Cross talk properties of AGATA detectors

Orsay 15 jan. 2007

B. Bruyneel, Juergen Eberth, Herbert Hess, Linda Heuser , Andreas Linnemann, Gheorghe Pascovici, Peter Reiter, Nigel Warr and Andreas Wiens -- IKP, uni zu Koln

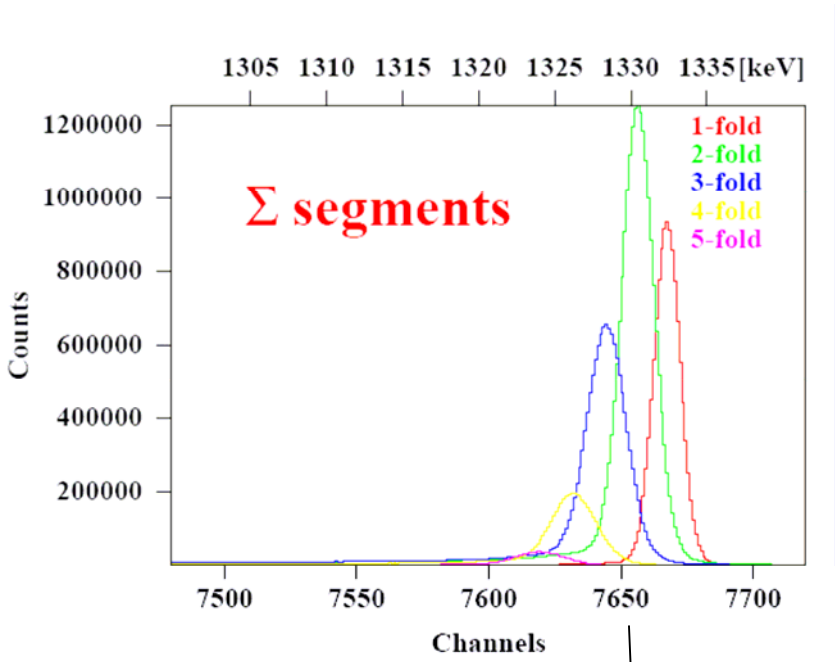
Overview

Part I : crosstalk data and theory
- -Motivation
- -Experimental results
- -Modelling of cross talk properties

Part II : extended cross talk models
- -Origin of detector Eigenfrequencies

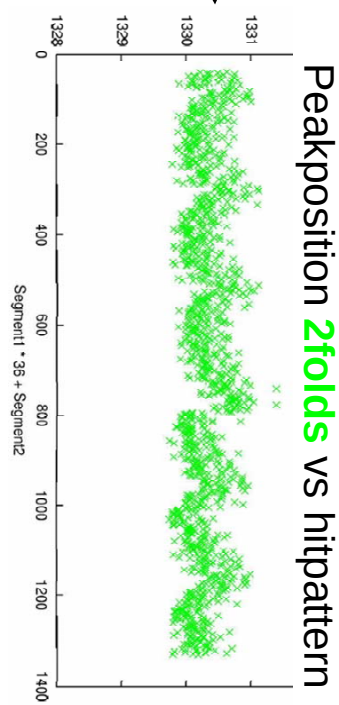
Motivation

Main aim is to understand cross talk results

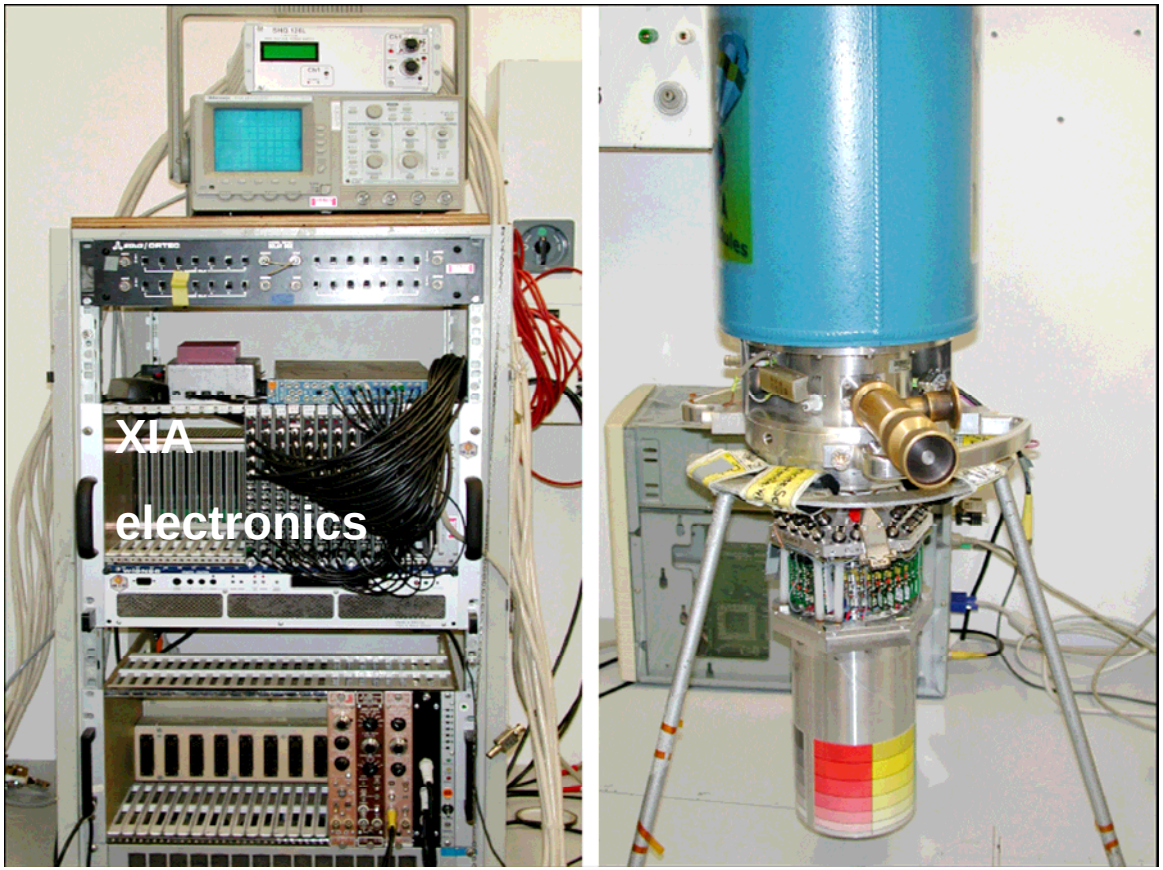


Cross talk is crucial for AGATA

- cross talk measurements via energy shifts show structures
- cross talk affects energy calibration
- cross talk is affecting PSA / tracking
- cross talk may be due to derivative and absolute parts
- cross talk and transfer function are entangled

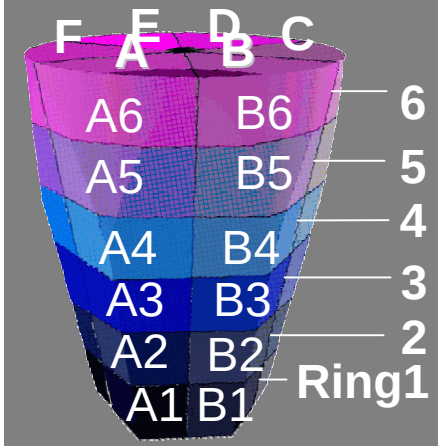


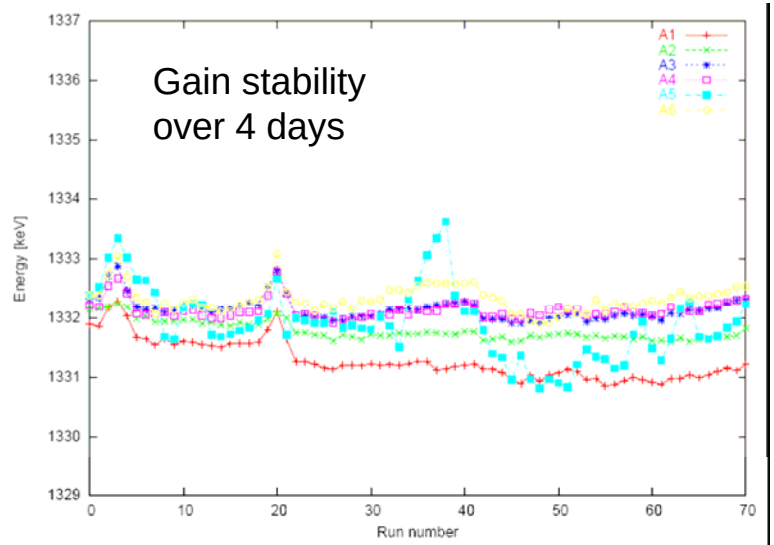
Experimental setup



convention :

Sectors labeled A..F
Rings labeled 1..6





Experimental Results:

-Cross talk measurements performed:

(i) acceptance tests (3 symmetric and 4 asymmetric detectors)

(ii) results from test cryostat and three single symmetric cryostats

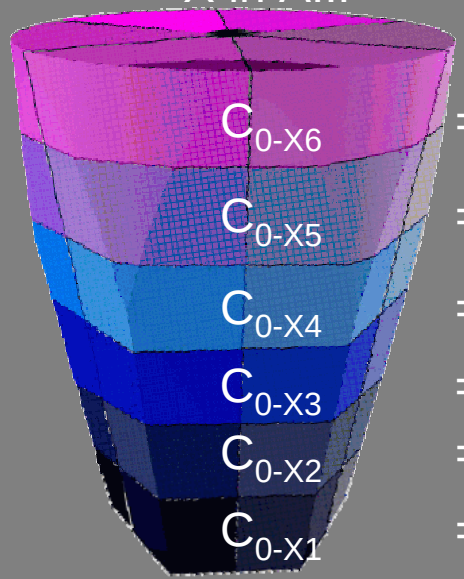
(iii) results from symm. cryostat with diff. γ-ray source positions.

-2 capacity measurements performed.

Core to Segment Capacities

- Pulser signal in segments: Inverse proportional to core-segment capacity.
- Capacities normalized to total capacity of crystal (46pF cfr. Eurisys)

AGATA measured capacities using pulser :



X in A..F		averaged values S001: TC	GSI cryo	
$C_{0\text{-}X6}$	=	1.27 pF	1.52 pF	← σ = 3%
$C_{0\text{-}X5}$	=	1.50 pF	1.43 pF	← ????
$C_{0\text{-}X4}$	=	1.54 pF	1.50 pF	
$C_{0\text{-}X3}$	=	1.27 pF	1.20 pF	
$C_{0\text{-}X2}$	=	0.86 pF	0.83 pF	← Low effective volume
$C_{0\text{-}X1}$	=	1.22 pF	1.18 pF	

Cross talk results symmetric detectors

Used to look at 2-folds

(in segments : calibrated on 1folds)

