Development detectors for PET at IRFU

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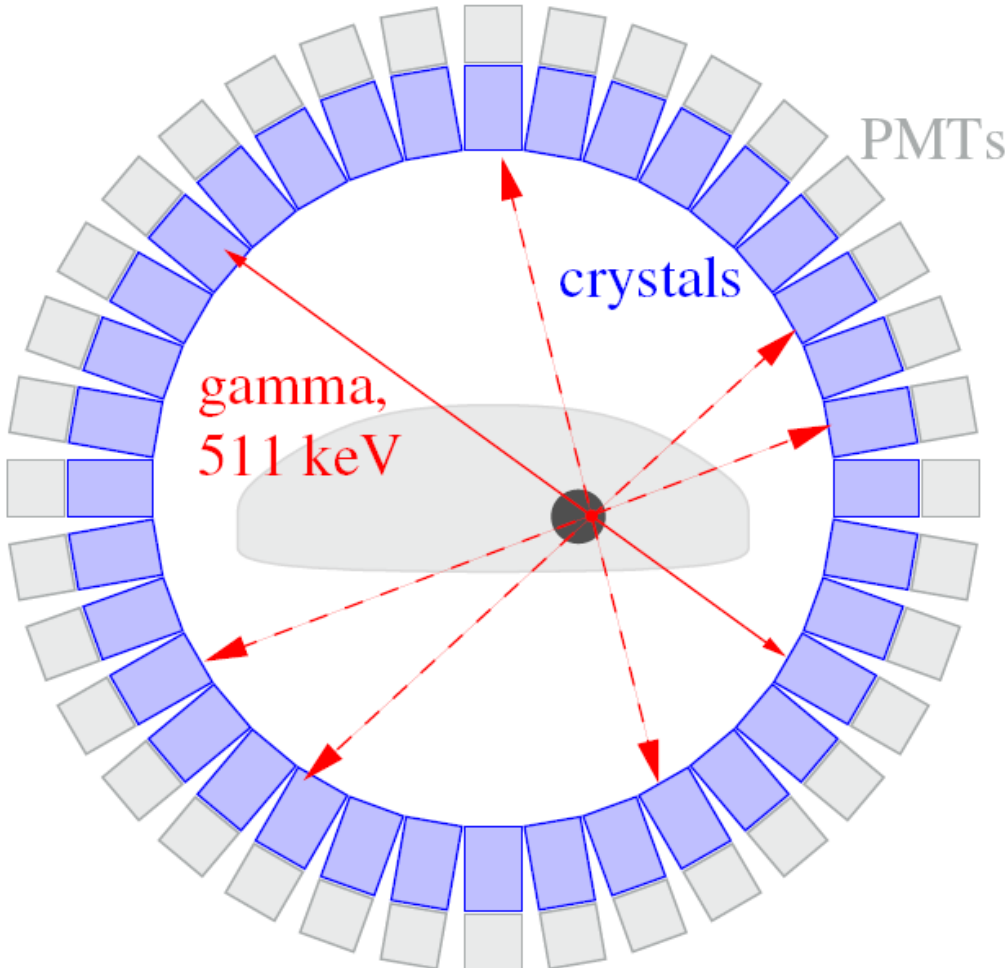
PET = Positron Emission Tomography

- PET is a powerful nuclear imaging technique used widely in our days in oncology, cardiology and neuropsychiatry
- To make an image, the radioactive tracer, is injected in the patient, often the F18 fluorodeoxyglucose with a half-life-time of 109.7 min. The tracer is retained more by tissues with the high metabolism, like most type of the tumors.
- Decay of the F18 ion emit a positron which annihilate with an electron from the tissue → 2 gamma quanta are emitted back-to-back
- Conventional scanners reconstruct decay vertex as a cross section of many line-of-response (**LOR**). Main figure-of-merit is an image quality.



