DIRECT ELECTRONIC RECOIL MEASUREMENT BY IONIZATION IN LXE FOR 3γ IMAGING

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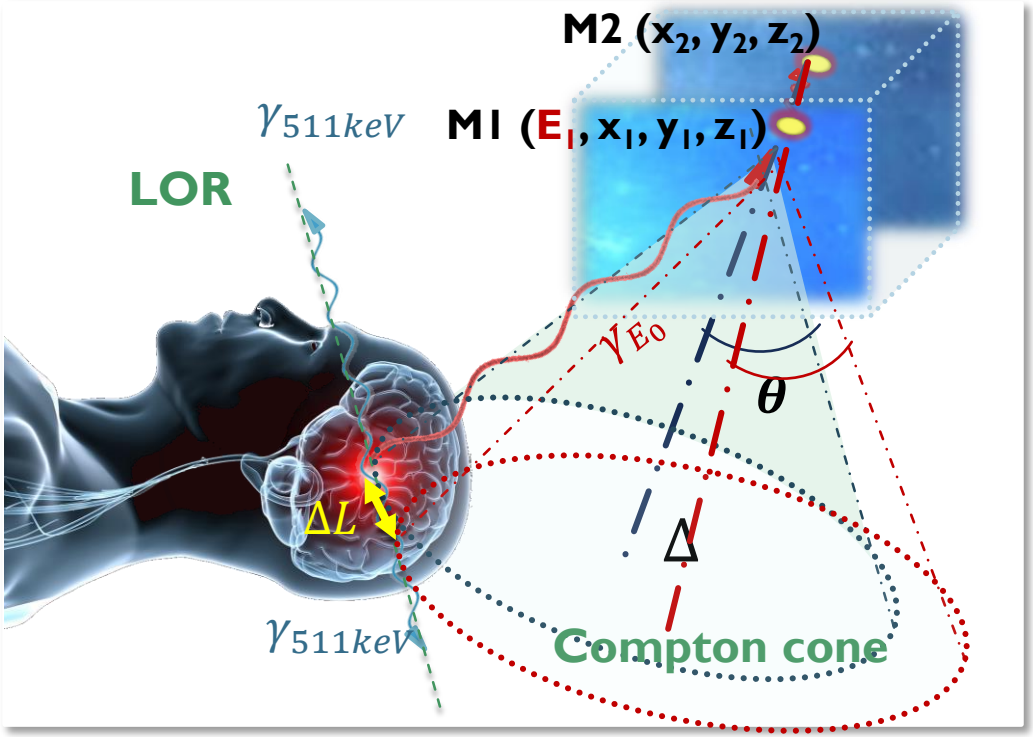
OUTLINE

- Introduction
- XEMIS1 R&D Prototype
- Analysis & Results
- Summary

Principe of 3γ Imaging

----- Line of response LOR & Compton cone



^{44}Sc
- β^+ (E_{max} = 1.472 MeV)
- γ (E_0 = 1.157 MeV)
- $T_{1/2}$ = 4 h

γ direction reconstruction :

$$\cos\theta = 1 + m_e c^2 \left(\frac{1}{E_\gamma} - \frac{1}{E_1} \right)$$

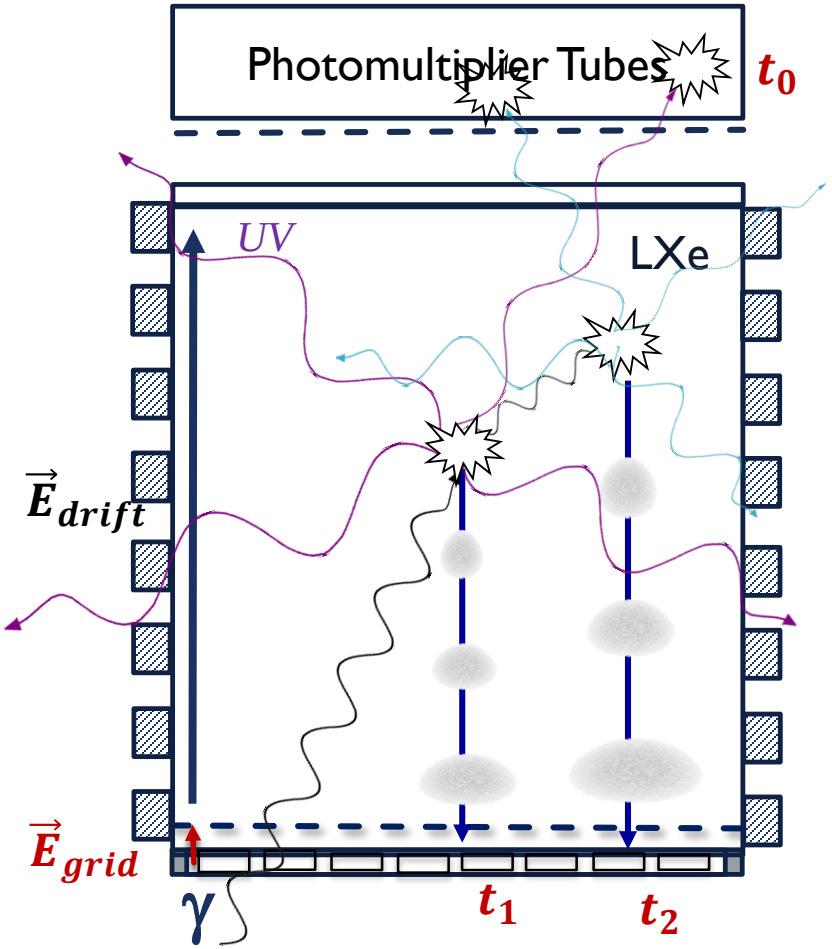
Spatial Resolution
↪ Axis of the cone Δ

Energy Resolution
↪ Opening angle θ

- Direct 3D location of the radioactive source
- Administered dose reduction &/or shorter scan times

