A calibration experiment for the AGATA pulse shape analysis

Stefanie Klupp

Technische Universität München

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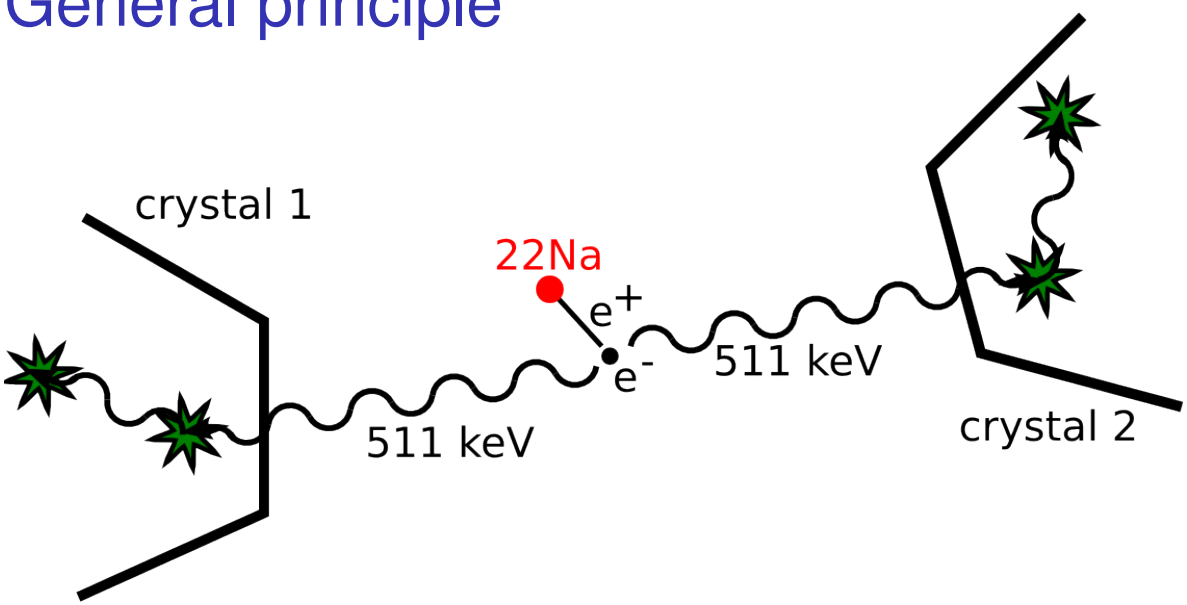
Contents

Experimental concept

Goals

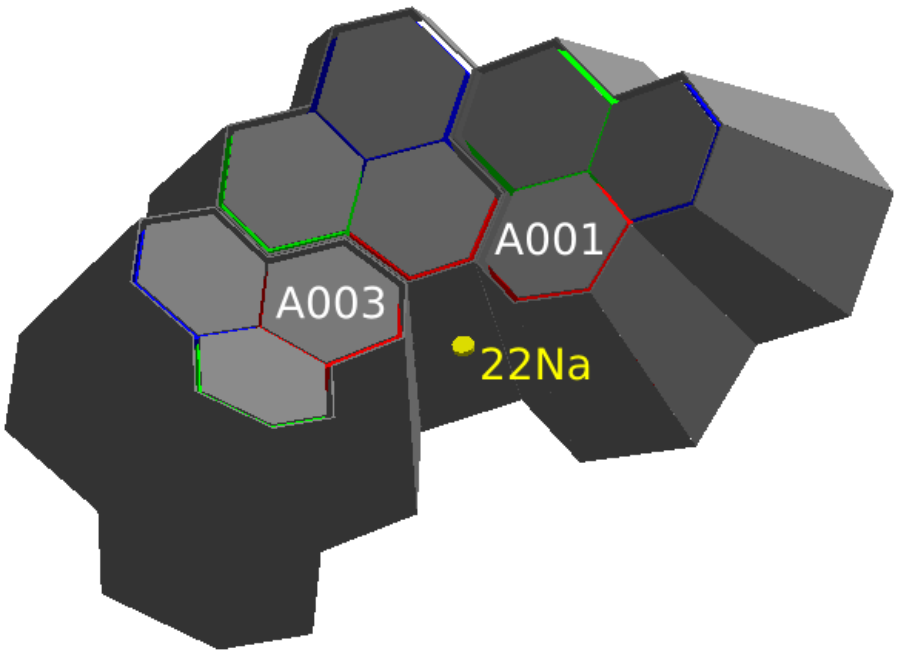
- Investigate parameters of PSA systematically
- Experimental method that could be used online
- Simple mechanical setup
- No extra effort on DAQ
- Short measurement time

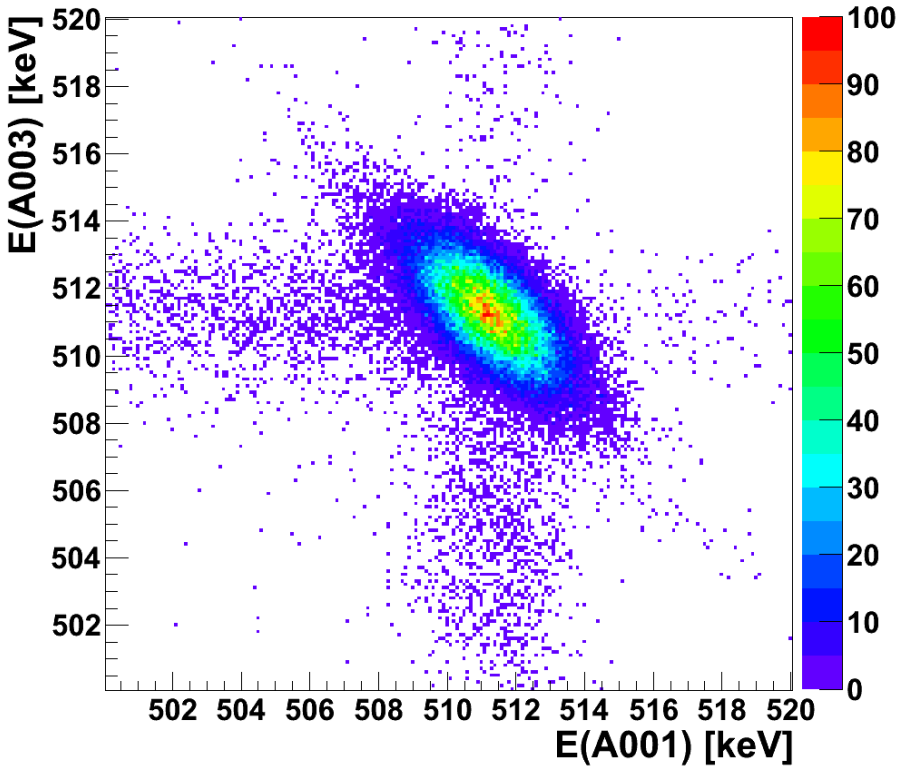
General principle



1st test experiment: Position resolution of A001 and A003

- Measurement with a Na22 source at LNL Legnaro
- Only one source position measured





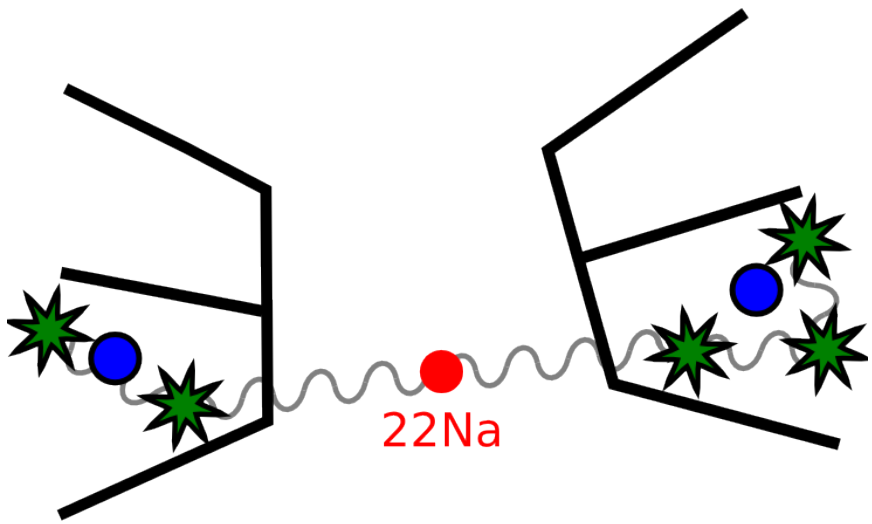
Overview of the analysis

Two possible event selections

- **Barycentre analysis:** Events with coincident energy depositions of 511 keV in one segment
- **Compton analysis:** Events with a Compton scattering from one segment into another segment

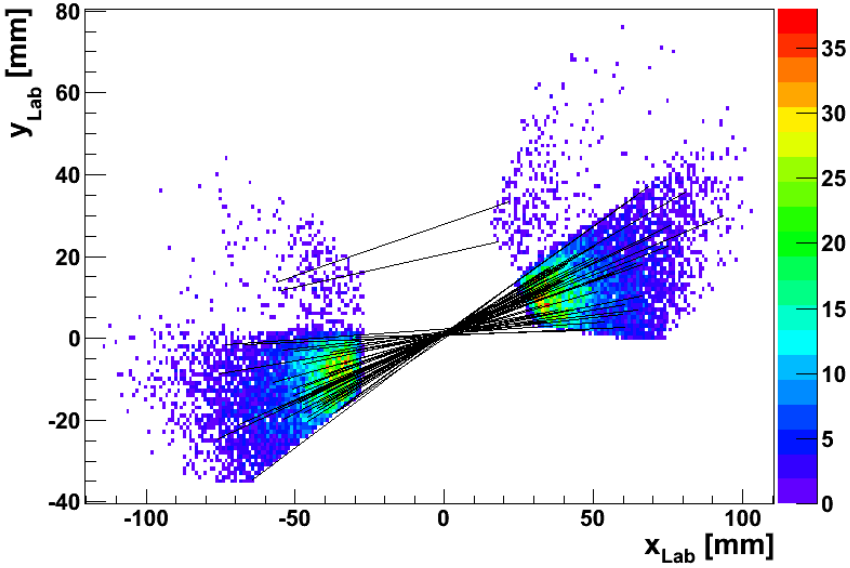
Narval settings

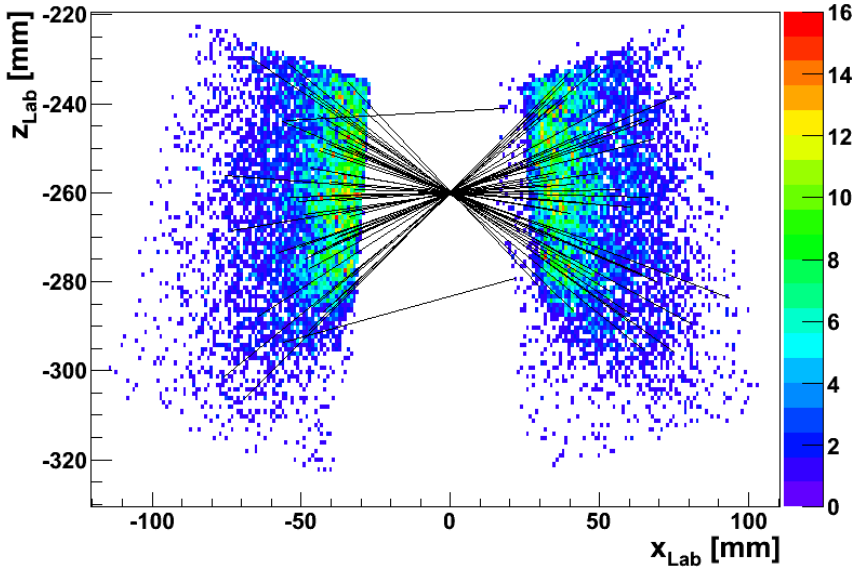
- Different signal basis: JASS, ADL (and MGS)
- Extensive grid search
- Barycentre



