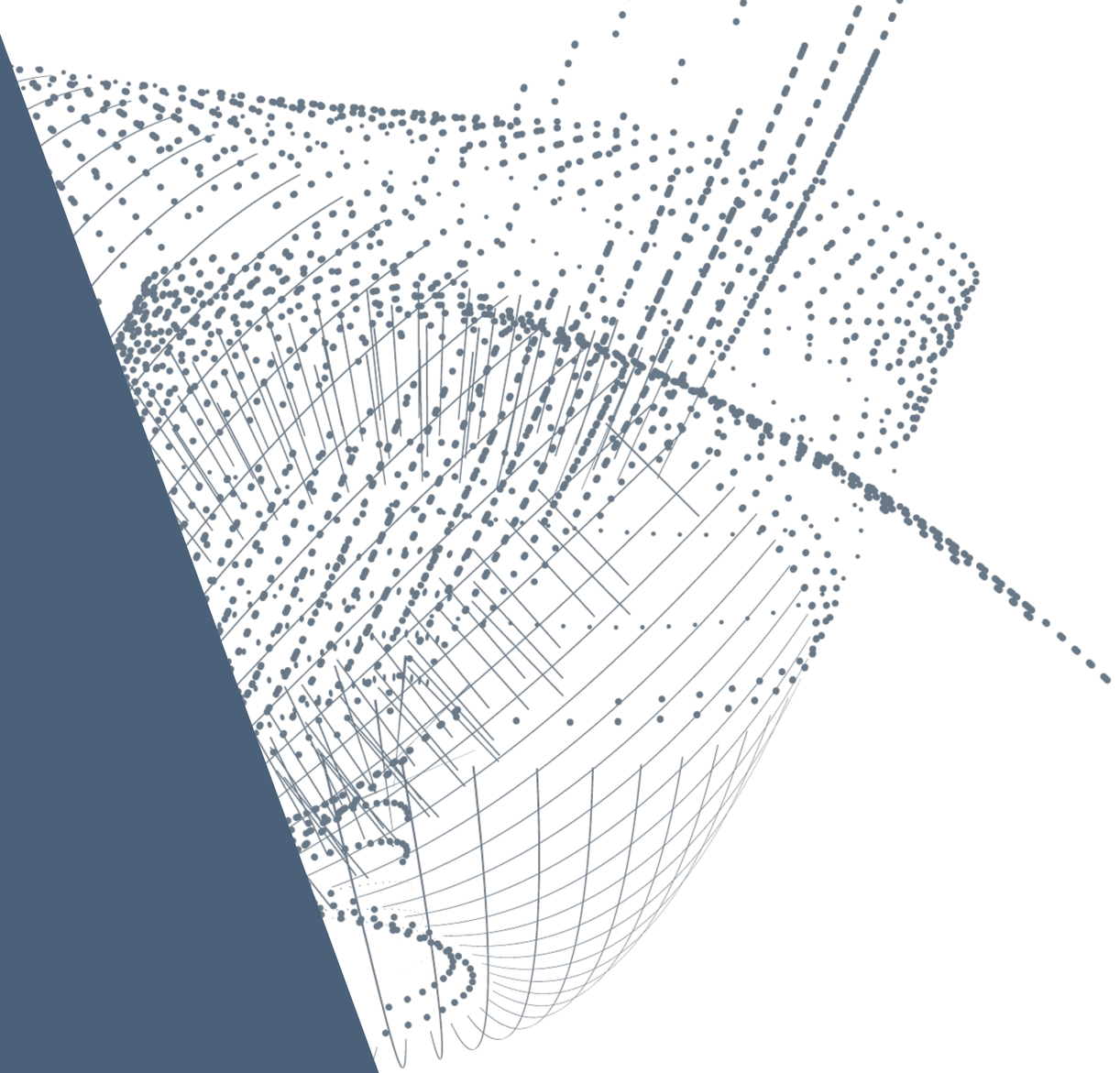
Nikhef



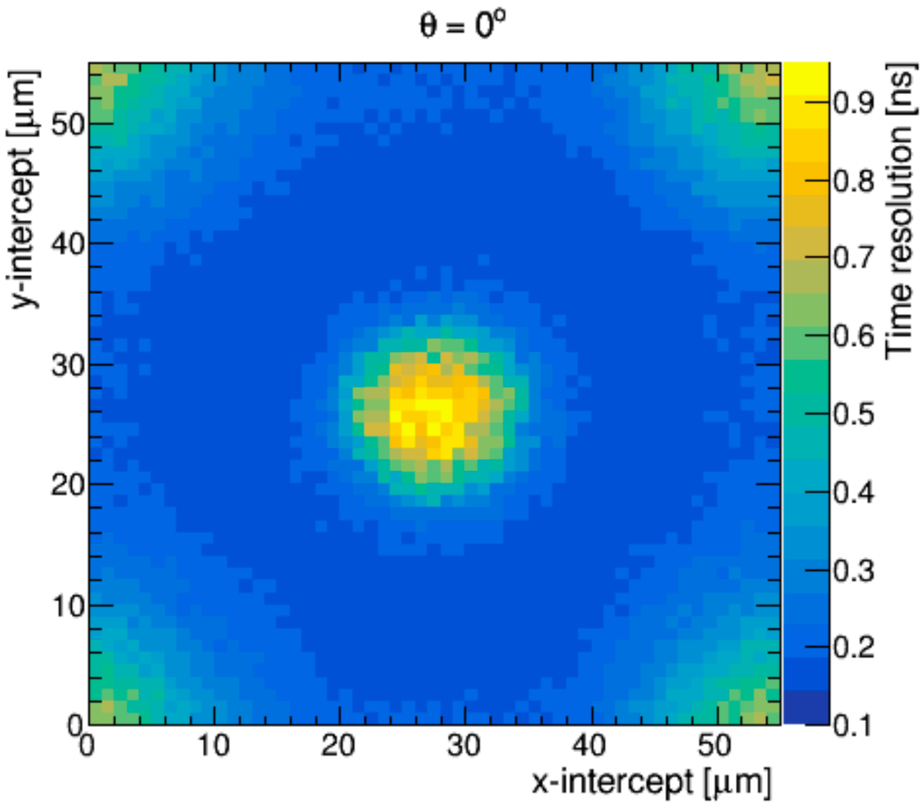
FASTER SUMMER MEETING — 24/10/2025

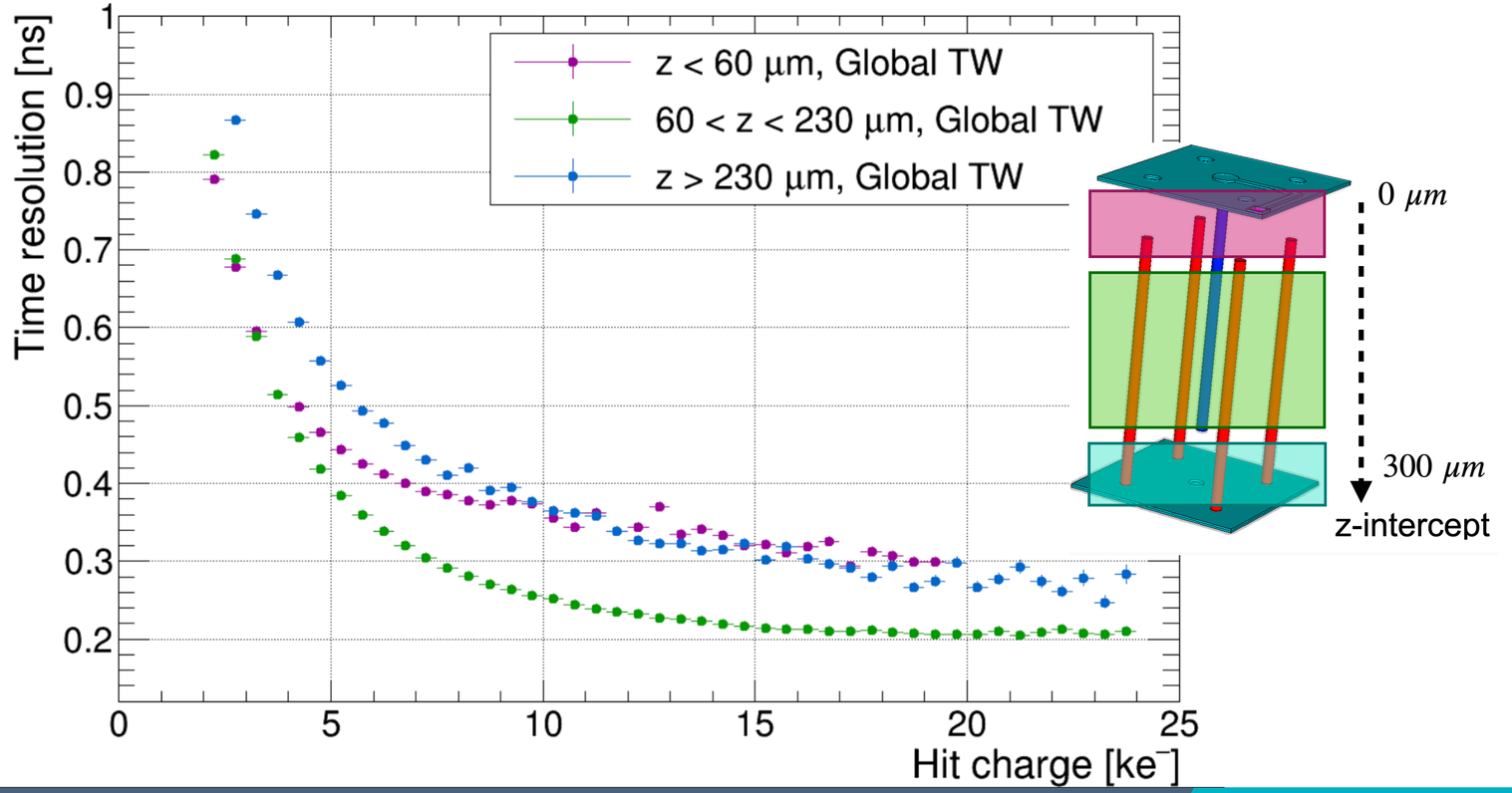
3D SILICON SENSORS

Evridiki Chatzianagnostou

Lessons learnt from beam test

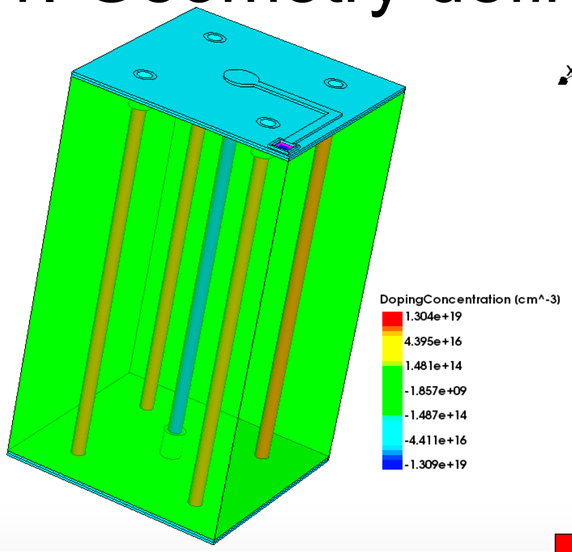
- DUT: 3D sensor on Tpx4 ASIC
- Worse time resolution in the area of the electrodes → Minimized electrode width
- Slow charge drift in depths where opposite type electrodes are absent → Full 3D



