Update on TCAD Simulations of CMOS Sensors

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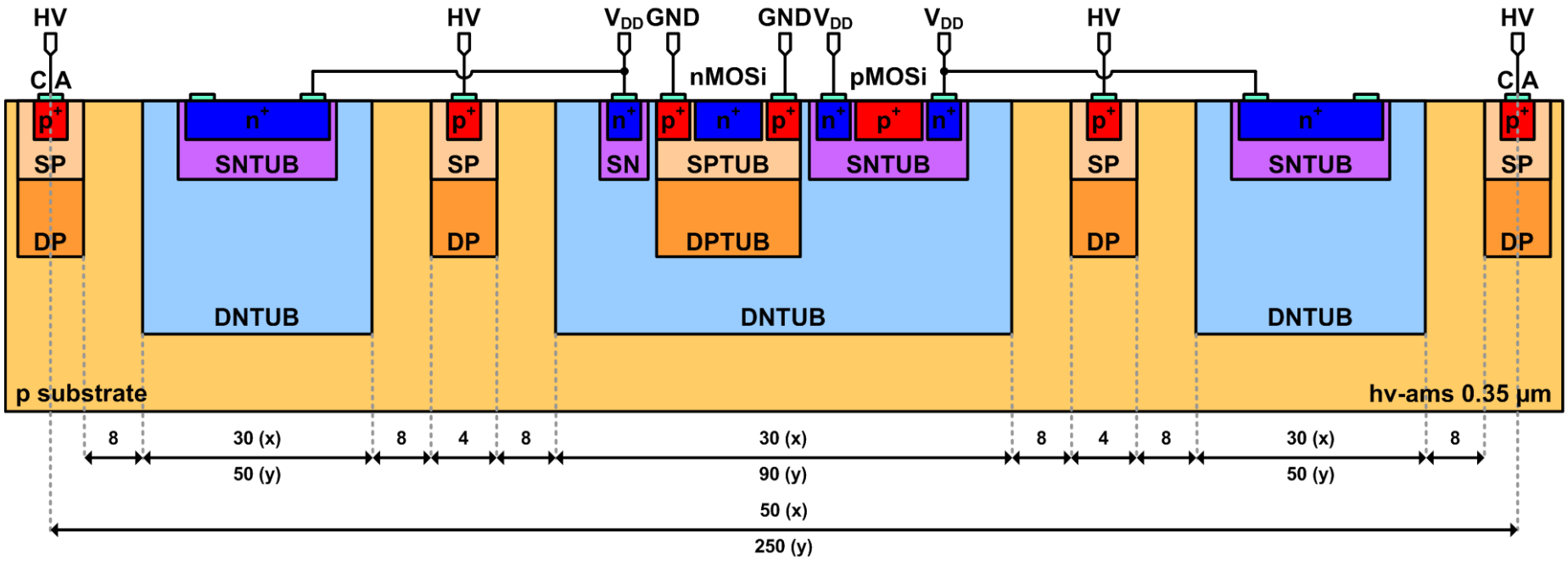
CERN, 09 Jun. 2015

Outline

- Geometric structure
- Depletion and field properties
- Radiation effects
- Back biasing
- Transient simulation with a MIP
- Summary and outlook

Pixel Crosssection

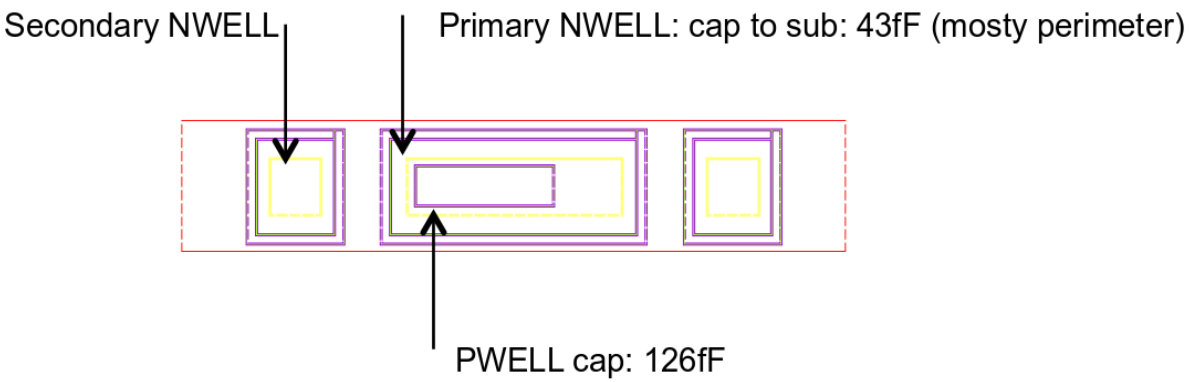


Eva Vilella-Figueras

- VSS: 0.0 V
- VDD: 3.3 V
- HV: 0 – -200 V

- Resistivity: 20, 80, 200, 1000 Ωcm
- Fluence: 0, 1e14, 1e15, 1e16 n_{eq}
- Top bias without back process
- Back bias with floating top contacts

Pixel Capacitance



Results of measurements with PixCap chip:

Pixel size: 50 µm x 250 µm	Planar	Diamond	3D
[fF]	105.5 1.8 111.7 3.8	21.4 0.1	169.4 1.5

"Measurement of pixel sensor capacitances with sub-femtofarad precision", M. Havranek, F. Hügging H. Krüger, N. Wermes – NIMA 714 (2013), 83-89

