Status of PSA investigation and optimization

AGATA Week 2015 Valencia

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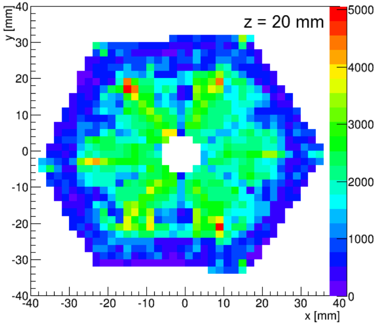
Outline

- PSA performance characterization
  - Clustering
  - High statistic grid points
  - Investigation of grid search
- PSA optimization
  - Input parameters
    - Detector properties
    - Proper setup of algorithm
  - Exemplarily shown for optimization of transfer function

PSA characterization

- **Distribution of hits**
- If unexpected behavior: Segment/Detector/general?
- Dependence on interaction position and energy



- Clustering!

PSA characterization

- **Distribution of hits**
- If unexpected PSA results: Segment/Detector/general?
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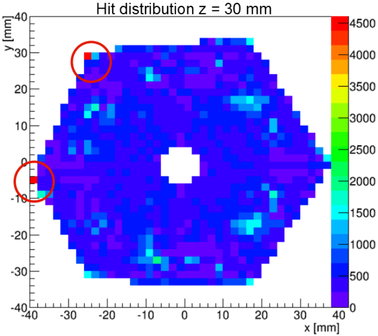
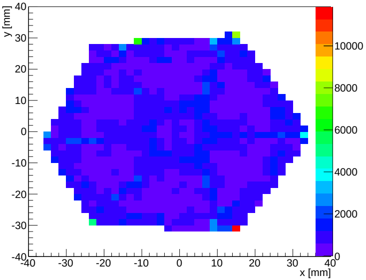


- High Statistic Grid Points (HSGP)!

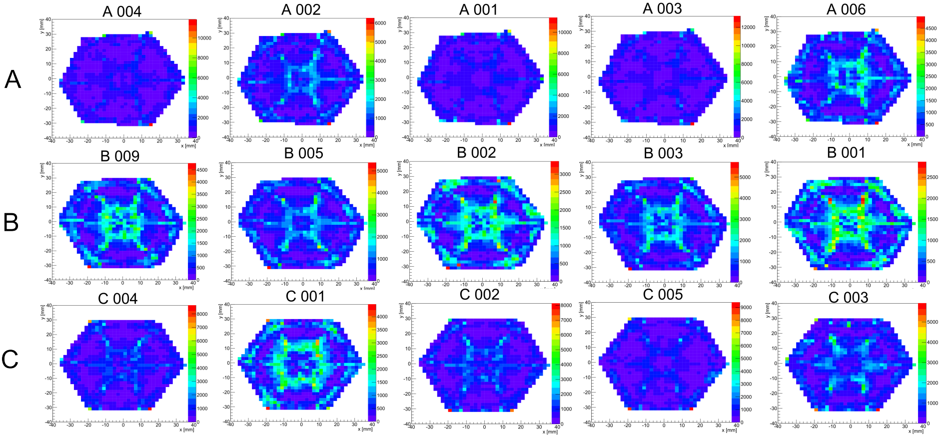
PSA characterization

- Distribution of hits
- **If unexpected PSA results: Segment/Detector/general?**
- Dependence on interaction position and energy

Detector 0 (A004),
z=10-12 mm

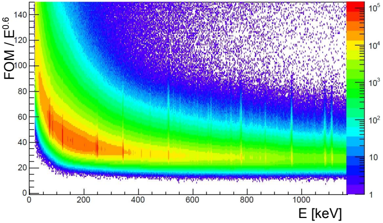


z=10-12 mm


A
A 004
A 002
A 001
A 003
A 006
B
B 009
B 005
B 002
B 003
B 001
C
C 004
C 001
C 002
C 005
C 003
x [mm]
y [mm]

PSA characterization

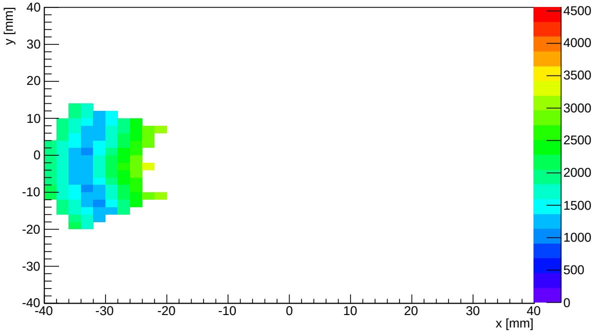
- Distribution of hits
- If unexpected PSA results: Segment/Detector/general?
- **Dependence on interaction position and energy**



