HK 16: Nuclear Astrophysics II

Time: Tuesday 16:15–18:30 Location: PHIL A 602

Group Report HK 16.1 Tue 16:15 PHIL A 602

Constraining the s-Process Path Using Indirect Methods at MESA and FAIR — •Tanja Heftrich[1], Jan Butz[1], Pierre Capel[2], Leon Fähnrich[1], Alina Gottschalk[1], Carolin Grün[1], Michael Heil[3], Felix Panholzer[1], René Reifarth[4], Concettina Sfienti[2], Monica Alejandra Sanjinez Ortiz[2], and Davud Sokolovic[1] — [1]Goethe University Frankfurt — [2]Johannes Gutenberg University Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]Los Alamos National Laboratory

The slow neutron-capture process (s-process) is responsible for the synthesis of about half of the elements heavier than iron in stellar environments. Its modeling relies critically on precise neutron-capture cross sections, in particular for unstable nuclei that are not directly accessible to conventional measurements.

In this contribution, we present indirect approaches to determine (n,γ) reaction rates relevant for the s-process. In Mainz at the future MESA accelerator, neutron-capture cross sections are constrained via the inverse reaction using electron-induced processes, using $(e,e'n)$ reaction to access the nuclear response to virtual photons. Complementarily, experiments at FAIR employ Coulomb breakup measurements of the type (γ^*,n) at the R3B setup, where electromagnetic excitation in the Coulomb field of a heavy target provides access to the radiative capture process by detailed balance.

HK 16.2 Tue 16:45 PHIL A 602

Results for the $(\mathbf{n},\gamma)$-reaction on natural Krypton via the actiavion method. — •Jan Butz, Leon Fähnrich, Carolin Grün, Alina Gottschalk, Tanja Heftrich, Samira Ikerkourn, Felix Panholzer, and Davud Sokolovic — Goethe-Universität, Frankfurt am Main, Germany

An important step in understanding the origin of life is to study stellar nucleosynthesis. The abundance of elements up to iron is produced almost exclusively through nuclear fusion, whereas most heavy elements are formed via neutron-capture in the s- and r-processes. The s-process occurs inside the shell burning of massive and asymptotic giant branch stars, while the r-process, however, requires extreme conditions, like type II supernovae or neutron star mergers.

Krypton plays a vital role in the s-process due to the branching points of ^{81}Kr and ^{85}Kr. These branching points are nuclei where the decay rate is of the same order of magnitude as the neutron capture rate, $r_\beta \approx r_n$. To gain insight into these points, it is crucial to study the (n,γ) reaction and how these nuclei behave under stellar conditions. The cross sections for the $^{78}\mathrm{Kr}(\mathrm{n},\gamma)^{79}\mathrm{Kr}$ and $^{84}\mathrm{Kr}(\mathrm{n},\gamma)^{85\mathrm{m}}\mathrm{Kr}$ reactions could be determined at various temperatures using a natural krypton sample and the activation method. The resulting values and outlook will be presented.

HK 16.3 Tue 17:00 PHIL A 602

Updates on constraining the ^{95}Zr(n,γ) cross section via the Oslo-method — •Tom Sittig[1], Abdallah Karaka[1], Anna Bohn[1], Artemis Spyro[2], Devin Hymers[1], Markus Müllenmeister[1], Michael Weinert[1], Sarah Prill[1], Sebastian Schröder[1], and Dennis Mücher[1] — [1]Institute of Nuclear Physics, University of Cologne, Cologne, Germany — [2]Facility for Rare Isotope Beams, Michigan State University, East Lansing, Michigan, USA

The ^{95}Zr(n,γ) cross section is of pivotal understanding for the slow neutron capture process (s-process) as the long-lived ^{95}Zr isotope is a branching point at which β-decay is in competition with the production of ^{96}Zr.

In the case of the unstable isotope ^{95}Zr, a direct measeuements of the neutron capture cross section is currently not possible. Using the Oslo method, we have constrained the neutron capture cross section of ^{95}Zr(n,γ) experimentally, for the first time. We utilized the ^{96}Zr(p,p') reaction at the 10 MV FN-Tandem accelerator of the Institute for Nuclear Physics at the University of Cologne using the SONIC@HORUS detector array. We have successfully used the newly developed "Shape" method to significantly reduce the model uncertainties of our result by extracting the absolute nuclear level density at the neutron separation energy.

The preliminary results of these measurements and their impact on the s-process will be presented.

Group Report HK 16.4 Tue 17:15 PHIL A 602

Study of the ^{14}N$(\alpha,\gamma)^{18}$F reaction at Felsenkeller underground lab with the gas-jet target setup — •Anup Yadav[1,2], Daniel Bemmerer[1], Konrad Schmidt[1], Eliana Masha[1], Axel Boeltzig[1], Peter Hempel[1,2], and Kai Zuber[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR) — [2]Technische Universität Dresden

