CALORIMETER TELESCOPE FOR IDENTIFICATION OF RELATIVISTIC HEAVY ION REACTION CHANNELS*

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A new ΔE–E CAlorimeter TElescope, CATE, has been developed to identify the reaction products from secondary fragmentation reactions or Coulomb excitation. Radioactive relativistic beams with energies between 90 and 400 MeV/u and instantaneous rates of up to 5×10^4 particles/s bombarded the detector system. CATE distinguishes the reaction channels in terms of charge (Z) and mass (A) and gives position information about the impinging ions, used for impact parameter determination.

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1. Introduction and motivation

During the recent RISING [1] campaign at GSI, stable and radioactive heavy-ion beams separated by the FRS [2] at relativistic energies between 90 and 410 MeV/u have been used to perform fragmentation reactions and Coulomb excitation on secondary targets. To identify the outgoing reaction

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products and to get an information about their scattering angle, a new ΔE–E CAlorimeter TElescope (CATE [3]) has been designed. The CATE detector was so far employed for the detection of heavy ions from ^{55}Ni up to ^{132}Xe. The performance for ^{58}Ni primary beam particles and ^{55}Ni secondary fragments is described.

2. The CATE detectors

The CATE array consists of nine Si-CsI(Tl) ΔE–E telescopes. Downstream from the secondary target position, the array covers an opening angle from 0 to 3 degrees in θ. The size of each Si detector is (50×50) mm^2, the active thickness is 300 μm and the resistive sheet amounts to 2 kΩ/cm^2. The energy resolution of such a detector is typically 80 keV for 5.5 MeV ^{241}Am α particles. The intrinsic position resolution, measured with the same α-source $(\Delta x, \Delta y)$, is better than 3 mm in x and y. Each CsI(Tl) scintillator has a size of (54×54) mm^2 and a nominal thickness of 10 mm. It is read out by a photodiode with a size of (18×18) mm^2, attached to an integrated low gain preamplifier [4]. The nine telescopes are arranged in three by three configuration. Because of the dead layer of 4mm between each two telescopes the geometrical efficiency of the total array is 92 % with respect to the incoming particles.

3. The position measurement

When a reaction product impinges on the Si resistive sheet it creates charge carriers. They migrate to the four corners, where the contacts for the outgoing signals are located. By a relative comparison of the produced pulses the position of that particle can be obtained following a simple geometrical algorithm. As the detector response is not everywhere linear, several linearization procedures have to be performed in order to obtain the square geometrical shape from the detector response [3].

4. The energy measurement

The energy ΔE, deposited in the Si detector, is measured at the back contact. Therefore the atomic number Z of the impinging particle can be deduced. The CsI(Tl) measures the particle's residual energy, $E_{\rm res}$, which together with ΔE is proportional to its mass, A, under the assumption that all particles with the same mass have the same velocity. Several effects influence the energy measurement, *i.e.* position, velocity distribution, beam intensity, and the reaction mechanism. The position dependence of the impinging particle is an effect connected to the nature of the detectors, while the velocity spread and the ion intensity are beam related effects. With

^{58}Ni primary beam, the measured mean energy resolution values of CATE of 2.0 % (FWHM) for the Si and 0.8% (FWHM) for the CsI(Tl) detectors were determined using only position corrections. In order to obtain a precise energy determination with a ^{55}Ni fragment beam and hence unambiguous identification, the effect of the velocity spread also needs to be corrected for. After applying an absolute energy calibration, the experimental data were compared with a simulation. Such ΔE–E spectra are shown in figure 1. A simulation (using the code LISE++[5]), corresponding to the experimental conditions, is plotted on the left and the experimental spectrum is plotted on the right. A unique Z identification can be expected from the simulation

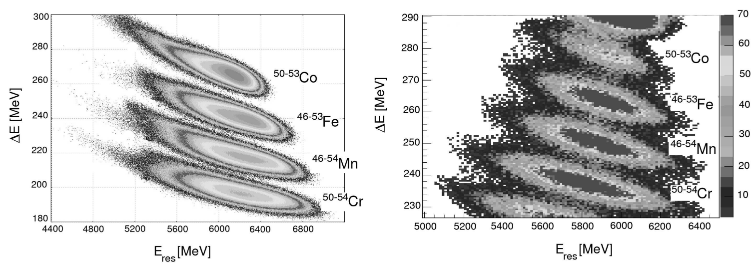

Fig. 1. Comparison of a simulation (left) and the experimental data (right) for the reaction ^{9}Be(^{55}Ni,xn, yp).

