Exp 24.01
Development of a self-calibration technique for gamma-ray tracking arrays

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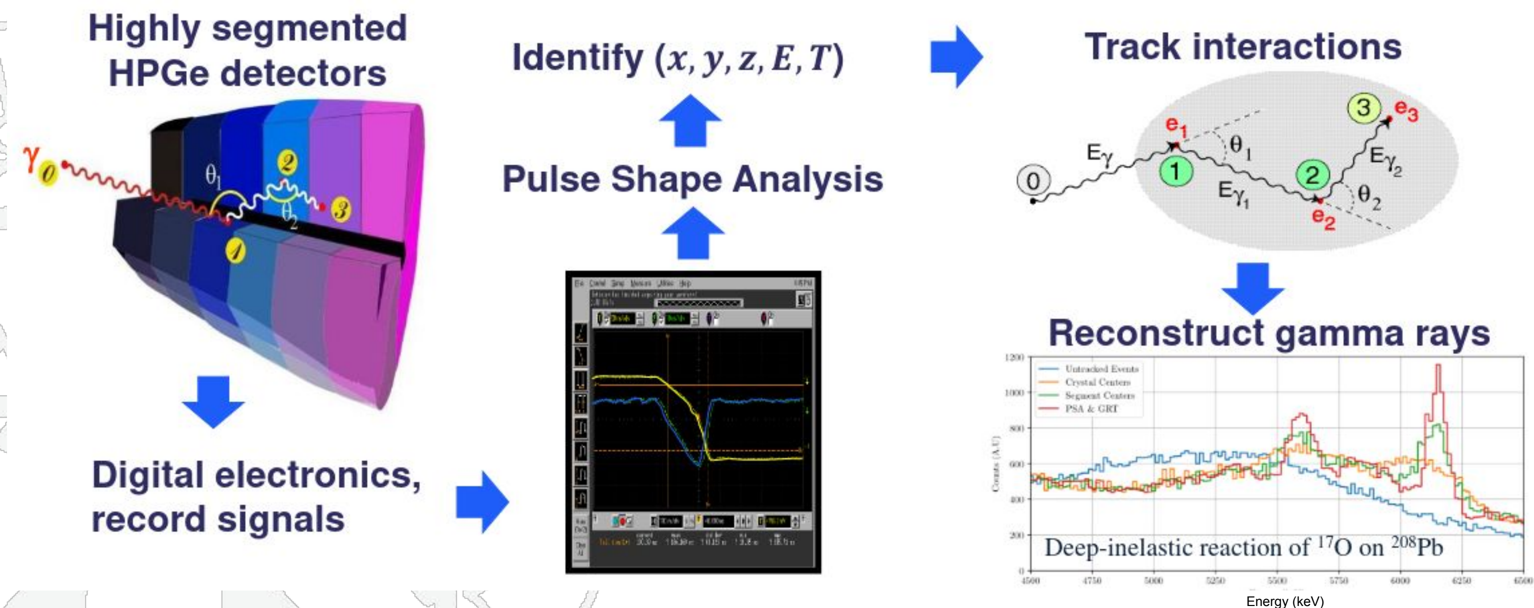
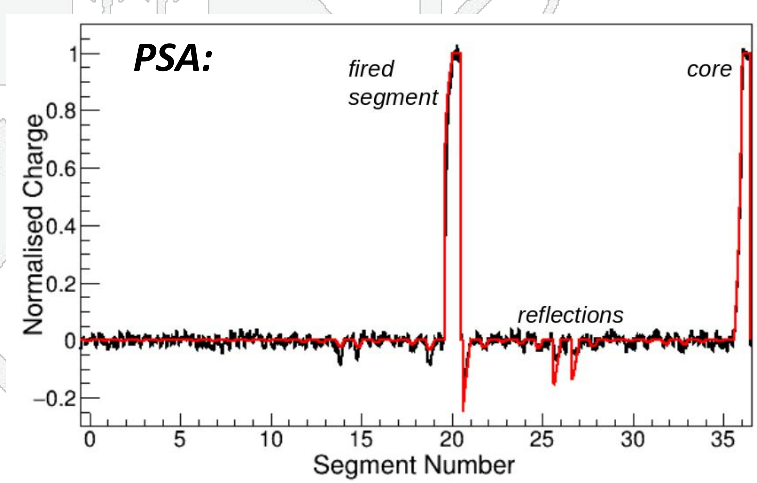
the 26th AGATA week
11th September 2026

Gamma-ray tracking array

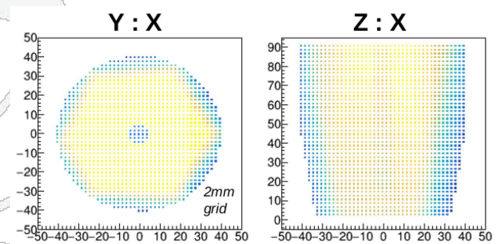




- Gamma-ray tracking array: highly segmented HPGe (36 segments)
- Pulse Shape Analysis (PSA) => interaction position
- PSA performed by comparing with **signal basis** for every detector

Current challenges

signal basis generation

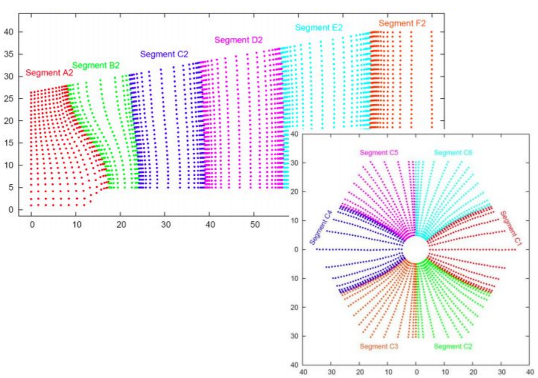


Experimental (scanning)

- long acquisition times
- different conditions between scanning and experiment, e.g. noise, radiation damage
- mechanical alignment

Analytical (calculated)

- intrinsic space-charge density
- the electron/hole mobility
- crystal temperature and
- crystal orientation
- passivated and contact thickness
- shape of charge cloud



Self-calibration concept

Generate signal basis experimentally & in situ

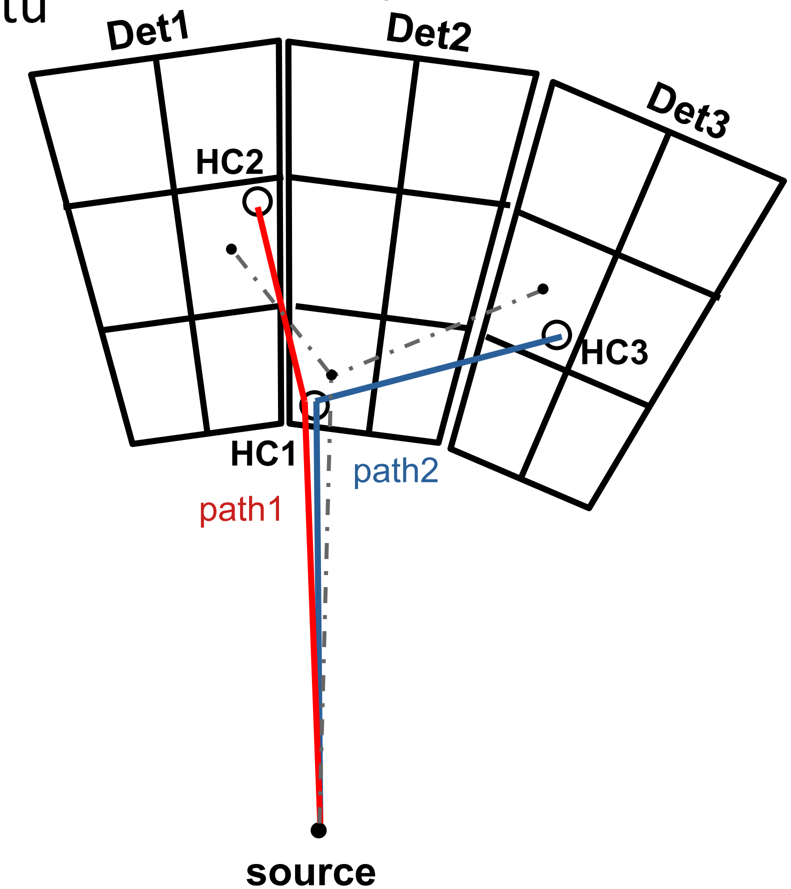
S. Heil, S. Paschalis, and M. Petri,
Eur. Phys. J. A (2018) **54**: 172

Group interaction points from different gamma-rays into hit collections

Use Compton formula to order interaction points

Define tracks between interaction points that also link the hit collections with each other

