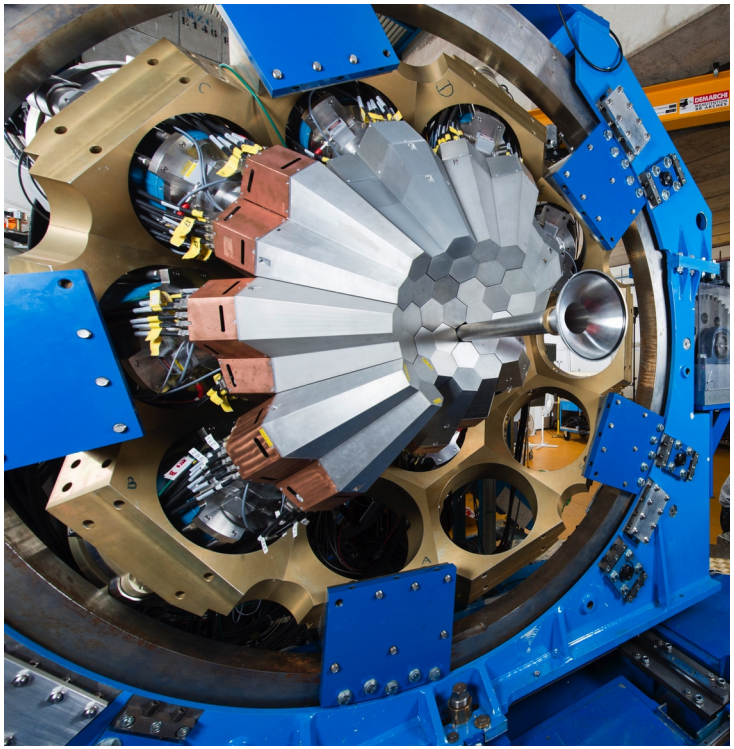
Tracking in AGATA with GRETA code



AGATA Data analyis workshop, January 21-24, 2018

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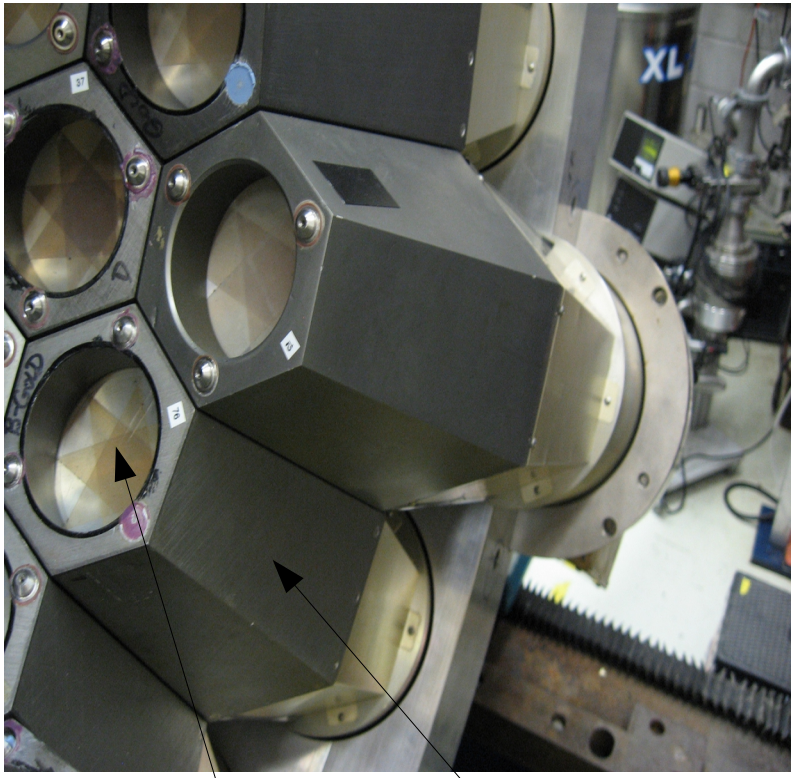
cnrs
advancing the frontiers

Idea of Tracking arrays

GAMMASPHERE 110/100 modules

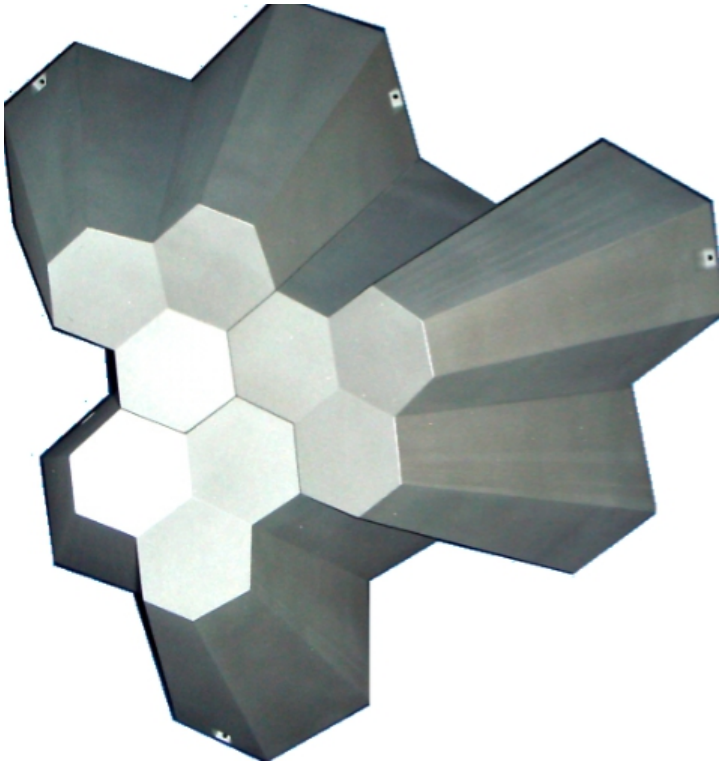


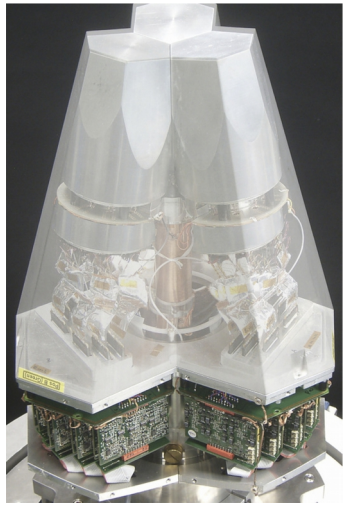
Germanium BGO

P/T=55 %

Suppress gamma rays that scattered out of the germanium crystal with highly efficient BGO detectors surrounding the crystal on all sides.

