# Laser Tests of a p-type 3D-stc ministrip detector, equipped with LHC-Speed electronics

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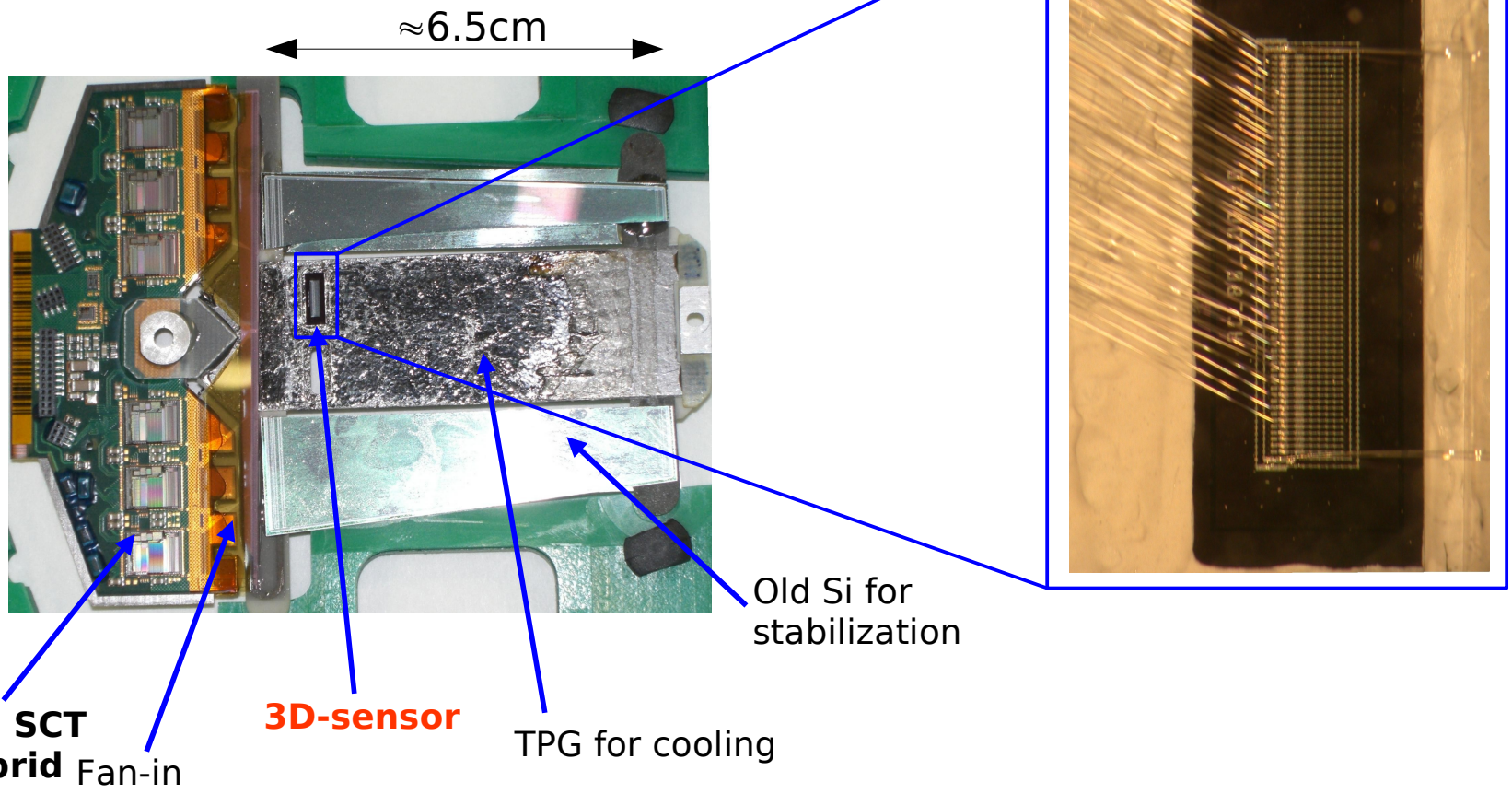
# Outline

- 3D prototype module
- Results before irradiation
- Results after irradiation
- Summary

