The next generation of monolithic sensors for ALICE

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Maastricht FASTER meeting
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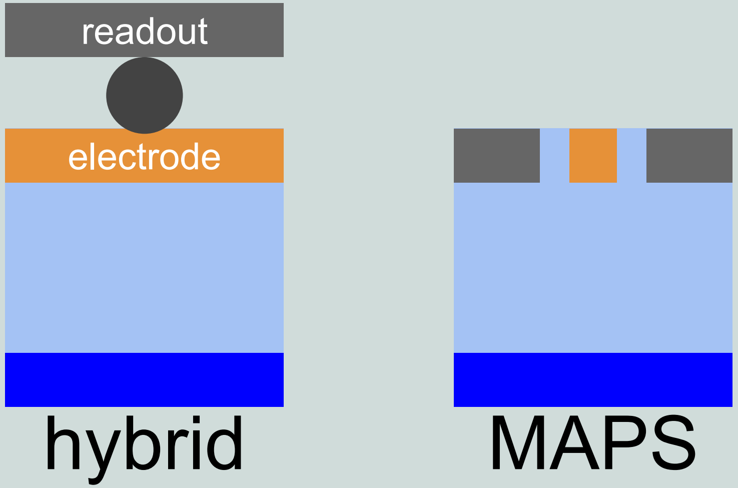
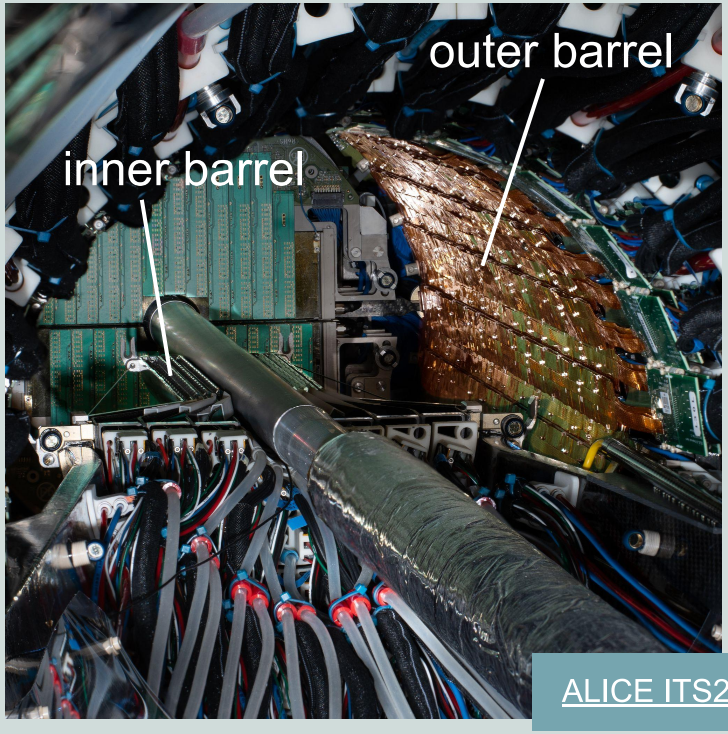
Nikhef

MAPS

- **M**onolithic **A**ctive **P**ixel **S**ensors
- Readout and sensor integrated in the same chip
- Compared to hybrid sensors:
  - + Easier detector assembly
  - + Lower material budget
  - + Lower cost
- ALICE ITS2 → 10 m² of ALPIDEs
- The future
  - ALICE ITS3: installation in LS3, commissioning 2029
  - ALICE3: installation in LS4, commissioning 2035





ALICE ITS2

DOI: 10.22323/1.420.0083

Improved design

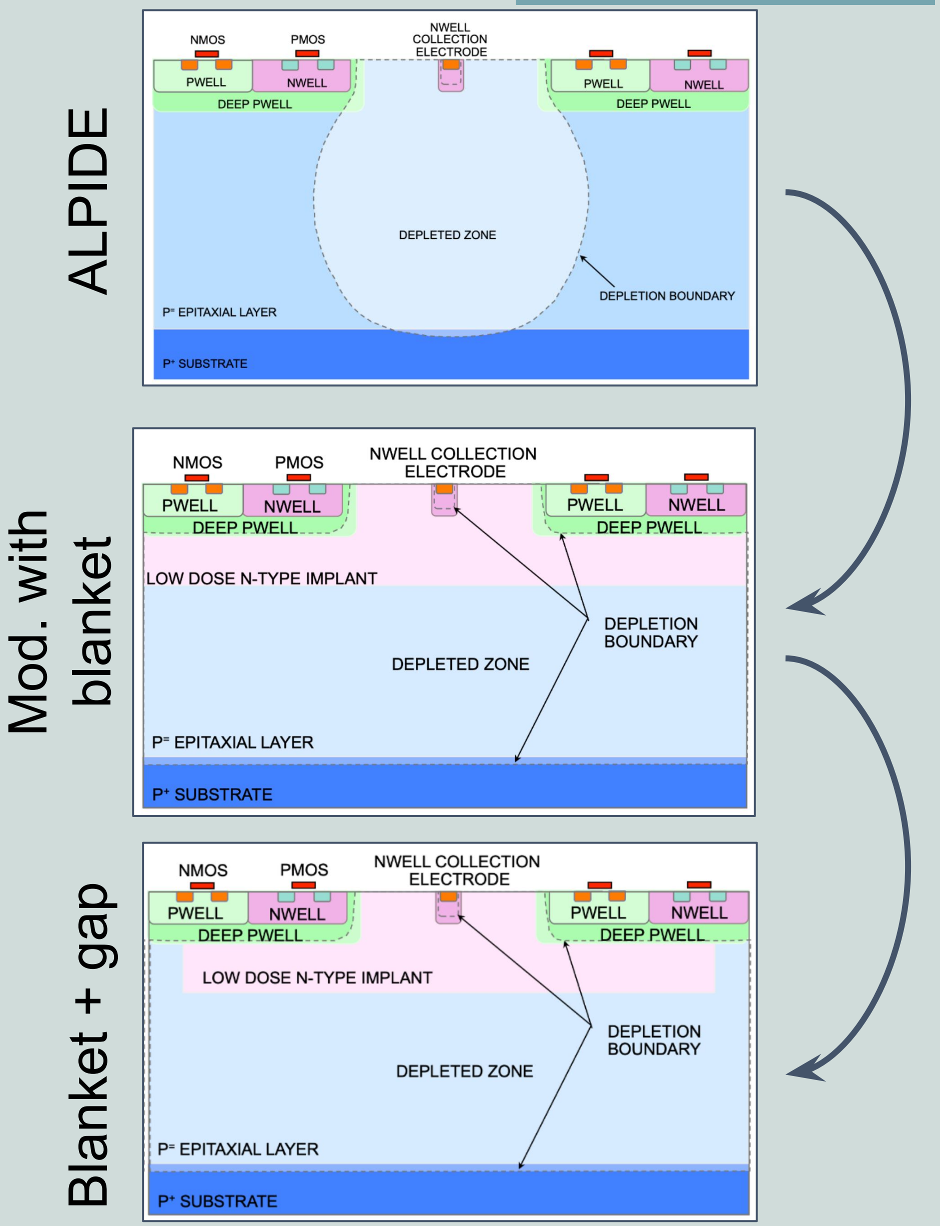
Disadvantage!

