8th p-process workshop 2024

Wednesday 16 October 2024 - Friday 18 October 2024

Book of Abstracts

Contents

Afternoon session / 1

Effect of the explosion properties on γ-process nucleosynthesis in core-collapse supernovae

Author: Lorenzo Roberti[1]

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The γ-process in core-collapse supernovae (CCSNe) can produce a number of neutron-deficient stable isotopes heavier than iron (p-nuclei). However, current model predictions do to not fully reproduce the solar abundances. We investigate the impact of different explosion energies and parameters on the nucleosynthesis of p-nuclei, by studying stellar models with different initial masses and CCSN explosions. We find that the total p-nuclei yields are only marginally affected by the CCSN explosion prescriptions if the γ-process production is already efficient in the stellar progenitors due to a C-O shell merger. In most of CCSN explosions from progenitors without C-O shell merger, the γ-process yields increase with the explosion energy up to an order of magnitude, depending on the progenitor structure and the CCSN prescriptions. The trend of the p-nuclei production with the explosion energy is more complicated if we look at the production of single p-nuclei. The light p-nuclei tend to be the most enhanced with increasing the explosion energy. In particular, for the CCSN models where the α-rich freeze-out component is ejected, the yields of the lightest p-nuclei increase by up to three orders of magnitude. We provide the first extensive study using different sets of massive stars of the impact of varying CCSN explosion prescriptions on the production of the p-nuclei. Unlike previous expectations and recent results in the literature, we find that the average production of p-nuclei tends to increase with the explosion energy. We also confirm that the pre-explosive production of p-nuclei in C-O shell mergers is a robust result, independently from the subsequent explosive nucleosynthesis. A realistic range of variations in the evolution of stellar progenitors and in the CCSN explosions might boost the CCSN contribution to the galactic chemical evolution of p-nuclei.

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Afternoon session / 2

Constraining the Astrophysical γ Process: Cross Section Measurements of (p,γ) Reactions in Inverse Kinematics

Author: Artemis Tsantiri[1]

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Understanding the origin of the *p* nuclides has been an ongoing challenge within the astrophysics community for over 60 years. In the extensively researched γ process the reaction flow involves photodisintegration reactions on a vast network of mostly radioactive isotopes. However, as experimental cross sections of γ-process reactions are very limited, and almost entirely unknown when it comes to radioactive nuclei, the related reaction rates are based on Hauser-Feshbach (HF) theoretical calculations and therefore carry large uncertainties. Therefore, it is crucial to develop techniques to accurately measure these important reactions within the astrophysically relevant Gamow window with radioactive beams. The SuN group at FRIB has been developing such a program for the past decade.

This work focuses on two of the first measurements of (p,γ) reactions in inverse kinematics with this setup, namely the ^{82}Kr(p,γ)^{83}Rb with a stable beam, and the ^{73}As(p,γ)^{74}Se reaction in our first radioactive beam experiment. Specifically the latter reaction is found to be of significant importance to the final abundance of the lightest p-nucleus, ^{74}Se, as the inverse reaction ^{74}Se(γ,p) is the main destruction mechanism of ^{74}Se. The experiments took place at Michigan State University using the ReA facility. The ^{82}Kr and ^{73}As beams were directed onto a hydrogen gas cell located in the center of the Summing NaI(Tl) (SuN) detector and the obtained spectra were analyzed using the γ-summing technique. In addition to the total cross section measurement of the particular reaction, statistical properties of the compound nucleus (nuclear level density and γ-ray strength function) can also be extracted. Results from the two experiments along with their comparison to standard statistical model calculations using the NON-SMOKER and TALYS codes will be presented.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 3

Exploring the Origin of the Rarest Stable Isotopes Naturally Occurring on Earth with Photon Beams

Author: Adriana Banu[1]

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This presentation brings into focus ^{78,80}Kr(γ,γ'), ^{93}Mo(γ,n) and ^{90}Zr(γ,n) cross section measurements carried out using real photons at the HIGS/TUNL facility. The overarching physics motivation for these experimental investigations is to advance knowledge on a forefront topic in nuclear astrophysics –the nucleosynthesis beyond Fe of the rarest stable isotopes naturally occurring on Earth (the origin of p-nuclei) by constraining the statistical models that are used to calculate the unknown stellar reaction rates. In particular, these stellar reaction rates are highly sensitive to the low-energy tail of the nuclear photon strength function (pSF).

Due to its high selectivity for dipole excitations, real photon scattering via nuclear resonance fluorescence (NRF) is the method of choice to extract experimentally, with high accuracy and model independently, the dipole pSFs in stable nuclei. The quasi-monochromatic and linearly polarized photon beam of very high flux available at HIGS makes this facility ideal for investigation of photoabsorption reaction cross section with p-nuclei as targets.

The NRF measurements on ^{78,80}Kr will provide for the first time information for the low-energy

part of the E1-pSF in ^{78,80}Kr, as direct input into the p-process nucleosynthesis modeling. In this presentation we will report on the status of data analysis of these very recent measurements.
The cross sections for ^{94}Mo(γ,n) and ^{90}Zr(γ,n) reactions were measured with high precision, from the respective neutron emission thresholds up to 13.5 MeV. In order to constrain the dipole pSFs in the A $\approx$ 90 mass region, the measured cross sections were compared with predictions of Hauser-Feshbach statistical model calculations using two different dipole pSF models. Since these models are based on fundamentally different physics, they can reflect the existing uncertainties affecting the pSF, and also the impact of such uncertainties on reaction cross sections and corresponding astrophysical reaction rates. In this presentation we will showcase our final results that show how sensitive the ^{94}Mo(γ,n) and ^{90}Zr(γ,n) stellar reaction rates can be to the corresponding measured cross sections, as discussed in detail in our recent publication, Phys. Rev. C 99, 025802 (2019).

