ICTR-PHE 2014

XEMIS: Medical imaging with liquid xenon

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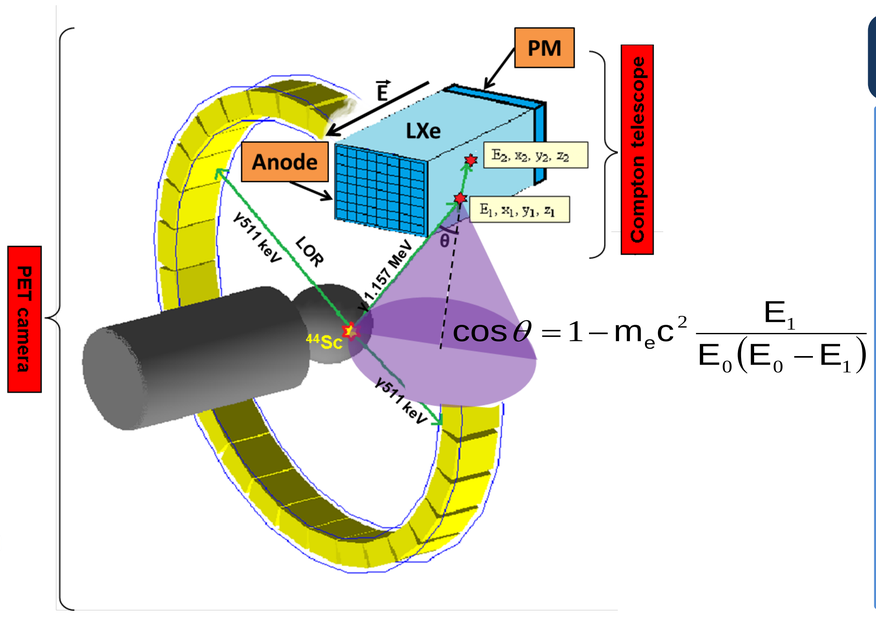
3γ imaging principle

3γ imaging is a **new functional nuclear imaging technique [1]** proposed by Subatech laboratory, which allows to locate the position of a radioactive source in 3D, reducing also the dose administered to the patient.

This technique requires the use of a specific radioisotope, which emits a γ ray and a β^+ in quasi-coincidence. The ^{44}Sc is a perfect candidate.

^{44}Sc :
- β^+(Emax = 1.474 MeV)
- γ(E_0 = 1.157 MeV)



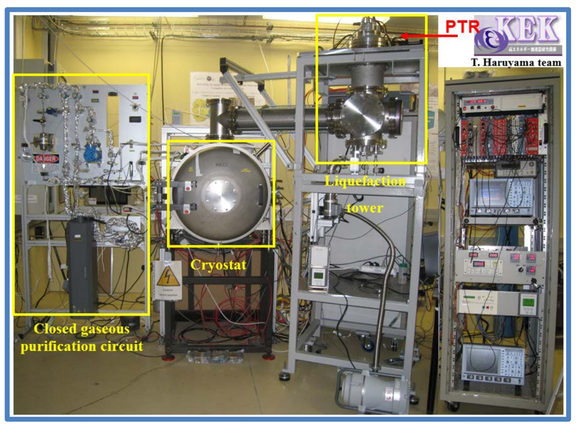
[1] C. Grignon, PhD thesis, 2007, Université de Nantes

Purpose

The main goal of this project is the development of the 3γ imaging technique and its application in medical imaging. For this purpose a careful study consisting in three main phases is being carried out:

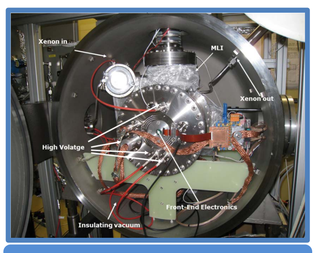
1. Proof of the feasibility of the 3γ imaging technique.
2. Study of its capability for small animal imaging.
3. Application in human body imaging.

XEMIS1 Prototype

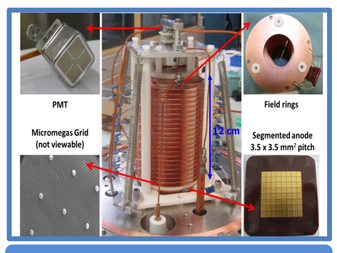


First prototype of a Compton telescope with **Liquid Xenon [2]**, XEMIS1 (XEnon Medical Imaging System), has been developed at Subatech laboratory.

