T-CAD Simulations of 3D Microstrip detectors

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Acknowledgements:

The corresponding author acknowledges the Science and Technology Facilities Council, Swindon, UK for funding

Outline

- Introduction
  - Motivation
  - Double-sided 3D detectors
- Different designs
  - CNM-IMB (C.S.I.C.)
  - FBK-irst
  - Full3D
- Experimental data available
- Simulations

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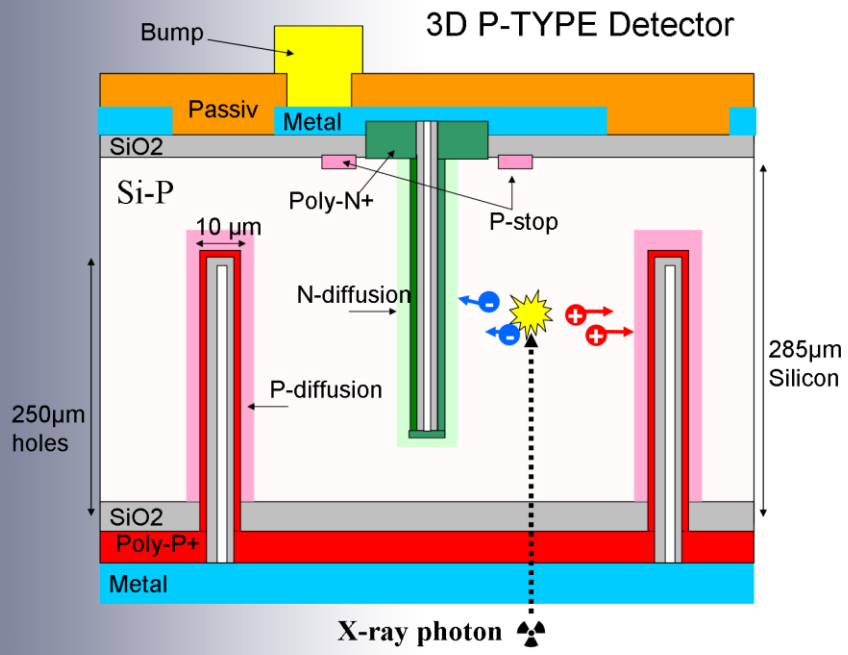
Aims

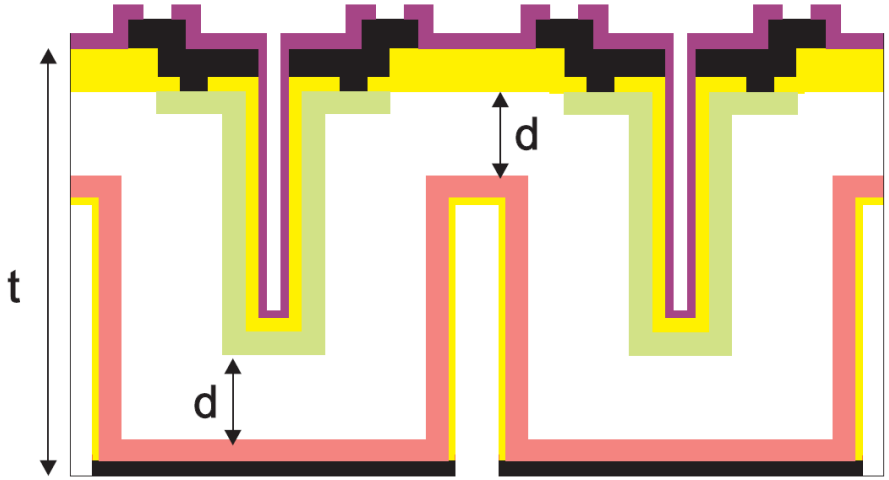
- Simulate negative pulses that have been experimentally observed from 3D detectors in Test Beam and Laser tests measured at Freiburg
- Examine charge multiplication after irradiation
  - Builds on simulations of David Pennicard

3D Detectors

3D-DDTC (CNM-IMB)

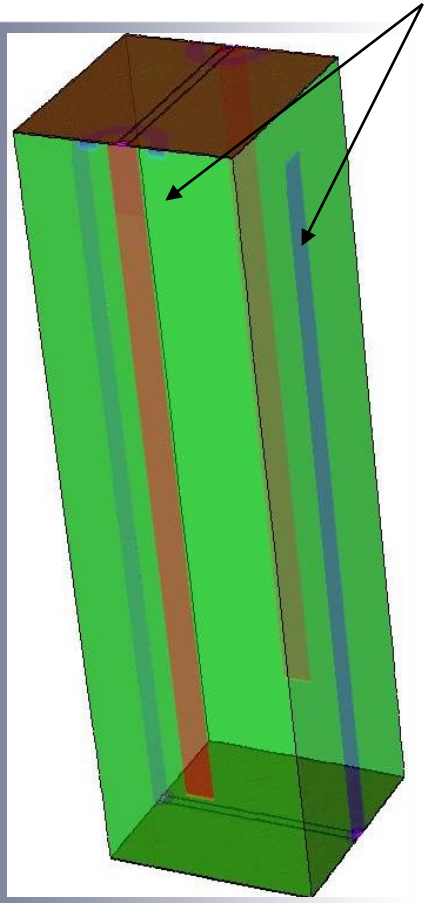


3D-DDTC (FBK-irst)



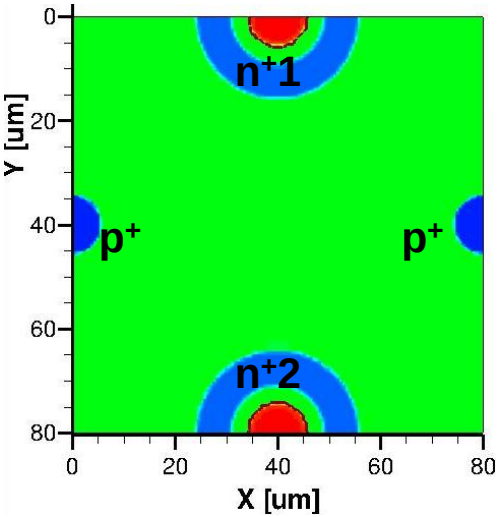
Designs simulated: CNM (p-type)

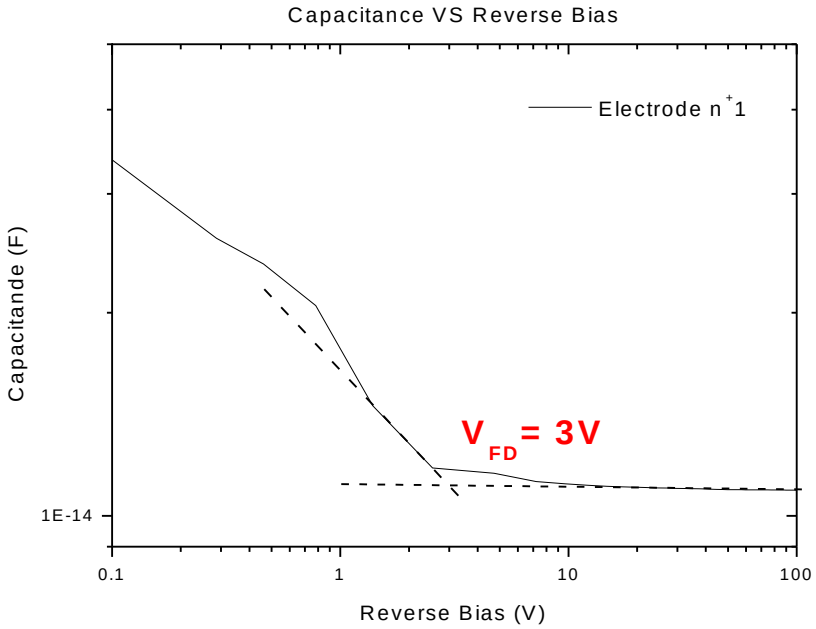
Columns filled with single crystal silicon



