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CHARACTERIZATION OF DEPLETED MONOLITHIC ACTIVE PIXEL SENSORS IN 180NM TOWERJAZZ TECHNOLOGY

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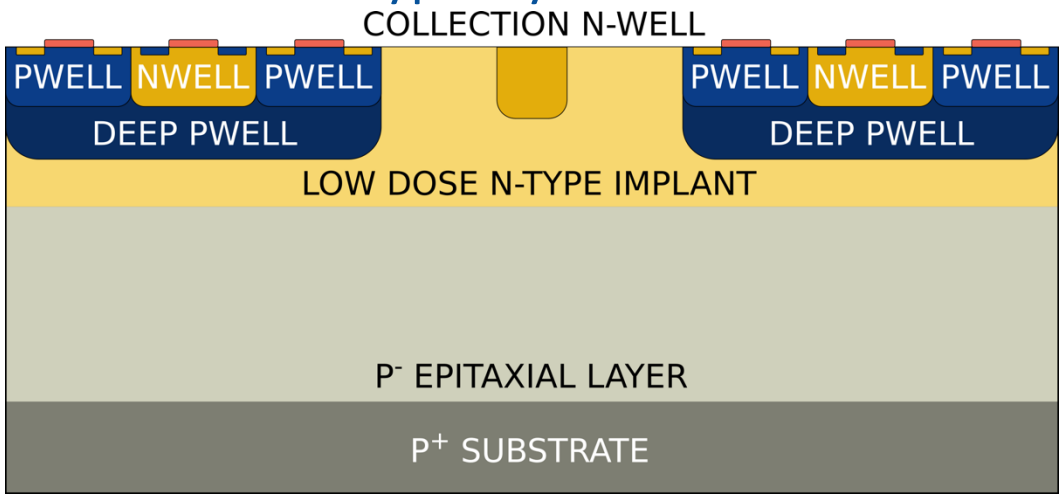
TJ-MONOPIX1

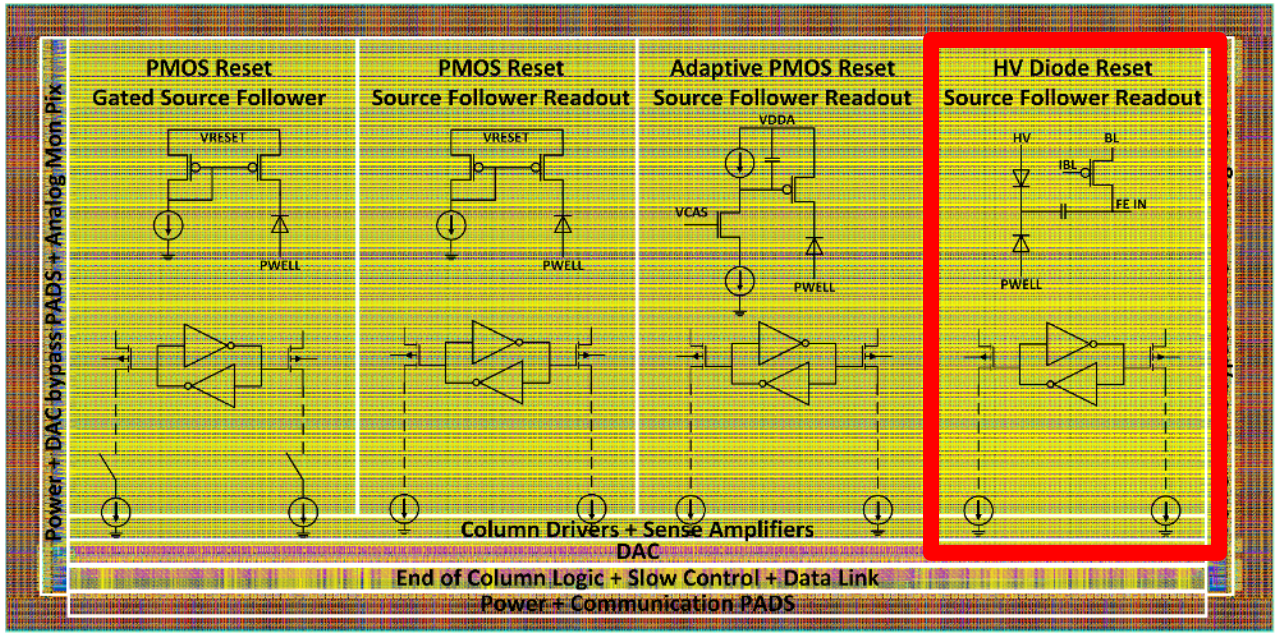
- Depleted monolithic active pixel sensor prototype in 180 nm TowerJazz Technology
- Small electrode → small capacitance → low noise and power
- Based on ALICE ITS pixel detector ALPIDE
- Modification to existing process to increase radiation hardness for ATLAS ITk specs
  → additional n-type layer

