



Mediterranean
Thematic Workshops
in Advanced Molecular Imaging

MEDAMI 2016 - IV Mediterranean Thematic
Workshop in Advanced Molecular Imaging



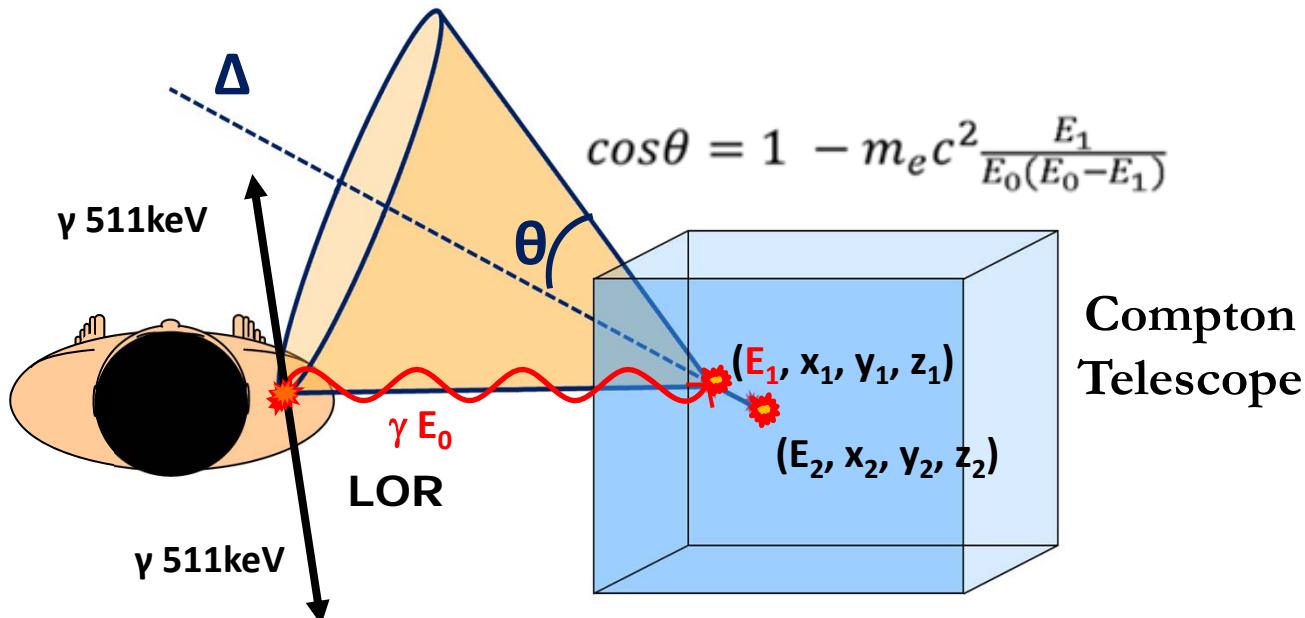
Low dose small animal 3γ imaging with the XEMIS2 liquid xenon Compton telescope

D. Thers, Ecole des Mines de Nantes



Principle of the 3γ Compton Imaging

LOR reconstruction + Compton Telescope



Reconstructed γ direction {

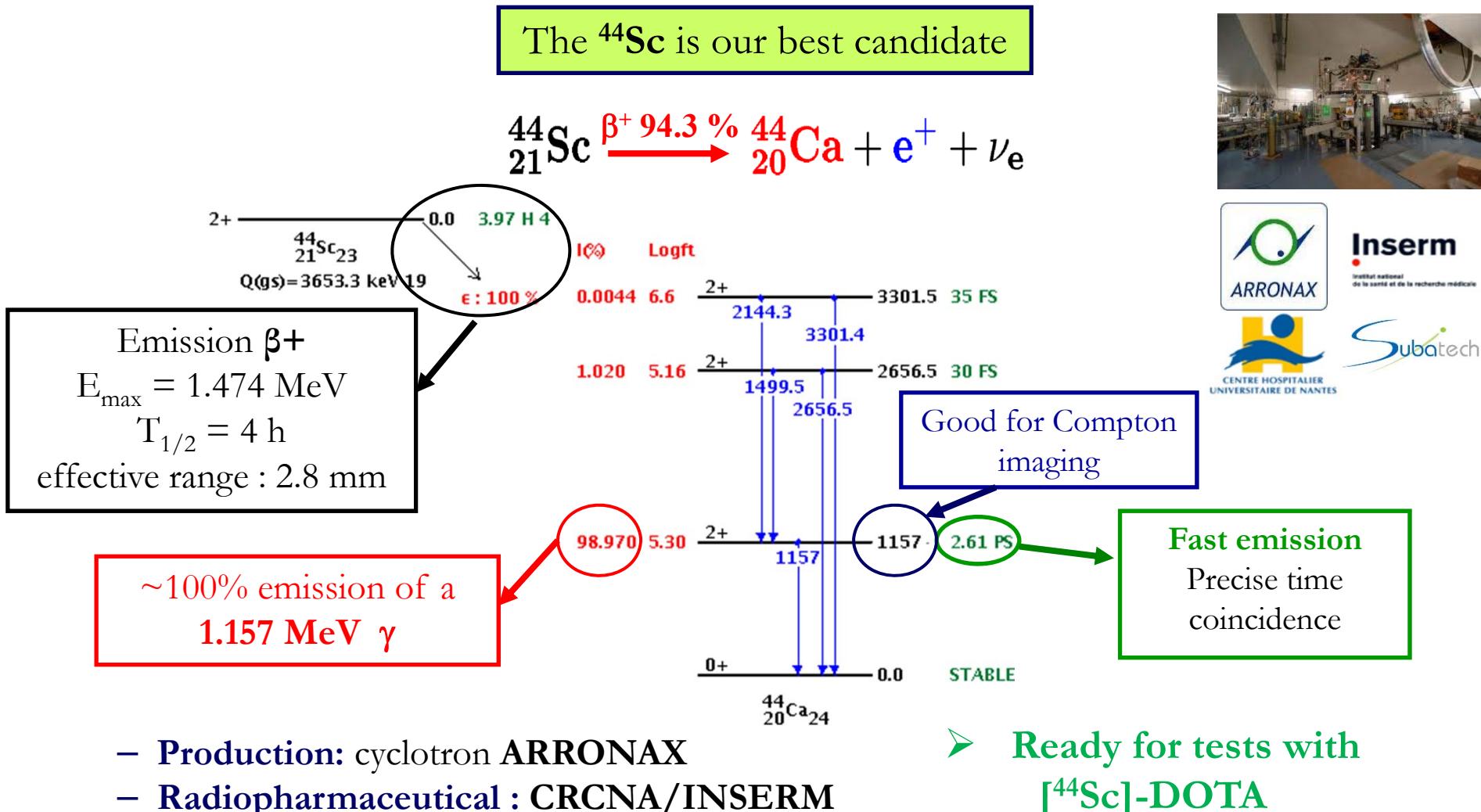
- Spatial resolution \Rightarrow axis Δ of the cone
- Energy resolution \Rightarrow opening angle θ

- Direct 3D location of the radioactive source
- Administered activity reduction, shorter scan times

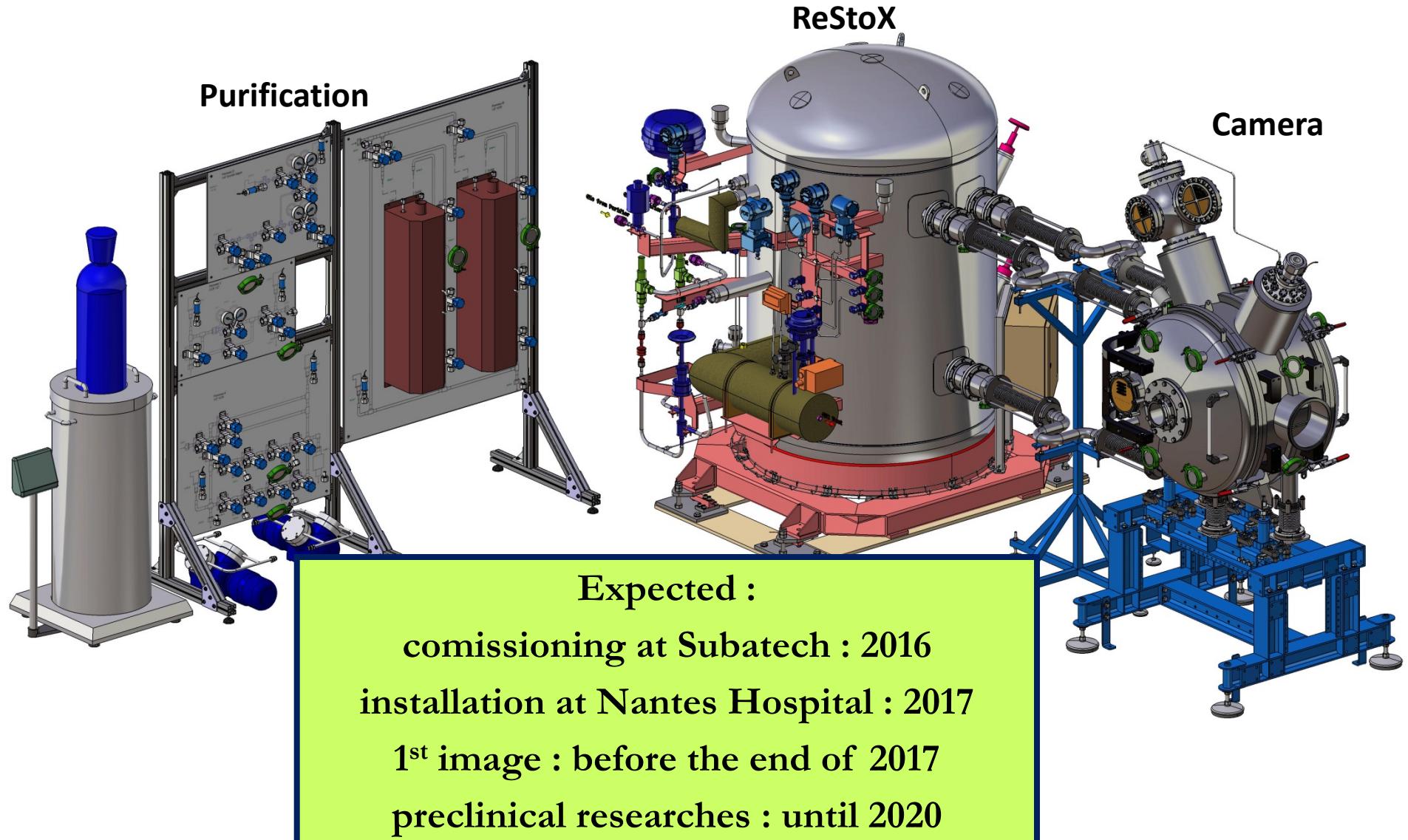
➤ Both new medicament and new camera technology !