Replace the BGO with active segmented germanium crystals





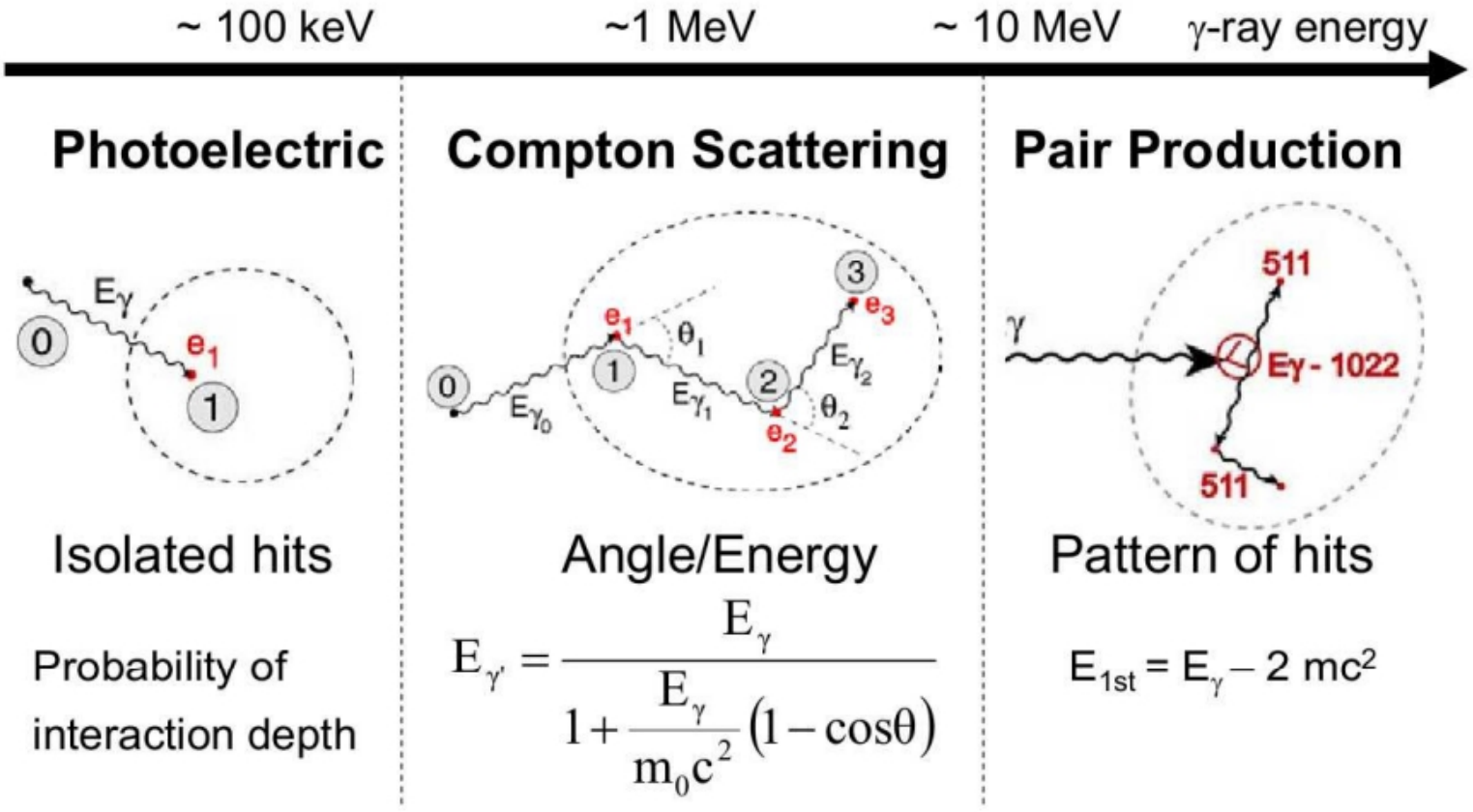
Scattering between crystals becomes important :

P/T=20 %

Need PSA & tracking → P/T=55-60 %

But the data analysis becomes quite a bit more complicated ...

Gamma ray interaction in germanium



Gamma ray interaction cross-sections in germanium

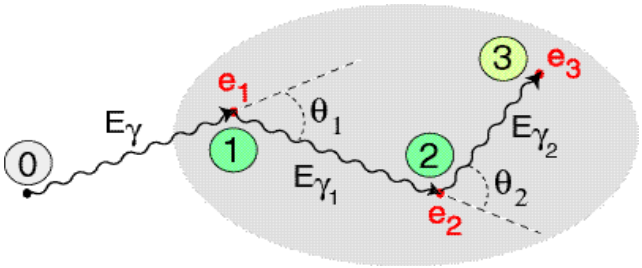
Bread and butter for tracking !

Goal of Tracking

- From the deposited energies and the positions of all the interactions points of an event in the array, reconstruct individual photon trajectories and write out photon energies, incident and scattering directions

e1 x1 y1 z1 t1
e2 x2 y2 z2 t2
e3 x3 y3 z3 t3

……
en xn yn zn tn



Doppler correction

Linear Polarisation

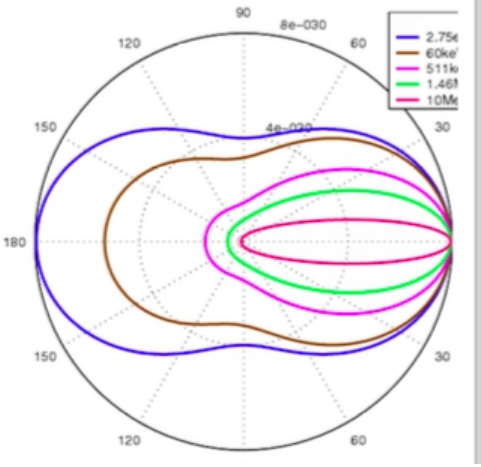
Eγ1, (θ,φ)incident 1, (θ,φ)scattered 1
Eγ2, (θ,φ)incident 2, (θ,φ)scattered 2

……

Eγi, (θ,φ)incident i, (θ,φ)scattered i

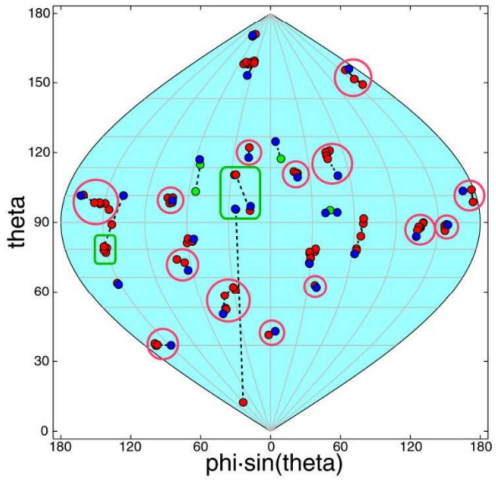
- « Discard » events corresponding to incomplete energy release

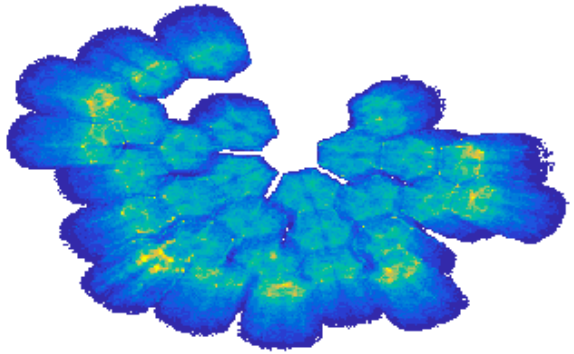
Current used tracking codes :



Forward peaking of Compton cross-section implies that the hits of one gamma tend to be localized along the emission direction : Compton-Fomulae

The most used algorithm (G.Schmid et al. NIMA 430 1999, GRETA) starts by identifying clusters of points which are then analyzed as individual candidates gammas, Clusterization





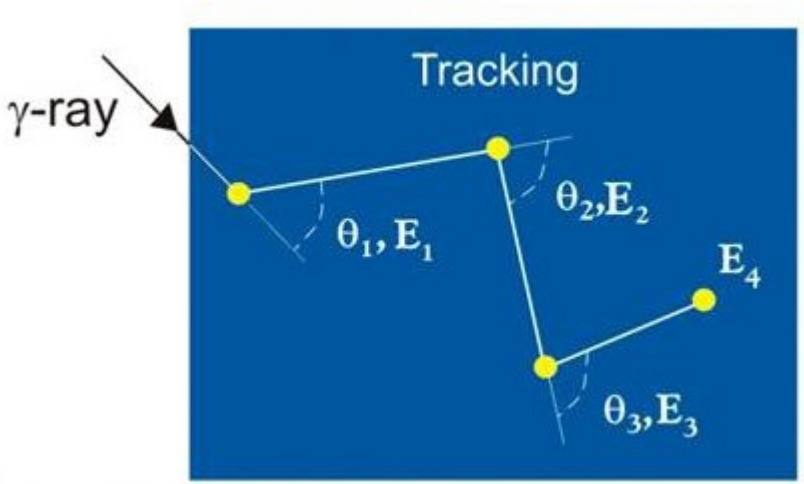
Evaluation of the candidates gammas

Figure of merit is ambiguous : FOM of a “true” sequence **not necessarily the minimum**

Tracking 101: determining the interaction sequence and how 'good' a gamma ray is

ANL tracking code steps :

