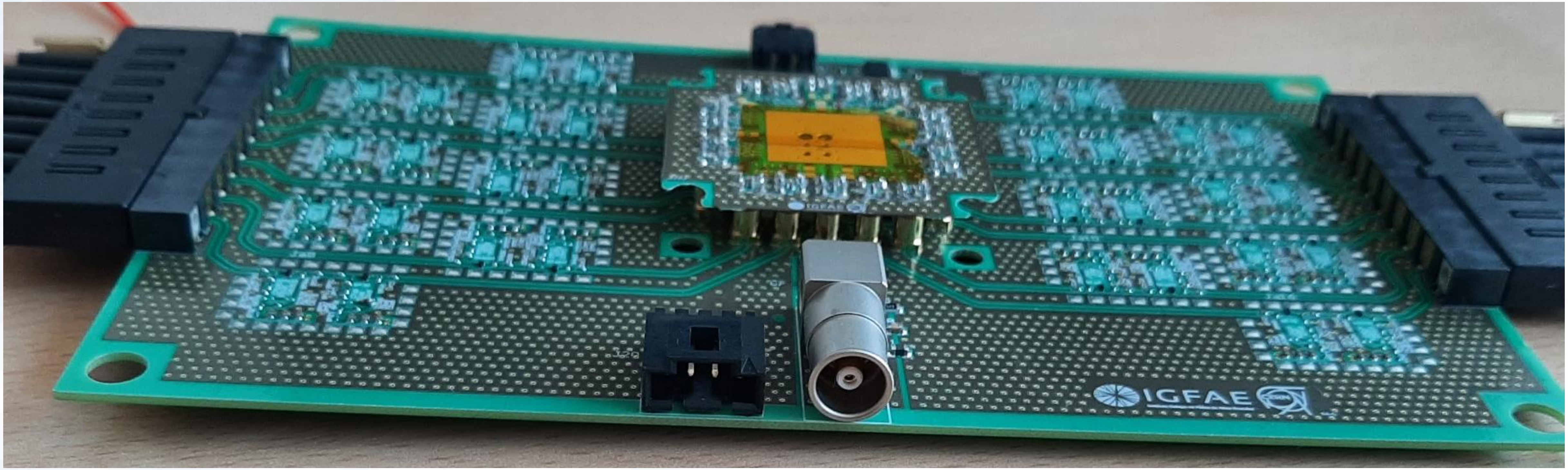
Multichannel board for picosecond timing measurements of silicon sensors



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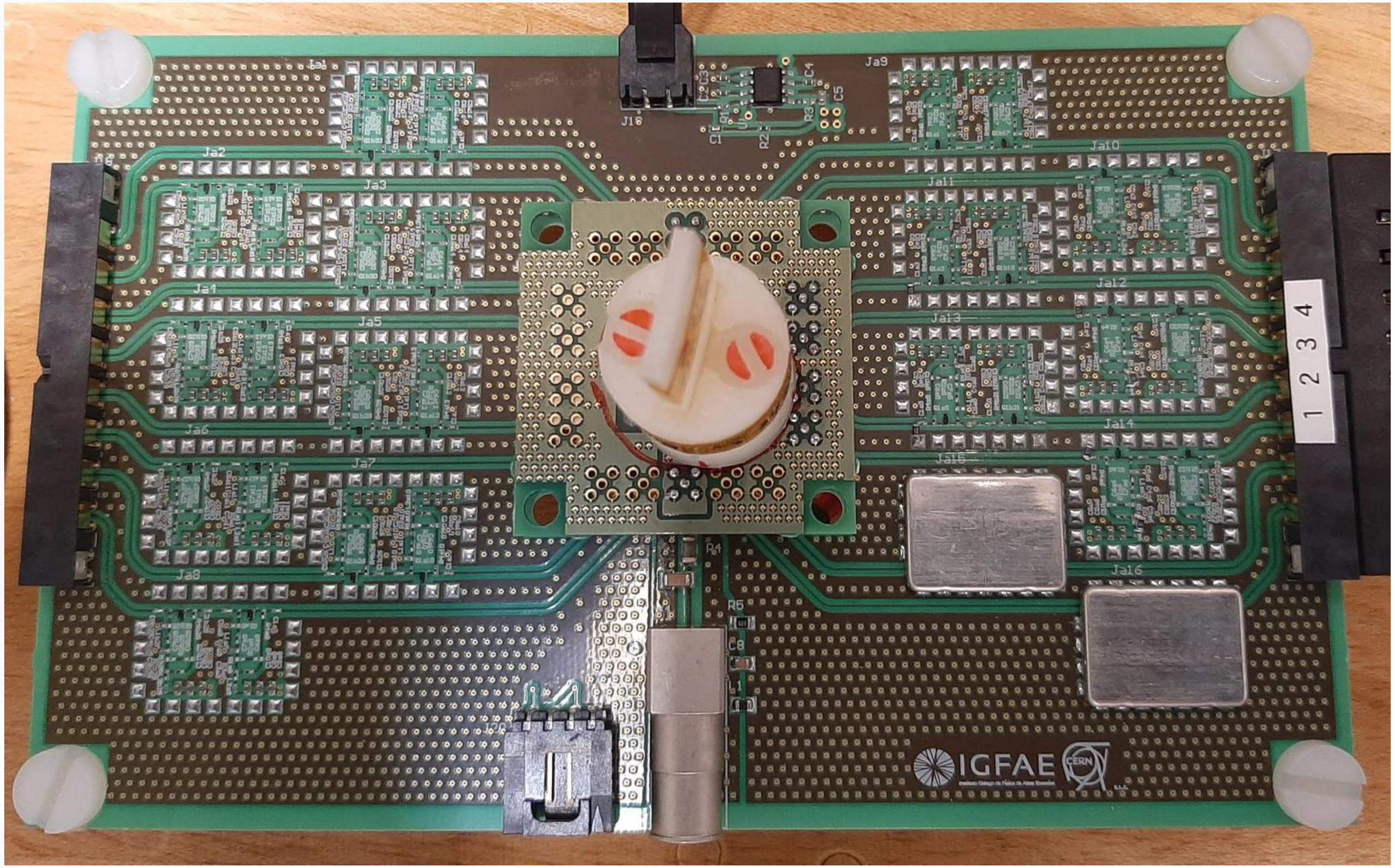
1- Instituto Galego de Física de Altas Enerxías (IGFAE) Universidade de Santiago de Compostela (ES).

2- CERN.

Outline

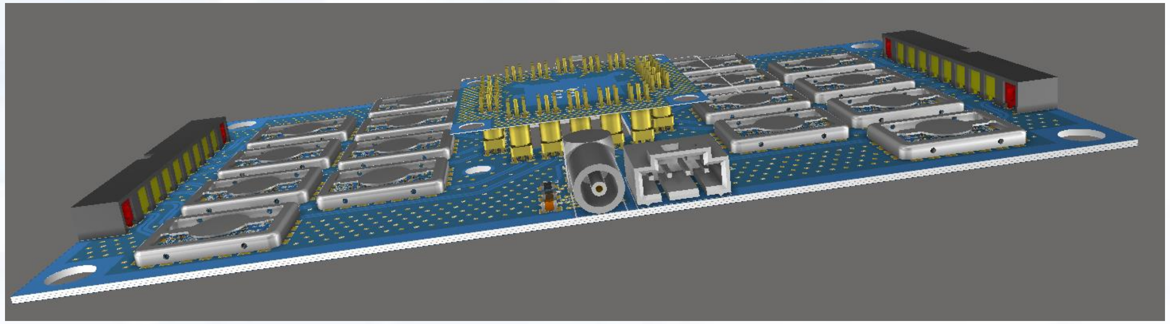
- Boards assembly.
- Base board.
- Sensor board.
- Simulation.
    - Frequency domain.
    - Time domain.
- Measurements.
    - Pulse response.
    - 3D sensors.
    - Noise.
    - Planar sensors.
- Conclusions.
- Future steps.



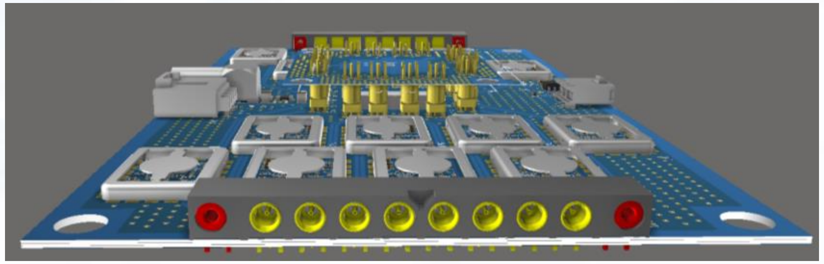
Boards Assembly

- Setup composed of a base board and a sensor board.
  - Sensor board is fully passive, with low noise and has temperature monitoring. It has compatibility with variety of sensor sizes, low material budget and easy alignment. Moreover, it is cheap.
    - Allows quick sensor test turn around.
    - Allows group wire bonding.
    - Possibility to use for other purposes. (IV, CV, …).
  - Base board is active with electronics for the signal amplification.

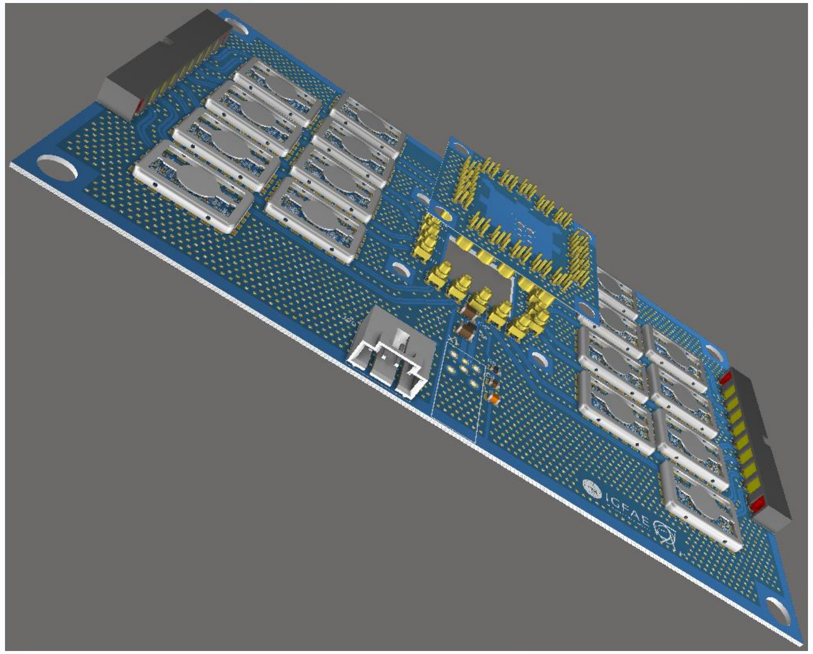
Front view



Side view

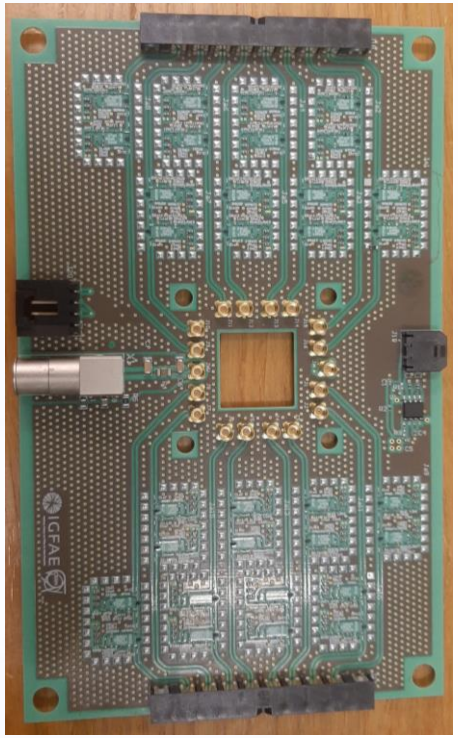


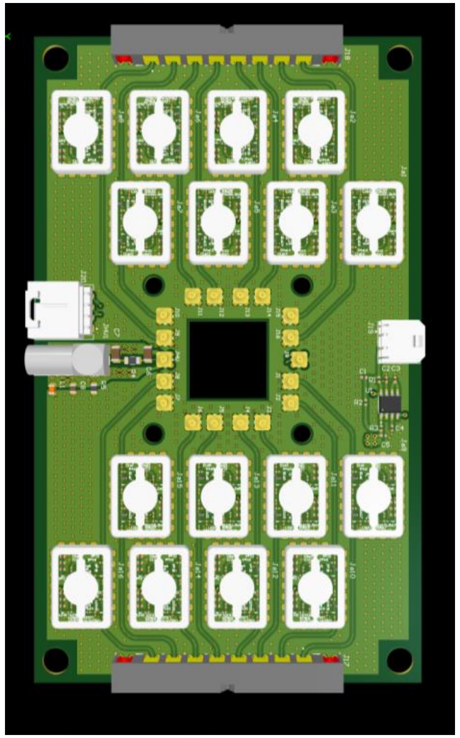
Interconnection



Base boards design

- **16-channel readout board with integrated first and second stage.**
- **High Frequency SiGe technology (Infineon BFR840L3RHESD).**
- **High frequency design up to 12GHz.**
- Low current (~220mA) for the full board (32 stages).
- Rogers 4350B (100 µm) for the high speed signals.
- Small packaging with 0201-size components for multichannel integration.
- Independent Shielding per channel.
- 18 mm x 18 mm central opening.
- 140 mm x 90 mm dimensions.
- Pre-assembled miniaturized coaxial edge connectors with panel-mounted SMA plugs.
- Vertical miniaturized coaxial plug connectors for sensor board (16 channels + HV/RTD) .
- Keyed connectors with high life cycle.



