Trento Institute for Fundamental Physics and Applications

UNIVERSITÀ DI TRENTO

ARCADIA MAPS process qualification through the electrical characterization of passive pixel arrays

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on behalf of the ARCADIA collaboration

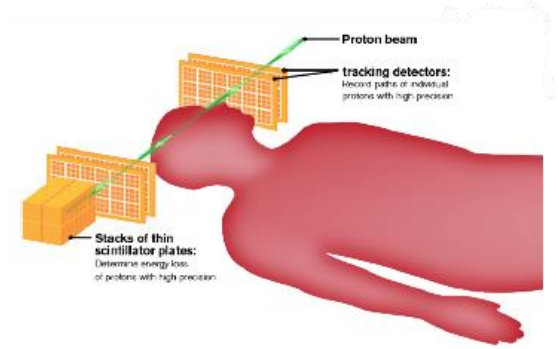
ARCADIA

***A**dvanced **R**eadout **C**MOS **A**rchitectures with **D**epleted **I**ntegrated sensor **A**rrays*

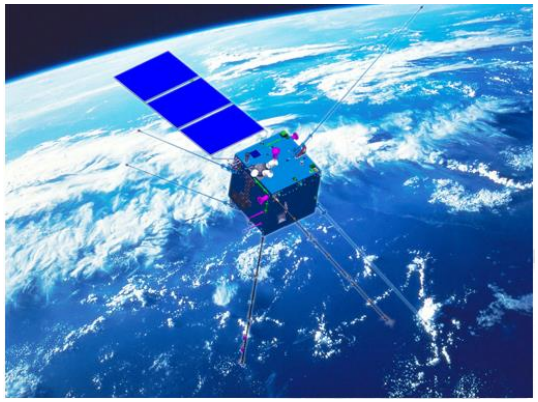
Outline

1) Sensor concept
2) ARCADIA test structures
3) Electrical characterization
4) Laser characterization
5) Conclusions

ARCADIA Project



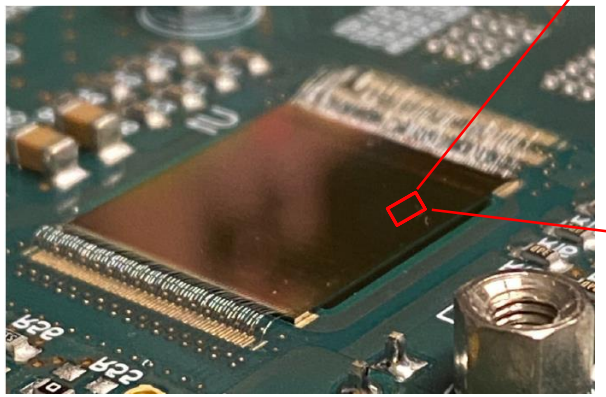
Piero Giubilato

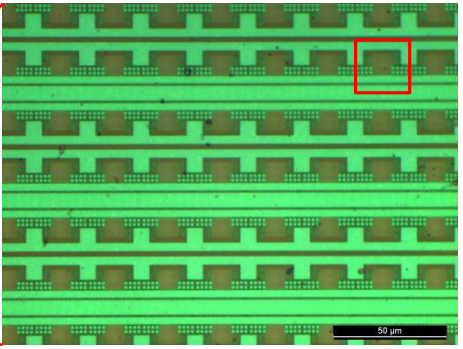


CSES-01
http://cses.roma2.infn.it

- Fully depleted MAPS
- Target applications:
  - medical imaging (e.g. PCT)
  - particle detection on satellites
  - HEP experiments

Andrea Paternò, Vertex 2021
ARCADIA MD1 chip

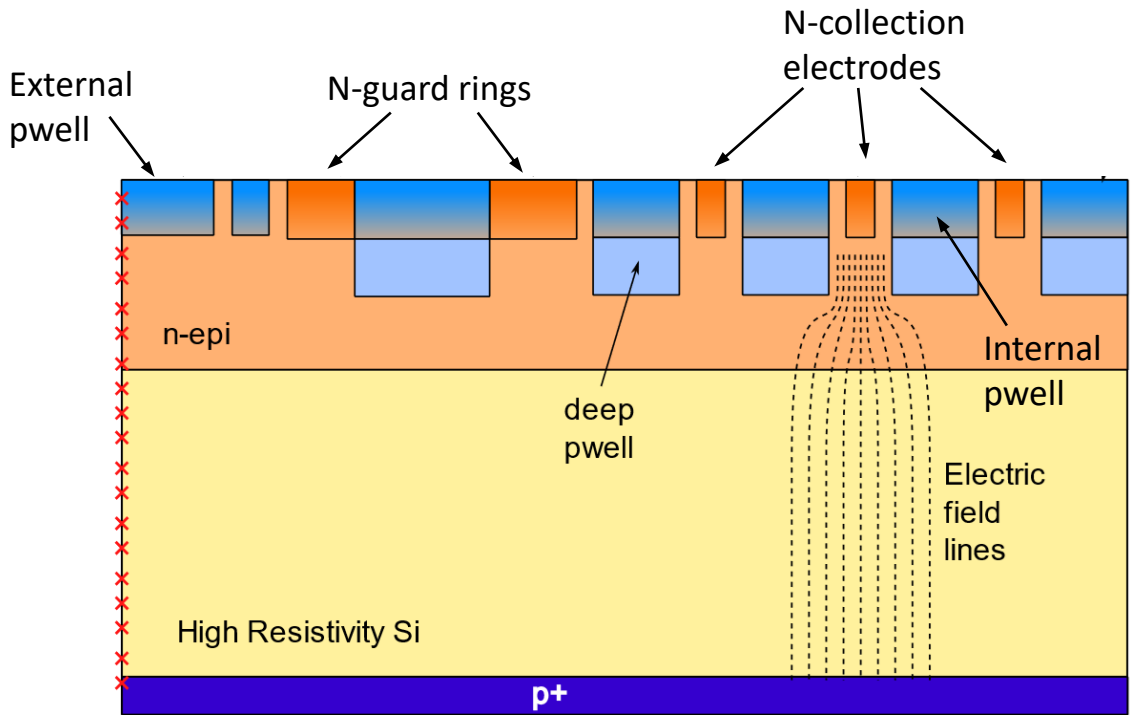




MD1 chip micrograph

- Main Demonstrator (MD1) with sensor array composed of 512x512 pixels with 25µm pixel pitch
- Embedded analog and digital frontend electronics
- Samples from 1st engineering run (mid 2021), 2nd engineering run (beginning of 2022), 3rd engineering run submission (mid 2022)

