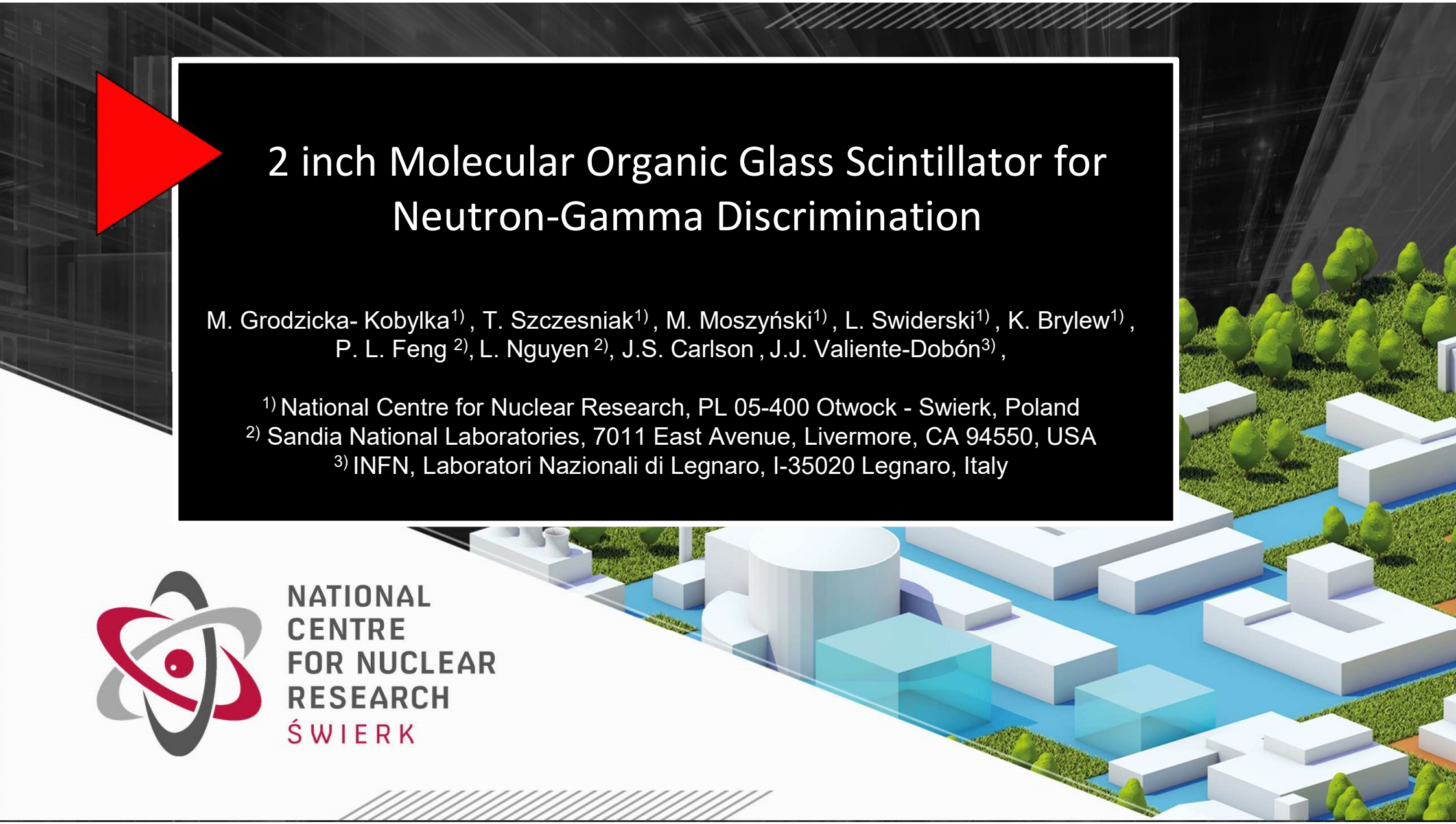
2 inch Molecular Organic Glass Scintillator for Neutron-Gamma Discrimination

M. Grodzicka- Kobylka[1)] , T. Szczesniak[1)] , M. Moszyński[1)] , L. Swiderski[1)] , K. Brylew[1)] , P. L. Feng [2)], L. Nguyen [2)], J.S. Carlson , J.J. Valiente-Dobón[3)] ,

[1)] National Centre for Nuclear Research, PL 05-400 Otwock - Swierk, Poland
[2)] Sandia National Laboratories, 7011 East Avenue, Livermore, CA 94550, USA
[3)] INFN, Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy



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The goal of this work

Characterisation of scintillation properties and pulse shape discrimination (PSD) performance of new organic glass scintillator (OGS)

