Pulse Shape Analysis Optimization with segmented HPGe-Detectors

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2 Analysis and Optimization of PSA
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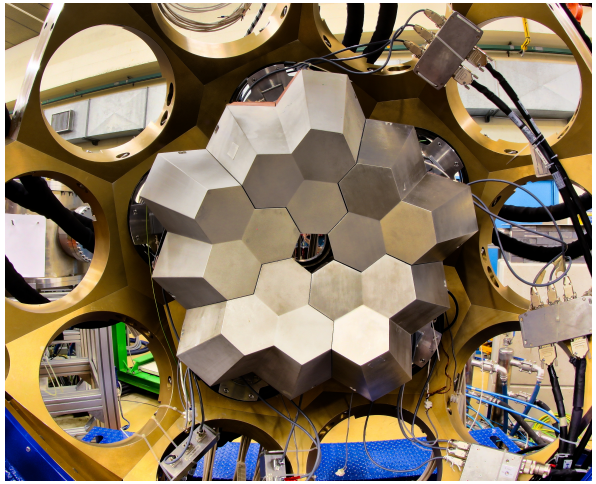
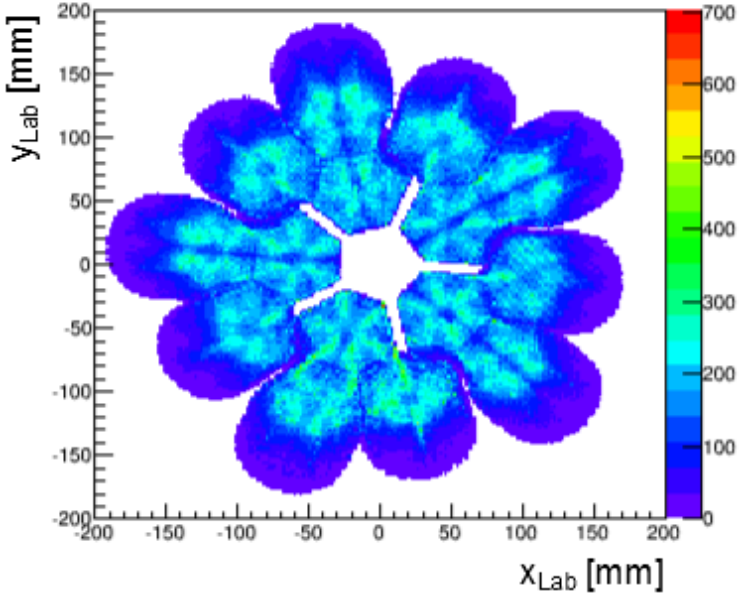
The AGATA Array

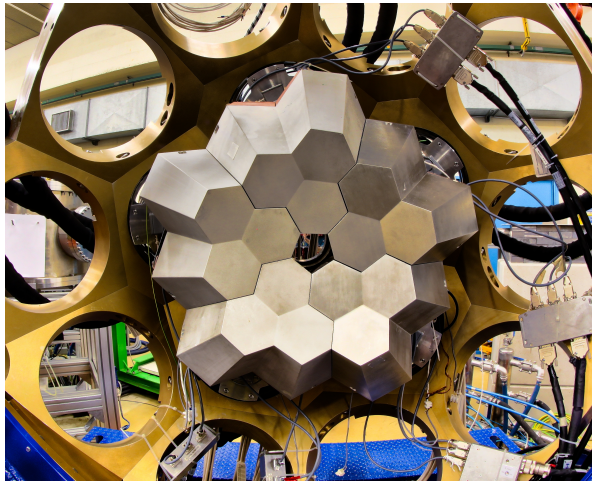


AGATA Demonstrator at Laboratori Nazionali di Legnaro (LNL)

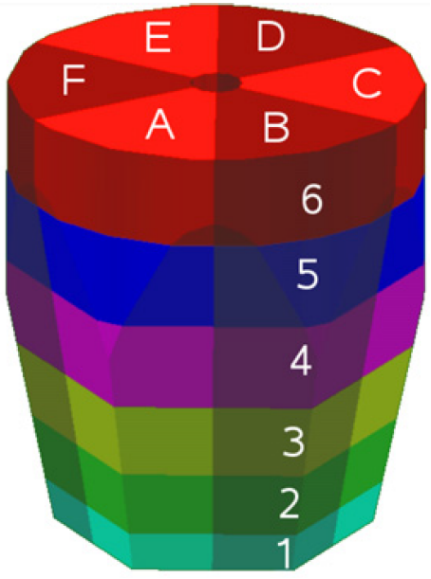


- 36 fold segmented HPGe detectors
- Interaction position within segments with PSA
- γ-ray tracking $\Rightarrow$ Doppler correction, polarization measurements and P/T comparable to BGO anti Compton supression

The AGATA Array



AGATA Demonstrator at Laboratori Nazionali di Legnaro (LNL)



Bart Bruyneel et al., Crosstalk properties of 36-fold segmented symmetric hexagonal HPGe detectors, NIM A, Volume 599, 2009

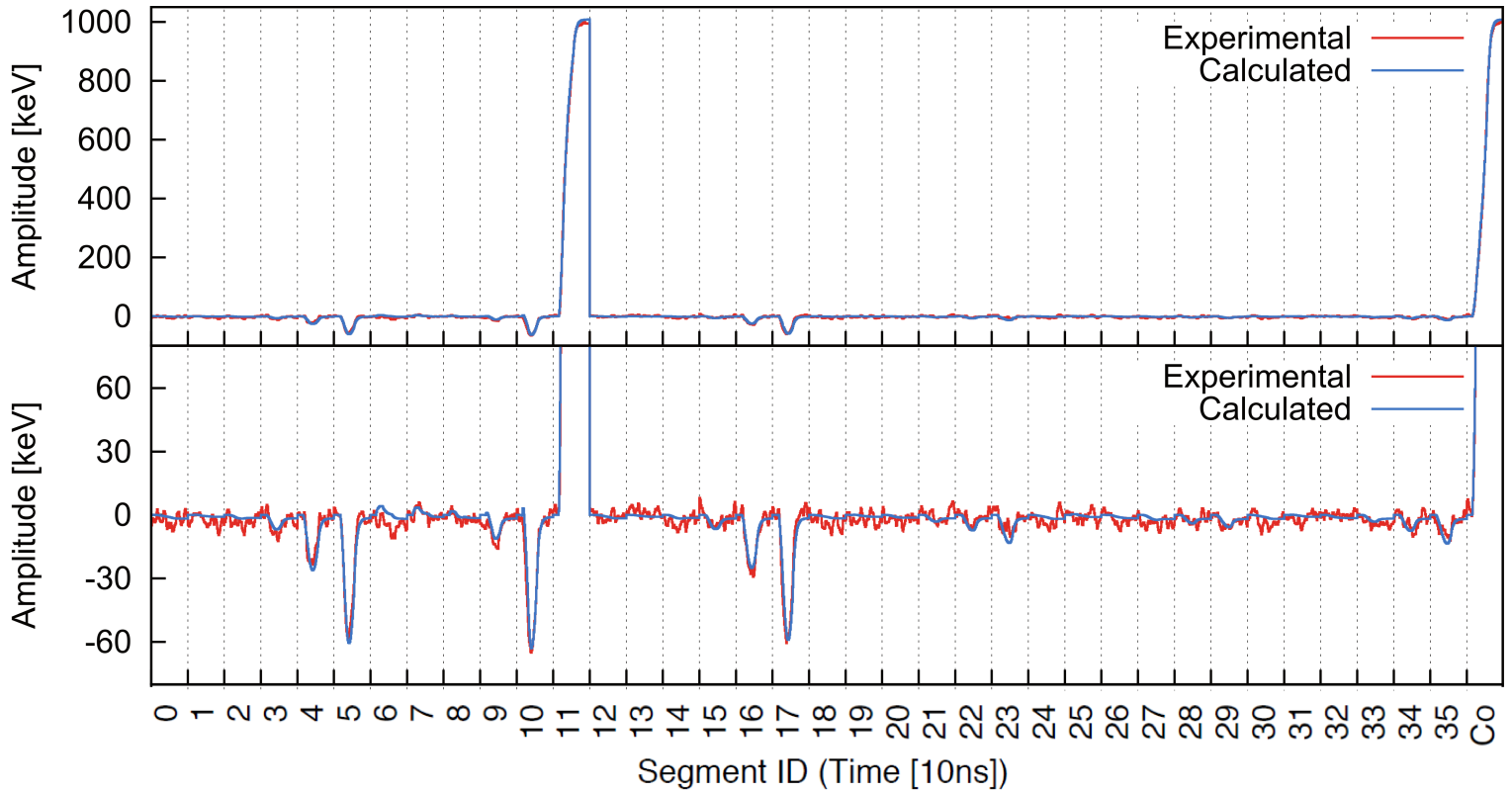
- 36 times segmented HPGe detectors
- Interaction position within segments with PSA
- γ-ray tracking $\Rightarrow$ Doppler correction, polarization measurements and P/T comparable to BGO anti Compton supression

