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## Development of a hybrid radiation monitor based on NaI(Li+Tl) and PVT scintillators for homeland security

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NSS-06-N-21-01 | Scintillators, Photodetectors and Applications V

# Developpement of a hybrid radiation monitor based on NaI(Tl+Li) and Plastic Scintillators for Homeland Security



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November 09, 2022

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## Outline :

- I. Introduction
- II. Approach
- III. Proof-of-concept setup
- III. Main performances
- IV. Conclusion and prospects



## ➤ General context :

- Research & Development program to fight against **CBRN-E threats** (Chemical, Biological, Radiological, Nuclear and Explosives)
- Focus on the development of technologies for **civil zones monitoring** (stadium, airports, train stations...)

Tense Geopolitical context : Press paper October 27, 2022

**The Washington Post**  
*Democracy Dies in Darkness*

## U.N. looks to ‘cool’ fears of dirty bomb with visit to Ukraine

Example of classical NaI based radiation monitor



## ➤ Objectives :

- Development of a new generation of Radiation Portal Monitors (RPM) able to **detect, identify and discriminate** radioactive and nuclear threats





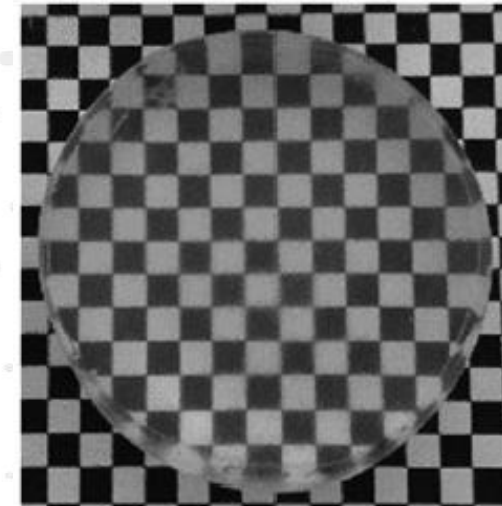
## ➤ Background developments :

- CEA List know-how in the development of **plastic scintillators based** Radiation Portal Monitors (RPM)
- Know-how and experience in the synthesis of **organic scintillators for neutron/gamma discrimination**

Example of plastic scintillator based RPM



Example of a 1.70 wt%  $^6\text{Li}$  loaded lab. synthesized Plastic Scintillator : 15 mm height, 30 mm diam.



III. Proof-of-concept setup

IV. Performances

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G. Sannie et al., "Scintilla European project, the successful research results," 2015 4th International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA), 2015, pp. 1-4

C. Frangville, M. Hamel, et. al, "Large solubility of lithium carboxylates reaching high rates of  $^6\text{Li}$  incorporation in polystyrene based plastic scintillators for fast/thermal neutron and gamma ray detection", Mater. Chem. Front., 2019, 3, 1626





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## ➤ Lithium-doped NaI<sup>TM</sup>:



- **high Z** molecules (Na,I,Tl) and density close to  $\sim 3,7 \text{ g.cm}^{-3}$
- ➔ **Gamma spectrometry** possible
- <sup>6</sup>Li concentration up to 8-9 %
- Sensibility to **thermal neutrons** :  ${}^6\text{Li}(n_{\text{th}},\alpha)t$

## ➤ Plastic Scintillators :



- **Low Z** molecules (C,H) and density close to  $\sim 1 \text{ g.cm}^{-3}$
- ➔ **Neutron thermalization** properties
- Fast light response  $\sim 100 \text{ ns}$
- Neutron and gamma rays sensibility

**Approach** : Plastic scintillators signal **confirms** the presence of a **NR threat** (Go/No go), **identification** by means of a **gamma ray spectrometry**, **enhance** the **neutron sensitivity** in the NaI<sup>TM</sup> if N threat presence





