Book of Abstract for:

The 16th International Symposium on Origin of Matter and Evolution of Galaxies

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Contents

1. Observational studies of r- and s-process elements for Milky Way stars

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Session: Wednesday - Session 4: Astronomical Observations with Light, X-Ray, Gamma-Ray, and Cosmic-Ray

Elements heavier than iron-group are produced by rapid and slow neutron-capture processes (r-process and s-process) in the universe. The site of the processes and history of the enrichment in the Milky Way Galaxy have been studied by spectroscopic observations of stars with different ages and population (Galactic disks, halo etc.). I will review the abundance studies of neutron-capture elements for Milky Way stars, including our long-term observational efforts using the Chinese survey telescope LAMOST and the Japanese large telescope Subaru. I will cover the observational results on the abundance distributions of heavy elements (Sr, Ba and Eu), and elemental abundance patterns of r- and s-process enhanced stars.

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2. Nonlinear evolution of fast collective neutrino oscillations in core-collapse supernovae

Milad Delfan Azari[1], Hirokazu Sasaki[2], Tomoya Takiwaki[3], Hirotada Okawa[1], Shoichi Yamada[1]

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Session: Thursday - Session 3: Explosive Stellar Objects and Nuclear Physics - Supernovae

Speaker: Milad Delfan Azari

In one of the most promising supernova theories, neutrino-heating mechanism, neutrinos carry the majority of the energy released during the gravitational collapse of massive stars. If neutrino flavors are converted fast in the cores, by depositing energy, they can rejuvenate stalled bounce shocks and provide the energy for supernova explosions. In this talk, I will present the results of our investigations on the dynamics of fast neutrino flavor conversions with collisions under energy-dependent treatment in detail, based on the results of self-consistent, realistic Boltzmann simulations of core-collapse supernovae in two spatial dimensions under axisymmetry.

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3. Development of the segmented plastic scintillation detector GARi for studying r-process nucleosynthesis at RIBF

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Session: Poster session - II

Speaker: Hue Bui

The β-decay properties of very neutron-rich nuclei, such as half-lives and β-delayed neutron emission probabilities, play an essential role in the astrophysical rapid neutron capture process (r-process), where the elements heavier than iron may be synthesized [1,2]. The investigation of those crucial properties has been one of the main objectives of the experimental programs at the RIKEN RI Beam Factory (RIBF) [3,4]. Recently, the development of a fast-timing detector system comprising a highly-segmented plastic scintillation detector GARi (Gas-cell Active detector for Radioisotope decay), a neutron time-of-flight detector array and a $LaBr_3$ detector array is being conducted for the measurement of β-delayed neutron emission and other related β-decay properties of neutron-rich nuclei at the F11 decay station of RIBF. The GARi detector has been constructed from a fast, segmented plastic scintillator coupled with nine multi-anode photomultiplier tubes (PMTs), resulting in enhanced position sensitivity. Therefore, this detector can be employed as an implantation detector and also served for providing a trigger signal in neutron time-of-flight experiments. This poster details the development of the GARi detector and the results tested with the radioactive sources.

[1] E.M. Burbidge et al., Rev. Mod. Phys. 29, 547 (1957).

[2] T. Kajino et al., Prog. Part. Nucl. Phys. 107 (2019) 109-166

[3] S. Nishimura, Prog. Theor. Exp. Phys. 2012, 03C006 (2012)

[4] I. Dillmann and A. Tarifeño-Saldivia. Nuclear Physics News 28-3, (2018)

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4. Experimental study of resonances in 22Mg through the 18Ne(α,α)18Ne measurement

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Session: Thursday - Session 4: Explosive Stellar Objects and Nuclear Physics: Explosive Hydrogen Burning II

Speaker: Soomi Cha

The 18Ne(α,p)21Na 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 compound nucleus 22Mg by measuring the 18Ne(α,α)18Ne resonant scattering in inverse kinematics. The 18Ne 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, and recoiling particles were measured by silicon detector telescopes. The excitation function of 18Ne+ α (scattering) was obtained for the excitation enregy region of 22Mg in Ex = 11 − 16 MeV by adopting a thick target method. In order to investigate the energy level properties of 22Mg, the experimental excitation function was compared with theoretical R-matrix analysis using the SAMMY8 code. The cross section was evaluated in the astrophysically-important energy range, and the 18Ne(α,p)21Na reaction rate was estimated based on a possible strong resonance at Ex = 10.890 MeV.

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5. Light Element Abundances Constrain Primordial Black Holes in the Critical Collapse Model

Chao Chen[1], Yudong Luo[2], Motohiko Kusakabe[3], Toshitaka Kajino[3]

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Session: Tuesday - Session 3: First Generation Stars and Galactic Chemical Evolution II

Speaker: Chao Chen

We study the photodisintegration process triggered by the nonthermal electromagnetic Hawking radiation from primordial black holes (PBHs) in the critical collapse model. The presence of a low-mass tail of critical collapse mass function could enhance energetic photon emissions from Hawking radiation of PBHs. Nuclear photodisintegration rates are calculated with a nonthermal photon spectrum derived by solving the Boltzmann equation iteratively. With the newest observational limit on the 3He abundance in Galactic H II regions, the updated 3He constraints on PBH mass spectrum in the horizon mass range $10^{12} - -10^{13}$ g are derived. Our results show that 3He constraints on the critical mass function are about one order of magnitude severer than the monochromatic one, although the fraction of PBHs in the low-mass tail region is relatively small.

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6. Impact of Direct Urca Process on Heavy-Element Nucleosynthesis in X-ray Bursts

Akira Dohi[1], Nobuya Nishimura[2]
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Session: Poster session - II
Speaker: Akira Dohi
Note: Akira Dohi is going to join OMEG16 in person, but depending on the situation of infectious diseases, he may change online participation later.

Type-I X-ray bursts are rapidly brightening phenomena induced by unstable hydrogen/helium burning near the surface of accreting neutron stars (NSs). During X-ray bursts, heavy proton-rich nuclei maximally up to the mass number $A \sim 107$ are synthesized by a rapid-proton capture (rp) process, but how the nucleosynthesis proceeds depend on many model parameters such as the accretion rate, the composition of accreted matter, nuclear reaction rates, NS structure and temperature. This time, we focus on the internal temperature, which is dominated by the losses of neutrinos inside NSs. Among many neutrino cooling processes, we focus on the nucleonic direct Urca process, which significantly decreases the temperature inside NSs. In this study, we investigate the impacts of the direct Urca process on the final products of X-ray bursts based on our general relativistic evolutionary code.

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7. The study of the cosmogenic radiation effects on condensed matter and living organisms on the Earth using the EG-5 accelerator (JINR)

Aleksandr Doroshkevich[1], Tatuana Zelenyak[1], Anastasia Kruglyak[1], Yulia Aleksiayenak[1], Bozena Jasinska[2], Afag Madadzada[3,1], Maria Balasoui[4,1], Petre Badica[5], Marius Stef[6], Tran Van Phuc[7,8], Le Hong Khiem[7,8], Phan Luong Tuan[1,9], Ivan Ristić[10], Vesna Teofilović[10], Roman Balvanović[11,12,13], Anca Stanculescu[5], Diana Mardare[14], Carmen Mita[14], Dorin Luca[15], Vitaliy Ksenevich[16], Nurbol Appazov[17,18], Kurmambek Bakiruly[17,18]

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Session: Poster session - I

Speaker: Aleksandr Doroshkevich

The electrostatic accelerator (ESA) EG-5 occupies its unique niche as part of the complex of nuclear physics facilities of the FLNP JINR (Dubna, Russian Federation). The beams of high-energy particles (H+, He+, D+) produced using EG-5 have high energy stability (± 15 keV per 2 MeV), which makes it possible to conduct unique studies of the elemental composition of solids (meteorites), including deep profiling, conducting studies of nuclear reactions on fast neutrons (4.1-4.5 MeV). The energy of the accelerated particles is in the energy range of cosmic rays (from 10^5eV) which makes it possible to study the effects of cosmic rays on the properties of the Earth and astrophysical objects. The mechanisms of the effect of cosmic radiation on the evolution of living organisms of the Earth on the example of rice seeds are beginning in the group "EG-5 Installation" of the JINR [1]. A cross sections of the 25Mg(n,α)22Ne reaction it has been clarified compared with existing measurements (evaluations and talys-1.8 code calculations). According to the detailed balance principle, a new information about the 22Ne(α,n)25Mg reaction, which is one of the main neutron sources for the astrophysicals process was obtained [2]. The Al2O3 - ZrO2 - Y2O3 - ceramics, NbTi - alloys high-entropy alloys promising for the manufacture of thermonuclear reactor; unique studies of degradation of semiconductor heterojunctions of solar cells (SiO2/TiO2) under the action of cosmogenic radiation are conducted in JINR using the EG-5 accelerator.

Acknowledgments

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[1] A.I. Kruglyak, A.S. Doroshkevich, Yu. Aleksiayenak, N.O. Appazov, K.B. Bakiruly, M. Balasoui, M.N. Mirzayev, A.A. Nabiyev, E. Popov APPLICATION OF THE ACCELERATOR MASS SPECTROMETRY METHOD TO STUDY THE MECHANISMS OF RADIATION MUTAGENESIS OF RICE CROPS: THE CURRENT STATE OF THE ISSUE. // Condensed Matter Research at the IBR-2: Programme and Abstracts of the International Conference (Dubna, Apr. 25–29, 2022). — Dubna: JINR, 2022, Pp. 65-66.

[2] Yu. M. Gledenov, M. V. Sedysheva, G. Khuukhenkhuu, Huaiyong Bai, Haoyu Jiang, Yi Lu, Zengqi Cui, Jinxiang, Chen, and Guohui Zhang Measurement of the cross sections of the 25Mg (n, α)22Ne reaction in the 4-6 MeV region //Phys. Rev. C 98, 034605.

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8. Big-Bang Nucleosynthesis: Beyond the Lithium Problem?

Brian Fields[1]

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Session: Tuesday - Session 1: Big Bang Cosmology and Primordial Nucleosynthesis

We will summarize the status of big-bang nucleosynthesis (BBN), which describes the production of the lightest nuclides during the first three minutes of cosmic time. We will emphasize the transformational influence of cosmic microwave background (CMB) experiments culminating today with Planck, which pin down the cosmic baryon density to exquisite precision. Standard BBN combines this with the Standard Model of particle physics, and with nuclear cross section measurements. These allow BBN to make tight predictions for the primordial light element abundances, with the result that deuterium observations agree spectacularly with these predictions, and helium observations are in good agreement. This CMB/BBN concordance marks a great success of the hot big bang, and BBN and the CMB together now sharply probe cosmology, neutrino physics, and dark matter physics at times around 1 second. But this success is tempered by lithium observations (in metal-poor halo stars) that are significantly discrepant with BBN+CMB predictions. We will summarize possible resolutions to this "lithium problem," highlighting recent work that strengthens the case for a a solution involving stellar astrophysics, while solutions involving new physics are becoming ever more constrained. We conclude with an outlook for how future CMB, astronomical, and laboratory measurements can better probe new physics in the early Universe, and shed light on the solution to the lithium problem.

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9. Deep underground laboratory measurement of 13C(a,n)16O in the Gamow windows of the s- and i-processes

Bingshui Gao[1] for the JUNA collaboration, R.J. deBoer, M. Wiescher, M. Pignatari

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Session: Friday - Session 1: Stellar Evolutions and Hydrostatic Burning Processes & Underground Nuclear Astrophysics

Speaker: Bingshui Gao

The 13C(a,n)16O 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 Ec.m. = 0.24 MeV to 1.9 MeV using the accelerators at the China JinPing underground Laboratory (CJPL) and Sichuan University. Thick target technique was used in the measurement, eliminating target-thickness induced uncertainties. 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 alpha strength for the near-threshold state.

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10. GalCEM: the Galactic Chemical Evolution of all the isotopes

Eda Gjergo[1], Aleksei Sorokin[2], Anthony Ruth[3], Marco Limongi[4], Emanuele Spitoni[5], Francesca Matteucci[6], Jinning Liang[7], Yuta Yamazaki[8], Motohiko Kusakabe[9], Toshitaka Kajino[9], Xilong Fan[7]

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Session: Tuesday - Session 2: First Generation Stars and Galactic Chemical Evolution I

Speaker: Eda Gjergo

We introduce a user-friendly detailed and modular GALactic Chemical Evolution Model, GalCEM, that tracks isotope masses as a function of time in a given galaxy. The list of tracked isotopes automatically adapts to the complete set provided by the input yields. The present iteration tracks 89 elements broken down into 456 isotopes. We include the following enrichment channels: massive stars (SNII), low-to-intermediate mass stars (LIMs), Type Ia supernovae, dynamic and jet components of neutron star mergers, collapsars, and magneto-rotational supernovae.

We have developed a pre-processing tool that extracts multi-dimensional interpolation curves from the input yield tables. In this work, we have applied this pre-processing tool to SNII and LIMs yields. The extrapolated interpolation curves improve the computation speeds of the full convolution integrals, which are computed for each isotope and for each enrichment channel. We map the integrand quantities onto consistent array grids in order to perform the numerical integration at each time step.

We will present two sets of results: the evolution of all the light and intermediate elements from carbon to zinc, with lithium, and the evolution of heavy elements. Our results are consistent up to the extremely metal-poor regime with Galactic abundances. We will conclude with a discussion on our assumptions and on the landscape of a selection of open problems in the field of Galactic Chemical Evolution.

11. Gamow Teller strength distributions of N Z nuclei for astrophysical application

Eunja Ha[1], Myung-Ki Cheoun[2]
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[2]Soongsil Univ.