The AGATA Array

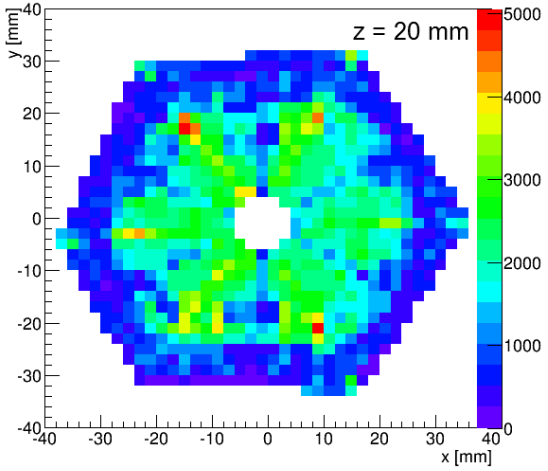
AGATA @GANIL

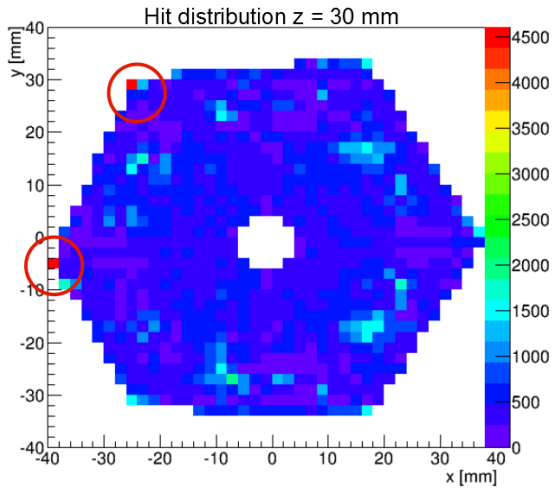
- 36 times segmented HPGe detectors
- Interaction position within segments with PSA
- γ-ray tracking $\Rightarrow$ Doppler correction, polarization measurements and P/T comparable to BGO anti Compton supression

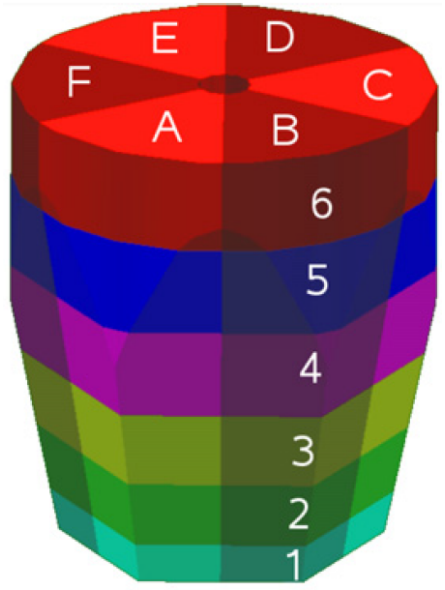
Pulse Shape Analysis



- For every interaction position: set of simulated signals (ADL)
- Compare with measured signal ⇒ Best fit ⇒ Interaction position
- Use signal of hit segment, neighbors and core







- PSA working well in general: FWHM 4-5 mm, F. Recchia et al., Position resolution of the prototype AGATA triple-cluster detector from an in-beam experiment, NIM A, Volume 604, 2009
- Clustering and High Statistics Grid Points (HSGP) motivated further investigation
- Previously: Systematic investigation of all crystal and electronic properties (crosstalk, transfer function,...) + search algorithm
- PSA performance improved, but still not perfect

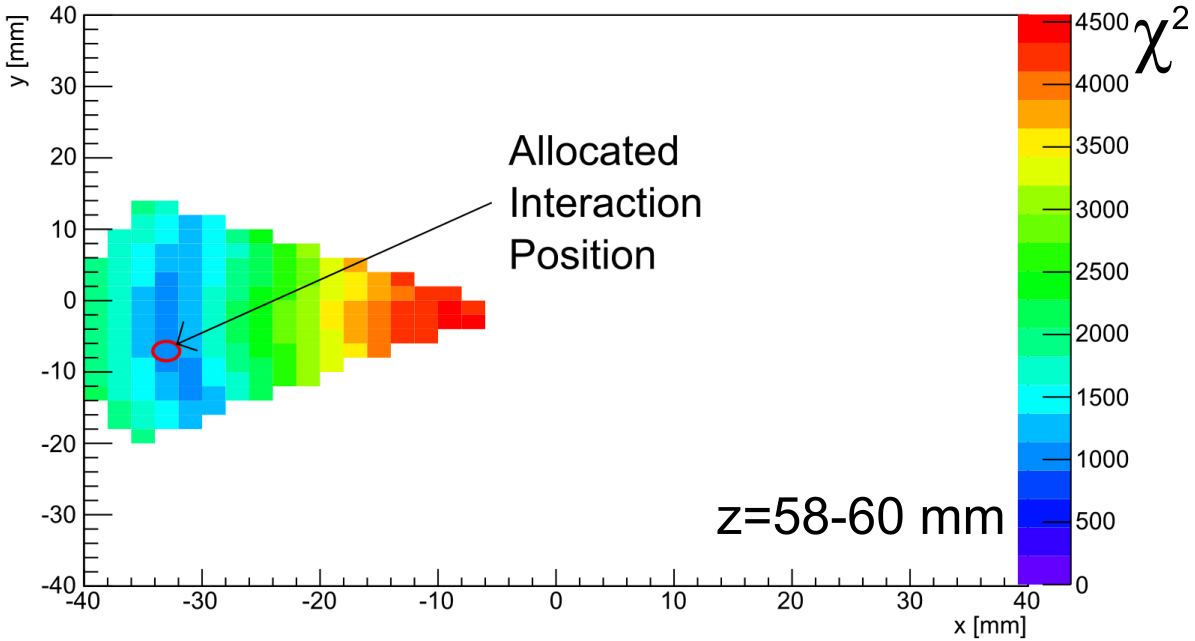
Comparison of Measurement and Simulation

