Production and test of polysiloxane scintillator for neutron and gamma discrimination

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INTRODUCTION

In this article we report on design, production and laboratory test of a polysiloxane scintillator for neutron detection.
In section one we will describe the drafting and 3D printing of the support for the double replica moulding process as well as the scintillator production.
In section two we show the performances of the scintillators under neutron and gamma irradiation.
At the end we compare our detectors with a commercial liquid EJ301 scintillator [1].

SECTION ONE: DESIGN AND PRODUCTION

Following the double replica moulding process described in Ref. [2], we 3D printed the PolyCarbonate (PC) master with the shape shown in Fig.1 in order to obtain a truncated cone with bases with about 1 and 2 inches diameters.

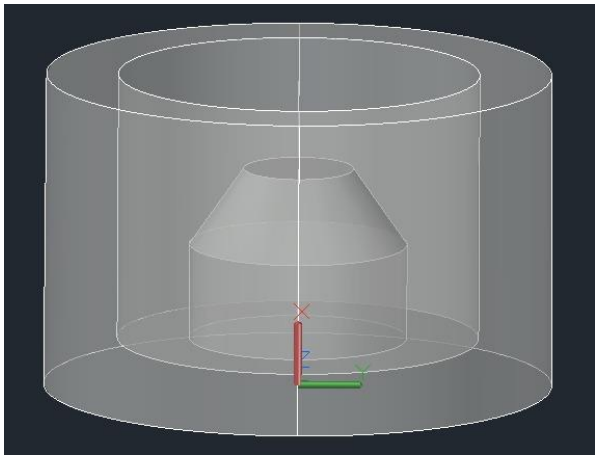

Fig. 1: CAD design of the PC master

After the polishing with abrasive paper, we poured Bluesil RTV 3527 A-B silicon elastomer in the master and cured at 70° C in the oven for 15 hours. To coat this first replica with an anti-stiction layer we activated its surface in a UV ozone cleaning system for 10 minutes and vapour deposited perfluoroctyltrichlorosilane (PFOCTS) overnight. We then proceed to load the PDV-2331 vinyl terminated (22-25% diphenylsiloxane)-dimethylsiloxane copolymer with 0.02% wt Lumogen Violet (LV) and 2% wt diphenyloxazole (PPO) for one sample (A) and 1.5% wt for a second sample (B) [3]. The two samples are shown in Fig. 2. Finally, we vulcanised these polysiloxane truncated cones via polyaddition and cured at 70° C during the night.

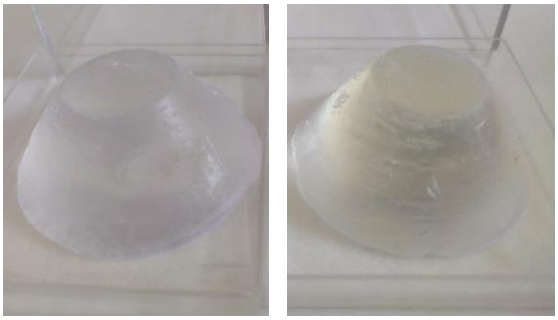

Fig. 2: Sample A (left) and Sample B (right)

SECTION TWO: LABORATORY TEST

The two samples were tested in laboratory using gamma (^{60}Co, ^{137}Cs, ^{54}Mn) and neutron (Am-Be) sources. Their lateral surfaces were wrapped with PTFE tape and a thin aluminium foil. Their bases were coupled with photomultiplier tubes (PMT) via optical grease. We tested two configurations: for each sample we used a 1 inch Hamamatsu 6524 PMT for the upper surface and a 2 inches Philips XP2020Q PMT for the lower surface (see Fig. 2). The two configurations under test are shown in Fig. 3.

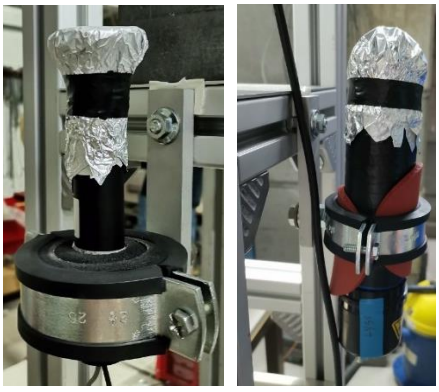

Fig. 3: 1'' PMT (left) and 2'' PMT (right) configurations

The PMT signals were acquired by a CAEN DT5725 fast digitizer (250 MSamples/s, 14-bit ADC resolution and

Digital Constant Fraction Discriminator embedded in the firmware for precise timing measurements). This digitizer allows to record the PMT current pulses as digitized waveforms, to perform subsequent off-line analysis. The installed firmware can pre-process data determining the pulses timestamps and integrating them over two gates, in order to perform particle discrimination using the so-called double integration method. After the calibration of the scintillators with gamma sources we irradiated the samples with the Am-Be neutron source to evaluate gamma and neutron discrimination performances.

