Measurements on the CERN Electrode Prototype V2 in IJCLab

04/07/2025

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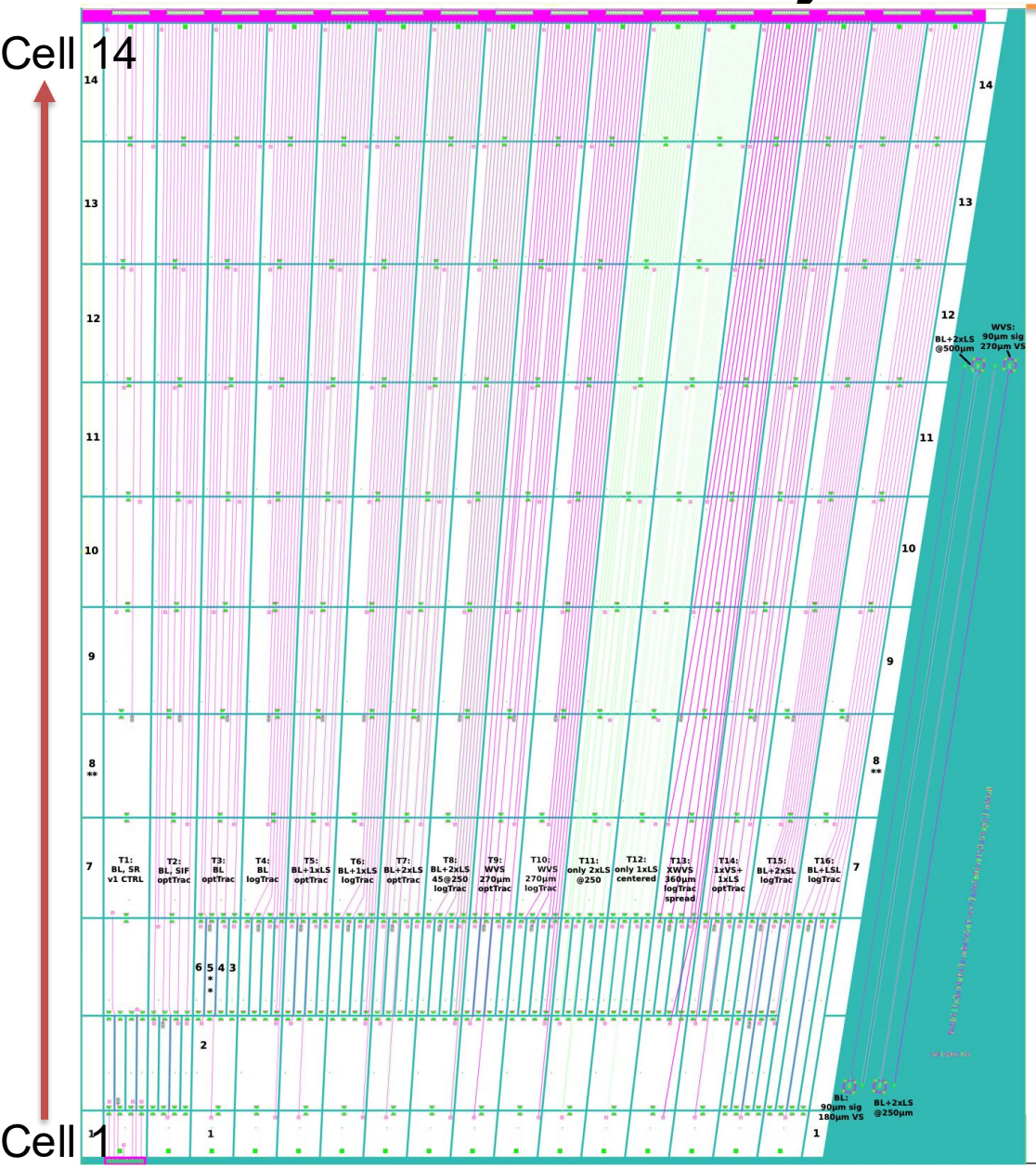
IJCLab – CNRS/IN2P3

