5 - 2 Development of a Multi-layer Scintillator Telescope for the External Target Experiments

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A new ΔE-E telescope has been constructed at the external target hall of CSRm[?]. It is composed of 7 layers of CsI(Tl) crystals. For each crystal, 4 photomultiplier tubes (PMTs) is coupled to the truncated corners for collecting scintillation light. Each crystal has an active area of 50 mm × 50 mm, and the thickness of the crystals are between 5 and 10 mm. According to the requests of different experiments, the combination and the ordering of the layers could be different. In order to achieve good uniformity of light collection, the dressing of each crystal was carefully chosen. The first three layers of the crystals are coated with ESR film, and the others are packed with 7 μm Al-Foil.

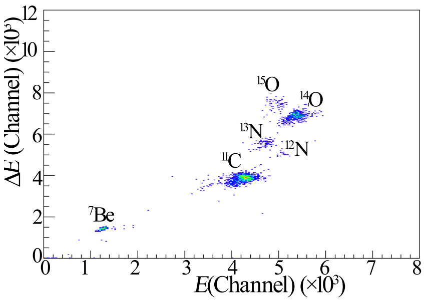

Fig. 1 (color online) ΔE-E spectrum obtained by the scintillator telescope. The energy of ^{14}O beam is 236 MeV/u.

The performance of the detector has been tested with beams at the external target hall of HIRFL-CSR. The secondary beams were produced by the fragmentation of ^{16}O primary beam (360 MeV/u) on Be target. The radioactive ions were chosen by RIBLL2 and transmitted to the External Target for the test. Because the scintillation efficiency of CsI(Tl) depends not only on the energy deposition but also on A and Z values of the incident nuclei, the particle identification must be applied before the calibration. Fig. 1 Shows the ΔE-E spectrum obtained by the scintillator telescope, where ΔE was measured by the first scintillator layer and the total energy was given by the sum of the energy loss in all the 7 crystals. The isotopes were separated well. With the measurement of the energy loss in the first scintillator layer (7 mm in thickness) with ^{14}O beam (236 MeV/u), the energy resolution better than 5% is obtained.

The energy calibration of the CsI(Tl) crystals was performed by two parts. The first part is to calibrate the energy loss in the first layer of the CsI(Tl) crystals. Because of the relatively high energy of the incident ions, the relation between energy loss and light output in the first scintillator layer is nearly linear. And the linear fitting was applied, which is shown in Fig. 2. The second part is to calibrate the total energy deposition for all the isotopes which stopped in the full detector. The energy deposition was calculated by using LISE++ program. As the incident ions were slowed down in the crystals, the energy loss of the ions became larger and larger. And the

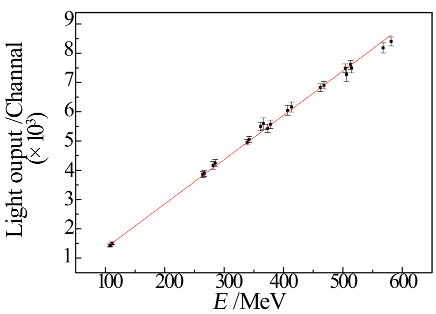

Fig. 2 (color online) Light output versus energy loss of the incident ions in the first CsI(Tl) crystal.

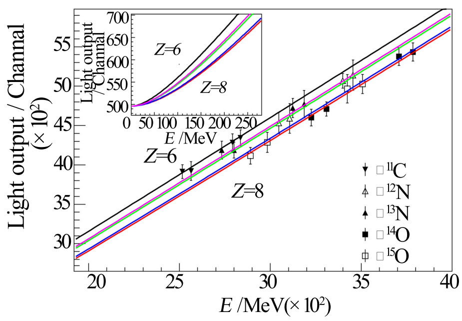

Fig. 3 (color online) The sum of light output obtained by all the CsI(Tl) crystals versus total energy deposition of the incident ions. The inset picture shows the calibration results in the low energy region.

relation between total light output and energy loss became non-linear, which depends on A and Z values of the incident isotopes. This is called saturation effect of luminescence center. In order to fit total light output of the incident isotopes which stopped in the crystals, the equation below was used[?]:

$$L = a + b \times [E + cAZ^2 \times \ln(1 + \frac{E}{cAZ^2})] \quad ,$$

where a, b, c are free coefficients. The calibration results are shown in Fig. 3. The fitting lines are in good agreement with the experiment data (Z=6 ∼ 8) in the high energy region. The reasonable results in the region we cared were obtained by this calibration method. And the relative error between measurements and calculations is better than 2%. Considering the lack of experiment data at very low energy in this work, the calibration results in very low energy part just could be used as a reference, which is shown in the inset picture of Fig. 3.