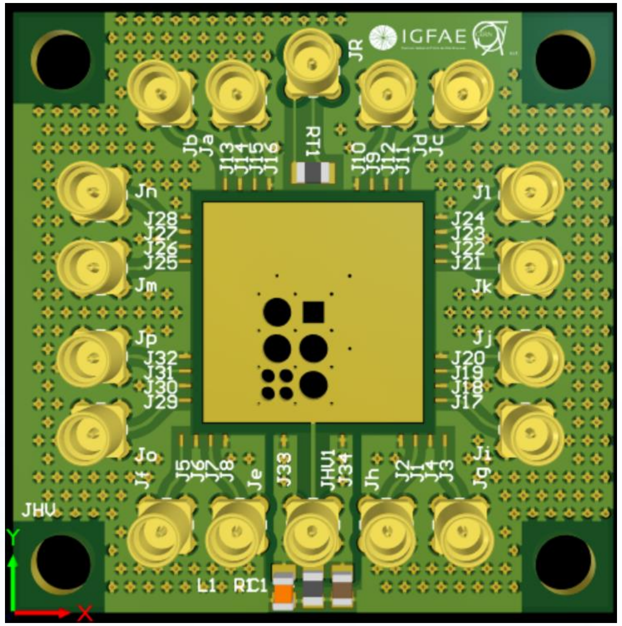


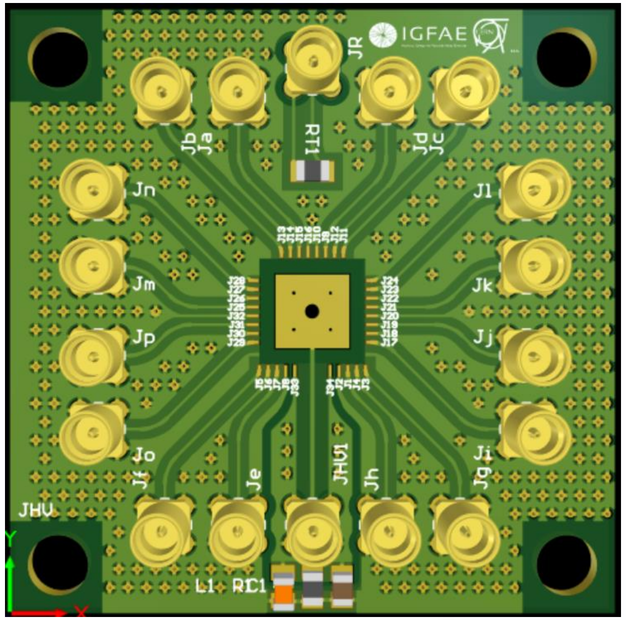
First and second stage

Infineon	BFR840L3RHESD
G_{max}	26.5 dB
I_C max	35.0 mA
NF	0.5 dB
OIP3	17.0 dBm
OP1dB	4.0 dBm
V_{CEO} max	2.25 V
Frq. Range	Up to 12 GHz

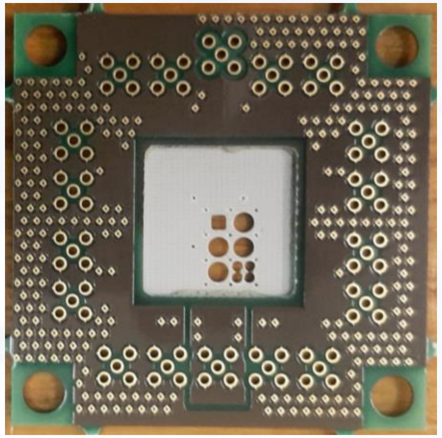
Sensor board

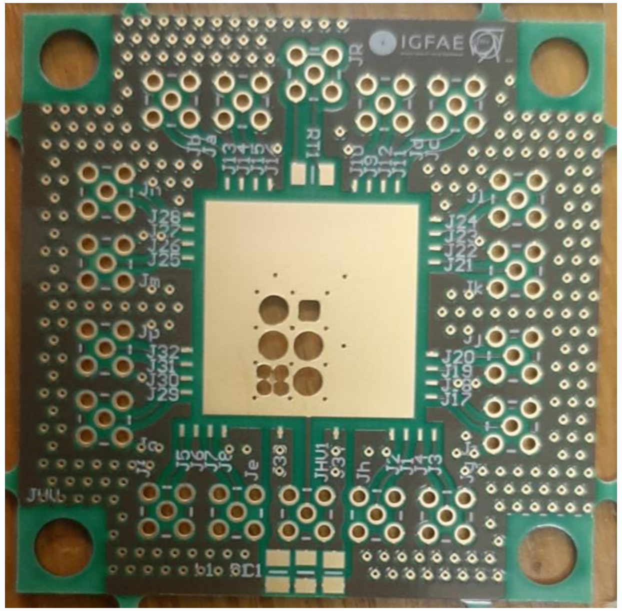
- Two types of designs. (15x15 mm and 5x5 mm central pad).
- 41 x 41 mm square shape.
- Rogers 4350B for the high speed signals.
- Connector area reinforce with 0.3 μm FR4.
- Under sensor pad thickness of 100 μm.
- Multiple drills design on the central pad to place different types and sensors sizes.
- 140 boards produced at Gacem.

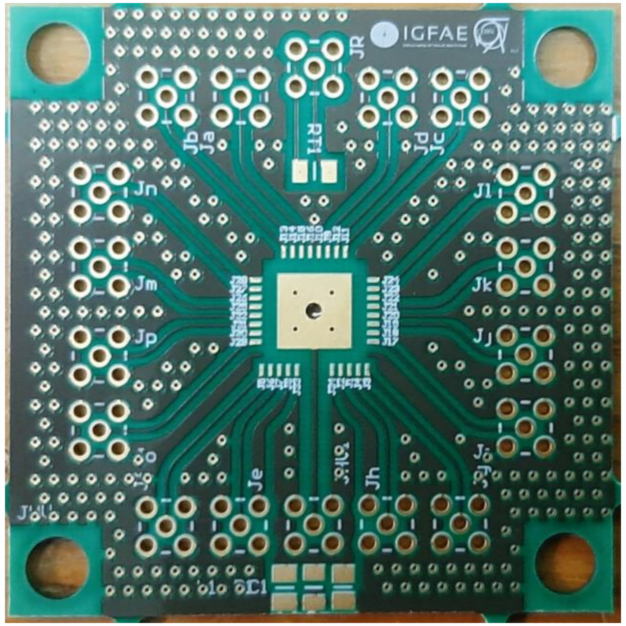




Back side



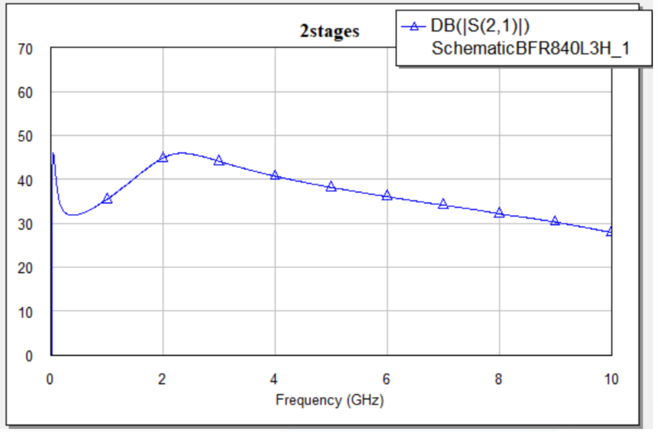




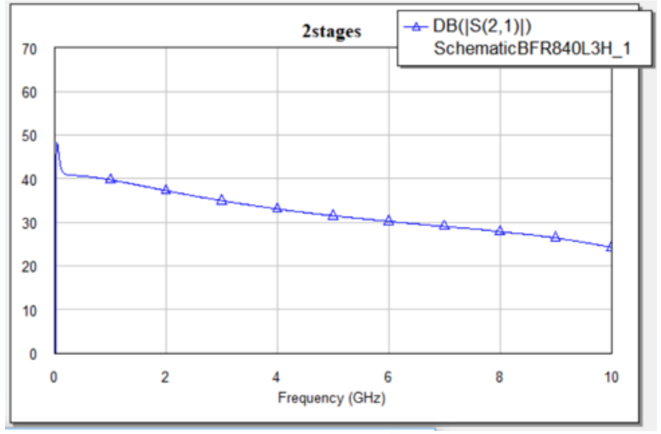
Frequency domain simulation

- Initial frequency domain simulation to optimize the design for uniform response with frequency.
- No sharp gain change discontinuities.
- Gain ~70 for a two-stage configuration.
- Tested injecting a pulse of 300ps width and -10 mV amplitude. Readout with 10 GHz bandwidth scope and sampling rate of 50 Gsps.

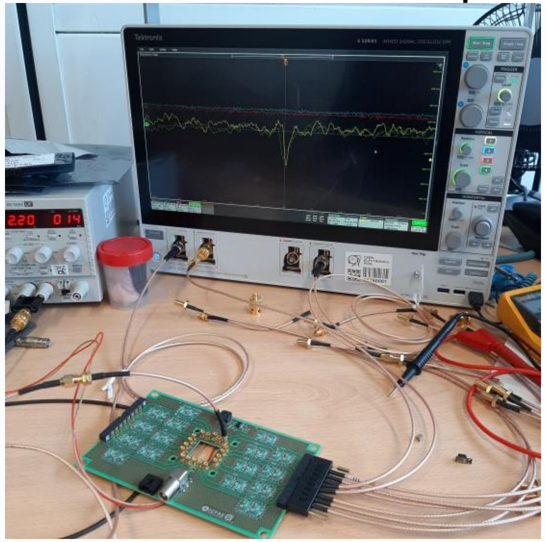
S21 before freq. optimization



S21 after freq. optimization



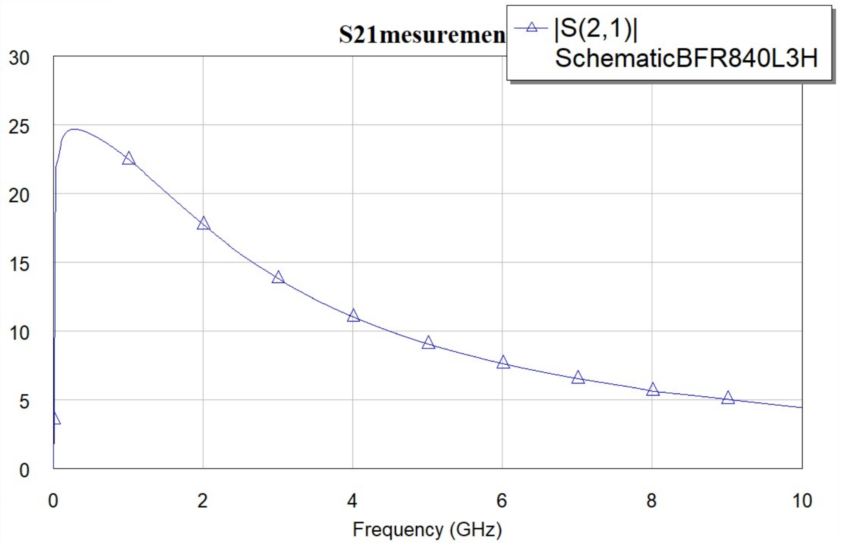
Measurement Setup



Time domain simulation

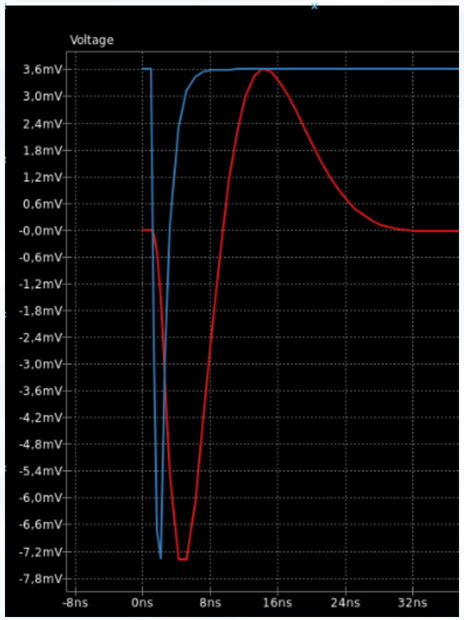
- Spice time domain simulation using an ideal I source.
- Decreasing exponential pulse with time constant of 1 ns.