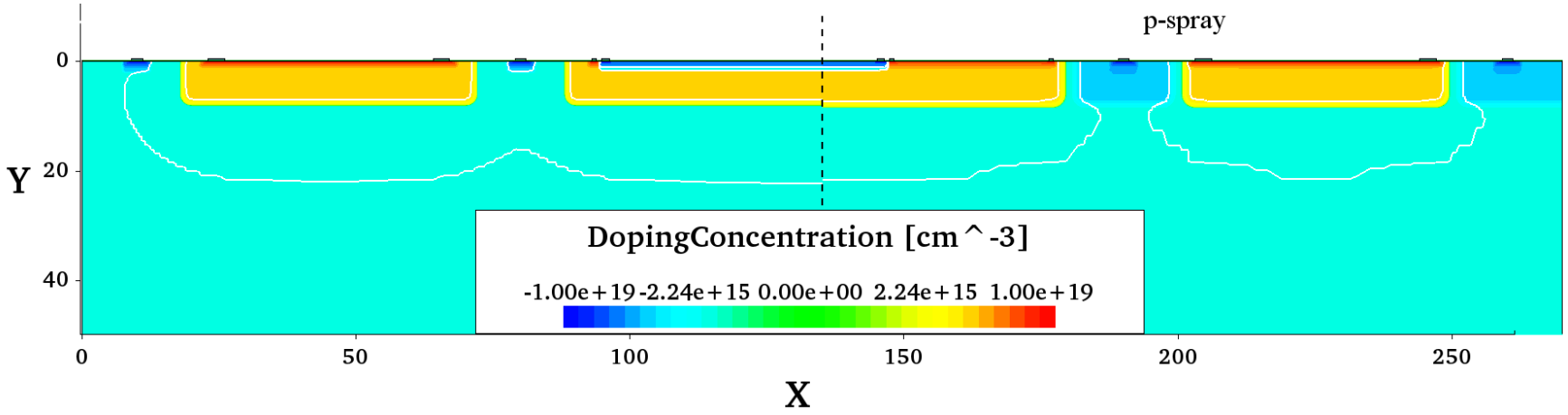
M. Tavassoli

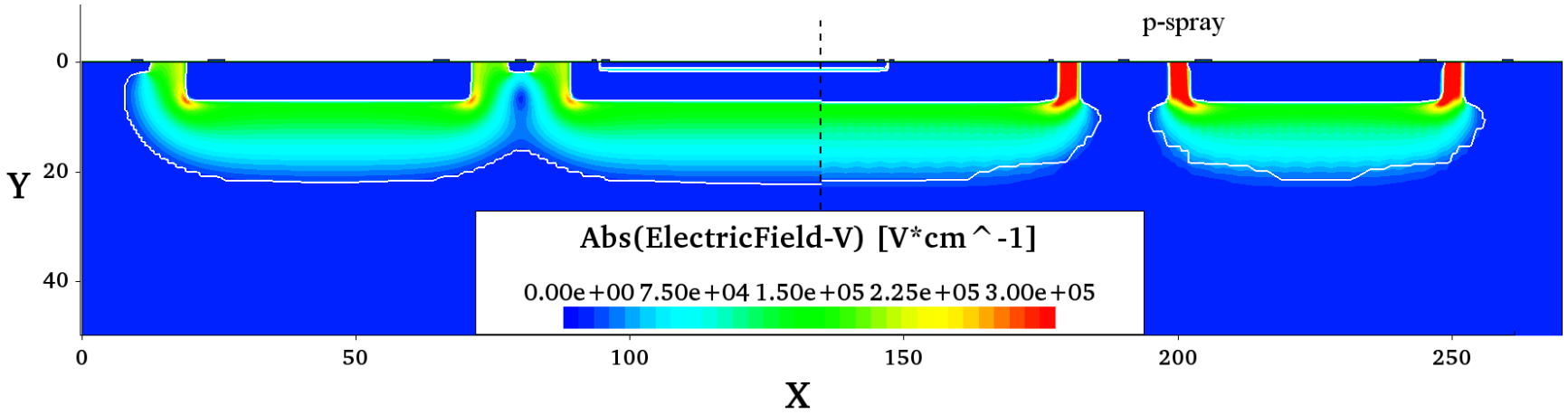
- Estimated large capacitance
- Discontinuous n-wells to reduce capacitance

Doping and Electric Field

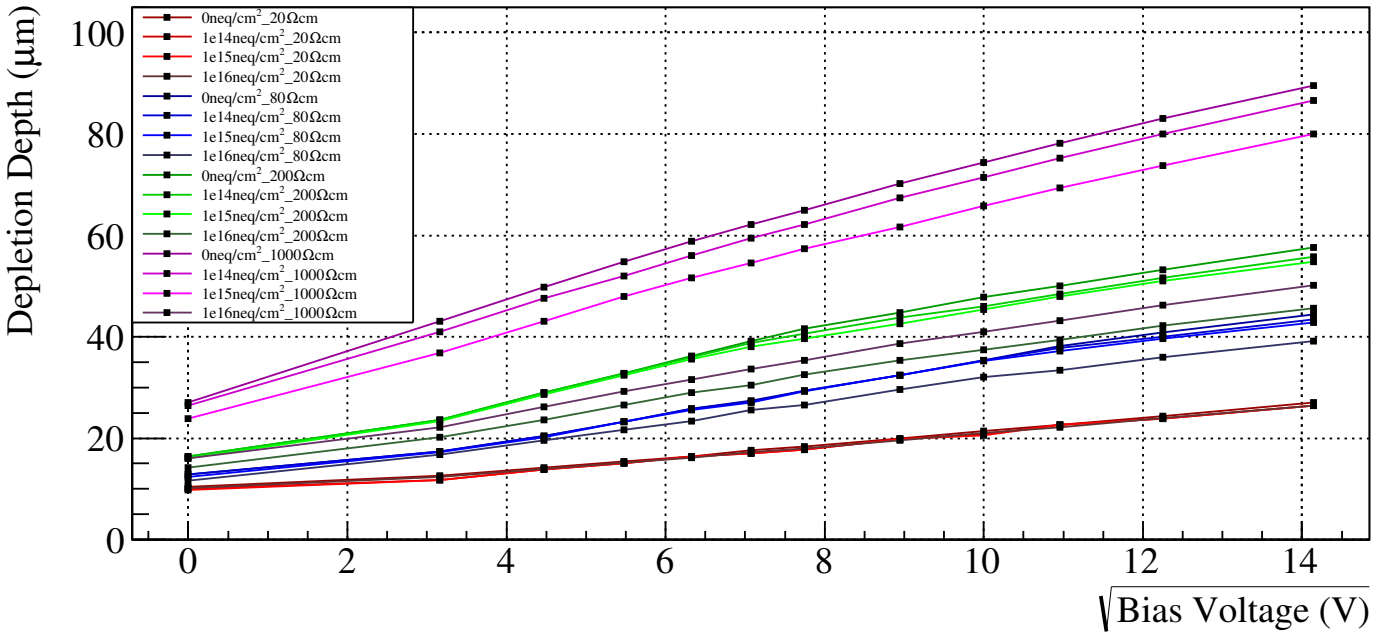
Extra deep p-well (M. Benoit in comm. with AMS)

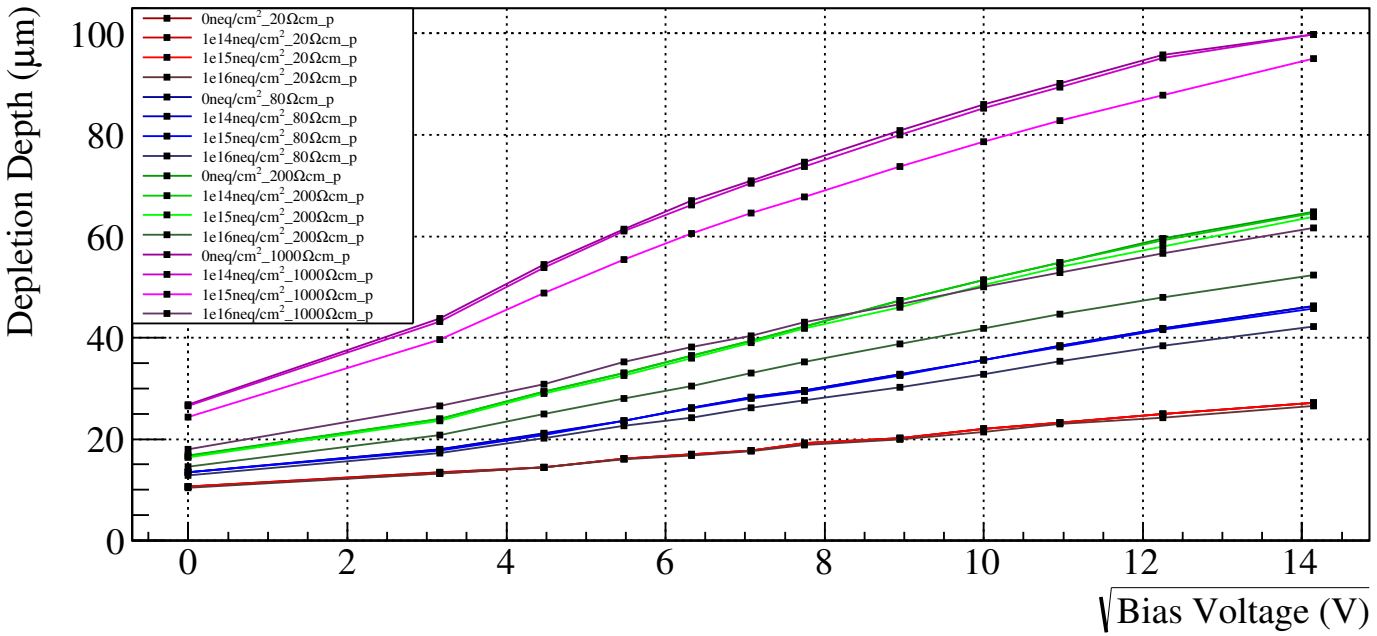
- Inverting DNTUB mask
- Same doping concentration as DNTUB