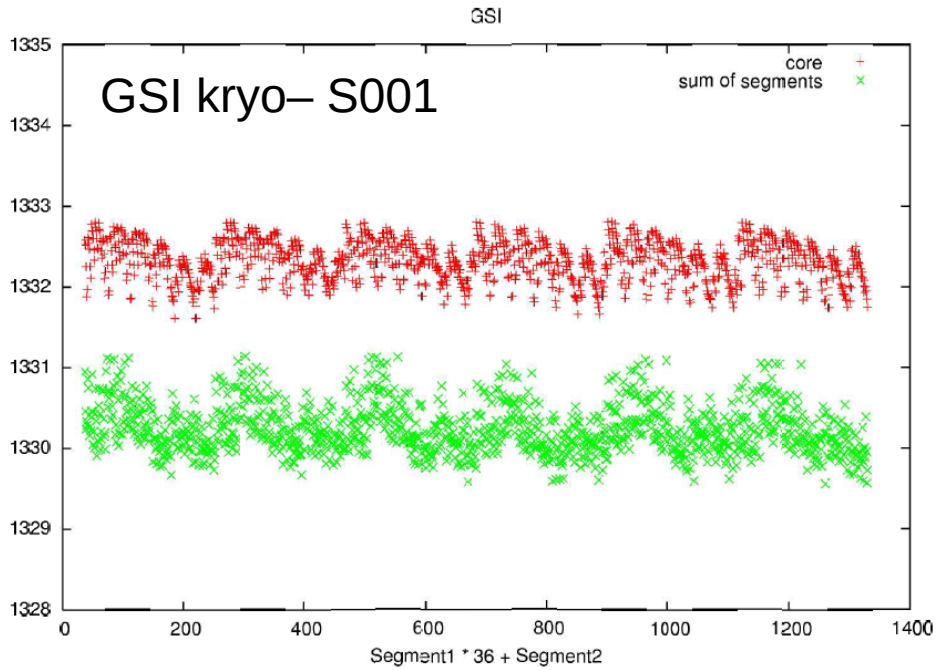
36 x 36 combinations

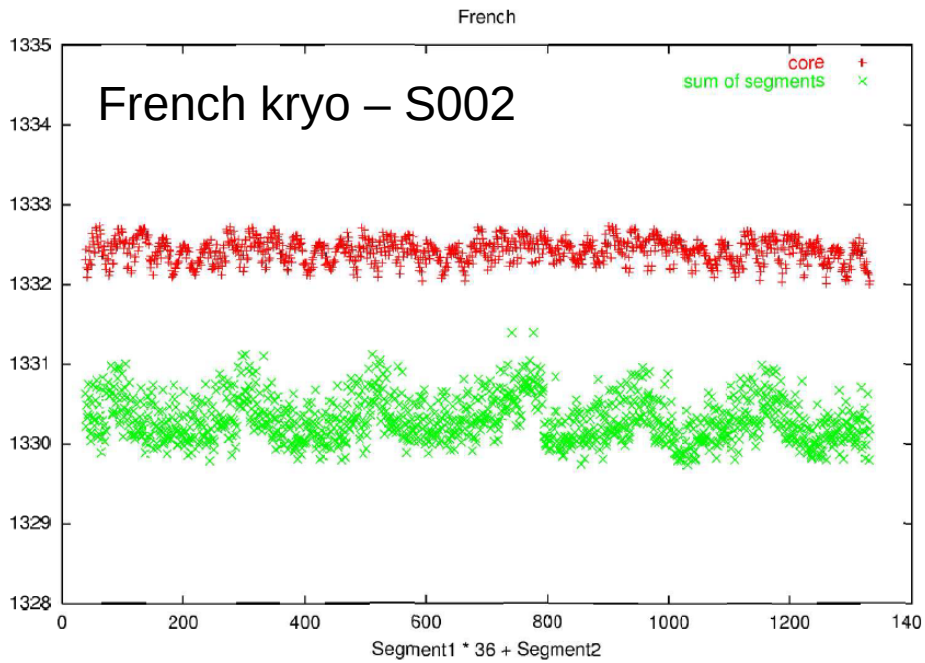
Segment numbering:

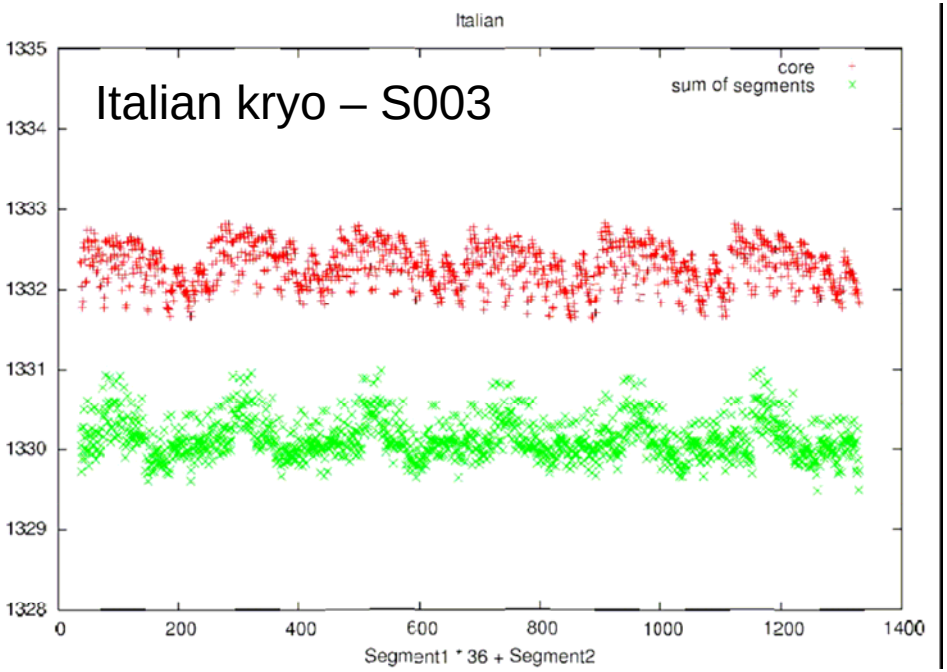
sector1 – sector2 – sector3…

1 2 … 6 - 7 8 … 12 - …

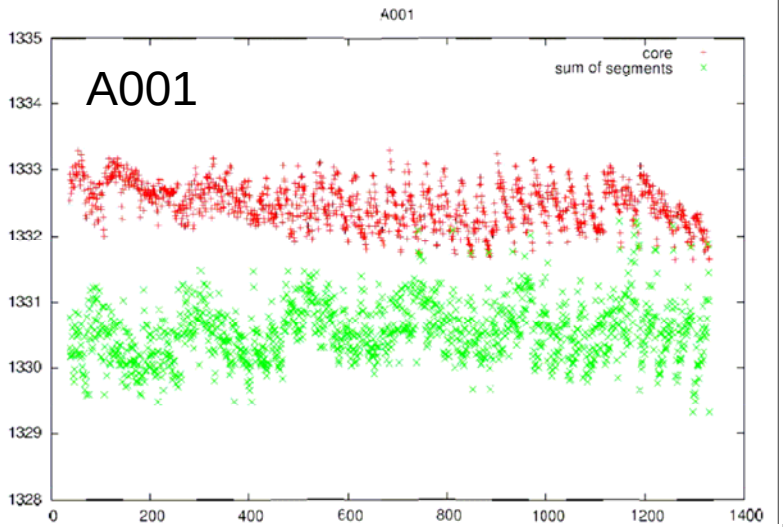
A1 A2 A3 A6 - B1 B2 B3 B6 - E2 …

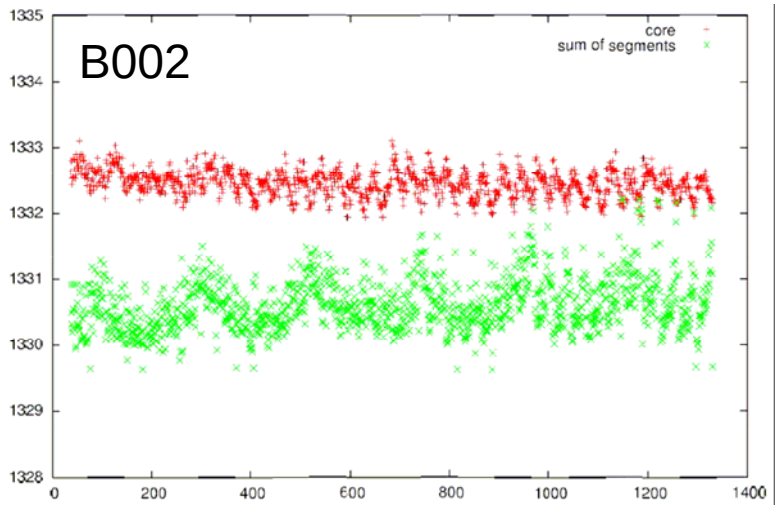


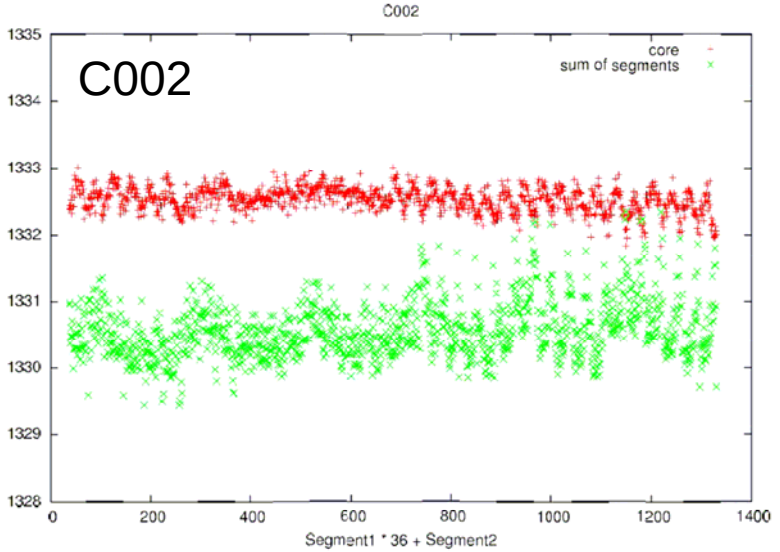


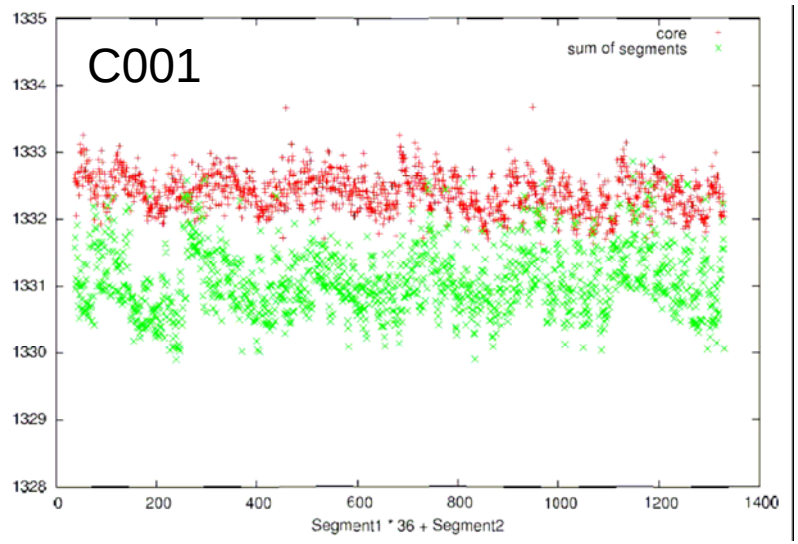


Data acceptance test (testcryostat)



