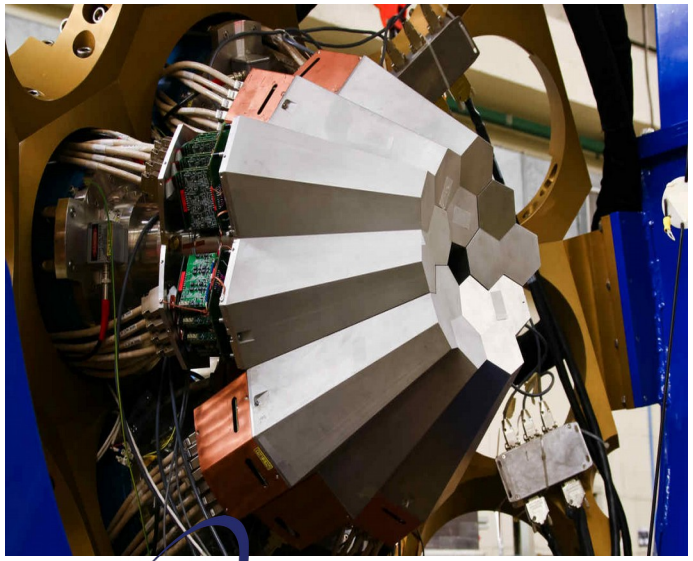
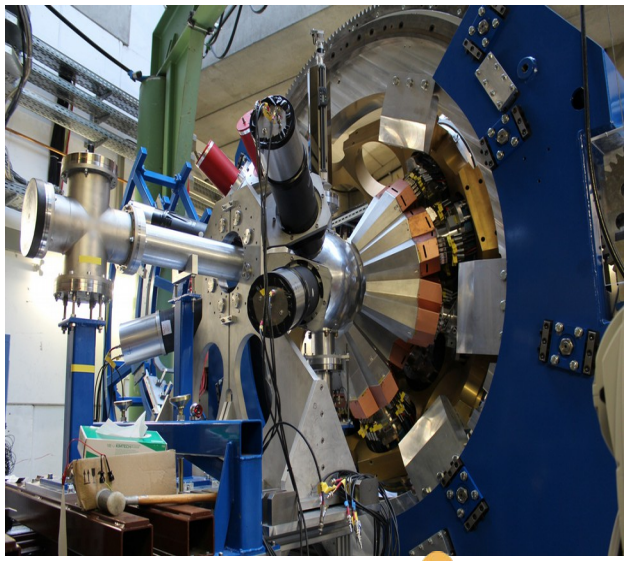
Numerical correction of neutron damages in AGATA HPGe detectors

R.Hetzenegger, L.Lewandowski, B.Birkenbach, B.Bruyneel,
P.Reiter, J.Eberth, H.Hess, R.Hirsch, A.Vogt
Institute of Nuclear Physics – University of Cologne

2nd AGATA-GRETINA
Tracking Arrays
Collaboration Meeting
Orsay

AGATA campaigns





AGATA @ INFN Legnaro 2010-2011

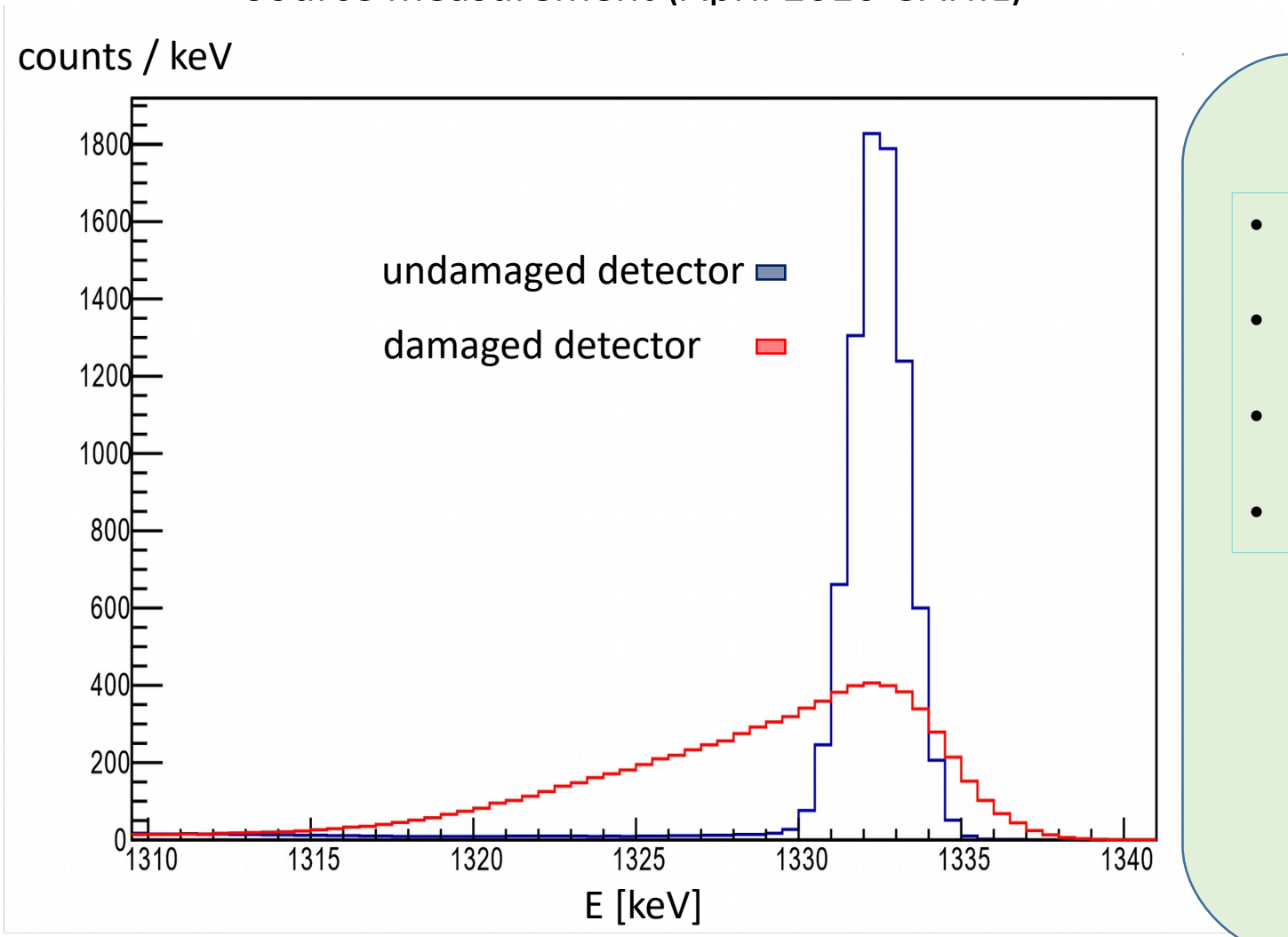
AGATA @ GSI Darmstadt 2012-2014

AGATA @ GANIL (Caen) 2014-2019+

stable beam → **RIB** → **stable beam**

60Co gamma-ray spectra

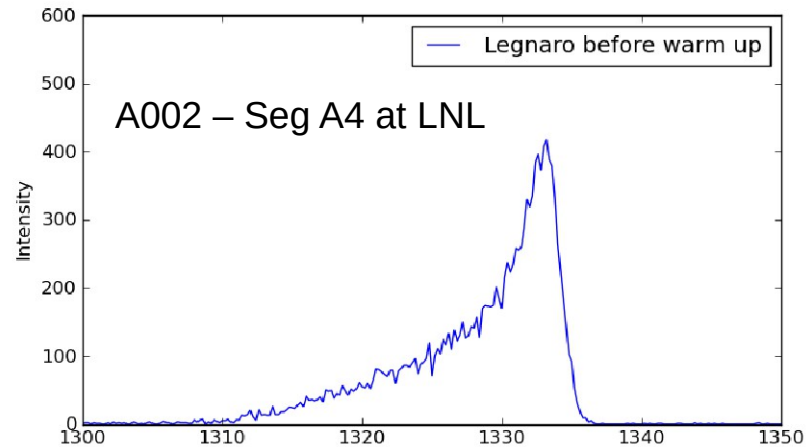
Source measurement (April 2016 GANIL)

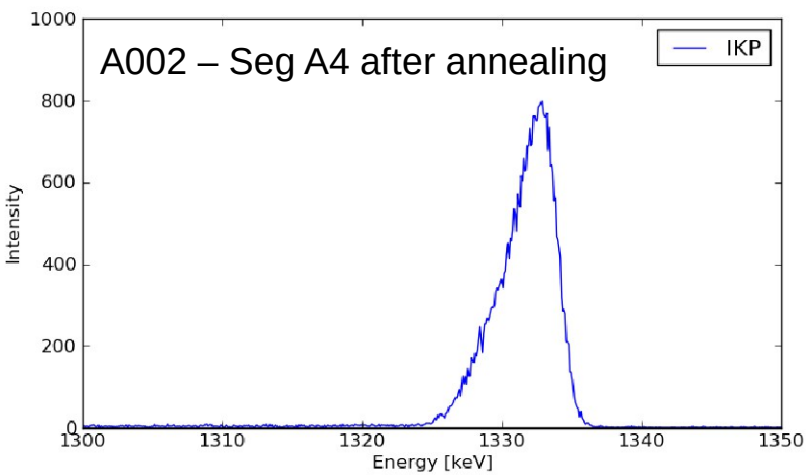


Quality criteria

- Minimum Full Width at Half Maximum (FWHM)
- Minimum Full Width at Tenth Maximum (FWTM)
- Maximum peak height
- Ratio $\frac{FWTM}{FWHM} \approx 1.82\,(Gauss)$

Annealing





- Disassembly/assembly of cryostats
- Risk of detector damage
  e.g. leakage currents after annealing
- After 120h at 102°C the original perfomance is not restored

→ Numerical correction method

Numerical description

Amount of measured charge carriers: $$q_{e,h}(t)=q_{e,h}(0)\exp[-\int_0^t(\langle\sigma v\rangle N_{e,h}dt')]$$

