OFT improvements

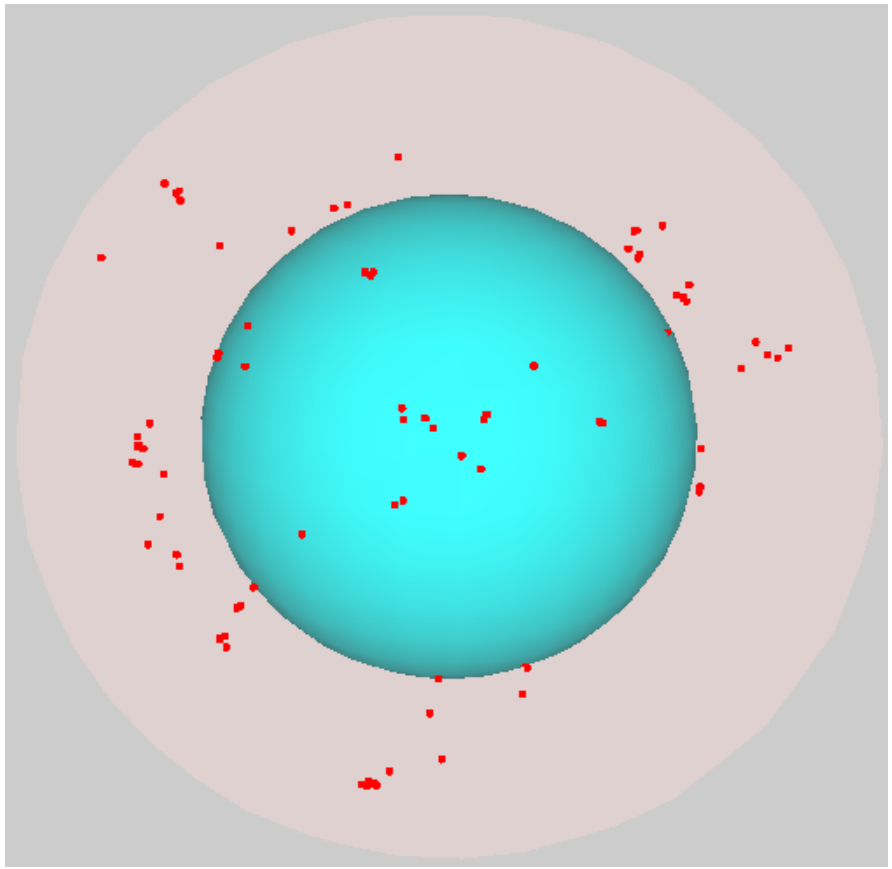
A. Lopez-Martens
CSNSM

Outline

- Introduction
- Details of the Orsay Forward Tracking code
- Improving single interaction reconstruction
- Perspectives

Aim of tracking

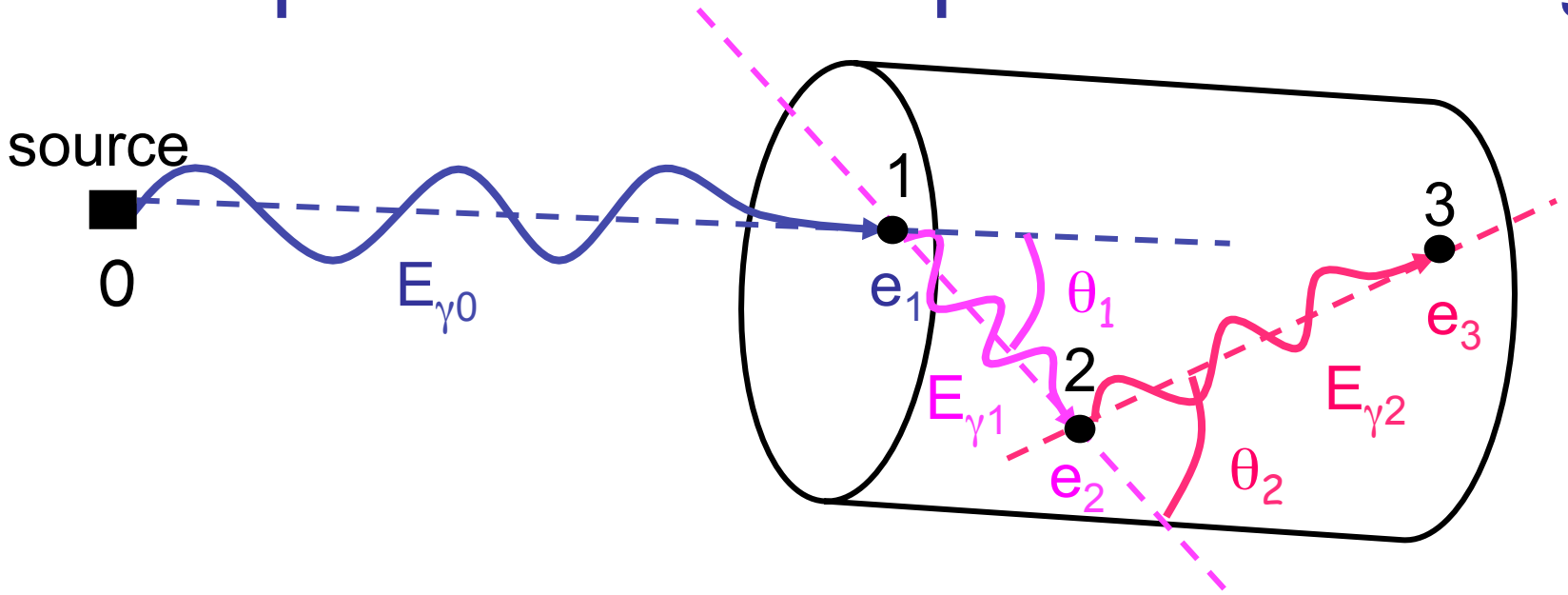
Reconstruct multi-gamma events: $E_{incident}$, $(x,y,z)_{first}$, $(x,y,z)_{second}$



Forward tracking philosophy:

- Identify cluster of interaction points
- Test for Compton, Pair production or Photoelectric interaction

Properties of Compton Scattering



Assuming that the e^- is at rest, from conservation of energy & momentum:

incident energy = Σe_i at i=1 (if absorption)

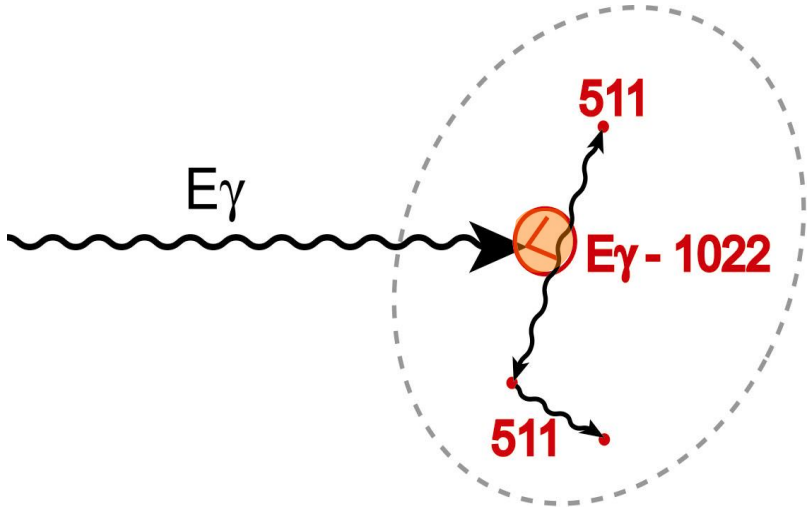
$$E_{\gamma i} = \frac{E_{\gamma i-1}}{1 + \frac{E_{\gamma i-1}}{m_0 c^2}\left(1 - \cos\theta_i\right)}$$

