Investigation of Charge Multiplication in Silicon Strip Detectors

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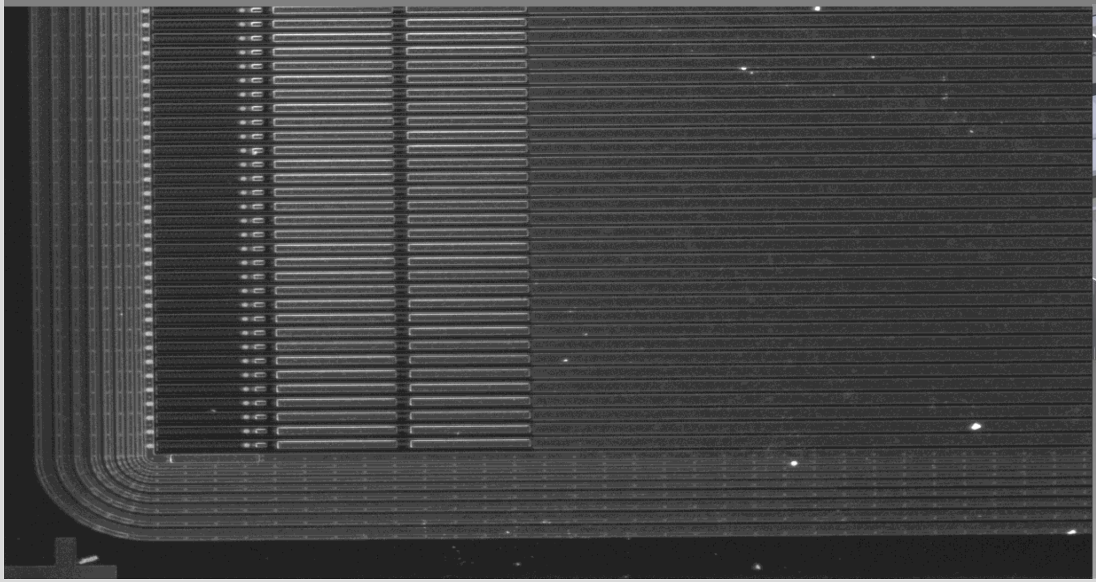
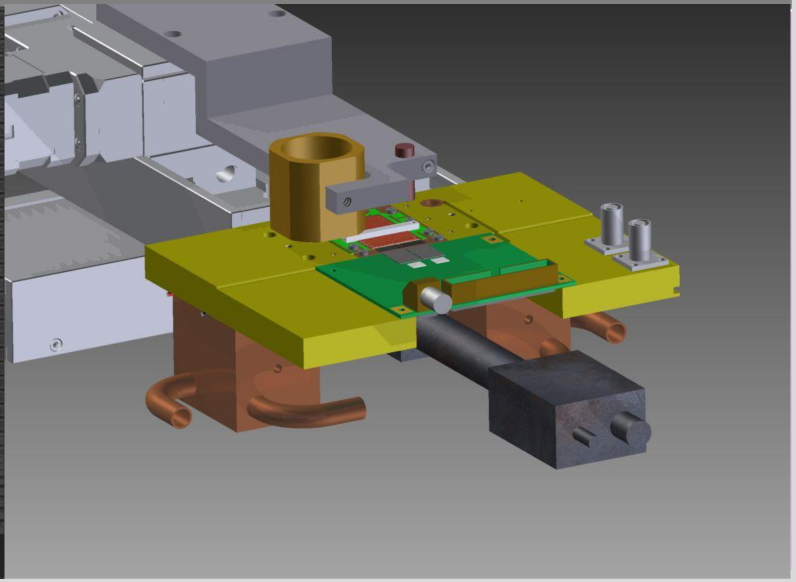


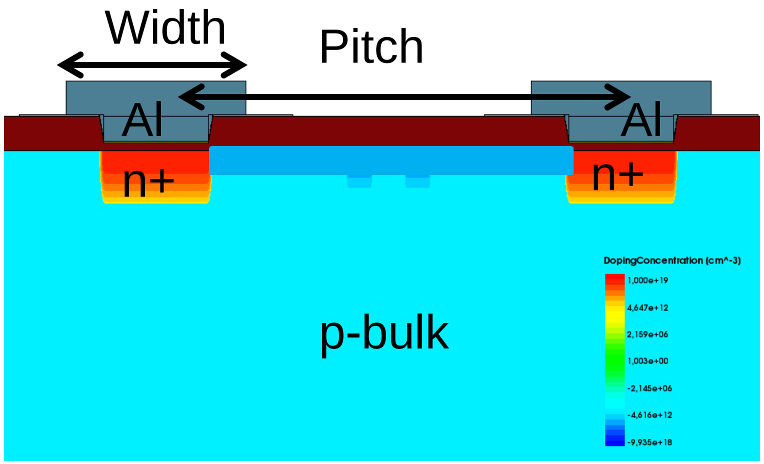


Overview

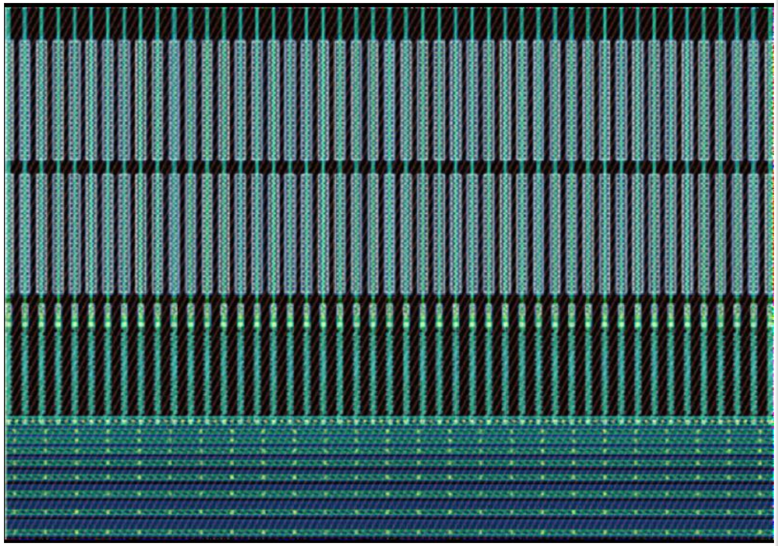
- Introduction
  - Overview of sensor properties
- Comparison between neutron and proton irradiation
  - CCE
  - Signal to noise ratio
  - Leakage current
- Simulation: Which factors influence Charge Multiplication?
- Investigation of Charge Multiplication as a function of oxide charge
- Summary

RD50 CM-Sensor: Properties

- **P-type sensors**
- **2 geometries**
  - **Depth d = 305 µm**
  - **Pitch p = 80 µm, width w = 6 µm**
    pitch p = 80 µm, width w = 60 µm
  - **Width/pitch w/p = 0.075 and w/p = 0.75**
  - **Active area: 10.18 mm x 11.76 mm**



- **2 irradiation**
  - **Irradiations with protons in Karlsruhe**
  - **Irradiations with neutrons in Ljubljana**
  - **Fluence: $5*10^{15}$ n_{eq}/cm^2, $1*10^{16}$ n_{eq}/cm^2 and $5*10^{16}$ n_{eq}/cm^2**