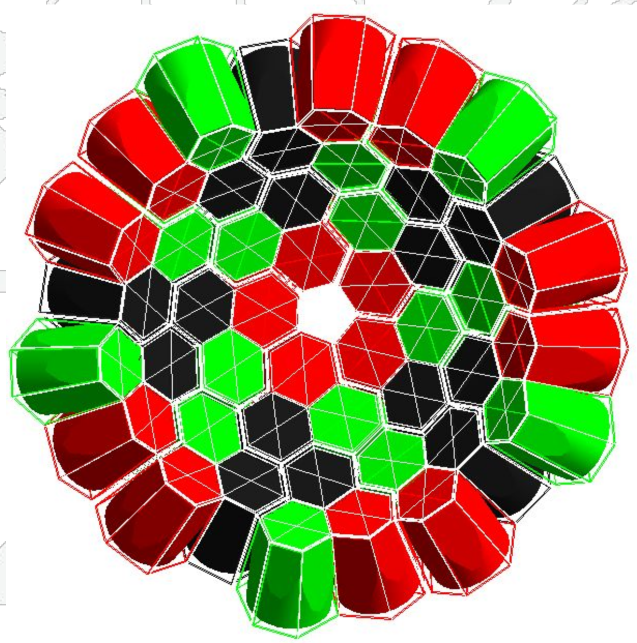
Optimise coordinates of hit collection using the tracks that link their constituent points and Compton formula



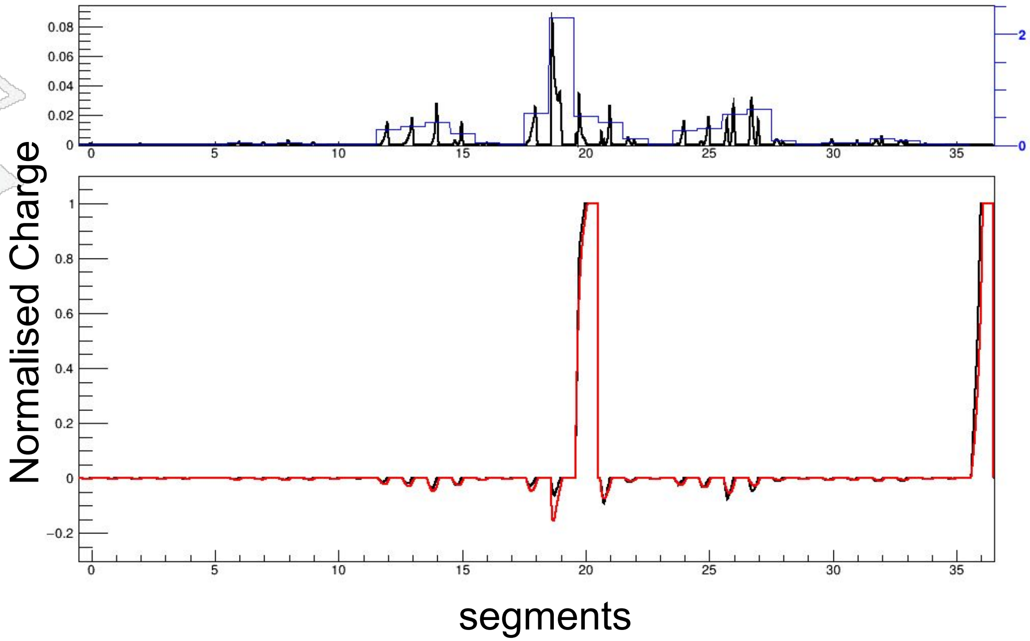
- Produce pulse shape basis for all detectors
- Strong gamma source illuminate the whole array
- Compton formula optimize scattering events

Simulation with Pulse Shape

Geant4 simulation:

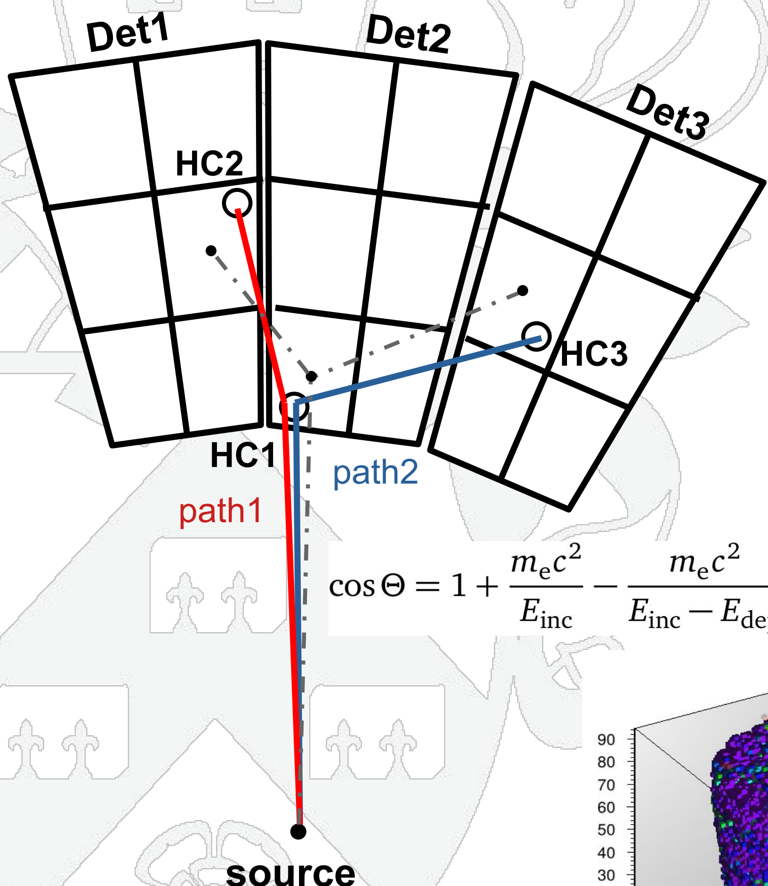


Group pulse shape:

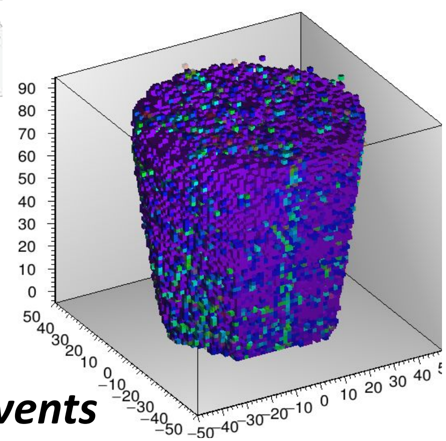


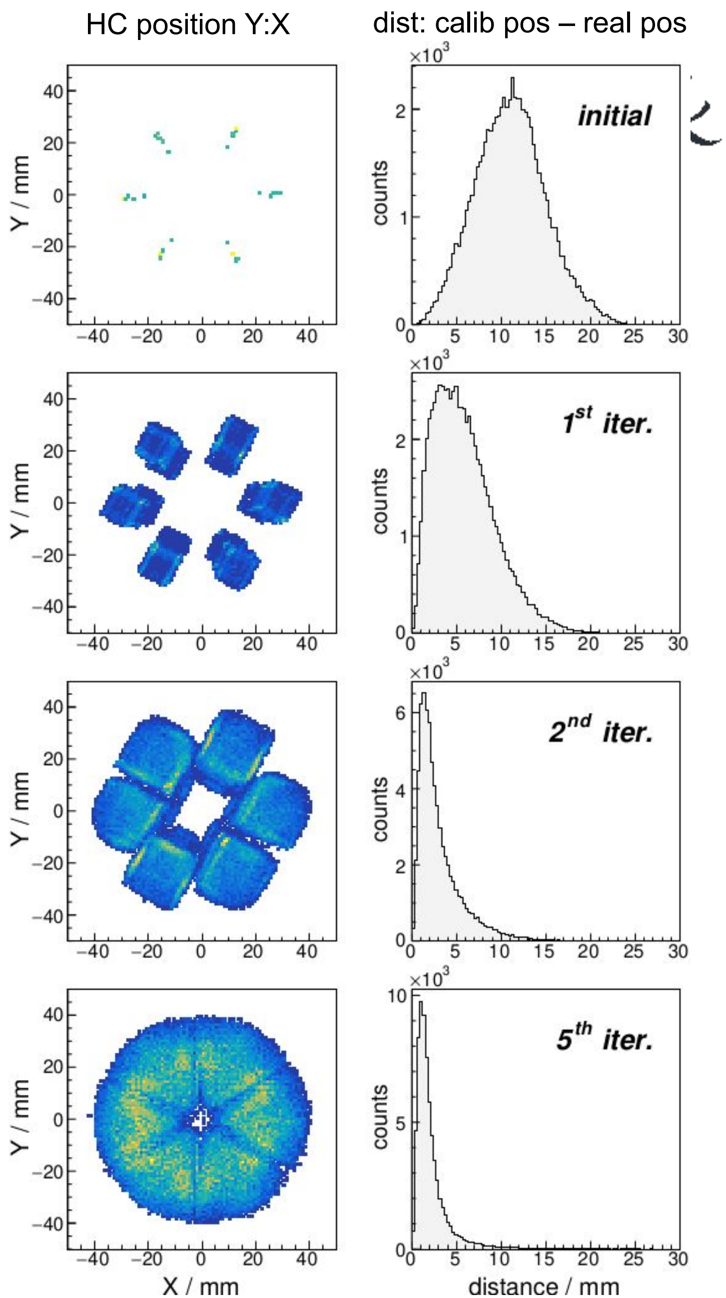
- Geant4 simulate AGATA-1Pi array, save Compton scattering events
- Pulse shape basis linear interpolation → simulation pulse data
- Group pulse shape according to similarity