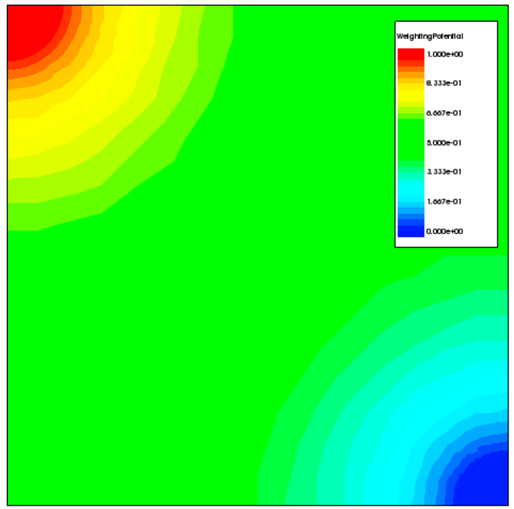


TCAD Simulations workflow

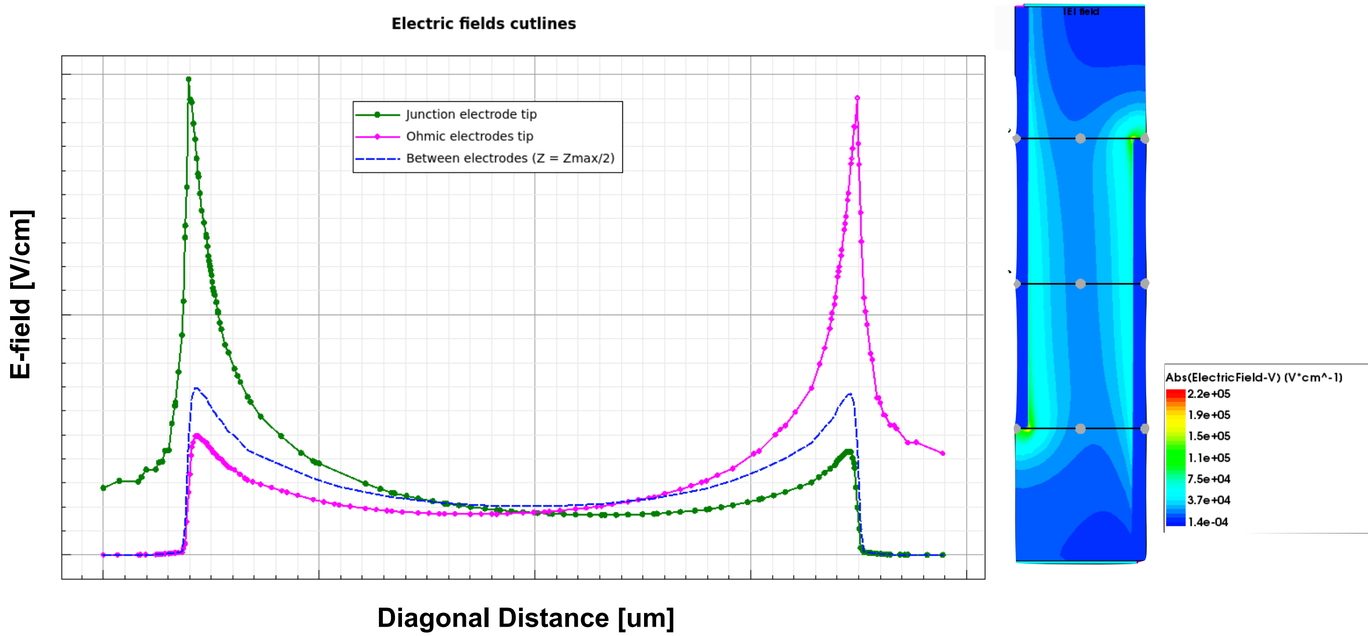
1. Geometry definition



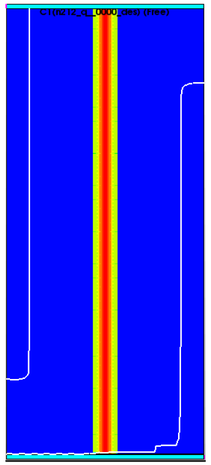
2. Reverse bias

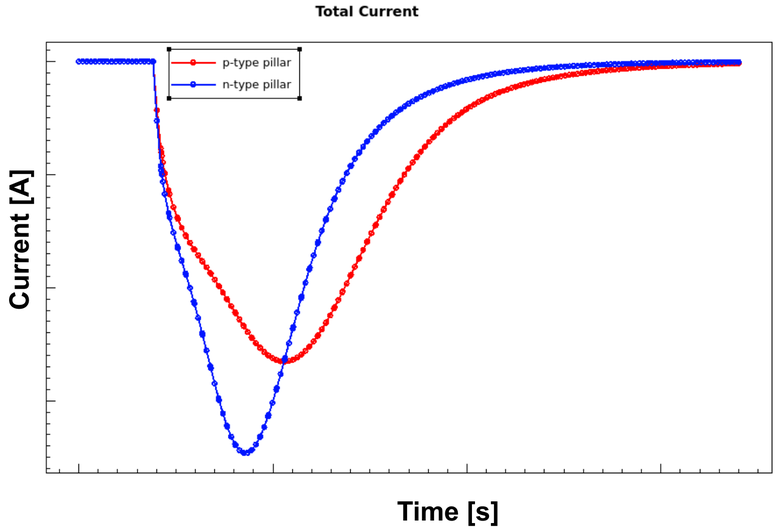


3. Electric fields

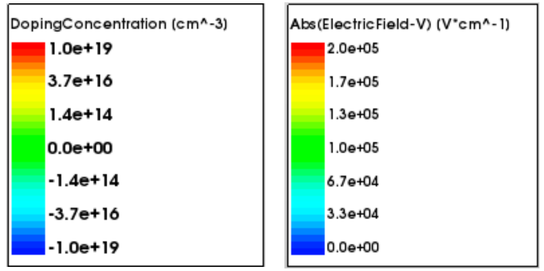


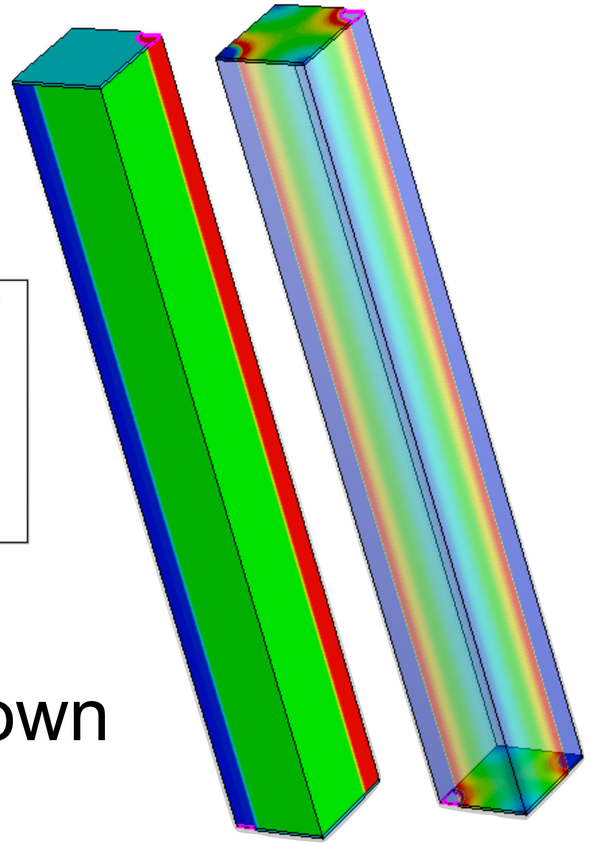
4. Transient Heavy Ion model

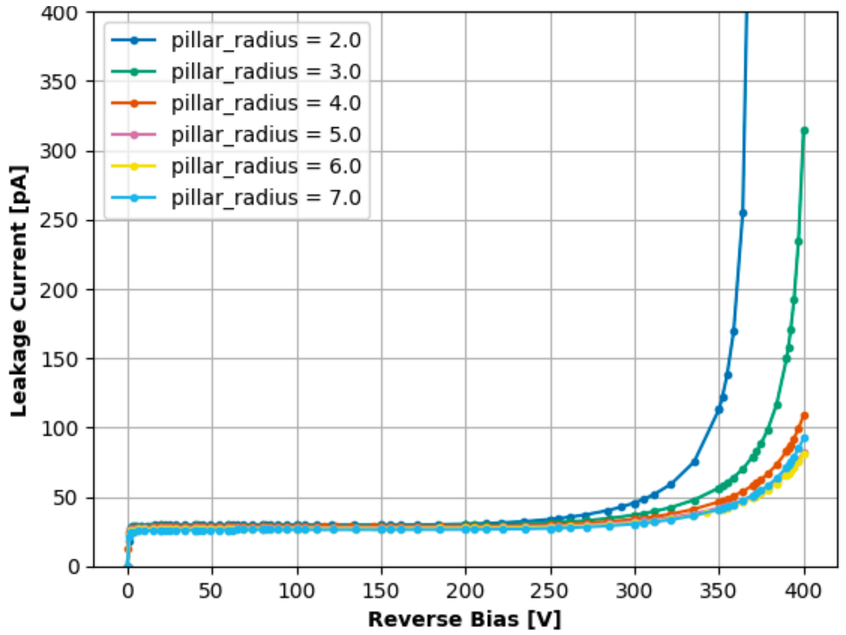




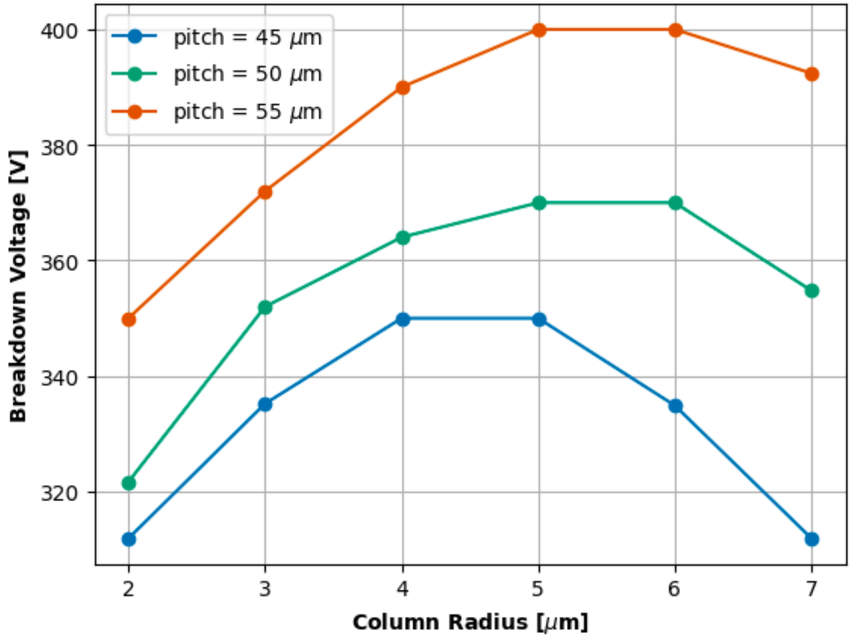
Fully penetrated pillars





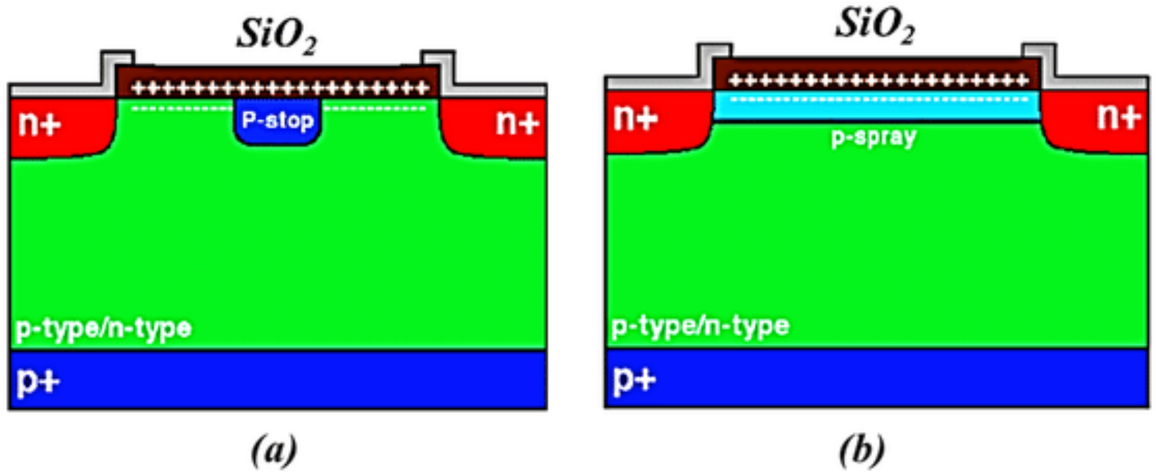


- Even for thin pillars break down occurs for $V_b \geq 300V$
- Able to sustain high voltages for all tested pitch sizes
- Not taking into account surface effects

