Tracking performance with position-dependent position resolution

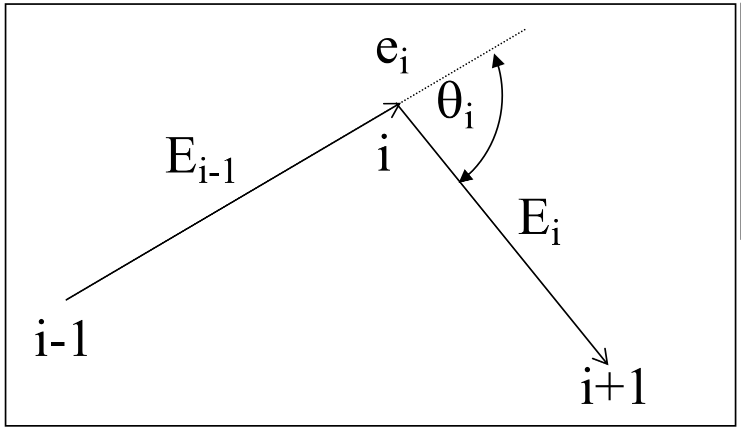
D. Kalaydjieva* and K. Stoychev*
(IJCLab, Orsay)

A. Lopez-Martens
(IJClab, Orsay)

J. Ljungvall
(IPHC, Strasbourg)

*present affiliation: U. of Guelph, Canada

Compton vertex evaluation



$$E_i = \frac{E_{i-1}}{1 + \frac{E_{i-1}}{mc^2}\left(1 - \cos\theta_i\right)}, E_i = E_{i-1} - e_i$$

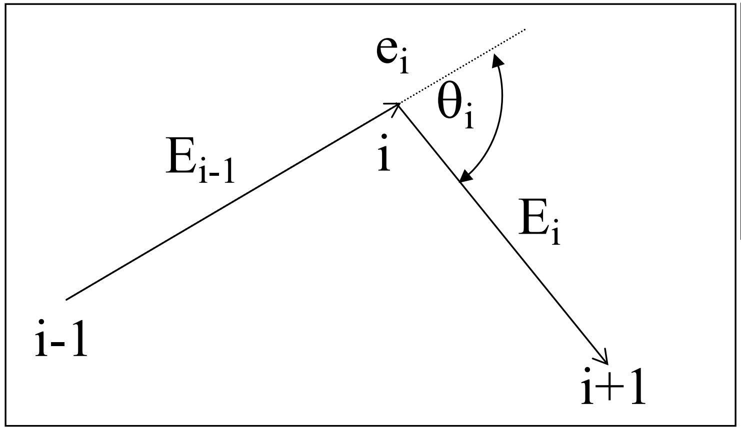
1) $V_i^E = E_i - E_i^P$

2) $V_i^e = e_i - e_i^P$

3) $V_i^{\cos\theta} = \cos\theta_i^E - \cos\theta_i$

4) $V_i^{\theta} = \theta_i^E - \theta_i$

Compton vertex evaluation



$$E_i = \frac{E_{i-1}}{1 + \frac{E_{i-1}}{mc^2}\left(1 - \cos\theta_i\right)}, E_i = E_{i-1} - e_i$$

1) $V_i^E = E_i - E_i^P$

2) $V_i^e = e_i - e_i^P$

3) $V_i^{\cos\theta} = \cos\theta_i^E - \cos\theta_i$

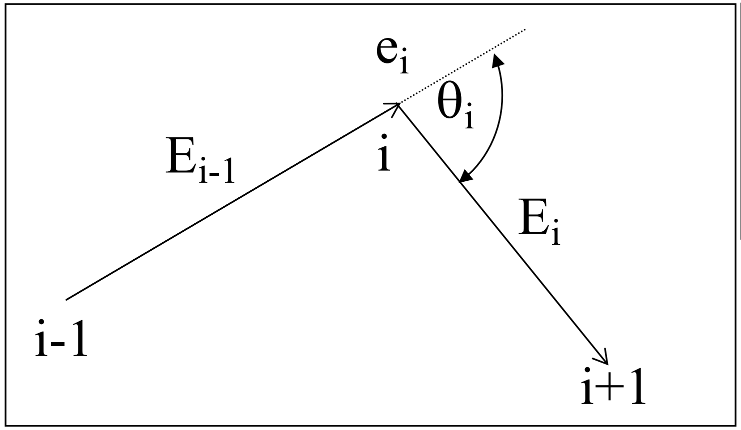
4) $V_i^\theta = \theta_i^E - \theta_i$

mgt: $$\chi^2 = \sum_{i=1}^{N_V} w_i \left(\frac{V_i^E}{E_{i-1}}\right)^2$$

Gretina: $$FOM = \frac{1}{N_V}\sqrt{\sum_{i=1}^{N_V}\left(V_i^\theta\right)^2}$$

OFT: $$L = \prod_{i=1}^{N_V} P_i \exp^{-a\left(\frac{V_i^E}{\sigma_E}\right)^2}$$

Compton vertex evaluation



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

1) $V_i^E = E_i - E_i^P$

2) $V_i^e = e_i - e_i^P$

3) $V_i^{\cos\theta} = \cos\theta_i^E - \cos\theta_i$

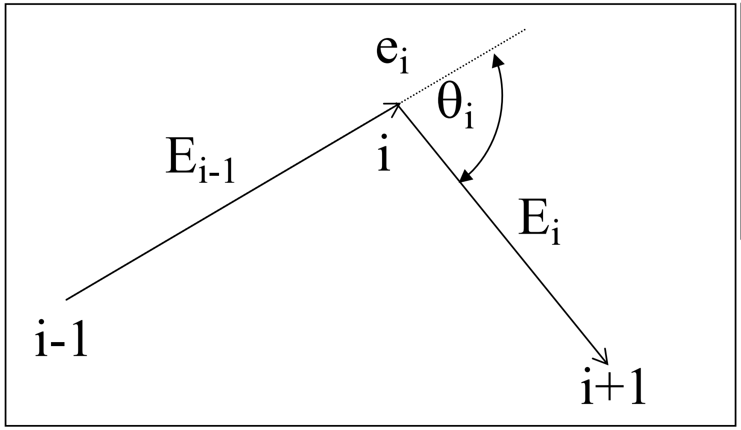
4) $V_i^\theta = \theta_i^E - \theta_i$

mgt: $$\chi^2 = \sum_{i=1}^{N_V} w_i \left(\frac{V_i^E}{E_{i-1}}\right)^2$$

Gretina: $$FOM = \frac{1}{N_V}\sqrt{\sum_{i=1}^{N_V}\left(V_i^\theta\right)^2}$$

OFT: $$L = \prod_{i=1}^{N_V} P_i \exp^{-a\left(\frac{V_i^E}{\sigma_E}\right)^2}$$