Energy of scattered γ

$$e_i = E_{\gamma i-1} - E_{\gamma i}$$

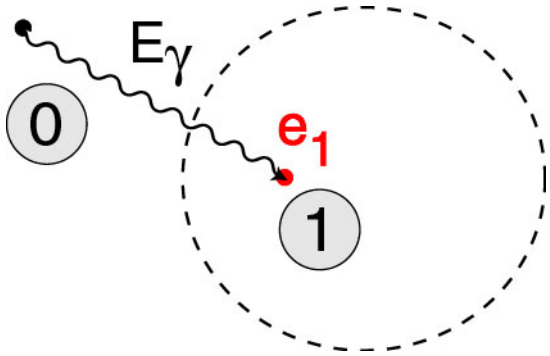
Energy of scattered e^-

Reconstruction of Pair-Production Events



Recognition of the first hit

Reconstruction of single interaction events

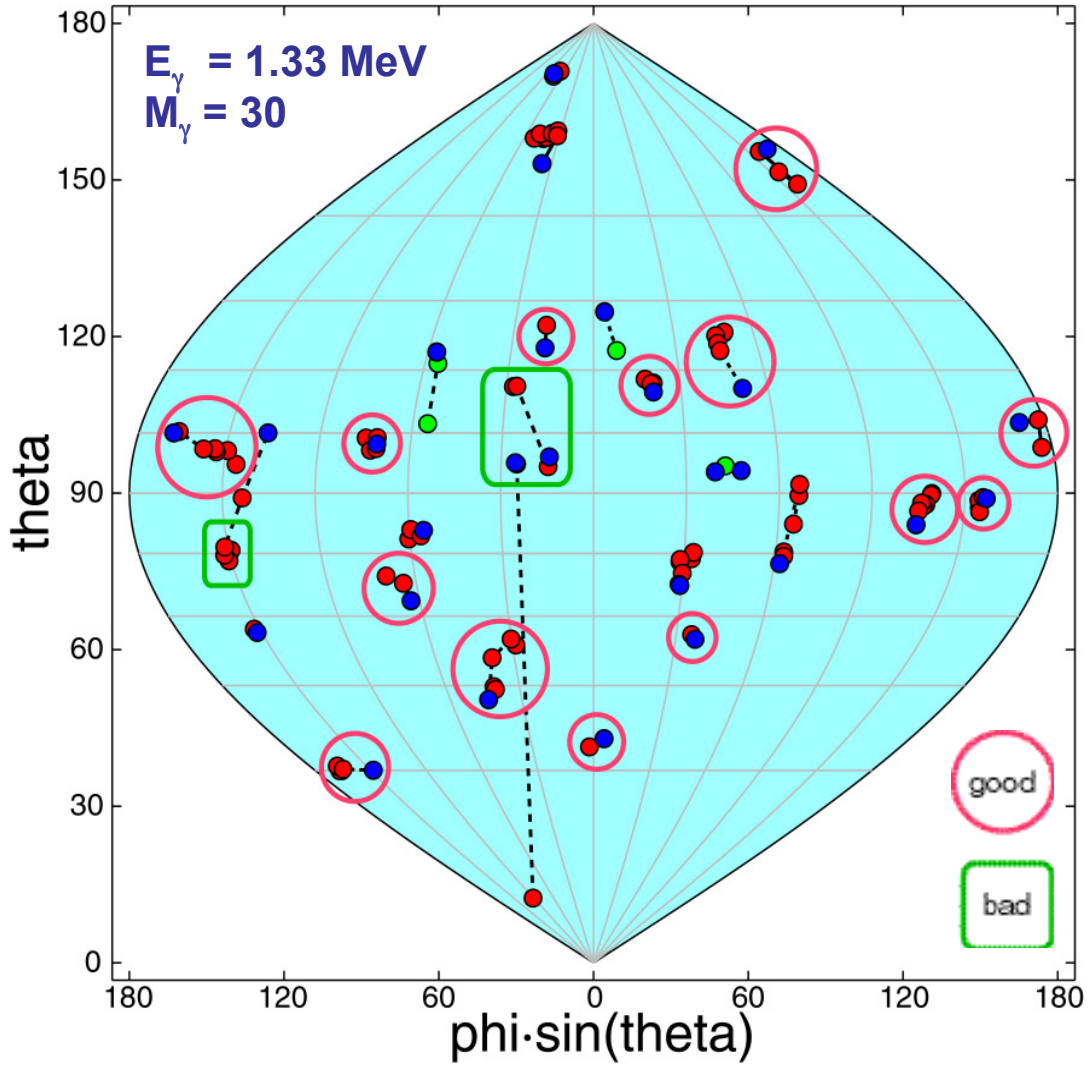


There is not much we can do…

Does it satisfy photoelectric condition (cross section, range) ?

Example of reconstruction in the 4p Ge shell with MGT*

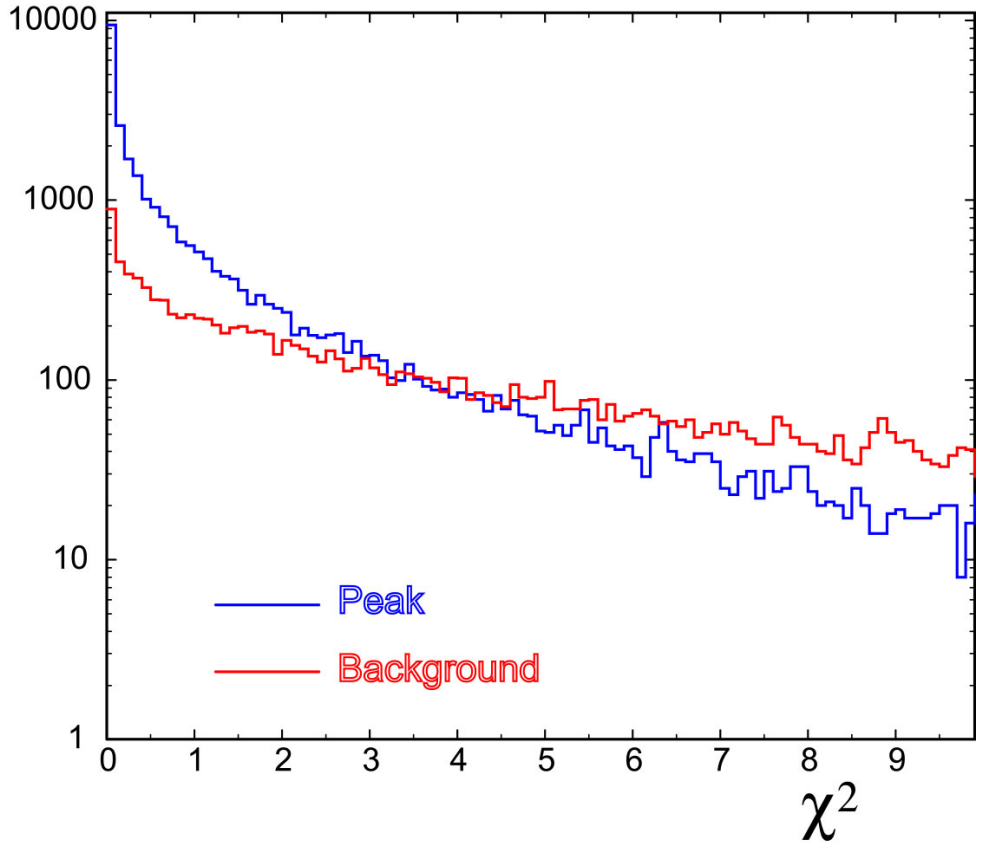
* D. Bazzacco , TMR



27 gammas detected -- 24 in photopeak

16 reconstructed -- 14 in photopeak

Identification is not 100% sure



=> spectra will always contain background

=> Acceptance value determines the quality of the spectrum

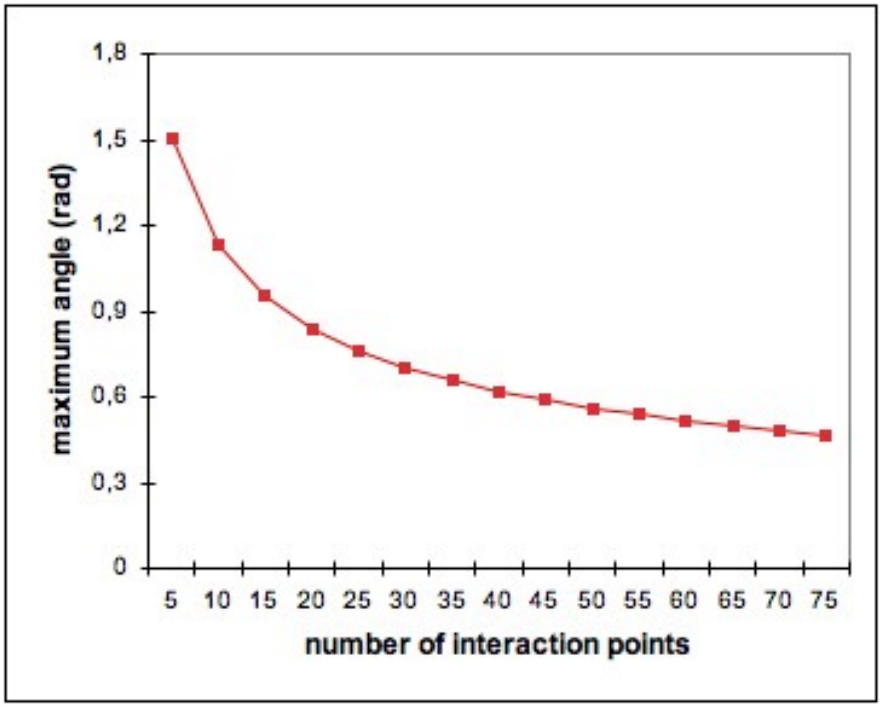
=> Use R = Efficiency x P/T to qualify the reconstructed spectrum

