Simulation and test of 3D detectors in Glasgow

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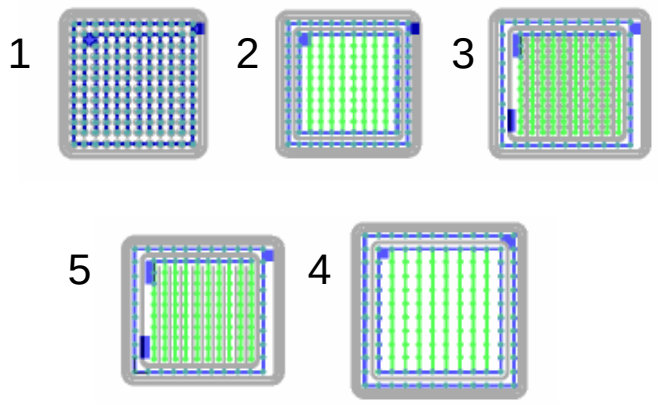
Outline

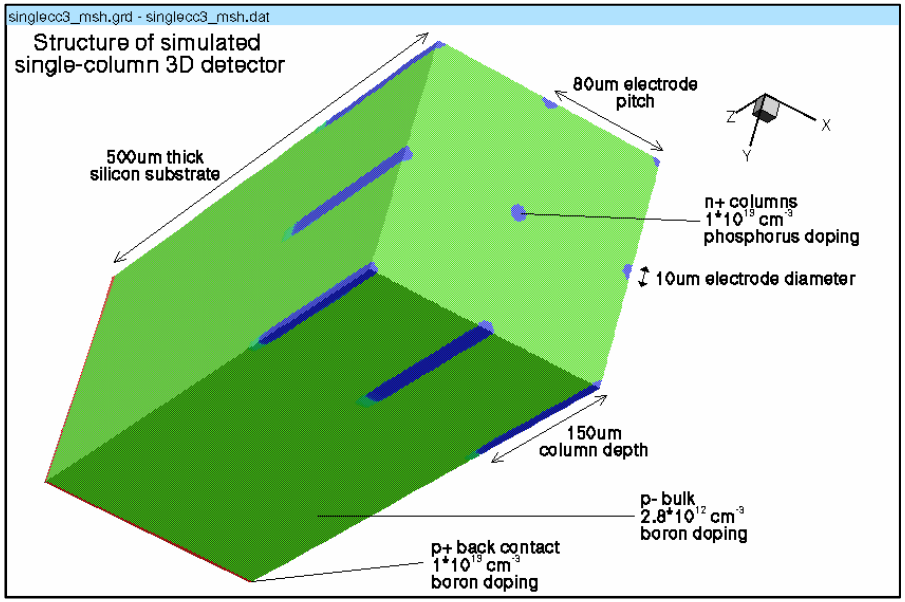
- Single-type column 3D detectors
  - Fabricated by ITC-irst (Trento) and CNM (Barcelona)
  - Results from simulation and test
- Double-sided 3D detectors
  - Designed by CNM
  - Results from simulation
- Conclusions

Single-type column 3D detectors

- n+ columns on p- substrate, p+ implant on backside
  - 10x10 columns arrays
  - Column depth 150 μm
  - Diameter 10 μm
  - Pitch 80 μm (100 μm for detector 4)
- FZ silicon, 500 μm, ρ >5 kΩ.cm (doping conc. $2.8*10^{12}$ cm^{-3})