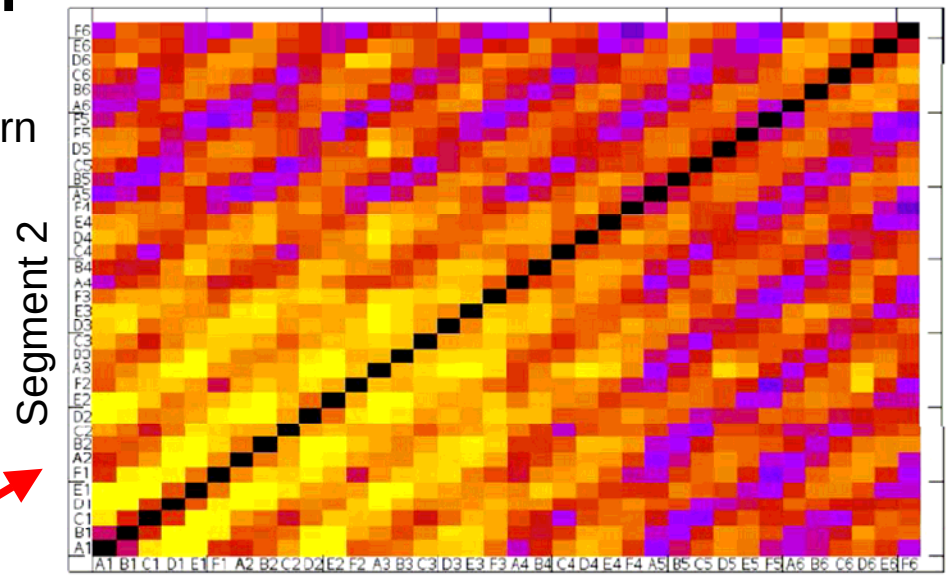






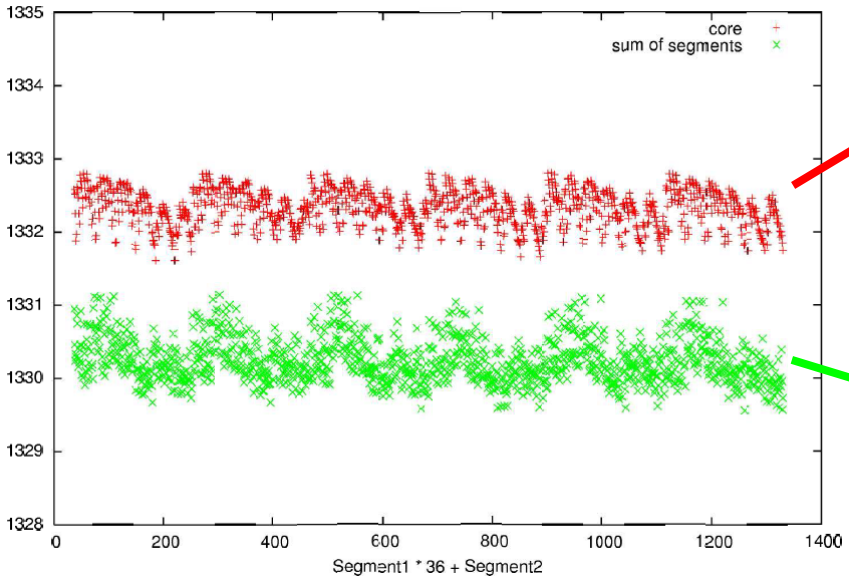
Crosstalk matrix representation

Core 2folds vs hitpattern

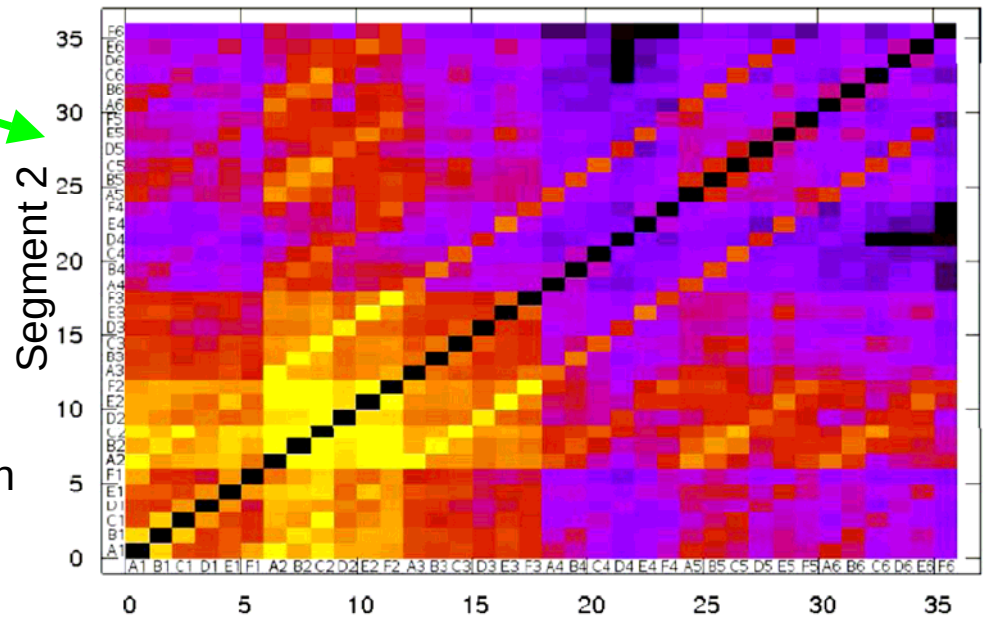


Structures most visible in

“ring1 - ring2 - …” representation

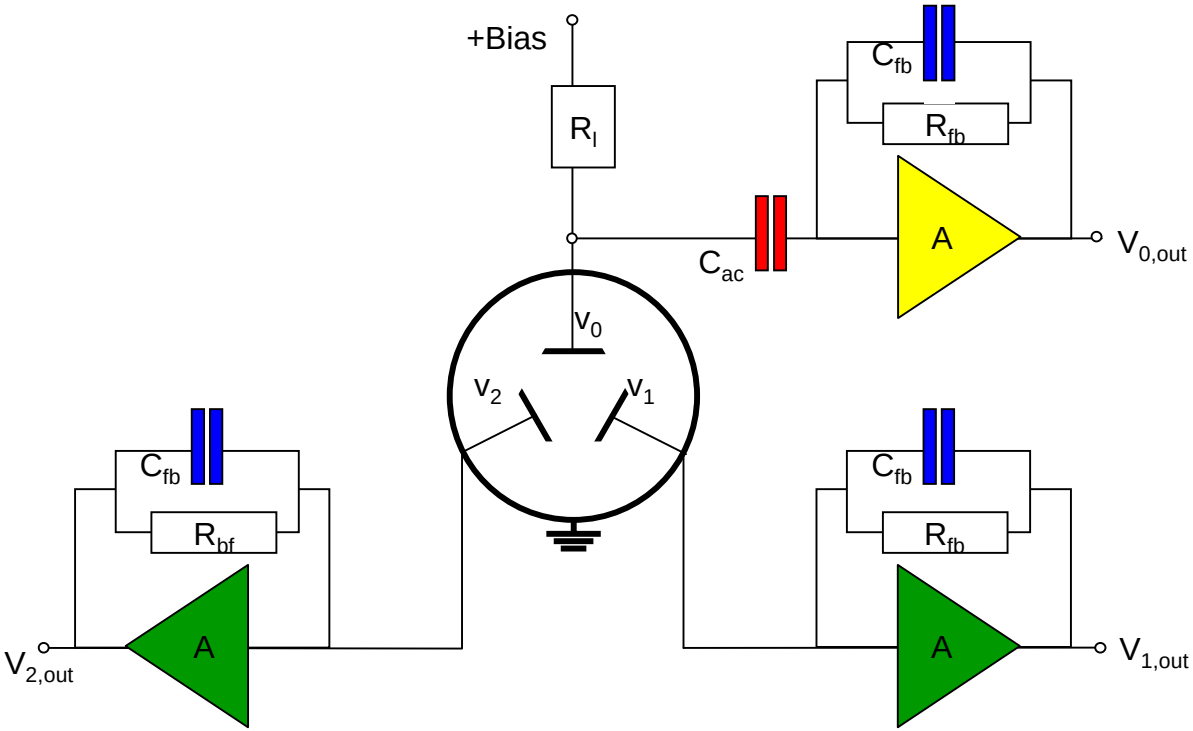


Segment sum 2folds vs hitpattern



From here on only “ring1 - ring2 - …” representation

A simple detector model to describe **crosstalk** in segmented detectors



AGATA:

C_{ac} = 1000pF

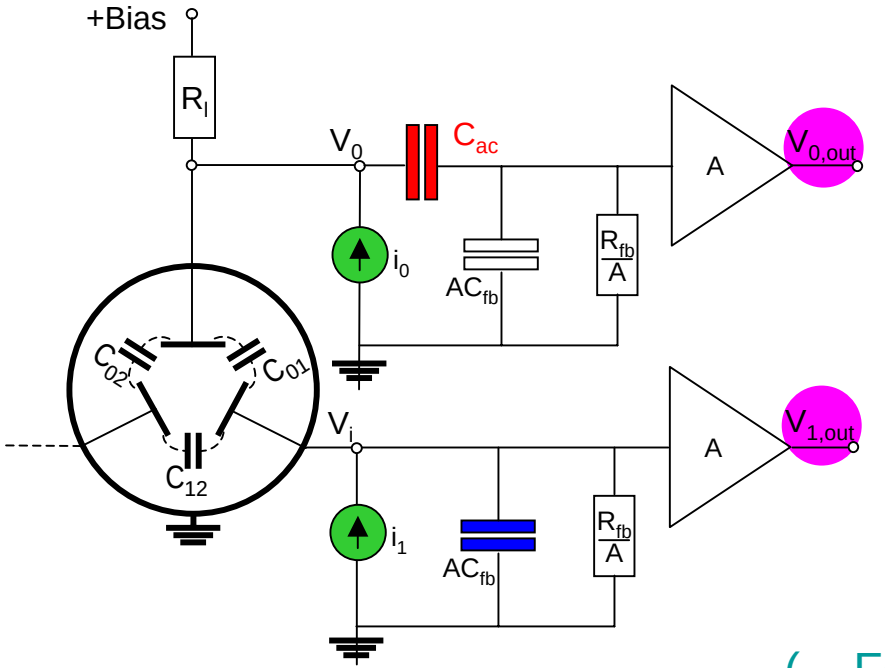
C_{fb} = 1.2pF

A (Core) = 80000

A (Seg) = 10000

($R_I = R_{fb}$ = 1GΩ)

Scheme for a twofold segmented detector
(extension to 36-fold is trivial)



Miller Equivalent

Since C_{ac} << AC_{fb}, Core-to-Segment crosstalk dominates

(... For the steps inbetween, Click here...)

Segment-to-Core

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

Core-to-Seg

~ 1pF/1000pF

Segment-to-Segment

~1pF/(10000.1pF)

What do we calibrate on?
What is the energy resolution?

Assume a general linear X-talk matrix

$$v_{out} := \begin{bmatrix} 1+\Delta_{00} & \Delta_{01} & \Delta_{02} & \dots \\ \Delta_{10} & 1+\Delta_{11} & \Delta_{12} & \dots \\ \Delta_{20} & \Delta_{21} & 1+\Delta_{22} & \dots \\ \dots & \dots & \dots & \dots \end{bmatrix} \cdot i$$

…And a general event

$$i := \begin{bmatrix} -1 \\ x \\ y \\ \dots \end{bmatrix}$$

$$x + y + \dots := 1$$

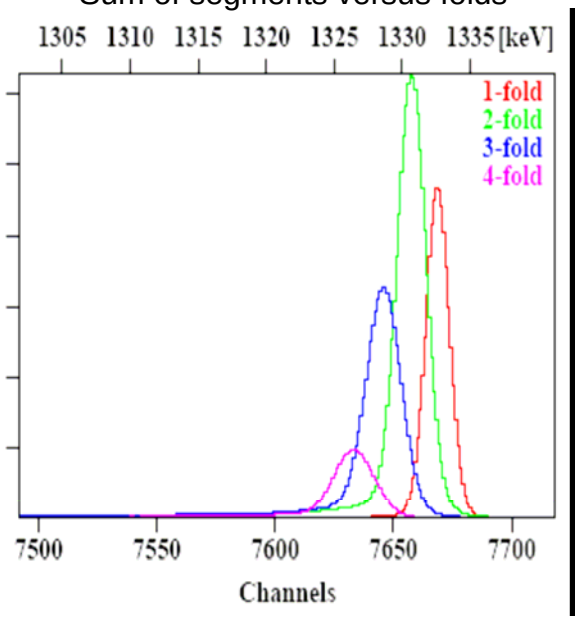
The observed E-shift become:

$$v_{out} := \begin{bmatrix} -\left(1+\Delta_{00}\right) + x\cdot\Delta_{01} + y\cdot\Delta_{02} + \dots \\ -\Delta_{10} + x\cdot\left(1+\Delta_{11}\right) + y\cdot\Delta_{02} + \dots \\ -\Delta_{20} + x\cdot\Delta_{21} + y\cdot\left(1+\Delta_{22}\right) + \dots \\ \dots \end{bmatrix}$$

E(.) = expectation value and depends on projection, eg:

core calibration:	$E(x)+E(y)+\dots := 1$	E(x), E(y) source position dependent
twofolds seg 1 and seg 2 :	$E(x)+E(y) := 1$	E(x), E(y) source position dependent
seg 1 calibration:	$E(x) := 1 \quad E(y),\dots := 0$	source position INDEPENDENT

Sum of segments versus folds



Without correction for X-talk effects:

Core energy resolution is broadened

Calibration depends on:

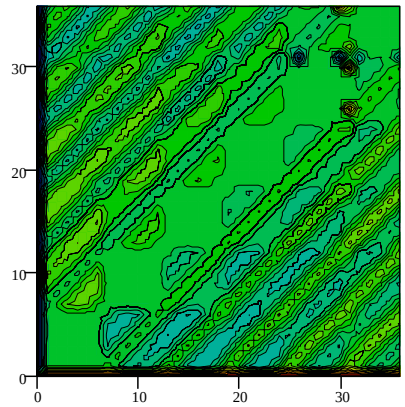
- gated events
- position of calibration source

Segment sum: Theory (GSI std meas)

<u>Simulation with:</u>

+ Measured Core-Seg capacities
+ adjustment AC decoupling cap.