Basic steps of OFT (1)

1. Create cluster pool

- Computes the maximum angular separation α_{max} between points in a cluster

$$\alpha_{\max} = \cos^{-1}\left(1 - \frac{2}{\left((n_{\text{int}} + 2)/3\right)^{0.9}}\right)$$



NEW: α_{max} can be multiplied by a reduction factor

- Assigns interaction points i and j to the same cluster if their angular separation is < α (k_{max}= 7 interaction points per cluster)

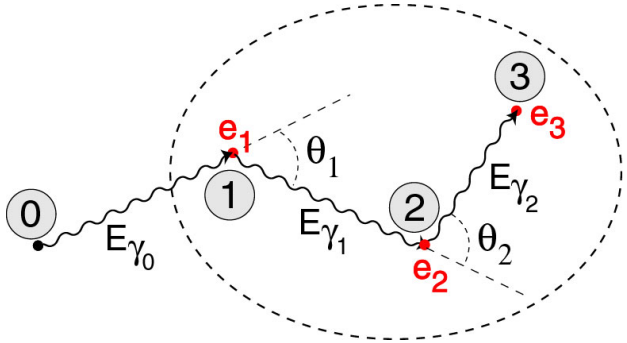
- Loops on $\alpha < \alpha_{max}$ and find m different clusters (α_{min}=0.15, rad, $\delta\alpha$=0.1 rad)

Basic steps of OFT (2)

2. Find most probable sequence of interaction points for each cluster

Which sequence satisfies best the Compton scattering rules ?

$$L = \prod_{n=1}^{N-1} P_n \exp^{-a\left(\frac{E_{\gamma n} - E_{\gamma n,pos}}{\sigma_E}\right)^2}$$



Probability for Compton or photoelectric interaction and for travelling a given distance in Germanium

Depends on energy resolution e_{res} and position resolution σ_θ (same in x,y,z and independent of e_i and the position in the detector)

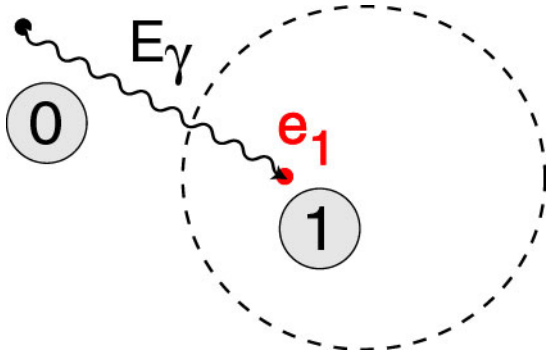
$$er\cos = \sigma_\theta \sqrt{\left(\frac{\partial \cos\theta_1}{\partial x_0}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial y_0}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial z_0}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial x_1}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial y_1}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial z_1}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial x_2}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial y_2}\right)^2 + \left(\frac{\partial \cos\theta_1}{\partial z_2}\right)^2}$$

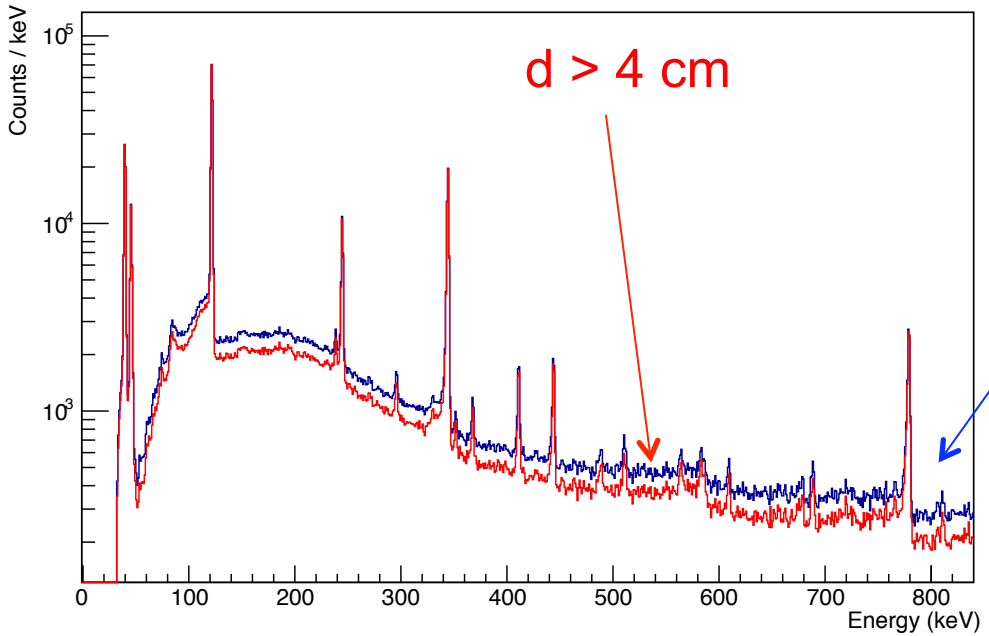
3. Accept or reject clusters on the basis of (2xN-1)th root of L

Single interaction points

- Does the interaction point satisfy photoelectric conditions (interaction depth, energy)

- Is the interaction point sufficiently isolated from other points ?