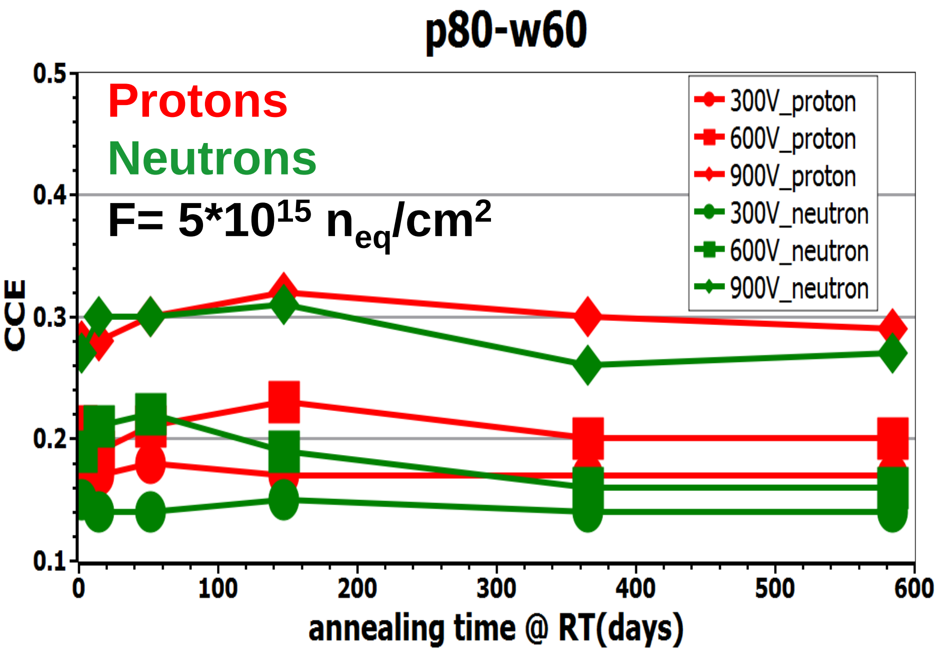
- **Annealing study:**
  Several steps at 60°C and 80°C

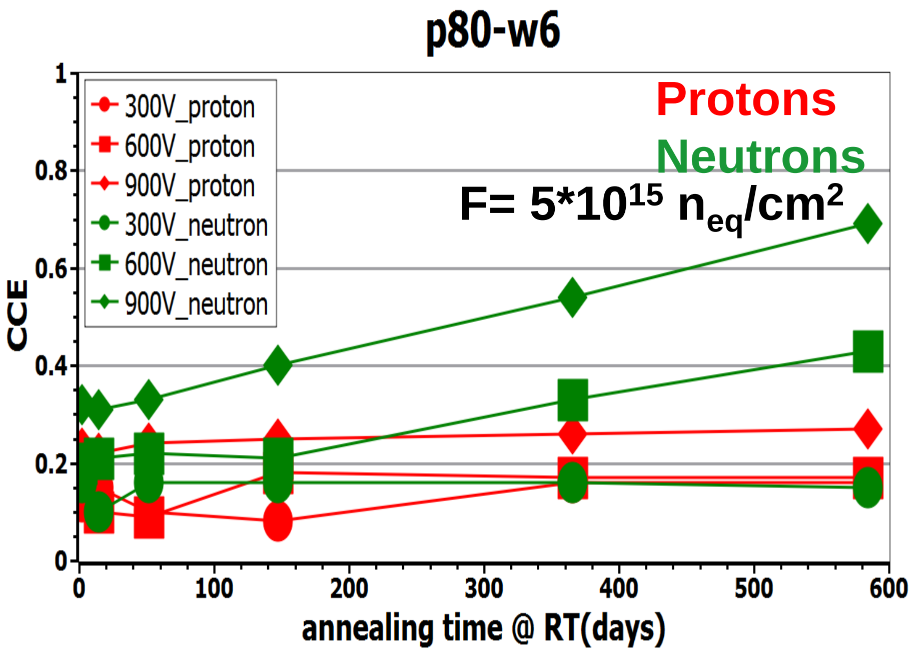
Measurement Results

Strip Sensor Readout System with ALiBaVa

Settings: T= -20°C, S/N 5/2 Cut

Comparison between proton and neutron irradiation (CCE)



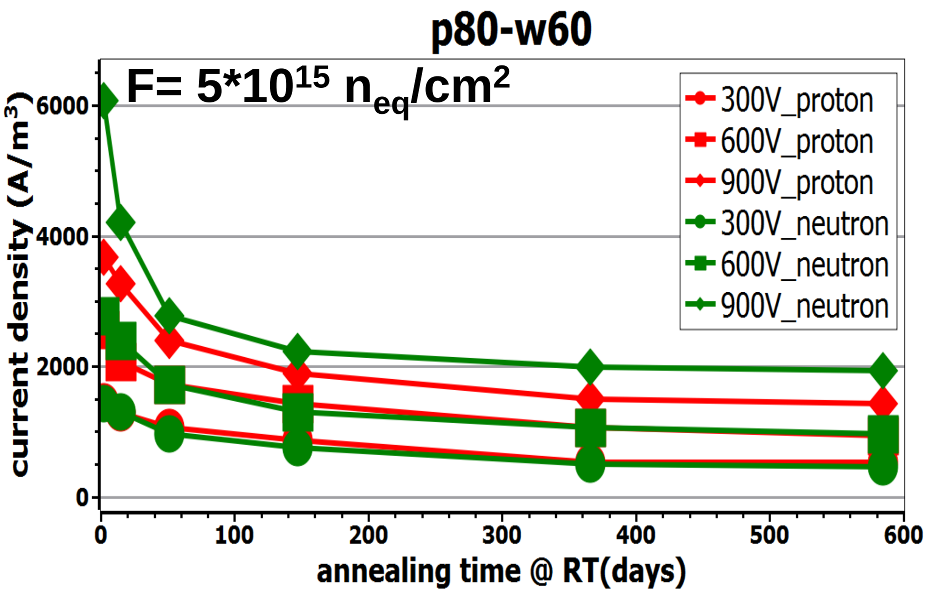


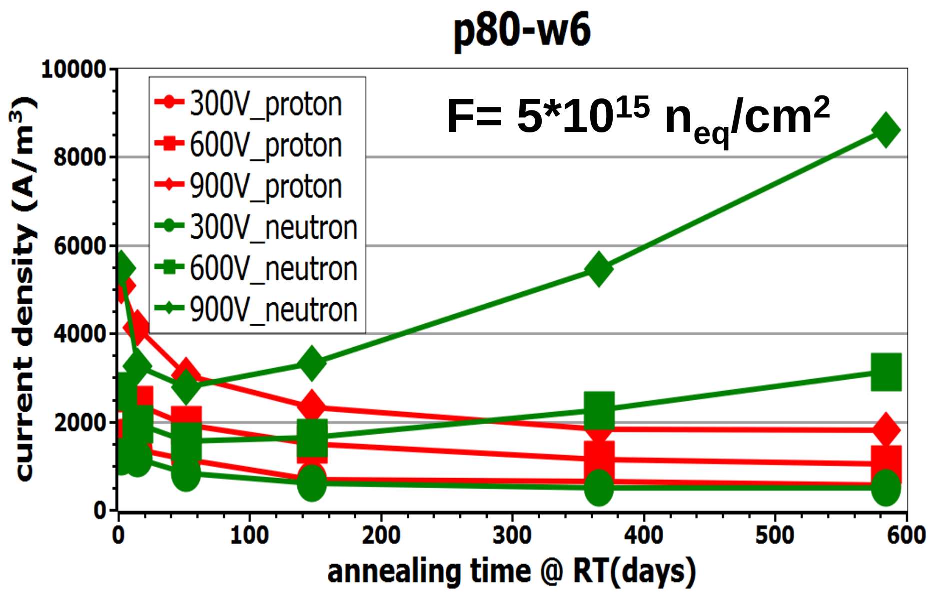
Broad implants show usual annealing behaviour

- Beneficial annealing up to 150d
- Reverse annealing later

Narrow implants show difference between protons and neutrons: more CCE after neutron irradiation
Charge multiplication?

