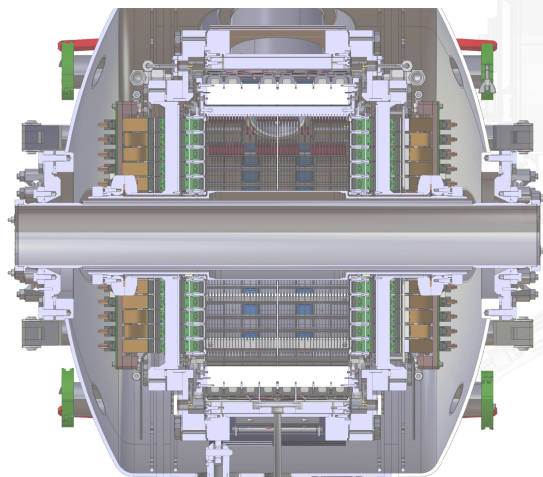
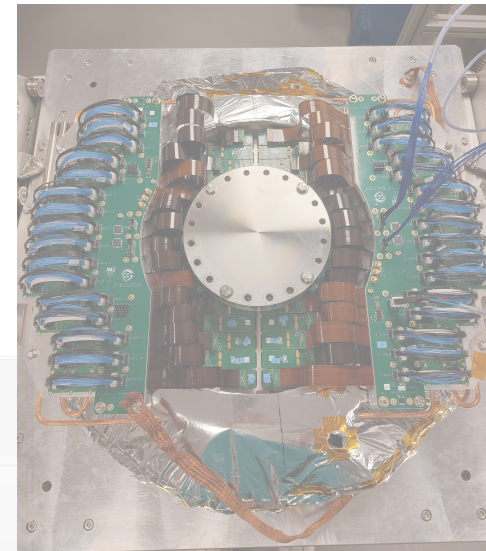


Review on the XEMIS2 camera installation progress at the Nantes University Hospital



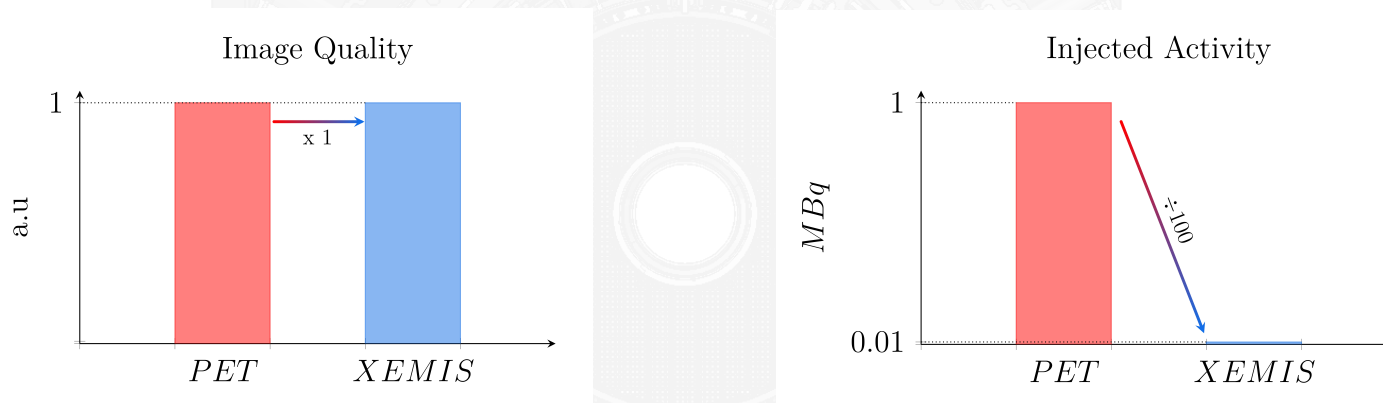
Nicolas Beaupère, Physicist, AP (MC) at IMT Atlantique,
office H111, email: beaupere@subatech.in2p3.fr
Subatech laboratory, Nantes, France



A new camera technology for metabolic imaging

The XEMIS project (Xenon Medical Imaging System)

Targets:

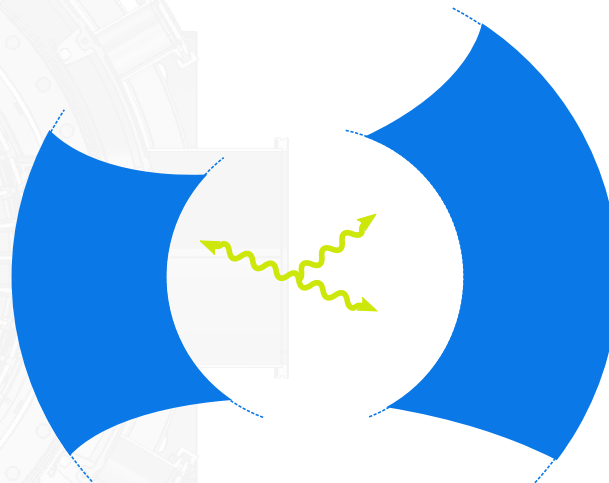


Technologies:

