Simulations of 3D-DDTC Silicon detectors

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1 Motivation

2 Simulation: Layout and parameters

3 Simulation: Electric field

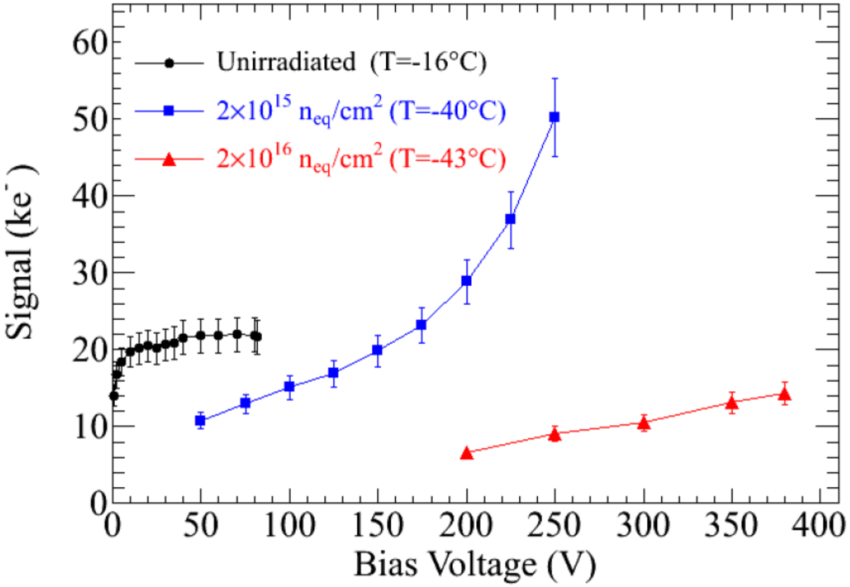
4 Simulation: Charge multiplication

5 Conclusions/Future work

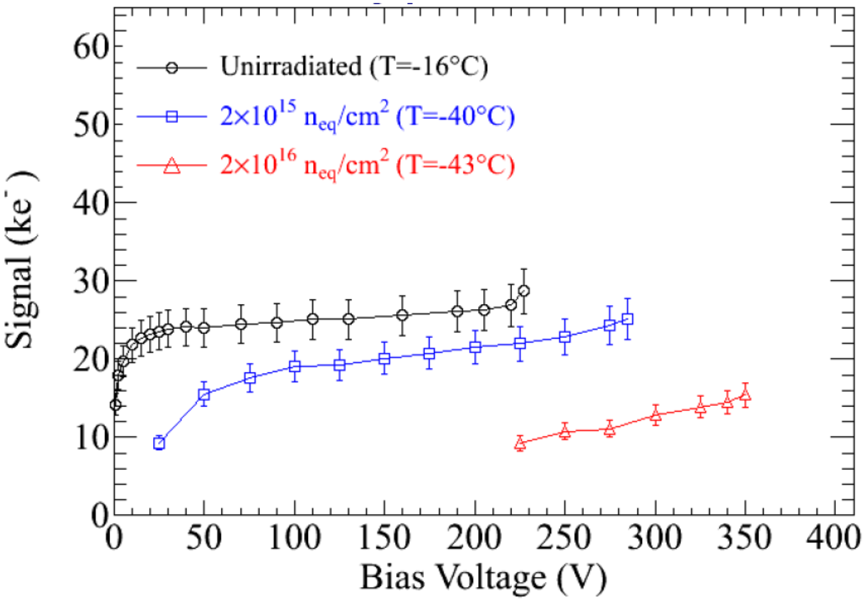
3D-DDTC measurements

Irradiated 3D detectors present Charge multiplication effect:

- above 150V for p-type



- above 260V for n-type



[M. Köhler, University of Freiburg, Germany]

Objective

Develop 3D detectors with Charge multiplication effect for low Bias voltages before irradiation by changing the bulk doping concentration.

1 Motivation

2 Simulation: Layout and parameters

3 Simulation: Electric field

4 Simulation: Charge multiplication

5 Conclusions/Future work

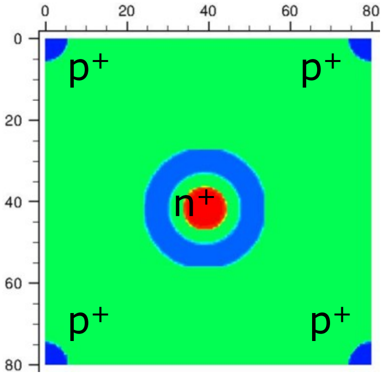
P-type

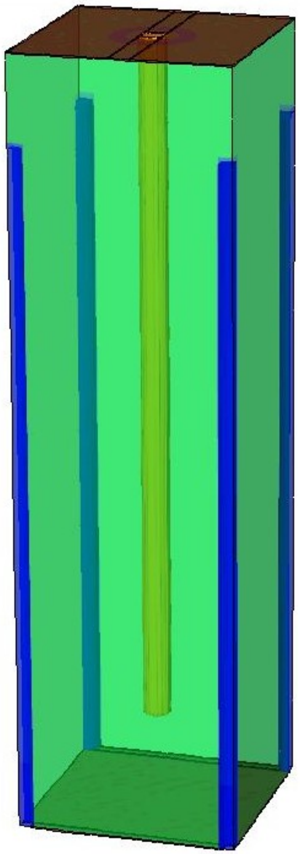
Geometry

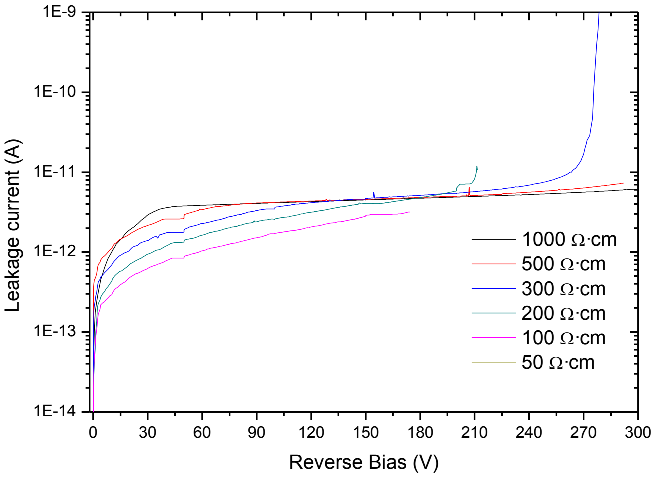
- pitch: 80 μm
- wafer thickness: 285 μm
- column depth: 250 μm
- column diameter: 10 μm

Doping levels

- n^+ columns: 10^{19} cm^{-3}
- p^+ columns: 10^{19} cm^{-3}
- p-stop: 10^{18} cm^{-3}
- Si/SiO_2 charge: $5 \cdot 10^{11}$ cm^{-2}







Resistivity (Ω·cm)	**Doping N_{eff} (cm^{-3})**	**V_{FD} nominal (V)**
1000	1.33×10^{13}	33
500	2.66×10^{13}	66
300	4.43×10^{13}	110
200	6.65×10^{13}	165
100	1.33×10^{14}	329
50	2.66×10^{14}	658

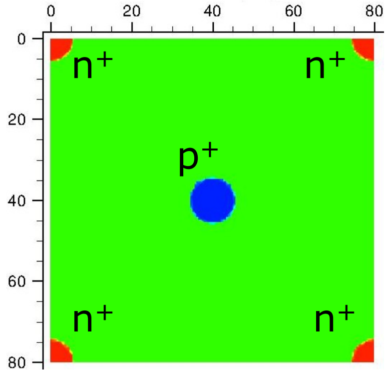
N-type

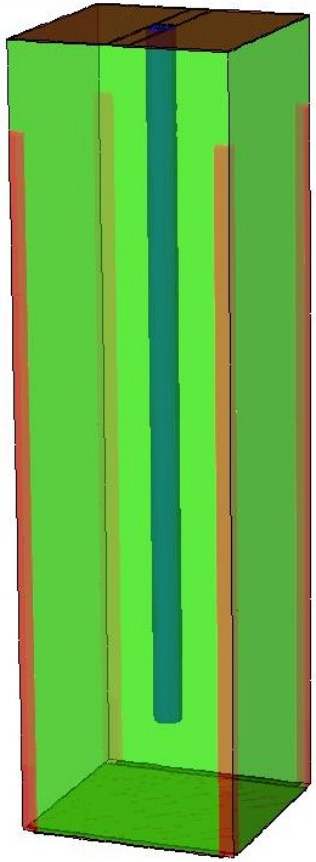
Geometry

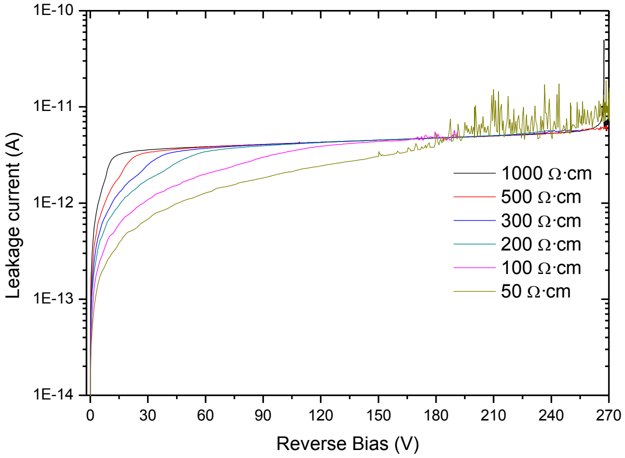
- pitch: 80 µm
- wafer thickness: 285 µm
- column depth: 250 µm
- column diameter: 10 µm

Doping levels

- n^+ columns: 10^{19} cm^{-3}
- p^+ columns: 10^{19} cm^{-3}
- Si/SiO_2 charge: $5\cdot10^{11}$ cm^{-2}

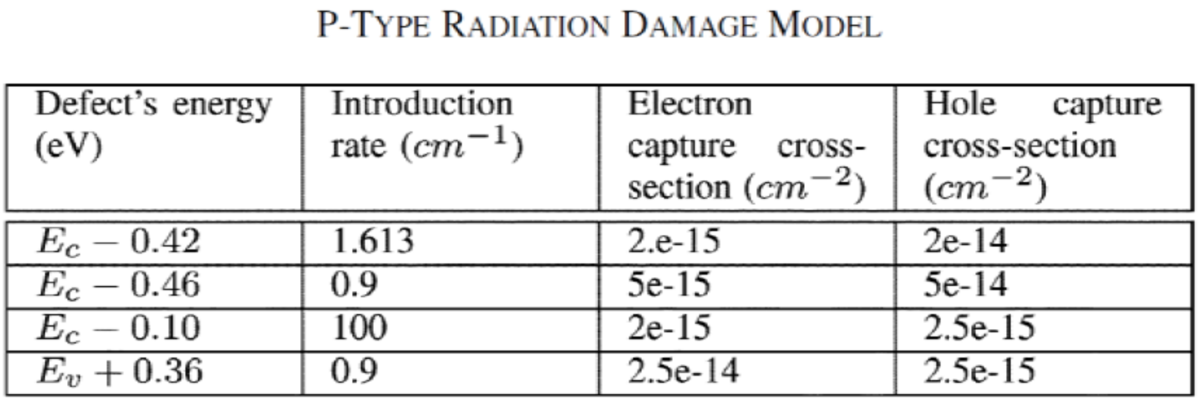






Resistivity (Ω·cm)	Doping N_{eff} (cm^{-3})	V_{FD} nominal (V)
1000	4.12×10^{12}	10
500	8.37×10^{12}	21
300	1.4×10^{13}	37
200	2.12×10^{13}	53
100	4.27×10^{13}	106
50	8.64×10^{13}	214

Physics	Model
Mobility	Doping dependance, High Electric field saturation
Generation and Recombination	Doping dependant Shockley-Read-Hall Generation recombination, Surface recombination model
Impact ionization	University of Bologna impact ionization model
Tunneling	Band-to-band tunneling, Hurkx trap-assisted tunneling
Oxide physics	Oxide as a wide band gap semiconductor for mips (irradiated), interface charge accumulation
Radiation model	Acceptor/Donor states in the band gap (traps)

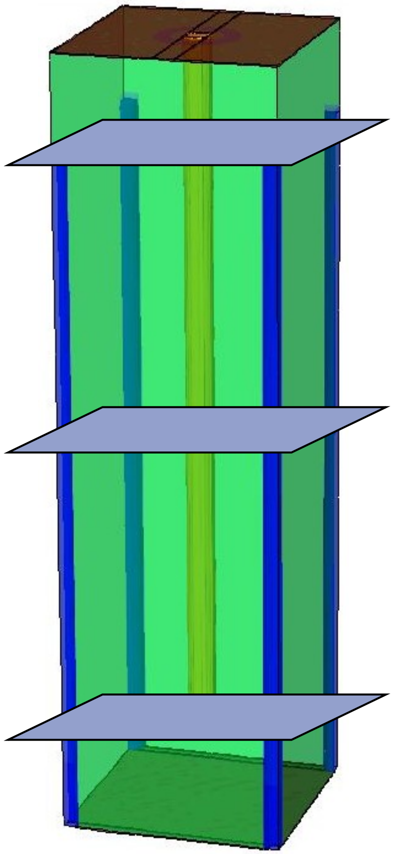


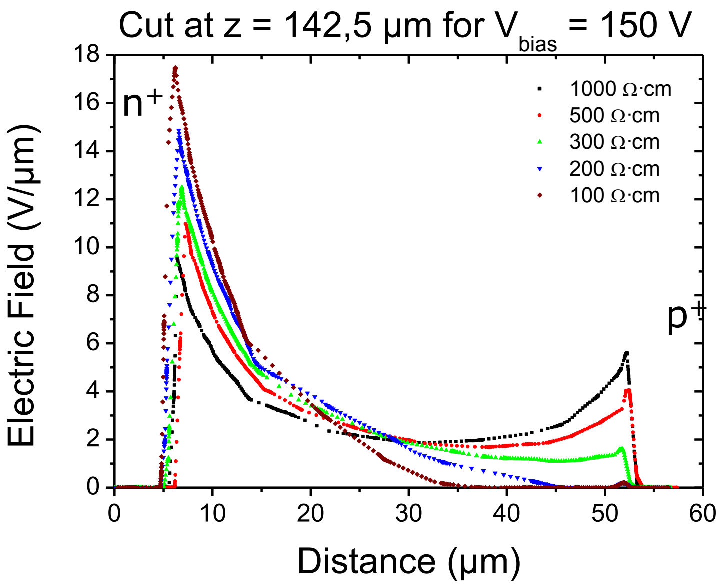
P-TYPE RADIATION DAMAGE MODEL

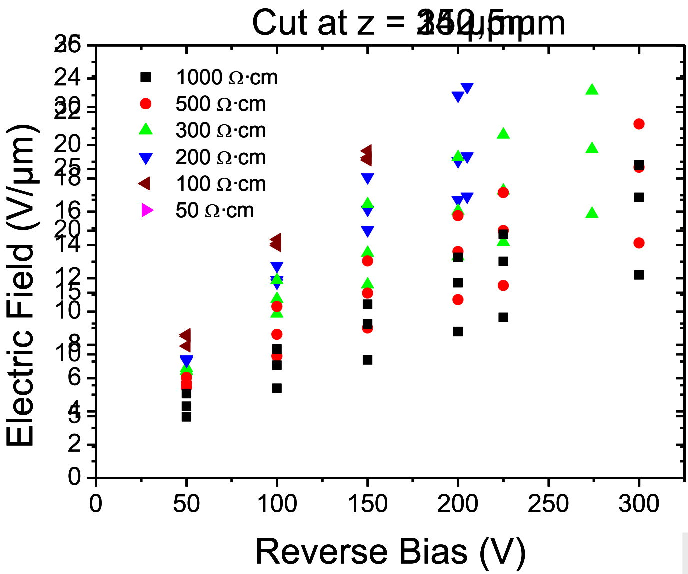
Defect's energy (eV)	Introduction rate (cm^{-1})	Electron capture cross-section (cm^{-2})	Hole capture cross-section (cm^{-2})
$E_c - 0.42$	1.613	2.e-15	2e-14
$E_c - 0.46$	0.9	5e-15	5e-14
$E_c - 0.10$	100	2e-15	2.5e-15
$E_v + 0.36$	0.9	2.5e-14	2.5e-15

[M. Benoit, Laboratoire de l'accélérateur linéar (LAL), Orsay, France]

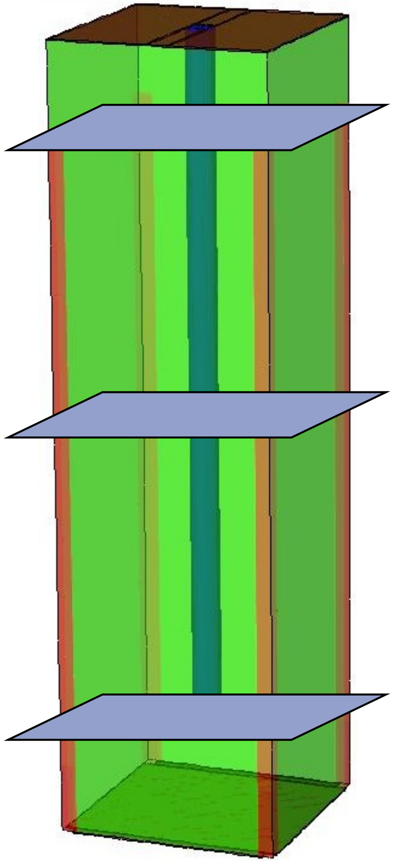
Electric Field (p-type)

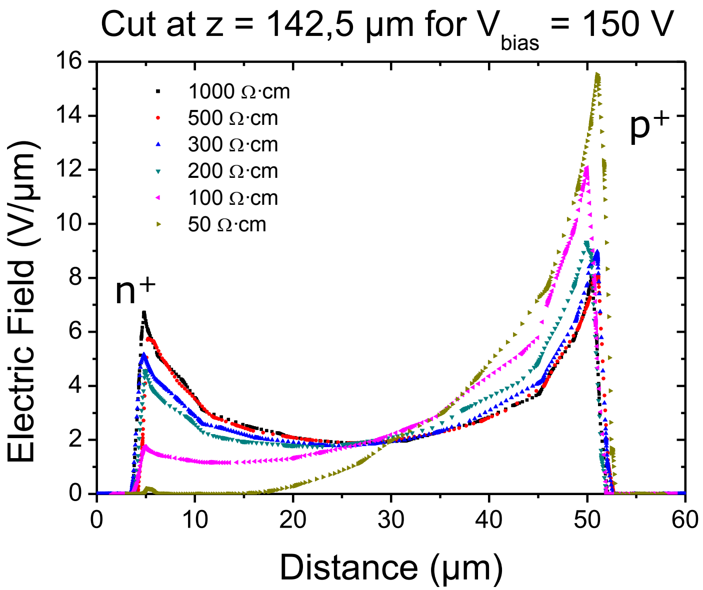


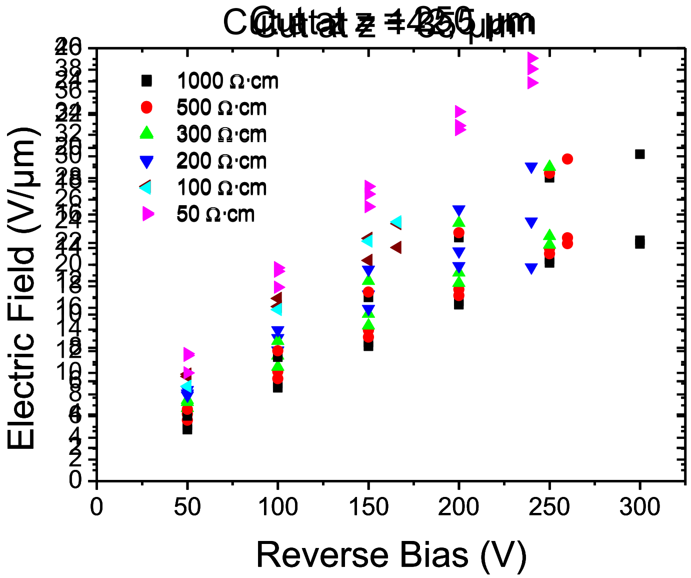




Electric Field (n-type)

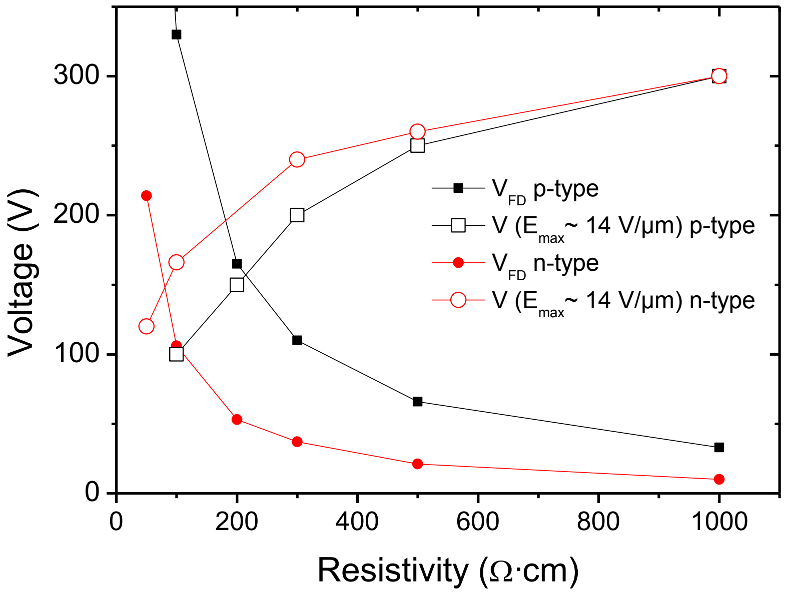


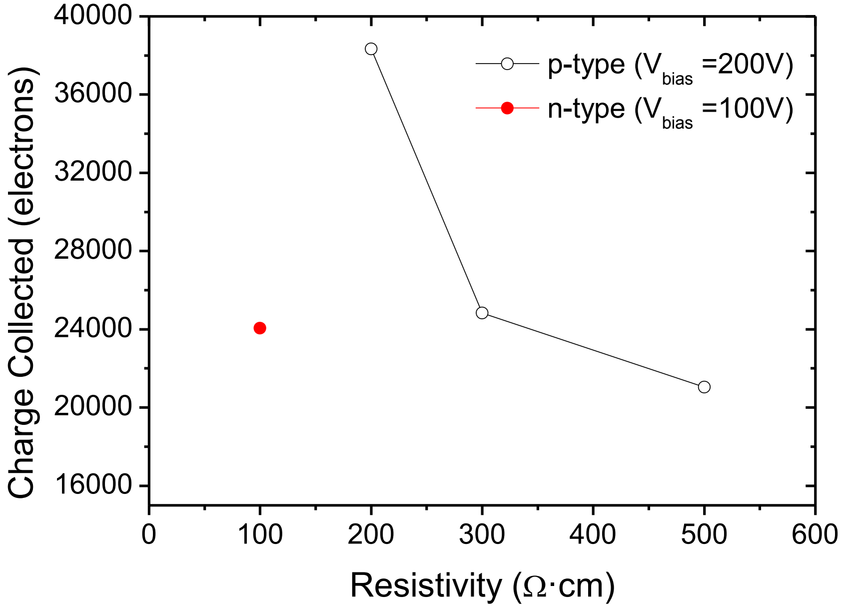




Charge multiplication

Compromise between low full depletion voltages and high enough voltages for Charge multiplication





V = 150 V for both n and p-type

ρ_n = 100 Ω·cm ρ_p = 200 Ω·cm

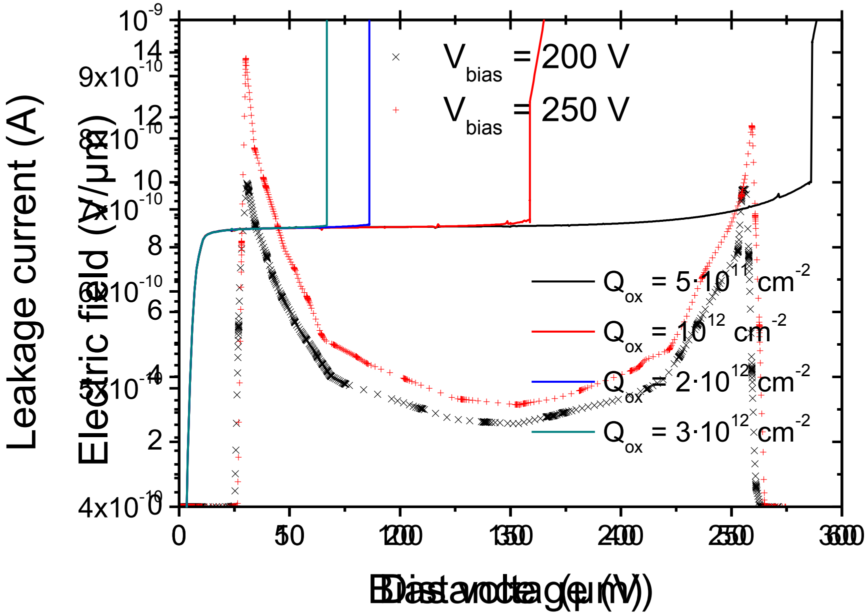
MIP ⇨ 22800 electrons

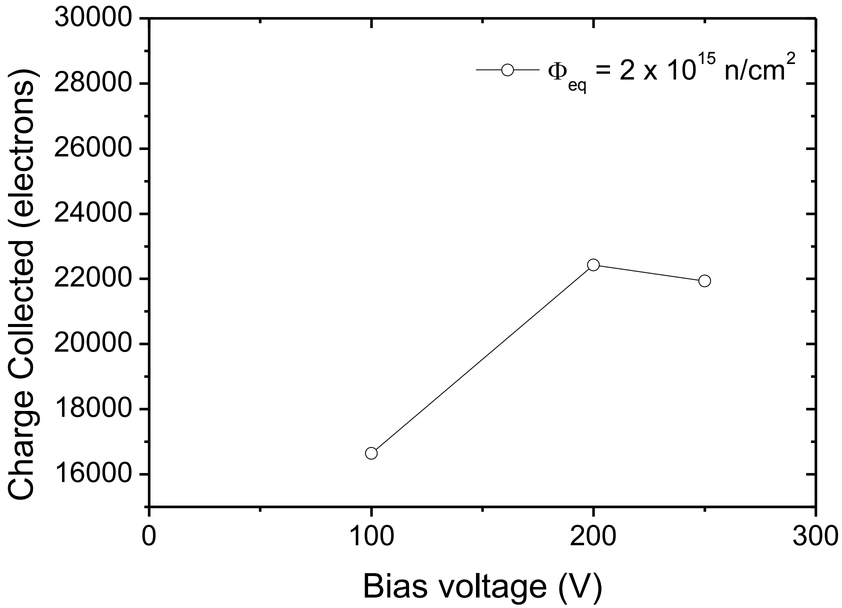
Charge multiplication

Charge multiplication in the irradiated 3D model

Doping concentration: $N_{eff} = 7 \cdot 10^{11}$ cm^{-3} (p-type)

Fluence: $\Phi_{eq} = 2 \cdot 10^{15}$ n_{eq}/cm^2





Interface charge: $Q_{ox} = 5 \cdot 10^{11}$ cm^{-2}

Electric field compatible with Charge multiplication for 250V

Unexpected reduction of the charge collected for 250V !!

Conclusions

- Obtained charge multiplication effect in both n and p-type substrates without irradiation

Future work

- Complete the study on multiplication effect for different doping levels at different biasing voltages
- Solve problems of charge multiplication in the irradiated 3D model.