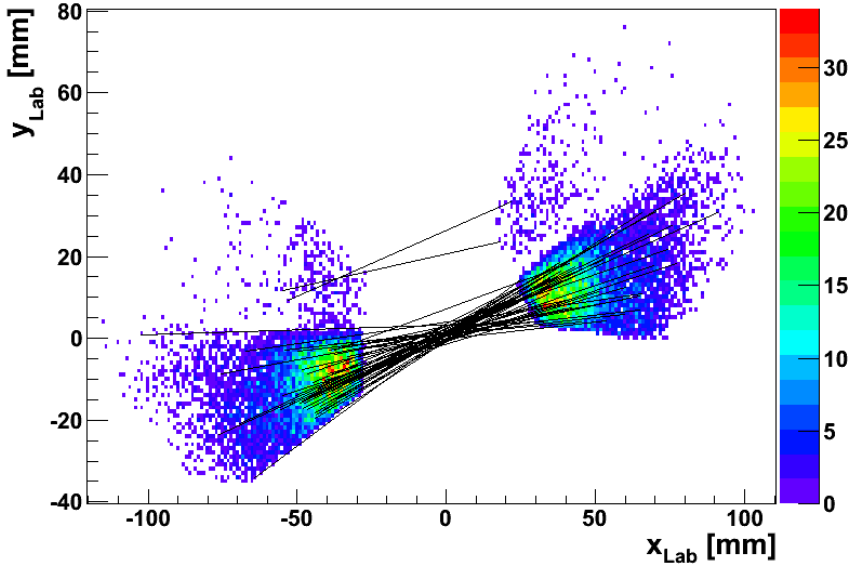
Barycentre analysis: Geant4 simulation

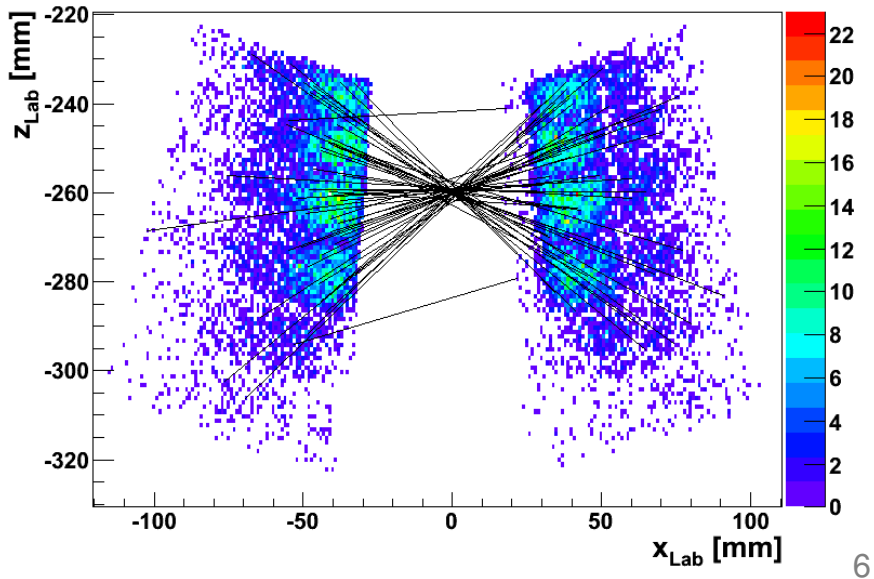
1st interaction points





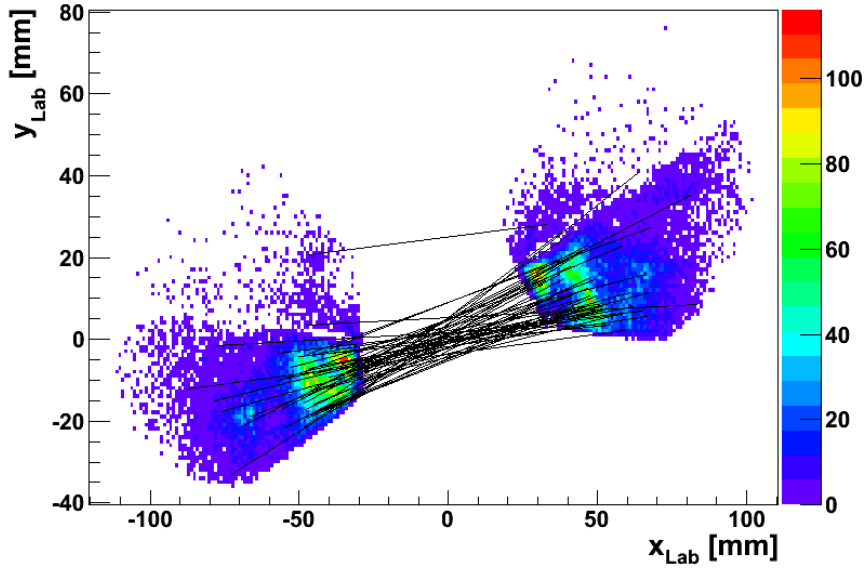
Barycentre

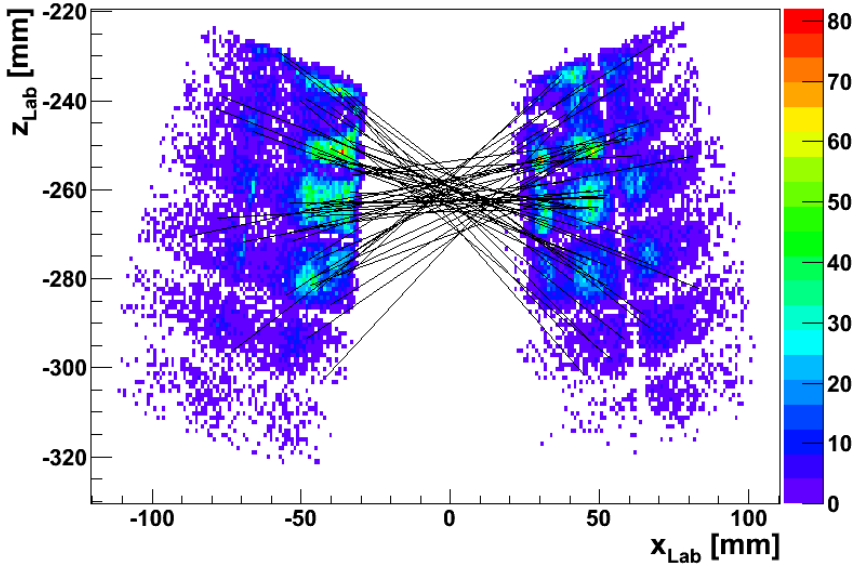




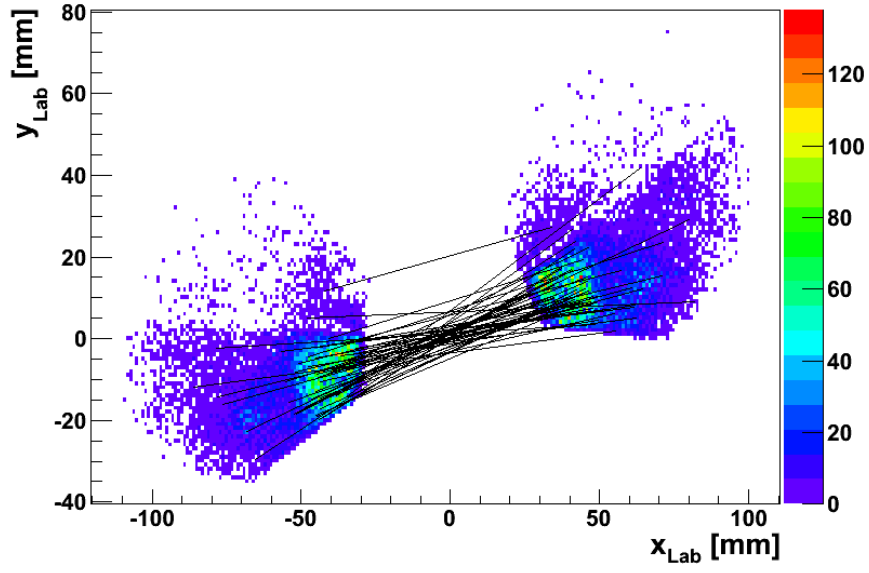
Barycentre analysis: Experimental results

