Commissioning of Experimental Setup for Conversion Electron Spectroscopy of the Fission Isomer in ^{239}Pu ◇

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Fission or shape isomers occur in the (superdeformed) second minimum of the potential energy surface of actinide nuclei due to a superposition of the (macroscopic) liquid drop barrier and (microscopic) shell model corrections. Due to improved experimental techniques significant progress has been achieved in recent years in studying these extremely deformed nuclei, where super- and hyperdeformation, i.e. axis ratios of 2:1 and 3:1, respectively, can be studied already at low spins in contrast to other mass regions, where superdeformation occurs only at very high spins and hyperdeformation despite huge experimental efforts still has not been observed. Moreover, while in the high spin regime Coriolis forces lead to a strong mixture between rotational and vibrational states, thus often leading to complicated spectroscopic transition patterns, fission isomers offer the unique property of a clear separation between rotational and vibrational collective excitations, thus ending up in a clear spectroscopic situation.
In our experimental project we aim at investigating single-particle- and collective β vibrational states of the odd-N 8 μs fission isomer in ^{239f}Pu via conversion electron spectroscopy. Knowledge of single-particle states in strongly deformed actinide isotopes will help to refine nuclear structure models and predictions for fission barriers in neutron-rich heavy elements. Fig. 1 shows the double-humped fission barrier landscape with the fission isomeric ground state in the superdeformed second potential minimum. The zoomed insert shows the low-energy nuclear structure on top of the 8 μs fission isomer as obtained from conversion electron studies by Backe et al. [1]. We aim at extending this level scheme by higher-lying E0 transitions and β-vibrational states.

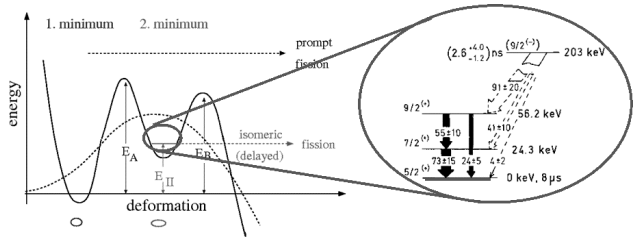

Fig. 1: Schematical view of the double-humped fission barrier landscape with the fission isomeric ground state in the superdeformed second potential minimum. The zoomed insert shows the low-energy level scheme of ^{239f}Pu as obtained from conversion electron spectroscopy by Backe et al. [1].

In order to populate the fission isomer in ^{239}Pu, the ^{238}U(α,3n)^{239}Pu reaction with a beam energy of E_α = 34 MeV was used. The ^{238}U target (diameter 2mm, thickness 20μg/cm^2) is located in the central hole of an annular fission fragment detector, retracted by about 0.1 mm behind the detector surface. A 1 mm thick Ta plate shields back side of the detector from direct α beam particles and dominant prompt fission fragments. Eventually populated fission isomers will recoil out of the target and isomeric fission will occur in front of the detector surface, while the abundant prompt fission events occur behind the shadow edge of the detector surface. Thus only fission fragments from isomeric fission can be detected in the fragment detector, providing a clean trigger for the rare isomeric fission events. Fig. 2b) displays a schematics of this recoil-shadow technique, while in panel a) the subsequent detection of conversion electrons with a Mini-Orange spectrometer is indicated. Mini-Oranges are magnetic transport and filter systems consisting of (in our case) 8 permanent magnet wedges, arranged azimuthally around a central lead absorber that blocks the direct view from the target to the lN_2-cooled Si(Li) detector placed behind the Mini-Orange. The Mini-Orange forms a toroidal magnetic field to focus electrons from the target within a certain energetic transmission range onto the detector surface.

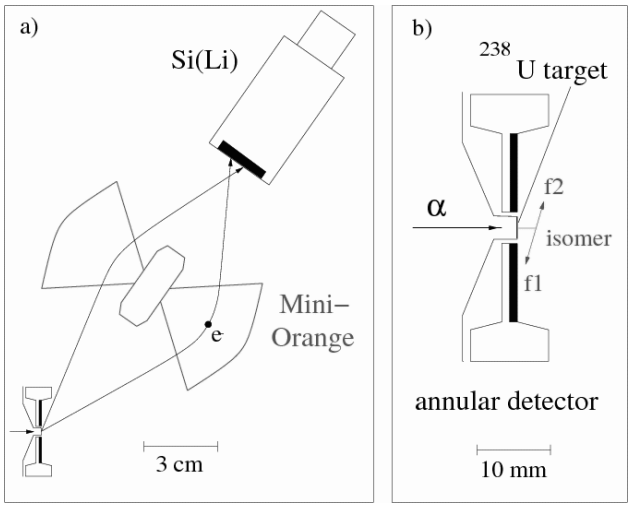

Fig. 2: Part a) illustrates the detection of conversion electrons using a Mini Orange spectrometer, while part b) explains the principle of the recoil-shadow technique used for the selection of fission isomeric decays (see text).

Due to the long lifetime (8 μs) of the fission isomer in ^{239}Pu, without further precautions the isomeric decay would happen far outside the detector setup. Therefore a catcher foil is required in front of the detector. This annular Mylar implantation foil needs to stop efficiently the recoiling compound nuclei prior to fission, while leaving enough central space for the non-reacting primary α beam without back-scattering into the detector. This requires a central hole of 5 mm and a distance between target and catcher foil of about 20 mm. In order to account for the rather large distance between implantation foil and fission fragment detector, a large-area fission detector is needed. For this purpose we realized an economical solution based on commercial solar cells used for fission fragment detection. An array of 15 solar cells has been set

◇ Supported by the DFG Cluster of Excellence 'Origin and Structure of the Universe' and by DFG under contract HA 1101/12-2.