

OFT improvements

(since last AGATA-GRETINA workshop)



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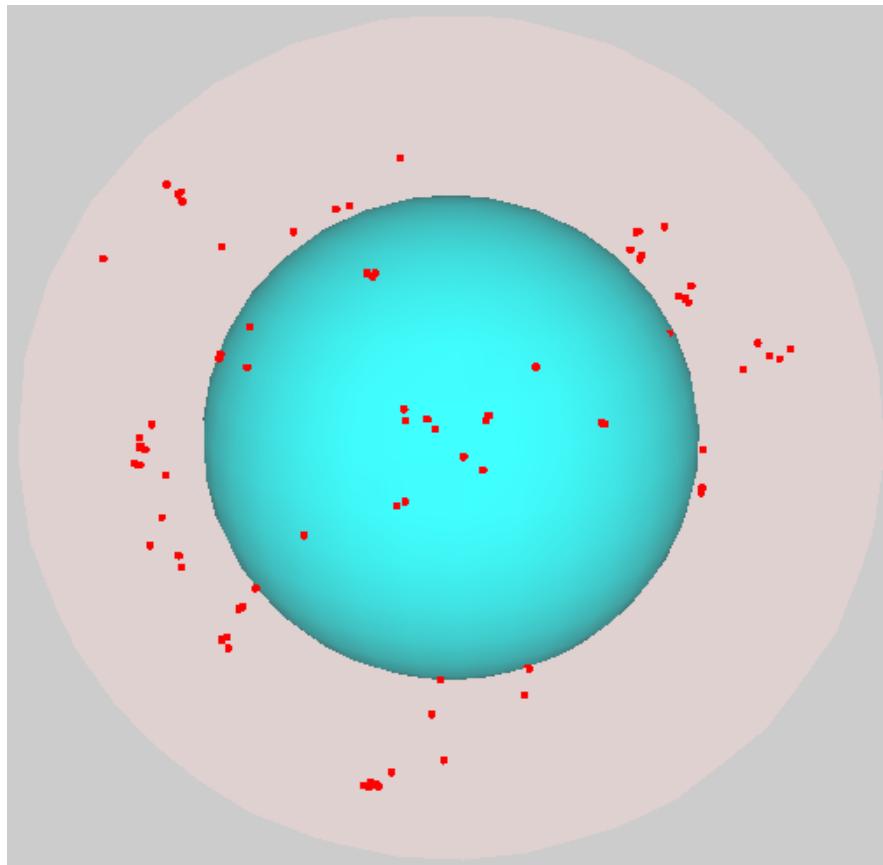
AGATA-GRETINA workshop

Outline

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

Aim of tracking

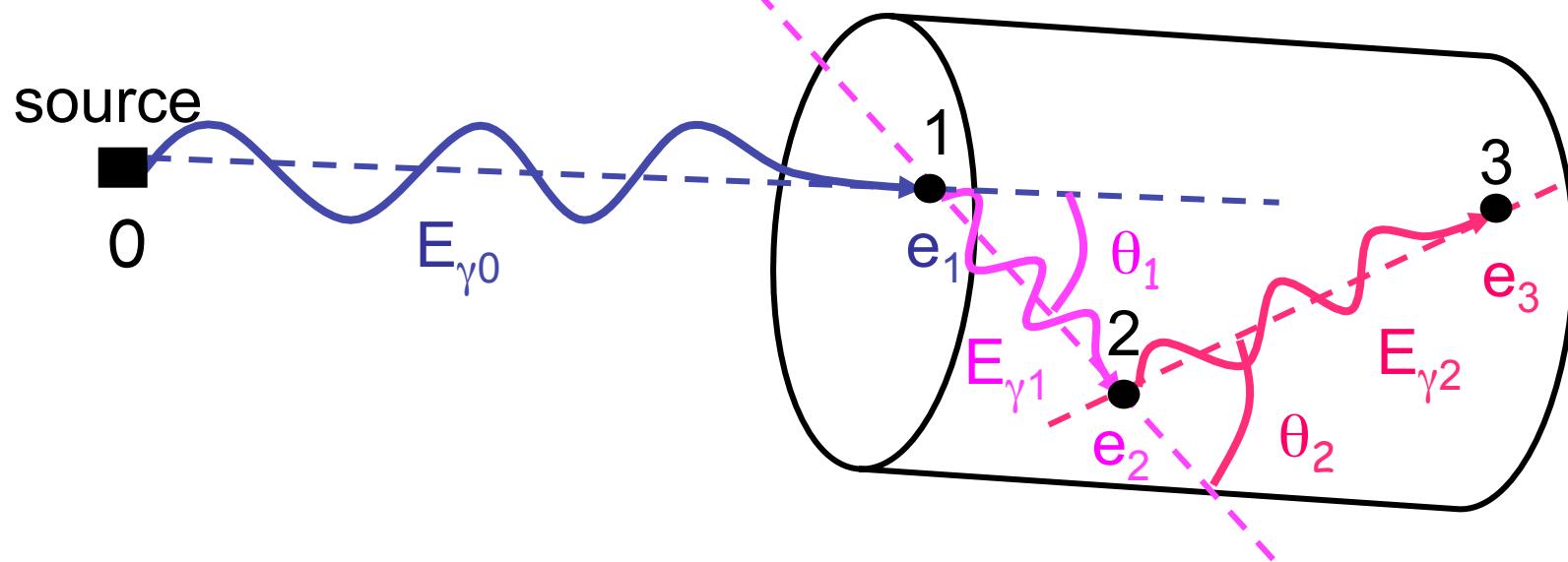
Reconstruct multi-gamma events: E_{incident} , $(x,y,z)_{\text{first}}$, $(x,y,z)_{\text{second}}$



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:

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

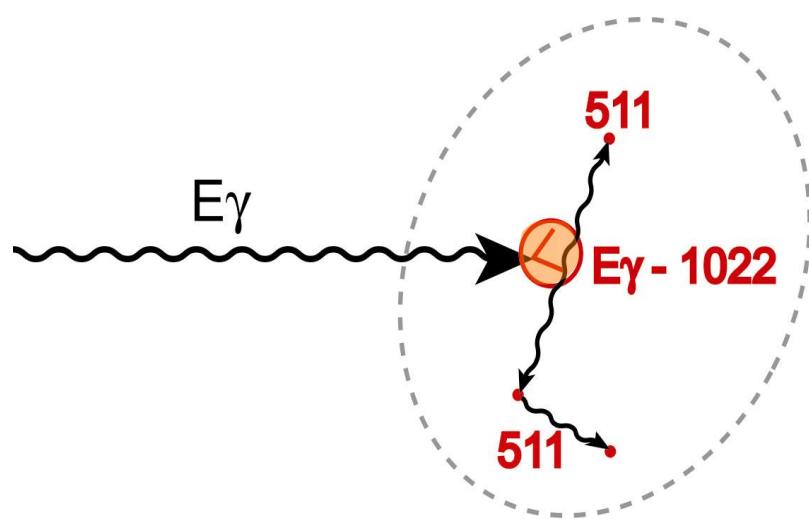
↑
Energy of scattered γ

incident energy = $\sum e_i$ at $i=1$ (if absorption)