- **Detection medium** : Xenon in liquid phase (LXe)
- **Detector** : Compton Telescope → Compton Microscope
- **Radio-isotopes** : 3 photons emitters (β^+ et γ)

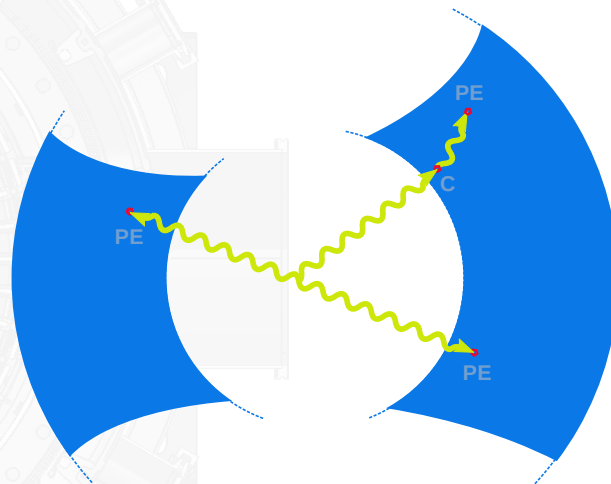
- **Principles**

- 3 photons emission (>400 keV)
- Detector (LXe)



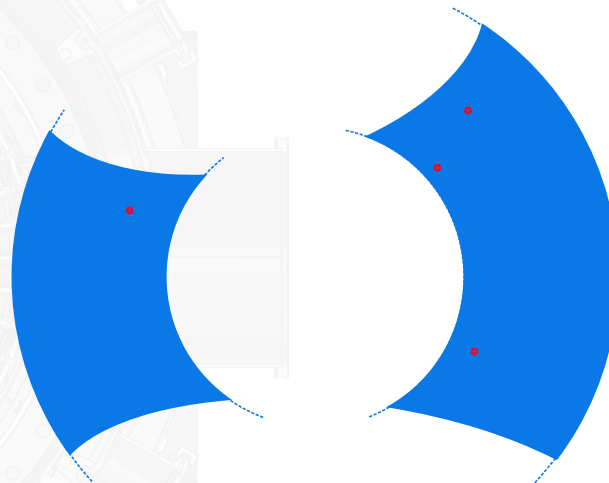
- **Principles**

- 3 photons emission (>400 keV)
- Detector (LXe)
- Interactions (PE, C)



- **Principles**

- 3 photons emission (>400 keV)
- Detector (LXe)
- Interactions (PE, C)
- Observables (x, y, z, E_{dep})

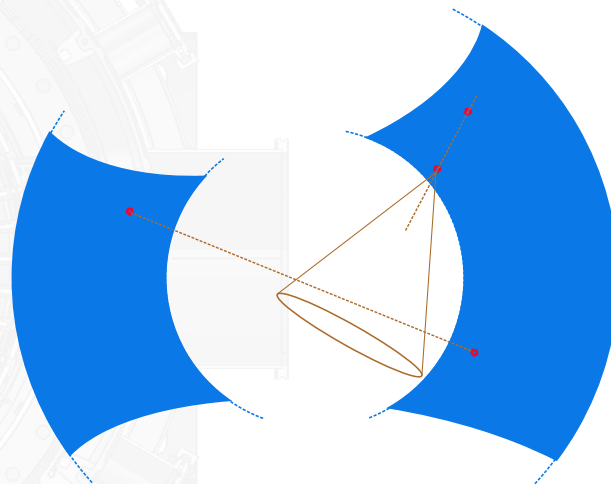


■ Principles

- 3 photons emission (>400 keV)
- Detector (LXe)
- Interactions (PE, C)
- Observables (x,y,z,E_{dep})
- Reco cone-LOR

Compton kinematic:

$$\theta^C = \arccos \left[1 - m_e c^2 \left(\frac{E_{dep}}{E_i(E_i - E_{dep})} \right) \right]$$

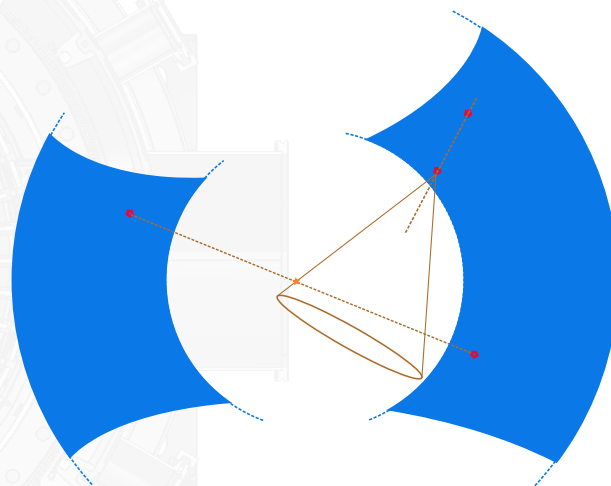


Principles

- 3 photons emission (>400 keV)
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- Reco cone-LOR
- Cone-LOR crossing points