Session: Thursday - Session 4: Explosive Stellar Objects and Nuclear Physics: Explosive Hydrogen Burning II

Speaker: Eunja Ha

Gamow-Teller (GT) strength distributions play a significant role in the neutrino-induced reactions supposed to be occurred in the supernova explosion. Most of the reactions are dominated by the GT transition among the other multipole transitions.

However, some nuclei show interesting behavior, so to say, GT peak in the lower energy region, due to the tensor force. We are going to discuss the shift of the GT strength using the deformed quasiparticle random phase approximation and argue their effects on the neutrino-induced reactions..

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12. Status of the RI accelerator facility and nuclear astrophysics experiments in Korea

Kevin Insik Hahn[1,2]

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Session: Tuesday - Session 4: Facilities and new technology for Nuclear Astrophysics

The RI beam accelerator facility called RAON is under construction in Korea. One of the experimental facilities called KoBRA is expected to carry out nuclear astrophysics and nuclear structure experiments in the early phase of RAON. Several experiments using both stable and RI beams of tens of MeV/nucleon are considered for understanding explosive nuclear synthesis in stellar sites such as X-ray bursts and novae as well as the origin of proton-rich elements in the rp-process. Several important detector systems are being developed by CENS, which was established three years ago. The status of RAON and prospect for nuclear astrophysics experiments will be discussed.

13. Accurate half-life determination of a nuclear cosmochronometer 176Lu

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Session: Friday - Session 3: Meteorite Analysis and Isotopic Abundance
Speaker: Takehito Hayakawa

An unstable isotope Lu-176 decays to Hf-176 with a half-life of approximately 4×10^{10} y. The Lu-176 could be used as a nuclear cosmochorometer for dating the nucleosynthesis event before the solar system formation. However, the half-lives measured with various nuclear experiments are inconsistent with each other. Furthermore, the half-lives evaluated from the Lu and Hf isotopic abundances in meteorites and terrestrial rocks are also inconsistent. Thus, a new measurement by nuclear experiment being insensitive to gamma-ray branching ratios and the capitulation of detection efficiency. Here, we have measured a half-life using a new method being not sensitive to the various parameters. We have measured the half-life using a windowless 4pi-type BGO scintillation detector with a total detection efficiency of approximately 99.9%. The presently obtained half-life is consistent with that obtained from the meteorites and terrestrial rocks within the uncertainty. The present value is the most precise among the previously measured half-lives. This result provides a nuclear cosmochronometer for studying geological events and stellar nucleosynthesis.

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14. New measurement of the 7Be + n reactions and its impact on the primordial 7Li abundance

Seiya Hayakawa[1], M. La Cognata[2], Livio Lamia[2], Hidetoshi Yamaguchi[1], David Kahl[3,4], Keijiro Abe[1], Hideki Shimizu[1], Lei Yang[1], Olga Beliuskina, Soomi Cha[5], Kyung Yuk Chae[6], Silvio Cherubini[2,7], Pierpaolo Figuera[2], Zhuang Ge[8], Marisa Gulino[2,9], Azusa Inoue[10], Naohito Iwasa[8,11], Aram Kim[12,13], Dahee Kim[14], Gabor Kiss[15], S. Kubono[8], Marco La Commara[16], Marcello Lattuada[2], Eunji Lee[6], Jun Young Moon[14], Sara Parmelini[17], Concettina Parascandolo[18], Suyeon Park[13,19], Vi Ho Phong[8], Dimitra Pierroutsakou[18], Rosario Gianluca Pizzone[2], G.G. Rapisarda[7], Stefano Romano[2], Claudio Spitaleri[2,7], Xiaodong Tang[20], Oscar Trippella[17], Aurora Tumino[2,9], Ningtao Zhang[20]

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Session: Tuesday - Session 1: Big Bang Cosmology and Primordial Nucleosynthesis

Speaker: Seiya Hayakawa

It has been known that there is an outstanding discrepancy between theoretical predictions and astronomical observations of primordial lithium abundances, so called cosmological lithium problem (CLP). From the point of view of nuclear physics, 7Be(n,p)7Li and 7Be(alpha,n)4He are the most important reactions which act to decrease 7Li in Big Bang nucleosynthesis (BBN). There was still lacked information on cross sections of these reactions to further constrain BBN, such as the contribution of the exit channel to the first excited state of 7Li, in spite of several relevant experiments reported recently. We measured the cross sections of the 7Be(n,p0)7Li, 7Be(n,p1)7Li* and 7Be(alpha,n)4He reaction channels by Trojan Horse method. An R-matrix analysis both to the present and the previous data improved uncertainty of the (n,p0) channel cross section, and the first-ever quantification of the (n,p1) contribution in the BBN energy range. The updated total reaction rate of (n,p0) + (n,p1) leads a reduction of the predicted 7Li abundance by about one-tenth. We expect this work to reduce the nuclear physics uncertainty, and to offer a closer standing point to the CLP solution.

[Reference]
Hayakawa et al., Astrophys. J. Lett. **915**, L13 (2021). DOI: 10.3847/2041-8213/ac061f

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15. Direct Measurement of the Astrophysical $^{19}F(p, \alpha\gamma)^{16}O$ Reaction in the Deepest Operational Underground Laboratory

Jian Jun He[1]

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Session: Tuesday - Session 2: First Generation Stars and Galactic Chemical Evolution I

Fluorine is one of the most interesting elements in nuclear astrophysics, where the $^{19}F(p, \alpha)^{16}O$ reaction is of crucial importance for Galactic ^{19}F abundances and CNO cycle loss in first generation Population III stars. As a day-one campaign at the Jinping Underground Nuclear Astrophysics experimental facility, we report direct measurements of the essential $^{19}F(p, \alpha\gamma)^{16}O$ reaction channel. The γ-ray yields were measured over $E_{\text{c.m.}} = 72.4$–344 keV, covering the Gamow window; our energy of 72.4 keV is unprecedentedly low, reported here for the first time. The experiment was performed under the extremely low cosmic-rayinduced background environment of the China JinPing Underground Laboratory, one of the deepest underground laboratories in the world. The present low-energy S factors deviate significantly from previous theoretical predictions, and the uncertainties are significantly reduced. The thermonuclear $^{19}F(p, \alpha\gamma)^{16}O$ reaction rate has been determined directly at the relevant astrophysical energies.

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16. The stellar evolution models and the critical nuclear reactions (tentative)

Alexander Heger[1]

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Session: Friday - Session 1: Stellar Evolutions and Hydrostatic Burning Processes & Underground Nuclear Astrophysics

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17. Collapsar r-process nucleosynthesis associated with i- and s-processes

Zhenyu He[1], Motohiko Kusakabe[1], Toshitaka Kajino[1]
[1]Beihang University, School of Physics, International Research Center for Big-Bang Cosmology and Element Genesis

Session: Thursday - Session 2: Explosive Stellar Objects and Nuclear Physics: r process - II

Speaker: Zhenyu He

The origin of nuclei heavier than iron is still an unsolved biggest question in nuclear astrophysics. The rapid and slow neutron-capture processes (r- and s-processes) are believed to be the origin of the neutron-rich heavy nuclei in the solar system. In addition to the two processes, recent spectroscopic observations of metal deficient asymptotic giant branch stars have raised the need for an intermediate neutron-capture process (i-process). These processes are considered to operate under distinctive conditions (temperature, neutron density, etc.) in different astrophysical sites. Here we show for the first time that the i- and s-processes in addition to the r-process produce heavy nuclei ($100 < A$) in the explosive nucleosynthesis of collapsar jets [1] which have recently been identified to be one of the most viable astrophysical sites for the r-process [2]. We find that the i- and s-processes operate at relatively later time as secondary processes, where the primary r-process nuclei are the seeds that capture neutrons produced by fission recycling of neutron-rich heavy actinides. We also find that only the collapsar r-process is followed by the subsequent i- and s-processes by exploring the nucleosyntheses in the magneto-hydrodynamic driven jets from core-collapse supernovae and the dynamical ejecta from binary neutron star mergers. We propose that the pronounced odd-even effect in the mass abundance pattern near ^{151}Eu and the rare earth elements in metal-deficient halo stars could be observational evidence for the collapsar yield. Since the collapsar is one of the viable astrophysical sites to provide the Milky Way with heavy nuclei, our findings might impact the traditional interpretation of the r-process components of the solar system materials.

[1] Z. He, M. Kusakabe, T. Kajino, et al., in preparation for submittal to Phys. Rev. Lett. (2022).
[2] Y. Yamazaki, Z. He, T. Kajino, et al., Astrophys. J. 933 (2022), 112.

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18. Role of magnetic fields in fueling Seyfert nuclei

Yue Hu[1]

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Session: Wednesday - Session 4: Astronomical Observations with Light, X-Ray, Gamma-Ray, and Cosmic-Ray

Molecular gas is believed to be the fuel for star formation and nuclear activity in Seyfert galaxies. To identify the role of magnetic fields in funneling molecular gas into the nuclear region, measurements of the magnetic fields embedded in molecular gas are needed. By applying the new velocity gradient technique (VGT) to ALMA and PAWS's CO isotopolog data, we obtain for the first time the detection of CO-associated magnetic fields in several nearby Seyfert galaxies and their unprecedented high-resolution magnetic field maps. The VGT-measured magnetic fields globally agree with the one inferred from existing HAWC+ dust polarization and VLA synchrotron polarization. An overall good alignment between the magnetic fields traced by the VGT-CO measurement and synchrotron polarization supports the correlation between star formation and cosmic ray generation. We find that CO-traced magnetic fields have a more significant radial component in the central regions of most Seyferts in our sample, where efficient molecular gas inflows are expected. In particular, we find the misalignment between the magnetic fields traced by CO and dust polarization within the nuclear ring of NGC 1097, and the former follows the secondary central bar. It reveals different magnetic field configurations in different gas phases and provides an observational diagnostic for the ongoing multi-phase fueling of Seyfert activity.

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19. Modification of thermonuclear reaction in the astrophysical plasma

Eunseok Hwang[1], Myong-ki Cheoun[1]
[1]Department of Physics, Soongsil University

Session: Poster session - II
Speaker: Eunseok Hwang

In the astrophysical plasma, such as the early universe or inside stars, elements are created through thermonuclear reactions. Therefore, we can understand the evolution of elements through the network calculation of nuclear reactions. However, because of the medium effects of plasma, nuclear reactions in these environments are different from what we understand in free space. Therefore, a more realistic nuclear reaction network can be reproduced by correcting the effect of plasma on the nuclear reaction. In this work, we investigate the dynamical screening effect and the electromagnetic fluctuation as a correction of thermonuclear reactions and apply these effects to the big bang nucleosynthesis (BBN) and solar core condition.

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20. Uncertainties in the 18 F(p, α) 15 O reaction rate in classical novae

Daid Kahl [1]

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Session: Thursday - Session 1: Explosive Stellar Objects and Nuclear Physics : Explosive Hydrogen Burning I

Direct observation of γ-ray emission from the decay of 18F ejected in classical nova outbursts remains a major focus of the nuclear astrophysics community. However, modeling the abundance of ejected 18F, and thus the predicted detectability distance of a γ-ray signal near 511 keV emitted from these transient thermonuclear episodes, is hampered by significant uncertainties in our knowledge of the key 18F(p,α) reaction rate. We analyze uncertainties in the most recent nuclear physics experimental results employed to calculate the 18F(p,α) reaction rate. Our goal is to determine which uncertainties have the most profound influence on the predicted abundance of 18F ejected from, novae in order to guide future experimental works. We calculated a wide range of 18F(p,α) reaction rates using the R-Matrix formalism, which allowed us to take all interference effects into account. Using a selection of 16 evenly spaced rates over the full range, we performed 16 new hydrodynamic nova simulations. We have performed one of the most thorough theoretical studies of the impact of the 18F(p,α) reaction in classical novae to date. The 18 F(p, α) rate remains highly uncertain at nova temperatures, resulting in a factor of $\sim$10 uncertainty in the predicted abundance of 18F ejected from nova explosions. We also found that the abundance of 18F may be strongly correlated with that of 19F. Despite numerous nuclear physics uncertainties affecting the determination of the 18F(p, α) reaction rate, dominated by unknown interference signs between 1/2 + and 3/2 + resonances, future experimental work should focus on firmly and precisely determining the directly measurable quantum properties of the subthreshold states in the compound nucleus 19 Ne near 6.13 and 6.29 MeV.

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21. The origin of r-process and ν-process elements in neutron star mergers, supernovae and collapsars

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Session: Wednesday - Session 1: Explosive Stellar Objects and Nuclear Physics: r process - I

There is a growing consensus in recent multi-messenger astronomy that the neutron star merger (NSM) as well as core collapse supernova (CCSN) and collapsar (which is very massive single star collapsing to a black hole) could be a possible site for the r-process nucleosynthesis. We will first discuss when and how these three astrophysical sites have contributed to enrichment of the r-process elements in the universe in our Galactic chemical evolution model [1]. We will then discuss the roles of nuclear fission, neutron-captures, beta-decays, nuclear isomers, and the magnetic fields in each of these astrophysical sites of the r-process. These explosive phenomena emit extremely large flux of energetic neutrinos and provide unique information to study the neutrino-nucleus interactions in high-density environments through the nuclosynthesis [2,3]. We will secondly discuss the neutrino-process and propose how to determine the still unknown neutrino mass hierarchy in terms of collective and MSW effects on the nuclear abundances of specific nuclei produced in CCSN and collapsar nucleosynthesis. We will also discuss the critical roles of not only the primary neutrino-nucleus reactions but also the radioactive nuclear reactions to secondarily destroy these neutrino-isotopes [4].

