Ultrafast Detector Development for EAR2 (UFD)

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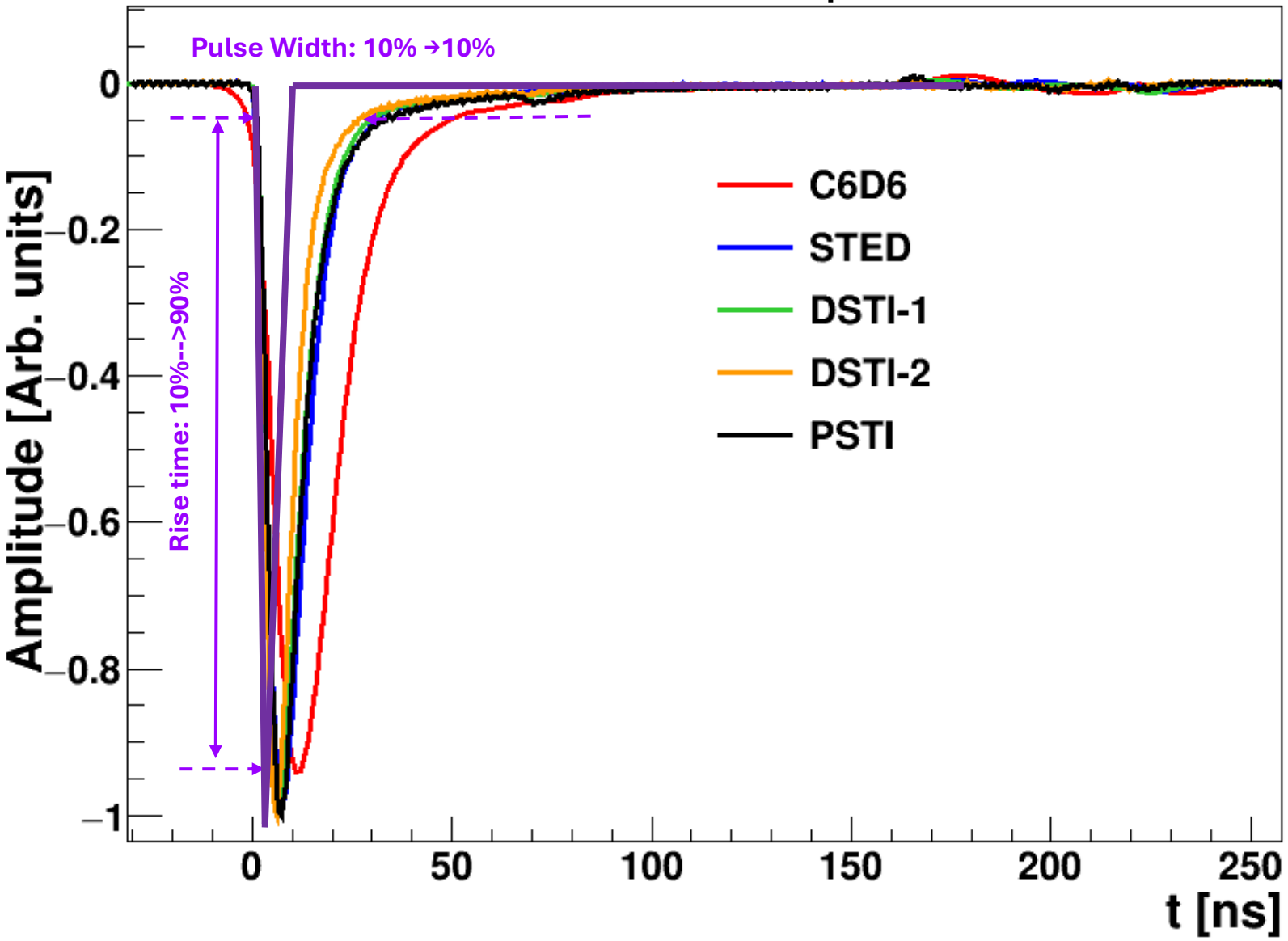
Preliminary characterization of the EJ-232 scintillator (quenched version) coupled with an integrated PM-VD readout

and more…

EAR2 fast-timing scintillators detectors

«Need for speed»



Detector	Rise time [ns]	Pulse width [ns]
C6D6	8	40
sTED	4	24
DSTI-1&2	3	20
PSTI	3	20

