PSA Optimization using Coincident Gamma Ray-Detection after Positron Annihilation

17th AGATA Week

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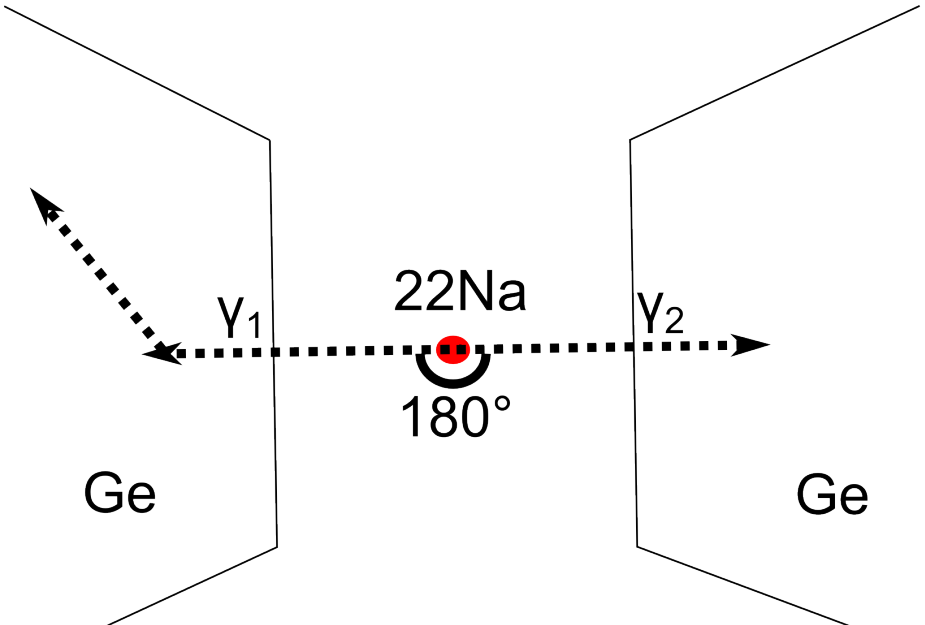
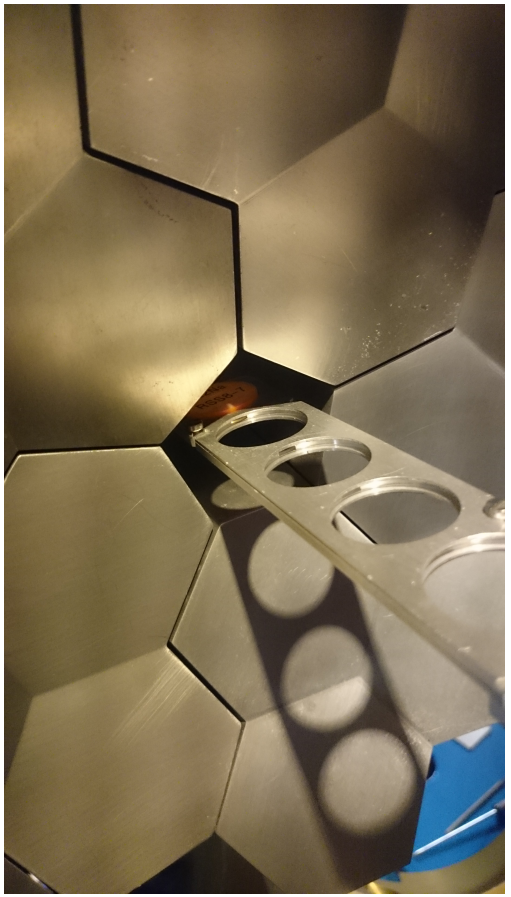
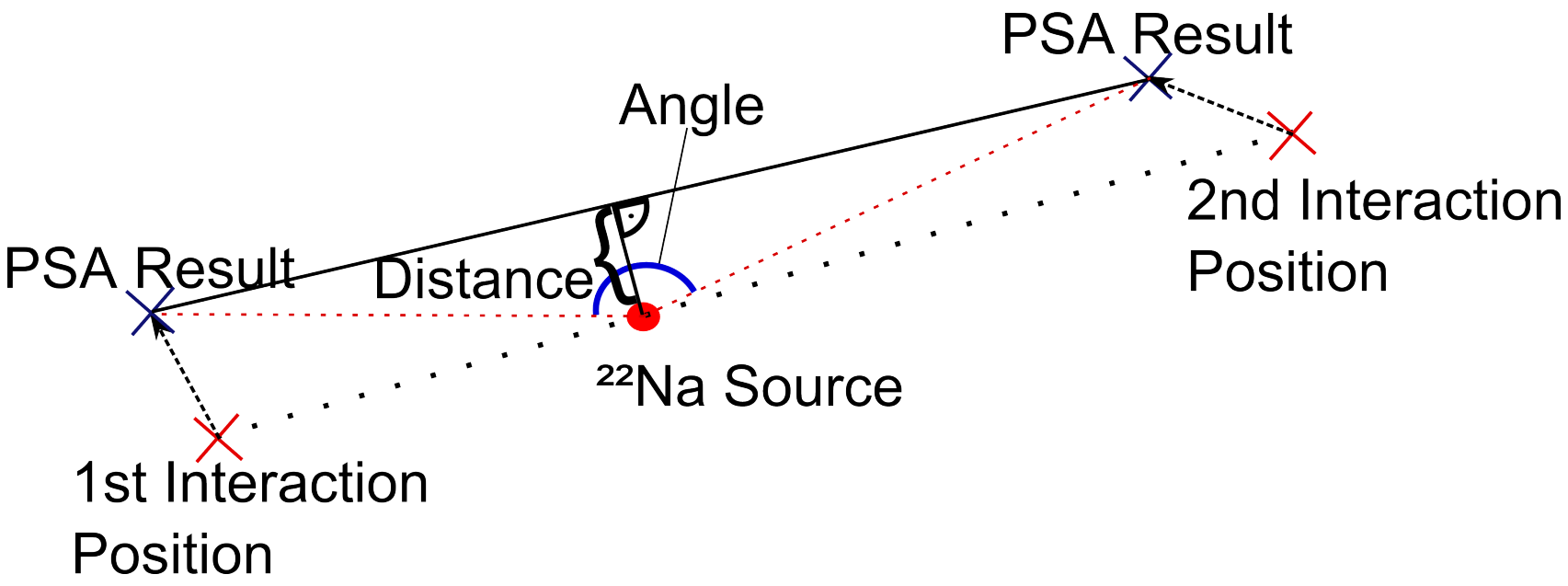
Motivation

- Main goal: Improve PSA performance
- Reliable way to assess quality of PSA is needed
- $\Rightarrow$ Exploit β^+ from ^{22}Na and the following 511 keV γ rays
- ^{22}Na measurement in April