First step: time coincidence (TS)
Second step: Clustering
Evaluation



Cluster, find interaction sequence
Evaluate scattering angle
<–> energy consistency with
the Compton scattering formula:

$$E'_\gamma = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_0 c^2}(1 - cos(\theta))}$$

(rad)

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

Sum up interaction energies
to get gamma ray energy

Find the interaction sequence
Evaluate how 'good' the gamma rays is

Note: Single interactions cannot be tracked

(BTW : We re-scale to CC energy before tracking)

GT 'trackMain' and selected Chat file options:

```
./trackMain \
  track_GT.chat  \ DATA/mode2.dat  \DATA/mode1.gtd 2> DATA/trackMain.log
```

Fixed clustering angle (function of the multiplicity and the # of interactions)

```
dtwin          30        (10 nsec units)
target_x 0
target_y 0
target_z 0
CCcal CCenergy.cal
useCCEnergy
clusterangle   1  20
clusterangle  30  20
enabled "0-180"
trackingstrategy 1 0
trackingstrategy 2 0
trackingstrategy 3 0
trackingstrategy 4 0
trackingstrategy 5 0
trackingstrategy 6 5 ggtttt
trackingstrategy 7 5 gggtttt
trackingstrategy 8 5 gggttttt
```

```
recluster1   0.01  0.1  3 10  0.90
nprint 20
singlehitmaxdepth 23 1.9 23.5 1.0
0.000 0.59
0.500 0.59
.
.
8.000 10.17
10.00 10.01
16.3  20.0
```

There are many more options! Here we just show the basic ones.

We add mode1 data to the mode 2 data (tracked+PSA data as in Tracked.adf)

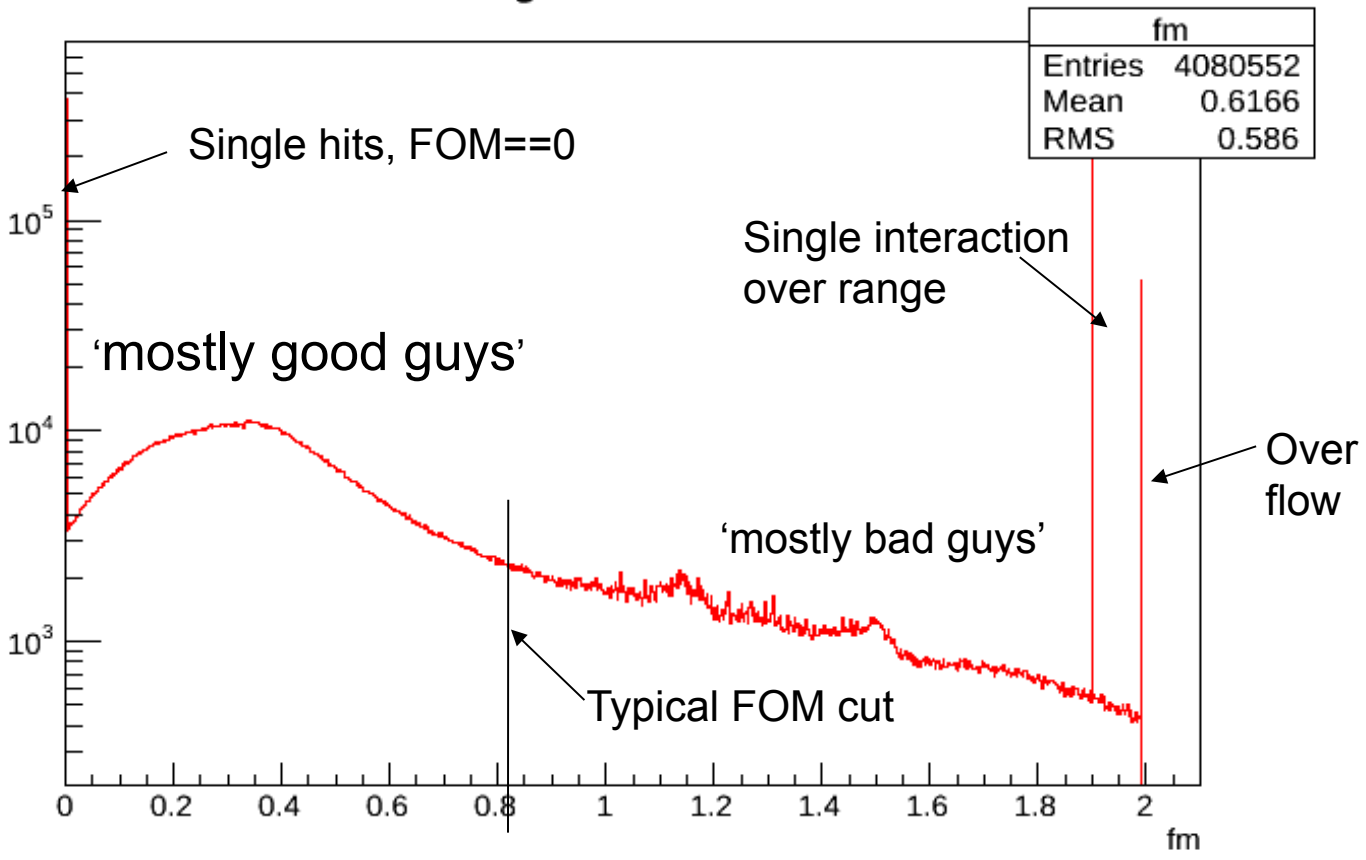
More details in GRETA-tracking school (Torben Lauritsen talk)
http://greta.lbl.gov/workshops/gamma-ray-tracking-array-school/schedule

The FOM: ***a measure of how well the interaction angles and interaction energies follow the Compton scattering formula for the interaction points in a gamma ray. Typical spectrum of FOM values (in log):***