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 4

Production of p-nuclides in accreting neutron star common envelopes

Author: Sophie Abrahams[1]

Co-authors: Alexander Hall-Smith [1]; Alison Laird [1]; Christian Diget [1]; Chris Fryer [2]

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In massive-star binary systems, upon reaching later stages of stellar evolution one star can expand as a giant and envelope its companion in what is called a common envelope phase. The enveloped companion, here a neutron star, begins to accrete matter. The angular momentum of the accreting material results in the formation of an accretion disk. Accretion of hydrogen rich onto common-envelope-phase neutron stars can result in material ejected from the accretion disk having undergone burning near the neutron star's surface [1]. Not much is understood about what nucleosynthesis occurs in this system. However, Keegans et al. (2019) found that accreting neutron star common envelopes have the potential to impact galactic chemical evolution (GCE) [1].
Our preliminary results show that this astrophysical scenario can produce large amounts of light p-nuclides 92Mo, 96Ru and 98Ru - upwards of one order of magnitude more than their initial abundances in our simulations. This is significant as these isotopes are all underproduced in current p-process models and their origins are not known [2, 3].
The presented work builds on Keegans et al. (2019), which modelled accreting neutron star common envelopes without the inclusion of angular momentum, and Abrahams et al. (2023), which presented initial results on updated models which included the impact of angular momentum [1,4]. We will present yields from our common envelope simulations and discuss the nucleosynthesis which leads to high production of particular light p-nuclides.

[1] Keegans J., Fryer C.L., Jones S.W., Côte B., Belczynski K., Herwig F., Pignatari M., et al., 2019, MNRAS, 485, 620. doi:10.1093/mnras/stz368

[2] Roberti L., Pignatari M., Psaltis A., Sieverding A., Mohr P., Fulop Z., Lugaro M., 2023, A&A, 677, A22. doi:10.1051/0004-6361/202346556

[3] Travaglio C., Rauscher T., Heger A., Pignatari M., West C., 2018, ApJ, 854, 18. doi:10.3847/1538-4357/aaa4f7

[4] Abrahams S.E.D., Fryer C., Hall-Smith A, Laird A.M., Diget C., 2023, EPJWC, 279, 10002. doi:10.1051/epjconf/2023279

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Morning session / 5

Updates on P-Process Related Measurements Using the Summing Technique with HECTOR

Author: John McDonaugh[1]

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The High EffiCiency TOtal absorption spectrometeR (HECTOR) is a summing spectrometer comprised of 16 NaI(Tl) segmented crystals with 2 PMTs on each segment to allow for optimal light collection from incident γ-rays. The arrangement of the 16 NaI(Tl) crystals allows for almost total 4π angular coverage to capture and sum together all γ-rays following the dexcitation of the compound nucleus formed during the reaction. An overview of the recent and current measurements with HECTOR to constrain the p-process will be discussed, including: 1) Cross-sections measured with HECTOR for (p,γ) and (α,γ) reactions on ^{102}Pd and ^{108,110}Cd and their impact on the predictions of the γ-process abundances along with new branching point temperature constraints for ^{111}In(γ,n)/(γ,p). 2) Cross-section measurements over possible resonant structures for ^{92,94}Mo(p,γ) and their reaction rate impacts. 3) Current work on measuring the cross-sections for (p,γ) and (α,γ) on ^{112,114,116}Sn and ^{108}Pd(p,γ)^{109}Ag. 4) Future projects to continue measurements in this mass region. This project was supported by the National Science Foundation (NSF) under grant numbers PHY-2011890 and PHY-2310059.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Afternoon session / 6

Astrophysical signatures in meteorites and their components, with emphasis on p-process

Authors: Ulrich Ott[1]; Ulrich Ott[None]

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Study of the isotopic compositions of meteorites and their variations has revealed signatures that can be related to processes of nucleosynthesis in stars. Generally, the size of variations scales inversely with the size of the phases that show such "anomalies". For the small effects seen in "bulk"it is not always trivial distinguishing astrophysical variations from such of more mundane origin. The largest effects are seen in "pre-solar grains", i.e., "stardust", and the study of silicon carbide grains, in particular, provides a wealth of information on the s-process. Bulk compositions of primitive chondrites, on the other hand, define the "Solar System abundances"(e.g., [1]). Among isotopic variations that are relevant with respect to p-process nucleosynthesis and cosmochemistry, prominent and having received the most attention are observations related to the presence and decay in the Early Solar System of now-extinct radioactive nuclides such as 92Nb, 97Tc and 146 Sm (see, e.g., [2]). Especially useful for setting constraints on properties of the p-process and possible variability are those cases where an element has more than one p-only isotope, like, e.g., Mo, Ru and Xe. Interestingly, Mo isotopes indicate no variability in the 92Mo/94 Mo ratio, nor in the ratio of p- to r-process contributions, between presolar SiC grains and bulk meteorite samples [3], while [4] favor a different p/r mixing ratio for Ru in refractory metal nuggets from the Allende meteorite. Finally, the ratio of the two p-only Xe isotopes 124Xe/126 Xe in presolar nanodiamonds is distinctly different from that in the average p-process contribution to the Solar System [5].
References: [1] Lodders K. (2003) ApJ 591, 1220. [2] Lugaro M. et al. (2018) Progr. Part. Nucl. Phys. 102, 1. [3] Stephan T. et al. (2019) ApJ 877, 101. [4] Fischer-Gödde M. et al. (2018) Astron. J. 156, 176. [5] Ott U (2014) Chemie der Erde-Geochemistry 74, 519-544.