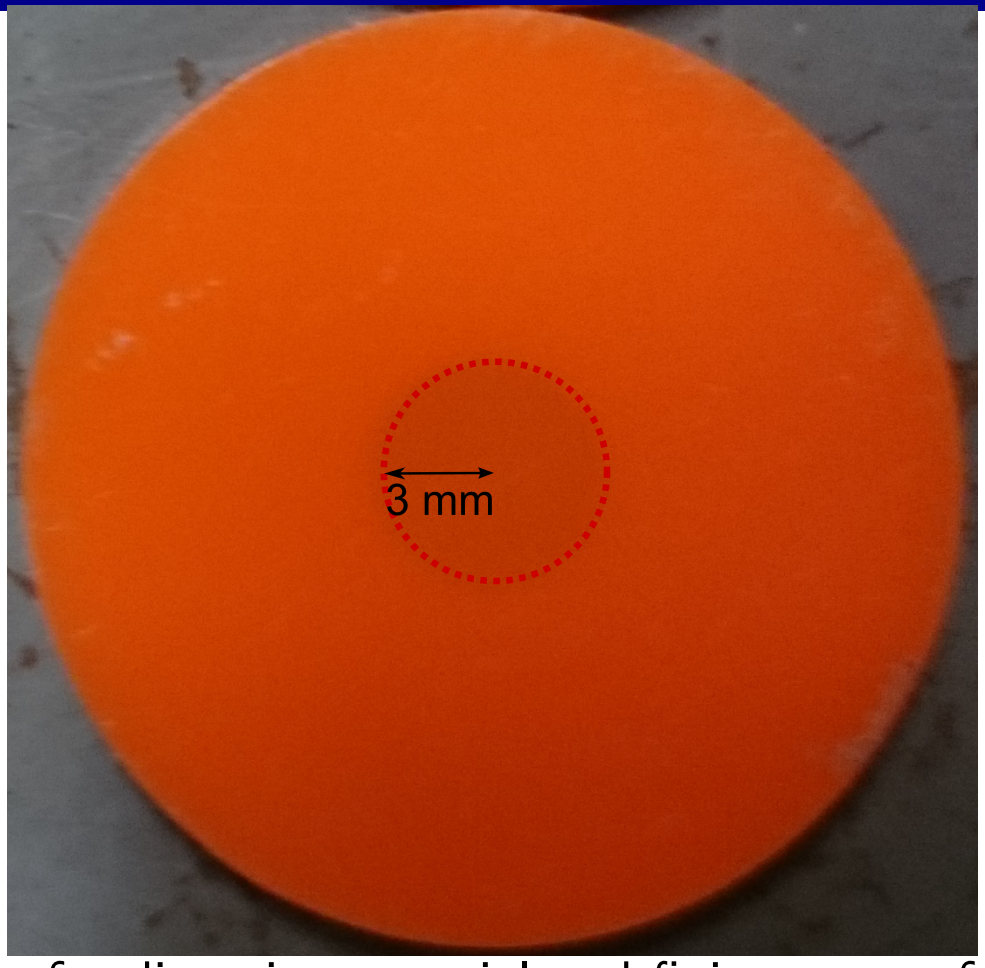


Principle



- β^+-decay of ^{22}Na (mean β^+ energy of 250 keV)
- Coincident detection
- Difference PSA result and physical interaction position cause deviation
- Distance describes PSA performance

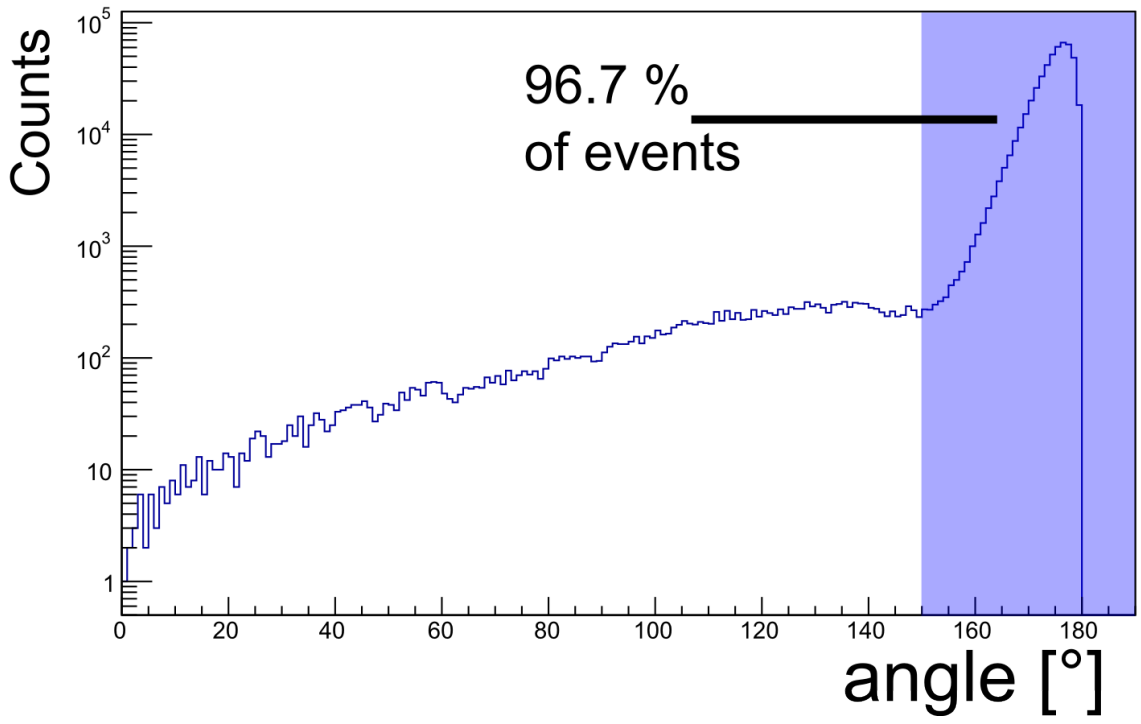
Source Position



- Finite size of radioactive material and finite range of β^+
- Mean deviation of annihilation pos. to source pos. $\approx 1.5\,\mathrm{mm}$
- No **systematic** deviation $\Rightarrow$ no problem for analysis

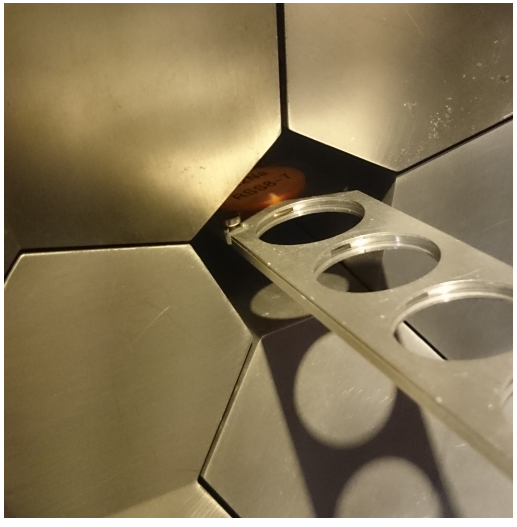
Coincident Detection

- Gate on:
  - Multiplicity $= 2$ (not in same detector)
  - Individual energy of 511 ± 3 keV
  - Angle $> 150°$

