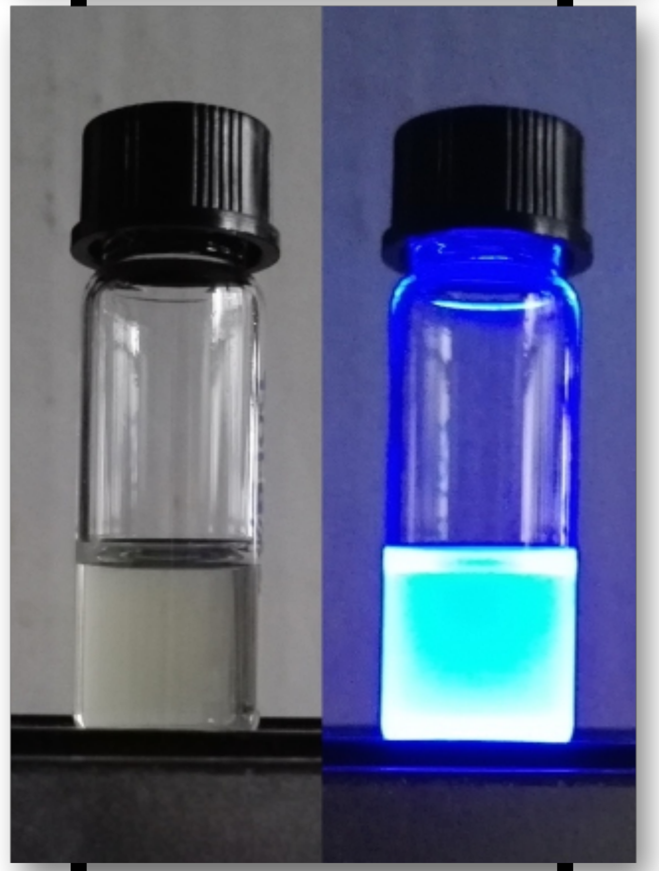

INFN Workshop on Future Detectors
Sestri Levante, 17-19 Marzo 2025

DEVELOPMENT OF HIGH-Z DOPED PLASTIC SCINTILLATORS FOR SPECT IMAGING AND RADIOMETABOLIC DOSIMETRY

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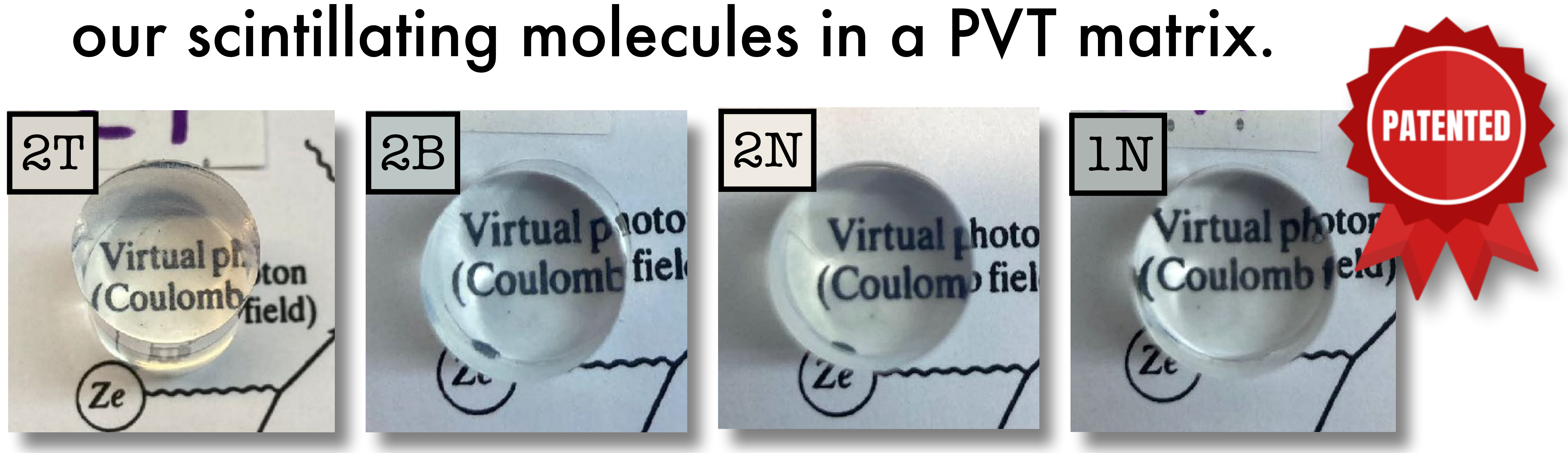
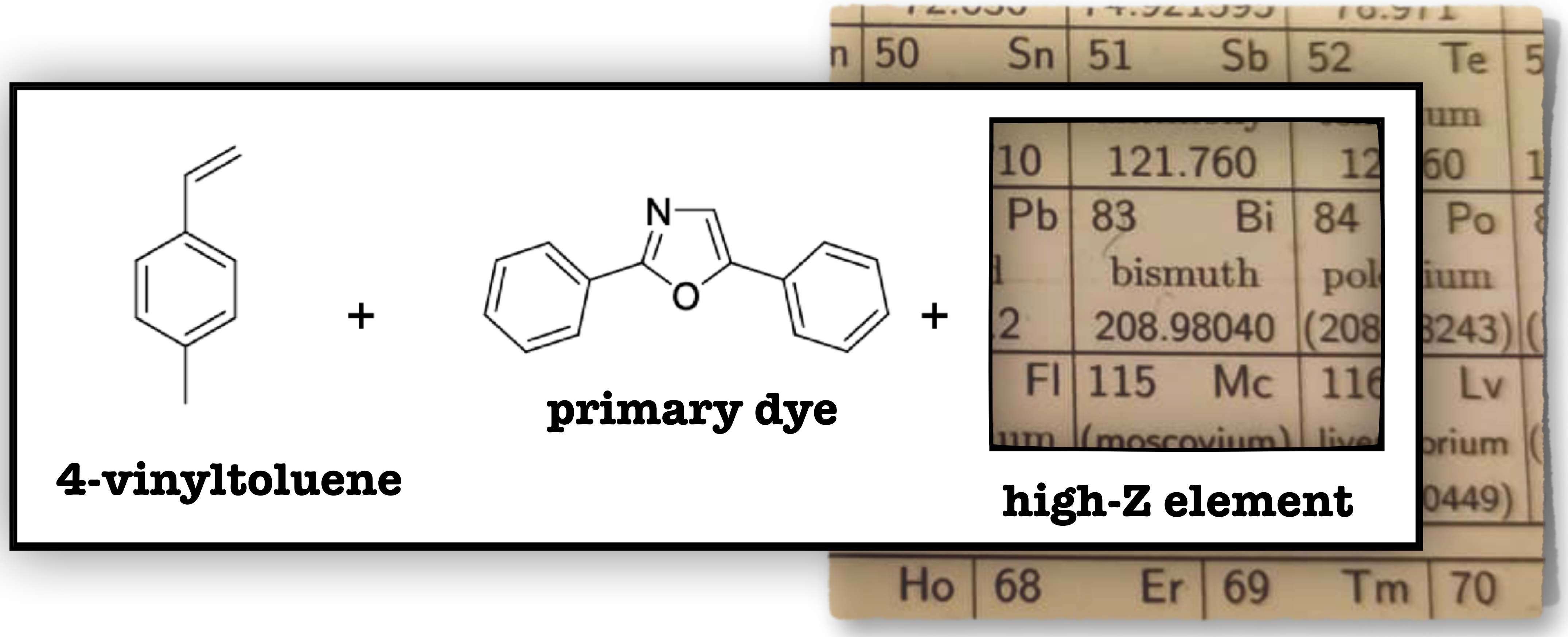
NEW ORGANIC SCINTILLATING MOLECULES

- Plastic scintillators are **faster, easier to manipulate and cheaper** than inorganic crystals, but they have a low atomic number.
- They can be optimised for the detection of gamma rays by <u>adding high-Z impurities</u>.

