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

Aleš Jančář[1], Jiří Čulen[1], Filip Mravec[1], Michal Košťál[3], Daniel Dlhopolček[2], Elisa Pirovano[4], Ralf Nolte[4], František Cvachovec[2], Václav Přenosil[2], Zdeněk Matěj[2]

[1]VF, a.s., Svitavská 588, 67921 Černá Hora, Czech Republic
[2]Masaryk University, Botanická 68a, 612 00 Brno, Czech Republic
[3]Research Center Řež Ltd, 250 68 Husinec-Řež 130, Czech Republic
[4]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany
ales.jancar@vfnuclear.com

***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.

***Keywords* —Scintillation detectors, Mono-energetic neutron sources, Pulse-shape discrimination, FWHM, Digital-signal processing.**

I. Introduction

THIS paper presents preliminary results from measurements at the PTB facility in Germany. Several monoenergetic neutron beams were used together with three scintillators connected to fast digitizer NGA-01: stilbene, p-terphenyl and EJ-299-33 [5].

II. 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 [1, 2]. The three neutron energies considered in this campaign 1.5, 2.5 and 19 MeV, see Tab. 1.

TABLE I
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}.

E_{proj} [keV]	Target	Reaction	En [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

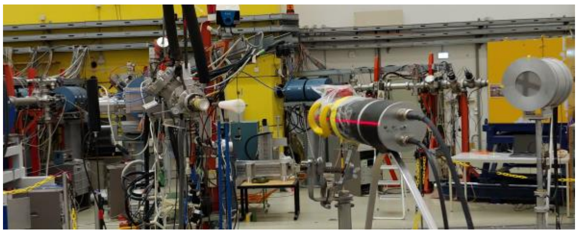

Fig. 1. Position of the detector (on the right-front) and the beam target (on the left-rear) as used for the measurements. In between there is a shadow cone.

Neutron-Gamma spectrometric system NGA-01 has been used for the measurements [4]. 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. 2. Neutron gamma analyser NGA-01.

III. Evaluation

NGA-01 has been used for the measurements of the apparatus proton recoil spectra. These spectra were evaluated using Maximum Likelihood Estimation method of Expectation Maximization [3]. Response functions needed for this evaluation were calculated with Monte Carlo simulation code using ENDF/B-VII.1 nuclear data.

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

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. For this further analysis will be performed.

IV. RESULTS

Stilbene scintillators 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.

TABLE II
THE ENERGY RESOLUTION FWHM/E FOR NEUTRON ENERGIES 2.5 AND 19 MEV.

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
19.0 MeV	0.102	0.184	0.184	0.063

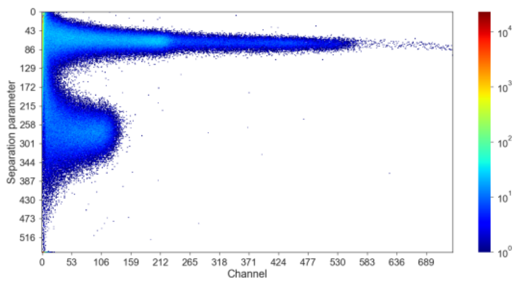

Fig. 3. PSD matrix for 1.5 MeV measurement with stilbene 10x10 mm.

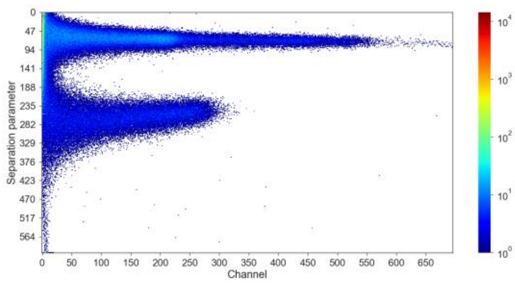

Fig. 4. PSD matrix for 2.5 MeV measurement with stilbene 10x10 mm.

