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Gamma-ray spectroscopy with relativistic exotic heavy-ions

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Abstract. Feasibility of gamma-ray spectroscopy at relativistic energies with exotic heavy-ions and new generation of germanium detectors (segmented Clover) is discussed. An experiment with such detector array and radioactive is discussed.

Keywords. γ-ray spectroscopy; relativistic energy; segmented Clover detector.

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1. Introduction

Presently available segmented germanium detectors [1] together with radioactive beams from relativistic primary beam fragmentation offer a new opportunity to study the structure of drip line nuclei which are diffcult to access by other reaction mechanisms. Such studies can be broadly classified as: i) decay spectroscopy and ii) in-beam spectroscopy. The angular momentum induced in fragmentation reactions at relativistic energies is sufficiently large [2,3] to perform a meaningful high spin decay spectroscopy of exotic nuclei. At the same time relativistic Coulomb excitation using a radioactive beam from the fragmentation reaction offers an excellent tool to probe the structure of exotic nuclei at low spin. The feasibility of such studies is discussed in this presentation.

The advantages of using relativistic exotic beams for Coulomb excitation are as follows:

- (i) It is possible to produce the nuclei close to the drip line which are hardly accessible by fusion evaporation or transfer reactions using stable beams and targets.
- (ii) The Coulomb excitation cross-section is sufficiently large.
- (iii) Forward focusing due to the Lorentz boost.
- (iv) Thick secondary targets can be used which results in large yields and compensates for the low beam intensity.

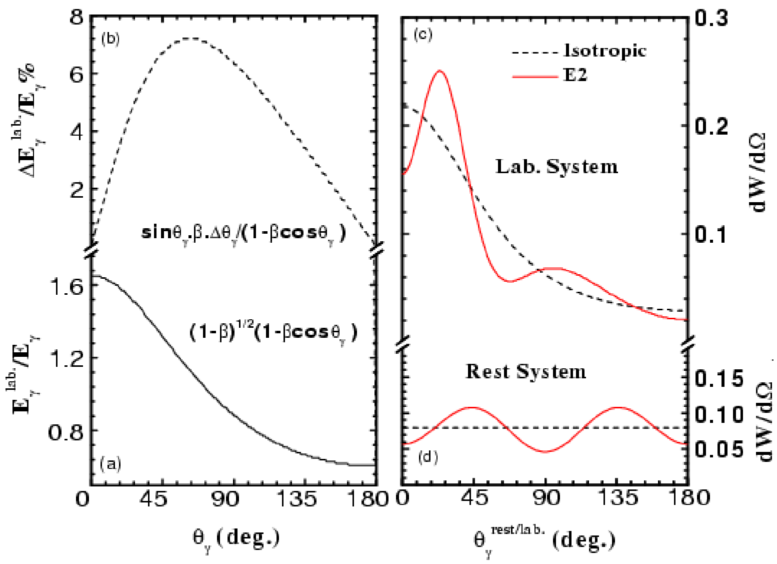

Figure 1. Doppler effect: (**a**) Doppler shift, (**b**) Doppler broadening, (**c**) angular distribution of γ-rays in the lab. (after the Lorentz transformation) and (**d**) in the rest system (see text).

However, such method has few disadvantages. The energy resolution of a gamma detector is affected by the Doppler effect associated with fast moving gamma emitting fragments. We performed the Doppler shift and Doppler broadening calculations for a single crystal of a 4 fold segmented clover detector with an opening angle of $\sim 6^\circ$ for a ^{72}Kr beam of 120 MeV/u on a ^{208}Pb target figure 1a, b. Figure 1c, d shows the γ-ray angular distributions for both an isotropic case and for the $2^+ - 0^+$-transition (E2). The γ-ray angular distribution in the lab. system is peaked at forward angles where the Doppler broadening is large. A highly granulated detector array is needed to reduce the Doppler broadening. Besides that it reduces the multiple hits probability in events with high γ-multiplicity. It also helps to correct for the large Doppler shift accurately.

A rather severe disadvantage of this method with relativistic exotic beam is a huge contribution of the atomic background. The main atomic processes contributing to this background are: (i) K and L shell x-rays from ionized target atoms. (ii) Radiative electron capture (REC) of the target electron into the projectile K and L shells. (iii) Primary Bremsstrahlung (PB) from the target electrons produced by the collisions with the projectile. (iv) Secondary electron Bremsstrahlung (SEB) from energetic knock-out electrons re-scattering in the target and the surrounding material. The cross-section of all these processes strongly depends on the target ($Z_{\rm t}$) and projectile ($Z_{\rm p}$) charge and the total cross section is of the order of a few kilobarn. The calculated total atomic cross section using a Pb target with 120 MeV/u ^{72}Kr projectile is shown in figure 2. In the calculation the target K x-ray production, REC, PB and SEB have been considered.