Figure of Merit

$$\chi^2 = \sum_{t,j} |A_j^m[t] - A_j^s[t]|^p$$

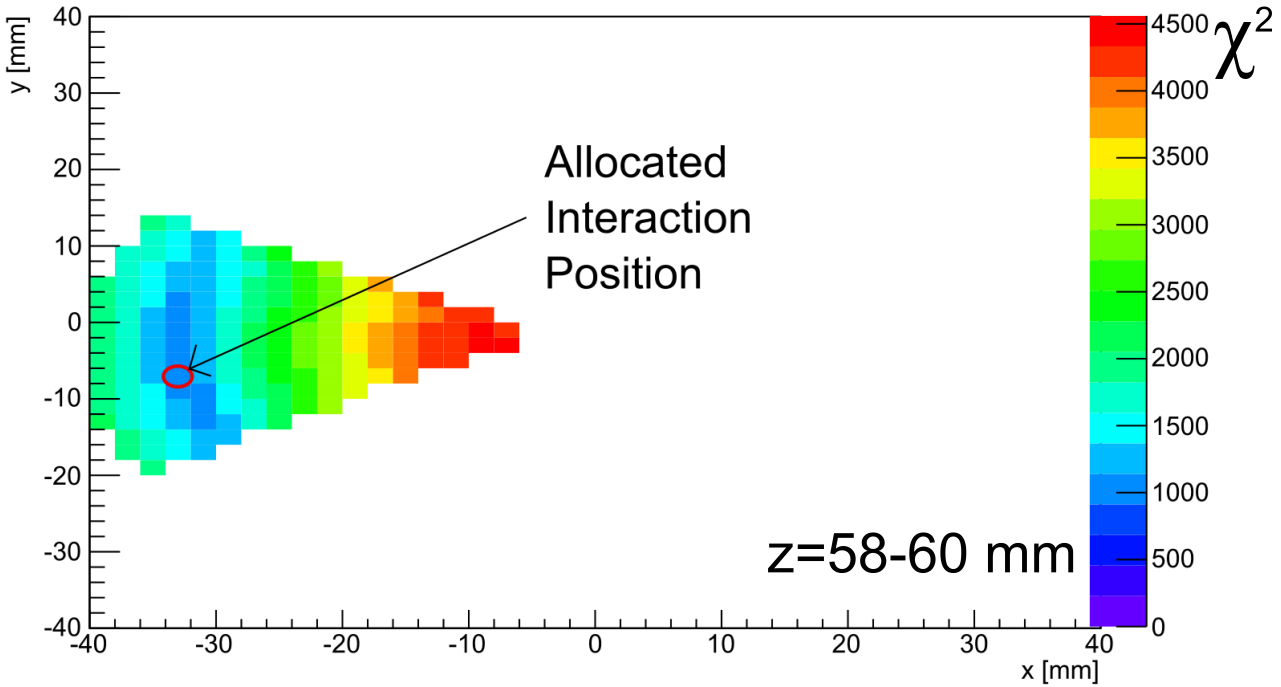
Measured A^m and simulated signal height A^s of segment id j at time t

χ^2 values for one segment



Visualization of Grid Search

- E = 257 keV, Segment=22 (D5), x=-32.25 mm, y=-6.25 mm, z=59.25 mm
- Radial resolution is better than angular resolution
- Angular position mainly determined by transient signals of neighboring segments



Weighting of Transient Signals

- Introduce new figure of merit

Weighted figure of merit

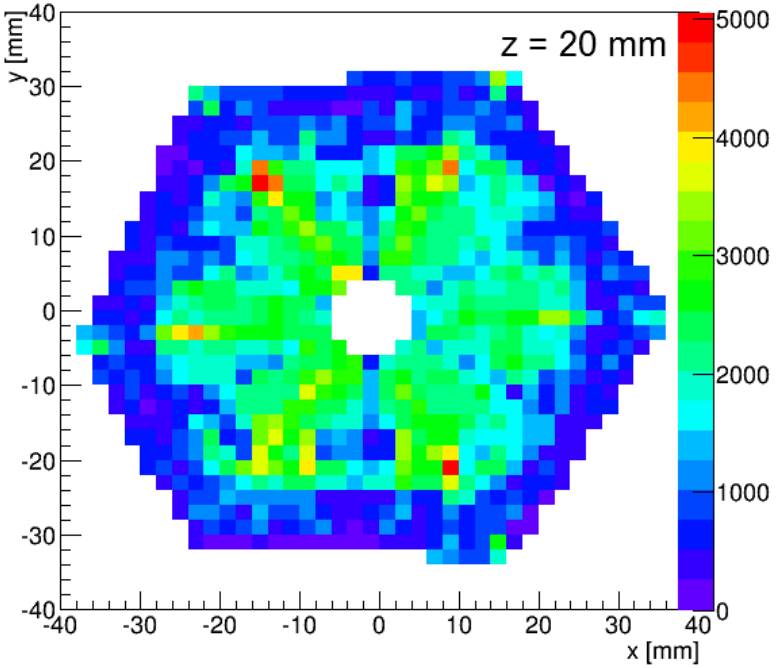
- Interaction of γ ray in Segment k

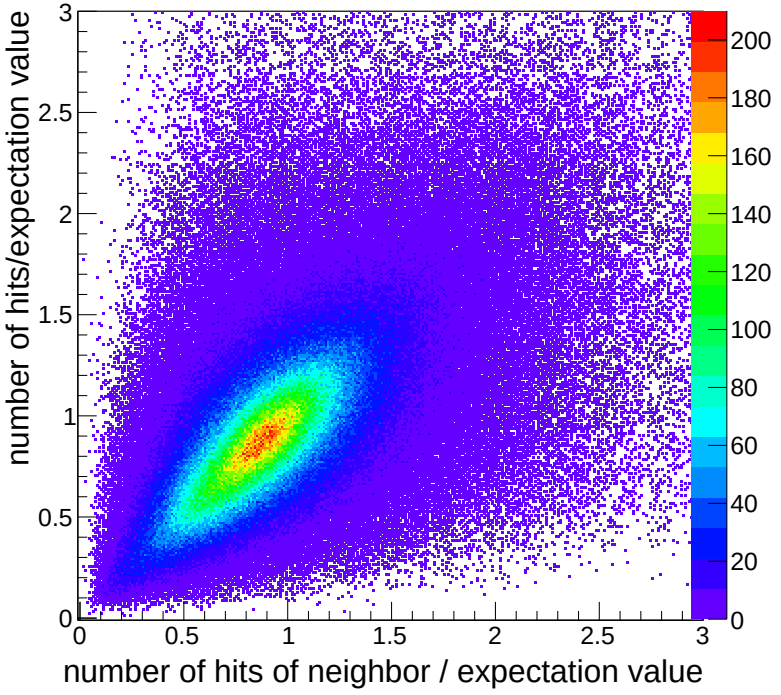
$$\chi^2 = \sum_i w_{i,k} \sum_t |A_i[t]^s - A_i[t]^m|^p$$

- $w_{i,k} = 1$ for the hit segment (i=k) and for the core
- $w_{i,k}$ for nearest neighbors has to be determined
- $w_{i,k} = 0$ else

Determination of the Weighting factors

- Comparison with expected hit distribution (known for source runs - statistical fluctuation)
- Introduce three Criteria:
- **1.) Clustering/Correlation (Covariance)**
  - Ideal scenario: No correlation expected