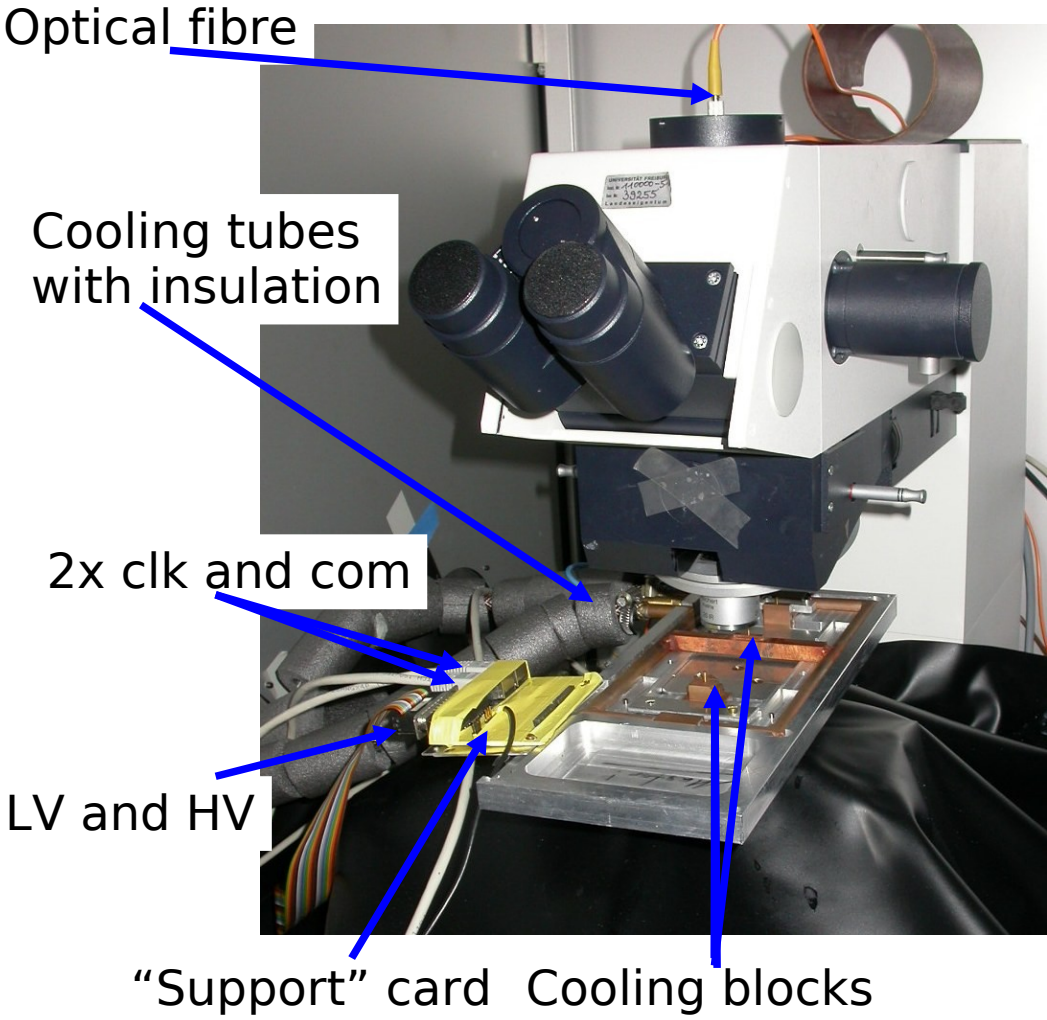
# 3D module prototype

- AC coupled sensor
- Based on 40Mhz ATLAS SCT electronics – shaping time 20ns



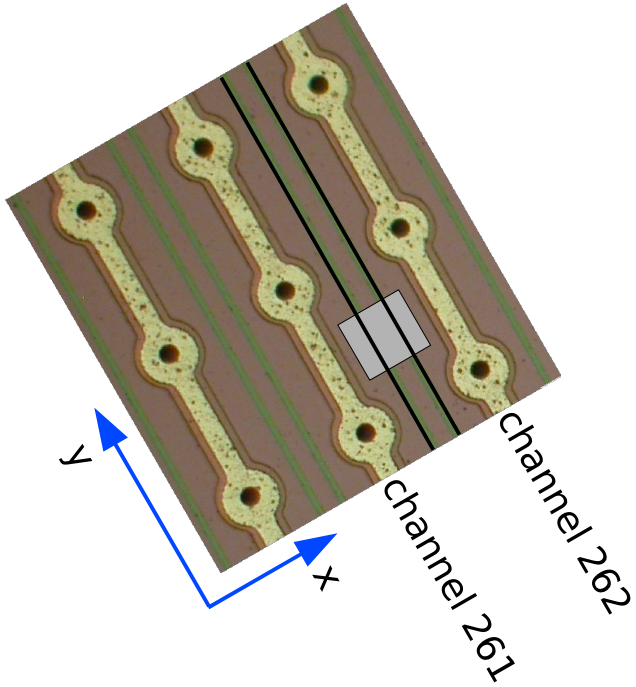
# Laser Set-up

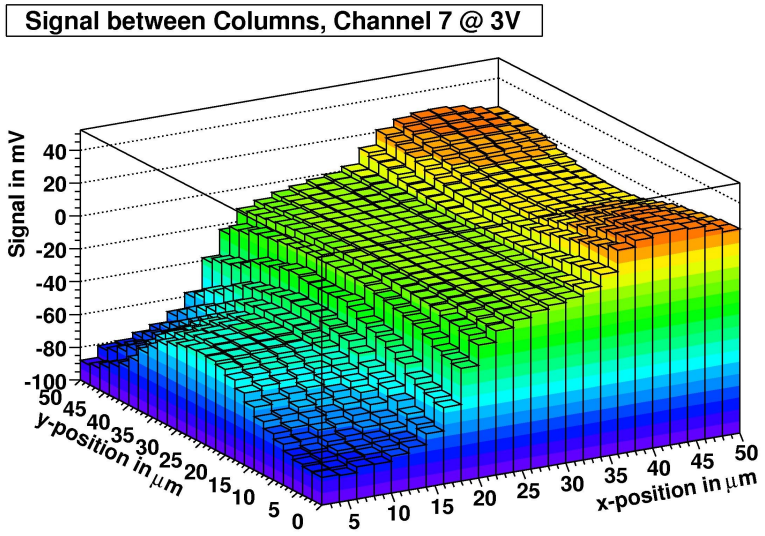
- Penetration depth @ $\lambda$ = 982nm ≈ 100µm
- Length of pulse ≈ 1-2ns
- Microscope to focus optically → laser spot Ø ≈ 4–5µm
- *x*-*y* stages with µm resolution
- *z*-axis manual, but also with µm accuracy
- Nitrogen flushed test box with cooling system