Collection efficiency: $$\eta^i_{e,h}=\left|\int_0^{t_{coll}}(\nabla\Phi_i(x(t))*v_{e,h})\frac{q_{e,h}(t)}{q_{e,h}(0)}dt\right|$$

Total collection efficiency: $$\eta^i_{tot}\approx 1-[\frac{tSG^i_e(x_0)}{\lambda_e}+\frac{tSG^i_h(x_0)}{\lambda_h}]$$

Position-sensitive trapping sensitivity in cm³

$$E_{corr}(\vec{x})=\frac{E_0}{1+\frac{tSG_e(\vec{x})}{\lambda_e}+\frac{tSG_h(\vec{x})}{\lambda_h}}$$

$\vec{x}\in R^3$

Inverse trapping centre density N in cm³

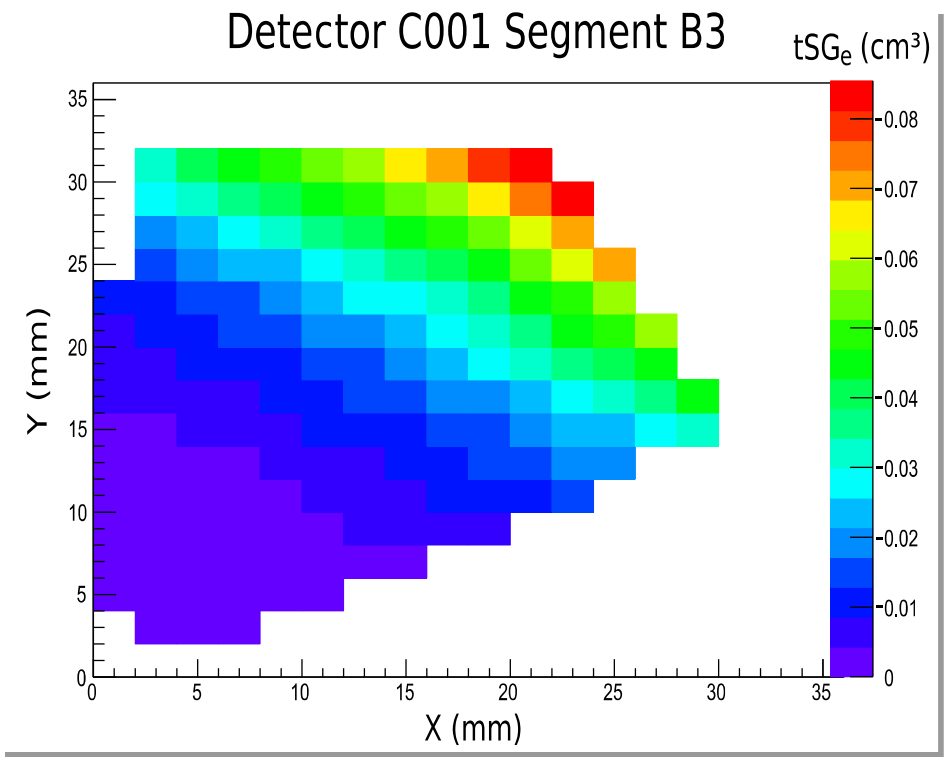
B.Bruyneel *et al.* EPJA (2013) 49:61 DOI i2013-13061-4

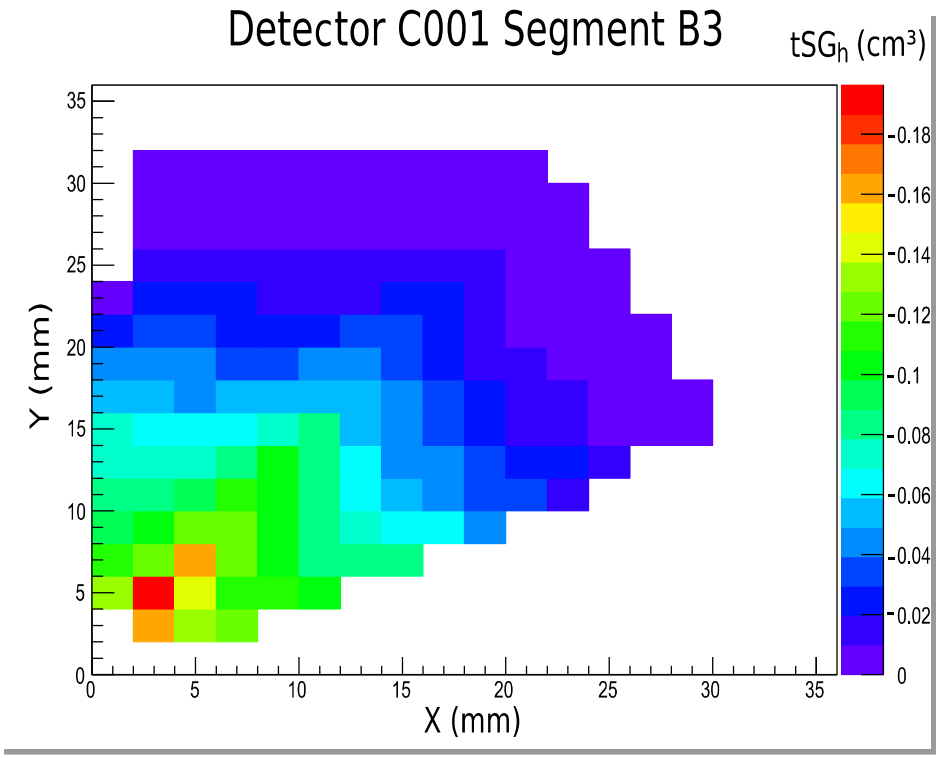
Position dependence of trapping sensitivities

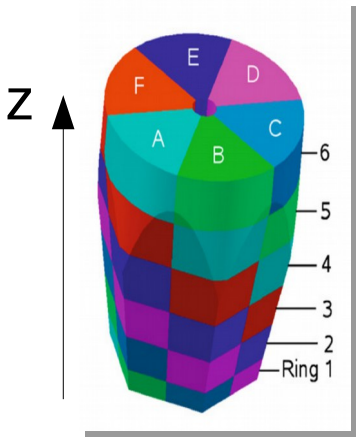
Electrons

fixed z-value

Holes

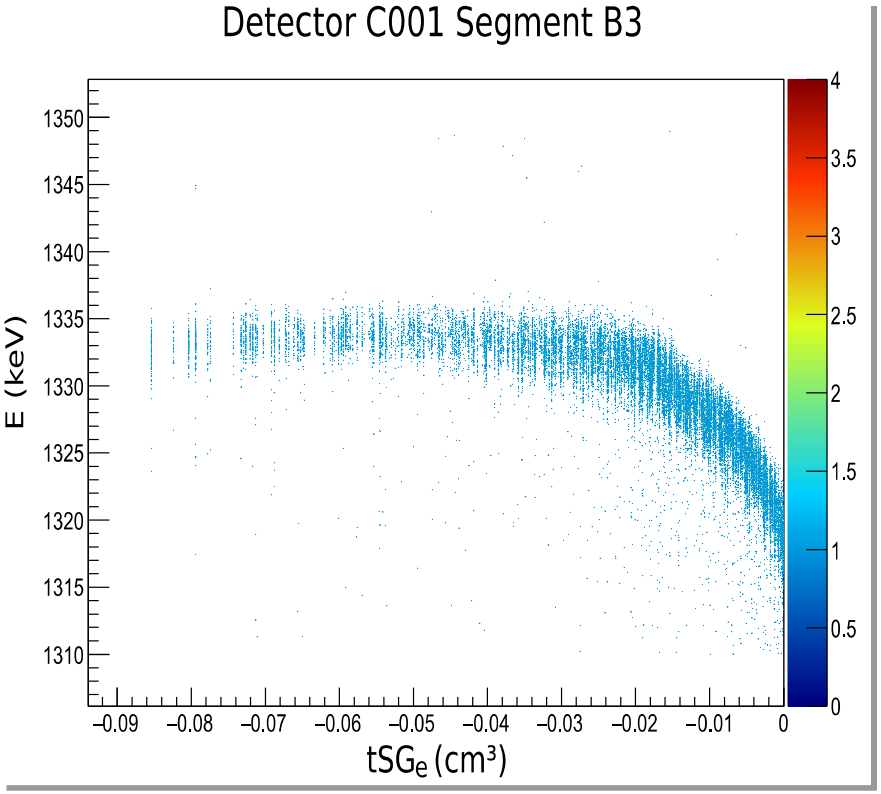


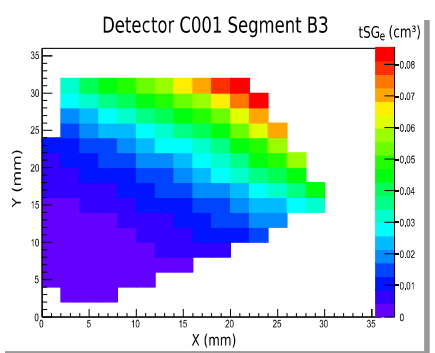




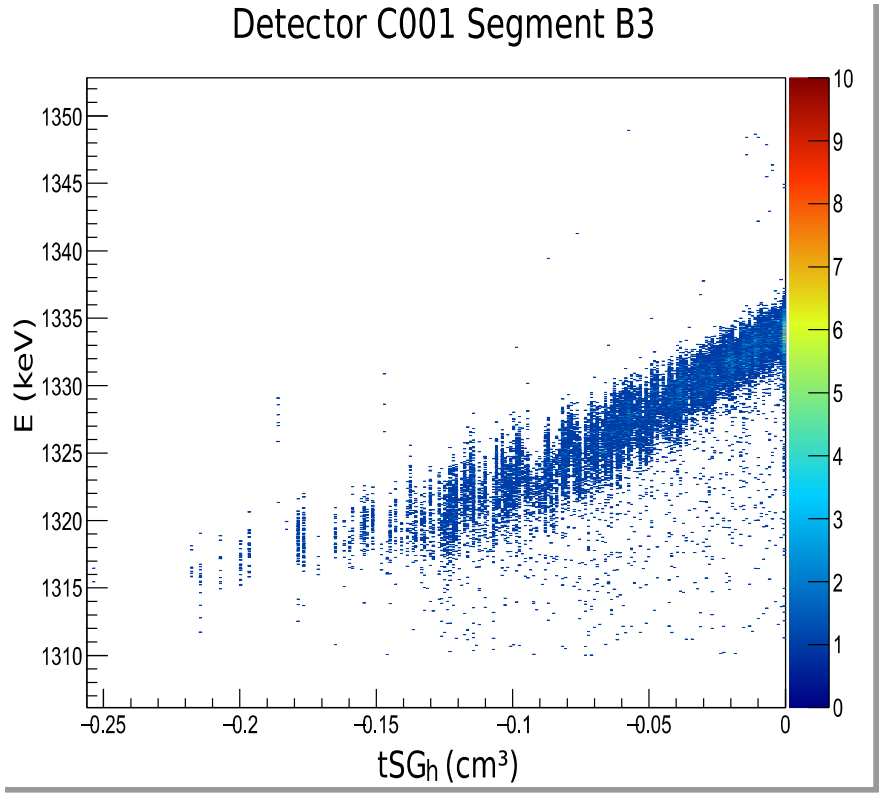
Uncorrected energy E in dependency of trapping sensitivities