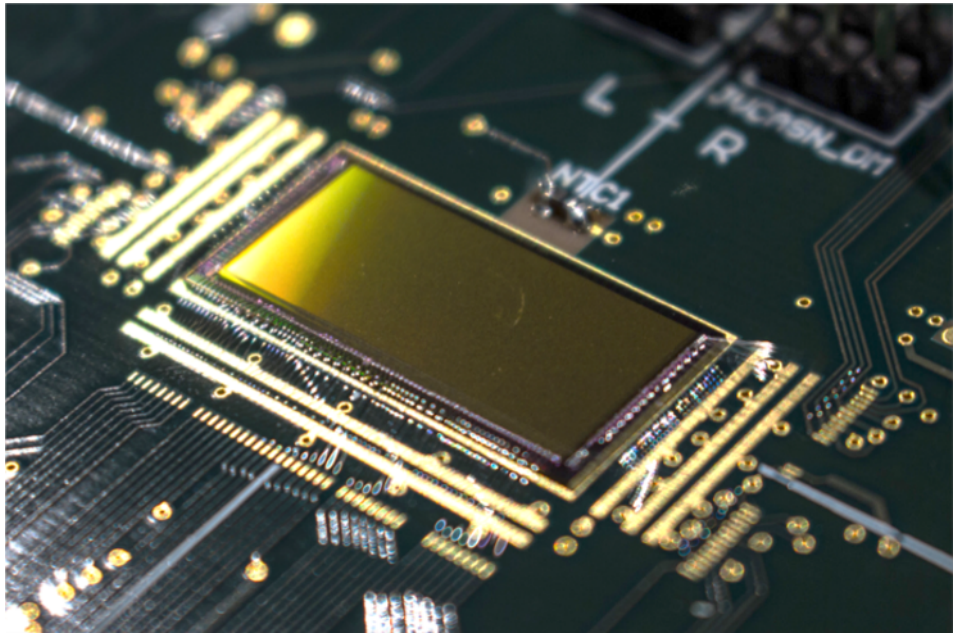


	TJ-Monopix1
Chip size	1 x 2 cm^2
Pixel size	36 x 40 μm^2
Pixel number	448 x 224
Matrix power	130 mW/cm^2
ENC	10 e
Threshold	400 e

TJ-MONOPIX1

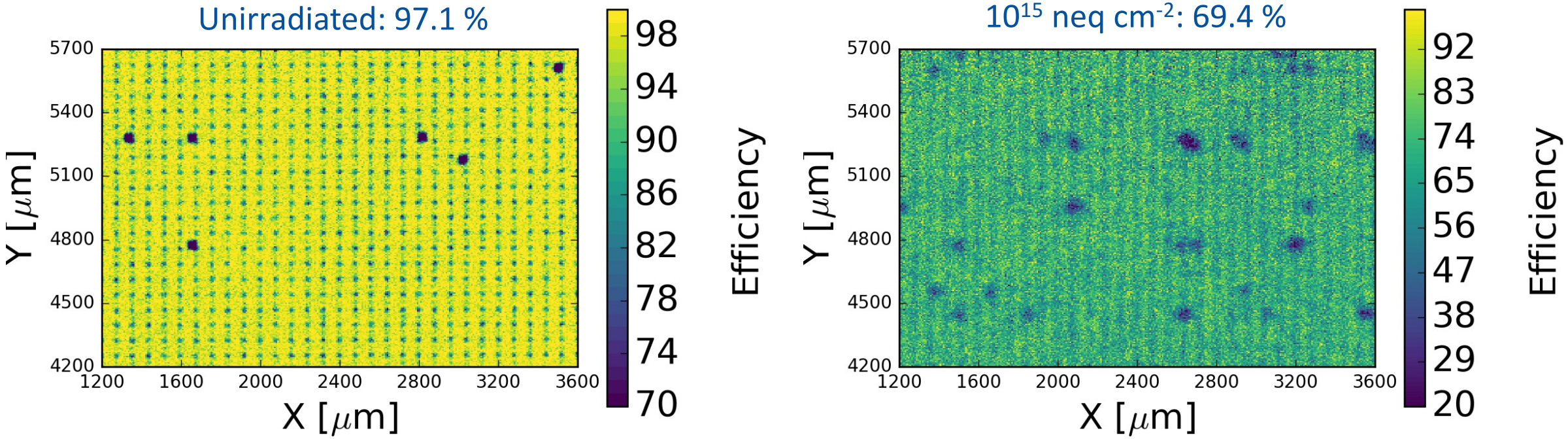
- Fully monolithic DMAPS prototype chip
- FE-I3 like column-drain readout architecture that can cope with ATLAS ITk outer pixel layer hit rate
- 36 µm x 40 µm pixel size arranged as 448 x 224 pixels in four flavors





