Resistive Silicon Detector: 4D tracking with low electrode density

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on behalf of the 4DSHARE project

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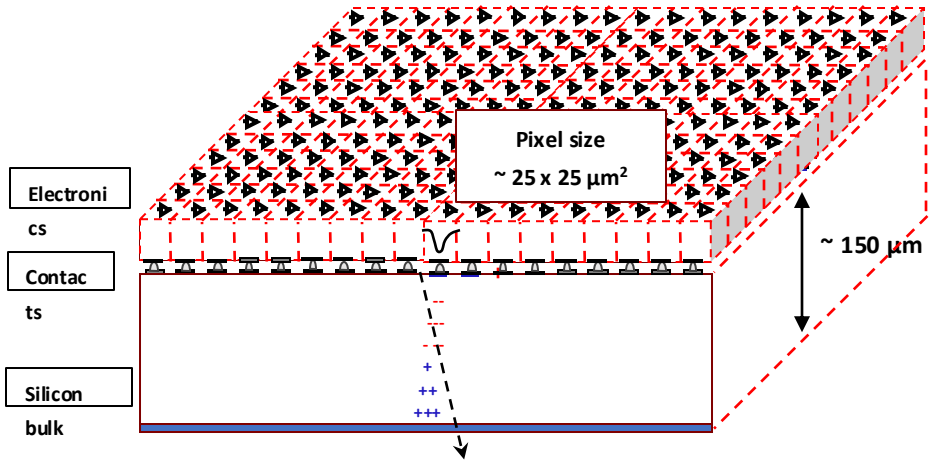
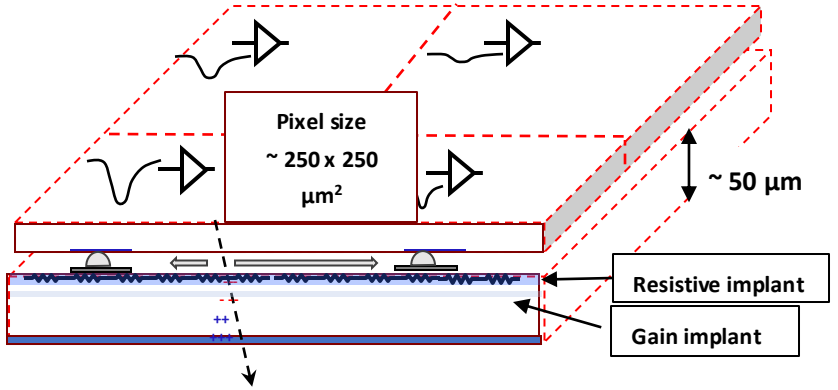
The motivation: silicon trackers using “resistive read-out”

Standard pixelated silicon sensor



Resistive Silicon Detector (RSD)



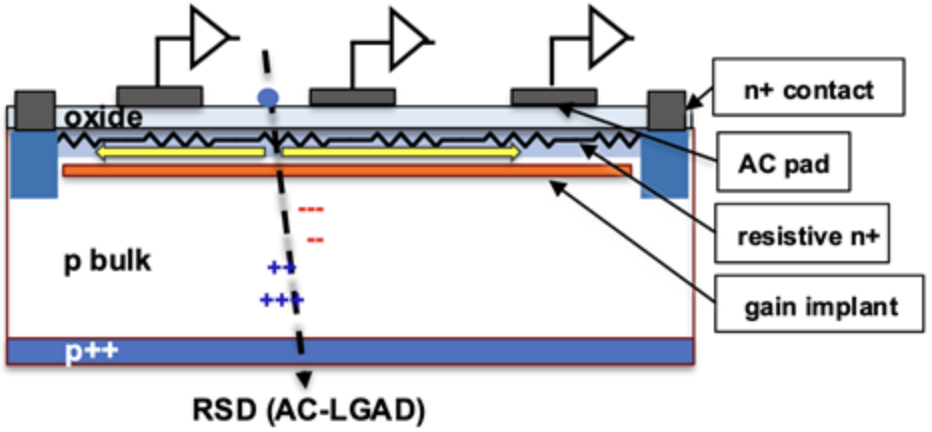
- **Standard pixel sensor:** binary read-out with a **space resolution σ_{Pixel} ~ 0.3·pitch**
- **Resistive silicon detector** based on LGAD technology:
  - **space resolution σ_{Pixel} ~ 0.03-0.05·pitch (3%-5% of the pitch)**
  - **Time resolution of 30-40 ps**
  - Fill factor close to 100%