Leakage Current

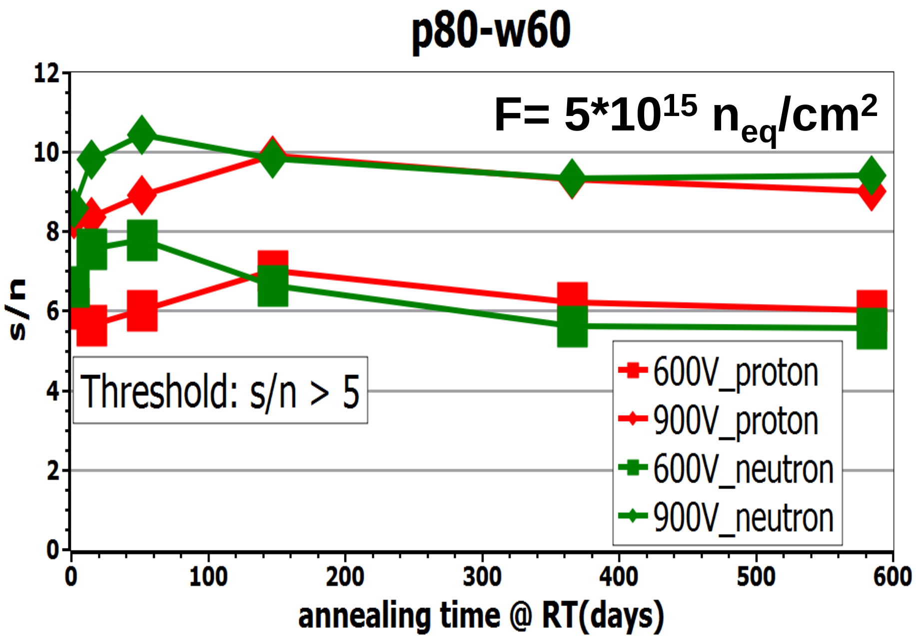


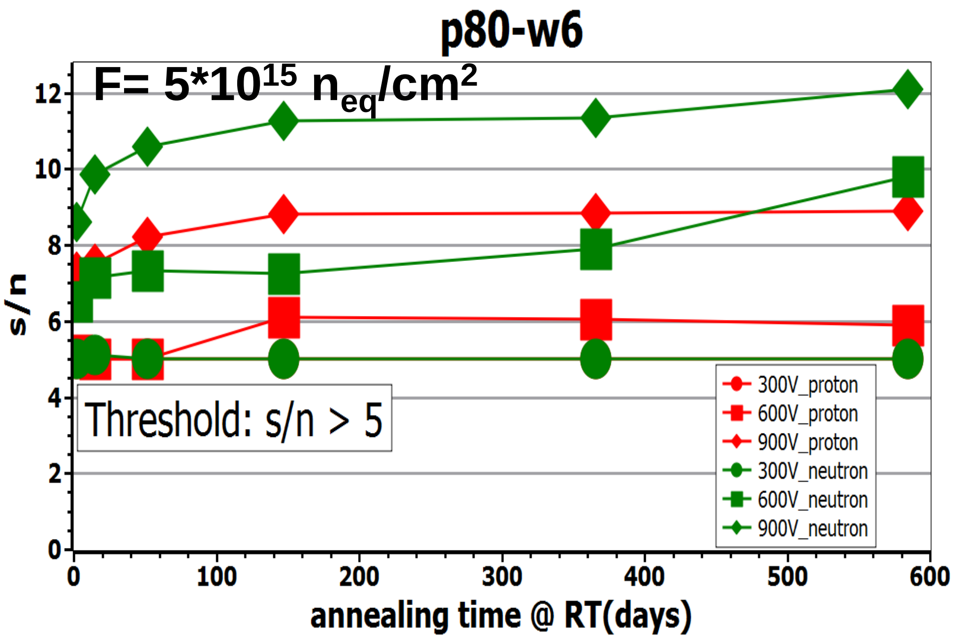


- **Decrease of current after annealing, both for neutrons and protons**

- **Increase of current after annealing for neutron irradiation**
- **More CCE, more leakage current**

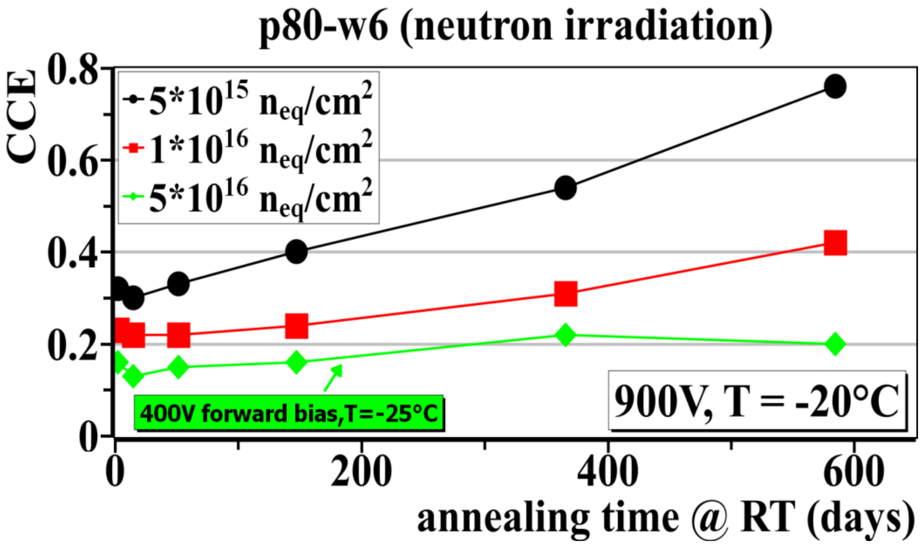
Signal to Noise (s/n)

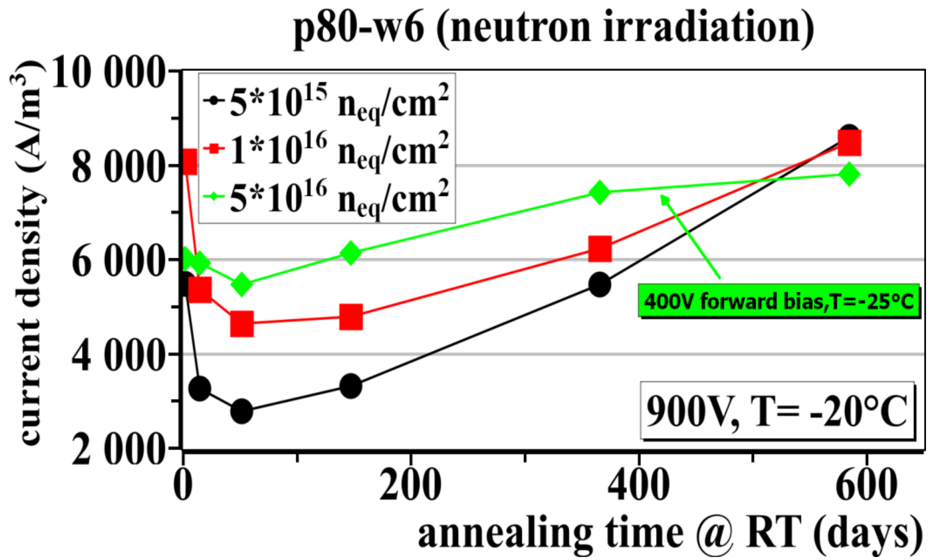


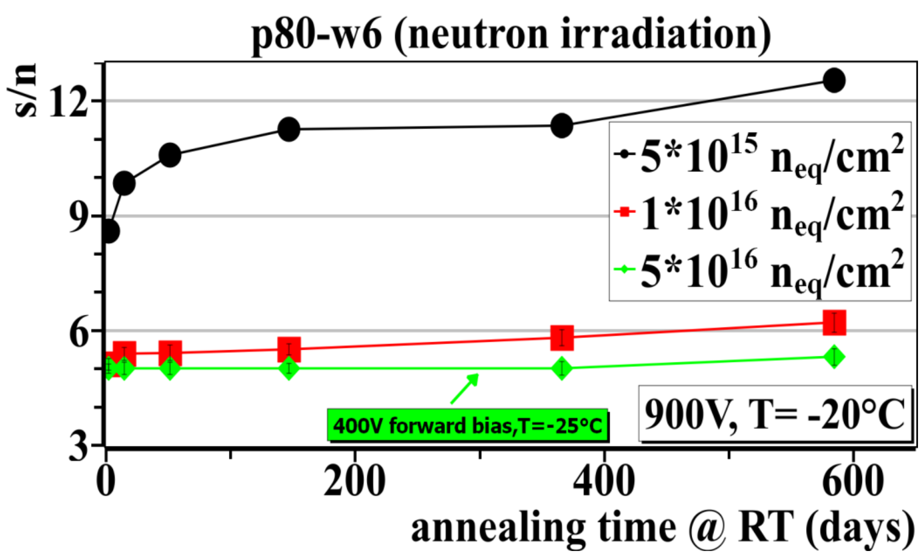


- s/n for proton irradiation independent of width
- s/n for neutron irradiation 25% larger for narrow strips