Frequency measurement after time optimization



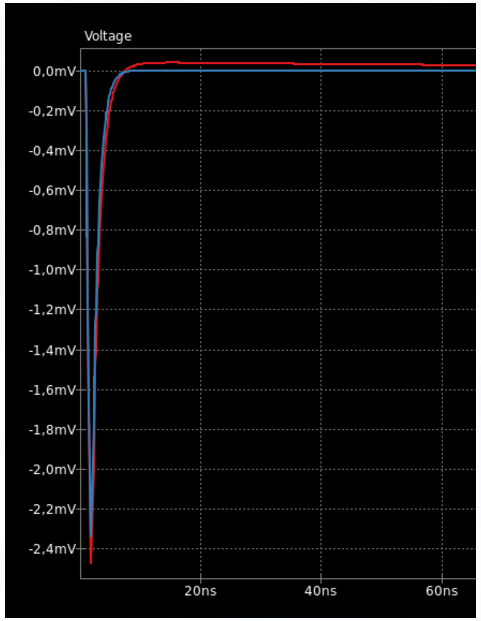
Before time optimization

- Red output.
- Blue input.

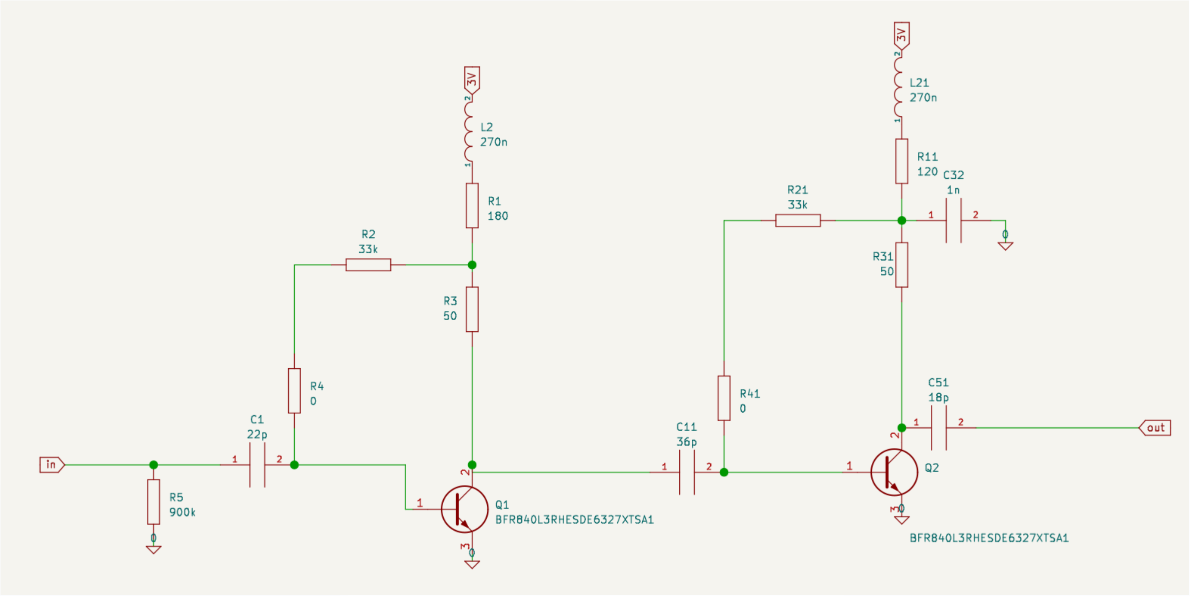


After time optimization

- Red output.
- Blue input.



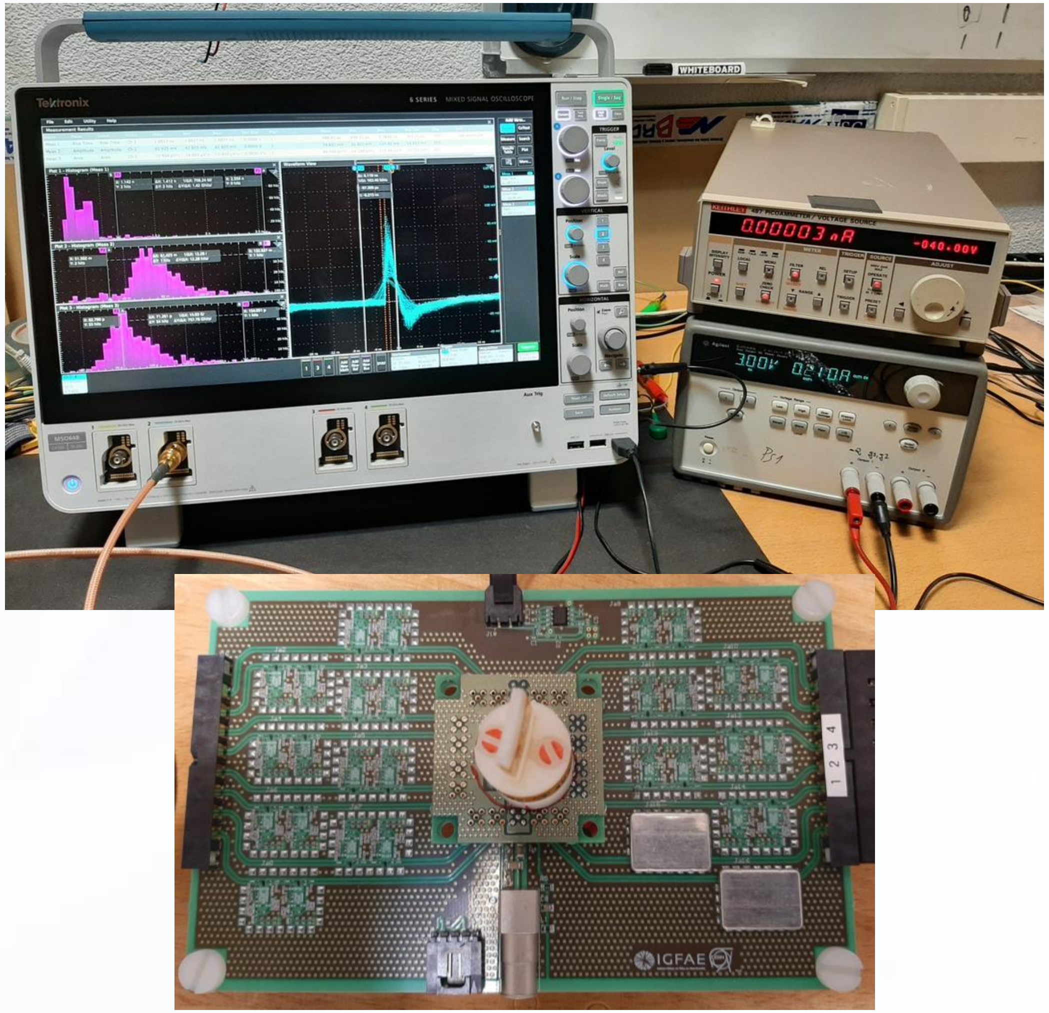
Final Schematic



Measurements

- Pulse response.
- 3D sensors using a Sr90 (4.15MBq).
  - 55 µm pitch.
- Noise using a 3D sensor and Sr90 (4.15MBq).
- Planar sensors (1 and 4 pixels) using a Sr90 (4.15MBq).
  - 50 µm, 100 µm, 200 µm, 300 µm thickness.

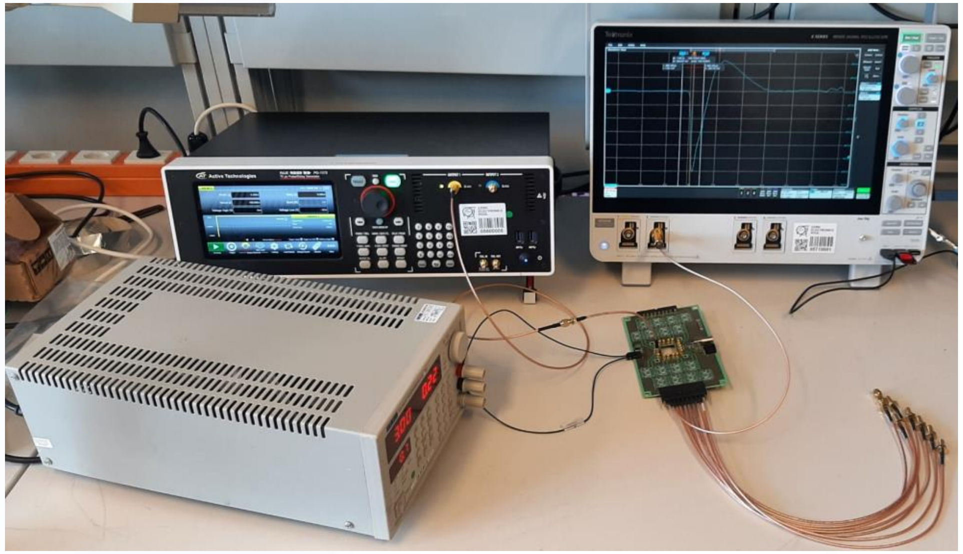
Measurement Setup with source



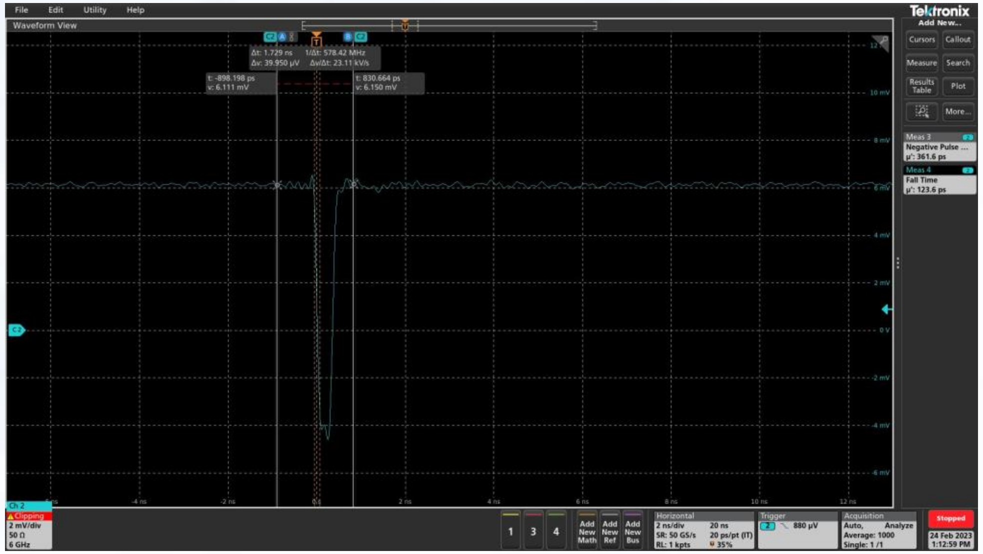
Pulse response

- After the optimization in frequency and time.
- Tested injecting a pulse of 300ps width and -10 mV amplitude. Readout with 10 GHz bandwidth scope and sampling rate of 50 Gsps.
- Output fall time of 276 ps.