Table I
Properties of the scintillators used

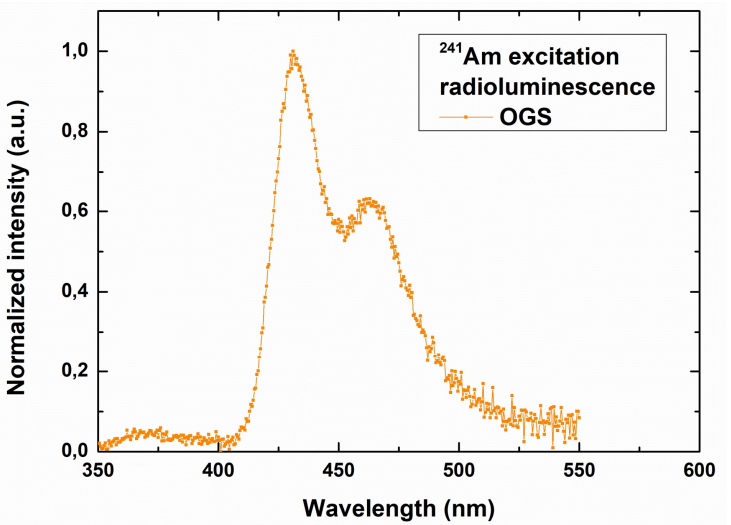
Crystal	Size (inch)	Shape	Peak emission [nm]	Type of scintillator	Manufacturer
OGS	**2x2**	Cylinder	428	glass	Sandia National Laboratories
OGS	**2x4**				
EJ-276	**2x2**		425	plastic	Eljen Technology
EJ-309	**2x2**		424	liquid	
Stilbene	**3x1**		430	single crystal	Inrad optics
Stilbene	**3x3**				

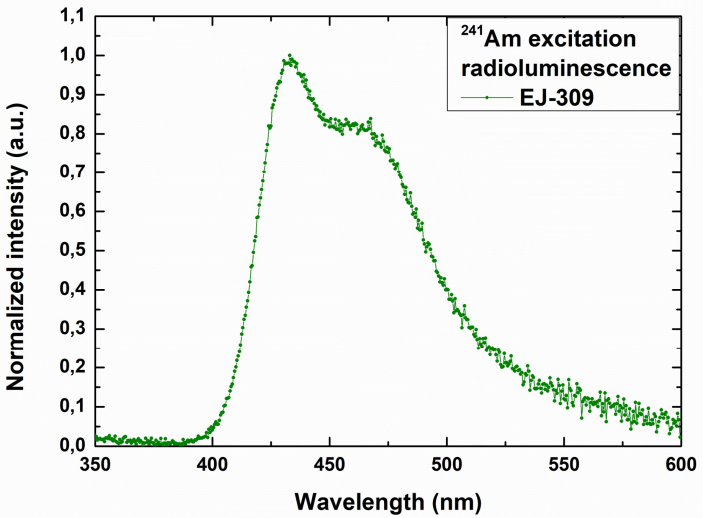
Photodetector: spectrometry photomultiplier (PMT) **Hamamatsu R6233-100** characterized by a high photocathode blue sensitivity of 15.4 μA/lmF, high quantum efficiency of 41% and 76 mm diameter of the photocathode.

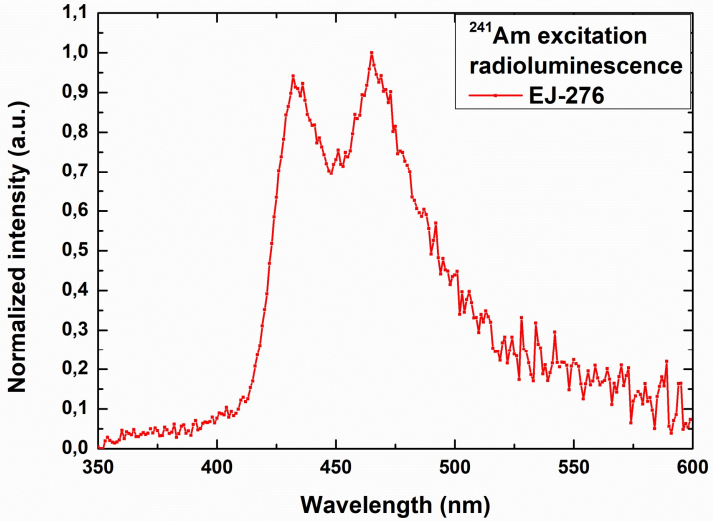
The paper covers the measurements of:

- **emission spectra,**
- **photoelectron yield and light output,**
- **neutron/gamma discrimination,**
- **analysis of the light pulse shapes originating from events related to gamma-rays and fast neutrons.**

Emission spectra







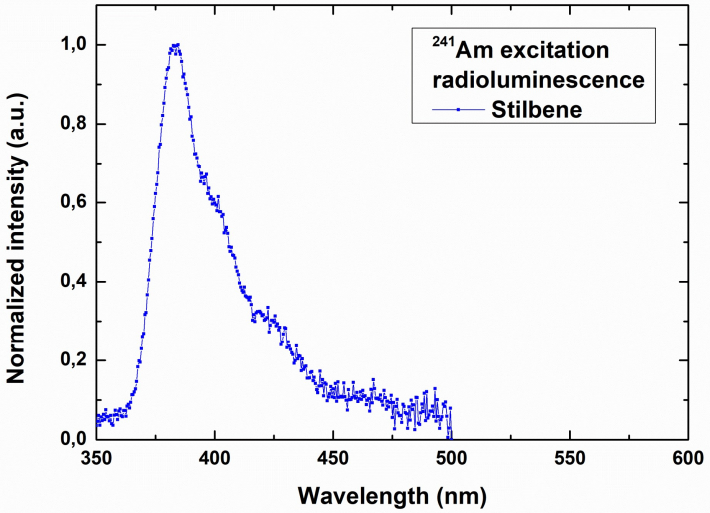
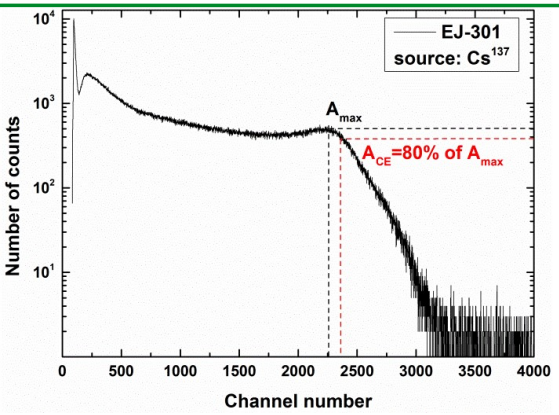