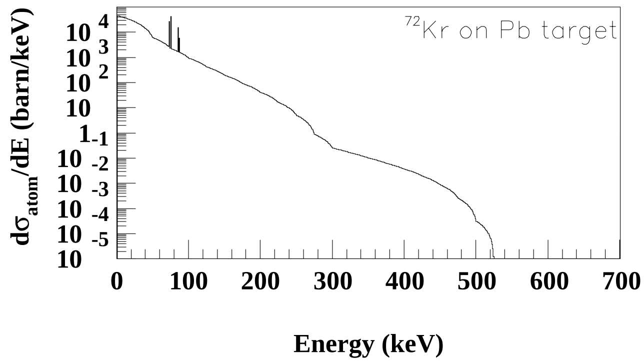

Figure 2. Angle integrated cross section of the atomic background from 120 MeV ^{72}Kr on Pb target.

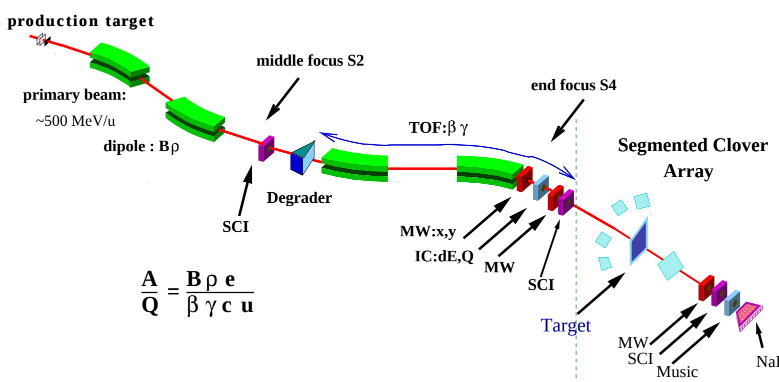

Figure 3. Experimental set-up for relativistic Coulomb excitation.

2. Experiment

Earlier an experiment was performed using relativistic exotic beam with a NaI array to study nuclear structure [4]. In our present experiment we try to perform a similar study using a high efficiency segmented germanium array. A relativistic secondary beam was taken from the fragment separator (FRS) of GSI after fragmentation of 500 MeV/u ^{92}Mo primary beam on Be target. The Pb target was used as Coulex target and placed at the S4 area of the FRS. Four small segmented Clover detectors were placed at backward direction, 20 cm from the target. The GSI super Clover (segmented Clover detector) was placed at forward direction. Mass and Z identification was done using the time of flight and $\Delta E - E$ method by placing several scintillator detectors (SCI), multi-wire proportional counters (MW) and large ionisation chamber (MUSIC) detectors. The set up is shown in figure 3. At the Coulex target position we got a cocktail of different isotopes, figure 4.

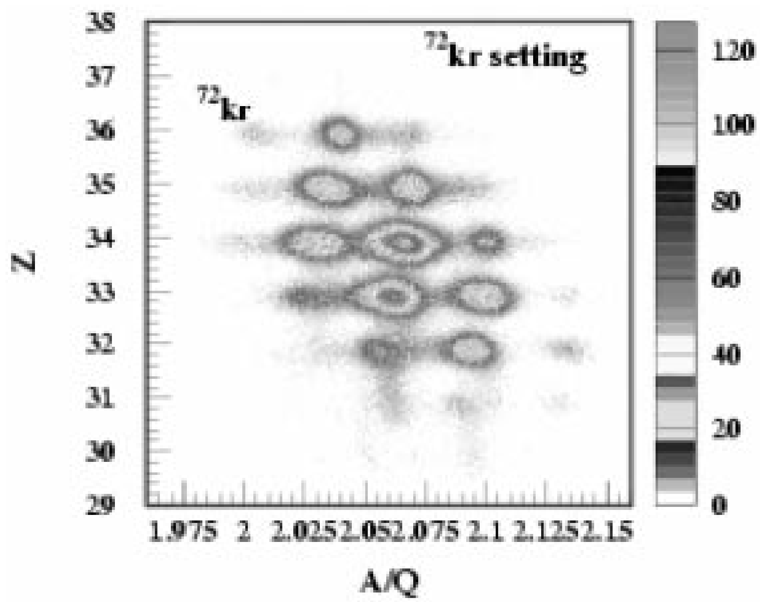

Figure 4. Isotope identification plot. FRS was set for the ^{72}Kr isotope.

By selecting the isotope of interest γ-ray specta will be analysed to extract the B(E2) values of the corresponding transitions. The details of the experimental set-up and results will be published elsewhere.

3. Conclusion

The new possibility of in-beam γ-ray spectroscopy with relativistic radioactive beams and a segmented germanium array was discussed. A large number of fragments in the secondary beam (cocktail beam) at the target position helps to study several nuclei at the same time which will counteract the low intensity beam.

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