Geometrics

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



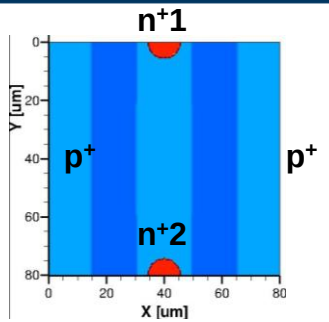


Doping levels

- p-type bulk: 7× 10^{11} cm^{-3}
- n+ columns: 10^{19} cm^{-3}
- p+ columns: 10^{19} cm^{-3}
- column doping has error profile
- p-stop: 10^{18} cm^{-3}
- Si/SiO_2 interface charge: 10^{11} cm^{-2}

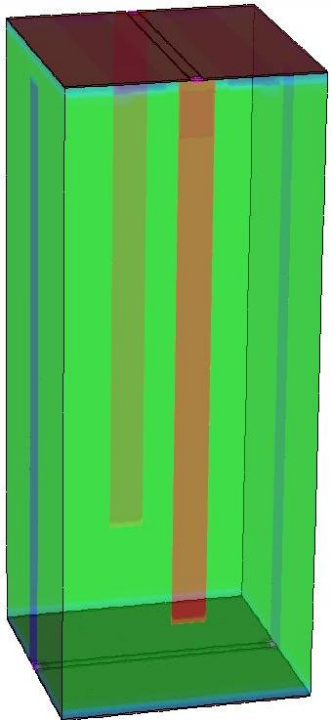
Designs simulated: FBK (n and p type)

P-type



Geometrics

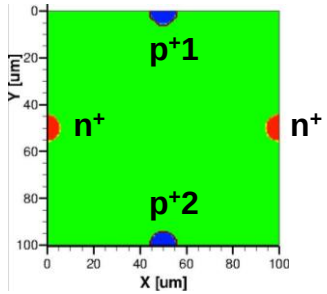
- pitch: 80 µm
- wafer thickness: 200 µm
- p^+ column depth: 190 µm
- n^+ column depth: 170 µm
- column diameter: 10 µm



Doping levels

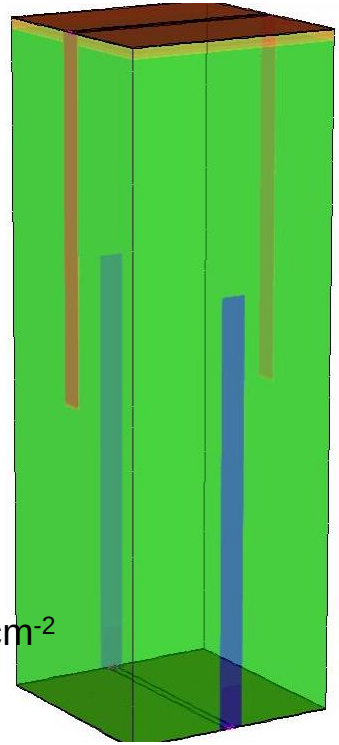
- p-type bulk: 7× 10^{11} cm^{-3}
- n+ columns: 10^{19} cm^{-3}
- p+ columns: 10^{19} cm^{-3}
- p-stop: 10^{18} cm^{-3}
- p-spray: 5 10^{16} cm^{-3}
- p-layer: 10^{19} cm^{-3}
- Si/SiO_2 interface charge: 10^{11} cm^{-2}

N-type



Geometrics

- pitch: 100 µm
- wafer thickness: 300 µm
- p^+ column depth: 190 µm
- n^+ column depth: 160 µm
- column diameter: 10 µm

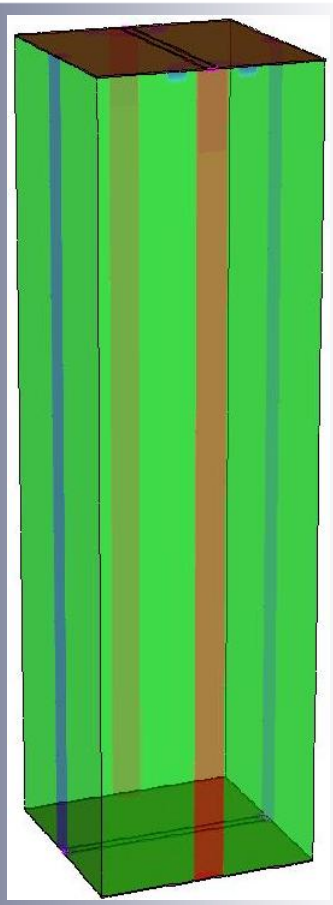


Doping levels

- n-type bulk: 10^{12} cm^{-3}
- n+ columns: 10^{19} cm^{-3}
- p+ columns: 10^{19} cm^{-3}
- p-layer: 10^{19} cm^{-3}
- Si/SiO_2 interface charge: 10^{11} cm^{-2}

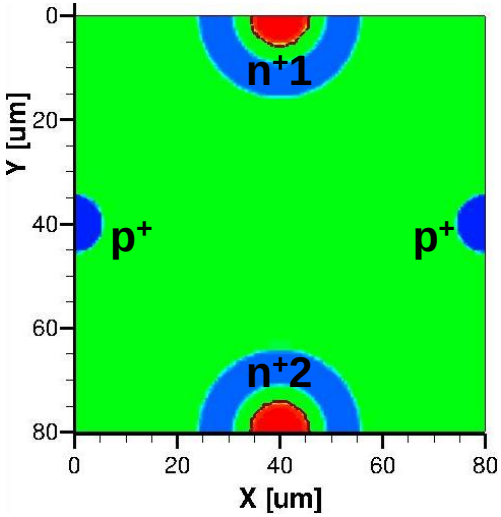
Designs simulated: Full3D (p-type)

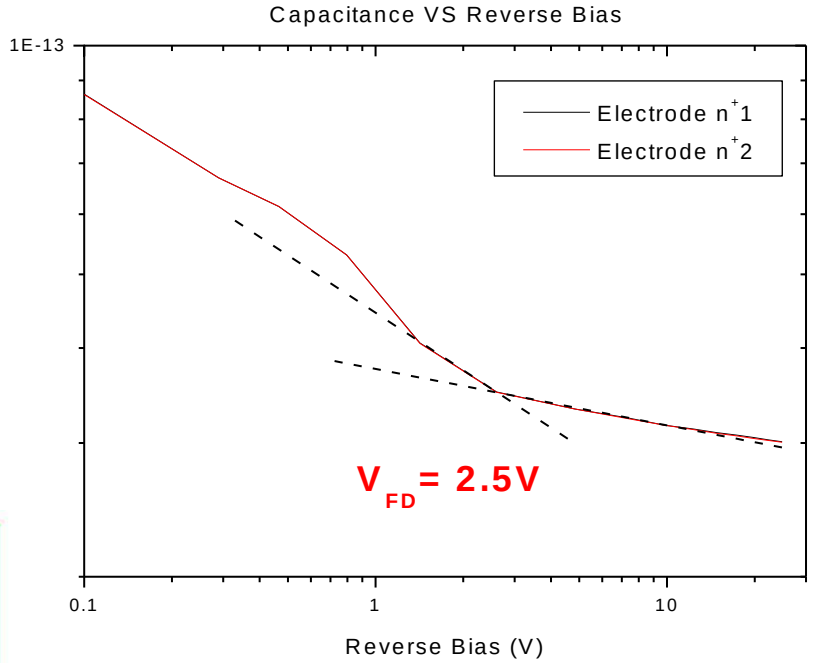
Columns completely filled with doping material