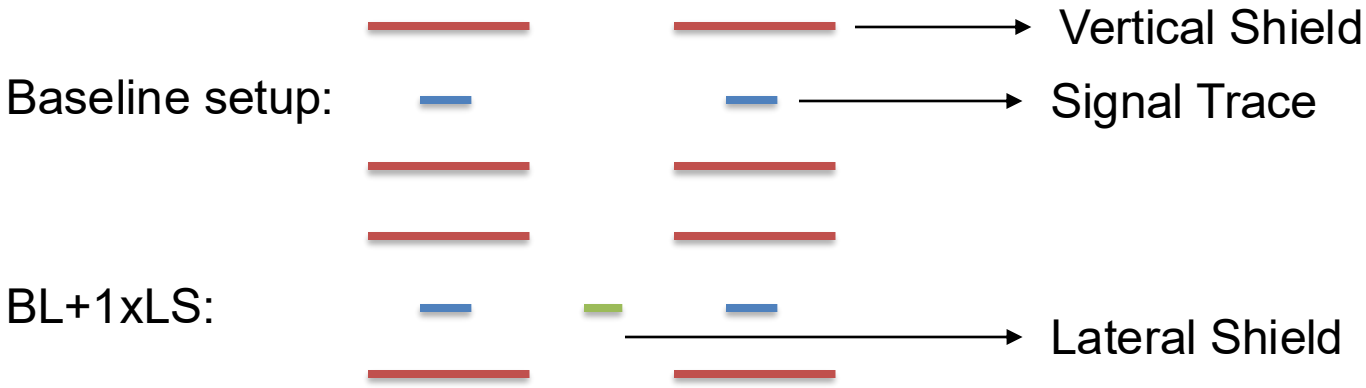
Introduction

- The ALLEGRO detector concept aims to construct a High granularity noble liquid EM calorimeter (ECAL). More details in Zhibo's talk.
- A prototype multilayer PCB, featuring the main characteristics necessary for a high granularity liquid argon sampling calorimeter, has been produced in CERN
- More details in Juska's talk: https://indico.cern.ch/event/1468746/contributions/6190824/attachments/2957775/5201766/DRD6_ALLEGRO_electrode_design_v1.pdf
- In IJCLab, we want to measure the cross-talk and capacity of different setups of towers, to have a better understanding of the PCB board.

Measurement objects

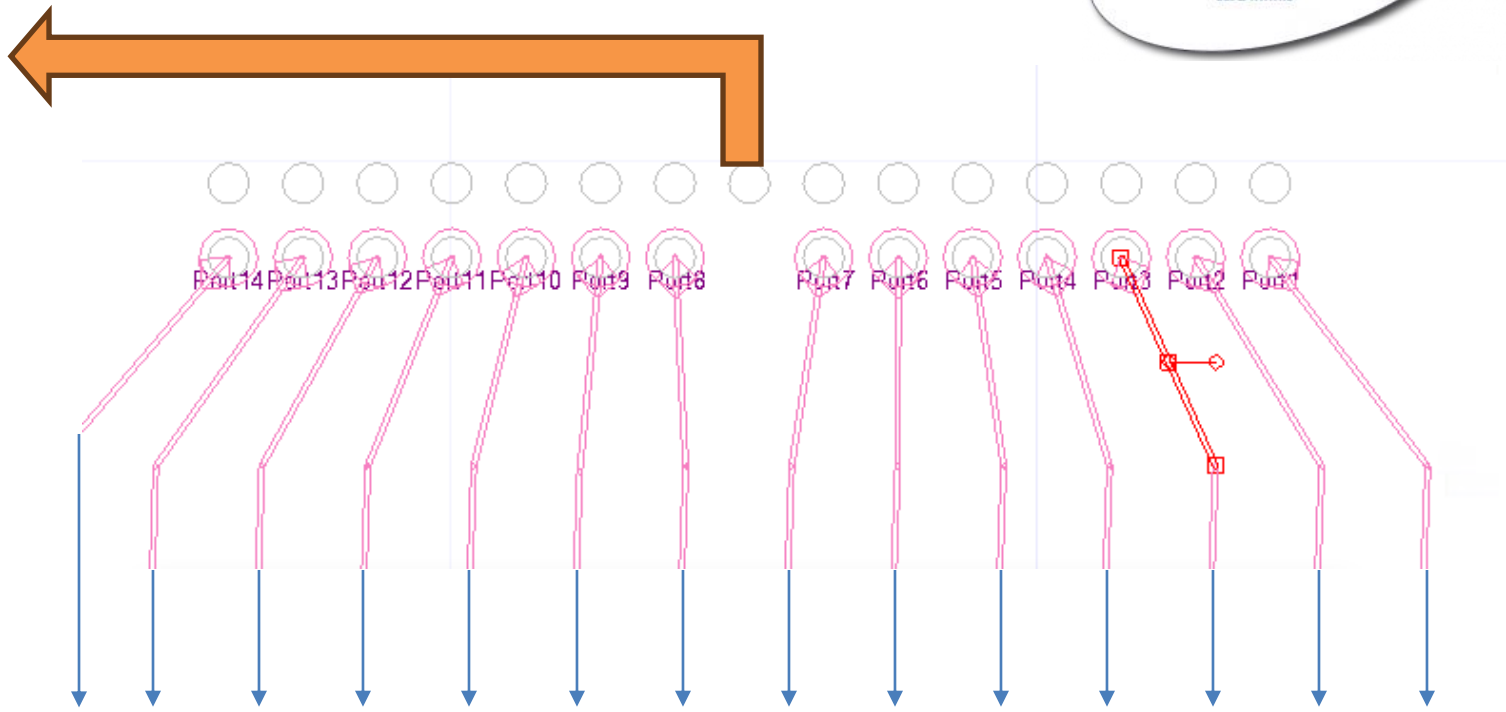


- The CERN PCB board has in total 16 towers with different setups.
- Setups vary in:
  - Vertical shields (VS) length and number
  - Lateral Shields (LS) number
  - The order of connecting signal traces
- Examples:



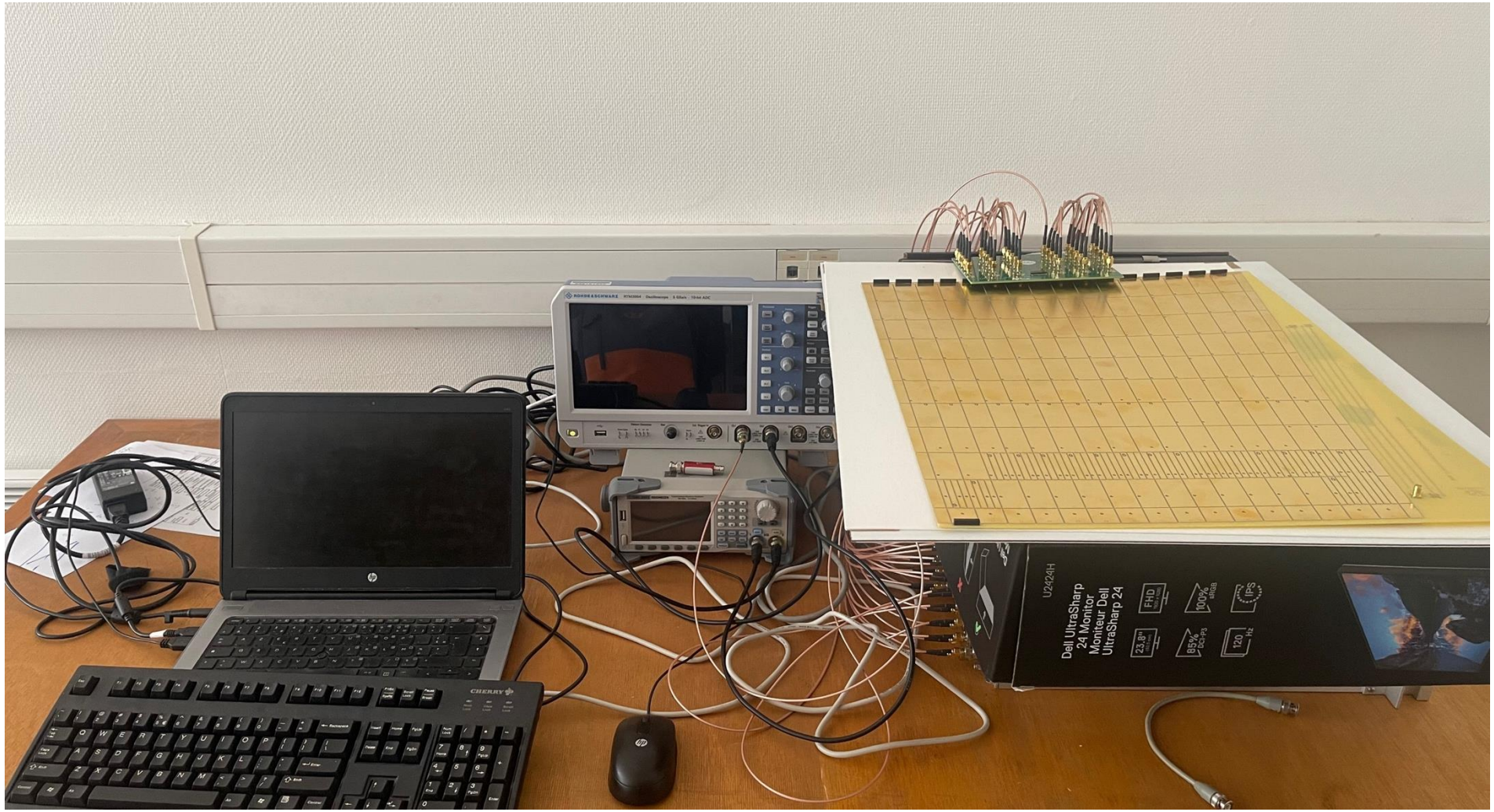
Measurement objects

Empty pin, not connect to any cells.