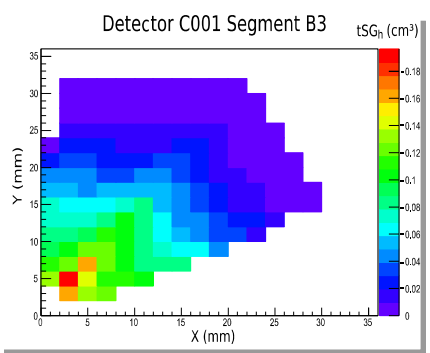
Electrons



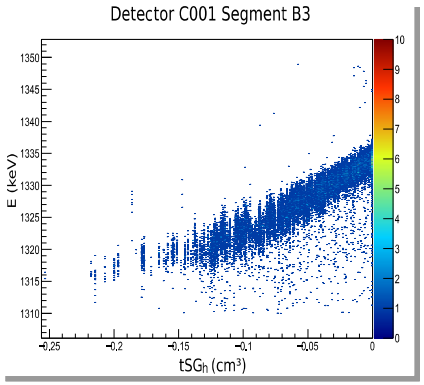


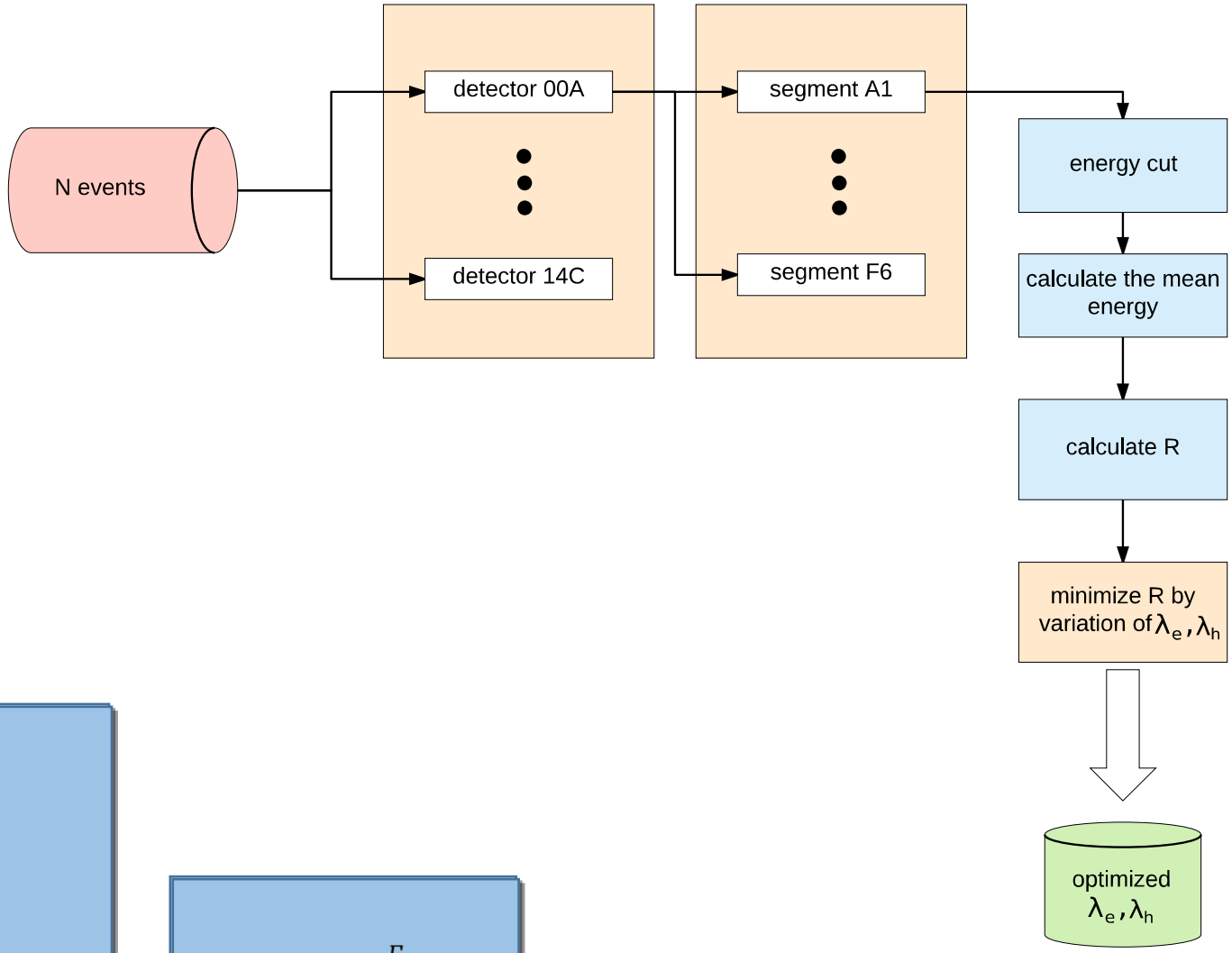
Holes





Determination of inverse trapping centre densities



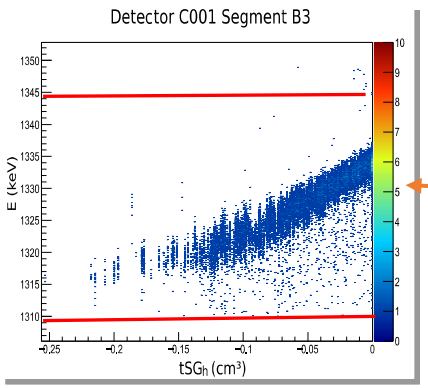


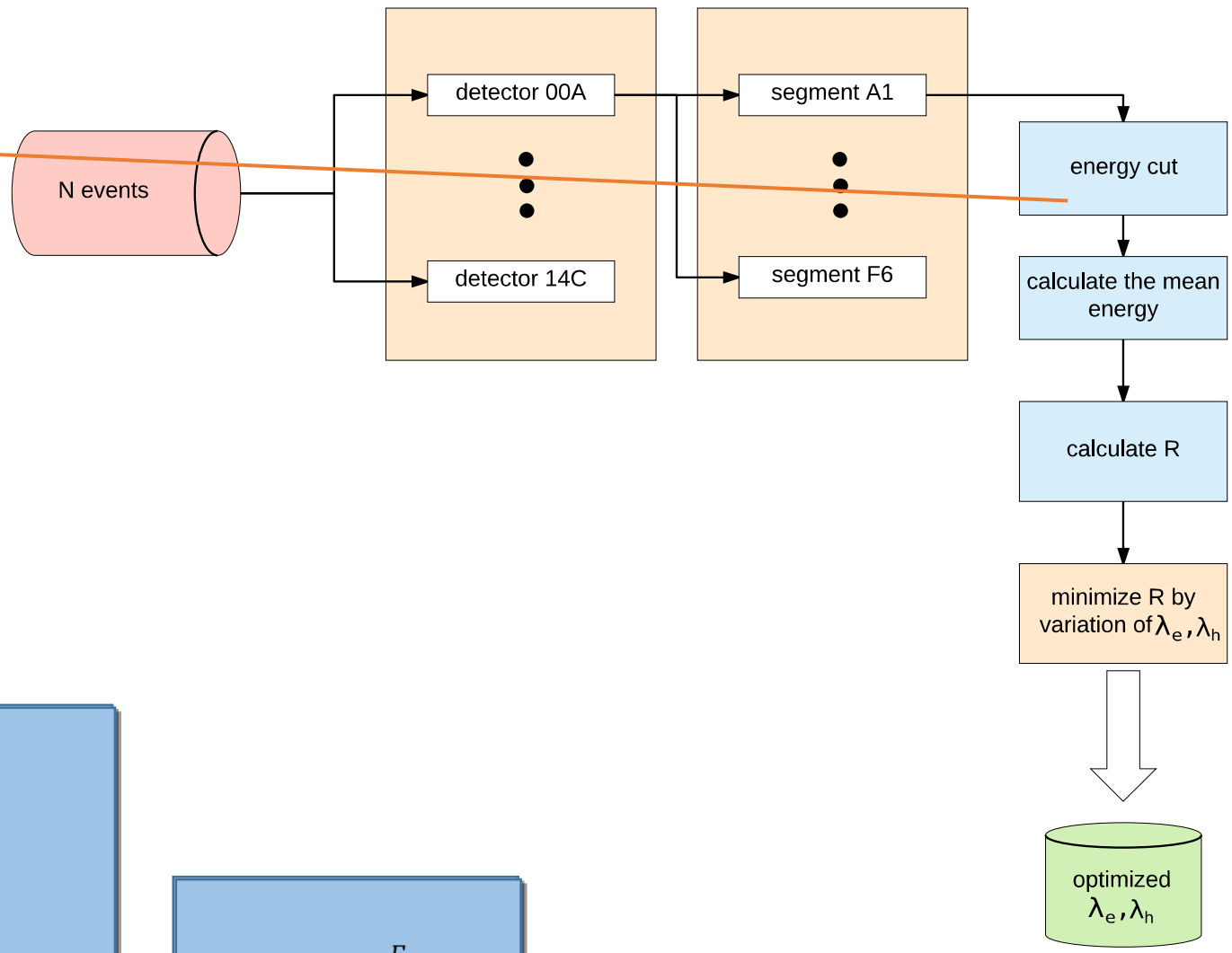
$$E_{mean} = \frac{\sum_{i=1}^{N} E_i}{N}$$