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

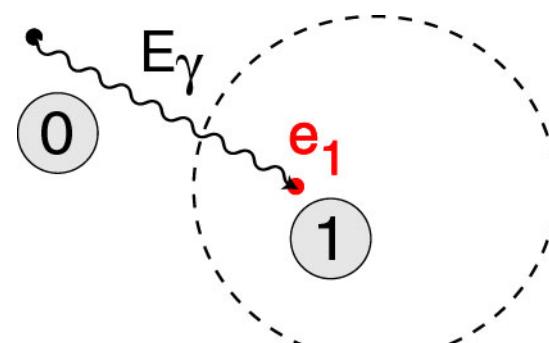
↑
Energy of scattered e^-

Reconstruction of Pair-Production Events



Recognition of the first hit

Reconstruction of single interaction events

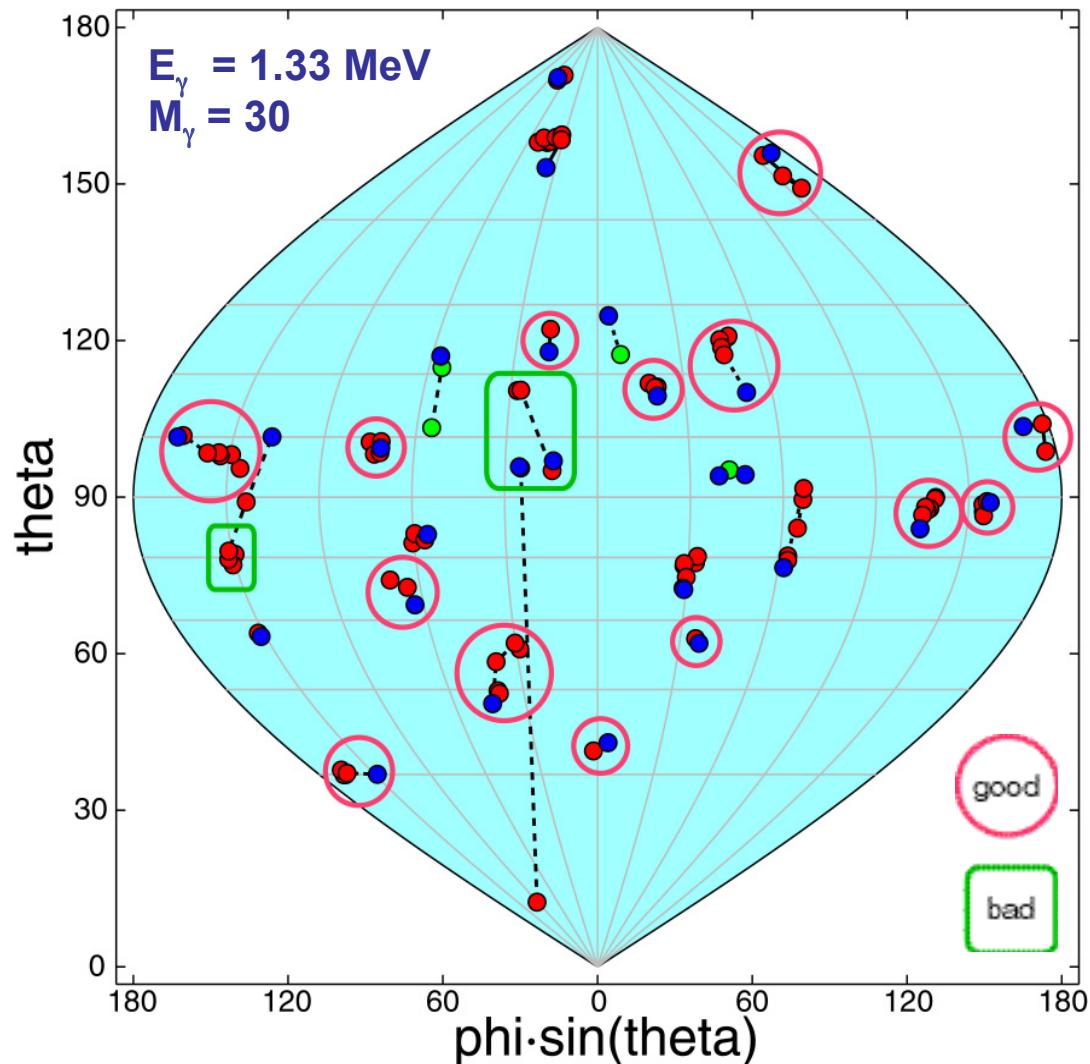


There is not much we can do...

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

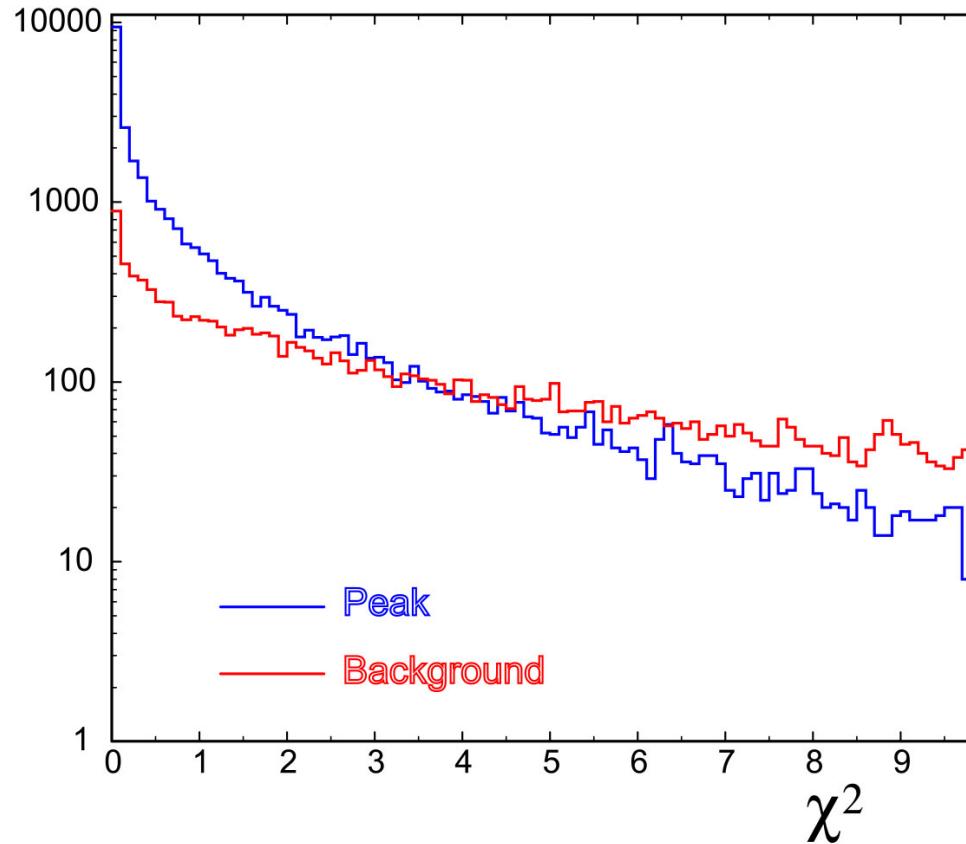
Example of reconstruction in the 4p Ge shell with MGT*

