Performance Measurements with Tracking Arrays

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ACC Meeting June 30th 2016

Performance of tracking arrays

What progress have we made in demonstrating AGATA performance?
Are Tracking performances complete and feasible?

- The energy resolution
- The absolute photo-peak efficiency
- The peak-to-Total ratio
- Count rate capability

Emphasis of this talk : Absolute efficiency and P/T
Formalism developed : ANL – CSNSM collaboration
AGATA-GRETINA collaboration

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Efficiency and P/T of tracking arrays, *it is complicated*

Observed areas for [60]Co source with

[N==1,Cs==0] for Cccal
[N== number of crystals and Cs>0] for CCsum

$$A^{obs}(1173) = S\,\epsilon_p(1173)(1 - C_k(1333)) \times (1 - C_R)(1 - C_s(1173)),$$

$$A^{obs}(1333) = S\,\epsilon_p(1333)(1 - C_k(1173)) \times (1 - C_R)(1 - C_s(1333)),$$

$$A^{obs}(2506) = \frac{1}{N} S\,\epsilon_p(1173)\epsilon_p(1333)C_f(1 - C_R) \times (1 - C_s(1173))(1 - C_s(1333)),$$

C_f is the angular correlation factor

Correct for the fact that the 1173 can knock out counts in the 1333 line and vice versa.

$$C_k(e) = \frac{C_f \epsilon_T(e)(1 + C_s(e))}{N},$$

$$C_s = \frac{F - 1}{F}$$

$$(P/T) \equiv \epsilon_p / \epsilon_T,$$

$$C_R = \frac{\epsilon_R \Delta t}{N} \frac{dR}{dt},$$

$$S = A_S t L_F.$$

CR is the correction for random γ rays hitting the detector

S is the Number of γ rays emitted
LF is the Life Fraction (dead time or other loss)

The probability for a γ ray to scatter out of a crystal, to be detected by other crystals in the array and successfully sum up to the photo-peak

F: addback factor

Summed Peak Method: SPM [A(2506)/A(1173)]

$$\epsilon_p(1333) = N\left\{\frac{A^{obs}(2506)}{A^{obs}(1173)C_f}\right\} / \left\{1 - C_s(1333) + \frac{A^{obs}(2506)}{A^{obs}(1173)}\frac{(1 + C_S(1173))}{N(P/T)(1333)}\right\}$$

Calibrated Source Method: CSM [S and L_f must be known]

$$\epsilon_p(1333) = \frac{A^{obs}(1333)}{S(1 - C_R)(1 - C_s(1333))} + \frac{(1 + C_S(1173))A^{obs}(2506)}{NS((P/T)(1173))(1 - C_R)(1 - C_s(1173))(1 - C_s(1333))}$$

External Trigger Method

$$A^{obs}(1333) = A^{obs}_{ext}(1173) \times \epsilon_p(1333)C_f(1 - C_R)$$

With CCcal and CCsum: five measurements of the array efficiency

True P/T- true peak Areas (new concepts)

We saw how the observed peak areas relate to the actual array efficiencies.

Once the peak areas have been correctly determined, efficiencies, true peak areas and peak–to–total ratios can be extracted.

$$A^{true}(1173) \equiv S\,\epsilon_p(1173) = \frac{A^{obs}(1173)}{(1-C_k(1333))(1-C_R)(1-C_s(1173))},$$

$$A^{true}(1333) \equiv S\,\epsilon_p(1333) = \frac{A^{obs}(1333)}{(1-C_k(1173))(1-C_R)(1-C_s(1333))},$$

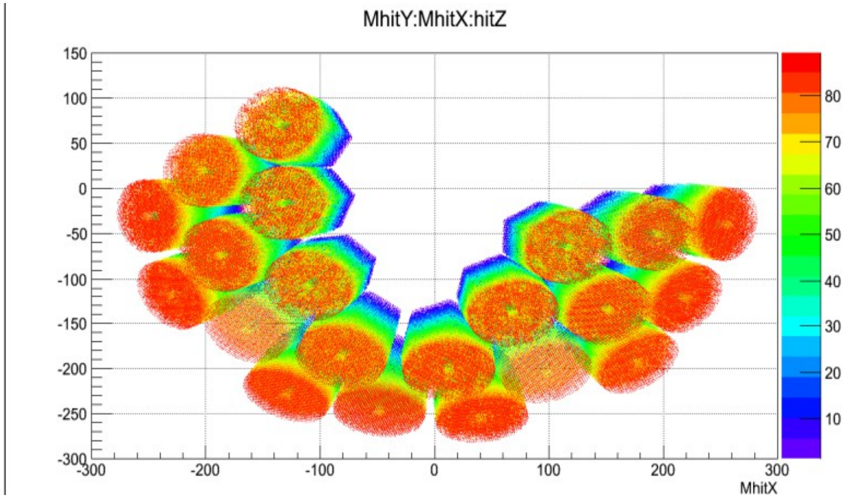
$$A^{true}(2506) \equiv S\,\epsilon_p(1173)\epsilon_p(1333)C_f = \frac{A^{obs}(2506)}{(1-C_R)(1-C_s(1173))(1-C_s(1333))}.$$

$$(P/T)^{true} = \frac{A^{true}(1173) + A^{true}(1333) + A^{true}(2506)}{A^{true}_{tot}},$$

Include for CCcal and CCsum but not for tracked spectra

$$A^{obs}_{tot} = (1 + C_s)A^{true}_{tot}$$

Performance of AGATA@GSI with ^{60}Co source



Input	Efficiency (%)	P/T (%)
AGATA (external trigger method)		
Core Common	2.38(2)	18.3(2)
Calorimetric	3.30(2)	32.2(3)
Tracked with single interactions	2.55(3)	37.5(4)
Tracked without single interactions	2.53(3)	42.3(5)
Add-back 100 mm	2.86(4)	24.6(2)

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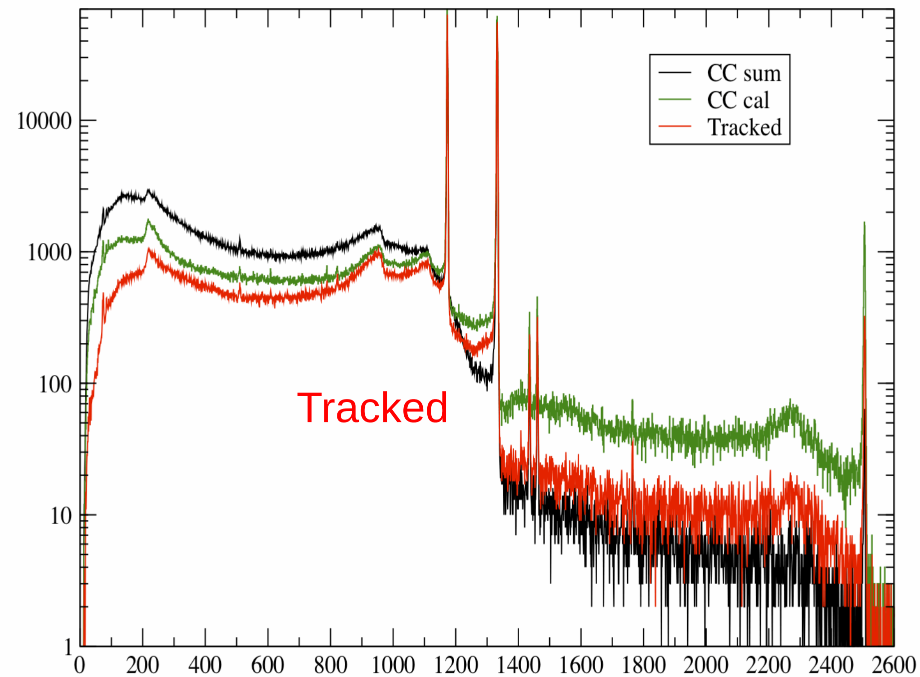


$$\epsilon_{track} = \frac{A_T(1333)}{S\,\epsilon_p(1333)}$$

	SPM cal	CSM cal	SPM sum
ϵ_P(pure)	3.39(3)%	3.10(20)%	3.50(12)%
$(P/T)^{obs}$	0.291(5)	0.294(5)	0.174(5)
$(P/T)^{true}$	0.331(5)	0.327(5)	0.333(5)
$\epsilon_{track,nsi}$	78(1)%	78(1)%	77(1)%
$\epsilon_{track,wsi}$	91(1)%	94(1)%	94(1)%
C_f	1.0342	1.0342	1.109
C_s	0	0	0.299(5)

$$\epsilon_{track} = \frac{A_T(1333)}{\frac{A^{obs}(1333)}{(1-C_k(1173))(1-C_R)(1-C_s)}} \equiv \frac{A_T(1333)}{A^{true}(1333)}$$