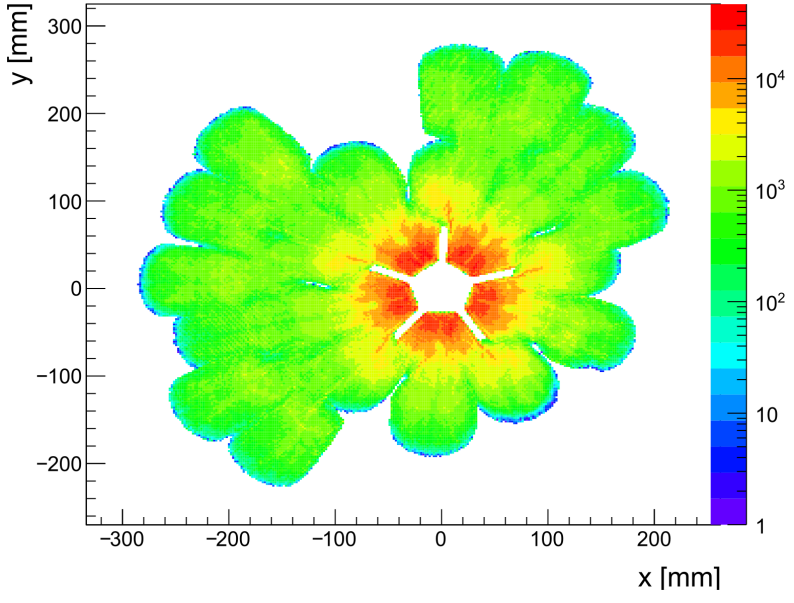


Setup

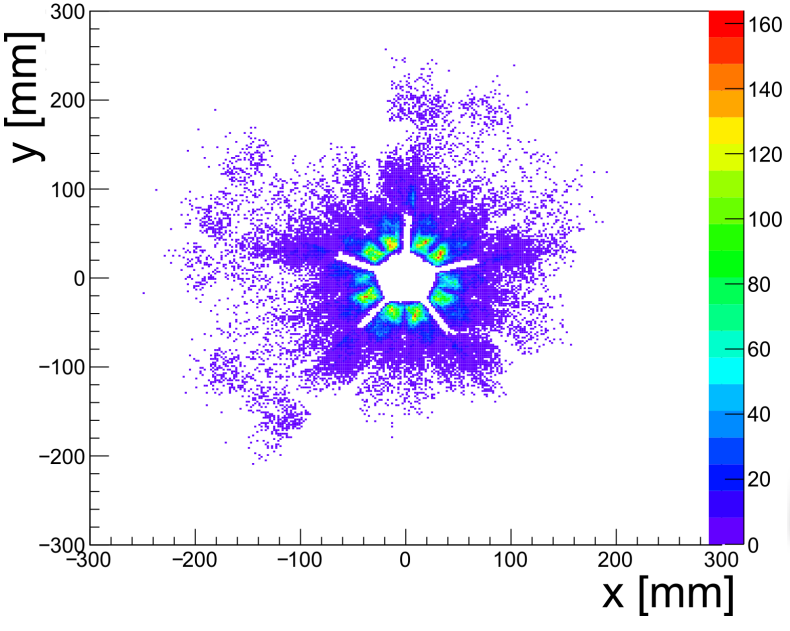
- ^{22}Na source placed inside pentagon
- Rates per crystal $< 1\,\mathrm{kHz}$ for inner ring, < 200 for rest