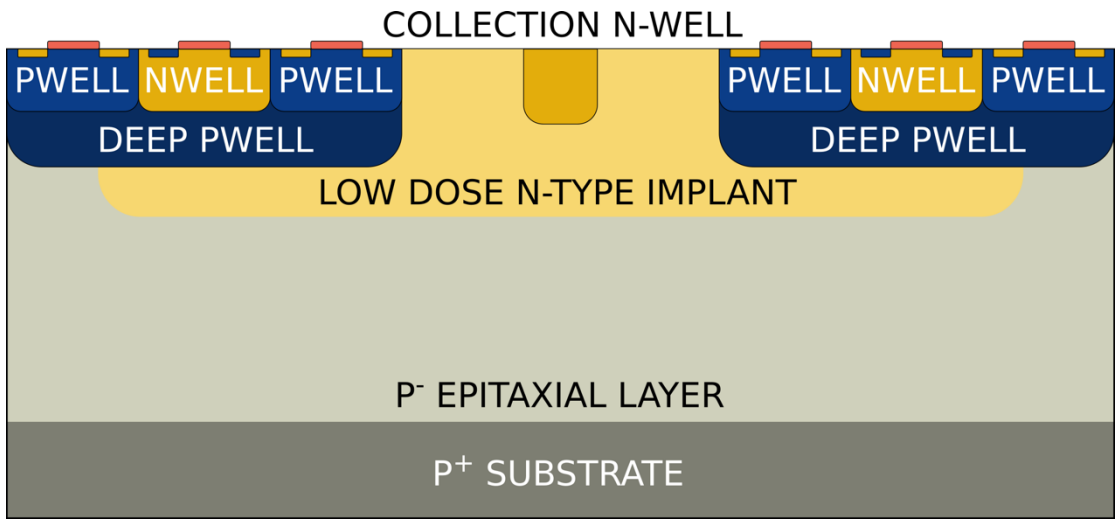
MEAN EFFICIENCY RECAP

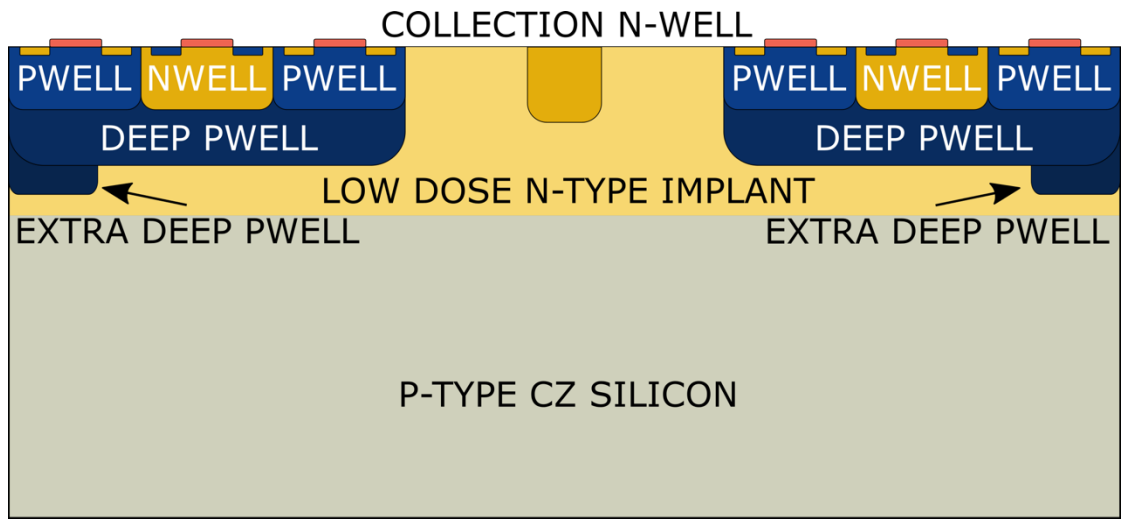
- Testbeam measurement of standard design, epi wafer chip with 2.5 GeV electron beam at ELSA, Uni Bonn
- 28 % efficiency loss after irradiation due to low charge / high threshold and loss in pixel corners



SENSOR MODIFICATIONS

- Adding additional p-well or gap in n-layer for better E-field configuration in this region
- Usage of Czochralski silicon with possibly larger depletion depth (300 um thick) and higher charge
- Compare epitaxial and Cz chips with n-gap and additional p-well respectively
  - Simulation shows that n-gap and additional p-well serve the same purpose equally well





THRESHOLD

Cz chip with additional deep p-well

	Unirradiated sample	Neutron irradiated sample (10^{15} neq cm^{-2})
Threshold	405 e^-	490 e^-
Threshold dispersion	35 e^-	58 e^-

Epi chip with gap in n-implant

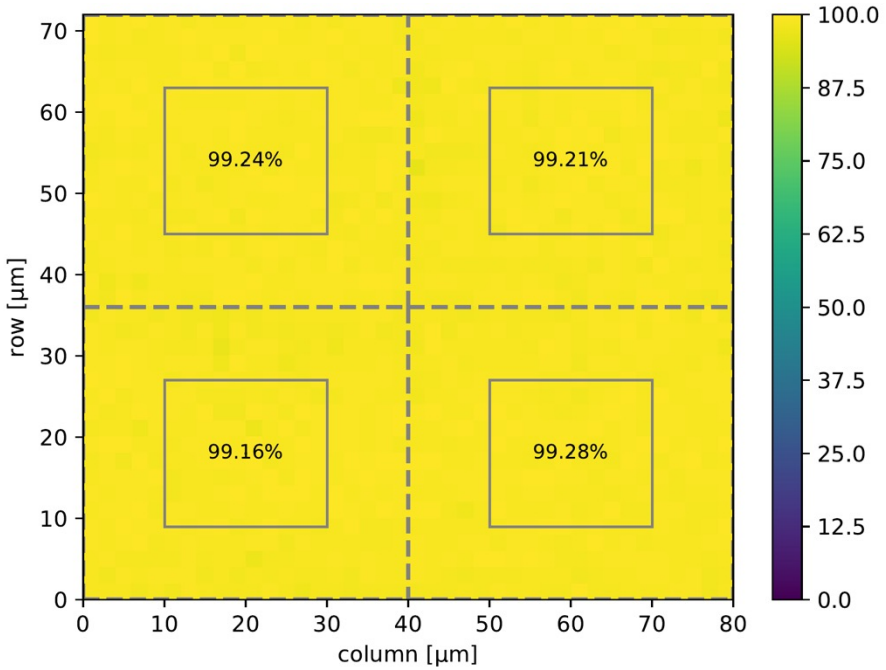
	Unirradiated sample	Neutron irradiated sample (10^{15} neq cm^{-2})
Threshold	485 e^-	500 e^-
Threshold dispersion	37 e^-	45 e^-

Not lowest achievable threshold

EFFICIENCY (UNIRRADIATED)

- 5 GeV electron beam at DESY in 2020 -> preliminary results
- Unirradiated chips with 300um Cz silicon and 30um epitaxial layer

300 um: 99.2 % @ 405 e^-



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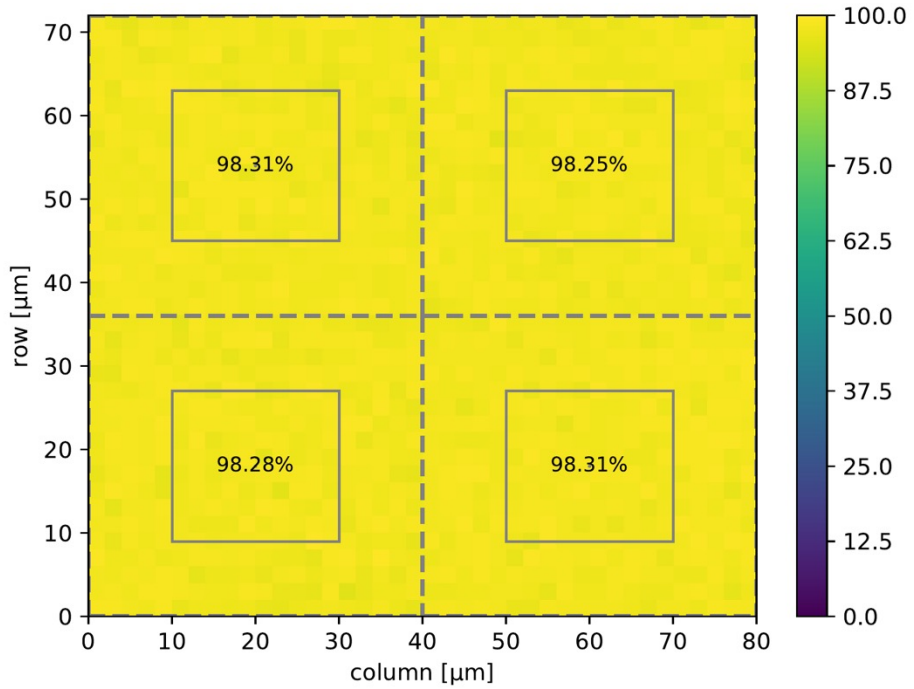

