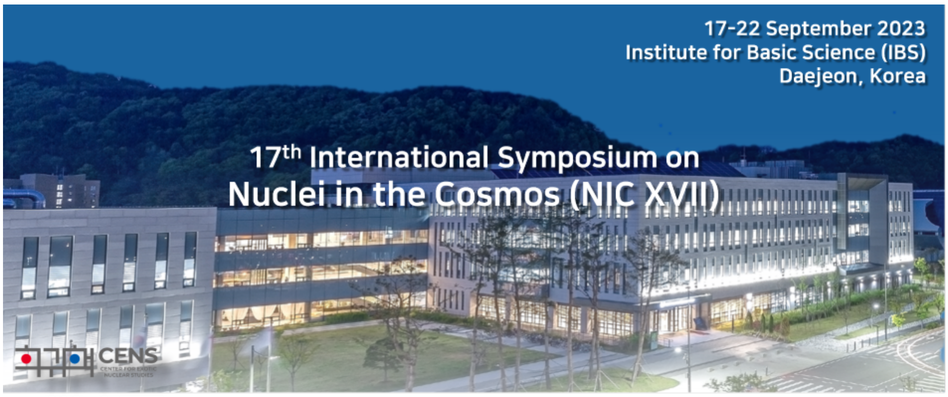
Nuclei in the Cosmos (NIC XVII)



Report of Contributions (Oral presentations)

https://indico.ibs.re.kr/e/NIC2023

Questions in Experimental Nuclear Astrophysics

Monday, 18 September 2023 09:15 (30 minutes)

Nuclear Astrophysics is low energy reaction physics –with stable and radioactive nuclei. The goal of the field is to understand critical reaction cross sections at stellar energies which are typically not directly accessible by experiment. The reaction rates therefore depend on reliable extrapolation of the reaction rates towards the stellar energy regime. A number of near threshold effects may cause unexpected changes in the reaction cross sections at those conditions. I will present a number of these cases and will discuss how such changes may impact the reaction rates and the corresponding stellar observables.

Primary author: Prof. WIESCHER, Michael (University of Notre Dame)

Presenter: Prof. WIESCHER, Michael (University of Notre Dame)

Session Classification: The s-process

Track Classification: The s-process

New constraints on the ^{13}C$(\alpha,n)^{16}$O reaction

Monday, 18 September 2023 09:45 (15 minutes)

Neutron production for the slow neutron capture process (s-process) is dominated by (α,n) reactions on light nuclei during stellar helium burning. Chief amount these is the ^{13}C$(\alpha,n)^{16}$O reaction, whose low energy cross section is enhanced by the presence of broad resonances and subthreshold states. Experimental measurements have been reported recently at both the LUNA and JUNA underground facilities, reaching to unprecedentedly low energies. These measurements have verified R-matrix extrapolations, constrained by transfer reaction determinations of the dominant subthreshold resonance strength, that the cross section is lower than previous above ground measurements indicated. To further reduce the uncertainty we report measurements of the differential cross section of the ^{13}C$(\alpha,n)^{16}$O reaction, which extend from laboratory α-particle energies of 0.8 to 6.5 MeV in approximately 10 keV energy steps at 18 unique angles between 0 and 160°, resulting in over 700 distinct angular distributions. These measurements are the first accurate differential cross section measurements of this reaction below 1 MeV. We use these differential data to augment the previous state-of-the-art R-matrix fit of the low energy ^{13}C$(\alpha,n)^{16}$O reaction and use Bayesian uncertainty estimation to demonstrate that the differential data decreases the uncertainty by a factor of two, from ≈10\% to ≈5\% over the energy region of astrophysical interest.

Primary author: DEBOER, Richard (University of Notre Dame)

Co-authors: FRITSCH, A. (Gonzaga University); GULA, A. (University of Notre Dame); HACKETT, B. (University of Tennessee); BOOMERSHINE, C. (University of Notre Dame); BRUNE, C.R. (Ohio University); ODELL, D. (Ohio University); ROBERTSON, D. (University of Notre Dame); Prof. BARDAYAN, D.W. (University of Notre Dame); STECH, E. (University of Notre Dame); FANG, F. (University of Notre Dame); HAMAD, G. (Ohio University); GYURKY, Gy. (ATOMKI); DERKIN, J. (Ohio University); MCDONAUGH, J. (University of Notre Dame); NATTRESS, J. (ORNL); BRANDENBURG, K. (Ohio University); MANUKYAN, K. (University of Notre Dame); SMITH, K. (LANL); COUDER, M. (University of Notre Dame); Dr FEBBRARO, M. (ORNL); MATNEY, M. (University of Notre Dame); WIESCHER, M. (University of Notre Dame); SMITH, M.S. (ORNL); PARIS, M.W. (LANL); SINGH, N. (Ohio University); O'MALLEY, P. (University of Notre Dame); KELMAR, R. (University of Notre Dame); COIL, S. (University of Notre Dame); DEDE, S. (University of Notre Dame); MOYLAN, S. (University of Notre Dame); SHAHINA (University of Notre Dame); TAN, W. (University of Notre Dame); JONES-ALBERTY, Y. (Ohio University); MEISEL, Z. (Ohio University)

Presenter: DEBOER, Richard (University of Notre Dame)

Session Classification: The s-process

Track Classification: The s-process

New determination of ^{17}O+α reaction rates and impact on the s-process in metal-poor rotating massive stars

Monday, 18 September 2023 10:00 (15 minutes)

The efficiency of the weak s-process in low metallicity rotating massive stars depends strongly on the ratio of the reaction rates of the two competing ^{17}O(α,n)^{20}Ne and ^{17}O(α,γ)^{21}Ne reactions, which impacts the poisoning effect of ^{16}O that consumes the neutrons released by the ^{22}Ne(α,n)^{25}Mg reaction [1] .
However, the reaction rates of these two competing reactions are poorly known in the astrophysical energy range of interest due to the lack of spectroscopic information (partial widths, spin-parities) on the relevant states in the compound nucleus ^{21}Ne. Therefore, the α-widths of these states were determined experimentaly for the first time by measuring their α-spectroscopic factors using the α-transfer reaction ^{17}O(^{7}Li,t)^{21}Ne. The latter was performed at MLL-Munich using the high-energy resolution magnetic spectrometer Q3D [2].
The measured differential cross sections of the different populated states as well as their analysis using the DWBA formalism will be presented, along with the obtained α-spectroscopic factors and α-widths of the relevant states in ^{21}Ne. The new ^{17}O(α,n)^{20}Ne and ^{17}O(α,γ)^{21}Ne reaction rates calculated using the obtained α-widths will be presented and compared with previous evaluations. The new rates favour neutron recycling through the ^{17}O(α,n)^{20}Ne reaction and suggest an enhancement by more than 1.5 dex of the weak s-elements between zirconium and neodymium in metal-poor rotating massive stars.

[1] A. Choplin, R. Hirschi et al. Astron. Astrophys. 618, A133 (2018)
[2] F. Hammache, P. Adsley, L. Lamia et al., submitted

Primary author: HAMMACHE, Faïrouz (IJCLab-Orsay)

Co-authors: MEYER, Anne; Dr CHOPLIN, Arthur (ULB); TUMINO, Aurora (Kore University, Enna); BASTIN, Beyhan (GANIL); FOUGÈRES, Chloé (Argonne National Laboratory); HARROUZ, Djamila Sarah; DE OLIVEIRA SANTOS, François (Grand Accélérateur National d'Ions Lourds (GANIL, CEA/DRF-CNRS/IN2P3); WIRTH, Hans-Friedrich (Technische Universität München); LAMIA, Livio (University of Catania); LA COGNATA, Marco (INFN - LNS); DE SÉRÉVILLE, Nicolas (IJCLab); ADSLEY, Philip (Texas A&M University); HERTENBERGER, Raph (Technische Universität München); HIRSCHI, Raphael (Keele University); PIZZONE, Rosario Gianluca (INFN LNS); PALMERINI, Sara (University of Perugia and INFN Perugia, Italy); ROMANO, Stefano (University of Catania); FAESTERMANN, Thomas (Technische Universität München)

Presenter: HAMMACHE, Faïrouz (IJCLab-Orsay)

Session Classification: The s-process

Track Classification: The s-process

The s-process in AGB stars

Monday, 18 September 2023 10:45 (30 minutes)

About half of the solar abundance of elements heavier than iron are made by the slow neutron capture process (s-process) occurring in low and intermediate-mass asymptotic giant branch (AGB) stars. Elements are mixed from the core to the surface and then expelled into the interstellar medium through strong stellar winds. In comparison to the rapid neutron capture process, modelling the s-process has presented fewer difficulties owing to the fact that most of the nuclei involved are near the valley of stability, and we observe stars enriched in heavy elements produced by the s-process. However, many important uncertainties still remain including the mechanism leading to the formation of ^{13}C pockets and the details around mixing in AGB stars. There is an increasing wealth of observational data that is being used to constrain s-process modelling in AGB stars. In recent years the main improvements to these observations have come from accurate distance estimates owing to Gaia. In this talk I will review the current status of theoretical models of the s-process in AGB stars. I will also provide an update on observations, highlighting results from Galactic AGB stars, which may provide a constraint on the minimum stellar mass required for a star to produce s-process elements. I will also briefly touch on the intermediate neutron capture process (or i-process) and show evidence that this process occurred in the early Galaxy. I will show that a potential site is AGB stars experiencing proton ingestion episodes during convective He-shell burning but other sites exist, and are still debated.

Primary authors: KARAKAS, Amanda (Monash University); LUGARO, Maria (Konkoly Observatory, CSFK)

Presenter: KARAKAS, Amanda (Monash University)

Session Classification: The s-process

Track Classification: Underground nuclear astrophysics

The s process - nuclear physics aspects

Monday, 18 September 2023 11:15 (30 minutes)

About half of the elements heavier than iron are produced in rather quite stellar environments during long exposures of seed material with neutrons. The interplay between neutron captures and beta-decays enables the production of all elements between iron and bismuth. This process is called slow neutron capture process, or s process.

Radioactive isotopes on the s-process path can act as branch points. The anaylsis of the branching ratios allows conclusions about the stellar conditions during the process. However, it requires the knowledge of the corresponding reaction rates as a function of the environmental parameters. The most important reacions are neutron captures and beta-decay rates.

I will present the basic ideas of the s process nucleosysnthesis, discuss the latest developments constraining the reaction rates and give an outlook towards possible future developments.

Primary author: REIFARTH, Rene (Goethe University Frankfurt (DE))

Presenter: REIFARTH, Rene (Goethe University Frankfurt (DE))

Session Classification: The s-process

Track Classification: The s-process

New s-process yields and surface abundances from asymptotic giant branch models

Monday, 18 September 2023 11:45 (15 minutes)

Theoretical stellar nucleosynthesis calculations allow direct comparison between predicted stellar abundances and observations, as well as interpretation of the isotope composition of meteoritic components. Our computational method for calculating predictions for stellar abundances from AGB stars involves two steps: first, the evolution of the stellar structure is calculated by the *Stromlo* stellar structure evolution code[1], and second we feed the stellar structure inputs (T, ρ, and convective velocities) into the *dppns45* post-processing code[2] that solves simultaneously the abundance changes due to nuclear reactions and to convective mixing for 328 nuclear species. In this study we upgrade the reaction network of the post-processing code to account for the temperature and density dependence of the radioactive decay and electron captures following the compilation of NETGEN (Nuclear NETwork GENerator)[3], and a large number of neutron-capture rates based on ASTRAL (ASTrophysical Rate and rAw data Library)[4], which contains re-evaluated experimental MACS of several neutron-capture reactions. The results of the work are new theoretical *s*-process yields and surface abundances for AGB stars with initial masses 2.5, 3 and 4 $M_{\odot}$ for half-solar and double-solar metallicity, and 2 $M_{\odot}$, 3 and 4 $M_{\odot}$ for solar metallicity. We compare our predictions with the previous model predictions, predictions from the FRUITY database[5], and isotopic ratios measured in presolar SiC grains.

[1] Lattanzio, J. C. 1986, ApJ, 311, 708
[2] Cannon, R. C. 1993, MNRAS, 263, 817
[3] Xu, Y., Goriely, S., Jorissen, A., Chen, G. L., & Arnould, M. 2013, A&A, 549, A106
[4] Reifarth, R., Erbacher, P., Fiebiger, S., et al. 2018, European Physical Journal Plus, 133, 424
[5] Cristallo, S., Straniero, O., Gallino, R., et al. 2009, ApJ, 696, 79

Primary author: SZÁNYI, Balázs (Konkoly Observatory, CSFK; University of Szeged)

Co-authors: YAGÜE LÓPEZ, Andrés (Los Alamos National Laboratory); KARAKAS, Amanda (Monash University); SOÓS, Benjámin (Konkoly Observatory, CSFK); LUGARO, Maria (Konkoly Observatory, CSFK)

Presenter: SZÁNYI, Balázs (Konkoly Observatory, CSFK; University of Szeged)

Session Classification: The s-process

Track Classification: The s-process

JUNA investigation of star evolution in deep underground laboratory

Monday, 18 September 2023 13:30 (30 minutes)

The Jinping Underground experiment for Nuclear Astrophysics (JUNA) has leveraged the ultralow background of the CJPL to conduct experiments aimed at directly studying crucial reactions occurring at relevant stellar energies during the evolution of stars. In 2020, JUNA successfully commissioned an mA level high current accelerator based on an ECR source, as well as BGO and ^{3}He detectors. These advancements enabled JUNA to perform direct measurements of several key reactions, including $^{25}\mathrm{Mg}(\mathrm{p},\gamma)^{26}\mathrm{Al}$, $^{19}\mathrm{F}(\mathrm{p},\alpha\gamma)^{16}\mathrm{O}$, $^{19}\mathrm{F}(\mathrm{p},\gamma)^{20}\mathrm{Ne}$, $^{13}\mathrm{C}(\alpha,\mathrm{n})^{16}\mathrm{O}$, $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$, and $^{18}\mathrm{O}(\alpha,\gamma)^{20}\mathrm{Ne}$ with improved precision and across a wider energy range, closer to the Gamow window. These experiments provide valuable insights into the astrophysics implications (neutron source, F and Ca over production etc.) with their precise reaction rates.

1. Liu W P et al., Sci. China Phys. Mech. 59(2016)642001
2. Zhang L Y et al., Phys. Rev. Lett. 127(2021)152702
3. Su J et al., Sci. Bull. 67(2022)125
4. Gao B et al., Phys. Rev. Lett. 129(2022)132701
5. Zhang L Y et al., Nature 610(2022)656
6. Wang L H et al. , Phys. Rev. Lett. 130(2023)092701

Primary author: Prof. LIU, Weiping (SUSTech/CIAE)

Presenter: Prof. LIU, Weiping (SUSTech/CIAE)

Session Classification: Underground nuclear astrophysics

Track Classification: Underground nuclear astrophysics

Nuclear Astrophysics in underground laboratories: the LUNA experiment

Monday, 18 September 2023 14:00 (30 minutes)

In nuclear astrophysics, a crucial aspect is understanding the thermonuclear reactions that power the stars and lead to the synthesis of chemical elements. At astrophysical energies, the cross section of nuclear processes is significantly reduced by the Coulomb barrier, making direct measurements challenging. In addition, the low value of cross sections often hinders their measurement on Earth's surface, necessitating extrapolations. To overcome this problem, the Laboratory for Underground Nuclear Astrophysics (LUNA) is located under the Gran Sasso mountain. This position reduces the effects of cosmic-ray background and allows cross sections investigations at energies close to the Gamow peak in stellar scenarios. The LUNA-50kV and LUNA-400kV accelerators have been used to directly measure many crucial reactions involved in hydrogen burning at astrophysical energies, and work continues with the installation of a 3.5MV machine that will explore helium and carbon burnings. Due to this progress, there are currently running projects in several countries using underground accelerators. This presentation will describe the typical techniques used in underground nuclear astrophysics and review the most significant results achieved. The talk will also highlight the exciting science that can be probed with the new facilities.