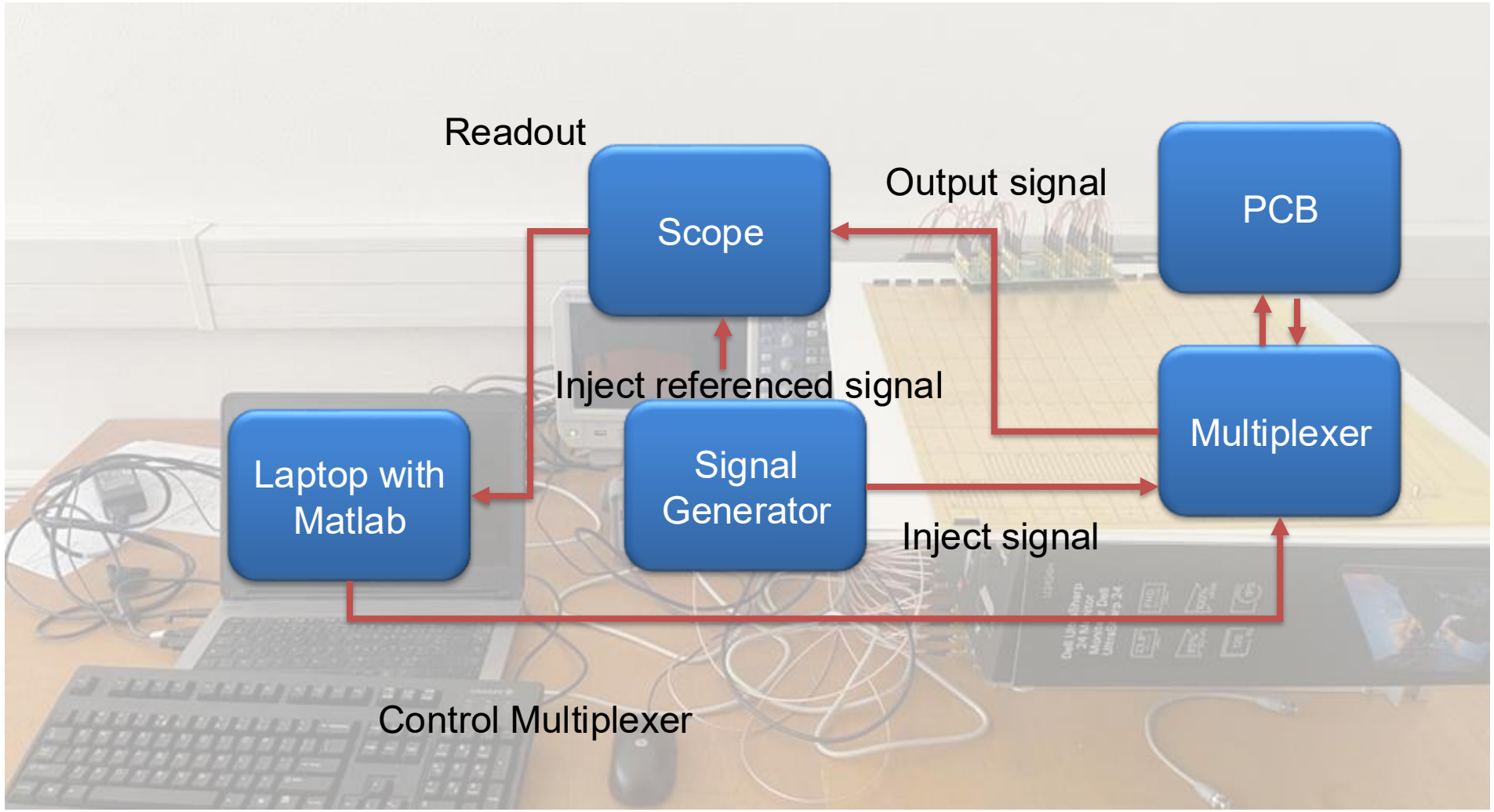


- logTrac: logical traces: Cell 14 13 12 11 10 9 8 7 6 5 4 3 2 1
- optTrac: optimized traces: Cell 14 3 2 9 4 11 1 12 7 10 5 8 6 13

Measurement setup

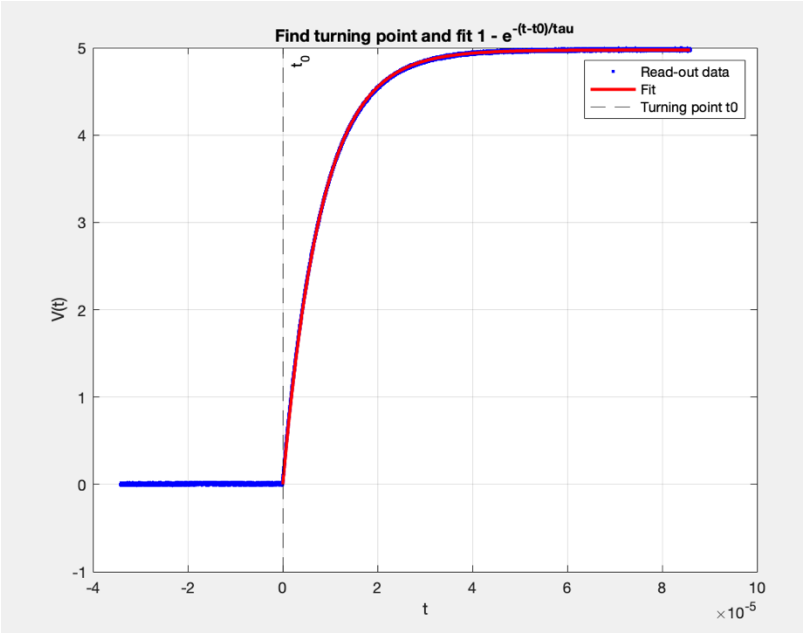


Measurement setup



Capacity measurement

- Inject square wave:
  - Frequency: 1.0 kHz
  - Amplitude 5.0 Vpp
- A 9.1 kOhms resistor is connected to the generator output -> to ensure the rising time being above the natural bandwidth of the measurement and to integrate the short reflection peaks in the measured signal.



- RC Series Circuit voltage:

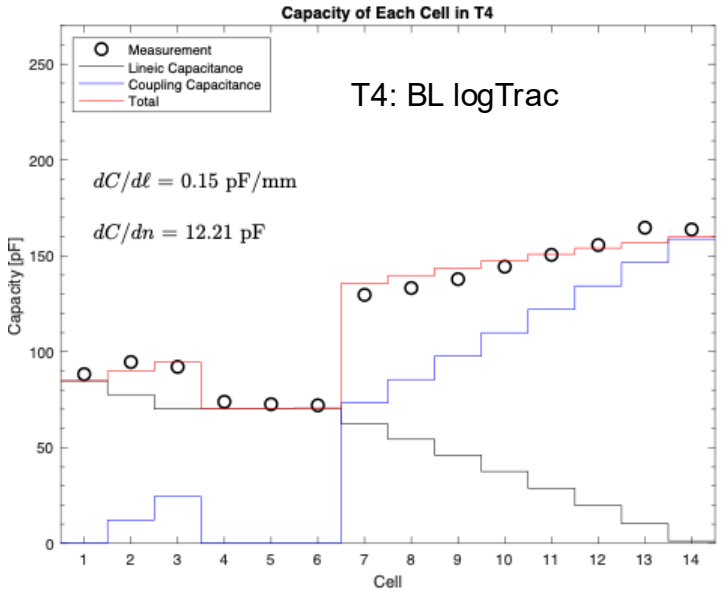
$$V_c(t) = V(1 - e^{-t/\tau})$$

- where:

$$C = \tau/R$$

- τ is determined by fits.