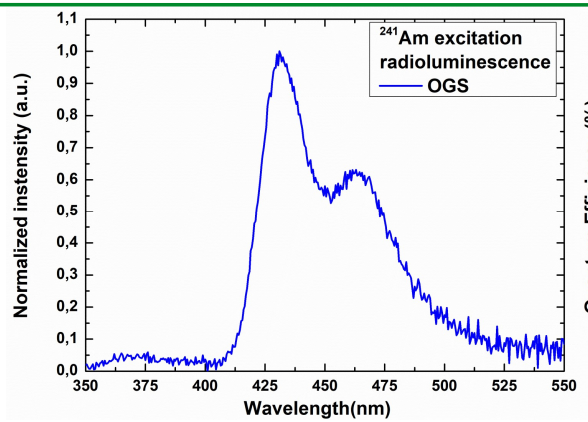
Table II
Scintillation properties of the tested scintillators

Scintillator	Wavelength of Maximum Emission (nm)	
	First maximum	Second maximum
OGS	431±16	463±16
EJ-276	434±16	466±16
EJ-309	433±16	460±16
Stilbene	383±15	-

Fig. 1. Emission spectra of EJ-276, EJ-309, Stilbene and OGS recorded with calibrated R928P PMT. The results were corrected for the quantum efficiency of the PMT and for the spectral response of the grating system.

PHE number and Light Output





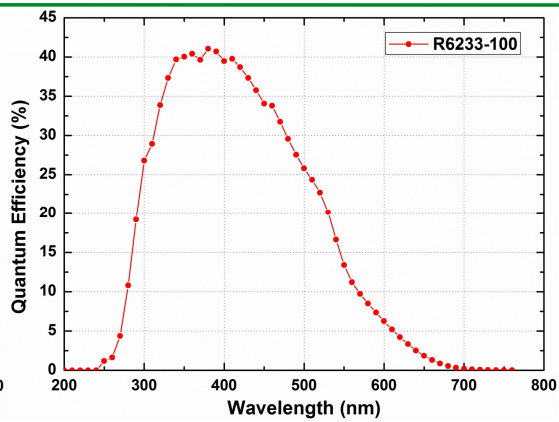
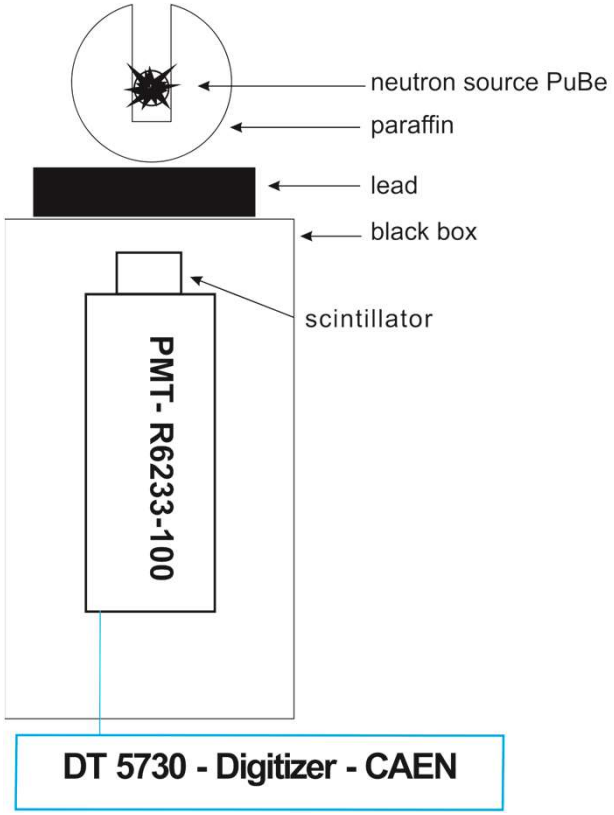


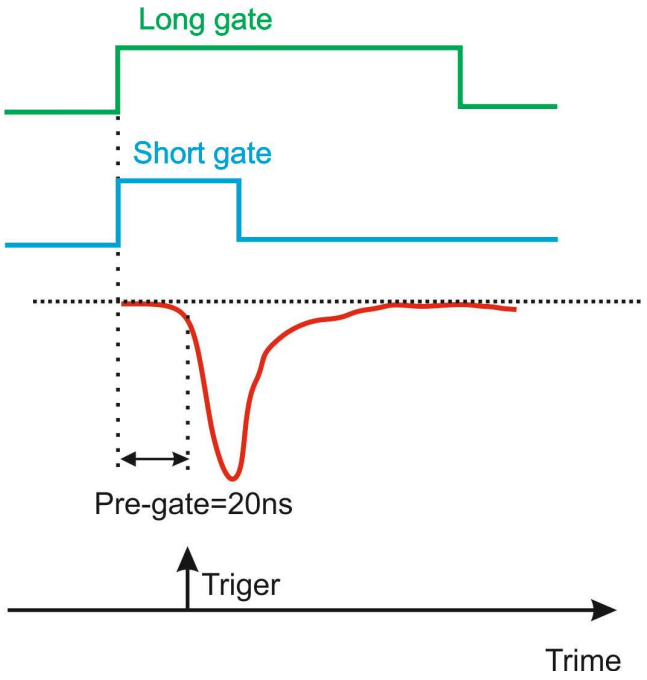
Table III : Photoelectron yield (with Hamamatsu R6233-100) and Light Output of all measured detectors