CaLIPSO project

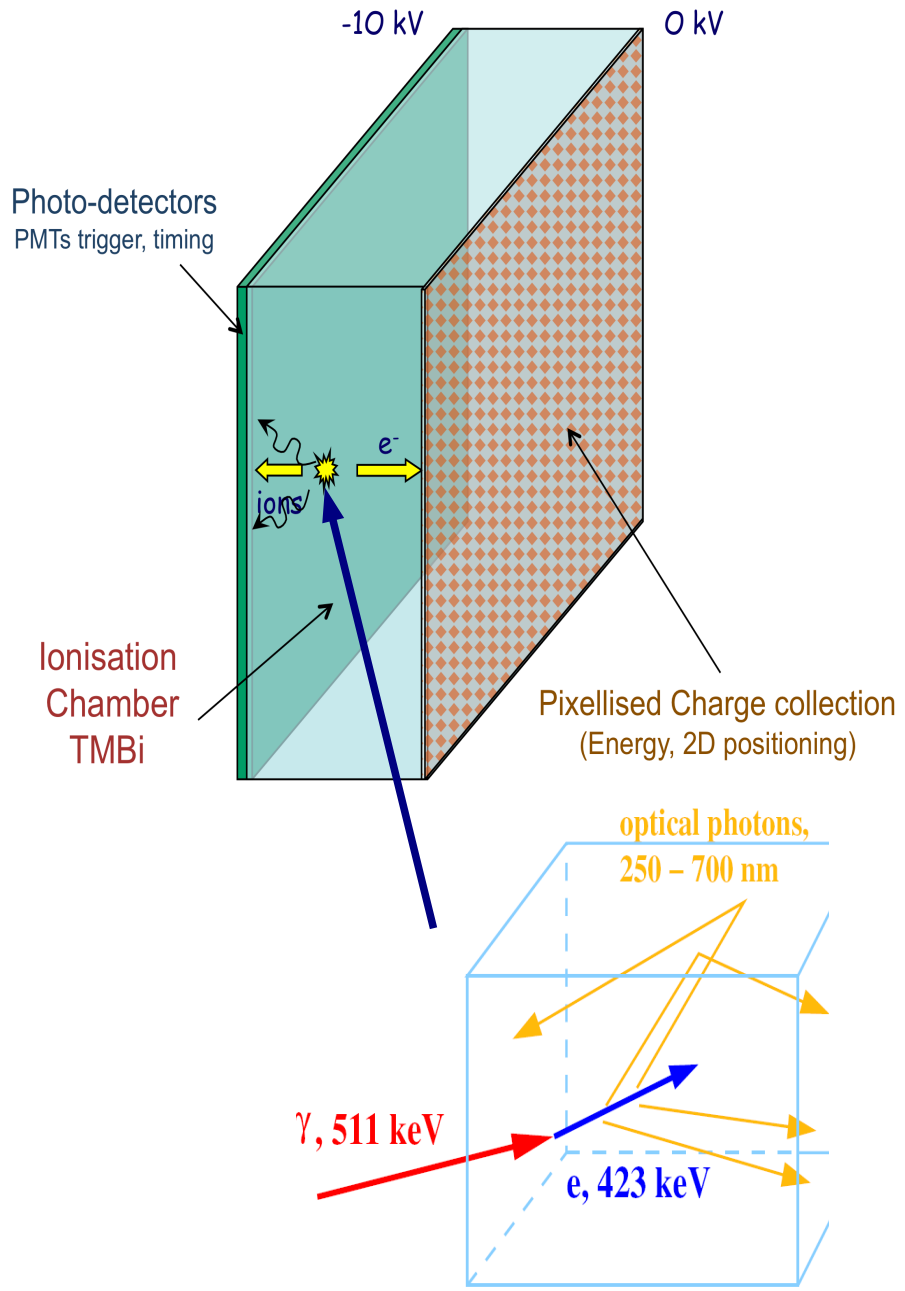
- Trimethyl Bismuth (TMBi) is a dielectric transparent liquid, 82% by weight of Bismuth, density 2.3, highly efficient for photoelectric conversion of photons of energies below 1MeV.