Without gates

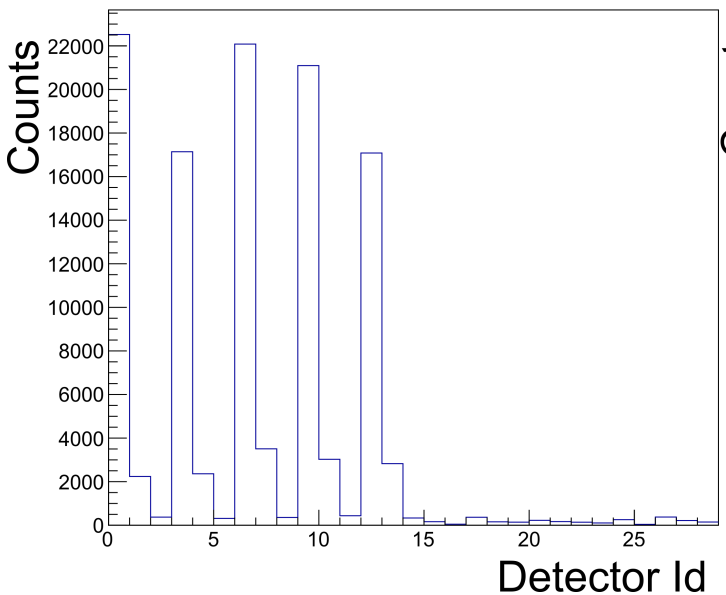


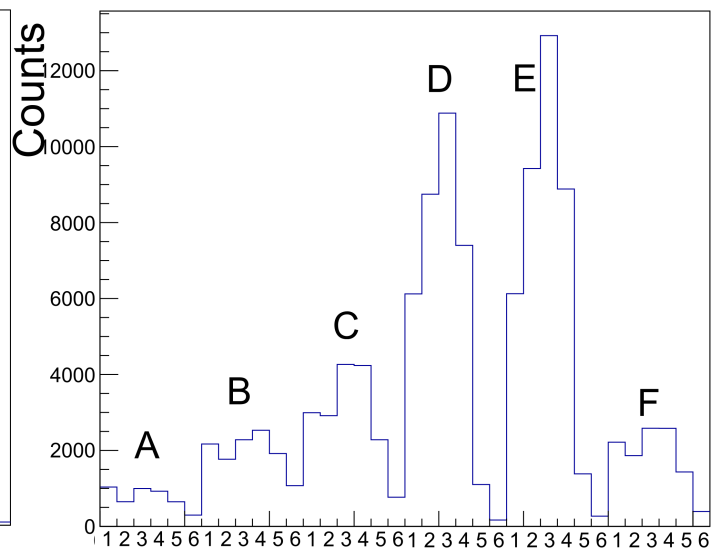
Gated

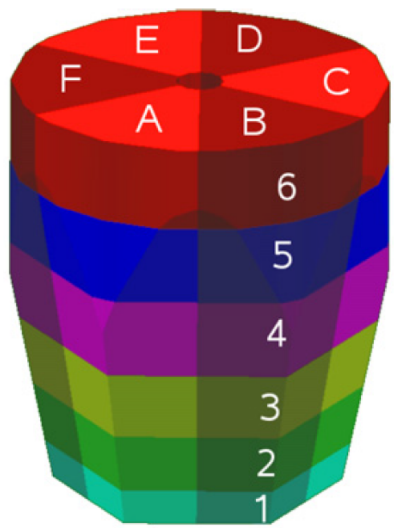


Coincidences

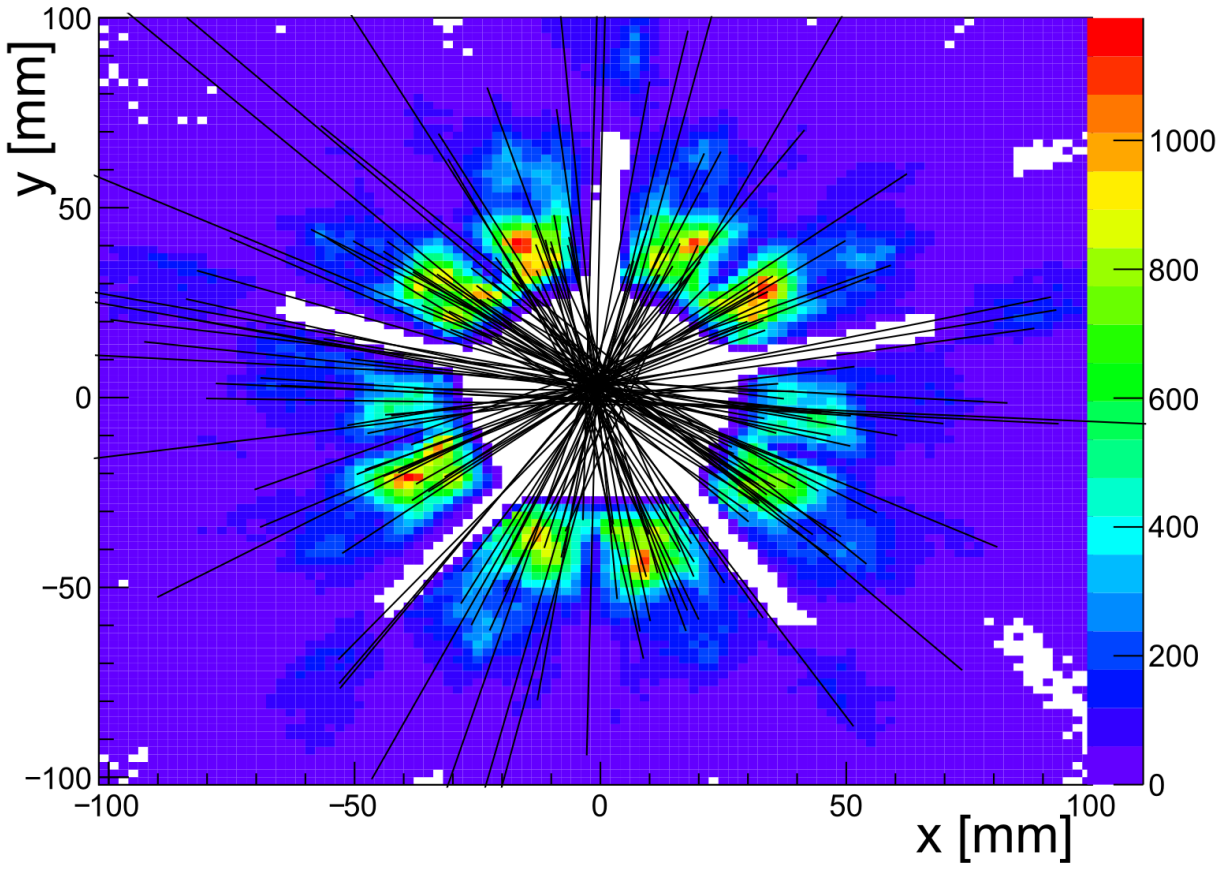
- Coincidences mainly in inner ring of detectors
- All segments hit
- Full characterization of inner detectors possible