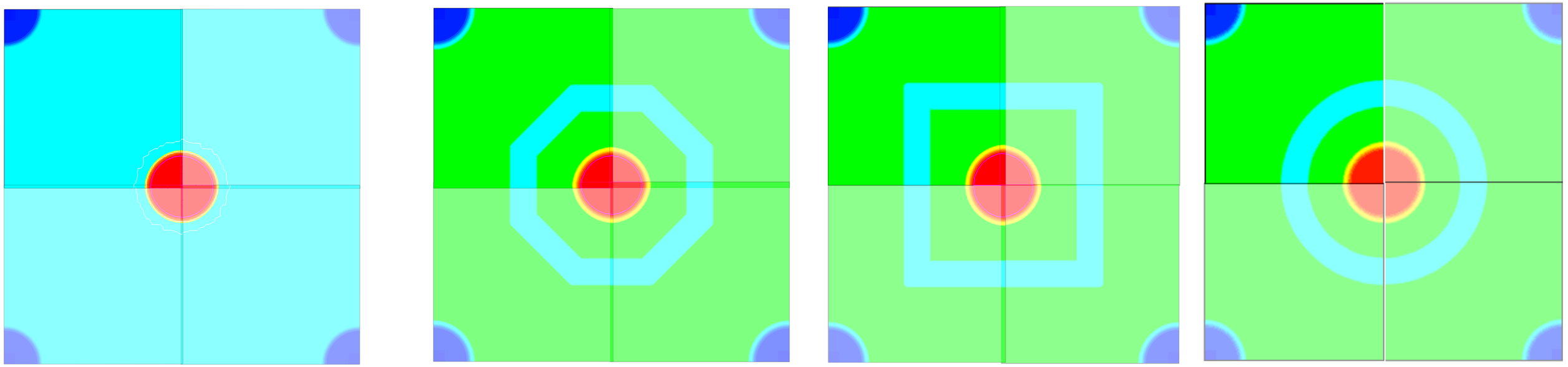


Si/SiO2 interface and p isolation layers

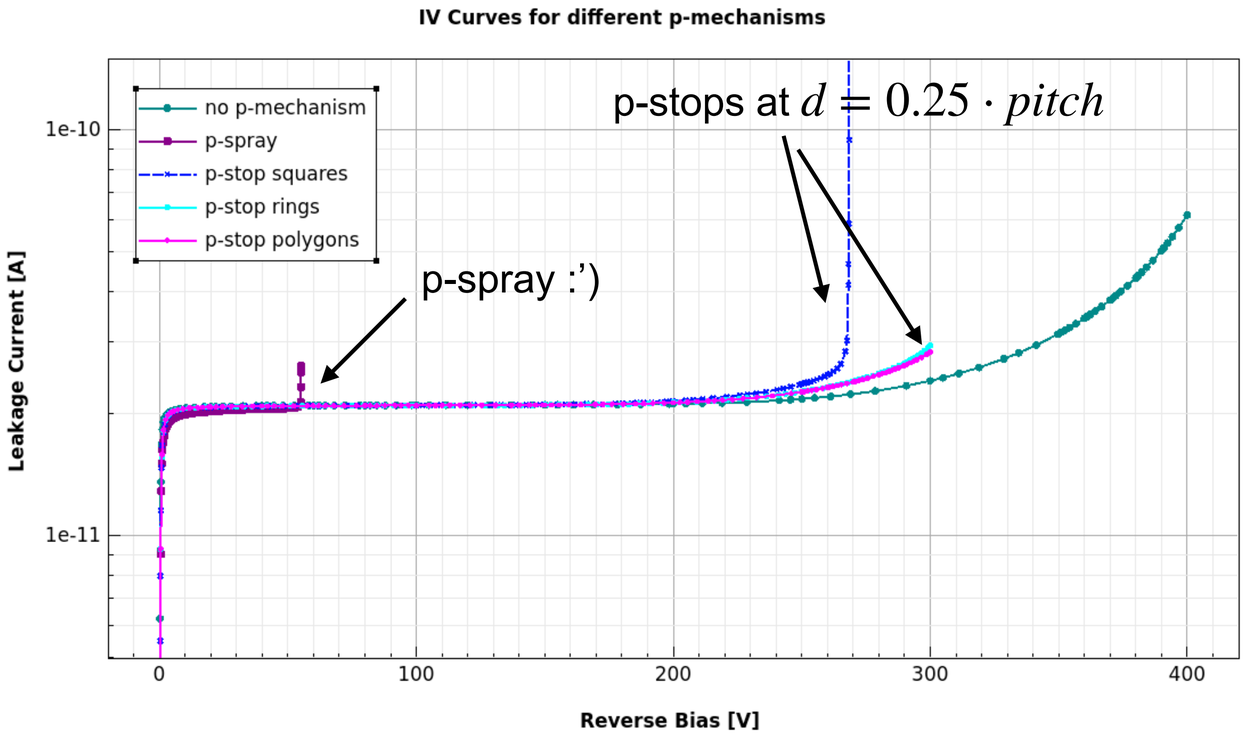
- Radiation damage: fixed positive charge in the SiO2 and interface traps
- Accumulation of electrons: form a conductive layer between implants



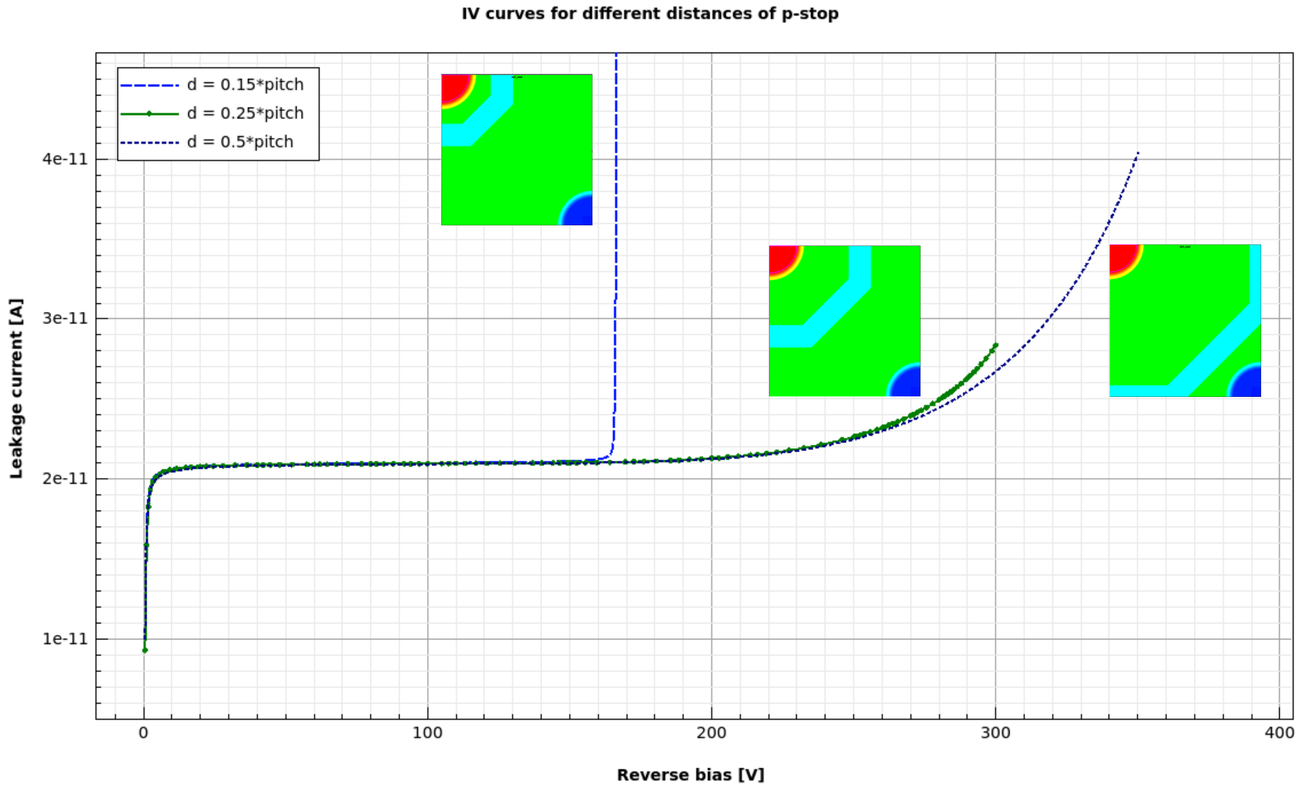
- p-spray is a uniform p+ layer
- p-stop are floating p+ implants



- Different p-mech. geometries



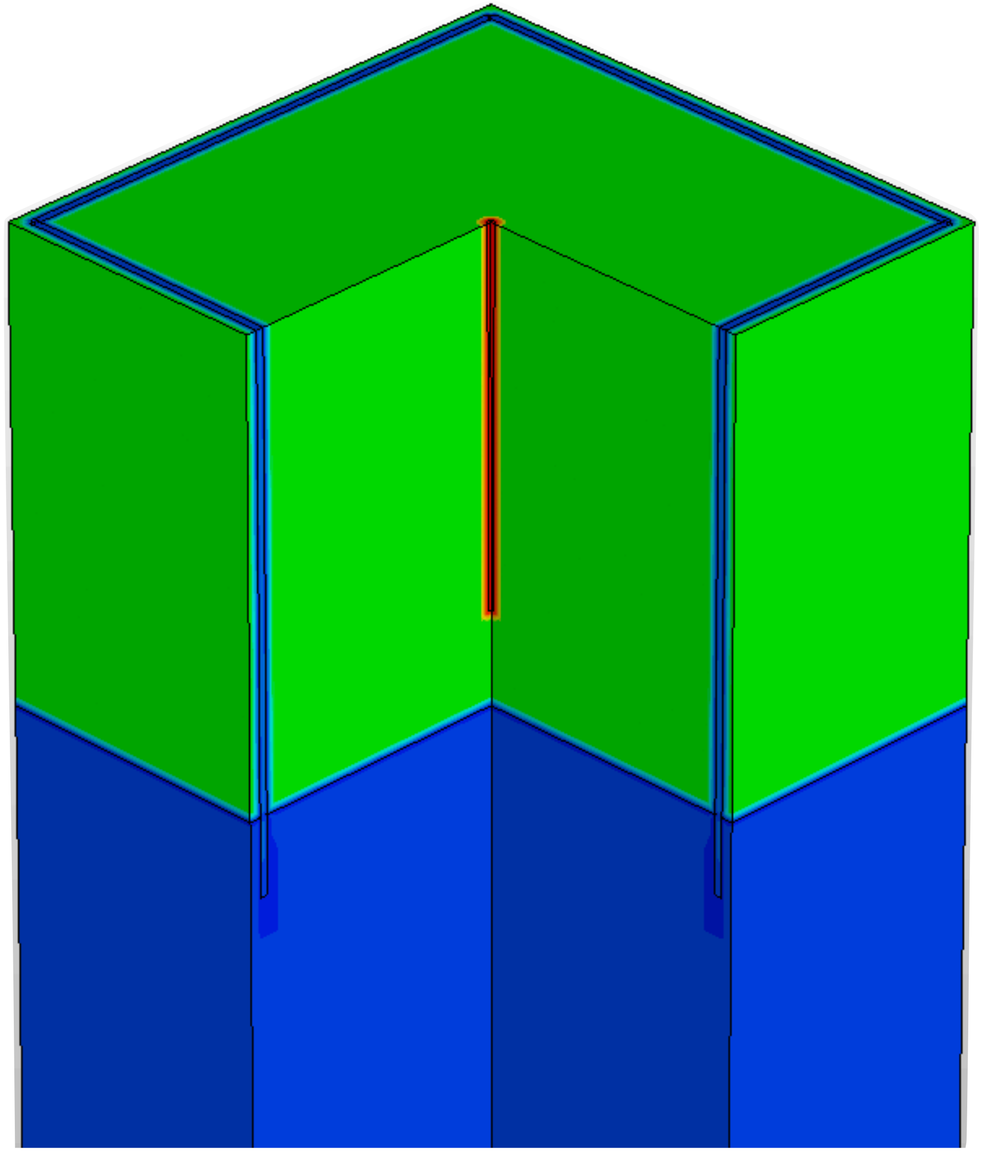
$$pitch = 55\ \mu m$$
$$radius = 6\ \mu m$$
$$gap = 0\ \mu m$$
$$p - stop/spray = 2e16cm^{-3}$$



- Distance of p-stop from n++ implant
- Effect of misalignment

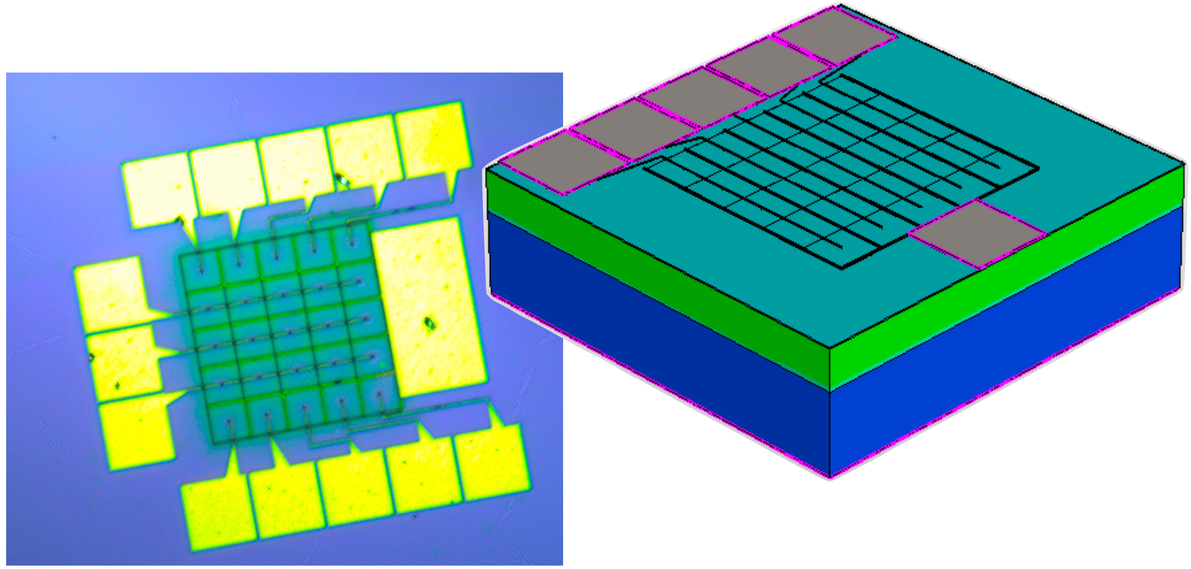
Test & Characterization of new 3D-Trench test structures

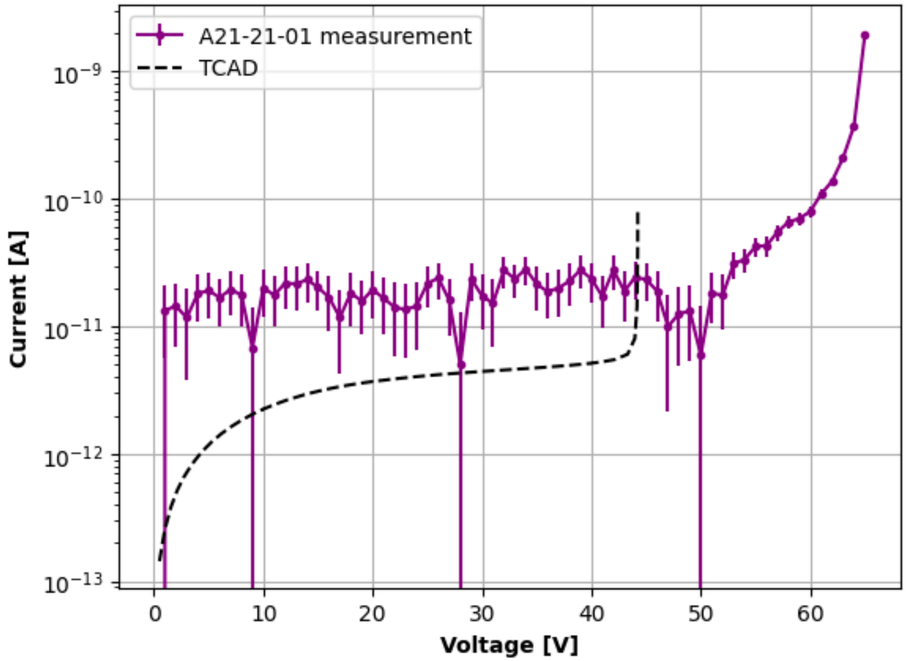
- Single sided 3D-Trench test structures produced at IMECAS in 2025
- 30 μm epitaxial layer grown on top of p++ substrate
- Ultra thin etching holes / trenches, aspect ratio $\sim 1:70$
- Varying pitch size 10 - 35 μm and electrode width 0.5 - 2 μm
- Trenches can also work as p+ surface isolation layers