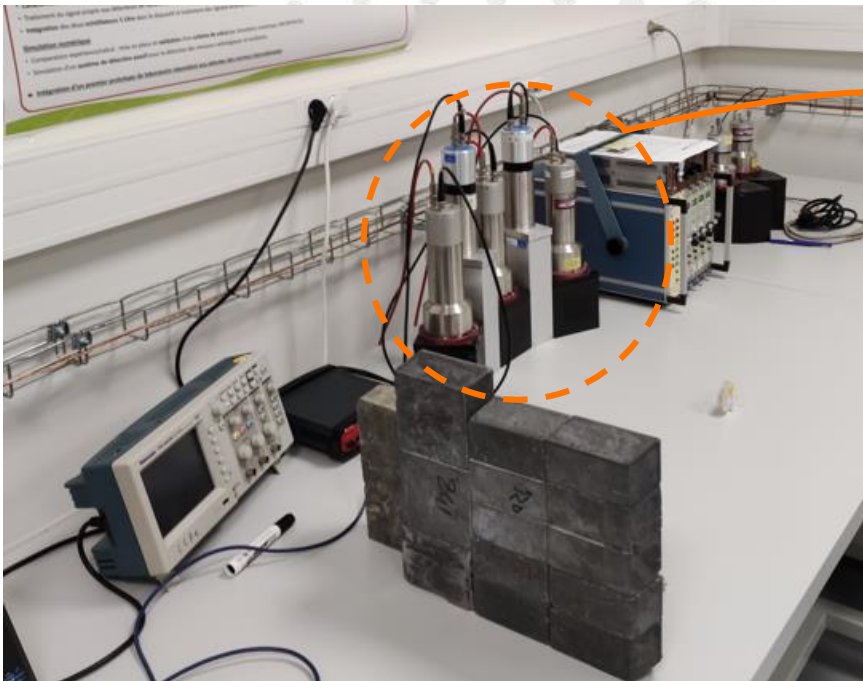
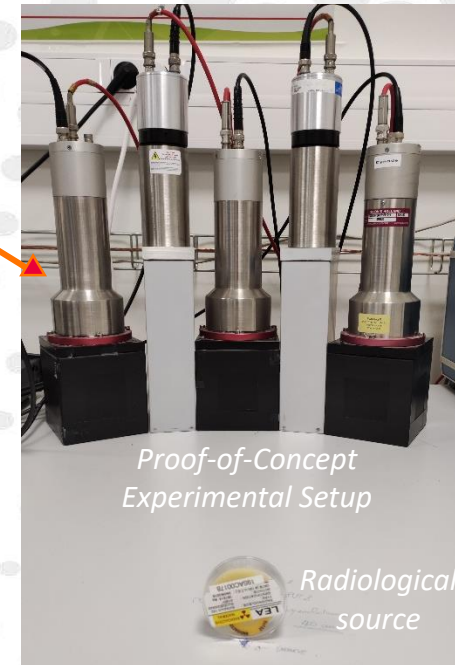
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Zoomed-in  
Front ViewProof-of-Concept  
Experimental SetupRadiological  
source

- Two NaI<sup>TM</sup> inorganic scintillators of  $5 \times 10 \times 20 \text{ cm}^3$  dimensions and three EJ-200<sup>®</sup> plastic scintillators of  $10 \text{ cm}^3$
- Irradiations sources for the simulation of a radiological environment :  $^{152}\text{Eu}$ ,  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$ ,  $^{68}\text{Ge}$ ,  $^{252}\text{Cf}$
- CAEN DT5730SB 8 channels digitizer with a **sampling @500Mhz** | Canberra and ORTEC High Voltage modules







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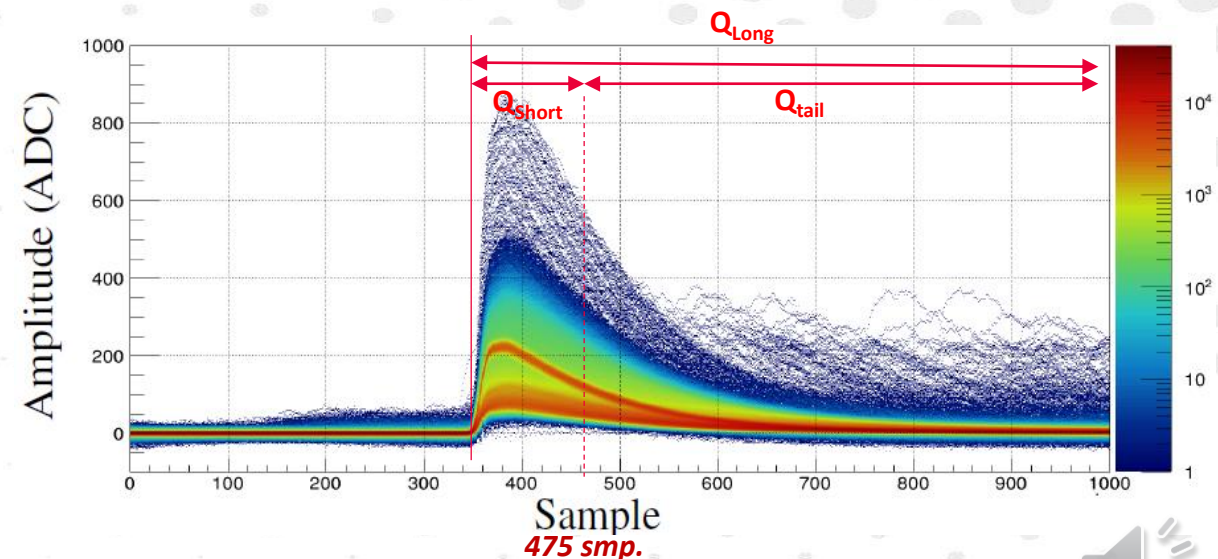
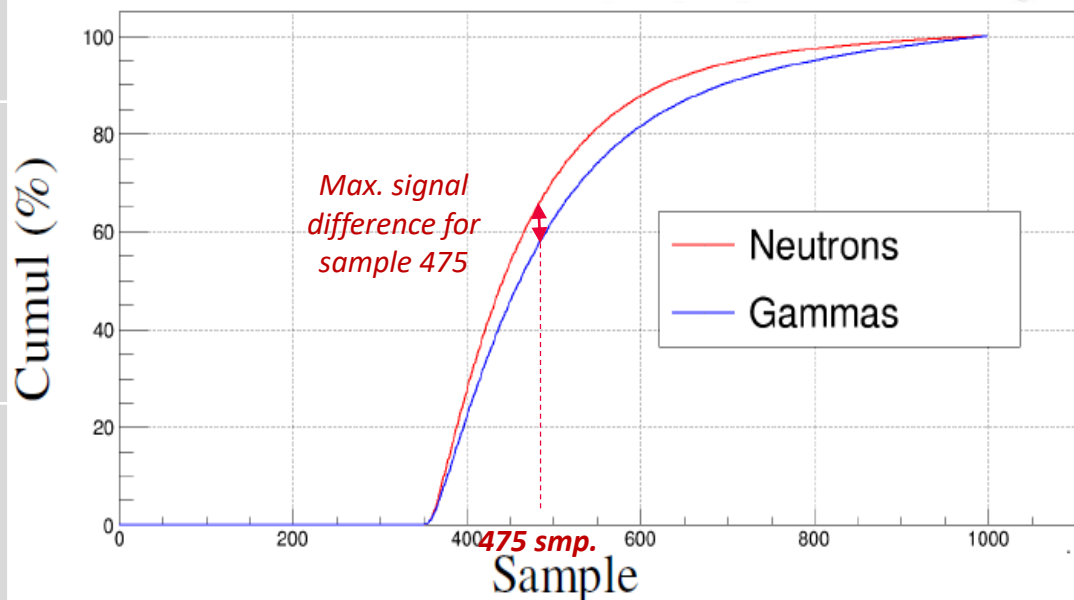
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### ➤ Main parameters :

