SCANNING OF CsI(Tl) SCINTILLATORS FOR UNIFORM LIGHT OUTPUT

W.P. Tan, K. Chalut, C.K. Gelbke, T.X. Liu, X.D. Liu, W.G. Lynch, A.M. Ramos, M.B. Tsang,
A. Wagner, H.S. Xu, R. deSouza[a], B. Davin[a], Y. Larochelle[a], R. Charity[b], L. Sobotka[b]

In the past decade, multifragmentation has been firmly established as one of the decay modes undergone by the excited nuclear systems formed in intermediate heavy ion collisions [1]. With the availability of radioactive beams, it is possible to explore the isospin dependence of multifragment decays. In general, such studies require detection devices which have excellent angular, energy and isotope resolution with a large solid angle coverage. To cover the dynamic ranges of the reaction products ranging from high energy protons to low energy fragments produced in heavy ion collisions, it is important to optimize the detector arrays to detect as many of these particles as possible over a large dynamic range.

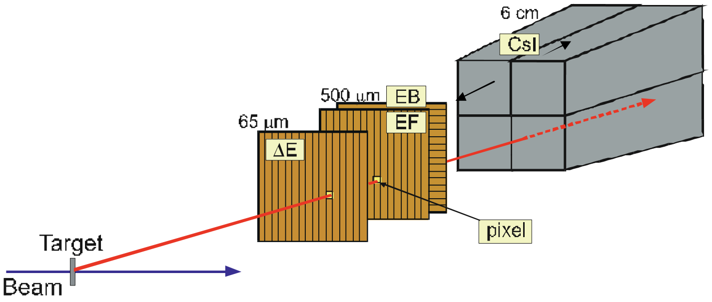

Figure 1

In a recently constructed detector array, the Large Silicon Strip detector Array (LASSA) [2], each of nine telescopes, shown in Fig. 1, consists of two Si strip detectors, each 65 µm and 500 µm thick, backed by four 6 cm long CsI(Tl) scintillator crystals with photodiode readouts. The large area (5 cm x 5 cm) strip Si detectors are used as the DE-detectors providing the energy loss information about the emitted particles. The 500 µm Si detector situated between the 65 µm Si detector and the CsI(Tl) crystals have 16 horizontal and 16 vertical strips with a pitch of 3 mm between strips.

In the LASSA array, CsI(Tl) scintillators are chosen as the E detectors where most high energy particles stop, mainly because of cost and the relative sturdiness of the crystals against radiation damage. However, to provide good isotope information comparable to the Si detectors, the CsI crystals must have uniform and good energy resolutions. This is achieved by pre-selecting crystals before construction, followed by careful energy calibrations with real beam particles. This article mainly focuses on the procedure we developed to select uniform CsI(Tl) crystals.

To ensure that the CsI(Tl) crystals used in the LASSA array have the best energy resolutions, only crystals which have uniform scintillation response to better than 1% were used. The quality of the crystals ordered directly from the manufacturer was monitored by scanning them with a collimated α-source in a vacuum using a procedure similar to that described in Ref. [3].

All crystals ordered from Scionics [4] were rectangular in shape with dimensions of 3.5x3.5x6 cm^3. They were polished at the front and sanded at the sides. Before scanning, the crystals were inspected for visual cracks or imperfections. Then, the back side was sanded down and polished. It was then optically coupled to a clear acrylic light guide which, in turn, was optically connected to a 2x2cm^2 photo-diode. The sides of the crystals and the light guide were wrapped with two layers of white Teflon tape. The front face of the crystal was covered with an aluminized mylar foil to ensure uniform light collections.

Figure 2a shows the location of nine points uniformly spaced on the front face of the crystal, where “O” denotes the center of the crystal. The peak location of the 5.486 MeV α-line from a collimated ^{241}Am α-source was detected in vacuum at each position. The alpha spectra were recorded with a simple multichannel analyzer equipped with a peak sensing ADC. The spectra were then transferred to be analyzed offline.

Fig. 2b shows the scanning results of two crystals, number 652 which was accepted (top panel) and number 291 which was rejected (bottom panel). Plotted are the deviations of the alpha peak of each point from the mean. The x-axis represents the horizontal distance from the point with respect to the center, O. For illustration, x1 and x2 are plotted at +16 and -16 mm from O, respectively, and c1, c2 c3 and c4 are +8 and -8 mm from the center. To distinguish c1 from c2, c3 from c4, and y1 from y2, these points are displaced slightly, 1 mm on the left (c2, c3) and on the right (c1, c4). One advantage of plotting this way is that any horizontal gradient in the uniformity can be detected at first glance from the graph. The vertical gradient can be discerned easily by examining the points y1, O and y2 as in the case of crystal number 291 in the bottom panel.