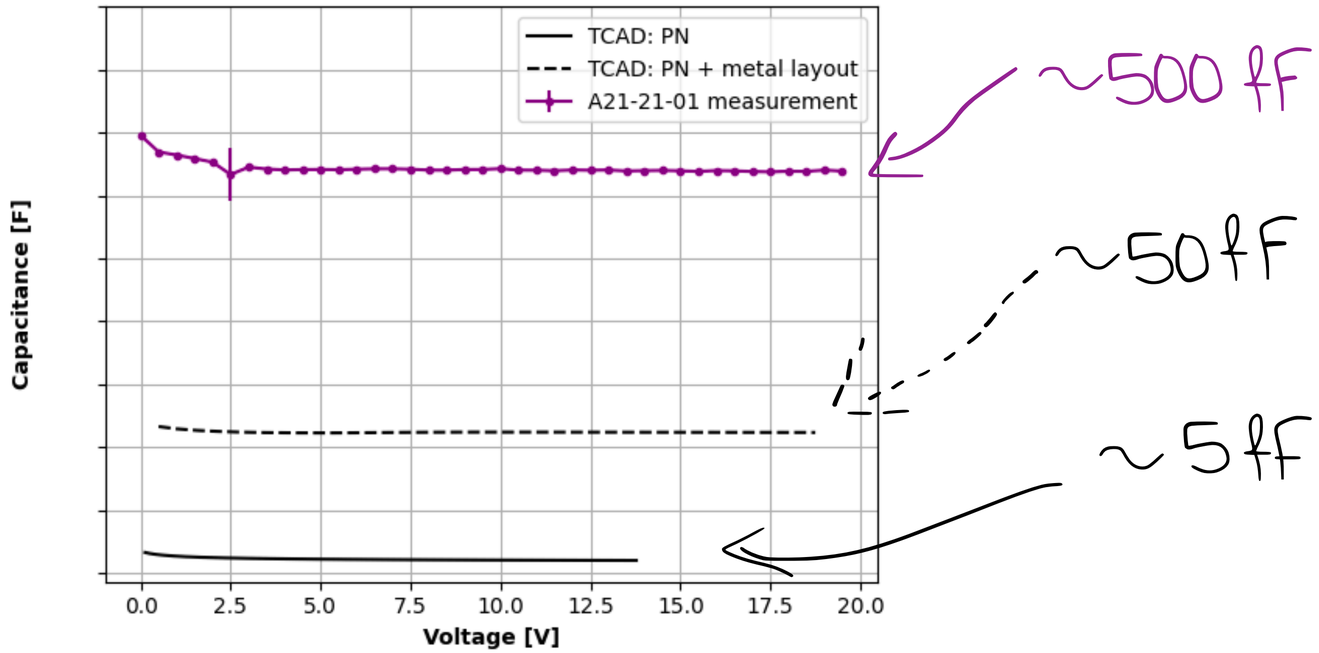


IV, CV measurements Vs Simulations

- TCAD predicts earlier breakdown voltage than reality
- Metal layout and parasitic capacitances affect CV measurement

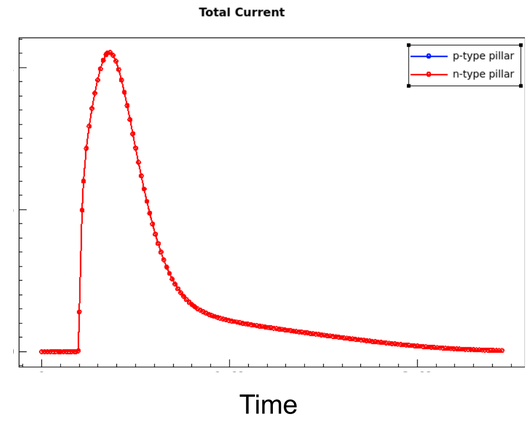


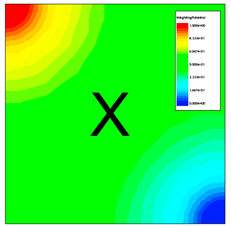


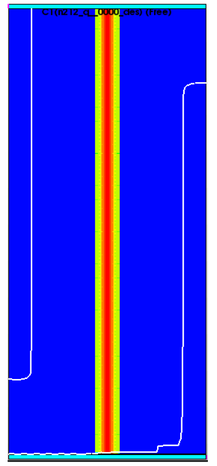


Gain estimation: MIP-like deposition

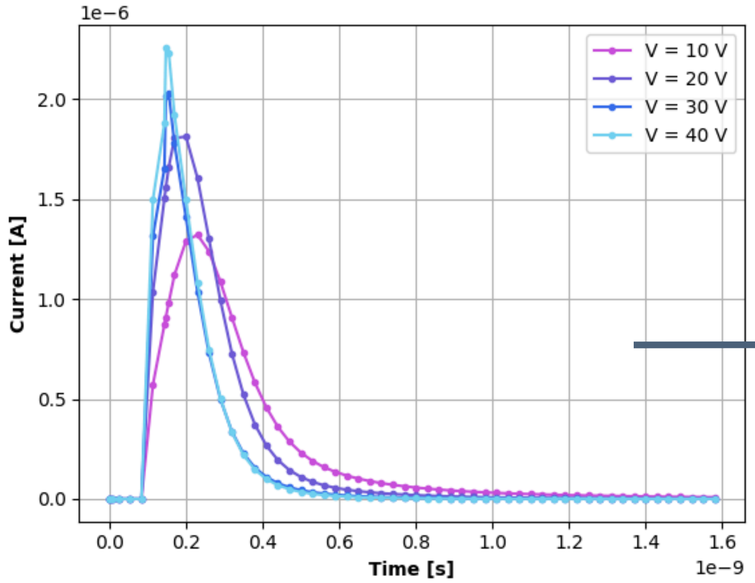
$$\text{Gain} = \frac{\text{Collected Charge}}{\text{Deposited Charge at } \text{x}} = \frac{\int \text{Current} \; dt}{q_{e-} \cdot \int dx^3}$$

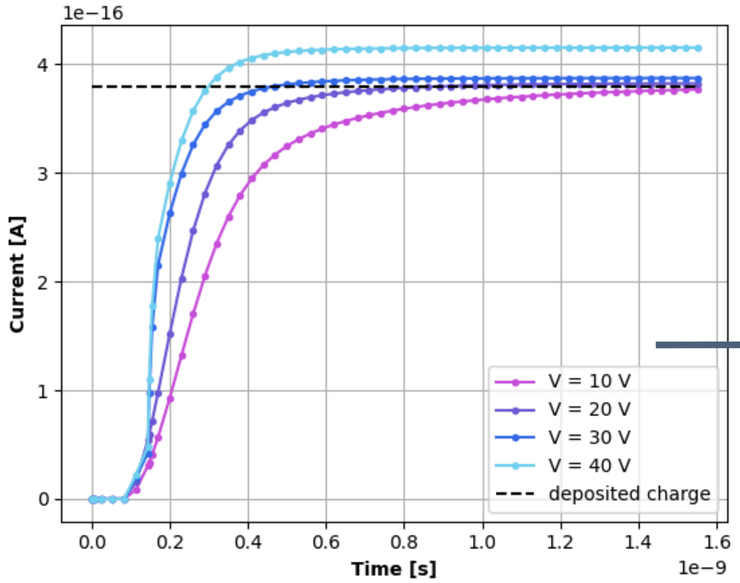


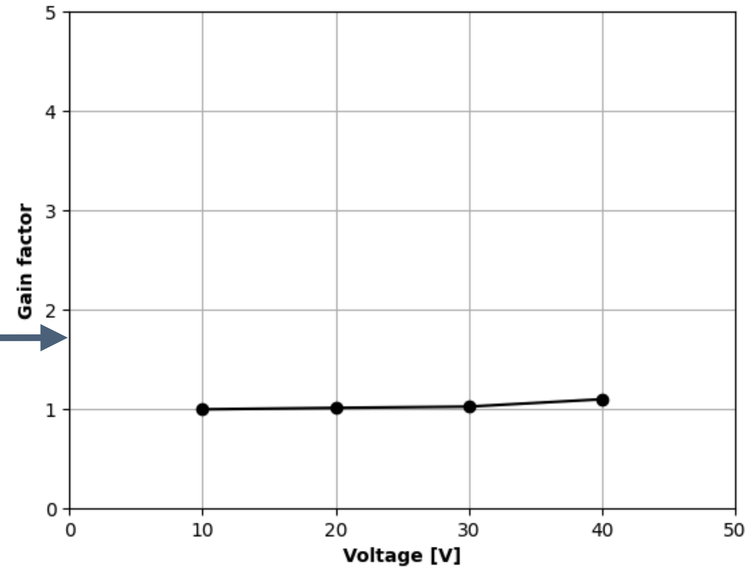




Gain estimation: MIP-like deposition



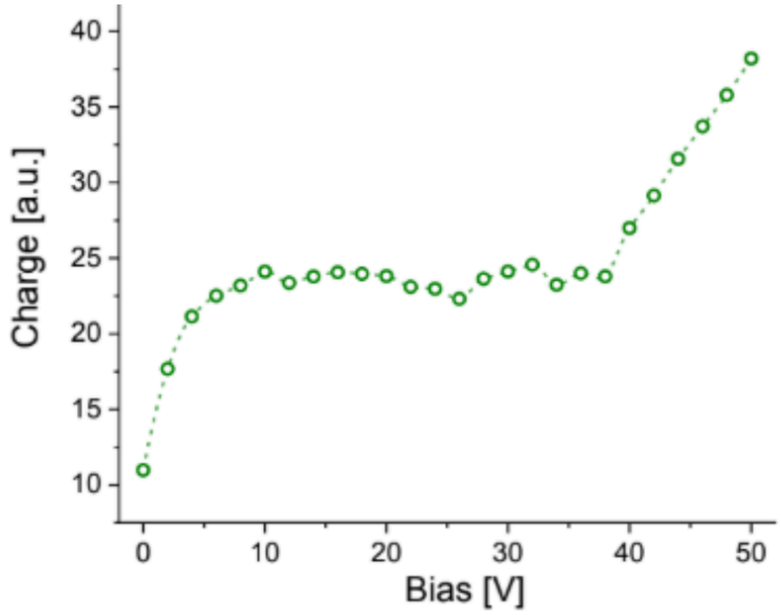




3D-Trench A21-21

$$pitch = 35\ \mu m$$
$$diameter = 0.5\ \mu m$$
$$gap = 5\ \mu m$$

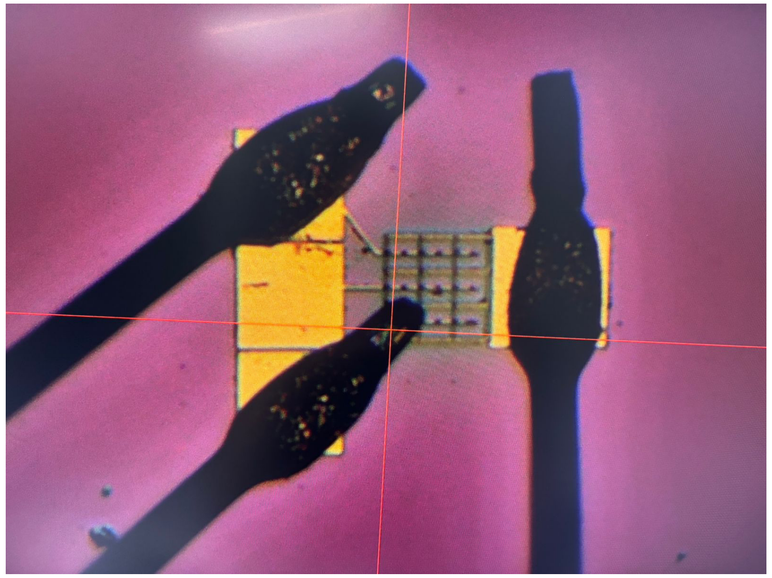
- Charge multiplication observed with laser data above 40V (internal communication)