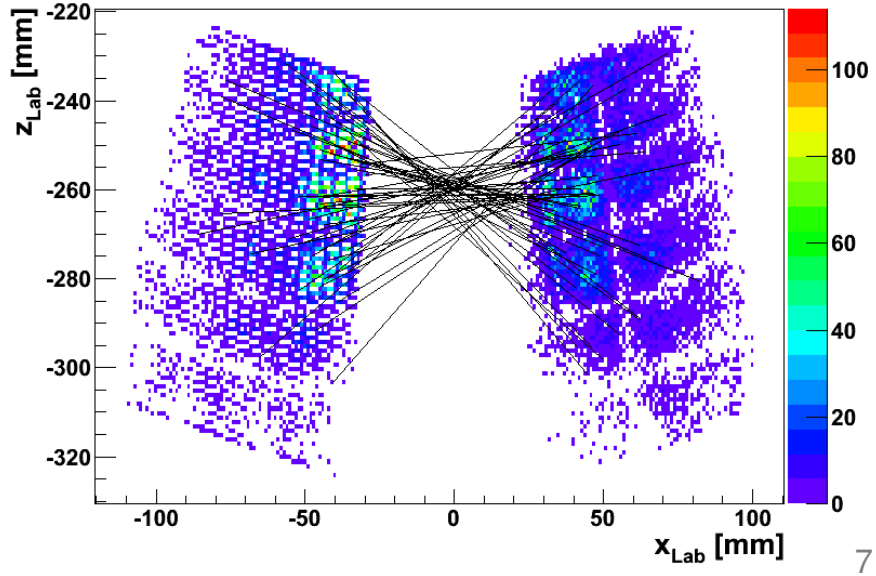
JASS: 1 mm grid





ADL: 2 mm grid

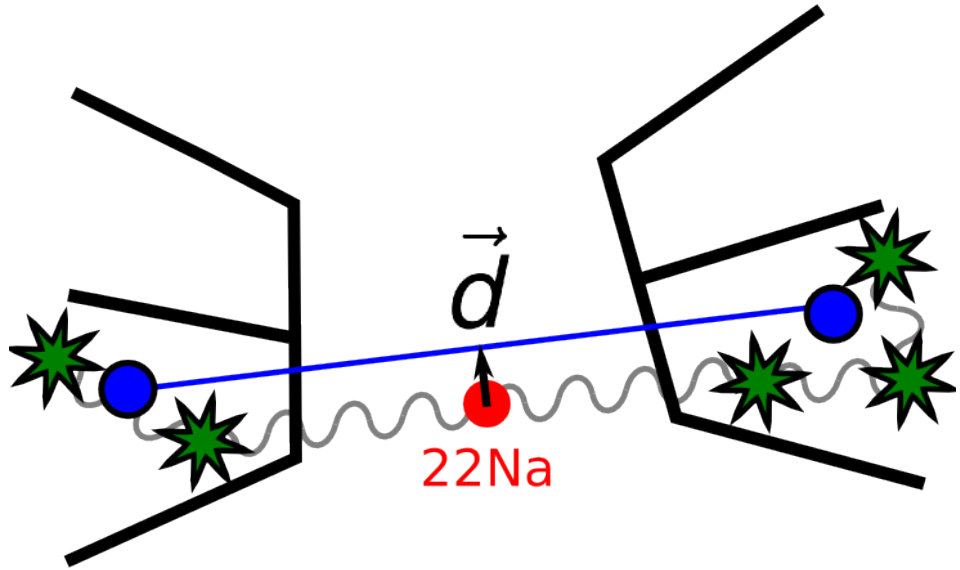




Barycentre analysis: Distance spectrum

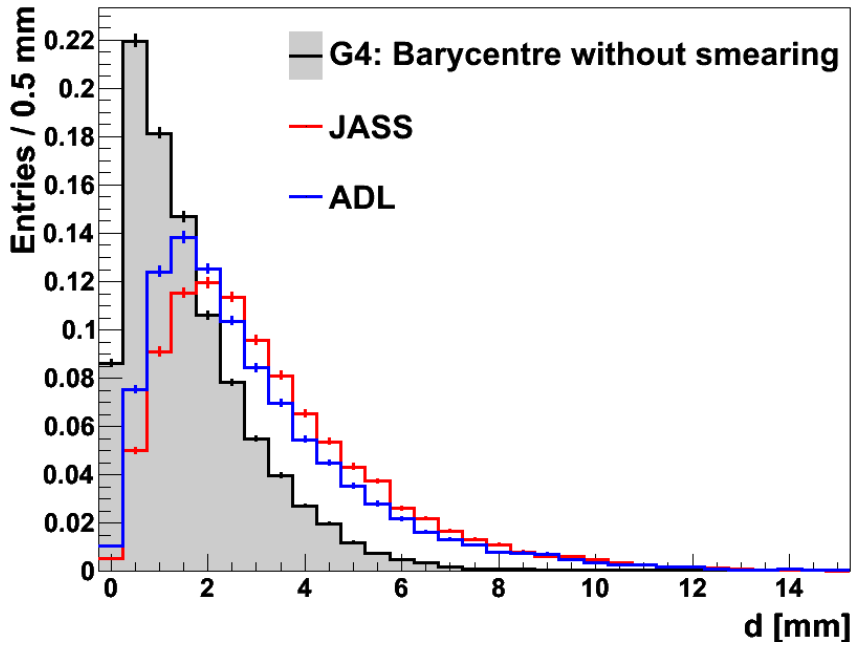
Definition

- $d = |\vec{d}|$: Distance between line and source position

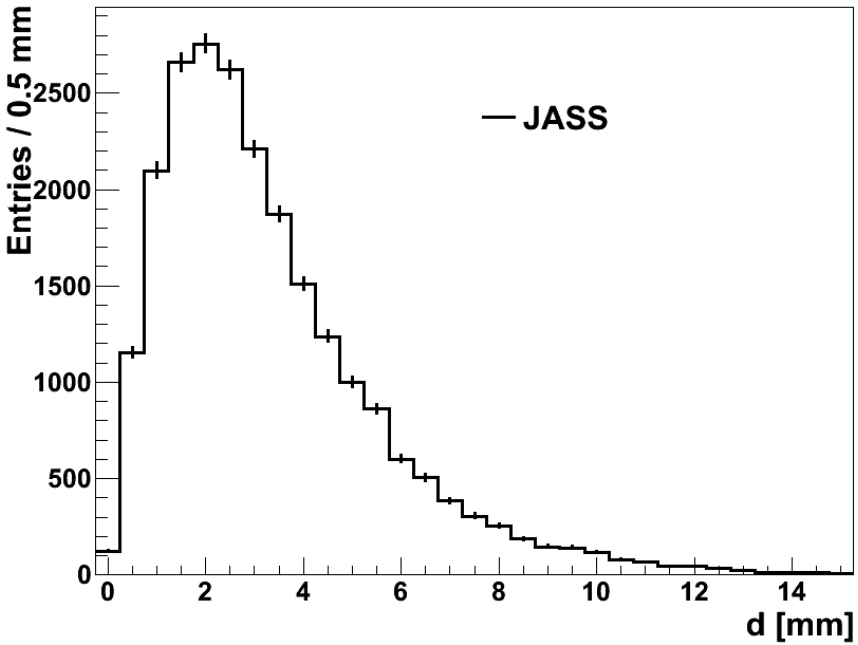


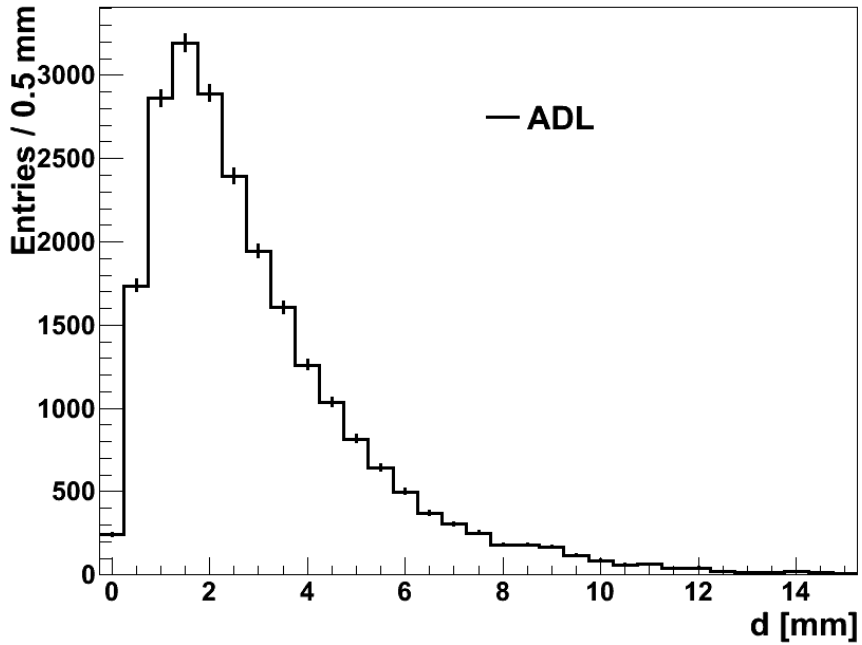
Obtained results

- JASS and ADL show different distributions.
- Geant4 and experiment differ due to finite resolution of PSA.

