Summary of the Compton-PET project

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Compton-PET stands for:

"Feasibility study of using Compton scattering for medical imaging with positrons" (2008-2011)

Motivation

Scattering in the patient body: (~70 to 90%)

Scattering in the detector:

Probability of the first interaction to be a Compton:

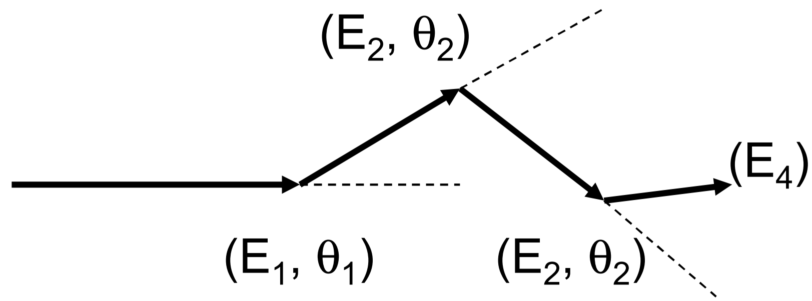
BGO – 53%	BGO – 78%	of coincidences involve scattered events
LSO – 62%	LSO – 86%	
LXe – 79%	LXe – 95.6%	
LAr – 95%	LAr – 99.8%	

Using these events for image reconstruction:

improves statistics and/or allows reducing the dose administered to patient,

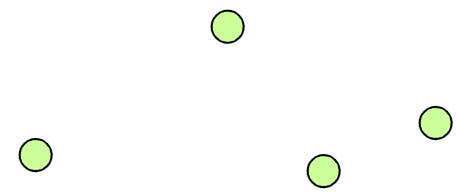
but deteriorates resolution

Possible solution: Compton tracing

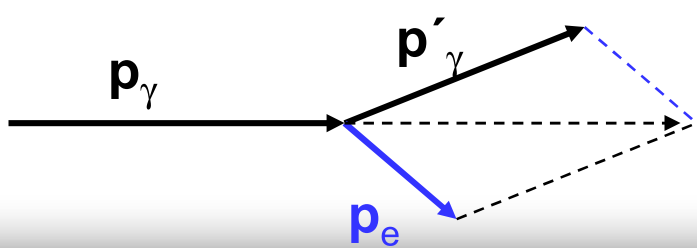


$$E_{i+1} = \frac{E_i}{1 + \frac{E_i}{mc^2}(1 - \cos\vartheta)}$$

This is what we see (or not) in the detector:



Reconstruction of the true sequence depends strongly on resolutions on *E* and *θ* (i.e. position)



$\mathbf{p}_\gamma$, $\mathbf{p}'_\gamma$, $\mathbf{p}_e$ are in the same plane

Knowing electron track orientation can help

Objective: explore what can be done with the scattered events

Compton tracing :