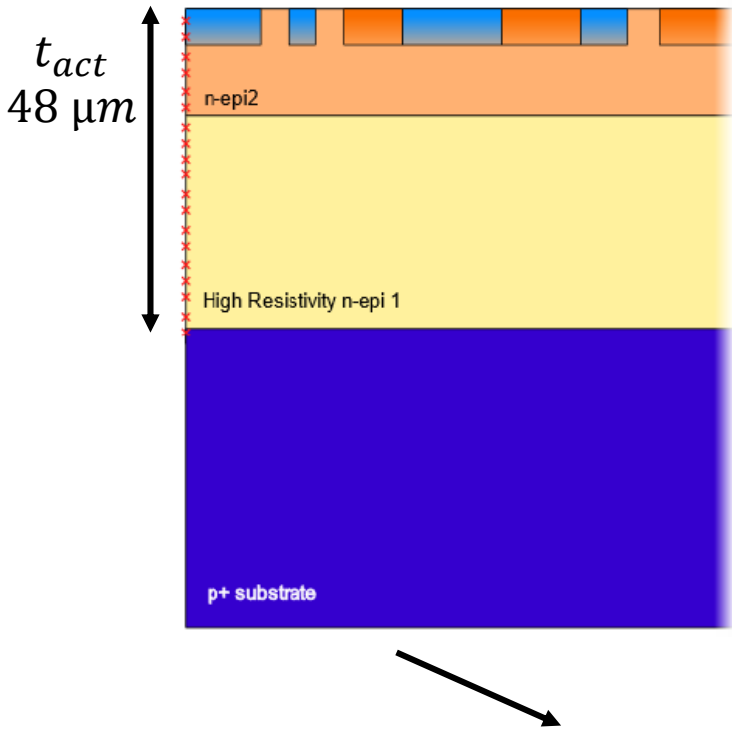
Sensor concept



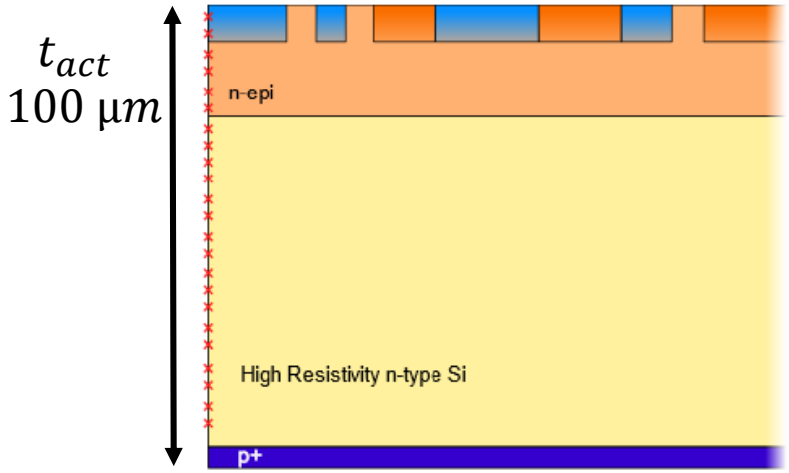
- Produced with commercial CMOS 110nm process (LFoundry)
- High resistivity silicon substrates
- N-type epitaxial layer to delay the onset of the punch through
- Operation in full depletion condition
- Independent frontside and backside bias electrodes

Substrate types

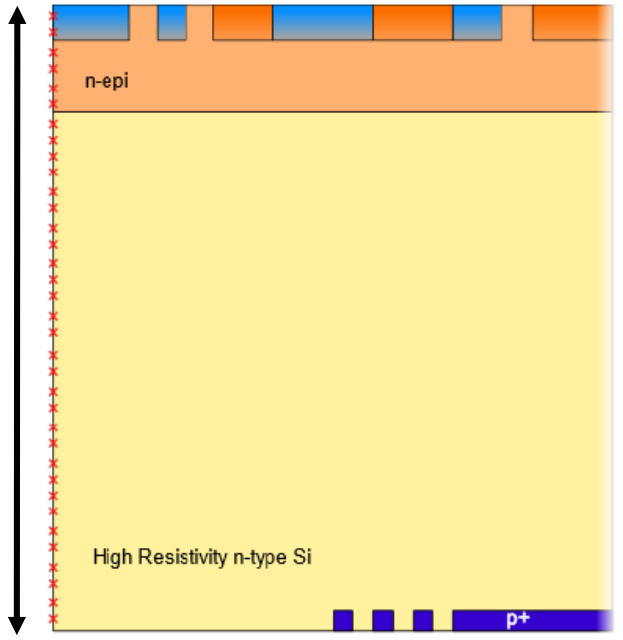
Type 1



Type 2



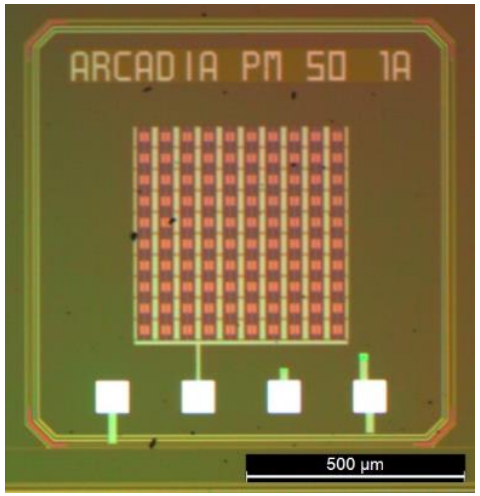
Type 3



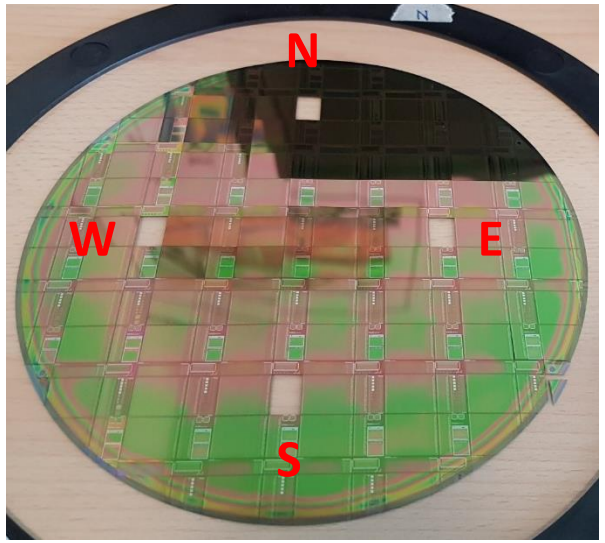
Possibility to apply the bias from the top and from the bottom

Bias only from the bottom

ARCADIA Test Structures

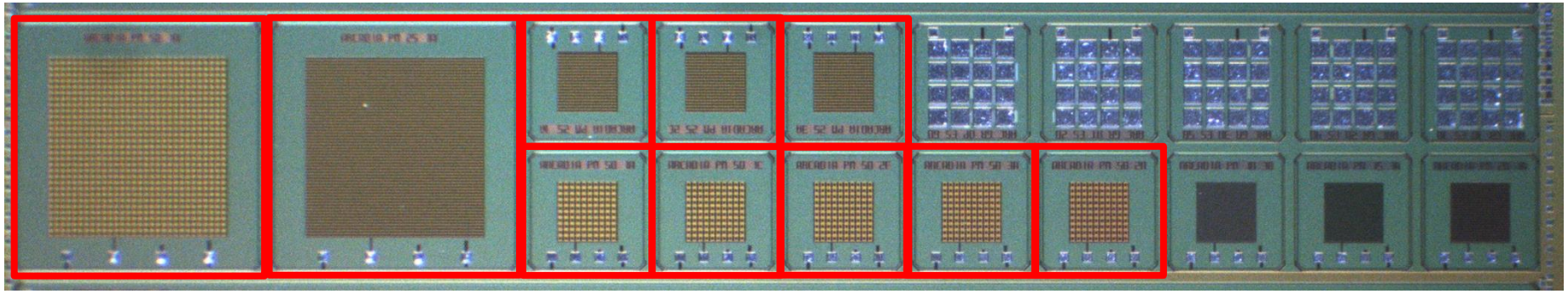


- Chip frontside electrodes
  - External pwell
  - N-type sensor nodes
  - Internal pwell
  - N-guard rings