Primary author: CACIOLLI, Antonio (University and INFN of Padua)

Presenter: CACIOLLI, Antonio (University and INFN of Padua)

Session Classification: Underground nuclear astrophysics

Track Classification: Underground nuclear astrophysics

Measurements of Proton Capture on Carbon at Astrophysical Energies

Monday, 18 September 2023 14:30 (15 minutes)

Direct measurements of the cross sections for the radiative capture reactions $^{12,13}\mathrm{C(p,\gamma)}^{13,14}\mathrm{N}$ at energies of astrophysical interest are challenging, due to the rapidly falling cross sections towards lower energies, and for the absence of narrow resonances at low proton energies required for target characterization. The two reactions have been studied at the Laboratory for Underground Nuclear Astrophysics (LUNA). Exploiting the low-background setup at the deep-underground location, and using different solid targets and complementary detection techniques, a comprehensive data set for energies between $E_{\mathrm{c.m.}} = 60\,\mathrm{keV}$ and $370\,\mathrm{keV}$ has been obtained, providing direct data on this reaction at the lowest energies to date. We will present the performed experiments, and the results for the cross sections of both reactions.

Primary authors: BOELTZIG, Axel (Helmholtz-Zentrum Dresden-Rossendorf (HZDR)); Mr SKOWRONSKI, Jakub (Università degli Studi di Padova & INFN, Sezione di Padova)

Presenter: BOELTZIG, Axel (Helmholtz-Zentrum Dresden-Rossendorf (HZDR))

Session Classification: Underground nuclear astrophysics

Track Classification: Underground nuclear astrophysics

22Ne+a measurements deep underground

Monday, 18 September 2023 14:45 (15 minutes)

The reactions 22Ne(a,n)25Mg and 22Ne(a,g)26Mg are of high importance for the formation of heavy elements in the weak s process, main s process branchings and strongly influence the Mg isotopic ratios that we can directly observe in stellar atmospheres. For an accurate astrophysical modeling, both reaction cross sections need to be known at energies far below the Coulomb barrier, where direct measurements are severely hampered due to the low event rates to be detected. Many indirect studies have probed the relevant compound nucleus energy region (> 10.6 MeV), but large uncertainties remain regarding the contributions of the various excited states to the astrophysical reaction rates.

To tackle this issue, a new campaign of direct measurements of both reactions is currently being prepared at the new 3.5 MV accelerator in the Bellotti Ion Beam facility of the INFN-LNGS deep underground laboratory. The ultra-low gamma and neutron background in combination with novel detection setups and high ion beams will greatly extend the detection sensitivity, allowing to measure much lower cross sections than previously possible. The measurement of the neutron channel using an innovative hybrid detection setup is taking place in the framework of the "SHADES" ERC grant.

We will give an overview of the state of the art and the current status of the experimental projects.

Primary author: BEST, Andreas (University of Naples Federico II)

Presenter: BEST, Andreas (University of Naples Federico II)

Session Classification: Underground nuclear astrophysics

Track Classification: Underground nuclear astrophysics

Measurement of the low energy resonances in 22Ne(a,g) and 22Ne(a,n) reaction

Monday, 18 September 2023 15:00 (15 minutes)

The interplay and correlation between the ^{22}Ne$(\alpha,\gamma)^{26}$Mg and the competing ^{22}Ne$(\alpha,n)^{25}$Mg reaction determines the efficiency of the ^{22}Ne$(\alpha,n)^{25}$Mg reaction as a neutron source for the weak s-process. In both cases, the reaction rates are dominated by the strength of the α cluster resonance at 830 keV. This plays a particularly important role in determining the strength of the neutron flux for weak and main s-process environments. We performed the measurement of the 830 keV resonance in ^{22}Ne$(\alpha,\gamma)^{26}$Mg at the Sanford Underground Research Facility using a γ-summing detector. We confirmed the previous studies of the resonance strength and obtained a strength of $\omega\gamma$ = 35 $\pm$ 4 μeV, however the strength of the corresponding resonance in the ^{22}Ne$(\alpha,n)^{25}$Mg still carries large uncertainties. In a new and independent study performed at Notre Dame using a stilbene crystal detector, we confirmed previous results and demonstrate that the resonance strength in the competing ^{22}Ne$(\alpha,n)^{25}$Mg reaction channel is significantly higher.

Primary author: Ms SHAHINA, Shahina (University of Notre Dame)

Co-authors: GULA, A.; SIMON, A.; ROBERTSON, D. (University of Notre Dame); STECH, E.; STRIEDER, F.; GORRES, J.; NATTRESS, J.T.; COUDER, M. (University of Notre Dame); FEBBRARO, M.; HANHARDT, M.; WIESCHER, M. (University of Notre Dame); GOMEZ, O.; SCHOLZ, P.; KELMAR, R.; DEBOER, Richard (University of Notre Dame); KADLECEK, T.

Presenter: Ms SHAHINA, Shahina (University of Notre Dame)

Session Classification: Underground nuclear astrophysics

Track Classification: Underground nuclear astrophysics

Deep underground laboratory measurement of ^{13}C(α,n)^{16}O in the Gamow windows of the s- and i-processes

Monday, 18 September 2023 15:15 (15 minutes)

The ^{13}C(α,n)^{16}O reaction is the main neutron source for the slow-neutron-capture (s-) process in Asymptotic Giant Branch stars and for the intermediate (i-) process. Direct measurements at astrophysical energies in above-ground laboratories are hindered by the extremely small cross sections and vast cosmic-ray induced background. We performed the first consistent direct measurement in the range of $E_{c.m.}$ =0.24 MeV to 1.9 MeV using the accelerators at the China JinPing underground Laboratory (CJPL) and Sichuan University. Our measurement covers almost the entire i-process Gamow window in which the large uncertainty of the previous experiments has been reduced from 60% down to 15%, eliminates the large systematic uncertainty in the extrapolation arising from the inconsistency of existing data sets, and provides a more reliable reaction rate for the studies of the s- and i-processes along with the first direct determination of the α-strength for the near-threshold state.

Primary author: Dr GAO (ON BEHALF OF THE JUNA COLLABORATION), Bingshui (Institute of Modern Physics)

Presenter: Dr GAO (ON BEHALF OF THE JUNA COLLABORATION), Bingshui (Institute of Modern Physics)

Session Classification: Underground nuclear astrophysics

Track Classification: Underground nuclear astrophysics

Exploring the Potential for Astrophysical Neutrino Detection at JUNO

Monday, 18 September 2023 15:30 (15 minutes)

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20-kton liquid scintillator detector currently under construction in an underground laboratory in South China. It is expected to complete detector construction by the end of 2023. With excellent energy resolution, a large detector volume and superb background control, JUNO will become a flagship experiment in the coming decades. Its primary aims are determining the neutrino mass ordering, and providing precise measurements on the neutrino oscillation parameters with reactor antineutrinos. As a multi-purpose neutrino observatory, JUNO has world-competitive potential on astrophysical phenomena such as diffuse supernova neutrino background (DSNB), core-collapse supernova (CCSN) neutrinos, solar neutrinos, and more. This talk will present the astrophysical potential of neutrino research at JUNO.

Primary author: Dr CHENG, Jie (NCEPU)

Presenter: Dr CHENG, Jie (NCEPU)

Session Classification: Underground nuclear astrophysics

Track Classification: Underground nuclear astrophysics

Neutron-capture reactions and heavy element nucleosynthesis

Monday, 18 September 2023 16:15 (30 minutes)

In recent years, new astronomical observations have revealed abundance patterns that cannot be explained by the classic nucleosynthesis picture. A description of the synthesis of heavy elements using only the s, r and p processes is not adequate anymore and for this reason new scenarios had to be proposed. In this talk I will focus on neutron-capture processes that involve exotic nuclei, specifically the r process and the intermediate (i) process. I will discuss possible contributions from each and, in particular, I will address uncertainties related to the nuclear physics input. Neutron-capture reactions play a major role in both processes, and I will present recent developments in providing experimentally constrained reaction rates using indirect techniques. I will share recent results from experiments at Argonne National Laboratory in the US and future experiments at the Facility for Rare Isotope Beams (FRIB).

Primary author: ARTEMIS, Spyrou (Michigan State University)

Presenter: ARTEMIS, Spyrou (Michigan State University)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

The status and future of nuclear property experiments at CENS

Monday, 18 September 2023 16:45 (30 minutes)

Observations of astrophysical phenomena, such as the luminosity of X-ray bursts and the abundance pattern of stars, can be explained by nuclear reactions occurring in the stars. It is well known that the nuclear properties of isotopes involved in the nuclear reactions have a direct impact on stellar evolution, such as energy generation, the nucleosynthesis path, and final abundance distribution of the elements. However, because most of the key nuclei constraining the nucleosynthesis models including the rapid proton capture process (rp-process) and the rapid neutron capture process (r-process) are far from stability, our understanding of astronomical observables is still very limited due to large uncertainties in calculated properties of the nuclei and a lack of measurements with radioactive ion beams for the spectroscopic information. One recent sensitivity study, for example, shows the light curve of X-ray bursts is extremely sensitive to (α,p) reactions on proton-rich radioactive nuclei, including ^{14}O(α,p)^{17}F, ^{15}O(α,γ)^{18}Ne and ^{34}Ar(α,p)^{37}K. However, measurement of these reaction cross sections in the laboratory is challenging due to low beam intensities and short lifetimes.

In order to reduce the uncertainties, new experimental studies of nuclear properties with heavy ion radioactive beam accelerators are critical. Moreover, because most of key nuclei allowing us to explore new models of nuclear structure are far from stability, it is only possible to perform the research with powerful rare isotope beam (RIB) facilities. Recent experimental studies of nuclear properties performed by the Center for Exotic Nuclear Studies (CENS), Institute for Basic Science at will be presented as well as new device developments. Future plans on how to take advantage of the existing and new RIB facilities including RAON (Rare isotope Accelerator complex for ON-line experiment) in Korea will also be addressed.

*This work was supported by the Institute for Basic Science (IBS-R031-D1), Ministry of Science and ICT(MSIT), Republic of Korea.

Primary author: Dr AHN, Sunghoon(Tony) (Center for Exotic Nuclear Studies, Institute for Basic Science)

Presenter: Dr AHN, Sunghoon(Tony) (Center for Exotic Nuclear Studies, Institute for Basic Science)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Realistic fission transmission coefficients in the statistical Hauser-Feshbach compound-nucleus reaction theory

Monday, 18 September 2023 17:15 (15 minutes)

Albeit recent development of dynamical approaches to the nuclear fission phenomena has been significantly improving our understanding of this complex nuclear reaction mechanism, conventional fission models in the statistical Hauser-Feshbach theory remain the extremely simplified fission barrier model with the WKB approximation. Due to the inherent deficiencies in calculating nuclear fission probabilities (fission transmission coefficients), it is very difficult to reduce uncertainties in predicting reaction rates both for β-delayed and neutron-induced fissions in the astrophysical environments. As the first step to overcome the existing deficiencies such as the WKB approximation, we solve the Schroedinger equation for an arbitrary one-dimensional potential energy to calculate the transmission coefficient in the fission channel of compound nucleus reactions, and incorporate the calculated transmission coefficients into the statistical Hauser-Feshbach model. Some calculated results are given to neutron induced reactions on stable actinides, where experimental fission cross section data are abundant. We show that a resonance-like structure appears in the transmission coefficient as well as in the fission cross section when a double-humped fission barrier shape including an intermediate well is adopted. This is understood to be a quantum mechanical effect in the fission channel, since the resonance-like structure is remarkably enhanced when the penetration and reflection waves are in phase.

Primary author: Dr KAWANO, Toshihiko (LANL)

Presenter: Dr KAWANO, Toshihiko (LANL)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Experimentally determined 56Ni(n.p) cross section and its impacts on nu-p process

Monday, 18 September 2023 17:30 (15 minutes)

To constrain the nu-p process, we studied the ^{56}Ni(n,p) reaction by directly measuring the cross section on the radioactive ^{56}Ni (a half-life of 6 days) at Los Alamos Neutron Science Center. This reaction has been identified as one of critical reactions for understanding the heavy element production in core-collapse supernovae. The radioactive ^{56}Ni was produced by irradiating protons on a ^{59}Co foil via the (p,4n) reaction at the Isotope Production Facility and the ^{56}Ni target was chemically separated, fabricated, and characterized at the Hot Cell facility. Using the LENZ (Low Energy NZ) instrument, the first directly measured cross sections of ^{56,59}Ni(n,p), ^{56}Co(n,p), and ^{59}Ni(n,α) will be reported along with experimentally deduced reaction rates of ^{56}Ni(n,p) and ^{56}Co(n,p). The impacts of these newly obtained reaction rates and potential further constrains on the nu-p process will be discussed. Ongoing LENZ efforts on (n,p) and (n,α) reaction studies with radionuclides such as ^{40}K, ^{44}Ti, and ^{26}Al, and the optimized solenoidal spectrometer development at LANSCE will be presented.

This work benefits from the LANSCE accelerator facility and is supported by the U.S. Department of Energy under contracts DE-AC52-06NA25396, the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20180228ER, and the U.S. Department of Energy Office of Science-Nuclear Physics.

LA-UR-23-25925

Primary author: LEE, Hye Young (Los Alamos National Laboratory)

Co-authors: FROHLICH, Carla (North Carolina State University); VERMEULEN, Christian (Los Alamos National Laboratory); PERDIKAKIS, Georgios (Central Michigan University); SASAKI, Hirokazu (Los Alamos National Laboratory); GASTIS, Panagiotis (Los Alamos National Laboratory); TSINTARI, Pelagia (Central Michigan University); KUVIN, Sean (Los Alamos National Laboratory); MOSBY, Shea (Los Alamos National Laboratory); KAWANO, Toshihiko (Los Alamos National Laboratory); MOCKO, Veronika (Los Alamos National Laboratory)

Presenter: LEE, Hye Young (Los Alamos National Laboratory)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Measuring the ^{15}O$(\alpha,\gamma)^{19}$Ne Reaction Rate in Type I X-ray Bursts using ^{20}Mg β-decay

Monday, 18 September 2023 17:45 (15 minutes)

A neutron star can accrete hydrogen-rich material from a low-mass binary companion star. This can lead to periodic thermonuclear runaways, which manifests as a Type I X-ray bursts detected by space-based telescopes. Sensitivity studies have shown that $^{15}O(\alpha,\gamma)^{19}$Ne carries one of the most important reaction rate uncertainties affecting the modeling of the resulting light curve. This reaction is expected to be dominated by a resonance corresponding to the 4.03 MeV excited state in ^{19}Ne. This state has a well-known lifetime, so only a finite value for the small alpha-particle branching ratio is needed to determine the reaction rate. Previous measurements have shown that this state is populated in the decay sequence of ^{20}Mg. $^{20}Mg(\beta p\alpha)^{15}$O events through the key $^{15}O(\alpha,\gamma)^{19}$Ne resonance yield a characteristic signature: the emission of a proton and alpha particle. To identify these coincidence events the GADGET II detection system was used at the Facility for Rare Isotope Beams during Experiment 21072. An ^{36}Ar primary beam was impinged on a ^{12}C target to create a fast beam of ^{20}Mg that fed the ^{19}Ne state of interest. We are presenting here the preliminary results from this experiment, which includes discussion of the data processing and analysis methods being used on the newly acquired data, as well as a primer on the development of convolutional neural networks for rare event identification.

Primary author: WHEELER, Tyler (Michigan State University)

Co-author: 21072 COLLABORATION, FRIB

Presenter: WHEELER, Tyler (Michigan State University)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Neutrino process for ^{10}Be with updated relevant nuclear reactions

Tuesday, 19 September 2023 09:00 (30 minutes)

We investigated ^{10}Be production mechanism in the neutrino-process in the core collapsing supernova (CCSN) by including recent updated nuclear reactions relevant to dominant production and destruction of ^{10}Be. They involve production reactions by neutrinos ^{12}C and ^{16}O and other production reactions ^{10}B(n,p)^{10}Be, ^{11}Be(γ, n)^{10}Be. Inverse reactions of the latter two reactions, ^{10}Be(p,n)^{10}B and ^{10}Be(n, γ)^{11}Be play destruction channels for ^{10}Be with ^{10}Be(p,α)^{7}Li, ^{10}Be(α, n)^{13}C. By using recent updated information of relevant reactions and nearby nuclei we tried to pin down the ambiguities from those nuclear reactions. Our results display that other nuclear reactions not discussed yet, such as neutrino reaction on ^{16}O and ^{11}Be(γ, n)^{10}Be could play vital roles for the ^{10}Be production int the CCSN.

