Cross-talk and signal readout from sapphire strip detector using FERS cards

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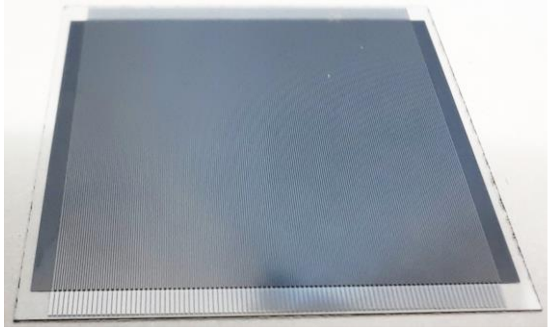
Main Goal for Developing and Creating the Gamma Beam Profiler

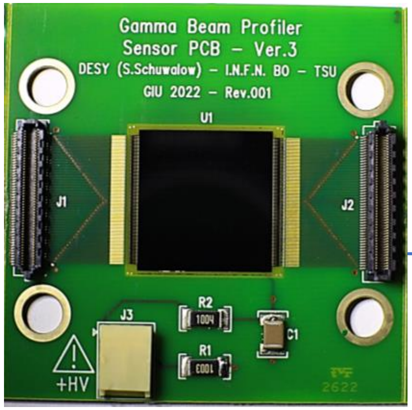
The primary goal is to accurately measure the transverse angular distribution of gamma-ray photons produced in the LUXE experiment.

This measurement is critical for obtaining detailed information about the intensity of the laser pulse colliding with the electron beam at the interaction point.

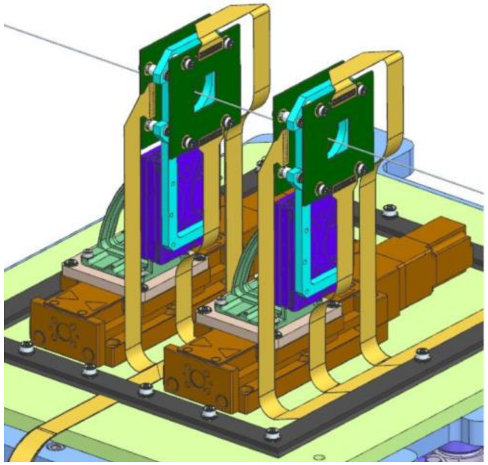
The GBP must be capable of withstanding high radiation levels (several MGy per year) and reconstructing the beam profile with high spatial resolution (approximately 5 µm).



odd strips



even strips



Challenges Encountered

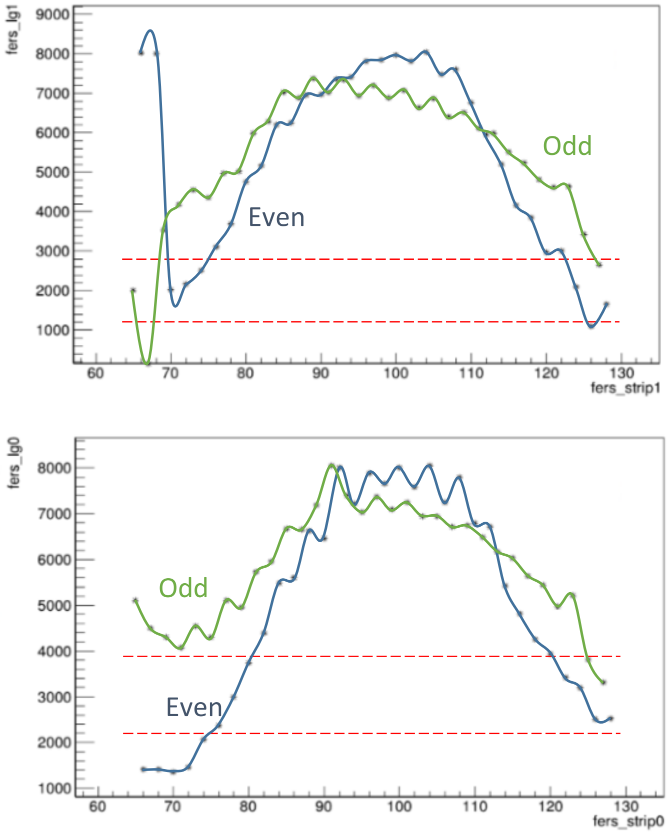
1. High Background Level

- **Description:** When the signal intensity reaches maximum, the baseline noise level ranges from 8 to 25 %.
- **Impact:** This high background noise complicates the accurate detection and reconstruction of the beam profile, introducing significant uncertainties of the beam charge estimation.

2. Odd-Even Channel Asymmetry

- **Description:** There is an unusual pattern where the intensity distribution of even and odd channels (sensor strips) splits into two distinct peaks instead of forming a single, smooth distribution.
- **Impact:** This distribution distorts the expected normal distribution, making it challenging to interpret the true beam profile even if reconstruction is based on only even or odd channels.

Gaussian Beam reconstruction by GBP
(sigma ~ 1x1 mm)



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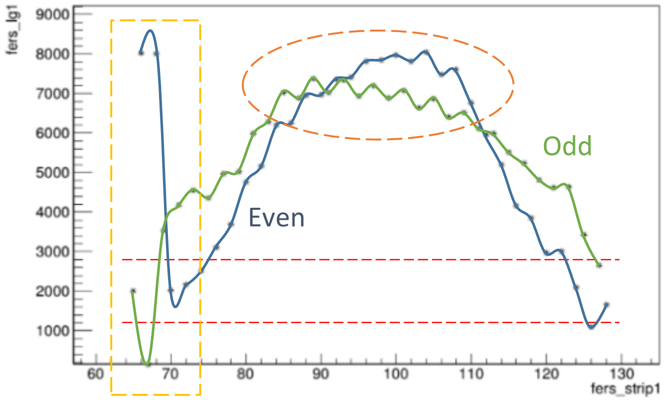
3. Profile Shape Distortions

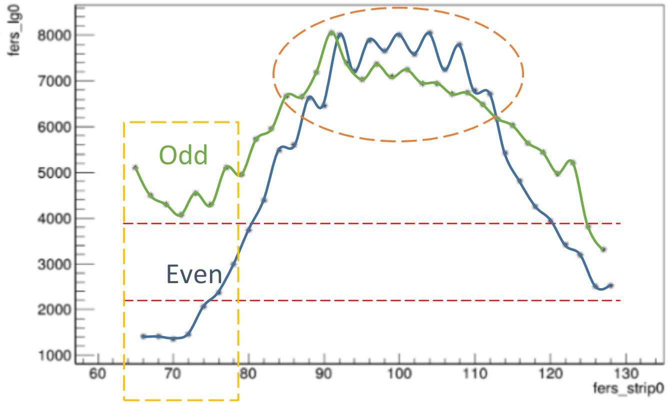
- **Description:** The beam profile is significantly distorted both at the centre and the edges. There are significant intensity spikes at the extreme channels.
- **Impact:** These distortions lead to incorrect reconstruction of the beam profile and estimation of all parameters.

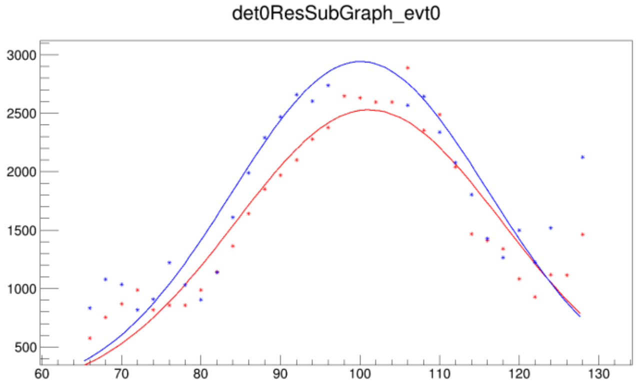
4. Systematic Signal Fluctuations

- **Description:** There are systematic fluctuations in the signal of neighbours' channels that do not appear randomly. The synchronic intensity 'jumping' of even and odd strips with/without beam was observed.
- **Impact:** These fluctuations lead to errors that have yet to be assessed.