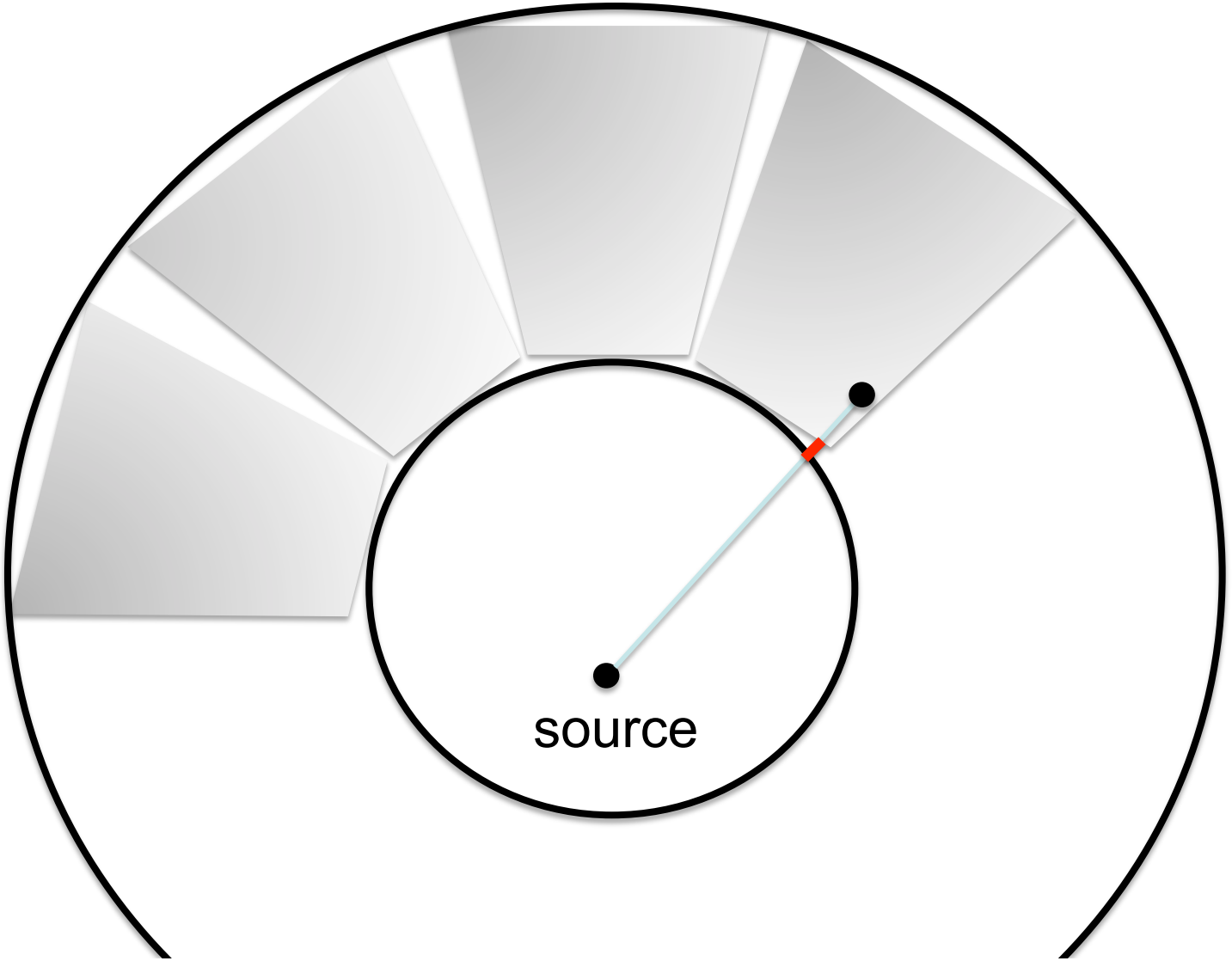




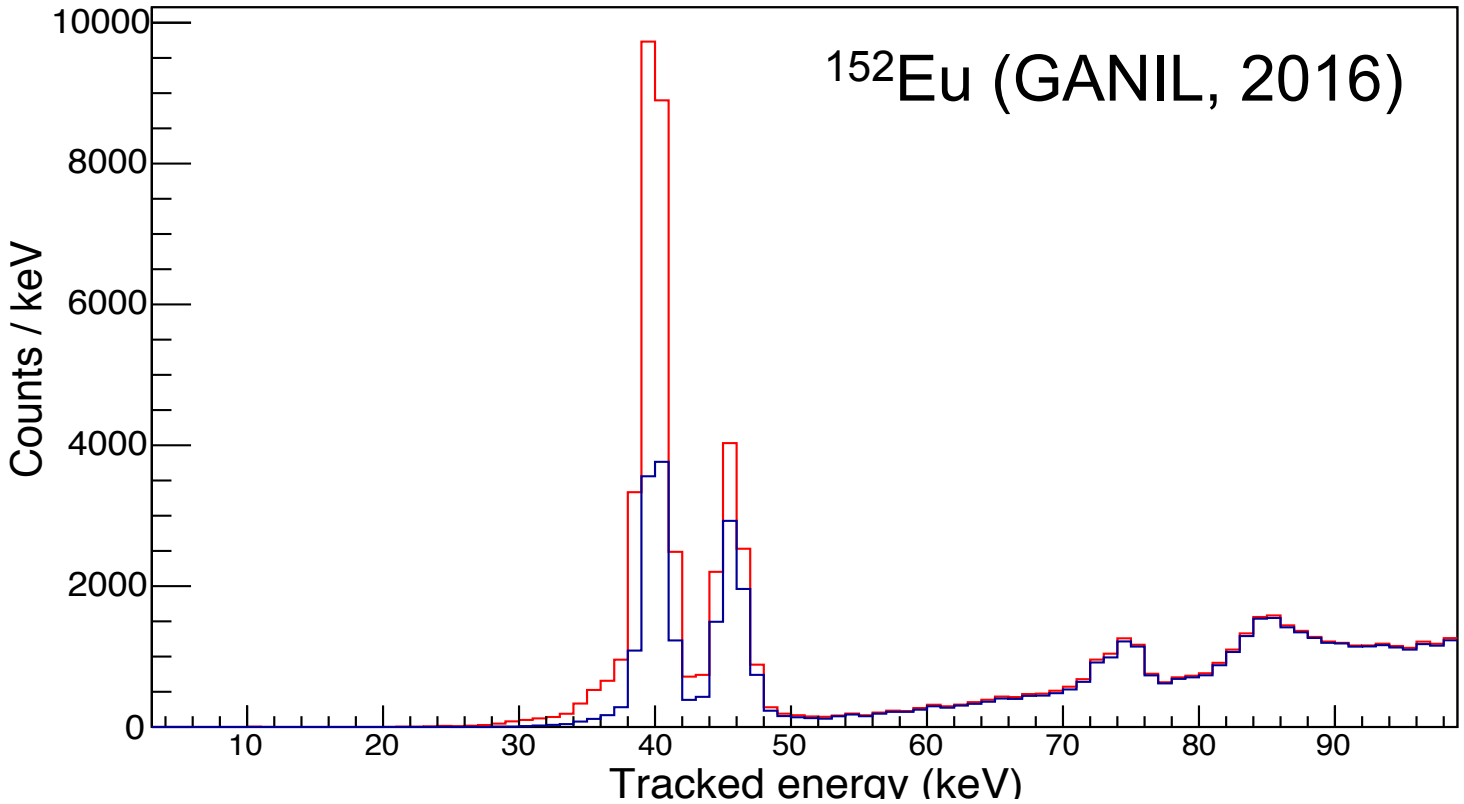
no proximity criterion

Setting d=4cm has very little effect on efficiency

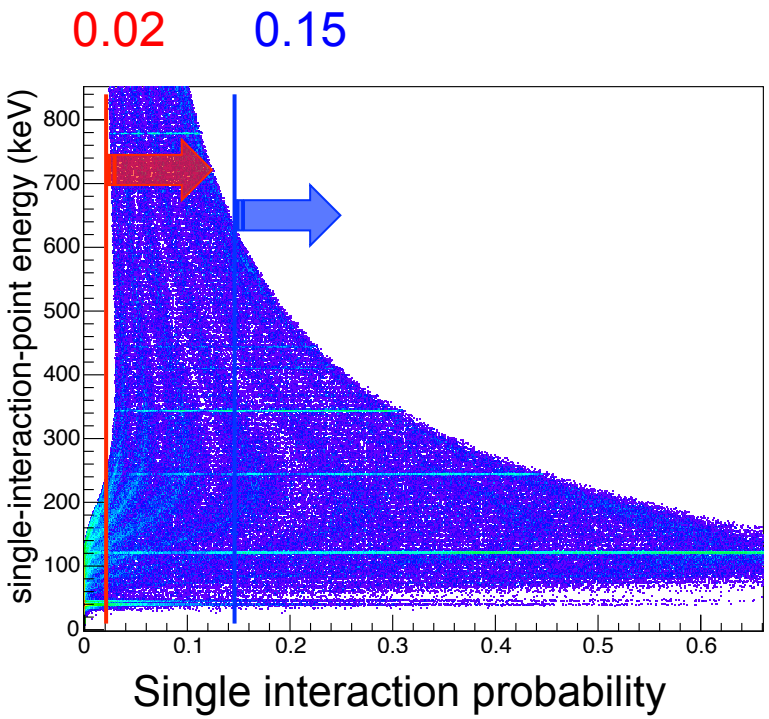
Ge sphere approximation for very low energies