3 γ imaging will be investigated with ^{44}Sc based pharmaceutics

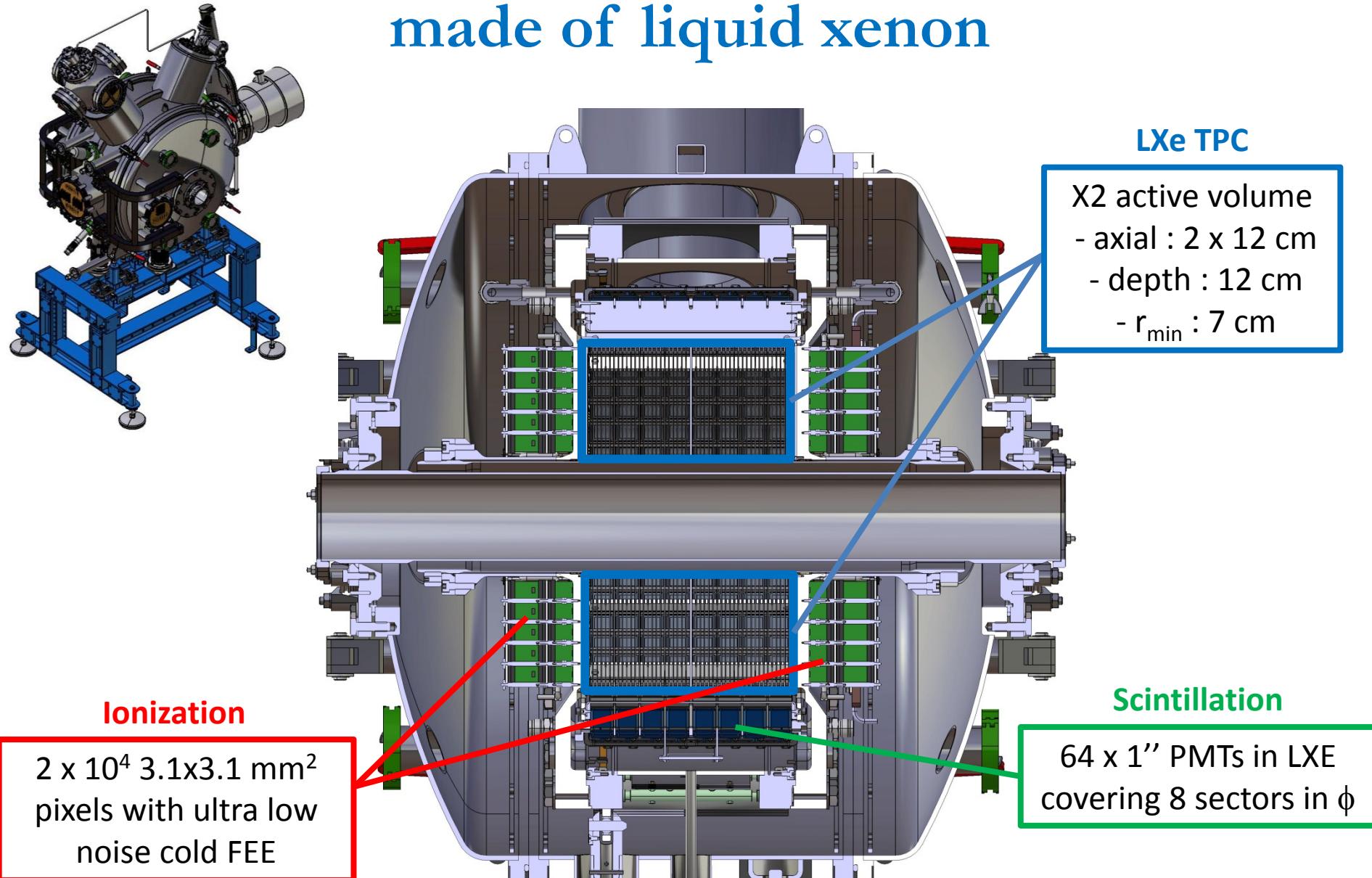
Requires the use of a specific nucleus, which emits a $\beta^+ + \gamma$ ray in quasi-coincidence:



3 γ imaging will be experimentally proved with XEMIS2 and small animal



3γ imaging cameras will be made of liquid xenon



XEMIS2 complete simulation with Geant4

RAT PHANTOM

Geometry :

Cylinder :

$$\begin{aligned} > r_c &= 2.6 \text{ cm} \\ > l &= 12 \text{ cm} \end{aligned}$$

Sphere:

$$> r_s = 5 \text{ mm}$$

Material :

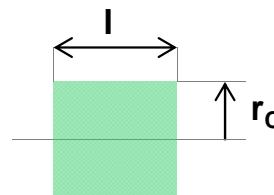
Water

^{44}Sc

Radio-Activity :

- Total = 20,0 kBq
- Bkg (cylinder) = 19,5 kBq
- Src (sphere) = 0,5 kBq
- Uniform distribution

➡ Contrast = 15



CAMERA

Geometry :

Uniform Tube of LXe

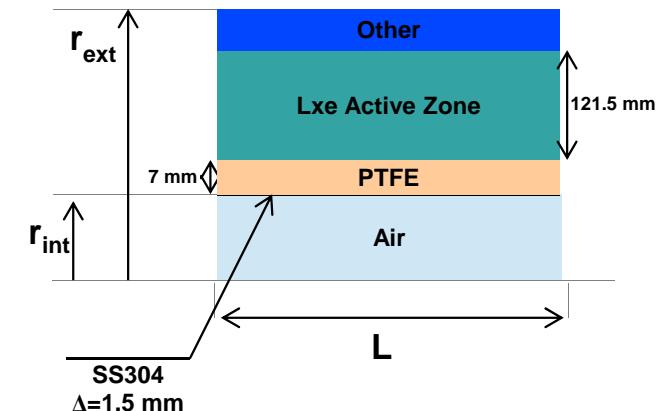
$$\begin{aligned} > r_{\text{int}} &= 7 \text{ cm} \\ > r_{\text{ext}} &= 19 \text{ cm} \\ > L &= 24 \text{ cm} \end{aligned}$$

Material :

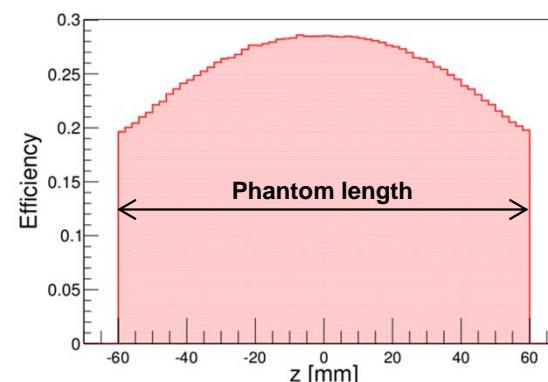
Liquid Xenon

Acquisition time :

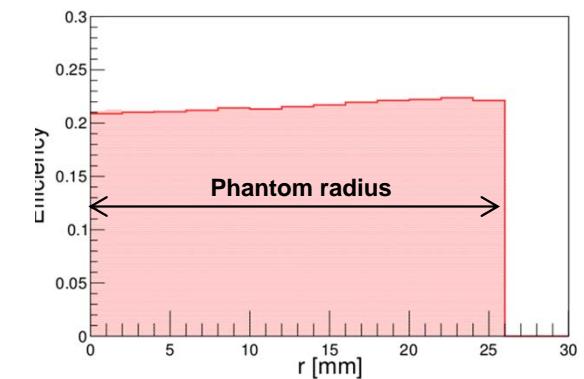
$$t_A = 20 \text{ min}$$



Detectable Event Fraction



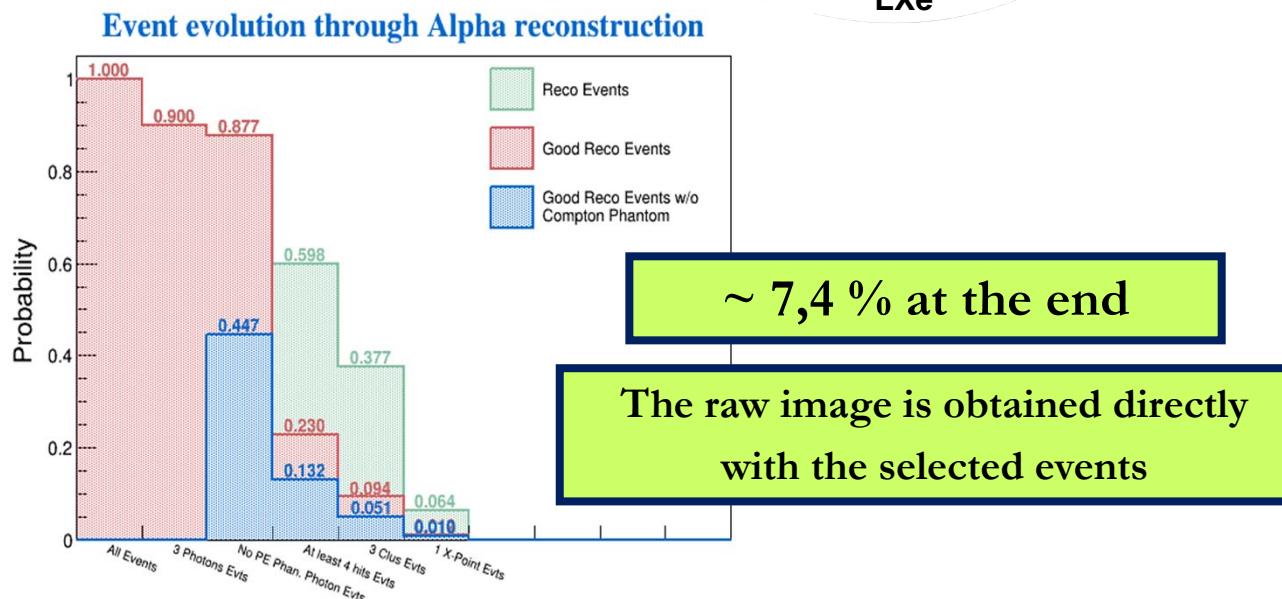
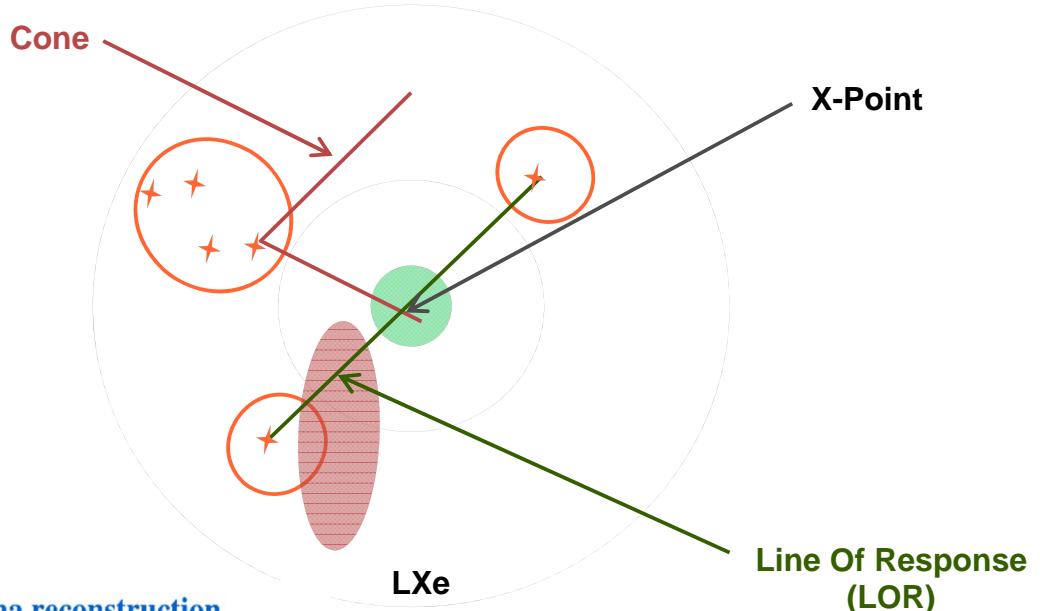
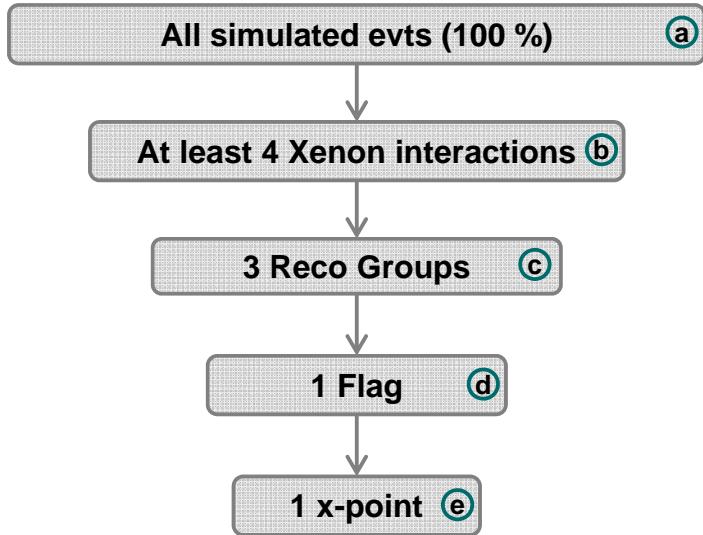
At least 4 Hits in Lxe :
→ 1 for each 511 keV photons
→ 2 for 1157 keV photon



quite uniform !

