Comparison of neutron/gamma separation qualities of various organic scintillation materials

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***Abstract*— In this work we compare the pulse-shape discrimination (PSD) properties of EJ-299-33A, BC-501A, stilbene, p-terphenyl and Hidex Aqualight in neutron field generated by the LVR-15 reactor with silicon filter utilization. Pulses from the scintillators are processed by Neutron-Gamma spectrometer. This spectrometric system with fast digitizer card contains two analog-digital (A/D) converters with a resolution of 12 bits and sampling frequency 500 MHz. For photomultiplier (PMT) linearity improvement active divider has been used. Measured data from scintillators have been processed using the integration method and compared. Results are presented.**

***Keywords*— organic scintillators, neutron, gamma, impulse separation, FPGA, FoM, LVR-15**

I. INTRODUCTION

The scintillators that enable the separation of neutron-gamma radiation are widely used for measurements of mixed radiation fields. Several competing types of PSD capable scintillators were compared (EJ-299-33A, BC-501A, stilbene, p-terphenyl and Hidex Aqualight).The reactor LVR-15 with well-known radiation field has been used for measurements in the energy range 1 to 10 MeV [1, 2]. Measured data have been processed using digital Neutron-Gamma spectrometer which we developed. The digital spectrometric system minimizes the drawbacks of analog devices and provides substantial simplification for the operation and setting of the system. The spectrometer is connected with a computer via Ethernet.

II. EXPERIMENTAL SETUP

Laboratory with experimental reactor LVR-15 has been used for the measurement, see Fig. 1.

We utilized well defined moderate neutron beam from the horizontal channel HK-1, see Fig. 2. Reactor thermal power output was 10 MW. Neutron beam has been moderated via 1 m wide silicon single crystal which provides spectrum with characteristic energy peaks, see unfolded spectrum in Fig. 3 [4].

The experimental arrangement is shown in Fig. 2. Influence of thermal neutrons and gammas was reduced via filter composed of ^{6}Li, Cd, Bi and Pb.

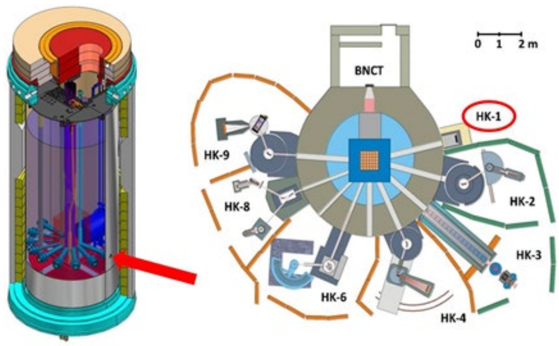

Fig. 1. - LVR-15 reactor (left) and its horizontal channels (right) [1]

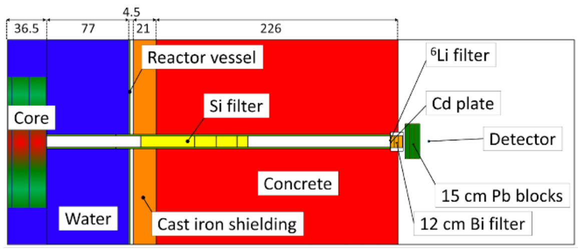

Fig. 2. The experimental arrangement in the reactor laboratory. The detectors were placed along the beam axis at 1.5 m distance from the silicon filter target [1].

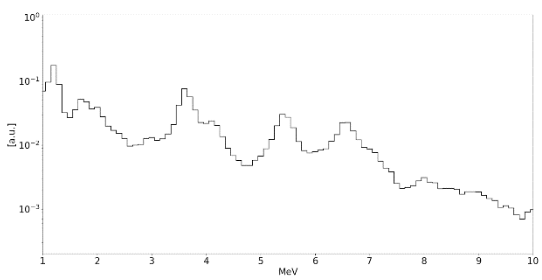

Fig. 3. Unfolded silicon moderated neutron spectrum measured with stilbene.

III. RESULTS

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.