Geometrics

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



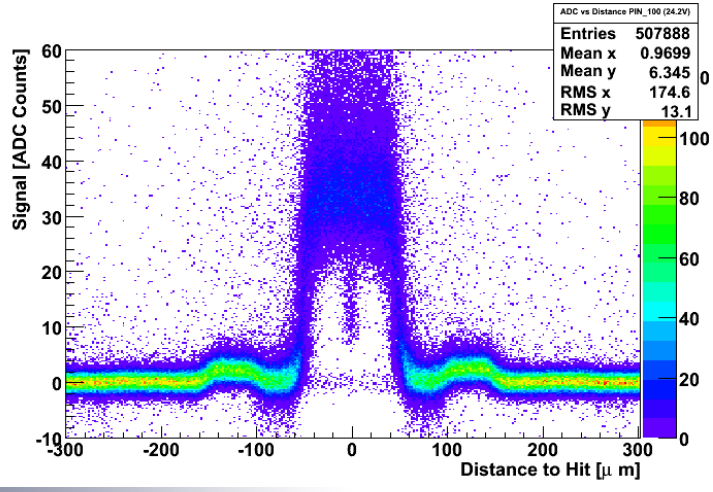


Doping levels

- p-type bulk: 7× 10^{11} cm^{-3}
- n+ columns: 10^{19} cm^{-3}
- p+ columns: 10^{19} cm^{-3}
- column doping has error profile
- p-stop: 10^{18} cm^{-3}
- Si/SiO_2 interface charge: 10^{11} cm^{-2}

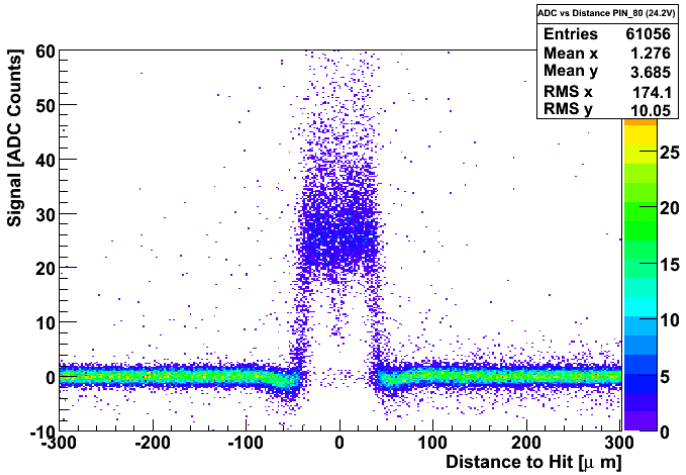
Charge signal from CMS SiBT 2008 Testbeam

FBK n-type. 24V bias



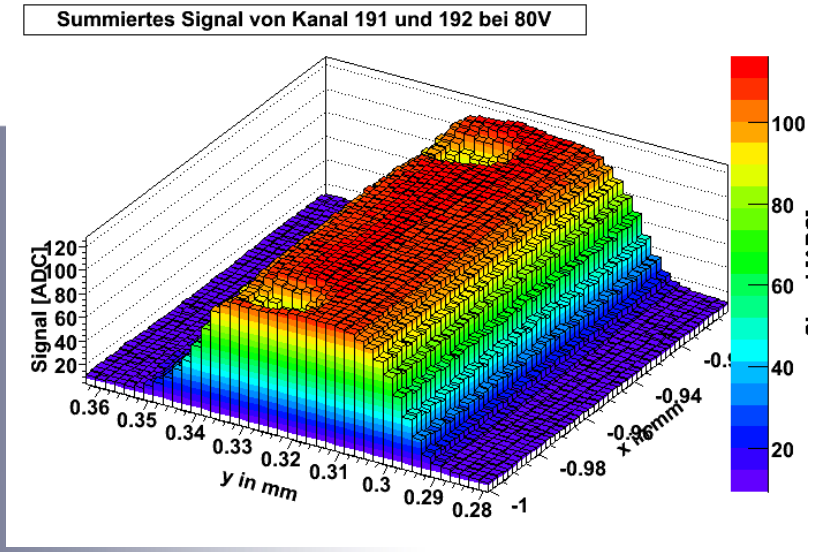
- Pitch is 100um
- Readout strip centred at x = 0
- Negative pulses seen for tracks from 50 to 100um
  - First half of neighbouring cell
- Positive pulses seen for tracks in 2nd half of neighbouring cell

CNM n-type. 24V bias

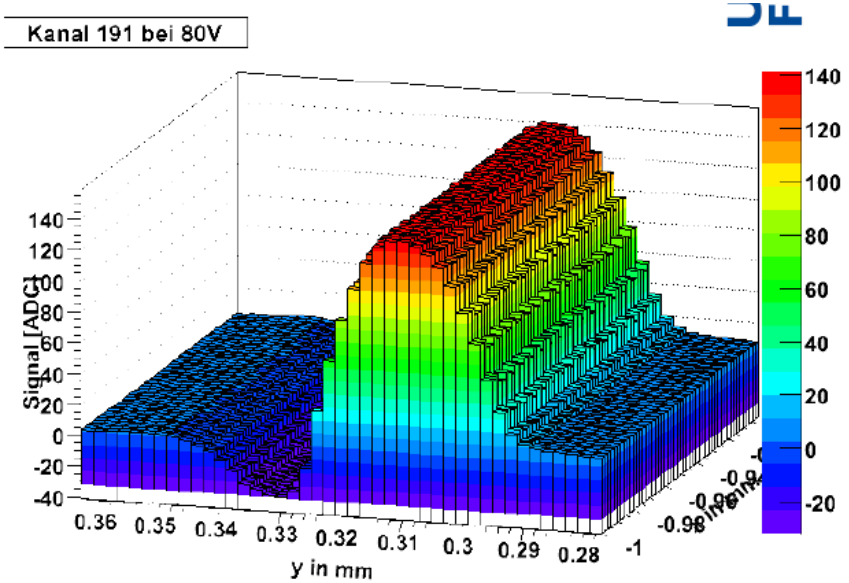


- Pitch is 80um
- Readout strip centred at x=0
- Negative pulses seen from 40 to 80um on either side of readout strip
- No positive pulses seen in 2nd half of neighbouring cell

