Future of tracking

- Our examples follows
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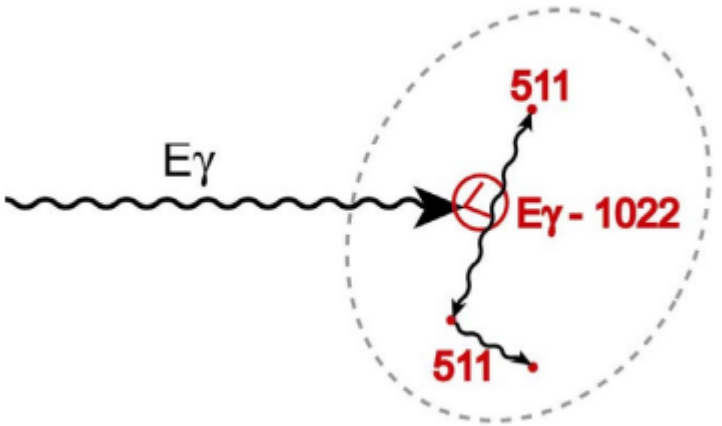
-
- Hopefully you will have new ideas too

Pair production

- Starts to dominate over ~9MeV
- None of the codes we use now has this process included. Well, MGT has an approximation...
- *This would be a good research project!* ***Machine Learning (ML) maybe?***, *pattern recognition?*
- Can produce single and double escape peaks



Best discussion I know of is in:
evince ~/d6/epapers/Agata-proposal.pdf

Some other FOM measures

$$FOM = \frac{\sqrt{\sum_i^N [cos(\theta_i^{theo}) - cos(\theta_i)]^2}}{N-1}$$

Dirk

$$\chi^2 \sim \sum_{n=1}^{N-1} W_n \Big(\frac{E_{\gamma'} - E_\gamma^{pos}}{E_\gamma} \Big)_n^2$$

MGT

$$F_E = exp(\frac{-2(E_{s,p} - E_{s,e})^2}{\sigma^2})$$

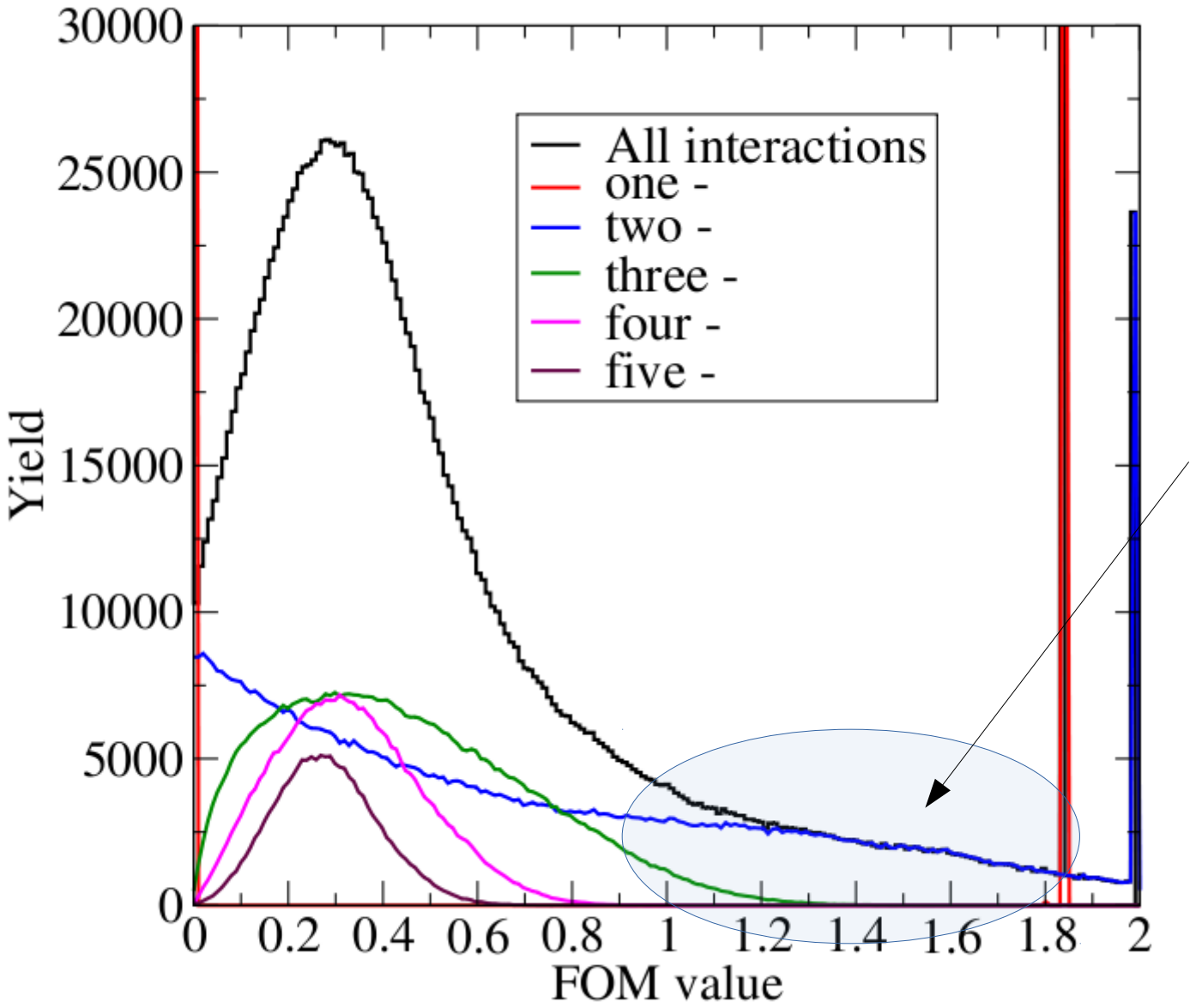
OFT (in some versions)

