



Crosstalk Analysis of ATC2 and impurity measurements

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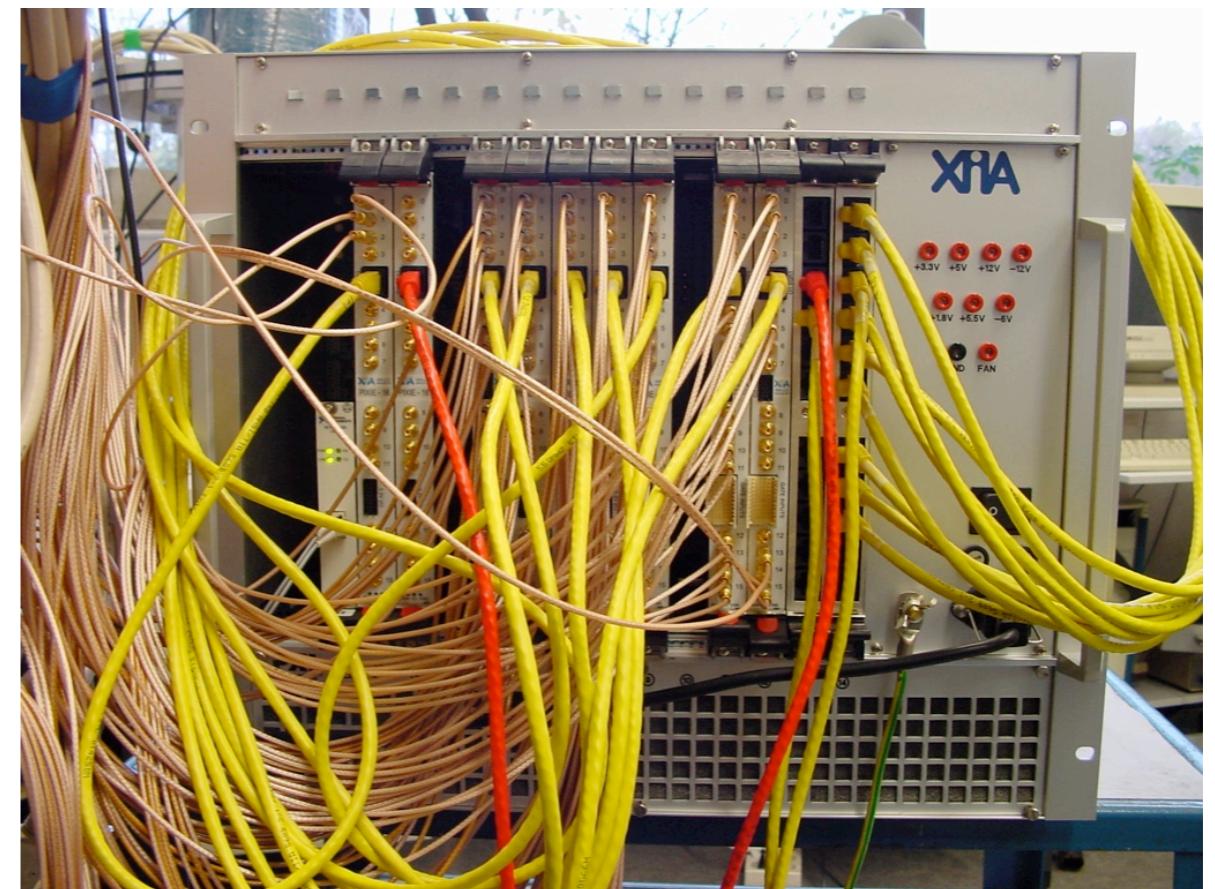
- Crosstalk correction is needed for AGATA
 - Crosstalk is present in any segmented detector*
 - Creates energy shifts proportional to fold*
 - Can be corrected*
 - No crosstalk between detectors in ATC1**
 - Is there crosstalk between detectors in ATC2?

* Crosstalk properties of 36-fold segmented hexagonal HPGe detectors; B. Bruyneel, et al.; Nuclear Instrument and Methods in Physics A; 2009

** Technical design report on AGATA detectors: detectors, crystals and cryostat performance

ATC2 measurements with XIA's Pixie16 modules

- ^{60}Co and ^{137}Cs
- 105 of 111 Channels
- 7 Pixie16 Modules
- 100 MHz, 12 bit
- 500GB Listmode



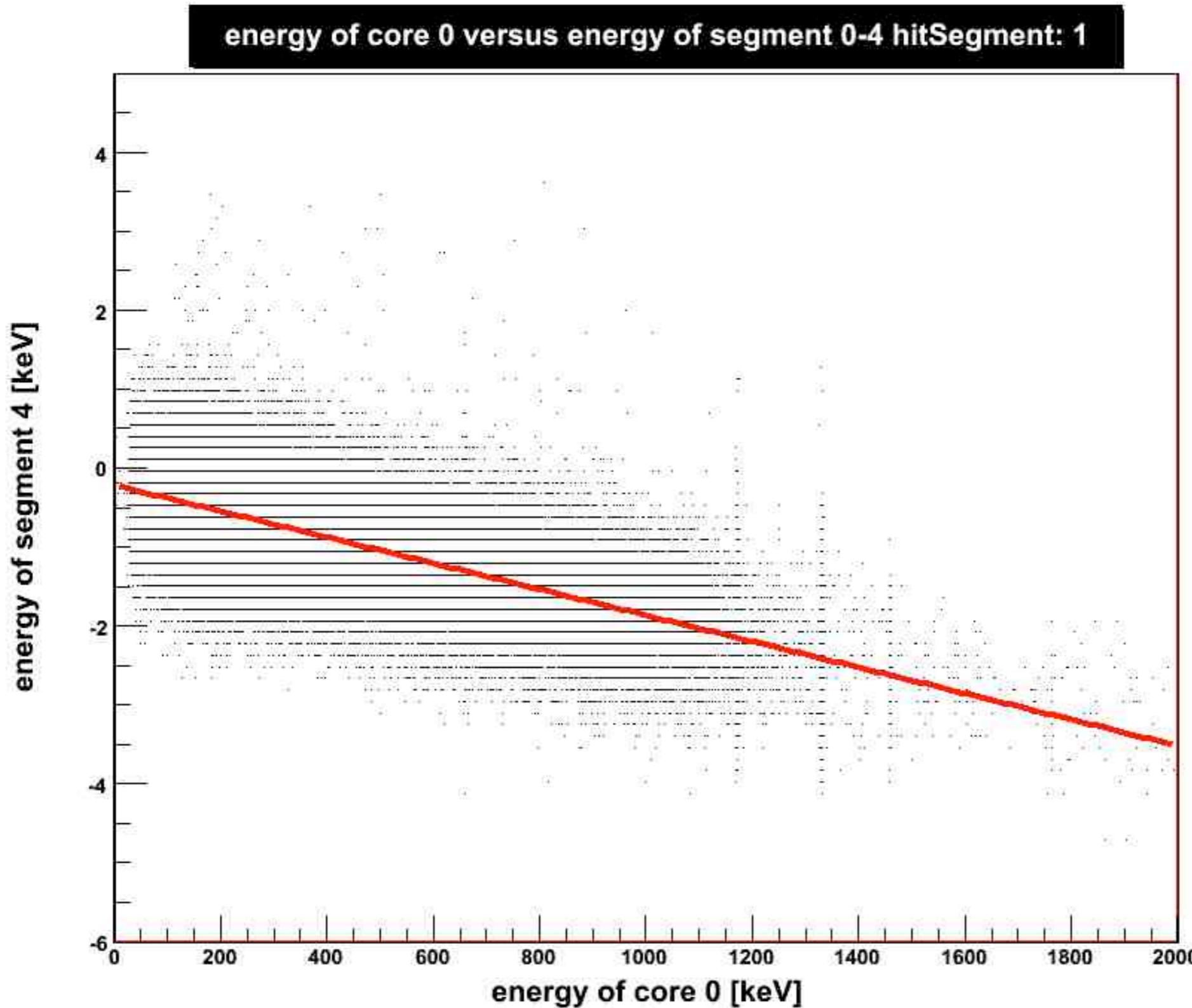
^{60}Co	ΔE [keV] with XIA	ΔE [keV] with analog
Red Core (A, 0)	Not final version of ATC2 2.37	2.35
Green Core (B, 1)	2.31	2.26
Blue Core (C, 2)	2.45	2.45

Without Crosstalk

$$\begin{pmatrix} E_{\text{core}} \\ E_{\text{seg}_1} \\ E_{\text{seg}_2} \\ \vdots \\ E_{\text{seg}_n} \end{pmatrix}_{\text{meas}} = \begin{pmatrix} 1 & 1 & \dots & 1 \\ 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & 1 \end{pmatrix} \cdot \begin{pmatrix} E_{\text{seg}_1} \\ E_{\text{seg}_2} \\ \vdots \\ E_{\text{seg}_n} \end{pmatrix}_{\text{true}}$$

With Crosstalk

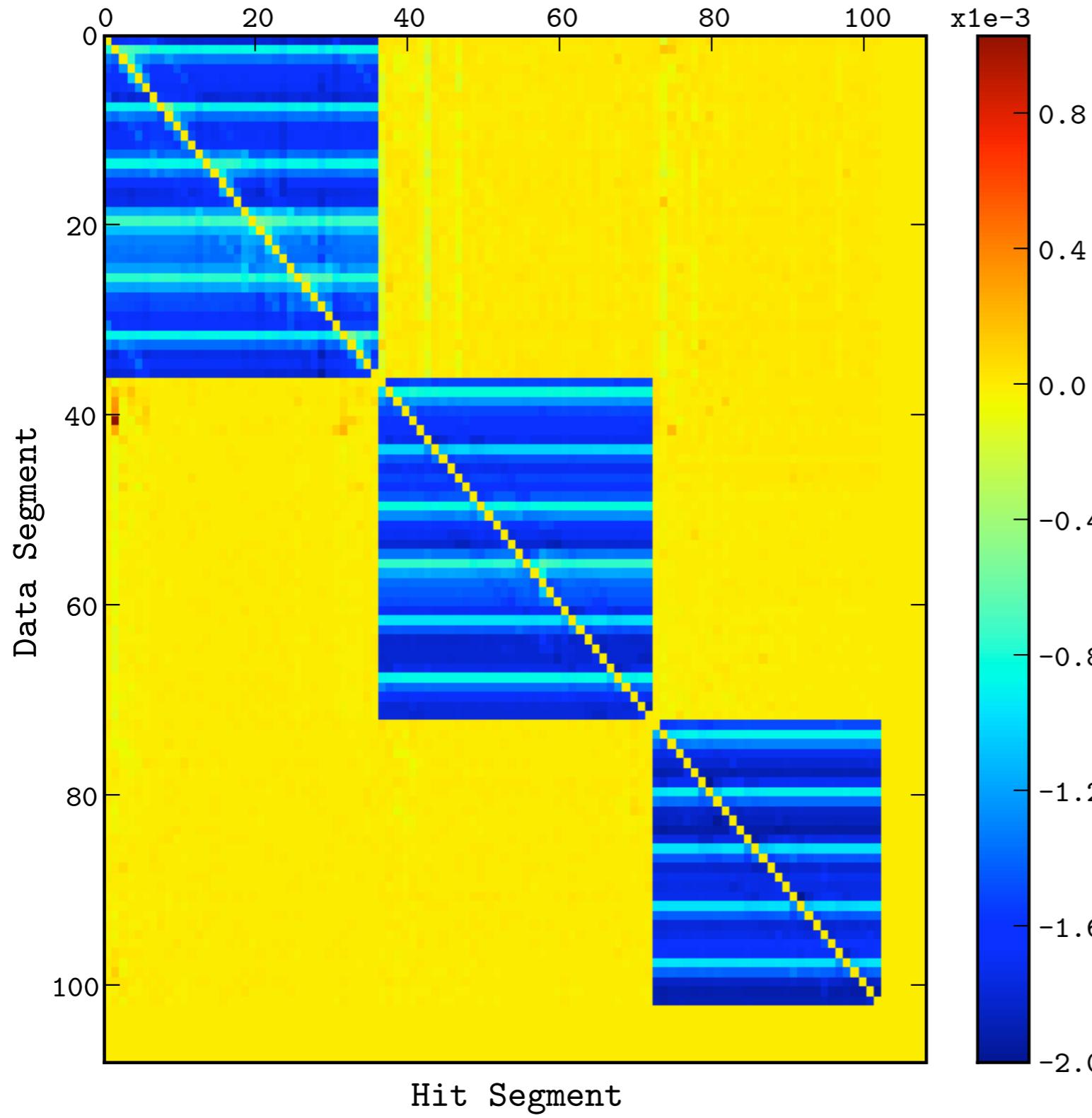
$$\begin{pmatrix} E_{\text{core}} \\ E_{\text{seg}_1} \\ E_{\text{seg}_2} \\ \vdots \\ E_{\text{seg}_n} \end{pmatrix}_{\text{meas}} = \begin{pmatrix} 1 + \delta_{01} & 1 + \delta_{02} & \dots & 1 + \delta_{0n} \\ 1 & \delta_{12} & \dots & \delta_{1n} \\ \delta_{21} & 1 & \dots & \delta_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \delta_{n1} & \delta_{n2} & \dots & 1 \end{pmatrix} \cdot \begin{pmatrix} E_{\text{seg}_1} \\ E_{\text{seg}_2} \\ \vdots \\ E_{\text{seg}_n} \end{pmatrix}_{\text{true}}$$