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

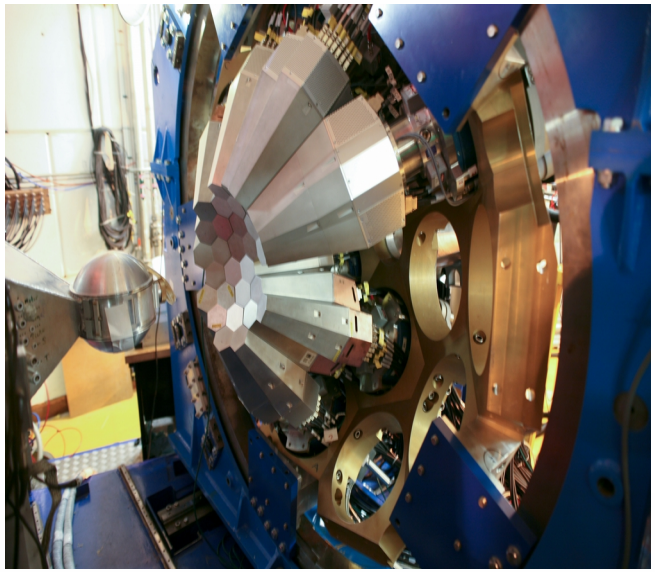
figure of merit

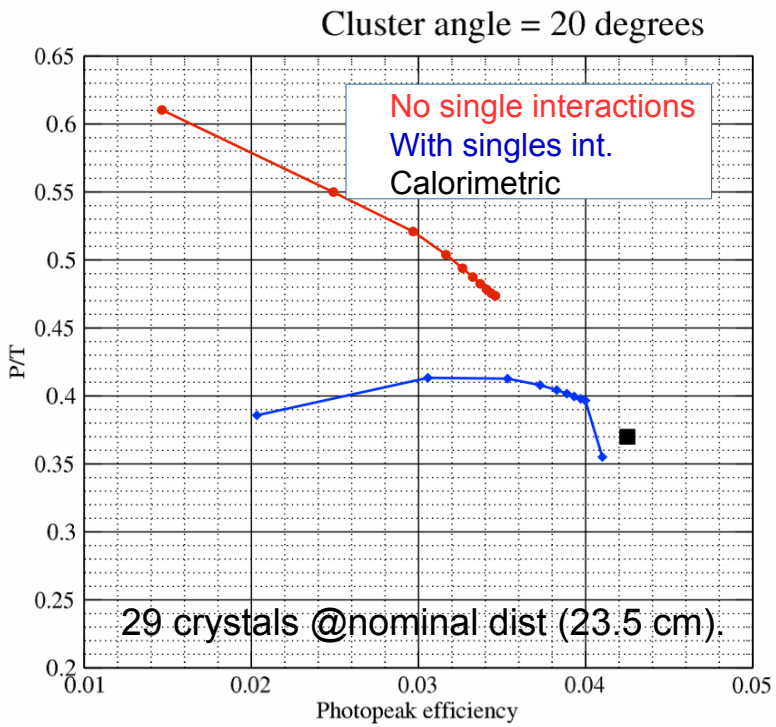
No rejection of tracked events

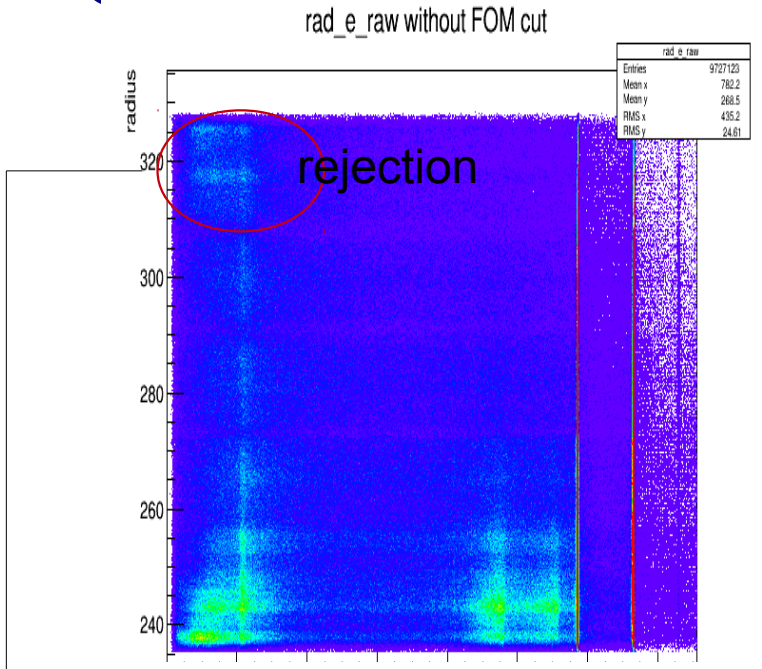


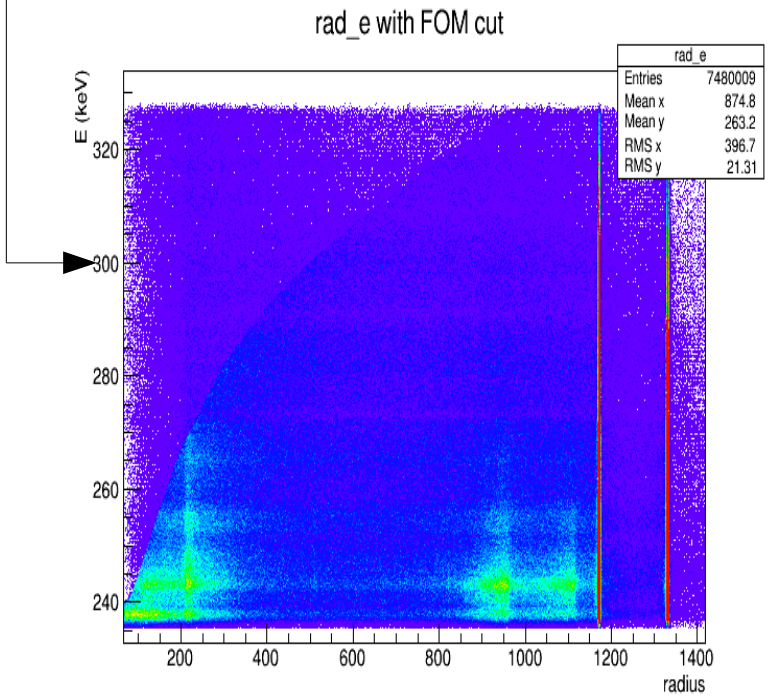
The users specify the cut on the FOM : compromise between P/T and efficiency

Example with AGATA@GANIL

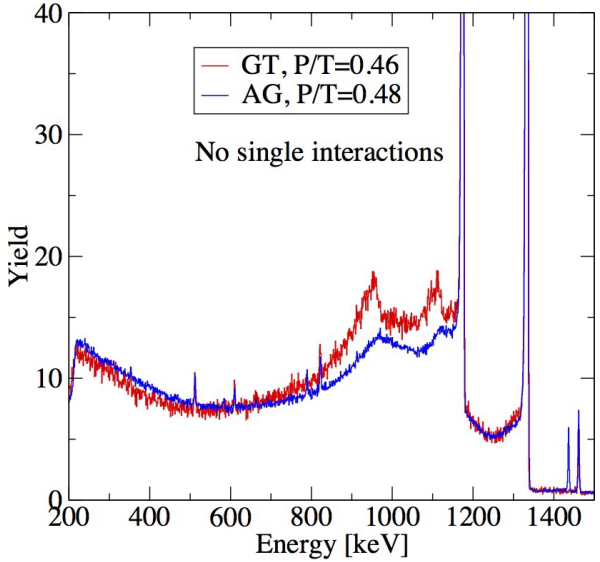


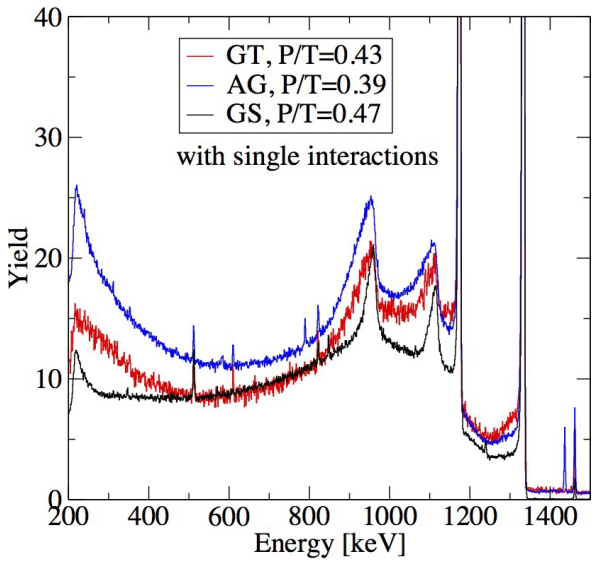


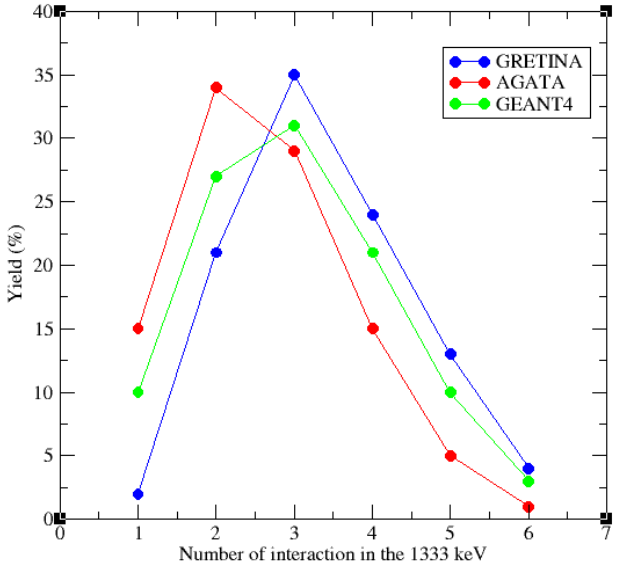


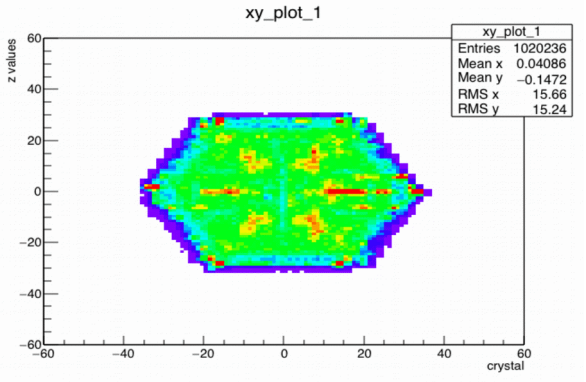


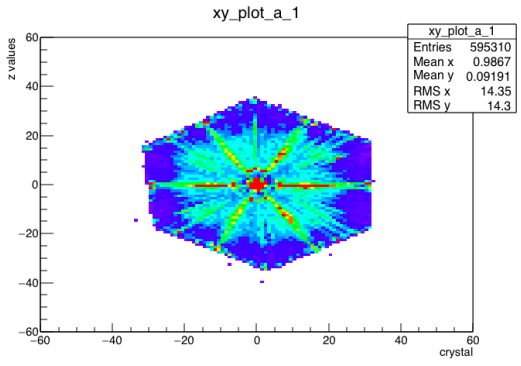
Comparing the spectra : P/T











PSA/Decomposition :

