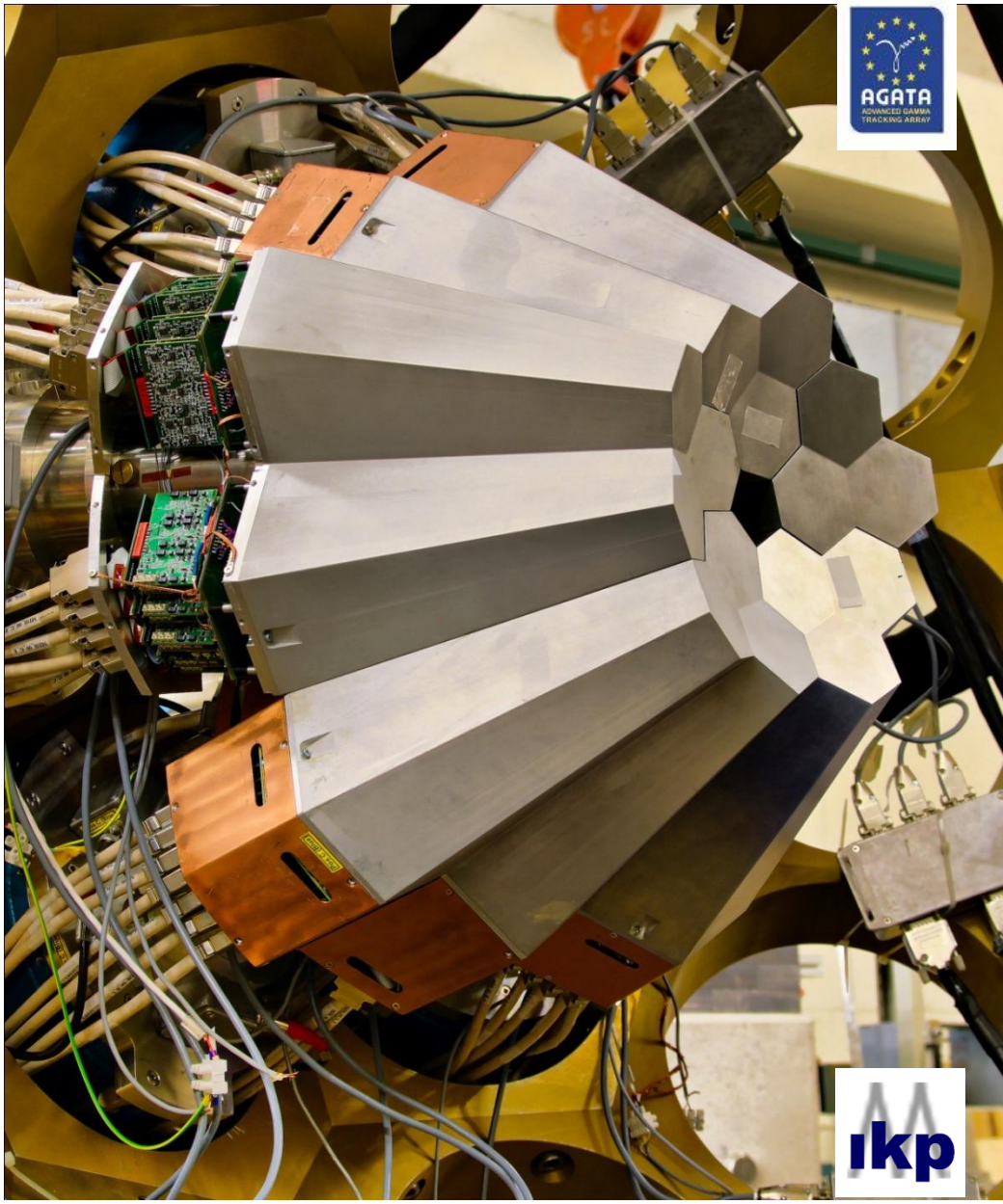
AGATA Week Sept. 2011
Darmstadt

Status of the AGATA detectors



Andreas Wiens

University of Cologne

B. Birkenbach, J. Eberth, H. Hess, D. Lersch, G. Pascovici, F. Radeck, P. Reiter, D. Schneiders, T. Steinbach - IKP Cologne

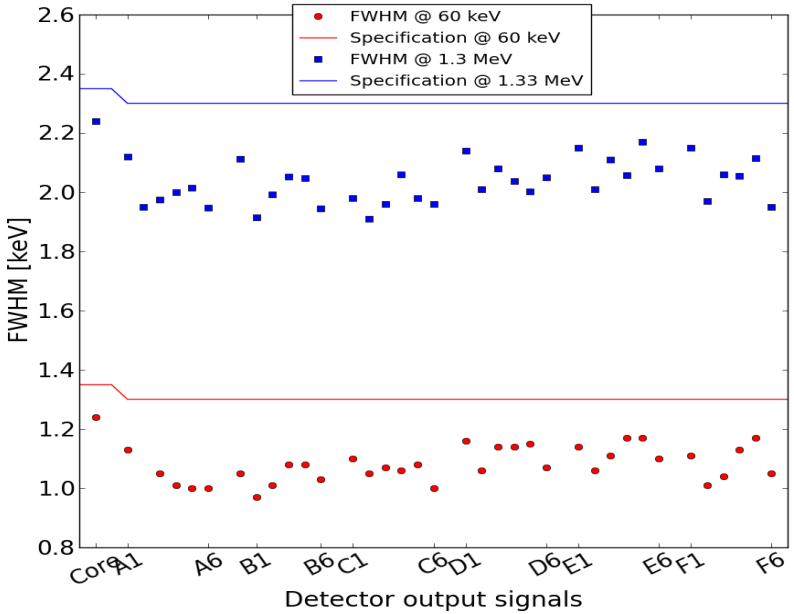
B. Bruyneel – CEA Saclay

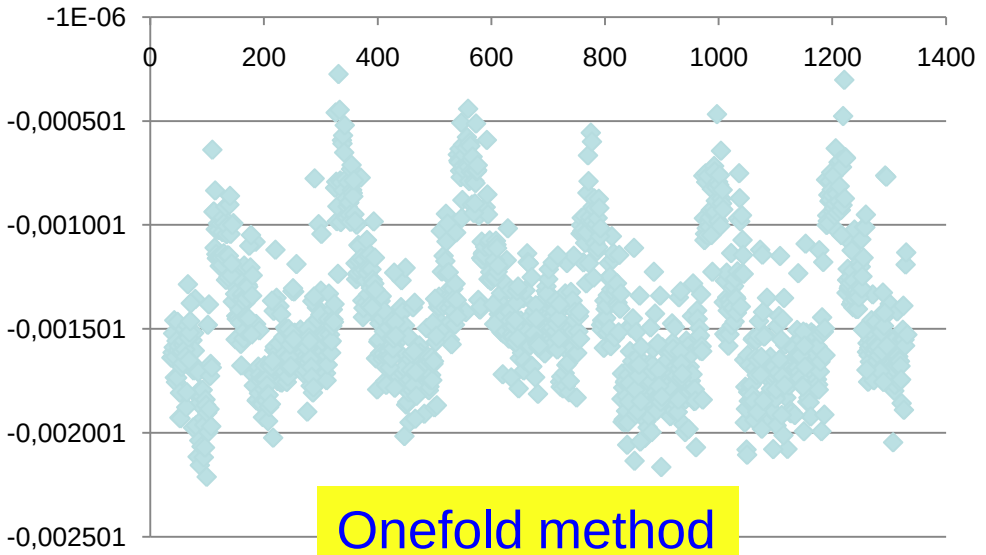
H.-G. Thomas - CTT

Outline

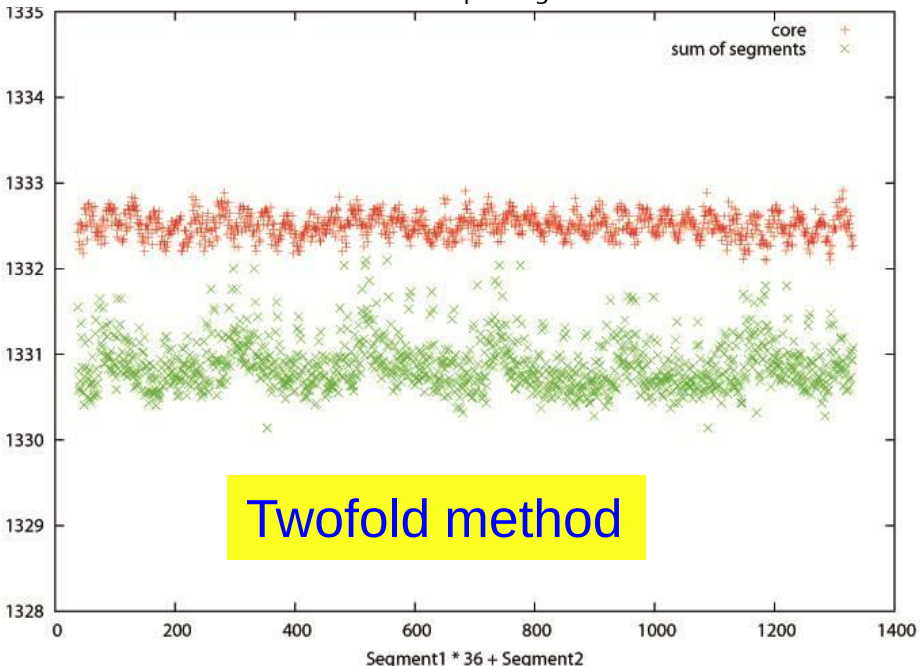
- Acceptable detectors (C004, B008, B010, B004)
- Malfunctioning detectors (B007, C006, C007)
- Performance of ATCs
- Annealing of crystals
- Optimized energy resolution
  - Averaging of core and segment signals
  - Electron trapping correction

AGATA crystals – B010





Onefold method



Twofold method

Core:

at 1.3MeV: ≤ 2.35keV

at 122keV: ≤ 1.35keV

Segments:

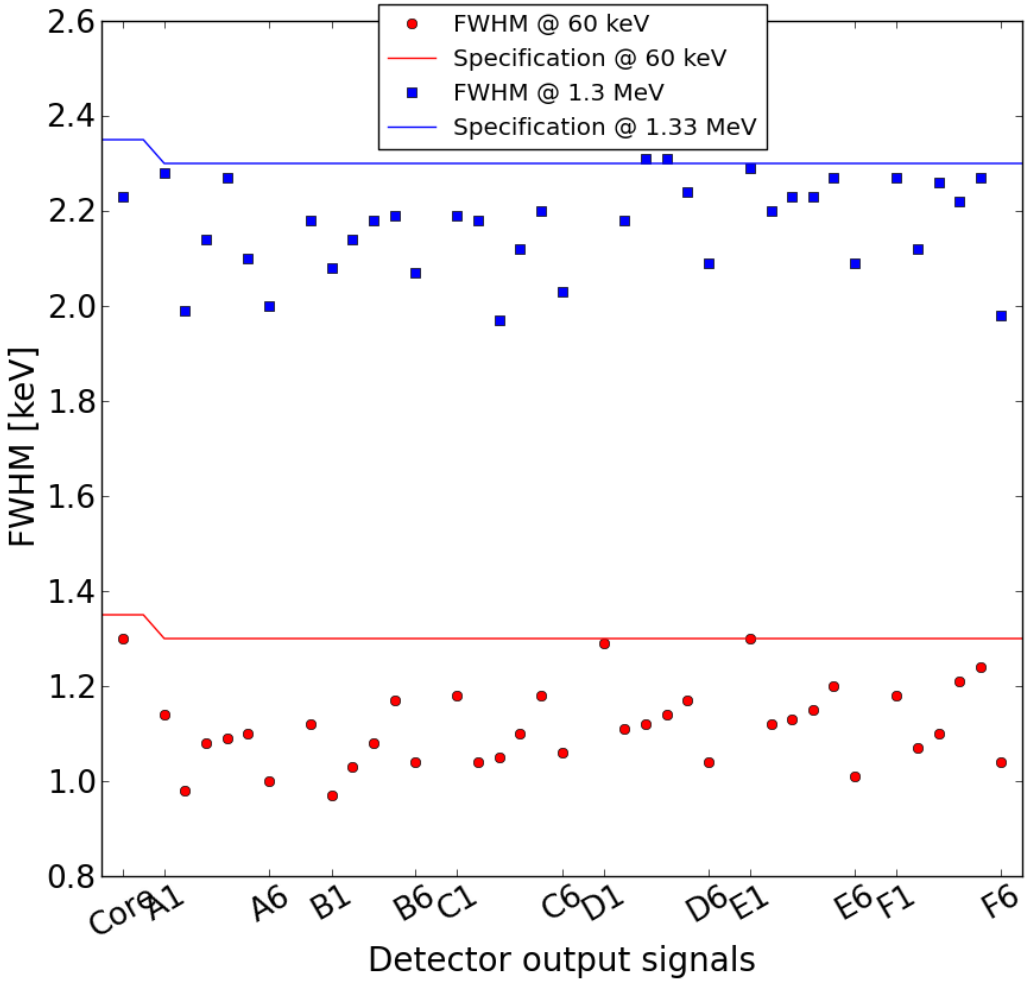
at 1.3MeV: ≤ 2.30keV, mean ≤ 2.10keV

at 60keV: ≤ 1.30keV, mean ≤ 1.20keV

Crosstalk ≤1‰

Detector within specification

AGATA crystals – C004



First delivery: 01.09.07

Shipment to Ankara

Repair

Test in Cologne in April 10

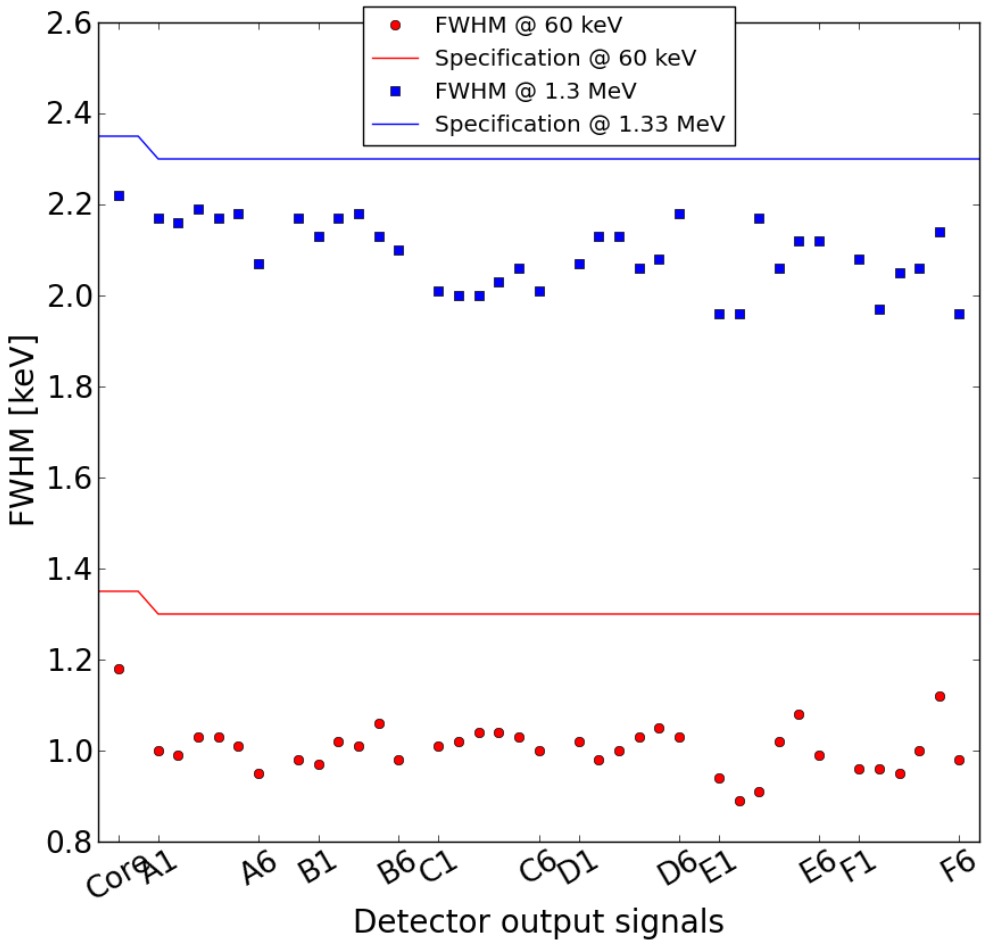
Detector returned Nov 10 and repaired

Last delivery: March 11

mounted in ATC5

Detector within specification

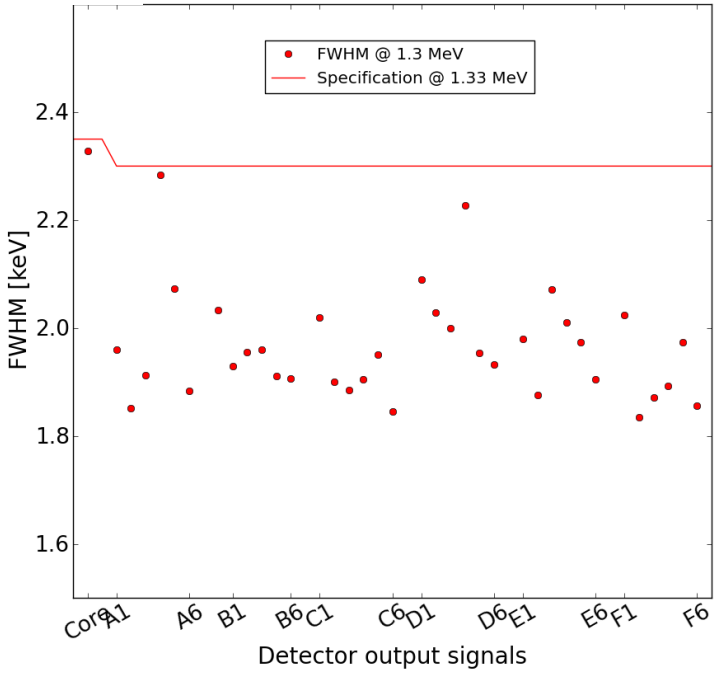
AGATA crystals – B008

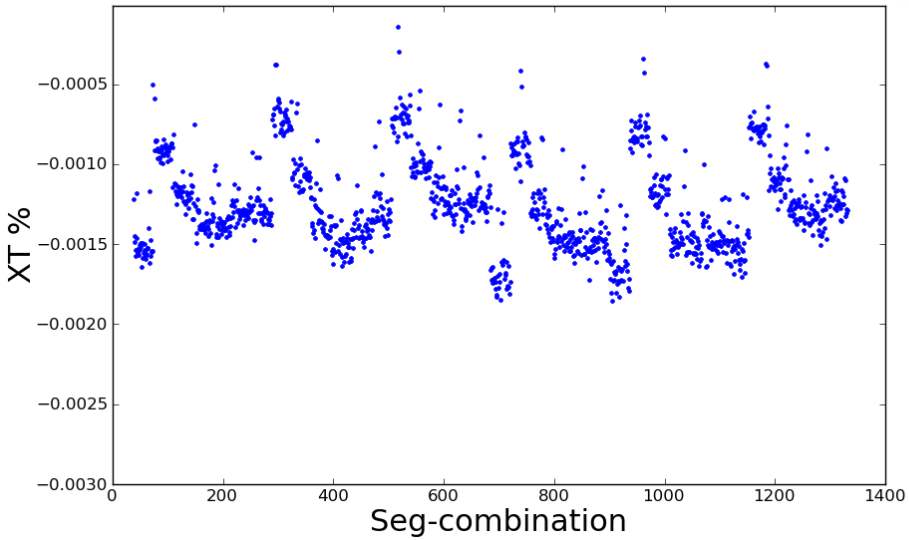


crosstalk test pending

Detector within specification

AGATA crystals – B004





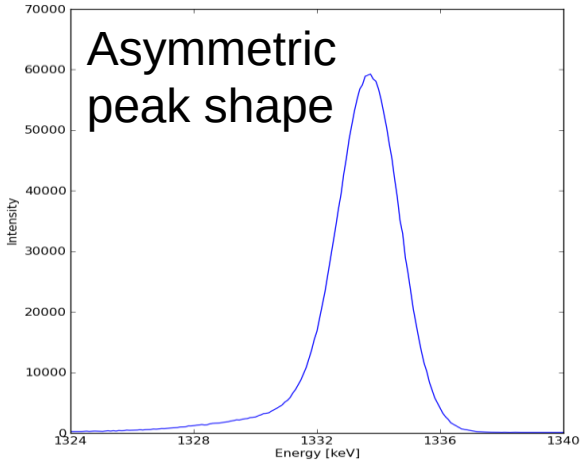
Core FWHM @ 60 keV = 1.27 keV
Small crystal size
first results promising

First delivery: Dec 07 with missing segment F6 and opposite impurity concentration gradient

Second delivery: June 08

Returned for repair

Latest delivery: Jul 11



Crystal problems

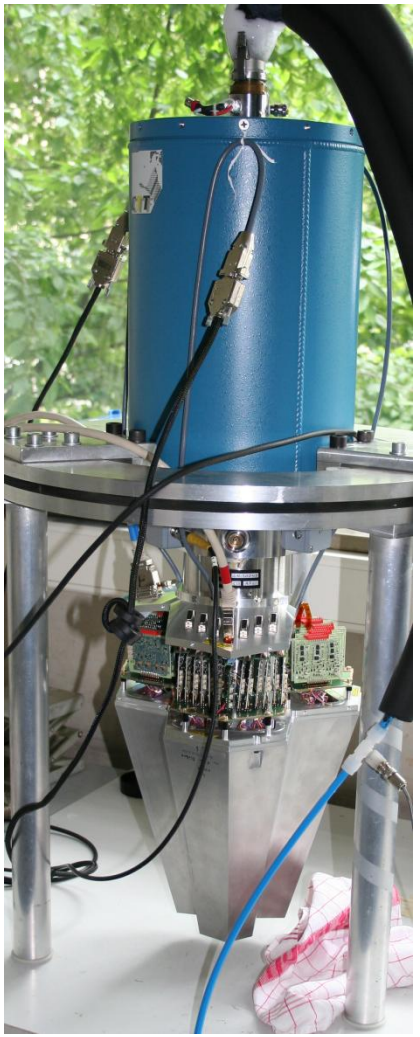
B007:
Leakage current on core and segments F1 and F5 (noise > 200 mV)
CAT failed!
Detector returned to Canberra

C006:
Operated in ATC3 and annealed after neutron damage
Leakage current of 5 nA on core and segment B1 with FWHM =10 keV
Detector returned to Canberra

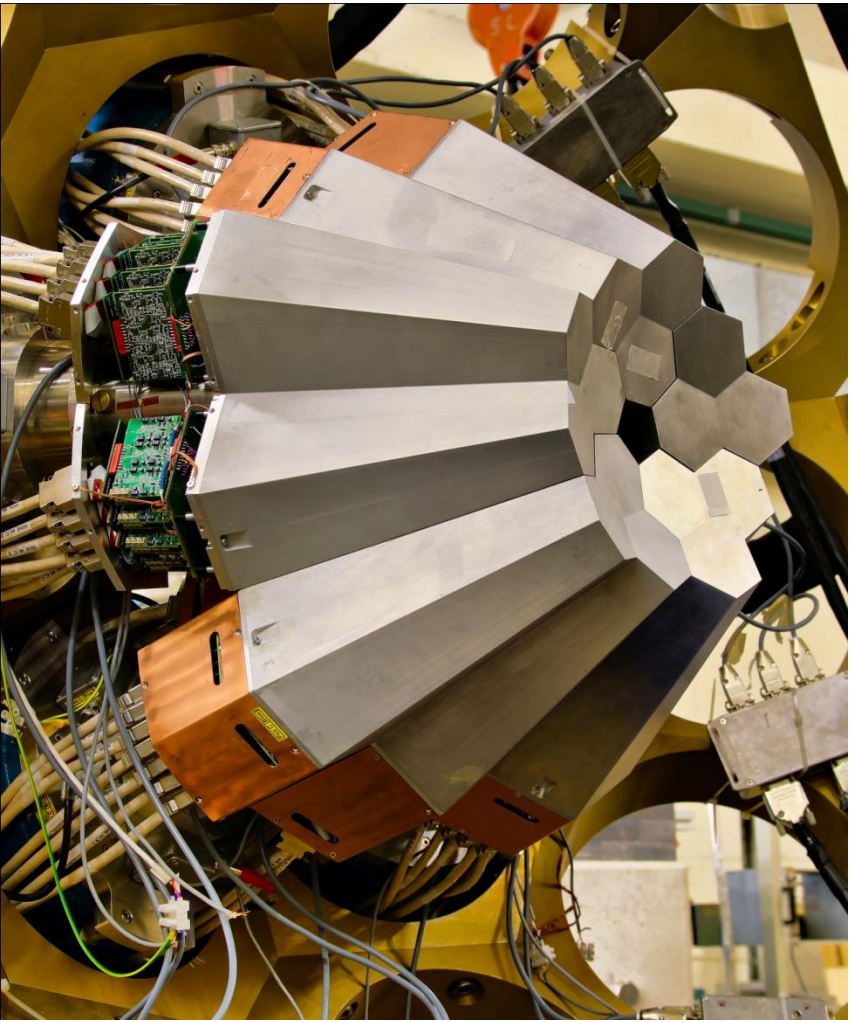
C007:
Acceptance test in Saclay with poor core resolution
Mounted in ATC in Cologne – leakage current on core and segment E2
Mounted in test cryostat - leakage current confirmed
Annealed at 80 ° for 24 h to recover performace
Mounted in ATC – leakage current on core and segments E1, F1 and F6
Detector will be shipped to Canberra son

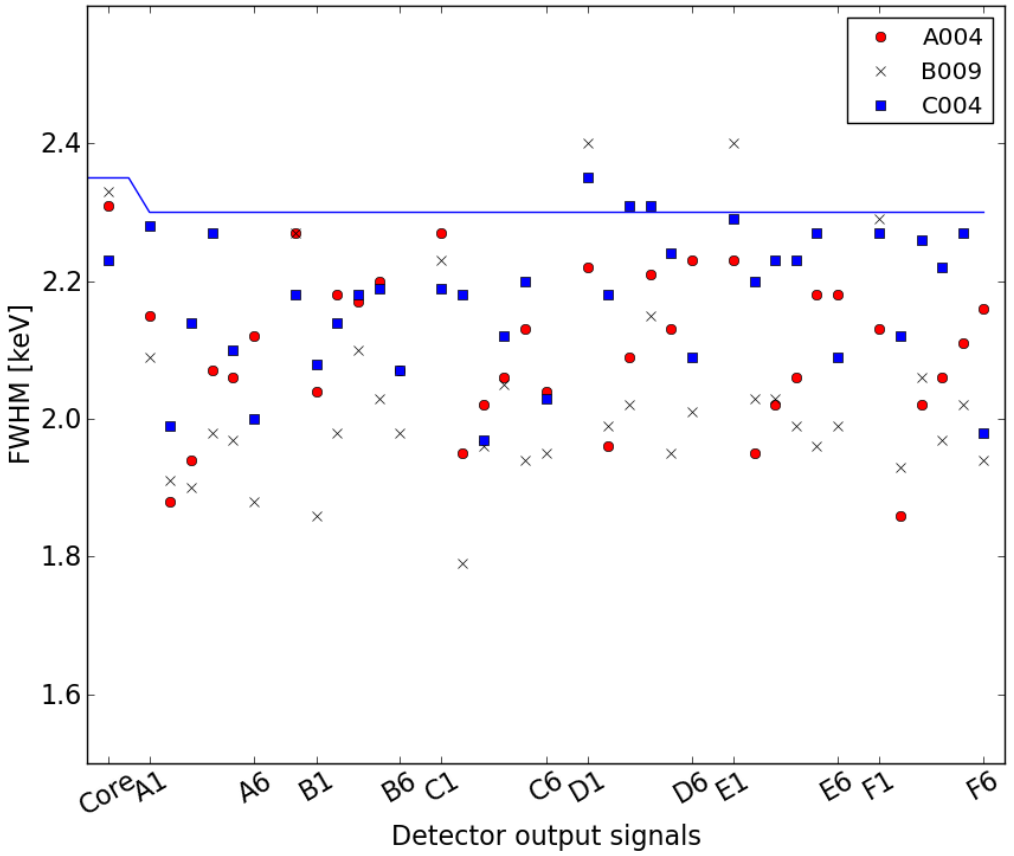
Assembly of ATC5

- Defect crystals C004, C007, C006 and B007 delayed completion
- Full set of working crystals was only available in May 11
- ATC5 equipped with A004, B006 and C004



