14th International Conference on Nucleus-Nucleus Collisions (NN2024)

Sunday, 18 August 2024 - Friday, 23 August 2024

Whistler Conference Centre

Programme

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Sunday, 18 August 2024

Registration Grand Foyer (15h00 - 17h00) (15:00 - 18:00)

Public Lecture (18:00 - 19:00)

[350] How Nuclear Physics Can Treat Cancer - Radiotherapy at TRIUMF (18:00)

Presenter: HOEHR, Cornelia (TRIUMF)

Besides being Canada's particle accelerator centre with emphasis on nuclear, particle and accelerator physics, TRIUMF has a long history of medical isotope production and radiotherapy. Cancer treatment with different particles has been a long-standing commitment at TRIUMF, first with pion therapy and then with proton therapy, for many years operating Canada's only proton therapy facility. To improve treatment further, we are researching and establishing FLASH radiotherapy, where the total treatment dose is delivered in less than a second. In addition, we are investigating using alpha and auger emitters for targeted radioisotope therapy. Both have the potential to revolutionize cancer treatment by increasing the therapeutic index.

Monday, 19 August 2024

Welcome (08:45 - 09:00)

Plenary: 1 (09:00 - 10:30)

-Conveners: Dasgupta, Mahananda (Australian National University)

[270] Experimental Prospects for Research on Superheavy Elements (09:00)

Presenter: RUDOLPH, Dirk (Lund University)

What are the heaviest elements that can exist or be created in Nature? Does an 'Island of Stability' exist beyond uranium? Questions like these are often asked in connection with Long Range Plans of nuclear physics communities or large-scale accelerator facilities. Information on the chemical and physical properties of superheavy elements (*Z*>103) or nuclei is notoriously difficult to collect, mainly because of the low production and thus observation rates. This in turn limits experimental constraints of nuclear structure theory in particular. Ongoing efforts and future possibilities to improve the experimental situation will be presented in terms of observational rates, ground-state nuclear masses and spins, decay modes and decay spectroscopy, to name but a few.

[326] The Electron Ion Collider (EIC): Physics and Status (09:30)

Presenter: DESHPANDE, Abhay (SUNY Stony Brook)

In 2019 US Department of Energy initiated the process of realizing the Electron Ion Collider (EIC) - by giving the project a Critical Decision 0 - status. This resulted after an almost twenty year effort by scientists around the world to make the scientistic and technical feasibility case for the same. Now the EIC project - being realized jointly by BNL and Jefferson Lab - is well underway. The collider accelerators and one detector (ePIC) are being designed. The EIC will use one of the existing accelerators of the RHIC, and install a new electron beam facility in the same tunnel. The scientific program will need a new detector which will sit at one of the existing experimental halls. In this talk I will review the unique science case of the EIC as originally planned, and some additional topics that have emerged since then. I will summarize status of the project.

[41] (Zoom) Nuclear Uncertainties and the Interpretation of r-Process Observables (10:00)

Presenter: SURMAN, Rebecca (U)

The astrophysical origins of the heaviest elements via rapid neutron capture remain unresolved, even with exciting recent progress in gravitational wave and astronomical observations. One key barrier to elucidating *r*-process origins using these new observables are the uncertainties that arise from the unknown properties of the thousands of nuclear species that participate in the *r* process. Here we consider the role played by nuclear physics uncertainties in our interpretations of *r*-process observables such as light curves, abundance patterns, and isotopic ratios. We will discuss the prospects for reducing these uncertainties via advances in nuclear theory and experiment and point out potential observables that may rise above current uncertainties.

Coffee Break (10:30 - 11:00)

Plenary: 2 (11:00 - 12:30)

-Conveners: Aumann, Thomas (TU Darmstadt)

[265] In-Flight Rare Isotope Facilities and Related Instrumentation (11:00)

Presenter: GADE, Alexandra (Facility for Rare Isotope Beams)

Rare isotopes far from the valley of beta stability can be efficiently produced in-flight via projectile fragmentation or fission. This presentation will provide an overview of the facilities and their associated instrumentation that makes them unique.

[212] Learning from Exotic Hadrons by Using Lattice QCD (11:30)

Presenter: LEWIS, Randy (York University)

Nuclear physics is built on a solid understanding of individual nucleons, which can ultimately be described in terms of light quarks and gluons. The surprising recent discoveries of several tetraquark and pentaquark candidates, each containing both light and heavy quarks, offer new insight into the physics of quarks and gluons. Lattice QCD is a rigorous first-principles computational approach that can calculate some properties of these new exotic hadrons. The status of lattice QCD studies will be reviewed, including possible implications for our understanding of light quark physics.

[159] The Contribution of Nuclear Experiments to the Bayesian Inference of the Neutron Stars Equation of State (12:00)

Presenter: GULMINELLI, Francesca (LPC Caen/Université de Caen/ENSICAEN)

General relativity imposes a one-to-one correspondence between the Equation of State (EoS) of nuclear matter and the static properties of neutron stars (NS). Because of that, since the LIGO/Virgo exceptional detection GW170817, nuclear theory and experiments were used to directly constrain the NS properties, together with the information coming from the observations. Gravitational waves and X-rays exclude extremely large and low radii, respectively. Radio timing reveals the existence of very massive neutron stars, above twice the mass of the Sun. Ab-initio nuclear theory and a wealth of different nuclear experiments (heavy-ion collisions, collective modes, mass and skin measurements, dipole polarizability, just to cite a few) put stringent constraints of the lower density part of the star. In the past years, the combined consideration of these different constraints within Bayesian techniques has allowed controlled predictions on the mass-radius relation of a neutron star, hence the maximal compacity that baryonic matter can sustain. The present challenge arising with the expected improved future observations concerns fundamental physics questions such as the existence of deconfined phases of ultra-dense matter and the viability of alternative theories of gravity. For nuclear physics to contribute to this endevour, establishing controlled and correlated uncertainties in the multi-dimensional parameter space of the nucleonic EoS is of paramount importance. In this contribution, we will outline the present status of the field and the ongoing progress concerning an improved Bayesian treatment of the correlated information between different nuclear experiments.

Lunch Break (12:30 - 14:00)

Plenary: 3 (14:00 - 14:40)

-Conveners: Schwenk, Achim (TU Darmstadt)

[177] Ab Initio Theory of Nuclear Scattering and Reactions (14:00)

Presenter: QUAGLIONI, Sofia (LLNL)

A predictive theory of low-energy scattering and reactions between light nuclei is desirable to aid in precisely determining thermonuclear reaction rates that play an important role in fusion-energy experiments, the evolution of stars and the synthesis of the chemical elements in the universe, and tests of fundamental symmetries. First-principle (or ab initio) methods that solve the quantum many-nucleon problem with controlled approximations based on validated chiral nucleon-nucleon and three-nucleon forces are currently the best path to achieving such predictive theory. Among them, the ab initio no-core shell model with continuum (NCSMC) is perhaps the most advanced, having enabled a wide range of ab initio calculations for neutron and deuteron-induced capture and fusion reactions in light nuclei. In this talk, I will provide an overview of recent developments in the ab initio description of solar fusion cross sections and discuss progress towards the extension of the NCSMC to heavier systems and to reactions induced by α-particles and light p-shell nuclei.

Applications, Facilities & Instrumentation: AFI 1 - Garibaldi A (14:40 - 16:10)

-Conveners: Hoehr, Cornelia (TRIUMF)

[156] The CBM Time-of-Flight Project (14:40)

Presenter: DEPPNER, Ingo (Physikalisches Institut, Uni. Heidelberg)

In order to provide an excellent particle identification (PID) of charged hadrons at the future high-rate Compressed Baryonic Matter (CBM) experiment the CBM-TOF group has developed a concept of a 120 m^2 large Time-of-Flight (ToF) wall (with 93000 channels) with a system time resolution below 80 ps based on Multi-gap Resistive Plate Chambers (MRPC). The MRPC detectors were extensively tested in several beam campaigns at particle fluxes of up to a 30 kHz/cm^2 and reached by now the close to final design. Prior to its destined operation at the Facility for Antiproton and Ion Research (FAIR), a preproduction series of MRPCs is being used for physics research at two scientific pillars of the FAIR Phase0 program. At STAR, the fixed-target program of the Beam Energy Scan II (BES-II) relies on 108 CBM MRPC detectors enabling forward PID for center of mass energies in the range of 3 to 7.7 AGeV Au+Au collisions. At mCBM, high-performance benchmark runs of Λ production at top SIS18 energies (1.5/1.9 AGeV for Au/Ni beams) and CBM design interaction rates of 10 MHz became feasible. Apart from the physics perspectives, these FAIR Phase-0 involvements allowed for high rate detector tests including aging studies and long term stability tests. Results, observations and conclusions important for the mass production of the detectors and the status of the CBM TOF project will be presented.

[178] Status of the GRETA Project (15:05)

Presenter: FALLON, Paul (LBNL)

The Gamma-Ray Energy Tracking Array (GRETA) is a next-generation γ-ray spectrometer, capable of reconstructing the energy and three-dimensional position of γ-ray interactions. Its design provides the unprecedented combination of full solid-angle coverage and high efficiency, excellent energy and position resolution, and good background rejection needed to carry out a large fraction of the nuclear structure and nuclear astrophysics science programs at FRIB. GRETA is in the final stages of construction, with delivery to FRIB anticipated in 2025. In this talk we will discuss the technical capabilities of GRETA including the electronics and computing systems which represent a significant advancement compared to the GRETINA predecessor. We will also provide an overview of the current status of the project.

[164] The Upgrade of the Facility EXOTIC (15:20)

Presenter: MAZZOCCO, Marco (University of Padova and INFN-Sezione di Padova)

The facility EXOTIC [1] at the Laboratori Nazionali di Legnaro (LNL, Italy) has been operational for the in-flight production of light Radioactive Ion Beams (RIBs) since 2003. RIBs are produced via two-body inverse kinematics reactions induced by a heavy-ion beam, delivered from the LNL-XTU tandem accelerator and impinging on a gas target. So far, secondary beams of ^{8}Li, ^{7}Be, ^{8}B, ^{10}C, ^{11}C, ^{15}O and ^{17}F have been delivered with intensities between 10^3 and 10^6 pps in the energy range of 3-5 MeV/u. These RIBs were mostly used for reaction dynamics studies at Coulomb barrier energies, resonant scattering experiments and measurements of astrophysical interest using the Trojan Horse (indirect) Method. The facility has been recently upgraded to explore the possibility of coupling to the gamma-ray spectrometer AGATA [2], presently installed in the same experimental hall at LNL and located just 2.68 meters downstream the original focal plane of EXOTIC. According to the ion optical simulations, the coupling of EXOTIC and AGATA should be possible with the existing equipment at the cost of a 50%-reduction in the RIB intensity with respect to the original “EXOTIC stand-alone” configuration. A new tracking system based on two large-area x-y sensitive MicroChannelPlate (MCP) detectors is currently under development. The MPCs will be placed along the beam-line to provide an event-by-event reconstruction of the target position hit by the RIB particles and for timing purposes. The perspectives for the combined use of EXOTIC and AGATA will be presented. [1] F. Farinon et al., NIM B 266, 4097 (2008) [2] J.J. Valiente-Dobón , et al. NIM A 1049, 168040 (2023)

[146] Inside Nuclear Properties with g-factors (15:35)

Presenter: LOZEVA, Radomira (IJCLab, IN2P3/CNRS)

Nuclear moments are fundamental probes to study the intrinsic structure of the nucleus. Various methods and applications are used in the past depending on the specific decay or de-exitation mode of the nucleus. Such experimental investigations for isomeric states were performed for example in various facilities as RIBF/RIKEN, ALTO, GSI/FAIR employing some of the well-known methods in combination with dedicated gamma-ray and particle detectors. The states of interest are produced in different nuclear reactions, including fragmentation and fission at high to relativistic energies. Recent g-factor measurements using these reactions for nuclei in the vicinity of the doubly-magic 132Sn will be shown, together with future feasibilities for such nuclear structure measurements.

[226] Earthquake Precursor Measurements Employing a Network of Radon Sensors (15:50)

Presenter: GERL, Juergen (GSI/FAIR)

The artEmis project is addressing one of the most damaging natural hazards on earth: earthquakes. The ultimate goal is to improve radon based earthquake forecasting methods. The artEmis project develops a smart and cheap sensor system with about 100 units monitoring radon, temperature, acidity and other observables in ground water in real time. The data from the sensor system will be combined with seismic and geological data and analysed via machine learning algorithms. The sensors will be placed along fault zones in earthquake prone areas in Greece and Italy, and in Switzerland. For the demonstrator phase of the project, a series of sensors has been built and is being tested in specific locations. The layout of the sensor system and first results will be reported.

Equation Of State: EOS 1 - Harmony B (14:40 - 16:10)

-Conveners: Tsang, Betty (FRIB/MSU Michigan State University)

[268] Extracting Properties of Dense Nuclear Matter from Heavy-Ion Collisions (14:40)

Presenter: SORENSEN, Agnieszka (Institute for Nuclear Theory, University of Washington)

Constraining the dense nuclear matter equation of state (EOS) has been the goal of numerous theoretical and experimental efforts worldwide. Recent advancements include inferences from observations of neutron stars and neutron star mergers, measurements of neutron skins, and various theoretical developments. This makes complementary efforts relying on models of relativistic heavy-ion collisions, which allow one to probe the dense nuclear matter EOS in laboratory experiments, ever more timely. In this talk, I will discuss recent results in obtaining reliable constraints on the EOS from comprehensive comparisons of heavy-ion collision simulations to experimental data.

[311] Search for Toroids in Excited Nuclear Material (15:05)

Presenter: YENNELLO, Sherry (Texas A&M; University)

Ground state nuclei usually have compact geometries. However, there have been theoretical predictions that excited nuclei can take on more extended shapes such as toroids or bubbles. There have been many attempts to identify signatures of such shapes in experimental data. One signature both predicted by theory and reported in experimental data is narrow resonances at high excitation energy in peripheral intermediate-energy heavy-ion collisions. This potential evidence for toroidal states was reported in the alpha particle disassembly of 28Si after collision with a 12C target at 35 MeV/nucleon. The prior work was limited by angular resolution and statistical uncertainties. The present work aims to measure the excitation energy distribution for these disassembly events with improved angular resolution and reduced statistical uncertainty using the Forward Array Using Silicon Technology (FAUST). FAUST is equipped with resistive dual-axis duo-lateral (DADL) position-sensitive silicon detectors capable of sub-millimeter position resolution. The measured excitation energy distributions α disassembly events showed no strong evidence for highly excited states at the cross section and widths suggested by previous experiment. A statistical likelihood analysis was performed to provide an upper limit to toroidal high-spin isomer cross section, as evidenced by this observable, as a function of the excitation energy and width of potential states.

[232] Heavy-Ion Collisions and the Low-Density Neutron Star Equation of State: from the Lab to Space (15:30)

Presenter: BOUGAULT, Rémi (LPC/ENSICAEN)

Light nuclear clusters are expected to be ubiquitously present in astrophysical environments and play an important role in different astrophysical phenomena involving ultra-dense baryonic matter, but the estimation of their abundancy demands to correctly estimate the in-medium modification of their binding energy. In the original measurements, Equilibrium Constants were extracted detecting clusters emitted by a hot expanding source identified in the mid-rapidity region in central heavy-ion collisions. The measured Equilibrium Constants for 2H, 3H, 3He, 4He and 6He were compared to a relativistic mean-field model, and seen to be reasonably compatible with a universal correction of the attractive σ-meson coupling. Recently the data/model confrontation was analysed again by using a Bayesian analysis in order to reproduce the isotope mass fractions. This new analysis will be presented. From the experimental point of view, different entrance channels, reaction mechanisms and incident energies have to be explored to validate the results and heavier clusters (Z>2) should also be considered to challenge the theoretical hypothesis of universal couplings. This is why a new experiment has been carried out in order to analyse vaporization-like events of heavy ion reactions measured at GANIL using the INDRA-FAZIA multi-detector. We propose to present these new results within the Bayesian approach that has already been settled. References: R.Bougault, et al., J.Phys.G 47, 2 (2020). H. Pais, et al. J. Phys. G 47, 105204 (2020). H.Pais, et al, Phys. Rev. Lett. 125, 012701 (2020). A. Rebillard-Soulié, et al, J. Phys. G 51, 015104 (2024).

Hot & Cold QCD: QCD 1 - Wedgemount (14:40 - 16:10)

-Conveners: Lewis, Randy (York University)

[240] Nucleon Structure Functions at Large-x (14:40)

Presenter: PARK, Sanghwa (Jefferson Lab)

In this talk, I will review the recent progress in the nucleon structure functions at large-x region. The ratio of F2 structure functions between the proton and neutron is of particular interest as it’s closely related to the d/u ratio, and its behavior at x->1 limit provides insights into the dynamics of quarks in non-perturbative region. The PDFs are poorly constrained in large-x low Q^2 region due to the limited data and theoretical uncertainties when extracting the neutron structure functions from nuclear target data. The data from recent and planned fixed target experiments at Jefferson Lab can significantly improve constraints on PDFs at large-x.

[135] Collision-Energy Dependence of the Breit-Wheeler Process in Heavy-Ion Collisions and its Application to Nuclear Charge Radius Measurements (15:05)

Presenter: WANG, Xiaofeng (Shandong University)

In ultra-relativistic heavy-ion collisions, strong electromagnetic fields arising from the Lorentz-contracted, highly charged nuclei can be approximated as a large flux of high-energy quasi-real photons that can interact via the Breit-Wheeler process to produce $e^{+}e^{-}$ pairs. The collision energy dependence of the cross section and the transverse momentum distribution of dielectrons from the Breit-Wheeler process in heavy-ion collisions are calculated with lowest-order EPA-QED. Within a given experimental kinematic acceptance, the cross section is found to increase while the pair transverse momentum decreases with increasing beam energy. The corresponding results are also compared with STAR measurements, which are consistent with each other and found to be sensitive to the nuclear charge distribution and the infrared-divergence of the ultra-Lorentz boosted Coulomb field. Following this approach we demonstrate that the experimental measurements of the Breit-Wheeler process in ultra-relativistic heavy-ion collisions can be used to quantitatively constrain the nuclear charge radius. The extracted parameters show sensitivity to the impact parameter dependence, and can be used to study the initial-state and final-state effects in hadronic interactions.

[251] Tantalizing Structure in Long Range Correlations in High Multiplicity e+e- Collisions and Fourier Decomposition Using Archived ALEPH Data at 91-209 GeV (15:20)

Presenter: MCGINN, Chris (MIT)

We present measurements of two-particle angular correlations of charged particles emitted in high-energy e+e- collisions using data collected by the ALEPH detector at LEP between 1992 and 2000. The correlation functions are measured over a wide range of pseudorapidity and azimuthal angle as a function of charged particle multiplicity. Previous studies using LEP1 data at 91 GeV did not reveal significant long-range correlations in lab or thrust coordinates, and the associated yield distributions aligned with predictions from the archived PYTHIA v6.1 event generator. With the higher collision energy in LEP2, we gain access to increased event multiplicity and additional production channels beyond the Z->qq process. The highest multiplicity bin suggests an intriguing deviation from archived MC and implies the potential to search for collective phenomena in small systems. This measurement extends the exploration of long-range correlations to the smallest collision systems, introducing the first flow coefficient measurement and a Fourier decomposition analysis in e+e- collisions to quantify anisotropy in the azimuthal two-particle correlation relative to charged particles' transverse momentum. It is also compared with modern MC generators. This work supplements our understanding of small-system references to long-range correlations observed in proton-proton, proton-nucleus, and nucleus-nucleus collisions.

Nuclear Astrophysics: NA 1 - Garibaldi B (14:40 - 16:10)

-Conveners: Davids, Barry (TRIUMF)

[271] (Zoom) JENSA: Past, Present, and Future (14:40)

Presenter: CHIPPS, Kelly (ORNL)

Nuclear reaction studies rely on three main physical components: the beam of nuclei provided by the facility, the detector systems used to measure the outgoing particles of interest, and the target. Target fabrication is thus a critical aspect of studying the reactions that power stars and probe the evolution of nuclear structure. The Jet Experiments in Nuclear Structure and Astrophysics (JENSA) gas jet target is the most dense helium jet target for rare isotope beam reaction studies in the world, providing targets of gaseous elements such as helium, nitrogen, and neon. In this talk, I will describe the design and operation of JENSA, including commissioning and recent science experiments, and discuss the future of JENSA coupled to the dedicated recoil separator SECAR.

[73] Nuclear Astrophysics with TPCs and Gamma-Beams (15:05)

Presenter: GAI, Moshe (University of Conmecxticut)

Measurements of cross section and their extrapolation to stellar conditions are now routinely performed with accuracy of 5% or better. But the formation of 16O in the fusion of helium with 12C, in the 12C(a,g)16O reaction, is still not known with sufficient accuracy, in spite of the central role that this reaction plays in stellar evolution theory. We developed [1] a new method to measure this cross section by measuring with (mono-energetic) gamma-beams the inverse process of the photo-dissociation of 16O to 12C and an alpha-particle. The measurements are performed at the HIgS facility using TPC detectors [1] operating with CO2 gas, hence also serving as an active target TPC (AT-TPC). We will discuss initial measurements with the UConn-TUNL optical readout TPC (O-TPC) [2] that demonstrated the viability of our method [3] and recent results obtained in 2022 [4], with the Warsaw electronic readout TPC detector (eTPC). *Supported in part by the U.S. Department of Energy grant no. DE-FG02-94ER40870 and National Science Centre, Poland, contract no. 2019/33/B/ST2/02176. [1] M. Gai et al., Nucl. Instr. Meth. A954, 161770 (2020). [2] M. Gai et al., JINST 5, 12004 (2010). [3] R. Smith, M. Gai, S. R. Stern, D. K. Schweitzer, M. W. Ahmed, Nature Communications 12, 5920 (2021). [4] M. Ćwiok, W. Dominik, A. Fijałkowska, M. Fila, Z. Janas, A. Kalinowski, K. Kierzkowski, M. Kuich, Ch. Mazzocchi, W. Okliński, M. Zaremba, M. Gai, D.K. Schweitzer, S.R. Stern, S. Finch, U. Friman-Gayer, S.R. Johnson, T. Kowalewski, D.L. Balabanski, C. Matei, A. Rotaru, K.C.Z. Haverson, R. Smith, R.A.M. Allen, M.R. Griffiths, S. Pirrie, and P.S.R Alcibia, EPJ Web Conf. 279, 04002 (2023),

[100] Radiative α Capture on ^{12}C in Cluster Effective Field Theory (15:20)

Presenter: ANDO, Shung-Ichi (Sunmoon University)

Astrophysical S factors of $E1$ and $E2$ transitions of radiative α capture on ^{12}C, ^{12}C(α,γ)^{16}O, at Gamow peak energy, $E_G=0.3$ MeV, in the helium-burning process are estimated in cluster effective field theory (EFT). We construct an EFT for the reaction by choosing a separation scale as the breakup energy of p-^{15}N open channel and introduce α and ^{12}C as point-like scalar fields. The theory is applied to the studies of elastic α-^{12}C scattering at low energy, β-delayted α emission from ^{16}N, and radiative decay of the sub-threshold 1_1^- and 2_1^+ (l_{ith}^π) states of ^{16}O. Some of the coefficients appearing in the radiative capture amplitudes of the ^{12}C(α,γ)^{16}O process are determined through those studies. We report the estimate of the S factors at E_G by fitting the parameters to the experimental data of the S factors and discuss uncertainties of the estimate in the theory.

[84] (Zoom) Study of $\nu p-$ Process Nucleosynthesis in Core Collapse Supernovae via ^{56}Ni(d,p) Reaction (15:35)

Presenter: LI, Jiatai (Center for Nuclear Study, the University of Tokyo & RIKEN Nishina Center)

Understanding the origin of elements in our universe is inevitable for modern nuclear physics. It is known that neutron-deficient stable isotopes, referred to as $p-$nuclei, are synthesized through the p-process triggered by photo-disintegration in supernovae. One of the major issues that remain unresolved is the anomalously large abundances for certain lighter $p-$nuclei in current astrophysical scenario, such as ^{92,94}Mo and ^{94,96}Ru. A new scenario to account for the production of lighter $p-$nuclei is the neutrino driven rapid-proton capture (νp) process, which is predicted to occur in the core collapse supernovae. While the $\nu p-$process has been well-understood theoretically for the past decade, large uncertainties remain due to the lack of experimental data, especially for the neutron capture rate of the most critical waiting point in the $\nu p-$process: ^{56}Ni, which has a long β decay lifetime of 6 days and thus dominates the abundance of heavier $p-$nuclei. Since direct determination of the reaction cross section of ^{56}Ni(n,p)^{56}Co is challenging, we have applied the surrogate method instead by measuring the (d,p) reaction. The experiment was performed at OEDO-SHARAQ beamline at RIBF, RIKEN. The secondary ^{56}Ni beam was produced by projectile fragementation of ^{78}Kr, purified by BigRIPS separator and energy-degraded by OEDO. Recoiled protons were measured to establish the missing mass spectroscopy. Decay channels were identified by measuring projectile-like nuclei transporting through the high-resolution spectrometer SHARAQ. In this presentation, details of the experiments and preliminary results will be presented.

Nuclear Reactions I: NR 1 - Rainbow Theatre (14:40 - 16:10)

-Conveners: Christian, Greg (St Mary's University)

[208] Advances in Solenoidal-Spectrometer Techniques for Reaction Studies (14:40)

Presenter: KAY, Benjamin (Argonne National Laboratory)

The solenoidal-spectrometer technique for direct-reaction studies has advanced significantly since it was first demonstrated with the HELIOS spectrometer at Argonne's ATLAS facility and has become an essential tool for nuclear structure, reaction mechanism, and nuclear astrophysics studies. There are now three dedicated solenoidal spectrometers: the ISOLDE Solenoidal Spectrometer at HIE-ISODLE, HELIOS, and SOLARIS at FRIB, each with unique attributes. Both HELIOS and SOLARIS operate in a vacuum, silicon-array mode, and with the Active Target Time Projection Chamber. Recent results that highlight the advantages of these approaches will be briefly shown. The main focus will be on the use of the (d,pγ) reaction in inverse kinematics as a method to obtain (n,γ)-reaction cross sections. This was recently demonstrated via a study of the ^{85g}Kr(d,pγ) reaction with HELIOS and the Apollo scintillator array. The neutron capture cross section on the radioisotope ⁸⁵Kr (T_{1/2} = 10.7 yr), an *s*-process branching point nucleus, carries a significant uncertainty due to the challenges of direct studies. The technique has significant potential for future indirect (*n*,γ)-reaction studies. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract Number DE-AC02-06CH11357. This research used resources of ANL’s ATLAS facility, which is a DOE Office of Science User Facility.

[34] First Observation of New Isotopes at FRIB (15:05)

Presenter: TARASOV, Oleg B. (FRIB / MSU)

The Facility for Rare Isotope Beams (FRIB) [1] is currently providing primary beams of up to 300 MeV/u (most mid-mass beams are available at about 250 MeV/u) at 10 kW beam power. With this new facility and as the beam power is increased, FRIB is poised to provide access to a wide range of rare isotope beams. In this contribution, the initial results of the observation of new isotopes at FRIB [2] will be discussed. These isotopes were generated through the interaction of a ^{198}Pt beam with a carbon target at an energy of 186 MeV/u and with a primary beam power of 1.5 kW. Particle identification of *A*, *Z*, and *q* for the reaction products was conducted event by event, combining measurements of energy loss, time of flight, magnetic rigidity, and total kinetic energy. These findings are compared to NSCL results with a 198Pt beam at an energy of 85 MeV/u [3]. This successful new isotope search took place within a year of FRIB's initiation, showcasing the facility's discovery potential. FRIB, already providing access to a wide range of rare isotope beams at the current primary beam power level of 10 kW, anticipates reaching the full 400 kW capacity. References: 1. T. Glasmacher et al., Nuclear Physics News 27,28(2017). 2. O.B. Tarasov et al., accepted in PRL, 2023. 3. K. Haak et al., PRC 108, 034608 (2023).

[152] (Zoom) Measurements of Interaction and Charge-Changing Cross-Section of Carbon Isotopes 10,11,12C at the FRS (15:20)

Presenter: PRAJAPAT, Rinku (GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291-Darmstadt, Germany and Saint Mary's University, Halifax, Canada)

The advancement of production techniques to access unstable nuclei far from the stability line has resulted in the discovery of many exotic nuclei characterized by short half-lives and an unusual neutron-to-proton ratio. Such nuclei are of particular interest in fundamental and applied physics. For instance, measurement of interaction (σ_{I}) and charge-changing cross sections are essential for the deduction of the interaction and charge radii, respectively and input in treatment planning programs for radiotherapy with heavy ions such as ^{12}C. However, the case of positron emitters (^{10,11}C) is of special interest in ion beam therapy owing to their potential application in range verification in patients directly. Thus, an experiment has been performed at GSI Darmstadt to produce and separate the fragments (^{10,11}C) of interest using the in-flight fragment separator and spectrometer FRS. The aim of the experiment was to measure the interaction and charge-changing cross-sections of ^{10,11,12}C nuclei on a carbon interaction target at therapeutically relevant energies. The measurements were done with the transmission method, which means that the unreacted part of the beams is being analysed for σ_{I} using the FRS spectrometer. The measurements were accompanied with Monte Carlo simulations using the MOCADI. In this contribution, the experimental overview, data analysis, together with the preliminary results will be presented. This work is supported by European Research Council (ERC) Advanced Grant 883425 (BARB) to Marco Durante. The measurements were performed within the Super-FRS Experiment Collaboration at GSI under the FAIR Phase-0 program.

[106] Interaction Cross Sections and Neutron Skin Thickness of Ni Isotopes (15:35)

Presenter: FUKUTOME, Miki

Since nuclear matter is composed of two Fermi particles, protons and neutrons, the equation of state of nuclear matter has a term that depends on the density difference between the two, which is called the symmetry energy. From previous studies, it is known that the first-order density dependence of the symmetry energy is closely related to the thickness of the neutron skin [1]. In this study, interaction cross sections ${\sigma}_{\rm{I}}$ and charge changing cross sections ${\sigma}_{\rm{CC}}$ for $^{58-77}$Ni on a carbon target at 260 MeV/nucleon have been measured to derive matter radii and charge radii respectively. Recently, the charge radii of Ni isotopes up to mass number 70 were measured by isotope shift method [2]. In order to derive the neutron skin thickness in the more neutron-rich region, we attempted to derive the charge radii from charge changing cross section measurements. The experiment was performed at the Radioactive Isotope Beam Factory(RIBF) at RIKEN by using the BigRIPS fragment separator. In this presentation, we'll report the matter radii and charge radii derived from the experimental cross sections using Glauber calculations. Also, in the region where the charge radii are known, from A = 58 to 70, we'll discuss the neutron skin thickness of Ni isotopes, which is obtained by the present data combined with known charge radii. On the other hand, in the neutron-rich region with A ${\geq}$ 71, we'll discuss the neutron skin thickness by combining present ${\sigma}_{\rm{I}}$ and ${\sigma}_{\rm{CC}}$ data. References [1] M. Centelles et al., Phys. Rev. Lett. 102 (2009) 122502. [2] S. Malbrunot-Ettenauer et al., Phys. Rev. Lett. 128 (2022) 022502

[48] Short-Range Correlations in Dynamical Intranuclear Cascade Models for Describing Nucleon Knockout and Fission Reactions (15:50)

Presenter: RODRIGUEZ SÁNCHEZ, Jose Luis (University of Coruña)

The dynamical intranuclear cascade model INCL[1] has been improved by including short-range nucleon-nucleon correlations (SRCs), which are mainly dominated by the formation of np pairs. This new development allows us to obtain a better description of peripheral collisions involving the knockout of a few nucleons in spallation and fragmentation reactions. The new version of our dynamical model successfully describes isotopic cross sections of neutron-rich nuclear residues and inclusive single-neutron and single-proton knockout cross sections for various stable and exotic nuclei. The results show that the systematic strong dependence of the single-knockout cross section reduction factor on the neutron-proton separation energy asymmetry parameter (ΔS) obtained by Tostevin and Gade disappears when SRCs are taken into account. Finally, I will present the use of this model to study the evolution of fission yields with excitation energy for exotic nuclei between Pb and U elements, as new ideas proposed for the future fission experiments [2,3,4] at the GSI-FAIR facility. [1] J.L. Rodríguez-Sánchez et al, Phys. Rev. C 105, 014623 (2022) [2] A. Chatillon et al, Phys. Rev. Lett. 124 (2020) 202502 [3] A. Graña-González et al, Proceedings of Science 419 (2023) 017 [4] J.L Rodríguez-Sánchez et al, EPJ Web of Conf. 284 (2023) 04020

Nuclear Structure I: NS 1 - Ballroom B (14:40 - 16:10)

-Conveners: Ball, Gordon (TRIUMF)

[300] (Zoom) Observation of a Correlated Free Four-Neutron System (14:40)

Presenter: PANIN, Valerii (GSI, Darmstadt)

The experimental search for an isolated four-neutron system has been a long standing quest in nuclear physics. With only a few indications for its existence the tetraneutron remains an elusive nuclear system. In the recent experiment performed at RIKEN Nishina Center a resonance-like structure near 4n threshold was observed for the first time using quasi-free knockout of alpha particles from radioactive 8He beam impinging on a thick liquid-hydrogen target. The results and details of the experiment will be presented in this talk.

[112] Search for Beta-Delayed Protons in the Decay of 11Be (15:05)

Presenter: PFUTZNER, Marek (University of Warsaw)

Even though beta-delayed proton emission is a phenomenon that typically occurs for neutron-deficient nuclei, the energy window for this process is open also in a few light, neutron-rich isotopes. Particularly interesting in this respect is 11Be, which is also a one-neutron halo nucleus. Several channels for beta-delayed particle emission from this isotope are open, including the proton branch, with a decay energy of 280 keV. The branching ratio (BR) for the latter process is interesting for the determination of the Gamow-Teller strength at high excitation energy and for testing models that predict a direct relation between delayed proton emission and the halo structure. Recently some conflicting experimental results for the value of this branching ratio were published which increased the interest of both experimental and theoretical physicists in this decay channel. We have undertaken a project to search for beta-delayed protons in the decay of 11Be using the Warsaw Optical Time Projection Chamber (OTPC). The main experiment was performed at the HIE-ISOLDE facility in CERN. Postaccelerated 11Be ions were implanted into the OTPC detector and their subsequent decays with the emission of charged particles were recorded.In the talk, our experimental method will be described and the main results of this project will be presented.

[199] Search for the Gamma Decay of the Narrow Near-Threshold Proton Resonance in 11B (15:20)

Presenter: BOTTONI, Simone (Università degli Studi di Milano and INFN)

We present recent results on the gamma decay of a peculiar near-threshold state in 11B, expected to be located in the continuum just above the proton-decay threshold. The relevance of such a state is due to the observation of the rare beta-delayed proton emission process in the neutron-rich 11Be nucleus, with an unexpectedly high rate, at odds with the narrow energy window available for this decay [1,2]. This phenomenon might be explained by the presence of a near-threshold proton resonance in 11B, recently suggested by [3,4] in two different experiments using particle spectroscopy techniques. A step forward can be made by searching for the gamma decay of this near-threshold proton state in 11B, since the gamma-decay branch is extremely sensitive to the structure of the resonance wave function [5]. The experiment was performed at Laboratori Nazionali di Legnaro using the 6Li(6Li,p)11B fusion-evaporation reaction and the GALILEO-TRACE setup for the coincident detection of gamma rays and charged particles. For the first time, limits on the gamma-decay branch were established and implications for the description of 11B as an open quantum system will be discussed [7]. [1] K. Riisager et al., Phys. Lett. B 732, 305 (2014). [2] Y. Ayyad et al., Phys. Rev. Lett. 123, 082501 (2019). [3] Y. Ayyad et al., Phys. Rev. Lett. 129, 012501 (2022). [4] E. Lopez-Saavedra et al., Phys. Rev. Lett. 129, 012502 (2022). [5] J. Okołowicz, M. Płoszajczak, and W. Nazarewicz. Phys. Rev. Lett. 124, 042502 (2020). [6] S. Bottoni et al., to be submitted to Phys. Lett. B

Coffee Break (16:10 - 16:40)

Applications, Facilities & Instrumentation: AFI 2 - Garibaldi A (16:40 - 18:10)

[220] Nuclear Data for Fission and Fusion Reactors (16:40)

Presenter: BERNSTEIN, Lee (UC Berkeley/Lawrence Berkeley National Lab)

Since the 1938 $\it{Annus}$ $\it{mirabilis}$ which included the discovery of fission by Meitner and Frisch [1] and the recognition by Ruhlig that the D-T reaction was “highly probable” [2], nuclear science has offered society the promise of abundant energy. In the last decade the onset of global climate change has accelerated the development of advanced nuclear energy systems that utilize new fuels, coolants, and fast neutrons. Most recently, the achievement of controlled thermonuclear fusion at the National Ignition Facility [3] has similarly heightened interest in fusion-based energy systems, leading to a plethora of private investment. While engineering challenges are forefront in the attention of the nuclear energy community, significant nuclear data needs have been clearly identified for both fission and fusion energy systems that can be addressed by the nuclear physics research community through the combination of targeted measurement and theory-based reaction modeling known as evaluation. In this talk I will discuss some of these data needs and present several examples of how they are being addressed. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Berkeley National Laboratory under Contract No. DE-AC02-05CH11231. [1] “Disintegration of Uranium by Neutrons: a New Type of Nuclear Reaction”, Lise Meitner & O. R. Frisch, Nature 143, pages 239–240 (1939). [2] “Search for Gamma-Rays from the Deuteron-Deuteron Reaction”, Arthur J. Ruhlig, Phys. Rev. 54, 308 (1938). [3] “Lawson Criterion for Ignition Exceeded in an Inertial Fusion Experiment”, H. Abu-Shawareb et al., Phys. Rev. Lett. 129, 075001 (2022).

[338] Nuclear Structure and Reaction Studies at the FSU John D. Fox Laboratory (17:05)

Presenter: SPIEKER, Mark (Florida State University)

In this invited contribution, I will present highlights from recent nuclear structure and reaction studies conducted at the John D. Fox Superconducting Linear Accelerator Laboratory at Florida State University. I will focus on light-ion induced reactions measured with the Super-Enge Split-Pole Spectrograph (SE-SPS) and its ancillary detector systems, including the CeBrA demonstrator for particle-γ coincidence experiments and arrays of silicon detectors for coincident particle detection. In this part, I will also point out future possibilities for experiments with the SE-SPS and the newly commissioned triton beam at the Fox Laboratory. A few highlights from the first experimental campaigns with the combined CLARION2-TRINITY setup will also be presented. The experimental program at the FSU John D. Fox Laboratory is supported by the U.S. National Science Foundation (PHY-2012522) and U.S. National Nuclear Security Administration (DE-NA0004150) as part of CENTAUR.

