AGATA detector characterisation

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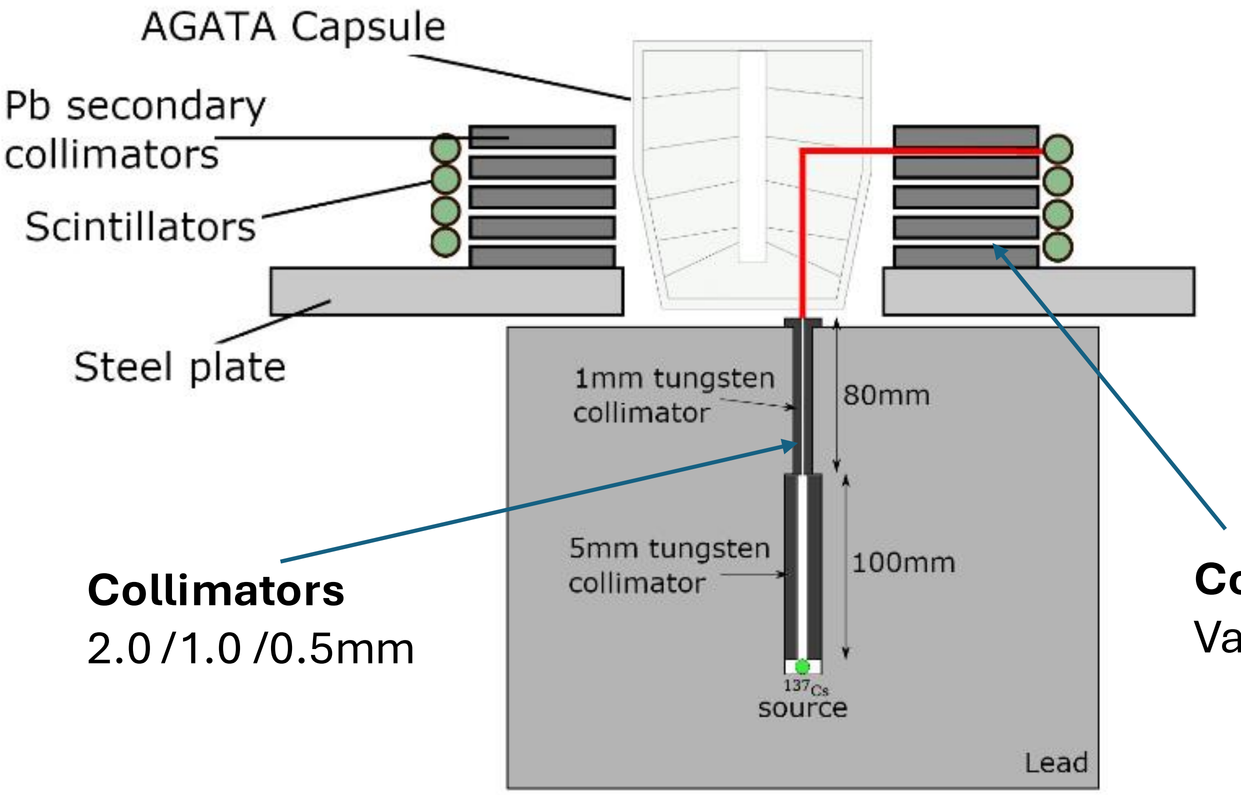
Overview

- Scanning techniques used in the Agata collaboration
- Validation of techniques
- Recent / ongoing characterisation in the labs
  - Liverpool
  - Strasbourg (IPHC)
  - Salamanca / GSI
- (Brief update on neural network basis generation - Jérémie Dudouet, CNRS Lyon)

Scanning methodologies

- Different scanning methodologies used at different labs within the collaboration
- **Liverpool + Orsay** – coincidence scanning with collimated gamma-ray beams



Collimators
2.0 /1.0 /0.5mm

Collimators
Variable

Very precise
Simple data analysis
Accurate t_0 from scintillators
Very slow (several months)

Sources
^{241}Am (60 keV)*
^{57}Co (121 keV)*
^{137}Cs (662 keV)
* surface scanning only

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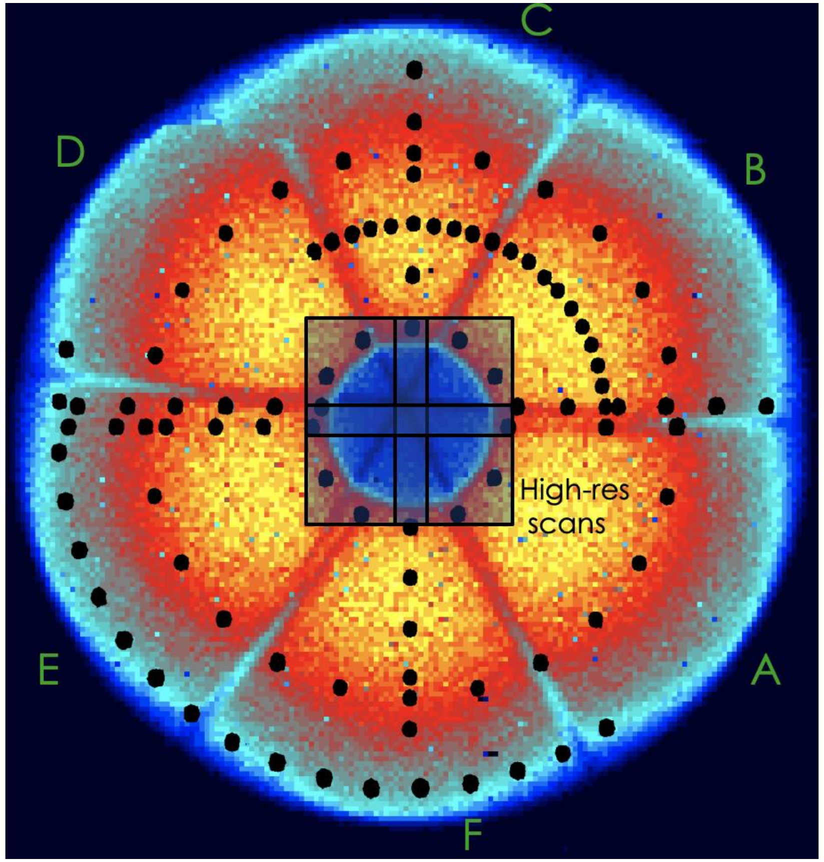
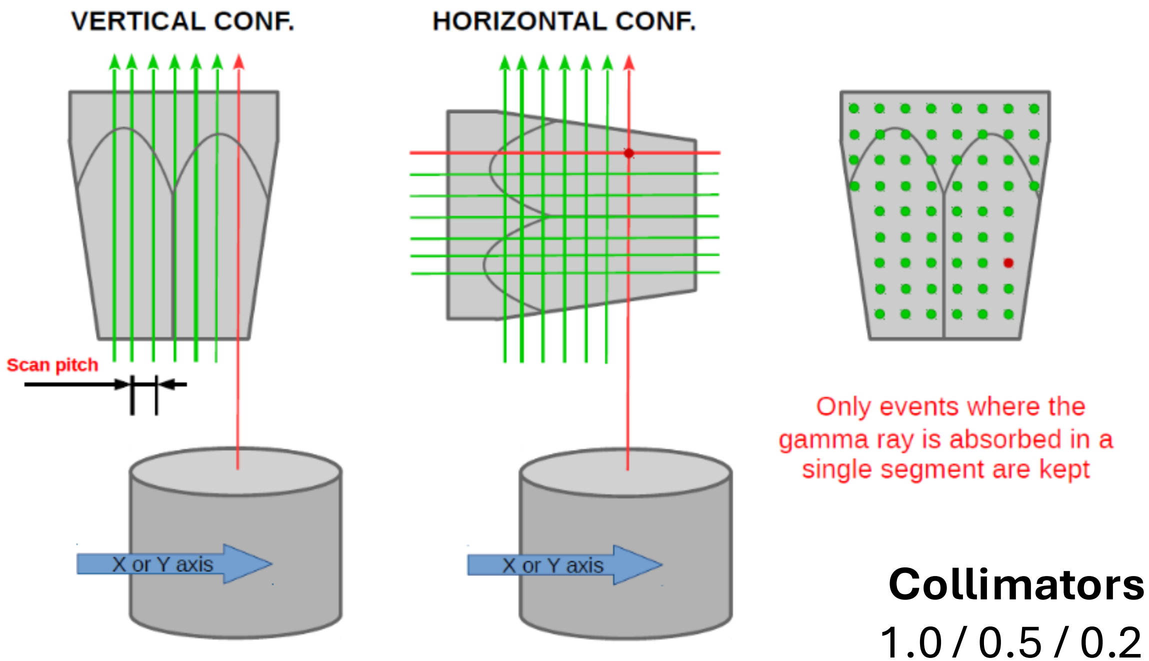


Very precise
Simple data analysis
Accurate t_0 from scintillators
Very slow (several months)
Only subset of positions can be measured

Sources
^{241}Am (60 keV)*
^{57}Co (121 keV)*
^{137}Cs (662 keV)
* surface scanning only

Scanning methodologies

- Different scanning methodologies used at different labs within the collaboration
- **Liverpool + Orsay** – coincidence scanning with collimated gamma-ray beams
- **IPHC** – Pulse Shape Comparison Scan with collimated gamma-ray beams



Collimators
1.0 / 0.5 / 0.2 mm

Much faster (several weeks)
Characterise full volume of detector
Different gamma energies

Complicated data analysis
Difficulties determining t_0 from Ge signal alone

Sources
^{241}Am (60 keV)
^{137}Cs (662 keV)
^{152}Eu (122 keV to 1408 keV)

