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Mass measurements of neutron-rich gallium and indium isotopes for r-process studies

The astrophysical rapid neutron-capture process (r-process) is believed to be responsible for the production of approximately half of the chemical elements heavier than iron. The accurate modelling of the r-process nucleosynthesis needs reliable experimental nuclear data, especially for nuclei around closed neutron shells serving as waiting points, this has been shown by sensitivity studies [1]. One of the important nuclear physics inputs influencing the final r-process abundances is the nuclear masses. Observing the gravitational waves from the binary neutron star (BNS) merger (GW170817) and the subsequent detection of the electromagnetic counterpart (AT2017gfo) served as the first direct evidence that heavy elements, including the lanthanide region, were synthesized by the r-process, but the production of the elements of the first r-process abundance peak remains uncertain. To gain more knowledge on the formation of the first r-process peak and investigate whether the ejecta of a BNS merger can indeed be one of the possible sites for the formation of A ≈ 80-84 r-process elements is of general interest.

Exotic nuclei can be produced with very high rates at the ISOL facility ISAC at TRIUMF (Vancouver, Canada). TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN) is a multiple ion-trap system for high-precision mass measurements and in-trap decay spectroscopy. A multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS) has been installed and integrated into the TITAN experiment. It is based on an established concept tested at the FRS Ion Catcher at GSI. It is well suited to perform high precision mass measurements, particularly for short-lived isotopes produced at low rate. Furthermore, the ion of interest can be separated from isobaric contaminations with mass-selective re-trapping prior to the mass measurement itself, thus improving the background handling capabilities of the MR-TOF-MS.

Such improved capabilities of TITAN have been used to investigate the r-process nucleo-synthesis for masses at A ≈ 84. The measurements determine the masses of $^{80-85}$Ga with uncertainties between 25-48 keV; the masses of ^{84}Ga and ^{85}Ga were measured for the first time [2]. The new mass values reduce the nuclear uncertainties associated with the production of A ≈ 84 isotopes by the r-process for astrophysical conditions that might be consistent with a BNS merger producing a blue kilonova. In addition, high-precision mass measurements of neutron-rich indium isotopes were performed by TITAN's MR-TOF-MS covering the N = 76–85 region and including measurements of ground states as well as isomeric states. The masses of ^{133,134}In were measured for the first time and the ^{132}In marks the first direct mass measurement [3]. The uncertainties of several neutron-rich indium ground-state masses and isomer excitation energies have been improved compared to previous literature values providing valuable input for future r-process calculations.

[1] M. Mumpower et al., Prog. Part. Nucl. Phys. 86, 86 (2016).
[2] M. P. Reiter et al., Phys. Rev. C 101, 025803 (2020).
[3] C. Izzo et al., Phys. Rev. C 103, 025811 (2021).

Length of presentation requested

Oral presentation: 17 min + 3 min questions

Please select between one and three keywords related to your abstract

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Authors: KRIPKÓ-KONCZ, Gabriella (II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany); AYET SAN ANDRES, Samuel (GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany); IZZO, Christopher (TRIUMF, Vancouver, British Columbia, Canada); LIPPUNER, Jonas (CCS-2, Los Alamos National Laboratory, Los Alamos, New Mexico, USA); NIKAS, Stylianos (GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany); REITER, Moritz P. (School of Physics and Astronomy, University of Edinburgh, Edinburgh, Scotland, United Kingdom); DICKEL, Timo (GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany); DILLING, Jens (Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA); JACOBS, Andrew (TRIUMF, Vancouver, British Columbia, Canada); KOOTTE, Brian (TRIUMF, Vancouver, British Columbia, Canada); KWIATKOWSKI, Anna A. (TRIUMF, Vancouver, British Columbia, Canada); MARTINEZ-PINEDO, Gabriel (Institut für Kernphysik (Theoriezentrum), Technische Universität Darmstadt, Darmstadt, Germany); MUKUL, Ish (TRIUMF, Vancouver, British Columbia, Canada); PAUL, Stefan F. (TRIUMF, Vancouver, British Columbia, Canada); PLASS, Wolfgang R. (II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany); SCHATZ, Hendrik (National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan, USA); SCHEIDENBERGER, Christoph (II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany); WILL, Christian (II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany)

Presenter: KRIPKÓ-KONCZ, Gabriella (II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Gießen, Germany)