Single Phase LXe TPC

Direct Electronic Recoil Measurement by Ionization



Scintillation signal

UV detection by PMT

↪ γ−Xe Interaction Time t_0

Ionization signal

Ionized electrons transport

&

Electronic signal forming

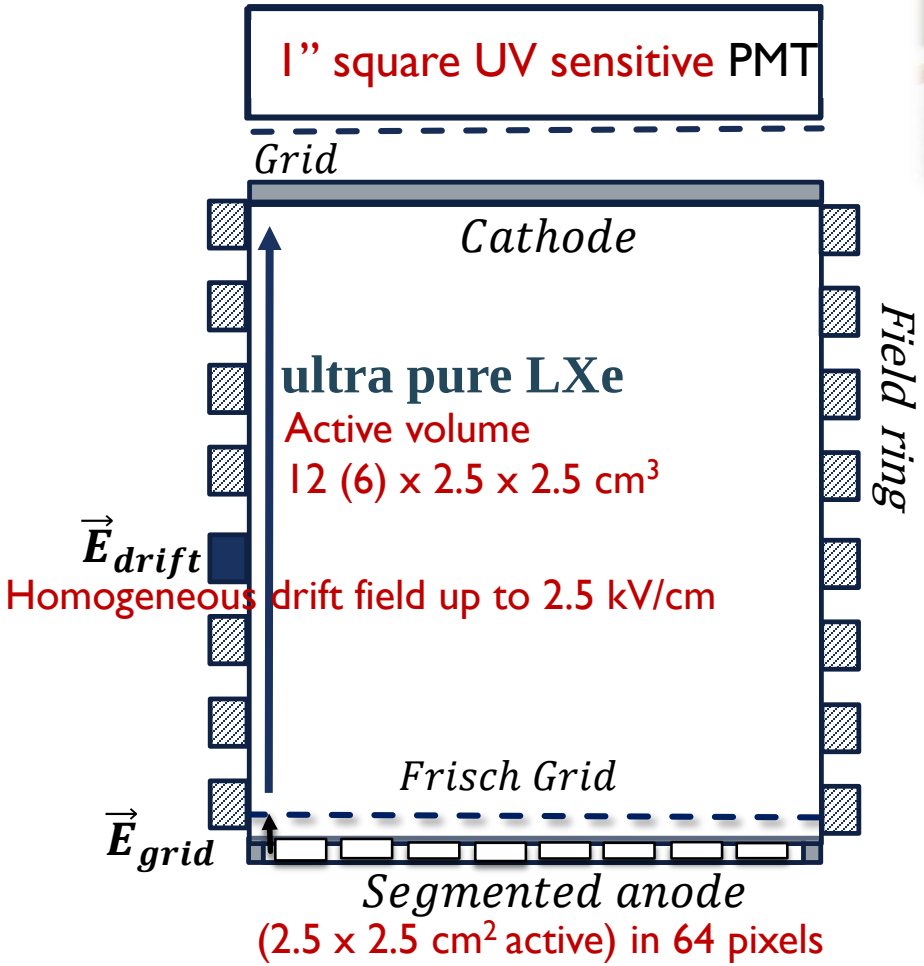
↪ Drift time $t_1 \rightarrow z$

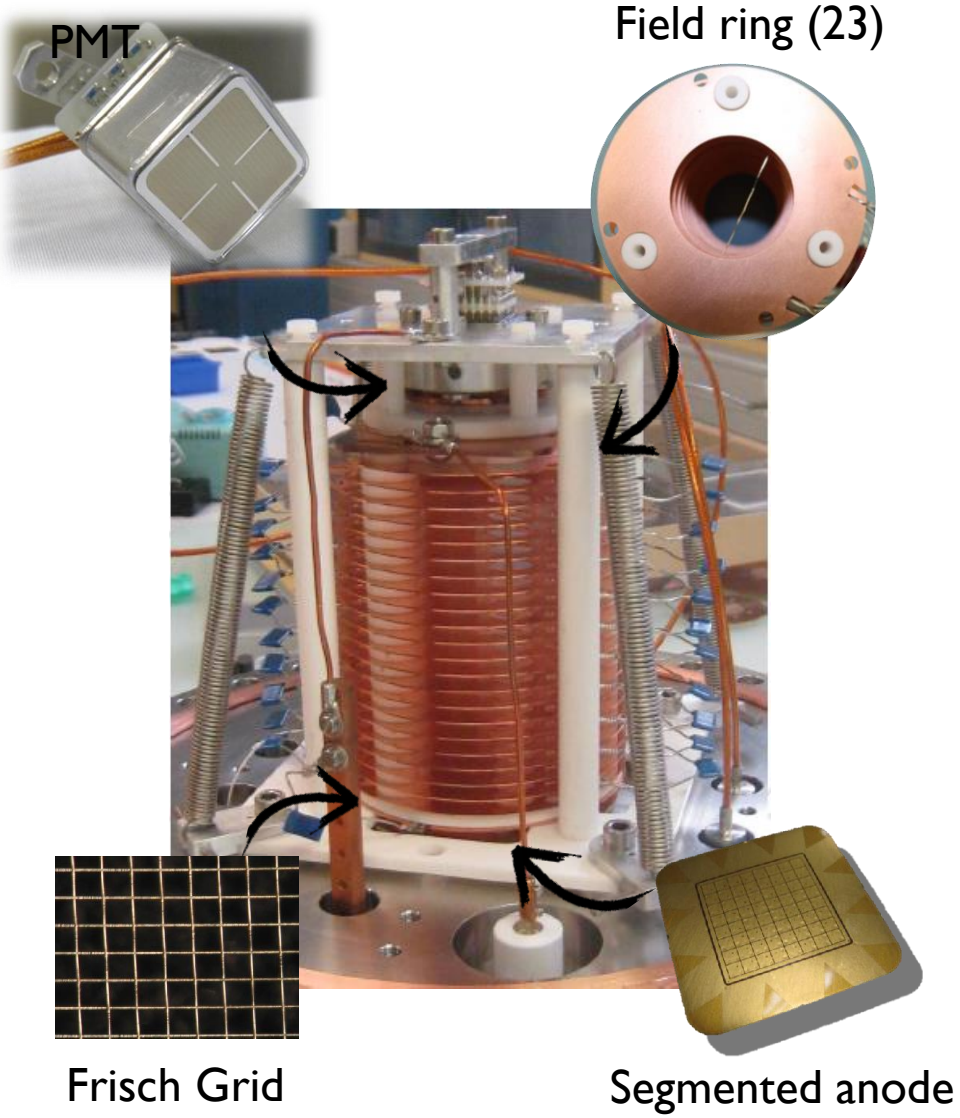
↪ Amplitude $N_e \rightarrow$ E

↪ (x, y)