	Dens.	Att. Coeff	Rap. PE	Light Yield	Decay Time	Ion. Yield	Elec. Mobility	Cryo. needed
	$g.cm^{-3}$	cm^{-1}	%	MeV^{-1}	ns	keV^{-1}	$cm^2/\mu s/kV$	
CdZnTe	6.0	0.52	16	-	-	200	1.35	No
Xenon	2.95	0.28	24	1.9-4.5e5	2.2 - 27 and 45	46	0.18	Yes
TMSi	0.648	0.063	0.04	54-84	~0.1	10	0.08	No
TMBi	2.3	0.40	57	44 - 93	~0.1	TBM*	TBM*	No

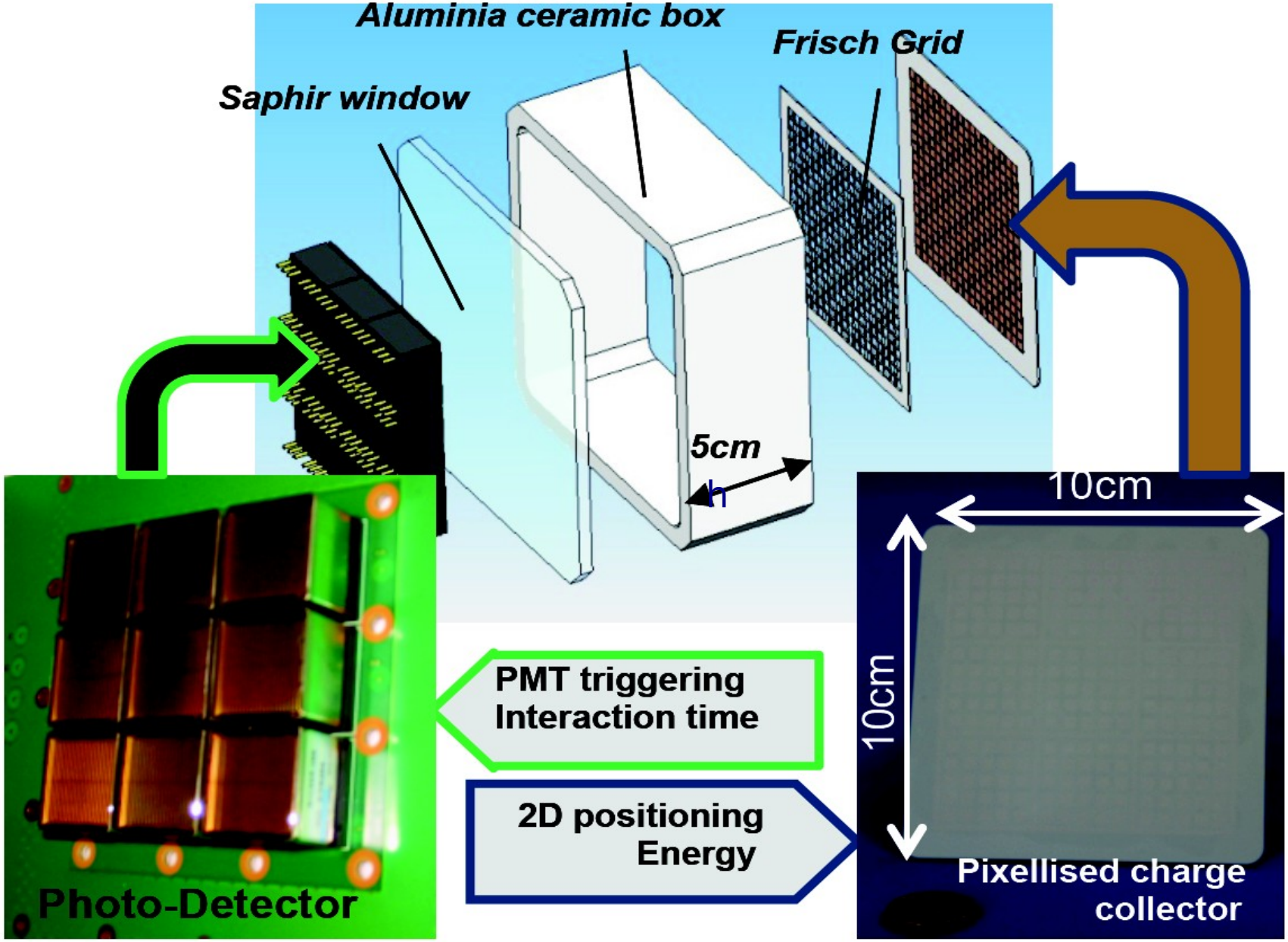
D. Yvon, et al., "CaLIPSO: An novel detector concept for PET imaging", IEEE TNS, 61(2014) 60.