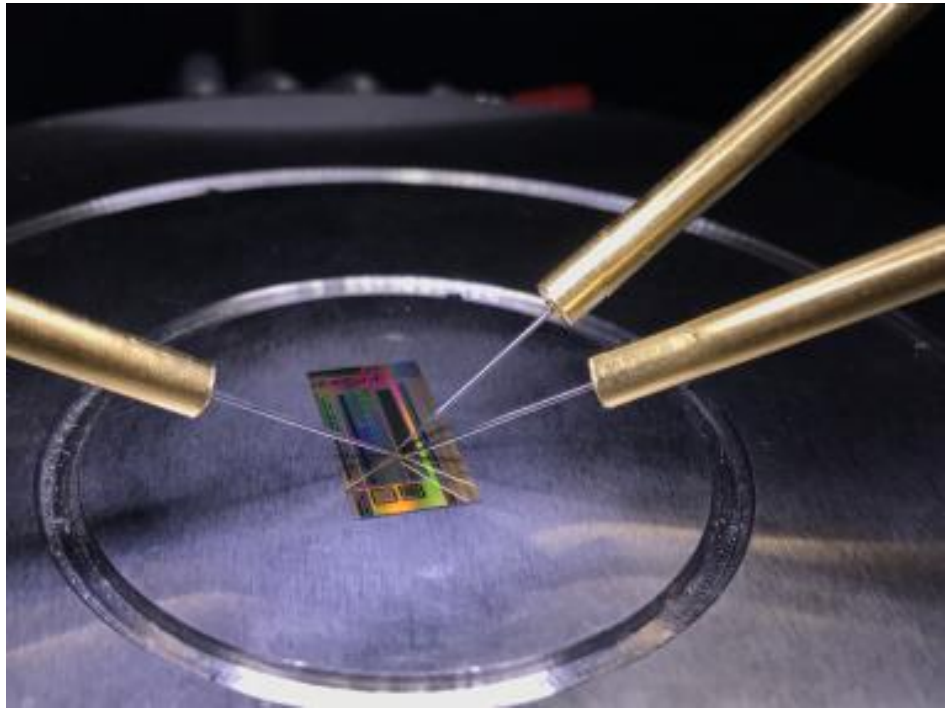


- 4 different positions: N, E, S and W
- Evaluate the variability due to the production process

- Passive TS chip
  - 50µm pixel matrices
  - 25µm pixel matrices

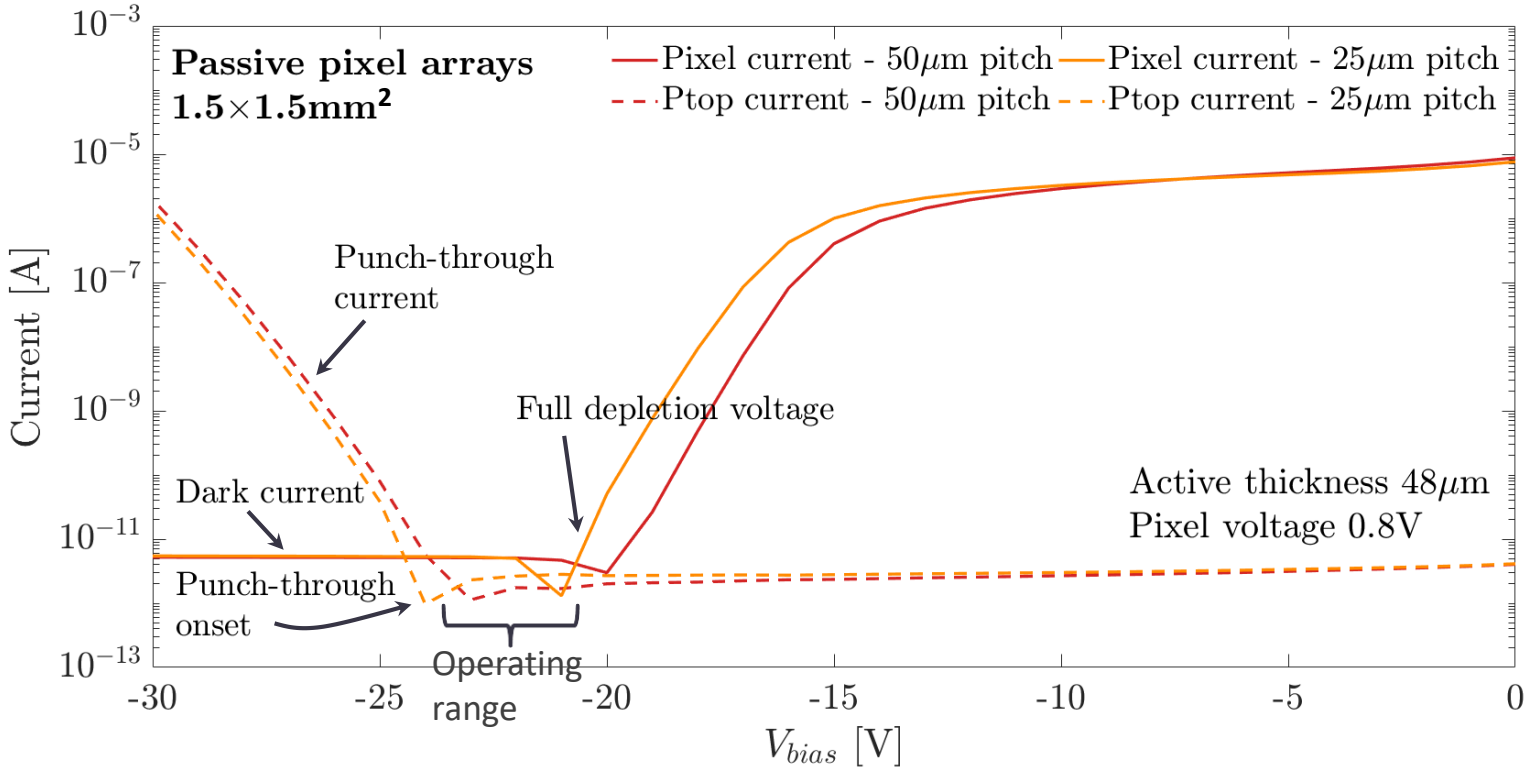


Electrical characterization – IV curves

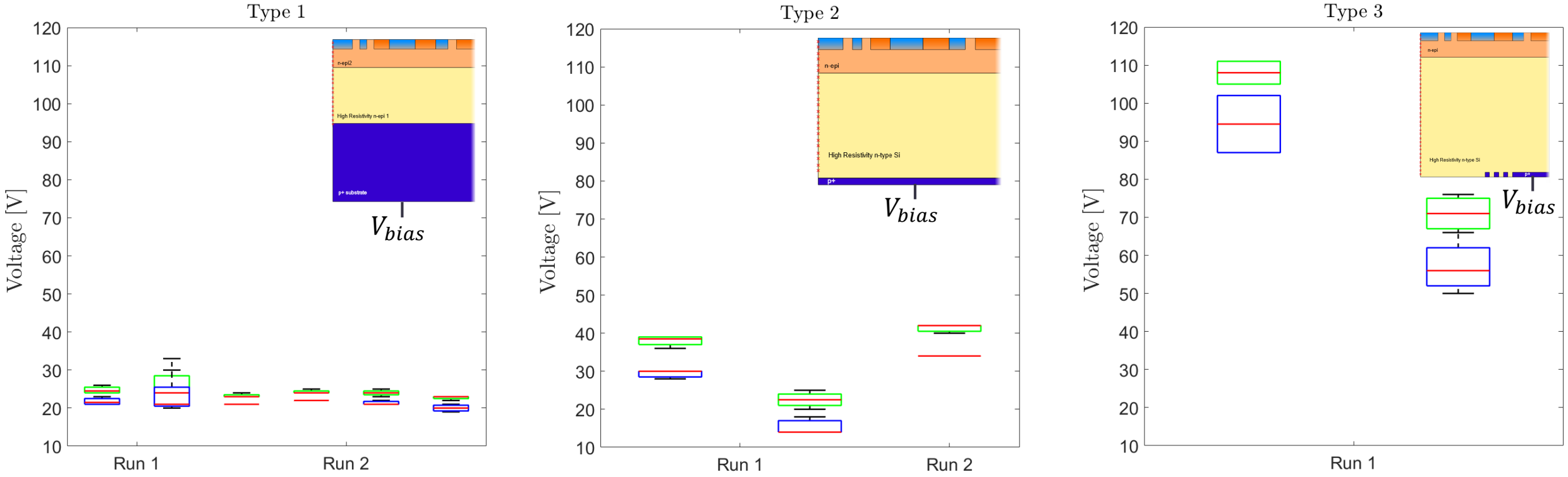


Coralie Neubüser, TIFPA-INFN

- Dips in the pwell and pixel currents reference to extract V_{depl} and V_{PT}
- Similar operating voltage ranges for pixels with 50 and 25 µm pitch