Performance of ATC5 @INFN





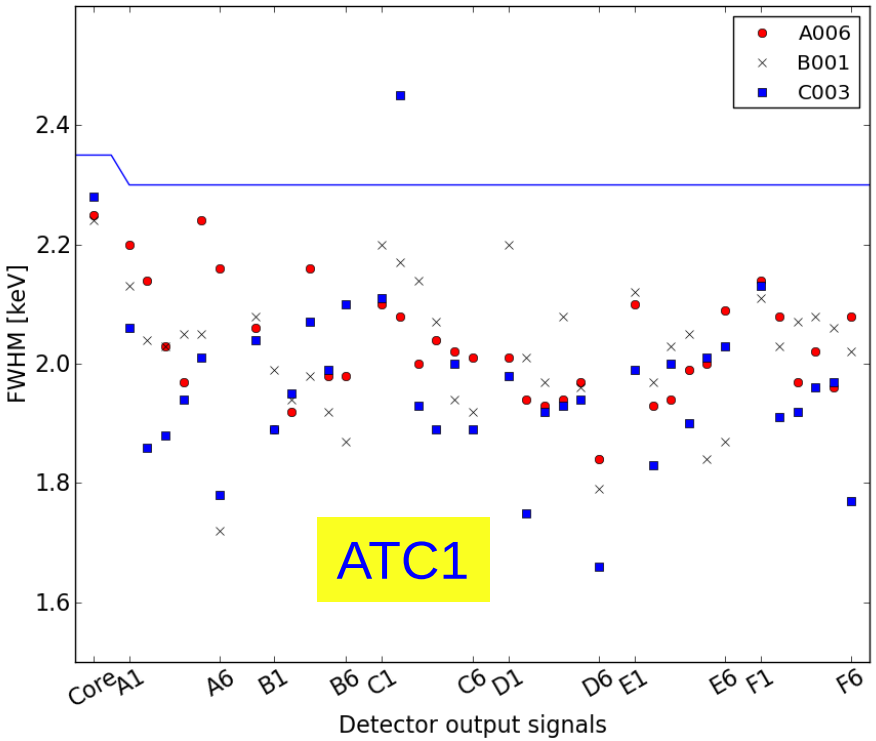
Energy resolution of all ATCs at low energy

Detector	Core FWHM [keV]		Segment average FWHM [keV]	
	Single cryostat	ATC @ IKP	Single cryostat	ATC @ IKP
ATC1:				
A001	1.34	1.44	1.079 ± 0.072	1.012 ± 0.053
B002	1.29	1.41	1.094 ± 0.086	1.039 ± 0.07
C002	1.275	1.21	1.034 ± 0.079	0.965 ± 0.063
ATC2:				
A003	1.22	1.42	1.142 ± 0.08	1.053 ± 0.065
B003	1.28	1.36	1.062 ± 0.068	0.995 ± 0.073
C005	1.24	1.49	1.163 ± 0.073	1.14 ± 0.107
ATC3:				
A002	1.26	1.44	1.033 ± 0.075	0.931 ± 0.11
B005	1.08	1.43	1.053 ± 0.078	1.045 ± 0.076
C006	1.09	1.42	1.153 ± 0.099	1.144 ± 0.106
ATC4:				
A005	1.23	1.28	1.039 ± 0.087	1.108 ± 0.171
B001	1.29	1.27	1.021 ± 0.071	1.029 ± 0.098
C003	1.16	1.33	0.998 ± 0.092	1.11 ± 0.378
ATC5:				
A004	1.27	1.21	1.17 ± 0.08	
B009	1.36	1.54	1.11 ± 0.07	1.05 ± 0.11
C004	1.3		1.11 ± 0.08	

Energy resolution of all ATCs at high energy

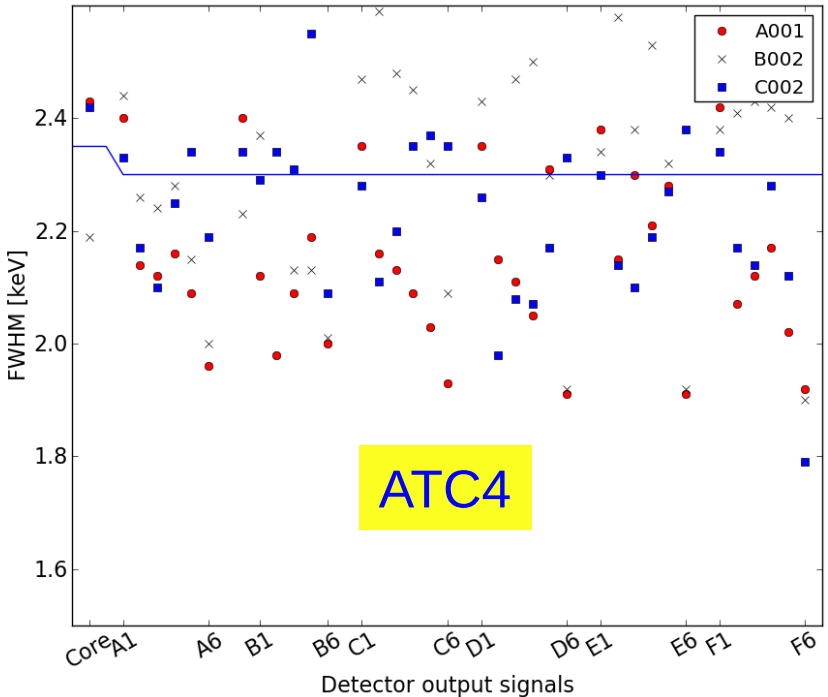
Detector	Core FWHM [keV]			Segment average FWHM [keV]		
	Single cryostat	ATC @ IKP	ATC @ INFN	Single cryostat	ATC @ IKP	ATC @ INFN
ATC1 :						
A001	2.33	2.46	2.4	2.092 ±0.156	2.194 ± 0.099	2.007 ± 0.129
B002	2.27	2.33	2.28	2.131 ± 0.105	2.099 ± 0.142	1.985 ± 0.085
C002	2.25	2.33	2.2	2.027 ± 0.115	2.108 ± 0.117	1.943 ± 0.114
ATC2:						
A003	2.280	2.41	2.56	2.098 ± 0.128	2.064 ± 0.078	2.057 ± 0.095
B003	2.23	2.52	2.42	2.081 ± 0.106	2.024 ± 0.086	1.937 ± 0.078
C005	2.2	2.21	2.39	2.207 ± 0.088	2.207 ± 0.077	2.077 ± 0.106
ATC3:						
A002	2.31	2.4	2.52	2.067 ± 0.108	2.019 ± 0.088	1.978 ± 0.087
B005	2.29	2.42	2.485	2.093 ± 0.139	2.132 ± 0.111	2.039 ± 0.127
C006	2.16	2.27	2.58	2.121 ± 0.087	2.085 ± 0.089	2.131 ± 0.148
ATC4:						
A005	2.230	2.400	2.190	2.033 ± 0.102	2.082 ± 0.127	1.914 ± 0.108
B001	2.170	2.500	2.300	2.055 ± 0.113	2.041 ± 0.105	1.906 ± 0.110
C003	2.340	2.350	2.400	2.084 ± 0.110	2.081 ± 0.092	2.042 ± 0.207
ATC5:						
A004	2.31	2.36	2.33	2.10 ± 0.11		2.04 ± 0.12
B009	2.33	2.49	2.63	2.03 ± 0.14		1.96 ± 0.14
C004	2.23		2.26	2.17 ± 0.1		2.04 ± 0.24

Repair of ATC1 & ATC4 after warm up



Neutron damaged detectors after annealing

ATC1 fully recovered



Crystals of ATC4 not fully recovered due to stronger neutron damage

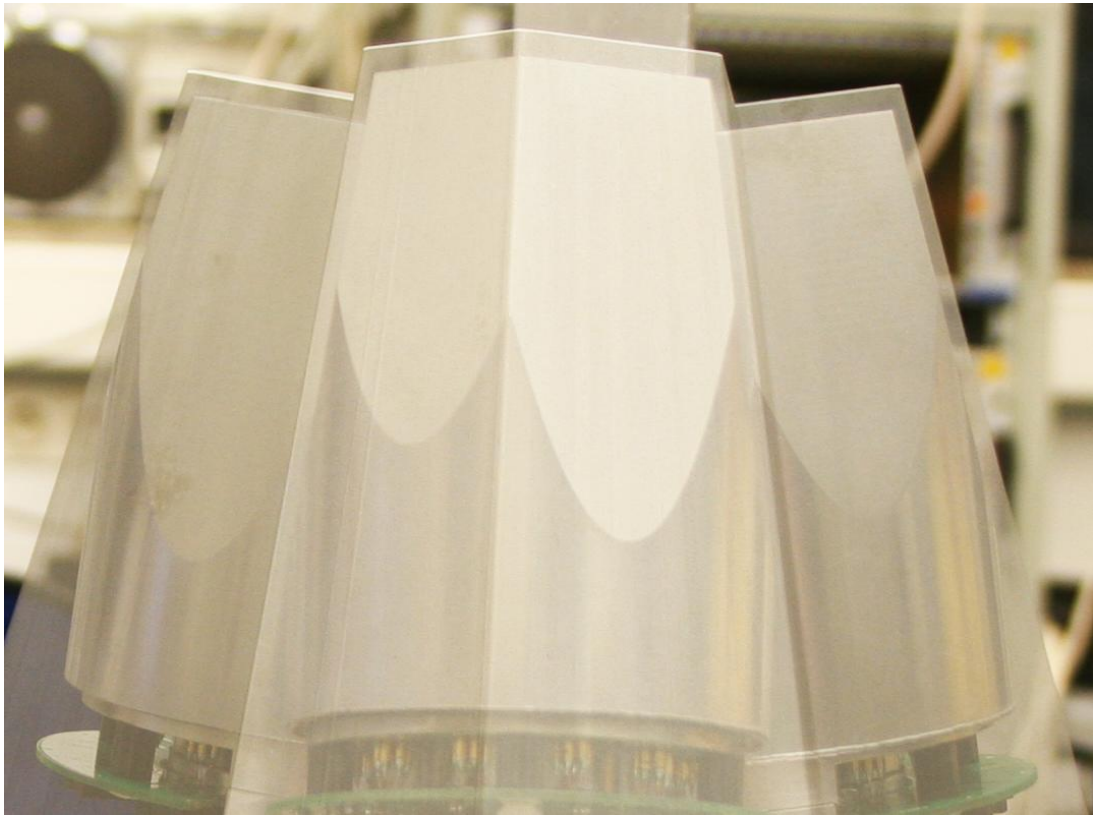
Thermal properties of ATC4

Change of performance during operation

FWHM of some segments orientation dependent

Lower temperature of end cap of $\Delta t=2°C$

ATC4 will be inspected by CTT



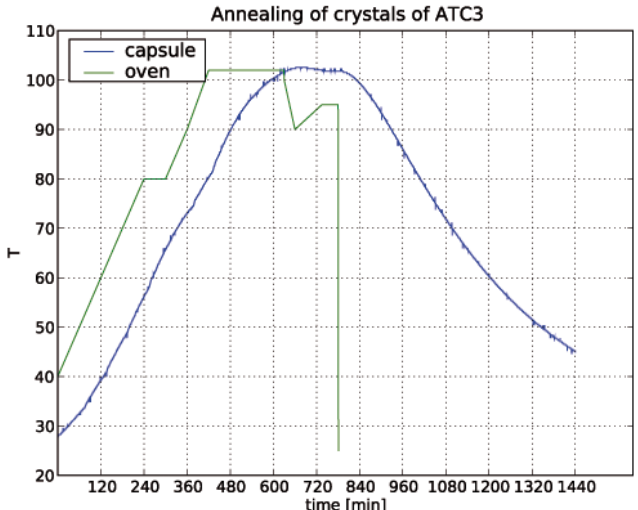
Annealing of detectors

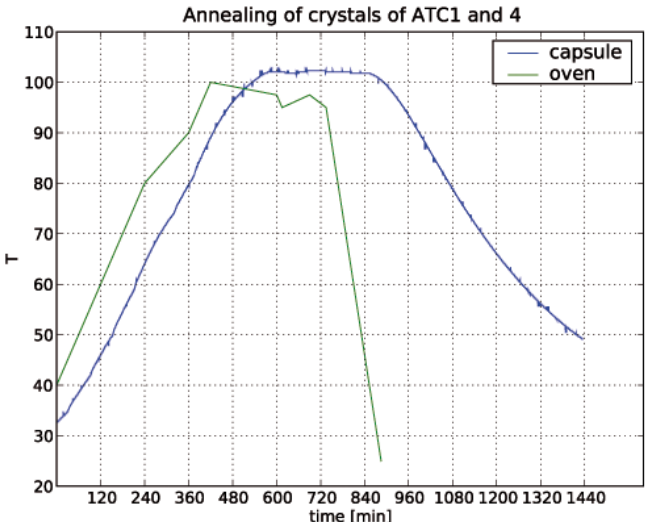
12 crystals annealed
ATC2 & ATC3 in Legnaro (Sept 10)

ATC1 & ATC4 in Cologne (Nov 11)

C006 (ATC3) broken with leakage current after annealing

Remaining neutron damage - Insufficient annealing time?



