Full 3D scan of an AGATA crystal using the PSCS technique

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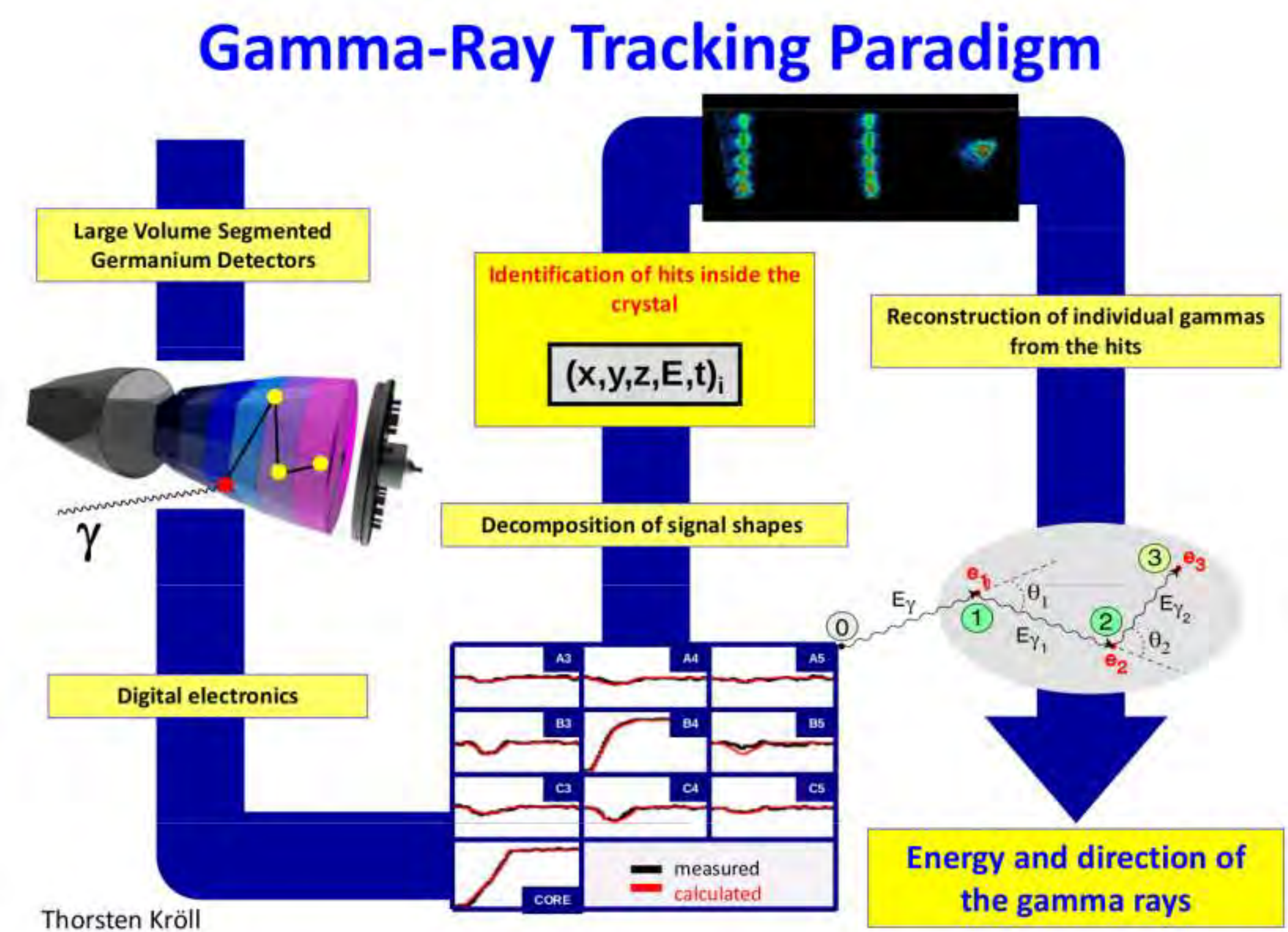
IPHC, Strasbourg, France

Gamma-ray tracking Ge spectrometers



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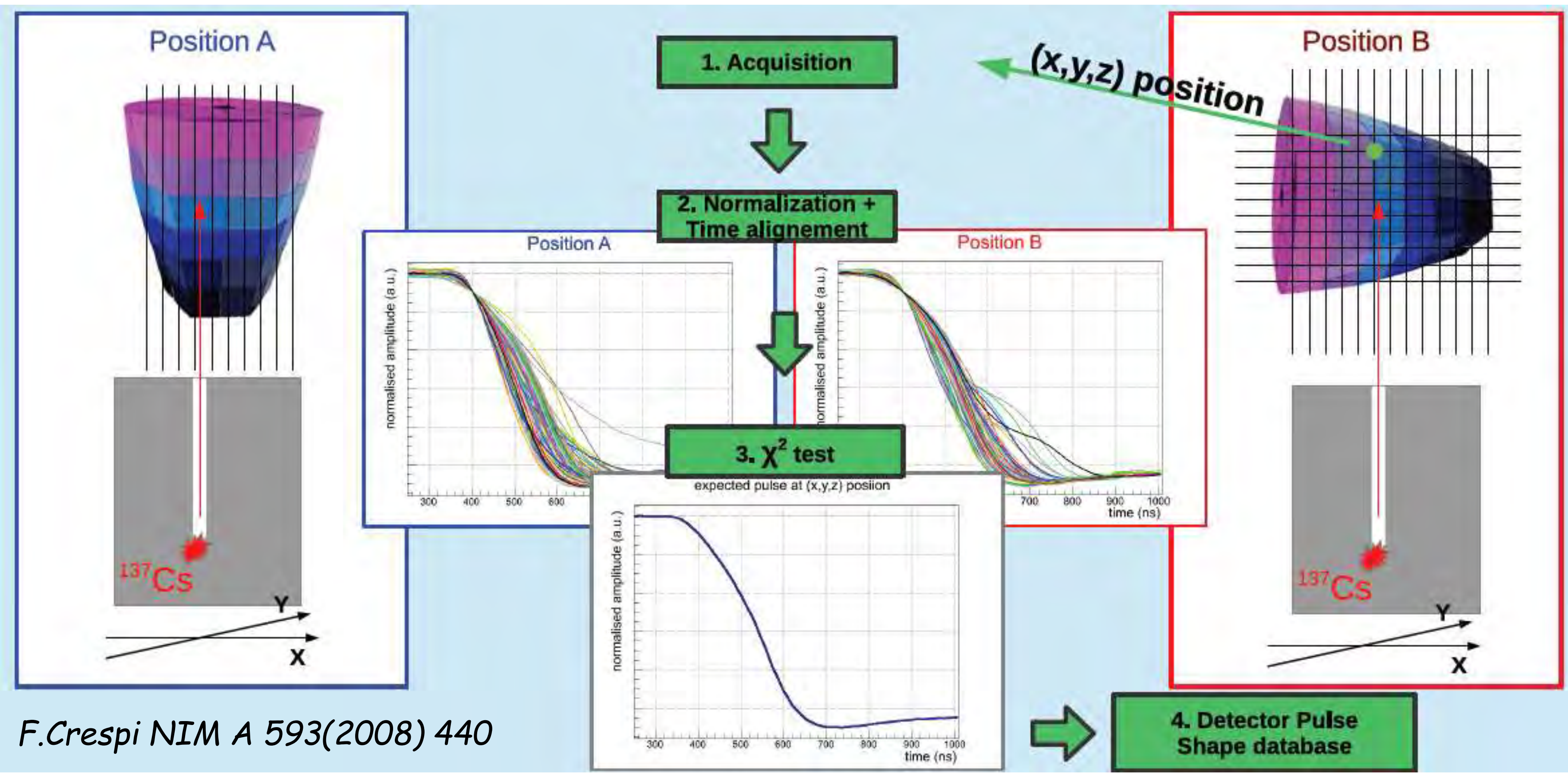
PSCS technique at IPHC

PSCS = Pulse Shape Comparison Scan



F.Crespi NIM A 593(2008) 440

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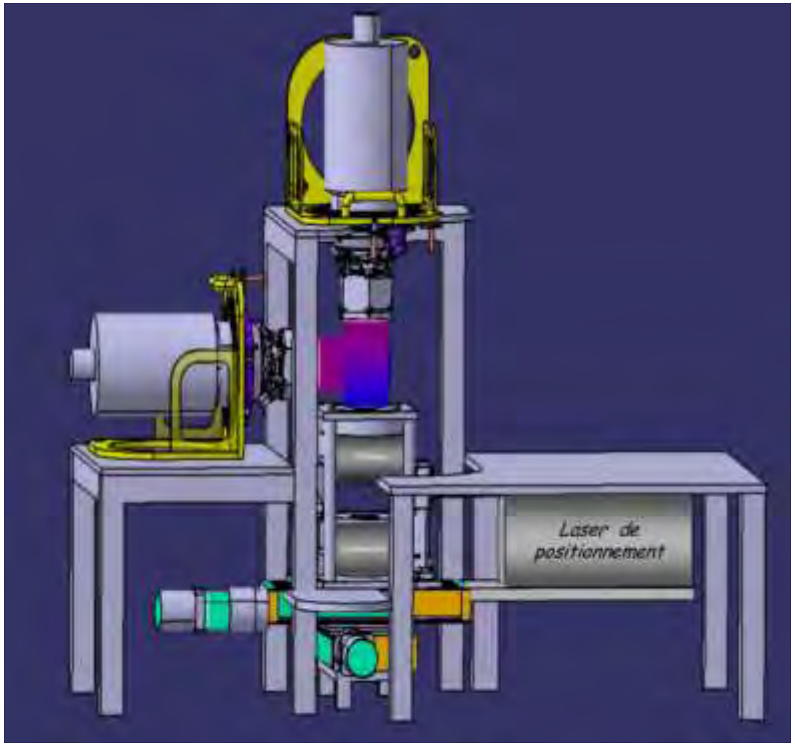
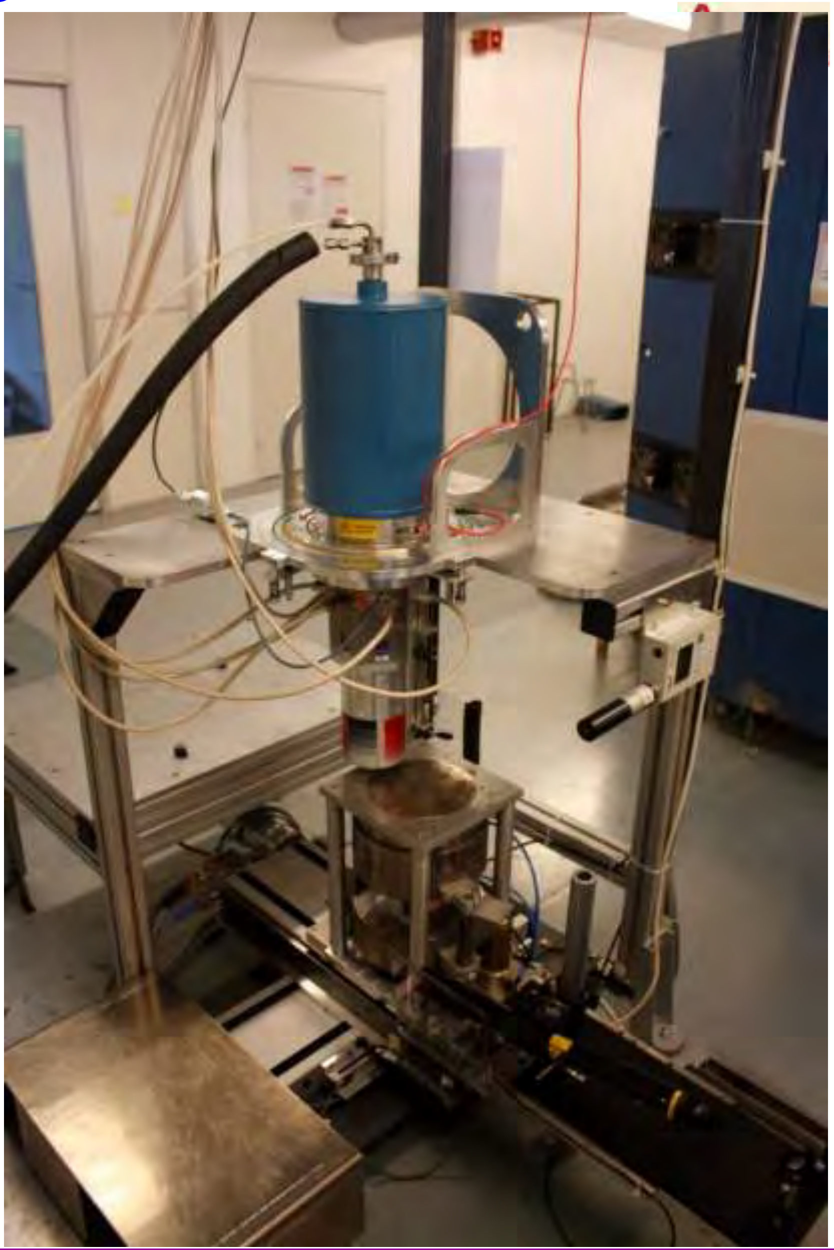
IPHC scanning table





- XY positioning +/- 10 μm
- Adjustment frame: detector position fine tuning using micrometric screws
- 360° rotation of the crystal
- Laser alignment reference

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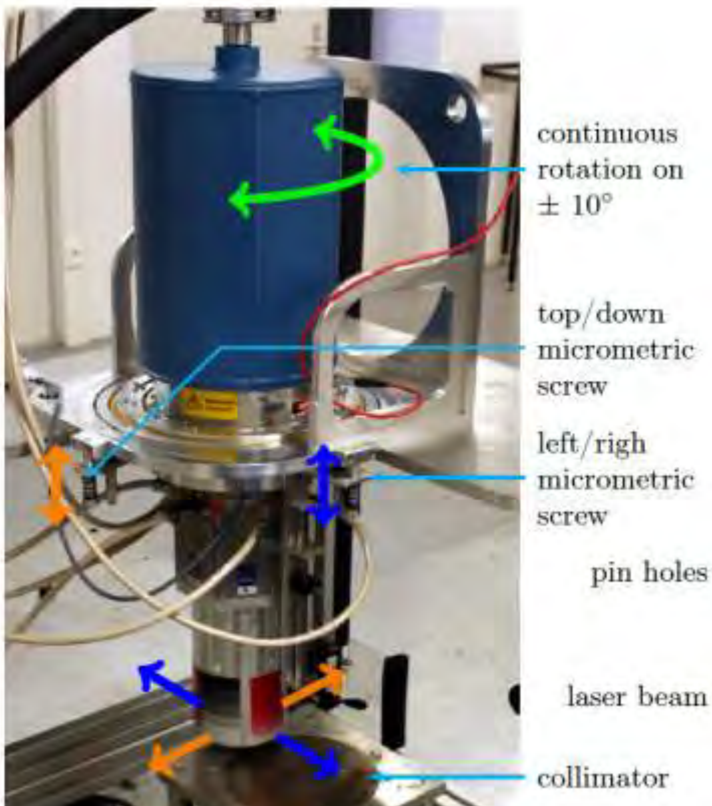
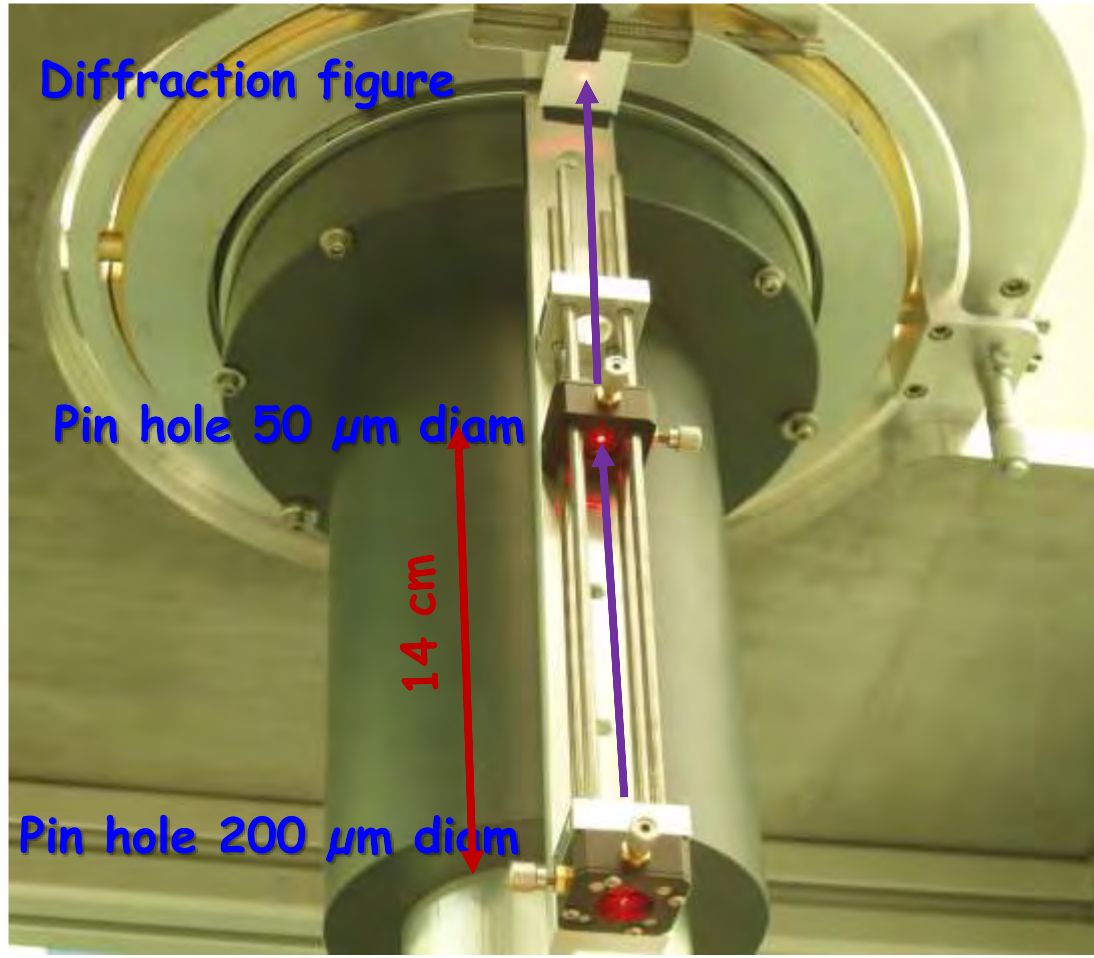
IPHC scanning table