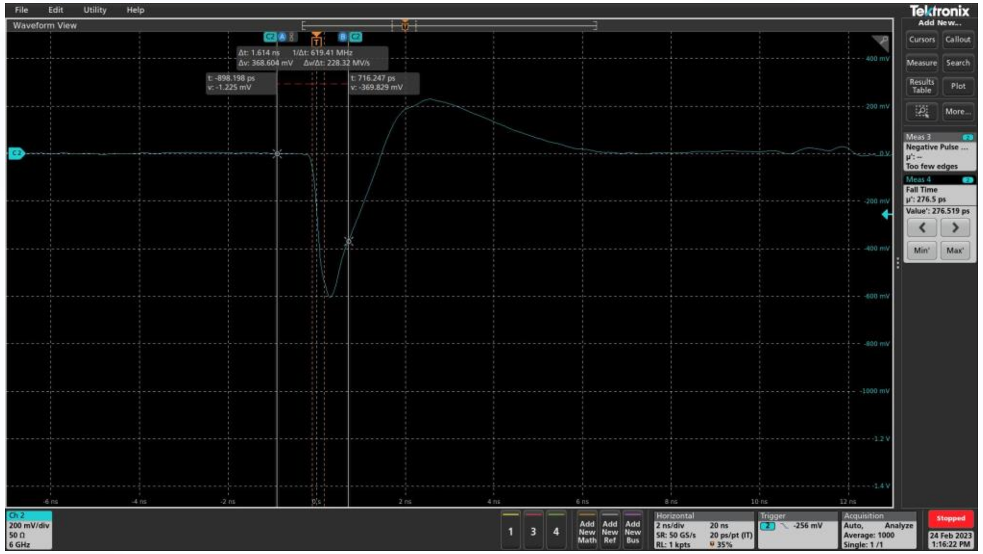
Measurement Setup for pulse response



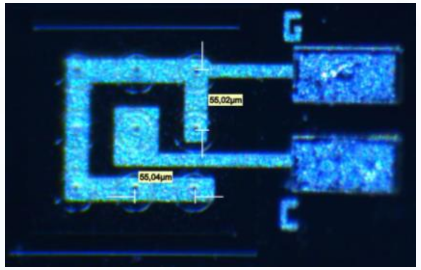
Input signal

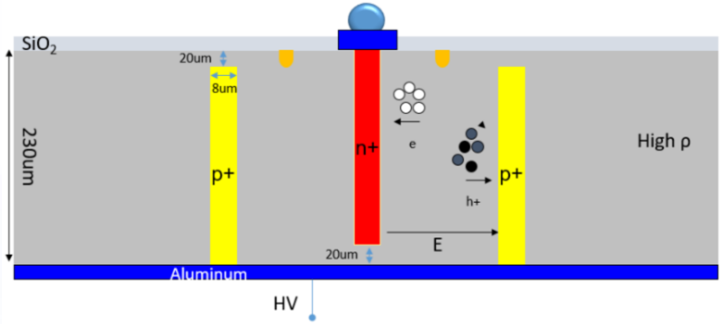


Output signal

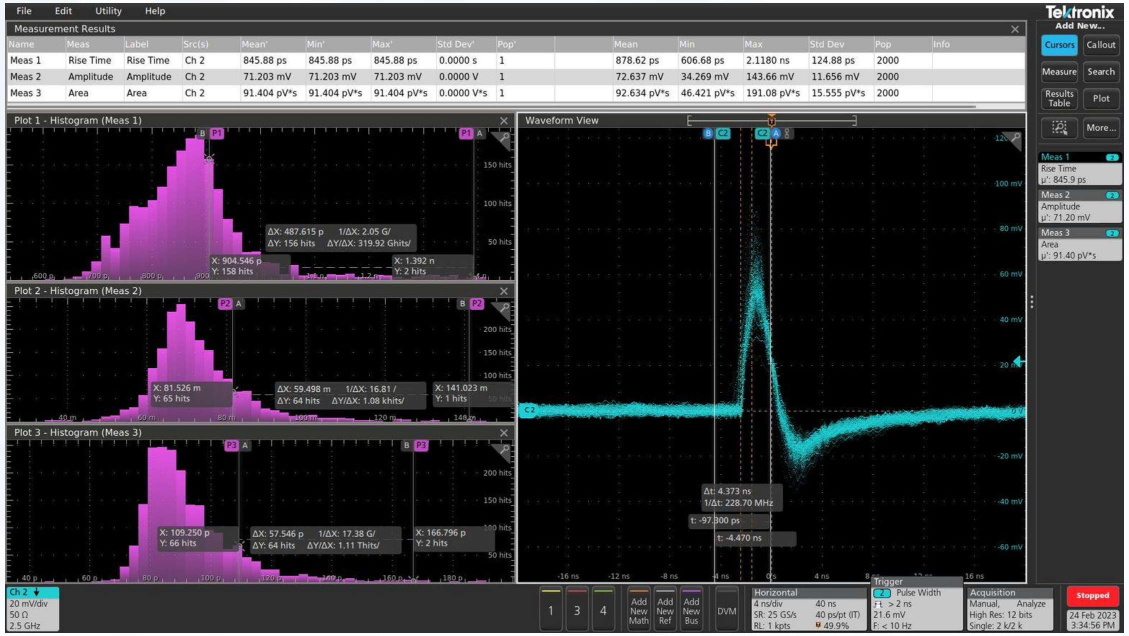


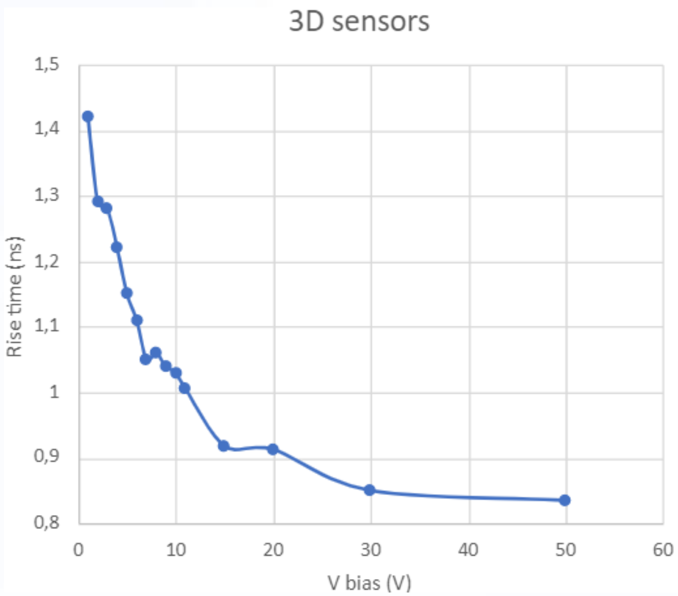
3D sensors





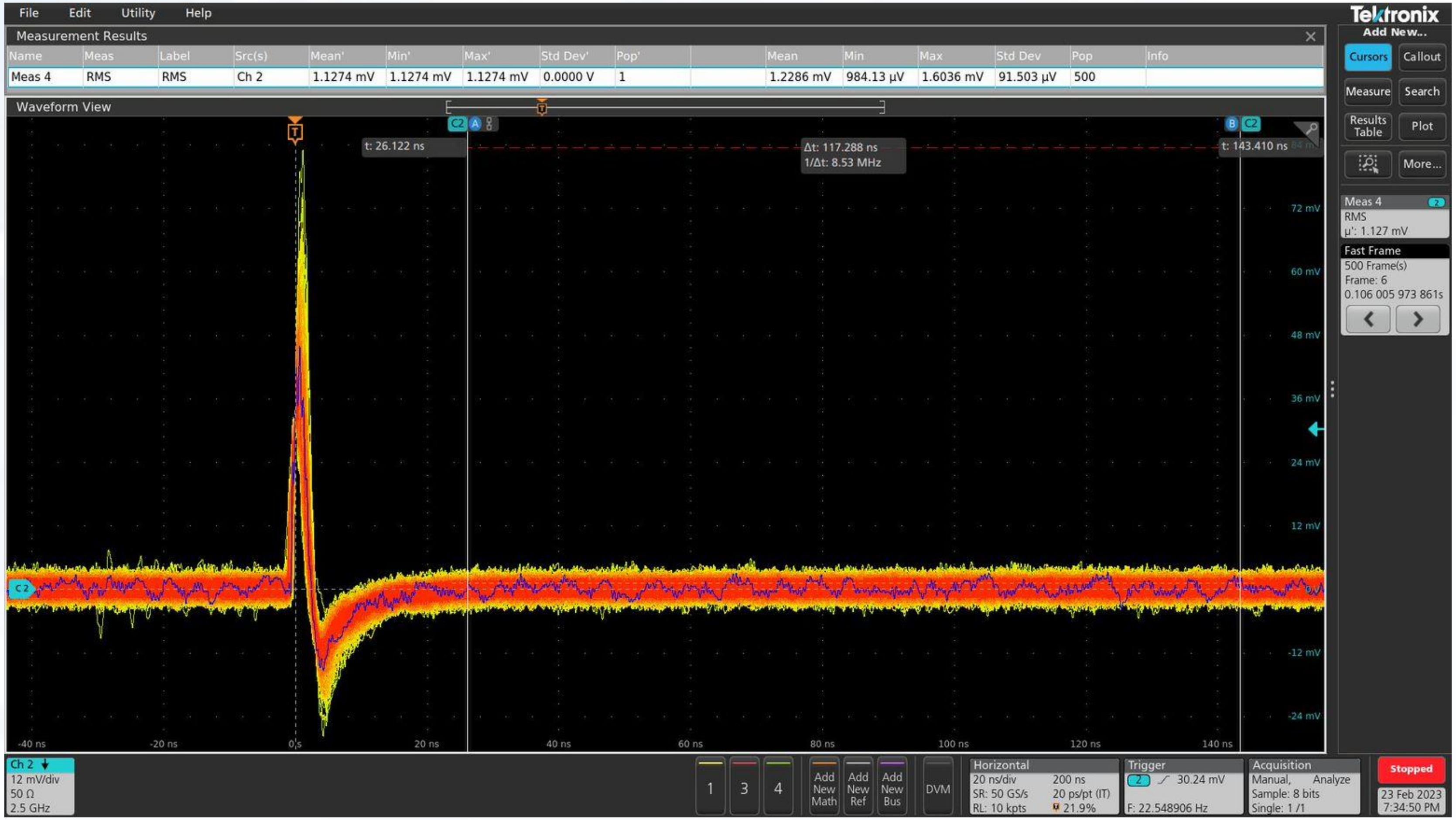
- CNM 3D sensors 55 um pitch.
- Used in:
  - Timing resolution and CCE of n-on-n silicon sensors with TCT setup - Oscar David Ferrer Naval (CNM). 41st RD50.
  - Timing performance of small cell 3D silicon detectors - G. Kramberger, et al.
- Timing performance compatible with what was measure before.