Results: p80-w6 & neutron irradiation





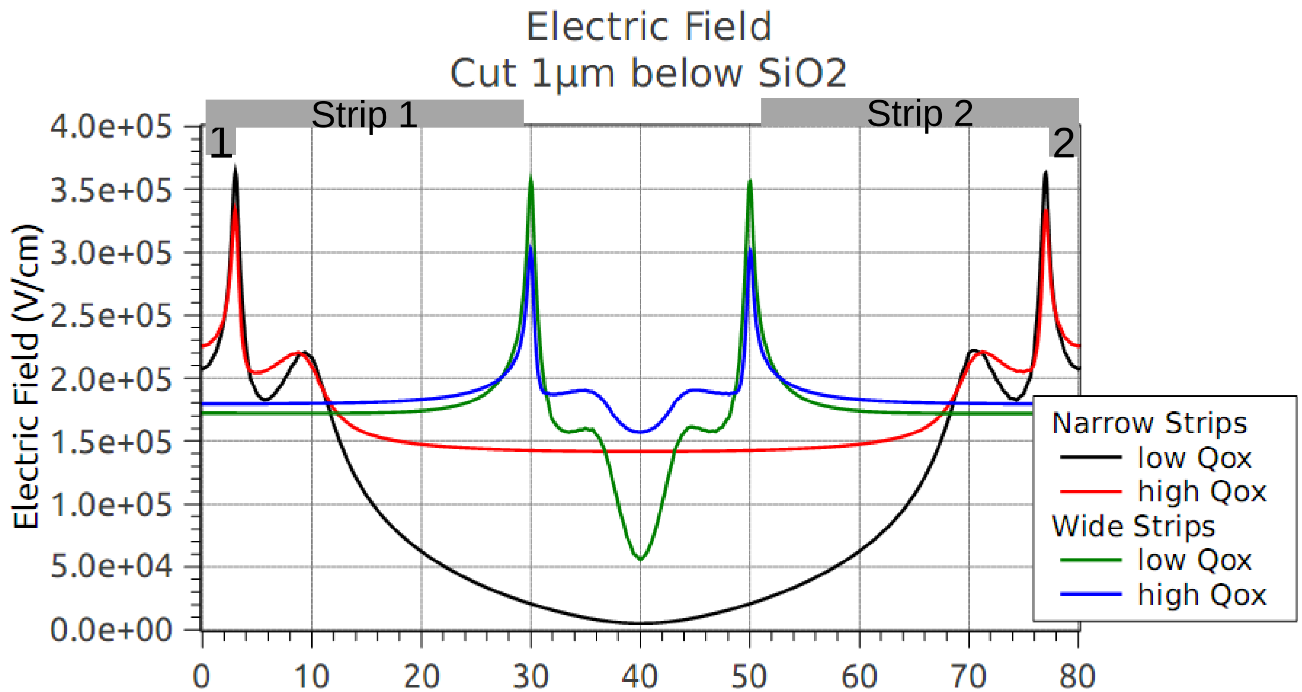


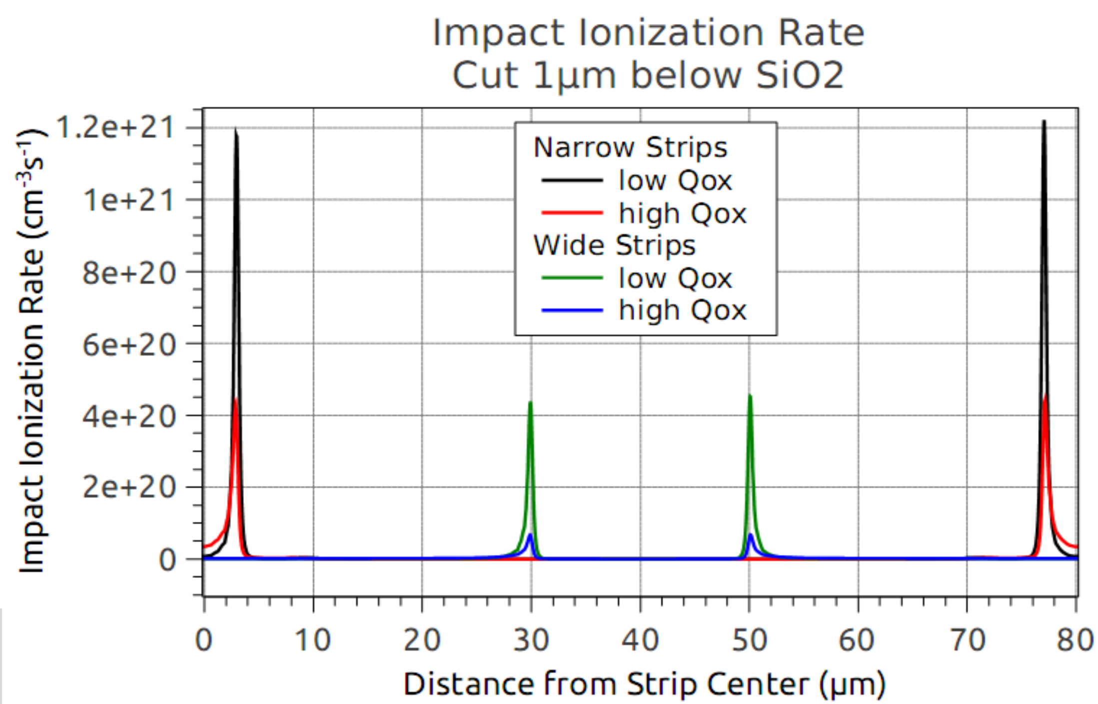
- s/n: Threshold > 5
- Only samples with narrow implants and after long annealing show CM
- $5*10^{15}$ n_{eq}/cm^2 & $1*10^{16}$ n_{eq}/cm^2 : neutron irradiated samples show CM
- $5*10^{16}$ n_{eq}/cm^2: No CM visible

Simulation: Which factors influence CM?