Scintillators	Size (mm)	Phe number (phe/MeV)	LO (Ph/MeV)	Integral QE (R6233-100+emission spectrum of scintillator)
OGS (sample 1 sample 2)	2”x2”	6730 ± 200 6960 ± 200	20 200 ± 2 000 20 900 ± 2 000	33 ± 3%
OGS	2”x4”	4450 ± 140	13 400 ± 2 000	
EJ-276 (sample from 2017)	2”x2”	2450 ± 70 (in 2017- 3140 ± 150)	8 200 ± 1 000 (in 2017- 10 500±1000)	30 ± 3%
EJ-309	2”x2”	4100 ± 130	13 200± 1 100	31 ± 3%
Stilbene	3”x1”	6400 ± 190	16 500± 1 600	39 ± 3%
	3”x3”	4420 ± 140	11 400± 1 200	

Experimental setup for PSD measurements



$$PSD=(Q_{long\ gate}-Q_{short\ gate})/Q_{long\ gate})$$



Optimalization for each scintillator:

-length of the short gate was changed in 10ns step from 50ns to 90ns

- length of the long gate was changed in 100ns step from 200ns to 1200ns

Fig. 2. The experimental setup for PSD measurements.

PSD

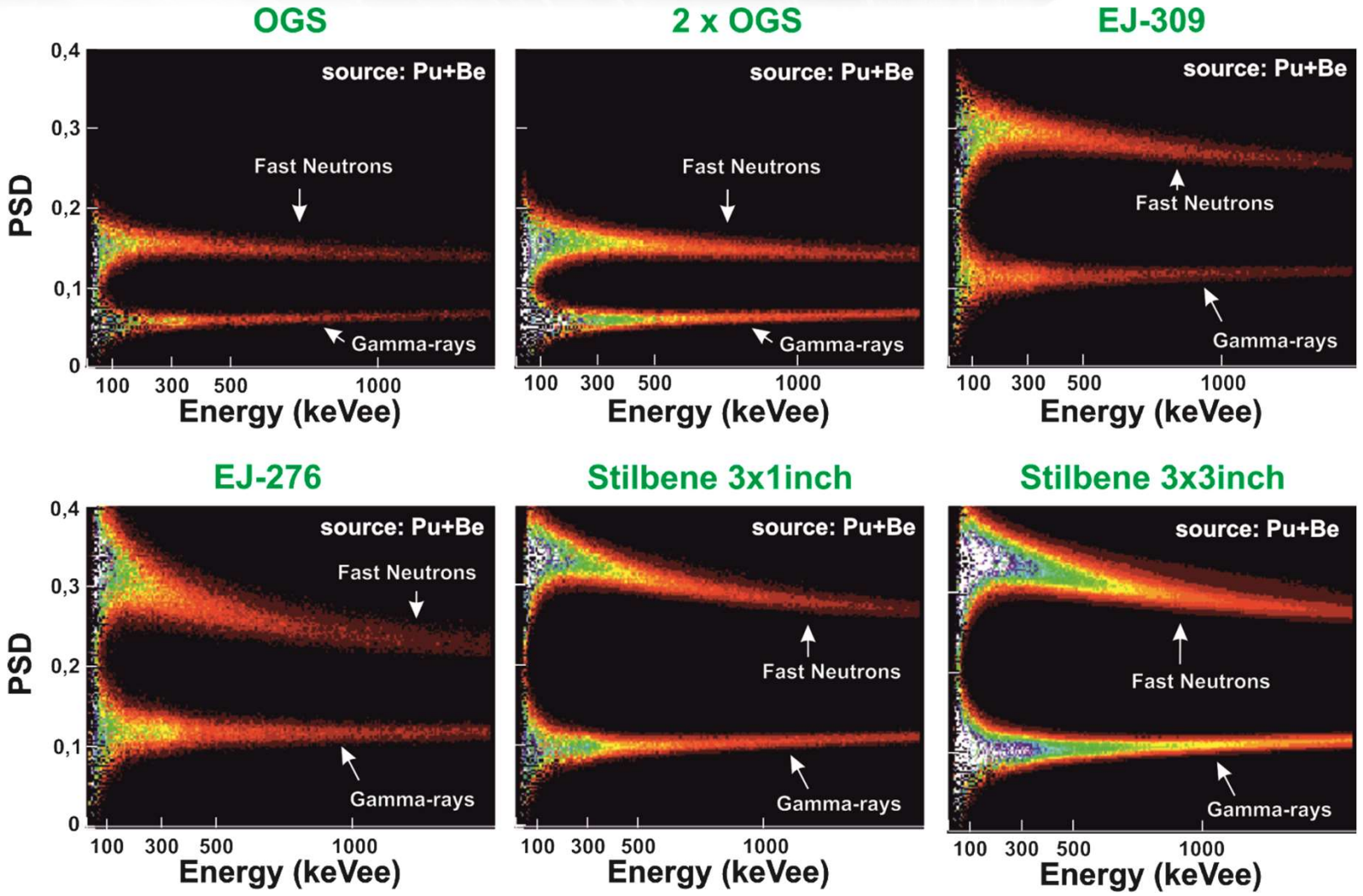


Fig.3. 2D plots of PSD versus energy recorded with PuBe sources for OGS, EJ-309, EJ-276 and Stilbene.