Depletion Depth

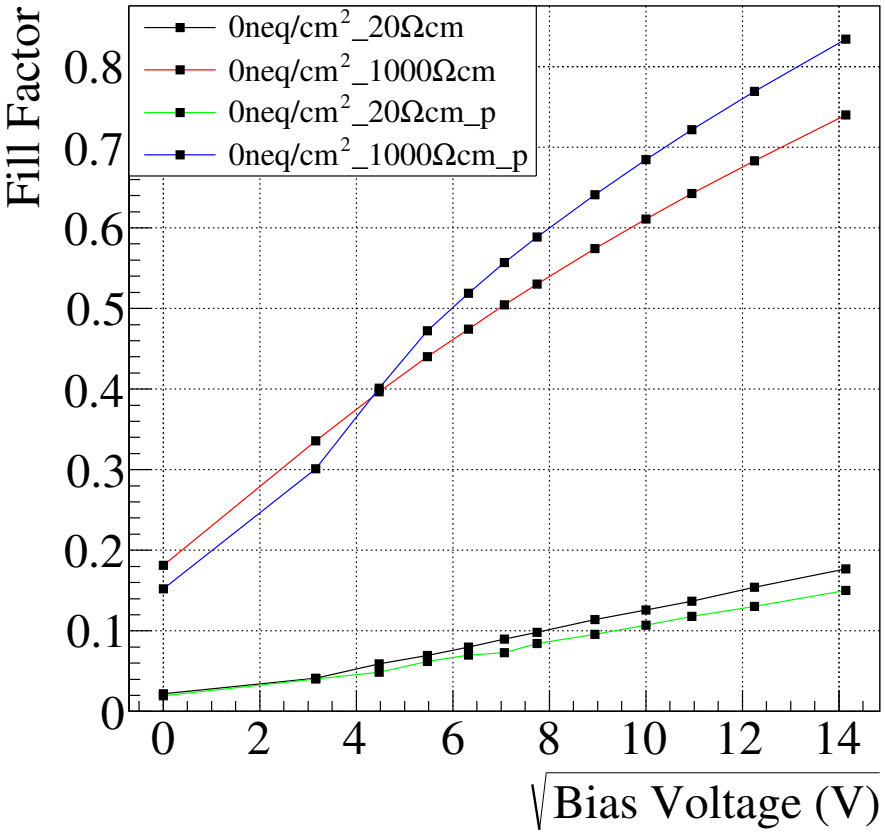


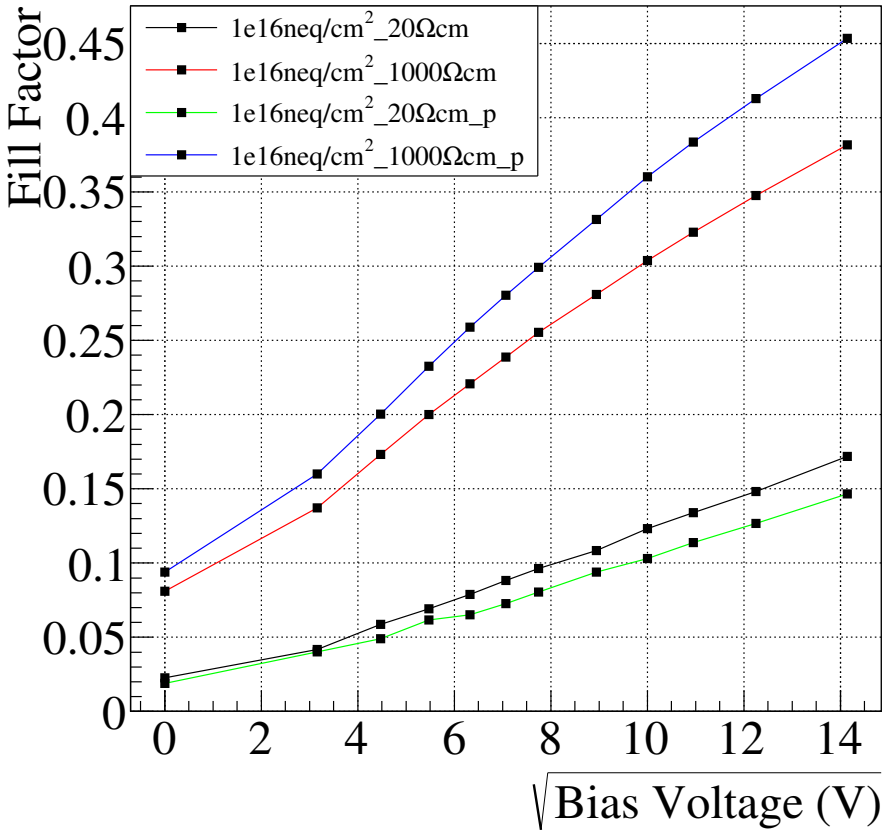


1000 Ωcm
200 Ωcm
80 Ωcm
20 Ωcm

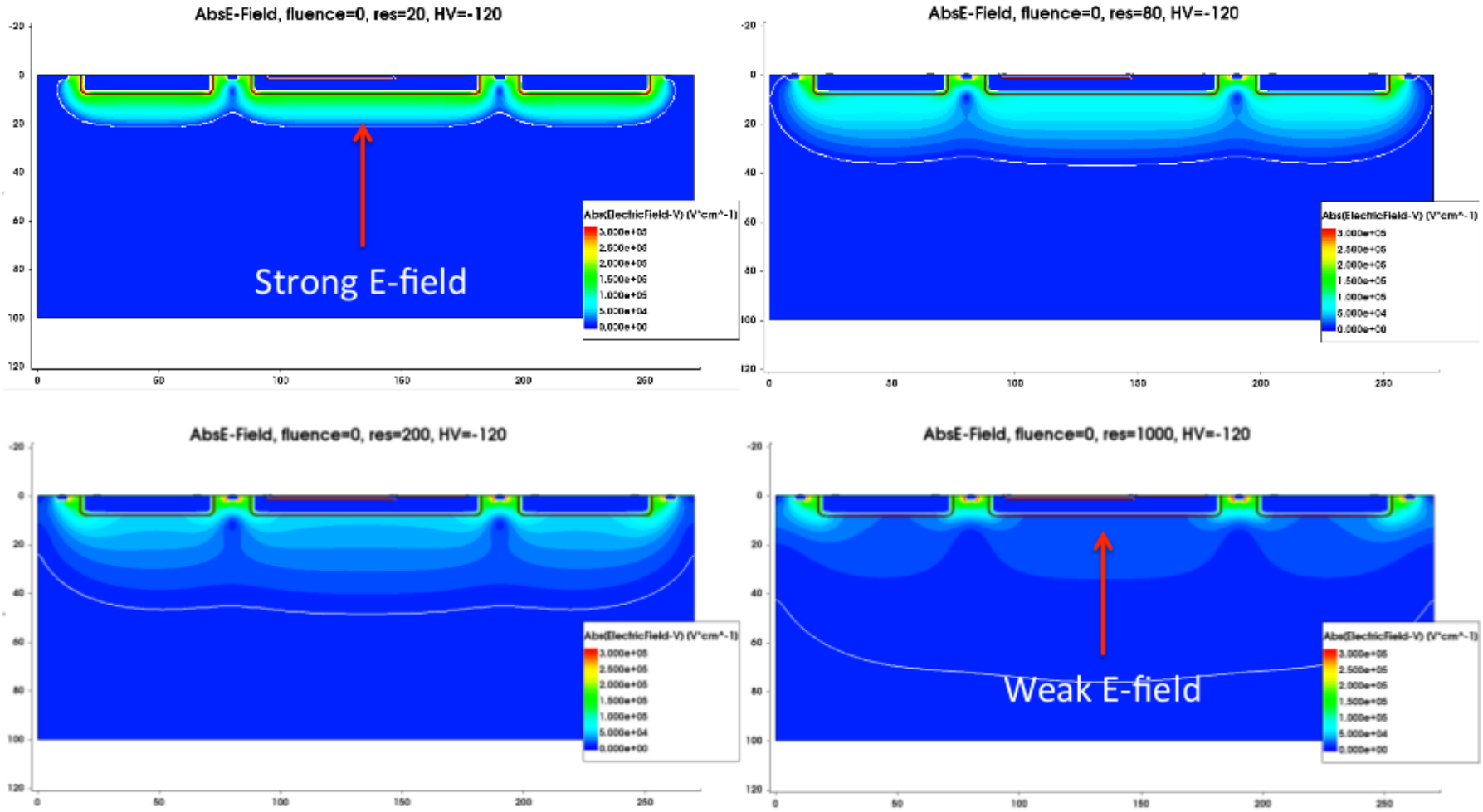
P-well:
Larger depletion depths for higher resistivities