Electric Field at the Strips

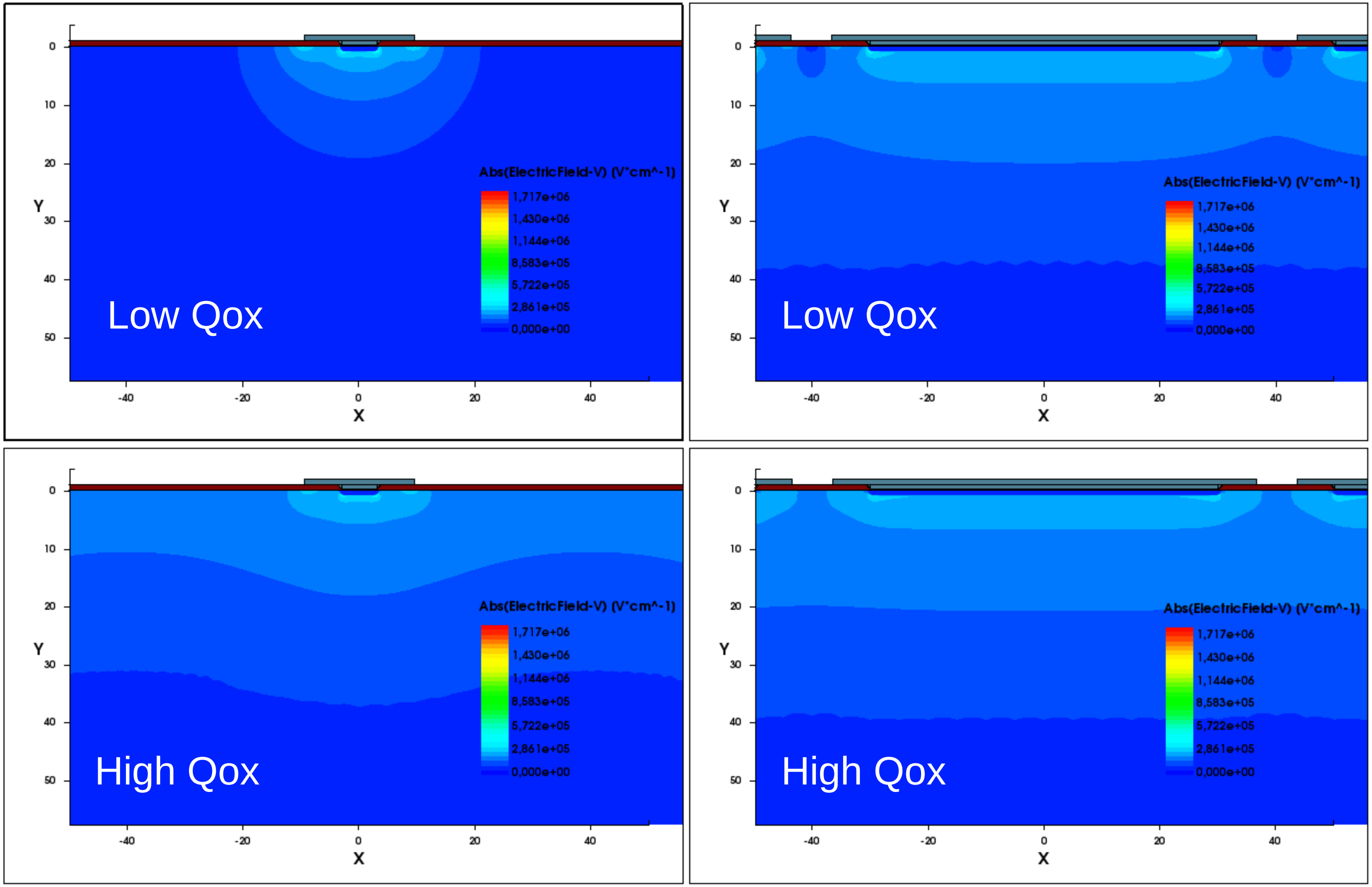
- **F = 5e15 n_{eq}/cm^2**
- **E-field highest at strip edges**
- **Slightly larger fields for narrow strips**
- **Impact ionization rate much higher at narrow strip edges (higher current at narrow implants)**





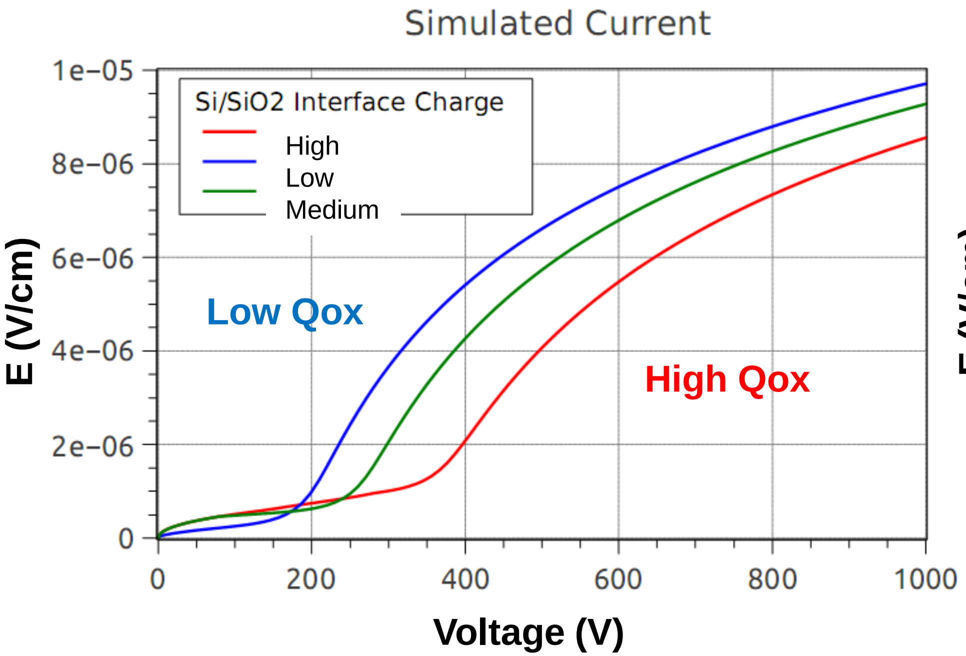
CM: Influence of Strip Width on E-field

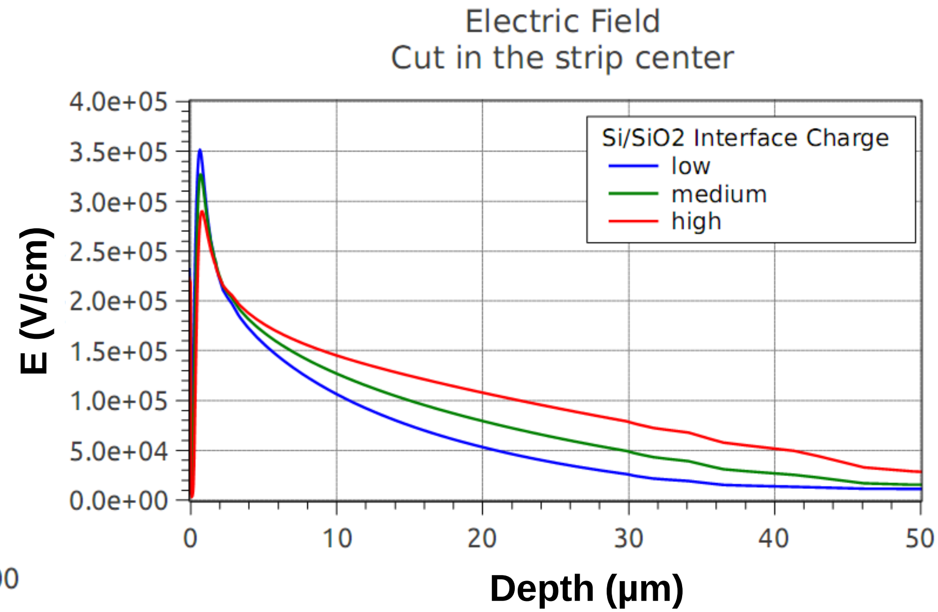
Width 6µm **Pitch 80µm** **Width 60µm**



Possible explanation for difference between protons and neutrons

- Proton irradiation generates positive charge in the oxide / interface between silicon and oxide
- Neutron irradiation doesn't create much oxide / interface charge (Qox)
- Simulation with interface charge shows:
  - Electric field decreases at the strip with increasing charge