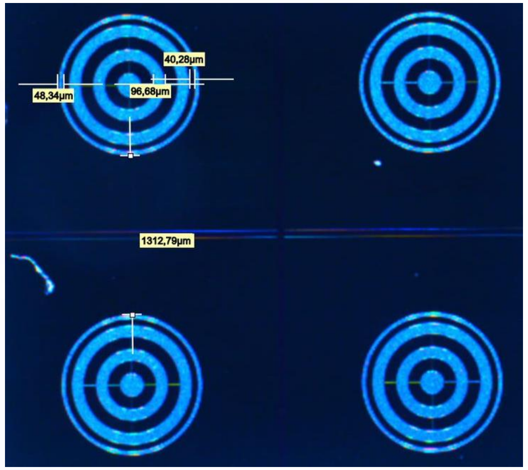
Noise

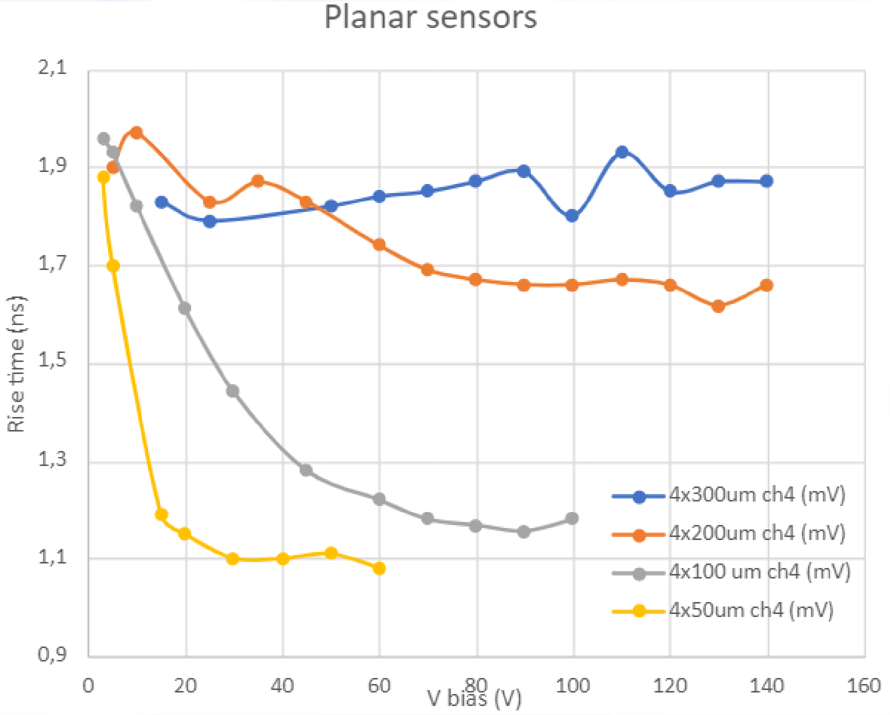
- Measurement of the board output noise level with a 3D sensor.
- Noise RMS of 1.2 mV.



Planar sensors

- Measurements of time response for different sensors thickness.
  - 50 µm, 100 µm, 200 µm, 300 µm.
- 4 sensors wirebonded per board in adjacent channels to measure board crosstalk.



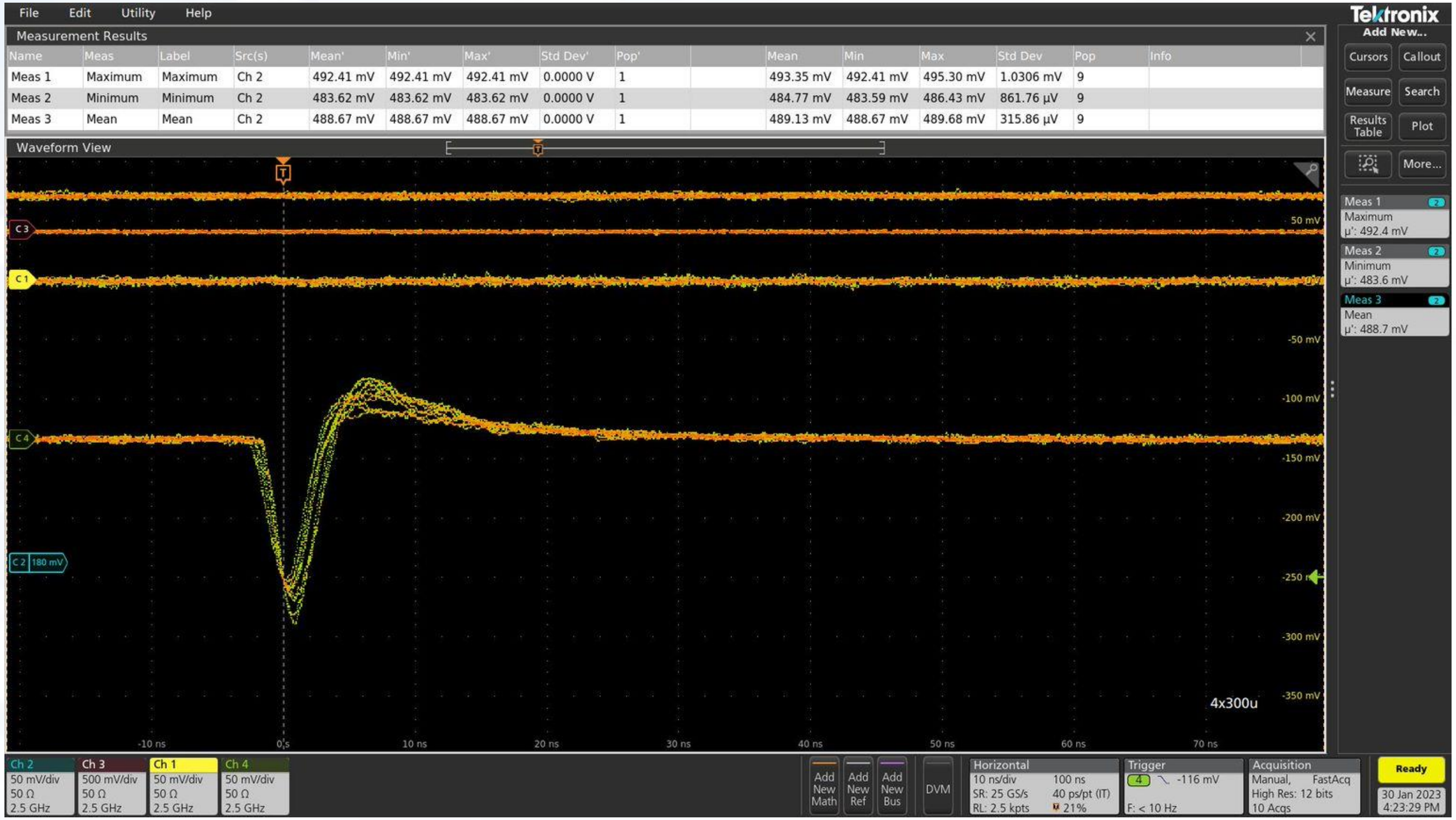


Planar sensors

Measurement example for the 100 µm sensor thick.

Planar sensors: Crosstalk

- No crosstalk observed between channels.
- One sensor connected in each oscilloscope channel.



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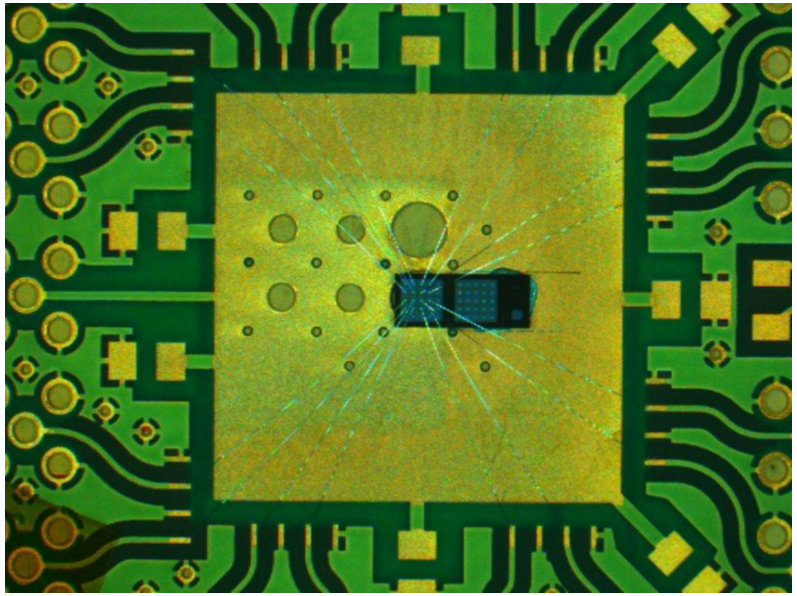
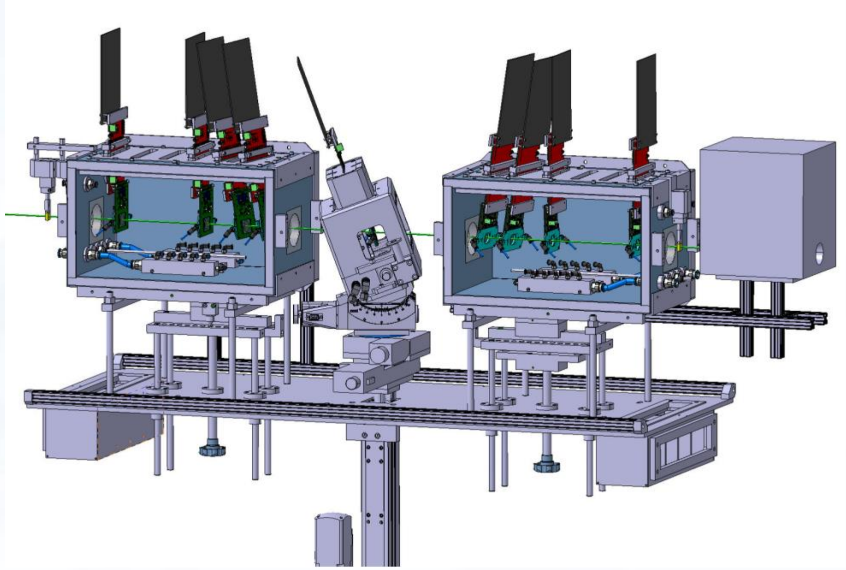
Conclusions

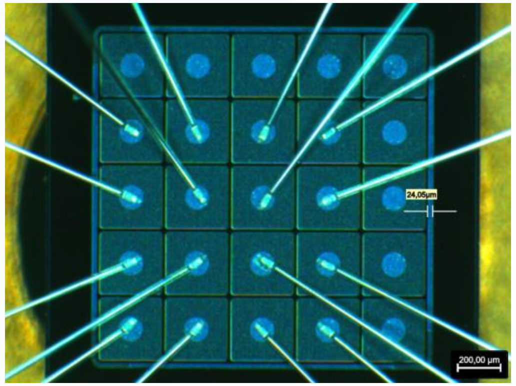
- Successful design, simulation and test of a platform for sensor characterization.
- Design of a 16 channels board to characterize single or multiple pixel sensors. Compact and versatile.
- Time and frequency domain studies for a better signal to noise ratio on the electronics.
- Measurement of the circuit pulse response.
- Test of planar and 3D sensors.

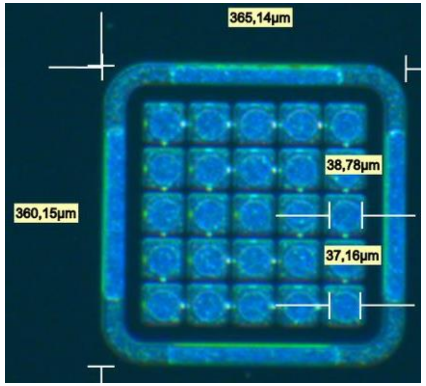
Future steps

- Test setup with collimated source for angle measurements & position scans.
- Test with laser.
- Cold test.
- Test 4x4 pixel matrix.
- Optimize to be used in the DUT of the Timepix 4 Telescope.