- HV for the NaI<sup>TM</sup> at **+1kV** | HV rounding **-1.8 kV** for the EJ-200<sup>®</sup> scintillators
- Signal acquisition : **Channels 0 & 6** for both NaI<sup>TM</sup> | **Channels 2,3,4** for the EJ-200<sup>®</sup> scintillators
- **Optimisation** of  $Q_{\text{Long}}/Q_{\text{Short}}$  integration parameters for **n/ $\gamma$  discrimination** for Ch. 0 & 6



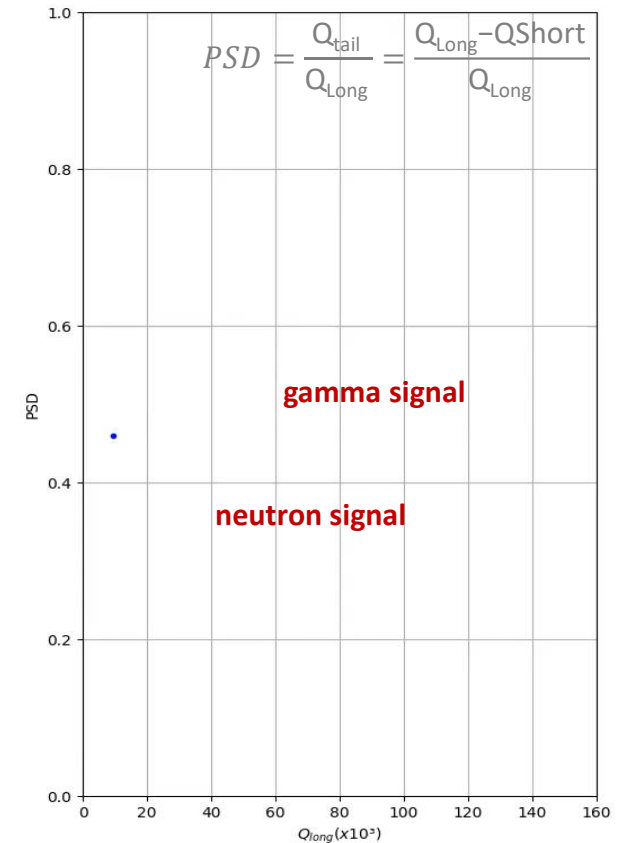