- We synthesized and patented [1] several new organic scintillating molecules (T2, 2N, 1N, 2B...) containing aromatic fragments.
- We realised novel plastic scintillators embedding our scintillating molecules in a PVT matrix.

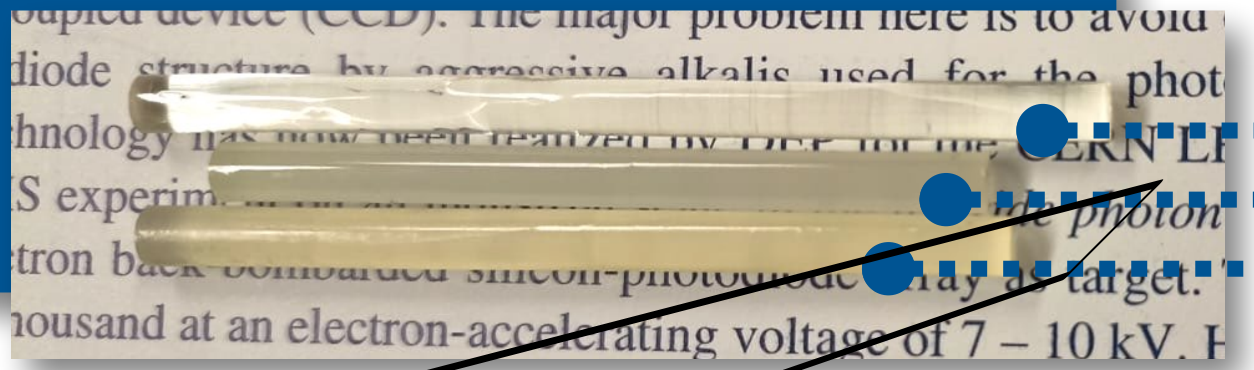




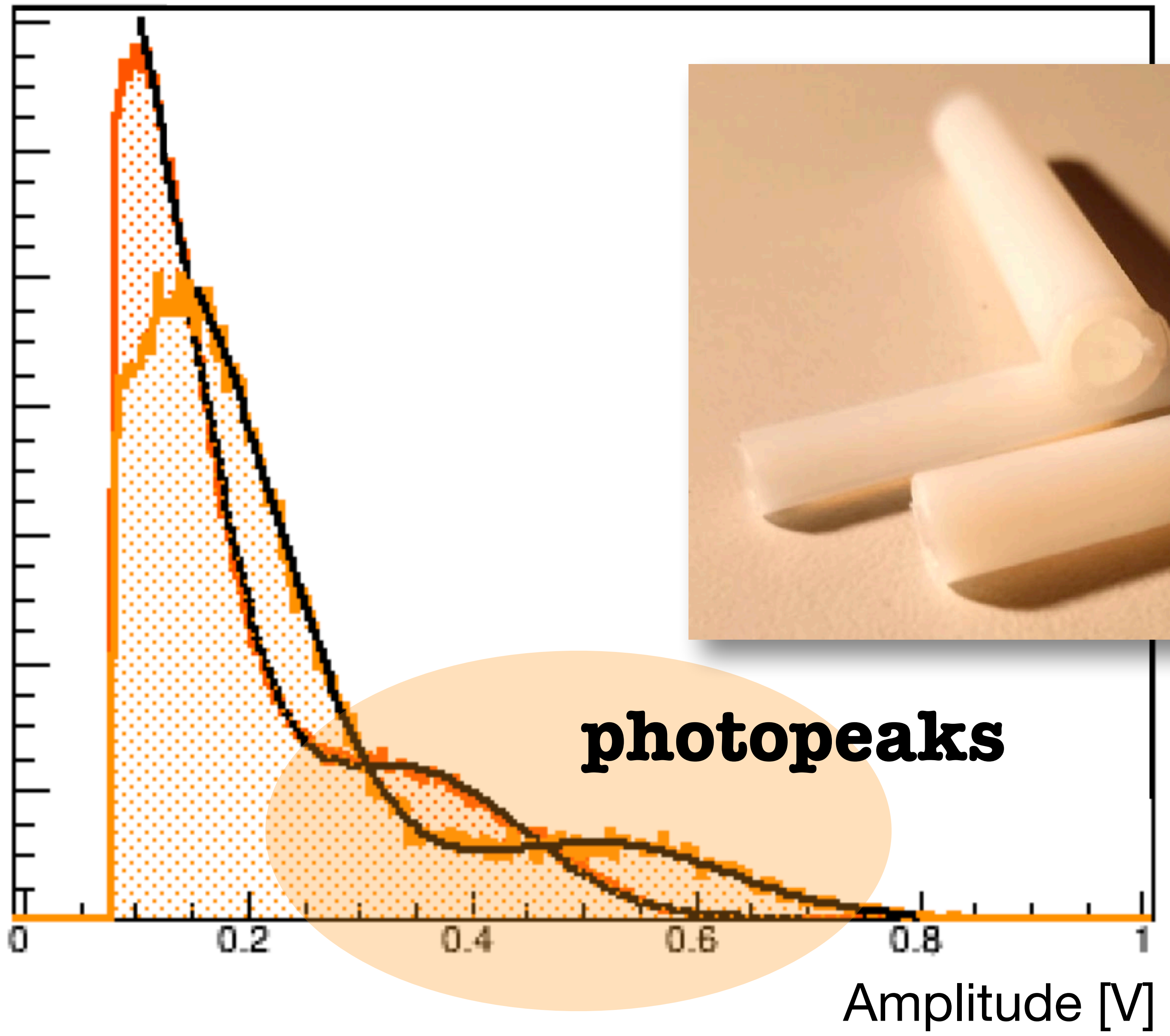
[1] *Patent* WO2023156957A1
Mattiello L.; Patera V.; Belardini A.; Rocco D.; Marafini M.; Organic Scintillator. 2023.

