A new testing system for multipad RSD sensors based on the new FAST2 ASIC

Development of a comprehensive software solution

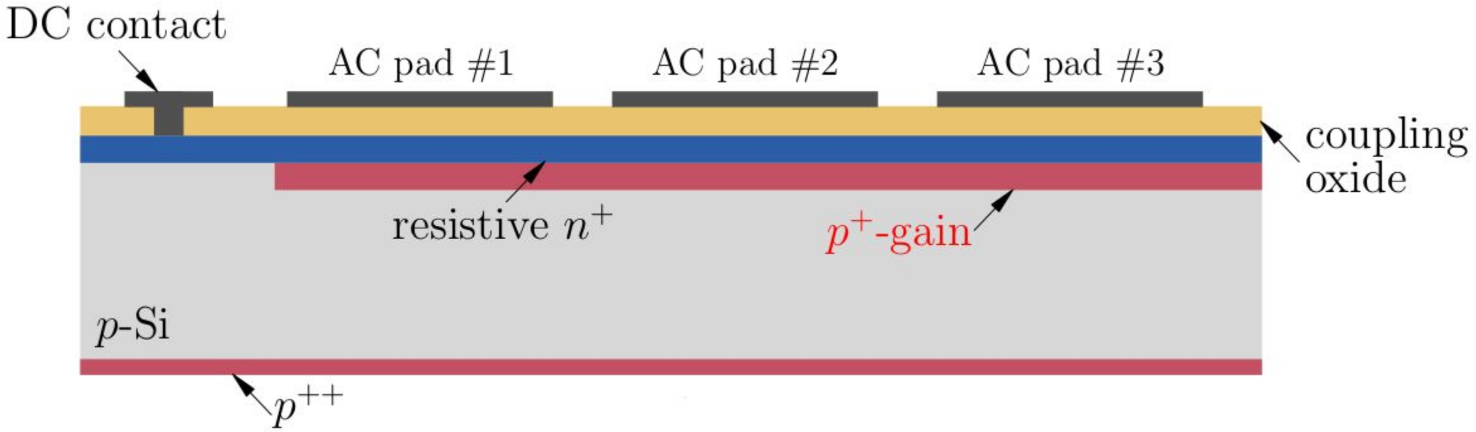
Miserocchi F. and the UFSD group, Torino

Outline

1. **Sensors**: RSDs and their distinctive distributed signal
2. **Front-end**: the FAST2 family of ASICs
3. The data acquisition system of RSD+FAST2 demonstrator
4. First examples of event acquisition
5. Summary and outlook

Intro to RSDs: what and how

- AC coupled LGADs
- Feature distributed AC pads that capacitively couple with the *n+* layer
- Segmented readout happens on the metal pads, allowing for full coverage of gain layer



Intro to RSDs: why

- Signal sharing is desired, can be leveraged to obtain very good spatial resolution
- Data obtained presents itself well to machine learning algorithms (Siviero et al., 2021)
- **Need to concurrently measure as many pads as possible to get the best training data**
- **Need to characterize the device at different bias voltages**
- **Need to evaluate the relationship between signals on the pads and incident particle position**

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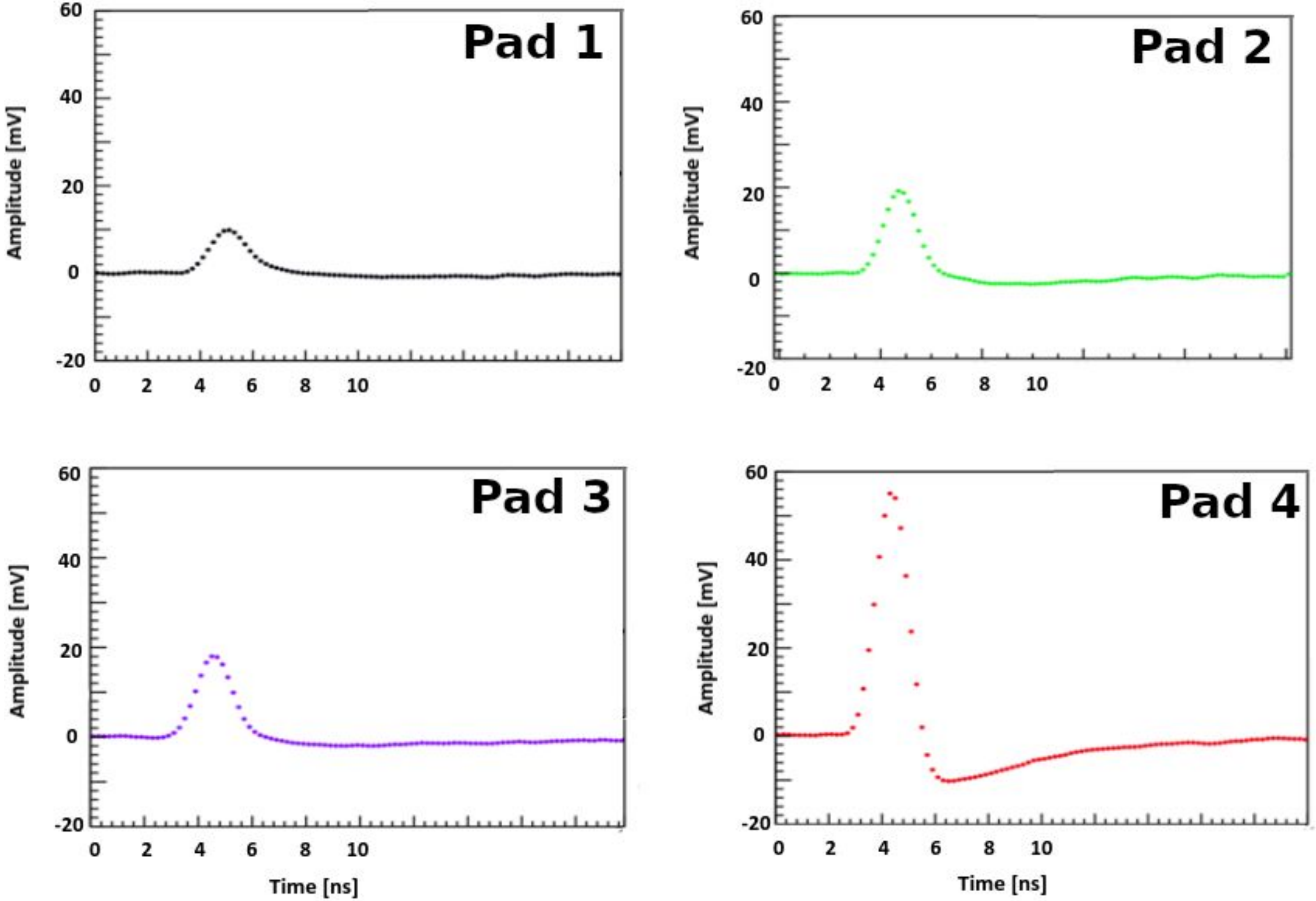
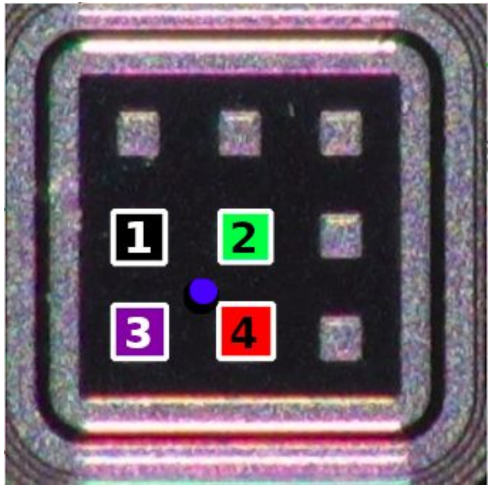
Intro to RSDs: signal sharing example