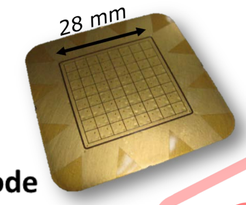
[2] T. Oger et al., NIM A, 2012, 695, 125-128.



Internal cryostat



TPC components



64 pixels anode
3.5 x 3.5 mm² pixel

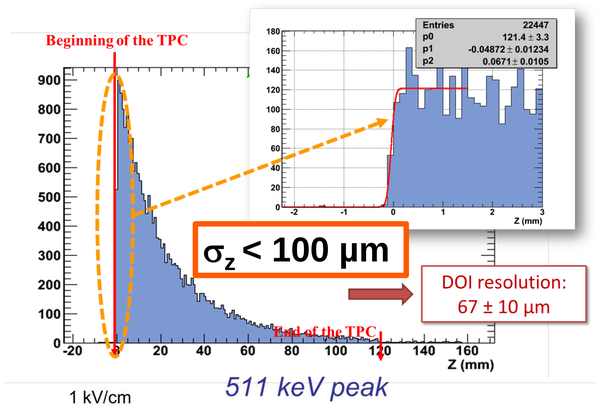
DONE

Experimental confirmation of the feasibility of the 3γ imaging technique and the use of liquid Xenon as a perfect candidate for gamma detection.

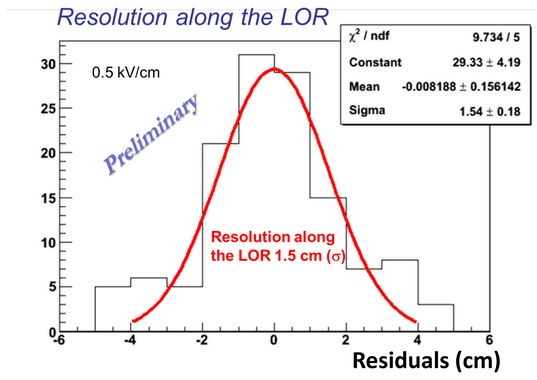
XEMIS1 Results

Very good experimental results for the temporal and spatial resolutions for the ionization signal in liquid Xenon.

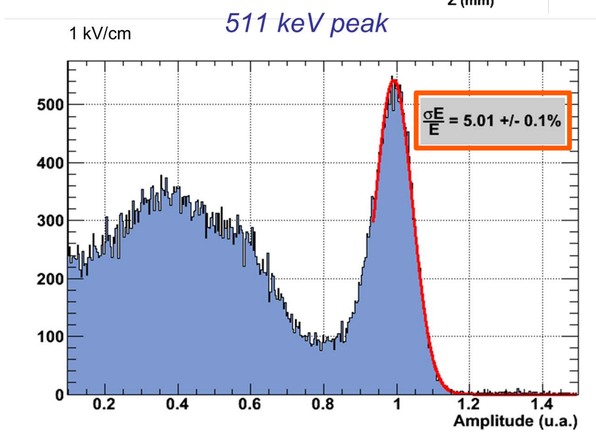
Depth of interaction (@ 511 keV)