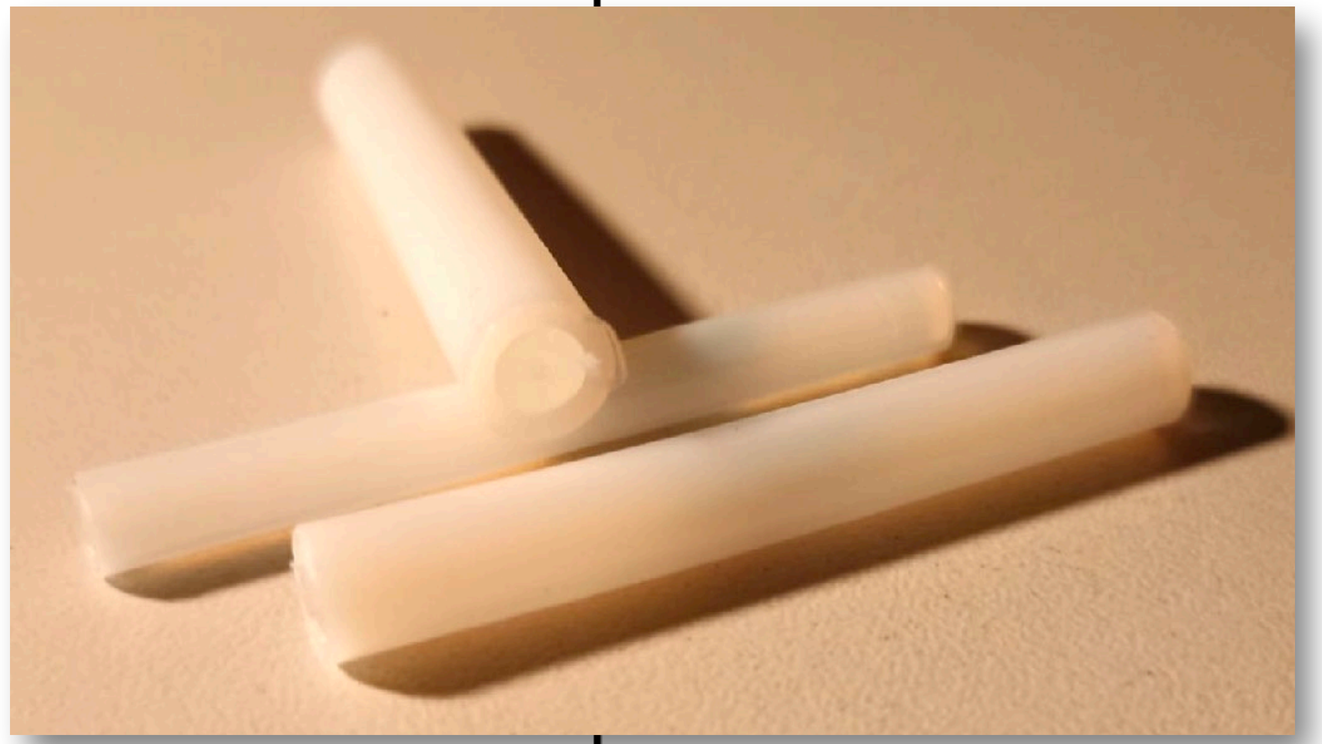
HIGH-Z DOPED PLASTIC SCINTILLATORS

On the market, the highest available dopant concentration is 5% → we target a 10% dopant (Bismuth) concentration



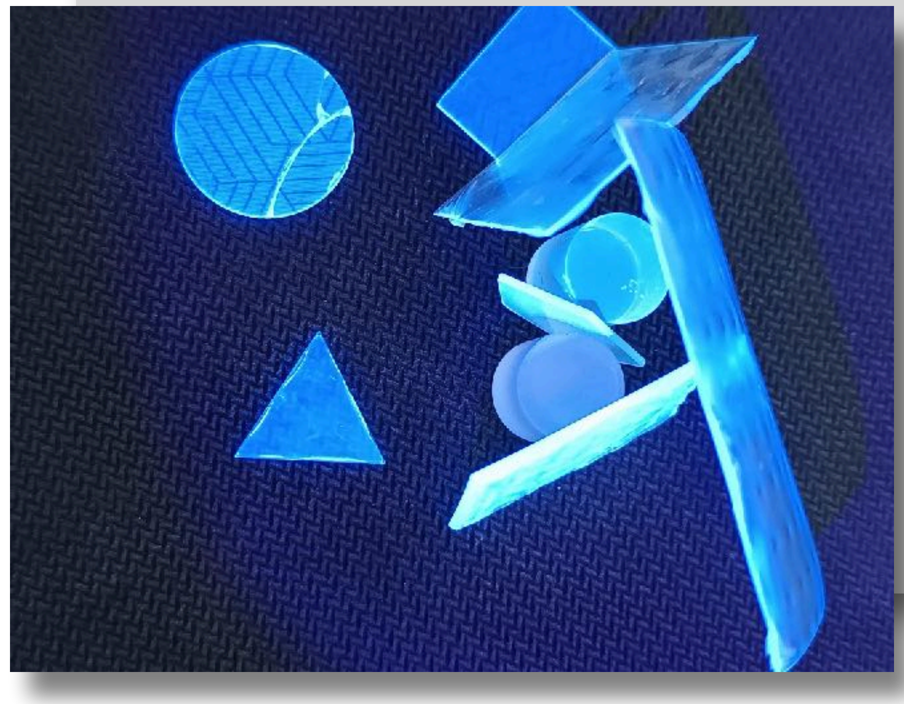
- 2N+10%Bi samples
- Co-57 source (122 keV)
- PTFE coating to increase light collection

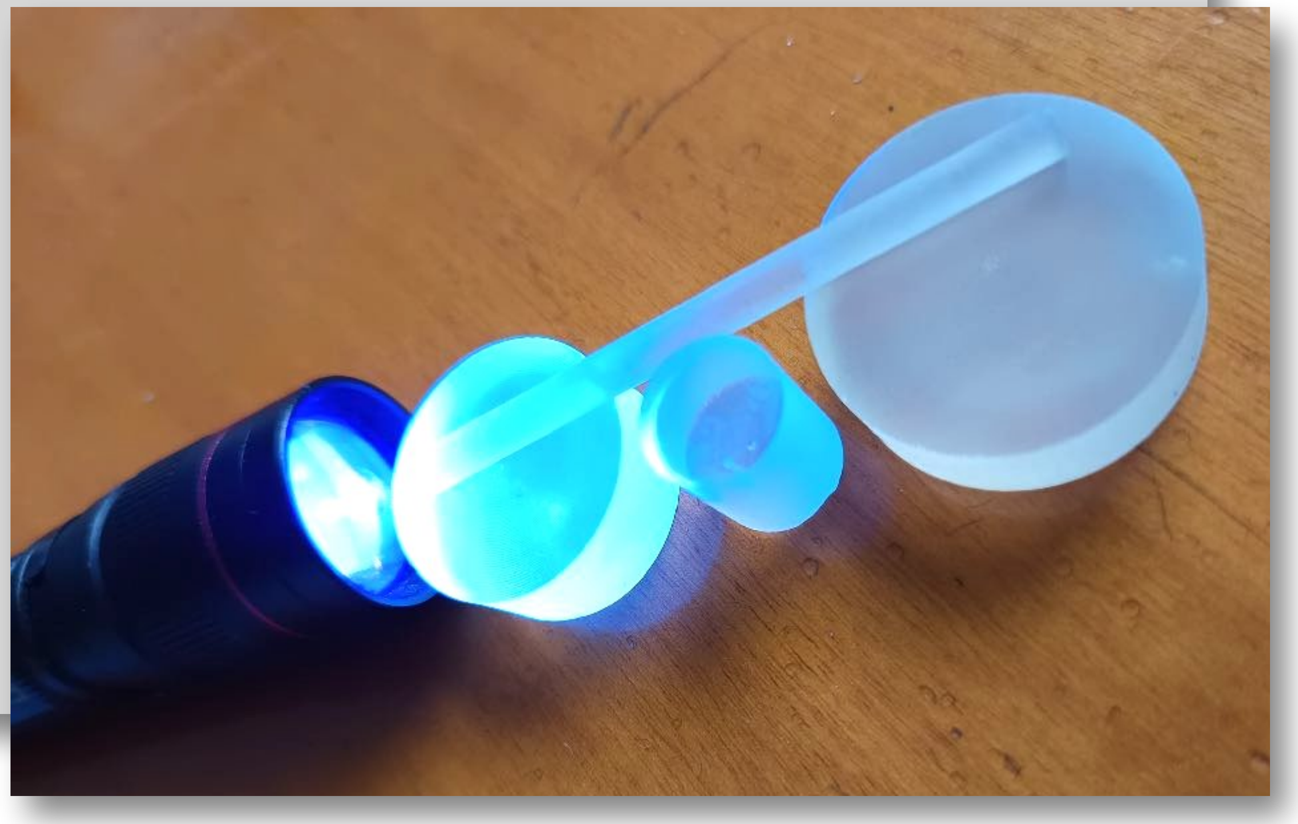




3dSPARK Project (Progetto PRIN 2022)

For a synergic project (3dSPARK: 3D-printed Scintillating Polymer Assembly for Rare events at milliKelvin temperature), our scintillating fluorophores will be dissolved in a 3D-printed resin substrate.





