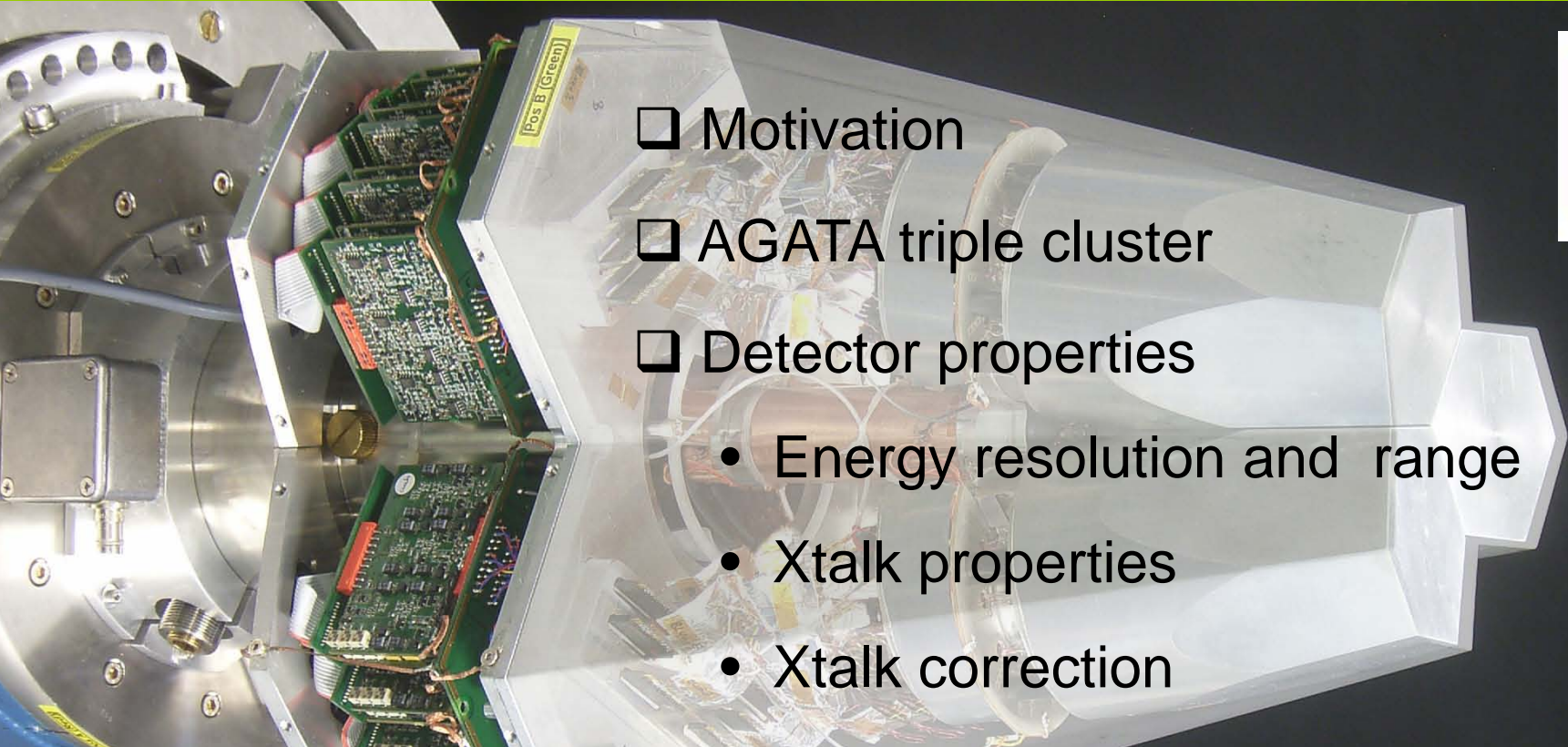


Development and performance of the AGATA cluster detector



- ❑ Motivation
- ❑ AGATA triple cluster
- ❑ Detector properties
 - Energy resolution and range
 - Xtalk properties
 - Xtalk correction

B. Birkenbach, B. Bruyneel, J. Eberth, H. Hess, D. Lersch,
G. Pascovici, P. Reiter, A. Wiens — IKP, Köln

A. Pullia, F. Zocca — INFN, Milano

D. Bazzacco — INFN, Padova

H. G. Thomas — CTT Montabaur

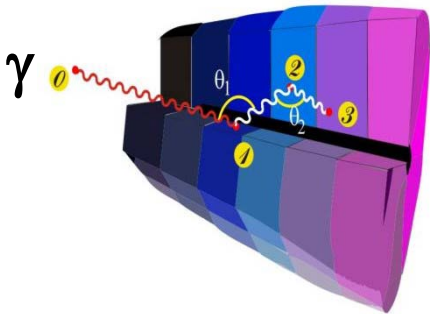
for the AGATA collaboration

Workshop on Germanium-Based Detectors and Technologies
Berkeley, CA **May 18-20, 2010**

Ingredients of γ -ray tracking

1

Highly segmented
HPGe detectors



2

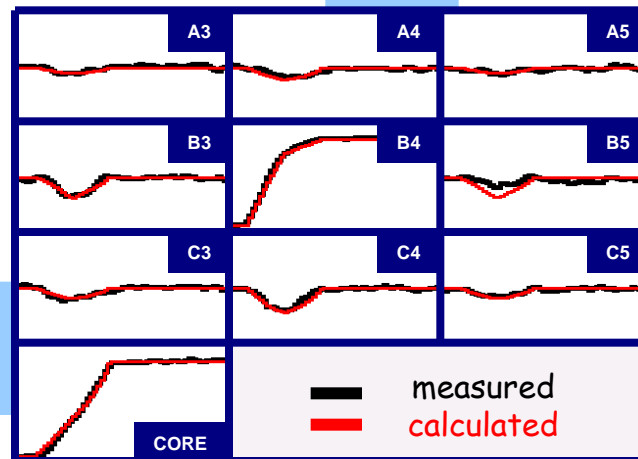
Digital electronics
to record and
process segment
signals

Identified
interactions

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

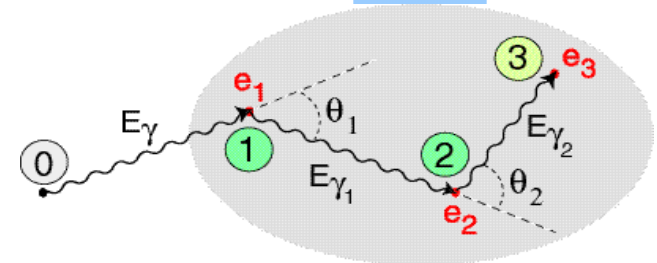
Pulse Shape Analysis
to decompose
recorded waves

3



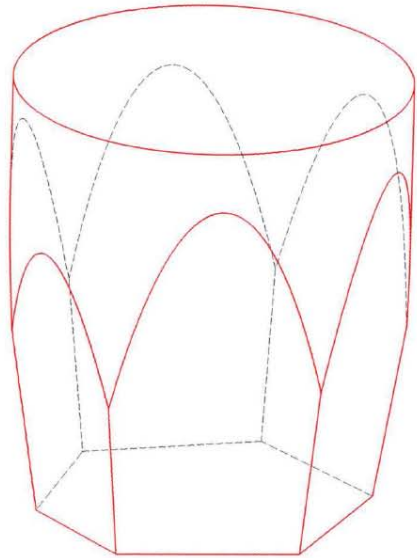
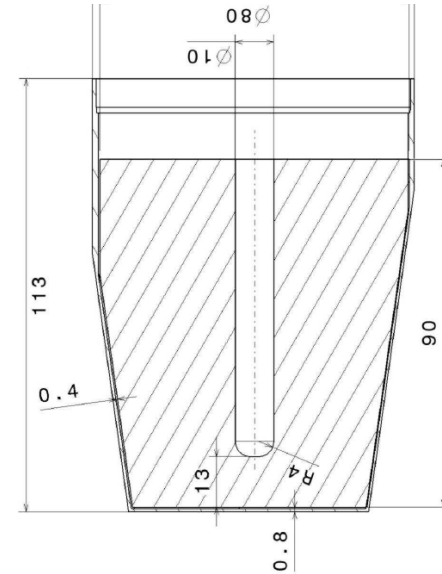
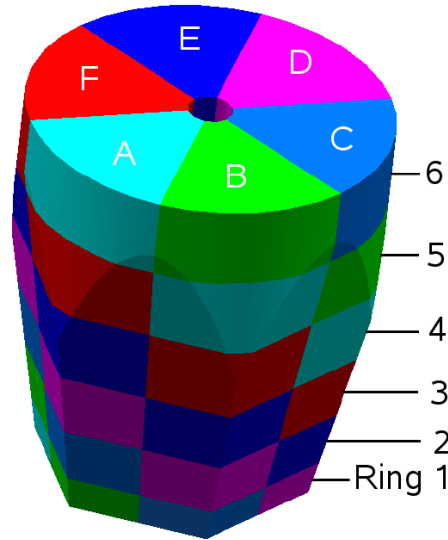
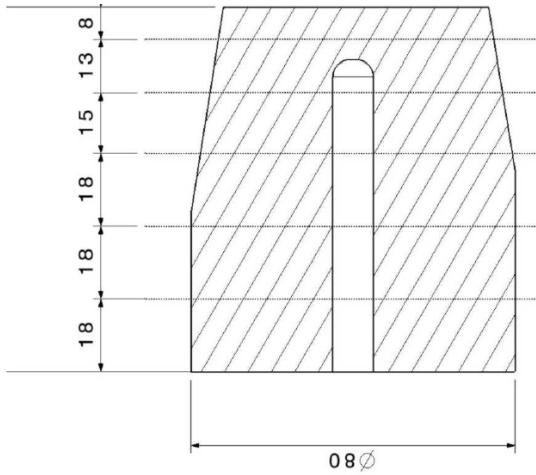
4

Reconstruction of tracks
e.g. by evaluation of
permutations
of interaction points