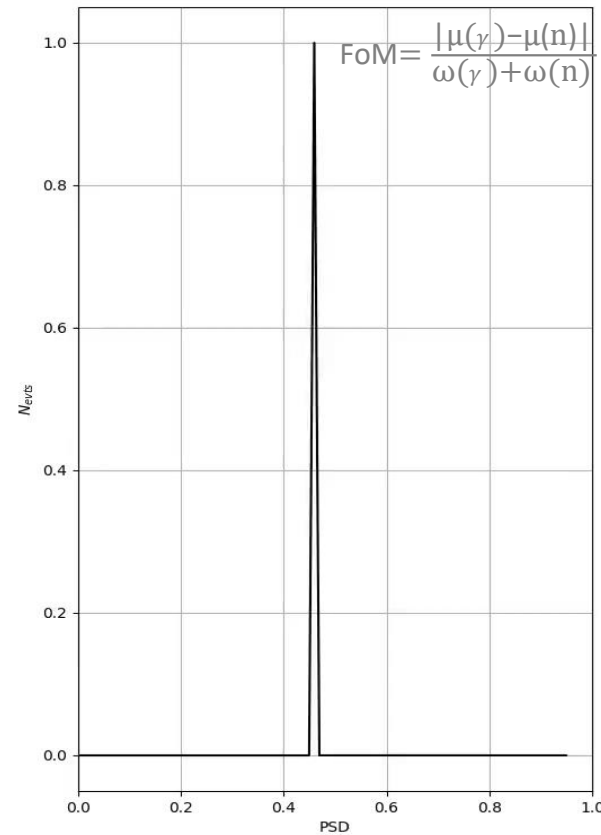
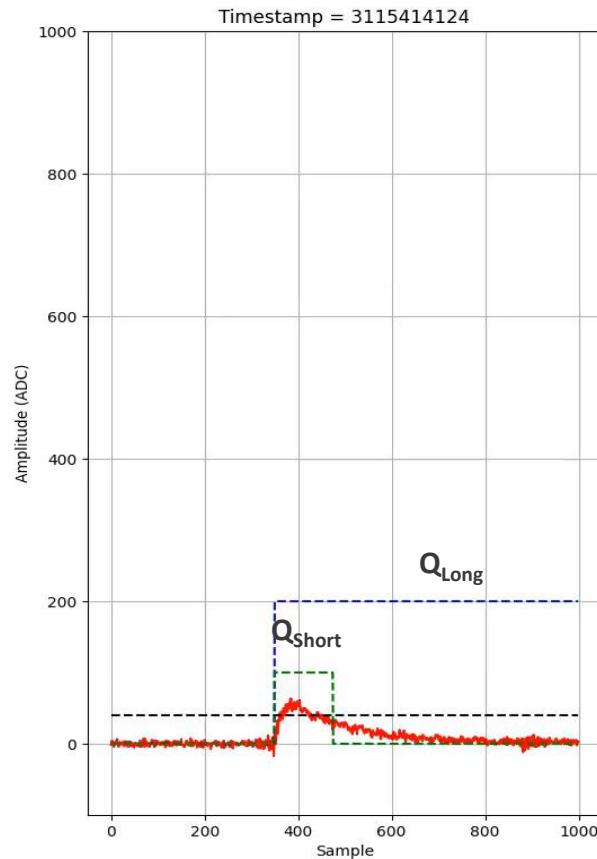
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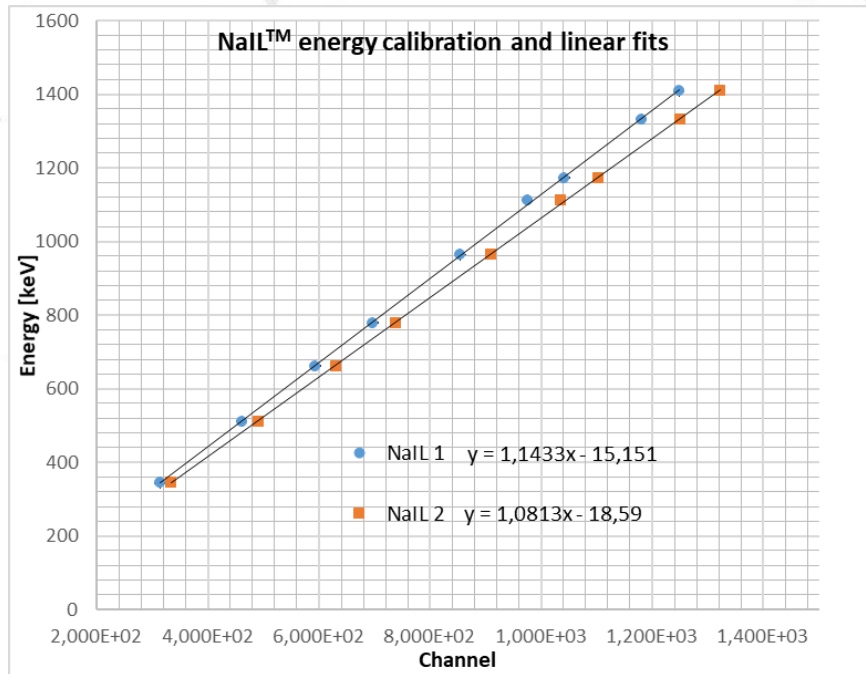
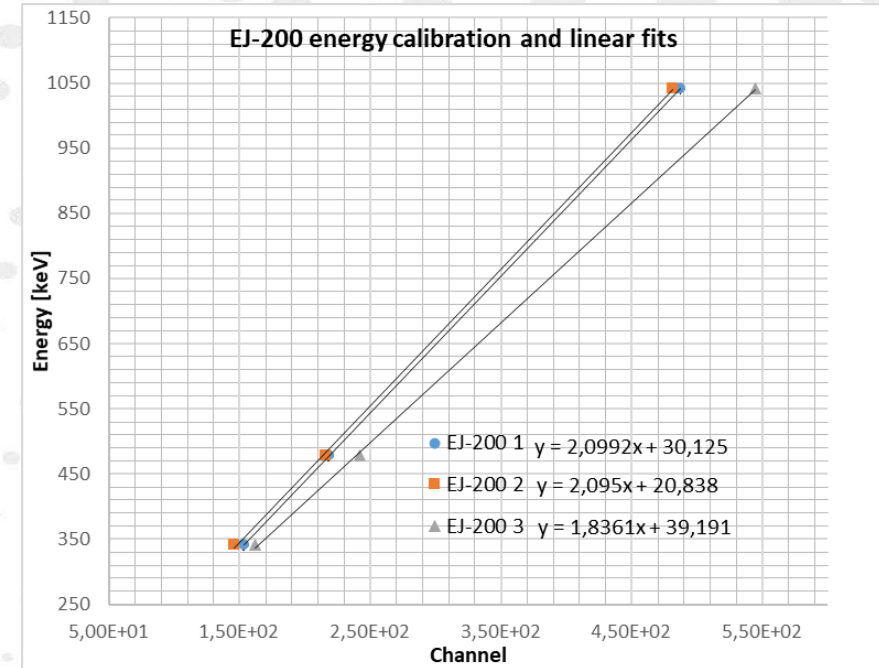
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- **Figure of Merit of 4.37** (> 3.89 from *Lai Caifeng, et.al (2020)*) and accurate neutron/gamma discrimination capabilities by means of Pulse Shape Discrimination