- Problems with: Low energies, front of the detector, segment borders, edge of detector

Visualization of Grid Search

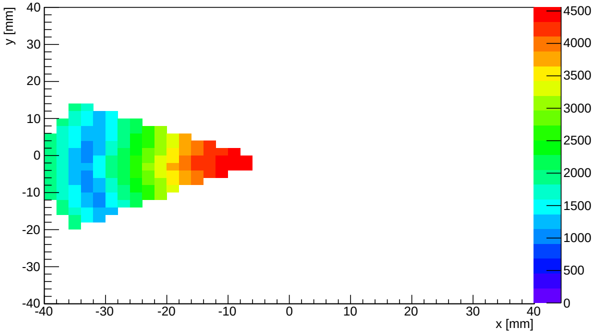
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=54-56 mm

Visualization of Grid Search

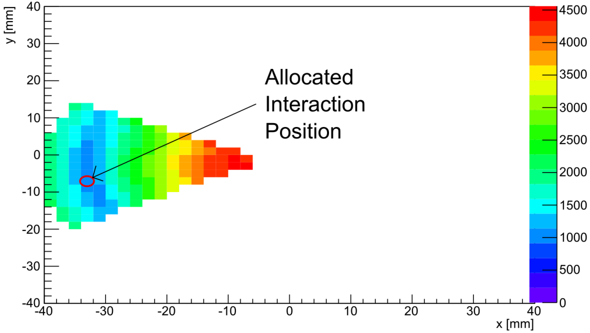
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=56-58 mm

Visualization of Grid Search

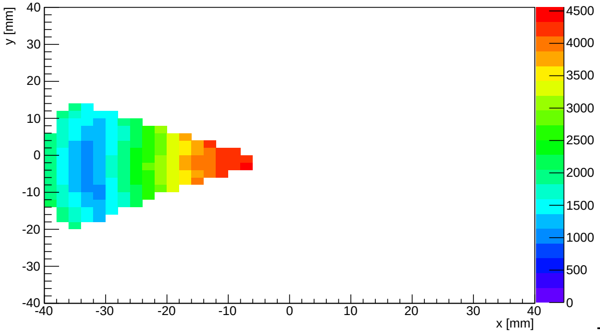
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=58-60 mm

Visualization of Grid Search

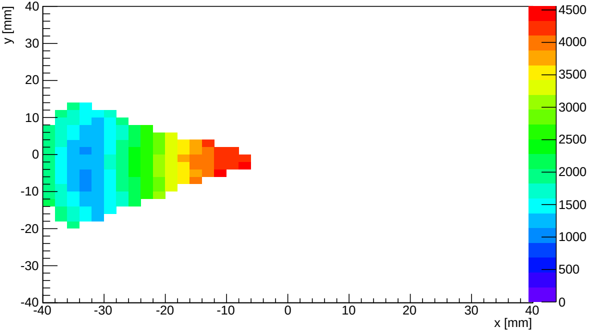
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- $E = 257\,\mathrm{keV}$, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=60-62 mm

Visualization of Grid Search

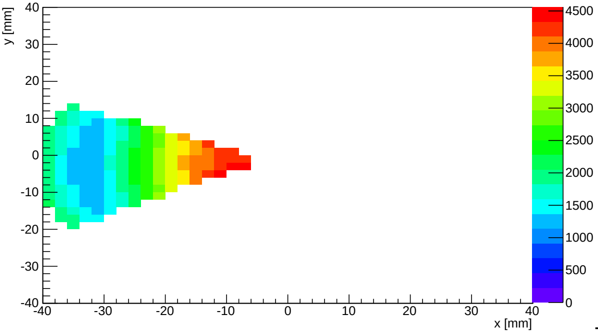
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=62-64 mm

Visualization of Grid Search

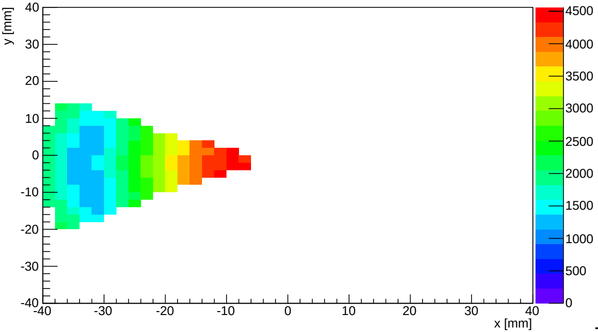
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=64-66 mm