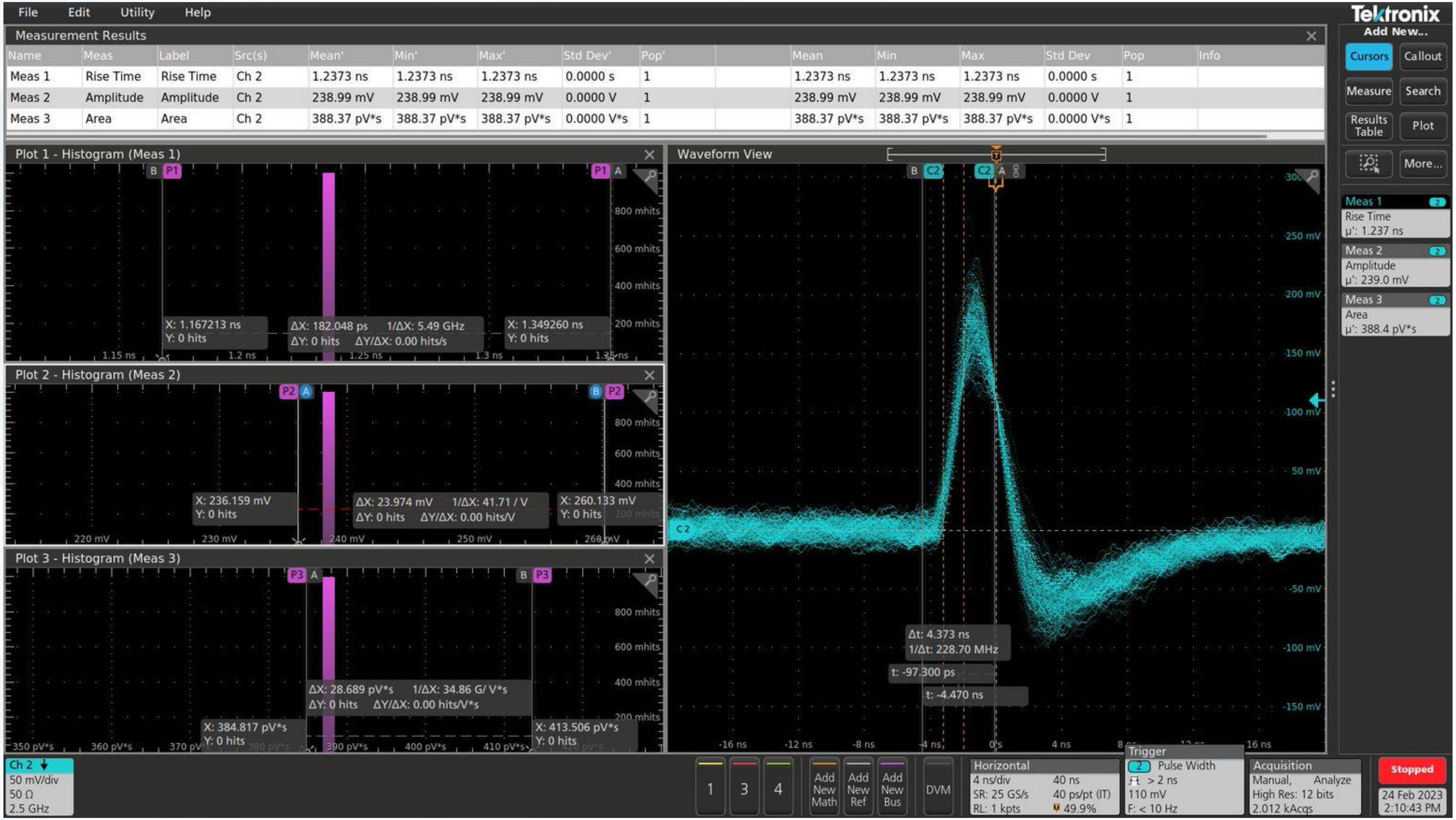
Thanks

Back up

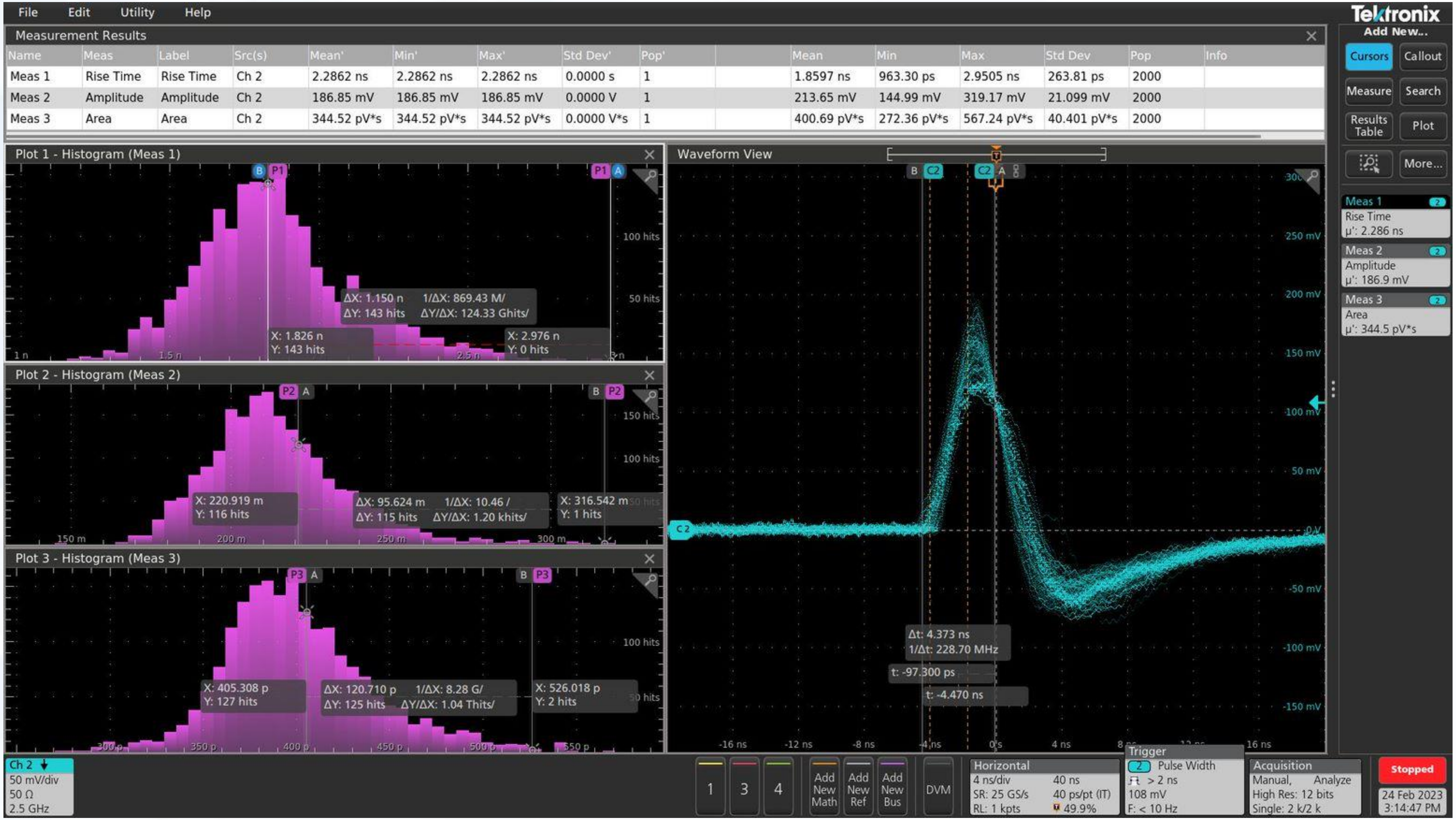
50 um sensor


File
Edit
Utility
Help
Measurement Results
Name Meas Label Src(s) Mean' Min' Max' Std Dev' Pop' Mean Min Max Std Dev Pop Info
Meas 1 Rise Time Rise Time Ch 2 1.1505 ns 1.1505 ns 1.1505 ns 0.0000 s 1 1.1122 ns 858.48 ps 3.5135 ns 163.66 ps 2178
Meas 2 Amplitude Amplitude Ch 2 148.35 mV 148.35 mV 148.35 mV 0.0000 V 1 177.67 mV 122.72 mV 408.22 mV 24.246 mV 2178
Meas 3 Area Area Ch 2 196.04 pV*s 196.04 pV*s 196.04 pV*s 0.0000 V*s 1 223.39 pV*s 48.928 pV*s 400.01 pV*s 28.750 pV*s 2178
Plot 1 - Histogram (Meas 1)
X: 1.403 n
Y: 3 hits
ΔX: 2.118 n 1/ΔX: 472.13 M/
ΔY: 2 hits ΔY/ΔX: 944.26 Mhits/
X: 3.521 n
Y: 1 hits
Plot 2 - Histogram (Meas 2)
X: 162.802 m
Y: 261 hits
ΔX: 181.233 m 1/ΔX: 5.52 /
ΔY: 260 hits ΔY/ΔX: 1.43 khits/
X: 344.035 m
Y: 1 hits
Plot 3 - Histogram (Meas 3)
X: 128.648 p
Y: 0 hits
ΔX: 211.755 p 1/ΔX: 4.72 G/
ΔY: 4 hits ΔY/ΔX: 18.89 Ghits/
X: 340.402 p
Y: 4 hits
Waveform View
Δt: 4.924 ns
1/Δt: 203.10 MHz
t: -97.300 ps
t: -5.021 ns
Tektronix
Add New...
Cursors
Callout
Measure
Search
Results Table
Plot
More...
Meas 1
Rise Time
μ': 1.151 ns
Meas 2
Amplitude
μ': 148.4 mV
Meas 3
Area
μ': 196.0 pV*s
Ch 2
40 mV/div
50 Ω
2.5 GHz
Horizontal
4 ns/div 40 ns
SR: 25 GS/s 40 ps/pt (IT)
RL: 1 kpts 49.9%
Trigger
Pulse Width
> 2 ns
52.8 mV
F: < 10 Hz
Acquisition
Manual, Analyze
High Res: 12 bits
2.178 kAcqs
Stopped
24 Feb 2023
1:42:06 PM