CaLIPSO project

- Photo-electric interactions ionize TMBi and produce an electron.
  - Cherenkov Light is detected at the front face of the CaLIPSO detector.
  - Free electrons drift in the liquid along the electric field, pass through a Frisch Grid and induce a pulse on a pixelated plane on of the detector.
- Expect an energy resolution of 10% FWHM, 3D position reconstruction inside the detector of 1 mm^3. Time-of-flight resolution of around 150 psec (sigma).

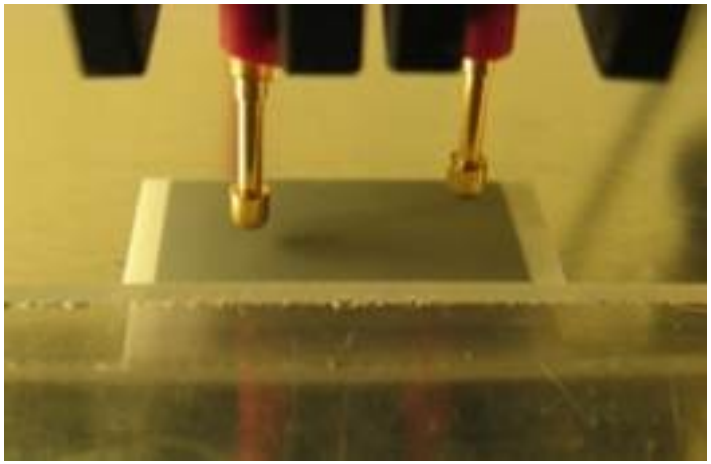


The CaLIPSO detector

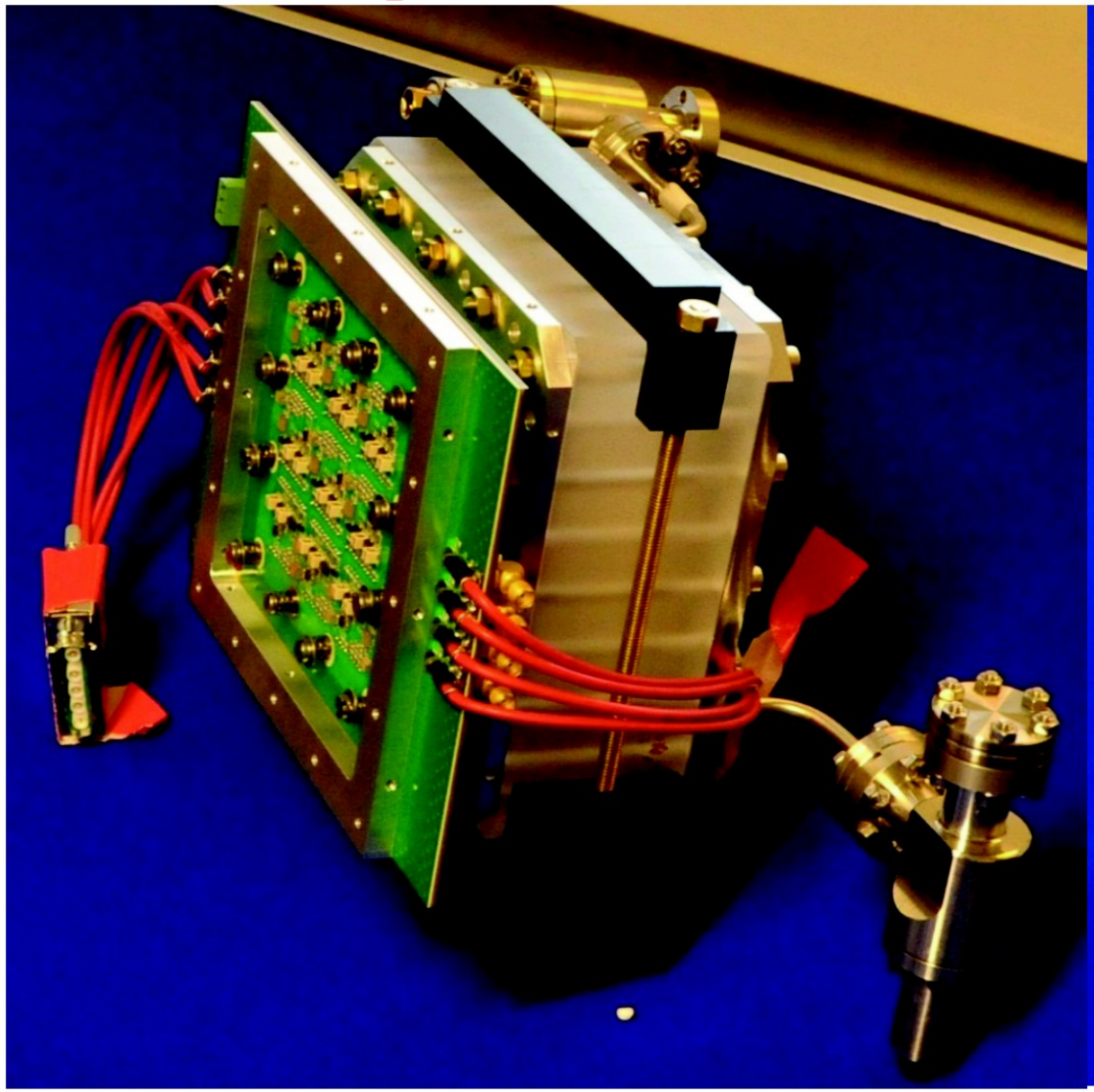


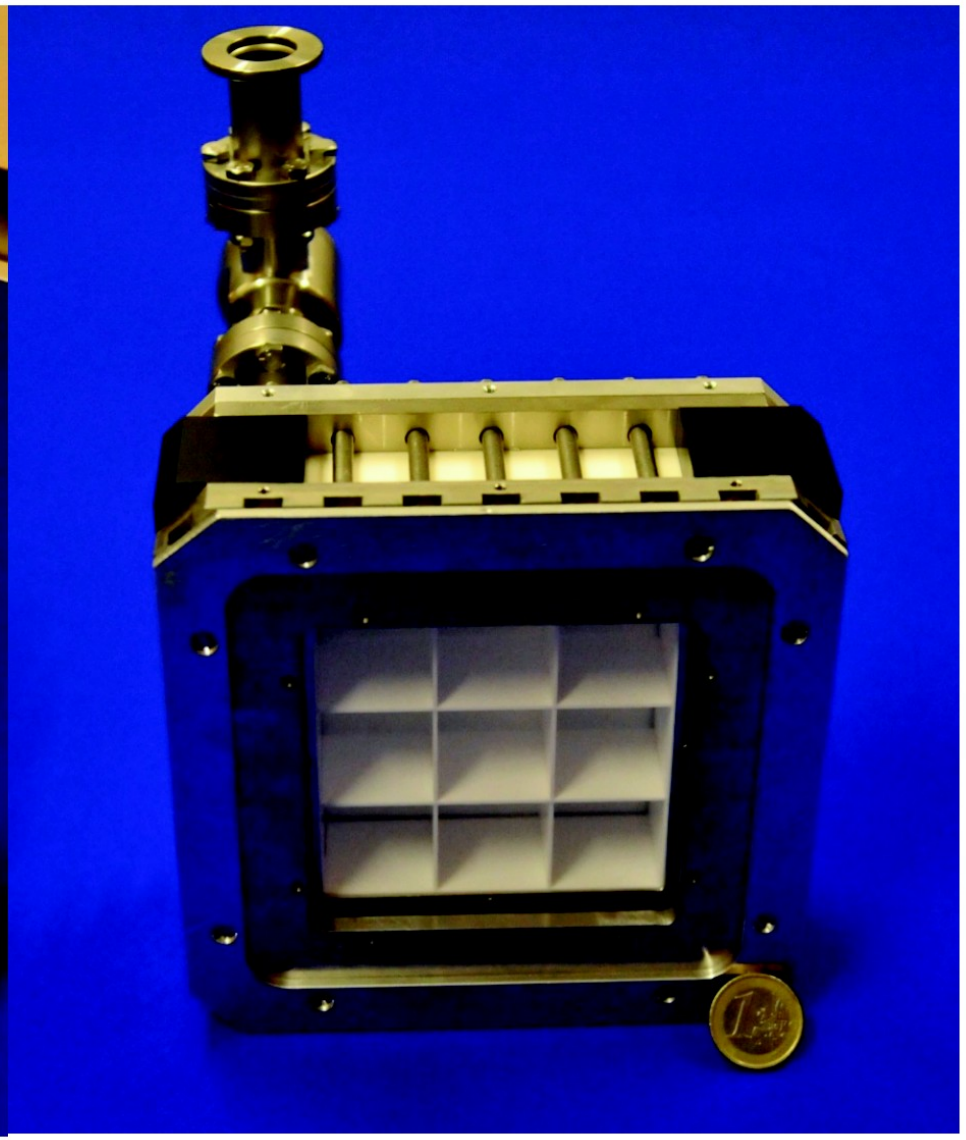
Milestones