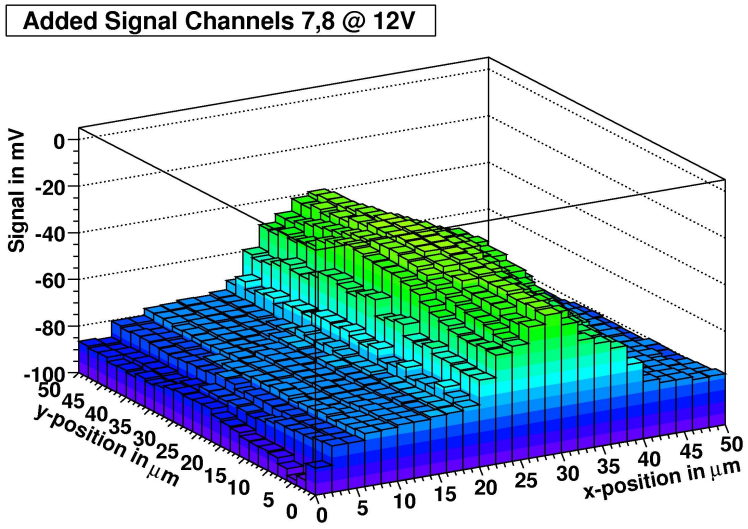


# Laser Results

- Before irradiation



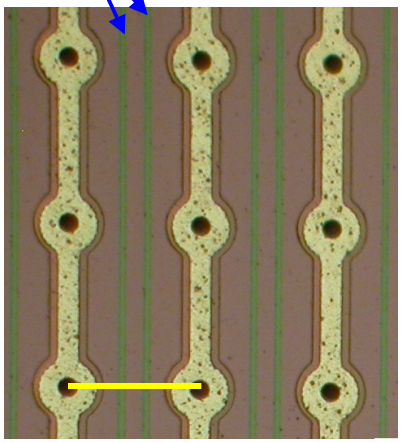




Lateral depletion around 12V

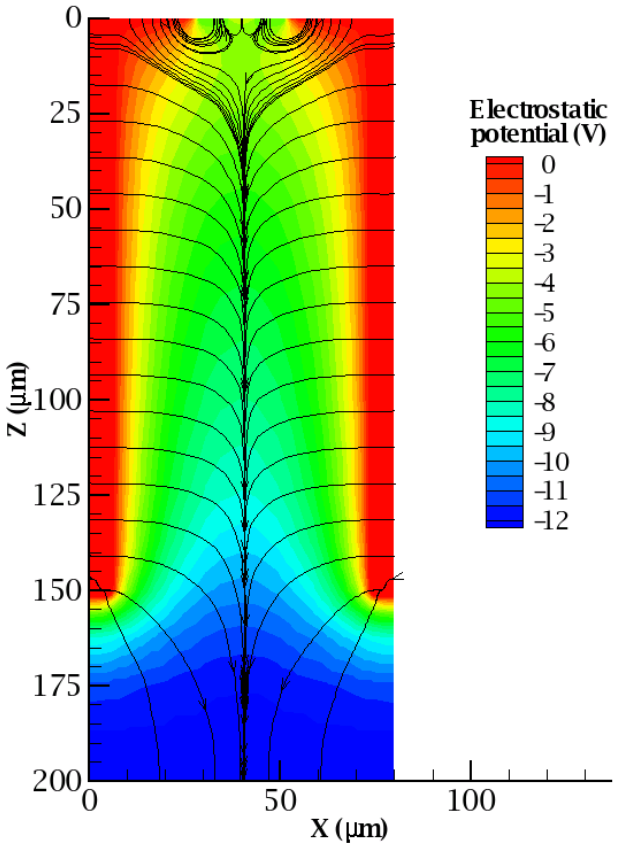
# P-stops affect the electric field

- Electrostatic potential between the columns

p-stops



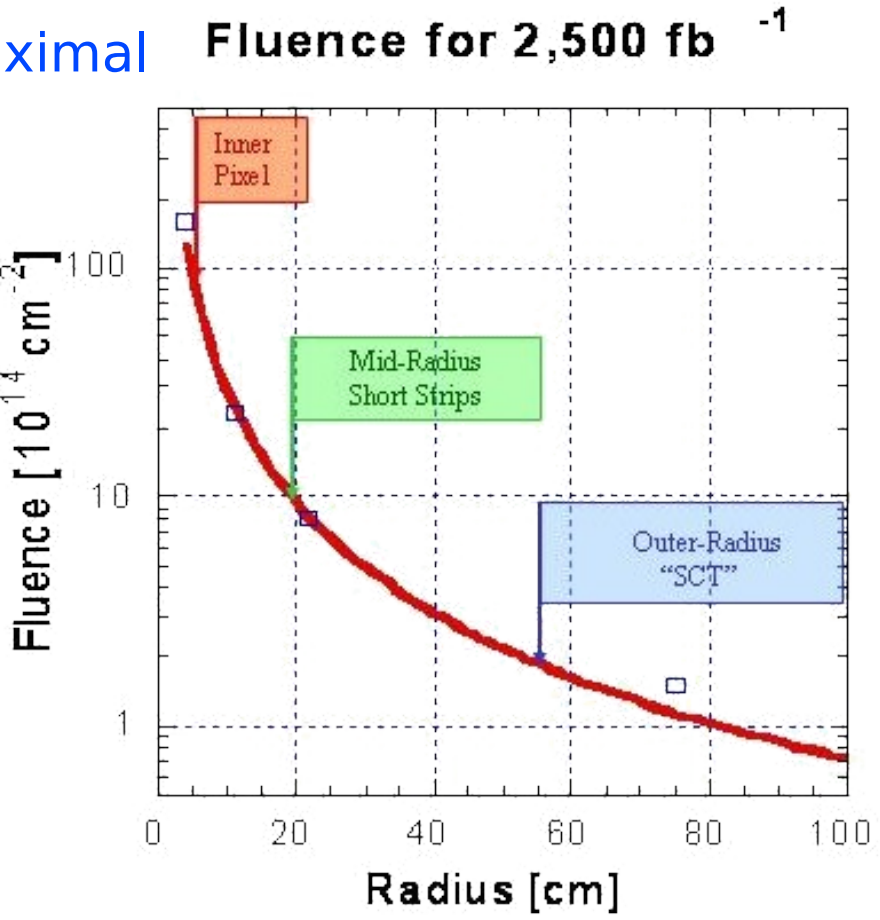
With p-stops



# Irradiation

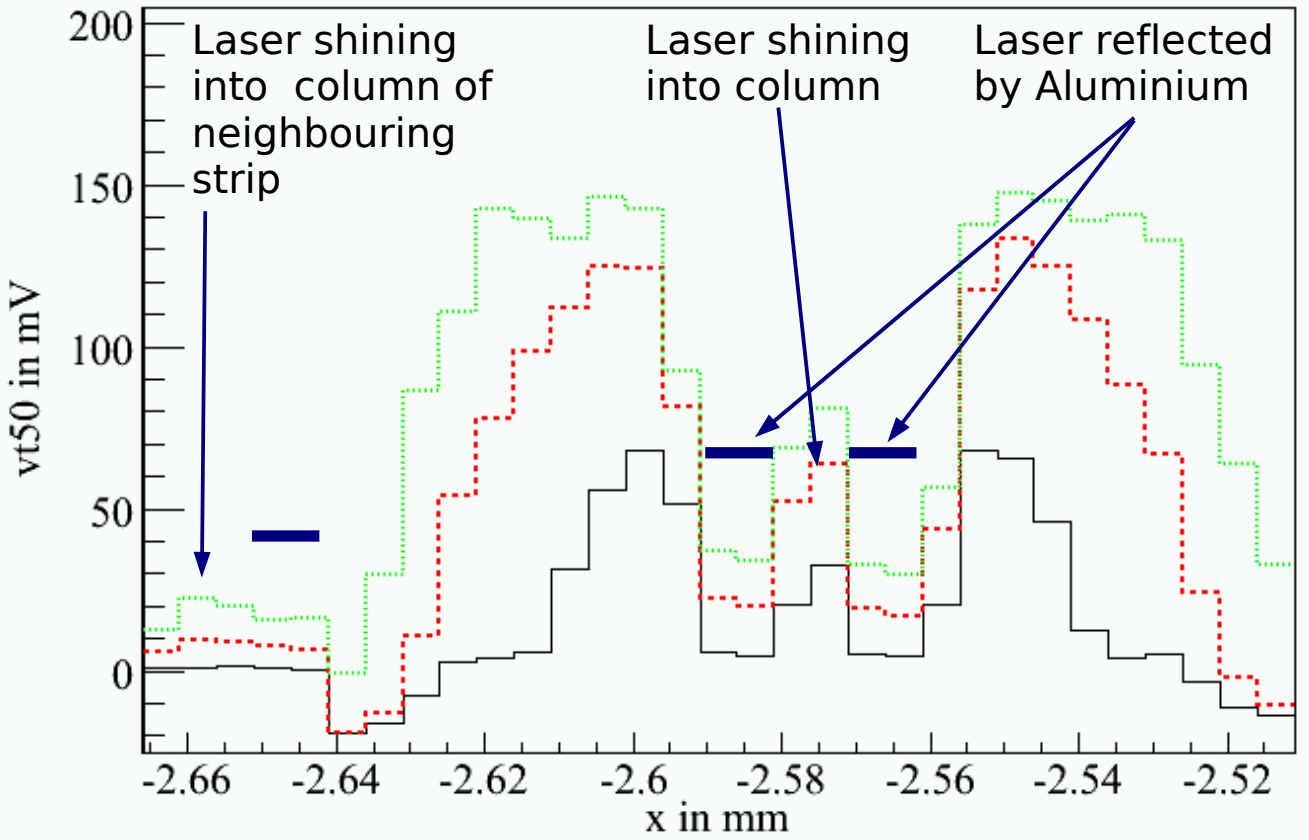
- Irradiated with 26MeV protons
- $10^{15} N_{eq}/cm^2$ corresponds to maximal fluence for short strips in sLHC

- Initial measurements without annealing (module in freezer)
- Annealed 80min at 60˚C
  (→ minimum of $N_{eff}$ and $V_{fd}$).

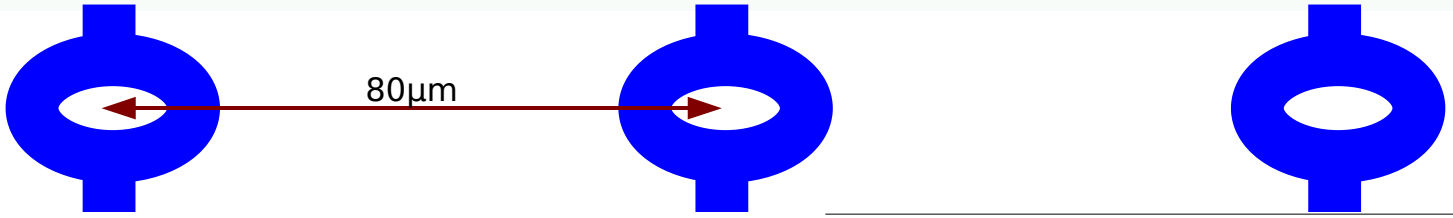


# Post-Irradiation: Depletion characteristics

- From scan over 1 column for different bias voltages




- Rapid lateral depletion between the columns
- Diode-like depletion inside column



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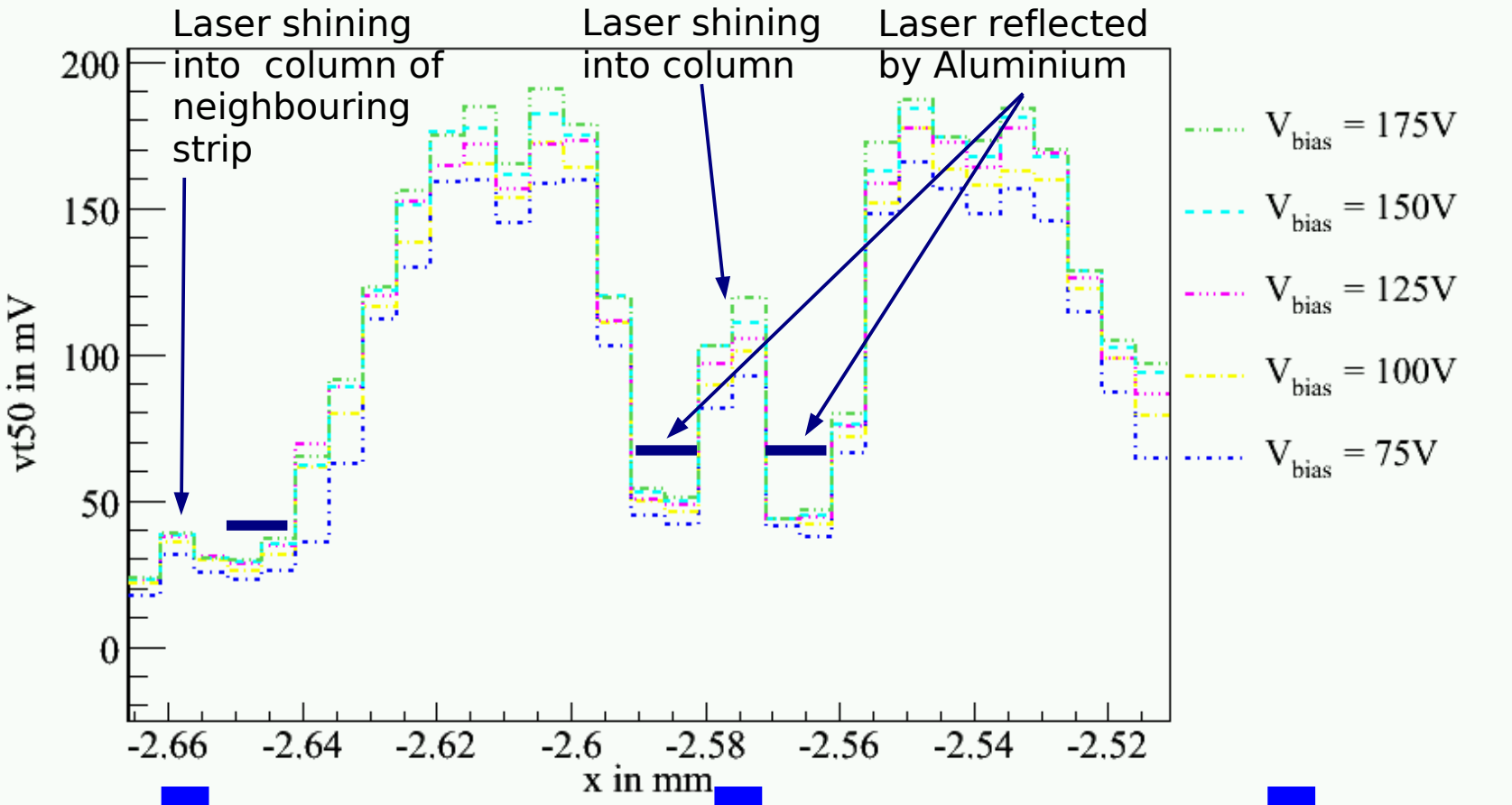