RSD sensors have similar space resolution of standard pixel sensors, with number of **read-out channels ~100 lower**

lower material budget and power consumption

Resistive silicon Detectors – the technology

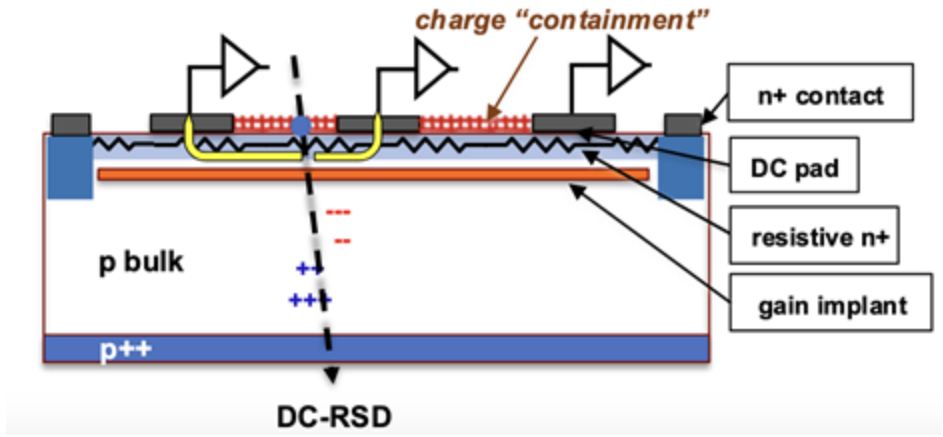
AC-Coupled Resistive silicon Detectors



Main Characteristics of AC-RSD:

- Fill factor of 100%
- Bipolar signals with long second lobe
- Baseline fluctuation (leakage current collected at the sensor edge)
- Signal confinement determined by the resistive electrode and coupling capacitance

DC-Coupled Resistive silicon Detectors

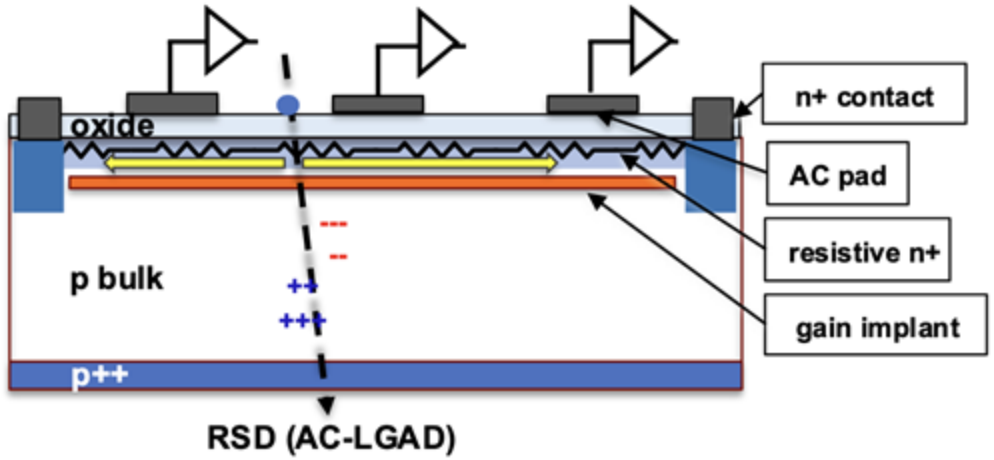


Main Characteristics of DC-RSD:

- Excellent Signal confinement obtained with trenches
- Fill factor ~ 99%
- Unipolar signals