Visualization of Grid Search

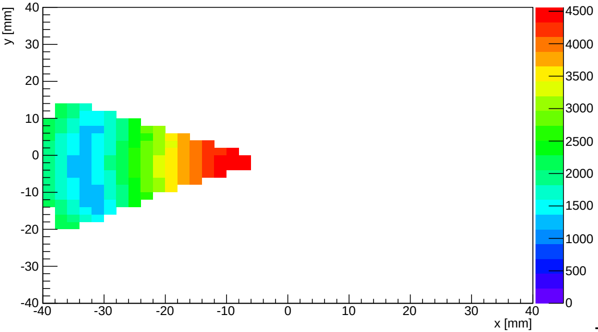
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=66-68 mm

Visualization of Grid Search

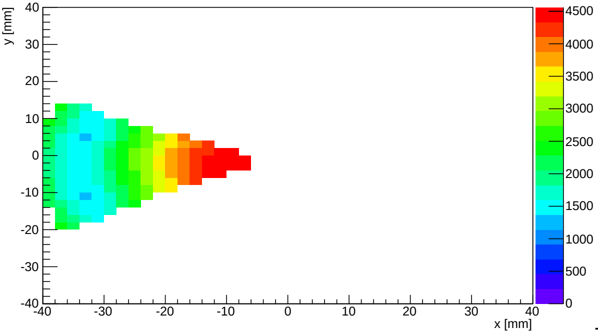
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=68-70 mm

Visualization of Grid Search

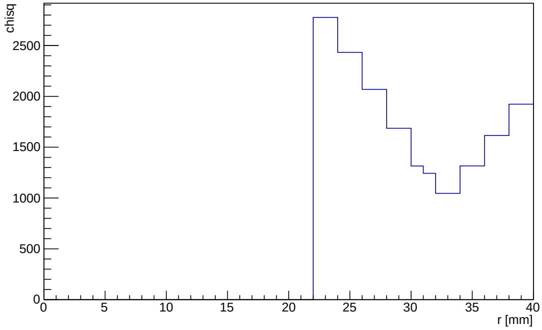
- Consider $\chi^2(\vec{r})$ of ONE event
- Local χ^2 minima?
- E = 257 keV, Segment=22, x=-32.25 mm, y=-6.25 mm, z=59.25 mm



z=70-72 mm

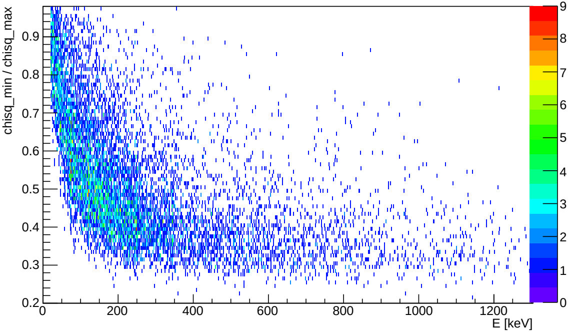
Visualization of Grid Search

- Radial dependence of $\chi^2(\vec{r})$ ($\pm$ 10 mm from minimum)
- Radial position seems reliable. Angular resolution difficult
- Depth of minimum $= \chi^2_{min}/\chi^2_{max} \Rightarrow$ **reliability** of PSA result



Visualization of Grid Search

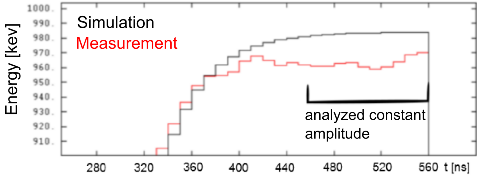
- Energy dependence of depth of minimum (10k events)
- Small energies problematic



PSA optimization

Detector and electronics properties:

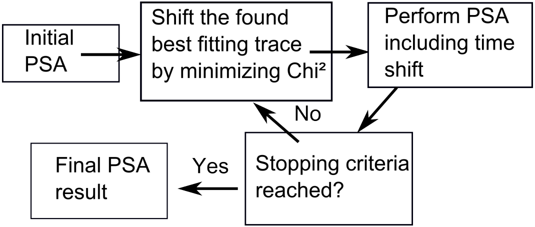
- Transfer function of preamplifier and digitizer (rise times)
- Preamplifier decay times for every segment and core (Scaling of database)
- Differential Crosstalk
- Space Charge (impurity concentrations)



PSA optimization

Setup of the algorithm:

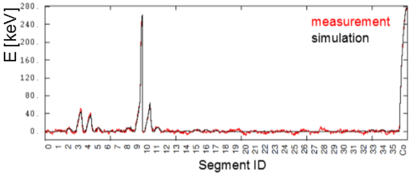
- Distance metric $\chi^2 = \sum_t |\mathrm{Simulation}(t) - \mathrm{Measurement}(t)|^p$
- Time alignment:
  - Constant shift for every segment/core
  - **Dynamic Shift during PSA on event by event basis**
    - Stopping criteria (number of loops, min/max shift)
    - Number of ticks included (only $\approx$ rise time)
    - Metric $\chi^2 = \sum_t |\text{Simulation}(t)$ - $\text{Measurement}(t + t_{\text{shift}})|^p$



How to chose parameters

No information on real interaction position

- χ^2

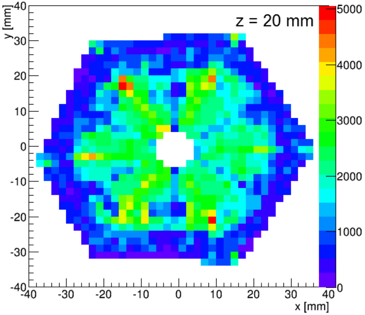


- Comparison with expected hit distribution (known for source runs - statistical fluctuation)
  - Clustering/Correlation (Covariance)
  - High statistic grid points (Ratio)

How to chose parameters

No information on real interaction position

- χ^2
- Comparison with expected hit distribution (known for source runs - statistical fluctuation)
  - **Clustering/Correlation (Covariance)**

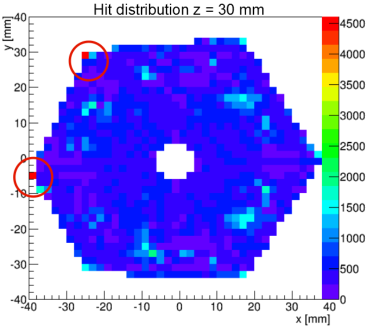


  - High statistic grid points (Ratio)

How to chose parameters

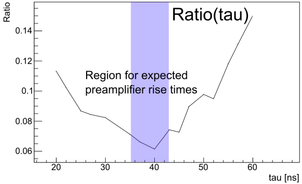
No information on real interaction position

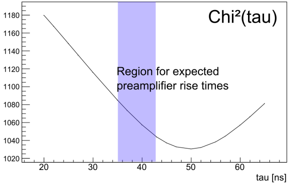
- χ^2
- Comparison with expected hit distribution (known for source runs - statistical fluctuation)
  - Clustering/Correlation (Covariance)
  - **High statistic grid points (Ratio of hits inside HSGP compared to rest)**



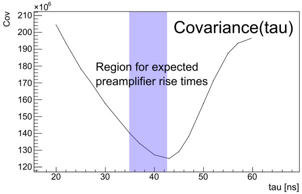
Example of optimization - Transfer function

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



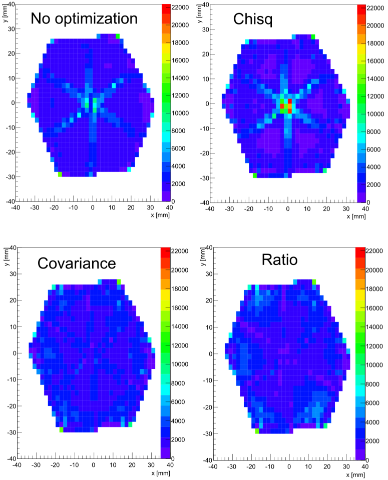


-Minima correspond to optimal tau value
-Shown for segment 7 of detector 13



Impact on hit distribution

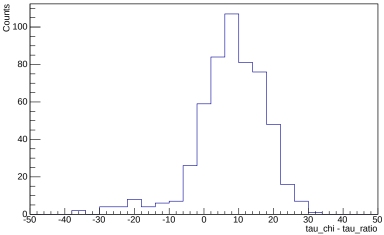
- Results with different optimization methods

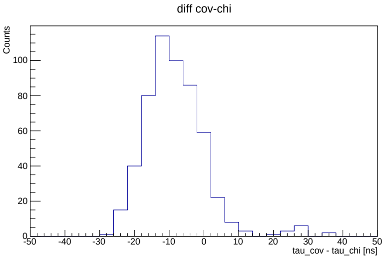


Detector 1, z=0-2 mm

Transfer Function

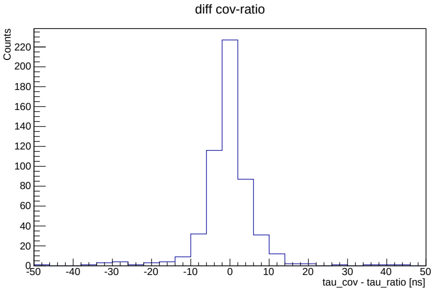
- Minima positions are similar, but do not coincide 100%
- Differences of optimal τ values derived via different determination methods