Figure of merit (FoM)

In order to quantify the performance of the tested detectors, the PSD figure of merit (FOM) was calculated, as follows:

$$FOM = \frac{(peak\ separation)}{(FWHM_{\gamma}) + (FWHM_{n})} \qquad (1)$$

Due to the slight dependence of the PSD on energy (neutrons and γ-rays) in the used PSD method, FOMs were measured for narrow energy cuts, which ensured that the ZC time projection were Gaussian–shaped. Energy gates were set at 100, 300, 500 and 1000 keVee and energy window between 100 and 1000 keVee, of recoil electron energies in the 2D spectrum.

FOM

Table IV : FOM for energy cut 100, 300, 500 and 1000 keVee and energy window between 100-1000keVee measured with used scintillators

Scintillator	OGS	2x OGS	EJ-309	EJ-276	Stilbene 3x1inch	Stilbene 3x3inch
Short gate Long gate	70 400	70 400	60 800	74 700	70 800	70 800
100 keVee	1.41±0.04	1.22±0.03	1.48±0.04	1.27±0.03	2.07±0.06	1.82±0.05
300 keVee	2.59±0.07	2.18±0.06	2.88±0.08	2.06±0.06	3.8±0.1	3.4±0.1
500 keVee	3.0±0.1	2.57±0.07	3.31±0.1	2.16±0.06	4.5±0.1	3.8±0.1
1000 keVee	3.4±0.1	2.81±0.08	3.71±0.1	2.33±0.07	5.1±0.1	4.4±0.1
100-1000keVee	2.17±0.06	1.93±0.05	2.34±0.07	1.32±0.04	2.81±0.06	2.68±0.08