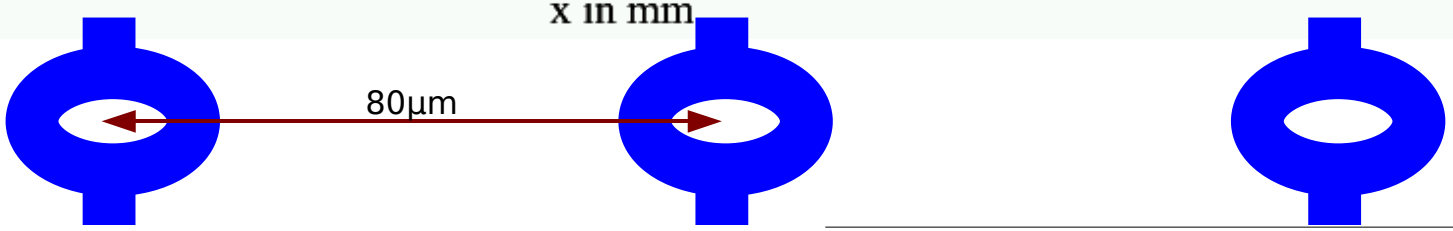

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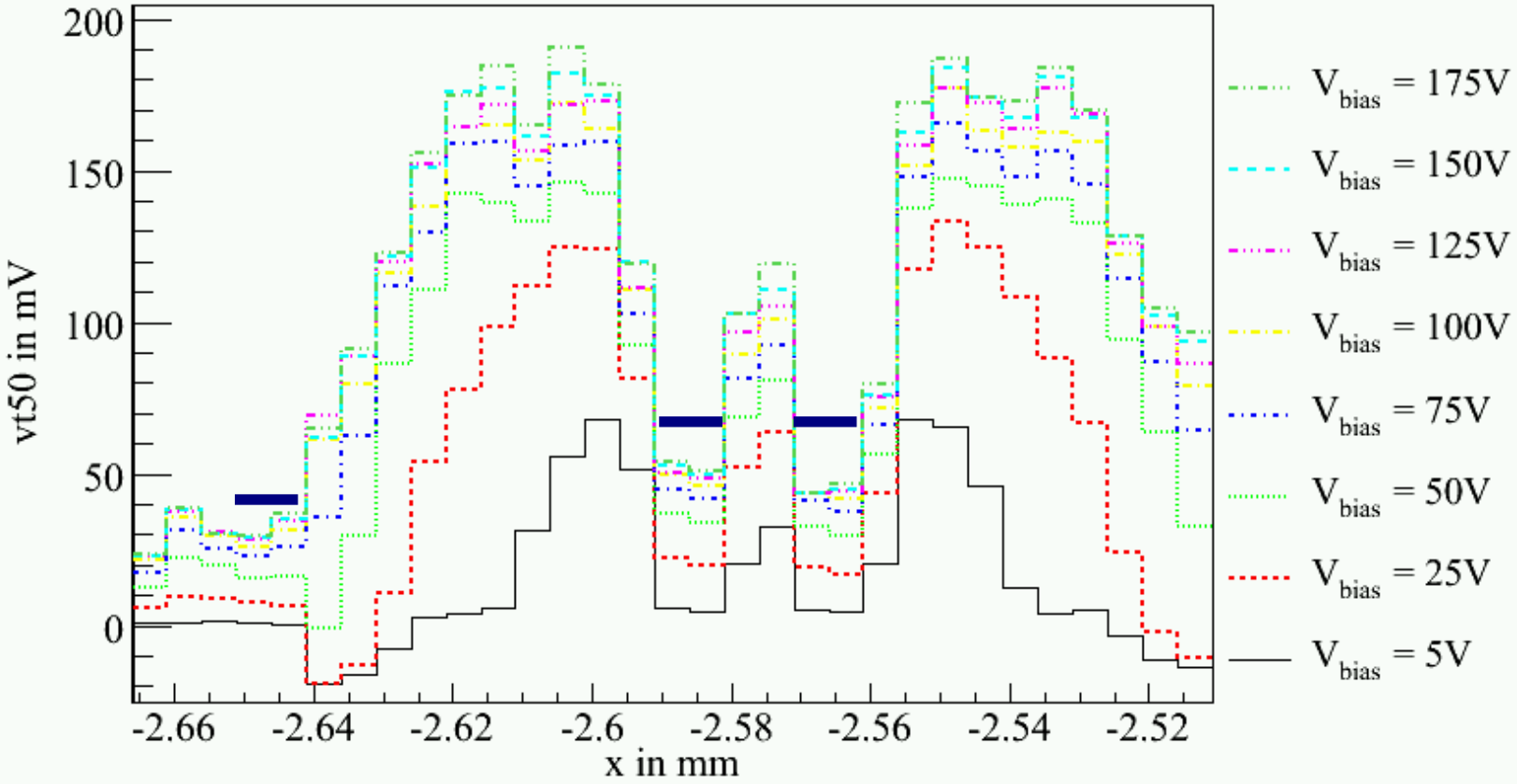
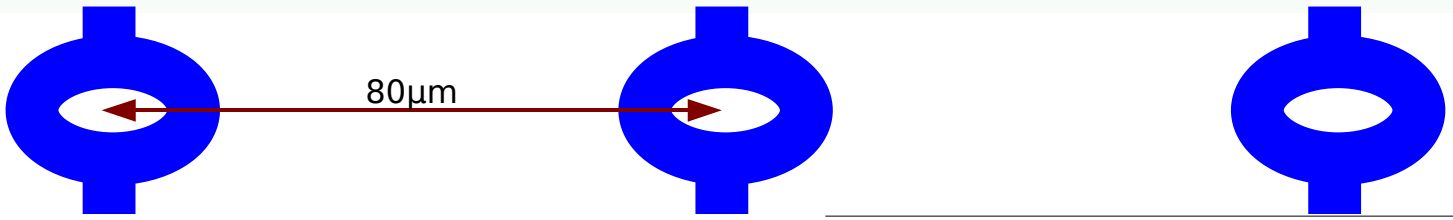
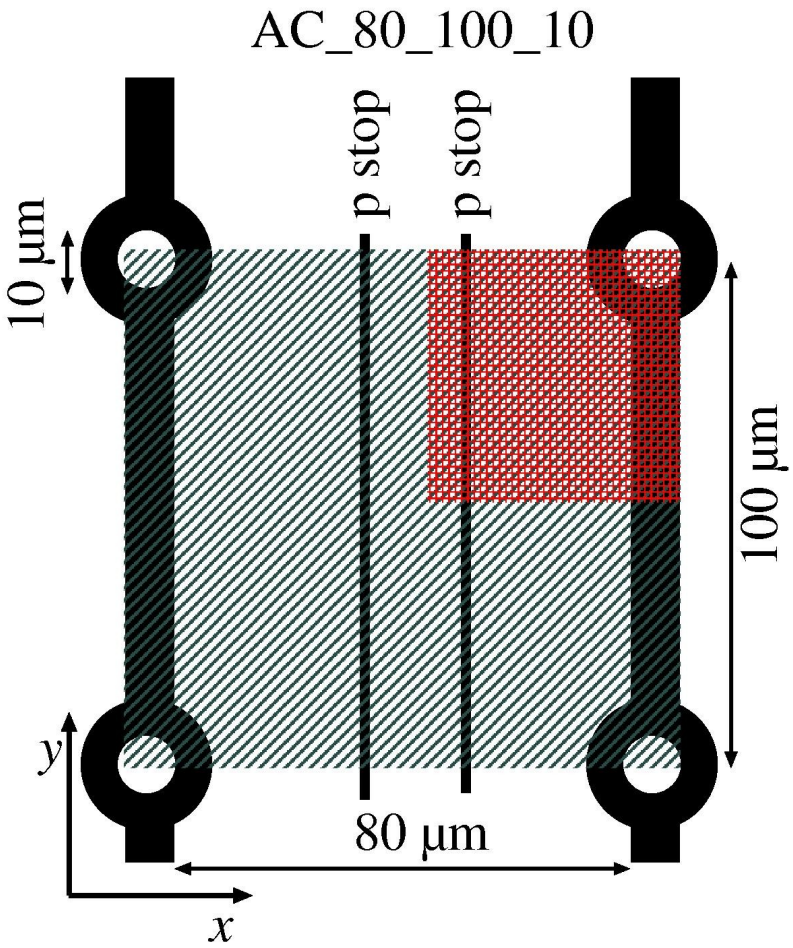