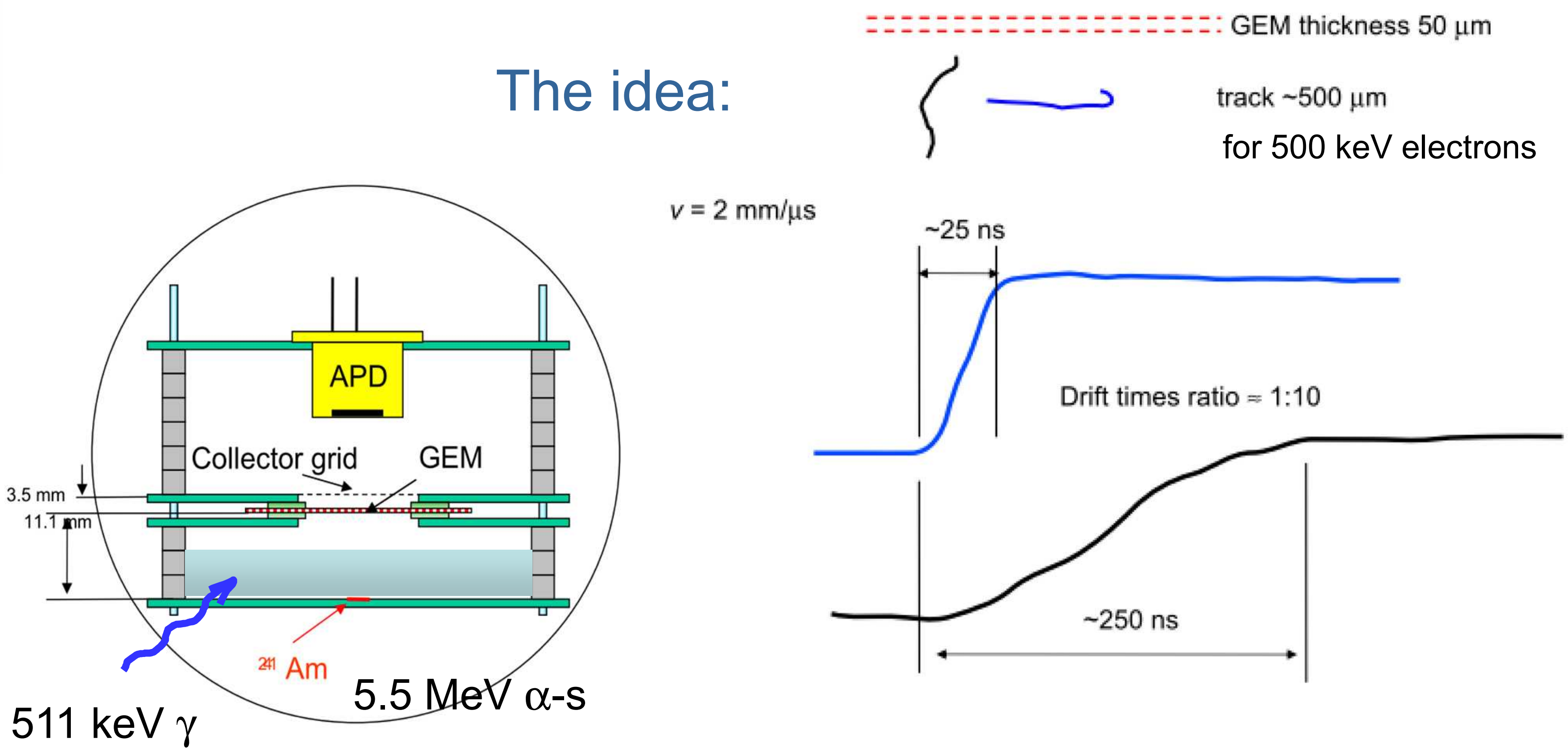
1. Compton electron track orientation: can we get some useful information on it ?
2. If one can measure polarization of the γ-par – would it help ?
3. Do we really need to trace (i.e. reconstruct in detail) scattered γ-rays ?

Method: Monte Carlo and experimental

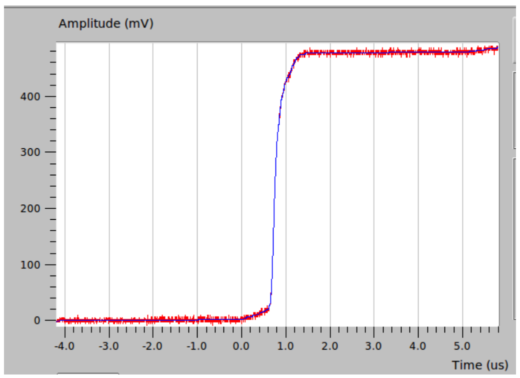
4. How Geant deals with the electron binding ? (see talk by A.Mangiarotti on validation)