5 Different p-stop configurations

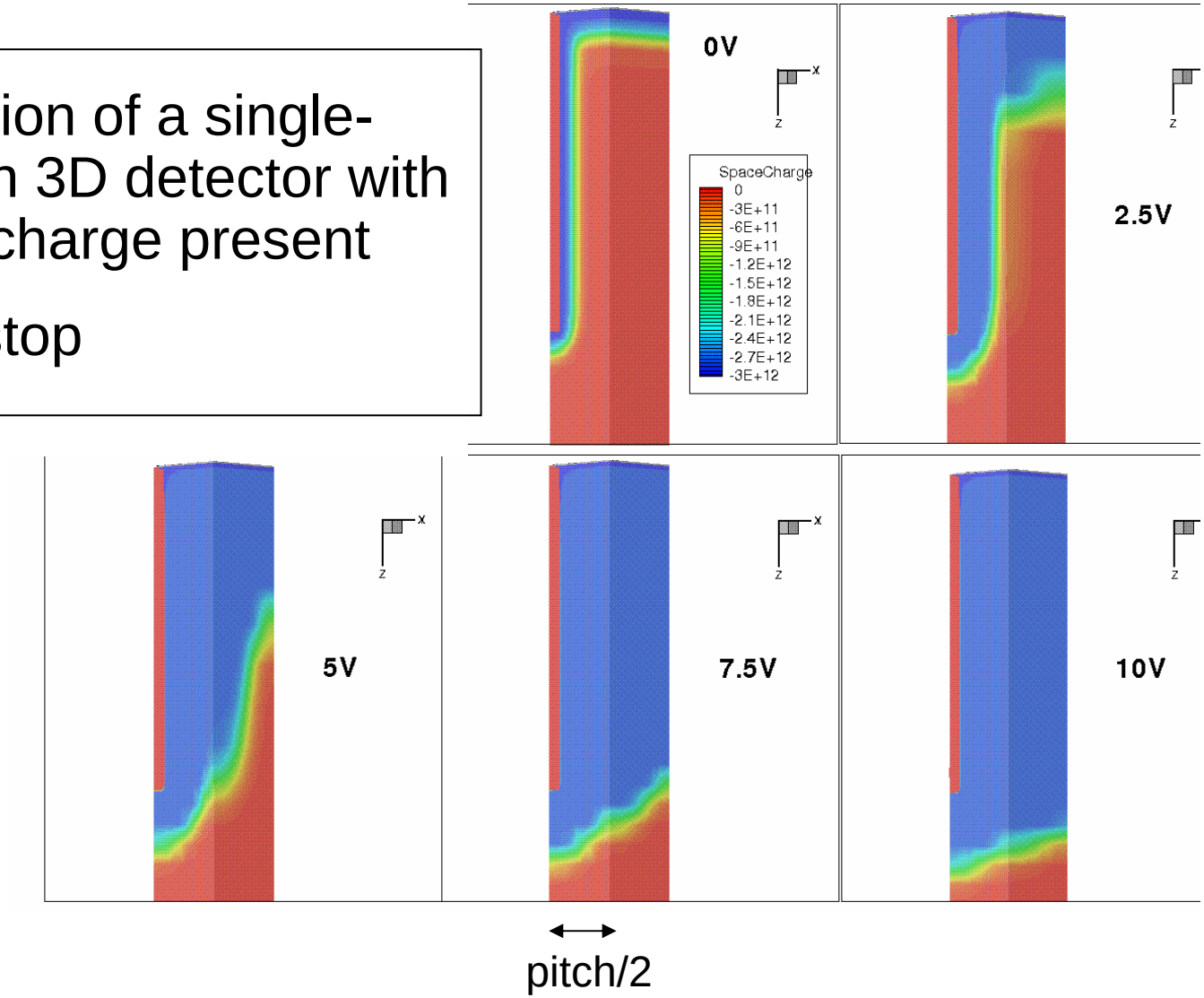




Depletion behaviour without p-stop

Depletion of a single-column 3D detector with oxide charge present

No p-stop

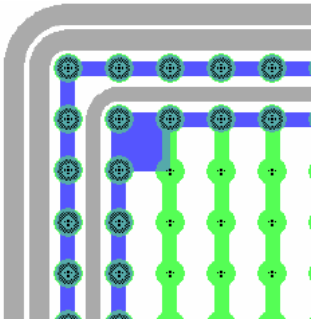


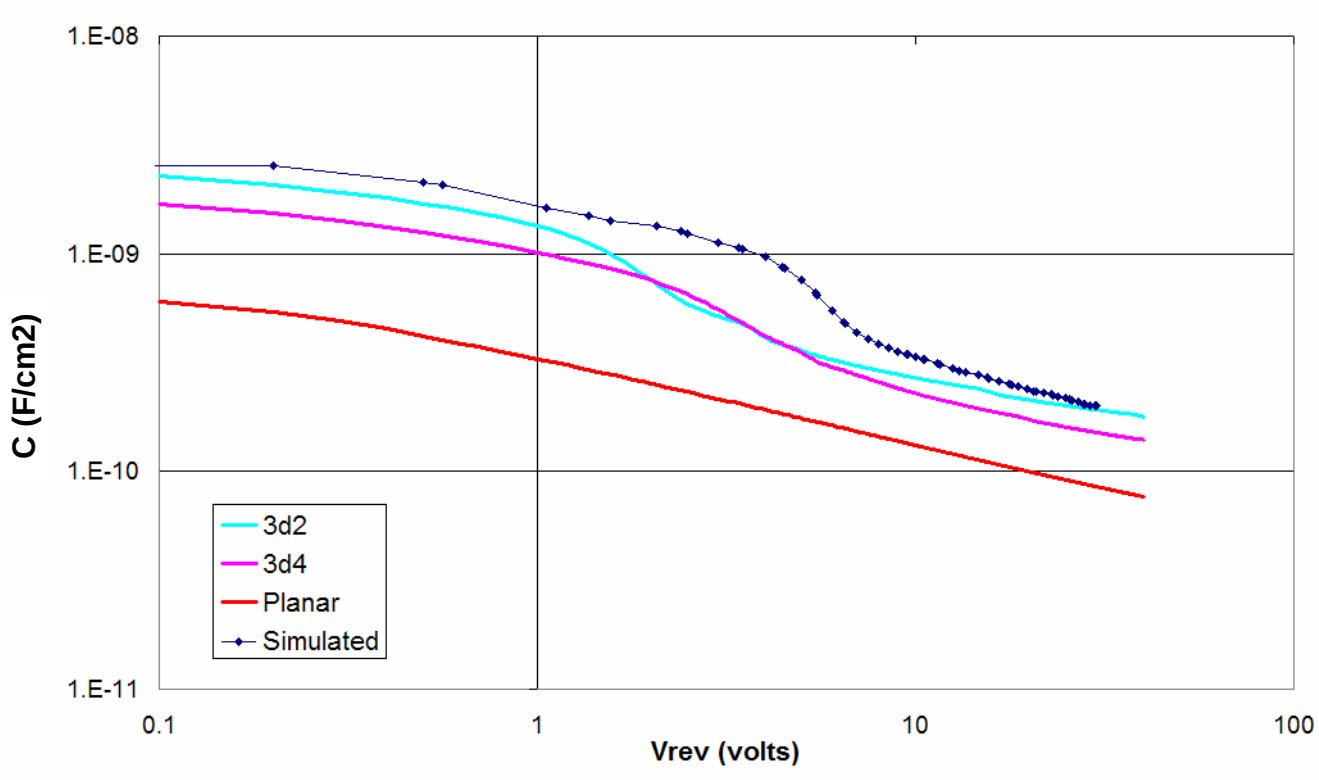
C-V measurements: without p-stop

3d2 and **3d4**

-P-stop between guard ring and active area

-No single-hole p-stop





- Guard ring not biased
- 10 kHz
- **Full depletion between electrodes at ~ 7 V.**
- **Planar-like depletion afterwards**

C-V measurements: with p-stop

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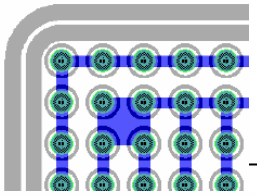
•3d1