Compton kinematic:

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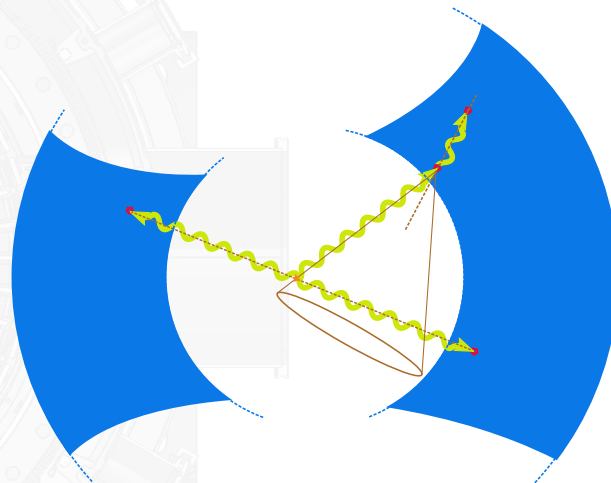


Principles

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Compton kinematic:

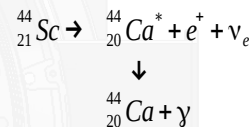
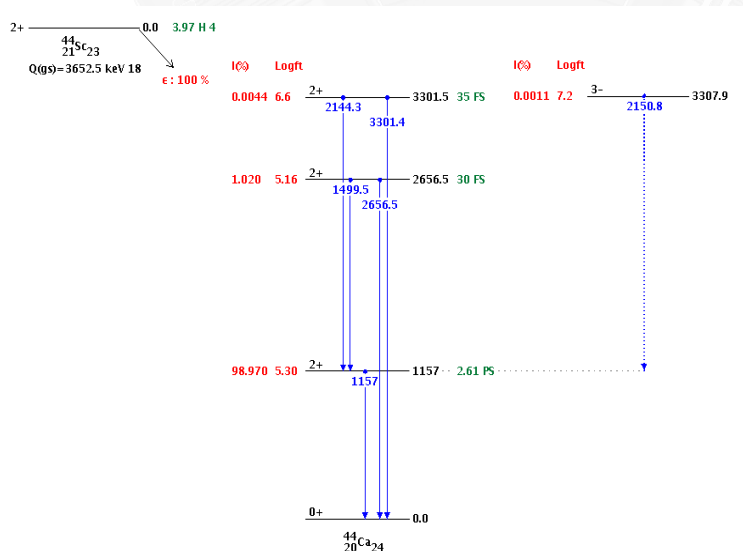
$$\theta^C = \arccos \left[1 - m_e c^2 \left(\frac{E_{dep}}{E_i(E_i - E_{dep})} \right) \right]$$



Interests

- Direct 3D localisation of each isotopes
- No photon time of flight (TOF) measurement
- Low activity imaging technic

Radio-isotope : ^{44}Sc



- Mainly 2 photons of 511 keV and 1 photon of 1157 keV
- Time correlation between photon emissions
- Around $\sim 4 \text{ h } \frac{1}{2}$ life
- Vectorisation with chelator peptides (dota, dota-toc,...)
- Cyclotron production (Arronax) and $^{44}\text{Ti}/^{44}\text{Sc}$ generator

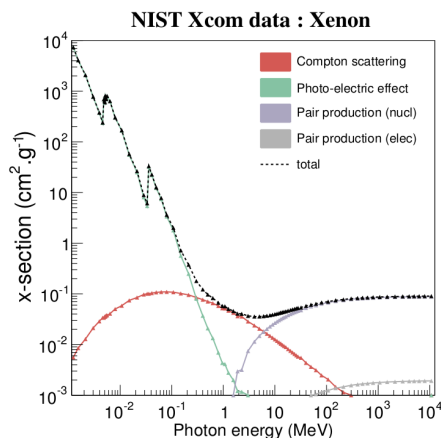


▪ Detector medium:

- ➔ Liquid Xenon (LXe)
- ➔ Many suitable properties

▪ Detector technology:

- ➔ Time Projection Chamber (TPC)
- ➔ Detection of photon interactions (x, E_{dep})



	Physic properties of liquid xenon	Values
Basic	Atomic number Z	54
	Average atomic weight A	131.293
	Density at $-109\text{ }^{\circ}\text{C}$ ($\text{g}\cdot\text{cm}^{-3}$)	2.95
	Boiling point ($^{\circ}\text{C}$) *	-108.09
	Melting point ($^{\circ}\text{C}$) *	-111.74
Ionization	Radiation length X_0 (cm)	2.77
	Ionization potential in liquid phase I (eV)	9.28
	Average ionization energy W -value (eV)	15.6 ± 0.3
	Electron mobility μ_{el} ($\text{cm}^2\text{V}^{-1}\text{s}^{-1}$)	2000 ± 200
	Electron saturation velocity v_s (cm s^{-1})*	$2.6 \times 10^5 \pm 10\%$
	Transverse diffusion coefficient D_T (cm^2s^{-1})**	50 - 80
	Longitudinal diffusion coefficient D_L (cm^2s^{-1})	$0.1 D_T$
Scintillation	W_{ph} in liquid for relativistic e^- (eV) e^- *	21.6
	Peak emission wavelength (nm)	178
	Refractive index (at 178 nm)	[1.6,1.72]
	Fast decay time (singlet state τ_s) (ns) *	2.2
	Slow decay time (triplet state τ_t) (ns) *	27
	Recombination time (τ_r) (ns) *	45