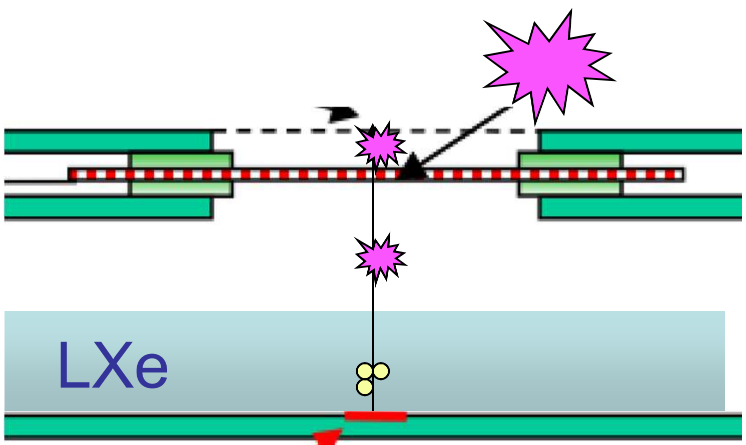
1. Attempting to measure electron track orientation in LXe

The idea:



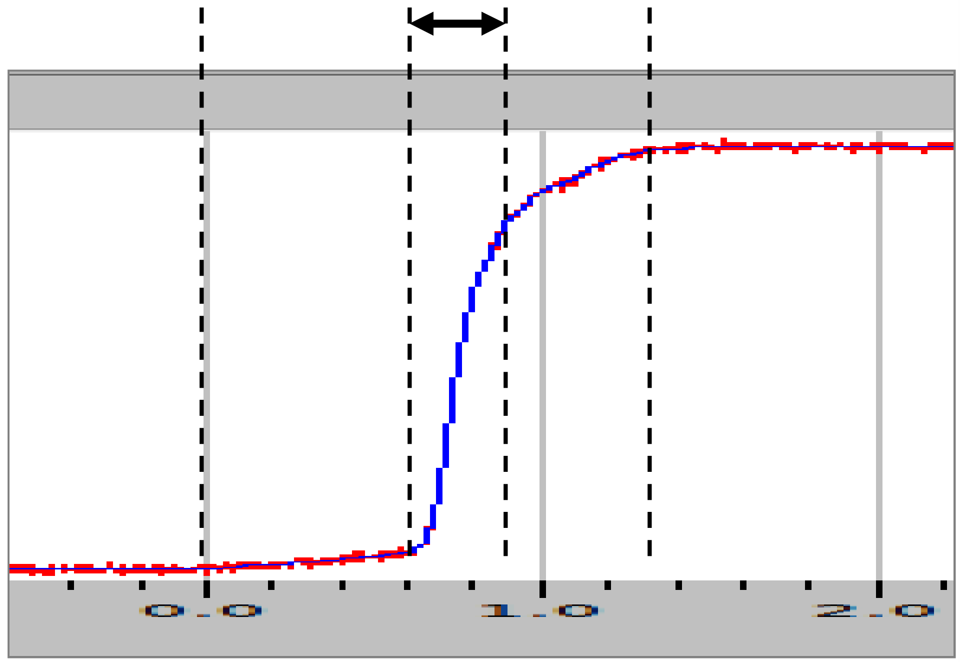
1. Attempting to measure electron track orientation in LXe





α-s, range 40 μm

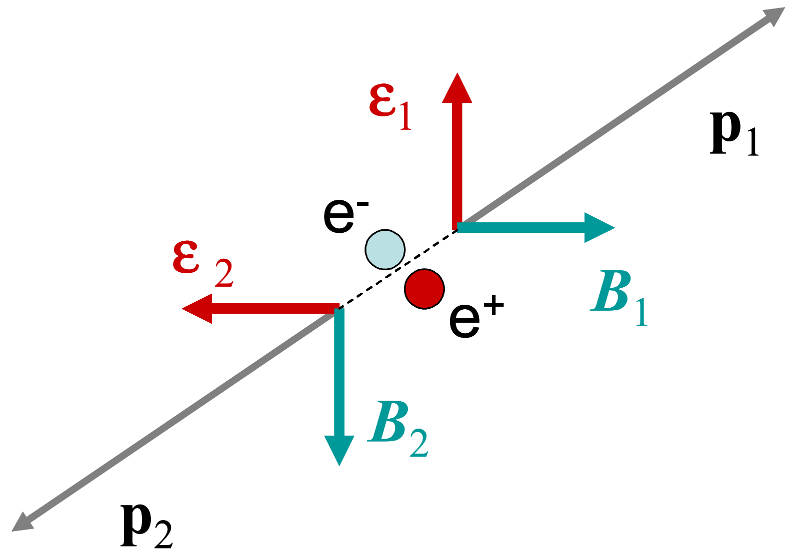
300 ns (expected ~25 ns)