XEMIS2 reconstruction strategy

Event Reconstruction Algorithm :



XEMIS2 deconvolution

From Direct Image to Deco Image

Idea :

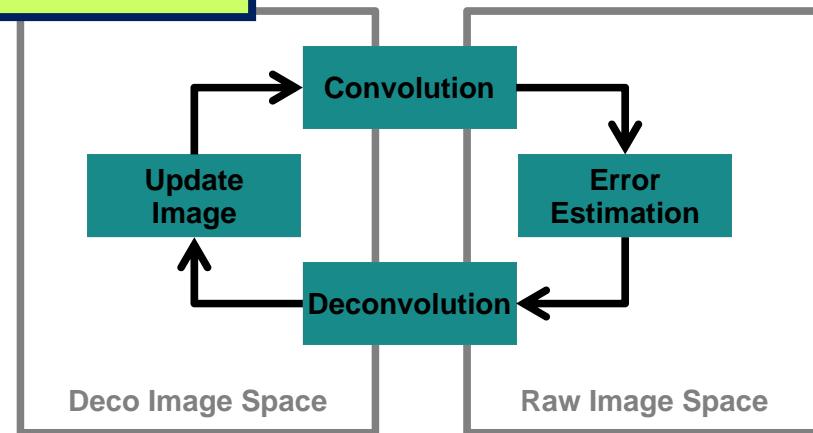
- Inverse pb of convolution
- Points image to points image

Asumption : PSF uniform in all the field of view

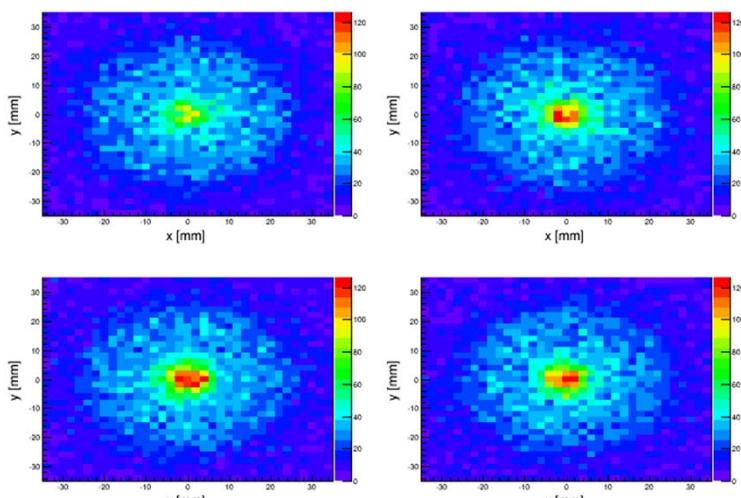
Algorithm :

- Iterative ML-EM based on Poisson Distribution
- Convolution in frequency domain

$$\lambda_i^{(n+1)} = \lambda_i^{(n)} \cdot \frac{1}{\sum_{j \in J} f_{ij}} \sum_{j \in J} \sum_{k \in I} \frac{p_j}{f_{kj} \lambda_k^{(n)}} \cdot f_{ij}$$

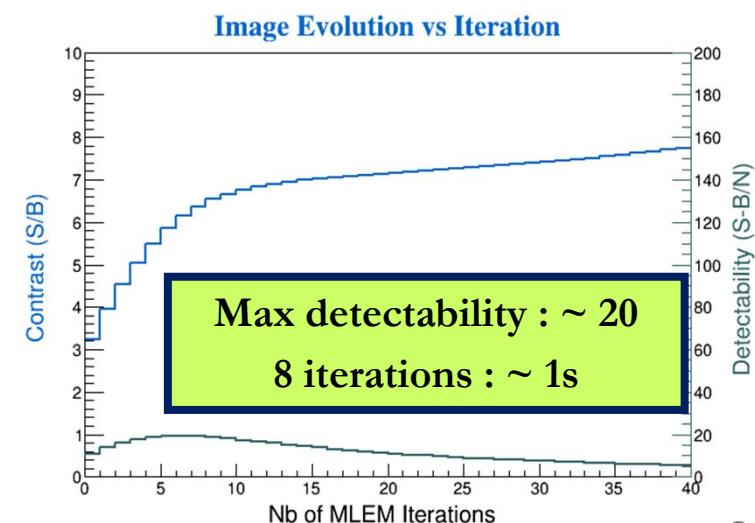


Raw Image :



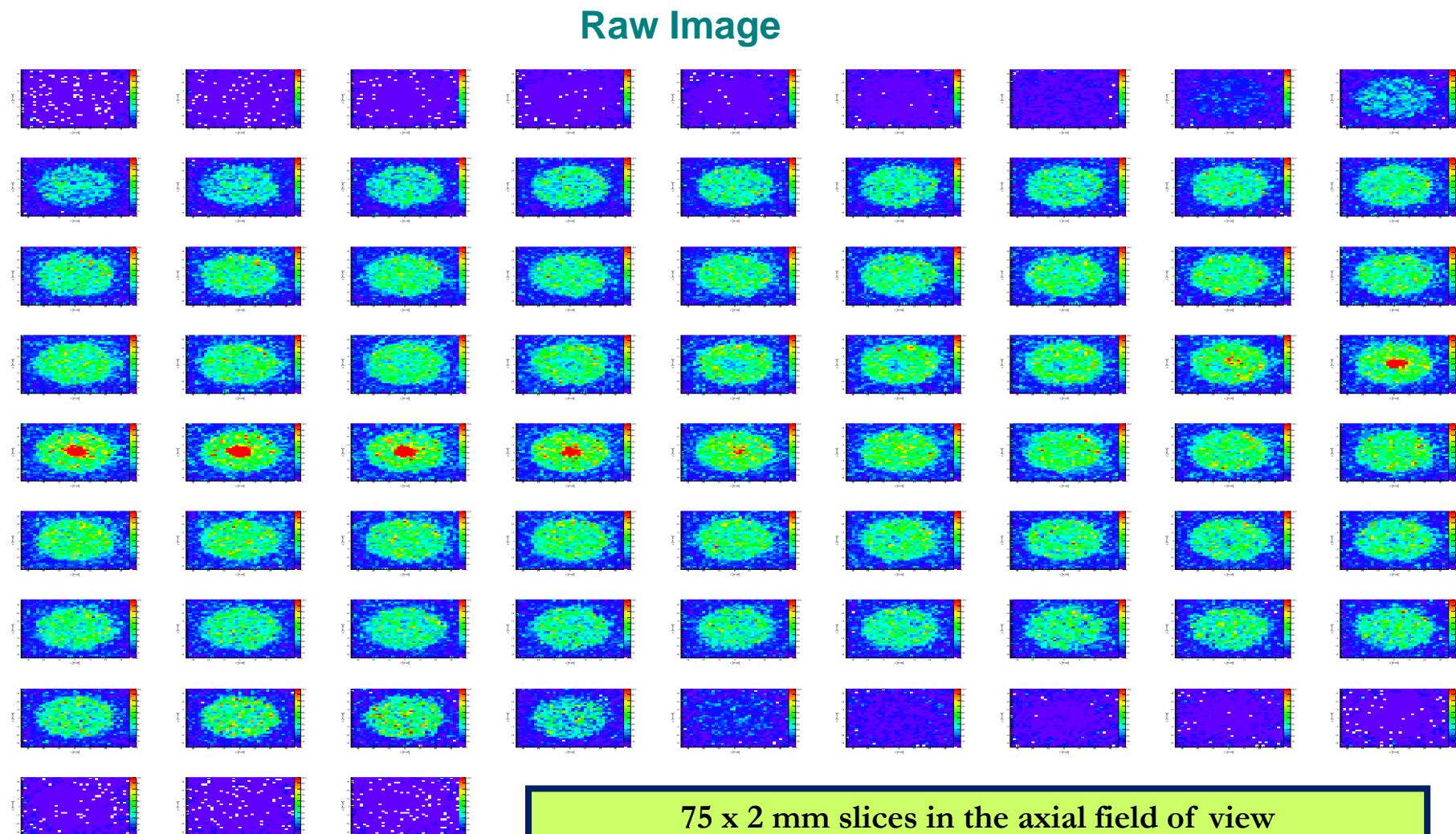
MEDAMI2016

03 – 05 – 2016



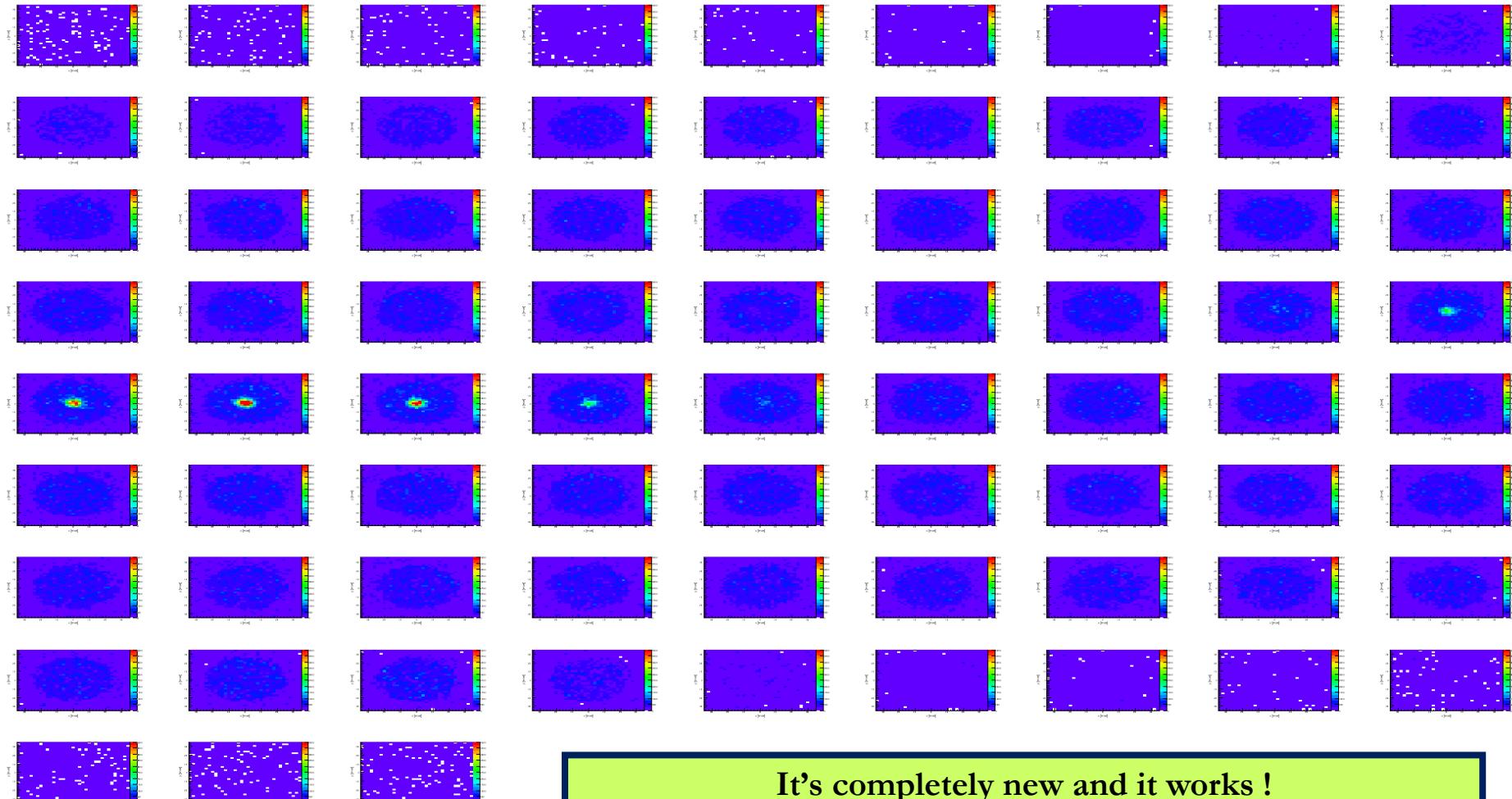
8

XEMIS2 expected image 20 kBq, 20 mns



XEMIS2 expected image 20 kBq, 20 mns

Deco Image



It's completely new and it works !

