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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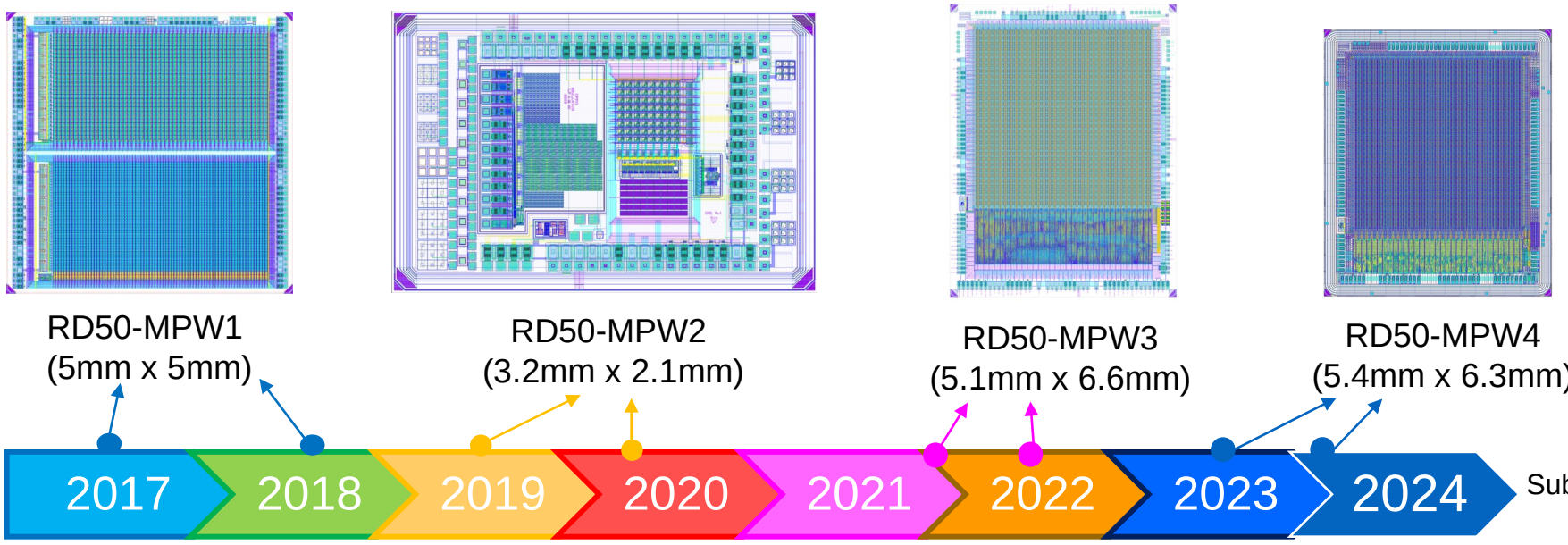
on behalf of the (former) CERN RD50 CMOS working group

RD50 DMAPS Series

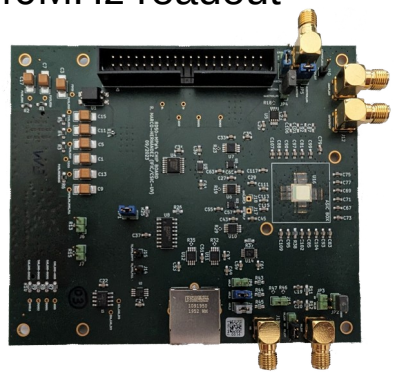


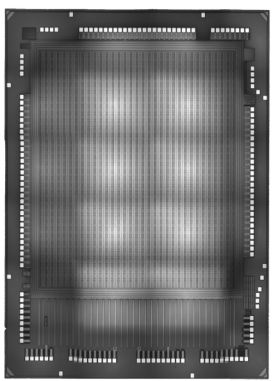
- HV-CMOS sensors fabricated in *LFoundry* 150nm process
- **Goals**: Evaluation of technology for
  - Radiation hardness
  - High granularity
  - Timing performance