Neither field non-uniformity, nor diffusion in the gas explain such long rise time (unless diffusion in Xe vapour is much stronger than in non-saturated gas)

2. Polarization of annihilation photons

$e^+ + e^- \rightarrow \gamma + \gamma$

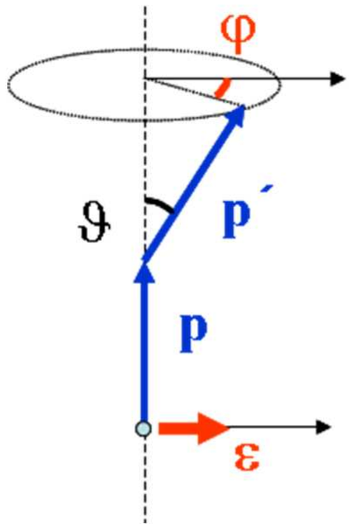


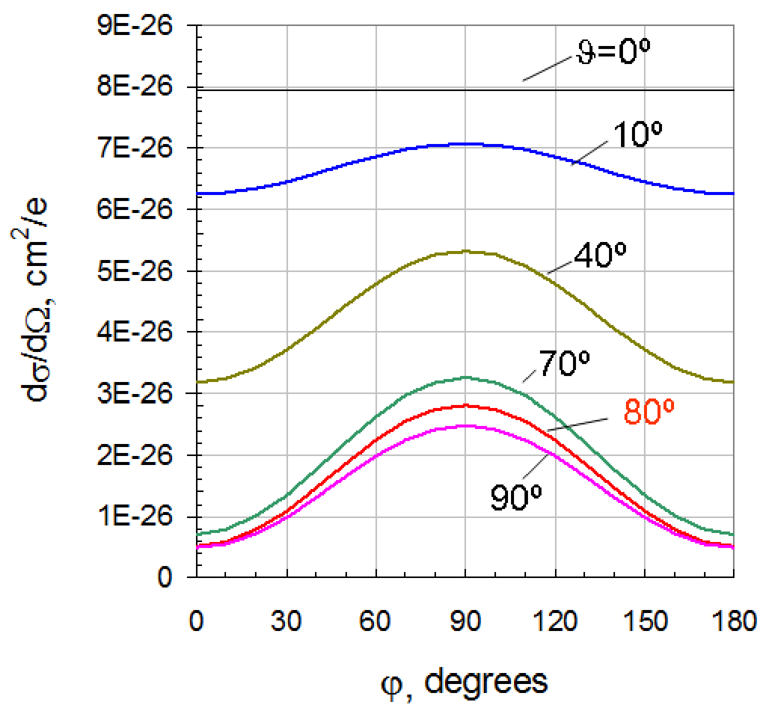
What if we could measure polarization of each γ ?

Any help with Compton tracing ?

Any information about scattering in the patient body ?