* at 1 bar

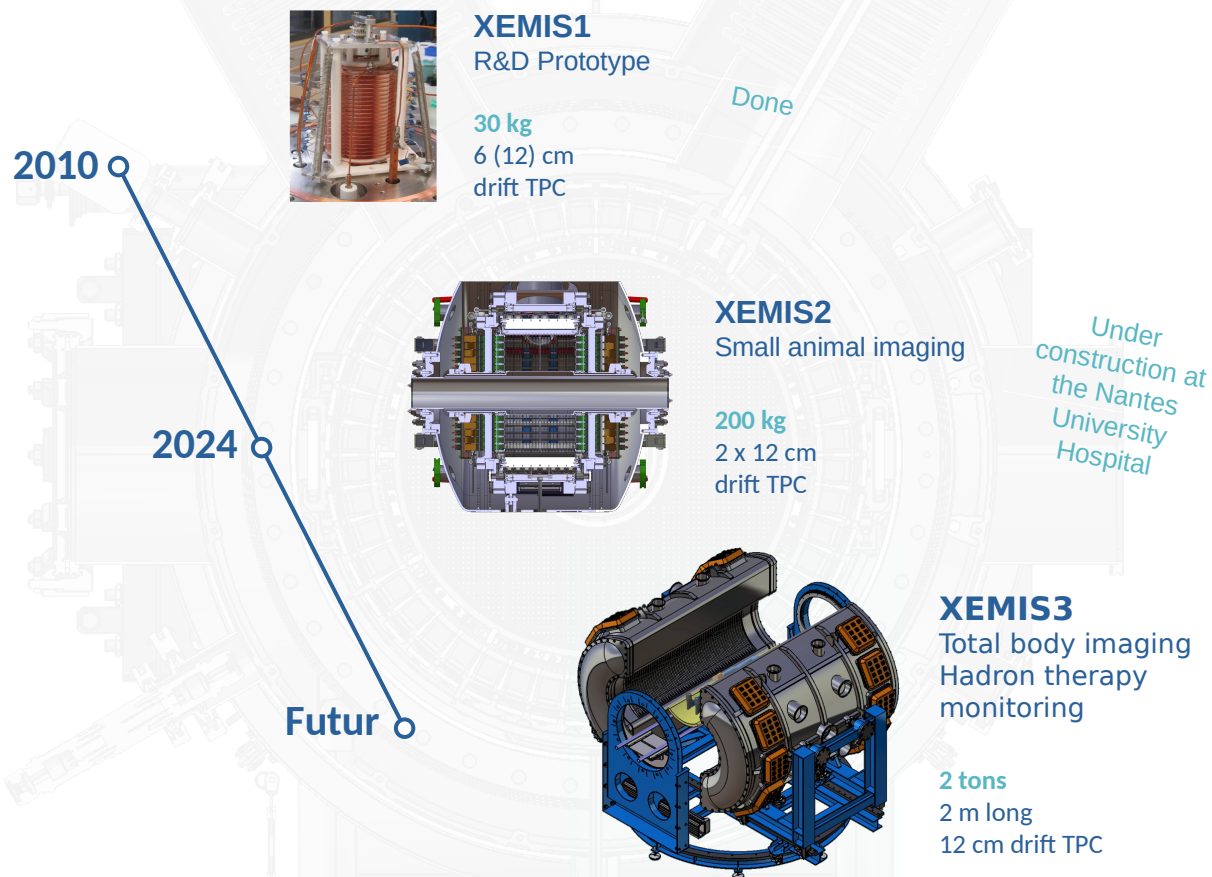
* at an electric field of 3-10 kV/cm

** at an electric field of 1-10 kV/cm

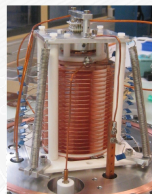
* for detectors without electric field

Element	LHe	LNe	LAr	LKr	LXe
Atomic number Z	2	10	18	36	54
Average atomic weight A	4.00	20.18	39.95	83.80	131.30
Density ($\text{g}\cdot\text{cm}^{-3}$)	0.145	1.2	1.40	2.41	3.06
Boiling point at 1 atm (K)	4.22	27.1	87.3	119.9	165.0
Average ionization energy W (eV)	41.3	29.2	23.6	18.4	15.6
Light yield (photons/MeV)	15000	30000	40000	25000	42000