50 um thick RSD, gain ~20

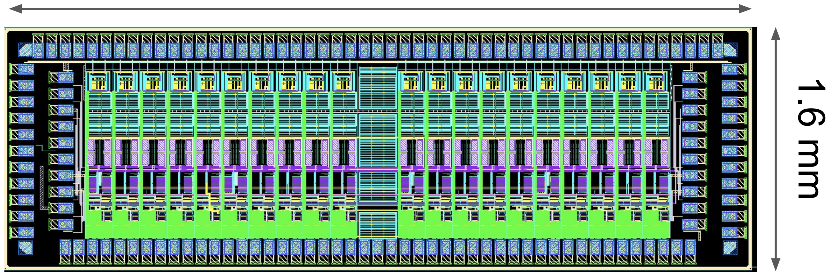


The laser is shot at the position of the blue dot: the signal is seen in 4 pads

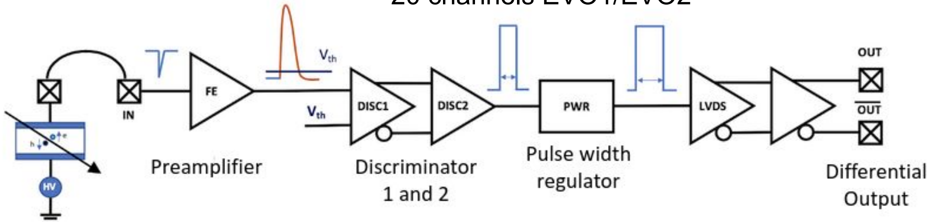
FAST2: a new front-end ASIC

Recently developed in Torino and manufactured using 110 nm node process. The IC is available in two families:

FAST2 digital



20 channels EVO1/EVO2



- EVO1 and EVO2 flavors feature different amplification stages design
- Threshold discriminator
- Digital output

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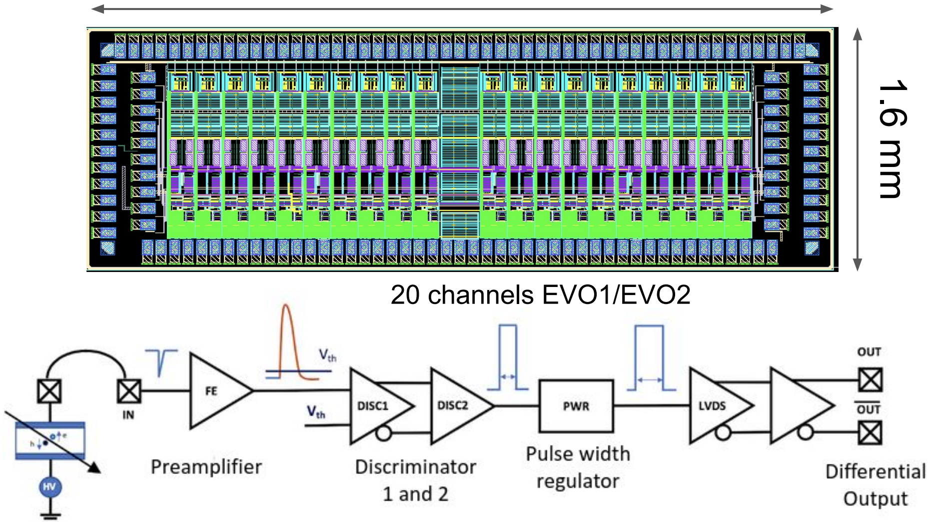