SECTION THREE: ANALYSIS AND COMPARISON WITH EJ301 LIQUID SCINTILLATOR

In Fig. 4 we show the 2D plot of the deposited energy vs the PSD factor which is defined as the ratio between the charge collected in the long tail of the signal and the total charge [4]. The upper line corresponds to neutron signals, while the lower one to gamma.

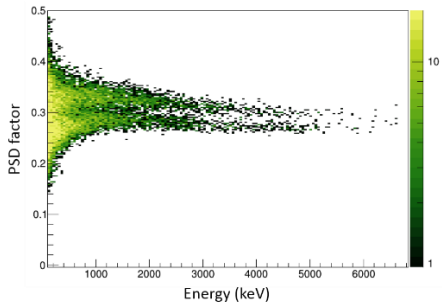

Fig. 4: 2D plot of deposited energy vs PSD factor for the Sample A coupled with 2'' PMT

From Fig. 4 we can see that the separation between neutron and gamma signals is improved as the deposited energy increases. To evaluate the quality of the PSD we considered the Y-axis projection for different cuts in minimum energy deposited (E_{cut}>500, 1000, 2000, 3000 keV). As an example we show in Fig. 5 the PSD spectrum for the E_{cut}>3000 keV cut.

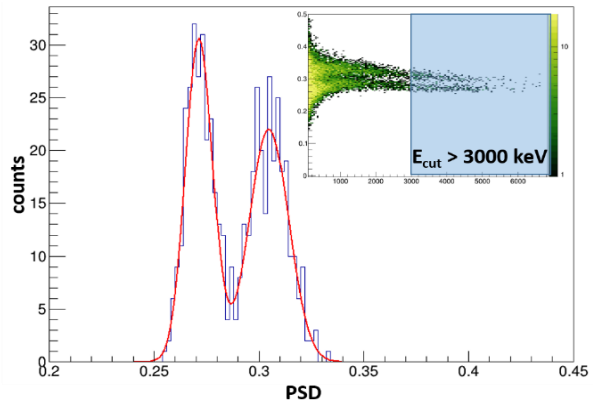

Fig. 5: PSD spectrum for E_{cut}>3000 keV relative to Fig. 4

For the PSD spectrum related to each cut we calculated a Factor Of Merit (F.O.M.) defined as $(x_2-x_1)/(\sigma_2+\sigma_1)$ were x_i and σ_i are the centroids and the standard deviations of the gaussians fitting the two peaks as shown in Fig. 5. A higher value of the F.O.M. means a better neutron and gamma discrimination. Finally, in Fig. 6 we report the F.O.M. for different samples and configurations as a function of the energy cut E_{cut}.

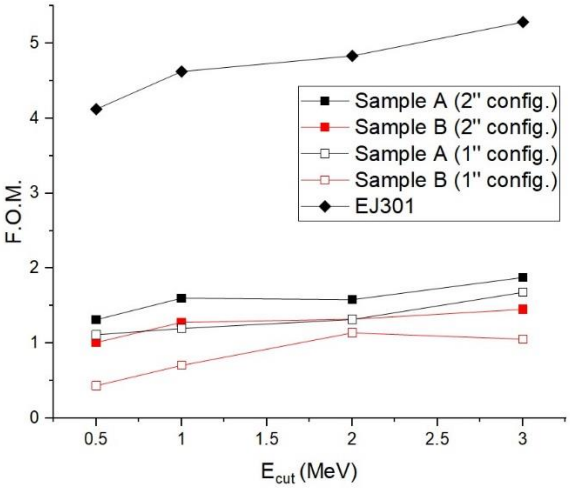

Fig. 6: F.O.M. vs Energy cut for all samples and configuration. A comparison with EJ301 liquid scintillator is also shown.

From the figure we observe that the best performance is obtained with Sample A in both configurations, in particular the best results in neutron and gamma discrimination are obtained with Sample A coupled with the 2'' PMT. However, the F.O.M. obtained with our siloxane scintillators are worse with respect to a liquid EJ301 commercially available detector. In fact, it is well known that liquid materials better discriminate between gammas and neutrons.

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REFERENCES

[1] https://www.eljentechnology.com/
[2] G. Zhuang and J. P. Kutter, J. Micromech. Microeng **21** 105020 (2011)
[3] A. Quaranta et al., Mater. Chem. Phis. **137** 951 (2013)
[4] T. Marchi et al., Scientific Report 9:9154 (2019)