RD50-MPW3 / -MPW4

Both sensors feature:

- 64x64 pixel matrix arranged in 32 FEI-3 style double columns
- Active area of 4x4mm²
- Pixel-size of 62x62µm²
- 8 bit timestamp information (based on 25ns) for each hit
- 4 bit in-pixel trimming
- 640MHz readout



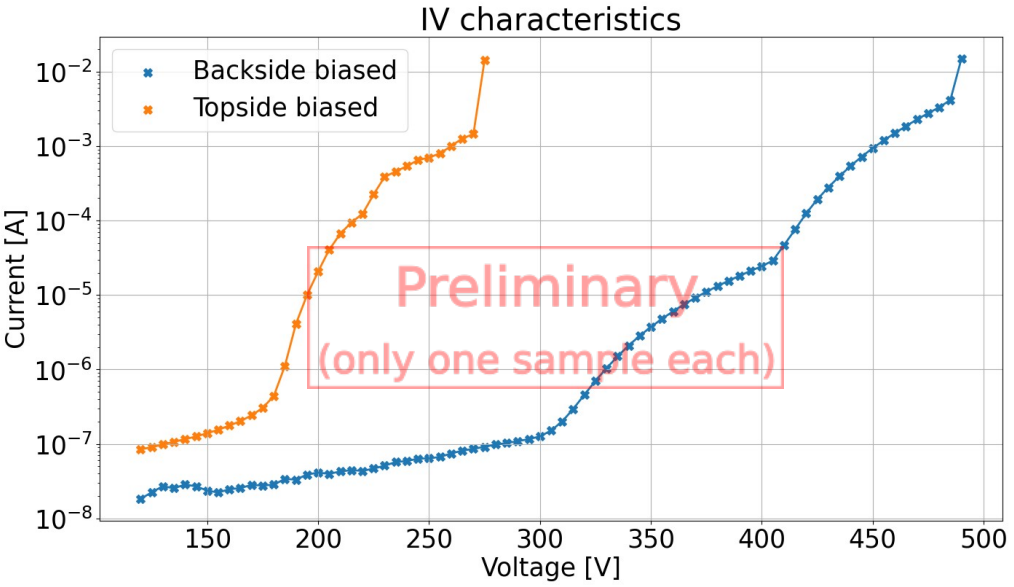


Modifications / Improvements MPW3 → MPW4

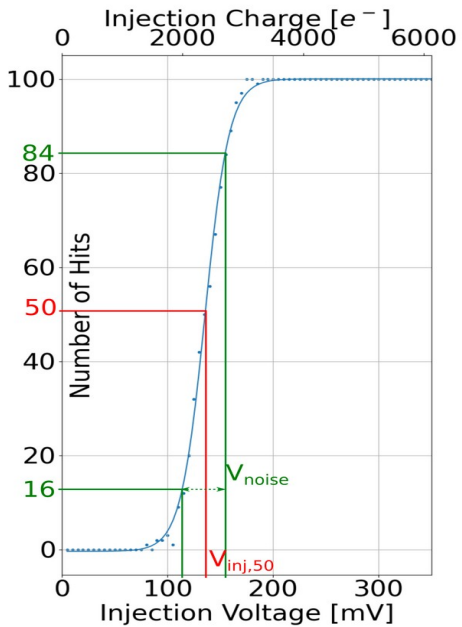
- Noise significantly reduced by
  - separating power domains of in-pixel and peripheral digital readout
  - improved routing of power lines
- Optimized guard rings
  - higher breakdown → improved radiation hardness
- Backside processing
  - higher breakdown → improved radiation hardness
- Length of EOC readout signals adjustable