↪ Energy E and 3D position (x, y, z) of each interacion

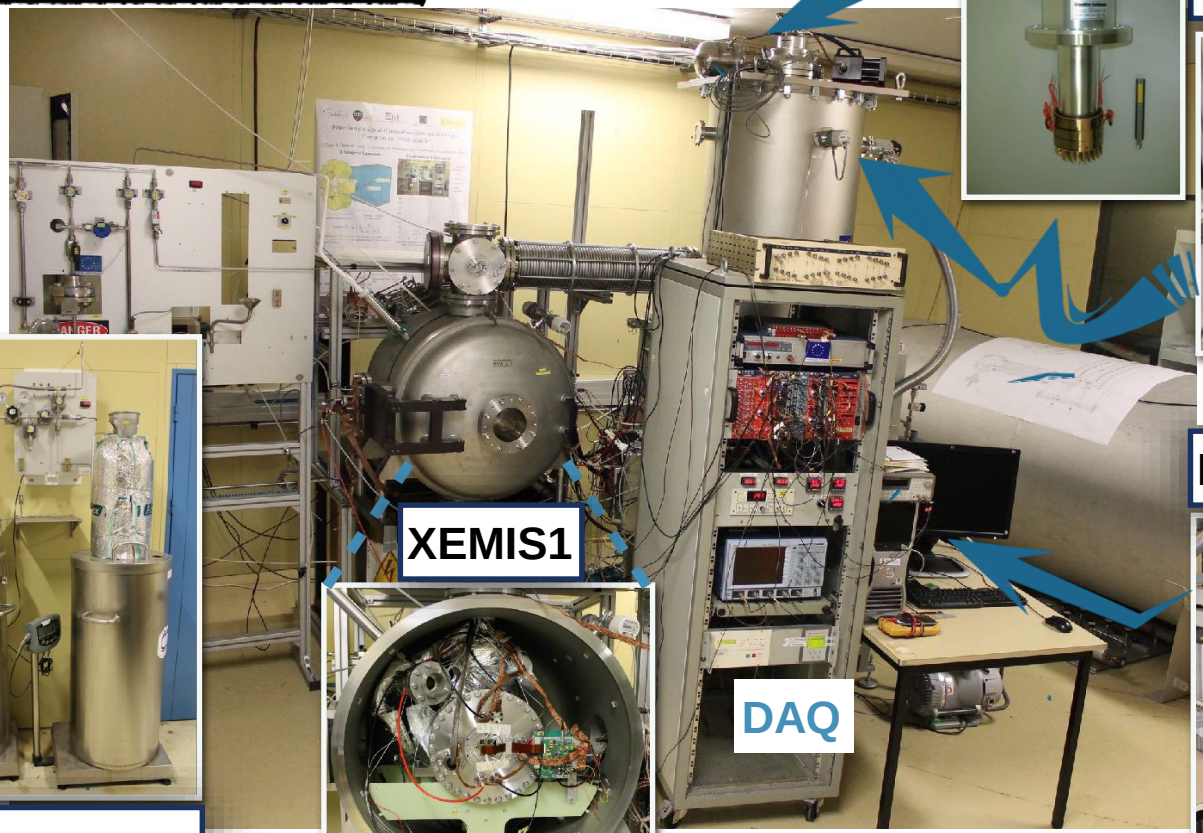
XEMIS1 R&D Prototype





XEMIS1 Facility

Experimental Conditions:
168 K - 1.2 bar



PTR

Liquefaction

Heat exchanger

Purification

Getters

XEMIS1

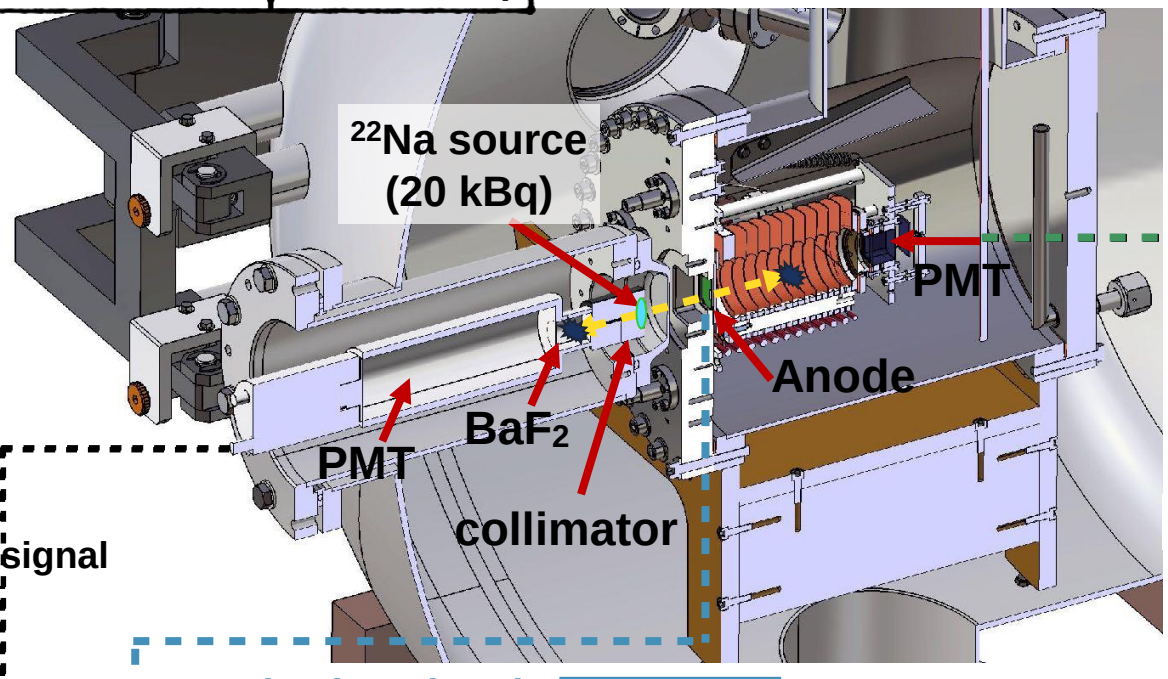
Cryostat

DAQ

Storage

Experimental Set-up @ 511 keV

^{22}Na: ($E_{max}\beta^{+}$= 545 keV, E_{γ}= 1.274 MeV)