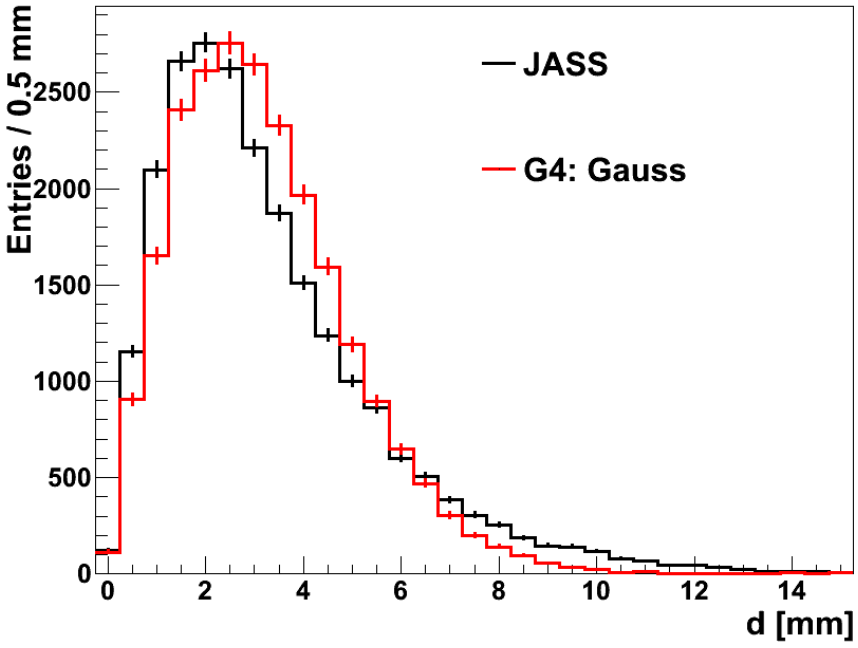


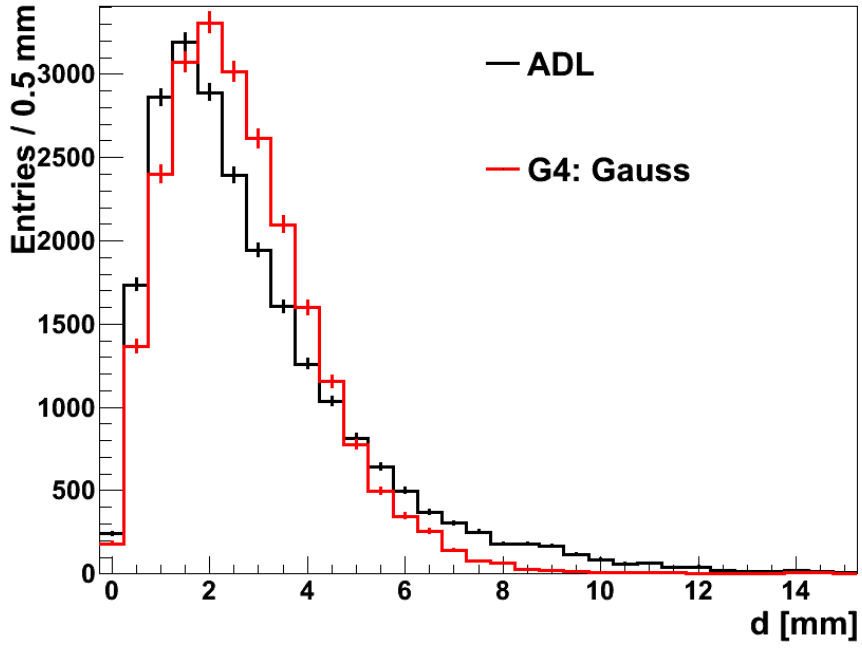
Position resolution of the barycentre





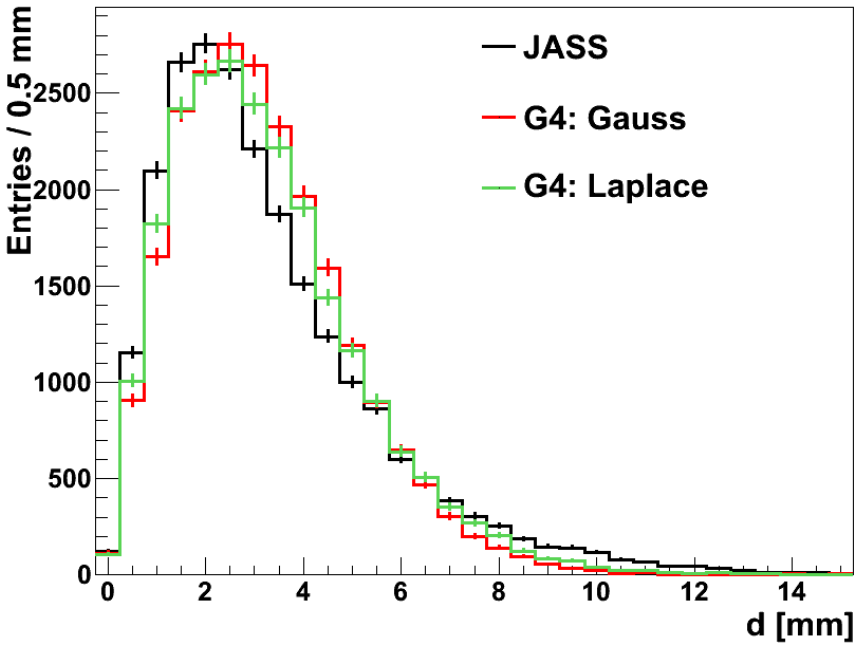
Position resolution of the barycentre

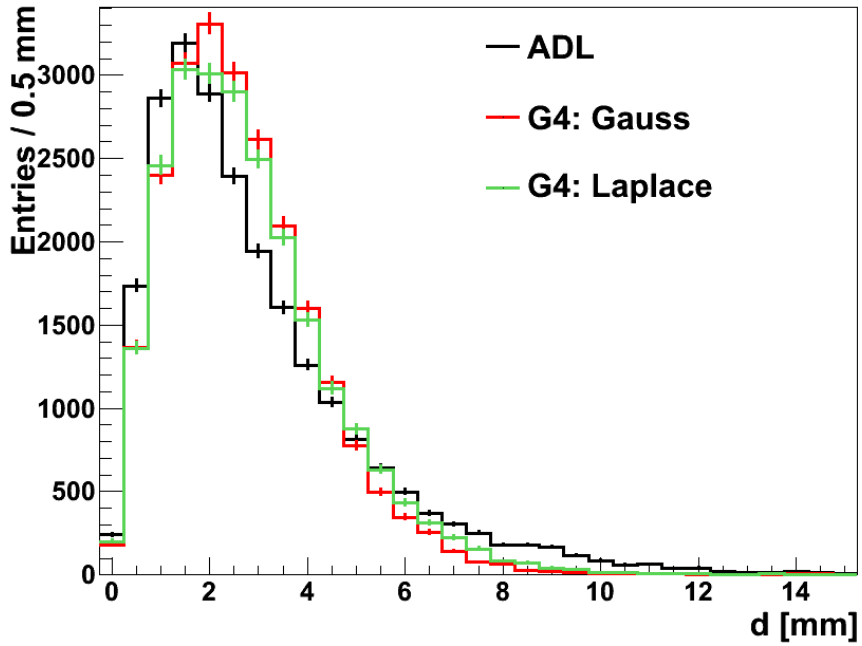




smearing distribution (JASS/ADL)	σ [mm]	χ^2/Ndf
Gauss	3.0 / 2.3	11.5 / 17.4

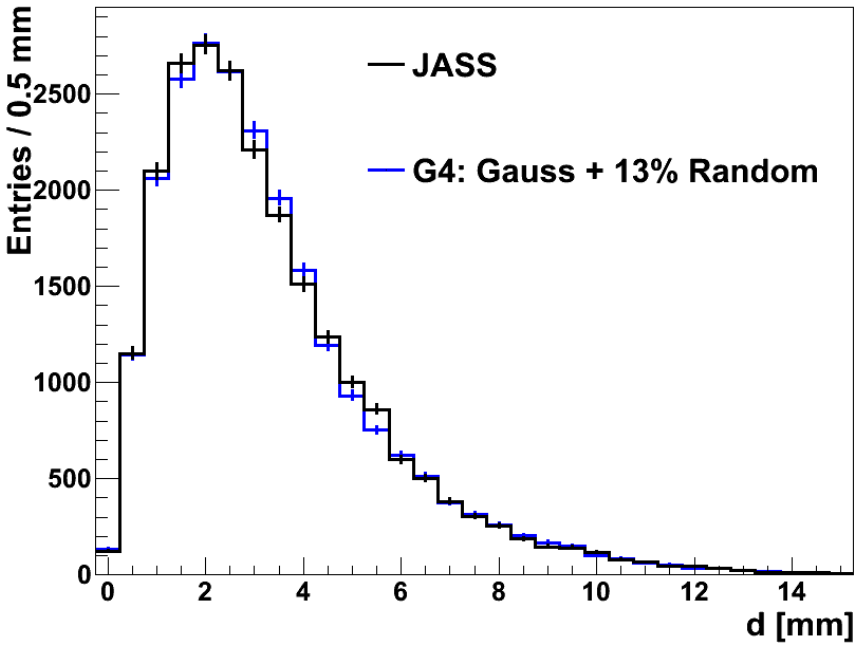
Position resolution of the barycentre

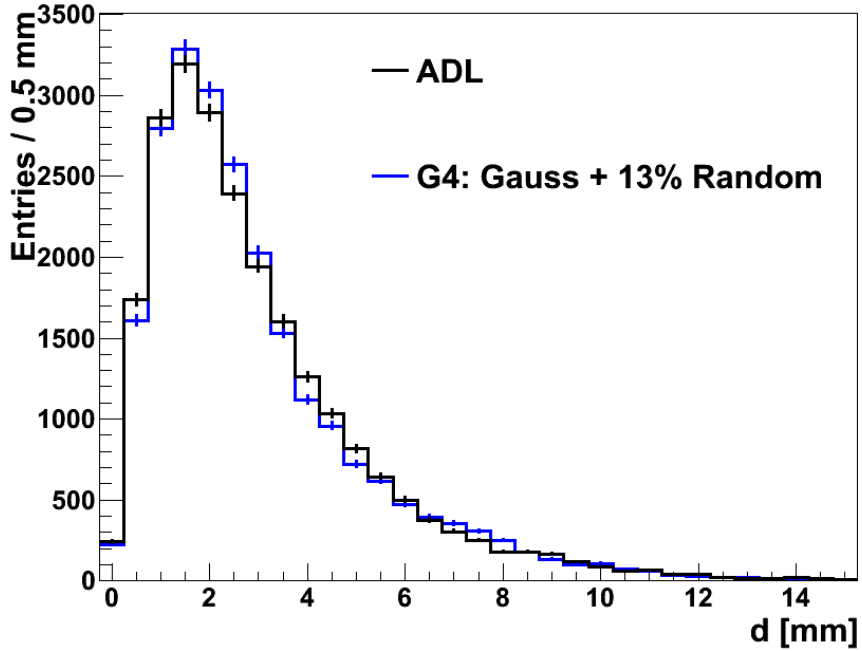




smearing distribution (JASS/ADL)	σ [mm]	χ^2/Ndf
Gauss	3.0 / 2.3	11.5 / 17.4
Laplace	2.3 / 1.8	6.1 / 12.2

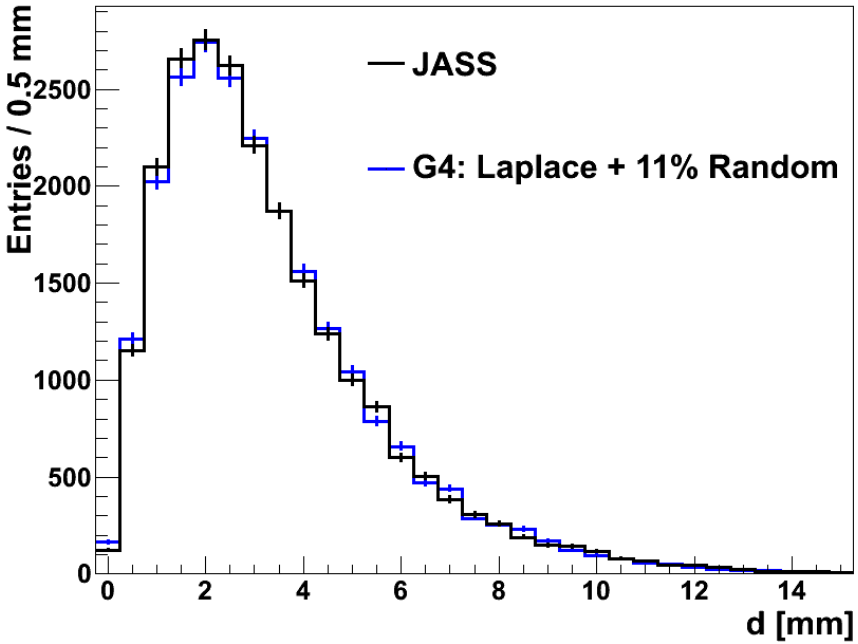
Position resolution of the barycentre

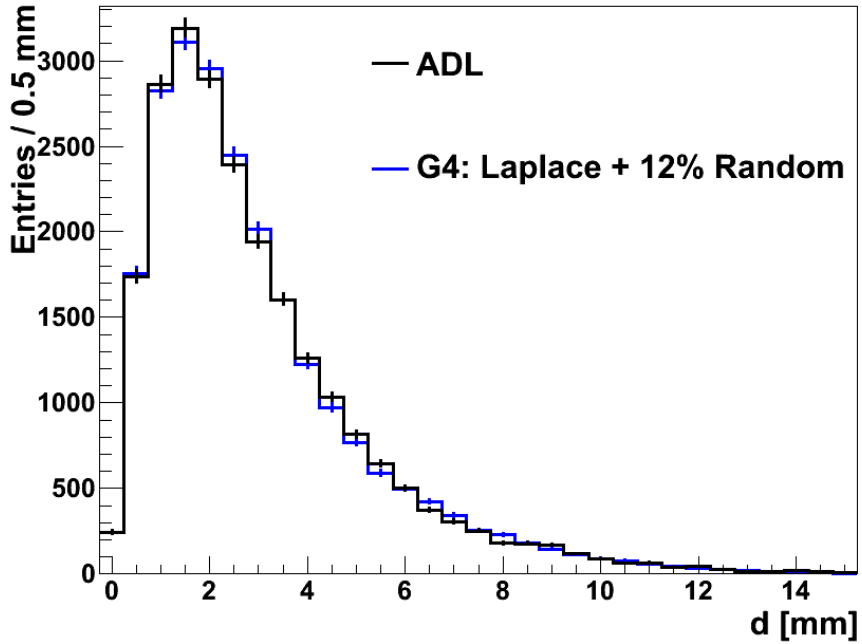




smearing distribution (JASS/ADL)	σ [mm]	χ^2/Ndf
Gauss	3.0 / 2.3	11.5 / 17.4
Laplace	2.3 / 1.8	6.1 / 12.2
87(87)% Gauss + 13(13)% randomly assigned points in the hit segment	2.2 / 1.6	1.3 / 2.2