2. Compton scattering cross section for polarized photons



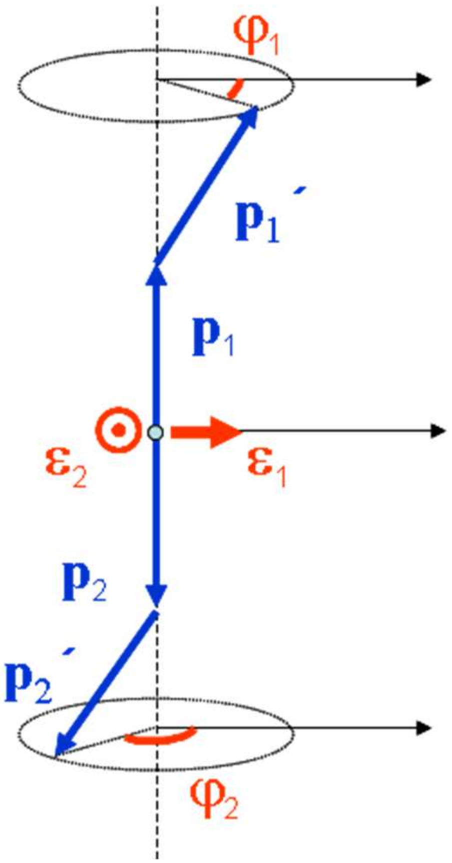


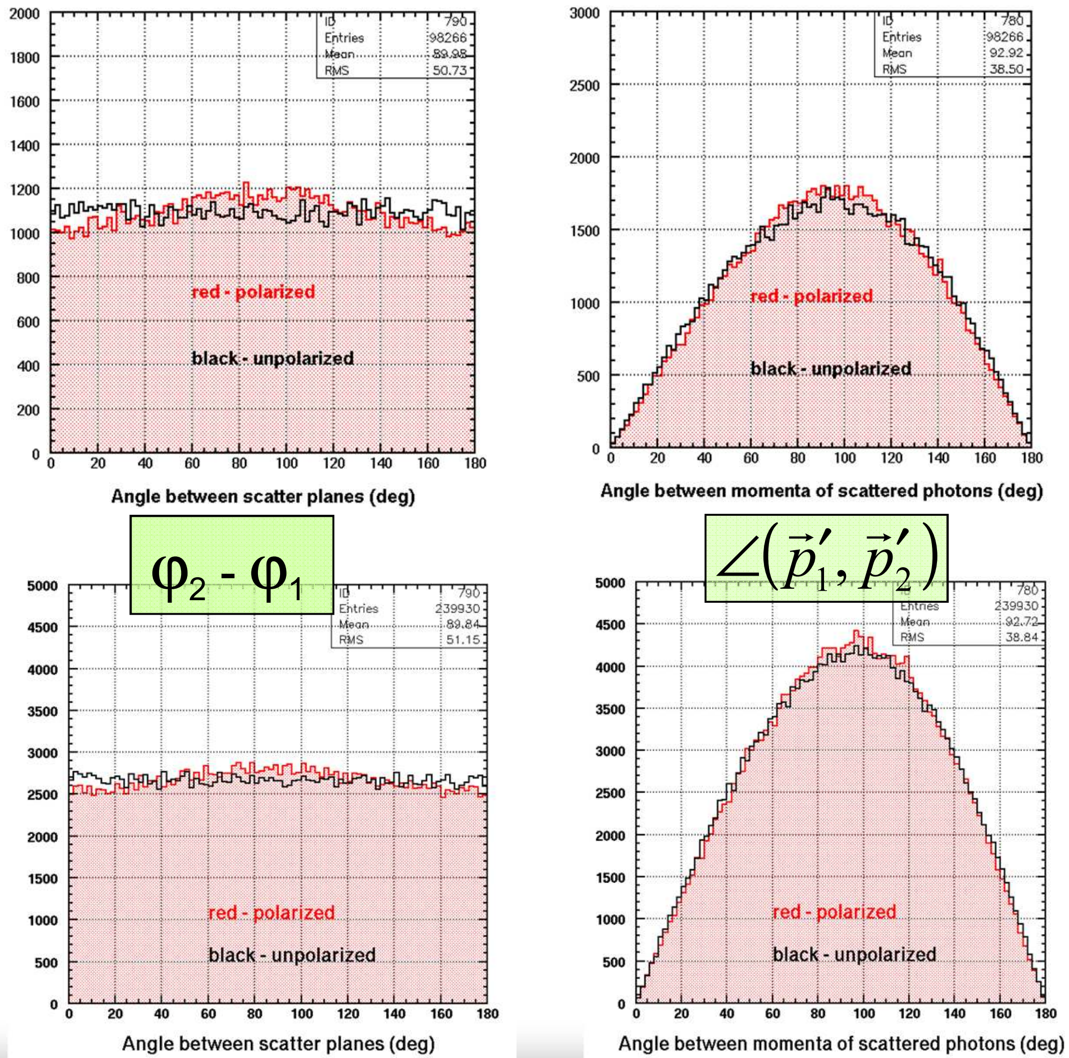
E_γ = 511 keV

Maximum anisotropy = 5.5
(for $\vartheta \approx 82°$)

$$\frac{d({}_e\sigma)}{d\Omega} = \frac{r_0^2}{2}\left(\frac{1}{1+\alpha(1-\cos\vartheta)}\right)^2\left(\frac{1}{1+\alpha(1-\cos\vartheta)} + 1 + \alpha(1-\cos\vartheta) - 2\sin^2\vartheta\cos^2\varphi\right).$$