Gaussian Beam reconstruction by GBP
(sigma ~ 1x1 mm)



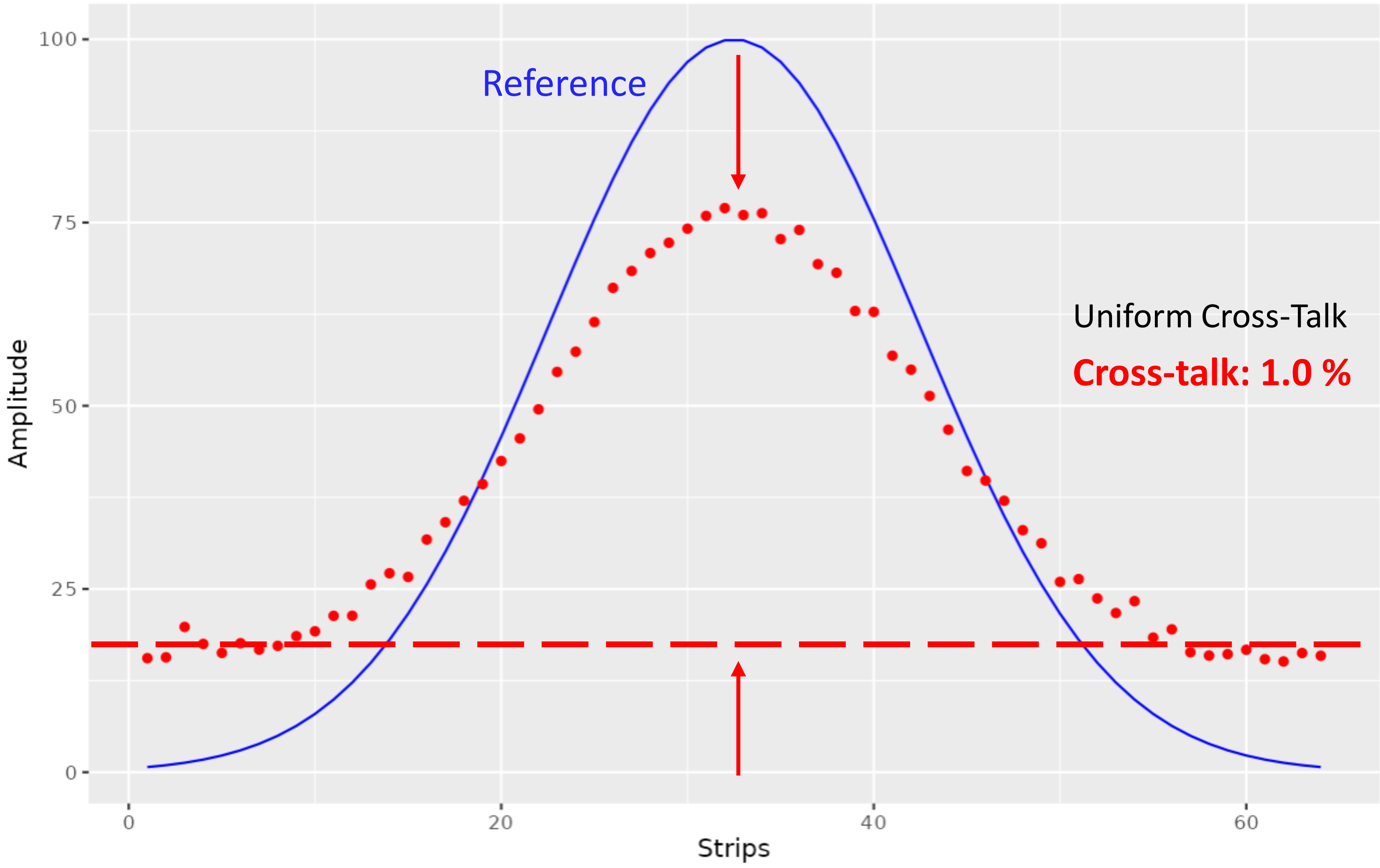




Cross-talk Simulation: Uniform type

Type of Signal: Gaussian
Mean Amplitude: 100

RMS Spread: 0
Noise RMS Value: 1



Reference

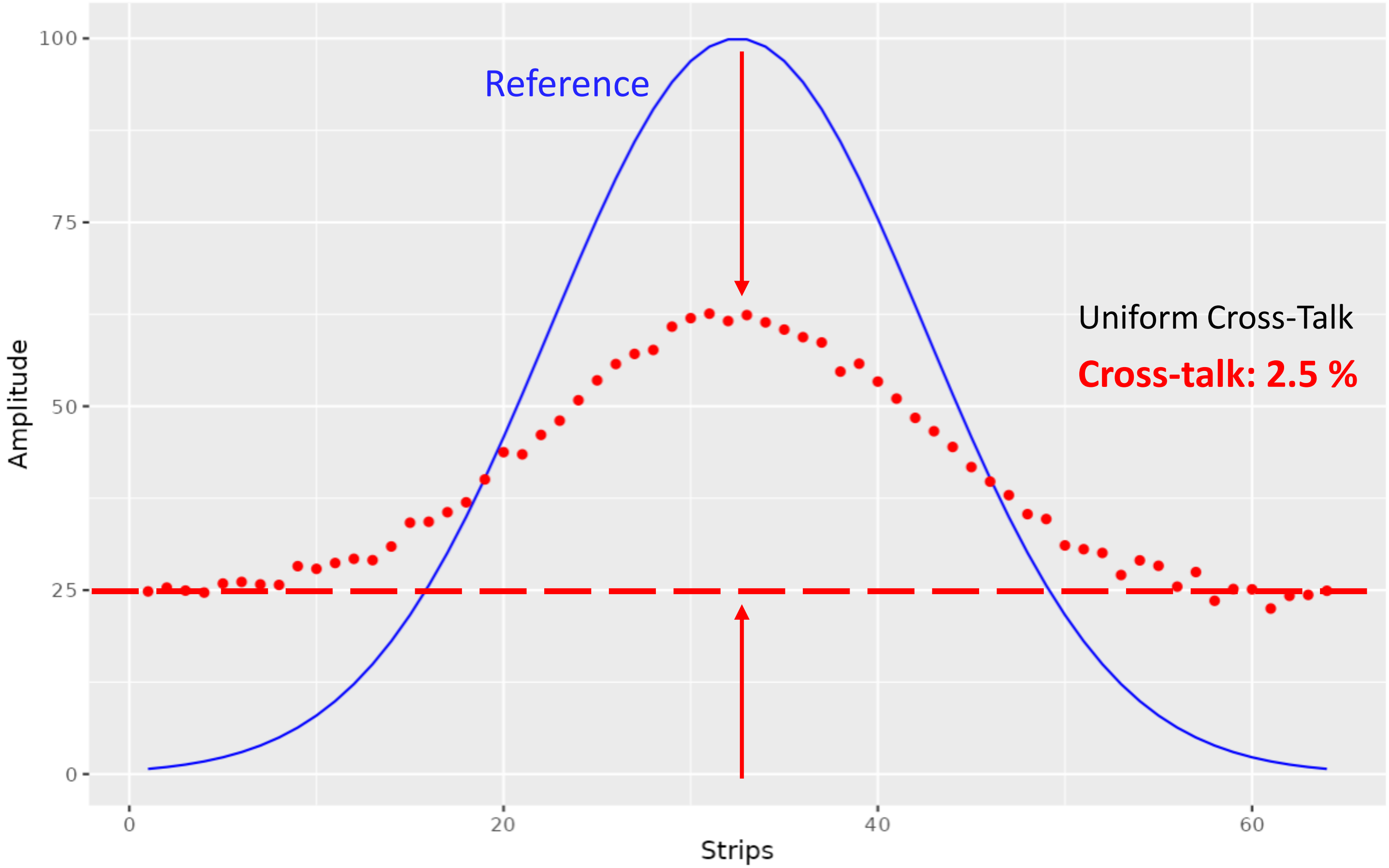
Uniform Cross-Talk

Cross-talk: 1.0 %

Cross-talk Simulation: Uniform type

Type of Signal: Gaussian
Mean Amplitude: 100

RMS Spread: 0
Noise RMS Value: 1



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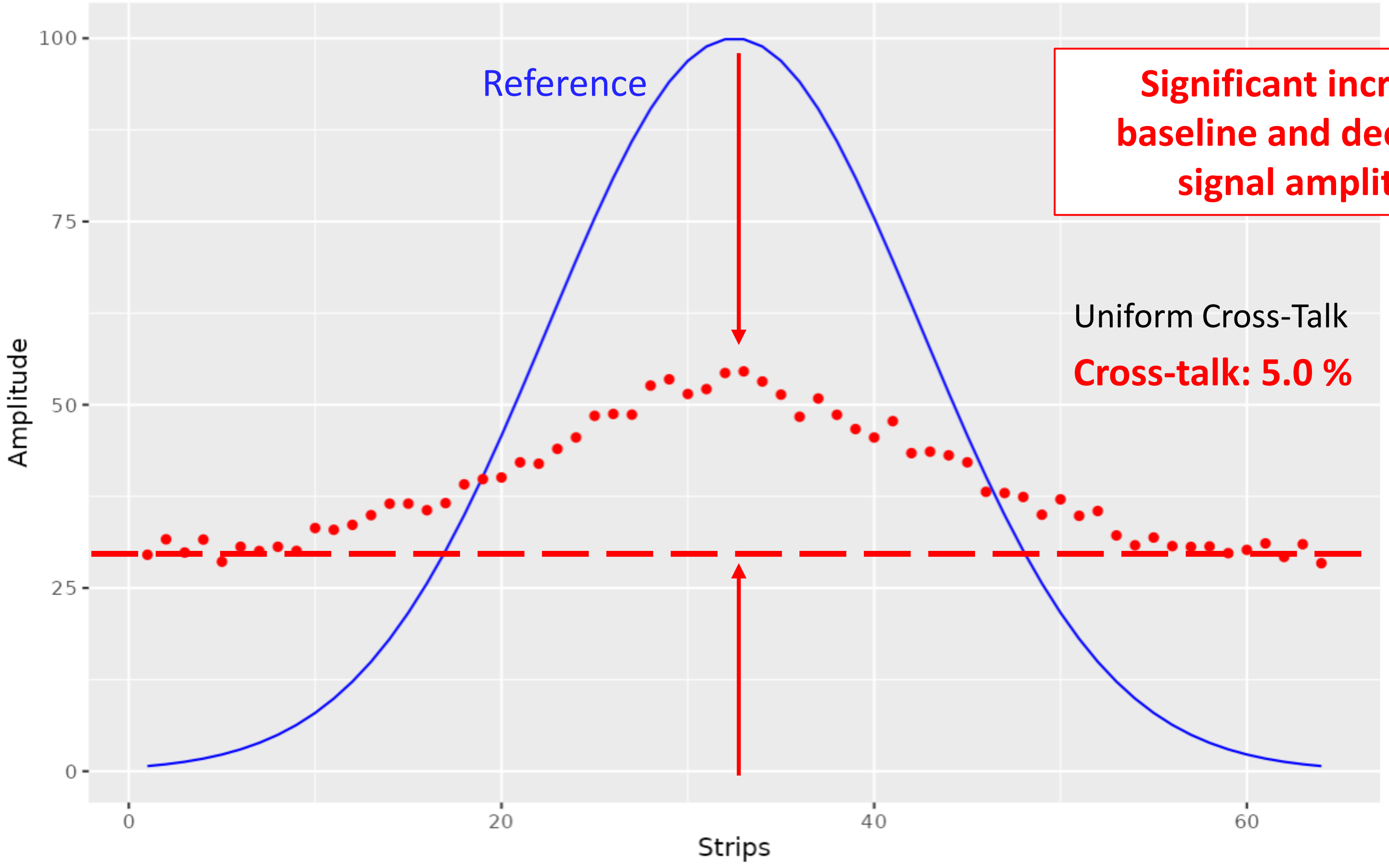