Primary authors: Ms KO, Heamin (Soongsil University); CHEOUN, Myung-Ki (Soongsil University)

Presenter: CHEOUN, Myung-Ki (Soongsil University)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Experimental Study of the ^{30}Si(p,γ)^{31}P for understanding elemental anomalies in Globular Clusters

Tuesday, 19 September 2023 09:30 (15 minutes)

Globular clusters are key grounds for models of stellar evolution and early stages of the formation of galaxies. Abundance anomalies observed in the globular cluster NGC 2419, such as the enhancement of potassium and depletion of magnesium [1] can be explained in terms of an earlier generation of stars polluting the presently observed stars [2]. However, the nature and the properties of the polluting stellar sites are still debated. The range of temperatures and densities of the polluting sites depends on the strength of a number of critical thermonuclear reaction rates. The ^{30}Si(p,γ)^{31}P reaction is one of the few reactions that have been identified to have an influence for elucidating the nature of polluting sites in NGC 2419 [3]. The current uncertainty on the ^{30}Si(p,γ)^{31}P reaction rate has a strong impact on the range of possible temperatures and densities of the polluter sites.

Hence, we investigated the ^{30}Si(p,γ)^{31}P reaction with the aim to reduce the uncertainties associated to its reaction rate by determining the strength of resonances of astrophysical interest. In this talk, I will present the study of the reaction ^{30}Si(p,γ)^{31}P that we performed via the one proton ^{30}Si(^{3}He,d)^{31}P transfer reaction at the Maier-Leinbnitz-Laboratorium Tandem, using the high resolution Q3D magnetic spectrograph to measure the angular distributions of the light reaction products. These angular distributions are interpreted in the DWBA (Distorted Wave Born Approximation) framework to determine the proton spectroscopic factor information needed to deduce the proton partial width of the states of interest. This information was used to calculate the ^{30}Si(p,γ)^{31}P reaction rate. The uncertainties on the reaction rate have been significantly reduced, and key remaining uncertainties have been identified [4]. Complementary direct measurements of ^{30}Si+p resonance strengths, performed using the DRAGON recoil spectrometer at TRIUMF, will be presented as well. Finally, I will present post-processing calculations showing that the ^{30}Si(p,γ)^{31}P reaction rates are now sufficiently constrained. Further efforts to unravel the nature of the stellar sites at the origin of the abundance anomalies in globular clusters should now be focused on the other identified key reactions.

[1] C. Iliadis et al., The Astrophysical Journal, 470:140 (2016)
[2] R. G. Gratton et al., The Astronomy and Astrophysics Review 20:50 (2012)
[3] J. R. Dermigny and C. Iliadis, The Astrophysical Journal 848:14 (2017)
[4] D. S. Harrouz et al., Physical Review C 105:015805 (2022)

Primary author: DE SÉRÉVILLE, Nicolas (IJCLab)

Co-authors: Ms LAIRD, Alison (University of York); Ms MEYER, Anne; TUMINO, Aurora (Kore University, Enna); Ms BASTIN, Beyhan (GANIL); RUIZ, Chris (TRIUMF & University of Victoria); Ms HARROUZ, Djamila Sarah; HAMMACHE, Faïrouz (IJCLab-Orsay); Mr WIRTH, Hans-Friedrich (Technische Universität München); JAYAMANNA, Keerthi (TRIUMF); LAMIA, Livio (University of Catania); LA COGNATA, Marco (INFN - LNS); WILLIAMS, Matthew (TRIUMF); ADSLEY, Philip (Texas A&M University); Mr HERTENBERGER, Raph (Technische Universität München); LONGLAND, Richard (North Carolina); PIZZONE, Rosario Gianluca (INFN LNS); PALMERINI, Sara (University of Perugia and INFN Perugia, Italy); Mr KIY, Spencer (TRIUMF); UPADHYAYULA, Sriteja (TRIUMF); ROMANO, Stefano

(University of Catania); PSALTIS, Thanassis (TRIUMF); FAESTERMANN, Thomas (Technische Universität München); Mr GREIF, Uwe (Colorado School of Mines)

Presenter: DE SÉRÉVILLE, Nicolas (IJCLab)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Isotopic ratios from (sub)millimetre observations of AGB stars

Tuesday, 19 September 2023 09:45 (15 minutes)

Asymptotic giant branch (AGB) stars are a late evolutionary phase of low- and intermediate-mass star. They are typified by rapid mass loss through a stellar wind rich in molecular diversity, which is also a key site of dust formation in the universe. Their stellar winds provide a unique opportunity to study the isotopic ratios of various key atomic species that form molecules and whose isotopologues can be easily distinguished in their millimetre and submillimetre spectra. This means that spectrally resolved observations of various isotopologues can tell us about either the properties of the AGB star being studied or the conditions of its natal environment. For example, we can use oxygen isotopic ratios to determine the initial masses of low-mass AGB stars, magnesium isotopic ratios to determine the isotopic ratios of intermediate-mass AGB stars and the isotopic ratios of silicon and sulphur to gauge the initial metallicities of AGB stars. With these direct observations, we can constrain the origins of silion carbide and silicate pre-solar grains. I will discuss my recent results calculating AGB isotopic ratios based on sensitive ALMA observations and future prospects of for this field.

Primary author: DANILOVICH, Taïssa (Monash University)

Presenter: DANILOVICH, Taïssa (Monash University)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Nucleosynthesis in the tellurium-xenon region

Tuesday, 19 September 2023 10:00 (15 minutes)

A detailed analysis of nucleosynthesis in the environment of xenon (Z=54) may provide a valuable insight into the interior of stars. The stable isotopes of xenon are produced in a variety of astrophysical environments. The different combinations of nucleosynthetic pathways are: γ-process for ^{124}Xe and ^{126}Xe, γ- and s-processes for ^{128}Xe,
s-process for ^{130}Xe, s- and r-processes for ^{129}Xe, ^{131}Xe and ^{132}Xe, and r-process only for ^{134}Xe and ^{136}Xe.
The isotopic composition of Xe observed in different solar system bodies is used as a genetic mark to identify the origin of volatiles on Earth, however, the stellar origin of the many of the observed nucleosynthetic fingerprints is not known.
The xenon isotopic composition has not been observed only in the solar system material. Xenon isotope abundances have been measured also in different types of presolar grains, e.g., in silicon carbide grains and in nano-diamonds, where the contribution of single nucleosynthesis components can be measured.
We present in this work new experimental results relevant for the p-process nucleosynthesis in the Xe region.
Reaction rates of ^{118}Te(p,γ), as well as reaction rates for ^{124}Xe(p,γ), have been measured in an energy region close to the gamow window.
The performed nucleosynthesis studies include core-collapse supernovae and TP-AGB stars. We study the impact of our preliminary results on the p-process nucleosynthesis of Xe in core-collapse supernovae. In the second part of this work, we discuss the s-process nucleosynthesis in Asymptotic Giant Branch stars for the isotopes of the xenon region.

Primary author: DELLMANN, Sophia Florence

Co-authors: HÄRTH, Alexandra (Goethe Universität Frankfurt); GLORIUS, Jan (GSI Helmholtz Centre); ROBERTI, Lorenzo (Konkoly Observatory, CSFK); PIGNATARI, Marco (Konkoly Observatory, CSFK); LUGARO, Maria (Konkoly Observatory, CSFK); REIFARTH, Rene (Goethe University Frankfurt (DE)); LITVINOV, Yury (GSI Helmholtz Center)

Presenter: DELLMANN, Sophia Florence

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

The Impact of 1D and 3D NLTE Effects on neutron-capture elements

Tuesday, 19 September 2023 10:15 (15 minutes)

For a long time, 1D LTE (local thermal equilibrium) modelling has been the main approach in spectroscopic abundance determination of elements. However, the recent computational advancements has allowed us to explore both 1D NLTE (non-LTE) and 3D NLTE effects on elemental abundances. In my presentation, I will begin by briefly revisiting the known s-process elements Strontium (Sr) (Bergemann et al., 2012; Gallagher et al., in prep) and Barium (Ba) (Gallagher et al., 2020), as well as discussing the effects of NLTE and 3D on them.

The highlight of this talk will be the introduction of findings from 1D NLTE and 3D NLTE models for Yttrium (Y) (Storm & Bergemann, subm.) and Europium (Eu) (Guo et al. (incl. Storm), in prep). These results, derived using state-of-the-art 3D radiative transfer modeling using code MULTI3D and the most recent nuclear data, will give insight on the implications of NLTE and 3D effects on classification and abundance determination of neutron-capture elements.

Primary author: STORM, Nicholas (MPIA)

Presenter: STORM, Nicholas (MPIA)

Session Classification: Nuclear reaction rates and stellar abundances

Track Classification: Nuclear reaction rates and stellar abundances

Radioactive Decay Lines from the Milky Way - the Pathways of Stellar Ejecta

Tuesday, 19 September 2023 11:00 (30 minutes)

Soft gamma ray lines from radioactive decay
of 26Al and 60Fe as well as annihilation of positrons have been
observed from the Milky Way. The respective emission contains information
about the ejecta of supernovae, massive-star winds and possibly winds related to neutron stars and
black holes. The distinct spatial structure of the different lines allows
to trace the flow of the ejecta through the interstellar medium.
We have modelled these processes with 3D hydrodynamic simulations.
We find that a large fraction of the massive star ejecta leaves their immediate
surroundings quickly, likely in large superbubble structures, and may even
diffuse into the Galactic halo on the decay timescale of 26Al (~1 Myr).
I will discuss our simulaton results and prospects of the upcoming
NASA mission COSI to trace nucleosynthesis ejecta in the interstellar medium.

Primary author: KRAUSE, Martin (University of Hertfordshire)

Co-author: THE COSI SCIENCE TEAM

Presenter: KRAUSE, Martin (University of Hertfordshire)

Session Classification: The early Universe, galactic evolution

Track Classification: Galactic evolution

Lithium in the most iron-poor unevolved stars known and the cosmological lithium problem

Tuesday, 19 September 2023 11:30 (15 minutes)

The most metal-poor low-mass stars formed in the very Early Universe, at about 300 Myr after the Big Bang, are still observable today in the Galactic Halo. These stars hold crucial information of the early epochs of the Universe, such as the properties of the first stars and supernovae and the early chemical evolution of the Universe, and the formation of low-mass stars in the Early Universe.

We identified two very primitive stars, SDSS J0815+4729 and SDSS J0023+0307, using the BOSS survey and follow-up observing campaigns at the 4.2m-WHT and 10.4m-GTC telescopes in La Palma (Aguado et al. 2018a, 2018b; González Hernández et al. 2023). These stars have extremely low iron content (with a [Fe/H] < -5.5) and a unique abundance pattern. The high-quality UVES@8.2m-VLT and HIRES@10m-KeckI spectroscopic data of J0023+0307 (Aguado et al. 2019) and J0815+4729 (González Hernández et al. 2020), respectively, allows us to clearly measure the Li abundance in J0023+0307 at the level of the lithium plateau , whereas in J0815+4729 we are unable to detect Li, thus exacerbating the cosmological lithium problem (González Hernández et al. 2023).

We have also investigated the 6Li/7Li in the most metal-poor spectroscopic binary CS22876-032 using extremely high-resolution (at R~110,000) and high-quality (S/N~580) UVES spectra. CS22876-032, with a metallicity of [Fe/H] ~ -3.7, is about 0.5~dex below the attempts to investigate the 6Li/7Li isotopic ratio in very metal-poor stars from a 3D-NLTE analysis (González Hernández et al. 2019). The lack of evidence of the detection of 6Li has been demonstrated in the re-analysis of some metal-poor stars, using 3D hydrodynamical simulations of metal-poor atmospheres and an appropriate treatment of the Li feature
using 3D-NLTE spectral synthesis (e.g. Steffen et al. 2012; Lind et al. 2013).

In this talk I will show a brief summary of the Li and 6Li/7Li abundances at the
lowest metallicities and the implications and prospects to solve the cosmological Li problem.

Primary author: Dr GONZALEZ-HERNANDEZ, Jonay (Instituto de Astrofisica de Canarias)

Presenter: Dr GONZALEZ-HERNANDEZ, Jonay (Instituto de Astrofisica de Canarias)

Session Classification: The early Universe, galactic evolution

Track Classification: The early Universe

Rapidly Rotating Massive Pop III Stars : A Solution for High Carbon Enrichment in CEMP-no Stars

Tuesday, 19 September 2023 11:45 (15 minutes)

Very metal-poor stars that have [Fe/H]< -2 and are enhanced in C relative to Fe ([C/Fe]> 0.7) but have low enhancement of heavy elements ([Ba/Fe]< 0) are known as carbon-enhanced metal-poor-no (CEMP-no) stars. These stars are thought to be produced from the interstellar medium (ISM) polluted by the supernova (SN) ejecta of the very first generation (Pop III) massive stars. Although theoretical models of SN explosions from massive Pop III stars can explain the relative abundance pattern reasonably well, the very high enrichment of C $A(\mathrm{C}) > 6$) observed in many of the CEMP-no stars is difficult to explain when reasonable dilution of the supernova ejecta, that is consistent with detailed simulation of metal mixing in minihaloes, is adopted. We explore rapidly rotating Pop III stars that undergo efficient mixing and reach a quasi-chemically homogeneous (QCH) state. We find that rapidly rotating models that reach the QCH state can eject large amounts of C in the wind and the resulting dilution of the wind ejecta in the interstellar medium can lead to a C enrichment of $A(\mathrm{C}) < 7.7$ and can naturally explain the high C enrichment observed in CEMP-no stars. Additionally, the core of QCH stars can produce up to an order of magnitude of higher C than non-rotating progenitors of similar mass and the resulting SN can also lead to high C enrichment of $A(\mathrm{C}) < 7$. We find that the abundance pattern from our models that use dilution masses that are consistent with simulations can provide an excellent match to observed abundance patterns in many of the CEMP-no stars. We find that rapidly rotating massive Pop III stars are a promising site for explaining the high C enhancement in the early Galaxy as deduced from CEMP-no stars. This indicates that a substantial fraction of Pop III stars were likely rapid rotators.

Primary authors: S K, Jeena (Indian Institute of Technology Palakkad); BANERJEE, Projjwal (Indian Institute of Technology Palakkad)

Co-authors: HEGER, Alexander (School of Physics and Astronomy, Monash University, Vic 3800, Australi); CHIAKI, Gen (Astronomical Institute, Graduate School of Science, Tohoku University, Aoba, Sendai 980-8578, Japa)

Presenter: S K, Jeena (Indian Institute of Technology Palakkad)

Session Classification: The early Universe, galactic evolution

Track Classification: The early Universe

The 12C/13C isotopic ratio at the dawn of chemical evolution

Tuesday, 19 September 2023 12:00 (15 minutes)

The 12C/13C isotopic ratio is an important diagnostic tool in astrophysics, providing insights into the formation and evolution of stars and galaxies. In this talk, we will discuss the measurement of this ratio using data from the ESPRESSO instrument, which is one of the most powerful spectrographs in the world.

We will focus on the information obtained from the oldest stars in the Milky Way, the carbon-enhanced metal-poor (CEMP-no) stars. By analyzing the isotopic ratios in these stars, we can determine the changes in the ratio over time and how this has affected the overall composition of the Galaxy. We will also highlight the importance of these measurements for our understanding of the chemical evolution of the Milky Way and the critical role of spectrographs like ESPRESSO in the understanding of our Galaxy.

Primary author: Dr AGUADO, David (Instituto de Astrofísica de Canarias)

Presenter: Dr AGUADO, David (Instituto de Astrofísica de Canarias)

Session Classification: The early Universe, galactic evolution

Track Classification: The early Universe

Retrospective r process and supernova signatures in deep-sea archives

Tuesday, 19 September 2023 13:45 (30 minutes)

Half of the heavy elements are produced in r-process nucleosynthesis, which is exclusively responsible for actinide production, such as Pu-244 ($t_{1/2}$=81 Myr). The r-process requires an explosive scenario but is far from being fully understood; in particular, its sites and history.

