POSITION DEPENDENCE OF THE ENERGY RESOLUTION OF CSi(Tl) SCINTILLATORS

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Investigations of isotopic effects in the decay of excited nuclear systems, require detection devices with an excellent angular, energy and isotopic resolution with a large solid angle coverage. Recently, a detector array, the Large Area Silicon Strip Array, has been constructed by a collaboration between Michigan State University, Indiana University and Washington University [1]. Each telescope of such array consists of two Si strips detectors, each 65μm and 500m thick, backed by four 6cm long CsI(Tl) crystals with photodiode readout.

Preselection of CsI(Tl) crystals for Light Output Uniformity

Typically, commercial CsI(Tl) crystals can manifest non-uniformities in the light output across the detector face on the order of one percent per centimeter [2,3]. To a large extent this non-uniformity can be limited to better than 0.3% per centimeter by controlling the manufacturing process and by scanning the CsI(Tl) crystals and rejecting those that do not meet this criterion[2,3]. Such selection procedure has been performed by scanning them with a collimated α-source in vacuum [5] and measuring the peak location (5.486 MeV) at nine equally spaced positions on the crystal face.

The left panel in Figure 1 shows the results of such scanning for a crystal, #655, that was accepted. The different gray levels of the big squares correspond to the percentage deviation of the α peak of each point from the median value. Crystals with deviations larger than ±0.5% were rejected and sent back to the manufacturer.

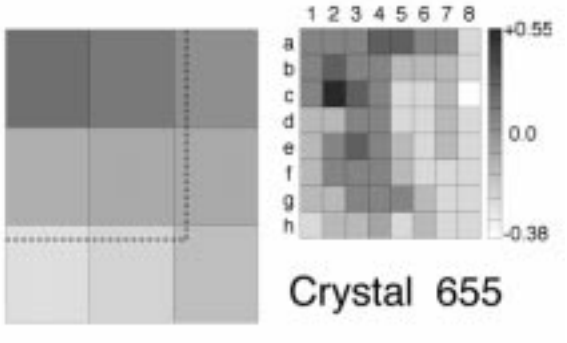

Figure 1: Variations in light output from the scanning of 5.486 MeV alpha particles (left panel) and from 240 MeV ^{4}He particles pixel by pixel (right panel). The 8x8 pixel shaded area in the right panel corresponds to the area enclosed by the dashed line in the left panel. Column numbers (***1-8***) and row letters (***a-h***), used to identify each pixel in Figure 2, are marked.

Position Dependence of the Energy resolution

To determine the influence of small (<0.3%) residual light output non-uniformity, we need finer position resolution and higher energy particle to penetrate deep inside the crystal. This can be accomplished by combining the CsI(Tl) scintillator with a position sensitive silicon detector and by using a high energy α beam.

To measure the energy response of the crystals for energetic beams, 240 MeV α particles extracted from the NSCL K1200 cyclotron were injected directly into the CsI(Tl) crystals. To search for and identify any position dependence in the crystals light output, the position information of each α particle was measured by passing the α's through a 500μm 2 dimensional position sensitive silicon detector placed in front of the CsI(Tl) crystals. The double-sided Si-strip detector has 16 strips in the x- and 16 strips in the y-direction. These strips provide 256 co-ordination points (pixels). As the front face of the CsI(Tl) crystal is one-quarter the surface area of the Si-strip detector, 64 measurements of the light output were obtained as a function of position for each crystal.

The right panel of Fig. 1 shows the variations in percent of the light output measured at each of the 64 pixels of crystal #655 for the 240 MeV ^{4}He beam. The area corresponds to that enclosed by the dotted lines in the left panel of the figure. In contrast to the α source measurements that display rather smooth variations, the α beam measurement show significant local variations in the light output, of the order of 0.5%.