Sort one fold events
Estimate slope parameter for all combinations ($\sim 11\,000$)



Matrix Elements



$$\begin{pmatrix} 1 + \delta_{01} & 1 + \delta_{02} & \dots & 1 + \delta_{0n} \\ 1 & \delta_{12} & \dots & \delta_{1n} \\ \delta_{21} & 1 & \dots & \delta_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \delta_{n1} & \delta_{n2} & \dots & 1 \end{pmatrix}$$

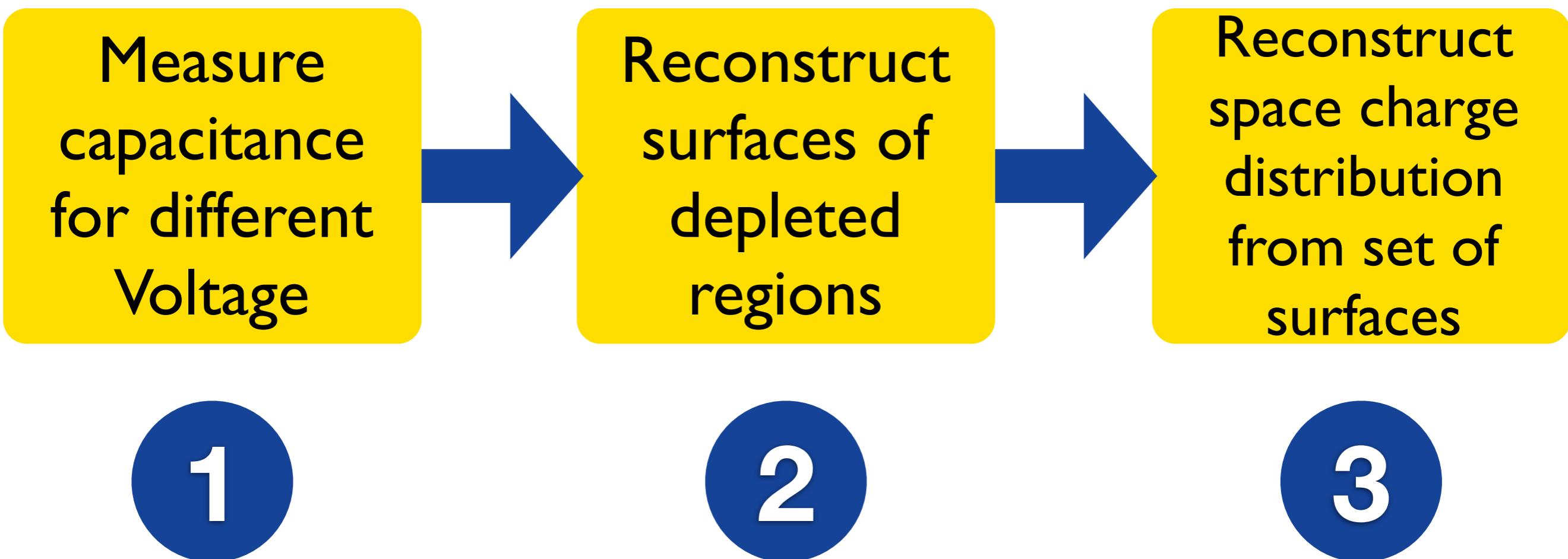


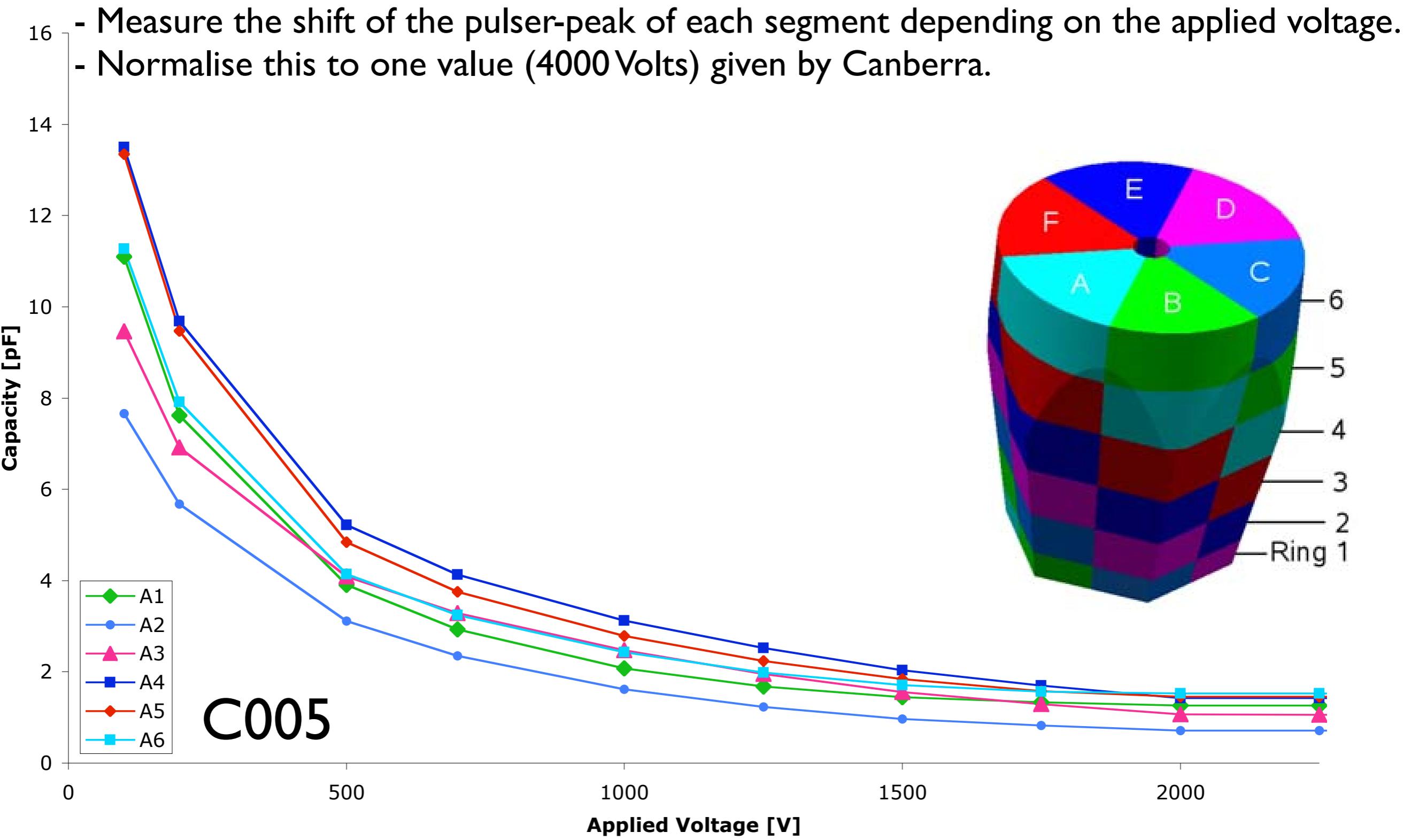
- Why measure the impurity concentration?
 - Detector Simulations need input:
 - ✓ Lattice orientation (fixed by Canberra)
 - ✓ Mobility parameters (expected as constant)
 - Crosstalk parameters
 - ✓ proportional
 - ? derivative
 - ? Space charge distribution
 - ! Best is a fast direct measurement independent of other crystal properties

Capacitance Voltage (CV) Measurements*

*First proposed in 1942 (W. Schottky; 1942; Z. Phys.; 118:539)