Position resolution of the barycentre

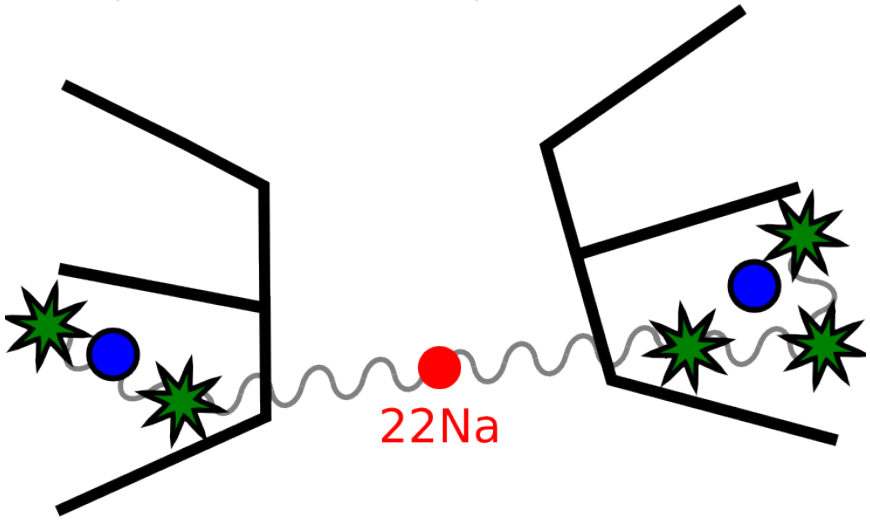


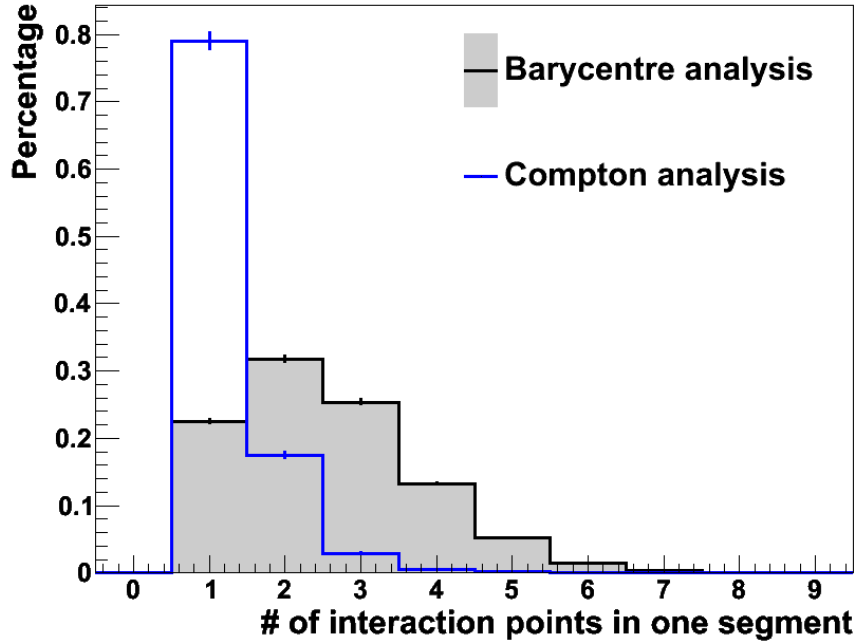


smearing distribution (JASS/ADL)	σ [mm]	χ^2/Ndf
Gauss	3.0 / 2.3	11.5 / 17.4
Laplace	2.3 / 1.8	6.1 / 12.2
87(87)% Gauss + 13(13)% randomly assigned points in the hit segment	2.2 / 1.6	1.3 / 2.2
89(88)% Laplace + 11(12)% randomly assigned points in the hit segment	1.8 / 1.3	1.5 / 1.4

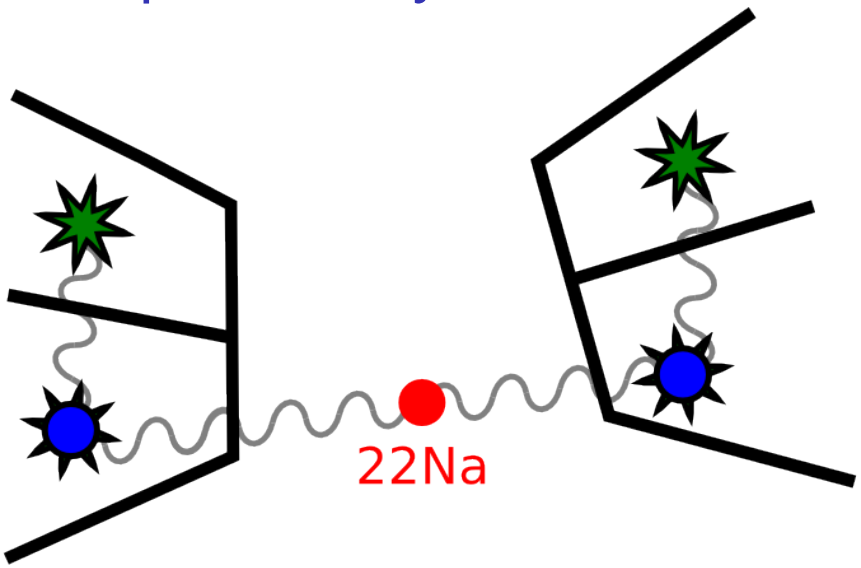
From the barycentre to a single interaction analysis

Barycentre analysis





Compton analysis



$\Rightarrow$ Compton analysis selects mostly single hit events.

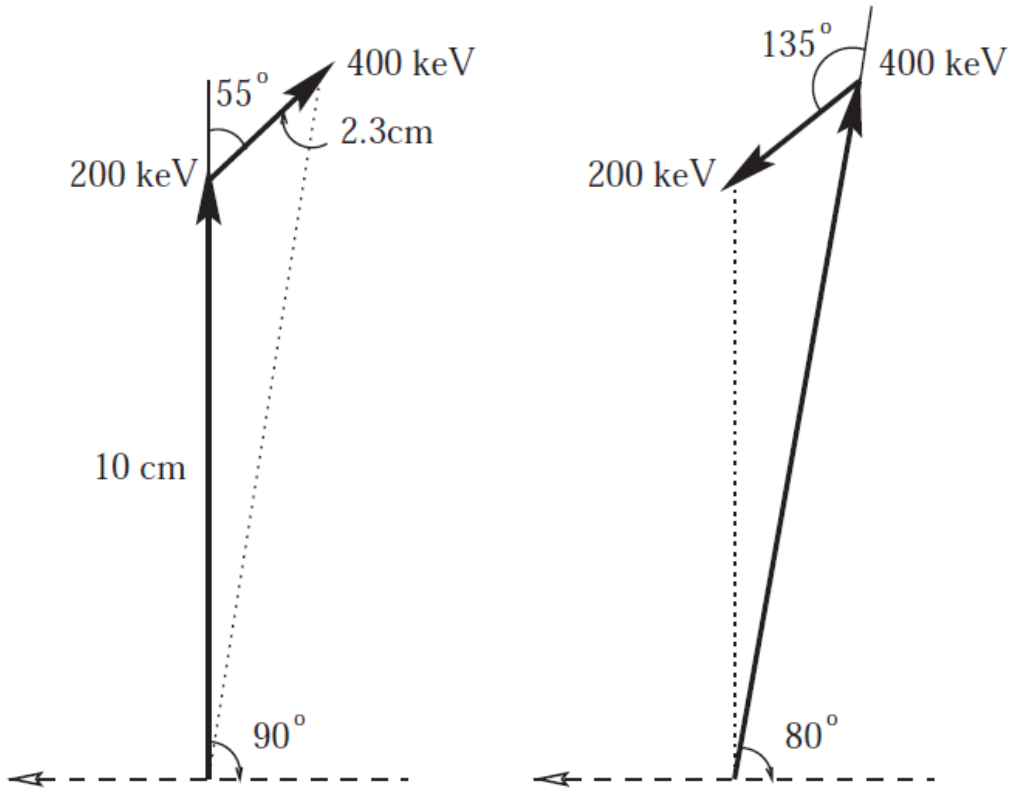
Selection of Compton scattered events

- 2 hit segments with $\sum E_{\text{segment}} \approx 511\,\text{keV}$ (each crystal)
- Scattering angle: $|\theta_{\text{Compton formula}} - \theta_{\text{geometry}}| < \Delta\theta_{\text{max}} = 0.3$

Additionally the time order of the interactions has to be determined:

- Problem: Ambiguity of Compton formula leads to correct identification of 1st hit segment only in 78% of all events.

$\Rightarrow$ Geometric determination of 1st hit segment (succeeds in 94% of all events)

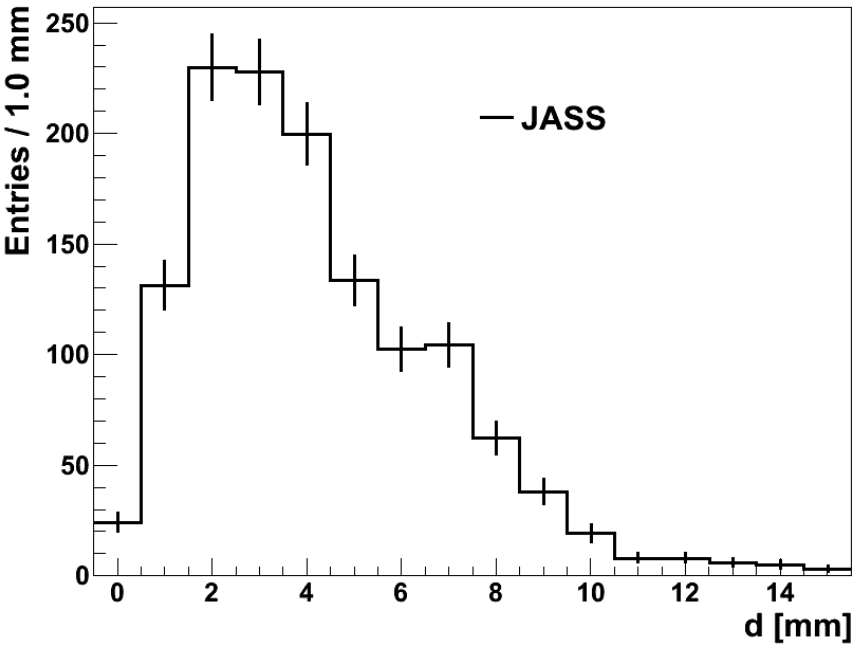


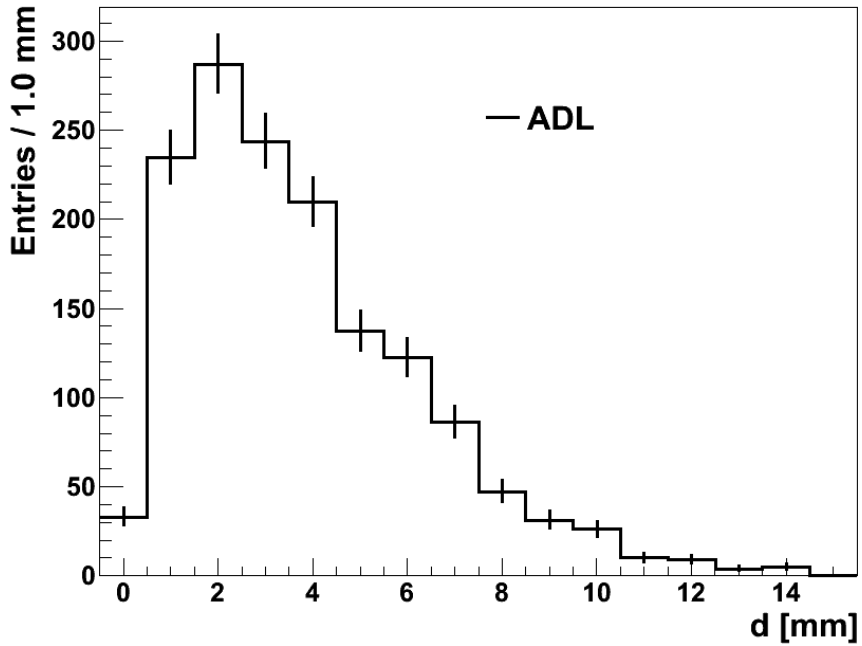
N.J. Hammond et al. / Nuclear Instruments and Methods in Physics Research A 547 (2005) 535–540

Position resolution of a single interaction

Energy dependant position resolution

$\rightarrow$ assumption: $\sigma(E) = \sigma_0 \sqrt{\frac{511\,\text{keV}}{E}}$, $E \geq 150\,\text{keV}$