and is observed in the experimental data. For the ^{55}Ni beam the nuclear charge is determined with an accuracy $\Delta Z/Z = 0.7$ (FWHM). From the simulation no separation of two neighboring masses ($\Delta A/A \leq 1$) for this ($A \approx 55$) region can be expected, what is confirmed by the experimental spectrum. The reason is the reaction mechanism, an effect that in case of fragmentation reactions turns to be severe. When the ^{55}Ni fragment particle interacts with a target nucleus (in this case ^{9}Be) its momentum distribution is broadened. By removing nucleons the broadening of the energy distribution can reach up to several percent. This effect was described in the past by Goldhaber [6] and later parametrized to match experimental data by Tarasov [5,7]. Furthermore, the measured energy distribution of relativistic heavy ions according to the Universal parametrisation of Tarasov [7], does not follow a Gaussian shape, but is slightly asymmetric. For a single Z, *i.e.* $Z = 25$, the all produced isotopes are overlapping and creating one common ΔE–E distribution according to the simulation. When a separate calculation for each single isotope is performed, a clear shift in the centroid of the total ($\Delta E + E_{\rm res}$) energy distribution is observed. To compare the expected energy distributions with the experimental data, a linearization procedure is applied as described in reference [3]. Simulated total energy distributions for each Mn isotope are shown on the left of figure 2. The total mass dis-

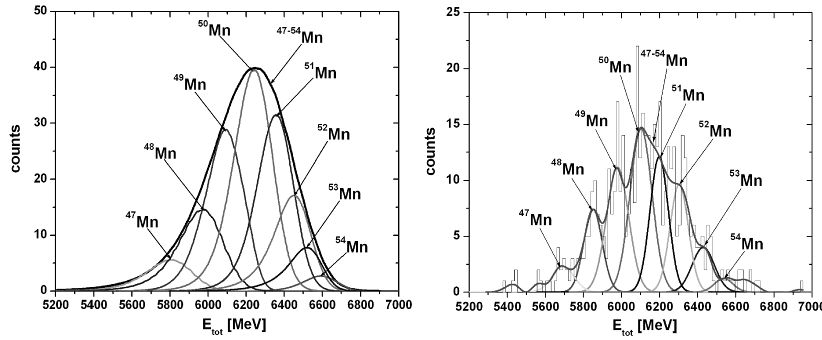

Fig. 2. A simulated single mass distribution spectrum (left), for the Mn isotopes, produced in the reaction $^{9}Be(^{55}Ni, xn, yp)$, is compared with the experimental single mass distribution spectrum (right). The total mass distribution for all $^{47-54}Mn$ in both cases are plotted as top curves.

tribution for $Z = 25$ is plotted as an envelope curve. The corresponding experimental data are shown on the right. The total experimental mass distribution can be decomposed to single mass distributions by comparison of the peak positions and widths with the simulation. The different masses of Mn isotopes are indicated by the arrows. Obviously the measured resolution is significantly better compared to the theoretical model. The parametrization used in the model had been optimized for lower particle energies. Our new data allow now to improve the model parametrization.

5. Summary

The newly developed ΔE–E calorimeter telescope identifies relativistic heavy ions at energies around 100 MeV/u. It has a good position resolution of 3 mm for scattering angle reconstruction, an unique nuclear charge resolution $\Delta Z/Z$ of 0.7 (FWHM) and a mass resolution for fragmentation reactions of 2–3 % (FWHM).

REFERENCES

[1] H.-J. Wollersheim *et al.*, *Nucl. Instrum. Methods A*, in press.
[2] H. Geissel *et al.*, *Nucl. Instrum. Methods* **B70**, 286 (1992).
[3] R. Lozeva *et al.*, *Nucl. Instrum. Methods* **B204**, 678 (2003); and to be published.
[4] A. Pulia *et al.*, private communication.
[5] O. Tarasov, D. Bazin, *Nucl. Instrum. Methods* **B204**, 174 (2003).
[6] A. Goldhaber *et al.*, *Phys. Lett.* **B53**, 306 (1974).
[7] O. Tarasov *et al.*, *Nucl. Instrum. Methods* **A734**, 536 (2004).