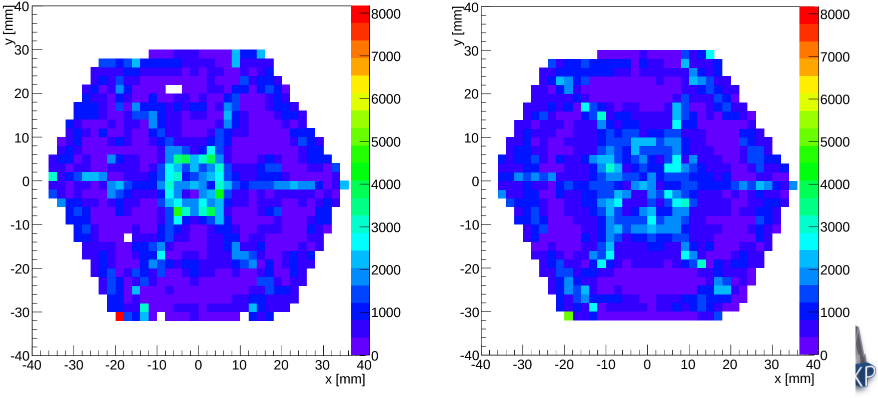
Transfer Function

- 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



Optimization

- Before (left) and after (right) **complete** Optimization
- Exemplarily for det 1, z=10-12 mm. All energies



Summary and Outlook

Summary

- Characterization and optimization of PSA performance
- Clustering and non physical allocation of hits could be reduced...
- ...but not removed

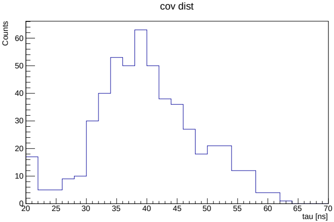
Outlook:

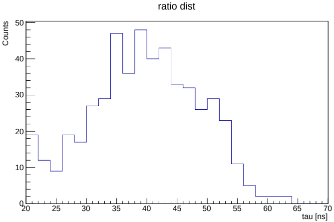
- Reiteration of optimization (input parameters are not independent)
- Measure transfer function of digitizer and preamplifier
- Use scanning table data / collimated source measurements
- Impact of PSA optimization on tracking performance

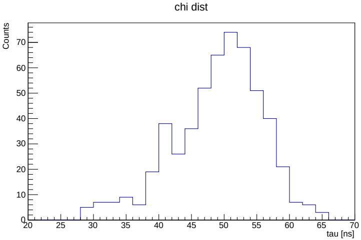
Thank you for your attention

Transfer function

- Distribution of found τ values (one for each segment)

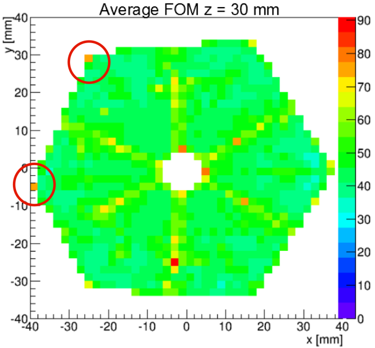






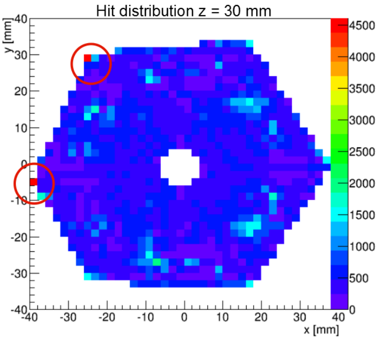
PSA characterization

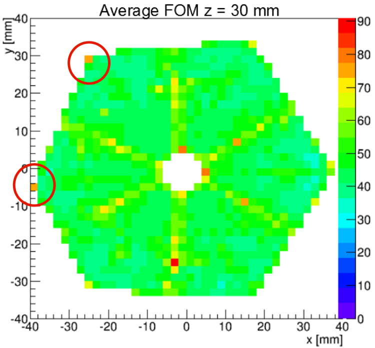
- Distribution of hits
- **Distribution of final $\chi^2(\vec{r}, E)$ ('Figure of Merit')**
- If unexpected PSA results: Segment/Detector/general?
- Dependence on interaction position and energy



- Non homogeneous!