Expected resolution : [2-3 mm] on all the field of view

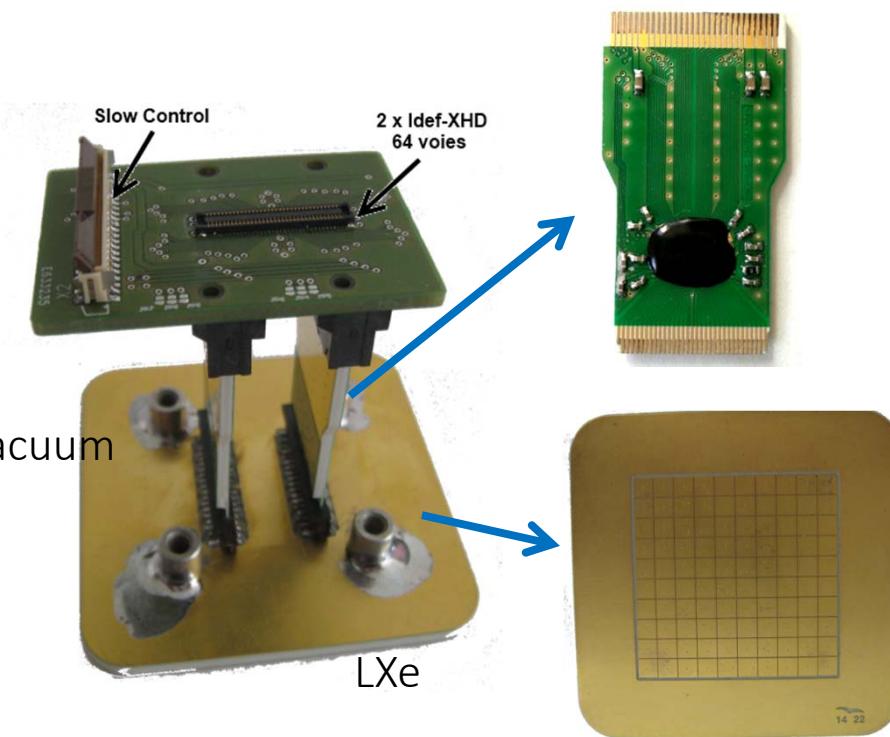
Alot of works for the future ...

Results with XEMIS1 : Ionization read-out

IDEF-X Asics

Developed for CdTe @ IrFU (Gevin et al. 2006)

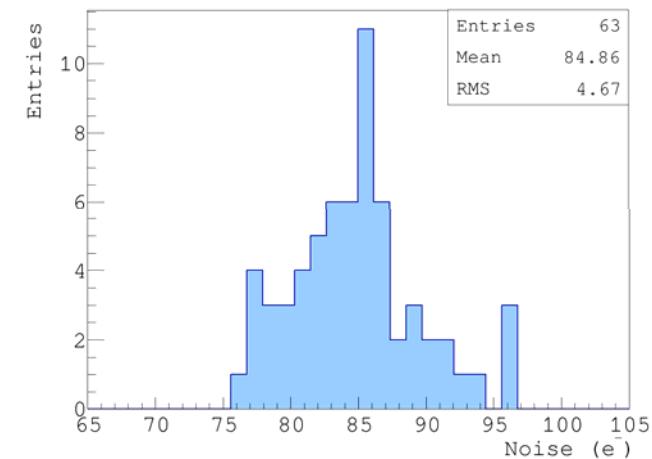
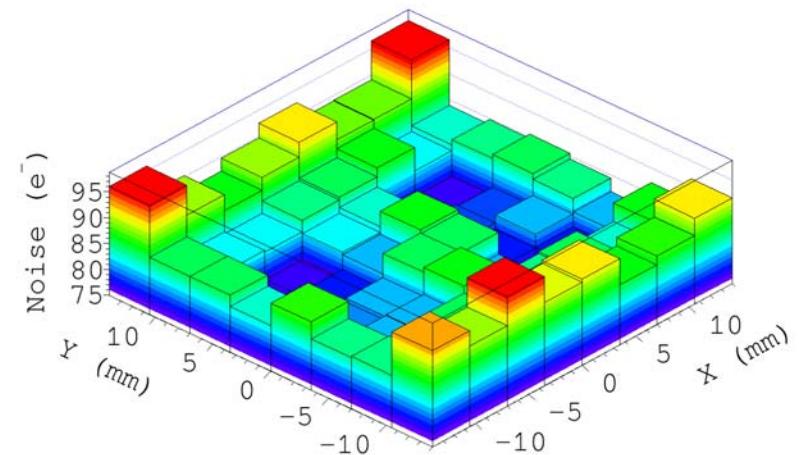
Adapted by Subatech for LXe



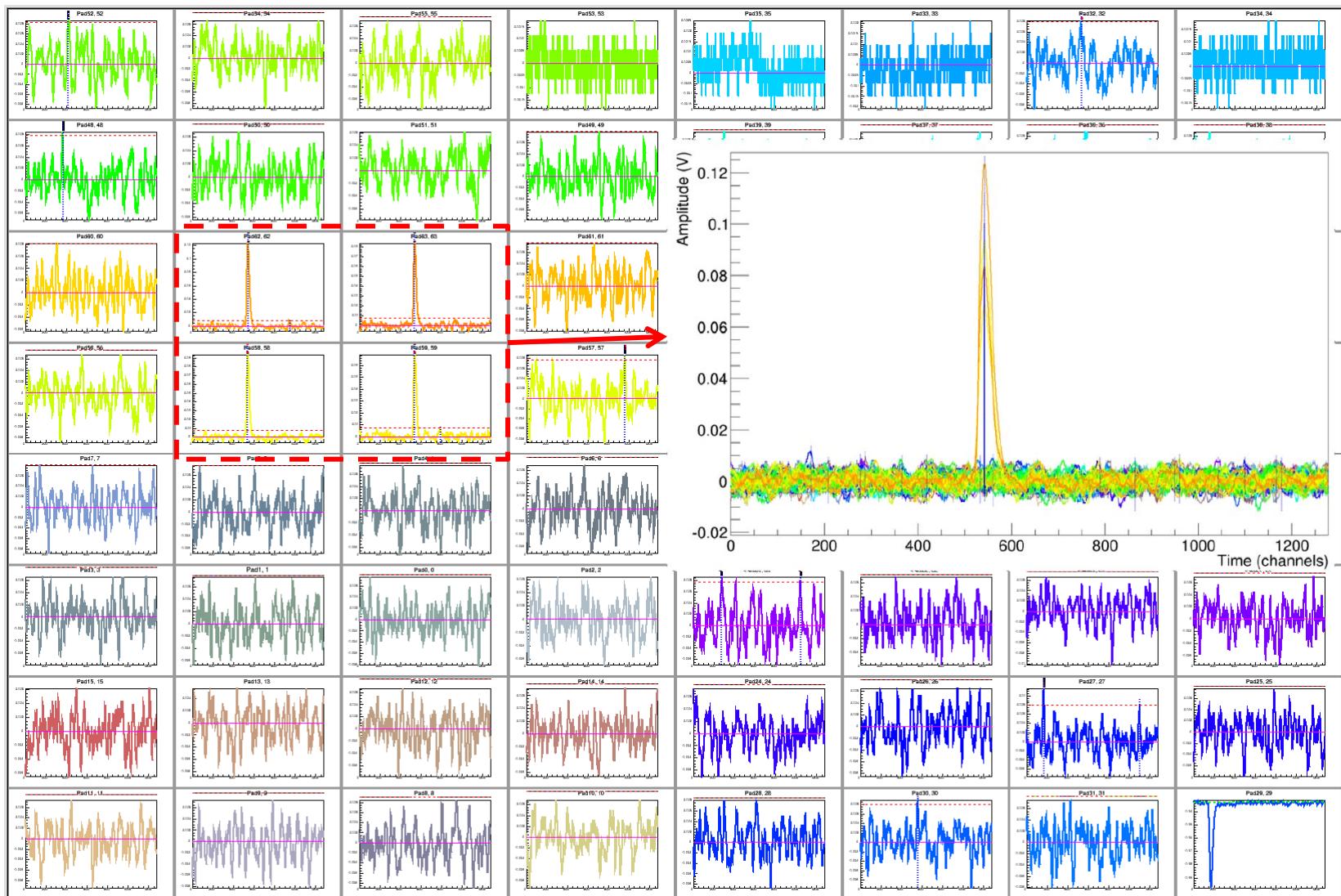
Anode 64 pixels
3.1 x 3.1 mm²

Noise : 85 +/- 5 e- (at -100 °C)