Moving to a X10 decrease in pulse width (pile-up suppression)

2 ns pulse width

Increasing time resolution

Fast scintillator crystal coupled with dedicated PM

Try to achieve

2-3 ns pulse width

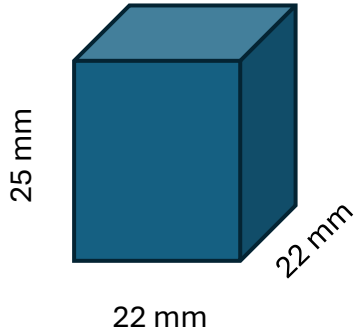
100 MHz max rate

EJ-232 plastic scintillator is intended for very fast timing applications or when very high pulse pair resolution is required. Due to the small emission wavelength, the optical mean free path of this scintillator is approximately 10 cm. Therefore, to achieve the best light collection and to optimize the timing performance, EJ-232 should be used in a small size with the largest scintillator dimension less than 10 cm to minimize photon scattering effects. The use of light guides is best avoided.

EJ-232Q plastic scintillator is a quenched variant of EJ-232 specifically formulated for ultra-fast counting applications. The introduction of small amounts of benzophenone to EJ-232 significantly shortens the timing properties for purposes of achieving very high counting rates or improved coincidence timing. The quenching does not affect the emission spectrum but does reduce the scintillation efficiency (see table below). While it is recommended to keep the scintillator size and shape small in order to achieve the best timing performance, it is not recommended to use EJ-232Q in thin films (thicknesses ≤ 3 mm) due to the vapor pressure of benzophenone.

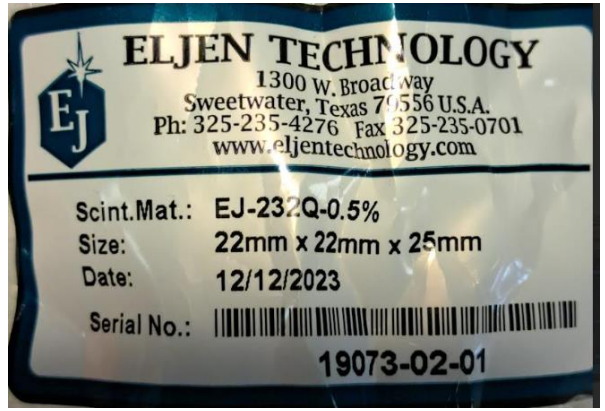
PROPERTIES	EJ-232	EJ-232Q (% BENZOPHENONE)				
		0.5	1.0	2.0	3.0	5.0
Light Output (% Anthracene)	55	19	11	5	4	3
Scintillation Efficiency (photons/1 MeV e^-)	8,400	2,900	1,700	770	610	460
Wavelength of Maximum Emission (nm)	370	370	370	370	370	370
Rise Time (ps)	350	110	105	100	100	100
Decay Time (ps)	1,600	700	700	700	700	700
Pulse Width, FWHM (ps)	1,300	360	290	260	240	220
H Atoms per cm³ ($\times 10^{22}$)	5.13	5.12	5.12	5.12	5.12	5.12
C Atoms per cm³ ($\times 10^{22}$)	4.66	4.66	4.66	4.66	4.66	4.66
Electrons per cm³ ($\times 10^{23}$)	3.30	3.38	3.38	3.38	3.38	3.38
Density (g/cm³)	1.023	1.023	1.023	1.023	1.023	1.023

scintillator delivered by SCIONIX on january 2024



Same P-STIL volume

Matching PMT size



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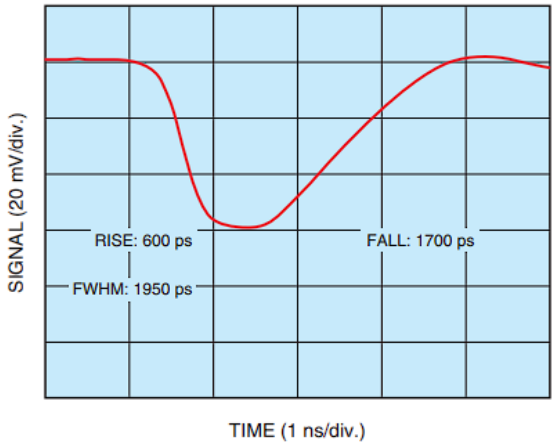
HIGH-SPEED RESPONSE PMT MODULES
FOR UNDERWATER OPTICAL COMMUNICATIONS