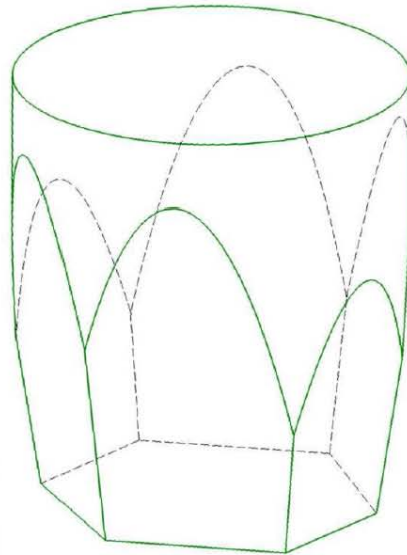


reconstructed γ -rays

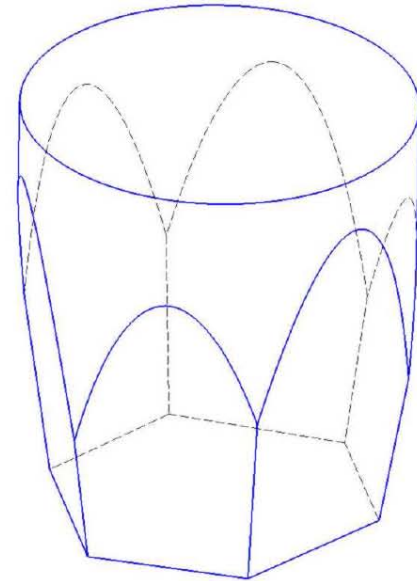
AGATA detectors



A - red

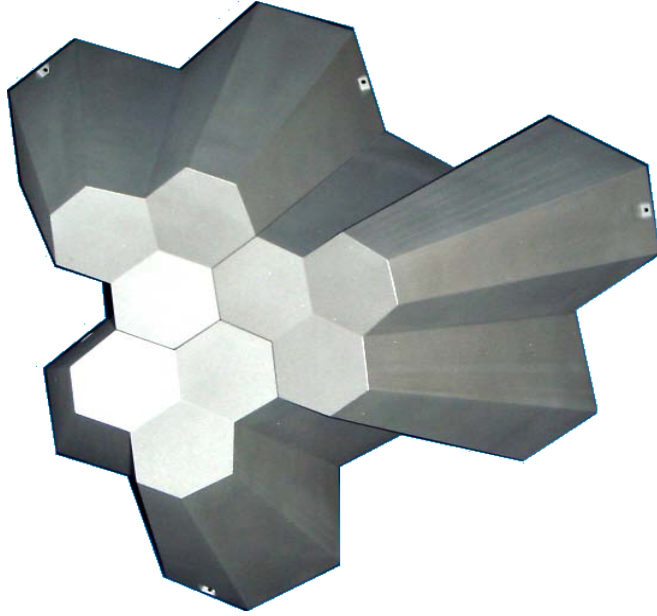


B - green



C - blue

Asymmetric AGATA Triple Cryostat

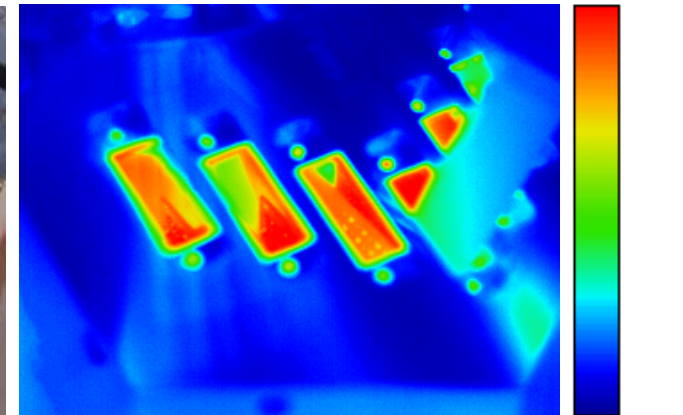
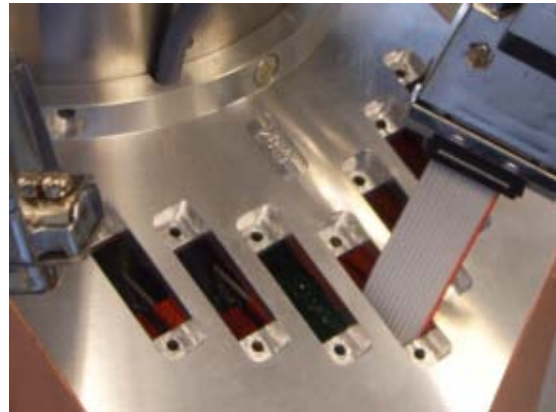
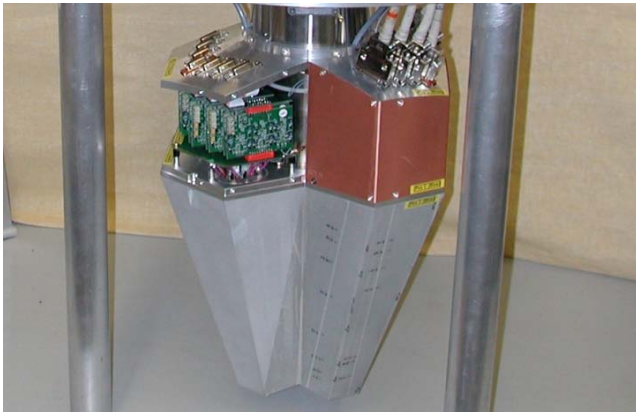


Mechanical precision
(bending under vacuum
within tolerances)

Detectors position
inside the triple
Spacing 0.5 mm

Heat development of
111 preamps
(Limit 65°C not exceeded)

LN2 consumption

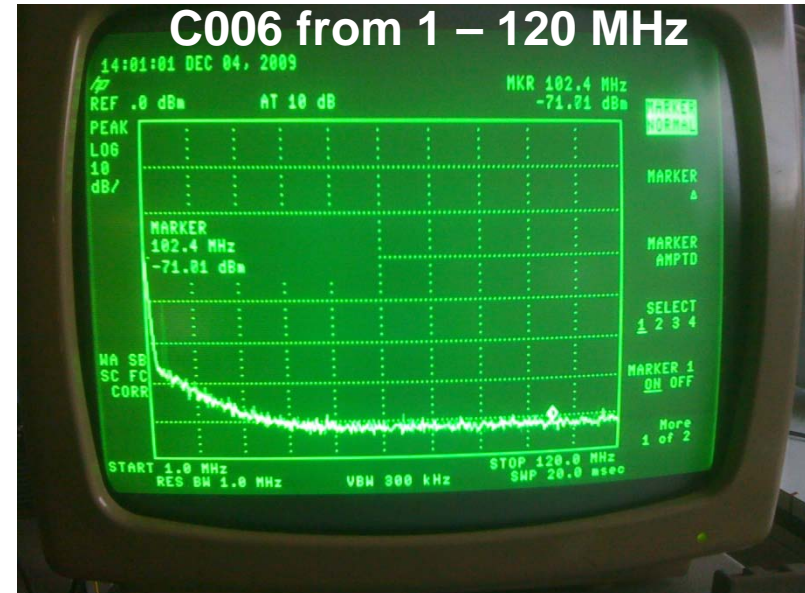
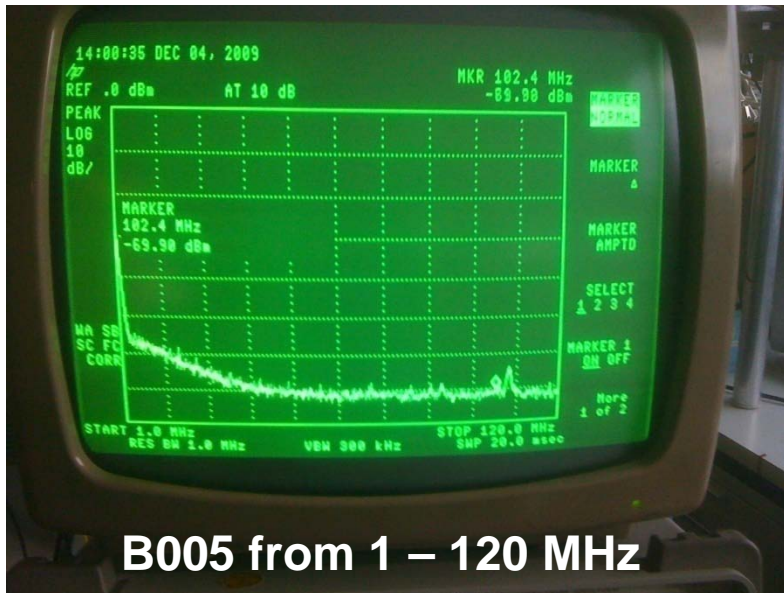
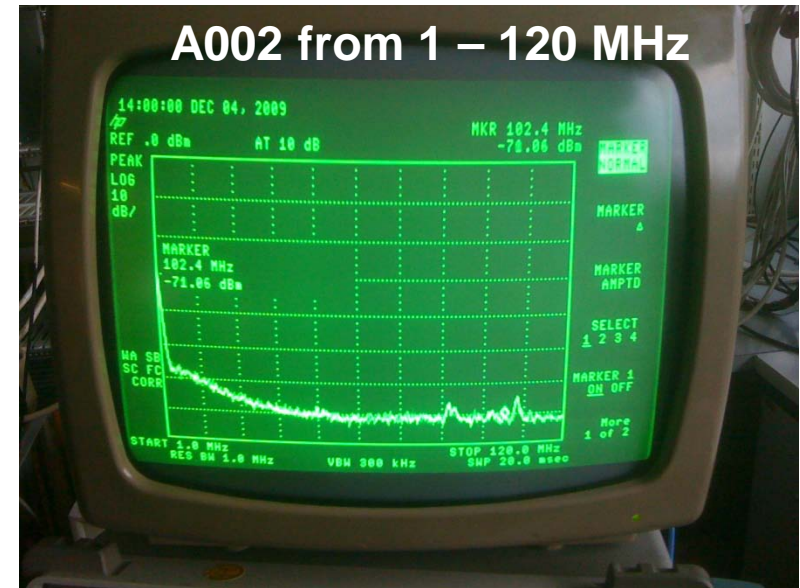
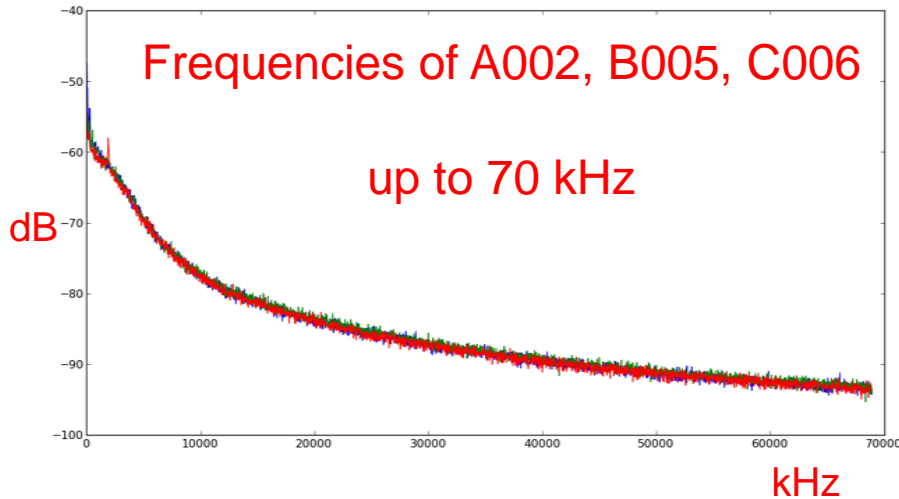