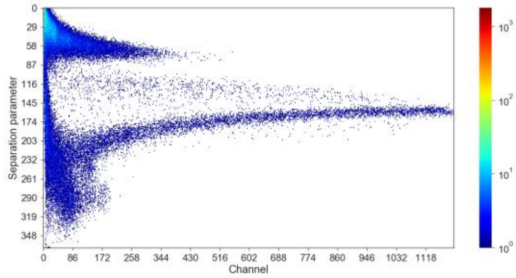

Fig. 5. PSD matrix for 19 MeV measurement with stilbene 10x10 mm.

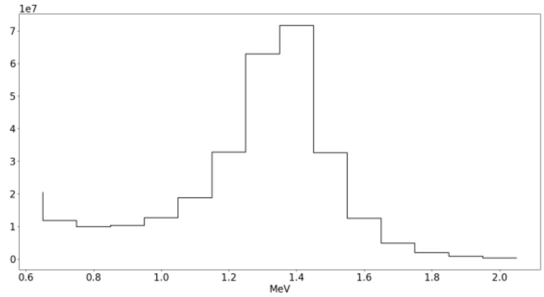

Fig. 6: Neutron spectral flux density for 10x10 mm stilbene for 1.5 MeV neutrons.

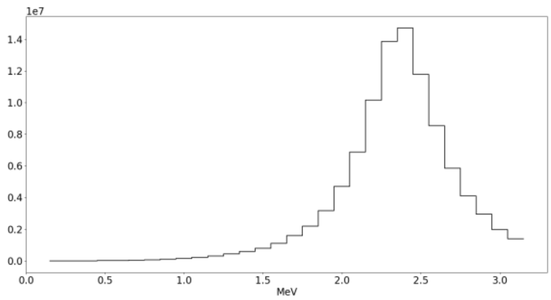

Fig. 7: Neutron spectral flux density for 10x10 mm stilbene for 2.5 MeV neutrons.

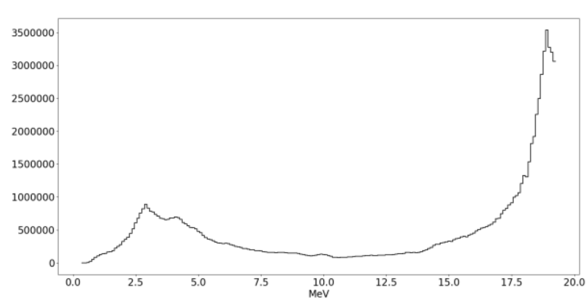

Fig. 8: Neutron spectral flux density for 10x10 mm stilbene for 19 MeV neutrons.

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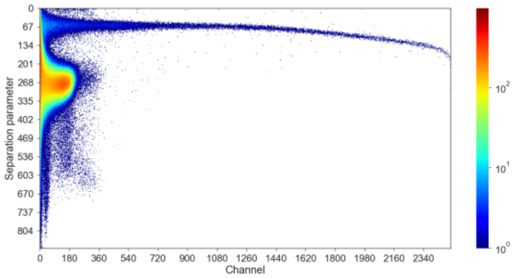

Fig. 9. PSD matrix for 1.5 MeV measurement with stilbene 45x45 mm.

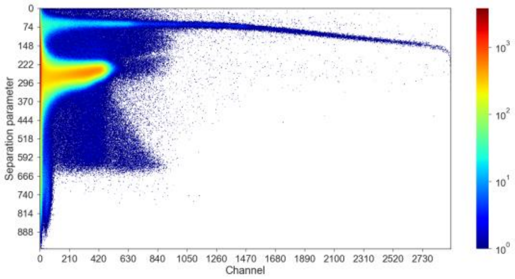

Fig. 10. PSD matrix for 2.5 MeV measurement with stilbene 45x45 mm.

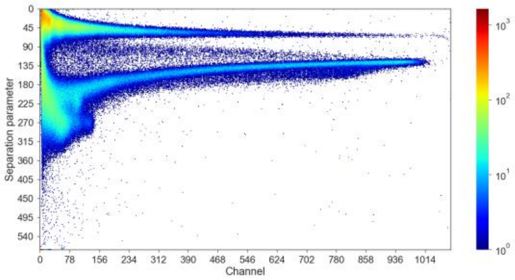

Fig. 11. PSD matrix for 19 MeV measurement with stilbene 45x45 mm.