The solar system moves through the interstellar medium (ISM) and collects interstellar dust particles that contain such signatures, including the radionuclides Fe-60 ($t_{1/2}$=2.6 Myr) and Pu-244. These nuclides are incorporated into terrestrial archives over millions of years and once recovered can be measured with Accelerator Mass Spectrometry (AMS) with high sensitivity.

Recent technical developments have seen an exceptional gain in measurement efficiency and sensitivity, in particular for actinides, including Pu-244. On the other hand, very large accelerators with >10 million volts allow for effective isobar separation using techniques derived from nuclear physics research. Such AMS systems are unique but required for the identification of small traces of interstellar Fe-60.

New data demonstrate a global Fe-60 influx and is evidence for exposure of Earth to recent (<10 Myr) supernova explosions. In addition, the recent finding in deep-sea archives of ISM-Pu-244, exclusively produced by the r-process, allows to link supernovae and r-process signatures. The low concentrations of Pu-244 measured in deep-sea archives suggest a low abundance of interstellar Pu and supports the hypothesis that the dominant actinide r-process nucleosynthesis is rare. However, the data allow some actinide production in supernovae while implying r-process contributions from additional sources.

Primary author: Prof. WALLNER, Anton (HZDR)

Presenter: Prof. WALLNER, Anton (HZDR)

Session Classification: Radioactivity and meteorites

Track Classification: Radioactivity and meteorites

Nucleosynthesis from the Galaxy's current stellar generations

Tuesday, 19 September 2023 14:15 (15 minutes)

Radioactive parts of nucleosynthesis ejecta transmit the results of nucleosynthesis in stars and supernovae from the current and most recent stellar generations. INTEGRAL observations have measured emission from the long-lived (My) isotopes 26Al and 60Fe over the past 20 years. It is a challenge to decipher these signals in the context of other patchy knowledge and models about these recent stellar populations. Here we report our latest findings about where and how nucleosynthesis ejecta are spread within our Galaxy.

Primary author: DIEHL, Roland (MPE Garching, Germany)

Presenter: DIEHL, Roland (MPE Garching, Germany)

Session Classification: Radioactivity and meteorites

Track Classification: Radioactivity and meteorites

Proposed Lunar Measurements of r-Process Radioisotopes to Distinguish the Origin of Deep-sea ^{244}Pu

Tuesday, 19 September 2023 14:30 (15 minutes)

The astrophysical sites where r-process elements are synthesized remain mysterious: it is clear that neutron-star-mergers (kilonovae, KNe) contribute, and some classes of core-collapse supernovae (SNe) are also possible sources of at least the lighter r-process species. The discovery of ^{60}Fe on the Earth and Moon implies that one or more astrophysical explosions have occurred near the Earth within the last few Million years (Myr), probably SNe. Intriguingly, ^{244}Pu has recently been discovered in deep-sea deposits spanning the past 10 Myr, a period that includes two ^{60}Fe pulses from nearby supernovae. ^{244}Pu is among the heaviest r-process products, and we consider whether it was created in the supernovae, which is disfavored by nucleosynthesis simulations, or in an earlier kilonova event that seeded ^{244}Pu in the nearby interstellar medium that was subsequently swept up by the supernova debris. We discuss how these possibilities can be probed by measuring ^{244}Pu and other r-process radioisotopes such as ^{129}I and ^{182}Hf, both in lunar regolith samples returned to Earth by missions such as *Chang'e* and *Artemis*, and in deep-sea deposits.

Primary author: WANG, Xilu

Co-authors: CLARK, Adam; ELLIS, John; ERTEL, Adrienne; FIELDS, Brian; FRY, Brian; LIU, Zhenghai; MILLER, Jesse; SURMAN, Rebecca

Presenter: WANG, Xilu

Session Classification: Radioactivity and meteorites

Track Classification: Radioactivity and meteorites

Type Ia supernovae: from explosion models to observations

Tuesday, 19 September 2023 15:15 (30 minutes)

In this biased review talk I will first summarise a modelling workflow (the "pipeline") that connects rapid binary evolution progenitor models to supernova observables, via supernova explosion and nucleosynthesis simulations. I will then highlight how we can use model specific nucleosynthetic signatures of different explosion models to make inferences about what kind of white dwarfs explode as Type Ia supernovae. This includes population arguments based on the galactic chemical evolution of iron group elements such as manganese, as well as inferences on individual supernovae from the signatures long-lived radioactive isotopes leave in their late-time light curve.

Primary author: SEITENZAHL, Ivo (UNSW Canberra)

Presenter: SEITENZAHL, Ivo (UNSW Canberra)

Session Classification: Novae and X-ray bursts, Type IA supernova and the p-process

Track Classification: Type Ia supernova and the p-process

Recent Advances in the Modeling of Type I X-Ray Bursts and Nova Outbursts

Tuesday, 19 September 2023 15:45 (20 minutes)

Type I X-ray bursts (XRBs) are thermonuclear explosions in the H/He-rich envelopes accreted onto neutron stars in close binary systems. These events constitute the most frequent type of thermonuclear stellar explosion in our Galaxy (the third, in terms of total energy output after novae and supernovae). To date, most of the efforts undertaken in the modeling of XRBs have relied on non-rotating, 1D hydrodynamic simulations. Here, we present pioneering XRB models computed with different angular velocities (up to 80% of the critical value) and discuss the differences obtained in the lightcurves and in the associated nucleosynthesis with respect to non-rotating models.

It is worth noting that, while all XRB hydro simulations performed to date report that ejection from a neutron star is unlikely, radiation-driven winds during photospheric radius expansion have been suggested to lead to the ejection of a tiny fraction of the accreted envelope. Here, we will report our results of the coupling of a non-relativistic radiative wind model with a series of XRB hydrodynamic simulations, quantifying the expected contribution of XRBs to the Galactic abundances.

Classical novae (CNe) are a related class of thermonuclear explosions that involve mass-accreting white dwarfs, rather than neutron stars. The low-mass, main sequence companion (or a red giant, particularly for recurrent novae) overfills its Roche lobe and matter flows through the inner Lagrangian point of the system. While nova simulations have focused on the early stages of the explosion and ejection, a fraction of the ejecta will collide, first with the accreting disk that orbits the white dwarf, and later with the secondary star. As a result, part of the ejecta is expected to mix with the outermost layers of the secondary. The resulting chemical contamination may have potential implications for the next nova cycle, once mass transfer from the secondary resumes. New multidimensional simulations of the interaction of the ejecta with the accretion disk, and ultimately with the stellar companion, will also be presented.

Primary authors: JOSE, Jordi (UPC Barcelona); MARTIN, David (UPC Barcelona); FIGUEIRA, Joana (UPC Barcelona); HERRERA, Yago (ICE-CSIC Bellaterra); SANZ, Axel (UPC Barcelona); GARCIA-SENZ, Domingo (UPC Barcelona); SALA, Gloria (UPC Barcelona)

Presenter: JOSE, Jordi (UPC Barcelona)

Session Classification: Novae and X-ray bursts, Type IA supernova and the p-process

Track Classification: Novae and X-ray bursts

Understanding the abundance of 22Na in novae by measuring femtosecond lifetimes in 23Mg with a new method

Tuesday, 19 September 2023 16:05 (15 minutes)

Simulations of explosive nucleosynthesis in novae predict the production of the radioisotope ^{22}Na. Its half-life of 2.6 yr makes it a very interesting astronomical observable by allowing space and time correlations with the astrophysical object. Its γ-ray line at 1.275 MeV has not been observed yet by the γ-ray space observatories. This radioisotope should bring constraints on nova models. It may also help to explain abnormal ^{22}Ne abundance observed in presolar grains and in cosmic rays. Hence accurate yields of ^{22}Na are required. At peak nova temperatures, the main destruction reaction ^{22}Na$(p,\gamma)^{23}$Mg has been found dominated by a resonance at 0.204 MeV corresponding to the E_x =7.785 MeV excited state in ^{23}Mg. However, the different determinations of the strength of this resonance disagree, resulting in uncertainties of one order of magnitude for the expected mass of ^{22}Na ejected in novae [1].

An experiment was performed at GANIL facility to measure both the lifetime and the proton branching ratio of the key state at E_x =7.785 MeV. The principle of the experiment is based on the one used in [2]. With a beam energy of 4.6 MeV/u, the reaction ^{3}He(^{24}Mg,α)^{23}Mg* populated the state of interest. This reaction was measured with particle detectors (magnetic spectrometer VAMOS++, silicon detector SPIDER) and γ-ray tracking spectrometer AGATA. The expected time resolution with AGATA high space and energy resolutions is 1 fs. Particle and γ-ray emissions were analyzed with a new simulation code EVASIONS to determine the spectroscopic properties of the key state.

Our new results [3] will be presented. Doppler shifted γ-ray spectra from ^{23}Mg states were improved by imposing coincidences with the excitation energies reconstructed with VAMOS++. This ensured to suppress the feeding from higher states. Lifetimes in ^{23}Mg, down to the femtosecond, were measured with a new approach based on particle - γ-ray correlations and velocity-difference profiles. Protons emitted from unbound states in ^{23}Mg were also identified. With an higher precision on the measured lifetime and proton branching ratio of the key state, a new value of the resonance strength $\omega\gamma$ was obtained, it is below the sensitivity limit of direct measurement experiments. The ^{22}Na$(p,\gamma)^{23}$Mg thermonuclear rate has been reevaluated with the statistical Monte Carlo approach. The amount of ^{22}Na ejected during novae has been proven to be a tool for better understanding the underlying novae properties. Thanks to the highly-accurate rate, derived here, robust estimates of the detectability limit of ^{22}Na in novae have been determined with respect to the next generation of γ-ray space telescopes, and the detection of the ^{22}Na γ-ray line found promising in the coming decades.

References

[1] C. Fougères *et al*, EPJ Web Conf **279**, 09001 (2023).
[2] O. S. Kirsebom *et al*, Phys. Rev. C **93**, 1025802 (2016).
[3] C. Fougères *et al*, arXiv:2212.06302, 09001 (2022).

Primary authors: FOUGÈRES, Chloé (Argonne National Laboratory); Dr DE OLIVEIRA SANTOS, François (Grand Accélérateur National d'Ions Lourds (GANIL, CEA/DRF-CNRS/IN2P3); Prof. JOSÉ, Jordi (Universitat Politècnica de Catalunya and Institut d'Estudis Espacials de Catalunya)

Presenters: FOUGÈRES, Chloé (Argonne National Laboratory); Dr DE OLIVEIRA SANTOS, François

(Grand Accélérateur National d'Ions Lourds (GANIL, CEA/DRF-CNRS/IN2P3)

Session Classification: Novae and X-ray bursts, Type IA supernova and the p-process

Track Classification: Novae and X-ray bursts

Simulations of One and Two Star Explosions in the Double Degenerate Double Detonation Scenario for Type Ia Supernovae

Tuesday, 19 September 2023 16:20 (15 minutes)

The precise origin of Type Ia supernovae (SNe Ia) is unknown despite their value to numerous areas in astronomy. While it is a long-standing consensus that they arise from an explosion of a C/O white dwarf, the exact progenitor configurations and explosion mechanisms that lead to a SN Ia are still debated. One popular theory is the double detonation in which a helium layer, accreted from a binary companion, detonates on the surface of the primary star, leading to a converging shock-induced detonation of the underlying core. Across a mass range of sub-Chandrasekhar progenitors, the double detonation scenario produces light curves and spectra that match many characteristics of individual SNe Ia as well as the breadth of the population. It has also recently been shown via simulation that the elusive donor companion may not survive but rather undergo its own double detonation triggered by the impact from the core detonation of the primary star. If this explosion of the companion does indeed occur in reality, it could have numerous implications for the observables and nucleosynthesis from SNe Ia. In this talk, we show 2D simulations of detonations in white dwarf binaries that model both stars undergoing a double detonation in addition to double detonations in isolated, thin helium shell progenitors. We also present radiative transfer results from these two scenarios, which includes the first multi-dimensional synthetic observables of the two star double detonation. We find that within a range of mass configurations of the degenerate binary, the synthetic light curves and spectra of these events match observations as well as theoretical models of single double detonations do. Notably, one and two star double detonations that are spectrally similar and reach the same peak brightnesses produce different amounts of Si- and Fe-group elements which would affect the impact of SNe Ia on the chemical evolution of the universe. Further understanding of this scenario is needed in order to determine if at least some observed SNe Ia actually originate from two stars exploding.

Primary author: BOOS, Samuel (University of Alabama)

Co-authors: Dr TOWNSLEY, Dean (University of Alabama); Dr SHEN, Ken (University of California, Berkeley)

Presenter: BOOS, Samuel (University of Alabama)

Session Classification: Novae and X-ray bursts, Type IA supernova and the p-process

Track Classification: Type Ia supernova and the p-process

Astrophysics program at Yemilab

Wednesday, 20 September 2023 09:00 (30 minutes)

IBS has recently constructed a new underground laboratory, Yemilab, in Korea. It is 1000 meters underground and spacious with more than 3000 m^2 experimental area. The Center for Underground Physics has developed programs for weakly interacting dark matter searches with scintillators and low-temperature detectors. We also have plans to search the rare nuclear decays, such as neutrinoless double beta decays, 180mTa decays, etc. I will describe the current status of the research and address a few issues related to nuclear physics.

Primary author: KIM, Yeongduk (Institute for Basic Science)

Presenter: KIM, Yeongduk (Institute for Basic Science)

Session Classification: New facilities, instruments and tools

Track Classification: Others (new facilities, instruments, tools, etc)

Nuclear Astrophysics at the Notre Dame Nuclear Science Lab

Wednesday, 20 September 2023 09:30 (30 minutes)

There is a distinguished history of nuclear astrophysics research at the Notre Dame Nuclear Science Lab (NSL). This has been fostered by University investment and strong support from the National Science Foundation. The NSL provides the research base for some 20 Notre Dame faculty members and approximately 35 graduate students as well as supporting the research programs of a number of external users. The laboratory hosts a number of unique facilities and instruments that help facilitate astrophysical research such as the St. George recoil separator coupled to the high-intensity 5U accelerator, the worlds-only triple solenoid in-flight radioactive beam facility, and one of only three operating Enge split-pole spectrometers in the U.S. The NSL maintains three on-site accelerators, which can operate simultaneously and continuously as well as the only underground nuclear accelerator in the U.S. at the SURF facility in South Dakota. The current research program at the NSL will be presented along with plans for future instrument upgrades and additions.

Research supported by the National Science Foundation grant NSF PHY-2011890 and the University of Notre Dame.

Primary author: BARDAYAN, Dan (University of Notre Dame)

Presenter: BARDAYAN, Dan (University of Notre Dame)

Session Classification: New facilities, instruments and tools

Track Classification: Others (new facilities, instruments, tools, etc)

Nuclear Astrophysics with low-energy RI beams at CRIB

Wednesday, 20 September 2023 10:00 (15 minutes)

Astrophysical reactions involving radioactive isotopes (RI) often play an important role in explosive stellar environments. Although the RI are seldom seen on the earth due to the finite lifetime, they do exist in stars, and contribute to the evolution and thermal dynamics of stellar objects. Experimental efforts have been made for the studies on such RI-involving reactions.

CRIB (CNS Radioisotope Beam Separator) is a low-energy RI beam separator
operated by Center for Nuclear Study, the University of Tokyo, located at the RI beam factory (RIBF) of RIKEN Nishina Center.
Various experimental projects based on interests for nuclear astrophysics have been carried out at CRIB, forming international collaborations.
The present status of CRIB, including the new developments for the RI beams, is reported.
Recent projects of astrophysical reaction studies with RI beams at CRIB are also discussed;

1) Trojan Horse Method measurement for the 7Be+n reactions which may affect the 7Be abundance in the Big-Bang nucleosynthesis, to find a solution for the cosmological 7Li abundance problem.

2) Resonant scattering measurement for the 22Mg(alpha, p) reaction, which affects the light curve of X-ray bursts.

3) Direct measurement of the 26Si(alpha, p) reaction, another relevant RI reaction in X-ray bursts.