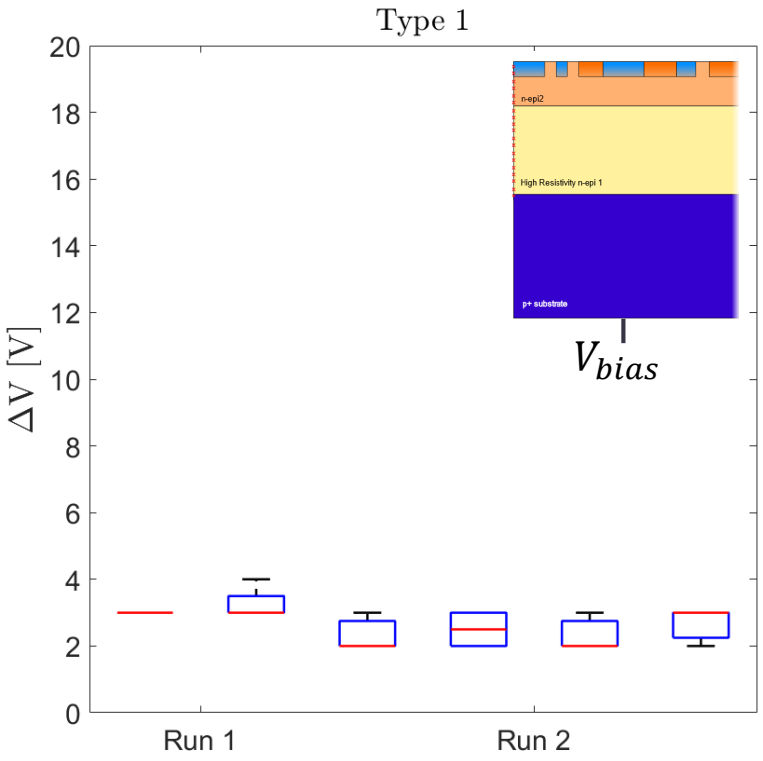


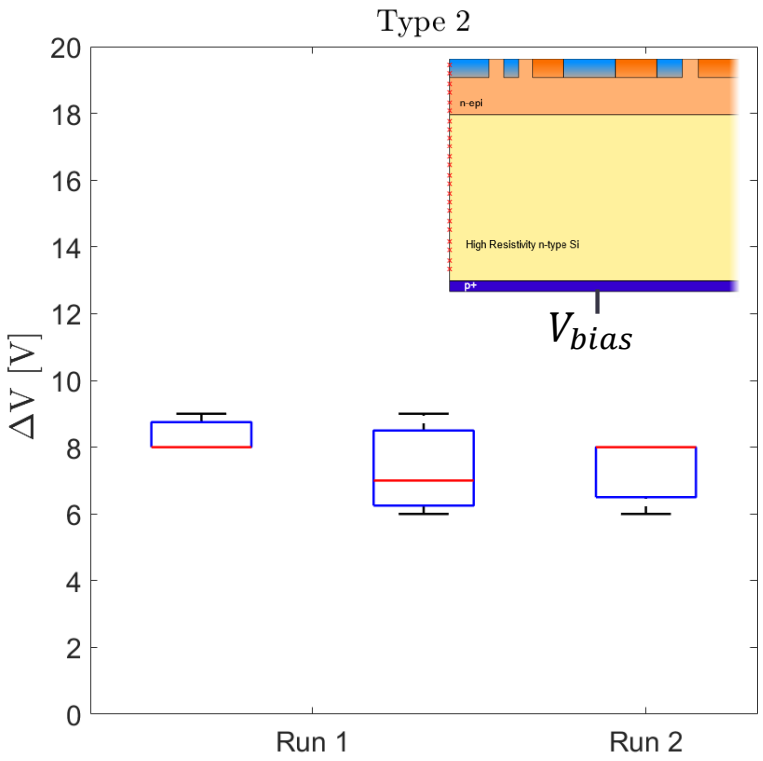
PT and Depl. – Bias from bottom

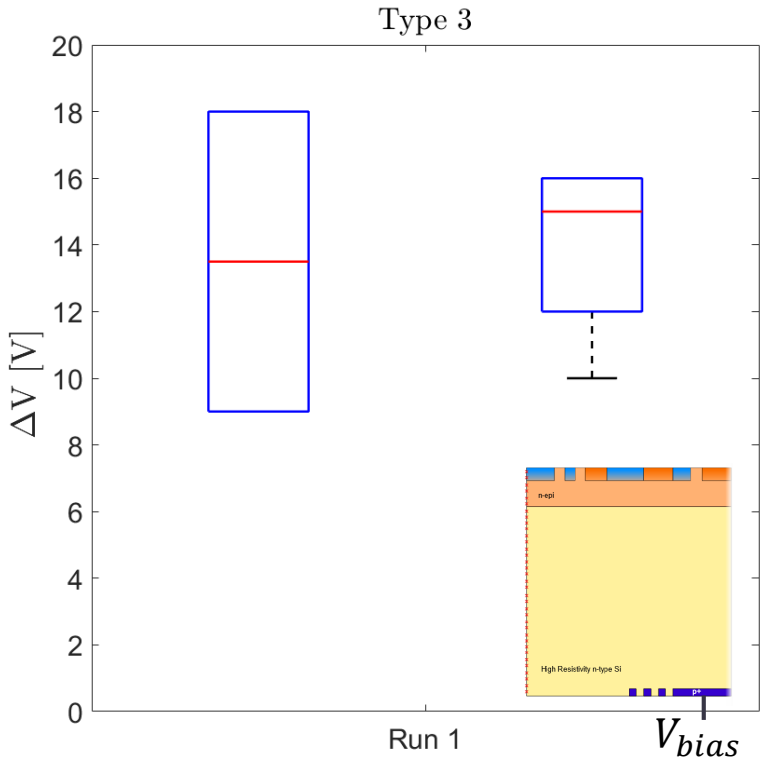


- Two different epitaxial layer thicknesses in Type 2 and Type 3 wafers of Run 1
- Type 1 wafers showed low V_{depl} and V_{PT} variability