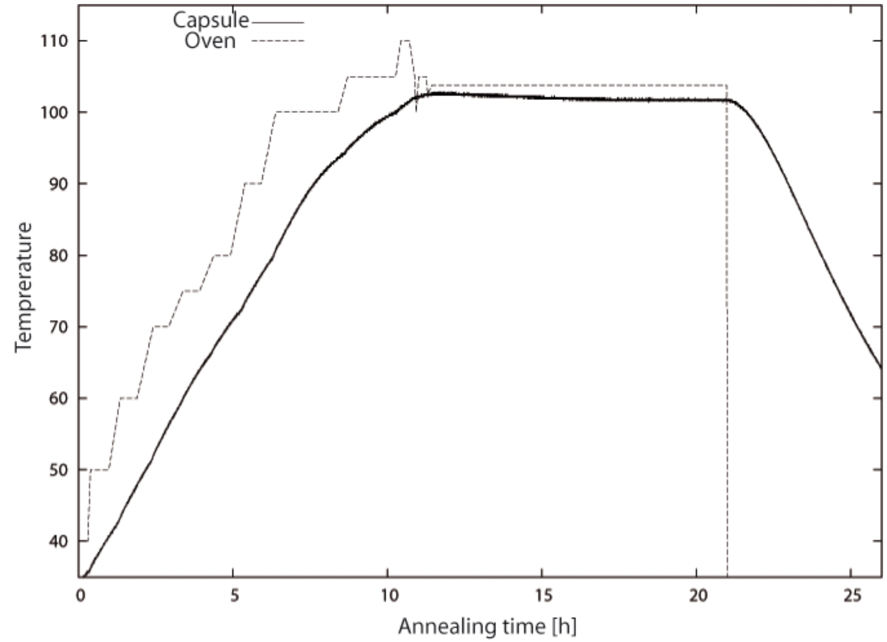


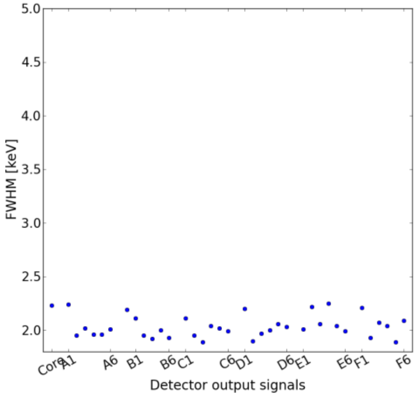
Annealing of detectors

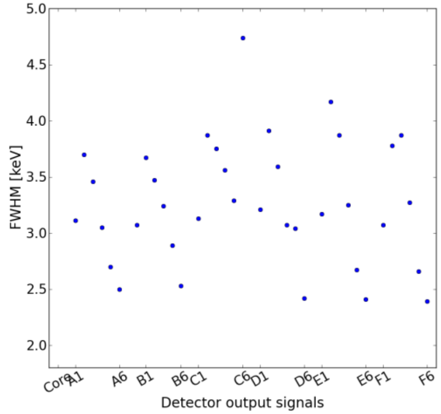
Annealing time investigation with detector A005

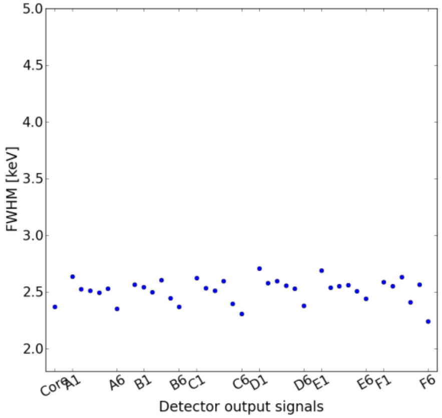
More than 10 h at full temperature needed

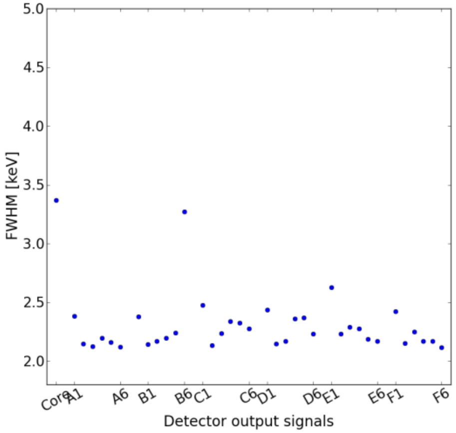
Leakage current on A005 segment B6 after second annealing





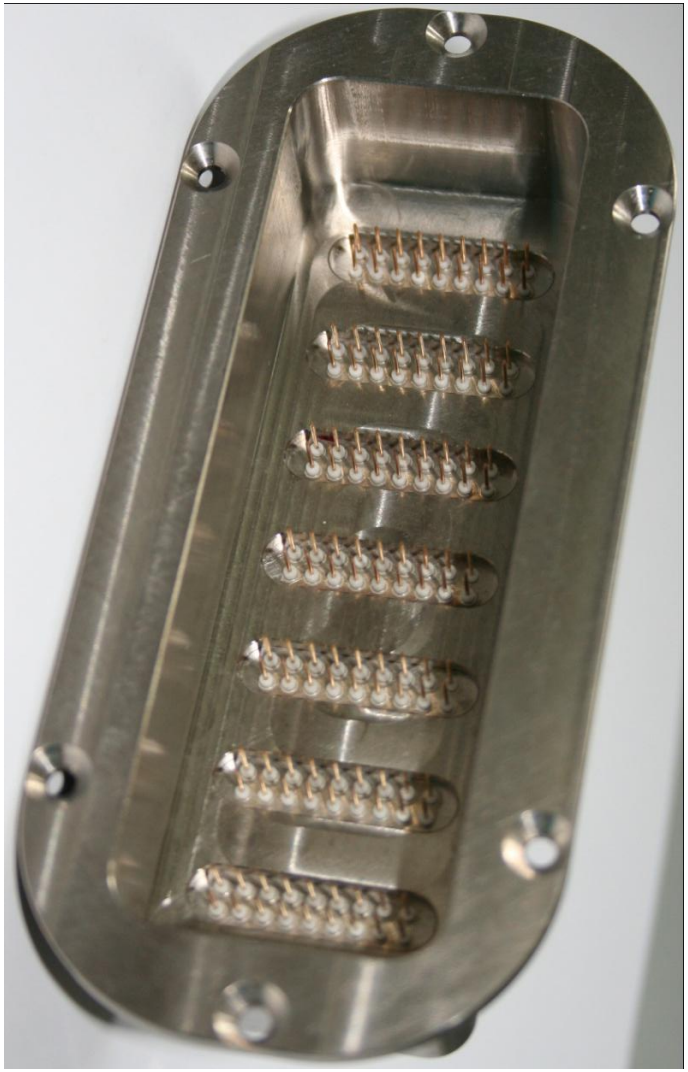


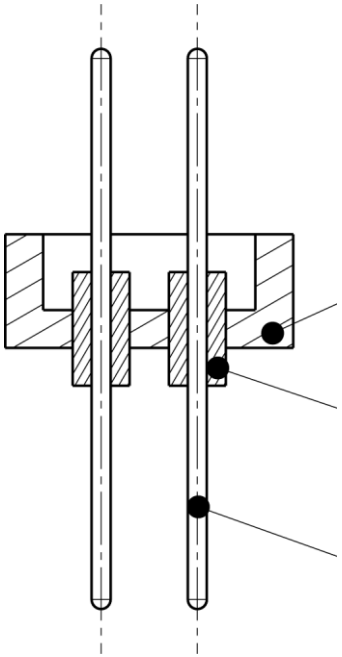




AGATA double cryostats

New feed throughs





Titanium shell

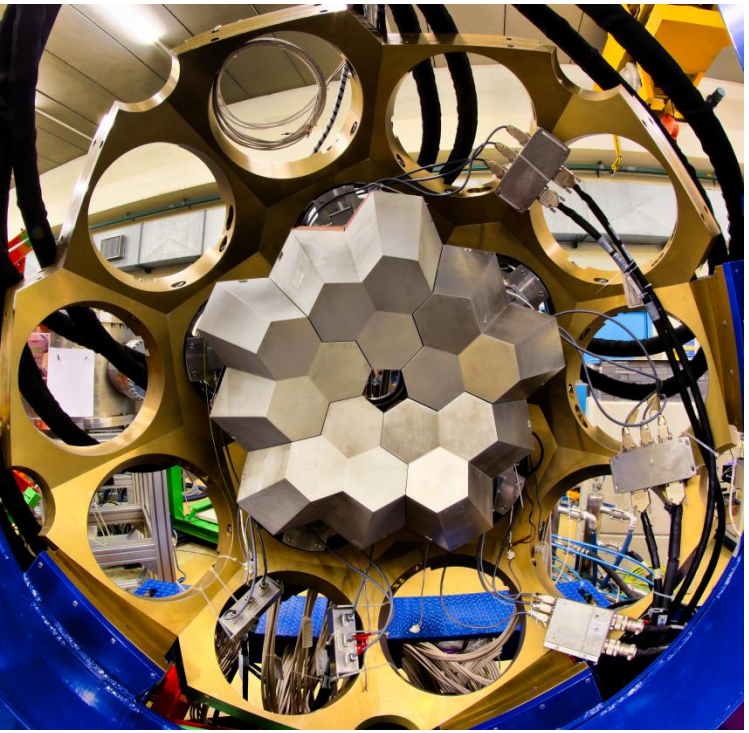
Ceramic feedthrough

Gold plated pin
0.5 mm diameter

Ultra-high vacuum capable

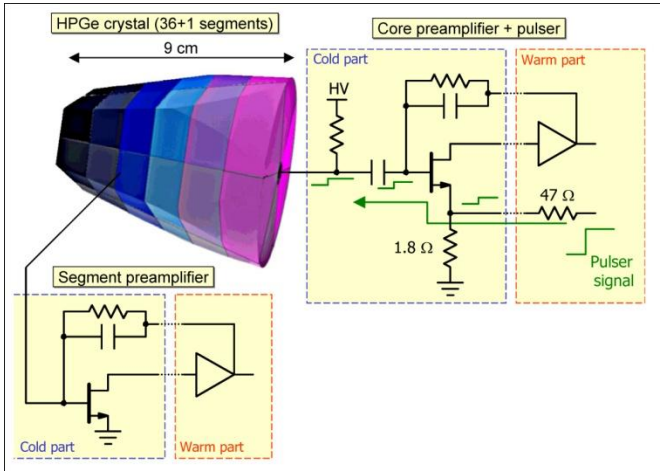
Will be part on the first
double cryostat

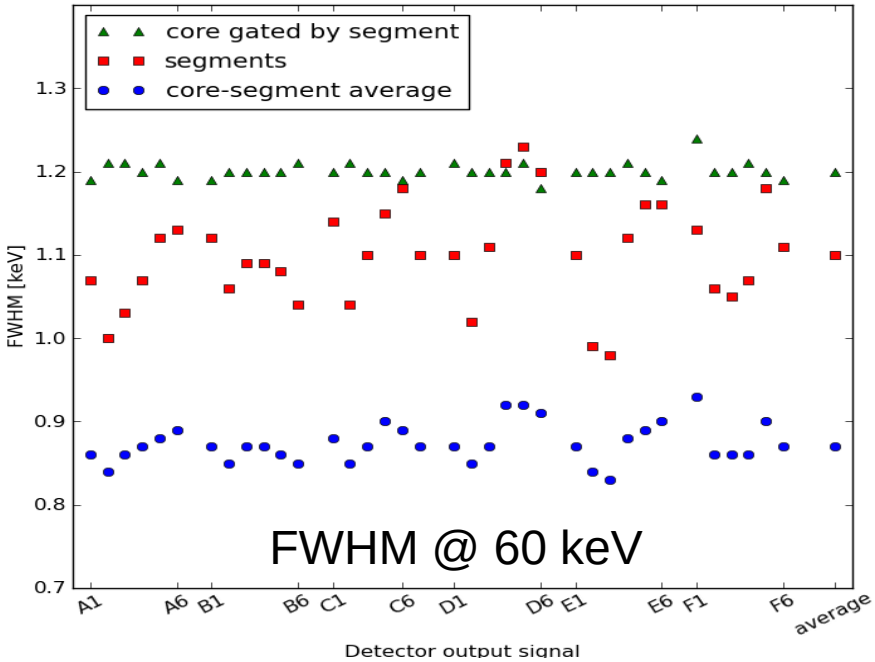
Summary Part 1



- Demonstrator completed!
- B008, B010, C004 accepted
- B004 promising
- B007, C006, C007 and A005 with leakage current
- Repair of ATC1 and ATC4
- Longer annealing time needed
- Detectors vulnerable to annealing

Improving signal-to-noise ratio

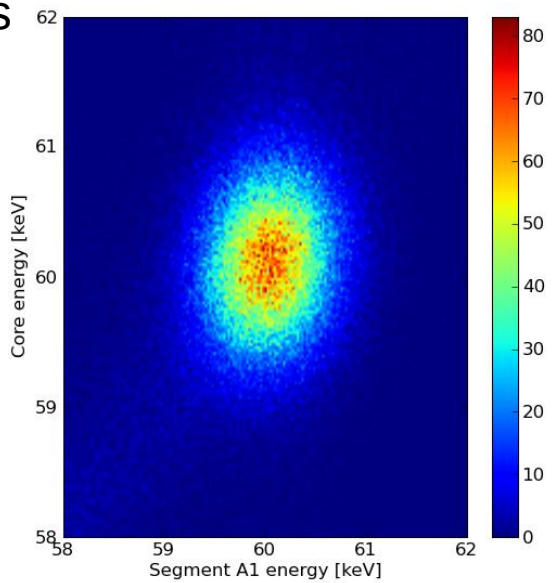


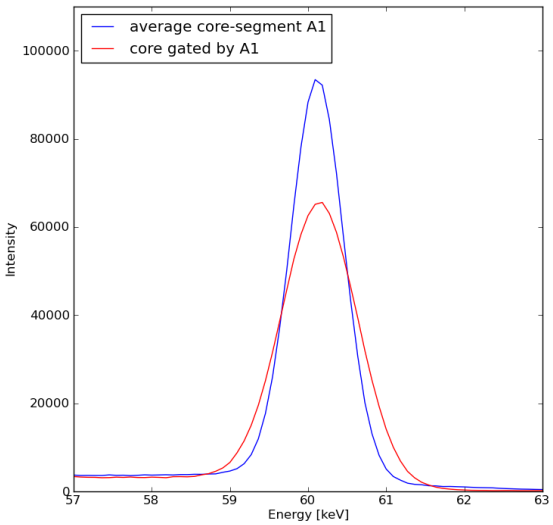


Combining core and segment signals

$$W_T = \sqrt{W_D^2 + W_X^2 + \left(\frac{1}{\sqrt{2}} W_E\right)^2}$$

Improvement applies to uncorrelated electronic noise

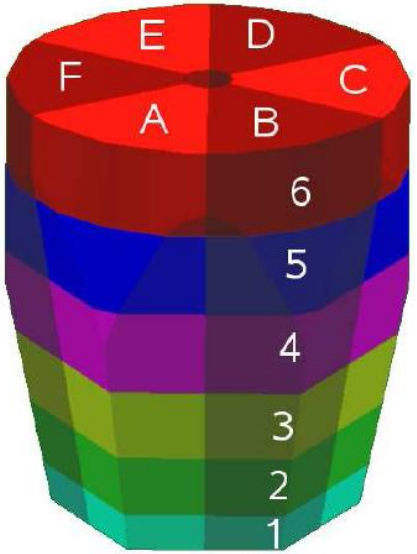




Trapping correction

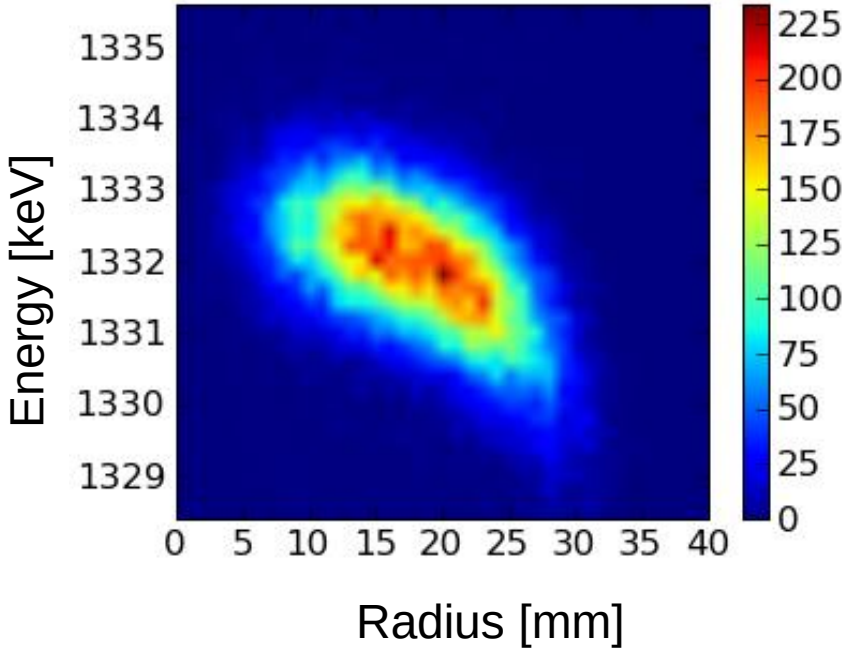
Electron trapping due to
crystal defects and impurities
in n-type germanium