Principle work flow of a 3d CV-Analysis



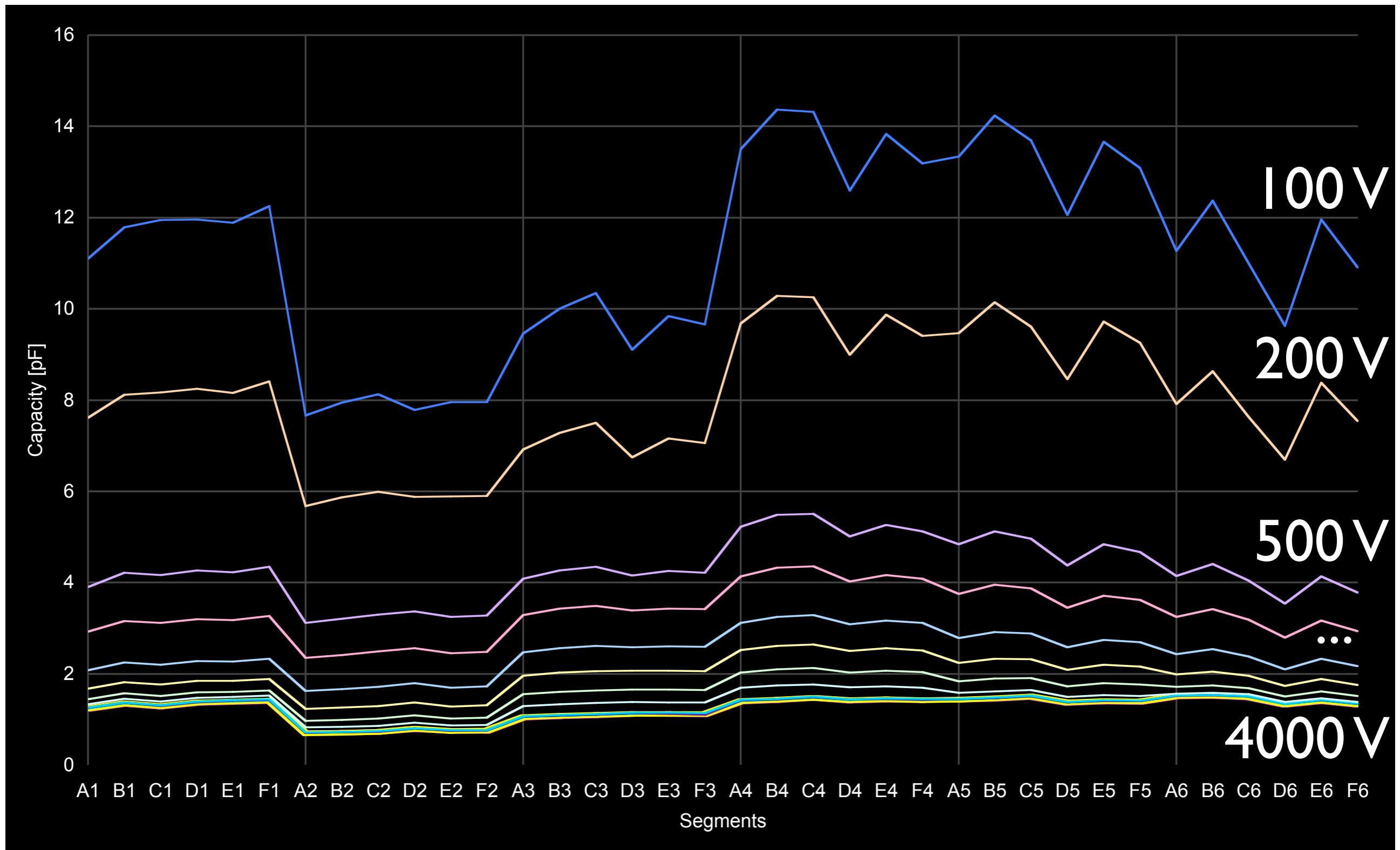




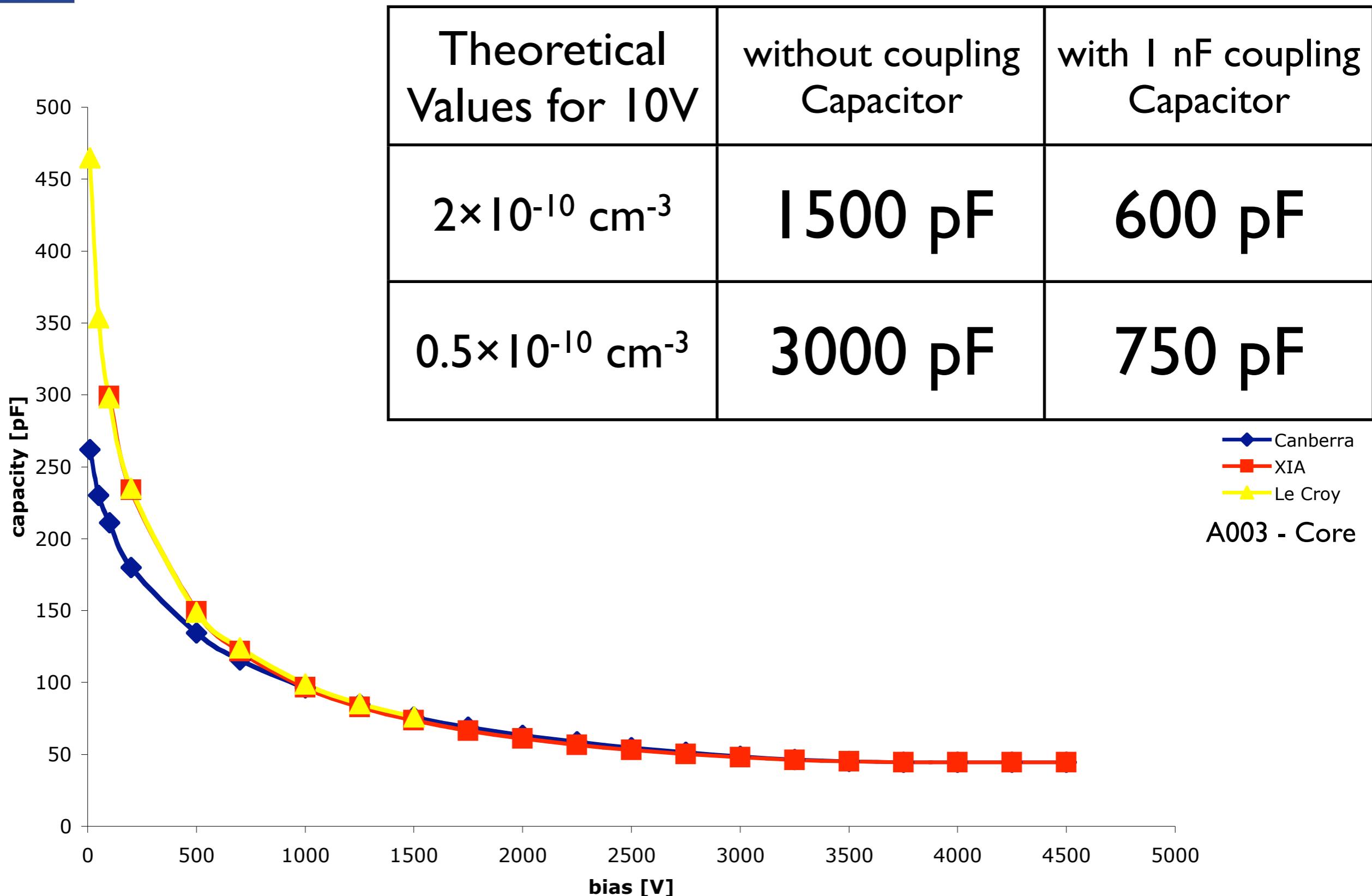
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8th AGATA week

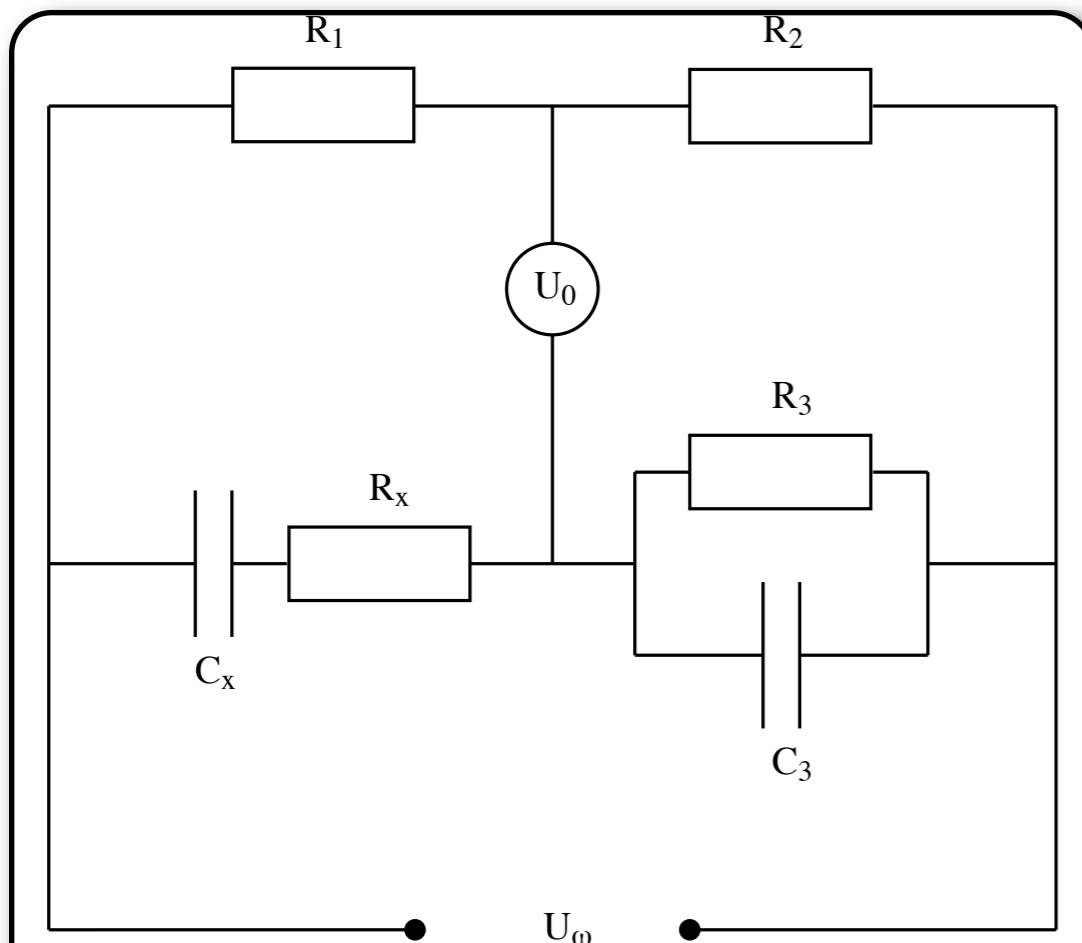
Measure the capacity for different Voltages



Differences between data from Canberra and measured data

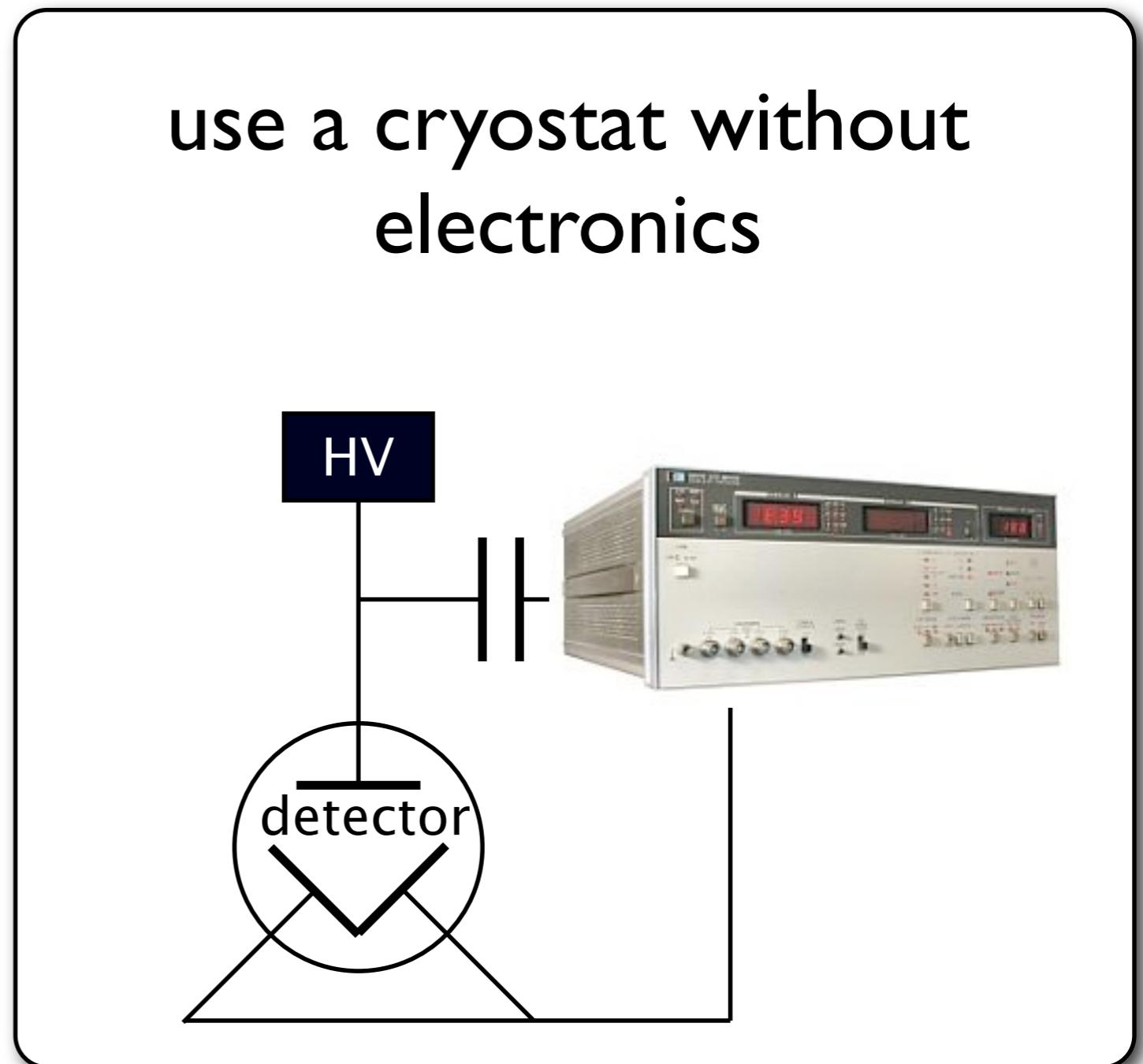


Use a Wien-bridge to measure capacities and resistivity



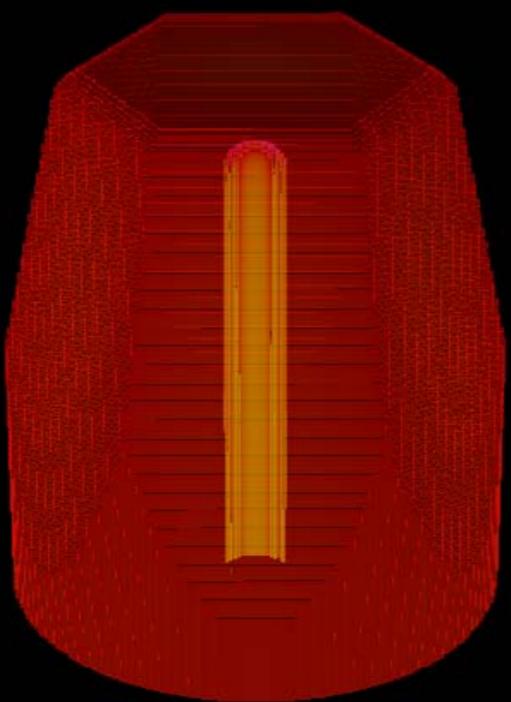
$$\frac{R_1}{R_2} = \left(R_x + \frac{1}{i\omega C_x} \right) \left(\frac{1}{R_3} + i\omega C_3 \right)$$