Operating range – Bias from bottom

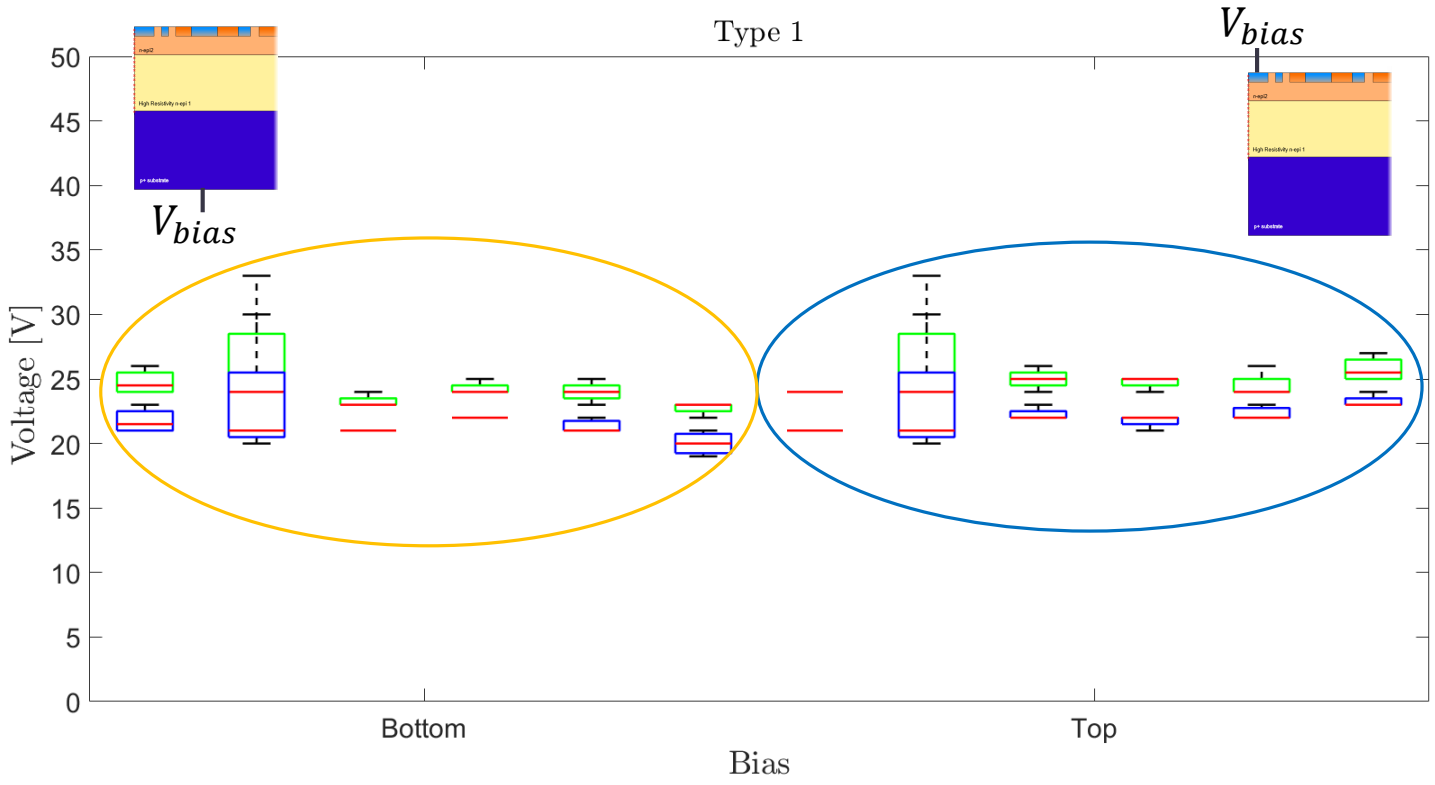


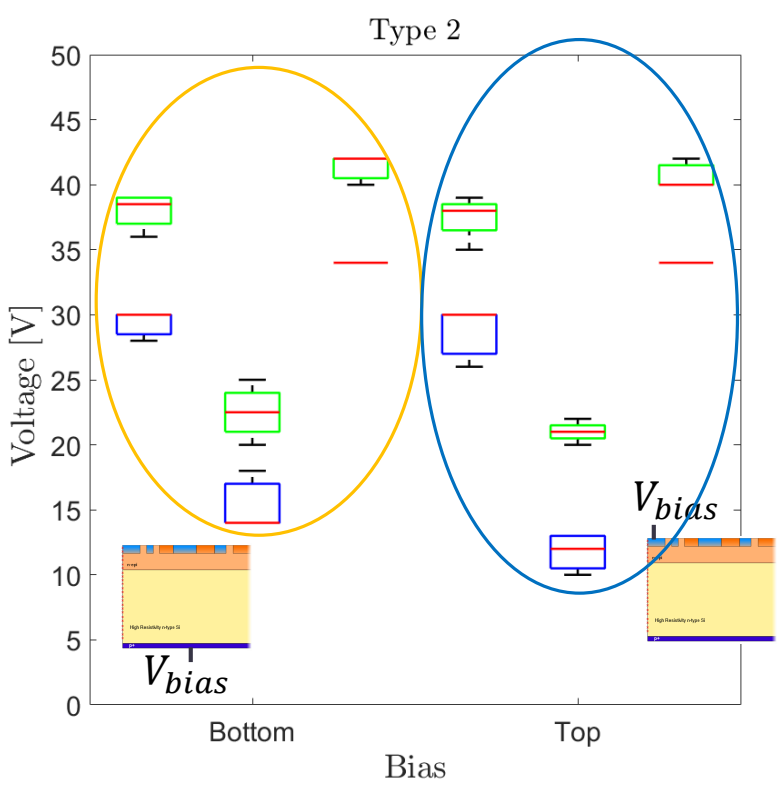




- Larger operating voltage range for increasing substrate thicknesses

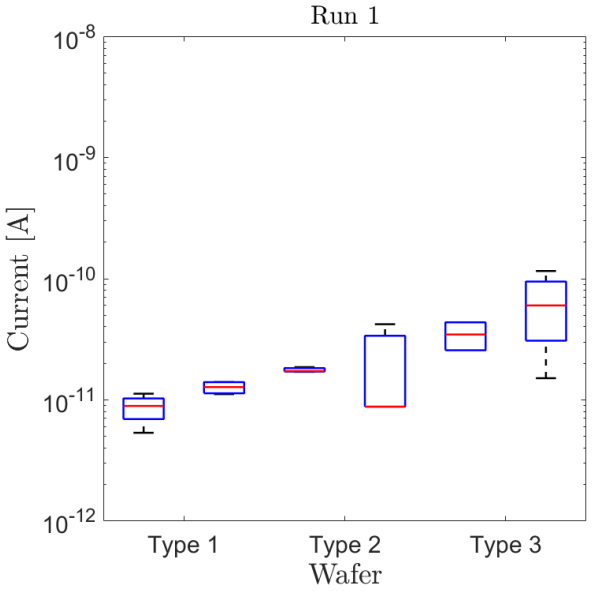
PT and Depl. – Comparison of biasing schemes

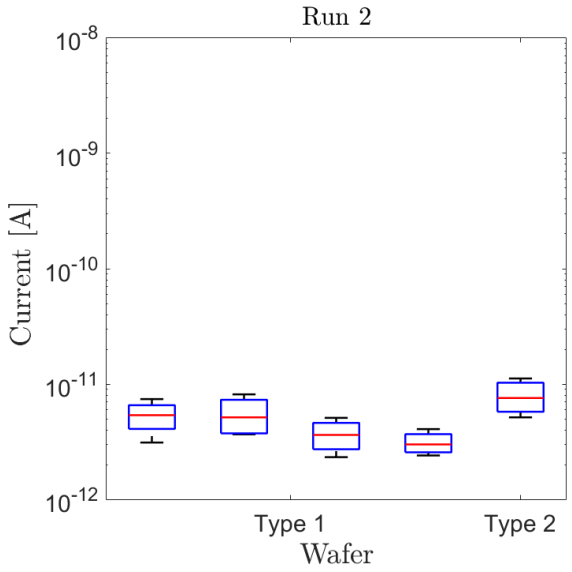




- Small differences in the obtained V_{depl} and V_{PT} for the two considered biasing schemes