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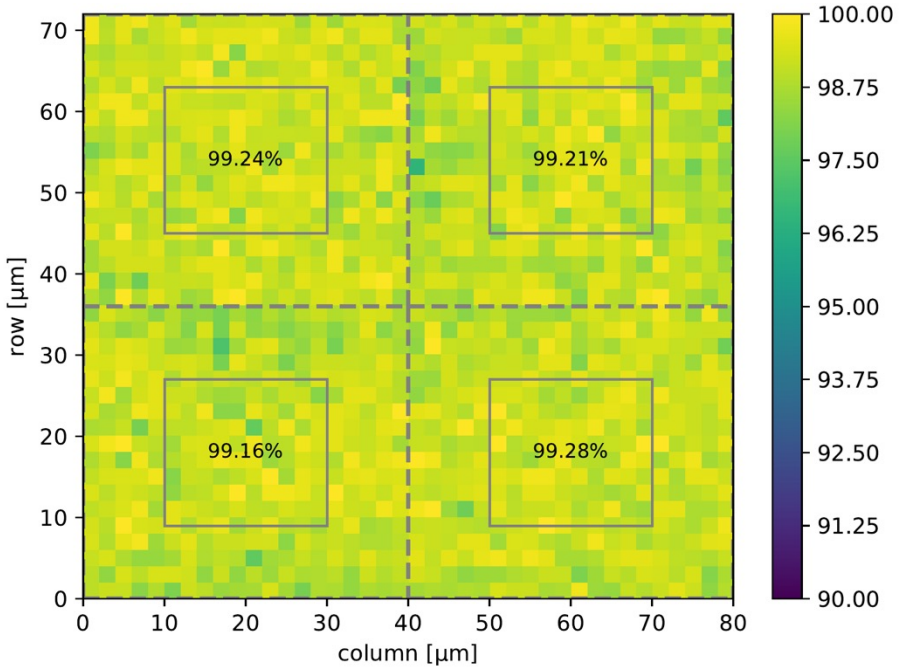

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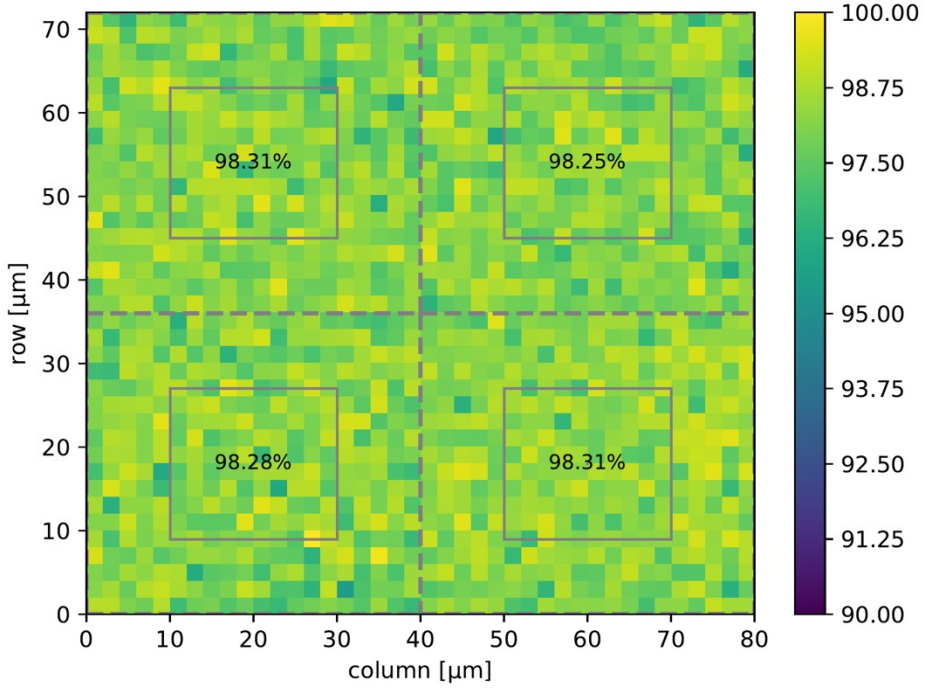

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- 10^{15} neq / cm^{-2} neutron irradiated chips with 300um Cz silicon and 30um epitaxial layer