-Single p-stop around holes

-Width 5 mm

FD @ ~8 volts

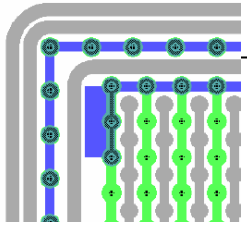


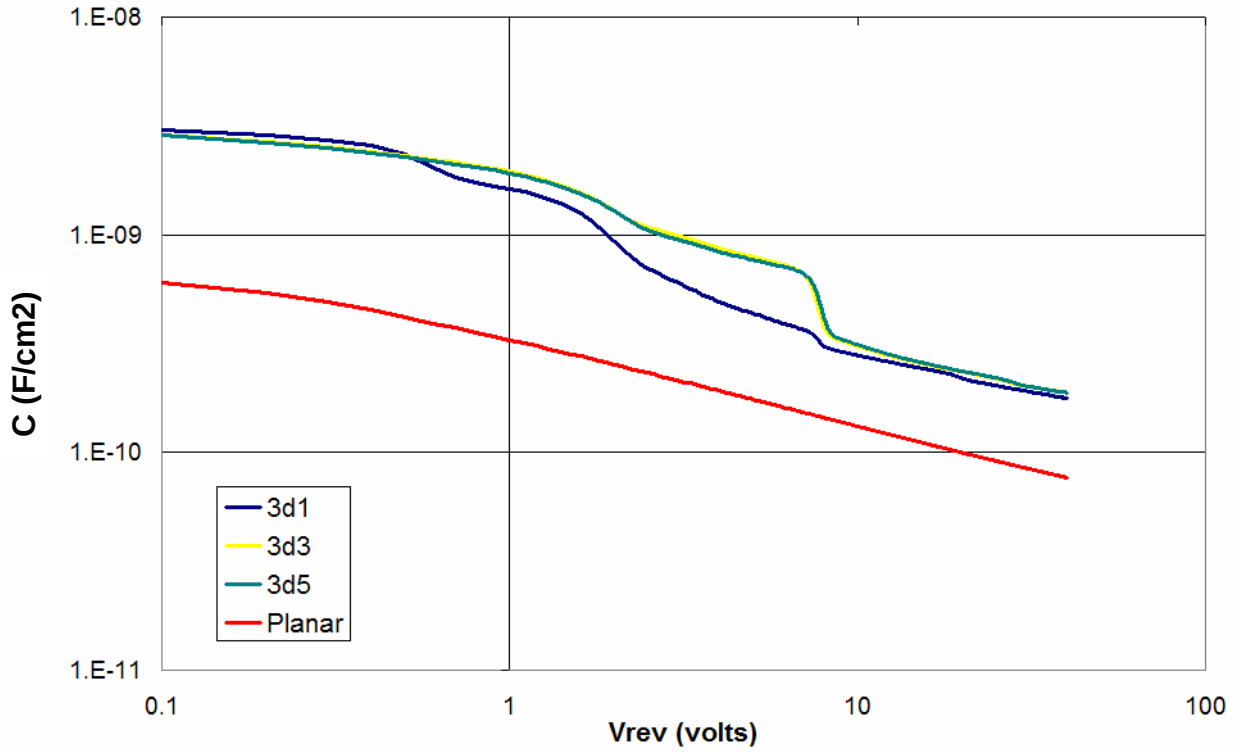
3d3 and 3d5

-P-stop between GR and active area

-Strip-like p-stop, width: 20 or 15 µm

FD @ ~8.5 volts

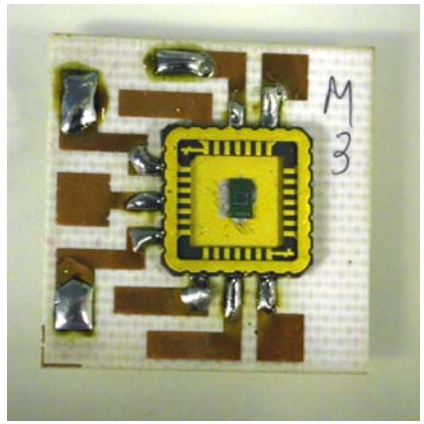


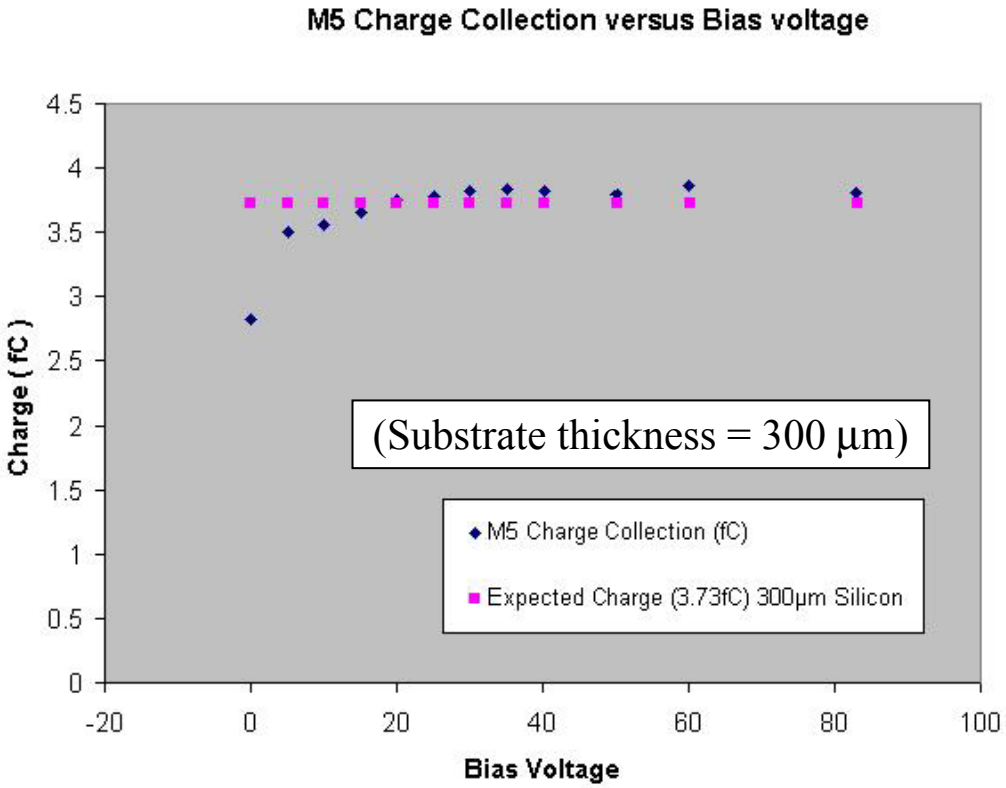


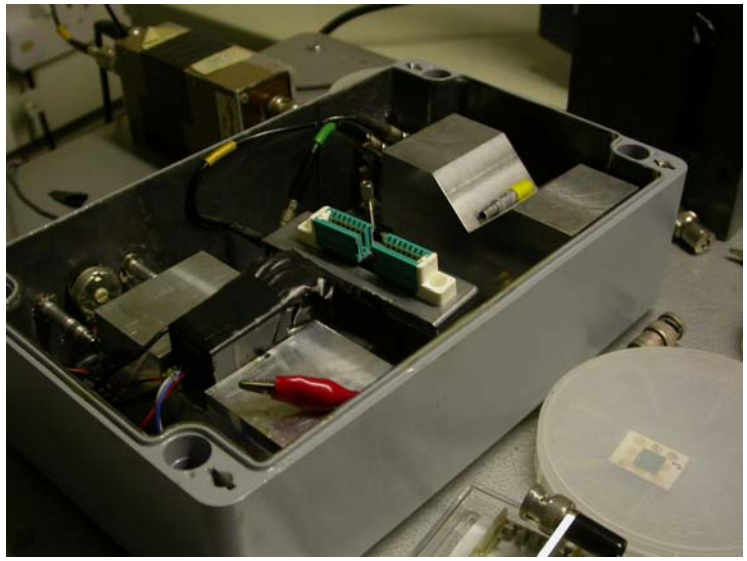
- **P-stop modifies depletion behaviour**