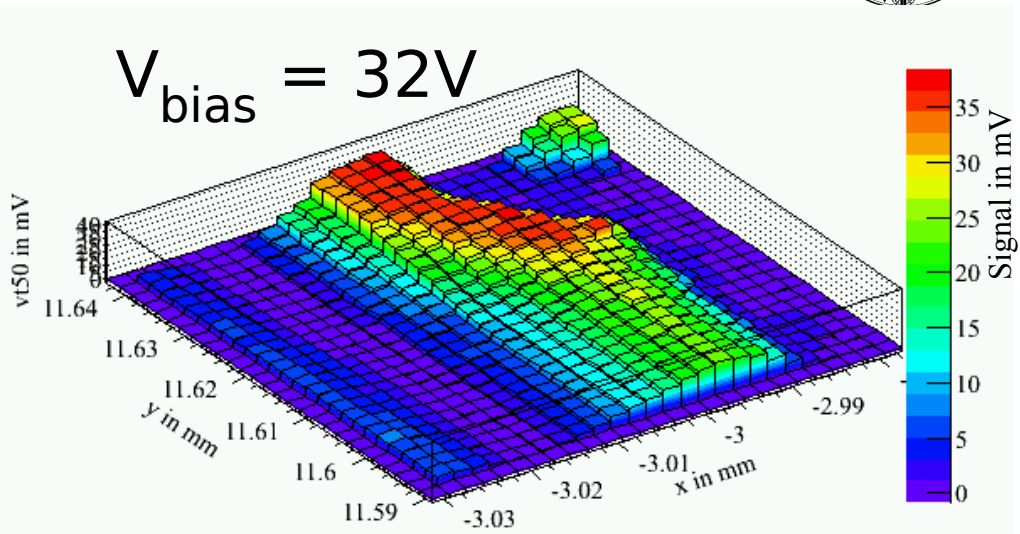
# Scanned areas

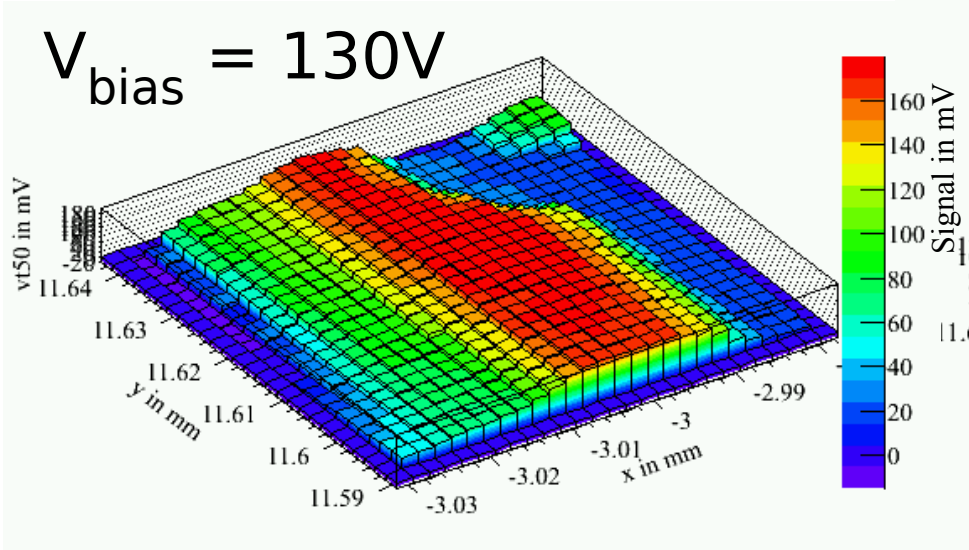


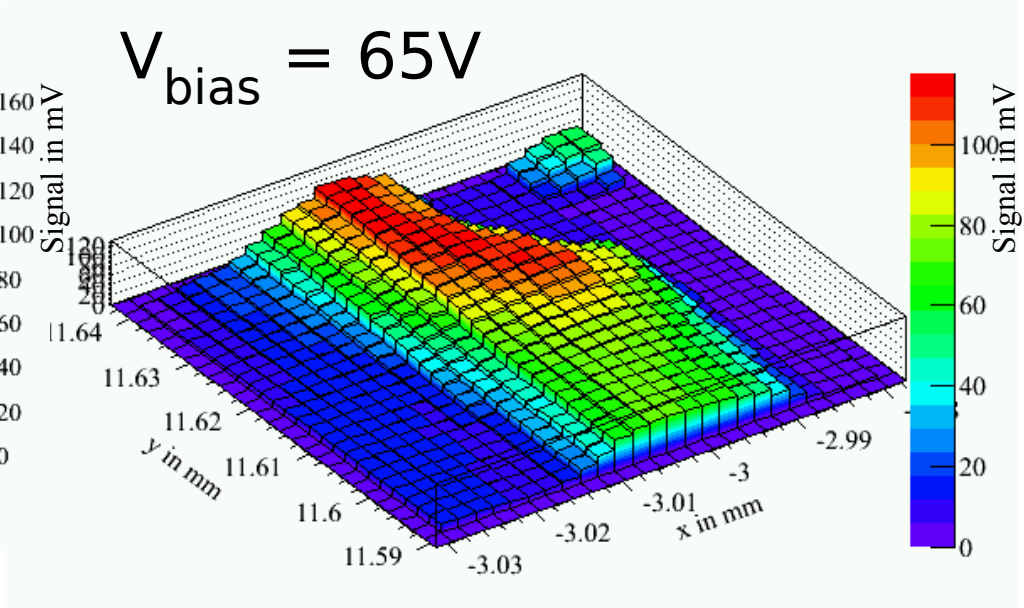

- Red: high resolution scan
- Grey: medium resolution scan

# Post-Irradiation

- Performing a scan with high granularity you can nicely see how the depleted region is growing with increasing bias voltage
- 2 µm step-size
- Note the different scale in the figures

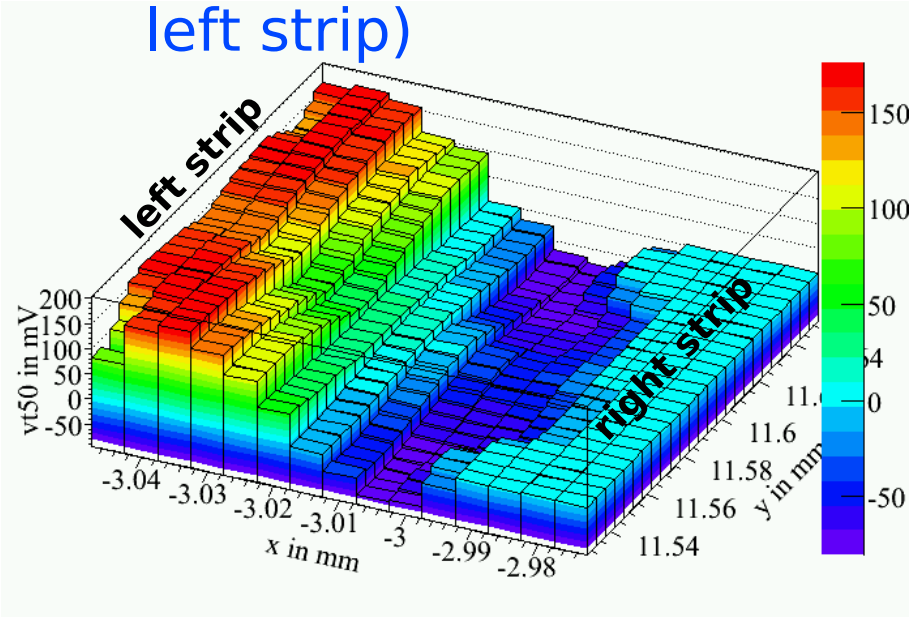


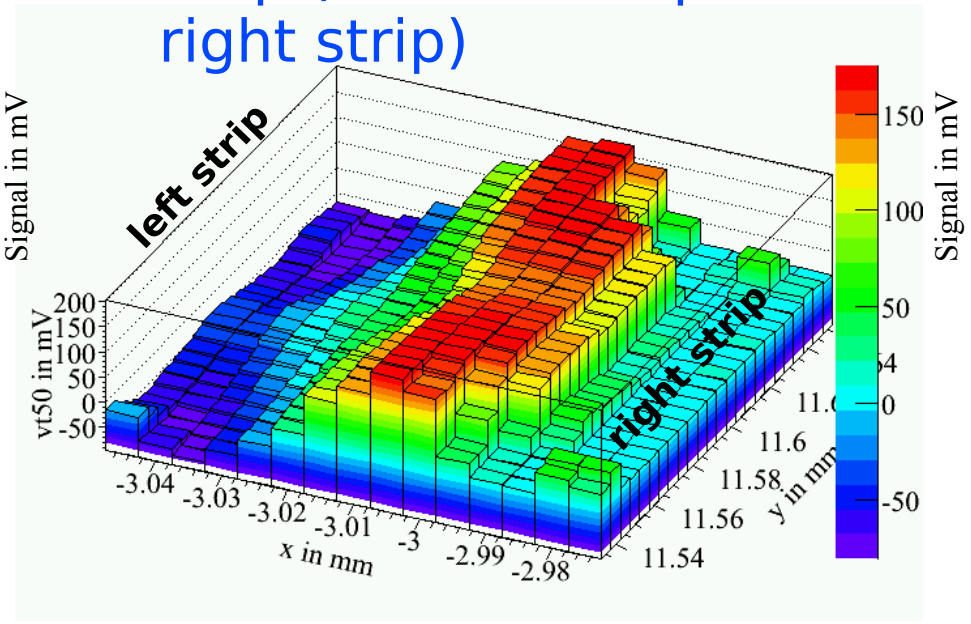



# Post-Irradiation: CCE @ 130V

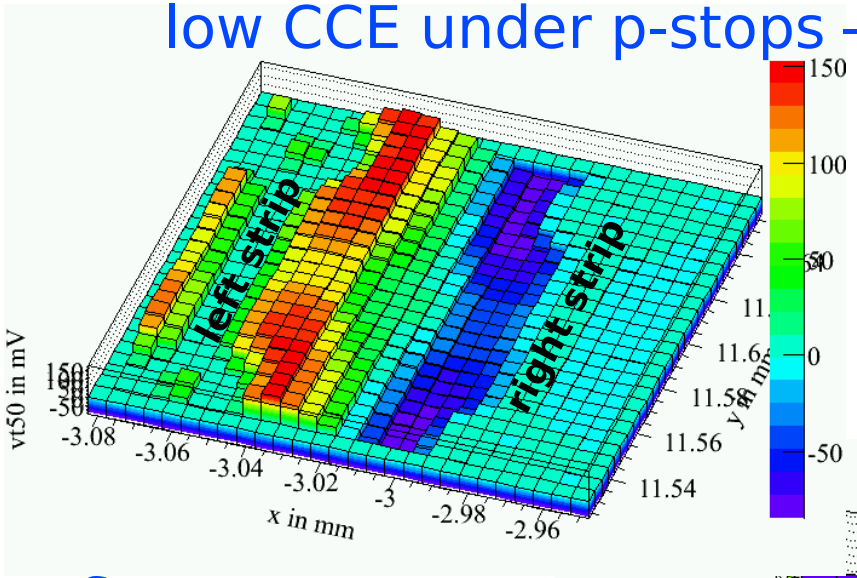
- Good Uniformity within 10% of CCE around columns, low CCE under p-stops – as before irradiation
- Response from left and right channel of a single scan shown separately
- 5 µm step-size
- Response from left strip (readout strip: left strip)
- Response from right strip (readout strip: right strip)