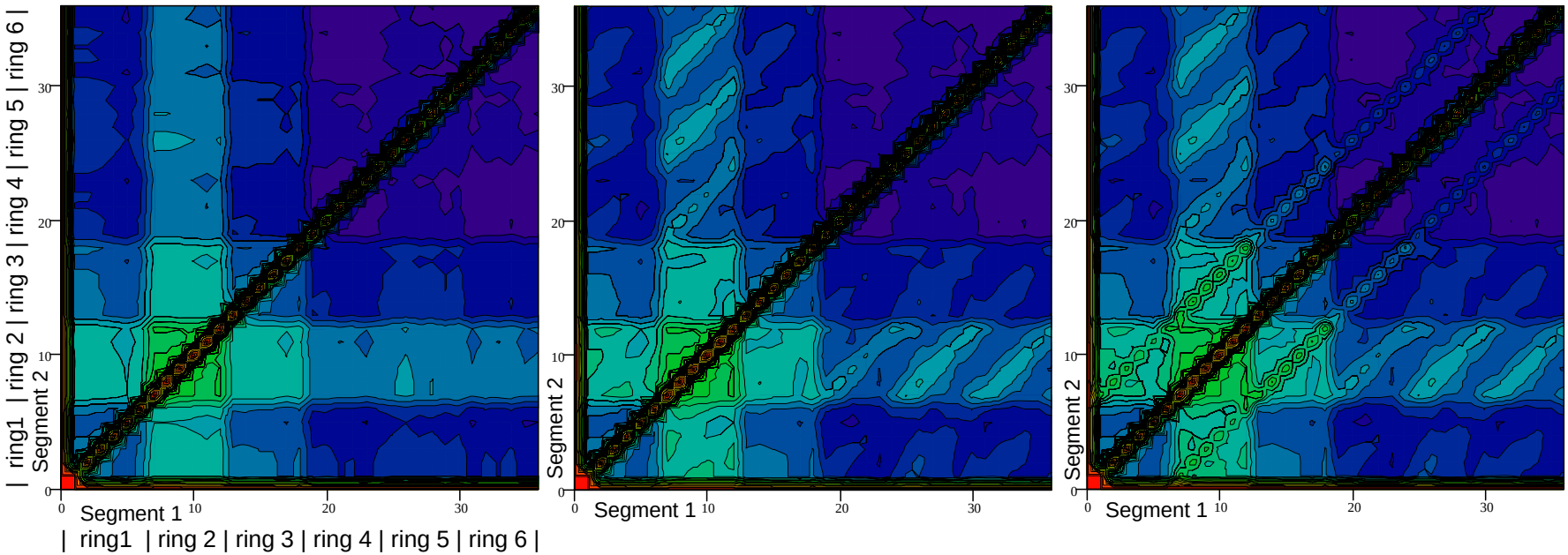
  1000pF → 770pF (or A smaller)
+ E(x) = E(y) = ½
+ no seg-seg crosstalk



E(x) = 1-E(y) from data

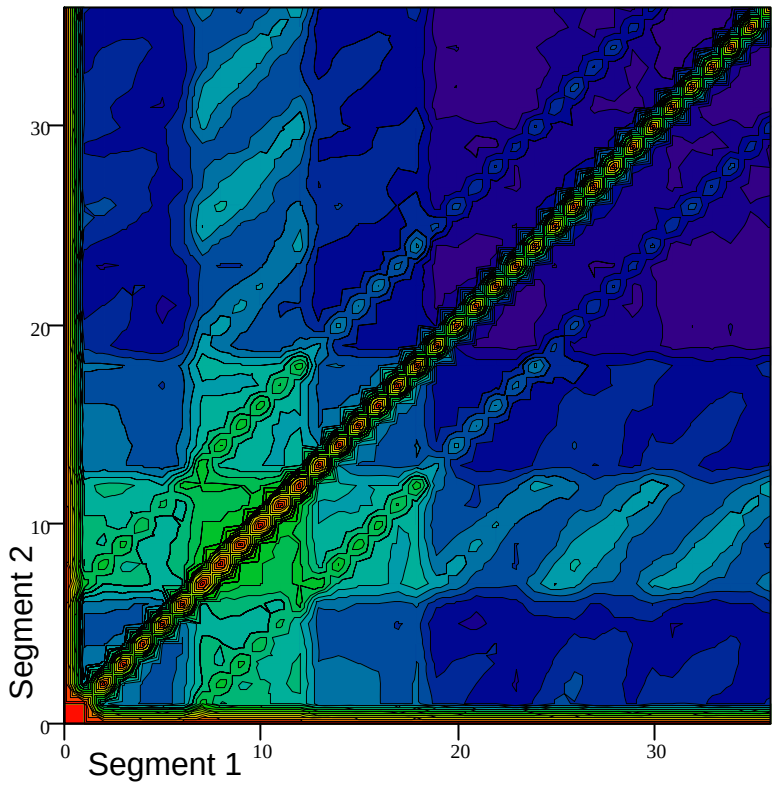
+ Measured Core-Seg capacities
+ adjustment AC decoupling cap.

  (1000pF -> 770pF)
+ E(x) = 1-E(y) from data
+ ~ 3.5pF seg-seg neighb. Ring
+ ~ 1pF seg-seg neighb. sector