- Non-uniformity of field
  - Charge collection by drift and diffusion
  - Relatively slow
  - Prone to charge trapping

→ Blanket
  - Full depletion of epitaxial layer

→ Blanket + gap
  - Improve lateral field near pixel edges

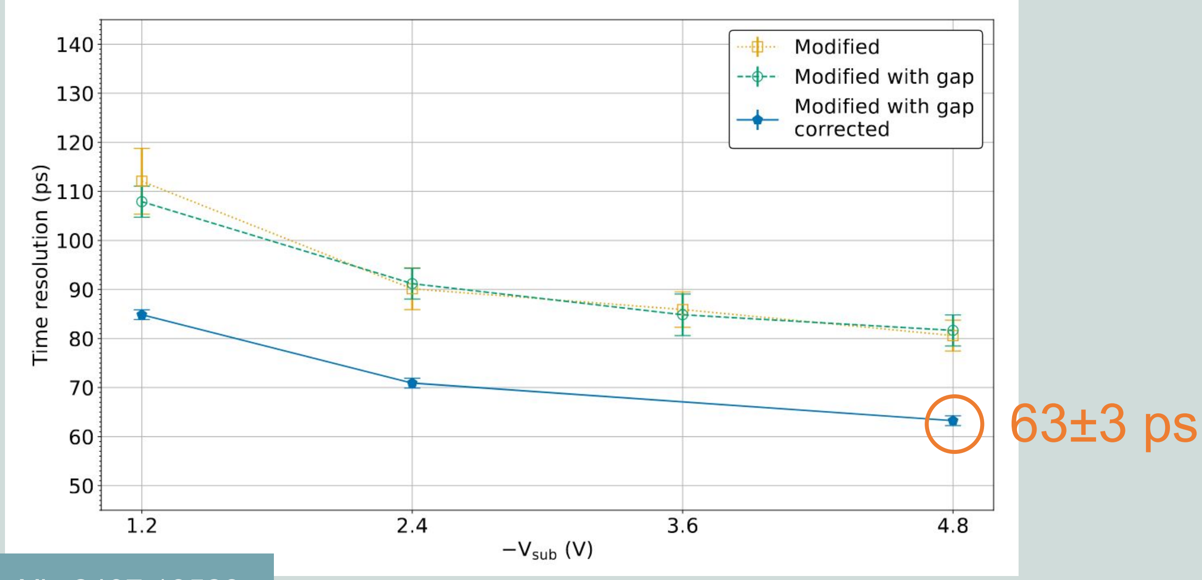
→ 65 nm transistor technology



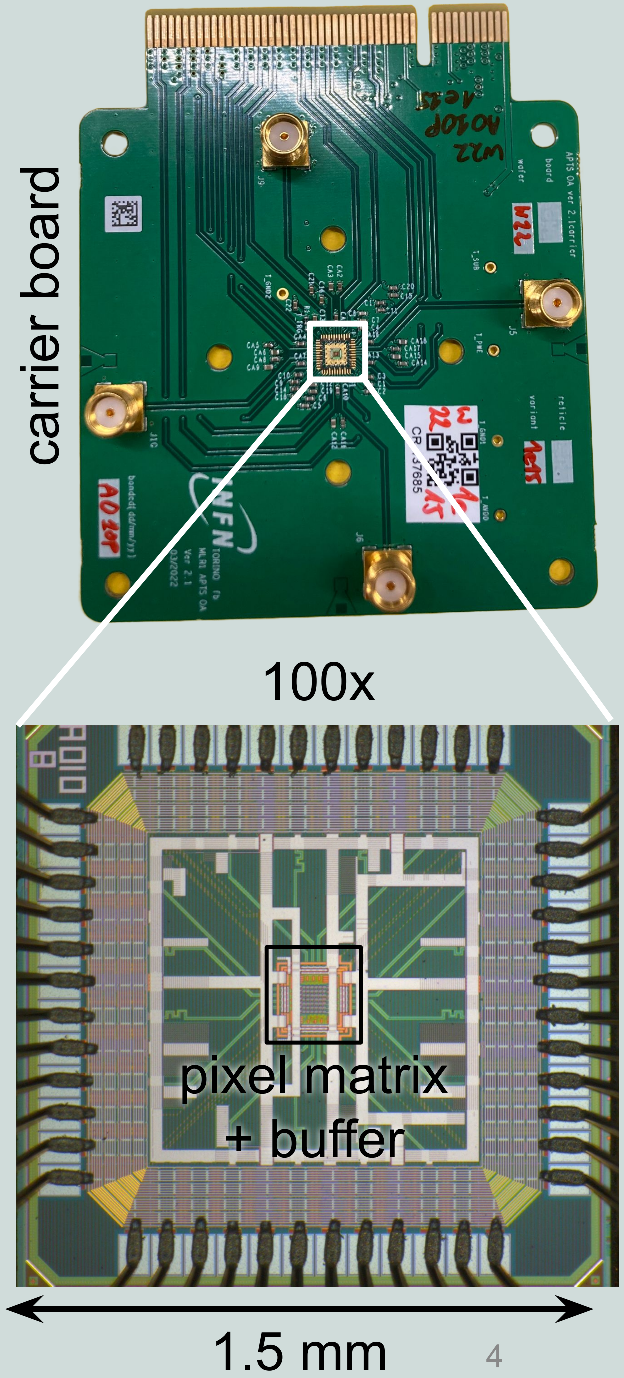
APTS

Improved timing and radiation hardness

- **A**nalogue **P**ixel **T**est **S**tructure
- Pixel prototype of 65 nm technology
- Different flavours: standard, modified, **with gap**
- 6x6 pixel matrix
- Direct analogue readout of central 4x4 pixels
- Different pixel pitches: **10**, 15, 20, 25 μm
- Source follower/**OpAmp** output driver