Primary author: YAMAGUCHI, Hidetoshi (Center for Nuclear Study, the University of Tokyo)

Co-authors: Dr LIU, Fulong (Center for Nuclear Study, the University of Tokyo); OKAWA, Kodai (CNS, the University of Tokyo); Mr ZHANG, Qian (Center for Nuclear Study, the University of Tokyo); HAYAKAWA, Seiya (Center for Nulear Study, University of Tokyo)

Presenter: YAMAGUCHI, Hidetoshi (Center for Nuclear Study, the University of Tokyo)

Session Classification: New facilities, instruments and tools

Track Classification: Others (new facilities, instruments, tools, etc)

Recent astrophysics results from the Enge Split-pole Spectrograph Program at the Triangle Universities Nuclear Laboratory

Wednesday, 20 September 2023 10:15 (15 minutes)

The Triangle Universities Nuclear Laboratory (TUNL) is home to one of the only functioning magnetic Enge split-pole spectrographs in North America. The spectrograph was recommissioned in 2017 and has been used to perform a suite of experiments aimed at constraining nucleosynthesis in stars. An overview will be presented of the successful experiments and results that have been performed at the facility in the last 5 years. These include constraining the 18F(p,a)15O reaction, a key reaction in understanding gamma-ray signals from classical novae; measurements of states important for the 17O(a,n)20Ne which strongly affects the s-process efficiency in rotating massive stars; and determining the spin-parities of resonances in the 39K(p,g)40Ca reaction, reducing its reaction rate uncertainty by over factor of 10. The high resolution of the spectrograph coupled with a dedicated high-precision beamline at TUNL enables us to differentiate closely-spaced energy levels astrophysics that are currently impossible in inverse kinematics. A modern statistical analysis pipeline will also be showcased, which helps drive particle transfer reaction measurement analysis for astrophysics into a new era.

Primary author: LONGLAND, Richard (North Carolina)

Presenter: PSALTIS, Thanassis (NCSU/TUNL)

Session Classification: New facilities, instruments and tools

Track Classification: Others (new facilities, instruments, tools, etc)

Improved measurements of (α, p) reactions with a new ANASEN design

Wednesday, 20 September 2023 10:30 (15 minutes)

Several (α, p) reactions on proton-rich nuclei are among the most important nuclear reactions occurring during Type I X-ray bursts. However, large uncertainties remain in these reaction rates due to the lack of direct measurements. The Array for Nuclear Astrophysics and Structure with Exotic Nuclei (ANASEN) is a gas target and charged particle detector designed for studying (α, p) reactions. A previous ^{18}Ne$(\alpha, p)^{21}$Na measurement with ANASEN used a position-sensitive proportional counter along the beam axis with a barrel of thick silicon detectors far from the beam axis to track protons from these reactions [1]. Due to the poor tracking resolution of the proportional counter, this measurement achieved a center-of-mass energy resolution of only 1.4 MeV. We have developed a new approach, replacing the proportional counter with a hexagonal barrel of thin (~80 μm) silicon detectors. This allows pure helium gas to be used and improves the tracking resolution, though at a cost of overall efficiency. The new setup was used in stable beam tests at the Fox Laboratory at Florida State University, and in both stable and radioactive beam measurements at TRIUMF-ISAC. Results from stable beam tests and from a measurement of the ^{18}F$(\alpha, p)^{21}$Ne excitation function, which may impact asymptotic giant branch nucleosynthesis [2] and helium burning on accreting white dwarfs [3], will be presented. Plans for future measurements at TRIUMF-ISAC and FRIB will be discussed.

Funding Acknowledgement: This material is based upon work supported by NSF Grant No. PHY-2012522, US DOE Grant No. DE-FG02-96ER40978, and the National Science Foundation Graduate Research Fellowship Program under Grant No. GR-00010333.

[1] M. Anastasiou, I. Wiedenhöver, J.C. Blackmon, L.T. Baby, D.D. Caussyn, A.A. Hood, E. Koshchiy, J.C. Lighthall, K.T. Macon, J.J. Parker, T. Rauscher, and N. Rijal, Phys. Rev. C 105, 055806 (2022).
[2] A.I. Karakas, H.Y. Lee, M. Lugaro, J. Görres, and M. Wiescher, Astrophys. J. 676, 1254 (2008).
[3] K.J. Shen and L. Bildsten, Astrophys. J. 699, 1365 (2009).

Primary author: DAVIS, Keilah (Louisiana State University)

Co-authors: BLACKMON, Jeffery (Louisiana State University); DEIBEL, Catherine (Louisiana State University); WILSON, Gemma (Louisiana State University); BALAKRISHNAN, Sudarsan (Rutgers University); SITARAMAN, Vignesh (Florida State University); MCCANN, Gordon W. (Florida State University); WIEDENHÖEVER, Ingo (Florida State University); BABY, Lagy (Florida State University); TOLSTUKHIN, Ivan (Argonne National Laboratory); LENNARZ, Annika (TRIUMF); ALCORTA, Martin (TRIUMF); CHAKRABORTY, Soham (University of York); LAIRD, Allison (University of York); GLORIUS, Jan (GSI Helmholtz Centre for Heavy Ion Research); BARDAYAN, Dan (University of Notre Dame); CARMICHAEL, Scott (University of Notre Dame); PAIN, Steve (Oak Ridge National Laboratory); CHIPPS, Kelly (Oak Ridge National Laboratory); RUSSELL, Reuben (University of Surrey); WAGNER, Louis (TRIUMF); ESPARZA, Chris (Florida State University)

Presenter: DAVIS, Keilah (Louisiana State University)

Session Classification: New facilities, instruments and tools

Track Classification: Others (new facilities, instruments, tools, etc)

Status of the RAON Facility

Wednesday, 20 September 2023 10:45 (30 minutes)

The construction of the RAON (Rare Isotope Accelerator complex for ON-line experiments) facility was launched in 2011 as the Rare Isotope Science Project (RISP). The RAON was designed to produce a variety of stable and rare isotope beams to be used for basic science research and applications. The RAON consists of a heavy ion superconducting linear accelerator (SCL2) as the driver for the In-flight Fragmentation (IF) system, a proton cyclotron as the driver for the ISOL (Isotope Separation On-Line) system, and a superconducting linac (SCL3) for the post-acceleration of ISOL beams. The ISOL and IF systems can be operated independently, while the rare isotopes produced by the ISOL system can be injected to the superconducting linac SCL3 and then to the SCL2 for further acceleration to produce even more exotic rare isotopes through a two-step method (ISOL+IF). This combined scheme (ISOLIF) for producing more exotic rare isotopes in sequence is the uniqueness of the RAON facility.
The first phase of the RISP, constructing the superconducting linear accelerator SCL3, cryo-plant systems, an ISOL system with a cyclotron, supporting facilities, buildings, and seven experimental systems is completed. The construction of the superconducting linac SCL2 to deliver a wide range of heavy ion beams, e.g. uranium beams of 200 MeV/u with a beam current of 8.3 pμA and proton beams of 600 MeV with 660 pμA will be done as the second phase.

The first beam commissioning of the SCL3 was carried out successfully by accelerating the Argon beam through 22 QWR modules up to 2.47 MeV/u with 34 μA, and then through 32 HWR modules to accelerate Ar beams to 17.6 MeV/u with 21 μA. The accelerated Ar beams were delivered to the KoBRA (Korea Broad acceptance Recoil Spectrometer and Apparatus) system to produce rare isotopes.

Also, the ISOL system was commissioned by bombarding the SiC target with proton beams to generate radioactive isotopes such as Na and Al. The beam commissioning of other low energy experimental facilities such as the MMS (Mass Measurement System), CLS (Colinear Laser Spectroscopy), and NDPS (Nuclear Data Production System) will also be prepared soon. We will report on the current status of the RAON facility.

Primary authors: HONG, Seung-Woo (Institute for Rare Isotope Science, IBS); SHIN, Taeksu (IRIS, IBS)

Presenter: SHIN, Taeksu (IRIS, IBS)

Session Classification: New facilities, instruments and tools

Track Classification: Others (new facilities, instruments, tools, etc)

The r-process and neutrinos in neutron star mergers

Thursday, 21 September 2023 09:00 (30 minutes)

The merging of two neutron stars is a true multimessenger event that includes gravitational waves, an electromagnetic signal, and the emission of enormous numbers of neutrinos. In order to understand these signals we need a careful accounting of the microphysics that occurs during and after the merger. I will focus on the elements produced in these objects and the effect of two aspects of this microphysics; nuclear models/reactions and neutrino flavor transformation physics. In particular, I will discuss the importance of new developments in these areas to predictions of r-process observables and the astrophysical origin of the r-process.

Primary author: MCLAUGHLIN, Gail (North Carolina State University)

Presenter: MCLAUGHLIN, Gail (North Carolina State University)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Binary Neutron Stars, Core Collapse Supernovae and the Nuclear Equation of State

Thursday, 21 September 2023 09:30 (15 minutes)

The properties of nuclear matter at extremely high densities and temperatures remain a mystery. This talk discusses two environments for which the nuclear matter can be found at the highest densities. These are: during the collapse of the core of a massive star to form a supernova or black hole; and during the merger of two neutron stars to form a black hole. Here, we highlight recent progress by our group toward exploring the nuclear equation-of-state effects in these environments. In particular, we describe new insight into the explodability of supernova progenitors and a probe of the the non-perturbative regime of quark matter in the gravitational radiation emitted during binary neutron-star mergers.

Primary author: MATHEWS, Grant (University of Notre Dame)

Co-authors: Dr KEDIA, Atul (Univ. Notre Dame); BOCCIOLI, Luca (Univ. Notre Dame)

Presenter: MATHEWS, Grant (University of Notre Dame)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Role of light-mass nuclear reactions in the r-process nucleosynthesis, revisited

Thursday, 21 September 2023 09:45 (15 minutes)

We study the sensitivity of the r-process nucleosynthesis to the nuclear reactions of light nuclei. We first update nuclear reaction data in Libnucnet code if available in experiments. We then calculate the r-process nucleosynthesis in the core-collapse supernovae and collapsar. For core-collapse supernovae we consider two different scenarios: the magnetohydrodynamic (MHD) jet model and a simple exponential model for the weak r-process.
We find important reactions such as 14C(n, gamma)15C to which the r-process is sensitive. We finally discuss reaction network flows under the various conditions.

Primary authors: KIM, Kyungil (IRIS, IBS); KUSAKABE, Motohiko (Beihang Univ.); SHIBAGAKI, Shota (Univ. of Wroclaw); KAJINO, Toshitaka (Beihang Univ./NAOJ/Univ. of Tokyo); YAO, Xingqun (Beihang Univ.); KIM, Youngman (CENS, IBS); HE, Zhenyu (Beihang Univ.)

Presenter: KIM, Youngman (CENS, IBS)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Chemical compositions of r-process enhanced metal-poor stars discovered by the LAMOST/Subaru telescopes

Thursday, 21 September 2023 10:00 (15 minutes)

Metal-poor stars are thought to have the result of nucleosynthesis in the early stages of galaxy formation in their atmospheres. A variety of surveys and follow-up observations have been performed to determine detailed abundance patterns for many metal-poor stars. The r-process, which provides about a half of the elements heavier than iron, is thought to be caused by neutron star mergers. However, an r-process enhanced extremely metal-poor star ([Fe/H] $= -3.5$) has been discovered (Yong et al. 2021), which should be formed in the early stages of galaxy formation, suggesting that the r-process needs to occur with very short time scale through, for instance, special types of supernovae.
We have obtained chemical abundances by high-dispersion spectroscopic observations with Subaru/HDS for about 400 metal-poor stars estimated to be [Fe/H] < -2, which were discovered by the LAMOST spectroscopic survey (Aoki et al. 2022, Li et al. 2022). These observations have identified many r-process enhanced stars, of which the most metal-poor J1109+0754 ([Fe/H]$= -3.4$) and the brightest J0040+2729 ([Fe/H]$= -2.7$) were followed-up with long exposures with Subaru/HDS. The observations were conducted in the wavelength region around 4000A, where there are many absorption lines for neutron-capture elements including thorium, and for J0040+2729, observations were also conducted in the near-UV region up to around 3300A. We have obtained the abundances for many elements, including thorium, and upper limits for lead and uranium from the spectra. The overall abundance patterns of both stars exhibit a good agreement with the solar r-process pattern as found for r-process-enhanced stars previously studied, but some of the lighter elements show slight deviations from the solar r-process pattern. This result could indicate the diversity of the r-process. The abundance patterns of r-process elements in very metal-poor stars constrain the timing of neutron star mergers in the early stages of galaxy formation and models of supernova explosions.

Primary author: HONDA, Satoshi (University of Hyogo)

Co-authors: AOKI, Wako (National Astronomical Observatory of Japan); Dr LI, Haining (NAOC); Dr MATSUNO, Tadafumi (Univ. of Groningen); Dr XING, Qianfan (NAOC)

Presenter: HONDA, Satoshi (University of Hyogo)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Optical properties of magneto-rotaional jet-driven supernovae associated with r-process nucleosynthesis

Thursday, 21 September 2023 10:15 (15 minutes)

Magnetorotational-driven supernovae (MRNSe) are a peculiar type of core-collapse SNe. Their progenitors are fast-rotating massive stars with strong magnetic fields and they are candidates for the central engine of hypernovae and gamma-ray bursts. They are also expected to be astronomical sites for the r-process, as they have a different explosion mechanism from regular SNe. MRSNe may have very neutron-rich ejecta suitable for the r-process due to the strong effect of the jet-driven explosion. In studies of galactic chemical evolution, MRSNe are expected to be additional r-process sources because they have different frequencies and delay times from neutron-star mergers. Although some observations suggest jet-like SNe, the occurrence of r-process nucleosynthesis has never been directly confirmed. In this presentation, we focus on the effect of r-process nucleosynthesis in MRSNe on possible observational properties in SN light curves. The r-process occurring in the central region of the SN provide different opacity and heating sources compared to canonical core-collapse SNe. We quantitatively investigate the effects of r-process elements and ^{56}Ni abundances on the light curves based on a series of radiative hydrodynamics simulations. We confirm that the influence of the r-process is not significant for all models, which is consistent with the fact that we have not still identified r-process elements in SNe. However, there are some models where the existence of r-process elements can be observationally confirmed by current high presicition obervations (e.g., JWST) and future telescopes.

Primary author: Dr NISHIMURA, Nobuya (RIKEN)

Co-authors: KAWAGUCHI, Kyohei (University of Tokyo); TANAKA, Masaomi (Tohoku University); DOMOTO, Nanae (Tohoku University); SAITO, Sei (Tohoku University); HASEGAWA, Tatsuki (Tohoku University)

Presenter: Dr NISHIMURA, Nobuya (RIKEN)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Building relativistic mean-field models for neutron stars in light of the PREX-2 and CREX results

Thursday, 21 September 2023 11:30 (15 minutes)

We construct new effective interactions using the relativistic mean-field model with the isoscalar- and isovector-meson mixing. Taking into account the results of neutron skin thickness of ^{208}Pb and ^{48}Ca by the PREX-2 and CREX experiments as well as the particle flow data in heavy-ion collisions, the observed mass of PSR J0740+6620, and the tidal deformability of a neutron star from binary merger events, we study the ground-state properties of finite nuclei and the characteristics of nuclear matter and neutron stars. It is found that the σ-δ mixing is very important to understand the terrestrial experiments and astrophysical observations of neutron stars self-consistently. Especially, we present that the equation of state for neutron stars exhibits the rapid stiffening around twice the nuclear saturation density, which is caused by the soft nuclear symmetry energy due to the σ-δ mixing. It is also noticeable that the small dimensionless tidal deformability of a canonical neutron star observed from GW170817 can be explained within the current relativistic mean-field models.