B. De Canditiis, PhD, Univ. Strasbourg, 2020

Scanning methodologies

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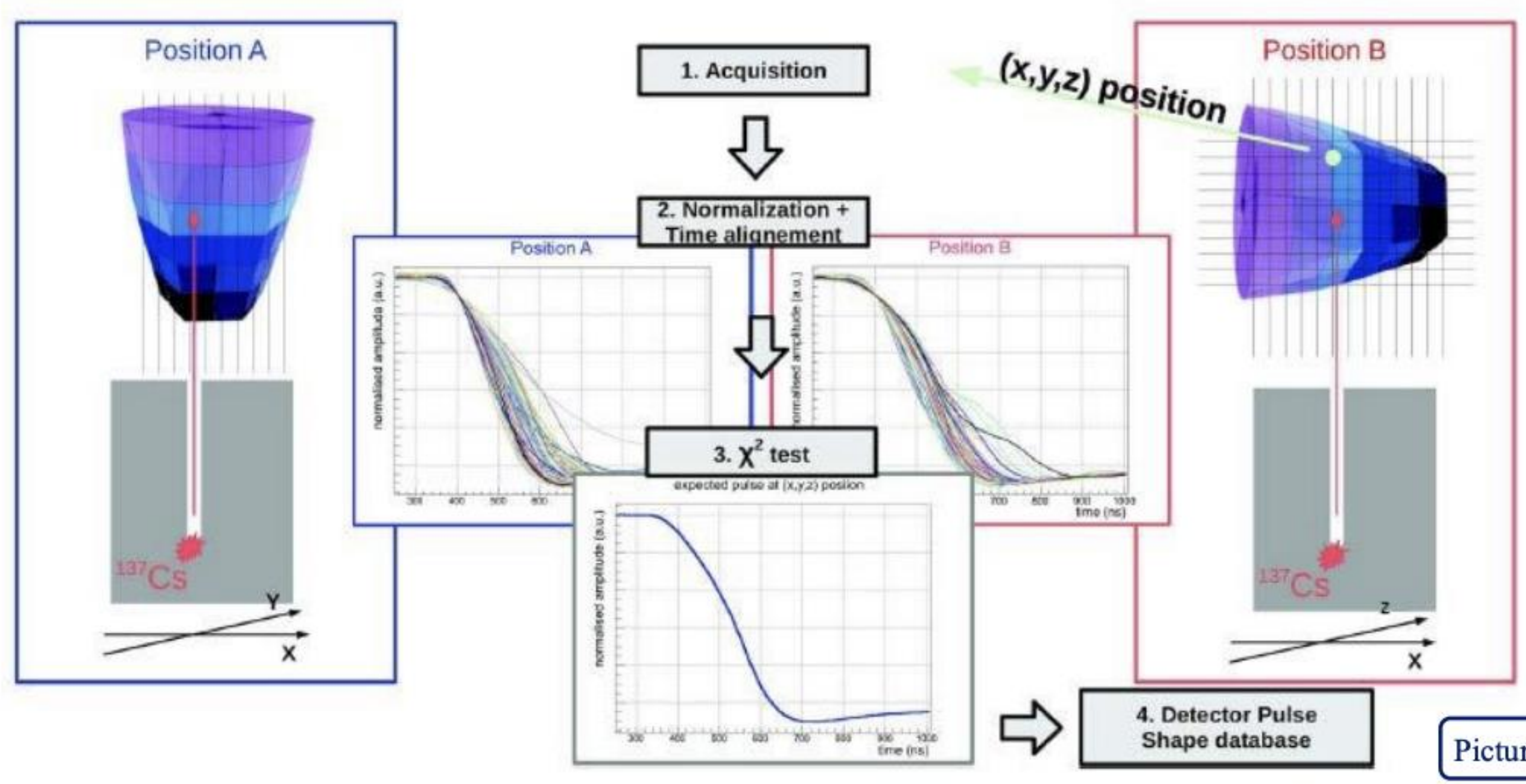

Picture from Michael Ginsz's PhD thesis

Much faster (several weeks)
Characterise full volume of detector
Different gamma energies

Complicated data analysis
Difficulties determining t_0 from Ge signal alone

Scanning methodologies

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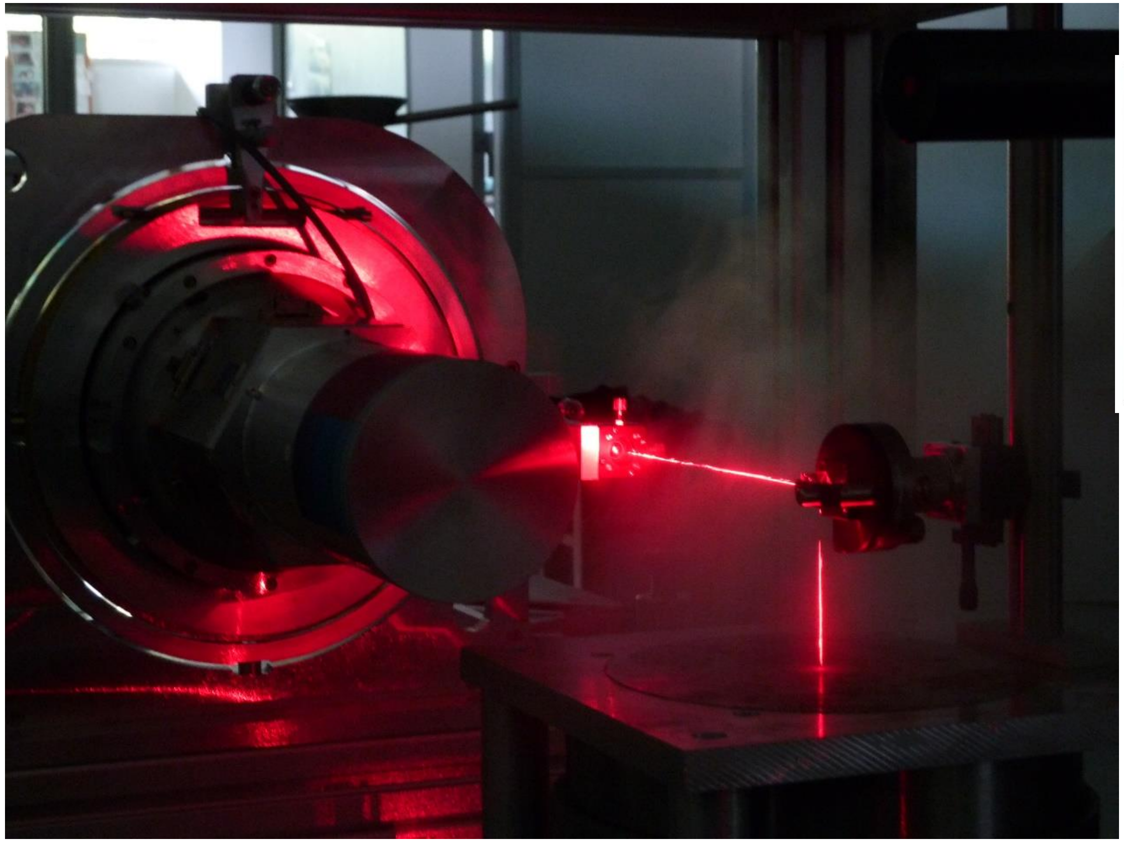
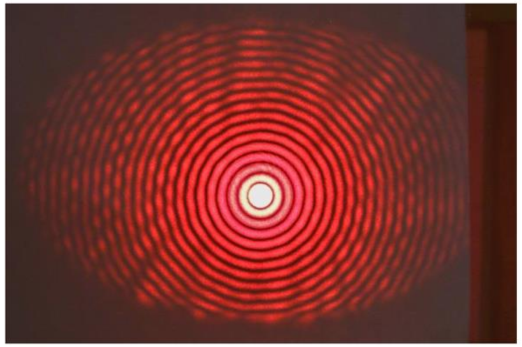


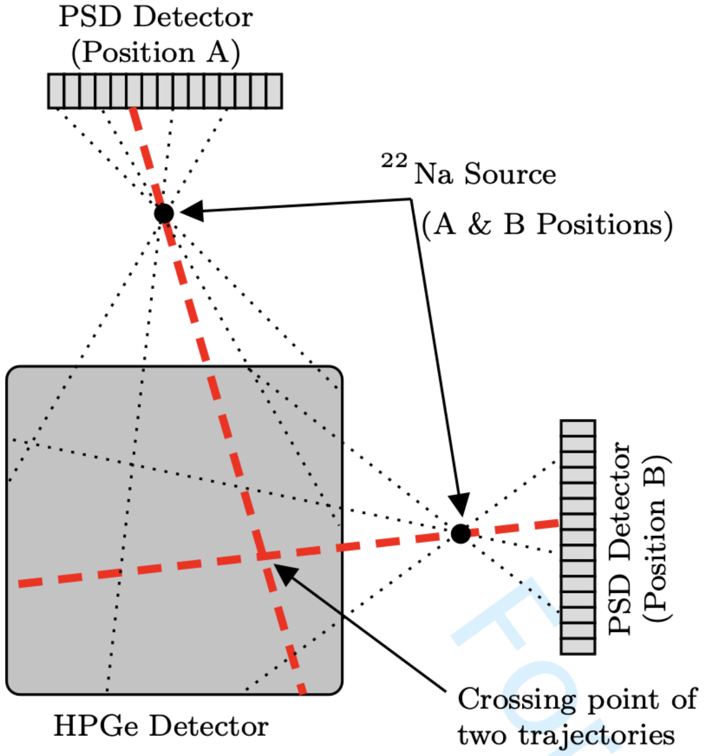


Much faster (several weeks)
Characterise full volume of detector
Different gamma energies

Complicated data analysis
Difficulties determining t_0 from Ge signal alone
Requires very precise alignment

Scanning methodologies

- Different scanning methodologies used at different labs within the collaboration
- **Liverpool + Orsay** – coincidence scanning with collimated gamma-ray beams
- **IPHC** – Pulse Shape Comparison Scan with collimated gamma-ray beams
- **Salamanca + GSI** – Pulse Shape Comparison Scan with electronic collimation