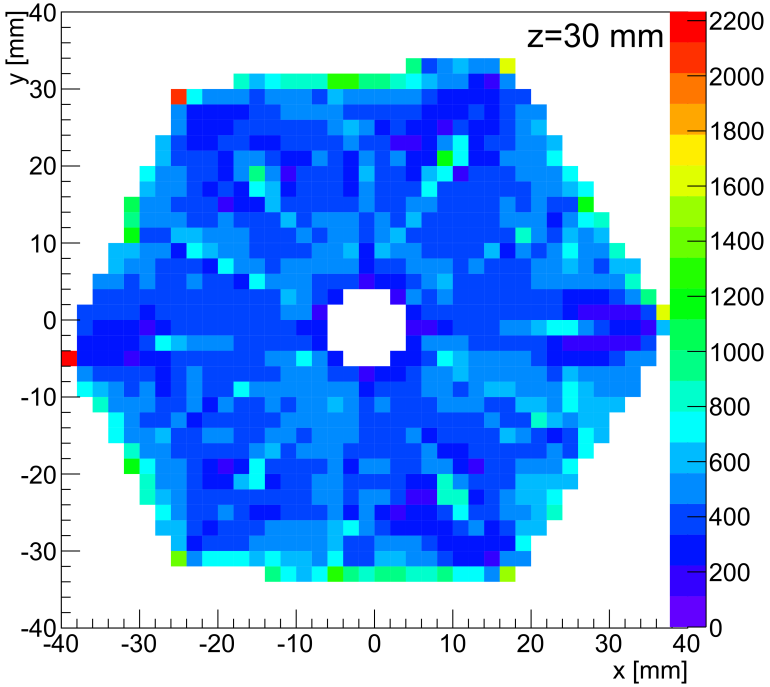


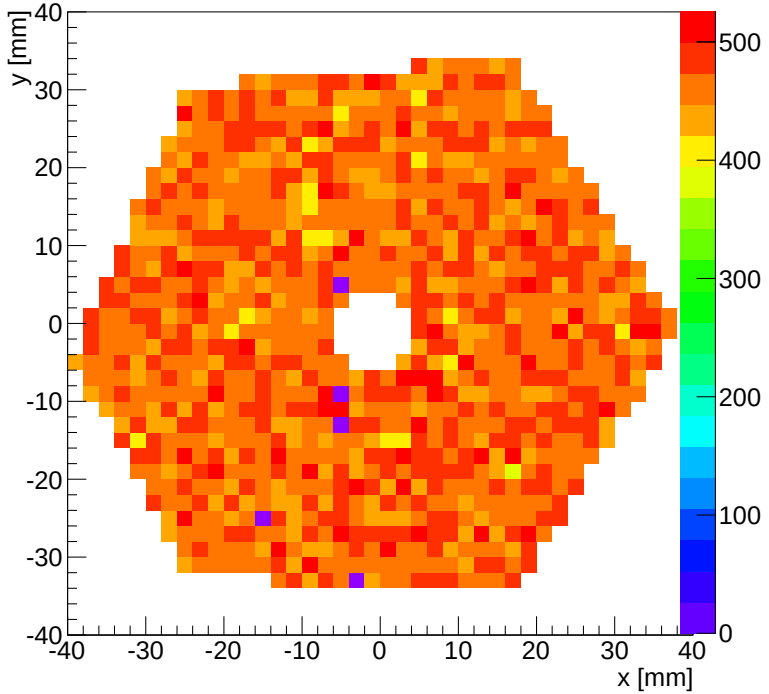


Determination of the Weighting factors

- Comparison with expected hit distribution (known for source runs - statistical fluctuation)
- Introduce three Criteria:
- **2.) Deviation from the expectation value**

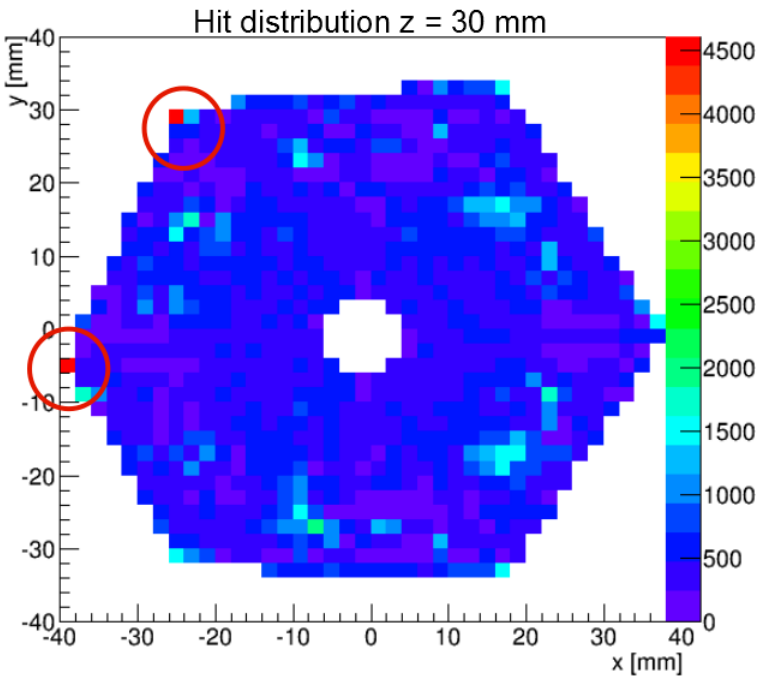
Random interaction position - no uncertainty





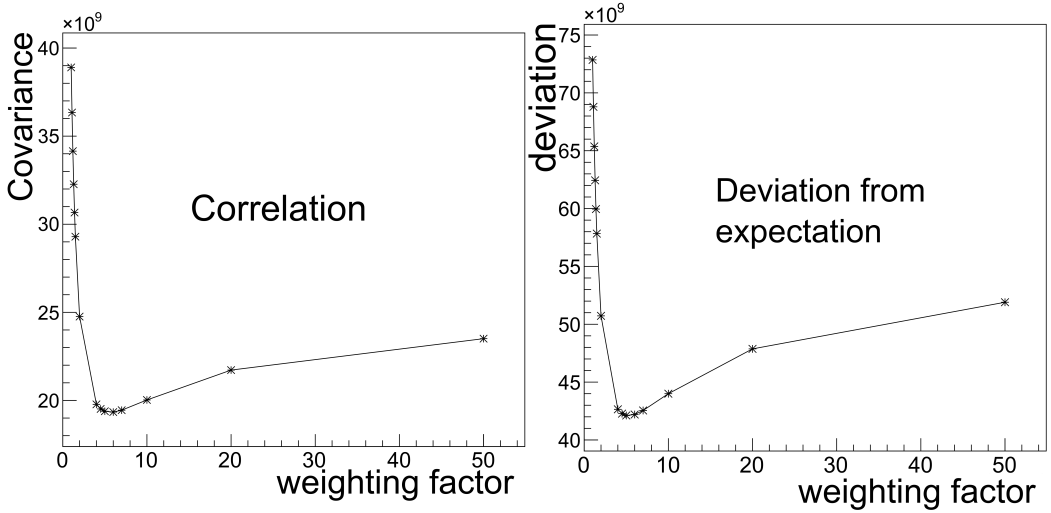
Determination of the Weighting factors

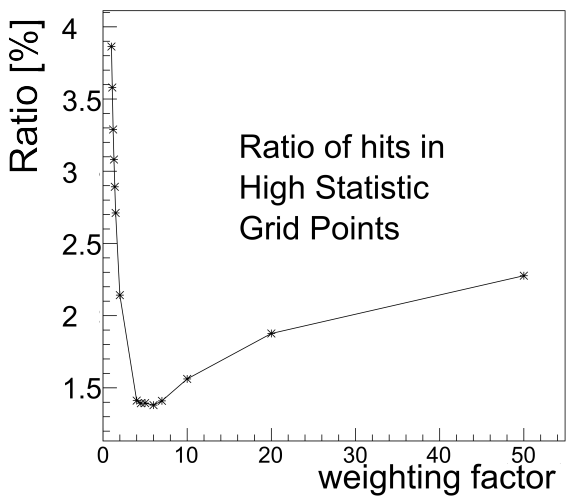
- Comparison with expected hit distribution (known for source runs - statistical fluctuation)
- Introduce three Criteria:
- **3.) High statistic grid points (Ratio of hits inside HSGP compared to rest)**