Large drift length causes trapping



Position dependent trapping
sensitivity calculated

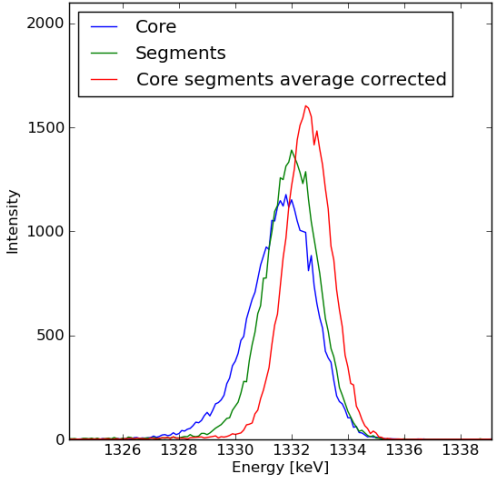
Sensitivities used to achieve
charge collection efficiency

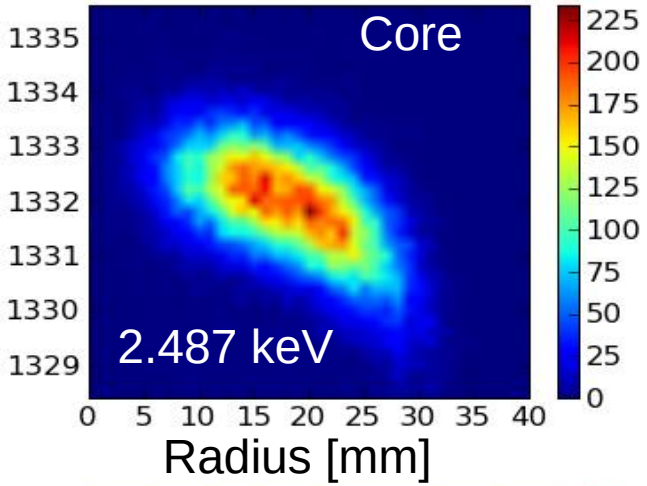


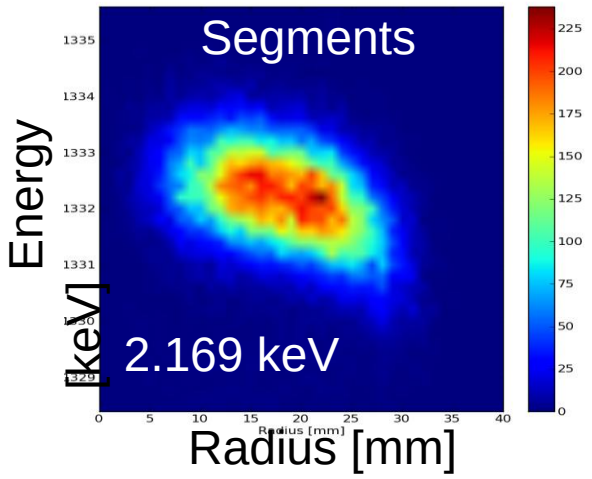
B. Bruyneel et al., LNL Annual Report (2011) 64–65.

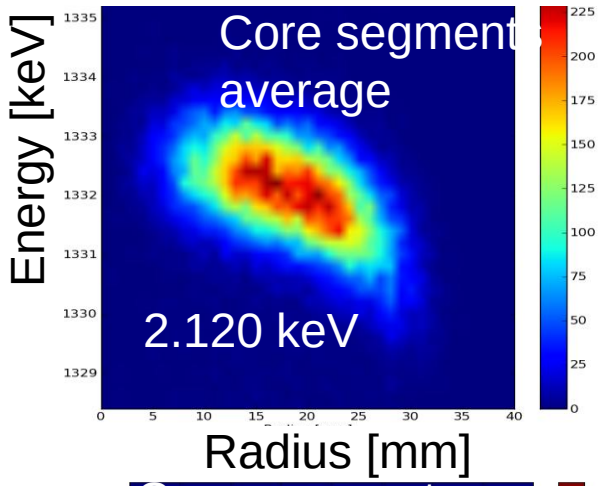
Position-dependent energy

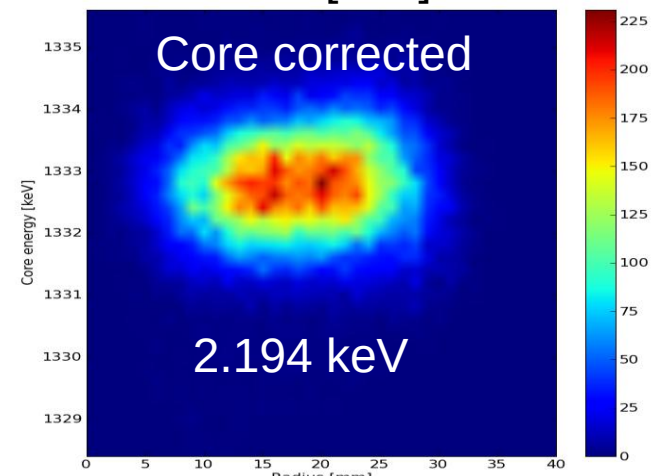
Onefold events in front ring @ 1.3 MeV

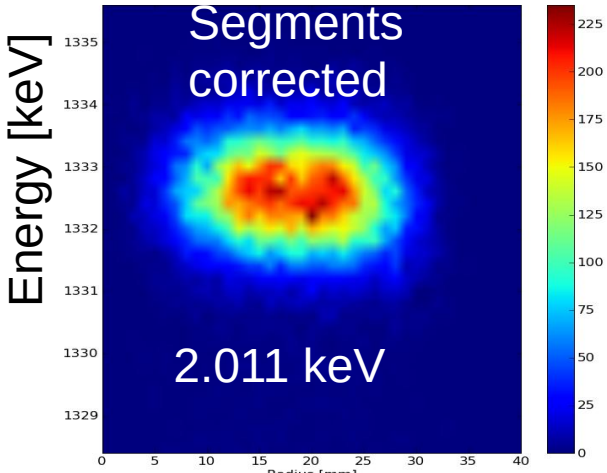


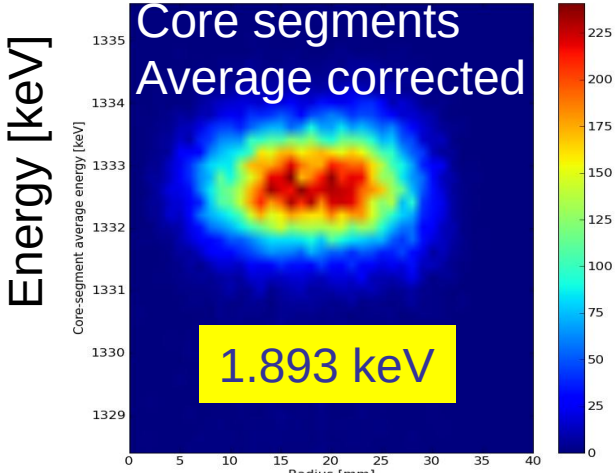




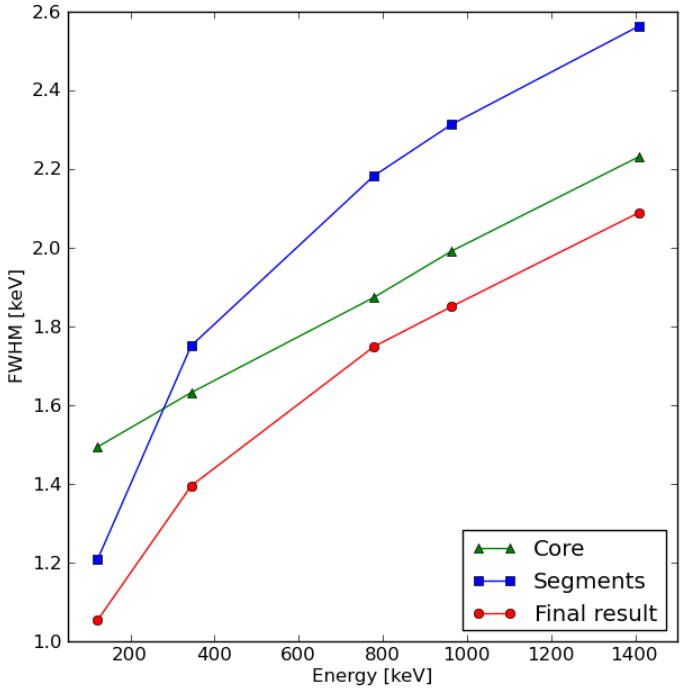








Improved energy resolution

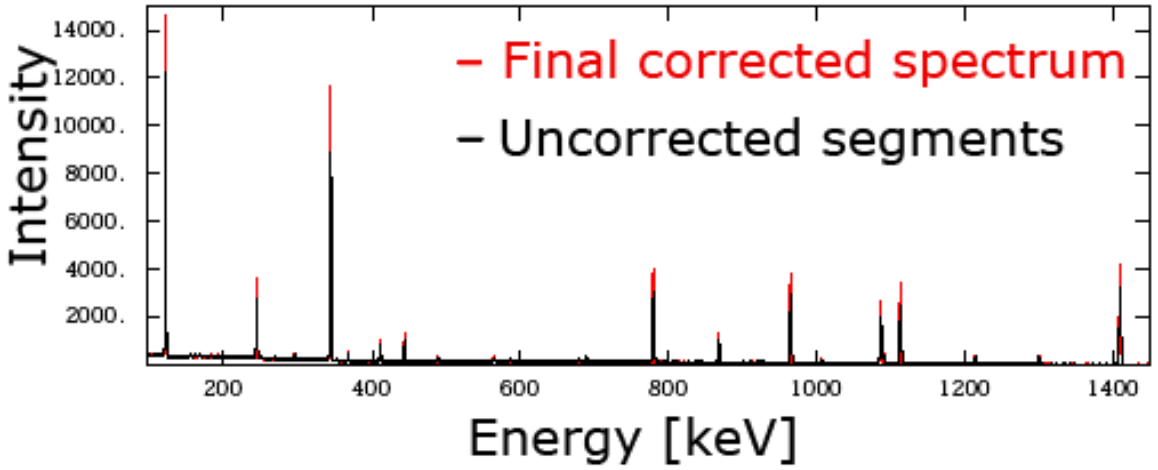


Combination of all multifold events

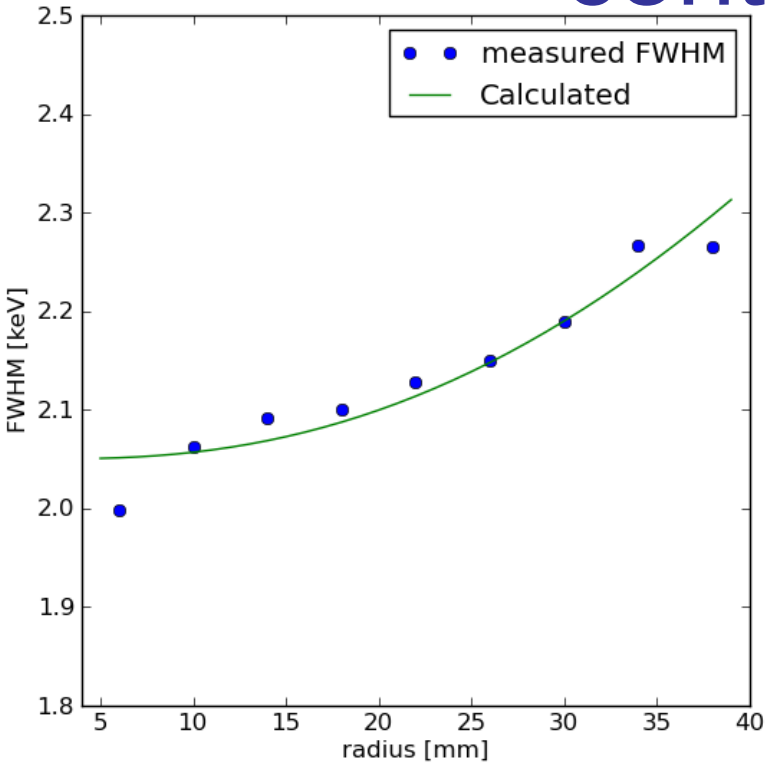
Multifold events with noise of more than one preamplifier

