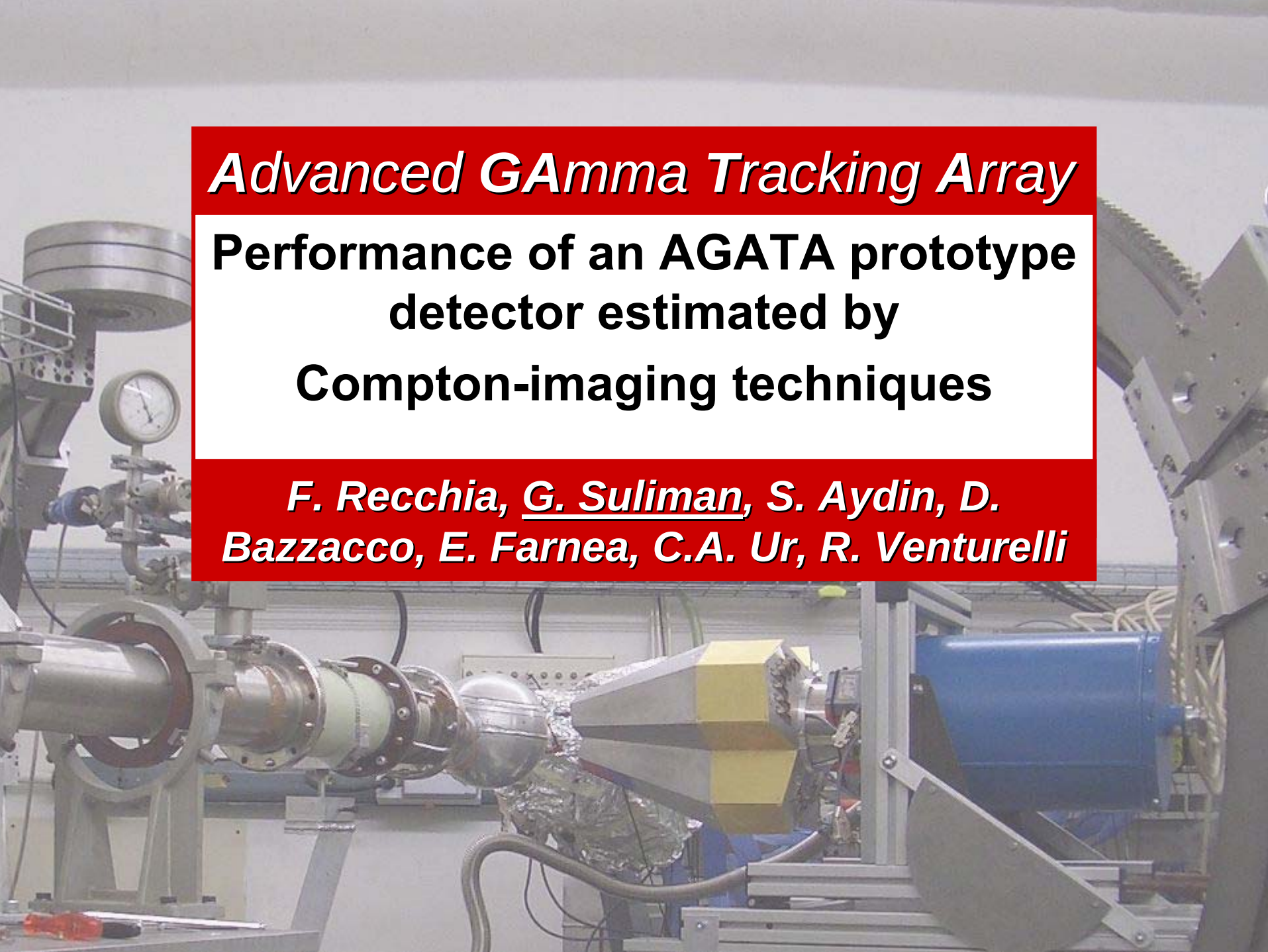


Advanced GAmma Tracking Array

Performance of an AGATA prototype detector estimated by Compton-imaging techniques

F. Recchia, G. Suliman, S. Aydin, D. Bazzacco, E. Farnea, C.A. Ur, R. Venturelli

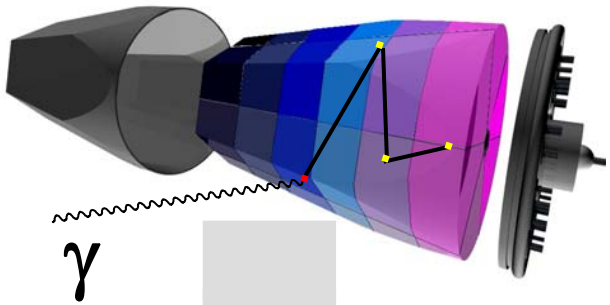
Outline

- The AGATA spectrometer
- Performance estimate from in-beam experiment
  - Results
  - Comparison to Monte Carlo simulation
- Performance estimate from off-line experiment
  - Imaging Principle
  - Measurements and results
- Conclusions

Ingredients of γ-ray tracking

1

Highly segmented HPGe detectors



2

Digital electronics to record and process segment signals

Identified interaction points

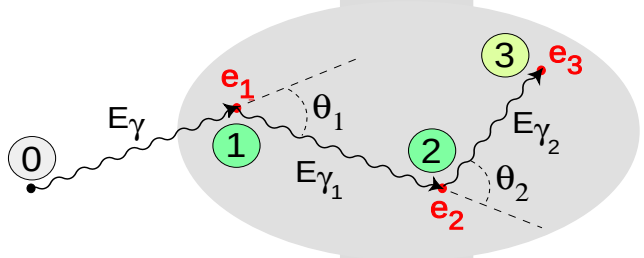
$(x,y,z,E)_i$

Pulse Shape Analysis to decompose recorded waves

3

4

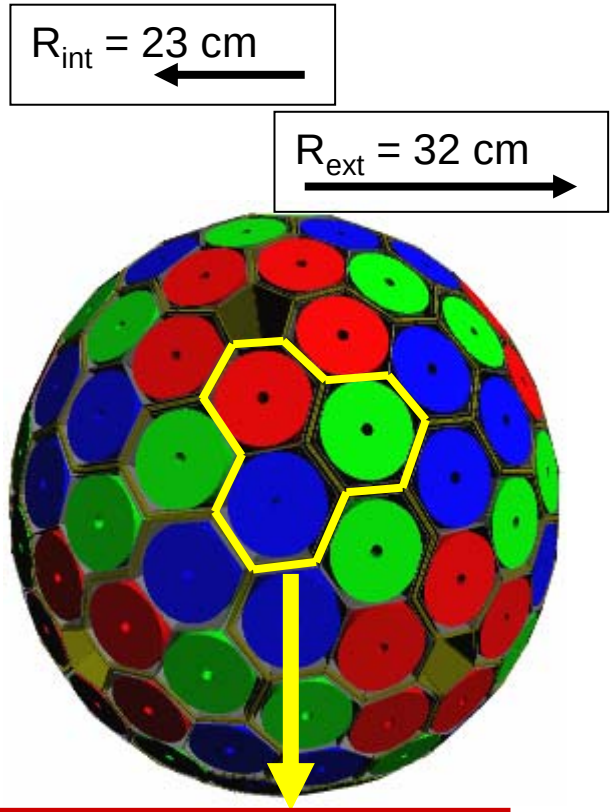
Reconstruction of scattering sequence from Compton vertices



$$E_{\gamma'} = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_0 c^2}(1 - \cos\theta)}$$

Reconstructed gamma-rays

The γ-ray spectrometer AGATA

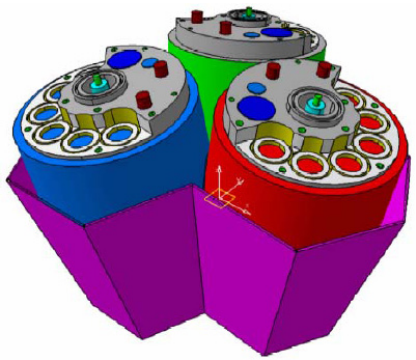


Design values:
5 mm of position resolution assumed

Efficiency:	**43% (M_γ=1)**	**28% (M_γ=30)**
today's arrays	~10%	5%
Peak/Total:	**58% (M_γ=1)**	**49% (M_γ=30)**
today	~55%	40%