Improving low-energy efficiency

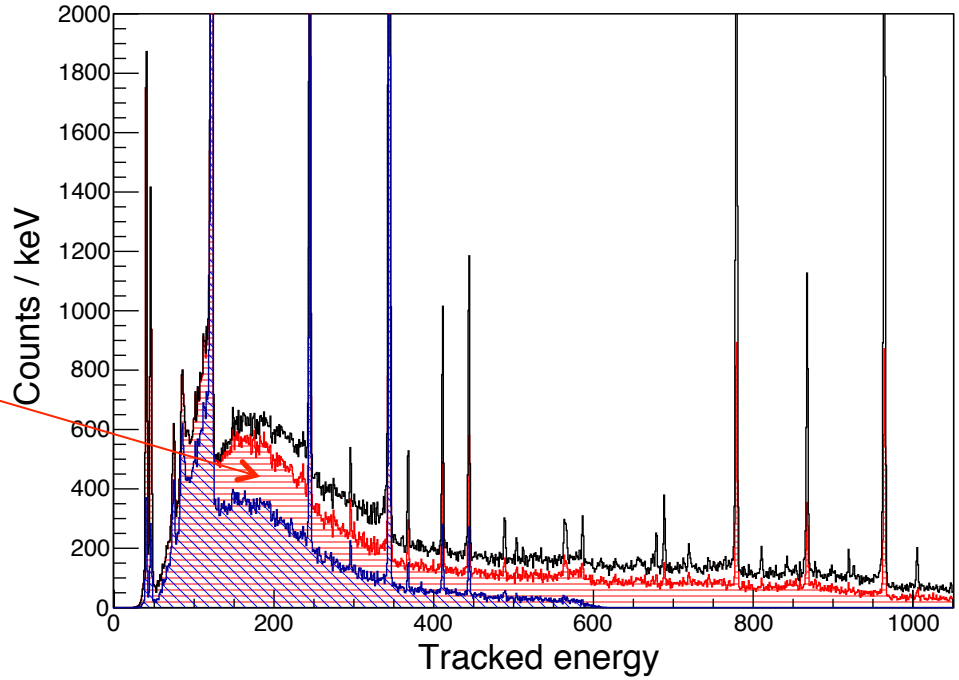


Fine tuning single interactions



Energy (keV)	Fraction of core total absorption (%)
121	95
344	48
778	27
1408	21

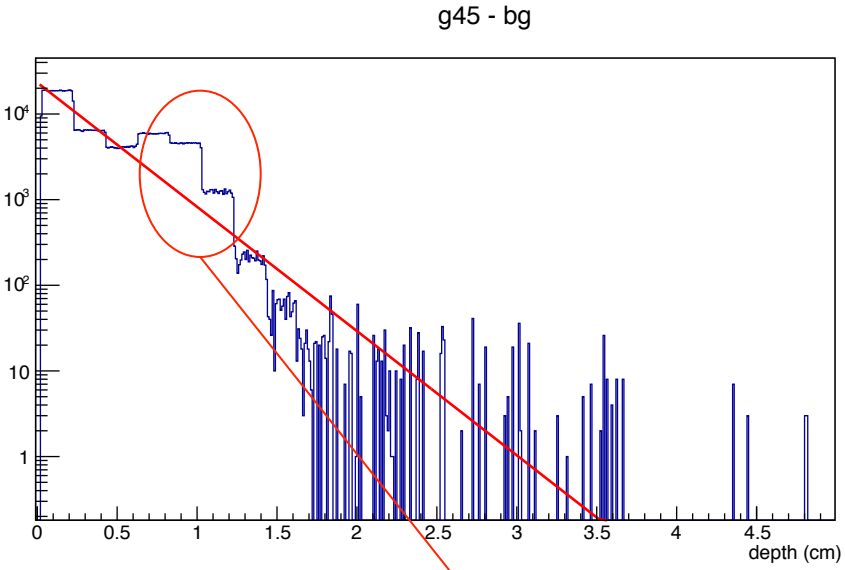
Peak recovered at high energy but the single interactions account for 2/3 of the total background !

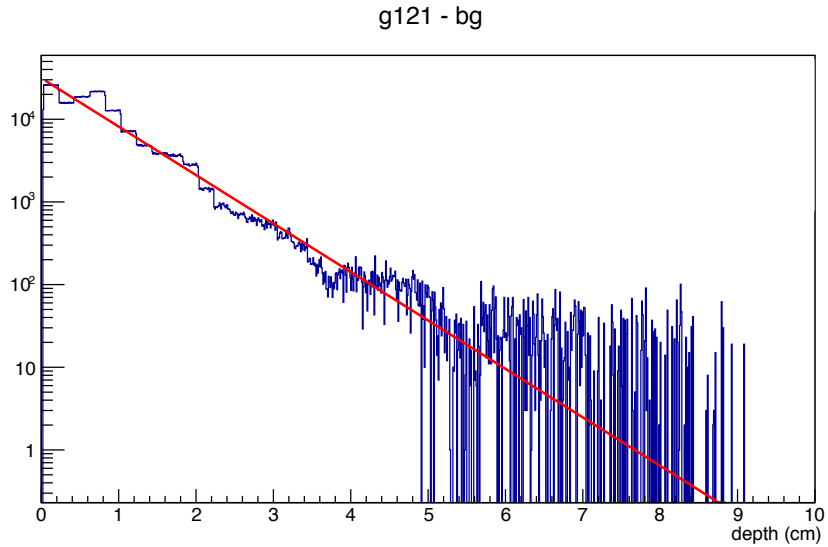


How to better validate single interaction points ?

- OFT standard: Probability (range in Ge) x Probability (photoelectric int.)
- Range only: distance *d* in Ge from source corresponds to 85,95-99 % absorption probability, i.e *d* ~2,3-4.6 interaction lengths λ
- New: use the data

Why ?





λ_data = 0.3 cm
λ_table = 0.04 cm

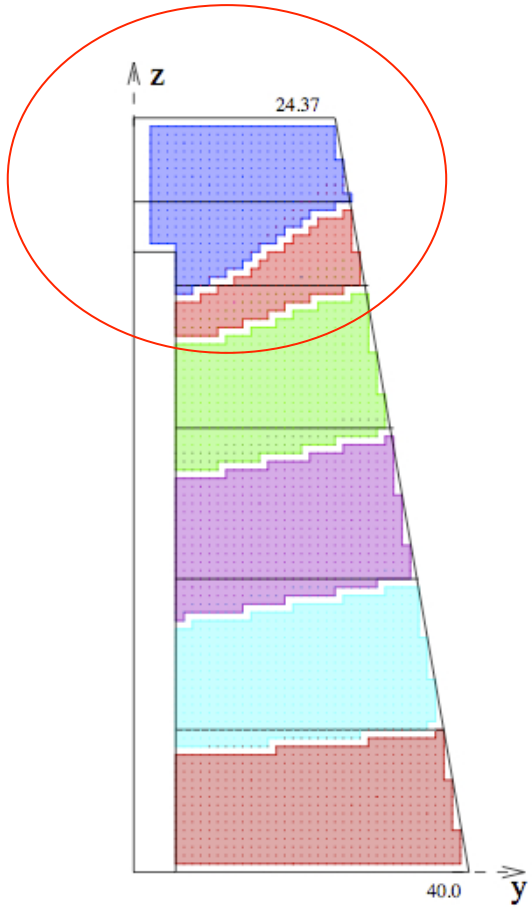
λ_data = 0.74 cm
λ_table = 0.55 cm

exp (-1.2/0.04) = 10^{-14} !!!