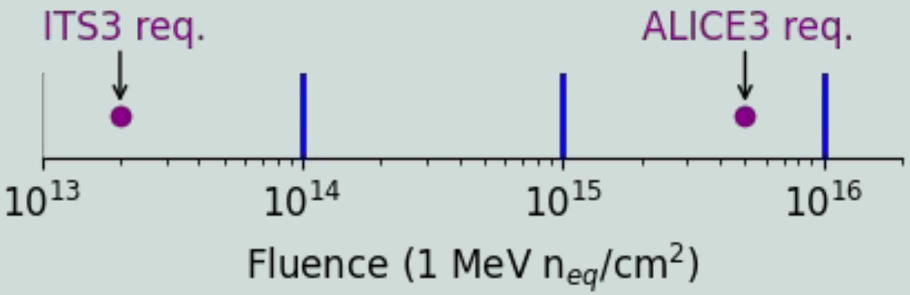
arXiv:2407.18528

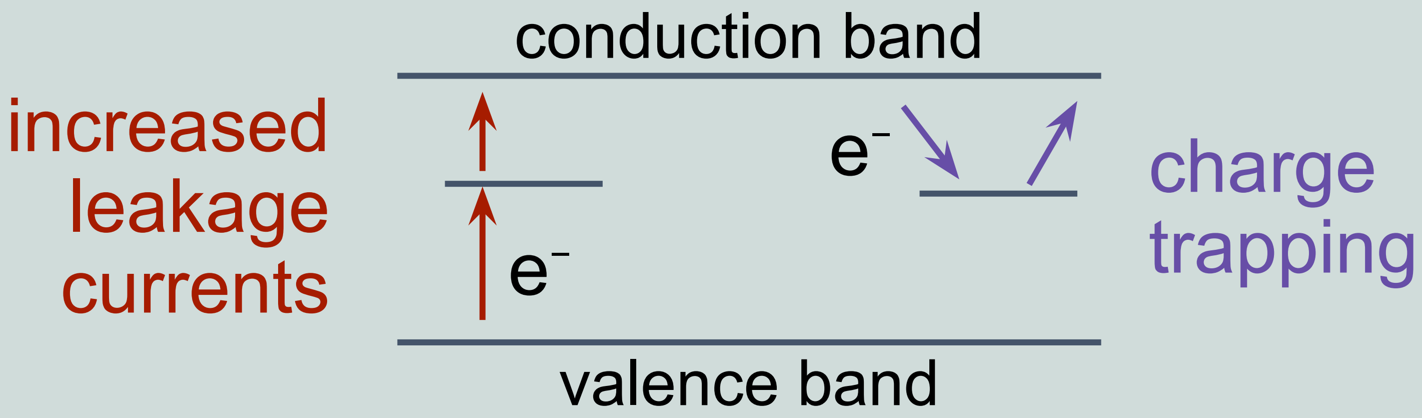


Irradiated APTS

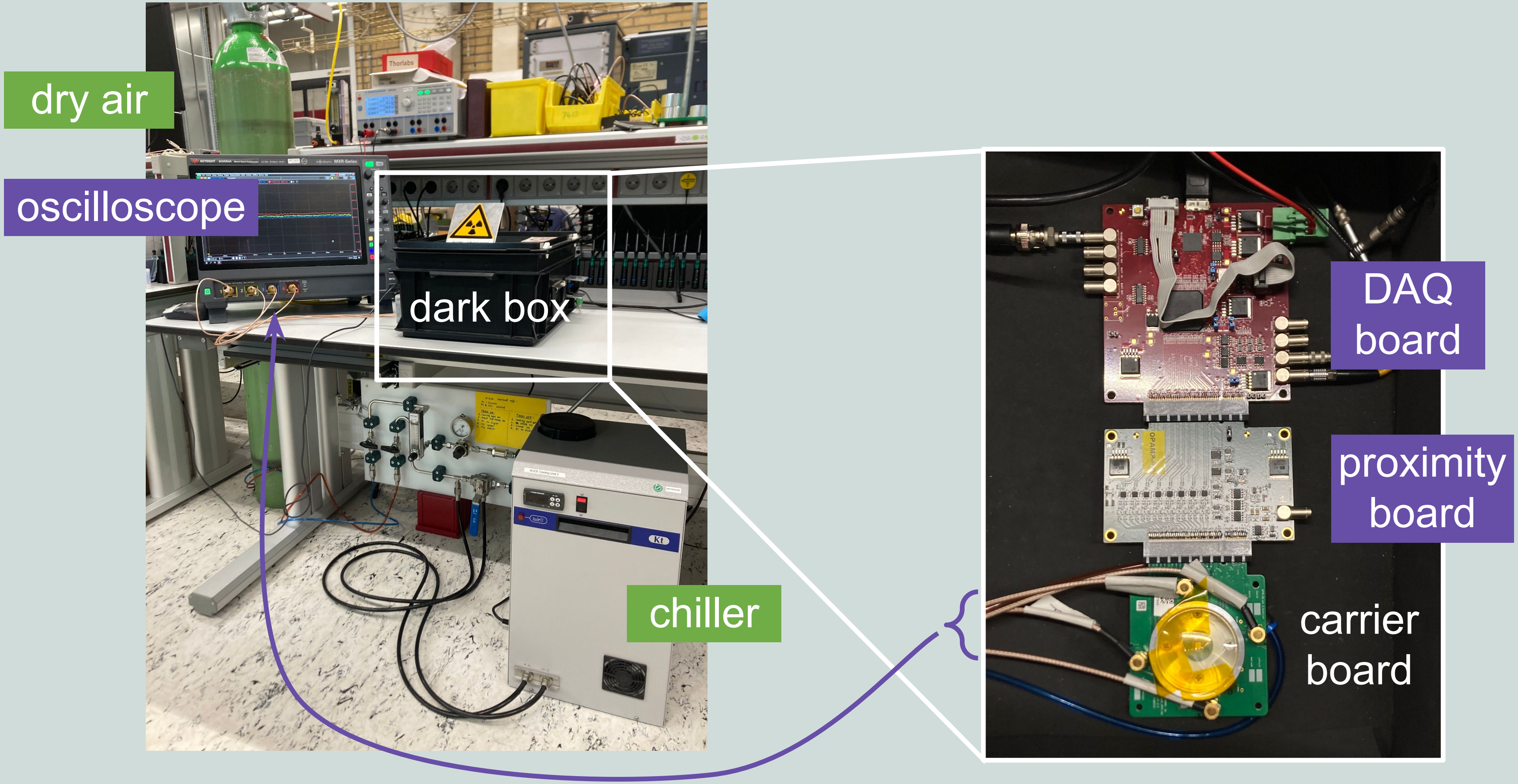
To study the radiation hardness

- Neutrons @ reactor Ljubljana
- Three different levels of irradiation





Setup



Innermost 4 pixels
readout with oscilloscope

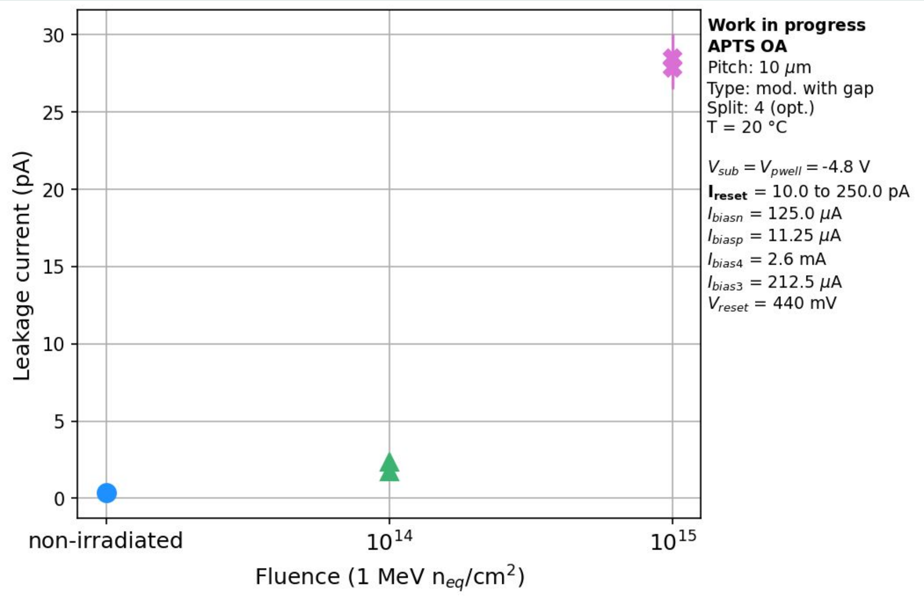
Leakage current

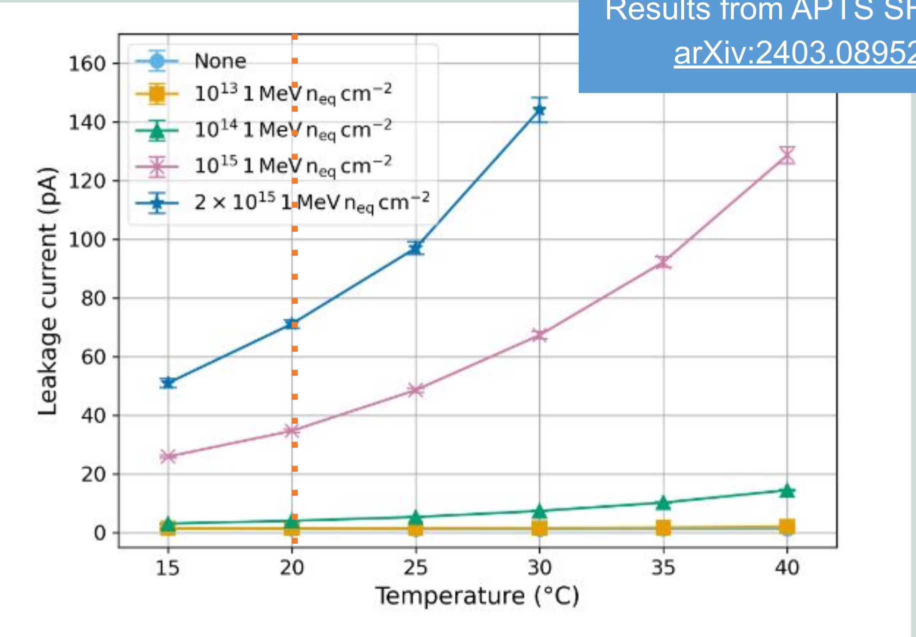
- Radiation damage can create defect levels in the bandgap
- Studying return to baseline of pulsed waveforms