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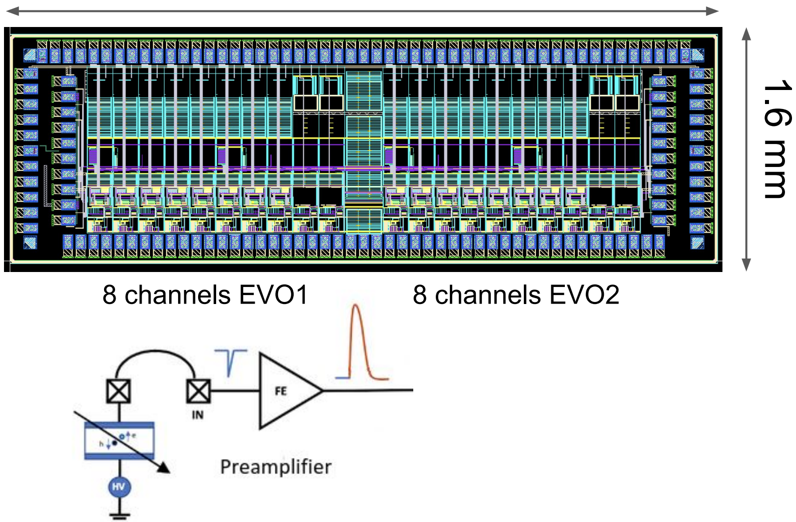
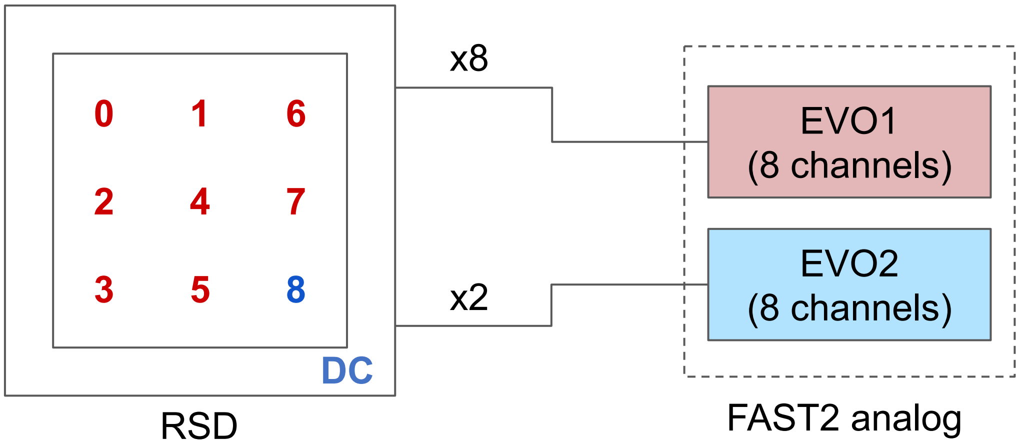
FAST2 analog