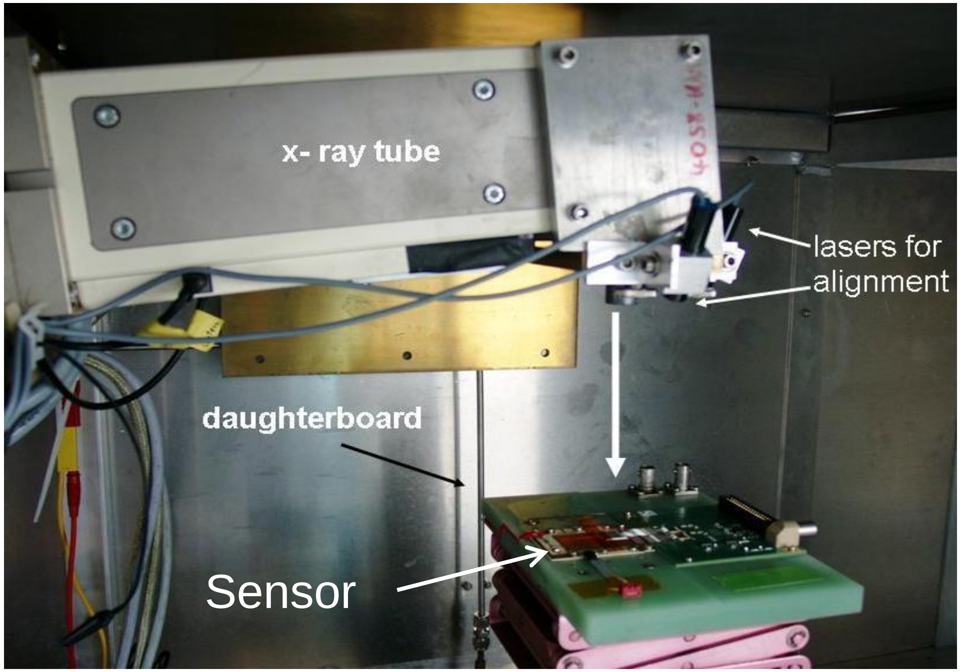
Irradiation Model: modified EVL model for neutrons, Later talk of Robert Eber

Investigation of CM as a function of oxide charge

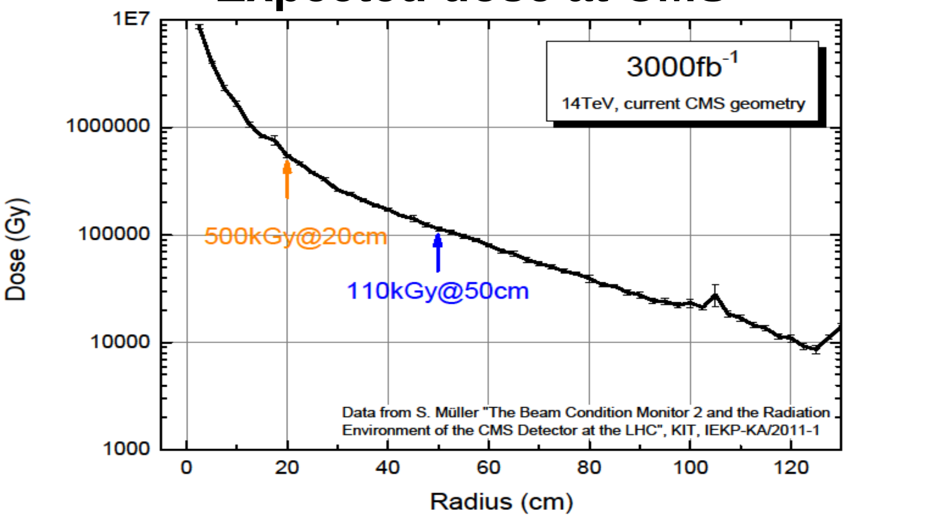
oxide charge: gamma irradiation (x-ray tube)

- Sample with neutron irradiation (p80-w6, 5e15 n_{eq}/cm^2) has been irradiated with x-ray tube to generate additional oxide charge in SiO_2
- Comparison with unirradiated sample
- After each step sample has been investigated with ALiBaVa readout system

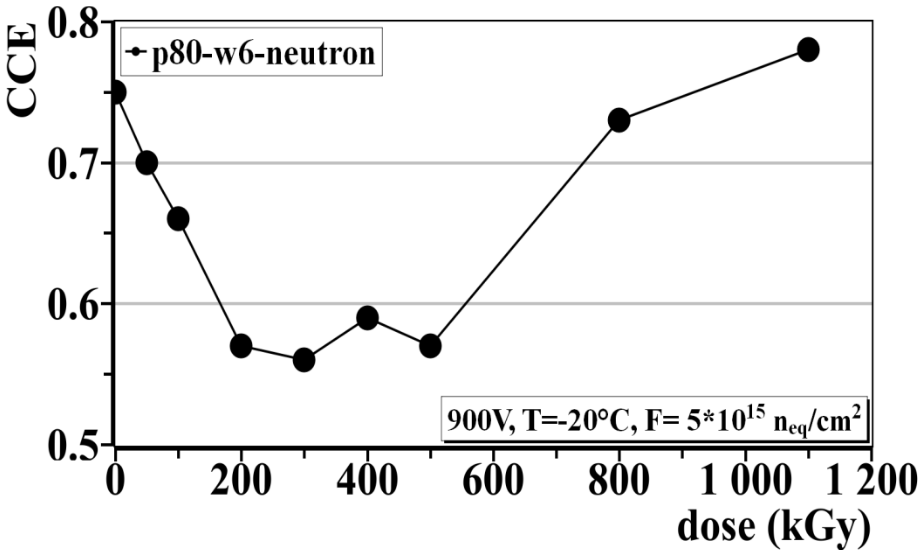
dose [kGy]	sum dose [kGy]
50	50
50	100
100	200
100	300
100	400
100	500
300	800
300	1100