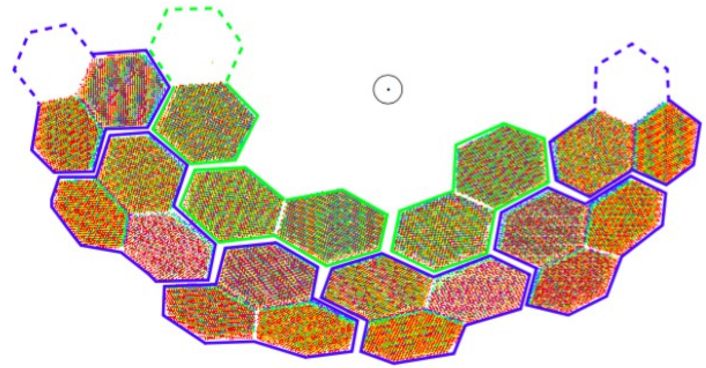
$$(P/T)^{tracked} = \frac{A_T(1173) + A_T(1333)}{A_{tot}},$$

A. Korichi to be published

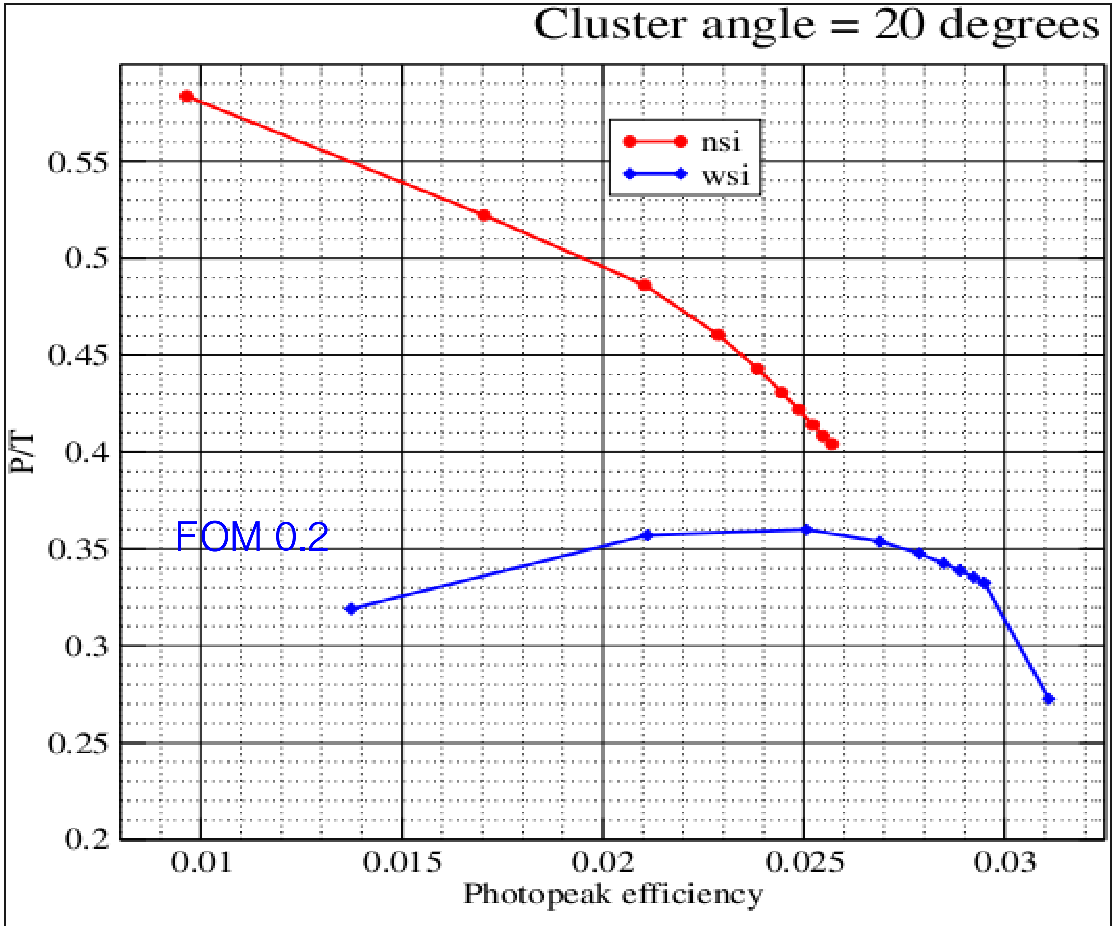
Tracking efficiency and P/T

$$E'_\gamma = \frac{0.511}{1 + \frac{0.511}{E_\gamma} - cos(\theta)}$$

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

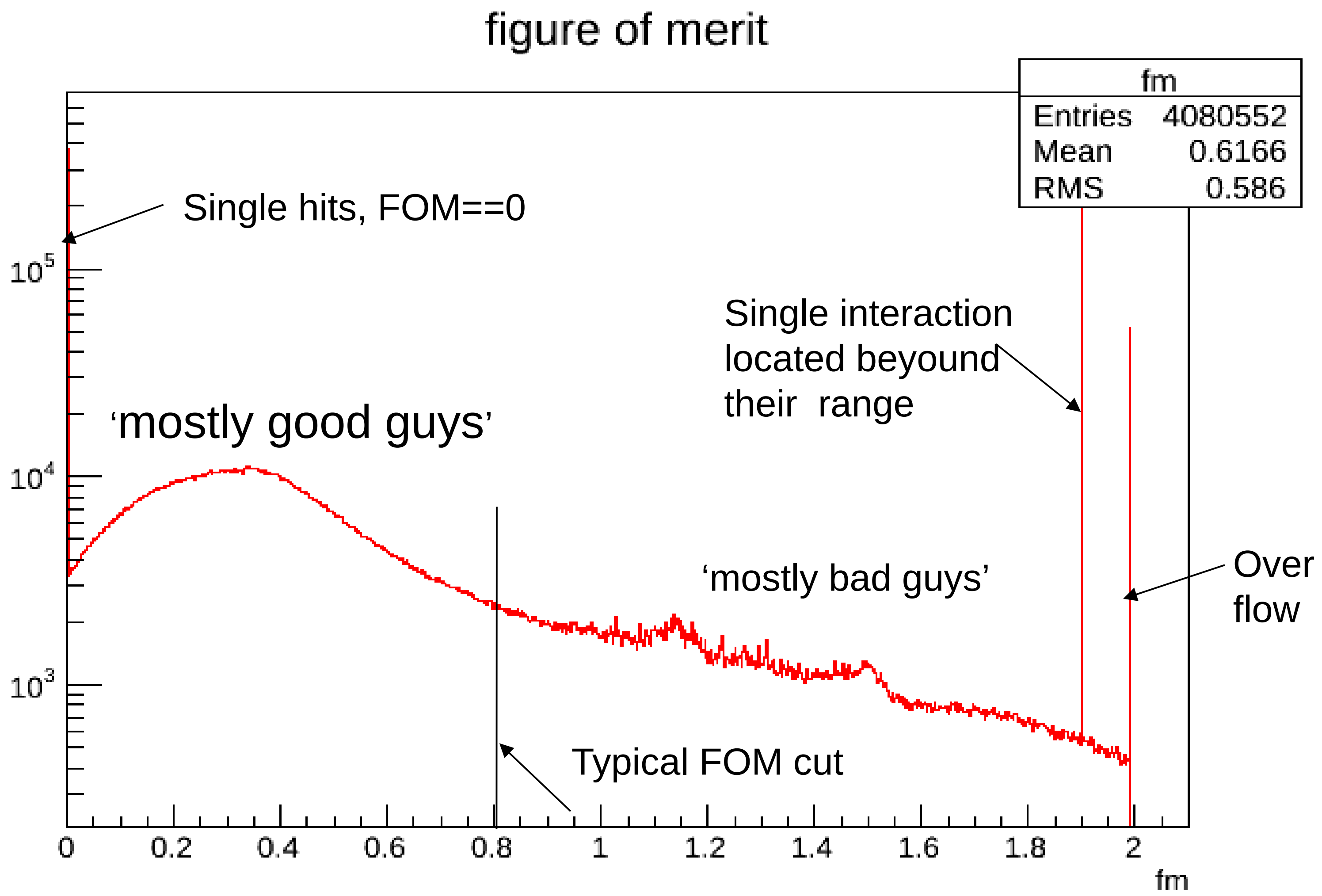


FOM : a measure of how well the interaction angles and interaction energies follow the Compton scattering formula inside a gamma ray



FOM < ~0.6-0.8 considered GOOD   FOM > ~0.8 considered BAD(Compton events)

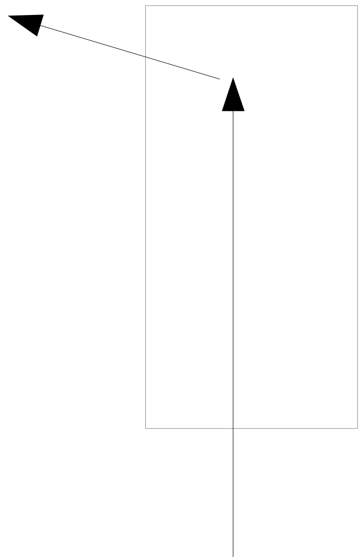
FOM spectrum, a measure of how well the interaction angles and interaction energies follow the Compton scattering formula inside a gamma ray. Typical spectrum of FOM values (in log):