* 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

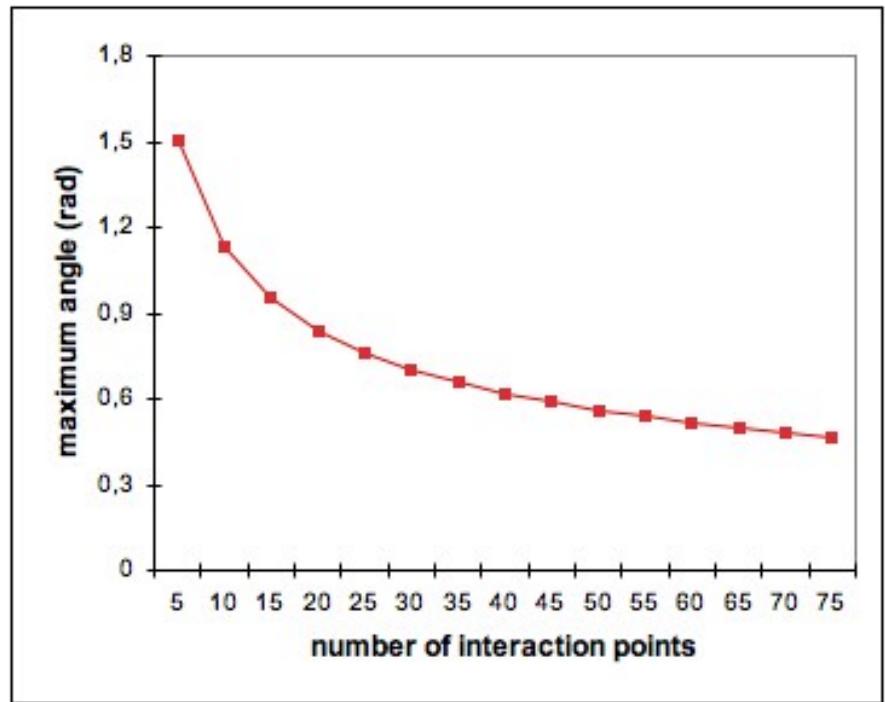
=> Use $R = \text{Efficiency} \times P/T$ to qualify the reconstructed spectrum

Basic steps of OFT (1)

1. Create cluster pool

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

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



α_{\max} can be multiplied by a reduction factor

- Assigns interaction points i and j to the same cluster if their angular separation is $< \alpha$ ($k_{\max} = 7$ interaction points per cluster)
- Loops on $\alpha < \alpha_{\max}$ and find m different clusters ($\alpha_{\min} = 0.15$, rad, $\delta\alpha = 0.1$ rad)

Basic steps of OFT (2)

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

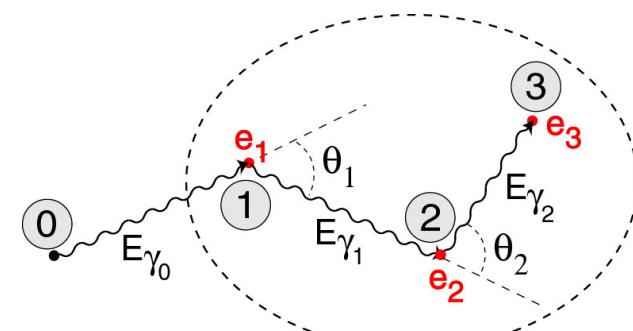
Which sequence satisfies best the Compton scattering rules ?

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

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)

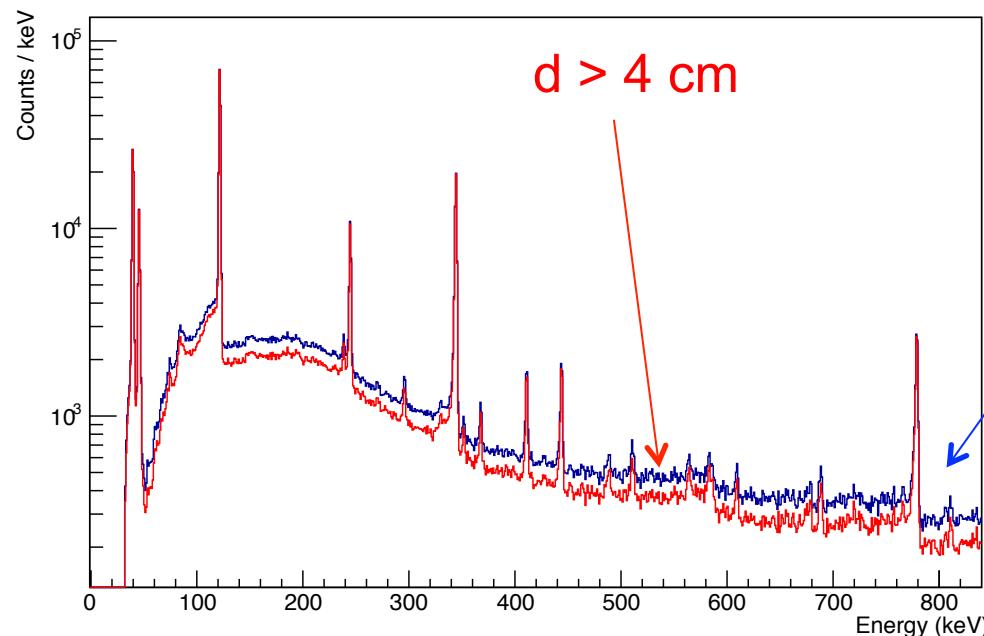
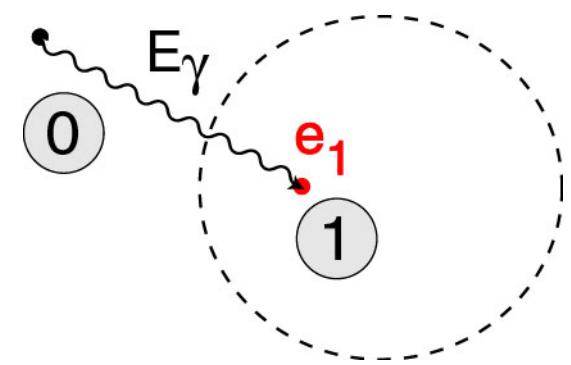
$$er_{cos} = \sigma_\theta \sqrt{\left(\frac{\partial \cos \theta_1}{\partial x_0} \right)^2 + \left(\frac{\partial \cos \theta_1}{\partial y_0} \right)^2 + \left(\frac{\partial \cos \theta_1}{\partial z_0} \right)^2 + \left(\frac{\partial \cos \theta_1}{\partial x_1} \right)^2 + \left(\frac{\partial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