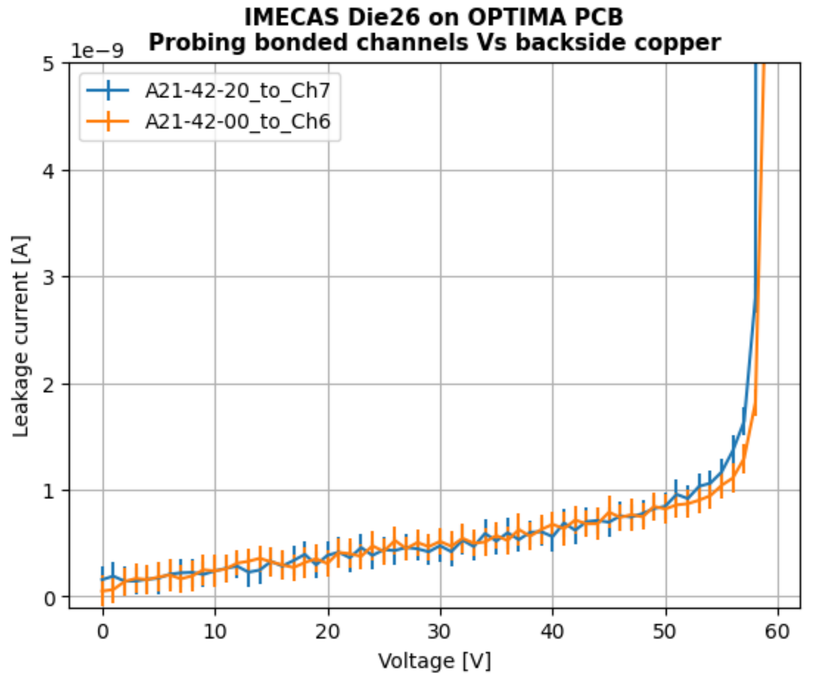


Near future tests

- Timing performance studies using LASER setups at Nikhef

- Maybe even take them to next beam test

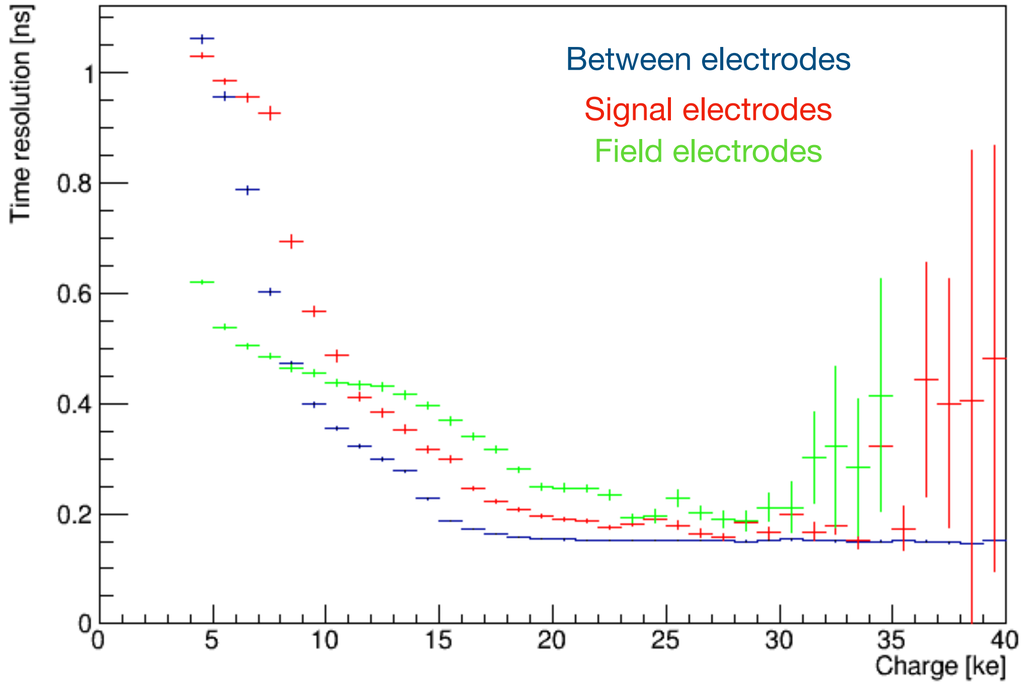


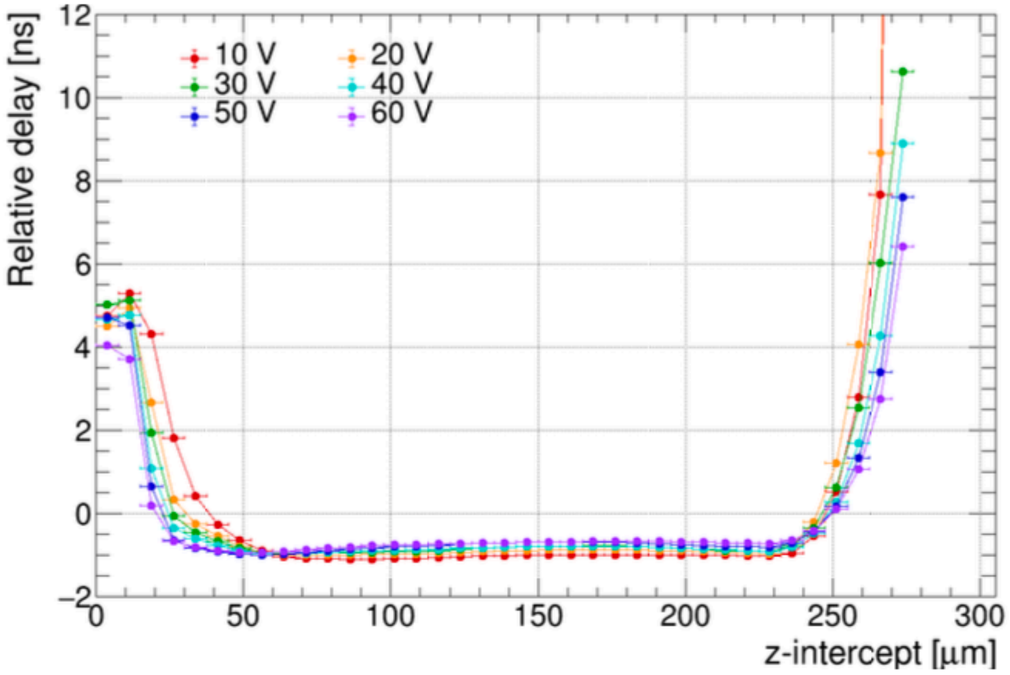


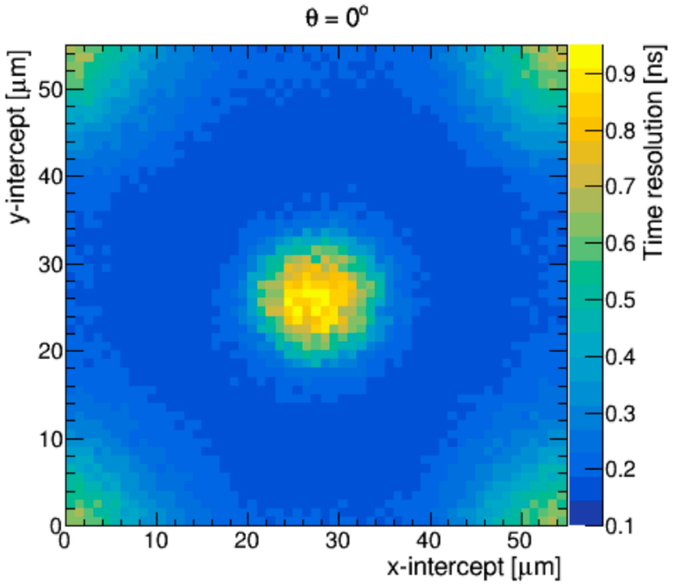
THANK YOU!!