Optical module



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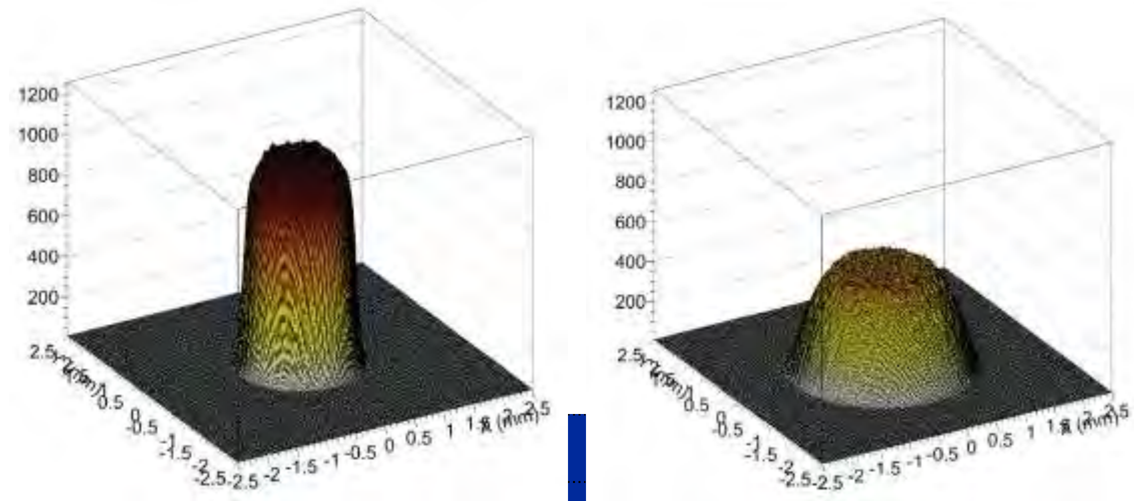
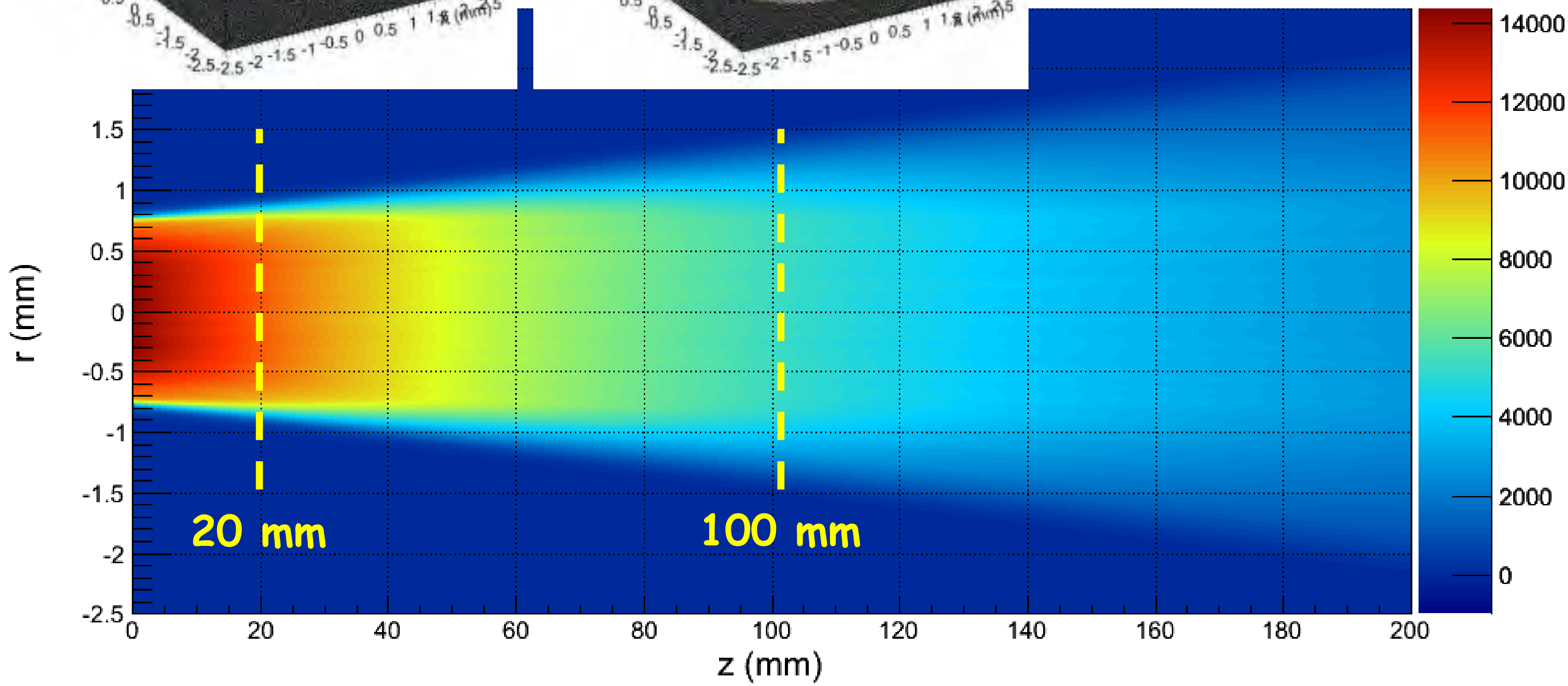
IPHC scanning table

diameter along 165 mm

(75 MBq): 60 keV, ~90 cts/s

555 MBq): 662 keV, ~1000 cts/s





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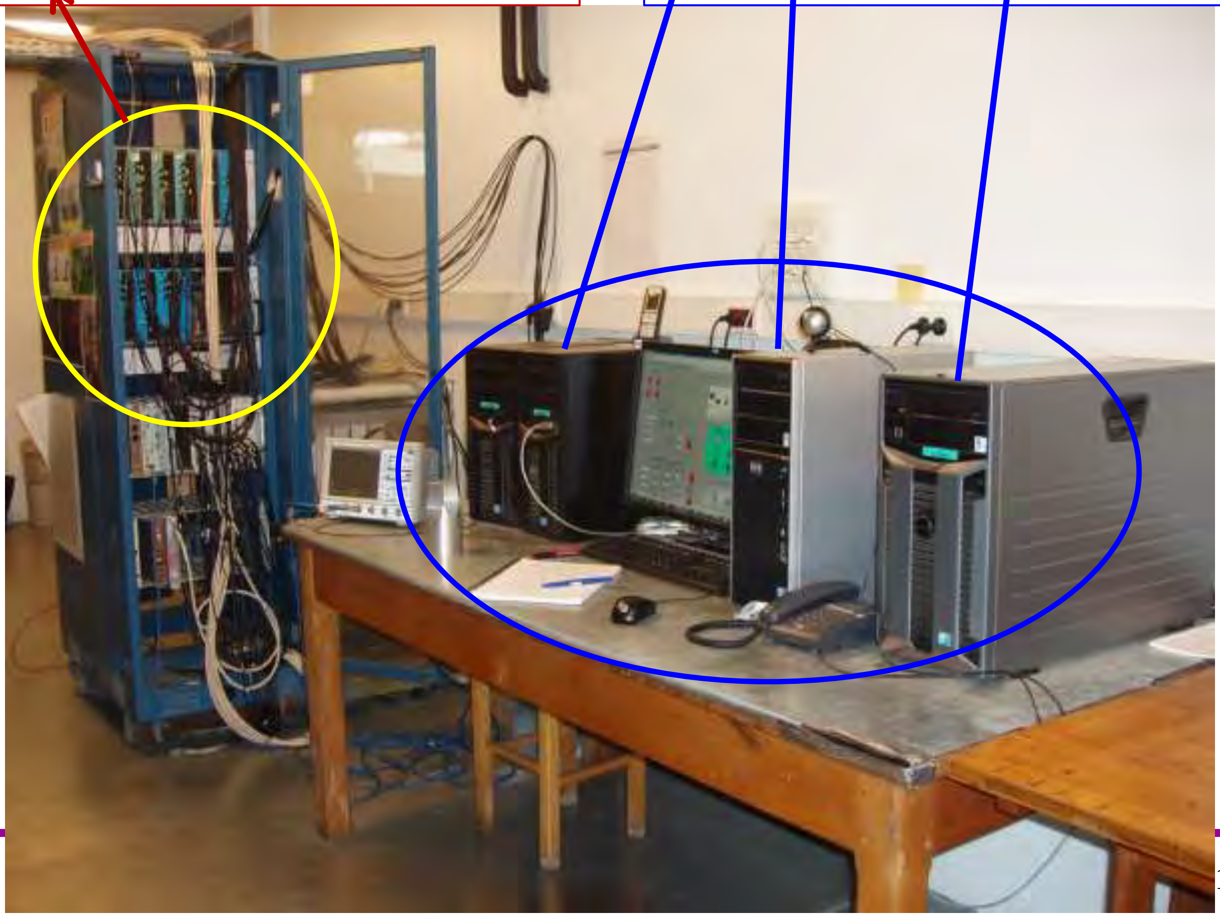
IPHC scanning table

Electronics

- 10 TNT2 boards (*L. Arnold et al., IEEE TNS 53 (2006)723*)
- 100 MHz, 14 bits flash ADCs
- Common clock; up to 40 channels sync.
- Mixed mode: energy + samples readout
- USB data transfer

DAQ

- 2 acquisition PCs (5 USB input each)
- 1 control PC (Labview, DTUC)
- 1 storage and analysis PC (10 TB)



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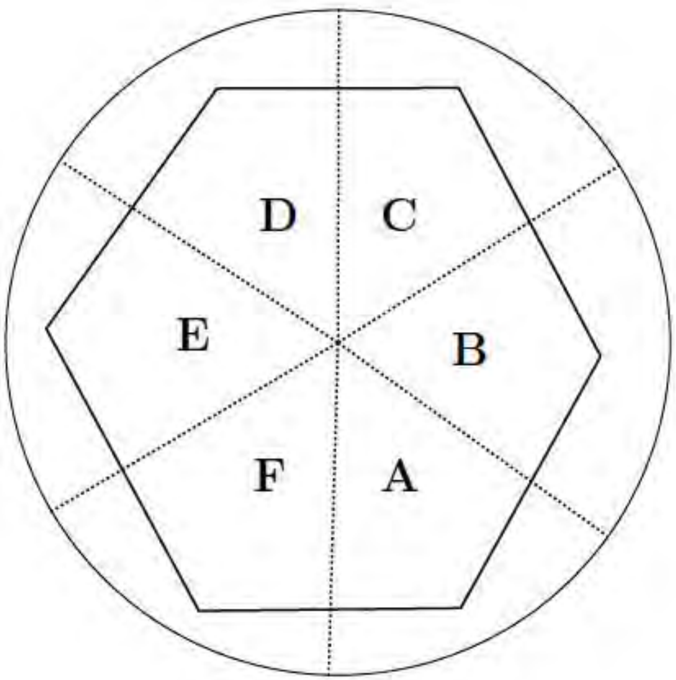
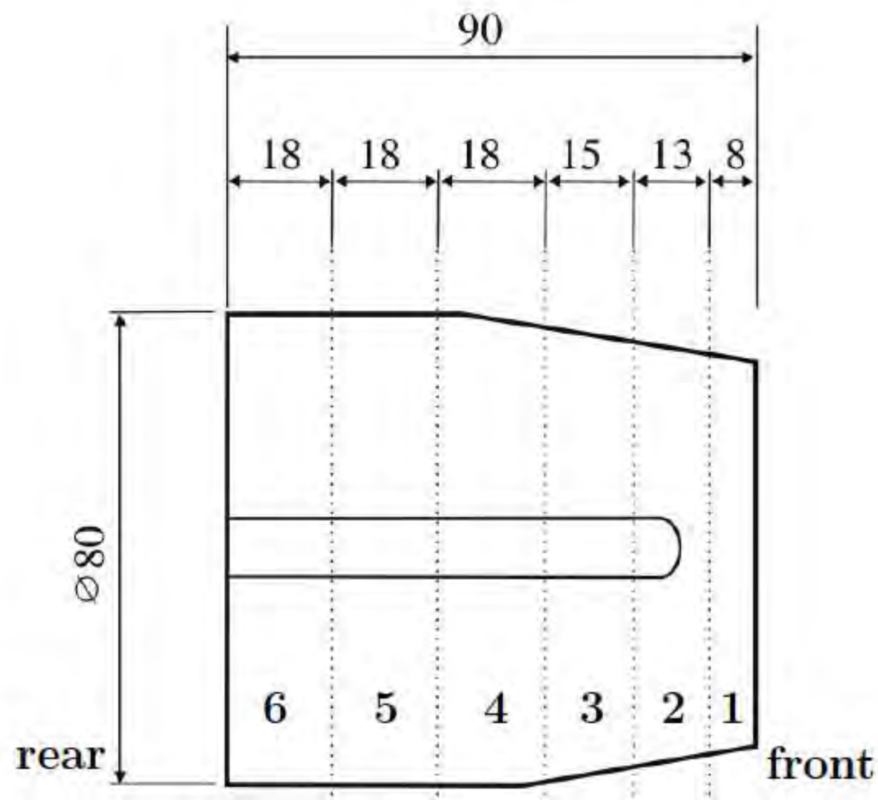
AGATA B type crystal





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Scan characteristics

	source	mode	pitch [mm]	timeout [s]	number of points	total time [days]	volume of raw data [Go]	info
				VERTICAL POSITION				
1	^{137}Cs	E	1	100	5520	7.5	260	charge collection analysis
2	^{137}Cs	M	2	110	1310	2	1 500	PSCS
3	^{137}Cs	E	0.2	150	300	0.6	22	check vertical tilt 4×
4	^{241}Am	E	0.05	60	160	0.1	41	segmentation line analysis
				HORIZONTAL POSITION				
5	^{137}Cs	M	2	110	1840	2.7	1 400	PSCS 0°
6	^{137}Cs	M	2	120	1840	3	1 500	PSCS 90°
7	^{137}Cs	E	0.2	150	400	0.8	25	PSCS check lateral tilt

- E = energy mode
- M = Mixte mode

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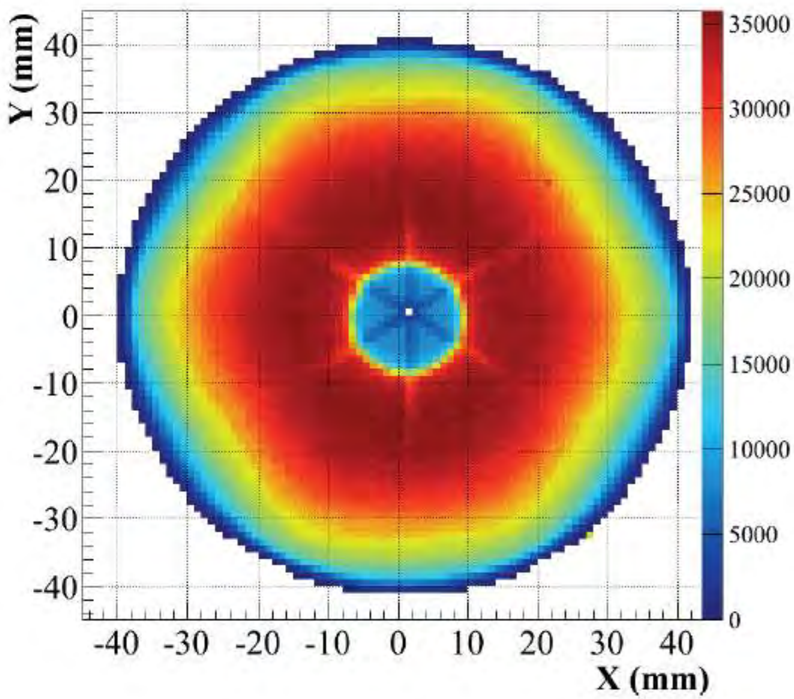
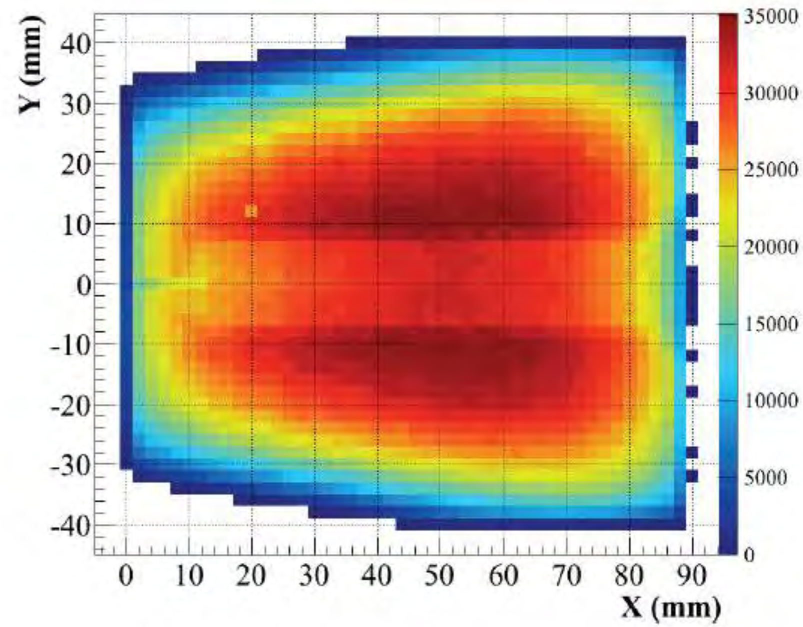
2D ^{137}Cs scans

Photopeak efficiency: Core signal

Front scan 1mm pitch



Lateral scan 2 mm pitch



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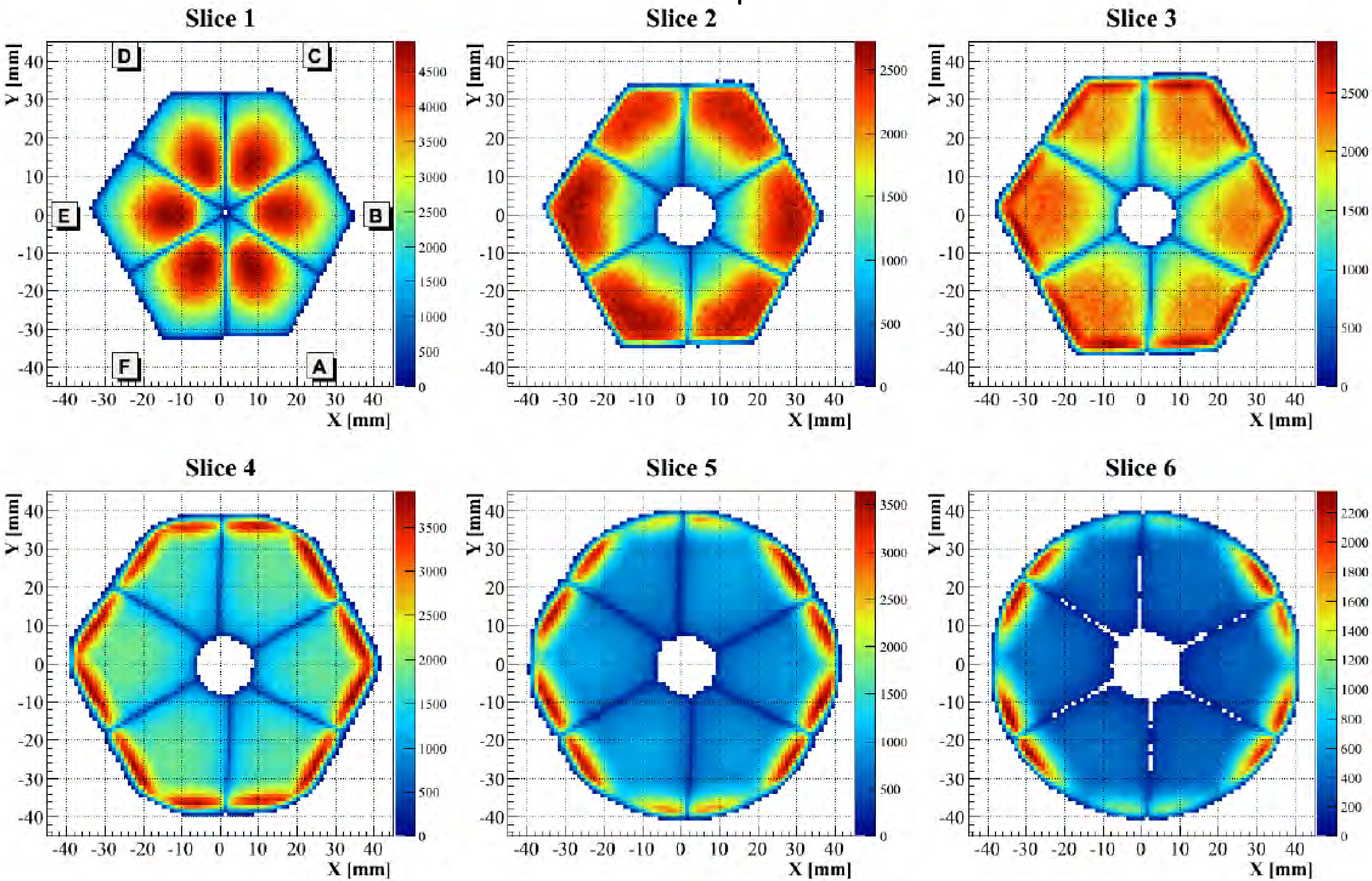
2D ^{137}Cs scans

