Prompt gamma spectroscopy and isomer tagging. Deformation of isomeric states in the A=180–200 region

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GSI with the FRS has the unique capability of providing isomeric beams of heavy ions. The high resolution of RISING will allow to pick up low intensity γ-ray transitions from the continuum of the atomic background. This combination makes GSI an unique place in the physics of isomers, and encourages the development of new experimental tehniques.

One question is whether or not the deformation of the nucleus in multiquasiparticle states is the same as in their groundstate. The question is strongly related to the fundamental question of pairing correlations and their quenching when several nucleon pairs are broken. It can be addressed by comparing the moments of inertia of different rotational bands. Although the moment of inertia can be easily deduced from the energy spacings of the levels, it depends both on the pairing and the deformation. This requires that the deformation is determined experimentally.

Because of the technical difficulties, few attempts have been made to measure the deformation of high-K isomers. Considering the A=180-200 mass region, in ^{178}Hf [1] and ^{176}W [2] similar groundstate and high spin (high-K) deformations were measured, but in ^{182}Os [3,4] and ^{179}W [4] the deformation of the multi-quasiparticle states seem to be less than those of the groundstates. The situation is unclear because of uncertainties coming from the techniques that have been used.

Currently there are few methods to measure quadrupole moments. The quadrupole moment (and consequently the deformation) can be determined from its interaction with the lattice electric field gradient, in the case of isomers with lifetimes in the range 100 ns-1 ms. This technique gives results with large uncertainties originating from insufficient knowledge of the electric field gradient and its temperature dependence in crystals. In the case of longer lived isomers, the quadrupole moment can be determined by studying the atomic hyperfine spectrum with lasers, but few such isomers are accessible.

Here we propose a new method to measure the quadrupole moments of multi-quasiparticle states: the Coulomb excitations of isomeric states. Since the mechanism of Coulomb excitation is well known, the obtainable values will be accurate (depending only on statistics). The use of fragmentation reactions at the FRS will allow the employment of this method also in the case of neutron-rich nuclei.

Previous experiments have shown that isomeric beams can be produced in projectile fragmentation, with intensities up to 20% of the total intensity of a given nuclide [5]. The ions in an isomeric state can be Coulomb excited on a lead target at the final focal point of the FRS. The prompt gamma-rays are detected with RISING. Further on, the beam is stopped in a catcher and the decay out of the isomer can be detected with some additional Ge detectors (for the setup see fig. 1.) This isomeric decay is used as a tag, and gives us the identification of the ion after the Coulomb excitation target (before the target the identification is made with the FRS). In order to have an unambiguous correlation between the delayed γ rays and the incoming ions, the isomers should have lifetimes less than few 100 μs.

Technically, the Coulomb excitation of isomeric states is simpler than the more traditional Coulex of groundstates (at the FRS). In the latter one, the ions have to

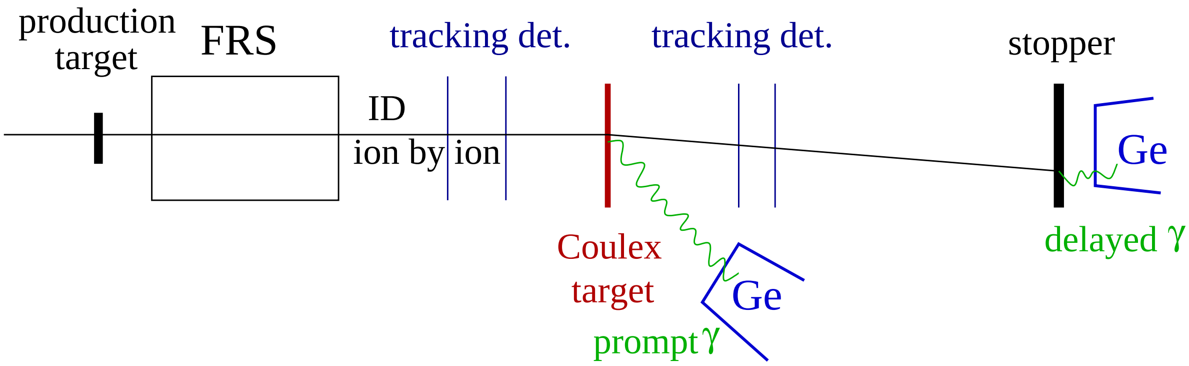

Figure 1: Experimental setup for the Coulomb excitation of isomeric beams.

be identified after the Coulex target using magnetic fields, ion chambers, total energy detectors etc., and previous experiments proved that this is a very difficult task. In the case of the Coulomb excitation of isomeric states, the γ-rays deexciting the isomers are used as a tag to identify the ions after the Coulex target. The feasibility of these experiments depends mainly on the background in the prompt spectra, where the huge atomic background might obscure the Coulex γ-rays (this problem is common for all the Coulex experiments and a test should be made).

The Coulex of the isomer gives not only the transition probabilities, but the energies of the states based on the isomer. This is important in the case of neutron-rich nuclei, where these states cannot be identified using other methods.

We propose to use the technique for the cases listed below.
(i) study of the deformation of the high-K isomers in the Hf-Os region, in order to compare with the groundstate deformations (explained earlier) (ii) study of the shape coexistence in the neutron-deficient lead nuclei. Recently, coexistence of medium-spin spherical, oblate and prolate isomers were observed, for example in ^{188}Pb [6]. The structure of these isomers is from theory, but without a conclusive deformation measurement. (iii) study of the isomers in the neutron-rich platinum isotopes. The even-even $^{196-202}$Pt nuclei are known to have two-particle isomers. They were observed in former FRS experiments with isomeric ratios around 20%. The deformation of these isomers can be studied as approaching the shell-closure at N=126, and shape-coexistence effects can be investigated.

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