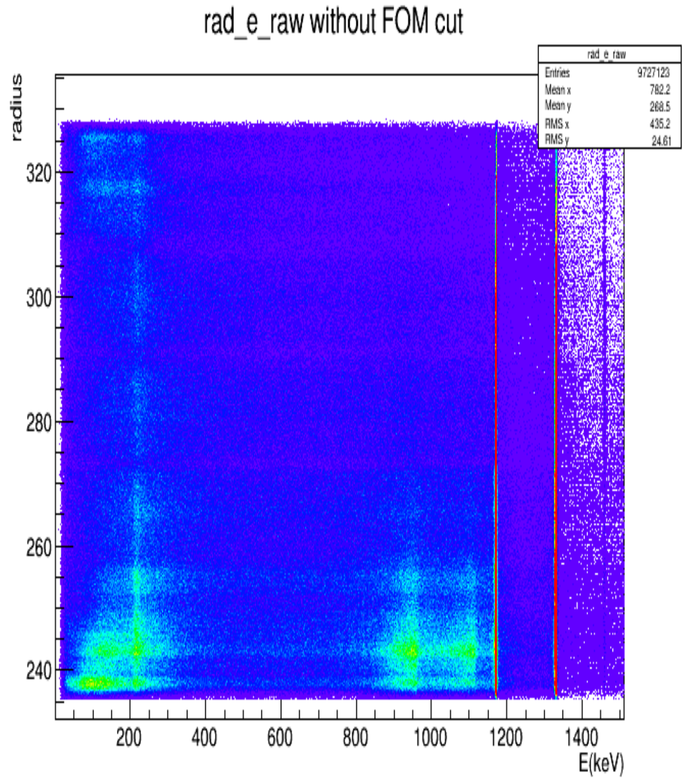


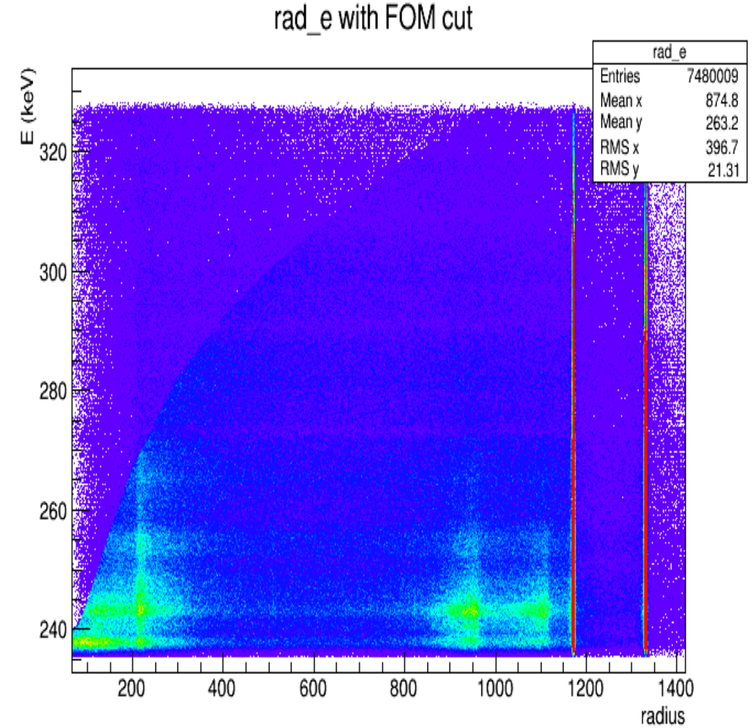
For single hits: We can improve the tracking by other means:

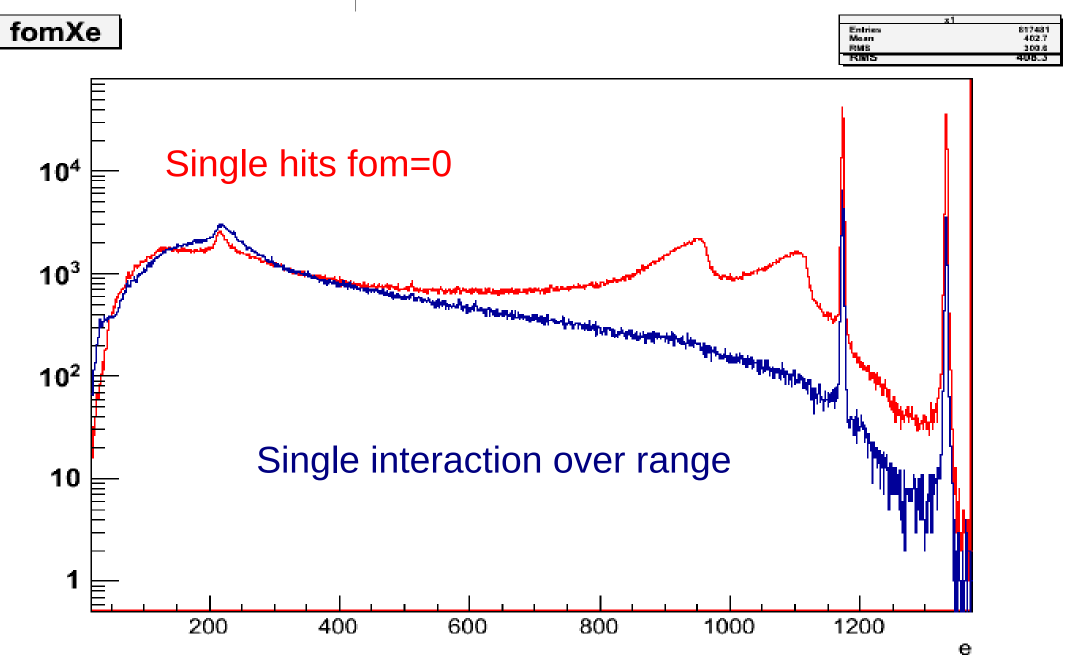
Escape lost

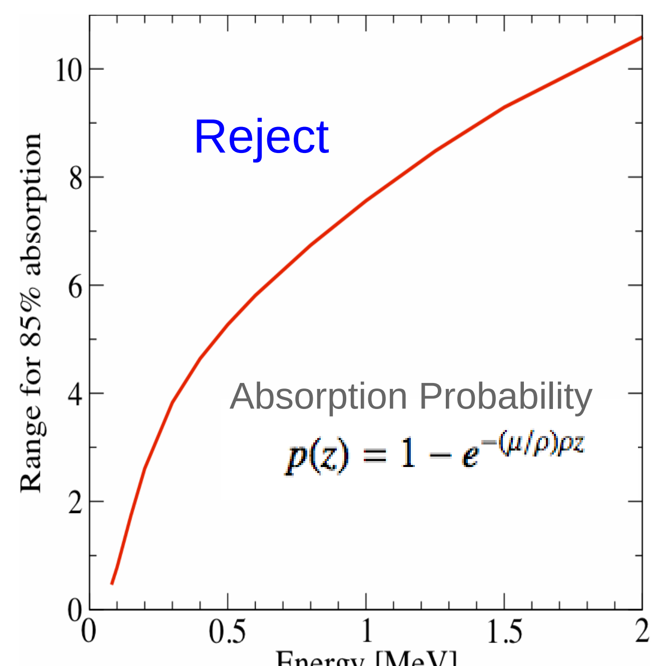
Looks like a low energy 'single interaction'