$$w_1^{tot} = \frac{1}{N-1} \sum_{i=1}^{N-1} w_i^{step}$$

$$w_2^{tot} = \sqrt[N-1]{\prod_{i=1}^{N-1} w_i^{step}}$$

$$\text{with} : w_i^{step} \sim |\theta^{en} - \theta^{pos}|$$

L. Milechina and B. Cederwall. *Nucl. Instrum. Methods. A*, 508:394, 2003.



Many of **these** gamma rays, that are counted as gamma rays with two interactions and bad FOM, might be recovered using the TANGO tracking method if the loss of energy resolution can be tolerated

Probably worth adding a TANGO tracking option to the GT tracking code (TBD)

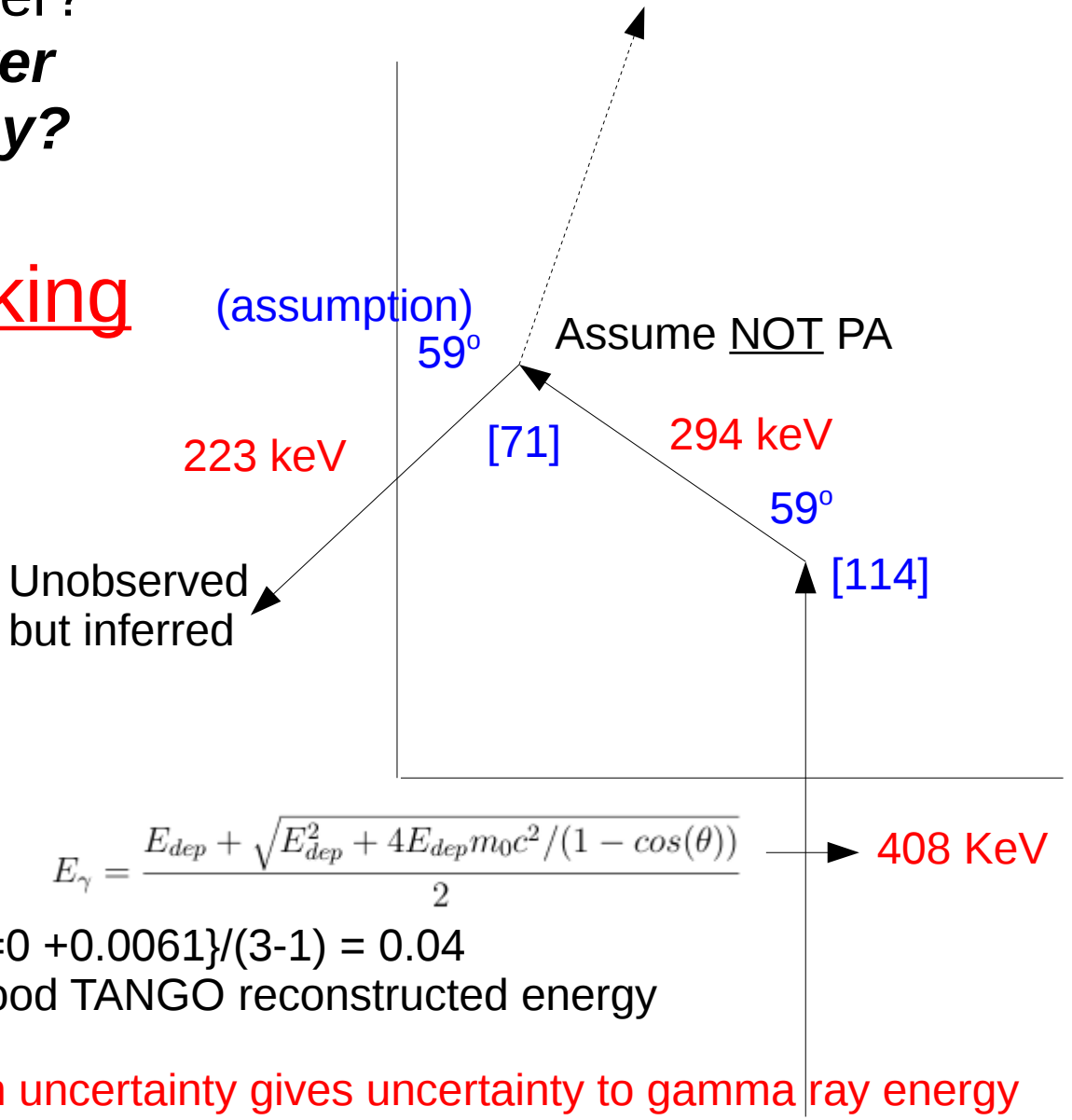
S. Tashenov and J. Gerl. Nucl. Instrum. Methods. A, 622:592, 2010.