Significant increase in baseline and decrease in signal amplitude!

Uniform Cross-Talk

Cross-talk: 5.0 %

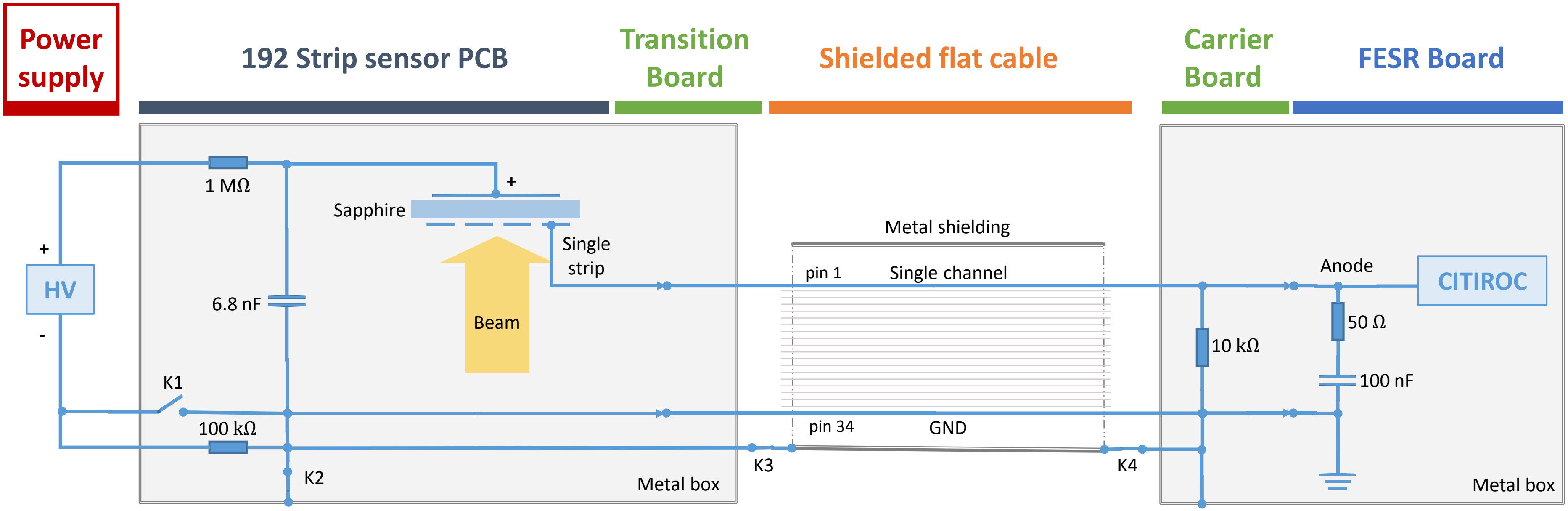
Key Issue:
Signal Distortions Affecting Beam Reconstruction

Problem:
The primary issue leading to errors in beam reconstruction is signal distortion. One of the most likely causes of this distortion is cross-talk. The cables cause most of the significant cross-talk effects.

Question:
How can we improve the signal readout system to suppress (minimize or compensate) cross-talk?

The meeting goal is to develop a roadmap to identify the main causes of beam shape distortion and to formulate an action plan to reduce the impact of crosstalk on the signal.

LUXE test setup

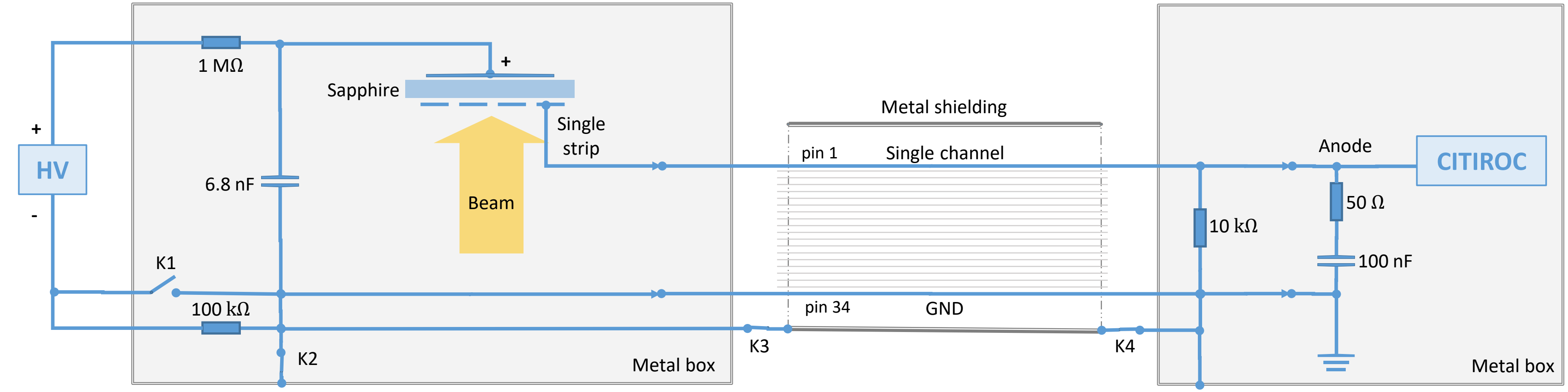


High Voltage Power Supply Unit (A1560H):

- Voltage range: 0 to 1 kV (positive)
- Isolated and floating

LUXE test setup

Power supply | **192 Strip sensor PCB** | **Transition Board** | **Shielded flat cable** | **Carrier Board** | **FESR Board**



Test Box:

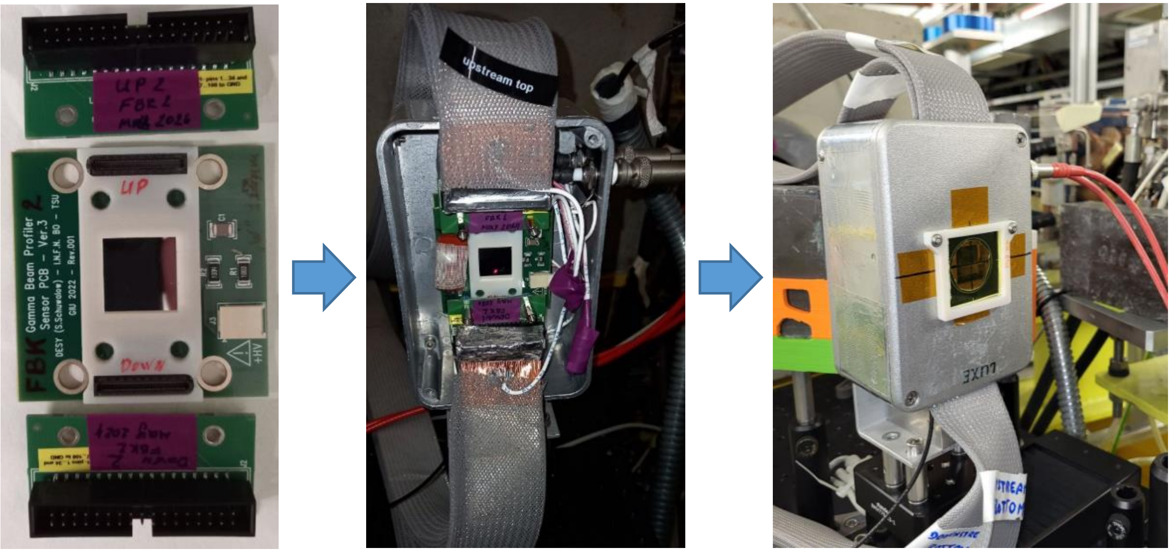
An aluminum box with two GBP samples connected through the transition boards to the cables. It's electrically isolated from the test bench.