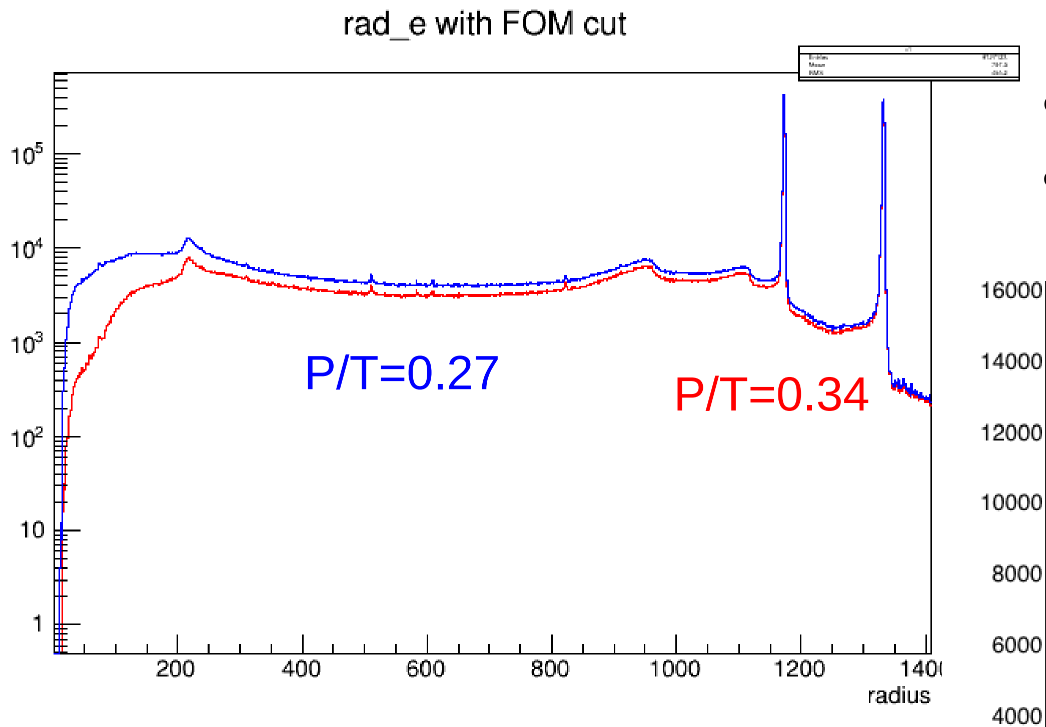




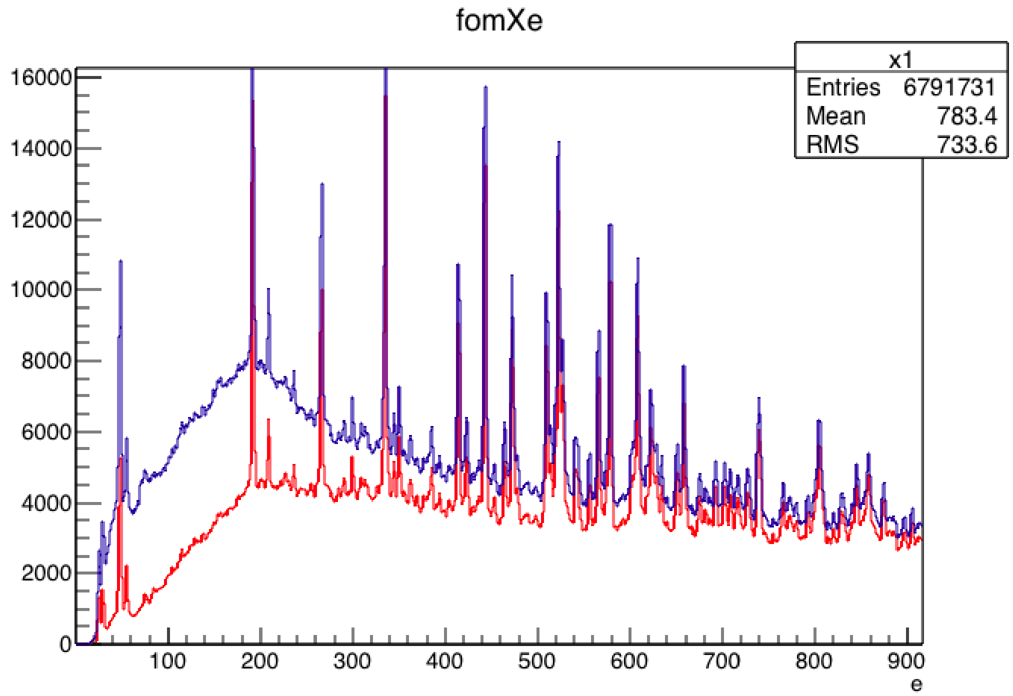




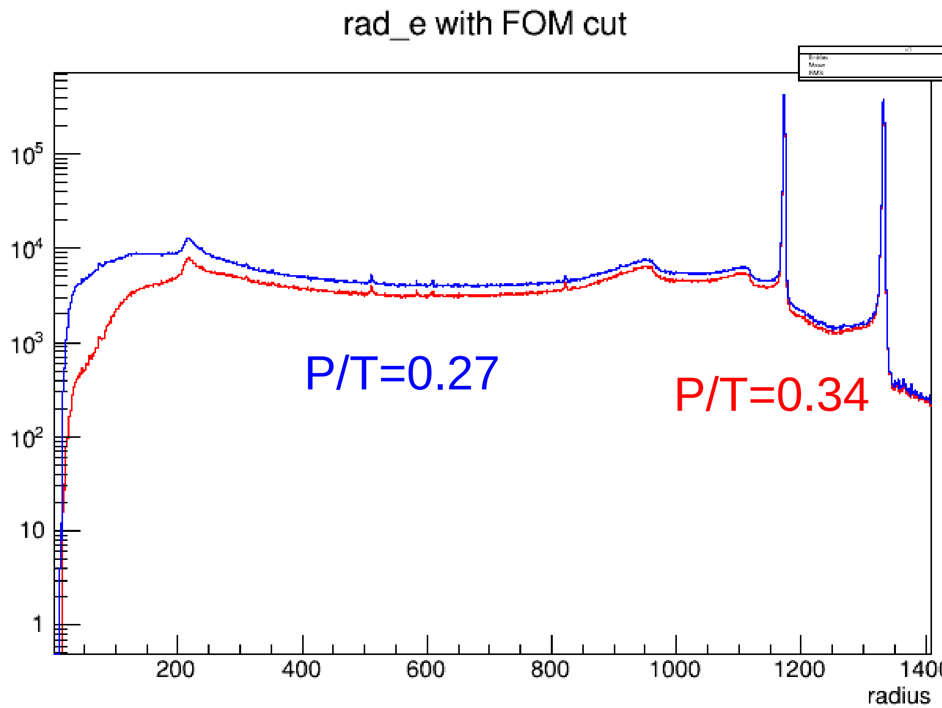
It Helps!



- $^{122}Sn(^{40}Ar[170MeV],4n)^{158}Er$
- June 5-6, 2015-



It Helps!



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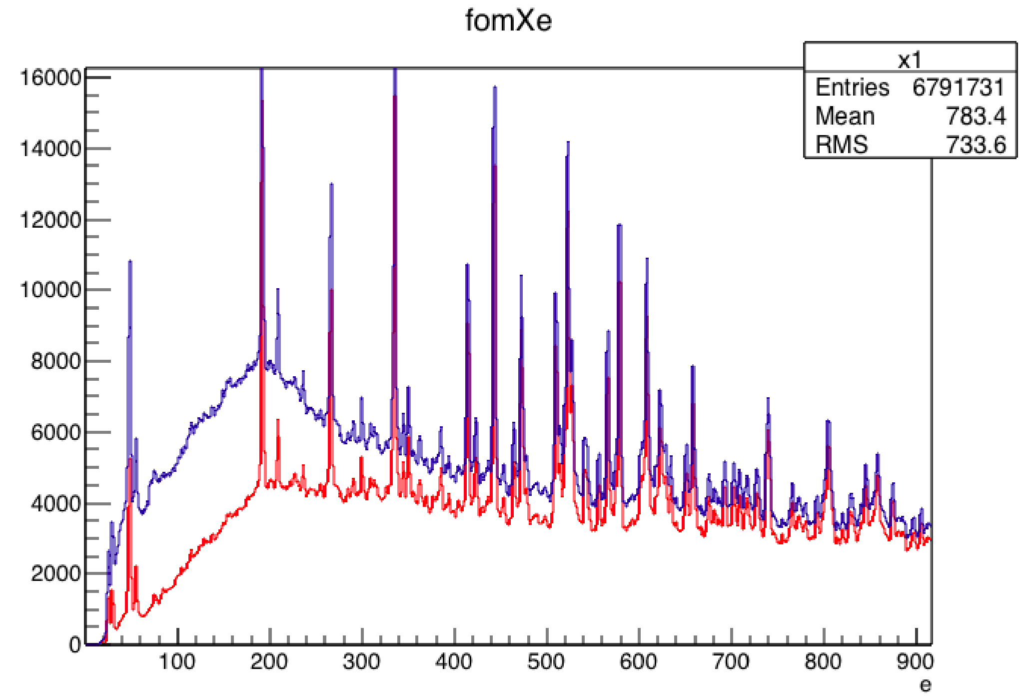
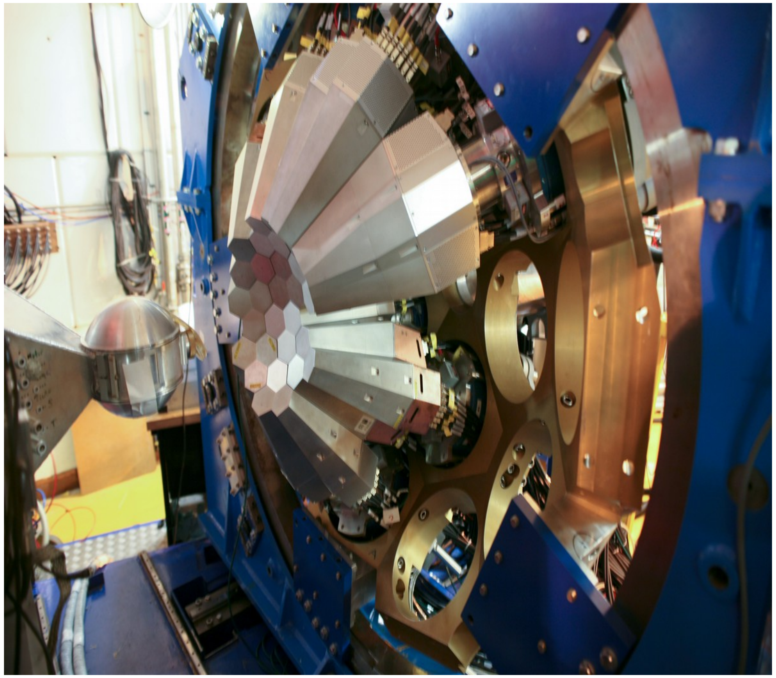