[1] Y. Yamazaki, Z. He, T. Kajino, G. J. Mathews, M. A. Famiano, X.-D. Tang, J.-R. Shi, ApJ. 933 (2022), 112.
[2] H. Sasaki, Y. Yamazaki, T. Kajino, M. Kusakabe, T. Hayakawa, M.-K. Cheoun, H. Ko, G. J. Mathews, ApJ. 924 (2022), 29.
[3] H. Ko, M.-K. Cheoun, E. Ha, et al., ApJ. 891 (2020), L24; H. Ko, D. Jang, M.-K. Cheoun, M. Kusakabe, H. Sasaki, X. Yao, T. Kajino, T. Hayakawa, M. Ono, T. Kawano, G. J. Mathews, ApJ. (2022), in press.
[4] X. Yao, M. Kusakabe, T. Kajino, S. Cherubini, S. Hayakawa, and H. Yamaguchi, In European Physical Journal Web of Conferences, vol. 260 (2022), p. 01007.

22. Direct triple-alpha process in non-adiabatic approach

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Session: Poster session - I

Triple-alpha reaction plays an important role in nucleosynthesis heavier than ^{12}C, because no stable nuclei exist in mass number $A = 5$ and $A = 8$ [1,2]. Followed by $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$, it controls the C/O ratio at the end of helium burning phase in stars, and it affects up to the nucleosynthesis in supernova explosion. In contrast to $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$, the 3-$\alpha$ reaction is currently well-understood through the experimental studies of the 0_2^+ state in ^{12}C ($E_r = 0.379$ MeV) (e.g. [3,4]), and the reaction rates have been determined successfully with the sequential process via the narrow resonances: $\alpha + \alpha = {}^8\mathrm{Be}$, $\alpha + {}^8\mathrm{Be} = {}^{12}\mathrm{C}$.

As for the theoretical studies, formulae in hyper-spherical coordinates have been applied to tackle the 3-α continuum problem (e.g. [5]), and their adiabatic approaches have paved the way for a non-adiabatic full approach of [6]. The recent Faddeev method [7] and adiabatic channel function expansion method [8] may have also achieved the successful progress quantitatively. However, non-adiabatic quantum-mechanical description at off-resonant energies still seems to remain in unsolved problems. Apart from the sequential process, the 3-α reaction from continuum states is referred to as the direct 3-α process: $\alpha + \alpha + \alpha = {}^{12}\mathrm{C}$. This process is generally expected to be very small, because 3-α almost simultaneously collide and fuse into a ^{12}C nucleus.

In this presentation, the contribution of the direct 3-α process is estimated with a non-adiabatic method. In addition, Faddeev hyperspherical harmonics and R-matrix expansion method [9,10] is reviewed, and the difference between adiabatic and non-adiabatic calculations is discussed. In a result, the direct component is shown to be $10^{-15} - 10^{-3}$ pico-barn order in the photo-disintegration cross sections of 12C ($2_1^+ \to 0^+$) for $0.15 < E < 0.35$ MeV. This is far below the values ($10^{-11} - 10^{2}$ pico-barn) predicted by [7,8] including the long resonant tail of 0_2^+, i.e. sequential process. In spite of the large difference, the derived reaction rates at the helium burning temperatures are illustrated to be concordant with [4].

[1] F. Hoyle, Astrophys. J. Suppl. Ser. 1, 121 (1954).
[2] E.E. Salpeter, Astrophys. J. 115, 326 (1952).
[3] D. Dell'Aquila, et al., Phys. Rev. Lett. 119, 132501 (2017).
R. Smith, et al., Phys. Rev. Lett. 119, 132502 (2017).
[4] C. Angulo, M. Arnould, et al., Phys. Lett. B 389, 631 (1996).
[5] D.V. Fedorov, A.S. Jensen, Phys. Lett. B 389, 631 (1996).
[6] N.B. Nguyen, F.M. Nunes, I.J. Thompson, Phys. Rev. C 87, 054615 (2013).
[7] S. Ishikawa, Phys. Rev. C 90, 061604 (2014).
[8] H. Suno, Y. Suzuki, P. Descouvemont, Phys. Rev. C 94, 054607 (2016).
[9] I.J. Thompson, F.M. Nunes, Nuclear Reactions for Astrophysics, (Cambridge University Press, 2009).
[10] P. Descouvemont, Theoretical Models for Nuclear Astrophysics, (Nova Science Publishers, 2003).

23. Isospin dependence on fission properties of nuclear matter

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Session: Wednesday - Session 1: Explosive Stellar Objects and Nuclear Physics: r process - I

Speaker: Deby Treasa Kattikat Melcom

Study of bulk properties of nuclear matter in general, and of the fission-fragment mass distribution (FFMD) in particular, is important for understanding of nuclear abundances in astrophysical processes. More specifically, the structure and composition of the FFMD is relevant for the description of abundances of elements within the 110≤A≤170 mass range in the neutron star merger scenarios. The latter use projection of fission properties gathered with actinides (N/Z∼1.6) to nuclei with high isospin values (N/Z∼2.0), i.e., to the nuclei currently inaccessible for experimental studies. Such a projection is therefore strongly model-dependent which leads to controversial results [1].

The spontaneous and low-energy fission of actinides is known to indicate dominance of asymmetric mass division in the measured FFMDs. This feature is understood to be due to microscopic effects in the fragments that are known to evolve along the nuclear chart [2] in the direction of lower isospin values, leading to a transition in the FFMD shape (symmetric fission for nuclei below A∼226). However, fission of neutron-deficient nuclei around ^{180}Hg (N/Z∼1.25) has revealed prominent asymmetric mass division, despite the presence of strong microscopic effects (closed shells) in ^{90}Zr (Z=40, N=50) [3-5]. Similar studies made with ^{179}Au, ^{178}Pt and several Hg isotopes have further proved that the asymmetric mass split is a typical property of neutron-deficient nuclei in this region [6].

This work deals with the multi-parameter study of fission properties of highly neutron-deficient nuclei isotones ^{176}Os, ^{177}Ir and ^{179}Au ($N = 100$). This exotic nuclear matter has been produced in fusion reactions of the ^{35}Cl beam with the ^{144}Sm, ^{142}Nd and ^{141}Pr targets. The experiment was conducted at the Advanced Science Research Center (ASRC) of the Japanese Atomic Energy Agency (JAEA). The simultaneous measurement of the FFs, neutrons and gamma-rays was done for the three used targets and at different beam energy thus leading to different excitation energy of the compound nucleus (CN).

Results on FFMD and Total Kinetic Energy (TKE) distribution will be addressed, from the point of view of fission modes coexistence, as well as their evolution with the excitation energy and isospin of the CN, all that in comparison with the Langevin calculations.

[1] S. Goriely *et al.*, Phys. Lett. Phys. **111**, 242502 (2013).
[2] A. Andreyev *et al.*, Rep. Prog. Phys. **81(1)**, 016301 (2017).
[3] A. Andreyev *et al.*, Phys. Rev. Lett. **105(25)**, 252502 (2010).
[4] K. Nishio *et al.*, Phys. Lett. B **748**, 89-94 (2015).

[5] C. Schmit *et al.*, Phys. Rev. C **126**, 132502 (2021).
[6] I. Tsekhanovich *et al.*, Phys. Lett. B **790**, 583-588 (2019).

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24. New Attempt to the 12C(α,γ)16O measurement with an active-target TPC and LaBr3 arrays in a 3-T superconducting magnet

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Session: Friday - Session 1: Stellar Evolutions and Hydrostatic Burning Processes & Underground Nuclear Astrophysics

Speaker: Shin Hyung Kim

The $^{12}C/^{16}O$ abundance ratio is of prime importance to understand stellar evolution and energy generation in the universe. A tiny change in the abundance ratio can change an entire scenario of the stellar nucleosynthesis from carbon burning to the iron core in the last years of stellar life. Despite many experimental efforts in the last 50 years, none of the associated reactions like $^{12}C+\alpha\rightarrow^{16}O+\gamma$ has yet been measured at the relevant stellar energies. Extrapolation from experimental data taken at higher energies can only help theoretical modeling of stellar evolution and nucleosynthesis. The COREA (Carbon Oxygen Reaction Experiment with Active-target TPC) is an experiment to measure the precise reaction rates with a novel detector system near stellar energies. We constructed a conduction-cooled superconducting magnet with a maximum field of 3 T. We tested the cooling performance and mapped out the field strengths over the AT-TPC volume. In addition, we studied the energy response of $LaBr_3$ detectors using an Am/^{13}C neutron source and a Ni disc in the energy region up to 10 MeV. Furthermore, Geant4 simulation was performed to study the performance of the AT-TPC with the superconducting magnet. We will present the development of the unique COREA detector system and the simulation results.

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25. Study of the neutron-rich 252Cf-fission-fragments with MRTOF-MS

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Session: Thursday - Session 2: Explosive Stellar Objects and Nuclear Physics: r process - II

Speaker: Sota Kimura

The nuclear data of neutron-rich nuclei, e.g., mass, lifetime, and neutron-capture cross section, are important for understanding the rapid neutron-capture (r-) process, because a balance of net neutron-capture rate and β-decay rate is crucial to determine its path. It is difficult to access the r-process nuclei due to their locations far from stability; thus, theoretical predictions are needed to obtain the final isotopic abundances. However, in the region where there are no experimental data on nuclear masses, the predicted mass values show a large variance. To improve them, accurate and precise mass and nuclear data of neutron-rich nuclei are required. At RIKEN, the studies of neutron-rich unstable nuclei produced by the spontaneous fission of ^{252}Cf has been performed with a multi-reflection time-of-flight mass spectrometer (MRTOF-MS), which has been developed for not only mass measurement but also isobar separation. The experimental setup consists of a cryogenic helium gas-cell, a suite of ion traps, and the MRTOF-MS. We have achieved extraction form the gas-cell and observation of more than 250 isotopes so far. In this presentation, we report the recent results of the mass measurements of neutron-rich unstable nuclei and, in addition, other related studies with the MRTOF-MS.

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26. Application of neutron physics methods for studying the Chelyabinsk meteorite

Andrey Kirillov[1], Aleksander Doroshkevich[1], Akhmed Islamov[1], Tatyana Vasilenko[2], Sergey Kichanov[1], Denis Kozlenko[1], Bekhzodjon Abdurakhimov[1], Tatiana Ivankina[1], Sergey Zamozdra[3], Evgenii Lukin[1]

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Session: Poster session - I

Speaker: Andrey Kirillov

The fragments of one of the Chelyabinsk meteorite shower were investigated by methods of neutron physics. The source of thermal neutrons was the IBR-2 pulsed reactor (Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna). The neutron activation elemental analysis (NAA) of the meteorite was carried out for 10 major and 17 trace elements [1]. Comparison with the results of the neutron prompt gamma activation analysis (PGAA) for 15 elements carried out. Small-angle neutron scattering (SANS) indicated the fractality of the pore space and the exponential distribution of the thicknesses of scattering centers in the form of monodisperse flat structures. Non-destructive research techniques, such as neutron diffraction and tomography, as well as neutron diffraction texture analysis, made it possible to obtain the volumetric distribution of mineral phases of olivine, orthopyroxene, plagioclase and troilite and discovered the presence of the kamacite phase in the studied meteorite fragment. A heterogeneous distribution of iron in olivine and orthopyroxene was found, which can identify iron-exchange processes between silicate minerals and iron-containing compounds [2]. The detailed quantitative textural analysis of another fragment of the Chelyabinsk meteorite is discussed, with the help of which it was possible to determine the predominant orientation of its main mineral phases [3]. It is suggested that the texture originated as a result of the thermobaric impact of a meteorite during its entry into the Earth's atmosphere. Moreover, the studied meteorite fragment rotated during the movement, as evidenced by its streamlined shape and fibrous type of the texture.

The study was performed in the framework of the JINR-Romania cooperation program in 2022 (topic 03-4-1128-2017/2022 and 04-4-1143-2021/2025) and JINR - Serbia Projects in 2022 (Order 178 p. 7 and 8).

[1] A. Kirillov, D. Grozdov, I. Zinicovscaia, T. Vasilenko. Elemental composition of the Chelyabinsk meteorite determined by neutron activation analysis. Journal of Radioanalytical and Nuclear Chemistry, 2022, 331(1), 249-253.

[2] S.E. Kichanov, D.P. Kozlenko, A.K. Kirillov, E.V. Lukin, B. Abdurakhimov, N.M. Belozerova, A.V. Rutkauskas, T.I. Ivankina, B.N. Savenko, A structural insight into the Chelyabinsk meteorite: Neutron difraction, tomography and Raman spectroscopy study. SN Appl. Sci., 2019,1,1563.

[3] S.B. Borzakov, A. Zh. Zhomartovaa, T. I. Ivankina, A.Yu. Dmitriev, V.V. Lobachev. The Elemental and Texture Analysis of the Chelyabinsk Meteorite Frag-

ment by Non-Destructive Neutron Methods. Physics of Particles and Nuclei Letters, 2022, 19(2), 176–182.

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

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Session: Thursday - Session 3: Explosive Stellar Objects and Nuclear Physics - Supernovae

Speaker: Heamin Ko

A large number of neutrinos emitted in a supernova explosion interacts with a dense plasma. The interaction between neutrinos and electrons changes the neutrino oscillation probability remarkably at the specific electron density, known as the Mikheyev–Smirnov–Wolfenstein (MSW) resonance effect. Previous studies for the neutrino process in core-collapsing supernova (CCSN) 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 magnetic field polarizes the electrons, whose effective potential including axial-vector interaction changes the MSW effect region. 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 profiles. Also, we discuss those effects through the abundance of ^{92}Nb, ^{98}Tc, and ^{138}La with the SN1987A model.

