Response of uni-directionally grown 1, 3, 5-Triphenylbenzene single crystal in neutron detection

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Introduction

Hydrogen based organic scintillators are usually effective for detection of neutrons. However, these detectors are also sensitive to gamma radiation. Moreover, as the effective atomic numbers of these crystals are low - the gammas only produce Compton continuum spectrum. Thus it is essential that additional techniques like pulse shape discrimination (PSD) and /or time-of-flight (TOF) techniques are utilized to distinguish between gamma and neutron events. For both basic research as well as several applications, it is important that the large size unidirectional organic single crystals are grown by new methods that improve the light output and particle discrimination properties. The present authors had reported the unidirectional growth technique [1] and gamma ray energy responses of 1, 3, 5-Triphenylbenzene (3PB) organic single crystal with different radioactive sources [2].

In the present work, the capability of this 3PB single crystal to detect neutrons and its performance for neutron-gamma discrimination has been tested by TOF technique.

Experimental Details

TOF experiment is one of the standard techniques for neutron-gamma discrimination. It distinguishes between gamma photons and neutrons based on their flight time differences over a flight path.

The time-of-flight (TOF) setup (Fig.1) utilized in the present work consists of two detectors $LaCl_3$(Ce) and 3PB. The $LaCl_3$(Ce) detector was fixed at 90° angle, very close to the radiation source and was used as a start detector. The 3PB detector was kept at different distances from the source at 0^o and was utilized as the stop detector to measure the flight time. A spontaneous fission source ^{252}Cf was used as a mixed source of neutrons and gammas. The output signals from detectors were recorded for energy information as well as for generating the time distribution spectrum utilizing a Time to Amplitude Converter (TAC) circuit.

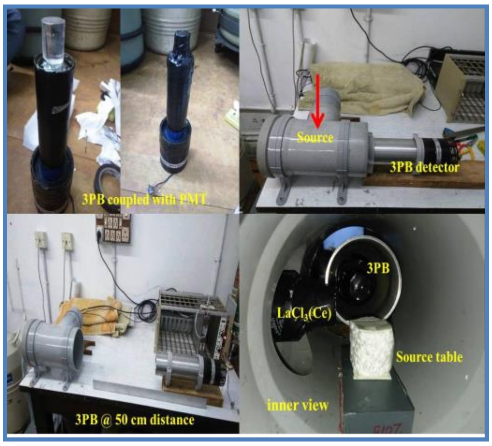

Fig.1 Time of flight experimental setup

Timing measurements

To determine the time resolution of the TOF setup with $LaCl_3$(Ce) - 3PB detectors, the coincidence TAC spectra was recorded with the gamma source (^{60}Co). The spectrum was calibrated by introducing known delays (*viz.*, 25, 33, 47, 63ns) in stop detector pulse. Reliable linearity of the TAC was observed with time resolution ~1.5 ns (Fig.2). The figure also demonstrates that the 3PB crystal timing property compares quite well with that of $LaCl_3$.

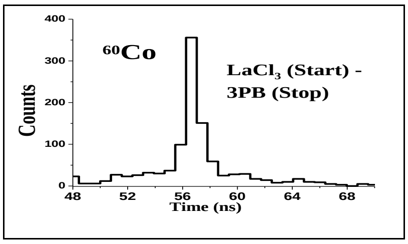

Fig. 2 The prompt TAC spectrum with a ^{60}Co source, without any selection in energy.

The 3PB detector was placed at different distances from 20cm - 50 cm at intervals of 10 cm. Two peaks were observed in the TAC spectra which can be identified as gamma and neutron peaks. While increasing the distance of the 3PB detector, the TAC peak arising from gamma events are almost at the same position, while the peak arising from neutrons shows definite shift towards higher channel (Fig. 3) - indicating longer time taken by the neutrons to reach the stop detector at larger distances. Due to the low activity of ^{252}Cf source, the maximum distance was 50 cm.

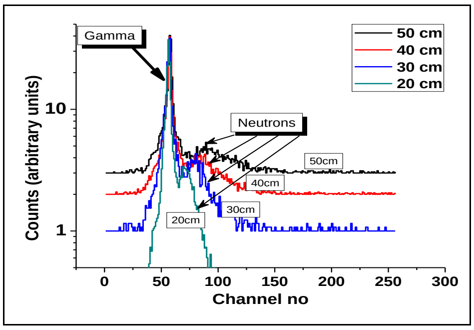

Fig. 3 TAC spectra for distances 20 to 50 cm with 16 ns fixed delay in the stop signal. The spectra for different distances are shifted vertically to show the shift in neutron peak clearly.

Neutron energy measurement

To determine variation of the efficiency of the detector for changing distances, TOF spectrum has been converted to energy spectrum of neutrons (Fig. 4) through the relativistic kinetic energy equation using the flight path length and flight time [3]. The prompt gamma peak in the TOF was used as a reference. During this conversion, gamma contributions in neutron energy spectrum have been removed. The figure indicates that at larger distances, the weak source strength introduces substantial error in the energy determination.

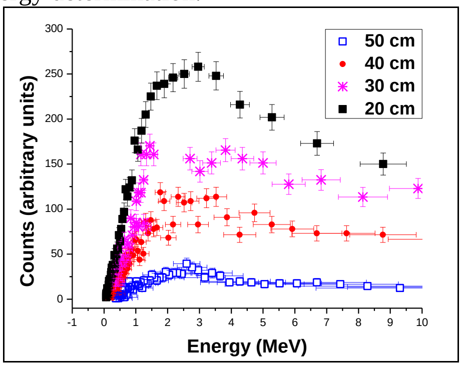

Fig. 4 Neutron energy spectrum with varying distances.

Conclusion

The results show that the single crystal grown by unidirectional method has good timing properties and hence it works reliably as a neutron detector with the potential of discriminating against gamma background.

Future Scope

PSD method will be utilized to test the neutron-gamma discrimination property of the crystal further. Combination of the PSD and TOF techniques can be combined to improve the results. Sensitivity of the detector for alpha particle detection may also be tested through PSD technique.

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References

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