$$R = \sum_{i}^{N} \left| E_{mean} - E_{i_{korr}} \right|$$

$$E_{korr} = \frac{E_0}{1 + \frac{tSG_e}{\lambda_e} + \frac{tSG_h}{\lambda_h}}$$

Determination of inverse trapping centre densities



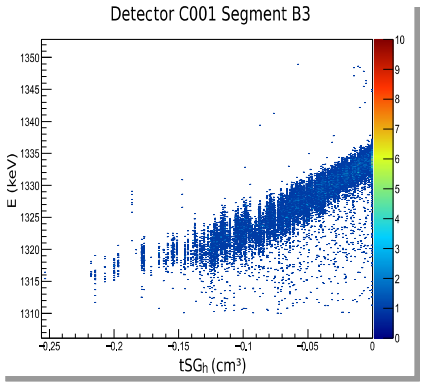


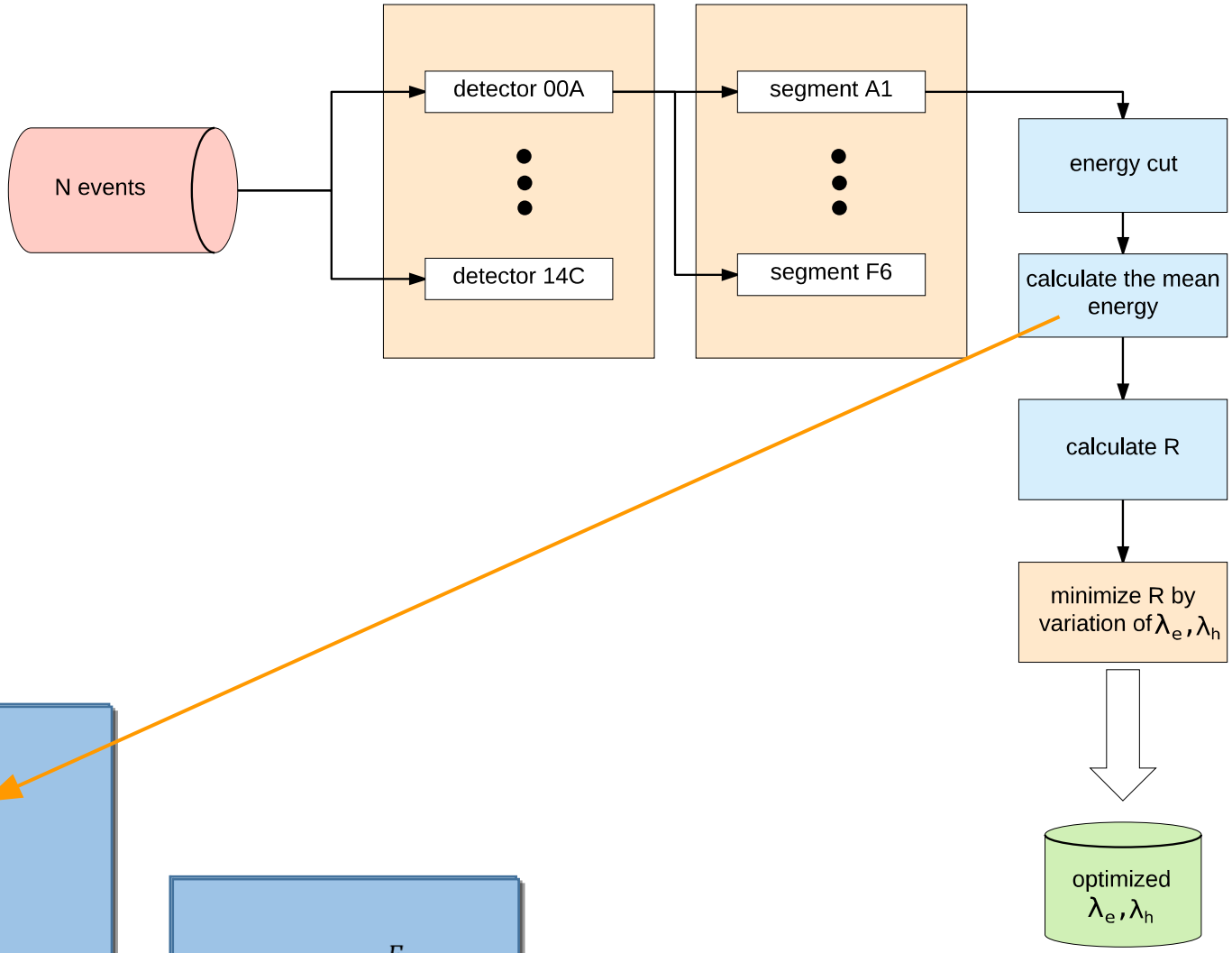
$$E_{mean} = \frac{\sum_{i=1}^{N} E_i}{N}$$

$$R = \sum_{i}^{N} \left| E_{mean} - E_{i_{korr}} \right|$$

$$E_{korr} = \frac{E_0}{1 + \frac{tSG_e}{\lambda_e} + \frac{tSG_h}{\lambda_h}}$$

Determination of inverse trapping centre densities



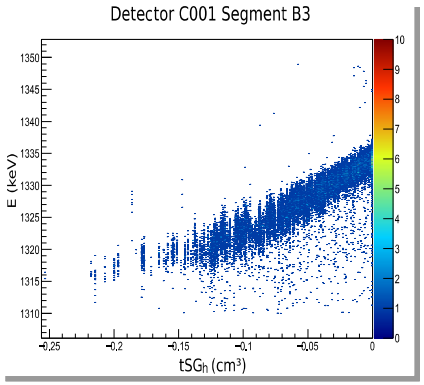


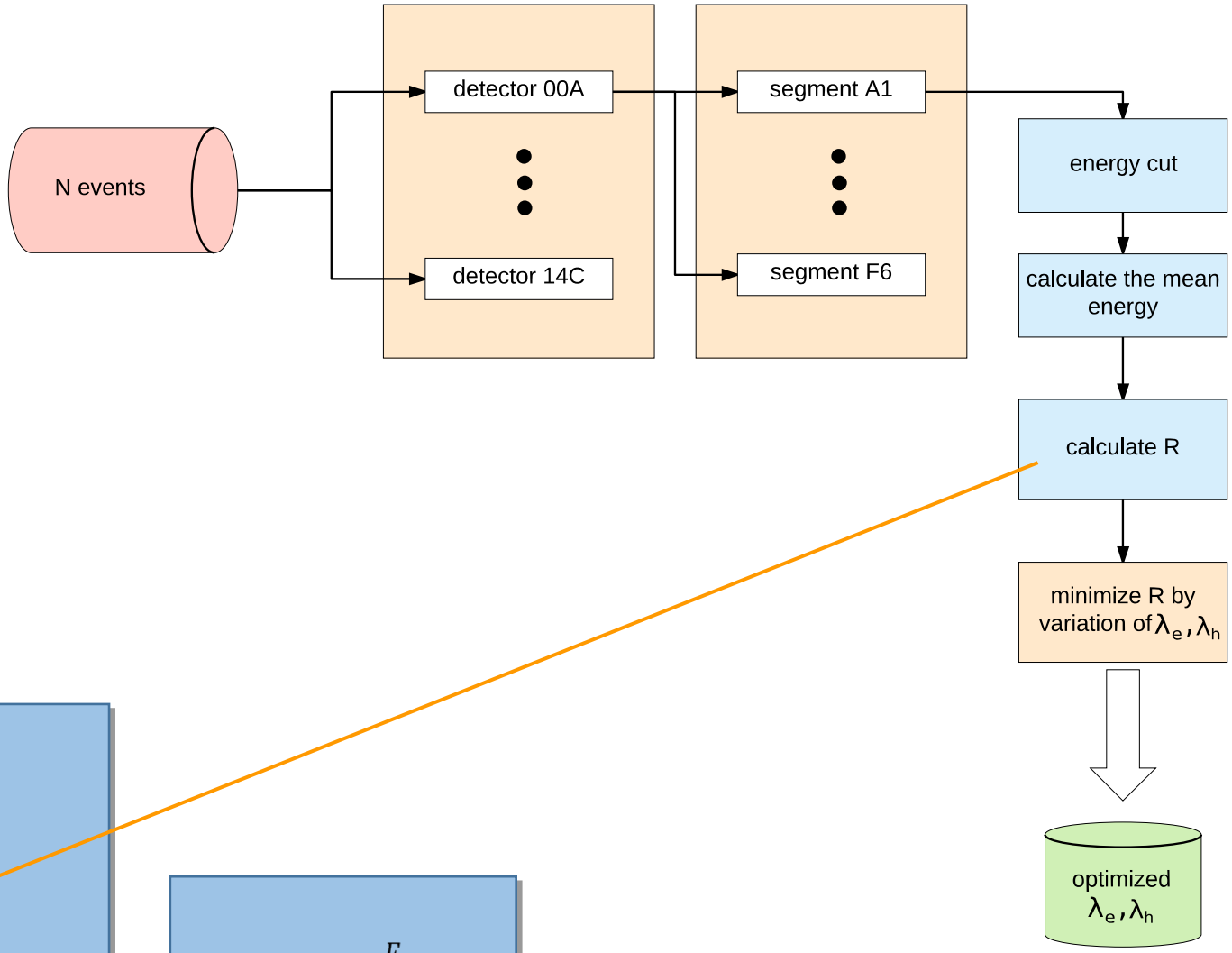
$$E_{mean} = \frac{\sum_{i=1}^{N} E_i}{N}$$