Capacity measurement

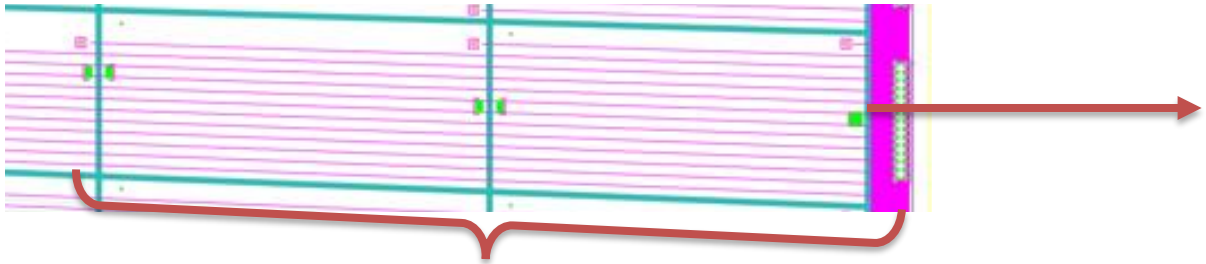


Capacity fitted by a simple model:

$$c_{total} = L_i \frac{\mathrm{d}C}{\mathrm{d}l} + n\frac{\mathrm{d}C}{\mathrm{d}n}$$

where L_i is the length of signal track, $\frac{\mathrm{d}C}{\mathrm{d}l}$ is the lineic capacity / mm, n is the number of track under the cell and $\frac{\mathrm{d}C}{\mathrm{d}n}$ is the coupling capacitance of the cell.

This model does not consider the cross-talk capacities.



L_i is the length of the i-th trace from the connector, bringing the **Self-Capacitance.**

n is the # of traces under cell, resulting in the **Coupling Capacitance**.

Capacity measurement – quick discussion

- The tower configuration does not change so much the lineic capacitance of the track except the setups have only LS. But the coupling capacitance relate pretty much to the shield width and number.

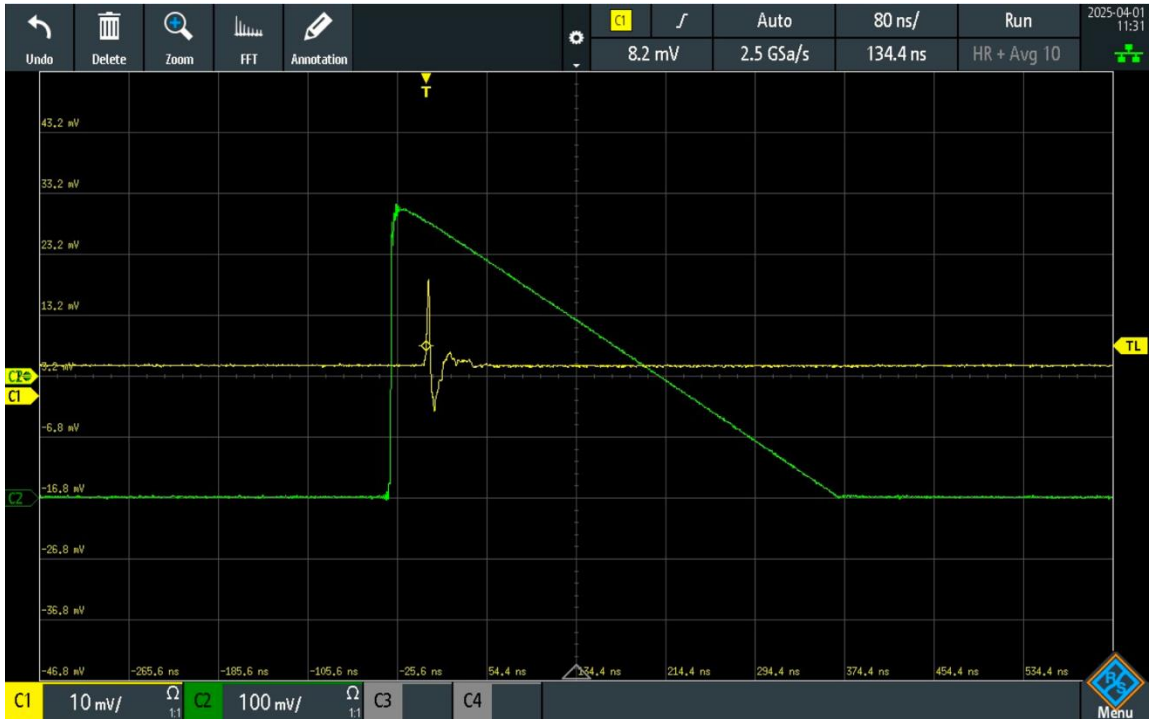
- T7 BL+2LS shows the highest capacity overall. And as expected, T12 with only 1LS shows the lowest capacity.