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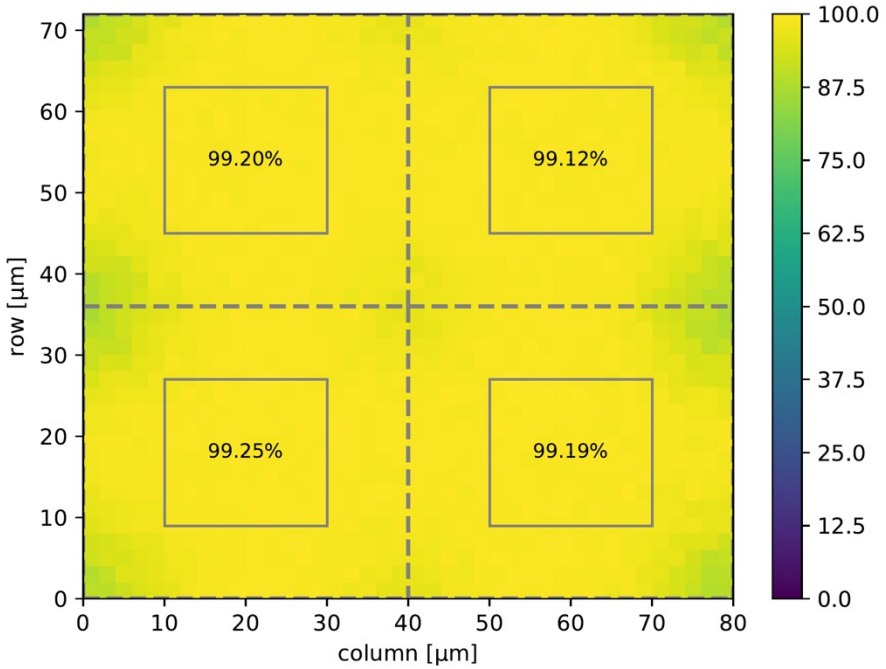
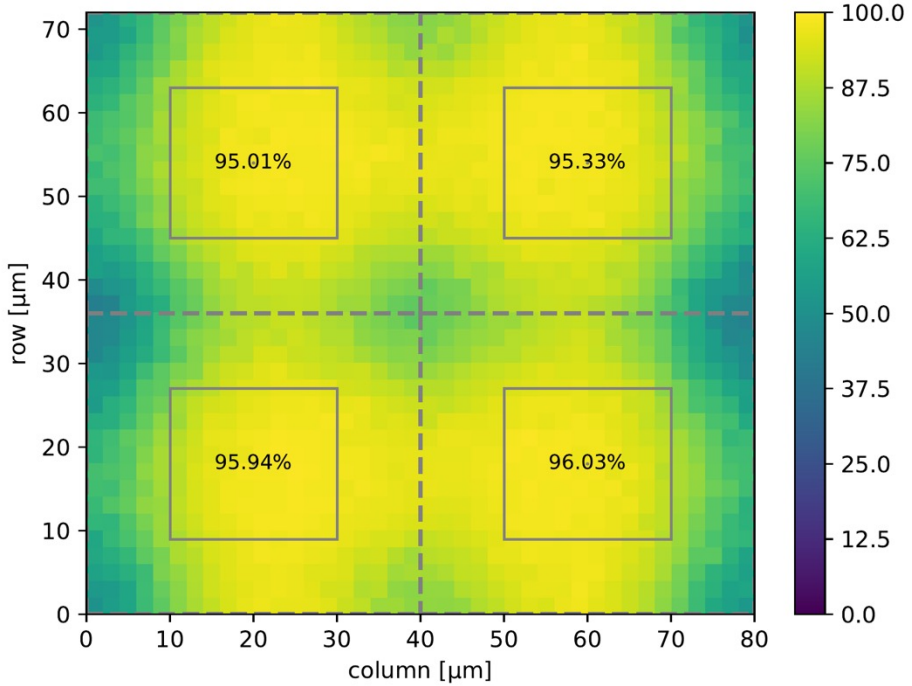


30 um: 87.1 % @ 500 e^-



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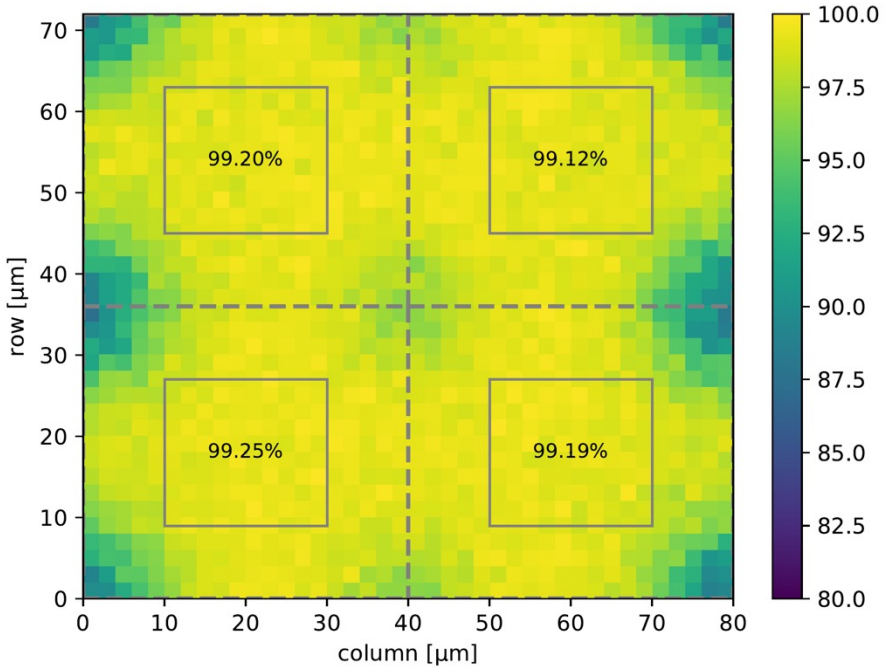