use a cryostat without
electronics

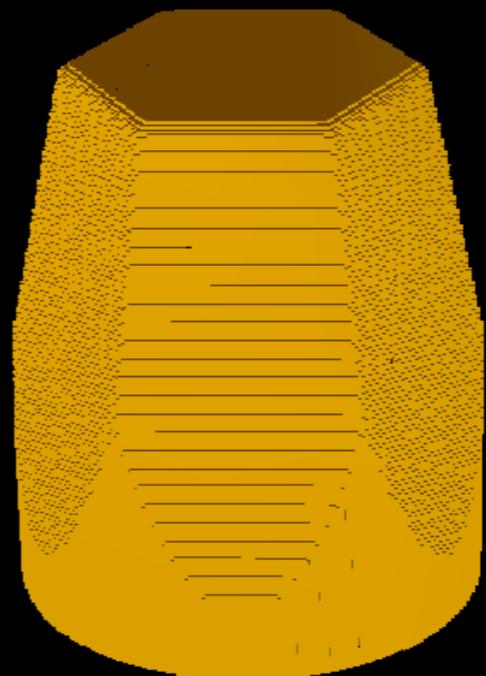




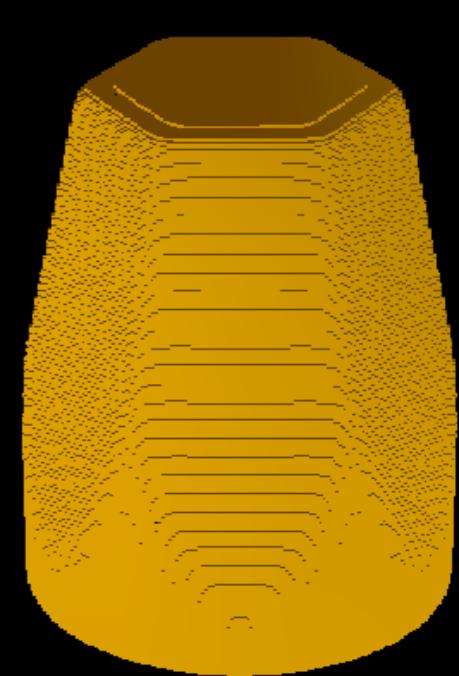
A



B



C: HV = 10V



D: HV = 100V

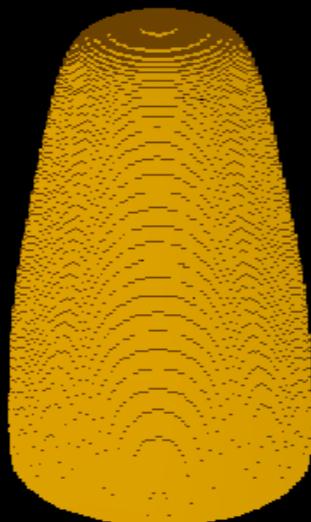
Depletion of a HPGe detector

A: Bare HPGe germanium crystal
symmetric AGATA detector

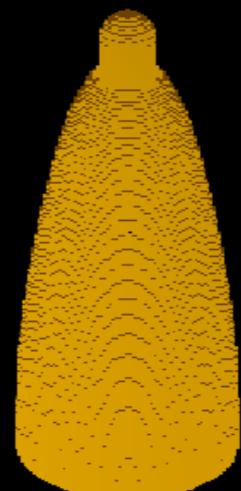
B: Geometry in simulation
The HV contact is colored yellow

C-G: Undepleted volume
as function of HV.

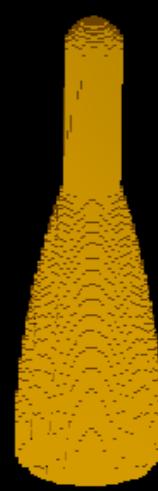
(assumption: 10^{10} impurities / cm³)



E: HV = 1kV



F: HV = 2kV



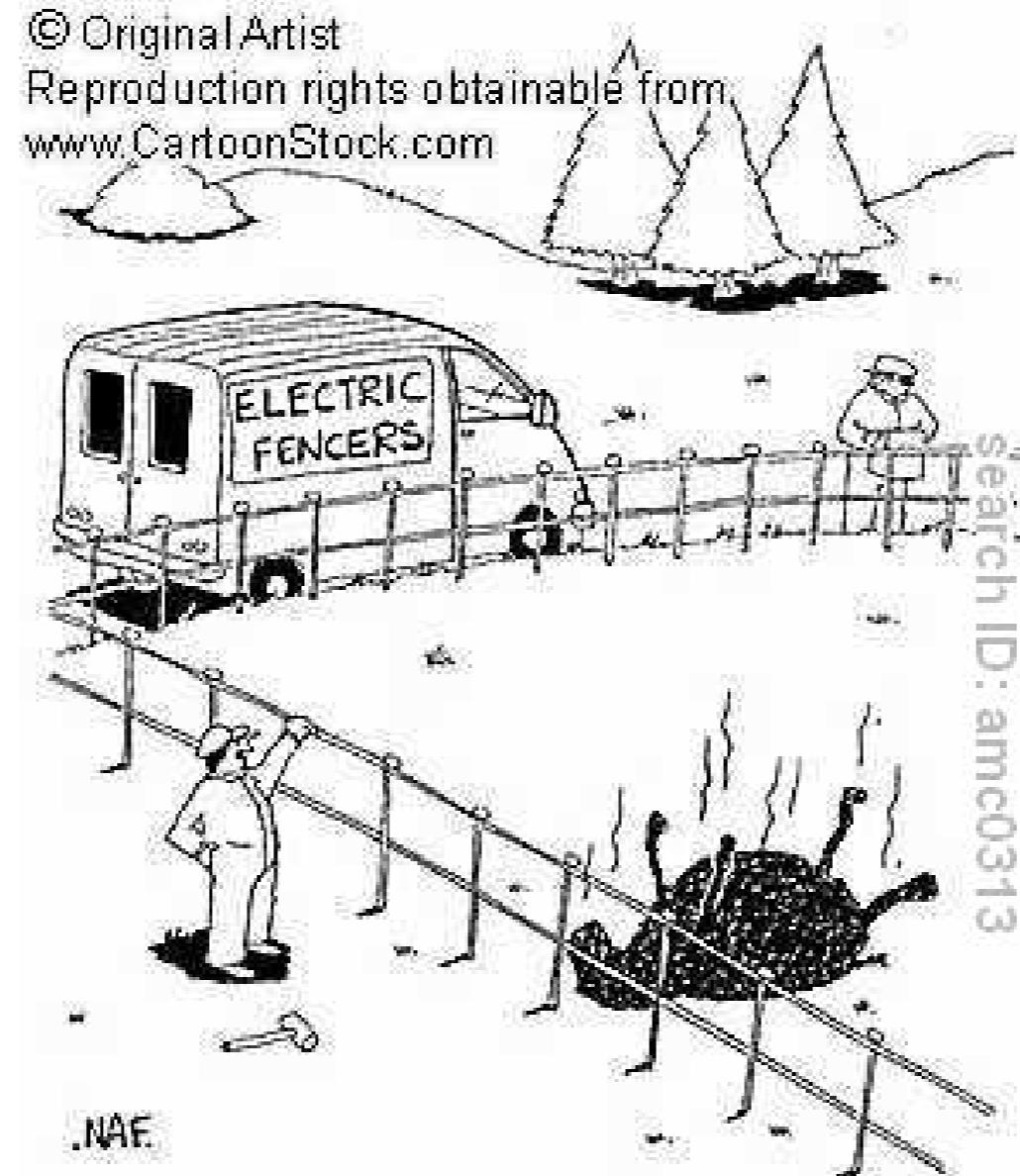
G: HV = 3kV



- Summary
 - No crosstalk between detectors in ATC2
 - First steps in impurity measurements are made
 - Capacity measurements work in principle, some differences with data provided by Canberra
 - First Simulations are made and look promising
- Outlook
 - Do our own absolute measurements with a bridge
 - Further development analysis



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Thank you



"Down a few volts yet Harry!"

Thank you!

The capacity data given by the manufacturer

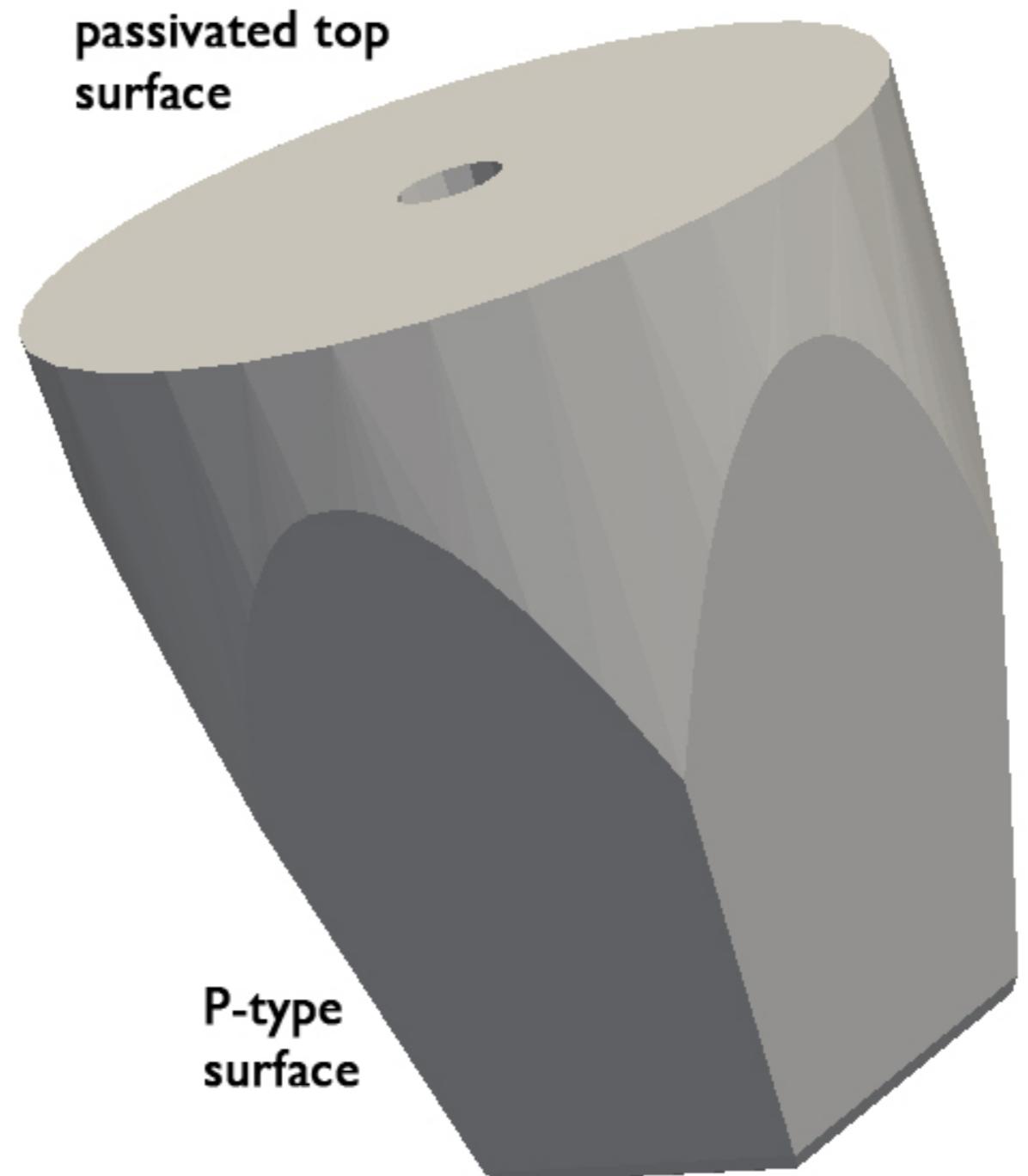
The data given was taken by the manufacturer before segmentation and before encapsulation

