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Investigation of scintillation detectors for relativistic heavy ion calorimetry

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Abstract

The new $\Delta E/E$ detection system, calorimeter telescope (CATE), for charge and mass determination of heavy ions at high energies ($\geqslant$100 MeV/n) has been designed. CATE, a calorimeter telescope will consist of position sensitive Si detectors for ΔE determination and scintillators, readout by either PIN diode or PMT, for total-E determination. Different scintillation detectors were tested with ^{130}Sn, ^{186}Pb, ^{197}Au and ^{238}U beams of (100–300) MeV/n ion energy. By properly selecting the beam species from the FRS and applying position corrections, an energy resolution of $\simeq$0.5% FWHM was observed. The corresponding mass resolution of 1/200 is adequate for employment of CATE in the Fast Beam RISING campaign at GSI.

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1. Introduction and motivation

The RISING project [1] will make use of radioactive beam energies ~100 MeV/n for relativistic Coul-ex and fragmentation reactions with a secondary target in order to yield nuclear structure information. To distinguish the fragments resulting from the interaction with the secondary target, we have to determine their charge and mass with a resolution of ~1/100. This correlates with an energy resolution of 1% if a calorimeter is used for mass detection instead of the standard Bρ-measurement with a large dipole magnet. For that purpose a calorimeter telescope (CATE) system was developed, consisting of a ΔE-detector for charge and position determination and an E-detector for calorimetric mass determination.

2. Experimental conditions

The experimental set-up (Fig. 1) that was used during the tests of the CATE system and that will be used as a standard set-up during the Fast Beam Campaign of RISING [1] is described in the following: a high energetic heavy-ion beam, extracted from the synchrotron accelerator (SIS) at GSI, hits

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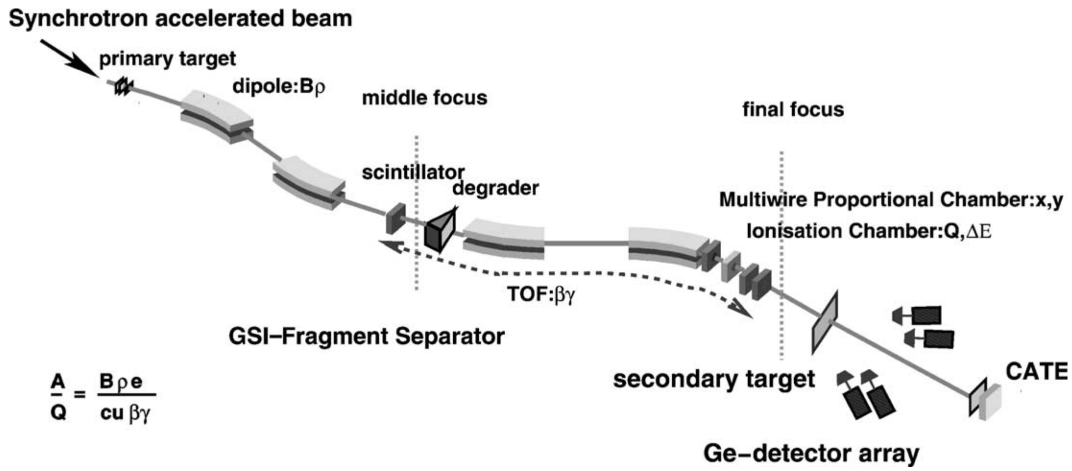

Fig. 1. The experimental set-up.

a primary target, and reaction products from fragmentation or fission are transported through the FRagment Separator, FRS [2]. Once the ions are separated by their Bρ, they reach the final focal plane, where a system of tracking detectors is placed to measure the particle position (MWPC), energy loss (IC) and time-of-flight (TOF). The selected heavy ions reach a secondary target, that will be surrounded in forward angles by the EUROBALL Ge-detectors for RISING. The secondary reaction products shall be identified in charge and mass by the CATE system placed down stream.