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

Single interaction points

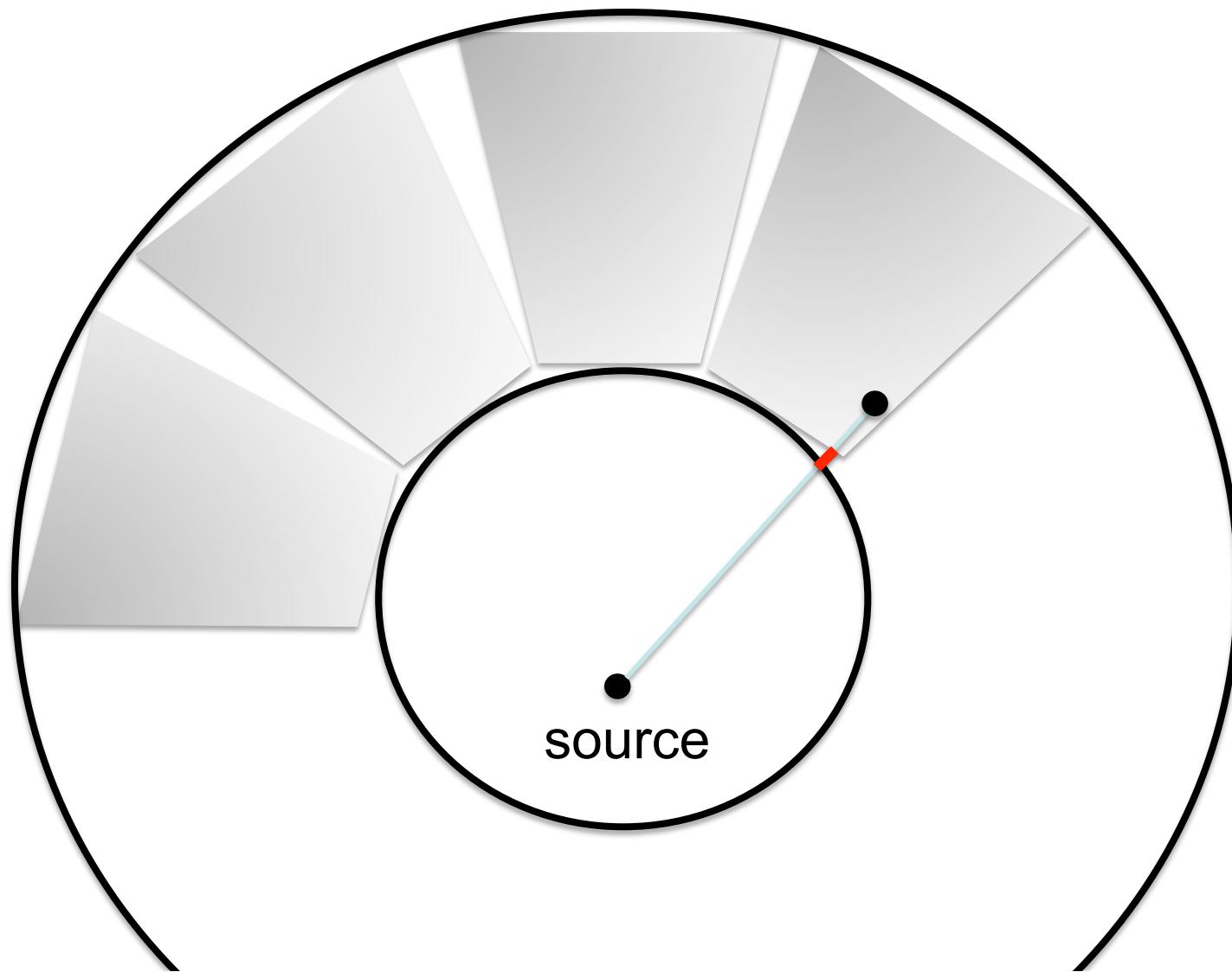
- Does the interaction point satisfy photoelectric conditions (interaction depth, energy)
- Is the interaction point sufficiently isolated from other points ?



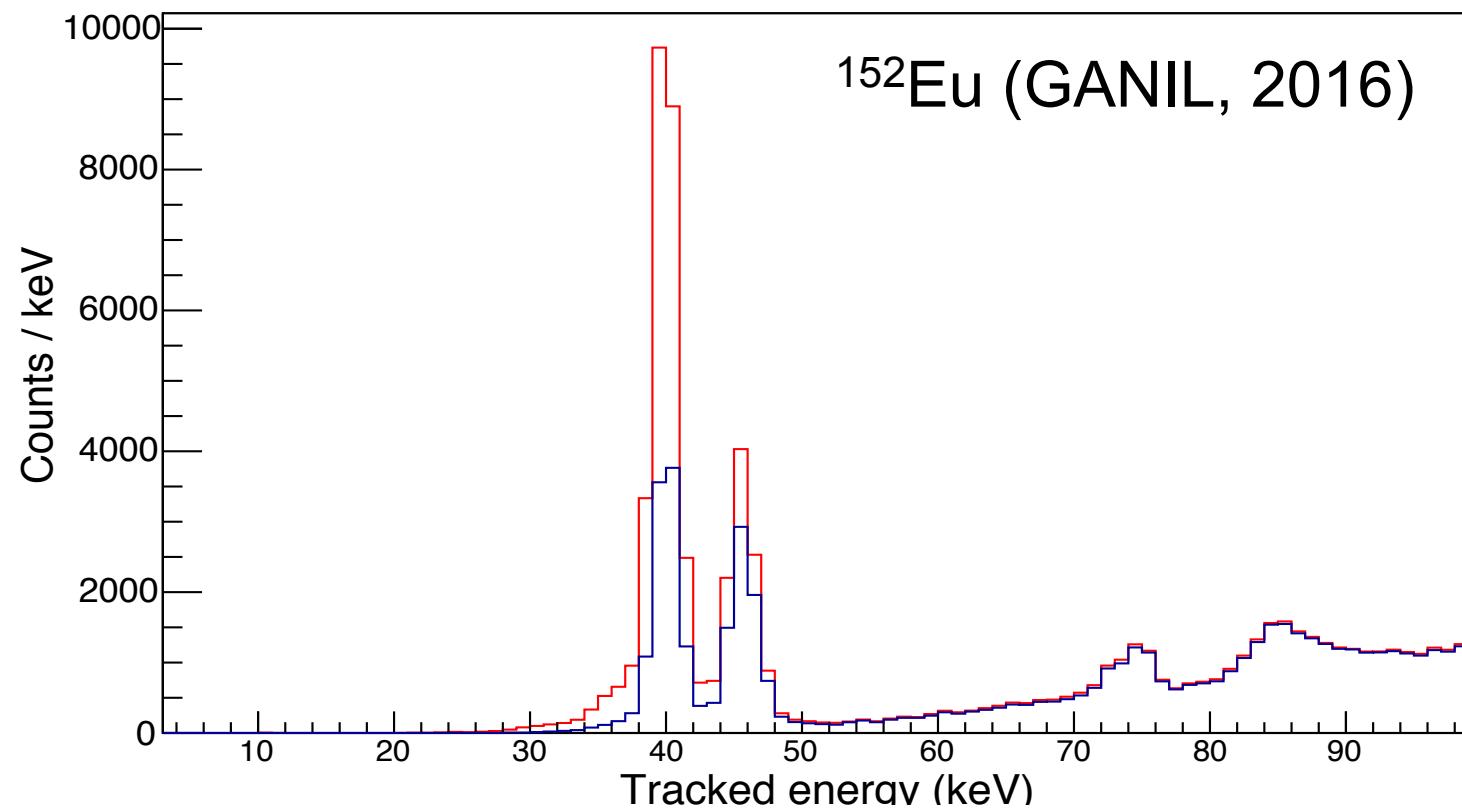
no proximity
criterion

Setting $d=4\text{cm}$ has very
little effect on efficiency

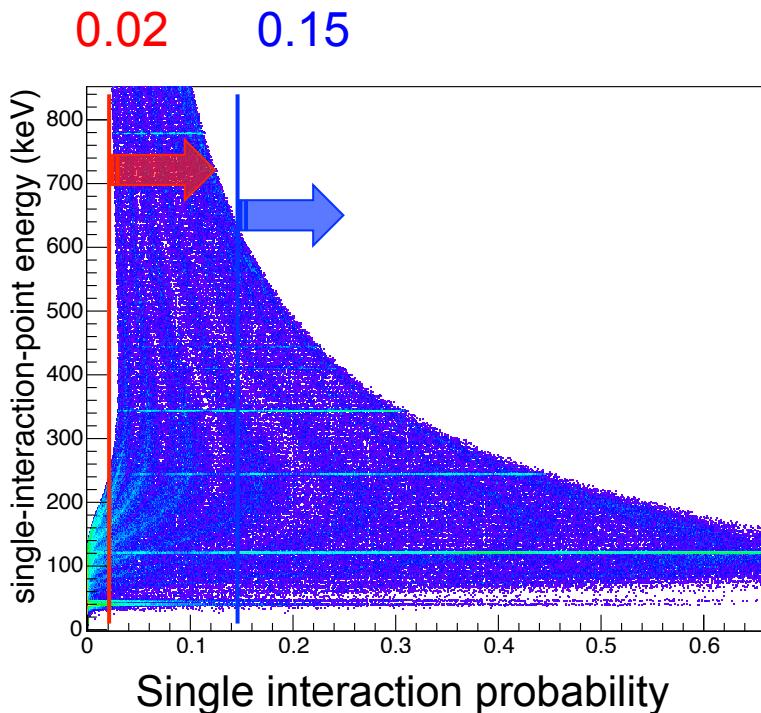
Ge sphere approximation for very low energies