>60,3°C

27,7°C

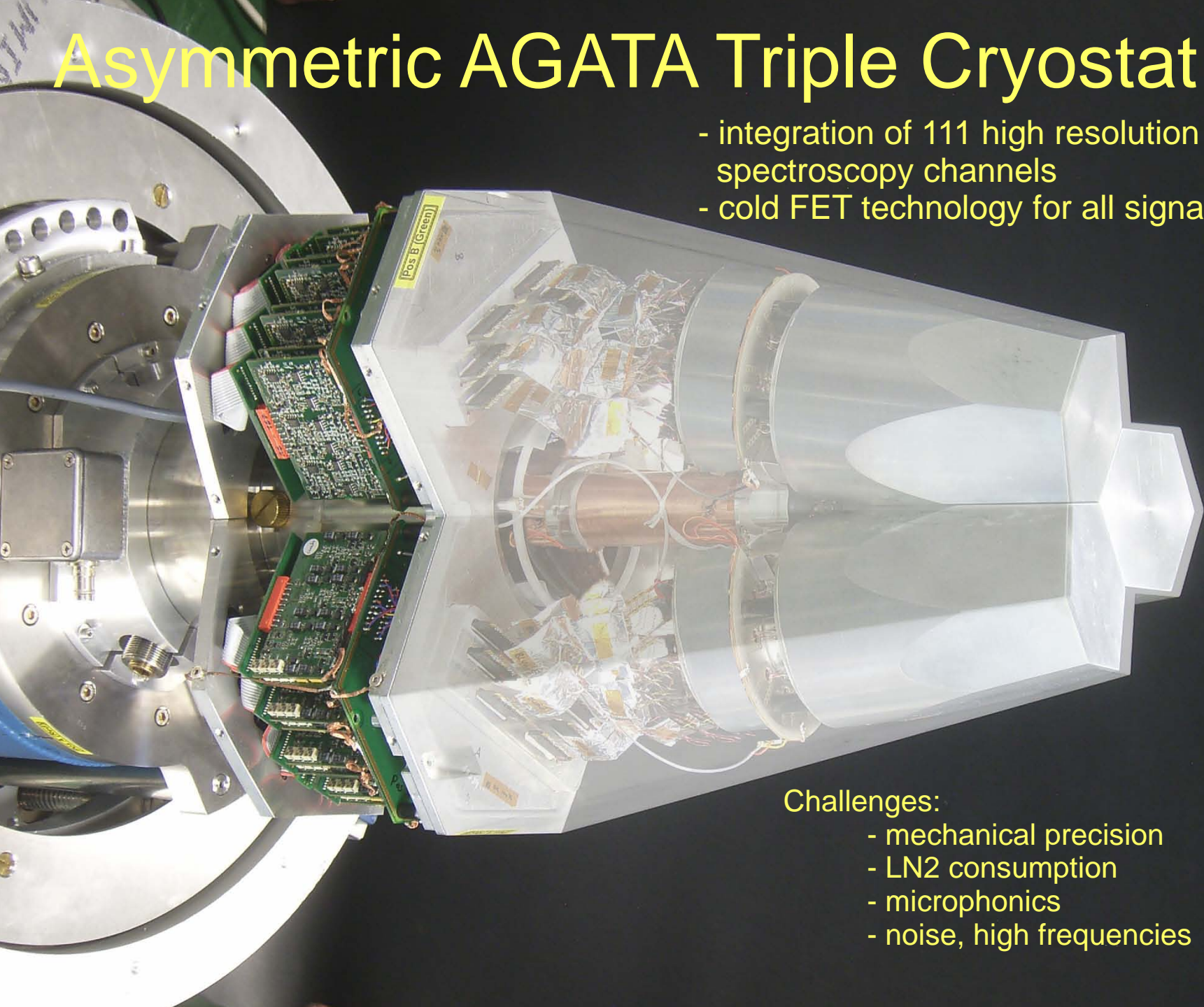
Frequency spectra

ATC 3 operated with MILANO preamps



Asymmetric AGATA Triple Cryostat

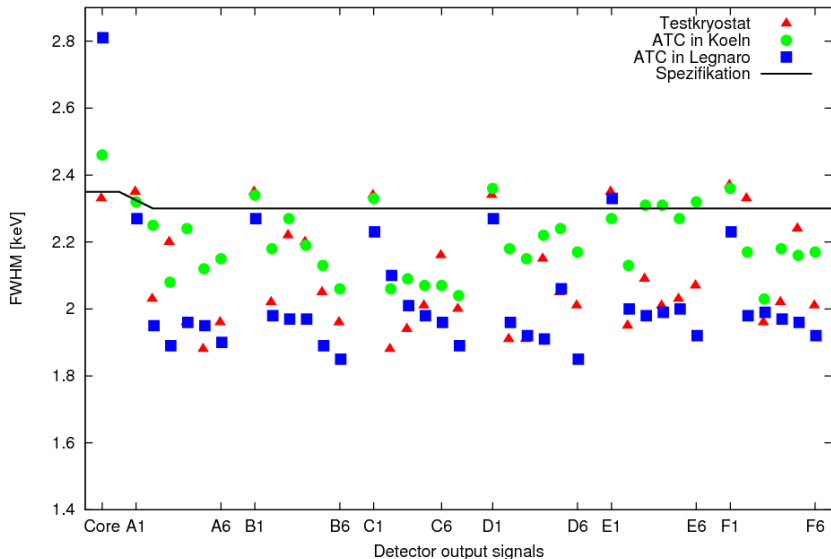
- integration of 111 high resolution spectroscopy channels
- cold FET technology for all signals



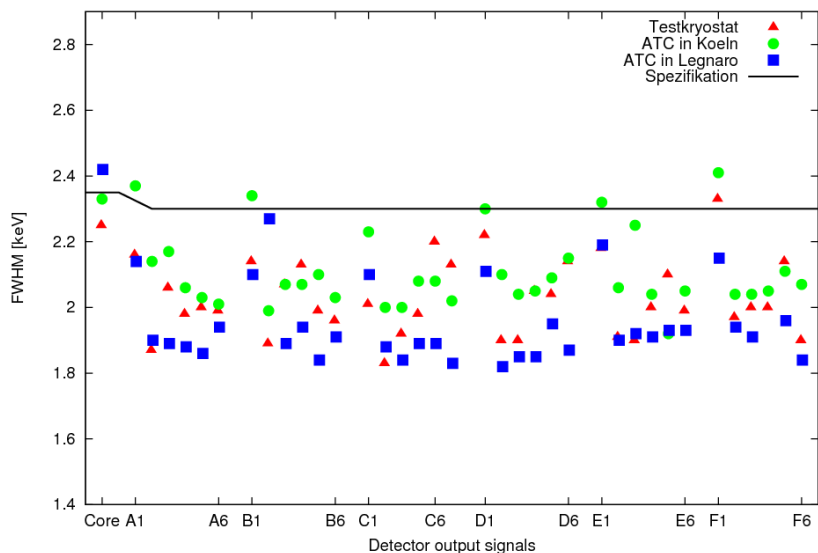
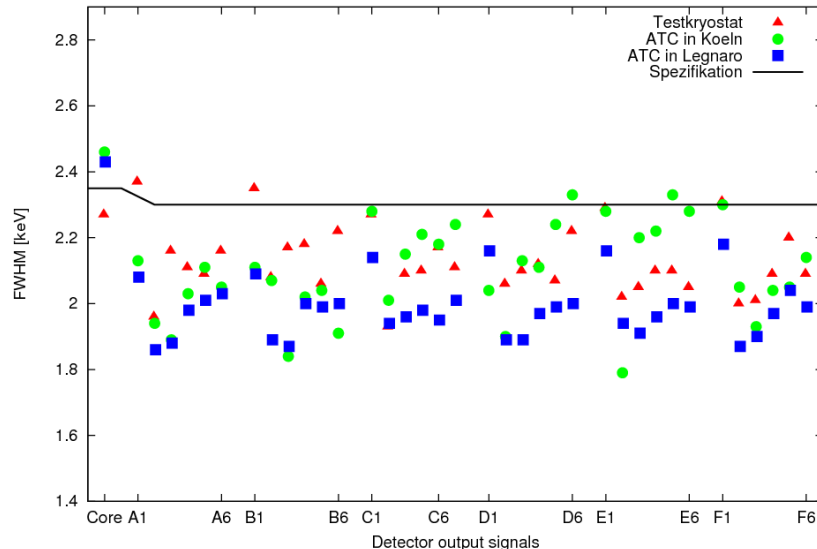
Challenges:

- mechanical precision
- LN2 consumption
- microphonics
- noise, high frequencies

ATC1 A001



ATC1 B002



Measured at Köln and Legnaro

Mean values energy resolution segments at 1,3 MeV:

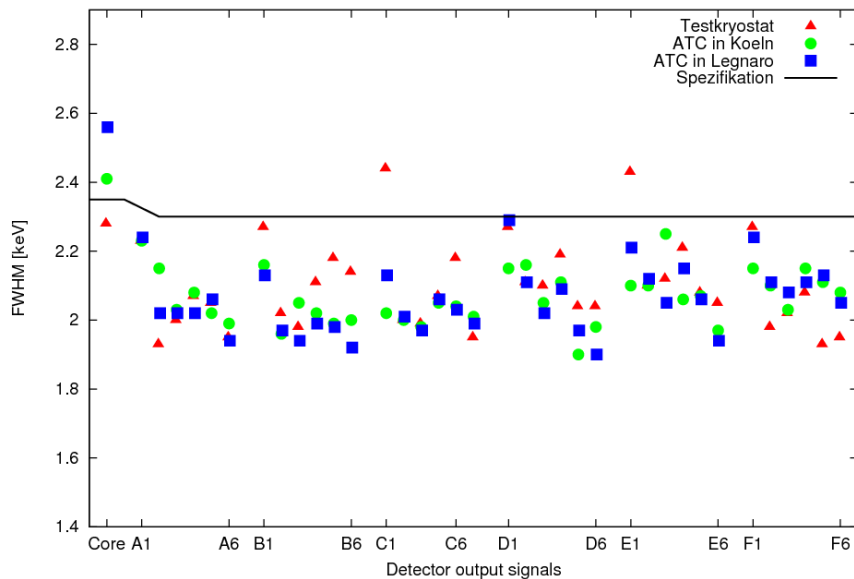
IKP / Legnaro

A001: 2,19 keV / 2,00 keV

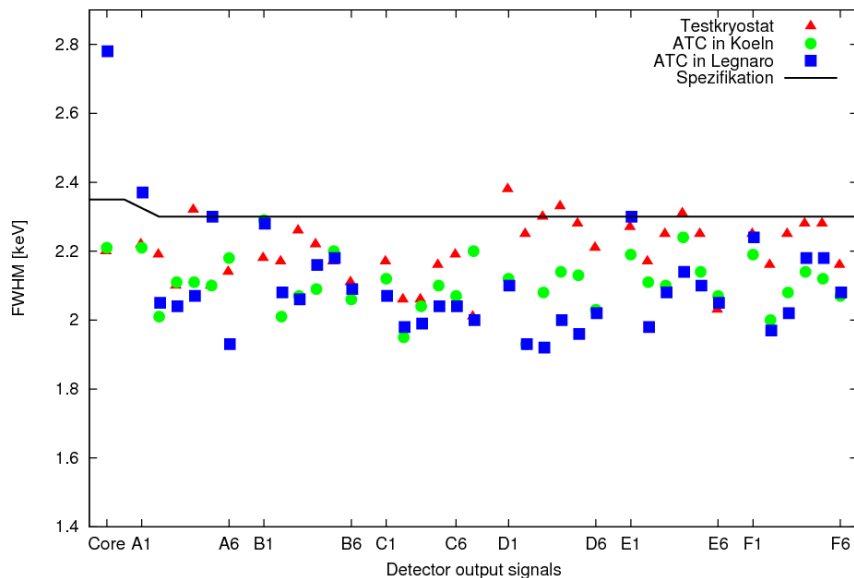
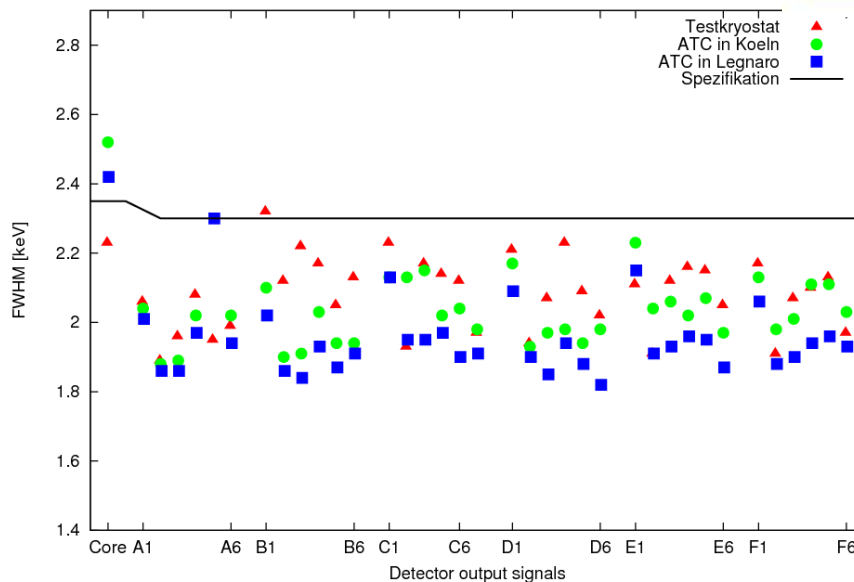
B002: 2,09 keV / 1,98 keV