Please select a keyword related to your abstract:

Observations

Length of presentation requested:

Oral presentation: 25 min + 5 min questions (Review-type talk)

Afternoon session / 7

The impact of systematic and statistical nuclear uncertainties on the p-process nucleosynthesis

Author: Sébastien Martinet[None]

Co-author: Stephane Goriely

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The p-process nucleosynthesis can explain proton-rich isotopes that are heavier than iron, which are observed in the Solar System, but discrepancies still persist (e.g. for the Mo and Ru p-isotopes).

We investigate both the systematic and statistical uncertainties associated with theoretical nuclear reaction rates of relevance during the p-process and explore their impact on the p-process elemental production in exploding rotating massive stars and in type Ia supernovae.

We discuss the effect of nuclear uncertainties on the p-process production and especially their impact on the Mo and Ru p-isotopes production.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Afternoon session / 8

Impact of temperature- and density-dependent decay rates on the production of p-nuclei in low-mass AGB stars

Author: Balázs Szányi[1]

Co-authors: Andrés Yagüe López [2]; Amanda Karakas [3]; Maria Lugaro [4]

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By definition, the proton-rich isotopes that cannot be reached by neutron-capture processes are the *p*-only isotopes or the *p*-nuclei. However, several *p*-nuclei can produced by the *s* process in low-mass AGB stars, e.g. (1) ^{94}Mo by two consecutive neutron captures of ^{92}Mo and following the decay of ^{93}Zr and ^{94}Nb, (2) ^{108}Cd depending on the β-decay rate of ^{107}Pd and ^{108}Ag, and (3) ^{152}Gd due to the operation of ^{151}Sm and ^{152}Eu branching points. We present how the use of temperature- and density-dependent β-decay and electron-capture rates instead of terrestrial/constant values affects the production of ^{94}Mo, ^{108}Cd and ^{152}Gd in *Monash s*-process nucleosynthesis models.

Length of presentation requested:

Oral presentation: 8 min + 2 min questions (Poster-type talk)

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Morning session / 9

Total reaction cross sections: a basic building block for astrophysical reaction rates

Author: Peter Mohr[1]

[1] *HUN-REN Institute for Nuclear Research (ATOMKI), Debrecen, Hungary*

Corresponding Author: mohr@atomki.hu

Thirty years ago, the pioneering experiment on ^{44}Sm(α,γ)^{148}Gd by Somorjai $et\ al.$ [1] (discussed first at a workshop in Budapest in 1994) showed that the prediction of astrophysical reaction rates of α-induced reactions is very uncertain. The α-nucleus potential (AOMP) was realized as the main source of the wide range of predictions. Only a few years ago, it became clear that the wide range of predictions results from the tail of the imaginary part of the AOMP at large radii. This problem was overcome by the construction of the Atomki-V2 AOMP which is based on a folding potential in the real part and a very narrow and sharp-edged imaginary part. The Atomki-V2 AOMP is able to predict the total reaction cross section of α-induced cross sections at low energies for intermediate mass and heavy target nuclei with small uncertainties, typically far below a factor of two [2,3]. This was verified by a series of experiments of mainly (α,n) type (see also presentation by Gy. Gyürky).

Recently, this work was extended to the study of total reaction cross sections of various projectiles and targets, including tightly bound, weakly bound, and halo-type projectiles. A comparison between the different systems under study can be made using the so-called geometrical reduction scheme, leading to reduced energies $E_{\rm red}$ and reduced cross sections $\sigma_{\rm red}$. A normalization to a

reference calculation with the Atomki-V2 AOMP helped to reveal hitherto unknown details of the $\sigma_{\rm red}$ vs. $E_{\rm red}$ systematics, in particular towards low energies [4]. This opens the way towards an improved assessment of the energy dependence of the total ^{12}C + ^{12}C cross section.

[1] E. Somorjai $et\ al.$, Astron. Astroph. **333**, 1112 (1998)
[2] P. Mohr $et\ al.$, Phys. Rev. Lett. **124**, 252701 (2020)
[3] P. Mohr $et\ al.$, At. Data Nucl. Data Tables **142**, 101453 (2021)
[4] P. Mohr, Europ. Phys. J. A, submitted

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Afternoon session / 10

Accelerator-based experiments for the p-process from Vravron to Budapest and beyond

Author: György Gyürky[None]

Corresponding Author: gyurky@atomki.hu

Since the very first p-process workshop in Vravron, Greece (2002), theoretical study of the astrophysical p-process is accompanied by nuclear physics experiments. These experiments always try to follow the requirements from astrophysical models and reaction cross sections relevant to the p-process have been measured on various type of reactions with various techniques. These experiments do not only provide data for p-process network calculations, but often identify some key nuclear physics quantities where our knowledge is not sufficient yet and further experiments are needed.
In this talk I will try to review the experimental efforts (in Atomki and worldwide) aiming at the better understanding of the synthesis of those still somewhat elusive p-isotopes.

Length of presentation requested:

Oral presentation: 25 min + 5 min questions (Review-type talk)

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 11

Elastic alpha scattering on Sm: adding experimental data to constrain a-OMP

Author: Charles Soto[1]

[1] *IP2I, Lyon*

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The p-nuclei, rich in protons, are created through a specific nucleosynthesis process involving numerous reactions such as (γ, n), (γ, p), and (γ, α) in explosive astrophysical events like supernovae. The research aims to adjust astrophysical scenarios to replicate the observed abundances of these nuclei. A significant challenge in this research is the uncertainty in alpha-nucleus optical potentials (α-OMP), crucial for the formation of heavy p-nuclei. Our collaboration aims to characterize α-OMP through elastic alpha scattering on Samarium isotopes (148Sm and 144Sm) at 20 MeV. These isotopes are quite important for p-process nucleosynthesis and are a relevant choice due to the existing data on 144Sm, offering a comparison possibility with 148Sm. This experiment was conducted at ALTO (IJCLab) in March 2024 by a collaboration between IP2I, GANIL, Demokritos, and IJCLab. The experimental setup focused on angular distribution measurement, involving high-resolution energy measurements using a split-pole spectrometer and silicon telescopes to better constrain the backward angles, where the OMP diverge the most. Simulations using Talys and SToGS (GEANT4 frameworks) were employed for preparation and analysis. The results of this experiment are currently being analyzed, and a complete cross-section angular distribution should be ready by October 2024.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 12