BaF2 signal

LXe Scintillation signal

Ionization signal

Time Coincidence

Trigger

ADC

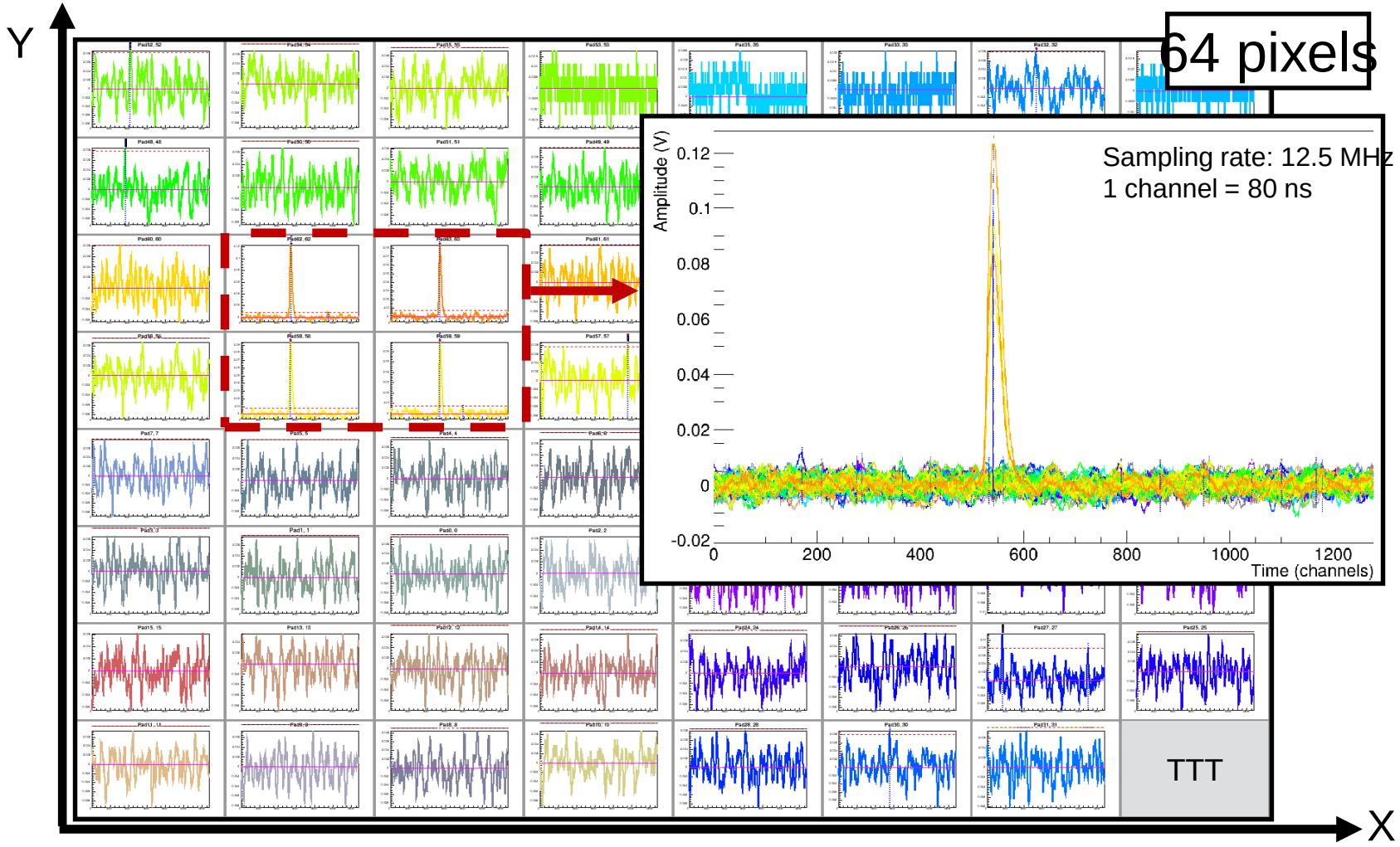
ADC

12.5 MHz digitizer

250 MHz digitizer

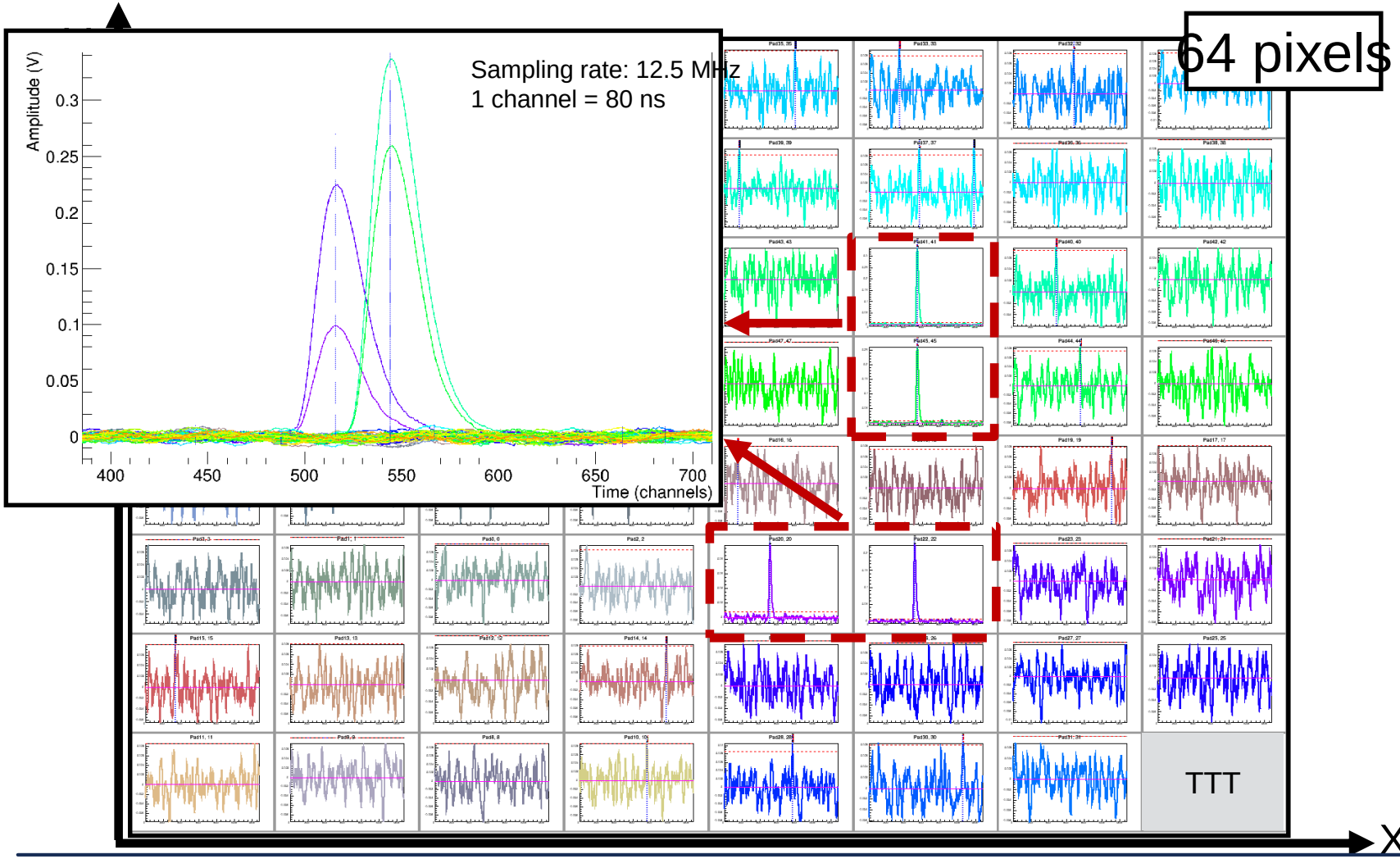
Ionisation signal @ 511 keV for Photoelectrics

Event reconstruction: Compton scattering /**photoelectric effect** identification



Ionisation signal @ 511 keV for Compton

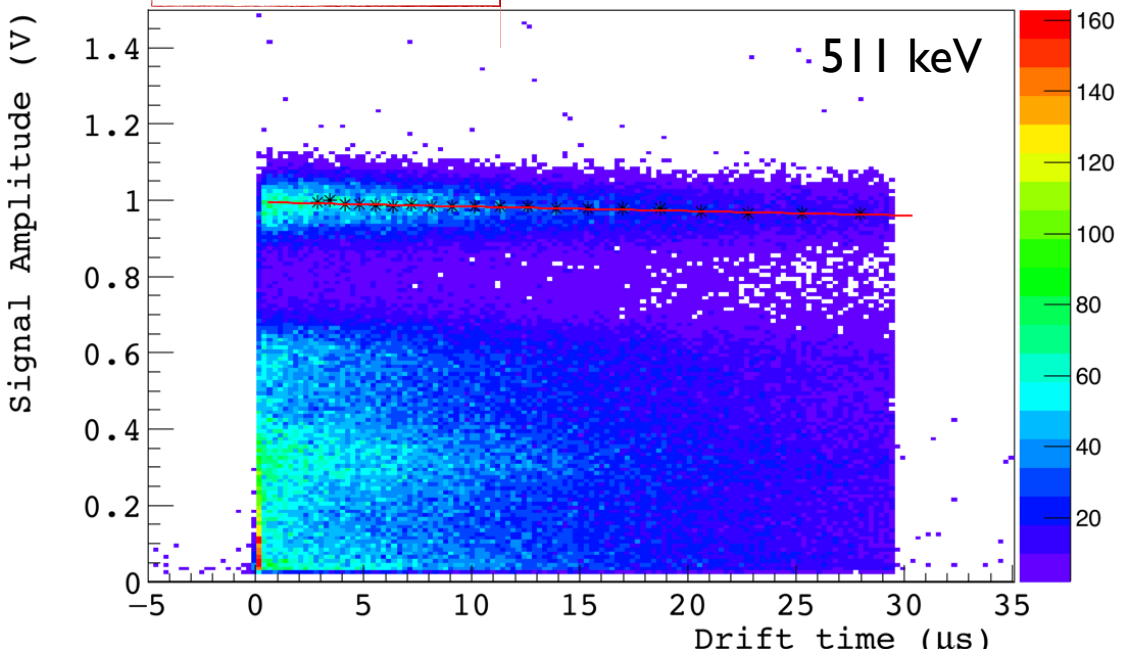
Event reconstruction: Compton scattering /photoelectric effect identification



Electron Attenuation Length

Electronegative impurities → electron loss during drift

$$Q(t) = Q_0 \, e^{\frac{-t}{\tau}}$$



One week → Attenuation length >1 m

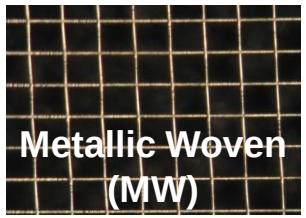
⬇

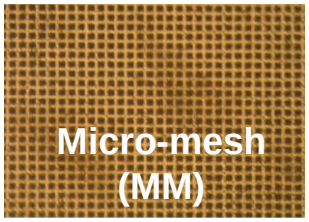
Concentration of 1 ppb O_2 equivalent

Gridded Ionization Chamber

Ionization signal affected by:

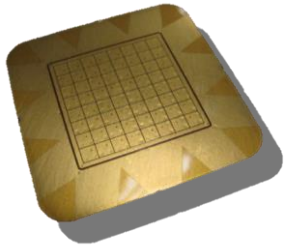
Frisch grid





- Transparency of the grid
- Efficiency of the grid

Segmented Anode



64 pixels

Pixel size:
3.125*3.125 mm^2

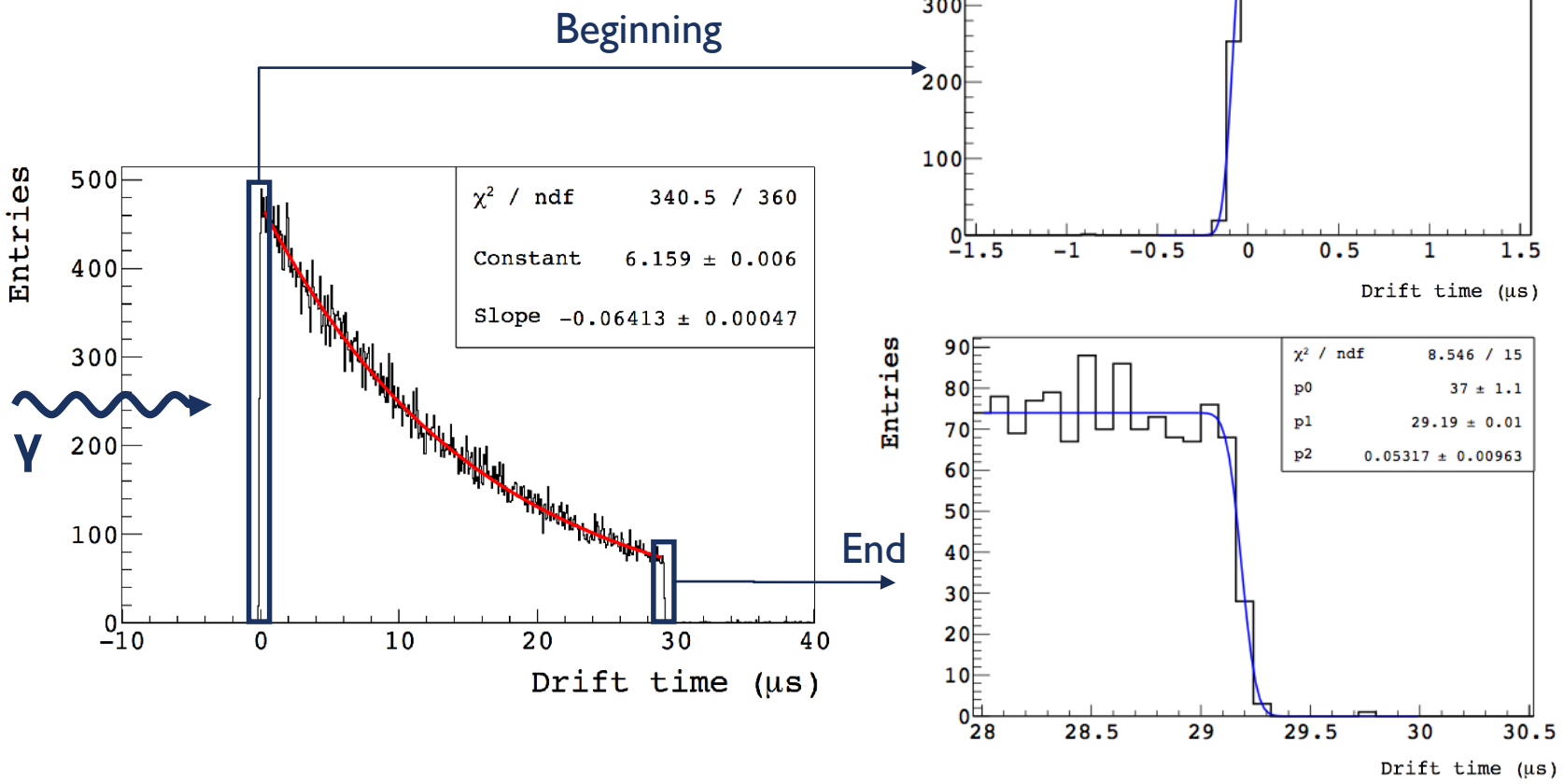
Small pixel effect:
induction in non-collecting pixels

Grid	Tech	Pitch	Thickness	Bar thickness
500 LPI	MM	50.8 µm	5 µm	12 µm
200 LPI	MM	127 µm	5 µm	24 µm
100 LPI	MW	254 µm	50 µm	25 µm
70 LPI	MM	362 µm	5 µm	18.5 µm
50.3 LPI	MW	505 µm	60 µm	30 µm

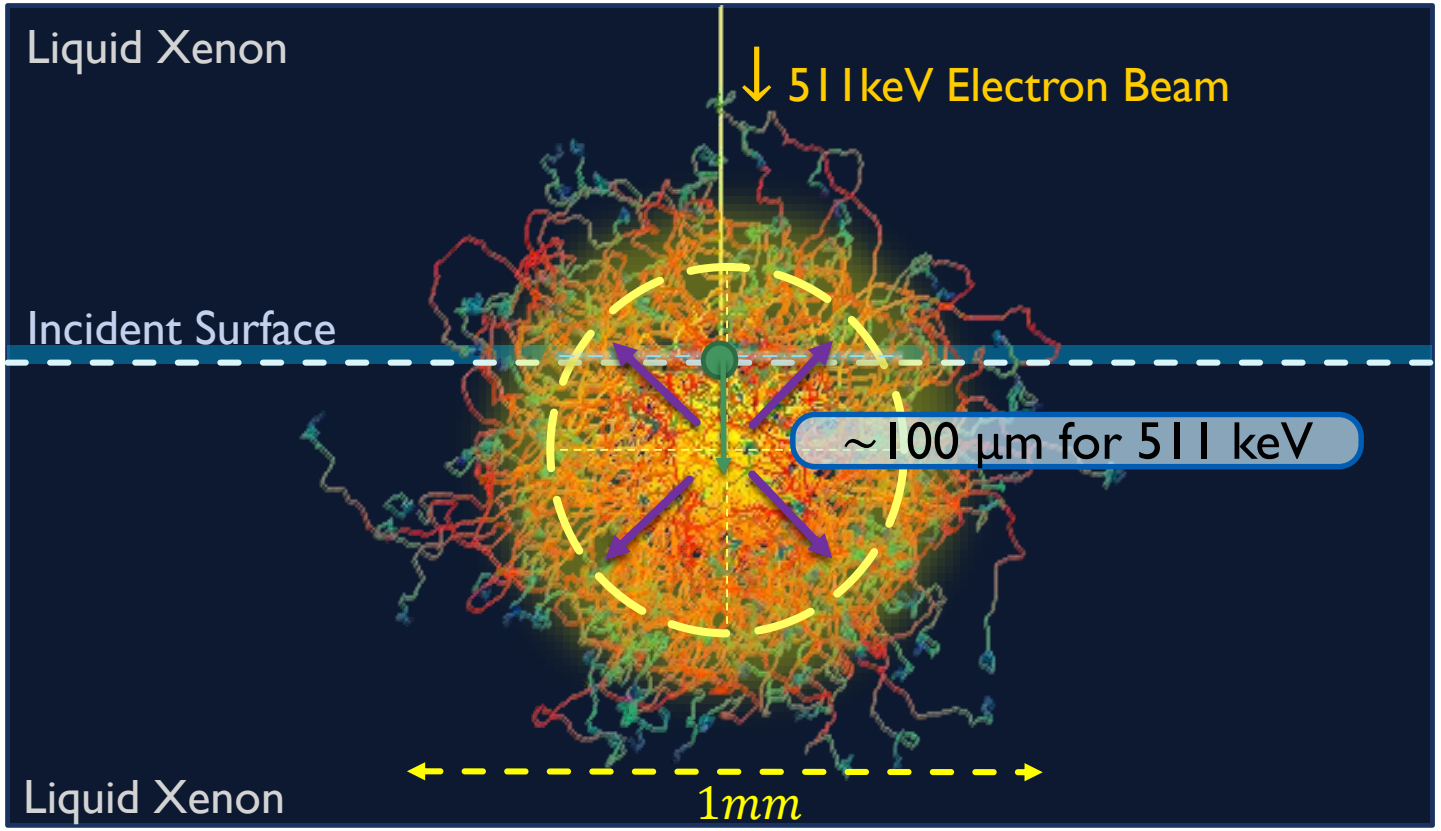
Gap grid-anode
1 mm
500 µm
125 µm

XEMIS1: DOI resolution @511 keV (1 kV/cm)