Improving low-energy efficiency

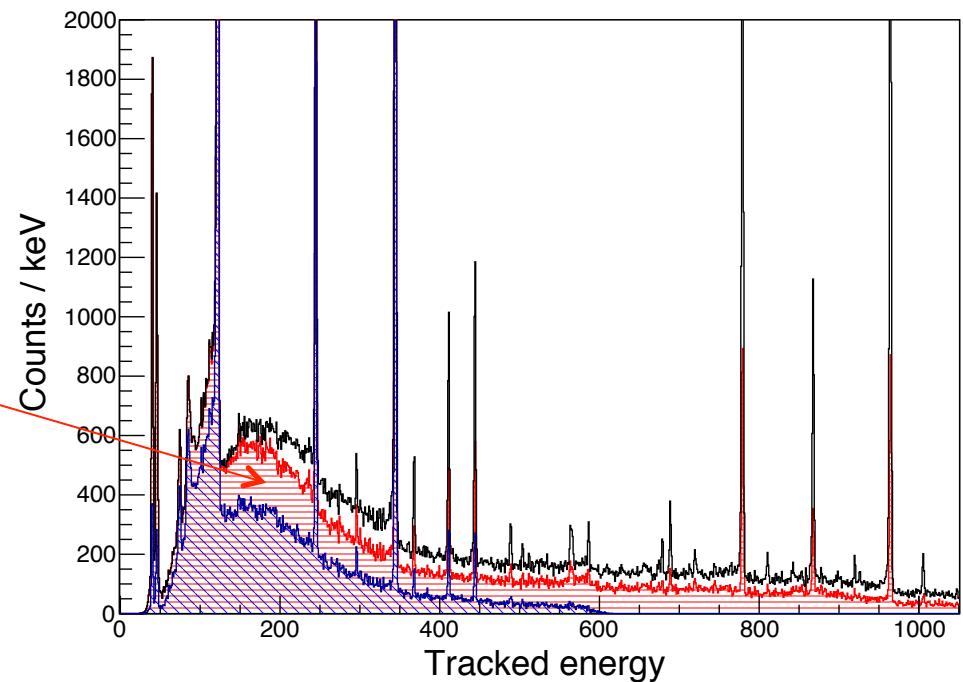


Fine tuning single interactions



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

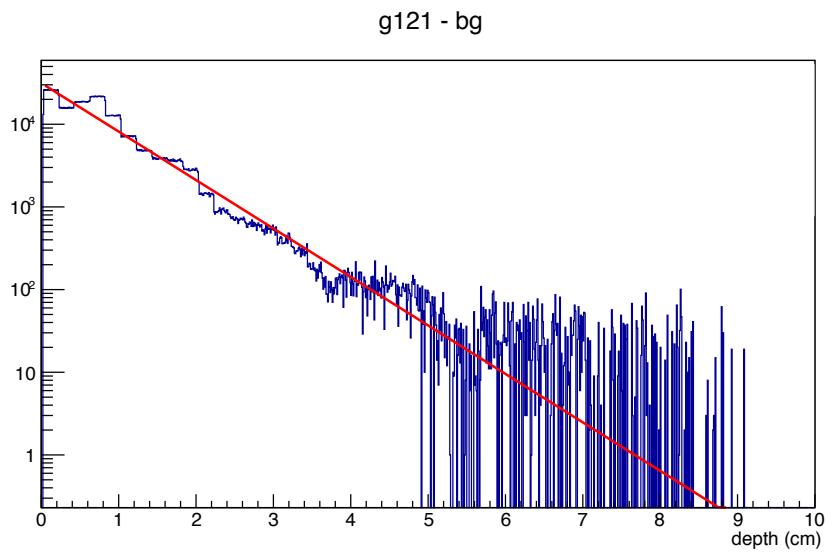
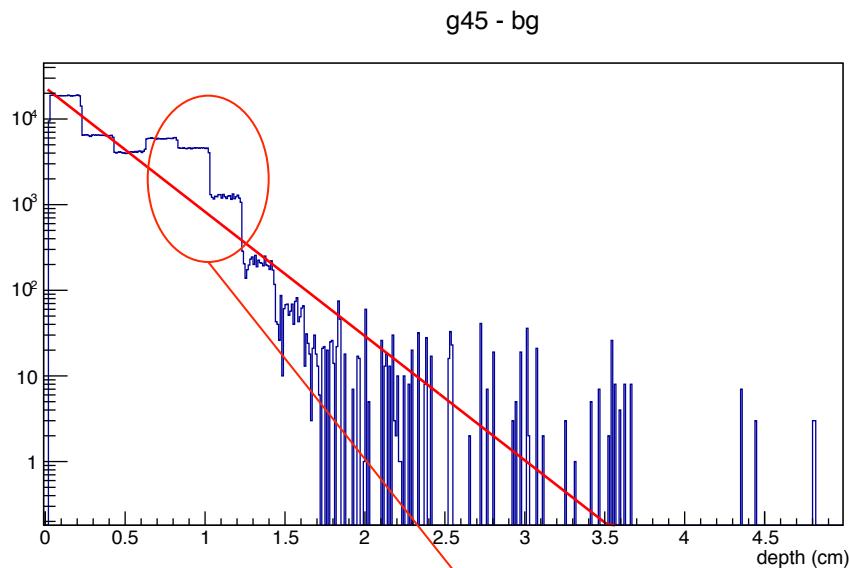
Peak recovered at high energy
but the single interactions
account for 2/3 of the total
background !



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 $d \sim 2,3\text{-}4,6$ interaction lengths λ
- New: use the data

Why ?



$\lambda_{\text{data}} = 0.3 \text{ cm}$
 $\lambda_{\text{table}} = 0.04 \text{ cm}$

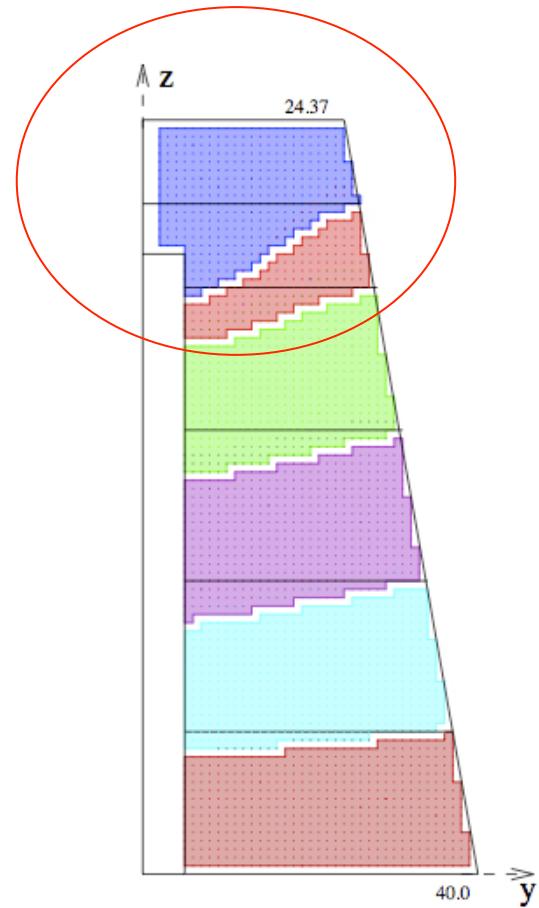
$\lambda_{\text{data}} = 0.74 \text{ cm}$
 $\lambda_{\text{table}} = 0.55 \text{ cm}$

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

How does a 45 keV photon interact at 1 cm ?