A precise reaction rate for $^{14}\mathrm{N}(\alpha,\gamma)^{18}\mathrm{F}$ is required for modeling stellar evolution. The $^{14}\mathrm{N}(\alpha,\gamma)^{18}\mathrm{F}$ reaction takes place during the helium-burning phase in asymptotic giant branch (AGB) stars other helium-burning sites. This reaction influences different nucleosynthesis pathways and is part of the reaction chains $^{14}\mathrm{N}(\alpha,\gamma)^{18}\mathrm{F}(\beta^+)^{18}\mathrm{O}(\alpha,\gamma)^{22}\mathrm{Ne}$ and $^{14}\mathrm{N}(\alpha,\gamma)^{18}\mathrm{F}(\beta^+)^{18}\mathrm{O}(p,\alpha)^{15}\mathrm{N}(\alpha,\gamma)^{19}\mathrm{F}$, which are important for the production of ^{22}Ne and ^{19}F, respectively. However, at helium-burning energies the cross section is dominated by low-energy resonances whose properties remain insufficiently constrained. The reaction was studied at the Felsenkeller shallow-underground laboratory using a newly developed gas-jet target setup, in which an α beam was directed onto a nitrogen gas jet and the emitted γ rays were detected with high-purity germanium detectors. Precise angular distributions, branching ratios, resonance energies, and strengths were measured for three selected resonances at $E_r = 573$, 1136, and 1618 keV, with the lowest-energy resonance being relevant for helium-burning temperatures. We will present the new experimental results and discuss their astrophysical impact. Future measurements using the gas-jet target at the Felsenkeller underground laboratory will also be outlined.

HK 16.5 Tue 17:45 PHIL A 602

Low energy resonances in the ^{15}N$(\alpha,\gamma)^{19}$F-reaction — •Peter Hempel[1,2], Daniel Bemmerer[1], Axel Boeltzig[1], Eliana Masha[1], Felix Mayer[1,2], Konrad Schmidt[1], Simon Vincent[2,3], Anup Yadav[1,2], and Kai Zuber[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR) — [2]TU Dresden — [3]Deutsches Zentrum für Astrophysik (DZA)

The $^{15}\mathrm{N}(\alpha,\gamma)^{19}\mathrm{F}$-reaction contributes to fluorine production in several astrophysical sites including AGB stars, type II supernovae, and Wolf Rayet stars. The reaction occurs during the helium burning phase. However, the reaction rate at astrophysical energies is still poorly known. Here we report on data from a measurement of astrophysically relevant resonances in the 0.5 - 1.1 MeV center of mass energy range. The experiment has been carried out at the Felsenkeller 5 MV shallow-underground accelerator in Dresden using tantalum nitride solid targets enriched in ^{15}N and the new FeliciTAS 4π BGO γ-ray calorimeter.

HK 16.6 Tue 18:00 PHIL A 602

Constraining r-process nucleosynthesis with multi-objective Galactic chemical evolution models — •Marta Molero — Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 2, Darmstadt 64289, Germany

The astrophysical site(s) of the r-process are uncertain, with candidates such as neutron star mergers and magneto-rotational supernovae predicting different event rates, delay times, and heavy-element yields. Galactic chemical evolution models constrain these properties by comparing model predictions with observed abundances. We explore, in a systematic and data-driven way, the astrophysical conditions under which r-process enrichment can reproduce the observed trends of multiple neutron-capture elements in the Milky Way. Rather than assuming a fixed site, we adopt a flexible, parametric approach to test whether a common set of r-process parameters can explain the chemical evolution of several heavy elements. We compute a grid of one-infall, homogeneous models varying: Eu yield per event, r-process event rate, enrichment delay time, and progenitor mass range. For each of the $\sim 10^5$ models, we predict [X/Fe] vs. [Fe/H] trends by scaling Eu yields with the solar r-process pattern. A multi-objective optimisation based on Pareto fronts identifies models that best reproduce the abundance trends. In this talk, I will present and discuss best fitting Eu models as well as the limitations in reproducing, at the same time, both light and heavy neutron-capture elements, reflecting how the solar r-process scaling relation becomes less robust towards lightest elements.

HK 16.7 Tue 18:15 PHIL A 602

Constraining neutron capture rates for the r-process
— •Christan Schlaier[1], Jessica Berkman[2], Konstantinos Bosmpotinis[2], Sean Liddick[2], Andrea Richard[2], Artemis Spyrou[2], and Dennis Muecher[1] — [1]Institute for Nuclear Physics, University of Cologne, Cologne, Germany — [2]FRIB, Michigan State University, USA

The formation of the second r-process peak ($A \approx 130$) depends critically on neutron capture rates of nuclei below ^{132}Sn. Current theoretical predictions for these rates vary by orders of magnitude.

In 2025, an experiment at the Facility for Rare Isotope Beams (FRIB) at the Michigan State University was performed, aiming to experimentally constrain the neutron capture rates of these key nuclei for r-process nucleosynthesis, for the first time. The measurement utilized the SuN^{++} setup, which consists of the Summing NaI and CeBr3 (SuN^{++}) detector coupled with an Double Sided Strip Detector (DSSD) for particle identification and beam correlation. A cocktail beam of neutron-rich isotopes centered around ^{128}Ag was implanted into the setup to measure β-decay properties. The high efficiency and 4π coverage of SuN^{++} allow for the precise determination of β-decay intensities and the extraction of statistical nuclear properties, such as nuclear level densities and γ-ray strength functions. This contribution will discuss the experimental procedure and present preliminary results.