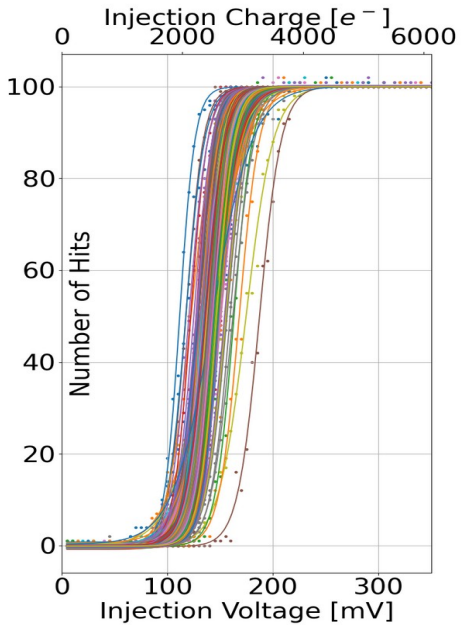
IV measurements

- 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

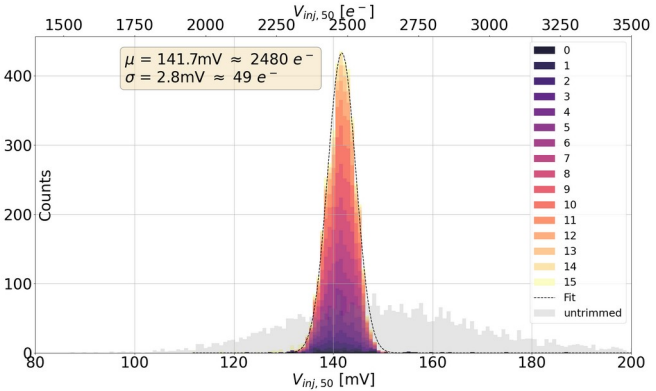


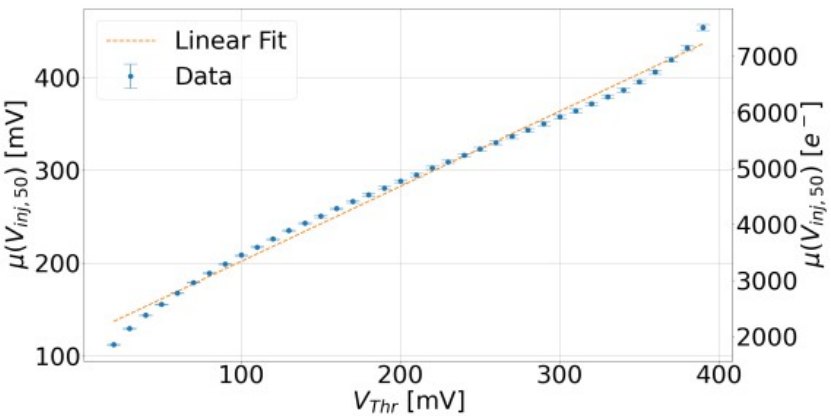


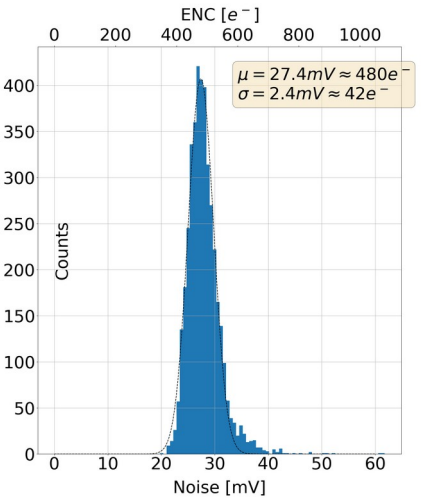
- Utilizing In-Pixel injection capacity of C ≈ 2.8fF
- Inject 100 times for V_{inj} from 0 → 350mV in 5mV steps for full matrix
- Record and fit data to S-curve
- $V_{inj,50}$: voltage at which 50% of injected hits detected
- V_{noise} : voltage difference from 16% → 84% of injected hits detected