[171] TACTIC: a Novel Detector for Nuclear Astrophysics (17:30)

Presenter: CHAKRABORTY, Soham (TRIUMF)

TACTIC (TRIUMF Annular Chamber for Tracking and Identification of Charged particles), a cylindrical active target detector with an extended gas target, is being jointly developed by the University of York, UK and TRIUMF, Canada. The design of TACTIC is suitable for the direct measurement of alpha-induced charged particle reactions at multiple centre of mass energies utilising a single beam energy. The cross section measurements rely on the detection and identification of charged particles by means of differential energy loss in the detection medium. In order to detect the reaction products over a wide range of energies, the novel μ-RWELL (micro-Resistive WELL) detectors are used in TACTIC as the gas multiplication stage. An unique concentric cathode cage configuration enables the detector to accommodate higher beam intensities (~ 5-10 pA), compared to other active target detectors. The first successful cross section measurement using TACTIC was performed recently at the TRIUMF ISAC-I facility. The astrophysically important and experimentally well-constrained 23Na(α, p)26Mg reaction was studied as a commissioning experiment. Prior to their installation in TACTIC, a detailed charecterisation of the μ-RWELL detectors was performed utilising the test chamber, which is a planar analogue of TACTIC. The installation marked the very first integration of the state-of-the-art μ-RWELL technology inside a cylindrical geometry for charged particle tracking. Furthermore, the μ-RWELL detectors were also tested for the first time in helium-based gas mixtures. We will present the test results, underlying physics and astrophysical motivation behind the development of TACTIC.

[139] Recent Results and Prospects of the SCRIT Electron Scattering Facility (17:45)

Presenter: TSUKADA, Kyo (ICR, Kyoto University)

The world's first electron scattering off online-produced Radioisotope (RI) was successfully conducted at the SCRIT electron scattering facility. Electron scattering stands out as one of the most potent and reliable tools for investigating the structure of atomic nuclei, owing to the well-understood mechanism of electromagnetic interaction. Despite a long-standing desire to explore exotic features of short-lived unstable nuclei through electron scattering, it has been impeded by the difficulty in preparing thick targets. However, we have recently achieved a significant milestone by realizing electron scattering from 137Cs, which was generated via the photo-fission of uranium and promptly transferred to the SCRIT system for trapping within a short time. This experiment serves as a noteworthy emulation of electron scattering from short-lived unstable nuclei produced online, especially considering future upgrades to the power of the ISOL driver. In this contribution, we will present recent progress and prospects of the SCRIT electron scattering facility. Additionally, we will discuss several topics that may only be feasible in the future using the SCRIT method.

Heavy & Superheavy Elements: SHE 1 - Harmony B (16:40 - 18:10)

-Conveners: Gates, Jacklyn (Lawrence Berkeley National Laboratory)

[299] Surprising Decay Properties of the New SHE Isotope ^{255}Db (16:40)

Presenter: PORE, Jennifer (Lawrence Berkeley National Laboratory)

Isotopes of SuperHeavy Elements (SHE) boast extraordinary numbers of protons and neutrons and push the boundaries of the nuclear chart and our understanding of nuclear structure. Typically, SHE isotopes follow one of two primary decay paths: emission of an α particle or Spontaneous Fission (SF). A more robust understanding of the mechanism for SF in the SHE region is of great interest. Experiments conducted at Lawrence Berkeley National Laboratory's 88-inch cyclotron facility aimed to produce and study the decay of the previously unobserved isotope ^{255}Db. This isotope was produced in the ^{206}Pb(^{51}V,$2n$)^{255}Db reaction, separated from unreacted beam material and reaction byproducts with the Berkeley Gas-filled Separator (BGS), and then implanted into a double-sided silicon-strip detector at the BGS focal plane. Decay properties of ^{255}Db were determined from the analysis of Evaporation Residue (EVR)-Fission and EVR-α-α correlations. The properties of this new isotope of dubnium are intriguing as they differ dramatically from those of its isotopic neighbors. ^{255}Db was found to decay primarily by Spontaneous Fission (SF) with a small α-decay branch, where the average half-life of the observed decays was t$_{1/2}$ = 2.6$^{+0.4}_{-0.3}$ ms. Theoretical calculations were performed using the Wentzel-Kramers-Brillouin (WKB) approximation, with parameters calculated within a self-consistent microscopic approach, to see if these unique properties could be reproduced. A SF half-life estimate is obtained that closely matches the measured value, while simultaneously pointing out the sensitivities that need to be further constrained in future work.

[170] Reaction Dynamics of Heavy and Superheavy Nuclei Synthesis: Towards Understanding the Isotopic Dependent Reaction Dynamics in Zeptsecond Order (17:05)

Presenter: TANAKA, Taiki (GANIL)

Mass-angle distribution (MAD) measurements of nuclear fission fragments have illuminated many aspects of the physical variables controlling quasifission [1]. This tool has been exploited to probe the dynamics of the nuclear fusion reactions used for synthesizing heavy and superheavy nuclei. A fundamental understanding of quasifission, and how it can be minimized, is sought to optimize the synthesis of new superheavy isotopes. In this contribution, I will discuss our recent results related to the quasifission process. A new experimental method [2,3], involving the subtraction of two measured MADs, has enabled the first direct determination of the dependence of the fast quasifission sticking time, zeptsecond (10-21 sec) order, on the angular momentum, Lħ, as well as obtaining new information on fast quasifission mass evolution. The results are consistent with a transition from slow quasifission (and fusion) at the lowest L, through fast quasifission at intermediate L, to deep-inelastic collisions at the highest L. I will also introduce our future studies of quasifission at GANIL utilizing the Variable Mode Spectrometer and inverse kinematics method. The approach enables us to study the isotopic-dependent reaction dynamics in zeptsecond order, which can be a probe to study the correlations of neutron-proton equilibration [4], kinetic energy dissipation, shell effect [5], and even-odd effect [6]. [1] J. Toke et al., NPA 440, 327 (1985). [2] T. Tanaka et al., PRL 127, 222501 (2021), [3] T. Tanaka et al., PRC 107, 054601 (2023). [4] C. Simenel et al., PRL 124, 212504 (2020). [5] C. Simenel et al., PLB 822, 136648 (2021). [6] D. Ramos et al., PRC 107, L021601 (2023).

[196] Towards a New Element Search with the Berkeley Gas-Filled Separator (17:20)

Presenter: ORFORD, Rodney (Lawrence Berkeley National Laboratory)

At the 88-inch cyclotron facility of Lawrence Berkeley National Laboratory (LBNL) the decay properties of heavy and superheavy elements are studied using the Berkeley Gas-filled Separator (BGS). So far, the heaviest known elements found on the periodic table are best produced through fusion-evaporation reactions involving actinide targets and intense beams of ^{48}Ca. To search for potential new elements beyond Oganesson (Z = 118), beams heavier than ^{48}Ca must be utilized due to a lack of available target material with Z $>$ 98. At LBNL, preparations are underway to begin a search for Element 120 with the BGS using the ^{50}Ti $+$ ^{249}Cf reaction. Recently, the SuperHeavy RECoil (SHREC) detector was commissioned at the BGS focal plane alongside an upgrade to a digital data acquisition system. In this presentation I will give an overview of the BGS and the new focal-plane detector system before highlighting recent results from preliminary milestone experiments on the path to Element 120, including a campaign to produce Livermorium with a beam of ^{50}Ti for the first time.

[213] Quasi-Fission in Reactions Leading to the Superheavy Elements (17:35)

Presenter: GUMBEL, Richard (Michigan State University)

Quasi-fission reactions present a substantial hindrance to the formation of super heavy elements. The collision of two heavy nuclei leading to a quasi-fission reaction produces fragments with strikingly similar characteristics to those of fusion-fission reactions. However, unlike fusion-fission, there is no intermediate formation of a fully equilibrated compound nucleus. This departure from the dynamics of fusion-fission, where the exit channel is largely a consequence of the compound nuclei and does not exhibit a dependence on the specifics of the entrance channel, leads to a strong memory of the properties of the entrance channel for quasi-fission. This presents an opportunity to deepen our understanding of the interplay between entrance and exit channels through extensive modeling and experimental study. It will aid in optimizing the entrance channels employed in experiments for the synthesis and study of super heavy nuclei. For my project, I will present the results of modeled collisions between a U-238 target with projectiles of Ca-46 and Ca-48, which combined produce isotopes of the super heavy nuclei copernicium (Cn-284 and Cn-286, respectively). Each collision set is studied through the use of time-dependent Hartree-Fock (TDHF) methods, for a range of different angular momenta and orientations of the U-238 target, at incident energies hovering just above the potential barrier. I will explore quasi-fission’s potential as a unique probe of the quantum many-body dynamics of out-of-equilibrium nuclear systems, for example, the information it can provide on mass equilibration, timescales of interactions, and the impact of shell effects on exit channels.

[35] Deformation Effects on the Survival of Radon and Radium Compound Nuclei (17:50)

Presenter: MILDON, Jordan (Texas A&M; University)

Several campaigns have been undertaken in order to synthesize new superheavy elements (SHEs). In order to determine the optimal experimental parameters for success, there has been much attention given to factors that are important to the survival of the compound nucleus. Among these factors is the effect of nuclear deformation: it is known that a larger quadrupole deformation results in an increase in the level density for the neutron decay mode. This in turn increases the probability that the compound nucleus deexcites through neutron emission rather than by fission, allowing the compound nucleus to survive and form a fusion-evaporation residue. However, the effects of level density on survival in deformed nuclei have not been well explored. Due to its implications in the survival of spherical SHE nuclei, it is important to understand these effects. A series of fusion-evaporation reactions of 48Ti on 156,157,158,160Gd and 164,163Dy were studied at the Cyclotron Institute at Texas A&M University to systematically investigate the production of a series of radon and radium nuclei at varied excitation energies. The resulting compound nuclei span a large range of deformations and allow for exploration into the effects of deformation on the survival of the compound nucleus. Further, the use of 48Ti as an analog of 50Ti is significant due to the latter's role in the efforts to synthesize new SHEs. This talk will present the most recent results.

Hot & Cold QCD: QCD 2 - Wedgemount (16:40 - 18:10)

-Conveners: Deshpande, Abhay (Stony Brook University & BNL)

[327] New Approaches to Light Hypernuclei with Heavy Ion Beams, Image Analyses and Machine Learning (16:40)

Presenter: SAITO, Takehiko (High Energy Nuclear Physics Laboratory, RIKEN)

Studies of hypernuclei have been contributing for understanding the fundamental baryonic interactions as well as the nature of dense nuclear matters. They have already been studied for almost seven decades in reactions involving cosmic rays and with meson- and electron-beams. In recent years, experimental hypernuclear physics enters a new era. Hypernuclei can also be studied by using energetic heavy ion beams, and some of these experiments have revealed unexpected results on the lightest hypernucleus, the hypertriton, on its short lifetime and large binding energy. One of the experiments has also shown a signature of the unprecedented bound state with a Lambda hyperon with two neutrons. We are studying those light hypernuclear states by employing different approaches from the other experiments. We employ heavy ion beams on fixed nuclear targets with the WASA detector and the Fragment separator FRS at GSI (the WASA-FRS project) in Germany for measuring their lifetime precisely. The experiment was already performed in 2022. We also analyze the nuclear emulsions with machine learning, that were irradiated by kaon beams in the J-PARC E07 experiment. We have already uniquely identified events associated with the production and decays of the hypertriton, and the binding energy of the hypertriton is to be determined. We also search events of other single-strangeness hypernuclei and double-strangeness hypernuclei in the E07 emulsion to understand the nature of Lambda-nucleon, Lambda-Lambda and Xi-nucleon interactions. We are using Machine Learning techniques for all our projects with heavy ion beams and nuclear emulsions. We'll discuss on these project and the current status of data analyses, we'll also present future plans of these projects.

[247] Dilepton Measurements with HADES as Probes of Hot and Dense Hadronic Matter (17:05)

Presenter: SCHILD, Niklas (GSI)

Dileptons are an excellent probe to investigate strong-interaction matter under extreme conditions. Their penetrating nature not only enables e.g. temperature measurements unbiased by the collective expansion of the fireball, but also an insight to the microscopic structure of the matter under investigation. The HADES collaboration has measured virtual photons in the di-electron channel, in heavy-ion collisions as well as in proton- and pion-induced reactions of protons. In the latter, for the exclusive channel $\pi+p \to n_\mathrm{missing}+e^++e^-$ at center of mass energies in the second resonance region the dilepton invariant mass reveals the coupling of the baryon to the virtual photon via intermediary ρ mesons as expected from Vector Meson Dominance. It is the first measurement of a baryon transition form factor in the time-like region. Intermediary off-shell ρ meson is also the central source of dileptons emitted from the transient hot and dense state created in collision of Au+Au ($\sqrt s_{NN}$ = 2.4 GeV) and Ag+Ag ($\sqrt s_{NN}$ = 2.65 & 2.4 GeV). The respective invariant mass spectra evidence a strong broadening of the ρ meson in the medium. The talk will also address other dilepton observables and will give an outlook to measurements with the future CBM detector.

[233] Exploring Baryon-Rich QCD Matter with CBM at FAIR: Status and Prospects (17:20)

Presenter: FRIESE, Volker (GSI Helmholtzzentrum Darmstadt)

The Compressed Baryonic Matter (CBM) experiment aims to explore the phase structure of strong- interaction (QCD) matter at large net-baryon densities and moderate temperatures by means of heavy-ion collisions in the energy range $\sqrt{s_{NN}}$ = 2.9 - 4.9 GeV. The CBM is under construction at the Facility for Antiproton and Ion Research (FAIR) and will be equipped with fast and radiation hard detector systems and a triggerless data acquisition allowing online space-time (4D) reconstruction and event selection at the interaction rates up to 10 MHz. This contribution will be an overview of the CBM physics goals among which are the equation-of-state of compressed QCD matter, the possible phase transition from hadronic to partonic phase, and chiral symmetry restoration. The CBM will measure rare probes not studied so far such as di-leptons, higher-order cumulants, multi-strange hadrons and their flow, and double-strange hypernuclei. Physics performance will be demonstrated for (multi-)strange particle production, thermal di-leptons, collective phenomena and femtoscopy. Preparations towards CBM commissioning and performance evaluation of the CBM components at FAIR Phase-0 experiments will be presented as well.

[285] Chiral Symmetry in Nuclear Medium Observed in Pionic Atoms (17:35)

Presenter: ITAHASHI, Kenta (RIKEN)

We have deduced an order parameter of the chiral symmetry in nuclear medium by making precision spectroscopy of pionic Sn 121 atoms at the RIKEN RIBF. The binding energies and widths of the pionic states were measured, and the pion-nucleus interaction was accurately determined. The in-medium interaction exhibited enhanced isovector repulsive interaction due to the medium effect. Further analyses showed that the enhancement is due to the partial restoration of the chiral symmetry in the nucleus. We deduced that the chiral condensate at nuclear saturation density is reduced by a factor of 60+-3% (T. Nishi, K. Itahashi et al., Nature Phys. (2023) doi:10.1038/s41567-023-02001-x). We also discuss the future plans to derive the density dependence of the chiral condensate.

Nuclear Astrophysics: NA 2 - Garibaldi B (16:40 - 18:10)

-Conveners: Surman, Rebecca (U)

[174] Thermonuclear Runaways Investigated Using Beta-Delayed Charged Particle Emission (16:40)

Presenter: WREDE, Christopher

The Gaseous Detector with Germanium Tagging (GADGET) was developed and operated at the National Superconducting Cyclotron Laboratory to measure weak, low energy, beta-delayed proton branches calorimetrically using the gaseous Proton Detector subsystem. The results constrain the strengths of the dominant resonances in key radiative proton capture reactions affecting the modeling of nucleosynthesis observables in classical novae. An upgrade (GADGET II) has recently been implemented in which the Proton Detector operates as a Time Projection Chamber at the Facility for Rare Isotope Beams providing particle identification and distinguishing beta delayed single and multiple charged-particle emissions. The first GADGET II experiments (one completed and another approved) seek to investigate resonances in key reactions affecting the modeling of X-ray burst light curves and ash compositions.

[312] (Zoom) Progress of Underground Nuclear Astrophysics JUNA Experiments (17:05)

Presenter: LIU, Weiping (Southern University of Science and Technology)

The Jinping Underground experiment for Nuclear Astrophysics (JUNA) takes advantage of the ultra-low background of the CJPL to conduct experiments for directly studying crucial reactions at stellar energies in the evolution of stars. In 2020, JUNA commissioned an mA level high current accelerator based on an ECR source, as well as high efficiency BGO and ^{3}He detectors. These combination enabled JUNA to perform direct measurements of key nuclear reactions In 10^{-13} b sensitivity with the beam exposure of few hundreds of Coulomb, including $^{25}Mg(p,γ)^{26}Al$, $^{19}F(p,αγ)^{16}O$, $^{19}F(p,γ)^{20}Ne$, $^{13}C(α,n)^{16}O$, $^{12}C(α,γ)^{16}O$, and $^{18}O(α,γ)^{20}Ne$ with improved precision and closer to the Gamow window. These precise reaction rates provide valuable insights into the high precision astrophysics simulation. The highlights of JUNA experiments will be presented. [1]:
https://www.notion.so/wpliu/NN2024-f09a9cf2065e4fab95fbe6904677b67b?pvs=4#97ad2 aa1d0914717930664e1f4947f09

[207] The Surrogate Reactions for the Neutron-Capture Rate Using OEDO and SHARAQ in RIBF (17:30)

Presenter: IMAI, Nobu (Center for Nuclear Study, Univ. of Tokyo)

The origin of the elements in the universe is one of the long-standing problems in nuclear physics. In particular, the r-process attracts much attention since the hint of the heavy elements were detected after the gravitational wave was detected. To reveal the astrophysical conditions such as the neutron densities and the temperature, the nuclear physics parameters are highly demanded. Among the parameters, the neutron capture rate is one of the challenging quantities since both the target nucleus and the neutron are radioactive. To determine the neutron capture rate of the radioactive nuclei, we have developed an experimental technique of the surrogate reaction employing (d,p) reaction in inverse kinematics. The gamma emission probabilities from the unbound states were determined by identifying the reaction residues instead of detecting the photons. Such experiments become feasible employing the decelerating and focusing device OEDO and the spectrometer of SHARAQ in RIBF. We applied the technique to the neutron capture rates of 130Sn for r-process study and of 79Se for the nuclear data of the transmutation. In this contribution, we will discuss these results with the experimental setup.

[4] Indirect Measurement of the $^{27}{\rm Al}(p,\alpha)^{24}{\rm Mg}$ and $^{27}{\rm Al}(p,\gamma)^{28}{\rm Si}$ Cross Sections and Astrophysical Implications (17:45)

Presenter: LA COGNATA, Marco (INFN-LNS)

The abundance of ^{26}Al carries a special role in astrophysics, since it probes active nucleosynthesis in the Milky Way and constrains the Galactic core-collapse supernovae rate. It is estimated through the detection of the 1809 keV γ-line and from the superabundance of ^{26}Mg in comparison with ^{24}Mg in meteorites. For this reason, high precision is necessary also in the investigation of the stable ^{27}Al and ^{24}Mg. These nuclei also enter the so-called MgAl cycle playing an important role in the production of Al and Mg. Recently, high-resolution stellar surveys have shown that the Mg-Al anti-correlation in red-giant stars in globular clusters may hide the existence of multiple stellar populations. The common thread running through these astrophysical scenarios is the ^{27}Al(p,α)^{24}Mg and $^{27}{\rm Al}(p,\gamma)^{28}{\rm Si}$ reactions, which are the main ^{27}Al destruction channels. Since available spectroscopic data and reaction rates show large uncertainties owing to the vanishingly small cross section at astrophysical energies, we have applied the Trojan Horse Method to the $d(^{27}{\rm Al},\alpha{}^{24}{\rm Mg})n$ reaction. This has allowed us to extract important information on the $^{27}{\rm Al}(p,\alpha)^{24}{\rm Mg}$ and $^{27}{\rm Al}(p,\gamma)^{28}{\rm Si}$ cross sections in the energy region of interest for astrophysics, not accessible to direct measurements. In particular, the indirect measurement made it possible to assess the contribution of the 84~keV resonance and to lower upper limits on the strength of nearby resonances, with important impact for astrophysics, especially for massive-star nucleosynthesis.

Nuclear Reactions I: NR 3 - Rainbow Theatre (16:40 - 18:10)

-Conveners: Gade, Alexandra (Facility for Rare Isotope Beams)

[98] Exploring Exotic Nuclear Structure by Medium- to High-Energy Nuclear Collisions (16:40)

Presenter: HORIUCHI, Wataru (Osaka Metropolitan University)

Various information on the nuclear structure is imprinted on the density profiles, especially, near the nuclear surface. The total reaction cross section of medium- to high-energy nuclear collision has been a standard observable to extract the nuclear radius of unstable nuclei. As higher order information of the nuclear density profile, evaluating a surface diffuseness of the nuclear density distribution is quite useful. This nuclear “diffuseness” can be quantified by evaluating high-energy proton-nucleus elastic scattering cross sections at the first diffraction peak. The emergent mechanisms of the exotic nuclear structure, including deformation [1,2] and clustering [3,4,5,6] will be presented by taking examples from our recent works. I also demonstrate that types of the deformation can be clarified by using proton-nucleus inelastic scattering at medium- to high-incident energies [7] References [1] W. Horiuchi, T. Inakura, and S. Michimasa, Phys. Rev. C 105, 014316 (2022). [2] W. Horiuchi, T. Inakura, S. Michimasa, and M. Tanaka, Phys. Rev. C 107, L014304 (2023). [3] W. Horiuchi and N. Itagaki, Phys. Rev. C 106, 044330(2022). [4] W. Horiuchi and N. Itagaki, Phys. Rev. C 107, L021304 (2023). [5] Y. Yamaguchi, W. Horiuchi, and N. Itagaki, Phys. Rev. C 108, 014322 (2023). [6] M. Okada, W. Horiuchi, N. Itagaki, in preparation. [7] W. Horiuchi, Y. Yamaguchi, and N. Itagaki, in preparation.

[17] Simultaneous Calculation of Elastic Scattering, Transfer, Breakup, and Other Direct Cross Sections for d+^{197}Au Reaction (17:05)

Presenter: MARIDI, Hasan (University of Manchester, UK)

Simultaneous analyses are performed for cross section data of elastic scattering, Coulomb breakup, transfer and other direct yields for the d+^{197}Au system at all available energies. The data are reproduced well by the optical model using bare and dynamical polarization potentials. This method of calculation can be successfully applied to the reactions of deuteron with with heavy targets.

[43] New Measurements of the ^{19}F(p,α_0)^{16}O and ^{19}F(p,α_π)^{16}O* Reaction Cross Sections close to the Coulomb Barrier (17:20)

Presenter: REDIGOLO, Luigi (Università di Catania / INFN, Sezione di Catania, Italy)

We present new data for the ^{19}F(p,α_0)^{16}O and ^{19}F(p,α_π)^{16}O* reaction channels in the energy region close to the Coulomb barrier, thanks to a new experiment performed at the Singletron accelerator, in Catania (Italy). This measure allowed us to to extract new integrated cross section data and to reach two important goals: *i)* to solve an important discrepancy between pre-existing data sets at around 1.6 MeV of bombarding energy in the α_0 channel and *ii)* to add very needed new measured data for the α_π channel, in the E$_{beam}$ = 1.3 MeV region. The spectra obtained through these measurements, which had high energy resolution and signal-to-noise ratio, show an unprecedented separation of the peaks belonging to the 6.05-6.13 MeV doublet in $^{16 }$O. Moreover, in the framework of a comprehensive R-matrix fit of a database composed of the new data and previous reliable data-sets, we present a clarification of the spectroscopy of some of the resonances states populated through the present experiment, with the aim of finding some candidate to exhibit a quartet nature.

[66] Determination of Point Proton Radii of Neutron-Rich Nitrogen Isotopes (17:35)

Presenter: ROY, Aritra (SAINT MARY'S UNIVERSITY, HALIFAX, NOVA SCOTIA)

Exploring neutron-rich nuclei near the drip-line with significant N/Z asymmetry exposes exotic phenomena like the existence of neutron halo or skin and (dis)appearance of existing magic numbers. Nuclear halos result from spatial distribution of outermost neutrons, causing a low-density extended neutron surface and a notable increase in matter radius. A systematic study of the point proton radii along an isotopic chain reveals insight into the impact of the extended neutron wavefunction on protons. This work presents the first determination of the point proton radius for ^{23}N, as well as the radius of ^{21}N. The systematic study of $^{21-23}$N radii will be performed. The RI beams of $^{21-23}$N are produced via projectile fragmentation reaction after the primary beam of ^{48}Ca (345A MeV) interacts with a rotating ^{9}Be target at the BigRIPS facility at RIKEN Nishina Center in Japan. The charge-changing cross section (σ_{cc}) was measured with a carbon target placed at the final focal plane using the transmission technique. The ratio of the number of particles transmitted through the target without any loss of protons to the number of incoming particles provides the desired cross-section. The proton radii will be extracted from the measured σ_{cc} using the finite-range Glauber model framework. The proton radii derived from this study, combined with the previously reported significantly large matter radius of ^{23}N, offer valuable insights into the structural features of the neutron-rich isotope ^{23}N. As a result, the findings of this study promise to shed light on the presence of the N=16 magic number in the nitrogen isotopic chain.

[79] Investigation of the Proton Radius of the Neutron-Rich Borromean Halo Nucleus ^{19}B (17:50)

Presenter: PRAJAPATI, Divyang (Saint Mary's University, Halifax, Canada)

The Borromean structure of the dripline nucleus ^{19}B has garnered the attention of theories and experiments. The enigma is whether the structure of ^{19}B is '^{15}B core + 4n' or '^{17}B core + 2n'. The point proton radius (R_p) is an ideal measure for probing the structure of the nucleus. Further, a combined knowledge of R_p and the point matter radius enables us to understand the average distance between the core and halo neutrons and the distance between the halo neutrons. Some theoretical models predict a similar R_p for ^{19}B as its neighboring isotope ^{17}B, while others predict a significantly lower R_p than ^{17}B. Hence, experimental measurement of R_p leads to a conclusive understanding of the structure of ^{19}B. The measurement of the charge-changing cross-section (σ_{cc}) has emerged as a new method for probing the R_p of exotic nuclei. Therefore, the σ_{cc} of the ^{19}B nucleus was measured at RIBF, RIKEN using the BigRIPS and ZDS. The secondary beam of ^{19}B was produced via projectile fragmentation of a ^{48}Ca primary beam at 345A MeV on a ^{9}Be production target and identified using the $TOF-B\rho-\Delta E$ method. The σ_{cc} was measured with a carbon target. The presentation will describe the experimental details. Preliminary observations from the data analysis will be discussed. The radius that will be extracted from the measured cross-sections via Glauber model analysis will aid in understanding the evolution of neutron skin in ^{19}B and its Borromean structure. It will also help to resolve the conflicting theory predictions.

Nuclear Reactions II: NR 4 - Harmony A (16:40 - 18:10)

-Conveners: Grzywacz, Kate (University of Tennessee Knoxville)

[283] Reaction Studies with the Active Target Time Projection Chamber (16:40)

Presenter: BAZIN, Daniel (Michigan State University)

The Active Target Time Projection Chamber (AT-TPC) has been used in experiments aimed at the exploration of structural effects in radioactive nuclei using one step reactions such as transfer or elastic and inelastic scattering. When used as a solenoidal spectrometer by placing it inside a magnetic field, the AT-TPC allows to perform this type of measurement in inverse kinematics with much reduced beam intensities, down to 100 particles per second, while preserving a good resolution and a wide range of angular coverage. This presentation will showcase the performance of this detector, based on recent results obtained on nuclei in the beryllium to carbon region using pure proton, deuterium and alpha targets. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract No. DE-AC02- 06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility and used resources of the Facility for Rare Isotope Beams (FRIB) Operations, which is a DOE Office of Science User Facility under Award Number DE-SC0023633.

[6] Neutron and Proton Inelastic Scattering on ^{56}Fe: Insights from the GELINA-Geel and 9-MV Tandem-Bucharest Measurements (17:05)

Presenter: COMAN, Adina (Horia Hulubei National Institute for R&D; in Physics and Nuclear Engineering (IFIN-HH))

Recent investigations into the inelastic scattering cross sections of neutrons and protons off ^{56}Fe were conducted at the GELINA neutron source of the EC-JRC in Geel (Belgium) and at the 9 MV Tandem accelerator of IFIN-HH (Romania). For each reaction, distinct HPGe-based spectrometers were employed to determine the production cross section of the first transition in ^{56}Fe (E$_{\gamma}$=846 keV). At GELINA we used the GAINS spectrometer, incorporating 12 HPGe detectors, while at IFIN-HH we used two HPGe detectors. The GELINA neutron flux was monitored via a fission chamber with ^{235}U, while proton quantification at the Tandem was achieved using a Faraday Cup coupled to a high-precision charge integrator. During the talk we will present the two experimental setups and their particularities, the data analysis methodologies, and we will discuss the obtained results. Comparative analysis of our results with previously reported values and TALYS 1.96 theoretical predictions using standard parameters of the nucleon-^{56}Fe optical model potential will also be presented.

[116] First Test of MNT Reactions with Secondary Beams at the FRS Ion Catcher (17:20)

Presenter: MOLLAEBRAHIMI, Ali (Justus-Liebig-University Giessen and TRIUMF)

Studying exotic nuclei exhibiting an extreme ratio of neutrons to protons is the primary means for better understanding of fundamental nuclear properties, which is crucial to comprehend the formation and existence of heavy elements in our universe. Nevertheless, it is well understood that nuclei from certain regions on the chart of nuclei, i.e., heavier and more neutron-rich than the heaviest stable primary beams (^{238}U), will not be efficiently produced in commonly used production methods. However, the multinucleon transfer (MNT) reaction mechanism has been found to be the most promising pathway to reach this region. The MNT reaction may also be more efficient for the production of other heavy neutron-rich nuclei, e.g., $N=126$ nuclei relevant for the origin of the 3rd abundance peak in the r-process. The Super-FRS experiment collaboration is preparing to perform MNT experiments using both stable and secondary beams at FRS with the FRS Ion Catcher at GSI Helmholtz Centre in Germany in the summer of 2024. This contribution will present the plans and preliminary results of the performed experiments with MNT reactions using ^{238}U stable beams and the first test with secondary beams.

[166] First In-Beam Experiment in K500 Superconducting Cyclotron at VECC (17:35)

Presenter: RANA, Tapan Kumar (Variable Energy Cyclotron Centre)

The K500 Superconducting Cyclotron had been developed at Variable Energy Cyclotron Centre, Kolkata, for the basic nuclear physics experiment. Recently, the machine had delivered beam, for the first time, to the user for nuclear physics experiment. Detail characterization of the beams was performed with elastic scattering experiment with a 197Au target. Two independent approaches (one method by using the fold back position in a known thickness detector and other using the calibrated precision pulsar input voltages) have been used to estimate the beam energy and its energy resolutions. The estimated beam energy from both the approaches are found to be consistent with the energy calculated using the RF frequency of cyclotron. The energy spread was found to be around 0.2% including system resolution. Apart from the characterization of beam, one experiment has been carried out to study the fragment emission mechanism, systematically from low to high excitation energy of the composites; particularly the isospin equilibrium in fragment emission. For that, inclusive as well as exclusive energy and angular distributions of isotopes of the fragments emitted from the composites formed in 20Ne + 56Fe and 16O + 58Ni reactions have been measured at same excitation energy of the composites . Four silicon strip telescopes (each telescope made up of three elements; large area (50 by 50 mm2), ~50µm single sided silicon strip detector as DE then ~1000/1500µm double sided silicon detector as E/DE and finally backed by four CsI(Tl) detectors of thickness ~6cm as E) have been used to measure all the fragments. The details of the data analysis will be presented during the conference.

Nuclear Structure I: NS 2 - Ballroom B (16:40 - 18:10)

-Conveners: Quaglioni, Sofia (LLNL)

[353] Dipole Excitations in Nuclei (16:40)

Presenter: TSONEVA, Nadia (Extreme Light Infrastructure (ELI-NP), Horia Hulubei National Institute for R & D in Physics and Nuclear Engineering (IFIN-HH), 077125 Bucharest-Magurele, Romania)

Dipole strengths of direct and cascade transitions to GDR energies in medium and heavy atomic mass nuclei are investigated in a theoretical approach based on EDF theory and extended by multiphonon degrees QRPA [1]. Recent developments of the method, including a reaction theory [2,3], have been applied in spectroscopic studies of two-phonon states [4], pygmy and giant resonances [1-5], thus demonstrating its effectiveness and reliability. Besides the single-particle nature of the excited nuclear states from the PDR region, different properties of the low-energy dipole strength emerge from the analysis of inelastic photon-, proton- and alpha-scattering spectral distributions and branching ratios, from which the fine structure of the low-energy dipole strength can be probed and the role of quasicontinuum coupling [5]. Due to the latter, we observe a shift of the dipole strength from the low-energy GDR region to nuclear excitations below the neutron threshold, indicating a strong increase in the overall low-energy dipole strength. Experimentally, the determination of the dipole strength distribution and the associated photoabsorption cross section requires knowledge of the intensity distribution of the ground state transitions and their branching ratios. These quantities cannot be derived directly from the measured spectra. However, they can be determined theoretically from our microscopic calculations and thus support the experiment. [1] N. Tsoneva, H. Lenske, Phys.of At. Nucl.79, 885 (2016). [2] M. Spieker, et al., PRL125, 102503 (2020). [3] M. Weinert, et al., PRL127, 242501 (2021). [4] J. Isaak, et al., PRC108, L051301 (2023). [5] T. Shizuma, et al., PRC106, 044326 (2022).

[122] B(E2) Measurements in ^{28}Mg: Implications on the $N=20$ Island of Inversion (17:05)

Presenter: MARTIN, Matthew (Simon Fraser University)

In nuclei near the $N=20$ island of inversion, the non-central tensor components of the nuclear interaction drive the preferential population of pf-shell orbitals over the sd-shell orbitals predicted by the spherical shell model. High precision excited state lifetime measurements in nuclei across the Mg isotopic chain provide a means by which this evolution of neutron shells can be studied systematically and the onset of the island of inversion can be better understood. At TRIUMF, Canada's particle accelerator centre, an experiment was performed employing both the Doppler shift attenuation and recoil distance methods to precisely measure excited state lifetimes in ^{28}Mg with sensitivity ranging from tens of fs to a few ps. Using TIGRESS for gamma ray detection and TIP for charged particle detection and identification, lifetimes of eleven excited states were measured including those in the $(6^+_1) \to 4^+_1 \to 2^+_1 \to 0^+_{\mathrm{g.s.}}$ yrast band of ^{28}Mg. Corresponding transition strengths indicate a loss of collectivity in the yrast band of ^{28}Mg with increasing spin, allowing to distinguish between current theoretical predictions. These results also indicate that the Mg isotopic chain, and ^{28}Mg in particular, are key testing points for theoretical models which include the non-central tensor components of the nuclear interaction. In this talk, the implications of the measured transition strengths will be discussed in relation to the evolution of neutron shells across the Mg isotopic chain and the onset of the $N=20$ island of inversion.

[131] Higher-Lying Level Structure of 25Ne Probed via Fusion Evaporation (17:20)

Presenter: LONGFELLOW, Brenden (Lawrence Livermore National Laboratory)

The conventional magic number N=20 has been shown to break down in the region of neutron-rich nuclei centered around ^{32}Mg (Z=12, N=20) known as the N=20 Island of Inversion. At the same time, a new magic number at N=16 has been suggested to emerge around ^{24}O (Z=8, N=16). The neutron-rich nucleus ^{25}Ne (Z=10, N=15) lies in this zone of rapid change in nuclear structure. Consequently, its detailed spectroscopy can provide important benchmarks to probe the underlying mechanisms of shell evolution. The ongoing analysis of an ^{18}O on ^{9}Be fusion evaporation experiment using the state-of-the-art Gamma Ray Energy Tracking In-beam Nuclear Array (GRETINA) and the Fragment Mass Analyzer (FMA) at Argonne National Laboratory (ANL) will be presented. In this work, states in ^{25}Ne at high excitation energy were populated following the evaporation of two protons. By exploiting the significant degree of alignment in fusion evaporation, gamma-ray angular distribution and linear polarization analyses were performed to obtain information on the multipolarities of the observed transitions, clarifying the ^{25}Ne level scheme. Shell model calculations using the FSU multishell effective interaction show good agreement with the experimental results. Prepared by LLNL under Contract DE-AC52-07NA27344. For the Argonne Experiment 1883 collaboration.

[1] Lifetime Measurement of the 0^+_3 State in ^{120}Sn (17:35)

Presenter: WU, Frank (Tongan) (Simon Fraser University)

The semi-magic $^{120}_{50}$Sn$_{70}$ lies in the neutron mid-shell among the other stable Sn isotopes, where $2p-2h$ intruder configurations built on excited 0$^+$ states have been recently observed. However, the transition rates from the 0^+_3 state in ^{120}Sn are not well-known because its lifetime only has a lower limit of 6 ps, which prevents a firm assignment or exclusion of the 0^+_3 state into the intruder band. The first thermal neutron capture experiment, ^{119}Sn(n,γ^many)^{120}Sn, was performed at the Institut Laue-Langevin, where the world's highest-flux thermal neutron beam was delivered at 10^8 n/cm^2/s at the target position on an isotopically enriched ^{119}Sn target. Low-spin states in ^{120}Sn were populated up to $S_n=9.1$ MeV, and the decaying gamma-ray cascades were detected with the Fission Product Prompt Gamma-ray Spectrometer (FIPPS) comprised of eight Compton-suppressed HPGe clovers coupled to an array of 15 LaBr$_3$(Ce) scintillation detectors. The LaBr$_3$(Ce) scintillators, which were used for gamma-ray detection and lifetime measurement using the Mirror Symmetric Centroid Difference (MSCD) method, have fast timing responses and are ideal for extracting lifetimes between 10 and a few hundred ps. In total, there are 4×10^9 counts in the $\gamma\gamma\gamma$ cube where two LaBr$_3$(Ce) events were in coincidence with one HPGe. Preliminary lifetimes in ^{120}Sn using the MSCD technique will be reported.

Reception (18:30 - 20:00)

Tuesday, 20 August 2024

Plenary (08:30 - 10:30)

-Conveners: Tribble, Robert (TAMU)

[186] Nuclear Reaction Experiments at TRIUMF-ISAC (08:30)

Presenter: RUIZ, Chris (TRIUMF)

The ISAC (Isotope Separator and Accelerator) Facility at TRIUMF contains two room temperature & one superconducting linear accelerators able to provide rare isotope beams from 0.107 to 16.5 MeV/u, enabling reaction studies from well below the Coulomb barrier to far above it, accessing fusion-evaporation or highly-peripheral transfer reactions. Coupled with a suite of experimental facilities including a recoil separator (DRAGON), recoil spectrometer (EMMA), Compton-suppressed gamma-ray array (TIGRESS), charged particle scattering devices (TUDA, SONIK, SHARC) and a solid hydrogen target facility (IRIS), a diverse program of nuclear reaction studies has been pursued. These range from direct and indirect cross section (or lifetime or branching ratio) measurements for nuclear astrophysics, to the study of nuclear shell evolution near the drip lines and islands of inversion, nuclear pairing, nuclear halo, cluster, or sub barrier fusion enhancement studies. These include the usage of devices brought by external users such as active target TPCs or custom reaction arrays. Recently effort has also been spent on reaction & scattering studies related to in-house ab initio nuclear theory calculations. For this broad program I will give an overview of the facility and experimental stations and a summary of recent scientific results using radioactive and stable beams, with a hint of forthcoming upgrades or new directions.