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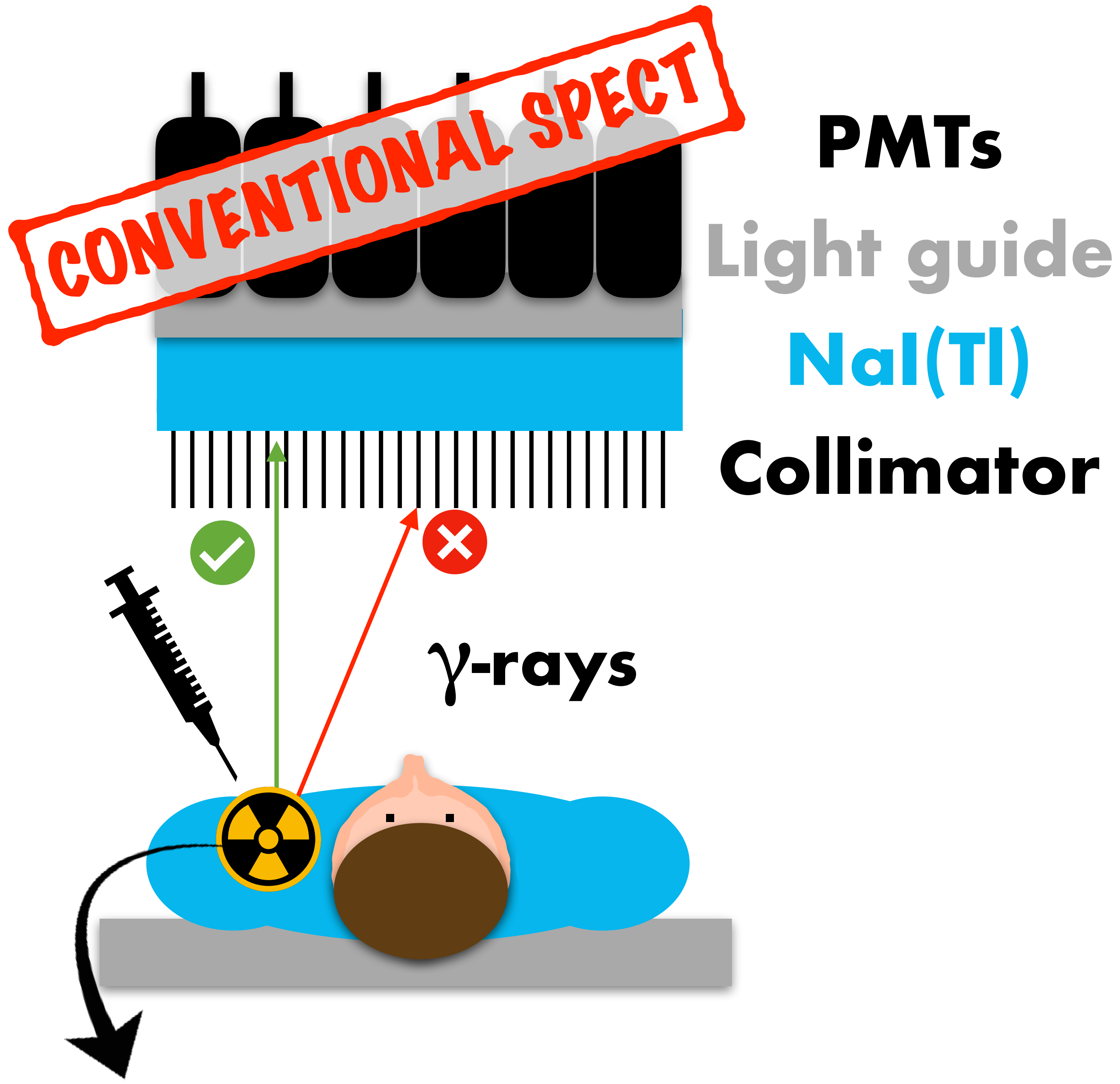
MEDICAL APPLICATION: SPECT IMAGING

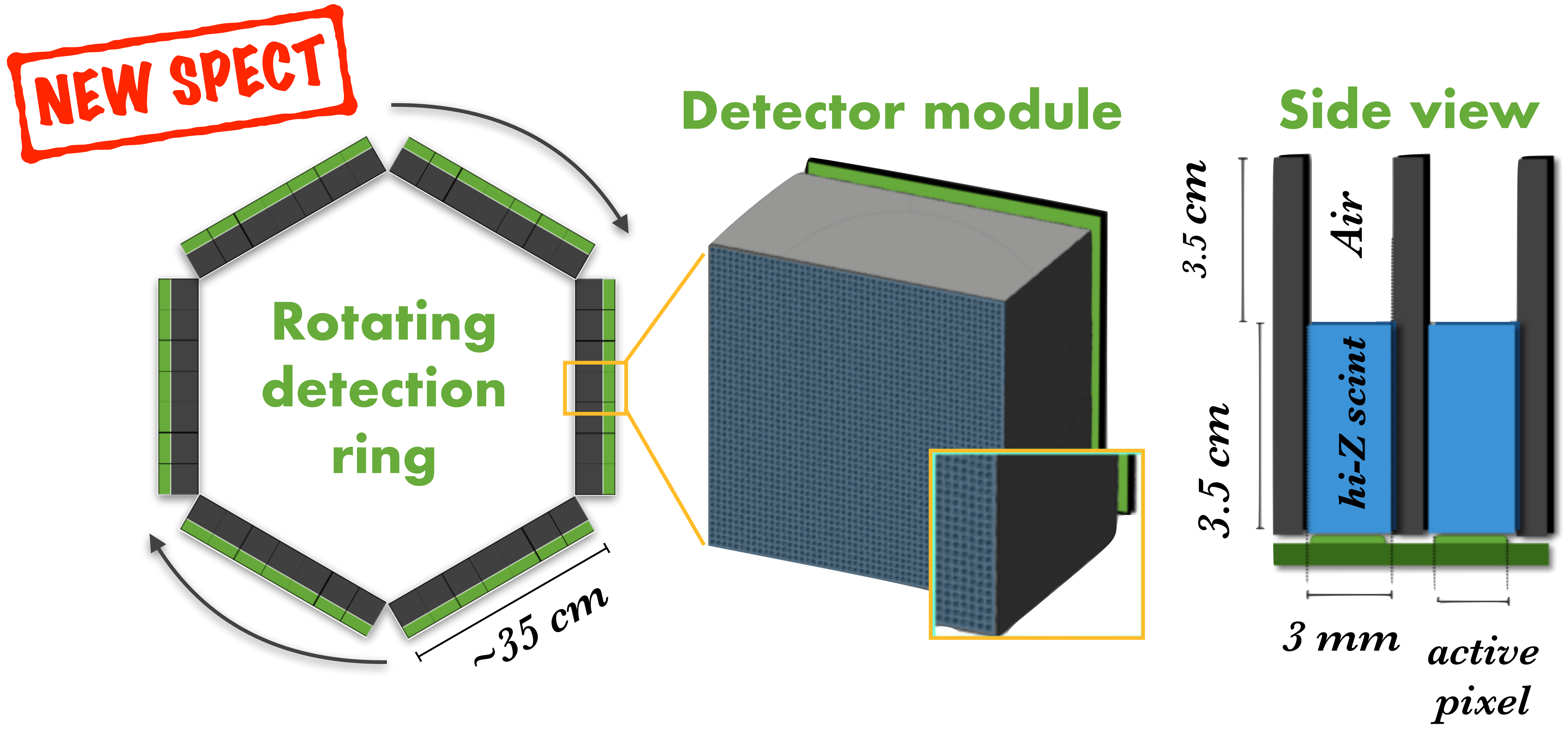


^{99m}Tc: 141 keV, $T_{1/2}$ ~ 6 h

SPECT (*Single Photon Emission Computed Tomography*) is a nuclear imaging technique used for cancer detection.

reSPECT Project (Progetto PRIN 2022 U40)

- 3D-printed tungsten collimator
- high-Z doped plastic scintillators polymerised in the septa and individually coupled with Si readout
- wrt conventional SPECT: lower cost, increased rate capability, compatibility with MRI, possibility of total-body acquisitions.