Resolution along the LOR



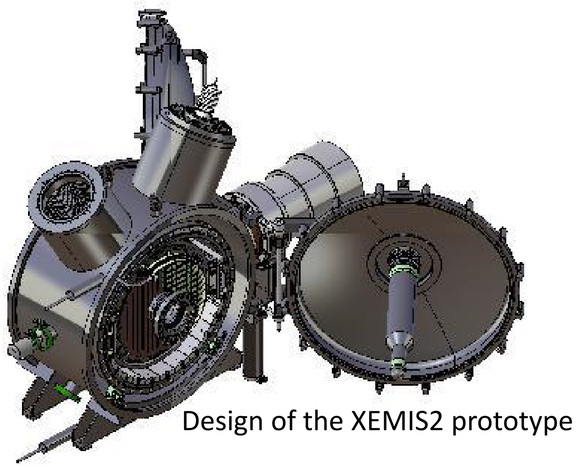
511 keV peak



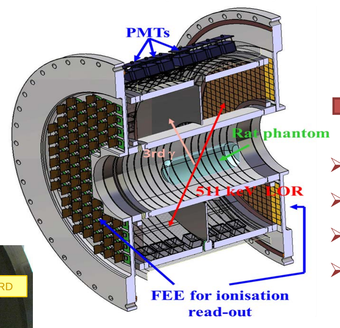
XEMIS2 Small Animals Prototype

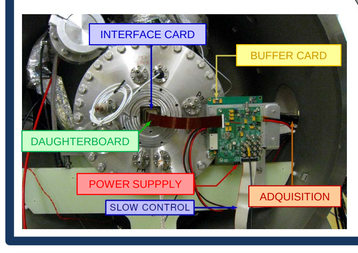
A new prototype, XEMIS2, based on a full liquid xenon cylindrical camera dedicated to small animal imaging, is being developed at Subatech laboratory.
The device characteristics are:

- **2 TPCs**
- radius 7 < r < 19 cm
- axial (z) Length = 2 x 12 cm
- Electric Field in z direction 2 kV/cm
- **192 PMTs**
- Micromegas ionisation read-out
- FEE Idef-X, **pixels 3.175 x 3.175 mm²** (25k channels)
- Electronic noise **100 e-** RMS (~2 keV)
- ~ 130 kg LXe



Design of the XEMIS2 prototype





Start of XEMIS2 project

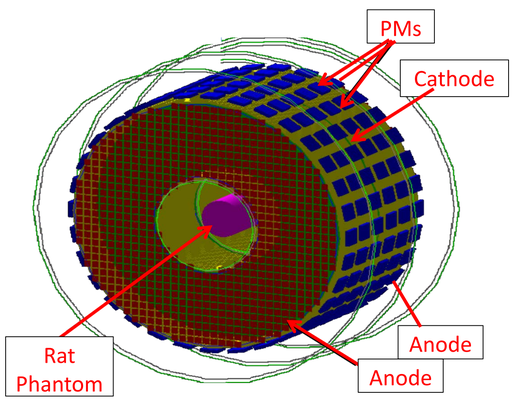
- Advanced simulation with GATE since 2012
- Design study 2013
- Construction 2014
- Test and characterisation 2015

Proof of the LXe superiority

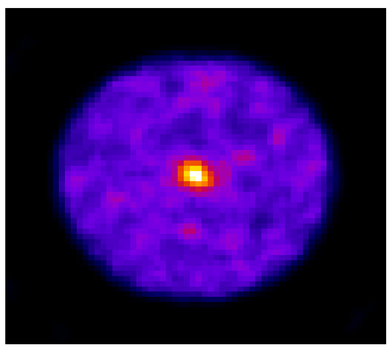
- Installation at Nantes Hospital in 2016

Expectations for XEMIS2

Complete simulation with GATE [3], a Geant4 Application for Emission Tomography of **XEMIS2.**

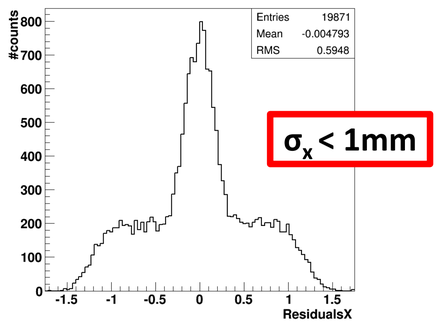


Reconstructed image



Very promising preliminary results:

- Transversal spatial resolution of less than 1mm.
- Sensitivity of 2.7%.



GATE simulation:

- Water cylindrical phantom filled with an homogeneous source of ^{44}Sc (length 15 cm, diameter 5 cm) **+** sphere of ^{44}Sc located at the center (diameter 5 mm).
- **Low activity 20 kBq**
- **Acquisition time 20 minutes**

Specially developed for low activities

[3] http://www.opengatecollaboration.org/

Conclusions and Perspectives

- Very good results for the ionization signal in liquid Xenon have been obtained with the first prototype (XEMIS1).
- A complete simulation of XEMIS2 using GATE shows very promising results for the sensitivity, energy and spatial resolutions.
- Simulated tomographic reconstructed images reveal the possibility of imaging a whole animal in a short time with a very low administered dose.
- First tests with XEMIS2 are planned to start in 2015.