[281] Jets in Heavy-Ion Collisions (09:00)

Presenter: CHEN, Yi (Vanderbilt University)

Heavy-ion collisions have been a fascinating venue to study Quantum Chromo-Dynamics (QCD), the theory of strong nuclear force, under extreme conditions. When the nuclei collide, an exotic phase of matter, the quark-gluon plasma (QGP), is created. The QGP is believed to have existed in the early universe microseconds after the Big Bang. Jets, sprays of particles originating from high-energy quarks or gluons, are one of the exciting probes of heavy-ion collisions due to their extended size and nontrivial colored interaction with the hot medium. The study of jets in heavy-ion collisions provides insights into the underlying interaction mechanisms between jets and the QGP, shedding light on the properties of the medium itself. In this talk, I will summarize some of the latest results from jet studies in heavy ion collisions, what we have learned from them, and where we might go from here.

[130] Pursuing New Superheavy Elements: Progress Update from Berkeley Lab (09:30)

Presenter: GATES, Jacklyn (Lawrence Berkeley National Laboratory)

In the past two decades, significant progress has been made with the discovery of elements Z=114-118 through reactions between 48Ca beams and actinide targets, achieving production rates of atoms-per-day or more. Unfortunately, the pursuit of elements beyond Oganesson (Z=118) faces substantial challenges. The synthesis of elements with Z=119 or 120 using 48Ca would necessitate targets of Es (Z=99) or Fm (Z=100), but these elements cannot be produced in sufficient quantities. This limitation necessitates exploring new reaction pathways. Numerous theoretical studies have aimed at predicting production rates for new elements using actinide targets and heavier ion beams. While these models reliably reproduce excitation functions for SHE production with 48Ca beams, predictions diverge significantly for reactions involving heavier beams. For instance, the predicted cross section for reactions to produce Z=120 vary by more than three orders of magnitude and tens of MeV. These discrepancies hinder experimental efforts, as the low expected cross sections suggest the detection of only one event every few weeks or months under ideal conditions. Berkeley Lab has been proactively addressing these challenges to push beyond E118. By testing theoretical predictions, we have begun the 50Ti+244Pu experiment to understand the impact of using 50Ti instead of 48Ca beams on cross sections. This presentation will highlight significant upgrades to our experimental facilities, including ion sources, target setups, detectors, and electronics, aimed at enhancing our capability to produce and detect elements beyond E118. We will also present the initial results from the 50Ti+244Pu experiment, showcasing our progress in this ambitious endeavor. Financial Support was provided by the Office of High Energy and Nuclear Physics, Nuclear Physics Division, and by the Office of Basic Energy Sciences, Division of Chemical Sciences, Geosciences and Biosciences of the U.S. Department of Energy, under Contract No. DE-AC02-05CH11231

[214] Spectroscopy of Neutron-Rich Nuclei Produced in Multinucleon Transfer Reactions at KISS (10:00)

Presenter: WATANABE, Yutaka (WNSC, IPNS, KEK)

Multinucleon transfer (MNT) reactions have recently gained renewed interest as they provide access to heavy neutron-rich (n-rich) nuclei, particularly around N = 126 and actinides, which are relevant to r-process nucleosynthesis [1]. They produce a wide variety of nuclides around both the projectile and the target, with a wide distribution of angles and energies, requiring the development of experimental techniques to collect, separate, and identify the reaction products of interest. In particular, exotic nuclei far from the projectile or target are produced so infrequently that they can get buried among more abundant reaction products. Furthermore, for short-lived nuclei of less than a few minutes, rapid separation becomes important. We are developing the KEK Isotope

Separation System (KISS) at the RIKEN Nishina Center, which focuses on the extraction of MNT reaction products [2]. It is an argon-gas-cell-based laser-ion-source coupled with an isotope separator on-line system. The MNT reaction products are thermalized and neutralized in argon gas, element-selectively ionized, and mass-separated by a magnetic field. We perform decay, mass, and laser spectroscopy of n-rich nuclei of refractory elements around the N = 126 region. A multi-reflection time-of-flight mass spectrograph is used for high-precision mass measurements and unique identification of isobars. Recently, research has been extended to mass spectroscopy of n-rich actinides by using a 238U beam. We will report on the experimental methods and results of KISS, as well as our next plan for further n-rich regions. [1] Y.X. Watanabe et al., PRL 115, 172503 (2015). [2] Y. Hirayama et al., NIM B 353, 4 (2015).

Coffee Break (10:30 - 11:00)

Plenary (11:00 - 12:30)

-Conveners: Garg, Umesh (University of Notre Dame)

[236] Recent Nuclear Structure Studies with Gamma-Ray Spectroscopy (11:00)

Presenter: LENZI, Silvia M. (University of Padua and INFN)

A comprehensive picture of nuclear structure results from the complementary information obtained at the different facilities by means of a variety of nuclear reactions and complex experimental setups. Gamma-ray spectroscopy is the ideal tool to obtain detailed information on different nuclear properties. The coupling of gamma-arrays to particle detectors has increase enormously the selective power. In the recent years, the experimental research has explored different regions of the nuclear chart far from stability, allowing to test theoretical predictions and, in other cases, challenging theory with unexpected observations. A selection of recent experimental results obtained at different facilities will be presented together with the theoretical interpretation.

[257] Nucleon Spin Structure (11:30)

Presenter: EYSER, Oleg (Brookhaven National Laboratory)

The partonic structure of the proton has been established in deep inelastic scattering and a detailed picture of the nucleon has emerged from a wide range of experiments and global analyses. Hadronic collisions allow direct access to the gluon content in the nucleon and polarized beams introduce an additional degree of freedom, spin, which is naturally connected to parton kinematics. Polarized proton collisions at the Relativistic Heavy Ion Collider (RHIC) at BNL have, for the first time, established a significant contribution of the gluon spin to the spin of the proton. They have similarly improved our knowledge of the sea quark polarization. In addition, transverse spin phenomena are enabling studies of transverse momentum dependent distribution functions and spin-orbit correlations beyond a one-dimensional image of the nucleon. At the same time, they are closely linked to questions about universality of the process dependence of color exchanges, factorization, and possibly saturation effects a very small partonic momenta. These questions will be especially important in the context of the future Electron-Ion Collider.

[295] Determination of the Equation of State from Nuclear Experiments and Neutron Star Observations (12:00)

Presenter: TSANG, Betty (FRIB)

Nuclear experiments become the latest ‘messenger’ to help with unravelling the mysteries of neutron stars. Combining information from astronomical observations and laboratory experiments reveals how nucleons interact in both nuclei and stars. In this talk, I’ll review the current status of the Equation of State obtained from experiments and astrophysics constraints and how they compare to ab initio and modern theoretical calculations.

Lunch Break (12:30 - 14:00)

Plenary (14:00 - 14:30)

-Conveners: Dillmann, Iris (TRIUMF)

[310] Ultra-Sensitive Accelerator Mass Spectrometry for Detection of Interstellar Fe-60, Hf-182 and Pu-244 (14:00)

Presenter: WALLNER, Anton (HZDR)

Earth is exposed to nearby cosmic events. Freshly produced radionuclides in the interstellar medium contain information about how and where the heavy elements are made in nature. The solar system moves through the interstellar medium (ISM) and collects interstellar dust particles that contain fresh nucleosynthetic signatures, including the radionuclides Fe-60 (t$_{1/2}$=2.6 Myr) and Pu-244 (t$_{1/2}$=81 Myr). These nuclides are incorporated into terrestrial archives over millions of years. Detection of interstellar nuclides remains extremely challenging and so far was successful only with Accelerator Mass Spectrometry (AMS). Recent technical developments have seen an exceptional gain in measurement efficiency and sensitivity, in particular for actinides, including Pu-244 and more recently for Hf-182 (t$_{1/2}$=9 Myr). On the other hand, very large accelerators with >10 million volts are required for the identification of small traces of interstellar Fe-60. Recent data demonstrate a global Fe-60 influx and is evidence for exposure of Earth to recent (<10 Myr) supernova explosions. In addition, first evidence of ISM-Pu-244 presence in deep-sea archives, an actinide nuclide exclusively produced by the r-process, supports the hypothesis that the dominant heavy element r-process nucleosynthesis is rare. Besides new data for the direct search for interstellar signatures I will also present preliminary results of recent laboratory measurements using AMS for understanding Fe-60 and Hf-182 production in massive stars - both nuclides predominantly produced via double neutron capture reactions.

Equation Of State: EOS 2 - Ballroom B (14:40 - 16:10)

-Conveners: Sorensen, Agnieszka (Institute for Nuclear Theory, University of Washington)

[37] Nuclear Incompressibility and the Asymmetry Term from Measurements of the Giant Monopole Resonance in Neutron-Rich Nuclei (14:40)

Presenter: GARG, Umesh (University of Notre Dame)

The nuclear incompressibility parameter, K$_{\infty}$, is an important component characterizing the nuclear equation of state, with crucial bearing on diverse nuclear and astrophysical phenomena. The only direct experimental measurement of this quantity comes from the compression-mode giant resonances--the isoscalar giant monopole resonance (ISGMR) and the isoscalar giant dipole resonance(ISGDR). In this talk, I will review the current status of determination of nuclear incompressibility, especially the asymmetry term, K$_{\tau}$, and discuss some recent and forthcoming measurements on neutron-rich nuclei, including on ^{132}Sn at FRIB. This work has been supported in part by the U. S. national Science Foundation (Grant No. PHY-2310059).

[113] PREX/CREX: Neutron Skins and Nuclear Symmetry Energy (15:05)

Presenter: MAMMEI, Juliette (University of Manitoba)

PREX 2 and CREX, recently completed at Jefferson Lab in Newport News, Va, measured the weak form factors of lead and calcium. The PREX 2 result has confirmed that the neutron skin of lead is relatively large and has provided a precise determination of the interior baryon density of a heavy nucleus. The CREX measurement was performed at a non-optimal momentum transfer and has produced a result which is puzzling, given the PREX 2 result. The measured form factor in PREX 2 can be related to various nuclear and neutron-star properties and the CREX result has inspired some discussion within the community. I will present a summary of both experiments and their results.

[55] Cluster Production Dynamics in Xe+Sn Collisions from 32 and 150 MeV/Nucleon (15:30)

Presenter: CHBIHI, Abdou (GANIL)

Heavy-ion collisions is a unique tool for studying thermodynamical properties of nuclear matter. In particular, the study of clusters is a key ingredient in better understanding and constraining the nuclear equation of state. During the collision, the system is expected to undergo a compression followed by expansion, while a copious number of light and intermediate clusters are emitted [1]. Nevertheless, it is still unclear whether clusters formation is favored during the compression or expansion phase. A better understanding of cluster production is also crucial when modeling compact astrophysical objects. The present work will focus on the systematic characterization of clusters formed during Xe+Sn collisions, at incident energies between 32 and 150 MeV/nucleon. These data were measured with the INDRA multidetector array. They are compared with a semi-classical model, ELIE[2] and also BUU[3]. We will first characterize the participant zone in Xe+Sn collisions. This zone is expected to emit clusters, which may reflect the conditions of the nuclear medium at the time of their formation. Isospin effects will be of particular interest. The second part of this analysis focuses on the dynamic characterization of clusters in the participant zone. We find that the maximum densities deduced from the kinetic energy of the clusters largely exceed the saturation density $\rho 0$, up to 2 $\rho 0$, for an incident energy of 150 MeV/nucleon. These results are compatible with those of transport models[3]. [1] A. Ono, Prog. Part. Nucl. Phys., 105 139 (2019). [2] D. Durand, Technical Report arXiv :0803.2159 (2008). [3] S. Mallik et al., Physical Review C, 91 044614 (2015).

[50] (Zoom) Machine Learning Transforms the Inference of the Nuclear Equation of State (15:45)

Presenter: WANG, Yongjia (Huzhou University)

Our knowledge of the properties of dense nuclear matter is usually obtained indirectly via nuclear experiments, astrophysical observations, and nuclear theory calculations. Advancing our understanding of the nuclear equation of state (EOS, which is one of the most important proper□ties and of central interest in nuclear physics) has relied on various data produced from experiments and calculations. In this talk, I will review how machine learning is revolutionizing the way we extract EOS from these data, and summarize the challenges and opportunities that come with the use ofmachine learning.

Hot & Cold QCD: QCD 3 - Wedgemount (14:40 - 16:10)

-Conveners: Ruan, Lijuan (BNL)

[111] Lattice QCD & Relativistic Heavy-Ion Collision Phenomenology (14:40)

Presenter: KARTHEIN, Jamie (Massachusetts Institute of Technology)

In this talk, I will describe first-principles-based equations of state (EoSs) for QCD that serve as crucial input for simulations of hot, dense strongly-interacting matter. The first is solely informed by the fundamental theory by utilizing all available diagonal and off-diagonal terms that contribute to the Taylor expansion of the pressure up to $\mathcal{O}(\mu_B^4)$. This allows for the reconstruction of a full EoS that depends on all three conserved charge chemical potentials namely baryon number, electric charge, and strangeness. For the second, we go beyond information from the lattice in order to explore the conjectured phase structure, not yet determined by Lattice QCD methods. We incorporate critical features into the EoS by relying on universal scaling behavior. This allows for the study of the effects of such a singularity on the thermodynamical quantities that make up the equation of state. Additionally, we ensure that these EoSs are valid for applications to heavy-ion collisions via constraints on the conserved charge chemical potentials that yield strangeness neutrality and fixed electric-charge-to-baryon-number ratio of 0.4, as these are the conditions in the laboratory.

[90] Toward Extracting the Scattering Phase Shift from Integrated Correlation Functions in LQCD (15:05)

Presenter: GUO, Peng

In this presentation, I will show how the difference of interacting and non-interacting integrated two-particle correlation functions in finite volume is related to infinite volume scattering phase shift through an integral weighted by a factor exp(-Et). The difference of integrated finite volume correlation functions converge rapidly to its infinite volume limit as the size of periodic box is increased, which offers a suitable framework to overcome the challenges that the Luscher formula faces at large volume limit.

Nuclear Astrophysics: NA 3 - Garibaldi B (14:40 - 16:10)

-Conveners: Lotay, Gavin (University of Surrey)

[294] Probing Heavy Element Nucleosynthesis Through Electromagnetic Observations (14:40)

Presenter: MARTÍNEZ-PINEDO, Gabriel (GSI Darmstadt and TU Darmstadt)

Half of the elements heavier than iron are produced by a sequence of neutron captures, beta-decays and fission known as r-process. It requires an astrophysical site that ejects material with extreme neutron rich conditions. Once the r-process ends, the radioactive decay of the freshly synthesized material is able to power an electromagnetic transient with a typical intrinsic luminosity. Such kilonova was observed for the first time following the gravitational signal GW170817 originating from a merger of two neutron stars. This observation answered a long lasting question in nuclear astrophysics related to the astrophysical site of the r-process. In this talk, I will summarize our current understanding of r-process nucleosynthesis. I will also illustrate the unique opportunities offered by kilonova observations to learn about the in-situ operation of the r-process and the properties of matter at extreme conditions. Achieving these objectives, requires to address fundamental challenges in astrophysical modeling, the physics of neutron-rich nuclei and high density matter, and the atomic opacities of r-process elements required for kilonova radiative transfer models. Finally, I will introduce a new nucleosynthesis process, the νr-process, that operates in ejecta subject to very strong neutrino fluxes producing p-nuclei starting from neutron-rich nuclei. It may solve a long standing problem related to the production of ^{92}Mo and the presence of long-lived ^{92}Nb in the early solar system.

[94] Improving the Theoretical Description of β-Decay Half-Lives for Nuclear r-Process (15:05)

Presenter: RAVLIC, Ante (Facility for Rare Isotope Beams, Michigan State University)

The rapid neutron capture process (r-process) is responsible for creating more than half of the nuclei heavier than iron. Through a series of neutron captures, r-process facilitates the creation of neutron-rich nuclei up to the neutron drip line. A theoretical input for the description of this process requires knowledge of nuclear masses, neutron capture mechanisms, α-decays, induced fission rates and yields, β-decay rates, as well as β-delayed neutron capture rates, from the vicinity of the stability valley to the neutron drip line. Due to huge extrapolations involved, however, any theoretical model faces significant challenges when making predictions toward the neutron drip line. The nuclear energy density functional theory (NEDFT) is an effective model for evaluating required theoretical inputs. With a goal to describe all nuclear data essential for r-process within the NEDFT, in this work, we focus on β-decay rates. The β-decay rates are evaluated within the relativistic NEDFT framework. First, the axially-deformed covariant Hartree-Bogoliubov theory based on point-coupling interactions is employed to determine the nuclear ground state, and the excitations are described within the linear response quasiparticle random-phase approximation (pnQRPA). Calculations are performed throughout the nuclear landscape for $8 \leq Z \leq 120$ and employed in r-process simulations to obtain nuclear abundance patterns. Uncertainties of the model are calculated using the emulators based on the reduced basis methods (RBMs). The preliminary results of our simulations will be presented.

[216] Nuclear Fission of Neutron-Rich Nuclei Based on Dynamical Calculations for r-Process Nucleosynthesis (15:20)

Presenter: NISHIMURA, Nobuya (RIKEN)

Nucleosynthesis by the rapid neutron-capture process (r-process) represents the cosmic origin of the heaviest elements (e.g., gold and uranium) beyond iron. Nuclear fission plays a key role in terminating the r-process path toward heavier elements and determining the final abundance pattern due to fission products. Additionally, fission serves as a heating source for kilonovae at late times ($\sim$ 10 days to months) and electromagnetic transients of neutron star mergers (one event observed with gravitational waves from GW170817). However, experimental data on nuclear fission in the neutron-rich region are scarce. In this study, we calculated the fission fragment mass distributions of highly neutron-rich nuclei. In this study, we utilized Langevin equations to explore fission dynamics based on a widely adopted dynamical model for low-energy fission. By integrating Langevin calculations with a statistical model, we determined independent yields and prompt neutron emissions. Our calculated fission fragment mass distributions revealed a significant change in fission mode as the mass number increased. This systematic behavior can profoundly influence the final abundances in r-process calculations. Furthermore, our calculated prompt neutron emission multiplicities accurately reproduced the sawtooth structure observed in ^{236}U experimental data. The change in fission mode also affects the neutron emission multiplicities, with more neutron-rich isotopes emitting fewer neutrons around the transition region. Leveraging our fission calculations, we further discuss their implications for astrophysical r-process nucleosynthesis

[238] Illuminating Astrophysical Actinide Production Using MeV Gamma-Rays and Metal-Poor Stars (15:35)

Presenter: VASSH, Nicole (TRIUMF)

Fingerprints of the properties of exotic nuclei on nucleosynthesis observables have been used for decades to frame our picture of how the heaviest elements in our Solar System came to be. The abundance of elements in our Sun, as well as nearby metal-poor stars, hints at multiple neutron capture nucleosynthesis processes, the slow (s), intermediate (i) and rapid (r) neutron capture processes. While the s-process terminates its heavy element production at Pb-208, we know that the r-process or i-process must be capable of going beyond since we observe long-lived actinides like U-238 in stars and traces of Cm-247 in meteorites. However which astrophysical site(s) are responsible for actinide production, and how heavy of actinides ultimately can be produced, remains unclear. Utilizing metal-poor stars rich in r-process elements, we show that signatures of fission fragments of isotopes with A~260 can be observed [1]. Then, utilizing MeV gamma-rays, we show that a 2.6 MeV emission line of Tl-208 could be used to hunt locally for in situ neutron capture nucleosynthesis, from both i-process and r-process sources [2]. I will also discuss the opportunity to refine our understanding through measurements at radioactive isotope beam facilities in the near future, such as constraints on neutron captures along the Tl isotopic chain. It is via studies such as these, which work to combine the current picture of leading astrophysical candidates with carefully considered nuclear data, that the big picture of heavy element origins can be teased out. [1] Roederer, Vassh, et al. Science 382, 6675, 1177-1180, Dec 2023 [2] Vassh, Wang, Lariviere, et al. Phys.Rev.Lett. 132, 052701, Jan 2024

[346] SiRoP Implementations: The Alpha Process, Mass Models and Sensitivity Analysis (15:50)

Presenter: TRUJILLO, Jose (UNIVERSITY OF CALGARY)

The r-process nucleosynthesis (in explosive astrophysical events) is responsible for about half of the heavy elements observed in the universe. However, r-process outputs in the literature are difficult to replicate and vary across studies due to differences in nuclear mass models or initial conditions (e.g., seed nuclei). I will discuss why a thorough sensitivity analysis is required to assess the degree of agreement between r-process trajectories predicted by different nuclear mass models and the observed abundances. I will review the SiRoP code for r-process nucleosynthesis, which now includes (i) an alpha-capture module that allows for a variety of initial conditions of the r-process, (ii) a mass-model module that allows changes in nuclear properties, and (iii) a nuclear sensitivity module to test how closely the r-process trajectories from different nuclear mass models align with observed heavy element abundances.

Nuclear Reactions I: NR 5 - Rainbow Theatre (14:40 - 16:10)

-Conveners: Kay, Benjamin (Argonne National Laboratory)

[219] Surrogate Reactions: Concepts and Recent Advances (14:40)

Presenter: ESCHER, Jutta (Lawrence Livermore National Laboratory)

Obtaining reliable data for nuclear reactions on unstable isotopes remains an important task and a formidable challenge. Cross sections for neutron-induced reactions are particularly elusive, as both projectile and target are unstable. Various indirect methods have been proposed to address this problem. The 'surrogate reaction method' [1] uses inelastic scattering or transfer ('surrogate') reactions to produce the compound nucleus of interest and measure its subsequent decay. When combined with a proper theoretical description of the reaction mechanisms that produce the compound nucleus, it is possible to extract the desired cross section from this indirect decay data [2]. I will illustrate the procedure for obtaining (n,g), (n,n'), and (n,2n) cross sections and present results for both known (benchmark) and unknown reactions. The method makes no use of auxiliary constraining quantities, such as neutron resonance data, or average radiative widths, which are not available for short-lived isotopes; thus it can be applied to isotopes away from stability. I will discuss key challenges for applying the method and highlight new opportunities. [1] Escher et al, Rev. Mod. Phys. 84, 353 (2012). [2] Escher et al, PRL 121, 052501 (2018), Ratkiewicz et al, PRL 122, 052502 (2019), Perez Sanchez et al, PRL 125, 122502 (2020). This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Support from the Laboratory Directed Research and Development Program at LLNL, Projects No. 19-ERD-017, 20-ERD-030, 21-LW-032, 22-LW-029, 23-SI-004, and 24-ERD-023 is acknowledged.

[47] First Experimental Test of the Ratio Method (15:05)

Presenter: CAPEL, Pierre (Johannes Gutenberg Universität Mainz)

The ratio [1,2] is a new reaction observable suggested to extract accurately structural information on halo nuclei. It is based on the Recoil Excitation Breakup (REB) model [3], which predicts that taking the ratio of angular distributions for breakup and scattering, the uncertainty related to the reaction dynamics is strongly reduced [1,2]. It exhibits a much better accuracy than traditional methods, such as Coulomb breakup. We present here the first experimental test of the method for the ^{11}Be + ^{12}C collision at Elab=20 MeV/u. The experiment was performed at Texas A&M University cyclotron. Angular differential cross sections for scattering and inclusive one-neutron breakup cross sections have been measured with the new Si + phoswich detector array, BlueSTEAl [4], at θcm =10°–30°. The ratio of the inclusive breakup to elastic cross sections is, as predicted, very smooth and independent of the projectile-target interaction. This demonstrates the validity of the new method. We have extended our analysis to ^{11}Be + ^{208}Pb data [5], confirming that the method works well both for nuclear- and Coulomb-dominated reactions. This augurs well for our plan to extract accurate structure information of further exotic halo nuclei at FRIB. References: [1] P. Capel, R. C. Johnson, and F. M. Nunes, Phys. Rev. Lett. B705, 112 (2011). [2] P. Capel, R. C. Johnson, and F. M. Nunes, Phys. Rev. C 88, 044602 (2013). [3] R. C. Johnson, J. S. Al-Khalili, and J. A. Tostevin, Phys. Rev. Lett. 79, 2771 (1997). [4] S. Ota et al., Nucl. Instr. Meth. A 1059, 168946 (2023). [5] F. F. Duan et al., Phys. Rev. C 105, 034602 (2022).

[209] Interaction and Charge-Changing Cross Sections of Neutron-Rich Cu Isotopes, and Derivation of Proton and Neutron Distribution Radii (15:20)

Presenter: TAKAYAMA, Gen (Osaka Univ.)

Determining the equation of state (EoS) for nuclear matter is essential in order to understand the macroscopic properties of nuclear matter in equilibrium states in both finite systems (nuclei) and infinite systems (neutron stars). The purpose of this study is to derive the density-dependent parameter L of the symmetry-energy term of the EoS from the isotope dependence of neutron skin thickness. To this end, we measured the interaction cross sections and the charge-changing cross sections of 61-79Cu at 260 MeV/u using the BigRIPS fragment separator at the RIBF, RIKEN. The matter radius were derived from the interaction cross sections, and then the neutron skin thicknesses were obtained from the derived matter radii incorporating the point-proton radii. While the existing point-proton-radius data were used for 61-78Cu [ref1], the point-proton radius was derived from the present charge-changing cross section result for 79Cu. The L parameter was deduced from the neutron skin thicknesses of 61-79Cu. In addition to the interest in nuclear matter property, these data would also take us to discuss the nuclear structure. The staggering of odd-even nuclei in the charge radius has been a long-standing unresolved issue [ref1]. The odd-even staggering of matter radii for 61-79Cu was also studied based on the present results. [ref1] R. P. de Groote, et al., Nature Phys. 16, 620-624 (2020)

[145] Anisotropic Momentum Distribution of Projectile-Like Fragments with ${\Delta}A=1$ Observed at around 100 MeV/Nucleon (15:35)

Presenter: MOMOTA, Sadao (Kochi University of Technology)

The projectile fragmentation reaction is crucial in experimental studies that use radioactive nuclear beams. The isotropic momentum (P) distribution of produced fragments, which is observed at relativistic energies, is reasonably explained by a simple model based on the Fermi motion of nucleons in a projectile [1]. At lower energies around 100 MeV/nucleon, the contribution of reaction processes with frictional effects [2] and of internuclear potentials increases, causing anisotropy in P

distributions. However, most of the previous studies were limited to examining reaction processes with frictional effects based on empirical formulas, and there were few quantitative studies based on fundamental reaction processes. In this paper, *P* distribution of fragments with small mass change (${\Delta}A=1$) is experimentally examined to disclose reaction processes and internuclear potentials contributing to the fragmentation reaction. The longitudinal (P_L) and transverse (P_T) momentum distributions of fragments produced from ^{12}C and ^{40}Ar beams and targets with a wide range of masses at 100 and 200 MeV/nucleon were observed. For a comprehensive understanding of the observed P_L and P_T distributions, (1) the two-step reaction channel consisting of the abrasion and transfer processes [3] and (2) the contribution of attractive nuclear potentials [4] were found to be important factors. References [1] A. S. Goldhaber, Phys. Lett. 53B, 306-308 (1974). [2] M. Notani *et al*., Phys. Rev. C 76, 044605 (2007). [3] G.A. Souliotis *et al*., Phys. Rev. C 46, 1383-1392 (1992). [4] S. Momota *et al*., Phys. Scr. 98, 085301 (2023).

[132] Study of Tensor Correlations in High-Momentum Nucleon via 16O(p,dN) Reaction (15:50)

Presenter: TERASHIMA, Satoru (Institute of Modern Physics, Chinese Academy of Sciences)

The isospin character of the p-n pair at large relative momentum has been observed for the first time in the 16O ground state. We have measured the 16O(p,dp) and 16O(p,dn) cross sections for the neutron pick-up domain with 392 MeV incident proton at RCNP. The outgoing deuteron was momentum analyzed by the high-resolution spectrometer GrandRAIDEN. Recoiled nucleons N [p or n] were measured by plastic scintillator telescopes and the newly developed stacked neutron detector BOS^4[1], which were placed opposite to the spectrometer at angles corresponding to the recoilless condition for a residual nucleus. The momentum transfer covers higher than 1.4 fm^{-1}, thus picking up the high-momentum neutrons correlated with protons in nuclei. In the (p,dp) reaction, the final states of 14N were clearly identified by deuteron and proton coincidence measurements. Although those states were almost equally populated in low momentum transfer reactions, we observed a strong population of J, T=1,0 state in 14N but a very weak population of J, T=0,1 state [2]. In the neutron channel 16O(p,dn)14O of T=1, the observed cross section was found to be also strongly suppressed. The observed strong isospin dependence in the p-n pair indicates the presence of a high-momentum neutron by the tensor interaction in the 16O ground state. The new measurement at 230 MeV was conducted recently at RCNP to investigate the phenomena in the momentum space. In this talk, we will present new results of the experiment with 16O(p,dN) and discuss future prospects for the study of tensor interactions. [1] L.Yu, S.Terashima et al., Nucl.Inst.A866(2017)118 [2] S.Terashima et al., Phys.Rev.Lett.121, 242501(2018)

Nuclear Reactions II: NR 6 - Harmony A (14:40 - 16:10)

-Conveners: Doornenbal, Pieter (RIKEN)

[339] Physics Opportunities with Relativistic Rare Ion Beams at R3B (14:40)

Presenter: CORTINA GIL, Dolores (Instituto de Física Corpuscular IFIC (CSIC-UV))

Since its inception, nuclear physics has used nuclear reactions to deepen our understanding of a quantum system as complex as the atomic nucleus. The arrival of the FAIR beams, in particular the improvement in the intensity delivered, and the development of state-of-the-art instrumentation, open up a wide range of possibilities for carrying out frontier experiments. R3B is a scientific collaboration of FAIR working towards the realization and exploitation of an instrument characterized by the excellent resolution and high acceptance of its detectors. Located after the Super-FRS at the end of the High Energy Branch of this facility, it will receive exotic isotopes of all chemical elements, from hydrogen to uranium, moving at energies around 1 A GeV. Nuclear reactions induced by these projectiles, in conditions of complete and inverse kinematics, will allow us to explore the limits of the nuclear shell model, to investigate exotic (baryonic and strange) nuclear systems and to reproduce in the laboratory some relevant astrophysical scenarios as neutron stars. In this talk we will give an overview of the scientific program of R3B, the first experimental results obtained during FAIR Phase-0 and future perspectives.

[343] Studying Fission Cross Sections near 198Pb with Rare Isotope Beams (15:05)

Presenter: LYNCH, William (FRIB and the Dept. of Physics and Astronomy Michigan State Univ.)

In the region of the neutron deficient pre-actinides, around 198Pb and 180Hg, there is an unexpected island of asymmetric fission. That these asymmetric fission decay modes evaded detection until recently, but now are feasible, is a testament to the capabilities of rare isotope facilities. To develop a method to determine fission barriers for rare isotopes and to study the transition between symmetric and asymmetric fission near 198Pb, rare isotopes were produced in the A1900 separator at the NSCL and fused with 4He target nuclei in the Active Target Time Projection Chamber (AT-TPC). In the experiment, the incident rare isotope beam particles were isotopically identified by the HEavy ISotope Tagger (HEIST), which allow the identification of the fissioning nucleus on an event by event basis. A combination of analytical and machine learning methods allowed the identification of fission events. The stopping power of the beam particles in the helium gas has been measured by analyzing the Z and velocity of fission fragments at large folding angles. These experimental techniques and the energy dependence of isotopically resolved fusion fission cross-sections will be presented. Preliminary fission barriers extracted from the cross sections will also be presented.

[70] Probing the Pygmy Dipole Resonance of 50Ca by Coulomb Excitation (15:30)

Presenter: LEMARIE, Julien (RIKEN - JSPS)

Astrophysical objects such as neutron star formation and structure and supernovae explosion, as well as nuclei properties and structure are described using the equation of state of nuclear matter. However, the coefficients of the equation state describing the nuclear matter with a huge charge asymmetry, notably the symmetry energy, is lacking constraints [1,2]. When a medium-to-heavy neutron-rich nuclei near the neutron drip-line is submitted to an external electric field, its response is concentrated in the Giant Dipole Resonance (GDR) and particularly in its low lying part, referred as the Pygmy Dipole Resonance (PDR). The electric dipole polarizability aD, which represents the inversely energy-weighted sum of dipole strength, allow to quantify this response. Neutron skin presents a strong correlation to symmetry energy and can be constrained through the use of aD [3,4], and theoretical calculation has shown that the PDR strength has a rapid increase with the neutron number number in the range $15 < N \leq 16$, $28 < N \leq 34$, and $50 < N \leq 56$ [5]. In this context, both 50Ca and 52Ca, who respectively have 30 and 32 neutrons, has been a subject to experimental investigation: they were produced in flight at RIBF – RIKEN and they have been submitted to coulomb excitation using a 208Pb target in order to probe the neutron number dependence of PDR. We will present preliminary results for 50Ca. [1] F. J. Fattoyev and J. Piekarewicz – Phys. Rev. C 86, 015802 (2012) [2] J. Margueron et al – Phys. Rev. C 97, 025805 (2018) [3] A. Tamii et al. – Phys. Rev. Lett., 107 062502 (2011) [4] A. Tamii et al. – Eur. Phys. J. A, 50 (2014) 28 [5] T. Inakura et al – Phys. Rev. C 84, 021302R (2011)

[115] First In-Beam Spectroscopic Study of the T=3/2 p-Unbound ^{55}Cu (15:45)

Presenter: PIGLIAPOCO, Sara (University of Padova, INFN)

Mirror energy differences act as a magnifying glass into the evolution of the nuclear structure phenomena as a function of angular momenta. In recent years, detailed studies aimed to probe the influence of isospin non-conserving interaction and the effects of halo orbits and their occupation on the displacement of analogue excited states of mirror partners were performed, showing excellent agreement between data and large scale shell model calculations. Thanks to the nowadays intensities of radioactive ion beams, the evolution of such phenomena can be extended toward the proton drip line. In this presentation, we will report on some preliminary results from in-beam γ-ray spectroscopy studies of excited states in the T$_z$=-3/2 ^{55}Cu carried out at the Radioactive Isotope Beam Factory, RIKEN (Japan). The mirror energy differences are interpreted within the shell model framework where Coulomb and isospin-breaking terms have been included. In this work, we will extend the investigation on the structure of proton-rich nuclei to the middle of the fp shell and beyond the proton stability. Experimental inclusive knockout cross sections, populating the ^{55}Cu, are interpreted within the Shell Model and Eikonal reaction theory and compared with the state-of-the-art systematics. Finally we will try to address how the competing processes of proton decay and γ-ray de-excitation can impact on cross section estimations.

Nuclear Structure I: NS 3 - Garibaldi A (14:40 - 16:10)

-Conveners: Garret, Paul (University of Guelph, Canada)

[302] Neutron Dripline Search for Fluorine, Neon and Sodium and Discovery of 39Na at RIKEN RIBF (14:40)

Presenter: KUBO, Toshiyuki (RIKEN Nishina Center)

A search for new isotopes near the neutron dripline was conducted for fluorine, neon and sodium at RIKEN RIBF [1], in which isotopes were produced by projectile fragmentation of an intense 48Ca beam at 345 MeV/nucleon, and separated and identified in flight using the large-acceptance two-stage separator BigRIPS [2,3]. The 48Ca beam intensity was as high as ~540 pnA. In the experiment we determined the neutron dripline at fluorine and neon to be 31F and 34Ne, respectively [4] and discovered an extremely neutron-rich isotope 39Na with neutron number N = 28 [5]. These results provided us with a key to understanding the nuclear structure at extremely neutron-rich conditions. The location of neutron dripline and the nuclear binding near the existence limit are determined reflecting details of underlying nuclear structure, such as the evolution of the nuclear shell property and the associated nuclear deformation. The nuclear deformation, caused by the magicity loss at N = 20 and 28, plays a key role in the nuclear binding in this region and thus in determining the particle stability of 39Na as well as the location of the neutron dripline at fluorine and neon. In this talk I will outline the discussions of such intriguing nuclear structure as well as overview the experiment. [1] Y. Yano, Nucl. Instrum. Methods Phys. Res., Sect. B 261, 1009 (2007). [2] T. Kubo, Nucl. Instrum. Methods Phys. Res., Sect. B 204, 97 (2003). [3] T. Kubo et al., Prog. Theor. Exp. Phys. 2012, 03C003 (2012). [4] D. S. Ahn et al., Phys. Rev. Lett. 123, 212501 (2019). [5] D. S. Ahn et al., Phys. Rev. Lett. 129, 212502 (2022).

[81] Exploring the Mysteries of 32Mg via Precision In-Beam Gamma-Ray Spectroscopy (15:05)

Presenter: KITAMURA, Noritaka (Center for Nuclear Study, University of Tokyo)

In the area known as the “island of inversion,” neutron-rich nuclei around N=20 exhibit substantial admixtures of intruder configurations in their ground states, thus leading to the breakdown of the N=20 major shell gap. Central to this island of inversion is the nucleus 32Mg, which has been the subject of study for several decades and serves as a critical benchmark for nuclear models and our understanding of the driving forces behind this structural change. We performed detailed in-beam gamma-ray spectroscopy of 32Mg using GRETINA at NSCL. We utilized two direct-reaction probes: one-neutron removal from 33Mg and two-proton removal from 34Si, positioned inside and outside the island, respectively. The measurement has allowed us to construct a significantly updated level scheme, shedding light on various coexisting structures within 32Mg. Notably, this study has provided the first indication of the third 0+ state, which is presumed to correspond to a spherical nuclear shape, identified among excited states characterized by different particle-hole excitations. To explore the theoretical understanding of this key nucleus, extensive calculations were performed. These calculations highlighted the incompleteness of the state-of-the-art theoretical models, and unresolved discrepancies with experimental observations suggest that the structure of 32Mg has not yet been fully deciphered [1,2]. In this contribution, we will present and discuss findings and broader implications of our study. [1] N. Kitamura, K. Wimmer, A. Poves et al., Phys. Lett. B 822, 136682 (2021). [2] N. Kitamura, K. Wimmer, T. Miyagi et al., Phys. Rev. C 105, 034318 (2022).

[5] Cross-Shell Excited States in 32Si and 29Al Populated Using Fusion-Evaporation (15:20)

Presenter: WILLIAMS, Jonathan (TRIUMF)

In recent years, fusion-evaporation reactions have increasingly been used to study neutron-rich nuclides near the $N=20$ 'island of inversion' [1 - 3]. In this region, the evolution of the $N=20$ shell gap is indicated by the energies of negative parity states which primarily arise due to single neutron excitation to the higher lying fp orbitals. These negative parity states often have high spin (due to the participation of the $0f_{7/2}$ orbital) and are therefore preferentially populated using fusion-evaporation. Using a ^{12}C(^{22}Ne,$2p$) fusion-evaporation reaction, we have performed a detailed study of a nanosecond isomer in ^{32}Si [4], showing that it is a high spin intruder state ($J^{\pi} = 5^-$) that decays via an unusually high energy (3563 keV) hindered $E3$ transition. The first 4^+ state was also identified at higher energy based on angular distribution and Compton polarization data. This suggests that the isomer is located in a 'yrast trap', a feature rarely seen in lower mass nuclei. A comparison to phenomenological and *ab-initio* shell model calculations suggests that this inverted ordering of yrast states is influenced by the $Z=14$ subshell closure, as well as proton and neutron cross-shell excitation. Further analysis of the ^{32}Si (and ^{29}Al side channel) data is underway, with several newly observed high spin states and accompanying transitions identified. The current status of the analysis will be discussed. [1] Deacon et al. PRC 82 034305 (2010). [2] Steppenbeck et al. Nuclear Physics A 847 149-167 (2010). [3] Williams et al. PRC 100 014322 (2019). [4] Williams et al. PRC 108 L051305 (2023).