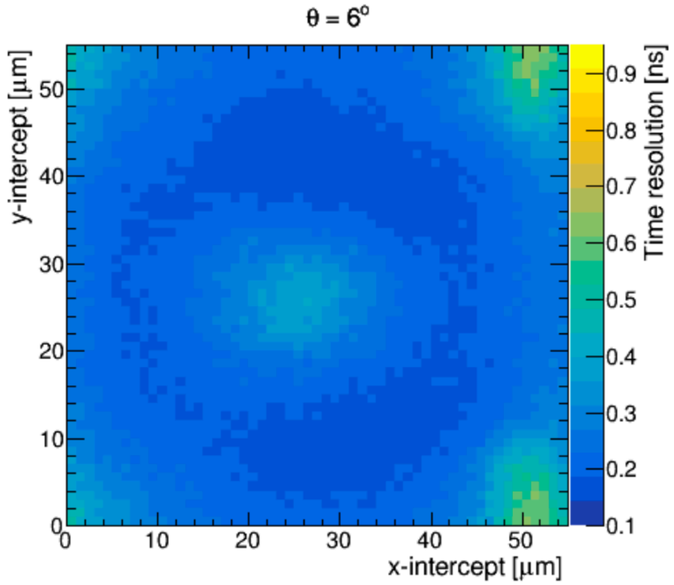
Backup

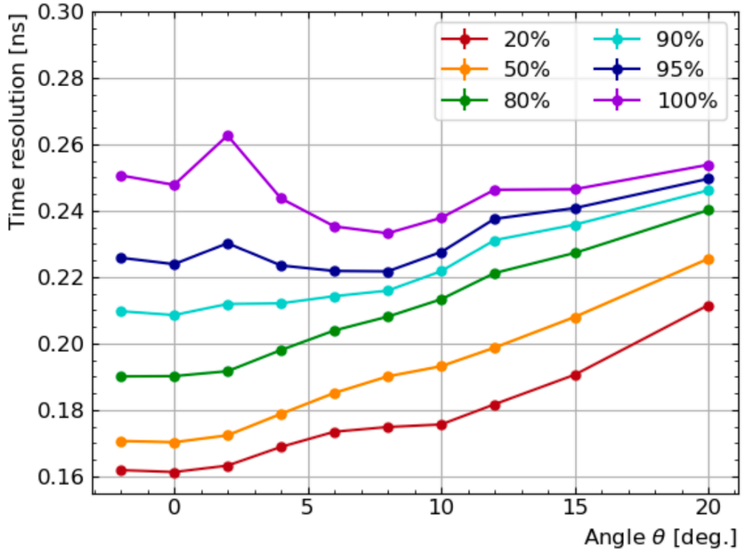
TEST BEAM





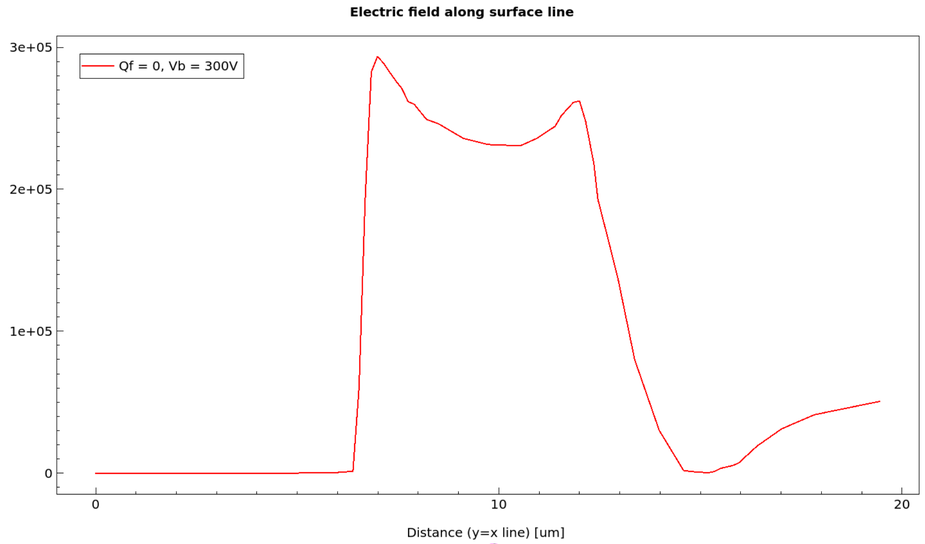




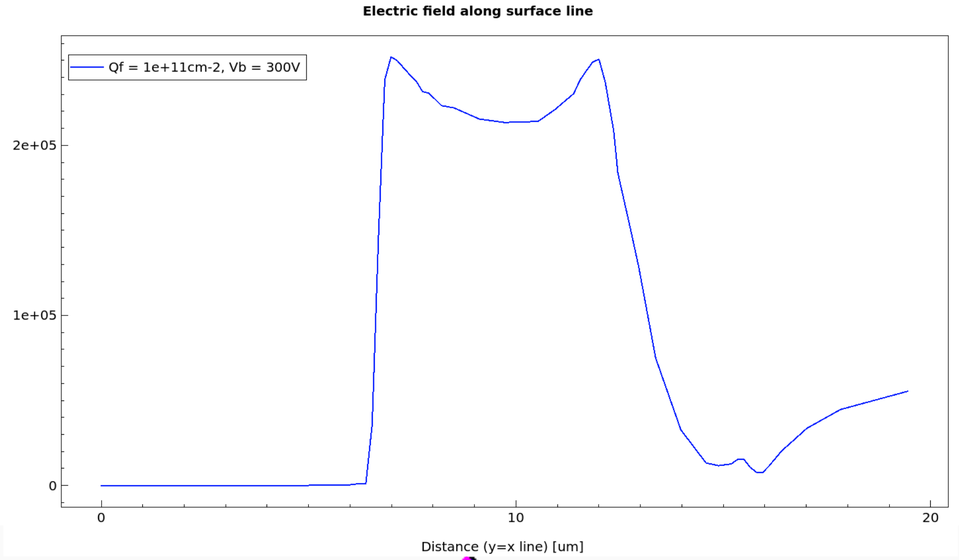


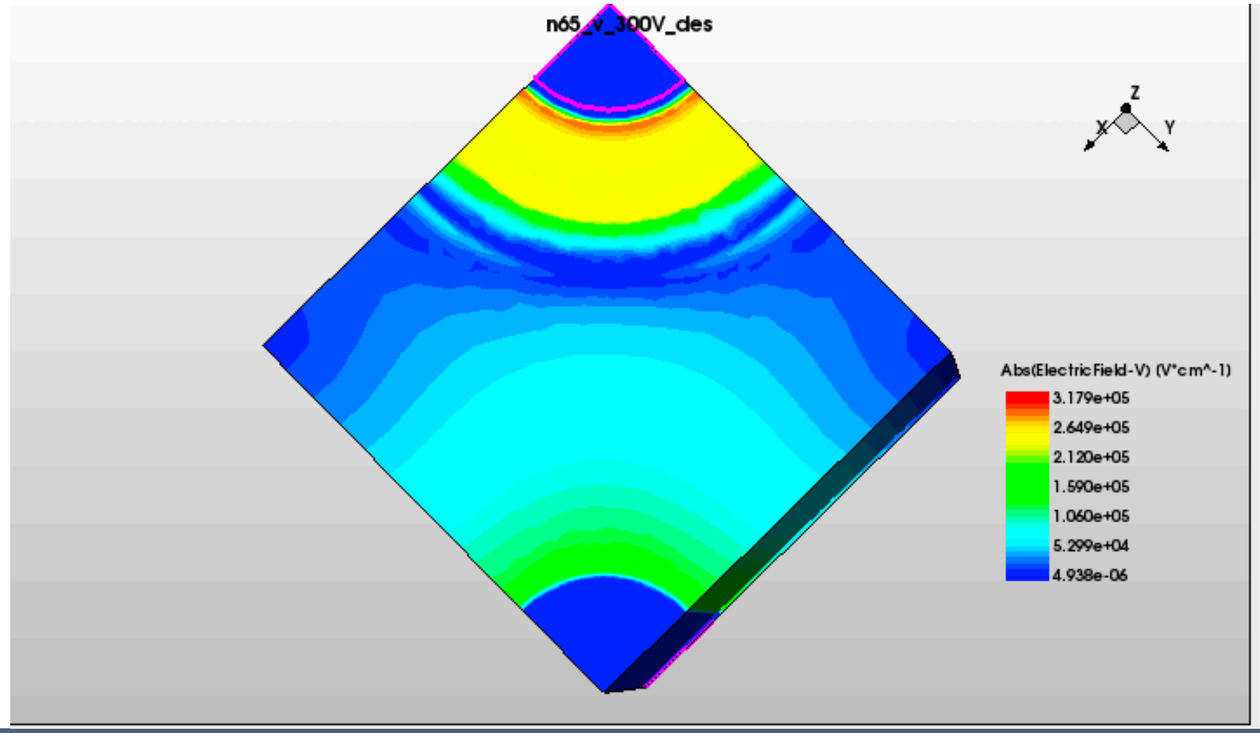
Nikhef

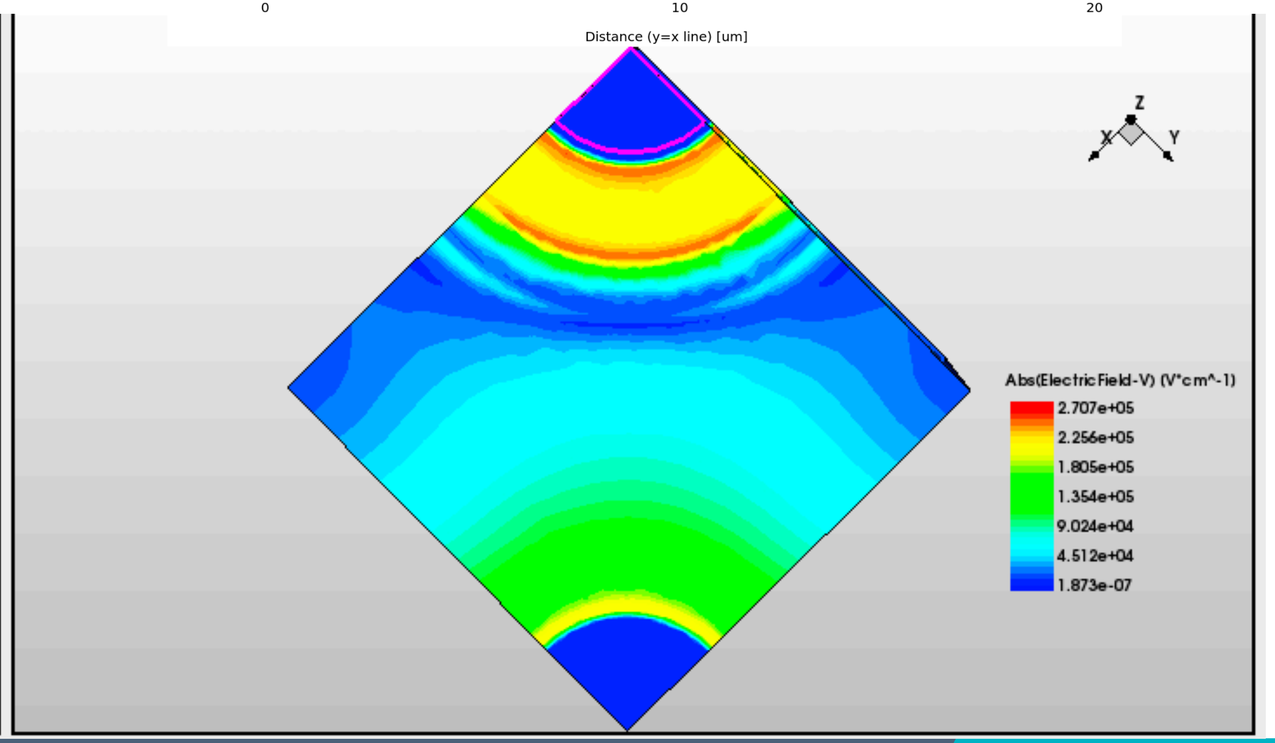
Qf = 0

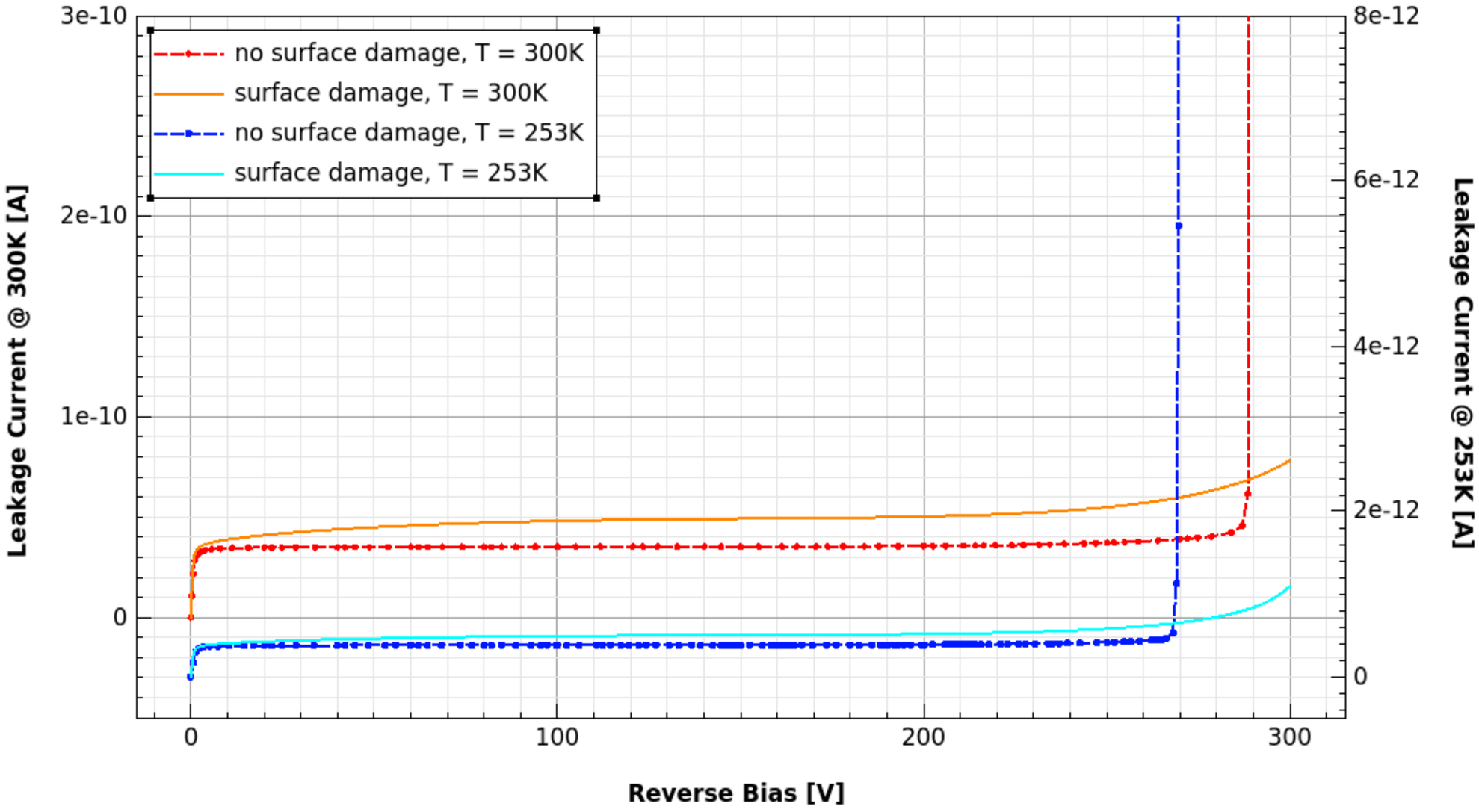


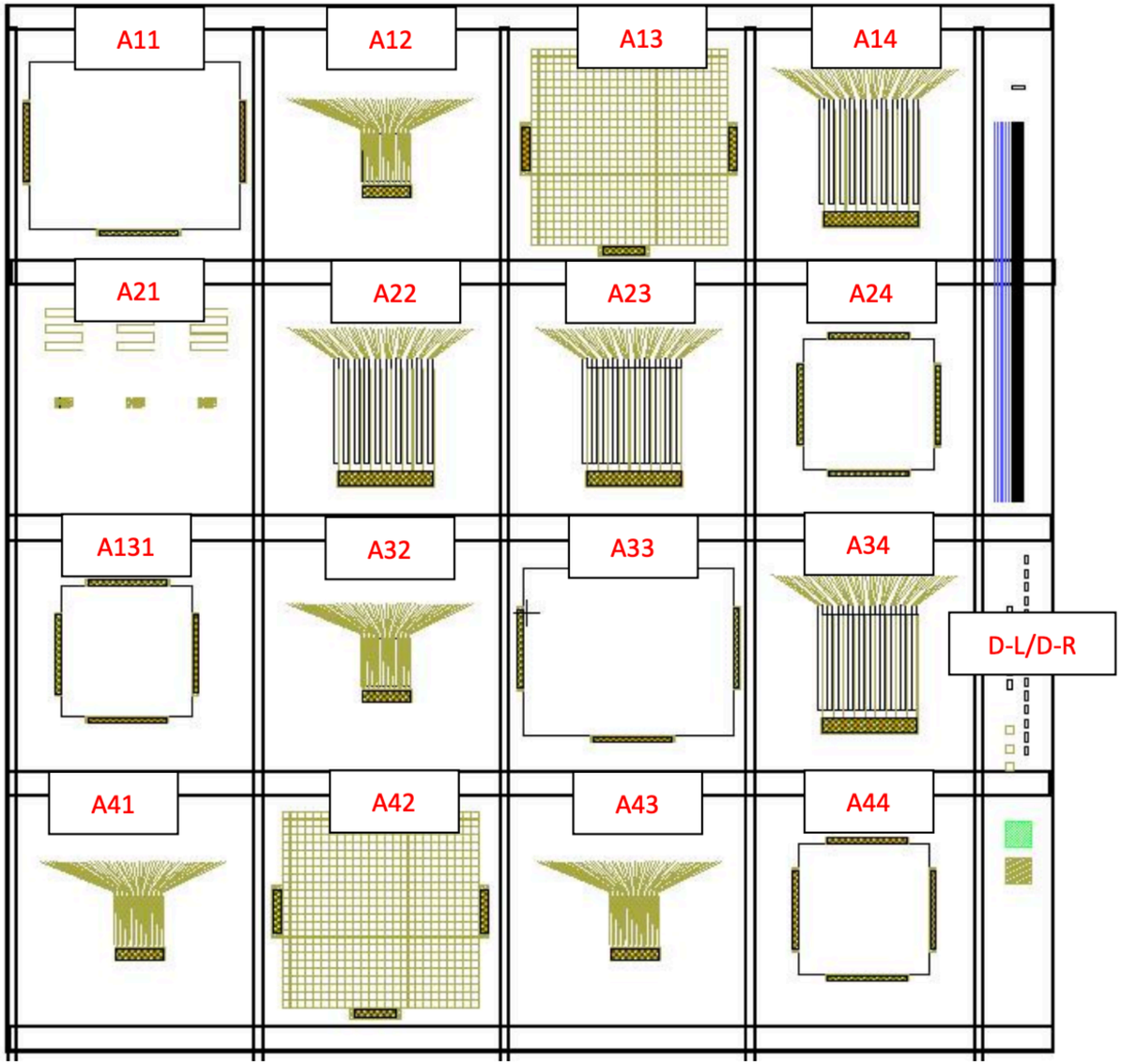
Qf = 1e+11 cm-2