Photopeak efficiency: Segment signals

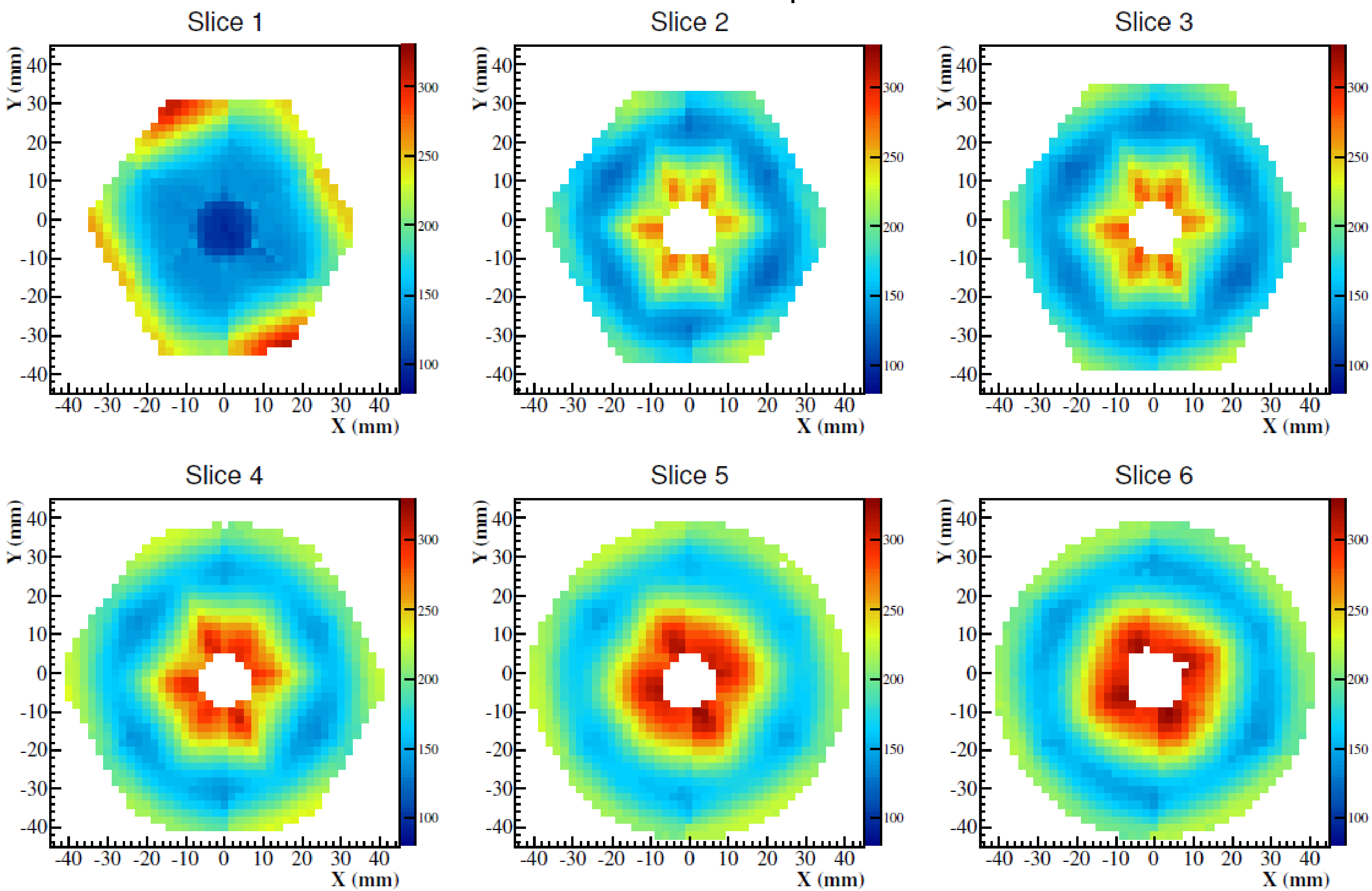
Front scan 1mm pitch



2D ^{137}Cs scans

Segment T90 = t(ampl 90%) – t(ampl 10%)

Front scan 2mm pitch



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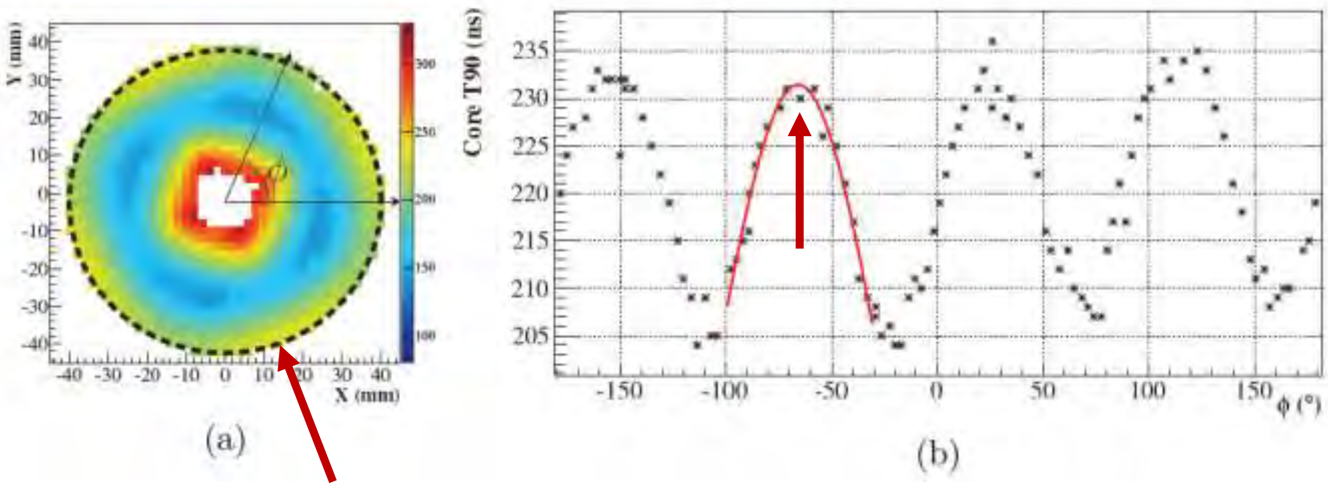
2D scans

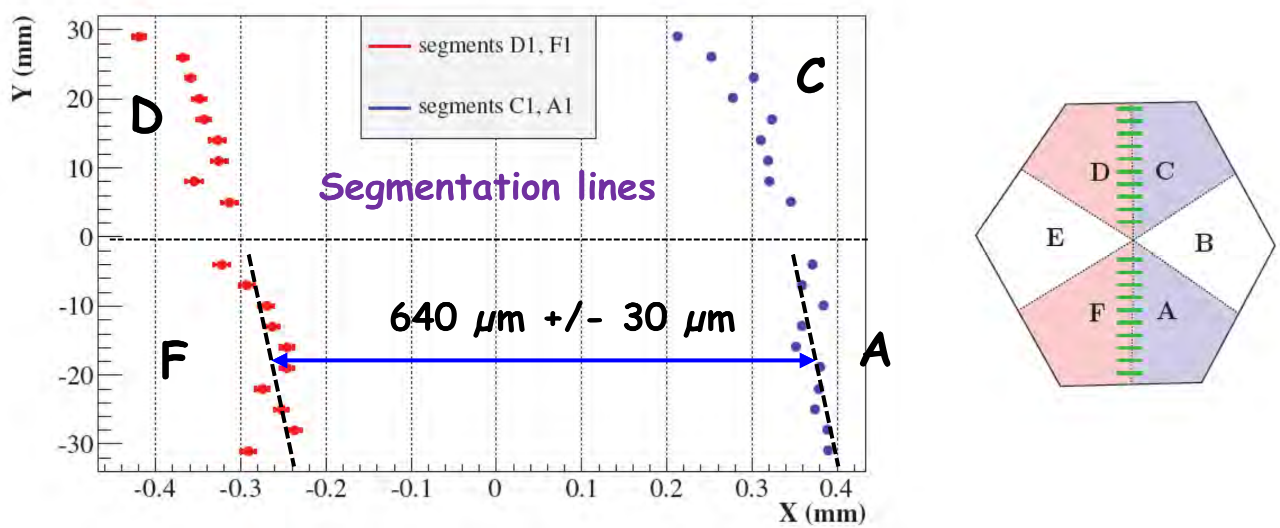
Crystal lattice anisotropy

- ^{137}Cs
- 2 mm pitch
- Slowest axis in corner of segment A



Segmentation

- ^{241}Am
- 200µm pitch
- AF seg alignment on X axis
- Seg line width



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2D scans

Other possibilities

- Image charge asymmetry
- Photopeak shift -> charge trapping
- FWHM
- Charge sharing on segmentation lines
- Li contact thickness

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3D scans

Data analysis

- ~50000 voxels to evaluate by χ^2
- Each voxel: 15000 (A) x15000 (B) supertraces to evaluate
- Each supertrace: 4400 samples of 2 bytes
- 100 peta bytes of data to compare
- ~170 days needed

A faster analysis is mandatory

Calculation speed improvements

- Same segment hit in both data sets (A) and (B)
- Consider only Core, hit segment, direct neighbor segments (left/right + top/down)
- Only 40 samples compared among the 120
- Take into account only the 200 lowest χ^2 values

NB: at the end of the comparison process, the final χ^2 value is a confidence criterion

Effective data analysis duration

Reduced to 5 days

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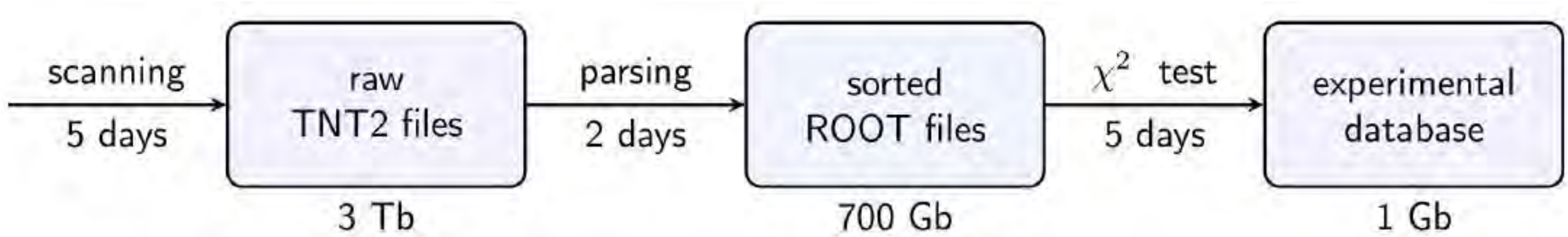
3D scans

3D scans in full volume -> ^{137}Cs

Typical AGATA scan planning:

- T_{init} : crystal @ IPHC
- $T_0 = T_{init}$ + 1 week: crystal operational in the test cryostat (AGATA)
- T_0 + 2 weeks: scans performed
- T_0 + 3 weeks: database available



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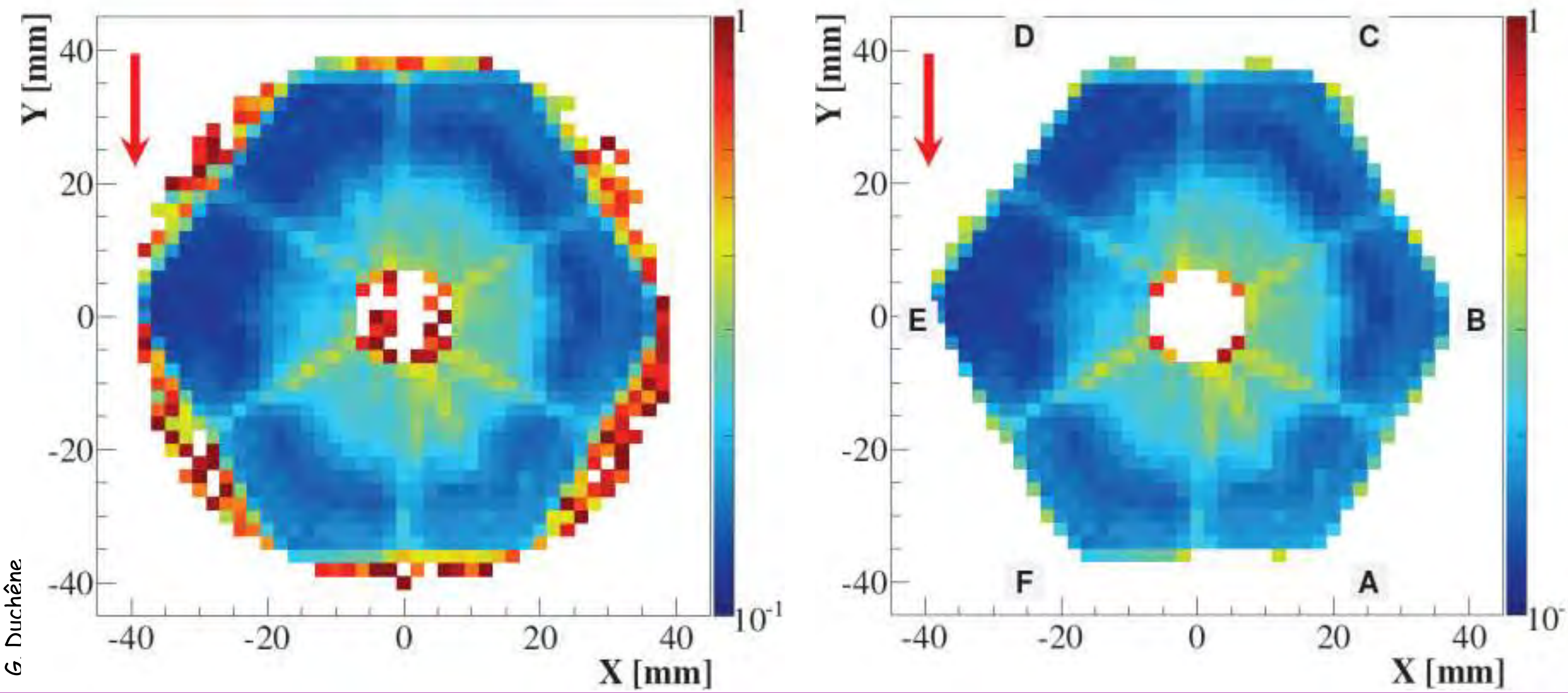
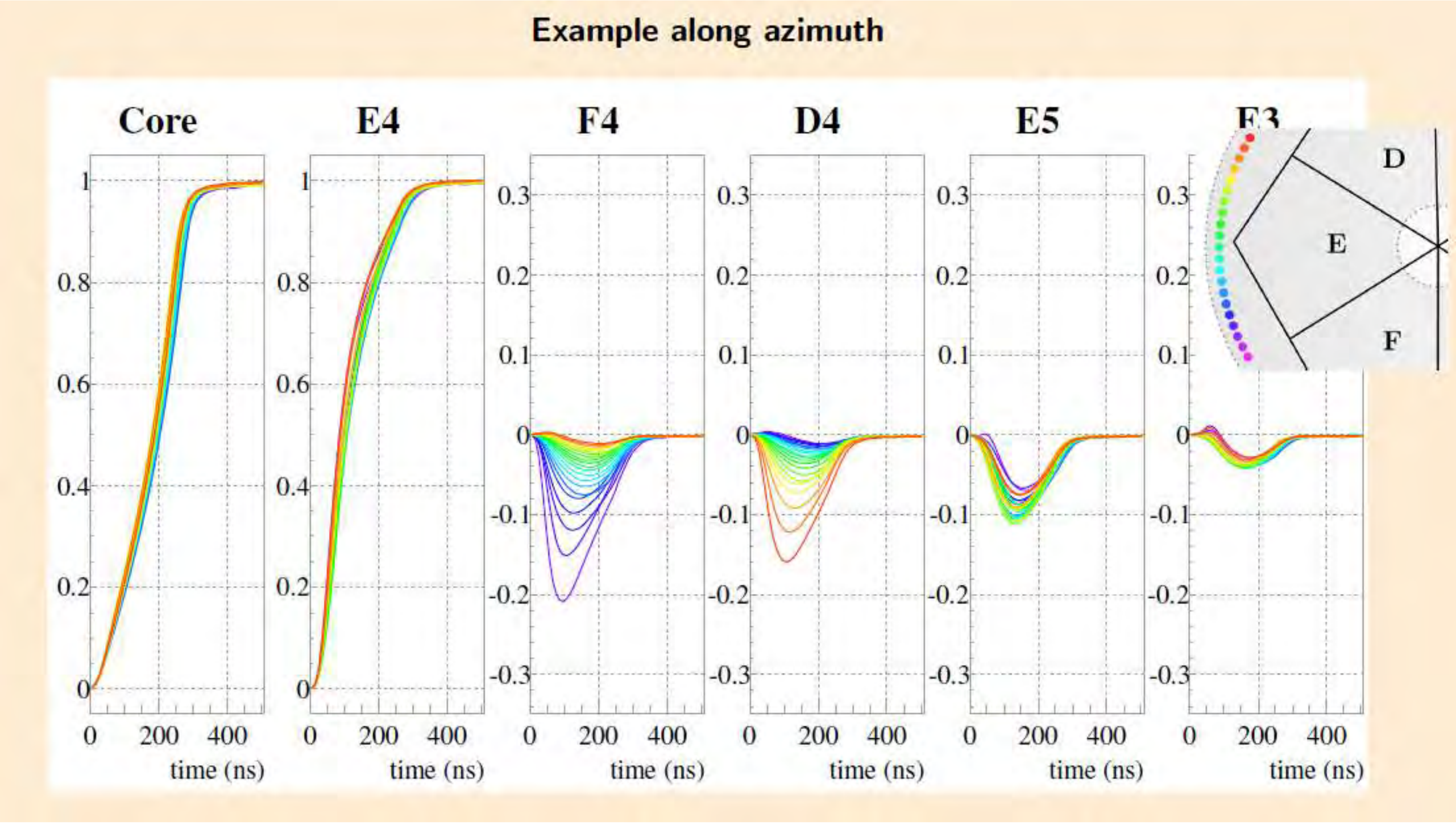
3D scans

PSCS: no detector geometry input

- Voxel inside the crystal -> large statistics -> low final χ^2 value
- Voxel outside crystal -> low statistics -> high final χ^2 value



3D scans: pulse shapes



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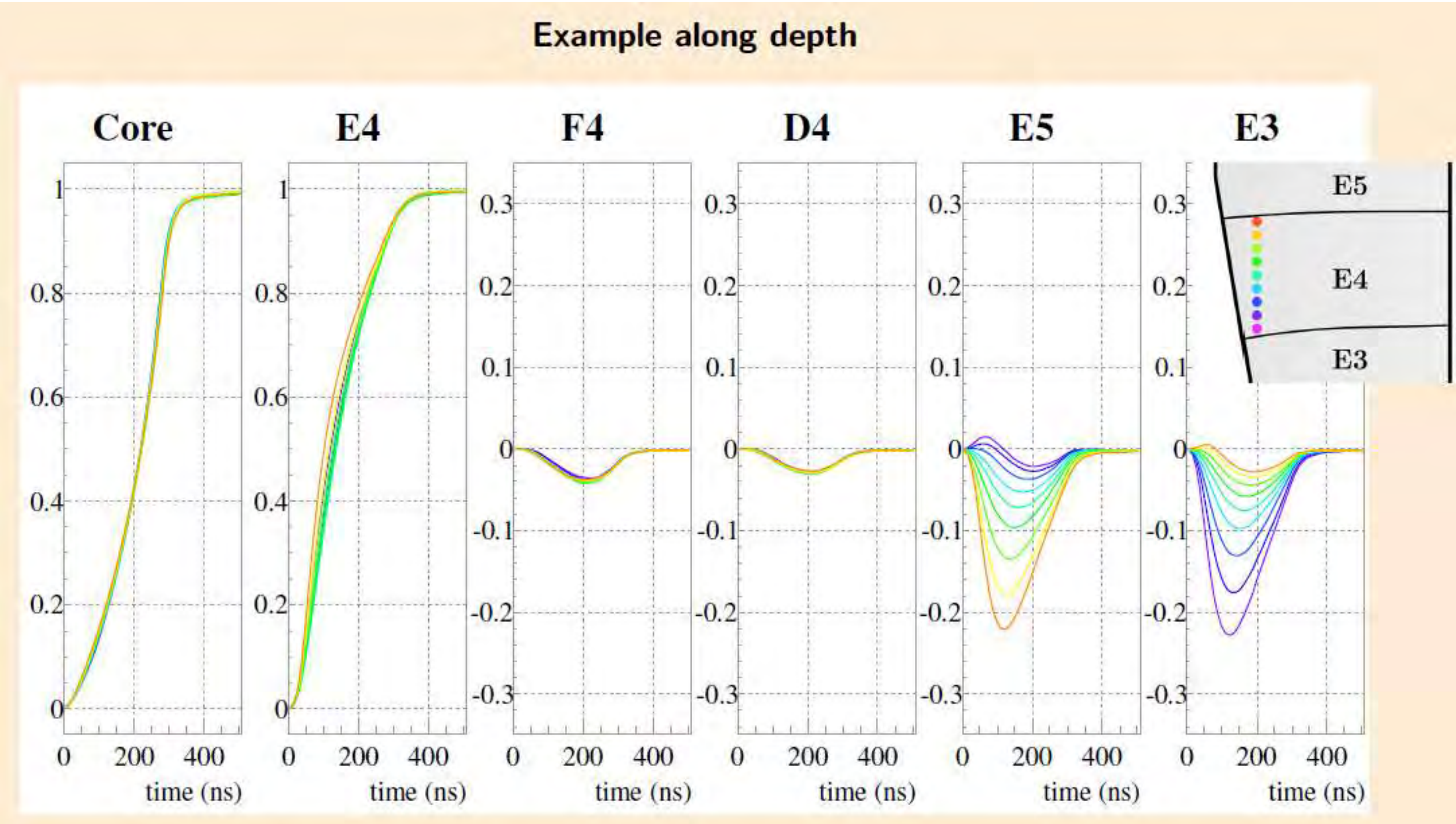
3D scans: pulse shapes