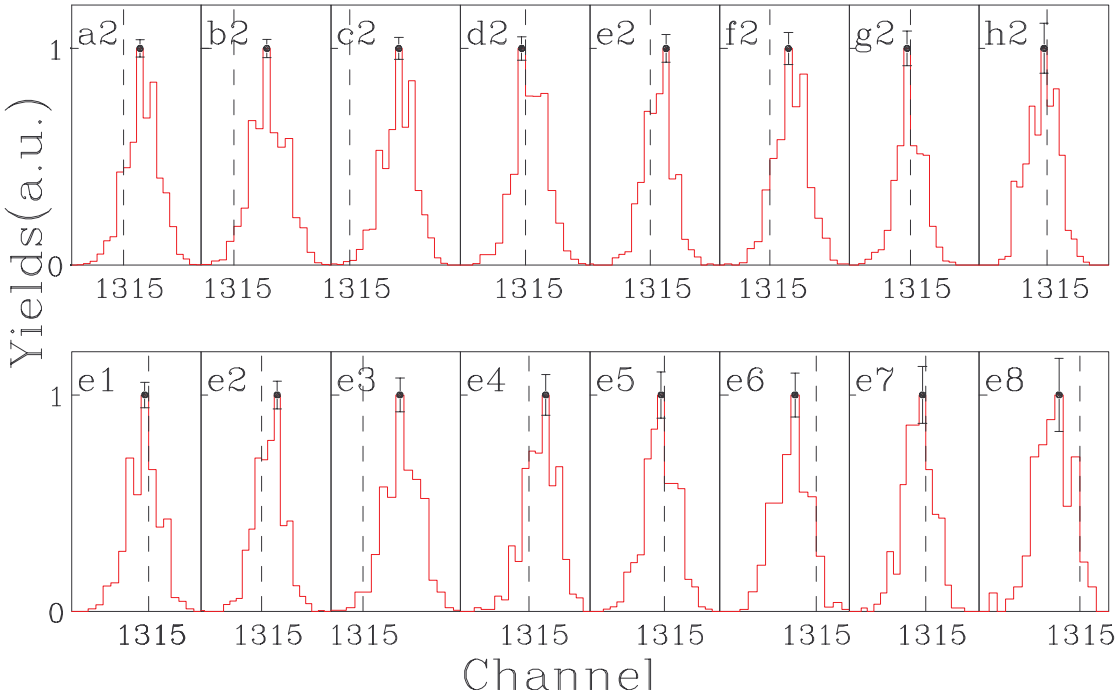

Figure 2: Energy spectra of 240 MeV ^{4}He particles for individual pixels. The upper panel shows 8 spectra down column ***"2"*** and the lower panel shows 8 spectra across Row ***"e".*** See Figure 1 captions for explanation of pixel identification.

This average trend appears to be approximately the same in both α source and α beam measurements. To show that these variations are not an experimental artifact and that they are indicative of real variations in the light output of the crystal, the upper and lower panels of Fig. 2 shows energy spectra obtained for pixels along column "***2***" and row "***e***" as labeled in the right panel of Fig. 1, respectively. The exact coordinates of the pixels are labeled inside each panel of the figures. Neighboring pixels correspond to trajectories that are on the average, separated by 3 mm at the front face of the CsI(Tl) crystal. To provide a fixed reference point, the average peak position of the alpha particles detected by the whole crystal is marked by a dashed line (Channel 1315) in each panel. Since different pixels are exposed to different number of particles, the counts in the peak of each pixel are

normalized to 1. For clarity, only the statistical error bars of the peaks are indicated. Clearly, there are shifts in these individual spectra, going from one pixel to another, that exceed the resolution of the spectra. Moreover, the trends were not monotonically varying from one direction to another. While the light output near the edge of the crystals (in the extreme left and right panels of Fig. 2) may be sensitive to imperfections in the surface treatment in the crystal, variations in the light output elsewhere must be correlated to local light output variations in the crystal. We speculate that these variations arise from local variations in the thallium doping introduced during the crystal growing. We cannot exclude, however, that these variations could be the result of local impurities that could vary with position on the scale of 3 mm. In either case, one might expect equivalent variations in the light output along the unobserved longitudinal axis of the crystal. Thus one might expect the local variations in the light output to be different for different energy particles, reflecting their different ranges.

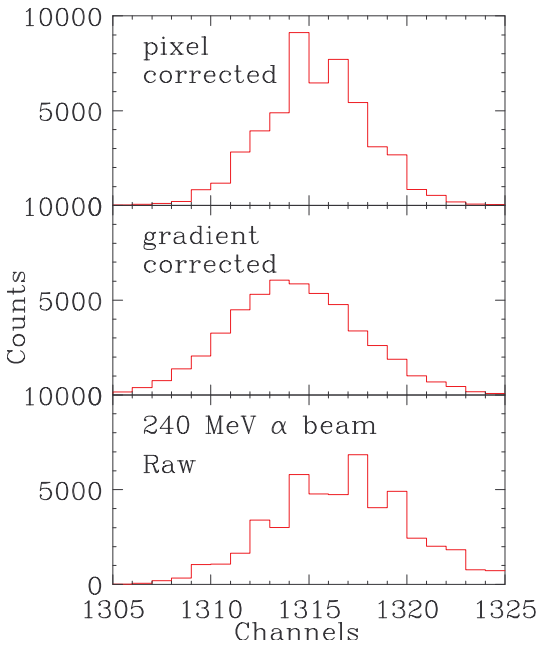

Figure 3: Energy resolutions for 240 MeV ^{4}He particles detected by the CsI crystal. The uncorrected energy spectrum is shown in the bottom panel. It has an energy resolution of about 1.54 MeV (0.65%) FWHM. The spectrum corrected for an average gradient determined by scanning is shown in the middle panel. The energy resolution for this spectrum is 0.59% or 1.41 MeV FWHM. The spectrum corrected for local variations (pixel by pixel) is shown in the top panel. It has an energy resolution of 0.45% or 1.08 MeV FWHM.

The bottom panel of Fig. 3 shows the energy spectra for the 240 MeV ^{4}He beam particles detected with CsI crystal #655 without selection on position. The energy resolution is about 1.54 MeV (0.65%). Several attempts can be made to improve this resolution. First, one can correct the light output for the average trend. This was accomplished by fitting the light output with a 3 parameter function $L=L_0(1+ax)(1+bx)$. The spectra are then corrected for each pixel by the relation

$$Ch' = \frac{Ch}{(1+ax)\cdot(1+bx)}. \qquad (1)$$

After making this correction and summing the data from all pixels into one spectrum, there is a slight improvement in the resolution, from 0.65% to 0.59% (1.41 MeV). This corrected spectrum is shown in

the middle panel. Alternatively, one can correct the energy-light output pixel by pixel by correcting the energies of particles in one pixel by the ratio of the average energy in that pixel divided by the average energy in the entire crystal. When this was done, the resolution improves dramatically as shown in the top panel, to 0.45% or 1.08 MeV, about twice the noise width of 500 keV. In comparison, the peaks corresponding to the single pixel spectra as shown in Figure 2, have a resolution of 1.04 MeV, nearly the same as the overall resolution obtained after summing up all the single spectra. Since the typical beam energy width is better than 0.1%, the resolution of 0.45% probably represents the upper limit of the resolution of the crystals. Unfortunately, the possible depth dependence of the light output variation excludes the possibility to generalize such corrections to all particles emitted in nuclear reactions.

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