➤ NaI<sup>TM</sup> :➤ EJ-200<sup>®</sup> :

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- Classical approach by means of Gaussian fits in the RoI
- Energy resolution at 661.7 keV :

NaI<sup>TM</sup> n°1: 9.26 %NaI<sup>TM</sup> n°2: 9.14 %

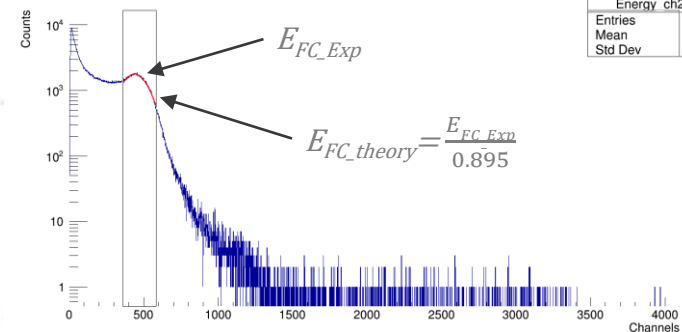
Slightly higher than Classical NaI:Tl

γ identification possible

- Siciliano et. al (2008) approach :

$$E_{FC\_Theory} = \frac{E_{\gamma}}{\left(1 + \frac{2 \cdot E_{\gamma}}{m_e \cdot c^2}\right)}$$

Energy ch2 can	
Entries	1157008
Mean	232.8
Std Dev	193.7



V. Conclusion &amp; Prospects



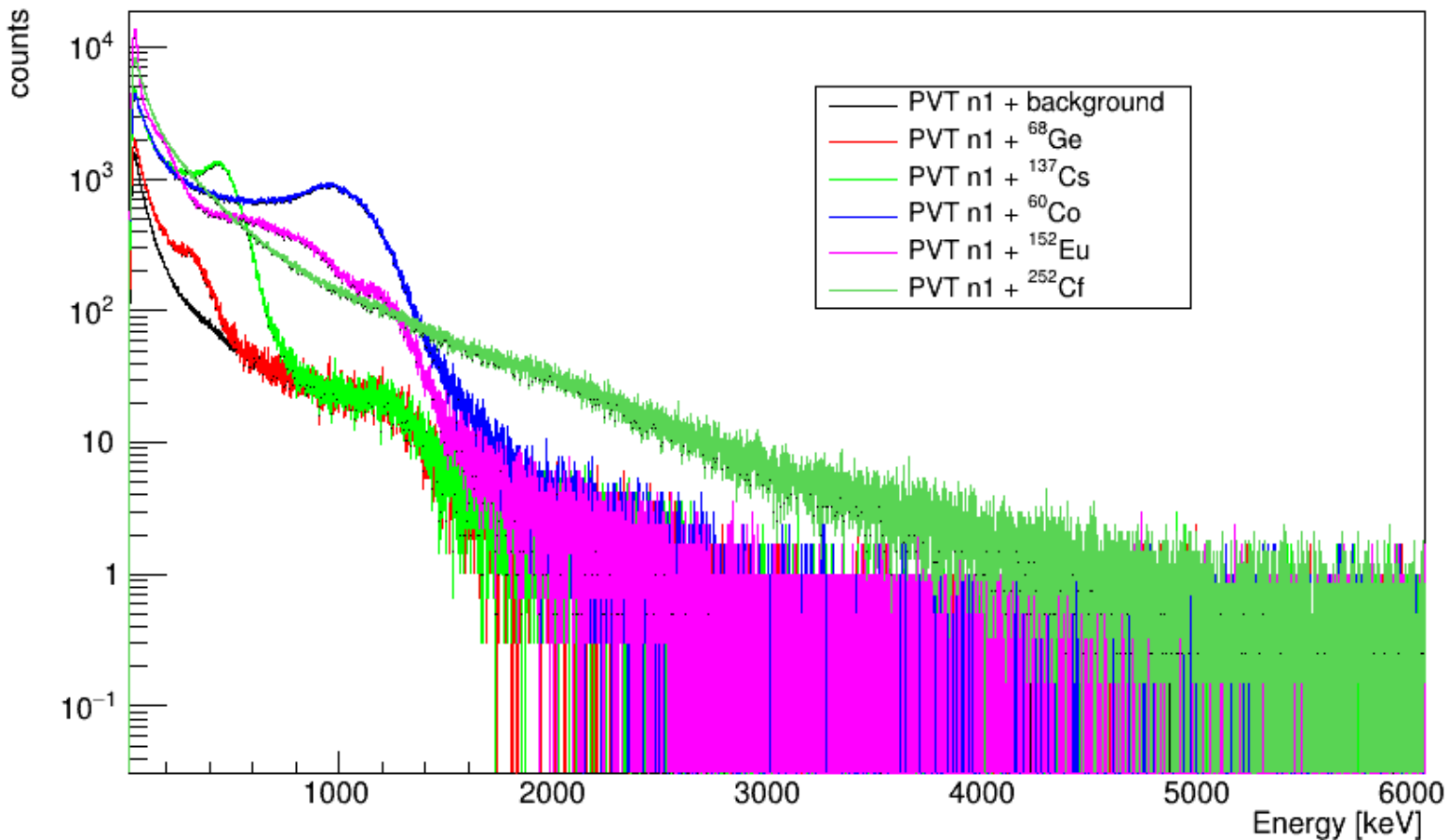


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- Sources activities on the day of measurements :