The p-process in exploding rotating massive stars

Authors: Arthur Choplin[1]; Stephane Goriely[None]

[1] *Université Libre de Bruxelles*

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Massive stars are thought to experience p-process nucleosynthesis when they explode as supernovae (and during their last hydrostatic burning stages to a smaller extent). Thanks to the mixing induced by rotational instabilities, rotating massive stars can experience an enhanced s-process during the core helium-burning phase. This can significantly affect the subsequent p-process during their explosions. In this talk, I will discuss how the p-process is altered in exploding rotating massive stars, and especially how the p-process yields depend on the initial rotation rate, the explosion energy and the nuclear uncertainties.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Morning session / 14

Exploring p-process through statistical model code TALYS

Author: Satabdi Mondal[1]

Co-authors: Balaram Dey [1]; Deepak Pandit [2]; Enakshi Senapati [1]; Srijit Bhattacharya [3]

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The astrophysical p-process is crucial for the synthesis of proton-rich isotopes (p-nuclei) that cannot be formed via the s-process or r-process. Occurring primarily in supernovae, this process involves photodisintegration reactions like (γ, n), (γ, p) and (γ, α), driven by high-energy gamma photons, (p, γ) reactions are also relevant in this context. Recent experimental advances, including inverse kinematics and activation methods, have provided essential cross-section data, enhancing the accuracy of theoretical model codes such as TALYS, NON-SMOKER, etc.
In this work, the proton capture (p, γ) cross-sections for p-nuclei in the mass range A = 74–108 have been calculated using TALYS. Consistent input models, including the back-shifted Fermi gas model for level density parameters, Goriely's hybrid (mic-mac) γ-strength function (option V), and local optical model parameters, are used. Adjusting the 'fiso' parameter for isospin corrections significantly improved our results, which match the experimental data, especially near the energy threshold where the (p,n) channel opens.

References

[1] C. Rolfs, Cauldrons in the Cosmos (University of Chicago Press,1988).
[2] S. Mondal et al., IJMP E, Vol. 31, No. 7 (2022) 2250064
[3] A. J. Koning et al., Nuclear reaction program (NRG-report 21297/04.62741/P).
[4] J. Bork et al., Phys. Rev. C, 58(1), 524 (1998).

Length of presentation requested:

Oral presentation: 8 min + 2 min questions (Poster-type talk)

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 15

The role of gamma-induced experiments in the p-process

Author: Dario Lattuada[1]

Co-authors: Giovanni Luca Guardo ; K.A. Chipps [2]; Steven Pain [3]; catalin matei

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Photonuclear reactions are critical in p-process nucleosynthesis, which produces rare proton-rich isotopes (p-nuclei) through γ-induced reactions like (γ, n), (γ, p), and (γ, α). These reactions occur at temperatures from 1.5 to 3.5 GK, typically in explosive environments such as ty-pe II or type Ia supernovae. Theoretical estimates of p-nuclei nucleosynthesis are uncertain, requiring accurate photodisintegration reaction rates for about 3000 stable proton-rich nuclei. Our experimental campaign at the High Intensity Gamma-Ray Source (HIγS) focused on measuring the (γ, p) and (γ, α) reactions of ^{112}Sn and ^{102}Pd, whose cross-sections were previously only theoretically calculated, usually using a Hauser-Feshbach approach. Understanding the alpha optical model potential (α-OMP) is crucial for these calculations, especially at astrophysical energies, as it is one of the main sources of uncertainties.
Utilizing the SIDAR array of highly-segmented, high-resolution silicon detectors coupled with the

ORRUBA/GODDESS data acquisition system, the P-Process HIγS Collaboration measured the charged particle spectra of the fusion products. Through dedicated and accurate beam dia-gnostics, the total and partial cross sections can be efficiently derived with small uncertainties and compared to predictions.
In this presentation, the experimental setup, preliminary analysis, and future plans will be discussed.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Afternoon session / 16

Investigation of 170,172Yb(□, □)173,175Hf cross sections in a stacked-target experiment

Author: Martin Müller[1]

Co-authors: Andreas Zilges [1]; Benedikt Machliner [1]; Felix Heim [1]; Svenja Wilden [1]

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Some of the largest nuclear physics uncertainties in p-process nucleosynthesis stem from the α-optical model potential (α-OMP). Especially, at high masses the available α-OMPs often fail to accurately reproduce experimental results [1]. If the α-emission probability in a photodisintegration reaction is comparable to the emission probabilities for other particles, uncertainties related to the α-OMP can significantly alter the p-process path, leading to large uncertainties in the calculated abundances [2]. This is the case for the ^{168}Hf nucleus and sensitivity studies have shown, that the ^{168}Hf$(\gamma, \alpha)^{164}$Yb reaction is a key reaction in the production of the ^{168}Yb p-nucleus and is very sensitive to the α-OMP [3]. A stacked-target activation experiment was performed to measure the ^{170,172}Yb$(\alpha,)$ reactions at the *Cologne Clover Counting* setup. By combining the results with a previous measurement of ^{168}Yb$(\alpha,)$ cross sections, the α-OMPs evolution with the proton-to-neutron ratio was investigated [4]. The resulting constrains on the α-OMP can then be used to improve the extrapolation to ^{164}Yb.
Supported by the DFG (ZI 510/8-2).
[1] P. Mohr *et al.*, Phys. Rev. Lett. **124** (2020) 252701.
[2] W. Rapp *et al.*, Astrophys. J. **653** (2006) 474.
[3] T. Rauscher *et al.*, Mon. Not. R. Astron Soc. **463** (2016) 4153.
[4] M. Müller *et al.*, Phys. Rev. C **107** (2023) 035804.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 18

p-process from Slow White Dwarf Mergers

Author: Umberto Battino[None]

