Development of the segmented plastic scintillation detector GARi

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The investigation of β-decay of neutron-rich nuclei far from stability is crucial to understand nuclear structure and astrophysical processes. Typically, intense secondary beams generated by fragmentation reactions have been used in these β-decay experiments. Implantation detector in such experiments are used to measure energies and positions of both implantation and decay events, conventionally served by double-sided silicon-strip detectors such as AIDA[1] or WAS3ABi.[2] Recently, the segmented plastic scintillation detector (SPSD) has attracted considerable attention owing to its excellent timing performance,[3–6] which are fundamental for β-decay spectroscopic studies of neutron-rich nuclei, including β-delayed γ and time-of-flight (TOF) of β-delayed neutrons. In this report, the recent development of the plastic scintillation-based implantation detector Gas-cell Active detector for Radioisotope decay (GARi) is outlined, which is expected to achieve the position and timing resolution requirements for β-decay spectroscopic studies of neutron-rich nuclei in the F11 of the RIBF.

GARi comprises one segmented plastic scintillator and six position-sensitive photo multiplier tubes (PSPMT). The scintillator (EJ-228) is manufactured by ELJEN with a dimension of $150 \times 100 \times 6$ mm^3, and is segmented 4 mm deep into 100×66 pixels. The cross section of each pixel is 1.3×1.3 mm^2, leaving a 0.2 mm gap. The position resolution will be enhanced by the non-segmented part with a thickness of 2 mm, used as a light diffuser. Six Hamamatsu H12700 PSPMTs are coupled with the scintillator pad on the non-segmented side using optical grease. Each PSPMT has 8×8 anodes measuring 6×6 mm^2 each. Each anode row is interconnected by a resistor chain and readout from two sides, thereby reducing the number of readout channels to 16 for each PSPMT. The scintillation position (x, y) can be determined from the integrated charge Q^{left} and Q^{right} collected from the ith anode row using the following formulas:

$$x = a_x \frac{\Sigma_{i=1}^{8}[(Q_i^{left} - Q_i^{right}) \times w_i]}{\Sigma_{i=1}^{8}[(Q_i^{left} + Q_i^{right}) \times w_i]} + b_x, \qquad (1)$$

$$y = a_y \frac{\Sigma_{i=1}^{8}[(Q_i^{left} + Q_i^{right}) \times w_i \times i]}{\Sigma_{i=1}^{8}[(Q_i^{left} + Q_i^{right}) \times w_i]} + b_y, \qquad (2)$$

$$w_i = sqrt\left[\frac{Q_i^{left} + Q_i^{right}}{\Sigma_{i=1}^{8}(Q_i^{left} + Q_i^{right})}\right] \qquad (3)$$

where a_x, a_y and b_x, b_y are the position calibration factors. To collect the integrated charge, anode signals are recorded by the CAEN V1741 flash-ADC after being shaped via a CAEN N568B shaping amplifier. Dynode signals with better timing performance than anode signals are delivered directly to a CAEN V1730 flash-ADC.

^{90}Sr β source was employed to perform the position resolution test. The two-dimensional position distribution of one PSPMT is shown in Fig. 1(a), and the selected parts (red line) are projected to y and x axes, as shown in Fig. 1(b) and (c) respectively. The projections were fitted using multi-gaussian functions to obtain the mean value and standard deviation for each gaussian peak. The distance between each two centers of pixels (1.5 mm) and the mean value of each gaussian peak were used to obtain the position calibration factors. Results of multi-gaussian fits yielded a position resolution in FWHM of 1.01(1) mm in the X dimension and 0.85(1) mm in the Y dimension. Timing performance test of dynode is ongoing.

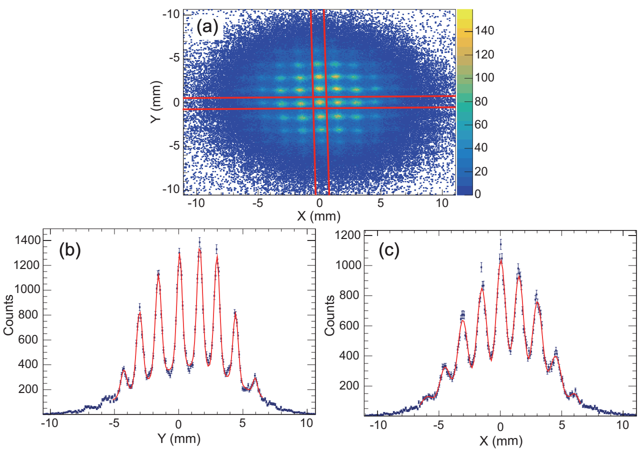

Fig. 1. (a) Two-dimensional position distribution of one PSPMT determined using Eqs. (1) and (2) with ^{90}Sr source. (b, c) Projections on the y and x axes of the selected parts, fitted by multi-gaussian functions.

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DOI:10.34448/RIKEN.APR.57-133