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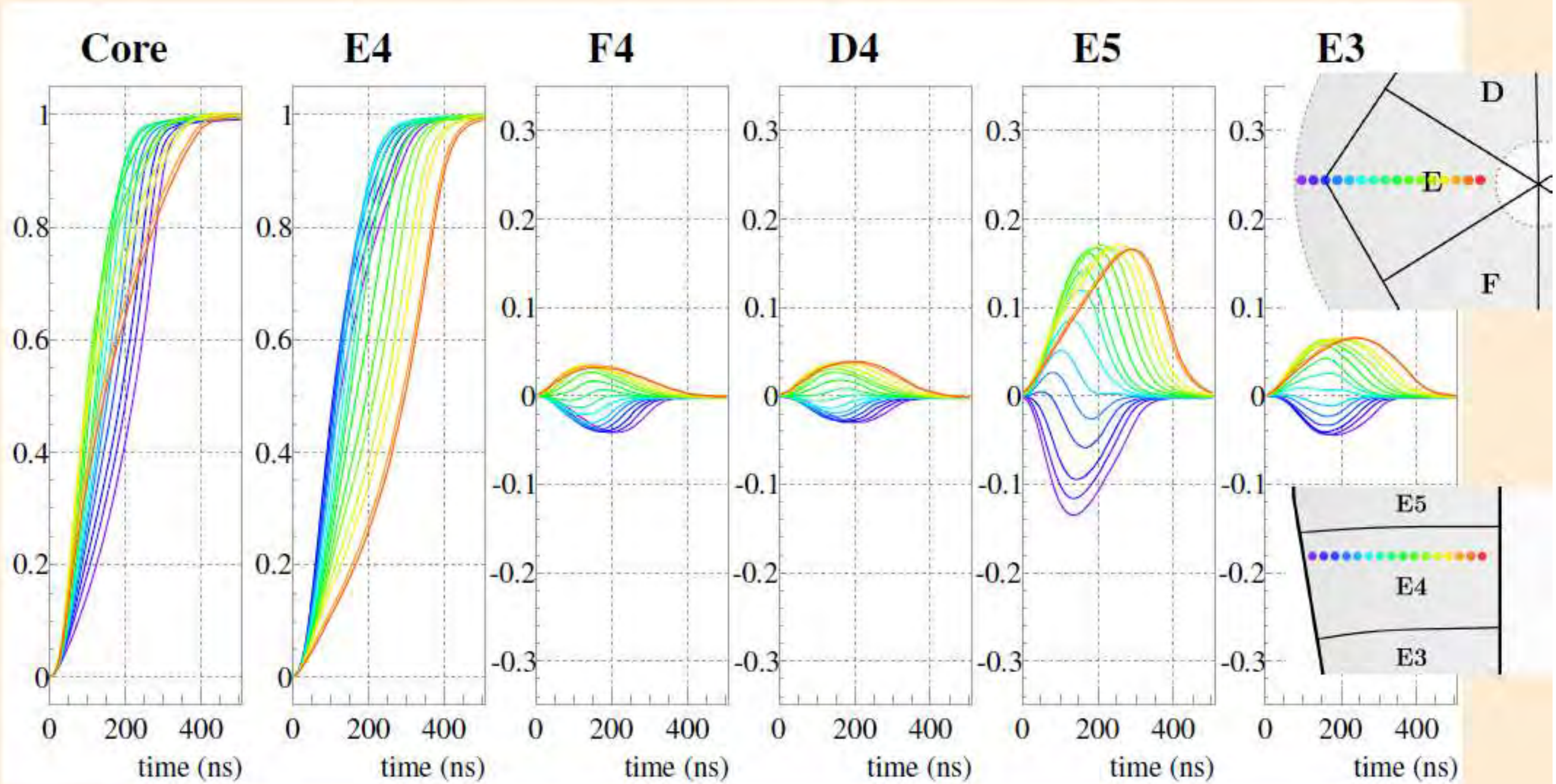
3D scans: pulse shapes

Example along radius Z=50 mm



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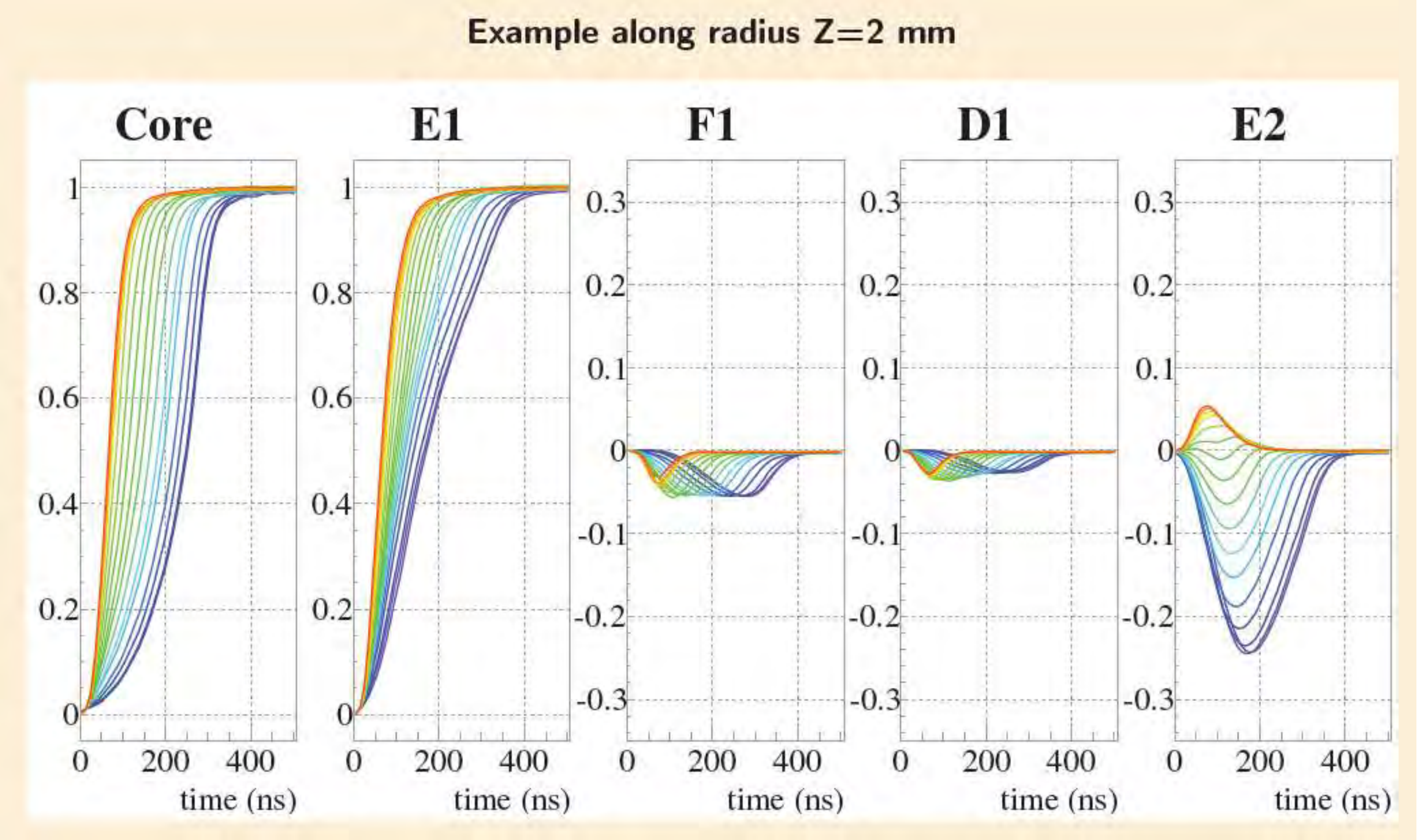
3D scans: pulse shapes



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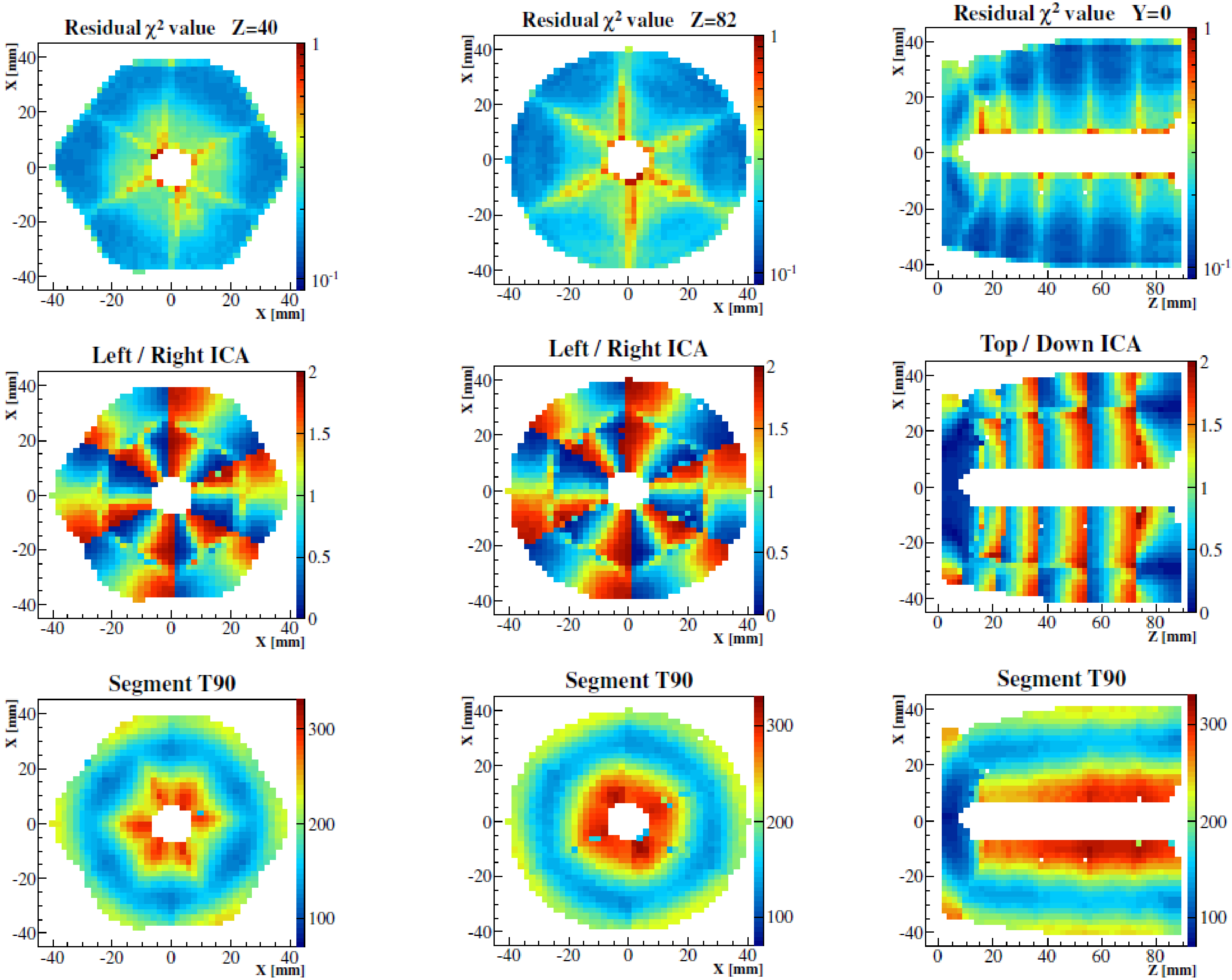
3D scans



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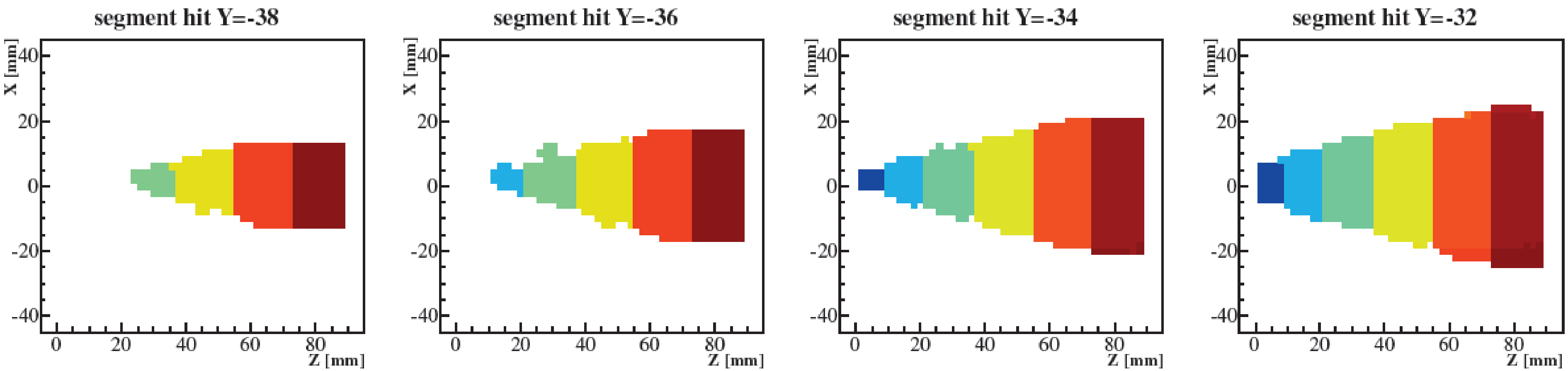
3D scans: hit segments



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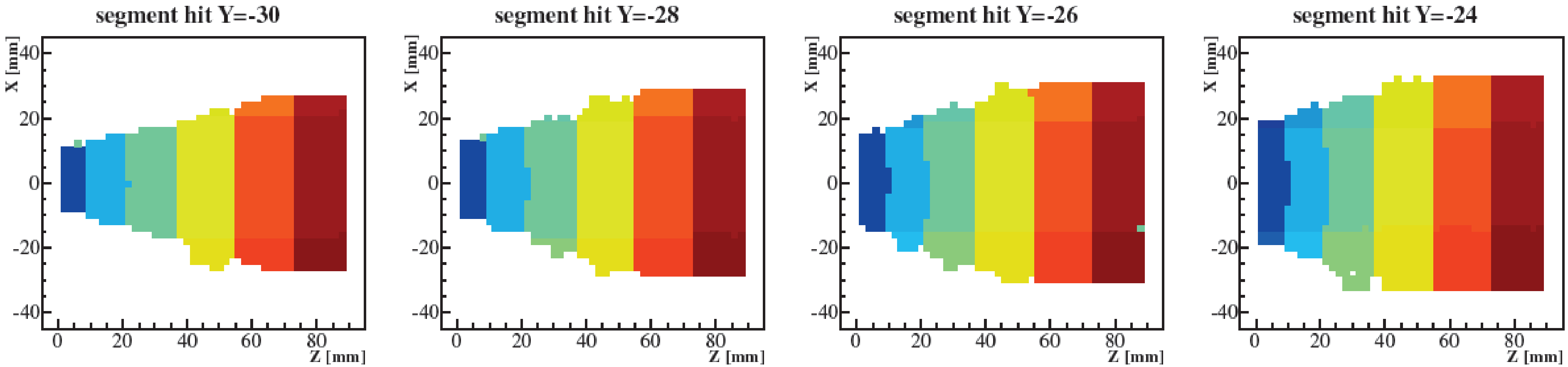
3D scans: hit segments



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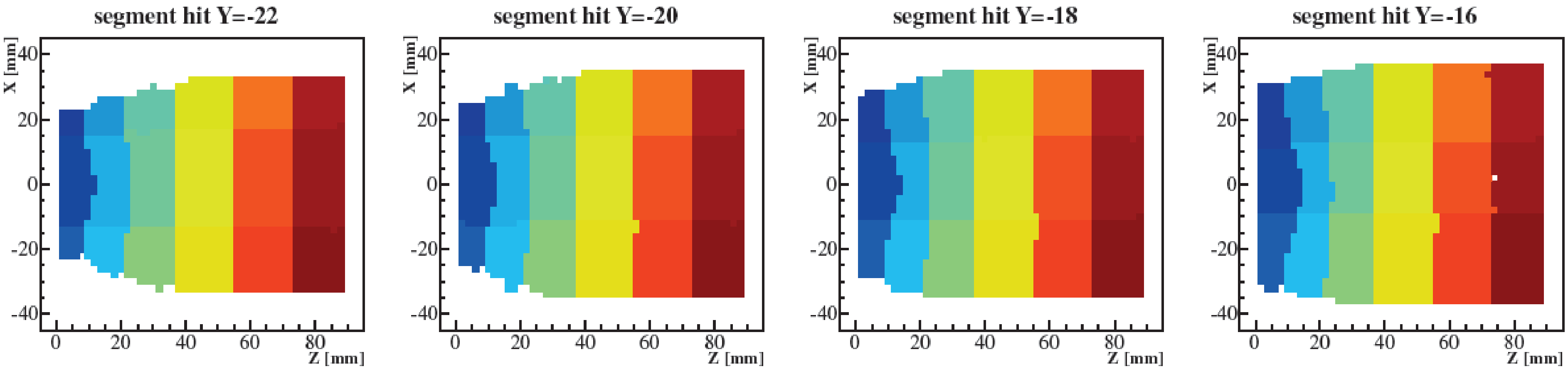
3D scans: hit segments