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The astrophysical origins of the heaviest stable elements that we observe today in the Solar System are still not fully understood. Recent studies have demonstrated that H-accreting white dwarfs (WDs) in a binary system exploding as type Ia supernovae could be an efficient p-process source beyond iron. However, both observational evidence and stellar models challenge the required frequency of these events. In this work, we calculate the evolution and nucleosynthesis in slowly merging carbon-oxygen WDs, exploring the impact of different accretion rates, mixing properties and compositions of both the primary and secondary white dwarf. As our models approach the Chandrasekhar mass during the merger phase, the ^{22}Ne(α,n)^{25}Mg neutron source reaction is activated in the external layers of the primary WD, where the carbon-rich material accreted from the secondary WD is burned via the ^{12}C+^{12}C reaction, which provides the necessary α-particles via the ^{12}C(^{12}C,α)^{12}Ne channel. Most importantly, surface carbon-burning is ignited in all our models, once the accretion rate onto the primary is larger than 2 10^{-6} $M_\odot$ yr^{-1}. The resulting neutron capture abundance distribution closely resembles a weak s-process one and peaks at Kr-Rb-Sr-Y-Zr, which are overproduced by a factor of 1000 compared to solar. The mass of the most external layers enriched in first-peak s-process elements crucially depends on the accretion rate of the CO-rich material from the secondary white dwarf, ranging between 0.05 M and ˜0.1 M . These results indicate that slow white dwarf mergers could potentially produce the lightest p-process isotopes (such as ^{74}Se, ^{78}Kr, ^{84}Sr, ^{92}Mo and ^{94}Mo) in significant abundance via γ-induced reactions, if they explode via a delayed detonation mechanism. Alternatively, they may eject the unburned external layers highly enriched in first peak s-process elements in the case of a pure deflagration. In both cases, we propose for the first time that slow WD mergers in binary systems may be a new relevant source for elements heavier than iron.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Afternoon session / 19

Convective-Reactive Nucleosynthesis in O-C Shell Mergers

Author: Joshua Issa[1]

Co-authors: Falk Herwig [1]; Pavel Denisenkov [1]

[1] *University of Victoria*

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O-C shell mergers in massive stars have been proposed as a potential site for the production of p-process isotopes. These mergers provide a convective-reactive environment where the timescales for the nucleosynthesis of C-shell ashes such as $^{20}\mathrm{Ne}$ and convective mixing of species are of the same order. However, the nucleosynthetic pathways of these convective-reactive processes remain largely unexplored. In this study, we use the $15M_\odot, Z=0.02$ model from the NuGrid stellar data set II (Ritter et al., 2018) to create a detailed post-processed model of an O-C shell merger event. Three preliminary experiments were conducted by varying the reaction rates of $^{20}\mathrm{Ne}(\gamma,\mathrm{p})^{16}\mathrm{O}$, the (γ,p) rates for the odd-Z isotopes $^{31}\mathrm{P}$, $^{35}\mathrm{Cl}$, $^{39}\mathrm{K}$, $^{45}\mathrm{Sc}$, and all (p,γ) rates by a factor of 10 up and down from their default values. The results show that altering the $^{20}\mathrm{Ne}(\gamma,\mathrm{p})^{16}\mathrm{O}$ rate has the strongest effect on the production of p-nuclei, notably $^{115}\mathrm{Sn}$, $^{138}\mathrm{La}$, $^{162}\mathrm{Er}$, $^{168}\mathrm{Yb}$, and $^{180}\mathrm{Ta}$. The other two experiments show a smaller impact on all isotopes. We will present the results of a full multizone Monte Carlo analysis of the impact from varying all reaction rates.

Length of presentation requested:

Oral presentation: 8 min + 2 min questions (Poster-type talk)

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Afternoon session / 20

Self-consistent neutrino-driven core-collapse supernova explosions of low-mass electron-capture like stellar progenitors

Author: Noshad Khosravi Largani[None]

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I will discuss recent simulation results of neutrino-driven supernova explosions launched from a low-mass 9.6 solar mass iron-core progenitors of low metalicity. The supernova simulations are based on general relativistic neutrino radiation hydrodynamics in spherical symmetry featuring six-species Boltzmann neutrino transport and a complete set of neutrino opacities. Special emphasis is devoted to the treatment of the Urca processes at the mean-field level.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Afternoon session / 21

Nucleosynthesis of low-mass electron-capture like stellar progenitor explosions

Author: Tobias Fischer[None]

Corresponding Author: tobias.fischer@uwr.edu.pl

One of the questions of heavy element nucleosynthesis associated with massive star explosions will be discussed in this talk, namely the realization of possible conditions enabling neutron capture processes. It depends sensitively on the neutrino fluxes and spectra as well as their evolution, which, in turn are determined by the treatment of neutrino transport in the supernova models. It is found that in self-consistent spherically symmetric supernova explosion models, the presence of the inverse neutron decay as electron antineutrino opacity channel prevents any neutron-rich ejecta and hence the nucleosynthesis proceeds along the neutron-deficient side.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Morning session / 22

A new tool to understand isotopic anomalies in meteorites

Author: Gábor Balázs[1]

Co-authors: Lorenzo Roberti [2]; Marco Pignatari [3]; Maria Lugaro

[1] *Konkoly Observatory, HUN-REN CSFK*

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In this talk, I will show the SIMPLE python code we have developed and its capabilities. The code allows us to use 6 different sets of core-collapse supernova model sets with 15, 20 and 25 solar mass progenitors in order to compare the nucleosynthesis process data from the simulated supernova models with the isotope ratios measured from meteorites. The main objective of the code is to help understand the origin of the anomalies found in the measurements for different isotopes -for example in the case of Molybdenum- and to facilitate the application of several CCSNe models published over the years.