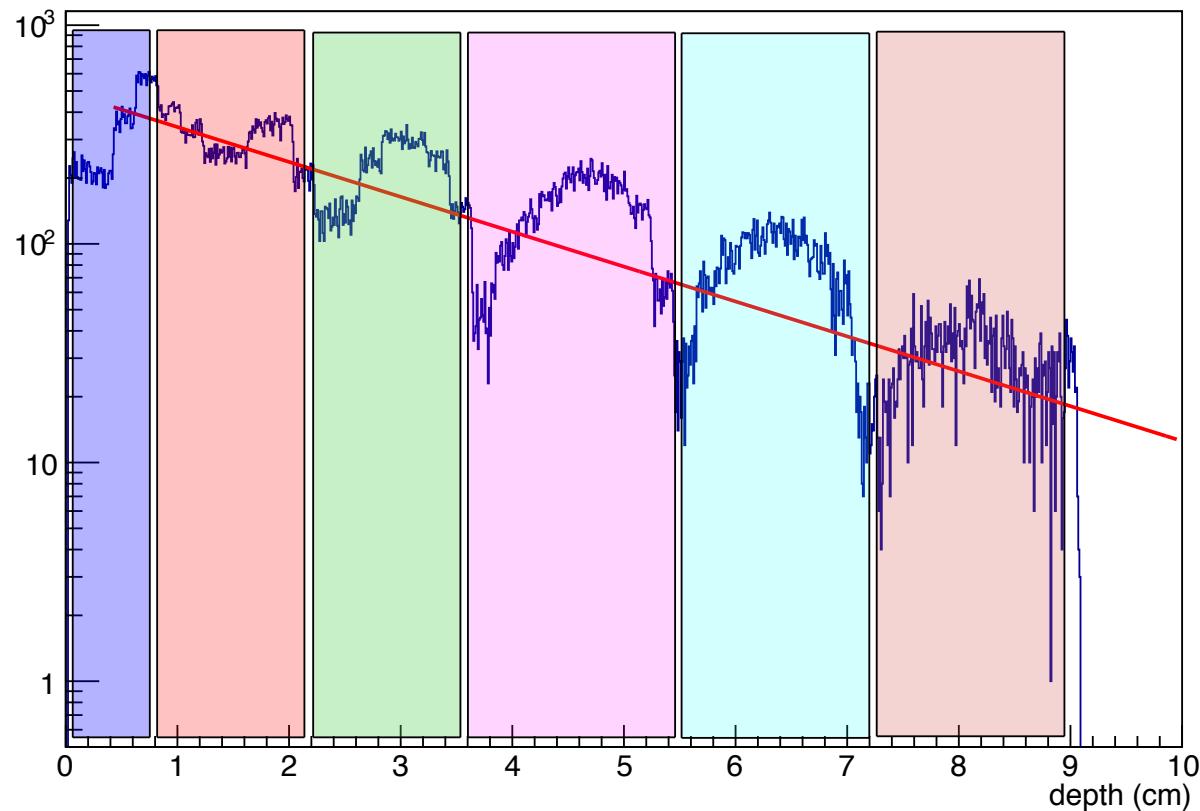
What do the signals look like ?

