Tests of Various Scintillator Detectors in Selected Mono-Energetic Neutron Beams

In this paper we study quality of three types of organic scintillators - stilbene, pterphenyl and EJ-299-33A. We used monoenergetic neutron fields with a wide range of neutron energies in PTB Braunschweig. All the tests were carried out with NGA-01 spectrometer. The results of the measurements are evaluated spectra from the spectrometer. We discuss the quality of each scintillator, such as the FWHM of the peaks.

Experimental setup

- PTB - 1,5; 2,5; 19 MeV
- **NGA-01** 12-bit; 1 GS/s
- Evaluation neutron spectral flux density

E_n [MeV]	stilbene 45 mm	EJ-299-33	p-terphenyl	stilbene 10 mm
2.5 MeV	0.216	0.361	0.280	0.232
19 MeV	0.102	0.184	0.184	0.063

Table: The energy resolution $FWHM/E$ for neutron energies 2.5 and 19 MeV.

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Abstract

In this paper we study quality of three types of organic scintillators - stilbene, p-terphenyl and EJ-299-33. We used monoenergetic neutron fields with a wide range of neutron energies in PTB Braunschweig. All the tests were carried out with NGA-01 spectrometer. The results of the measurements are evaluated spectra from the spectrometer. We discuss the quality of each scintillator, such as the FWHM of the peaks.

Experimental Setup

The irradiations were performed at the PTB Ion Accelerator Facility, where monoenergetic neutron fields are produced via selected reactions of proton and deuteron beams with light or medium-weight target nuclei. The measurements were carried out in open geometry in the low-scattering hall where the contribution of room-return neutrons is minimized by having grid floors. The three neutron energies considered in this campaign 1.5, 2.5 and 19 MeV, see Tab. 1.

E_{proj} [keV]	Target	Reaction	E_n [MeV]
2336	Ti(T), 961 μg/cm^2	^{3}H(p,n)^{3}He	1.5
3350	Ti(T), 1831 μg/cm^2	^{3}H(p,n)^{3}He	2.5
2676	Ti(T), 1831 μg/cm^2	^{3}H(d,n)^{4}He	19.0[1)]

Table 1: Mean neutron energy E_n obtained at the neutron emission angle of zero degrees relative to the direction of the incident beam, for the given targets and ion beam (projectile) energies E_{proj}.
1) The 19 MeV field contained parasitic low-energy neutrons from D(d, n), Ti(d, n) and Ag(d, n) reactions which were not subtracted using a non-tritiated target.

Neutron-Gamma spectrometric system NGA-01 has been used for the measurements. The input analog signal from the detector was digitized by two fast A/D converters working with a sampling frequency of 500 MHz. Digital signal processing is implemented in FPGA Xilinx Virtex-6. Integration method based on the pulse charge comparison was implemented in FPGA. Separation parameters for various scintillators calculated with this method are shown below in PSD matrices. Hamamatsu R329-02 photomultiplier was used for these measurements.
^{137}Cs and ^{60}Co sources were used for calibration.

Fig. 1: Neutron gamma analyser NGA-01.

Fig. 2: Position of the detector (on the right-front) and the beam target (on the left-rear) as used for the measurements. In between there is a shadow cone.

Evaluation

NGA-01 has been used for the measurements of the apparatus spectra. For the evaluation of the measurements we developed the spectrometric software. MCNP simulations of response functions using ENDF/B-VII.1 nuclear data were used. Neutron spectral flux densities are displayed.

Results

Stilbene scintillator of the sizes of 10x10 mm and 45x45 mm have been used for measurements of neutron energies of 1.5, 2.5 and 19 MeV. In all measurements corresponding peaks are identified in evaluated spectra, Fig. 3 - 14. Measurements with neutron energies of 2.5 and 19 MeV were carried out with EJ-299-33 scintillator (Fig. 15 - 18) and with p-terphenyl scintillator (Fig. 19 - 22). We compared spectra from EJ-299-33 and p-terphenyl scintillators with 45x45 mm stilbene scintillator (shown in dotted gray line in Fig. 17,18,21,22). Arbitrary units have been used for the y-axis in the graphs of evaluated spectra. Tab. 2 shows resolution values calculated from evaluated spectra.