CCE (work in progress)

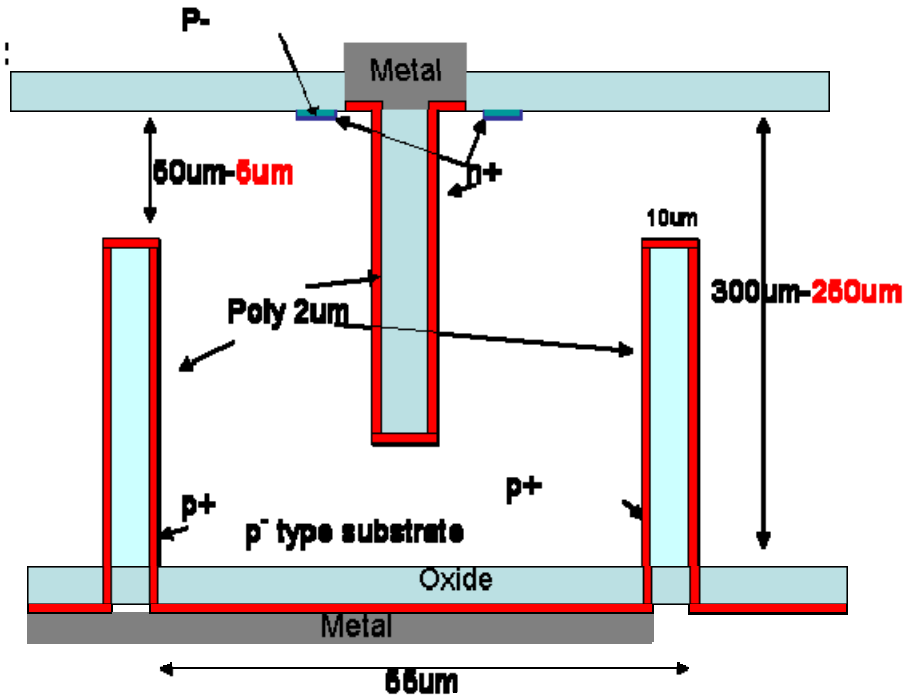
- New CCE setup
  - Strontium-90 2.283MeV β- source
  - Operational, but still needs calibration
  - Results ready for next RD50 meeting