Angular Resolution: ~1º

FWHM (1 MeV, v/c=50%)	**~ 6 keV**
today	~40 keV



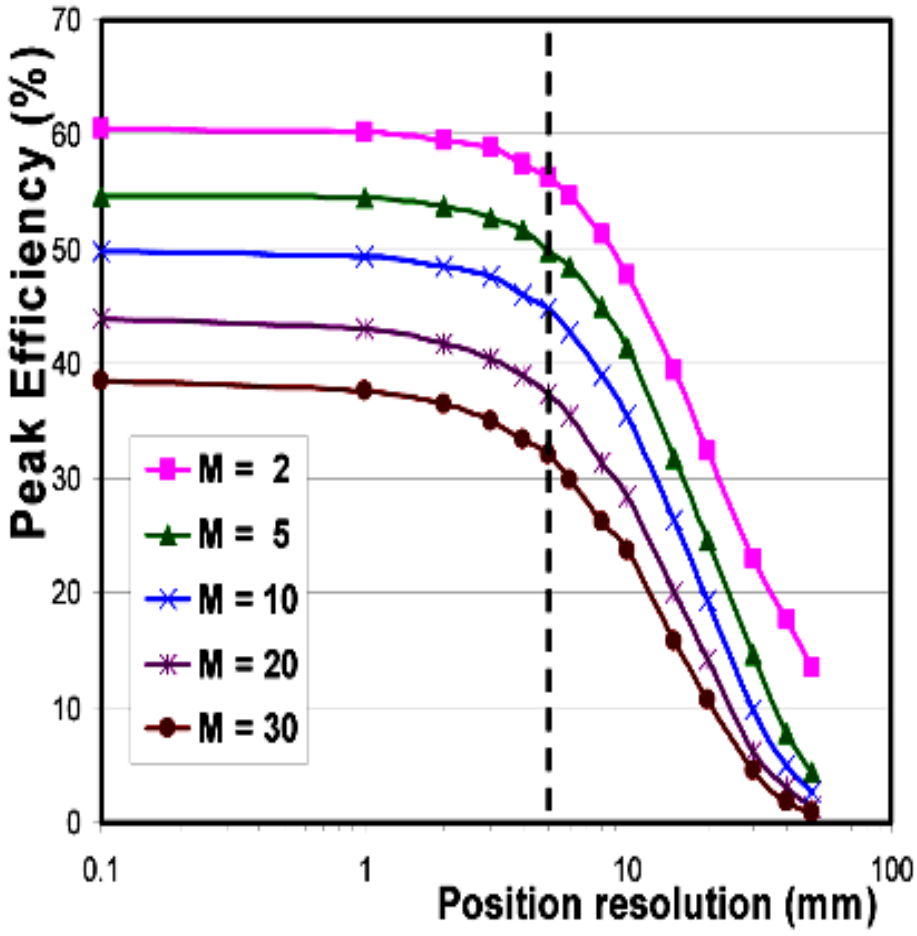
Triple cluster

- 180 large volume 36-fold segmented Ge crystals packed in 60 triple-clusters
- Digital electronics and sophisticated Pulse Shape Analysis algorithms
- Operation of Ge detectors in position sensitive mode for γ-ray tracking

The position resolution required for the AGATA detectors

Simulations suggest that the overall performance depends on the attainable **position resolution**

A **test-beam experiment** has been performed to measure this parameter in realistic experimental conditions



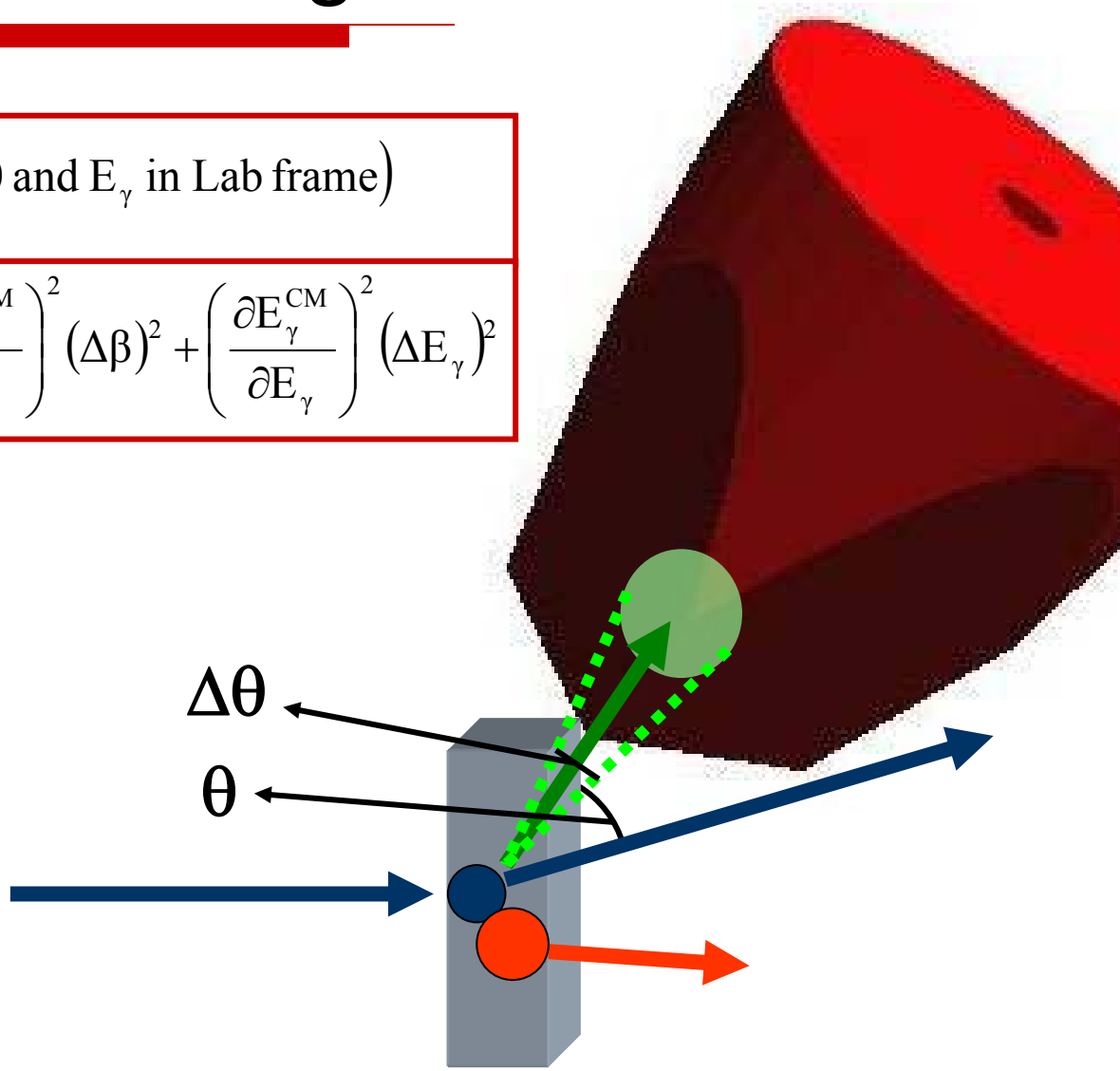
Doppler broadening

$$E_\gamma^{CM} = E_\gamma \frac{1-\beta\cos(\theta)}{\sqrt{1-\beta^2}} \qquad (\beta,\ \theta \text{ and } E_\gamma \text{ in Lab frame})$$

$$\left(\Delta E_\gamma^{CM}\right)^2 = \left(\frac{\partial E_\gamma^{CM}}{\partial \theta}\right)^2 (\Delta\theta)^2 + \left(\frac{\partial E_\gamma^{CM}}{\partial \beta}\right)^2 (\Delta\beta)^2 + \left(\frac{\partial E_\gamma^{CM}}{\partial E_\gamma}\right)^2 (\Delta E_\gamma)^2$$