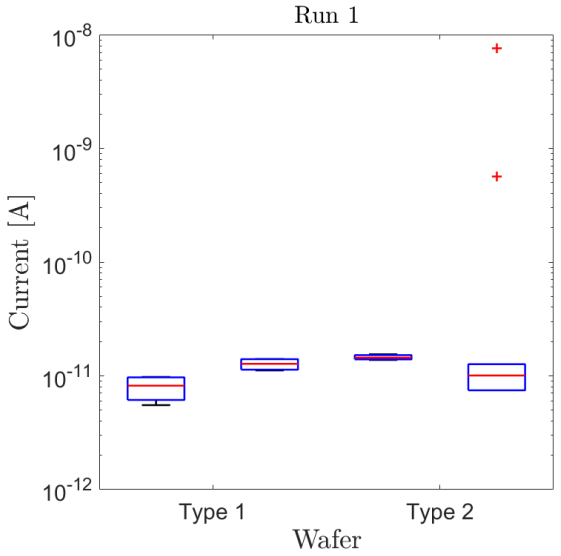
Pixel dark current

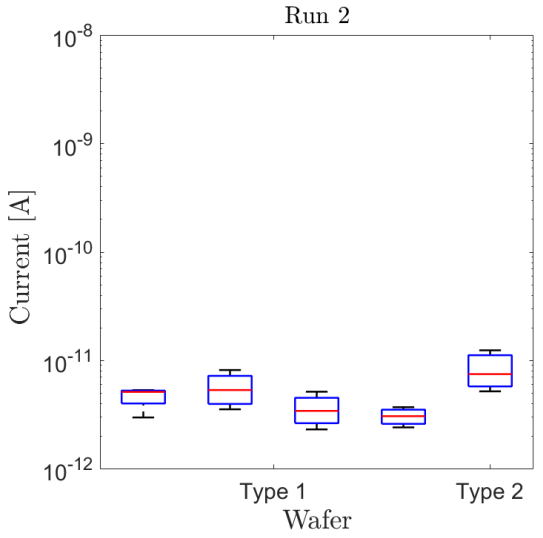




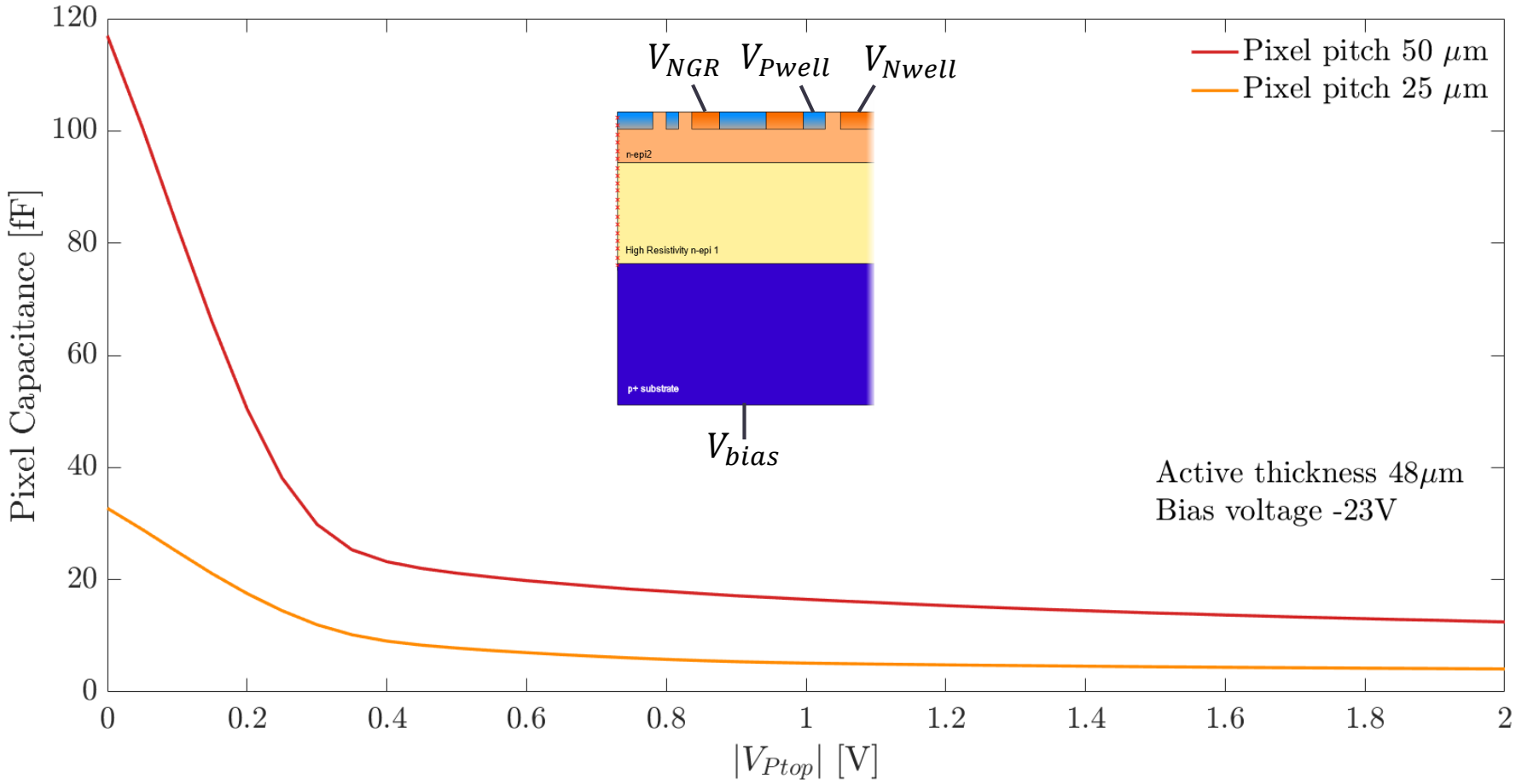
- Bias from the bottom
- Increase in the pixel dark current for samples coming from wafers with thicker substrates
- Passive pixel arrays $1.5 \times 1.5\ mm^2$

- Bias from the top
- Good uniformity in the dark current values measured in samples coming from wafers of same type



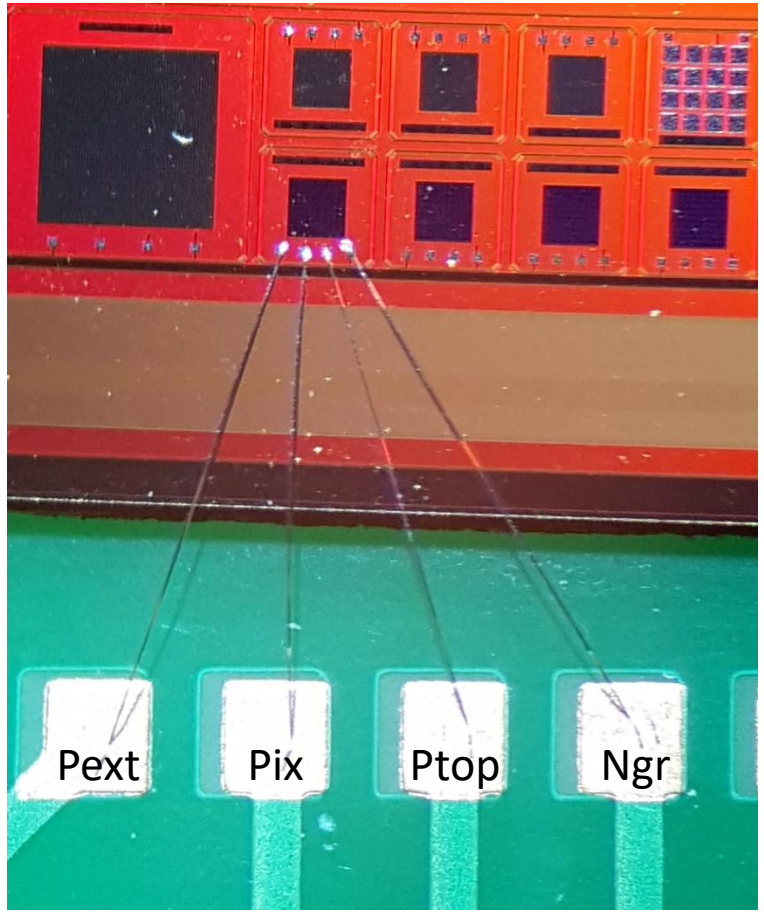


Electrical characterization – CV curves

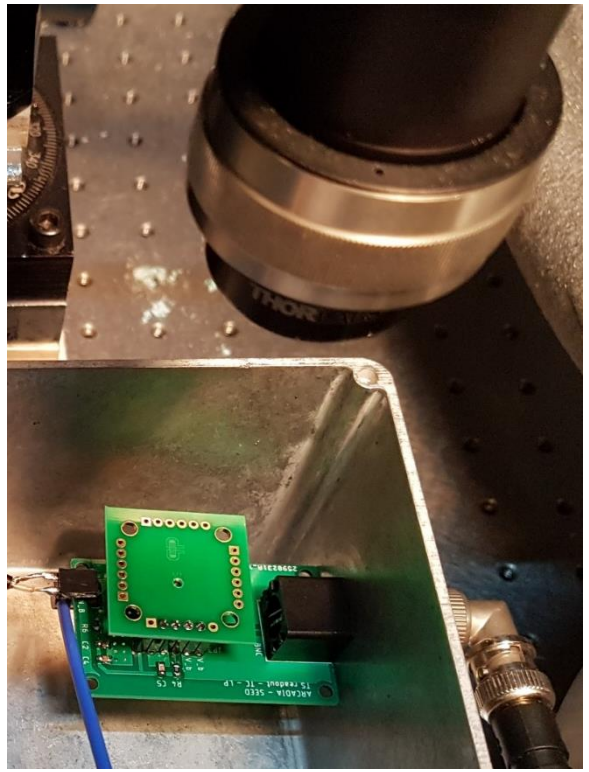


- Fixed bias voltage larger than V_{depl}
- Nwell and N-GR voltages set to 0V as ground reference
- Voltage sweep applied to the frontside pwell
- Once depleted the perimeter capacitance represents the main contribution to the pixel capacitance
- More details in the next talk of Coralie Neubüser