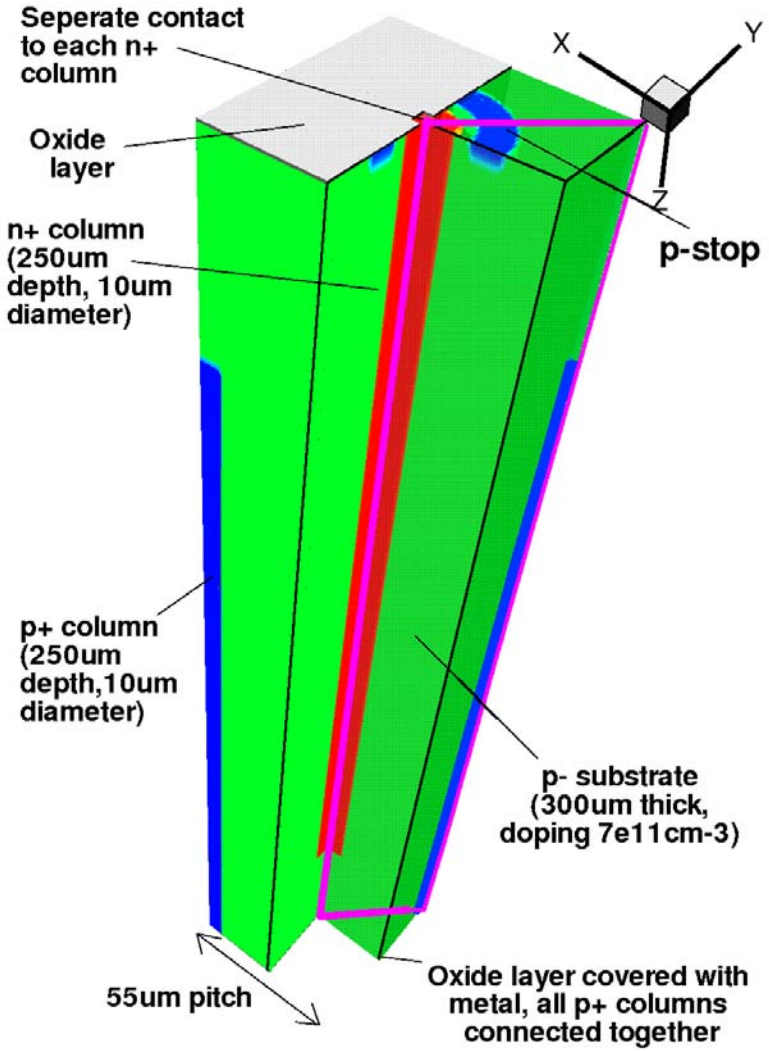




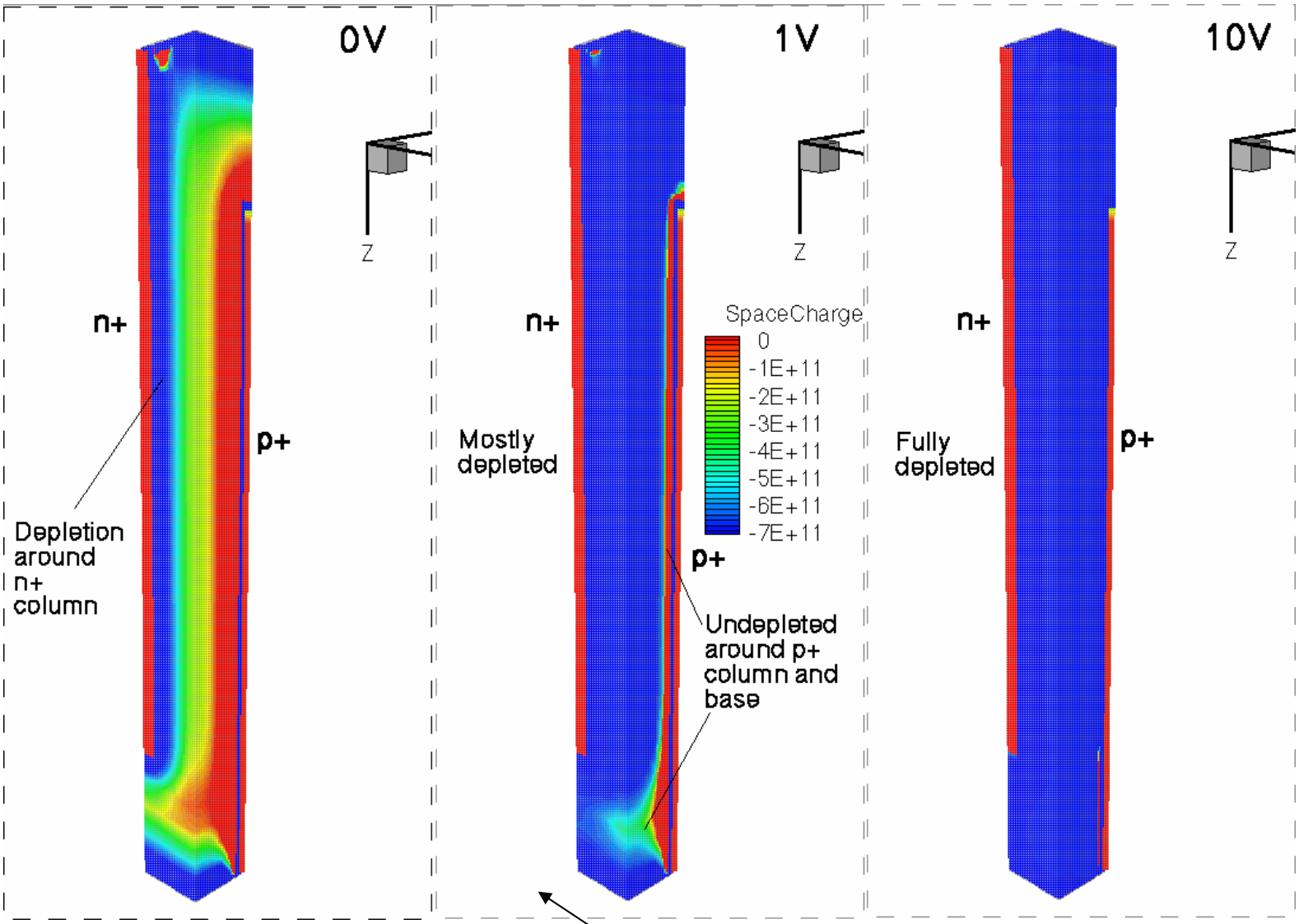


Double-sided 3D detectors

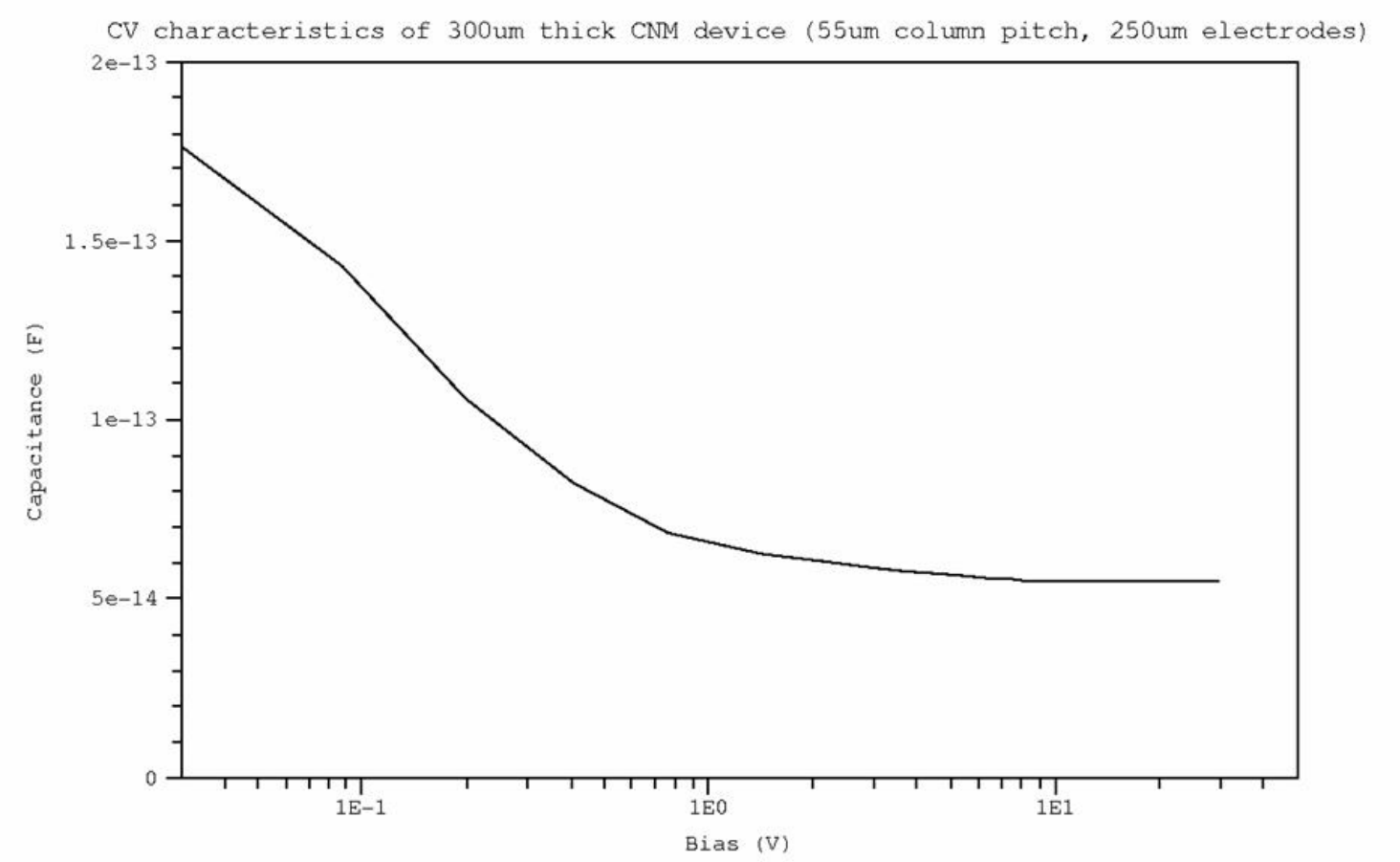




Depletion behaviour

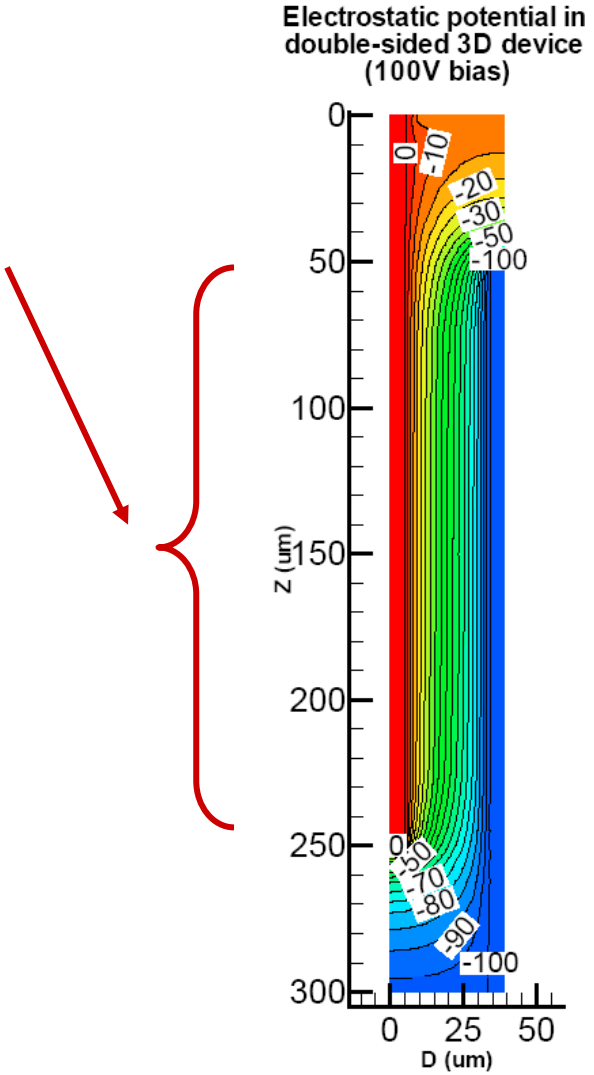


Depletion behaviour



Electric potential and field

1. Overlap region
   - 50 to 250μm