Simulation: Position optimization



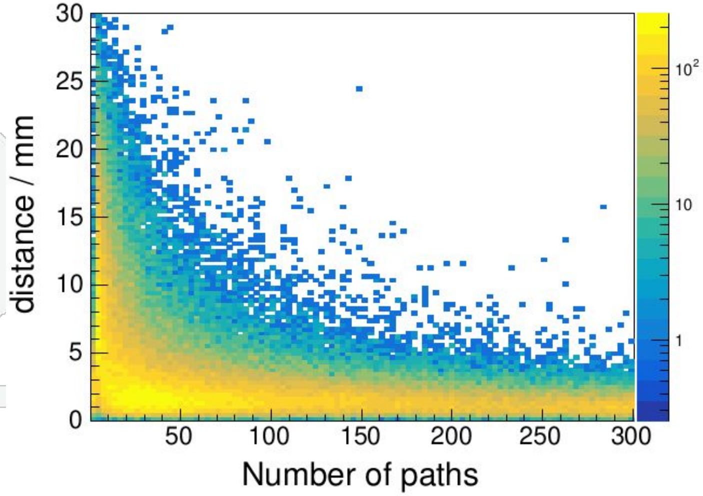
$$\cos\Theta = 1 + \frac{m_e c^2}{E_{\mathrm{inc}}} - \frac{m_e c^2}{E_{\mathrm{inc}} - E_{\mathrm{dep}}}$$

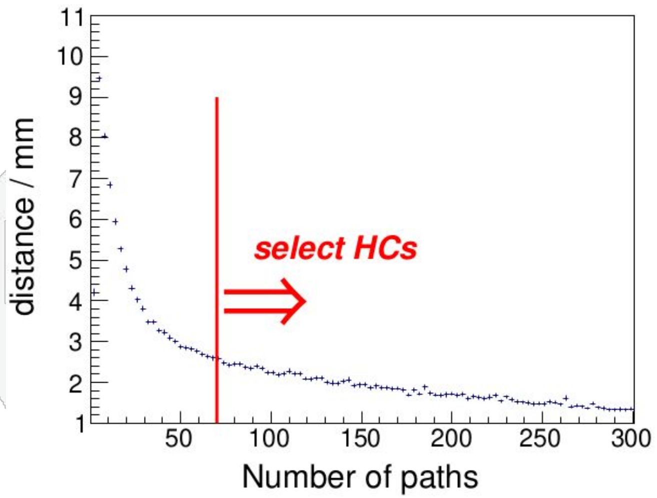




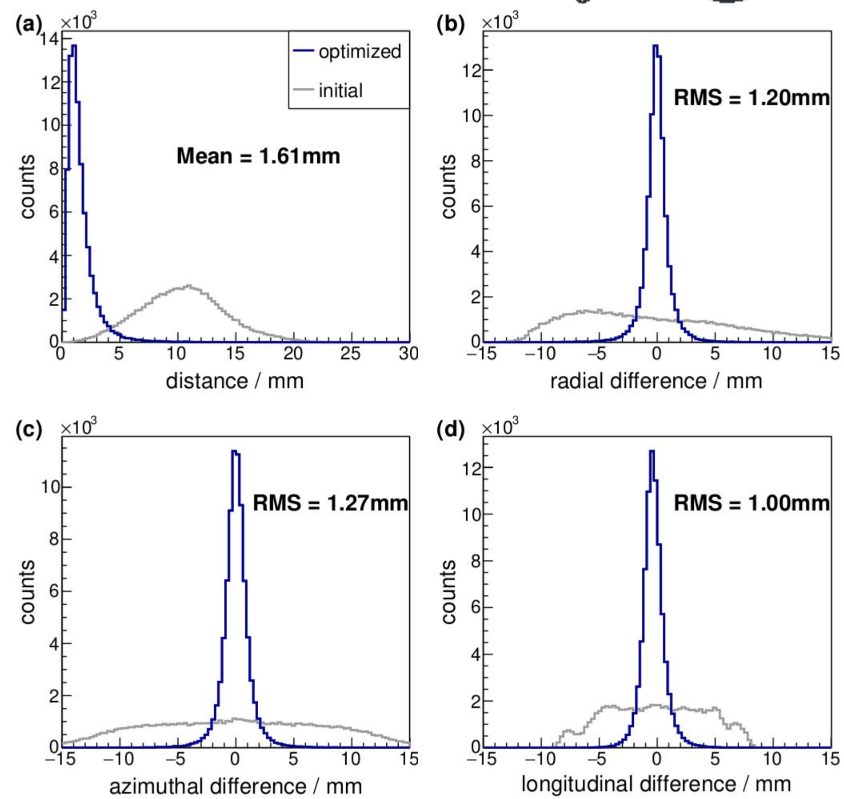
Simulate 2MeV gamma 2e10 events

Simulation: Position fidelity





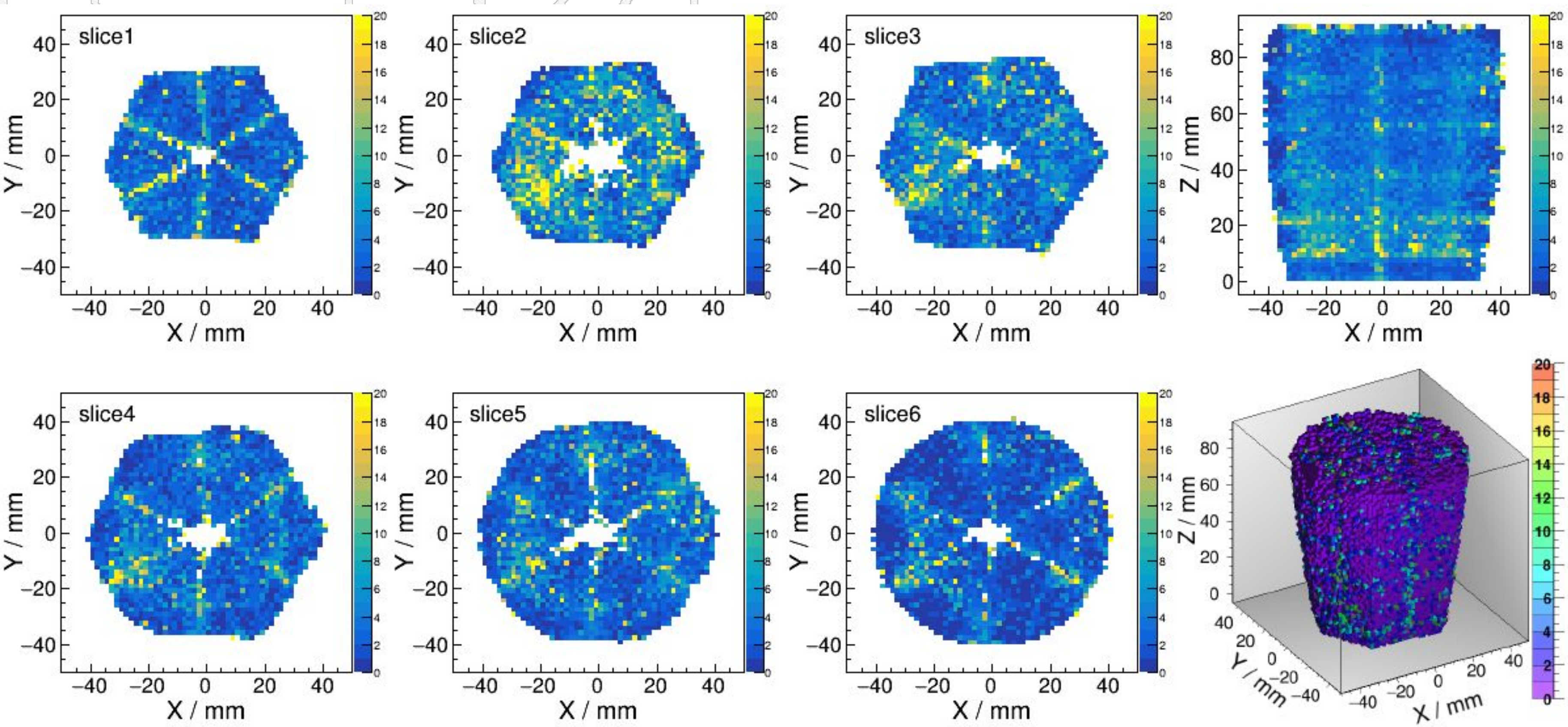
Simulate 2MeV gamma 2e10 events



- Select HC linked with large number of paths
- Converged HC position reach ~1mm (RMS) fidelity