3. The CATE system

The complete CATE system (Fig. 2) will consist of Si-ΔE and of CsI(Tl)-E arrays. Nine Si-PIN

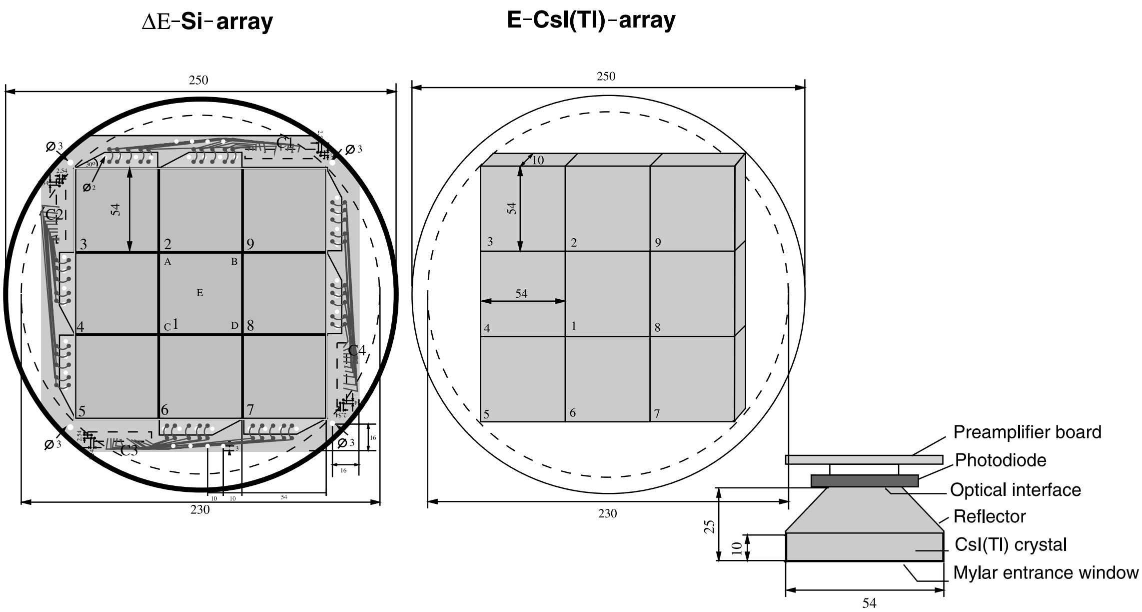

Fig. 2. The calorimeter telescope system.

diodes of 50×50 mm^2 size and 0.3 mm thickness will be used.The position of the impinging particle is detected through the charge division between the four contacts placed at the corners of the resistive layer back side. The following CsI(Tl) scintillator array will consist of nine crystals of 54×54 mm^2

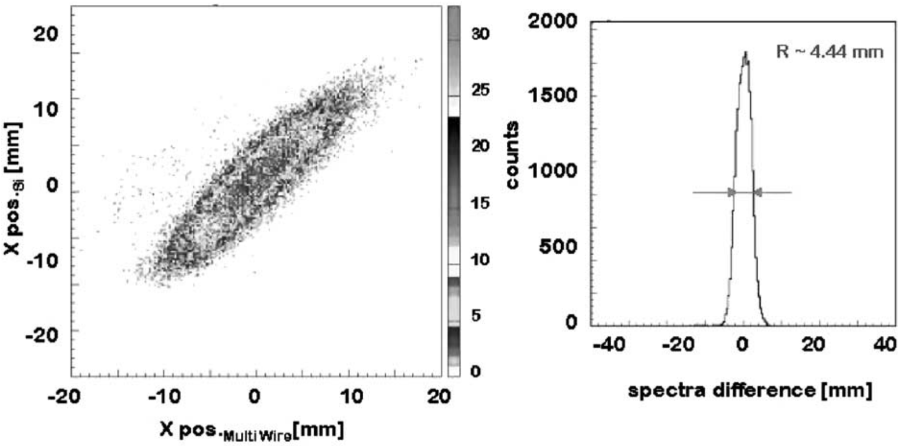

Fig. 3. Position resolution of the Si ΔE-detector.