Injection Scan results

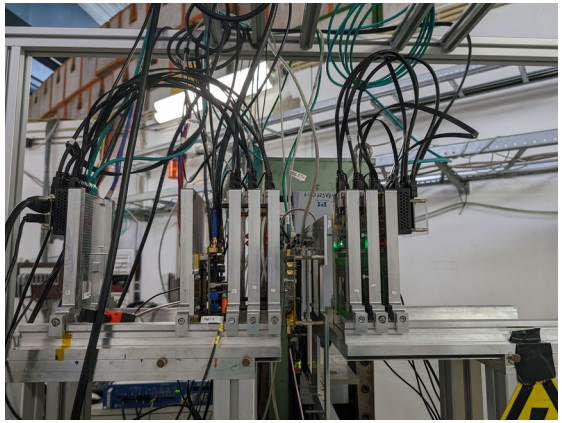
- After trimming pixel response σ ≈ 50e$^-$
- Equivalent Noise Charge: 480(±42)e$^-$
- Scanning threshold voltage → convert threshold voltage to charge
  - CSA (+ comparator) show linear behavior for wide range of V_{Thr} and V_{Inj}

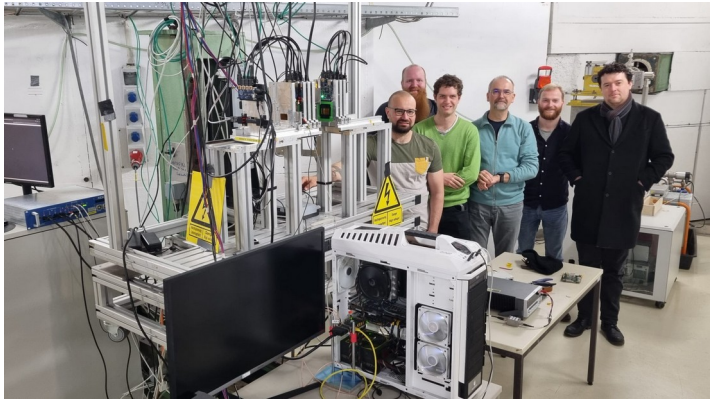






Testbeam Setup

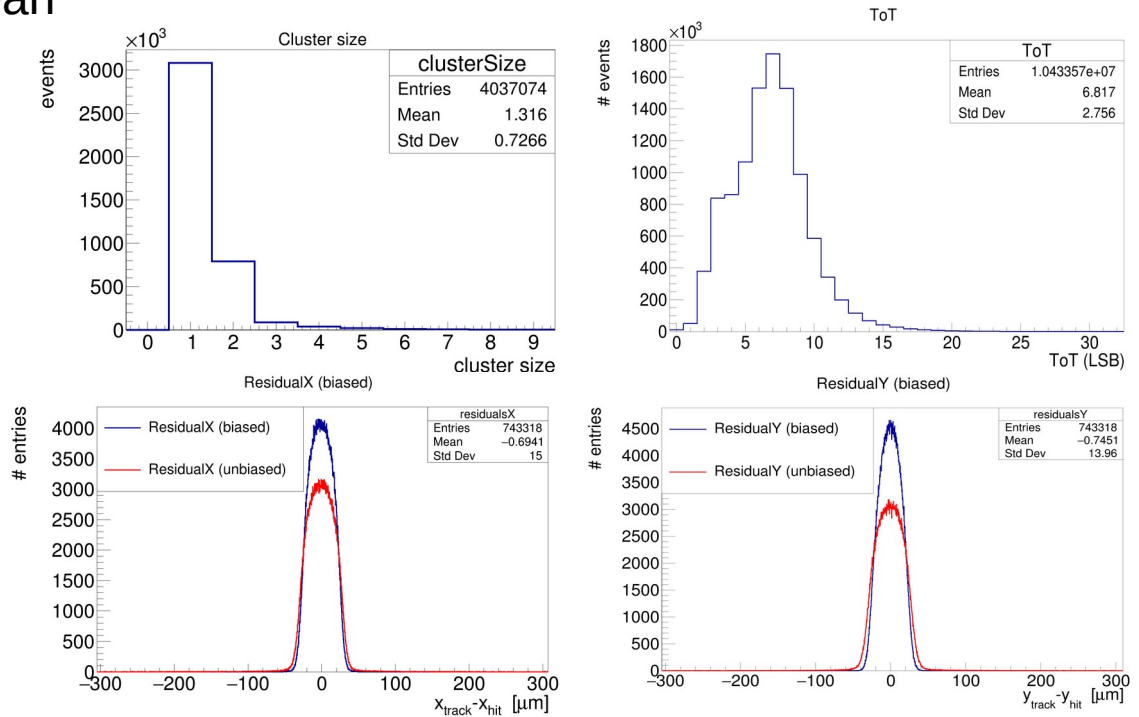




- Test-Beam at DESY in Apr. 2024
- Focus on non-irradiated samples / comparison of top- and backside biasing
- 4.2 GeV electrons at f ≈ 10kHz
- *Adenium* (*Alpide* based) telescope
- *AIDA 2020 TLU* for synchronization