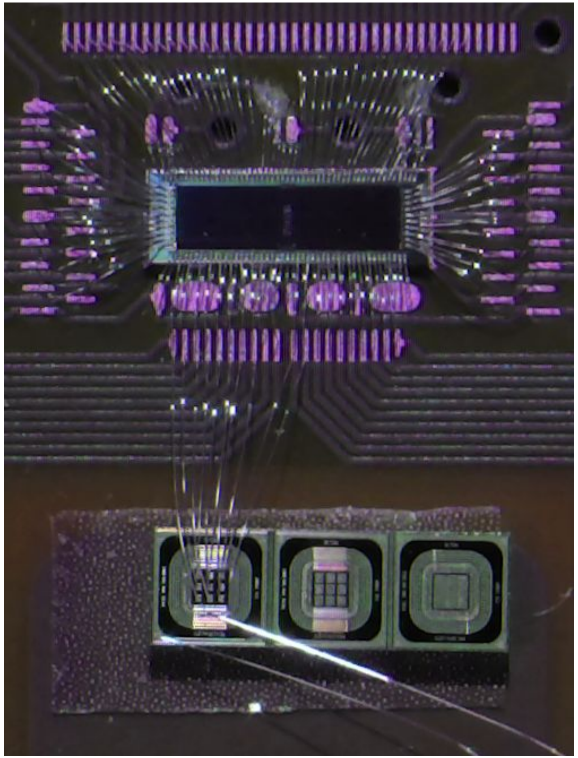


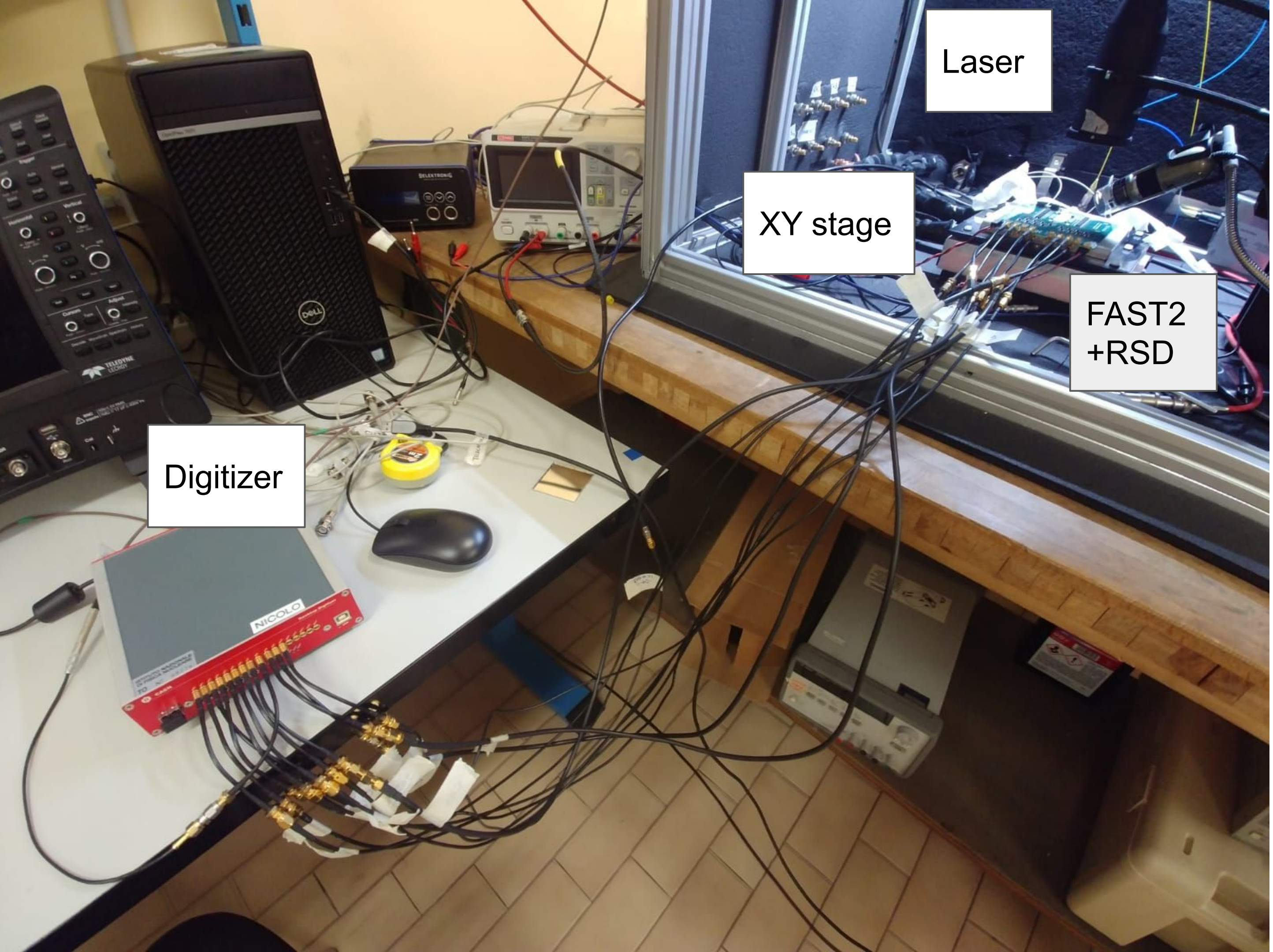
- 8 EVO1 and 8 EVO2 channels
- Single-ended buffered analog output with signal polarity inversion

Combining RSDs and FAST2

- Need to characterize the readout chain as a whole, moving towards 4D tracking
- First results from 3x3, 100-200 μm pitch RSD topology coupled with FAST2 analog
- Pads 0 to 7 using EVO1 amplifier design, pads 8 and DC connected to EVO2





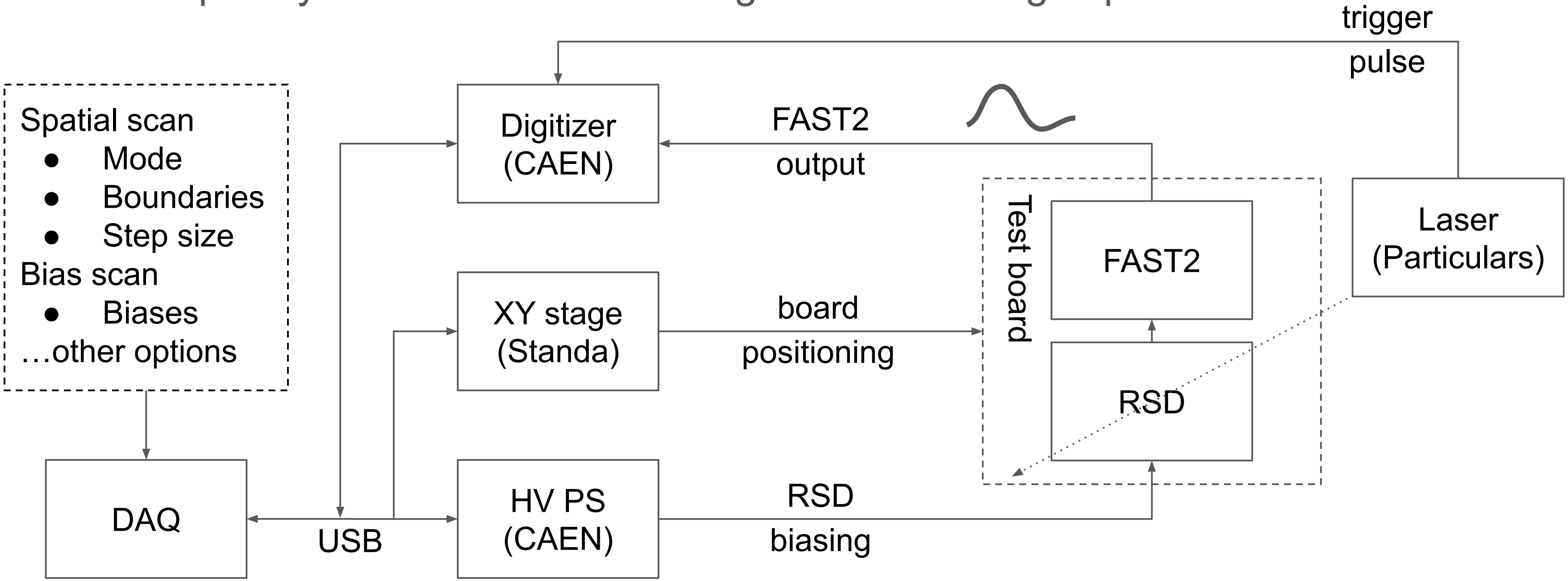


Experimental setup

- Digitizer
- TCT equipment
- Test board

Automatic data acquisition

- Transient Current Technique (TCT) used to simulate incident MIPs
- XY stage controls laser pulse delivery (e.g.: 1000x1000 μm^2 grid, 10 um step)
- Front-end output sampled by digitizer, 9 channels + DC pad
- Completely autonomous and configurable scanning capabilities