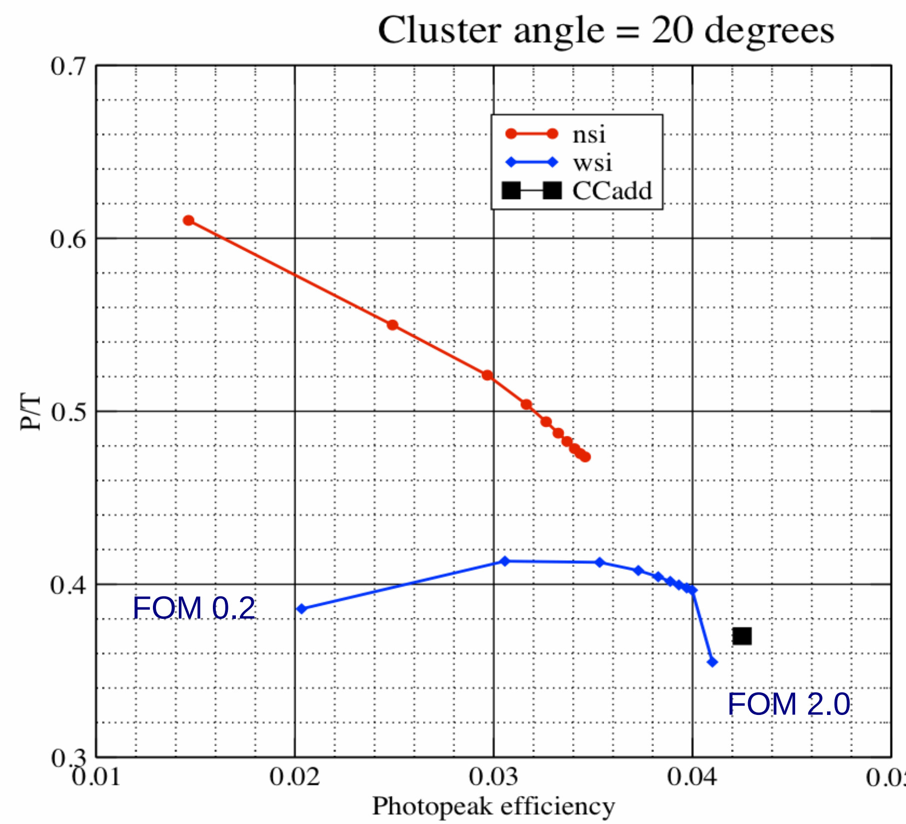
Performance of AGATA@GANIL with ^{60}Co source



	SPM cal	CSM cal	SPM sum
	source1	source2	source1
ϵ_P(pure)	4.26(12)%	4.48(13)%	4.00(16) %
$(P/T)^{obs}$	0.328(5)	0.224(5)	0.184(5)
$(P/T)^{true}$	0.371(5)	0.270(5)	0.363(5)
$\epsilon_{track,nsi}$	82(1)%	81(1)%	82(1)%
$\epsilon_{track,wsi}$	95(1)%	94(1)%	95(1)%
C_f	1.0275	1.0275	1.109
C_s	0	0	0.307(5)

Very Preliminary results

Abs. Eff (External Trigger Method)= 4.29 (10)

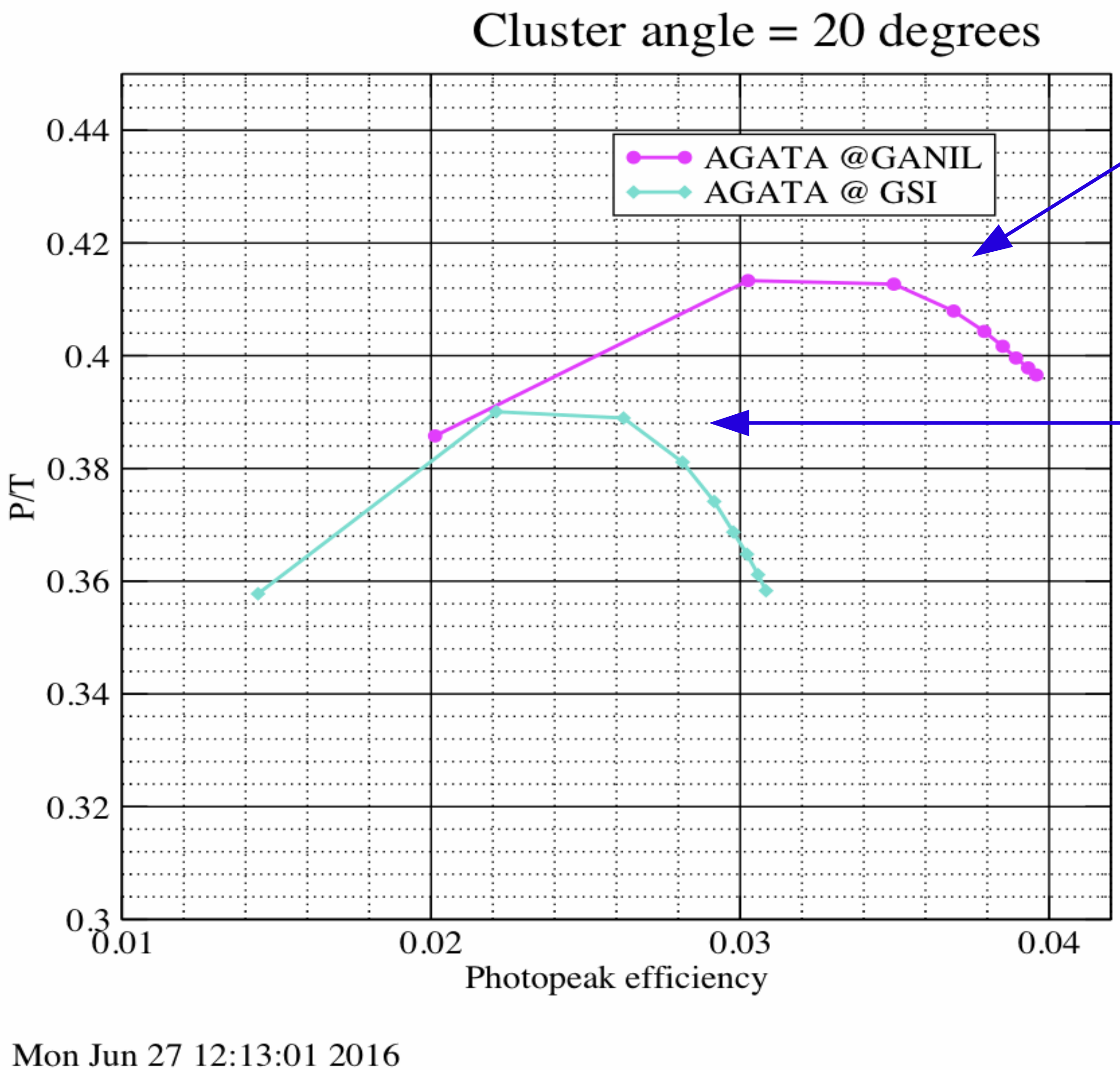


Abs_Eff_tracked=3.80% P/T=41% FOM cut=1.0
Abs_eff_tracked=3.25% P/T= 49 no_singles
(29 crystals)