Primary author: Dr MIYATSU, Tsuyoshi (Soongsil University)

Co-authors: Prof. CHEOUN, Myung-Ki (Soongsil University); Prof. KIM, Kyungsik (Korea Aerospace University); Prof. SAITO, Koichi (Tokyo University of Science)

Presenter: Dr MIYATSU, Tsuyoshi (Soongsil University)

Session Classification: High-density matter

Track Classification: High-density matter

Supernova equation of state and neutrino-nucleon reaction rates based on bare nuclear forces

Thursday, 21 September 2023 11:45 (15 minutes)

The equation of state (EOS) for dense matter is one of the crucial ingredients in numerical simulations for astrophysical phenomena, such as core-collapse supernovae, cooling of nascent protoneutron stars, and binary neutron star mergers. While considerable efforts have been devoted to understanding the dense-matter EOS from terrestrial experiments, astrophysical observations, and theoretical calculations, the nuclear EOS still remains rather uncertain. In particular, since the properties of dense nuclear matter appearing in those simulations are governed by the repulsion of nuclear forces, it should be described with a nuclear Hamiltonian composed of realistic nuclear potentials. In the above situation, we have recently constructed a new nuclear EOS based on the variational many-body theory with realistic nuclear forces (AV18 + UIX) [1], and the resultant EOS table is available on the Web [2] for the use in various astrophysical simulations.
In this presentation, we will discuss the properties of our nuclear EOS and its applications to core-collapse simulations starting from several progenitor models to investigate the EOS effects on the mechanism of successful and failed core-collapse supernova explosions. Furthermore, we will report on the newly obtained neutrino-nucleon reaction rates in supernova matter with the consistent variational method, which is an extension of the present EOS.

[1] H. Togashi, K. Nakazato, Y. Takehara, S. Yamamuro, H. Suzuki, and M. Takano, Nucl. Phys. A 961 (2017) 78.
[2] http://www.np.phys.waseda.ac.jp/EOS/

Primary author: Dr TOGASHI, Hajime (Daegu University)

Co-author: TAKANO, Masatoshi

Presenter: Dr TOGASHI, Hajime (Daegu University)

Session Classification: High-density matter

Track Classification: High-density matter

The Dawn of 3D Stellar Evolution and Nucleosynthesis

Thursday, 21 September 2023 13:30 (30 minutes)

Stars play a key role in the Cosmos through the light they shine, the chemical elements they produce and the kinetic energy they inject into their surroundings via winds and supernova explosions. For many decades, our understanding of the structure, evolution and fate of stars has greatly benefitted from comparing spherically symmetric, one-dimensional (1D) theoretical models to a variety of observations. The large increase in the number and quality of observations combined with the advent of asteroseismology probing the interior of stars, however, has exposed the limitation of 1D models. The increasing computing power available has now reached the point where significant fractions of a star and for an increasing duration can be simulated in 3D using realistic stellar conditions, which represents the dawn of multi-D stellar evolution and nucleosynthesis modelling of stars. In this talk, I will review some of the most critical limitations of 1D models and the latest 3D simulations providing new insight and guidance to improve 1D models and our understanding of stars and their impact.

Primary author: Prof. HIRSCHI, Raphael (Keele University)

Presenter: Prof. HIRSCHI, Raphael (Keele University)

Session Classification: Stellar modelling

Track Classification: Stellar modelling

Evolution of accreting white dwarfs in close binary systems including the effects of rotation and magnetic fields and implications for Type Ia supernovae

Thursday, 21 September 2023 14:00 (30 minutes)

Accreting white dwarfs in interacting binary systems are closely related to explosive events like novae and Type Ia supernovae, which play an important role in the chemical evolution of the universe. Although numerous studies on the evolution of accreting white dwarfs have been presented in the literature, there has been a relatively limited focus on exploring the impact of rotation and magnetic fields on these systems. Given that the accreted matter is supposed to carry a large amount of angular momentum to spin-up the white dwarf, the resulting rotational and magnetic instabilities would lead to a significant chemical mixing as well as a change of the hydrostatic structure. This can in turn have important consequences in the pre-explosion structure and the nucleosynthesis of novae and supernovae. In this talk, I will present some recent evolutionary models of helium-accreting white dwarfs including these effects and discuss how they can alter our view on the so-called double-detonation scenario for Type Ia supernovae.

Primary author: YOON, Sung-Chul (Seoul National University)

Presenter: YOON, Sung-Chul (Seoul National University)

Session Classification: Stellar modelling

Track Classification: Stellar modelling

On the bridge: Asteroseismology meets nuclear astrophysics in massive stars

Thursday, 21 September 2023 14:30 (15 minutes)

Massive stars (10 solar masses and up) play an important role in the synthesis of new elements in the Universe. They enrich the interstellar medium with these newly synthesized isotopes via their stellar winds and via their final supernova explosions. To understand the nuclear yields of these stars, especially before the supernova explosion, there are three key ingredients; the nuclear reaction rates that govern the creation of new isotopes, internal mixing processes that bring the newly synthesized isotopes from the interior of the star to the surface, and the stellar winds that bring these isotopes into the interstellar medium. In our work, we focus on the effects of interior mixing processes on the nucleosynthetic yields. Up to now, the calculations of stellar yields have relied on stellar evolution models that have remained uncalibrated in terms of chemical mixing in the stellar interior. We take the recent observationally driven advances in asteroseismic and binary analysis of the interior structure and evolution of intermediate- to high-mass stars and the proposed mixing profiles based on these observations into account. In this way, our models will bridge the gap between theoretical yield calculations and asteroseismically calibrated mixing profiles. This is a vital step to improve our understanding of the evolution of stars with initial masses of 7-30 solar masses and their role in enriching the galaxy with newly synthesized isotopes. We focus on this mass-range because it includes the most massive asteroseismically constrained stars, and because it covers the stars just below the supernova boundary (8-10 solar masses). Due to the strong dependence between the interior structure of a supernova-progenitor and its final fate, changes in the interior mixing of these stars not only affect the nucleosynthetic yields (both in the stellar winds and from the supernova explosion), but also might affect which stars will end their lives as supernovae and might affect the mass of the supernova remnant. Therefore, a proper understanding of the impact of this calibrated mixing on stellar evolution is especially valuable for the community working on nucleosynthesis and galactic chemical evolution.

Primary author: BRINKMAN, Hannah (Institute of Astronomy, KU Leuven)

Presenter: BRINKMAN, Hannah (Institute of Astronomy, KU Leuven)

Session Classification: Stellar modelling

Track Classification: Stellar modelling

Nucleosynthesis and stellar evolution in 3D hydrodynamic simulations

Thursday, 21 September 2023 14:45 (15 minutes)

Our knowledge of stellar evolution is limited by uncertainties coming from complex multi-dimensional processes in stellar interiors, usually reproduced in 1D stellar models with simplifying prescriptions. 3D hydrodynamic models can improve these prescriptions by studying realistic multi-D processes, usually for a short timerange (minutes or hours). Recent advances in computing resources are starting to enable 3D models to run for longer time and include nuclear reactions, making the simulations more realistic and allowing to study the effects of nuclear reactions on the stellar evolution.
In this talk, I will present results coming from a new set of hydrodynamic simulations of a massive-star burning shell, run continuously from early development to fuel exhaustion, and including different nuclear species. I will discuss the implications for stellar nucleosynthesis, convective boundary mixing, and the possibility of deriving simplifying laws that can be used in 1D stellar models.

Primary author: RIZZUTI, Federico (Keele University)

Co-authors: HIRSCHI, Raphael (Keele University); Dr VARMA, Vishnu (Keele University)

Presenter: RIZZUTI, Federico (Keele University)

Session Classification: Stellar modelling

Track Classification: Stellar modelling

The Impact of Binary Evolution on Stellar Nucleosynthesis

Thursday, 21 September 2023 15:00 (15 minutes)

Almost all of the nuclei in the cosmos originate from stars. Low-mass (~1-8$M_{\odot}$) stars are thought to synthesise a large fraction of the universe's carbon, nitrogen, and fluorine, and about half of all elements heavier than iron making them an important ingredient in galactic chemical evolution (GCE) models. Low mass stars synthesise material through a variety of nuclear processes such as H-burning, He-Burning, and the slow neutron capture process. Most theoretical nucleosynthesis calculations assume that the stars are single, and these calculations are commonly used for GCE models. However, over half of low mass stars are observed to have at least one stellar companion in what is known as a binary system. Binary evolution could lead to mass transfer and stellar mergers which in turn could influence the conditions within the stellar interior. In this talk, we question the use of only single star calculations within GCE models and investigate the influence of binary evolution on the production of carbon-12, nitrogen-14, aluminium-26, and s-process elements (e.g., Pb208) by a low-mass stellar population at solar metallicity. We find that for a stellar population with a binary fraction of 0.7 the overall output of carbon-12 decreases by ~12%, nitrogen-14 decreases by <5%, aluminium-26 increases by ~25%, and lead decreases by <5%. We also find that binary evolution could explain some of the anomalous abundances observed in globular clusters and planetary nebulae.

Primary author: OSBORN, Zara (Monash University)

Co-authors: KARAKAS, Amanda (Monash University); KEMP, Alex (KU Leuven); IZZARD, Robert (University of Surrey)

Presenter: OSBORN, Zara (Monash University)

Session Classification: Stellar modelling

Track Classification: Stellar modelling

Experiments related to Neutron-Rich Nuclei in r-Process Nucleosynthesis

Thursday, 21 September 2023 15:45 (30 minutes)

Where and how were heavy elements which contain many neutrons relative to proton, synthesized? With regards to the origin of these heavy elements, a reaction in which nuclei capture neutrons in a fast and continuous manner during the explosion of a star was proposed and named the rapid neutron capture process (r process) [1].
In 2017, a binary neutron star merger event was discovered by simultaneous observations of gravitational and electromagnetic waves, and its kilonova was also identified, suggesting the synthesis of heavy elements. Were heavy elements such as gold, platinum, and even uranium synthesized in binary neutron star mergers, supernova explosions, or collapsars [2-4]? Analysis of the unique heavy-element compositions left behind in the solar system, meteorites, and old metal-poor stars has begun. The key to deciphering the traces left behind by isotopic elements lies in the thousands of neutron-rich nuclei that disappeared in an instant.
Here, we introduce the experimental research on the explosive r-process nucleosynthesis and future perspective at RIBF [5,6].

[1] E.M. Burbidge, G.R. Burbidge, W.A. Fowler, and F. Hoyle, Rev. Mod. Phys. 29, 547 (1957).
[2] S. Wanajo et al., Astrophys. Jour. Lett. 789: L39 (2014).
[3] C. Kobayashi, A.I. Karakas, and M. Lugaro, Astrophys. Jour. 900, 179 (2020).
[4] J. Barnes and B.D. Metzger, Astrophys. Jour. Lett. 939: L29 (2022).
[5] V.H. Phong et al., Phys. Rev. Lett. 129, 172701 (2022).
[6] S. Nishimura, Prog. Theor. Exp. Phys. 2012, 03C006 (2012).

Primary author: NISHIMURA, Shunji (RIKEN)

Presenter: NISHIMURA, Shunji (RIKEN)

Session Classification: Nuclear properties for astrophysics

Track Classification: Nuclear properties for astrophysics

Experimental study on astrophysically important ^{22}Mg nucleus via resonant scattering of ^{18}Ne+ α

Thursday, 21 September 2023 16:15 (15 minutes)

The ^{18}Ne(α,p)^{21}Na reaction is one candidate of the breakout reactions from hot-CNO cycle, and it plays an important role in understanding the X-ray bursts and the nucleosynthesis in the rp-process. We investigated energy levels of the ^{22}Mg by measuring the α resonant scattering on ^{18}Ne in inverse kinematics. The ^{18}Ne rare isotope beam was produced at the CNS Radio-Isotope Beam Separator (CRIB) of Center for Nuclear Study, the University of Tokyo, located at the RIBF of RIKEN Nishina Center. Recoiling α particles were measured by silicon detector telescopes. The excitation function of ^{22}Mg was obtained for the excitation energies of 10–16 MeV by adopting the thick-target method. To clarify the energy level properties of ^{22}Mg, the experimental excitation function was compared with theoretical R-matrix analysis using the SAMMY8 code. Since energy levels were not clearly observed at the astrophysically important energy range, upper limits on the ^{18}Ne (α,α)^{18}Ne cross section were set. The astrophysical impact was also investigated by estimating the ^{18}Ne(α,p)^{21}Na cross section.

Primary authors: CHA, Soomi (Center for Exotic Nuclear Studies, Institute for Basic Science); Prof. CHAE, K.Y. (Department of Physics, Sungkyunkwan University)

Co-authors: Mx ABE, K. (Center for Nuclear Study, The University of Tokyo); Dr BAE, S. (Center for Exotic Nuclear Studies, Institute for Basic Science); Dr BINH, D.N. (30 MeV Cyclotron Center, Tran Hung Dao Hospital); Prof. CHOI, S.H. (Department of Physics and Astronomy, Seoul National University); Dr DUY, N.N. (Institute of Postgraduate Program, Van Lang University); Dr GE, Z. (GSI Helmholtzzentrum für Schwerionenforschung GmbH); Prof. HAHN, K.I. (Center for Exotic Nuclear Studies, Institute for Basic Science); Dr HAYAKAWA, S. (Center for Nuclear Study, The University of Tokyo); Prof. HONG, B. (Department of Physics, Korea University); Prof. IWASA, N. (Department of Physics, Tohoku University); Dr KAHL, D. (School of Physics and Astronomy, University of Edinburgh); Prof. KHIEM, L.H. (Institute of Physics, Vietnam Academy of Science and Technology); Dr KIM, A. (Department of Physics, Korea University); Dr KIM, D. (Center for Exotic Nuclear Studies, Institute for Basic Science); Prof. KIM, E.J. (Division of Science Education, Jeonbuk National University); Dr KIM, G.W. (Center for Underground Physics, Institute for Basic Science); Mr KIM, M.J. (Department of Physics, Sungkyunkwan University); Prof. KWAK, K. (Department of Physics, College of Natural Science, Ulsan National Institute of Science and Technology (UNIST)); Dr KWAG, M.S. (Rare Isotope Science Project, Institute for Basic Science); Mx LEE, E.J. (Department of Physics, Sungkyunkwan University); Dr LIM, S.I. (Department of Physics, Ewha Womans University); Dr MOON, B. (Center for Exotic Nuclear Studies, Institute for Basic Science); Dr MOON, J.Y. (Rare Isotope Science Project, Institute for Basic Science); Dr PARK, S.Y. (Center for Underground Physics, Institute for Basic Science); Dr PHONG, V.H. (RIKEN Nishina Center); Mx SHIMIZU, H. (Center for Nuclear Study, The University of Tokyo); Prof. YAMAGUCHI, H. (Center for Nuclear Study, The University of Tokyo); Dr YANG, L. (Center for Nuclear Study, The University of Tokyo)

Presenter: CHA, Soomi (Center for Exotic Nuclear Studies, Institute for Basic Science)

Session Classification: Nuclear properties for astrophysics

Track Classification: Nuclear properties for astrophysics

New half-lives and beta-delayed neutron branchings for neutron-rich Ba to Nd nuclei (A~160) relevant for the formation of the r-process rare-earth peak

Thursday, 21 September 2023 16:30 (15 minutes)

Rapid neutron capture nucleosynthesis (the r-process) produces nearly half of the nuclei heavier than iron in explosive stellar scenarios.
The solar system r-process residual abundances show two peaks located at $A \sim 130$ and $A \sim 195$. Between these peaks lies the Rare-Earth Peak (REP), a distinct but small peak at mass number $A \sim 160$ that arises from the freeze-out during the final stages of neutron exposure. According to theoretical models and sensitivity studies, half-lives $(T_{1/2})$ and β-delayed neutron emission probabilities (P_{xn}) of neutron-rich nuclei, in the mass region $A \sim 160$ for 55≤Z≤64 are critical for the formation of the REP [1,2]. The BRIKEN collaboration [3] conducted an extensive measurement program of β-decay properties of nuclei involved in the r-process at the Radioactive Isotope Beam Factory (RIBF) located in the RIKEN Nishina Center, Japan. The BRIKEN-REP experiment has measured $T_{1/2}$ and P_{1n} of nuclei from Ba to Eu (A $\sim$ 160), belonging to the region that is the most influential to the REP formation [4,5]. In this contribution, we will present the experimental results of new $T_{1/2}$ and P_{1n} branchings within the Ba to Nd region. Furthermore, we will discuss how these new experimental data trends match with the trends from recent nuclear model calculations used for r-process simulations of the REP.

[1] M. R. Mumpower et al , Phys. Rev. C 85, 045801 (2012).
[2] A. Arcones and G. Martinez Pinedo , Phys. Rev. C 83, 045809 (2011).
[3] J.L. Tain et. al , Acta physica polonica B 49(03), 417 - 428 (2018).
[4] G. G. Kiss, et al., The Astrophysical Journal 936 2, 107 (2022).
[5] A. Tarifeño-Saldivia et al , RIKEN Accel. Prog. Rep. 54, 27. (2021).