$$I_{\mathrm{eff}} = m \cdot I_{\mathrm{reset}} - \mathbf{I}_{\mathrm{leakage}}$$

measured set fitted

- Dependency on operating temperature to be studied



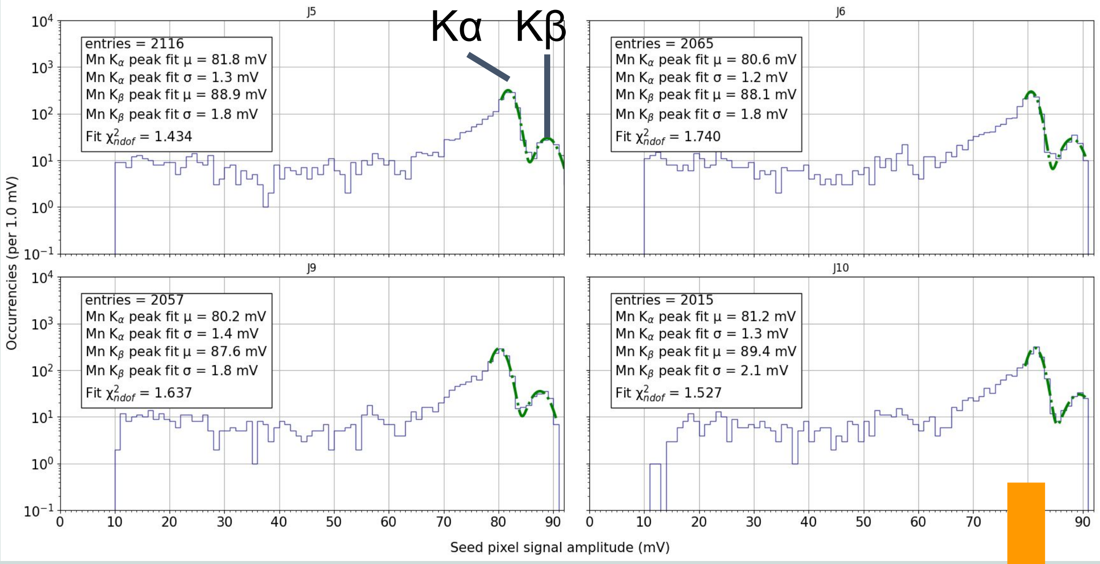


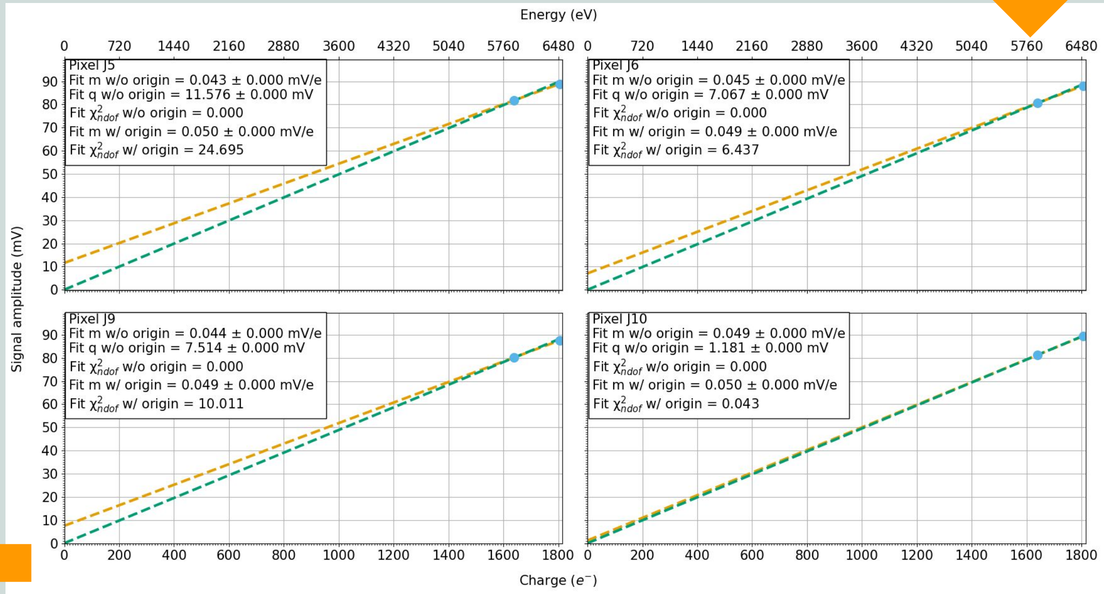
Results from APTS SF
arXiv:2403.08952

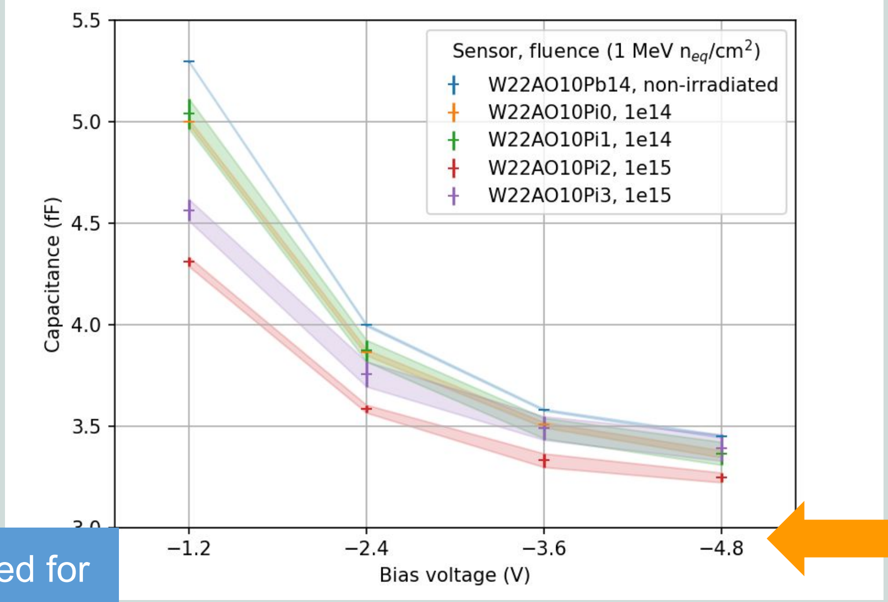
Charge calibration

- Iron-55 →2 X-ray peaks
  - Mn-Kα @ 5.9 keV
  - Mn-Kβ @ 6.5 keV
- charge → signal amplitude
- Pixel capacitance

$$C = \frac{q}{V} = \frac{\text{electron charge}}{\text{V per electron}}$$





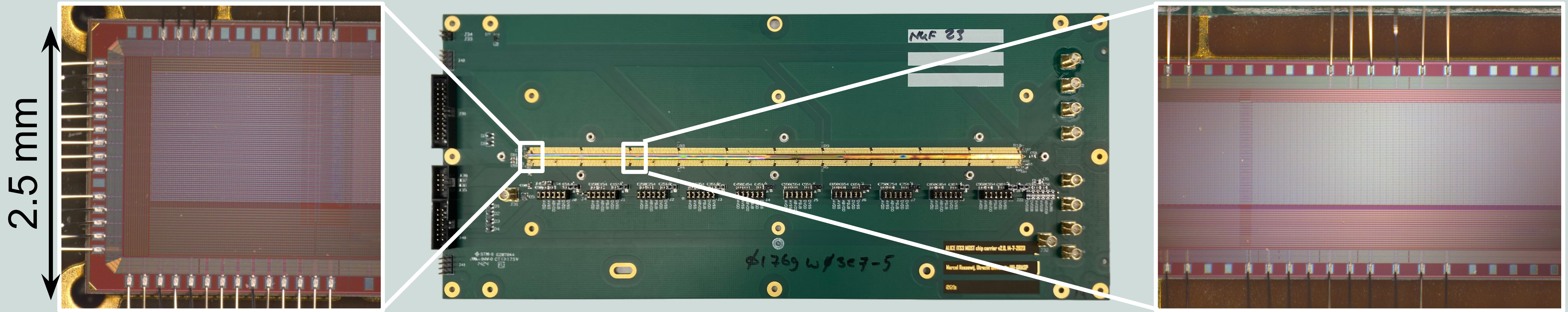


Needs be corrected for gain → factor 0.6!