Compton vertex evaluation



$$E_i = \frac{E_{i-1}}{1 + \frac{E_{i-1}}{mc^2}\left(1 - \cos\theta_i\right)}, E_i = E_{i-1} - e_i$$

1) $V_i^E = E_i - E_i^P$

2) $V_i^e = e_i - e_i^P$

3) $V_i^{\cos\theta} = \cos\theta_i^E - \cos\theta_i$

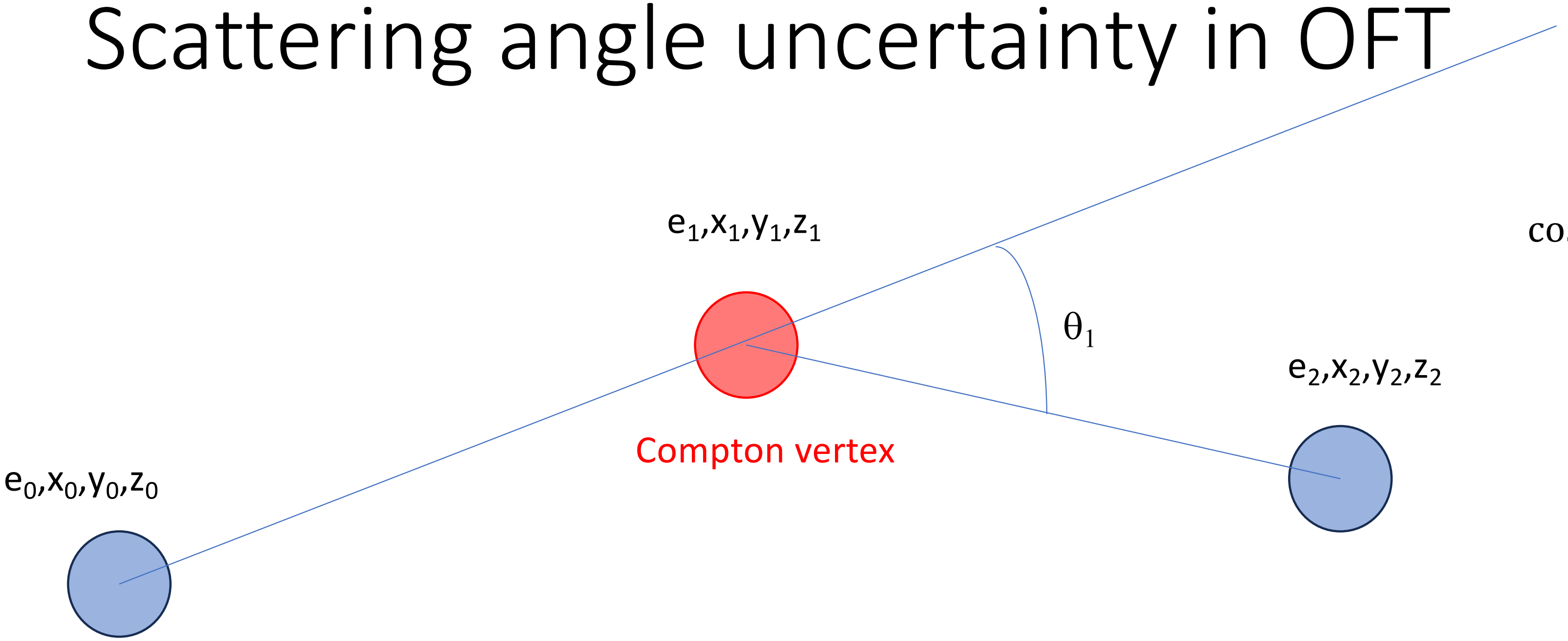
4) $V_i^\theta = \theta_i^E - \theta_i$

mgt: $$\chi^2 = \sum_{i=1}^{N_V} w_i \left(\frac{V_i^E}{E_{i-1}}\right)^2$$

Gretina: $$FOM = \frac{1}{N_V}\sqrt{\sum_{i=1}^{N_V}\left(V_i^\theta\right)^2}$$

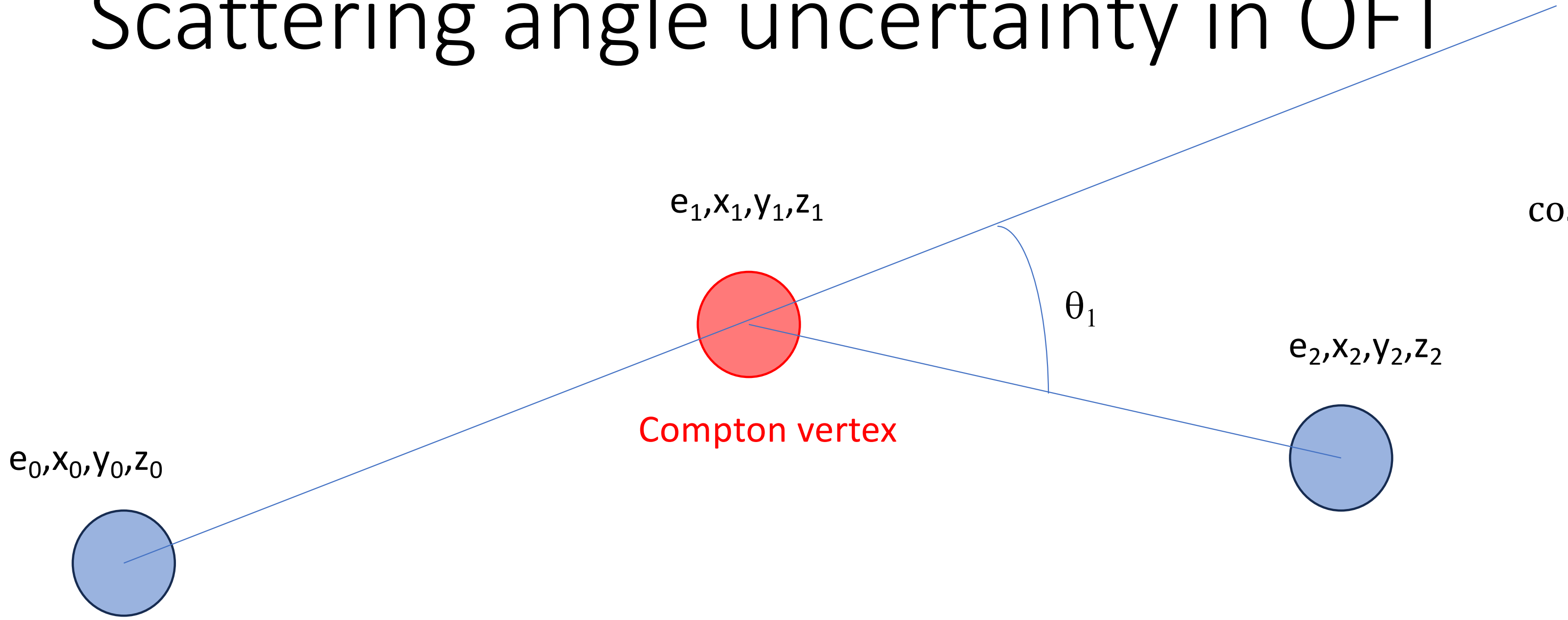
OFT: $$L = \prod_{i=1}^{N_V} P_i \exp^{-a\left(\frac{V_i^E}{\sigma_E}\right)^2}$$