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5 - 3 A New Method of Energy Calibration of Position Sensitive Silicon Detector

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In α-decay spectroscopy, there are two steps in the energy calibration of a position sensitive silicon detector (PSSD), the linear calibration and the correction of it. Here we present a new method to correct the linear calibration. The procedure of this new method is much simpler than that of the traditional one[1]. Moreover, by using this new method, the energy resolution is improved.

In our recent experiment, three PSSD detectors were used, each of which is divided into 16 position sensitive strips. Each strip has two outputs, E_1 and E_2, from top and bottom end, respectively. The total energy deposited in the strip is $E = E_1 + E_2$, while the relative position of an event is given by $\eta=(E_1 - E_2)/(E_1 + E_2)$. So a simple relation between energy and relative position, $E/E_1=2/(1+\eta)$, can be deduced. The general expressions of E_1, E_2 and η have been obtained by linear calibration[2]. As shown in Fig. 1(a), after the linear energy calibration, the distribution of events of each individual external α source looks like a curve rather than a straight line. The main goal of the correction of linear calibration is to make the curve become a straight line.

Now we take E, in $E/E_1=2/(1+\eta)$, to be the literature values of the external α sources. Then, a new relation of top energy and relative position, $E/E_1=f(g)$ where $g=2/(1+\eta)$ and f is a function to be found, is created. Three groups of events circled with color lines in Fig. 1(a) are presented in Fig. 1(b), respectively, in a coordinate system of $g - E/E_1$. It can be seen that the three groups of events almost overlap together completely.

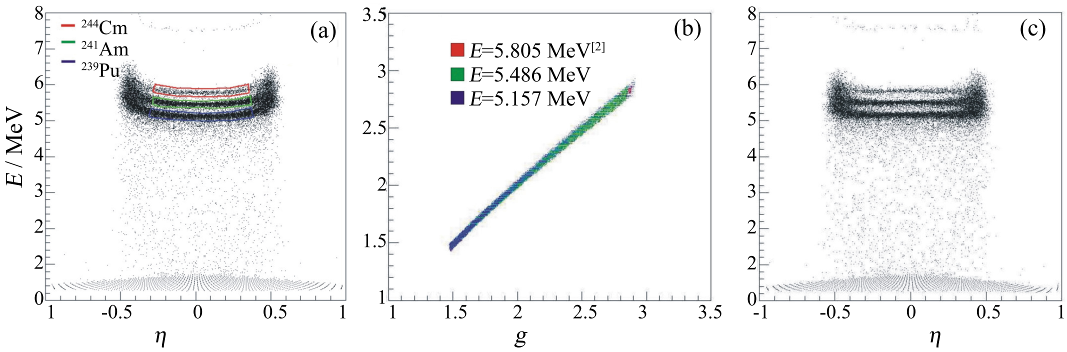

Fig. 1 (color online) (a) Distribution of the events of three external α sources(^{244}Cm, ^{241}Am, ^{239}Pu) after the linear calibration. Three groups of events circled with color lines are created by the three external α sources respectively and exclude the events contaminated by noise. (b) Three groups of events circled with color lines in (a) are drawn in a coordinate system of $g - E/E_1$. (c) The corrected results of (a) using the new method.

The function $f(g)$ can be found by a fitting of these three groups of events. $f(g)= ag^2+bg+cg^{1/2}+d$ was found to fit the events well. Finally, the corrected energy, $E = E_1 \times f(g)$, is obtained and shown in Fig. 1(c). For the problems of dead layer of the detector and pulse-height-defect of heavy nucleus in silicon[3], the α decay energy calibrated by the three external sources is different from the literature values. This difference can be reduced by a general linear correction of the calibrated energy with the help of identified internal α sources. The energy resolution obtained using this new method is improved compared with the traditional one[4].

References

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