A Better P/T compared to GSI
But the array Is more compact :
72% versus 68%

But also more passive material :
3 crystals not active at GSI
I

AGATA GSI & GANIL
Tracked data including single interactions



FOM =0.8
Eff=3.7 % P/T= 41%

FOM=0.8
Eff=2.8 % P/T= 38%

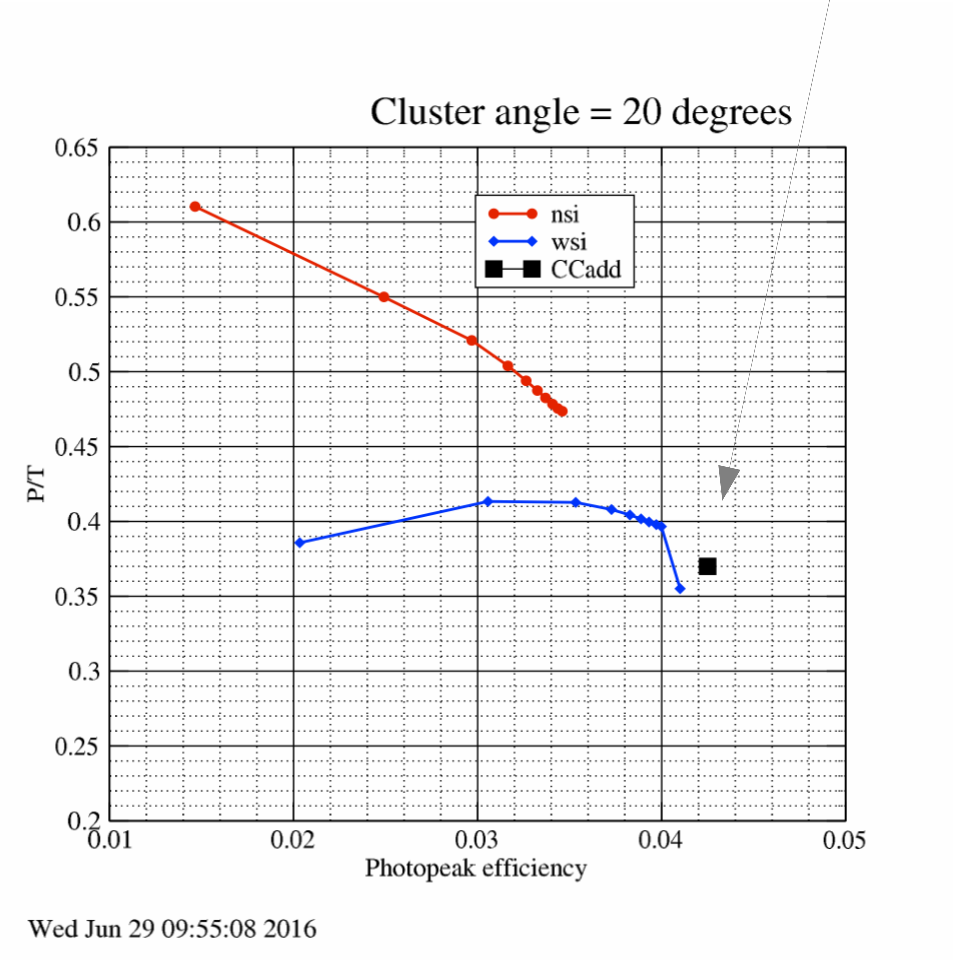
Scaling :
21/29 * 3.7% = 2.7 %

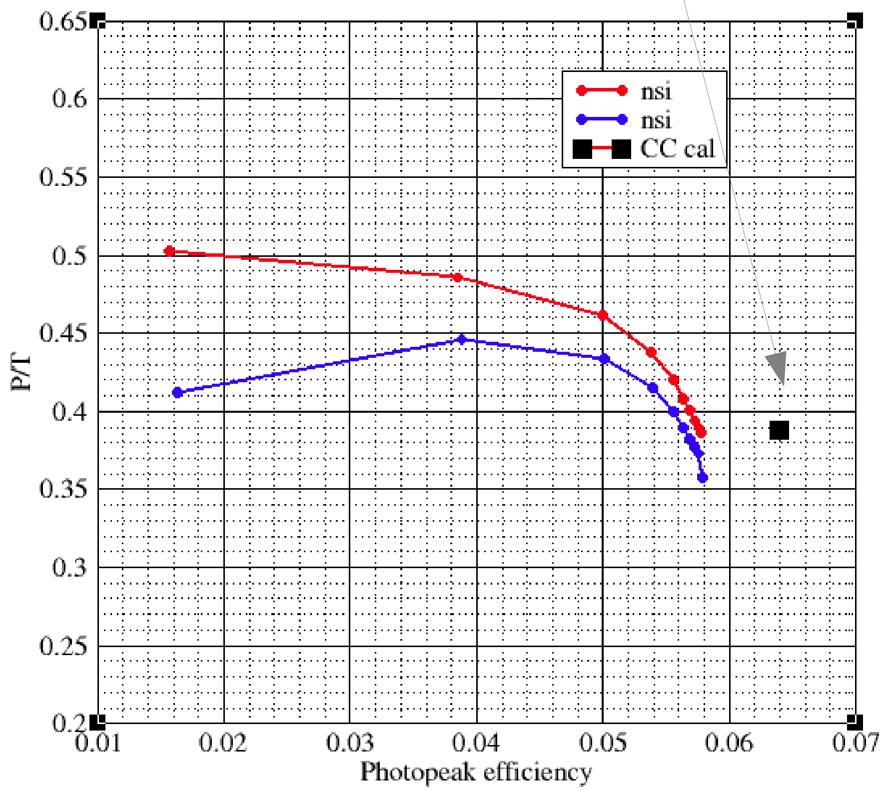
AGATA and GRETINA

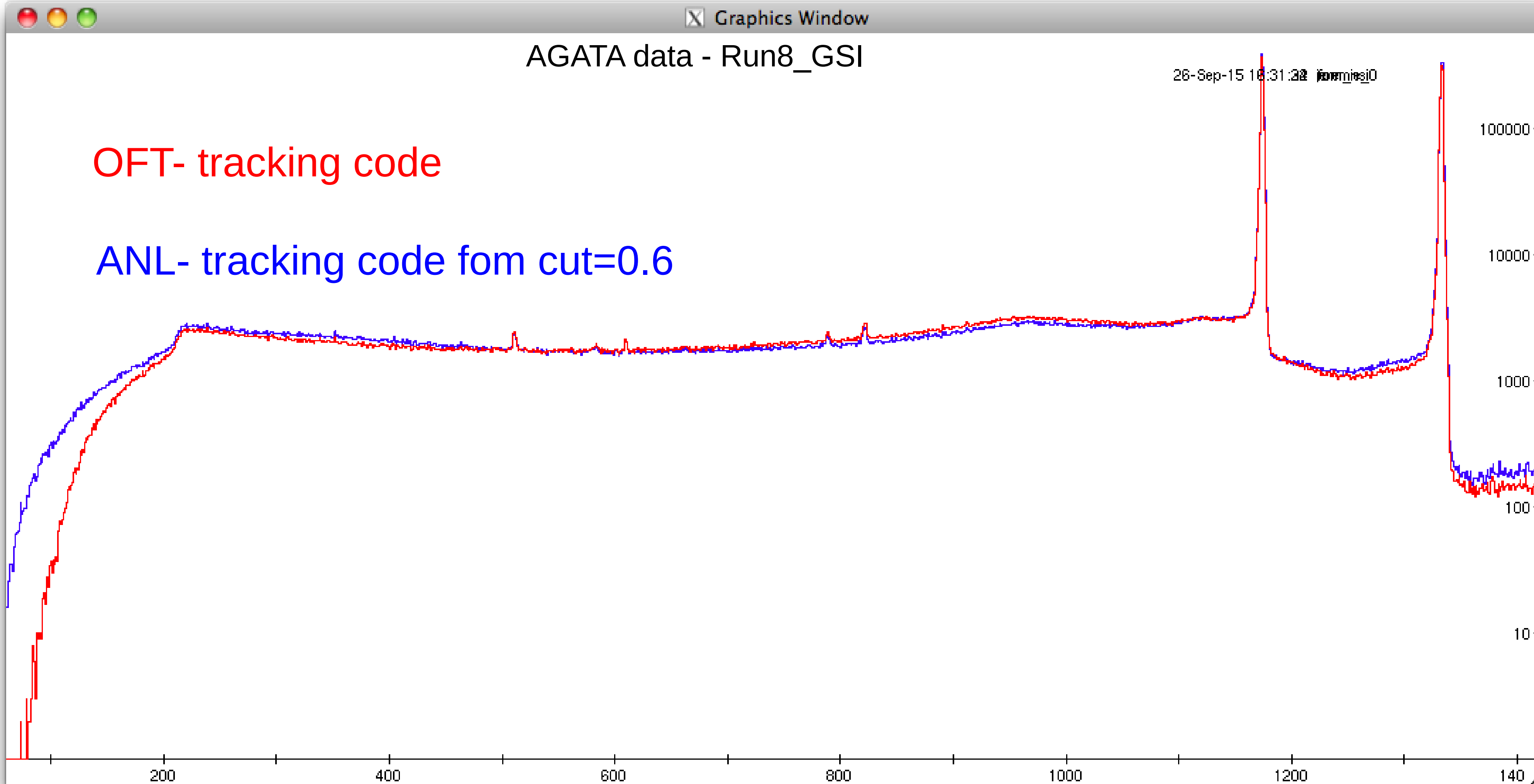
29 crystals positioned at 23.5 cm

28 crystals positioned at 18.5 cm

4.25% = 29/28 [(18.5/23.5)^2] * 6.4%







Tracking codes are doing the job (despite some deficiencies)
Similar performances

Conclusion…

Rate capabilities of AGATA : 50 kHz

Doppler correction capabilities : beautiful for fast beams

Tracking : we Improve some deficiencies for high multiplicity
But dependent of the input data

Problem : PSA?