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28. Galactic chemical evolution of light-to-heavy elements

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Session: Tuesday - Session 3: First Generation Stars and Galactic Chemical Evolution II

Speaker: Chiaki Kobayashi

I will summarize the origin of elements using my Galactic chemical evolution model; only light elements such as hydrogen and helium were produced during the Big Bang. Heavier elements then helium are created inside stars. Alpha elements are mainly produced from core-collapse supernovae, while the majority of iron-peak elements are from Type Ia supernovae. Neutron-capture elements are produced by asymptotic giant branch stars, electron-capture supernovae, magneto-rotational supernovae, collapsars, and/or neutron-star mergers. I will also discuss the (surprisingly high) fluorine abundance recently obtained for a distant galaxy (at redshift 4.4). Then I will show predictions from more realistic, chemodynamical simulations of Milky Way-type galaxies, which include the effects of stellar migrations and inhomogeneous enrichment, and compare with observational data from the galactic archaeology surveys.

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29. Big-bang Nucleosynthesis on a bubble universe nucleated in Kerr-AdS_5

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Session: Poster session - II
Speaker: Issei Koga

We investigated the big-bang nucleosynthesis (BBN) on an expanding four-dimensional bubble nucleated in Kerr-AdS_5. This nucleation is caused by vacuum decay between two AdS vacua, and the bubble that separates the two vacua and surrounds a black hole is assumed to have a uniform tension. The black hole behaves like dark radiation on the bubble, and its ”radiation density” depends on the mass and spin of the black hole. In this study, we investigate how the primordial helium abundance, Yp, is changed in the scenario of bubble spacetime BBN compared with that of the standard BBN. We show that Yp decreases due to this dark radiation. A discussion of comparison with recent observations of Yp is also presented.

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30. Influence of cosmogenic neutron radiation on the evolution of terrestrial biological forms on the example of rice and Oyster mushrooms cultures

Anastasiya Kruglyak[1], Aleksandr Doroshkevich[1], Yulia Aleksiayenak[1], Nurbol Appazov[2,3], Kurmambek Bakiruly[2,3], Vasilisa Volgina[4], Ekaterina Didenko[5], Nelya Doroshkevich[1], Le Hong Khiem[6,7], Phan Luong Tuan[1,8], Tran Van Phuc[6,7], Afag Madadzada[9,1]

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Session: Poster session - II
Speaker: Anastasiya Kruglyak

It is known that viruses and cosmic rays make a decisive contribution to the evolution of biological species on Earth, participating in their transformation at the genetic level, largely determining the processes of selection [1]. Nuclear reactions involving primary cosmic radiation and atmospheric ions can lead to the formation of secondary neutrons. The density of the background neutron flux near the Earth's surface is 4×10-3 neutron/cm2×s [2]. While neutrons are considered as a risk factor for humans at high latitudes [3, 4] and some health problems are registered among aircraft crews [5] there is lack of studies about neutron interaction with biological objects at the level of the near earth surface. This work is conducted to the mechanism study of the cosmogenic neutron radiation effect on the mutagenesis of biological objects on the example of rice cultures and the Oyster mushroom. The first stage of our study was to irradiate rice seeds of different varieties with neutrons with E=4.1 MeV to obtain dose of 50 Gy. Irradiation was conducted at the electrostatic generator EG-5 in the FLNP, JINR. Rice was provided by the Zhakhaev Kazakh Rice Research Institute within the framework of the project BR10765056. The effect of the dose on the physiological activity of the studied rice crops has been established. The next stage of the study is to irradiate mushroom samples and to compare irradiation effects on the two different biological objects.

The study was funded by the Plenipotentiary Representative of the Government of the Poland Republic in JINR within the framework of the Poland-JINR Cooperation Projects PPPB/120- 25/1128/2022, PPPB/120-26/1128/2022 and JINR-Serbia Cooperation Program Order 178 items 7 and 8, JINR-Belarus Cooperation Program, Order 529, paragraphs 22 and 23

[1] M.V.Ragulskaya (2019), Sun and biosphere, Radiotekhnika, 170 p.
[2] N.A.Vlasov (1982), Atomic Energy, 52(2), 87-91

[3] K.Kojo, et al. (2005), Occup.Environ.Med., 62, 488-493.
[4] G.P.Hammer, et al. (2009), Radiat.Prot.Dosim, 136, 232-239.
[5] R.Aspholm, et al. (1999), Occup.Environ.Med., 41(6), 486-491.

31. Exploring the astrophysical energy range of the ^{27}Al(p,α)^{24}Mg reaction: A new recommended reaction rate

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Session: Thursday - Session 1: Explosive Stellar Objects and Nuclear Physics : Explosive Hydrogen Burning I

The ^{26}Al abundance holds a special role in present-day astrophysics, since it is a probe of active nucleosynthesis in the Galaxy and a valuable constraint of Galactic core-collapse supernovae rate. It is estimated through the detection of the 1809-keV γ-line of the daughter ^{26}Mg and from the superabundance of ^{26}Mg in comparison with the most abundant ^{24}Mg isotope in meteorites. Accurate knowledge of the reaction rates involving ^{26}Al, its stable counterpart ^{27}Al and ^{24}Mg is then mandatory. Moreover, these nuclei enter the MgAl cycle playing an important role in the production of Al and Mg isotopes. Recently, high-resolution stellar surveys have shown that the Mg-Al anti-correlation in red giants of globular clusters may hide the existence of multiple stellar populations, and that the relative abundances of Mg isotopes may not show correlation with Al.The common thread running through these astrophysical scenarios is the ^{27}Al(p,α)^{24}Mg reaction, which is the main ^{27}Al destruction channel and directly correlates its abundance with the ^{24}Mg one. Since available reaction rates show an order of magnitude uncertainty owing to the vanishingly small cross section at astrophysical energies, we have applied the Trojan Horse Method to deduce the reaction rate with no need of extrapolation. The indirect measurement made it possible to assess the contribution of the 84-keV resonance and to lower the upper limits on the strength of nearby resonances, with potential important impact for astrophysics. In particular, modifications in the ^{27}Al and ^{24}Mg abundances up to 30% are predicted for intermediate mass stars. More details can be found in Ref.[1].

[1] M. La Cognata et al. Physics Letters B 826 (2022) 136917

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32. Deciphering the Hidden Morphology of Periodic Thermonuclear X-Ray Bursts

Yi Hua Lam[1], Ning Lu[1], Alexander Heger[2], Nadezda Smirnova, David Kahl[3,4], Adam Jacobs[5], Zac Johnston[5], Zi Xin Liu[1], Shigeru Kubono[6]

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Session: Thursday - Session 4: Explosive Stellar Objects and Nuclear Physics: Explosive Hydrogen Burning II

Speaker: Yi Hua Lam

Since the first detected extrasolar X-ray source of Scorpius X-1 (aka Sco X-1) by Giacconi et al. in 1962, more than 7083 Type-I X-ray bursts generated by the respective 115 bursters have been observed. Reproducing the burst light curve is the key to accurately understanding thin-shell burning in Type-I X-ray bursts, nova outbursts, and Type-Ia supernovae, and to identifying important seed nuclei for superburst and neutron-star crust cooling. Up to now, there has been no theoretical model capable of producing X-ray bursts closely conformed with an observed X-ray burst profile. Here we present the first benchmark Type-I X-ray burst model that unprecedentedly reconciles the simulated periodic burst light curve properties with the observed ones. The observed periodic bursts were generated from the GS 1826−24 burster discovered by Makino et al. in 1988. It is for the first time since its discovery that a theoretical model remarkably reproduces the observed burst fluence, recurrence time, light curve profile, conforming with the observed burst peak until tail end and revealing the morphology of periodic X-ray burst.

33. Microscopic radiative strength function model

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Session: Poster session - II

Speaker: Phuc Le-Tan

The radiative strength function (RSF), defined as the average electromagnetic transition probability per unit of γ-ray energy E_γ, is an important quantity to study the nuclear reaction properties such as emission rate, cross section, and nuclear astrophysical processes. We proposed a new method to describe the RSF within a microscopic approach, which is based on the damping of phonon in the framework of the giant resonances. The pairing correlation is also taken into account via the exact thermal pairing solution. The obtained results show that not only the contribution of the giant dipole resonance (GDR) but also the Pygmy dipole resonance (PDR) in the RSF are well described in the new model. Moreover, the temperature of hot nuclei has a significant contribution to the RSF below neutron separation energy, questioning again the validity of the Brink-Axel hypothesis in this energy region.

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34. STUDY ON p+10,11B REACTIONS IN THE PROTON ENERGY RANGE Ep=0.35-3.2 MeV

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Session: Thursday - Session 4: Explosive Stellar Objects and Nuclear Physics: Explosive Hydrogen Burning II

Speaker: Le Xuan Chung

We report on a study of the reactions p+10,11B at low energy. The reactions are relevant in the field of astrophysics, nuclear physics, and also for applications. Studying these reactions provides additional input data for astrophysical models in particular towards astrophysical energies [1-2]. We have used the 5SDH-2 peletron accelerator at Hanoi University of Science to investigate the nuclear reactions p+10,11B using proton beam with energy in the range 0.35-3.2 MeV. The target were 10B and 11B of around 60 g/cm2 onto 4 g/cm2 formvar substrate. Six silicon detectors were placed at θLab= 40deg, 50deg, 90deg, 120deg, 130deg and 159deg. The excitation function of 11B(p,α0) channel detected by the detector at 159° reproduces well the published ones in the 0.9-3.2 MeV energy range, and is extended down to 0.35 MeV. Preliminary results and its perspectives will be presented and discussed.

[1]. Pierre Descouvemont, Frontier in Astronomy and Space Science 7 (2020) 9.
[2]. T. Rauscher and G. Raimann, Physical Review C 53 (1996) 2496.

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35. JUNA: Probing star evolution in deep underground lab

Weiping Liu[1] for JUNA collaboration
[1]CIAE

Session: Tuesday - Session 4: Facilities and new technology for Nuclear Astrophysics

Jinping Underground experiment for Nuclear Astrophysics (JUNA) takes advantage of the ultralow background of the CJPL. Commissioning of mA level high current accelerator based on an ECR source and BGO and 3He detectors finished in 2020. JUNA started experiments to directly study the many crucial reactions occurring at relevant stellar energies during the evolution stars. JUNA performed the direct measurements of 25Mg(p,g)26Al, 19F(p,ag)16O, 13C(a,n)16O, and 12C(a,g)16O. Research highlights, which provide reaction rates in higher precision, wider energy range near Gamow window and their astrophysics implications will be presented.

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36. The Impact of the New ^{65}As(p,γ)^{66}Se Reaction Rate on the Two-Proton Sequential Capture of ^{64}Ge,Weak GeAs Cycles, and Type-I X-Ray Bursts such as the Clocked Burster GS 1826−24

Yi Hua Lam[1], Zi-Xin Liu[1], Ning Lu[1], Alexander Heger[2], Adam Michael Jacobs[3], Zac Johnston[3]

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[3]Joint Institute for Nuclear Astrophysics, Michigan State University

Session: Thursday - Session 1: Explosive Stellar Objects and Nuclear Physics : Explosive Hydrogen Burning I

Speaker: Zi-Xin Liu

In this work, we re-assess the ^{65}As(p,γ)^{66}Se reaction rates based on a set of proton thresholds of ^{66}Se, S_p(^{66}Se), estimated from the experimental mirror nuclear masses, theoretical mirror displacement energies, and full *pf*-model space shell-model calculation. The mirror displacement energies with much reduced uncertainty of the self-consistent relativistic Hartree-Bogoliubov calculations, and thus reducing the proton-threshold uncertainty up to 161 keV compared to the AME2020 evaluation. Using the simulation instantiated by the one-dimensional multi-zone hydrodynamic code, Kepler, which follows the trend of the observed GS 1826−24 clocked bursts, the present forward and reverse ^{65}As(p,γ)^{66}Se reaction rates based on a selected S_p(^{66}Se) = 2.469±0.054 MeV, and the latest ^{22}Mg(α,p)^{25}Al, ^{56}Ni(p,γ)^{57}Cu, ^{57}Cu(p,γ)^{58}Zn, ^{55}Ni(p,γ)^{56}Cu, and ^{64}Ge(p,γ)^{65}As reaction rates, we study the waiting point status of and two-proton sequential capture on ^{64}Ge, weak-cycle feature of GeAs at region heavier than ^{64}Ge, and impact of other possible S_p(^{66}Se), which could be a reference for future nuclear mass measurements.