AC-Resistive silicon Detectors

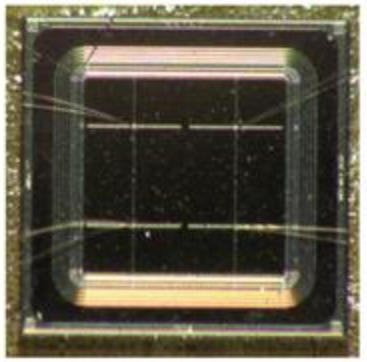
AC-Coupled Resistive silicon Detectors

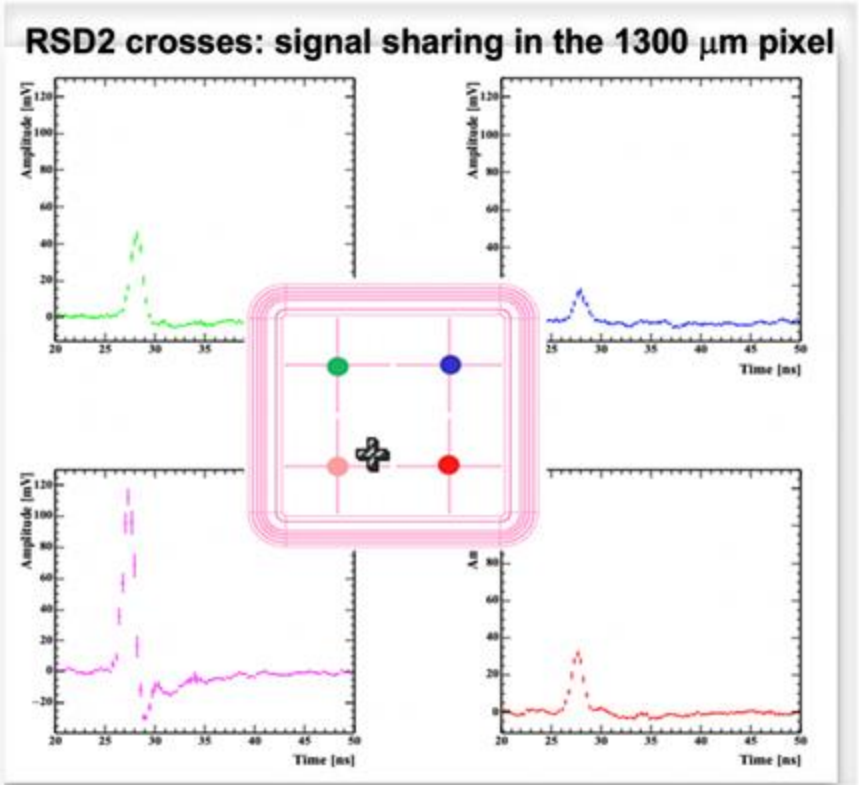


The proof-of-concept of signal sharing with resistive read-out in silicon sensors