$$R = \sum_{i}^{N} \left| E_{mean} - E_{i_{korr}} \right|$$

$$E_{korr} = \frac{E_0}{1 + \frac{tSG_e}{\lambda_e} + \frac{tSG_h}{\lambda_h}}$$

Determination of inverse trapping centre densities



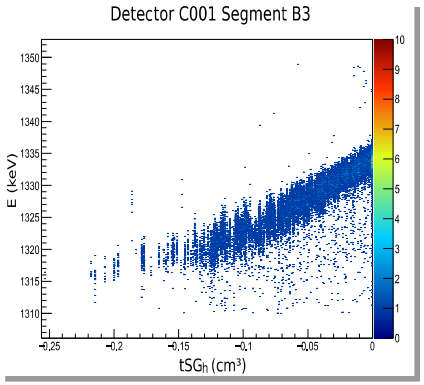


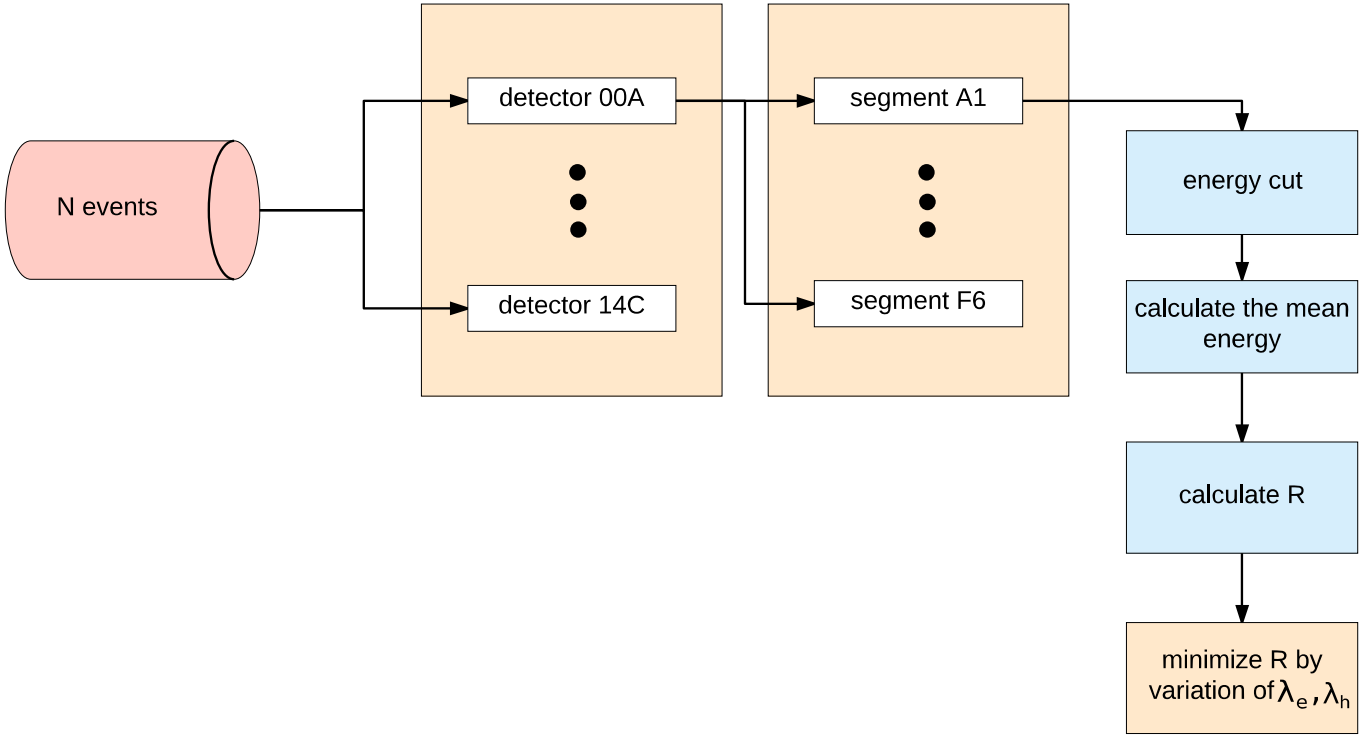
$$E_{mean} = \frac{\sum_{i=1}^{N} E_i}{N}$$

$$R = \sum_{i}^{N} \left| E_{mean} - E_{i_{korr}} \right|$$

$$E_{korr} = \frac{E_0}{1 + \frac{tSG_e}{\lambda_e} + \frac{tSG_h}{\lambda_h}}$$

Determination of inverse trapping centre densities

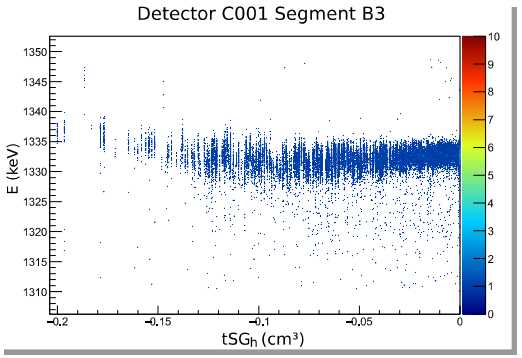




$$E_{mean} = \frac{\sum_{i=1}^{N} E_i}{N}$$

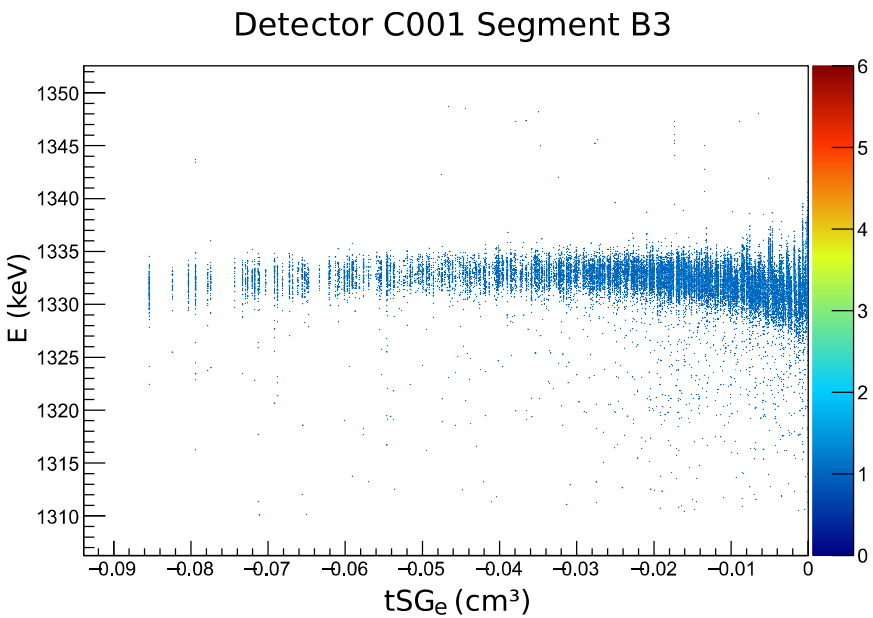
$$R = \sum_{i}^{N} \left| E_{mean} - E_{i_{korr}} \right|$$

$$E_{korr} = \frac{E_0}{1 + \frac{tSG_e}{\lambda_e} + \frac{tSG_h}{\lambda_h}}$$

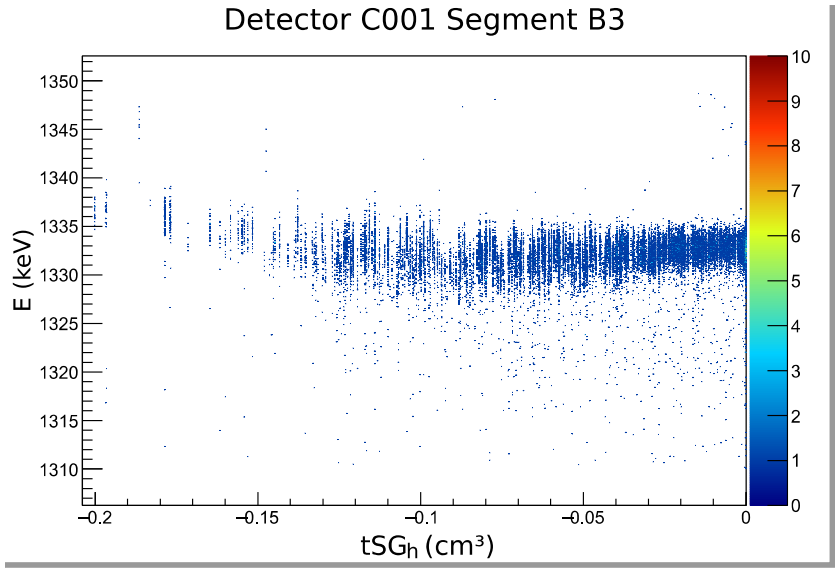


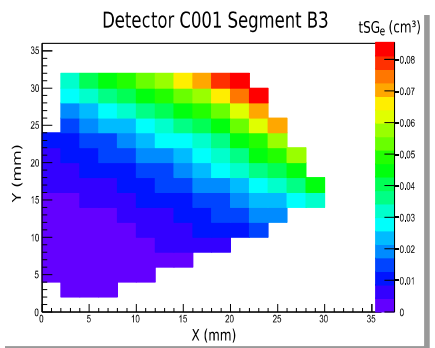
Corrected energy E in dependency of tSG_e, tSG_h

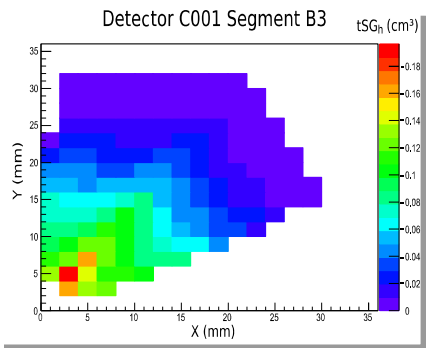
Electrons



Holes







Dataset e696 23.04.2016

- 29 crystals → 1044 segments
- 21 h measurement
- Very high statistics $7 \cdot 10^7$ events per detector
- Rawdata available → Replay with improved PSA possible

