Comparison of different calibration methods for Si-strip detectors

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Introduction

At present, nuclear physics experiments with rare isotope beams involve the use of large arrays of Silicon strip detectors with very good energy and spatial resolutions. These highly segmented detector setups like MUST2, GLORIA, TIARA, GASPARD [1] cover a significant part of 4π. The large active area and high granularity of the double sided Silicon stripped detectors (DSSDs) are indispensable for experiments involving low intensity radioactive beams. However, online and offline analysis of the data present challenges such as dead layers in detectors, interstrip gaps, incomplete charge deposition, calibration of large numbers of independent strips etc. In this work, we compare and discuss the results of three different procedures of energy calibration of the DSSDs used in our experiment at the CERN, HIE-ISOLDE using a 5 MeV/A ^{7}Be beam on a CD_2 target [2].

Experimental setup

The experimental setup consisted of a set of five silicon ΔE-E telescopes in pentagon geometry covering $40^\circ - 80^\circ$ in lab. Each telescope consists of a thin 16×16 DSSD (60 μm) backed by a thick unsegmented silicon pad detector (1500 μm). The forward angles from $8^\circ - 25^\circ$ were covered by a 1000 μm thick annular detector with 24 rings and 32 spokes. The back angles from $127^\circ - 165^\circ$ were covered by a set of two 32×32 ΔE-E telescopes placed right and left to the beam direction consisting of 60 μm and 140 μm DSSDs backed by 1500 μm pads. More details regarding the experimental setup are discussed in [2–4].

Energy calibration

For energy calibration of the silicon detectors, a 4×1.15 kBq ^{148}Gd$-^{239}$Pu$-^{241}$Am$-^{244}$Cm mixed α source was used. Three different calibration procedures have been followed to compare the calibration of the DSSDs as described below.

1. Strip calibration : This is one of the most widely used procedures for the rough calibration of DSSDs. In strip calibration, we plot the raw $\alpha-$energy spectrum (in channels) of each independent strip of the front and back sides of the silicon DSSDs and fit the individual peaks to single-Gaussian functions. Thus we have the channel numbers of peaks corresponding to each individual strips. A linear function is then fitted to get the conversion between channel and energy, giving the calibration coefficients. The number of calibration parameters obtained in this process is $2\times2\times16$ for a 16×16 DSSD.

2. Relative calibration of strips : This procedure takes the advantage of the double acquisition of a signal at its front and back side when the DSSD registers a particle hit. It reduces the number of unknown calibration parameters from $2\times2\times16$ to only 2. We start with one strip, say the first vertical strip, and take its uncalibrated energy spectrum (raw channel) as the reference against which all other horizontal strips (raw channels) are plotted one by one to obtain 16 least-square linear fits for 16 pixels of the reference strip. The obtained coefficients are used to relate energy signal of each horizontal strip to the energy signal of the reference strip. The refer-

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ence strip is then changed and the procedure is repeated for all other strips as reference to arrive at the best possible calibration [5].

3. Pixel calibration : In pixel calibration, we have the information of the angle of emission of each hit at the DSSD. Thus, we can accurately determine the energy-losses of each particle traversing different dead-layers. Hence we get more accurate values of the calibration parameters [6].

Results and discussions

We used the above three procedures to calibrate the DSSDs in our experiment. It may be noted that, the above two strip calibration methods are significantly faster to implement compared to the pixel method. However, the pixel calibrated DSSDs give more accurate measurement of the energy values. The energy spread of the α peaks are minimum for pixel calibration as shown in Table I. The relative strip calibration gives the least favourable results. In particular, the energy spread of the ^{148}Gd peak is reduced by around 28% using the pixel calibration method compared to the strip calibration. The FWHM of the front and back energy difference (ΔE) for pixel calibration is $\sim$ 74.9 keV, for strip calibration it is $\sim$ 89.2 keV and for relative strip calibration it is $\sim$ 157.9 keV (Fig. 1). Thus, the energy matching of the front and back side is best in pixel calibration. We can thus select a tolerance of 200 keV for the front-back matching of the DSSDs in order to select the "good" events for analysis.

TABLE I: Comparison of the FWHM of the $\alpha-$energy peaks at the front side of one pentagon DSSD after the strip, relative strip and pixel calibration methods.

Isotope	Source energy[a] (keV)	Strip (keV)	Rel. strip (keV)	Pixel (keV)
^{148}Gd	3182.69	91.3	132.9	65.7
^{239}Pu	5156.59	83.5	105.3	73.2
^{241}Am	5485.60	81.9	117.7	71.5
^{244}Cm	5804.82	76.4	124.4	75.8

[a]Our detectors resolved only the most intense $\alpha-$energy of each decay.

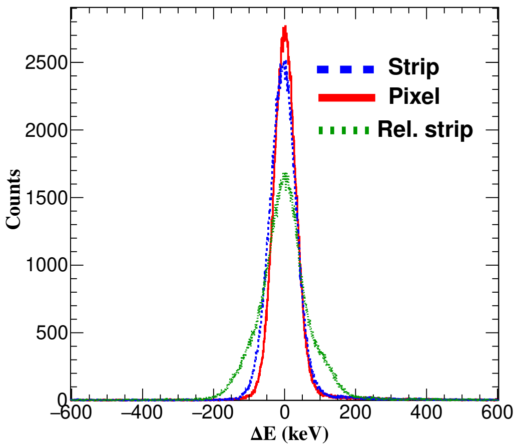

FIG. 1: Difference between the energy deposited in the front and back strips (ΔE) for one pentagon DSSD in our experiment. The difference is minimum for pixel calibration.

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