Self-calibration basis

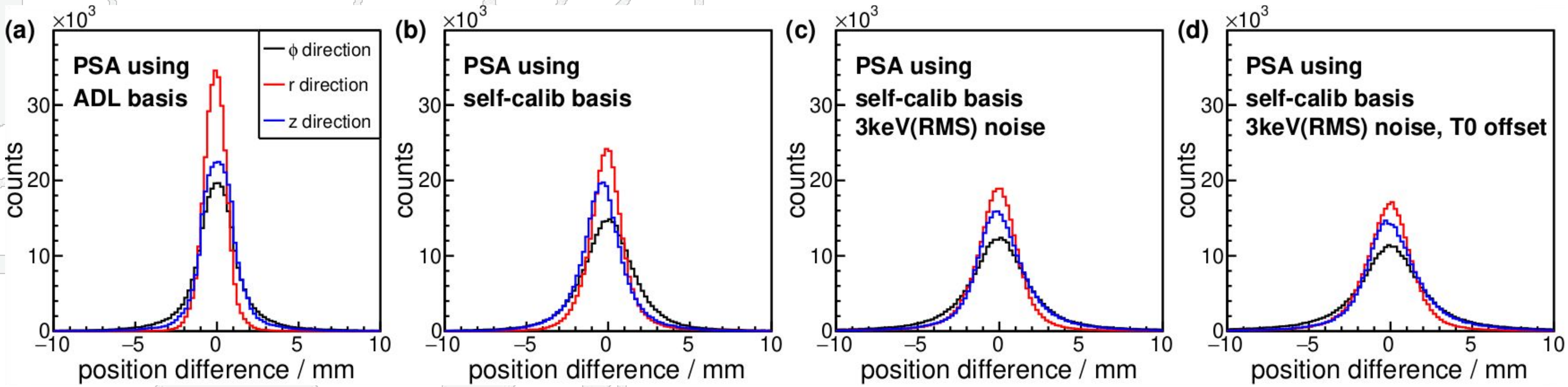
Chi2 difference: self-calib pulse vs. ADL pulse



- Large Chi2 observed around segment boundary

Simulate 2MeV gamma 2e10 events

PSA position resolution



- Compare PSA position resolution using different basis
- Electronic noise in pulse shapes and T0 offset are included in simulation, and their influences to self-calibration basis are studied

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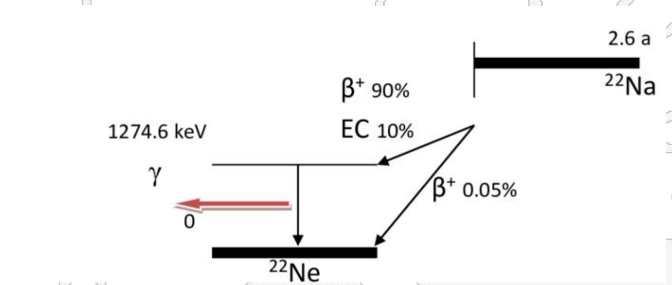
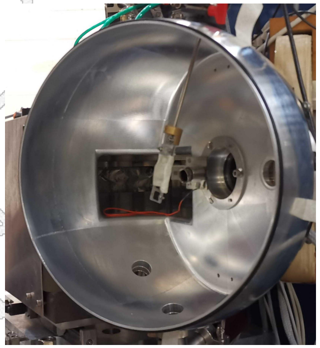
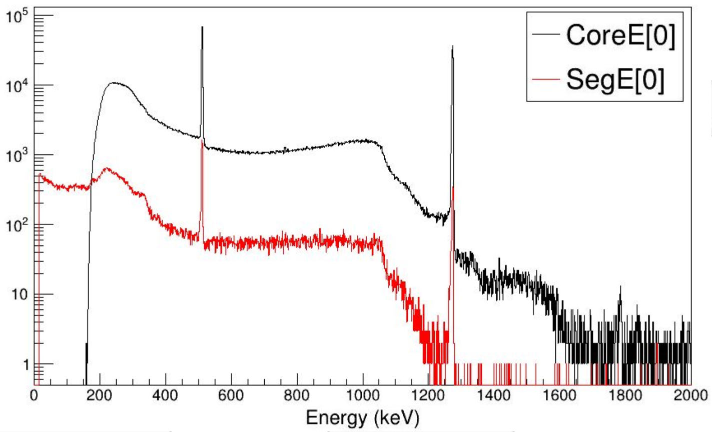
Experiment: source data

^{22}Na source, 130kBq

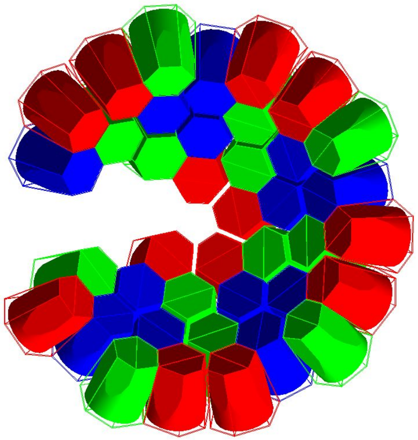


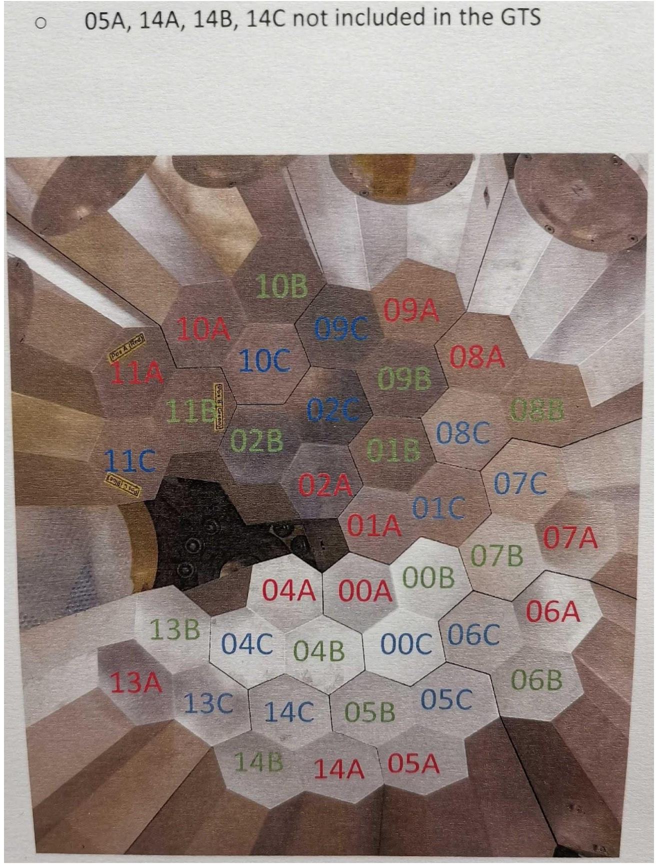
source at target position





13 ATC at LNL

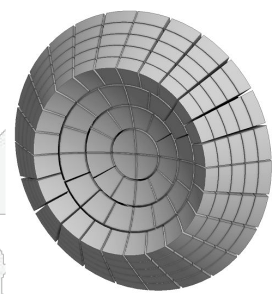


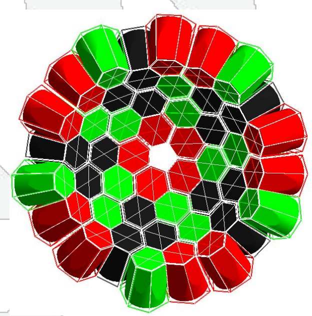


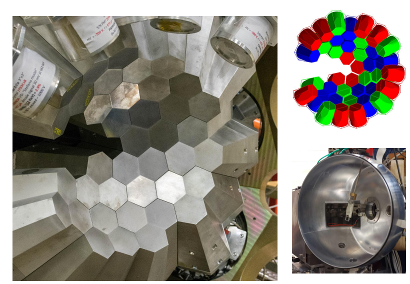
- ^{22}Na source at center of array
- Large signals, CoreE>200keV (CoreE>300keV data is used for self-calibration)
- Compton scattering events (fold 2 trigger)