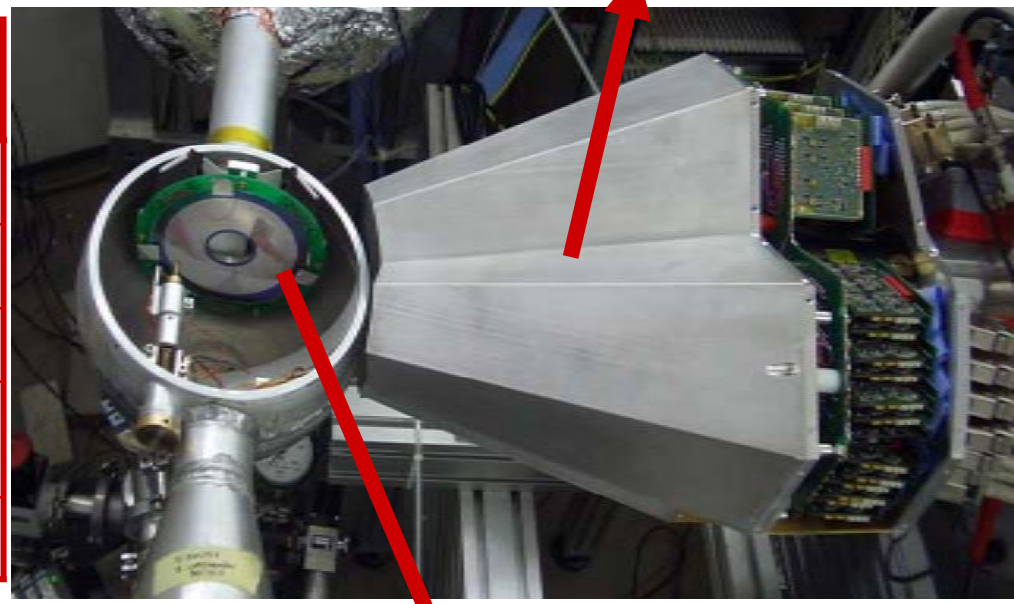
Position resolution

Angular resolution

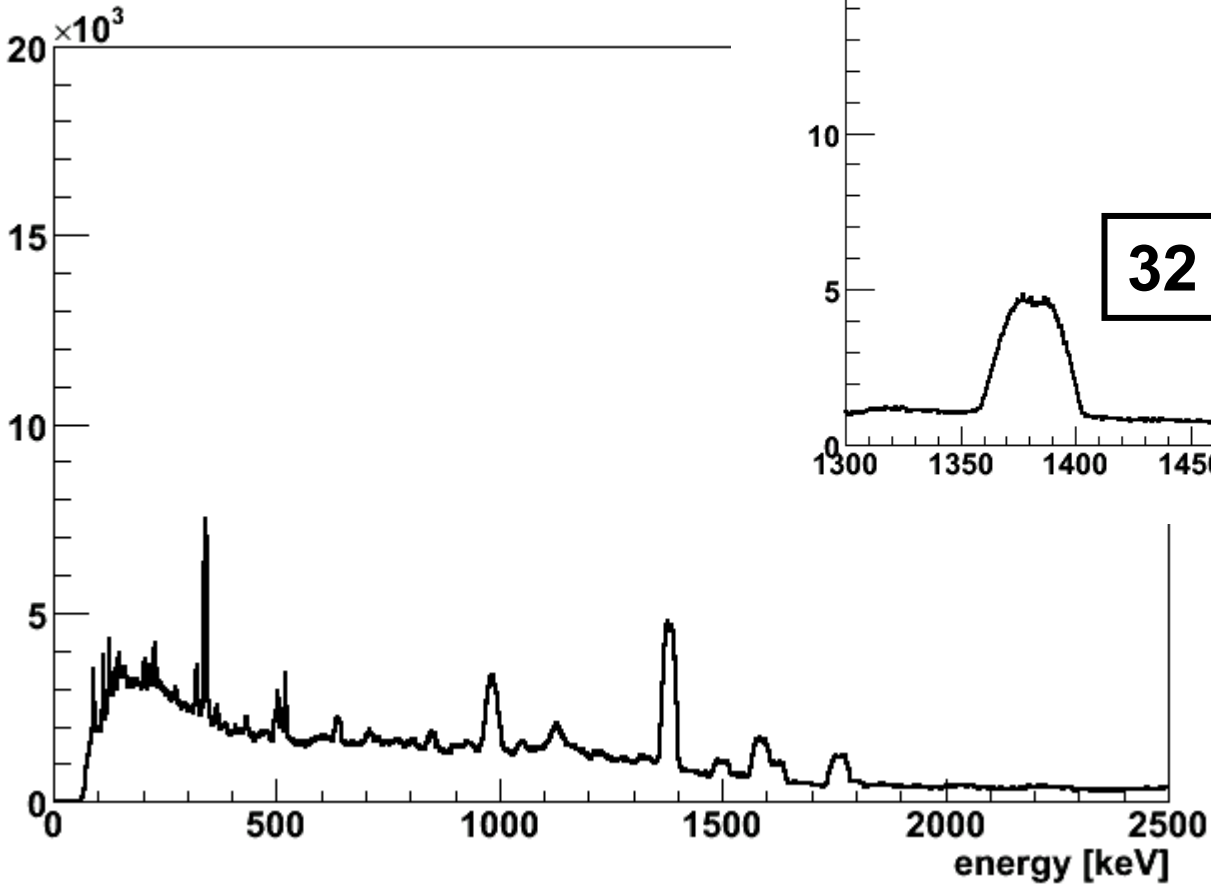


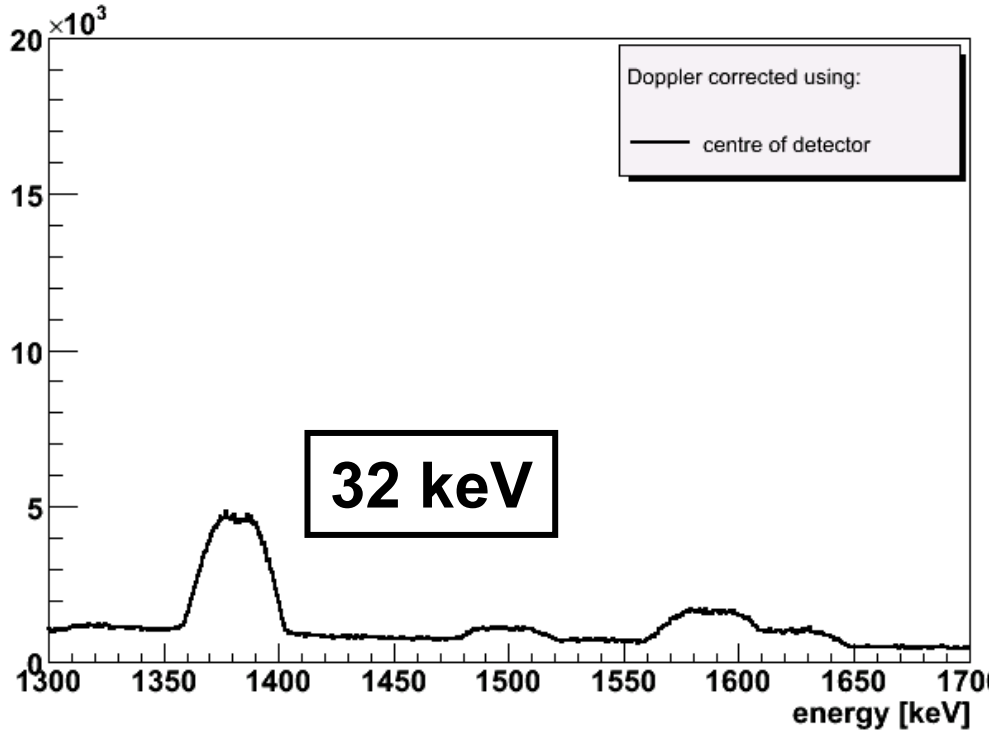
Setup of the in-beam experiment

d(^{48}Ti,^{49}Ti)p		
BEAM	^{48}Ti	100 MeV
TARGET	^{48}Ti + ^{2}H	220 μg/cm^2
Si detector DSSSD	Thickness: 300 μm	
	32 rings, 64 sectors	
AGATA symmetric triple-cluster		