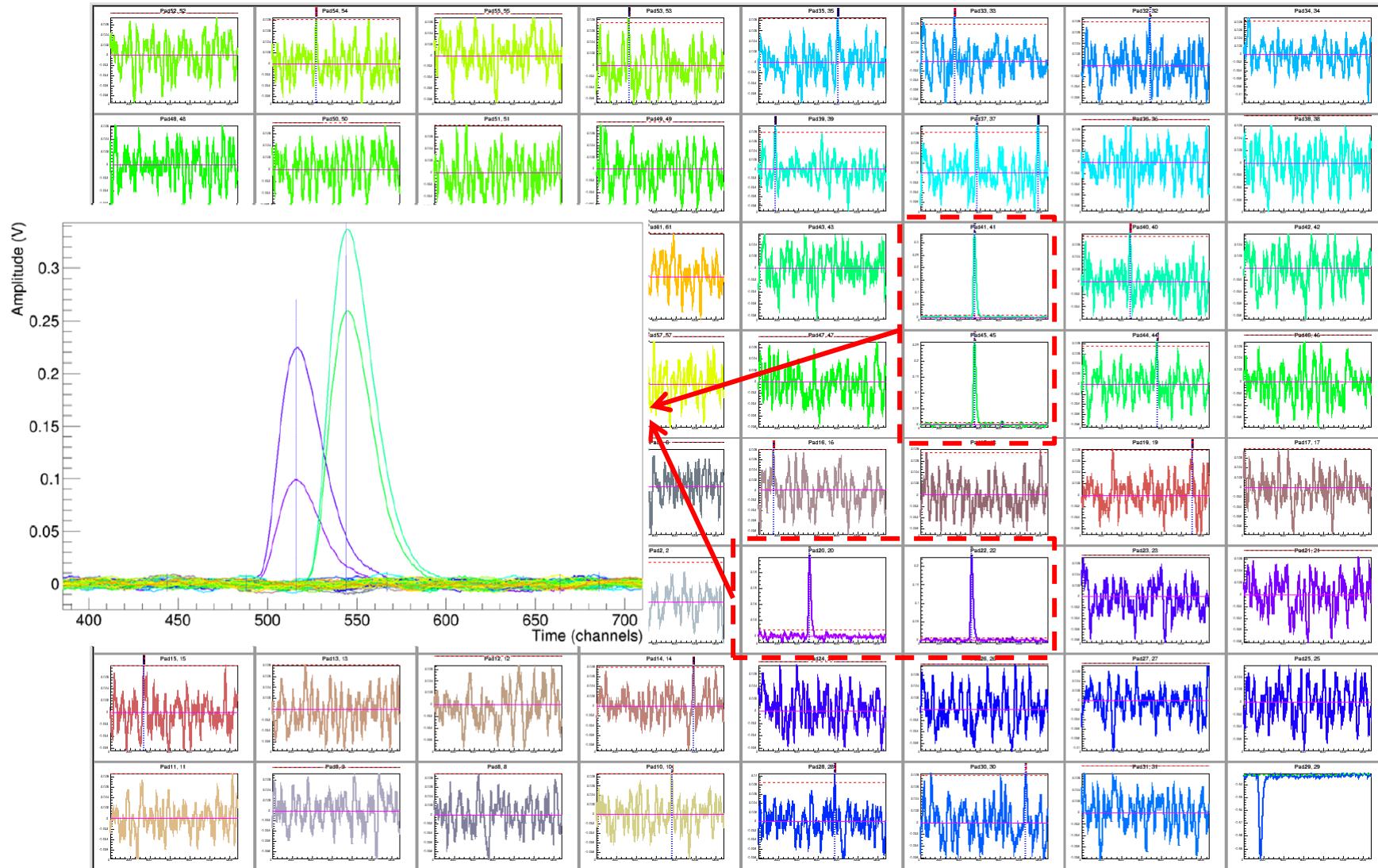
511 keV (@1 kV/cm) \Rightarrow 27200 e-



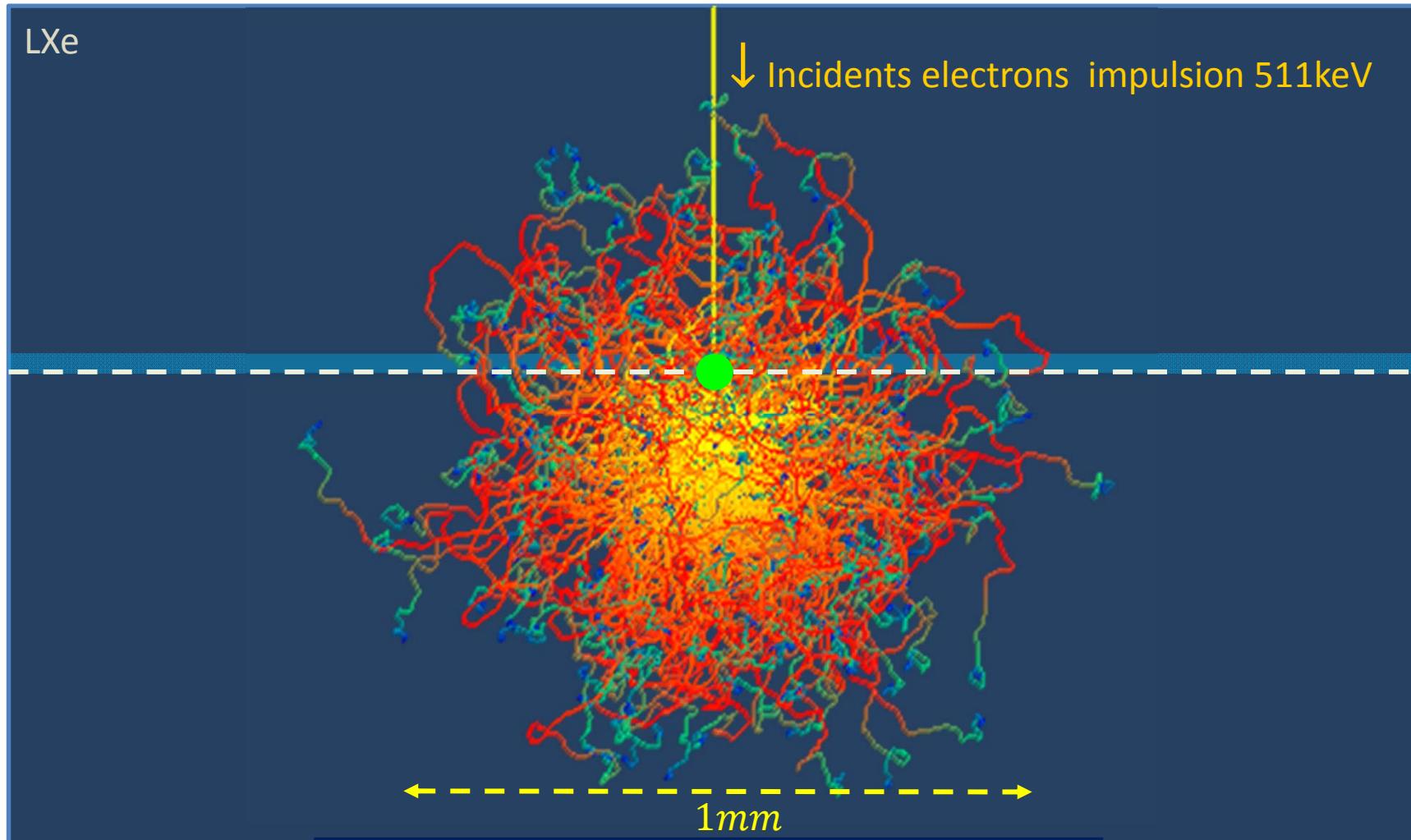
Ionization : signal @ 511 keV for Photoelectrics