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37. Regulated NiCu Cycles with the New ^{57}Cu(p,γ)^{58}Zn Reaction Rate and the Influence on Type-I X-Ray Bursts: GS 1826−24 Clocked Burster

Yi Hua Lam[1], Ning Lu[1], Alexander Heger[2], Adam Michael Jacobs[3], Nadezda A. Smirnova[4], Teresa Kurtukian Nieto[4], Zac Johnston[3], Shigeru Kubono[5]

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[4]CENBG, CNRS/IN2P3 and University of Bordeaux
[5]RIKEN Nishina Center

Session: Thursday - Session 1: Explosive Stellar Objects and Nuclear Physics : Explosive Hydrogen Burning I

Speaker: Ning Lu

During type I X-ray bursts, the rapid-proton capture (rp-) process has to pass through the NiCu cycles and ZnGa cycles before reaching the region above germanium and selenium isotopes that hydrogen burning occurs in. According to the sensitivity study by Cyburt et al. (2016), the ^{57}Cu(p,γ)^{58}Zn reaction located in the NiCu cycles is the fifth important rp-reaction influencing the burst light curves. Nevertheless, Langer et al. (2014) experimentally confirmed some low-lying energy levels of ^{58}Zn, but the order of 1^+_1 and 2^+_3 resonance states that dominate at $0.2 \leq T(\mathrm{GK}) \leq 0.8$ is still not clear. The 1^+_2 resonance state, which dominates at the XRB sensitive temperature regime $0.8 \leq T(\mathrm{GK}) \leq 2$ was also not detected. We use isobaric-multiplet-mass equation to propose the order of energy levels and resonance states that dominantly contribute to the total reaction rate but is outside the experimental range. Therefore, combine with calculations from large-scale shell model, we deduce the ^{57}Cu(p,γ)^{58}Zn reaction rate. The new rate is up to a factor of five lower than the Forstner et al. (2001) rate recommended by JINA REACLIBv2.2. With new ^{57}Cu(p,γ)^{58}Zn reaction rate in 1D implicit hydrodynamics KEPLER code to model the thermonuclear X-ray bursts of GS 1826−24 clocked burster, we find that the new rate redistributes the matter flow in the NiCu cycles and reduces the production of ^{58}Zn, whereas the ^{59}Cu(p,α)^{56}Ni and ^{59}Cu(p,γ)^{60}Zn reactions suppress the influence of the ^{57}Cu(p,γ)^{58}Zn reaction and strongly diminish the impact of matter flow by-passing the important ^{56}Ni waiting point induced by the ^{55}Ni(p,γ)^{56}Cu reaction on burst light curve.

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38. Neutron-capture nuclei and the formation of the Solar System

Maria Lugaro[1]

[1]Konkoly Observatory, Hungary

Session: Wednesday - Session 4: Astronomical Observations with Light, X-Ray, Gamma-Ray, and Cosmic-Ray

Signatures of stellar material affected by neutron-capture processes were not completely diluted in the early Solar System and are still found recorded in meteorites. These fingerprints of neutron captures range from radioactive isotopes produced by neutron captures, to stardust from asymptotic giant branch stars and core-collapse supernovae, as well as widespread highly diluted, but still measurable, anomalies in the isotopic abundances of refractory elements, from Mo and Ru to Cr and Ti. I will review the status of such observations and what they can tell us about the formation of the Sun, the evolution of its proto-planetary disk, and the formation of our planetary system.

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39. Strong magnetic field impact on the neutrino process inside SNe explosion

Toshitaka Kajino[1], Motohiko Kusakabe[1], Yudong Luo[1],

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[2]Beihang University
[3]Peking University

Session: Thursday - Session 3: Explosive Stellar Objects and Nuclear Physics - Supernovae

Speaker: Yudong Luo

Strong magnetic fields could exist in the inner region of the explosive astrophysical site such as MHD-Jet SNe. The phase space of the electrons is quantized inside the magnetic field so that the weak interaction rates deviate from the field-free case. This talk focuses on the (anti)neutrinos absorption process. This process is essential since it determines the opacity of neutrino and the position of the (anti) neutrino sphere. Moreover, we will show that the evolution of the electron fraction Y_e is also affected by the magnetic field since its value depends on the inverse reaction of the neutrino process. Such impact could leave an imprint on the r-process nucleosynthesis yields.

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40. Prospects for anisotropic flow measurements in the MPD experiment at NICA collider

Vinh Luong[1,2,3], Petr Parfenov[2], Dim Idrisov[2], Alexander Demanov[2], Arkadiy Taranenko[2] for the MPD collaboration

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[2]National Research Nuclear University MEPhI, Moscow, Russia
[3] Dalat Nuclear Research Institute, Dalat, Vietnam

Session: Poster session - II
Speaker: Vinh Luong

The goal of the Multi-Purpose Detector (MPD) [1] at the Nuclotron-based Ion Collider fAcility (NICA) [2] is to explore the QCD phase diagram of strongly interacting matter produced in nucleus-nucleus collisions at center-of-mass energy per nucleon pair $\sqrt{s_{NN}}$ = 4–11 GeV in the region of high net baryon chemical potential and moderate temperatures. The anisotropic flow is a key observable in such collisions due to its sensitivity to both the transport properties and equation of state of the created strongly interacting quark gluon plasma (sQGP). MPD performance for anisotropic flow measurements is studied using Monte Carlo generators with MPD detector response simulated by GEANT4. Different flow measurement methods are applied to investigate the contribution of non-flow correlations and flow fluctuations.

[1] V. Golovatyuk, V. Kekelidze, V. Kolesnikov, O. Rogachevsky and A. Sorin, Eur. Phys. J. A **52** (8), 212 (2016).
[2] V. Kekelidze, Phys. Part. Nucl. **49**, 457 (2018).

41. Experimental study of symmetry energy (tentative)

William G. Lynch[1]

[1]Michigan State University

Session: Wednesday - Session 2: Nuclear Matter and Neutron Stars & weak interaction I

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42. Generation of Photon Vortex by Synchrotron Radiation in Astrophysical Magnetic Fields

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Session: Wednesday - Session 4: Astronomical Observations with Light, X-Ray, Gamma-Ray, and Cosmic-Ray

Speaker: Tomoyuki Maruyama

Photon vortices caring orbital angular momentum (OAM) [1] with a wave function of Laguerre Gaussian (LG) wave or Bessel wave are one of the most interesting topics in various fields of physics. The interaction between a photon vortex and a material such nucleus may be different from that with standard photons because the photon vortex is the eigen-state of the z-component of the total angular momentum when the photon goes along z-axis. It is expected that photon vortices are created in astronomical systems such as black holes [2]. Gamma-ray bursts (GRBs) are one of the most energetic explosive phenomena in the universe, where highly linear (circular) polarization in the energy region of several hundred keV was observed. It may be generated by synchrotron radiations from relativistic electrons under strong magnetic fields.

The harmonic radiations from a spiral moving electron under a uniform magnetic field is a candidate for photon vortex production. We have theoretically presented that photon vortices are predominantly generated in astrophysical environments with strong magnetic fields such as magnetars or magnetized accretion disks around black holes [3]. This suggests that nucleosynthesis with photons should be changed from that with standard photons. A photon vortex is generated through a transition of an electron between two Landau levels and has a Bessel wave-function. We also calculate the decay widths from an electron in Landau levels and the energy spectra. The present result suggests a possibility that magnetic fields in neutron stars such as magnetar play an important role in the interpretation of many observed phenomena. Magnetars show properties different than normal neutron stars. Particularly large luminosity of photon and neutrino emission attract attention from many researchers. We also discuss a possible method using Compton scattering to identify photon vortices from the universe [4].

[1] L. Allen, et al. Phys. Rev. A 45, 8185 (1992).
[2] F. Tamburini, et al. Nature Phys. 7, 195 (2011).
[3] T. Maruyama, et al. Phys. Lett. B826. 136779 (2022).
[4] T. Maruyama, et al. Sci. Rep. 9, 51 (2019).

43. Cooling Processes of Neutron-Stars with Strong Magnetic Field in a Relativistic Quantum Approaches: Neutrino Anti-neutrino Pair Emission and Direct Urca Processes

Tomoyuki Maruyama[1], A.Baha Balantekin[2], Myung-Ki Cheoun[3], Toshitaka Kajino[4], Motohiko Kusakabef[4], Grant Mathews[5]

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Session: Poster session - II

Speaker: Tomoyuki Maruyama

Neutrino and antineutrino emission is dominant for the cooling process of neutron-stars (NSs). Since neutrino emission rates depend on physical circumstances inside NSs, the study of NS cooling through neutrino emission gives important information for constraining internal NS structures On the other hand, magnetic fields in NSs play important roles in the interpretation of many observed phenomena. In particular, magnetars, which are associated with super strong magnetic fields, have properties different from normal neutron stars (NSs). Thus, phenomena related magnetars can provide a lot of information about the physics of the strong magnetic field. There are several kinds of the cooling processes such as the direct Urca (DU) process, the modified Urca process and the neutrino and anti-neutrino pair emission process through the Bremsstrahlung in NN scattering (NN-pair) In these processes the neutrino emission rates must be affected by the magnetic-field because these processes are restricted by the energy-momentum conservation, and a magnetic field provides additional momentum to the particles. In this work, we study the NN-pair emission [1] and direct Urca [2] process under strong magnetic field in a relativistic quantum approach. We solve exact wave functions for protons and electrons in the states described with Landau levels and calculate neutrino (anti-neutrino) emissions from the transition between two different Landau levels, so that the NN-pair emission can be treated by one-body process. Then we obtain the following results. In 1015 G of the magnetic field, the energy loss of the NN-pair process is much larger than that of the modified Urca process. In addition, the neutrino emission increases as the magnetic field is weaker around 1014-1015 G. Therefore, the neutrino emissivity of the NN pair process must be very effective in relatively low density region. Even the direct Urca process can satisfy the kinematic constraints even in the density regions where this process could not normally occur in the absence of a magnetic field. Thus, the strong magnetic field plays a very important role to increase the neutrino emissivity in NSs with strong magnetic fields.

[1] T.Maruyama et al., Phys. Lett. B 805, 135413 (2020)
[2] T.Maruyama et al., Phys. Lett. B 824, 136813 (2022)

44. Core-collapse Supernovae, Binary Neutron Star Mergers and the Nuclear Equation of State at High Density

Grant Mathews[1], Kedia Atul[1], Luca Boccioli[1]
[1]University of Notre Dame

Session: Wednesday - Session 3: Nuclear Matter and Neutron Stars & Weak interaction II

Speaker: Grant Mathews

The properties of nuclear matter at extremely high densities and temperatures are still fraught with unknowns. Nevertheless, there are two environments in Nature for which the most dense forms of nuclear matter can be formed; these are during the collapse of the core of a massive star to form a supernova, and during the merger of two neutron stars to form a black hole. This talk will highlight recent progress by our group on exploring equation-of-state mysteries of these two environments. In particular, new insight into what determines the explodability of supernova progenitors and the possibility to probe the non-perturbative regime of quark matter are revealed.

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45. Core-collapse Supernova Models with Heavy Axion-like Particles

Kanji Mori[1], Tomoya Takiwaki[2], Kei Kotake[1], Shunsaku Horiuchi[3]
[1]Fukuoka University
[2]National Astronomical Observatory of Japan
[3]Virginia Tech

Session: Thursday - Session 3: Explosive Stellar Objects and Nuclear Physics - Supernovae

Speaker: Kanji Mori

Axion-like particles (ALPs) are a class of hypothetical bosons which feebly interact with ordinary matter. The hot plasma of stars and core-collapse supernovae is a possible laboratory to explore physics beyond the standard model including ALPs. Once produced in a supernova, some of the ALPs can be absorbed by the supernova matter and affect energy transfer. We recently calculated the ALP emission in core-collapse supernovae and the backreaction on supernova dynamics consistently. It is found that the stalled bounce shock can be revived even in one-dimensional models if the coupling between ALPs and photons is as high as $g_{a\gamma} \sim 10^{-9}$ GeV^{-1} and the ALP mass is 40-400 MeV.

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46. Cluster formation in neutron-rich Be and B isotopes

Hideaki Motoki[1], Masaaki Kimura[1], Yoshiki Suzuki[2], Tsuyoshi Kawai[1]
[1]Hokkaido University
[2]RCNP

Session: Friday - Session 2: Nuclear Data for Astrophysics and Related Topics
Speaker: Hideaki Motoki

Cluster formation is a universal phenomenon found in hierarchical layers of matter. The variation of clustering in the isotope chain toward the neutron drip-line is one of such interest. Recently, the negative correlation between the α cluster formation and neutron number in Sn isotopes has been reported by the experiment using the $(p, p\alpha)$ reactions showing the trend opposite to that of Be and B isotopes predicted by theoretical calculations. Although the observed charge radii of Be and B isotopes seem to support the conjecture of the development of clustering toward the neutron drip-line, those radii themselves are not a physical quantity that can directly probe the cluster structure. Here, we have investigated the cluster formations in Be and B isotopes to clarify the possible clustering toward the neutron drip-line using antisymmetrized molecular dynamics (AMD). It has been shown that the sum of α, ^{6}He, and ^{8}He spectroscopic factors increases toward the neutron drip-line, which is consistent with the previous studies.

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47. Nuclear data and theory for the astrophysical r-process

Matthew Mumpower[1]

[1]Los Alamos National Laboratory, USA

Session: Wednesday - Session 1: Explosive Stellar Objects and Nuclear Physics: r process - I

The astrophysical rapid neutron capture (r-) process is thought to be responsible for the production of all of the observed thorium, uranium and plutonium in the cosmos. While nuclear data is continually being produced by radioactive beam facilities, many properties of the heaviest nuclei remain unmeasured. Thus, simulations of the r-process must rely on theory models that can be extrapolated. I review some recent measurements along with theoretical developments relevant for r-process nucleosynthesis. I discuss the production of the actinides, where many challenges remain unsolved as the prime example of the current status of the field.

48. First result from the R3 ring and scope for the r-process nuclei (tentative)

Sarah Naimi[1]

[1]IJCLab, France

Session: Tuesday - Session 4: Facilities and new technology for Nuclear Astrophysics

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49. A systematic study of core-collapse supernovae based on 3D MHD simulations

Ko Nakamura[1], Tomoya Takiwaki[2], Jin Matsumoto[3], Shunsaku Horiuchi[4], Kei Kotake[1]

[1]Fukuoka University
[2]National Astronomical Observatory of Japan
[3]Keio University
[4]Virginia Tech

Session: Thursday - Session 3: Explosive Stellar Objects and Nuclear Physics - Supernovae

Speaker: Ko Nakamura

Systematic studies of core-collapse supernovae have been conducted based on hundreds of one-dimensional artificial models (O'Connor & Ott 2011,2013; Ugliano et al. 2013, Ertl et al. 2015) and two-dimensional self-consistent simulations (Nakamura et al. 2015;2019, Burrows & Vartanyan 2020). We have performed three-dimensional core-collapse simulations for 16 progenitor models covering ZAMS mass between 9 $M_{\odot}$ and 24 $M_{\odot}$. Our models show a wide variety of shock evolution and explosion energy, as well as multi-messenger signals including neutrinos and gravitational waves. We present the dependence of these explosion properties on the progenitor structure.