Detector A001 segment A3:

FWHM = 3.30 keV Ratio = 2.58

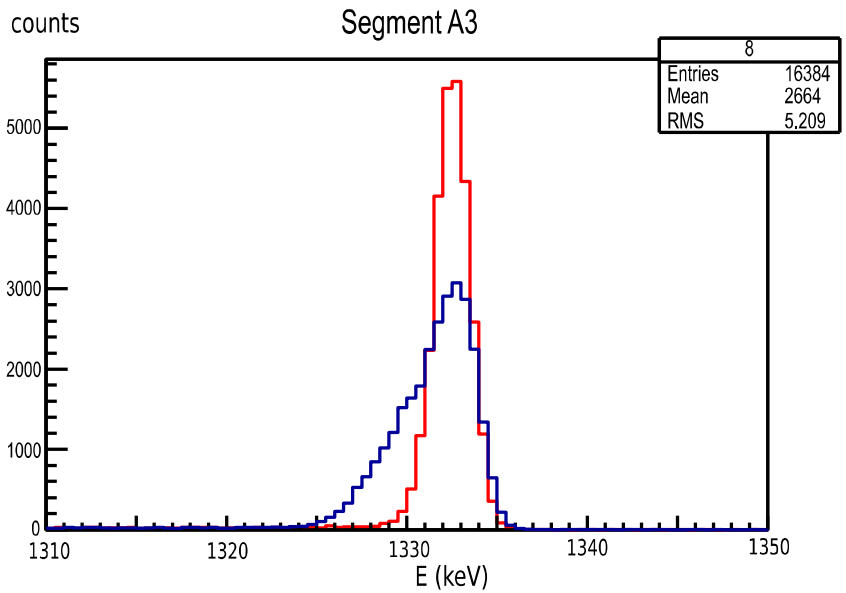
FWHM = 2.21 keV Ratio = 2.04

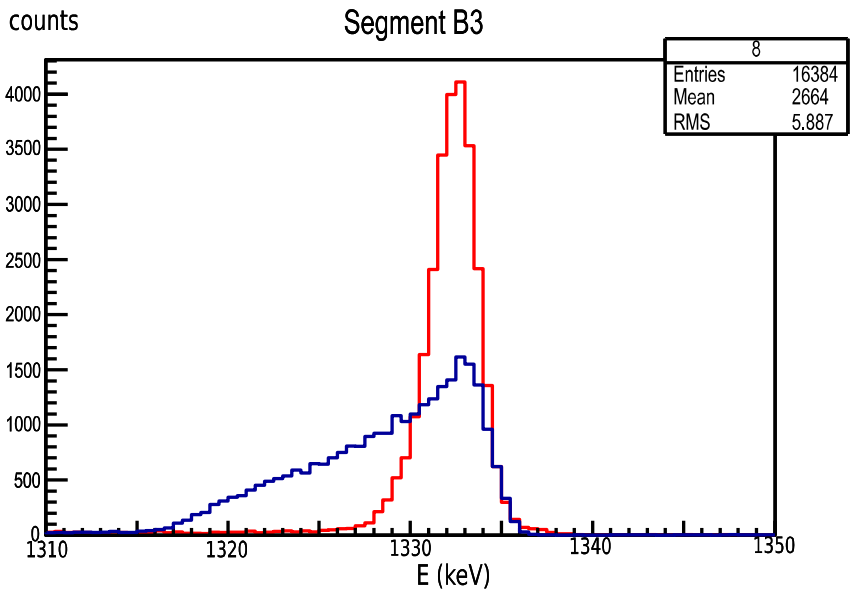
Detector C001 segment B3:

FWHM = 6.40 keV Ratio = 2.91

FWHM = 2.85 keV Ratio = 2.08

- uncorrected
- corrected

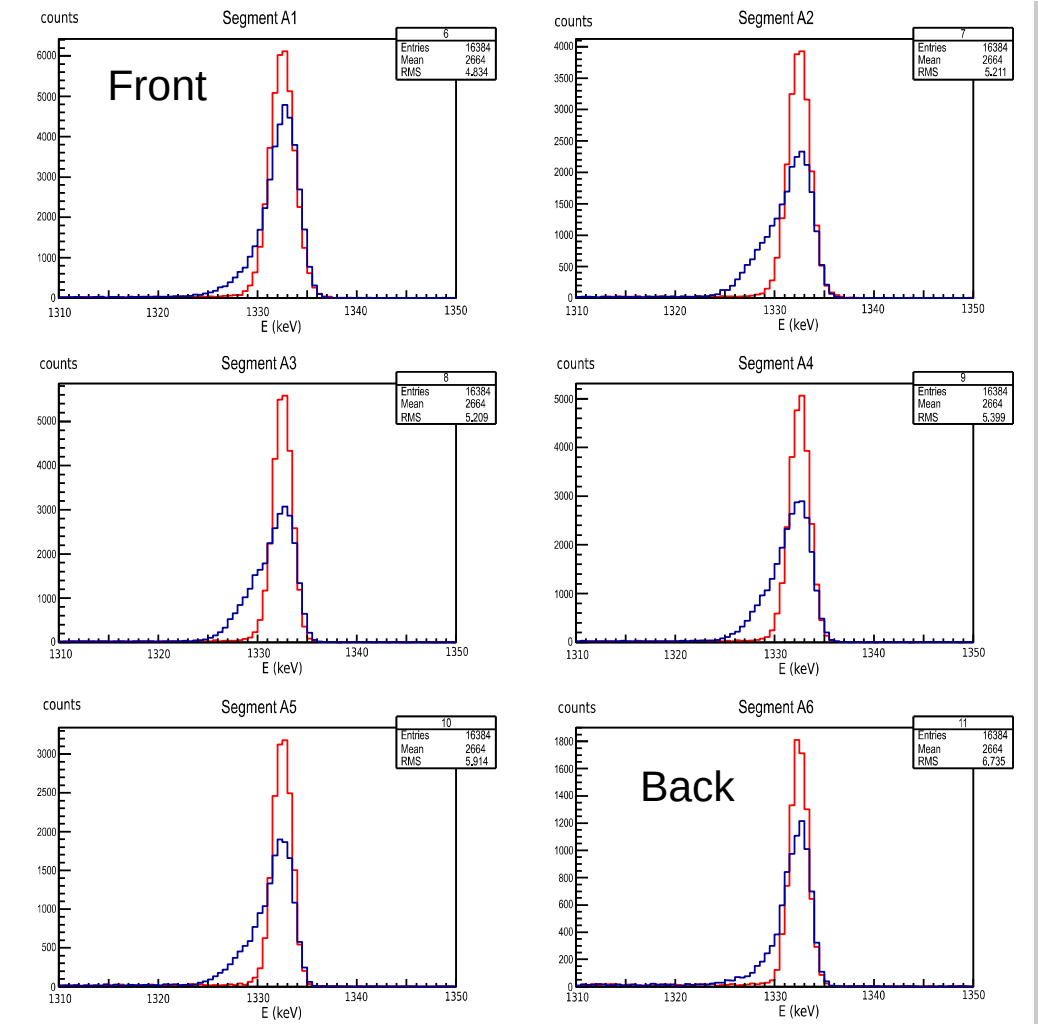




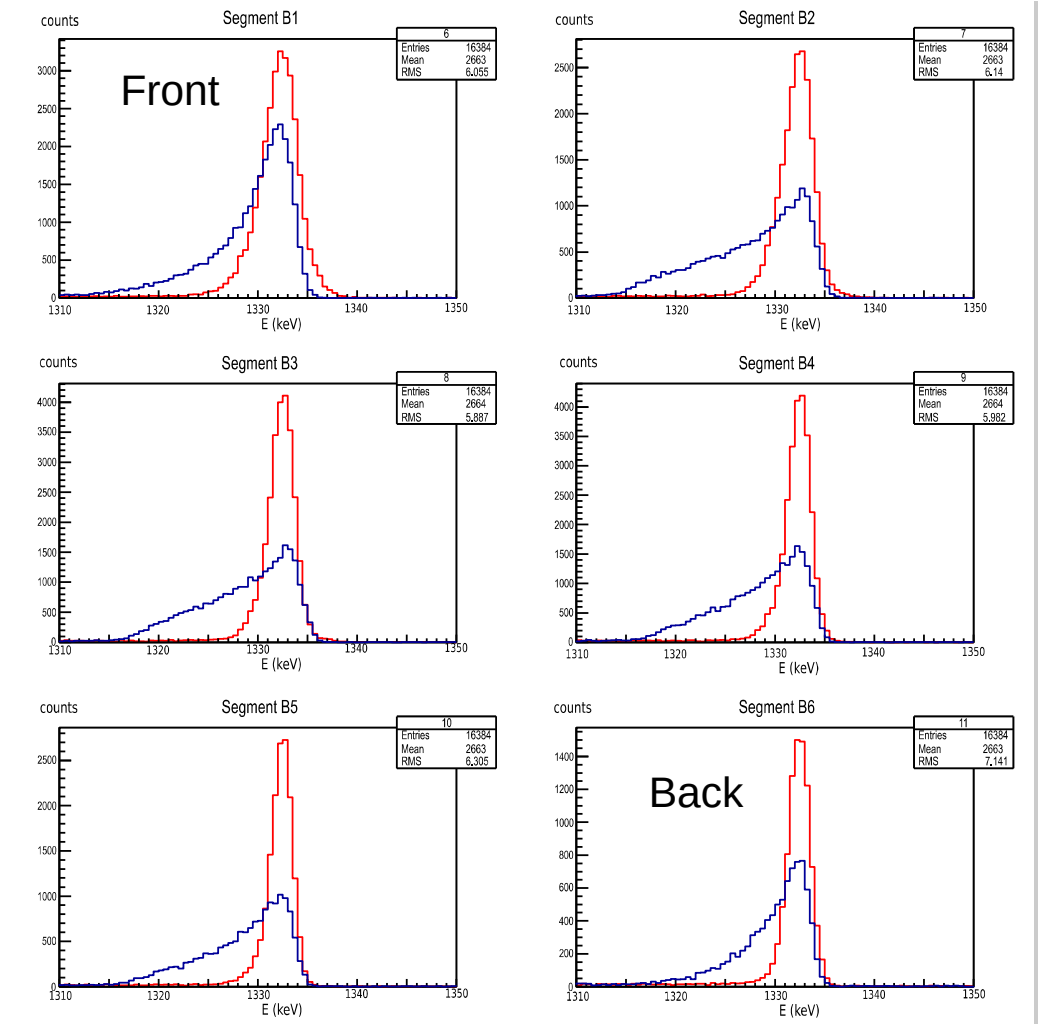
Results detectors A001 and C001

original corrected

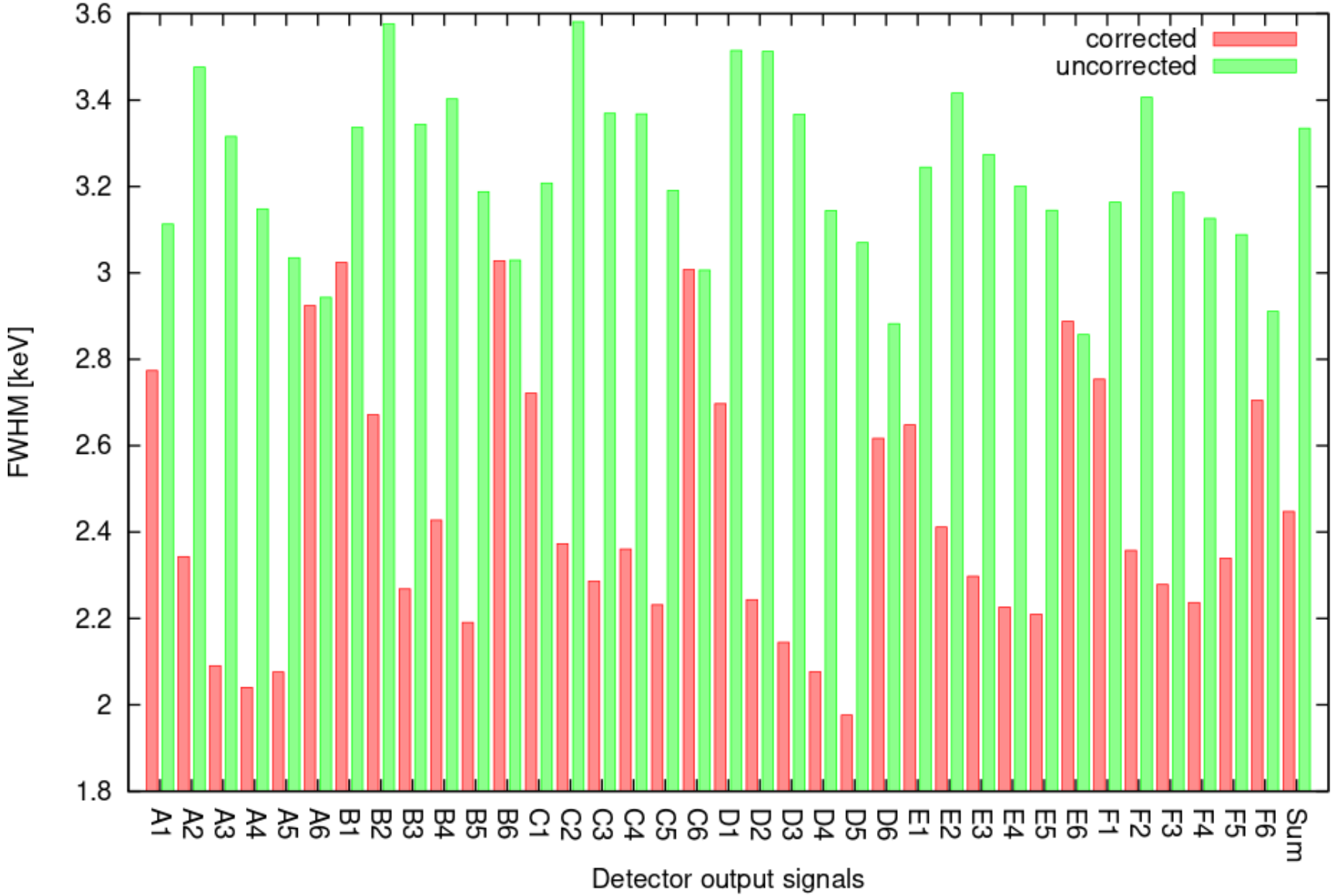
Detector A001



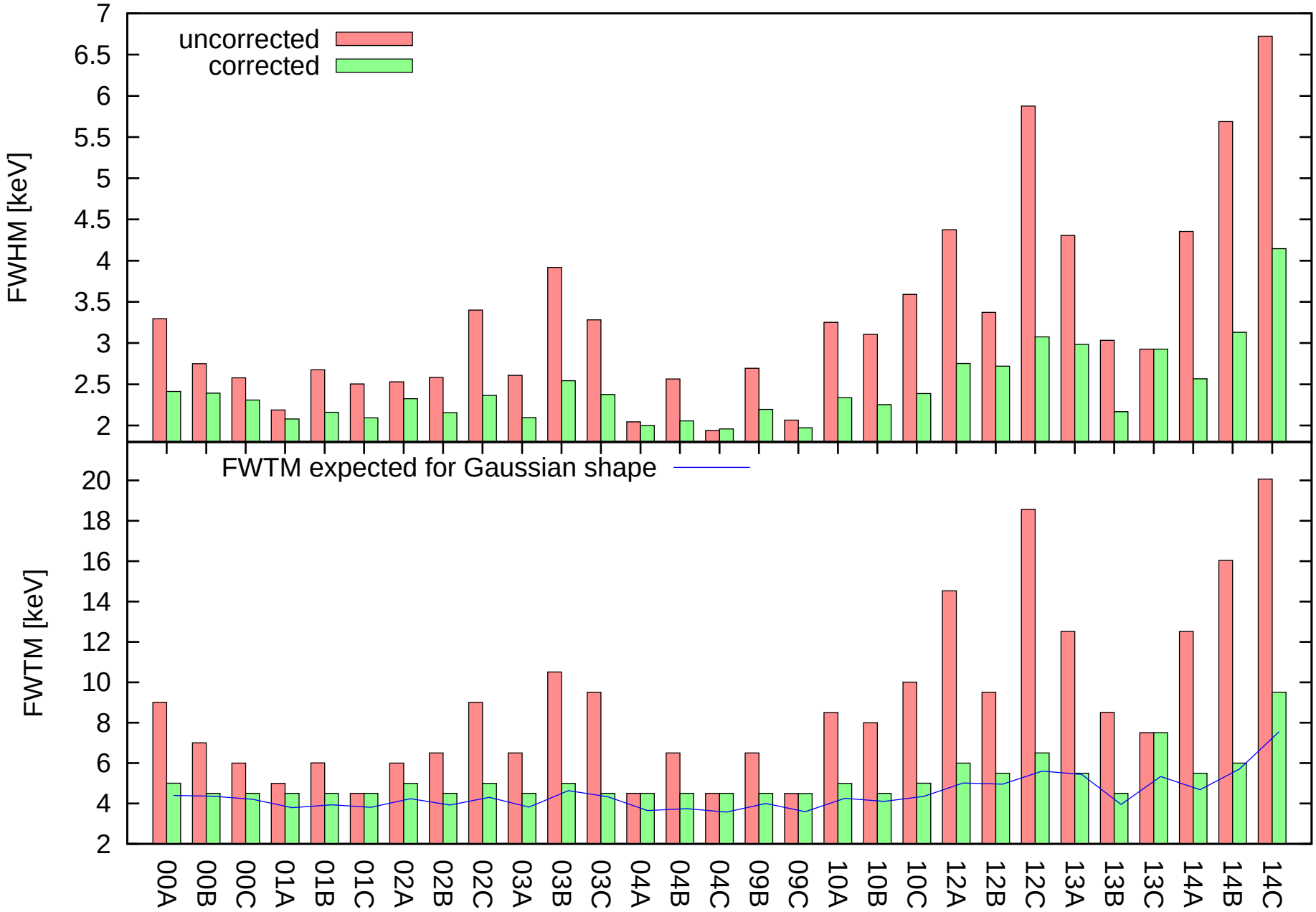
Detector C001



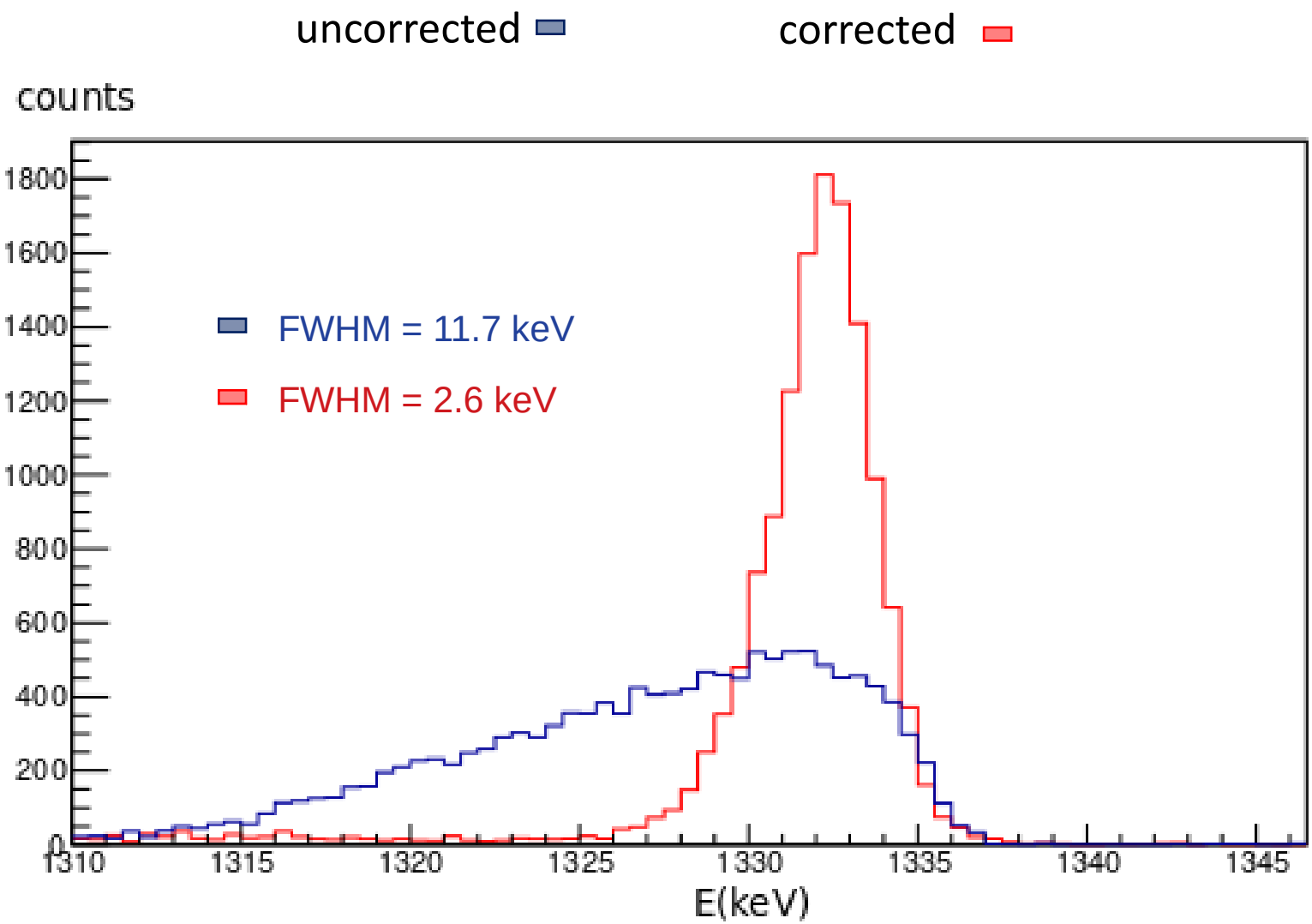
Single segments detector 00A



Segment sums of all detectors



Example: extremely damaged segment



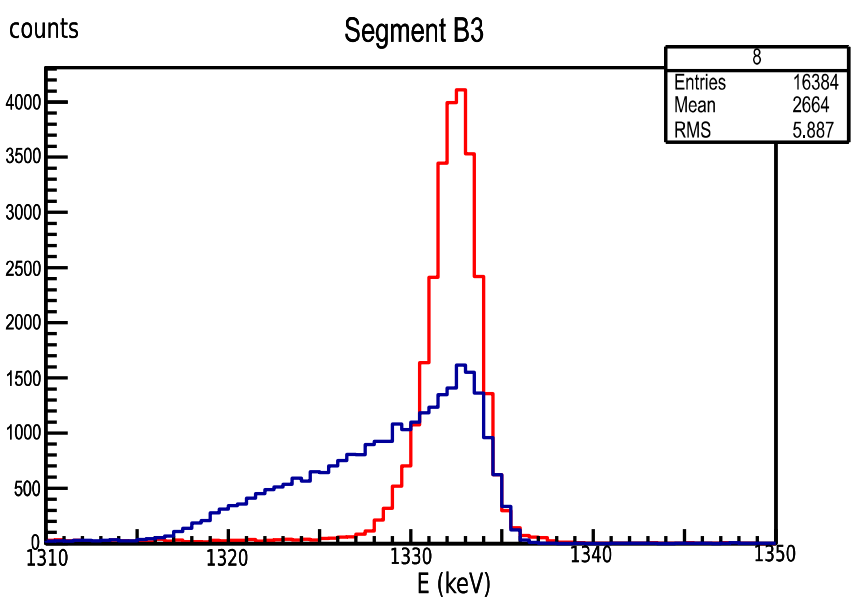
Summary and outlook

Summary:

- Numerical method for neutron damage correction
- Novel way to determine trapping centre densities
- Energy resolution and peak shape improved
- **Time between annealing procedures extended**