Determination of Weighting Factors

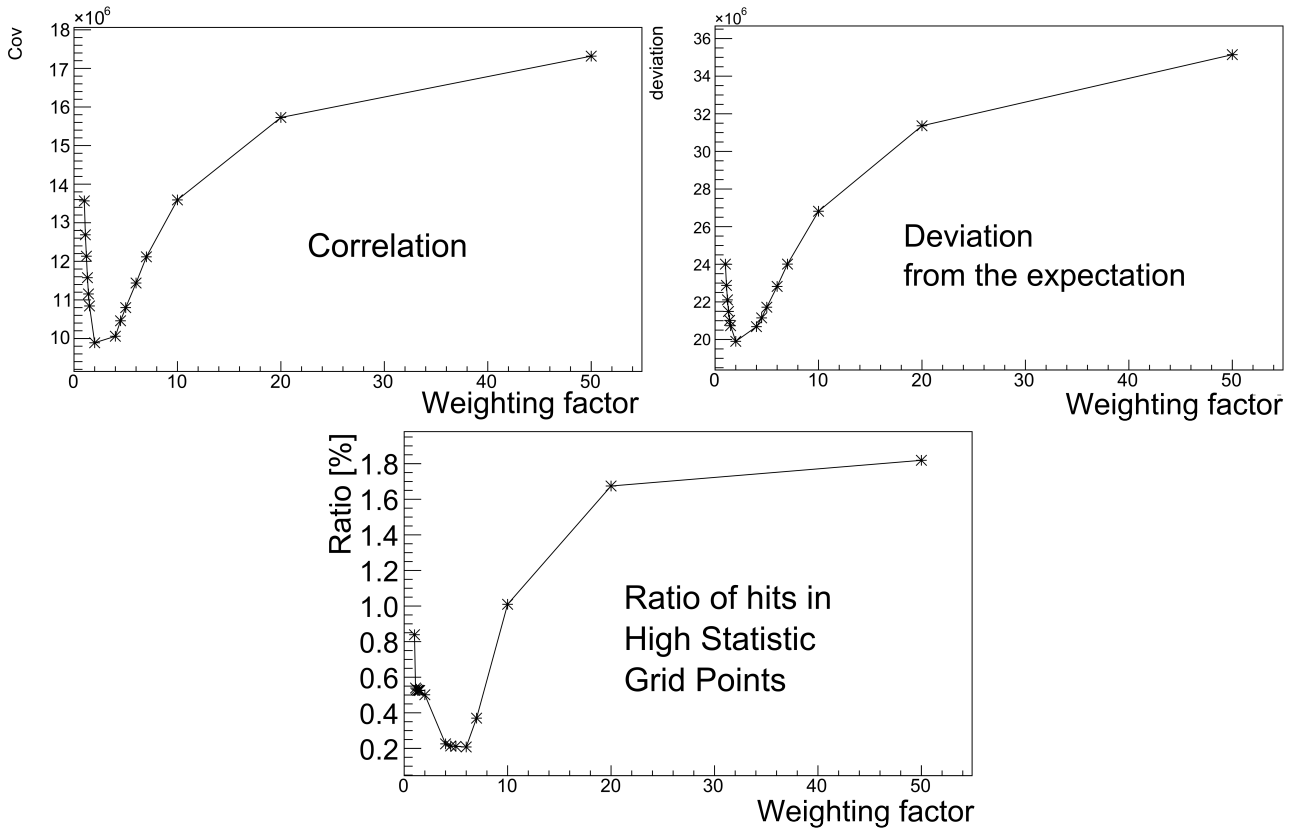
- First: Global weighting factor for neighboring segments
- Varied between 1 and 50



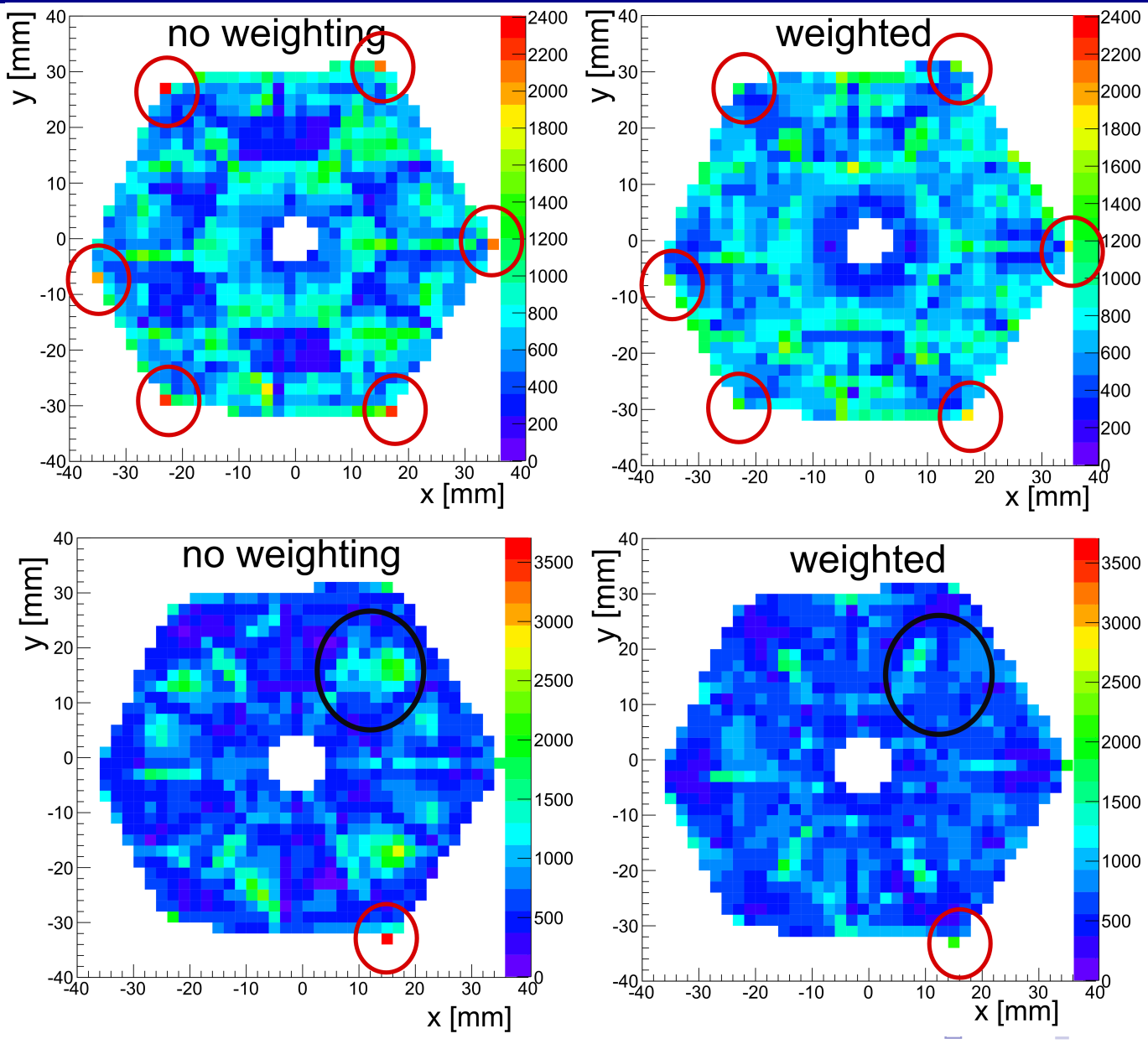


Determination of Weighting Factors

- Variation of weighting factors for each segment of every detector
- Exemplary shown for detector 13, segment 27



Impact on PSA Result



Summary and Outlook

Summary

- Algorithm that compares measured and simulated signals has been improved
- Stronger weighting of transient signals introduced
- Optimal weighting factors for every single segment by maximizing PSA performance

Outlook

- Energy dependent weighting
- Measurements with known interaction positions

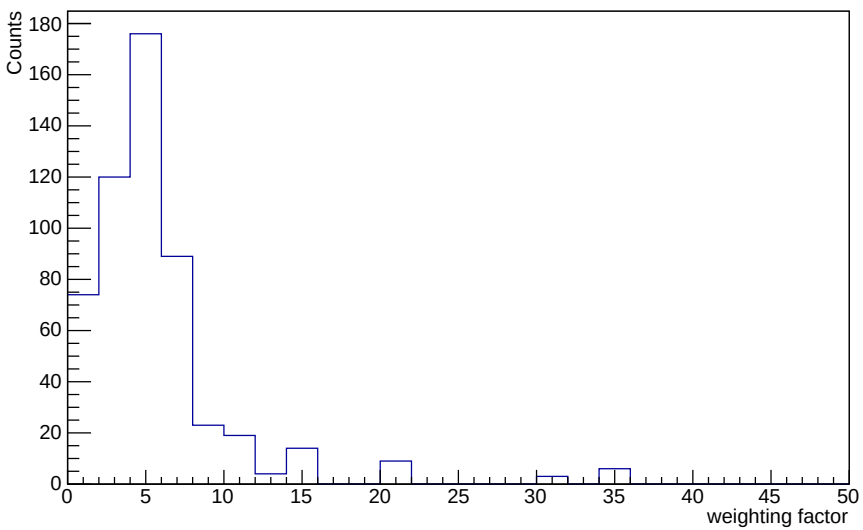
Thank you

Thank you for your attention!