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MEDICAL APPLICATION: RADIOMETABOLIC DOSIMETRY

TRONDHEIM Project (Bando di Ateneo)

UMBERTO I
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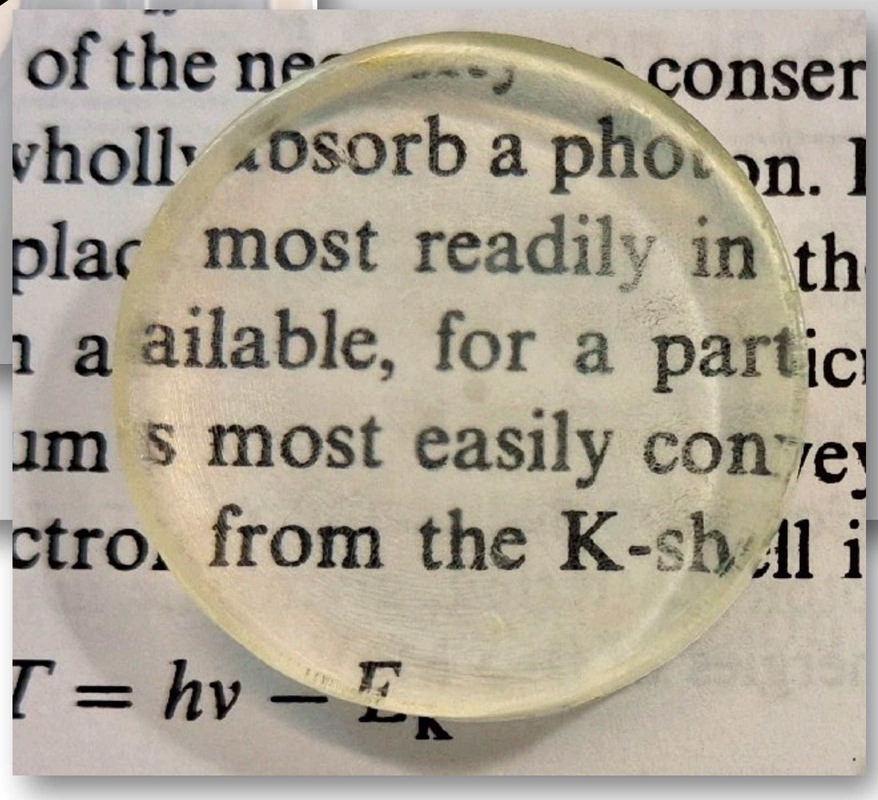
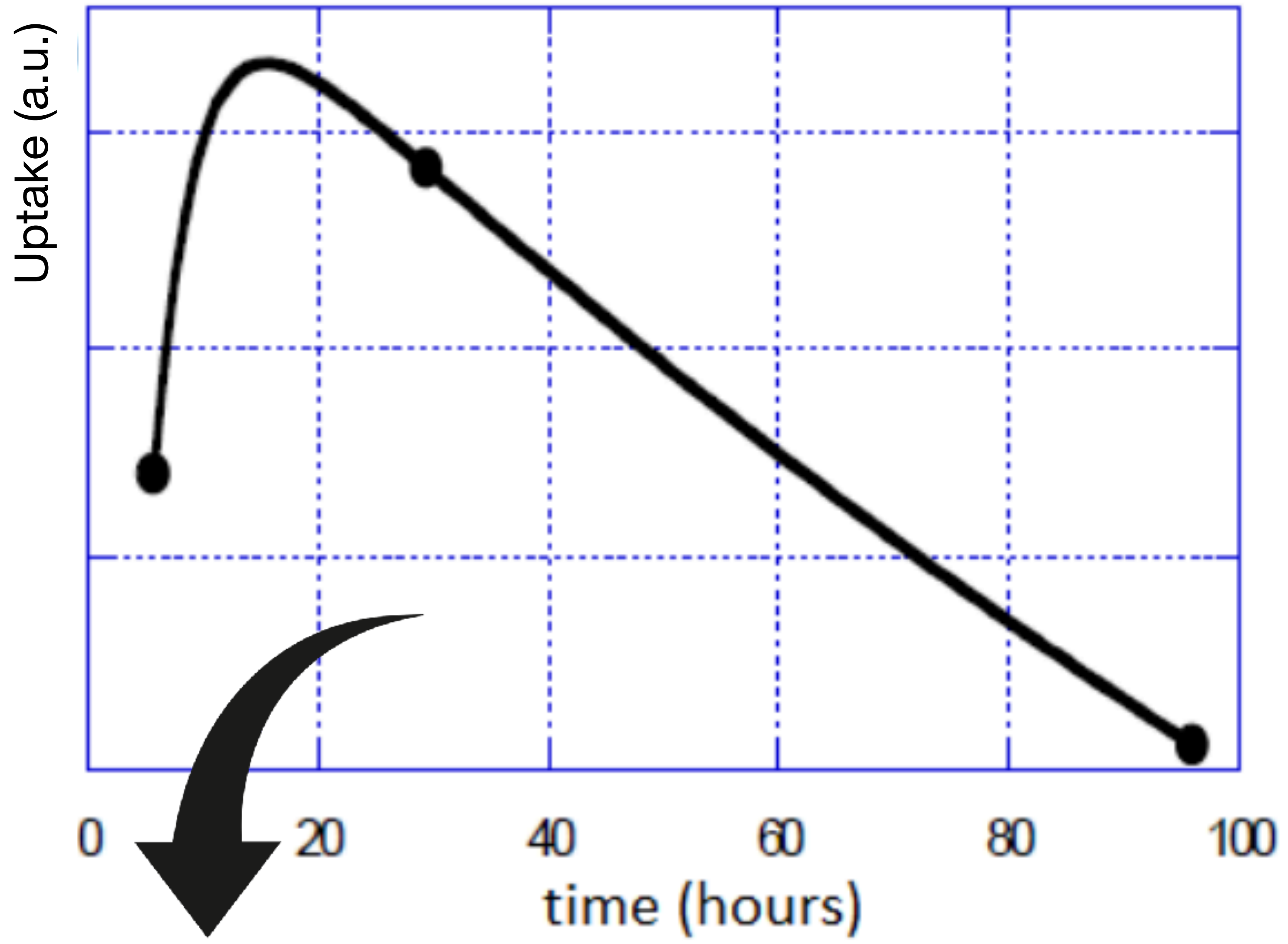
Dosimeter for a theranostic approach to radio-metabolic therapy with Lu-177 in patients affected by metastatic Castration Resistant Prostate Cancer (mCRPC).

^{177}Lu: 208 keV, $T_{1/2}$ ~ 7 d

Development of a wearable and portable γ-rays detector based on high-Z doped plastic scintillators: light, inexpensive, able to sustain high event rates.



- **reduction of the toxicity**
- **improvement of the therapeutic effectiveness**



GOAL: retrieve the uptake/clearance vs time curve to customise the administered dose

THANK YOU FOR YOUR ATTENTION!