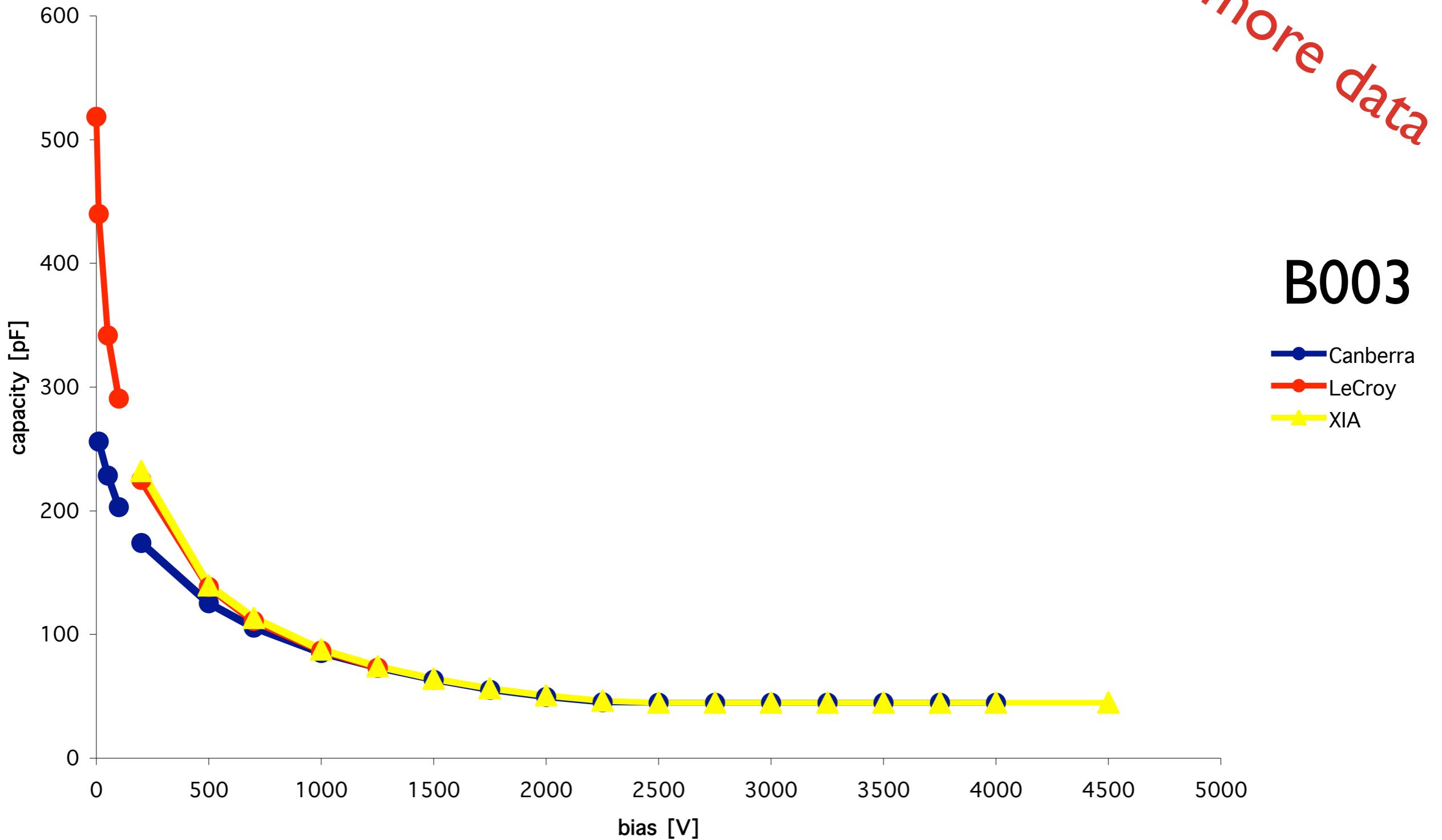


For the CV-analysis precise values are needed for each segment.

Space charge distribution in AGATA-Detectors

A crystal of AGATA
is made of N-type
Germanium with an
impurity concentration of
0.4 to $1.8 \times 10^{10} \text{ cm}^{-3}$.

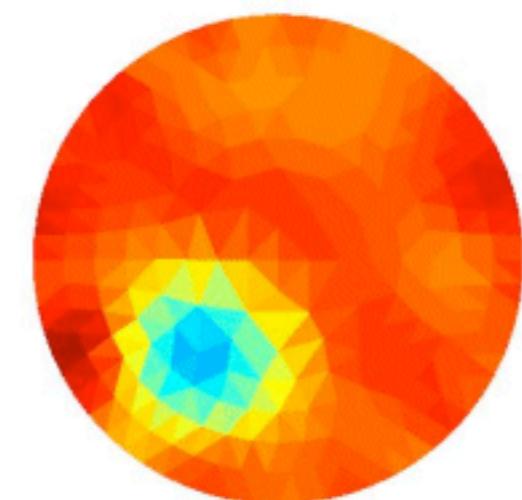
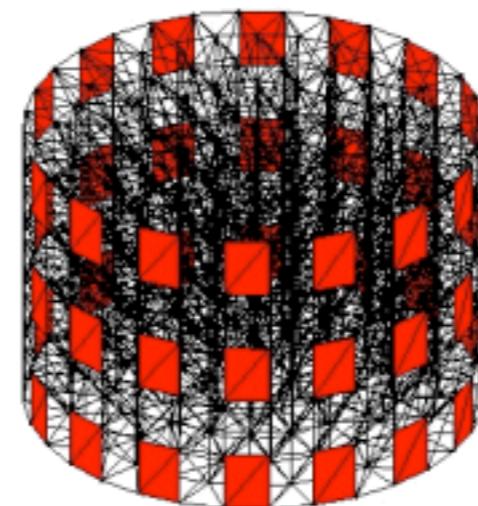




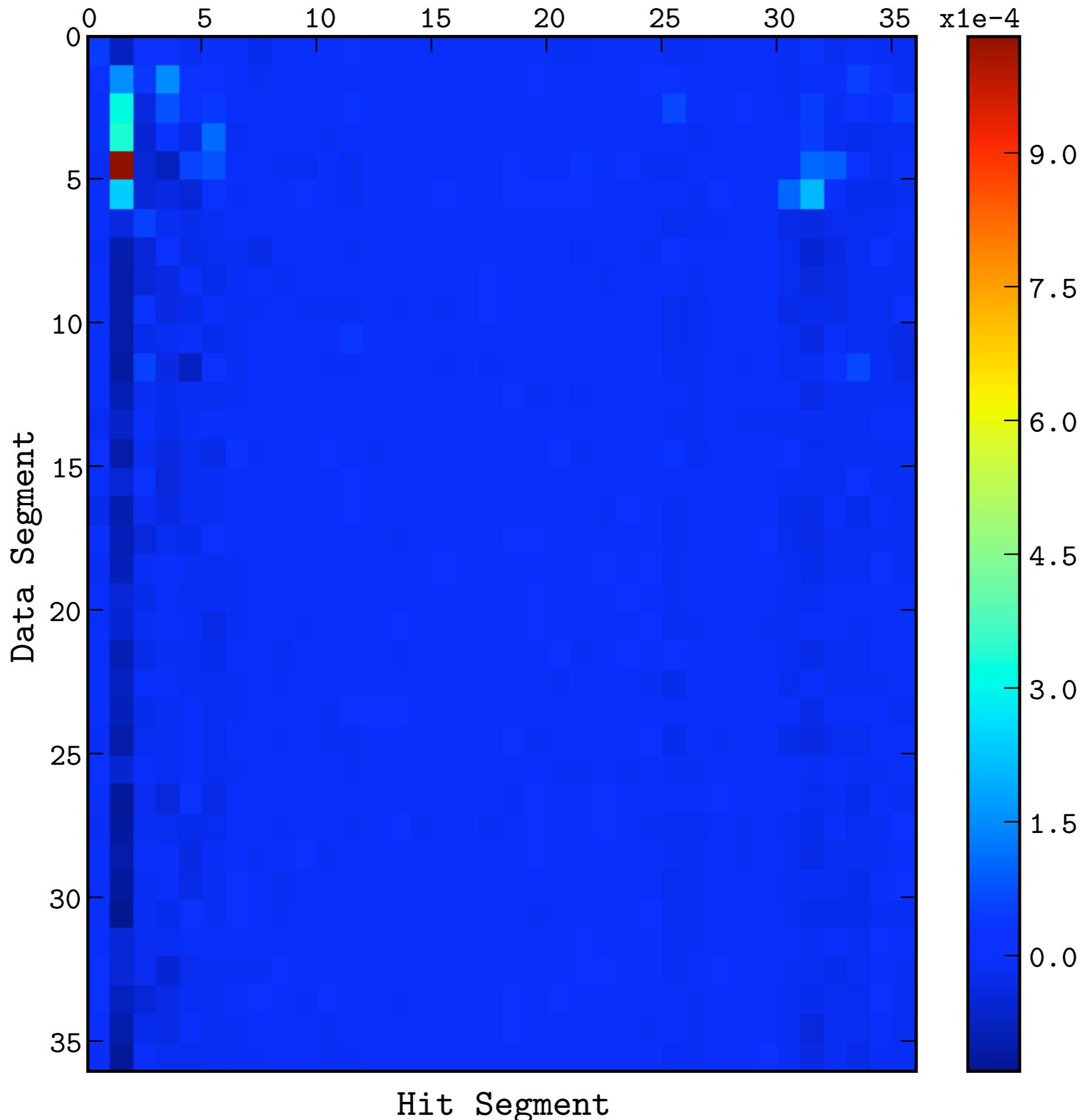
Three-dimensional electrical impedance tomography

apply sinusoidal currents through electrode to a volume and measure the resulting voltages on the electrodes

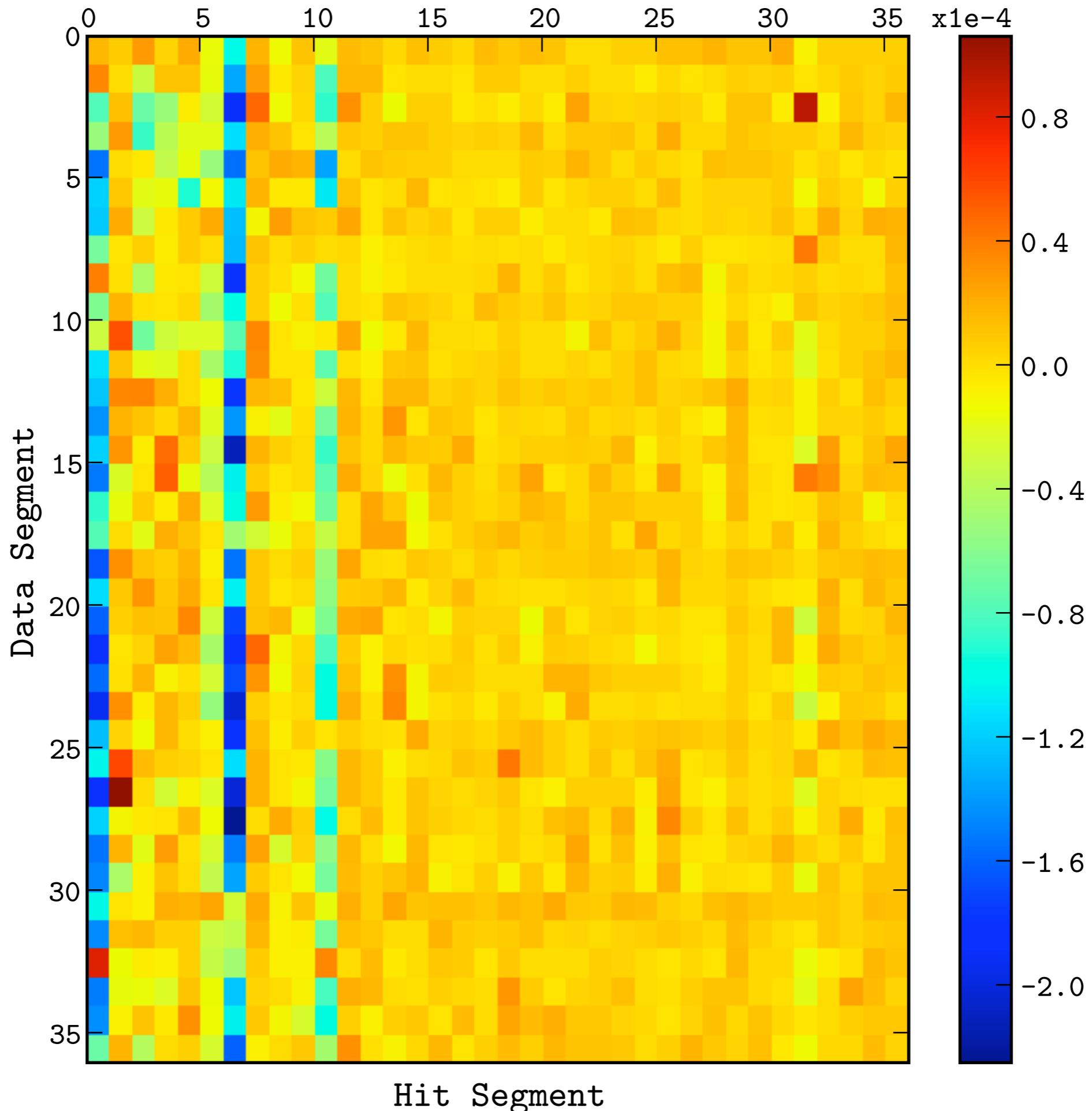
Compute the internal resistivity based on this boundary data