Length of presentation requested:

Oral presentation: 8 min + 2 min questions (Poster-type talk)

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Afternoon session / 23

Strontium-84 enrichments in presolar grains provide first evidence of p-process nucleosynthesis in core-collapse supernovae

Author: Ishita Pal[None]

Corresponding Author: palishita13@gmail.com

Presolar grains are relic dust grains from dying stars. These microscopic dust particles are found in primitive Solar System materials. Their distinct isotopic compositions record the nucleosynthetic processes in their parent stars and the galactic chemical environment in which these stars formed. We studied presolar graphite grains of high-density type from the Murchison meteorite and found five grains with subgrains that show enrichments in 84Sr compared to the solar abundance. 84Sr is the neutron-deficient isotope of strontium that can be produced in the deep oxygen-rich interior of high-mass stars that end their lives as core-collapse supernovae. The observed 84Sr-excesses cannot be produced in low-mass asymptotic giant branch stars, the source of most high-density presolar graphites found in meteorites. High-density graphites with embedded 84Sr-excesses are, instead, compatible with a core-collapse supernovae origin. The graphite subgrains condensed from carbon-rich materials in the outer layers of core-collapse supernovae, where 84Sr was destroyed by neutron-captures during hydrostatic evolution of the stars and their final explosion. Based on current theoretical stellar models, a few percent contribution from the inner regions of core-collapse supernovae, that are enriched in p-process nuclides, to the outer carbon-rich regions is the most likely explanation for the observed enrichment of 84Sr in the subgrains of the high-density graphites. Thus, in this study, we present the first observational evidence that core-collapse supernovae produce and eject isotopes made by the p-process.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Observations

Morning session / 24

Nucleosynthesis of the p-process isotopes, still an open problem for nuclear astrophysics

Author: Marco Pignatari[1]

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The production of the p-process nuclei in stars is still an open problem for nuclear astrophysics. Current supernova models seem to not produce enough of them, and their high abundances in the Solar System represent a challenge for stellar nucleosynthesis. Different scenarios have been proposed to solve these issues, but more work is needed. In this context, the p-process nuclei provide an ideal diagnostic to study the nucleosynthesis in supernovae in specific parts of the ejecta, and/or to define the relative contribution from different types of supernovae to galactic chemical evolution. Since the conditions favouring the production of the p-process nuclei in stars have been identified in stellar models, it is also possible to study their production taking into account the impact of nuclear uncertainties, and disentangle them from current stellar model uncertainties. I will discuss some of the main puzzles still affecting the p-process nucleosynthesis, and its relevance within the more general context of stellar nucleosynthesis.

Length of presentation requested:

Oral presentation: 25 min + 5 min questions (Review-type talk)

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Morning session / 25

P-process signatures in presolar grains

Author: Reto Trappitsch[1]

[1] *EPFL*

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Presolar stardust grains, bona-fide particles that formed in the death throes of dying stars and can today be extracted from meteorites, allow us to probe their parent star's isotopic composition. These grains are the sole messenger for directly probing the isotopic composition of the proton-rich isotopes associated with the p-process(es), since these isotopes generally only make up a minute part of each element. In my talk, I will present the current state of p-process signatures in presolar grains, especially focusing on molybdenum isotopes, and discuss potential implications for the astrophysical site(s) of the p-process. Challenges and future prospects for this research area will also be discussed.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Observations

Afternoon session / 26

A new 1D+ simulation pipeline to calculate explosion properties, remnants, and nucleosynthesis yields from core-collapse supernovae

Author: Luca Boccioli[None]

Corresponding Author: lbocciol@berkeley.edu

In this talk, I will introduce STIR, a model that incorporates neutrino-driven convection in 1D simulations of core-collapse supernovae (Couch et al. 2020, Boccioli et al. 2021). This model has the advantage of being more sophisticated than other 1D models adopted for similar studies and is able to reproduce recent results from 2D and 3D state-of-the-art simulations of core-collapse supernovae. Given its relatively small computational cost, this 1D model can be used to set up a robust pipeline to efficiently run hundreds (or even thousands) of simulations. I will highlight some recent work performed with this pipeline, and comment on ongoing work to analyze the nucleosynthesis signature of hundreds of pre-SN progenitors with different metallicities, and binary properties, computed with different stellar evolution codes.

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Morning session / 27

On the distribution of p-process nuclides 144Sm and 142Nd in the protoplanetary disc

Authors: J. M. J. Ball[None]; M. Schönbächler[None]; Paul Frossard[1]

