Contribution ID: **15** Type: **Oral presentation**

Measurements of isomeric yield ratios in proton-induced fission of $^{\rm nat}$U by the Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique

Thursday 24 May 2018 15:25 (20 minutes)

One of the many open questions regarding fission is the origin of the angular momentum of the primary fission fragments. Although it is well established that they carry considerable amount of angular momentum, there are competing theories on how this is generated. It is thus desirable to obtain information on the angular momenta of the fragments as it can provide insights on the properties of the dynamical evolution of the fissioning nucleus from the saddle point until its descent to scission. One of the means to accomplish this is by determining experimentally the isomeric yield ratios.

We report the first measurements of independent isomeric yield ratios, performed at the Ion Guide Isotope Separator On-Line and the JYFLTRAP facilities at the University of Jyväskylä, by employing a novel approach based on the projection of the Penning Trap ion motion onto a position-sensitive detector. The new Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique, recently implemented at JYFLTRAP, provides a superior mass resolving power, where isomers with excitation energies at 50 keV can be readily separated from the ground state. Furthermore, the phase-dependent isomeric cleaning is much faster, facilitating measurements of production ratios of isomers with half-lives at the order of one hundred milliseconds. As with the IGISOL-JYLFTRAP method the ions are estimated by direct ion counting, accurate knowledge of the decay scheme of the products is not required contrary to the measurements performed with γ-spectroscopy.

The isomer yield ratios of ^{119,120,121,122,123,125,127}In, ^{119,121,123,125,127}Cd, ^{81}Ge, ^{129}Sn, ^{129}Sb in the 25 MeV proton-induced fission of $^{\rm nat}$U were studied. For all odd-A isotopes of In and Cd, the ground state and the metastable state have the same spins [$(\frac{9}{2}^+\frac{1}{2}^-)$ and $(\frac{3}{2}^+\frac{11}{2}^-)$ respectively], with excitation energies from 300 to 450 keV for the former case and 150 to 300 keV for the latter.
Thus, the study of these isotopes can provide important information on the evolution of the initial root-mean-square angular momentum ($J_{\rm rms}$) of the primary fission fragments with respect to the mass number A and towards the closed neutron shell configuration (N=82). Moreover, the even-A isotopes of In can demonstrate the effect of the odd-Z products on the angular momentum for nuclides with the same neutron number. The case of ^{129}Sn with excitation energy of the metastable state at only 35 keV highlights the superior mass resolving power (MRP) of the new technique. The cases of ^{81}Ge and ^{129}Sb were used as a cross check to older measurements of isomeric yield ratios which were performed at the same facilities by employing only the first trap (purification trap). The 679 keV excitation energy of the metastable state of ^{81}Ge was at the limits of the achievable MRP with the previous technique.

In this work we describe the PI-ICR method which was followed in order to experimentally determine the isomeric yield ratios, and we also report the preliminary results of these measurements. In addition, from the experimentally determined isomer production ratios the root-mean-square angular momenta ($J_{\rm rms}$) of the initial fission fragments after scission are estimated using the TALYS code.

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Session Classification: session 10