[176] Structure within the N=40 Island of Inversion (15:35)

Presenter: CRAWFORD, Heather (Lawrence Berkeley National Laboratory)

The focus of this work is neutron-rich Fe and Mn isotopes with N~40, which lie within an Island of Inversion approximately centered at ⁶⁴Cr. Here, a quenching of the N=40 sub-shell gap allows multi-particle multi-hole excitations and deformation to develop in the ground-state configurations of nuclei in the region. Limited spectroscopic information has been collected so far in the region of N~40 below ⁶⁸Ni. For the even-even nuclei, the 2⁺₁ and 4⁺₁ state energy systematics has been explored and, for the Fe and Cr isotopes, of B(E2;

2⁺₁->0⁺₁) values have been measured up to ⁶⁸Fe and ⁶⁴Cr. Large-scale shell model calculations well reproduce the energy systematics of the observed low-lying states of the even-even Fe and Cr isotopes around N=40. However, spectroscopic factor and more complete level scheme predictions in the region have not yet been benchmarked by experimental results. Proton knockout reactions on the neutron-rich N=38 and N=40 isotopes ^{64,66}Fe and ^{63,65}Mn have been performed to investigate the proton spectroscopic factors of the parent nuclei. We will discuss the results of this measurement as well as another secondary fragmentation measurement which also expands the level schemes in this region.

[205] Exploring Nuclear Structures with Fast Neutrons at NFS (15:50)

Presenter: SENGAR, Hemantika (GANIL)

Systematic investigations of nuclear reactions are crucial for advancing the field of nuclear physics. So far, traditional methods, like charged particle probes, β-decay and heavy-ion fusion evaporation reactions, have been employed to explore the phase space of shell models. Using fast-neutron probes would further expand the horizon of possibilities. Despite their use for cross-section measurements, applications for nuclear structures were absent, leaving a gap in understanding their reaction mechanisms. The nuclei near ^{56}Ni are of particular interest allowing to examine the interplay between single-particle and collective excitations. Though ^{56}Ni has been studied using conventional methods (Fig. 1), a pure neutron probe has never been used. Using a deuteron breakup reaction on a Be target, at NFS we can go up to $\sim$40 MeV around which the maximum cross section (Fig.2) for the ^{58}Ni(n,3n)^{56}Ni reaction is reached. In October 2023 experiment using the EXOGAM array involved a high-energy neutron beam on a Ni target, resulting in 10^{10} $\gamma\gamma$ coincidences for Ni, Co and Fe isotopes. The talk aims to provide a comprehensive description of level scheme and excitation functions for the ^{57}Ni isotope formed by (n,2n) undergoing β^{+} decay to produce ^{57}Co in the system, which interestingly is also populated by (n,d) and (n,n'p). ![^{56}Ni Yrast Diagram][1] ![cs][2] This is a pioneering work using large gamma array and fast neutrons and is only possible at GANIL–Spiral2 today. The success of this program could open up new doors for nuclear structure studies. [1]: https://shorturl.at/ahxBY [2]: https://shorturl.at/efgzC

Nuclear Structure II: NS 4 - Harmony B (14:40 - 16:10)

-Conveners: Andreoiu, Corina (Simon Fraser University)

[306] Global Ab Initio Calculations for the Structure of Exotic and Heavy Nuclei (14:40)

Presenter: HOLT, Jason (TRIUMF)

Breakthroughs in our treatment of the many-body problem and nuclear forces are rapidly transforming modern nuclear theory into a true first-principles discipline. This allows us to address some of the most exciting questions at the frontiers of nuclear structure and physics beyond the standard model. In this talk I will briefly outline our many-body approach, the valence-space in-medium similarity renormalization group, and how recent advances now allow for global converged calculations of open-shell nuclei to the 208Pb region and beyond. I will focus on key topics in nuclear structure such as predictions of the proton and neutron driplines and evolution of magic numbers throughout the light and medium-mass regions, including new insights on the nature and existence of 28O including continuum degrees of freedom. In addition, I will discuss how correlation of the neutron skin and dipole polarizability in heavy nuclei to 208Pb provide first ab initio constraints on symmetry energy parameters for determining neutron star properties as well as opening paths to predictive nuclear theory for new physics searches.

[349] Low-Energy Electron Scattering for Nuclear Physics - ULQ2 for proton radius and SCRIT for exotic nuclei - (15:05)

Presenter: SUDA, Toshimi (Research Center for Electron-Photon Science, Tohoku University)

I will review research activities ongoing in Japan related to low-energy electron scattering conducted for nuclear physics will be presented. These include electron scattering for proton charge radius measurement (ULQ2) and for structure studies of short-lived exotic nuclei (SCRIT). ULQ2 (Ultra-Low Q2) for proton charge radius Electron scattering off proton covering an extremely low momentum transfer region is essential for precise determination of the proton charge radius. A series of low-energy electron-scattering measurements covering the lowest-ever momentum transfer, Q 2 , is underway at the ULQ2 facility of Tohoku University at Sendai, and the data collection has been completed. I will briefly overview the current status of proton-size studies worldwide and present the ULQ2 project, which includes very recent achievements. SCRIT (Self-Confining Radioactive Ion Target) for short-lived exotic nuclei Electron scattering is the gold standard for probing nuclear structures, consistently playing an essential role in revealing the internal structures of atomic nuclei and in establishing modern pictures of their structures. However, to date, electron scattering has primarily been applied to stable nuclei, with few exceptions such as 3 H, leaving short-lived exotic nuclei completely unexplored. Recently we have successfully achieved a ground-breaking milestone: the world's first electron scattering for an online-produced radioactive isotope at the SCRIT electron scattering facility of RIKEN RIBF in Japan. I will present the details of the SCRIT facility and recent achievements and outline additional research possibilities awaiting exploration at the facility.

[168] Study of Intruder States towards ^{78}Ni with Lifetimes Measurements Following ^{82}Se(d,p)^{83}Se (15:30)

Presenter: PELLUMAJ, Julgen (INFN-LNL, University of Ferrrara,)

Intruder states that originate from the promotion of neutrons across the N=50 shell gap are observed along the N=49 isotones (^{79}Zn, ^{81}Ge, ^{83}Se, ^{85}Kr), with the lowest energy in ^{83}Se. The reduction of the N=50 shell gap towards ^{78}Ni favors the lowering in the energy of these states. Moreover, since the ^{83}Se nucleus (Z=34) is in the middle of the proton fp-shell (28$<$Z$<$40), it should have the maximum quadrupole correlations, lowering further the energy of these deformed configurations. This makes ^{83}Se a good candidate for understanding the collectivity of the particle-hole intruder states in this region. Such information could also be used as a testing ground for theoretical models aiming to describe the region in the vicinity of ^{78}Ni. The nucleus of interest was populated using a (d,p) reaction in a recent experiment performed at the Laboratori Nazionali di Legnaro. The GALILEO γ-ray array at the phase II configuration was coupled to the SPIDER silicon array, allowing one to obtain the needed channel selectivity through coincidence measurements between γ rays and the protons from the (d,p) reaction. This work reports on the lifetime of the 540-keV 1/2^{+} and 1100-keV 3/2^{+} intruder states of ^{83}Se measured by using the Recoil Distance Doppler-Shift method (RDDS) and Doppler-Shift Attenuation Method (DSAM), respectively. The experimental outcome will be discussed in the framework of shell-model calculations and mean-field approaches. The present results challenge current theoretical models in this region.

[82] An Abrupt Shape Transition between 84Mo and 86Mo: a New Island of Inversion at N = Z (15:45)

Presenter: HA, Jeongsu (Center for Exotic Nuclear Studies, Institute for Basic Science)

The shell structure of nuclei is the backbone of the nuclear theory. A large energy gap with the completely filled spherical orbitals defines shell closure and magic number. One of the intriguing experimental findings is the disappearance of shell closure at certain N and Z, which is not predicted from the classical shell model. This Island of Inversion (IOI) has been successfully explained through the shell model with variants of dynamical SU(3) symmetry. The present work focused on the N = Z nucleus ^{84}Mo in which we probed unexpected large deformation. We measured the lifetime of the first 2^+ states in ^{84}Mo and ^{86}Mo using the plunger setup. The experiment was performed at the NSCL, Michigan State University. A 140-MeV/u

^{92}Mo beam bombarded a 235-mg/cm2 ^{9}Be target to produce an ^{86}Mo secondary beam. The HPGe tracking array GRETINA and the TRIPLEX plunger were used to measure the first 2^+ state lifetimes. The extracted B(E2; $2_1^+ \rightarrow 0_1^+$) shows a salient difference between ^{84}Mo and ^{86}Mo, which departs from the similar B(E2; $2_1^+ \rightarrow 0_1^+$) trends between other N = Z and N = Z+2 nuclides. DNO-SM and several theoretical approaches were employed to understand the behavior in the proton-rich Mo isotopes. The study revealed that the abrupt shape transition between ^{84}Mo and ^{86}Mo is due to the increase of energy gap between $g_{9/2}$ and $d_{5/2}$ orbitals, leading to different particle-hole configurations. The results can be interpreted as a fingerprint of the 3N nuclear force. The experimental finding and the interpretation set the boundary of IOI on the proton-rich side for the first time.

Coffee Break (16:10 - 16:40)

Plenary: EDI -Talk (16:40 - 17:25)

-Conveners: Yennello, Sherry (Texas A&M University)

[351] Isotopes and Identities: The Physics of Complex Interactions (16:40)

Presenter: GRINYER, Gwen (University of Regina)

We are all star dust. Everyone we know and everything we see here on Earth are the leftovers of massive nuclear explosions that occurred naturally in our universe, a long time ago. Understanding the origins of the chemical elements, and how we came to be, requires detailed knowledge of the complex subatomic interactions between neutrons and protons that led to the existence of bound nuclei and stable atoms. As scientists, we are made of the very same star stuff we wish to study and, while seeking answers to some of the most fundamental questions in the universe, many of us encounter barriers caused by complex social interactions that arise from our identities. Understanding these interactions is of fundamental importance because attracting and retaining the best people is what drives scientific innovation and enhances the potential for discovery. In this presentation, I will describe how both kinds of interactions are at the heart of my research and how I integrate nuclear physics with education in equity, diversity and inclusion in order to try and solve both of these many-body problems.

[360] IUPAP and Nuclear Physics (17:10)

Presenter: DILLMANN, Iris (TRIUMF)

Poster Session (17:30 - 20:00)

[14] Measurement of Radiative Decay Width of the Hoyle State of 12C via 12C(p, p)12C Reactions (17:30)

Presenter: TKRANA, Tapan Kumar (Variable Energy Cyclotron Centre)

The Hoyle state, second excited state of 12C at an excitation energy of 7.65 MeV, plays an important role in nucleosynthesis. Particularly the radiative decay of the Hoyle state is the doorway to the production of heavier elements in stellar environment. An exclusive experiment has been performed to measure the radiative decay width of the Hoyle state of 12C through the 12C(p, pγγ)12C reaction at 10.6 MeV beam energy. Triple coincidence measurement yields a value of radiative branching ratio, Γrad/Γ = 4.01 (30) × 10−4. The result has been reconfirmed by an independent experiment based on the complete kinematical measurement via. 12C(p, p)12C reaction at 11.0 MeV. Using our results together with the currently adopted values of Γπ(E0)/Γ and Γπ(E0), the radiative width of the Hoyle state is found to be 3.75 (28) × 10−3 eV.

[32] Mirror Symmetry in the f7/2 Shell below 56Ni, Excited States and Electromagnetic Transition Rates in 55Ni and 55Co (17:31)

Presenter: ASCH, Heinz (Simon Fraser University)

Nuclear theories often operate under the assumption that the strong nuclear force is independent of electric charge. Therefore, it is expected that exchanging the number of protons with the number of neutrons in a nucleus will produce a ${\it mirror~nucleus}$ with identical structure after electromagnetic considerations. However, charge dependence in nuclear theories is required due to isospin non-conserving interactions and resulting effects like Mirror Energy Differences in excited states for ${\it mirror~nuclei}$ which cannot be resolved by Coulombic forces. This charge dependence is being explored at TRIUMF, Canada's national particle accelerator centre. A stable ^{20}Ne beam experiment to produce ^{55}Co was conducted with a complimentary radioactive ^{21}Na beam experiment to produce ^{55}Ni expected in 2024. Production of this mirror pair leverages the TRIUMF-ISAC Gamma-Ray Escape Suppressed Spectrometer (TIGRESS) for gammas, SFU's TIGRESS Integrated Plunger for charged particles, ^{40}Ca targetry, and the Doppler-Shift Attenuation Method for lifetimes. The ^{55}Ni experiment will also utilize the Electromagnetic Mass Analyzer for A, Z, and E measurements of recoil nuclei for enhanced selectivity. This talk will discuss the state of the ^{55}Co experiment analysis which currently focuses on characterizing extracted proton and alpha spectra with the Weisskopf model of evaporation to extract compound nucleus temperatures under varying conditions. Future analysis will explore the charge dependence of the strong interaction, the f$_{7/2}$ hole configurations in ^{56}Ni and electromagnetic transition rates for excited states of ^{55}Ni and ^{55}Co.

[71] Detector Developments for HISPEC/DESPEC Collaboration @ Slovenian Nuclear Instrumentation Laboratory (17:32)

Presenter: VESIC, Jelena (Jozef Stefan Institute, Ljubljana, Slovenia)

The DEcay Spectroscopy (DESPEC) collaboration aims at measuring exotic nuclei produced via fragmentation and fission reactions at GSI/FAIR. In the DESPEC experiments, ions will be stopped in an active implanter and their subsequent decays measured. The active implanter's role is to provide implantation times and positions and then detect the times and positions of subsequent decaying particles (α or β) while providing rough energy information to distinguish the decay processes. For fast timing measurements, a time resolution of the implantation detectors lower than 1 ns and the capability to detect and distinguish between ion implantation and subsequent decays are needed. Scintillating fibres are used for a fiber IMPlanter (FIMP) to fulfil these requirements. The basic principle is to stack fibres in orthogonal layers, assuming that β and α particles (or their associated secondary electrons) will hit at least one fibre in two consecutive layers so that complete position information is available. The first in-beam test of the FIMP prototype is scheduled at GSI and the preliminary results will be presented. The high-resolution γ-ray spectrometer DEGAS (DEspec Germanium Array Spectrometer) is a key instrument of DESPEC and is planned to be operated in most of the future experimental campaigns. To further improve the sensitivity of the array, shielding of the environmental background with active and passive components is planned. Shielding directly behind the HPGe detectors is based on the BGO scintillation detectors. The BGO detector was characterized, and its performance was compared with a simple gamma-ray propagation simulation. The results will be presented.

[83] Probing Heavy-Ion Fusion Reaction ^{136}Xe + ^{64}Zn in Inverse Kinematics (17:34)

Presenter: LI, Jiatai (Center for Nuclear Study, the University of Tokyo & RIKEN Nishina Center)

Heavy-ion fusion reaction is powerful in expanding the chart of nuclides and exploring the nuclear structure beyond Pb, especailly for high excited states. The formation of Evaporation Residues (ERs) is governed by three terms: transmission coefficient to overcome the potential barrier, formation probability of Compound Nucleus (CN) and the survival probability of CN against fission. The dynamical evolution of the binary system from contact is rather complex, therefore fusion data are mandatory in facilitating the predictability of reaction models. Fusion reactions forming the CN ^{200}Po have been studied using ^{31}P + ^{169}Tm and ^{100}Mo + ^{100}Mo reactions before, for the first time, we applied inverse kinematics to form ^{200}Po in ^{136}Xe + ^{64}Zn system to study the possible occurance of quasi-fission caused by reducing mass asymmetry in entrance channel as well as the effect of magicity of the beam nuclei on the fusion-evaporation cross section. The experiment using

^{136}Xe beam to bombard ^{nat}Zn target was performed at Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan. The fusion-evaporation cross sections were obtained by the in-beam measurement of the α decays of ERs as well as the offline measurement of β-delayed γ rays from the decay chains of ERs. In this presentation, details of the experimental setup and data analysis will be given.

[126] Neural Network-Based Prediction of Particle-Induced Fission Cross Sections for r-Process Nucleosynthesis Trained with Experimental Data and Dynamical Reaction Models (17:35)

Presenter: RODRIGUEZ SÁNCHEZ, Jose Luis (University of Coruña)

Large-scale computations of fission properties play a crucial role in nuclear reaction network calculations simulating rapid neutron-capture process (r-process) nucleosynthesis. Due to the large number of fissioning nuclei contributing to the r-process, a description of particle-induced fission reactions is computationally challenging. In this contribution, we will use the experimental data on proton- and neutron-induced fission reactions, along with theoretical calculations based on the INCL+ABLA model, to train neural networks (NN). We will present the results for the prediction of proton- and neutron-induced fission cross sections, utilizing a large variety of NN models across the hyper-parameter space, that are relevant for the r-process nucleosynthesis.

[155] Measurements of Backward Angle Quasi-Elastic Scattering in ^{28}Si + ^{158}Gd: Sensitivity of β_{2}, β_{4}, and 2n Transfer (17:36)

Presenter: PRAJAPAT, Rinku (Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, Uttarakhand, India and GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291-Darmstadt, Germany)

In recent times, it is quite complex to determine various nuclear characteristics, e.g., shape, mass, quadrupole (β_{2}) and hexadecapole (β_{4}) deformations, which is the fundamental interest of contemporary research. In this context, sd-shell nuclei (^{20}Ne, ^{28}Si, ^{24}Mg, and ^{32}S) are of special interest as their deformation parameters vary in sign and magnitude with a significant uncertainty. Recently, fusion barrier distribution (FBD) via backward angle quasi-elastic (QEL) scattering has been initiated as a probe to precisely determine β_{2} and β_{4} parameters. In reactions where transfer channels are favourable, they can affect the extracted values of such parameters. Hence, an attempt has been made to determine the deformation parameters of ^{28}Si via FBD through backward angle QEL scattering. Thus, an experiment has been performed to measure the QEL excitation functions (EFs) for ^{28}Si + ^{158}Gd system at energies around the Coulomb barrier using the Heavy-Ion Reaction Analyzer (HIRA) at IUAC, New Delhi, India. The measured QEL EFs and derived FBD have been analyzed within the coupled channel (CC) calculations framework with β2 and β4 parameters. Furthermore, the impact of 2n transfer on FBD has been studied. The results obtained from CC calculations with an oblate shape of ^{28}Si in its ground state are in good agreement with experimental data, and the extracted values and sign of β_{2} and β_{4} are in accordance with those of different inelastic scattering experiments. A detailed analysis and the obtained results will be presented during the conference.

[217] Investigation of the Excited States of 114Sn Using the GRIFFIN Spectrometer at TRIUMF (17:37)

Presenter: SYEDA, Noor E Kainat (Simon Fraser University)

Tin (Sn),with its magic proton number Z=50, stands out in the periodic table for having the most stable isotopes. This rich array of isotopes makes Tin an ideal candidate for testing theoretical models aimed at describing the effective nuclear force. The singly-magic nucleus Sn-114, with N=64, is situated in the neutron mid-shell between the N=50 and N=82 magic numbers. Tin isotopes that are even-even such as Sn-114 typically have a spherical shape in their ground states, however, those isotopes exhibit excited states with characteristics of several deformed shapes in a narrow energy range; a phenomenon called shape coexistence. The deformed shape of Tin nuclei arises from a 2-particle 2-hole(2p-2h) excitation across the Z=50 proton shell gap. This excitation promotes two protons into higher unoccupied orbitals, leaving two holes in their original lower energy orbitals. The resulting 4-nucleon excited configuration causes nuclear deformation that gives rise to rotational intruder bands. These are identified by low-lying excited 0^+ states. The key information about these intruder bands on Sn-114 remains missing. To investigate these intruder bands, the competing beta-decay and electron capture of Sb-114 were used to populate excited states in Sn-114 at TRIUMF's ISAC facility. GRIFFIN is a gamma-ray spectrometer, coupled to a plastic scintillator detector for beta particle detection, and 5 Si(Li) detectors for conversion electrons were used to detect events associated with Sn-114. The investigation will allow a more in-depth understanding of the intruder configurations and their band-heads in Sn-114. The poster will focus on the current analysis and recent findings.

[235] Study of Multinucleon Knockout Reactions of Exotic Nuclei in the Region of Nitrogen (17:38)

Presenter: FEIJOO FONTÁN, Martina (USC)

Several works focused on light isotopes [1,2,3] have shown a reduction of the cross sections with respect to the theoretical predictions for single-nucleon knockout reactions. These studies have reached different conclusions regarding the dependence of the reduction factor observed of the spectroscopic factor with respect to the N/Z of the projectile. The study of (p,pX) knockout reactions with the R3B versatile setup is a golden opportunity since the inverse kinematics technique can be used for kinematically complete measurements. Of particular interest is the systematic study of the probability of cluster formation. The successful experiments on stable Sn isotopes [4] indicating the pre-existence of alpha clusters, which are compatible with theoretical predictions [5], have aroused the interest to study this phenomenon also for other clusters such as d, t or 3He. This presentation will be focused on deuteron formation and its possible identification with CALIFA [6]. One of the goals is to study the dependence of the cluster formation probability with respect to the mass of the projectile. In addition, the occurrence of deuteron clusters embodies tensor force effects and should be relevant for short-range correlations (SRC) [7]. [1] J. A. Tostevin and A. Gade, Phys. Rev. C 90, 057602 (2014) [2] M. Gómez-Ramos and A.M. Moro, Phys. Lett. B 785,511 (2018) [3] L. Atar et al., Phys. Rev. Lett. 120, 052501 (2018) [4] J. Tanaka, Z.H. Yang et al., Science 371, 260 (2021) [5] S. Typel, Phys. Rev. C 89, 064321 (2014) [6] H. Alvarez-Pol, Nucl. Instrum. Methods A 767, 453-466 (2014) [7] M. Duer et al., Nature 560 620 (2018)

[246] Simulations of Neutron Unbound Physics for Geant4 (17:39)

Presenter: MENDEZ, Nicholas (Michigan State University / Facility for Rare Isotopes / Los Alamos National Laboratory)

The study of neutron unbound systems via the invariant mass technique is the primary focus of the MoNA Collaboration, which built and operates the Modular Neutron Array (MoNA) and the Large multi-Institutional Scintillator Array (LISA) at FRIB. Advancements in nuclear structure from theory and experiment along the neutron dripline have presented opportunities to understand the nature of unbound systems in higher mass nuclei. The GEometry And Tracking (Geant4) platform has been used in high-energy and nuclear physics to simulate particle interaction with as much detail as the user desires. Geant4 currently does not have a physics class to simulate neutron unbound systems. Given the advancement of accelerator facilities and active searches along the neutron dripline, detailed simulations to study the breakup of neutron unbound systems, are necessary. The implementation of the breakup of neutron unbound systems in Geant4 will be presented.

[258] Investigation of States Populated in the 102Ru(p,t)100Ru Two Neutron Transfer Reaction (17:40)

Presenter: BUCK, Samantha (University of Guelph)

Accurately characterizing the behaviour of collective states within the context of the shell model and capturing how this feature evolves throughout the chart of nuclides are ubiquitous objectives in the field of nuclear structure. This initiative continues to present as extraordinarily non-trivial when considering regions of heavy nuclei, as such nuclei are highly unique many-body systems with a complex array of properties. The investigation herein focuses on the study of the structure of 100Ru via the two-neutron transfer reaction, 102Ru(p,t)100Ru, that was performed using the Q3D magnetic spectrograph at the Maier-Leibnitz Laboratory, in Garching, Germany. The removal of the pair of particles from the system provides a direct study of the neutron-pair properties of the states that were observed in the reaction, which yields a more robust understanding of the pairing correlations present in 100Ru. These pairing correlations are a prime diagnostic tool used to characterize the behaviour of collective states within the context of the shell model, and can therefore be employed to investigate how this feature evolves, particularly within the Z = 40 − 50 region of the chart of nuclides, as 100Ru has Z = 44 and N = 56 and is situated near the middle of this region. This presentation will highlight the results from the analysis of the 102Ru(p,t)100Ru reaction, along with their significance for fundamental nuclear structure.

[269] Effects of Resonances on 6,7Li + 209Bi Reactions at Energy above the Coulomb Barrier (17:41)

Presenter: NDALA, Lucas Vusi (University of South Africa)

Nowadays, the study of exotic nuclei is an active area of research, from both experimental and theoretical perspective. Due to low binding energies, exotic nuclei are weakly bound and as a result can break up very easily. This makes it interesting to study their nuclear structure. Our goal in this work is to contribute towards better understanding of the breakup process and its effect on other reaction observables such as elastic scattering and fusion cross sections. To this end, we consider the 6,7Li on different target mass. Our theoretical investigation is based on the Continuum Discretized Coupled Channels (CDCC) formalism. Our results show that the continuum-continuum couplings have significant effects on elastic scattering, breakup cross sections and fusion cross sections.

[289] Single-Neutron Transfer on 86Kr and 93Sr (17:42)

Presenter: YATES, Daniel (TRIUMF)

The structure of nuclei around and above the N=50 shell closure provides insight into the interplay between single-particle and collective excitations in neutron-rich nuclei. As one adds neutrons above the N=50 shell closure, nuclei are observed to undergo a rapid change from single-particle excitations into collective modes around neutron number 60. Single-neutron transfer information on nuclei in this region helps to understand the evolution of the neutron orbitals above the shell gap. Experiments were performed at the TRIUMF-ISAC radioactive beam facility studying single-neutron transfer on ^{86}Kr and ^{93}Sr. In the resulting ^{87}Kr, single-particle structure analysis of this data shows the evolution of neutron orbitals directly above the N=50 neutron shell closure. Angular distributions were measured to 7 states in ^{87}Kr, and spectroscopic factors are compared with shell model calculations and previous experimental measurements of the ^{86}Kr(d,p)^{87}Kr reaction. The structure of ^{94}Sr was observed via (d,p) reactions on ^{93}Sr. This experiment is the first ever population of ^{94}Sr via a ^{93}Sr(d,p) reaction. Angular distributions and associate spectroscopic factors for the transfers to 5 states were measured for the first time.

Two excited states are updated to being spin $J^{\pi}=3^+$ states in contrast with previous spin assignments.

[342] Investigating Shell Evolution at the Proton Drip-Line through the 20Mg(d,p)21Mg Reaction at IRIS (17:43)

Presenter: SAUNDERS, Zach (Saint Mary's University, Canada)

Exotic nuclei are transforming our understanding of the nuclear force, one manifestation of which is seen in nuclear shells. The conventional nuclear shell model fails to explain the exotic structures seen in nuclei far from stability. In this experiment we examine the exotic borromean nucleus ^{20}Mg. ^{20}Mg is located at the proton drip-line with an expected conventional N=8 shell closure, which makes it an ideal nucleus to study in order to learn more about how shell structure evolves in proton-rich nuclei. We probed the shell closure through the one neutron transfer reaction ^{20}Mg(d,p)^{21}Mg. Based on the spin of the excited states of ^{21}Mg which get populated by the reaction as well as the spectroscopic factors we aim to determine whether there is a weakening of the conventional N=8 shell closure. The experiment was performed using the solid D2 target at the IRIS facility at TRIUMF. The preliminary observations will be presented.

[357] Excitation Energy Distribution of Projectile Prefragments Estimated from Intranuclear Cascade (17:44)

Presenter: RICHARDSON, Isaiah (FRIB)

The production of rare isotopes through projectile fragmentation often relies on reaction mechanism models like the abrasion-ablation model \cite{Campi_81} in simulation codes such as \texttt{LISE}$^{++}$ \cite{LISE2023} for experimental planning and success. However, these models lack accuracy, especially when simulating the production cross-sections of exotic neutron-rich nuclei at the limits of stability \cite{82Se,Kubeila21}. To address these inaccuracies, simulated excitation energy data from the Benchmark eA generator for leptoproduction \texttt{BeAGLE}) \cite{Chang_2022} was used to explore the improvement of existing reaction mechanism models. \texttt{BeAGLE} simulates the interaction between an electron, proton, or deuteron with a nucleus, mediated by deep inelastic scattering followed by an intranuclear cascade resulting in an excited prefragment. The resulting excitation energy distributions from \texttt{BeAGLE} were found to be primarily log-normal. Log-normal distributions were fitted to pre-fragment excitation energy distributions using nine primary beams interacting with an electron: ^{58}Ni, ^{64}Ni,,^{78}Kr,^{90}Zr, ^{124}Xe,^{136}Xe, ^{198}Pt, ^{208}Pb, ^{238}U. From these fits, the $median/dA$ and $\sqrt{variance}/\sqrt{dA}$ were extracted and parameterized using various models, such as a linear excitation energy model expressed as $a_0 + a_1dN + a_2dZ$, where \textit{dA} is the number of abraded nucleons, \textit{dN} is the number of abraded neutrons, and \textit{dZ} is the number of abraded protons. The results of these fits and parameterizations will be presented.

[359] The IRIS Facility with Solid H2/D2 Targets at TRIUMF for Reaction Studies of Rare Isotopes (17:45)

Presenter: GORBET, Gabriel (TRIUMF)

To probe the frontiers of knowledge on the short-lived isotopes near the neutron drip line for understanding their reactions of astrophysical significance, or hitherto unknown features of nuclear shell structure, one requires novel instrumentation. The IRIS facility features solid hydrogen and deuterium targets, yielding high areal density while remaining geometrically thin (50-100 μm), providing a better-defined reaction vertex point. The poster will describe the solid H2/D2 target, its cooling and vacuum conditions that were investigated for the robust operation of the target. In order to identify the various reactions channels originating from interactions of the rare isotope beams with the H2/D2 target, the IRIS facility utilizes particle identification using a segmented silicon semiconductor detector array and a CsI(Tl) inorganic crystal array, forming a ΔE-E telescope. The energy and angle recorded by the array provides knowledge on the reaction kinematics. Precise calibration of this telescope is necessary to extract the nuclear excitation spectra. The poster will also detail current investigations into the angular, proton number, and potentially mass number dependence of the detector gains.

Wednesday, 21 August 2024

Applications, Facilities & Instrumentation: AFI 3 - Harmony B (08:30 - 10:30)

-Conveners: Bernstein, Lee (UC Berkeley/Lawrence Berkeley National Lab)

[341] Fusion Ignition and Nuclear Physics on the National Ignition Facility (NIF) (08:30)

Presenter: MOORE, Alastair (Lawrence Livermore National Laboratory)

Fusion ignition by inertial confinement requires compression and heating of the Deuterium-Tritium (DT) fuel to temperatures in excess of 5 keV and densities exceeding hundreds of g/cc resulting in self heating of the DT by α-particles, and the release of more energy than use to implode the fuel capsule. In August 2021 this scientific milestone was surpassed at the NIF when the Lawson criterion for ignition was exceeded generating 1.37MJ of fusion energy; then in December 2022 target gain > 1 was realized with the production of 3.1MJ of fusion energy from a target driven by 2.0MJ of laser energy. To date on NIF fusion ignition has been repeated five times with a maximum of 5.2MJ of fusion energy being released. This extremely high neutron flux coupled with the plasma conditions present in a NIF experiment make NIF uniquely suitable for studying nuclear reactions closer to the real temperature and density conditions present in stellar interiors; this removes the need for corrections typically use to account for differences in electron screening between the dense, stellar interior and beam-target experiments. This paper will discuss progress on recent ignition experiments that have led to target gain > 2 and applications of NIF experiments to study nuclear reactions in plasma environments in the laboratory. LLNL-ABS-865084

[280] Using Laser Accelerated Proton Beams to Explore Radiobiological Effects in the Ultra-High Instantaneous Dose Rate Regime (08:55)

Presenter: NAKAMURA, Kei (Lawrence Berkeley National Laboratory)

Laser-driven (LD) proton sources are of interest for various applications due to their ability to produce short proton bunches with high charge and low emittance. These sources can be used in biological studies investigating improvements to radiation cancer therapy. Recently, the differential sparing effect on normal tissues versus tumors using the delivery of high radiation doses >10 Gy at extremely high dose rates (DR), has received increasing attention and was termed the FLASH effect. However, the molecular and cellular mechanisms underlying FLASH are not yet fully understood. To explore these mechanisms, we have implemented a beamline at the BELLA PW laser of Berkeley Lab that delivers proton bunches at ultra-high instantaneous DR (UHIDR) up to 10⁸ Gy/s to a sample irradiation site. This allowed us to study in vitro the differential sparing of normal versus prostate cancer cells [Bin Sci. Rep. 12:1585 (2022)]. More recently, we extended our capabilities to investigate in vivo the acute skin damage and late radiation-induced fibrosis in mouse ears after UHIDR with 10 MeV protons and prescribed doses up to 50 Gy.

[77] Nuclear Isomer Production via Laser-Driven Bremsstrahlung Irradiation for Astrophysical Applications at ELI-NP-1 PW (09:20)

Presenter: GIUBEGA, Georgiana (IFIN-HH/ELI-NP, CETAL/INFLPR Romania)

The aim of this contribution is to introduce the recently developed experimental setup for laser-driven isomer production at the 1-PW laser arm of ELI-NP (E7 experimental area). The study of nuclear isomers production and their photoreactions has been a subject of lasting interest in the nuclear physics community. Nuclear isomers play a crucial role in the creation of the elements in the Universe and in controlled nuclear energy release. The high-intense and ultra-short pulse lasers, available at ELI-NP facility, have a great advantage for studying isomeric states with life-times impractical for conventional accelerator or nuclear reactor experiments. This work is part of an ambitious staged experimental program aiming to photoexcite isomers relevant for nuclear structure and astrophysics investigations1. The 1-PW high-power laser2 having nominal pulse duration of 22 fs is focused on a supersonic gas jet at laser pulse energy on target of 20J in order to generate electron bunches via the Laser Wakefield Acceleration3. Bremsstrahlung radiation is further generated by impinging the electrons on high-Z photo-converters placed before the isomeric nuclear target. The experimental set-up, laser-plasma parameters leading to the generation of high-flux bremsstrahlung beams and the diagnostics techniques used for characterizing both bremsstrahlung and isomer production will be presented. References 1 K. Homma, O. Tesileanu, L. D'Alessi et al., Rom. Rep. in Phys., 68. Supp. 1 (2016) pp. S233 2 ELI-NP Annual Report 2020-2021, Final release of June 2022. https://www.eli-np.ro/documents/ELI-NP-Annual_Report-2020-2021.pdf 3 T. Tajima and J.M. Dawson, Phys. Rev. Lett. 43 (1979) pp. 267

[103] Demonstration of Nuclear Gamma-Ray Polarimetry Based on a Multi-Layer CdTe Compton Camera (09:35)

Presenter: GO, Shintaro (RIKEN Cluster for Pioneering Research, RIKEN)

To detect and track structural changes in atomic nuclei, the systematic study of nuclear levels with firm spin-parity assignments is important. While linear polarization measurements have been applied to determine the electromagnetic character of gamma-ray transitions, the applicable range is strongly limited due to the low efficiency of the detection system.The multi-layer

Cadmium-Telluride (CdTe) Compton camera can be a state-of-the-art gamma-ray polarimeter for nuclear spectroscopy with the high position sensitivity and the detection efficiency. We demonstrated the capability to operate this detector as a reliable gamma-ray polarimeter by using polarized 847-keV gamma rays produced by the $^{56}\rm{Fe}({\it p},{\it p'}\gamma)$ reaction [1]. By combining the experimental data and simulated calculations, the modulation curve for the gamma ray was successfully obtained. A remarkably high polarization sensitivity was achieved, compatible with a reasonable detection efficiency. Based on the obtained results, a possible future gamma-ray polarimetery is discussed in the presentation. [1] S. Go et al., accepted in Scientific Reports (2023) DOI: 10.1038/s41598-024-52692-2

[254] Update on the PYXIS Neutron Detector for the MoNA Collaboration (09:50)

Presenter: HE, Jiangshan (Facility for Rare Isotope Beams)

The MoNA-LISA neutron array is the primary detector to study neutron-rich nuclei along the neutron dripline by the MoNA Collaboration at the Facility for Rare Isotope Beams of Michigan State University. Recently, a Major Research Instrumentation funding request was awarded by the National Science Foundation to build a Next Generation neutron detector that will complement MoNA-LISA but also considerably enhance the current state of neutron detectors for such studies, improving on the decay energy resolution by at least a factor of five. Both arrays are located several meters away from the target and are thus more sensitive to high energetic neutrons emitted within a small solid angle. During the 2022 Physicists Inspiring the Next Generation: Exploring the Nuclear Matter (PING2022), and now in collaboration with PING2023, a novel neutron array was proposed using small scintillators (5 cm x 5 cm x 25 cm) and 64 channels position sensitive photomultiplier tubes that could be located closer to the production target and thus enabling the detection of lower energetic neutrons emitted at larger angles. The detection of these neutrons would expand the study of higher energy levels within nuclei. The design and test of several bars were conducted and results from this study will be presented and discussed.

Equation Of State: EOS 3 - Ballroom B (08:30 - 10:30)

-Conveners: Li, Bao-An (TAMU)

[193] Nuclear Equation of State from Nuclear Theory, Experiments, and Observations (08:30)

Presenter: SCHWENK, Achim (TU Darmstadt)

The nuclear equation of state plays a central role for the physics of nuclei and dense matter in neutron stars. We discuss constraints on the equation of state from nuclear theory, experiments, and observations, focusing on neutron-rich conditions. On the theory side, we present chiral effective field theory calculations for arbitrary proton fraction and temperature using a Gaussian process emulator, and their implications for the phase diagram of neutron-rich matter. For the phase diagram, we show that proton drip exists for any physically reasonable equation of state. Regarding experimental constraints, we discuss the impact of heavy-ion collisions for the equation of state and the properties of neutron stars. Moreover, we present density distributions and neutron skins from 16O to 208Pb based on new chiral low-resolution interactions. Our results show that neutron skins are narrowly predicted over all nuclei with interesting sensitivities for the most extreme, experimentally unexplored cases.