Fill Factor


Fill Factor
0neq/cm^2_20Ωcm
0neq/cm^2_1000Ωcm
0neq/cm^2_20Ωcm_p
0neq/cm^2_1000Ωcm_p
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
2
4
6
8
10
12
14
√Bias Voltage (V)

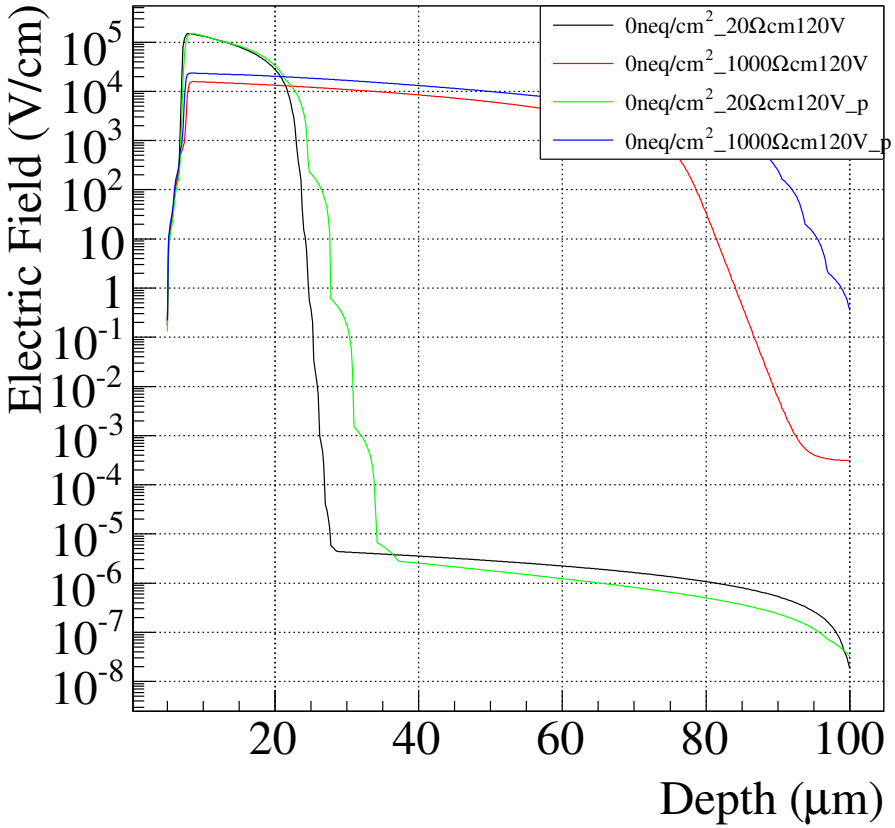

Fill Factor
1e16neq/cm^2_20Ωcm
1e16neq/cm^2_1000Ωcm
1e16neq/cm^2_20Ωcm_p
1e16neq/cm^2_1000Ωcm_p
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0
2
4
6
8
10
12
14
√Bias Voltage (V)