MOST

Stitched sensor with timing capabilities

- **MO**nolithic **S**titched Sensor with **T**iming
- Prototype for wafer scale chips
- 160 submatrices of 88x64 pixels
- Pitch of 18 µm



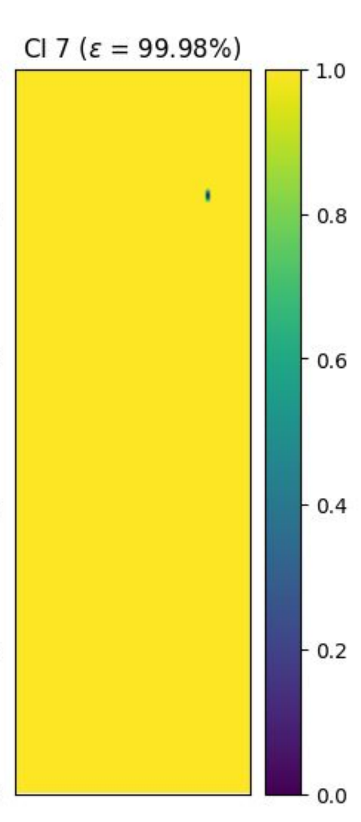
endcap | arrier board | stitch example

Ongoing work

Work by Artem, Mariia and Sergei!

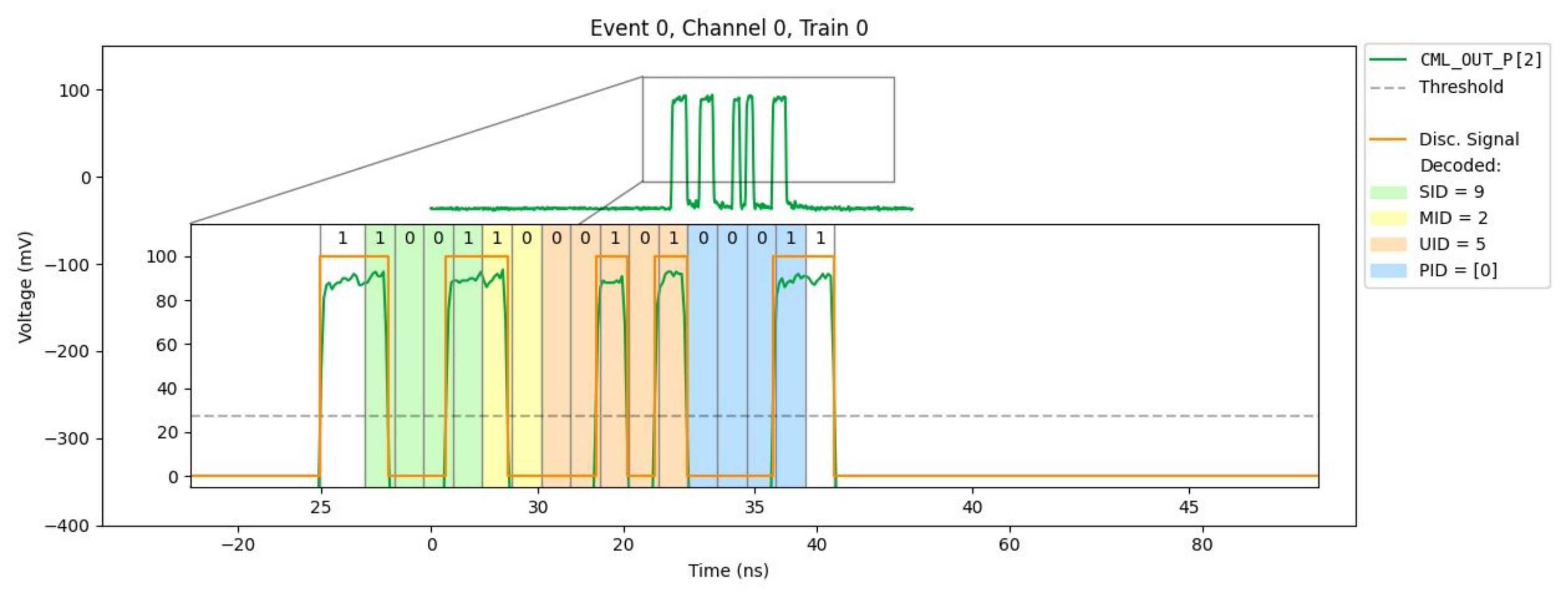
Yield

- Powering
- Check of shorts
- **Pixel responsivity**

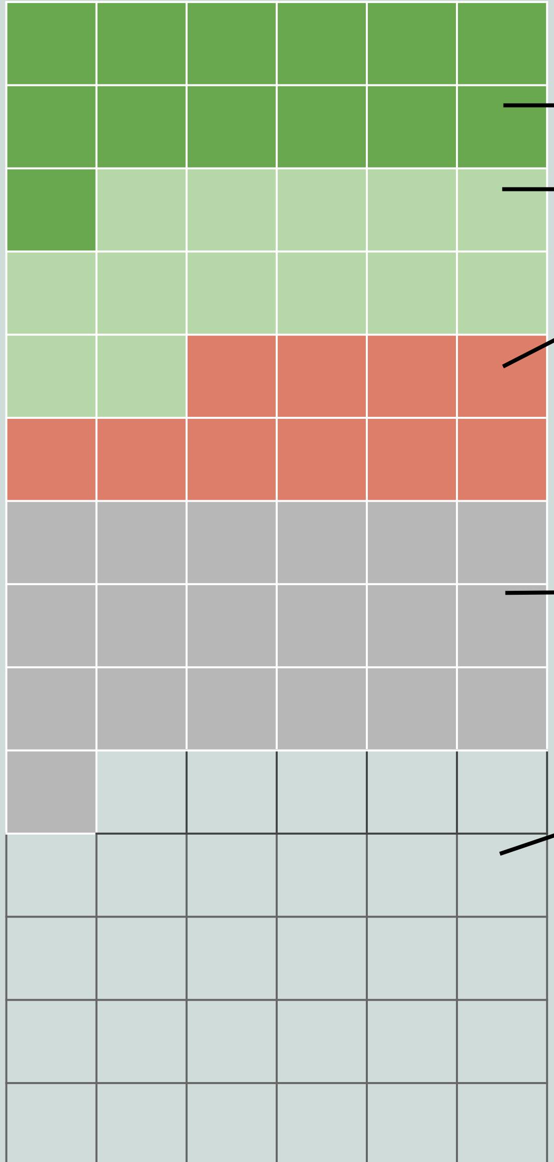


Sensor operation

- Scans to optimising the settings
- **Decoding of signal**



Yield results so far



Total of **36** tested:

- **13**: OK
- **13**: OK with increased currents
- **10**: NOK (short, trip)

(**26** of them glued, bonded and tested at Nikhef!)

19 more, ready to be tested

65 more produced, to be glued, bonded and tested

Outlook

APTS

Work ongoing to study radiation hardness

Irradiated sensors to be tested at the SPS test beam next week!