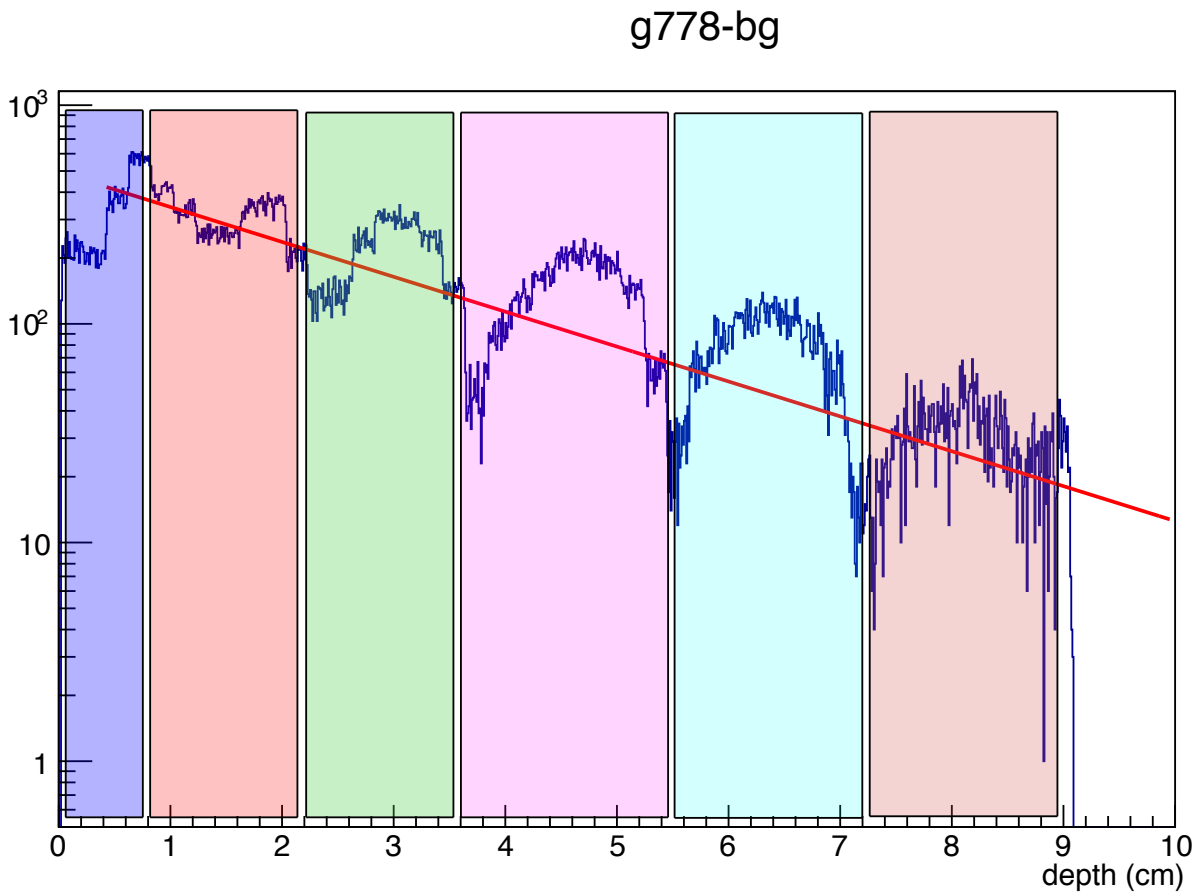
How does a 45 keV photon interact at 1 cm ?

What do the signals look like ?

Is it noise related ? Or is the effective segmentation different ?



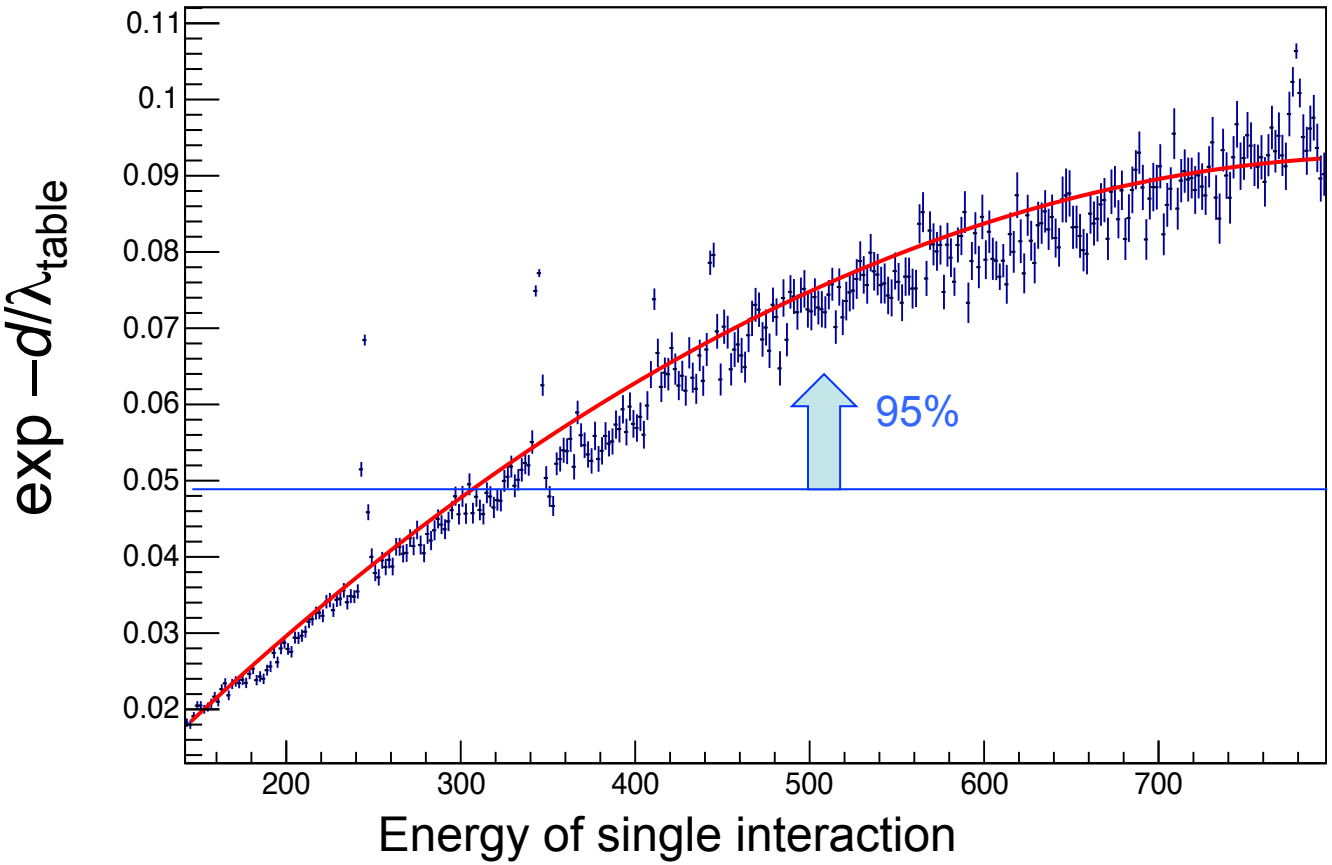
Experimental z distribution distorts ranges