Biasing scheme & Laser setup

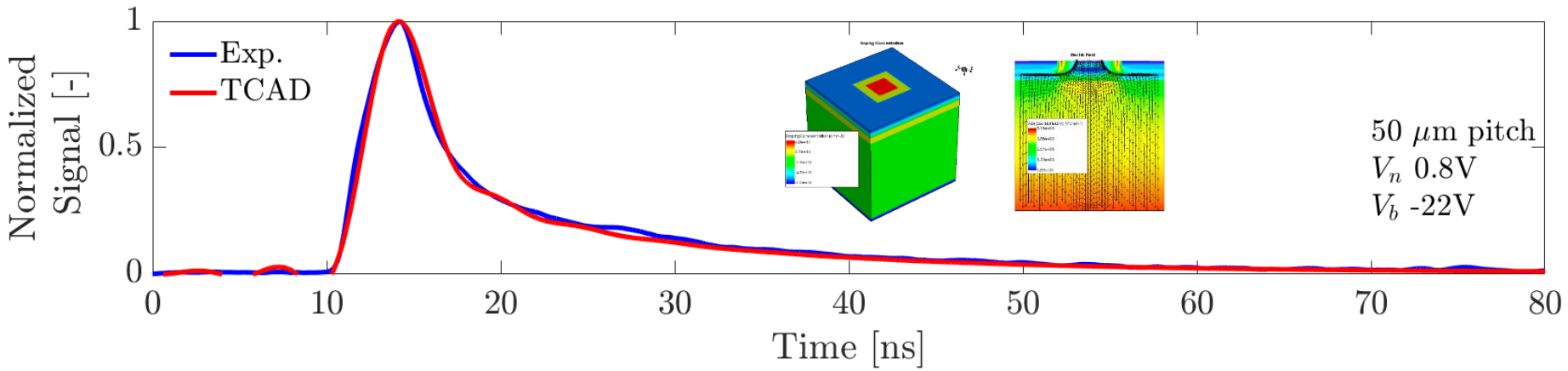


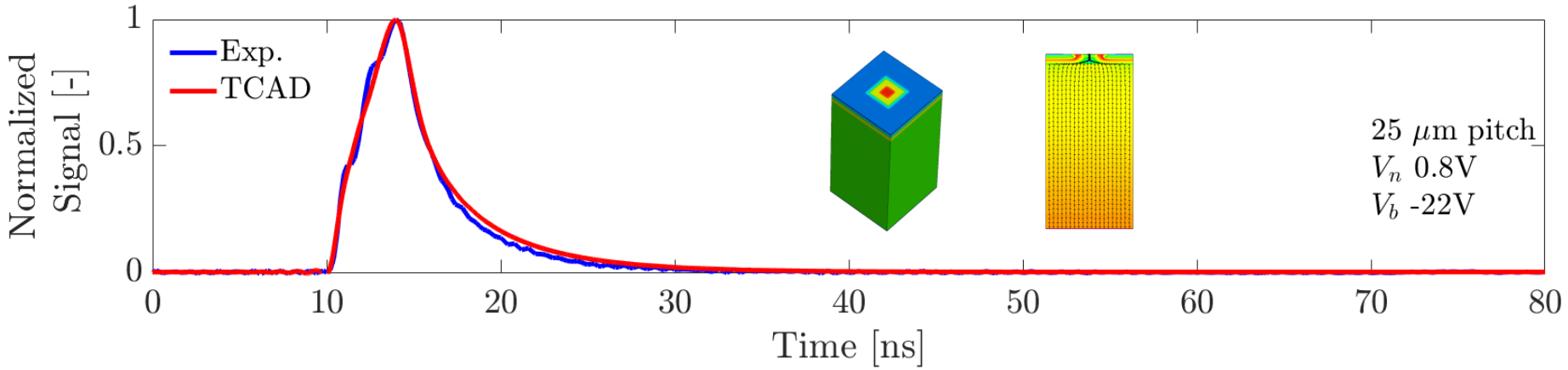
- Negative voltage bias applied to Pext electrode
- $V_{pix} = V_n = 0.8V$
- $V_{Ngr} = V_n$
- $V_{Ptop} = 0V$



- Red laser (660nm) with 350ps pulse at FWHM
- Infrared laser (1060nm) with < 100ps pulse at FWHM (Alphalas)
- External commercial amplifier with 1GHz bandwidth