Scattering angle uncertainty in OFT



$$\cos\theta_1 = \frac{\overrightarrow{01} \cdot \overrightarrow{12}}{\|\overrightarrow{01}\| \|\overrightarrow{12}\|}$$

Scattering angle uncertainty in OFT



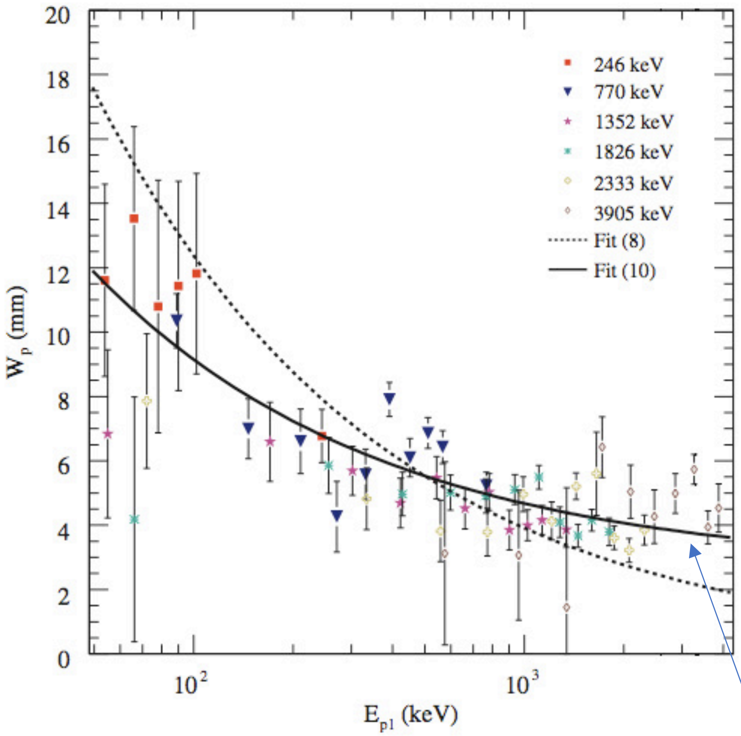
$$\cos\theta_1 = \frac{\overrightarrow{01} \cdot \overrightarrow{12}}{\|\overrightarrow{01}\|\|\overrightarrow{12}\|}$$

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

$\sigma_x=\sigma_y=\sigma_z$= constant = σ_θ = CONSTANT

Reality is different

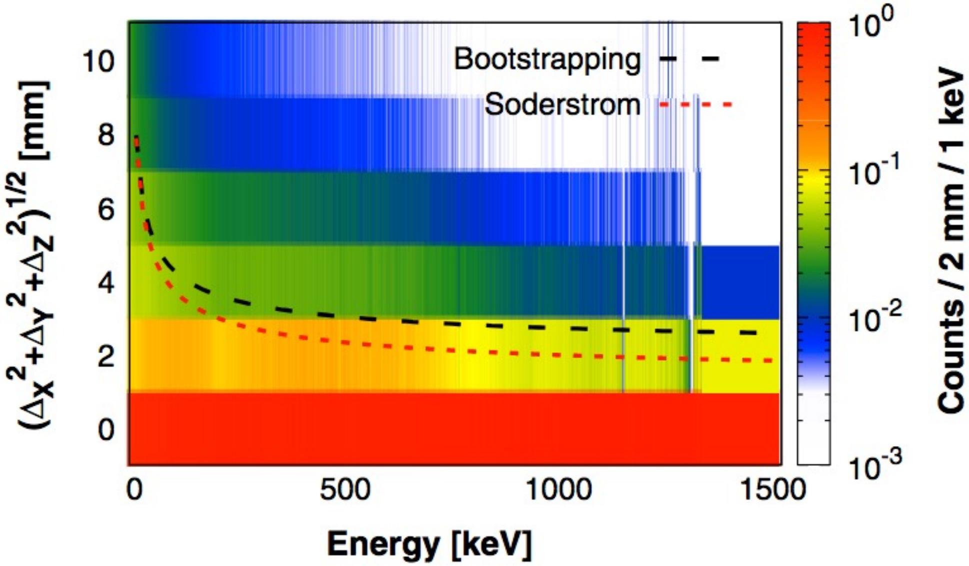
P.-A. Söderström et al., Nucl. Instr. Meth. A 638 (2011) 96



