First implementation of the new segmented implantation detector for decay studies with BRIKEN array

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A new implantation detector was developed at the University of Tennessee and implemented for the first time during the October 2017 BRIKEN[1)] campaign. The detector is an evolved version of the array proposed previously[2)] but uses YSO instead of a plastic scintillator. The developments were driven primarily by the need to have a fast trigger detector for the neutron time-of-flight array VANDLE.[3,4)] The benefits of using an inorganic-crystal scintillator such as YSO are its high effective atomic number ($Z = 35$) and density (4.4 g/cm^3) which result in a short range of beta particles. Both properties should enable a very high detection efficiency and good spatial correlation between ions and decay, thereby providing a good alternative to DSSDs. The YSO scintillator is also very fast and radiation hard, and therefore, it can be used with high rates. The disadvantage of using this high-Z material is its relatively high absorption for the γ-rays, which has to be considered with measurements at energies below $E_\gamma = 100$ keV. The detector unit consisted of a segmented YSO crystal and flat-panel multi-anode photomultiplier (Hamamatsu H8500 or H12700 series). The readout from the photomultiplier used a resistive-network scheme for event position determination. The signals were digitized and integrated with the BRIKEN digital data acquisition system. The YSO crystal was 5-mm thick and was assembled from 1×1 mm^2 segments arranged in a 48×48 array, as shown in Fig. 1. The isolation among segments of the detector, the cover of the detector face, and the sides used ESR (3M) reflector material. The YSO array was attached to the photomultiplier with a 2-mm quartz diffuser glass. The detector unit was enclosed in a 3D printed light-tight enclosure with a thin front window. It was placed inside the BRIKEN matrix directly behind the WAS3ABI[5)] detector array with the YSO crystal centered between two clover detectors. During the DA17-02 experiment ions with $Z < 30$ were partially implanted in the YSO detector enabling the ability to test the ion-implantation correlation performance of the detectors. Light yield for heavy ions in the YSO is unknown. It was critical to establish experimentally the optimum operating voltage that avoids the saturation of the photomultiplier and enables the detection of signals induced by ions and betas. The explored range of voltages was from 550 V to 1200 V. The electronic signals from the Anger logic and common dynode were split into two electronic tracks. One set of signals was dedicated to measuring heavy ions and was fed directly into electronics; the other signals used fast amplifiers and were needed to record beta particles. Owing to a very high light yield and very efficient light collection, the system had to be operated at a relatively low voltage of 575 V during the experiment. Despite the resulting small amplification, we were able to detect signals induced by beta particles with a very high efficiency of at least 65%. We observed moderate distortion of the image which will be corrected by the selection of a more appropriate voltage divider. The detector operation was very stable throughout the experiment. The advantages of the simplicity of operation of this new detector were clearly demonstrated.

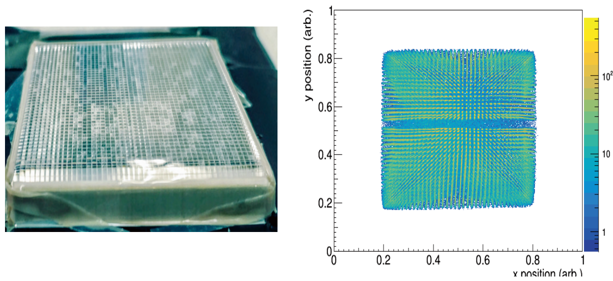

Fig. 1. (Left) Segmented YSO scintillator before coupling to the photomultiplier. (Right) Implantation profile recorded by the segmented YSO detector.

References
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