The reSPECT project: an innovative SPECT detection system based on high-Z organic scintillators

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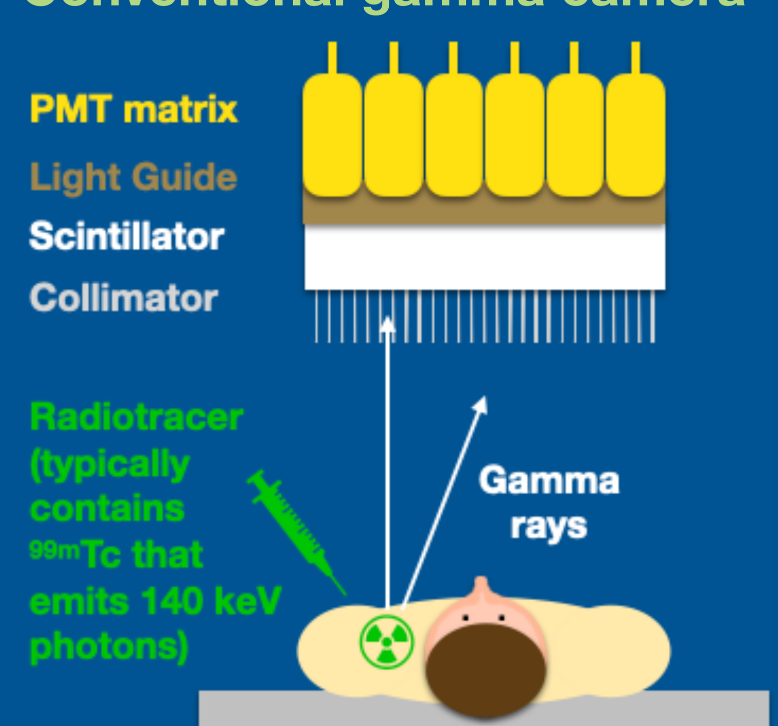
Single Photon Emission Computed Tomography

- Single-Photon Emission Computed Tomography (SPECT) is a nuclear imaging technique that allows to investigate the physiological processes that take place inside the patient's body.
- SPECT scans are powerful tools for the diagnosis of cancers and other pathologies.

