# Development of $\beta$ detector based on plastic scintillator for cross-section measurement

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## Introduction

Neutron cross-sections are measured by various methods such as online and offline $\gamma$-ray activation technique, neutron time of flight, surrogate reaction technique etc. Long half life of radio-active nuclei and low yield of $\gamma$-rays are limitations in the case of offline $\gamma$-ray activation technique which make it difficult to measure for a reasonable activity to deduce cross-section. $\beta$-ray measurement with plastic scintillator has been tried in the past by several groups [1, 2] for radiation monitoring and minimum detectable activity. The energy spectra of the beta rays are measured by magnetic and electrostatic spectrometers which are good in energy resolution but complex in nature [3, 4]. Plastic scintillator is a good detector candidate for beta rays which has much larger response than for $\gamma$-rays. This sensitivity varies with thickness of the scintillator and this property is encashed to determine the contribution of the $\beta$-ray in the $\beta$-$\gamma$-ray mixed environment. In this study, three plastic scintillator based beta detectors have been constructed and characterized to measure neutron induced cross-section measurements especially for the $\beta$-emitting radio nuclides. Various $\beta$-$\gamma$ mixed sources were used to characterize the detector signals.

## Materials and Methods

Large piece of plastic scintillator was cut into cylindrical shapes with one inch diameter and of thicknesses 1 mm, 2 mm, 10 mm and 90 mm in CDM workshop at BARC. The scintillators were coupled with PMTs (Make: Electron Tubes, Model: 9112B) of diameter one inch with the help of optical grease (BC-630, Saint-Gobain Crystals). The PMT was covered with black tape and was kept inside aluminium casing attached with base. The scintillator was wrapped with three layers of Teflon tape for reflection and later covered with black tape to reduce optical background. The whole setup was kept in a black box to further reduce the background light. The data were acquired in a VME based data acquisition system. Fig. 1 shows schematic diagram of the developed detector. The operation of the whole setup was characterized with $\beta$($^{90}$Sr-$^{90}$Y) and $\gamma$-ray ($^{60}$Co, $^{137}$Cs) source, kept at a distance of 30 mm. A 10 mm thick Aluminium sheet was kept in front of the detector to cut the beta activity and count only $\gamma$-rays. Attenuation correction was applied for the 10mm thick Aluminium sheet. The separation of $\beta$ from $\gamma$-ray is difficult as the spectra overlap in energy. Three detectors of thicknesses 2mm, 10mm and 90mm were used to see the sensitivity to gamma and beta rays.

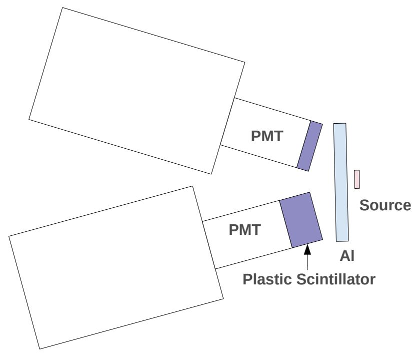


FIG. 1: Schematic diagram of the detector setup.

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TABLE I: Absolute efficiencies due to different sources and geometrical configuration for 2mm, 10mm and 90mm thick plastic scintillator detectors.

| Detector thickness | 2mm | 10mm | 90mm |
|---|---|---|---|
| Source | $\varepsilon_\gamma$% | $\varepsilon_\gamma$% | $\varepsilon_\gamma$ % |
| $^{137}$Cs+Al | 0.04 | 0.24 | 0.33 |
| $^{90}$Sr-Y+$^{137}$Cs+Al | 0.05 | 0.24 | 0.32 |
| $^{60}$Co+Al | 0.02 | 0.12 | |
| Source | $\varepsilon_{\gamma+\beta}$% | $\varepsilon_{\gamma+\beta}$% | $\varepsilon_{\gamma+\beta}$% |
| $^{137}$Cs | 0.10 | 0.31 | |
| $^{90}$Sr-Y | 2.3 | 4.3 | |
| $^{60}$Co | 0.03 | 0.13 | |

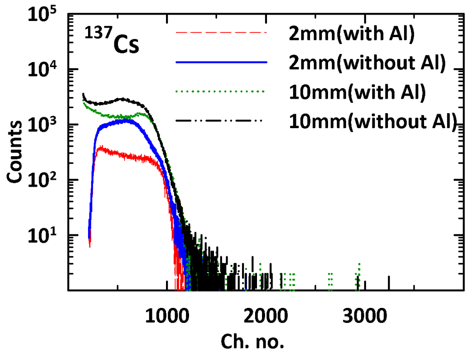


FIG. 2: $\beta - \gamma$ spectra for 2mm and 10mm thick detectors for $^{137}$Cs (2.3$\mu$Ci) source kept at a distance of 30mm, with and without 10mm thick Al.

## Results and Discussion

Plastic scintillator based beta detectors have been constructed and characterized for its response to beta and gamma rays. Both detectors were put closeby and sources were kept ∼30mm away with a solid angle ∼ 0.022sr. The absolute $\gamma$-ray efficiencies (see Table I) for $^{137}$Cs source for 2mm, 10mm and 90mm thick detectors were 0.04%, 0.24% and 0.33%, respectively where $\beta$-rays were stopped by placing 10mm thick Aluminium sheet. $^{137}$Cs source has two beta rays with end point energies of 0.514 MeV and 1.175 MeV. The measured spectra for $^{137}$Cs is given in Fig. 2. The low energy part of the spectra is enhanced without Al-sheet which is due to $\beta$-rays. The combined $\beta - \gamma$ efficiencies for $\beta$($^{90}$Sr-$^{90}$Y) (262Bq)+$^{137}$Cs (436Bq) mixed source for 2mm, 10mm and 90mm thick detectors were 2.8%, 0.3.8% and 4.0%, respectively. The end point energy of beta rays from $^{90}$Sr and $^{90}$Y are 0.546 MeV and 2.28MeV, respectively. It is observed that $\gamma$-ray give larger response in a detector with higher thickness compared to the detector of smaller thickness by a factor of ∼6 and the sensitivity is almost 2 times for thick detector due to mixed $\beta - \gamma$ ($^{90}$Sr-$^{90}$Y + $^{137}$Cs) source. The sensitivity to $\beta$-rays is similar for detectors of all thicknesses in terms of integral counts. The spectra of the beta will differ as it will depend on the full energy deposition depending on the thickness and energy of the $\beta$-rays. Details of the measurements and a scheme to measure neutron cross-sections will be presented.

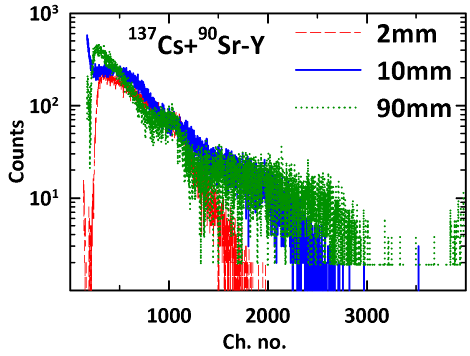


FIG. 3: $\beta - \gamma$ spectra for 2mm, 10mm and 90mm thick detectors. $\beta$($^{90}$Sr-$^{90}$Y) (262Bq) + $^{137}$Cs (436Bq) source was kept at a distance of 30mm.

## References

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