192 Strip sensor:

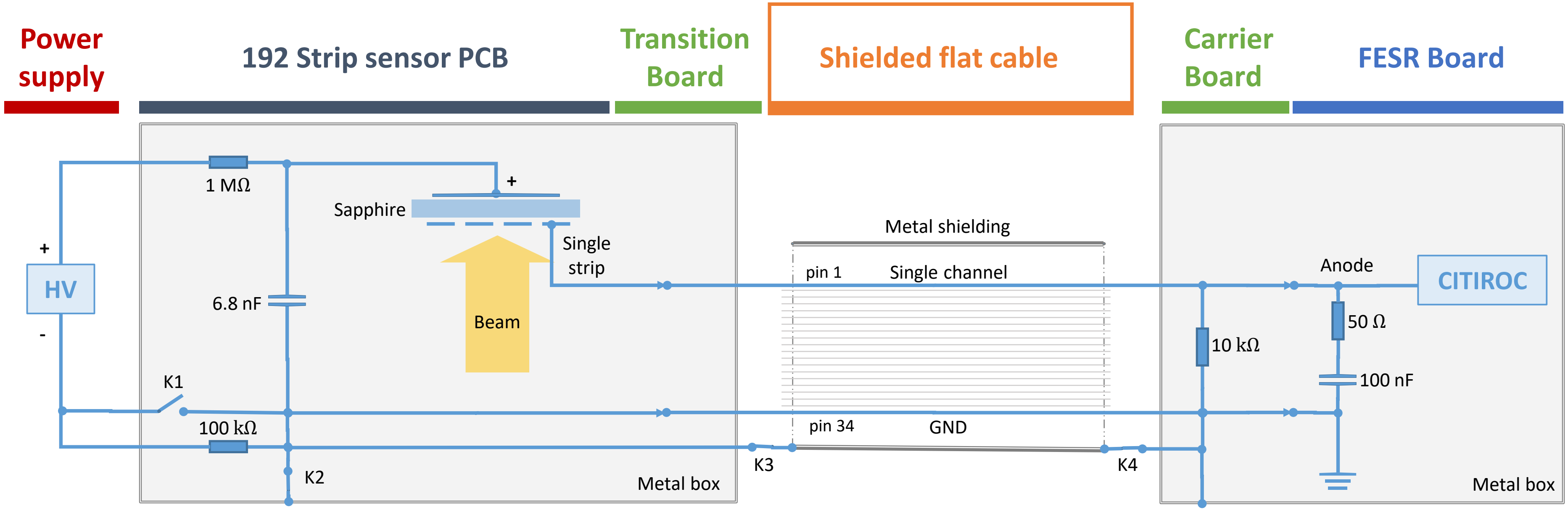
It interferes directly with the accelerator beam to reconstruct the beam profile.

Transition Board:

A small adapter board for connecting Samtec and a 34-pin flat cable.

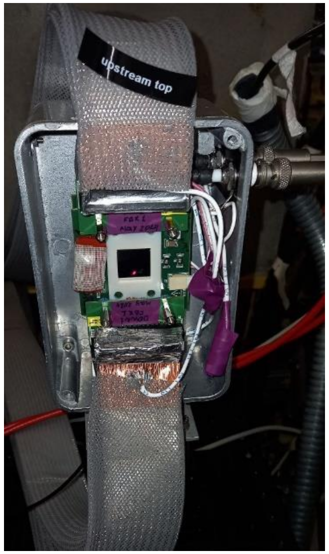


LUXE test setup

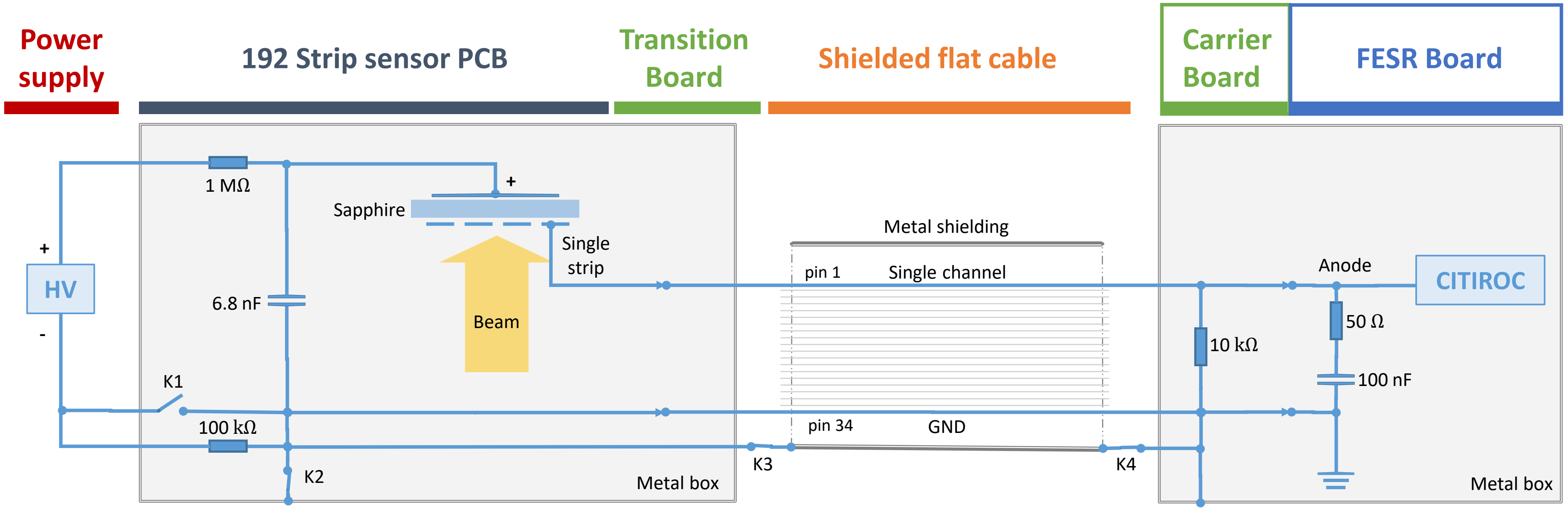


Cable:

- 34-pin flat cable with/without metal shielding. If the shielding is present it could be connected to the ground by key K3 and K4.
- 32 pins of the cable are used for transmitting signals from the 32 strips of the sensor, and 2 channels (pins 33 and 34) are for grounding.
- Cable type:
  1. 'Ribbon' - Flat Ribbon Cable (Copper shielding)
  2. 'Ribbon' - Flat Ribbon Cable (Aluminum shielding) – cable configuration in used now
  3. 'Nicomatic' - Shielded Flat Flexible Cable – next configuration for the tests