Photomultiplier+VD by HAMAMATSU

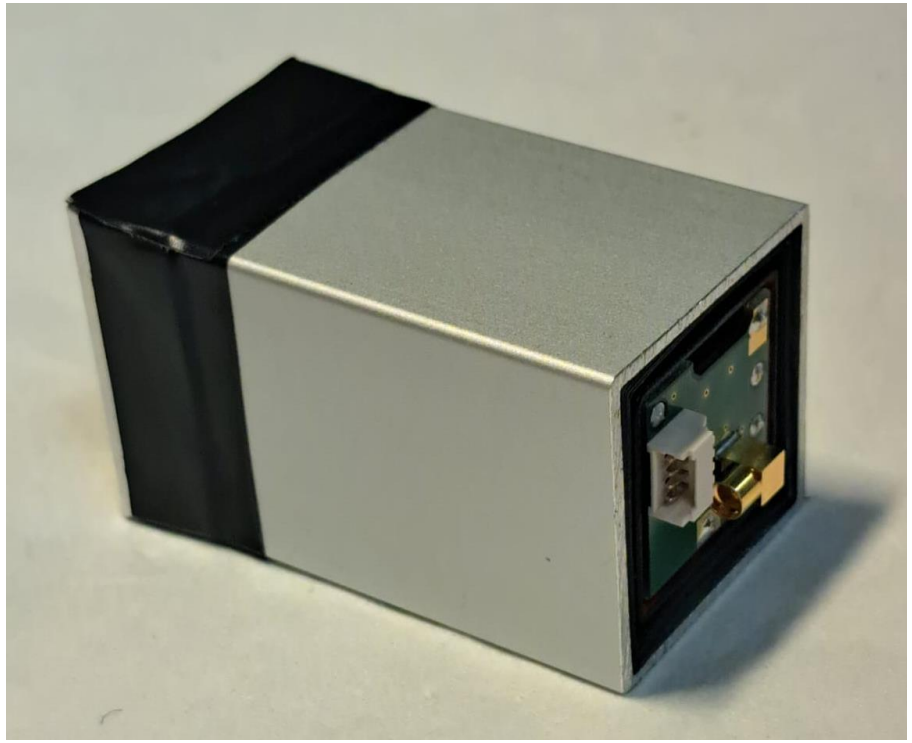
H14601-200

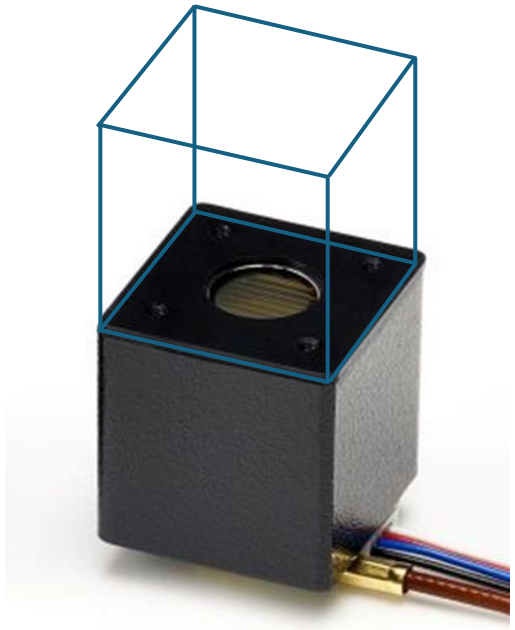
■H14600-100

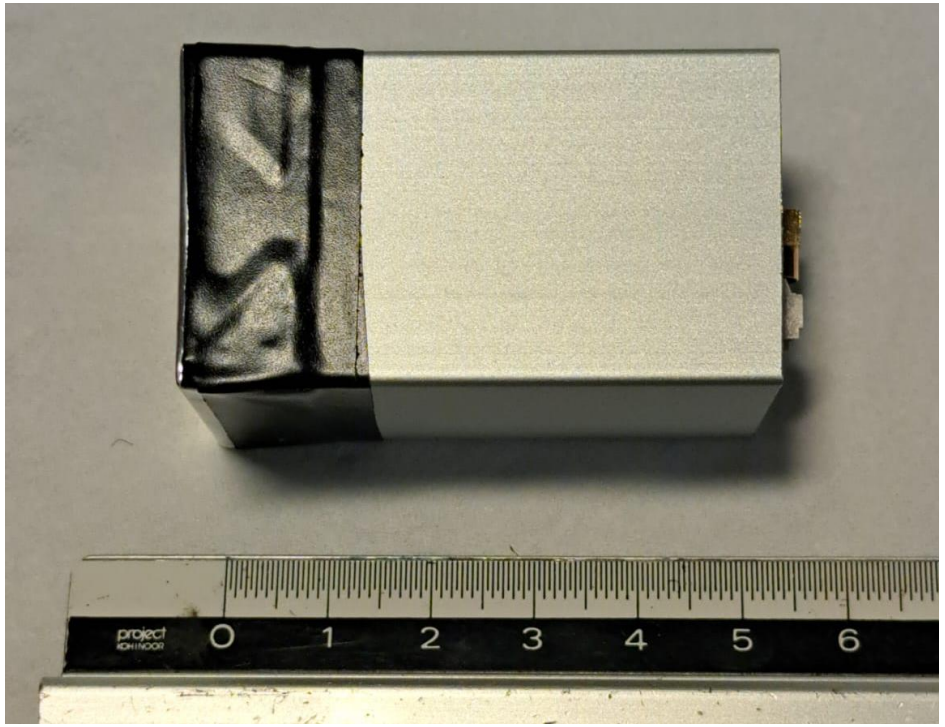


Parameter			H14600 / H14601 series				Unit
Suffix			-100, -103	-200	-01, -04	-20	—
Input voltage			+4.5 to +5.5				V
Max. input voltage			5.5				V
Max. input current *1			3.5				mA
Max. average output signal current *2			100				μA
Max. control voltage			+1.0 (Input impedance 1 MΩ)				V
Recommended control voltage adjustment range			+0.5 to +1.0 (Input impedance 1 MΩ)				V
Effective area			φ8				mm
Peak sensitivity wavelength			400	400	400	630	nm
Cathode	Luminous sensitivity	Min.	80	100	100	350	μA/lm
		Typ.	105	135	200	500	
	Blue sensitivity index (Blue filter)	Typ.	13.5	15.5	—	—	—
	Red/White ratio	Typ.	—	—	0.25	0.45	—
	Radiant sensitivity *3	Typ.	110	130	77	78	mA/W
Anode	Luminous sensitivity *2	Min.	30	40	40	140	A/lm
		Typ.	105	135	200	500	
	Radiant sensitivity *2*3	Typ.	1.1×10^5	1.3×10^5	7.7×10^4	7.8×10^4	A/W
	Dark current *2*4	Typ.	0.5	0.5	1	10	nA
		Max.	5	5	10	100	
Rise time *2		Typ.	0.6				ns
Ripple noise *2*5 (peak to peak)		Max.	0.2				mV
Settling time *6		Max.	10				s
Operating ambient temperature *7			+5 to +50				°C
Storage temperature *7			-20 to +50				°C
Weight			32 (H14600 series), 40 (H14601 series)				g

UFD or «the cube»