Drift time resolution: ~ 50 ns
DOI resolution: ~ 100 µm



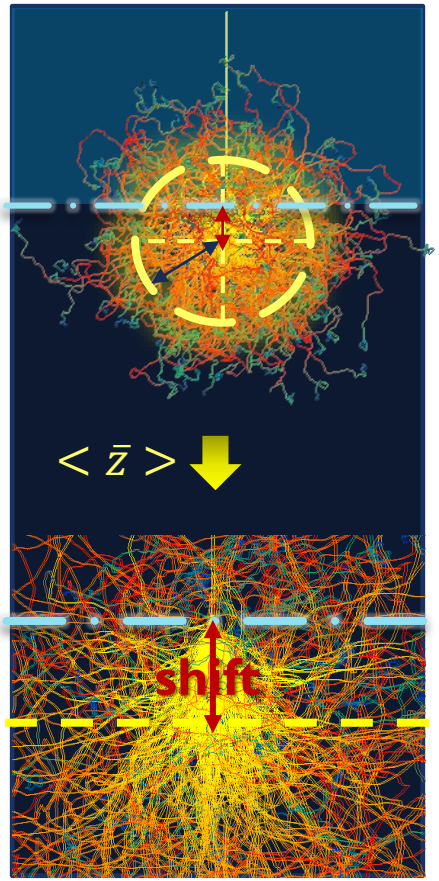
IONIZED ELECTRON CLOUD DISTRIBUTION

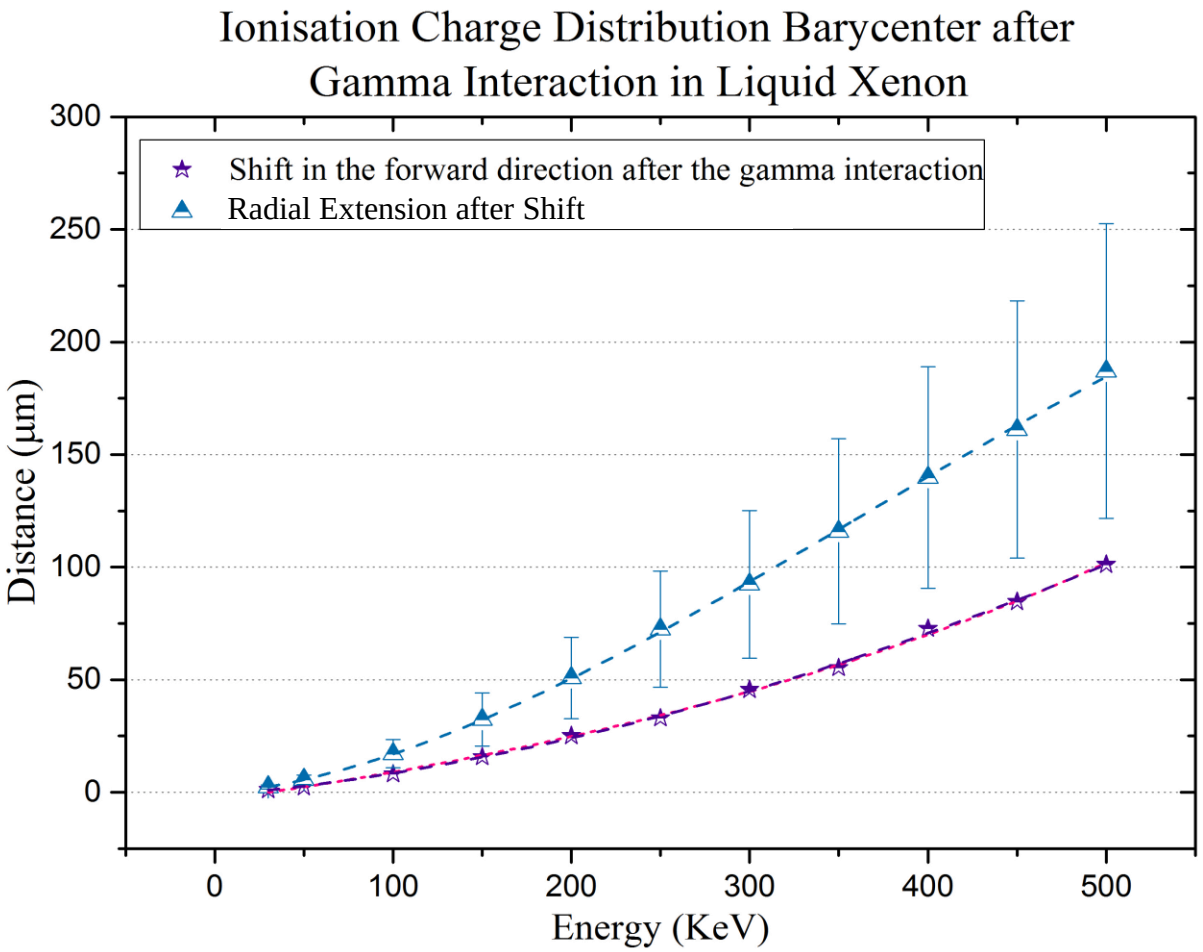


Spread of the electron cloud due to the chaotic trajectory of the primary electrons