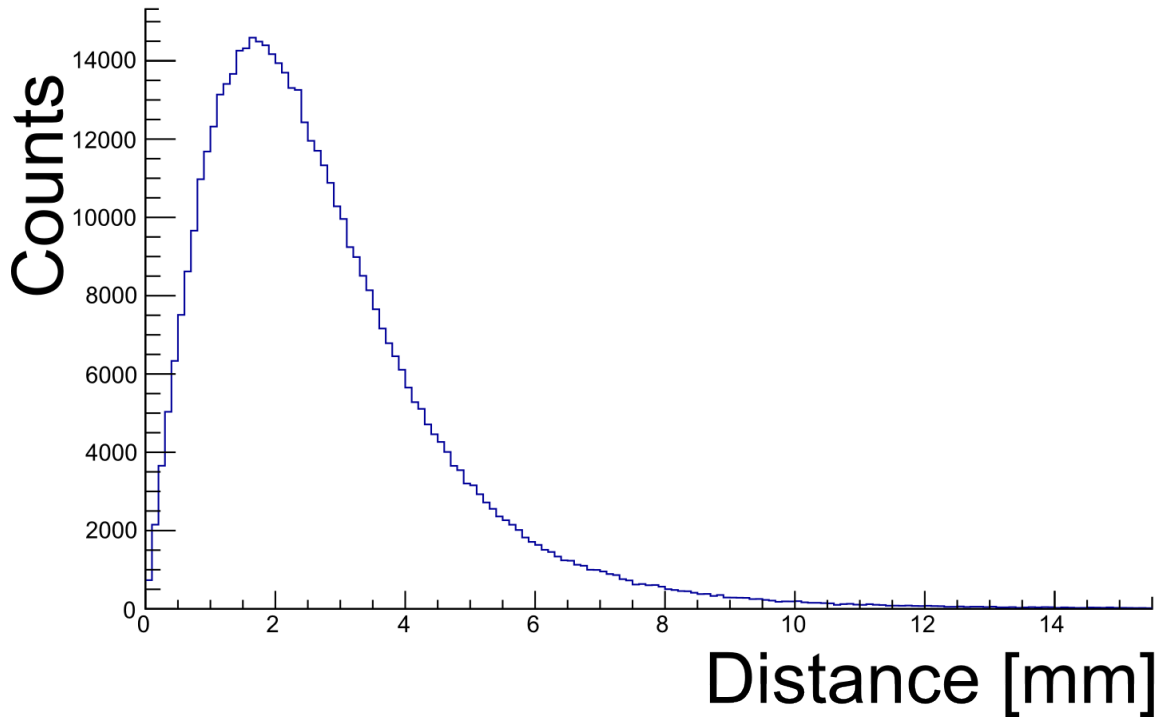




Visualization



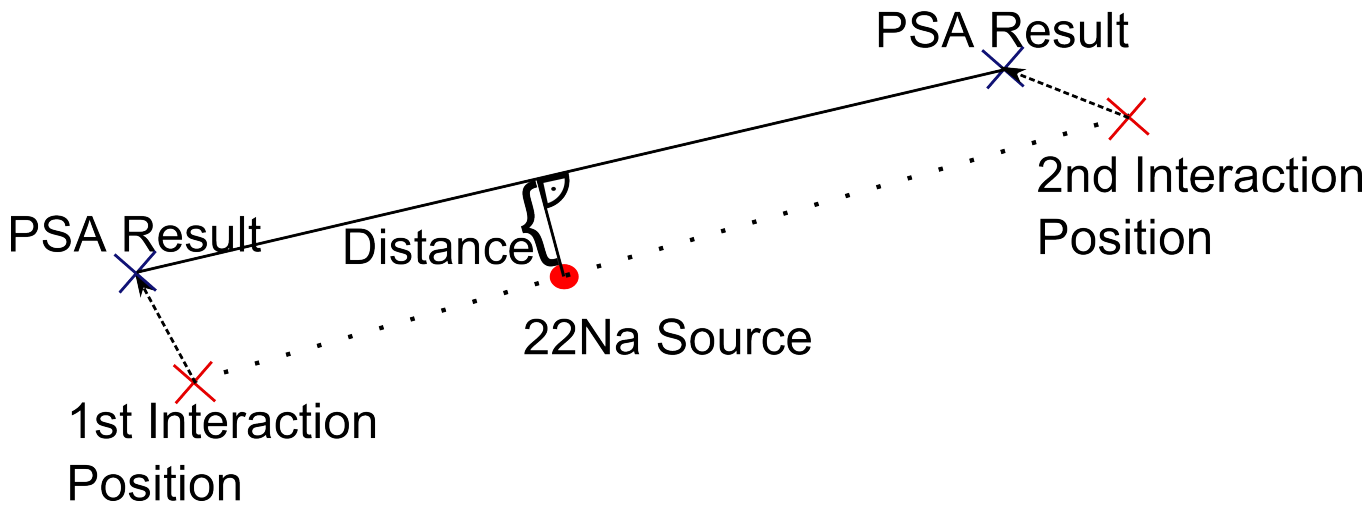
Distance to Source



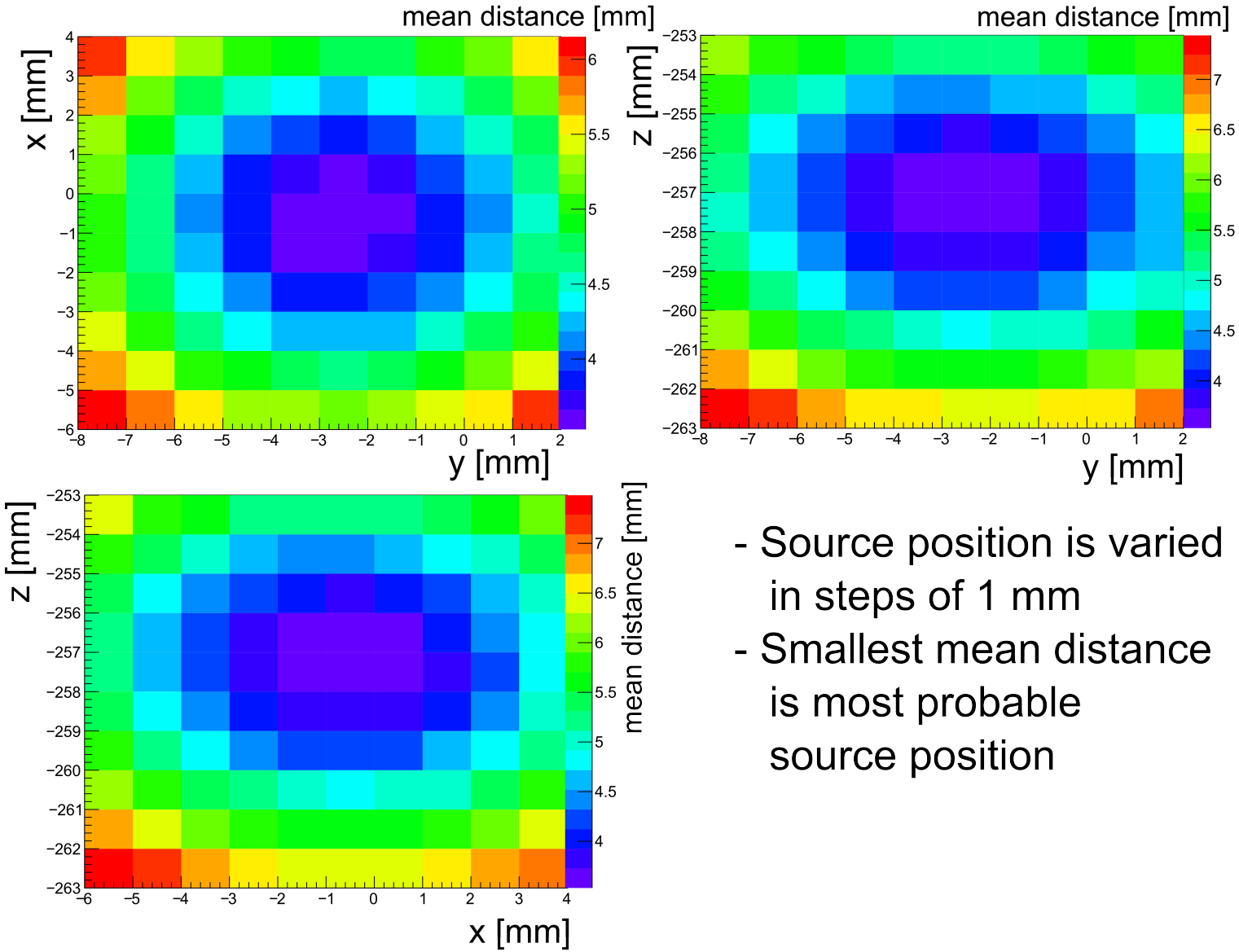
- Distance of line to source position is calculated
- Mean distance of all coincidences is used to optimize PSA

Source Position

- Source position has to be known as precisely as possible
- Calculate distance d on event by event basis
- Vary source position (PSA remains constant) and minimize mean distance

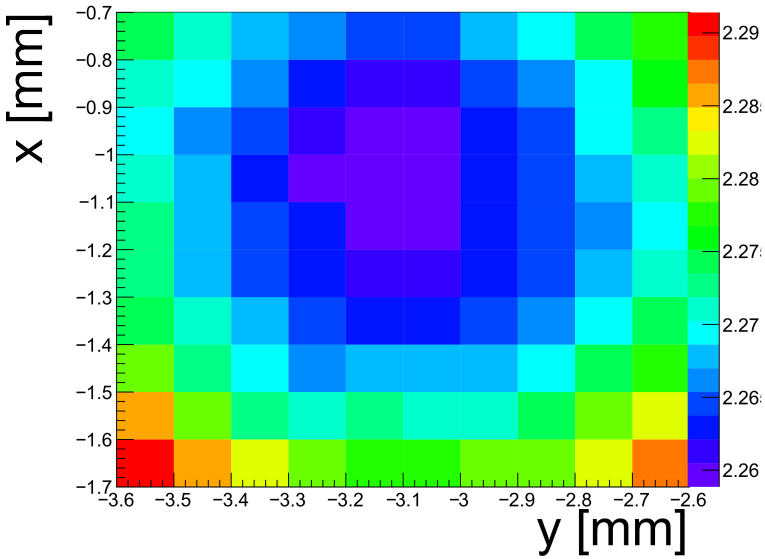


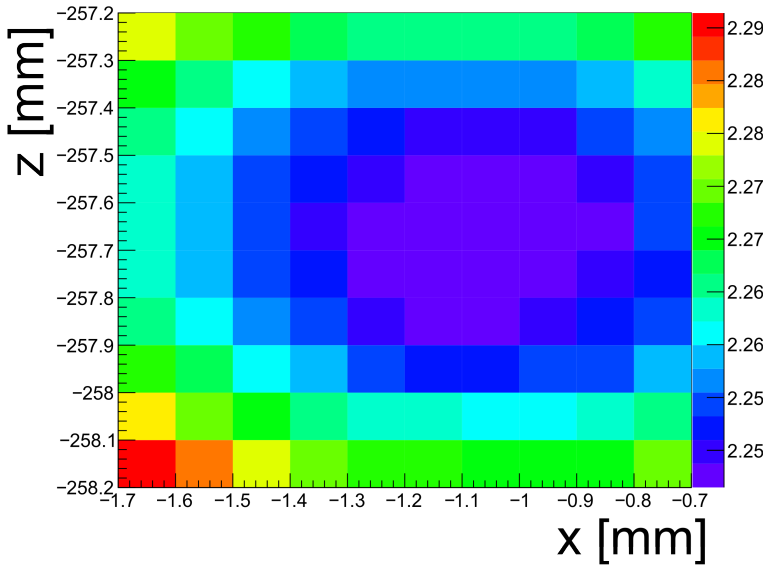
Variation of Source Position for the Second Setup