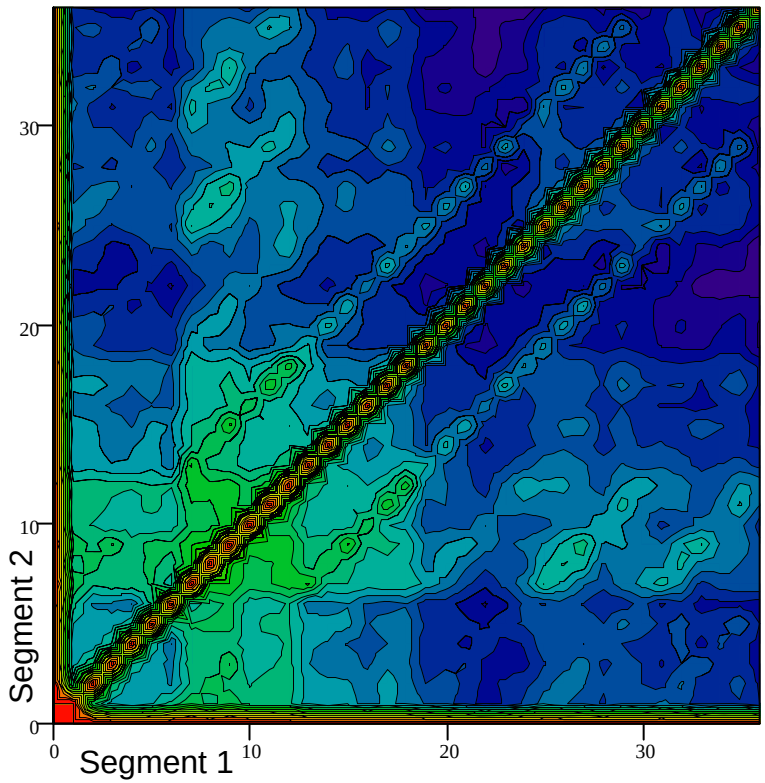


Model vs Experiment: Segment sum

Simulation

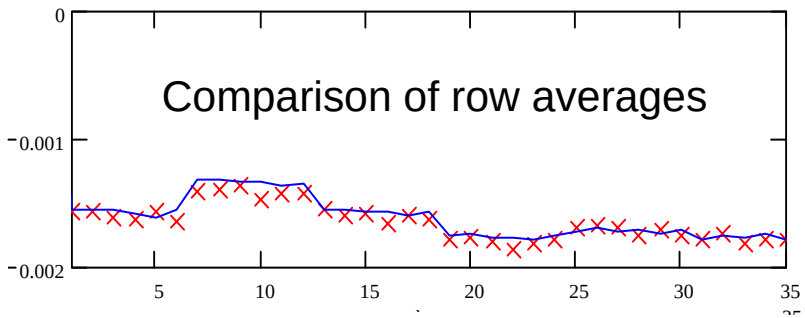


Measured



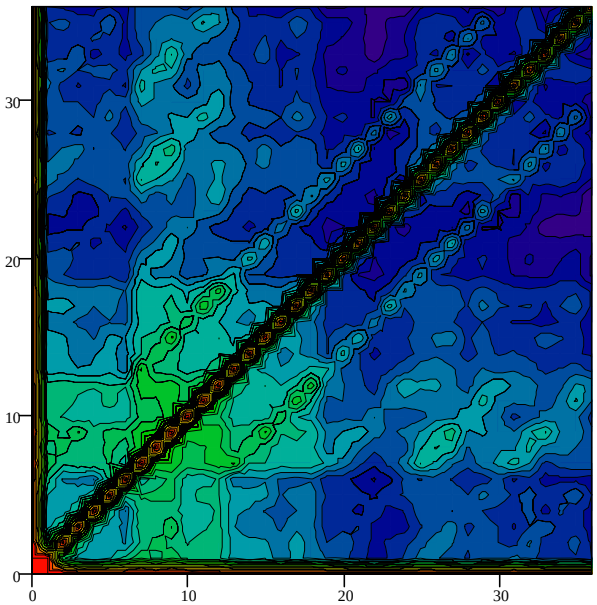
Meas. ×××

Theory ——

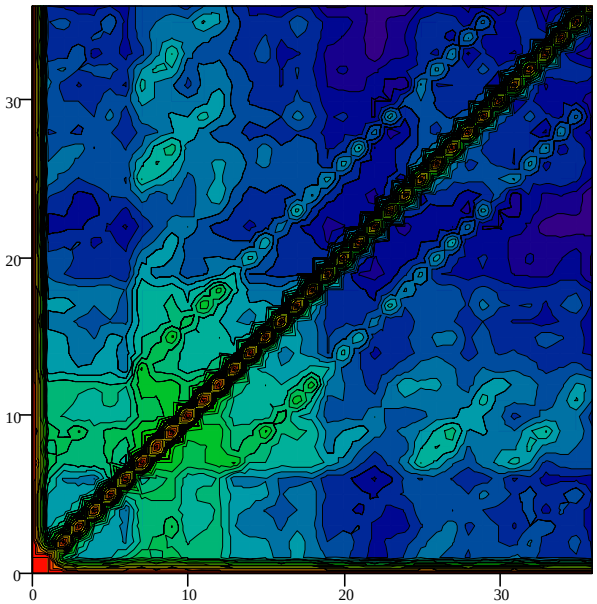


2folds - segment sum: experim. results

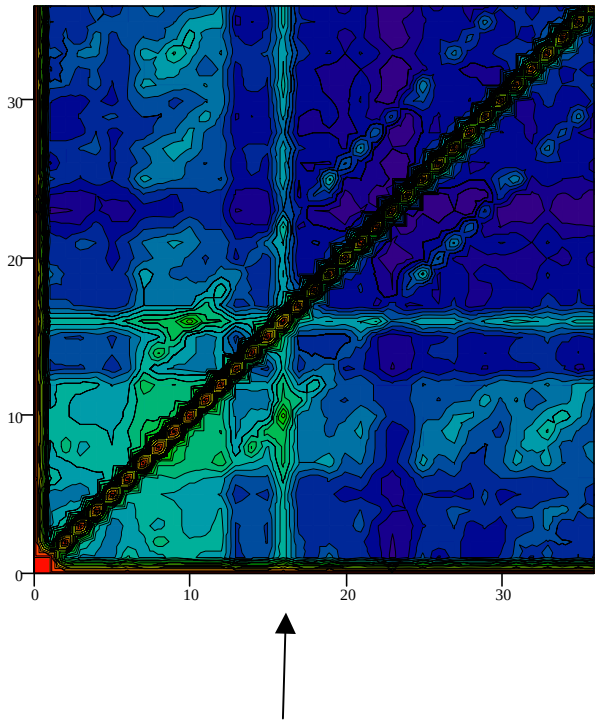
GSI cryostat – S001



French cryostat – S002

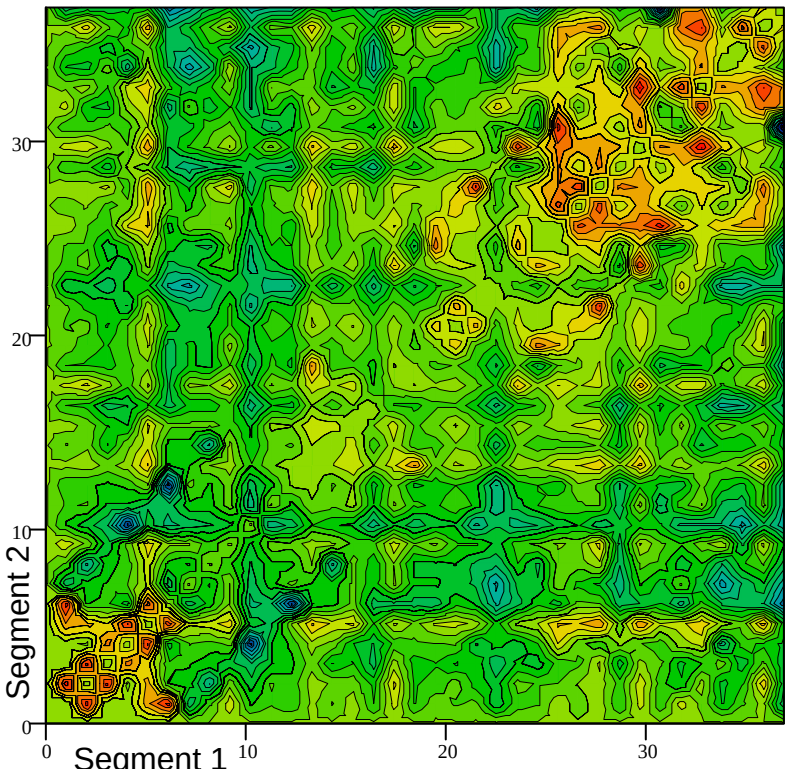


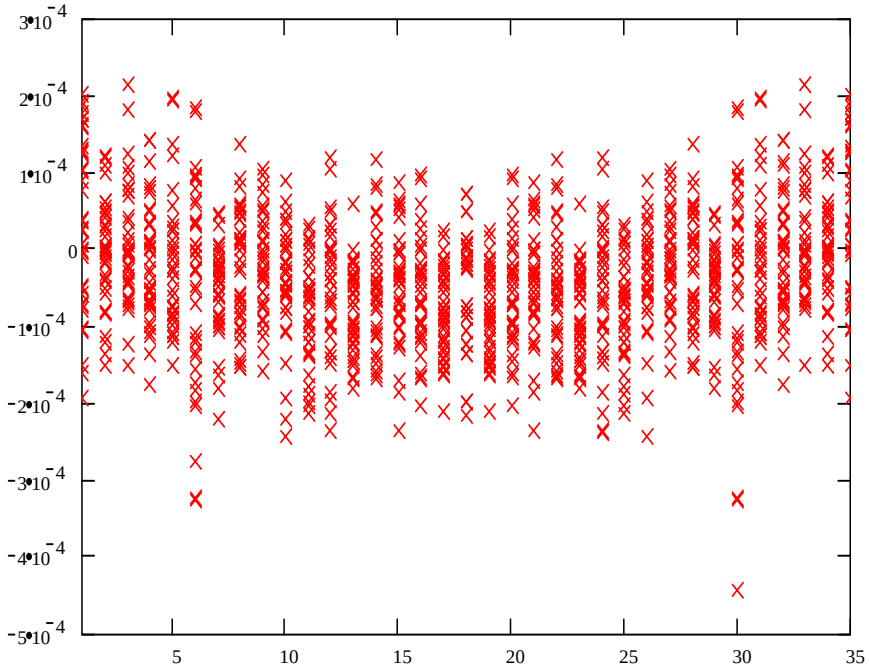
Italian cryostat – S003



(Crosstalk in XIA)

Exp - theory





(Story X3)

Core Xtalk matrix elements

$$v_{out} := \begin{bmatrix} 1+\Delta_{00} & \Delta_{01} & \Delta_{02} & \cdots \\ \Delta_{10} & 1+\Delta_{11} & \Delta_{12} & \cdots \\ \Delta_{20} & \Delta_{21} & 1+\Delta_{22} & \cdots \\ \cdots & \cdots & \cdots & \cdots \end{bmatrix} \cdot i$$

Core projection on singles:

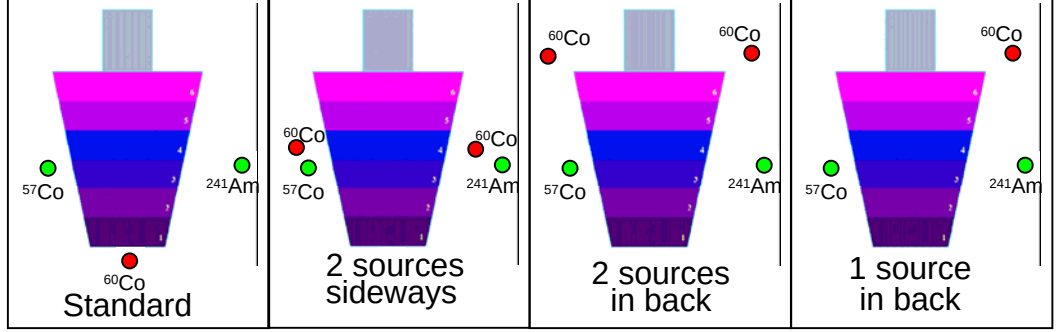
i	$v_{out}(core)$
$(-1 \mid 1 \quad 0 \quad 0 \ldots)$	$-(1+\Delta_{00})+\Delta_{01}$
$(-1 \mid 0 \quad 1 \quad 0 \ldots)$	$-(1+\Delta_{00})+\Delta_{02}$
$(-1 \mid 0 \quad 0 \quad 1 \ldots)$	$-(1+\Delta_{00})+\Delta_{03}$

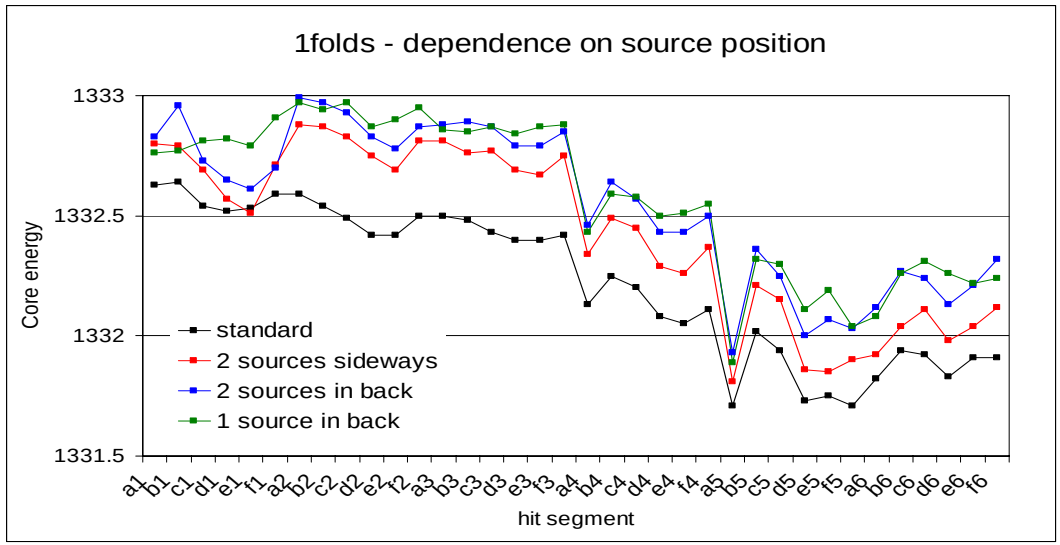
Measured core matrix elements

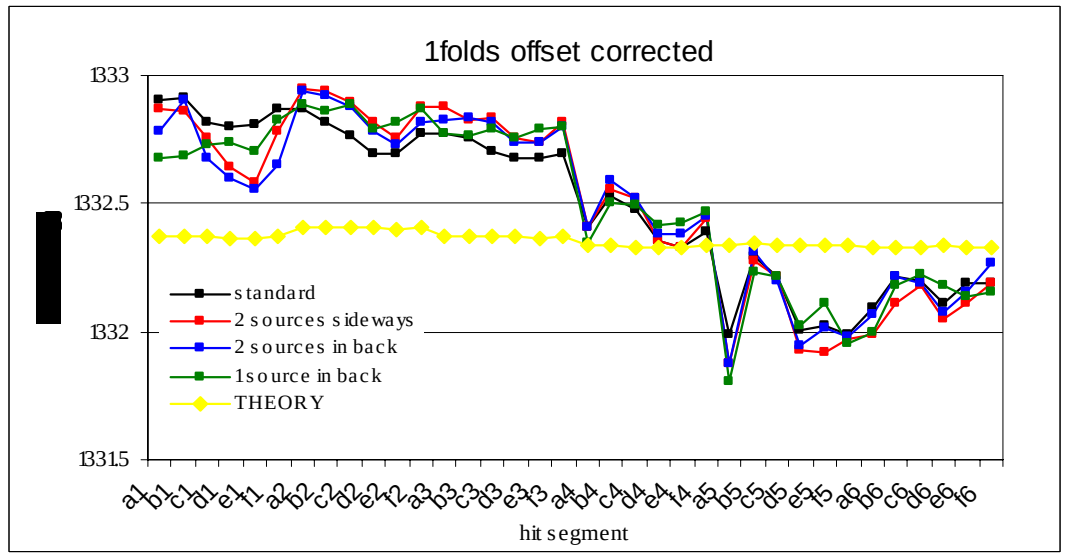
disagree with simple theory

⇓

Is it at least linear?

