PIXEL 2012

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

RD50 Objectives

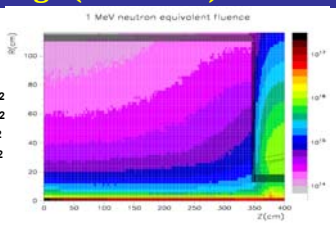
- Material characterisation & defect engineering
  - Understanding of radiation damage
    - Macroscopic effects and microscopic effects
    - Irradiation with different particles (p, n, π)
  - Oxygen enrichment
    - DOFZ, Cz, MCz, EPI
  - Understanding/tuning of influence of processing technology
- 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.**

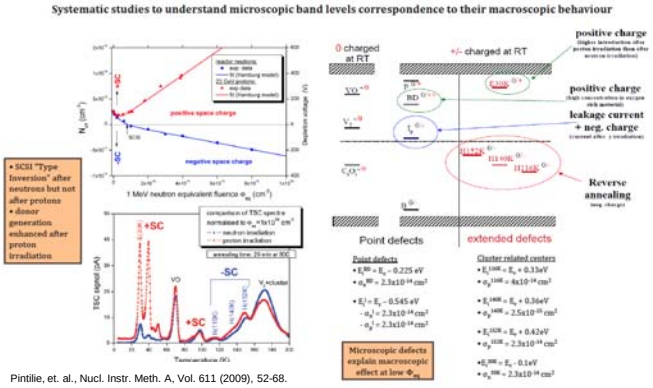
Radiation Challenge (HL-LHC)

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**



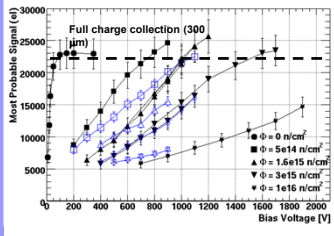
Microscopic studies RD50/WODEAN



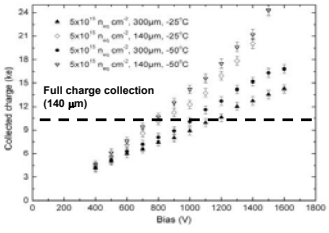
Pintilie, et. al., Nucl. Instr. Meth. A, Vol. 611 (2009), 52-68.

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.

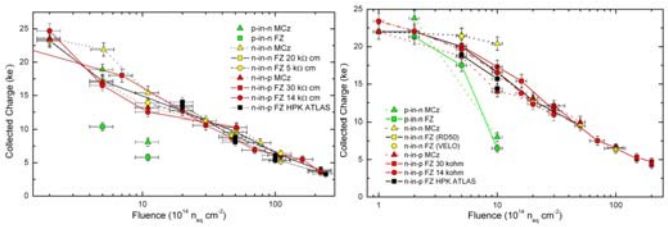


More than 100% charge collection seen at high bias voltages after irradiation for both n-in-p strips and EPI

- **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

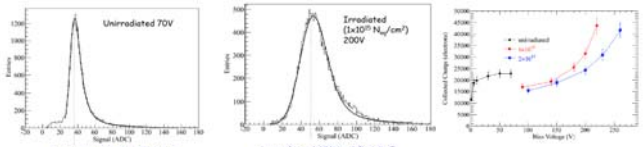
900 V, Unannealed, 26 MeV Protons | **900 V, Unannealed, Neutrons**

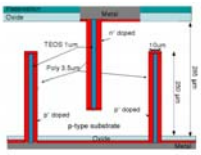


- **CCE crucial for high fluences.**
- **Different bulk materials irradiated with charged and neutral particles.**
- **p-in-n not radiation tolerant enough for inner HL-LHC radii**
- **No CCE annealing observed for p-bulk**
- **N-strip readout devices devices have sufficient CCE for even innermost HL-LHC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





- **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, Φ_{eq}=4 × $10^{15}cm^{-2}$, 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