- RSD1 batch
- RSD2 batch

The RSD batches have been funded by INFN CSN5

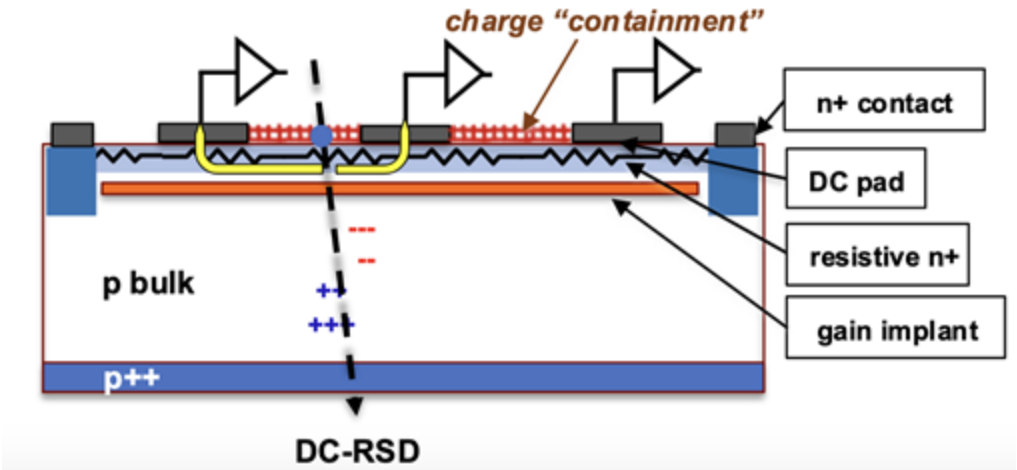


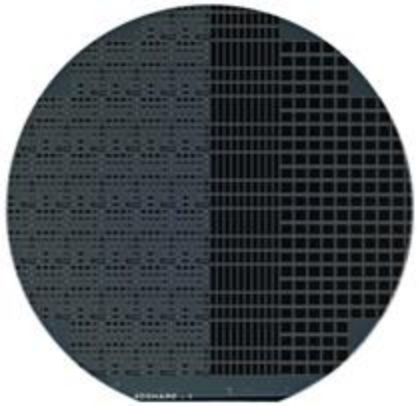


- Bipolar signals with long second lobe
- Signal amplitude related to the position of the hit