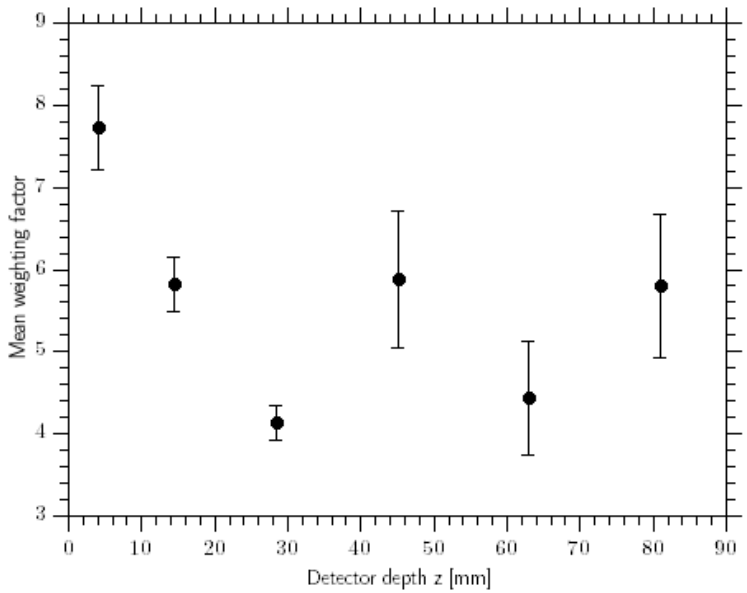
This project is supported by the German BMBF

Determination of Weighting Factors

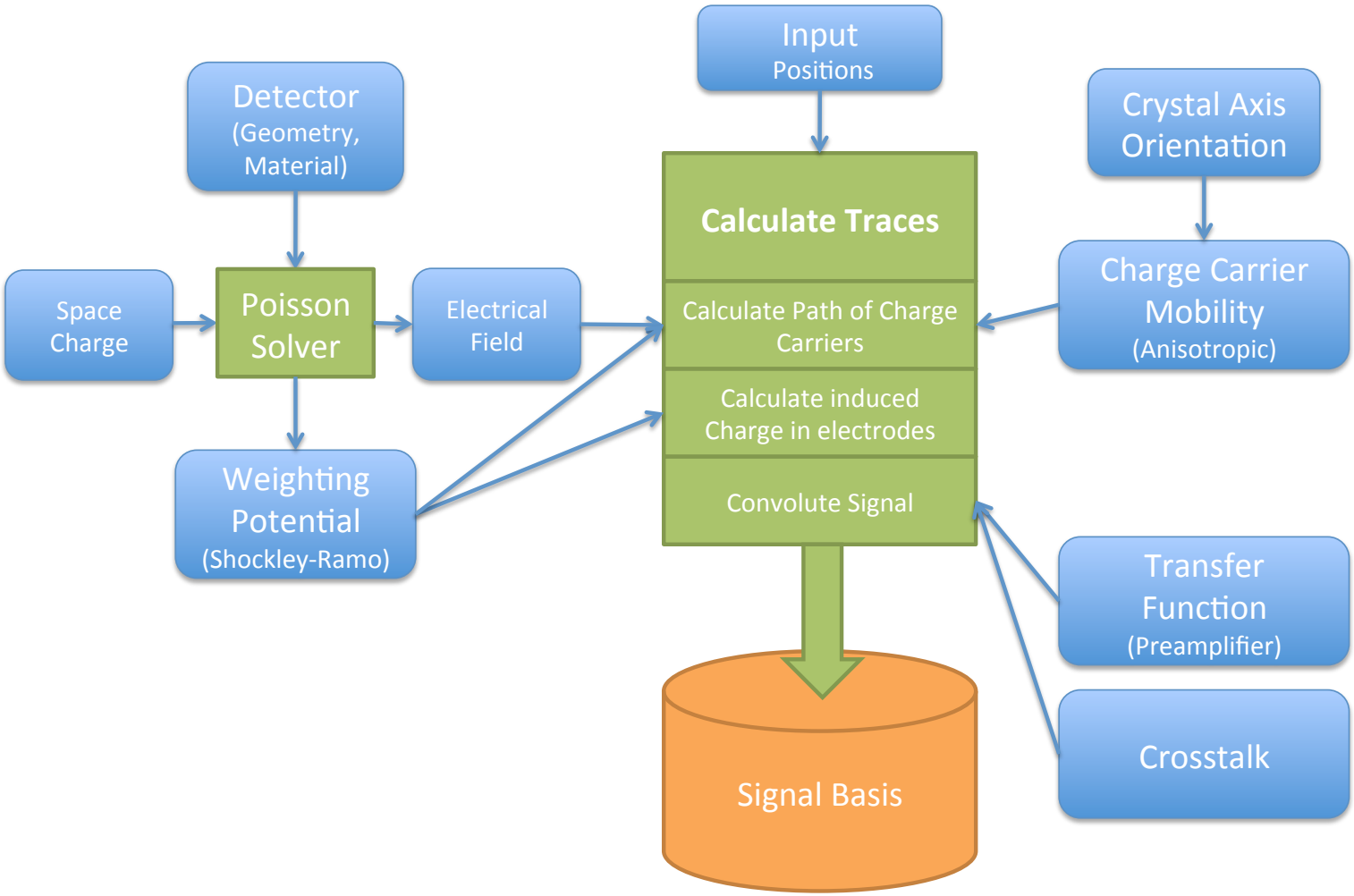
- Distribution of optimal weighting factors



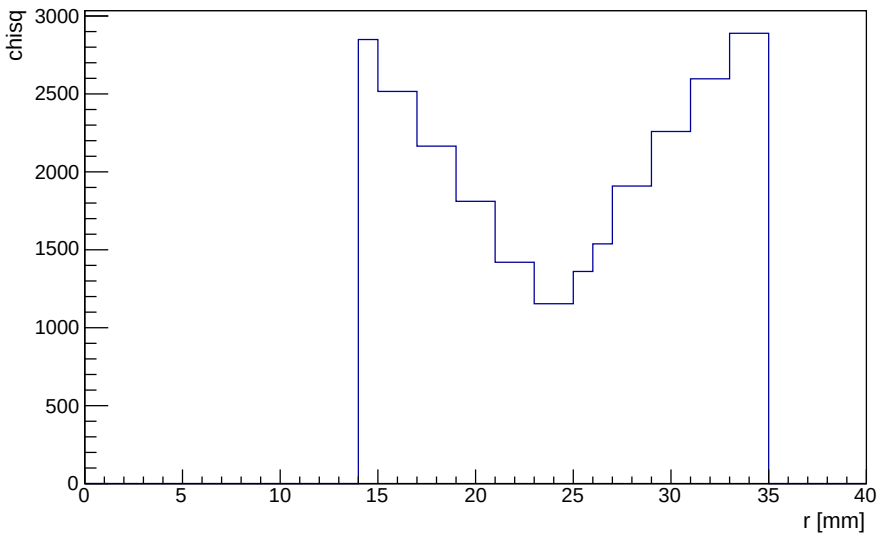
- Average weighting factors for each slice