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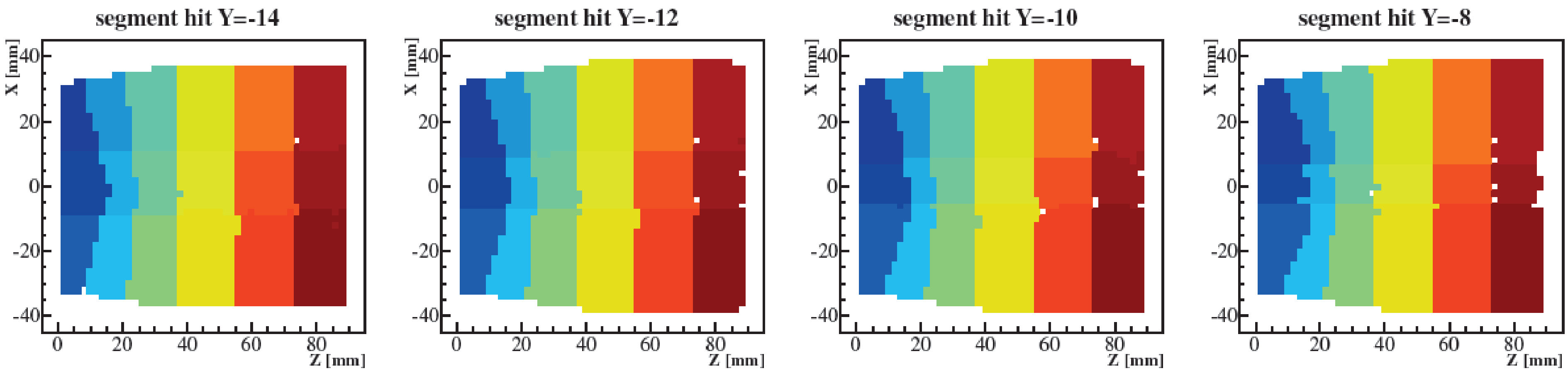
3D scans: hit segments



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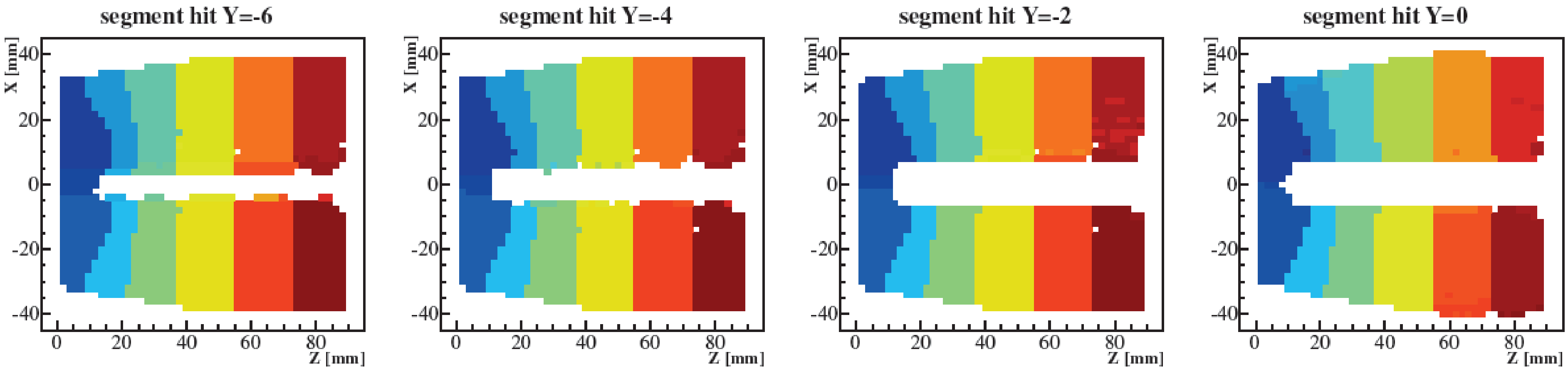
3D scans: hit segments



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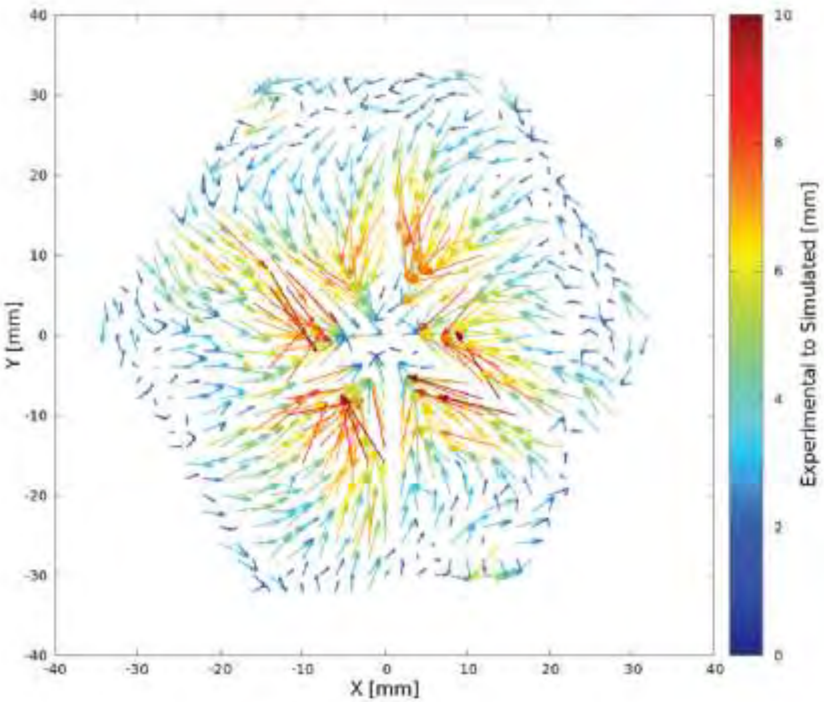
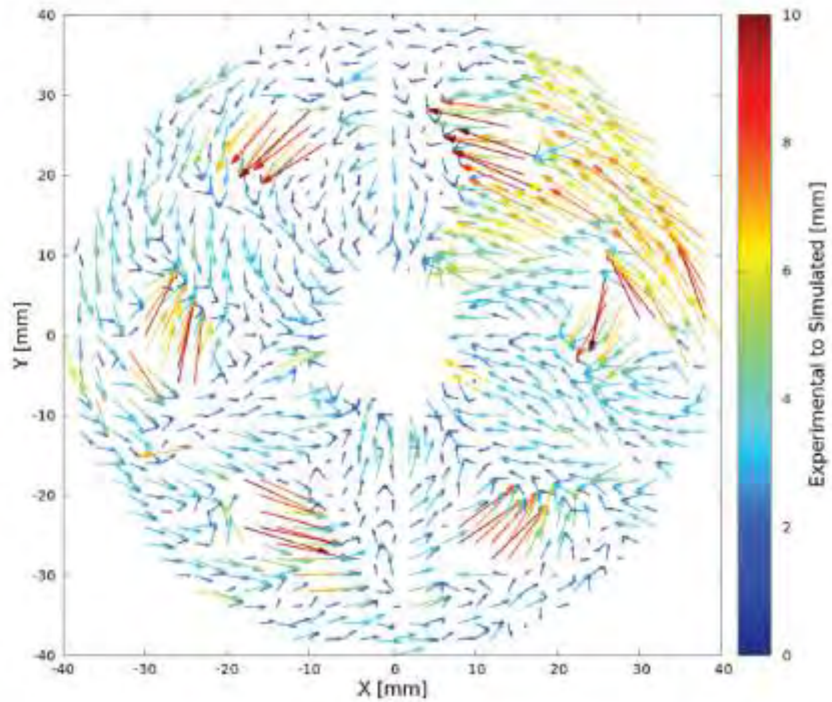
Databases comparison



Slice Z = 6 mm
Average shift : 4.2 mm



Slice Z = 68 mm
Average shift : 3.8 mm

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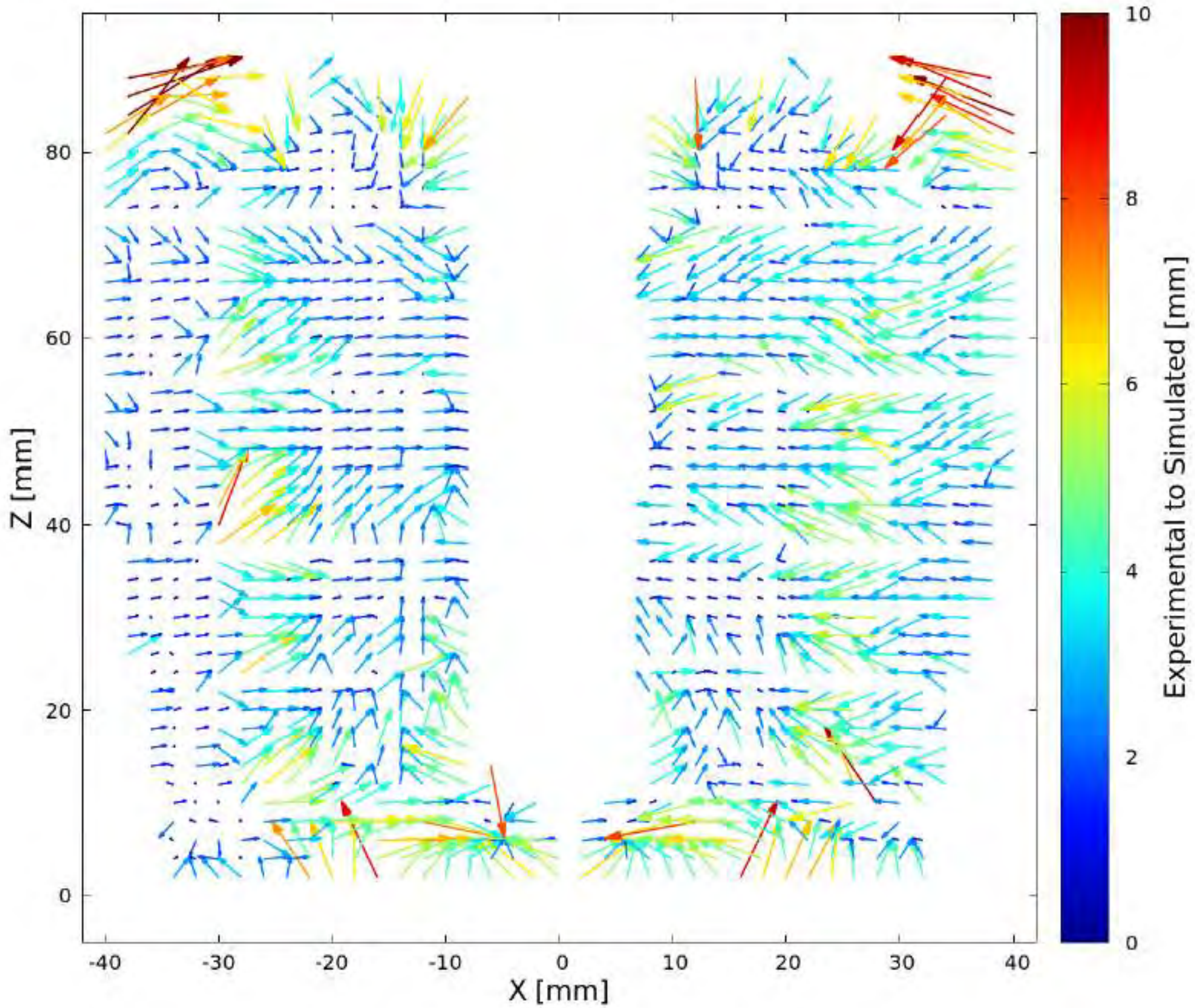
Databases comparison



Average shift : 3.5 mm

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Conclusions

2D scans -> many parameters may be studied

- Efficiency
- Lattice anisotropy
- Segmentation line
- Peak shift for charge trapping
- Li contact thickness

PSCS technique is operational at IPHC

- Efficient
- Reconstructs the 3D crystal geometry
- Enables comparing pulse-shape databases

- **Time considerations for AGATA crystal full-volume scan**
  - 2 weeks of scans
  - 1 week of offline analysis
  - Construction of a pulse-shape database of 48500 points

- **Mean pulse shape results**
  - Shapes well differentiated with 2mm pitch
  - Very low noise level in the final average pulse shapes

- **Take care**
  - Proper alignment mandatory
  - Collimated beam diameter limitation

Outlook

- Convert the B006 pulse-shape database to insert it in the AGATA PSA algorithm
  - Improved in-beam energy resolution?
  - Tracking efficiency improvement?

- R&D on Ge detectors
  - Improvement of pulse-shape modelling
  - Influence of dead layers on Ge bulk response
  - Response of non-standard Ge crystal geometries
  - Others…

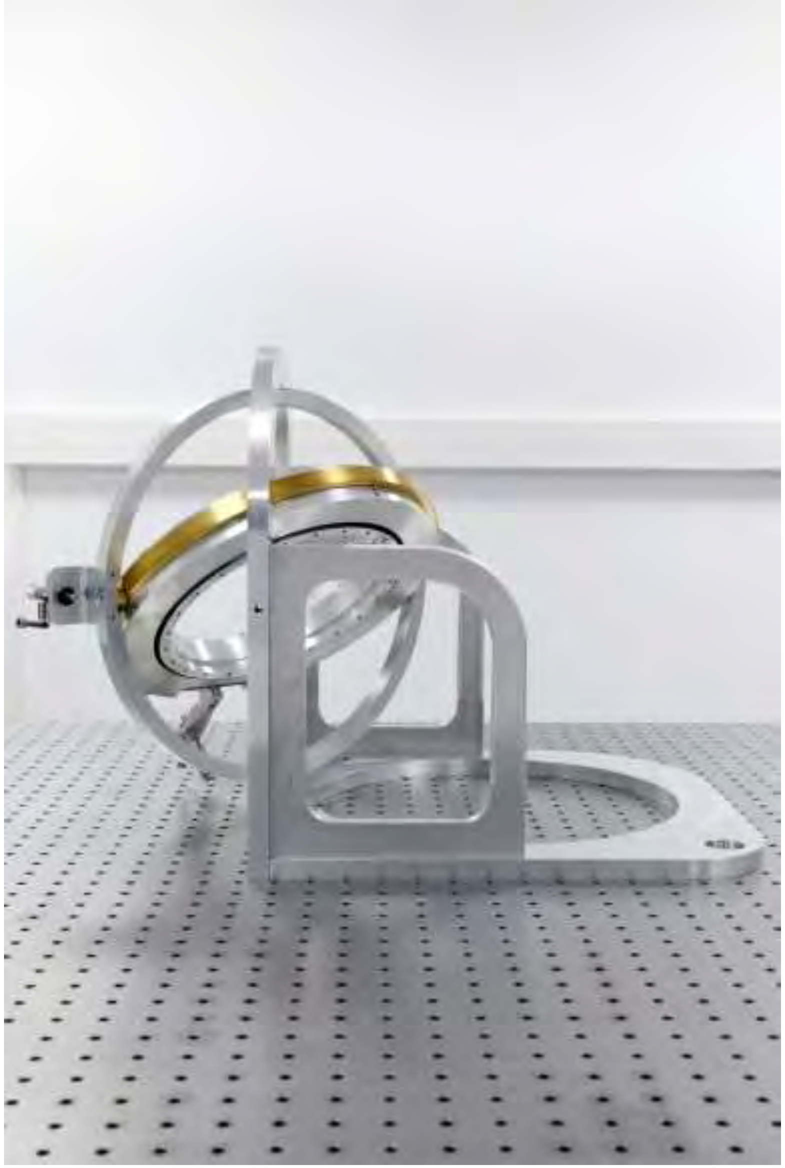
- Collaborations
  - AGATA
  - ENSAR2 JRA PSeGe
  - Canberra France

Any other is welcome…

THANK YOU

for your attention

Adjustment frame



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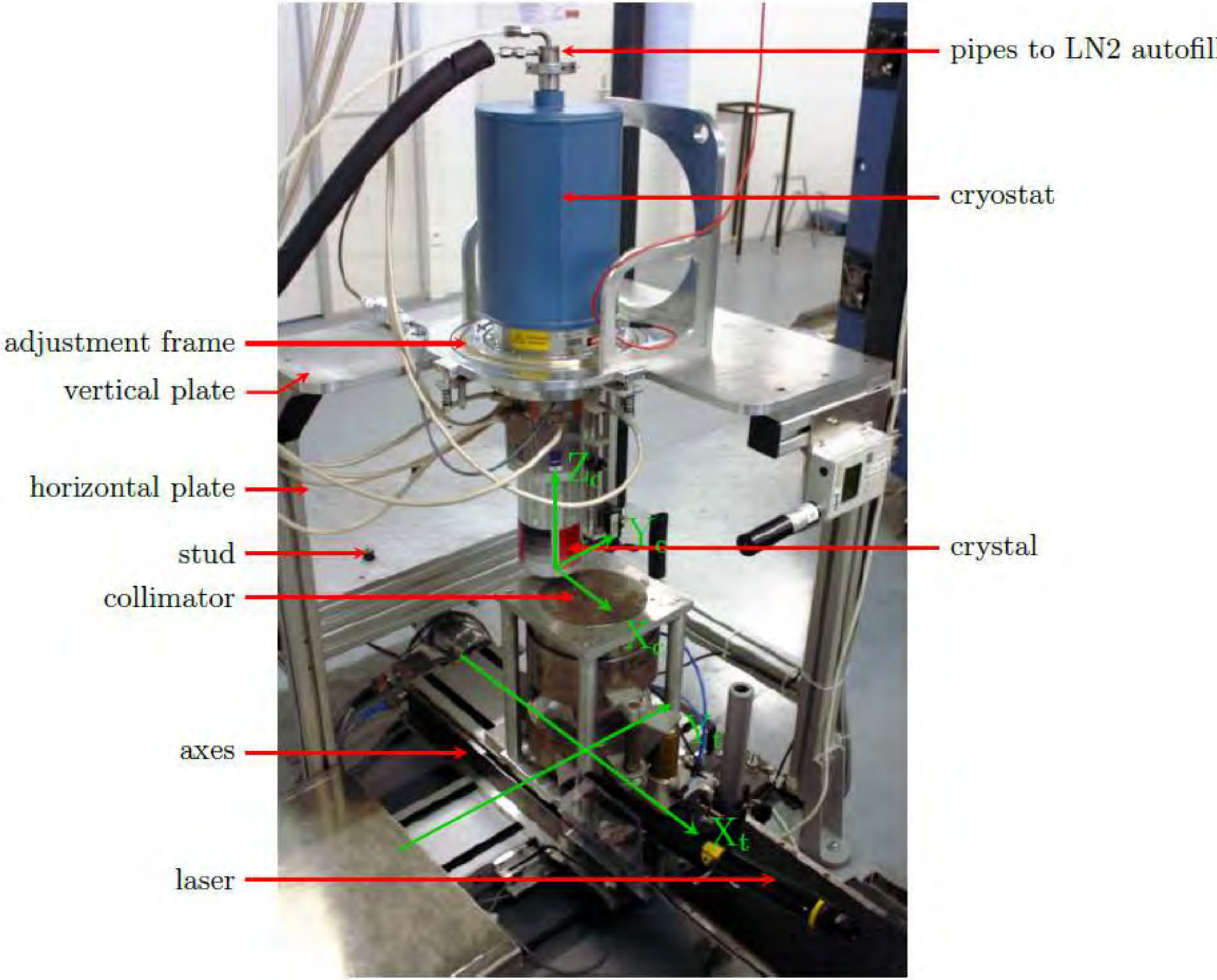
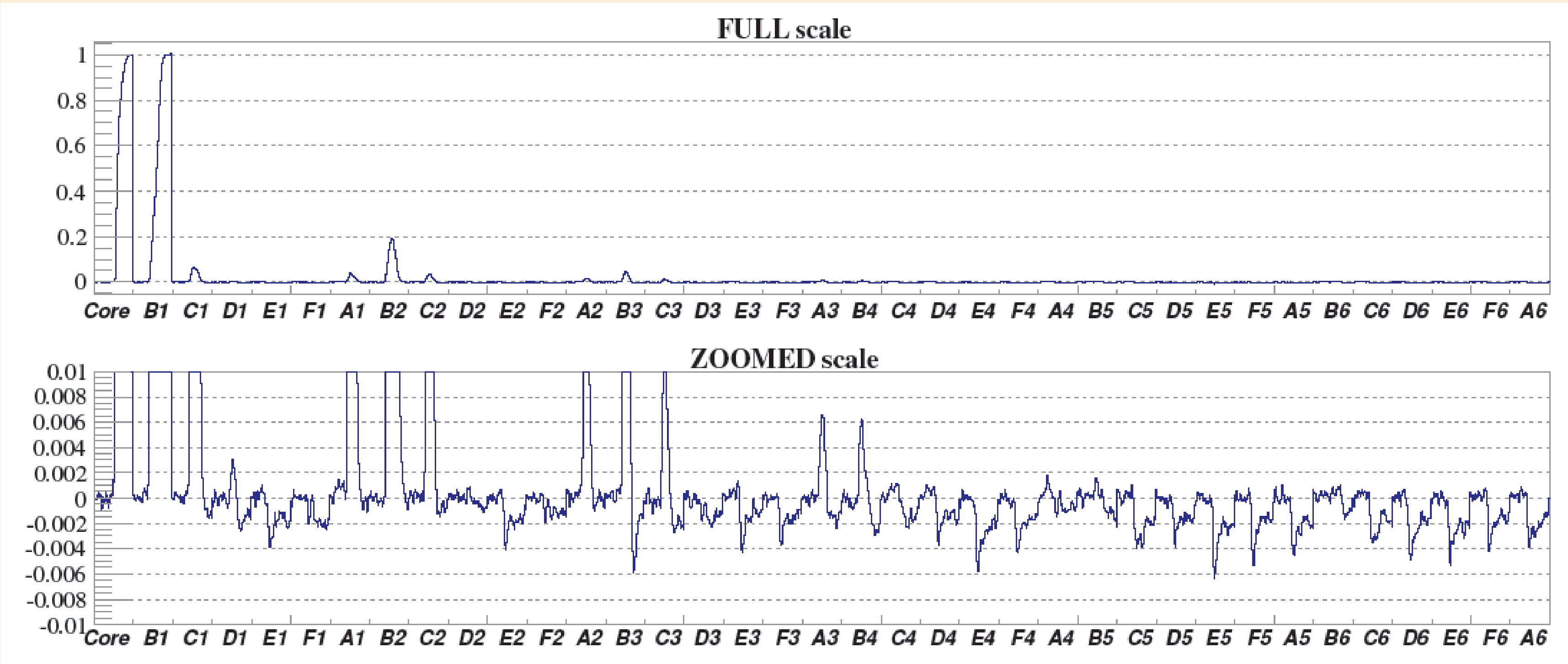

pipes to LN2 autofill
cryostat
adjustment frame
vertical plate
horizontal plate
stud
collimator
crystal
axes
laser
Zc
Yc
Xc
Yt
Xt