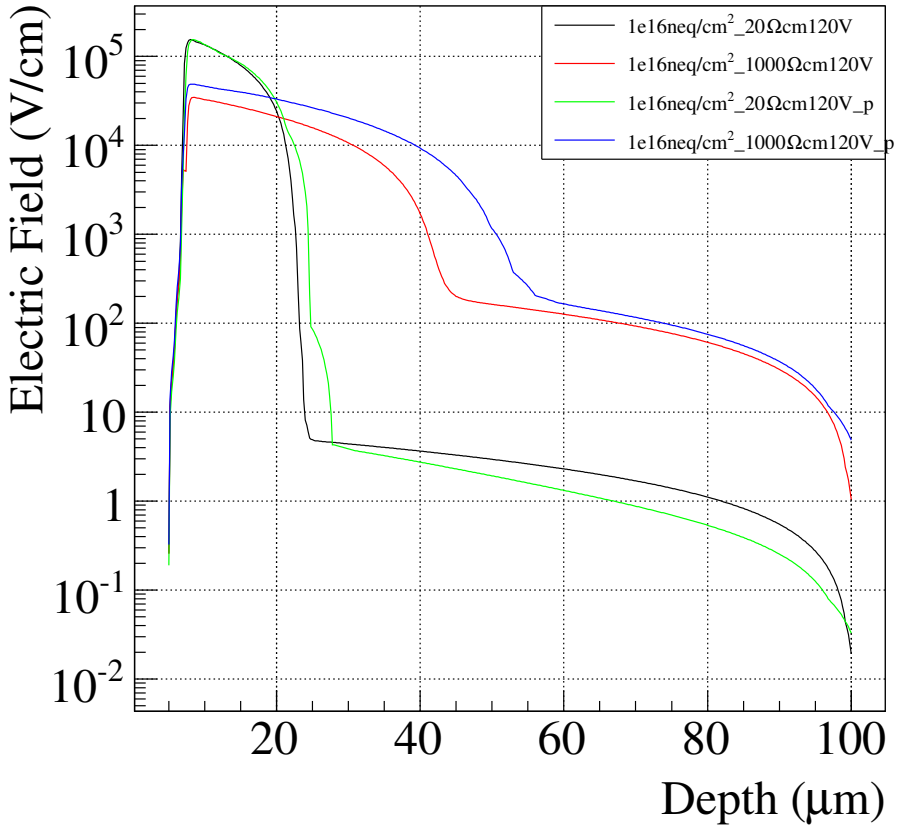
Electric Field



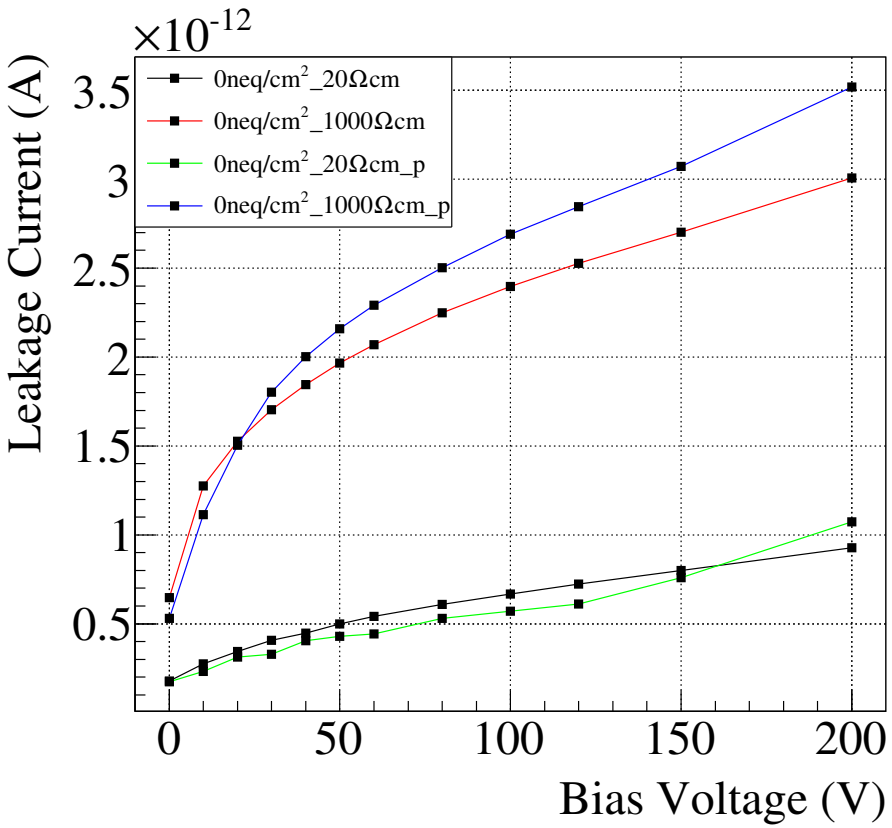
M. Buckland

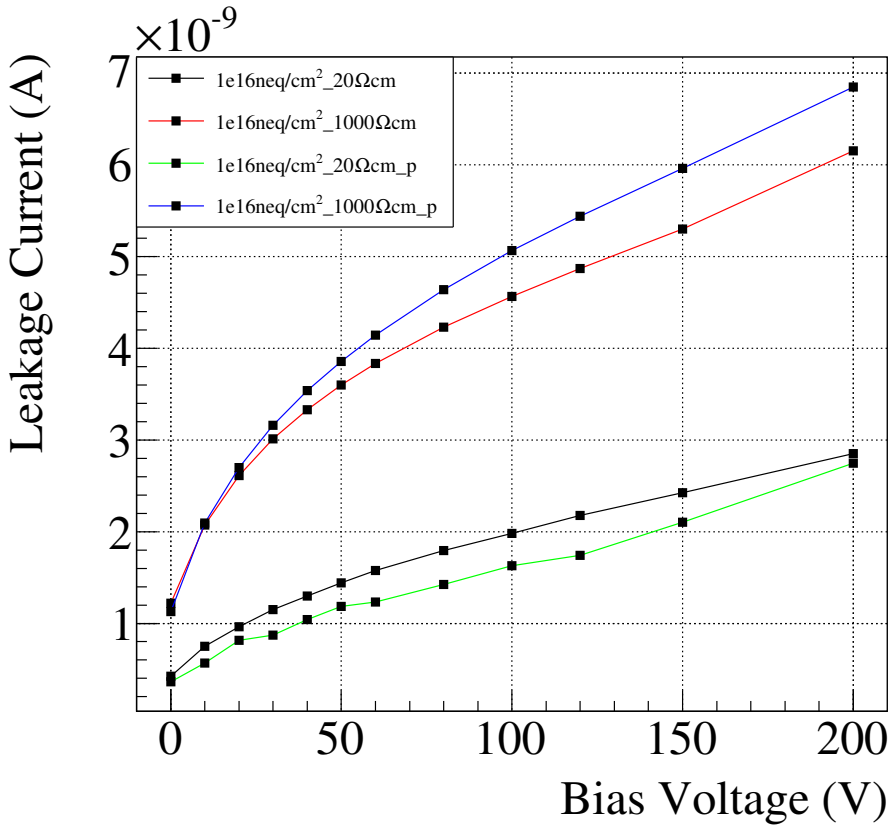
Electric Field



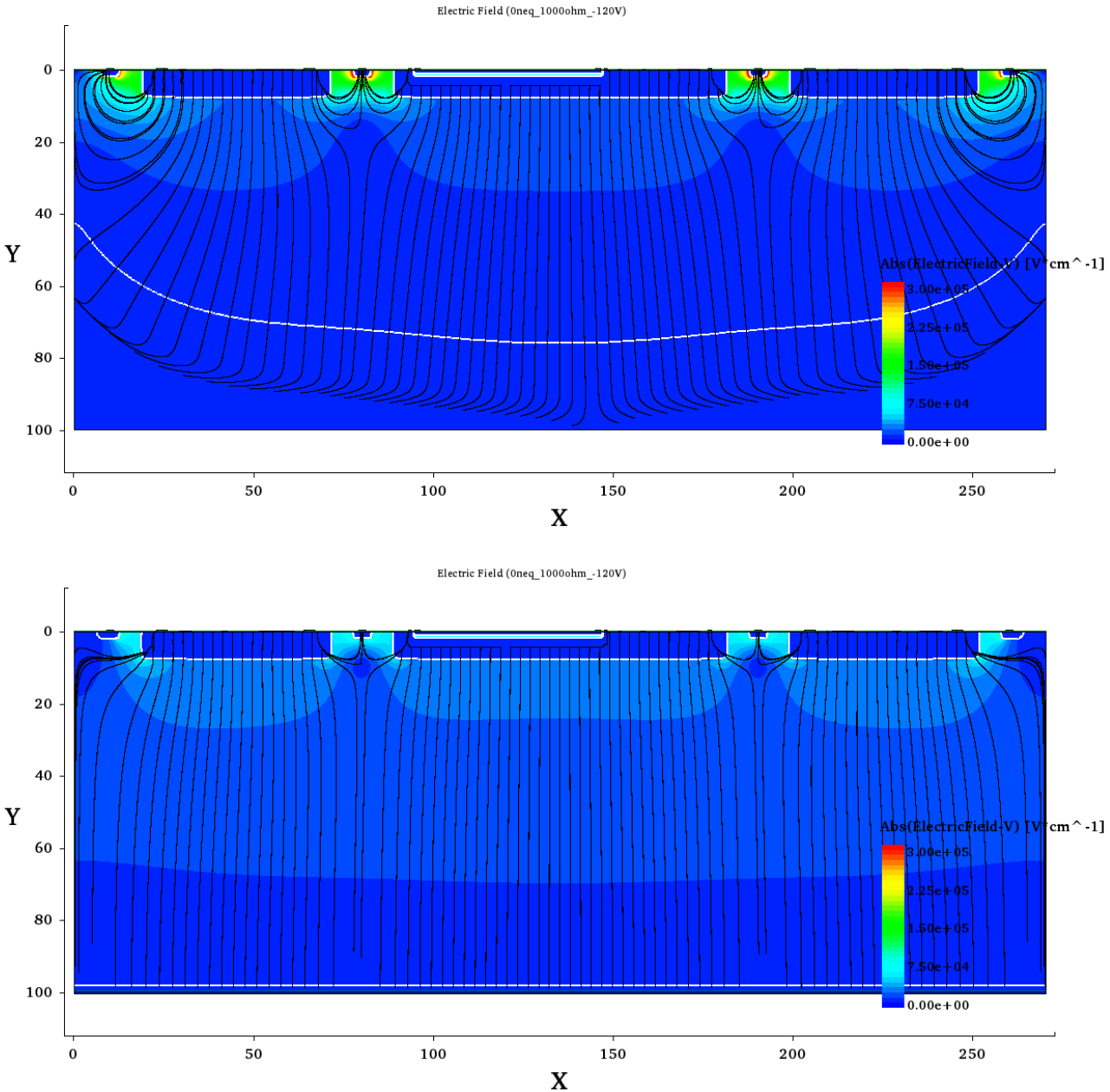


IV Curve


×10^-12
Leakage Current (A)
0neq/cm²_20Ωcm
0neq/cm²_1000Ωcm
0neq/cm²_20Ωcm_p
0neq/cm²_1000Ωcm_p
3.5
3
2.5
2
1.5
1
0.5
0
50
100
150
200
Bias Voltage (V)