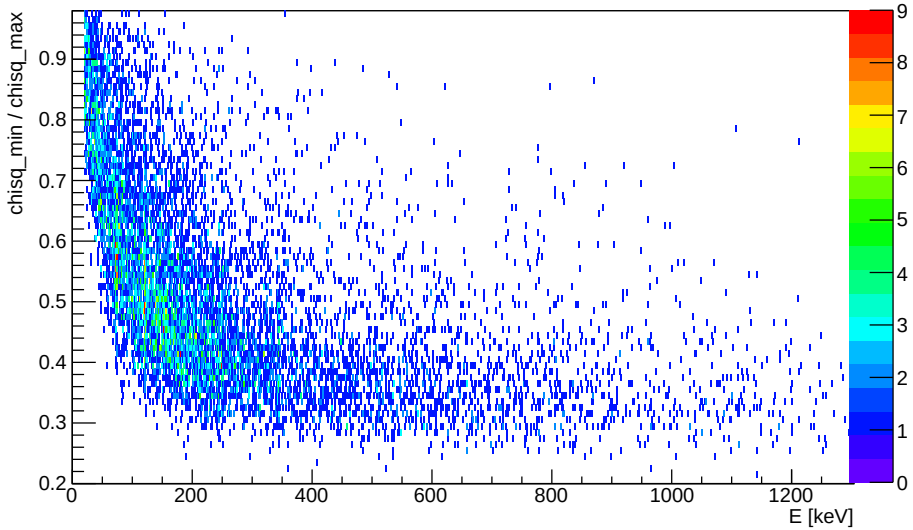


AGATA Data Library

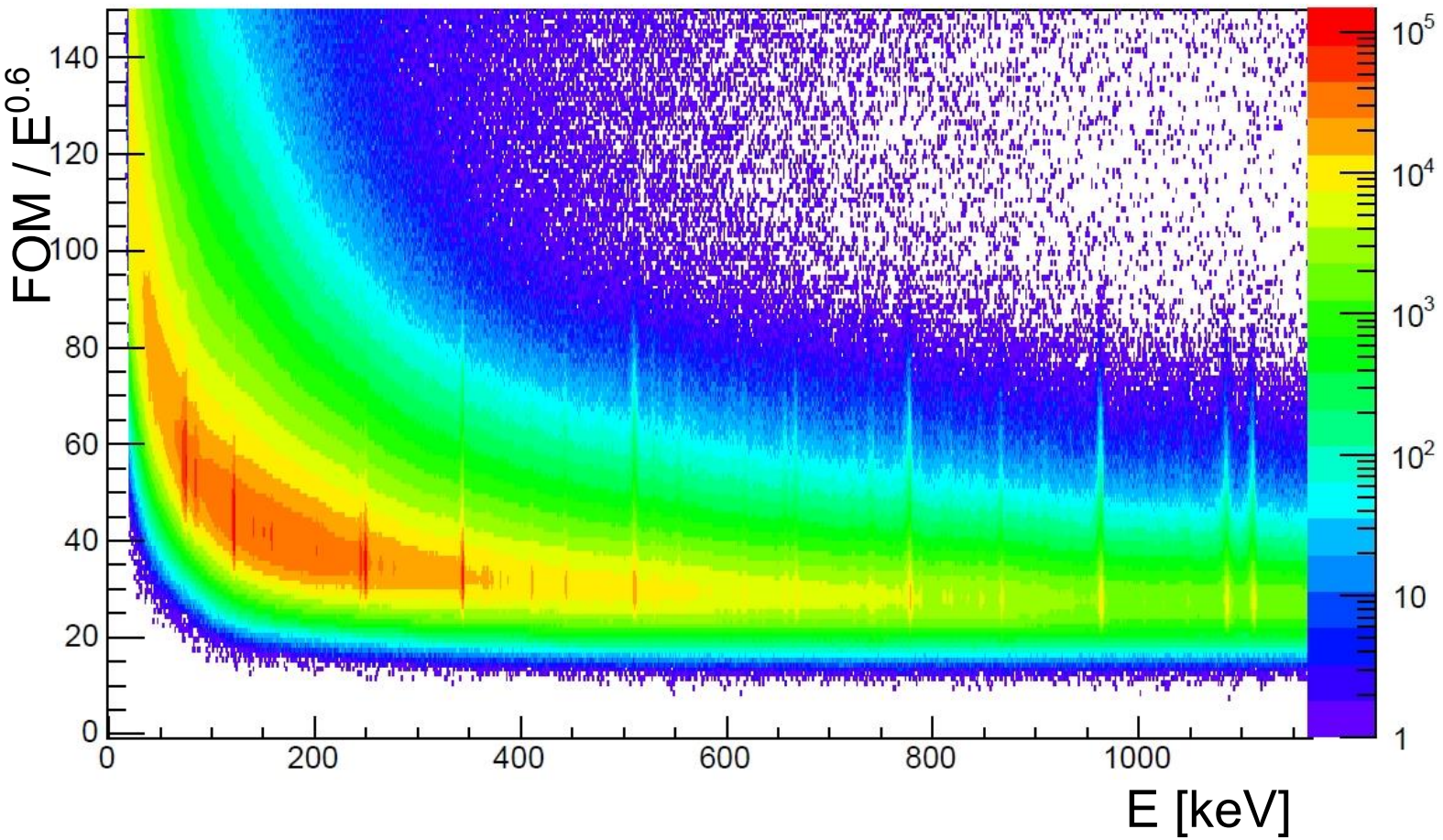


Appendix

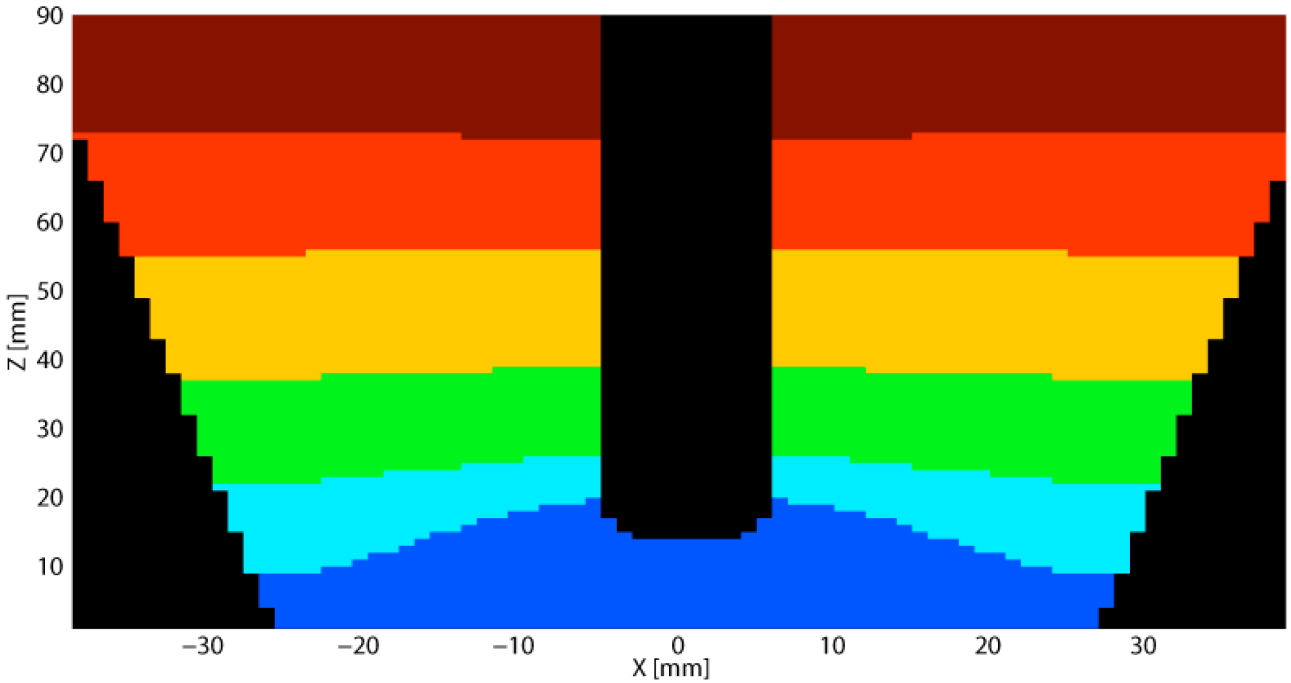

chisq
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
r [mm]


chisq_min / chisq_max
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
200
400
600
800
1000
1200
E [keV]
9
8
7
6
5
4
3
2
1
0

Appendix

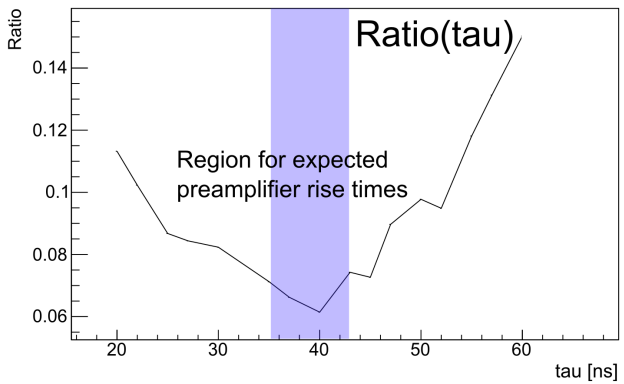

FOM / E^0.6
E [keV]
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
1
10
10^2
10^3
10^4
10^5