Supertraces

supertrace - noise evaluation B1 fired



- residual electronic noise < 0.1%
- segments away from the hit one: variations due to crosstalk

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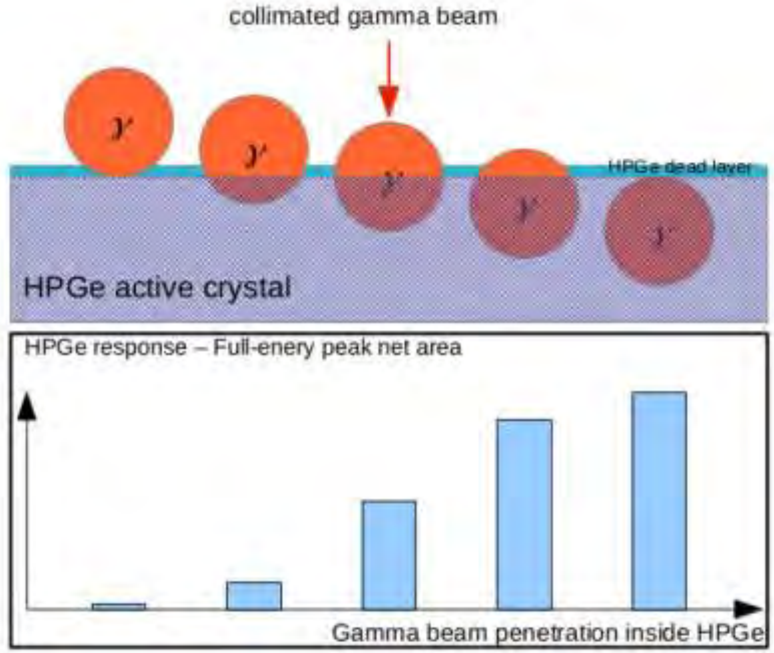
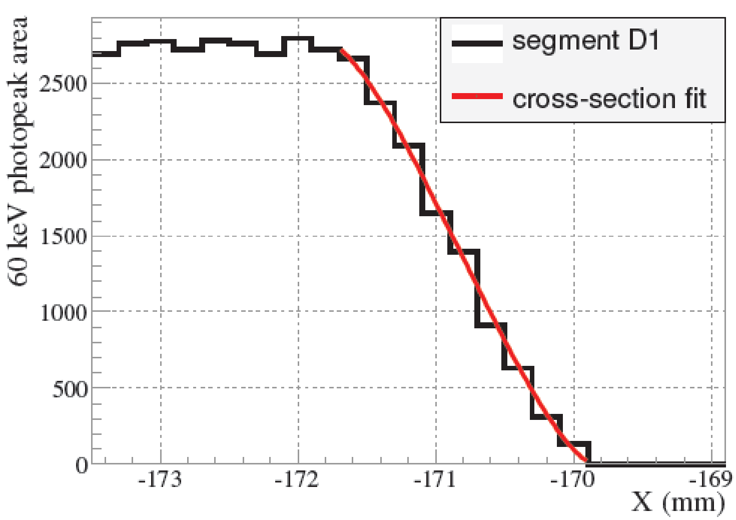
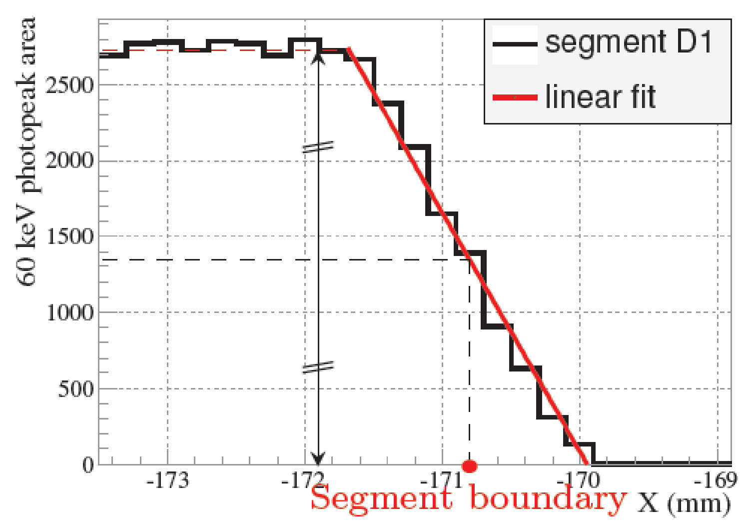
Segment boundaries



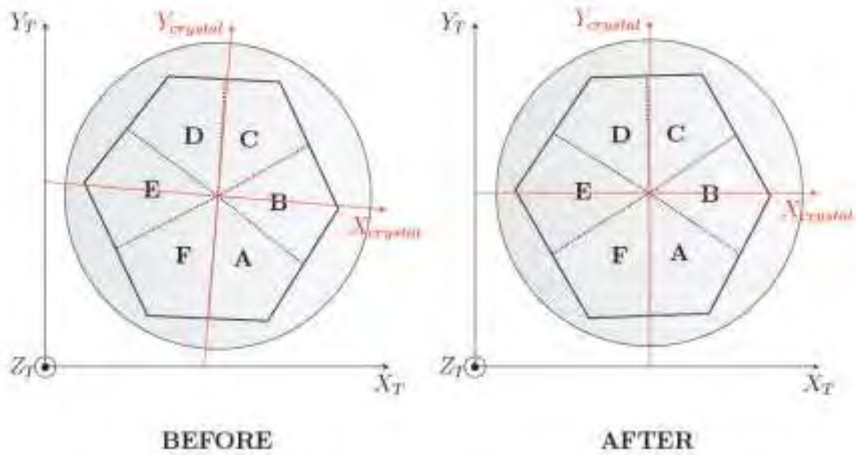
Fit with equation 3.1

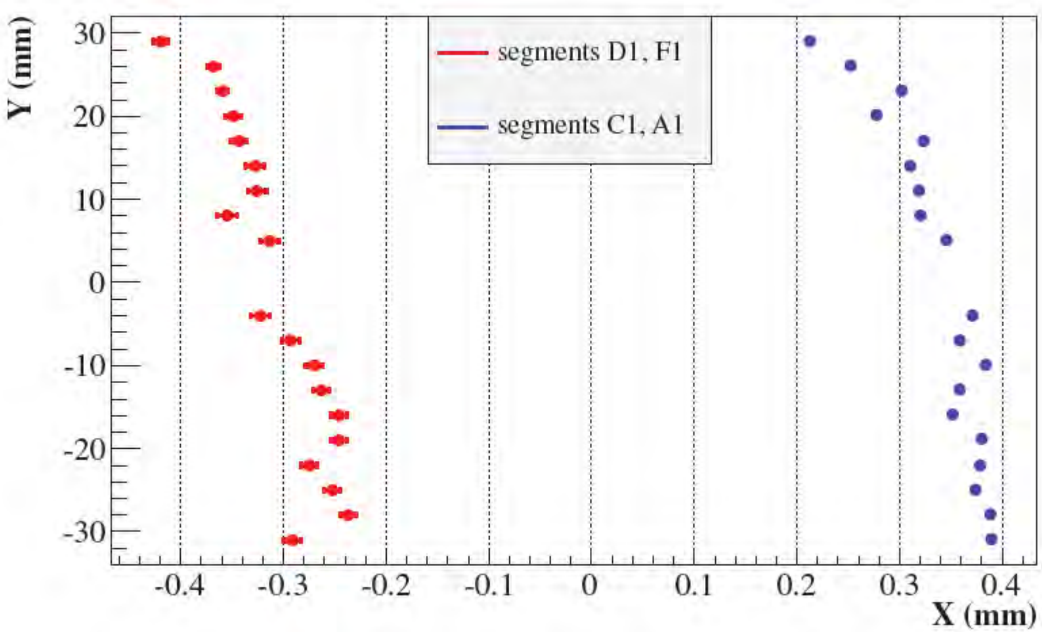


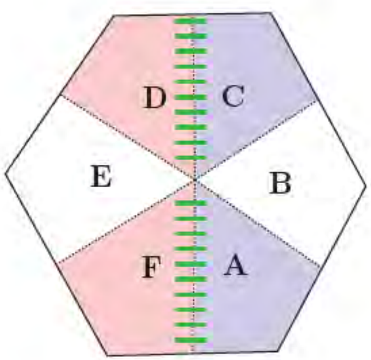
Linear fit



Rotation in vertical position







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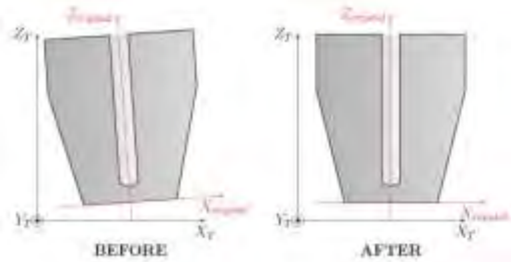
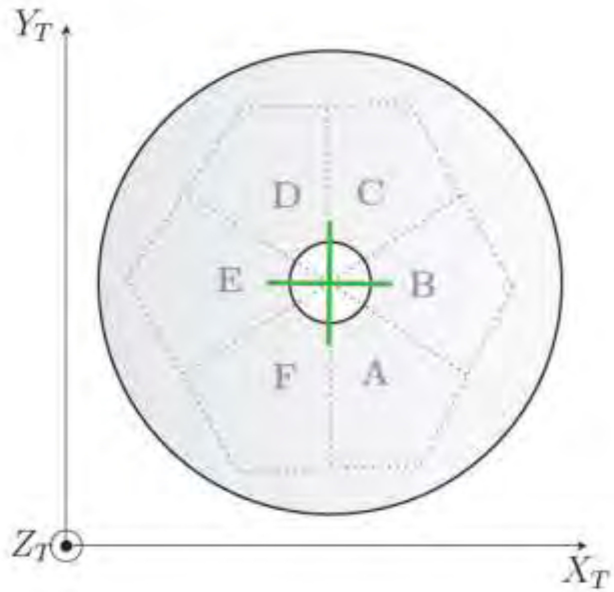
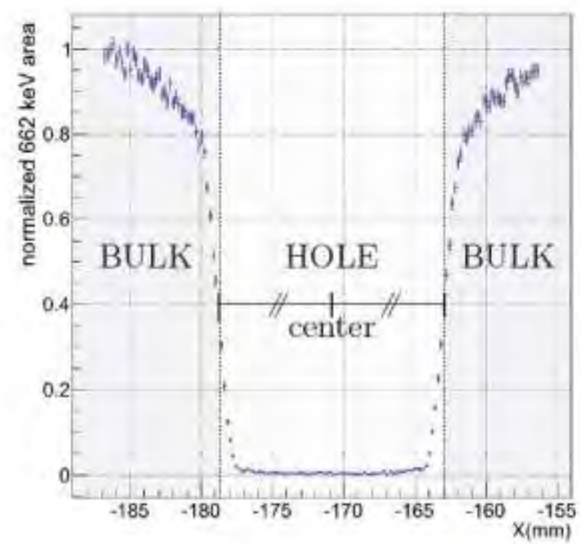
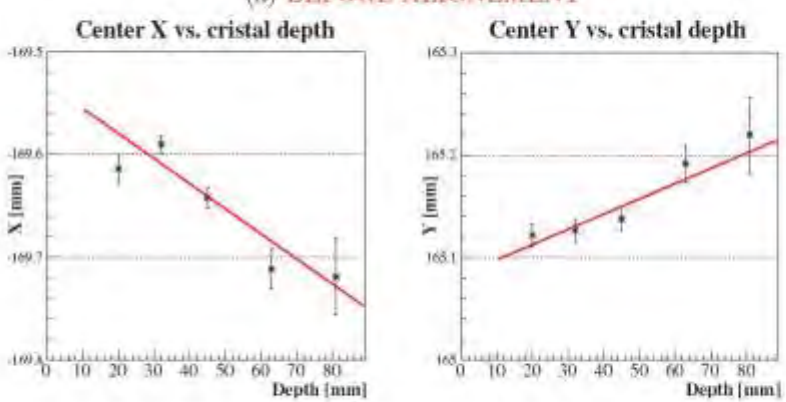
Vertical alignment



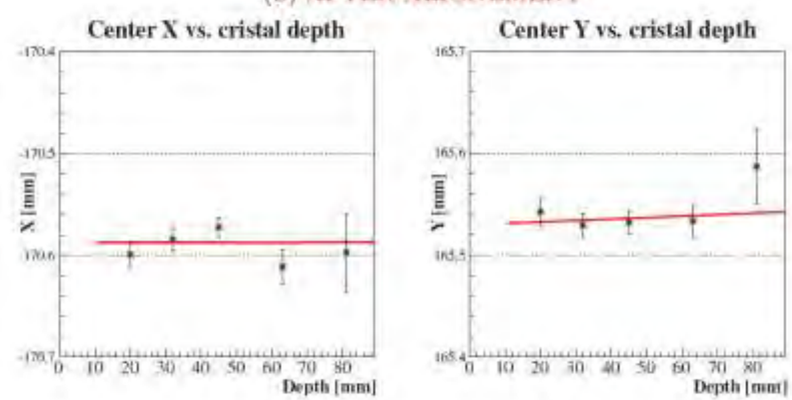




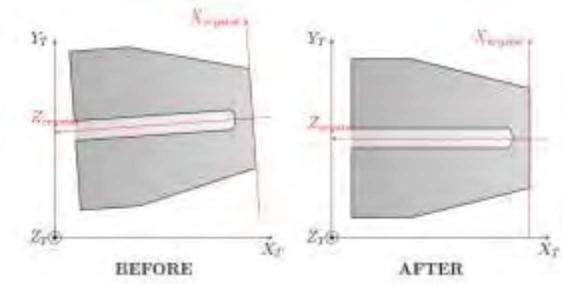
(a) BEFORE ALIGNEMENT

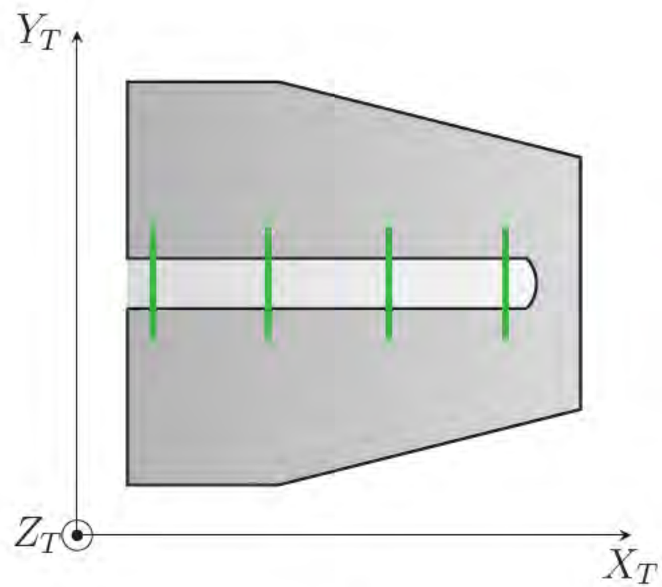


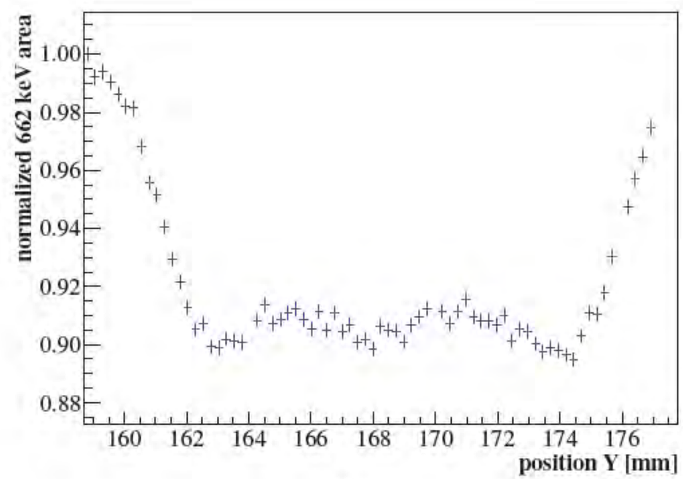
(b) AFTER ALIGNEMENT



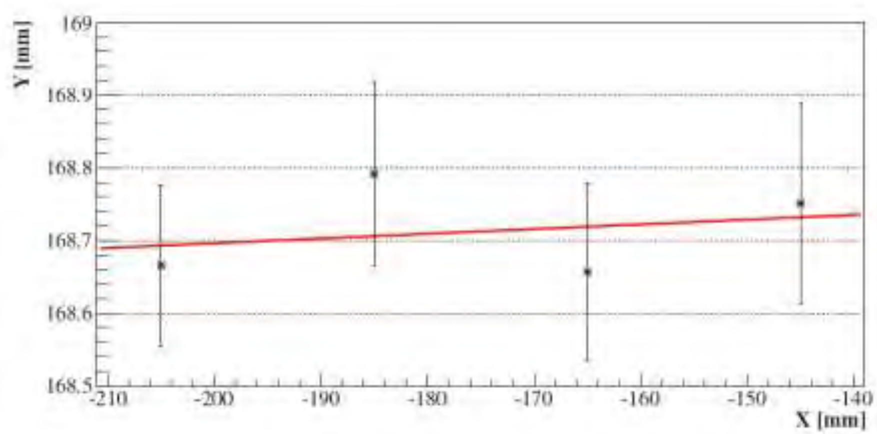
Horizontal alignment







(b)