FWHM = $W_p(E_p) = w_0 + w_1\sqrt{\frac{100\ \mathrm{keV}}{E_p}}$

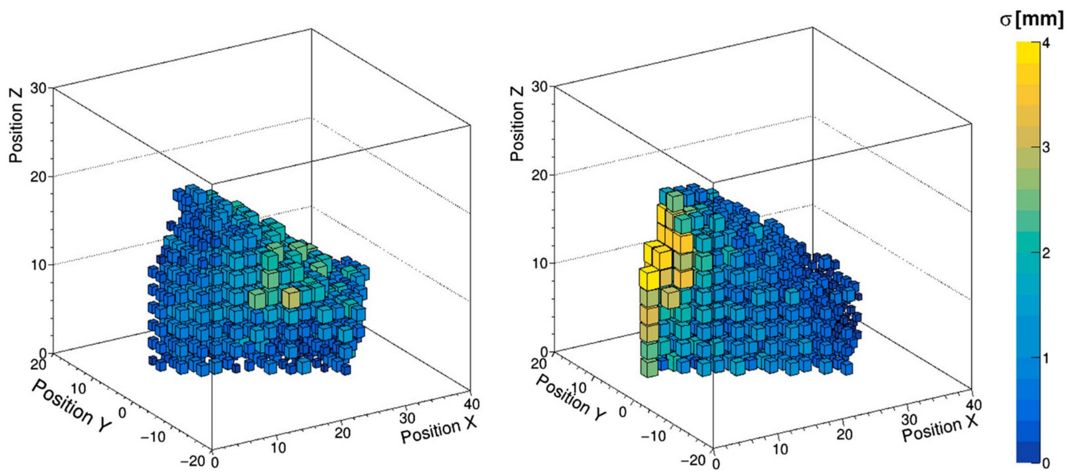
w1=2.7
w2=6.2

M. Siciliano et al., Eur. Phys. J. A (2021) 57:64



-σ_x(64 keV – 128 keV)

+σ_x(64 keV – 128 keV)



Can knowing the position-dependent position uncertainty improve the tracking performance of OFT ?

Two position-dependent position resolution data bases

1) M. Siciliano (Bootstrapping method) – asymmetric uncertainties, 3 LUTs for crystals A,B & C and for different deposited energy ranges, cartesian coordinates

(MS)

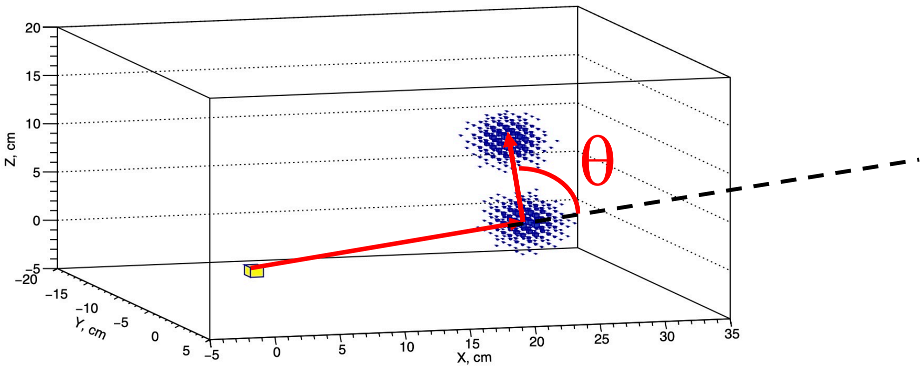
M. Siciliano et al., Eur. Phys. J. A (2021) 57:64

2) M. Labiche & S. Chong – symmetric uncertainties, 3 LUTs for crystals A,B & C scaled by Söderström energy dependence, cylindrical coordinates (data base pipeline: GEANT4 simulations -> signal generation via ADL -> PSA -> comparison between extracted positions from PSA and real positions)

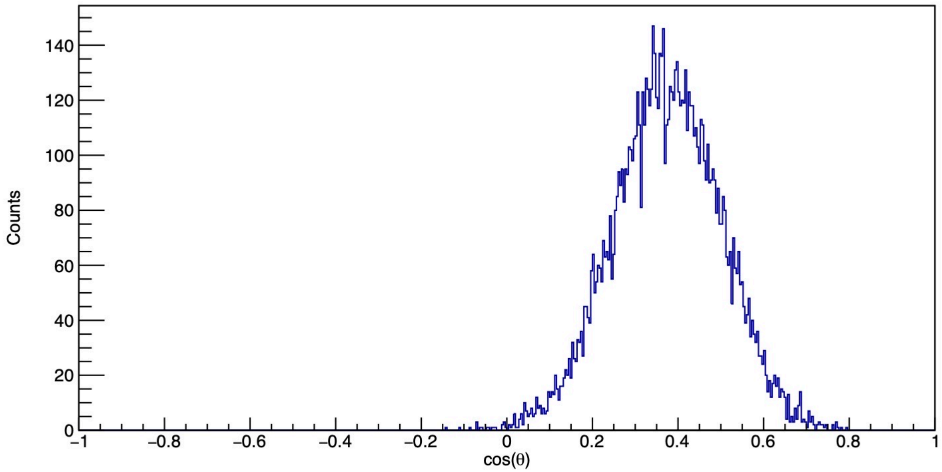
(ML)