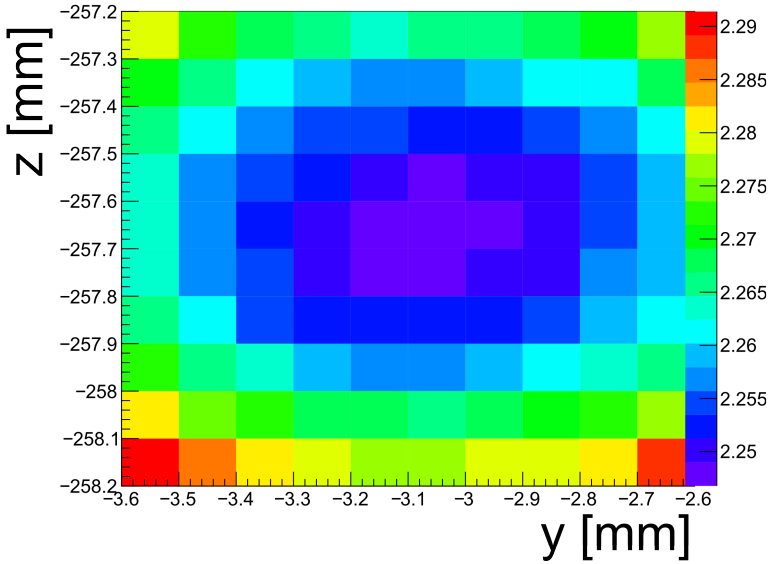


- Source position is varied in steps of 1 mm
- Smallest mean distance is most probable source position

Variation of Source Position for the Second Setup







- Source position varied in steps of 0.1 mm around previous minimum
- Final result in lab system
  x = 1.1 mm
  y = -3.1 mm
  z = -257.8 mm

PSA Optimiziation

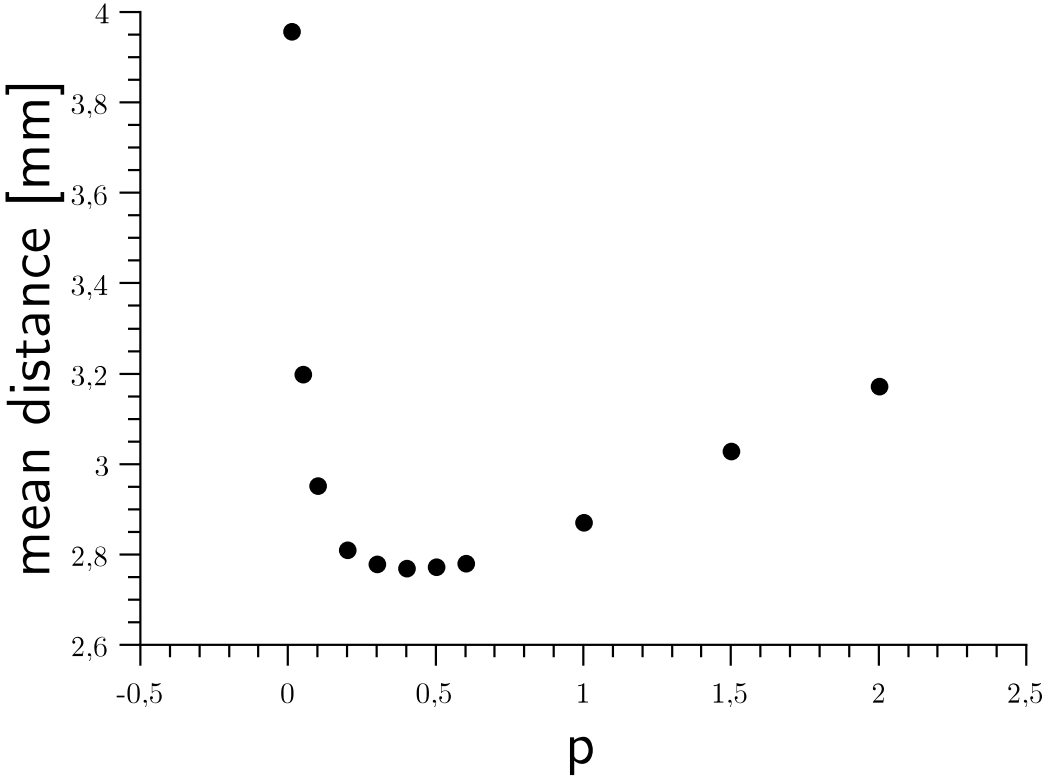
Figure of Merit

$$\text{Figure of Merit} = \sum_j \sum_{t_i} |A_j^m[t_i] - A_j^s[t_i]|^p \tag{1}$$

$A_j^m[t_i]$ ($A_j^s[t_i]$) is measured (simulated) signal of segment j at time step t_i

- Consider distance metric $\Rightarrow$ already investigated
- Exponent p changes which simulated signal minimizes the Figure of Merit

PSA Optimiziation



- Minimum at $p = 0.4$ with $d_{\mathrm{mean}} = 2.77\,\mathrm{mm}$
- Previous findings $p = 0.3$
- Consistent
- 12% improvement compared to Euclidian metric

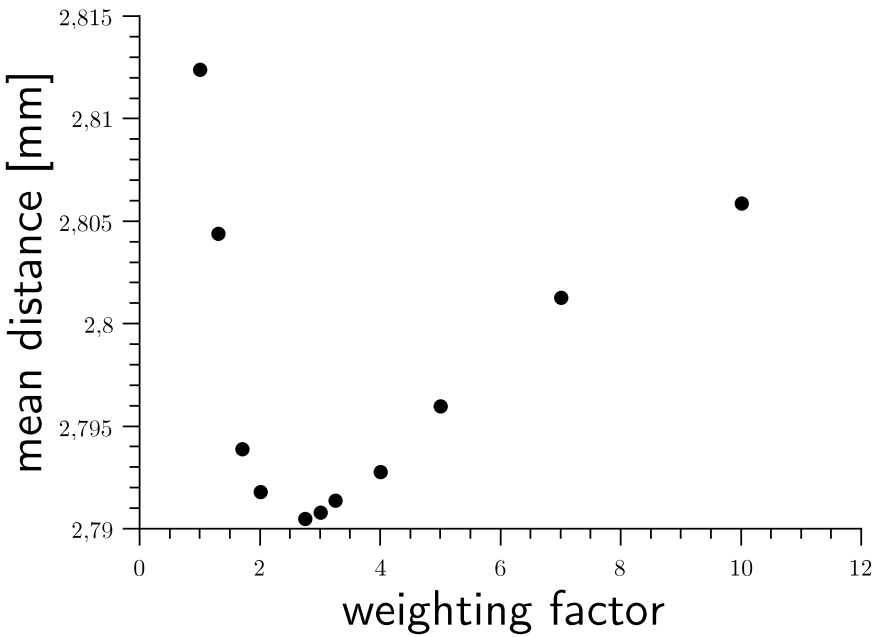
PSA Optimiziation

- Introduce stronger weighting for contribution of transient signals to Figure of Merit

Weighting of Neighboring Segments

$$\text{Figure of Merit} = \sum_j \mathbf{w_j} \sum_{t_i} |A_j^m[t_i] - A_j^s[t_i]|^p \quad (2)$$

w_j=1 for hit segment and core, to be determined for neighboring segments



- Minimum at $w_j = 2.75$
- 1% improvement compared to no weighting

Summary and Outlook

Summary

- $180°\gamma\gamma$ coincidences successfully used to asses PSA performance
- Mean distance of d$\approx$ 2.77 mm achieved (with angle gate of $>$ 150°)
- PSA improvement shown exemplarily for distance metric and weighting
- Consistent findings