Ionization : signal @ 511 keV for Compton

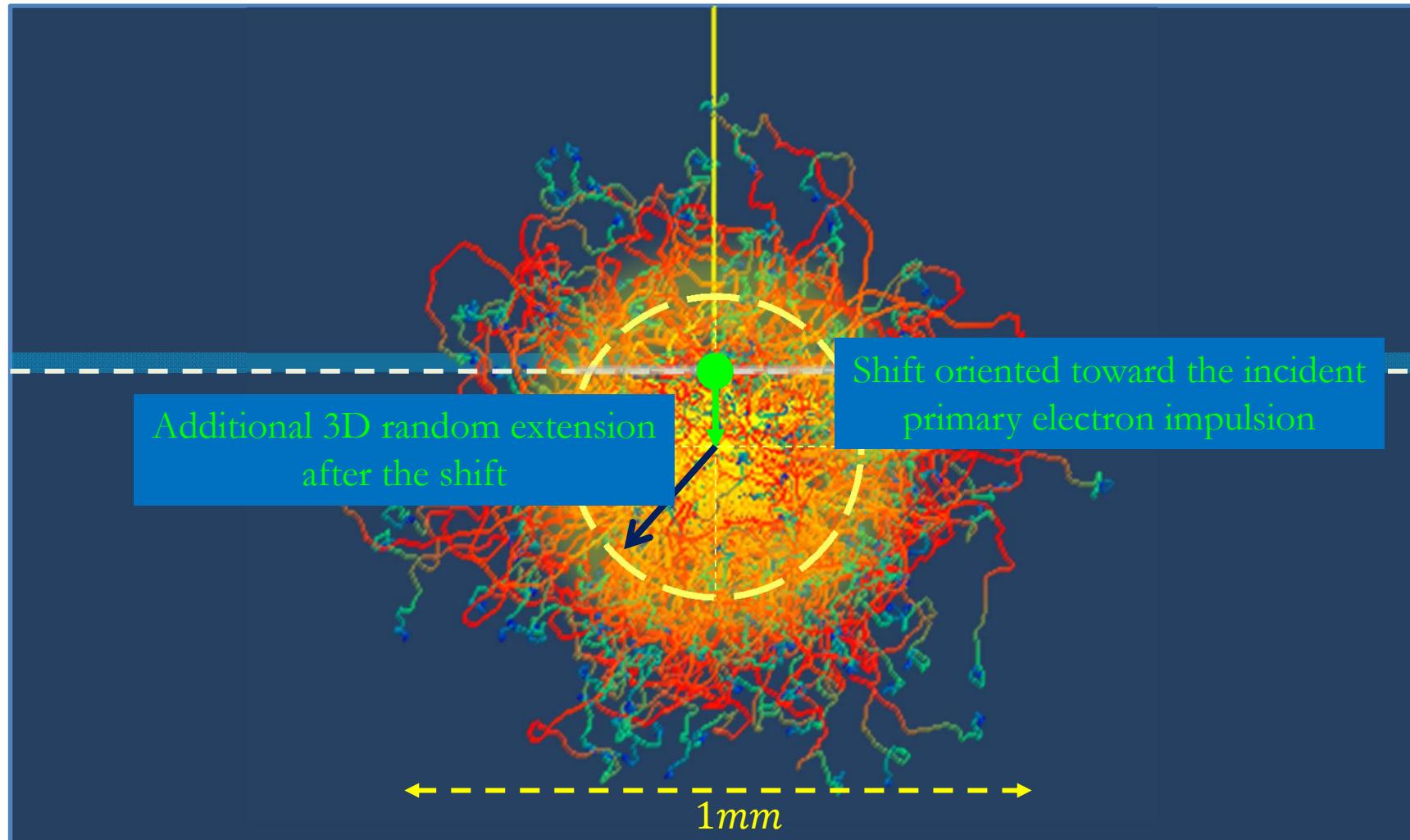


Ionization : recoil electrons in LXe with CASINO

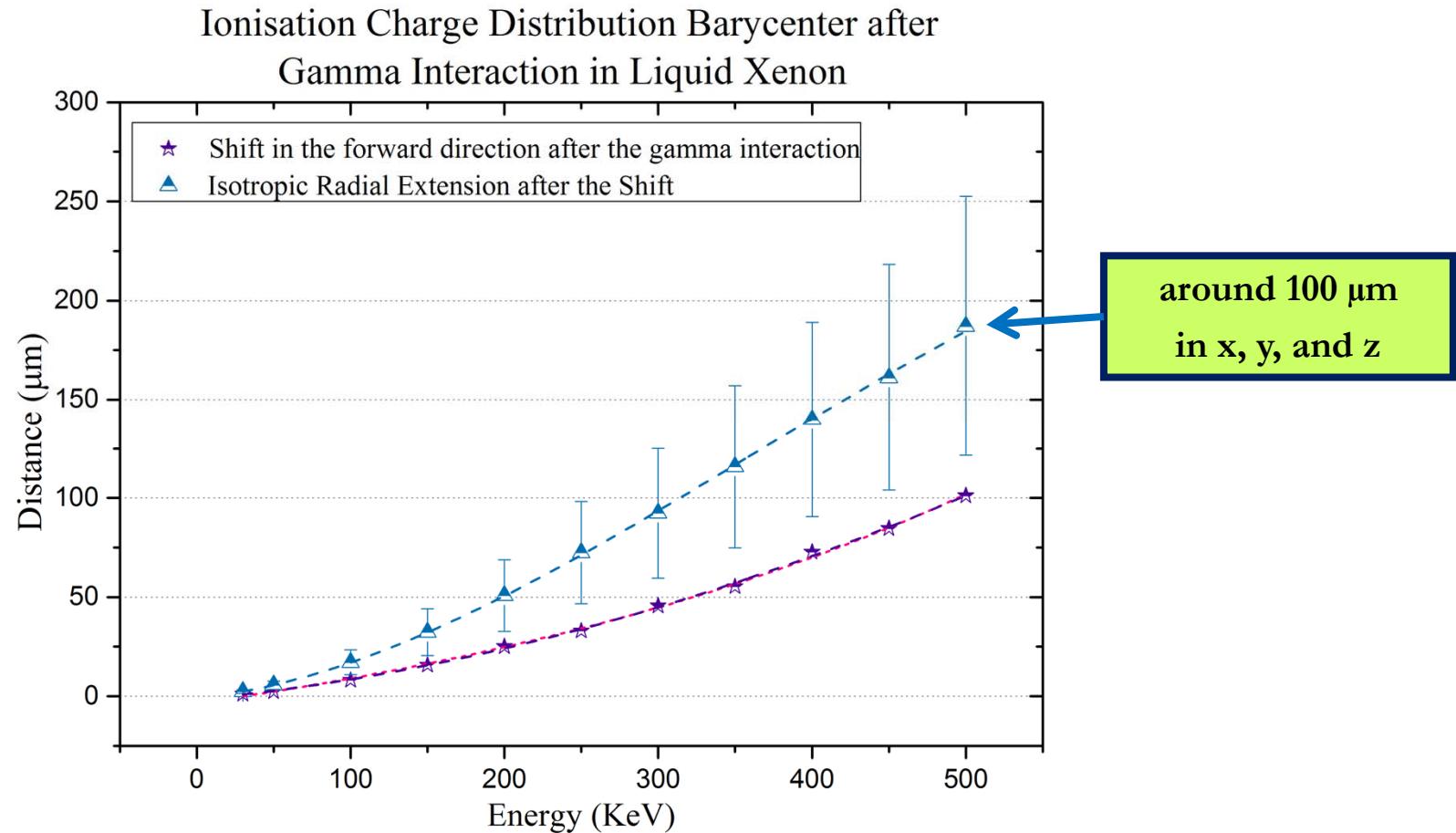


Ionization is generated on a dispersed cloud due to the chaotic trajectory of the primary electron

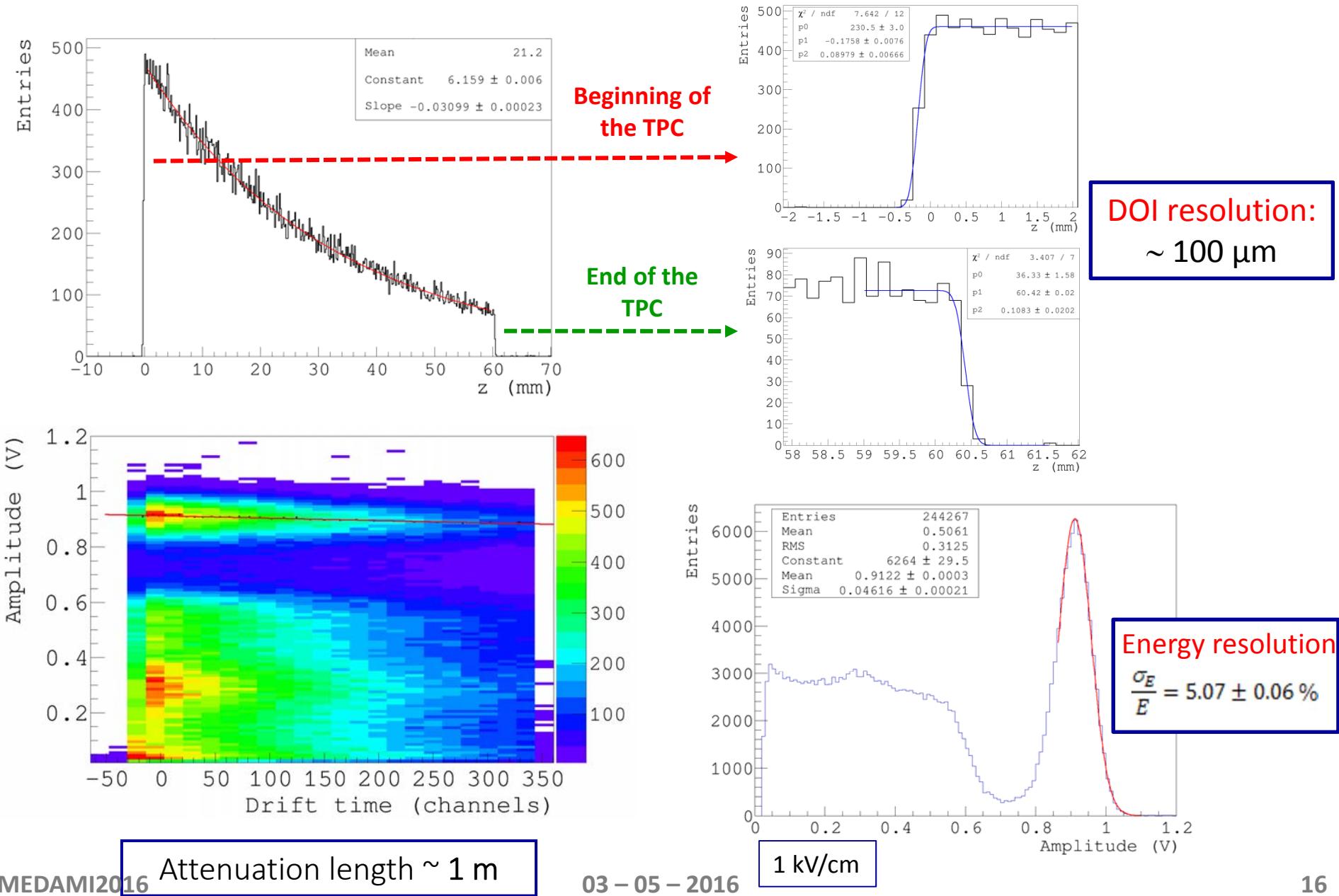
Ionization : recoil electrons in 1Xe



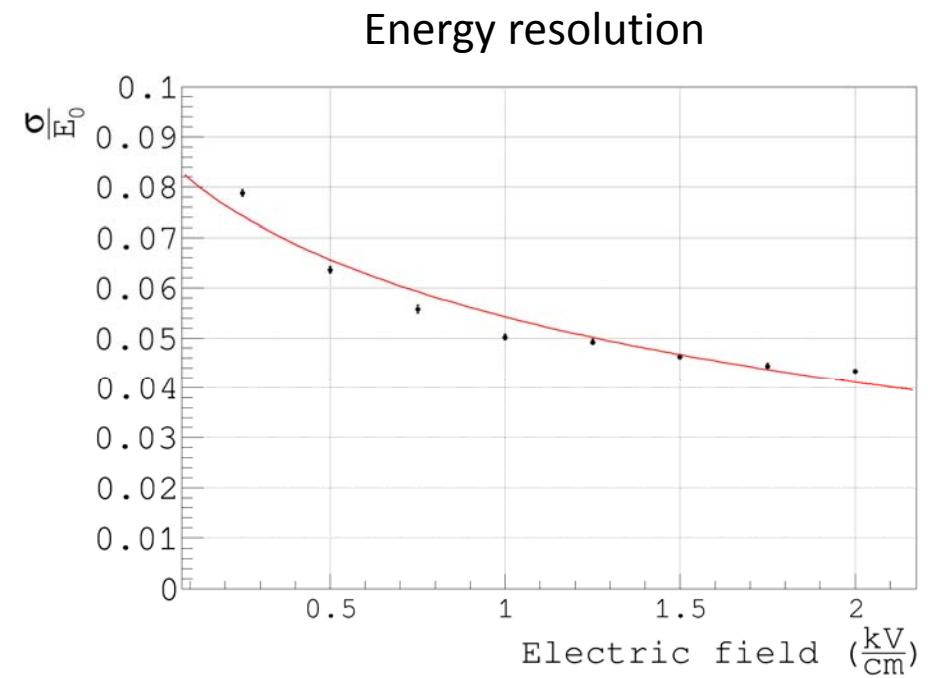
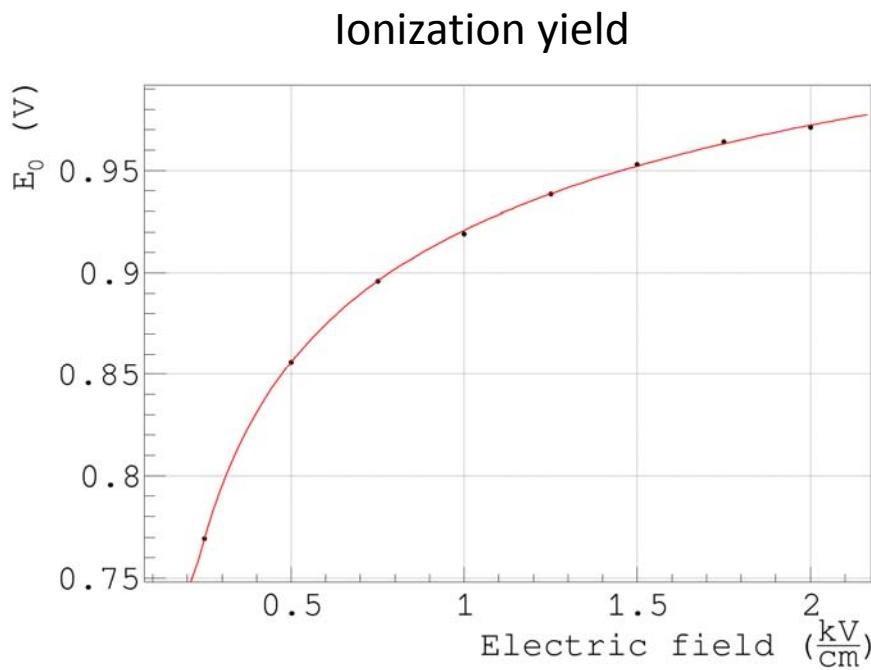
Ionization : achievable spatial resolution with recombinaison model (Thomas & Imel.)