Position resolution of a single interaction

Energy dependant position resolution

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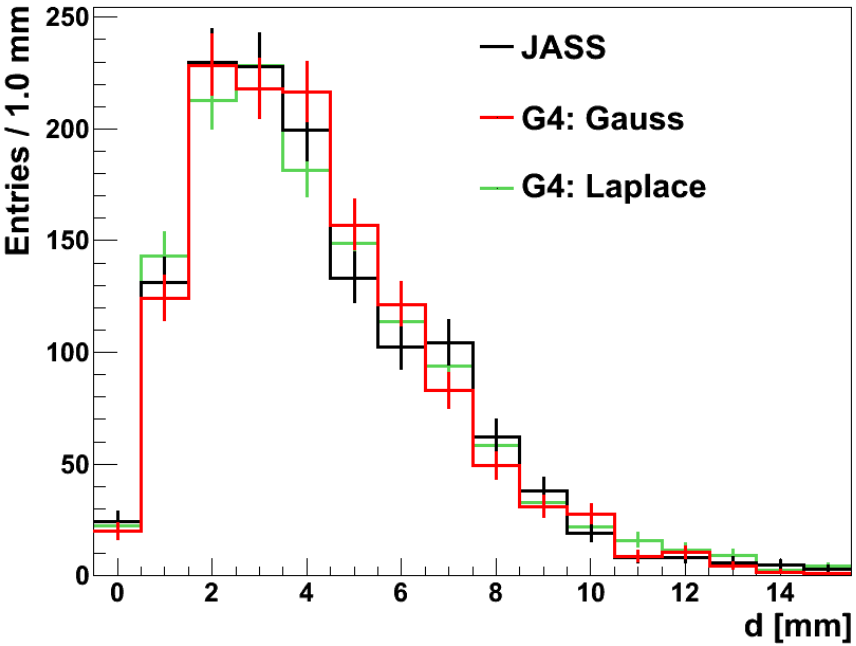
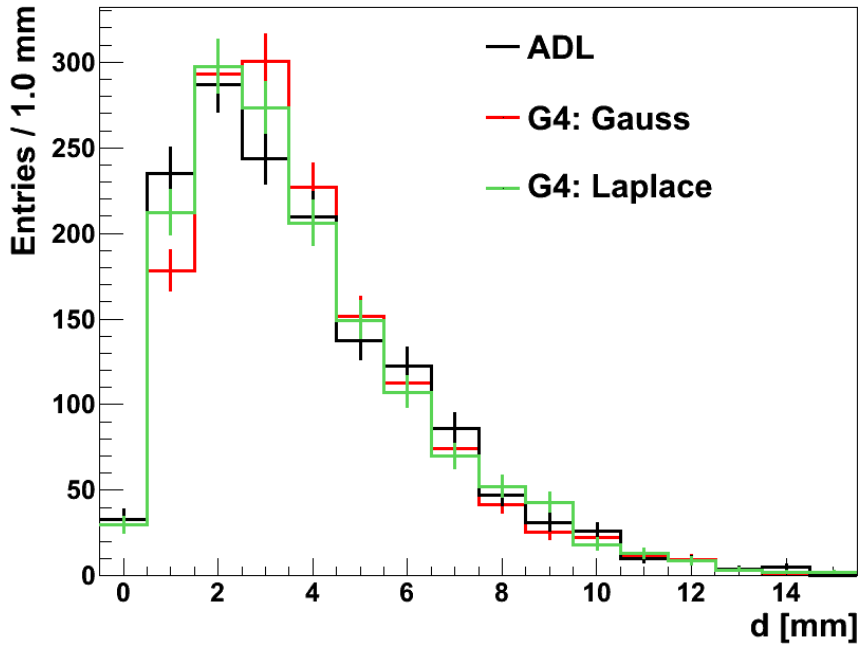




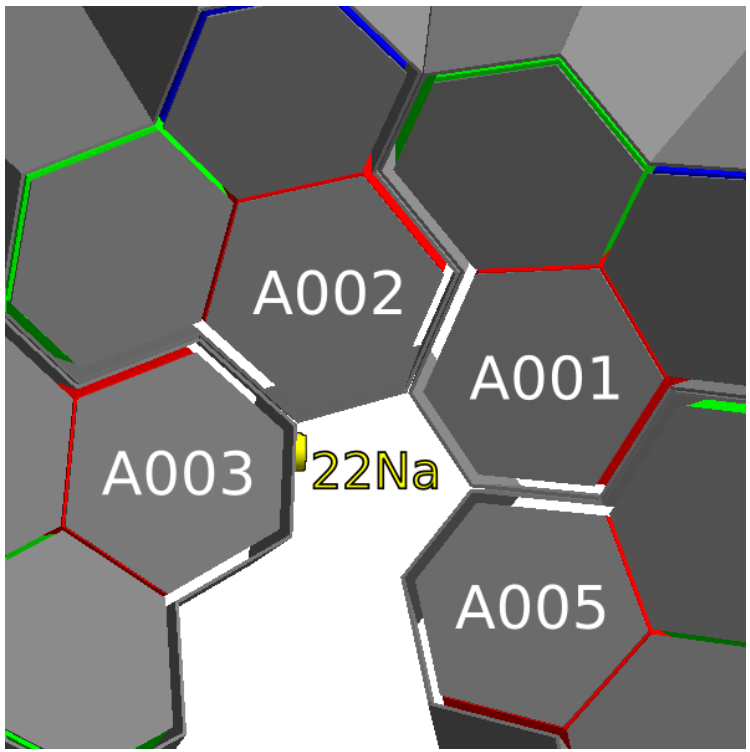
smearing distribution (JASS/ADL)	σ_0 [mm]	χ^2/Ndf
Gauss	2.7 / 2.3	0.5 / 0.6
Laplace	2.0 / 1.7	0.4 / 0.4

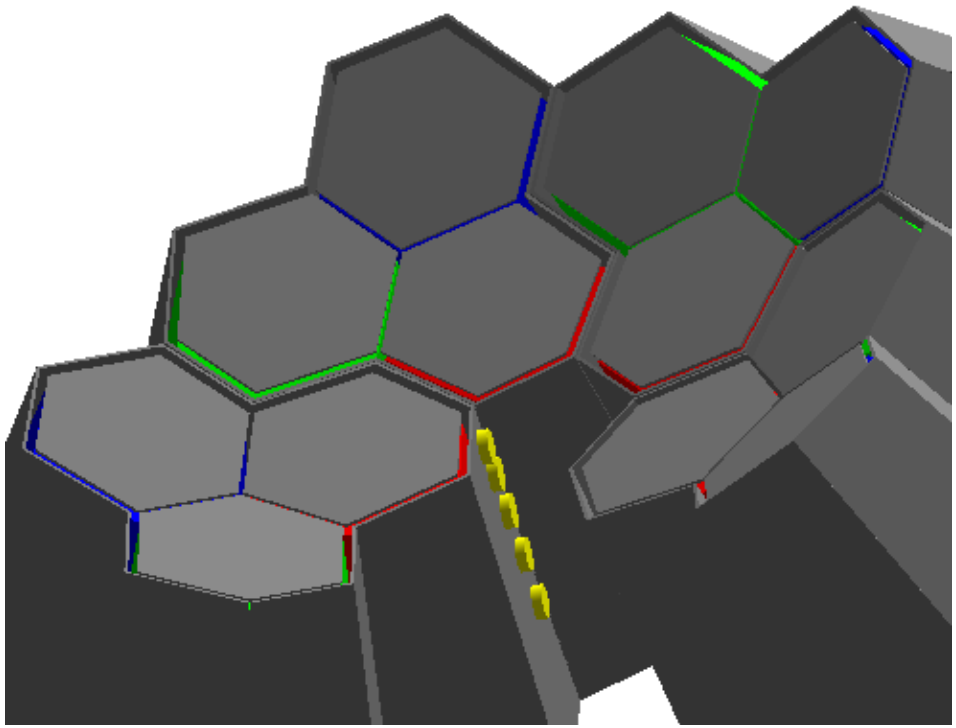
Needs for a real PSA calibration experiment

Disadvantage of the present Na22 measurement

- Symmetric setup $\Rightarrow$ Only an overall position resolution of both crystals can be determined.

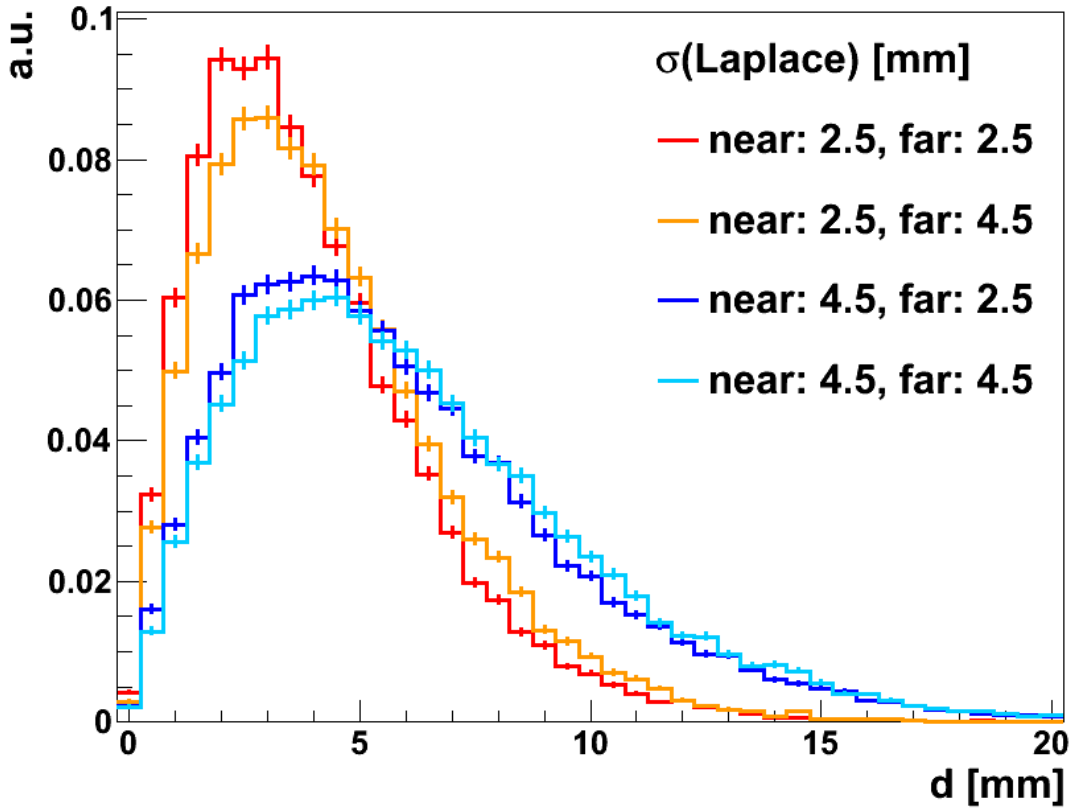
Setup of an improved Na22 measurement





Influence of the position smearing of the far detector

Near: barycentre, far: barycentre



⇒ Resolution of individual crystals (segments) can be determined.