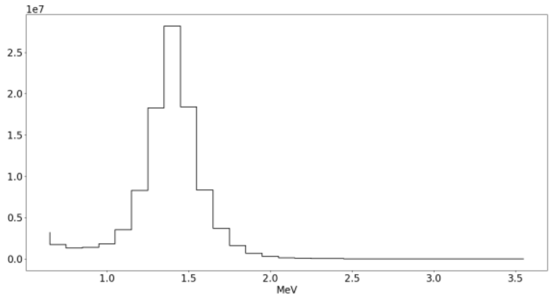

Fig. 12: Neutron spectral flux density for 45x45 mm stilbene for 1.5 MeV neutrons.

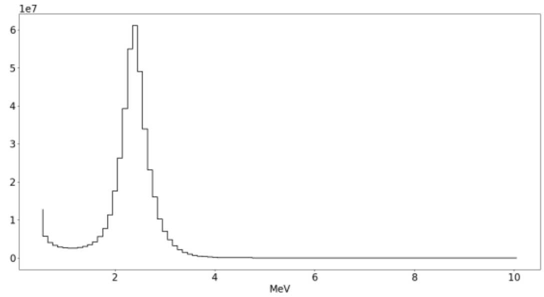

Fig. 13: Neutron spectral flux density for 45x45 mm stilbene for 2.5 MeV neutrons.

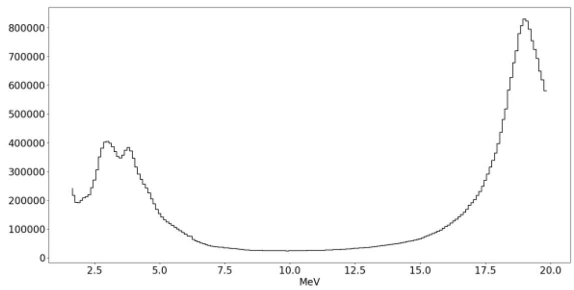

Fig. 14: Neutron spectral flux density for 45x45 mm stilbene for 19 MeV neutrons.

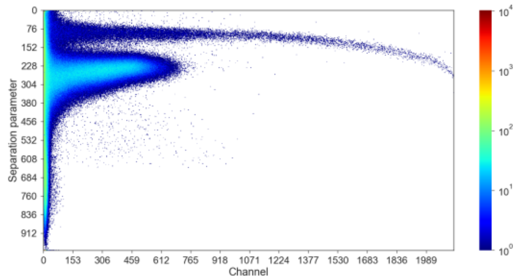

Fig. 15. PSD matrix for 2.5 MeV measurement with 1x1 inch EJ-299-33.

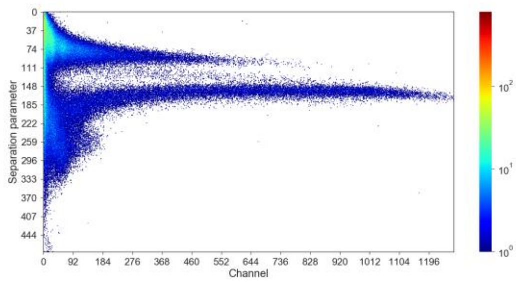

Fig. 16. PSD matrix for 19 MeV measurement with 1x1 inch EJ-299-33.

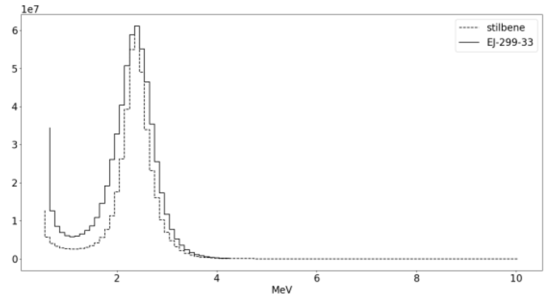

Fig. 17: Neutron spectral flux density for 1x1 inch EJ-299-33 for 2.5 MeV neutrons. Results for stilbene 45x45 were added for comparison.