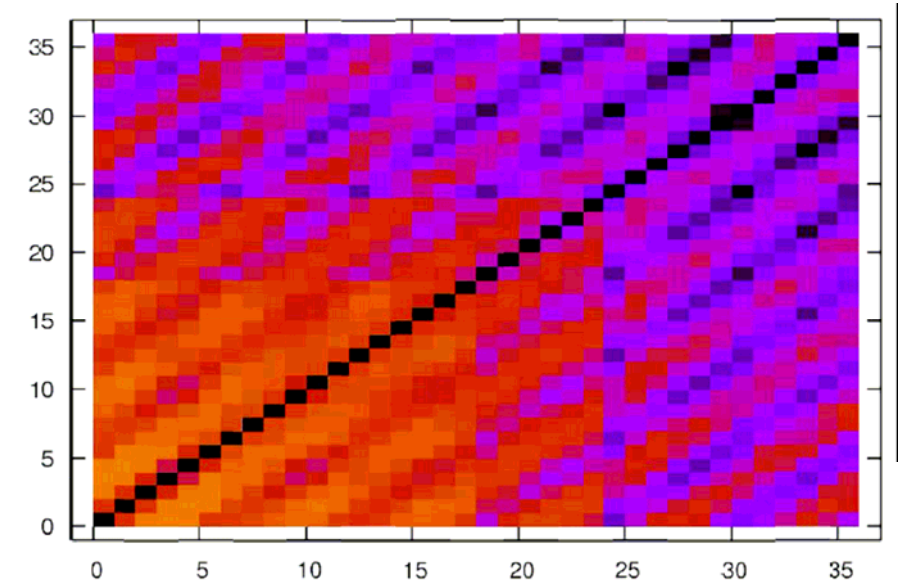




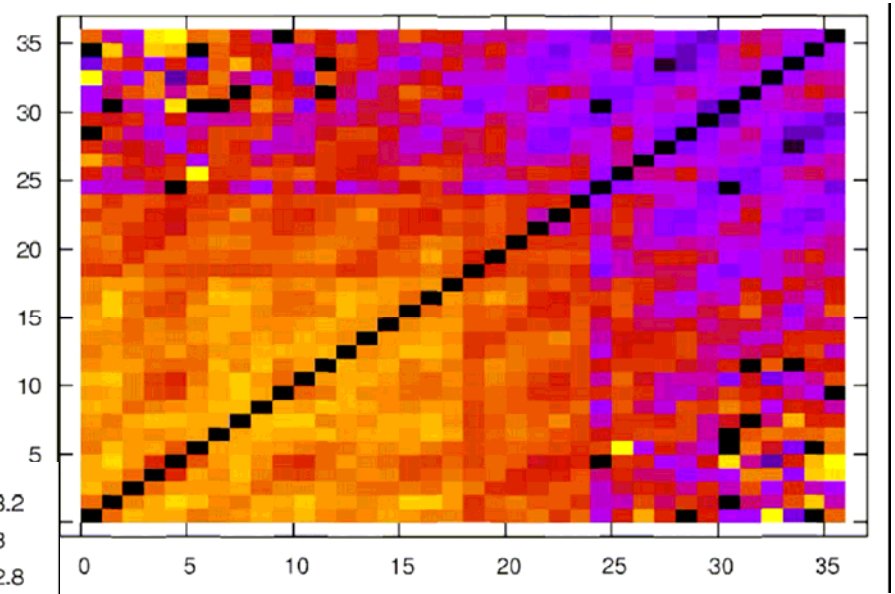


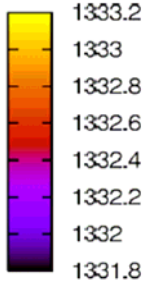
Crosstalk in doubles vs source position

GSI standard = source in front

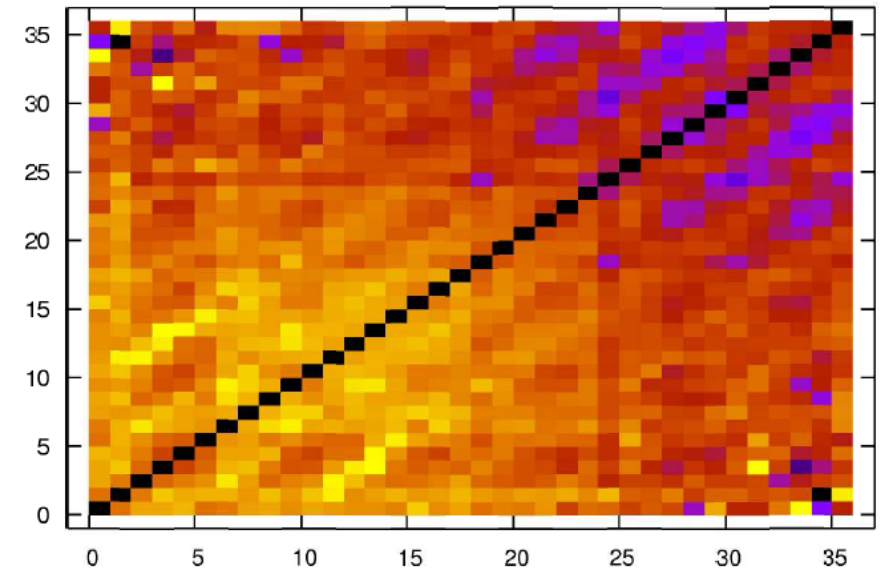


2 Sources aside

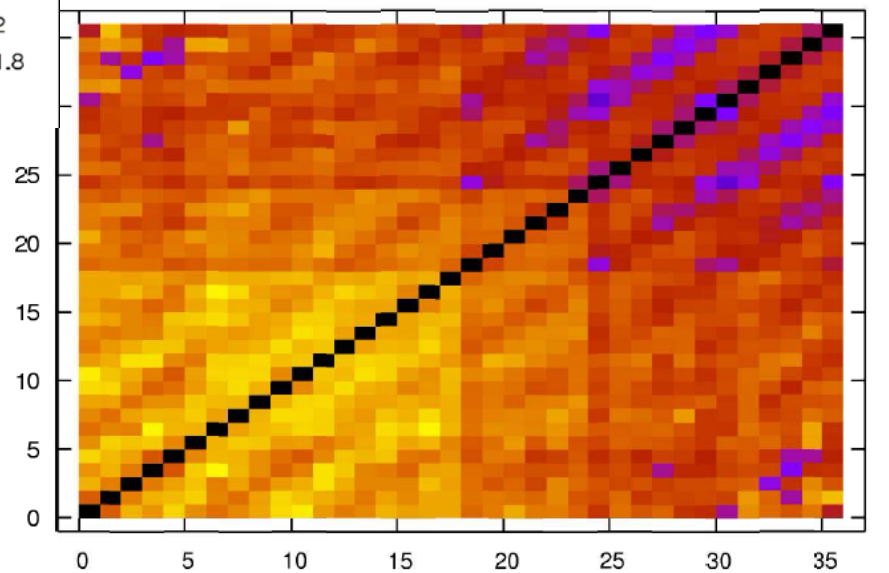




2 Sources in back



1 Source in back



Core: Theory (GSI std meas)

Simulation with:

+ E(x) = E(y) = ½

+ no seg-seg crosstalk

Simulation with:

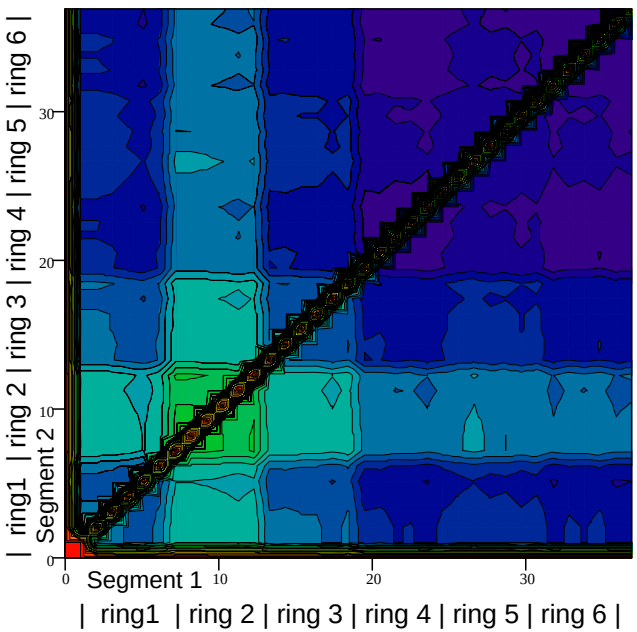
+ Exp. Xtalk matrix elements from singles

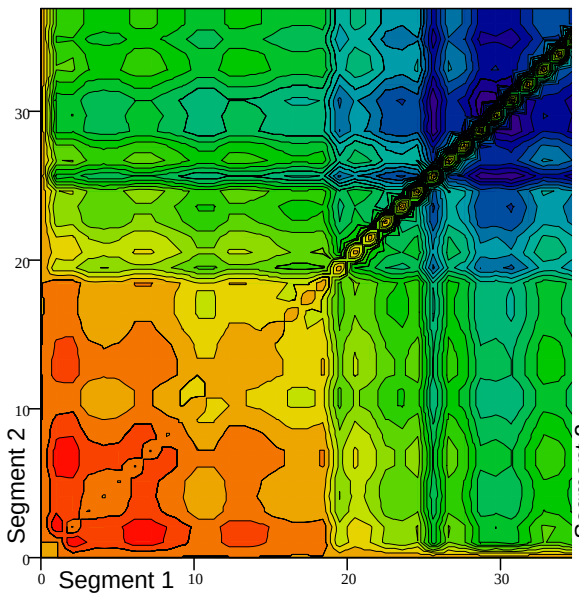
+ E(x) = E(y) = ½

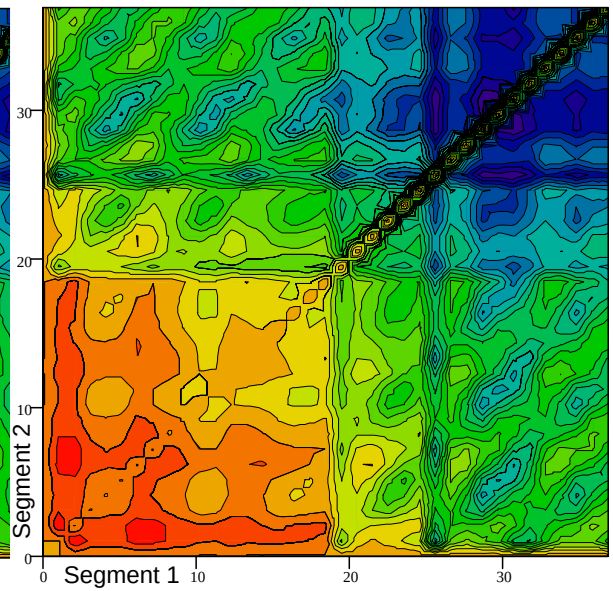
Simulation with:

+ Exp. Xtalk matrix elements from singles

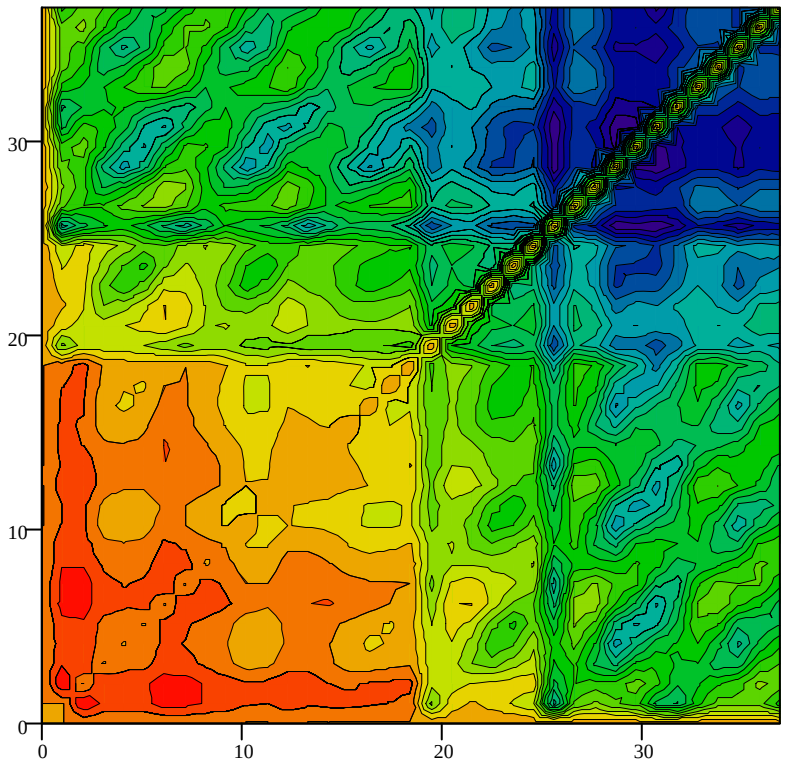
+ E(x) = 1-E(y) from data



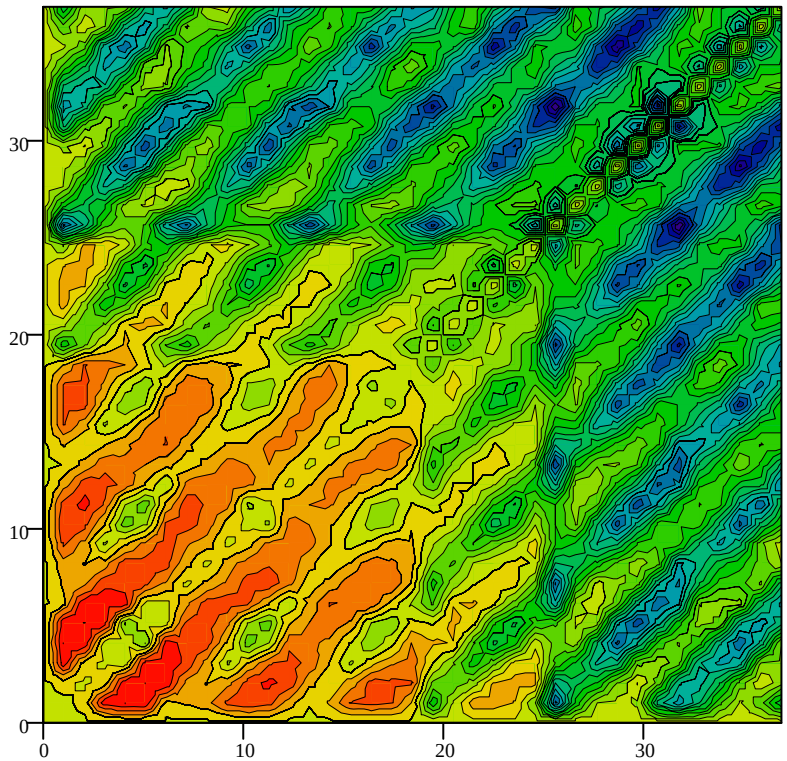




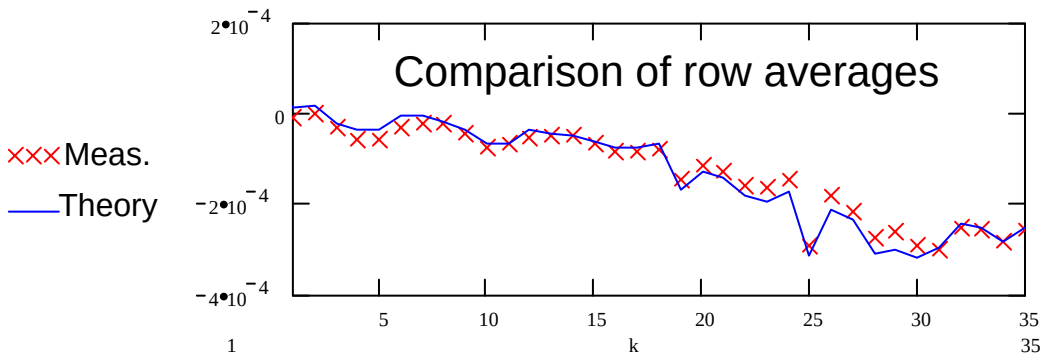
Core : “1folds” vs 2folds



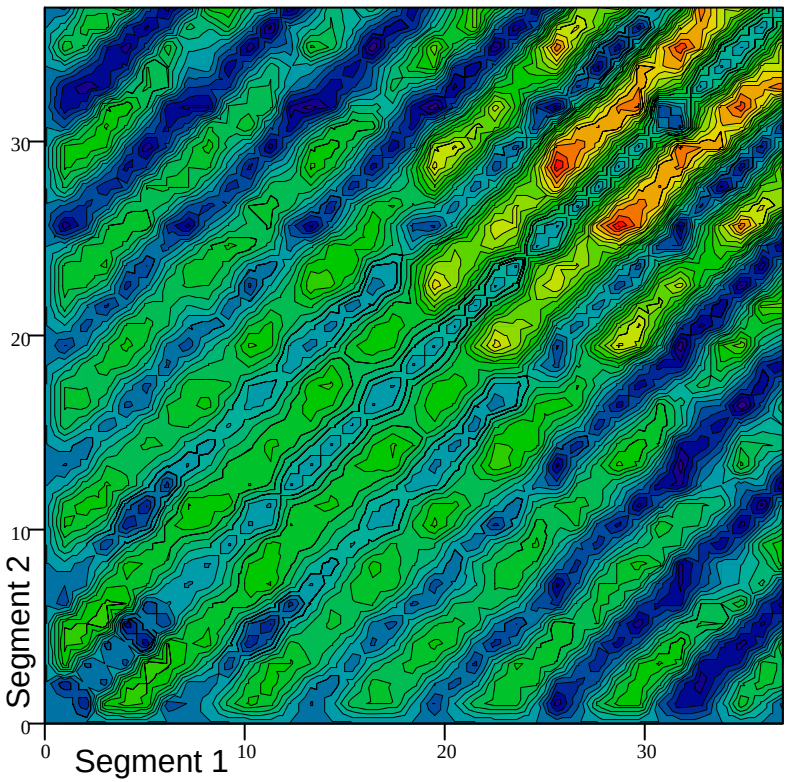
SimCore

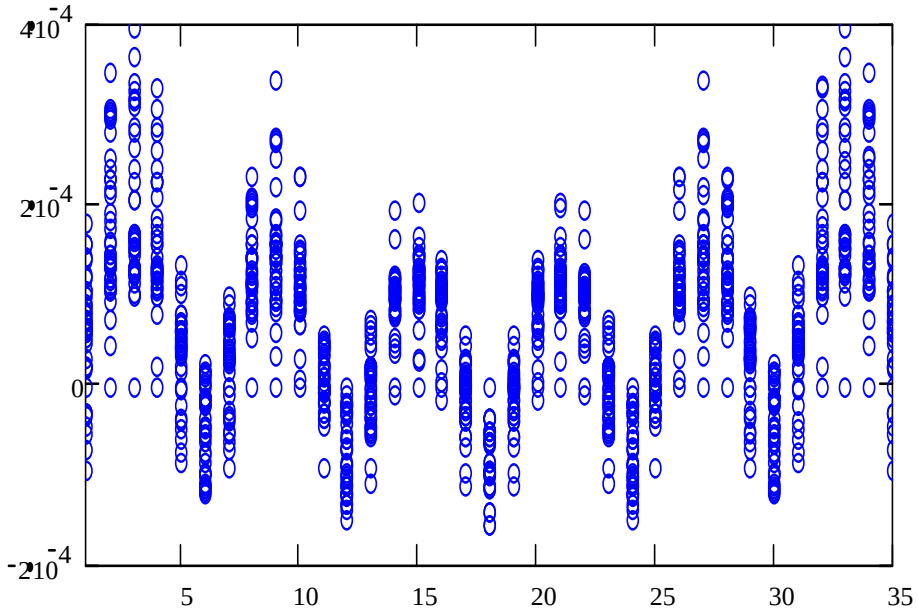


ExpCore



Difference “1folds”- twofolds

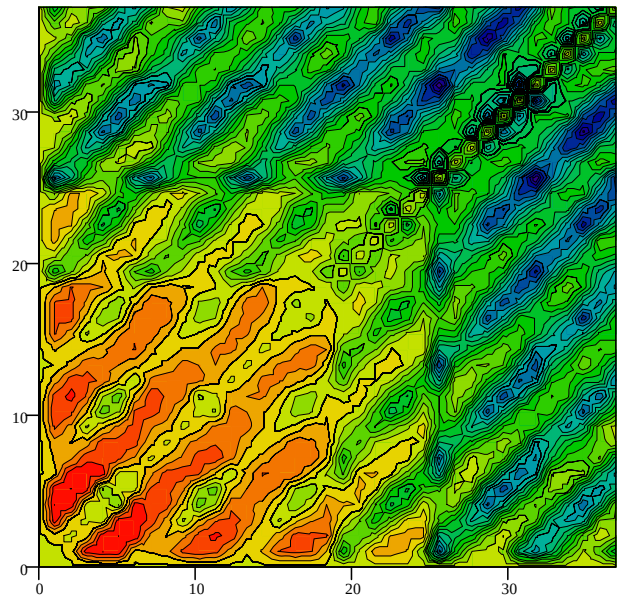




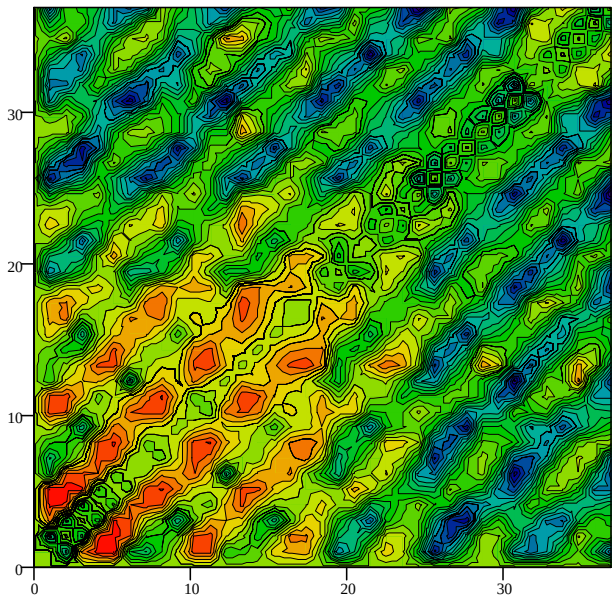
Core Xtalk is non-linear

2folds - core: experim. results

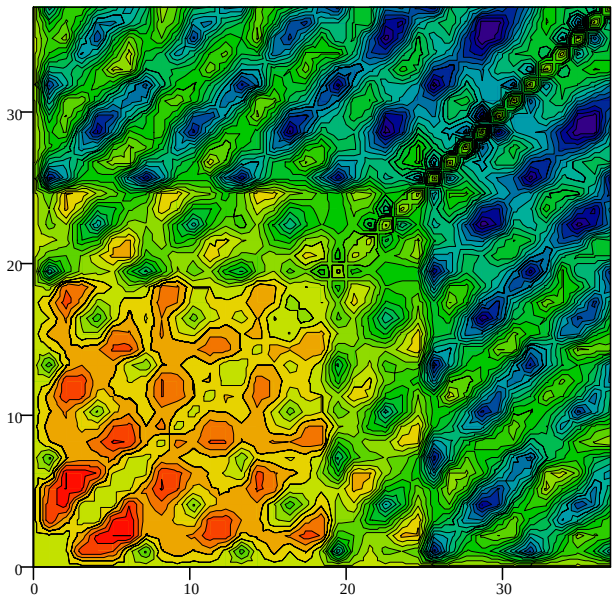
GSI cryostat –S001 (std)



French cryostat – S002



Italian cryostat – S002



Results:

Different crosstalk contributions:

- core to segment crosstalk:

  from core to segment on the 1.6 ‰ level in reality, 1.3 ‰ explained by the model (Most important !) – descrepancy is systematic.

- Segment to segment crosstalk negligible: maximally 0.4 ‰ between neighboring segments

- Segment to core crosstalk: ~ 0.3-0.6 ‰ level observed min 10 times bigger than predicted – behaves nonlinear

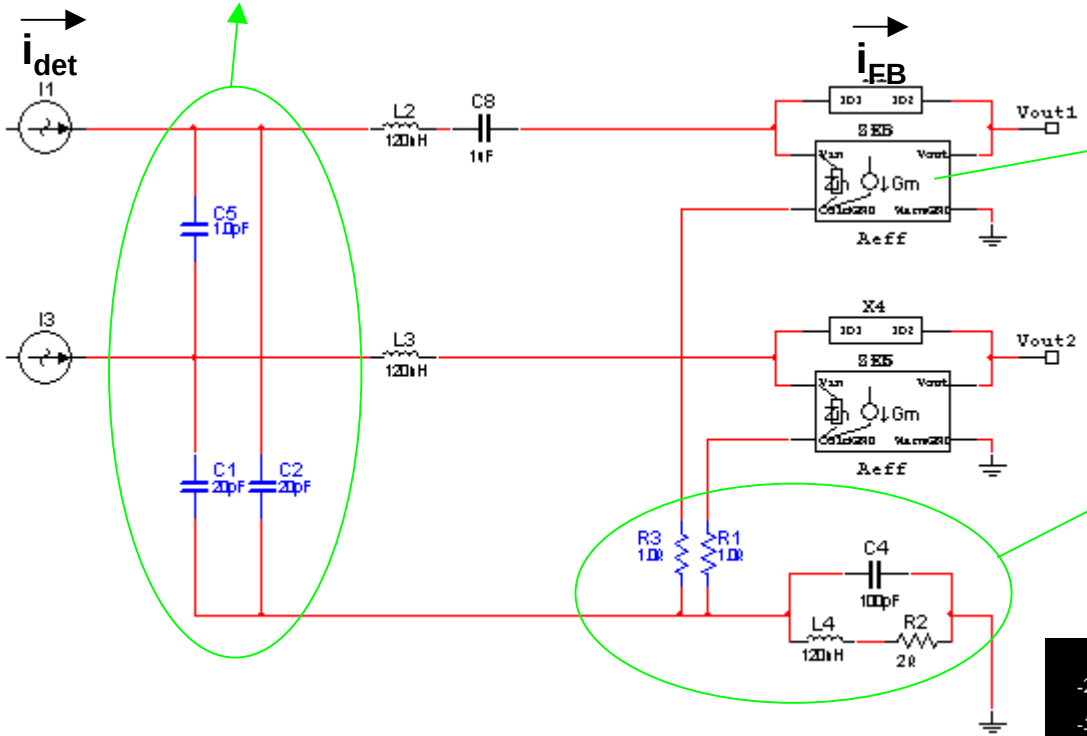
Segment-to-Core

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

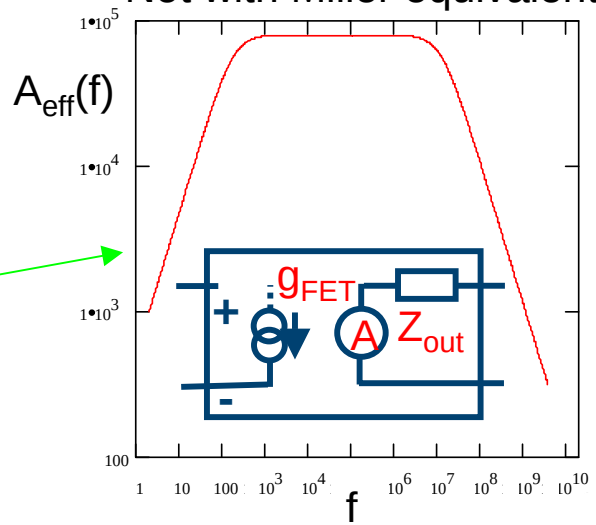
Core-to-Seg Segment-to-Segment

Towards more realistic models

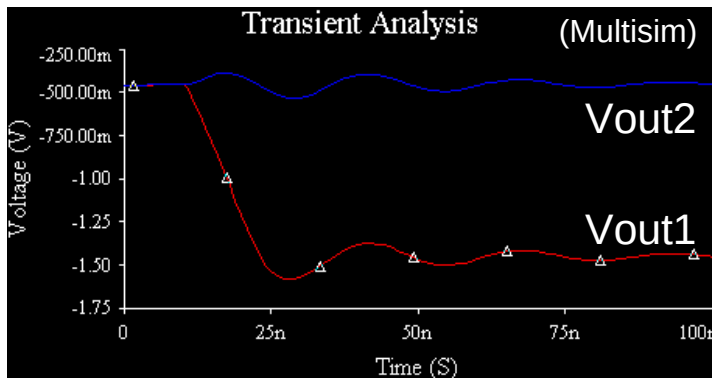
1st Source of crosstalk:
Capacitive coupling
+ wire inductivities