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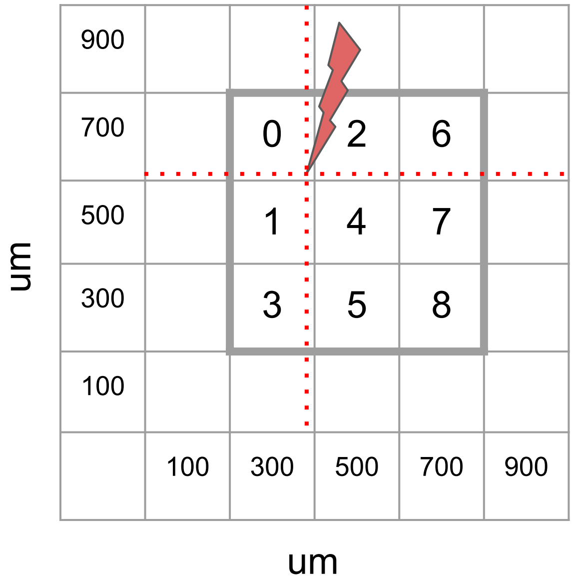
Results: raw waveforms at different locations



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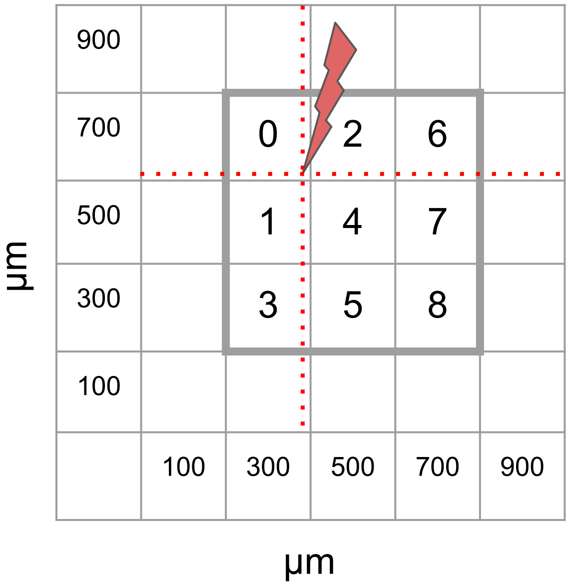
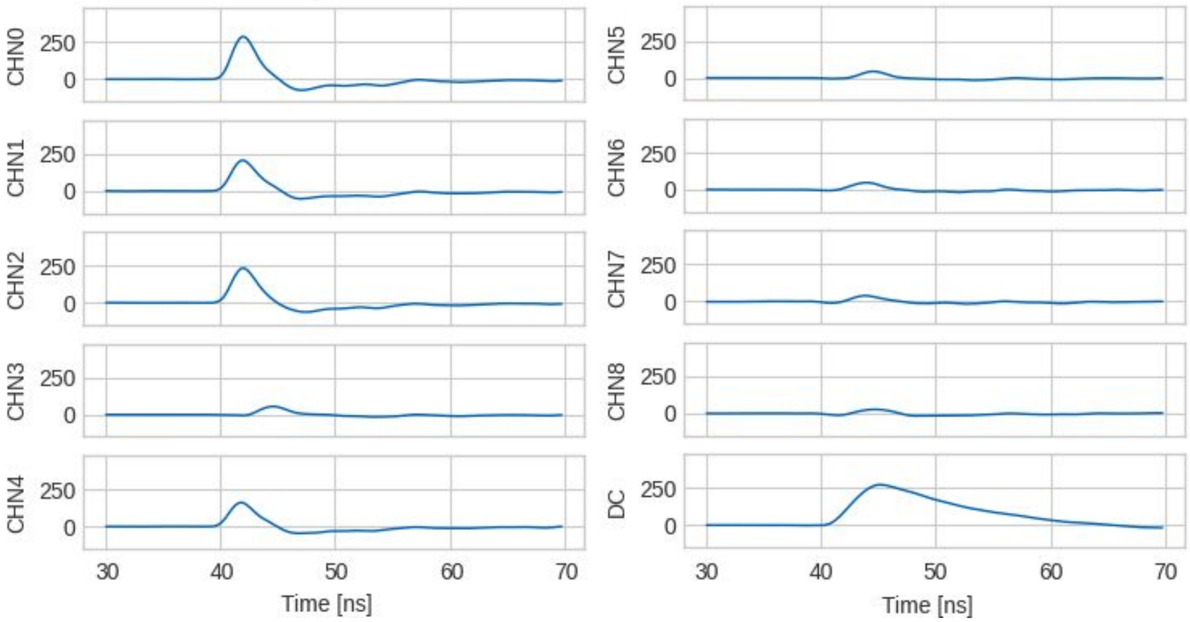