Can we do better?

Can we recover the gamma ray?

Maybe:

TANGO tracking



$$E_\gamma = \frac{E_{dep} + \sqrt{E_{dep}^2 + 4E_{dep}m_0c^2/(1-cos(\theta))}}{2}$$

FOM= sqrt{ ==0 +0.0061}/(3-1) = 0.04

Accept as a good TANGO reconstructed energy

Energy and position uncertainty gives uncertainty to gamma ray energy

We cannot rescale to CC energy because CC did not see all the charge

For some experiments it may be good enough

Add some internal range checking in the GT tracking code?

- As of now, there is no range checking in the GT tracking (apart from for single interactions)
- Maybe it would be good to check that the scattering length in the cluster with the lowest FOM does not have scatterings over ~4cm or so [make it a variable and optimize].
- If that is the case, place a penalty on that particular scattering sequence

Appendix B: improving FOM calculation

- Would really like to propagate the errors on x,y,z,e
- However, we know the errors are probably small for interaction that deposit a lot of energy and large for interactions with small deposited energies
- We suggest a new tracking formula with weights:

Proposed new GT FOM measure

$$FOM = \frac{\sqrt{\sum_i w_i(\theta_i^{Compton} - \theta_i^{obs})^2}}{n_i - 1}; n_i > 1$$

$$w_i = \frac{E_{dep}^i}{E_{total}}$$

$$E_{total} = \sum_i E_{dep}^i$$

Appendix: Including the “Compton profile”

$$cos\theta = 1 - mc^2(\frac{1}{E'_\gamma} - \frac{1}{E_\gamma}) - \frac{1}{E_\gamma E'_\gamma}(Q^2c^2 - Qc\{Q^2c^2 + 2mc^2(E_\gamma - E'_\gamma) + (E_\gamma + E'_\gamma)^2\}^{\frac{1}{2}}) \quad (15)$$

Q==0 gives old formula

where

$$Q = \frac{E_\gamma E'_\gamma(1 - cos\theta) - mc^2(E_\gamma - E'_\gamma)}{c^2\Delta p_\gamma} \quad (16)$$

Here $c^2\Delta p_\gamma$ is the absolute value of the momentum transfer and it can be written as

$$c^2\Delta p_\gamma = (\frac{1}{c})\{(E_\gamma + E'_\gamma)^2 + 2E_\gamma E'_\gamma(1 - cos\theta)\}^{\frac{1}{2}} \quad (17)$$

None of our tracking codes or GEANT4 simulators include this effect (yet...)

J. van der Marel and B. Cederwall. Nucl. Instrum. Methods. A, 477:391, 2002.

M. J Cooper. Rep. Prog. Phys., 48:415, 1985.

Remove some low energy interactions?

- We think that the decomposition gives us some ‘extra’ points
- They are possibly low energy
- We should try throwing away the low energy interaction in a cluster if the FOM was bad. See what the FOM is if we track without this interaction point

Scattering angle checking in the GT tracking code?

- We currently accept all angles when we make permutations.
- Maybe we should penalize when an angle is less the ~20% (make it a variable) probably according the Klein-Nichina formula

Appendix: catching long range scatter events

- Is it possible to catch gamma rays that Compton scatter from one side of the tracking array to the other?
- First scatter probably a single interaction that does not deposit much energy, i.e., the scattered gamma ray is energetic. How likely is this? *It is not likely*... backward scatters have scattered gamma rays with little energy to travel far...
- More likely to find such events in a cone of crystals that are not too far away.