Estimation of the measurement time using Geant4

- Assumed Na22 source activity: 10 kBq
- $\sim$ 7000 counts in distance spectra necessary for analysis

Event selection	approx. measurement time / source position
Barycentre (near), barycentre (far)	8 min
Compton (near), barycentre (far)	36 min
Compton (near), Compton (far)	335 min

Conclusion

Results of 1st test measurement

- Obtained barycentre position resolution of A001 and A003 at 511 keV: $\sigma(\text{JASS}) \approx 2.0$ mm, $\sigma(\text{ADL}) \approx 1.5$ mm
- Compton scattered events are suitable to study single hits. $\Rightarrow \sigma_0 \sim 2$ mm

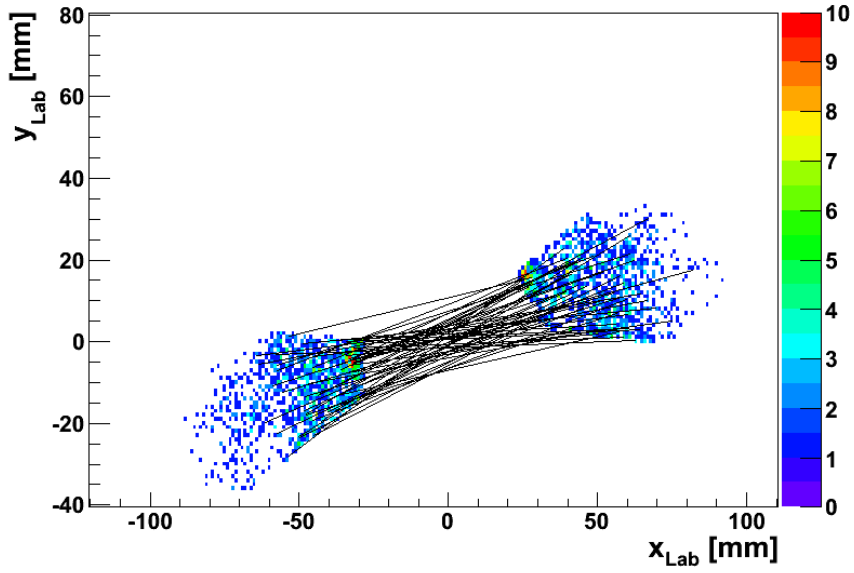
Outlook for new measurement

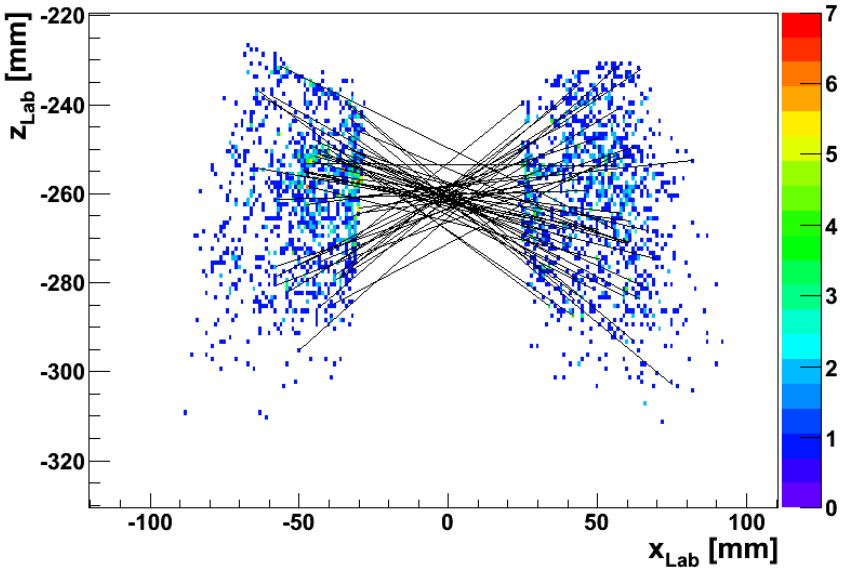
- Determination of the position resolution of single crystals / segments possible
- Simple and fast experimental procedure

Appendix

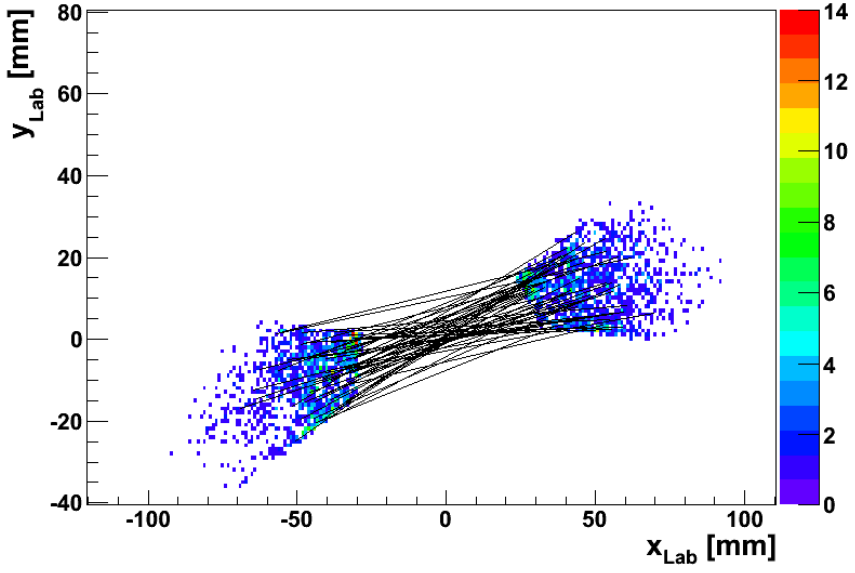
Compton analysis: Experimental results, $E \geq 150\,\mathrm{keV}$

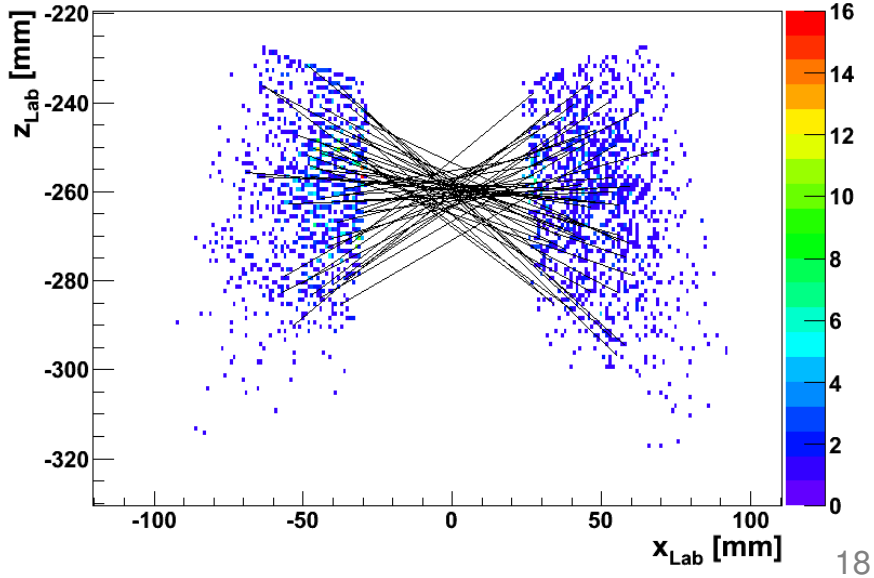
JASS





ADL

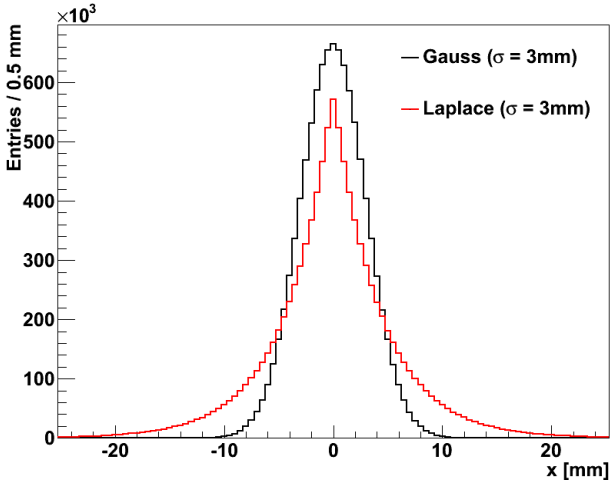


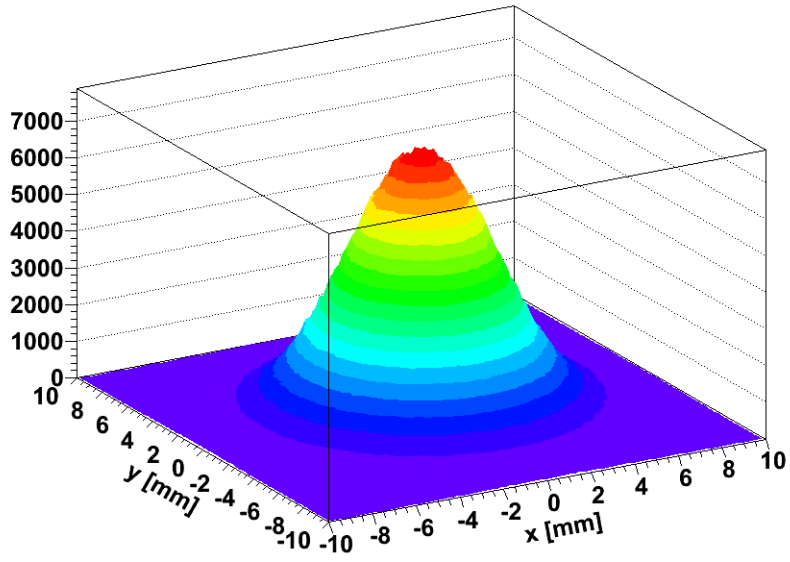


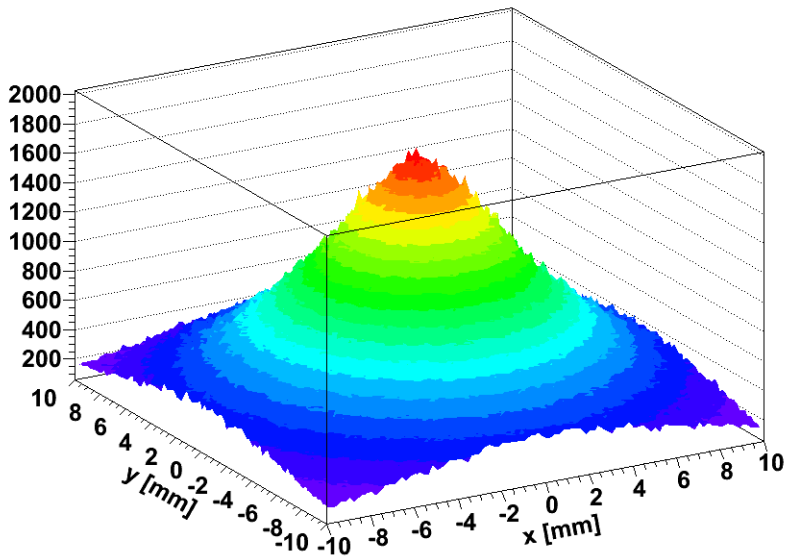
Comparison of the Gauss and Laplace distribution