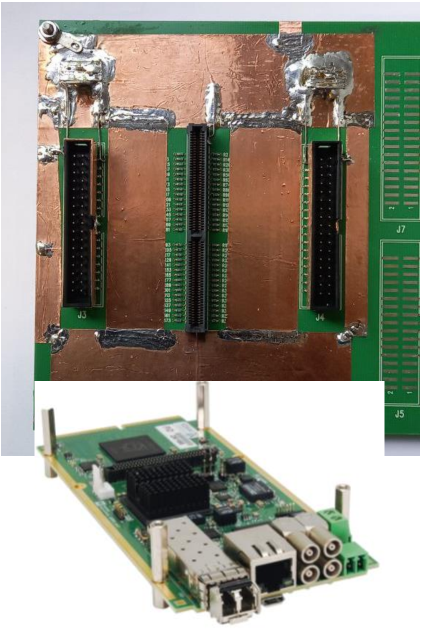


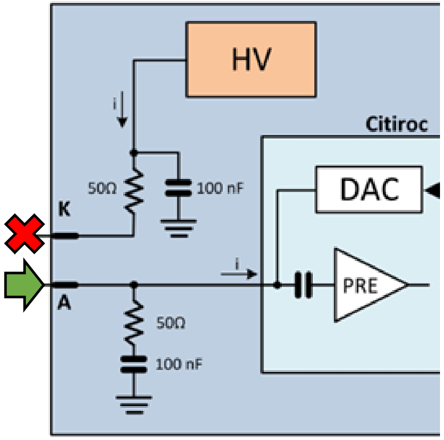
LUXE Test Setup



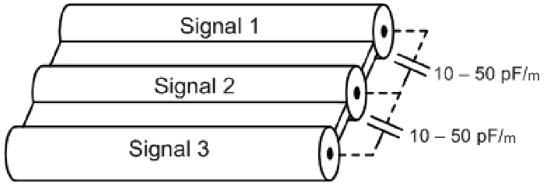
Carrier Board and **FERS Board:**

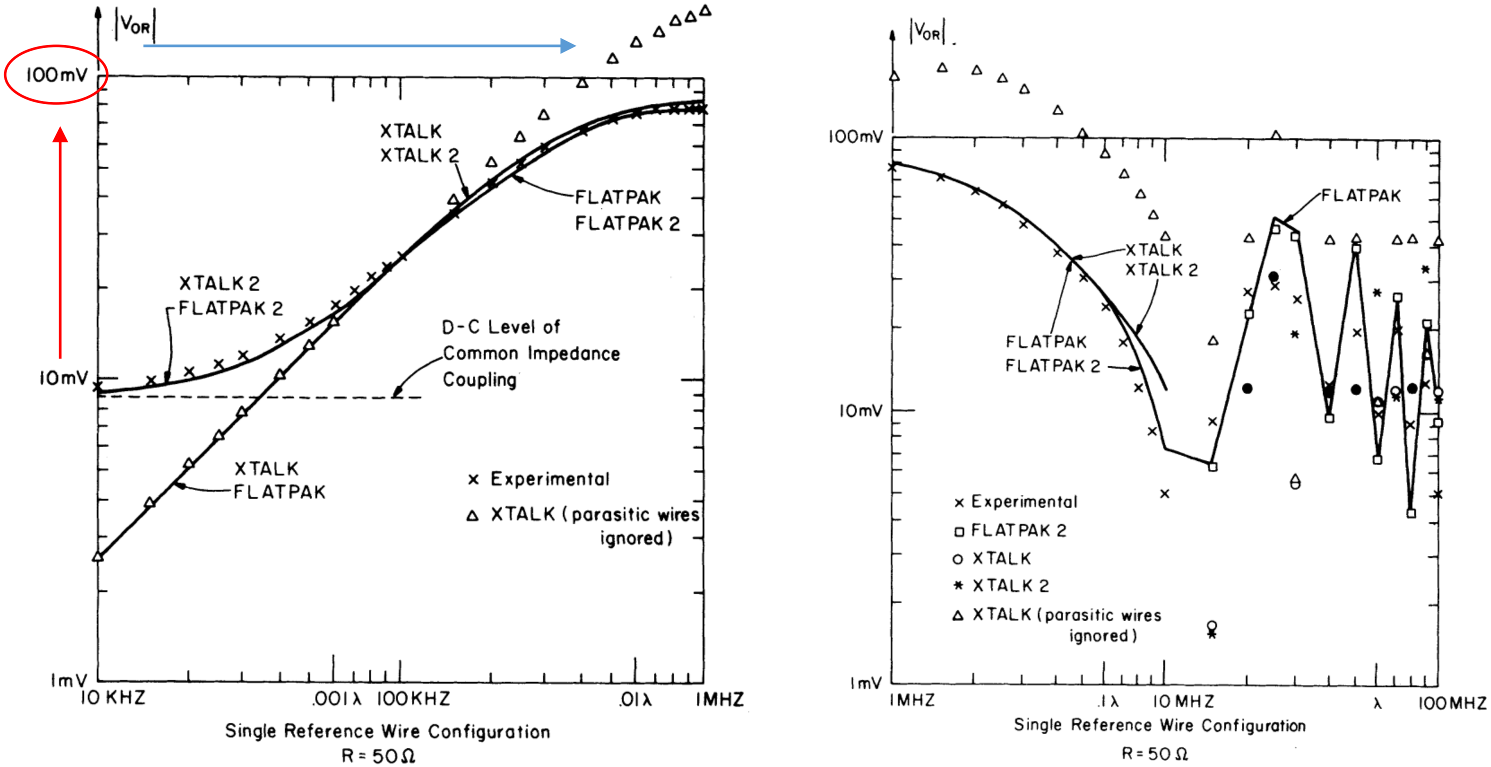
- An adapter board for connecting 34-pin flat cables and the FERS board.
- Two 34-pin cables connect to one FERS card and provide readout for 64 strips from one sapphire sensor.
- Each FERS anode (A) channel is connected to the ground through a 10 kΩ resistor. The cathode (K) channels are floating.





Cross-talk: Single-reference-wire configuration



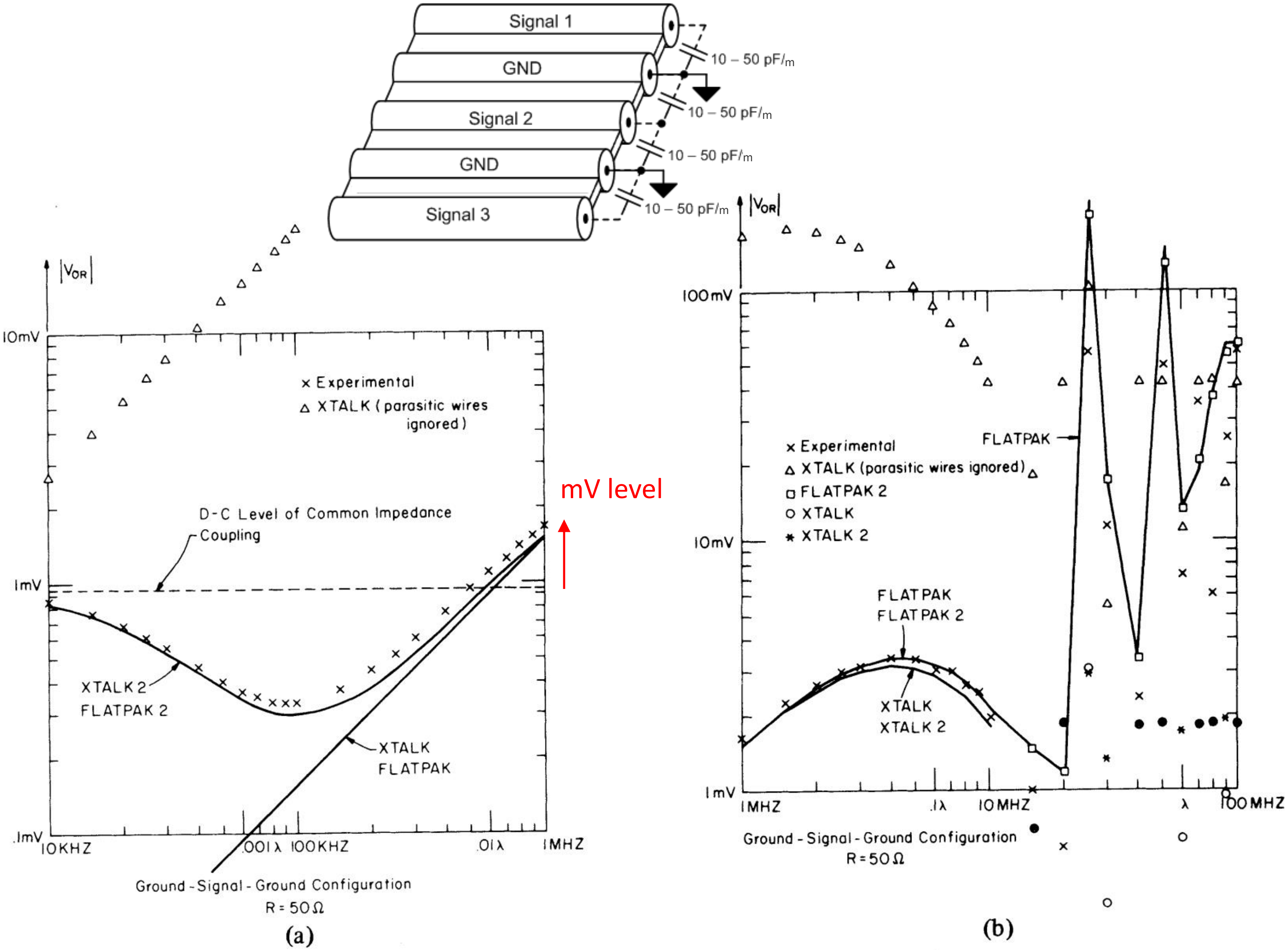


(a)

(b)

Fig. 7. Single-reference-wire configuration ($R = 50\ \Omega$).

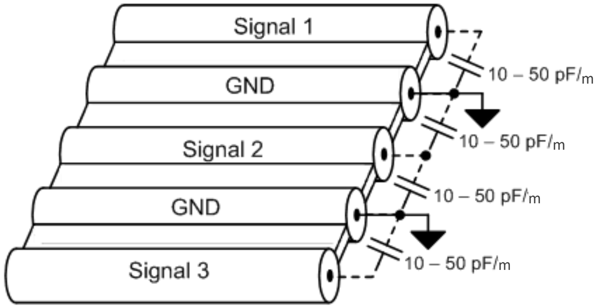
Cross-talk: Ground-signal-ground configuration



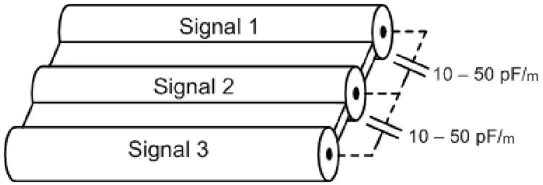
mV level

Fig. 9. Ground–signal–ground configuration ($R = 50\ \Omega$).

General approach to minimizing crosstalk



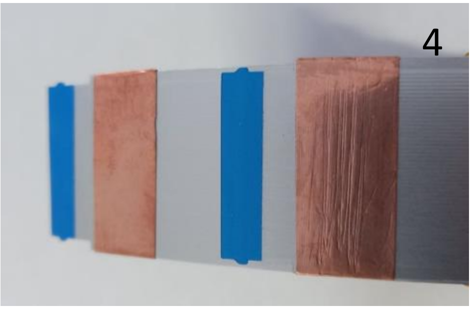
Crosstalk between adjacent channels is minimized when the signal and ground conductors are paired closely.



Conversely, the crosstalk levels increase significantly if the signal conductors are grouped without the accompanying ground return path (our case).

