HK 5: Nuclear Astrophysics

Time: Monday 16:30–18:30 Location: H4

Group Report HK 5.1 Mon 16:30 H4

Investigation of nuclear physics properties for p process nucleosynthesis — •Martin Müller, Felix Heim, Yanzhao Wang, Svenja Wilden, and Andreas Zilges — Institute for Nuclear Physics, University of Cologne

More than 60 years after the ground breaking paper by Burbidge, Burbidge, Fowler and Hoyle [1] many questions about the nucleosynthesis of neutron deficient nuclei in the p process remain unsolved. While the number of p nuclei is small, the number of reactions involved in their production is extremely large, necessitating a detailed and precise theoretical description. This talk will provide a brief overview of our group's contributions to the experimental determination of nuclear cross sections as well as studies of the underlying nuclear physics parameters such as the γ-ray strength function, the nuclear level density and the α-optical model potential. Recent experiments on proton- and α-induced reactions along with comprehensive comparisons with statistical model calculations will be presented [2-5].

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[1] E. Burbidge *et al.*, *Rev. Mod. Phys.* **29**, 547 (1957)
[2] P. Scholz *et al.*, *Phys. Rev. C* **101**, 045806 (2020)
[3] F. Heim *et al.*, *Phys. Rev. C* **103**, 025805 (2021)
[4] F. Heim *et al.*, *Phys. Rev. C* **103**, 055803 (2021)
[5] F. Heim *et al.*, *Phys. Rev. C* **103**, 054613 (2021)

HK 5.2 Mon 17:00 H4

Gravitational wave signatures of the hadron-quark phase transition in binary neutron star mergers — •Matthias Hanauske[1,2], Horst Stöcker[1,2], and Luciano Rezzolla[1,2] — [1]Institut für Theoretische Physik, Max-von-Laue-Straße 1, 60438 Frankfurt, Germany — [2]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Straße 1, 60438 Frankfurt, Germany

The long-awaited detection of a gravitational wave from the merger of a binary neutron star in August 2017 (GW170817) marked the beginning of the new field of multi-messenger gravitational wave astronomy. Reaching densities a few times that of nuclear matter and temperatures up to 100 MeV, such mergers also represent potential sites for a phase transition from confined hadronic matter to deconfined quark matter (HQPT). The appearance of a HQPT in the interior region of the merger remnant and its conjunction with the spectral properties of the emitted gravitational wave can be calculated by fully general-relativistic hydrodynamic simulations. The results show, that binary neutron star mergers probe a broad region of the QCD phase diagram, with matter crossing the phase boundary over a large range in densities and temperatures. Depending on the properties of the HQPT, a gravitational wave signature can be created promptly after the merger or during the post-merger evolution. Especially during the postmerger evolution of the produced hypermassive/supramassive hybrid star the occurrence of a "delayed HQPT" might give a clear gravitational wave signature of the production of quark matter.

HK 5.3 Mon 17:15 H4

Long-time simulations of neutron star mergers — •Maximilian Jacobi[1], Federico Guercilena[1], Almudena Arcones[1,2], Wolfgang Kastaun[3,4], Takami Kuroda[3], Bruno Giacomazzo[5,6,7], and Martin Obergaulinger[8] — [1]Technische Universität Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung — [3]Max Planck Institute for Gravitational Physics — [4]Leibniz Universität Hannover — [5]Universitá degli Studi di Milano - Bicocca — [6]INFN, Sezione di Milano-Bicocca — [7]INAF, Osservatorio Astronomico di Brera — [8]Universitat de València

Merging binary neutron stars (BNS) typically form a massive accretion disk around a compact object that can eject mass for up to several seconds. Explosive r-process nucleosynthesis in these ejecta make up a large contribution to the total mass of heavy elements produced in the event and play an important role in its optical and infrared transient (kilonova). Therefore, to interpret multi-messenger events such as GW170817, it is essential to perform long-term simulations. I will present GR simulations of BNS mergers following the in-spiral, merger, and accretion disk phases. Shortly after merger, we transition from 3D to 2D which significantly reduces the computational cost of the simulation. This setup allows us to simulate merging neutron stars consistently from the in-spiral to the accretion disk phase on the time scale of seconds.

HK 5.4 Mon 17:30 H4

Weak r-process nucleosynthesis: the impact of (α,xn) reactions — •Athanasios Psaltis[1], Almudena Arcones[1,2], Melina Avila[3], Max Jacobi[1], Zach Meisel[4], Peter Mohr[5], Fernando Montes[6], and Wei Jia Ong[7] — [1]TU Darmstadt, Germany — [2]GSI, Darmstadt, Germany — [3]Argonne National Laboratory, Argonne, IL, USA — [4]Ohio University, Athens, OH, USA — [5]ATOMKI, Debrecen, Hungary — [6]NSCL/MSU, East Lansing, MI,USA — [7]Lawrence Livermore National Laboratory, Livermore, CA, USA

'Light' heavy elements (Z = 38 – 47) can be synthesized in the neutrino–driven ejecta of core–collapse supernovae via the weak r–process [1]. This nucleosynthesis scenario exhibits uncertainties from the absence of experimental data from (α,xn) reactions on neutron–rich nuclei, which are currently based on statistical model calculations. A recent sensitivity study identified the most important (α,xn) reactions that can affect the production of 'light' heavy elements under different astrophysical conditions [2]. The current status of weak r–process nucleosynthesis calculations and the planning of experiments to experimentally determine (α,xn) reaction rates using the MUSIC detector at Argonne National Laboratory [3] and the SECAR recoil separator at FRIB [4] will be discussed.