	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
VS	180μm*2	180μm*2	180μm*2	180μm*2	180μm*2	180μm*2	270μm*2	270μm*2	0	0	360μm*2	180μm*1
LS	0	0	1	1	2	2	0	0	2	1	0	1
Trac	optTrac	logTrac	optTrac	logTrac	optTrac	logTrac	optTrac	logTrac	optTrac	optTrac	logTrac / Spread	optTrac
dC/dl (pF/mm)	0.16	0.15	0.16	0.15	0.17	0.16	0.17	0.17	0.12	0.11	0.17	0.14
dC/dn (pF)	12.2	12.21	16.33	16.29	18.82	15.34	13.8	13.51	13.06	11.3	15.11	15.04

Cross-talk Measurement

- Inject bursted triangle wave:
  - Frequency: 2.5 MHz
  - Amplitude 5.0 Vpp
  - Start phase = -1.0°
  - Burst period: 10.0 ms

- Inject channel 1, read out channel 1



- Inject channel 1, read out channel 2

Cross-talk Measurement

- In our PCB board, there are two typical sources of cross-talk:
  - Capacitive cross-talk caused by the electric field coupling between adjacent signal traces through parasitic capacitance.
  - Inducive cross-talk caused by magnetic field coupling via mutual inductance between signal traces.

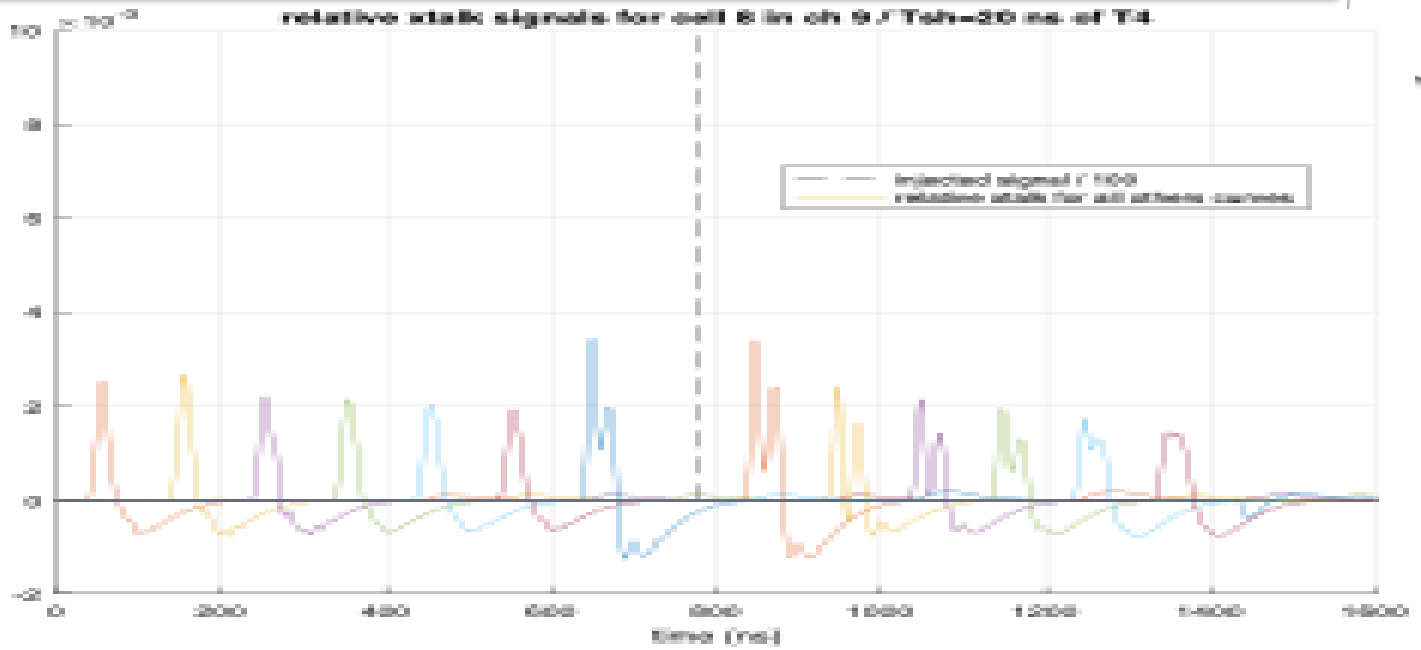
Mainly Capacitive cross-talk

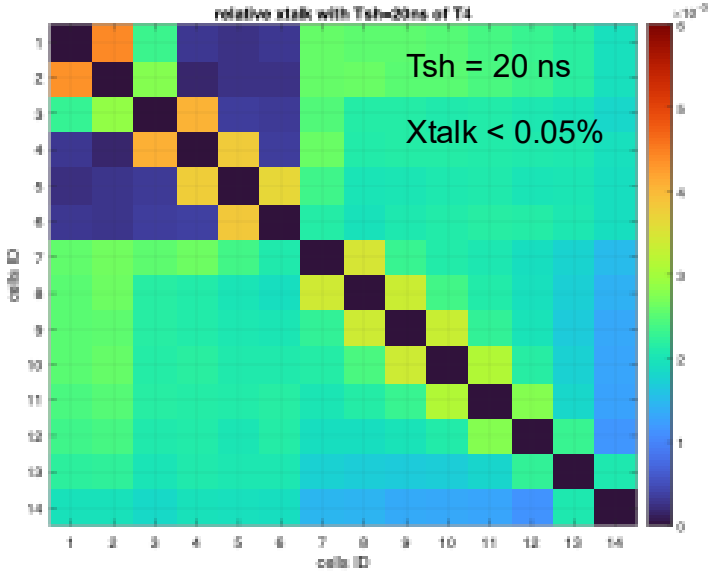
Mainly Inducive cross-talk

Cross-talk Measurement

- The shaping time is applied offline by numerical filtering on the measured data.