Faster still (days / weeks)

Much more complicated data analysis / potential for errors

Colimators

Electronic

POI in Agata σ ~2.0 mm *

Sources

^{22}Na (511 keV)

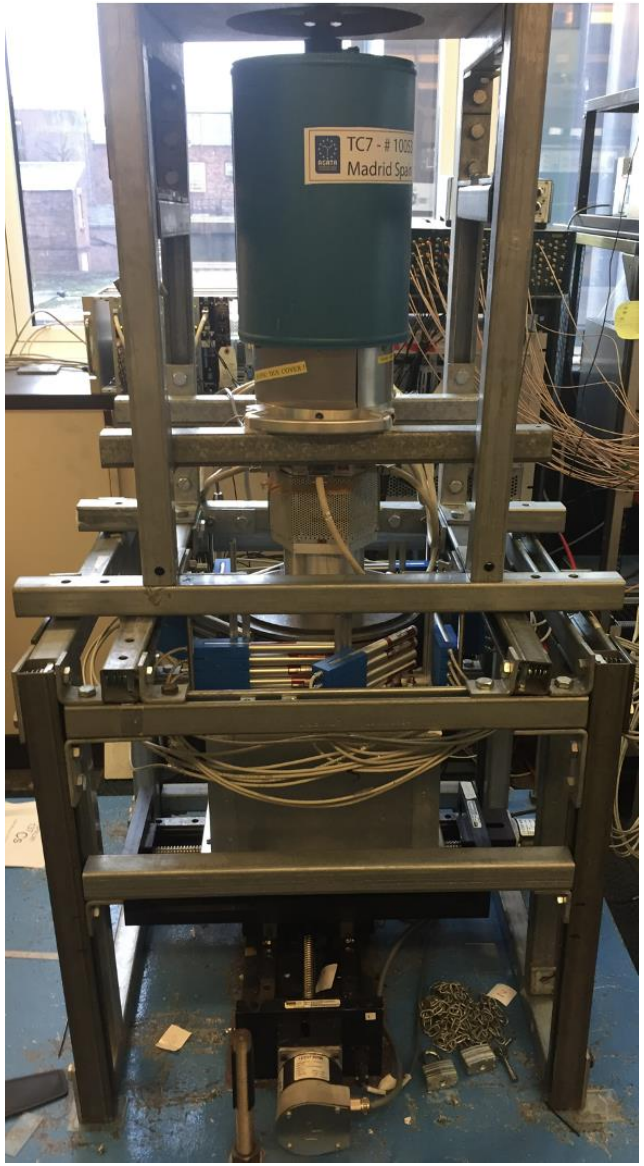
* https://doi.org/10.1016/j.nima.2016.03.103

Global pros and cons of each technique

	Liverpool	Strasbourg	GSI	Salamanca
Single interaction	90%	50% or gate on Compton edge	gate on Compton edge	gate on Compton edge
Speed	Slow ~ 3 months	Rather fast 8 days + ~2 weeks alignments	Fast Few days	Fast Few days
Voxel size (mm^3)	X,Y ~ 1.5 – 2.8 Z ~ 2.0 - 6.0 mm	Pos1 = 13, Pos2 = 11 Pos1’ = 14, Pos2’ = 16 Pos3 = 3,6, Pos4 = 3,2 Crossing accuracy ~0.5 mm	? Depends on POI	~ 2.0 mm Depends on POI
Database	1200 points	^{137}Cs and ^{152}Eu databases ~48000 points	511 keV database	511 keV database
Sources	^{241}Am, ^{57}Co, ^{137}Cs	^{241}Am, ^{137}Cs, ^{152}Eu	^{22}Na	^{22}Na
Tomography	No	Yes	?	?
t_0	Scintillators	Germanium	Scintillators	Scintillators
Monitoring	Quasi on-line	Quasi on-line	On-line	On-line
Type of scan	Hardware	Hardware	Software	Software

Validation of scanning methodologies

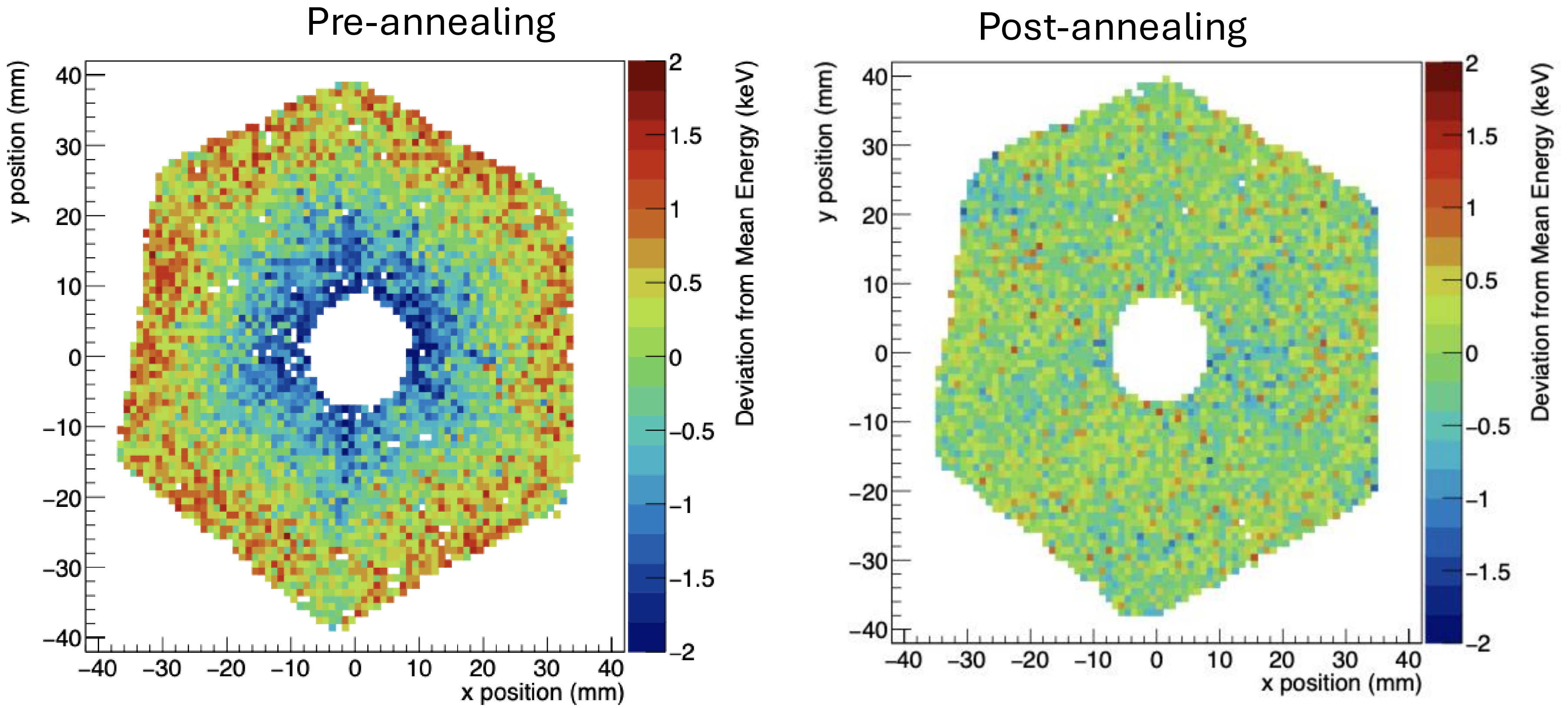
- Each lab has different set ups, cryostats, digital electronics
  Caen V1724, TNT2, Febex, Digi-Opt12 (Agata)
- Do these different equipment + techniques give directly comparable results?
- A005 capsule is currently being used to validate each method/setup is consistent with each other
- Scanning same positions within detector at each lab
- Mounted in Madrid test cryostat for all measurements
- Scanned at Liverpool using Coincidence technique and IPHC using PSCS
- Currently at GSI before going to Salamanca for PSCSec



Current / recent work

Liverpool

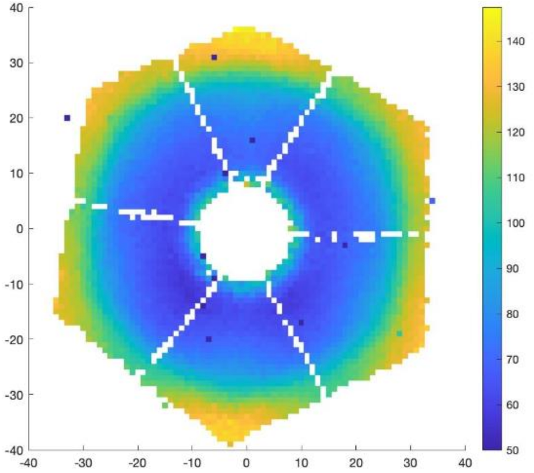
- Coincidence scans of capsules A005, neutron damaged A009 (before and after annealing) and C017