Laser results – CNM p-type



Signal from sum of two neighbouring strips

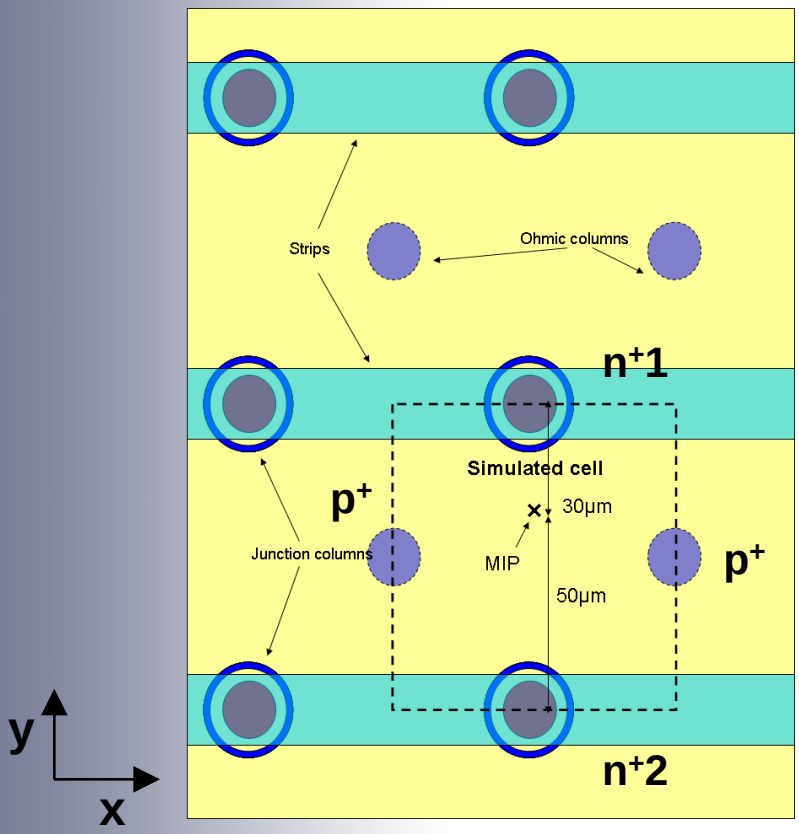


Signal from only one strip

- CNM double sided device
- P-type bulk, n-type readout strips, 80µm pitch
- Laser illumination, step size 2µm
- Negative pulse seen when laser illuminates neighbouring strip
- Maximum negative signal seen 50µm from centre of readout strip

Device simulated

Simulated cell for both CNM and Full3D designs



Deposited uniform charge cloud with 80e/h pairs / µm of thickness

⇒ 22800 Electrons in total (CNM)

The track had a Gaussian lateral distribution, with a standard deviation of 1 micrometer

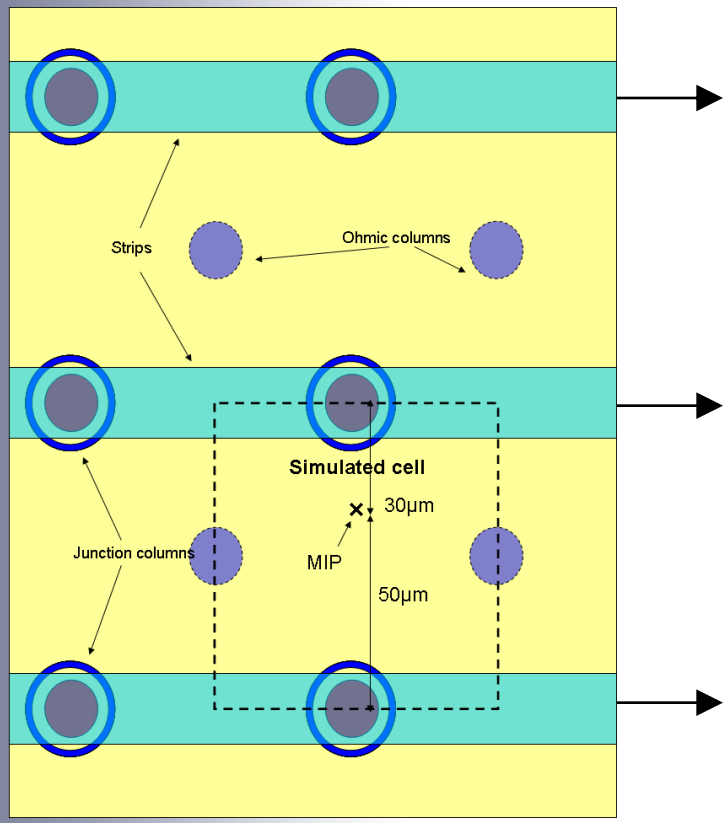
Track position:

Midway between p^+ back side contacts (x position)

10 µm off centre between n^+ readout columns of different strips (y position)

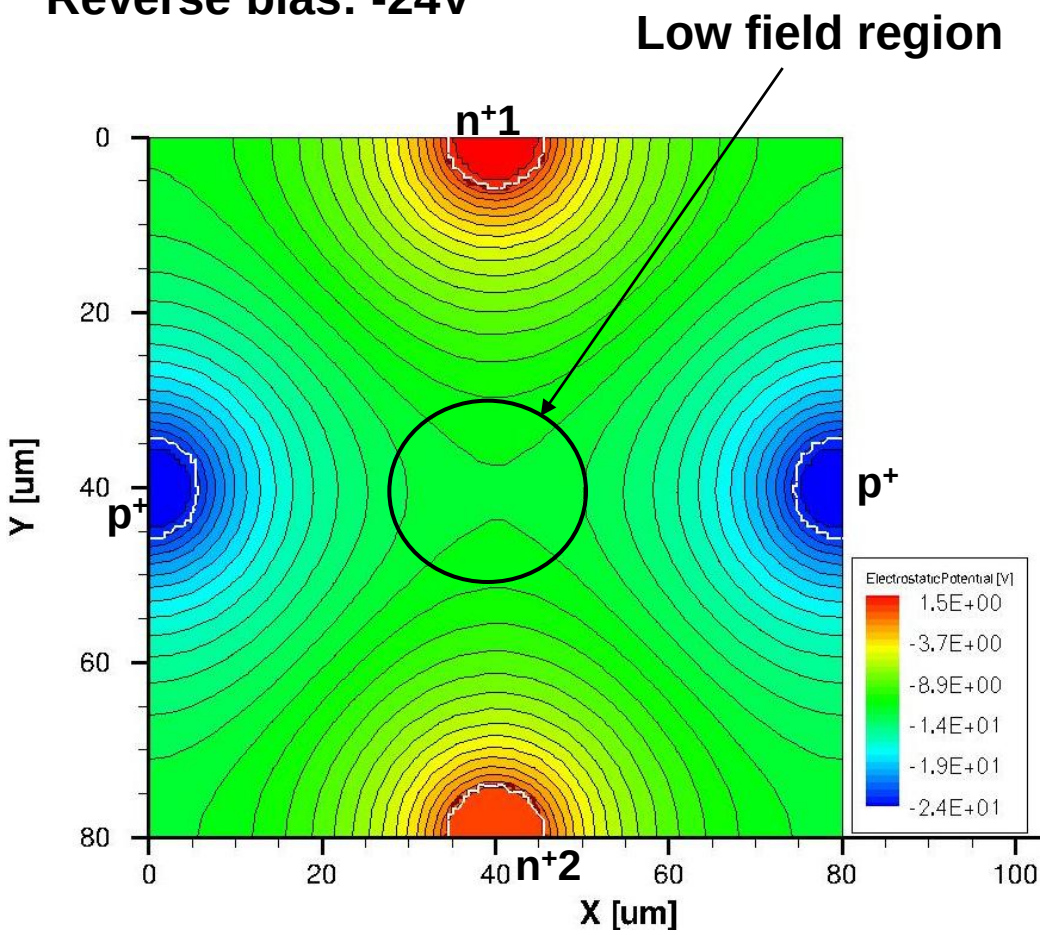
Potential in device

Simulated cell for both CNM and Full3D designs

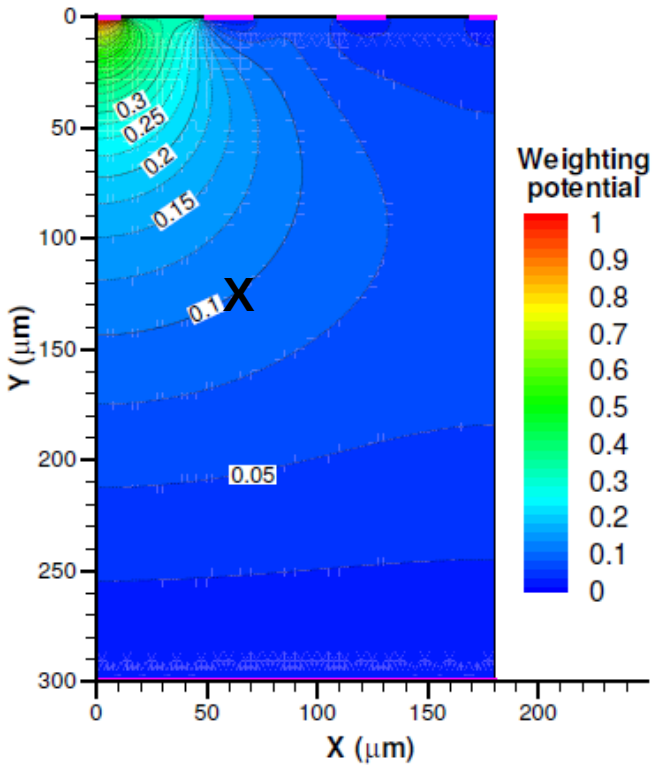


Simulated Potential. CNM P-type.