2. MC of γ-pairs with GEANT4:





Point source in vacuum

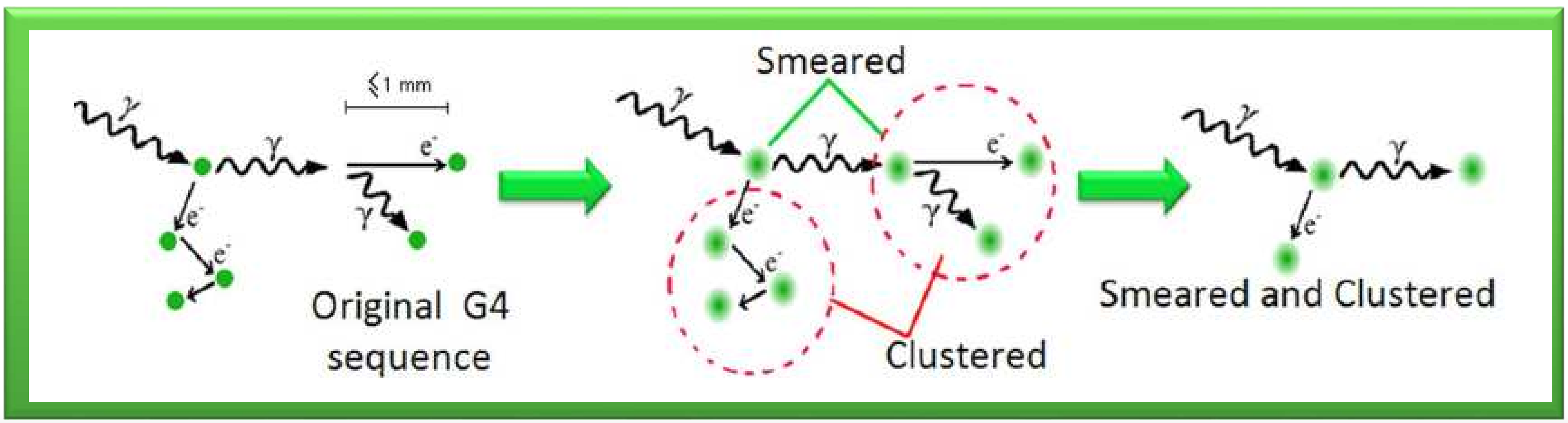
Point source in of water (∅20cm phantom)

3. Do we really need to do tracing ?

Computation tool:

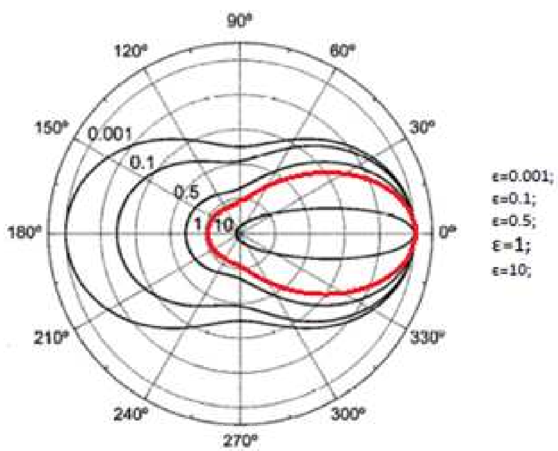
Interactions (physics) → Detector response → Compton tracing and LOR definition → Image reconstruction