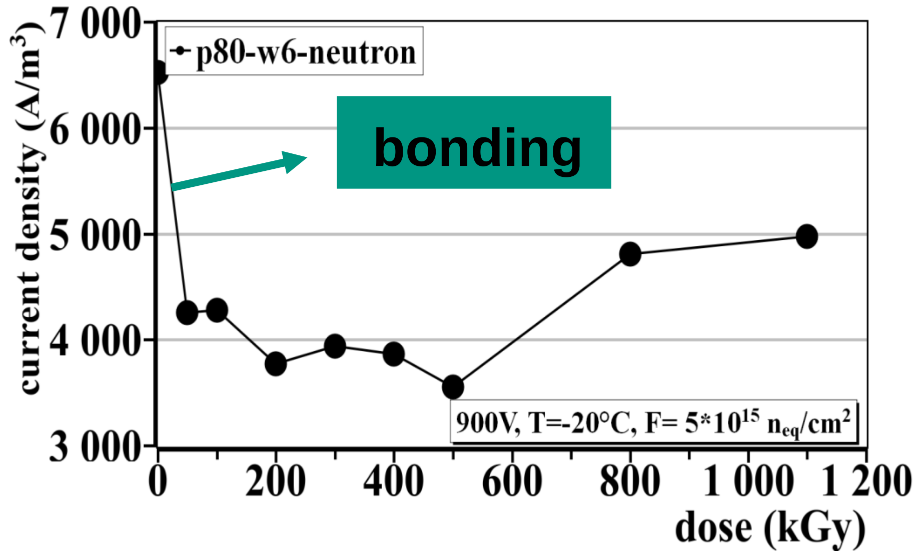


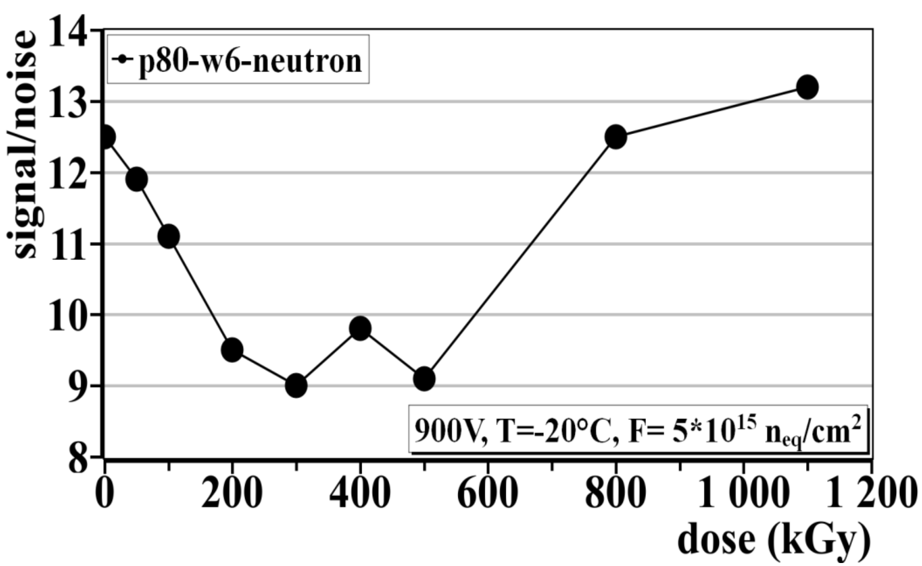
Expected dose at CMS



oxide charge: results

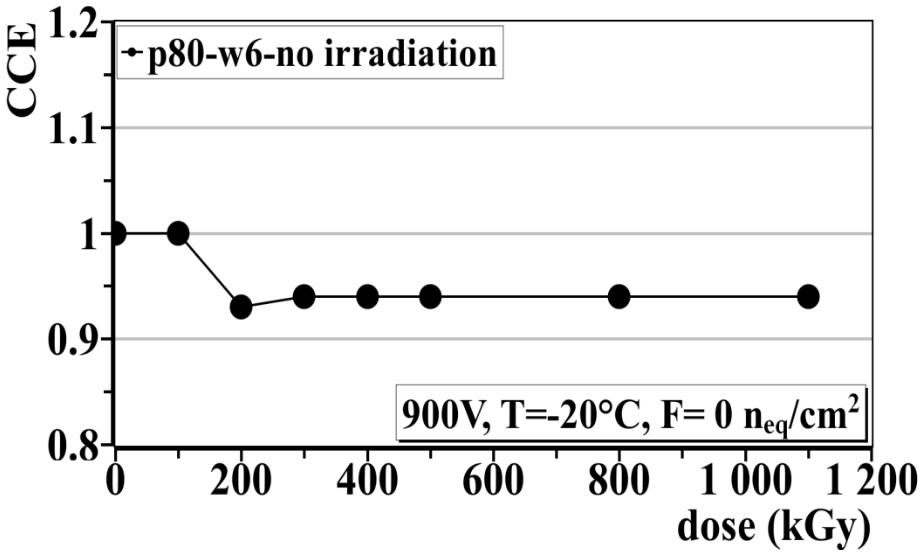


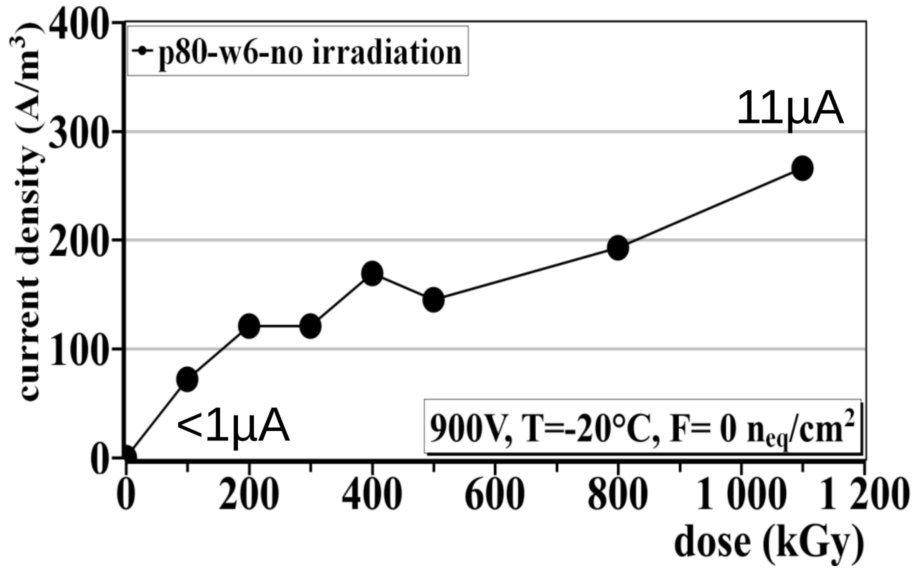


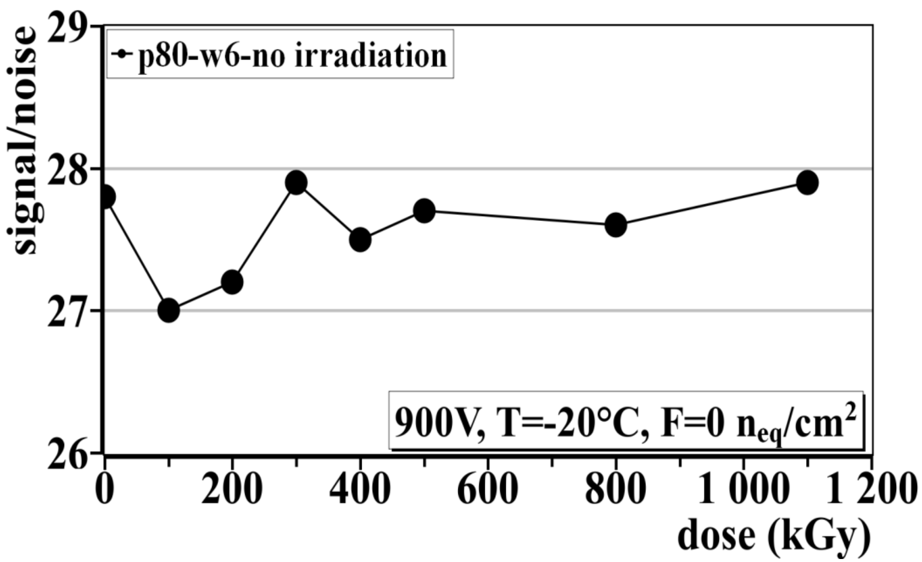


- As expected, charge collection efficiency decreases up to 500kGy
- For higher dose CCE increases (Why?)
- Leakage current and signal to noise show same behaviour

oxide charge: unirradiated sample







- **Charge collection efficiency is constant for different dose, CCE does not show a dependency**
- **signal to noise shows same behaviour**
- **Leakage current increases a bit with higher dose**