DC-Resistive silicon Detectors

DC-Coupled Resistive silicon Detectors





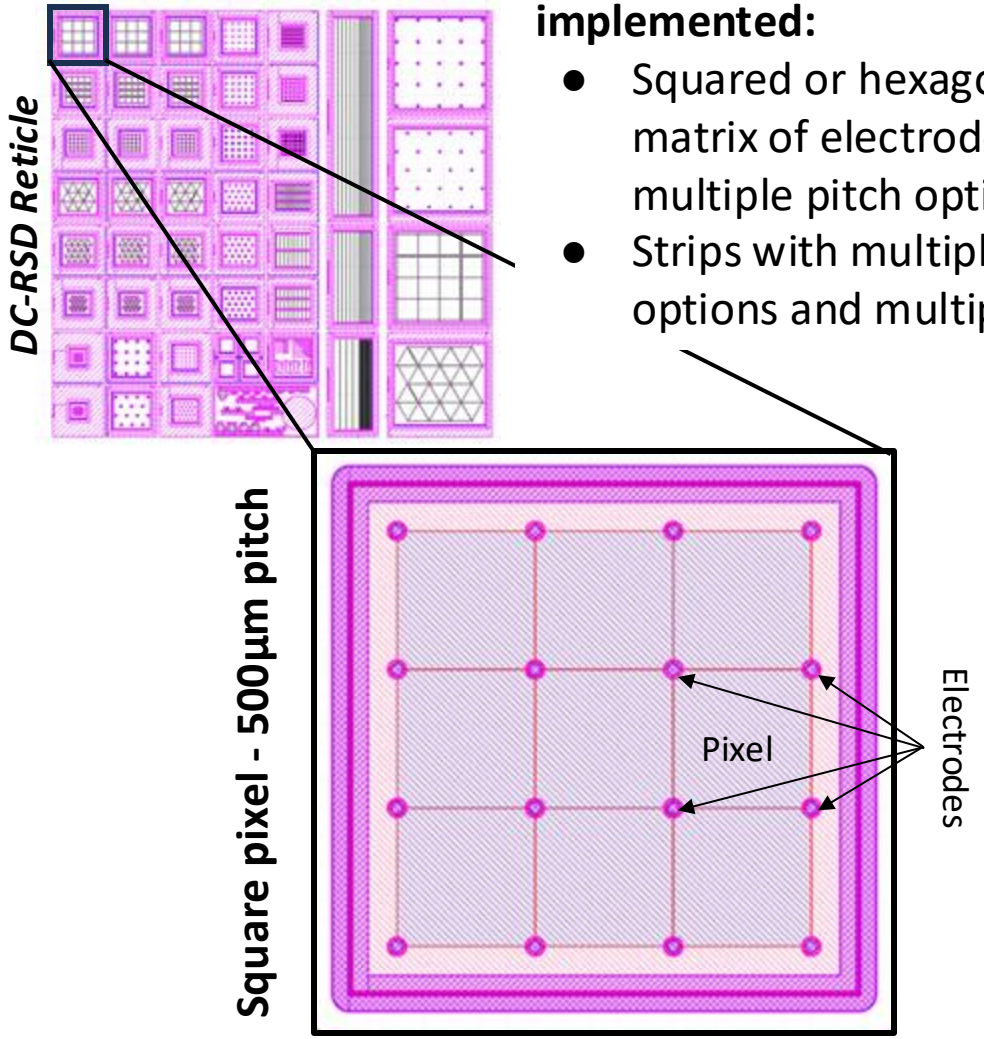
DC-RSD wafer

The first DC-RSD production was released by FBK in November 2024

The production was funded by INFN CSN5 through the 4D-SHARE project

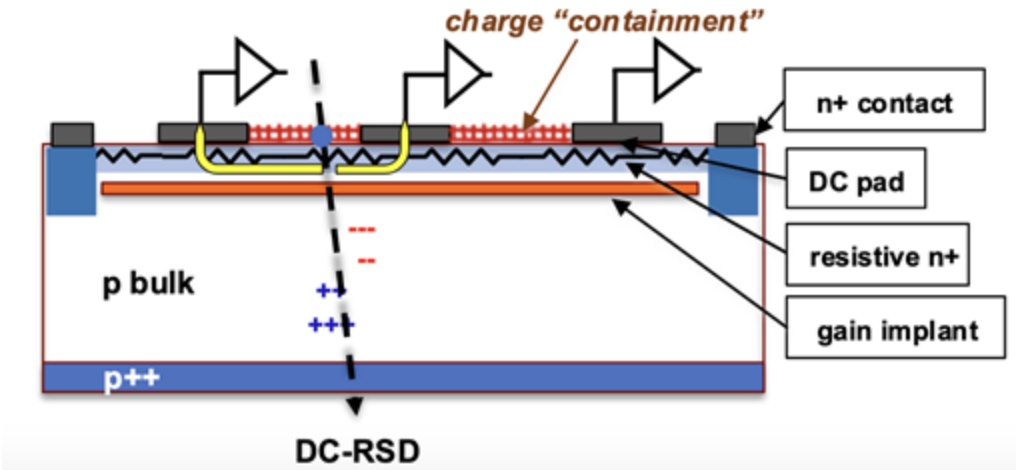
Several test structures implemented:

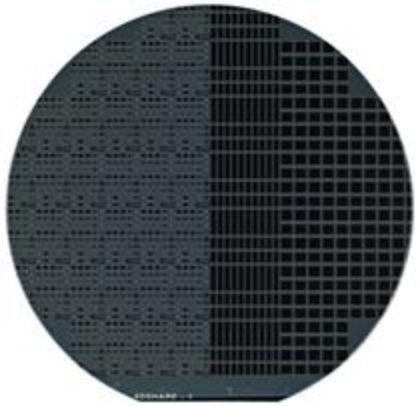
- Squared or hexagonal matrix of electrodes with multiple pitch options
- Strips with multiple pitch options and multiple length



DC-Resistive silicon Detectors

DC-Coupled Resistive silicon Detectors





DC-RSD wafer

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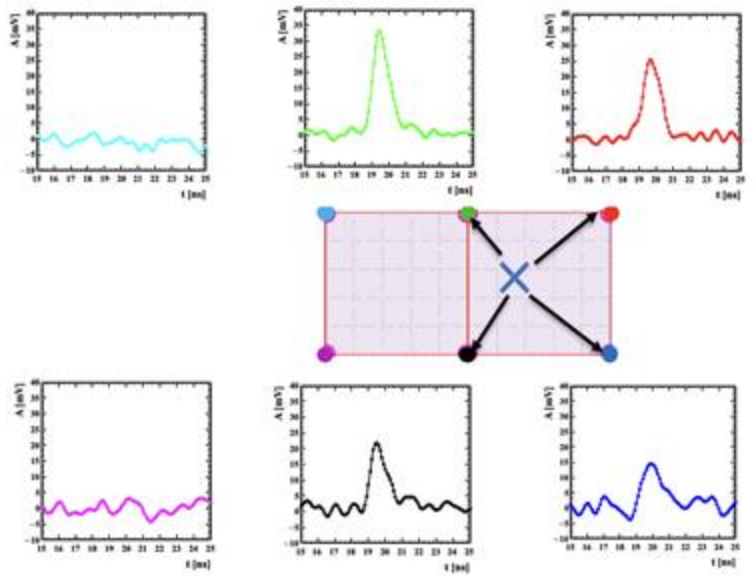
Hit inside the pixel:

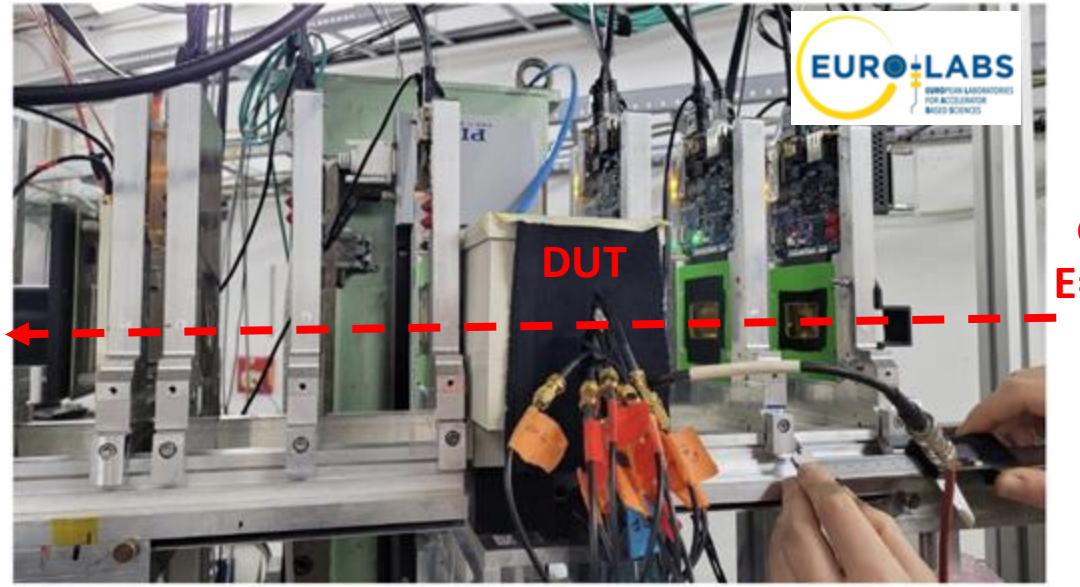
- **Signal sharing** between 4 electrodes
- **Perfect isolation**: the signal is seen only in the electrodes belonging to the hit pixel

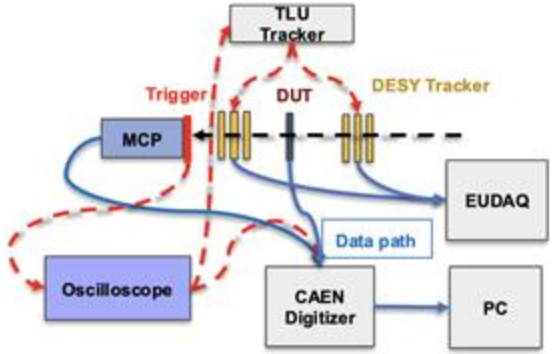
Square pixel - 500µm pitch



Beam test activities

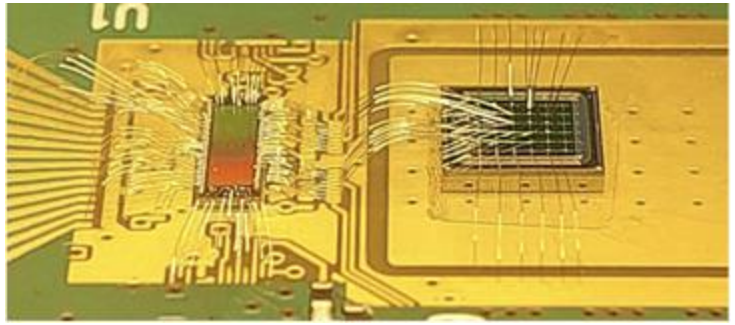
Space and time resolutions have been studied in several beam tests at DESY facility

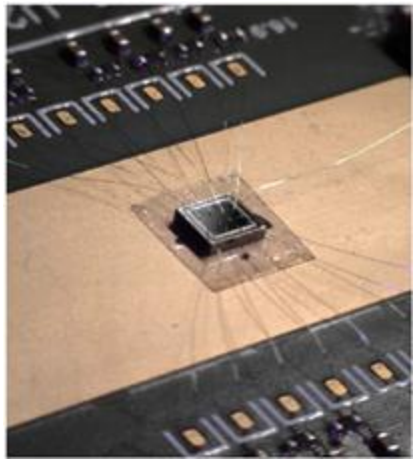




Beam test setup for study of spatial resolution

AC-RSD (5x5 matric) read out by FAST ASIC

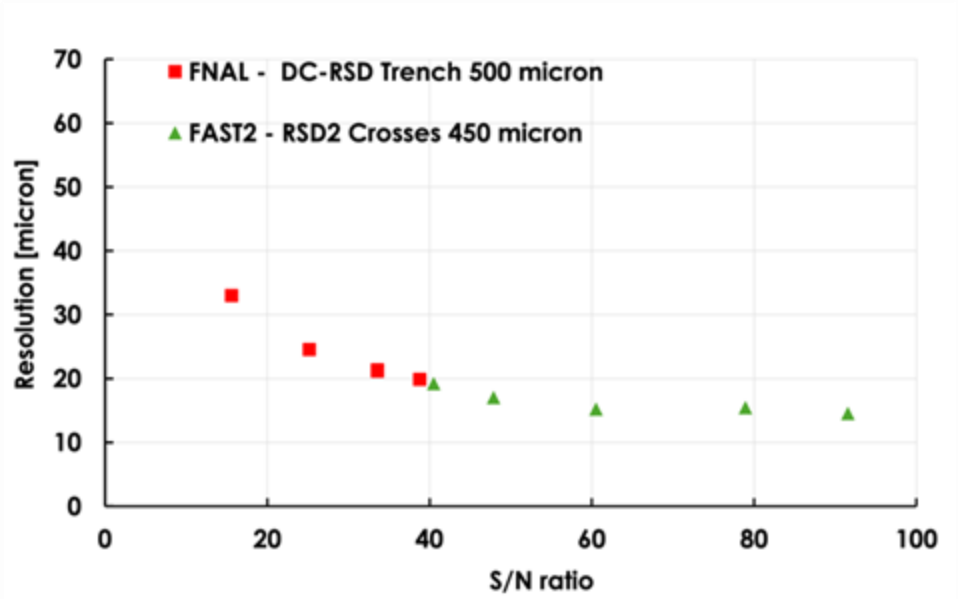




DC-RSD (Square pixel - 500µm pitch) wire bonded to 16ch board

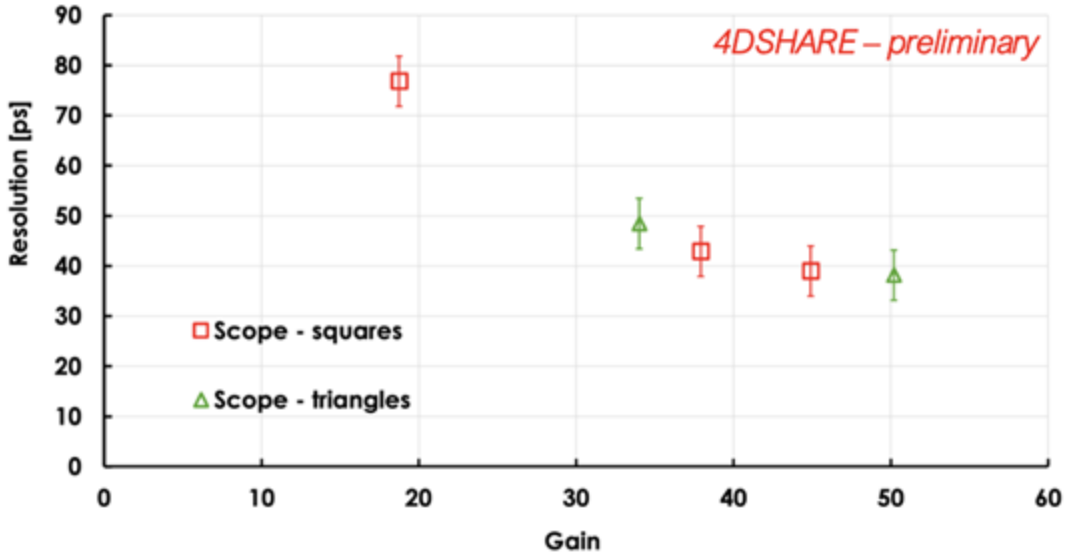
RSD resolution: space and time

Space resolution for DC-RSD 500-µm pitch square and AC-RSD 450-µm pitch square (crosses electrode)



- Space resolution **< 20 µm** for S/N ratio larger than 40
- Space resolution is **4-5% of the pixel** pitch

Time resolution for the 500-µm pitch square and triangular pixel matrix



- Time resolution **~40 ps** for gain larger than 40

References

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- R. Arcidiacono, “Innovative DC-coupled Resistive Silicon Detector for 4D tracking”,VCI2025, https://indico.cern.ch/event/1386009/contributions/6279050/

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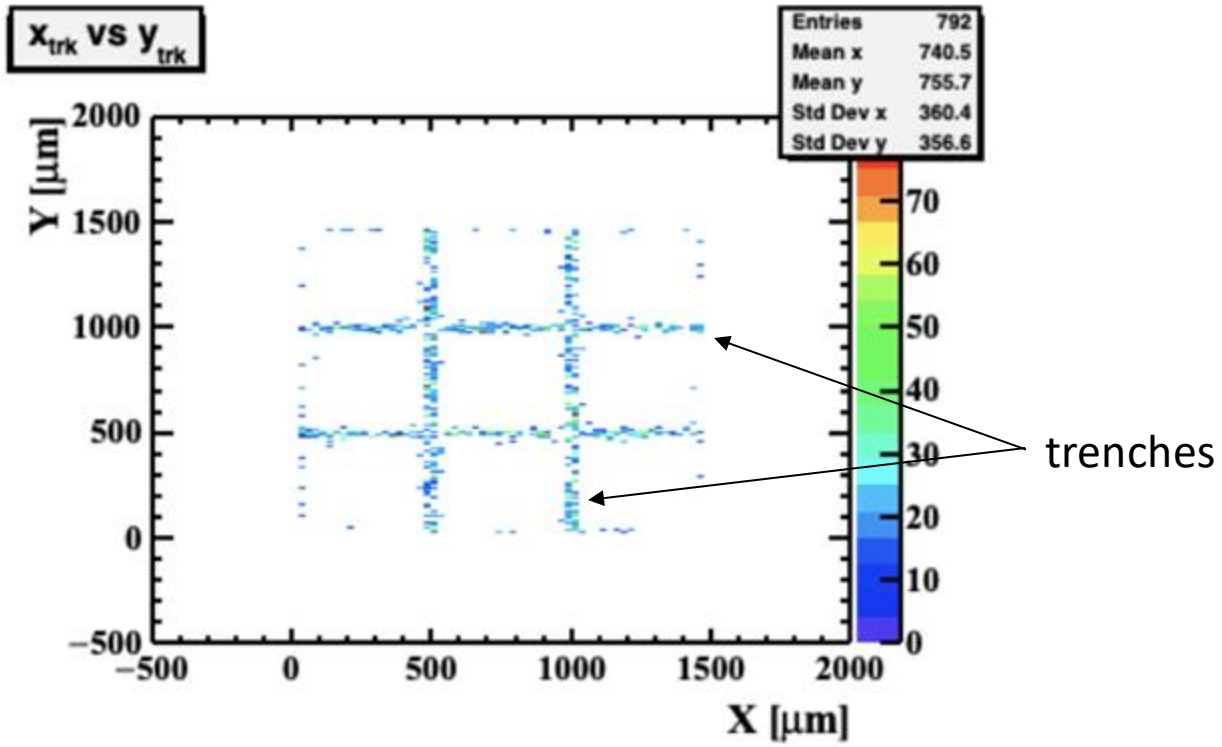
In particular, measurements leading to these results have been performed at the testbeam facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF).

Backup

Fill factor of DC-RSD



Selections:

- **Events with tracks inside the active area and**
- **Amplitude of the signal < 25 mA**

Fill Factor of ~ 99%

DC-RSD signal containment

Average signal amplitude seen by each electrode as a function of the $(X,Y)_{TRACKER}$