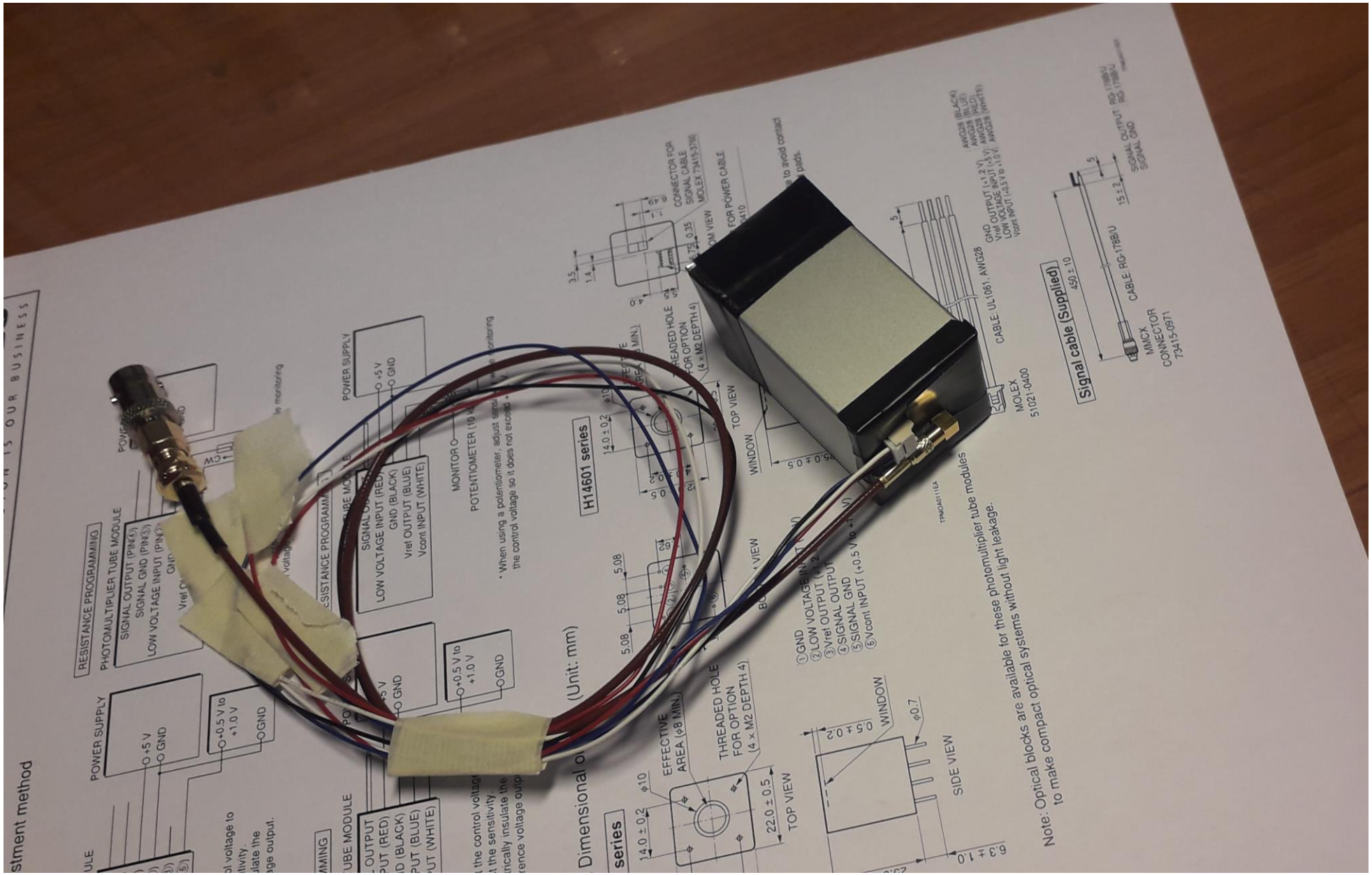




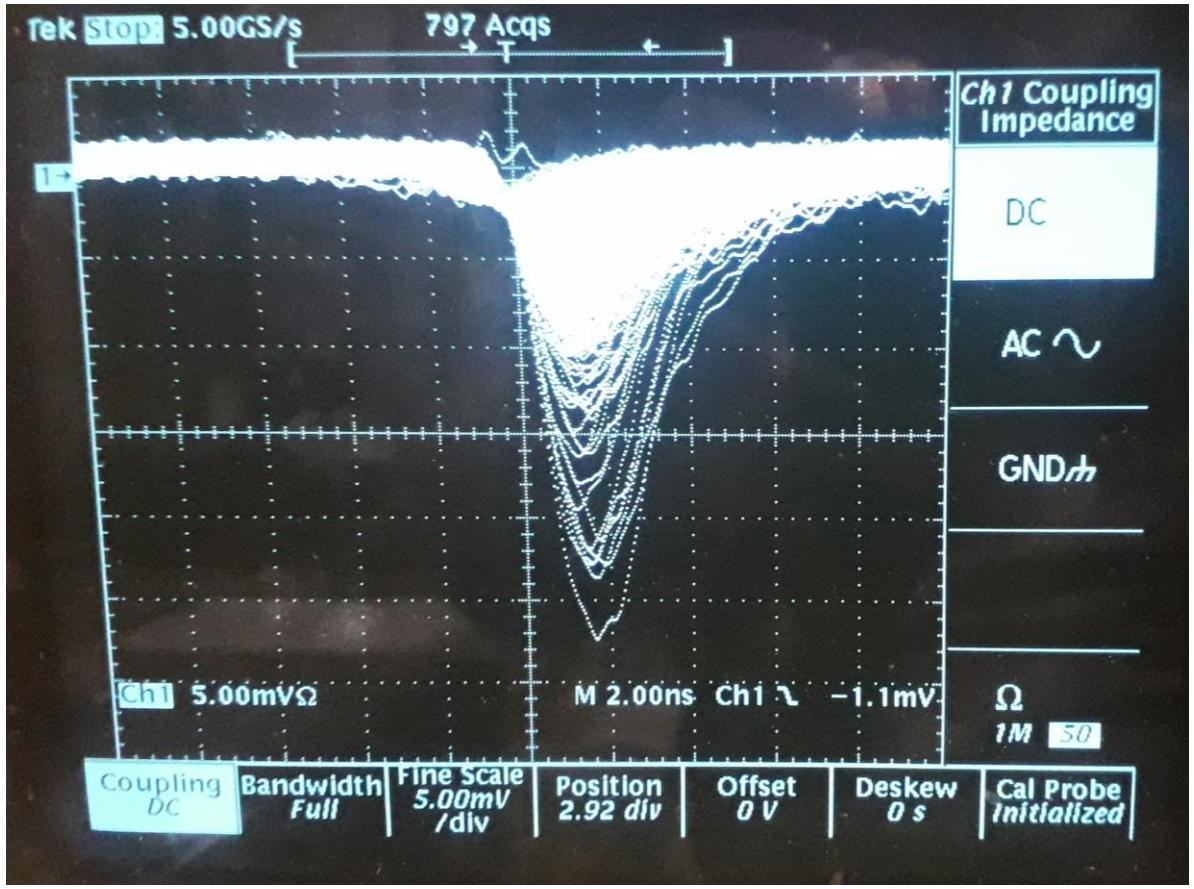
Half of the lenght (and material) with respect to P-STIL

The PM could be used also for a P-STIL upgrade

P-STIL-*like HV* and power supply (we expect to have the same noise immunity)



600-700 V - HV



Cosmic-ray single pulse

Cs-137

Better than *1 ns* fall-time *3 ns* pulse-width

To be used (preliminary) in EAR2:

- γ-flash and background characterization at full spill intensity.

- (n,γ) capture reaction benchmarks as already done for P-STIL (Investigating for a deuterated version)