100 event average @ (390, 610) µm



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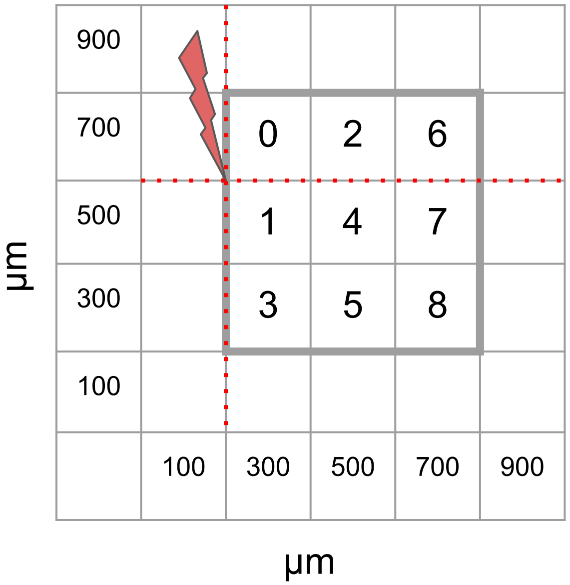

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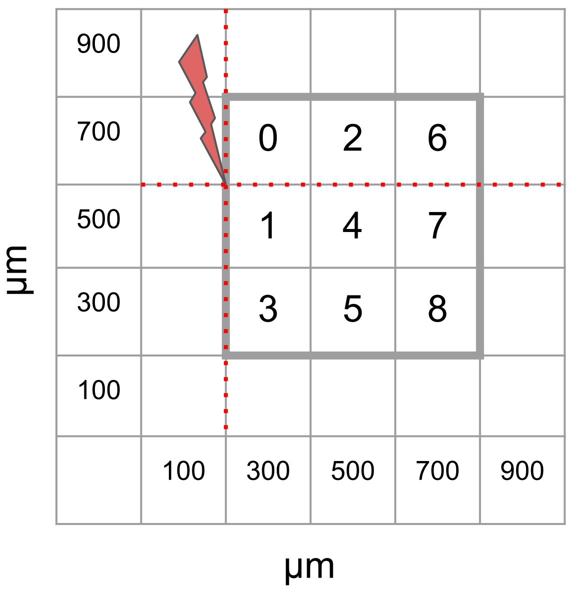
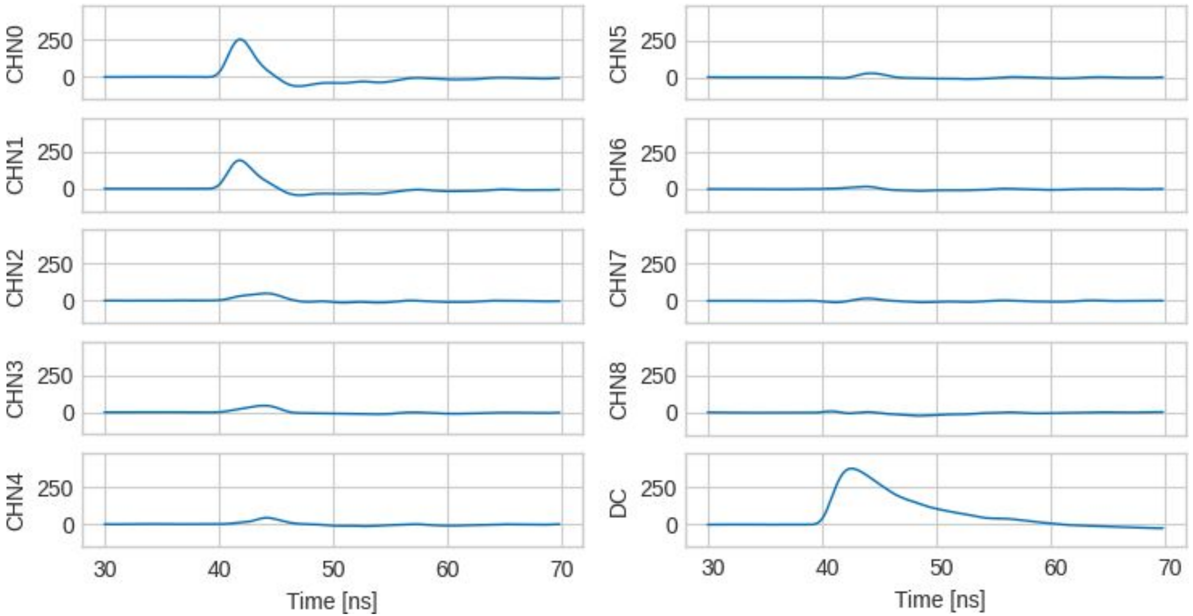
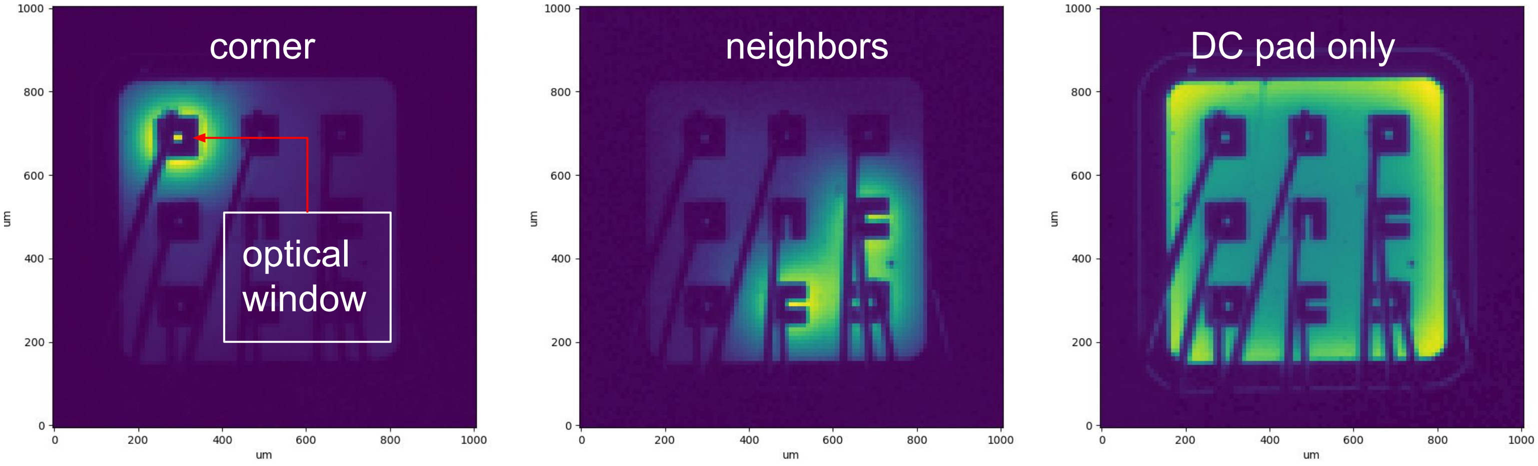