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50. Multi-Reflection Time-of-Flight technique for precise mass measurements in nuclear astrophysics

Kim Uyen Nguyen[1], Kyung Yuk Chae[1], Ngoc Duy Nguyen[2]
[1]Sungkyunkwan University
[2]Vanlang University

Session: Poster session - I

Speaker: Kim Uyen Nguyen

Nuclear mass is one of the most important input for nucleosynthesis calculations at extreme conditions. However, the masses of exotic isotopes usually have large uncertainties since they are only predicted by various models due to the difficulties in the measurements that originate from their short life-times and low production cross sections. The precise mass of exotic nucleus may provide new insights of nuclear structure as well. Recently, a few approaches have been developed for precise mass measurements. With the advantages of single-ion sensitivity, large mass range, short measurement time, and less expensive construction cost, the multi-reflection time-of-flight mass spectrometer (MRTOF-MS) is considered as a modern technique for precise mass measurement of exotic nuclei and molecules. The mass analyzer is accomplished by using two electrostatic mirrors in a coaxial arrangement to reflect the ions axially and focus them transversally to achieve a stable trajectory. In this work, we showed the optimized potentials on the electrodes of the mass analyzer in both of the mirror-switching and in-trap-lift modes with the kinetic energy of 1.5 keV. The effect of operating conditions, i.e., numbers of reflections, statistics, and beam size, were also investigated. The result shows that the resolving power may be changed by a few factors due to a deviation of 10 percent in the beam size. The results in the present study would be useful for operating MR-TOF spectrometers at RI beam facilities, i.e., RAON, in the future.

Key words: atomic mass, exotic-isotopes, mass analyzer, RI beam

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51. Assessment of the 42Ti(p,g)43V reaction rate for type I X-ray bursts

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[3]Vanlang University

Session: Thursday - Session 4: Explosive Stellar Objects and Nuclear Physics: Explosive Hydrogen Burning II

Speaker: Kim Uyen Nguyen

The 42Ti(p,g)43V reaction rate plays an important role in the nucleosynthesis in type I X-ray bursts. In this work, the 42Ti(p,g)43V rate at temperatures relevant for X-ray bursts has been assessed. The spins, parities, and excitation energies of low-lying 43V levels were calculated with the OXBASH code, and were used, along with a new mass measurement of 43V, to obtain an updated thermonuclear reaction rate for 42Ti(p,g)43V. The rate uncertainties were determined from the uncertainties in the 43V resonance parameters. Our new reaction rate differs from the most widely utilized rate by a factor of five at temperatures up to 3 GK, with reduced uncertainty by a factor of two compared to previous assessments. The final abundances calculated using the new rate differ by more than a factor of two for a number of critical isotopes including 44Ti, 56Ni, 60Zn, and 76Sr isotopes. Details of our approach and implications on X-ray burst nucleosynthesis will be presented.

Keywords: rp-process, nucleosynthesis, proton capture, precise mass, mass uncertainty.

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52. Skyrme Hartree-Fock approach for nucleon radiative capture reactions of astrophysical interest

Le-Anh Nguyen[1], Doan-Quang-Huy Mai[2], Nhut-Huan Phan[2], Minh-Loc Bui[2]
[1]Ho Chi Minh City University of Education (HCMUE)
[2]Institute of Fundamental and Applied Sciences, Duy Tan University (DTU)
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Session: Friday - Session 2: Nuclear Data for Astrophysics and Related Topics
Speaker: Le-Anh Nguyen

The consistent Hartree-Fock calculation from the discrete to the continuum is a powerful tool for the microscopic analysis of nucleon-induced reactions in nuclear astrophysics. The cross sections of nucleon radiative capture reactions were analyzed within the bound-to-continuum potential model. Both single-particle bound and scattering states in the calculation of reduced matrix element of the electromagnetic transition were obtained using the Skyrme Hartree-Fock approach. The low-energy behavior of the astrophysical S factor is investigated.

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53. Current Activities in Nuclear Data for Astrophysics in Vietnam

Nguyen Quang Hung[1]

[1]Institute of Fundamental and Applied Sciences, Duy Tan University

Session: Friday - Session 2: Nuclear Data for Astrophysics and Related Topics

Nuclear data activities for astrophysics in Vietnam have been mainly approached from both theoretical and experimental studies of neutron-capture cross section, nuclear level scheme (NLS), nuclear level density (NLD) and radiative strength function (RSF) of gamma-ray emissions. Experimental studies have been performed based on the neutron-capture (n,γ) reactions with different neutron sources. The latter were obtained by utilizing the neutron filtered technique on a research nuclear reactor at the Dalat Nuclear Research Institute (DNRI), which has produced the quasi-monoenergetic neutron beams of 24, 53, 133, 148 keV, etc [1]. In particular, by using the two-steps gamma cascade (n_{th}, 2γ) reaction with thermal neutron and gamma-gamma coincident spectrometer at DNRI, many new information on the NLS of some nuclei as 172Yb [2], 153Sm [3], 164Dy [4], etc., has been detected, some of which have been evaluated by the ENSDF nuclear database [5]. Theoretical studies have focused on the NLD and RSF owing to a recently proposed microscopic model that bases on the exact pairing plus independent-particle model at finite temperature (EP+IPM) coupled with the phonon-damping model (PDM) [6]. The calculated/predicted NLDs and RSFs have been recently used as inputs in the TALYS reaction code to describe the (n,γ) reaction cross section as well as the Maxwellian averaged cross section (MACS) [7]. This talk will briefly introduce the past, present, and future activities in nuclear data for astrophysics in Vietnam.

[1] P. N. Son, V. H. Tan, T. T. Anh, and M. X. Trung, J. Korean Phys. Soc. 59, 1757 (2011).
[2] N. N. Anh, N. X. Hai, P. D. Khang, N. Q. Hung, and H. H. Thang, Nucl. Phys. A 964, 55 (2017).
[3] N. N. Anh, N. Q. Hung, N. X. Hai, P. D. Khang, A. M. Sukhovoj, L. V. Mitsyna, H. H. Thang, and L. H. Khiem, Phys. Rev. C 100, 024324 (2019).
[4] N. K. Uyen, K. Y. Chae, N. N. Duy, S. M. Cha, M. Kwag, K. Duhyun, L. T. Phuc, N. Q. Hung, P. D. Khang, N. X. Hai, H. H. Thang, and N. N. Anh, Nucl. Phys. A 1007, 122136 (2021).
[5] N. Nica, Nucl. Data Sheets 170, 1 (2020).
[6] N. Q. Hung, N. D. Dang, and L. T. Q. Huong, Phys. Rev. Lett. 118, 022502 (2017).
[7] N. N. Le, S. Cristallo, D. Vescovi, L. T. Phuc, and N. Q. Hung, Nucl. Phys. A 1023, 122450 (2022).

54. Astrophysical Constraints on Self Interacting Dark Matter

Quynh Lan Nguyen[1]

[1]University of Notre Dame

Session: Tuesday - Session 1: Big Bang Cosmology and Primordial Nucleosynthesis

In this talk, we will present a mechanism that provides self-interacting dark matter that can explain the small-scale structure problems such as the core cusp and too big to fail issues. We summarize simulations of self-interacting dark matter in models for galaxy formation and evolution. Then, constraints on the self-interacting dark matter with the cosmic microwave background and gravitational wave are summarized.

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55. Sensitivity of alpha-decay half-lives and fission barriers to the r-process calculation

Thu Quyen Nguyen Thi[1]

[1]Van Lang University

Session: Poster session - I

The calculation of the r-process abundance depends on either nuclear inputs or dynamical conditions of the astrophysical sites. In the present study, we study the sensitivity of the r-process abundance to the alpha-decay rates and fission barriers of heavy nuclei. The alpha-decay half-lives were estimated using semi-empirical models and taken from the newly updated database (NUBASE2020). The fission barriers were deduced using the Thomas-Fermi model and micro-macroscopic approaches which were based on the FRDM and HFB21 mass models. We found that the recent uncertainties in the alpha-decay rates and fission barriers of the heavy exotic nuclei results in a large change in the r-process abundance, which is up to 3 orders of magnitude for the nuclei beyond Fe. The alpha decay and fission significantly impact the abundance at the low entropy in the range of 100 – 250 kB/baryon, but they become less important in the higher entropy winds. The results of this work indicate that, together with neutron capture and beta decay, the alpha decay and fission of heavy nuclei still have a certain impact on the r-process calculation. Subsequently, more precise measurements for the alpha-decay half-lives and mass of the exotic heavy isotopes are necessary to reduce the uncertainty in the astrophysical calculation of the r-process.

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56. Effects of primordial magnetic field on the formation rate of dark matter halos

Rahul Prasad Nigam[1], Cheera Varalakshmi
[1]BITS Pilani

Session: Poster session - II
Speaker: Rahul Prasad Nigam

We construct and demonstrate a method for computing the formation rate of the dark matter halo in the hierarchical model set up. This method uses the Press-Schecter distribution for the halos and hence applies only to the spherical halos. But this can be generalized to ellipsoidal structures also if one uses the Sheth-Torman distribution. After obtaining the formation rate, we study the effect of primordial magnetic field on the dynamics of these halos. We investigate the effect for different field strengths and conclude that a magnetic field stronger than 10 nG would impact the halos larger than 10^8 solar masses while a weaker field affects the formation rate of smaller halos.

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57. Presolar Grain Isotopic Ratios as Constraints to Nuclear and Stellar Parameters of Asymptotic Giant Branch Star Nucleosynthesis

Sara Palmerini[1,2]

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[2]INFN Perugia

Session: Friday - Session 3: Meteorite Analysis and Isotopic Abundance

Recent models for evolved low-mass stars (with M <=3 Mo), undergoing the asymptotic giant branch (AGB) phase assume that magnetic flux-tube buoyancy drives the formation of 13C reservoirs in He-rich layers. We illustrate their crucial properties, showing how the low abundance of 13C generated below the convective envelope hampers the formation of primary 14N and the ensuing synthesis of intermediate-mass nuclei, like 19F and 22Ne. In the mentioned models, their production is therefore of a purely secondary nature. Shortage of primary 22Ne has also important effects in reducing the neutron density. Another property concerns AGB winds, which are likely to preserve C-rich subcomponents, isolated by magnetic tension, even when the envelope composition is O-rich. Conditions for the formation of C-rich compounds are therefore found in stages earlier than previously envisaged. These issues, together with the uncertainties related to several nuclear physics quantities, are discussed in the light of the isotopic admixtures of s-process elements in presolar SiC grains of stellar origin, which provide important and precise constraints to the otherwise uncertain parameters. By comparing nucleosynthesis results with measured SiC data, it is argued that such a detailed series of constraints indicates the need for new measurements of weak-interaction rates in ionized plasmas, as well as of neutron-capture cross sections, especially near the N = 50 and N = 82 neutron magic numbers. Nonetheless, the peculiarity of our models allows us to achieve fits to the presolar grain data of a quality so far never obtained in previously published attempts.

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58. Constraints on big bang nucleosynthesis in Starobinsky gravity model with one additional term RabRab

Jubin Park[1,2], Myung-Ki Cheoun[1,2], Chae-min Yun[1,2], Dukjae Jang[3]
[1]Soongsil University
[2]OMEG institute
[3]Institute for Basic Science

Session: Tuesday - Session 1: Big Bang Cosmology and Primordial Nucleosynthesis

Speaker: Jubin Park

We investigate big bang nucleosynthesis (BBN) in Starobinsky gravity model with one additional term RabRab. This model includes various forms of cosmic evolution beyond the standard cosmic evolution based on the Einstein gravity model. Considering this interesting and rich forms of cosmic evolution, we calculate the primordial abundances of 4He, D, 3He, 7Li and 6Li during the BBN period and compare these values with the most recent observation data. We find that the constraint conditions can be most strongly constrained by recent observations of deuterium abundance as well as 4He abundance. In this talk, we introduce the interesting and important results mentioned above and discuss the impliction of these acquired constraints.

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59. Stellar 24 keV neutron capture cross section of W-186

Pham Son[1], Thi Tu Anh Trinh[2]
[1]Nuclear Research Institute
[2]Dalat University

Session: Poster session - II
Speaker: Pham Son

The neutron capture cross sections of W-186(n,g)W-187 reaction at 24 keV neutron energy were measured relative to the standard capture cross section of Au-197 by activation. The 24 keV filtered neutron beam at the Dalat nuclear research reactor has been used in the activation experiment. The measured cross section was normalized to obtain the Maxwellian averaged neutron capture cross sections at 30 keV for nucleosynthesis calculations.

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60. Role of the density-isospin dependence of G-matrix interaction in the study of (^{3}He,t) charge-exchange reactions

Nhut Huan Phan[1]

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Session: Poster session - I

The isobaric single charge-exchange reactions, which are determined directly by the Fermi transition ($\Delta L = 0, \Delta S = 0, \Delta T = 1$) between the isobaric analog state (IAS) and the ground state of target, can be used as a tool to study bulk properties of nuclear matter and probed the neutron skin thickness in heavy nucleus. In this work, the (^{3}He,t)IAS reactions are studied within the framework of Lane model. The folding model using the Argonne v18 G-matrix interaction derived from Brueckner–Hartree–Fock calculation is used to determine the microscopic nucleus-nucleus optical potential. The insight of the in-medium nucleon-nucleon interaction plays a key role in the study of some properties in nuclear matter such as symmetry energy, especially nuclear astrophysical aspects of neutron stars, core-collapse supernova, and kilonova. The results indicate that the density-isospin dependence of the G-matrices play a non-negligible role in the description of the experimental data.