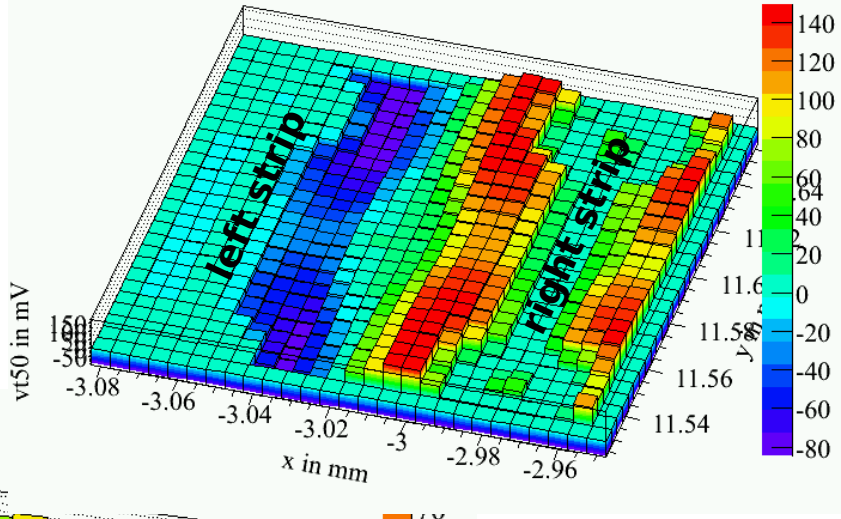


# Post-Irradiation: CCE @ 110V

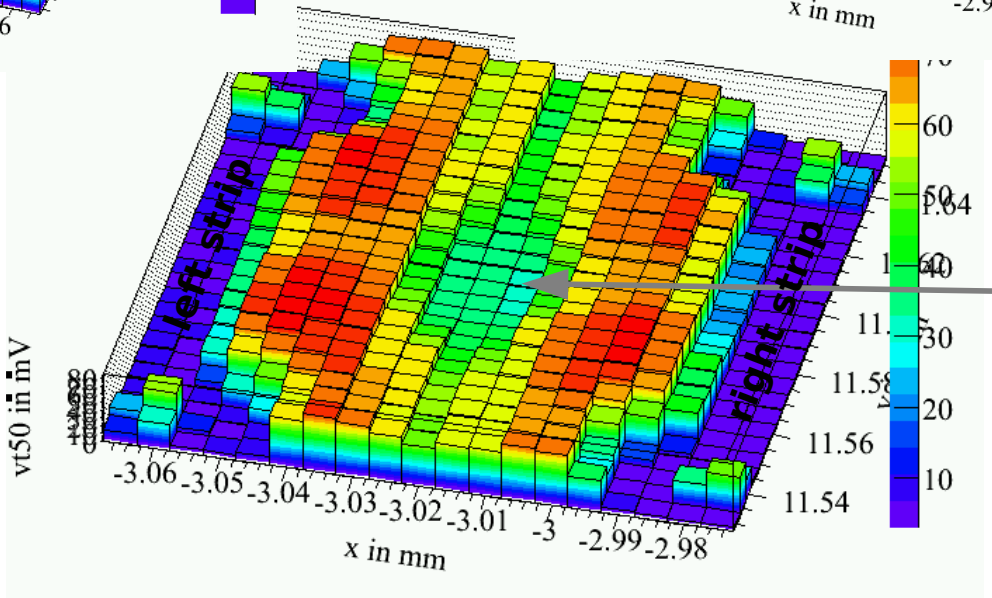
- Good Uniformity within 20% of CCE around columns, low CCE under p-stops – as before irradiation




- Same scan as on the slide before, but at $V_{bias}$ = 110V

Sum of both strips:




Low field region – or trapping?

# Summary & Outlook

- Prototype module built from 3D STC p-type micro-strip detector and ATLAS SCT electronics
- Pre-Irradiation: lateral depletion around 12V, low field region under p-stop
- Irradiated to $10^{15}$ $N_{eq}/cm^2$, annealed to min. $N_{eff}$ and $V_{FD}$
- Depletes laterally between around 75V, uniform CCE along strips, low CCE under p-stops and in the central part of a unit cell

- 3D detectors are a promising candidate for tracking detectors in very harsh radiation environments like the sLHC experiments

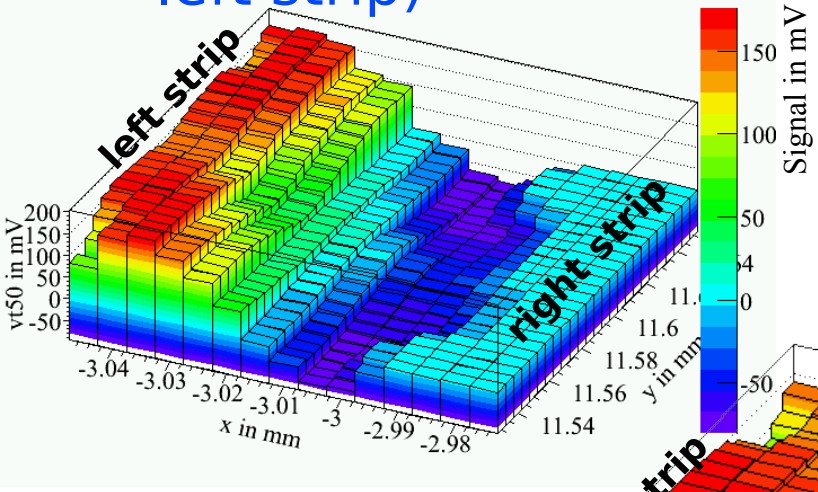
- Assembling reconnectable module with 3D-stc sensors with longer strips
  → interesting to investigate different strip isolation schemes and relative CCE as well as noise before and after irradiation

- Thanks to Alex Furgeri (Karlsruhe) for the irradiation, David Pennicard (Glasgow) for the simulations and FBK irst (Trento) for the sensors!

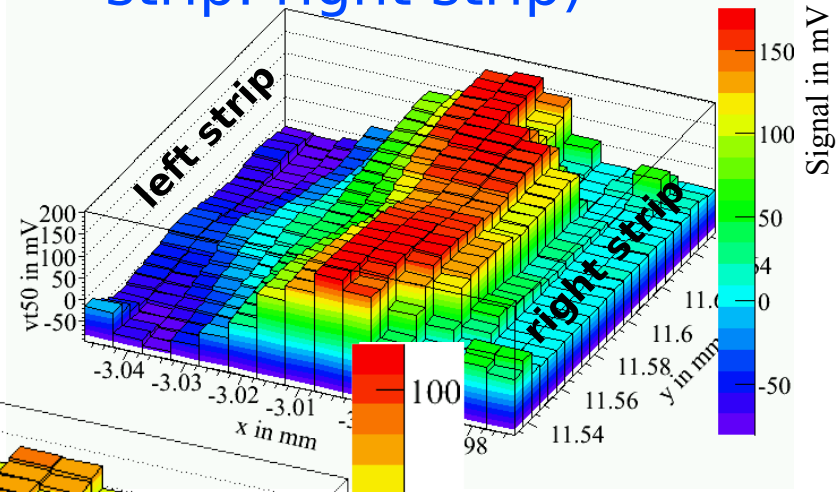
# THE END

# Post-Irradiation: CCE @ 130V

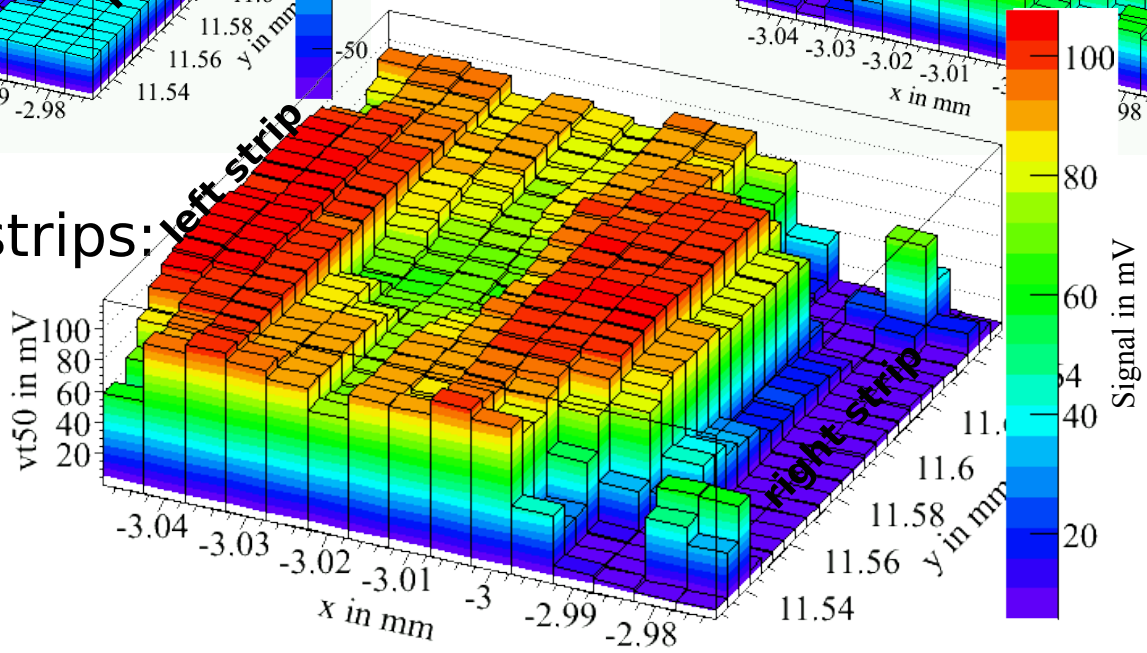
- Response from left strip (readout strip: left strip)