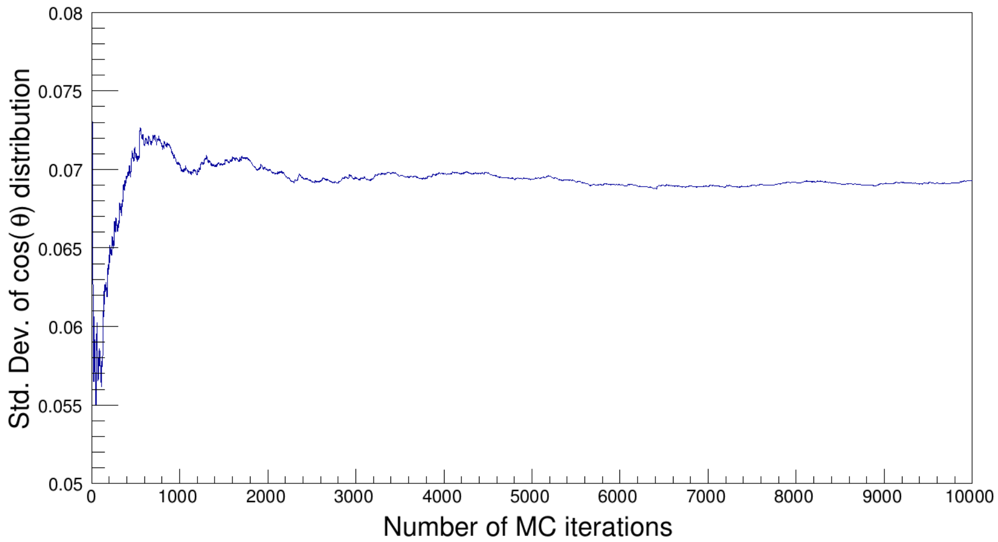
Computing $\partial\cos\theta$ when σ_x, σ_y and σ_x are different

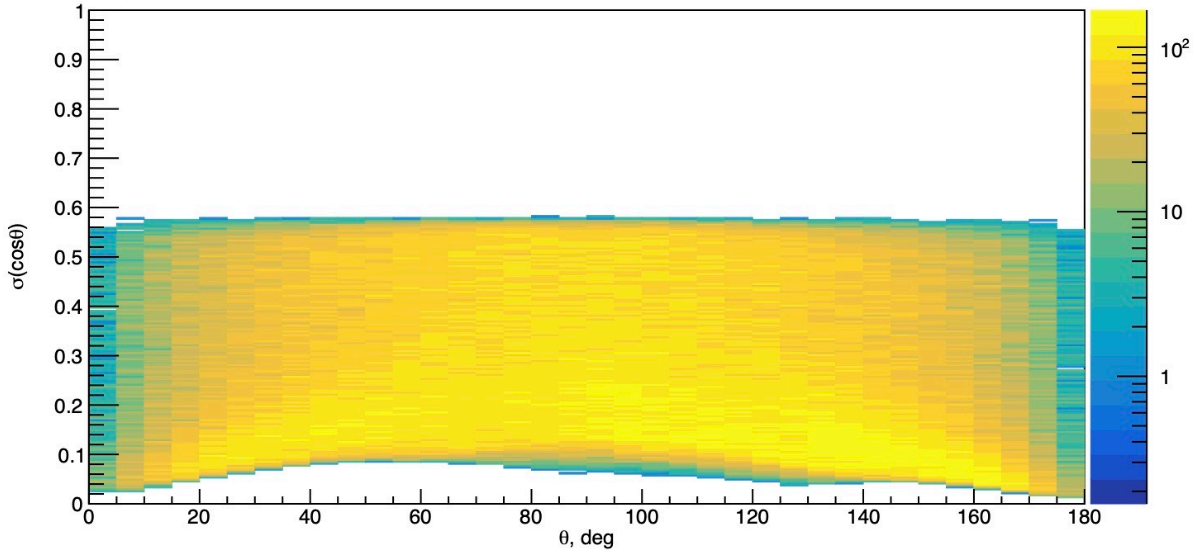
Monte Carlo sampling of positions @ every Compton vertex from a normal (symmetric case) or split normal distribution (asymmetric case)