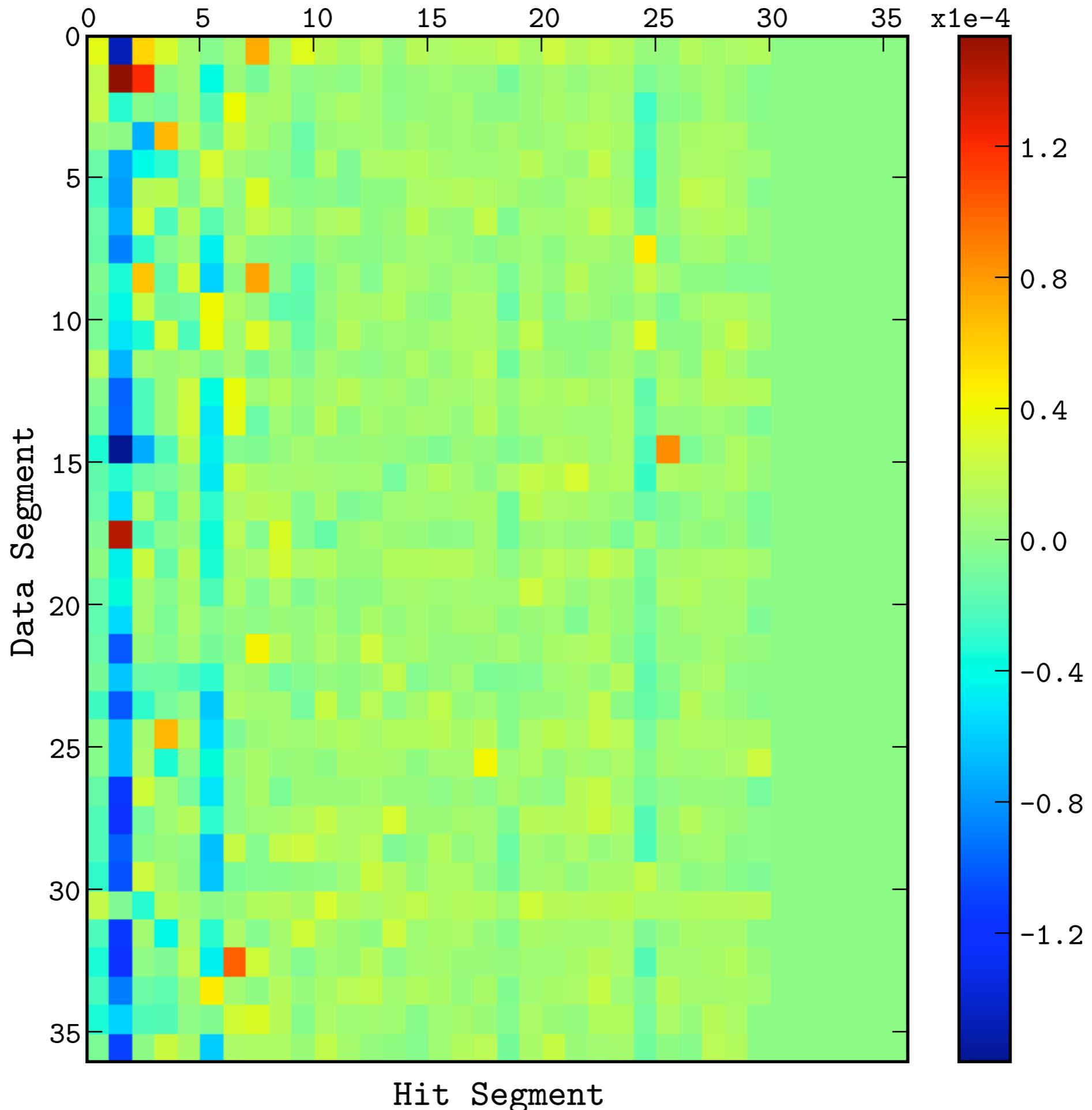
data core:1 hit core: 0



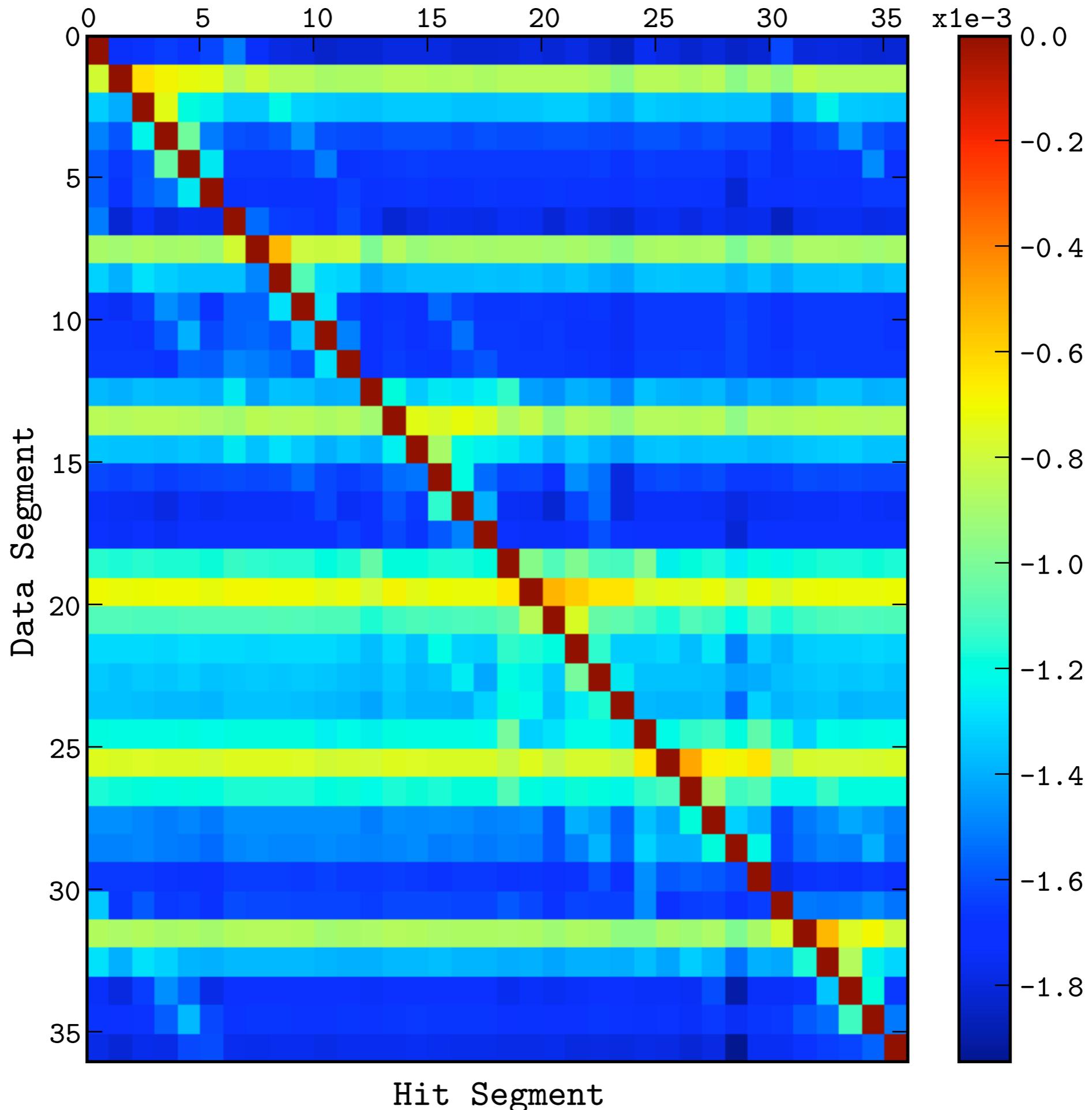
data core:0 hit core: 1



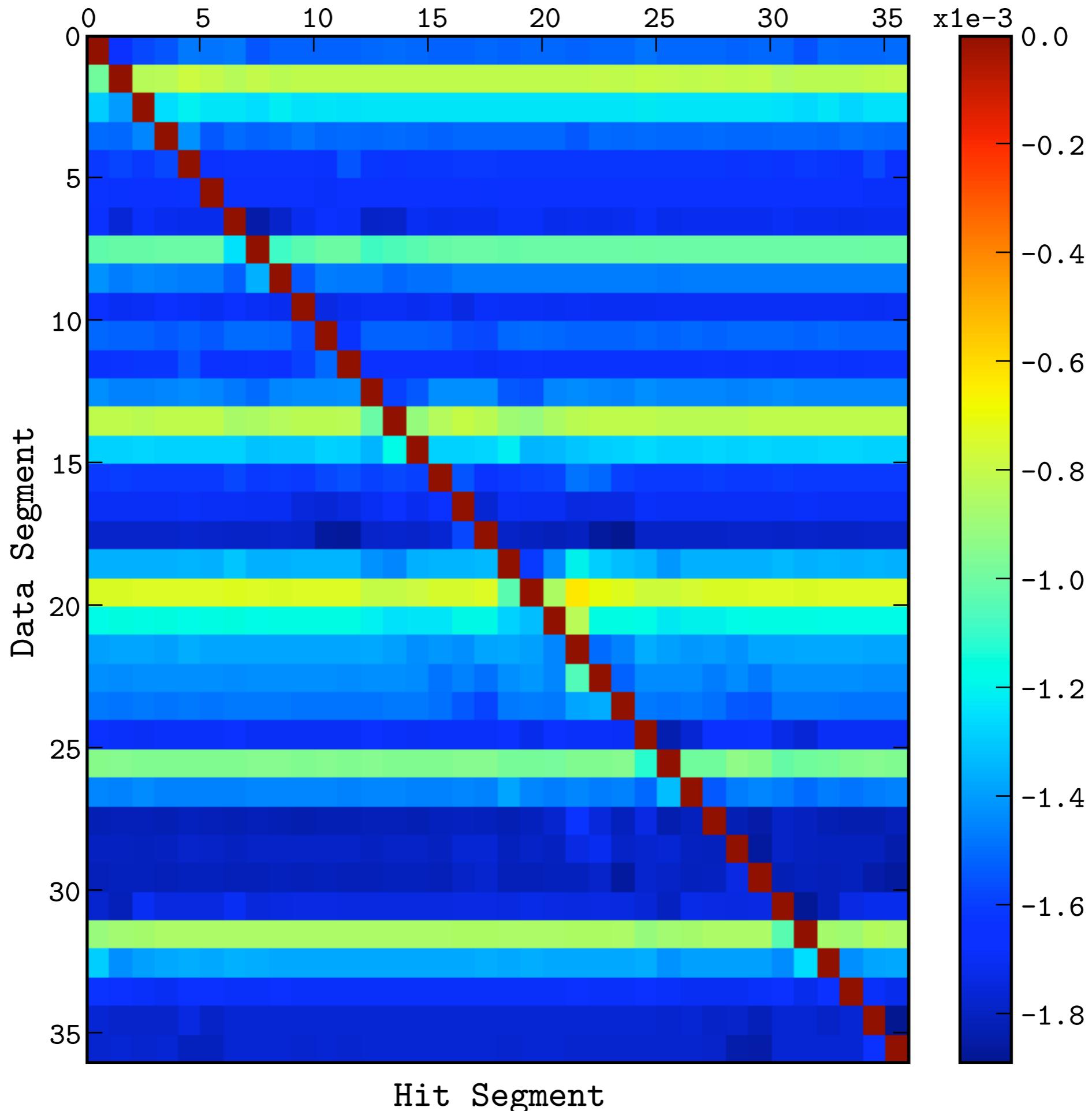
data core:0 hit core: 2



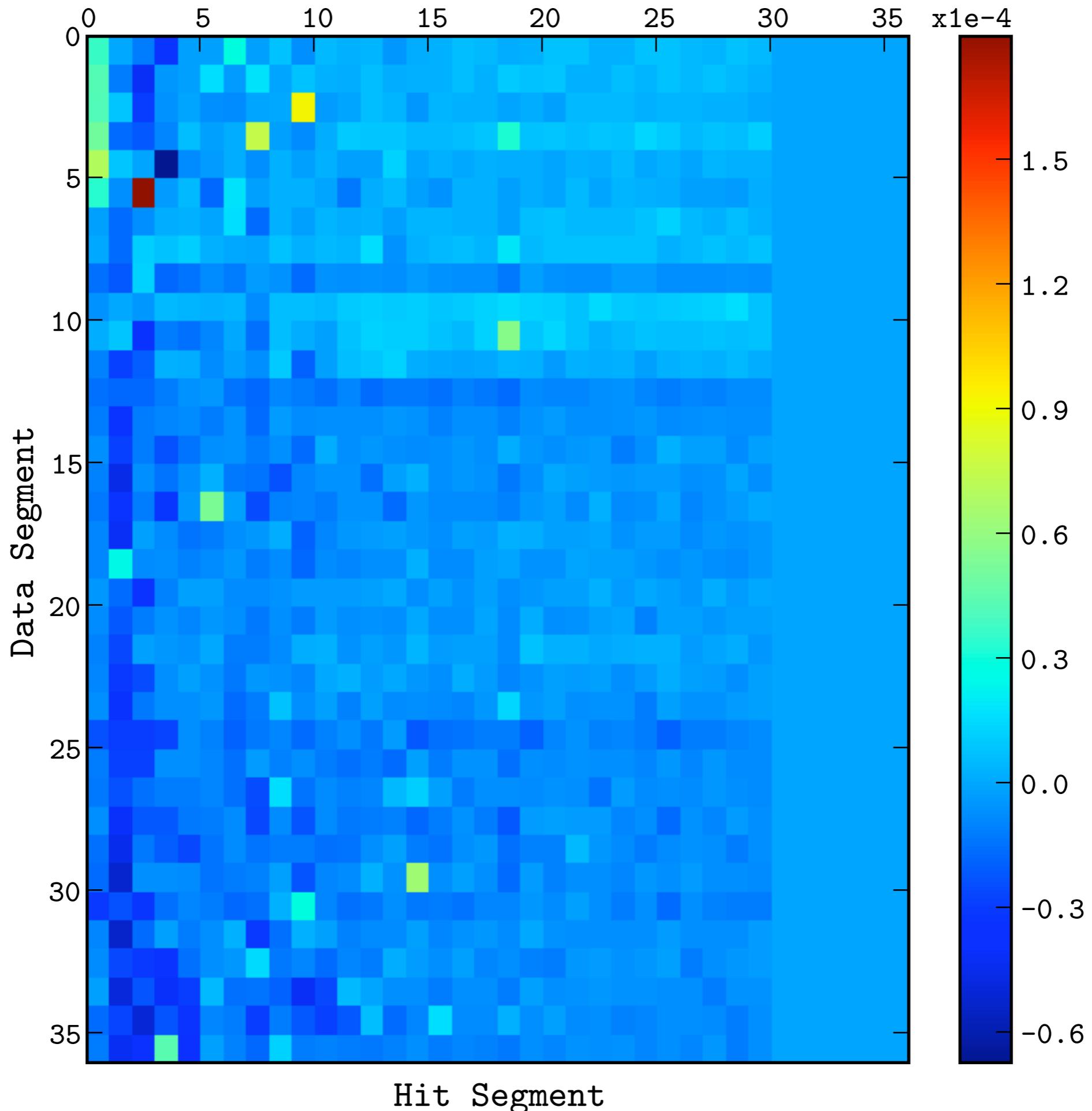
data core:0 hit core: 0



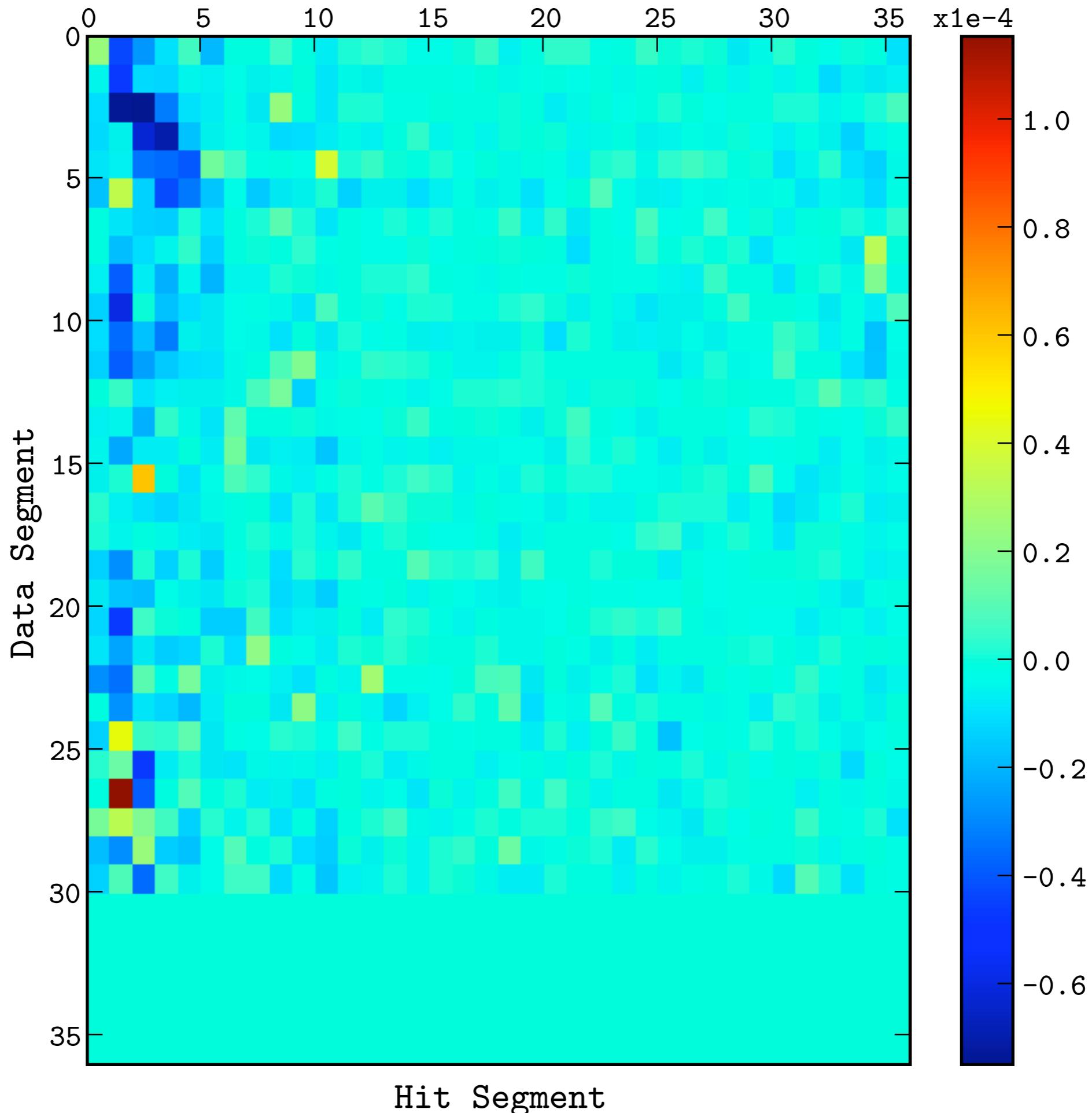
data core:1 hit core: 1



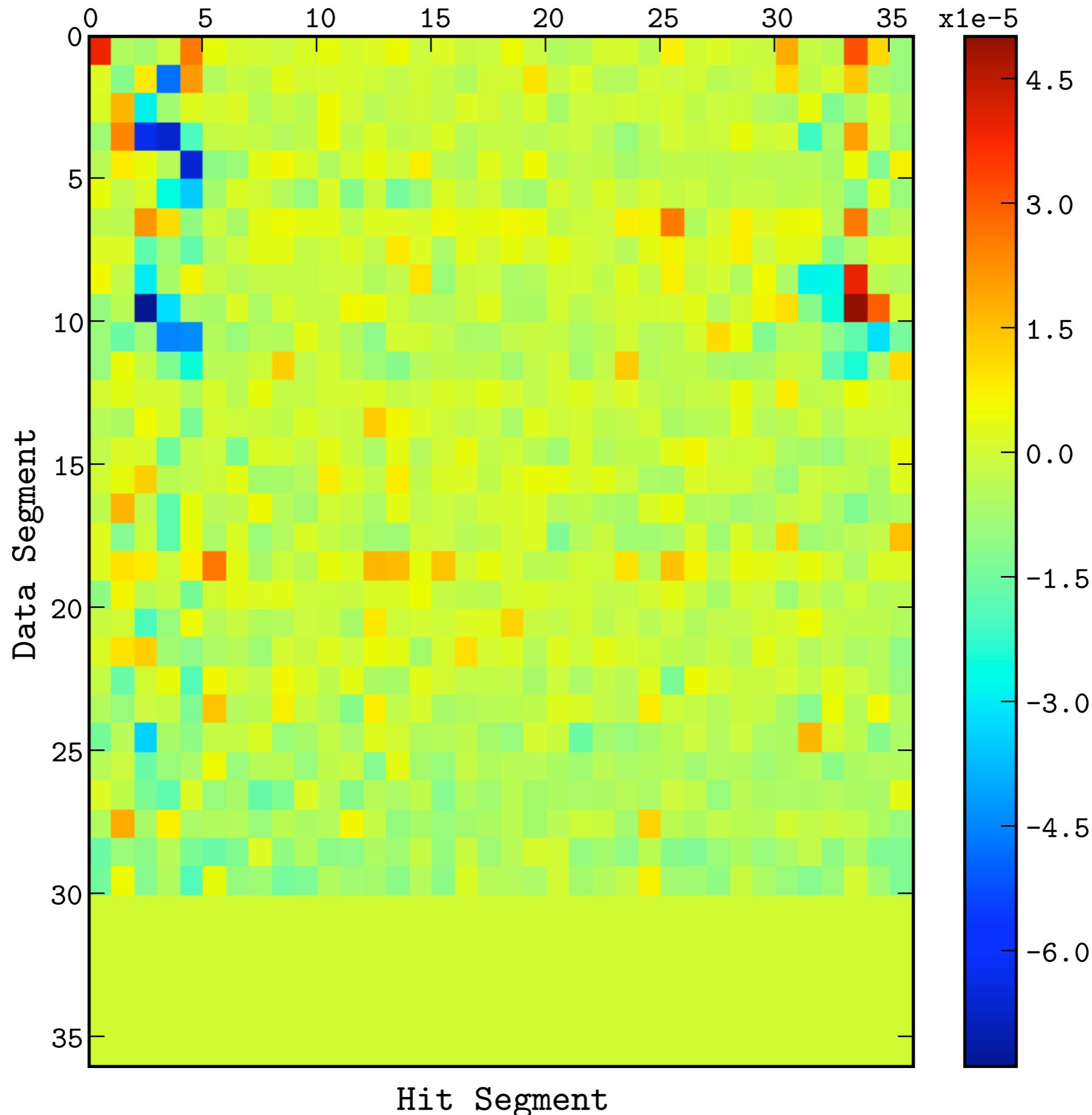
data core:1 hit core: 2



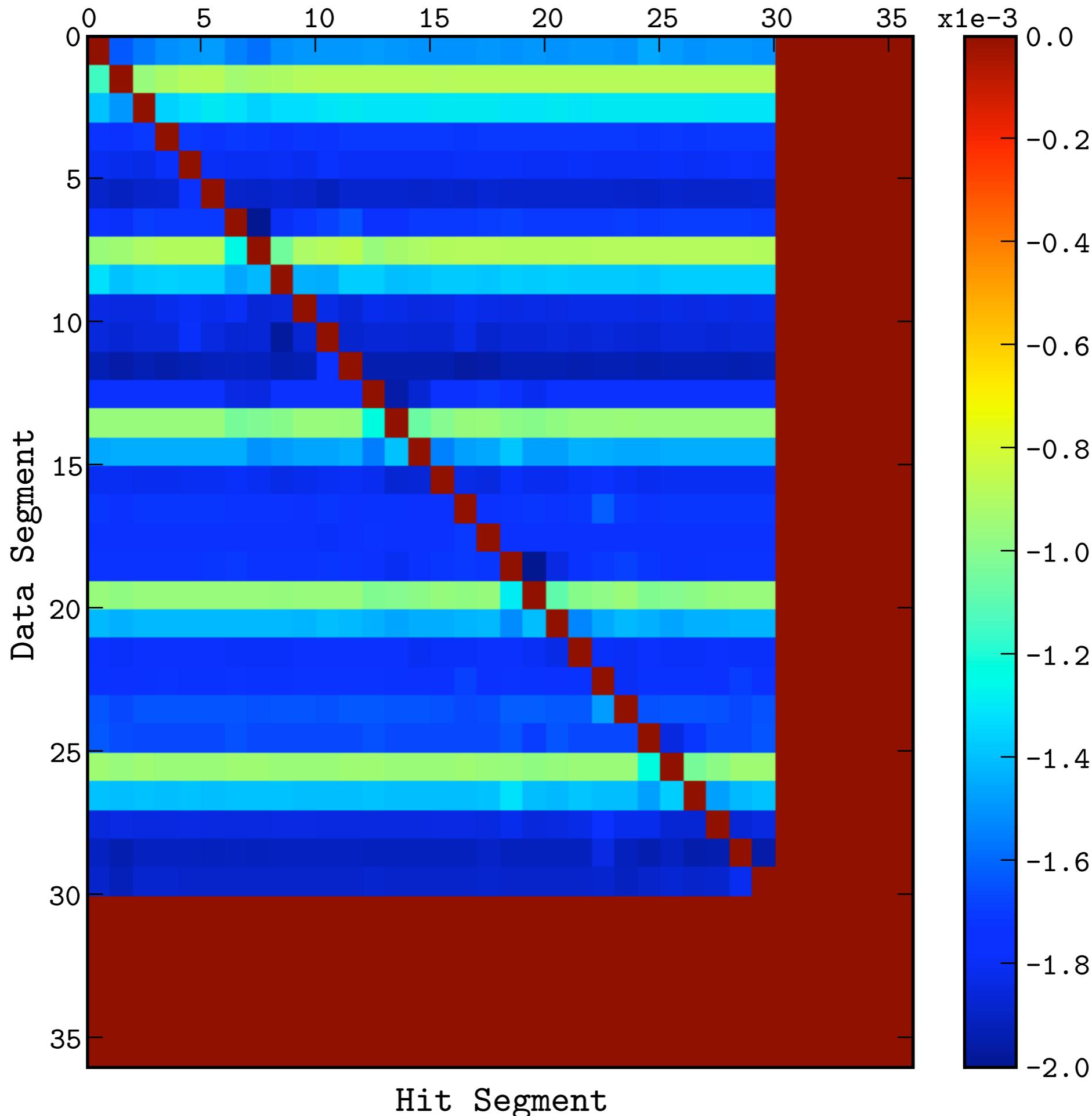
data core:2 hit core: 0



data core:2 hit core: 1

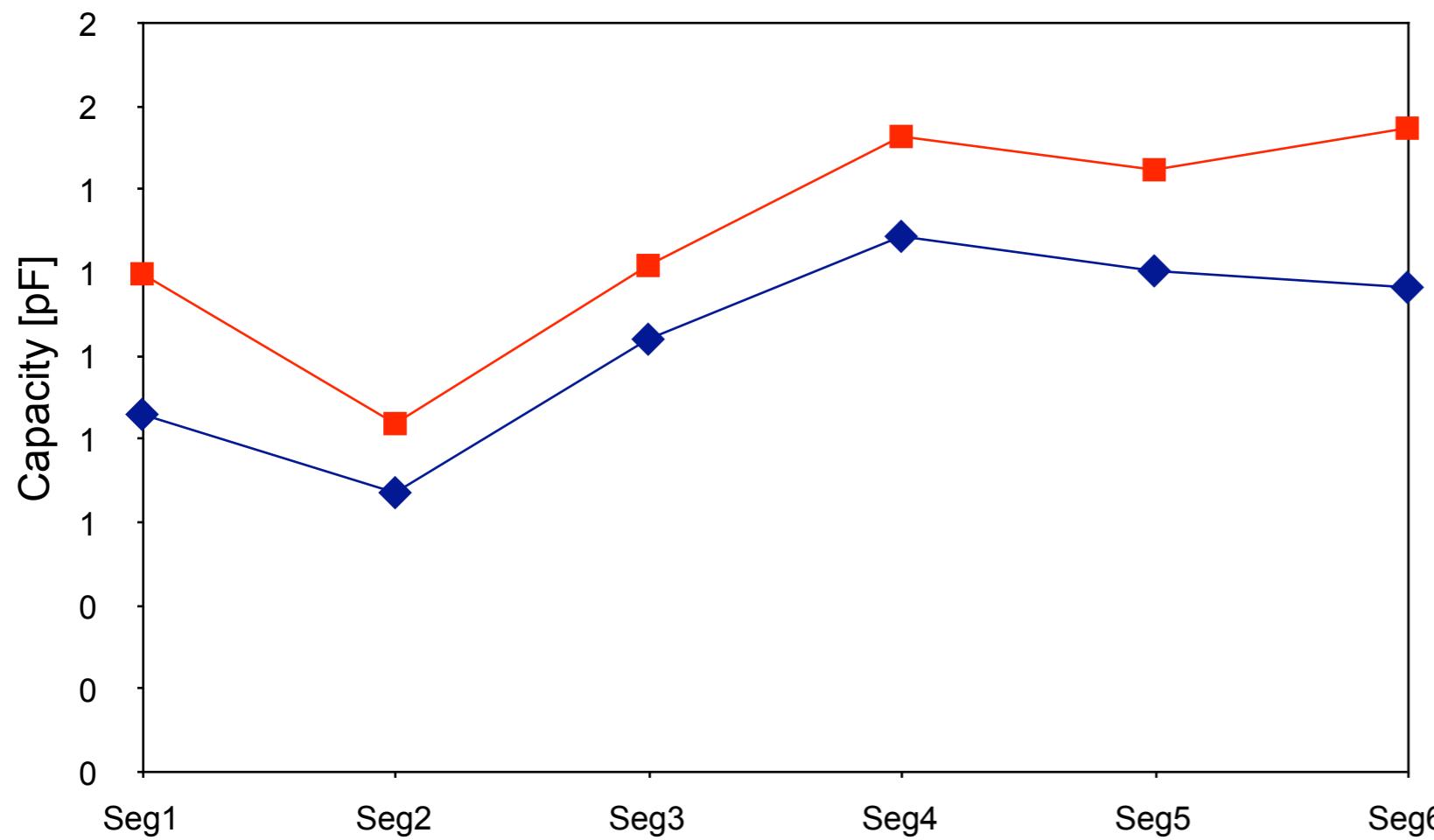


data core:2 hit core: 2



Capacity anomaly

Core to segment capacity (symmetric crystal)



Measured in S001, total = 46.7pF