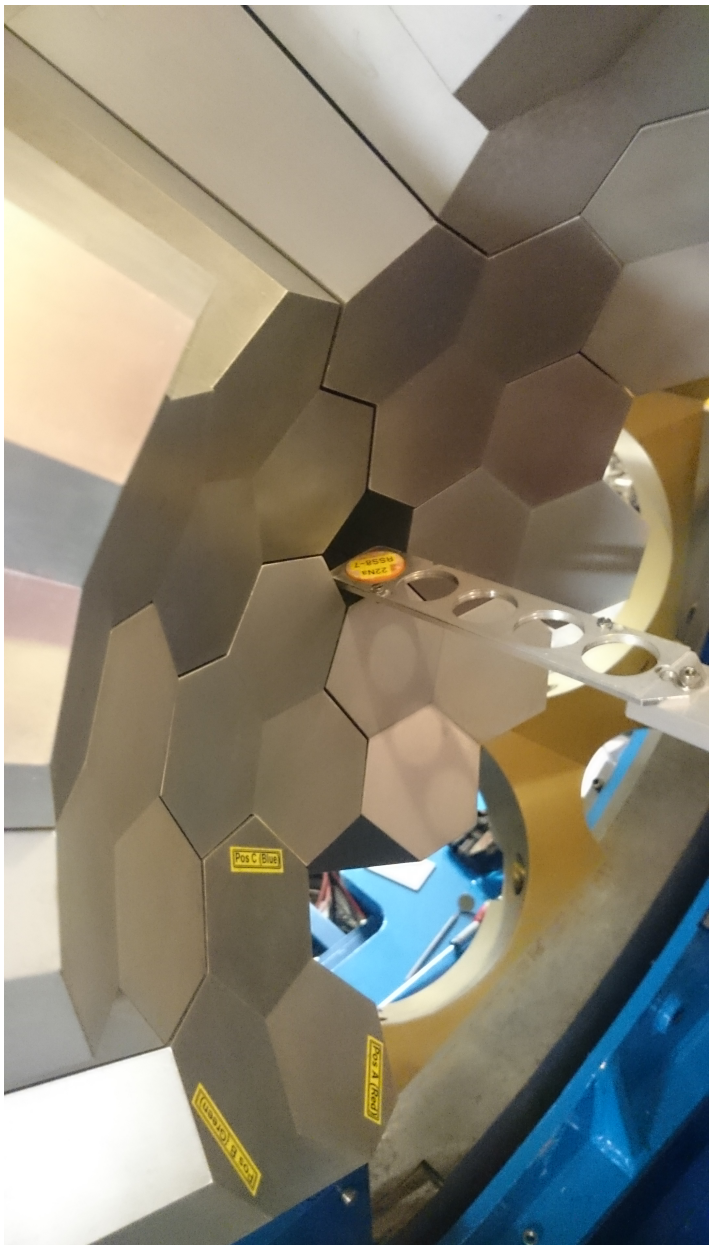
Outlook

- Systematic investigation of all input parameters and comparison with previous findings
- Evaluate performance of new approaches e.g. ADL vs IPHC measured base

Thank you for your attention!

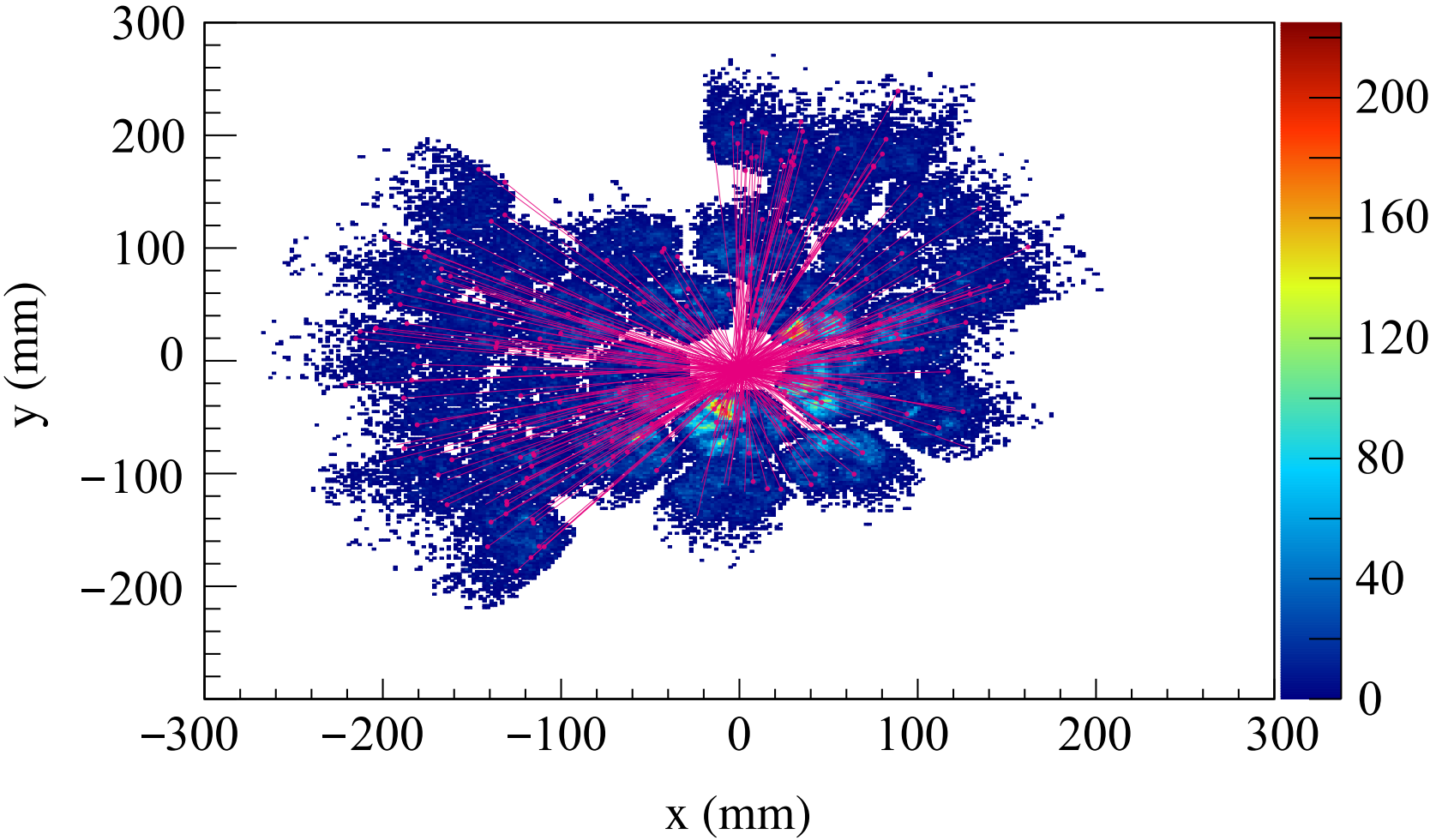
Thanks to the local team at GANIL!