[9] The INDRA-FAZIA Setup: Investigating Isospin Transport as a Signature for Symmetry Energy Effects in Heavy Ion Collisions (08:55)

Presenter: CIAMPI, Caterina (GANIL)

Heavy-ion collisions in the Fermi energy regime are widely used to probe the properties of nuclear matter far from equilibrium: among other topics, they allow to investigate isospin transport phenomena, which can be interpreted in the framework of the Nuclear Equation of State. The INDRA-FAZIA apparatus [1], operating in GANIL, features the best characteristics to study such kind of phenomena, combining the optimal (Z,A) identification of FAZIA for the ejectiles in the quasiprojectile (QP) phase space, and the large angular coverage of INDRA. This contribution will give an overview of the most recent INDRA-FAZIA results, mainly focusing on its first experiment, in which the reactions ^{64,58}Ni+^{64,58}Ni at 32 and 52AMeV have been measured. The isospin diffusion effect has been highlighted by studying the isospin content of both light and heavy fragments belonging to the QP phase space [2] by exploiting the isospin transport ratio technique [3]. A comparison with transport models has been carried out [4,5]. The high granularity of FAZIA also allowed us to study the isospin content of the two heavy fragments produced in the QP breakup, simultaneously detected and mass identified. Such exit channel of semiperipheral collisions has been selected and compared with the more populated binary output, leading to novel results that add valuable information for a comprehensive view of the breakup process [4,6]. [1] G. Casini et al., Nucl. Phys. News 32, 24 (2022) [2] C. Ciampi et al., PRC106, 024603 (2022) [3] F. Rami et al., PRL84, 1120 (2000) [4] A. Ono et al., PRL68, 2898 (1992) [5] S. Mallik et al., J. Phys. G 49, 015102 (2022) [6] C. Ciampi et al., PRC108, 054611 (2023)

[52] (Zoom) Effects of the Hadronic Potentials on Particle Correlation Effects in Heavy Ion Collisions at Intermediate and High Energies (09:10)

Presenter: LI, Pengcheng (Huzhou University)

Determination of equation of state (EoS) for nuclear matter at high baryon density region is a topic of current interest in high-energy heavy-ion collisions and astrophysics. The pion/kaon HBT correlation (also called HBT interferometry) and intermittency are sensitive probes of the nuclear EoS. Within the UrQMD framework, it is found that the correlations of protons, correlated proton pairs with small relative transverse momentum, will be boosted by hadronic interactions, these correlations contribute significantly to an intermittency analysis as performed at experiments. In addition, by adopting different EoSs, HBT correlations for charged pions in central Au+Au collisions at $\sqrt{s_{NN}}=2.4-7.7$ GeV are calculated. The effects of a phase transition at high baryon densities are clearly observed in the explored HBT parameters. The results show that the available data on the HBT radii, R_{O}/R_{S} and $R_{O}^{2}-R_{S}^{2}$, in the investigated energy region favour a relatively stiff EoS at low beam energies, which then turns into a soft EoS at high collision energies consistent with astrophysical constraints on the high-density EoS of QCD. The specific effects of two different phase transition scenarios on R_{O}/R_{S} and $R_{O}^{2}-R_{S}^{2}$ are investigated. A phase transition with a significant softening of the EoS below four times the nuclear saturation density can be excluded using HBT data. The results highlight that the pion's R_{O}/R_{S} and $R_{O}^{2}-R_{S}^{2}$ are sensitive to the stiffness of the EoS and can be used to constrain and understand the QCD EoS in a high baryon density region.

Fusion and Fission: FF 1 - Wedgemount (08:30 - 10:30)

-Conveners: Hinde, David (Australian National University)

[53] Shell Effects in Quasi-Fission in Reactions Forming Actinide and Superheavy Compound Nuclei (08:30)

Presenter: SIMENEL, Cedric (Australian National University)

Quasifission occurs in fully damped heavy-ion collisions following a significant mass transfer between the fragments, without formation of a compound nucleus. It is the primary reaction mechanism hindering the formation of a superheavy compound nucleus after the collision partners have reached contact. As in fission, quasi-fission is expected to be affected by quantum effects leading to asymmetric mass splits. In addition to shell effects in the compound nucleus, quantum shells stabilising fission fragments with octupole shapes have been invoked as a factor determining the distribution of nucleons between the fragments at scission, explaining the fact that the centroid of the heavy fragment charge distribution is found around $Z=54$ protons in fission of actinides. A supersymmetric fission mode influenced by shell effects in the ^{208}Pb region is also predicted in superheavy nuclei. Similar shell effects are predicted in microscopic studies of quasi-fission. In particular, time-dependent Hartree-Fock (TDHF) calculations have been performed for reactions forming actinide and superheavy compound nuclei, favouring formation of fragments with $Z\simeq54$ and 82, respectively. We discuss the possibility to use quasifission to obtain some information on fission modes in superheavy nuclei, which would benefit from the fact that quasifission cross-sections are much larger than for fusion-fission.

[16] Reviving Nuclear Fusion Reaction Cycles in Solido (08:55)

Presenter: FORTUNATO, Lorenzo (1) Dip. Fisica e Astronomia, Univ. Padova (Italy) and 2) INFN-Padova, Italy)

We present a new revision of nuclear fusion reaction cycles whereby a solid room temperature lithium-6 deuteride (^{6}LiD) is burnt with neutrons beams. New calculations of the time evolution of a network of differential equations for the abundances of various nuclear species are presented. Data on nuclear cross-sections and non-thermal reaction rates are used to forecast the full time evolution of the most relevant thermonuclear reactions. To cycles are considered: the Jetter n+^{6}Li and Post cycles p+^{6}Li. According to our calculations there are great expectations for energy extraction in devices not based on plasma confinement, but rather on controlled nuclear burning into final products (mainly alpha particles).

[26] Fusion Dynamics Far Below the Barrier for 12C + 28Si (09:10)

Presenter: BRUGNARA, Daniele (INFN-LNL)

Heavy-ion fusion reactions are essential to investigate the fundamental problem of quantum tunnelling of many-body systems with intrinsic degrees of freedom. Fusion of light systems is a base for understanding the astrophysical reactions responsible for energy production and elemental synthesis in stellar environments^1. Large fusion enhancements are found near the barrier, however, a hindrance effect shows up^2 at lower energies. Fusion of light systems has Q>0, and identifying hindrance needs challenging measurements, so studying slightly heavier systems allows a reliable extrapolation to the lighter cases. Fusion cross section measurements for 12C + 28Si have been performed at the INFN-Laboratori Nazionali di Legnaro, using 28Si beams from the XTU Tandem. We have used the combined set-up of the gamma array AGATA^3 and two 4" annular DSSD Si detectors to identify and count the fusion evaporation events by coincidences between the prompt gamma-rays and the light charged particles (p,alpha) evaporated from the compound nucleus. Five energies have been measured from 50 to 29.5 MeV. The figure (left panel) is the matrix of gamma-energy vs particle energy above the barrier (50 MeV). Several evaporation channels are identified. At the lowest energy 29.5 MeV (right panel) we observe the 9/7- to 7/2- transition of 39K (1p), whose estimated cross section is 20 nb. The final results will be presented. ![Figure][1] 1 C.L.Jiang et al., EPJA 57, 235 (2021) 2 C.L.Jiang et al., PRL 89, 052701 (2002) 3 J.J.Valiente-Dobón et al., NIMA 1049, 168040 (2023) [1]: http://otrebla51.altervista.org/wp-content/12_28_gamma-part_1p.pdf

[134] Dependence of α-Clustering on Neutron-Excess Associated with Fusion of Mid-Mass Nuclei (09:25)

Presenter: KUMAR, Rohit (Indiana University)

In nuclear matter at low density clusterization of α-particles is favored over nucleonic matter due to the density dependence of the nuclear symmetry energy. Time-dependent density functional theory calculations reveal that by driving regions of the system to low density during a collision formation of α-particles is enhanced. The dependence of this clusterization on neutron-excess is an open question. To address this question, we examined the emission of α-clusters associated with the fusion of silicon isotopes, specifically ^{28,30,32}Si + ^{28}Si. An experiment was conducted at the ReA3 facility at Michigan State University where stable and radioactive beams with intensities of < 1 x 10^{5} ions/s bombarded isotopically enriched Si targets. To enable the coincident measurement of α-particles with fusion evaporation residues (ERs) using these low-intensity beams, a highly efficient experimental setup was utilized. The ERs, indicative of fusion, were identified using an energy/time-of-flight (ETOF) approach. Use of an ExB microchannel plate as a target together with highly-segmented silicon detectors provided the time-of-flight with sub-nanosecond resolution -- necessary to distinguish ERs from unreacted beam. Emitted light charged particles (Z≤2) were detected using highly segmented Si-Si-CsI(Tl)/PD telescopes and identified using a ΔE-E approach. Bombardment at different incident energies allowed measurement of both the fusion excitation function as well the associated α-emission. The cross-section for α-ER coincidences and its dependence on incident energy and neutron-richness will be presented and compared with the predictions of theoretical models.

[110] Role of Dissipation on the Quasielastic Barrier Distributions of the 20Ne+92,94,95Mo Systems (09:40)

Presenter: COLUCCI, Giulia (Heavy Ion Laboratory, University of Warsaw)

The Coupled Channels (CC) model successfully explained the observed structures in the barrier distributions (BD) for many systems. However, there are several mechanisms whose influence on fusion is still not clear, as the role of weak (non-collective excitations) reaction channels. The experimental BD of some systems turned out to be without any structure, in contradiction to theoretical predictions. Such an effect is caused by the dissipation of part of the kinetic energy into the excitation of a multitude of internal non-collective levels of the system. This experimental evidence led to the development of a new model (CC+RMT) able to include the non-collective excitations in the fusion reactions. At the Heavy Ion Laboratory (HIL) of the University of Warsaw, a comparative study of the quasielastic BD of the 20Ne+92,94,95Mo systems was performed, aiming to study the influence of dissipation due to single-particle excitations. The theoretical calculations performed within the CC+RMT model are in good agreement with the experimental data, supporting the hypothesis that non-collective excitations can alter the structure of the barrier distributions. However, the 94Mo shows a smoother and wider structure in comparison to the 95Mo, despite its higher level density. This difference might be due to another mechanism of dissipation, being the projectile-target transfers of light particles. In this perspective, the transfer cross sections for each transfer channel will be measured to clarify the role of transfer couplings on the BD shape and the dynamic of the reactions of the three systems. Details on the recent results and plans at HIL will be discussed in this contribution.

Nuclear Astrophysics: NA 4 - Harmony A (08:30 - 10:30)

-Conveners: Arcones, Almudena (TU Darmstadt)

[291] The Importance of Isomeric States in Nuclear Astrophysics (08:30)

Presenter: LOTAY, Gavin (University of Surrey)

Proton and alpha captures on unstable nuclei play a key role in determining the pathway of nucleosynthesis in explosive astrophysical environments, as well as energy generation throughout the cosmos. With remarkable advancements in radioactive ion beam technology, we are now able to study such reactions in terrestrial laboratories, and hence, have dramatically increased our understanding of the chemical evolution of the Milky Way. However, experimental studies, to date, have focused almost exclusively on ground state captures, neglecting reactions on excited quantum states. These reactions may be particularly important in the special case of nuclear isomers, as these long-lived excited quantum states can act as entirely separate nuclear species in stellar environments, strongly influencing the final elemental abundances ejected into the interstellar medium. Theoretical models of explosive astrophysical environments, such as classical novae and supernovae, have highlighted the astrophysical 26mAl(p,g)27Si and 34mCl(p,g)35Ar reactions as being especially significant. Unfortunately, due to the immense difficulty in measuring these reactions, experimentally, their rates, for the most part, have been estimated from ground state reactions, using stellar enhancement factors. This approach may represent a considerable oversimplification and, in this talk, various methodologies for studying proton capture reactions on isomeric states will be discussed. In particular, the most recent developments in direct reaction studies with isomeric radioactive beams will be presented.

[129] Radiative Capture on Nuclear Isomers: Direct Measurement of the 26mAl(p,g)27Si Reaction with DRAGON (08:55)

Presenter: LENNARZ, Annika (TRIUMF)

In explosive astrophysical environments, such as novae, supernovae and neutron star mergers, a significant fraction of atomic nuclei are expected to exist in excited quantum states. These elevated levels participate in nucleosynthesis much in the same way as nuclear ground states and, as such, play an essential role in determining the abundance of chemical elements in our Galaxy. Due to the immense difficulty in measuring the rates of particle captures on excited nuclear states, experimentally, stellar rates are obtained from ground state (laboratory) rates, using theoretically estimated stellar enhancement factors. This approach may represent a considerable oversimplification for instances where nuclear isomers exist. In this contribution, I will present the results of the first direct measurement of an astrophysical reaction using a radioactive beam of isomeric nuclei. The Detector of Recoils And Gammas Of Nuclear reactions (DRAGON) was used to perform a direct measurement of the 26mAl(p,g)27Si reaction at the ISAC-I radioactive beam facility at TRIUMF. In particular, we have measured the strength of the key 447-keV resonance in the 26mAl(p,g)27Si reaction and find that this resonance dominates the thermally averaged reaction rate for temperatures between 0.3 and 2.5 GK. This work represents a critical development in resolving one of the longest standing issues in nuclear astrophysics research, relating to the measurement of proton capture reactions on excited quantum levels, and offers unique insight into the destruction of isomeric 26Al in astrophysical plasmas.

[211] Opportunities for Isomer Studies for Astrophysics at FRIB (09:10)

Presenter: PAIN, Steven (ORNL)

The role of nuclear isomers in astrophysical nucleosynthesis is gaining increased attention, as reactions on ground and isomeric states are both potentially important for determining the reaction rates and flow within the reaction network. A particular case is the odd-odd N=Z nuclides in the sd-shell, which play an important role in breakout from the CNO cycle in nova nucleosynthesis, affecting reaction flow, the nucleosynthesis end-point, and final abundances impacting potential astronomical observables. Because many of these nuclides have low-lying spin isomers, and the difference in structure between their ground and isomeric states leads to a different set of proton resonances in each case, it is important to constrain reactions on both ground and isomeric states. Developments in radioactive-beam experiments are opening such opportunities, via direct and indirect techniques. An overview of recent measurements will be presented, with a particular focus on a campaign of experiments using the ORRUBA silicon detector array. This will include the first measurement using a new technique for manipulating ground/isomer content in reaccelerated beams without affecting ion optics, applicable to future measurements at the nascent Facility for Rare Isotope Beams.

[101] Precise Measurement of Nuclear Interaction Cross Sections towards Neutron-Skin Determination with $R^{3}B$ (09:25)

Presenter: PONNATH, Lukas (Technische Universität Darmstadt)

The $R^{3}B$ (Reactions with Relativistic Radioactive Beams) experiment as a major instrument of the NUSTAR collaboration for the research facility FAIR in Darmstadt is designed for kinematically complete studies of reactions with high-energy radioactive beams. Part of the broad physics program of $R^{3}B$ is to constrain the asymmetry term in the nuclear equation-of-state and hence improve the description of highly asymmetric nuclear matter. A promising approach to constrain the density dependence of the symmetry energy near saturation density is by measuring the neutron-skin thickness of neutron-rich nuclei via total reaction or neutron-removal cross sections reactions. A direct comparison with predictions based on a realistic reaction model allows to determine the matter radius. For a precise determination, it is essential to quantify the uncertainty and challenge the reaction model under stable conditions. The measurement of the total interaction cross sections of ^{12}C+^{12}C collisions represents the perfect case for a direct comparison with theory. During the successful FAIR Phase-0 campaign of $R^{3}B$, we could precisely measure the energy dependence of total interaction cross-sections of ^{12}C+^{12}C, which will be an important input for current calculations based on the eikonal reaction theory. In this contribution I will present the results and discuss the technique also applicable for exotic nuclei in the future. Additionally, I will provide an overview of two distinct $R^{3}B$ experiments where various tin isotopes were utilized to measure the neutron-skin thickness, and present preliminary results of the currently ongoing analysis.

[183] Impact of Isoscalar- and Isovector-Meson Mixing on Properties of Asymmetric Nuclear Matter in Relativistic Mean-Field Models (09:40)

Presenter: MIYATSU, Tsuyoshi (Soongsil University)

Using the relativistic mean-field model with the isoscalar- and isovector-meson mixing, $\sigma^{2}{\mathbf{\delta}}^{2}$ and $\omega_{\mu}\omega^{\mu}{\mathbf{\rho}}_{\nu}{\mathbf{\rho}}^{\nu}$, we present a new nuclear equation of state (EoS), which satisfies the large neutron skin thickness, $R_{\rm skin}$, of ^{208}Pb and the small neutron-star radius, respectively reported by the PREX-2 experiment and the NICER observation. The model parameters are calibrated so as to fit the experimental data for binding energy per nucleon and charge radius of several finite closed-shell nuclei. We study the effects of δ meson and σ-δ mixing on properties of isospin-asymmetric nuclear matter, focusing on the density dependence of nuclear symmetry energy, $E_{\rm sym}$. It is found that the δ meson increases $E_{\rm sym}$ at high densities, while the σ-δ mixing softens $E_{\rm sym}$ around twice the nuclear saturation density to explain the dimensionless tidal deformability of a canonical neutron star observed from GW170817. In addition, the thick $R_{\rm skin}$ from the PREX-2 result can be achieved with the relatively small slope parameter of $E_{\rm sym}$ stemming from the isoscalar-meson mixing. Furthermore, we present the unique characteristics of EoS for neutron-rich nuclear matter and neutron stars due to the δ meson and the σ-δ mixing.

Nuclear Reactions I: NR 7 - Rainbow Theatre (08:30 - 10:30)

-Conveners: Bazin, Daniel (Michigan State University)

[282] Electric Response of Nuclei Studied by Proton Scattering (08:30)

Presenter: TAMII, Atsushi (Research Center for Nuclear Physics, Osaka University)

In this presentation, I will discuss recent advancements in understanding the electric response of stable nuclei through the inelastic scattering of protons, utilizing the high-resolution Grand Raiden spectrometer. Our study focuses on several key phenomena, including the excitation of giant and pygmy dipole resonances, the electric dipole polarizability of nuclei, and the gamma-decay of giant dipole resonances to the ground state. Additionally, I will cover the photo-nuclear reaction of light elements as part of the PANDORA project and discuss the experimental methods pertinent to these investigations. The content of my talk will be tailored to complement the topics addressed by other speakers.

[333] (Zoom) Probing Nuclear Pairing with 2-Neutron Transfer Reactions (08:55)

Presenter: POTEL AGUILAR, Gregory (Lawrence Livermore National Laboratory)

The existence of a superconducting phase associated with the breaking of particle number conservation, has been first identified in metals in the context of the BCS theory. It was realized very soon that the underlying mechanism, connected with pairing correlations at work in the formation of Cooper pairs, bore great generality and was expected to be relevant for a large variety of fermionic systems. More specifically, it's importance in nuclear structure was recognized just a few months after the seminal papers of Bardeen, Cooper, and Schrieffer, were published. Since that moment, the study of nuclear pairing has attracted much theoretical and experimental interest. Within this context, 2-neutrons transfer reactions have been the experimental method of choice for the quantitative probe of pairing correlations in nuclei. We want to address in this talk our theoretical understanding of 2-neutron transfer reactions, with a special emphasis on new perspectives associated with the current availability of high-intensity exotic beams.

[80] Ab Initio Investigation of 7Li(p, gamma)8Be and 7Li(p, e+ e−)8Be Processes (09:20)

Presenter: GYSBERS, Peter (Facility for Rare Isotope Beams)

The anomalies in the electron-positron angular correlations from high-energy decays of 8Be were interpreted by the ATOMKI collaboration as evidence of a new beyond-the-Standard Model boson. A theoretical understanding of the nuclear physics involved is an important step towards verification of this claim. Hence, we investigate proton capture with the ab initio no-core shell model with continuum (NCSMC). The NCSMC describes both bound and unbound states in nuclei in a unified way, with realistic two- and three-nucleon interactions as the only input. This allows simultaneous description of 8Be structure, p+7Li scattering, radiative capture and internal pair creation which can individually be benchmarked against available data. We compare pair correlations to ATOMKI data for different proton energies and examine the effect of proper treatment of the initial scattering state. Further, our technique will be applied to the 12C and 4He systems in which similar anomalies have been reported.

[95] Search for Tetraneutron States via Transfer Reaction on 8He at TRIUMF (09:35)

Presenter: ROJO, Jennifer (TRIUMF, Canada)

Neutron stars represent the only known place in the universe where neutrons are held in close proximity. This unique scenario results from the extreme gravitational forces that compress them together in nearly pure neutron matter. However, the existence of an isolated multi-neutron system is still an open question. Theoretical predictions have long suggested the existence of an exotic nuclear structure consisting of four neutrons, prompting a quest for experimental evidence that has persisted for over five decades. This elusive tetraneutron system could be observed in reactions that result in four neutrons as a possible exit channel. Numerous studies indicated a short-lived quasi-bound state of the tetraneutron, and recent advances in detection systems and experimental techniques have facilitated the measurement of a resonance-like structure associated with it. However, theoretical debate and controversy persist, fostering ongoing discussions within the scientific community. Transfer reactions can provide a clean probe to assess the presence of a true resonance (or bound) state. A new measurement has been carried out at the IRIS facility at TRIUMF by using a transfer reaction from a post-accelerated 8He beam. This measurement utilizes the missing mass technique to determine the excitation spectrum. The presentation will describe the experiment and the observations from the present status of data analysis.

Nuclear Reactions II: NR 8 - Garibaldi B (08:30 - 10:30)

-Conveners: Capel, Pierre (Johannes Gutenberg Universität Mainz)

[54] Surrogate Reactions in Inverse Kinematics at Heavy-Ion Storage Rings (08:30)

Presenter: JURADO, Beatriz

Obtaining reliable cross sections for neutron-induced reactions on unstable nuclei nuclei is crucial to our understanding of the stellar nucleosynthesis of heavy elements and for applications in nuclear technology. However, the measurement of these cross sections is very complicated, or even impossible, due to the radioactivity of the targets involved. Our aim is to circumvent this problem by using the surrogate-reaction method in inverse kinematics at heavy-ion storage rings, which offer unique and largely unexplored possibilities for the study of nuclear reactions. In this talk, I will present the technical developments and the methodology, which we are developing to perform high-precision surrogate-reaction experiments at the Experimental Storage Ring (ESR) of the GSI/FAIR facility. In particular, I will present the results of the first experiments, which we recently conducted at the ESR, and briefly describe the perspectives for future measurements.

[141] Exploration of the Decay Mechanisms and Associated Aspects of Z = 102 Nobelium Nucleus (08:55)

Presenter: KAUR, Shubhpreet (Thapar institute of Engineering and Technology, Patiala, Punjab)

The exploration of heavier elements has resulted in several unexpected discoveries and has enhanced our understanding of nuclear synthesis and related phenomena. Although new elements and their isotopes have been synthesized, the amount of information with the Z ≥ 102, remains somewhat scarce. Also, the nuclear shell effects are of significant relevance for ensuring nuclear stability. Our objective is to analyze the subsequent decay mechanisms of nuclides of Z = 102 nucleus, i.e. $^{248}No^*$ and $^{250}No^*$. The Dynamical cluster-decay model (DCM) is employed to conduct a comprehensive research of compound nucleus (CN) and non-compound nucleus (nCN) mechanisms such as fusion-fission (ff), Quasi fission (QF) and fast fission (FF) using the Skyrme energy density formalism (SEDF) with GSkI force parameters over the range of centre-of-mass $(E_{c.m.})$ by including the quadrupole deformation $(β_2)$ and optimum orientations $(θ_i)$ of decaying fragments. The probability of compound nucleus formation (P_{CN}) and the lifetimes for the fusion-fission (ff) quasi fission (QF) channels are explored. Among the considered isotopes of Z = 102 i.e., $^{248}No^*$ formed in ^{40}Ca + ^{208}Pb reaction and $^{250}No^*$ via to different entrance channels ^{44}Ca + ^{206}Pb and ^{64}Ni + ^{186}W show asymmetric fragmentation. Also, nCN (QF, FF) decay mechanisms compete with CN fission channels and give a nice agreement with the experimental data. The most probable fragments such as ^{122}Sn and ^{128}Te are observed near to the magic shell closure Z = 50 and N = 82. The ff and qf lifetime decreases with increase in the excitation energy.

[118] Fragments Features and Isoscaling in Ni+Ca Systems at the Entrance of Fermi Energy Domain (09:10)

Presenter: GERACI, Elena (Dipartimento di Fisica e Astronomia "Ettore Majorana", Università degli Studi di Catania - Catania, Italy & INFN, Sezione di Catania, Catania, Italy)

Heavy ion collisions are a powerful tool to explore nuclear matter at sub-saturation densities. Central collisions for 58,62Ni+40,48Ca systems at 25 and 35 AMeV were studied benefiting of the peculiarities of the CHIMERA 4π multidetector [1], an experimental apparatus installed at INFN-LNS in Italy, characterised by low identification thresholds, measurement of velocity by time-of-flight method, energy and charge of all the emitted fragments and partly also mass identification. The features of the fragments produced in central collisions will be analysed, as a function of the isospin asymmetry and beam energy. The role of the size of the biggest fragment in the event will be addressed, highlighting the link of its evolution with the available energy. The isoscaling properties of fragments produced in the formed composite sources will allow to assess the hypothesis of thermal and chemical equilibrium [2,3]. The dependence of the parameters on the size of the fragments will be addressed and an attempt to extract information on the symmetry-term coefficient of the nuclear mass formula from isoscaling parameters will be performed [4,5,6,7]. [1] A. Pagano, 2012, Nuclear Physics News, 22:1, 25-30 and reference therein [2] M B Tsang et al., 2001, Phys. Rev. C 64 054615 [3] E. Geraci et al., 2004, Nucl. Phys. A 732 173 [4] A S Botvina, O V Lozhkin and W Trautmann, 2002, Phys. Rev. C 65, 044610 [5] A. Hannaman,2020, Phys. Rev. C 101, 034605 [6] S. R. Souza et al., 2022, Phys. Rev. C 106, 034606 [7] A. Rebillard-Soulié et al, 2024 J. Phys. G: Nucl. Part. Phys. 51, 015104

[151] (Zoom) Fission Isomer Studies at FRS and IGISOL (09:25)

Presenter: ZHAO, Jianwei (GSI Helmholtzzentrum für Schwerionenforschung)

The ‘island’ of fission isomers identified in the actinide region (Z = 92 - 97, N = 141- 151) originates from multi-humped fission barriers, which can be described as the result of superimposing microscopic shell corrections to the macroscopic liquid drop barrier. For the first time, populating fission isomers by using the in-flight fragmentation and the electromagnetic dissociation methods were tried at GSI rather than light particle-induced reactions that are so far in use. With the fragment separator (FRS) at GSI, the fragmentation of 1 GeV/u ^{238}U projectiles gives access to isotopes that are hard or impossible to reach by light particle reactions. In-flight separation with the FRS allows studying fission isomers with half-lives as short as 100 ns. Most importantly, it provides beams with high purity and enables event-by-event identification. Two detection methods were employed to study fission isomers with half-lives in the range of approximately 100 ns to 50 ms: beam implantation in a fast plastic scintillator, and beam thermalization in a cryogenic stopping cell at the FRS Ion Catcher followed by subsequent detection.

Additionally, the excitation energy measurement of the long-lived fission isomer ^{242f}Am was performed via mass spectrometry at IGISOL, Finland. Results from these experiments will be presented in this contribution.

Nuclear Structure I: NS 5 - Garibaldi A (08:30 - 10:30)

-Conveners: Henderson, Jack (University of Surrey)

[307] Recent Highlights on In-Beam Gamma Spectroscopy at RIBF and Future Perspectives (08:30)

Presenter: DOORNENBAL, Pieter (RIKEN)

Since advent of the RIBF, the NaI(Tl) based scintillation array DALI2+ has been the workhorse for in-beam gamma-ray spectroscopy experiments with fast beams. Due to its modest energy resolution, caused by large opening angles and intrinsic energy resolution of NaI(Tl) scintillators, its suitable mostly for spectroscopy at the isospin limit. Accordingly, the "Shell Evolution and Search for Two-plus energies At RIBF" (SEASTAR) project was initiated in 2013. The project aimed to systematically study shell evolution in neutron-rich nuclei via in-beam gamma-ray spectroscopy and covers a wide range of nuclei from the neutron sub-shell closures at N=32,34 in Ca to the possible N=70 harmonic oscillator shell closure. In addition to SEASTAR, various various inelastic scattering experiments were carried with DALI2+. Experiments with DALI2+ were complemented in 2020 and 2021 by campaigns employing HiCARI, the "High-resolution Cluster Array at the RIBF", composed of Ge-tracking, Miniball, and Clover detectors. However, limited available budget makes low cost alternatives to 4 pi Ge tracking arrays with superior features in terms of time resolution, full energy peak efficiency and peak-to-total, desirable. Consequently, a new-generation scintillator array for in-beam gamma-ray experiments, the HYPATIA (HYbrid Photon detector Array To Investigate Atomic nuclei) project, has been launched in 2023. In my presentation, I will provide an overview of the recent results of in-beam experiments at the RIBF and will introduce the HYPATIA project, including how well its performance compares to other existing and planned gamma-ray spectrometers, and examples of possible future experiments beyond spectroscopy of the first excited 2+ state.

[124] Approaching 100Sn: Shell Evolution in 98,100Cd via Lifetime Measurements (08:55)

Presenter: MENGONI, Daniele (University and INFN - Padova)

The nuclear structure of doubly magic nuclei, such as 100Sn and its neighboring isotopes, has attracted significant attention from both experimental and theoretical perspectives. This interest stems from the unique insights it offers for testing the nuclear shell model and its relevance to the astrophysical rapid-proton capture process [1]. The Cd isotopic chain plays a crucial role in these studies, particularly nucleus 98Cd (Z=48, N=50), which represents the most proton-rich N = 50 isotone for which information about the excited states exists. The structure exhibits a typical behaviour of systems guided by the seniority quantum number introduced by Racah for atomic physics. However, no half-life information exist for the neutron-deficient Cd isotopes [2]. In this contribution, I will present recent results on lifetime measurements in 98Cd an 100Cd. The experiment was performed in May 2021 as part of the FAIR phase-0 campaign at GSI, using the DEcay SPECstroscopy setup [3]. The nuclei of interest were identified in the FRS separator, following the production via fragmentation reactions of a 124Xe beam on a 9Be target.The Cd isotopes have been stopped in the AIDA array and the decaying gamma rays collected by the FATIMA array, which allowed for a direct lifetime measurement with a precision up to few tens of ps. The final results will be discussed, together with their interpretation on seniority symmetry conservation and core-breaking effects. [1] T.Faestermann, M.Górska, H.Grawe, Prog.Part.Nucl.Phys. 69 (2013) 85. [2] R. M. Pérez-Vidal et al., R. M. Pérez-Vidal et al., Phys. Rev. Lett. 129 (2022) 112501. [3] A.K.Mistry et al., Nucl.Instr.Meth. A 1033 (2022) 166662.

[27] Fine Structure of the Isoscalar Giant Monopole Resonance in 58Ni, 90Zr, 120Sn and 208Pb (09:10)

Presenter: BAHINI, Armand (iThemba Laboratory for Accelerator Based Sciences (LABS))

Background: Over the past two decades high energy-resolution inelastic proton scattering studies were used to gain an understanding of the origin of fine structure observed in the isoscalar giant quadrupole resonance (ISGQR) and the isovector giant dipole resonance (IVGDR). Recently, the isoscalar giant monopole resonance (ISGMR) in ^{58}Ni, ^{90}Zr, ^{120}Sn and ^{208}Pb was studied at the iThemba Laboratory for Accelerator Based Sciences (iThemba LABS) by means of inelastic α-particle scattering at very forward scattering angles (including 0°). The good energy resolution of the measurement revealed significant fine structure of the ISGMR. Objective: To extract scales by means of wavelet analysis characterizing the observed fine structure of the ISGMR in order to investigate the role of different mechanisms contributing to its decay width. Methods: Characteristic energy scales are extracted from the fine structure using continuous wavelet transforms. The experimental energy scales are compared to different theoretical approaches performed in the framework of quasiparticle random phase approximation (QRPA) and beyond-QRPA including complex configurations using both non-relativistic and relativistic density functional theory. Results: All models highlight the role of Landau fragmentation for the damping of the ISGMR especially in the medium-mass region. Models which include the coupling between one particle-one hole (1p-1h) and two particle-two hole (2p-2h) configurations modify the strength distributions and wavelet scales indicating the importance of the spreading width. The effect becomes more pronounced with increasing mass number.

[13] Collectivity, Shape Coexistence and Isomerism in Lanthanide Nuclei Close to the Proton Drip Line (09:25)

Presenter: PETRACHE, Costel (University Paris-Saclay and IJClab, CNRS/IN2P3, 91405 Orsay, France)

New results on the strongly deformed proton-rich $A\approx 115 \div 130$ nuclei obtained from recent experiments performed using high-efficiency gamma-ray arrays and ancillary detectors will be presented. Shape coexistence in Cs nuclei and the extent of octupole correlations in Xe and Ba nuclei will be discussed. The experimental results will be compared with different theoretical models suitable for the description of collective excitations, like the particle number conserving cranked shell model, the quadrupole-octupole collective hamiltonian based on the relativistic Hartree Bogoliubov model, the triaxial projected shell model. The newly discovered high-K isomer in ^{129}Nd form the JUROGAM+MARA setup will also be discussed.

[188] First Measurements of the Quadrupole Moment of the 2+ State and B(E2) Value of the 4+ State in 110Sn from Coulomb Excitation (09:40)

Presenter: PARK, Joochun (Jason) (Center for Exotic Nuclear Studies, IBS)

The experimental B(E2) values in light even-even Sn isotopes are found to be enhanced compared to theory, a discrepancy which has eluded a satisfactory solution for over a decade. For further examination, supplementary information such as spectroscopic quadrupole moments (Q_s) are needed. A safe-energy Coulomb excitation of ^{110}Sn was conducted at HIE-ISOLDE, CERN. The ^{110}Sn beam was accelerated to 4.4 MeV per nucleon and Coulomb excited on a 4-mg/cm^2 ^{206}Pb target. Gamma rays from the beam and target nuclei were detected with the Miniball HPGe spectrometer. The $Q_s(2_1^+)$ of ^{110}Sn was newly determined with a preliminary value of $+0.22^{+0.08}_{−0.06}$ eb. Both the sign and the magnitude of $Q(2_1^+)$ are in agreement with the Monte Carlo shell model prediction of an oblate shape for the 2_1^+ state in ^{110}Sn [1]. Independent lifetime measurements of the 2_1^+ and 4_1^+ states were also performed with simulations. The preliminary $B(E2\uparrow)$ value of our work is 0.236(17) e^{2}b^2, consistent with previous experiments [2-4] but with a higher precision. A preliminary $B(E2\downarrow)$ value of the 4_1^+ state was determined as $200^{+50}_{−70}$ e^{2}fm^4. This B(E2) value suggests an enhanced pairing force in light Sn isotopes [5]. Details on the new and improved spectroscopic results will be presented and compared to theory. [1] T. Togashi et al., Phys. Rev. Lett. 121, 052601 (2018). [2] J. Cederkäll et al., Phys. Rev. Lett. 98, 172501 (2007). [3] C. Vaman et al., Phys. Rev. Lett. 99, 162501 (2007). [4] G. J. Kumbartzki et al., Phys. Rev. C 93, 044316 (2016). [5] A. P. Zuker, Phys. Rev. C 103, 024322 (2021).

Coffee Break (10:30 - 11:00)

Plenary (11:00 - 12:30)

-Conveners: Fallon, Paul (LBNL)

[218] Ab Initio Prediction of α(d,γ)6Li and Impact of the 6Li Properties onto α -Induced Reactions of Astrophysical Interest (11:00)

Presenter: HEBBORN, Chloe (Facility for Rare Isotopes Beam, Michigan State University)

Accurate predictions of nuclear reaction rates are essential to refine our comprehension of the nucleosynthesis and to support the experimental study of unstable nuclei. Reactions involving light nuclei at low energies can be accurately described using first-principle methods, treating all nucleons as active. For reactions with heavier nuclei and at energies above ~10 MeV/nucleon, such microscopic models are not tractable, and one usually simplifies the many-body problem into a few-body one, composed of tightly-bound clusters of nucleons assumed structureless. In this talk, I will present a first-principle prediction of α(d,γ)6Li capture at energies relevant for the Big Bang nucleosynthesis [1]. I will also discuss how this microscopic prediction can be integrated in few-body methods to improve our analysis of (6Li,d) transfer data and the extraction of reaction rates relevant for the s-process nucleosynthesis and helium burning [2]. [1] C. Hebborn, G. Hupin, K. Kravvaris, S. Quaglioni, P. Navrátil and P. Gysbers, Phys. Rev. Lett. 129, 042503 (2022). [2] C. Hebborn, M. L. Avila, K. Kravvaris, G. Potel and S. Quaglioni, arXiv:2307.05636. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under the FRIB Theory Alliance Award No. DE-SC0013617 and by LLNL under Contract No. DE-AC52-07NA27344.

[40] Recent Results on Hypernuclei (11:30)

Presenter: NAGAE, Tomofumi (Kyoto University)

New experimental data on various hypenuclei have been produced at J-PARC hadron experimental facility, in Japan. New information on hyperon-proton interactions are accumulated with high intensity hyperon proton scattering measurements one of which was J-PARC E40 measuring Σ^+p and Σ^-p scattering at rather high momentum. It was suggested that the effects of the repulsive core might show up in high-momentum scattering. Hybrid-emulsion measurements were carried out as J-PARC E07. Several new events were observed such as double-Λ hypernuclei in the p-shell region for the first time. Also, the bound state signals of Ξ-hypernuclei were observed in the Coulomb-assisted bound region. In addition, deeply-bound states of $1s$ state, of which binding energy were amounts to 5-7 MeV, were discovered. A new project to construct a dedicated (K^-, K^+) spectroscopy is on-going at K1.8 beam line. A good energy resolution of 2 MeV would be realized for the Ξ-hypernuclei. A beam commission runs were carried out for a short period in June, 2023, and to be continued to the next run in April, 2024. The J-PARC hadron hall extension is planned for the next step of hypernuclear programs. The status of the construction of the Strangeness -2 spectrometer (S-2S) and the budget proposal of the Hadron Hall extension program will be mentioned.

[63] SPES: Status and Plans for Completion (12:00)

Presenter: AZAIEZ, Faical (LNL-INFN)

INFN-LNL is constructing an ISOL (Isotope Separation On Line) facility to deliver neutron rich ion beams up to 10 A MeV, making use of the linear accelerator ALPI as the post-accelerator. In parallel, an applied physics facility based on the usage of the high intensity proton beam from the cyclotron driver of the ISOL facility, is included. The status and future plans for completion of the project implementation will presented and discussed.