E_n [MeV]	stilbene 45 mm	EJ-299-33	p-terphenyl	stilbene 10 mm
2.5 MeV	0.216	0.361	0.280	0.232
19 MeV	0.102	0.184	0.184	0.063

Table 2: The energy resolution $FWHM/E$ for neutron energies 2.5 and 19 MeV.

Fig. 3: PSD matrix for 1.5 MeV measurement with stilbene 10x10 mm.

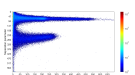

Fig. 4: PSD matrix for 2.5 MeV measurement with stilbene 10x10 mm.

Fig. 5: PSD matrix for 19 MeV measurement with stilbene 10x10 mm.

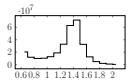

Fig. 6: Neutron spectral flux density for 10x10 mm stilbene for 1.5 MeV neutrons.

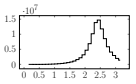

Fig. 7: Neutron spectral flux density for 10x10 mm stilbene for 2.5 MeV neutrons.

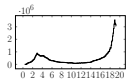

Fig. 8: Neutron spectral flux density for 10x10 mm stilbene for 19 MeV neutrons.

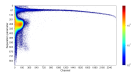

Fig. 9: PSD matrix for 1.5 MeV measurement with stilbene 45x45 mm.

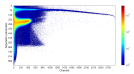

Fig. 10: PSD matrix for 2.5 MeV measurement with stilbene 45x45 mm.

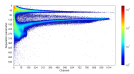

Fig. 11: PSD matrix for 19 MeV measurement with stilbene 45x45 mm.

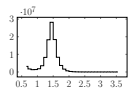

Fig. 12: Neutron spectral flux density for 45x45 mm stilbene for 1.5 MeV neutrons.

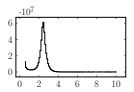

Fig. 13: Neutron spectral flux density for 45x45 mm stilbene for 2.5 MeV neutrons.

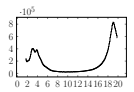

Fig. 14: Neutron spectral flux density for 45x45 mm stilbene for 19 MeV neutrons.

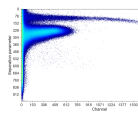

Fig. 15: PSD matrix for 2.5 MeV measurement with 1x1 inch EJ-299-33.

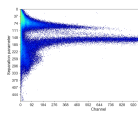

Fig. 16: PSD matrix for 19 MeV measurement with 1x1 inch EJ-299-33.

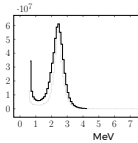

Fig. 17: Neutron spectral flux density for 1x1 inch EJ-299-33 for 2.5 MeV neutrons.

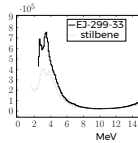

Fig. 18: Neutron spectral flux density for 1x1 inch EJ-299-33 for 19 MeV neutrons.

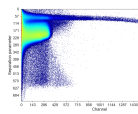

Fig. 19: PSD matrix for 2.5 MeV measurement with p-terphenyl 45x45 mm.

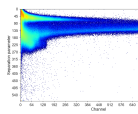

Fig. 20: PSD matrix for 19 MeV measurement with p-terphenyl 45x45 mm.

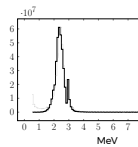

Fig. 21: Neutron spectral flux density for 45x45 mm p-terphenyl for 2.5 MeV neutrons.

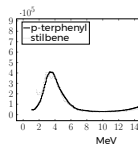

Fig. 22: Neutron spectral flux density for 45x45 mm p-terphenyl for 19 MeV neutrons.

Acknowledgements

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