Heaviest tin isotopes provide insights into element synthesis

July 2 2025, by Ingo Peter

Dr. Ali Mollaebrahimi inspects the MR-TOF-MS setup at TRIUMF in Canada. Credit: Coulter Walls

An international team of researchers, led by scientists from GSI/FAIR in Darmstadt, Germany, has studied r-process nucleosynthesis in measurements conducted at the Canadian research center TRIUMF in Vancouver. At the center of this work are the first mass measurements of three extremely neutron-rich tin isotopes: tin-136, tin-137 and tin-138. The results are published in the journal *Physical Review Letters*.

The high-precision measurements, combined with nucleosynthesis network calculations, help to better understand how heavy elements are formed in the universe, especially through the rapid neutron capture process (the r-process) occurring in neutron star mergers.

The data reveal the neutron separation energy, which defines the path of the r-process on the nuclear chart. The study found unexpected changes in the behavior of tin nuclei beyond the magic neutron number N=82, specifically, a reduction in the pairing effect of the last two neutrons.

"These changes could affect the r-process path on the nuclear chart at large and even alter where the limit of stability in this region of the chart of nuclides lies. Combining these mass measurements with new isotope production capabilities and cutting-edge theoretical calculations, this work improves our understanding of nuclear forces far away from the valley of stability," explains Dr. Ali Mollaebrahimi, first author of the publication and spokesperson of the experiment.

Mollaebrahimi has recently been appointed as a FAIR Fellow in the GSI/FAIR department "FRS/Super-FRS Experiments" and works closely with the departments "Nuclear Structure and Astrophysics," as well as the IONAS group at Justus Liebig University (JLU) Giessen.

A multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS)— developed by researchers from the IONAS group and GSI/FAIR and tailored to the specific opportunities of the TITAN facility at TRIUMF—plays a key role in the successful measurements, as well as the secondary beams that are available at TRIUMF, which provide the highest yields of exotic isotopes. A new type of reaction target was also employed.

"This achievement marks a significant milestone made possible through long-term collaboration among scientists from several research groups in Germany and Canada," says Dr. Timo Dickel, head of the GSI/FAIR research group "Thermalized exotic nuclei" that Mollaebrahi also belongs to.

"The MR-TOF-MS was installed and commissioned in Canada for the first experiments in 2017. In this year alone, the successful collaboration resulted in two more high-level publications on element synthesis and nuclear structure. In the past, the mass spectrometer allowed for the discovery of the isotope ytterbium-150, marking the first isotope discovery with an MR-TOF-MS," says Dickel.

The results reported in the publication mark an important contribution to the FAIR Phase 0 activities, where young researchers are trained with the future tools for experiments of the MATS and Super-FRS Experiment collaborations at the FAIR facility.

More information: A. Mollaebrahimi et al, Precision Mass Measurements Reveal Low Neutron Pairing in Tin beyond N=82 and Its Impact on Stellar Nucleosynthesis, *Physical Review Letters* (2025). DOI: 10.1103/ctyj-ls15

Provided by Helmholtz Association of German Research Centres