Let’s move to a further development for Stilbene 

Cutting-edge development: Stibene for (n,CP) measurements

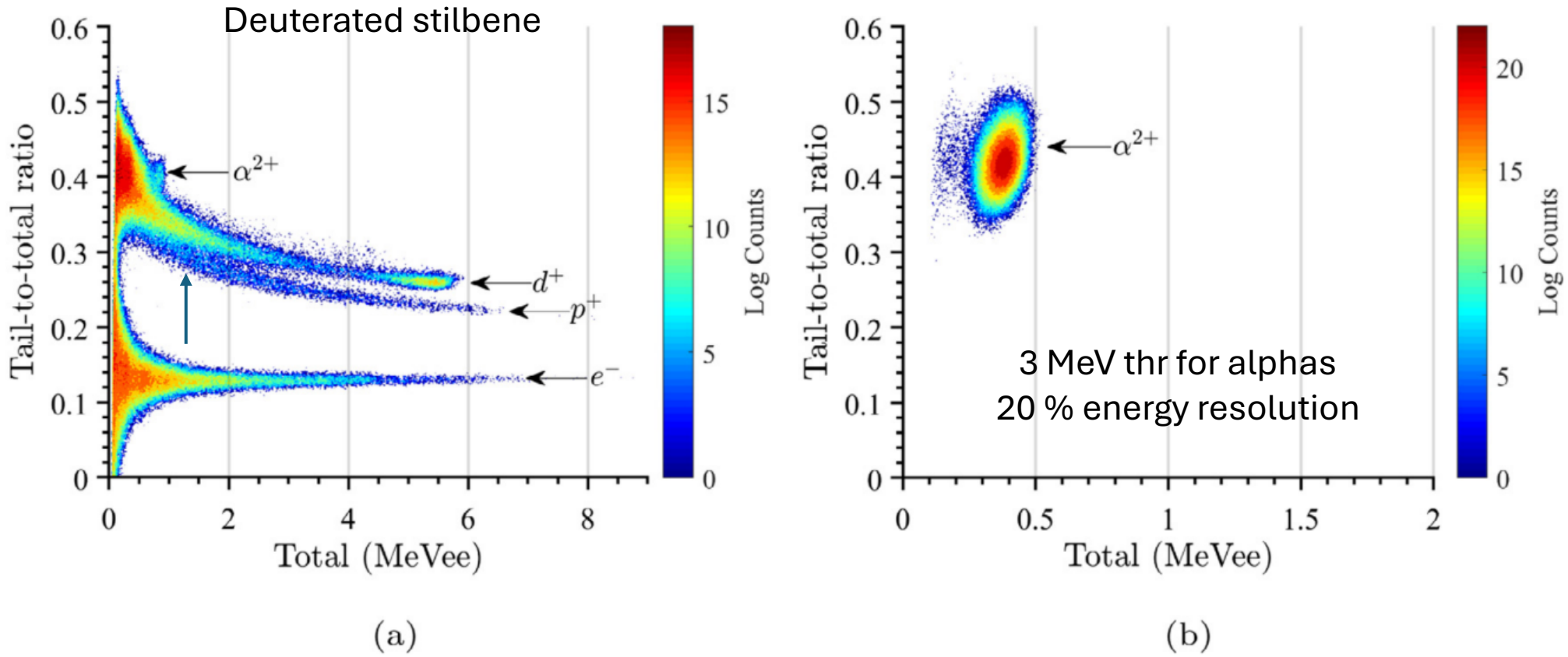


Fig. 4. (a) PSD scatter-density plot of the D-T