Dove siamo:

Dipartimento di Scienze di Base e Applicate per l'Ingegneria
Sapienza Università di Roma, Via Antonio Scarpa, 14, Roma

Contatti:

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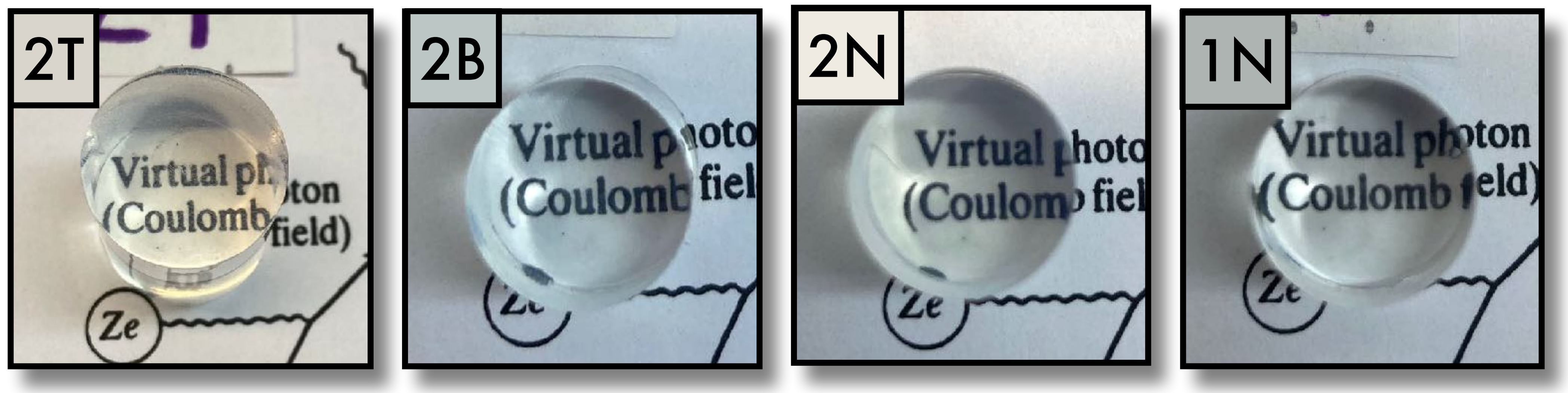
Come fai..SBAI

Spare Slides

PERFORMANCES OF OUR SCINTILLATING MOLECULES

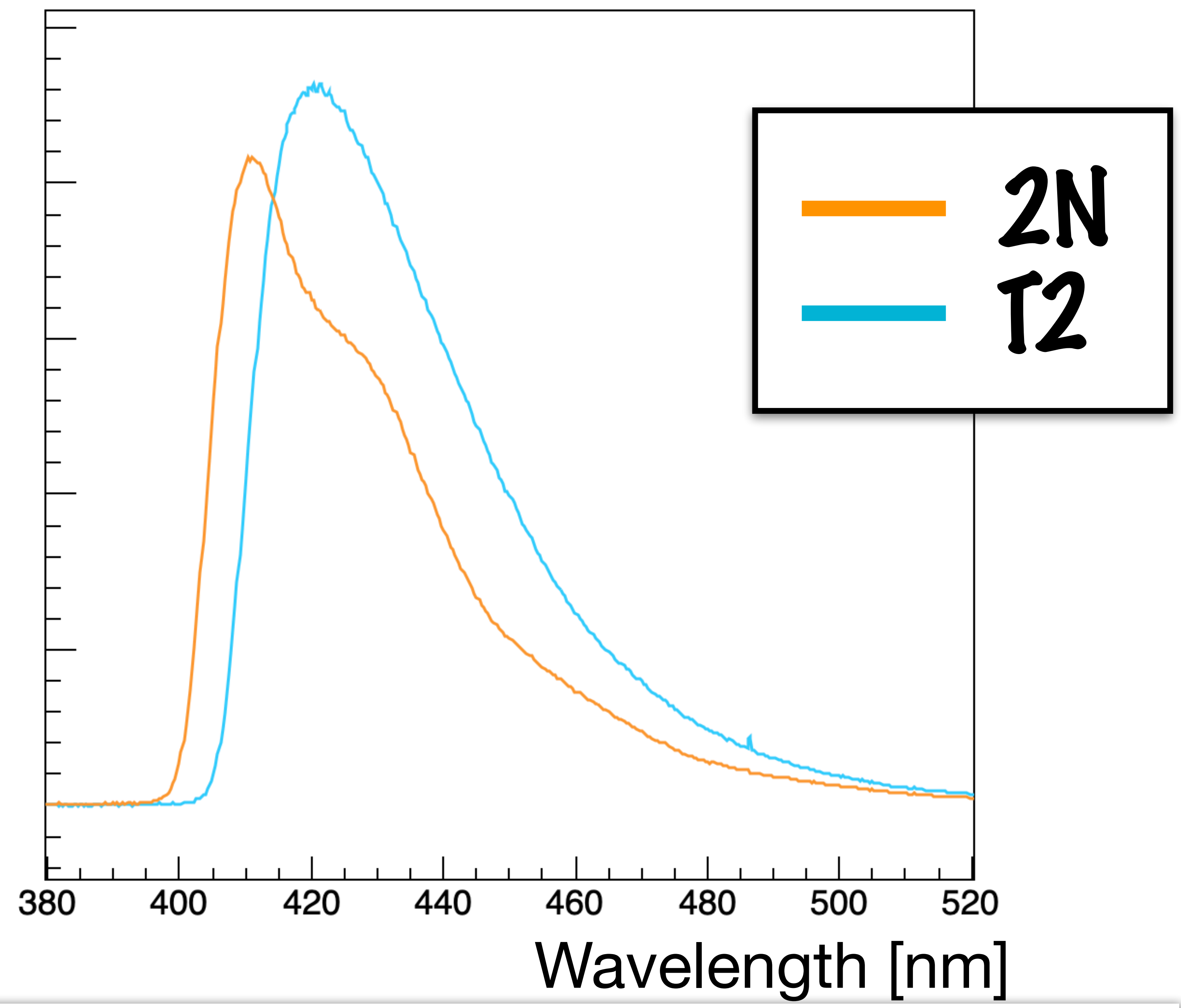
The performances in terms of scintillation efficiency and time resolution were measured (readout system based on H10721-210 Hamamatsu PMT) and compared with the commercial alternatives.

Sample	Fluorophore concentration	Light output* (%wrt EJ-232)	Time resolution* (@ 330 mV)	Rise Time*
EJ-232	–	100	208 ps	2.2 ns
BC-400	–	105	234 ps	2.5 ns
T2	14%	70-90	250 ps	2.8 ns
2B	14%	60-65	224 ps	2.4 ns
2N	14%	70-90	264 ps	2.3 ns
1N	14%	70-85	221 ps	2.3 ns



* 10% systematic and statistic uncertainty

Wavelength emission spectrum convoluted with the quantum efficiency of the PMT exploited in the setup (Hamamatsu H10721-210 PMT).