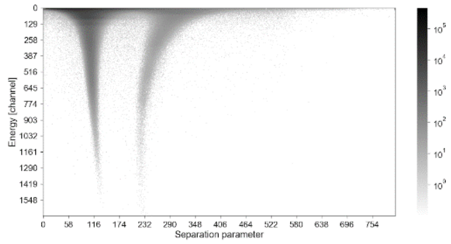

Fig. 4. Stilbene

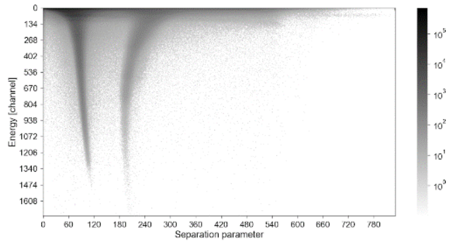

Fig. 5. BC-501A

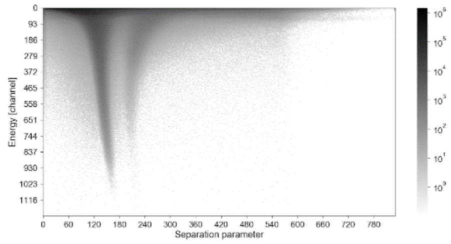

Fig. 6. EJ-299-33A

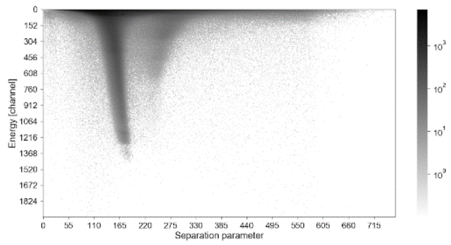

Fig. 7. P-terphenyl

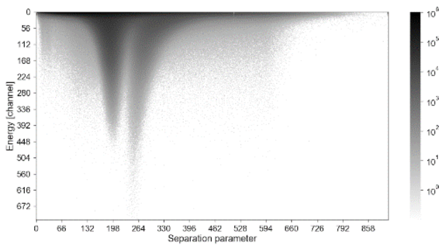

Fig. 8. Hidex Aqualight

Neutron-Gamma spectrometric system 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.

IV. FIGURE OF MERIT

The quality of neutron–gamma discrimination for a given scintillator is characterized by figure of merit (FOM), see Fig. 9.

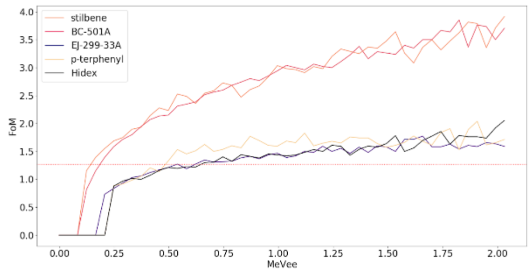

Fig. 9 FoMs for examined scintillators

Selected results of neutron-gamma separation quality are shown in Tab. 1. The critical value of FoM 1.27 is an indicator of good neutron-gamma separation [3]. Yellow fields indicate gamma energies where FoM values exceed the critical value. According to the combination of FoM and energy parameters we can evaluate the quality of neutron-gamma separation. Stilbene detector achieves the best quality of separation because the FoM exceeds the critical value at the smallest energy.

MeVee	0,12	0,17	0,2	0,29	0,5	0,62	0,66
stilbene	1,16	1,4	1,55	1,75	2,23	2,36	2,54
BC-501A	0,82	1,15	1,39	1,72	2,15	2,39	2,51
p-terphenyl	0	0	0	0,92	1,33	1,51	1,63
EJ-299-33	0	0	0,73	0,94	1,21	1,27	1,35
Hidex	0	0	0	0,97	1,21	1,22	1,3

Tab 1. Selected critical values of FoM from examined scintillators.

Among the examined scintillators the stilbene detector is considered to have the best energy resolution. Apparatus spectra from the two best scintillators from Tab. 1 were compared with stilbene detector in Fig 10. The x-axis contains channel number, y-axis contains ratio E_s/E_x, where E_s is apparatus spectrum of stilbene and E_x is a spectrum for BC-501A and p-terphenyl.

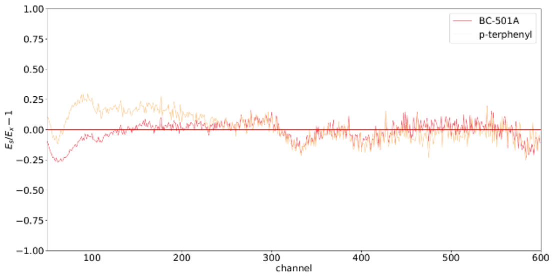

Fig. 10 E_s/E_x - 1 comparison of BC-501A and p-terphenyl with stilbene

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