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Nuclear Structure Studies of Actinides Using High-Precision Penning-Trap Mass Spectrometry at TRIGA-Trap

Penning traps are widely used in high-precision mass spectrometry to determine atomic masses with exceptional precision and accuracy, playing a crucial role in atomic and nuclear physics research [1]. TRIGA-Trap is a high-precision, double Penning-trap mass spectrometer located in the reactor hall of the TRIGA (Training, Research, Isotopes, General Atomic) research reactor in Mainz, Germany [2]. It also serves as one of the development platforms for the planned MATS (Measurements of very short-lived nuclides using an Advanced Trapping System) experiment at FAIR (Facility for Antiproton and Ion Research) which aims to investigate nuclei far from stability in order to enhance our knowledge on their fundamental nuclear properties [3, 4]. While the construction of FAIR is still underway, development platforms such as TRIGA-Trap conduct studies to optimise future experiments and test new emerging ideas.

At TRIGA-Trap, mass measurements of radioactive nuclides – particularly actinides – are performed with the PI-ICR (Phase-Imaging Ion-Cyclotron Resonance) technique [5]. This method offers high sensitivity, resolving power and accuracy, while requiring relatively short measurement times [2]. Recent mass measurements of actinides, including ^{244}Pu, ^{241}Am, ^{243}Am, ^{248}Cm, and ^{249}Cf have achieved uncertainties at the parts-per-billion (ppb) level [6]. These nuclides are in the vicinity of the neutron number $N = 152$, a region associated with a deformed sub-shell closure. The precise mass measurements allow the exploration of nuclear structure through trends in mass filters, such as S_{2n} (two-neutron separation energies) and $\delta V_{p,n}$ (average p-n interaction of the most loosely-bound two nucleons), as well as their differentials [6]. Currently, mass measurements in the Pu isotopic chain – including ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{242}Pu – are in progress. This will enhance the current dataset and contribute to ongoing nuclear structure studies. In particular, the trend in shell evolution with increase in neutron number N towards the $N = 152$ sub-shell closure for proton number $Z = 94$ can be investigated, and the predictive capabilities of various nuclear shell models for heavy and deformed nuclei can be assessed.

This presentation will provide an overview of the current status of the experiment, including recent mass measurements, their application in nuclear structure evaluation, and an outlook on future directions.

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Author: SAYED, Tanvir (Max-Planck-Institut für Kernphysik MPIK)

Co-authors: Dr NAGY, Szilard (Max-Planck-Institut für Kernphysik); Prof. BLAUM, Klaus (Max-Planck-Institut für Kernphysik); Prof. BLOCK, Michael (Helmholtz-Institut Mainz,); Dr CAKIRLI, Burcu (Max-Planck-Institut für Kernphysik); Dr CHENMAREV, Stanislav (Max-Planck-Institut für Kernphysik); Prof. DÜLLMANN, Christoph (Helmholtz-Institut Mainz,); Dr RENISCH, Dennis (Helmholtz-Institut Mainz)

Presenter: SAYED, Tanvir (Max-Planck-Institut für Kernphysik MPIK)

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