→ determine their time resolution and detection efficiency

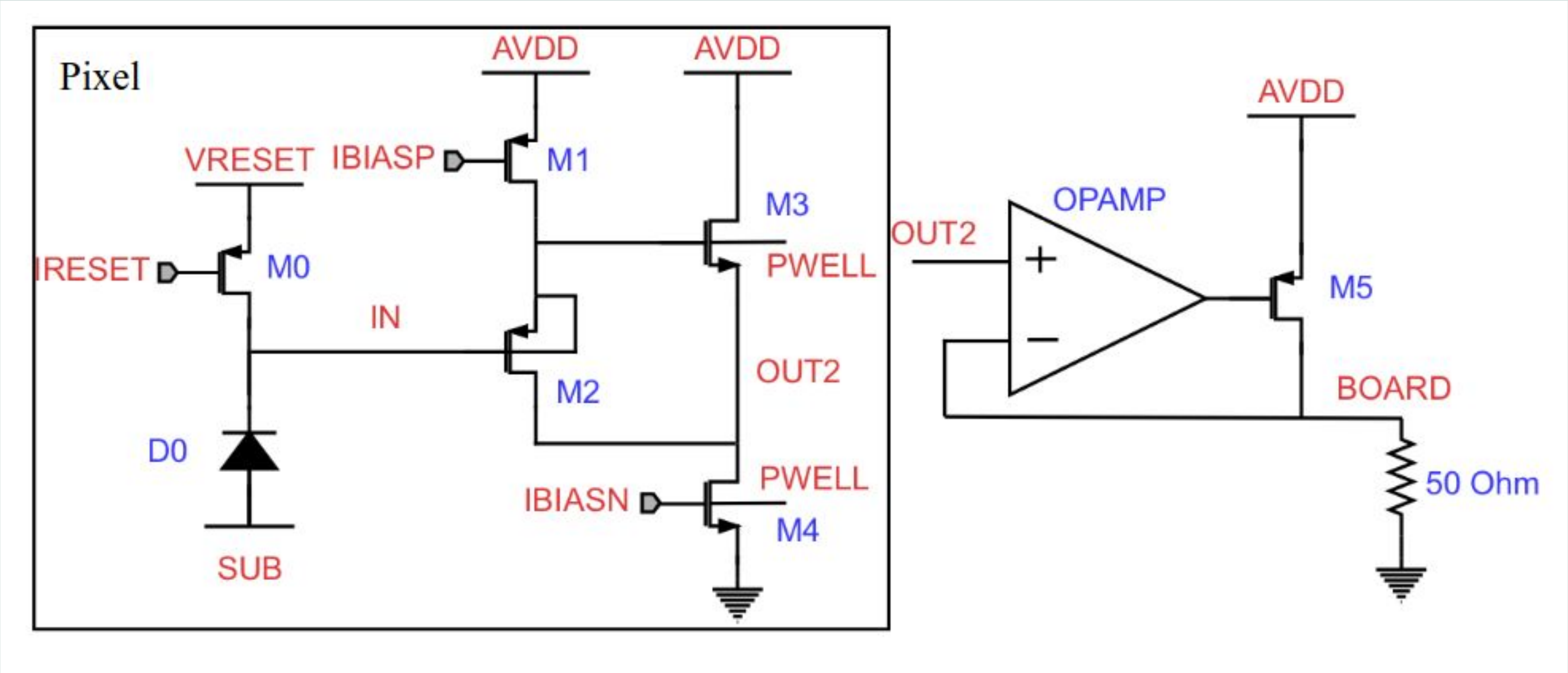
MOST

Study of yield and sensor operation ongoing

Thanks :-)