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

Ideas and suggestions are welcome

First AGATA-GRETINA tracking arrays collaboration meeting
December 5-7, 2016

First Circular

We are pleased to announce the first AGATA-GRETINA collaboration meeting to be held at ANL on 5-7 of December 2016.

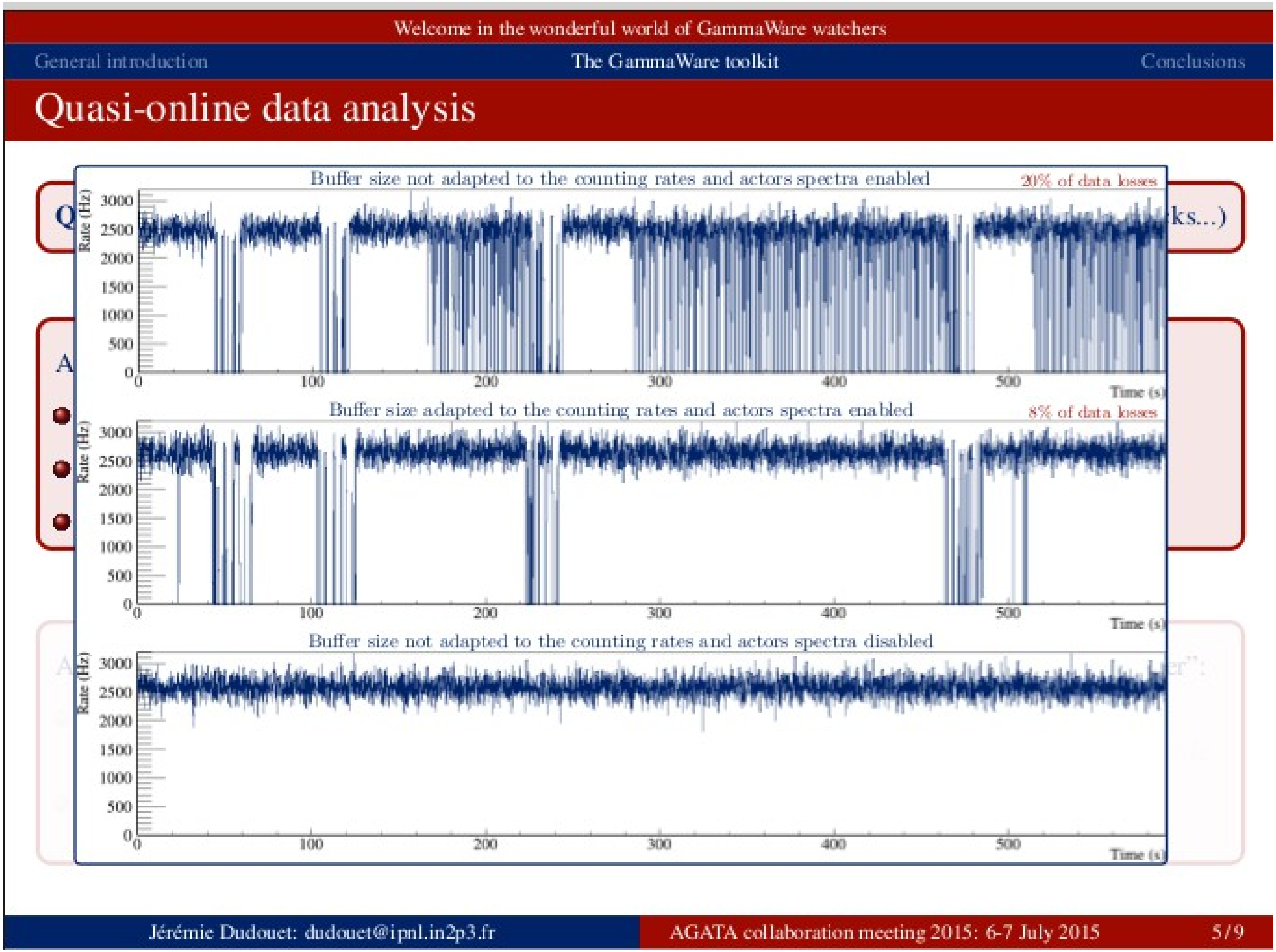
The workshop will be devoted to discussions about common challenges related to tracking arrays, including the physics, technical details and analysis of data from these arrays. We intend to organize these workshops on a yearly or bi-yearly basis, alternating between meeting places in the US and EU.

We are hoping these workshops will foster collaborations between the AGATA and GRETINA communities and help define and accomplish our common challenges.

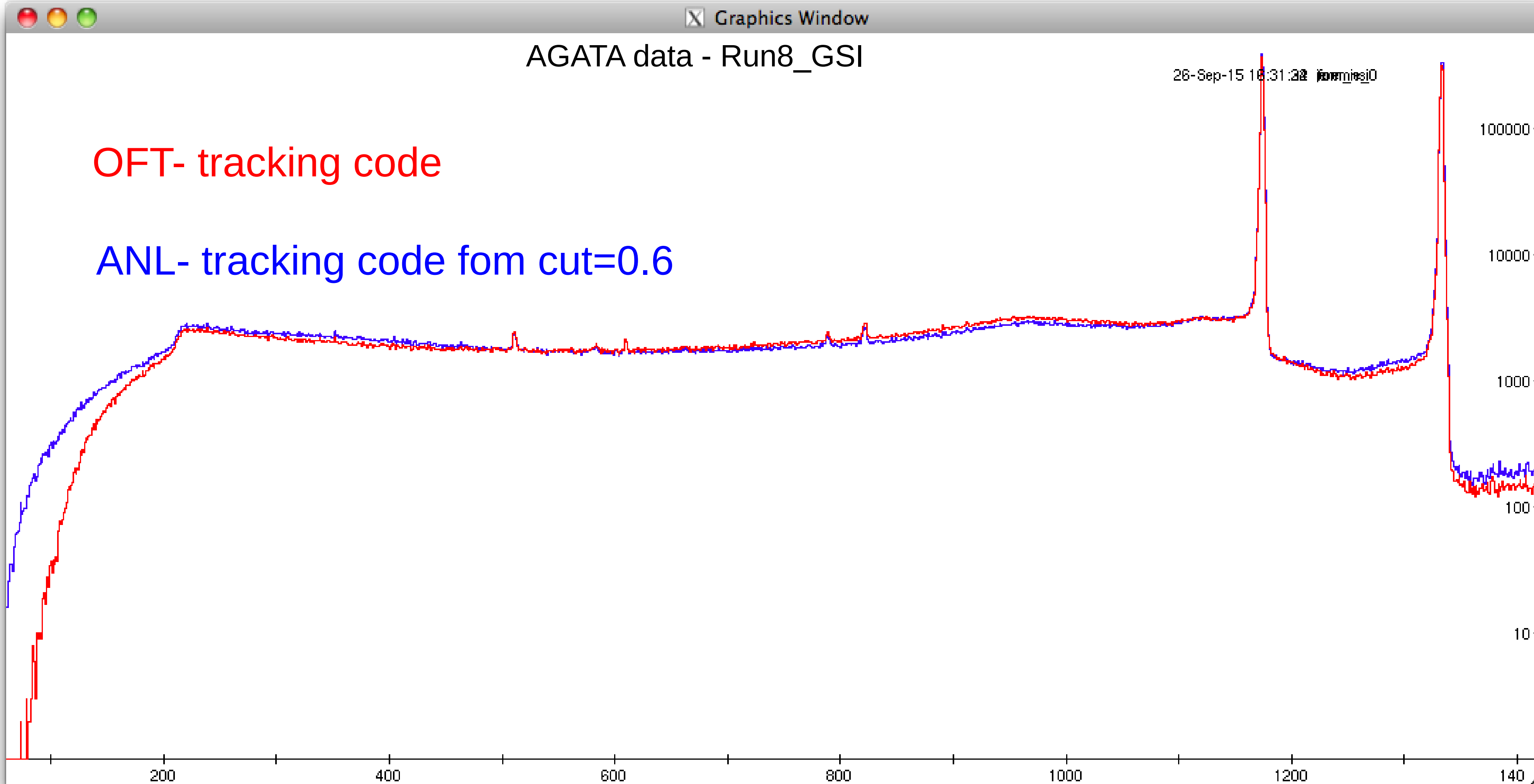
Organizing and Advisory committee :

B. Birkenback, IKP-Koeln, Germany.
A. Boston, Liverpool University, UK.
M.P. Carpenter, ANL, USA.
A. Gadea, IFIC-Valencia, Spain.
A. Korichi (co-chair) CSNSM-CNRS, France.
T. Lauritsen (co-chair) ANL, USA.
A.O. Macchiavelli, LBNL, USA.
D. Radford, ORNL, USA.
O. Stezowski, IPNL-CNRS, France.
D. Weisshaar, NSCL, USA.

