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Experimental details of the Stopped Beam RISING campaign

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Abstract. The RISING (Rare ISotope INvestigations at GSI) project constitutes a major pan-european initiative to study nuclear structure in exotic nuclei. A brief outline of the technical details specific to studies of isomeric decays following relativistic projectile fragmentation reactions is presented.

1 Introduction

The motivation behind the RISING collaboration is to utilise relativistic energy stable beams produced by the SIS synchrotron at GSI to synthesise exotic nuclei via projectile fragmentation which can then be studied via gamma-ray spectroscopic techniques. The GSI Fragment Separator (FRS) [1] allows the identification of the exotic secondary species of interest. A previous configuration of the RISING germanium detector array has been used to study in-beam γ-ray spectroscopy at relativistic energies [2]. In February 2006 the RISING detectors were moved to the Stopped Beam configuration which is the focus of this brief report. In this configuration, the RISING array consists of fifteen, seven-element, Euroball IV germanium 'cluster' detectors, mounted in a high-efficiency, close packed geometry around the final focal point of the FRS. The nuclei of interest were implanted in a series of passive stoppers made from either perspex, copper or berylium placed in the centre of the array. Gamma-ray transitions depopulating isomeric states could then be observed using the technique outlined in [3–5]. Reports of the first physics results obtained in the 2006 Stopped Beam campaign can be found in [6, 7]. A brief outline of the technical details and performance characteristics of the RISING array are presented below.

2 Technical details

2.1 Production, selection and identification of exotic nuclei

Exotic secondary beams were produced using the projectile fragmentation of high-energy stable beams from the SIS synchrotron at GSI on thick ($\sim$g/cm^2) ^{9}Be targets. The FRagment Separator (FRS) [1] was used in achromatic mode for the selection and identification of the reaction products using standard time of flight and energy loss techniques. Particle identification was achieved by the use of plastic scintillators at the middle and final focal points to define the magnetic rigidities and velocities of the secondary ions. MUlti Sampling Ionization Chambers (MUSIC) at the end of the FRS provided energy loss signals from which the atomic number of the incoming ion could be deduced. Details of the particle identification procedure can be found in [6].

2.2 The germanium array geometry and electronics

In its Stopped Beam configuration the RISING array ([7]) comprises fifteen, seven-element germanium cluster detectors [8]. The detectors are placed in three angular rings of five detectors at 51, 90 and 129 degrees to the primary

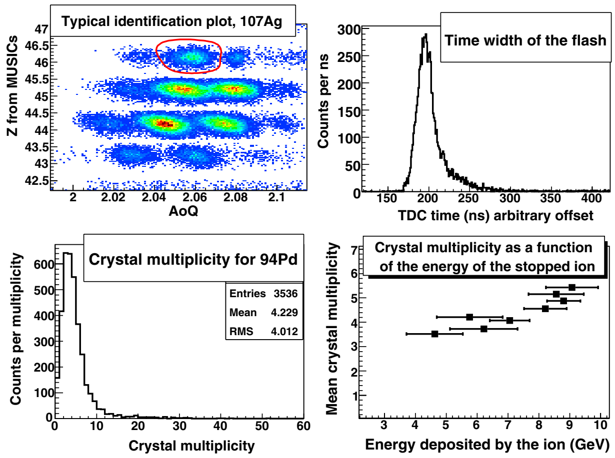

Fig. 1. (Upper left) Particle identification spectrum showing production of ^{94}Pd (highlighted ion) following the fragmentation of ^{107}Ag ions. (Upper right) Width of the prompt flash in time. (Lower left) Measured prompt crystal multiplicity in RISING Array for the ^{94}Pd. (Lower right) Mean crystal multiplicity of the prompt flash as a function of the energy they deposit in the stopper, see text for details.

beam axis. The average distance of the detectors to the centre of the array was approximately 22 cm. The photopeak efficiency of the array as measured using a standard ^{137}Cs source placed at the stopper was approximately 15% at 661 keV. Each individual germanium detector had two parallel pre-amplifier energy outputs which were sent to two separate branches of the electronics. One was used in the fully 'digital' branch and provided the input signal for 105 Digital Gamma Finder(DGF-4C) modules [9]. Three parallel CAMAC crates, each holding ten, quad-input modules were used for this part of the electronics. The individual DGF channel triggers were validated by a master trigger signal generated from a fast plastic scintilator detector at the FRS focal point. This signal was also sent to a DGF channel in each crate in order to provide an internal check of the synchronisation of the DGF clocks and also to provide a time-difference measurement between the arrival of an ion in the plastic scintillator and the measurement of a delayed gamma-ray via the DGF gamma time signal. The clock frequency of the DGF was 40 MHz (i.e., 25 ns time steps). The second output from the germanium preamplifier was sent to an analogue timing branch which was composed of a standard TFA-CFD-TDC timing circuit. The output of the CFD was sent to two seperate TDC modules, one 'short-range' (1 μs full range and 0.31 ns/channel step) and the other 'long range' (up to 800 μs and a 0.73 ns/channel step). The analogue branch allowed a precise definition of shorter-lived ($\sim$10 ns) isomers.

3 Array performance

Stopping ions with energies of several GeV in front of a high-efficiency germanium array such as RISING has a problem due to the production of atomic radiation (the so-called 'prompt flash'). This can cause multiple germanium detectors to fire with the prompt arrival of the ion and thus significantly reduces the effective efficiency for the measurement of delayed isomeric decays in the same event. This was a major concern in the previous fragmentation isomer campaign at GSI (see [4]) causing losses of up to 80% of the effective gamma-ray efficiency. The high granularity of the 105 element RISING array was intended to help to improve this problem. As in the previous campaign the current data show that the multiplicity of the prompt flash (i.e. number of detector elements which fire) is dependent on the energy of the ions as they implant in the stopper (see figure 1). Note that the values are small with respect to the number of detectors (typically about 5%). Figure 1 shows the particle identificaton plot form the fragmentation of a ^{107}Ag primary beam of energy 750 MeV/u on a 4 g/cm ^{9}Be target with the ions of the ^{94}Pd isotope outlined. This isotope has a known [10] 14^+ isomer we use for in-beam efficiency callibration. The flash width in time and mean flash multiplicity are also shown. The lower right figure shows the flash mean crystal multiplicity for the species in the identification plot, the energy deposition has been evaluated from a simulation of the FRS [11]. The stopper present for this setting was a 7 mm thick perspex foil.

4 Conclusion and outlook

The RISING Stopped Beam setup will continue with the development of a position sensitive silicon detector for use as an 'active' stopper. This will allow the correlation of implanted ions with subsequent beta-decays in the 100ms $\rightarrow$ 10s range, enabling beta-delayed gamma-ray spectroscopy of exotic, neutron-rich nuclei using the RISING array (see [12] for proof of principle of particle-β delayed correlation). The first experiments using this new setup are planned for mid-2007.

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