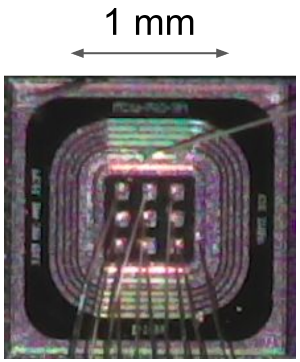
100 event average @ (200, 600) μm



DC channel rising earlier with respect to other location due to pulse being delivered closer to DC ring, displacement current across the oxide is significantly higher

Results: single- and multi-channel heatmaps





Channel map:

0	2	6
1	4	7
3	5	8

DC

1. Laser pulses are delivered across the whole sensor, scanning a 1x1 mm^2 area with 10 µm step size
2. Each pad (channel) is sampled concurrently, output waveforms are stored on a per-channel, per-event basis
3. Waveforms belonging to the same channel and position are averaged
4. Color lightness for each “pixel” is evaluated by calculating the peak amplitude for the averaged waveform at that location and channel
5. Lightness matrices relative to different channels are summed together

Summary

- We have fed the RSD distributed signal to FAST2 analog, a fully custom 16 channel front-end ASIC
- The output of the ASIC is read by a commercial 5 GS/s digitizer
- A software acquisition system has been developed to allow for fully autonomous mapping of the RSDs' performance
- Sensors are tested using TCT, scanning over the whole device's area
- Output data is saved in a ROOT file to allow for easy analysis

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Outlook

- The new system allows for mapping the distributed signal of RSDs
- It will be used to characterize the new geometries implemented in the forthcoming new RSD production RSD2
- The laser data obtained is ideal to train the NN algorithm developed to optimize RSD performance

Thank you for your attention!

Question time

Bibliography

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- Ministero della Ricerca, Italia, PRIN 2017, progetto 2017L2XKTJ – 4DinSiDe
- Ministero della Ricerca, Italia, FARE, R165xr8frt_fare

Data analysis workflow

1. To guarantee maximum acquisition speed, sampled waveforms are stored raw as ROOT TTrees (~100 GBs)
2. C++ script is used to extract waveform features such as peak height, rise time and total charge (~10 MBs)
3. Features are then applied to subsequent analysis

Instrumentation

- **Particulars TCT** setup with integrated **Standa 8MTF** motorized XY stage and Particulars PC-controlled IR laser
- **CAEN DT5742** 16+1 channel 12 bit 5 GS/s digitizer
- **CAEN DT1471ET** 4 channel high voltage power supply