Reverse bias: -24V



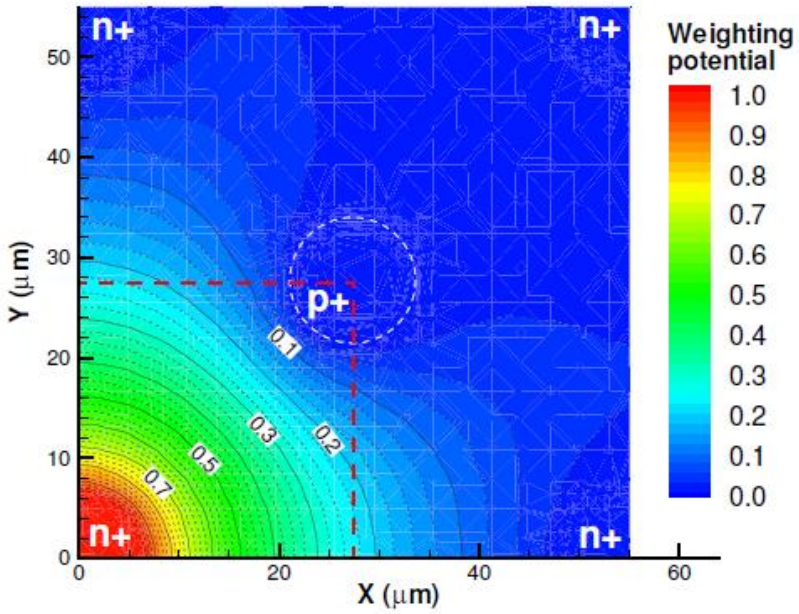
Weighting potentials



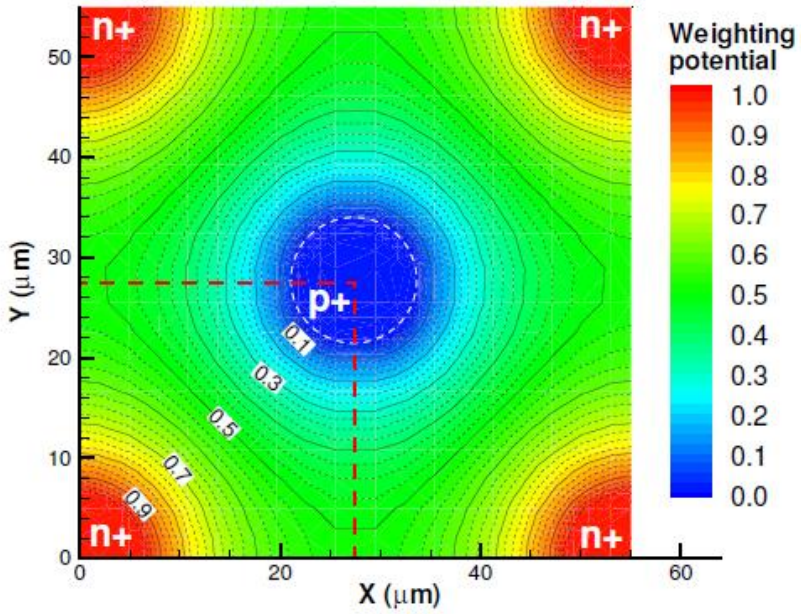
- Charge signal for carrier moving from point A to point B
  - $= q\,(\Psi_w(x_B) - \Psi_w(x_A))$
- So signal for e/h generates at X is
  - $-q(0 - 0.1) + q(0 - 0.1) = 0$
  - Which is nice
- Signal also bipolar due to charge carrier crossing higher weighting potential lines in both directions
  - 0.1 to 0.15 to 0.1 to 0