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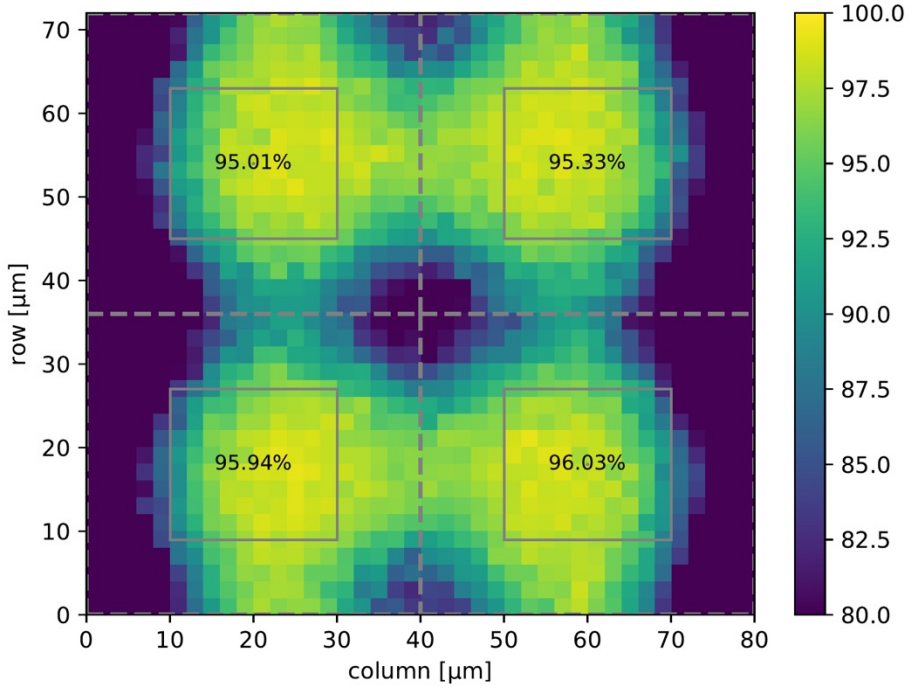
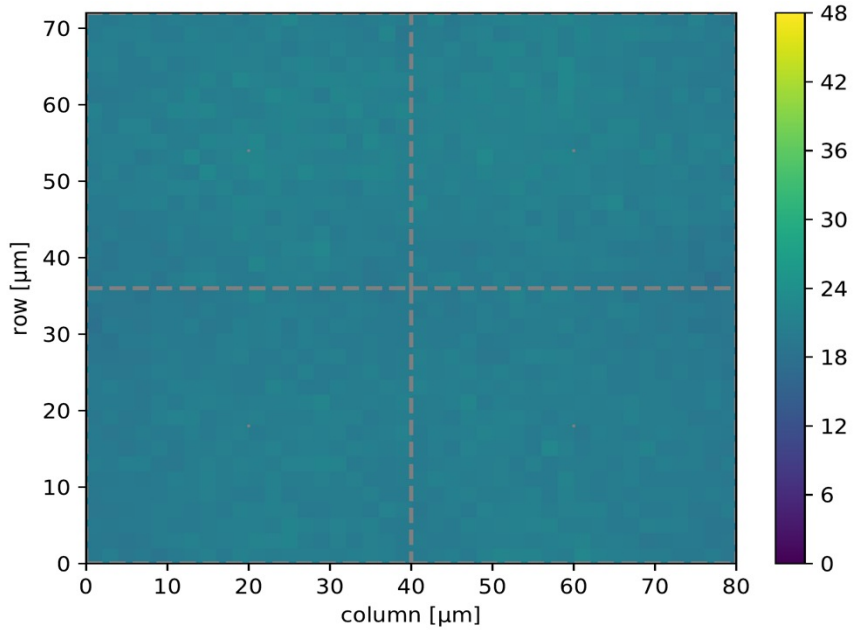


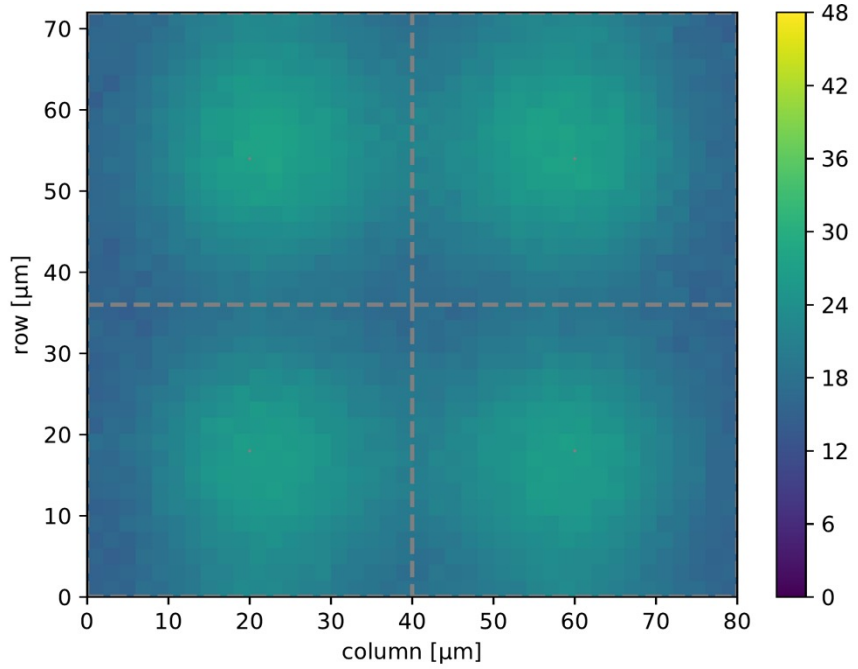
EFFICIENCY

- Losses after irradiation mainly in pixel corners
- Cluster charge too small / threshold too high because of charge sharing (charge in plots uncalibrated TOT)