GRETINA:
more than one interaction/segment

AGATA
only one interaction/segment

TBD : process the AGATA (or GRETINA) data through the same Decomposition PSA to conclude

Some functions in tracking

Single interaction range (already covered)

Split clusters: try to split clusters that have a bad FOM into two gamma rays that have good FOMs.

Combine clusters: try to combine two clusters that have bad FOMs into one gamma rays that has a good FOM

Recluster: split gamma rays with bad FOM decreasing the clustering angle. [TBD: *can go the other way too*]

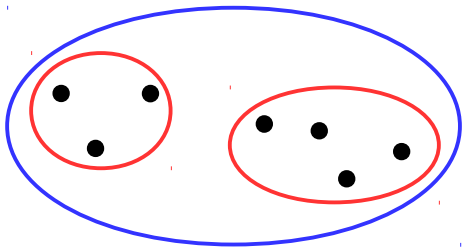
Matchmaker: combine two single interaction gamma rays into one gamma ray with a good FOM [tricky!]

We can execute these functions iteratively until we have made the best out of the data we were given

The problem: sometimes we make the wrong call because the experimental data is not perfect (i.e., we accidentally destroy good gamma rays)

Enhancement functions :

Nice Example,
Analysis by Vincent/CSNSM/Orsay

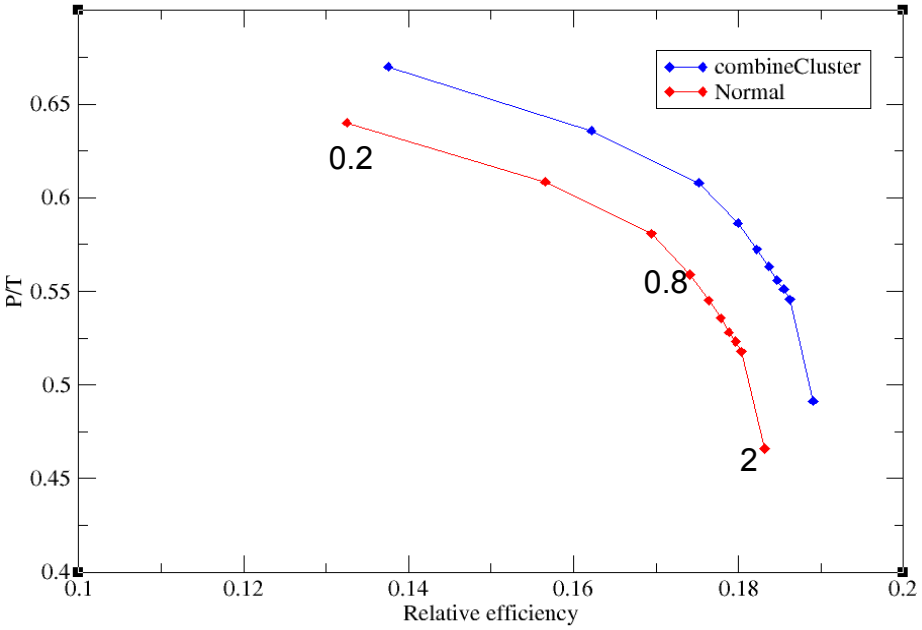


combineCluster :

If a cluster has a bad FOM, we merge it with another cluster of the same event and check if FOM is better.

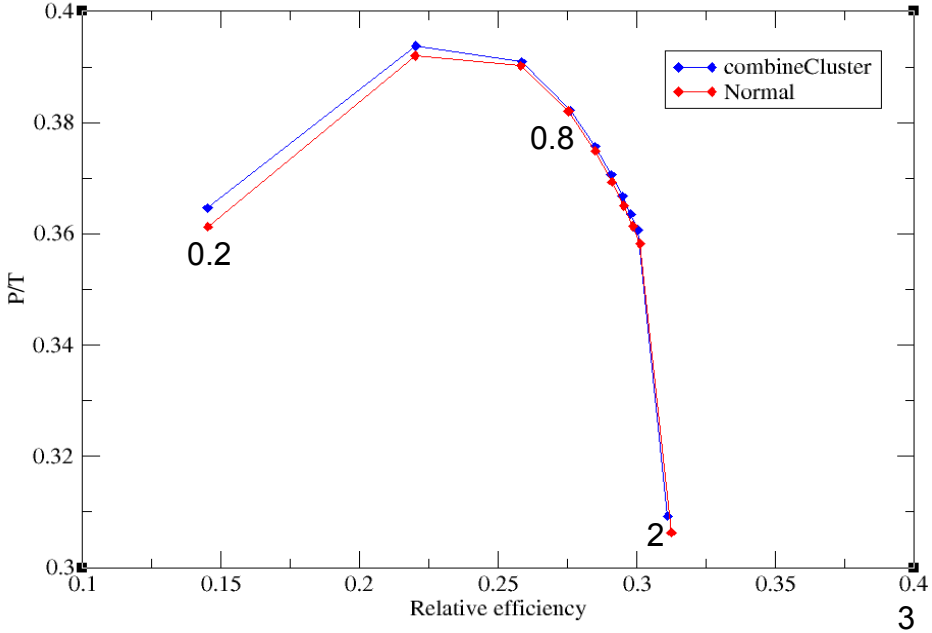
```
#                 +- threshold FOM for combining
#                 |   +- ndet maximum for combining
#                 |   |  +- max distance for inclusion attempt (cm)
#                 |   |  |
combineclusters 0.8   8  270
```