Weighting potentials

Pixel

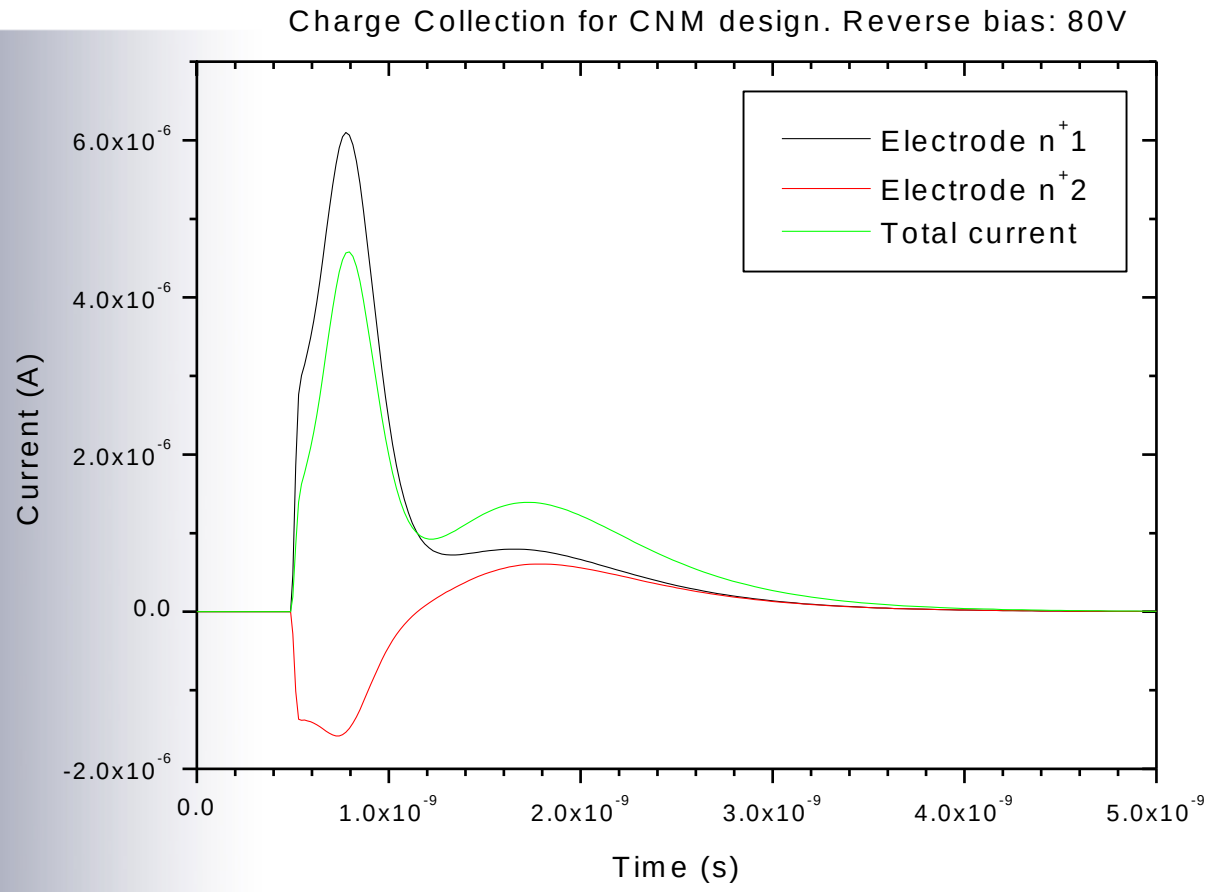


Diode



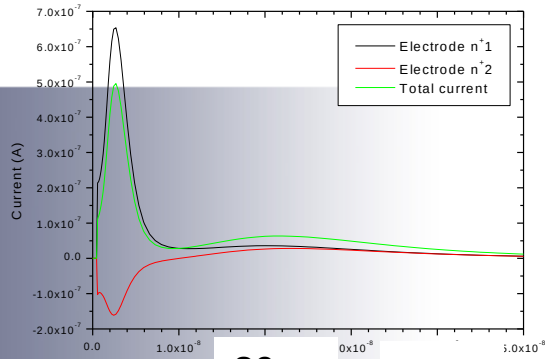
- Our weighting potential some where between these two cases
- Reasonable potential in neighbouring cell
  - Big current for movement in neighbouring cell
  - Should go to zero is all charge is collected

Results – current pulse CNM double sided at 3V bias



Results: Charge Collection (CNM p-type)