In-pixel mean charge in Epi unirradiated



In-pixel mean charge in Epi 10^{15} neq / cm^{-2}



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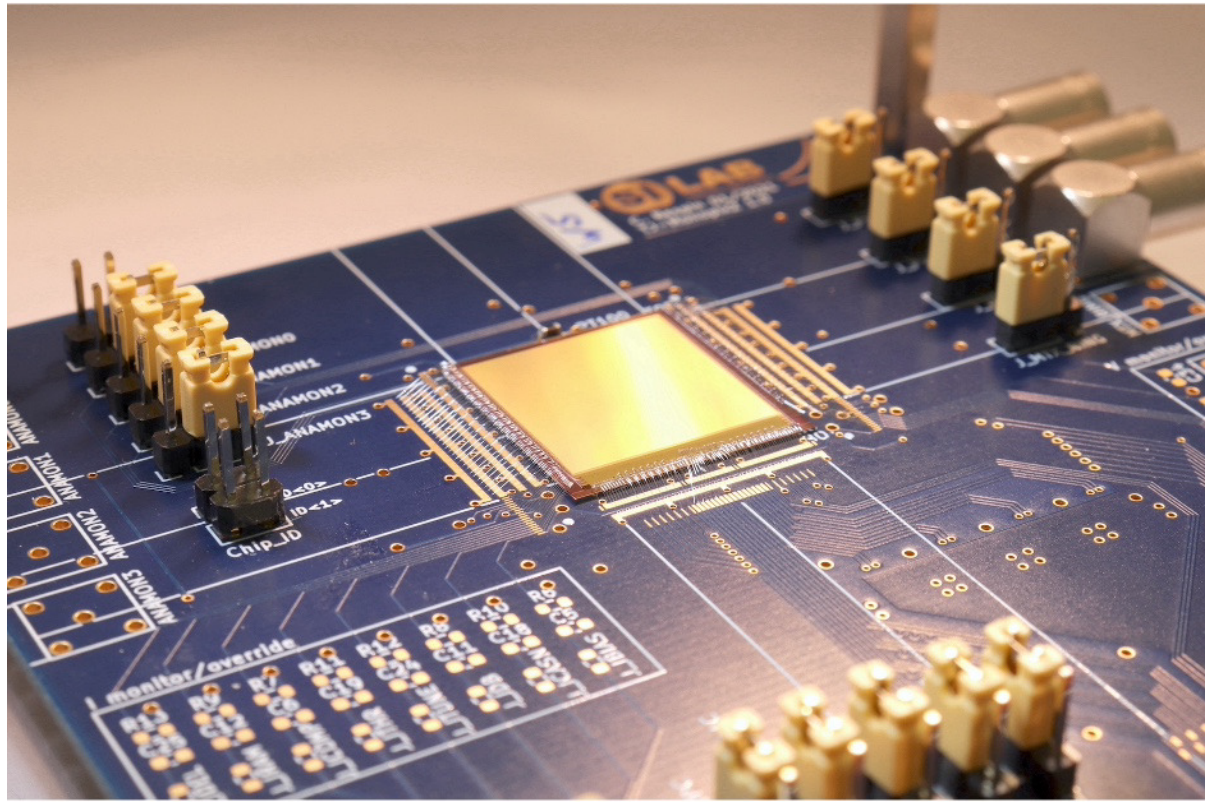
TJ-MONOPIX2

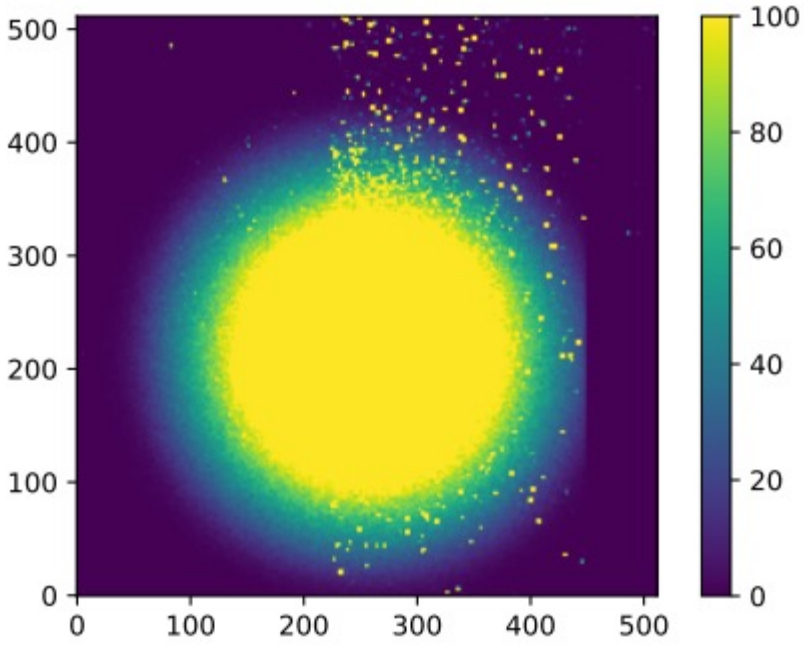
TJ-MONOPIX2

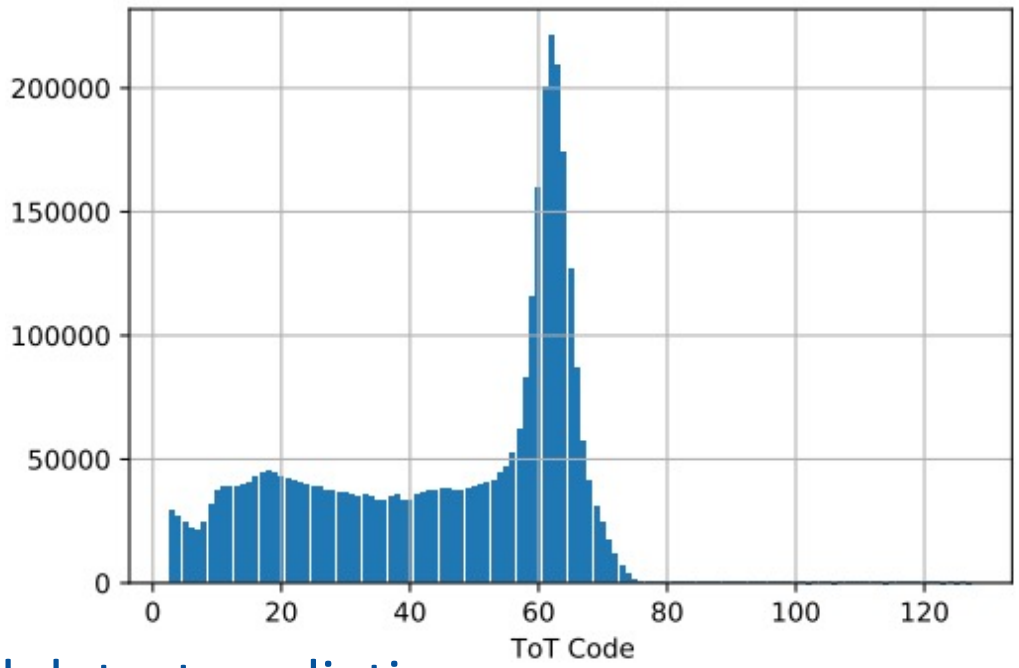
- 2×2 cm^2 chip with 33 um x 33 um pixels
- Larger matrix: 512 × 512 px
- Improved front end for higher gain, lower threshold achievable due to less noise
- Baseline for next Belle II upgrade
- ITkPix-like command decoder
- LVDS input and output
- 8b10b data encoding
- Chip ID