$$A_{\text{Eu-152}} : 325.03 \text{ kBq}$$

$$A_{\text{Co-60}} : 289.83 \text{ kBq}$$

$$A_{\text{Cs-137}} : 396.39 \text{ kBq}$$

$$A_{\text{Cf-252}} : 168.52 \text{ kBq}$$

- Acquisition time fixed to 5 min
- Simulant placed at a 40 cm distance from the setup

- *Go/no go information thanks to the over-signal from the energy deposit on the PVT with respect to the passive background measurement*



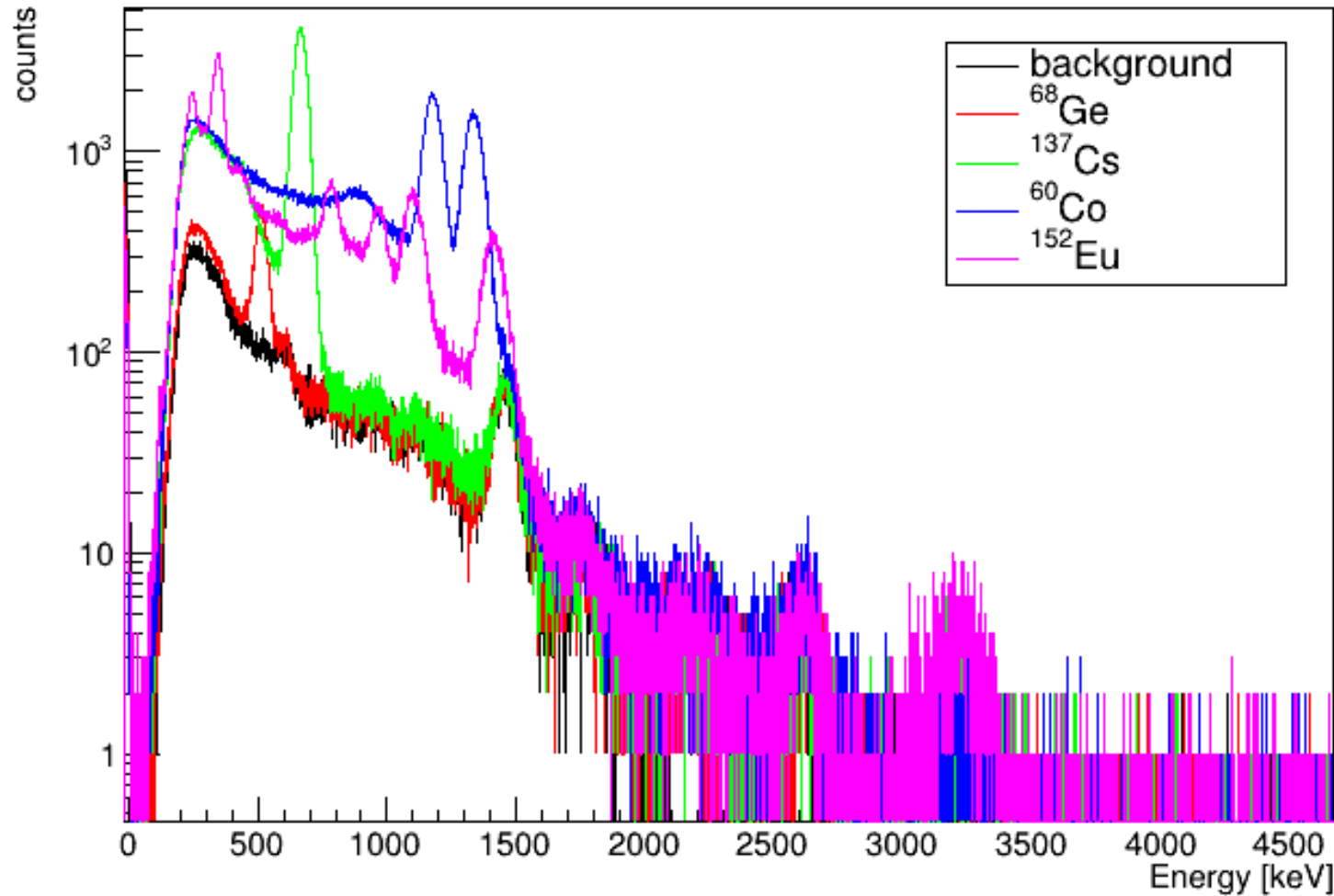
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- *Discrimination of the main radiological threats possible and identification by means of gamma-ray spectrometry*