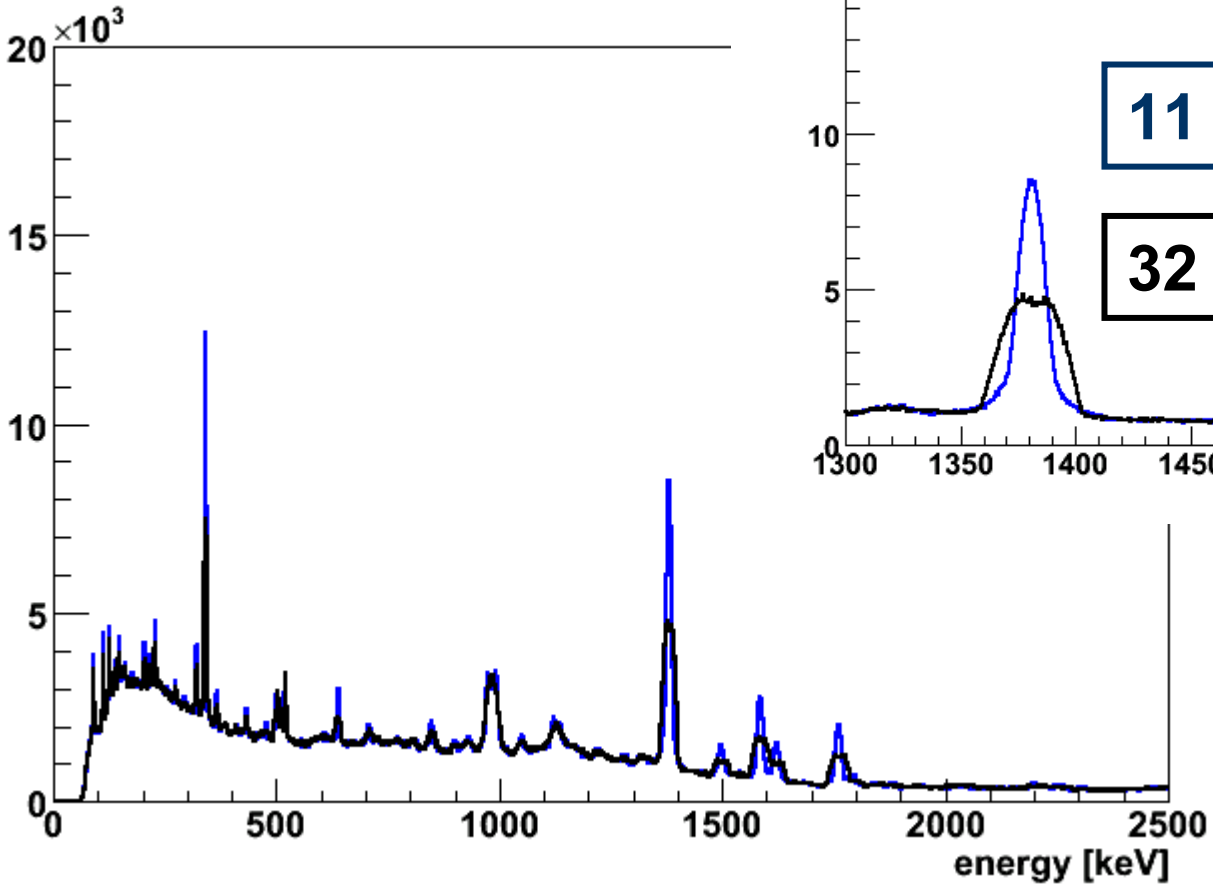
Doppler correction using PSA results

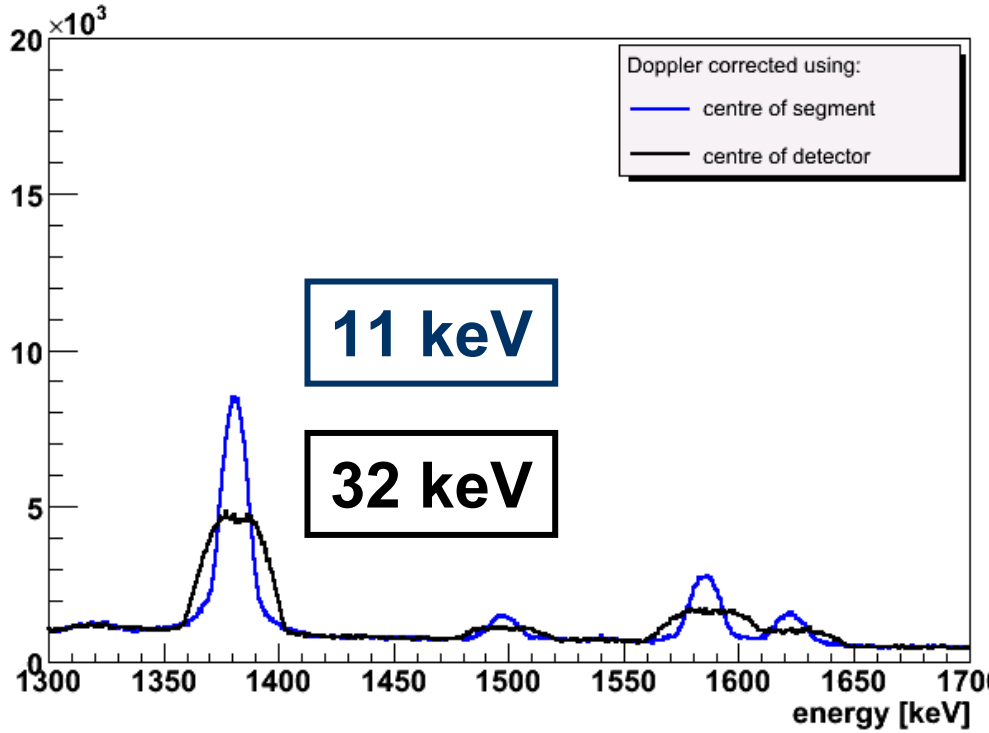




Full statistics used

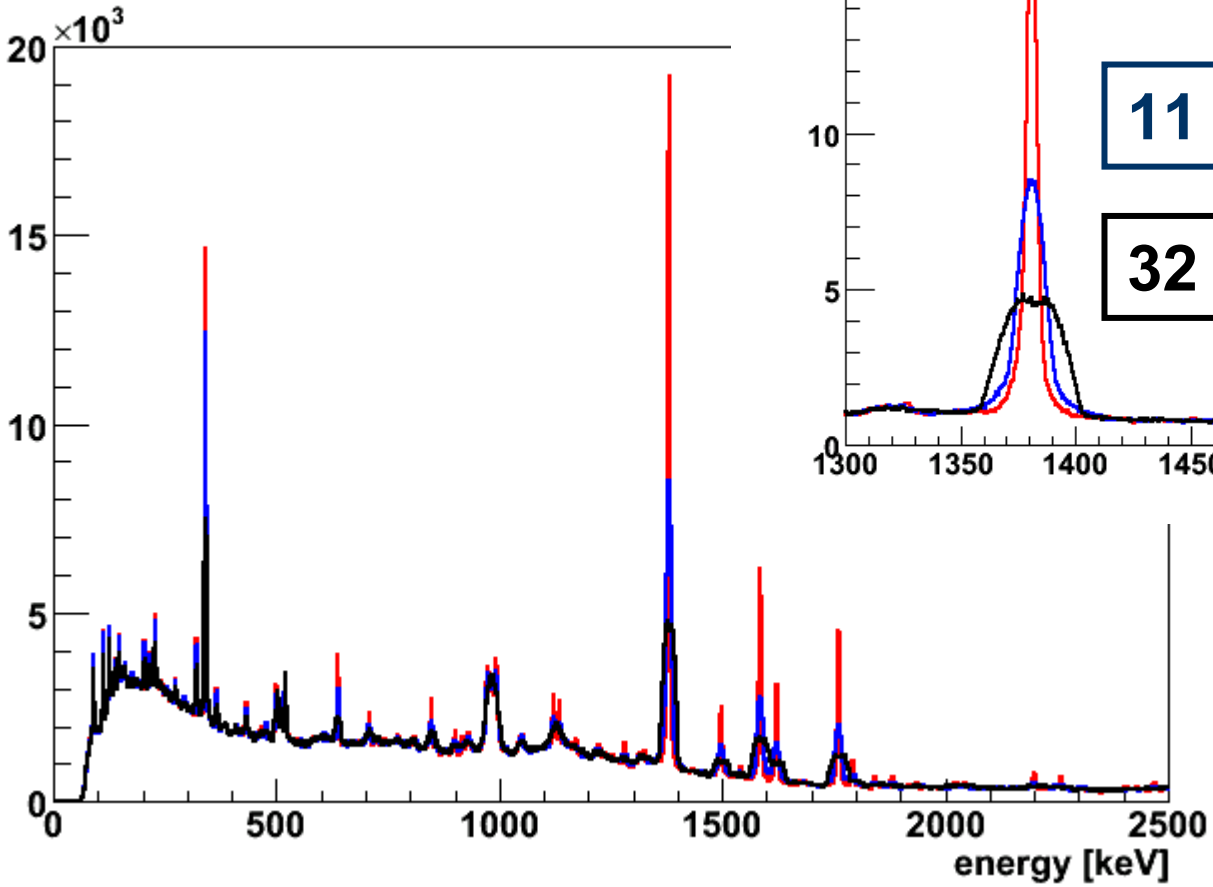
Doppler correction using PSA results

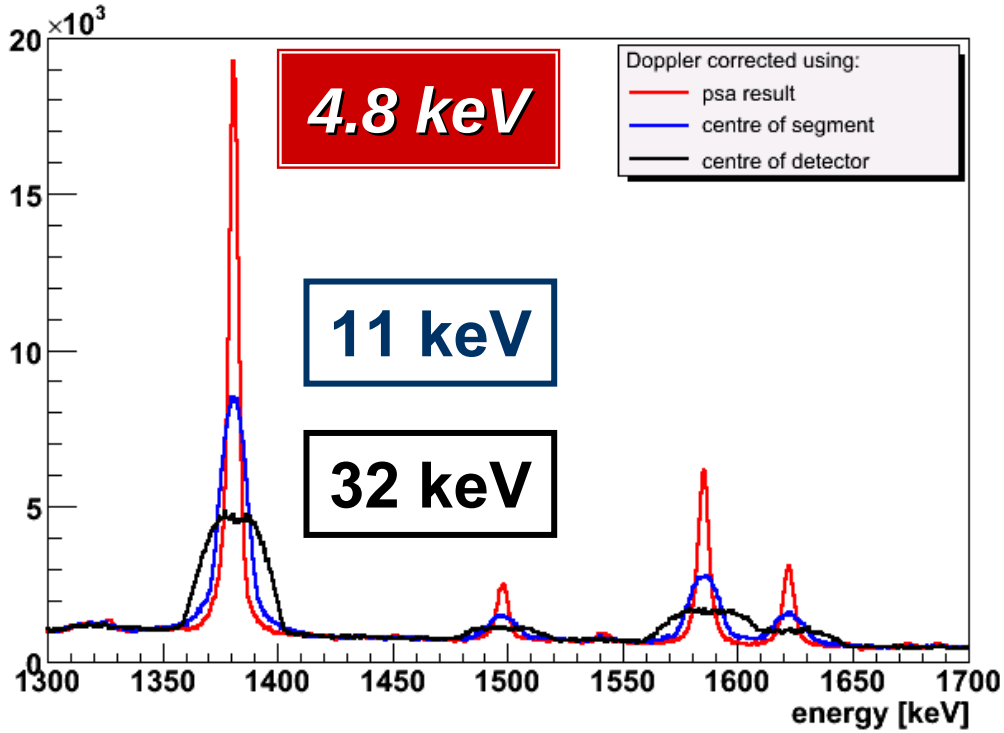




Full statistics used

Doppler correction using PSA results

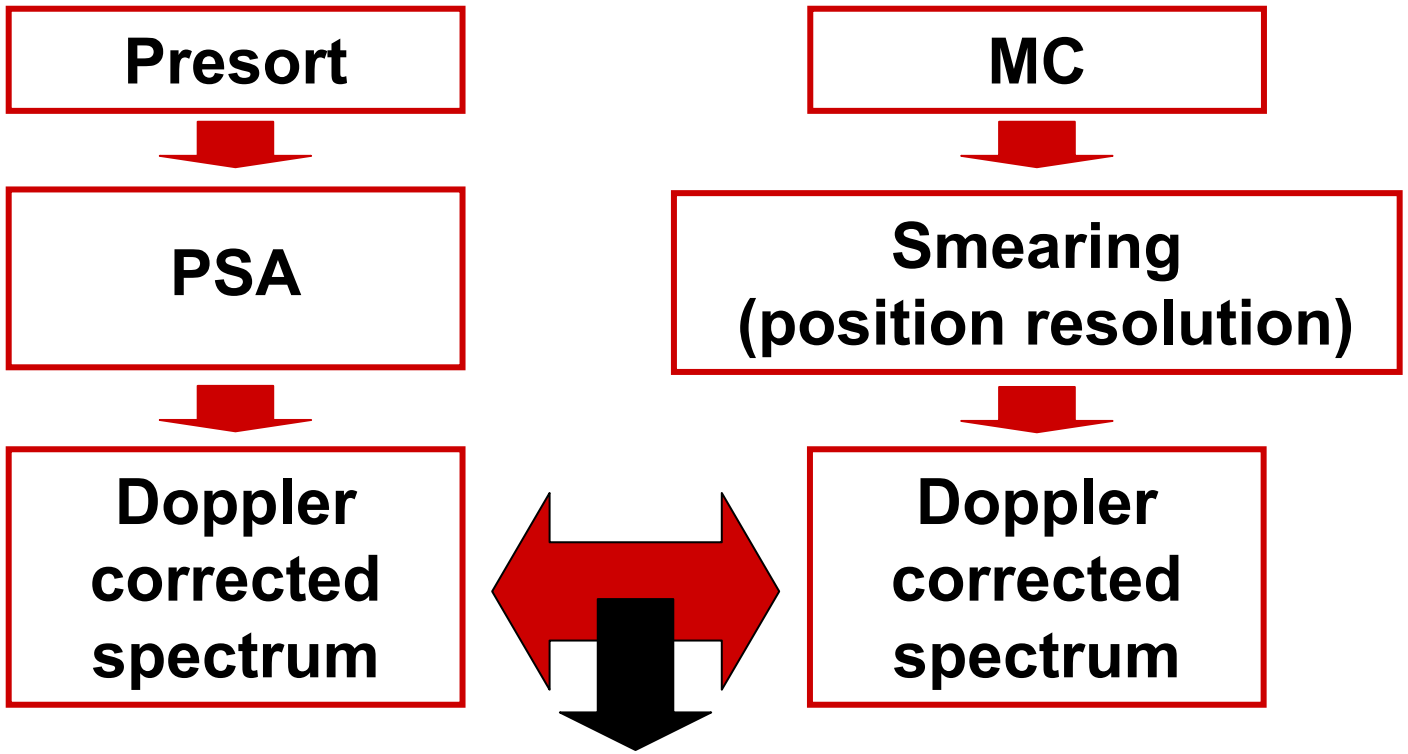




Full statistics used

PSA algorithm:
Grid Search

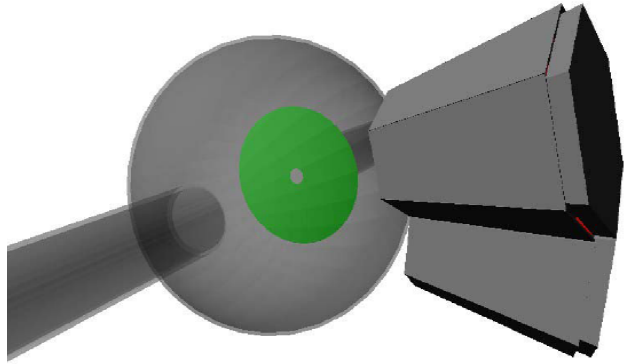
Outline of analysis/simulation

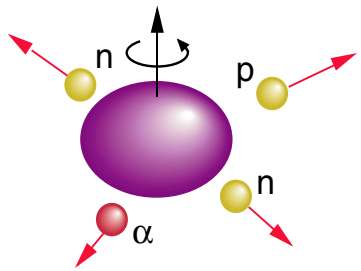


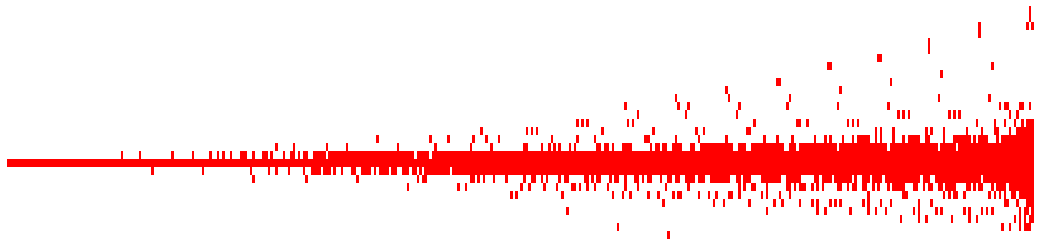
Position resolution

Simulation

- A **GEANT4 simulation** for the AGATA and other ancillary detectors
- A **Monte Carlo event generator** based on cascade and GammaWare
- **SRIM** calculations to estimate target thickness impact