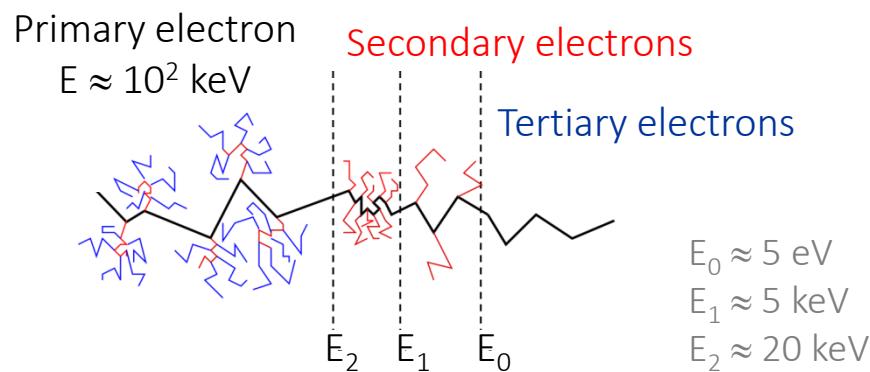
XEMIS1 : Ionization results @ 511 keV



XEMIS1 : energy resolution

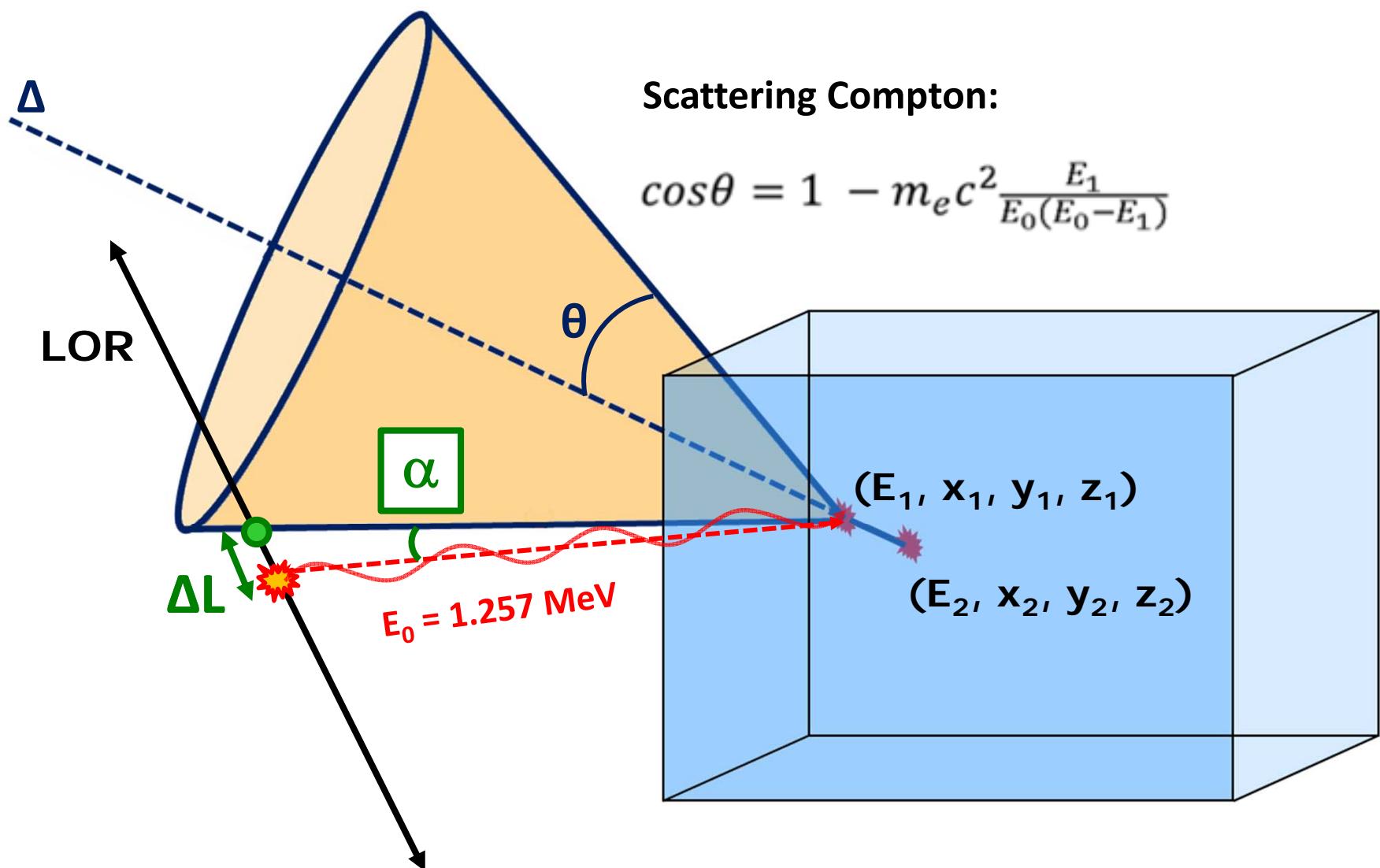


e-/ion Recombination :

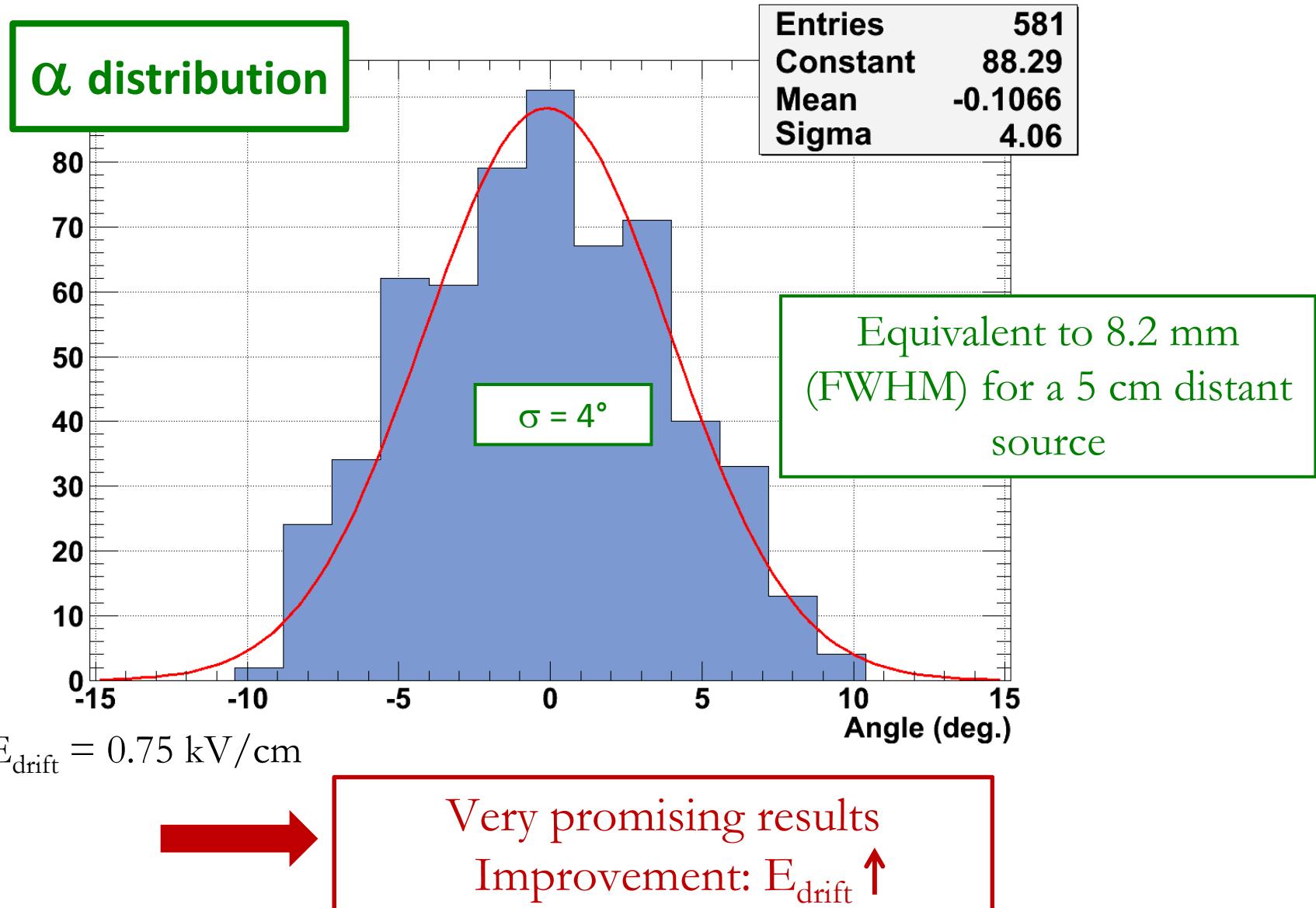


Best energy resolution
measured for the ionization
signal in LXe @ 511 keV.