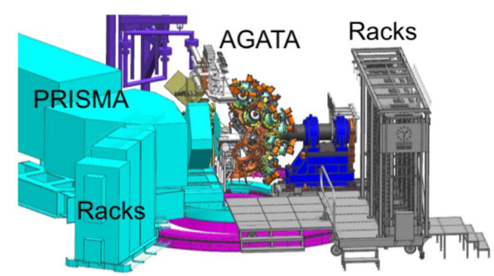
Method validation timeline

- ✔ simulation of realistic geometry of AGATA (even with 1Pi)
- ✔ end-to-end simulation including pulse shape analysis
- ✔ validation using experimental data (source and in-beam)
- ✔ **Exp 24.01** - dedicated in-beam LNL experiment Dec 2024









2018: proof of principle with a simple simulation

2022: test with AGATA simulation with pulse shape

2023: test with real gamma source (22Na) data at LNL

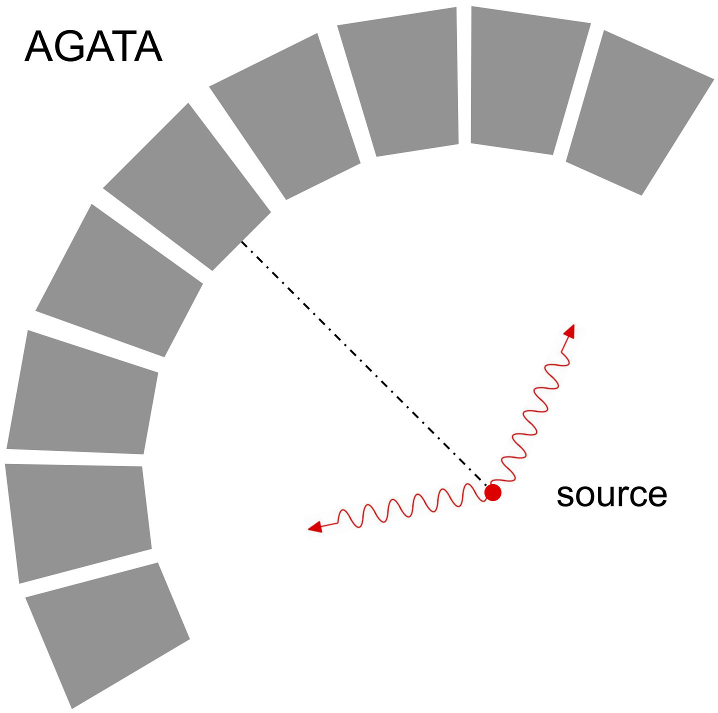
2024: produce optimized basis and validating with in-beam experiments

2018 2019 2020 2021 2022 2023 2024 2025

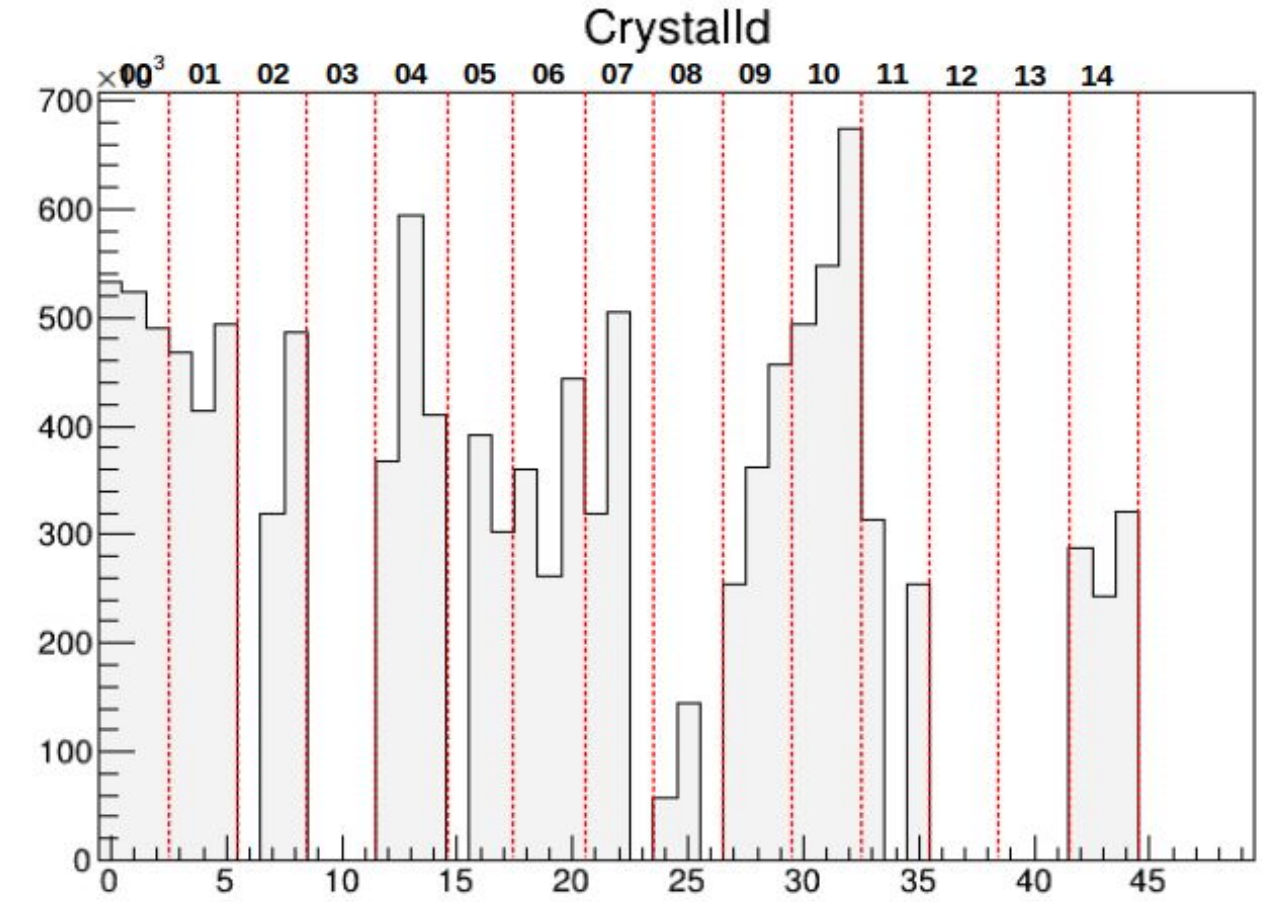
2025: complete simulation published

Experiment: source data

- Strong ^{88}Y source, ~540kBq
- source at target position, AGATA at nominal position
- Flod 2 trigger with core energy threshold ~300keV
- Saving trace data, validation rates ~900Hz per crystal
- Data taking for ~5 days (Dec. 2024)
- Data size ~26TB