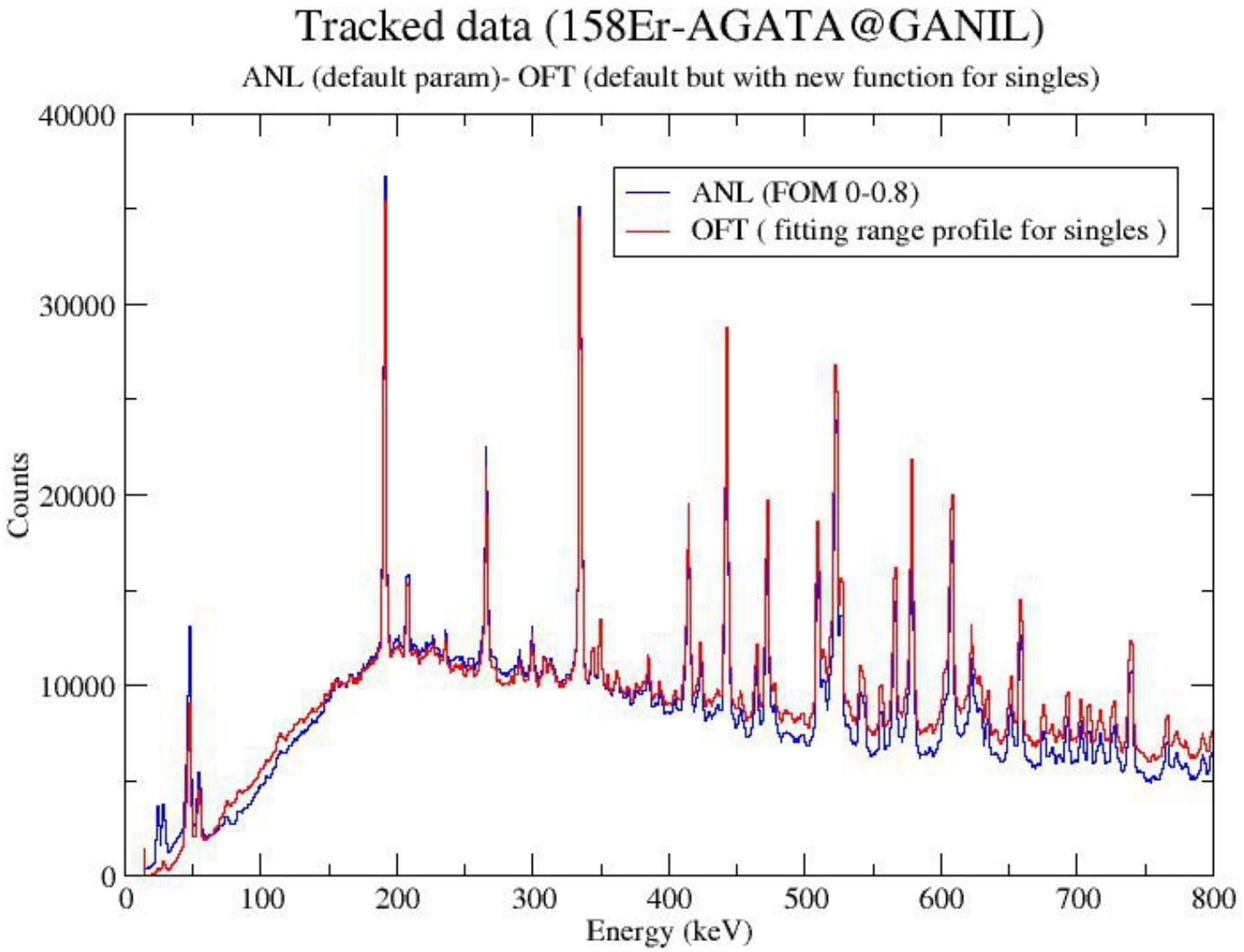
Simulated data



^{60}Co data AGATA @GANIL

Experimental data

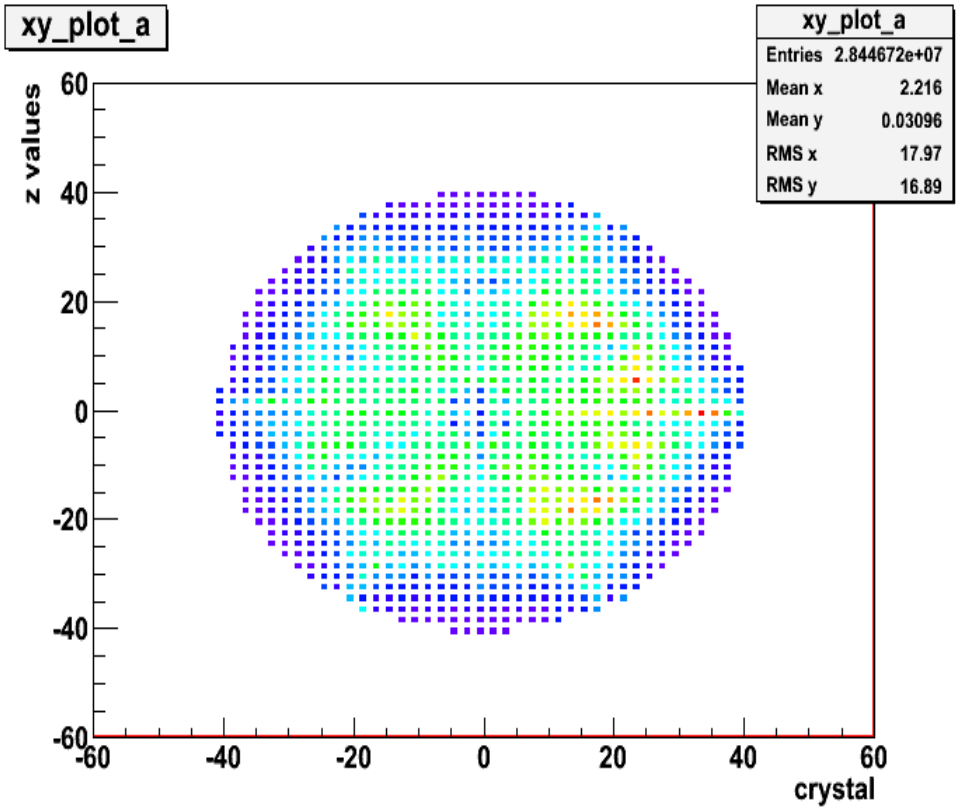




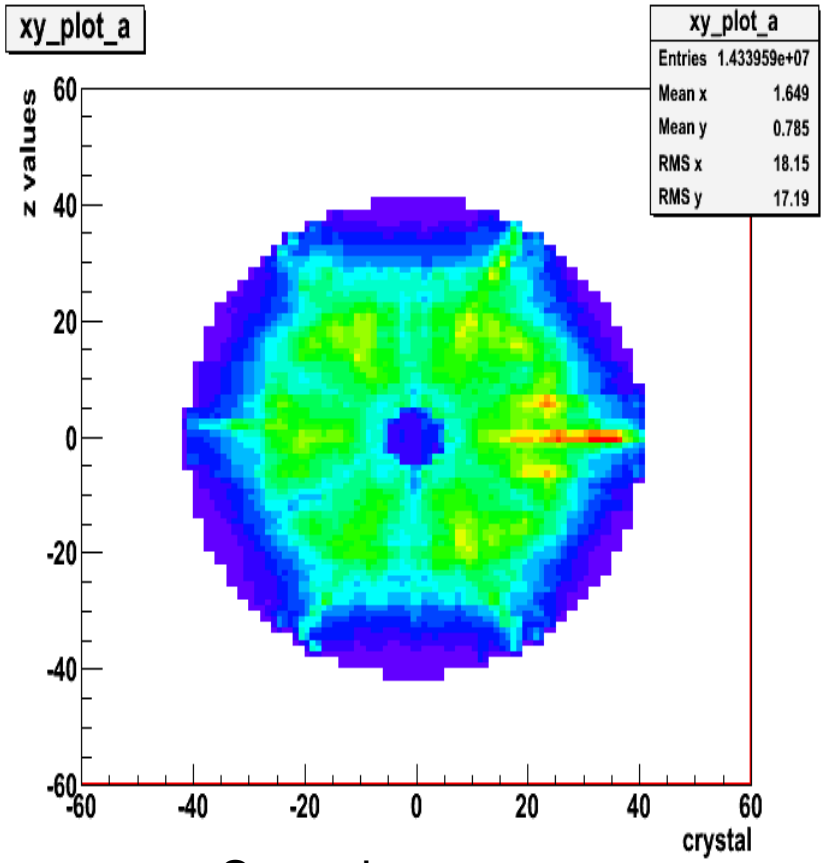
AGATA and GRETINA tracking codes with experimental data for high multiplicity!

Remenber the discussion of yesterday about position smearing

Results from the first AGATA-commissioning at GANIL 2014 (A. Korichi ACC meeting July 2015)



Without smearing the positions



Smearing

TrackMain and GEBsort practicalities

You can download the (combined) package as:

wget http://www.phy.anl.gov/gretina/GEBSort/AAAtar.tgz

(VPN no longer available outside ANL) New Git repo coming soon...

TrackMain is part of the GEBSort package

To compile GEBSort (the ROOT sorter), you will need to install ROOT. We prefer version: 5.34. Newer versions of ROOT, 6.xx, have given us problems

You can compile just 'trackMain' without root

We support most Linux distributions (especially Scientific Linux) and we try to cover MACs as well

The file 'go' in the package has all the examples that you need in order to track and sort your data. There is no neat manual but lots of examples.