FE55 SOURCE

- Occupancy and charge spectrum of Fe55 source
  - Left: two flavors activated, second one has lower threshold -> more noise at same FE settings

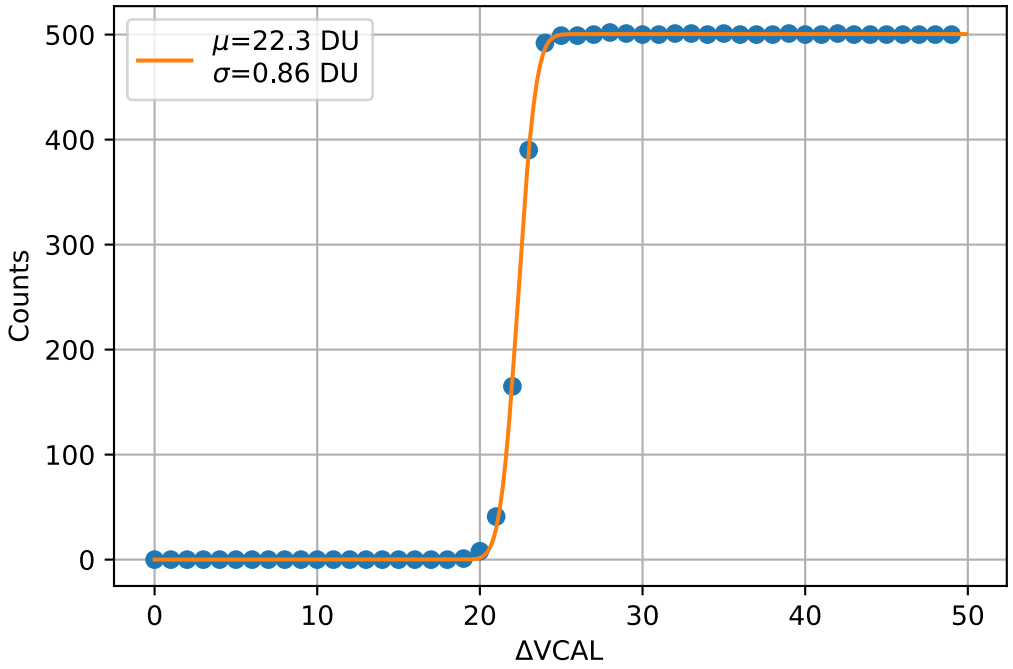


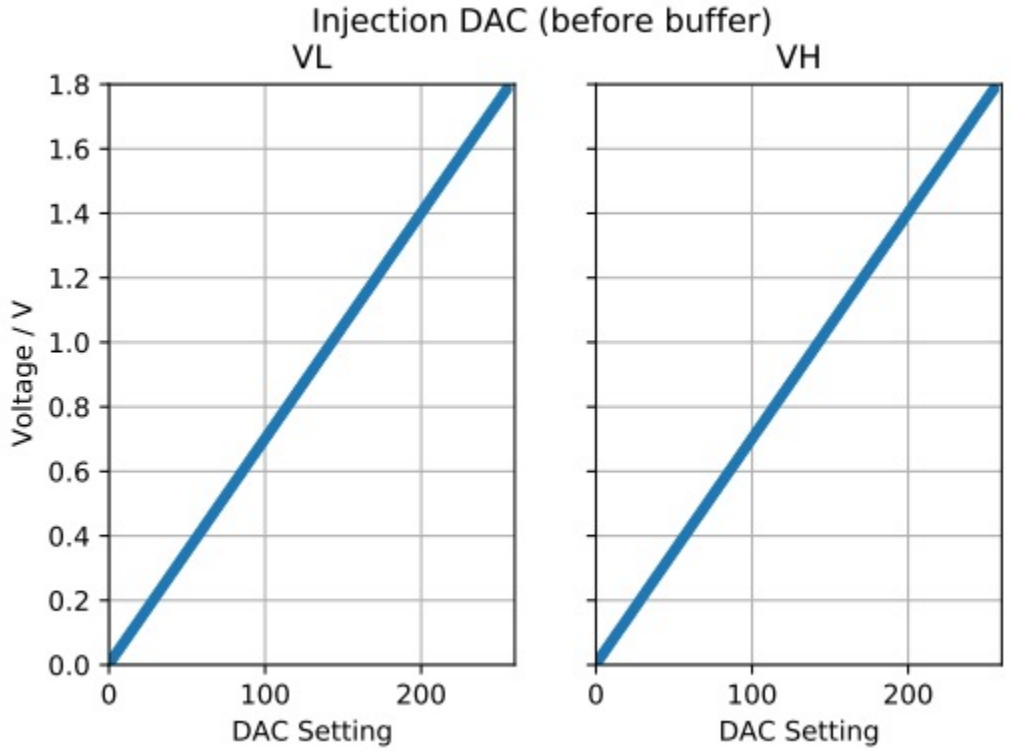


→ Chip works and detects radiation

S-CURVES

- Injection also works, calibration still to be done





CONCLUSIONS AND OUTLOOK

- Design and test of first iteration of a DMAPS detector in 180 nm TowerJazz CMOS technology
- Identified room for improvements in both sensor and electronics (latter with MiniMALTA@CERN)
- Working and efficient (> 98 % @ 10^{15} neq) fully monolithic detector with large matrix

- Second iteration with more improvements being tested at the moment
- Chip is operational and shows promising results so far
- First testbeam scheduled for August at DESY

ACKNOWLEDGMENTS

- 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)