Cables List

N	Cable name	Shielding	Length (m)	Pitch (mm)	Impedance (Ω)	Capacitance (pF/m)
0	‘Ribbon’ - Flat Ribbon Cable (link)	Unshielded	1.1	1.27	105	49.2 pF/m
1	‘Ribbon’ - Flat Ribbon Cable (link)	Copper braid 25mmq cross section	3.0	1.27	105	49.2 pF/m
2	‘Ribbon’ - Flat Ribbon Cable (link)	Aluminum tape (link)	1.5, 1.0	1.27	105	49.2 pF/m
3	‘Nicomatic’ - Shielded Flat Flexible Cable (050V550K2500-SHD48)	Original Aluminum shielding	2.5	0.5	100	?
4	‘Nicomatic’ - Shielded Flat Flexible Cable (050V550K2500-SHD48)	Original Aluminum shielding and copper tape SCEM at both ends, which electrically connect both FFC sides.	2.5	0.5	100	?
5	‘Coaxial’ – 34 cable set of RG-316/U	Original individual shielding for each pin	2.0	-	50	~ 95 pF/m

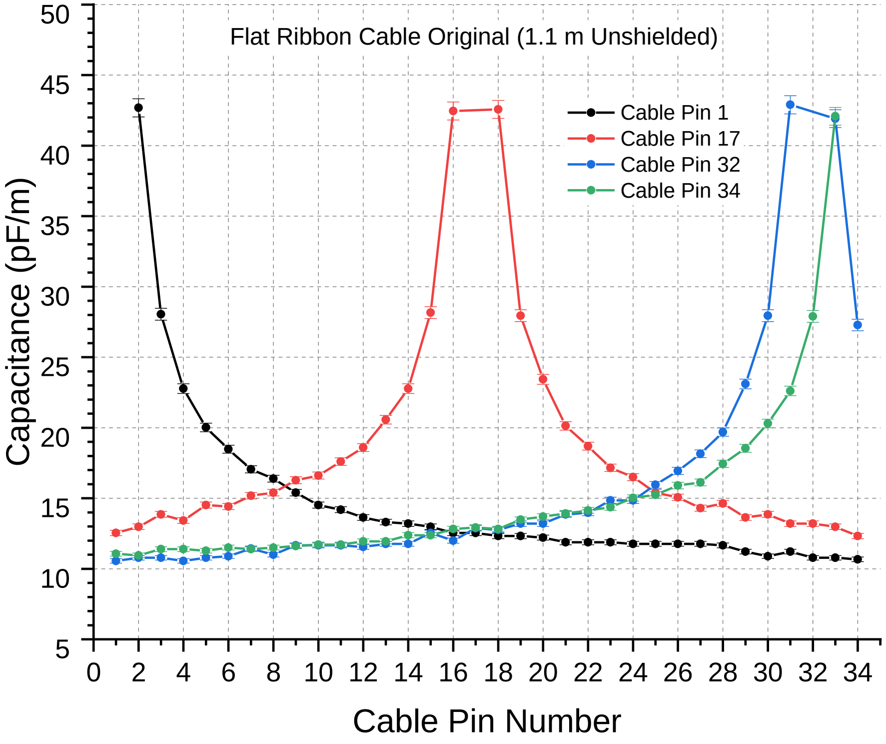


Cables Interchannel Capacitance Test

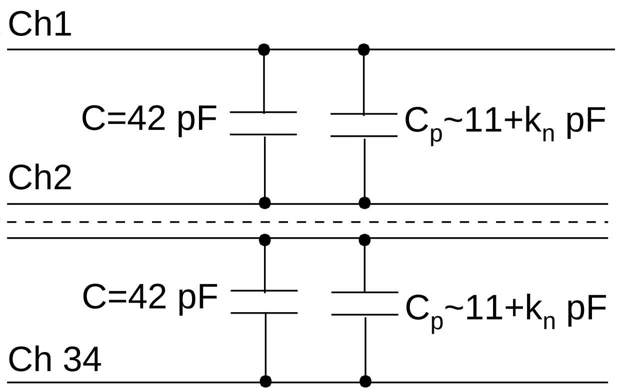
- Check the capacitance uniformity of the cables
- Determine the effect of metal shielding on a flat cable capacitance
- Create equivalent electrical circuits for cable based on interchannel capacitance

Cables Interchannel Capacitance Test

‘Ribbon’ - Flat Ribbon Cable Unshielded



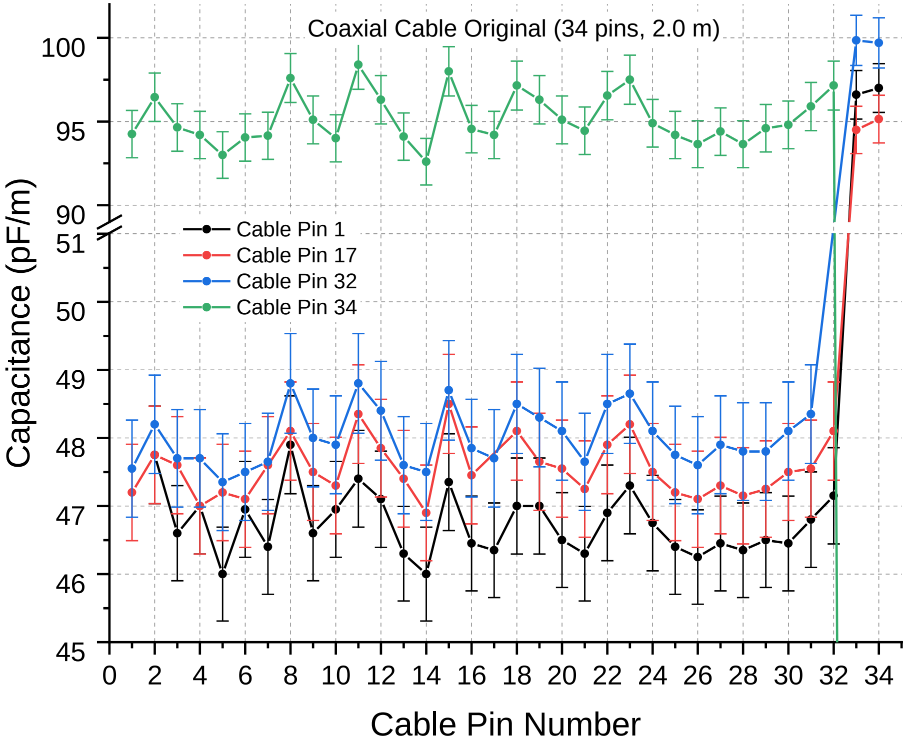
Equivalent electrical circuit like
a single-reference-wire configuration



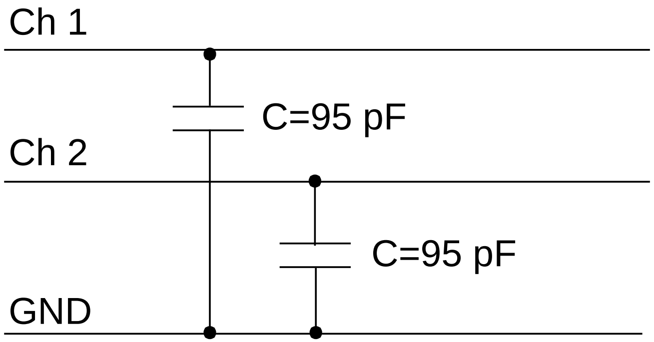
k_n = -9/n -1/(34-n)