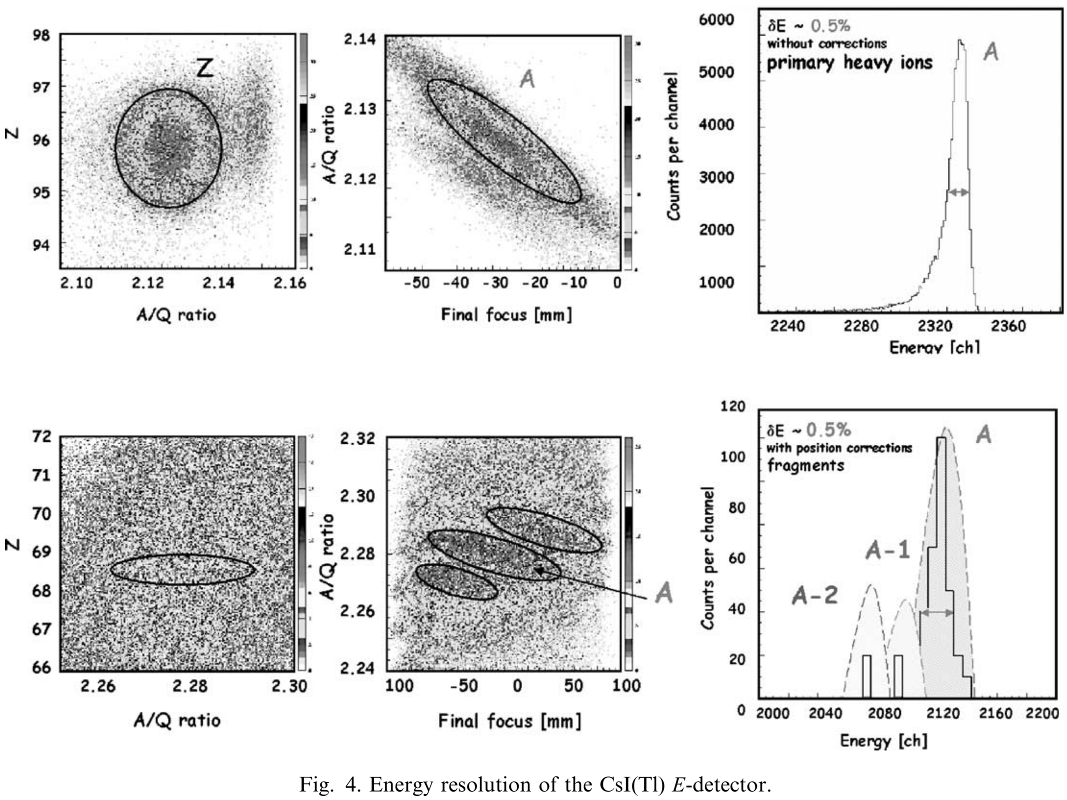

Fig. 4. Energy resolution of the CsI(Tl) E-detector.

size. The thickness of this array is 10 mm; that is enough to stop the high energetic heavy ions. The light collected in each crystal is read-out by a photo-diode.

4. $\Delta E - E$ behaviour

In an earlier investigation [3], the Si-PIN-diode ΔE-detector revealed a charge resolution of about 1/100. For the position resolution we determined a value of 4.4 mm (Fig. 3) by correlating the measured position to that of a MWPC (position resolution $\approx$1 mm) for a ^{238}U heavy-ion beam with an energy of 400 MeV/n. This result is sufficient for the intended use. In a first test the response of NaI(Tl) + PMT, CsI(Tl) + PIN, CsI(Tl) + PMT, CsI(Na) + PMT, BGO + PMT, Plastic + PMT scintillators to ^{197}Au heavy-ion beam with energies between 100 and 306 MeV/n was studied [4]. CsI(Tl) readout by either PMT or PIN-diode gave the best energy resolution determined to be up to 0.46% FWHM under appropriate analysis conditions [4]. The in-beam investigation of the prototype calorimeter system was performed, first, with a primary ^{238}U heavy-ion beam, with energies between 100 and 400 MeV/n, and second, with fragments. The energy resolution of the E-detector in case of primary beam was 0.46–0.52% FWHM without any correction (Fig. 4 top part). In case of ^{186}Pb fragments with energies between 130 and 150 MeV/n, and in case of ^{130}Sn fission fragments with an energy of 100 MeV/n, an energy resolution between 1.1% and 1.5% FWHM has been observed prior to any correction. By selecting charge and mass and by proper position correction, a remarkable energy resolution of 0.5% FWHM for fragments was reached with the calorimeter system (Fig. 4 bottom part). This corresponds to a mass resolution of 1/200 which is sufficient to select narrow mass regions and to determine masses for a given γ-transition. Therefore this method will be used in the coming experiments of the RISING campaign.

Acknowledgements

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