γ-Spectroscopy of the Superdeformed Odd - N Fission Isomer ^{237f}Pu ◇

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While so far spectroscopic studies of fission isomers concentrated on even - even nuclei, high - resolution γ-spectroscopy of odd - N fission isomers will allow for the identification of Nilsson orbitals in heavy, extremely deformed actinide nuclei [1]. Aiming at the investigation of ^{237f}Pu with two known fission isomers (a 1.1 μs isomer sitting on top of an isomer with $t_{1/2} = 110$ ns [2]), following the ^{235}U(α,2n) reaction, the small population cross section (ca. 2 μb with $\frac{\sigma_{iso}}{\sigma_{prompt}} = 1.2 \cdot 10^{-5}$ [2]), requires a large solid angle coverage for γ - rays and fission fragments. In order to detect the fission fragments a PPAC array was installed [3]. Eight trapezoidal detector modules combined into an octaeder structure with a diameter of 8.5 cm allowed for a solid angle coverage of about 70% of 4π. The segmentation of the anode was adapted to regions of equal time of flight of the fission products. Thus in each region individually optimized gating for the separation between prompt and delayed fission fragments is enabled.

Spectroscopy of ^{237f}Pu was performed during a 3-week MINIBALL campaign at the IKP in Cologne, using a rolled metallic ^{235}U target with a thickness of 3.7mg/cm^2, eight triple Ge MINIBALL clusters ($\varepsilon_{ph} \sim 10\,\%$) and an average beam intensity of 1 nA of the pulsed α beam ($E_\alpha = 24$ MeV). The trigger was provided by the detection of a fission fragment in the PPAC array (operated at a typical count rate of 1.2 kHz). The excellent time resolution of the PPAC's (< 0.5 ns) enabled to distinguish between the dominant prompt fission products and the rare isomeric fission events, resulting in approximately 20000 identified delayed fission events.

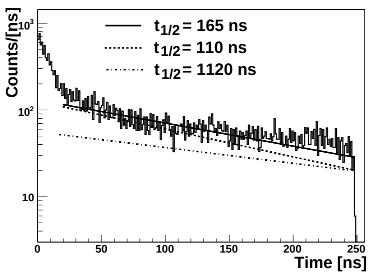

Fig. 1: Time spectrum of fission fragments measured with respect to the prompt beam pulse. An isomeric decay curve is visible in the delayed time regime, consisting of a superposition of contributions from the two fission isomers in ^{237}Pu ($t_{1/2}$=110 ns and 1.1μs)

Fig.1 shows the time spectrum of fission fragments measured with respect to the prompt α beam pulse. An exponential fit applied to the decay curve in the delayed time region exhibits a half-life of 165 ns, originating from a superposition of contributions from the two fission isomers in ^{237}Pu with $t_{1/2} = 110$ ns and 1.1 μs, respectively. Using a two-component fit with fixed decay constants for the two isomeric contributions(dashed and dash dotted lines in Fig. 1) results in a relative intensity of $\frac{\sigma_{long}}{\sigma_{short}} \sim 10$ in agreement with literature values [1].

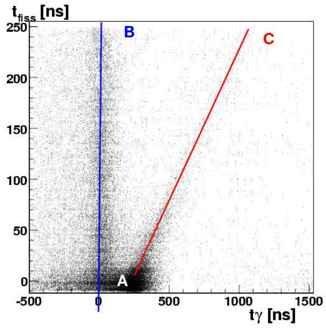

Fig. 2: Timing correlation between fission fragments and γ rays.

Fig.2 displays the timing correlations between fission fragments and γ rays. The dominant component stems from the prompt γ rays from the prompt fission events (region A), whilst the interesting events with prompt γ rays in coincidence with isomeric fission fragments can be found in region B. A third component (region C) is visible comprised of delayed γ rays following the delayed fission of shape isomers (therefore showing the same decay constant as in region B).

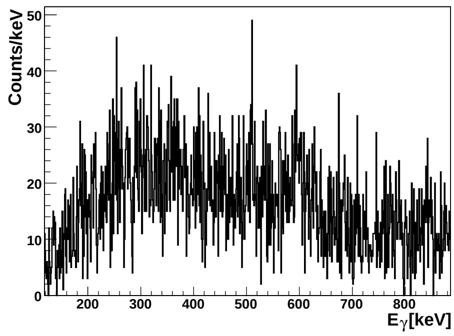

Fig. 3: Energy spectrum of prompt γ rays in coincidence with delayed fission fragments.

Fig.3 shows the γ ray spectrum, summed over all 24 Ge detectors, obtained by gating on region B in Fig. 2. In contrast to the situation in ^{240f}Pu no prominent lines can be identified and further offset stabilization and background subtraction will have to be applied to improve the peak-to-background ratio. However, as expected for an odd nucleus, a rather fragmented intensity distributed over many transitions can be identified and it will be the task of the ongoing analysis (e.g by exploiting the γ-γ coincidence correlations) to clarify the level structure of ^{237f}Pu. In the future also complementary conversion electron measurements will be performed to facilitate spin and parity assignments.

References

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