Cables Interchannel Capacitance Test

‘Coaxial’ – 34 cable set of RG-316/U

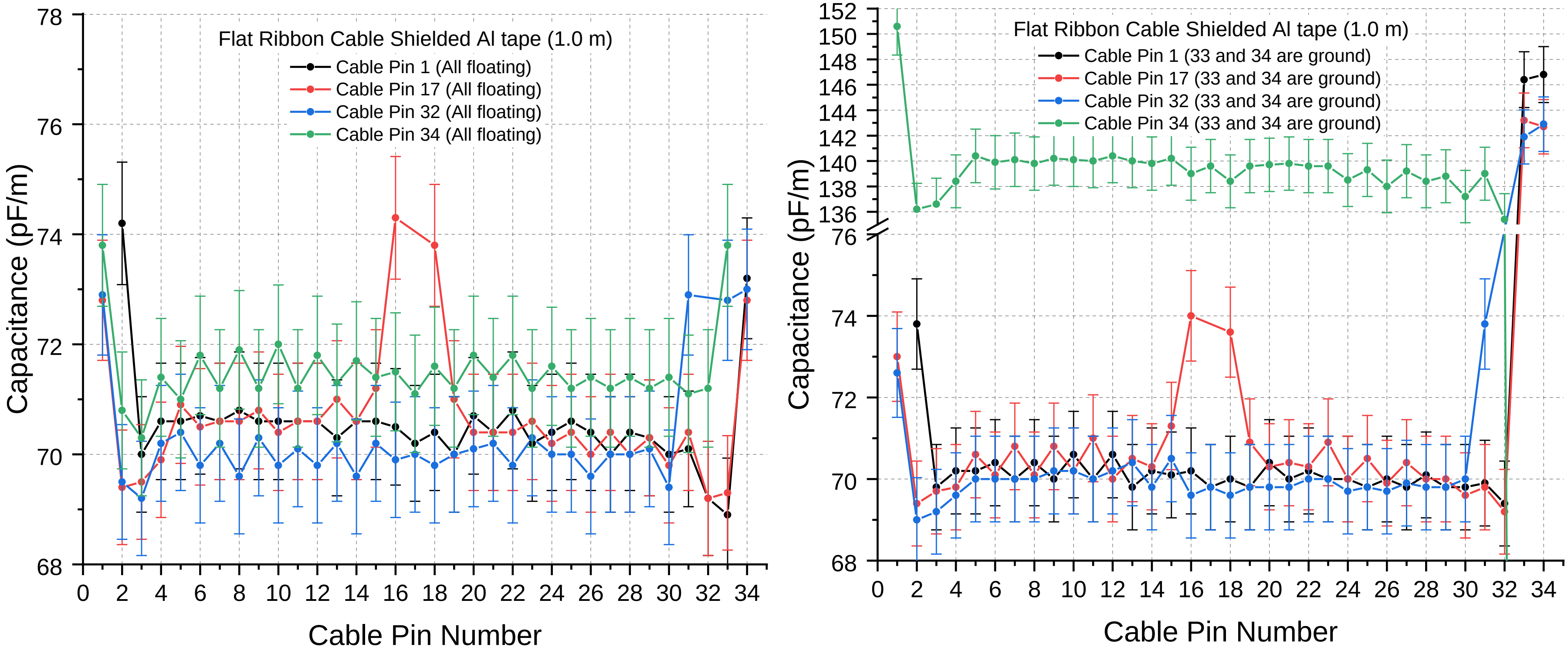


Equivalent electrical circuit like
a ground-signal-ground configuration



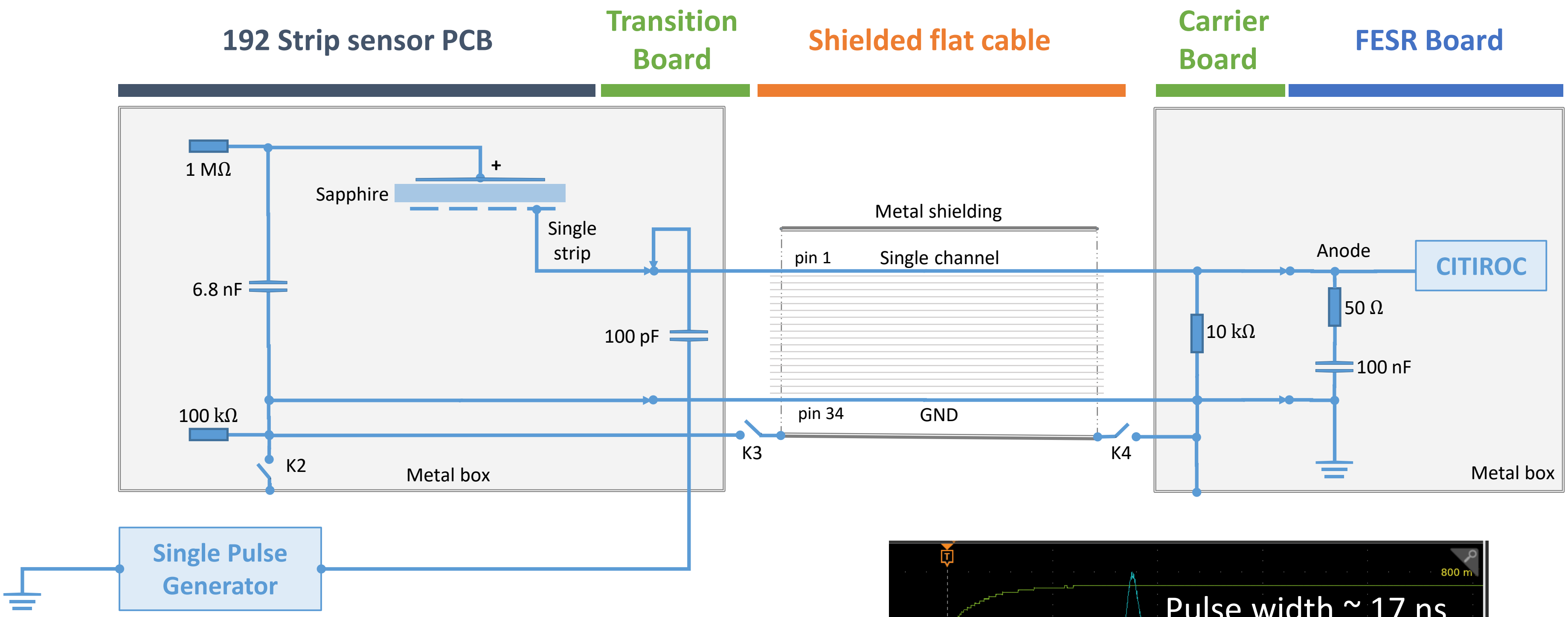
Cables Interchannel Capacitance Test

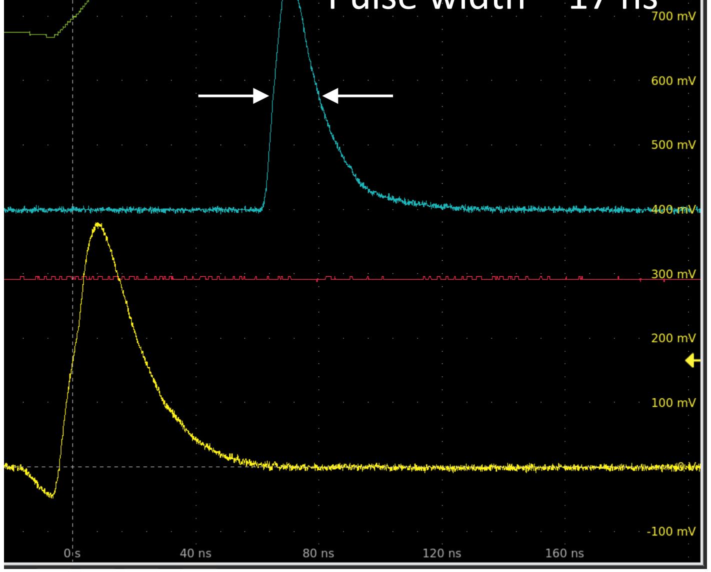
‘Ribbon’ - Flat Ribbon Cable Al shielded



No simple equivalent circuit!

Cross-talk test circuit





Measuring Crosstalk Using a Test Pulse

To identify and measure crosstalk, a test pulse can be used. By injecting a known test pulse into specific parts of the system, we can isolate and evaluate crosstalk at various stages: different cables, transition boards, connectors and other components.

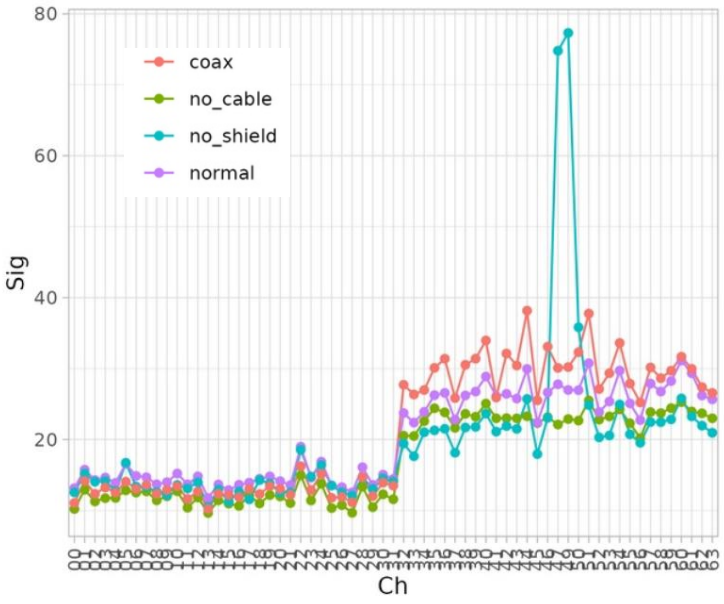
This method enables systematic verification and helps in pinpointing the exact sources of crosstalk, allowing targeted improvements to minimize interference.

Preliminary results: Crosstalk

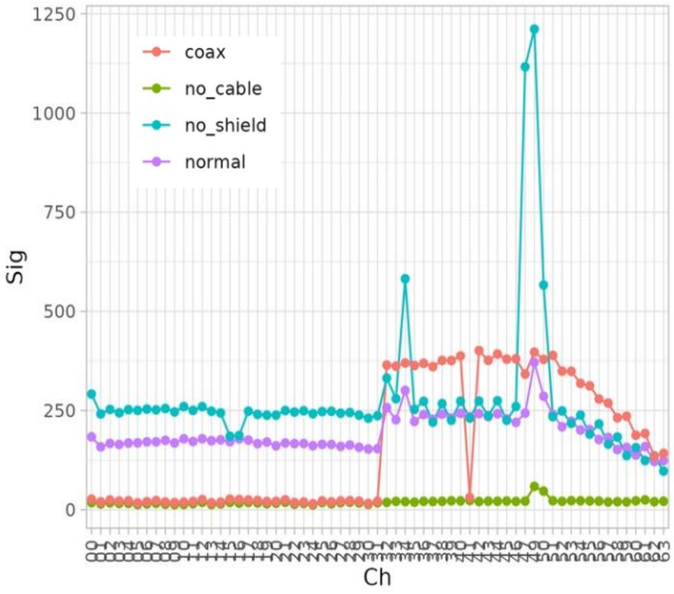
To identify and measure crosstalk, a test pulse method was employed. In these experiments, channel N48 was connected to a pulse generator and capacitor (100 nF) in series (test pulse width ~17 ns). A few different cables were tested to evaluate their contribution to crosstalk.

