PIXEL 2012

Paul Dervan on behalf of CERN RD50 Collaboration
Liverpool University, Liverpool, UK

Silicon Detectors for the HL-LHC
- Recent RD50 Results -

RD50 Objectives

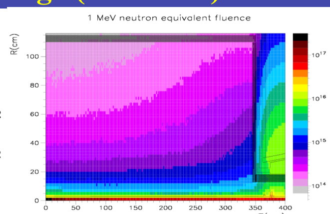
- Material characterisation & defect engineering
  - Understanding of radiation damage
    - Macroscopic effects and microscopic effects
    - Irradiation with different particles (p, n, π)
  - Oxygen enrichment
    - DOFZ, Cz, MCz, EPI
  - Understanding/tuning of influence of processing technology
- Device Engineering
  - p-type silicon (n-in-p)
  - thin sensors
  - 3D detectors

➔ **Proposal/understanding which sensor material and/or sensor configuration can be used at which radius to the beam for the HL-LHC and beyond.**

Radiation Challenge (HL-LHC)

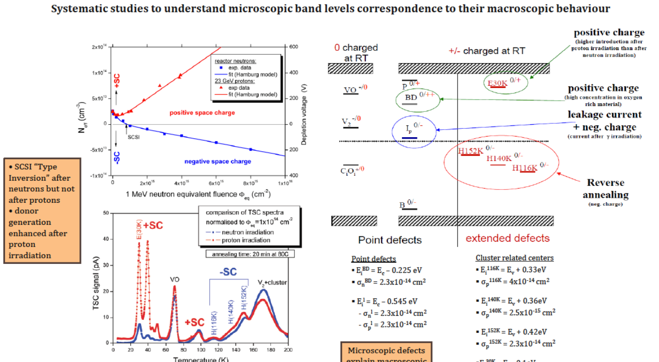
Radiation levels, including safety factor of 2:

Innermost Pixel Layer:	1×10^{16} n_{eq}/cm^2
Outer Pixel Layers:	3×10^{15} n_{eq}/cm^2
Short strips:	1×10^{15} n_{eq}/cm^2
Long strips:	4×10^{14} n_{eq}/cm^2



Microscopic studies RD50/WODEAN

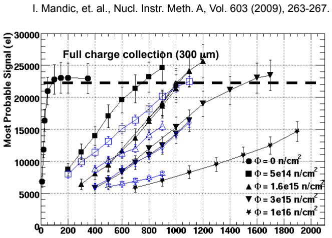
Systematic studies to understand microscopic band levels correspondence to their macroscopic behaviour



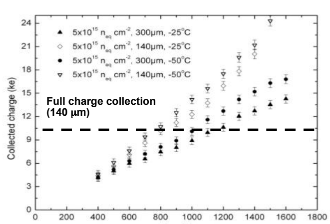
Pintilie, et. al., Nucl. Instr. Meth. A, Vol. 611 (2009), 52-68.

Charge Multiplication

I. Mandic, et. al., Nucl. Instr. Meth. A, Vol. 603 (2009), 263-267.



G. Casse, et. al., Nucl. Instr. Meth. A, Vol. 624 (2010), 401-404.

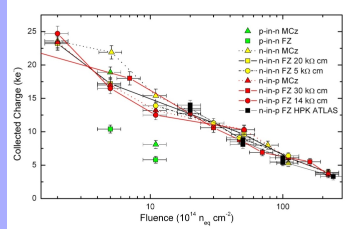


More than 100% charge collection seen at high bias voltages after irradiation for both n-in-p strips and EPI

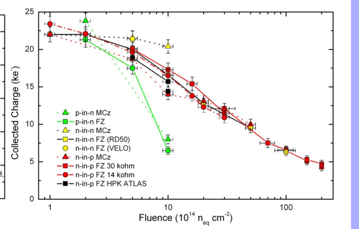
- Multiplication is consistent with high fields at implants
- Multiplication largest at segmented implant
- Current also correlated with charge as expected

Technology: p-in-n/n-in-p/n-in-n, FZ vs MCz

900 V, Unannealed, 26 MeV Protons



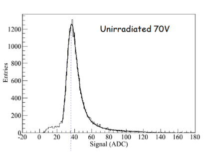
900 V, Unannealed, Neutrons



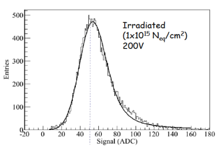
- CCE crucial for high fluences.
- Different bulk materials irradiated with charged and neutral particles.
- p-in-n not radiation tolerant enough for inner HL-LHC radii
- No CCE annealing observed for p-bulk
- N-strip readout devices devices have sufficient CCE for even innermost HL-LHC radii

Micron Neutrons: A. Affolder, et. al., Nucl. Instr. Meth. A, Vol. 612 (2010), 470-473.
Micron 26 MeV Protons: A. Affolder, et. al., Nucl. Instr. Meth. A, Vol.623 (2010), 177-179.
HPK Neutrons: K. Hara, et. at., Nucl. Inst. Meth. A, Vol. 636 (2011) S83-S89.

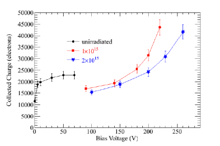
Device Engineering, 3D

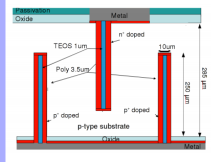


Landau MPV: 35 ADC



Landau MPV: 49 ADC





- Narrow columns along the detector thickness
- Diameter: 10µm, distance 50-100µm
- Lower depletion voltage needed
- Double sided p-type sensors (CNM) in SPS testbeam
- Irradiation at Karlsruhe) with 26MeV protons
- Higher signal after irradiation than before (multiplication)

Conclusions

At fluences up to 10^{15} $n_{eq}cm^{-2}$ (Outer radii of HL-LHC):

- MCz silicon detectors detectors could be a solution (more work still needed)
- P-type silicon microstrip detectors show promising results:
  - CCE ≈ 6500e, $\Phi_{eq}=4\times10^{15}cm^{-2}$, V=500V, 300µm, immunity against reverse annealing
  - Presently the baseline option for ATLAS upgrade.

At fluences up to 10^{16} n_{eq} cm^{-2} (Inner radii of HL-LHC):

Collection of electrons at electrodes essential. Use n-in-n or n-in-p detectors.

- Recent results show that planar silicon sensors will still have sufficient signal
- 3D detectors look promising

Many collaborations and sensor producers are working on this.

Disclaimer: This poster cannot present all recent results of the whole RD50 collaboration. Please see www.cern.ch/rd50 for more details