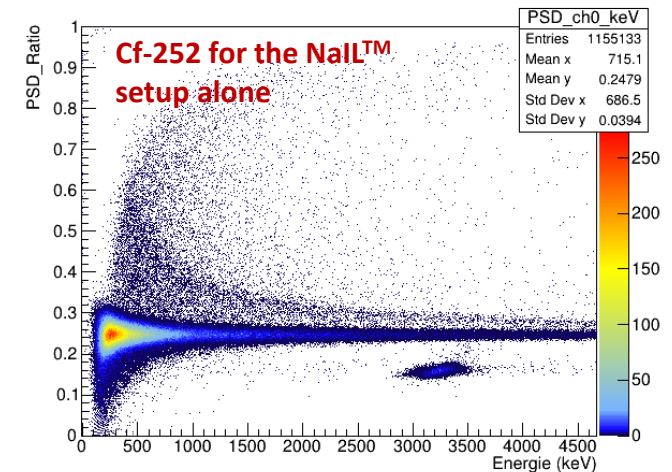
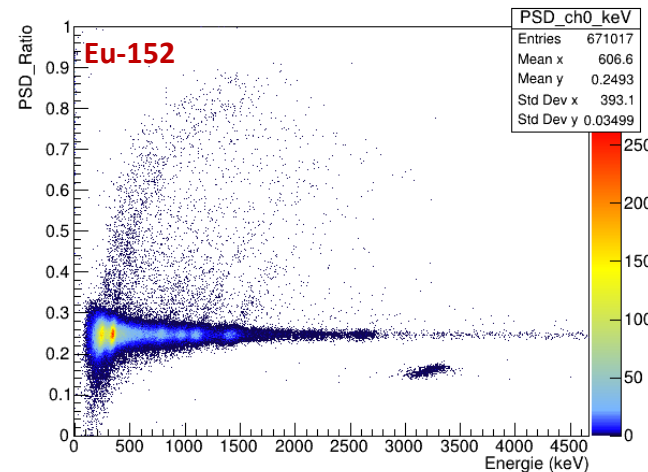
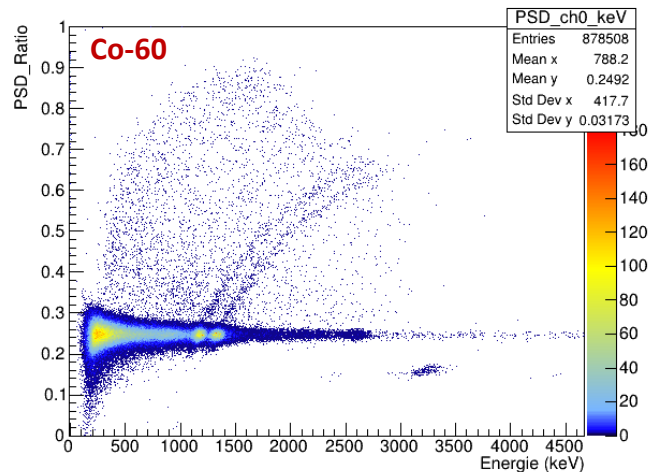
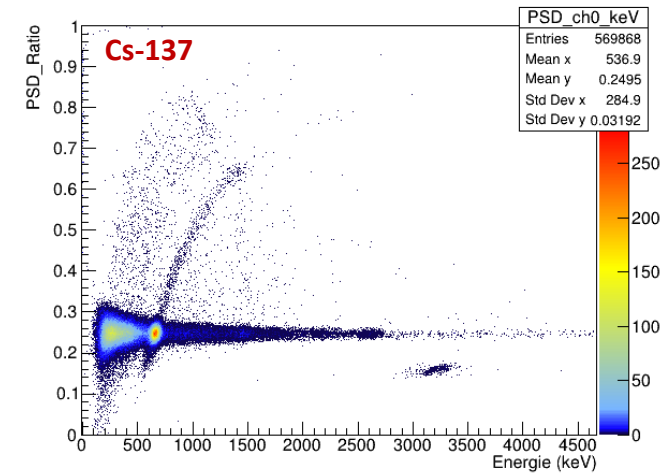
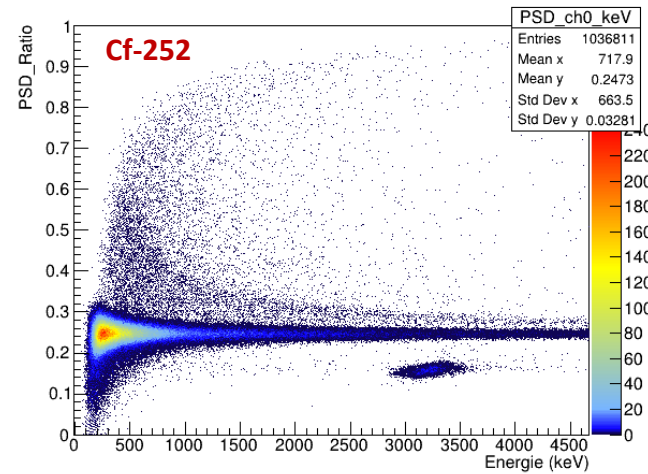
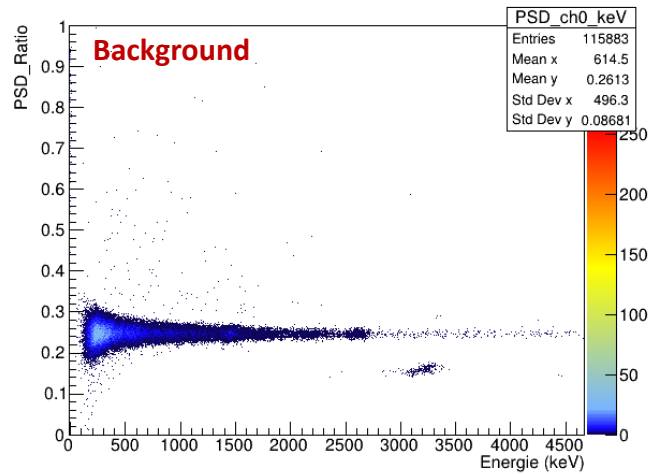
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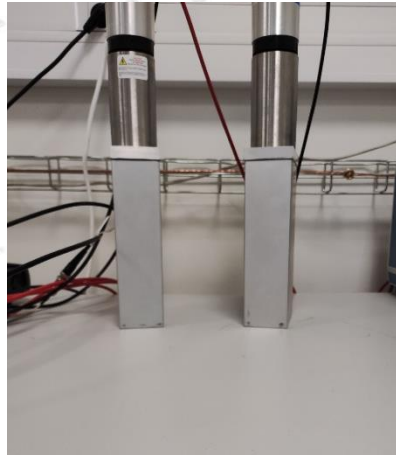
## V. Conclusion &amp; Prospects