The XEMIS three main steps



The XEMIS three main steps



XEMIS1
R&D Prototype

30 kg
6 (12) cm
drift TPC

Done

2010 ○

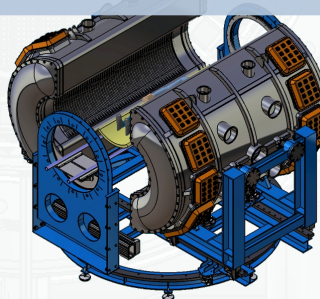


XEMIS2
Small animal imaging

XEMIS2 : low activity, inside field of view, for small animals: 20 kBq

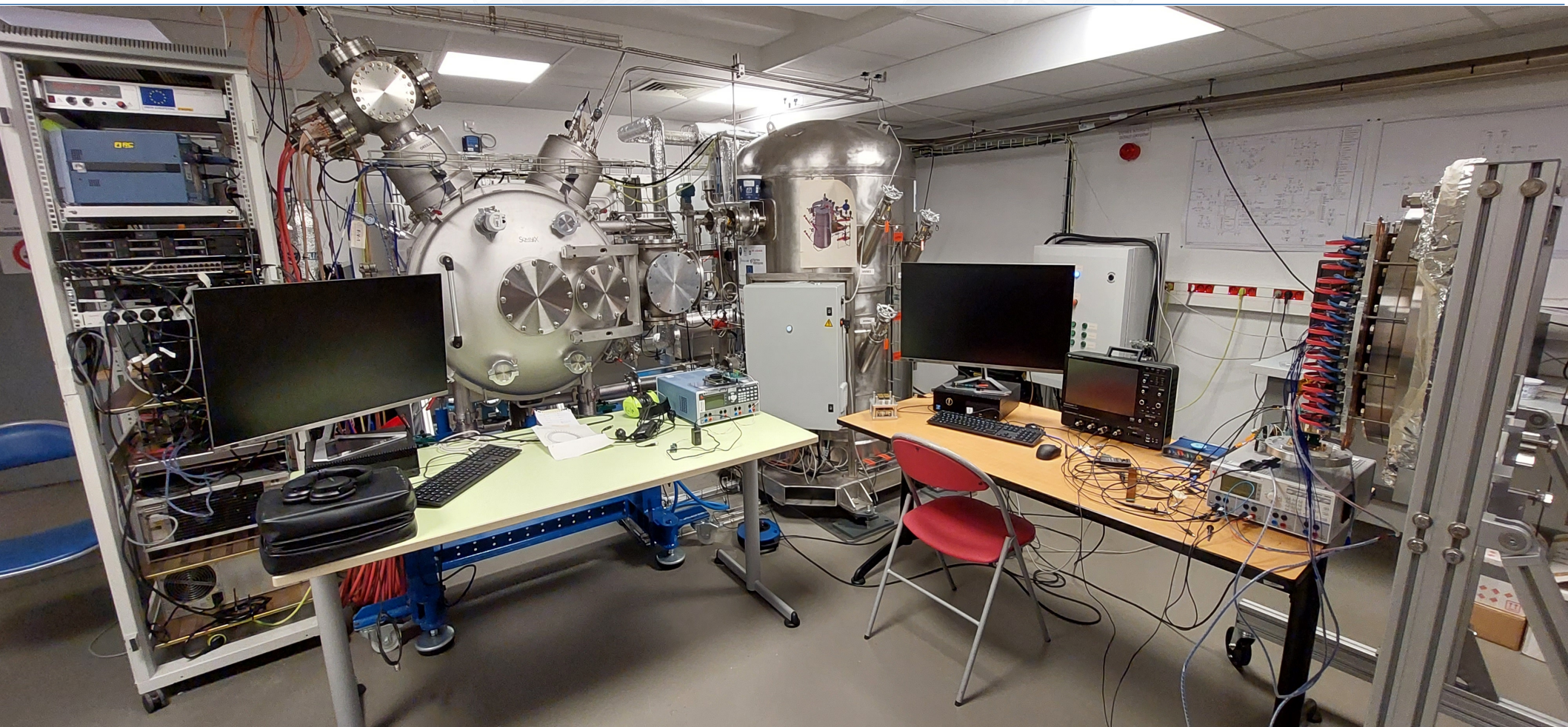
Under construction at the Nantes University Hospital