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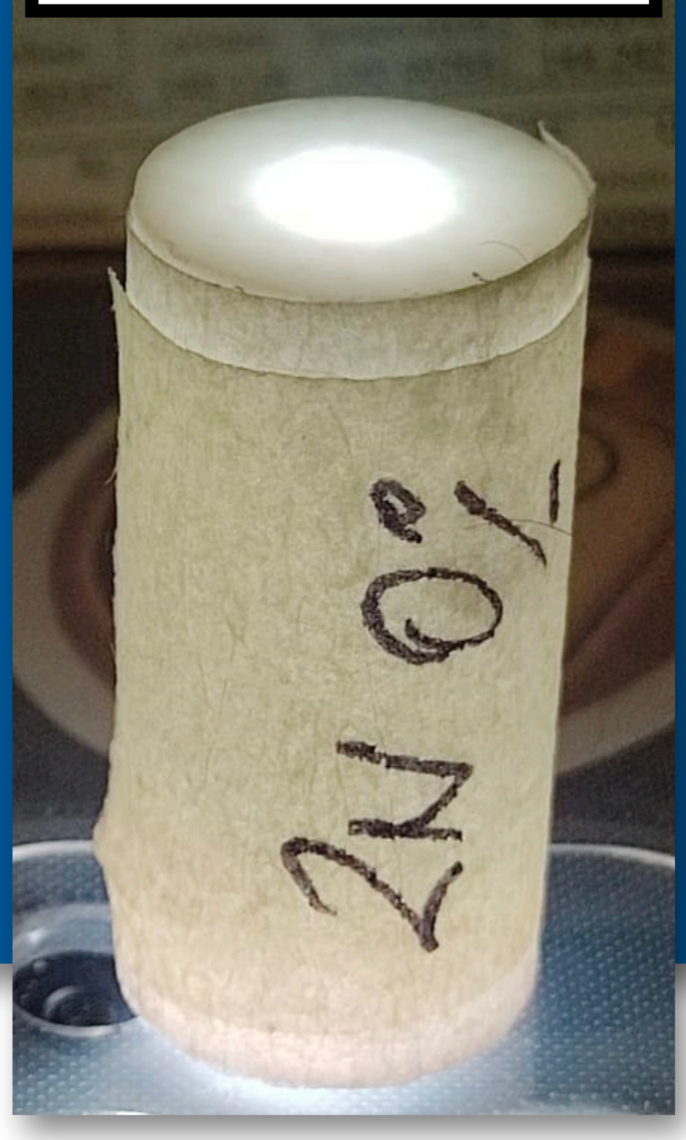
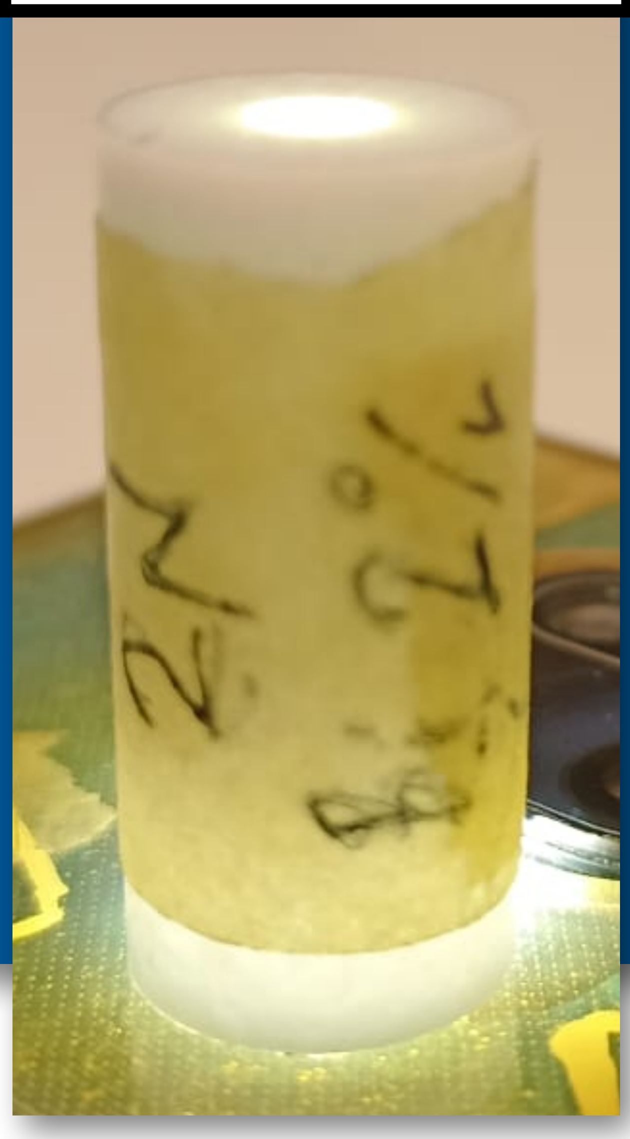
PERFORMANCES OF OUR DOPED SCINTILLATORS