C002: 2,1 keV / 1,94 keV

ATC2 A003



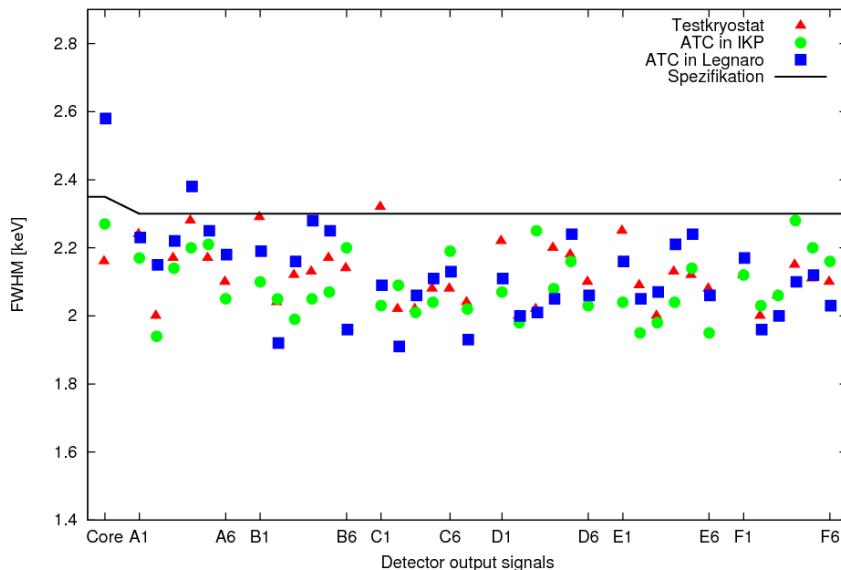
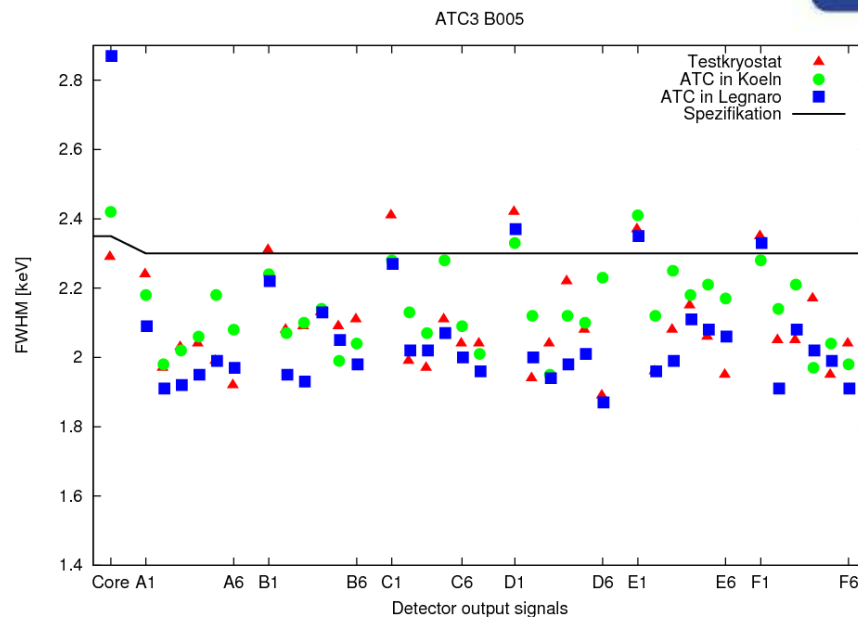
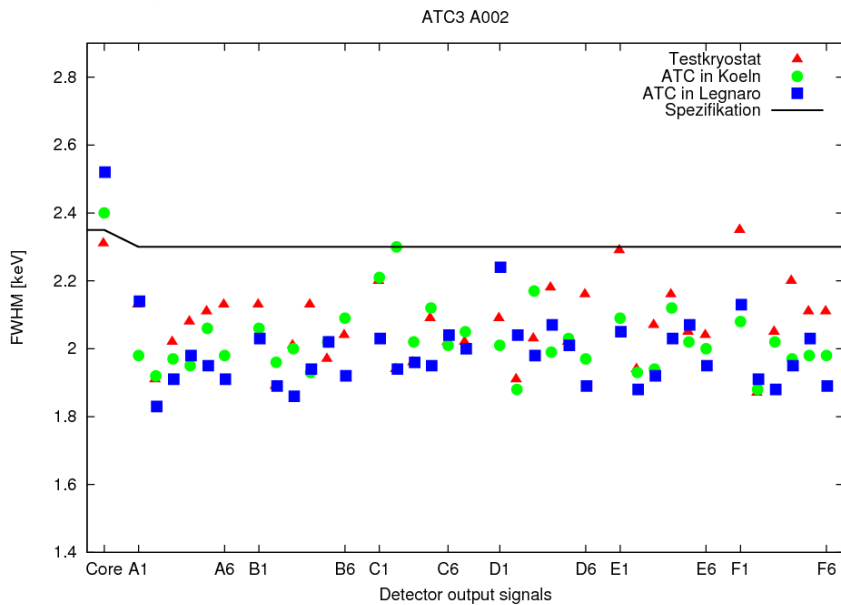
ATC2 B003



Measured at Köln and Legnaro

Mean values energy resolution segments at 1,3 MeV:

	IKP	/ Legnaro
A003:	2,06 keV	/ 2,06 keV
B003:	2,03 keV	/ 1,94 keV
C005:	2,11 keV	/ 2,08 keV

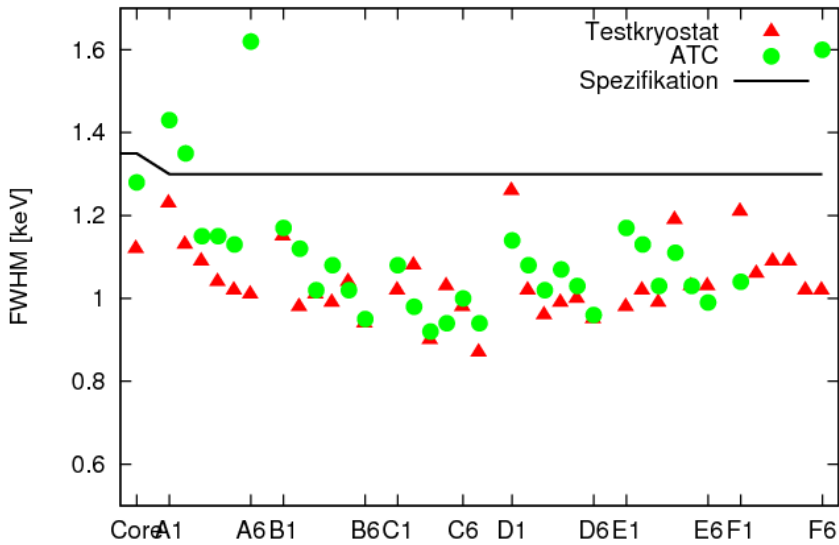


Measured at Köln and Legnaro

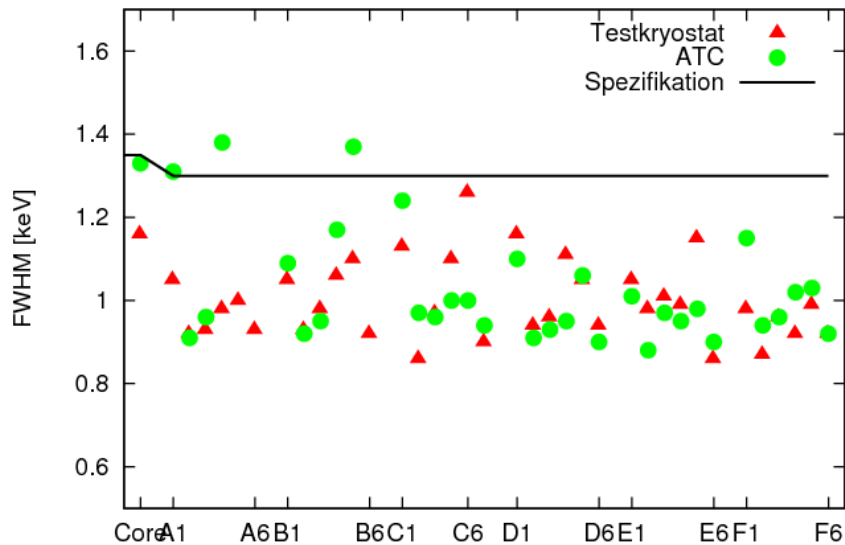
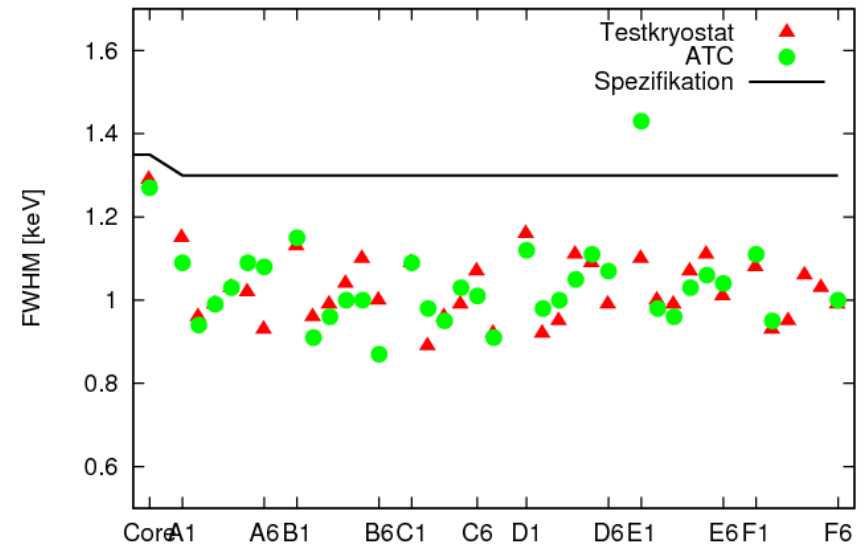
Mean values energy resolution
segments at 1,3 MeV:

	IKP	/ Legnaro
A002:	2,03 keV	/ 2,00 keV
B005:	2,13 keV	/ 2,06 keV
C006:	2,09 keV	/ 2,11 keV

ATC4 A005



ATC4 B001



Mean energy resolution
of segments at 60 keV:
(spezifikation: 1,3 keV)

test kryostat / ATC4:

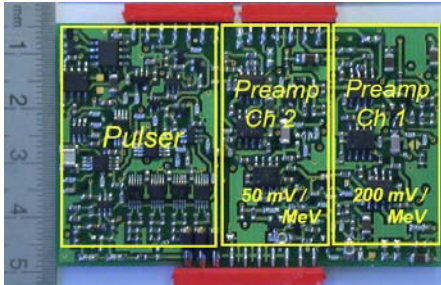
A005: 1,03 / 1,09 keV

B001: 1,02 / 1,03 keV

C003: 1,00 / 1,13 keV

Energy range - dual core preamplifier

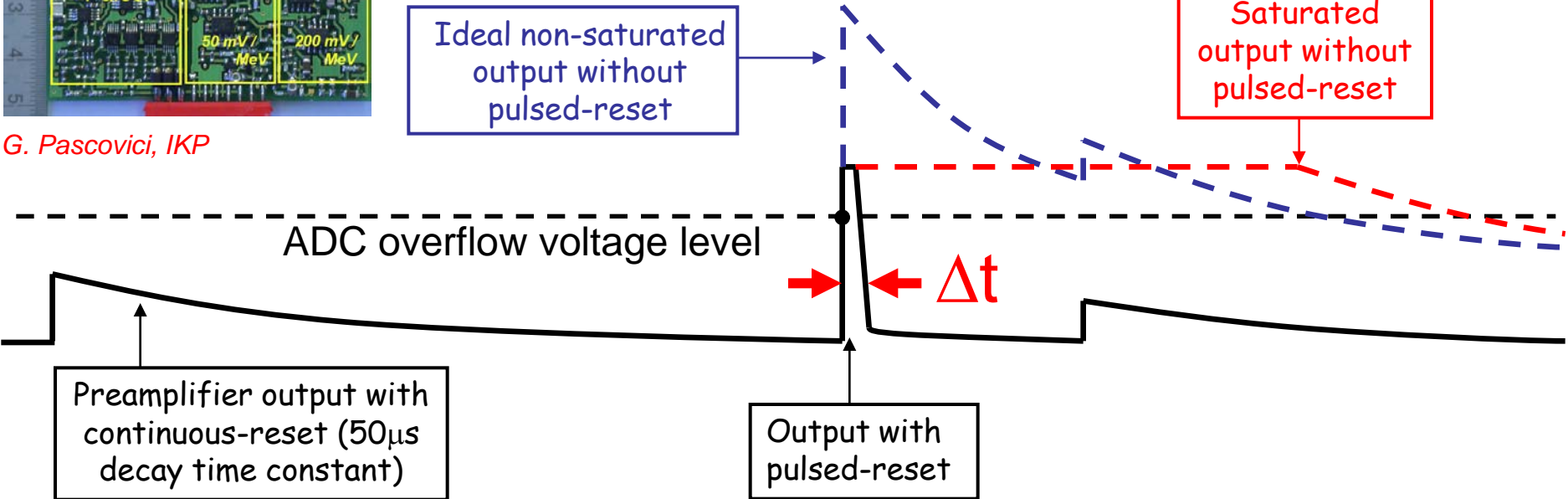
Mixed reset technique: continuous + pulsed



G. Pascovici, IKP

Ideal non-saturated output without pulsed-reset

Saturated output without pulsed-reset



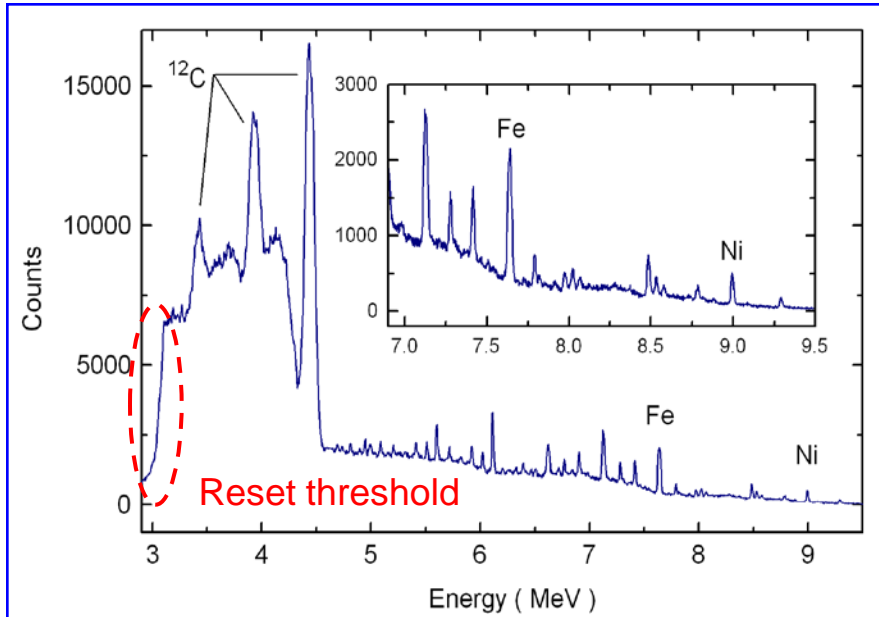
An ADC overflow condition would **saturate** the system for a long while



Pulsed-reset mechanism allows **fast recovery** of the output (up to x4/x5 in throughput)

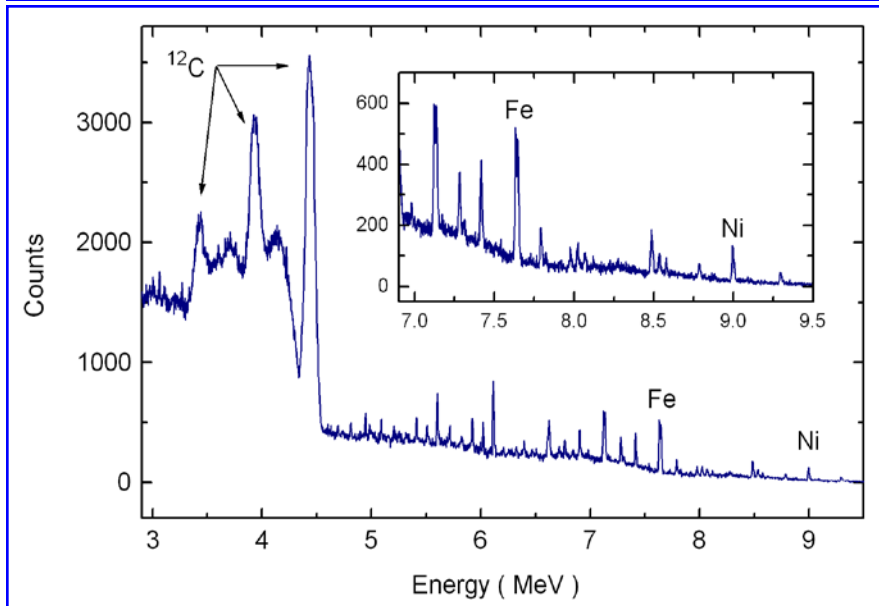
“Time Over Threshold” (T.O.T) : $\Delta t \propto E$

Extended energy range



“reset” mode
(by TOT technique)

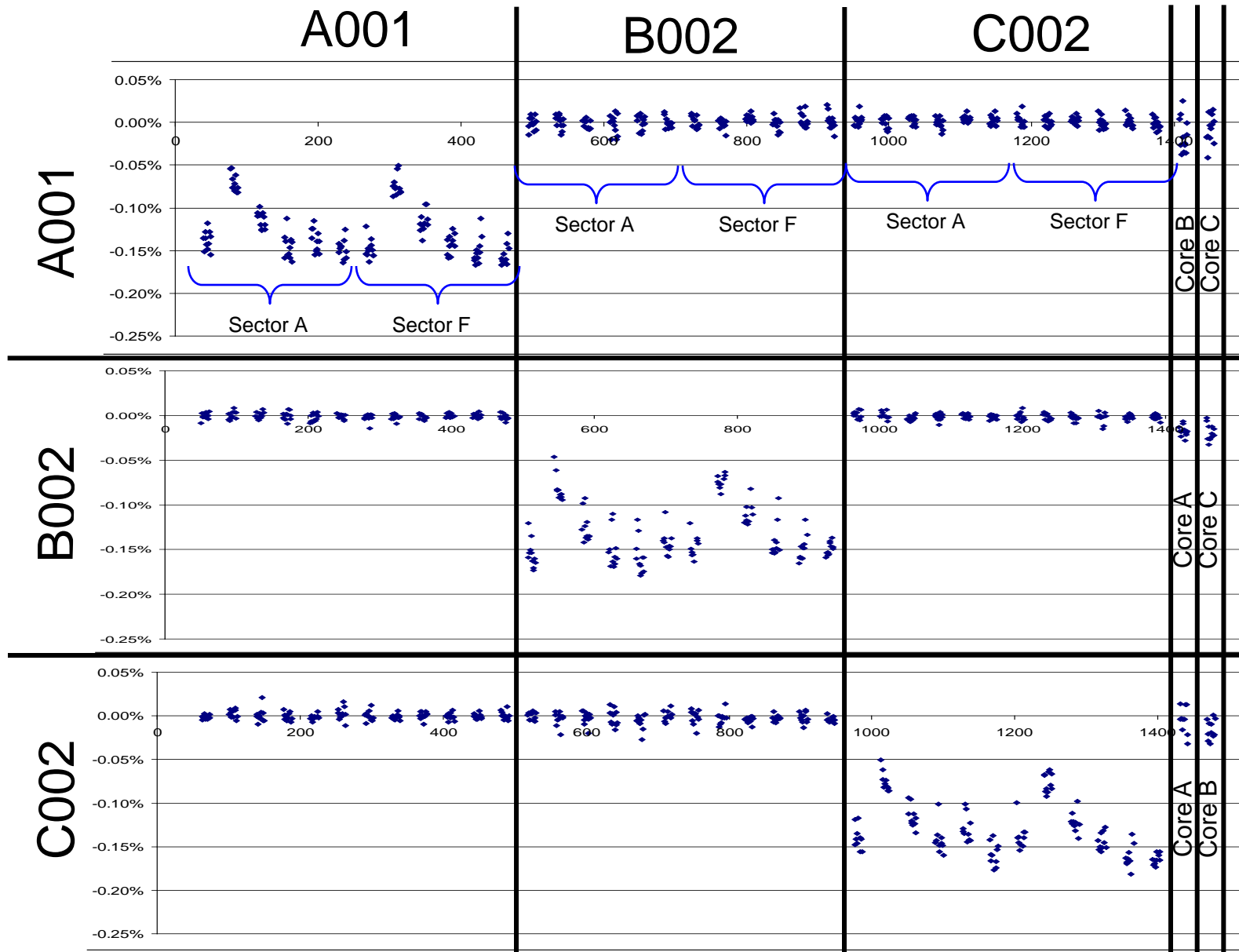
Energy	Resolution (fwhm)		Resolution (fwhm)	
	pulse-height mode		reset mode	
5.6 MeV	10.5 keV	0.14 %	18.8 keV	0.34 %
6.1 MeV	15.1 keV	0.17 %	17.1 keV	0.28 %
7.6 MeV	11 keV	0.14 %	18.8 keV	0.25 %
9.0 MeV	15 keV	0.17 %	18.9 keV	0.21 %