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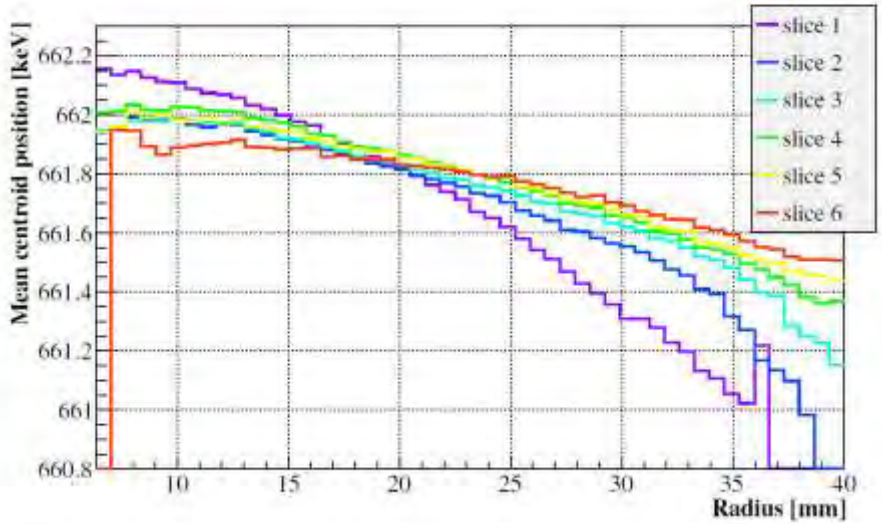
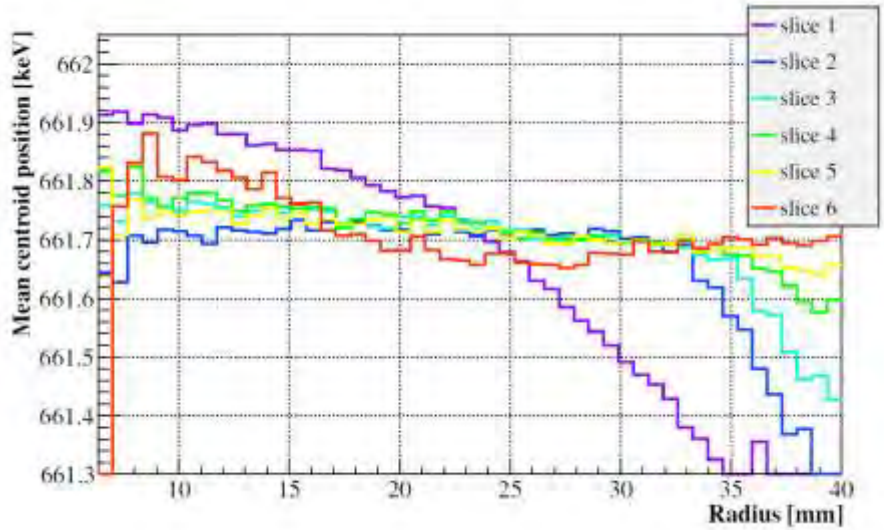
Peak shift

Average Core peak shift



Average Seg. peak shift



Electron trapping

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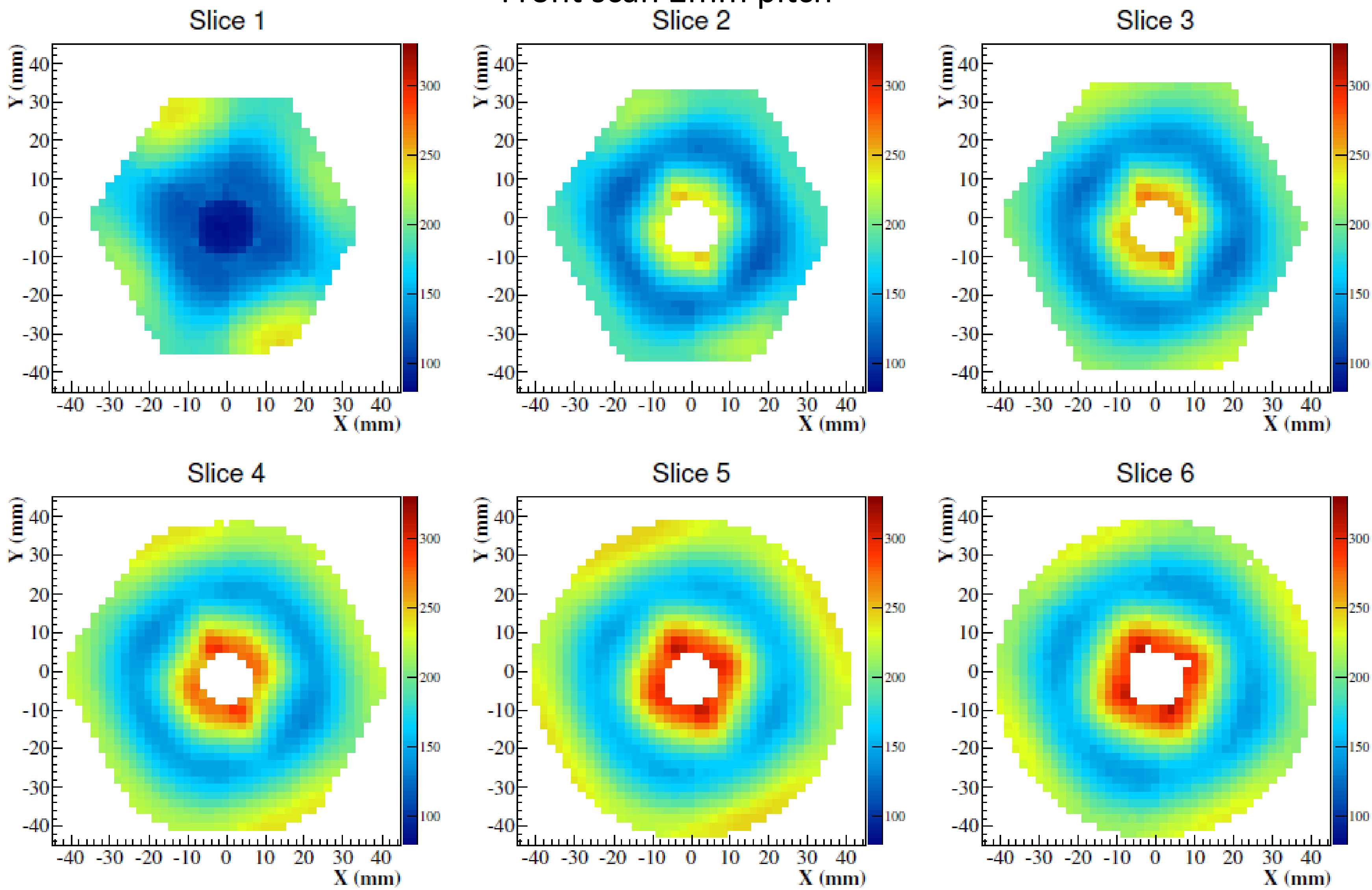
2D ^{137}Cs scans

Core T90 = t(ampl 90%) – t(ampl 10%)

Front scan 2mm pitch



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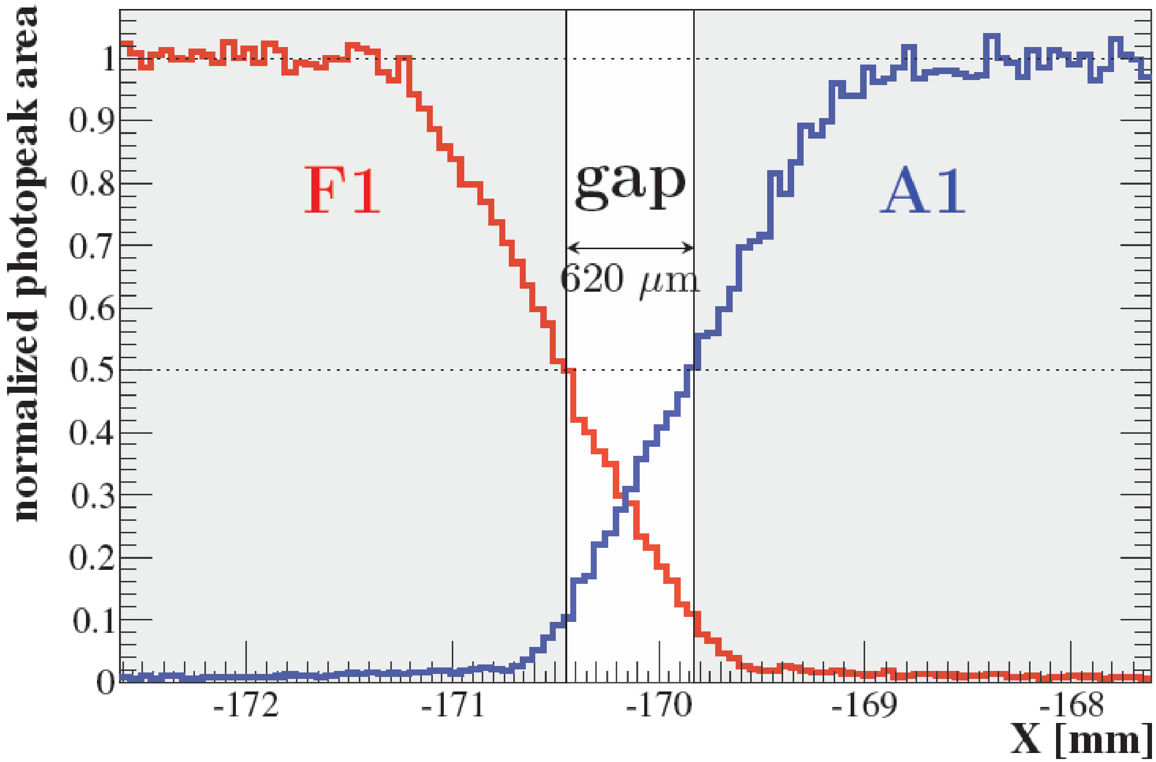
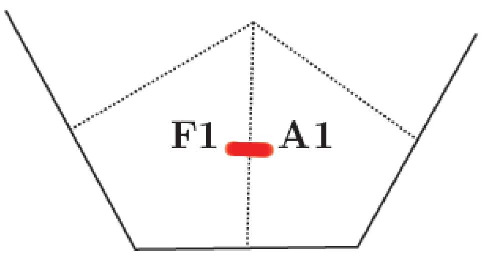
Charge sharing



50 μm pitch scan



- no efficiency loss if segments in addback mode **IF** large integration (55-61 keV) range
- **charge shared** between segments

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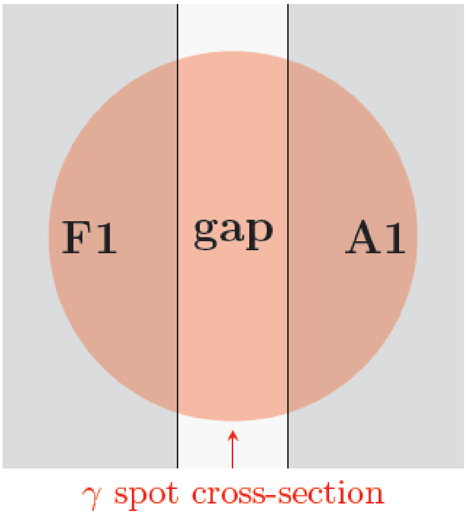
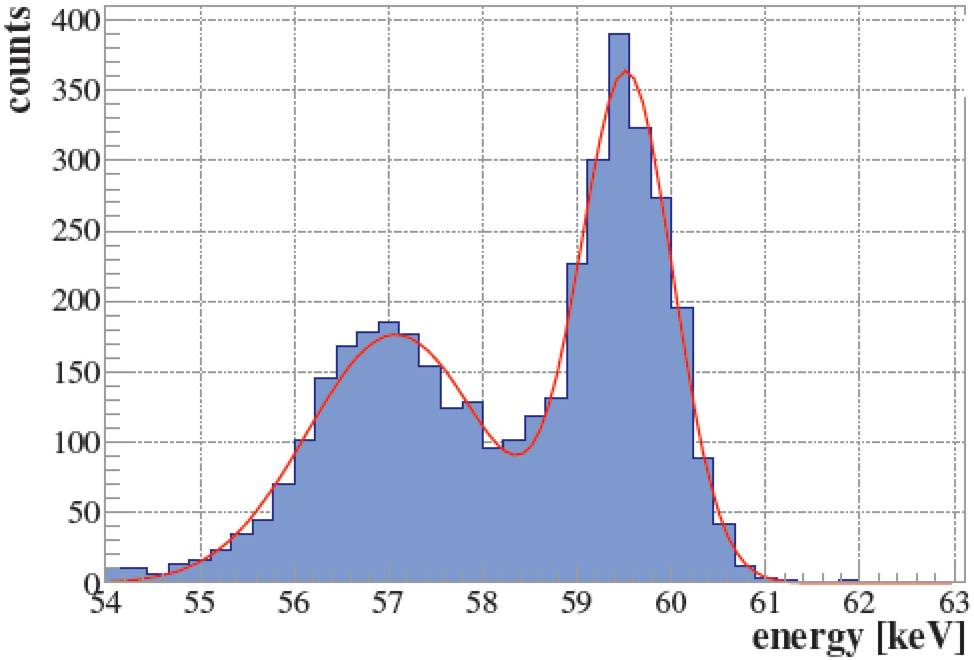
Charge sharing





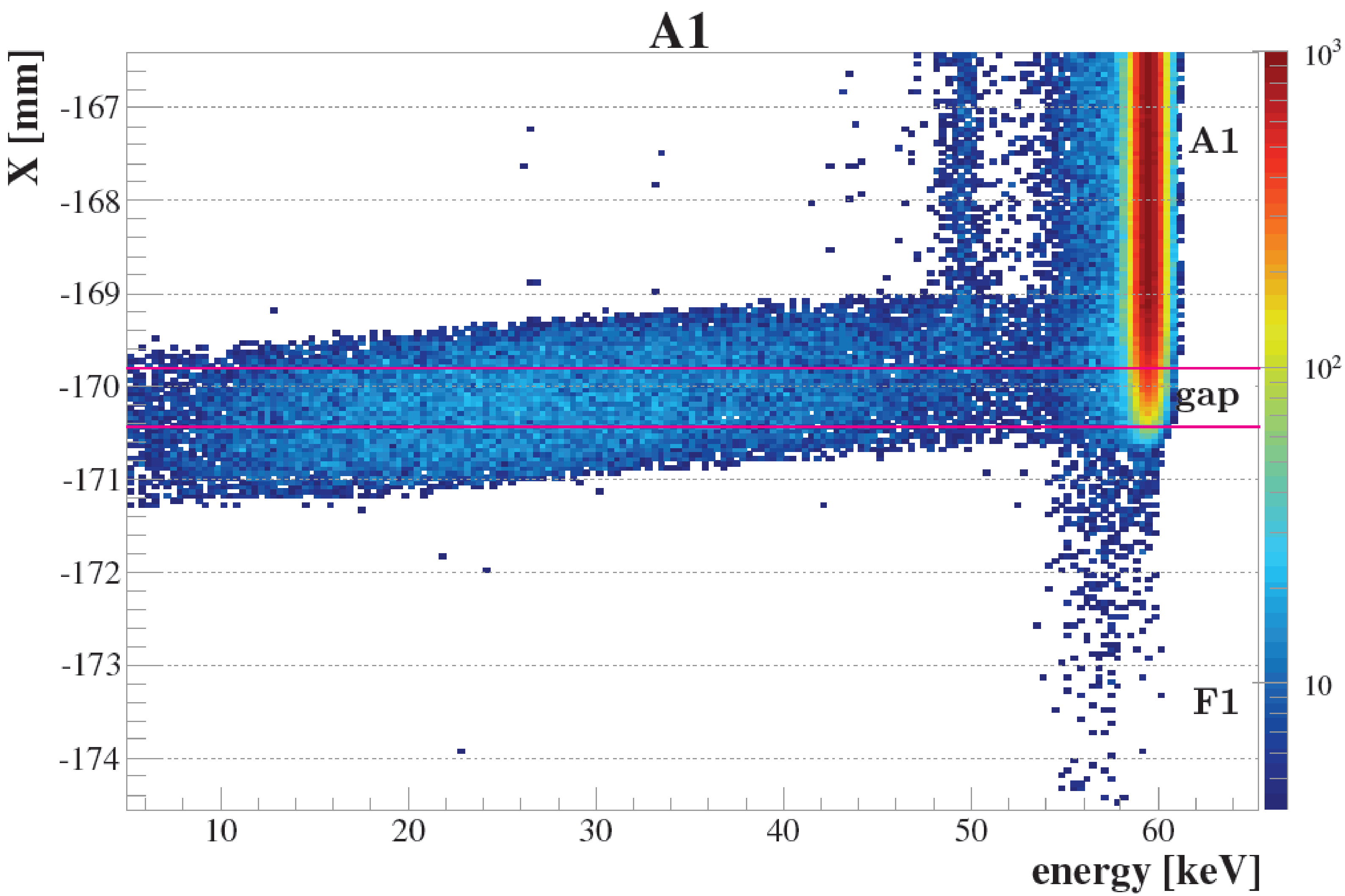
If Hole collection on inter-electrode gap

- 1 interaction, 2 segments hit
- 4% energy loss
- recognizable with $\sum E_{segment} << E_{Core}$

	low-energy component	full-energy component
Centroid [keV]	57.0	59.5
FWHM [keV]	2.20	1.16
Area [counts]	416	441

Charge sharing

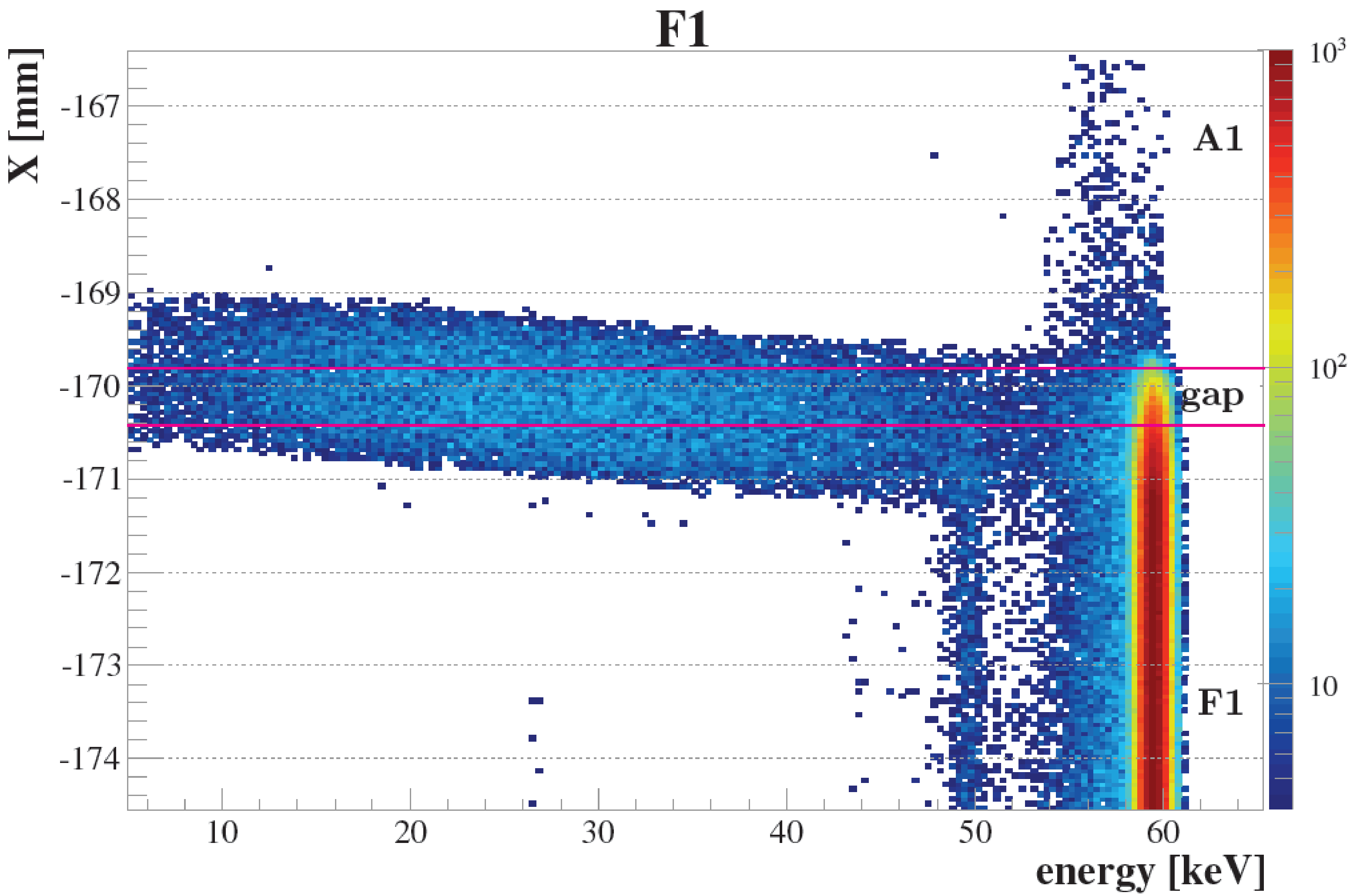
segment A1 spectrum vs scanning position