Fit of cosθ distribution to extract $\partial\cos\theta$ @ vertex

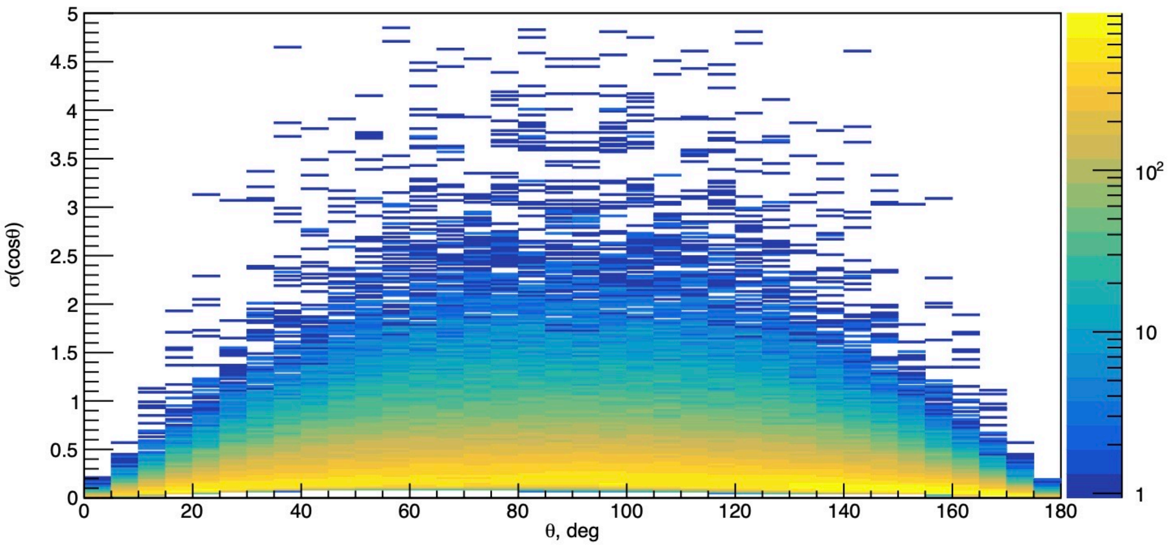




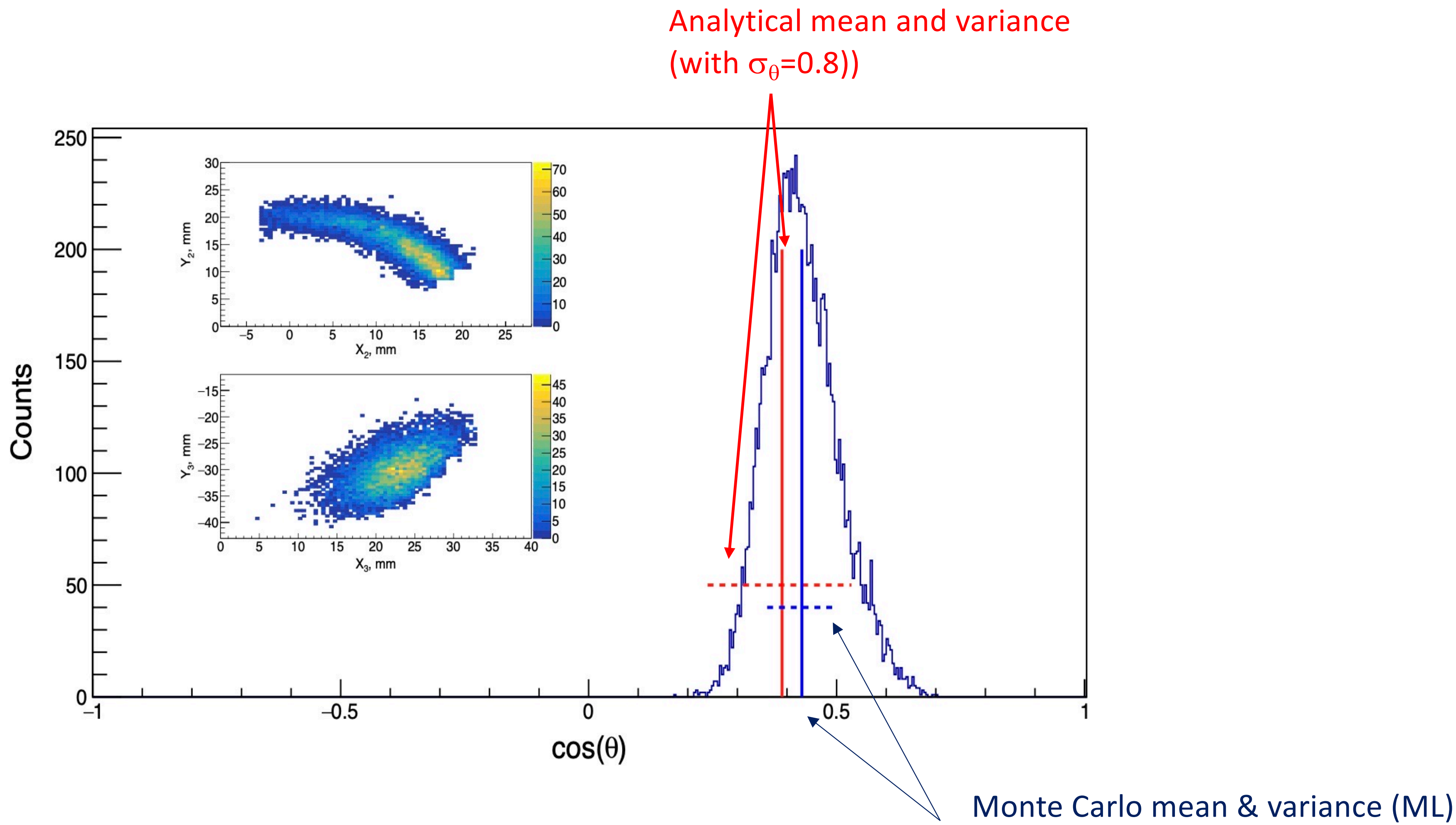


Monte Carlo cosine uncertainties for all accepted or rejected first vertices (constant position uncertainty)

OFT analytical cosine uncertainties (constant position uncertainty)