Software:

- ≈ 20 min for 29 detectors



Hardware:

- Complete disassembly of cryostats
- Annealing
- Possible damages
- Minimum one month

Thank you for your attention!

Universität zu Köln

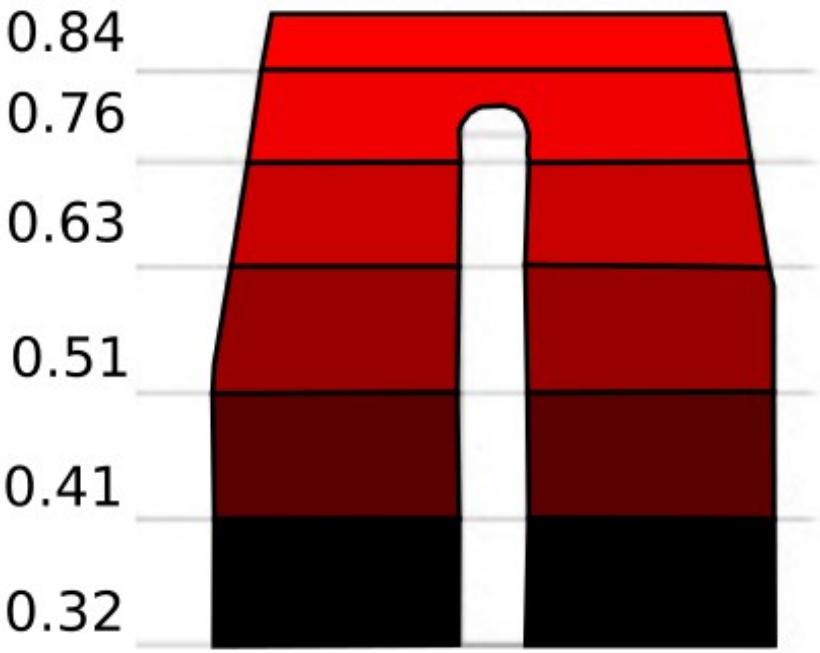
Bundesministerium für Bildung und Forschung

AGATA ADVANCED GAMMA TRACKING ARRAY

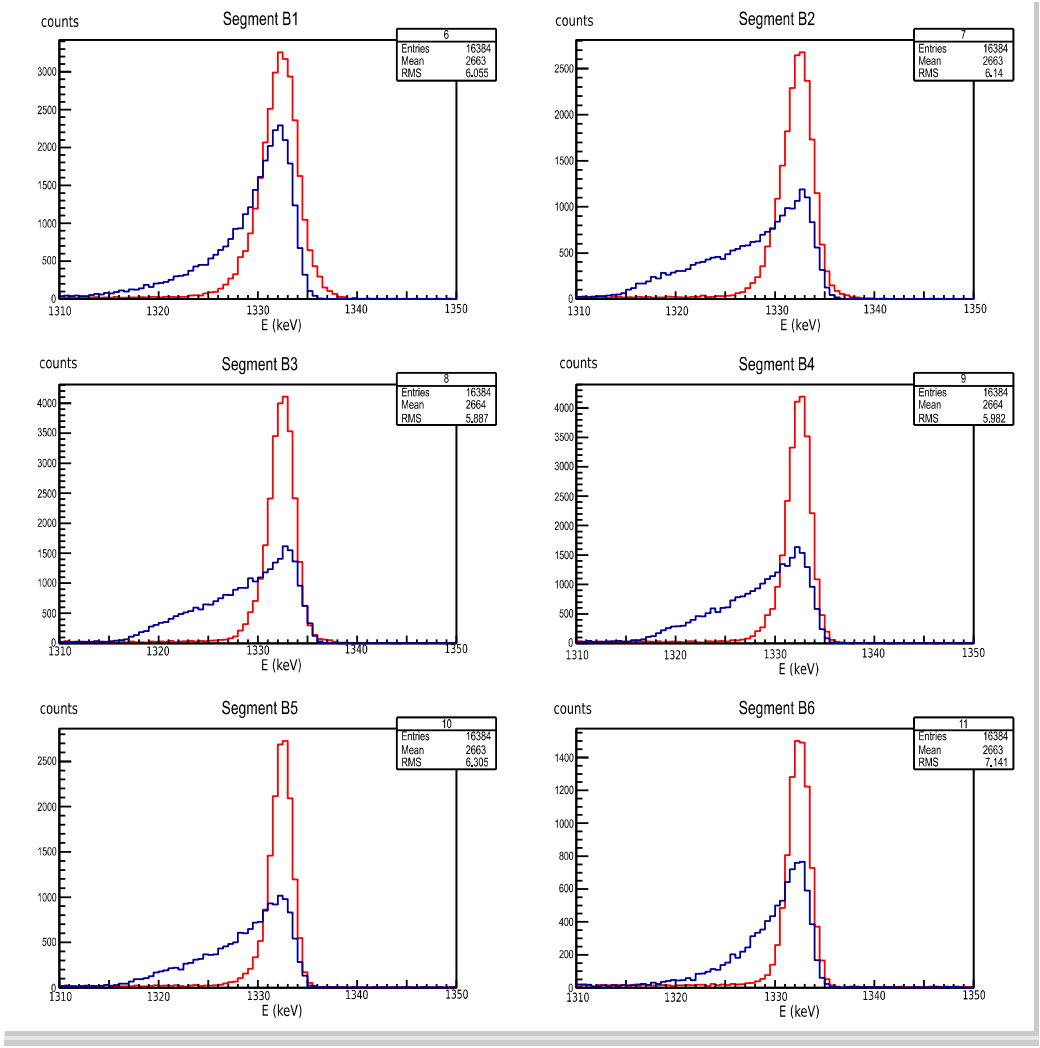
Results detectors A001 and C001

original corrected

Trapping centre densities in $10^{-2}cm^{-3}$



Detector C001



Average improvement of all detectors

AGATA ^{60}Co source runs at GANIL

23. April 2016
e696

26. May 2017
e705

6. June 2017
e673

Run	Events / detector	FWHM improvement
e696 April 2016	$1.3 \cdot 10^8$	26.2%
e705 May 2017	$1.9 \cdot 10^6$	27.2%
e673 June 2017	$1.7 \cdot 10^7$	29.8%