G. Duchêne

Charge sharing

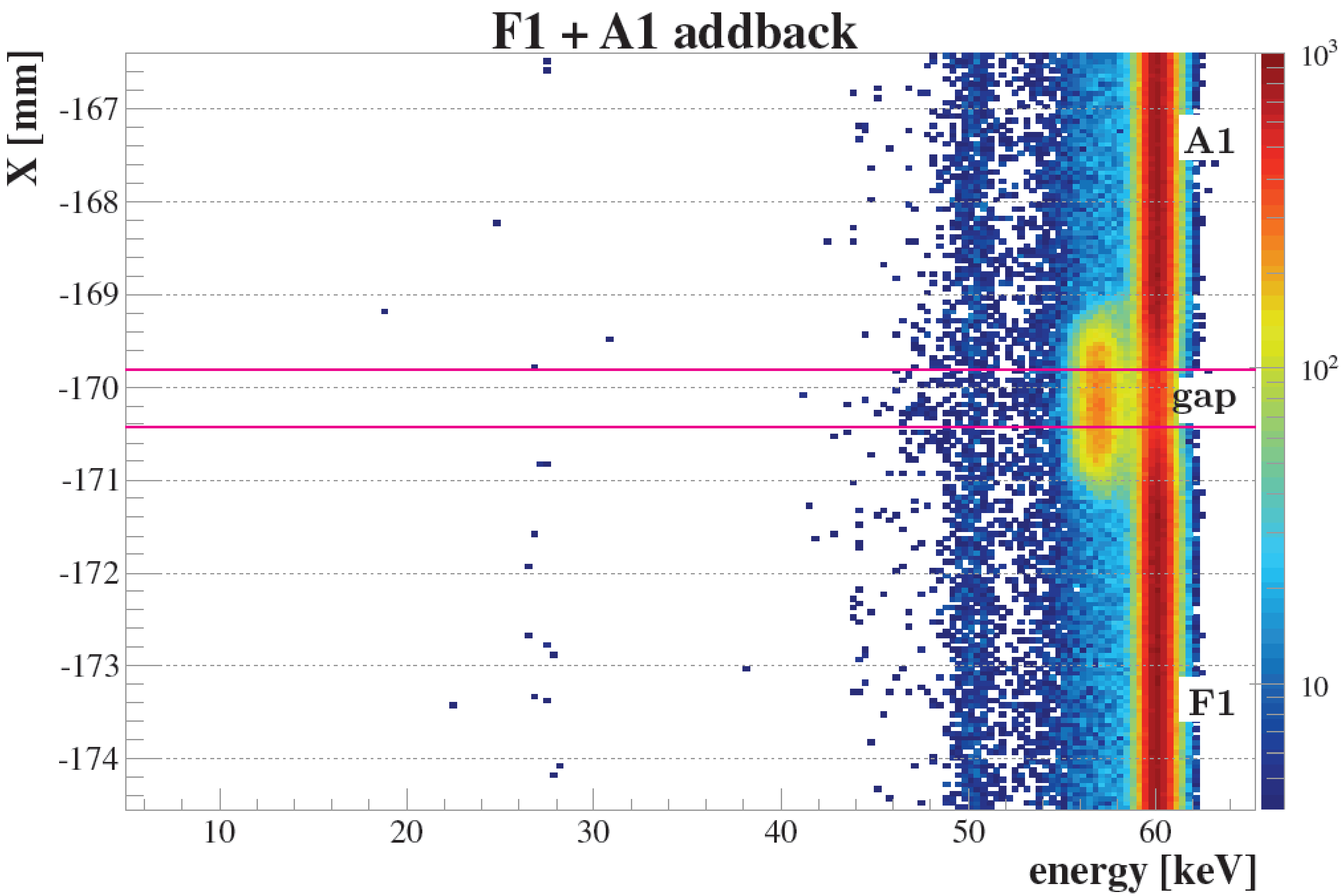
segment F1 spectrum vs scanning position



G. Duchêne

Charge sharing

segment A1+F1 addback spectrum vs scanning position



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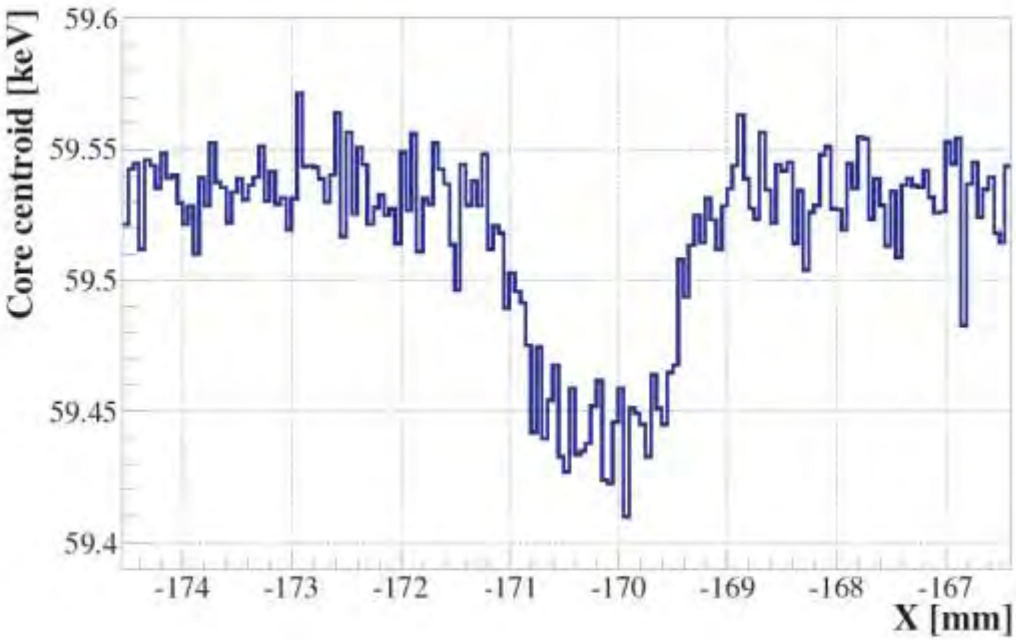
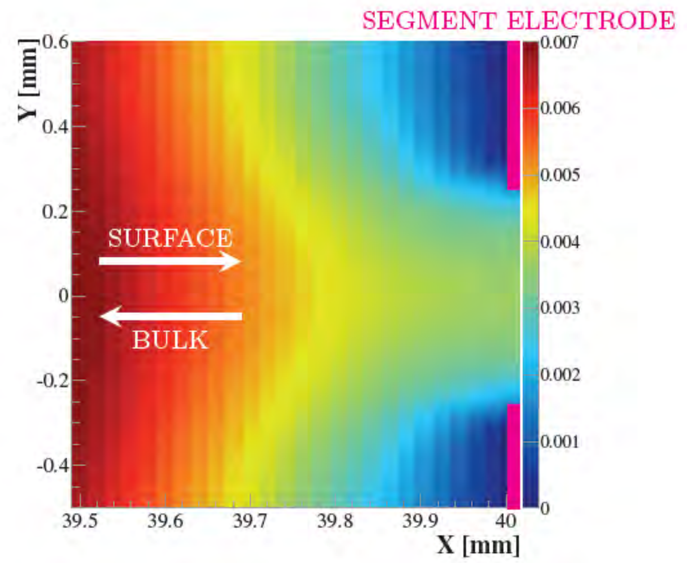
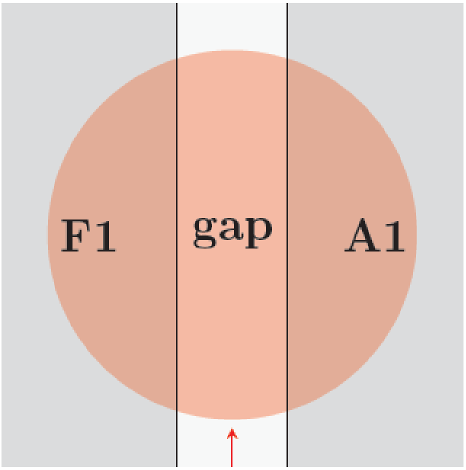
Charge sharing





- hole cloud reaching inter-segment gap
- charge NOT collected within the integration time
- readout value misses the weighting potential value @ hole cloud position



γ spot cross-section

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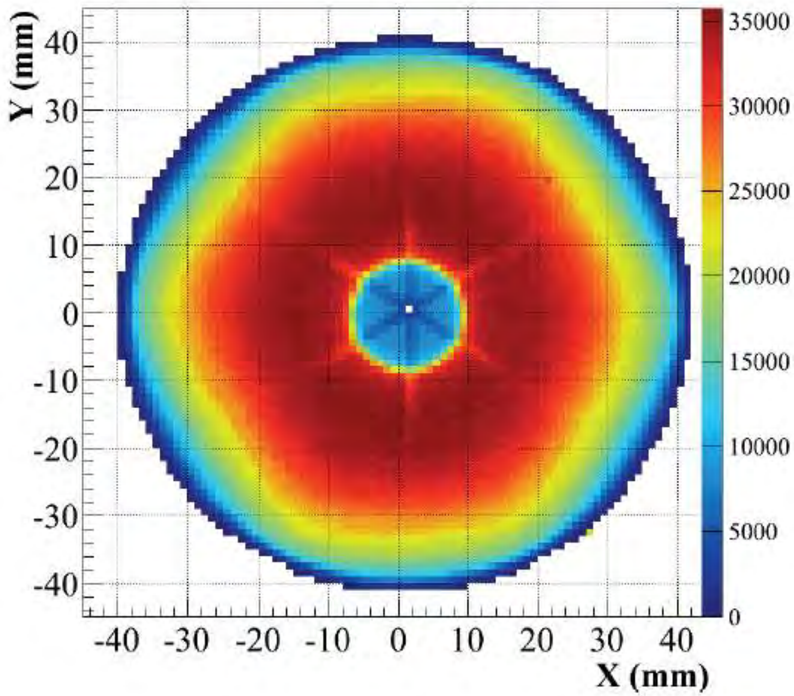
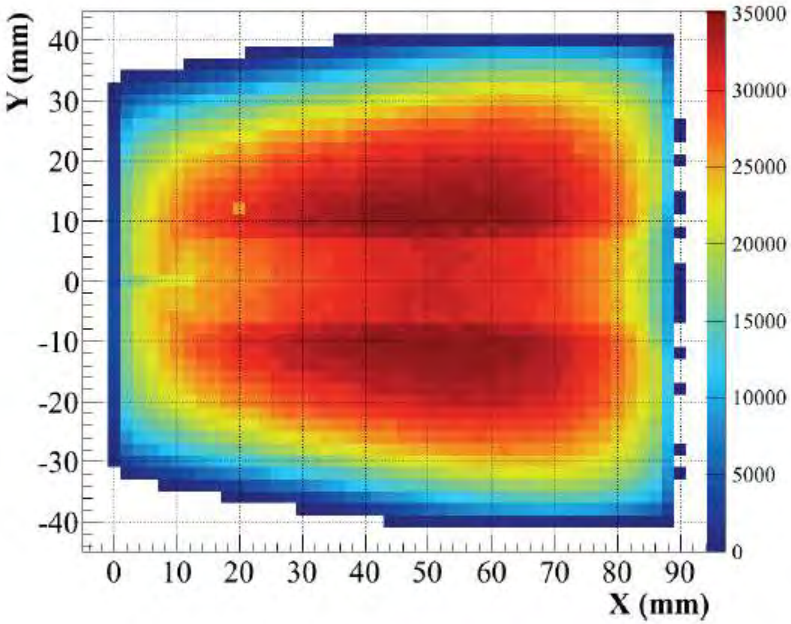
Charge sharing



(a)

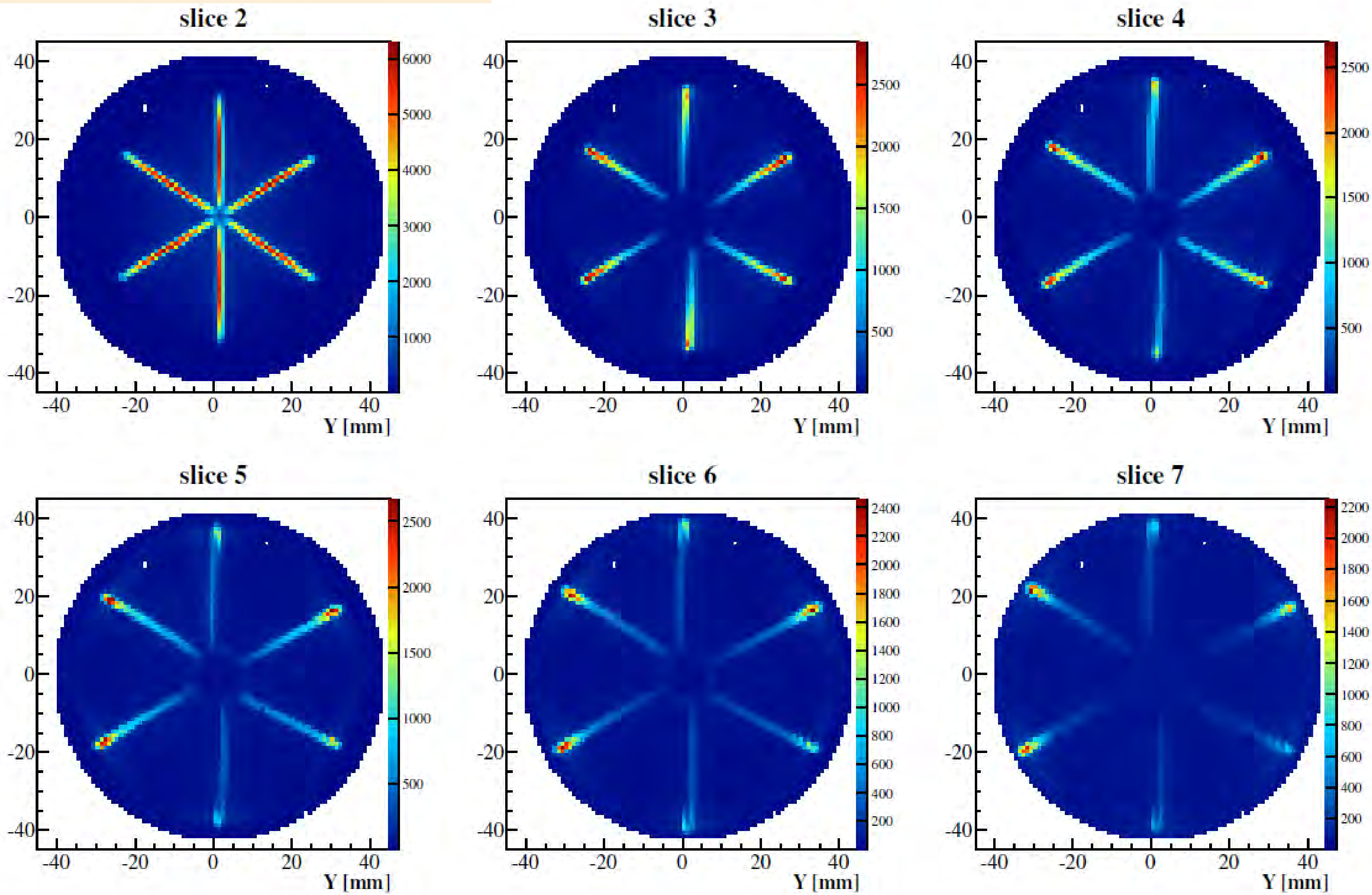


(b)

G. Duchêne

Charge sharing

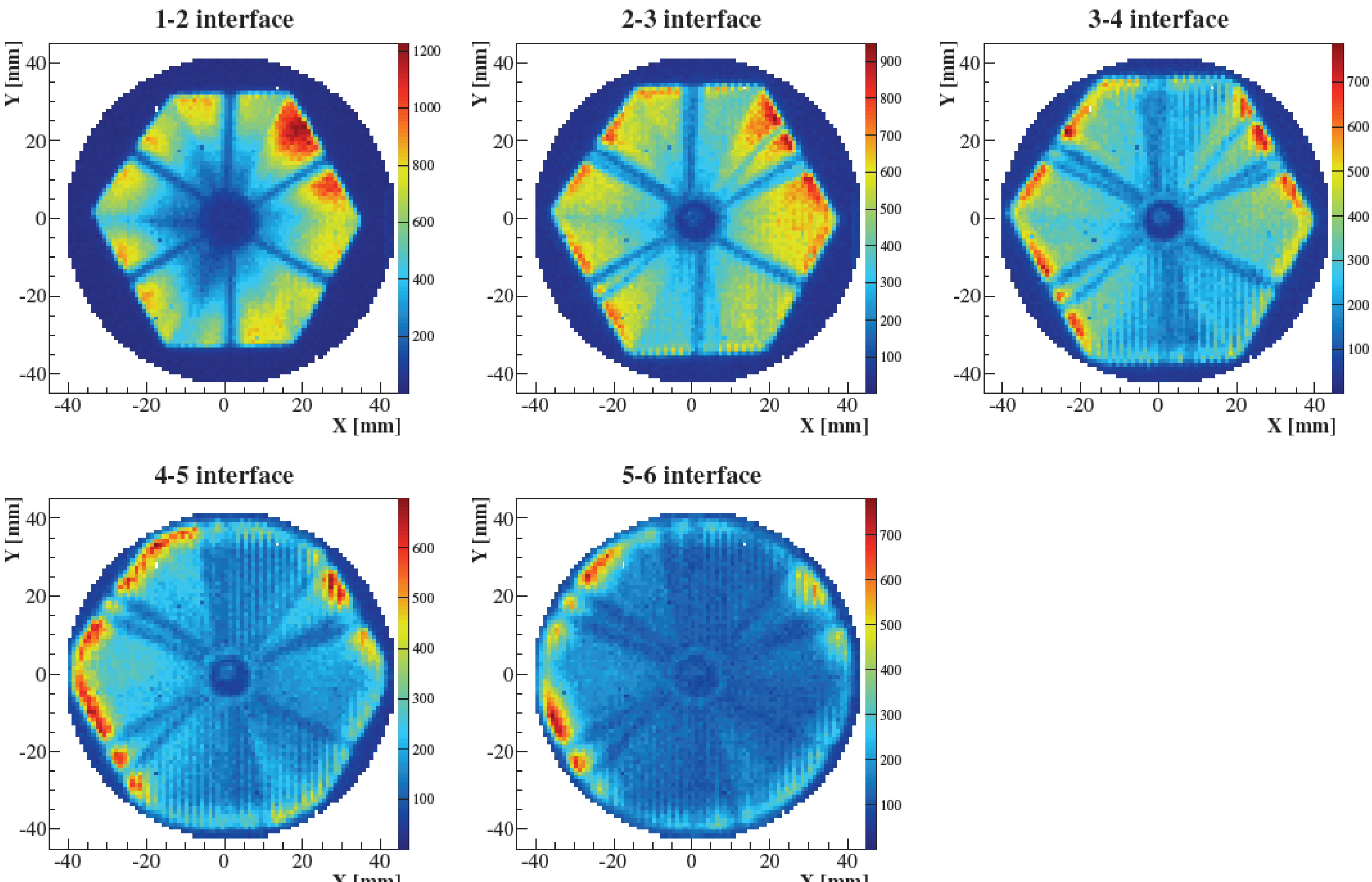
Charge charing intensity map



G. Duchêne

Charge sharing

Charge charing intensity map



G. Duchêne