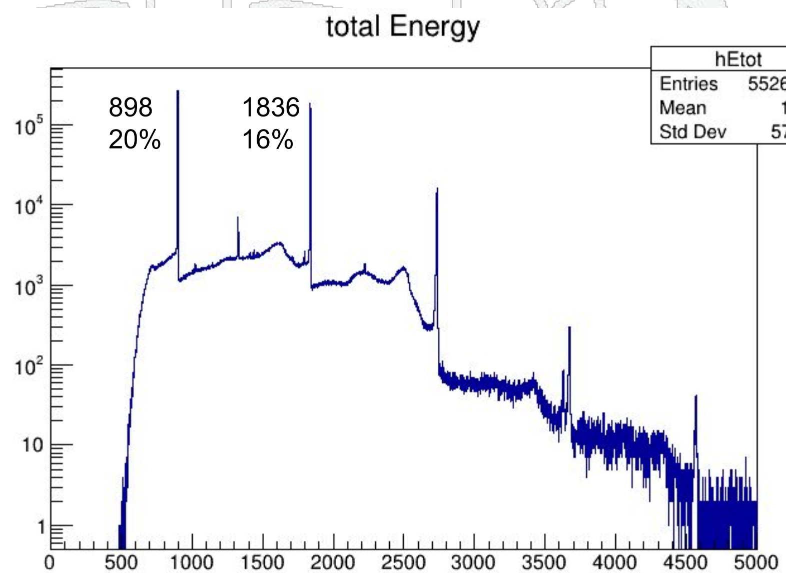


Experiment: source data

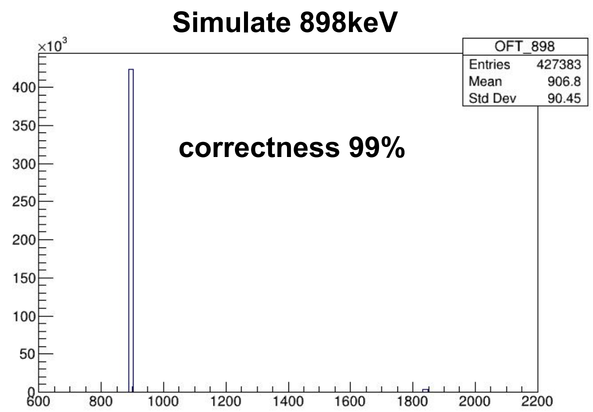


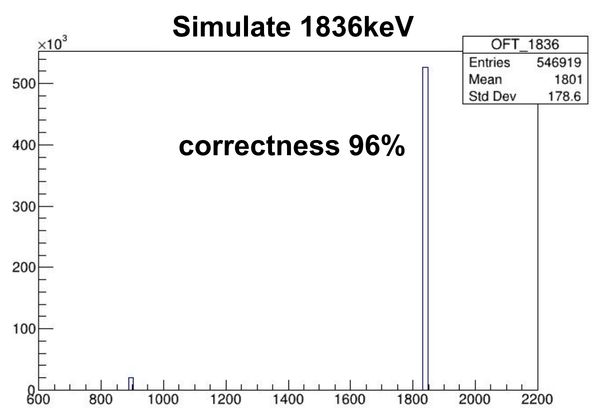
31 active crystals

Incidence gamma energy



Identify incidence energy according to FOM from OFT



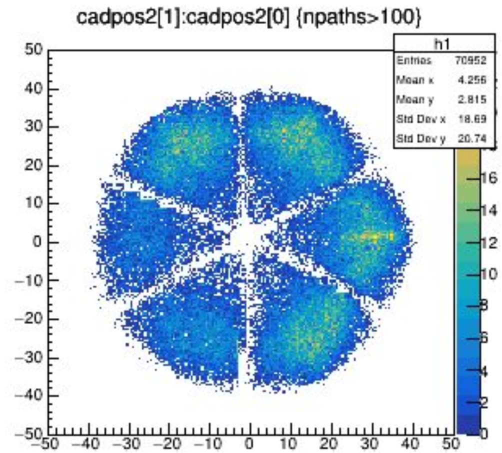


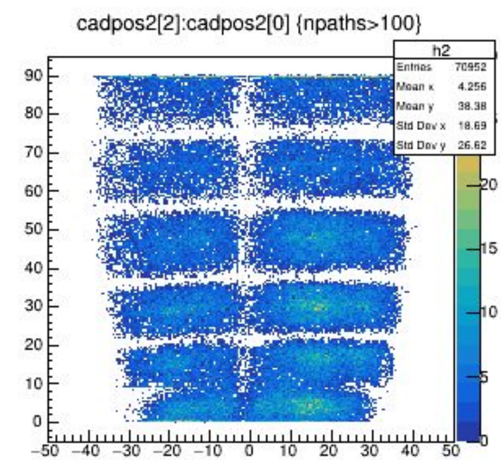
- Events with total energy around 898 and 1836 keV: directly assign incidence energy
- Other events: OFT tracking using segment centra position; Identify incidence energy according to figure of merit from OFT

SelfCalib basis

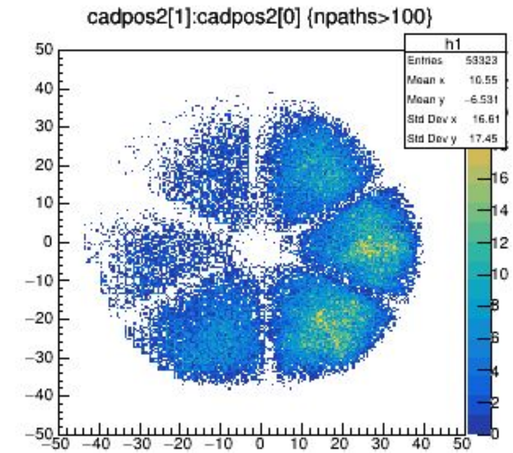
	A	B	C
00	0	1	2
01	3	4	5
02		7	8
04	12	13	14
05		16	17
06	18	19	20
07	21	22	
08	24	25	
09	27	28	29
10	30	31	32
11	33		35
14	42	43	44

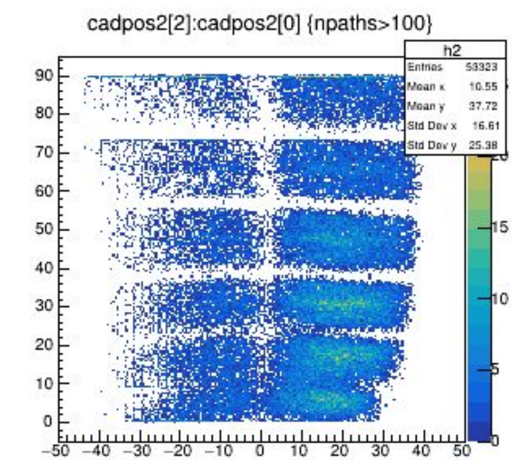
Det0 (00A)



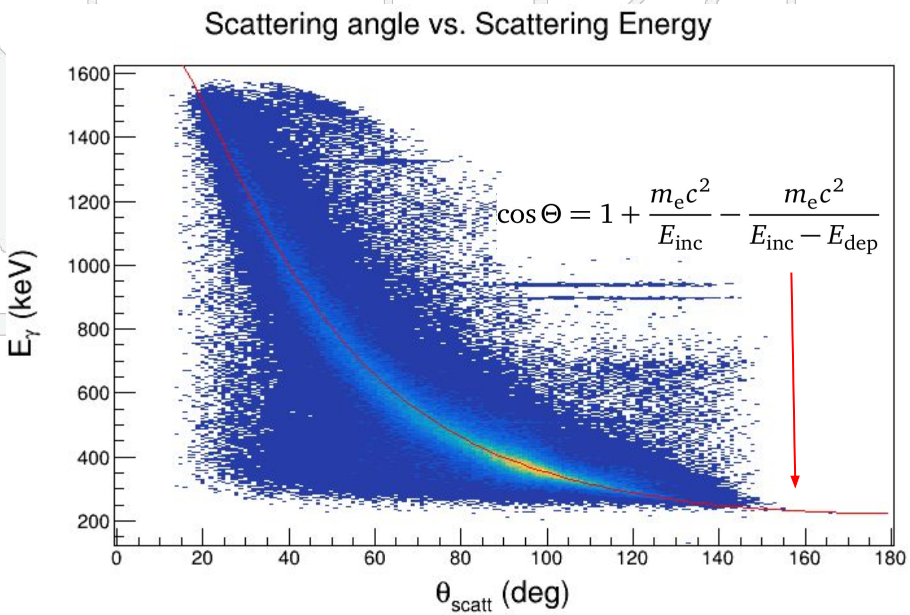


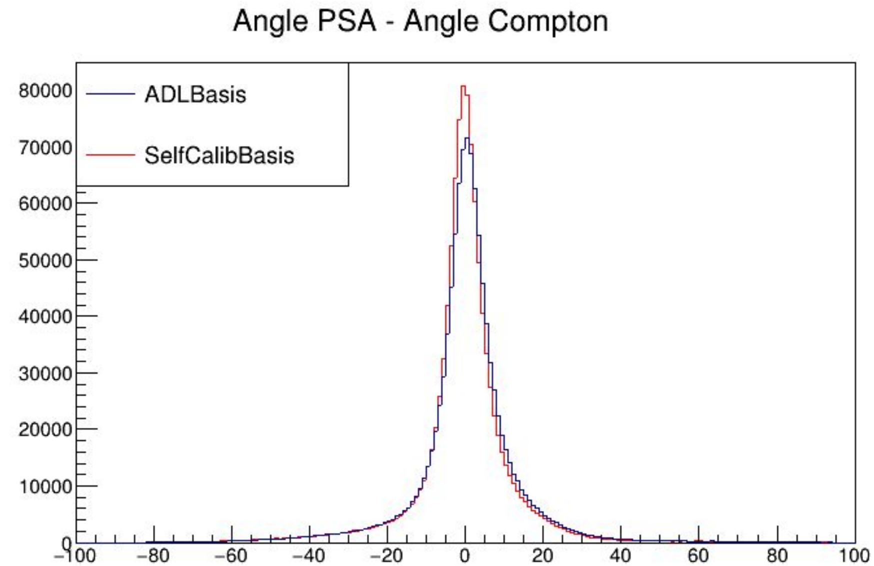
Det31 (10B)