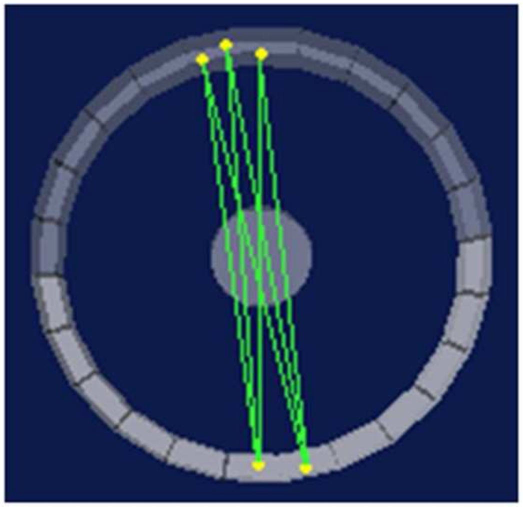
- Interactions (physics): **GEANT4**
- Detector response, Compton tracing and LOR definition: **C++**
- Image reconstruction: **Matlab**



3. Choosing LOR: a “childish” approach

Which is the true LOR?





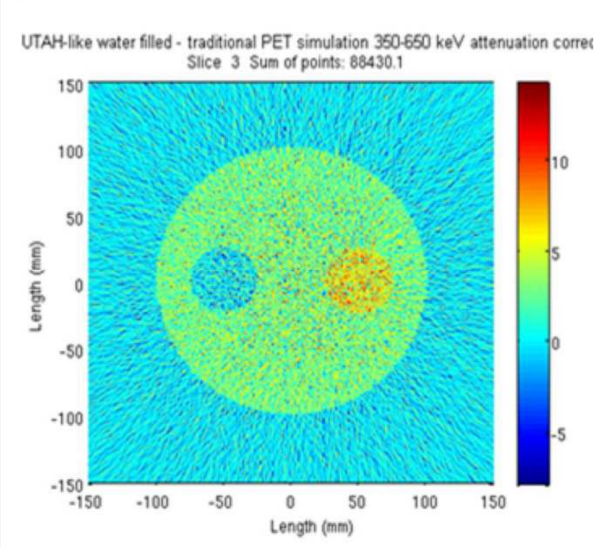
Two algorithms:

- Closest coordinates to the center (0,0,0).
- Coordinates that produce shortest LOR.