Extra slides

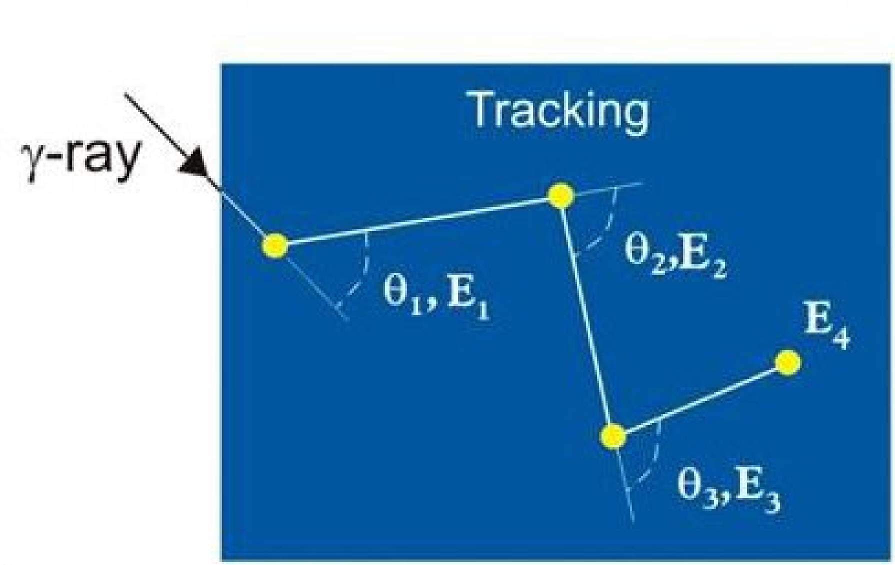


Courtesy of J. Dudouet- IPNL



Tracking codes are doing the job

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



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

$$E'_\gamma = \frac{0.511}{1 + \frac{0.511}{E_\gamma} - cos(\theta)}$$

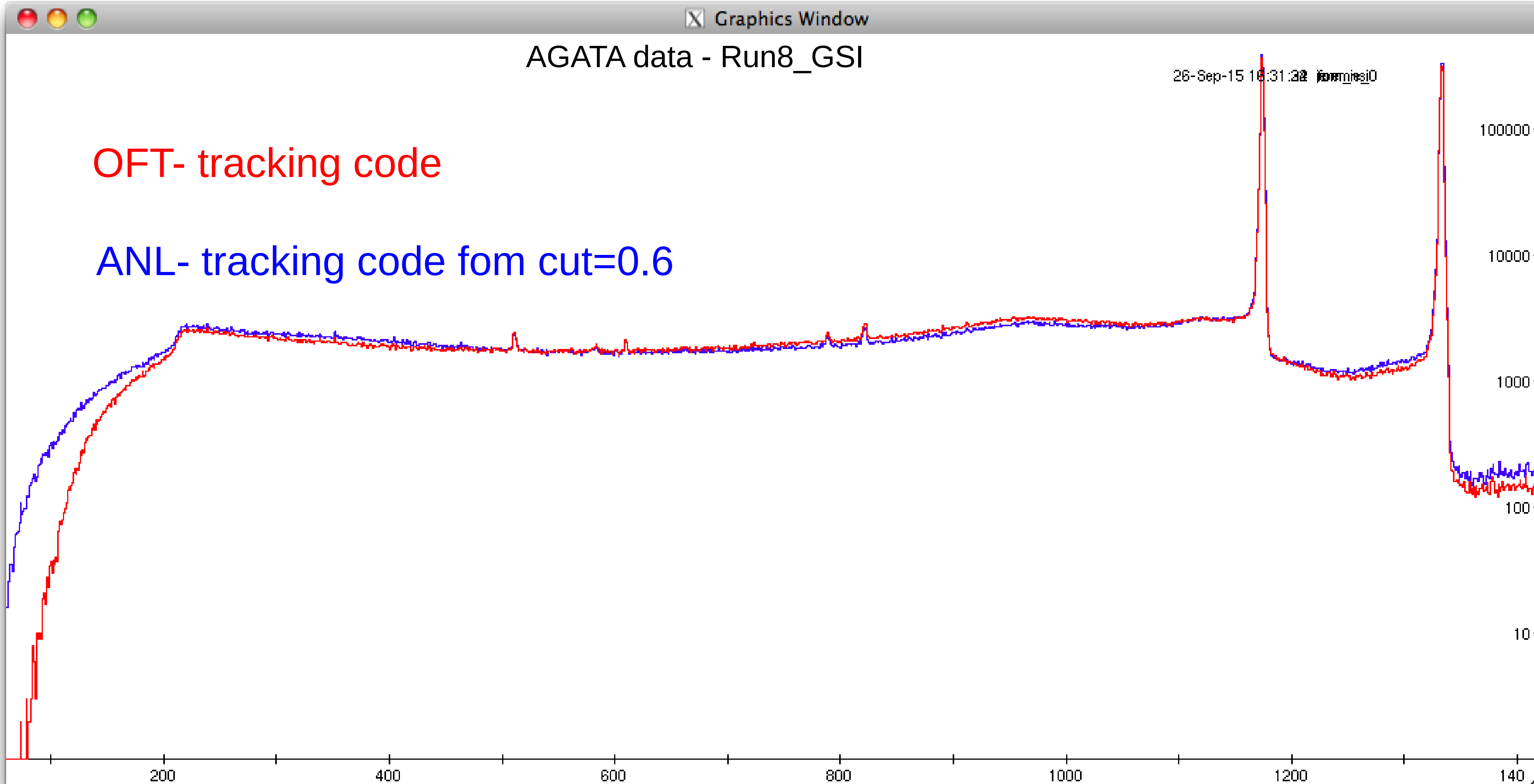
$$FOM = \sum_i \frac{\sqrt{(\sum_i(\theta_i^{theo} - \theta_i^{obs})^2)}}{n_i - 1}; n_i > 1$$

(in rad)

FOM < ~0.6-0.8
considered GOOD

FOM > ~0.8
considered BAD
(Compton events)

Note: Single interactions cannot be tracked



Tracking codes are doing the job

jeremie_nsi.spe ;P/T= 0.468 ;p1/p2/sum= 1146917/ 1084651/ 4764551 :: photoeff = 0.045 ;
totaleff = 0.095 ; p2eff = 0.043 ; *= 0.9791

fom_nsi06.spe ;P/T= 0.488 ;p1/p2/sum= 1247299/ 1184123/ 4984402 :: photoeff = 0.049 ;
totaleff = 0.100 ; p2eff = 0.047 ; *= 1.1571

fom_nsi08.spe ;P/T= 0.462 ;p1/p2/sum= 1353925/ 1289846/ 5722022 :: photoeff = 0.053 ;
totaleff = 0.114 ; p2eff = 0.052 ; *= 1.1288

Builder_000.adf only 28 crystals- counting correctly

Sum core

Abs. Efficiency
with error: eff1173= 4.50% +/- 0.12%

with error: eff1333= 4.23% +/- 0.11%

__input P/T is 0.3340
True P/T is 0.3341 +/- 0.0107

__obs P/T is 0.1715 +/- 0.0001

nsi tracking efficiency = 78.59% +/- 0.58%
FOM20_nsi efficiency point is 0.0332 +/- 0.0009
wsi tracking efficiency = 92.43% +/- 0.68%
FOM20_wsi efficiency point is 0.0391 +/- 0.0011

Calorimetric

Abs. Eff
with error: eff1173= 4.09% +/- 0.12%

with error: eff1333= 3.88% +/- 0.12%

__input P/T is 0.3315
True P/T is 0.3316 +/- 0.0024

__obs P/T is 0.2907 +/- 0.0002

nsi tracking efficiency = 79.58% +/- 0.82%
FOM20_nsi efficiency point is 0.0309 +/- 0.0010
wsi tracking efficiency = 93.59% +/- 0.97%
FOM20_wsi efficiency point is 0.0363 +/- 0.0012

Builder_0006.adf 29 crystals counting correctly

will show array efficiency
with error: eff1173= 4.73% +/- 0.13%

with error: eff1333= 4.44% +/- 0.12%

__input P/T is 0.3357
__true P/T is 0.3351 +/- 0.0107

__obs P/T is 0.1721 +/- 0.0001
nsi tracking efficiency = 80.35% +/- 0.59%
FOM20_nsi efficiency point is 0.0357 +/- 0.0010
wsi tracking efficiency = 94.20% +/- 0.69%
FOM20_wsi efficiency point is 0.0418 +/- 0.0012

with error: eff1173= 4.24% +/- 0.21%

with error: eff1333= 4.02% +/- 0.20%

__input P/T is 0.3380
__true P/T is 0.3368 +/- 0.0031

__obs P/T is 0.2945 +/- 0.0002
nsi tracking efficiency = 80.08% +/- 1.07%
FOM20_nsi efficiency point is 0.0322 +/- 0.0016
wsi tracking efficiency = 93.84% +/- 1.25%
FOM20_wsi efficiency point is 0.0377 +/- 0.0019