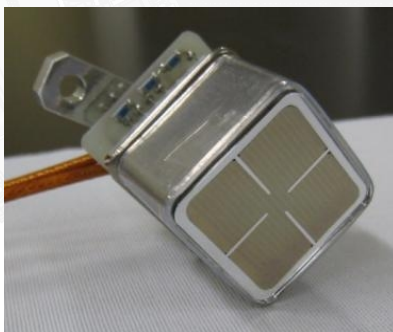
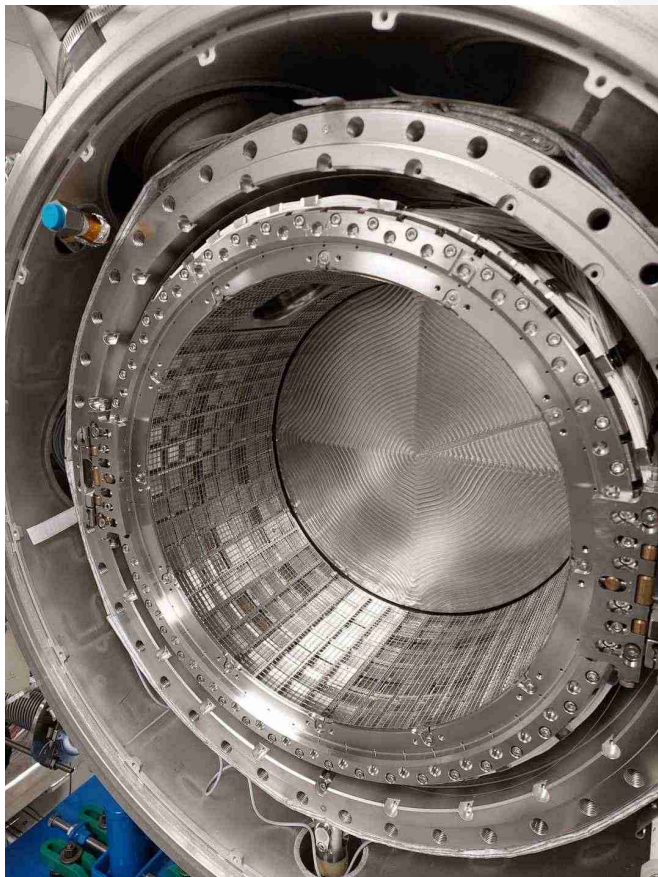
Futur ○