Conventional gamma camera



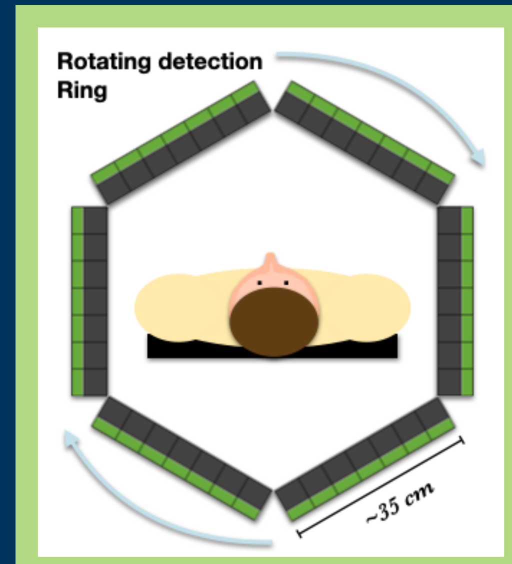
ADMINISTRATION OF THE RADIOTRACER

GAMMA RAYS DETECTION

TOMOGRAPHIC IMAGE RECONSTRUCTION

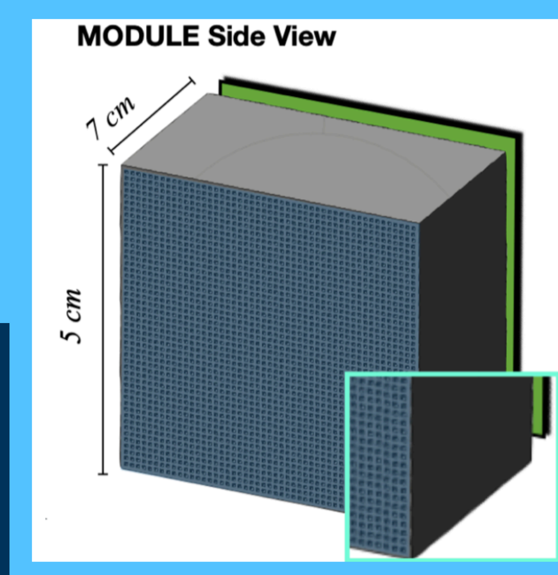
DIAGNOSIS

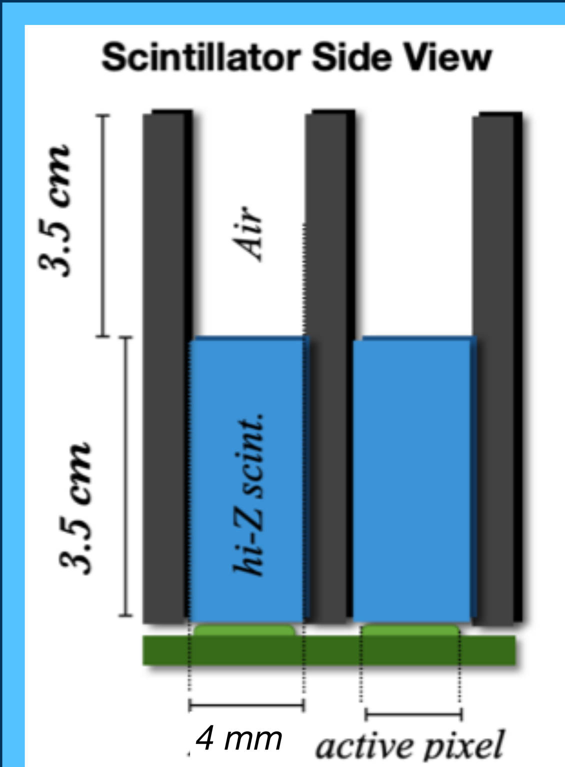
The reSPECT detection system



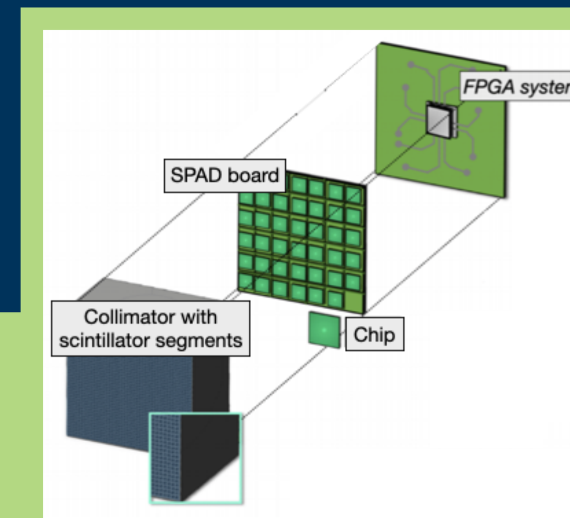
The reSPECT detection system will have a modular structure able to revolve around the patient, enabling multi-angle data acquisition.

Each module will consist of a 3D-printed tungsten frame that serves both as a collimator and as a container of the scintillator segments.





The readout will be performed by SPAD array silicon-based photodetectors arranged in small-size pixels, individually coupled to the scintillator segments. The polymerization occurs directly inside the holes.



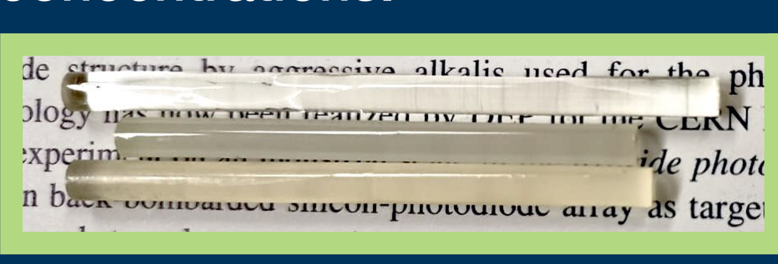
FPGA matrices will be placed on the back of each module to pre-process the acquired data.

- Use **plastic scintillators** instead of inorganic crystals to profit from their **fast signal, ease of manipulation and low cost.**
- Plastic scintillators are not optimized for the detection of gamma rays via photoelectric effect.
- The idea is to enrich our organic scintillators with high-Z impurities (e.g. Bismuth or Cerium) [1].

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

High-Z plastic scintillators

- We produced samples of high-Z organic scintillators and tested their performances with different radioactive sources and readout systems [2].
- Transparency turns out to be good up to very high dopant concentrations.



PVT matrix
high-Z impurities
(Bismuth 2-10%)

- The MC simulations showed that a 10% Bismuth concentration is needed to ensure good imaging performances.
- We realized a 10%-doped sample with promising results: such dopant concentrations are not available on the market.
- Light collection efficiency is crucial with this geometry!