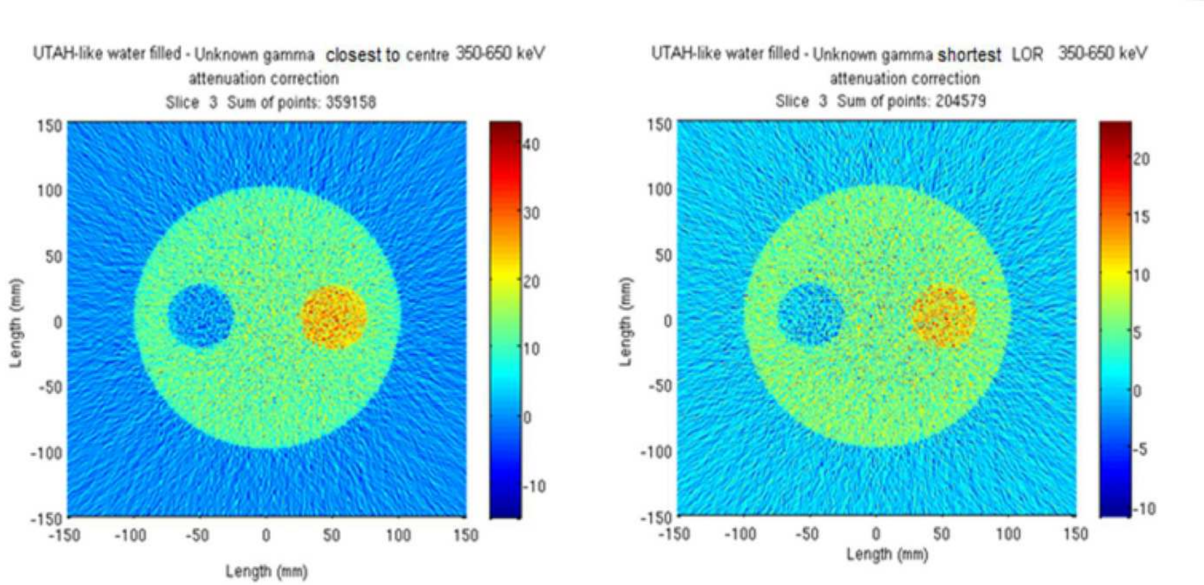
3. UTAH phantom simulated

Preliminary

Traditional PET:
Single energy deposition
in 350-650 keV



Compton PET:
Singles + doubles
With total E= 350-650 keV

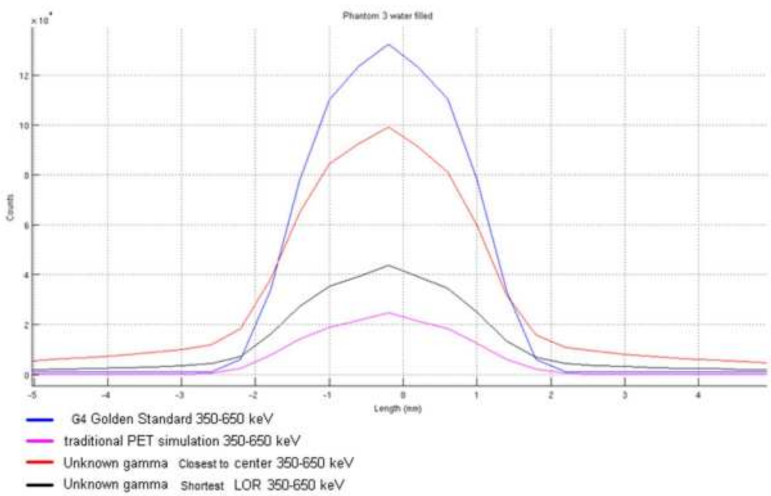


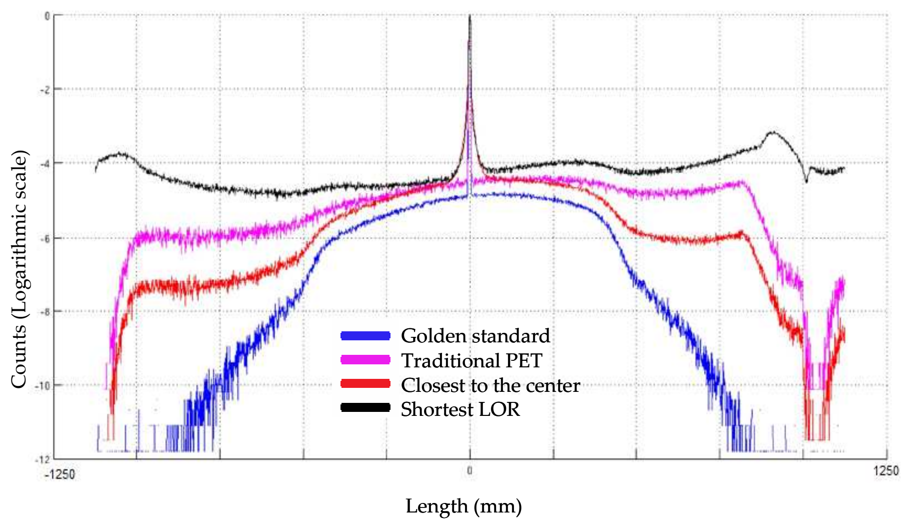
Same contrast
Statistics > x3

Detectors: LXe ring ∅80x5x5 cm^3
Resolution 2 mm, $\delta E/E$=20%

3. Line source 4.5 cm off centre in 20 cm of water

Preliminary





Traditional PET:
Scatter fraction ≈ 0.7

Compton PET:
Scatter fraction ≈ 0.86

Detectors: LXe ring ∅80x5x5 cm^3
Resolution 2 mm, δE/E=20%

Conclusions

1. Compton electron tracking does not seem to be feasible for <=511 keV (at least with the readout we have tried).
2. The effect of gamma-ray polarization on the observable distributions is small.
3. Events involving Compton scattering in the detector can be recovered for the imaging with the advantage of higher image statistics and without jeopardizing the image quality.
4. Complex Compton tracing does not to be necessary. Simple methods can be used for that.