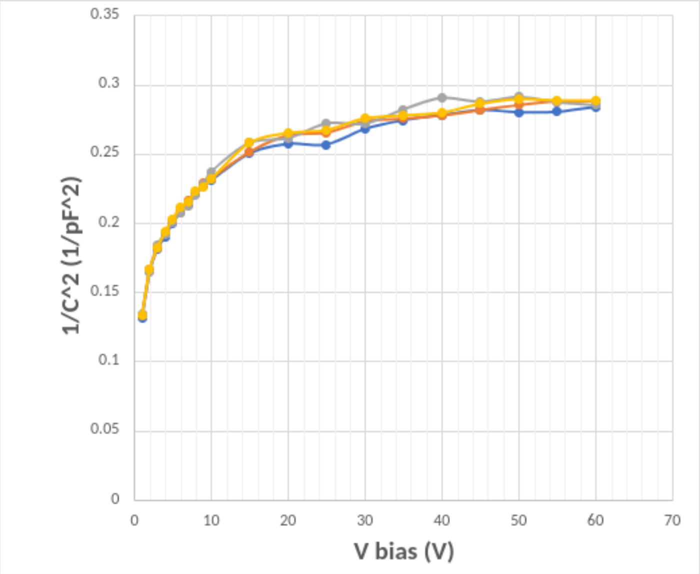
200 um sensor



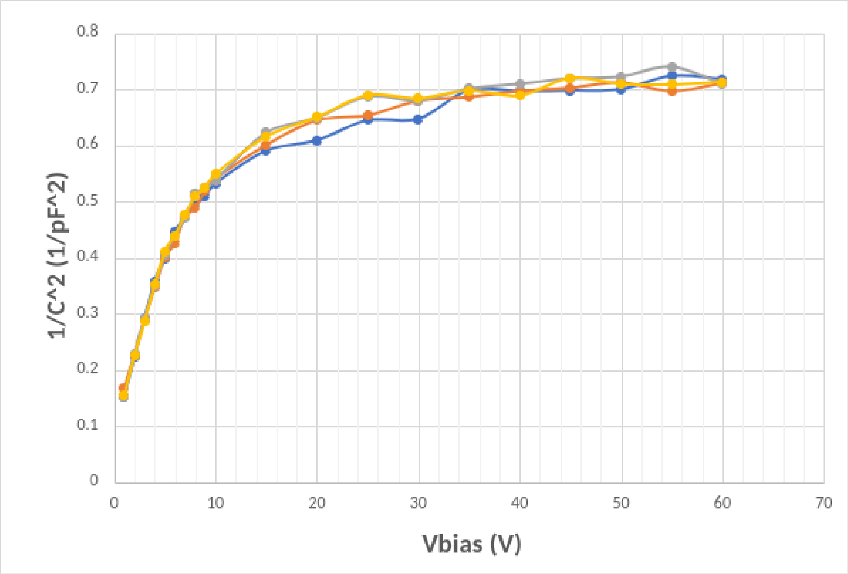
300 um sensor



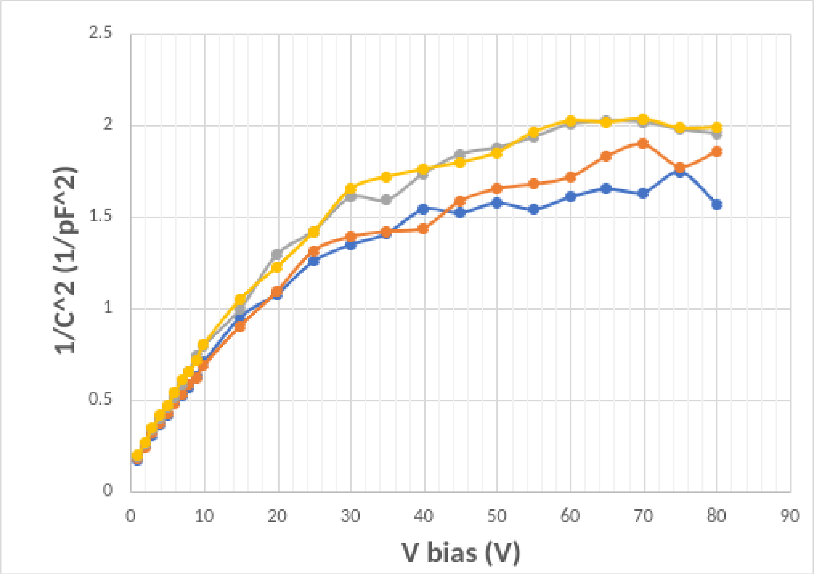
CV curves for 4 pixel planar sensors



50 um

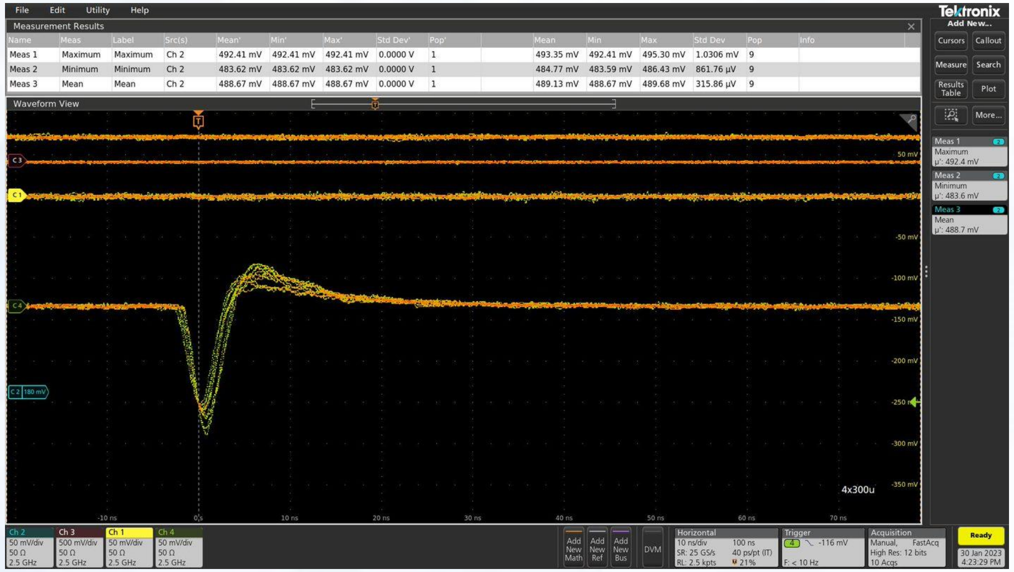


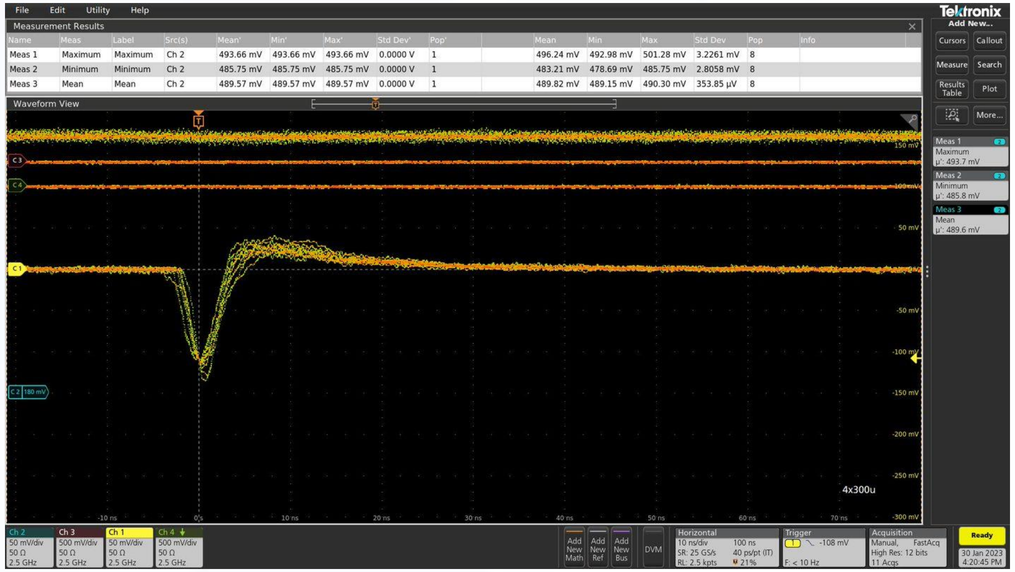
100 um

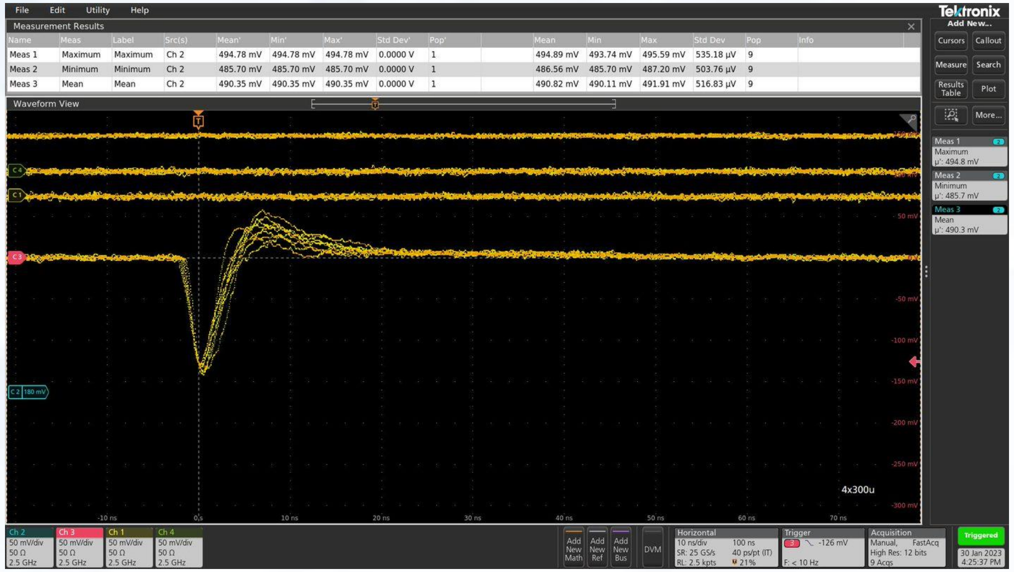


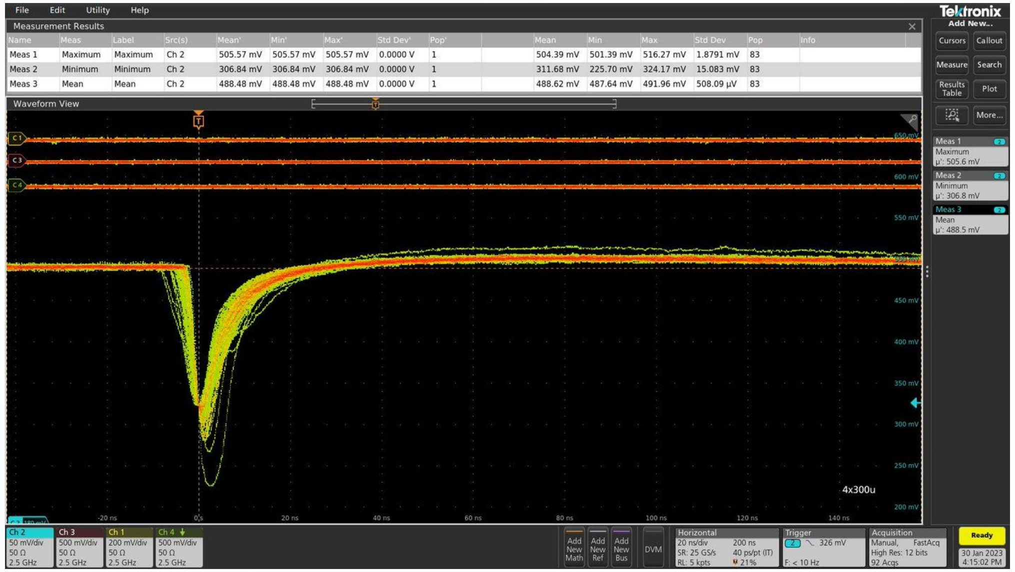
200 um

Crossstalk 300 um