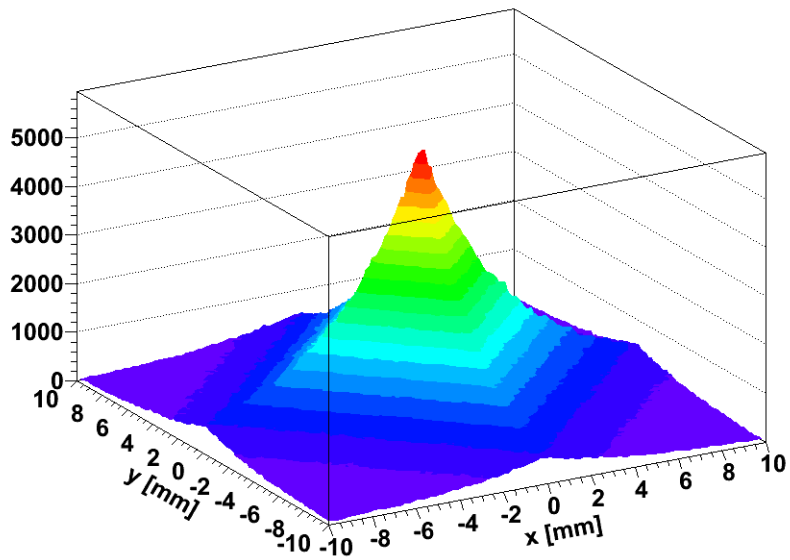
Gauss: $FWHM = 2.35 \cdot \sigma$

Laplace: $FWHM = 0.98 \cdot \sigma$



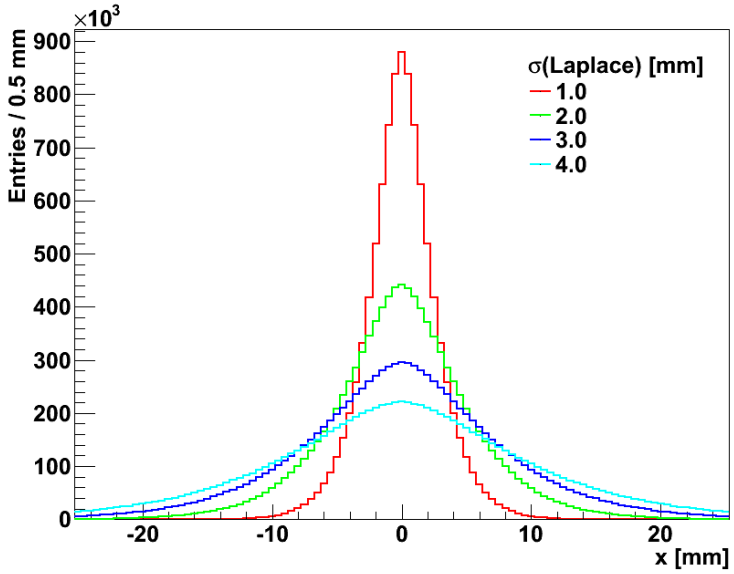


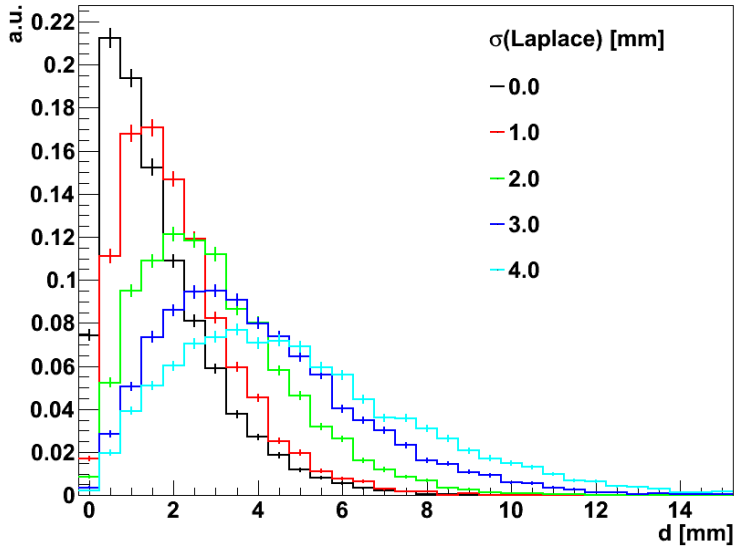




Position smearing and distance spectra

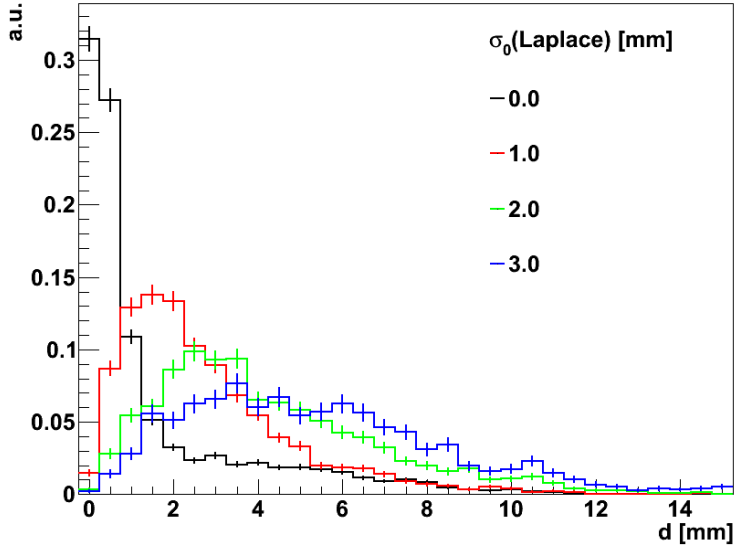
Barycentre analysis



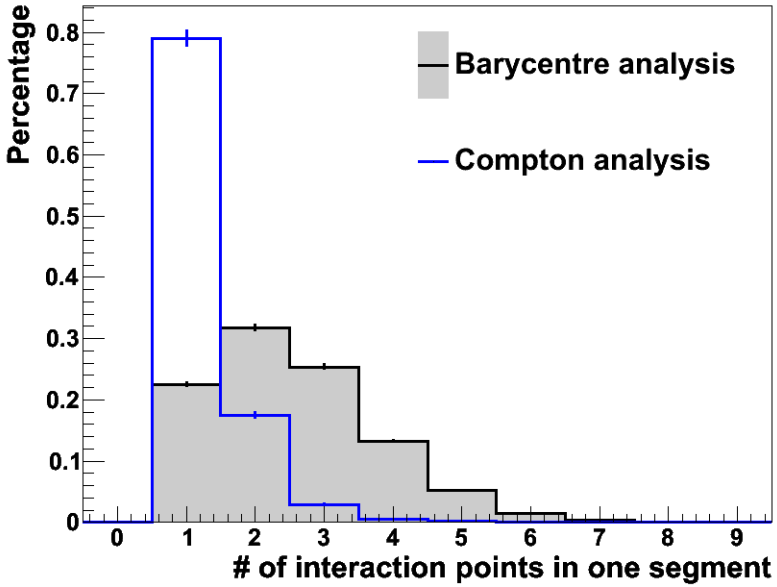


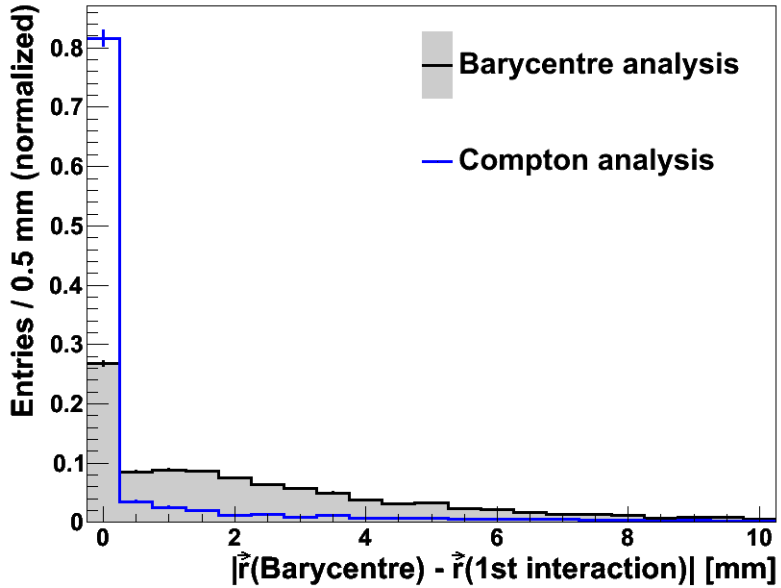
Compton analysis

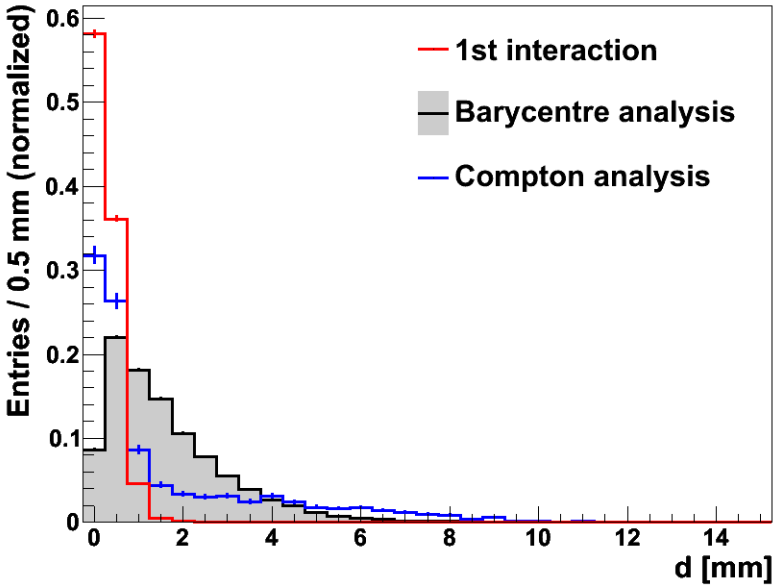
$$\sigma(E) = \sigma_0 \sqrt{\frac{511\,\mathrm{keV}}{E}}$$



From the barycentre to a single interaction analysis



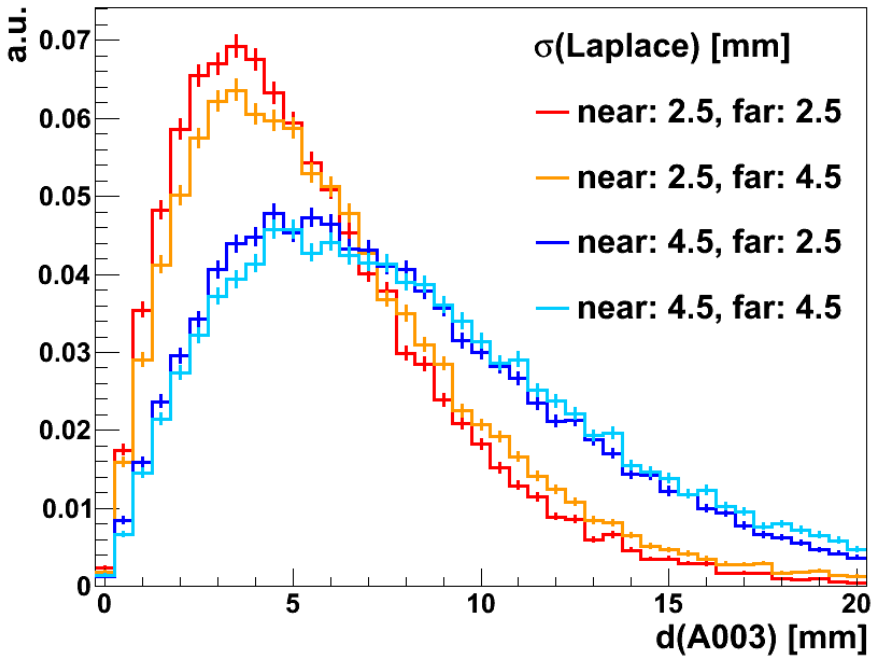


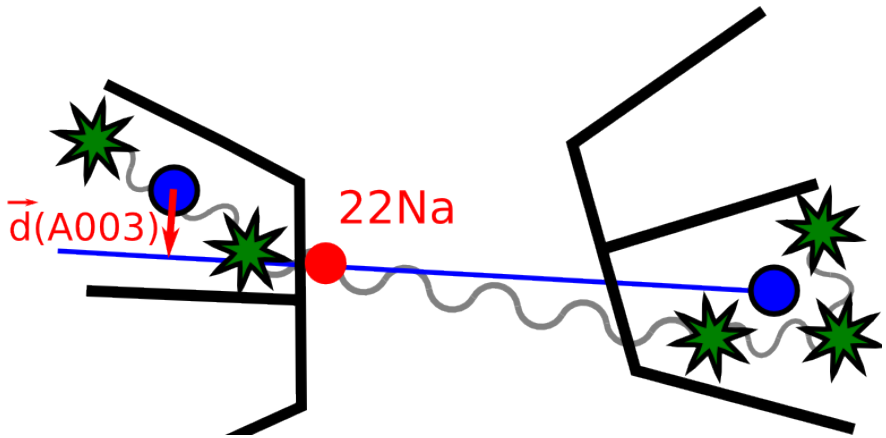


$\Rightarrow$ Compton analysis selects mostly single hit events

Influence of the position smearing of the far detector on the position resolution of the near detector A003

Near: barycentre, far: barycentre





⇒ Resolution of individual crystals (segments) can be determined with a roughly known resolution of one detector.

Examples for minimization functions