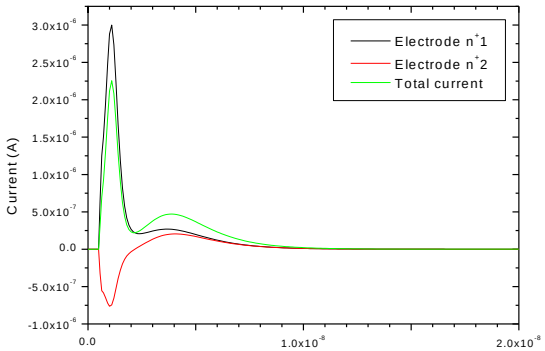
I at 3V bias



20ns 40ns

	25ns	50ns
n+1	17097	19753
n+2	-1868	585
total	15223	20338

I at 24V bias

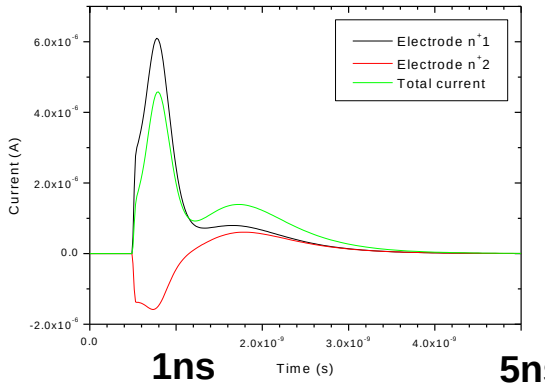


5ns 15ns

	20ns
n+1	20983
n+2	812
total	21795

4.5% CEI

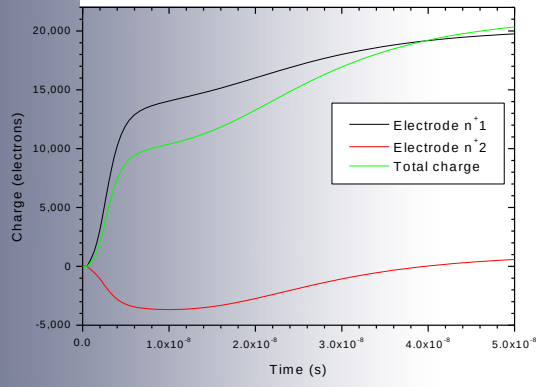
I at 80V bias



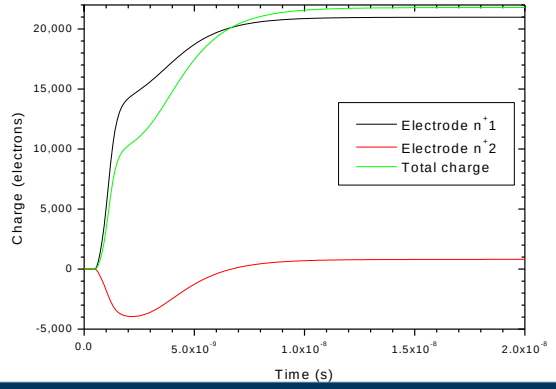
1ns 5ns

	5ns
n+1	21827
n+2	757
total	22584

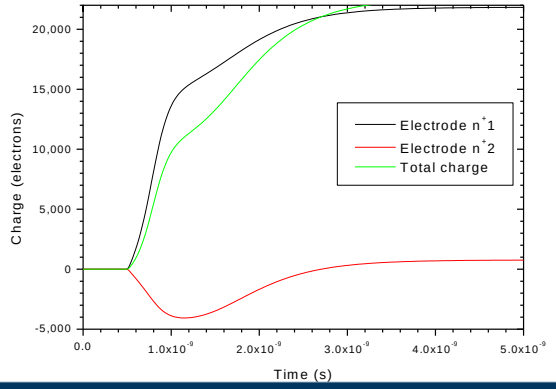
Q at 3V bias



Q at 24V bias

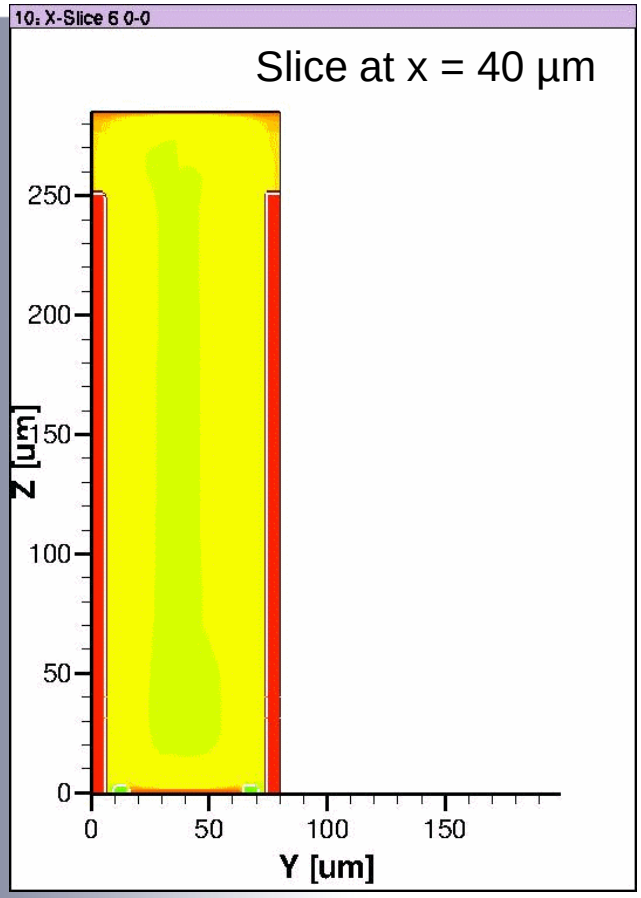


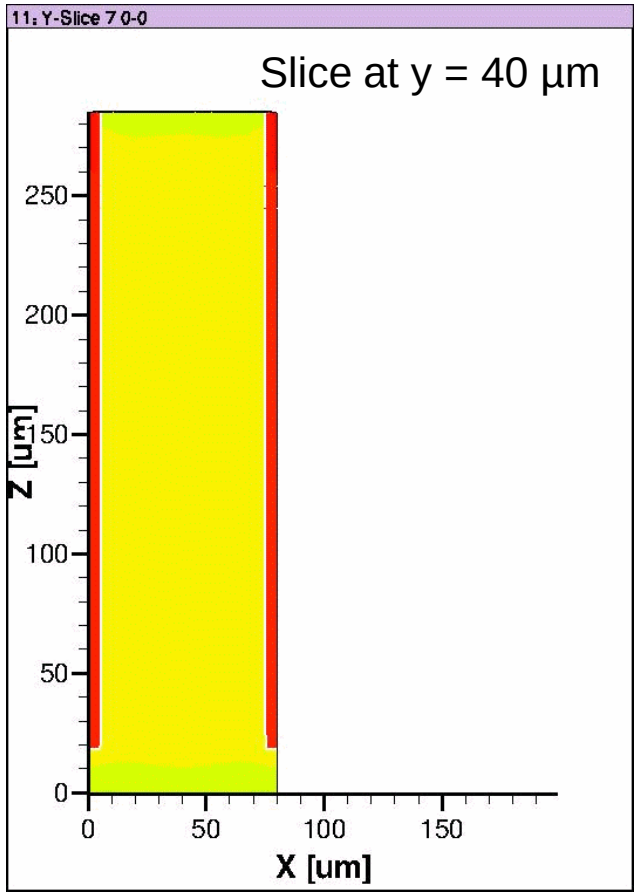
Q at 80V bias



Results: Charge Collection (CNM p-type)

Electrons collection **80V** **Holes collection**

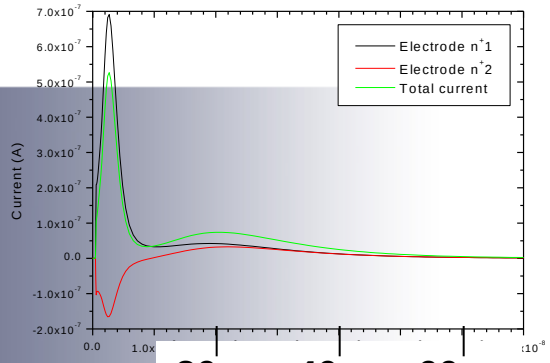




Time: 0 – 5 ns (step 0.5ns)

Results: Charge Collection (Full3D p-type)

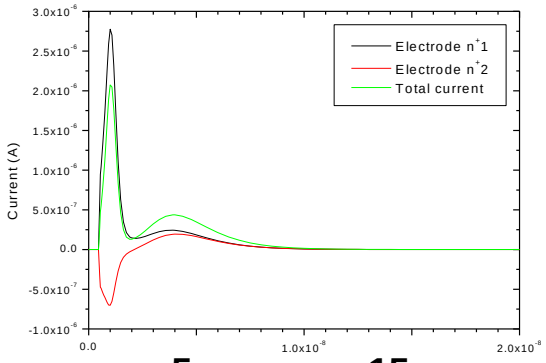
I at 3V bias



20ns 40ns 60ns

	25ns	70ns
n+1	18023	21113
n+2	-1422	1488
total	16600	22601

I at 24V bias

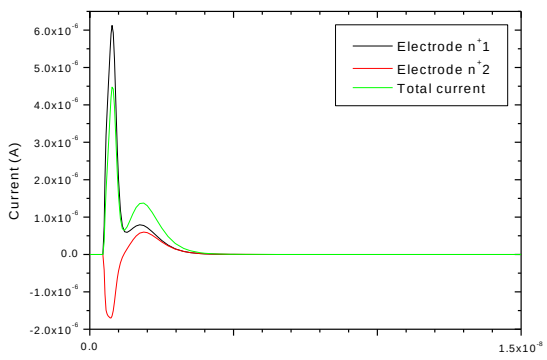


5ns 15ns

	20ns
n+1	17774
n+2	955
total	18729

Something wrong here!