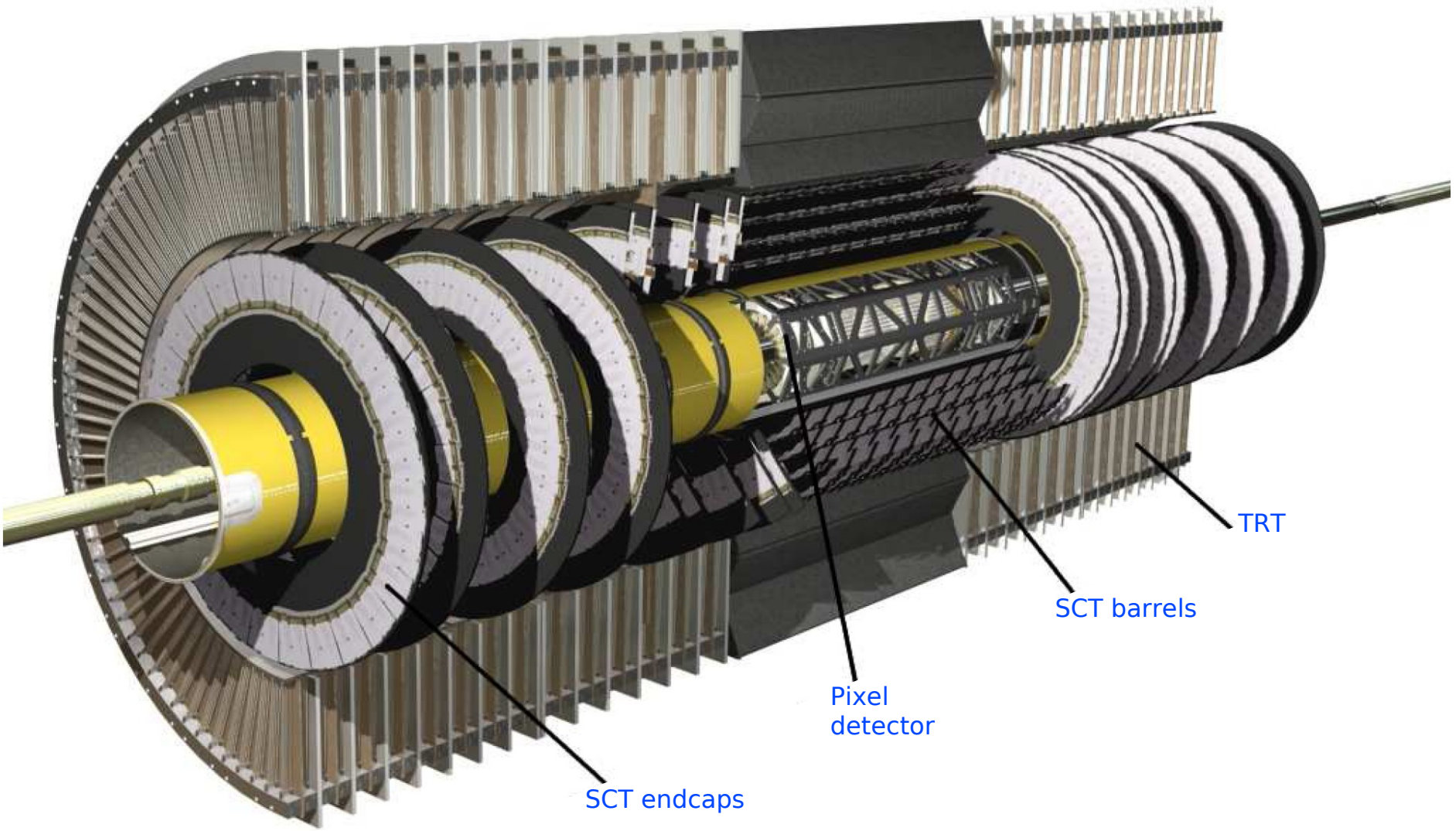

- Response from right strip (readout strip: right strip)




Sum of both strips:

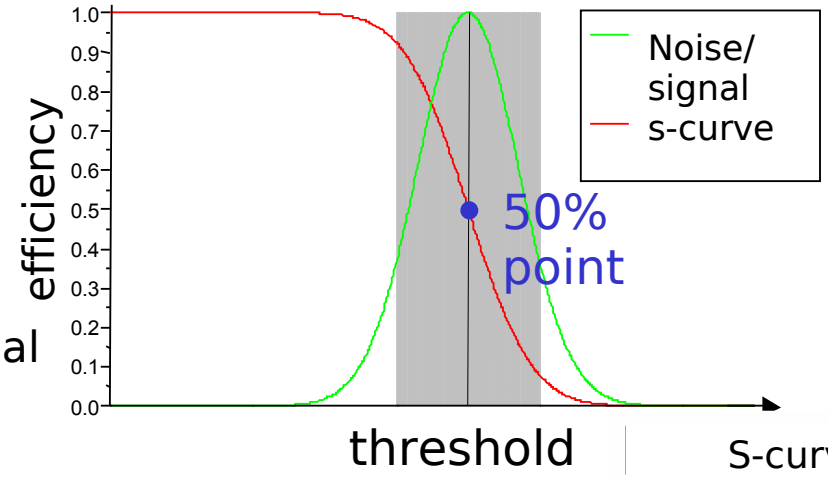


# The ATLAS Inner Detector

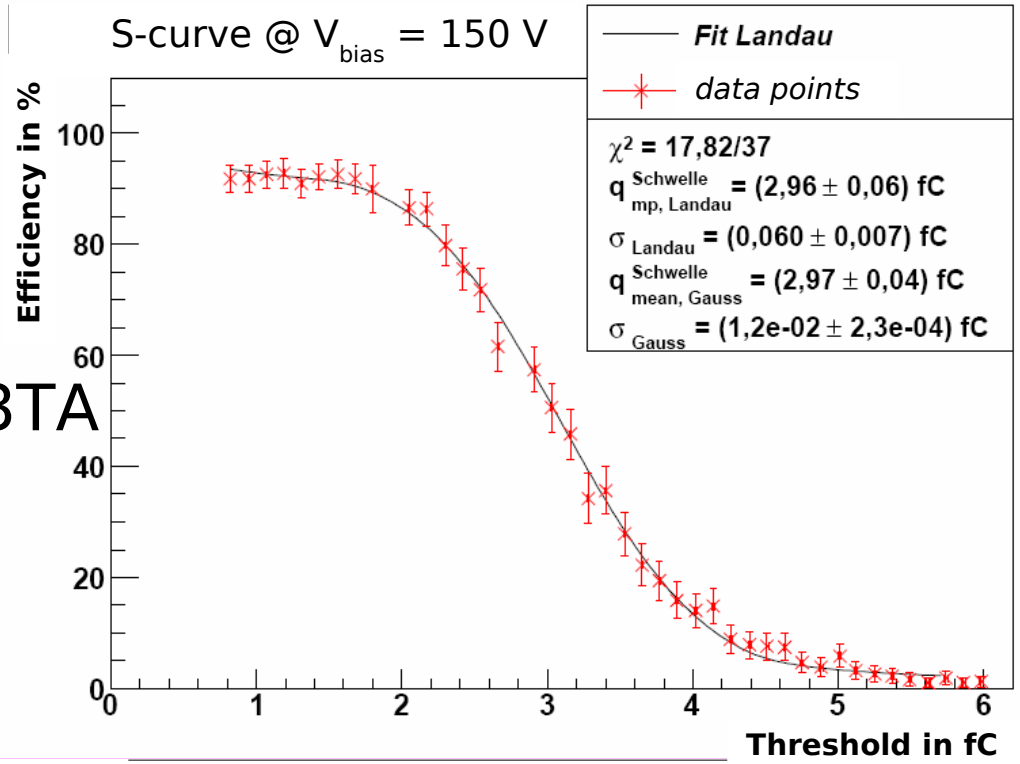


# Charge extraction: $\beta$ set-up

System with Gaussian noise/signal

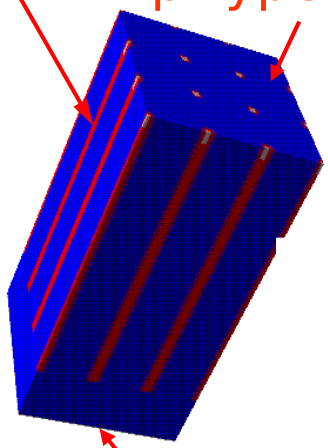


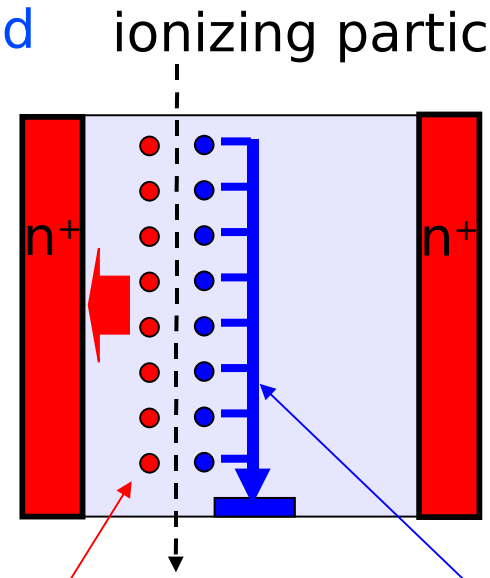

Binary readout system: based on the ATLAS SCT front-end ASIC: the ABCD3TA



# 3D STC Design

- Single-Type Column (STC) design: on the way to a full 3D device
- Reduction in processing steps and price by roughly a factor of 2