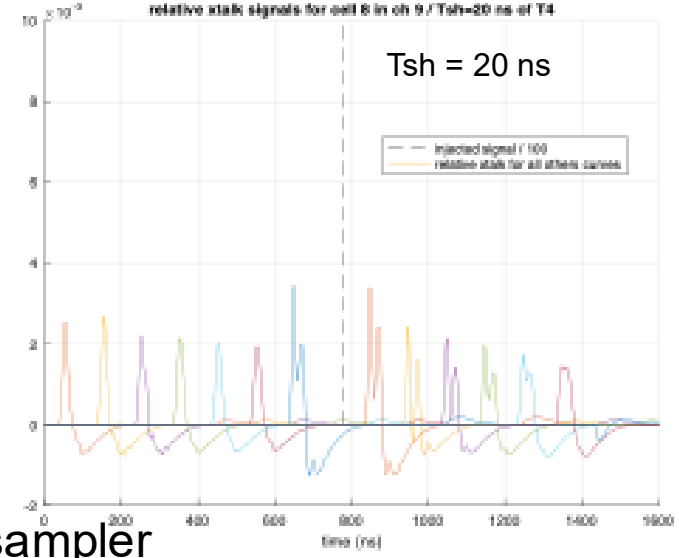
$$H(s) = \frac{T_{sh} \cdot s}{(T_{sh} \cdot s + 1)^3}$$

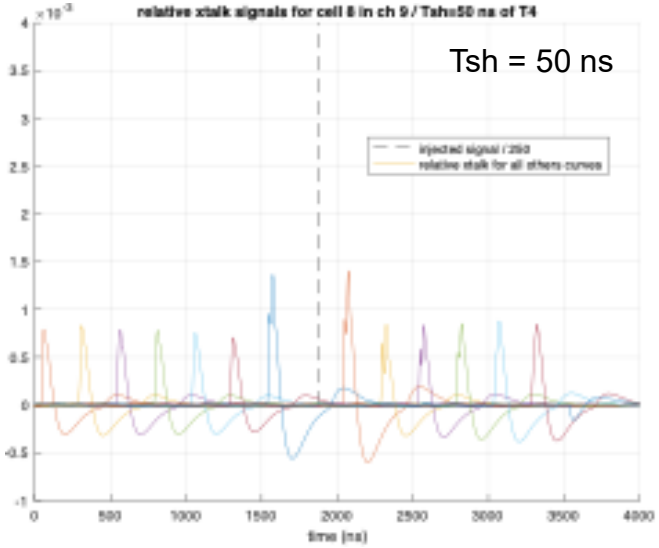


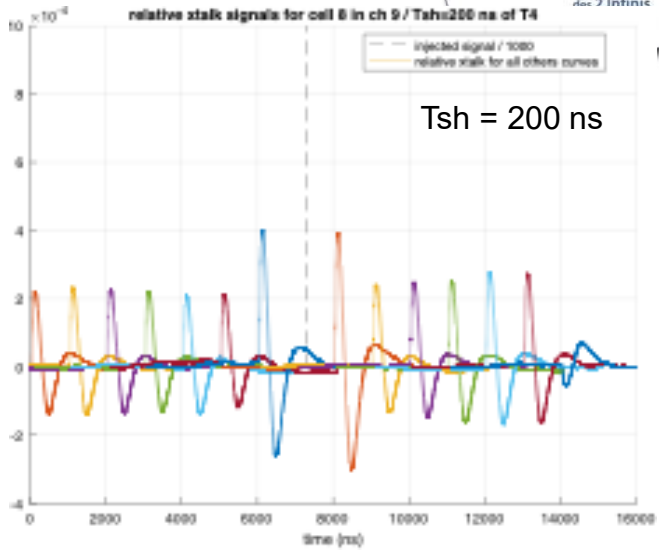


- All measurements are done injecting a voltage signal through 50 Ω at the connector position, directly on the signal layer. i.e. The signal is NOT injected on the pad/cell location on the HV layer.
- The results have to be checked with some other measurements or simulations to validate them.

Cross-talk Measurement Example: T4 (BL)