IR laser - PM 50 & PM 25

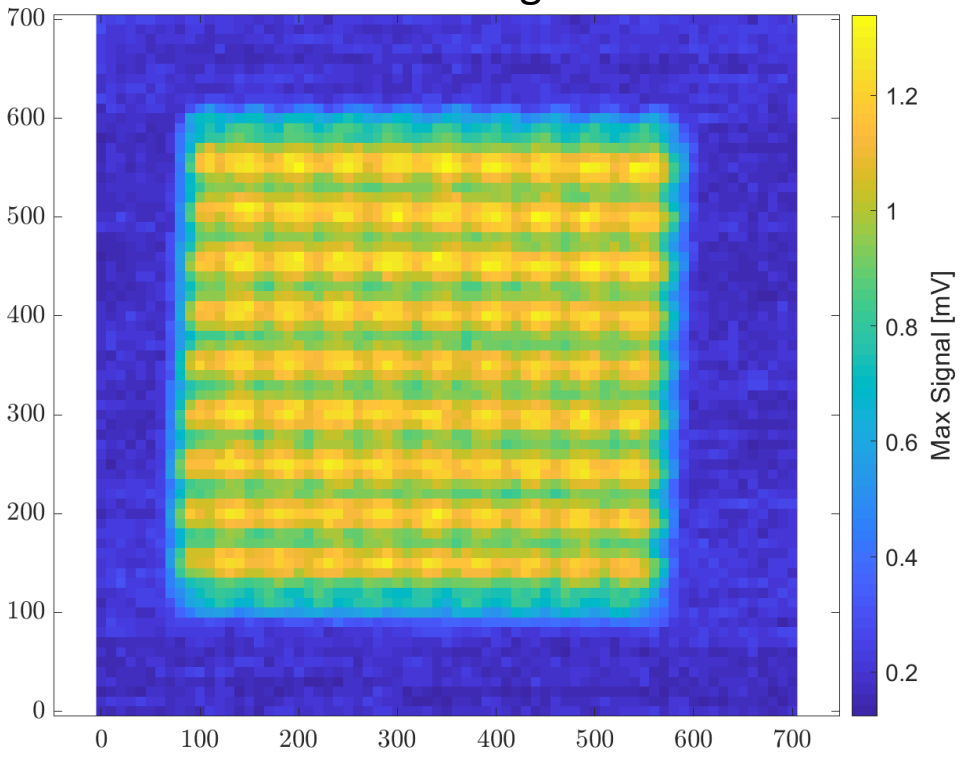




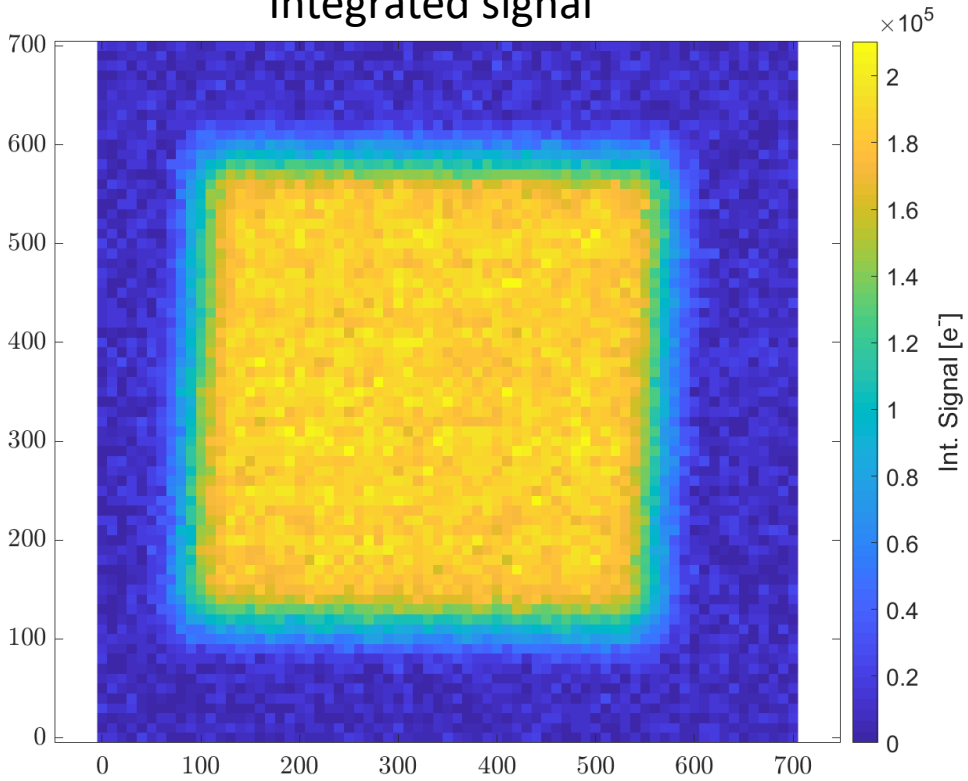
- t_{si} 100 µm
- V_{bias} applied from the top
- Backside illumination with an unfocused IR laser spot
- Faster signal obtained with smaller pixel pitch

Red laser scan - PM 50

Maximum signal



Integrated signal



- $V_n = 0.8V$
- $V_{bias} = -22V$
- Focused laser spot
- Uniform charge collection within the matrix area

10 µm motor step

Conclusions

- IV curves show that the sensors work properly with $V_{PT} > V_{depl}$
- Low V_{PT} and V_{depl} variability for wafers of same type in both production runs
- Sensors can be biased independently from the top or from the bottom
- Uniform charge collection within the pixel matrices
- Samples from 1st engineering run (mid 2021), 2nd engineering run (beginning of 2022), 3rd engineering run submission (mid 2022)

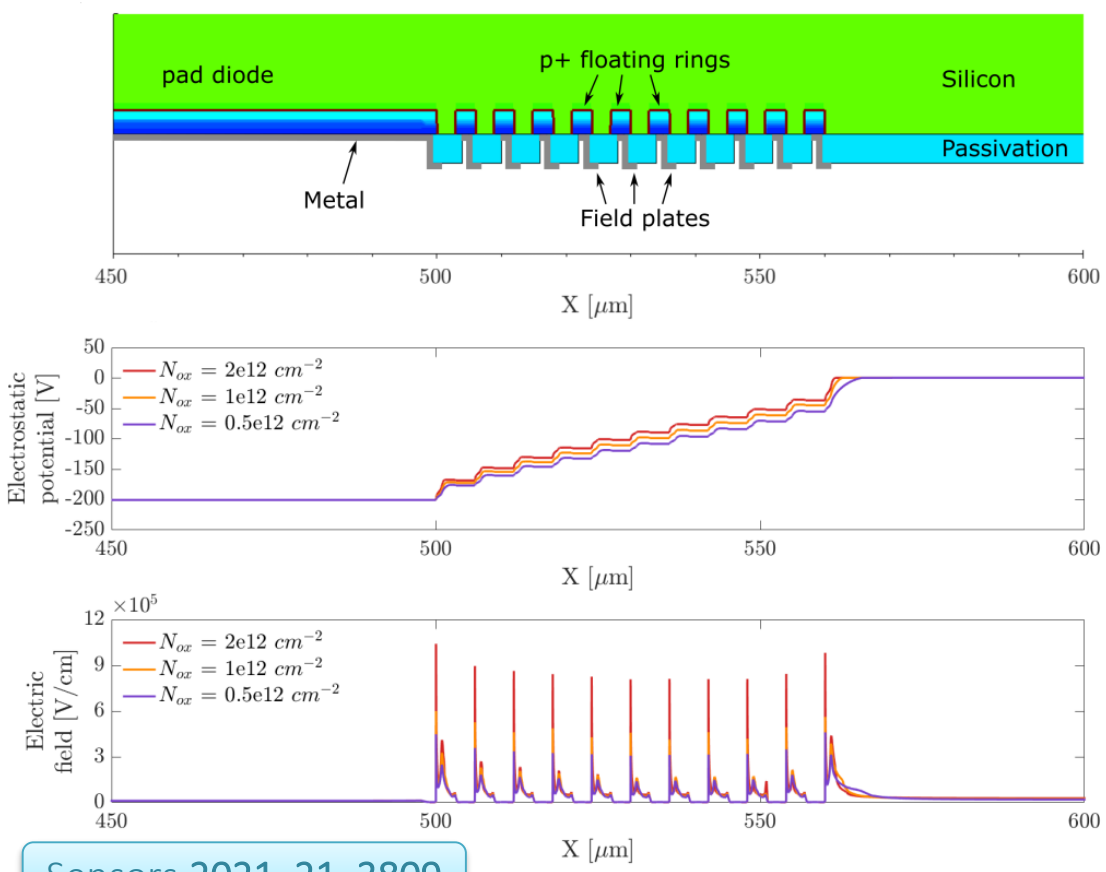
The ARCADIA collaboration

F. Alfonsi, G. Ambrosi, A. Andreazza, G. Andrini, E. Bianco, G. Balbi, M. Barbanera, S. Beolè, C. Bonini, J. Cai, M. Caccia, A. Candelori, D. Chiappara, F. Cossio, S. Cometti, T. Corradino, T. Croci, M. Da Rocha Rolo, G. F. Dalla Betta, A. De Angelis, G. Dellacasa, N. Demaria, L. De Cilladi, B. Di Ruzza, A. Di Salvo, S. Durando, D. Falchieri, C. Ferrero, A. Gabrielli, L. Gaioni, S. Garbolino, G. Gebbia, R. A. Giampaolo, N. Giangiacomi , P. Giubilato, R. Iuppa, M. Mandurrino, M. Manghisoni, M. Mignone, S. Mattiazzo, C. Neubüser, F. Nozzoli, L. Pancheri, D. Passeri, A. Paternò, M. Pezzoli, P. Placidi, L. Ratti, E. Ricci, S. B. Ricciarini, A. Rivetti, R. Santoro, L. Servoli, S. Tedesco, G. Torilla, G. Traversi, C. Vacchi, R. Wheadon, J. Wyss, P. Zuccon

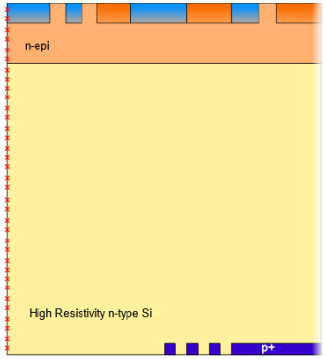
Thank you for your attention!

Backup

Electrical characterization – Breakdown



Sensors 2021, 21, 3809



- Backside diodes with variable guard ring number
- Good agreement between simulations and experimental results