Expected performances

- The expected performances of the reSPECT detection system have been obtained through **Monte Carlo simulations**.
- The simulated scintillators have a **10% Bismuth concentration**.
- The reSPECT detection system allows to realize a **total-body SPECT**.

*The spatial resolution can be improved by adjusting the geometrical parameters.

SPECT DETECTION SYSTEM	SENSITIVITY PER MODULE @140 keV	SYSTEM SPATIAL RESOLUTION (FWHM) @10 cm	DECAY TIME	RATE CAPABILITY	TOTAL COST	COMPLIANCE	
						MRI	DOSIMETRY
Anger Camera (NaI) FoV: 53 x 39 cm²	170 cpm/µCi	7.4 mm	250 ns	0.25k-3k cps/cm²	$$	✗	✗
CZT FoV: 39 x 51 cm²	190 cpm/µCi	7.6 mm	350 ns	30k-700k cps/cm²	$$$	✓	✗
reSPECT 6 rotating blocks, FoV: 35 x 35 cm²	184 cpm/µCi (energy cut @80 keV)	8.9* mm (2 mm pixels)	2-5 ns	50M-200M cps/cm²	$	✓	✓

Prototypes performances

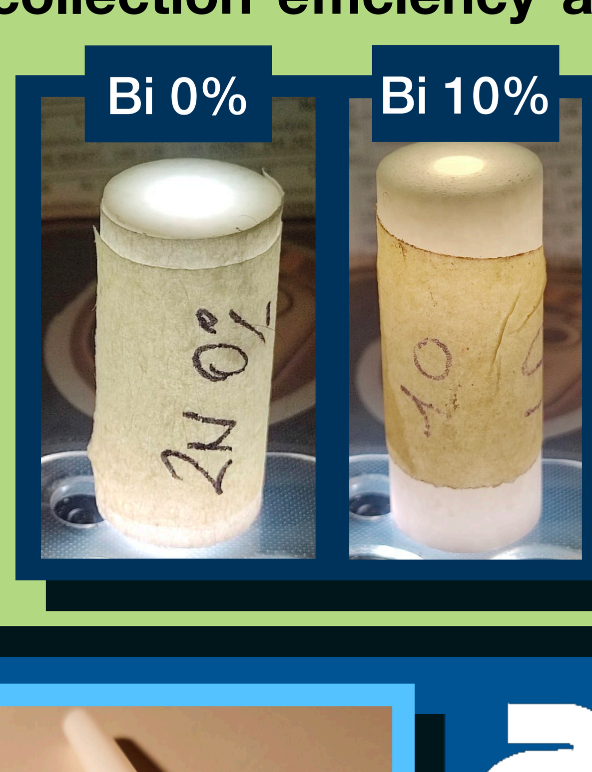
- The performances of the scintillator prototypes have been compared with those of the commercial alternatives (Eljen Technology) in terms of light output and time resolution.
- The realized high-Z enriched scintillators also showed better timing performances than the commercial loaded scintillators.
- Open possibilities for Time-of-Flight PET applications.

Sample	Time Resolution (Statistic Error)	Measured #photoelectrons
EJ-256 (Pb 1.5%)	(360 ± 17) ps	45 ± 10
EJ-256 (Pb 5%)	(520 ± 31) ps	14 ± 1
2N 14% (Bi 2%)	(233 ± 13) ps	42 ± 3
2N 14% (Bi 5%)	(278 ± 33) ps	17 ± 2
2N 14% (Bi 10%)	(340 ± 46) ps	21 ± 1

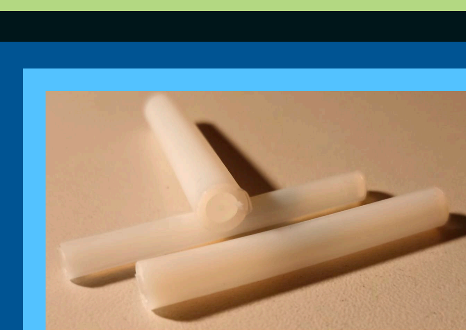
Data obtained with AdvanSiD NUV SiPMs (ASD-NUV3S-P)

- **We produced samples of high-Z organic scintillators polymerized in TEFLON in order to study the matching with this material.**
- **The results show a very good collection efficiency and transparency.**

Sample	Light Output [a.u.]	Ph.el
New 0% Bi	100	-
New 2% Bi	20	To do
New 10% Bi	Ongoing	To do



Next step



[2] L.Galli et al. WaveDAQ: An highly integrated trigger and data acquisition system. NIM A 936 (2019) 399–400 doi:10.1016/j.nima.2018.07.067

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