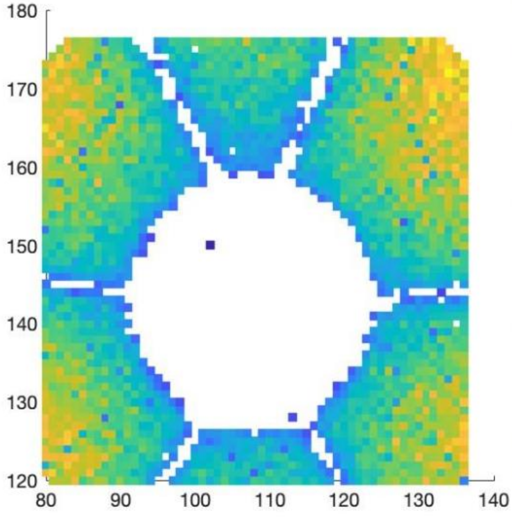


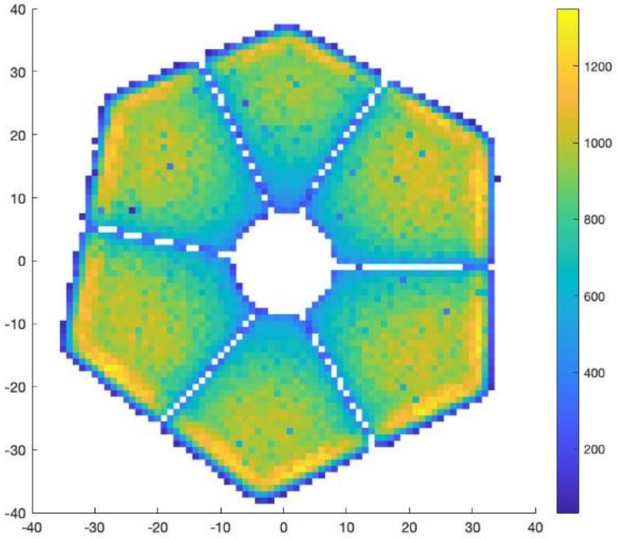
C. Everett
In preparation for submission to NIM A

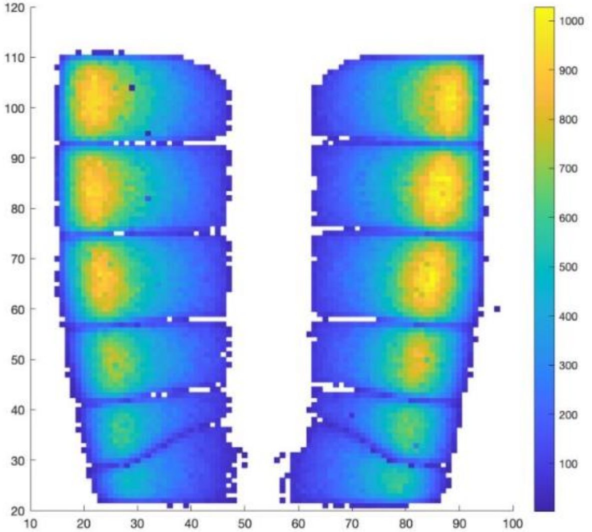
Liverpool

- Coincidence scans of capsules A005, A009 (before and after annealing) and C017
- Scanned A601, in preparation for neutron damage study (see Chris Everett's talk)





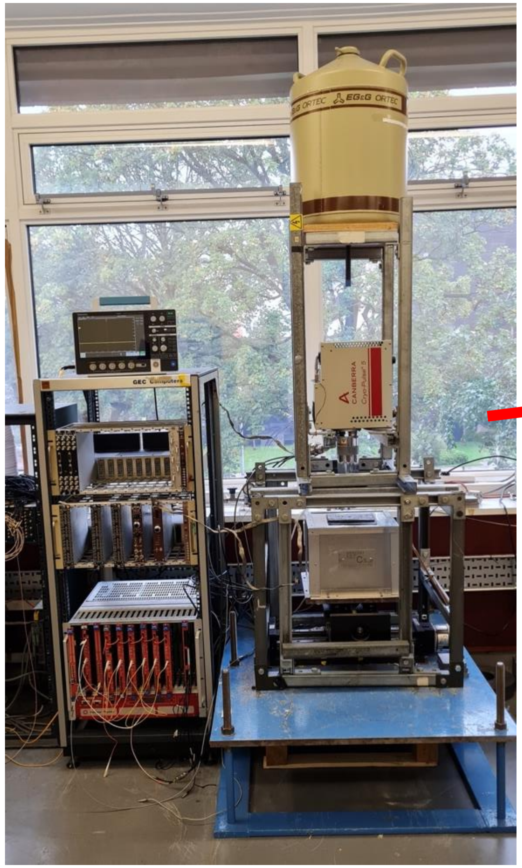


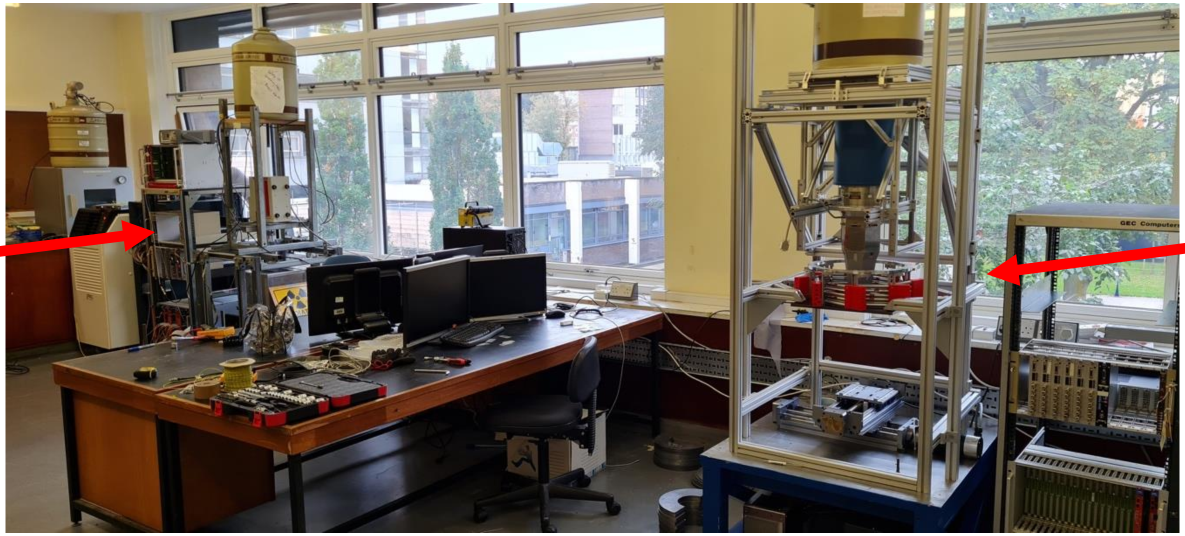


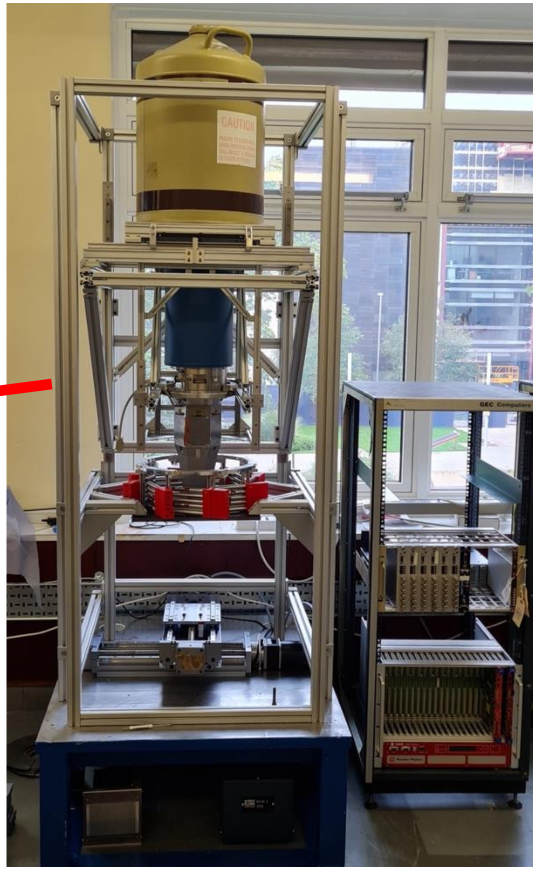
Current / recent work

Liverpool

- Coincidence scans of capsules A005, A009 (before and after annealing) and C017
- Scanned A601, in preparation for neutron damage study (see Chris Everett's talk)
- Commissioning new lab and scanning table