At high energies (> 10 MeV)
TOT mode ~ pulse-height mode

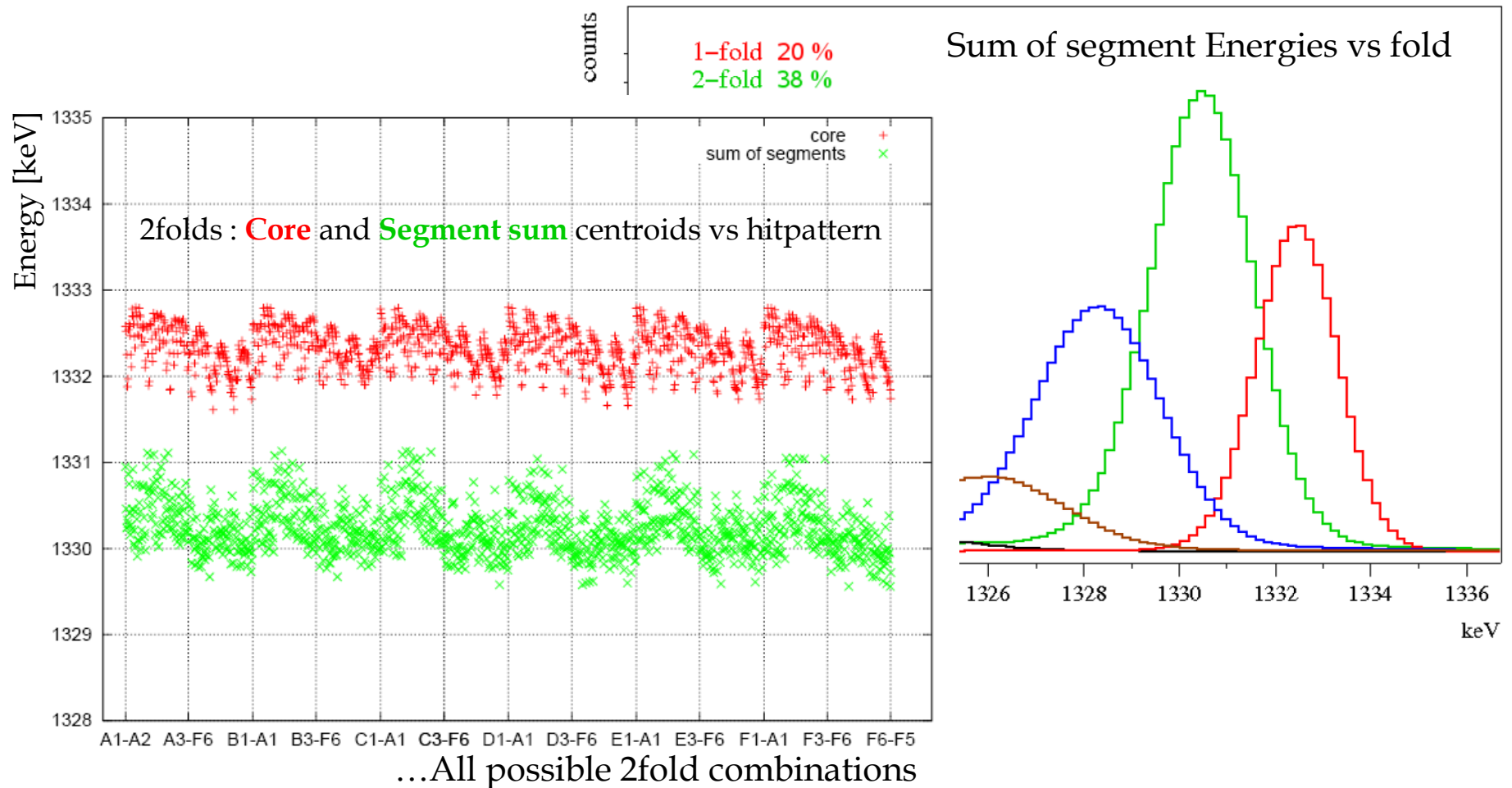
“pulse-height” mode

Cross talk in AGATA Triple Cluster

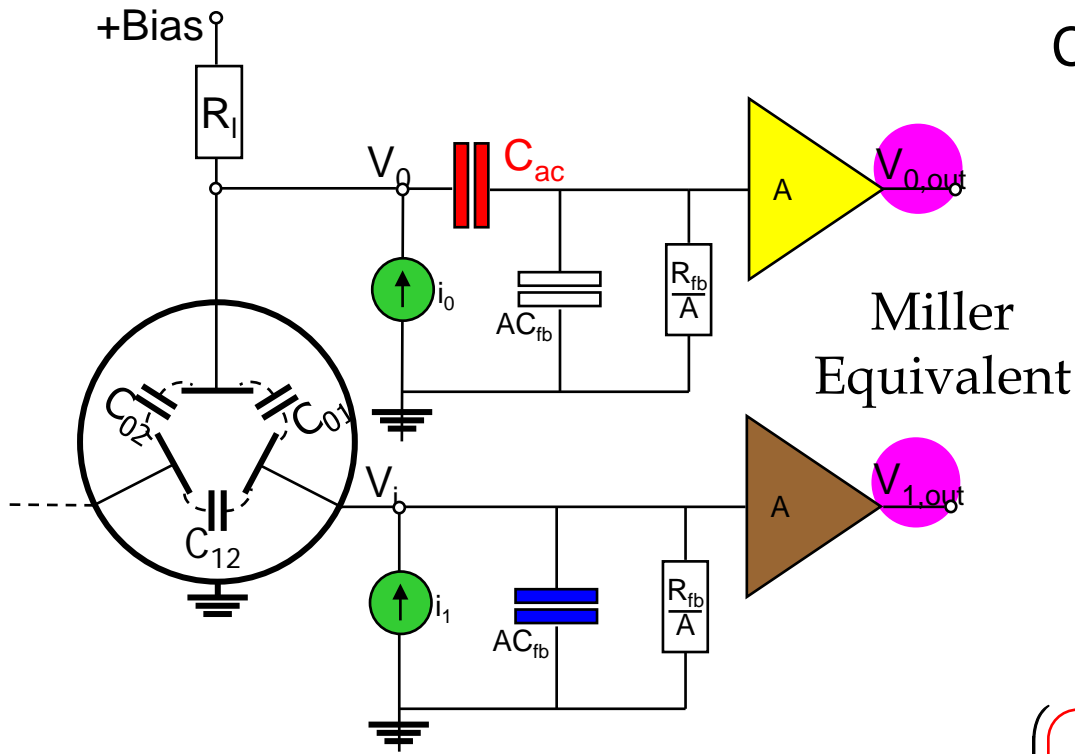


Crosstalk correction: Motivation

- Crosstalk is present in every segmented detector
- Creates strong energy shifts proportional to fold
- Tracking needs segment energies !



A model to describe cross talk



Cross talk is intrinsic property of segmented detectors !

Miller Equivalent

Proportional cross talk - Energy

Derivative cross talk – PSA

Talk by B. Bruyneel

$$\vec{v}_{out} \cong \frac{1}{sC_{fb}} \begin{pmatrix} \boxed{1} & \boxed{-C_{01}/AC_{fb} \quad -C_{02}/AC_{fb}} \\ \boxed{-C_{01}/C_{ac}} & \boxed{1 \quad -C_{12}/AC_{fb}} \\ \boxed{-C_{02}/C_{ac}} & \boxed{-C_{12}/AC_{fb} \quad 1} \end{pmatrix} \vec{i}$$

Core-to-Seg

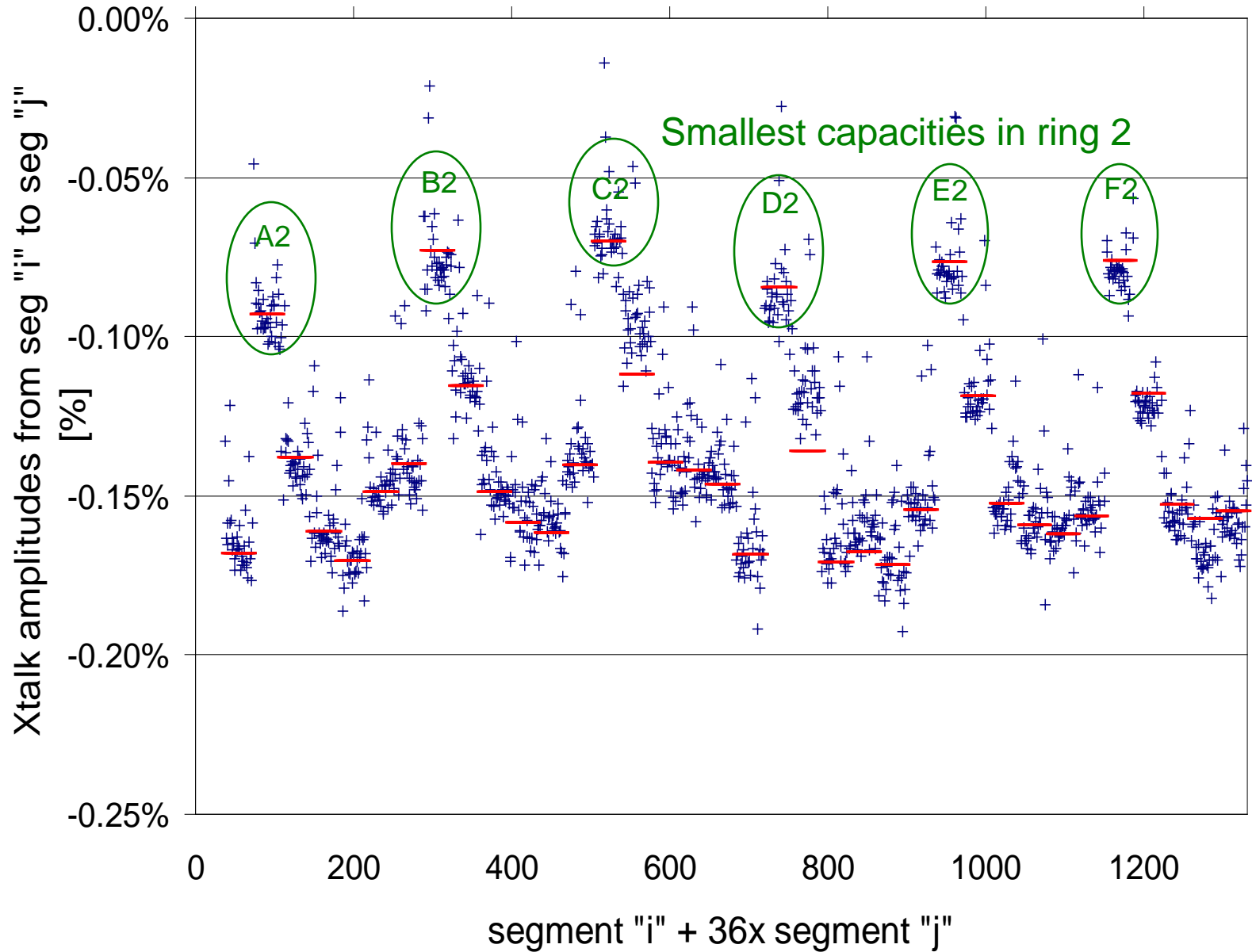
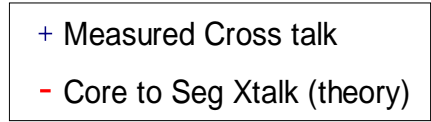
~ 1pF/1000pF