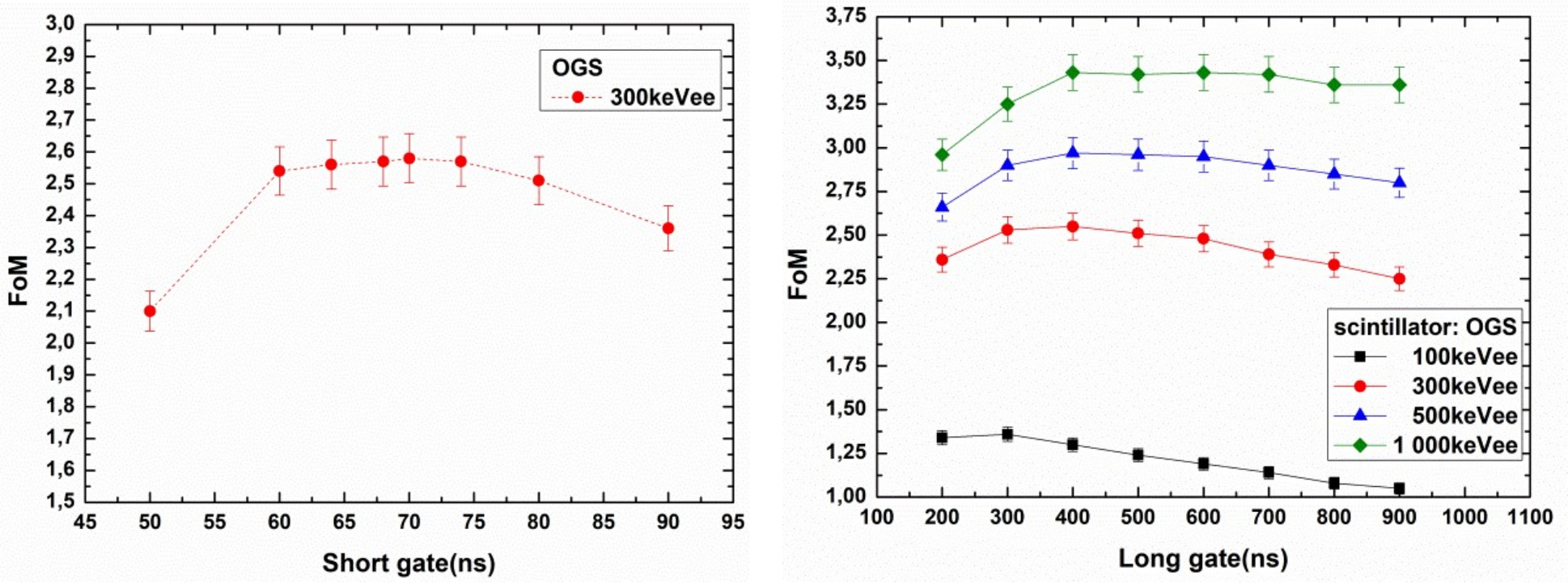
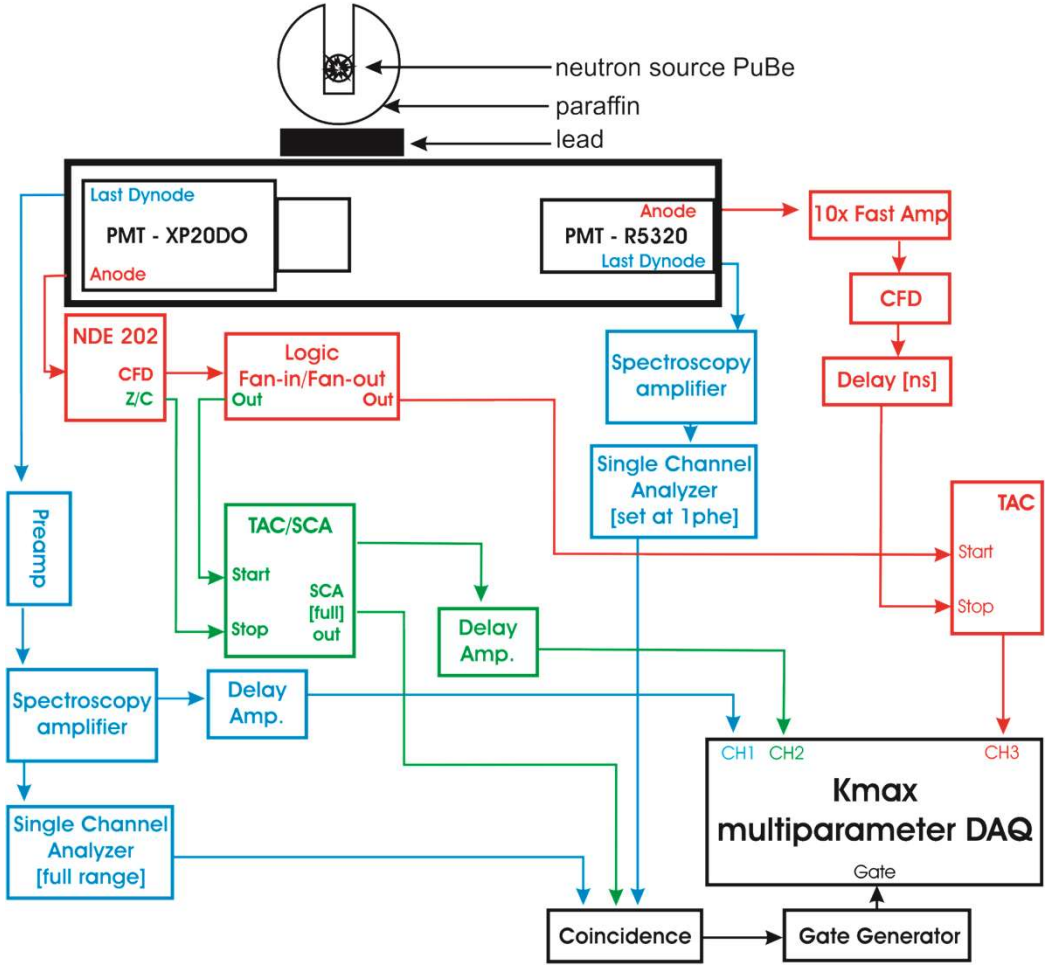


Fig. 4. The FoM calculation as a dependence of short integration gate and long integration gate for different Energy window.