XEMIS3
Total body imaging
Hadron therapy monitoring

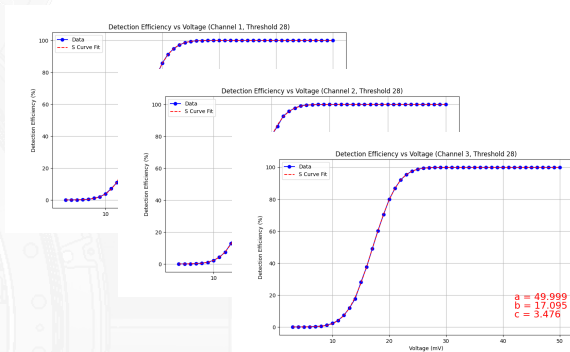
2 tons
2 m long
12 cm drift TPC



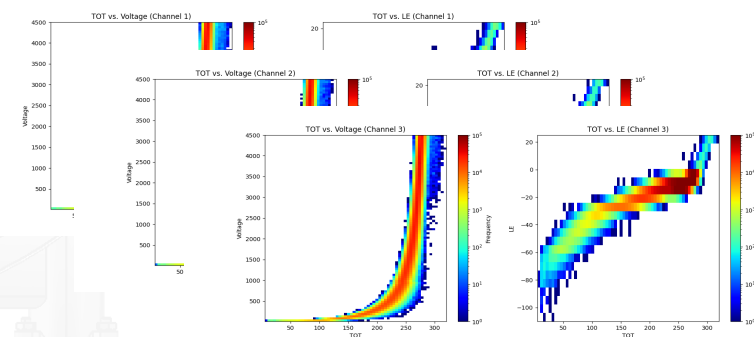


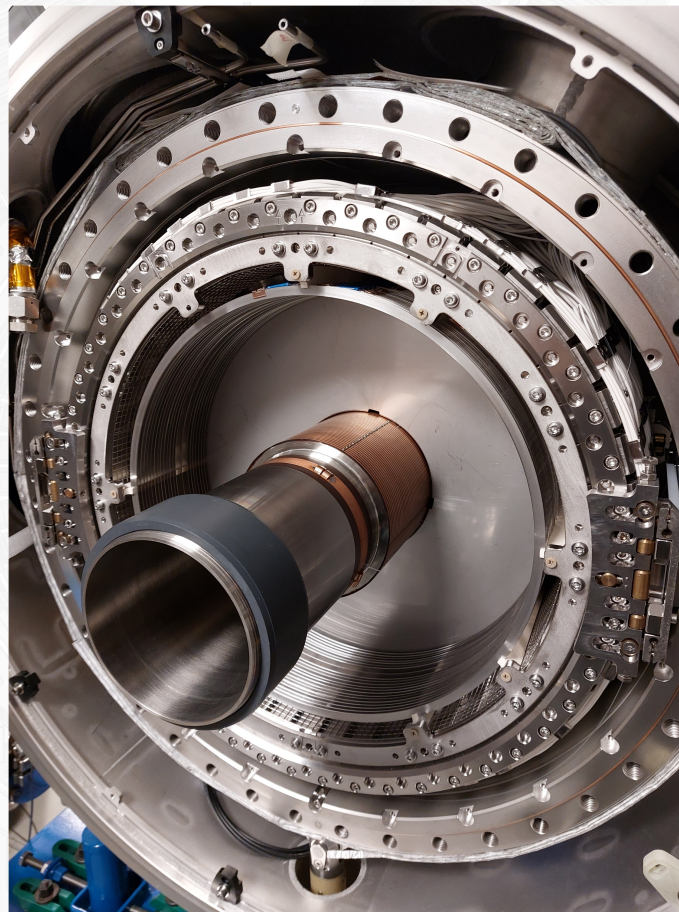
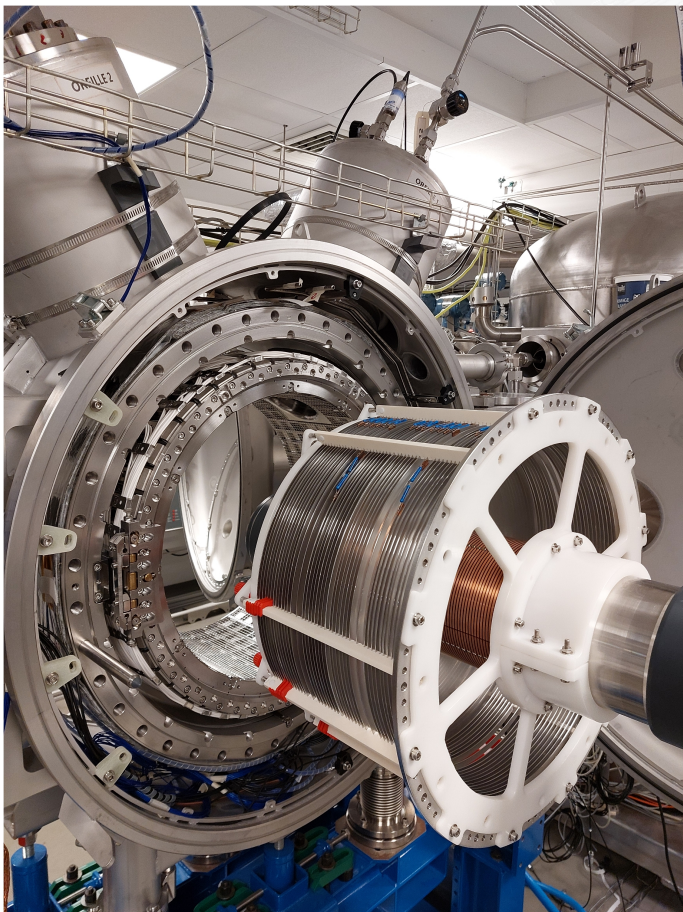
Light calibration