Simulation vs Experiment

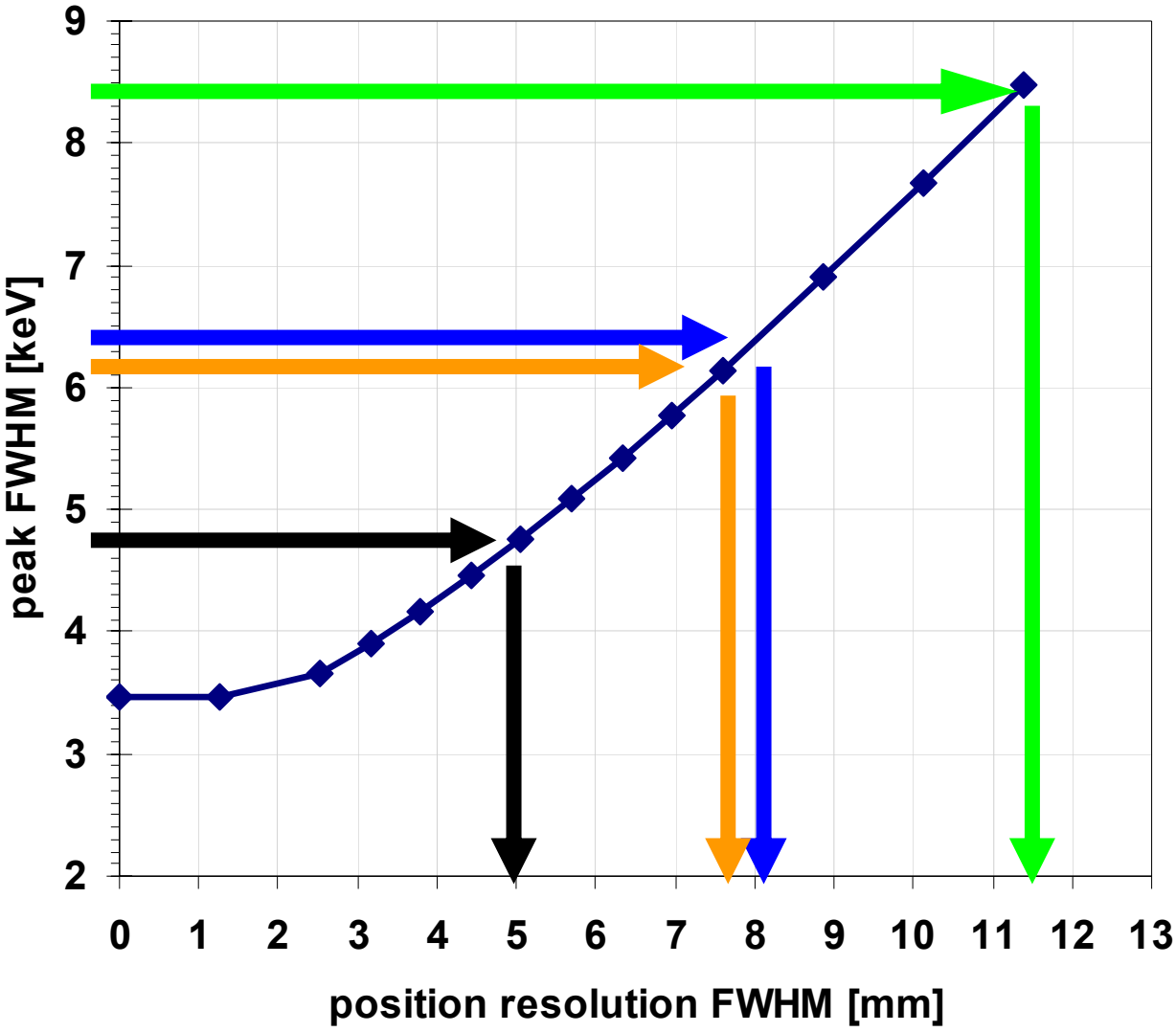
Recursive Subtraction

Matrix Method

Miniball Algorithm

Grid Search

Results obtained with different PSA algorithm



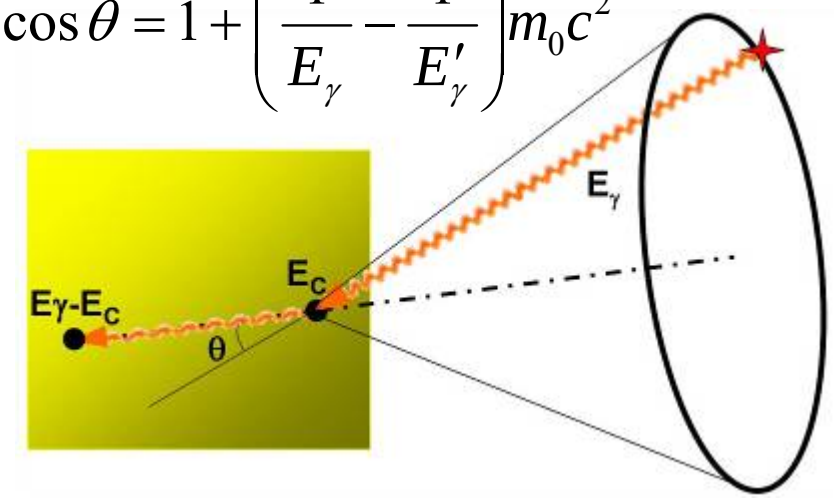
Performance estimate from experiment

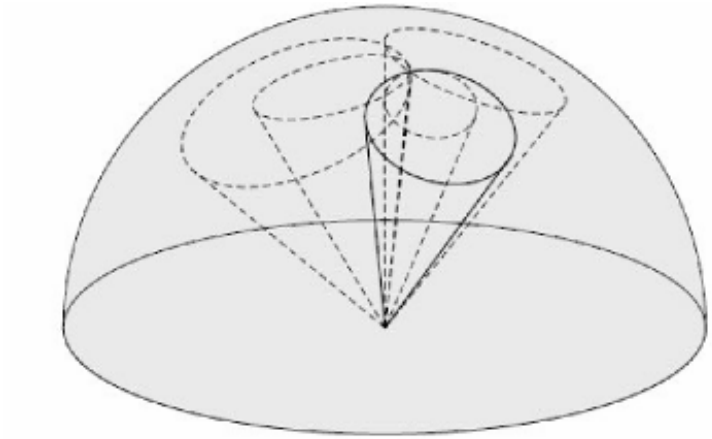
- Typical conditions of future use
- DSSD(or other ancillary)
- Beam Time
- Not trivial data analysis:
  - Gating on particles
  - Doppler correction
  - “Simple” physics case that can be simulated

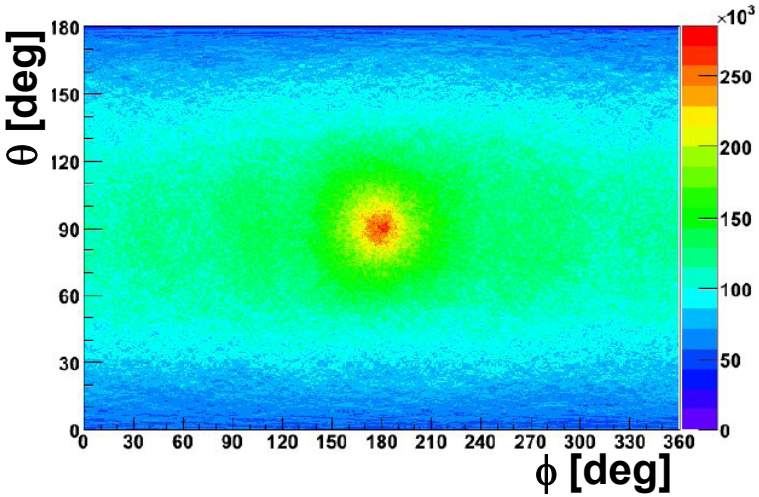
Is there no other simple way?