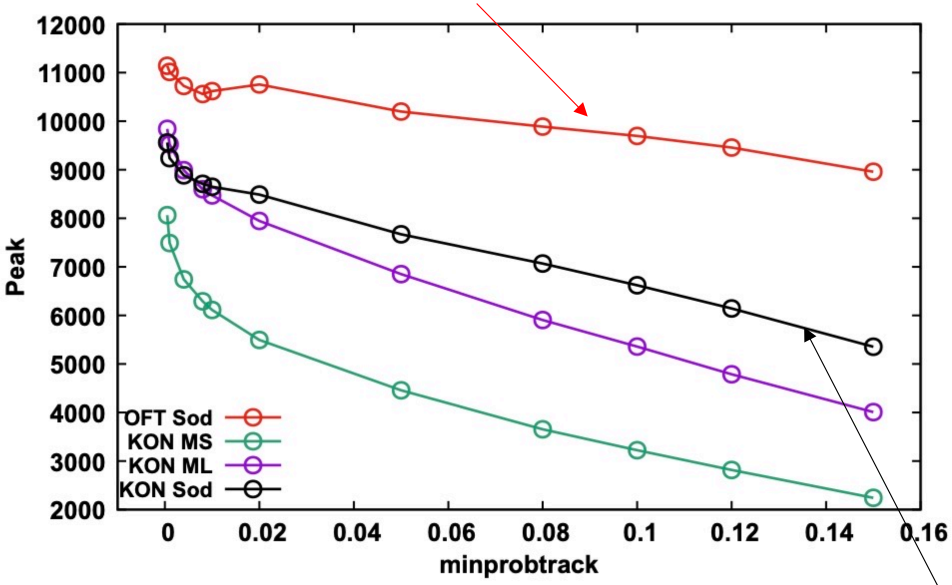
Effect of segment borders

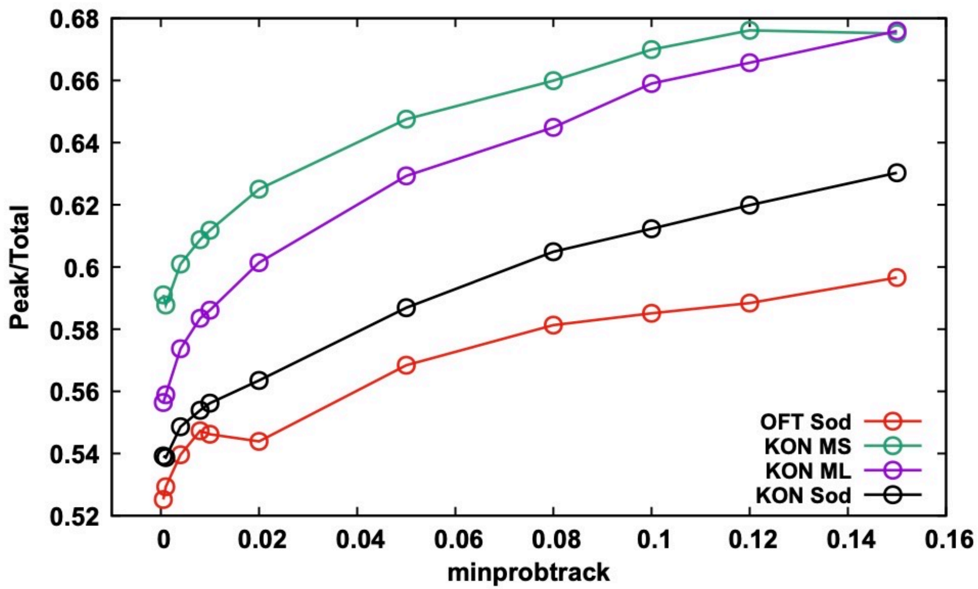


Ganil ^{60}Co source run

29 detectors – 1332 keV-gated data

Standard OFT = analytical calculation of $\partial\cos\theta$





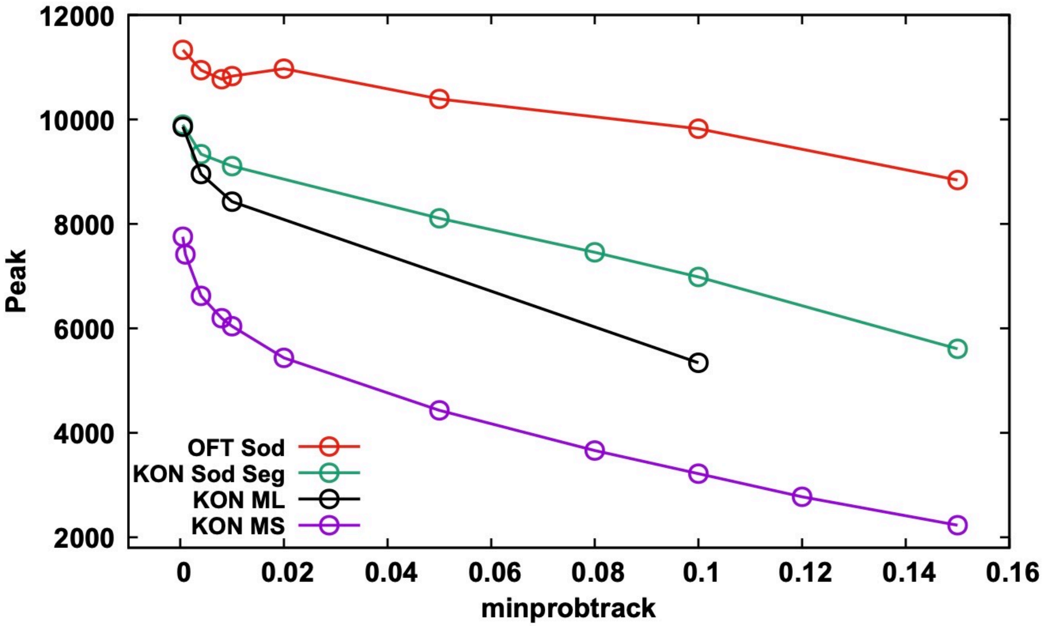
OFT modified by Konstantin = Monte Carlo extraction of $\partial\cos\theta$

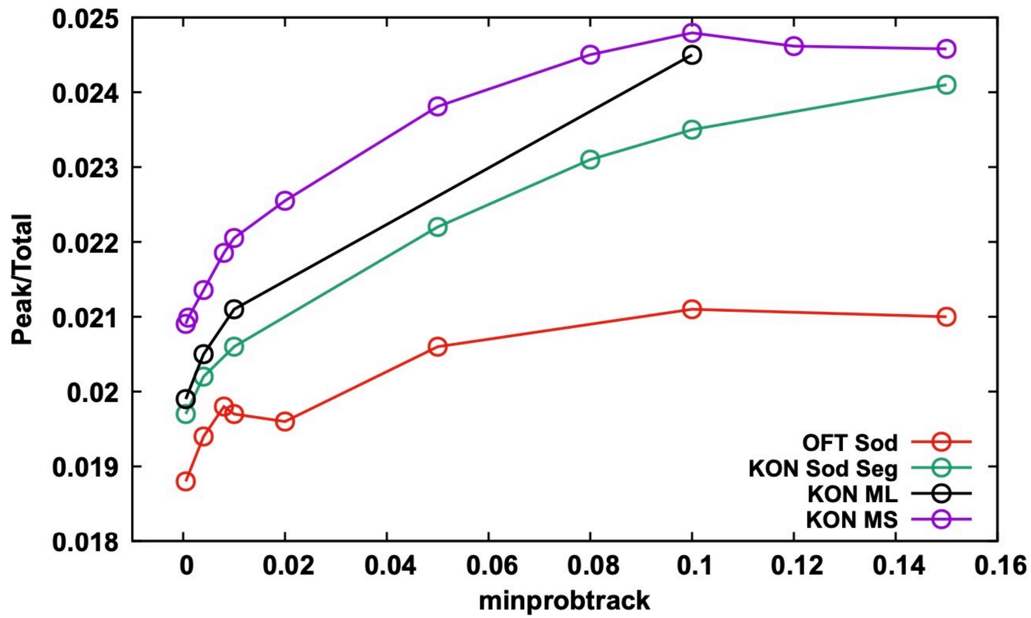
No single-point interactions

Fixed clustering angle

In-beam ^{98}Zr PSA test-bench data

Peak of interest: 1222.9 keV ($2_1^+ \rightarrow 0_1^+$)