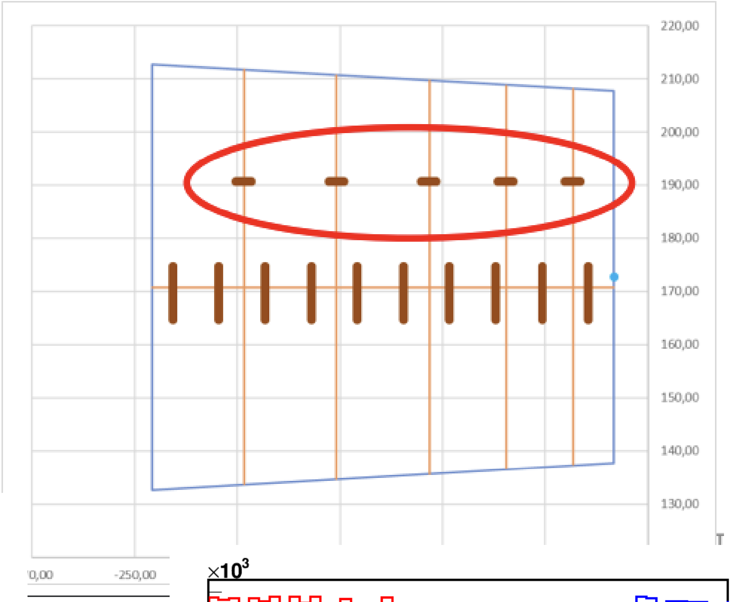




Current / recent work

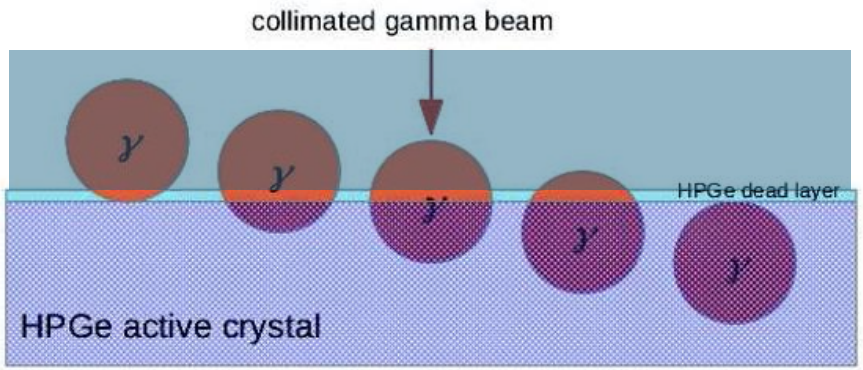
IPHC

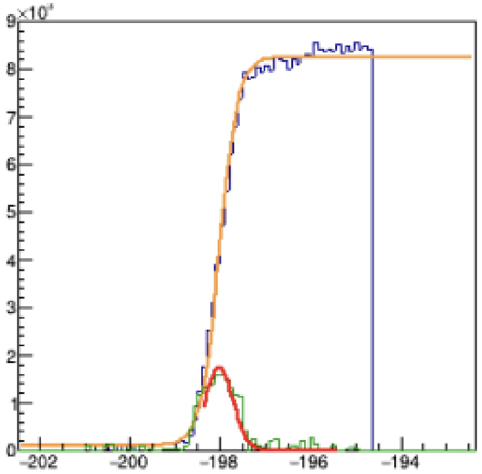
- Coincidence and detailed scans of A005 around segment boundaries at request of PSA team to determine exact size

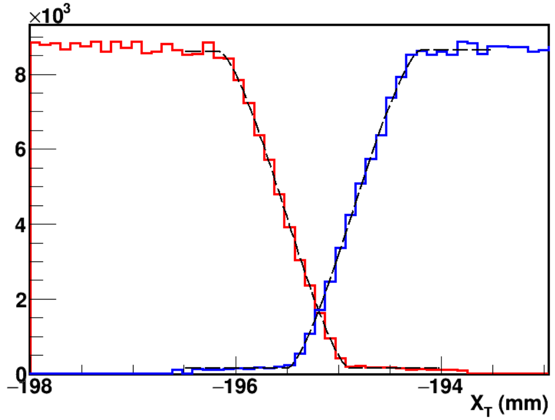


❑ Classical method

- Am horizontal (H) scans across segmentation BC
  - 10 scans of 10 mm length each, 5 < z < 86 mm
- Am H scans across slices
  - 5 scans of 4 mm length each, for z = 8, 21, 36, 54, 72 mm
- Fit with Wood-Saxon function







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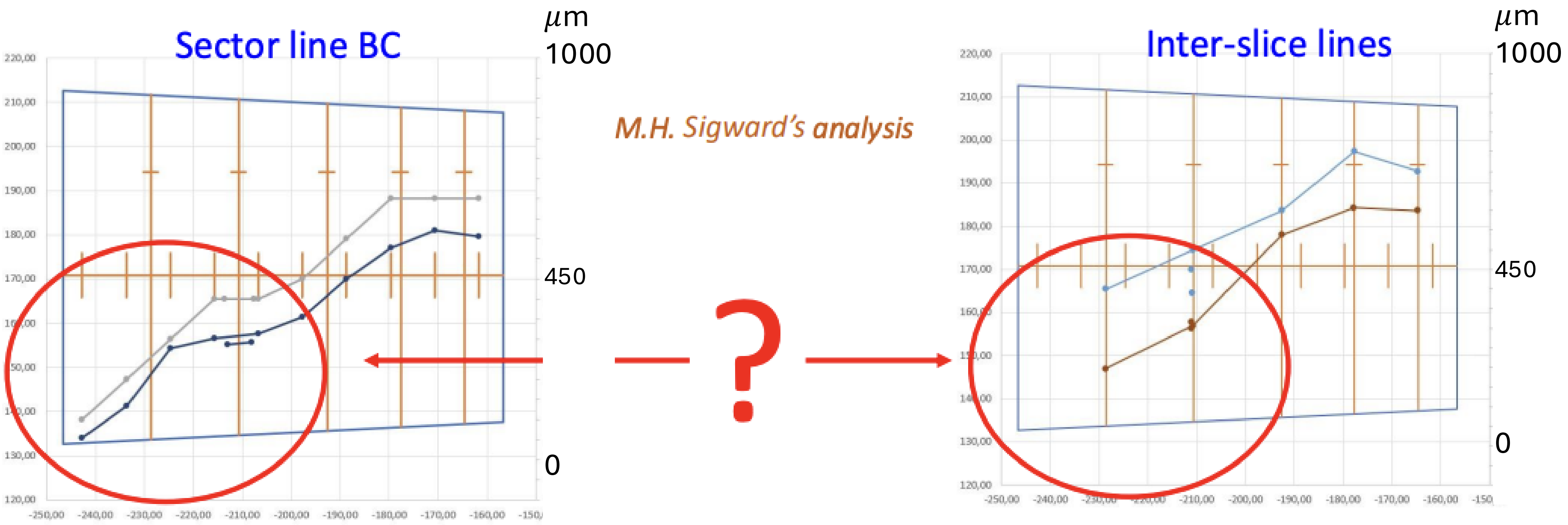
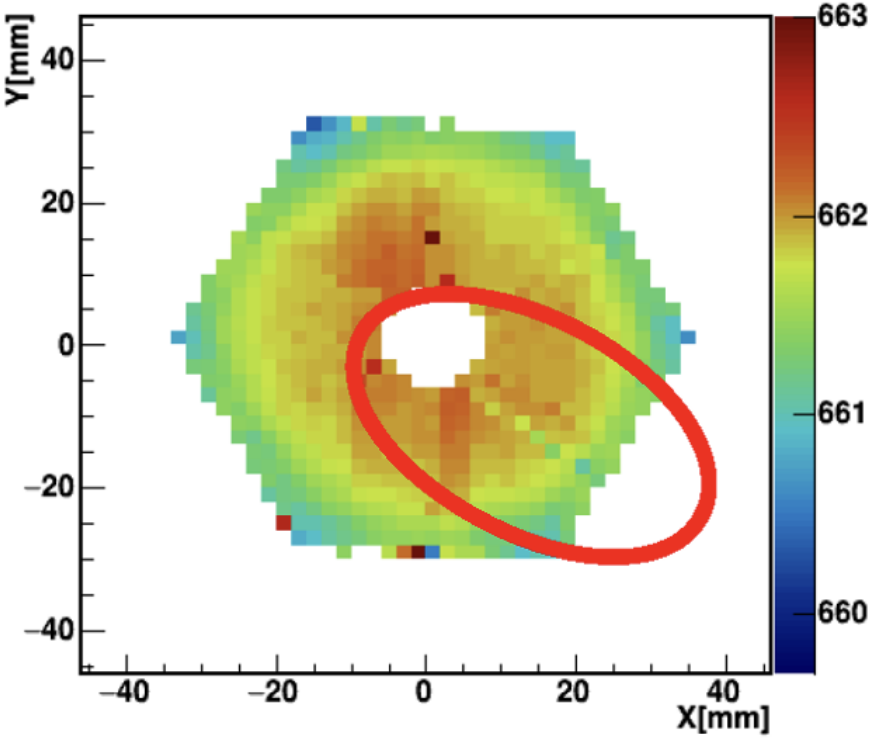


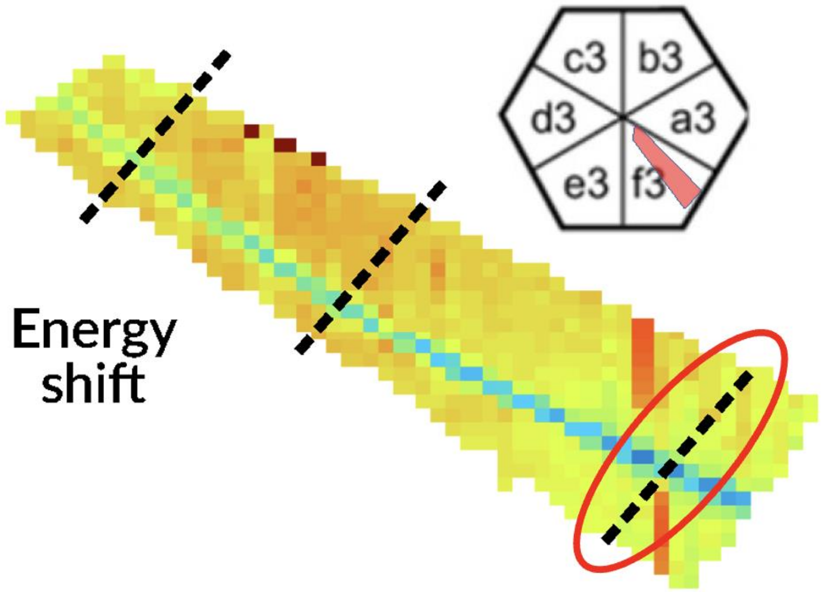
- Should be 500um (confirmed by Mirion) Why measured so small at rear of capsule?