Comparison of hit distribution and mean χ^2

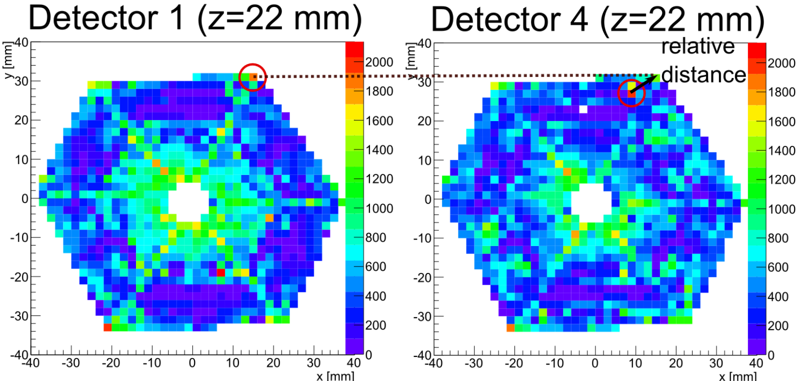




Segment and detector performance

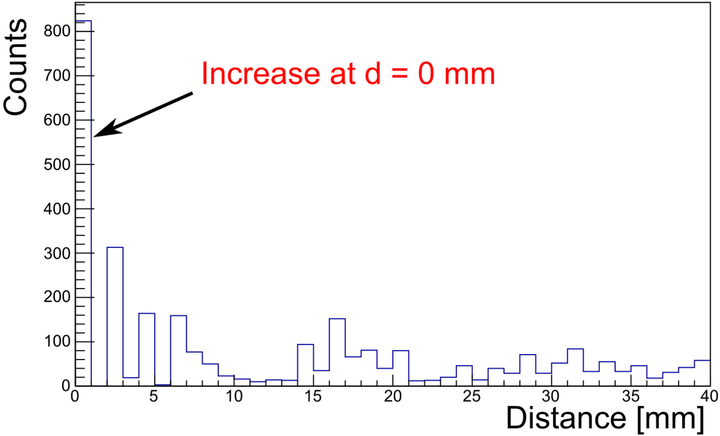
Distance of High Statistic Grid Points (HSGP)

- Investigate relative position of HSGPs
- Same or similar spot in all detectors?



Distance of High Statistic Grid Points

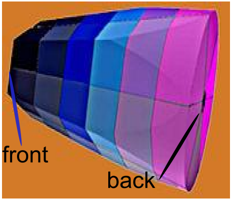
- Search for HSGP segment wise
- HSGP positions at characteristic spots
- *General* problem that exists for every detector

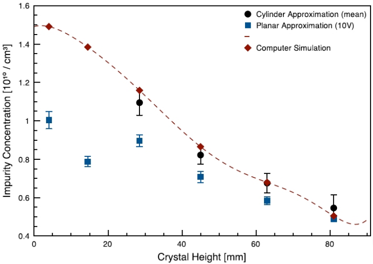


The AGATA Data Library

The AGATA Data Library (ADL) contains the signals for every possible interaction point

- Consider **impurity concentration of the crystal**
- Not constant over whole crystal
- Assumptions: cylindrical symmetry, no radial change, linear gradient from front to back
- Two dimensional optimization problem: Iterative method
- Impurity concentration in the order of $10^{10}/\mathrm{cm}^3$

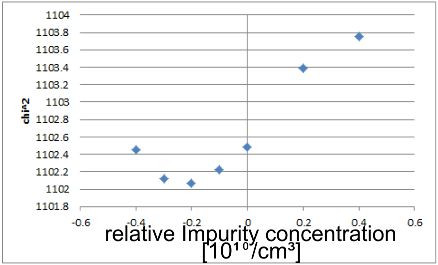


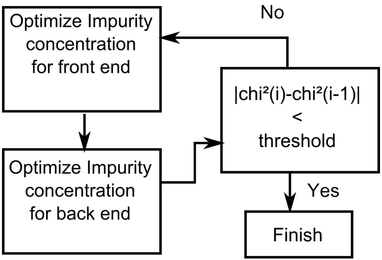


Optimization of the Impurity Concentration

- Use average χ^2 of best fit of all interactions of source run as minimization variable
- Imp. concentration is given relative to start value provided by manufacturer

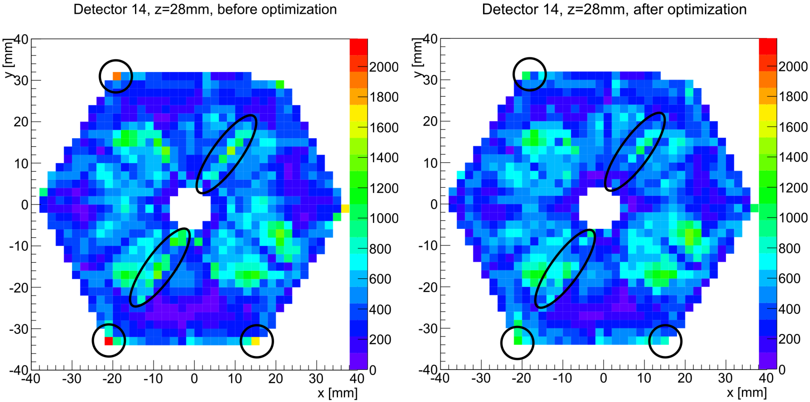
- Imp. Concentrations for back and front not independent and cannot be evaluated separately
- Iterative method uses output of previous step as input