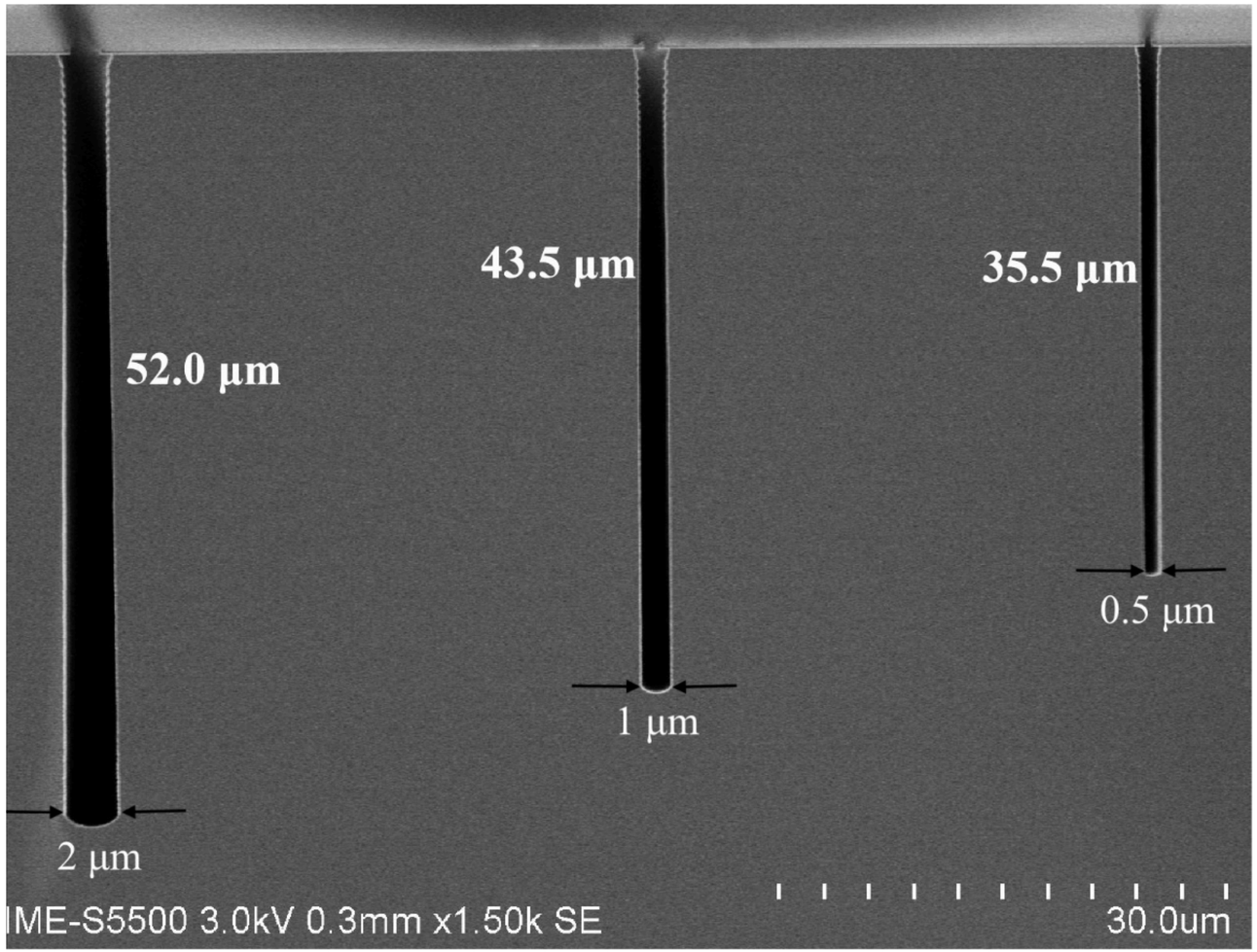


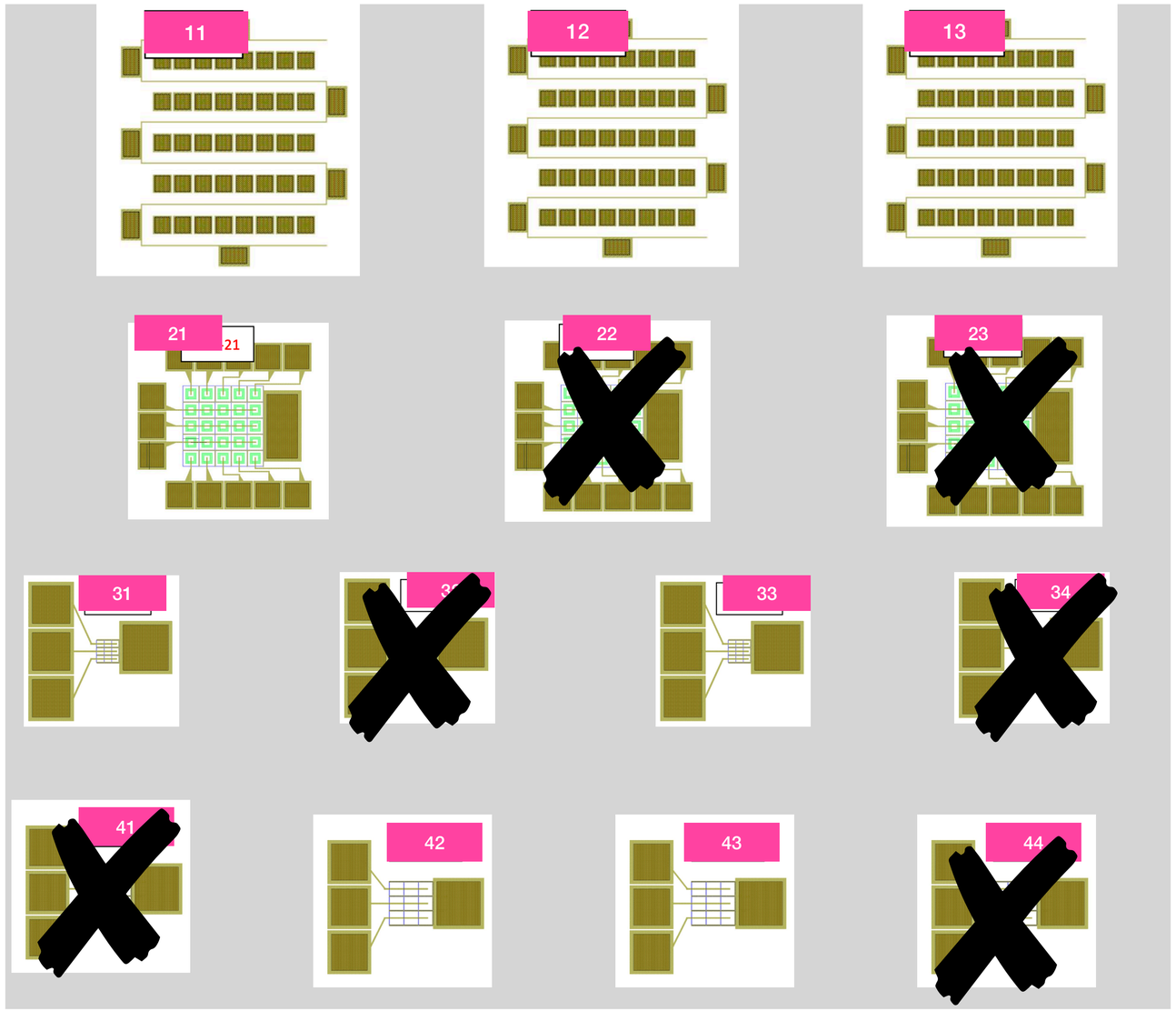


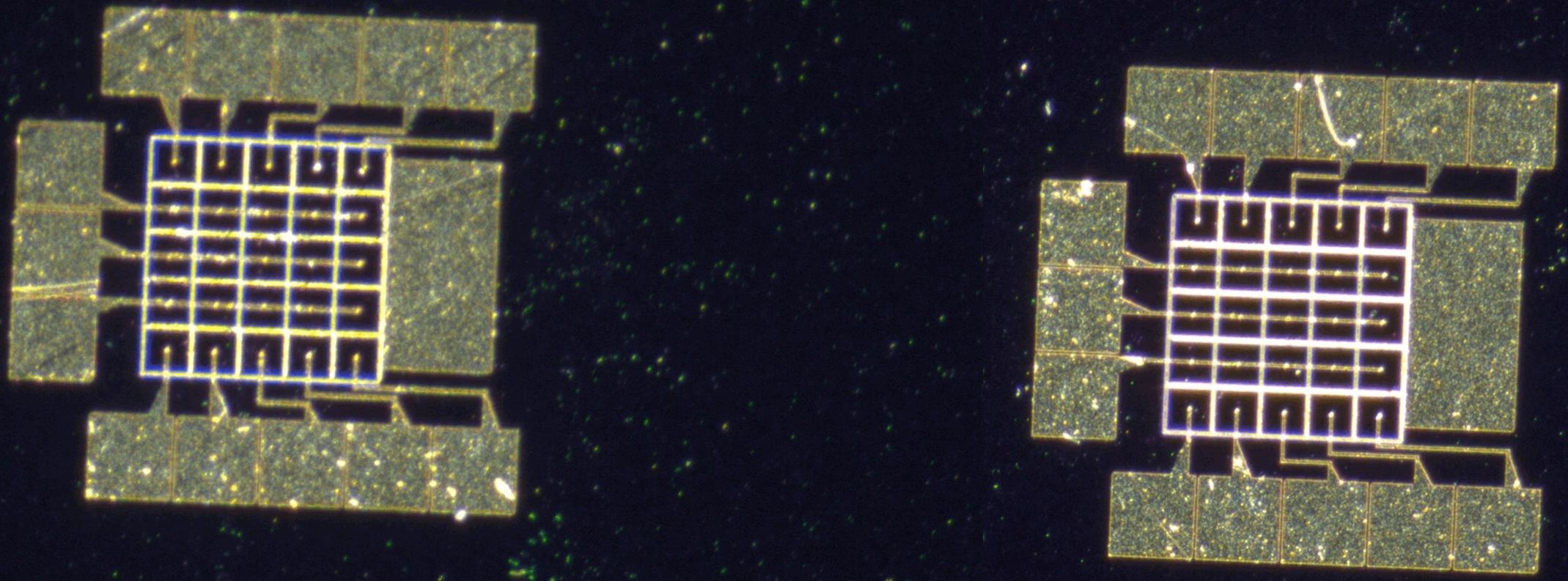


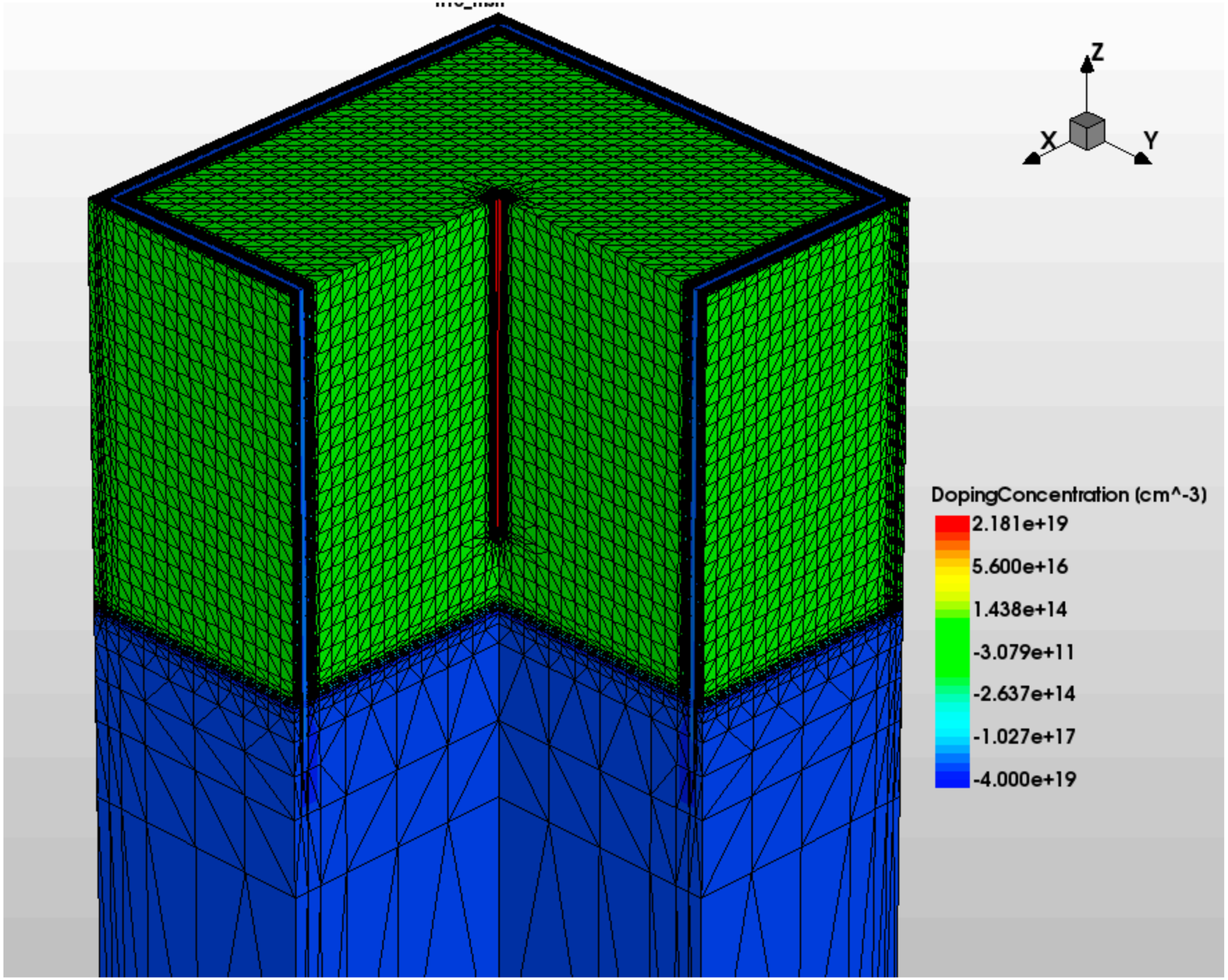

no surface damage, T = 300K
surface damage, T = 300K
no surface damage, T = 253K
surface damage, T = 253K
Leakage Current @ 300K [A]
Leakage Current @ 253K [A]
Reverse Bias [V]
3e-10
2e-10
1e-10
0
8e-12
6e-12
4e-12
2e-12
0
0
100
200
300