- Only Cherenkov radiation ⇒ light production yield is low. Need to ensure the high detection efficiency
  - Studies with the optical demonstartor (Ph.D. is about to finish).
  - First results are obtained and in a rough agreement with the simulation.
- Innovative technologies for pixelated charge detector are developed together with CSNSM, IN2P3, CNRS
  - Obtained the first samples with the surface resistivity of ~ 10 GOhm/□
- Ultra-purification of TMBi
  - Level of impurities of 0.1 ppb O_2 equivalent
  - Electron lifetime larger than 10 µs
- Ionization demonstrator (Ph.D. is ongoing).
- High-density readout electronic (ASICs) is required.



Optical demonstrator





Collaboration and further development

- Join project of the SPP and SEDI (Particle Physics Service and Service of the Detector and Electronics)
- In collaboration with SHFJ (Frédéric Joliot Hospital Service, I²BM, CEA) post-doc: “PET scanner simulation and image reconstruction”
  - To create a simulation of the real scale scanner, based on the CaLIPSO technology and corresponding image reconstruction program.
- CSNSM, IN2P3, CNRS: technology development of the resistive cathode
- Thesis:”Optical Cherenkov detector for the γ 511keV, fast and efficient, for the PET imaging”
  - to study different aspects of the Cherenkov detection, not only in TMBi, but also in crystals.