Barycenter of Ionized Electrons Clouds

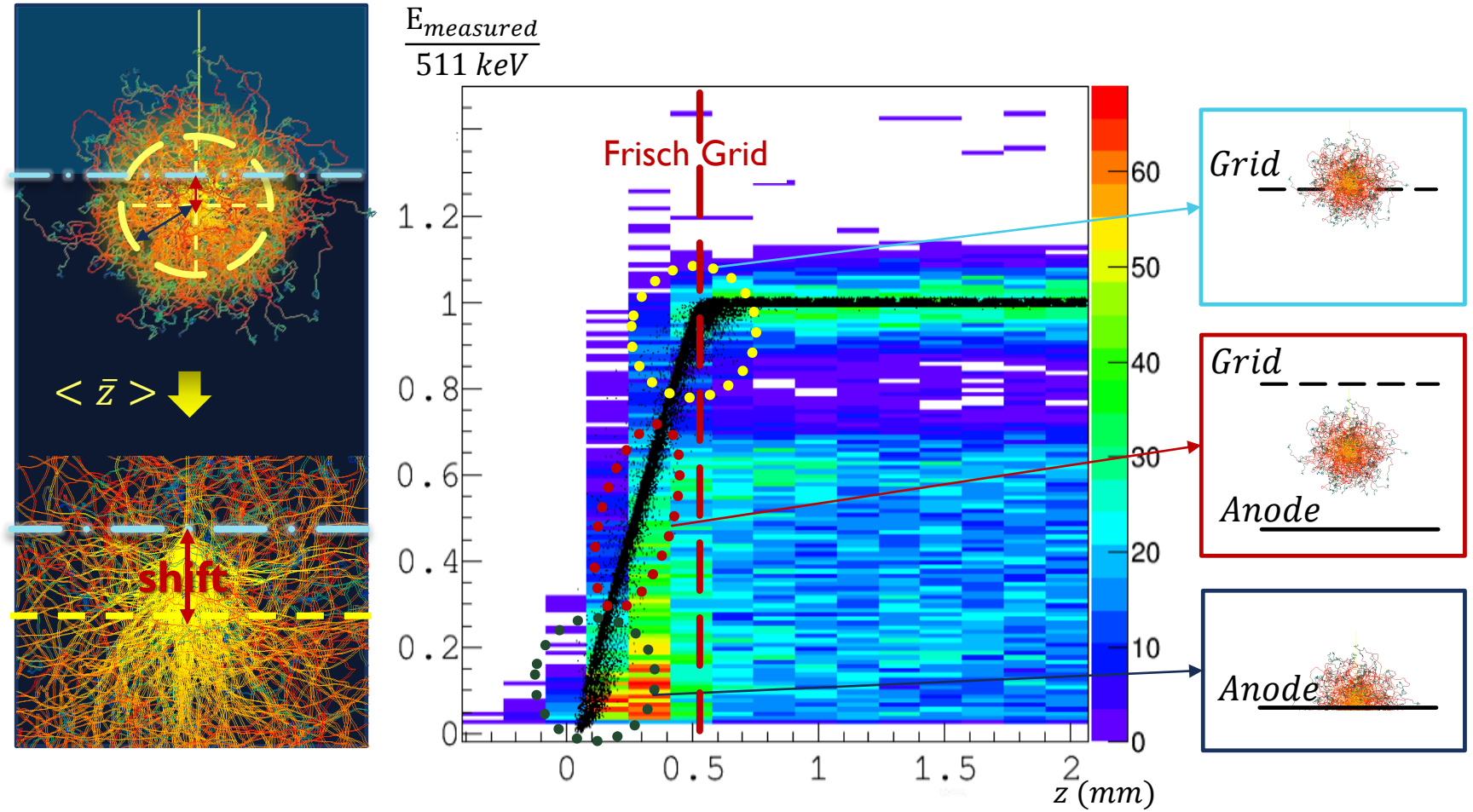
For primary electrons in different energy



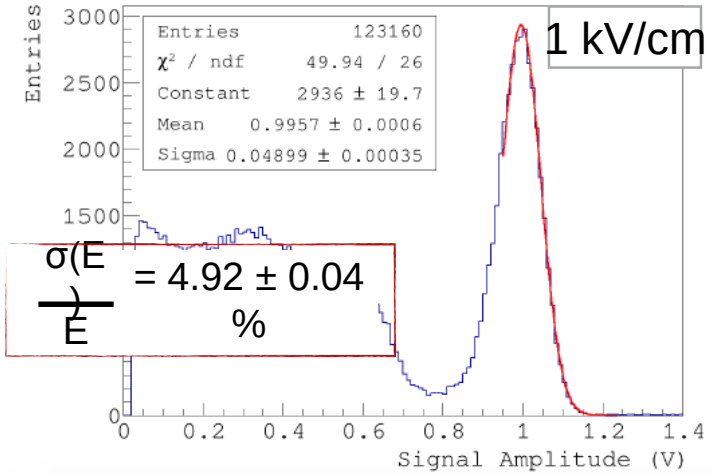


Barycenter of Ionized Electrons Clouds

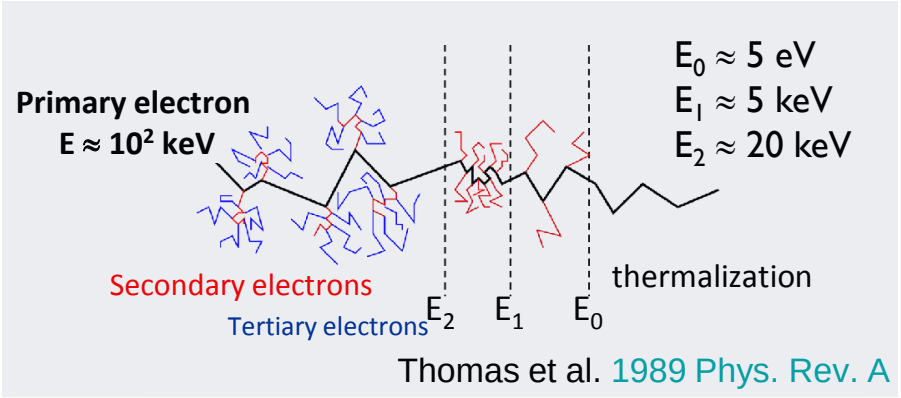
Simulation result compared to the experimental datas