Acknowledgements:
This work has been supported by the Spanish Ministerio de Economía y Competitividad under Grants nos. FPA2014-52823-C2-1-P, FPA2014-52823-C2-2-P, FPA2017-83946-C2-1-P, FPA2017-83946-C2-2-P and grants from Ministerio de Ciencia e Innovacion nos PID2019-104714GB-C21 and PID2019-104714GB-C22.

Primary authors: Dr TARIFEÑO SALDIVIA, Ariel (Instituto de Física Corpuscular); PALLÀS SOLÍS, Max (Universitat Politècnica de Catalunya)

Co-authors: Dr ALGORA, A. (Instituto de Física Corpuscular); Dr ESTRADE, A. (Central Michigan University); Dr MORALES, A. I. (Instituto de Física Corpuscular); Dr KORGUL, A. (Faculty of Physics, University of Warsaw); Dr NAVARRO, A. (Universitat Politècnica de Catalunya); Dr TOLOSA DELGADO, Alvaro (CERN); Mr VITÉZ SVEICZER, Andras (Institute for Nuclear Research (ATOMKI)); Dr RASCO, B. C. (Department of Physics and Astronomy, University of Tennessee); Dr RUBIO, B. (Instituto de Física Corpuscular); Dr DOMINGO PARDO, C. (Instituto de Física Corpuscular); Dr GRIFFIN, C. J. (TRIUMF); Dr KAHL, D. (School of Physics and Astronomy, The University of Edinburgh); Dr NACHER, E. (Instituto de Física Corpuscular); Dr MOLINA, F. (Centro de Investigación en Física Nuclear y Espectroscopía de Neutrones (CEFNEN)); Dr CALVIÑO, Francisco (Universitat Politècnica de Catalunya); Dr CORTES, G. (Universitat Politècnica de Catalunya); KISS, Gabor (RIKEN Nishina Center); Dr BABA, H. (RIKEN Nishima Center); Dr SAKURAI, H. (RIKEN Nishima Center); Dr SUZUKI, H. (RIKEN Nishima

Center); Dr TAKEDA, H. (RIKEN Nishima Center); Dr DILLMANN, I. (TRIUMF); Dr AGRAMUNT, J. (Instituto de Física Corpuscular); Dr LIU, J. (Department of Physics, University of Hong Kong); Dr ALLMOND, J. M. (Physics Division, Oak Ridge National Laboratory); Dr ROMERO BARRIENTOS, J. (Centro de Investigación en Física Nuclear y Espectroscopía de Neutrones (CEFNEN)); Dr TAIN, Jose Luis (Instituto de Física Corpuscular); Dr MIERNIK, K. (Faculty of Physics, University of Warsaw); Dr RYKACZEWSKI, K. P. (Physics Division, Oak Ridge National Laboratory); Dr WANG, K. (Central Michigan University); Dr HARKNESS BRENNAN, L. J. (Department of Physics, University of Liverpool); Dr LABICHE, M. (STFC Daresbury Laboratory); Dr MADURGA, M. (Department of Physics and Astronomy, University of Tennessee); Dr PIERSA SILKOWSKA, M. (Faculty of Physics, University of Warsaw); Dr SINGH, M. (Department of Physics and Astronomy, University of Tennessee); Dr WOLIŃSKA CICHOCKA, M. (Heavy Ion Laboratory, University of Warsaw); Dr FUKUDA, N. (RIKEN Nishima Center); Mr MONT GELI, N. (Universitat Politècnica de Catalunya); Dr NEPAL, N. (RIKEN Nishima Center); Dr BREWER, N. T. (Department of Physics and Astronomy, University of Tennessee); Dr HALL, O. (School of Physics and Astronomy, The University of Edinburgh); Dr AGUILERA, P. (Centro de Investigación en Física Nuclear y Espectroscopía de Neutrones (CEFNEN)); Dr COLEMAN-SMITH, P. J. (STFC Daresbury Laboratory); Dr WOODS, P. J. (School of Physics and Astronomy, The University of Edinburgh); Dr CABALLERO-FOLCH, R. (TRIUMF); Dr GRZYWACZ, R. K. (Department of Physics and Astronomy, University of Tennessee); Dr YOKOYAMA, R. (Center for Nuclear Study, The University of Tokyo); GO, S. (RIKEN Nishima Center); Dr KOVÁCS, S. (University of Debrecen); Dr KUBONO, S. (RIKEN Nishima Center); Dr NISHIMURA, S. (RIKEN Nishima Center); Dr DAVINSON, T. (School of Physics and Astronomy, The University of Edinburgh); Dr ISOBE, T. (RIKEN Nishima Center); Dr SZEGEDI, T. N. (Institute for Nuclear Research (ATOMKI)); Dr SUMIKAMA, T. (RIKEN Nishima Center); Dr KING, T. T. (Department of Physics and Astronomy, University of Tennessee); Dr PHONG, V. (RIKEN Nishima Center); Dr SAITO, Y. (TRIUMF); Dr SHIMIZU, Y. (RIKEN Nishima Center)

Presenter: PALLÀS SOLÍS, Max (Universitat Politècnica de Catalunya)

Session Classification: Nuclear properties for astrophysics

Track Classification: Nuclear properties for astrophysics

Astrophysical Reactions Important in r- and vp-processes Measured Using (d,p) Transfer Reactions at OEDO-SHARAQ

Thursday, 21 September 2023 16:45 (15 minutes)

The rapid (*r*) neutron-capture process produces half of the elements heavier than iron and is located on the neutron-rich side of the nuclear chart. Conversely, light nuclei on the neutron-deficient side may be produced in the neutrino-driven rapid-proton capture (*νp*) process. Considering the *r*-process, promising site candidates such as core-collapse supernovae (CCSNe) and neutron star mergers still show large discrepancies between observed and calculated abundances. The calculations rely on neutron-capture cross sections which depend on two reaction processes: direct radiative capture and compound nuclear (CN) mechanism. Neutron capture on ^{130}Sn strongly influences the final abundances around the second and third *r*-process peaks, however, the CN mechanism lacks empirical data. Considering the *νp*-process proposed to occur in the ejecta of CCSNe, this is a promising solution to synthesize isotopes not adequately produced in the rapid-proton (*rp*) capture process, particularly ^{92,94}Mo and ^{94,96}Ru. The ^{56}Ni(n,p)^{56}Co reaction is a crucial branching point between the *νp*- and *rp*- processes and thus governs the abundances of heavier elements, however, its cross section lacks measurement. To address these knowledge gaps of the ^{130}Sn(n,γ) and ^{56}Ni(n,p) reactions, the surrogate technique was employed using (d,p) transfer reactions on ^{130}Sn and ^{56}Ni, respectively, at the BigRIPS-OEDO beamline housed at RIBF in RIKEN, Japan. The radioactive beams were produced and separated by the BigRIPS accelerator. Using OEDO the ^{130}Sn (^{56}Ni) beam was decelerated to ~ 22 (15) MeV/u and focused onto a CD_2 solid target. Light particles were detected at backward lab angles using the TiNA array. Heavy reaction products were momentum-analyzed by the SHARAQ spectrometer and identified using the Bρ-dE-range technique. This approach has a distinct advantage whereby the gamma-emission probabilities of compound nuclear states may be determined with no gamma-ray detection necessary. In this talk, the experimental procedure and preliminary results are presented, with an emphasis on the capabilities of OEDO.

Primary author: CHILLERY, Thomas

Presenter: CHILLERY, Thomas

Session Classification: Nuclear properties for astrophysics

Track Classification: Nuclear properties for astrophysics

Bound-state beta-decay of Thallium-205 to constrain s-process predictions for the early Solar System

Thursday, 21 September 2023 17:00 (15 minutes)

Bound-state β-decay (β_b^--decay) is a radically transformative decay mode that can change the stability of a nucleus and generate temperature- and density-dependent decay rates. In this decay mode the β-electron is created directly in a bound atomic orbital of the daughter nucleus instead of being emitted into the continuum, so the decay channel is only significant in almost fully stripped ions during extreme astrophysical conditions. The β_b^--decay of $^{205}Tl^{81+}$ could influence our understanding of the production of ^{205}Pb, a short-lived radioactive (SLR, 17.3 Myr) nucleus that is fully produced by the s-process in stars. In the context of the early Solar system, SLRs are defined by half-lives of 0.1-100 My and their abundance in meteorites can be used to constrain the formation of the Solar System [1]. Historically, it has been noted that thermal population of the 2.3 keV state of ^{205}Pb in stellar conditions could dramatically reduce the abundance of s-process ^{205}Pb by speeding up the EC-decay to ^{205}Tl. This destruction of ^{205}Pb is potentially balanced by the β_b^--decay of $^{205}Tl^{81+}$ [2]. Currently, a theoretical prediction for the half-life of fully stripped ^{205}Tl is used in stellar models, but given the importance of the $^{205}Pb/^{204}Pb$ chronometer, a measurement of the β_b^--decay for $^{205}Tl^{81+}$ was conducted at the GSI Heavy Ion Facility in March 2020. A $^{205}Tl^{81+}$ beam was stored in the Experimental Storage Ring, and the growth of $^{205}Pb^{81+}$ daughters with storage time was directly attributable to the β_b^--decay channel. We will report the measured half-life and detail how this half-life can be used to more accurately predict the ^{205}Pb abundance in the early Solar System.

[1] M. Lugaro, et al. Progress in Particle and Nuclear Physics, 102:1–47, 2018.
[2] K. Yokoi, et al. Astronomy and Astrophysics, 145:339–346, 1985.

Primary author: LECKENBY, Guy (TRIUMF)

Co-authors: Mr SZÁNYI, Balázs (University of Szeged); Prof. MEYER, Bradley (Clemson University); Dr GRIFFIN, Chris (TRIUMF); Dr VESCOVI, Diego (Goethe University Frankfurt); Prof. MARTÍNEZ-PINDEO, Gabriel (GSI Helmholtz Centre); Dr WEICK, Helmut (GSI Helmholtz Centre); Dr DILLMANN, Iris (TRIUMF); Dr GLORIUS, Jan (GSI Helmholtz Centre); Prof. TAKAHASHI, Kohji (GSI Helmholtz Centre); Dr PIGNATARI, Marco (Konkoly Observatory); Dr LUGARO, Maria (Konkoly Observatory); Dr SIDHU, Ragandeep Singh (University of Edinburgh); Dr MANCINO, Riccardo (GSI Helmholtz Centre); Dr CHEN, Rui Jiu (GSI Helmholtz Centre); Dr CRISTALLO, Sergio (INAF); Dr SANJARI, Shahab (GSI Helmholtz Centre); Ms KAUR, Tejpreet (Punjab University); Dr FAESTERMANN, Thomas (Technische Universität München); Dr NEFF, Thomas (GSI Helmholtz Centre); Dr BATTINO, Umberto (University of Hull); Prof. LITVINOV, Yuri (GSI Helmholtz Centre)

Presenter: LECKENBY, Guy (TRIUMF)

Session Classification: Nuclear properties for astrophysics

Track Classification: Nuclear properties for astrophysics

Probing heavy element nucleosynthesis through electromagnetic observations

Friday, 22 September 2023 09:00 (30 minutes)

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.

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

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

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Molecule formation in the ejecta of SN 1987A: the impact of effective matter mixing based on 3D hydrodynamical models

Friday, 22 September 2023 09:30 (15 minutes)

More than 30 years after the discovery of SN 1987A, it entered a phase of a young supernova remnant. It is considered that molecules and dust are formed in the ejecta. Actually, recent ALMA observations (Abellán et al. 2017) have revealed that the 3D distribution of carbon monoxide (CO) and silicon monoxide (SiO) is rather non-spherical and lumpy. However, how molecules are formed in core-collapse supernovae has still been unclear. The distribution of seed atoms in the ejecta of SN 1987A, which is affected by matter mixing before the molecule formation, may play a role in the formation of molecules. Therefore, in order to investigate the impact of matter mixing on the formation of molecules in the ejecta of SN 1987A, time-dependent rate equations for chemical reactions are solved (arXiv:2305.02550) for one-zone and one-dimensional ejecta models of SN 1987A based on three-dimensional hydrodynamical models (Ono et al. 2020). It is found that the mixing of ^{56}Ni could play a non-negligible role in both the formation and destruction of molecules, in particular CO and SiO, through several reaction sequences. Some of the results and how ^{56}Ni, practically ^{56}Co, affects the formation and destruction of molecules are presented.

Primary author: ONO, Masaomi (Institute of Astronomy and Astrophysics, Academia Sinica (ASIAA), Taiwan)

Co-authors: Dr NOZAWA, Takaya (National Astronomical Observatory of Japan (NAOJ)); Dr NAGATAKI, Shigehiro (RIKEN, Japan); Dr KOZYREVA, Alexandra (Heidelberger Institut für Theoretische Studien, Germany); Dr ORLANDO, Salvatore (INAF-Osservatorio Astronomico di Palermo, Italy); Dr MICELI, Marco (Università degli Studi di Palermo, Italy); Dr CHEN, Ke-Jung (Institute of Astronomy and Astrophysics, Academia Sinica (ASIAA), Taiwan)

Presenter: ONO, Masaomi (Institute of Astronomy and Astrophysics, Academia Sinica (ASIAA), Taiwan)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Neutrino-Driven Outflows and the Origin of Light Heavy Elements

Friday, 22 September 2023 09:45 (15 minutes)

The light heavy elements between strontium and silver, can be synthesized in a primary process in either neutron- (weak r-process) or proton-rich (νp-process) neutrino-driven outflows of explosive environments [1]. Constraining the nuclear physics uncertainties, for example the (α,xn) reaction rates in the weak r-process [2,3], allows us to investigate the conditions that create the light heavy elements, by comparing to the abundances of Galactic metal-poor stars. In addition, the study of presolar stardust grains (SiC) can also reveal signatures of neutrino-driven nucleosynthesis in the Galaxy [4]. We have used an extensive library of astrophysical conditions of both neutron- and proton-rich neutrino-driven outflows, as well as combinations of the two to reproduce the abundance patterns observed in metal poor stars with enhanced light neutron-capture element production, such as HD 122563 (Honda star)[5]. Our preliminary results suggest that there are specific combinations of astrophysical conditions that can reproduce the light heavy elemental abundances observed in such stars.

*This work was supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)—Project No. 279384907—SFB 1245, the European Research Council Grant No. 677912 EUROPIUM, and the State of Hesse within the Research Cluster ELEMENTS (Project ID 500/10.006)

References

[1] A. Arcones and F. Montes, Astrophys. J. **731**, 5 (2011)
[2] J. Bliss *et al.*, Phys. Rev. C **101**, 055807 (2020)
[3] A. Psaltis *et al.*, Astrophys. J. **935**, 27 (2022)
[4] A. Psaltis *et al.* (in preparation).
[5] S. Honda *et al.*, Astrophys. J. **666**, 1189 (2007)

Primary author: PSALTIS, Thanassis (NCSU/TUNL)

Co-authors: ARCONES, Almudena (TU Darmstadt/GSI); HANSEN, Camilla (Goethe University Frankfurt); MONTES, Fernando (FRIB); SCHATZ, Hendrik (FRIB/MSU); JACOBI, Maximilian (TU Darmstadt); AVILA, Melina L (Argonne National Laboratory, Argonne, IL, USA); MOHR, Peter (ATOMKI); ONG, Wei Jia (LLNL)

Presenter: PSALTIS, Thanassis (NCSU/TUNL)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

The p-process nucleosynthesis in core-collapse supernovae

Friday, 22 September 2023 10:00 (15 minutes)

Neutron-capture processes made most of the abundances of heavy elements in the Solar System, however they cannot produce a number of rare proton-rich stable isotopes lying on the left side of the valley of stability. The p-process, or γ-process, is recognised and generally accepted as a feasible process for the synthesis of proton-rich nuclei in core collapse supernovae. However this scenario still leaves some puzzling discrepancies between theory and observations.
My aim is to explore in more detail the p-process production from massive stars in different sets of models and using the latest nuclear reaction rates. Here I will show some of the result of my analysis, by identifying the p-process sites and focusing on supernova progenitors that experience a C-O shell merger just before the collapse of the Fe core. I will also briefly discuss how the p-process depends on the supernova explosion energy.