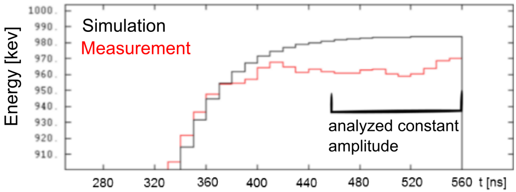
Optimization of the Impurity Concentration

Results of the optimization



Comparison of Measurement and Simulation

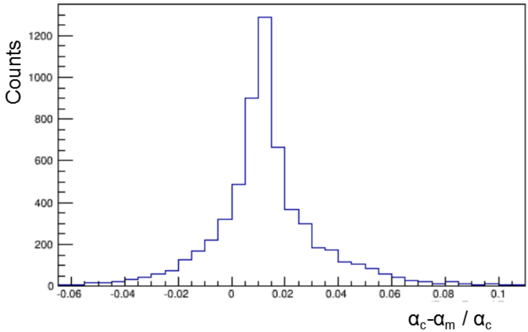
- Amplitudes of measurement and simulation do not coincide
- Systematic deviation



Calibration of calculated signals

- Amplitude of simulation depends on decay time τ of preamplifier

Energy shift of simulation

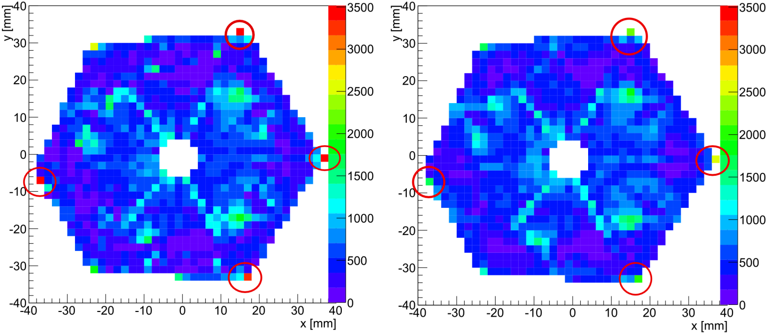


Variation of τ for every preamplifier: 555 parameters!

$$\tau_{\text{new}} = \tau(1 - m), \;\; m = \text{mean of distribution}$$

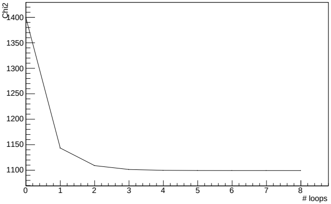
Impact on PSA

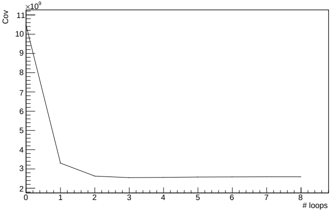
- Improvement of HSGP at highlighted spots

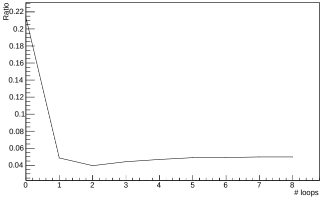


Maximum number of loops

- Vary allowed number of maximum loops for TA after PSA
- Algorithm converges ✓

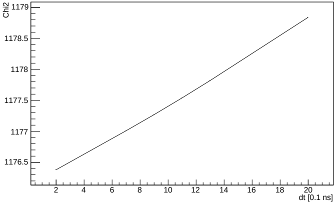


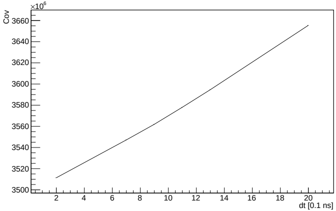


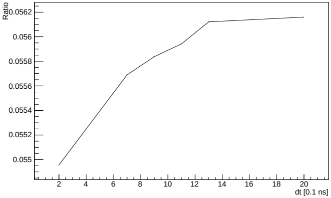


Minimum Shift

- If minimal time shift dt is reached, the algorithm stops
- (Obviously) small dt are preferred, but change is very small (std value=1.5 ns)