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



Experimental z distribution distorts ranges

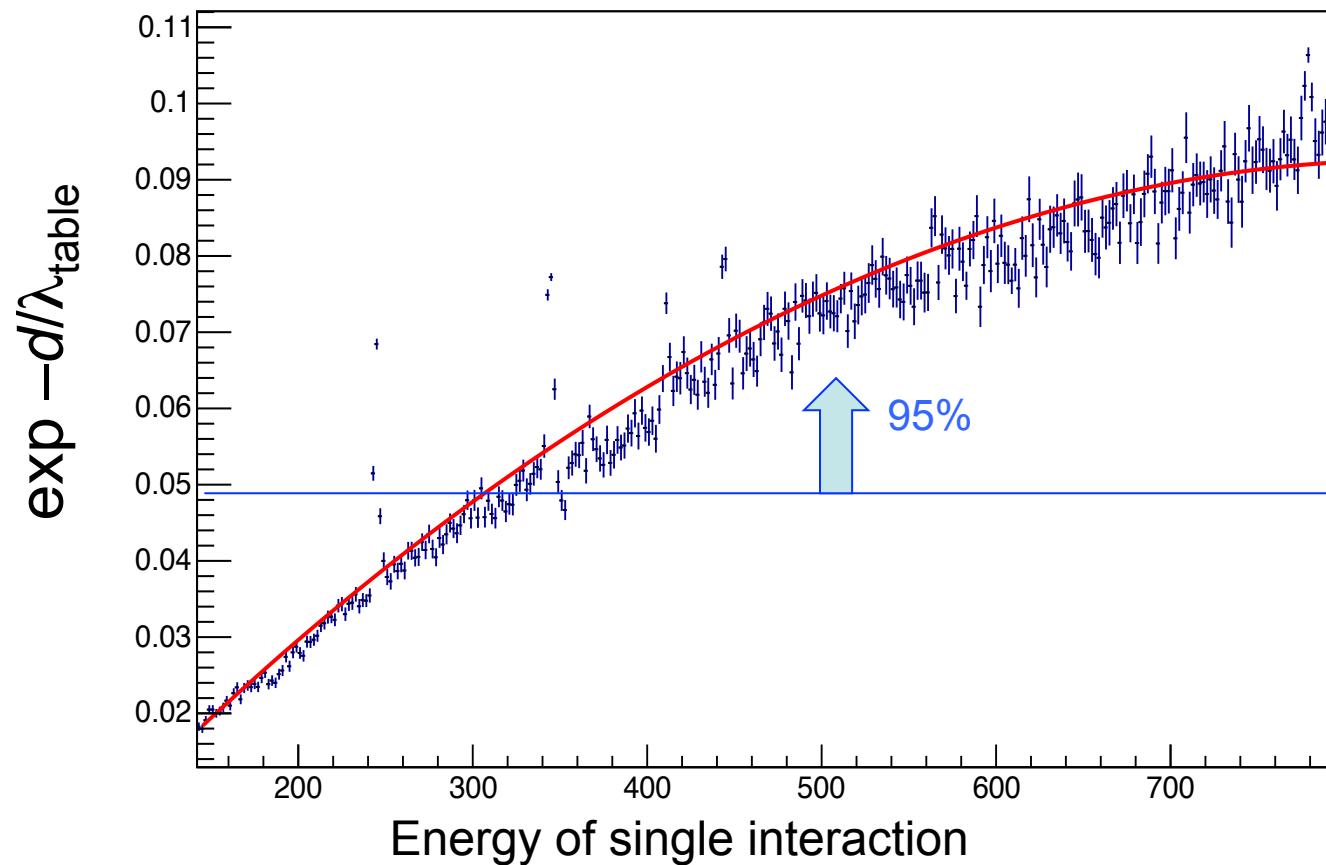
g778-bg



$\lambda_{\text{data}} = 2.8 \text{ cm}$

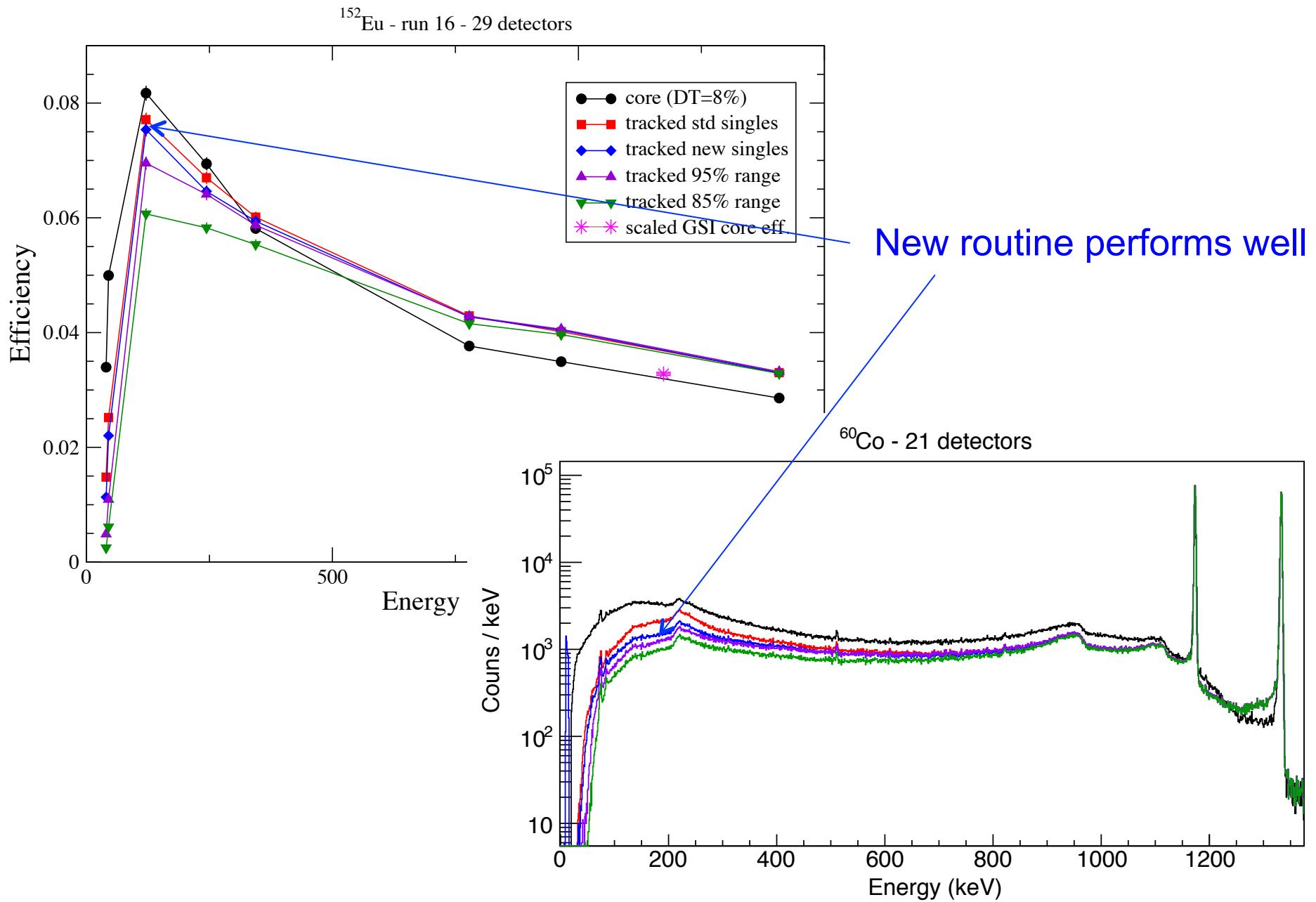
$\lambda_{\text{table}} = 2.99 \text{ cm}$