Setup



- Two different setups measured
- 1.) Centered source outside of AGATA
- Coincidences possible for all detectors
- Only coincidences in the front segments

Coincidences for the first setup



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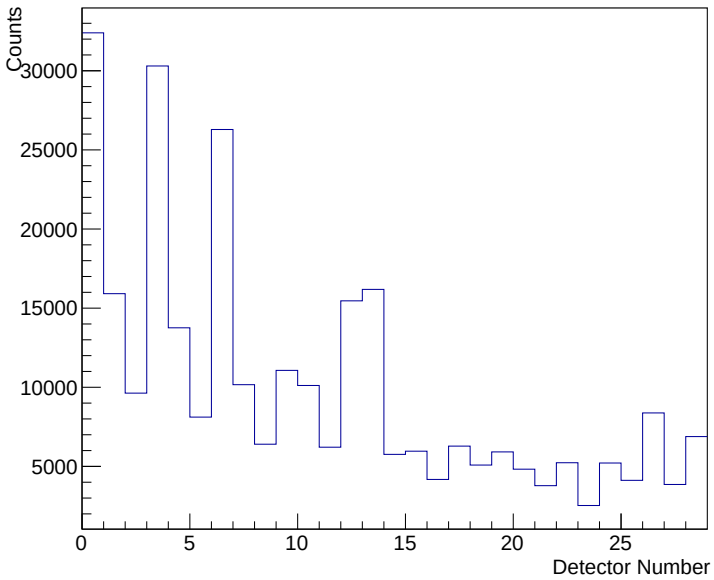
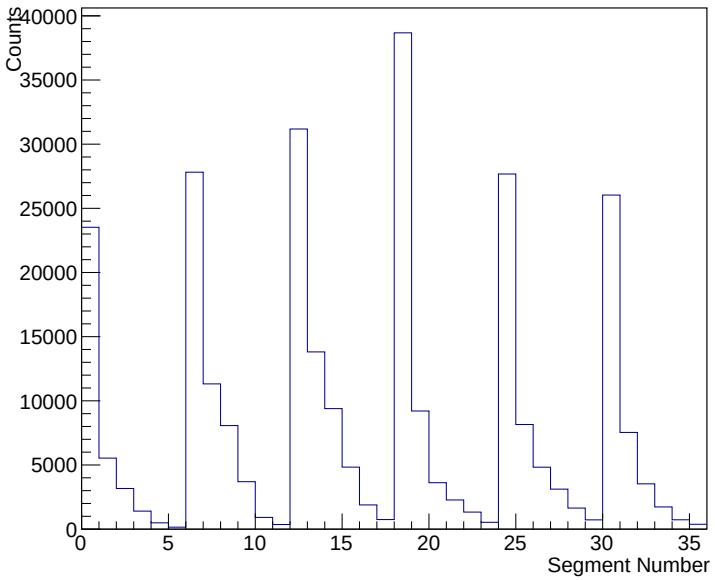
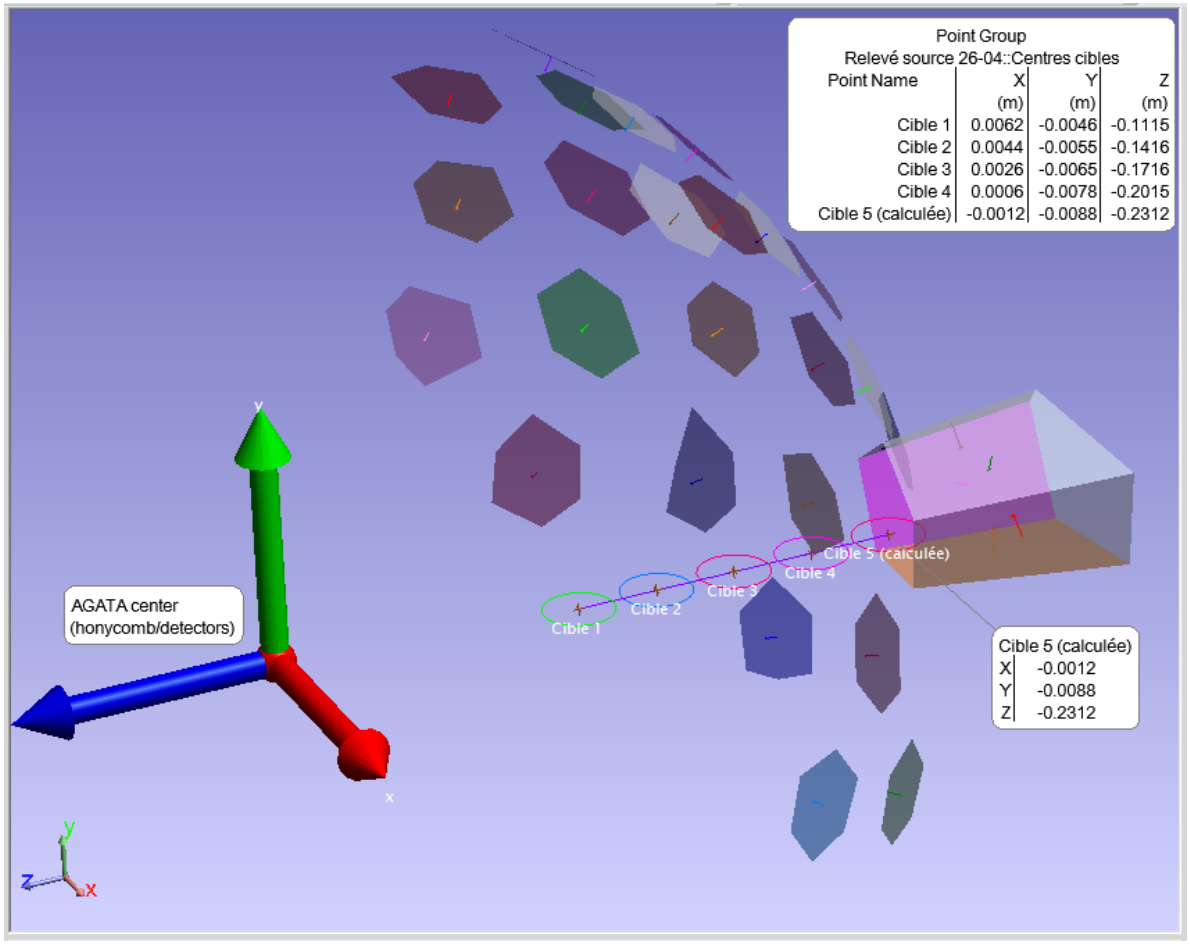




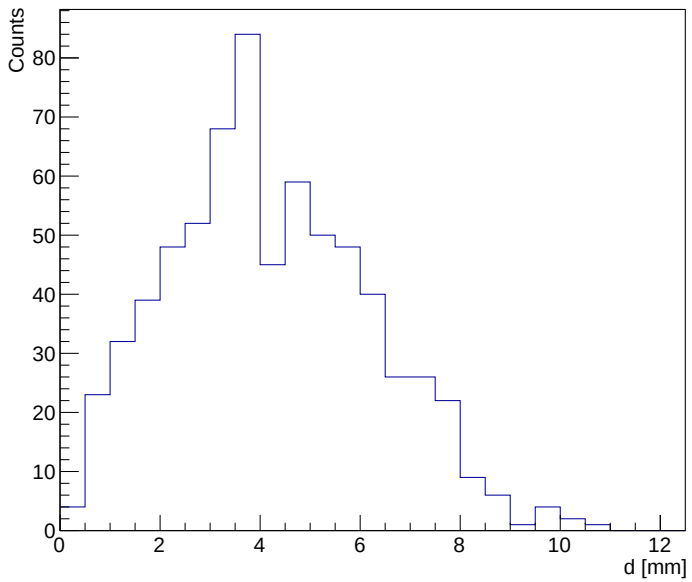
- Inner ring of has most statistics, but ALL detectors have coincidences
- Mostly front segments are hit

Source Position



- Source position measured with respect to center of AGATA
- Error is $\approx 1\,\mathrm{mm}$

Preliminary Compton Reconstruction



- $\frac{\text{Compton Coincidences}}{\text{Normal Coincidences}} \approx 1\%$
- Very Preliminary