   - Field pattern like in a standard 3D device
   - **Charge carriers swept horizontally towards the electrodes**



Electric potential and field

1. Overlap region
   - 50 to 250μm
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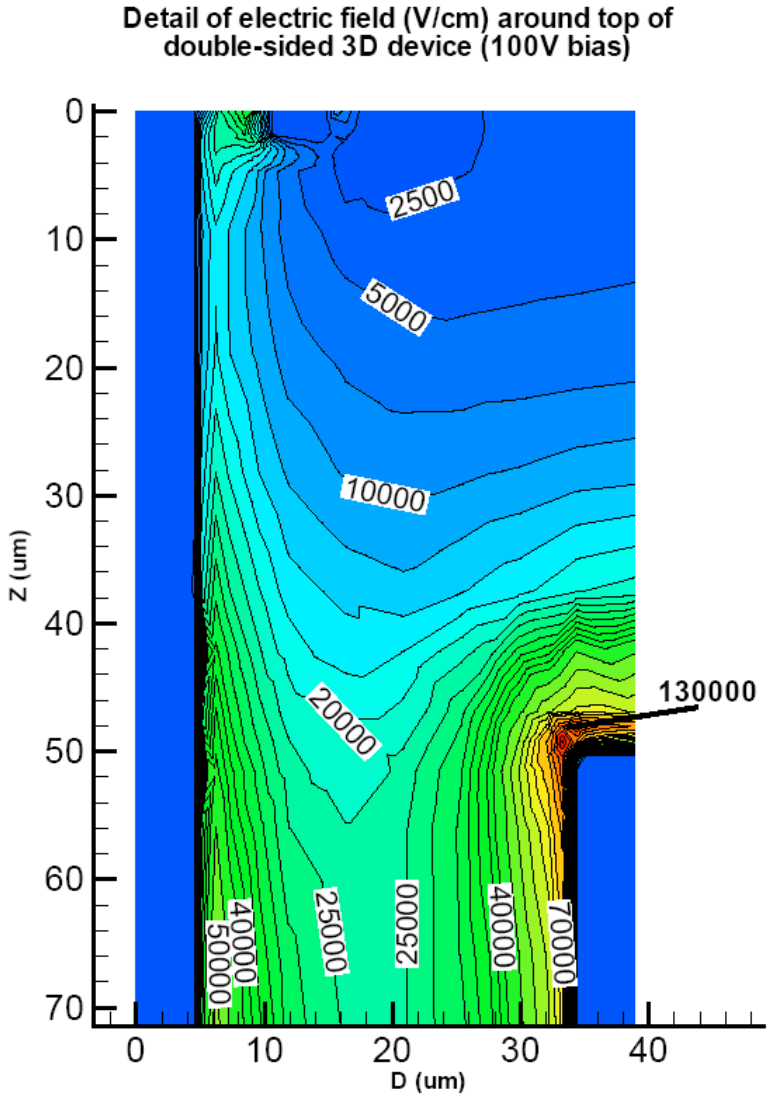
   - **Charge carriers swept horizontally towards the electrodes**

2. Near surface
   - Reduced field strength
   - Increased drift distance
   - **Longer collection times**

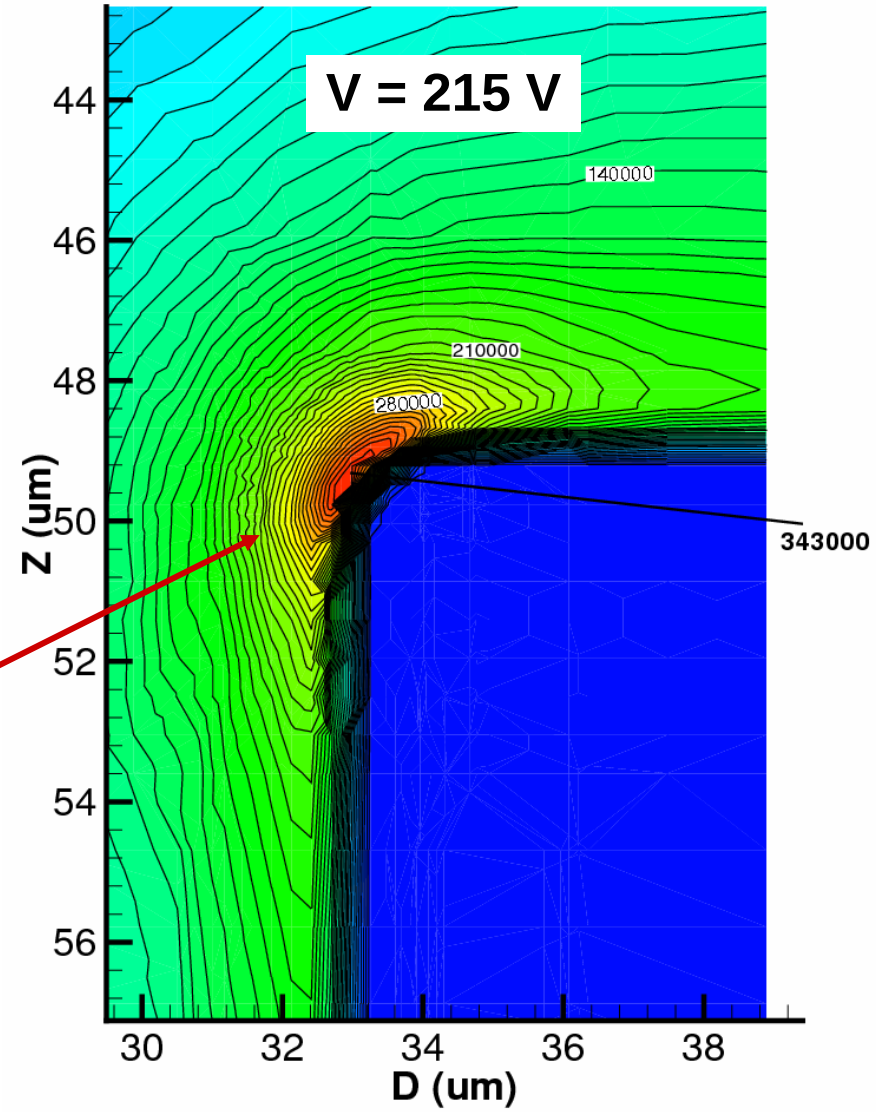


Electric potential and field

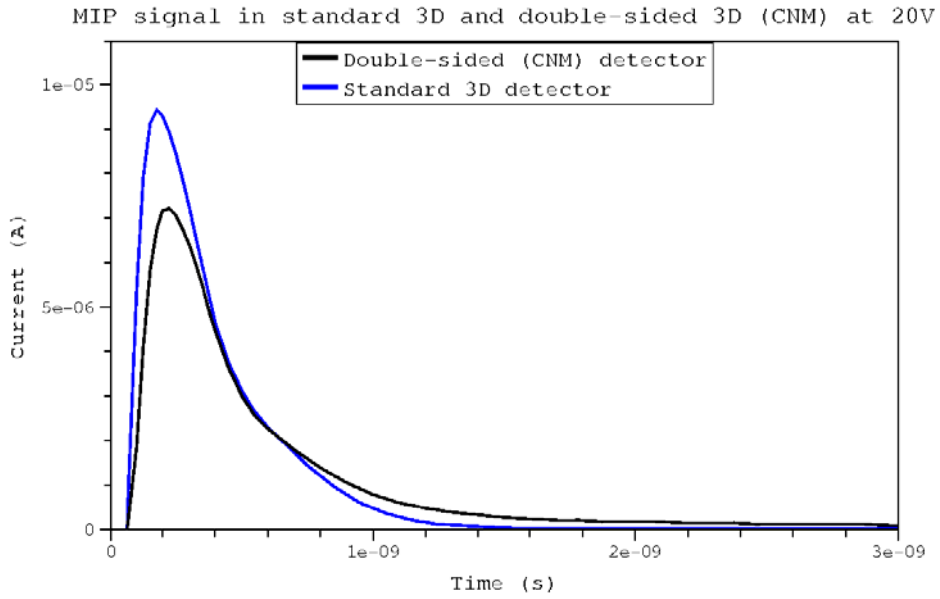
1. Overlap region
   - 50 to 250μm
   - Field pattern like in a standard 3D device
   - **Charge carriers swept horizontally towards the electrodes**

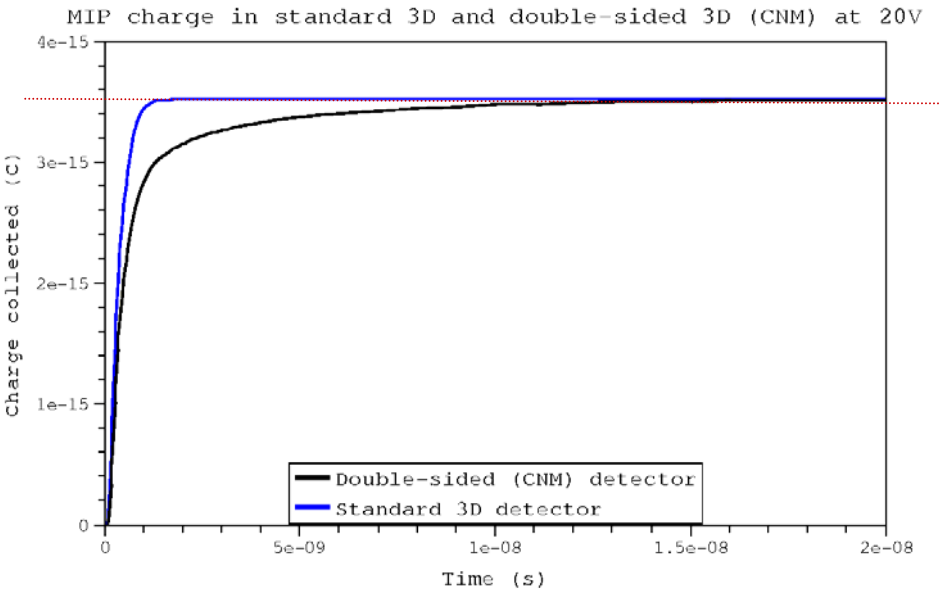
2. Near surface
   - Reduced field strength
   - Increased drift distance
   - **Longer collection times**

3. Top of the columns
   - High field region
   - VBD > 215 V
   - **The device can be safely operated**

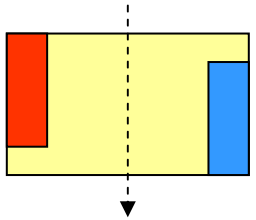


Charge collection





- Comparison with ideal 3D detector
  - Columns all the way through the wafer
  - Same dimensions as double-sided 3D
- V = 20 V
- MIP arriving midway between the electrodes