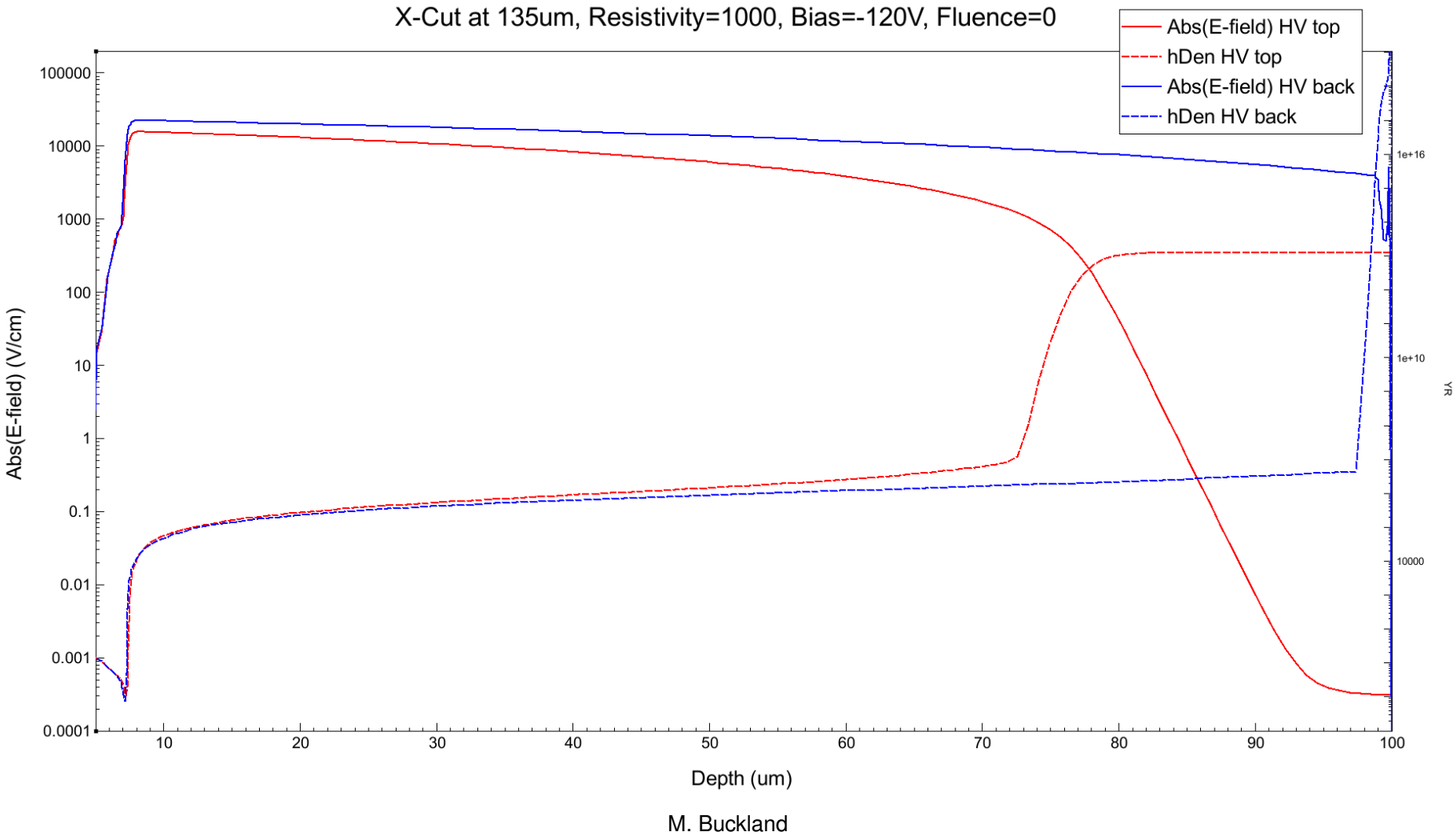

×10^-9
Leakage Current (A)
1e16neq/cm²_20Ωcm
1e16neq/cm²_1000Ωcm
1e16neq/cm²_20Ωcm_p
1e16neq/cm²_1000Ωcm_p
7
6
5
4
3
2
1
0
50
100
150
200
Bias Voltage (V)

Back Bias



- 1000 Ωcm @ -120 V
- Top contacts set to floating
- Back processing with shallow p-well, p+ and aluminium

Back Bias - Depletion and Field



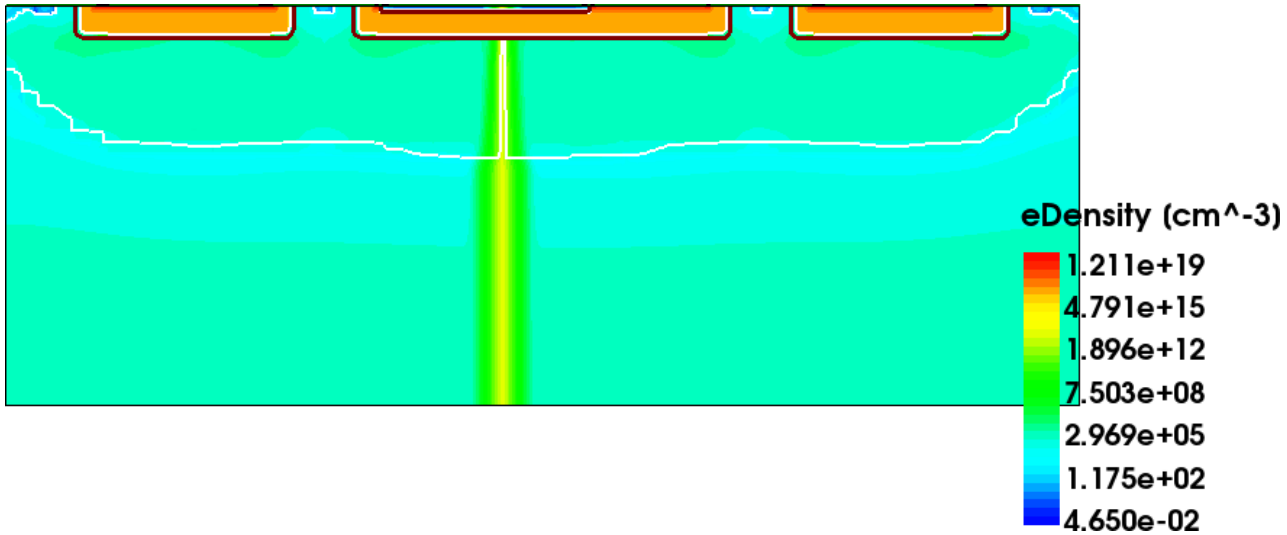
Top bias:

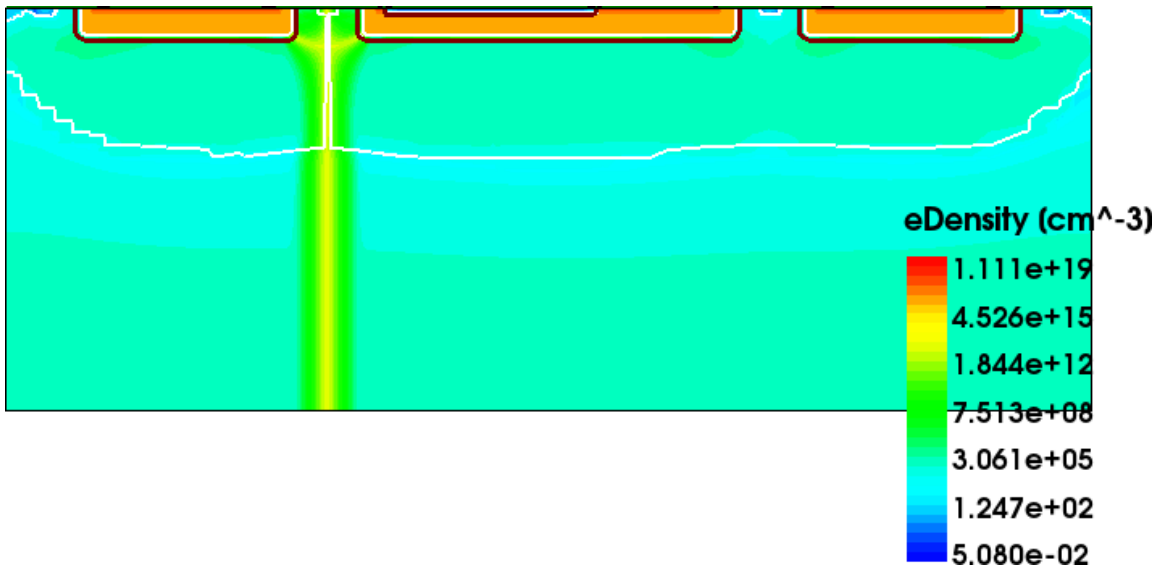
- No electric field at the back
- Depletion depth $\sim 70\mu m$

Back bias:

- Uniform electric field
- Fully depleted

Transient Simulation - MIP positions

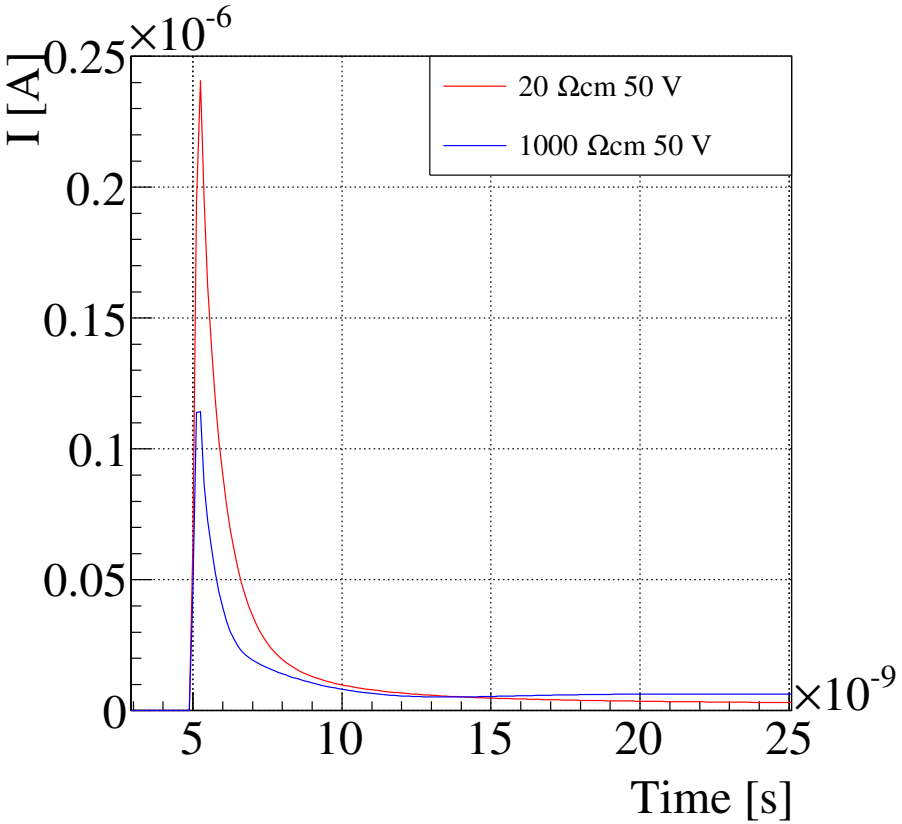


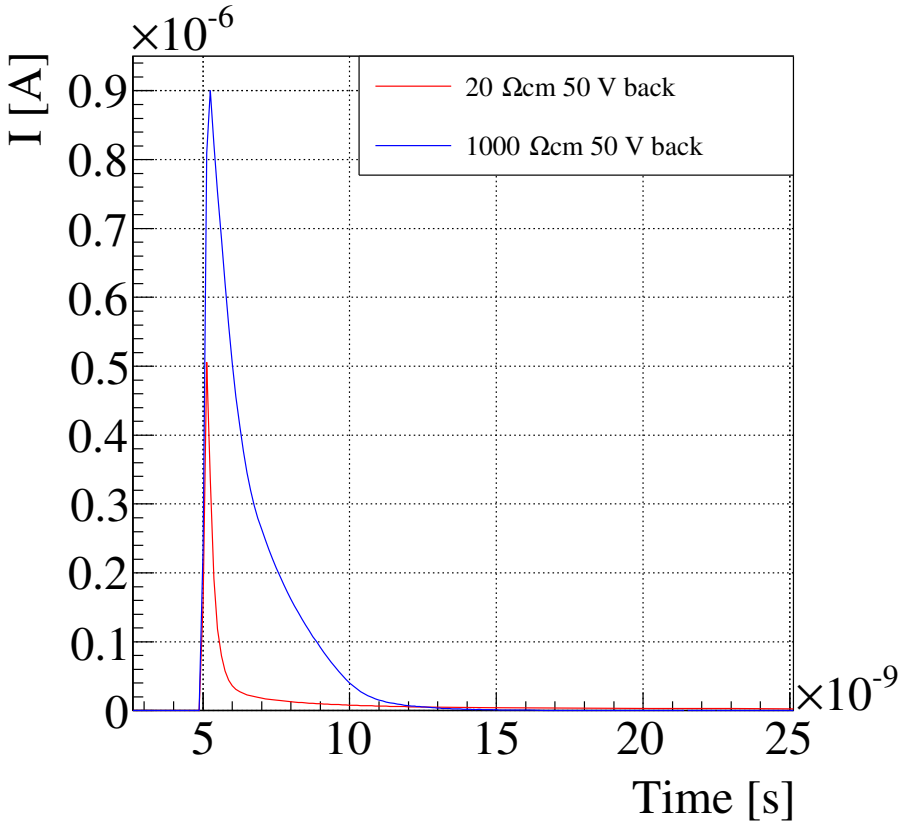


F. Di Bello

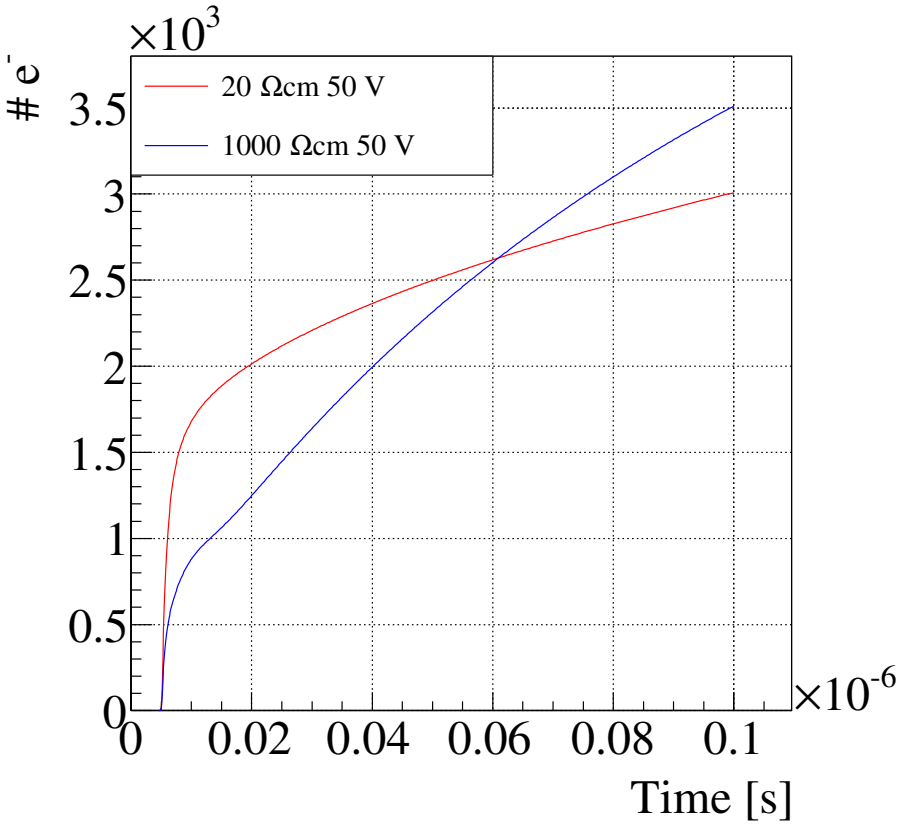
- MIP in the middle of a subpixel
- MIP between two subpixels
- Top and back bias
- 80 e-h pairs/μm