Improvement of energy resolution of 20 % in the whole energy range

2 keV energy resoltution @ 1.33 MeV

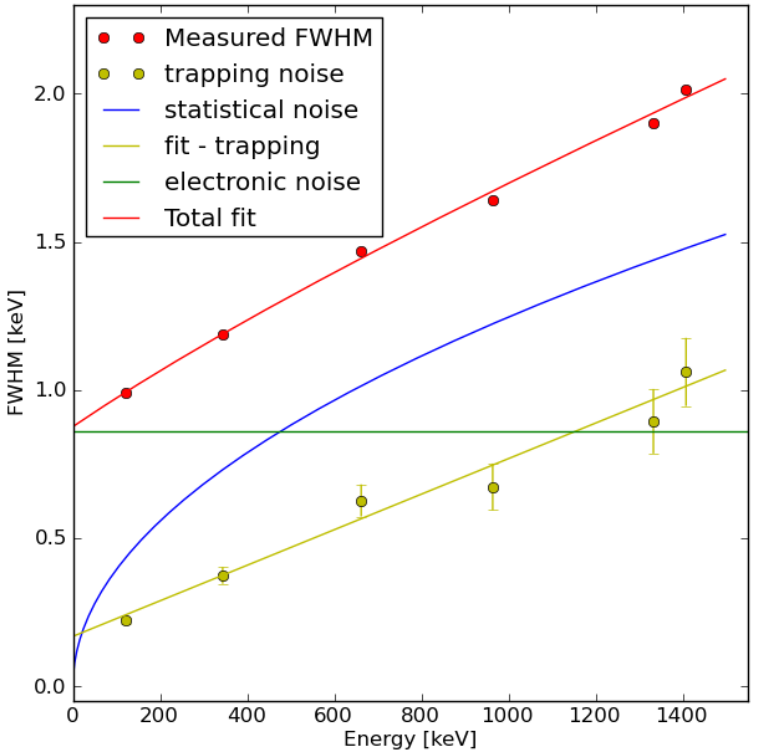


Separation of the noise contributions



Fit of radius-dependent trapping FWHM

$$W_X \propto \sqrt{(1-\eta(r))}$$

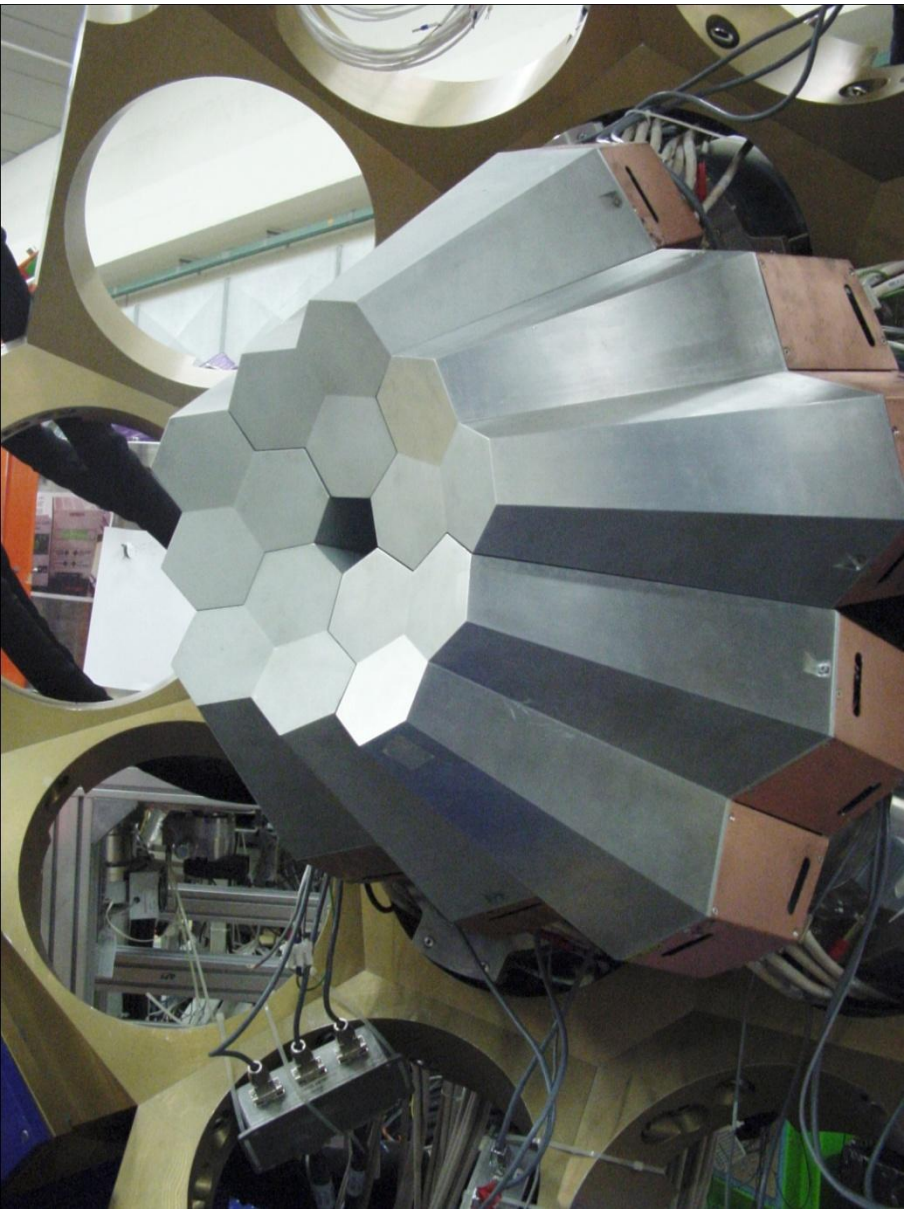


$$W_T^2 = W_D^2 + W_X^2 + W_E^2$$

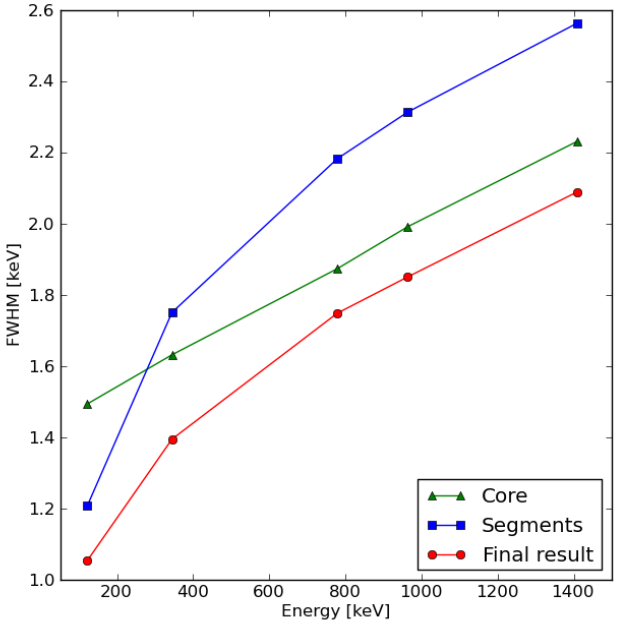
$$W_T = \sqrt{a \cdot E + b \cdot E^2 + c}$$

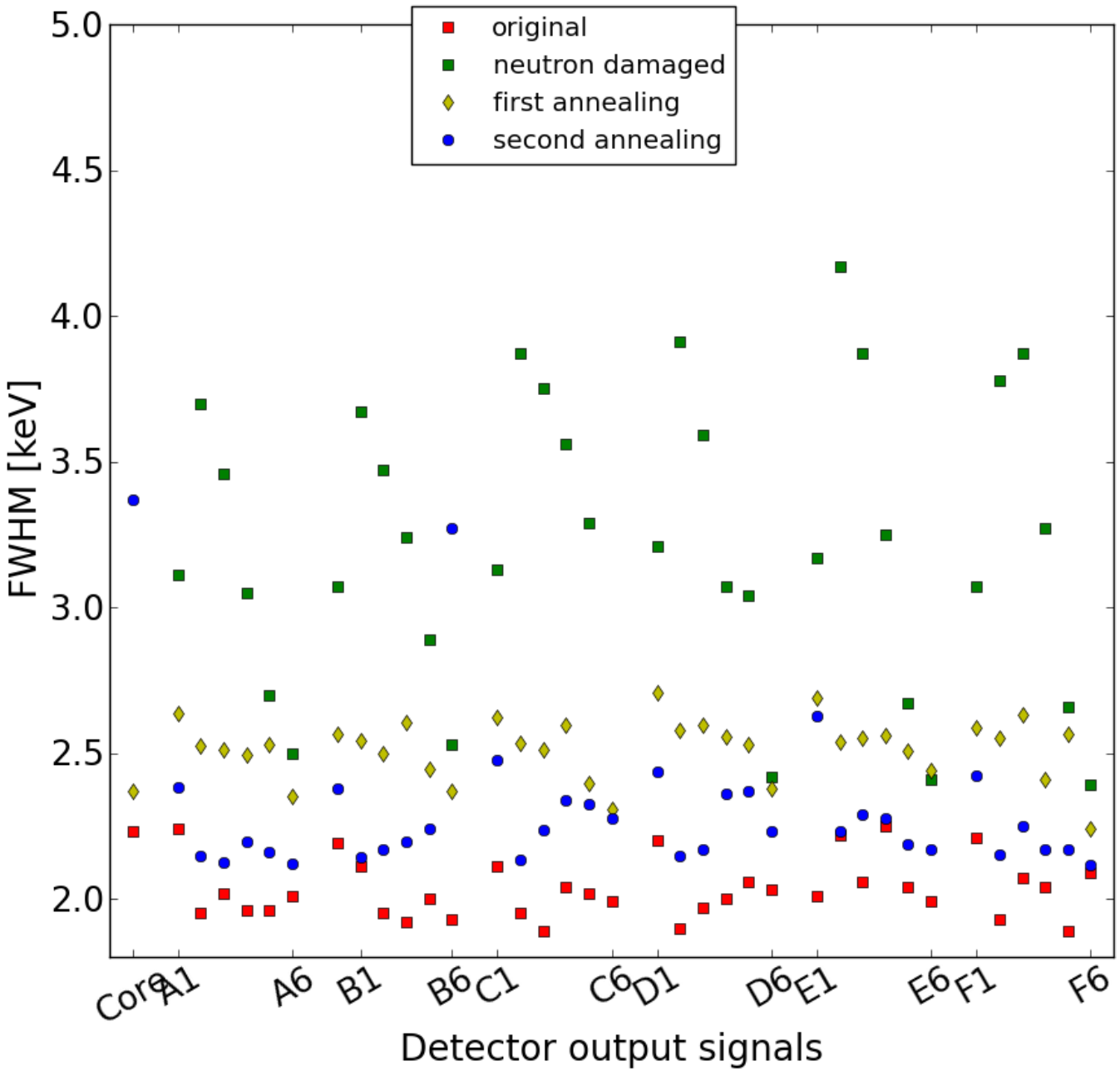
Position-dependent energy resolution used for Fano factor of 0.095 ± 0.005

Summary & Outlook

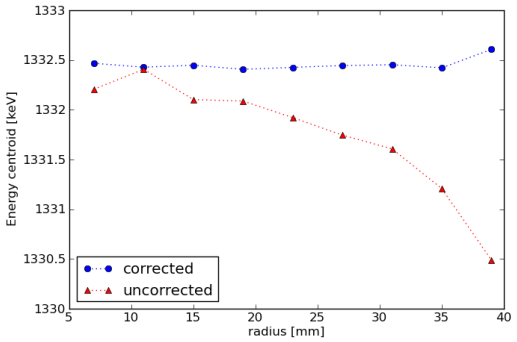


- Segmented detectors provide new analysis methods
- Increased energy resolution by combining core and segment signals & trapping correction
- FWHM of 2 keV @ 1.3 MeV



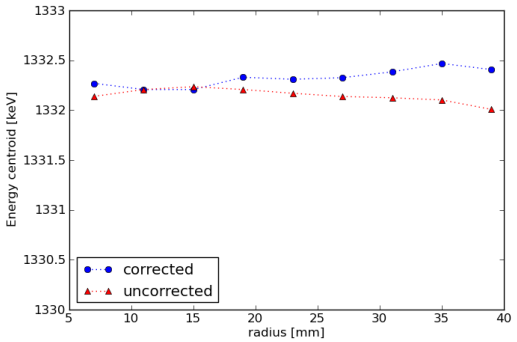

original
neutron damaged
first annealing
second annealing
5.0
4.5
4.0
3.5
3.0
2.5
2.0
FWHM [keV]
Core
A1
A6
B1
B6
C1
C6
D1
D6
E1
E6
F1
F6
Detector output signals

Position-dependent energy

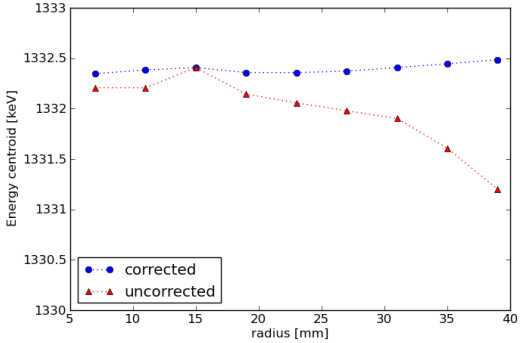


FWHM @ 1.3MeV

	original	corrected
Core:	2.22	2.11

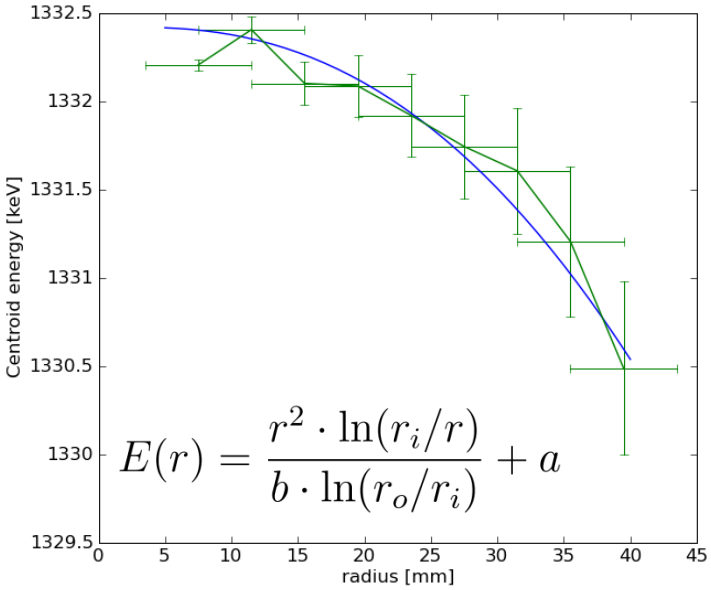


Segments:	1.97	1.97



Core segments Average:	1.89	1.82

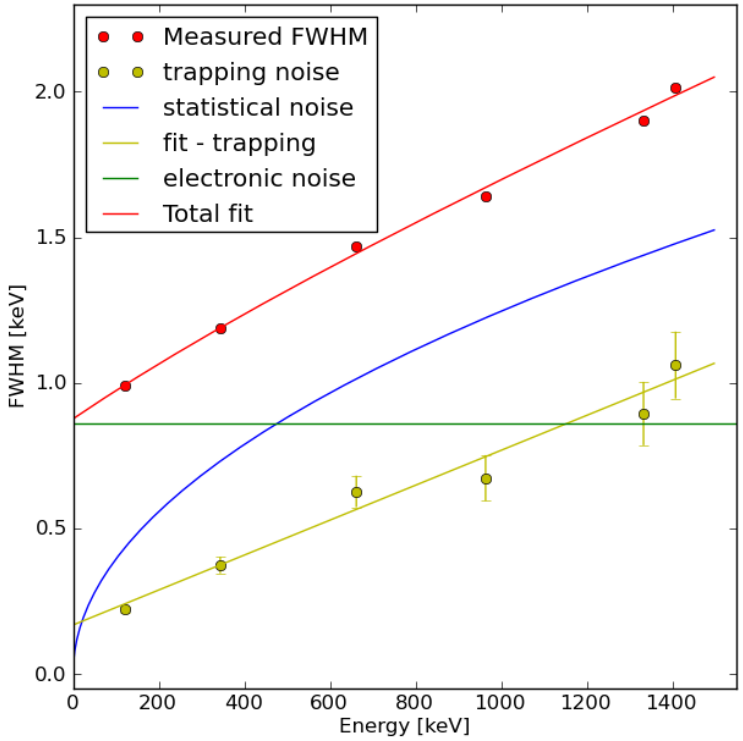
Onefold events in coaxial part of the detector