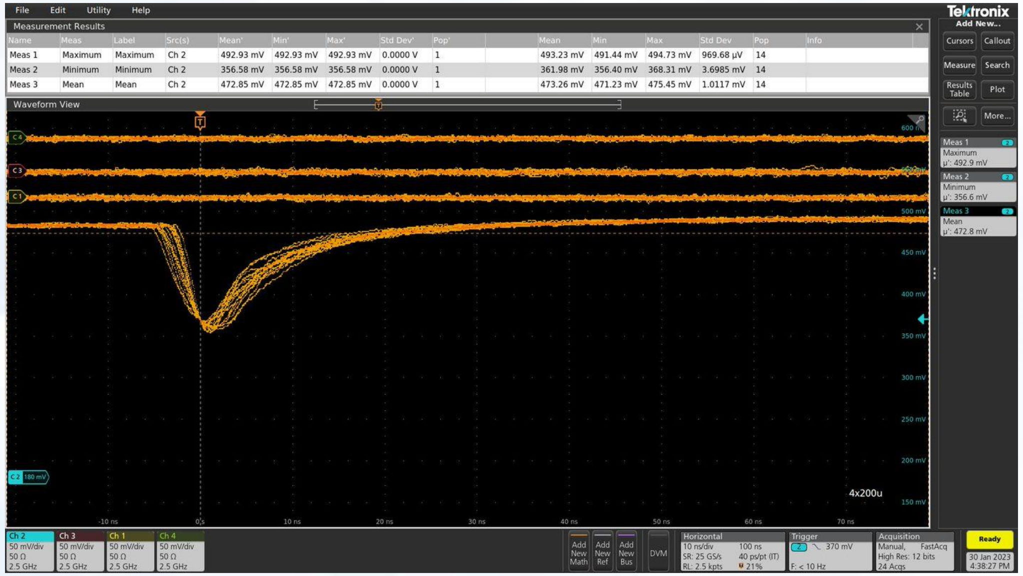


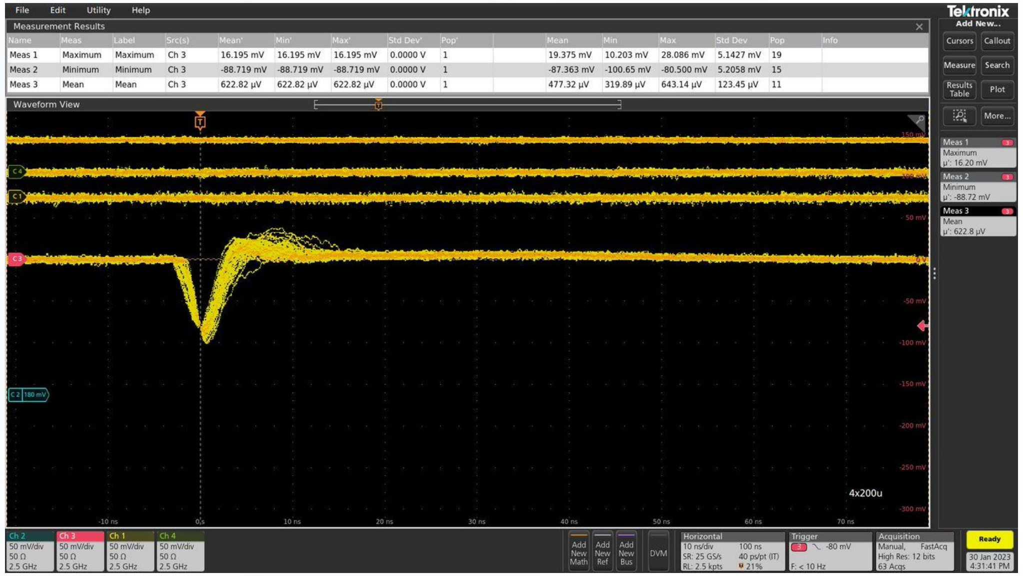


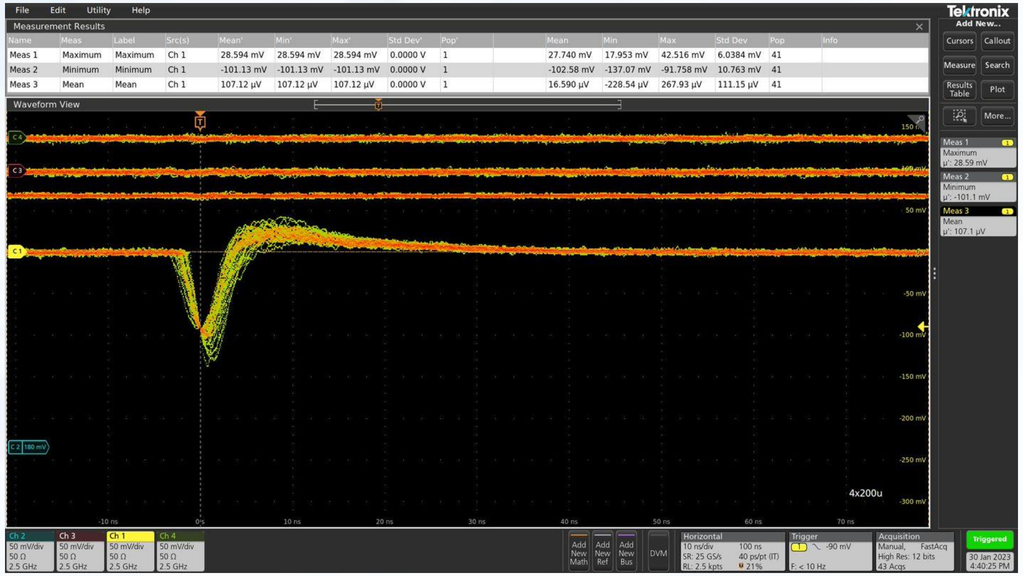


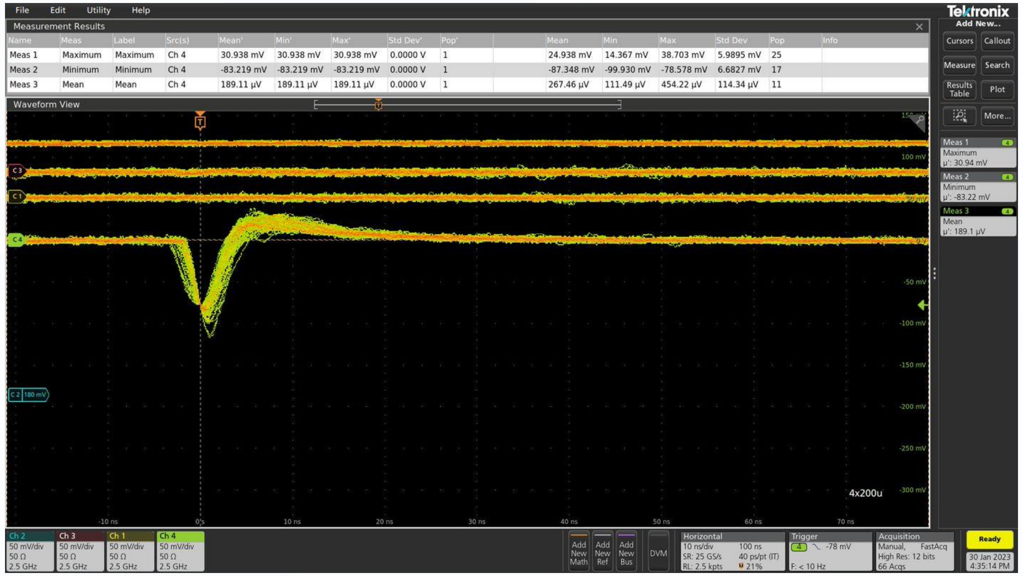


Crosstalk 200 um

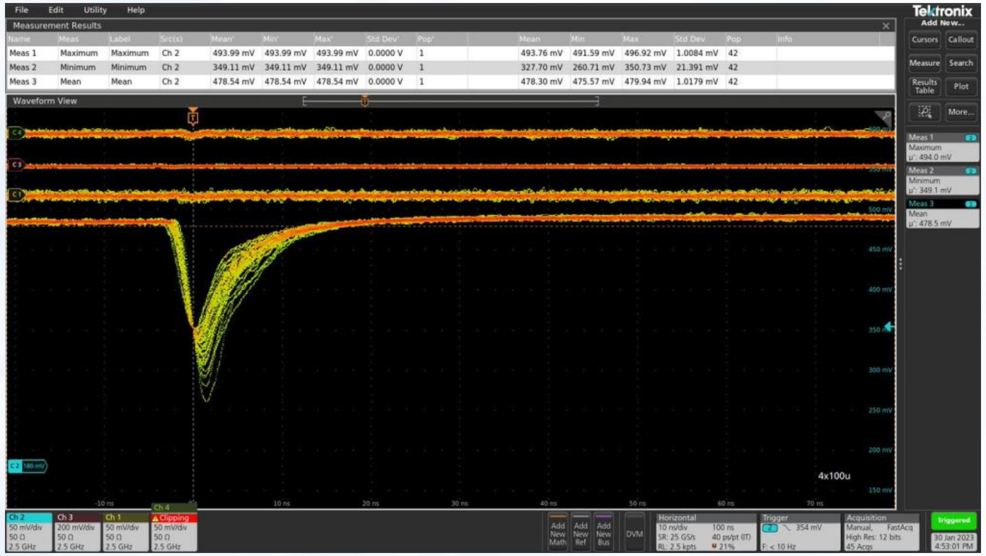


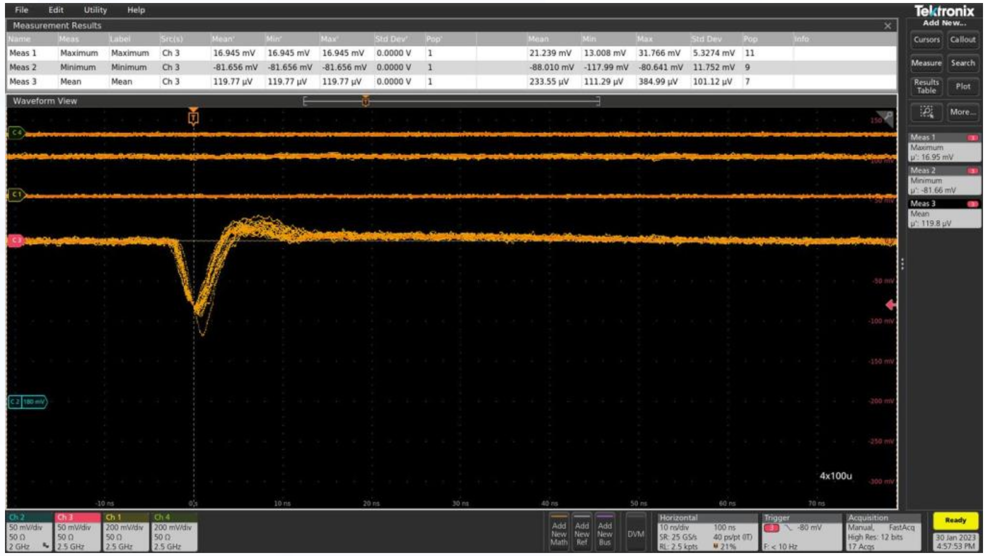


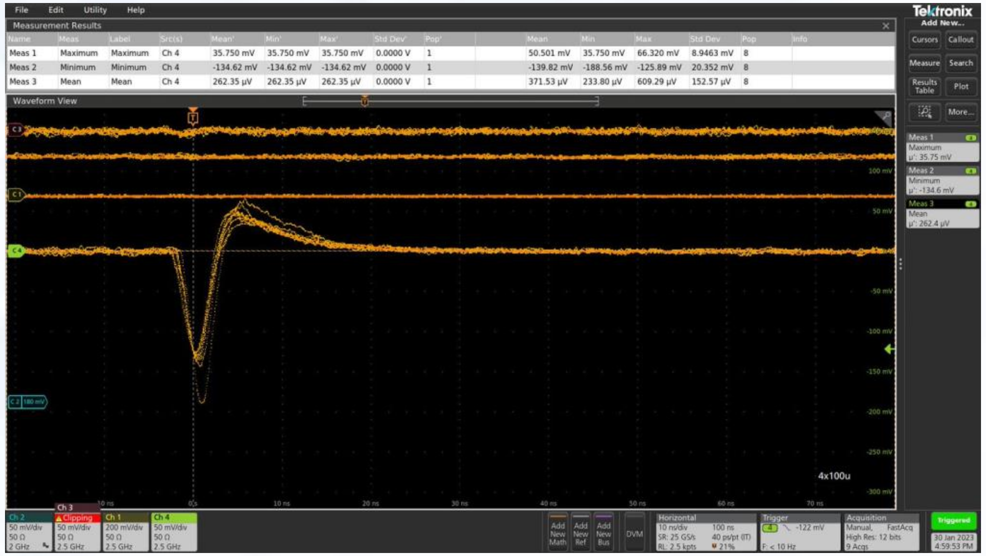


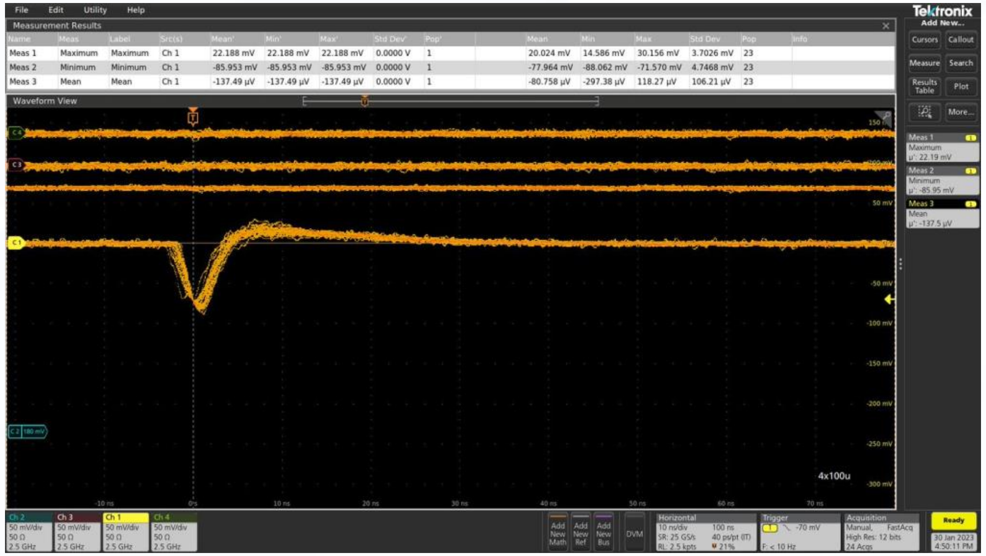


Crosstalk 100 um









Crosstalk 50 um