Primary author: ROBERTI, Lorenzo (Konkoly Observatory, CSFK)

Co-authors: Dr PIGNATARI, Marco (Konkoly Observatory, CSFK); Dr LUGARO, Maria (Konkoly Observatory, CSFK)

Presenter: ROBERTI, Lorenzo (Konkoly Observatory, CSFK)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

The neutrino-process in core-collapse supernova with strong magnetic field

Friday, 22 September 2023 10:15 (15 minutes)

A huge number of neutrinos emitted in a supernova explosion interact with a dense plasma. The interaction between neutrinos and electrons remarkably changes the neutrino oscillation probability at the specific electron density, known as the Mikheyev–Smirnov–Wolfenstein (MSW) resonance effect. Previous studies for the neutrino-process in core-collapsing supernova have well-established the effects of neutrino interactions with electrons and neutrino itself on the neutrino process. However, observations on magnetar surfaces imply that a strong magnetic field might exist in supernova environments. It turns out that such a strong or stronger magnetic field can polarize the electrons, whose effective potential, including axial-vector interaction, changes the MSW effect region or the effect of neutrino-neutrino interaction on neutrino oscillation. In this presentation, we show the effects of the strong magnetic field on neutrino oscillation, adopting a power law of electron number density and dipole magnetic field profiles. Also, we discuss those effects through the abundance of ^{92}Nb, ^{98}Tc, and ^{138}La with the SN1987A model.

Primary author: KO, Heamin (Soongsil University)

Co-authors: JANG, Dukjae (IBS); KUSAKABE, Motohiko (Beihang University); CHEOUN, Myung-Ki (Soongsil University)

Presenter: KO, Heamin (Soongsil University)

Session Classification: Core-collapse supernovae, mergers and the r-process

Track Classification: Core-collapse supernovae, mergers and the r-process

Galactic archaeology with metal-poor stars

Friday, 22 September 2023 11:00 (30 minutes)

TBD

Primary author: LI, Haining (National Astronomical Observatories, Chinese Academy of Sciences)

Co-authors: Prof. ZHAO, Gang (National Astronomical Observatories, CAS); XING, Qianfan (NAOC); MATSUNO, Tadafumi (Univ. of Groningen); AOKI, Wako (National Astronomical Observatory of Japan)

Presenter: LI, Haining (National Astronomical Observatories, Chinese Academy of Sciences)

Session Classification: The early Universe, galactic evolution

Track Classification: Galactic evolution

The role of Majorons on big bang nucleosynthesis

Friday, 22 September 2023 11:30 (15 minutes)

The Majoron, the Goldstone boson from the spontaneous lepton number symmetry breaking, is a theoretically and phenomenologically well-motivated hypothetical particle. As it is typically believed to be long-lived, it has the potential power of altering the big bang nucleosynthesis.
We find that non-thermal energetic neutrinos produced by decays of Majoron can cause various neutrino-induced nuclear reactions, providing additional neutrons from the inverse beta decay. It is of great interest to see whether such reactions can boost the reactions such as 7Be(n,p)7Li and 7Li(p,\alpha)4He processes, resolving the long-standing discrepancy between the observed abundance and the theoretical prediction of 7Li. Stating differently, the big bang nucleosynthesis can constrain the values of the parameters of the Majoron. These questions are addressed in our work by studying the effect of the Majoron on the big bang nucleosynthesis.

Primary authors: SHIN, Chang Sub (Chungnam National University); CHANG, Sanghyeon (Particle Theory and Cosmology Group (PTC), Center for Theoretical Physics for University (CTPU), IBS); GANGULY, Sougata (Chungnam National University); JUNG, Tae Hyun (Particle Theory and Cosmology Group (PTC), Center for Theoretical Physics for University (CTPU), IBS); PARK, Tae-Sun (CENS, IBS)

Presenter: PARK, Tae-Sun (CENS, IBS)

Session Classification: The early Universe, galactic evolution

Track Classification: The early Universe

High-precision nuclear chronometer for the cosmos

Friday, 22 September 2023 11:45 (15 minutes)

Nuclear chronometer provides an independent dating technique for the cosmos by predicting the ages of the oldest stars. Similar to geochronology, the ages are determined by comparing the present and initial abundances of long-lived radioactive nuclides. In nuclear cosmochronology, the present abundances can be obtained from the astrophysical observations whereas the initial abundances have to be determined by simulations of rapid neutron capture (r-process) nucleosynthesis. However, the previous Th/X, U/X, and Th/U chronometers suffer from the uncertainties of the r-process simulations, which leads to a poor identification on the cosmic age. Here we show that the precision of the nuclear chronometer can be significantly improved by synchronizing the three different types of nuclear chronometers, as it imposes stringent constraints on the astrophysical conditions in the r-process simulation. The new chronometer (Th-U-X) reduces the uncertainties of the predicted ages from the astrophysical conditions, more than ±2 billion years for the Th/U chronometer, to within 0.3 billion years. By the Th-U-X chronometer, ages of the six metal-poor stars with observed uranium abundances are estimated to be varying from 11 to 17 billion years, two of which disfavor the young cosmic age of 11.4 billion years by a recent measurement of Hubble constant from angular diameter distances to two gravitational lenses. Our results demonstrate that the Th-U-X chronometer provides a high-precision dating technique for the cosmic age. For perspective, the Th-U-X chronometer can serve as a standard technique in nuclear cosmochronology. It will be even more appealing in case that the r-process site is identified whereas the corresponding detailed conditions remain unknown, as it can filter out unreasonable conditions by synchronizing nuclear chronometers.

Primary authors: WU, Xinhui (Peking University); Prof. MENG, Jie (Peking University); Prof. ZHAO, Pengwei (Peking University); Prof. ZHANG, Shuangquan (Peking University)

Presenter: WU, Xinhui (Peking University)

Session Classification: The early Universe, galactic evolution

Track Classification: Galactic evolution

Constraining the key reaction rates using indirect methods

Friday, 22 September 2023 13:30 (30 minutes)

Indirect methods play an important role in constraining the astrophysical rates of nuclear reactions. This talk will review several recent indirect studies that provided almost model-independent constraints for the key rates.
Neutron-upscattering enhancement of the triple-alpha reaction responsible for the production of carbon, suggested in [1], was investigated by measuring a time-inverse process, 12C(n,n')12C(Hoyle), using the Texas Active Target Time Projection Chamber [2]. The total cross section for inelastic neutron scattering in carbon was measured in a wide range of energies, and the detailed balance and R-matrix analysis was used to establish the 12C(Hoyle)(n,n')12C reactions cross section at astrophysically relevant energies [3].
The radiative width of the Hoyle state has a direct impact on the triple-alpha reaction rate. Recent measurements by Kibedi [4] reported a radiative width significantly above the previously recommended value [5]. I will report the results of the new study performed at the Cyclotron Institute, Texas A&M University, which provides a definitive resolution to the controversy.
The α-cluster properties of the ground state of 16O (the alpha asymptotic normalization coefficient, ANC) influence the low energy extrapolation for the key 12C(α,γ)16O reaction rate [6]. The new measurements at Texas A&M University used 12C(20Ne,16O)16O alpha-transfer reaction at sub-Coulomb energy to provide nearly model-independent constraints to the respective ANC values.

[1] M. Beard, S.M. Austin, R. Cyburt, Phys. Rev. Lett., 119, 112701 (2017).
[2] E. Koshchiy, et al., Nucl. Inst. Meth. Phys. Res. A, 957, 163398 (2020).
[3] J. Bishop, et al., Nature Communications, 13, 2151 (2022).
[4] T. Kibedi, et al., Phys. Rev. Lett., 125, 182701 (2020).
[5] M. Freer and H. Fynbo, Prog. Part. Nucl. Phys., 78, 1 (2014).
[6] R.J. deBoer, et al., Rev. Mod. Phys., 89, 035007 (2017).

Primary author: Prof. ROGACHEV, G.V. (Department of Physics and Astronomy, Texas A&M University)

Presenter: Prof. ROGACHEV, G.V. (Department of Physics and Astronomy, Texas A&M University)

Session Classification: Nuclear properties for astrophysics

Track Classification: Nuclear properties for astrophysics

Novel Studies of Nucleosynthesis in the Lab

Friday, 22 September 2023 14:00 (30 minutes)

A variety of nucleosynthesis processes operate in our universe, producing elements across the nuclear chart. Using a range of tools and techniques, we can probe the nuclear reactions that comprise these processes. In explosive rp-process environments, direct reactions are possible using gaseous targets such as JENSA, with input from indirect techniques such as transfer reactions on both stable and radioactive isotopes. The role of long-lived isomeric states in rp-process nuclei, just as in 26Al, is beginning to be studied experimentally using beams of mixed ground state and isomer content, with indirect studies underway to populate the nuclear levels of interest, and direct measurements with SECAR planned. In supernovae, the mechanisms producing the rare p-process nuclei are being studied using monoenergetic gamma beams at the HIgS facility at TUNL. In this talk, I will provide a brief survey of these different experimental campaigns, and discuss the preliminary results and future directions.

Primary author: CHIPPS, Kelly (Oak Ridge National Laboratory)

Presenter: CHIPPS, Kelly (Oak Ridge National Laboratory)

Session Classification: Nuclear properties for astrophysics

Track Classification: Nuclear properties for astrophysics

Impact of the Hoyle state in 12C on hypernova neutrino-p process and Galactic chemical evolution

Friday, 22 September 2023 14:30 (15 minutes)

The hadronic deexcitation of the Hoyle state in 12C induced by inelastic scatterings of particles can enhance the triple-alpha reaction and the resultant accumulated seed nuclei prevent the synthesis of the heavier elements [1]. Quite recently, neutron-induced deexcitation cross sections were measured experimentally and this effect turns out to be less significant [2]. It therefore is even more interest to explore if the protons or alpha-particles could make a significant effect on the explosive nucleosynthesis in proton-rich environment. We study the impact of such particle-induced Hoyle state deexcitation on the νp-process nucleosynthesis in proton-rich ν-driven winds of core-collapse supernovae (CCSNe). We find that the productions of p-nuclei such as 92,94Mo and 96,98Ru are suppressed due to the effect of Hoyle state deexcitation in the wind models of ordinary CCSNe. On the other hand, we find also that these isotopic abundances are enhanced in explosive nucleosynthesis in an energetic hypernova (HN) wind models [3]. We then apply our new HN nucleosynthesis results to the Galactic chemical evolution of 92,94Mo and 96,98Ru, resulting in an interesting fact that the HN νp-process can enhance the calculated solar isotopic fractions of these p-nuclei, whose isotopic fractions are 1-2 orders of magnitude larger than the ordinary p-nuclei, regardless of the particle-induced Hoyle state deexcitation [3].

[1] S. Jin, L. F. Roberts, S. M. Austin & H. Schatz, Nature 588 (2020), 57.
[2] J. Bishop, C. E. Parker, G. V. Rogachev, et al., Nature Comm. 13 (2022), 2151.
[3] H. Sasaki, Y. Yamazaki, T. Kajino & G. J. Mathews, (2023) submitted.

Primary author: KAJINO, Taka (Beihang University/NAOJ/University of Tokyo)

Co-authors: Prof. MATHEWS, Grant (University of Notre Dame); Dr SASAKI, Hirokazu (Los Alamos National Laboratory); Dr YAMAZAKI, Yuta (University of Tokyo)

Presenter: KAJINO, Taka (Beihang University/NAOJ/University of Tokyo)

Session Classification: Nuclear properties for astrophysics

Track Classification: Galactic evolution

Study of two missing states of ^{19}Ne affecting the ^{18}F(p, α)^{15}O reaction rate in classical novae

Friday, 22 September 2023 14:45 (15 minutes)

Knowledge of the ^{19}Ne resonance information near the proton threshold (E_x=6.410 MeV) is important for studying the ^{18}F(p,α)^{15}O nuclear reaction rate in a classical nova [1-4]. Several states in the vicinity of the proton threshold still have not been observed in ^{19}Ne but were predicted by assuming isospin symmetry from its mirror state in ^{19}F [5,6]. The α-elastic scattering experiment in a Thick Target Inverse Kinematics method (TTIK) was performed at RIKEN using the CNS RI Beam separator (CRIB) with a ^{15}O radioactive beam for investigating the ^{19}Ne level structure [7,8]. Two missing states were identified near the proton threshold, and one of the missing states affects the ^{18}F(p,α)^{15}O reaction rate. Additionally, the candidates of rotational bands for the alpha cluster structure were measured. Experimental details and results will be discussed in the presentation.

[1] J. Jose et al., Eur. Phys. J. A 27, 107 (2006).
[2] A. Coc et al., Astron. and Astrophys. 357, 561 (2000).
[3] K. Chae et al., Phys. Rev. C 74, 012801 (2006).
[4] D. Kahl et al., Astron. and Astrophys. 653. A64 (2021).
[5] N. C. Shu et al., Phys. Rev. C 58, 1354 (1998).
[6] C. D. Nesaraja et al., Phys. Rev. C 75, 055809 (2007).
[7] Y. Yanagisawa et al., Nucl. Instrum. Methods Phys. Res. A 539, 74 (2005).
[8] H. Yamaguchi et al., Nucl. Instrum. Methods Phys. Res. A. 589, 150 (2008).

Primary authors: KIM, D. (Center for exotic nuclear studies, Institute Basic Science); HAHN, K. I. (Center for Exotic Nuclear Studies, IBS)

Co-authors: Prof. CHEN, A. A. (Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada); KIM, A. (Korea University); KAHL, D. (Extreme Light Infrastructure –Nuclear Physics, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering(IFIN-HH)); Ms LEE, E. J. (Department of Physics, SungKyunKwan University); Ms LEE, E. K. (Center for Underground Physics (CUP), Institute for Basic Science (IBS)); KIM, G. W. (Center for Underground Physic, IBS / Ewha Womans University); YAMAGUCHI, H. (Center for Nuclear Study, the University of Tokyo); Mr LEE, J. H. (Department of Physics, SungKyunKwan University); Dr MOON, J. Y. (Institute for basic science); ABE, K.; CHAE, K. Y. (Sungkyunkwan University); GWAK, M. S. (RISP, IBS); Dr IMAI, N. (Center for Nuclear Studies, University of Tokyo, Tokyo, Japan); Prof. IWASA, N. (Department of Physics, University of Tohoku); Mr KITAMURA, N. (Center for Nuclear Studies, University of Tokyo, Tokyo, Japan); Ms BELIUSKINA, O. (Center for Nuclear Study, University of Tokyo); Dr BAE, S. H. (Center for Exotic Nuclear Studies, Institue for Basic Science); Prof. CHOI, S. H. (Seoul National University); HAYAKAWA, S. (Center for Nulear Study, University of Tokyo); Dr KUBONO, S. (RIKEN Nishina Center); CHA, S. M. (Center for Exotic Nuclear Studies); Dr HONG, S. W. (Heavy-Ion Accelerator Research Institute, Institute for Basic Science); Dr PARK, S. Y. (Center for Underground Physics (CUP), Institute for Basic Science (IBS)); Dr PANIN, V. (RIKEN, Nishina Center); Mr SAKAGUCHI, Y. (Center for Nuclear Study, University of Tokyo); Dr WAKABAYASHI, Y. (RIKEN, Nishina Center)

Presenter: KIM, D. (Center for exotic nuclear studies, Institute Basic Science)

Session Classification: Nuclear properties for astrophysics

Track Classification: Novae and X-ray bursts

Nuclear Physics of Accreting Neutron Stars

Friday, 22 September 2023 15:00 (20 minutes)

I will review the current understanding of the nuclear physics of accreting neutron stars, including the rp-process and processes involving neutron rich nuclei, and their relation to observables such as X-ray bursts and the cooling of transiently accreting neutron stars. This will include new results from experiments on rp-process reactions and measurements related to crust Urca processes, modeling results using updated reaction libraries, nuclear physics sensitivity studies, and an overview of the new opportunities opened up by new radioactive beam facilities such as FRIB.

Primary author: SCHATZ, Hendrik (Michigan State University)

Presenter: JAIN, Rahul

Session Classification: Nuclear properties for astrophysics

Track Classification: Novae and X-ray bursts