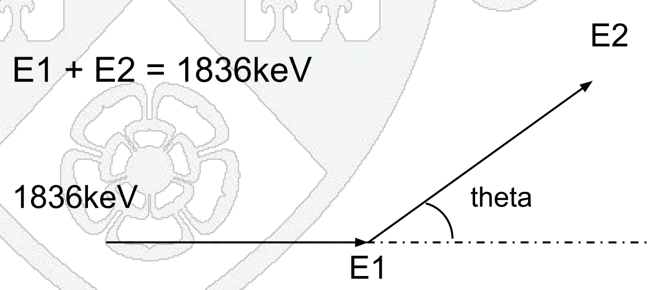




Compton Scattering Angle

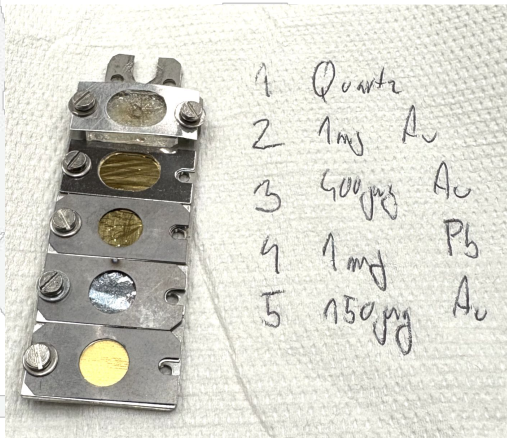


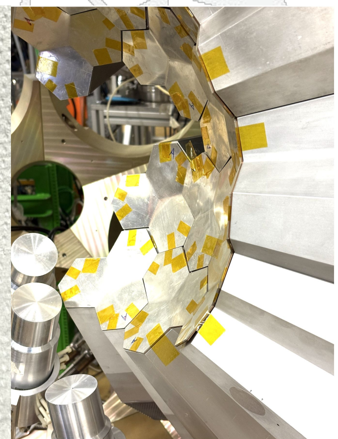


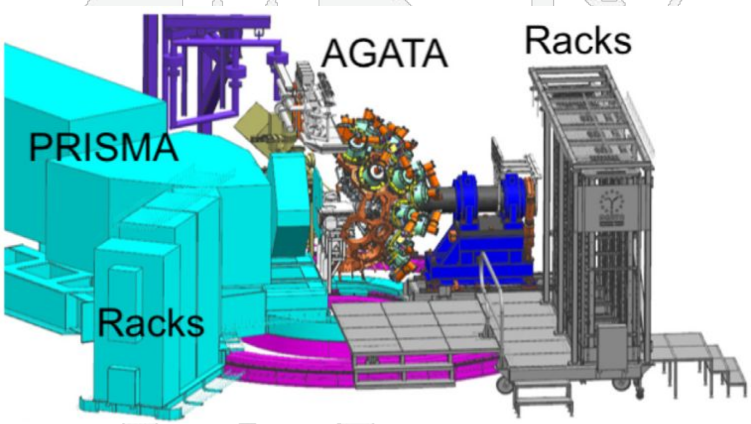


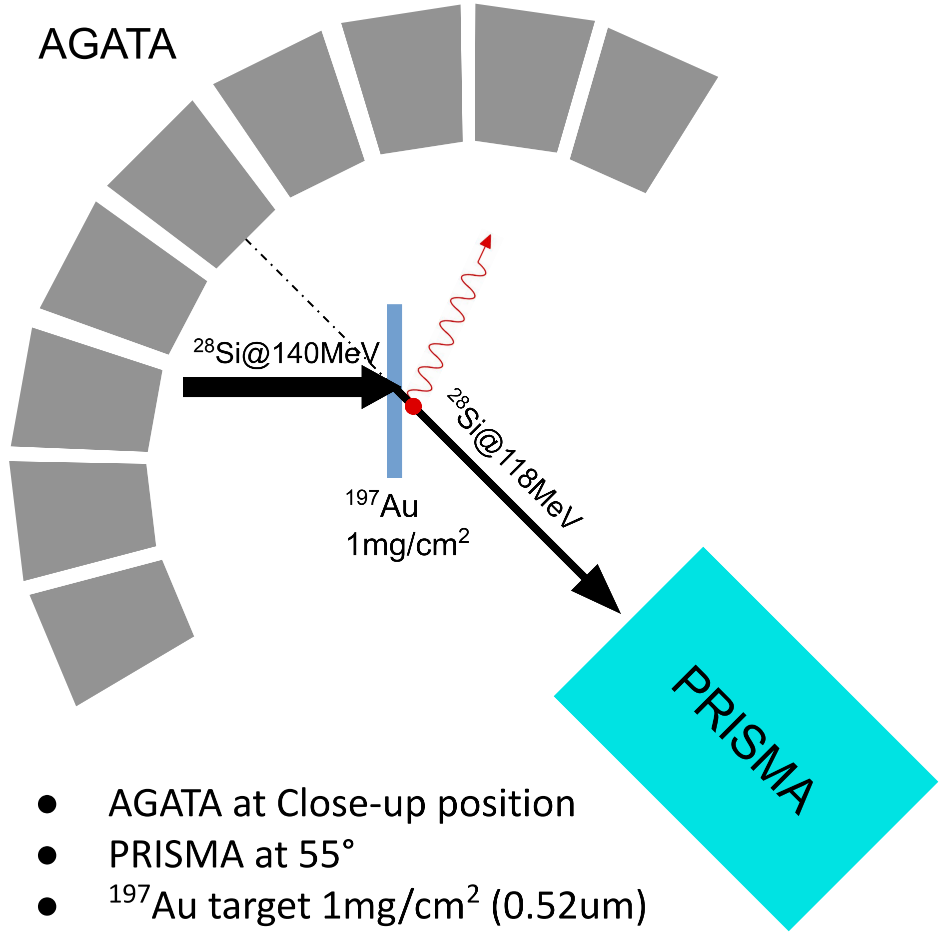
- Compton scattering of 1836keV gamma
- Interaction position from PSA with ADL basis and SelfCalib basis
- Comparing scattering angle from PSA and the Compton angle from energy deposit