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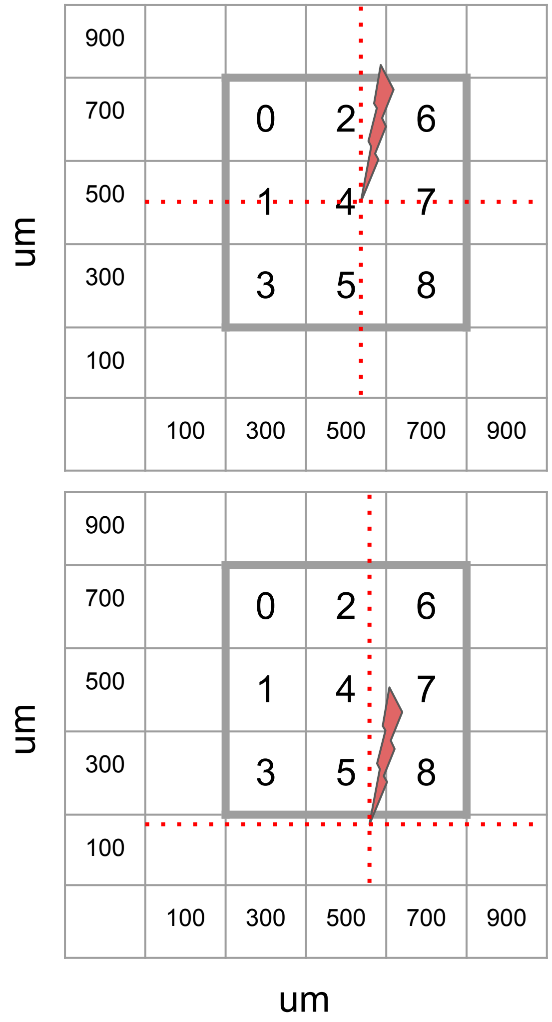
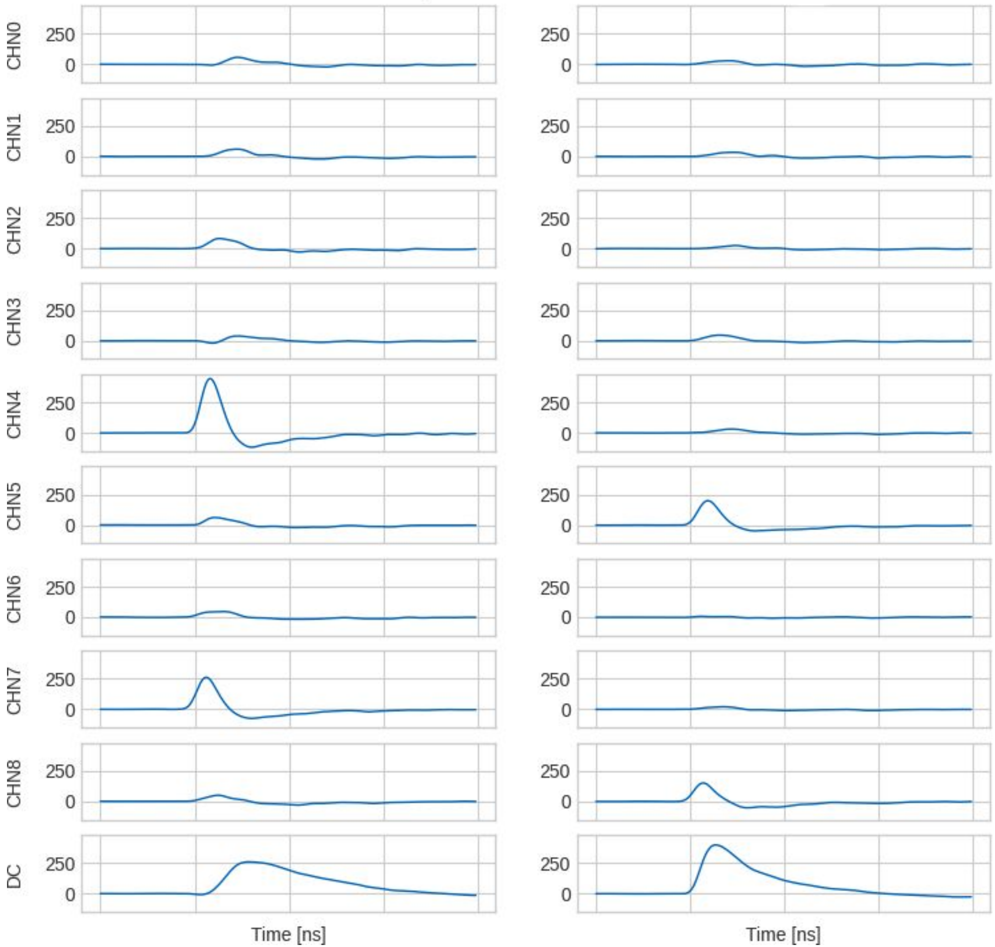


100 events @ (570, 500) um

100 events @ (580, 190) um



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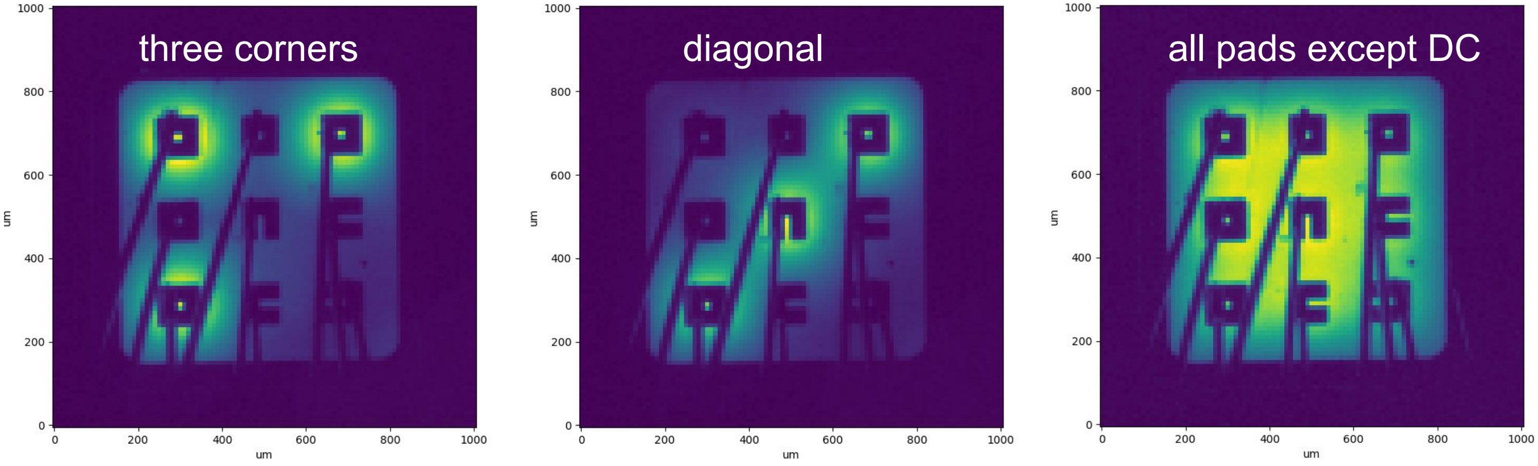

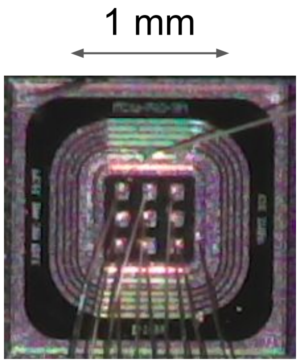

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