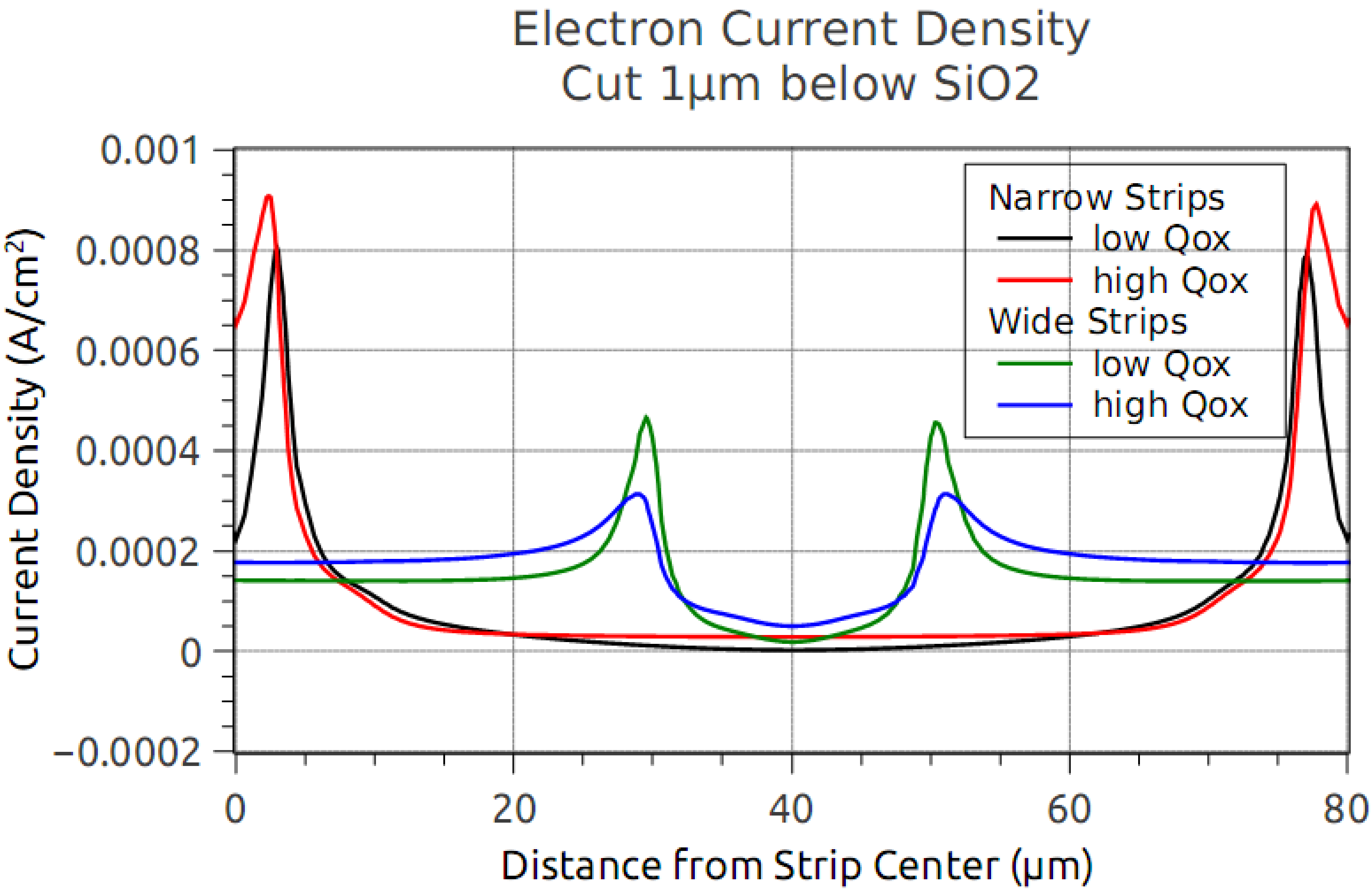
Summary

- Only narrow strips show charge multiplication after neutron irradiation ($F = 5 \cdot 10^{15}\ n_{eq}/cm^2$ & $F = 1 \cdot 10^{16}\ n_{eq}/cm^2$).
- Proton irradiated sample does not show charge multiplication
- $F = 5 \cdot 10^{16}\ n_{eq}/cm^2$ (neutrons): Sensor almost dead, no charge multiplication
- Proton irradiation generates more charge in the oxide and reduces the electric field at the strips (Simulation)
- Measurement with x-ray shows the influence of oxide charge in SiO_2.
For high doses, charge collection efficiency increases again.
  - Recombination of oxide charge?

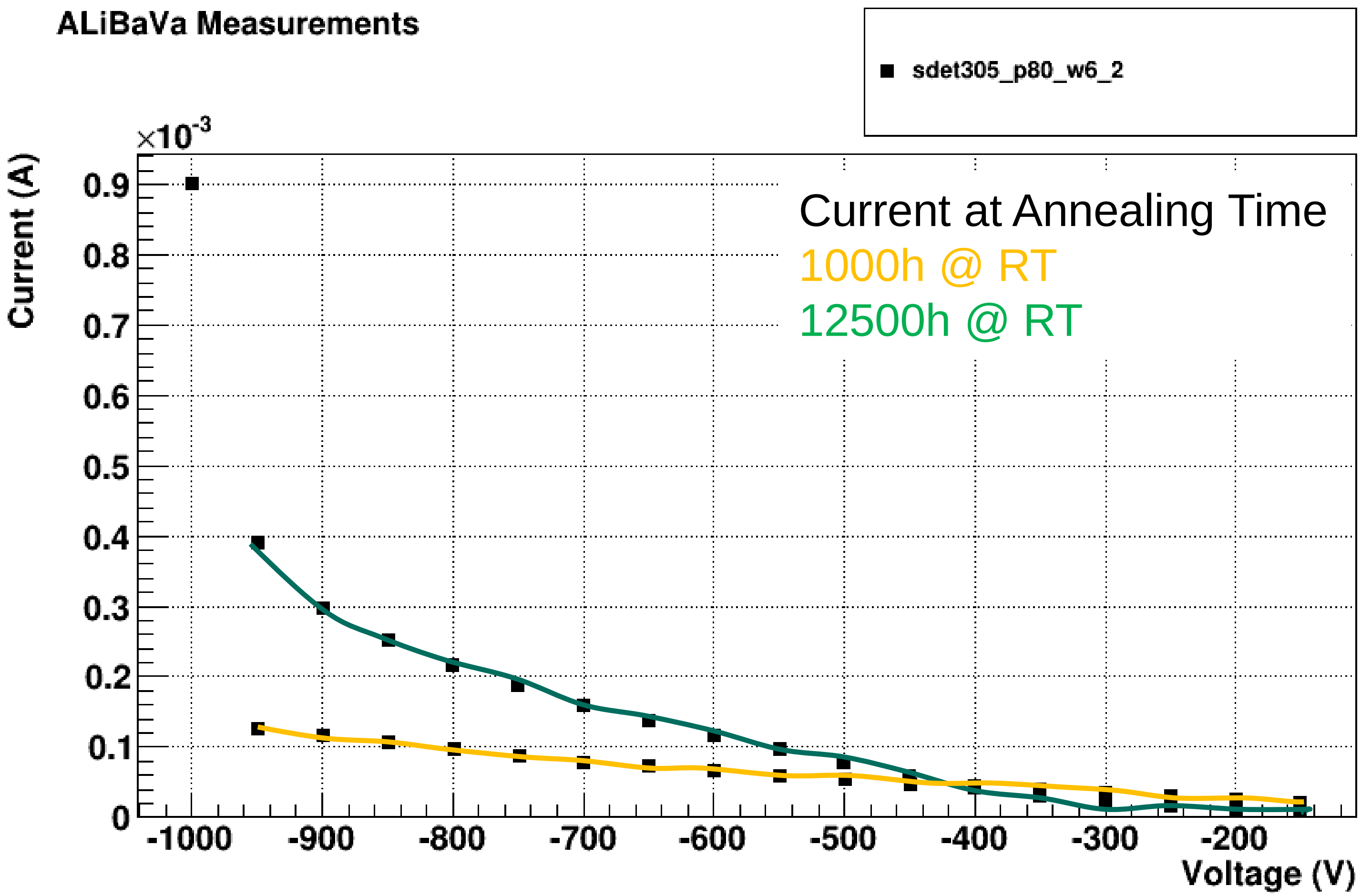
Thanks for your attention

Backup

Electron Density at the Strips



Current


ALiBaVa Measurements
sdet305_p80_w6_2
×10^-3
Current (A)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-1000
-900
-800
-700
-600
-500
-400
-300
-200
Voltage (V)
Current at Annealing Time
1000h @ RT
12500h @ RT