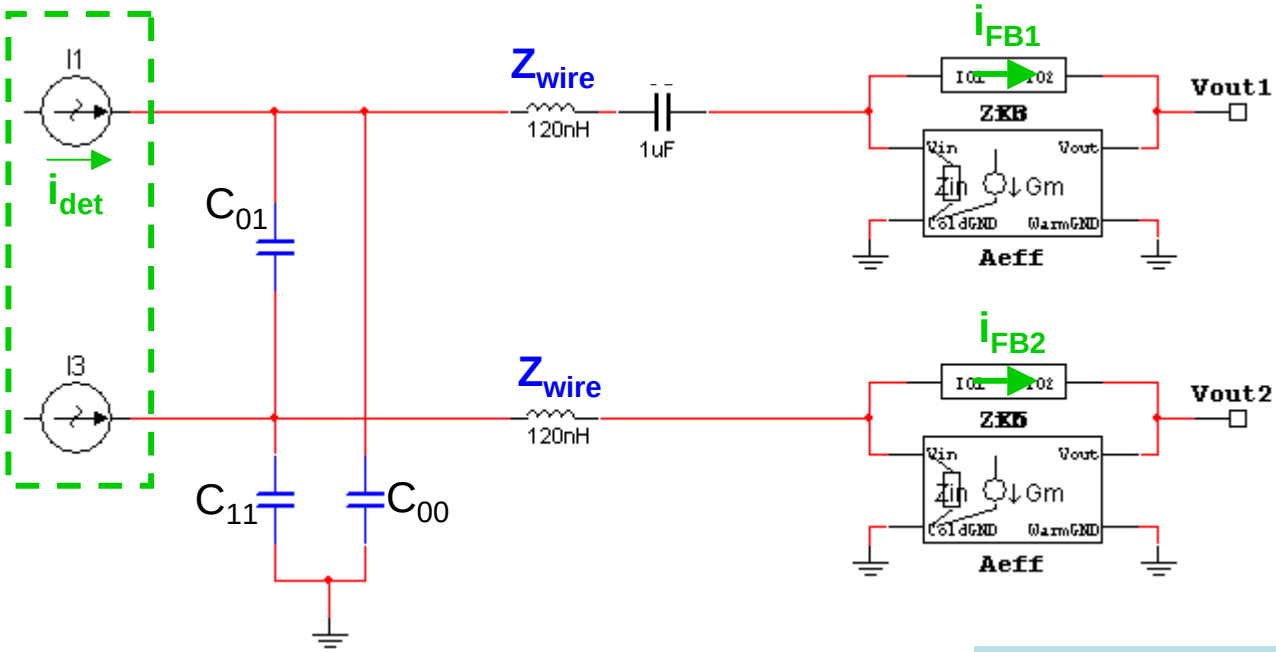
$A_{eff}(f)$ more realistic,
Not with Miller equivalent



2nd Source of crosstalk:
Weak ground connections
... See Gheorghe's talk...



Detector „eigenfrequencies“



$$i_{det} := Z \cdot i_{FB}$$

Z ~ identity ⇔ small crosstalk

$$i_{FB} := \frac{1}{\det(Z)} \cdot \left[\begin{bmatrix} 1+\Delta_{00} & \Delta_{01} \\ \Delta_{10} & 1+\Delta_{11} \end{bmatrix} + s \cdot Z_{wire} \cdot \begin{bmatrix} C_{00} & -C_{01} \\ -C_{01} & C_{11} \end{bmatrix} \right] \cdot i_{det}$$

=1 below resonance

Old solution

Extra term at high frequencies

Wire impedance Z_{wire} :

$$L_{wire} = \frac{\mu \cdot l}{2\pi} \left(\ln\left(\frac{2l}{r_0}\right) - 1 \right)$$

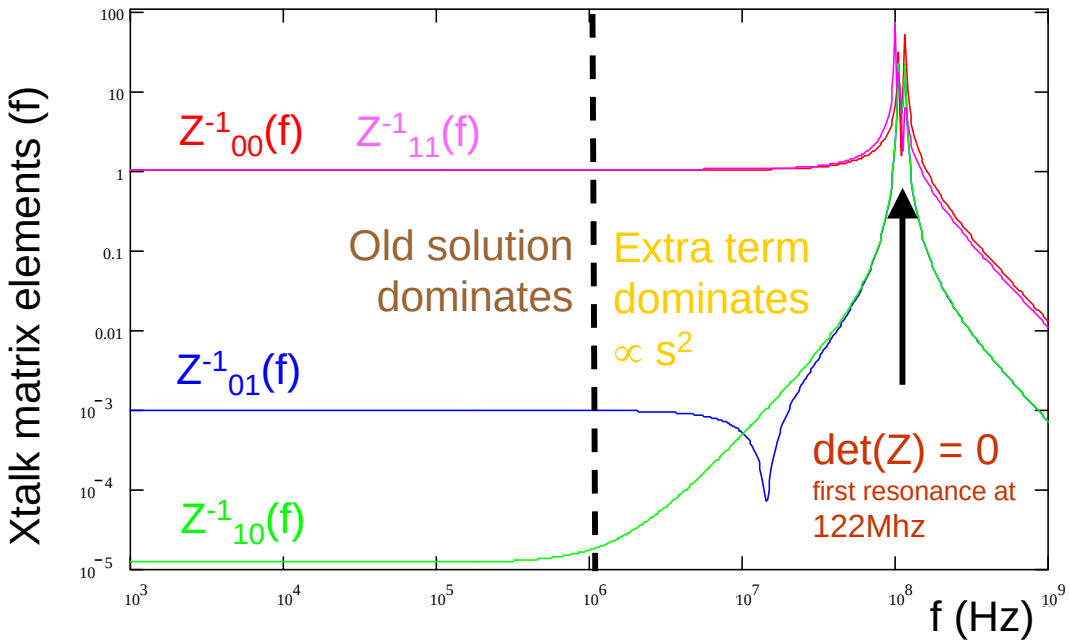
$r_0 = \text{wire radius} \approx 75\,\mu\text{m}$

$l = \text{length wire} \approx 9\text{cm}$

$\Downarrow$

$L_{wire} = 122nH$

Detector „eigenfrequencies“



Z^{-1}

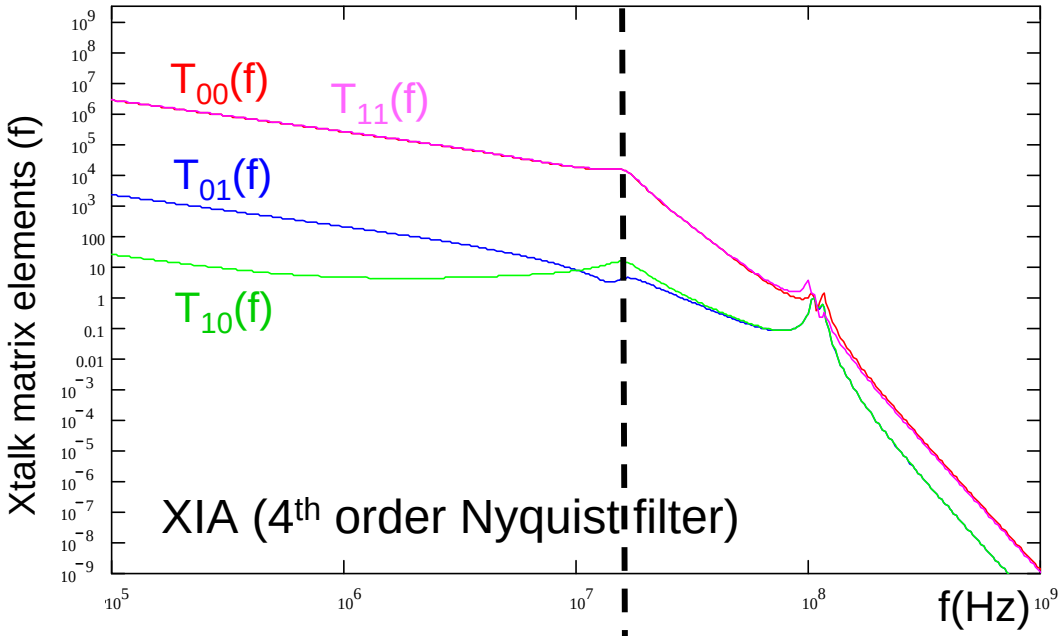
$$i_{FB} := \frac{1}{\det(Z)} \cdot \left[\begin{bmatrix} 1+\Delta_{00} & \Delta_{01} \\ \Delta_{10} & 1+\Delta_{11} \end{bmatrix} + s \cdot Z_{wire} \cdot \begin{bmatrix} C_{00} & -C_{01} \\ -C_{01} & C_{11} \end{bmatrix} \right] \cdot i_{det}$$

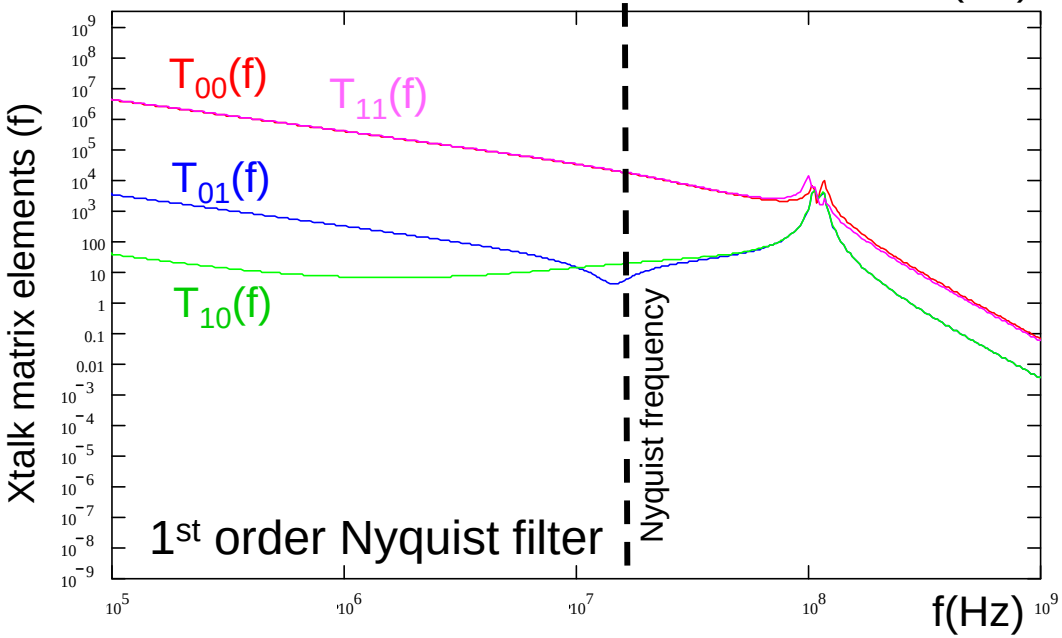
=1 below resonance

Old solution

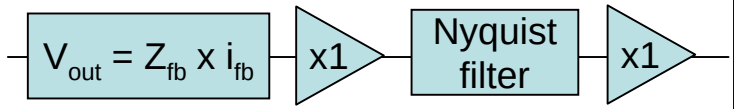
Extra term at high frequencies

AFTER NYQUIST FILTER…



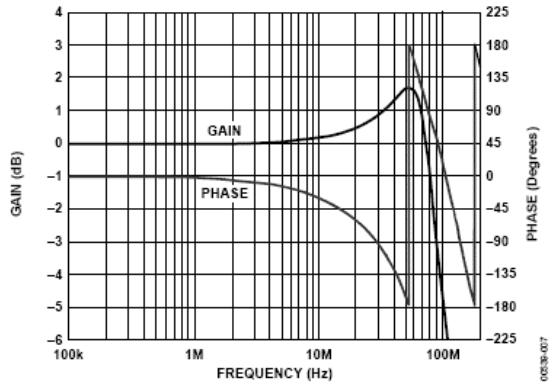


Define matrix **T** = transfer till digitizer =



In ideal case, but…

*Real buffer stages



*PCB design board

⇓

*Reality is worse