- *Telepix* as ROI trigger and timing layer

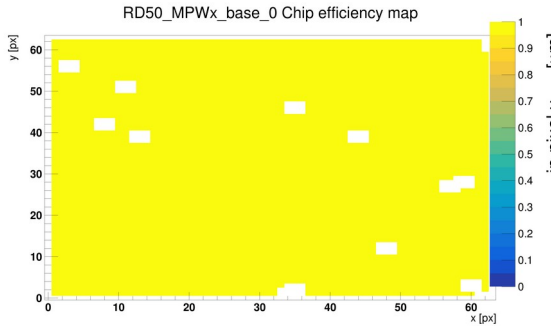
General Testbeam Results

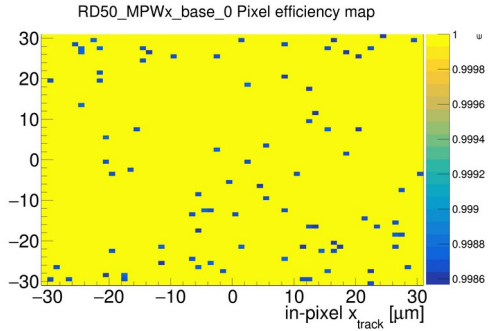
- Average cluster size ≈ 1.3
- Average Time over Threshold ≈ 6.8LSB
- Spatial resolution by geometric mean of σ of the residuals (biased and unbiased):
  - Resolution in X ≈ 17.8µm
  - Resolution in Y ≈ 16.4µm
  - Difference most likely due to rectangular *Alpide* pixels



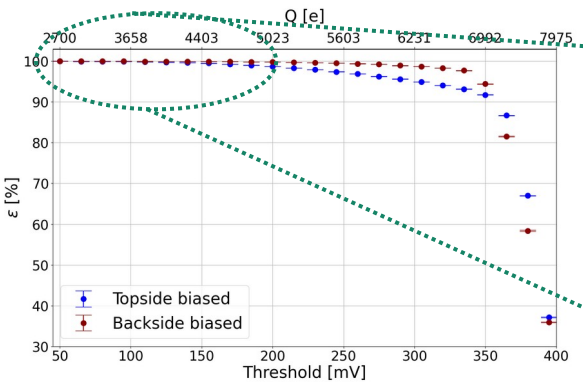
Efficiency

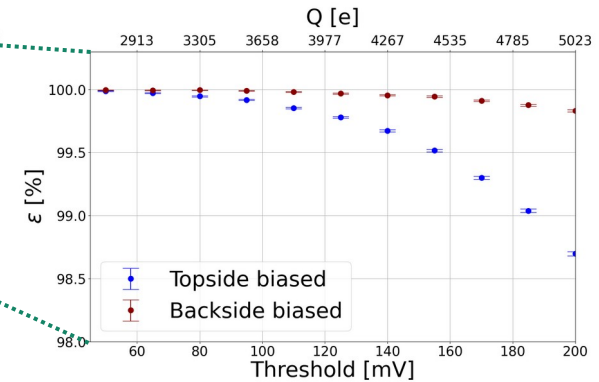
- Total efficiency > 99.99% evaluated
  - V_{Bias} = -190V
  - $Q_{Thr} \approx 2700e^-$
- Homogeneous in-pixel efficiency