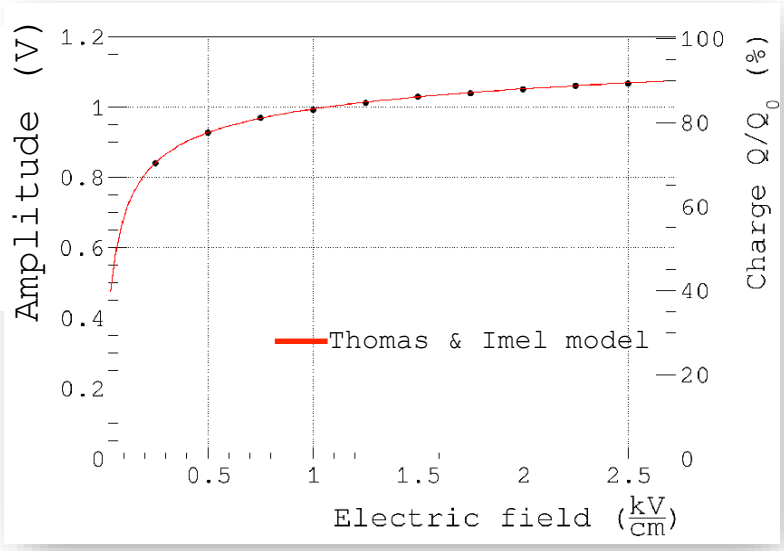
XEMIS1: Energy Resolution @511 keV

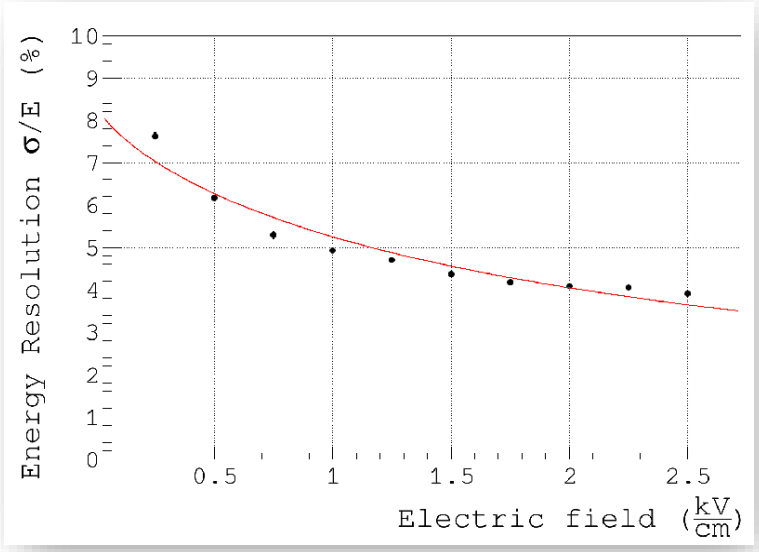


Recombination in LXe: Thomas & Imel model



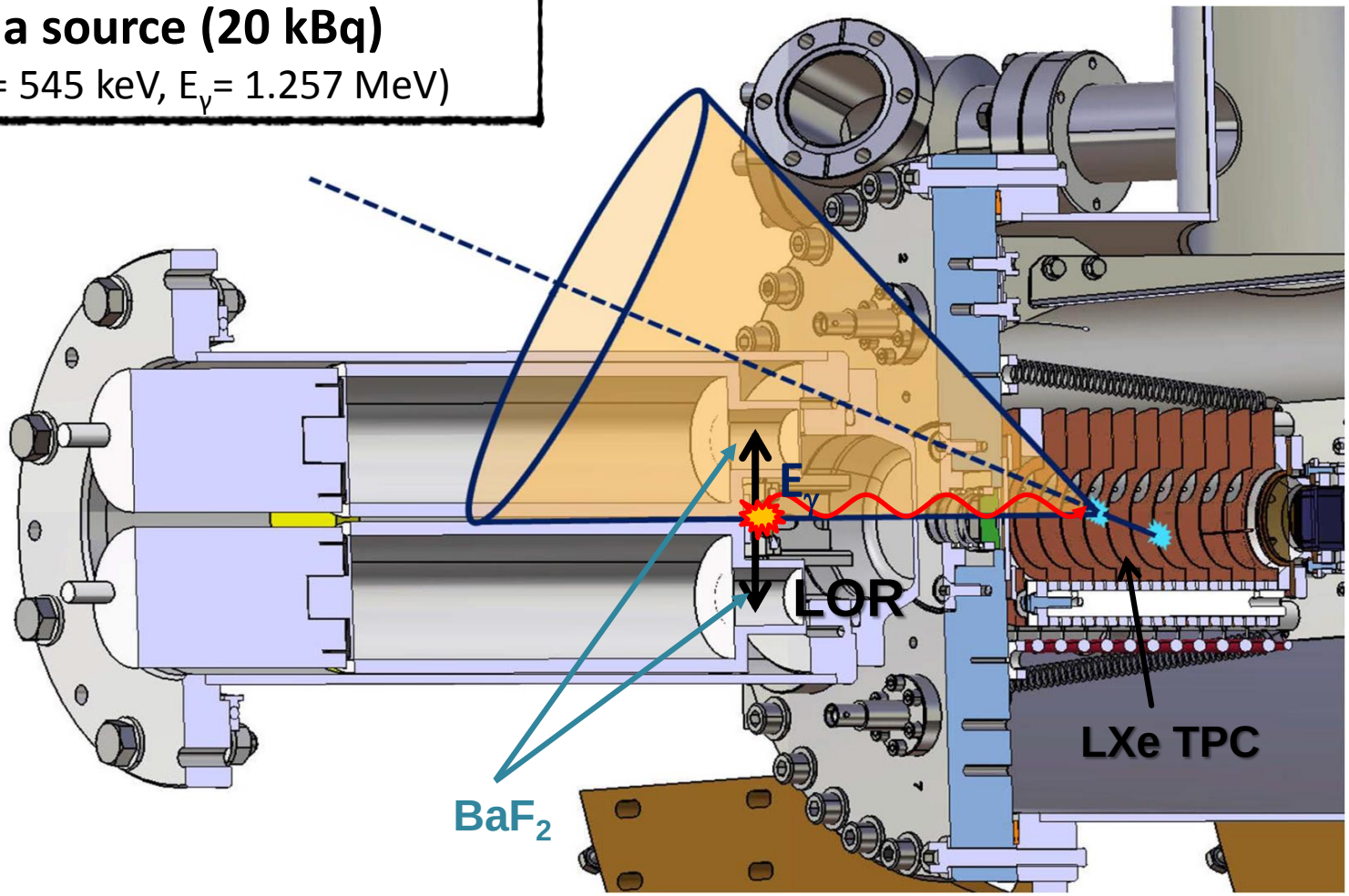
Thomas et al. 1989 Phys. Rev. A



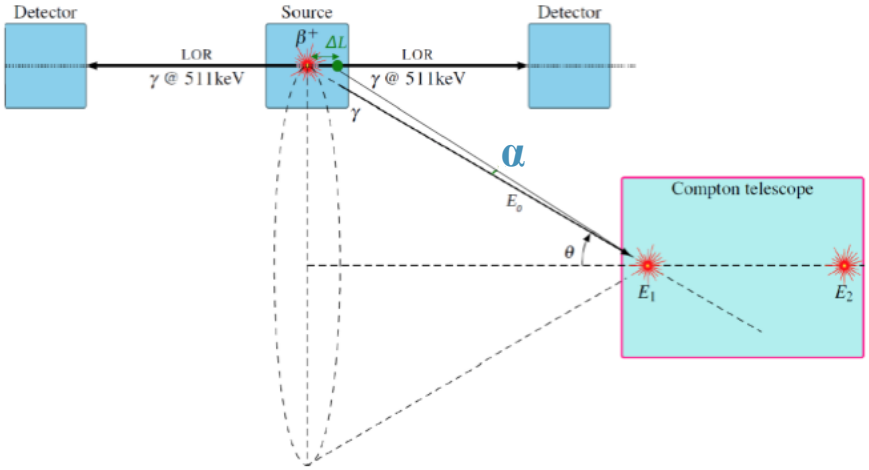


Experimental Set-up : Cone LOR intersection

^{22}Na source (20 kBq)
($E_{max}\beta^{+}$= 545 keV, E_{γ}= 1.257 MeV)



XEMIS1: Resolution along the LOR



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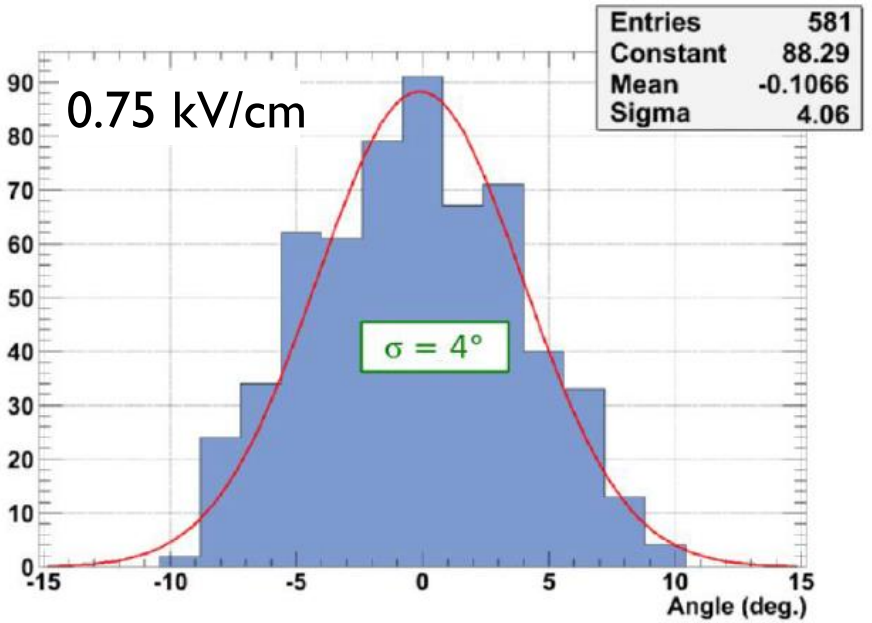

Gallego et al., NIMA (2015)

Equivalent to ΔL = 8.2 mm (FWHM) for a 5 cm distant source

- Angular resolution limited by active area of XEMIS1
- Improvement expected at higher electric field
- XEMIS2 is the key

SUMMARY

Single phase LXe TPC + low noise read-out

- Identifier different vertex of one gamma → 3γ feasibility
- 20keV – 1 MeV gamma Ionization signal direct measurement
- Recombination effect measurement (5% energy resolution @511 keV)
- Electronic recoil effect (100 μm @511 keV)

THANK YOU FOR YOUR ATTENTION