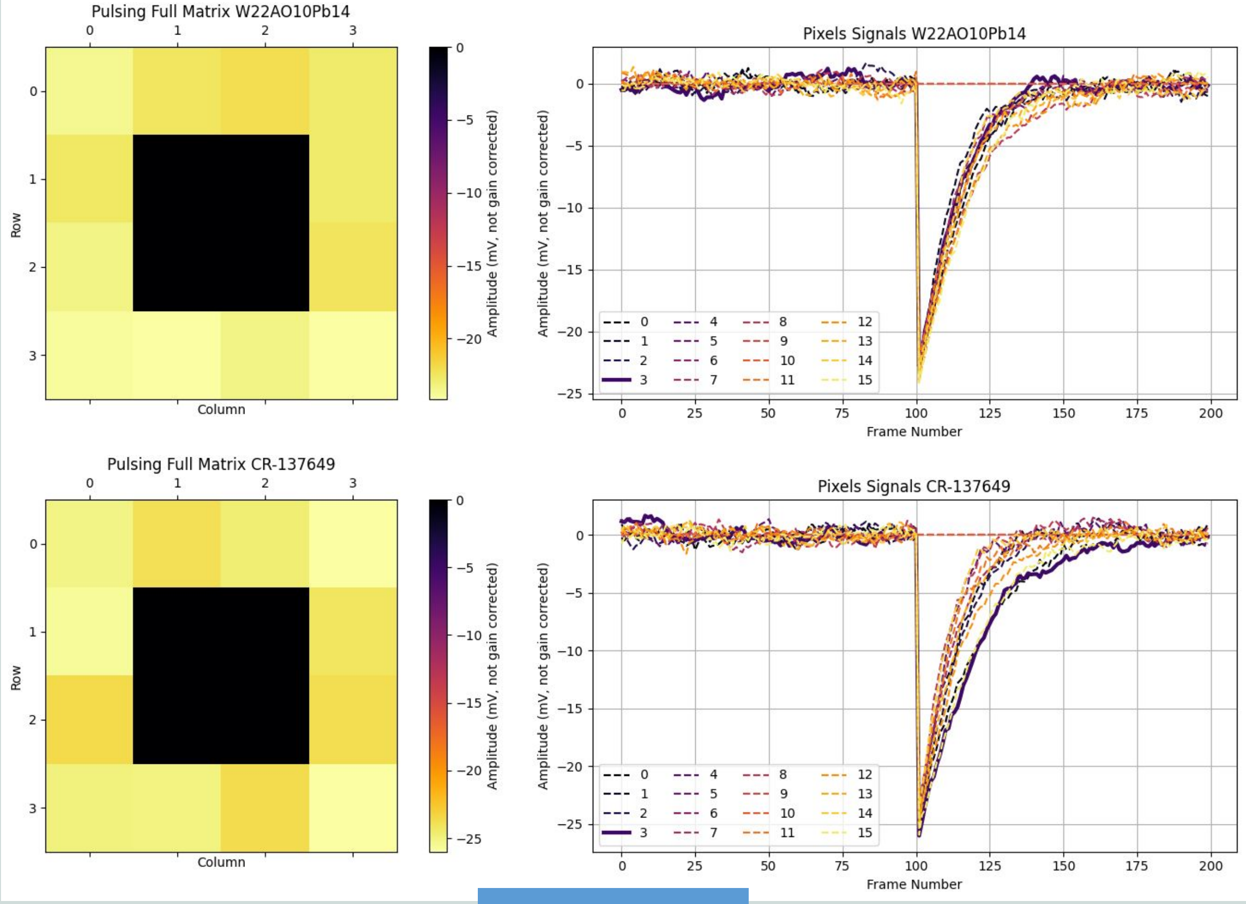
Back up

APTS OA schematic



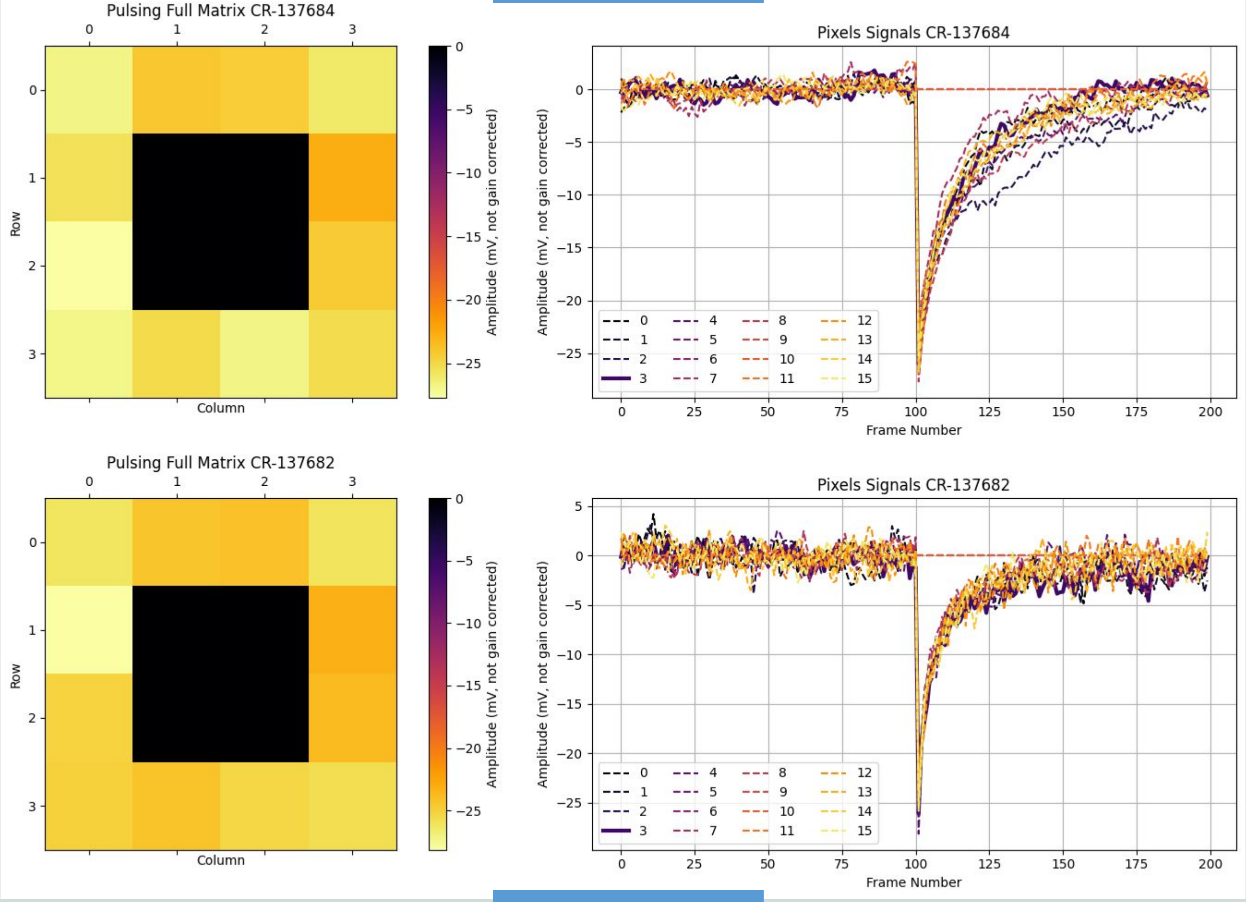
Test pulsing at different fluences

non-irradiated



1e14

1e15



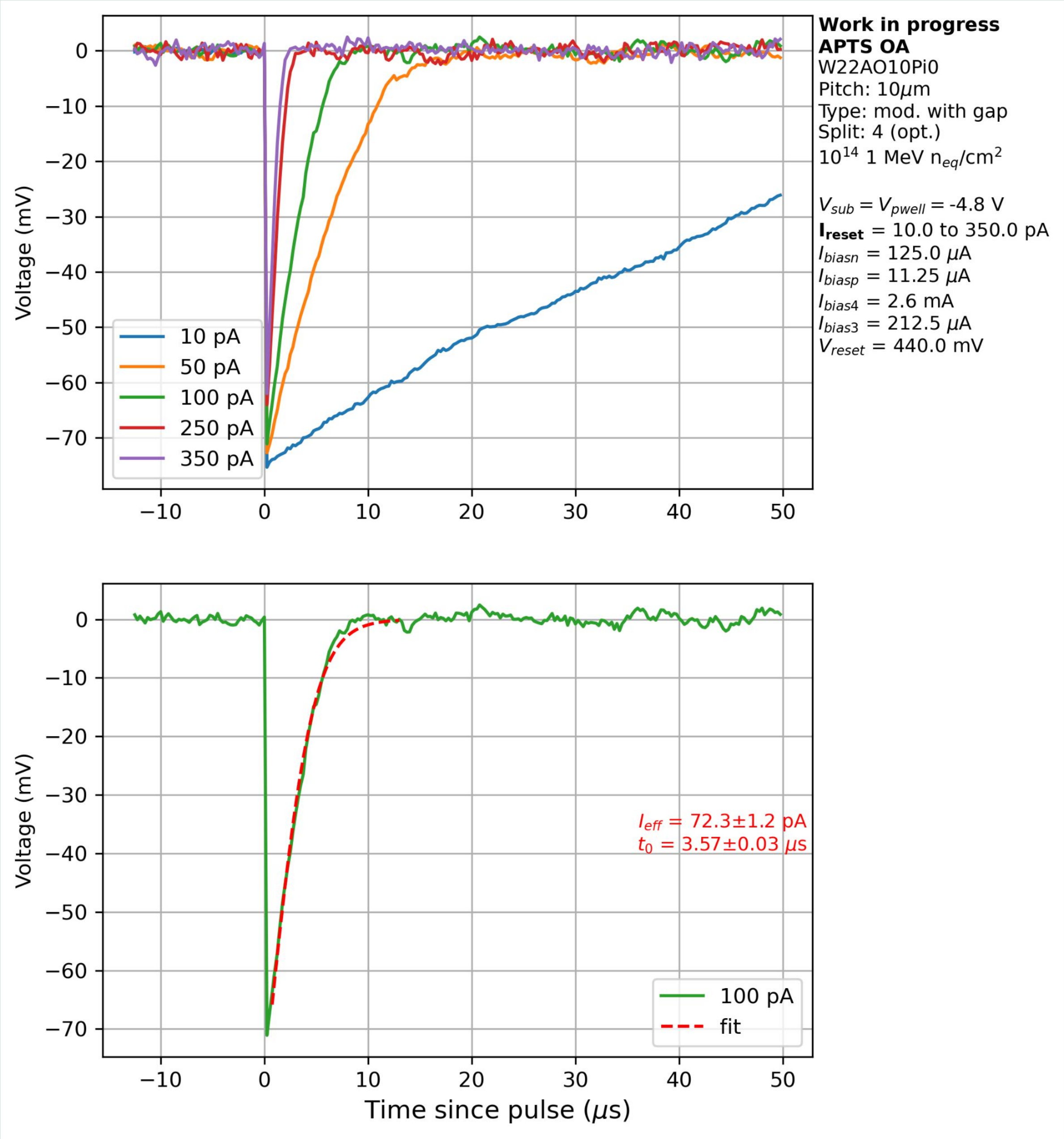
1e16

Pulsing for I_{eff}

- Pulsing at varying I_{reset}
- Fit for effective current

$$V(t) = -V_{\text{th}} \cdot \ln\left(e^{-(\mathbf{I_{eff}}\cdot(\mathbf{t}-\mathbf{t_0}))/(\mathbf{V_{th}}\cdot\mathbf{C})} + 1\right)$$