λ_data = 2.8 cm

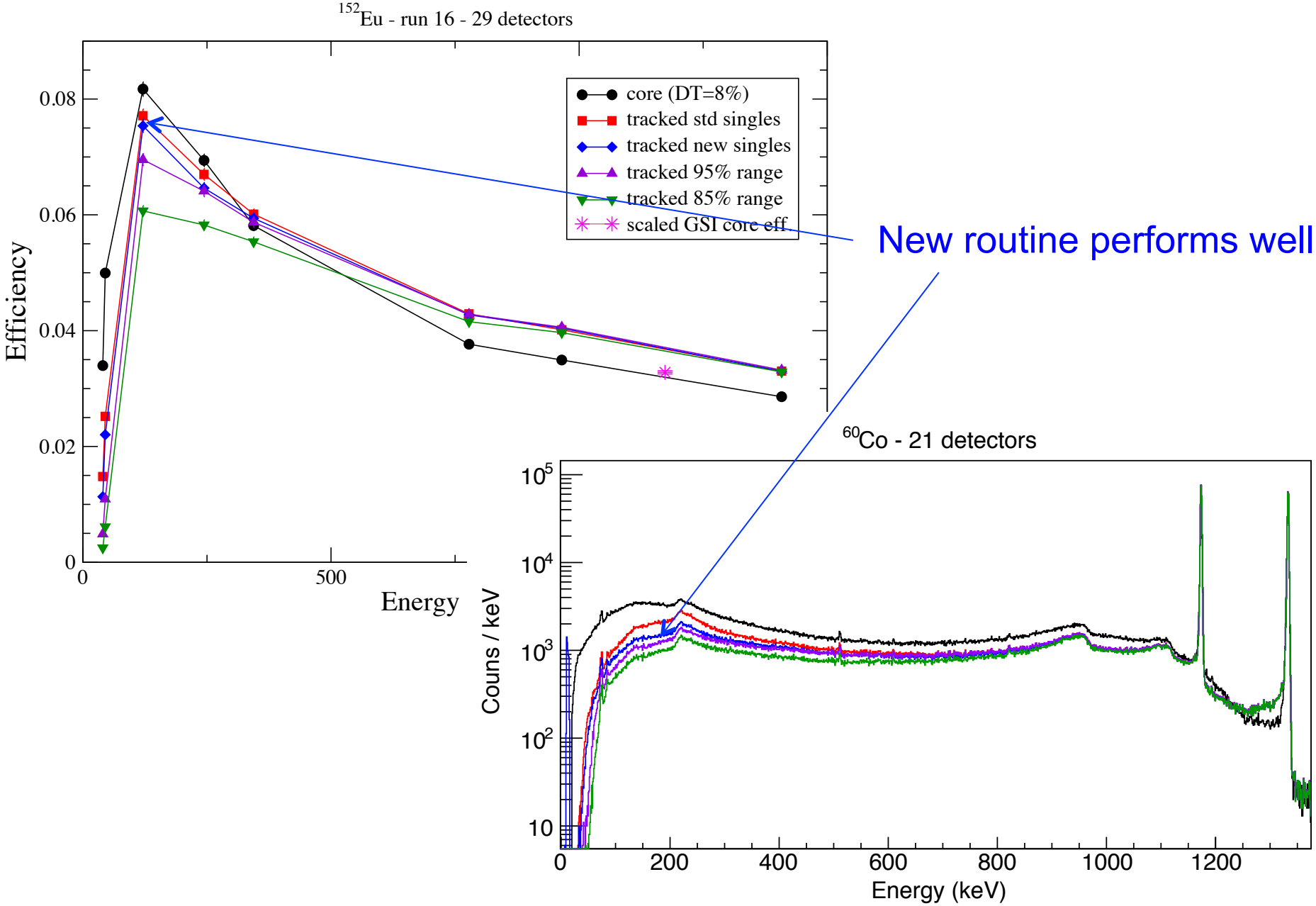
λ_table = 2.99 cm

Determine the ranges experimentally

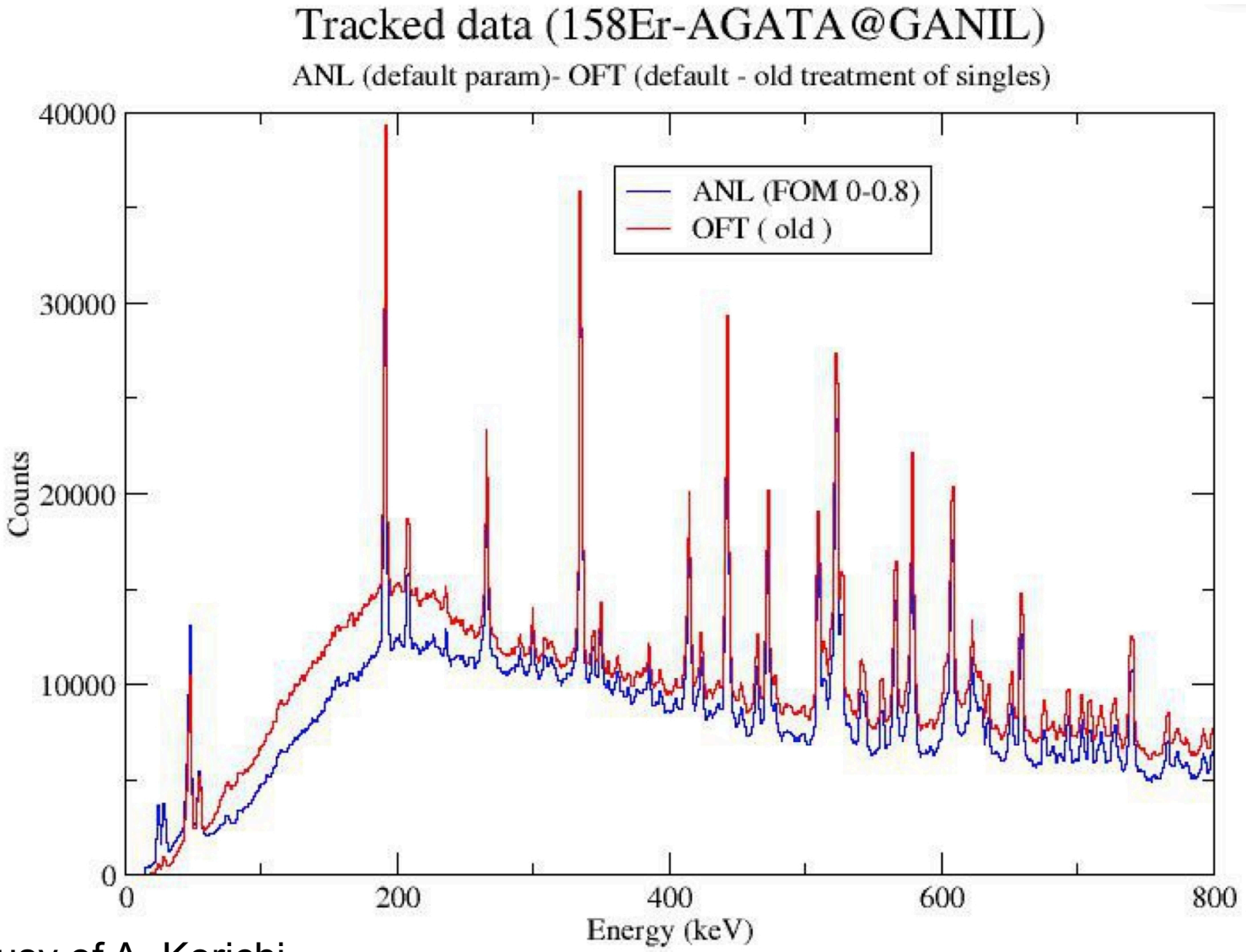


NB: this has to be done each time the PSA is changed

Compromise between P/T and efficiency

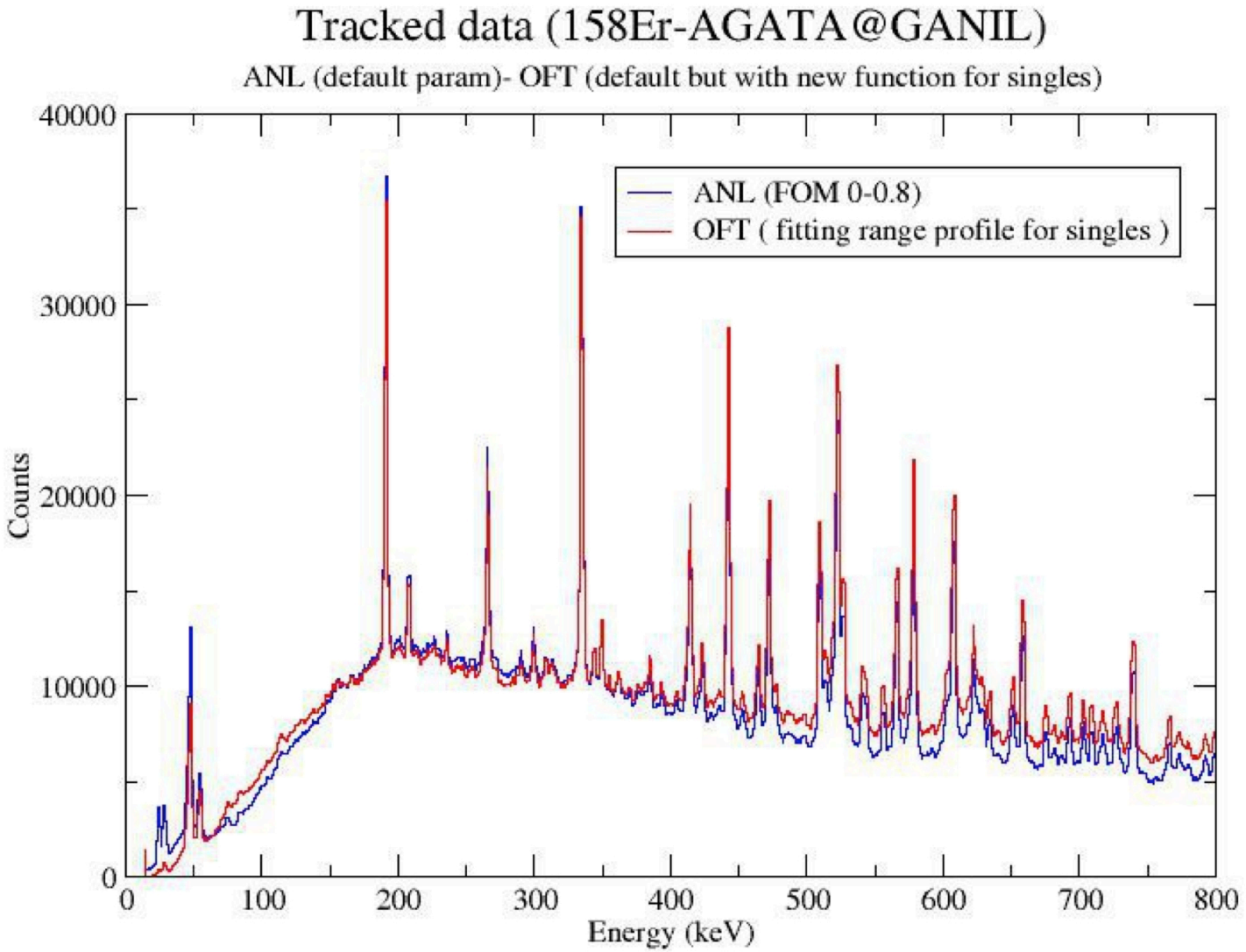


In-beam improvement



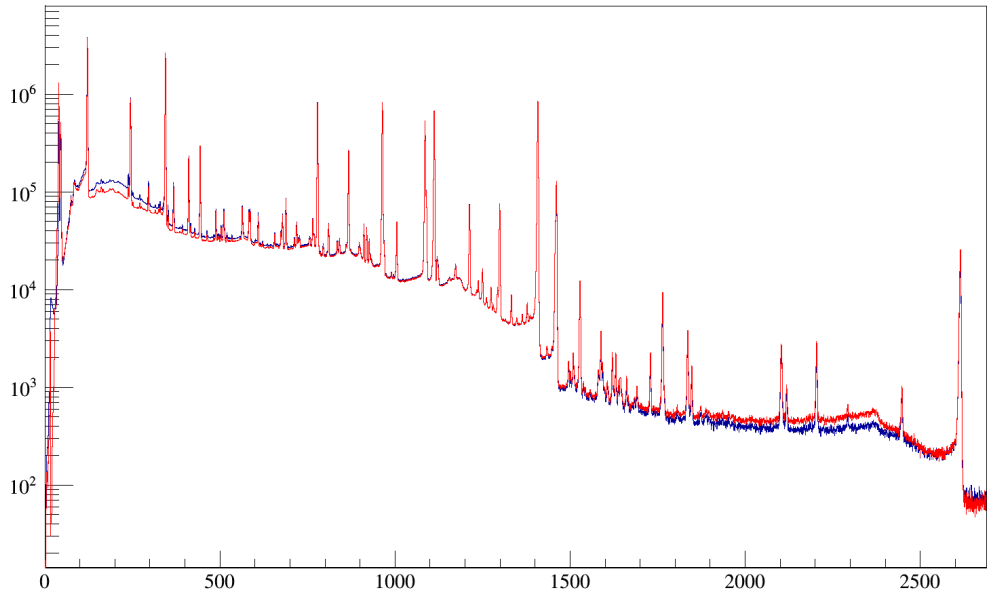
Courteousy of A. Korichi

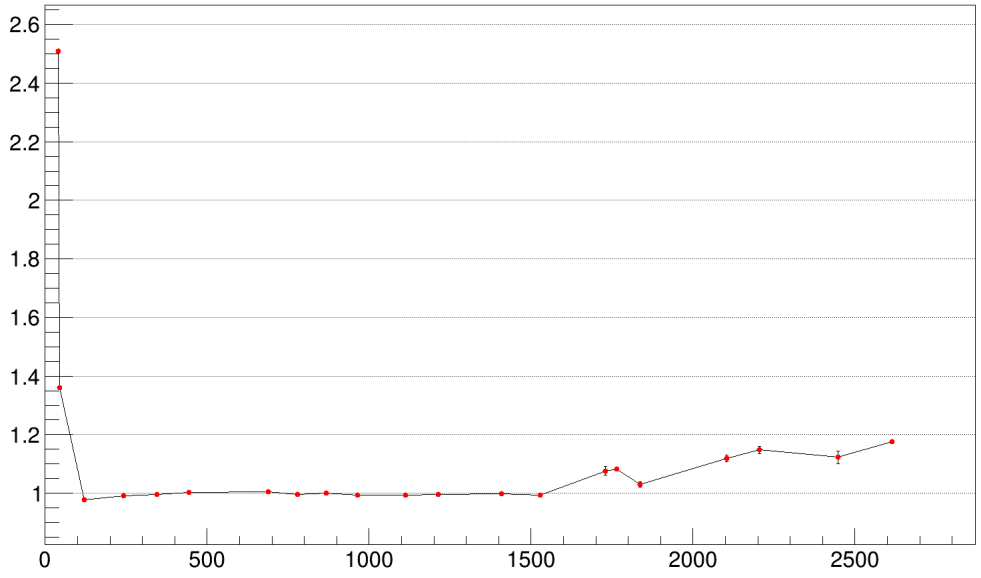
In-beam improvement



Courteousy of A. Korichi

Inclusion into Agapro (Jérémie & Joa)





Perspectives

OFT works well

Some improvements can be made:

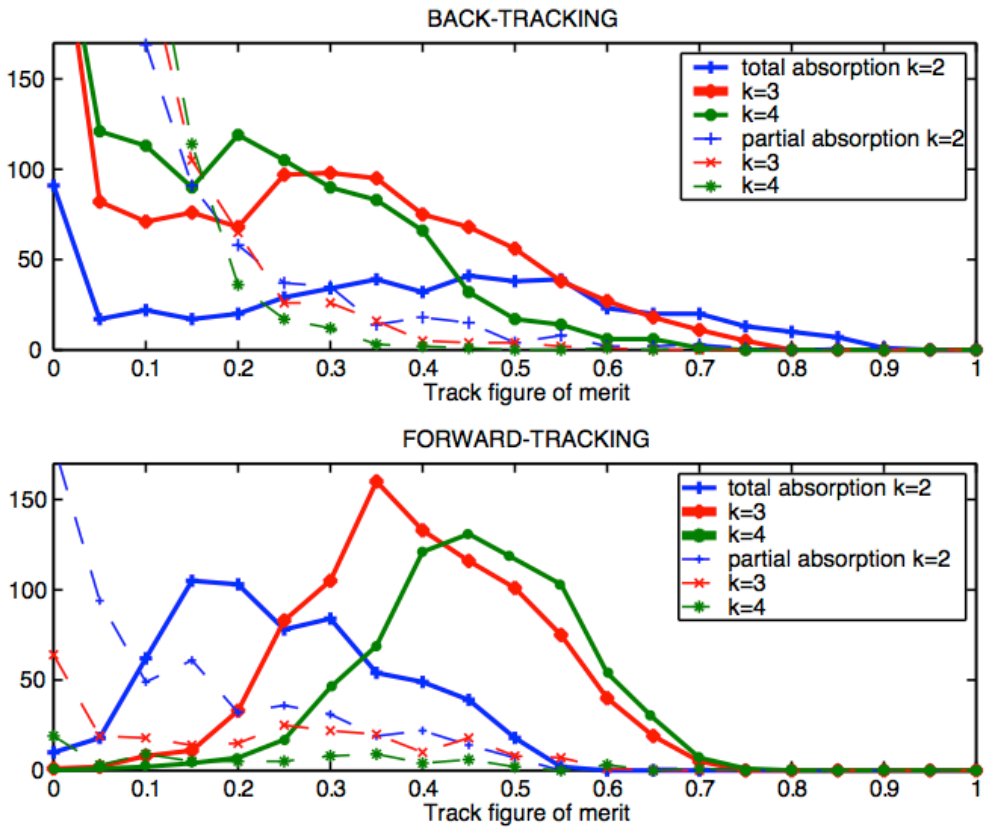
- energy & position dependent σ_θ (use uncertainties from PSA ?)
- Better cluster definition: other algorithm (DAF* for eg), iterative procedure (split/join) ? machine learning ?
- Backtrack the small clusters (k=2-3) to check for sneaky background & backtrack the non-accepted interaction points before checking for single-interaction points ?

Manpower is of course a problem….(new OASIS grant might help solve this)

Need for better PSA

* F. Didierjean et al., Nucl. Instr. Meth. A 615 (2010) 188

Extras…



A. Lopez-Martens et al., Nucl. Instr. Meth. A 533 (2004) 454