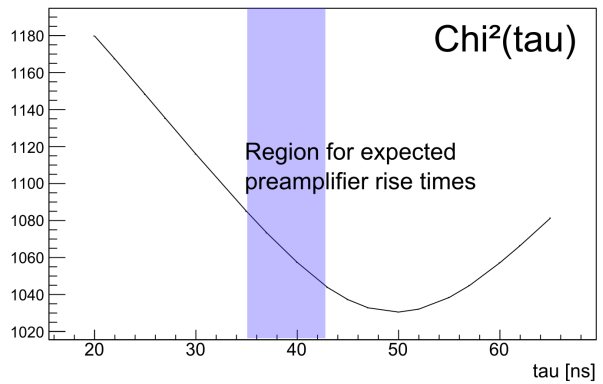
Electrical fields



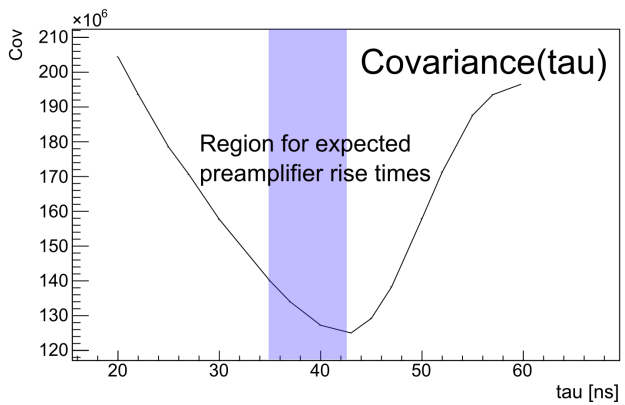
Example of optimization - Transfer function

- Transfer function of preamplifier and digitizer
- 'Effective' τ
- Performed for every 540 segments (and 15 cores)



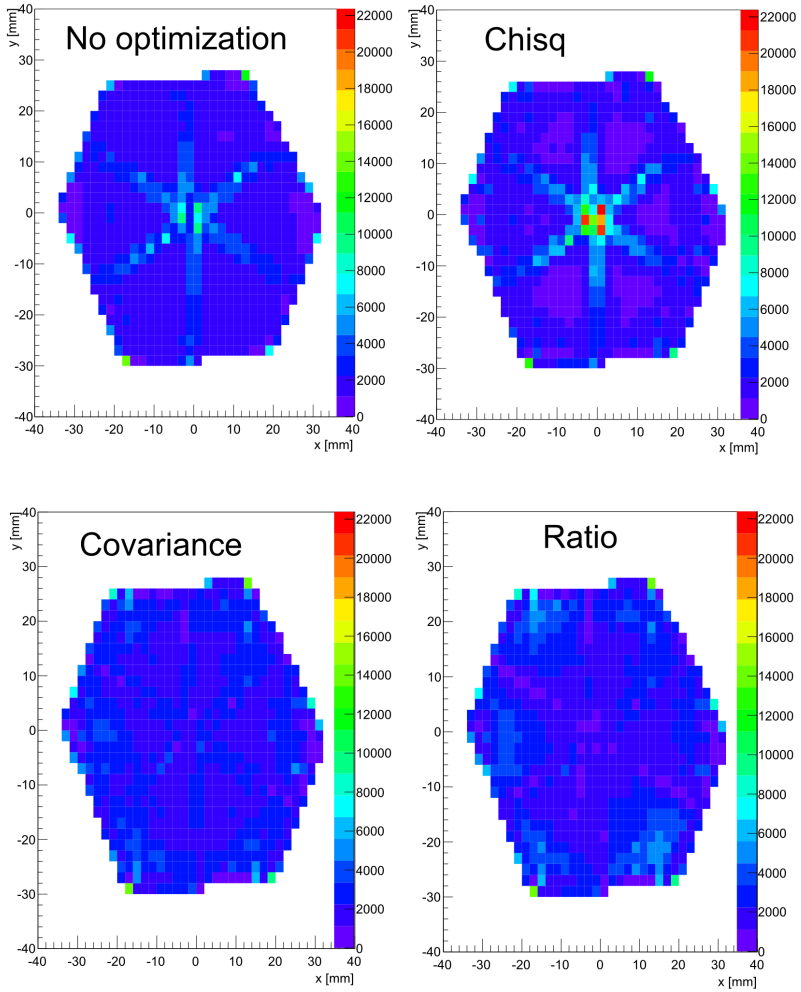


-Minima correspond to optimal tau value
-Shown for segment 7 of detector 13



Impact on hit distribution

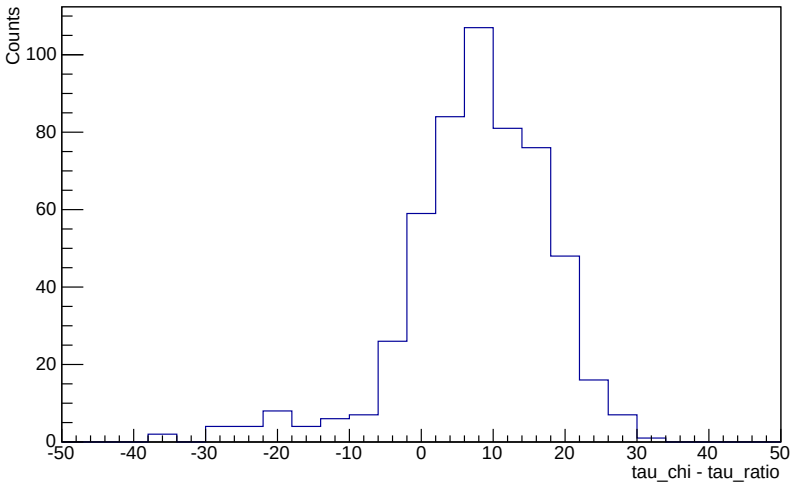
- Results with different optimization methods

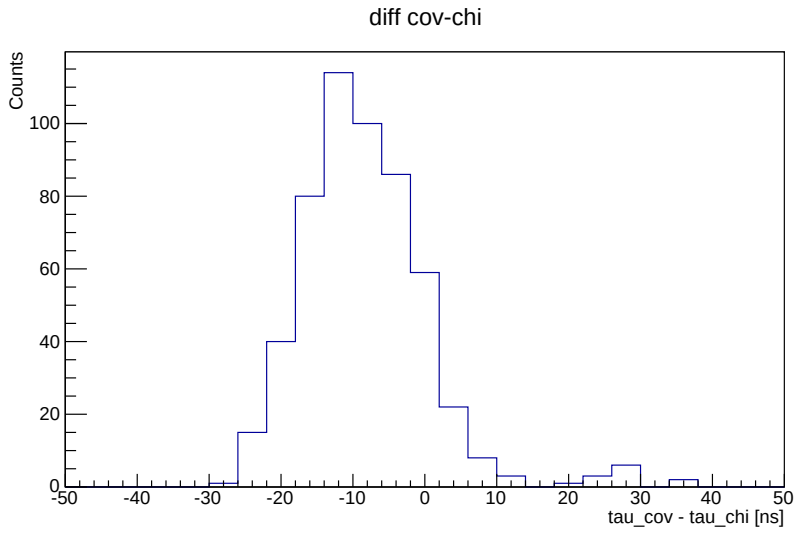


Detector 1, z=0-2 mm

Transfer Function

- Minima positions are similar, but do not coincide 100%
- Differences of optimal τ values derived via different determination methods





Transfer Function

- τ_{chi} is systematically bigger than τ_{cov} and τ_{ratio}
- τ_{cov} and τ_{ratio} coincide very well
- $\frac{\tau_{cov}+\tau_{ratio}}{2}$ is used for optimizing all 555 channels