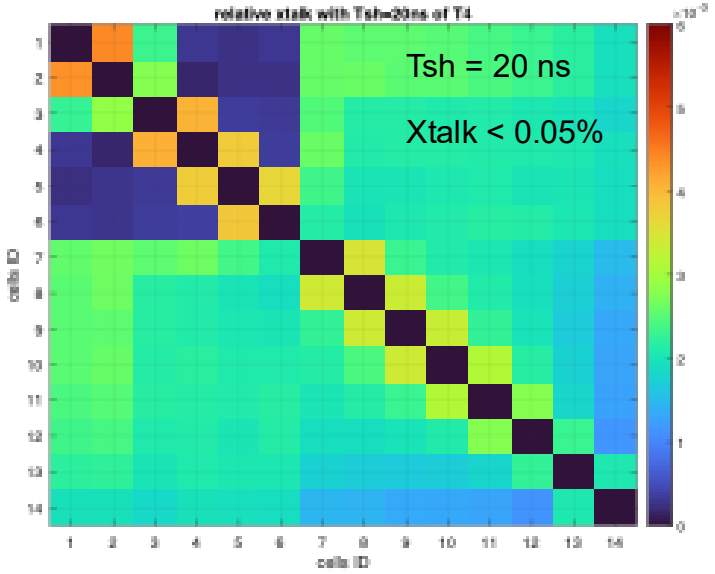


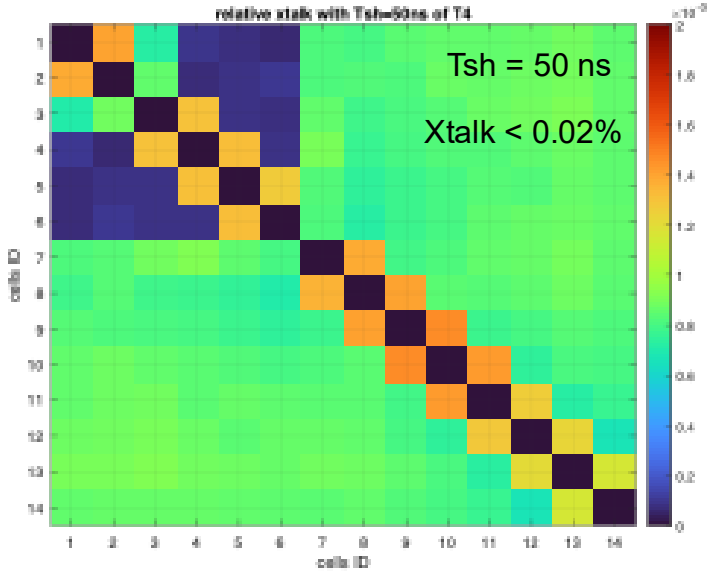


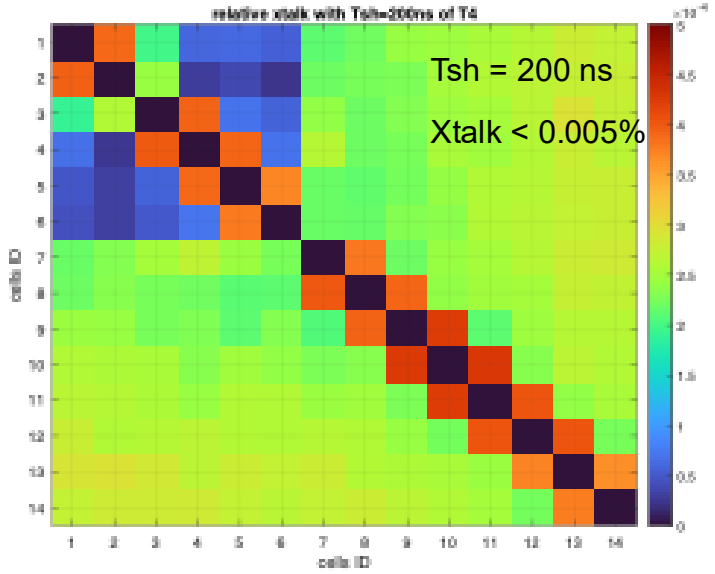


Presampler

Cell 1 Cell 14 Empty Pin







Summary

- We measured the capacity and x-talks of T3-T14 in the CERN PCB board, which have similar cell structures.

- From the perspective of the x-talk size, the T13 (XWVS 360μm logTrac Spread) has the best performance, while the T10 (WVS 270μm logTrac) is the runner-up. But T10 has a slightly smaller overall capacity.

	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
VS	180μm*2	180μm*2	180μm*2	180μm*2	180μm*2	180μm*2	270μm*2	270μm*2	0	0	360μm*2	180μm*1
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dC/dl (pF/mm)	0.16	0.15	0.16	0.15	0.17	0.16	0.17	0.17	0.12	0.11	0.17	0.14
dC/dn (pF)	12.2	12.21	16.33	16.29	18.82	15.34	13.8	13.51	13.06	11.3	15.11	15.04
maximum xtalk (20ns)	5.20E-03	4.40E-03	5.00E-03	4.30E-03	4.70E-03	4.10E-03	5.50E-03	3.90E-03	7.50E-03	9.10E-03	3.60E-03	6.30E-03
avg x-talk (without neibouring and strips) (20ns)	2.00E-03	2.10E-03	1.80E-03	1.80E-03	1.40E-03	1.10E-03	1.10E-03	1.20E-03	4.00E-03	6.10E-03	8.55E-04	3.10E-03
maximum xtalk (50ns)	1.70E-03	1.50E-03	1.60E-03	1.40E-03	1.40E-03	1.40E-03	1.70E-03	1.30E-03	2.50E-03	3.30E-03	1.30E-03	2.10E-03
avg x-talk (without neibouring and strips) (50ns)	8.00E-04	8.00E-04	7.00E-04	7.00E-04	6.00E-04	4.00E-04	4.00E-04	4.00E-04	1.70E-03	2.40E-03	2.78E-04	1.30E-03
maximum xtalk (200ns)	4.74E-04	4.28E-04	4.15E-04	4.08E-04	3.98E-04	4.03E-04	3.91E-04	4.07E-04	7.36E-04	9.95E-04	3.64E-04	5.94E-04
avg x-talk (without neibouring and strips) (200ns)	2.50E-04	2.52E-04	2.24E-04	2.12E-04	1.67E-04	1.13E-04	1.26E-04	1.30E-04	5.06E-04	7.52E-04	6.85E-05	3.97E-04

Outlook

- As stated previously, this cross-talk measurement is done by inject signal from the connector. That is not how it works during real data taking.
- A simulation should be done to validate this measurement.
- The next cross-talk measurement will be done by directly injecting signal to the HV layer, also with an absorber (metal plate) connected, to better simulate the practical functioning situation.

Thank You!