Experiment: in-beam data



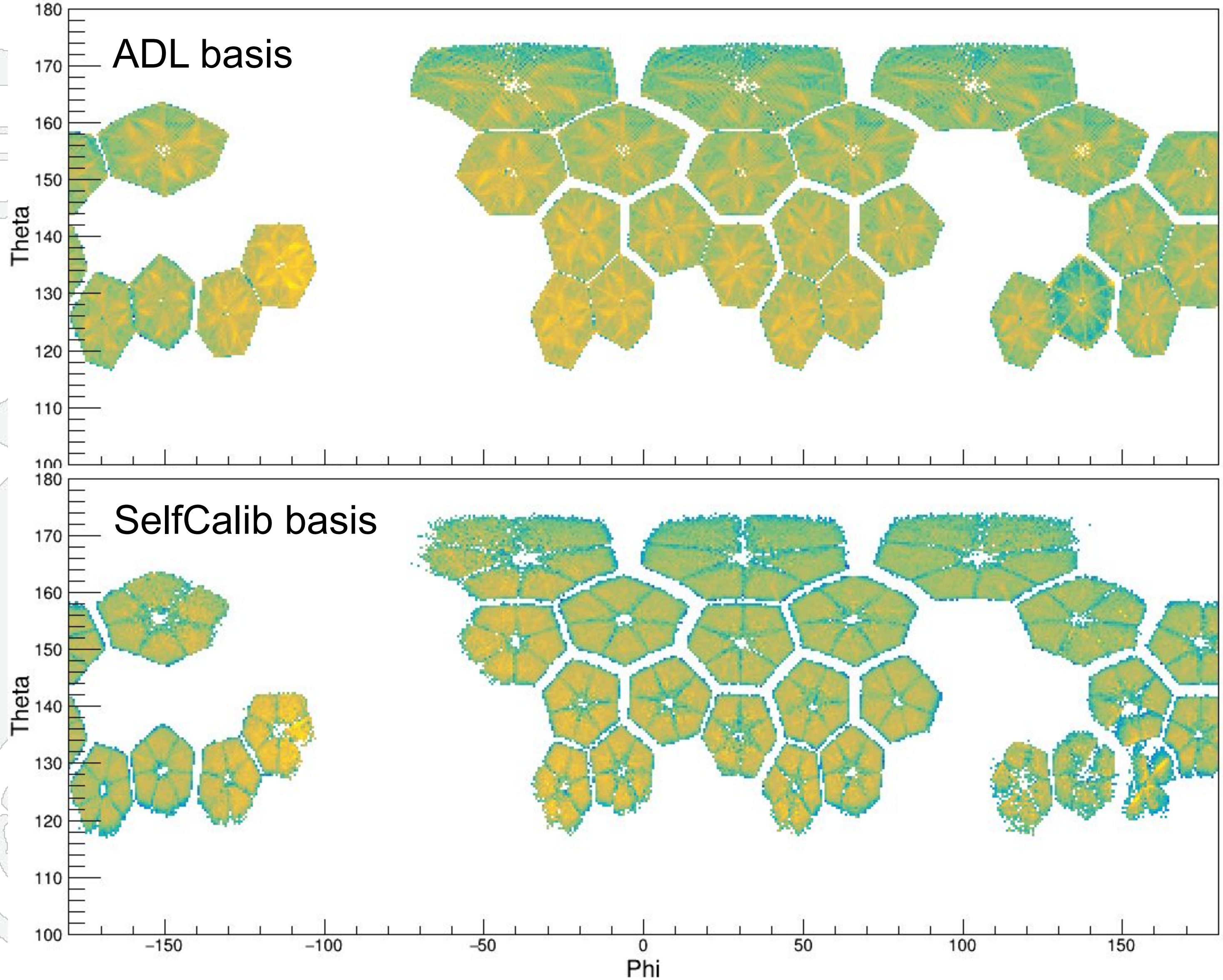






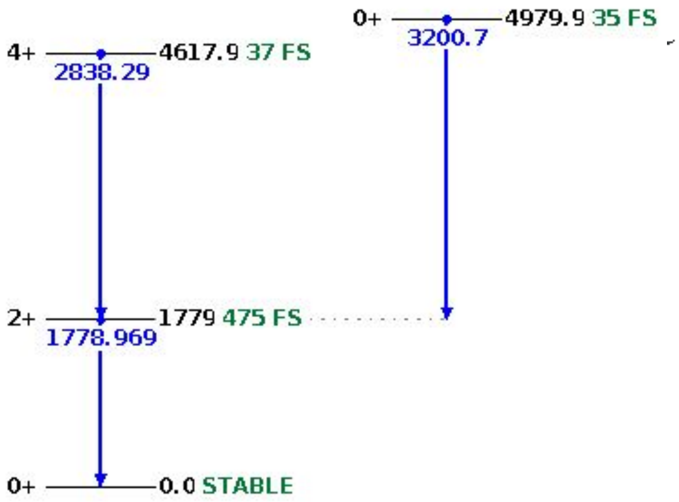
- AGATA at Close-up position
- PRISMA at 55°
- ^{197}Au target 1mg/cm^2 (0.52um)
- ^{28}Si scattered to 55°, 118MeV (β=0.09)
- ^{28}Si 2^+ $t_{1/2}$ = 0.475ps
- 10 – 12 December 2024 (~41h beam on target)

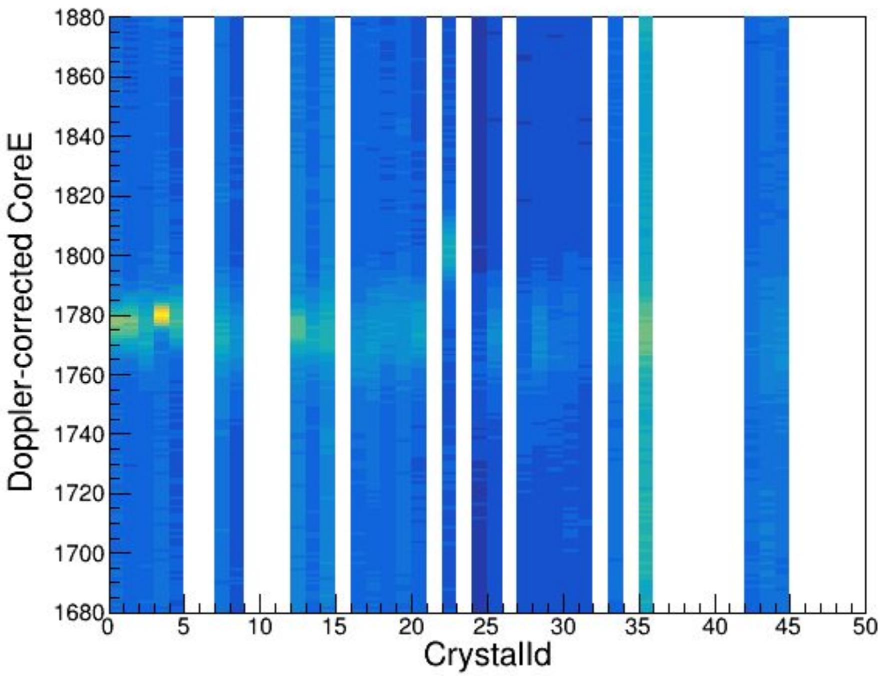
Experiment: in-beam data

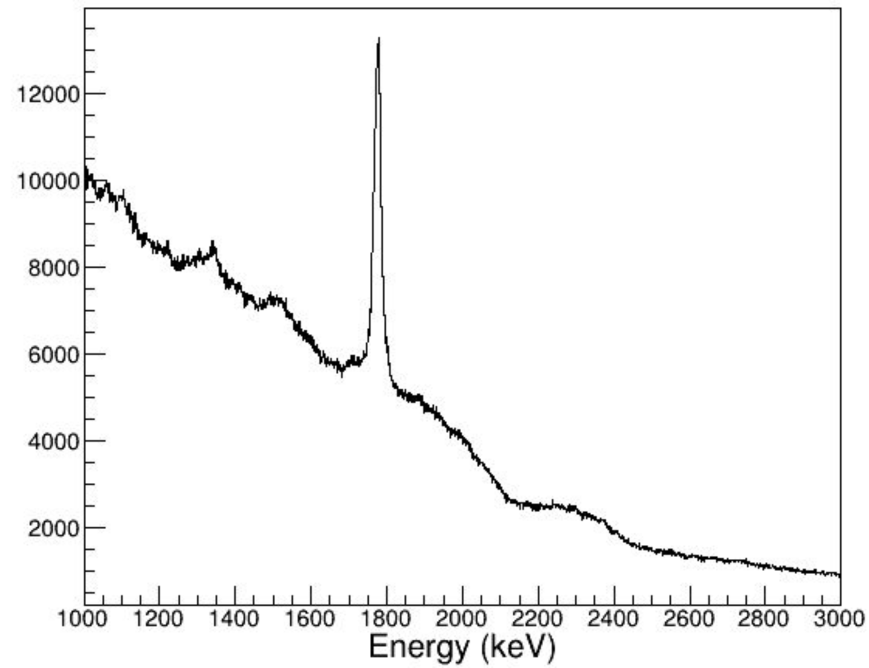


Experiment: in-beam data

- Assume highest-energy-deposit point as first interaction
- Core energy Doppler-corrected with
  - fixed velocity (β=0.095)
  - ZeroDegree Beam direction







Summary

- Self-calibration technique is developed with AGATA simulation data with pulse shape
- Self-calibration data taken with ~540kBq ^{88}Y source
- In-beam data obtained using ^{28}Si on Au target, clear 2^+ peak observed
- self-calibration basis generated from source calibration data looks promising
- Analyse in-beam data using ADL basis and self-calibration basis

Next steps

- perform PRISMA analysis
- Doppler-correction with OFT tracking

Collaboration

S. Chen[1], S. Paschalis[1], M. Petri[1], M. Bentley[1], M. Labiche[2], F. Holloway[3], L. Harkness-Brennan[3], A.J. Boston[3], J.J. Valiente Dobón[4], M. Rocchini[5], A. Goasduff[4,6,7], R.M. Pérez-Vidal[4], D. Kalaydjieva[8], K. Stoychev[8], N. Marchini[9], M. Zielińska[10], A.O. Macchiavelli[11], I.Y. Lee[12], J. Dudouet[13]

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Thank you for your attention