Experimental setup for the light pulse shapes measurments



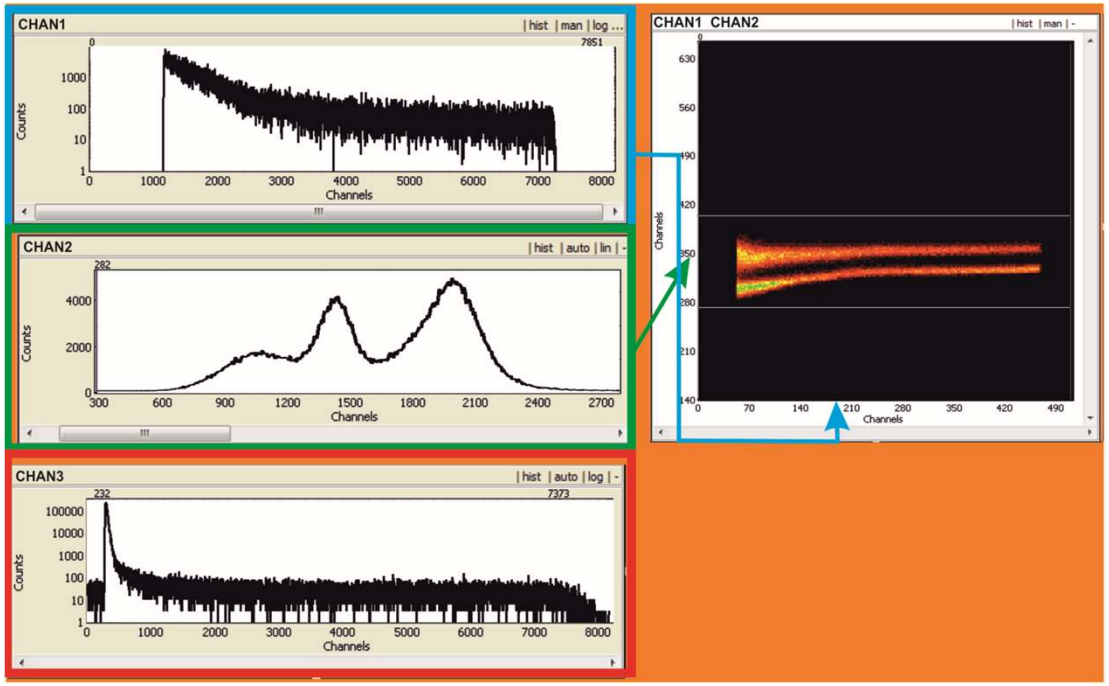
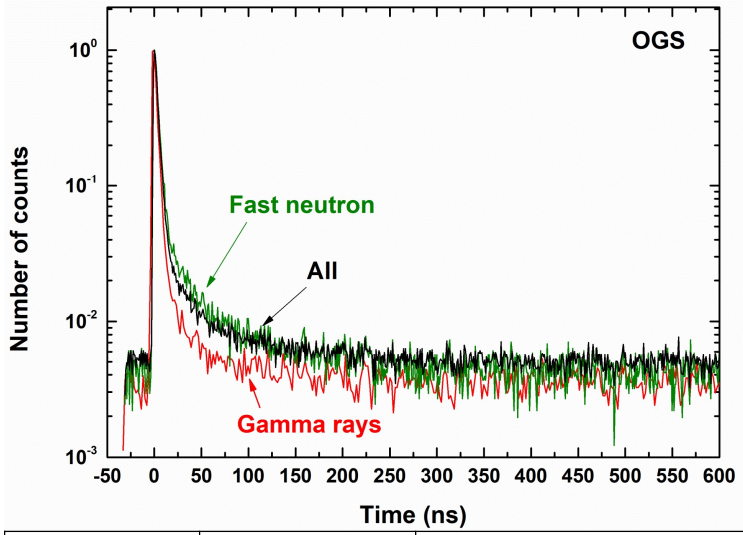
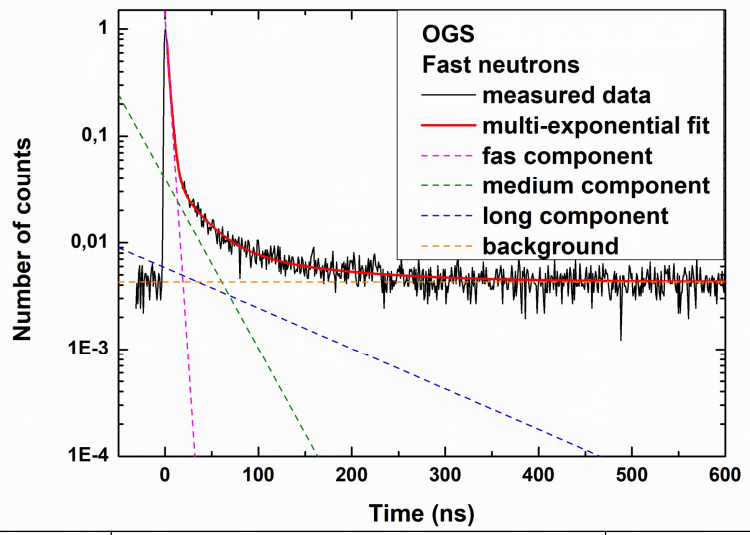


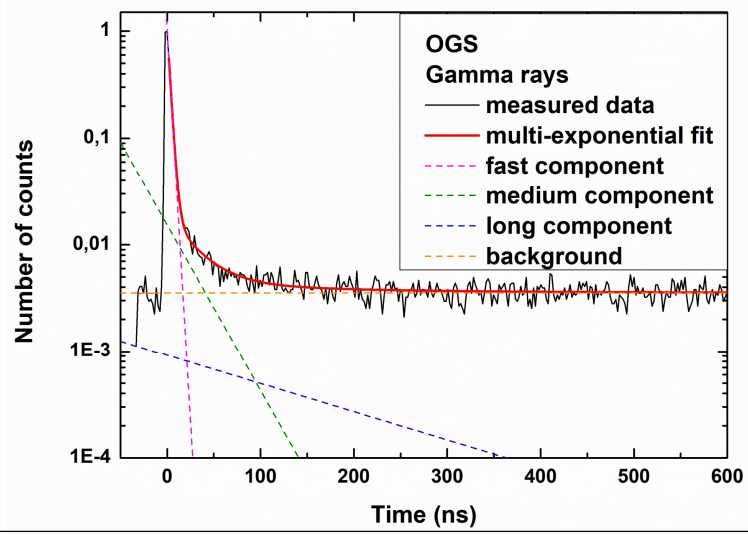
Fig. 6. An example of data acquisition system graphical interface together with the three measured parameters: channel 1 - energy spectrum (blue), channel 2 - zero-crossing time (green). A 2D plot of ZC time versus energy is also presented. Channel 3- light pulse shape (red).

Fig. 5. The experimental setup for the light shape measurements using Bollinger-Thomas single photon method with PSD.