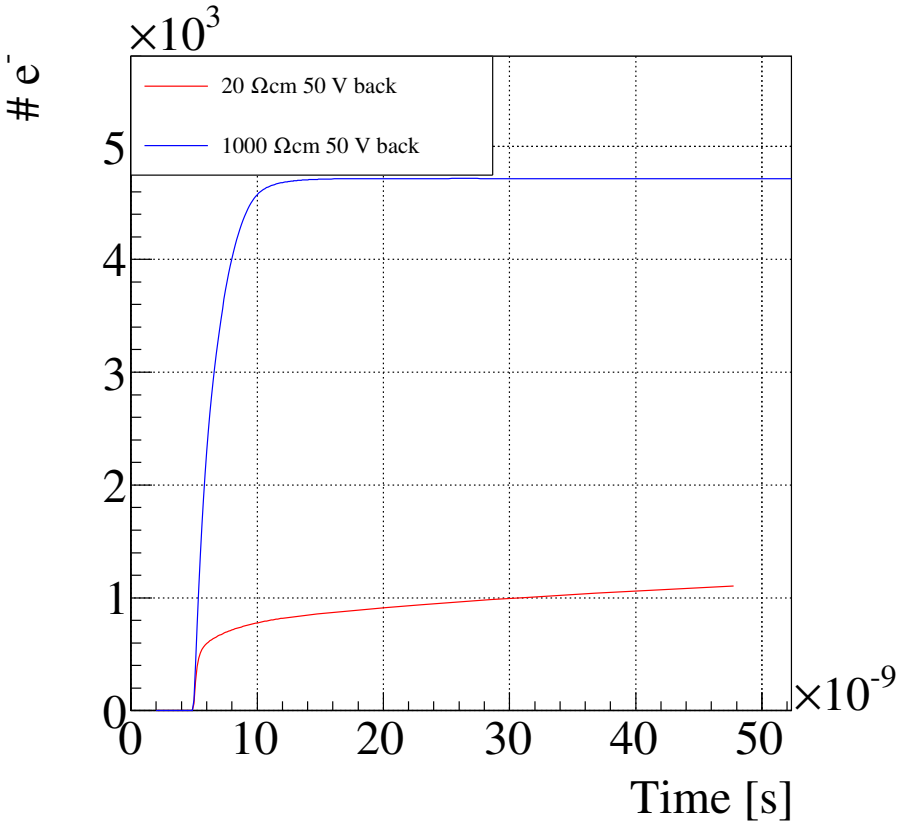
Transient Simulation - Signal Current



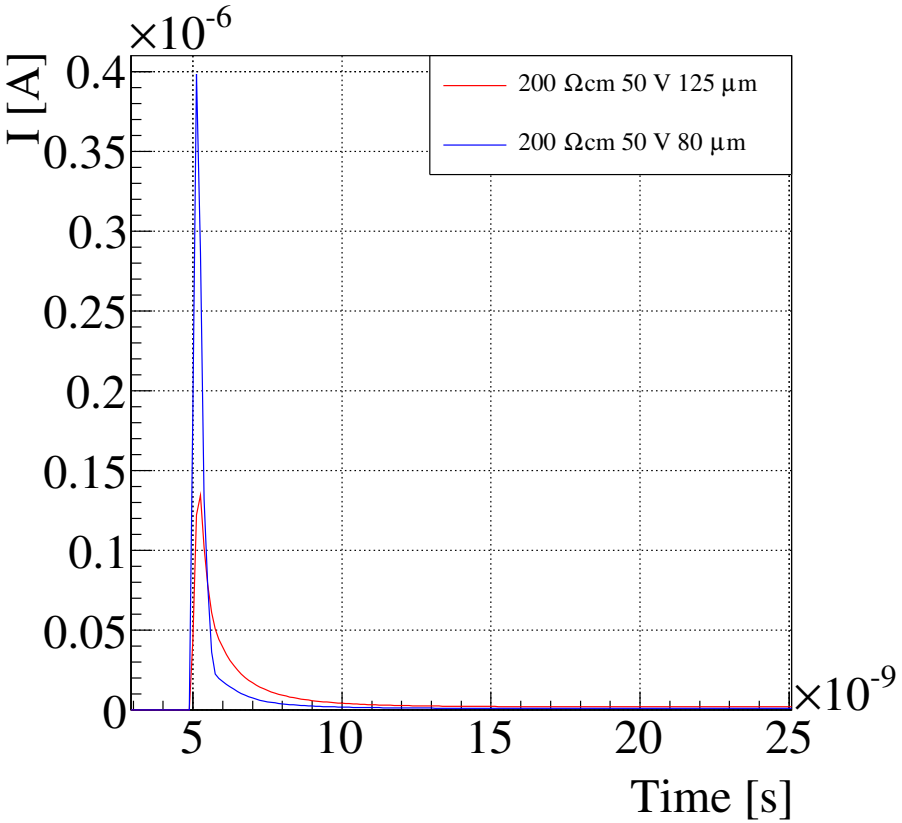


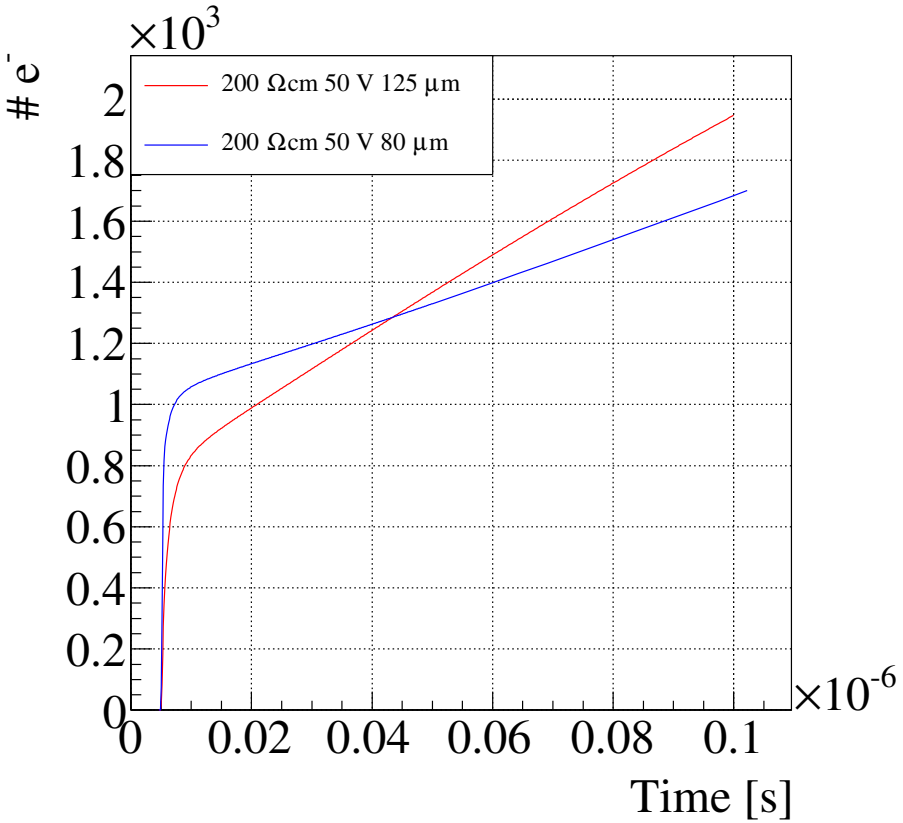
Transient Simulation - Integrated Charge





Transient Simulation - Diff. MIP positions





Summary and Outlook

- P-wells:
  improved depletion depth for HR materials
  wider electric field
  higher leakage current
- Back bias:
  uniform electric field
  larger depletion
  $\rightarrow$ efficient charge collection
- Radiation effects on depletion depth of low resistivity (maybe) inconsistent with measurements
  $\rightarrow$ Check on N_{eff} vs. fluence
- Transient simulation: charge sharing and crosstalk on multipixel
- Capacity simulation
- Improve current model, e.g. by measuring the doping profile