Crystals with deviations larger than ±0.5% such as the one shown in the bottom panel of Fig. 2b were rejected and sent back to the manufacturer. Only crystals with deviations less than ±0.5% were accepted. These crystals were then machined to the final shape. The dashed lines on Fig. 2a show the final dimension of the front face. Two sides would be tapered to form an array of detectors pointing at the target which is placed at 20 cm, as shown in Fig. 1. The crystals were then polished and scanned one more time. In general, the final surface preparation improved the scanned results only slightly.

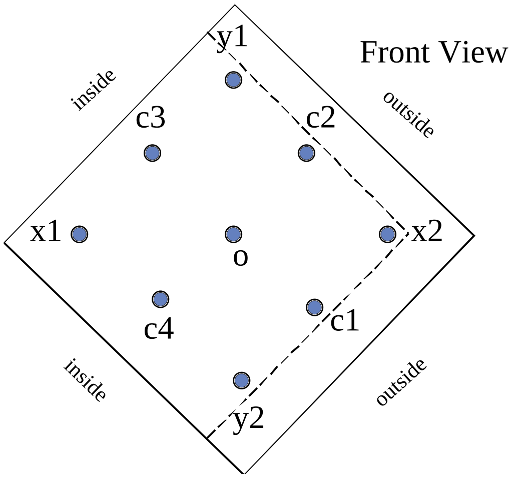

Figure 2a

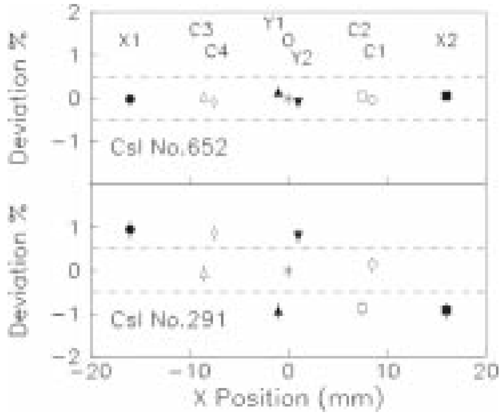

Figure 2b

It has been known that a reflective entrance foil is needed on the front face of a CsI(Tl) crystal to achieve optimal light collection efficiency. The sides of the crystal are generally sanded to defuse the light. To prevent light leak and to avoid cross-talks between crystals, the sides of the CsI(Tl) crystals were wrapped with layers of 0.5" wide Teflon tape. Plotted on Fig. 3 is the peak channel number (top panel) and the resolution (bottom panel) of the 5.486 MeV α-line from a collimated ^{241}Am α-source as a function of number of layers of Teflon tape. With increasing number of layers of Teflon tape, the light collection efficiency increases resulting in higher peak channels. With increasing light collection, the resolution of the crystals also improves. The improvement plateaus out at around five layers of Teflon tape. The light collection efficiency as well as the resolution improve dramatically using the cellulose Nitrate membrane (0.2 mm) as shown by the open points in Fig. 3.

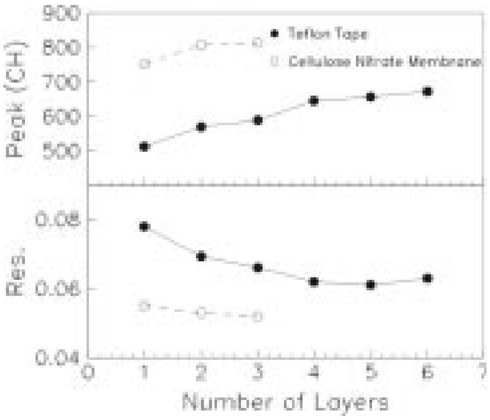

Figure 3

A light guide was glued to the back face of a crystal with epoxy (BC600), manufactured by Bicron. A 2cmx2cm pindiode was then attached to the light guide. To prevent light leak, the light guide and the pindiode were painted with a reflective white paint (BC620). Finally a cellulose Nitrate membrane filter was used to wrap the crystal. To prevent cross-talk, a thin aluminized mylar foil (15 µm) was inserted between the wrapped crystals that are adjacent to each other.

a. Department of Chemistry and IUCF, Indiana University, Bloomington, IN 47405, USA,
b. Department of Chemistry, Washington University, St. Louis, MO 63130, USA,

References

1. W.G. Lynch, Nucl. Phys. A545, 199c (1992).
2. A. Wagner et al, in preparation
3. W.G. Gong et al, Nucl. Inst. and Meth. A268, 190 (1988).
4. Scionix Holland BV, P.O. Box 143, 3980 CC Bunnik, The Netherlands.