Box Lunch - IAC Meeting 12:30-14:30 in Garibaldi A, Lunch provided (12:30 - 13:00)

Free Afternoon (13:00 - 18:00)

Thursday, 22 August 2024

Plenary (08:30 - 10:30)

-Conveners: Xu, Nu (LBNL)

[332] Frontiers in Ab-Initio Computations of Atomic Nuclei (08:30)

Presenter: HAGEN, Gaute

Atomic nuclei exhibit multiple energy scales ranging from hundreds of MeV in binding energies to fractions of an MeV for low-lying collective excitations. Describing these different energy scales within an ab-initio framework is a long-standing challenge that we overcome by using high-performance computing, many-body methods with polynomial scaling, and ideas from effective-field-theory. With the recent advancements of ab-initio methods we can now address how collectivity and shape coexistence emerge in nuclei from chiral interactions. We accurately describe the first 2+ and 4+ energies and the quadrupole transitions from the first 2+ to the ground-state in neon isotopes. For 32,34Ne less is known and we predict that they are strongly deformed and collective. For 30Ne we interestingly find that a deformed and nearly spherical shape coexist, similar to what is seen in 32Mg. We also confirm that 78Ni has a low-lying rotational band, and that deformed ground states and shape coexistence emerge along the magic neutron number N = 50 towards the key nucleus 70Ca. On the neutron-deficient side we also addressed structure of nuclei around the strongly deformed N = Z = 40 nucleus 80Zr, although there are challenges our results are competitive with mean-field calculations. We also made predictions for the magnetic dipole transition in 48Ca. Here we found that the transition strength is consistent with a (γ,n) experiment but is larger than the results from inelastic electron- and proton-scattering experiments. With this talk I hope to convey that the accurate computation of multiscale nuclear physics demonstrates the predictive power of modern ab initio methods.

[308] A Fluid Dynamic Perspective on High Energy Nucleus Collisions (09:00)

Presenter: FLOERCHINGER, Stefan (Friedrich-Schiller-Univ. Jena)

The soft or low transverse momentum physics of relativistic heavy ion collisions can be well described by relativistic fluid dynamics. This is a universal theoretical description which employs from QCD as the underlying quantum field theory the thermodynamic equation of state and transport properties like viscosities and conductivities, as well as relaxation times. I will review the overall picture and comment on contemporary conceptual questions like the limits of a fluid description for small systems, the description of heavy-quark related observables, and a possibility to extend the fluid description to the entire collision event, so to start it even before the collision.

[345] Ultrahigh Dose-Rate (FLASH) Radiotherapy at the TRIUMF ARIEL Beamline (09:30)

Presenter: BAZALOVA-CARTER, Magdalena (UVic)

This presentation will provide an overview of ultrahigh dose-rate (FLASH) radiotherapy, one of the most exciting recent advancements in radiotherapy of cancer. FLASH radiotherapy, delivered in a fraction of a second, is an experimental treatment modality that reduces normal tissue toxicity while maintaining tumor control compared to conventional radiotherapy. FLASH radiotherapy is typically administered with electron or proton beams at ultrahigh dose rates of >40 Gy/s. Most current treatments use x-ray beams for their deep tissue penetration, however, due to technical difficulties, x-ray beams cannot readily be delivered at ultrahigh dose rates. The focus of this presentation will be the development of the FLASH Irradiation Research Station at TRIUMF (FIRST). I will discuss the suitability of the ARIEL 10 MeV electron beamline for FLASH radiotherapy. Key developments include the electron-to-photon converter flange, supported by Monte Carlo simulations of expected dose distributions and thermomechanical simulations of converter heat deposition and its mechanical stresses. Additionally, data from the electron-to-photon converter installation and FIRST dosimetric evaluation including beam control will be discussed. The presentation will conclude with the initial results of healthy lung mouse irradiations. The challenges encountered in FLASH small animal experiments at FIRST will also be described.

[162] Active Targets and Time Projection Chambers for Nuclear Physics (10:00)

Presenter: ROGER, Thomas (GANIL)

The use of active targets and time projection chambers in nuclear physics experiments can be traced back nearly 30 years. These detectors have found profitable applications due to their intrinsic high efficiency and their ability to be operated with a very large effective target thickness while maintaining the ability to track low-energy recoil particles. The combination of rapidly decreasing beam intensities for nuclei produced furthest from stability with the properties of reactions performed in inverse kinematics provides an ideal niche for such high-luminosity detection systems at rare-isotope beam facilities around the world. Recent developments in micro-pattern gaseous detector technology, high-density mechanics and front-end electronics and high throughput data-acquisition systems now overcome many of the limitations associated with many of the existing detection systems. As a result, these detectors and their potential applications in nuclear physics are undergoing a renaissance with a large number of state-of-the-art detector development projects are underway. In this talk, we provide an introduction to the concept and detection principles of an active target and time projection chamber, review some of the existing detector technologies and physics programs, and present some of the planned and ongoing detector projects around the globe.

Coffee Break (10:30 - 11:00)

Plenary (11:00 - 12:30)

-Conveners: Hahn, Kevin (Center for Exotic Nuclear Studies, IBS)

[60] R-Process in Neutron Star Mergers and Supernovae (11:00)

Presenter: ARCONES, Almudena (TU Darmstadt)

In 2017, a multimessenger era started with the first gravitational wave detection from the merger of two neutron stars (GW170817) and the rich electromagnetic follow-up. The most exciting electromagnetic counterpart was the kilonova. The neutron-rich material ejected during the neutron star merger undergoes an r-process (rapid neutron capture process) that produces heavy elements and a kilonova. Moreover, observations of abundances from the oldest stars reveal an additional r-process contribution of a rare and fast event, which could be core-collapse supernovae with strong magnetic fields, so called magneto-rotational supernovae. Now we can use neutron star mergers and core-collapse supernovae as cosmic laboratories to test nuclear physics under extreme conditions and to understand the origin and history of heavy elements. We combine hydrodynamic simulations of neutron star mergers and supernovae including state-of-the-art microphysics, with nucleosynthesis calculations involving extreme neutron-rich nuclei, and forefront observations of stellar abundances in the Milky Way and in orbiting dwarf galaxies. This opens up a new frontier to use the freshly synthesized elements to benchmark simulations against observations. The nucleosynthesis depends on astrophysical conditions (e.g., mass of the neutron stars) and on the microphysics included (equation of state and neutrino interactions). Therefore, comparing calculated abundances based on simulations to observations of the oldest stars and future kilonovae will lead to ground-breaking discoveries for supernovae, mergers, the extreme physics involved, and the origin of heavy elements.

[358] (Zoom) The Superheavy Nuclei: Fusion and Fission (11:30)

Presenter: JADAMBAA, Khuyagbaatar (GSI Helmholtzzentrum fuř Schwerionenforschung)

Superheavy nuclei (SHN) with extremely large amount of nucleons (e.g., protons up to Z = 126) are still one of the main subject in nuclear physics 1. The main purpose of this research is to examine the fission-stability of SHN at around Z = 114 − 126 and N = 184, where occurrences of next closed shells are theoretically expected [1]. To date, SHN with Z up to 118 (Og, Oganneson) are known [2,3]. They were synthesized mostly in 48Ca-induced fusion reactions with atom-at-a-time rates. A current hot topic is the synthesis of superheavy elements beyond Og, for which one has to employ fusion reactions with projectile nuclei heavier than 48Ca [4]. The experimental data, e.g., partial spontaneous fission half-lives of the known SHN, confirm the concept of the island of stability. However, fission properties (fission hindrance, fragment mass distribution, etc.) are still poorly studied [5]. This situation stems mostly from a lack of comprehensive experimental data on fission. I will discuss the above-mentioned two topics and present the related recent experimental findings at the gas-filled recoil separator TASCA, GSI (e.g., [4,6]) and the Heavy Ion Accelerator Facility of the ANU, Australia (e.g., [7]). [1] Yu.Ts. Oganessian, A. Sobiczewski, G.M. Ter-Akopian, Phys. Scr. 92(2), 023003 (2017) [2] F.G. Kondev et al., 2021 Chinese Phys. C 45 030001 (2021). [3] Yu.Ts. Oganessian et al., Phys. Rev. C 106, 064306 (2022) [4] J. Khuyagbaatar et al., Phys. Rev. C 102, 064602 (2020). [5] F.P. Heßberger, Eur. Phys. J. A 53, 75 (2017). [6] A. Di Nitto et al., Phys. Lett. B 994, 121662 (2019). [7] H.M. Albers et al., Phys. Lett. B 808, 135626 (2020).

[237] Radionuclide Production and Chelation to Enable the Development of Radiopharmaceuticals for Imaging and Therapy (12:00)

Presenter: RAMOGIDA, Caterina (TRIUMF & Simon Fraser University)

Radiopharmaceutical therapy (RPT) is emerging as a promising method to treat advanced and hard-to-treat cancers. This approach relies on a radionuclide attached to a targeting vector that has strong affinity for unique cell biomarkers overexpressed on cancer cells, enabling the direct and selective delivery of a radioactive payload to diseased cells to facilitate diagnosis/staging or therapy, depending on the type of radiation emitted by the nuclide. In order for these drugs to meet their potential, new methods that increase production of the radionuclide as well as new chemical means to attach these nuclides to targeting vectors are desperately needed. Using TRIUMF's particle accelerators, a myriad of radionuclides with promising decay properties for applications in RPT can be produced. Two such nuclides of particular interest are lead-203 (²⁰³Pb, t_{1/2} = 51.9 h) and ²¹²Pb (t_{1/2} = 10.6 h) which form a chemically-matched theranostic pair. The former is compatible with imaging, and the latter with therapy. ²⁰³Pb can be produced via the ²⁰³Tl(p,n)²⁰³Pb reaction on our 13 MeV cyclotron, while ²¹²Pb is isolated via a thorium-228 (²²⁸Th, t_{1/2} = 1.9 y) generator which is co-produced in the spallation of ²³²Th at 500 MeV – a major effort underway at TRIUMF to make alpha emitter actinium-225 (²²⁵Ac). This talk will present an overview of the medical nuclides produced through ²³²Th spallation, and how our group is recycling waste generated from this production route to isolate and test the next generation of radionuclides for RPT.

Lunch Break (12:30 - 14:00)

Plenary (14:00 - 14:40)

-Conveners: Rudolph, Dirk (Lund University)

[49] Structure of the Heaviest Elements (14:00)

Presenter: LOPEZ-MARTENS, Araceli (IJCLab)

Heavy and super-heavy nuclei, which form the upper end of the chart of nuclei, owe their stability, and for the heaviest systems their sheer existence, to the delicate interplay between the repulsive Coulomb interaction between the many protons of the nucleus and the strong nuclear interaction, which binds the nucleons together. The study of the heaviest nuclei is not only an experimental challenge (due to the very low production cross sections involved), but it is also a theoretical one. Indeed, the combination of large Coulomb fields and high densities of single-particle states makes theoretical calculations difficult and leads to extreme model dependencies, such as for example the localisation of the so-called “island of stability” [1]. Moreover, recent experimental and theoretical studies have shed light on deficiencies of energy density functionals (EDF), which are used to describe nuclear properties across the entire nuclear chart. In particular, no EDF parametrization is able to properly describe the deformed shell structure around No (Z=102) and Hs (Z=108) [2,3]. This suggests that further improvements of the EDF methods are necessary and that new reliable data are required to benchmark and constrain the theoretical models. In this talk, recent results on the structure of transfermium nuclei will be presented and discussed. [1] M. Bender et al., Phys. Lett. B 515 (2001) 42 [2] Y. Shi et al, Phys. Rev. C 89 (2014) 034309 [3] Y. Shi et al., Phys. Rev. C 90 (2014) 014308

Applications, Facilities & Instrumentation: AFI 4 - Wedgemount (14:40 - 16:10)

-Conveners: Hands, Alex (TRIUMF)

[72] Quasi-Continuum Nuclear Data (14:40)

Presenter: WIEDEKING, Mathis (Lawrence Berkeley National Laboratory)

The gamma-ray decay of nuclear states in the quasi-continuum provides important nuclear data for various applications, insights into nuclear structure effects and constraints on nucleosynthesis processes. In particular, measurements of Nuclear Level Densities (NLDs) and Photon Strength Functions (PSFs) have and will continue to play a central role as we have entered an era of incredible potential for novel measurements. This is due to many institutes across the world having established programs to provide enhanced, state-of-the-art research infrastructure. These range from significant increases in efficiencies for particle and gamma-ray detectors to new or upgraded radioactive ion beam facilities. In parallel, several new experimental and analytical techniques were developed, allowing for more reliable PSF and NLD studies, even on nuclei away from stability. In this talk, I will provide an overview of the most significant advances made and how these have laid the foundation for novel and ambitious measurements of PSFs and NLDs at radioactive and stable ion beam facilities. I will further discuss recent progress in exploring the underlying nuclear structure of low-energy resonances from PSF measurements. I will conclude with an update and outlook on the compilation and evaluation of quasi-continuum data.

[276] Neutron Capture Measurements at UMass Lowell Research Reactor (15:05)

Presenter: JANDEL, Marian (University of Massachusetts Lowell)

A new facility was designed around the thermal column beam port of the 1 MW Research Reactor at the University of Massachusetts Lowell. Thermal neutrons are collimated to a narrow 1-inch diameter beam and incident on samples to induce the radiative neutron capture. The new measurements of capture gamma rays are planned for Mn, Cu, Ni, Cr, and Gd samples in the next three years. The experiments will be carried out in close collaboration with the ENSDF (Evaluated Nuclear Structure Data File) evaluation group at Brookhaven National Laboratory. The gamma rays are measured using an array of high-resolution HPGe detectors. Some of the HPGe detectors use active Compton shields that are designed from scintillation detectors and improve significantly the signal-to-background in the measured gamma-ray spectra with HPGe. The experimental spectra will be validated by the Geant4 simulations of the array and theoretical models of the emission of gamma rays from the compound nucleus. The new experimental results on the capture gamma ray intensities will be incorporated in future ENSDF evaluations. We will present our new capabilities and present preliminary results on capture gamma rays on selected datasets. This work is funded by the U.S. DOE Office of Science and the U. S. National Science Foundation.

[184] Microcalorimeters for Heavy Ions – a Tool to Investigate Multi-Nucleon Transfer Reactions (15:20)

Presenter: KRAFT-BERMUTH, Saskia (TH Mittelhessen University of Applied Sciences)

Microcalorimeters determine the energy of an incoming ion by measuring the temperature rise in an appropriate absorber. It has been frequently demonstrated that they can measure the kinetic energy of heavy ions up to uranium with a relative energy resolution of the order of $\Delta E/E \leq 5 \times 10^{-3}$. Such detectors have already been applied for the investigation of the stopping power of heavy ions in matter as well as for the identification of the nuclear charges of fission fragments by their Z-dependent energy loss. In addition, the determination of the nuclear mass number A by combining a high-resolution energy measurement with a time-of-flight (ToF) setup, was demonstrated. For uranium ions, a mass resolution of 1 amu was achieved. Multi-Nucleon Transfer reactions at the Coulomb barrier is the most promising nuclear reaction mechanism which could produce neutron-rich nuclei in the Terra Incognita region of the nuclides' chart. One issue for a deeper understanding of the reaction mechanism is to identify the products of the two body channels in mass (A) and charge (Z) numbers. To achieve this goal, a new ToF-ΔE-E method has been proposed at the GSI Laboratory and approved for an in-beam test. It combines four high-resolution time-of-flight detectors with a microcalorimeter and passive absorbers. In this contribution, the expected performance of this novel detection scheme will be discussed.

[203] Development of the Detector Array for Photons, Protons, and Exotic Residues (15:35)

Presenter: MCINTOSH, Alan B. (Texas A&M; University Cyclotron Institute)

DAPPER has been designed, developed, and commissioned at Texas A&M University to measure (d,p) reactions in inverse kinematics, allowing for measurements using radioactive nuclei. The array consists of a third of a ton of highly segmented BaF2 scintillator (TAMU/ORNL) to measure individual gamma ray energies as well as the total gamma ray energy with high efficiency. An annular silicon detector measures the ejected proton's energy and angle to determine the excitation energy of the heavy residue independently of the gamma ray energy. For low-rate (radioactive beam) experiments, a fast segmented axial-field ionization chamber (GODDESS IC) can be used to measure atomic number of reaction products around zero degrees. Reactions of 57Fe(d,pg) @ 7.5 MeV/u in inverse kinematics were studied in the DAPPER commissioning experiment to extract the photon strength function of 58Fe. Reactions of 54Fe(d,pg) @ 7.5 MeV/u in inverse kinematics have recently been measured in DAPPER. In this talk, the performance of the array will be highlighted, results will be summarized, and future prospects will be mentioned.

Fusion and Fission: FF 2 - Harmony B (14:40 - 16:10)

-Conveners: Cook, Kaitlin (Australian National University)

[158] Probing Optimal Energy for Synthesis of Element 119 from ^{51}V+^{248}Cm Reaction and Fusion Reaction Studies for Producing New Elements and Isotopes (14:40)

Presenter: SAKAGUCHI, Satoshi (Kyushu University / RIKEN Nishina Center)

The search for new element 119 is currently underway at RIKEN with the ^{248}Cm(^{51}V,xn)$^{299-x}$119 reaction [1]. The superconducting RIKEN heavy-ion Linear ACcelerator (SRILAC), the ^{248}Cm target material supplied from Oak Ridge National Laboratory and GAs-filled Recoil Ion Separator III (GARIS-III) are being used. For the effective synthesis of superheavy nuclei, it is extremely important to set the reaction energy so as to maximize the evaporation-residue cross section. The optimal reaction energy was estimated from the quasielastic barrier distribution extracted by measuring the excitation function of quasielastic backscattering [2,3] and adopted in the ongoing experiment. In this talk, details of the backscattering measurement and interpretation of the data based on the coupled-channels calculations will be presented. The second half of the talk will be devoted to research activities ongoing or planned at Kyushu University on fusion reaction mechanism for new elements and new isotopes. Research plans to study the fusion-fission process in the fusion reaction involving neutron-rich nuclei and the possibility of using spin-aligned deformed nuclei to study the dynamics of the fusion reaction [4] will be covered. [1] H. Sakai et al., Eur. Phys. J. A **58**, 238 (2022). [2] T. Tanaka et al., Phys. Rev. Lett. **124**, 052502 (2020). [3] M. Tanaka et al., J. Phys. Soc. Jpn. **91**, 084201 (2022). [4] K. Hagino and S. Sakaguchi, Phys. Rev. C **100**, 064614 (2019).

[15] Investigating the Systematics of Shell-Driven Fission Below the Actinides (15:05)

Presenter: BUETE, Jacob (The Australian National University)

The discovery in 2010 by Andreyev et al. of mass-asymmetric fission induced by the β-delayed fission of ^{180}Tl demonstrated for the first time the existence of mass-asymmetric fission outside the actinides. The analysis of this data showed a novel mass-asymmetric fission mode not seen in the actinides, with peaks near Z = 35, 45. Being a single measurement it was not clear with which of these peaks the mode was correlated, and many recent studies of the fission of nearby nuclei have demonstrated correlations with both values. In this talk I will present the results of a systematic study of heavy-ion induced fission performed at the Heavy Ion Accelerator Facility at the Australian National University. The measurement extends from ^{212}Th to ^{144}Gd (Z = 90 to 64) along the line of N/Z $\approx$ 1.3. Notably, we are able to demonstrate conclusively the existence of shell-driven, mass-asymmetric fission modes in all systems studied. Utilising recently published techniques for simultaneous fitting of both the measured mass and kinetic energy of the fission fragments we present evidence of a smooth transition of the main mass-asymmetric fission mode from the deformed shell effects near Z = 34, 36 for the isotopes below Pt and to Z = 44, 46 above. This includes a transition over the point of symmetry, demonstrating for some systems two symmetric modes; a classical liquid drop and shell-driven fission mode at symmetry which are differentiated by their kinetic energy. Finally, the data also suggest the consistent presence of a second mass-asymmetric mode correlated with the light fragment near Z = 28, 30.

[86] Scission Deformation of 120Cd/132Sn Neutronless Fragmentation in 252Cf(sf) (15:20)

Presenter: FRANCHETEAU, Alexis (GANIL)

The generation of the fission fragments spins is one of the least understood mechanism and its theoretical description has been subject to renewed interest following Wilson et al. [1]. We report on a study of the radiative decay of fission fragments populated via neutronless fission of 252Cf(sf). In such rare events the fragments are populated below their neutron separation energy, meaning that the radiative decay holds all the information on the generated angular momentum and excitation energy repartition of the fragments. Applying the double-energy method allows for a perfect mass identification of the neutronless fragmentations. In the case of the specific 120Cd/132Sn fragmentation, investigation of the coincident prompt γ-spectrum showed that 132Sn was systematically populated in its ground state, hence the excitation energy is solely given to 120Cd and can be measured. The reproduction of the coincident prompt γ-spectrum is sensitive to the angular momentum distribution of the studied primary fragment. The latter was estimated using a time-dependent collective Hamilton model [2], allowing us to constrain for the first time the deformation (β □ 0.4)of the studied fission fragment at scission. REFERENCES [1] J.N. Wilson, D. Thisse, M. Lebois et al., Nature 590, 566–570 (2021) [2] G. Scamps and G. Bertsch, Phys. Rev. C 108, 034616 (2023)

[163] Fission Studies Using Quasi-Free Scattering Reactions in Inverse Kinematics (15:35)

Presenter: BENLLIURE, Jose (University of Santiago de Compostela)

Fission reactions induced by relativistic heavy nuclei have recently allowed the first complete identification of both fission fragments in atomic and mass number [1]. By using different target materials (lead or protons), one could also favour fission reactions at low and high excitation energies. In addition, these kinematic conditions allow the study of a wide variety of unstable fissile nuclei. The first experiments addressed the role of shell effects in fission [2] and the dynamics of fission at high excitation energies [3]. This setup has been recently upgraded at the R3B/FAIR experiment. The R3B target area detectors (silicon tracker and Califa calorimeter) allow the determination of the missing energy in quasi-free scattering (p,2p) reactions using a liquid hydrogen target. In the case of (p,2p)-induced fission reactions the missing energy corresponds to the excitation energy of the fissioning nuclei. In addition the new setup is able to measure gamma rays and neutrons emitted during the fission process. This will be the first complete kinematic measurements of fission reactions. We will present the first results on the fission of 238U induced by quasi-free (p,2p) reactions. We will show how the complete identification of both fission fragments and the measurement of the excitation energy of the fissioning nucleus allowed us to study the disappearance of shell effects in the fission yields with temperature and the sharing of the excitation energy between the two fission fragments. [1] E. Pellereau et al., PRC 95, 054603 (2017). [2] A. Chatillon et al., PRL 124, 202502 (2020). [3] J.L. Rodríguez-Sánchez et al., PRC 94, 061601(R) (2016).

[224] The Role of Slow Quasifission in the Suppression of Fusion at Above-Barrier Energies (15:50)

Presenter: BEZZINA, Lauren (The Australian National University)

One of the most well-known challenges facing the field of nuclear physics is the creation of new superheavy elements via heavy ion collisions. As we increase the charge product in the entrance channel of these collisions (Z_pZ_t) in the pursuit of new elements, there is a corresponding increase in the suppression of the fused heavy product (evaporation residue). In order to investigate the behaviour of the processes leading to this suppression (namely, quasifission) measurements of both evaporation residues and fission characteristics were made at the Heavy Ion Accelerator Facility at The ANU. Evaporation residue cross sections were measured for the ^{28}Si+^{192}Os and ^{34}S+^{186}W reactions forming the compound nucleus ^{220}Th using implantation decay. the suppression of these systems and those from past works were determined relative to the reaction ^{16}O+^{204}Pb. Measurements of fission characteristics were made to correlate fusion suppression with evidence for the presence of quasifission. From these measurements, we have been able to examine the evolution of evaporation residue suppression and quasifission characteristics as charge product in the entrance channel increases. These measurements reveal new evidence that evaporation residue formation can be significantly suppressed without any evidence of a mass angle correlation in the fission characteristics - previously taken as a key indicator of the process in heavy ion collisions. This suggests that quasifission may compete with fusion on timescales longer than previously assumed.

Hot & Cold QCD: QCD 4 - Garibaldi B (14:40 - 16:10)

-Conveners: Karthein, Jamie (Massachusetts Institute of Technology)

[36] Electromagnetic Probes of the QCD Plasma (14:40)

Presenter: VUJANOVIC, Gojko (University of Regina)

The penetrating nature of electromagnetic radiation makes it an ideal candidate to investigate the properties of the Quark-Gluon Plasma (QGP). A selection of recent developments in the theory and phenomenology of electromagnetic probes is discussed, with an emphasis towards how they can be employed to constrain transport phenomena in the QGP. The complementary between electromagnetic radiation and other high-energy phenomena, such as jets, will also be explored. A Bayesian treatment of electromagnetic emissions, akin to the one performed using soft hadronic observables and jets, is suggested as a path towards imposing more stringent constraints on various transport coefficients of the QCD medium.

[91] Electromagnetic Fields in Relativistic Heavy Ion Collisions (15:05)

Presenter: WAKO, Tewodros (Aksum University)

Understanding the Quark Gluon Plasma (QGP), whose existence was known from the combination of three observations, is the central goal of high energy nuclear physics. All the three observations came from studying elliptic flow, and the purpose of this research was to investigate the effect of electromagnetic field evolution created in relativistic heavy ion collision on the flow of identified particles. To tackle these challenges, our model configuration proceeded through a tripartite methodology: delineating the entirety of relativistic viscous hydrodynamics pertinent to the contemplated heavy-ion collision employing the established iEBE-VISHNU framework, quantifying the electromagnetic field engendered by the system, incorporating potential drifting velocities, and subsequently scrutinizing the resultant alterations imposed upon the ultimate trajectory of said particles subsequent to the injection of said drift velocities. The progression of the computed electromagnetic fields has been observed to influence the curvature of the flow. In addition to the characteristics of the generated particles, the evolution of the field is influenced by the electrical conductivity of the evolving system. The field induces flow at lower transverse momentum levels and inhibits it at higher levels. This alteration in flow is more pronounced for heavier particles compared to lighter ones in the early stages of evolution. Lastly, our findings indicate that even flow harmonics are more impacted than odd ones.

[150] (Zoom) Deciphering Yield Modification of Hadron-Triggered Semi-Inclusive Recoil Jets in Heavy-Ion Collisions (15:20)

Presenter: HE, Yang (Shandong University)

Jet quenching is considered a key signature for the creation of the Quark-Gluon Plasma (QGP) in relativistic heavy-ion collisions, and can also provide valuable insights into the QGP properties. One particular observable utilized to study the jet quenching effect is the nuclear modification factor (I_{AA}) for semi-inclusive hadron-triggered recoil jets, which provides access to jets of low transverse momentum (p_T) and large radius, and has been measured at both RHIC and the LHC. However, recent results from the ALICE experiment shows the unexpected behavior that I_{AA} rises with jet p_T and exceeds unity at $p_T >$ 110 GeV/c in Pb+Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, posing a challenge for the traditional wisdom that jet quenching should result in $I_{AA} < 1$. To decipher various effects on the semi-inclusive jet measurements, particularly the surface bias of hadron triggers, we utilize the Linear Boltzmann Transport (LBT) model to simulate interactions between jet partons and the QGP. We construct a hybrid sample consisting of quenched triggers and their corresponding unquenched recoil jets. By comparing this new sample to those in vacuum generated by PYTHIA8 and in the medium by LBT, we are able to isolate medium effects on hadron triggers and recoil jets, and their influences on I_{AA}. We find that the quenching effect on the hadron triggers moves up the I_{AA} baseline of no jet quenching for recoil jets away from unity, which is responsible for the rising trend and larger-than-unity value of I_{AA} observed by ALICE.

[227] Multi-Messenger Analysis of Jet Quenching Using Bayeisan Inference (15:35)

Presenter: DU, Lipei (McGill University)

The interaction of jets with the Quark-Gluon Plasma ("jet quenching") provides incisive probes of QGP structure and dynamics, and extensive jet quenching measurements have been reported at RHIC and the LHC. However, the interpretation of such measurements in terms of properties of the QGP requires their comparison to realistic model calculations, which is computationally intensive. JETSCAPE is software framework incorporating state-of-the-art theoretical modeling of QGP dynamics and jet interactions, together with Bayesian Inference for rigorous, quantitative comparison of these models to a broad suite of experimental data. In this talk the JETSCAPE Collaboration presents a new, multi-messenger study of jet transport in the QGP using Bayesian Inference, for the first time incorporating all available inclusive hadron, inclusive jet, and jet substructure data. This study extends the previously published JETSCAPE Bayesian Inference analysis of jet quenching, which was based solely on inclusive hadron data. The multi-messenger nature of the analysis enables novel exploration of the correlation and differences between these diverse probes, and between different kinematic ranges in the measurements. This exploration illuminates the physics of the QGP that each is sensitive to, and constrains the properties of the QGP in new ways. These studies provide new insight into the mechanisms of jet interactions in matter, and point to next steps in the field for comprehensive understanding of jet quenching as a probe of the QGP.

Nuclear Astrophysics: NA 5 - Garibaldi A (14:40 - 16:10)

-Conveners: Martínez-Pinedo, Gabriel (GSI Darmstadt and TU Darmstadt)

[296] Understanding X-ray Bursts via Direct Measurements of (α,p) Reactions (14:40)

Presenter: AVILA, Melina (Argonne National Laboratory)

Type I X-ray bursts are the most common stellar explosions in our Galaxy, resulting from explosive hydrogen-helium burning. These bursts are triggered by thermonuclear ignition in the envelopes of accreting neutron stars within low-mass binary systems. Understanding the mechanisms behind these bursts requires knowledge of key nuclear reactions occurring in this stellar environment. However, recreating these conditions in the laboratory is challenging due to the typically small cross sections of these reactions and the experimental difficulties associated with low-intensity radioactive beams needed for their study. Consequently, many reaction rates remain unknown. Nevertheless, recent advances in radioactive ion beam facilities and experimental techniques have opened up new possibilities for studying these astrophysically important reactions. This presentation will discuss recent measurements of (α,p) reactions identified as relevant for this astrophysical scenario. This work was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract Number DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility

[7] Constraining the Astrophysical γ Process: Cross Section Measurements of (p,γ) Reactions in Inverse Kinematics (15:05)

Presenter: TSANTIRI, Artemis (Facility for Rare Isotope Beams / Michigan State University)

One of the main questions in nuclear astrophysics is understanding how the elements heavier than iron are forged in the stars. Heavy element nucleosynthesis is largely governed by the slow and rapid neutron capture processes. However, a relatively small group of naturally occurring, neutron-deficient isotopes, the so called *p* nuclei, cannot be formed by either of those processes. These ~30 stable nuclei are believed to be formed in the so called *γ* process from the "burning" of preexisting *r* and *s* process seeds through a sequence of photodisintegration reactions. Reproducing the solar *p*-nuclei abundances using nuclear reaction networks requires input on a vast network of mostly radioactive isotopes. However, as experimental cross sections of *γ* process reactions are almost entirely unknown, the related reaction rates are based on Hauser-Feshbach theoretical calculations and therefore carry large uncertainties. For this purpose it is of crucial importance to develop techniques to measure these important reactions within the astrophysically relevant Gamow window with radioactive beams. The SuN group at FRIB has been developing such a program for the past decade. The present work focuses on one of the first measurements of a (p,γ) reaction with stable beams, namely the ^{82}Kr(p,γ)^{83}Rb reaction, as well as the very first measurement using a radioactive beam for the ^{73}As(p,γ)^{74}Se reaction. Specifically the latter reaction is found to be of significant importance to the final abundance of the lightest p-nucleus, ^{74}Se, as the inverse reaction ^{74}Se(γ,p)^{73}As is the main destruction mechanism of ^{74}Se.

[78] Measurements of (alpha,n) Reactions for Astrophysics at TRIUMF (15:20)

Presenter: WILLIAMS, Matthew (University of Surrey)

Many important nucleosynthesis processes responsible for producing elements beyond iron are thought to be driven by (α,n) reactions, for example the s-process and weak r-process. However, measurements of (α,n) cross-sections present significant technical challenges, especially for reactions on radioactive nuclei or noble gases where targets are difficult or impossible to produce. In this talk I will give an overview of recent efforts at TRIUMF to overcome these challenges using two facilities: DRAGON, with the newly commissioned DEMAND neutron detector array; and EMMA, using novel helium sputtered targets. At DRAGON, the DEMAND array was successfully tested with a view towards measurements of the important ^{22}Ne(α,n) reaction, which is the main neutron source for the s-process in massive stars. At EMMA, novel targets were used to measure both the ^{86}Kr(α,n) and ^{94}Sr(α,n) reactions, which influence abundance signatures from a weak r-process in core-collapse supernovae. Data from both of these studies will be presented, providing the first steps in a future program of (α,n) reaction studies at TRIUMF.

[189] First Results From Measurements of Capture Reactions on Sn and Pd for the γ-Process Using HECTOR (15:35)

Presenter: MCDONAUGH, John (University of Notre Dame)

The formation of p-nuclei and their abundances are an important and ongoing study in nuclear astrophysical measurements. To understand and constrain theoretical models on the abundances of p-nuclei, further measurements of reactions on relevant nuclei and important branching points of the γ-process are needed. For this purpose the cross sections of (p,γ) and (α,γ) reactions on ^{112,114,116}Sn and ^{108}Pd(p,γ)^{109}Ag over a combined energy range of E$_p$=2-5MeV and E$_{\alpha}$=5-11.5MeV, for protons and alpha particles, respectively, are investigated. These measurements are performed using both the 5U and the FN accelerators at the Nuclear Science Laboratory at the University of Notre Dame. Preliminary cross-section results from the 5U experiments and future work for these ongoing experiments will be presented. This project was supported by the National Science Foundation (NSF) under grant numbers PHY-2011890 and

PHY-2310059.

[12] Neutron Induced Reactions for BBN: an Indirect Approach (15:50)

Presenter: PIZZONE, Rosario (INFN LNS)

Nuclear reactions induced by neutrons play a key role in several astrophysical scenario like primordial nucleosynthesis, s and r process and so on. From an experimental point of view, their reaction cross sections and reaction rates at astrophysically relevant temperatures are usually a hard task to be measured directly. Nevertheless big efforts in the last decades have led to a better understanding of their role in the different nucleosynthetic networks. In this work we will review the possibility of application of the Trojan Horse Method to extract the cross section at astrophysical energies for neutron induced reactions, examining validity tests as well as different applications. Moreover a detailed study of the ^{3}He(n,p)^{3}H reaction off the ^{2}H(^{3}He,pt)H three--body process will be discussed. The experiment was performed using the ^{3}He beam, delivered at a total kinetic energy of 9 MeV by the Tandem at the Physics and Astronomy Department of the University of Notre Dame. Data extracted from the present measurement are compared with other published sets available in literature. the reaction rate will be calculated and the astrophysical applications will also be discussed in details for the case of the Big Bang Nucleosynthesis.

Nuclear Reactions I: NR 9 - Rainbow Theatre (14:40 - 16:10)

-Conveners: Escher, Jutta (Lawrence Livermore National Laboratory)

[292] 36Ca and Recent Highlights from Reaction Studies with the LISE Spectrometer (14:40)

Presenter: LALANNE, Louis (IPHC)

Transfer reactions in inverse kinematics established itself as a very powerful tool to study nuclear structure, addressing many crucial aspects of nuclear structure such as shell evolution, isospin symmetry or physics of unbound states. In 2018, a fruitful experimental campaign took place at the GANIL facility, where the LISE spectrometer was used to produce radioactive beams for two transfer experiments. The beam was bombarded on the liquid hydrogen target CRYPTA [1]. An array of MUST2 telescopes was used to detect light outgoing particles in coincidence with the heavy recoil in a zero-degree detection. In the first experiment, neutrons removal reactions were used from radioactive beams of 37,38Ca in order to study 36Ca. Results were used to address isospin symmetry breaking [2], N=16 magicity at the proton drip-line [3] and reaction rate of astrophysical interest [4]. In the second experiment, one neutron removal reactions from 12,10,9C beams were used to explore the quenching of spectroscopic factors at and beyond the drip-line [5] as well as isospin symmetry in unbound nuclei [6]. Since 2023, a new transfer reaction campaign has been ongoing at the LISE spectrometer using a new-generation experimental setup: MUGAST [7]. In this presentation, recent results from reaction studies at the GANIL/LISE spectrometer will be presented, together with their implication in the context of isospin symmetry, shell evolution and drip-line physics. [1] S. Koyama, et al., NIM A 1010, 165477(2021) [2] L. Lalanne, et al., PRL 129, 122501(2022) [3] L. Lalanne, et al., PRL 131, 092501(2023) [4] L. Lalanne, et al., PRC 103, 055809(2021) [5] S. Koyama, et al., in preparation [6] S. Koyama, et al., PRC 109 (3), L031301(2024) [7] V. Girard-Alcindor, et al., Nuovo Cim. C 47, 59(2024)

[180] Isospin Dependence of the Nuclear Temperature in the Reactions 78Kr+40Ca and 86Kr+48Ca at 10 AMeV (15:05)

Presenter: GNOFFO, Brunilde (University of Catania-INFN Sezione di Catania)

The isospin dependence of the thermometric characteristics is investigated in the reactions 78Kr+40Ca and 86Kr+48Ca at 10 AMeV [1,2,3]. These reactions were realized in the context of the ISODEC experiment, performed at Laboratori Nazionali del Sud in Catania, by using the 4π multi-detector CHIMERA [4,5]. The results of the data analysis suggest that the temperature depends on the N/Z ratio. Two independent thermometric methods, the slope thermometer with the alpha par-ticles as probe and the double isotope yields ratio thermometer [6] are used to extract the temperature of compound nucleus. Higher values of the temperature were observed for the neutron rich system compared to neutron poor one. The slope thermometer was used also for the extraction of the temperature of the Quasi-Projectile. In this case, higher temperatures are evaluated for the neutron poor system, in contrast to what was observed for the fusion reactions. This trend is confirmed by the comparison with the GEMINI++ statistical model. References 1. Gnoffo B.,Il Nuovo Cimento C39, (2016) 275; 2. Pirrone S. et al., Eur. Phys. J. A 55, (2019) 22; 3. Politi G. et al., EPJ Web of Conferences 194, (2018) 07003; 4. Pagano A. et al., Nucl. Phys. A 681, (2001) 331; 5. Politi G. et al.,IEEE Nuclear Science Symposium Conf. Rec. 2005, (2005) 1140; 6. Albergo S. et al., Il Nuovo Cimento C 89, (1985) 1;

[175] (Zoom) Investigation of One Neutron Stripping Followed by Breakup Reaction for 9Be + 124Sn System (15:20)

Presenter: KAUR, Satbir (Nuclear Physics Division, Bhabha Atomic Reseach Centre, MUMBAI, Homi Bhabha National Institute, Mumbai, India)

Large α production cross sections are observed in the reactions involving stable weakly bound (6,7Li, 9Be) projectiles due to α+x cluster structure. In the case of 9Be, as the neutron separation energy is low, the neutron transfer cross sections are dominant. There are few energy correlation studies performed using charged particle coincidences with 9Be projectile. However, angular distributions and exclusive breakup cross sections are not available in the literature. In the present work, the angular distribution for 1n-stripping reaction from charged particle coincidence for 9Be+124Sn system at Elab = 35.2 MeV was studied using a Si strip detector array. The breakup and 1n-transfer breakup processes were identified by generating the energy correlation spectra of the two breakup α fragments in coincidence. The states of projectile-like (8Be) and target-like (125Sn) nuclei were identified using the Q-value vs Erel plot. From the Erel distribution, it is observed that the most dominant state is the ground state of 8Be at 92 keV, resulting from the 1n-stripping reaction. From the Q-value distribution, the excitation of the target-like nucleus is determined. The extracted scattered energy vs angle of 8Be prior to breakup was reconstructed from the measured energies of the breakup α fragments and scattering angles of the two α coincident fragments. Coupled reaction channel calculations performed using FRESCO fairly explain the measured angular distributions. The comprehensive experimental and theoretical analysis presented in this work contributes valuable insights into the reaction dynamics of 9Be projectiles, shedding light on α production and transfer processes.