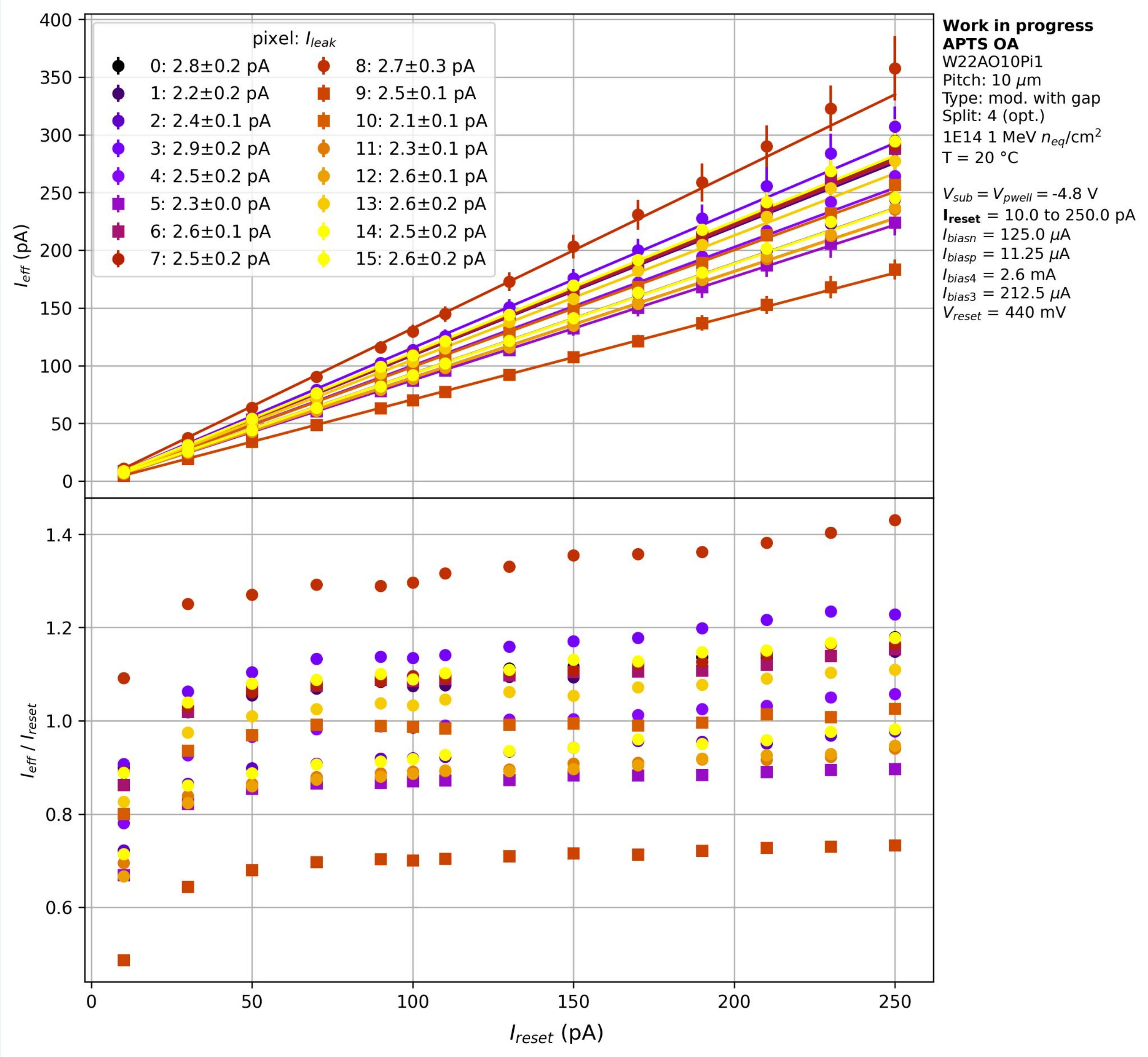
  - describes trailing edge
  - V_{th} - thermal voltage
  - C - capacitance → from charge calibration



Fitting for I_{leakage}

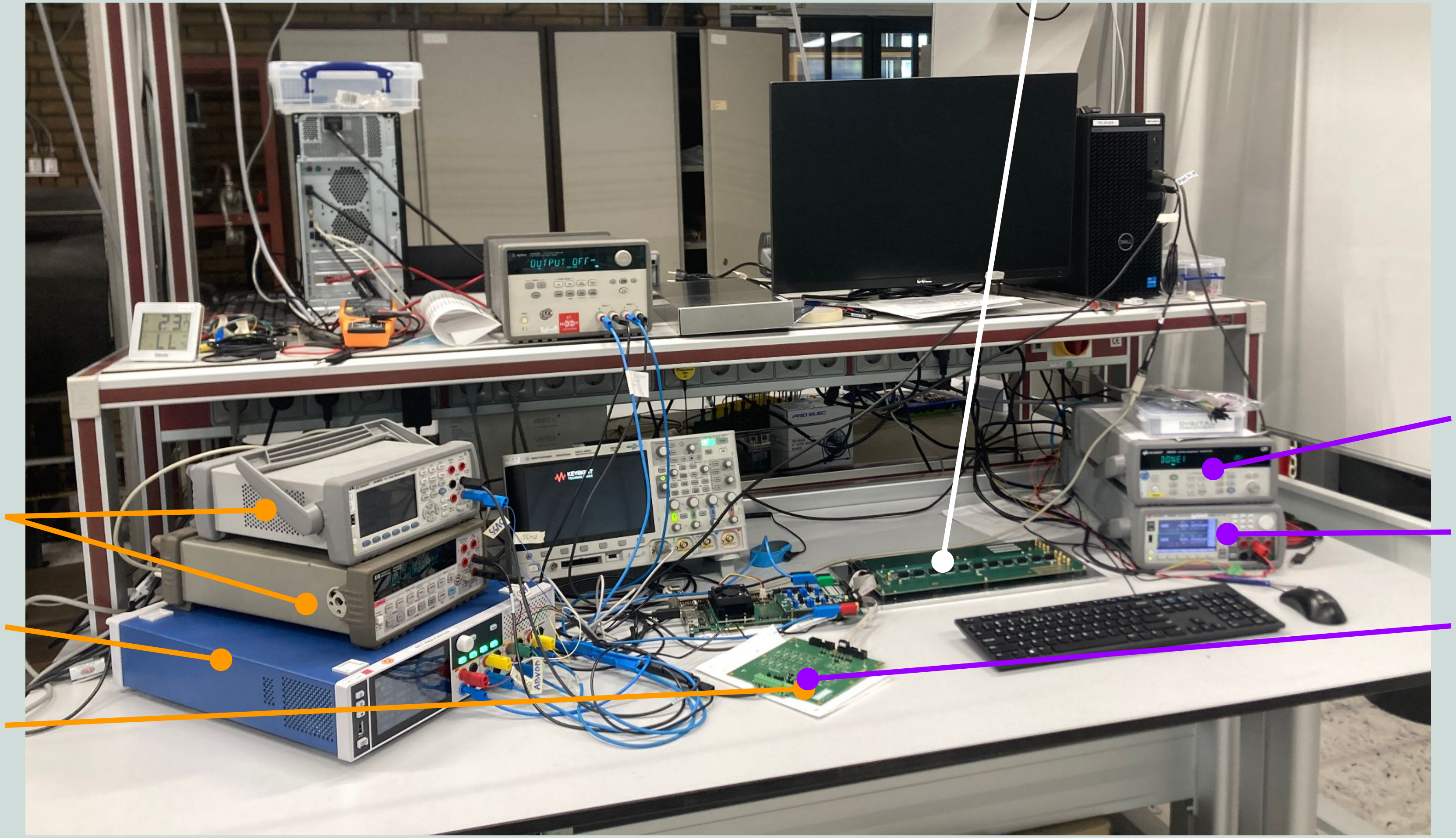
$$I_{\mathrm{eff}} = m \cdot I_{\mathrm{reset}} - \mathbf{I}_{\mathrm{leakage}}$$

Weighted fit



MOST setup at Nikhef

MOST under test



Power testing

Digital multimeters

Power supply

Breakout board

Impedance testing

Data Acquisition/ Switch Unit

Power Source

Breakout board

MOST architecture

10 stitched units
→ 4 matrices
→ 4 submatrices/control interfaces
→ 88x64 pixels