Local time alignment

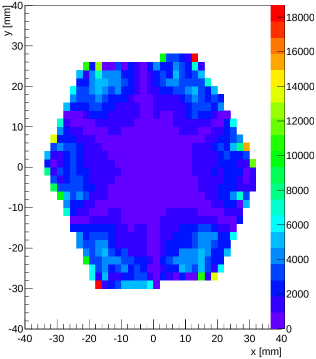
- For a fast algorithm the time alignment assumes a *convex* function
- The next time shift is only performed if χ^2 improved in the previous step
- If $\chi^2[n]$ is not a convex function only a local minimum will be found

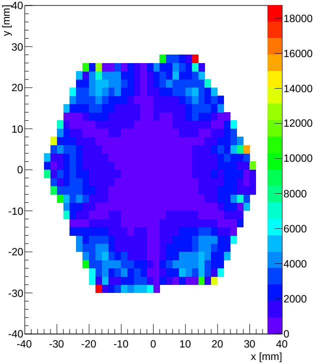
χ^2 of time shift n

$$\chi^2[n] = \sum_{i=0}^{21} (A^m[i+n] - A^s[i])^2$$

Global time alignment

- Therefore a global time alignment was implemented that evaluates the χ^2 for every time shift and then searches the minimum
- Good news: The global time alignment gives nearly the same results as the fast algorithm $\Rightarrow$ $\chi^2[n]$ behaves like a convex function





Standard and global time alignment algorithms (with nearly same results) [det1, z0]

Time alignment after PSA

- TA after PSA uses χ^2 like parameter
- Reminder: χ^2 in PSA is determined with set distance metric

Figure of Merit

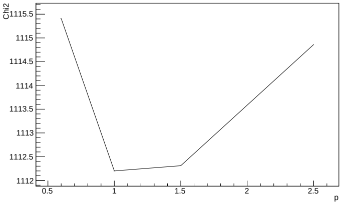
$$\chi^2 = \sum_{t_i,j} |A_j^m[t_i] - A_j^s[t_i]|^p$$

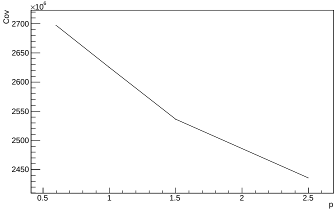
Measured A^m and simulated signal A^s of segment id j and time t_i

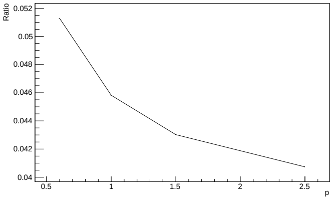
- In the time alignment only the sqare of the differences is used
  $\Rightarrow$ Room for improvement?

Distance metric in the time alignment

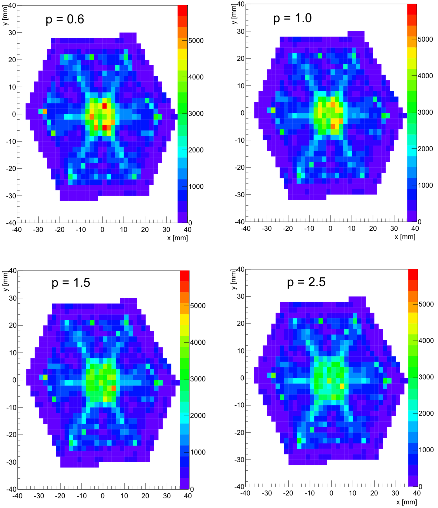
- The χ^2 in the TA is now derived in the same way as in the PSA
- The distance metric parameter p is varied
- Compared to PSA significantly higher values seem to be favored







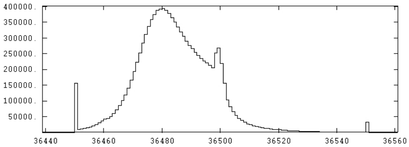
Impact of distance metric on hit distributions

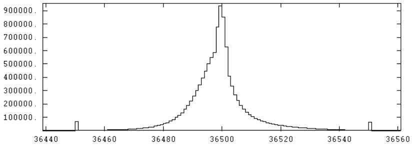


- Detector 1, z=6 mm
- The time alignment seems to favor higher values for p
- Even beyond Euclidian metric

Preprocessing time alignment

- Before the first PSA and time alignment afterwards, a constant time shift is applied to each core (and therefore to each segment)
- Values used from dissertation Birkenbach, choosing the values in such a way that the PSA TA has to shift minimal
- Shifts of PSA with and without preprocessing TA are shown for one
- Axis in ns + arbitrary offset





Preprocessing time alignment

With (left) and without (right) preprocessing time alignment