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High-precision mass measurements for reliable nuclear-astrophysics calculations

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The nuclear mass is an important parameter in nuclear physics and astrophysics. The experimental determination of precise and accurate values is a challenge, especially for short-lived radionuclides far away from the valley of stability with low production yields as well as half-lives down to the millisecond time scale. However, these mass values are required for testing and modelling nucleosynthesis theories that describe how elements and nuclides are formed in stellar evolution, e.g., violent processes like supernovae explosions.

For the calculations of the various pathways from hydrogen to the heavier elements the nuclear properties of a large number of nuclides need to be known [1,2]. Especially in the case of the r-process, where elements heavier than iron are formed by rapid neutron capture, nuclear structure data of neutron-rich nuclides far from the valley of stability are required. The path of the r-process is determined by and reflects nuclear structure. For example at the neutron shell N=50 it crosses through the waiting point nuclide 80Zn. Slight deviations in the nuclear physics parameters can lead to large discrepancies in the modeling of the subsequent nucleosynthesis processes. One crucial parameter is the mass of the nuclides, which enters the determination of neutron separation energies and the Q-values for the beta decays as well as interaction cross-sections. They are thus essential for the study of the r-process and other astrophysical aspects.

With the Penning trap mass spectrometer ISOLTRAP at ISOLDE/CERN very precise and accurate mass measurements with relative mass uncertainties down to dm/m=8x10-9 can be achieved. Recently, the atomic masses of the neutron-rich zinc isotopes 71-81Zn have been measured. For the first time the masses of 79Zn and 81Zn have been determined. The new experimental data allow the investigation of nuclear structure at the neutron shell N=50 for low Z. The possible impact on nuclear astrophysics and further examples are discussed.

[1] M. Mukherjee et al., Phys. Rev. 93, 150801 (2004)
[2] D. Rodriguez et al., Phys. Rev. Lett. 93, 161104 (2004)

Author: HERLERT, Alexander (European Organization for Nuclear Research (CERN))

Co-authors: Dr KELLERBAUER, Alban (CERN, Physics Department, 1211 Geneva 23, Switzerland); Mr YAZIDJIAN, Chabouh (GSI, Planckstr. 1, 64291 Darmstadt, Germany); Dr GUÉNAUT, Céline (CSNSM-IN2P3-CNRS, 91405 Orsay-Campus, France); Dr LUNNEY, Dave (CSNSM-IN2P3-CNRS, 91405 Orsay-Campus, France); Dr HERFURTH, Frank (GSI, Planckstr. 1, 64291 Darmstadt, Germany); Prof. KLUGE, H.-Jürgen (GSI, Planckstr. 1, 64291 Darmstadt, Germany); Dr BLAUM, Klaus (Johannes Gutenberg-University, Institute of Physics, 55099 Mainz, Germany); Prof. SCHWEIKHARD, Lutz (Ernst-Moritz-Arndt-University, Institute of Physics, 17487 Greifswald, Germany); Mr BREITENFELDT, Martin (Ernst-Moritz-Arndt-University, Institute of Physics, 17487 Greifswald, Germany); Mr DWORSCHAK, Michael (Johannes Gutenberg-University, Institute of Physics, 55099 Mainz, Germany); Dr DELAHAYE, Pierre (CERN, Physics Department, 1211 Geneva 23, Switzerland); Mr GEORGE, Sebastian (Johannes Gutenberg-University, Institute of Physics, 55099 Mainz, Germany); Mr BARUAH, Sudarshan (Ernst-Moritz-Arndt-University, Institute of Physics, 17487 Greifswald, Germany); Ms HAGER, Ulrike (University of Jyväskylä, Department of Physics, 40014 Jyväskylä, Finland)

Presenter: HERLERT, Alexander (European Organization for Nuclear Research (CERN))

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