Analysis of the light pulse shapes







scintillator	radiation	Fast component		Medium component		Long component			
		Decay const. [ns]	Intensity %	Decay const. [ns]	Intensity %	Decay const. [ns]	Intensity %	Decay const. [ns]	Intensity %
OGS	Gamma	3.0 ±0.3	84	28 ±3	12	163 ±20	4	-	-
	Fast N	3.4 ±0.3	70	27 ±3	18	114 ±10	11	-	-
EJ-309[a)]	Gamma	3.7 ±0.4	80	31 ±3	10	140 ±10	7	790 ±80	3
	Fast N	4.8 ±0.5	46	32 ±3	24	140 ±10	20	620 ±60	11
EJ-276[b)]	Gamma	4.0 ±0.4	70	16 ±2	12	98 ±10	8	690 ±70	8
	Fast N	3.9 ±0.4	47	18 ±2	13	106 ±10	13	800 ±80	27
Stilbene	Gamma	5.5 ±0.5	86	49 ±5	9	330 ±30	6	-	-
	Fast N	6.6 ±0.5	52	47 ±5	21	260 ±30	26	-	-

Conslusions

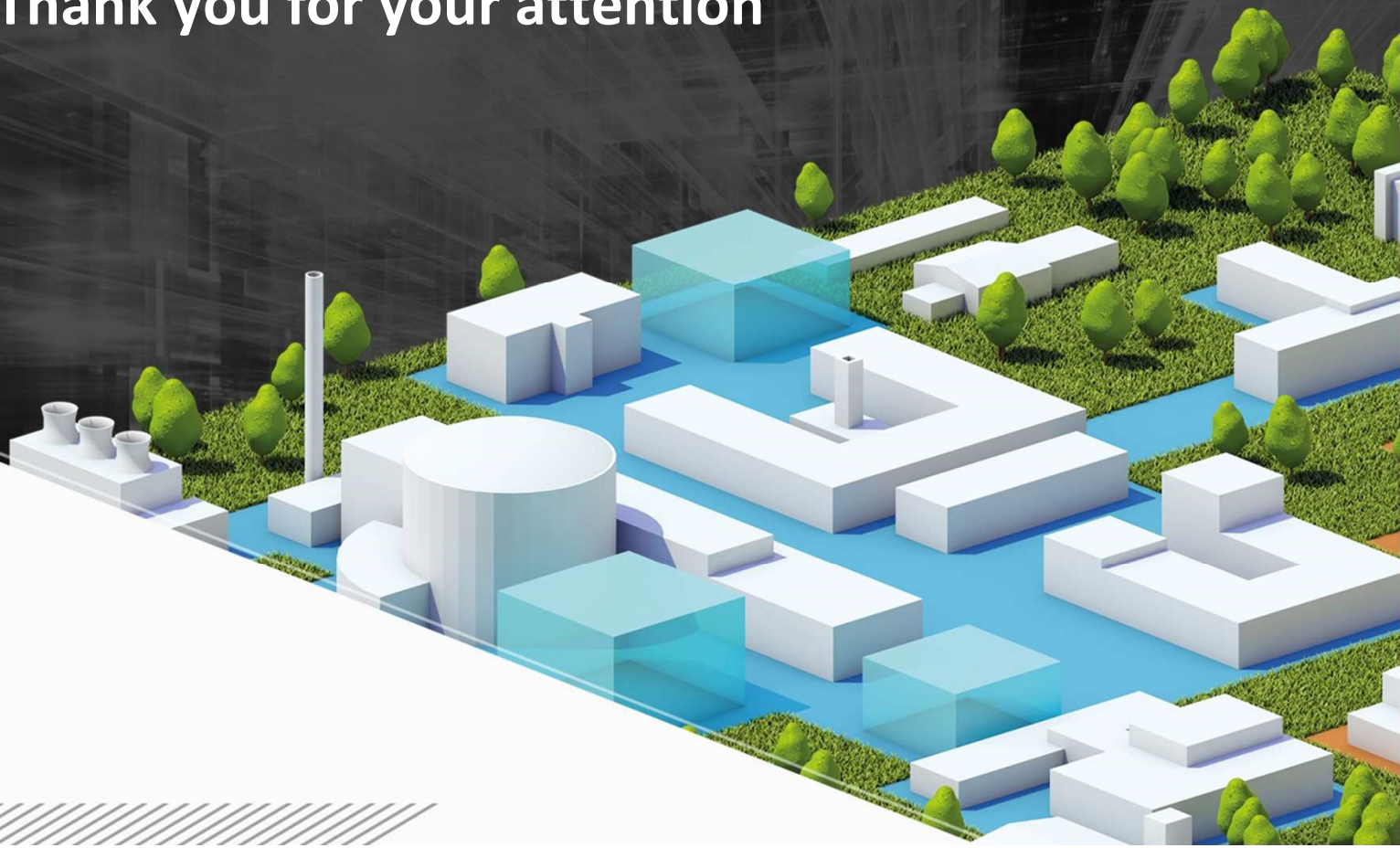
Advantages of OGS:

- **A very good PSD discrimination. Better than for EJ-276 plastic scintillator and almost as good as for the EJ-309 liquid scintillator.**
- **An excellent light output about 20 000ph/MeV,**
- **Emission spectrum with maximum at about 430nm, matched to most of the available photodetectors**
- **Fast decay of the pulse, which allows the measurement of larger neutron fluxes**
- **The highest speed and the intensity of the fast component of the OGS light pulse comparing to other tested detectors. Parameter is very important in fast timing in time-of-flight experiments.**
- **Safe to use: nontoxic, nonflammable**

Disadvantage:

- **slightly hygroscopic (the tested samples were not pack in any aluminium house)**

Thank you for your attention



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