[1] *nstitute of Geochemistry and Petrology, ETH Zürich*

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Heterogeneities in the nucleosynthetic composition of meteorites for the p-nuclides are less common than for s-process isotopes and have been identified for 84Sr (e.g. Charlier et al., 2021), 144Sm (e.g. Andreasen and Sharma, 2006), 174Hf (Peters et al., 2017) and 180W (Cook et al., 2018). The origin of p-nuclide heterogeneity is unclear and is not related to specific presolar grains found in primitive meteorites. The 144Sm variations in meteorites are particularly interesting because they can be used as a proxy for the extinct p-nuclide 146Sm (half-life of 103 Ma) that decays into 142Nd. This radioactive decay system is crucial in constraining the timing of early differentiation into the mantle and crust that took place on rocky bodies. However, Sm isotope data is scarce and high precision measurements are required to place constraints on the origin and extent of p-process heterogeneity

for Sm and Nd in our solar system. We therefore developed an analytical method to measure high-precision Sm isotope compositions and analysed both the Nd and Sm isotope compositions of an extensive set of meteorites.
Here we report significant variations from +31 ± 17 down to -154 ± 17 parts per million for the 144Sm/152Sm ratio in meteorites. The origin of the p-process variations in meteorites may partly related to the addition of early formed solar condensates bearing significantly different nucleosynthetic composition (e.g. Brennecka et al., 2013) to dust from the protoplanetary disc. This new data highlights the heterogeneous nature of the nebular cloud in p-nuclides at the earliest stages of the protoplanetary disc evolution. Combining these results with recent determinations of the natural s-process trend in meteorites (Frossard et al., 2022) and r-process composition estimates defined as the residuals of the s-process abundances (Bisterzo et al., 2014), we corrected the 144Sm/152Sm and 142Nd/144Nd ratios to display only p-process variations. Using this trend we constrained the p-process contribution of 142Nd to 13 ± 6 %. This contribution is considerably higher than estimates of 1 to 4 % derived from astrophysical s-process models (Arlandini et al., 1999; Bisterzo et al., 2014). Our independent estimate of the p-process contribution on 142Nd from meteorites can be used to refine astrophysical models for p- and s-processes.

References:
Andreasen R. and Sharma M. (2006) Science 314, 806-809. Arlandini C. et al. (1999) ApJ 525, 886-900. Bisterzo S. et al. (2014) ApJ 787, 10. Brennecka G. A. et al. (2013) Proc. Natl. Acad. Sci. USA 110, 17241-17246. Charlier B. L. A. et al. (2021) Science Advances 7, eabf6222. Cook D. L. et al. (2018) Earth Planet. Sci. Let. 503, 29-36. Frossard P. et al. (2022) Science 377, 1529-1532. Peters S. T. M., et al. (2017) Earth Planet. Sci. Let. 459, 70-79

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Observations

Morning session / 28

Details of (α,n) experiments aiming at the investigation of the Atomki-V2 potential

Author: Zsolt Mátyus[None]

Corresponding Author: matyus.zsolt@atomki.hu

The heavier p-isotopes can be produced through the γ-process, which involves a complicated reaction network. In this nucleosynthesis process (γ,α) reactions play a key role. To calculate such a reaction network, many input parameters are essential. One of these is the α-nucleus optical model potential (AOMP), which describes the interaction between the α particle and the nucleus. This potential can be studied with (α,n) reactions at low energies. At the HUN-REN Atomki several (α,n) experiments [1] were carried out in the last few years. In this short talk, the details of the recently published [2] Te(α,n) experiments will be presented.
Further details of the Atomki-V2 AOMP will be given in the talk of P. Mohr.
[1] Gy. Gyurky et al., Phys. Rev. C 107, 025803 (2023)
[2] Zs. Matyus et al., Phys. Rev. C 109, 065806 (2024)

Length of presentation requested:

Oral presentation: 8 min + 2 min questions (Poster-type talk)

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 29

The α-nuclear potentials along the Sn isotopic chain

Author: Daniel Galaviz[None]

Corresponding Author: galaviz@lip.pt

The lack of knowledge of α-nuclear potentials in unstable nuclei constitutes one of the main uncertainties associated to the modeling of the production of heavy p-nuclei [1,2]. Global parametrizations used to model the elastic scattering cross section of α particles on radioactive nuclei may differ up to a factor of 2, with a corresponding impact in the determination of (γ,α) reaction rates. This highlights the need of experimental data in the region around the heavy p-nuclei to solve this issue.

In this talk I will present the joint efforts for a detailed study of the mass dependence of the α-nuclear potentials along the tin isotopic chain, including the first measurement of the elastic scattering of α-particles on exotic heavy nuclei. The radioactive beam experiment was performed at the HIE-ISOLDE facility at CERN. It profited from the use of innovative thin silicon films with high amounts of He [3] and the high intensity beams for the isotopes 108, 109 and 110-Sn produced at ISOLDE. Further detailed angular distributions were measured on the stable isotopes 116Sn and 118Sn at the ATOMKI facility. I will introduce both experimental setups and the current status of the analysis of the data. The results from these efforts will provide the first precise study of α-nuclear potentials along the isotopic chain with the highest number of stable isotopes in nature, improving the knowledge of this nuclear quantity and as such reducing the uncertainties in network calculation studies.

References:

[1] A. Simon, et al. J. Phys. G 44, 064006 (2017)

[2] W. Rapp, et al. Astrophys. J. 653, 474 (2006).

[3] V. Godinho, et al. ACS Omega 1(6), 1229 (2016)

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 30

Development of the Charge-Exchange Oslo Method and Application Towards Constraining Reaction Rates for Nucleosynthesis of Cosmochronometer 92Nb

Author: Neshad Deva Pathirana[None]