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61. Neutron induced reactions for nuclear astrophysics: an indirect approach

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Session: Tuesday - Session 3: First Generation Stars and Galactic Chemical Evolution II

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

[1] R.G. Pizzone et al. Eur. Phys. Jour. A, 56, 199 (2020).

62. Survey of the astrophysical conditions that produce light heavy elements in metal-poor stars

Thanassis Psaltis[1], Almudena Arcones[1,2], Fernando Montes[3,4], Camilla Hansen[5], Maximillian Jacobi[1], Hendrik Schatz[6,4]

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[4]FRIB
[5]University of Frankfurt
[6]MSU

Session: Wednesday - Session 1: Explosive Stellar Objects and Nuclear Physics: r process - I

Speaker: Thanassis Psaltis

The light heavy elements between strontium and silver, can be synthesized in a primary process in either neutron- (weak r-process) or proton-rich (p-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. 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 heavy element production, such as HD 122563 [4]. Our preliminary results suggest that there are specific combinations of 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] S. Honda *et al.*, Astrophys. J. **666** 1189 (2007)

63. The impact of star-formation driven outflows in chemical evolution models and circumgalactic enrichment of galaxies

Michael Romano[1]

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Session: Tuesday - Session 3: First Generation Stars and Galactic Chemical Evolution II

Galactic feedback driven by massive stars and active galactic nuclei (AGNs) plays a fundamental role in regulating galaxy formation and evolution. In particular, intense starburst episodes could generate strong outflows able to suppress star formation (SF) by expelling large amount of dust and metals out of the galaxies, possibly enriching their circum (or even inter) galactic media. Galactic outflows are ubiquitous in high-redshift star-forming galaxies (SFGs) and quasars. However, local dwarf galaxies are particularly sensitive to feedback processes and offer a unique opportunity to study these phenomena in great details. State-of-the-art chemical evolution models predict very efficient outflows in such galaxies in order to reproduce their observational properties. To test these expectations, we searched for outflow signatures in a sample of 30 local dwarf SFGs drawn from the Dwarf Galaxy Survey. We made use of Herschel/PACS archival data to detect atomic outflows in the broad wings of observed [CII] 158 μm line profiles. We found that SF-driven outflows are less efficient than those induced by local AGNs, with typical mass-loading factors (i.e., the ratio between the outflow rate and the star-formation rate) slightly greater than unity. However, these findings could be underestimated by a factor 3 if accounting for the other phases of the interstellar medium (i.e., molecular and ionized gas). Our results could be used as input for chemical models, posing new constraints on the processes of dust growth and destruction in the interstellar medium of galaxies.

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64. Nuclear Physics of Accreting Neutron Stars

Hendrik Schatz[1]

[1]Michigan State University

Session: Thursday - Session 1: Explosive Stellar Objects and Nuclear Physics : Explosive Hydrogen Burning I

Accreting neutron stars show a broad range of observable phenomena that probe the properties of neutron stars. These phenomena are powered by nuclear reactions of proton-rich and neutron-rich unstable isotopes and include various types of X-ray bursts as well as the cooling neutron star crust in transiently accreting systems. Burst and crust observables are linked as the ashes of bursts determines composition and nuclear reactions in the crust, and heat generated in the crust impacts burst behavior. I will review the current understanding of the relevant nuclear processes and their link to astrophysical observables. I will also present the status of experimental programs at NSCL and FRIB facility to address open nuclear physics questions in X-ray bursts and accreted neutron star crusts, including the new SECAR recoil separator.

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65. Neutron induced reactions and unstable nuclei: recent THM investigations at astrophysical energies

Maria Letizia Sergi[1,2] for the ASFIN collaboration
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[2]INFN-LNS

Session: Thursday - Session 4: Explosive Stellar Objects and Nuclear Physics: Explosive Hydrogen Burning II

Neutron induced reactions on unstable nuclei play a significant role in the nucleosynthesis of the elements in the cosmos. Their interest range from the primordial processes occurred during the Big Bang Nucleosynthesis up to the "stellar cauldrons" where neutron capture reactions build up heavy elements. In the last years, several efforts have been made to investigate the possibility of applying the Trojan Horse Method (THM) to neutron induced reactions mostly by using deuteron as "TH-nucleus". Here, the main advantages of using THM will be given together with a more focused discussion on the recent 7Be(n,alpha)4He and the 14N(n,p)14C reactions. The former reaction was studied via the THM application to the quasi-free 2H(7Be,aa)p reaction and it represents the extension of the method to neutron-induced reactions in which an unstable beam is present. The 14N(n,p)14C reaction was studied via the 2H(14N,p14C)p experiment performed at INFN-LNS via a 50 MeV 14N beam provided by the TANDEM accelerator. These applications open new frontiers in the application of the method (i.e. the study of 7Be+d or 11C+alpha reactions) extending its range of applicability for contributing to astrophysically relevant problems.

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66. Flagship Projects of JINR in Astroparticle and Relativistic Heavy Ion Physics

Boris Sharkov[1]

[1]Joint Institute for Nuclear Research

Session: Friday - Session 3: Meteorite Analysis and Isotopic Abundance

Neutrino and astroparticle physics project BAIKAL-GVD is aiming at the identification of still unknown astrophysical sources of ultra-high energy (exceeding tens of TeV) neutrinos. The identification of sources will help to elucidate mechanisms of galaxies creation and evolution. Baikal-GVD - flagship experiment of JINR with its leading role in international collaboration. New experience in the detector design, construction, deployment, maintenance, simulation and data analysis is being gained. Expectations for the breakthrough discoveries is high. Relativistic heavy ion collider NICA covers an intriguing energy range for transition from hadronic to partonic states, appearance of 1-st order phase transition and possible critical End Point, transition from baryon to meson dominance, development of Lattice QCD. All that is also related to actively developing astrophysical studies as well. NICA Complex is JINR flagship facility, it will be put in operation in 2023.

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67. The production of 10Be in the supernova neutrino process with updated nuclear reaction rates

Andre Sieverding[1], Jaspreet Randhawa[2], Daniel Zetterberg[3], Riccardo Mancino[4], Tan Ahn[2], Richard J. DeBoer[2], Gabriel Martinez-Pinedo[4], William R. Hix[1]

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[3]University of Tennessee
[4]GSI Helmholtz Centre for Heavy Ion Research

Session: Wednesday - Session 3: Nuclear Matter and Neutron Stars & Weak interaction II

Speaker: Andre Sieverding

The radioactive isotope 10Be is among those that have been present when the solar system formed. We review the production of this isotope in core-collapse supernovae via the ν-process considering results from modern multi-dimensional simulations, as well as the sensitivity to nuclear reactions. Recent nuclear experiments suggest that the cross-section of the most important destructive reaction, 10Be(p,α)7Li, is higher than previously assumed, significantly reducing the expected production of 10Be by supernovae.

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68. Constraint on the neutron star model using high-frequency quasi-periodic oscillations in magnetar

Hajime Sotani[1]
[1]RIKEN

Session: Wednesday - Session 2: Nuclear Matter and Neutron Stars & weak interaction I

Quasi-periodic oscillations (QPOs) observed in giant flare from the magnetar, which is a strongly magnetized neutron star, are crucial information for extracting the neutron star properties. To theoretically explain the QPOs newly observed in GRB 200415A, we systematically examine the crustal torsional oscillations. Then, we find that the observed QPOs can be identified with several overtone frequencies of crustal oscillations, if the value of the combination of the nuclear saturation parameters, ς, is well-selected, depending on the neutron star mass and radius. Thus, we can inversely constrain the neutron star mass and radius for GRB 200415A by comparing to the appropriate range of ς expected with the fiducial value of nuclear saturation parameters obtained from the terrestrial experiments. We further make the neutron star mass and radius constraint more severe by assuming that the neutron star radius is almost the same as that for the neutron star model, whose central density is twice the nuclear saturation density. The resultant neutron star models are consistent with the constraints obtained from the other astronomical and experimental observations.

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69. Theoretical Approach to the Weak Rates in Nuclear Astrophysics

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Session: Wednesday - Session 2: Nuclear Matter and Neutron Stars & weak interaction I

Nuclear weak rates relevant to the study of astrophysical processes in stars are evaluated with the use of shell-model Hamiltonians that prove to be successful in describing Gamow-Teller (GT) and spin-dipole (SD) strengths in nuclei. Electron-capture and β-decay rates in stellar environments induced by GT transitions in sd-shell and pf-shell are applied to study nuclear URCA processes in degenerate ONeMg cores in stars with 8-10 solar masses [1] and synthesis of iron-group nuclei in type Ia supernovae [2]. Structure of ^{31}Mg in the island of inversion are studied with an effective interaction in sd-pf shell obtained by the extended Kuo-Krenciglowa method [3]. The weak rates for the nuclear pair with A=31, which are important for the Urca process in neutron star crusts [4], are evaluated with the effective interaction [5]. The multipole expansion method of Walecka as well as the Behrens-Buhring (BB) method are used to evaluate the weak rates induced by first- and second-forbidden transitions. The SD strengths and e-capture rates for ^{78}Ni are evaluated by shell-model with full pf-sdg shells including up to 5p-5h excitations outside the ^{78}Ni-core [5,6]. Results obtained are compared with RPA calculations and the effective rate formula [7]. Electron-capture rates for the second-forbidden transition in ^{20}Ne are evaluated by taking account of the conserved-vector-current (CVC) relation for the transverse E2 matrix element. Difference in the rates between the Walecka and BB methods is found to be small as far as the CVC relation is satisfied [5]. Possible important contributions of the forbidden transition to heating of the ONeMg core by double e- captures on ^{20}Ne in a late stage of the evolution of the core and implications on the final fate of the core, whether core-collapse or thermonuclear explosion, are discussed [5,8,9].

[1] H. Toki, T. Suzuki, K. Nomoto, S. Jones, and R. Hirschi, Phys. Rev. C 88, 015806 (2013); T. Suzuki, H. Toki, and K. Nomoto, ApJ. 817, 163 (2016).
[2] K. Mori, M. Famiano, T. Kajino, T. Suzuki et al., ApJ. 833, 179 (2016). K. Mori, T. Suzuki, M. Honma, et al, Astrophys. J. 904, 29 (2020).
[3] N. Tsunoda, T. Otsuka, N. Shimizu, M. Hjorth-Jensen, K. Takayanagi and T. Suzuki, Phys. Rev. C 95, 021304 (2017). [4] H. Schatz et al., Nature 505, 62 (2014).
[5] T. Suzuki, Prog. Part. Nucl. Phys. 126, 103974 (2022).
[6] Y. Tsunoda, T. Otsuka, N. Shimizu, H. Monma, and Y. Utsuno, Phys. Rev. C 89, 031301 (R) (2014).
[7] C. Sullivan, E. O'Connor, R. G. T. Zegers, T. Grubb, and S. M. Austin, ApJ. 816, 40 (2016). [8] S. Zha, S-C. Leung, T. Suzuki, and K. Nomoto, ApJ. 886, 22 (2019).
[9] O. S. Kirsebom et al., Phys. Rev. Lett. 123, 262701 (201); Phys. Rev. C 100, 065805 (2019).

70. Current status of KAGRA and observation of gravitational waves from compact binary coalescences

Hideyuki Tagoshi[1]

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Topic: Wednesday - Session 3: Nuclear Matter and Neutron Stars & Weak interaction II

Since the first direct observation of gravitational waves in September 2015, gravitational waves generated by binary black hole mergers and binary neutron star mergers have already been observed about 90 times. In particular, the binary neutron star merger in August 2017 was an extremely impactful astronomical phenomenon, as not only gravitational waves but also gamma-ray bursts were observed almost simultaneously and were also observed by astronomical instruments at all wavelengths based on sky-location information from the gravitational wave observation. Currently, there are two LIGO detectors in US, Virgo in Europe, and KAGRA in Japan. These detectors are planning to perform the next observing run which starts in the spring of 2023, and more gravitational signals are expected to be observed. KAGRA is preparing to contribute to gravitational wave astronomy in the coming observating runs. In this talk, I will discuss the observation of gravitational waves from coalescing compact binaries so far, the status of the KAGRA detectors, and the future prospects for gravitational wave observations.

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71. 12C+12C fuson reaction rate from a microscopic model

Yasutaka Taniguchi[1]

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Session: Friday - Session 1: Stellar Evolutions and Hydrostatic Burning Processes & Underground Nuclear Astrophysics

12C+12C fusion reaction rate is essential for explosional phenomena, such as X-ray superbursts and type Ia supernovae, and the evolution of massive stars. However, it has significant uncertainties in low-energy regions. Experimentally, the cross sections are tiny due to the thick Coulomb barrier. Theoretically, treatments of the rearrangement in the fusion reactions, in which alpha and p decay are dominant exit channels, are challenging. Extrapolations from higher energies, such as CF88, have been used for astrophysical simulations. Strong suppressions in low-energy regions called the hindrance model have also been proposed. We evaluate the 12C+12C fusion reaction rate using a microscopic model, the antisymmetrized molecular dynamics. Using the model, we calculated the fusion cross sections treating coupling of the entrance (12C+12C) and exit channels (alpha+20Ne and p+23Na). We obtained resonances that enhance the fusion cross sections in low-energy regions, which rejects the hindrance model.