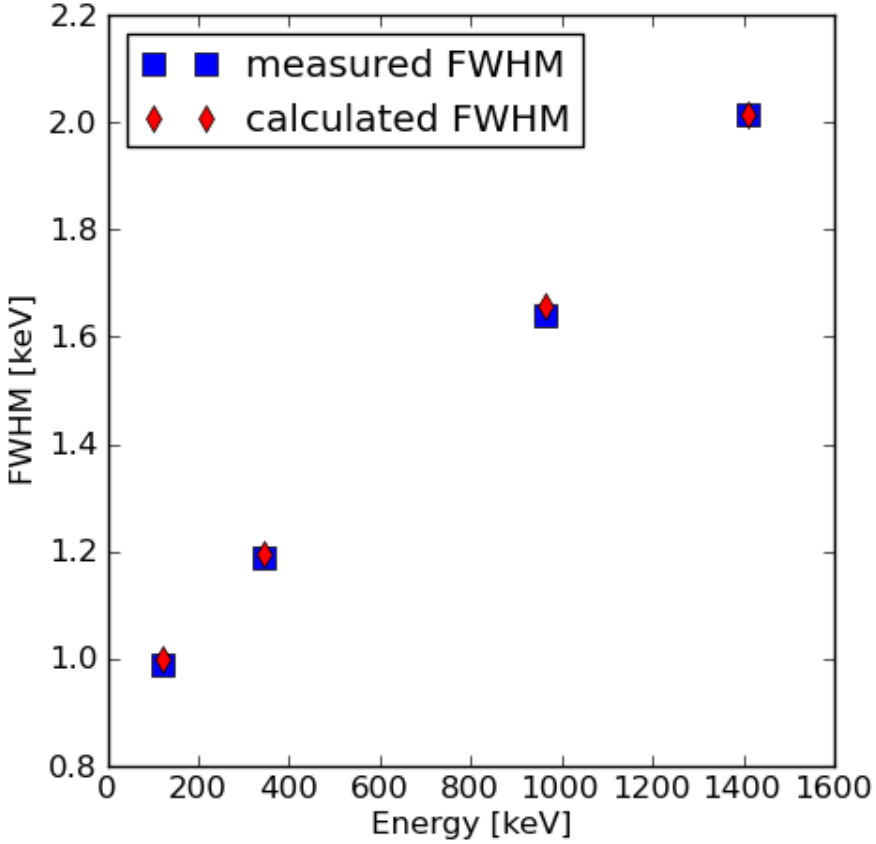


Position uncertainty of 4 mm
Radius dependent energy uncertainty

Improvement in PSA =improvement in FWH

Averaged signal of core and segments





$$W_T^2 = W_D^2 + W_X^2 + W_E^2$$

Noise contributions can be separated
Fano factor =0.095

$$W_X = 2.35\sqrt{\epsilon K E_0 (1 - \eta(r))}$$

Trapping sensitivity

•DEFINITION: electron / hole sensitivity of electrode i to trapping

$$s^i_{e,h} = \frac{d\eta^i_{e,h}}{dN_t}\,|_{N_t=0}$$

= fraction missing due to trapping
+ induced charge due to trail of trapped charges

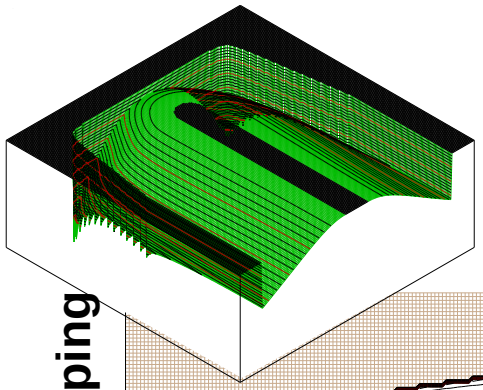
•Relation to total collection efficiency:

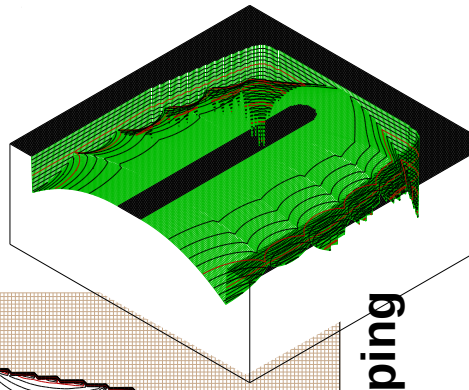
$$\eta^i_{tot}(\vec{x}_0) = 1 + \left[N_e s^i_e(\vec{x}_0) + N_h s^i_h(\vec{x}_0)\right] + O(2)$$

•Ne : density of electron traps, Nh: density of hole traps
•O(2) – higher order terms in taylor expansion - negligible
•sensitivities can be calculated in advance
•Ne, Nh are fit parameters

B. Bruyneel

Sensitivity $s^{i}_{e,h}$

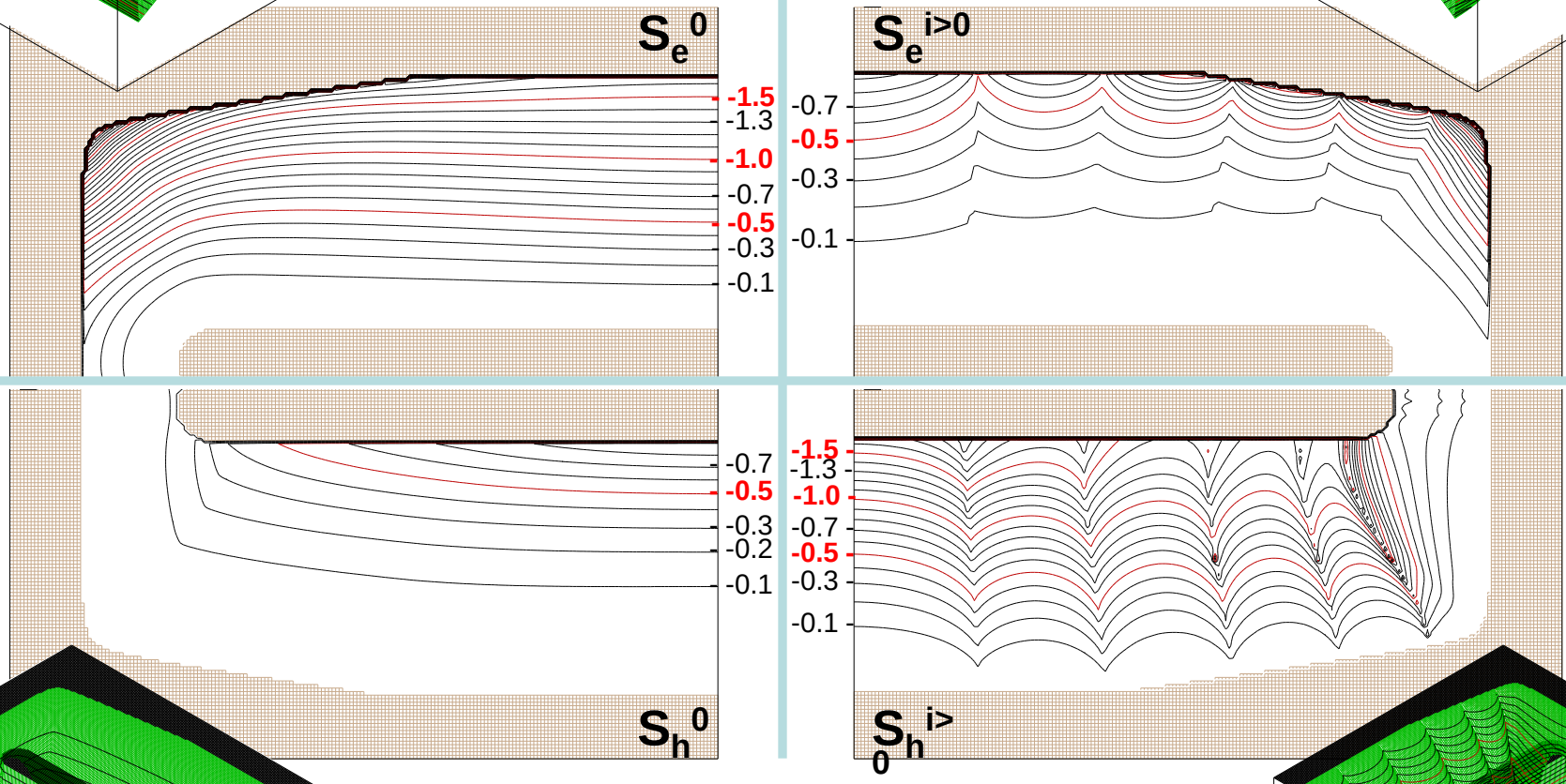




For Core **For Segments**

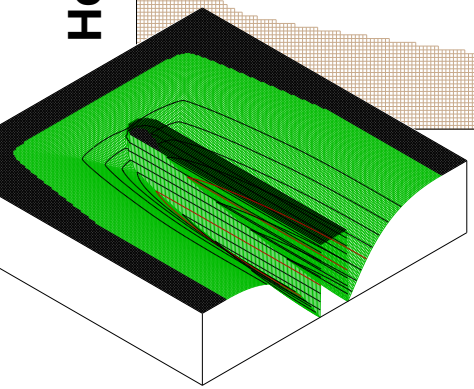
Electron trapping

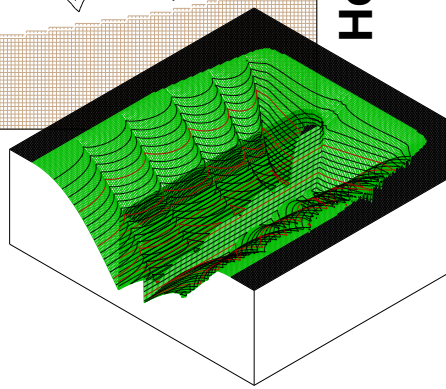
Hole trapping



Electron trapping

Hole trapping





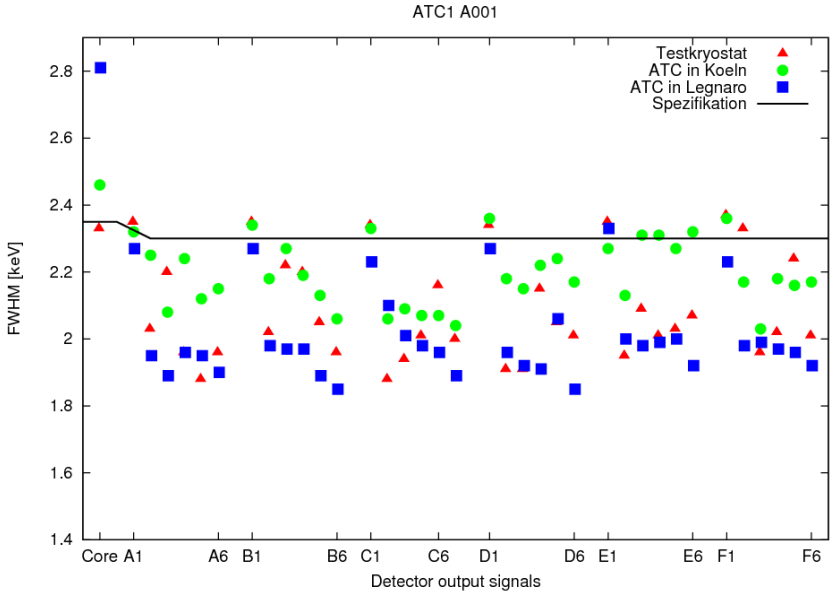
- Core more sensitive to E-trapping
- Segs more sensitive to H-trapping
- E-trapping maximal at large radius
- H-trapping minimal at large radius

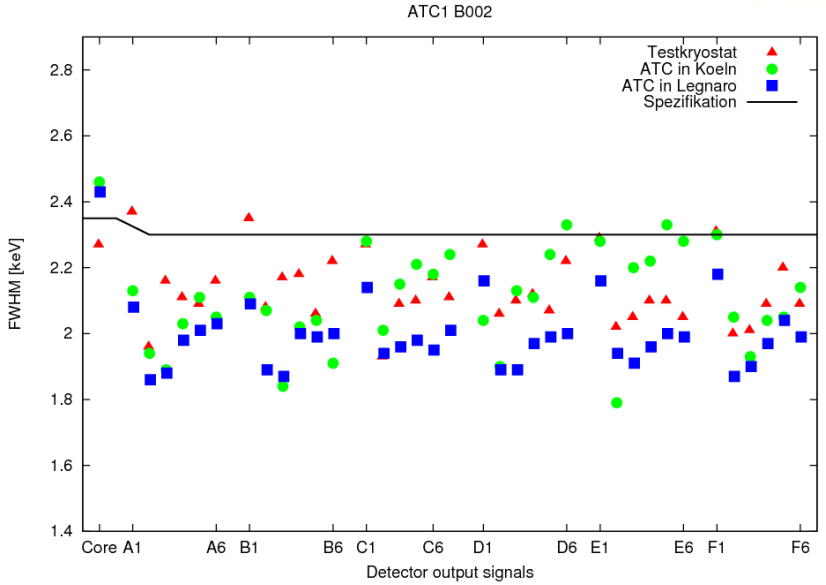
Signal averaging for B002 & C002

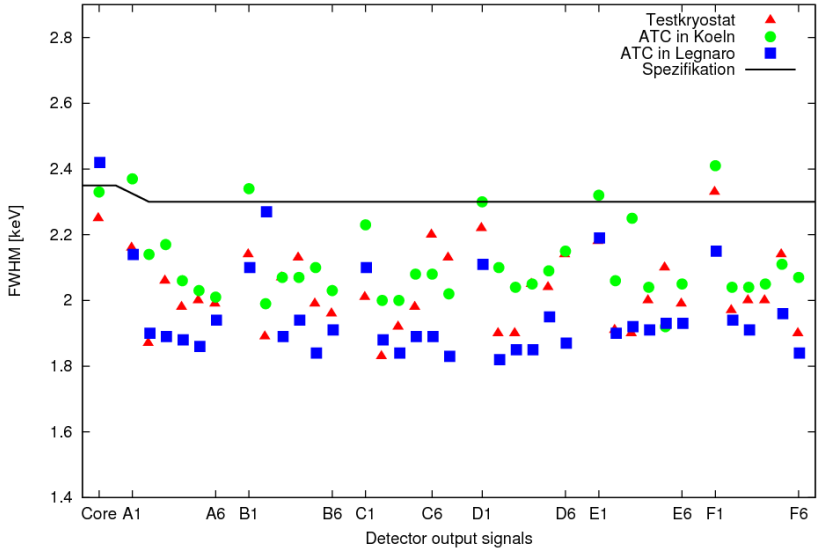
Energy [keV]	Core FWHM	Segments FWHM	Average FWHM
122	1.394	1.208	1.0
344	1.608	1.388	1.221
964	2.091	1.893	1.774
1408	2.457	2.259	2.174