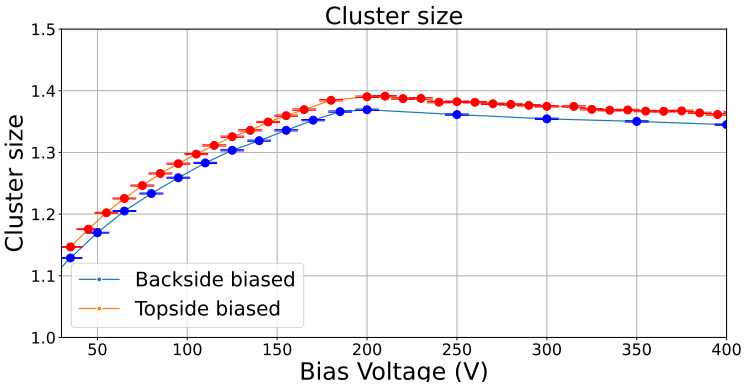
- Efficiency >99% up to threshold of O(5000e^-)
  - Backside biased sample working better at high thresholds (compared to topside biasing)

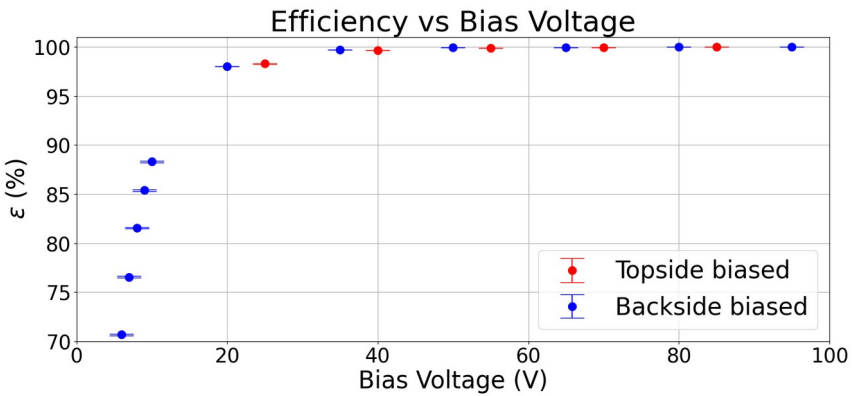


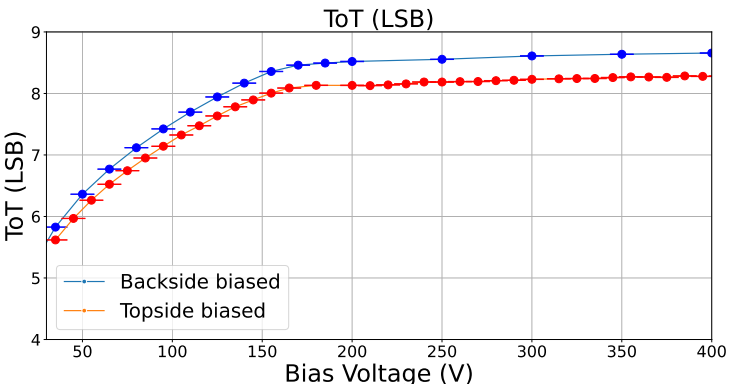


Bias Voltage scan

- Cluster size and ToT show saturation at $V_{Bias} \approx$ 200V
  - Full depletion reached
- Efficiency > 97% down to $V_{Bias} \approx$ 20V







Summary / Outlook

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

- RD50-MPW series is a success story and ready for optimization towards
  - Larger matrix
  - Improved spatial and time resolution
  - Reduce power consumption
- For more detailed ideas follow Eva's talk

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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.

BACKUP

Recap MPW3

- Noise coupling from digital periphery into analog matrix
  - Only top half of matrix usable
  - Thresholds > 5000e$^-$ necessary
- Total efficiency of ~97% evaluated
  - Strong corner effects (efficiency drop to ~80%) observed