In the following plots, the amplitude of the test signal is ~ 400 mV (2622 count in HG, corresponding to ~29000 in LG)

Cross-talk signal at low gain (LG)



Cross-talk signal at high gain (HG)



**Channel N48 excluded from the plots*

Crosstalk Observations

- Crosstalk is observed in all cases!
- Unshielded cables exhibit the highest level of crosstalk, significantly affecting the signal in the neighbor to 48 channels.
- Coaxial cables do not show a sharp increase in intensity in adjacent channels, but a baseline increase was observed.

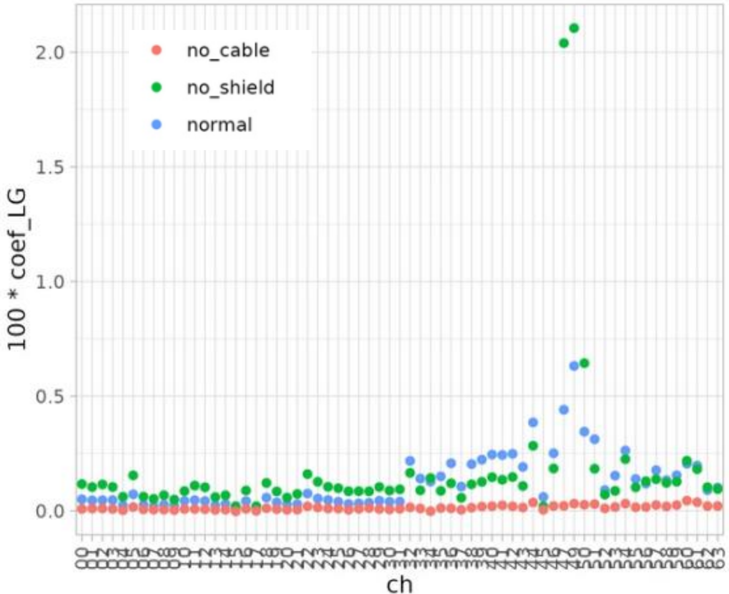
Legend:

- **normal**: shielded Ribbon flat cable with signal injected on the far (from FERS) end of the cable;
- **no_cable**: signal injected on the FERS board;
- **no_shield**: Ribbon unshielded flat cable;
- **coax**: 34 pins coaxial cable with external conductor of all coax connected together on both ends.

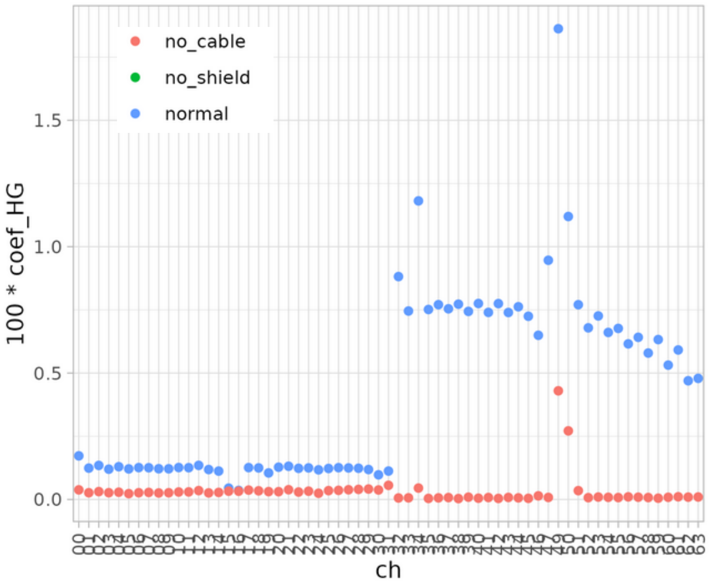
Preliminary results: Pick-up correlation coefficients

A method to separate the component of "cross-talk" proportional to the signal is presented here. It proposes to compute correlation coefficients between this component and the signal. This approach allows for a quantitative assessment of the relationship between the signal and cross-talk, which can be valuable for signal analysis and quality improvement purposes.

Corr. plot slope (%) at low gain (LG)



Corr. plot slope (%) at high gain (HG)



**Channel N48 excluded from the plots*

Legend:

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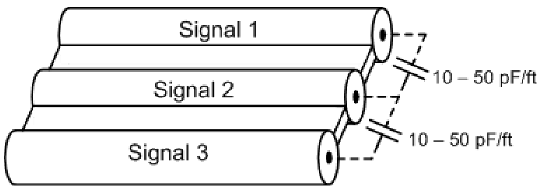
- **no_cable**: signal injected on the FERS board;
- **no_shield**: Ribbon unshielded flat cable.

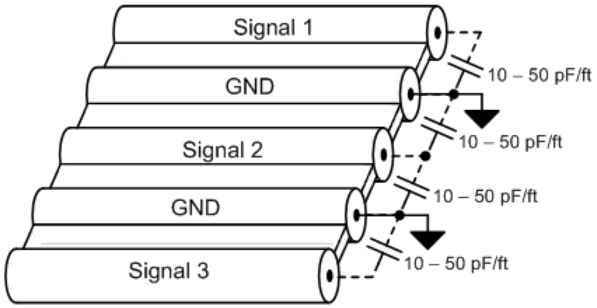
In closing

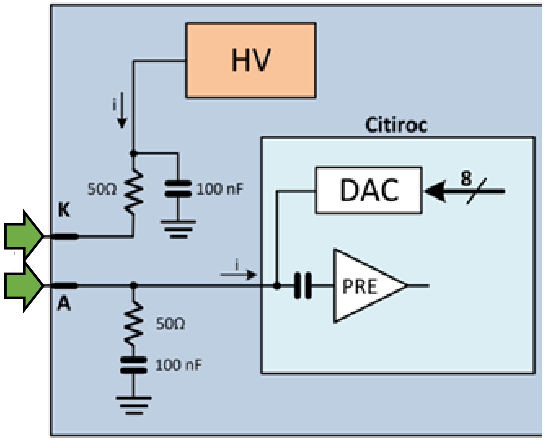
- Significant crosstalk effects have been observed.
- The type of cable and shielding significantly influence the baseline shape.
- Further tests with a more precise procedure are needed to evaluate crosstalk under different conditions.

Questions to open the discussion:

- How can we improve the signal readout system to suppress cross-talk?
- How to use Anode and Cathode of the FESR without HV bias onboard?
- It is not a correct matching of the impedance. How we can improve it?







Thank for your attention

LUXE

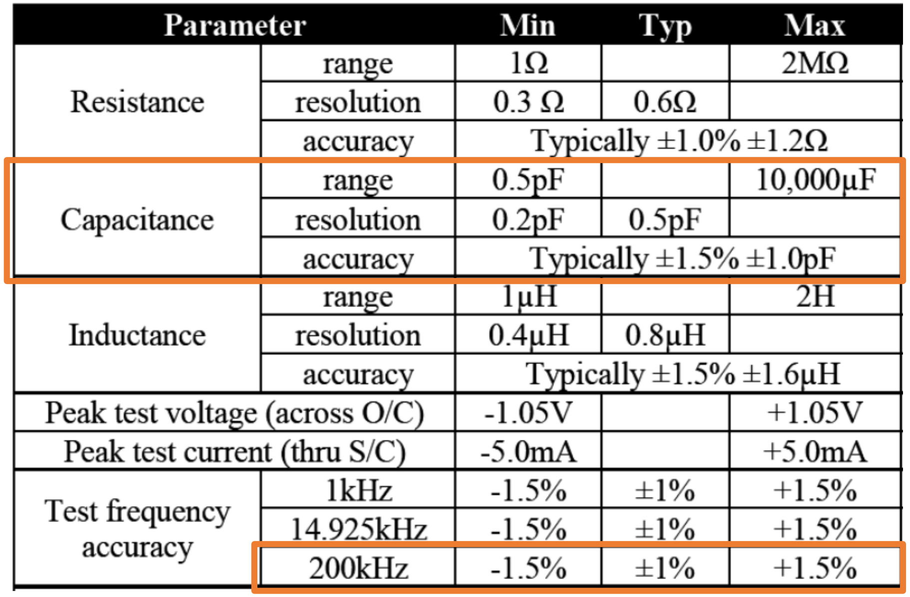
DESY.

INFN
PADOVA

FONDAZIONE
BRUNO KESSLER

TOMSK-1878

Peak Atlas LCR40
Passive Component
Analyzer



Parameter		Min	Typ	Max
Resistance	range	1Ω		2MΩ
	resolution	0.3 Ω	0.6Ω	
	accuracy	Typically ±1.0% ±1.2Ω		
Capacitance	range	0.5pF		10,000µF
	resolution	0.2pF	0.5pF	
	accuracy	Typically ±1.5% ±1.0pF		
Inductance	range	1µH		2H
	resolution	0.4µH	0.8µH	
	accuracy	Typically ±1.5% ±1.6µH		
Peak test voltage (across O/C)		-1.05V		+1.05V
Peak test current (thru S/C)		-5.0mA		+5.0mA
Test frequency accuracy	1kHz	-1.5%	±1%	+1.5%
	14.925kHz	-1.5%	±1%	+1.5%
	200kHz	-1.5%	±1%	+1.5%