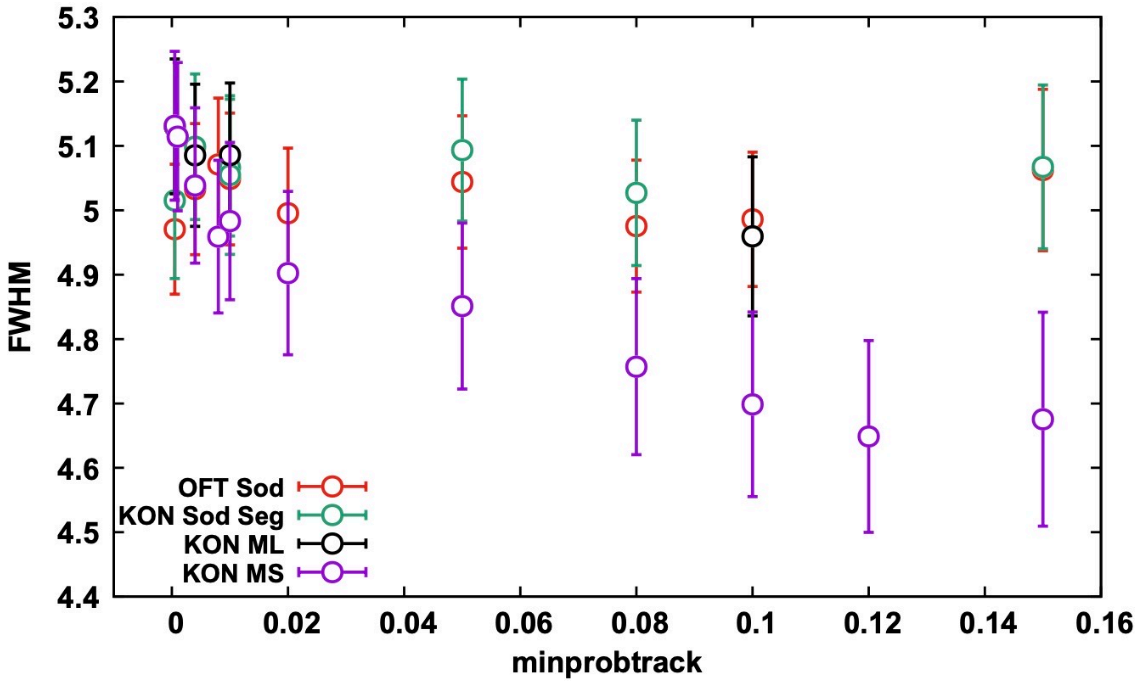




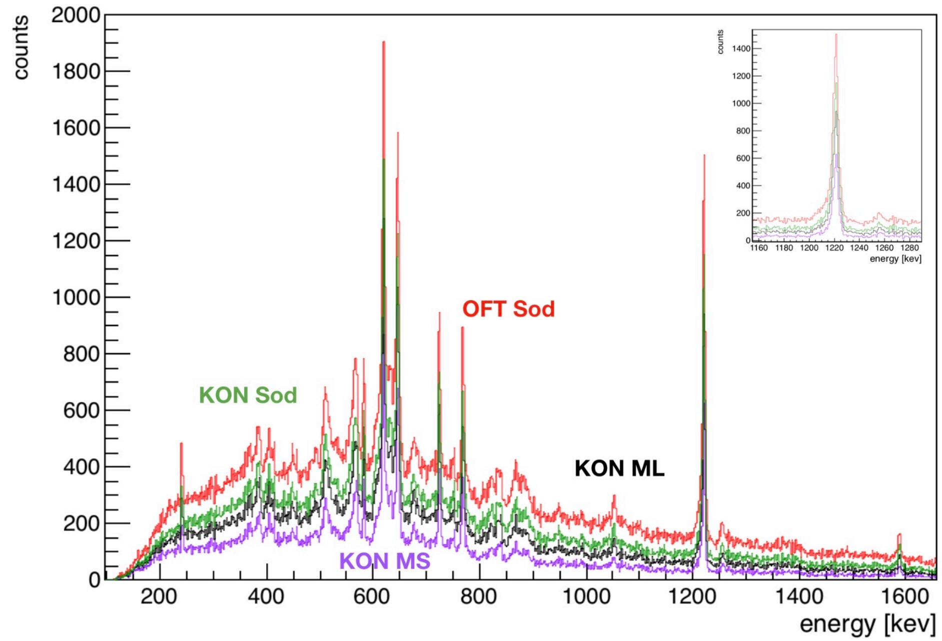
No single-point interactions

Fixed clustering angle

In-beam ^{98}Zr data



minprobtrack=0.08



Peak fits performed with gaussian + skewed gaussian + step function

Conclusions & perspectives

- The uncertainty in cosθ is overestimated in OFT (except at small and large angles, where it is underestimated)

- The vertex evaluator of OFT performs better (albeit with a worse P/T) with an average uncertainty on all points than with more realistic position uncertainty maps (effect of evaluator or non fidelity of uncertainty data base ?)

Some things to investigate:

- Scale OFT cosine uncertainties for forward and backscattered events to recuperate the forward and backward scattered events which are rejected due to the “close-to-0” cosθ uncertainties
- Investigate other types of evaluators
- Scale data base uncertainties ?