IPHC

- Study of localized charge trapping in S001



B. De Canditiis, PhD, Univ. Strasbourg, 2020



M. Moukaddam's analysis

Electron trapping
Very localised trapping line – width ~460 µm
Extension along z from slice 2 to 4 (~ 30 mm)

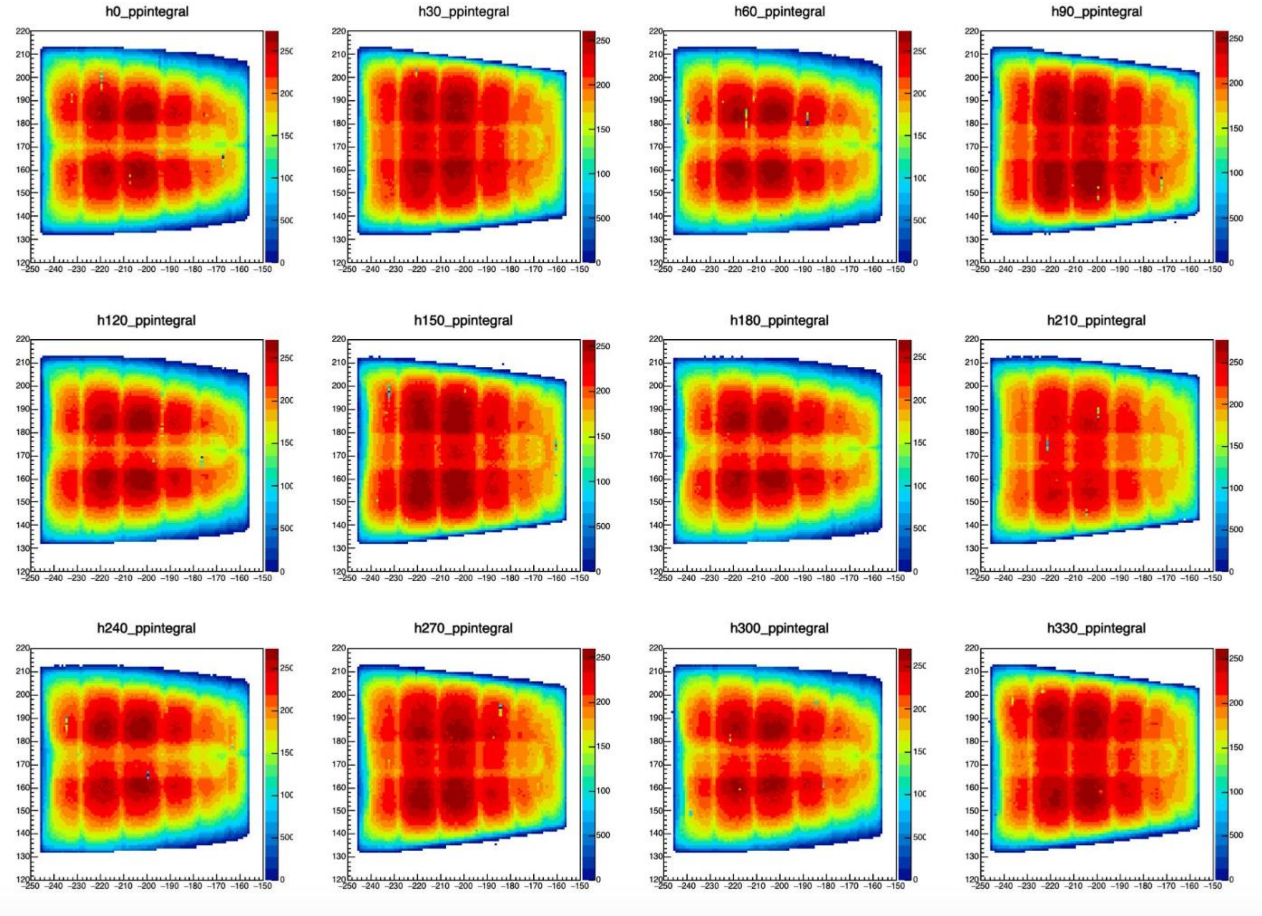
What could explain such a behaviour?

Likely a cleavage plan / crack

A005 Tomography

IPHC

- Ability to accurately reposition detectors between scans means tomographic imaging of the detector is possible - 30-degree rotation between scans



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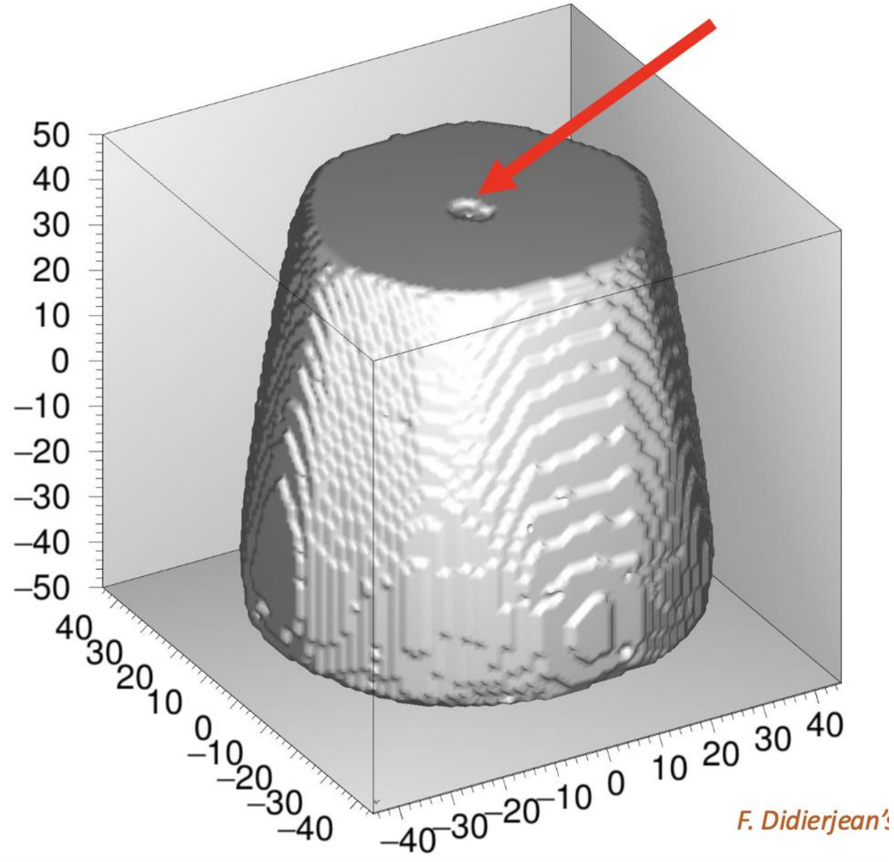
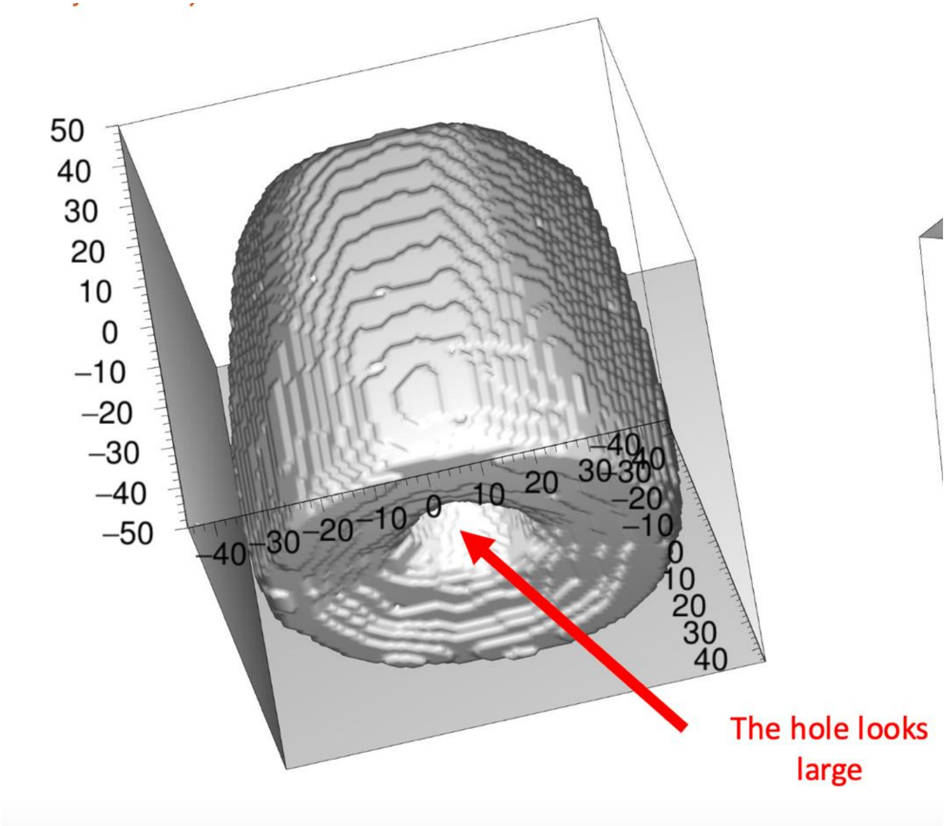




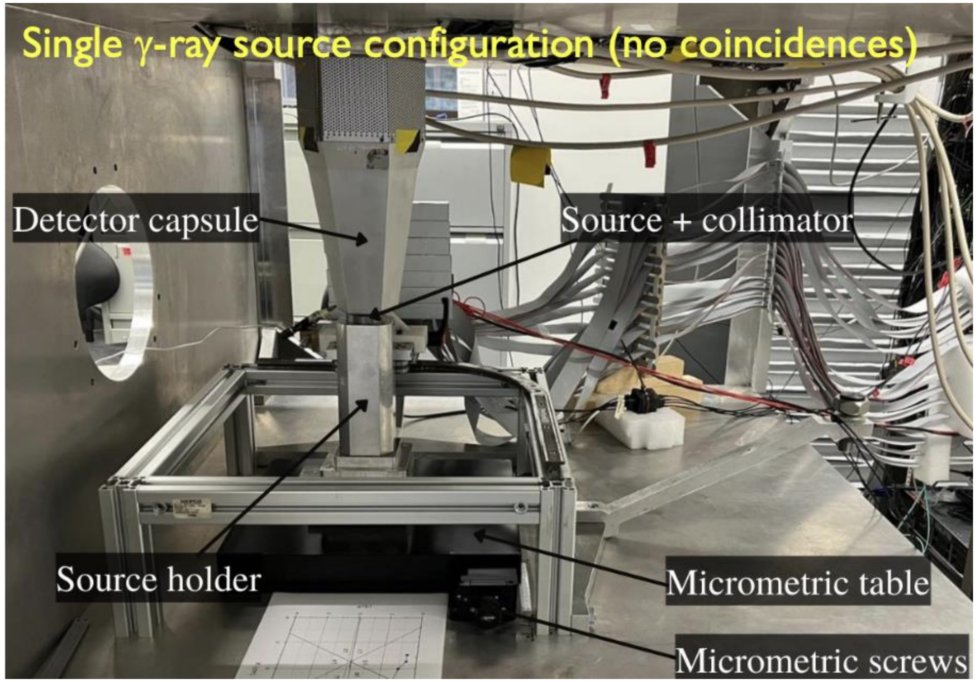
Current / recent work

GSI

- Taken delivery of A005, setting up for PSCSec scan

Salamanca

- Using B003 to set up and commission Agata system before A005 is scanned
- Developing new machine learning algorithm for PSC