Energy [keV]	Core FWHM	Segments FWHM	Average FWHM
122	1.448	1.139	0.989
344	1.603	1.308	1.189
964	1.986	1.729	1.640
1408	2.315	2.027	2.013

AGATA tripel cluster ATC1



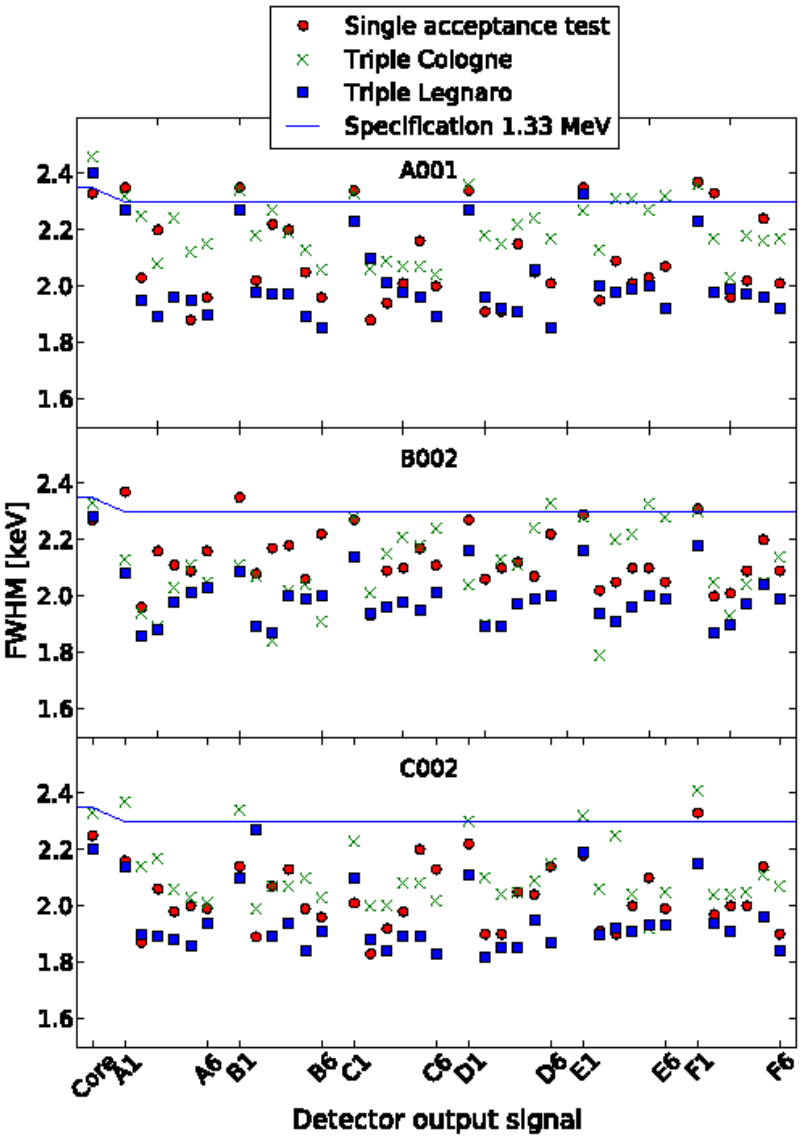


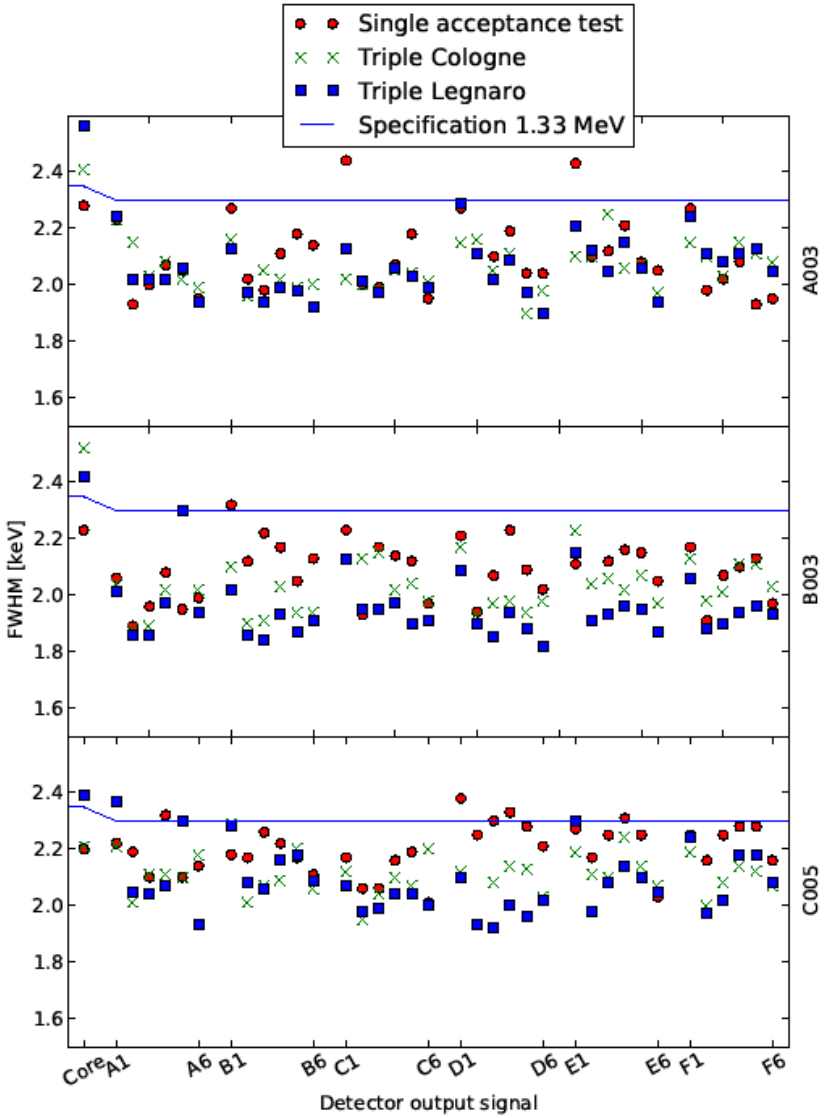


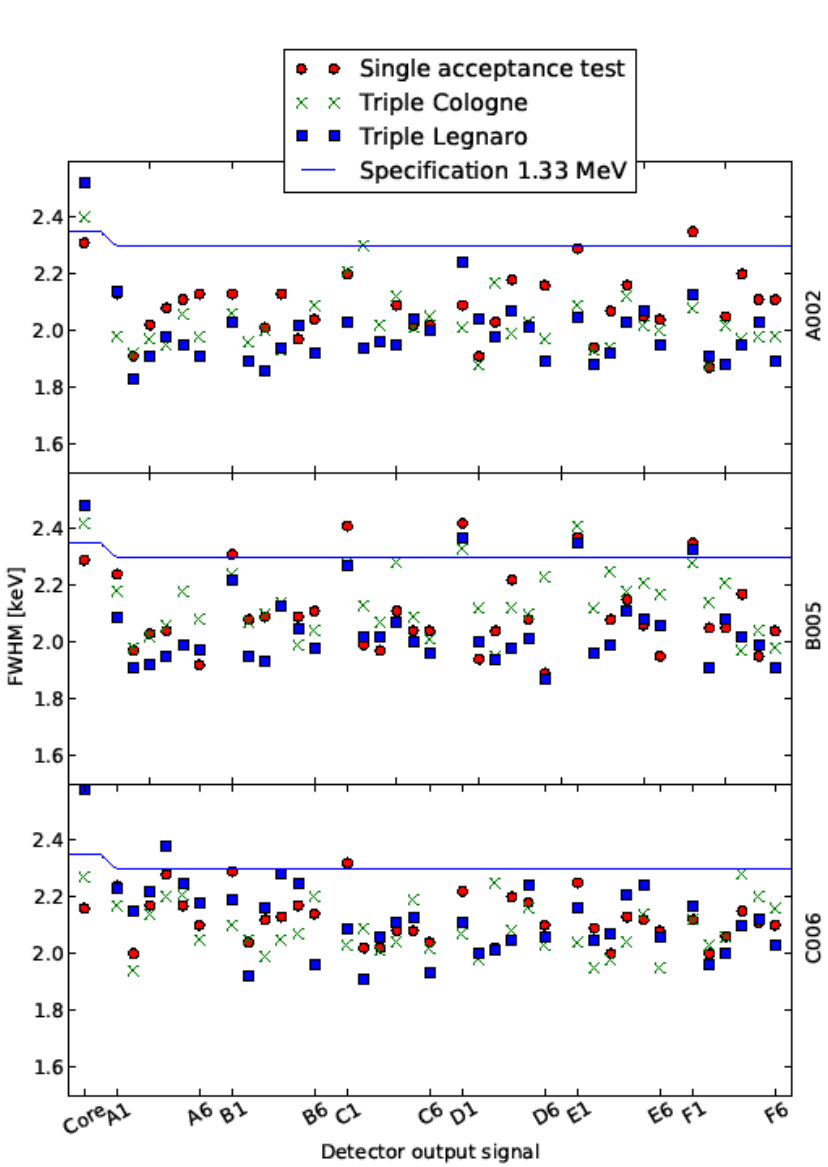
Measured at Köln and Legnaro

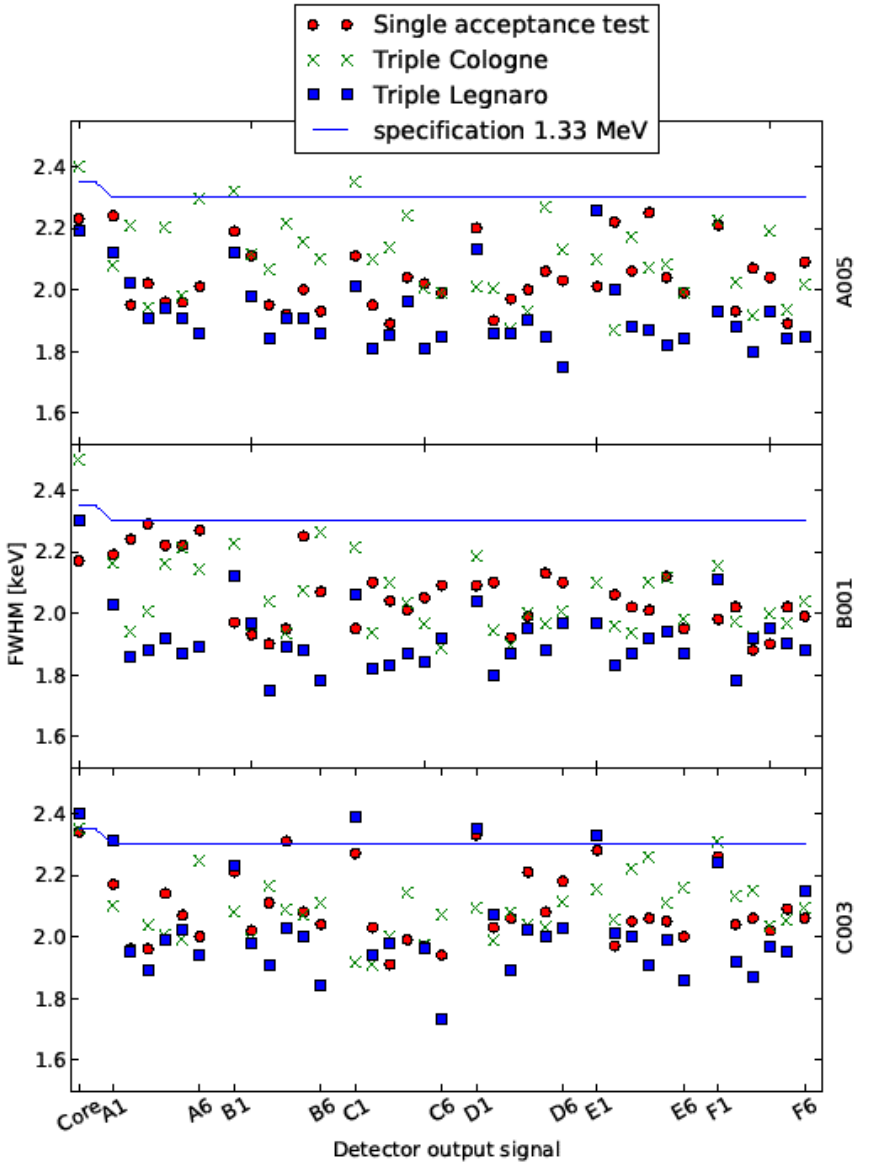
Mean values of energy resolution of segments at 60 keV and 1,3 MeV:

A001 :	1011 +/- 53 eV	2,00 keV
B002 :	1039 +/- 70 eV	1,98 keV
C002 :	965 +/- 63 eV	1,94 keV


Single acceptance test
Triple Cologne
Triple Legnaro
Specification 1.33 MeV
A001
B002
C002
FWHM [keV]
2.4
2.2
2.0
1.8
1.6
Core
A1
A6
B1
B6
C1
C6
D1
D6
E1
E6
F1
F6
Detector output signal


Single acceptance test
Triple Cologne
Triple Legnaro
Specification 1.33 MeV
A003
B003
C005
FWHM [keV]
2.4
2.2
2.0
1.8
1.6
Core
A1
A6
B1
B6
C1
C6
D1
D6
E1
E6
F1
F6
Detector output signal


Single acceptance test
Triple Cologne
Triple Legnaro
Specification 1.33 MeV
FWHM [keV]
A002
B005
C006
Core A1 A6 B1 B6 C1 C6 D1 D6 E1 E6 F1 F6
Detector output signal


Single acceptance test
Triple Cologne
Triple Legnaro
specification 1.33 MeV
FWHM [keV]
A005
B001
C003
Core A1 A6 B1 B6 C1 C6 D1 D6 E1 E6 F1 F6
Detector output signal