Segment-to-Core

Segment-to-Segment

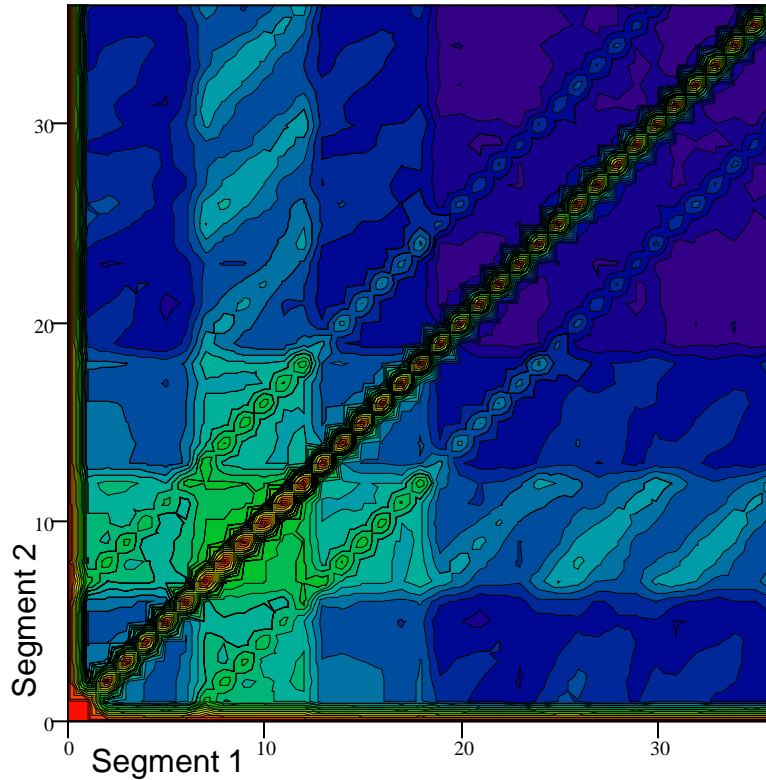
~ 1pF/(10000 · 1pF)

B002 in Triple Cryostat @ 5000 V

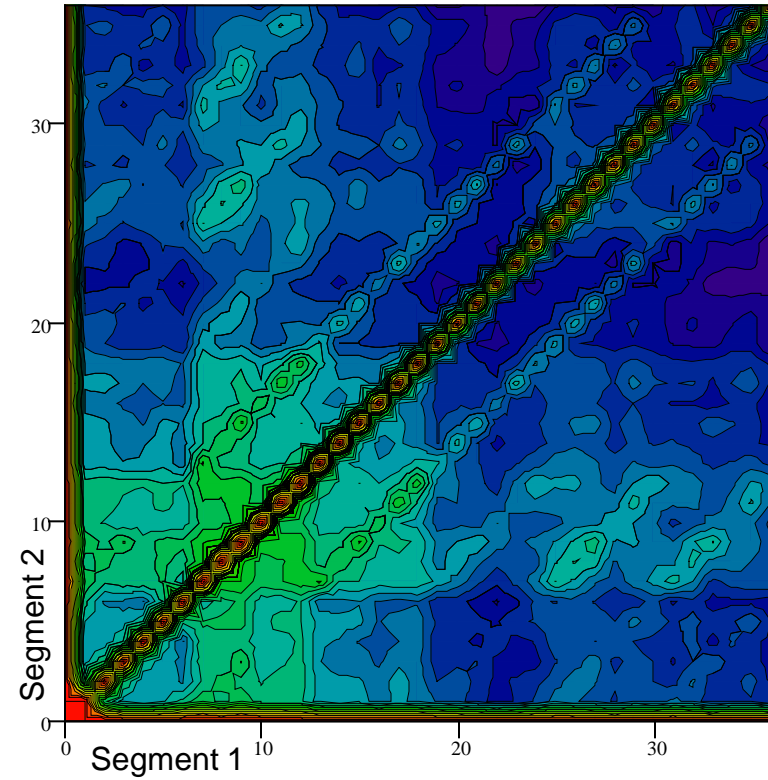


Core to segment cross talk in 2folds

Calculated



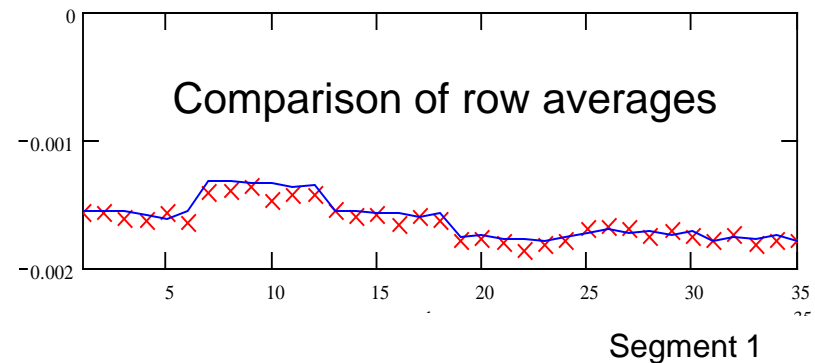
Measured



- For core to segment cross talk agreement between theory and observation

Meas. xxx
Theory —

- Cross talk limit reached in AGATA detectors



Cross talk correction: a pragmatic strategy

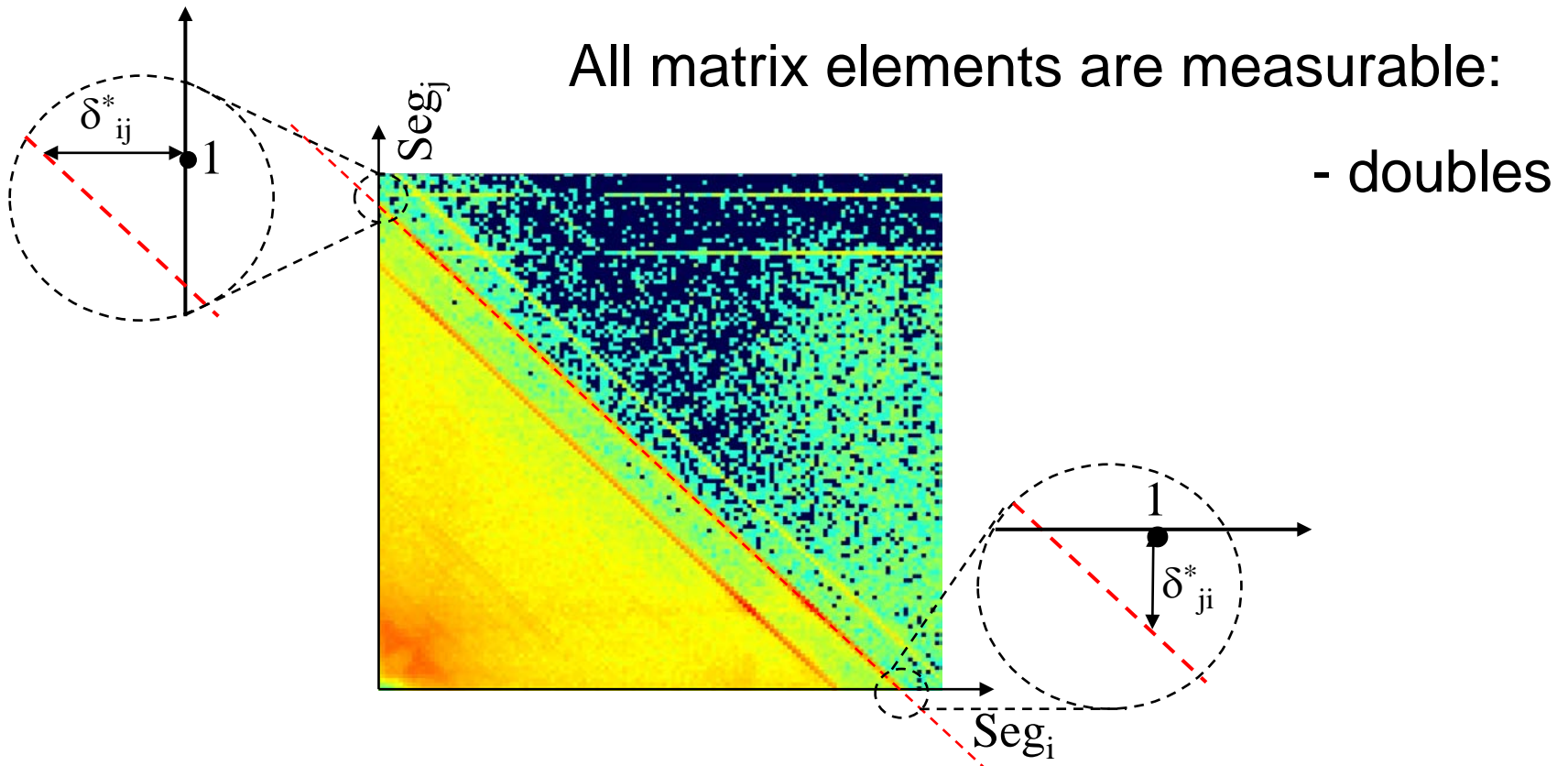
• Without cross talk:

$$\begin{bmatrix} E_{core} \\ E_{seg1} \\ E_{seg2} \\ E_{seg3} \end{bmatrix}_{meas} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} E_{seg1} \\ E_{seg2} \\ E_{seg3} \end{bmatrix}_{true}$$

identity

• With cross talk:

$$\begin{bmatrix} E_{core} \\ E_{seg1} \\ E_{seg2} \\ E_{seg3} \end{bmatrix}_{meas} = \begin{bmatrix} 1 + \delta_{01}^* & 1 + \delta_{02}^* & 1 + \delta_{03}^* \\ 1 & \delta_{12}^* & \delta_{13}^* \\ \delta_{21}^* & 1 & \delta_{23}^* \\ \delta_{31}^* & \delta_{32}^* & 1 \end{bmatrix} \cdot \begin{bmatrix} E_{seg1} \\ E_{seg2} \\ E_{seg3} \end{bmatrix}_{true}$$