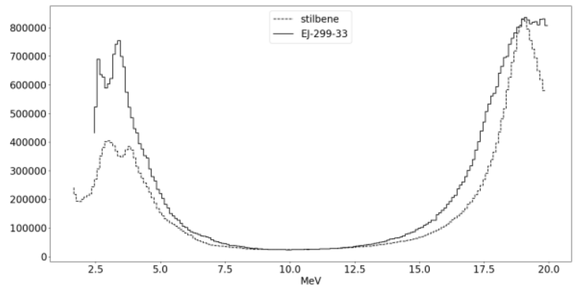

Fig. 18: Neutron spectral flux density for 1x1 inch EJ-299-33 for 19 MeV neutrons. Results for stilbene 45x45 were added for comparison.

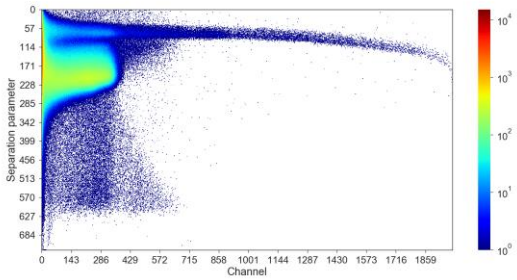

Fig. 19. PSD matrix for 2.5 MeV measurement with p-terphenyl 45x45 mm.

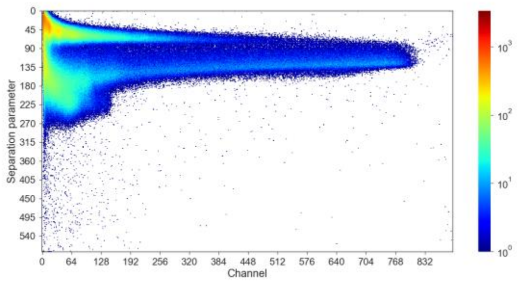

Fig. 20. PSD matrix for 19 MeV measurement with p-terphenyl 45x45 mm.

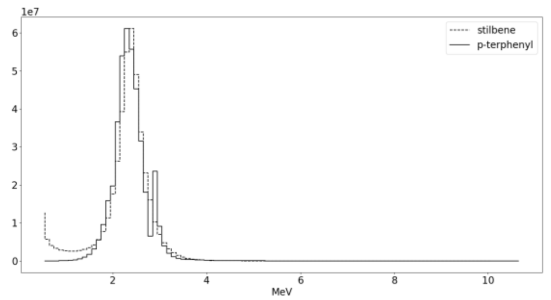

Fig. 21: Neutron spectral flux density for 45x45 mm p-terphenyl for 2.5 MeV neutrons. Results for stilbene 45x45 were added for comparison.

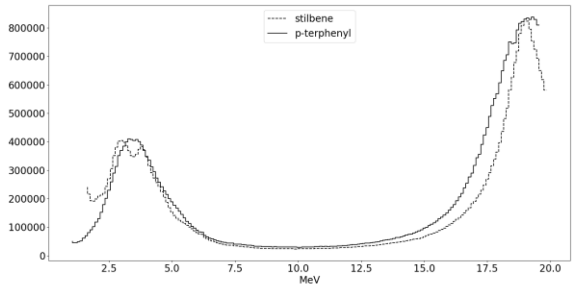

Fig. 22: Neutron spectral flux density for 45x45 mm p-terphenyl for 19 MeV neutrons. Results for stilbene 45x45 were added for comparison.

V. CONCLUSIONS

All presented scintillators show satisfactory spectrometric and pulse shape discrimination properties. Using unfolding it is possible to find characteristic peaks at expected energies.

The next step of the measurement processing would be the subtraction of the measurements with the shadow cone and with the blank target (for the 19 MeV experiment). The data can be also used to improve the light output functions for tested scintillation materials.

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