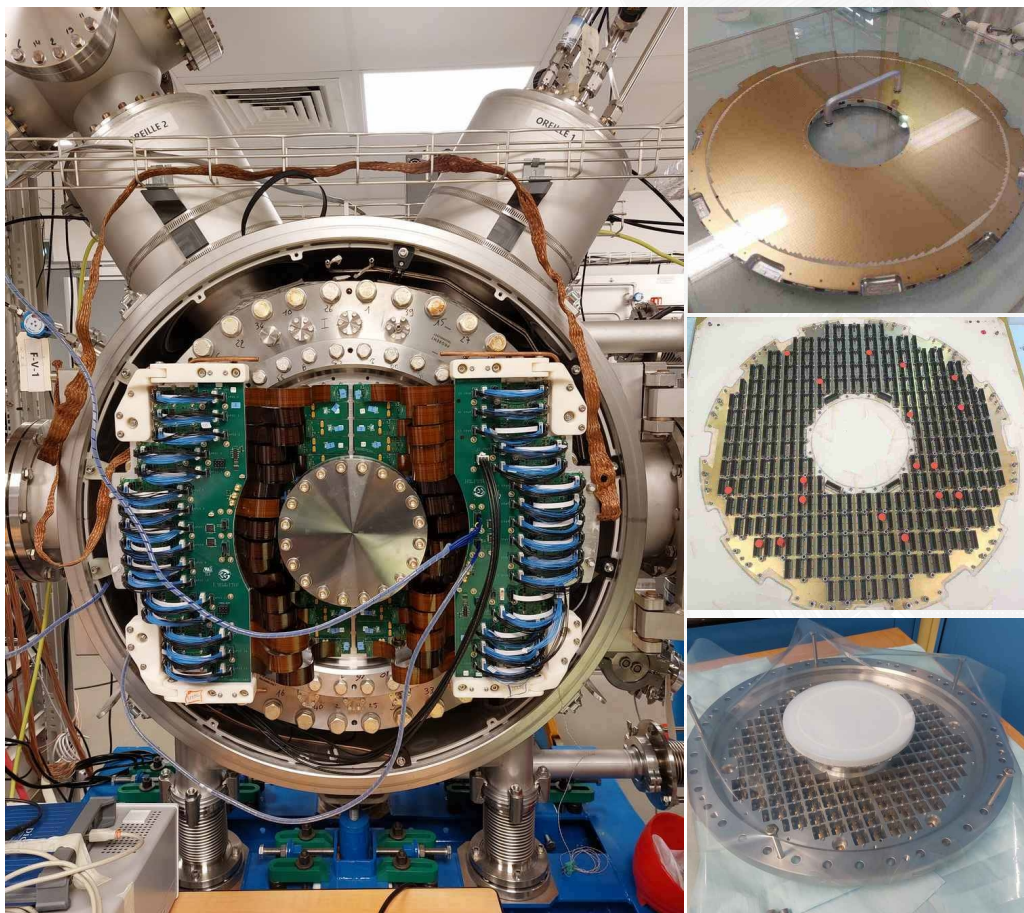
Signal count @ threshold



ToT vs Q

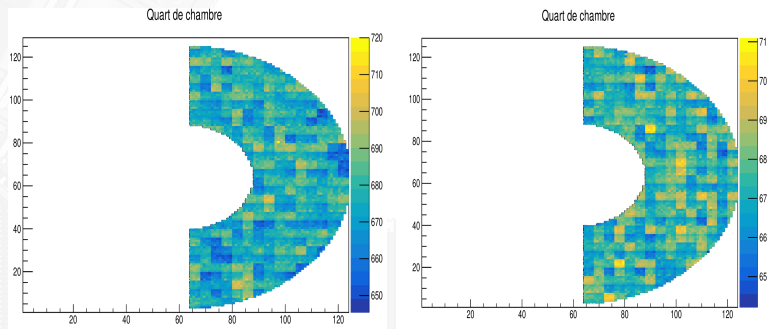




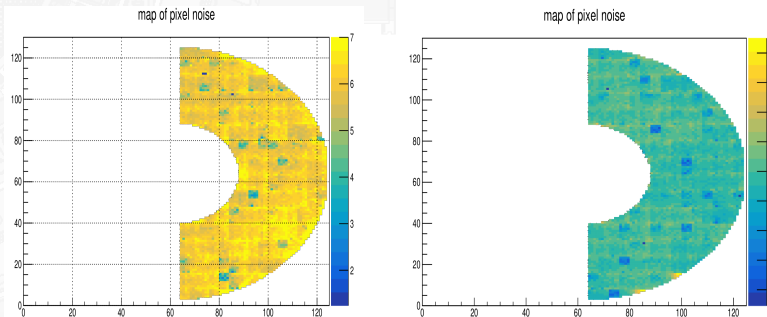


Charge calibration

Pedestals (5000 pixels)



Noise map (5000 pixels)



■ Conclusions

- HV stick installation and tests (-25 kV)
- Camera closing at the end of the year
- Calibration ongoing
- Image reconstruction collaboration with the LS2N, CRI2NA, and Nantes University hospital

■ Perspectives

- Image based on 3 photons emitters for small animals
- 2 photons and 1 photon emitters could be tested



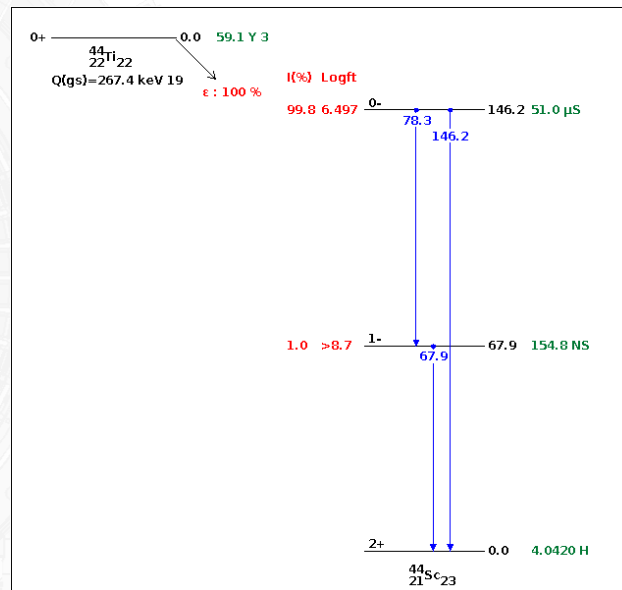
Backup

▪ Radio-isotopes : $^{44}\text{Ti}/^{44}\text{Sc}$

- Long Half-life ~ 59 years (not yet accessible due to resin)
- Electron capture
- Ti/Sc separation seems possible

▪ Cyclotron ^{44}Sc production reaction:

- Protons beam
 - $^{44}\text{Ca}(p,n)^{44}\text{Sc}$ (enriched Calcium target)
 - $^{\text{nat}}\text{Ca}(p,n)^{44}\text{Sc}$ (natural Calcium target)
- Deuterons beam
 - $^{44}\text{Ca}(d,2n)^{44}\text{Sc}$ ($^{44}\text{CaCO}_3$ target)



■ Positron energy:

- $\langle E(^{44}\text{Sc}) \rangle \sim 632 \text{ keV}$
- $\langle E(^{68}\text{Ga}) \rangle \sim 830 \text{ keV}$