Corresponding Author: devapath@frib.msu.edu

Charge-Exchange (CE) reactions are an important tool for studying the spin-isopin response of nuclei. They can be utilized to obtain information about interactions mediated by the weak nuclear force, such as β and electron capture decay. Using the proportionality between Gamow-Teller strength (B(GT)) and the CE differential cross section, B(GT) distributions can be extracted indirectly. Since CE reactions are not limited to a narrow Q value window, they provide information that is complementary to information obtained from β and electron capture decay. Such data are necessary for constraining reaction rates that happen in dense and hot astrophysical environments. In the near future, it is planned to combine measurements in which GT strengths are extracted with γ-decay measurements, utilizing the Oslo method to extract level densities and γ-ray strength functions, which are also important for constraining astrophysical reaction rates. It is proposed to measure the 92Zr(3He,t+γ) reactions at 420 MeV in RCNP to develop the Charge-Exchange Oslo (CE-Oslo) method and to extract reaction rates for the nucleosynthesis of cosmochronometer 92Nb. This high precision study will lay a solid foundation for using the CE-Oslo method in future (p,n+γ) experiments in inverse kinematics with rare isotopes and make it possible to simultaneously extract nuclear level densities (NLDs), γ-ray strength functions (γSFs), β-decay strengths and (β-delayed) neutron decay probabilities (Pn) on neutron-rich unstable nuclei, which are important for several nucleosynthesis processes, including the r, i, γ, and ν processes. The high resolution available for (3He,t) experiments at RCNP will make it possible to extract level densities in two independent manners: by using the Oslo technique and by using the fine-structure analysis. From the measurement on 92Zr, it will be possible to extract level densities and γ-ray strength functions which are relevant for the γ-process in type Ia supernovae and Gamow-Teller strength distributions of relevance for the ν-process in core-collapse supernovae. These astrophysical phenomena are the possible sites for the production of long-lived 92Nb, which can serve as a cosmochronometer. As an initial test, the CE-Oslo method is being tested on (t,3He+γ) data taken previously with the S800 spectrometer in coincidence with the GRETINA ⊠-ray detector at FRIB. Preliminary results of the analysis will be shown at the workshop.

This research is supported by the US National Science foundation, Grant No. 2209429, "Nuclear Astrophysics at FRIB".

References:
1. R. Zegers, Research Proposal, Submitted to the B-PAC at RCNP (2020)
2. T. Hayakawa et al., Ap.J.Lett. 779, L9 (2013)
3. A. Spyrou et al., Phys. Rev. Lett. 113, 232502 (2014)
4. B. Gao et al., Phys. Rev. C 101, 014308 (2020)

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Nuclear Theory and Experiments

Morning session / 31

Short-Lived Radioactive Nuclei in the Early Solar System

Author: Benjámin Soós[None]

Corresponding Author: bsos212@gmail.com

Several species of short-lived radioactive nuclei (SLRs) are known to have been present in the early solar system (ESS). They are a valuable source of our knowledge of our solar system's formation and early history. Here, we present the latest results from the ERC RADIOSTAR project in a representation usually used in cosmochemistry, where the abundances of SLRs in the early solar system, normalised to a stable or long-living isotope, are divided by their respective production ratios and plotted as a function of their mean-life. These data points are compared to the results obtained by combining the result of the steady-state formula with (i) the free decay scenario, where isotopes are left to decay for 10-30 Myr before the formation of the solar system and (ii) 3-phase interstellar medium mixing scenario. We apply this representation to s- and r-process nuclei as well as p-process nuclei. Even though the presence of two p-process nuclei (92Nb and 146Sm) is well-defined in the ESS, their usage as cosmochronometers is limited due to their poorly understood production ratio and astronomical origin.

Length of presentation requested:

Oral presentation: 8 min + 2 min questions (Poster-type talk)

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Afternoon session / 32

The origin of the rare 113In and 115Sn p-nuclei revisited

Author: Thanassis Psaltis[1]

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The production of the light p-nuclei 113In and 115Sn has been a long-standing problem for γ-process nucleosynthesis [1,2]. The reaction flow in the Cd-In-Sn region is rather complicated due to the existance of several long-lived β-decaying isomers, which leads to a general underproduction of these isotopes compared to the other p-nuclei. In this talk, I will discuss the current status of the origin of 113In and 115Sn along with their different production mechanisms and a recent experimental measurement regarding the production of 113In [3].

This work is supported by U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Award Number DE-SC0017799 and Contract Nos. DE-FG02-97ER41033 and DE-FG02-97ER41042.
References
[1] Zs. Németh et al., Astrophys. J 426, 357 (1994).
[2] Ch. Theis et al., Astrophys. J 500, 1039 (1998).
[3] A. Psaltis et al., Phys. Rev. C 99, 065807 (2019).

Length of presentation requested:

Oral presentation: 17 min + 3 min questions

Please select a keyword related to your abstract:

Stellar Models and Galactic Chemical Evolution

Morning session / 33

Results of cross-section measurements of proton-capture reactions on stable Rubidium isotopes

Author: Svenja Wilden[1]

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The existence of some stable neutron deficient nuclei - the p nuclei - can not be explained by neutron-capture processes [1]. Therefore, other types of reactions - dominantly photodisintegration reactions - come into play. This is called the γ process. Statistical model calculations play a crucial role in modelling this process as cross sections for many of these photodisintegration reactions are not known trough experiments.

Two in-beam experiments were performed at the University of Cologne's high-efficiency HPGe γ-ray spectrometer HORUS to study the ^{85,87}Rb$(p,\gamma)^{86,88}$Sr reactions. A 10 MV FN Tandem accelerator provided proton beams between $E_p = 2$ and 5 MeV. Total cross-section values were determined for six different proton-beam energies for the ^{87}Rb$(p,\gamma)^{88}$Sr reaction and for three different proton-beam energies for the ^{85}Rb$(p,\gamma)^{86}$Sr reaction. These first experimental cross-section values for

the ^{85,87}Rb$(p,\gamma)^{86,88}$Sr reactions help to constrain the nuclear physics input for statistical model calculations.

Supported by the DFG (ZI 510/8-2).

[1]T. Rauscher et al., Rep. Prog. Phys. 76 (2013) 066201.

Length of presentation requested:

Oral presentation: 8 min + 2 min questions (Poster-type talk)

Please select a keyword related to your abstract: