ÖAW AUSTRIAN ACADEMY OF SCIENCES

HEPHY INSTITUTE OF HIGH ENERGY PHYSICS

DRD3 Week Jun. 24 / WG1

Characterization of the RD50-MPW4 HV-CMOS pixel sensor

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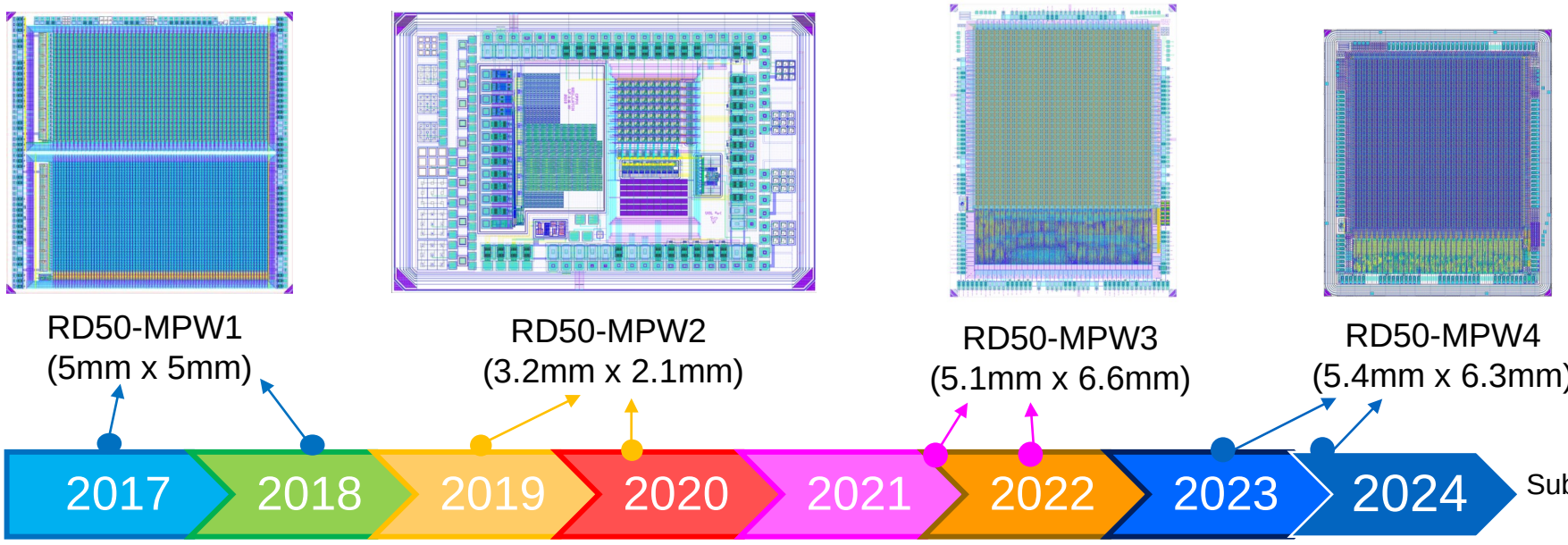
on behalf of the CERN RD50 CMOS working group

RD50 DMAPS Timeline

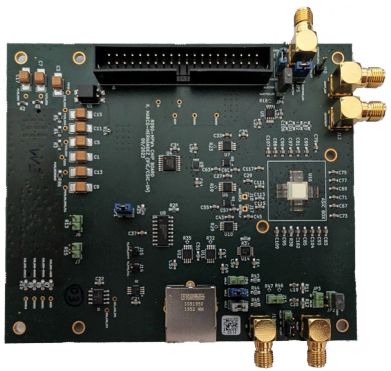


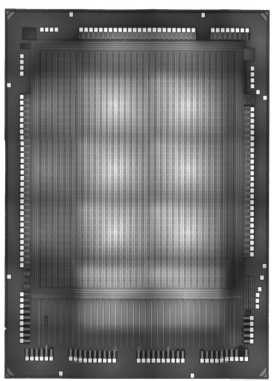
- RD50-MPW1: Analog on top design, suffered from high leakage current
- RD50-MPW2: Analog only chip, improved guard ring structure, fixed dark current problem

RD50-MPW3 / -MPW4

Both sensors feature:

- 64x64 pixel matrix arranged in 32 FEI-3 style double columns
- Active area of 4x4 mm²
- Pixel-size of 62x62µm²
- 8 bit timestamp information (based on 25ns) for each hit
- 4 bit in-pixel trimming
- 640MHz readout



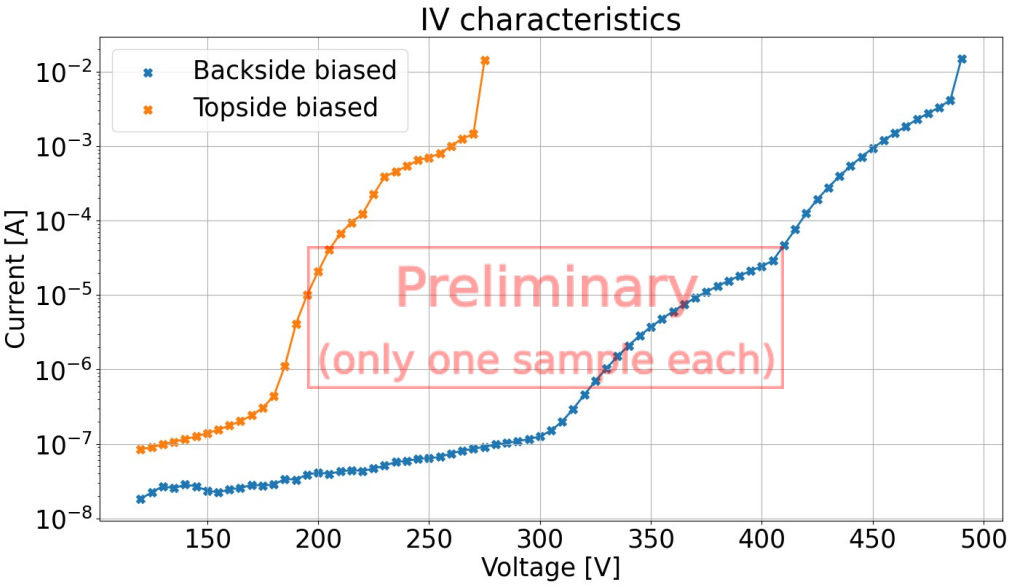


Modifications / Improvements MPW3 → MPW4

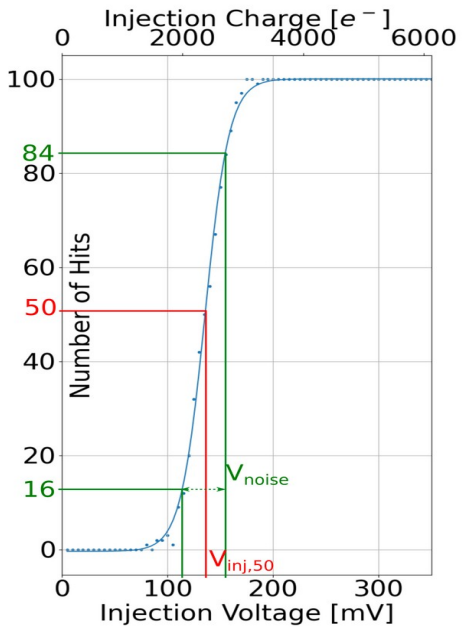
- Noise significantly reduced by
  - separating power domains of in-pixel and peripheral digital readout
  - improved routing of power lines
- Optimized guard rings
  - allow higher breakdown voltages
- Length of EOC readout signals adjustable
- Backside processing for better biasing

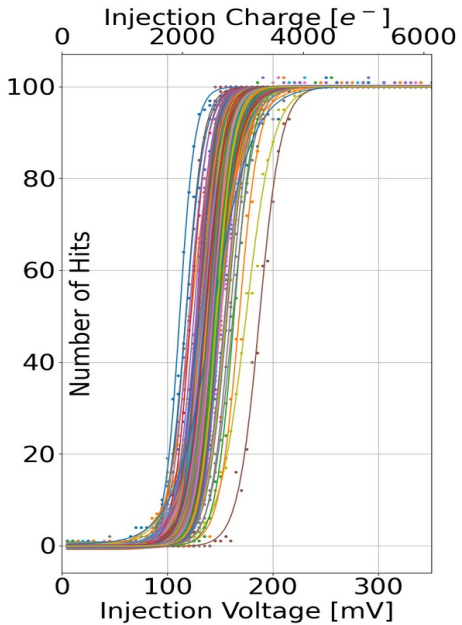
IV measurements

- IV measurements of whole chip
- Breakdown at:
  - Topside biased V ≈ 270V
  - Backside biased V ≈ 490V
- Current increase for topside biased already at V ≈ 190V
  - Full depletion reached
  - Depletion region touches back or sides of the sensor



Injection Scan methods

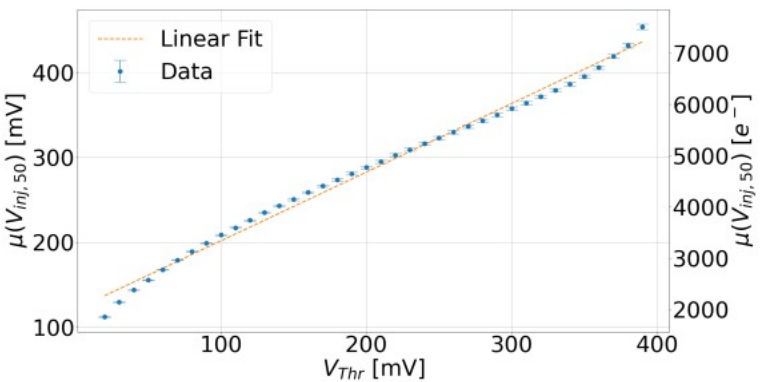


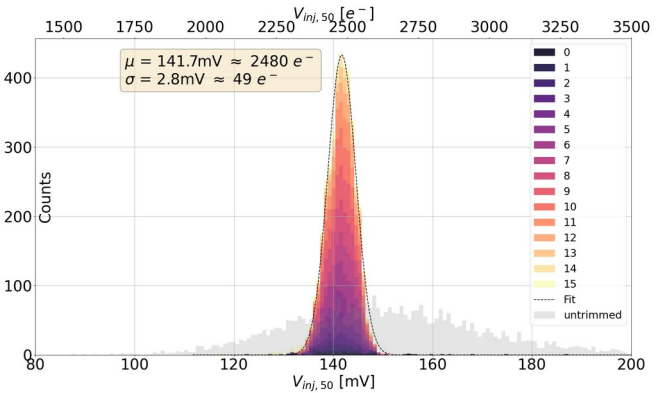


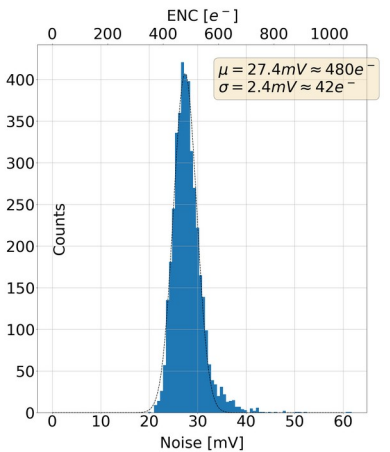
- Utilizing In-Pixel injection capacity of C ≈ 2.8fF
- Inject 100 times for V_{inj} from 0 → 350mV in 5mV steps for full matrix
- Record and fit data to S-curve
- $V_{inj,50}$: voltage at which 50% of injected hits detected
- V_{noise} : voltage difference from 16% → 84% of injected hits detected

Injection Scan results

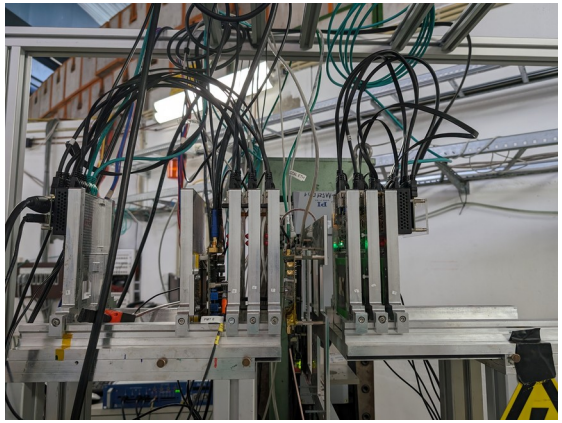
- After trimming pixel response σ ≈ 50e$^-$
- Equivalent Noise Charge: 480(±42)e$^-$
- Scanning threshold voltage → convert threshold voltage to charge
  - CSA (+ comparator) show linear behavior for wide range of V_{Thr} and V_{Inj}

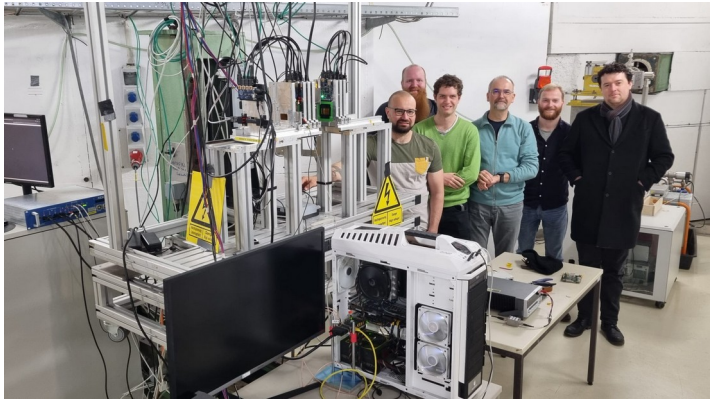






Testbeam Setup

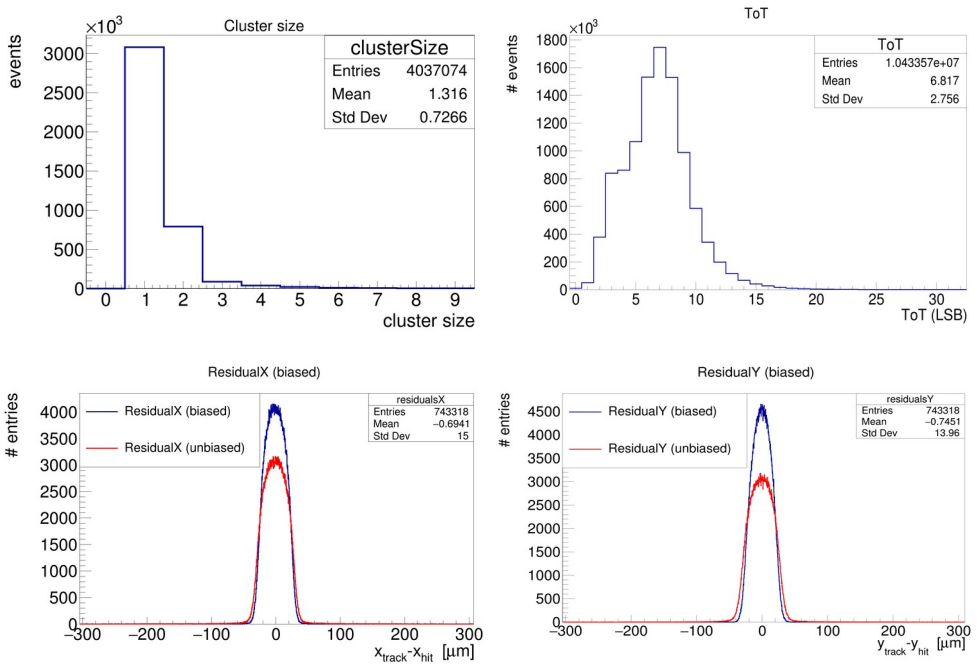




- Test-Beam at DESY in Apr. 2024
- Focus on non-irradiated samples / comparison of top- and backside biasing
- 4.2 GeV electrons at f ≈ 10kHz
- *Adenium* (*Alpide* based) telescope
- *AIDA 2020 TLU* for synchronization
- *Telepix* as ROI trigger and timing layer

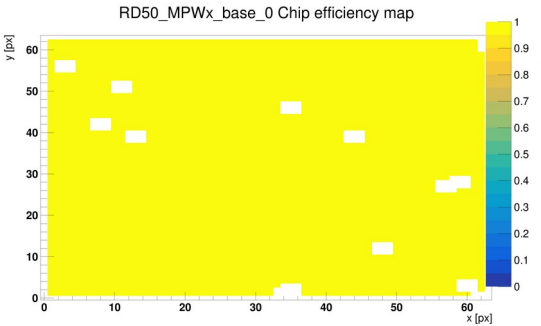
General Testbeam Results

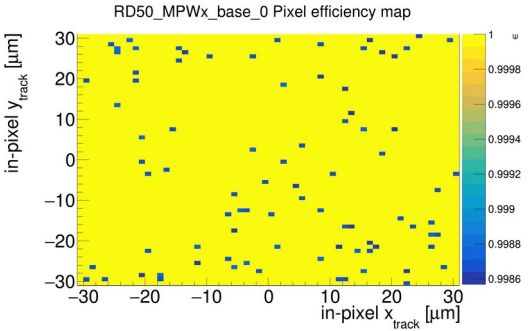
- Average cluster size ≈ 1.3
- Average Time over Threshold ≈ 6.8LSB
- Spatial resolution by geometric mean of σ of the residuals:
  - Resolution in X ≈ 17.8µm
  - Resolution in Y ≈ 16.4µm
  - Difference most likely due to rectangular *Alpide* pixels

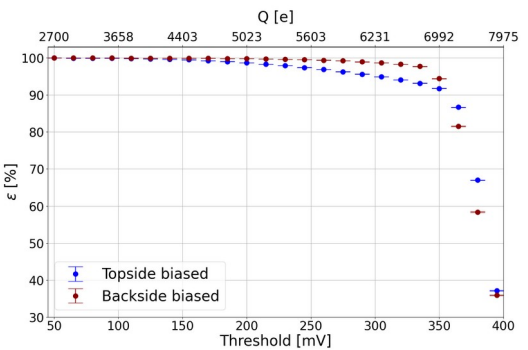


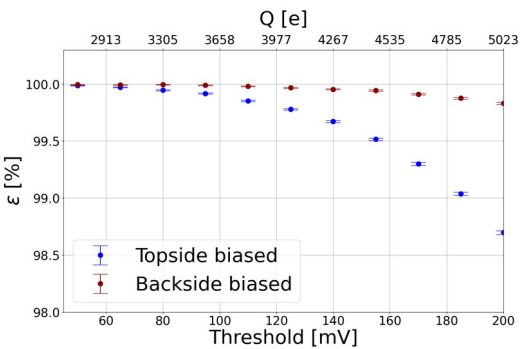
Efficiency

- Total efficiency > 99.99% evaluated
  - V_{Bias} = -190V
  - $Q_{Thr} \approx 2700e^-$
- Homogeneous in-pixel efficiency
  - Efficiency >99% up to threshold of O(5000e$^-$)
- Backside biased sample working better at high thresholds (compared to topside biasing)









Bias Voltage scan

- Plots of Cluster-size, ToT, Spatial resolution proving full depletion at 200V still to be produced

Summary / Outlook

- RD50-MPW4 fixed problems of MPW3
- Backside processing allows for higher bias voltages as well as threshold settings

- RD50-MPW series is a success story and ready for optimization towards
  - Larger matrix
  - Improved spatial and time resolution

- Beam campaign with irradiated samples planned in autumn 2024 at *DESY*
  - Samples irradiated from 1 x 10^{14} → 3 x 10^{16} 1MeV n_{eq}/cm^2

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Thank you for your attention!
Questions?

This work has been partly performed in the framework of the CERN-RD50 collaboration.

The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF).

The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101057511.

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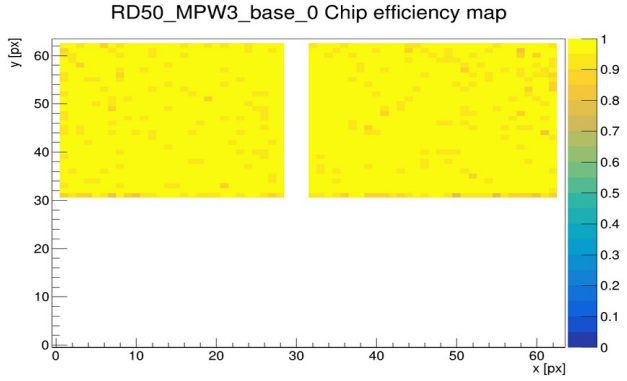
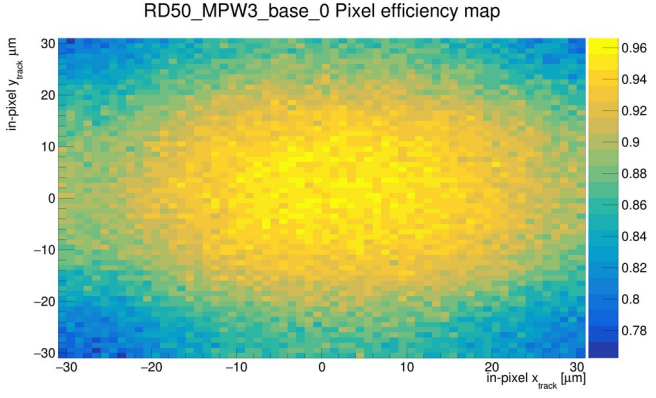
BACKUP

Recap MPW3


RD50_MPW3_base_0 Chip efficiency map
y [px]
x [px]


RD50_MPW3_base_0 Pixel efficiency map
in-pixel y_track µm
in-pixel x_track [µm]