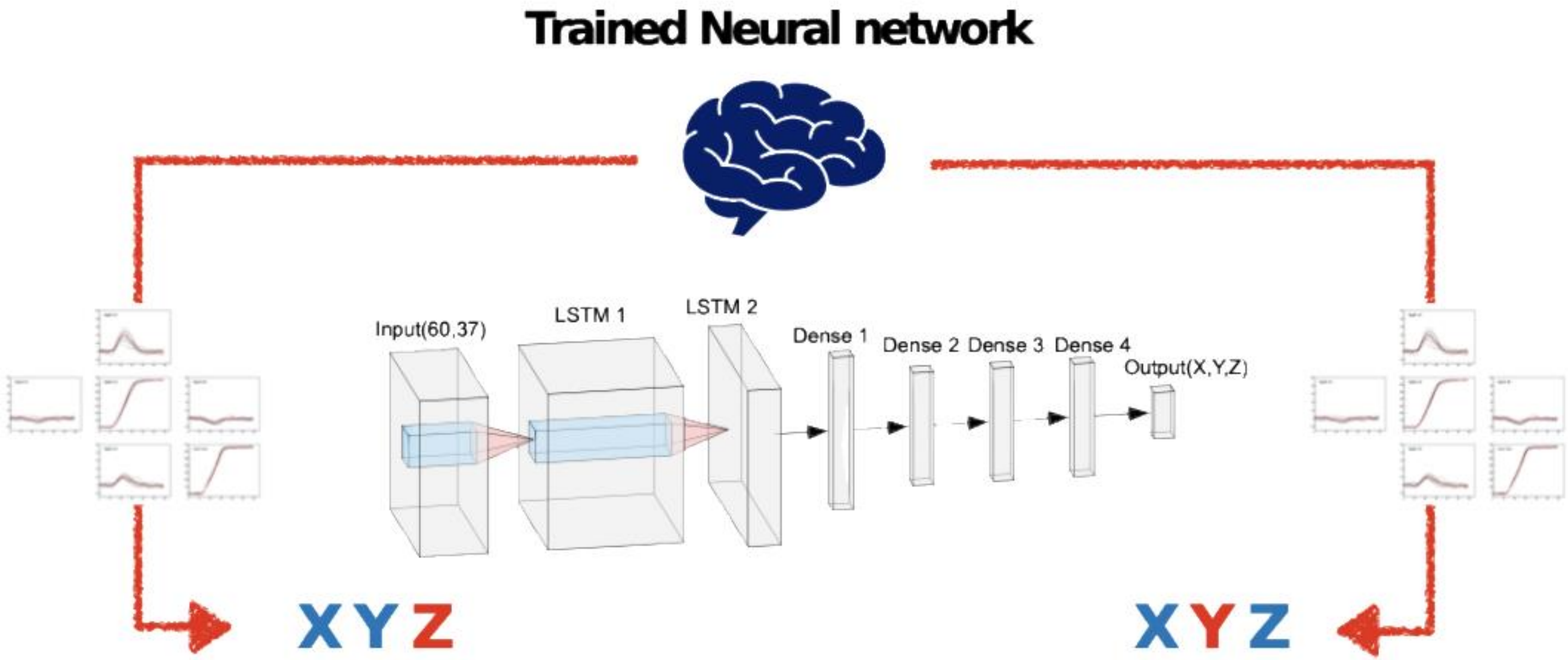


A005 analysis - Neural network basis

New method proposed @ IP2I based on neural networks

Jérémie Dudouet: j.dudouet@ip2i.in2p3.fr

- 2 Long short-term memory (LSTM) layers were used as starting point.
  - ➥very robust against time misalignment
- 4 dense layers are added to obtain a 3D output (X,Y,Z)
- The loss function is calculated only for the two known axes
  - ➥ this allows the network to learn patterns of each dataset without affecting the other.



A005 analysis - Neural network basis

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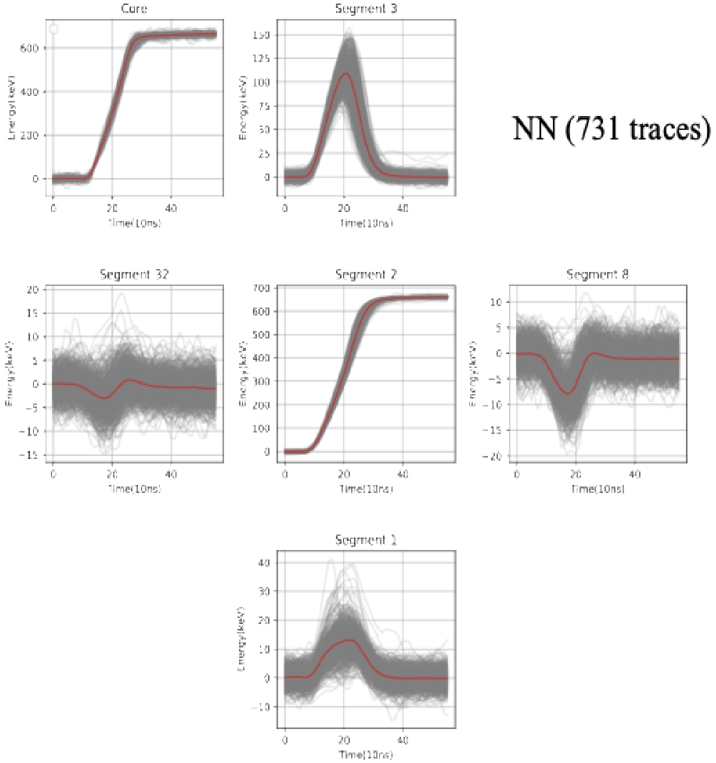
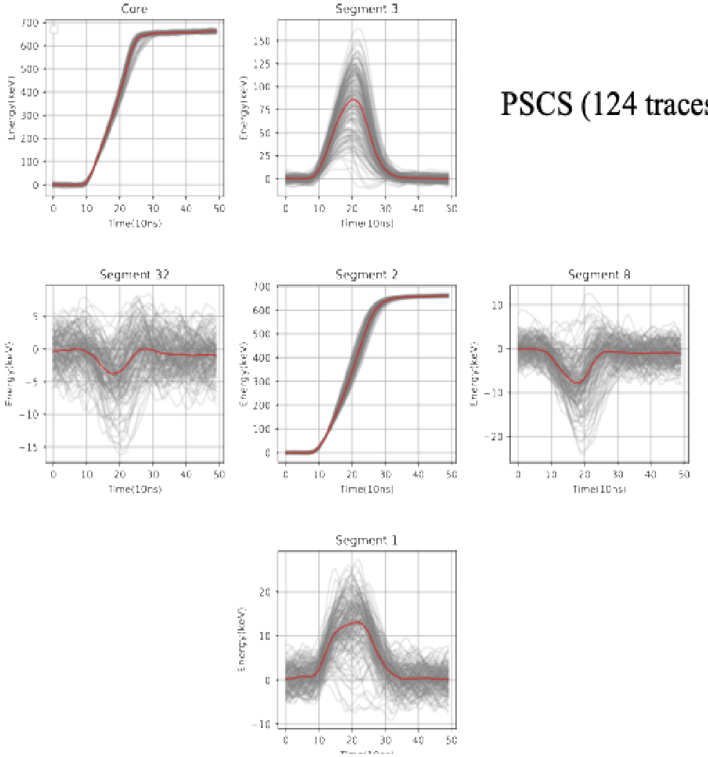
- Average trace between Neural network and PSCS looks similar but more statistics and less fluctuations in NN

Traces predicted at position (22,0,34) in segment 2



NN (731 traces)



PSCS (124 traces)