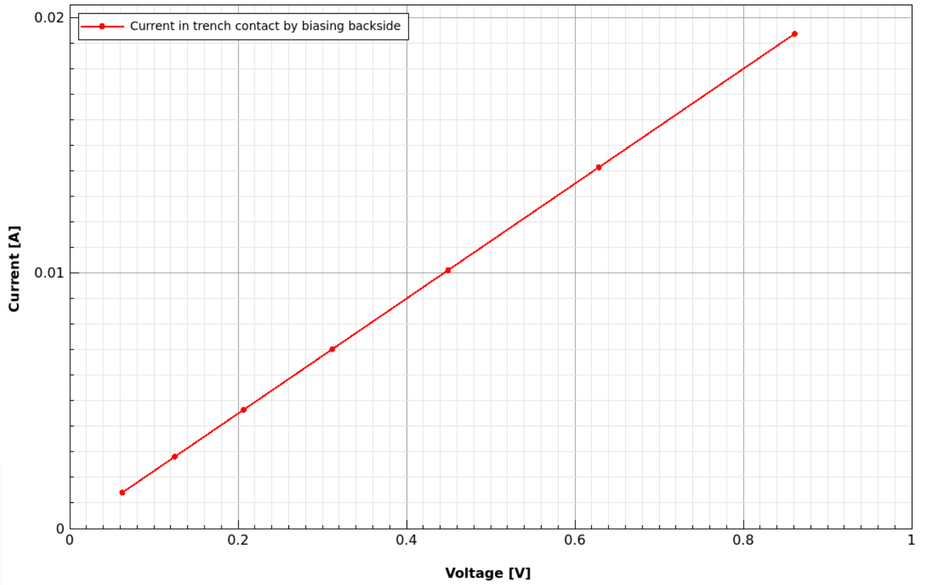

A11
A12
A13
A14
A21
A22
A23
A24
A131
A32
A33
A34
A41
A42
A43
A44
D-L/D-R

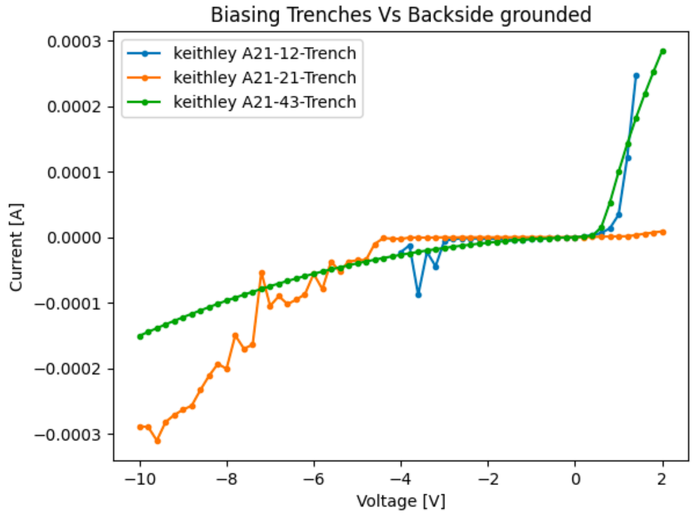

52.0 µm
43.5 µm
35.5 µm
0.5 µm
1 µm
2 µm
ME-S5500 3.0kV 0.3mm x1.50k SE
30.0um

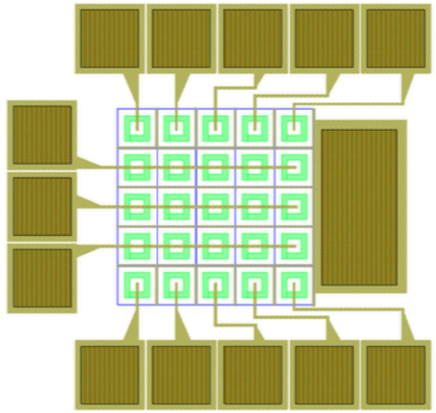

11
12
13
21
21
22
23
31
33
34
41
42
43
44

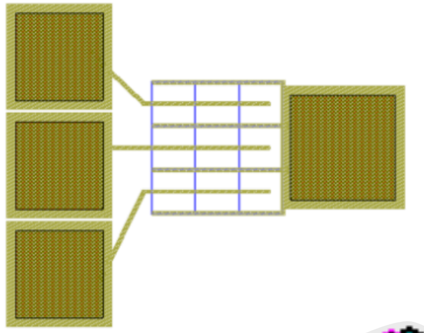



Z
X
Y
DopingConcentration (cm^-3)
2.181e+19
5.600e+16
1.438e+14
-3.079e+11
-2.637e+14
-1.027e+17
-4.000e+19

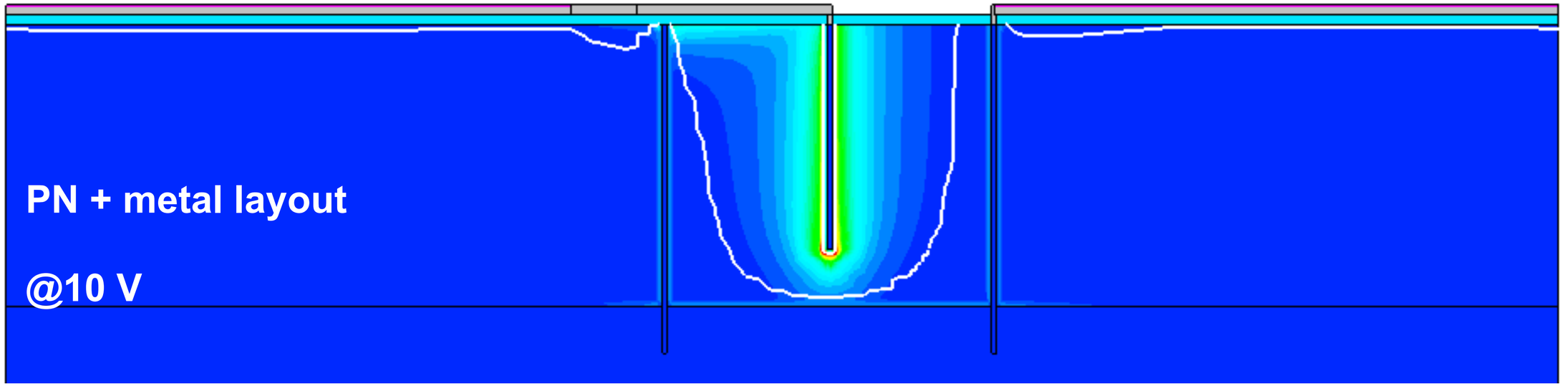

Current in trench contact by biasing backside
Current [A]
Voltage [V]
0.02
0.01
0
0
0.2
0.4
0.6
0.8
1

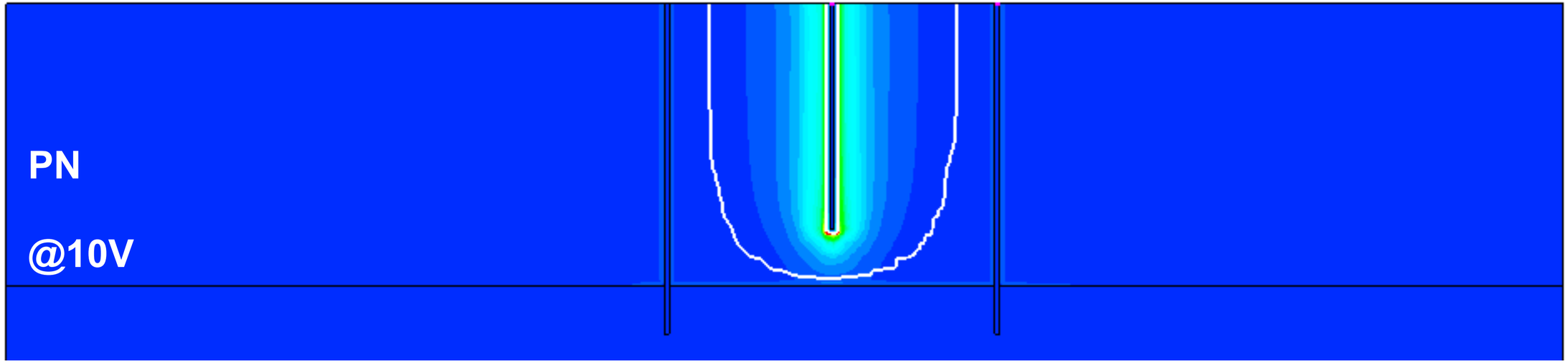

Biasing Trenches Vs Backside grounded
keithley A21-12-Trench
keithley A21-21-Trench
keithley A21-43-Trench
Current [A]
Voltage [V]
0.0003
0.0002
0.0001
0.0000
−0.0001
−0.0002
−0.0003
−10
−8
−6
−4
−2
0
2

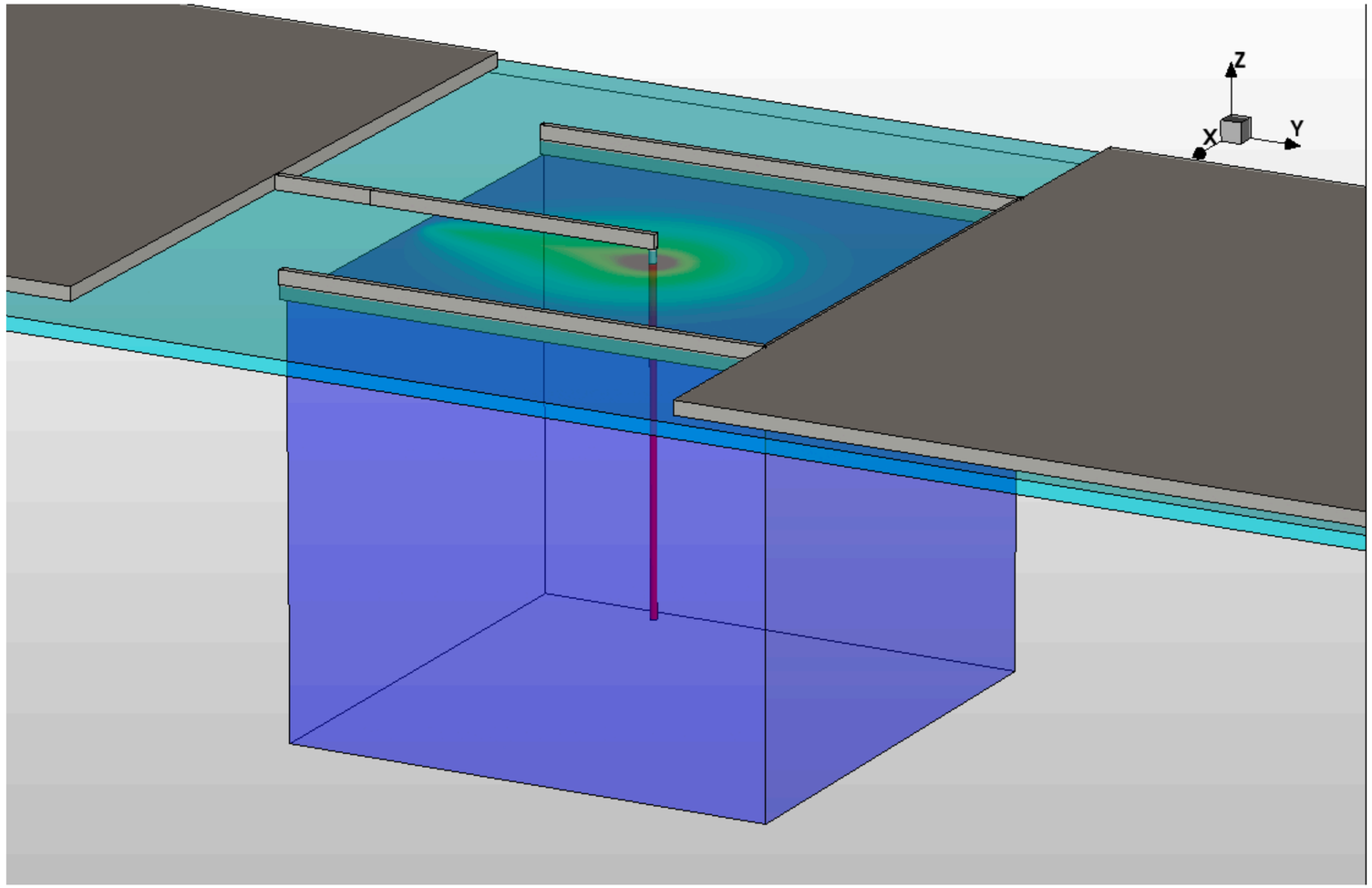




(a)


PN + metal layout
@10 V


PN
@10V


Z
X
Y