S002 46.0pF
S003 46.9pF
total = 37.4pF

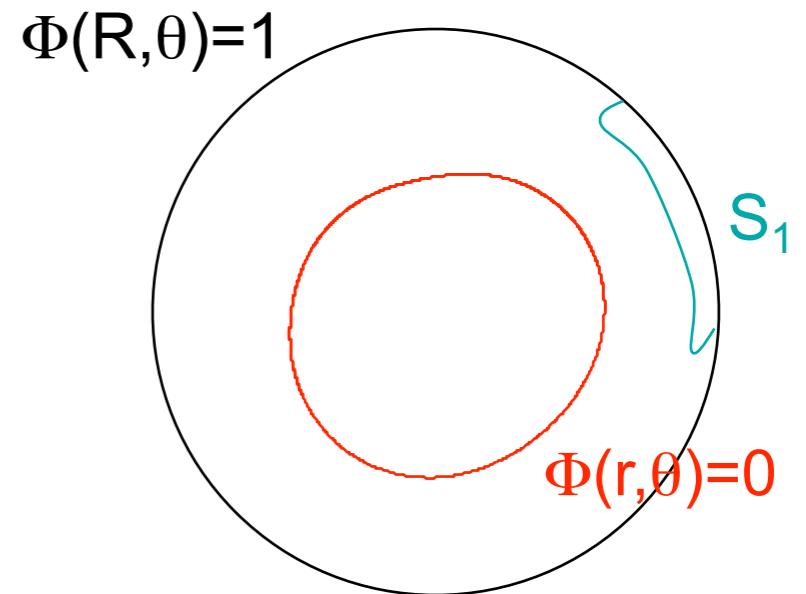
Calculation:

- Not a calculation error (est.< 3%)
- Not a volume effect (calc. 1920g)

⇒ Lithium contact ~ 2.5mm ?!?

1) Depletion layer boundary estimation

- Reconstruction is not unique:
- 2D example with coaxial geometry:
 - Given = 6 capacities $C_1 \dots C_6$
 - All solutions for field $\Phi(r,\theta)$:



$$\phi(r, \theta) := 1 + \frac{C_0 \ln\left(\frac{r}{R}\right)}{2\pi \cdot \epsilon \cdot \epsilon_0} + \sum_{n=1}^{\infty} \left[\left(\frac{r}{R}\right)^n - \left(\frac{r}{R}\right)^{-n} \right] (A_n \cos(n \cdot \theta) + B_n \sin(n \cdot \theta))$$

- Smoothest solution: limit to 6 lowest moments