- *Discrimination between radiological and nuclear threats thanks to the FoM of 4.37*



## ➤ Nail™ :

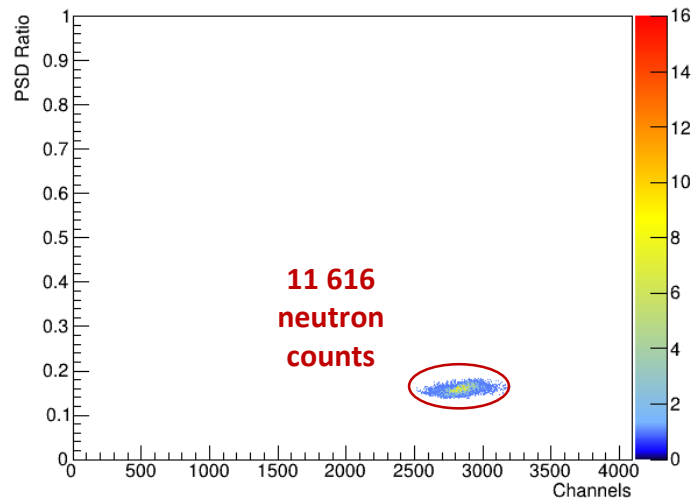


## ➤ Nail™ /EJ-200:



Cf-252 source of  $18\,705\text{ n.s}^{-1}$   
neutron emission

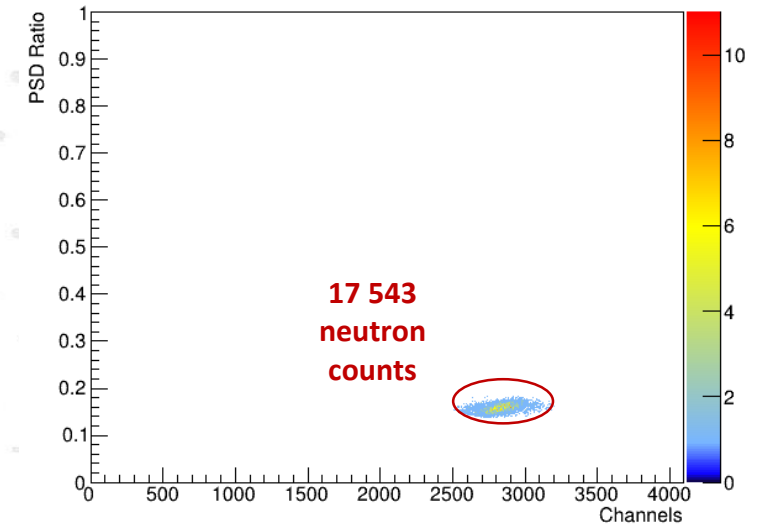
Acquisition time fixed to 5 min



Extraction of the useful neutron  
signal in the Ellipsoid *RoI*

$$\frac{(x-x_0)^2}{(x_{\max}-x_0)^2} + \frac{(y-y_0)^2}{(y_{\max}-y_0)^2} = 1$$

$$\left\{ \begin{array}{l} x_0 = 2850 \\ x_{\max} = 3200 \\ y_0 = 0.16 \\ y_{\max} = 0.185 \end{array} \right.$$



- Signal increase of **51.02 %** in the **neutron RoI** validating the use of combined Nail™ with Plastic Scintillators



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➤ **Conclusion:**

- **Optimization** of the **signal acquisition parameters** to reach a **FoM of 4.37**
- Proof-of-concept experimental **setup characterization** and **radiological/nuclear simulants detection and discrimination** by means of gamma ray-spectrometry and *Pulse Shape Discrimination (PSD)*
- **Validation** of the use of **combined NaI<sup>TM</sup>** with **plastic scintillators** to increase the **neutron signal** from **51.02 %**

➤ **Prospects:**

- Study of **additional signal information** by the use of coupled detectors
- **Performance assessment** in terms of **signal sensitivity** with respect to international regulations
- **Optimization and sizing** of a combined NaI<sup>TM</sup>/Plastic Scintillator based **RPM** by means of **Monte Carlo modeling**



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*Thank you for your attention*

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