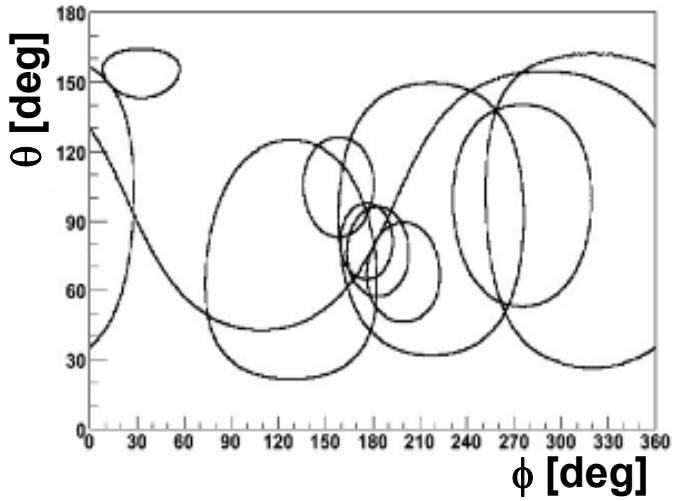
Compton imaging principle

$$\cos\theta = 1 + \left(\frac{1}{E_\gamma} - \frac{1}{E'_\gamma}\right) m_0 c^2$$





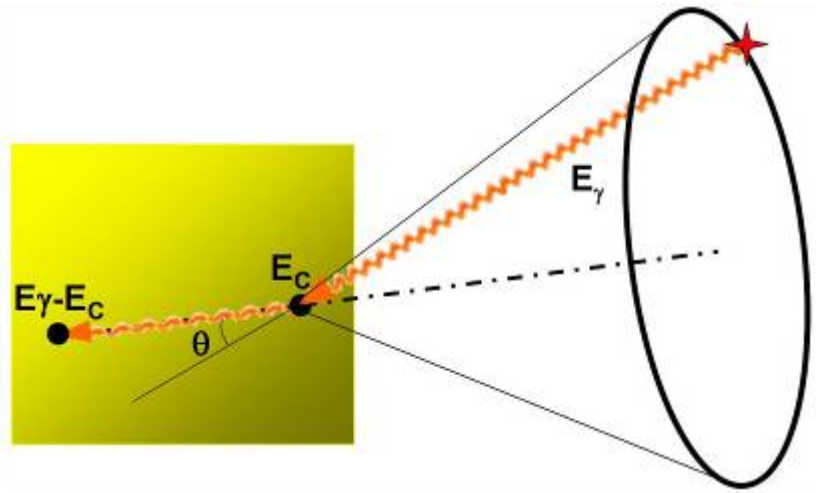


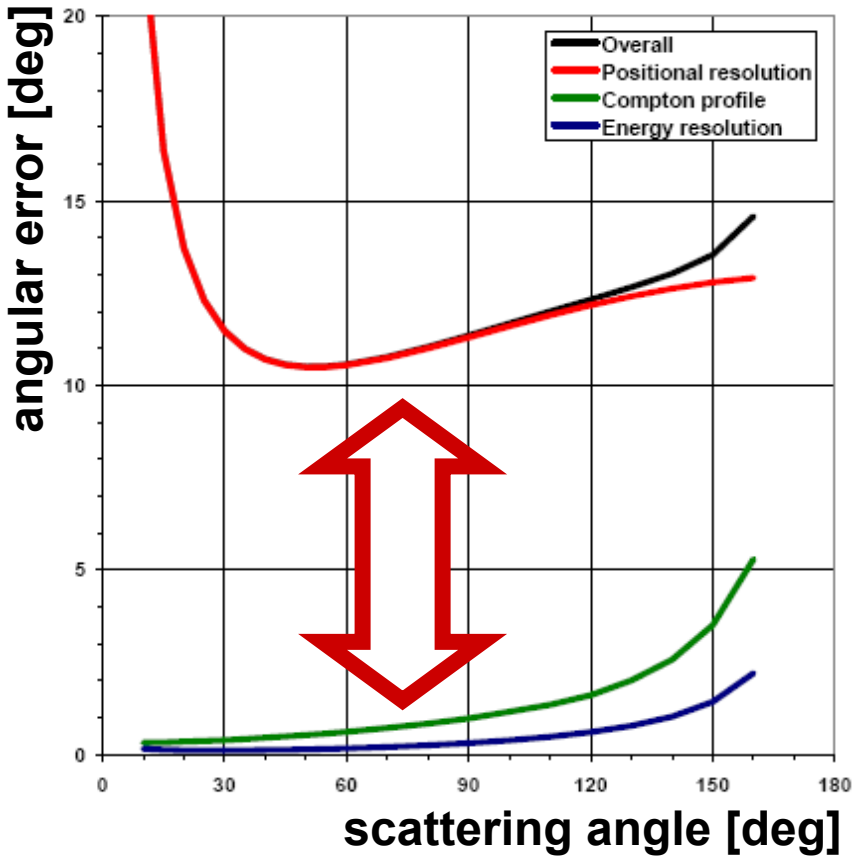


Compton imaging performance

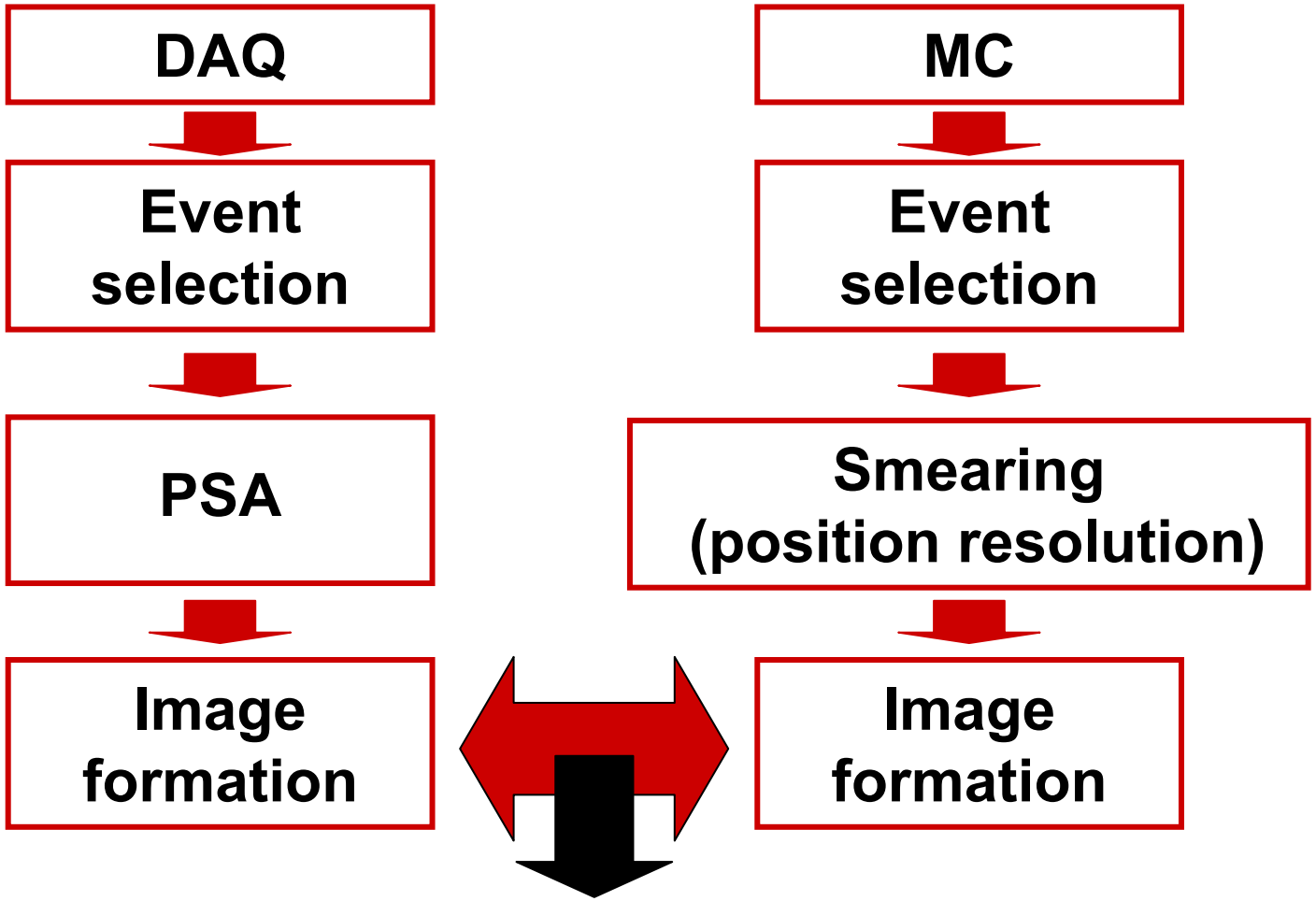
Error on Compton identification of source direction from:

- **Position resolution** (axis)
- Energy resolution (scattering angle)
- Compton profile (scattering angle)





Outline of analysis/simulation

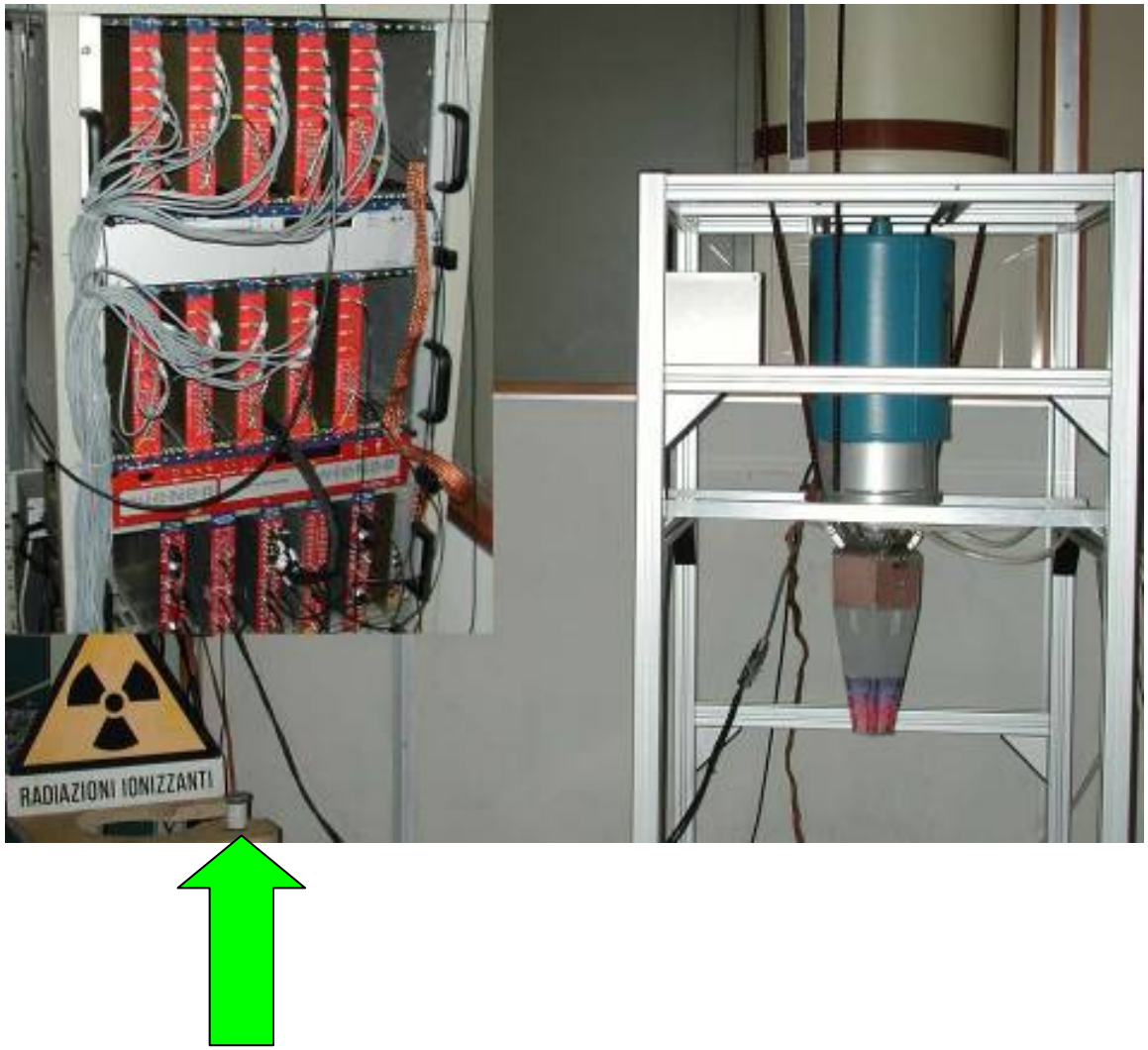


Imaging setup at LNL

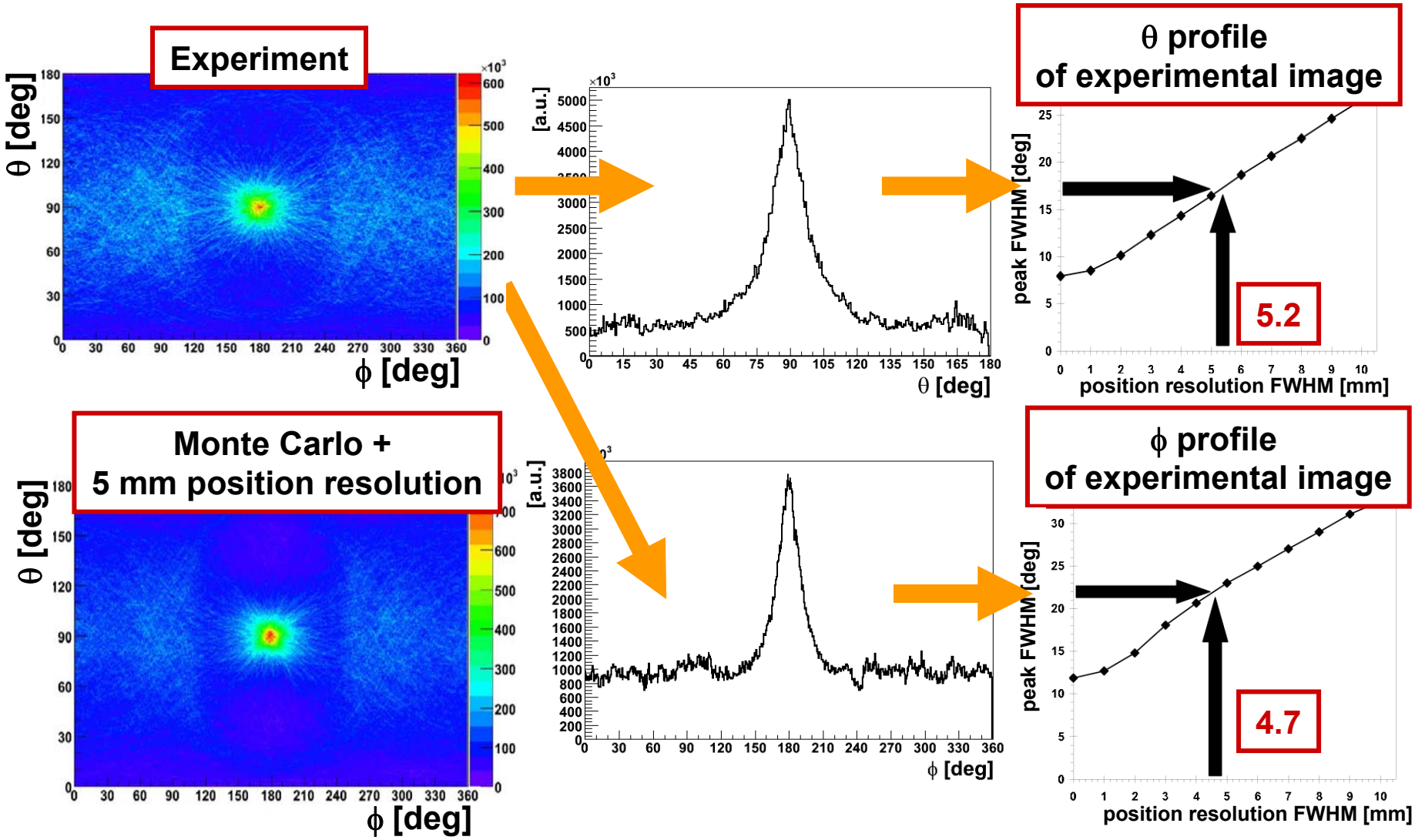
AGATA prototype detector

TNT2 Digitizers: 4ch 14bit 100MHz

^{60}Co source



Comparison to MC simulation



CONCLUSIONS

- Position resolution extracted by in-beam experiment and Compton imaging is **5 mm FWHM.**
- This value is in line with the **design assumptions** of the AGATA spectrometer, confirming the feasibility of γ-ray tracking.
- Imaging can be used as an alternative way to measure AGATA performance
- Possible **applications** of γ-ray tracking detectors to imaging.