Scintillator	Light Output [a.u.]
2N + 0% Bi	100%
2N + 2% Bi	30%
2N + 10% Bi	25%

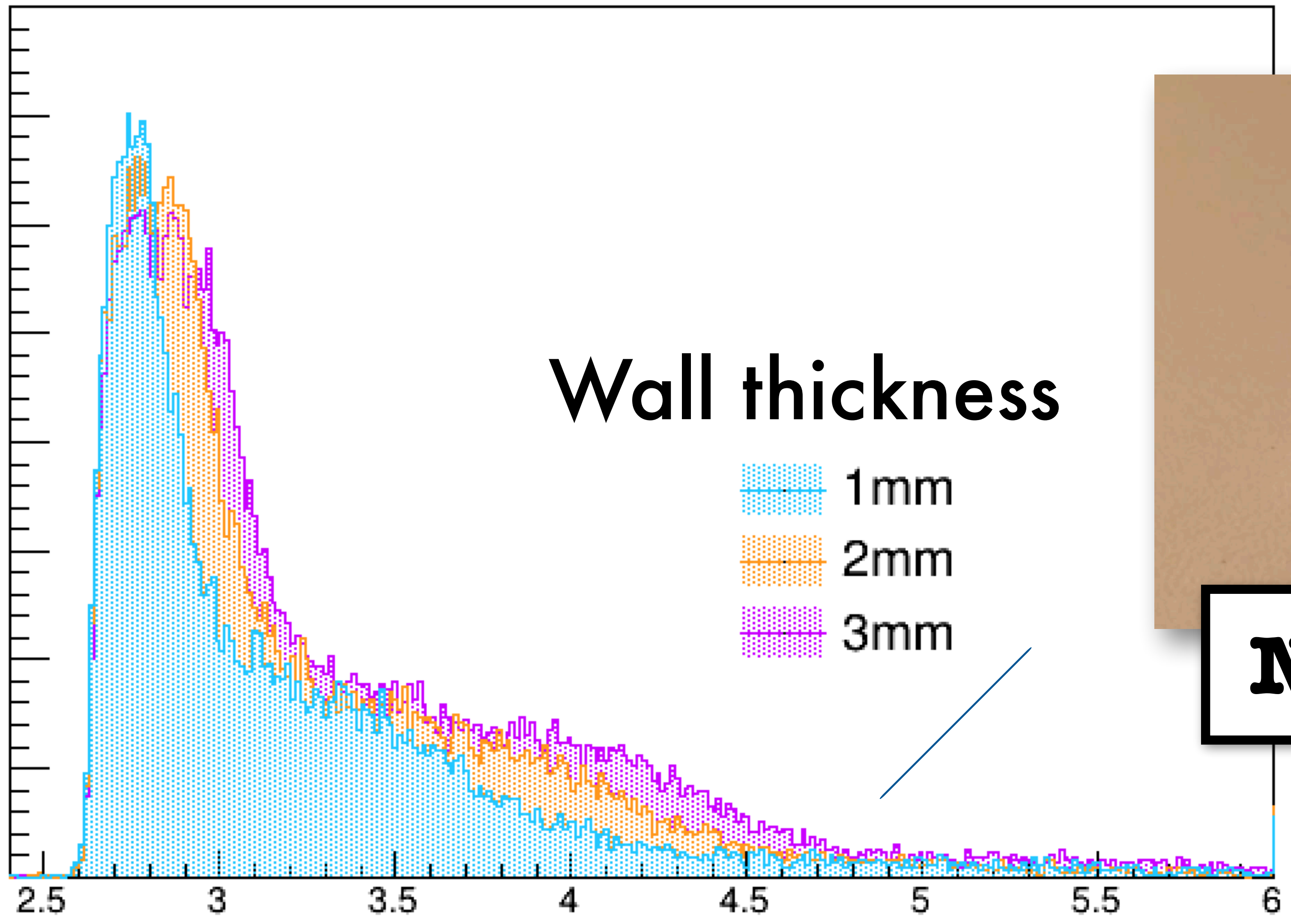
2N + Bi 0%

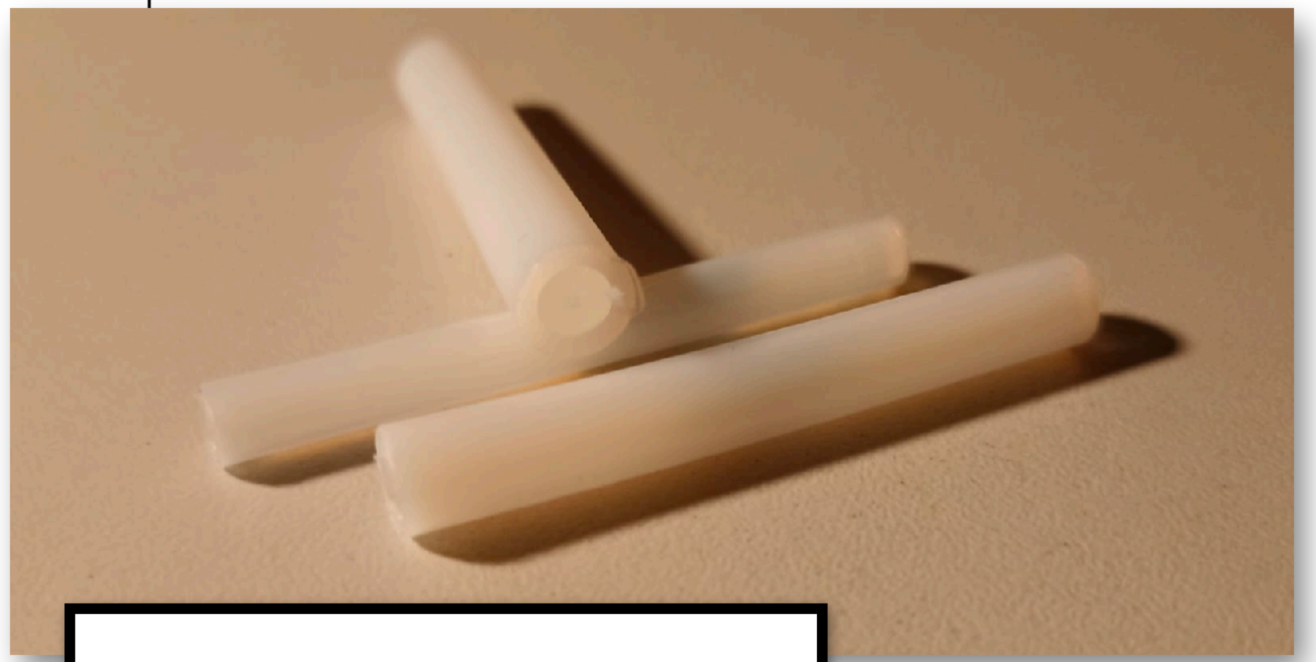


2N + Bi 2%

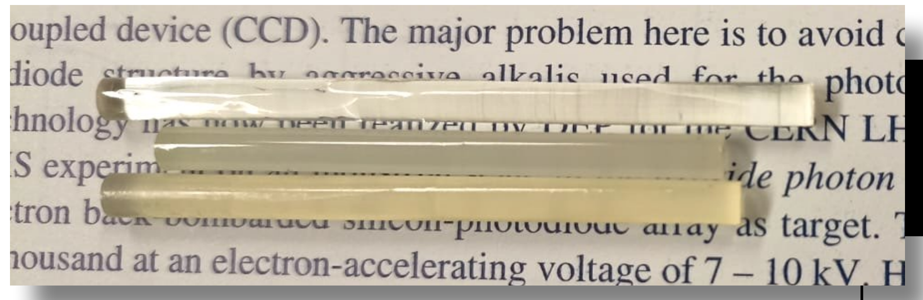


2N + Bi 10%





Na-22 source



Sample	Time resolution
EJ-256 (Pb 1.5%)	(360 ± 17) ps
EJ-256 (Pb 5%)	(520 ± 31) ps
2N 14% (Bi 2%)	(233 ± 13) ps
2N 14% (Bi 5%)	(278 ± 33) ps
2N 14% (Bi 10%)	(340 ± 46) ps

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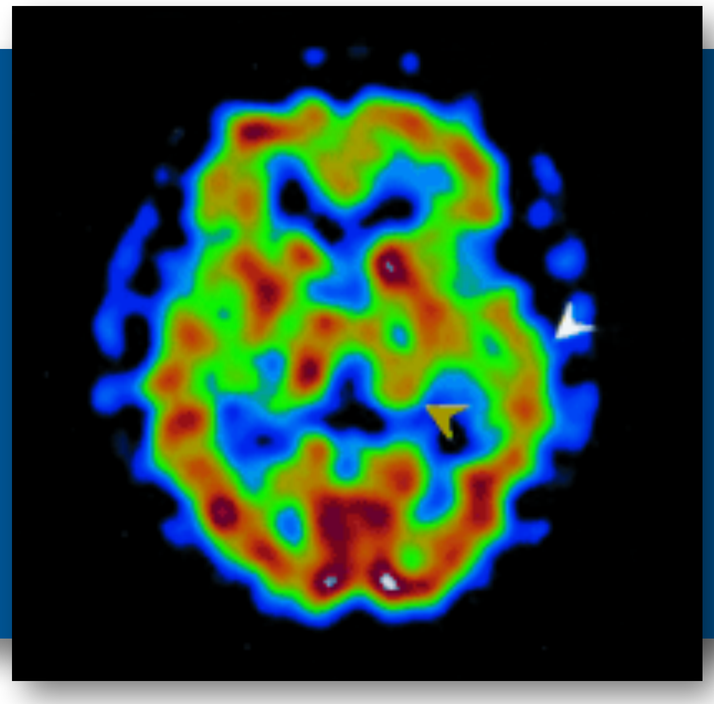
reSPECT EXPECTED PERFORMANCES



- The expected performances of the reSPECT detection system have been obtained through <u>MC simulations</u>
- The simulated scintillators have a <u>Bismuth concentration of 10%</u>

✓ Low cost
✓ Compliance with MRI and theranostic studies
✓ Possibility to conceive a total-body SPECT thanks to the modular structure
✓ Unparalleled counting rate capability

SPECT DETECTION SYSTEM	SENSITIVITY PER MODULE @140 keV [cpm/μCi]	SYSTEM SPATIAL RESOLUTION (FWHM) @10 cm [mm]	DECAY TIME [ns]	RATE CAPABILITY [cps/cm^2]	TOTAL COST –	MAGNETIC RESONANCE IMAGING COMPLIANCE	RADIOMETABOLIC DOSIMETRY COMPLIANCE
Anger Camera (NaI) FoV: 53 x 39 cm^2	170	7.4	250	0.25k-3k	$$	✗	✗
CZT FoV: 39 x 51 cm^2	190	7.6	350	30k-700k	$$$	✓	✗
reSPECT 6 rotating blocks, FoV: 35 x 35 cm^2	**184** (Energy cut 80 keV)	**8.9** (For pixel size: 2 mm)	**2-5**	**50M-200M**	**$**	✓	✓