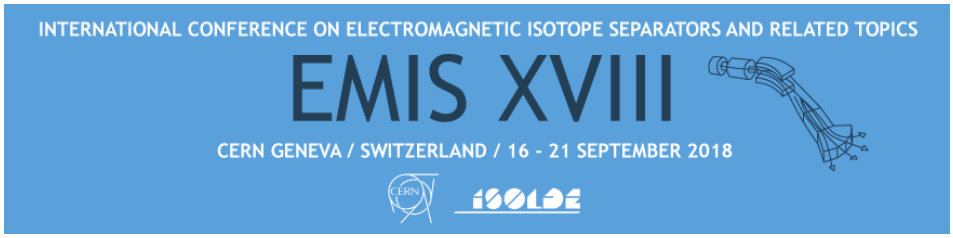

Contribution ID: **136** Type: **Submitted Oral**

Penning-Trap Mass Spectrometry of the Heaviest Elements with SHIPTRAP

Tuesday 18 September 2018 12:10 (15 minutes)

The quest for the heaviest element is at the forefront of nuclear physics. Superheavy elements (SHE), with 104 protons (Z) or more, owe their very existence to an enhanced stability resulting from nuclear shell effects. High-precision Penning-trap mass spectrometry (PTMS) is an established tool for investigations of nuclear structure-related properties, reflected in binding energy differences, for example two-nucleon separation energies [1]. Although elements up to oganesson (Z = 118) have been discovered, detailed studies of the elements with Z > 110 are hampered by low statistics due to low production cross sections in the order of picobarn. However, the use of PTMS in the region of Z > 100 provide indispensable knowledge on single-particle orbitals and pairing correlations affecting the properties of the heaviest elements. Furthermore, masses of anchor points for alpha-decay chains and benchmarks for theoretical models are obtained.

Pioneering experiments with SHIPTRAP, located behind the velocity filter SHIP at GSI in Darmstadt, Germany, have demonstrated that direct measurements of the heaviest elements are feasible for lowest yields [2,3], in the case of ^{256}Lr (Z = 103) with a cross section of 60 nb only about one ^{256}Lr ion every two hours was detected behind the trap. Recent developments of the setup allow pushing these limits to even heavier and more exotic nuclei in the upcoming beam time periods at GSI in 2018/19. The implementation of a cryogenic gas-catcher [4] increases the stopping, thermalization and extraction efficiency by almost one order of magnitude and was recently integrated in the relocated experimental setup. This will allow directly measuring ^{254}Lr and the SHE isotope ^{257}Rf (Z = 104) for the first time and extend the nuclear shell evolution studies at N = 152 [3]. In addition, anchor points in odd-A and odd-odd nuclides in this mass region will be obtained, affecting the masses of elements up to darmstadtium (Z = 110).

The development of the Phase-Imaging Ion-Cyclotron-Resonance technique at SHIPTRAP [5], the new standard in online PTMS worldwide, increases the mass resolving power, precision and detection sensitivity compared to the previously used techniques significantly. This will allow simultaneous measurements of ground and low-lying isomeric states of the heaviest elements that are difficult to access by any other method. The precise determination of their excitation energy allows studying pairing correlations and single-particle energies that are responsible for the spherical shell gap at Z = 114 and thus give significant input to nuclear models predicting the so-called island of stability.

To reach the ultimate goal to perform direct mass spectrometry on heavier elements for which the yields are smaller and only single ions are available, a second dedicated setup is being developed in parallel to the ongoing online mass measurement activities to adapt the non-destructive Fourier-Transform Ion-Cyclotron detection technique to this mass region.

Recent results and the status of the technical developments will be presented.

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Session Classification: Session 6 - Ion traps and laser techniques

Track Classification: Ion traps and laser techniques