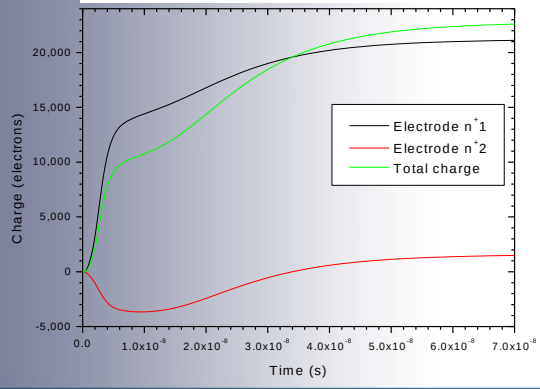
I at 80V bias



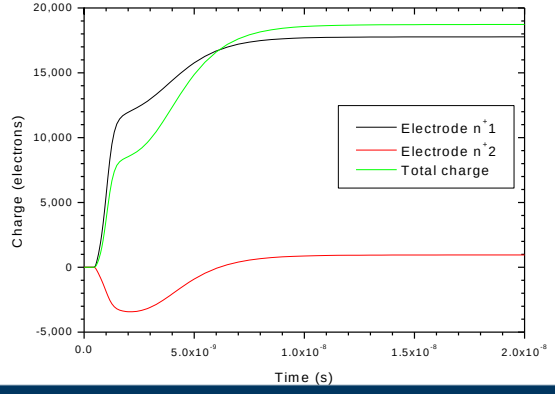
5ns 10ns

	15ns
n+1	21247
n+2	244
total	21591

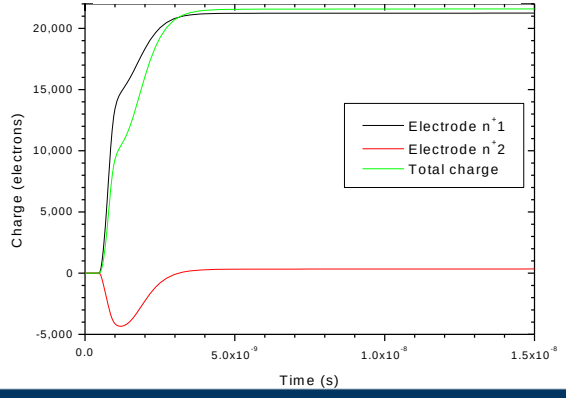
Q at 3V bias



Q at 24V bias

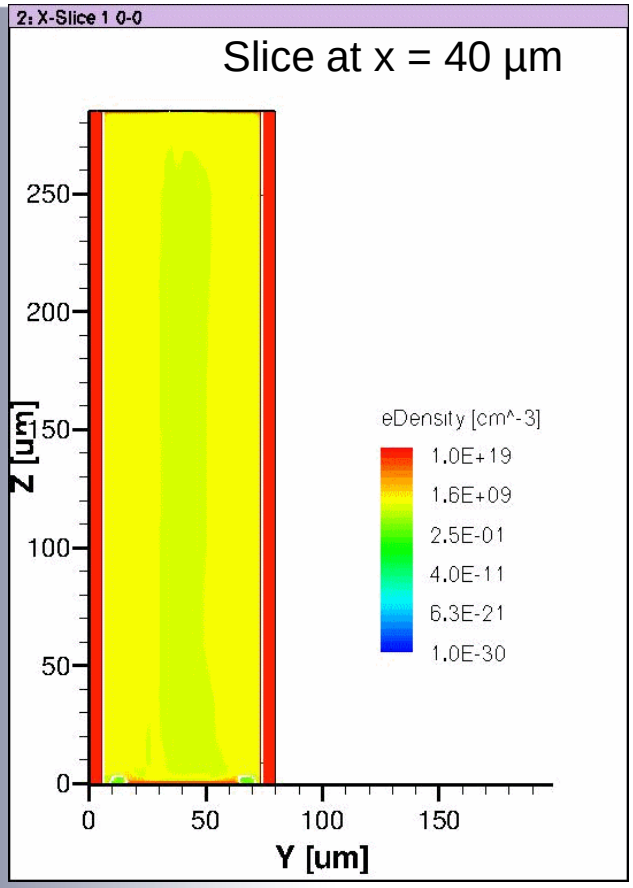


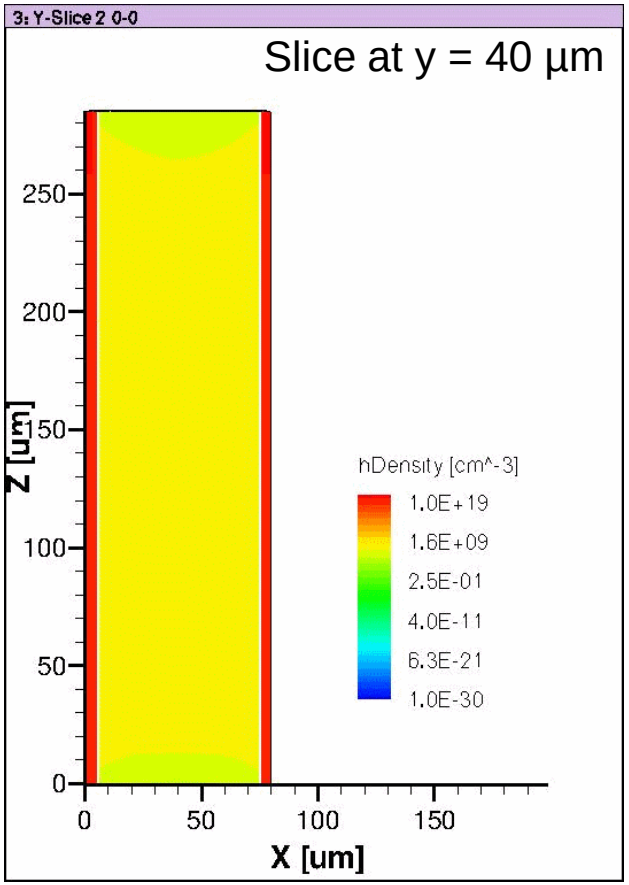
Q at 80V bias



Results: Charge Collection (Full3D p-type)

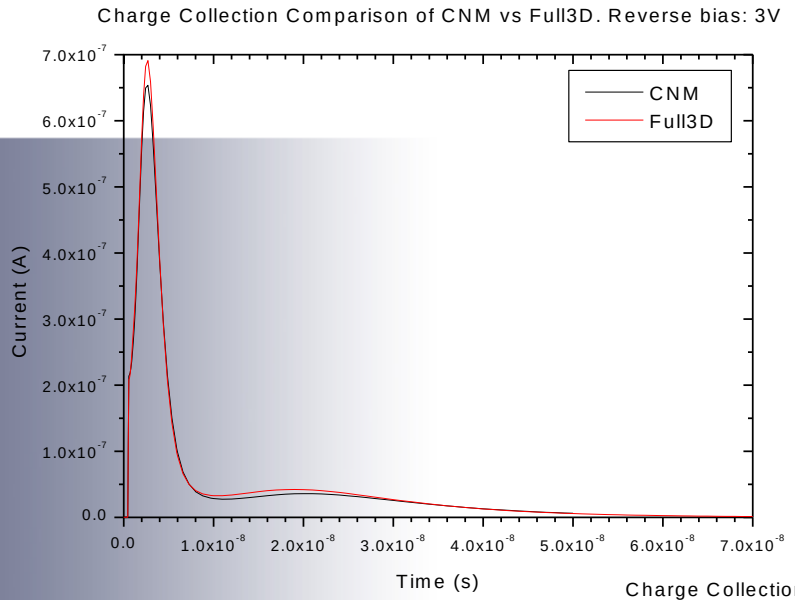
Electrons collection **80V** **Holes collection**

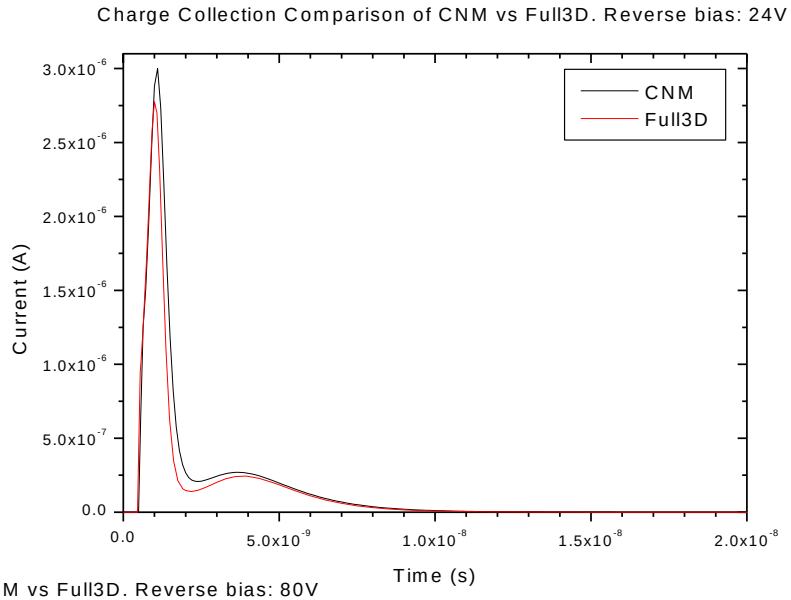


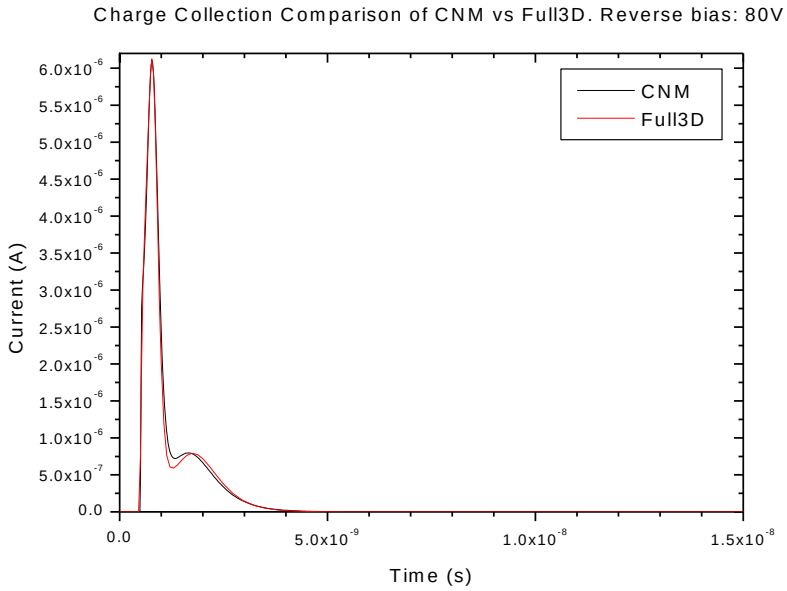


Time: 0 – 5 ns (step 0.5ns)

Results: CNM vs Full3D (p-type)







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Conclusions

- Early days
- 3D simulation of 3D detectors up and running again.
- We have not yet managed yet to simulate the negative signals that are observed in Testbeam and Laser tests.
- Need to improve mesh, time steps and model to be more realistic
  - More realistic electrodes - added some resistivity & recombination to the doped columns (poly rather than signal crystal)
  - Maybe a contact resistance?
  - Recombination at the oxide
- We can see what would be a negative pulse when operated at low bias and fast sampling time.
- But at high bias there is no negative charge signal.

Future work

- Simulate 3D negative pulses as observed in Test Beams and Laser tests.
  - Currently working on n-type devices
- Examine charge multiplication after irradiation