Tracking parameters are in a 'chat file' with comments

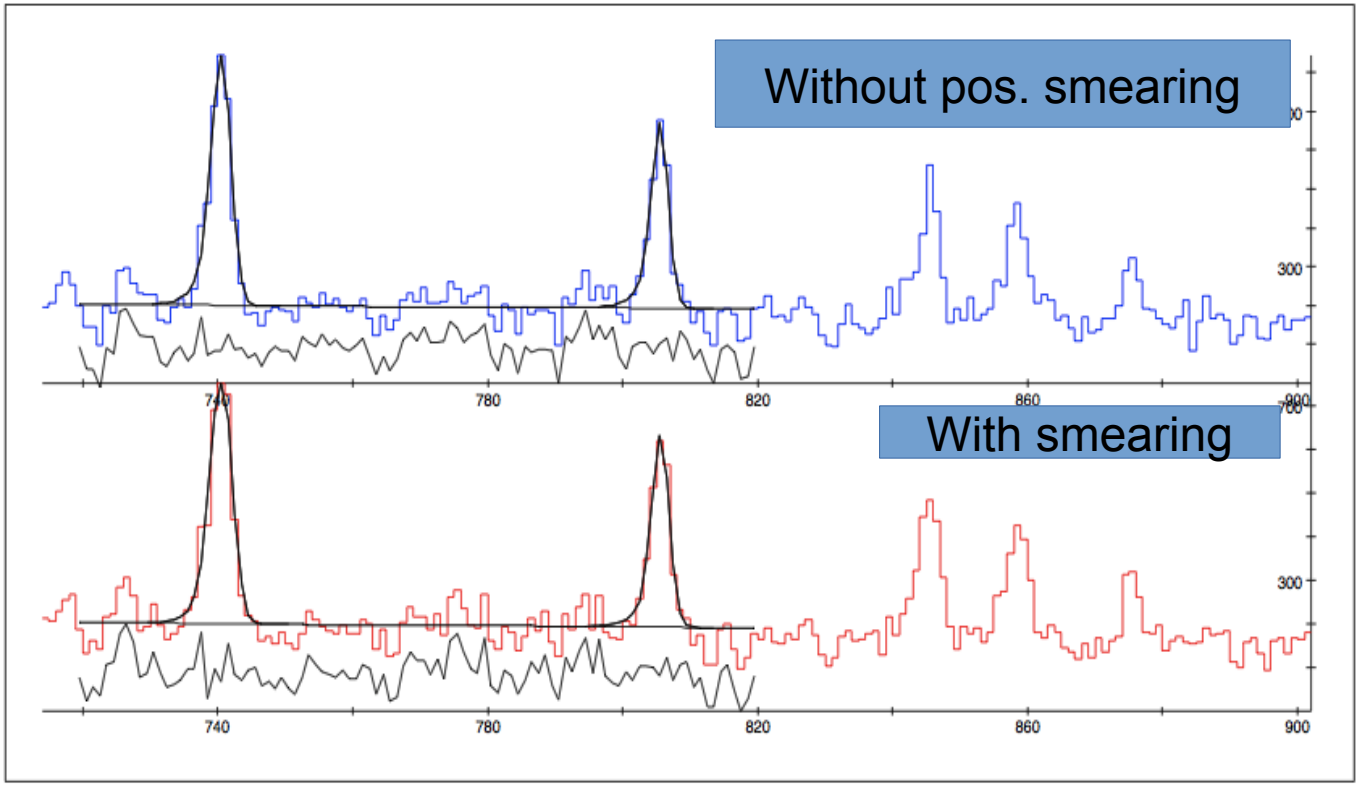
We can track online, but now mostly do it off-line

There are other utility programs: GEBMerge, AGtoMode2, G4toMode2, AG_mode3_to_GT

Merge and time order

Effect of smearing the position on the Doppler correction and tracking efficiency

Single gated spectra with bg subtraction



Radware gf3 fits (same parameters for both spectra)

Peak	FWHM	Height	Area	Efit	
1 740.11(9)	3.62(11)	574(19)	2447(69)	739.69(8)	with smearing
1 740.15(8)	3.19(10)	648(21)	2529(69)	739.61(7)	without smeating
2 805.22(9)	2.91(12)	438(19)	1545(58)	804.75(9)	
2 805.18(9)	2.77(11)	472(20)	1644(58)	804.61(8)	

GRETA forward tracking code :

Read the data from the PSA Hits from the Builder.adf or Merger.adf
Read data from GEANT4 simulations (ascii, adf)
Convert AGATA format into GRETA format

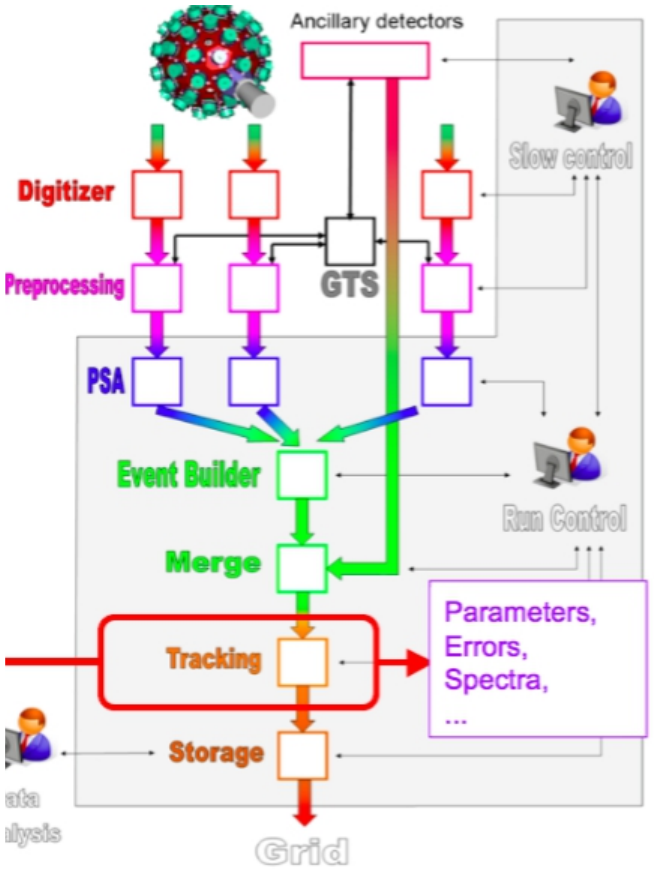
Available on git repository or contact T. Lauritsen at ANL

The code is being implemented In AGATA (O.Stézowski)

Should be possible to use In the next coming weeks

Online : default parameters
Option to modify the :
Clustering angle
The single int. Range

Offline : can play with all functions



Perspectives : additional improvements were discussed

AGATA-GRETINA tracking arrays collaboration meeting

Energy & position dependent σ_θ (use uncertainties from PSA)

Better cluster definition: other algorithm ?