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72. Nuclear physics for astrophysics at IFIN-HH, Romania

Livius Trache[1]
[1]IFIN-HH

Session: Tuesday - Session 4: Facilities and new technology for Nuclear Astrophysics

I will present the activities and results of doing nuclear astrophysics research in IFIN-HH Bucharest-Magurele, Romania, in the last few years. Mostly from the Nuclear Astrophysics Group (NAG), which continued the two basic types of experimental activities:

- Direct measurements at low and very low energies with beams from the local 3 MV tandetron accelerator. Extra sensitivity is provided by the ultra-low background laboratory in a salt mine and by a beta-gamma coincidence setup BEGA.

- Indirect measurements done with beams at international facilities with radioactive beams: Texas A&M University, RIKEN With help from colleagues, I will present some theory advances, too: EoS and stellar dynamics & nucleosynthesis.

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73. Studying the Luminosity Function of Lyman Alpha Emitters selected behind 17 lensing clusters from from Multi-Unit Spectroscopic Explored (MUSE/VLT) observations

Thi Thai Tran[1], Roser Pello [2], Tuan-Anh Pham [3], MUSE consortium

[1]Vietnam National Space Center

[2]Aix Marseille Univ, CNRS, CNES, LAM, Marseille, France

[3]Department of Astrophysics, Vietnam National Space Center

Session: Tuesday - Session 2: First Generation Stars and Galactic Chemical Evolution I

Speaker: Thi Thai Tran

We present the results of our study of the Luminosity Function of 521 LAEs having a Lya luminosity down to 10^{39} erg s-1 with redshift in the range (2.9, 6.7) based on deep observations of 17 clusters obtained with MUSE at the ESO/ VLT. Taking advantage of the magnification effect, this unique data allows us to set strong constraints on the contribution of the LAE population to cosmic reionization. We discuss the shape of the Luminosity Function up to the faintest limits and its evolution with redshift. The faint end of the Luminosity Function displays a steep slope, roughly in agreement with previous results obtained by de la Vieuville et al. (2019) using only four clusters.

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74. Experimental studies of β-decay properties among other important nuclear data inputs for the r-process nucleosynthesis at the RIKEN RIBF

Vi Ho Phong[1,2], Shunji Nishimura[1] for the BRIKEN and RIBF207-ZDMRTOF collaboration

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Session: Thursday - Session 2: Explosive Stellar Objects and Nuclear Physics: r process - II

Speaker: Vi Ho Phong

In the stellar rapid (r-) neutron-capture process nucleosynthesis, successive neutron-capture reactions under a large neutron-density environment push the matter toward the neutron-rich side until the beta-decay processes compete and heavier elements are formed. When neutron ceases, matters along the r-process path beta-decay to stability, yielding final r-process abundance pattern observed in the metal-poor stars [1] and the solar system [2]. Such a complex nuclear reaction network involves many neutron-rich nuclei whose properties such as nuclear masses, β-decay half-lives, β-delayed neutron emission probabilities play important roles in connecting the elemental distribution with the astrophysical conditions [3]. β-decay properties and masses of very neutron rich nuclei are among the subjects of several experimental programs at RIKEN Radioactive Isotope Beam Facility (RIBF) [4, 5, 6] where the obtained data span across nuclear regions relevant to the prominent r-process peaks. In this talk, recent experimental results [7, 8, 9, 10] and the planned programs will be highlighted.

[1] I. U. Roederer et al., Astrophys. J. Suppl. Ser. 260, 27 (2022).
[2] C. Sneden, J. J. Cowan, and R. Gallino, Annu. Rev. Astron. Astrophys. 46, 241 (2008).
[3] M. R. Mumpower, R. Surman, G. McLaughlin, A. Aprahamian, Prog. Part. Nucl. Phys. 86 (2016).
[4] I. Dillmann and A. Tarifeño-Saldivia, Nucl. Phys. News 28, 28 (2018).
[5] S. Nishimura, Prog. Theo. Exp. Phys. 2012, 03C006 (2012).
[6] M. Rosenbusch et al., arXiv preprint arXiv:2110.11507 (2021).
[7] R. Yokoyama et al., Phys. Rev. C 100, 031302(R) (2019).
[8] O. Hall et al., Phys. Lett. B 816, 136266 (2021).
[9] V. H. Phong et al., Phys. Rev. C 100, 011302 (2019).
[10] V. H. Phong et al., submitted.

75. Comprehensive mass measurements of short-lived nuclides

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Session: Tuesday - Session 4: Facilities and new technology for Nuclear Astrophysics

The study of the origins of heavy elements has been a critical issue for nuclear physics since short-lived nuclides far from the stability line are involved in synthesizing them. Notably, the rapid neutron capture process (r-process), which is considered to contribute to half of the nuclides heavier than iron, requires more knowledge of the nuclear properties of very neutron-rich nuclides. The pathway of the r-process is determined by the neutron separation energies, which are directly derived from the differences in the atomic masses of neighbor isotopes. Furthermore, the ”waiting points” of the process, which lead to the so-called r-process peak, are on the neutron magic numbers. A good indicator of the magic number is the shell gap energies derived from the double difference of the atomic masses. A comprehensive mass measurements campaign is in progress at Riken RIBF, where three RI-beam facilities (BigRIPS, GARIS, and KISS) provide the widest variety of nuclides using different reactions: projectile fragmentation, in-flight fission, fusion, and multi-nucleon transfer. Their beam energies are multi-orders of magnitude different, and the beam emittances are also very different. Different gas catchers with rf-carpets are used to accumulate the ions from these RI-beam facilities to ion traps. The multi-reflection time-of-flight mass spectrographs (MRTOF) measure the masses of these trapped ions. The MRTOF allows precise measurements of multiple ion species at once. We achieved a 1,000,000 mass resolving power via 10 ms of short flight time. This campaign has measured the atomic masses of more than 400 nuclides, from titanium isotopes to superheavy elements, dubnium. We continue measurements for more exotic and essential nuclides for r-process studies.

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76. r-Process Radioisotopes from Near-Earth Supernovae and Kilonovae

Xilu Wang[1]

[1]Institute of High Energy Physics, Chinese Academy of Sciences

Co-authors: Adam Clark, Jonathan Ellis, Adrienne Ertel, Brian Fields, Brian Fry, Liu Zhenghai, Jesse Miller, Rebecca Surman

Session: Wednesday - Session 1: Explosive Stellar Objects and Nuclear Physics: r process - I

Speaker: Xilu Wang

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 60Fe 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, 244Pu has now been detected, mostly overlapping with 60Fe pulses. However, the 244Pu flux may extend to before 12Myr ago, pointing to a different origin. Motivated by these observations and difficulties for *r*-process nucleosynthesis in SN models, we propose that ejecta from a KN enriched the giant molecular cloud that gave rise to the Local Bubble where the Sun resides. Accelerator Mass Spectrometry (AMS) measurements of 244Pu and searches for other live isotopes could probe the origins of the *r*-process and the history of the solar neighborhood, including triggers for mass extinctions, e.g., at the end of the Devonian epoch, motivating the calculations of the abundances of live *r*-process radioisotopes produced in SNe and KNe that we present here. Given the presence of 244Pu, other *r*-process species such as 93Zr, 107Pd, 129I, 135Cs, 182Hf, 236U, 237Np and 247Cm should be present. Their abundances and well-resolved time histories could distinguish between SN and KN scenarios, and we discuss prospects for their detection in deep-ocean deposits and lunar regolith. We show that AMS 129I measurements in Fe-Mn crusts already constrain a possible nearby KN scenario. Thus, we urge searches for *r*-process radioisotopes in deep-ocean Fe-Mn crusts, and in the lunar regolith samples brought to Earth recently by the Chang'e-5 lunar mission and upcoming missions including Artemis.

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77. Experimental studies of neutron-rich nuclei around N = 126 and beyond at KEK isotope separation system

Yutaka Watanabe[1], Yoshikazu Hirayama[1], Momo Mukai[2], Toshitaka Niwase[1], Peter Schury[1], Marco Rosenbusch[1], Michiharu Wada[1], Shun Iimura[3], Sota Kimura[2], Yuta Ito[4], Sun-Chan Jeong[1], Hiroari Miyatake[1], Hironobu Ishiyama[2], Jun Young Moon[5], Takashi Hashimoto[5], Akihiro Taniguchi[6], Andrei Andreyev[7]

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Session: Thursday - Session 2: Explosive Stellar Objects and Nuclear Physics: r process - II

Speaker: Yutaka Watanabe

The nuclear properties such as lifetimes and masses of the neutron-rich nuclei are important parameters to investigate the astrophysical rapid neutron capture process (r-process). However, the difficulty in the production of those neutron-rich nuclei, especially at the waiting points on the neutron closed shell $N = 126$ and beyond, makes their experimental studies difficult. Therefore, the theoretical nuclear models play crucial roles in the simulation of the r-process nucleosynthesis. The experimental studies of those nuclear properties and nuclear structures provide significant inputs to those theoretical models to improve their predictability for the neutron-rich nuclei relevant to the formation of the r-abundance peak around $A = 195$ and actinide elements such as uranium and thorium.

We are developing KEK Isotope Separation System (KISS) at RIKEN RIBF facility to produce and separate those nuclei for their spectroscopic studies [1-3]. The multi-nucleon transfer (MNT) reactions between the ^{136}Xe beam and the ^{198}Pt target are employed to produce the nuclei around $N = 126$ [4-5]. The KISS consists of an argon-gas-cell-based laser ion source and an isotope separation on-line system, which allow to provide the mass and atomic number selectivity. The detector systems consisting of a multi-segmented gas counter [6-7] combined with high-purity germanium detectors and a Multi-Reflection Time-Of-Flight Mass Spectrograph (MRTOF-MS) make it possible to perform their beta-gamma spectroscopy, mass spectroscopy, and laser spectroscopy. Recently, we have also successfully measured masses in the actinide region using the MNT reactions between the ^{238}U beam and the ^{198}Pt target.

In this presentation, we will report the present status of the KISS including the recent experimental results of nuclear spectroscopy and the future plan.

[1] Y. Hirayama *et al.*, Nucl. Instrum. and Methods B 353 (2015) 4.
[2] Y. Hirayama *et al.*, Nucl. Instrum. and Methods B 376 (2016) 52.
[3] Y. Hirayama *et al.*, Nucl. Instrum. and Methods B 463 (2020) 425.
[4] Y.H. Kim *et al.*, EPJ Web of conferences 66 (2014) 03044.
[5] Y.X. Watanabe *et al.*, Phys. Rev. Lett. 115 (2015) 172503.

[6] M. Mukai *et al.*, Nulc. Instrum. and Methods A 884 (2018) 1.
[7] Y. Hirayama *et al.*, Nucl. Instrum. and Methods A 997 (2021) 165152.

78. Galactic Chemical Evolution with short lived radioisotopes

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Session: Tuesday - Session 2: First Generation Stars and Galactic Chemical Evolution I

In addition to the insights gained by studying the galactic evolution of chemical elements, short lived radioisotopes contain additional information on astrophysical nucleosynthesis sites. Meteorites can carry information about the nucleosynthetic conditions in the early Solar System using short lived radioisotopes [1][2], while detections of live isotopes of cosmic origin in the deep sea crust help us understand recent nucleosynthetic processes in the Solar neighborhood [3]. We use a three dimensional, high resolution chemical evolution code to model the conditions at the time of the formation of the Solar System, as well as to explain why different classes of radioisotopes should often arrive conjointly on Earth, even if they were produced indifferent sites. Further, we included radioisotope production into a cosmological zoom-in chemodynamical simulation of a Milky Way-type galaxy, which provides a map of gamma-rays from the decay of radioactive Al-26 consistent with the observations by the INTEGRAL instrument [4]. Further, we'll apply the insights gained from these models to draw conclusions about the rapid neutron capture process, one of the most important nucleosynthesis process for the formation of the heaviest elements.

[1] Lugaro, Ott, Kereszturi, 2018 PrPNP 102, 1L
[2] Côté et al., 2021 Science 371, 945
[3] Wallner et al., 2021 Science 372, 742W
[4] Kretschmer et al., 2013 A&A 559, A99

79. Neutrino-induced nucleosynthesis in supernovae as a probe of neutrino mass hierarchy and the roles of neutrino-nucleus and radioactive nuclear reactions

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Session: Poster session - II
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The ν-process nucleosynthesis in core-collapse supernovae is a sensitive probe of unknown neutrino mass hierarchy through the Mikheyev–Smirnov–Wolfenstein effect of neutrino flavor conversion in matter. The ν-process depends on not only the neutrino-induced ν-nucleus reactions but also many other nuclear reactions. Based on updated theoretical calculations and experimental result of these reaction cross sections, we first discuss the dependence of the resultant nuclear abundances of ^{7}Li, ^{7}Be, ^{11}B, and ^{11}C on cross sections of the ν reactions on ^{4}He, ^{12}C and ^{16}O, and 91 different strong and electromagnetic interaction cross sections, related to ^{7}Li, ^{7}Be, ^{11}B, and ^{11}C. It is found that the $^{11}C(\alpha,p)^{14}N$ reaction rate is more effective to the ^{11}C abundance than other reactions we studied. The uncertainty of the $^{11}C(\alpha,p)^{14}N$ reaction is estimated in the present study taking into account experimental data and resonance structure. We secondly discuss how to constrain the hierarchy from the careful and quantitative comparison between our theoretical calculation and the measured isotopic abundance ratio $^{7}Li/^{11}B$ in SiC-X presolar grains, which are called the supernova grains. It is found that inverted hierarchy is more favorable statistically although the confidence level is weak at 2-σ. Reduction of the uncertainties in the reaction rates with precise experiments takes the key to constrain the neutrino mass hierarchy.

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