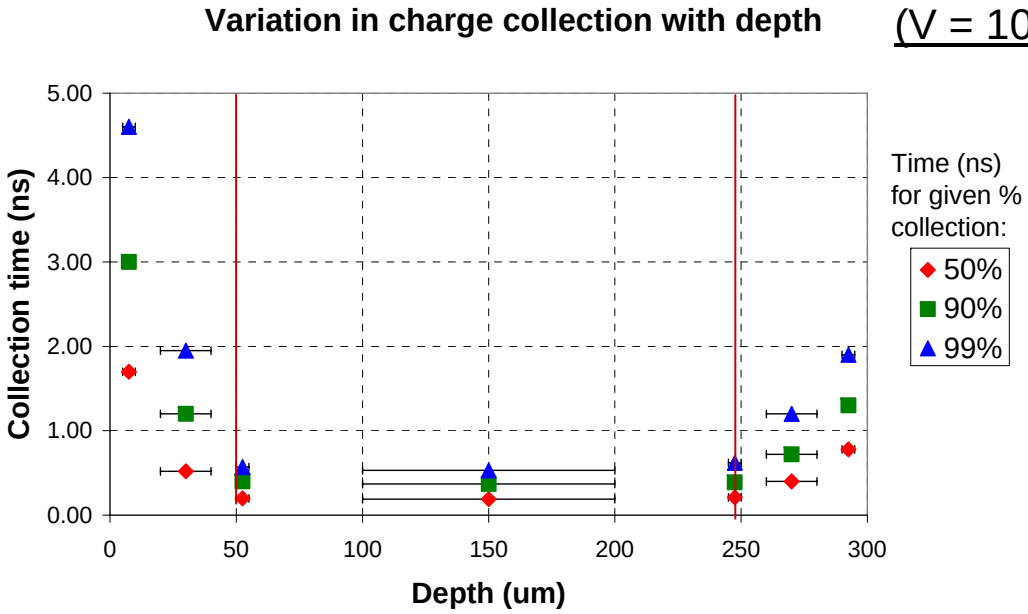
Ideal 3D:

- All charge collected in 1.5 ns

Double-sided 3D:

- 92% of charge in 3 ns
- 97% in 5 ns

Charge collection



- Charge carriers collected more slowly from the low-field regions near the surfaces
  - This causes the long tail-off
- However, with V = 100 V,
  - 90% of charge collected in 0.75 ns and 99% in 2.8 ns
  - 10-20 ns for a planar detector

Conclusions

- 3D-single-type columns detectors
  - Simulations and C-V measurements:
    - Depletion behavior depends on p-stop structure
    - Region between electrodes is fully depleted at ~8 V for all devices
    - Depletion continues to backplane much like in a planar device
  - Preliminary CCE results :
    - 100% of the charge collected at 30 V for a 300 µm thick detector
    - Charge collected even at 0 V due to already depleted regions
- Double-sided 3D detectors:
  - Very promising characteristics from simulations:
    - Device fully depleted at 10 V
    - Breakdown voltage > 200 V
    - Where columns overlap the behaviour is similar to that of an ideal 3D
    - There are low field regions but still rapid charge collection

Extra slides

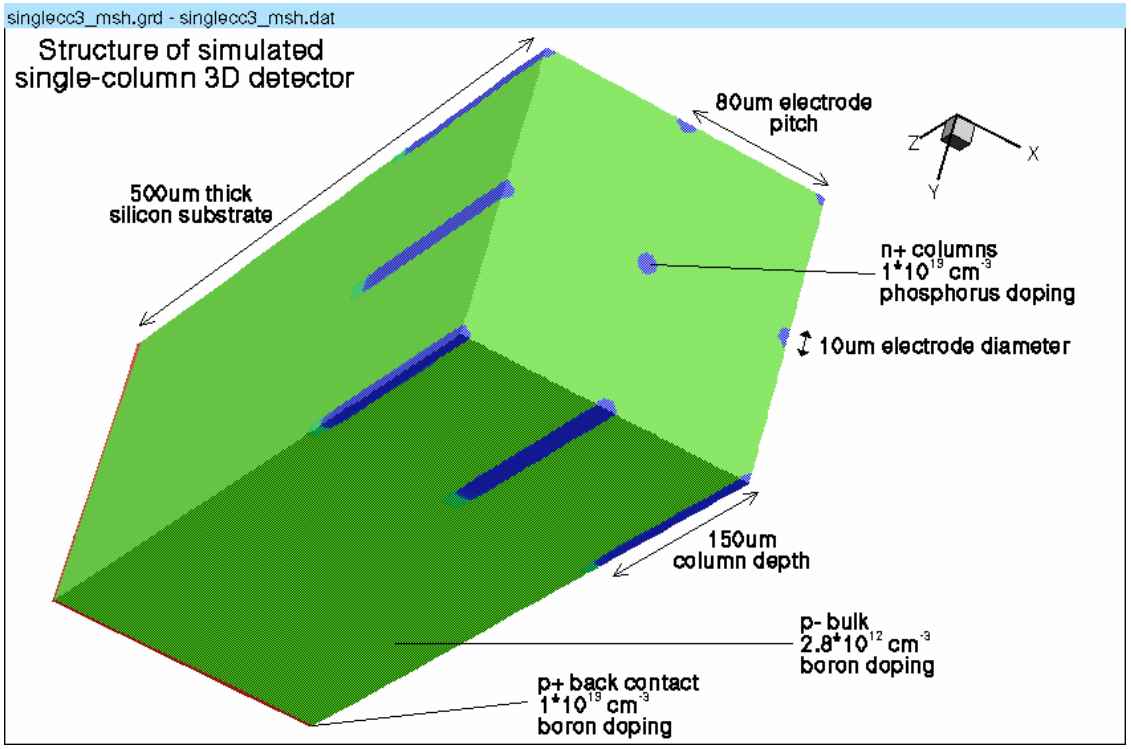
Experimental setup

- Glasgow has just installed a new Cascade Microtech probe station
  - Allows temperature and humidity control, electrostatic shielding, more reliable calibration etc.
  - Up to 12'' wafers
- Keithley 4200-SCS Semiconductor Characterization System
- HP 4284A LCRMeter
  - Measurements up to 40 V

Simulated devices

Simulations were produced using ISE-TCAD 7.0

- Dimensions match devices produced by ITC-irst
- Bulk doping concentration was obtained from the quoted minimum resistivity of the Float Zone silicon used by IRST



C-V measurements

- Guard ring not biased, 10 kHz
- For V > 10 V the C-V curve is similar to that of a planar device.
- P-stop modifies depletion behaviour