Nuclear Reactions II: NR 10 - Ballroom B (14:40 - 16:10)

-Conveners: Wimmer, Kathrin (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

[309] Search for Alpha-Condensed States in ^{20}Ne and ^{24}Mg (14:40)

Presenter: KAWABATA, Takahiro (Department of Physics, Osaka University)

Alpha clustering is a crucial concept to understand nuclear structures. Alpha particles, which are tightly bound with no excited states up to $E_x\sim 20$ MeV, often behave as well established subunits in nuclei, forming what are known as alpha cluster states. Of particular interest are alpha condensed states where all alpha clusters are condensed into the lowest s orbit. Due to this unique property, these states exhibit very sharp momentum distribution around zero. As a result, their density distributions spatially expand, becoming as dilute as about 1/5 compared to normal nuclei. In our research, we searched for the 5alpha condensed state by measuring alpha-particle decays from excited states in ^{20}Ne populated by inelastic alpha scattering at zero degrees, and found its candidate states. Additionally, we recently reported candidates for the 6alpha condensed state and its excited states with their spin and parity of 2$^+$ and 4$^+$ observed in the ^{12}C + ^{12}C resonance scattering. In the present talk, we will report our experimental findings in the search for the alpha condensed states in ^{20}Ne and ^{24}Mg.

[38] Cluster States at Very High Excitation Energy in 16O (15:05)

Presenter: REDIGOLO, Luigi (Università di Catania / INFN, Sezione di Catania, Italy)

We report new data on the 3He+13C->4He+12C* reaction investigated at very low bombarding energy with the solid-state OSCAR hodoscope at the AN-2000 accelerator of INFN-LNL. Thanks to the excellent identification capabilities of the HELICA setup, several nuclear reactions, including 13C(3He,p)15N, 13C(3He,d)14N, 13C(3He,alpha)12C, leading the residual nucleus to several excited states, were correctly identified. The latter, in particular, is an excellent probe for the detailed spectroscopy of the 16O compound nucleus. We will show angular distributions and excitation functions of the cross section for the 13C(3He,a0), 13C(3He,a1), 13C(3He,a2) reactions in a broad angular domain, and discuss the impact on the spectroscopy of 16O. The preliminary values of the branching ratios between the transitions populating the ground state and the Hoyle state show an energy dependence that suggest the occurrence of a strongly clustered, possibly 2+, state in 16O at about 24 MeV excitation energy. Its impact on the present knowledge of 16O cluster structure will be also discussed on the light of the existing model predictions.

[68] ONOKORO Project: Comprehensive Research of Cluster Formation in Medium to Heavy Nuclei (15:20)

Presenter: KUBOTA, Yuki (RIKEN Nishina Center)

The nuclear clustering is a cutting-edge topic with a rich historical background. It has been established for light nuclei, such as the Hoyle state in ^{12}C, and in alpha-decay nuclei. However, quite little is known in the case of medium and medium heavy nuclei. Furthermore, an important question is remain unanswered: How can the mean-field picture be compatible with that with clusters? The ONOKORO Project, initiated in 2021 with KAKENHI funding from JSPS, aims to conduct systematic study on nuclear clustering across a broad mass range by combining the capabilities of three facilities: RCNP, RIBF, and HIMAC, utilizing the cluster knockout reaction at intermediate energy. The construction of the detector array TOGAXSI is underway to perform measurements in inverse kinematics. The TOGAXSI array, combining Si strip detectors and GAGG scintillator calorimeters, has completed its basic development using HIMAC beams and is currently under construction at RIBF. Last summer, the first cluster knockout measurements for stable nuclei ^{40}Ca, ^{6,7}Li, ^{12}C, and ^{16}O has conducted at RCNP. We got preliminary separation energy spectra supporting the presence of cluster structures, including not only alpha clusters but also deuteron, triton, and ^{3}He clusters. This year, complemental measurements for ^{42,48}Ca at RCNP and for unstable ^{50,52}Ca at RIBF are planned. The construction status of the TOGAXSI detector array, preliminary results from experiments conducted so far, and future prospects will be presented.

[143] The Observation of Double Gamow–Teller Giant Resonance Using Double Charge Exchange (12C, 12Be(0+2)) Reaction (15:35)

Presenter: SAKAUE, Akane (CNS)

Double Gamow-Teller (DGT) transition is a nuclear process such that both of the spin and the isospin are flipped twice, which is represented by the double β decay. The nuclear response of the DGT transition is hardly known especially for the high excitation energy region. Although DGT giant resonance (DGTGR) is predicted[1], it still remains unobserved. The experimental observables of the DGTGR will provide the information about the two-phonon excitation in which the spin-degrees of freedom contribute. It is also regarded to be important in the connection to the nuclear matrix element of neutrino-less double β ($0\nu\beta\beta$) decay[2]. We are aiming at the first observation of the DGTGR using the double charge exchange reaction (DCX) of (^{12}C, ^{12}Be(0$^{+}_{2}$)). The first experiment at RIBF was performed in 2021, where the DCX on ^{48}Ca target with the primary beam of ^{12}C with the energy of 250 MeV/nucleon was measured. The excitation energy distribution of the double differential cross section for each scattering angles was obtained and the forward-peaking structure was observed at around 20 MeV. In addition, the components whose angular distribution is analogous to the DGT transition was extracted from the experimental one by comparing with the calculated one. In this contribution, the first result for the ^{48}Ca target and possible consequences on the $0\nu\beta\beta$ nuclear matrix element are reported. [1] N. Auerbach, L. Zamick, and D. Zheng, Annals of

Phys. 192, 77 (1989). [2] N. Shimizu, J. Menendez, and K. Yako, Phys. Rev. Lett. 120, 142502 (2018).

[204] Charge-Exchange Reactions as Probes of Neutrinoless Double-Beta Decays (15:50)

Presenter: JOKINIEMI, Lotta (TRIUMF)

Neutrinoless double-beta decay is a hypothetical weak-interaction process in which two neutrons inside an atomic nucleus simultaneously transform into protons and only two electrons are emitted. Since the electrons are emitted without accompanying antiparticles, the process violates the lepton-number conservation and requires that neutrinos are Majorana particles, hence providing unique vistas in the physics beyond the Standard Model of particle physics. The potential to discover new physics drives ambitious experimental searches around the world. Extracting interesting physics from the experiments however relies on nuclear-theory predictions, which remain a major obstacle. I will discuss the potential of charge-exchange reactions, mediated by the strong interaction, to provide insights on these nuclear-theory predictions. In particular, I will discuss theoretical studies relating double Gamow-Teller transitions and neutrinoless double-beta decay of the same nucleus.

Nuclear Structure I: NS 6 - Harmony A (14:40 - 16:10)

-Conveners: Lenzi, Silvia M. (University of Padua and INFN)

[263] Evolution of Shapes and Collectivity in the ^{78}Ni Mass Region (14:40)

Presenter: SAHIN, Eda (University of Oslo, Norway)

It is well known that nucleons are arranged in specific shells resulting in greater stability, analogous to the electron shells in the atom and that this shell structure was expected to be very robust in the whole nuclear chart. However, with new experimental techniques and progress in the production of radioactive ion beams during the last two decays, we are now aware that the shell structure changes when moving far away from stability. This so-called shell evolution is related to certain properties of the strong nuclear force, which affect the energies of proton and neutron orbitals when the neutron-to-proton ratio changes. *For the SEASTAR and SUNFLOWER Collaboration Furthermore, the shape coexistence where particle-hole excitations over a major shell and quadrupole correlations are favoured due to inversion of orbitals and reduced shell gaps. In extreme cases proven in the lighter mass regions, new magic numbers appear and some other conventional ones disappear and intruder correlations change the ground state deformation, causing the phenomena called island of inversion. In the present manuscript, these aspects will be discussed in the ^{78}Ni region. Recent experiments performed at RIKEN radioactive beam facility using different methodologies will be presented.

[18] New Results on the Nuclear Two-Photon Decay (15:05)

Presenter: KORTEN, Wolfram

The nuclear two-photon or double-gamma (2γ) decay is a second-order electromagnetic decay process whereby a nucleus in an excited state emits two gamma rays simultaneously. It proceeds via the virtual excitation of higher-lying intermediate states. Compared to first-order decay pathways, such as single photon emission or internal conversion, the two-photon decay rate is very small. Ideal cases for this search are 0$^+$ $\rightarrow$ 0$^+$ transition where single photon emission is prohibited. However, the only cases where the 2γ decay of a was successfully observed using γ-ray spectroscopy are ^{16}O, ^{40}Ca and ^{90}Zr [1, 2], where the high energy of the transitions is favourable for the 2γ branch. At lower energies the 2γ branch becomes prohibitively small for γ-ray spectroscopy (<10^{-6}). We have therefore combined the isochronous mode of a storage ring with Schottky resonant cavities to perform Schottky + Isochronous Mass Spectrometry (S+IMS) in order to study exotic decays of short-lived states at the Experimental Storage Ring at GSI. This novel technique allowed us to conduct the first direct measurement of the half-life for the nuclear two-photon decay branch of the 0$^+$ isomer in ^{72}Ge [3]. The obtained mass resolving power enables future experiments on nuclear isomers with excitation energies as low as □100 keV and half-lives as short as □10 ms. In addition, first results from experiments on ^{98}Zr and ^{98}Mo should also be presented. [1] J. Schirmer et al., Phys. Rev. Lett. 53, 1897–1900 (1984). [2] J. Kramp et al., Nuclear Physics A 474, 412–450 (1987). [3] D. Freire-Fernández et al., submitted to Phys. Rev. Lett.

[19] Probing Nuclear Structure and Dynamics via Near-Barrier Reactions (15:30)

Presenter: GODBEY, Kyle (Facility for Rare Isotope Beams)

The natural time scales of nuclear physics are such that, in the course of a collision at energies near the barrier, both structure and dynamic effects are vitally important to the resulting reaction outcomes. While this complicates theoretical descriptions of heavy-ion reactions, it opens an avenue to study difficult-to-probe phenomena like neutron skins and nucleonic equilibration across a wide range of nuclei. This talk will highlight recent work on elucidating methods to extract such information from fusion, deep-inelastic, and quasifission reactions and how advancements in nuclear theory, uncertainty quantification, and machine learning are necessary to make further leaps in understanding. I will close with perspectives on promising reactions to further explore these correlations with current and near-term capabilities at experimental facilities.

[181] Octupole Correlations in Neutron-Deficient Xenon Isotopes (15:45)

Presenter: PÉREZ VIDAL, Rosa María (IFIC-CSIC and INFN-LNL)

Octupole correlations in nuclei near □ = □ occur between nucleons when both protons and neutrons occupy the same orbitals. This phenomenon is prominent in light Te (□ = 52), I (□ = 53), and Xe (□=54) nuclei, especially around □ □ 56 and □ □ 56. The Fermi surface for neutrons and protons lies close to orbitals from the $d_{5/2}$ and $h_{11/2}$ subshells, leading to enhanced octupole correlations outside the ^{100}Sn core. The octupole band is known for a few cases near □ = □ = 56, with ^{114}Xe showing one of the largest measured octupole strengths. Identifying octupole structures and measuring the electromagnetic transition strengths in more neutron-deficient nuclei is crucial for refining nuclear models and understanding the octupole deformation in this region. This contribution focuses on quadrupole and octupole correlations in the exotic ^{110}Xe and ^{112}Xe isotopes through experimental studies. The ^{110}Xe nucleus was produced via fusion-evaporation reaction at JYFL. The detection system was composed by the MARA separator and the JUROGAM 3 □-ray spectrometer. The level scheme of ^{110}Xe is expanded in this work, with the identification of the octupole band for the first time. The ^{112}Xe isotope was produced via fusion-evaporation reaction at GANIL. The setup comprised the AGATA □-ray tracking array, the neutron detector NEDA and the light charged particle detector DIAMANT in combination with the OUPS plunger for the lifetime measurements. Preliminary reduced transition probabilities determined in this work for the first time for the yrast states in the ground-state and octupole bands will be discussed.

Coffee Break (16:10 - 16:40)

Applications, Facilities & Instrumentation: AFI 5 - Harmony B (16:40 - 18:10)

-Conveners: Wiedeking, Mathis (Lawrence Berkeley National Laboratory)

[266] An Overview of Nuclear Physics Programmes and Applications at the UK National Physical Laboratory (16:40)

Presenter: SHEARMAN, Robert (National Physical Laboratory)

The National Physical Laboratory (NPL) is the UK national metrology institute, providing cutting measurement science for the UK. As part of this NPL understands the importance of nuclear physics and the accurate measurement of nuclear decay data to underpinning research in healthcare, energy, and the environment. The Nuclear Metrology group at NPL has been undertaking a variety of programmes across these sectors that tackle major challenges in nuclear medicine, nuclear fusion, nuclear power, and climate change. This presentation will highlight current work at NPL on the accurate determination of decay data for emerging medical radionuclides that is being undertaken within the European PRISMAP project with a focus on the terbium theranostic quartet, the newest initiative for radionuclide production in the UK, and developments in neutron-induced nuclear data measurements relevant to new nuclear technologies.

[352] Liquid Fuel Fast Reactors and the Future of Nuclear Power (17:05)

Presenter: HUSSEIN, Ahmed (UNBC, TRIUMF, and DFE)

To mitigate climate change; the world energy use must achieve carbon neutrality by 2050. To achieve this goal, it is now realized that nuclear power must be a major component of the world energy system by 2030. Current nuclear reactors GIII (Generation III) are thermal reactors that use solid Uranium Fuel and cooled by water. They consume 235 U which is less that 1% of natural Uranium. In many aspects those reactors are far superior to other energy sources like the entire range of fossil fuels and all renewable ones. Among other issues they don’t produce any greenhouse gases during operation. However, they also suffer from serious problems, for example, very high initial cost, long construction times, very inefficient operation, very large amounts of long-life waste, susceptible to serious accidents like core melt down, costly enriched fuel, etc. Unfortunately, current generations of nuclear reactors don’t fit the bill of climate change mitigation scheme. We have designed a fast, liquid fuel, liquid coolant reactor, that alleviates or eliminates altogether most if not all the problems plagued GIII reactors. This design is similar, but drastically different, from the Molten Salt Nuclear Experiment that was carried out in the 1960s at the Oak Ridge National Laboratory in US and successfully proved the viability of the liquid fuel model. In this talk the principles and some design details of this reactor, the engineering and regulatory challenges will be explained. The superiority of the design relative to GIII reactors, Fossil Fuels and Renewables will be explored as well.

[355] General Fusion: Targeting Transformation of the World’s Energy Supply with the Most Practical Path to Commercial Fusion Energy (17:30)

Presenter: HILDEBRAND, Myles (General Fusion)

General Fusion's Director of Strategic Partnerships, Myles Hildebrand, will give an overview of MagneϴzedTarget Fusion (MTF) research at General Fusion and where it exists in the landscape of various fusion energy research concepts. General Fusion's proposed soluϴons to four long-standing barriers to commercial fusion will be highlighted. This overview will include past experimental work and validaϴon of subsystems including proof-of-concept explosive plasma compression tests, various piston-based compression systems, power plant relevant plasma injectors and plasmas formed in the presence of liquid lithium. The extensive diagnosϴc development that is underway to support experimentaϴon, including collaboraϴons with various enϴϴes will be summarized. This will include specific menϴon of the Neutron Emission Spectrometer collaboraϴvely being developed by TRIUMF, SFU, Université de Sherbrooke and General Fusion. Lawson Machine 26 (LM26) - the new MTF machine that is designed to achieve fusion condiϴons by 2025, and progress toward scienϴfic breakeven by 2026 will be presented. The path towards commercializaϴon will also be discussed.

[198] First Year of Physics with NEEDLE Setup (17:45)

Presenter: JAWORSKI, Grzegorz (Heavy Ion Laboratory, University of Warsaw, Poland)

Nuclei in the vicinity of the proton-drip line are experimentally accessible via fusion-evaporation reactions. The arrays of HPGe detectors used for these studies have to be complemented with ancillary devices, which make possible accurate identification of the reaction channel. The channels with neutron and/or alpha emission lead to the most exotic nuclear structures, which are produced with very small cross-sections. Noteworthy, in gamma spectroscopic studies in this region it is the detection efficiency and selectivity of the ancillary detectors which allow reaching the most exotic and interesting nuclei. In 2023 the EAGLE gamma spectrometer at the Heavy Ion Laboratory, University of Warsaw, was equipped with the particle detectors: NEDA as a neutron multiplicity filter and DIAMANT for registering protons and alpha particles. The new setup was named NEEDLE. Within the first year of operating, a number of two-week-long experiments were performed. Inter alia, lifetimes of excited states of ^{134}Sm were investigated, and the shape co-existence and octupole correlations in the light Xe-Cs-Ba region were probed. We performed an experiment aiming at the observation of the yrast excited states in ^{57}Cu, an important waiting point in the rp-process. The Coulomb Energy Differences between ^{70}Br and ^{70}Se and the high-spin structure of 134Sm were investigated. In this contribution, the status of the NEEDLE setup, its performances during the last measurements and the highlights from the first physics campaigns will be presented. The possibilities to perform experiments on this setup employing the beams of the HIL's cyclotron will be discussed.

Heavy & Superheavy Elements: SHE 2 - Wedgemount (16:40 - 18:10)

-Conveners: Pore, Jennifer (Lawrence Berkeley National Laboratory)

[267] Investigating the Nuclear Structure of the Heaviest Elements with the SHIPTRAP Mass Spectrometer at GSI (16:40)

Presenter: GIACOPPO, Francesca (GSI Helmholtzzentrum für Schwerionenforschung GmbH - Darmstadt, Germany)

Investigating the boundaries of the nuclear chart and understanding the structure of the heaviest elements are at the forefront of nuclear physics. The existence of the superheavy nuclei is intimately linked to nuclear shell effects which counterpart Coulomb repulsion and therefore hinder spontaneous fission. In the region of heavy deformed nuclei weak shell gaps arise around Z=100 and N=152 as well as Z=108 and N=162. However, the extension of these gaps and their impact in the structure of these exotic nuclei, especially the most neutron-reach ones, is not yet fully understood, as most of the relevant isotopes are not experimentally addressed due to limited production capabilities, i.e. available beam-target combinations and/or corresponding low yields. Moreover, heavy and superheavy nuclides feature often metastable excited states with half-lives that can exceed the one of the ground state. Long-lived isomeric states can have excitation energies of only few tens of keV or below, therefore, their identification is challenging, especially in decay-based measurements. On the other hand, Penning trap mass spectrometry can provide sufficient resolving power to allow the separation of isomeric states when they are populated in the same reaction as the ground state. In recent years, we have established tailored and highly sensitive experimental methods allowing us to extend the reach of Penning-trap mass spectrometry with the SHIPTRAP setup to heavy elements well beyond uranium. In my talk, I will review the latest mass measurements of nuclides up to dubnium isotopes.

[136] Study of Deformed Structure in 254Es by Coulomb Excitation (17:05)

Presenter: IDEGUCHI, Eiji (RCNP, Osaka University)

Exploring the new elements toward the high end of the nuclear chart is one of the most interesting topics in nuclear physics. The key ingredient to stabilize nucleus in this region is a nuclear shell structure and Z=114, 120, N=184 are predicted to be new magic numbers. However, the access to such nuclei and study of their shell structure is limited by the very low cross sections. To investigate and understand the shell structure there, we are focusing on the nuclei in the A~250 heavy mass region including ^{254}Es. By studying the excited states, spin and parity, and deformation, we will be able to access the single-particle orbitals relevant to new shellstructure at Z=114, 120, N=184 in the super-heavy mass region. To study nuclear deformation in the A~250 region, we have performed Coulomb excitation experiments to determine the deformation of low-lying states of ^{254}Es. The experiment was performed at the JAEA-Tokai Tandem accelerator using a 240-MeV ^{58}Ni beam irradiating a ^{254}Es target. Particle-gamma coincidence measurements were conducted using segmented CD-silicon detectors placed backward and forward from the target and an arrayof Ge and LaBr$_{3}$ detectors. From the gamma-ray spectrum analysis, a rotational band structure in ^{254}Es was observed. In the presentation, recent experimental results will be discussed. This work is supported by the International Joint Research Promotion Program of Osaka University, JSPS KAKENHI Grant Number JP 17H02893, the U.S. Department of Energy, Office of Science, Office of NuclearPhysics under Award No. DE-SC0013037.

[157] Functionalized Detectors for Superheavy Element Homolog Chemistry Experiments (17:20)

Presenter: KIRKLAND, Amelia (Texas A&M; University)

Several experiments aimed at chemical properties of superheavy elements (SHE) have studied the interactions of single atoms on the surface of Si-based solid-state α-detectors. Recent advancements include coating the detectors with thin layers, such as Au, to test the effects of different surfaces. Without advancements in α-spectroscopy, the results can be inconclusive. To overcome this, a chemically selective technique has been developed at Texas A&M University. Au-coated Si-based solid-state α-detectors are further coated with an alkanethiolate self-assembled monolayer (SAM), which has a terminal group selected for the SHE. This has been demonstrated to work both in solution and in online experiments for Ir and Rh, homologs of meitnerium (Mt). A detector array is in development to test the efficacy of the SAM-coated detectors. One current project is to develop a system to study livermorium (Lv) by characterization of the detector array with Po (homolog of Lv) in offline and online experiments. $^{21□}$Po ($t_{½}$: 0.145 s, 100% α-decay) is produced in the decay chain of ^{228}Th. It is extracted into a recoil transfer chamber (RTC), to which the detector array is attached. Online, Po can produced via nuclear-fusion evaporation reactions, with a $^{4□}$Ar ion beam on a $^{1□2}$Dy target, producing $^{1□□□1□8}$Po ($t_{½}$: 5.8 s, 84 s, 105.6 s, 98%, 44%, 57% α-decay, respectively). The radioisotopes are separated from the primary ion beam and reaction by-products using the gas-filled recoil separator AGGIE, and are thermalized with a simple RTC (sRTC). Here, we present our latest results.

[202] Heavy Element Research at Texas A&M; University (17:35)

Presenter: FOLDEN, Charles (Texas A&M; University)

At the Cyclotron Institute at Texas A&M University, the Heavy Elements Group has been working to study compound nucleus survivability, develop new techniques for heavy element chemistry experiments, and increase the sensitivity of the AGGIE gas-filled separator. As an analog of superheavy element production, we have investigated the effects excitation energy, deformation, and neutron binding energy using the ^{44}Ca + ^{154,156,157,160}Gd reactions. Current research is focused on the ^{48}Ti + Gd, Dy reactions. In addition, we have been modifying Si detectors by adding a covering layer of Au and various organic monolayers; these effectively convert the detectors into a chromatography column. We recently completed a study of the adsorption of Er, Ir, and At on two different self-assembled monolayer (SAM) surfaces, and we are planning a future experiment to study the adsorption of Po on a SAM created with 1,9-nonanedithiol. An offline source of ^{216}Po is being used for preparatory experiments and an online experiment using short-lived Po isotopes is planned. We are also collaborating with researchers from the Paul Scherrer Institute in Switzerland to perform chemical experiments on nuclides with sub-second half-lives. We are upgrading the maximum magnetic rigidity of AGGIE to enable future experiments with heavier elements, including a potential study of No adsorbed on a SAM. Operational improvements at the Cyclotron Institute, including the use of a metal ion volatile organic compound (MIVOC) as ion source material, have also increased our sensitivity. This talk will discuss the most recent results and future plans.

Hot & Cold QCD: QCD 5 - Garibaldi B (16:40 - 18:10)

-Conveners: Hornidge, David (Mount Allison University)

[262] (Zoom) Heavy Quarks and Pre-Equilibrium Dynamics in Heavy-Ion Collisions (16:40)

Presenter: RADHAKRISHNAN, Sooraj (Kent State University/Lawrence Berkeley National Laboratory)

Heavy quarks (c and b) are produced predominantly in initial hard-scatterings in heavy-ion collisions at RHIC and LHC, making them ideal probes of the matter created in heavy-ion collisions. Measurements at RHIC and LHC have shown heavy quarks acquire significant collective flow from the expanding Quark Gluon Plasma (QGP), and their yields show significant suppression compared to expectations from p+p collisions, from interactions with and energy loss in the QGP. Heavy quarks, owing to their early production, are also sensitive probes of the initial conditions -- such as the initial density distributions and very strong magnetic fields expected to exist in the early stages of the collision, and pre-equilibrium dynamics of the QGP. Measurements have also shown that more heavy flavor baryons compared to mesons are produced in heavy-ion and p+p collisions, compared to the heavy quark fragmentation ratios measured in e+e- collisions. Heavy quarks thus offer unique opportunities to learn about all stages of heavy-ion collisions, from initial conditions and pre-equilibrium dynamics to transport and energy-loss in the thermalized QGP medium to hadronization. In this talk I will discuss some of the recent measurements on heavy flavor hadron production, yield ratios and flow in p+p, p+A and A+A collision at the RHIC and LHC. Insights from these measurements on understanding initial conditions, pre-equilibrium dynamics, QGP properties and hadronization mechanism will be discussed.

[259] Probes of the Quark-Gluon Plasma with sPHENIX (17:05)

Presenter: CONNORS, Megan (Georgia State U.)

sPHENIX is a new detector at the Relativistic Heavy Ion Collider (RHIC), with state-of-the-art calorimeter, tracking, and forward detectors used to explore the properties and behavior of the strongly-coupled Quark Gluon Plasma (QGP) created in heavy-ion collisions. sPHENIX features qualitatively new capabilities never before available at RHIC, and a rare probes program intended to complement and extend that at the Large Hadron Collider. sPHENIX underwent commissioning with Au+Au beams in 2023 and will begin taking high-luminosity p+p reference data in 2024. This talks presents the first measurements by sPHENIX of bulk QGP properties performed in the 2023 commissioning data, including the charged particle pseudorapidity density, the total transverse energy, neutral pion production, and azimuthal anisotropies. The status of the 2024 data-taking and conclusion of the commissioning process will also be presented.

[336] Precision Measurements of Net-Proton Number Fluctuations in Au+Au Collisions at RHIC (17:20)

Presenter: XU, Nu (LBNL)

The main goal of the RHIC beam energy scan program (BES) is to study the strongly interacting nuclear matter phase structure and search for the possible QCD critical point in high-energy nuclear collisions. Over more than a decade, the scan (BES-I and BES-II) covered a wide range of collision energy, from the center of mass energy 3.0 GeV to 200 GeV corresponding to a wide range of baryonic-chemical potential □_□ = 750 MeV to 25 MeV. The STAR detector, with some crucial upgrades, was the main apparatus used in the scan. Observables, for studying the physics of collectivity, Chirality, criticality, including light/strange hadrons, leptons, correlations, (hyper-)nuclei have been measured with the highest precision to date. In this talk, we will focus on the physics of phase boundary and QCD critical point. Specifically, new BES-II data on collision energy and centrality dependence of proton, anti-proton and net-proton cumulants, up to the 4TH order, in Au+Au collisions energy at 7.7, 9.2, 11.5, 14.6, 17.3, 19.6 and 27 GeV, will be presented. The new experimental results will be discussed within the framework of non-critical model calculations.

Nuclear Astrophysics: NA 6 - Garibaldi A (16:40 - 18:10)

-Conveners: Wrede, Christopher (Michigan State University and Facility for Rare Isotope Beams)

[65] New Results on the Direct Measurement of Carbon Burning at Astrophysical Energies (16:40)

Presenter: COURTIN, Sandrine (IPHC-CNRS and University of Strasbourg)

Fusion reactions play an essential role in the energy production, the nucleosynthesis of chemical elements and the evolution of massive stars. Among these reactions, carbon burning is a crucial ingredient to understand the late stages of massive stars essentially driven by the 12C+12C reaction [1]. It presents prominent resonances at energies ranging from a few MeV/nucleon down to sub-Coulomb barrier energies, possibly due to molecular 12C-12C configurations of 24Mg and persisting down to the Gamow window [2]. The direct measurement of key fusion reactions at stellar energies offers an unbiased and evident experimental access to this region where cross sections are of the sub-nano barn range, but calls for innovative measures for efficient background reduction [3,4]. This contribution will discuss recent results from our last experimental campaigns obtained in the 12C+12C system at deep sub-barrier energies using the STELLA setup combined with the UK-FATIMA detectors, installed at the ANDROMEDE 4 MV facility of the University Paris-Saclay and IJC Lab (France). Novel background reduction techniques will be presented which have allowed to extract new astrophysical 12C+12C S-factors at the highest precision reached so far. These will be discussed in terms of sub-barrier hindrance effects as well as resonant features in the 24Mg compound system. [1] C. E. Rolfs and W.S. Rodney, Cauldrons in the Cosmos (Univ of Chicago Press, 1988). [2] D. Jenkins and S. Courtin J. Phys. G: Nucl. Part. Phys. 42, 034010 (2015). [3] M. Heine, S. Courtin et al., Nucl. Inst. Methods A, 903 1 (2018), and references therein. [4] G. Fruet, S. Courtin et al., Phys. Rev. Lett. 124, 192701 (2020).

[201] The Challenging Direct Measurement of the 65 keV Resonance Strength in ^{17}O(p,γ)^{18}F at LUNA (16:55)

Presenter: PIATTI, Denise (Università degli Studi di Padova e INFN Padova)

A precise determination of proton capture rates on oxygen is mandatory to predict the abundance ratios of the oxygen isotopes in a stellar environment where hydrogen burning is active. The ^{17}O(p,γ)^{18}F reaction, in particular, plays a crucial role in AGB nucleosynthesis as well as in explosive hydrogen burning occurring in type Ia novae. At temperature of interest for the former scenario (20 MK $\le$ T $\le$ 80 MK) the main contributions to the astrophysical reaction rate come from the E_r = 65 keV resonance. The strength of this resonance is presently determined only through indirect measurements, with an adopted value $\omega\gamma$ = (1.6 $\pm$ 0.3) $\times$ 10^{-11} eV. A new high sensitivity setup has been installed at LUNA, located at Laboratori Nazionali del Gran Sasso. The underground location of LUNA 400kV guarantees a reduction of the cosmic ray background by several orders of magnitude. The residual background was further reduced by a devoted shielding. On the other hand the 4π−BGO detector efficiency was optimized installing an Al target chamber and holder. With about 400 C accumulated on Ta$_2$O$_5$ targets, with nominal ^{17}O enrichment of 90%, the LUNA collaboration has performed the first ever direct measurement of the 65 keV resonance strength. In the talk the setup details and preliminary results of the challenging direct measurement performed at LUNA will be reported.

[225] Study of the Proton Capture Reaction on 20Ne and 21Ne Isotopes at LUNA (17:10)

Presenter: BARBIERI, Lucia (University of Edinburgh)

The NeNa-MgAl cycles are involved in the synthesis of Ne, Na, Mg, and Al isotopes. The 20Ne(p,γ)21Na (Q = 2431.68 keV) reaction is the first and slowest reaction of the NeNa cycle and it controls the speed at which the entire cycle proceeds. At the state of the art, the uncertainty on the 20Ne(p,γ)21Na reaction rate affects the production of the elements in the NeNa cycle. In particular, in the temperature range from 0.1 GK to 1 GK, the rate is dominated by the 366 keV resonance corresponding to the excited state of EX = 2797.5 keV and by the direct capture component. The present study focus on the study of the 366 keV resonance and the direct capture below 400 keV. At LUNA (Laboratory for Underground Nuclear Astrophysics) the 20Ne(p,γ)21Na reaction has been measured using the intense proton beam delivered by the LUNA 400 kV accelerator and a windowless differential-pumping gas target. The products of the reaction are detected with two high-purity germanium detectors. The same setups was used to study the proton capture on 21Ne isotope where several resonances at astrophysical enemies have been investigated with high precision by LUNA during the 2023. The first results on those two reaction will be discussed in this contribution with detailed analysis and the evaluation of the impact on the NeNa cycle and in the globular cluster Na-O anti correlation.

[245] A New Underground Measurement of the ^{14}N(p,γ)^{15}O Reaction at LUNA (17:25)

Presenter: COMPAGNUCCI, Alessandro (Gran Sasso Science Institute and INFN LNGS)

An accurate understanding of the slowest reaction of the CNO cycle, the ^{14}N(p,γ)^{15}O, is essential for estimating the lifetimes of massive stars and globular clusters. Additionally, it plays a crucial role in determining the CNO neutrino flux emitted by the Sun. Despite the significant efforts over the last twenty years, including pioneering underground measurements made by the LUNA collaboration, this reaction remains a predominant source of uncertainty when assessing the solar chemical composition. As a pilot project for the LNGS Bellotti Ion Beam Facility, the LUNA collaboration has measured

^{14}N(p,γ)^{15}O with a focus on its excitation function using Tantalum Nitride solid targets, developing novel approaches to limit the beam-induced background contributions. An excellent sensitivity was achieved in synergy with the high beam current provided by the Bellotti Ion beam facility 3.5 MV accelerator in its deep-underground location. New angular distribution data have been obtained in the energy range from 0.3 to 1.5 MeV, including also the weaker transitions, many of them not observed by previous authors. In this talk I will present the differential cross section results that provides a novel comprehensive picture of the reaction at astrophysical energies.

Nuclear Reactions I: NR 11 - Rainbow Theatre (16:40 - 18:10)

-Conveners: Ogata, Kazuyuki (Kyushu University)

[297] Bayesian Uncertainty Quantification of Nuclear Reaction Theory (16:40)

Presenter: NUNES, Filomena (Michigan State University)

Nuclear reactions are an essential probe into isotope structure and nuclear astrophysics. They are important to learn about where nuclei come from and how they are produced.They provide critical knowledge on how neutrons and protons organize themselves to form matter as we know it and at the limits of stability. However until recently, models for nuclear reactions included no uncertainty quantification. In this presentation, I will review the Bayesian analysis efforts developed over the last few years in reaction theory, including not only uncertainty quantification but also steps toward experimental design.

[88] (Zoom) The (d,p) Reaction on 11Be Using ISS: Bringing Clarity to the Structure of 12Be (17:05)

Presenter: CHEN, Jie (Southern University of Science and Technology)

A quantitative description of the single-particle configurations of the low-lying states in ^{12}Be still eludes us despite numerous attempts via direct and indirect reactions. For the three previous (d,p) reactions, their reaction energies and angular coverage were not optimized so the data could not be easily interpreted in terms of well-tested reaction mechanisms. For another, these measurements provided limited information on the unbound excited states and did not achieve good enough Q-value resolution to isolate the 0^+_2 and 2^+_1 states which are just 150 keV apart. To resolve this situation, a new ^{11}Be(d,p) measurement has been carried out using ISS at ISOLDE at an energy of 9.78 MeV/u. The 0^+_2 and 2^+_1 states have been isolated owing to the good resolution of ISS. The neutron $1s_{1/2}$ spectroscopic factor of the 0^+_2 level has been determined, which will allow for its matter radius extraction, and hence, if it has a two-neutron halo structure, similar to the ^{11}Li ground state. The recently observed 0^- state has been confirmed and its width and excitation energy have been precisely determined, located just ~20 keV above S_{n}. The spectroscopic factors of states below 5 MeV have also been determined and suggestions of the spin-parities of the unbound states have been made. In particular, a new resonance at ~4.2 MeV has been observed for the first time in ^{12}Be. The new results will be compared with shell model calculations incorporating effective interactions, Gamow shell model (GSM) calculations and Gamow coupled-channel method (GCC) calculations incorporating the continuum coupling effects.

[173] How the Study of the Continuum Structure of Light Nuclei Led to the Discovery of 7 New Isotopes and Exacting Tests of Nuclear Structure Models that Treat the Continuum (17:20)

Presenter: SOBOTKA, Lee (Washington University)

Over the past decade our group has studied the continuum structure of p-rich light nuclei using the invariant-mass technique. This effort has led to the discovery of 7 new isotopes beyond the proton-drip line. Just as important are the findings of new resonances in previously known nuclei and parameter refinement of previously known resonances. Some of the more interesting results (e.g. finding of previously unknown near threshold states, fission of 16O, and fixing 0+_2 in 10C and the rotational band built on it) will be mentioned. The failure to find states predicted by state-of-the-art structure theories which include some continuum effects, has also proven to be informative. Such a case is our failure to find a resonance in 7Li just above the proton-decay threshold predicted by no-core-shell-model-with-continuum (NCSMC) calculations. In the process of executing this program, we appreciated that we can offer a heuristic qualifier to the well-worn adage in barrier penetration problems that the forbidden momentum-distance (action) cannot be decomposed to inform on the shape of the barrier traversed.

[206] What's New? An Ab Initio Investigation of He-3 He-4 Radiative Capture into Be-i (17:35)

Presenter: ATKINSON, Mack (Lawrence Livermore National Laboratory)

The ^{3}He$(\alpha,\gamma)^7$Be reaction is an important part of ongoing processes occurring in stars like our very own sun. In the fusion reaction network of the sun, the ^{3}He$(\alpha,\gamma)^7$Be reaction is key to determining the ^{7}Be and ^{8}B neutrino fluxes resulting from the pp-II chain . In standard solar model (SSM) predictions of these neutrino fluxes, the low-energy ^{3}He$(\alpha,\gamma)^7$Be S factor, $S_{34}(E)$, is the largest source of uncertainty from nuclear input. The SSM uses $S_{34}(E)$ near the Gamow peak energy, roughly 18 keV, which cannot be experimentally measured since the Coulomb force between ^{3}He and ^{4}He suppresses the fusion reaction at such low energies. Theoretical calculations are needed to guide the extrapolation to the solar energies of interest. To this end, I will present *ab initio* calculations of the ^{3}He$(\alpha,\gamma)^7$Be reaction using the no-core shell model with continuum starting from two- and three-nucleon chiral interactions. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC.

[195] Quantifying Uncertainties on Nuclear Clustering and Dynamics Properties from a Symmetry-Informed Ab Initio Perspective (17:50)

Presenter: BECKER, Kevin (Louisiana State University)

By exploiting the near-perfect symplectic symmetry that emerges from the strong interaction, the symmetry-adapted no-core shell model provides a robust *ab initio* description of the nucleus capable of accurately capturing challenging collective correlations and clustering features [1,2,3]. Utilizing realistic nucleon-nucleon interactions within this framework allows for a completely *ab initio* treatment of nuclear structure that, with properly quantified model uncertainties, can be directly compared to experimental measurements to push the envelope of both theory and experiment [4,5]. I discuss results which propagate uncertainties in the low-energy constants parametrizing chiral potentials into uncertainties of reaction observables for 6Li, 12C, and 19Ne, with a focus on spectroscopic factors, asymptotic normalization coefficients, partial widths, and reaction rates, for single-nucleon, deuteron, and alpha channels. I additionally present error analysis of *ab initio*-deduced optical potentials. This study presents a first step towards a fully rigorous uncertainty quantification of *ab initio* predictions, and sheds new light on the interplay between clustering and collectivity. [1] T. Dytrych, K. D. Launey, J. P. Draayer et al., Phys. Rev. Lett. 124, 042501 (2020) [2] K. D. Launey, A. Mercenne, T. Dytrych, Annu. Rev. Nucl. Part. Sci. 71, 253–277 (2021) [3] A. C. Dreyfuss, K. D. Launey, J. E. Escher et al., Phys. Rev. C 102, 044608 (2020) [4] A. Ekström, G. Baardsen, C. Forssén et al., Phys. Rev. Lett. 110, 192502 (2013) [5] I. Svensson, A. Ekström, C. Forssén, Phys. Rev. C 107, 014001 (2023) HPC resources provided by LSU, NERSC, and the Frontera computing project.