Determine the ranges experimentally

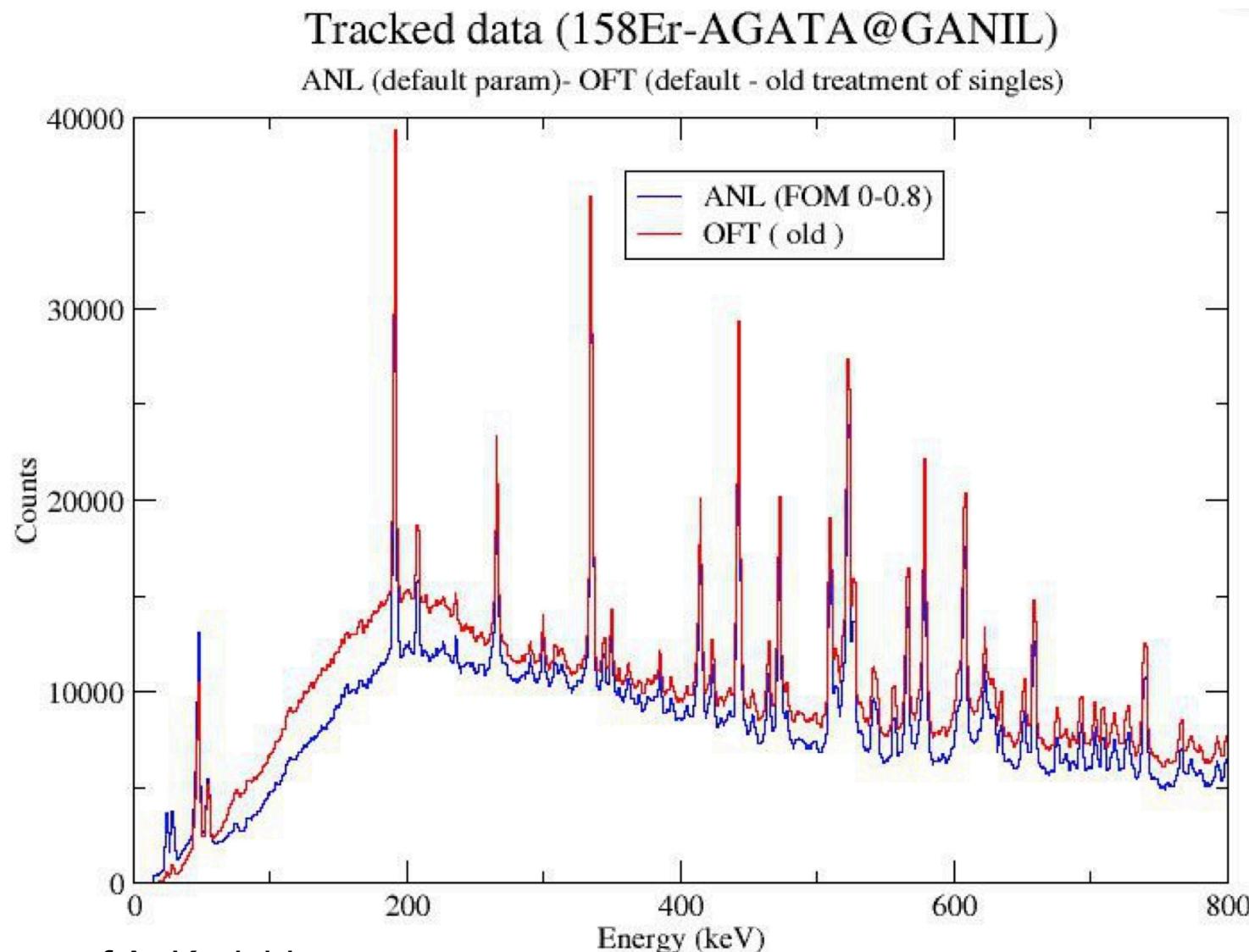


NB: this has to be done each time the PSA is changed

Compromise between P/T and efficiency

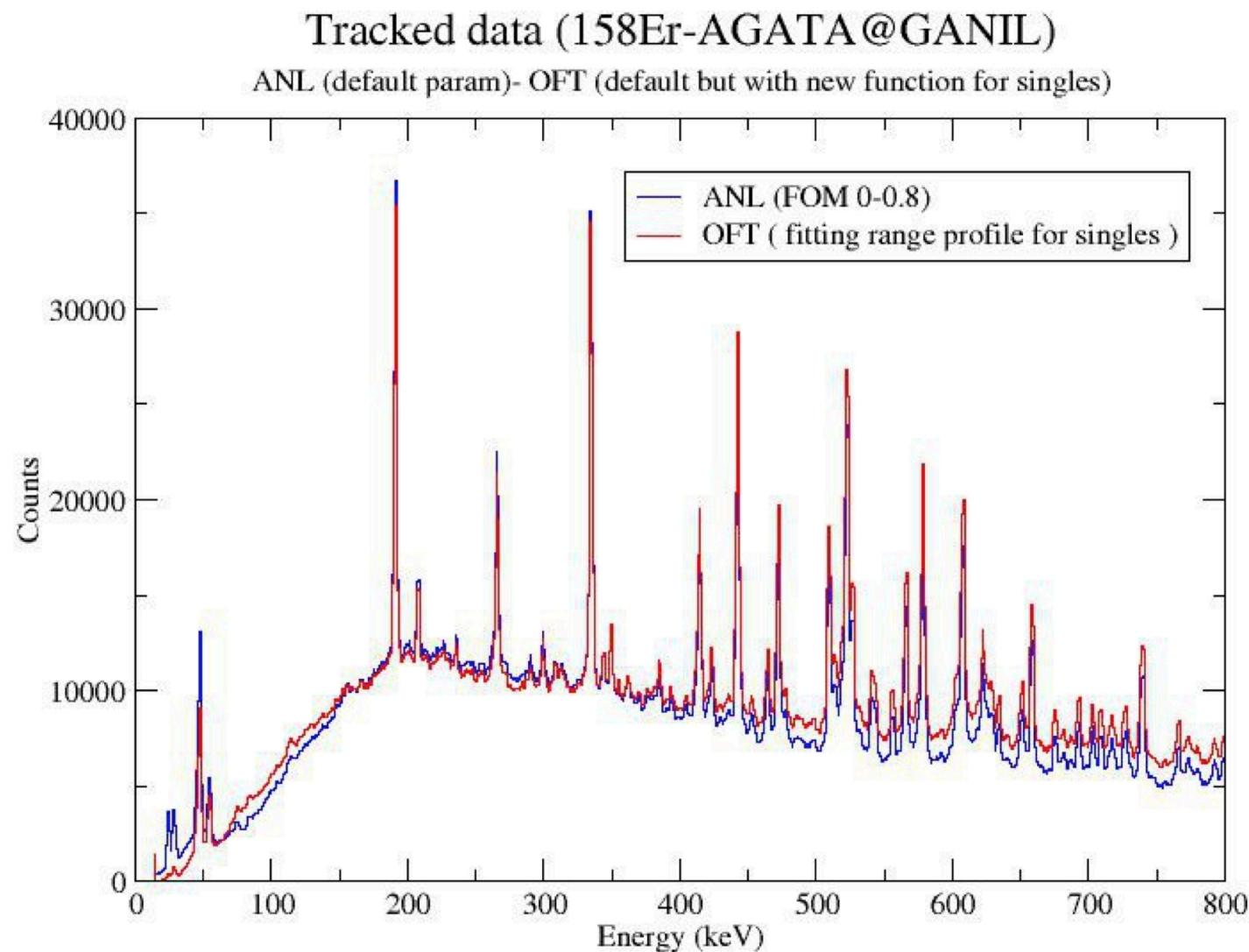


In-beam improvement



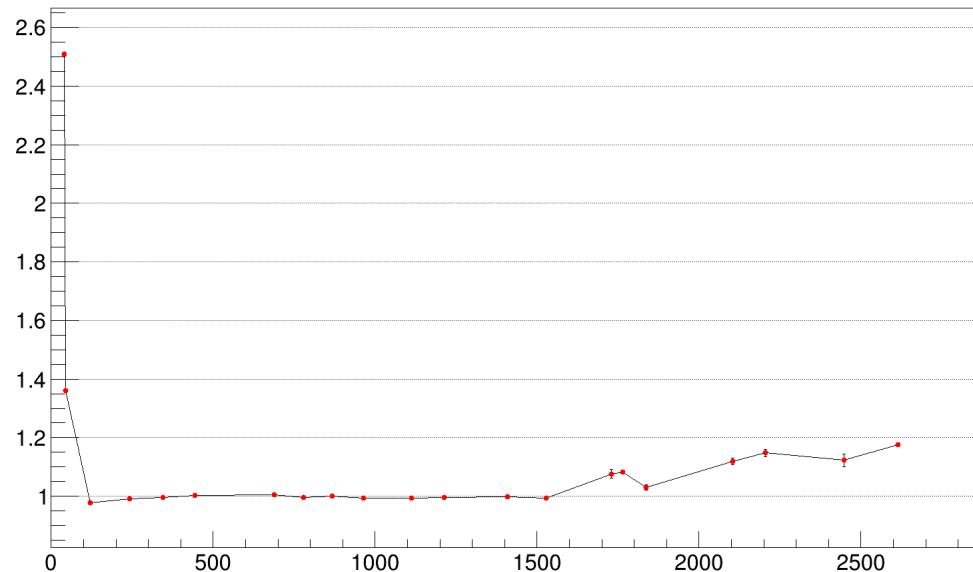
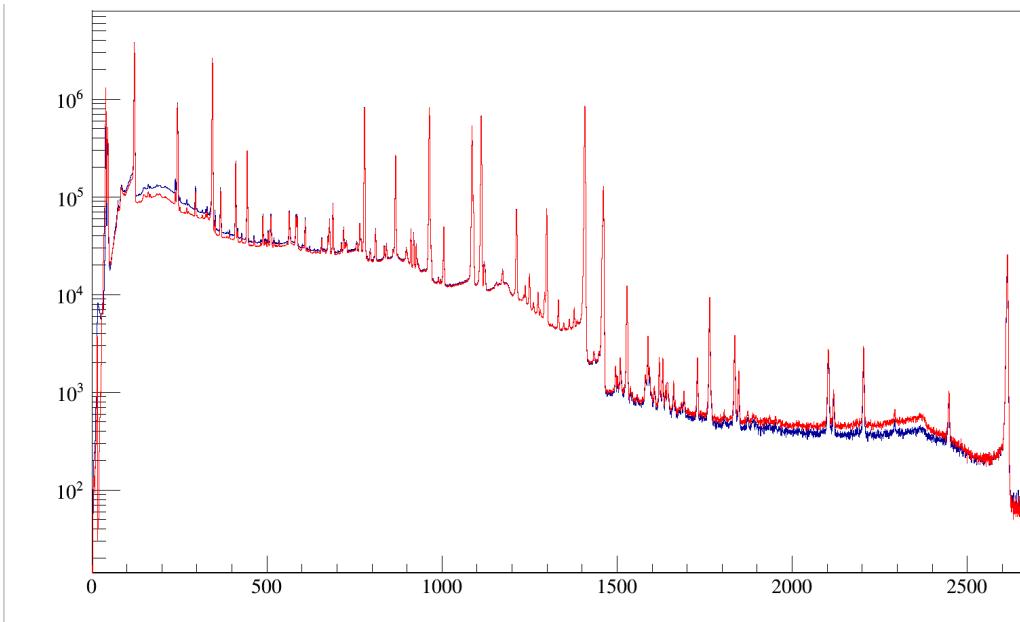
Courtesy of A. Korichi

In-beam improvement



Courtesy 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