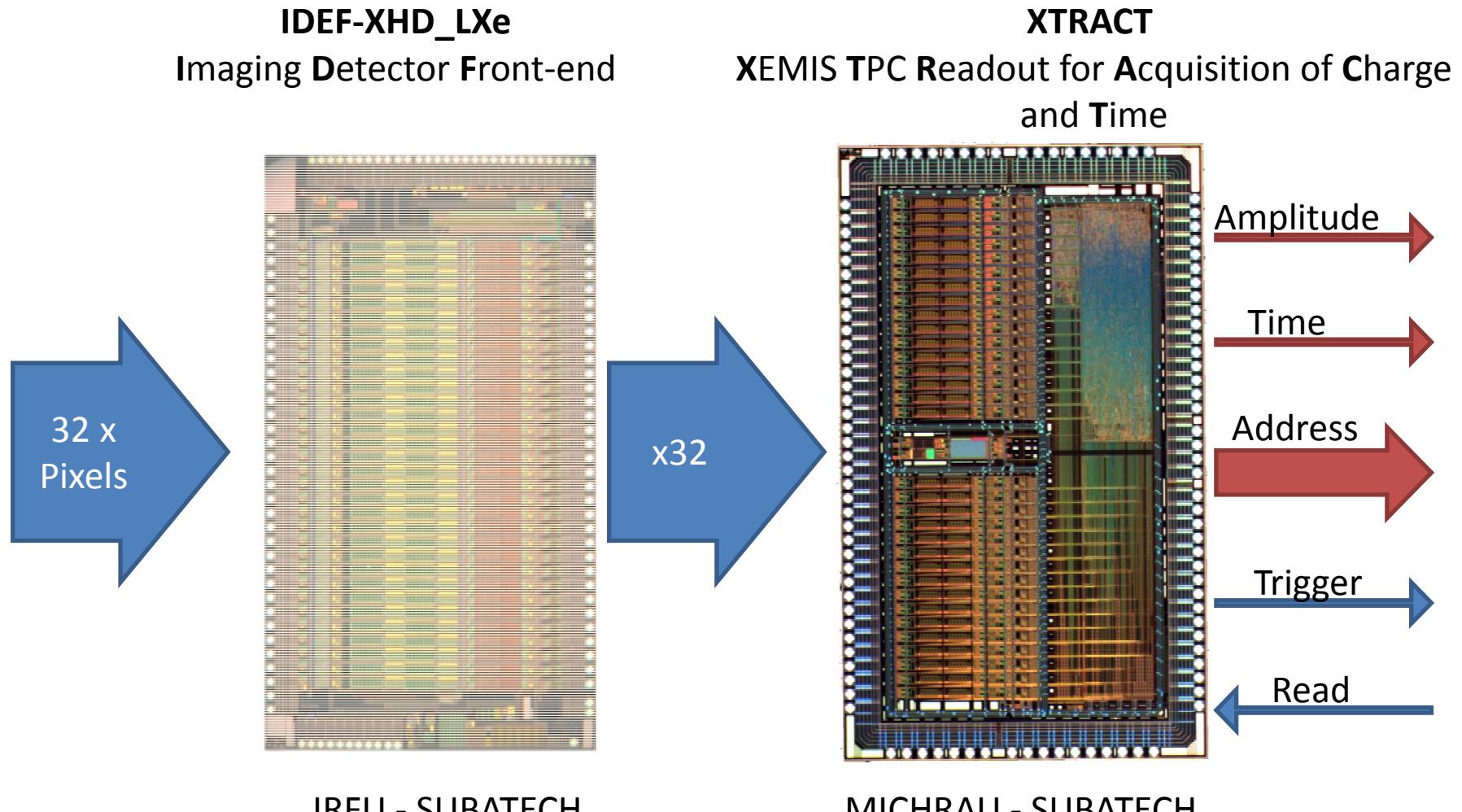
Cone – LOR intersection



XEMIS1 : resolution along the LOR

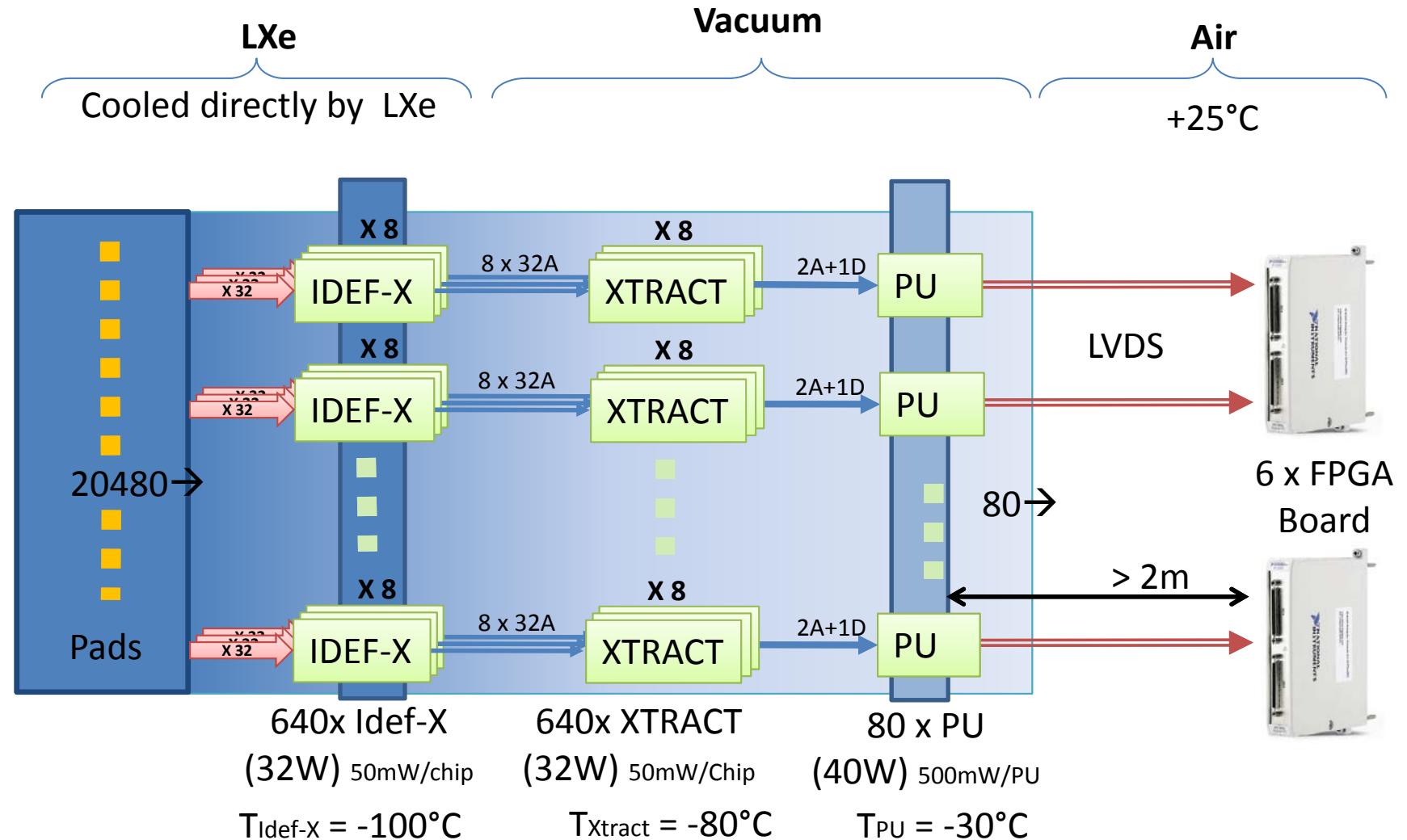


XEMIS2 : DAQ for Ionization



XTRACT v1 is on test, final version expected for 2017

XEMIS2 : ionization DAQ scheme



Challenge : Continuous read-out with negligible dead-time

Goal : record on disc 10^4 charge and time signals/pixel/s

XEMIS2 - ReStoX

ReStoX :

Recovering and Storage
system for liquid Xenon

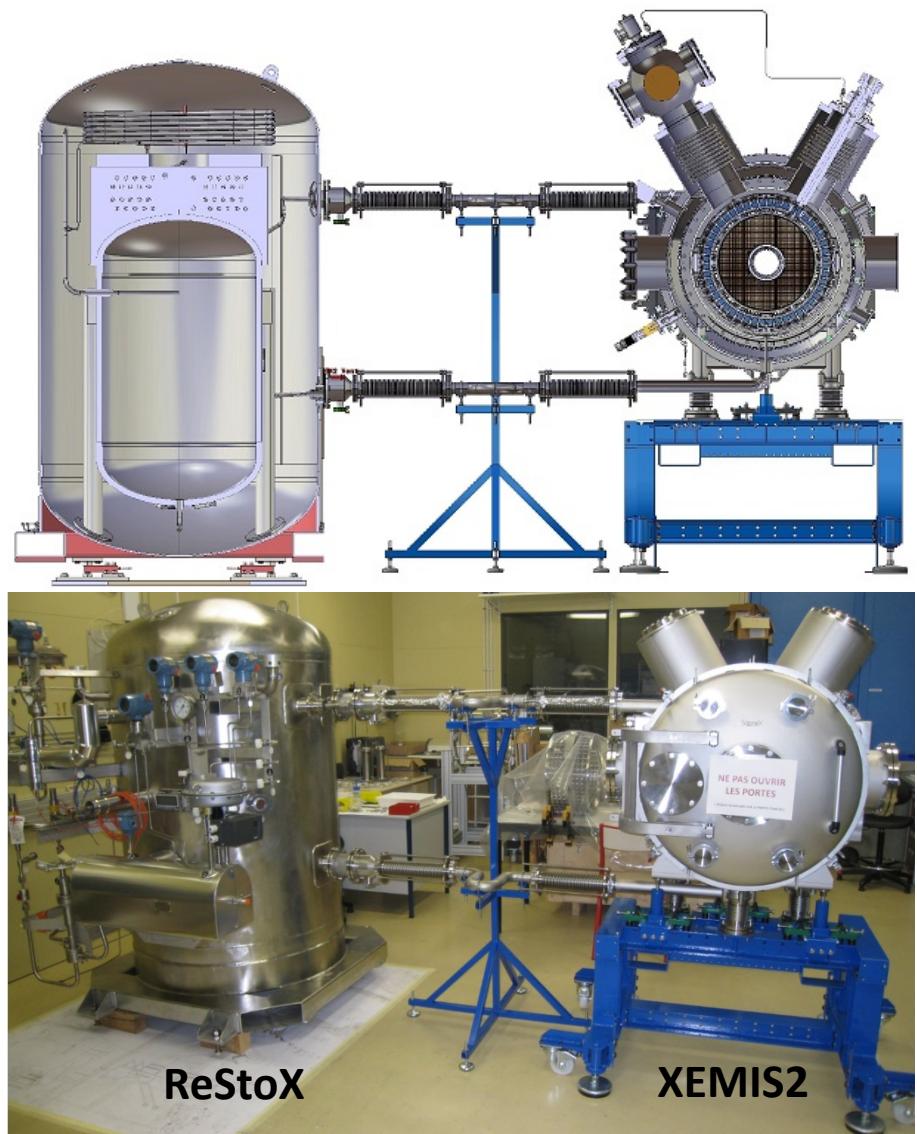
Scientific collaboration :



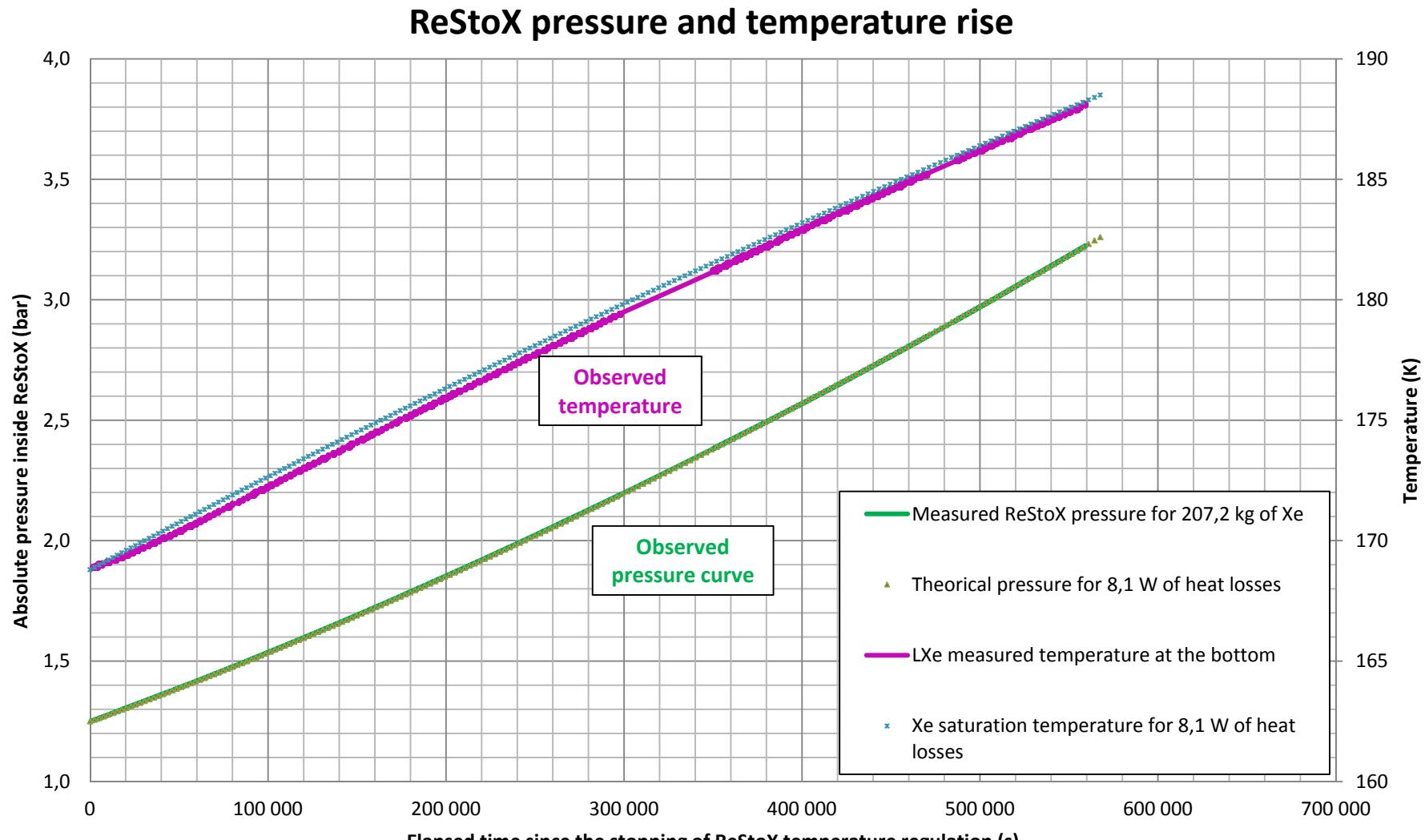
Install a liquid xenon
camera in a hospital ?

Xenon cryogenics of XEMIS2 :

- compact (210 kg capacity)
- safe (from RT to -110°C)
- powerfull (up to 10 kW)
- ultra clean (ppb impurities lvl)



Commissioning : ReStoX pressure rise-up



Conclusions

- 3γ imaging in a new approach targeting theranostics and phenotypics imaging
- It involves new technologies and a lot of innovations for the cameras design
- XEMIS covers initial TRLs inside a scope compatible with fundamental researches frame
- Expected image qualities are very promising :
 - very low activity in the FOV
 - good spatial resolution of in all the FOV
 - fast scan of all the FOV
- **It should be considered for precise and personnalise medecine**