source. (b) PSD scatter-density plot of the ^{241}Am alphas.

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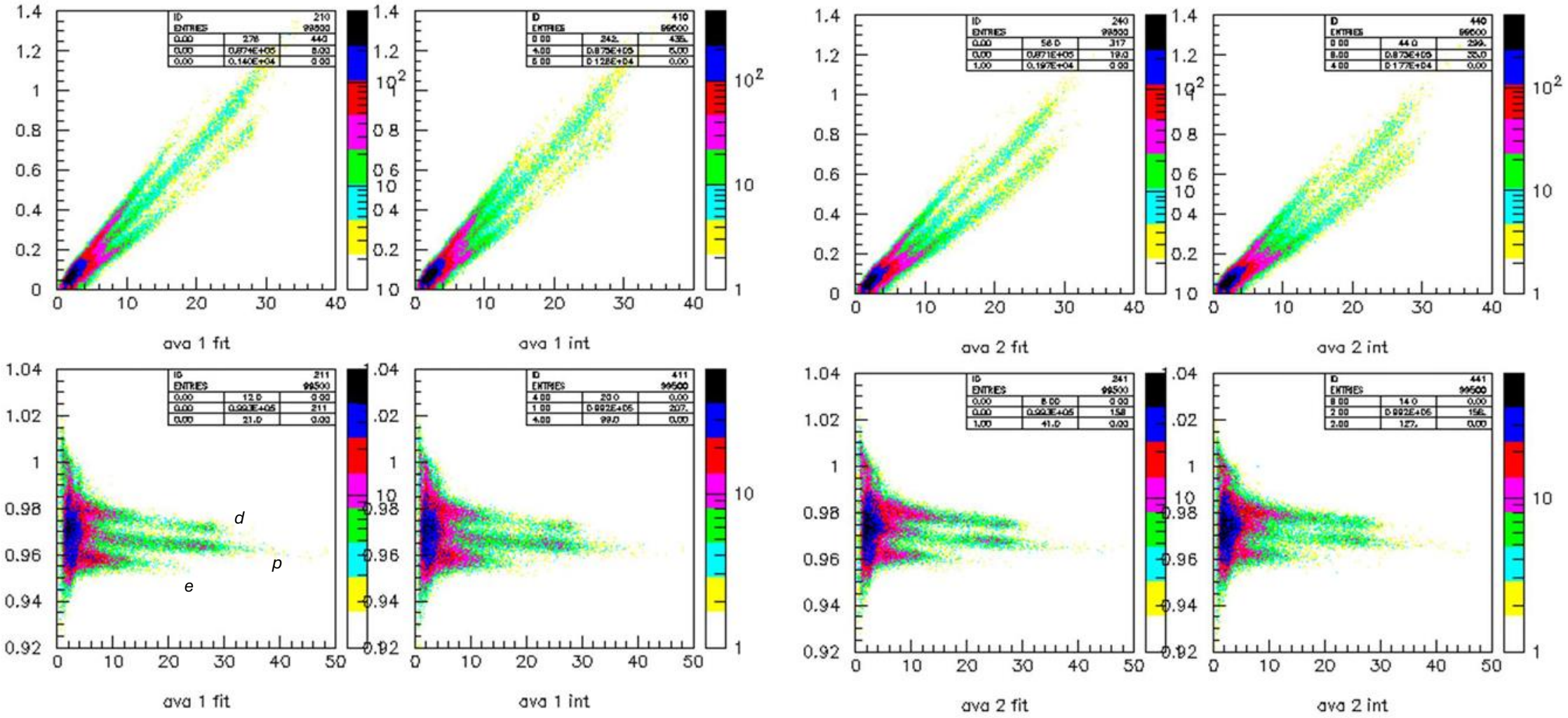
Also working with SiPM ! (TARAT-Demokritos)