References

[1] A. Arcones and F. Montes, Astrophys. J. 731, 5 (2011)
[2] J. Bliss et al., Phys. Rev. C 101, 055807 (2020)
[3] M. L. Avila et al., NIM A 859, 63 (2017)
[4] G. Berg et al., NIM A 877, 87 (2018)

HK 5.5 Mon 17:45 H4

Mass Measurements of Proton-Rich Strontium Isotopes for rp-Process Studies — •Tobias Murböck[1], Jack Henderson[1,2], Zach Hockenbery[1,3], Ania A. Kwiatkowski[1,4], and Daniel Lascar[1,5] for the TITAN-Collaboration — [1]TRIUMF, Vancouver, Canada — [2]Univ. of Surrey, England — [3]McGill Univ., Montreal, Canada — [4]Univ. of Victoria, Victoria, Canada — [5]Northwestern Univ., Evanston, Illinois, US

The rp-process (rapid proton-capture process) consists of a series of radiative proton captures along the N=Z line up to the proton dripline. It is believed to be the primary source of nuclei that are not generated via either the rapid or slow neutron-capture process.

The energy released during the rp-process may power type-I X-ray bursts which occur in binary star systems where a neutron star accretes material from its larger partner. The calculated luminosity from an X-ray burst crucially depends on the mass values of the involved nuclei, which affect the reaction flow through the the rp-process waiting points. Here we present high-precision mass measurements of the neutron-deficient isotopes $^{74-76}$Sr. Specifically, the mass of ^{74}Sr allows one to determine the two-proton separation energy of the 2p reaction from the waiting point ^{72}Kr. The achieved uncertainties of a few 10 keV/c^2 are precise enough to provide stringent constraints on the nuclear reaction rates in this region of the rp-process. The experiment has been performed with the multi-reflection time-of-flight mass spectrometer (MR-ToF-MS) which has been recently added to TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN).

HK 5.6 Mon 18:00 H4

Measurement of ^{39}K(p,γ)^{40}Ca resonance strengths below 900 keV for classical novae nucleosynthesis — •Philipp Scholz, Richard J. deBoer, Joachim Görres, Rebeka Kelmar, Shahina Shahina, and Michael Wiescher — Department of Physics, University of Notre Dame, IN

Classical novae are one of the most frequent explosive nucleosynthesis events in our universe but are still not sufficiently understood.

To this day, nuclear astrophysics cannot explain the endpoint of the nucleosynthesis networks in classical novae which is mainly due to a scarce experimental data base of nuclear reaction rates of proton-induced reactions in the the mass-region above silicon at temperatures between 0.1 GK and 0.4 GK.

Because some nova ejecta hint on the production of elements in the calcium range (Centauri V1065) and some possibly even up to the iron region (Cygni V1974), it is of utmost interest to investigate possible paths towards heavier elements.

Here we report on new measurements of resonance strengths of the $^{39}K(p,\gamma)^{40}Ca$ reaction below 900 keV at the 5U accelerator of the University of Notre Dame and their implications on the (p,γ) reaction rate on ^{39}K.

HK 5.7 Mon 18:15 H4

Production and study of new neutron-rich nuclei via a novel MNT-induced process using 238U+164Dy — •Deepak Kumar[1], Paul Constantin[2], and Timo Dickel[1] for the FRS Ion Catcher-Collaboration — [1]GSI Helmholtz Center for Heavy Ion Research and Justus-Liebig University of Giessen, Germany — [2]ELI-NP/IFIN-HH, Magurele, Romania

The crux of measuring the nuclear properties of heavy neutron-rich exotic nuclei and nuclear data with reduced uncertainties for known nuclei is to explore the r-process abundance pattern of the elements heavier than iron (Fe). However, the production of these neutron-rich nuclei is beyond the accessible limit of conventional methods. Nevertheless, a new possible alternative is the Multi-Nucleon Transfer (MNT) approach that manifests a strong potential to achieve this goal. In order to establish a new direction of research for the MNT-induced neutron-rich products using the FRS Ion Catcher (IC) facility at GSI, the 238U beam at 500 MeV/u has been proposed to deliver from the SIS18 and allowed to bombard on 164Dy target at 10 MeV/u placed inside the Cryogenic Stopping Cell (CSC). It offers a promising way to produce a significant amount of several new neutron-rich nuclei that have been speculated by the most reliable state-of-the-art Langevin-type model calculations. This research direction is based on a universal, fast, and efficient method to measure production cross-section and broadband masses of reaction products, including long-lived isomers. The developed methods and instrumentation will be extended to be utilized for LEB at the Super FRS facility with neutron-rich unstable beams.