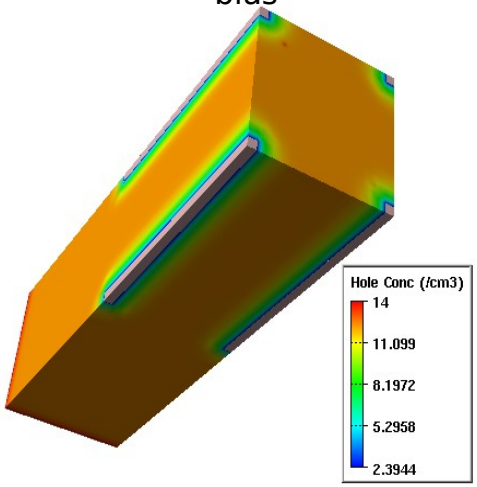




electrons are swept away by the transversal field

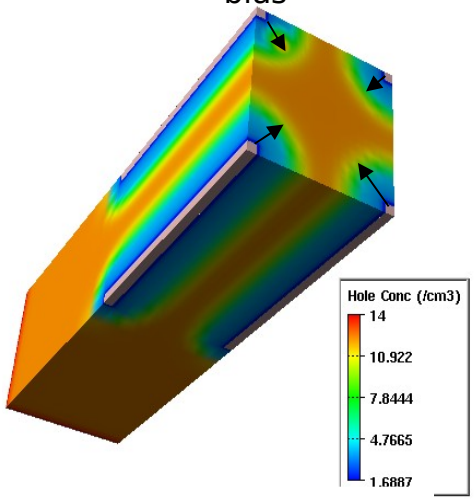
holes drift in the central region and diffuse towards p+ contact

# 3D-stc Simulations – depletion

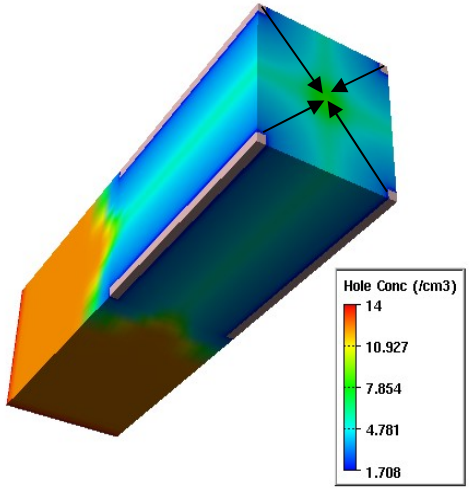
**1)** $V_{bias}$=0V



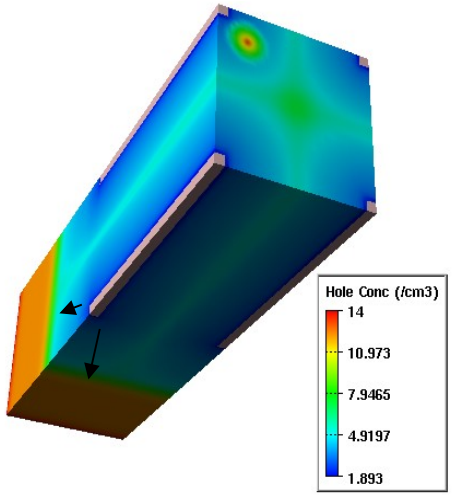

**2)** $V_{bias}$=2V




**3)** $V_{bias}$=5V

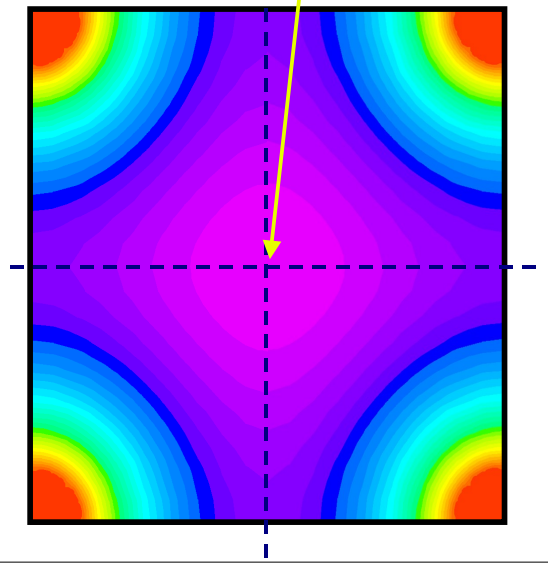



**4)** $V_{bias}$=20V




- Rapid lateral depletion at around 5V
- Then depleting like a planar device
- Low Field in the central region remains

*xy*-null field lines

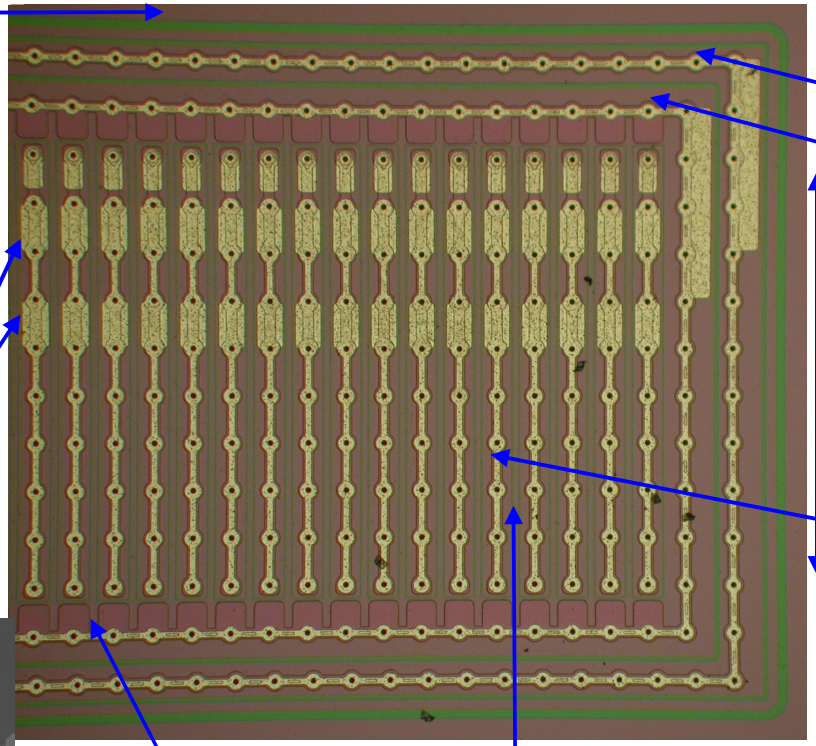


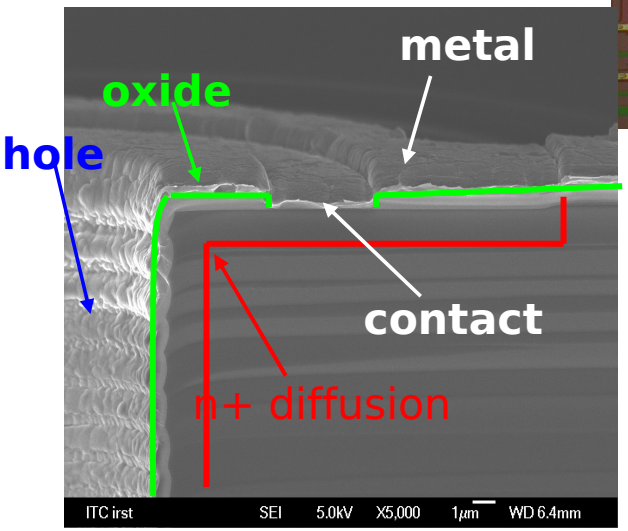
# 3D STC strip detector

p-type substrate

- Collection of $e^-$ instead of holes
  - Faster signal
  - Less trapping
- Non type-inverting even for very high fluences

AC-Pads




punch-through structure

p-stop around each strip