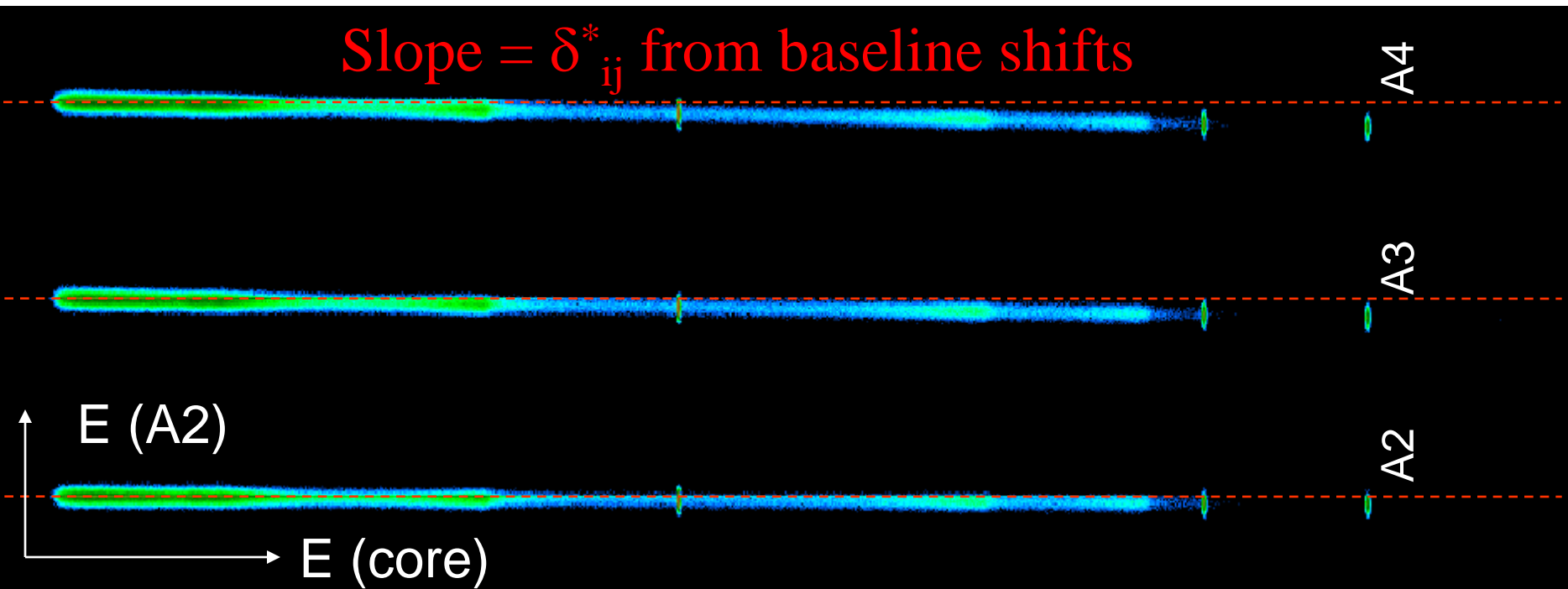


Measuring the cross talk parameters

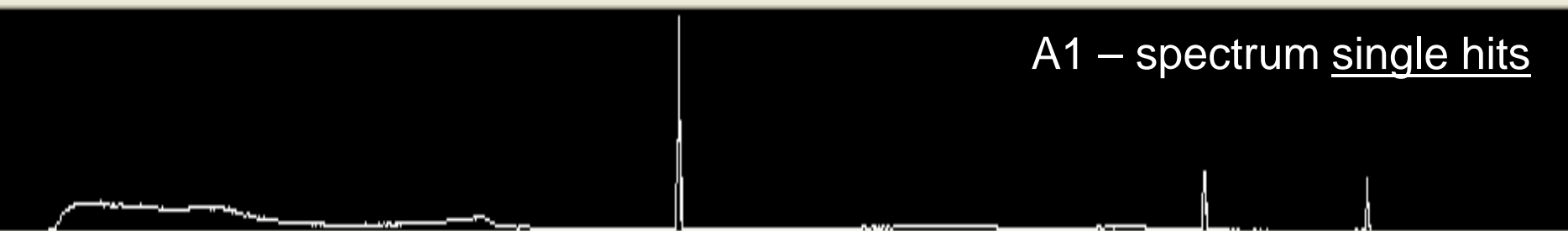
From singles:

$$\begin{pmatrix} 1 + \delta_{01}^* & 1 + \delta_{02}^* & 1 + \delta_{03}^* & \cdots \\ 1 & \delta_{12}^* & \delta_{13}^* & \cdots \\ \delta_{21}^* & 1 & \delta_{23}^* & \cdots \\ \delta_{31}^* & \delta_{32}^* & 1 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix}$$

Slope = δ_{ij}^* from baseline shifts

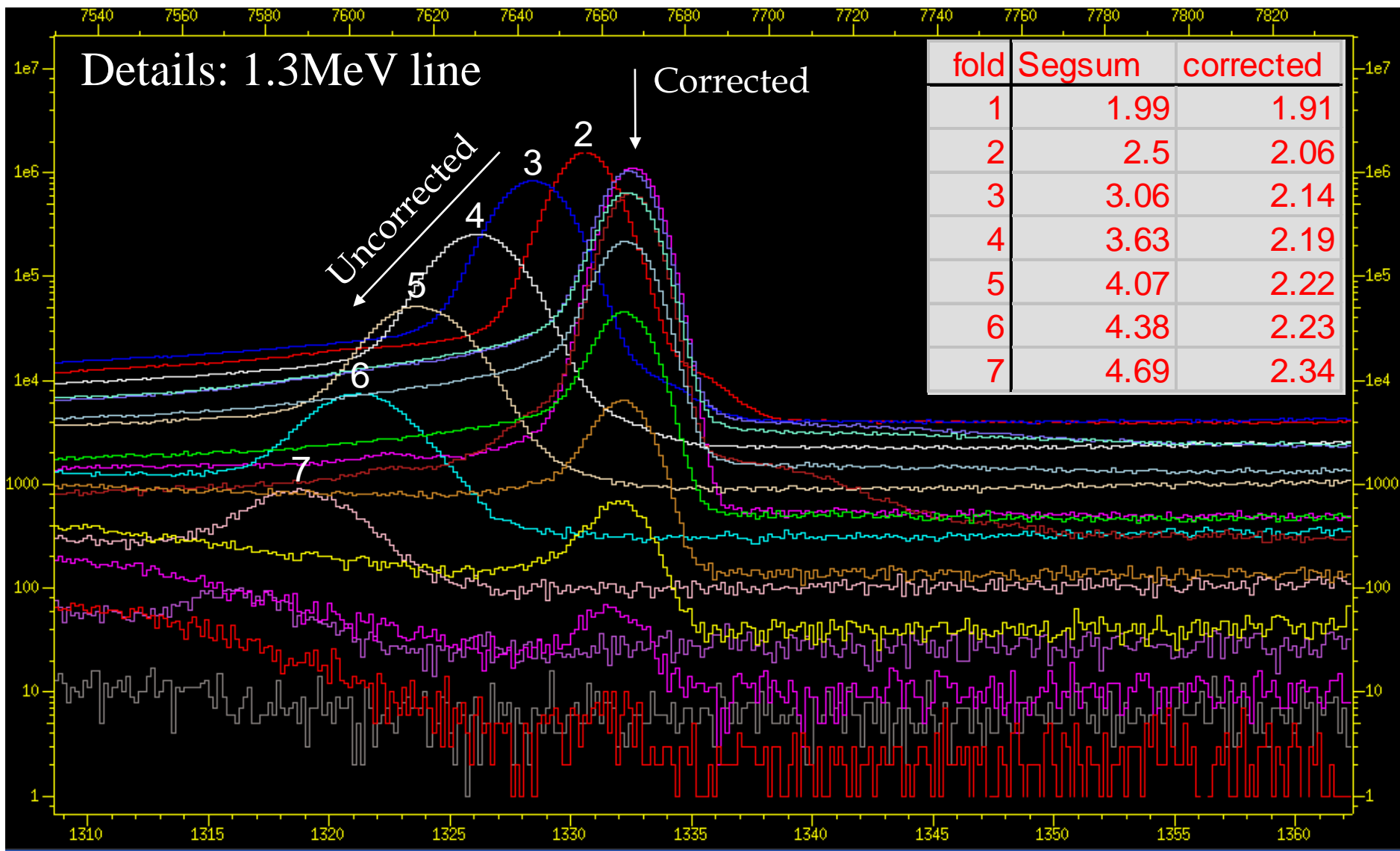


A1 – spectrum single hits



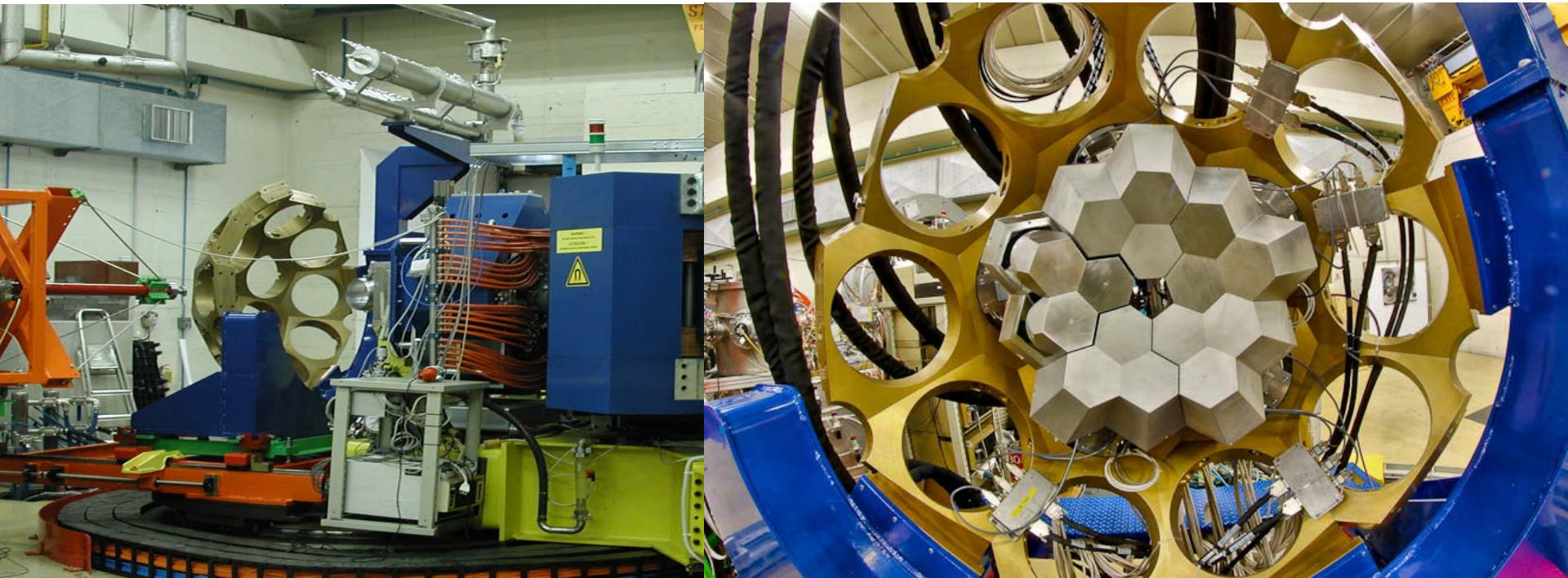
Cross talk correction: Results

FWHM 60keV: 1.20 → 1.02 !



SUMMARY: AGATA Triple Cluster Detectors

- cryostat, mechanics, vacuum, thermal properties of preamps
- new segment-preamps, core preamps & pulser
- high dynamic range and high energy resolution
- no cross talk between detectors
- cross talk within segmented detector: fundamental limit reached
- assembly of AGATA demonstrator nearly finished



AGATA demonstrator at target position of PRISMA at LNL