Iterative procedure (split/join clusters)

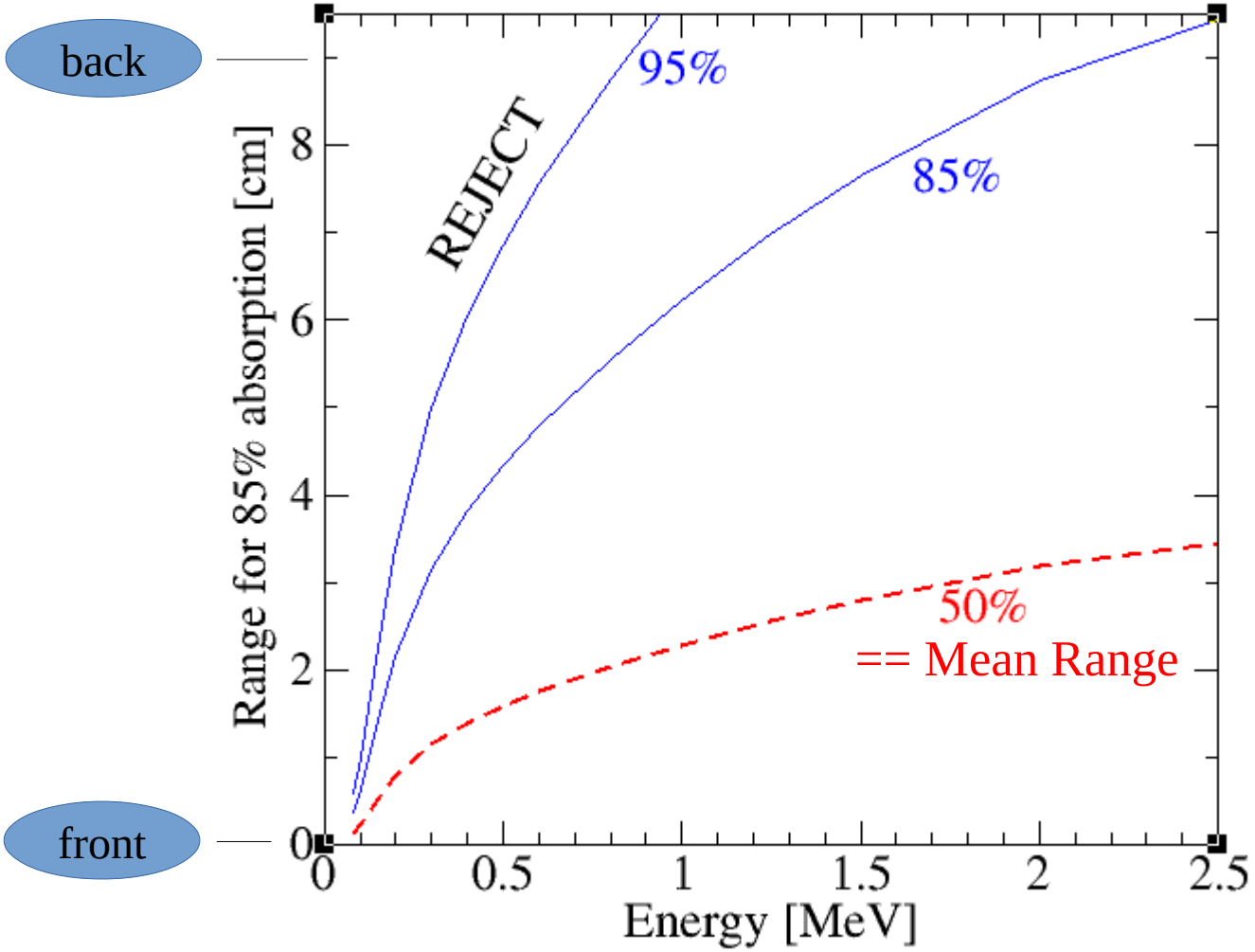
machine learning for the pair production

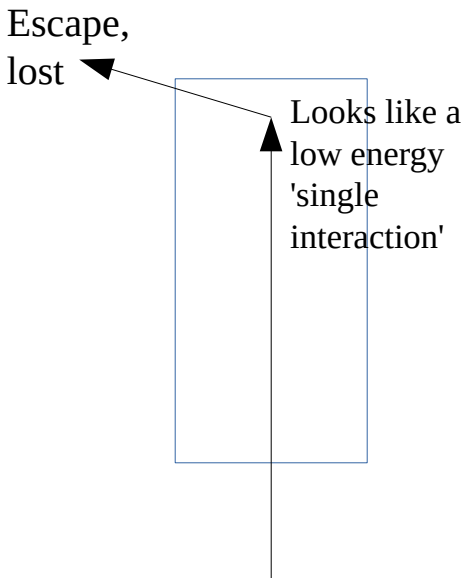
Backtracking for the small clusters (k=2-3) to check for sneaky background & backtrack the non-accepted interaction points before checking for single-interaction points ?

What do you think ?

Extra slides

For single hits: We can improve the tracking by other means:





50 % absorption

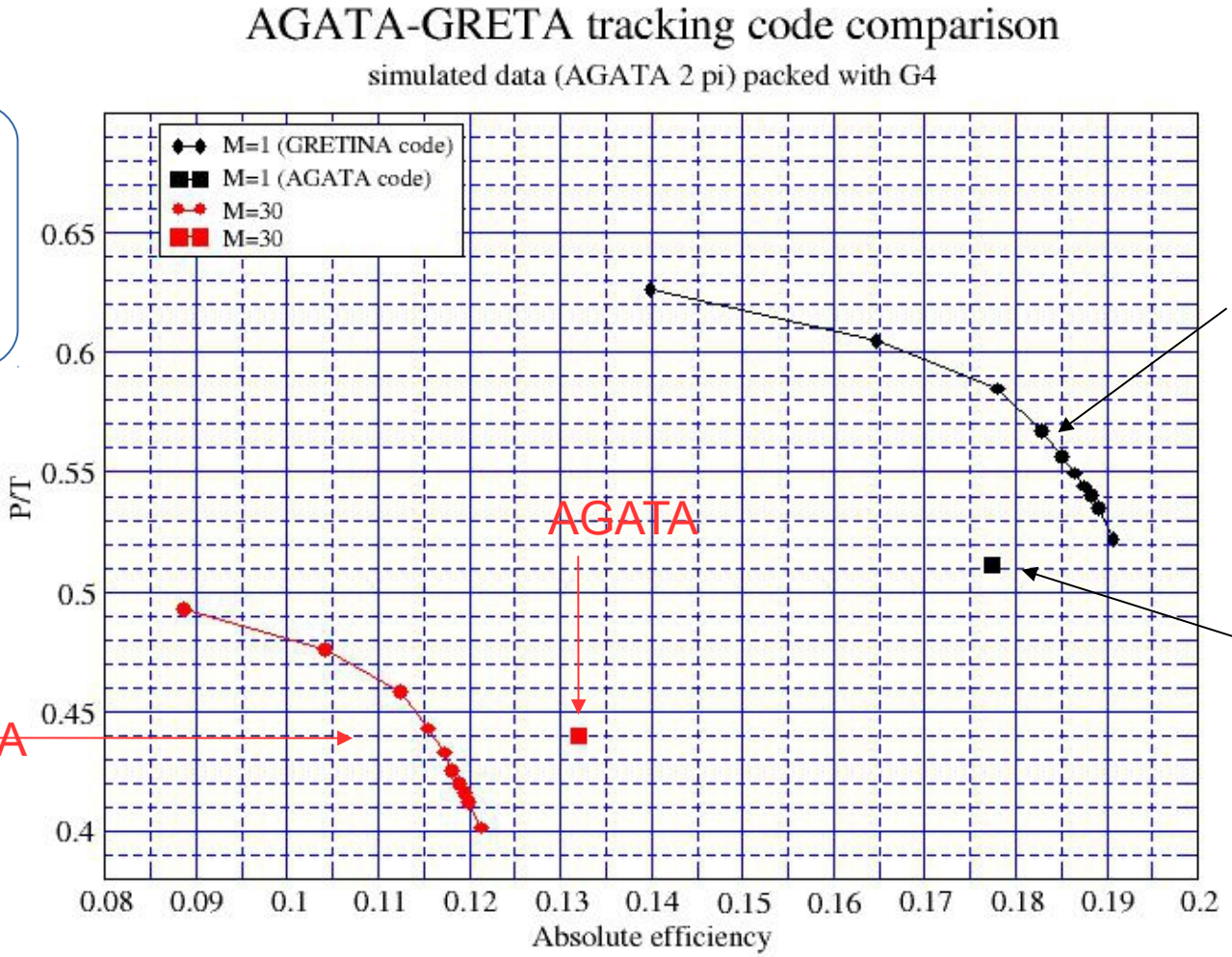
"Virtual Compton shield"

... it does help!

The clustering angle as performed in AGATA is powerful for high multicity
GEANT4 simulations : AGATA geometry 2π

Mγ=1
GRETINA
better

Mγ=30
AGATA
better



GRETINA
Tracking code
(FOM cut 0.8)

AGATA

AGATA
Tracking code

GRETINA

But when tracking experimental data :

AGATA and GRETA codes give similar results