A005 analysis - Neural network basis

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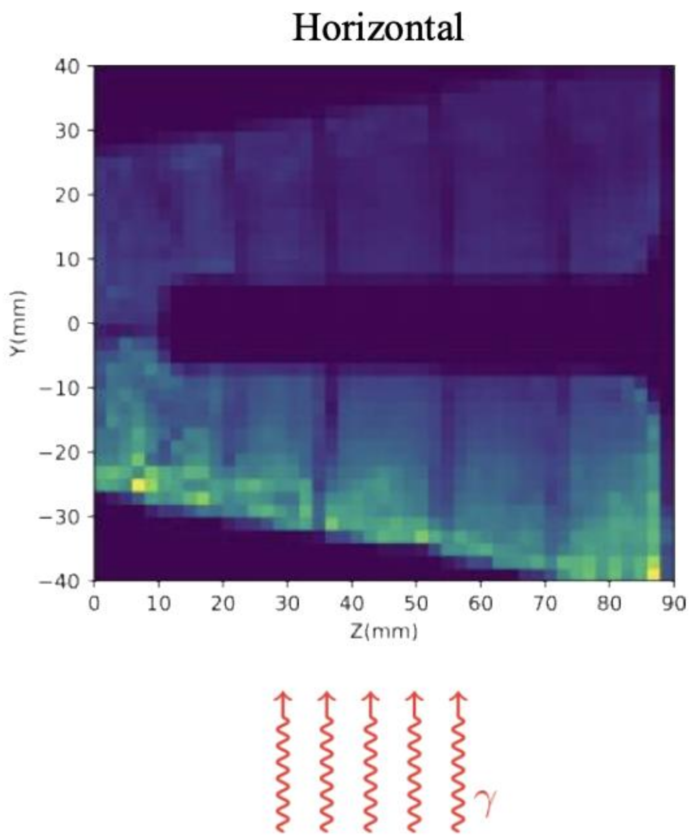
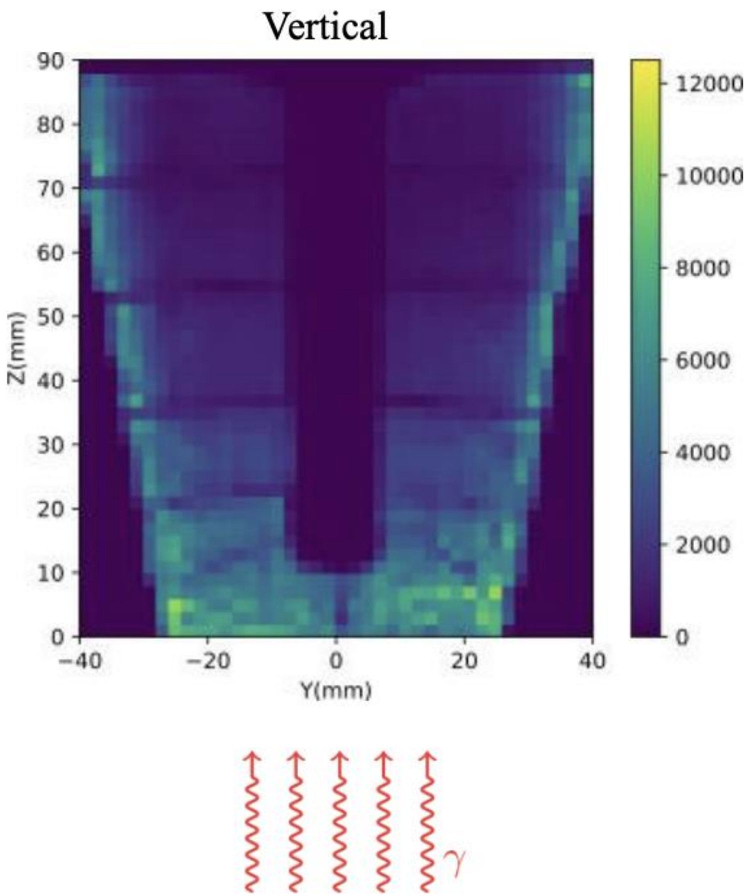
Predicted positions in (Y,Z) plane for X in [-3 mm ; 3 mm]





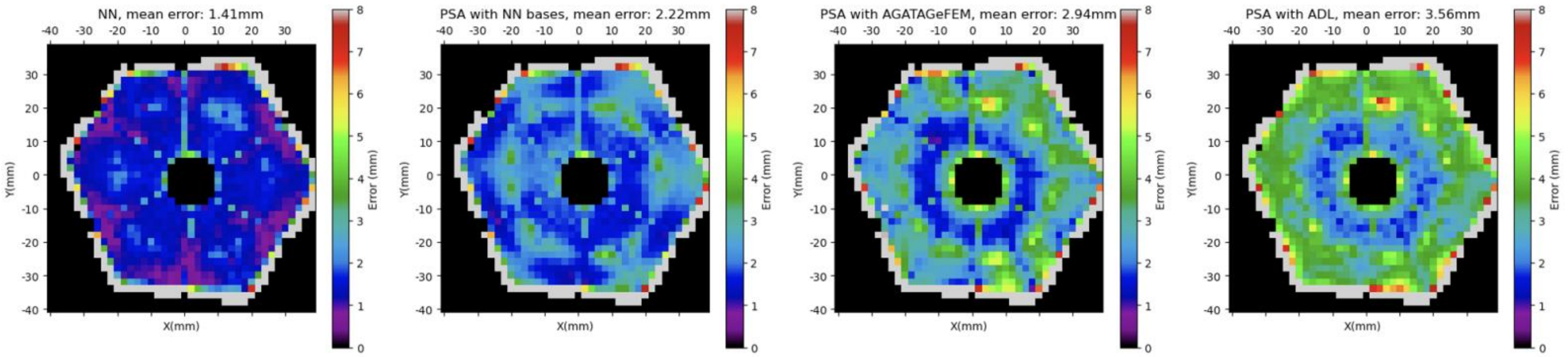
A005 analysis - Neural network basis

A005: Results

Jérémie Dudouet: j.dudouet@ip2i.in2p3.fr

- Comparison of:
  - NN results
  - PSA with NN basis
  - PSA with AGATAGeFEM, rotated to IKP convention (thanks Joa)
  - PSA with ADL, using IKP to AGATA filter and PSA rotation filter

B segments



A005 analysis - Neural network basis

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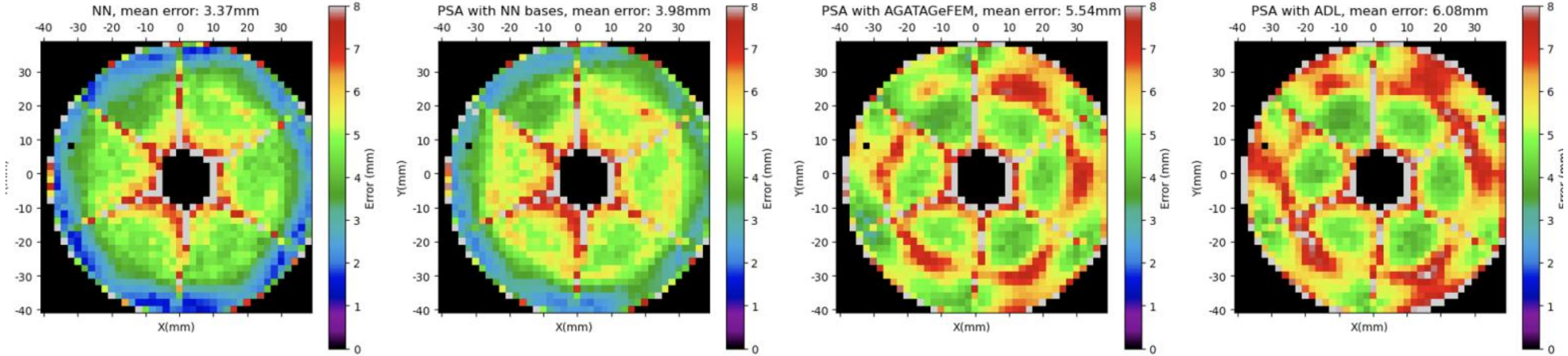
F segments



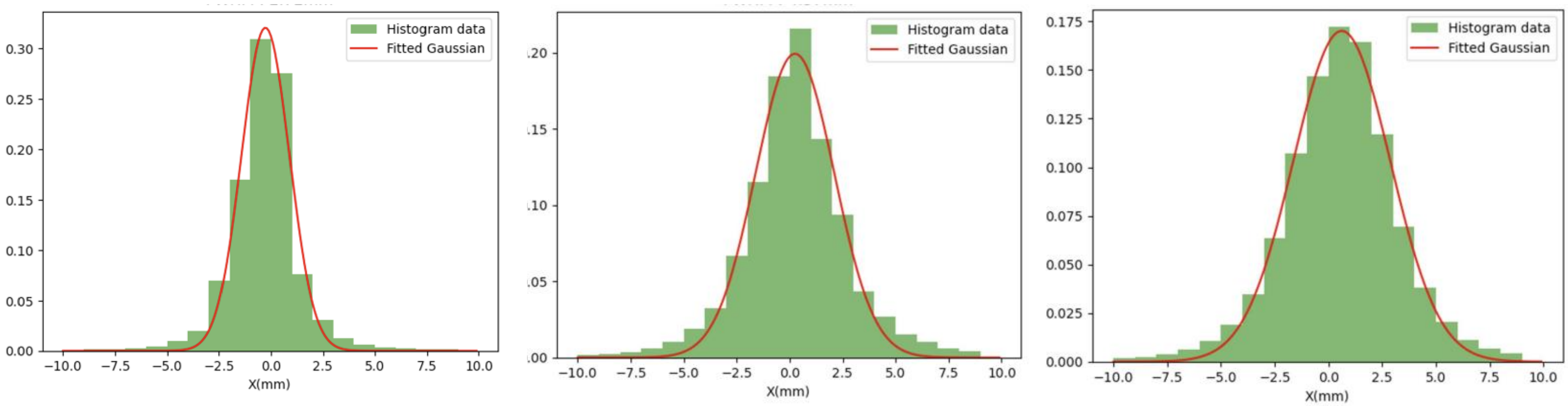
On average, the results comply with AGATA specifications, but there is room for improvement in the regions where the hot spots are located.

A005 analysis - Neural network basis

A005: Results

Jérémie Dudouet: j.dudouet@ip2i.in2p3.fr

- Average PSA Position resolution (FWHM):
  - ➥ NN: **2.4 mm**
  - ➥ AGATAGeFEM **4.3 mm**
  - ➥ ADL **4.9 mm**



Thanks

Thank you

IPHC Status

- Detailed scans of A005 around segment boundaries at request of PSA team to determine exact size + measure charge sharing at segment boundaries
- J. Dudouet copied the scanned data to Lyon for reformating them in AGATA standard with the goal to further analyse them
- Tomography of A005, Borehole diameter seen to increases towards rear of crystal, seem in S001, A005 and B006
- Lot of work understanding charge trapping in S001