Nuclear Reactions II: NR 12 - Ballroom B (16:40 - 18:10)

-Conveners: Watanabe, Yutaka (KEK WNSC)

[33] Colliding Heavy Nuclei Have Multiple Identities on the Path to Fusion (16:40)

Presenter: COOK, Kaitlin (Australian National University)

Barrier passing models of fusion implement absorption (irreversible energy dissipation) through an incoming-wave boundary condition or imaginary potential located inside the barrier, ensuring separation between channel coupling effects and absorption. Couplings to few-nucleon transfer channels are found to be important in selected cases, otherwise nuclei fuse essentially unchanged. Experiments show that this picture is too simple. Measured capture cross-sections for heavy-ion collisions at energies well above and well below the barrier are systematically smaller than model calculations. This may have a dynamical origin -- exchange of nucleons and the loss of kinetic energy outside the barrier separation, prior to capture leading to reduced cross-sections. Here, we seek to address the following question: is the state of the system at the barrier separation consistent with conventional models of fusion, that assume the nuclei are essentially unchanged prior to capture? Measurements of reflected flux in reactions of ^{32}S,^{40}Ca + ^{208}Pb were performed at a series of below-barrier energies using the PRISMA spectrometer. The isotopically-identified reflected flux reveals that the onset of energy damping occurs *outside* the fusion barrier. By the time the barrier radius is reached, the reflected flux highly fragmented into many nuclide pairs with high excitation energies, lowering their energy with respect to the fusion barrier, and broadening the barrier distribution. This provides a pathway that explains the observed above-barrier fusion hindrance and is critically neglected in barrier passing models.

[45] A New Understanding of Quasifission and Deep Inelastic Collisions: Non-Equilibrium Competitors to Superheavy Element Fusion (17:05)

Presenter: HINDE, David (Australian National University)

Fusion forming superheavy elements is strongly inhibited by the faster non-equilibrium Deep Inelastic (DIC) and quasifission processes. Long considered distinct, recent extensive measurements at ANU^{1,2,3} indicate that they form a continuum.^{1} For reactions with non-fissile heavy nuclei, a novel experimental approach^{2} gave *direct* information on the time dependence of mass evolution in fast quasifission. Results were consistent with increasing mass fluctuations with time^{2} rather than a rapid drift of the mean mass towards mass-symmetry inferred from reactions with actinide nuclides^{4}. For actinide reactions, *binary* mass-split spectra all show reduced yield between the target mass and fragments around ^{208}Pb^{4}, generally attributed to closed shells (giving increased binding). However, extensive binary *and three-body* cross-sections extracted for ^{50}Ti + actinide reactions^{3} could not be explained in this framework. Rather, the drop in yield is consistent with *sequential fission* of heavy deep inelastic/quasifission fragments^{3}. This dip in yield cannot now be taken as evidence of separation between DIC and quasifission mechanisms, nor for the importance of spherical closed shells in quasifission mass distributions. In support, quasifission mass spectra for non-actinide reactions^{5} showed negligible effects of the shells that cause *low energy* mass-asymmetric fission of the same (actinide) compound nuclei. [1] K. Banerjee et al. PRL 122(2019)252503 [2] T. Tanaka et al. PRL 127(2021)222501 [3] D.Y. Jeung et al. PLB 837(2023)137641 [4] D.J. Hinde et al. PPNP 118(2021)103856 [5] D.J. Hinde et al. PRC 106(2022)064614

[11] (Zoom) Study of the Neutron-Rich Nucleus $\rm ^{6}H$ in Electron Scattering Experiment at MAMI-A1 (17:20)

Presenter: SHAO, Tianhao (Fudan University)

The neutron-rich isotopes of hydrogen, such as $\rm ^{6}H$ and $\rm ^{7}H$, are good platforms for the study of NN interactions in neutron-rich environments because they have the largest neutron-to-proton ratios known so far. However, the experimental and theoretical studies of them are still limited. For $\rm ^{6}H$, the energy of its ground state is still controversial. It is about 2.7 MeV (above the $\rm ^{3}H$+3n threshold) in some experiments but about 6.6 MeV in others. The actual location of the $\rm ^{6}H$ ground state remains an open problem in theoretical work as well. To solve this puzzle, $\rm ^{6}H$ is studied for the first time in an electron scattering experiment with the reaction $\rm ^{7}Li(e, e'p\pi^{+})^{6}H$ at MAMI-A1. The 855 MeV electron beam of the Mainzer Microtron (MAMI) is used to hit a $\rm ^{7}Li$ target. The scattered electron, the produced proton, and π^{+} are measured by the three-spectrometer setup in the A1 hall. With the triple timing coincidence and momentum measurements of three spectrometers, the missing mass spectrum of $\rm ^{6}H$ can be obtained. In this talk, we will present the details of our experiment. The principle, setup, and data analysis of the experiment, including corrections and calibrations of the data, will be discussed. Our measurement of the $\rm ^{6}H$ ground state energy will be shown and compared with previous measurements and theoretical calculations.

Nuclear Structure I: NS 7 - Harmony A (16:40 - 18:10)

-Conveners: Pain, Steven (ORNL)

[298] Structure of 13Be Studied Through the 12Be(d,p)13Be Reaction (16:40)

Presenter: GRZYWACZ, Kate (University of Tennessee Knoxville)

The low-lying structure of 13Be has remained an enigma for decades. Despite numerous experimental and theoretical studies, inconsistencies remain. Being both unbound and one neutron away from 14Be, the heaviest bound beryllium nucleus, 13Be is difficult to study through simple reactions with weak radioactive-ion beams or more complex reactions with stable-ion beams. Data from a study of 13Be using the 12Be(d,p)13Be reaction in inverse kinematics using a 9.5 MeV per nucleon 12Be beam from the ISAC-II facility will be presented. The solid deuteron target of IRIS was used to achieve an increased areal thickness compared to conventional deuterated polyethylene targets. The Q-value spectrum below −4.4 MeV was analyzed using a Bayesian method with GEANT4 simulations. Two possible scenarios to explain the strength below 1 MeV above the neutron separation energy are proposed. Comparisons of the Q-value spectrum with GEANT4 simulations obtained using the energies and widths of states reported in four previous works will be presented.

[272] Study of Shell Gaps in Neutron-Rich Carbon Isotopes : Spectroscopy of 15C and 17C (17:05)

Presenter: FERNANDEZ DOMINGUEZ, Beatriz (University of Santiago de Compostela)

The evolution of the shell structure observed in exotic nuclei has led to a change of paradigm in our understanding of the nuclear force. Extensive knowledge of the modification of shell gaps in the oxygen chain has been gathered over the past decades. With two-protons below, the carbon isotopes show exotic properties and are a good testing ground for understanding new aspects of nuclear forces. Neutron adding and removing reactions from 16C have been used to locate the single-particle orbitals involved in the formation of shell gaps below N=20. The experiments were performed at GANIL with the TIARA+MUST2+EXOGAM+CHARISA set-up. In this work, I will present recent results of the low-lying spectroscopy of 15C and 17C. Excitation energies and spectroscopic factors have been used to track the shell evolution from 15C to 17C. Comparison with shell model calculations using state-of-the-art interactions such as SFO-tls show a good agreement with the experimental data. In addition, for 15C, the experimental results are compared to ab-initio self-consistent Green's function method employing the NNLOsat interaction. In the case of 17C, important effects of the continuum were observed.

[57] Probing 11Be Structure with Transfer Reactions in the AT-TPC (17:30)

Presenter: SERIKOW, Michael (MSU/FRIB)

The commissioning of transfer reaction measurements in inverse kinematics in the SOLARIS solenoid with the Active Target Time Projection Chamber (AT-TPC) was successfully completed in the summer of 2021 at the NSCL. The goal of this experiment was to demonstrate the possibility of performing transfer reaction measurements at low beam intensities (between 100 Hz - 1 kHz) using the high luminosity provided by the AT-TPC. A beam of 10Be was accelerated to 9 MeV/u in the ReA6 linac and delivered to the AT-TPC placed inside SOLARIS, which provided a 3 Tesla magnetic field. The AT-TPC was filled with pure deuterium gas at 600 Torr. Although multiple reaction channels were simultaneously detected, we focus on the 10Be(d,p) channel that populates bound and unbound states in 11Be, with a particular interest towards the 3.4 MeV resonance for which the parity is still an open question. We present the preliminary analysis of the 10Be(d,p) channel, including angular momentum transfer identification and determination of spectroscopic factors from comparison with DWBA calculations. The AT-TPC has since collected data on multiple transfer reactions, including those derived from 16C+d, 16C+p, 15C+d, 15C+p, 12Be+p, and 7Be+d at around 12 MeV/u, from which a few selected preliminary results will also be presented.

Banquet (19:00 - 21:00)

Friday, 23 August 2024

Plenary (09:00 - 10:30)

-Conveners: Galindo-Uribarri, A. (Oak Ridge National Laboratory)

[305] Exploring Nuclei at the Edge of Nuclear Landscape (09:00)

Presenter: NAKAMURA, Takashi

How many more neutrons can be added to a given atomic nucleus, and how do such extremely neutron-rich nuclei behave? These are fundamental questions for understanding nuclear structure and relevant nuclear interactions at the edge of stability of nuclei, the driplines. I will show the recent progress of spectroscopic studies of neutron-rich nuclei near and beyond the neutron drip line using direct reactions. After introducing the characteristic experimental methods with a variety of direct reactions, I focus on some of the selected experimental studies at RIBF, RIKEN. I show the first observation of the candidate doubly magic nucleus, 28O (Z=8, N=20)[1], beyond the neutron drip line. I also show the study of the deformed halo nuclei, such as 31Ne in the island of inversion, by using the combinations of different direct reactions: Coulomb breakup, inelastic scattering, and nucleon knockout reactions. Future perspectives on the spectroscopy of such extremely neutron-rich nuclei are also discussed. [1] Y. Kondo et al., Nature 620, 964 (2023).

[337] Neutrinos and Nuclear Security (09:30)

Presenter: HUBER, Patrick (Virgina Tech)

Nuclear reactors are the brightest artificial neutrino sources and have been the workhorse of neutrino physics since the discovery of the neutrino. In the 1970s Lev Mikaelyan realized that neutrinos also can be used to learn about the internal state of a nuclear reactor. The past decade has seen a significant increase in the interest in reactor neutrinos and their applications to nuclear security. I will review the underlying science and recent progress on detector technology.

[303] Nuclear Dynamics in the Framework of Time-Dependent Density Functional Theory with Pairing Correlations (10:00)

Presenter: MAGIERSKI, Piotr (Warsaw University of Technology)

Superfluidity and superconductivity are remarkable manifestations of quantum coherence at a macroscopic scale. The existence of superfluidity has been experimentally confirmed in many condensed matter systems, in He-3 and He-4 liquids, in nuclear systems including nuclei and neutron stars, in both fermionic and bosonic cold atoms in traps, and it is also predicted to show up in dense quark matter. Pairing correlations in nuclear systems are one of the most important characteristics of non-magic atomic nuclei. Various features related to high spin phenomena or to large amplitude collective motion, e.g., fission, indicate that these correlations are crucial for our understanding of nuclear structure and dynamics. The time dependent density functional theory (TDDFT) is, to date, the only microscopic method that allows to investigate fermionic superfluidity far from equilibrium. In nuclear physics, it offers a microscopic description of low energy nuclear reactions, where fermionic degrees of freedom and pairing field dynamics are explicitly taken into account. Using the most powerful supercomputers, we are currently able to study real-time 3D dynamics without any symmetry restrictions, evolving up to hundreds of thousands of superfluid fermions. During the talk, I will review several applications and qualitatively new results concerning nuclear collisions, including solitonic excitations and pairing instability in collision processes. I will also discuss the problem of effective mass determination for nuclear impurites in the neutron star crust. Last but not least, I will present the mechanism for vortex generation due to nuclear dynamics in the crust.

Coffee Break (10:30 - 11:00)

Plenary (11:00 - 12:00)

[323] Theoretical Perspectives on Hadron Structure (11:00)

Presenter: VANDERHAEGEN, Marc (U. Mainz)

Nucleons are the building blocks of atomic nuclei, and are responsible for more than 99 % of the visible matter in the universe. Around 50 years after the establishment of Quantum Chromo Dynamics as the quantum field theory describing the strong interaction within the Standard Model of particle physics, the precise way in which the quarks and gluons compose the nucleon and build up its global properties, i.e. its mass, momentum, charge, or spin distributions, as well as give rise to its excitation spectrum are still challenging our understanding. Accurate knowledge about e.g. the proton charge radius is not only essential for understanding how QCD works in the non- perturbative region, but also important for bound state QED calculations of atomic energy levels. In this talk, I will review the progress achieved in exploring nucleon structure both through hard processes and through measurement of low-energy precision quantities. It will be shown how the three-dimensional momentum-space imaging and tomography of the proton, as well as of nucleon resonances, is connected to low-energy structure quantities such as charge radii and polarizabilities which are crucial inputs in the interpretation of precision atomic spectroscopy experiments.

[230] Experimental Challenges in Underground Nuclear Astrophysics Laboratory (11:30)

Presenter: BEST, Andreas (INFN Naples)

Nuclear fusion reactions are at the heart of nuclear astrophysics as they control the energy production in stars and determine the synthesis of the elements in our Universe. Most cross sections are too small to be directly measured in a laboratory at the stellar energies. They are extrapolated by means of phenomenological nuclear models anchored to available high energy data. Cosmic rays, environmental radioactivity and beam-induced background reactions on target impurities, all represent a major limitation to the measurement of thermonuclear cross sections at stellar energies. The LUNA collaboration has achieved extremely important results with major implications not only in nuclear astrophysics but also in cosmology and particle physics, using the LUNA 400 kV accelerator installed in Laboratori Nazionali del Gran Sasso (LNGS). In 2023, a new LNGS facility a 3.5 MV Singletron accelerator, is running delivering intense proton, helium, and carbon beams with well-defined energy resolution and stability. A first experimental proposal, presented by the LUNA-Collaboration, has been approved and it focuses on the cross section measurements of the 14N(p,g)15O, 12C+ 12C, 22Ne(a,n)25Mg reactions. This talk will outline the general features of experimental techniques adopted in underground nuclear astrophysics presenting a summary of the LUNA main recent results and achievements. I will overview the status of the JUNA and Caspar projects located, in deep underground laboratory, in China and US, respectively.

Lunch Break (12:00 - 13:30)

Applications, Facilities & Instrumentation: AFI 6 - Ballroom B (13:30 - 15:00)

-Conveners: Hackman, Greg (TRIUMF)

[85] Analyzing Superheavy Element Nuclides with a Multi-Reflection Time-of-Flight Mass Spectrograph (13:30)

Presenter: SCHURY, Peter (KEK Wako Nuclear Science Center)

The atomic masses of superheavy elements is a valuable for calibrating and improving models of nuclear structure in the upper bound of nuclear existence. In many cases, as the difference in binding energy between ^A_ZX and $^A_{Z-1}$X far exceeds the variance among reasonable models, a sufficiently precise mass determination could provide an orthogonal method for element identification. To these ends, our group has developed a large multi-reflection time-of-flight mass spectrograph (MRTOF), coupled to a helium gas ion stopper located downstream from the gas-filled recoil ion separator GARIS-II at RIKEN. $\,\,\,\,\,\,$ Our MRTOF features an ion detector that provides an ion impact signal for ToF determination, along with a pair of embedded silicon PiN diodes to detect subsequent alpha- and beta-decays. When combined with the MRTOF's mass resolving of $m/\Delta m$$\sim$7.5$\times$10^{5} the decay-correlated ToF-MS this detector allows us to perform gives us the ability to absolutely exclude spurious ToF signal sources such as cosmic rays and stable molecular ions. The technique also allows for simultaneous determination of mass and half-life. In cases where an isomeric state emits an alpha-particle with sufficiently different energy from that of the ground state, we could use the technique to resolve even very low-lying isomers; this also allows the use of the MRTOF to determine the state ordering, which in many cases among SHE is not clear. $\,\,\,\,\,\,$We will present the status of and recent results from our system, and discuss plans for extending and improving the technique in the near future.

[114] Radiation Effects on Spacecraft and Aircraft (and How to Avoid Them) (13:55)

Presenter: HANDS, Alex (TRIUMF)

The space environment poses various threats to the survivability and durability of satellites and other spacecraft. One of the most prominent is the impact of radiation on electronics systems, which can be degraded, disrupted or even destroyed by background galactic cosmic rays and space weather events. Trapped protons and electrons in the Van Allen belts that surround the Earth also pose a significant risk to Earth-orbiting satellites, both through cumulative effects such as total ionisng dose (TID) and spontaneous single event effects (SEE). Mitigating these risks involves a multifaceted approach including radiation-hardened electronics, space environment modelling, multi-scale device simulations and ground testing at accelerator facilities. TRIUMF, home to the world’s largest cyclotron, has dedicated facilities for accelerated radiation effects testing with intense, high-energy proton beams. This capability is used by industrial and academic users from all over the world to study the effects of radiation on their components and systems. TRIUMF also has facilities for the accelerated testing of electronics with white-spectrum spallation neutrons. These are used to study the effects of atmospheric radiation on ground-based systems and aircraft electronics, which are susceptible to some of the same effects experienced by spacecraft. In combination, facilities at TRIUMF play a key role in a global effort to ensure the safe operation of electronics systems that operate in very different radiation environments from the surface of the Earth to interplanetary space.

[260] Testing a New Technology for Producing High Purity Germanium Segmented Detectors (14:20)

Presenter: NAPOLI, Daniel R. (INFN Legnaro National Labs, Italy)

Hyperpure Germanium (HPGe) gamma-ray detectors are fundamental tools for nuclear physics thanks to their exceptional energy resolution but have some well-known drawbacks. We present here recent advancements in HPGe-contacts technology based on the innovative pulsed laser melting (PLM) method. PLM promotes an efficient diffusion of high dopant concentrations into the melted HPGe subsurface layer, followed by a fast epitaxial regrowth. The resulting layer is perfectly pseudomorphic to the Ge substrate. While producing highly doped n+ and p+ junctions, PLM does not contaminate HPGe crystal due to the very low and surface-limited thermal budget. The resulting n+ or p+ contacts are both very thin (around 200nm), segmentable and stable against thermal cycles. After introducing the method, different results obtained with HPGe segmented detector prototypes will be shown, both before and after induced neutron damage and annealing.

[231] Enhancing Heavy Ion Accelerator Capabilities in Australia for Research and Industry (14:35)

Presenter: DASGUPTA, M. (Australian National University)

Heavy Ion Accelerators (HIA) is a network of ion accelerators in Australia funded by the Australian Government’s National Collaborative Research Infrastructure program. HIA supports frontier research into nuclear physics, quantum technologies, climate and environment, dark matter, astrophysics, material and space science. HIA and the unique capabilities built around them attract international users to Australia. The largest in the network is the Heavy Ion Accelerator Facility at the Australian National University, which comprises a 14UD tandem, and a superconducting booster accelerator. In continuous operation for 50 years, the facility, which has been upgraded several times, is the only capability for experimental research and hands-on training in nuclear physics in Australia. Its national importance, demands of Australian industries and new national priorities have resulted in recent investments to upgrade and build new capabilities. Examples of new enhancements include replacement of all ceramic acceleration tubes and posts within the tandem to increase peak achievable voltage, addition of an α-particle ion source, new control hardware and software and a beamline for testing of space-bound electronic components, devices and materials. Funded by the Australian Space Agency, the beamline is operating since 2023. I will describe some of these enhancements and the challenges in attaining them. The benefits of enhancing accelerator capabilities to industry is exemplified by the newly funded Industrial Transformation Training Centre in nuclear and radiation science – a partnership between Universities and resource, medical, quantum and space industries.

Nuclear Astrophysics: NA 7 - Garibaldi A (13:30 - 15:00)

-Conveners: Lennarz, Annika (TRIUMF)

[340] Experimental Constraints for i-Process Nucleosynthesis Using Indirect Techniques (13:30)

Presenter: RICHARD, Andrea (Ohio University)

One of the biggest questions in nuclear astrophysics regards the origin of heavy elements in the universe. The picture of traditional neutron-capture nucleosynthesis showed that two main processes contribute to elemental abundances heavier than iron, namely the slow (*s*) and rapid (*r*) processes. In recent years, observations and stellar evolution models of carbon-enhanced metal poor stars (CEMP) and Rapidly Accreting White Dwarf stars (RAWDs) suggest that an intermediate process, known as the *i*-process exists between the two traditional processes. Given that the *i*-process occurs ~ 2-8 neutrons from stability, many of the nuclear properties such as masses and half-lives are known, leaving neutron-capture cross sections as the main source of nuclear data uncertainty. Direct (n,γ) measurements are only feasible for long-lived nuclei, while for short-lived nuclei, indirect methods are necessary. In this presentation, I will discuss indirect neutron-capture techniques that have recently been developed and how they can be applied across the nuclear landscape at rare isotope beam facilities. Results from the Surrogate Reaction Method for the ^{93}Sr(d,pγ)^{94}Sr measurement performed at TRIUMF and experimental campaigns at the Facility for Rare Isotope Beams and CARIBU at Argonne National Laboratory will also be discussed.

[197] Constraining Neutron Capture Cross Sections via Surrogate Measurements with Hyperion (13:55)

Presenter: KOROS, Jes (University of Notre Dame)

Indirect measurements are necessary to constrain cross sections and reaction rates of nuclear reactions that are inaccessible for direct measurement. One such indirect technique is the surrogate method. This method uses an alternate reaction channel to populate a nucleus of interest, and combines resulting experimental data with theory to constrain the (n,γ) cross section. Individual γ-decay probabilities are experimentally extracted, and in-beam γ-ray spectroscopy enables these measurements for very short-lived nuclei. Experimental results are used with nuclear data as constraints in Hauser-Feshbach calculations. These statistical nuclear models of the desired and surrogate reactions use nuclear level densities, optical model potentials, and γ-strength functions (γSF) to predict cross sections. Experimental γ-decay probabilities may be used to constrain γSF models, and therefore the resulting n-capture cross section. This project involves surrogate analysis of data from Hyperion, a particle-γ coincidence array utilizing in-beam γ-ray spectroscopy. Reactions measured were ^{64,70}Zn(p,d) and ^{64,70}Zn(p,t) as surrogates for ^{61,62,67,68}Zn(n,γ). The experiment was performed in fall 2021 at Texas A&M University's Cyclotron Institute with a 27-MeV proton beam from the K150 cyclotron. Results presented are extracted γ-decay probabilities; further analysis is under way in constraining (n,γ) cross sections. Additional investigation will be done into the feasibility of a 'γ energy-integrated' approach to obtain a total γ-decay probability per nucleus of interest. Supported by NNSA grant NA-0003841 in collaboration with LLNL Contract DE-AC52-07NA27344 and LDRD 20-ERD-030

[117] Indirect Study of Alpha Capture on 17O for Determining the Impact of 16O on the s-Process (14:10)

Presenter: ANGUS, Cameron (TRIUMF)

Approximately half of the heavier-than-iron elements in the solar system today were made in the s-process. Of those elements, most between Iron and Strontium were made in massive stars. S-process nucleosynthesis in massive stars is driven by the reaction 22Ne(α,n)25Mg, the rate of which is enhanced by rotational mixing of 12C into the H-burning shell. However, 16O is a strong neutron poison, through the reaction 16O(n,γ)17O, and competes with the s-process. The relative rate of subsequent alpha-induced reactions on 17O has been shown to determine the efficiency of s-process nucleosynthesis in this site. However, lack of information on several resonances important to the 17O(α,n)20Ne and 17O(α,γ)21Ne reactions is a major source of uncertainty in nucleosynthesis modelling. A series of experiments have been conducted at several laboratories around the world, aiming to measure parameters, such as spin-parities and partial widths, of the energy levels that give rise to the resonances of astrophysical interest in the two α+17O reactions. A 17O(7Li,t)21Ne experiment has been conducted at TRIUMF, using the EMMA recoil mass spectrometer and the TIGRESS gamma-ray spectrometer. The choice of a (7Li,t) measurement complements other studies by aiming to determine which energy levels contribute significantly to the 17O(α,γ)21Ne reaction and to determine their associated alpha widths. The overall goal of this experiment is the reduce the uncertainty on the estimated rate of the 17O(α,γ)21Ne reaction. Preliminary results from the analysis of this experiment, along with a summary of the current status of the other experiments shall be presented.

Nuclear Reactions I: NR 13 - Rainbow Theatre (13:30 - 15:00)

-Conveners: Nunes, Filomena (Michigan State University)

[301] Reaction Theory Developments for Breakup and Quasifree Knockout Reactions (13:30)

Presenter: OGATA, Kazuyuki (Kyushu University)

I will review our recent activities on breakup and knockout reactions. The following topics will be covered: 1) New reaction model for describing knockout reactions for fragile/unbound particles, 2) Effective polarization of the reaction residue of alpha knockout reactions. 3) Description of high-energy transfer reactions with the impulse approximation. 4) Semiclassical distorted wave model approach to deuteron-induced inclusive knockout reactions 5) Studies of the thee-nucleon force effect via knockout reactions.

[92] Protons in ^{46}Ar: Bubbles and Transition Probabilities (13:55)

Presenter: BRUGNARA, Daniele (Laboratori Nazionali di Legnaro, INFN)

Departures from the conventional liquid-drop-like saturated density of the nucleus represent a key interest in the study of nuclear structure. Phenomena of such as bubble structures offer a unique insight into the macroscopic effects of the nuclear interaction. We present experimental indication of the occurrence of this phenomenon in ^{46}Ar, where the depletion is generated by the level inversion of the $s_{1/2}-d_{3/2}$ orbitals together with the unexpected presence of a sub-shell closure. The experiment is aimed at probing the proton component of the wavefunction via a proton-pickup direct reaction: ^{46}Ar(^{3}He, d)^{47}K at an energy of 350 MeV. The experiment, performed at the Spiral 1 facility in GANIL with a post-accelerated radioactive ^{46}Ar beam impinging on a high-density cryogenic ^{3}He target, has allowed to assess the transfer probability to the $d_{3/2}$ state relative to the $s_{1/2}$. The heavy reaction fragment was identified by the VAMOS magnetic spectrometer, while the silicon DSSSD detector, MUGAST, allowed the measurement of the angular distribution of the light ejectile while also performing particle identification. The AGATA gamma-ray tracking array measured the gamma rays produced by the decay of the ^{47}K excited states. It has been observed that measured transition probabilities in ^{46}Ar diverge by a factor of two from values predicted by the well-established shell model with SDPF-U interaction. We found this peculiar bubble structure of the proton wavefunction to be strongly tied with the puzzle of transition probabilities in ^{46}Ar by comparing the experimental result with ab initio calculations.

[210] Next-Generation Optical Potentials for Nuclear Reactions and Structure (14:10)

Presenter: PERROTTA, Salvatore Simone (Lawrence Livermore National Laboratory)

Nucleon-nucleus optical-model potentials are an effective model to characterize the nuclear interaction. They are an essential input for nuclear reaction calculations required in nuclear physics, astrophysics, cosmology, and engineering applications. Proper uncertainty quantification of the optical model is necessary to obtain reliable uncertainties on extrapolations and on any result using the potential as an ingredient [1]. A physically consistent optical potential is also expected to be dispersive [2,3]. This property allows the potential to be informed by and/or predict both reaction and structure observables within the same framework, and is very useful to constrain a phenomenological optical model, especially in regions of the nuclear chart where little or no experimental data are available. The combined use of these features can bring data-driven optical potentials to a new level of accuracy and sensitivity, which reflects on subsequent calculations and makes them suitable to guide the focus of future experiments. Here, I will discuss our preliminary efforts in this direction and a first application focused on the calcium chain of isotopes. [1] C. D. Pruitt, J. E. Escher, and R. Rahman. Phys. Rev. C 107.1 (2023), 014602 (https://doi.org/10.1103/PhysRevC.107.014602) [2] J. S. Toll. Phys. Rev. 104 (1956), 1760 (https://doi.org/10.1103/PhysRev.104.1760) [3] M. C. Atkinson. PhD thesis. Washington University in St. Louis, 2019 (https://doi.org/10.7936/2n1j-5949) This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Nuclear Structure I: NS 8 - Harmony A (13:30 - 15:00)

-Conveners: Wolfram KORTEN

[330] Symmetry and Collectivity of Mirror Nuclei (13:30)

Presenter: WIMMER, Kathrin (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

Unlike any other physical system, the atomic nucleus represents a unique dual quantum many-body system. Its constituents, protons and neutrons, are assumed to be identical, except for their electric charge. They can be seen as two representations of the nucleon, with isospin components $t_z = \pm 1/2$ for neutrons and protons, respectively. Under the assumption of charge independence of the strong interaction, hence invariance under rotation in the isospin space, the excitation energy spectra of mirror nuclei should be identical. Isospin breaking effects, besides the dominating electromagnetic force, are usually studied through mirror energy differences, testing the charge symmetry and triplet energy differences, probing the charge independence of the nuclear force. However, a more rigorous way to test isospin symmetry are electromagnetic matrix elements which are also sensitive to the underlying wave functions. Electromagnetic transitions furthermore probe the shape of a nucleus and measure collective deformations. In this talk, I will present the results of our studies of isospin symmetry performed at the Radioactive Isotope Beam Factory at the RIKEN Nishina Center in Japan. These studies address the interplay of isospin symmetry and the collective degrees of freedom.

[75] Probing the Wave-Functions through Mirror Energy Differences between 43Ti and 43Sc (13:55)

Presenter: REZYNKINA, Kseniia (INFN sezione di Padova)

Studying the nuclei along and near the N=Z line is the best way to find answers to some fundamental questions in nuclear structure, such as charge-dependence of the nuclear interaction or the role of the proton-neutron pairing. Despite our deep understanding of the electromagnetic interaction, the differences in the binding energies in mirror nuclei cannot be reproduced theoretically, thus pointing that the ISB could arise also from the residual nuclear interaction. Cross-shell particle-hole excitations from the sd to the fp shells in the mid-shell $42 \leq A \leq 54$ nuclei generate rotational bands of non-natural parity, particularly sensitive to the electromagnetic spin-orbit interaction. In the 43Sc-43Ti mirror pair such positive-parity bands extend up to 27/2+. There is a competition between proton-hole and neutron-hole excitations from the sd orbitals, and the MED are very sensitive to cross-shell single-particle excitations, which can be used to determine the type of nucleons excited across the shell gap. To explore this phenomenon, we performed spectroscopic studies, extending the level scheme of 43Ti up to the 25/2+ state. Excited states of 43Ti were populated in a fusion-evaporation reaction in JYFL, Jyvaskyla. The prompt γ-rays were detected with JUROGAM 3 spectrometer while the evaporation residues were selected with MARA separator. We find that the competition between protons and neutrons promoted from the sd shells yields, at medium-high spin, MED as high as 250 keV. This increase of the MED is interpreted within state-of-the-art large-scale shell model calculations as driven by the competition between the promotion of a proton and of a neutron across the shell gap.

[192] Exotic Nuclear Superfluidity in Heavy Nuclei (14:10)

Presenter: PALKANOGLOU, Georgios (TRIUMF)

Nuclear pairing, i.e., the tendency of nucleons to form pairs, has important consequences to the physics of heavy nuclei and compact stars. While the pairing found in nuclei typically happens between identical nucleons and in spin-singlet states, the exotic spin-triplet and mixed-spin pairing phases have also been hypothesized. In this talk, I will present new investigations confirming the existence of these novel superfluids, even at the face of the antagonizing nuclear deformation, at regions that can be experimentally accessible. These results also provide general conclusions on superfludity in deformed nuclei. These exotic superfluid phases can modify proposed manifestations of pairing in nuclear collisions and have clear signatures in experiments in spectroscopic quantities and two-particle transfer direct reaction cross sections.

[25] Imaging the Collective Structure of Atomic Nuclei in High-Energy Nuclear Collisions from STAR (14:25)

Presenter: ZHANG, Chunjian (Stony Brook University)

Recently, high-energy nuclear collisions have been proposed as a powerful tool to image the global structure of heavy atomic nuclei, such as their shapes and radial profiles. We present the first quantitative demonstration of this method by extracting the quadruple deformation β_2 and triaxiality γ for ^{238}U nuclei, known for its large prolate shape. We achieve this by comparing several flow observables in collisions of ^{238}U with collisions of near-spherical ^{197}Au. Though the extracted β_{2} of ^{238}U is consistent with low-energy experiments, the measurements indicate a non-zero γ of ^{238}U in its ground state. A similar comparative measurement is carried out in collisions of ^{96}Ru and ^{96}Zr. Large differences are observed in almost all flow observables in the two collision systems, reflecting strong impacts from the structure differences between the pair of isobars. In particular, our measurements suggest an intriguing octupole deformation β_3 in ^{96}Zr which is not predicted by mean field model calculations, as well as a larger neutron skin in ^{96}Zr. The prospect of the imaging method for studying nuclear structure is also discussed.

Nuclear Structure II: NS 9 - Garibaldi B (13:30 - 15:00)

-Conveners: Mammei, Juliette (University of Manitoba)

[89] Isospin Properties and Pair Correlations in 88Ru (13:30)

Presenter: CEDERWALL, Bo (KTH Royal Institute of Technology)

The character of nuclear superfluidity and the isospin modes of nucleonic pair correlations is a longstanding problem of large interest in nuclear structure physics. In recent years, intermediate-angular momentum states in heavy N~Z nuclei such as 88Ru are becoming accessible with advances in instrumentation, most notably the new generation of □-ray tracking arrays. The low-lying energy spectrum of the self-conjugate nucleus 88Ru has been measured using the Advanced Gamma Tracking Array (AGATA) spectrometer in conjunction with the NEDA and Neutron Wall neutron detector arrays, and the DIAMANT charged particle detector array. The observed □-ray cascade extends the previously established sequence of low-lying excited states as a rotational-like band structure which exhibits a band crossing at a rotational frequency notably exceeding conventional theoretical projections involving isovector pairing. The departure from standard theoretical predictions is further accentuated when compared with recent experimental observations in the neighboring odd-mass nuclides. In these systems the opposite trend in rotational alignments, i.e. a decrease in alignment frequency and interaction strength between the low-lying yrast band and the aligned structure is found when approaching the N=Z line. These seemingly conflicting experimental observations will be discussed in relation to state-of-the-art theoretical model predictions.

[102] Coulomb Excitation with Radioactive and Stable Beams (13:55)

Presenter: HENDERSON, Jack (University of Surrey)

The atomic nucleus is a complex many-body system, with behaviour dictated predominantly by the strong nuclear force. These features give rise to the emergent property of nuclear collectivity, in which the nucleus deviates from sphericity, becoming deformed. Understanding the onset of this deformation, predominantly in its quadrupole and octupole forms, therefore requires modelling both the interaction and many-body nature of the nucleus, making it a challenge for nuclear theory. The observables providing the best signatures of deformation are transition strengths and, in the case of quadrupole deformation, spectroscopic quadrupole moments. Experimentally, Coulomb excitation provides exceptional access to these properties, making use of the well-understood nature of the Coulomb interaction to extract them from the excitation probability. With the advent of radioactive beam facilities, a further benefit of the technique has become apparent, namely large cross-sections. Here, I will discuss recent results from TRIUMF, NSCL/FRIB and Argonne National Laboratory, presenting studies ranging from the sd-shell, strongly-deformed nuclei around N=Z=40, and nuclei in the vicinity of doubly-magic ^{208}Pb.

[172] (Zoom) Configuration Assignments of Three-Quasiparticle Quadruplets in Odd-A Nuclei (14:20)

Presenter: KAUR, Manpreet (Akal University)

In the present work, we explored the nuclear structure of three quasiparticle (3qp) quadruplets observed in deformed odd-A nuclei lying in the rare-earth mass region and assigned the most probable 3qp configuration among various possible competing configurations suggested in the literature. To accomplish our objectives, we have adopted a semi-empirical model formulation that includes all the physical interactions which can affect the magnitude of bandhead energy as well as the ordering among different member of given 3qp quadruplets. Presently, we have resolved the competing configuration assignments suggested for Kπ=17/2+ at 1551.7 keV, Kπ=17/2+ at 1522.9 keV, and Kπ=21/2+ at 1632 keV observed in 175Ta, 177Ta, and 179W nuclides, respectively. Kondev et al. identified a 3qp state observed at 1551.7 keV with bandhead assignment of Kπ=17/2+. Based on the comparison of experimental gK=0.72(7) with Nilsson model estimates, Kondev et al, suggested π:9/2[514]ν:(7/2[633]1/2[521]) or π:(7/2[404]9/2[514]1/2[541]) alternative 3qp configuration for this state. In the present work, we performed semi-empirical model calculations of bandhead energies for both π:9/2[514]ν:(7/2[633]1/2[521]) or π:(7/2[404]9/2[514]1/2[541]) 3qp configuration. Based on the comparison of calculated and experimental bandhead energies for both configurations, we suggested that the π:(7/2[404]9/2[514]1/2[541]) 3qp configuration is more probable candidate as compared to π:9/2[514]ν(7/2[633]1/2[521]) for Kπ=17/2+ bandhead at 1551.7 keV. The work pertains to configuration assignments in other odd-A rare-earth nuclides is in progress.

Coffee Break (15:00 - 15:30)

Plenary (15:30 - 16:30)

[61] Quasi-Free Scattering Experiments in Inverse Kinematics at GSI (15:30)

Presenter: AUMANN, Thomas (TU Darmstadt)

Quasi-free knockout reactions have been established in the past years as a versatile spectroscopic tool to study exotic nuclei accelerated to high energy of few hundred MeV/nucleon. The advantage of inverse kinematics is the possibility of kinematical complete measurements of the reaction including the detection of the remaining residue after the knockout. The applications of quasi-free knockout reactions are meanwhile manifold, examples are the study of the single-particle structure by single-nucleon knockout like (p,2p), or the population of nuclei beyond the drip line by nucleon or cluster knockout reactions as (p,2p) and (p,p alpha). Short-range correlations can be identified in (p,2p) and (p,pd) reactions. In general, (p,2p) is a suitable reaction to populate continuum states, as (p,2p fission) for example to investigate the fission process with control on the excitation energy and to extract fission thresholds. In this presentation I will discuss recent examples addressing the aforementioned processes and topics.
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[244] Charged Particle Tracking Detectors for Relativistic Heavy-Ion Collisions (16:00)

Presenter: KLEIN, Jochen (CERN)

Relativistic heavy-ion collisions provide unique opportunities to study a variety of physics questions, in particular in the realm of QCD matter at high temperatures and/or densities. The need to track and identify the large number of particles produced in individual collisions poses particular challenges on the detectors. This results in different optimisations of experiments targeting heavy-ion collisions instead of smaller collision systems. In this presentation, we will discuss the design of heavy-ion experiments and the evolution of tracking detectors incl. future plans.

Prizes & Closing Remarks (16:30 - 17:00)