- Gauss theoremme -> linear system \rightarrow defines $C_0, A_1, A_2, A_3, B_1, B_2$

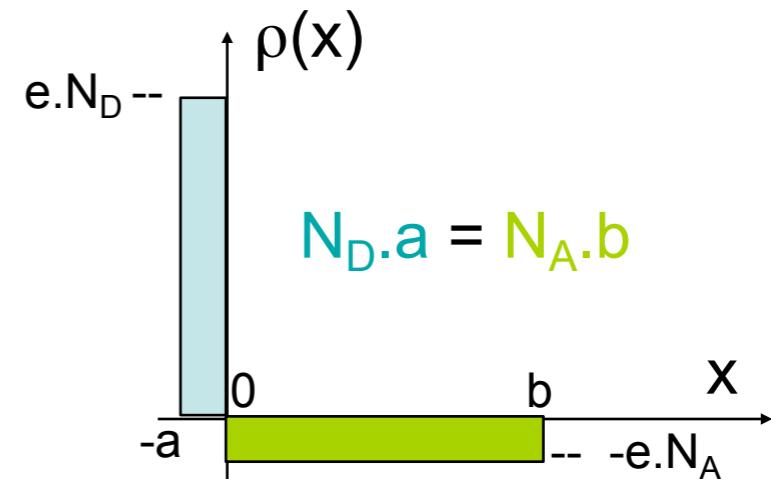
$$C_k := \epsilon \cdot \epsilon_0 \cdot \int_{S_k}^{\bullet} E(r, s) ds$$

- Solution given by $\Phi(r, \theta) = 0$!

2) Space charge reconstruction

- Idea is based on charge neutrality:
(e.g. Knoll 3rd ed. Pag. 373):
- In 3D, using weightingfields $\Phi_i(x)$:

$$Q_k = \int_{V_1}^{V_2} C_k(V) dV = \int_{Vol} \rho(x) \cdot \phi_k(x) dx$$



- Parametrization of $\rho(x)$, e.g. assume

$$\rho(x) := \sum_k \alpha_k \cdot \phi_k(x)$$

$$\longrightarrow \longrightarrow$$

- \Rightarrow linear system : $Q = M \cdot \alpha$