By M.G. Pellegriti data mining



Stilbene (0.5 cm thick) and PM available and ready to be mounted

PSTIL technology

Origina INRAD stilbene (**0.5 cm thick**) by CERN

HAMAMATSU **R1924A**

SENS - TECH

In-vacuum test to be performed (with Gigi and Simone)

DFA-LNS-CT (characterization plan)

- Alpha source
- Gamma
- Am-Be (*n (p)* e γ)

d-stilbene (TARAT)

- Am-Be (n (p), ***d***, e γ)

Highlights (Stilbene for CP discrimination):

- γ–flash and noise immunity (already tested)
- Multiparticle discrimination with low threshold (γ, p, d, t, 4He)
- Fast: 20 ns pulse width and 100 ns tail (PSD mandatory)
- Flexible readout (both PM or SiPM are working)
- Drawback: Energy resolution

- Physics case under study by N. Patronis and A. Musumarra in progress.

To conclude →

New deuterated fast (3 ns) fast scintillator

EJ-299-02D DEUTERATED PLASTIC SCINTILLATOR

Proposed by SCIONIX

This is a plastic scintillator based on deuterated polystyrene for fast neutron research. The scintillation and physical properties are very similar to those of standard premium quality scintillators. A similar plastic scintillator, EJ-299-02H, is based on normal polystyrene and therefore contains no deuterium. It is otherwise identical to the deuterated scintillator.

Physical and Scintillation Constants:

Light Output, % Anthracene	55
Scintillation Efficiency, photons/1 MeV e^-	8,500
Wavelength of Max. Emission, nm	430
Rise Time, ns	1.0
Decay Time, ns	2.3
Pulse Width, FWHM, ns	~2.7
No. of H Atoms per cm^3, x 10^{22}	0.13
No. of D Atoms per cm^3, x 10^{22}	4.33
No. of C Atoms per cm^3, x 10^{22}	4.64
No. of Electrons per cm^3, x 10^{23}	3.13
Ratio D:H Atoms	32.9
Ratio D:C Atoms	0.97
Density, g/cc:	1.04

Polymer Base: ..... Polystyrene
Refractive Index: 1.61
Vapor Pressure: ..... Is vacuum-compatible
Coefficient of Linear Expansion: ..... 7.8 x 10^{-5} below +67°C

Light Output vs. Temperature:
At +60°C, L.O. = 95% of that at +20°C
No change from +20°C to -60°C

Chemical Compatibility: Is attacked by aromatic solvents, chlorinated solvents, ketones, solvent bonding cements, etc. It is stable in water, dilute acids and alkalis, lower alcohols and silicone greases. It is safe to use most epoxies and silicone rubbers with EJ-299-02.

+

H14601-200

Requesting a quote for:

n.1 EJ-299-02D 22mmx22mmx25mm
n. 1 EJ-299-02H 22mmx22mmx25mm

A step forward *d-stilbene* and *p-stilbene*

Outlook

- 2 ns pulse-width plastic scintillator (UFD) to be tested in EAR2
- Thin *p*-stilbene for CP discrimination (under development)
- New fast deuterated scintillators (outperforming Stilbene and C6D6 in post LS3 campaign)