Radiation Hard Semiconductor Sensors for Very High Luminosity Colliders

- CERN-RD50 project –

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Main Objective:

Development of ultra-radiation hard semiconductor detectors for the luminosity upgrade of the LHC to $10^{35}cm^{-2}s^{-1}$ ("Super-LHC").

Challenges:
- **Radiation hardness up to 10^{16} cm^{-2} required**
- **Fast signal collection (~10 ns bunch crossing)**
- **Low mass (reducing multiple scattering close to IP)**
- **Cost effectiveness**

About CERN-RD50

- **Approved in June 2002 by CERN Research Board**
- **Presently 270 members from 52 Institutes**
- **Spokesperson:** Mara Bruzzi (INFN & Uni Florence)
  Deputy: Michael Moll (CERN – PH-TA1-SD)

Scientific Strategies

Three basic research strategies are followed by RD50:

- **Material Engineering**
  Oxygenation of silicon, Czochralski and epitaxial silicon, oxygen dimers, pre-irradiation, other semiconductors then silicon (SiC, ..), (Diamond: RD42)
- **Device Engineering**
  Improvement of present planar detector structures (3D detectors, thin detectors, cost effective detectors,…)
- **Variation of detector operational conditions**
  Operation at low temperature or under forward bias (.. RD39)

Radiation Damage in Detectors

In order to develop radiation hard detectors all levels of radiation damage have to be investigated and understood:

Damage to the semiconductor crystal

- Radiation induced lattice defects (point defects and clusters)

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Change of semiconductor properties

- reduced carrier life time and drift length
- increased resistivity and eventually type inversion

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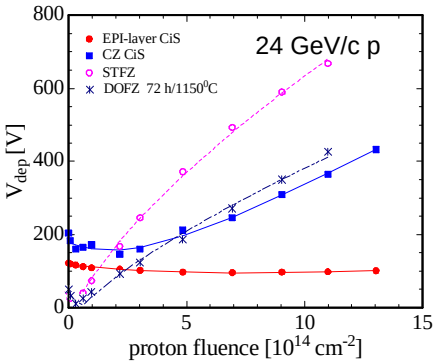
Change of detector properties

- Increase of leakage current (Noise, power dissipation)
- Change of depletion voltage (High voltage needed!)
- Decrease of Charge Collection Efficiency (Signal loss!)

Examples: Some recent RD50 results

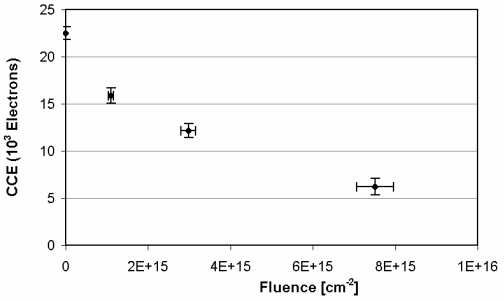
Czochralski and Epitaxial silicon

- **only small changes to V_{dep}**
- **no type inversion**
- **CCE and leakage current same as for FZ silicon**



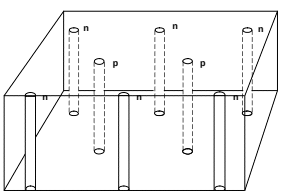
Oxygenated p-type detectors

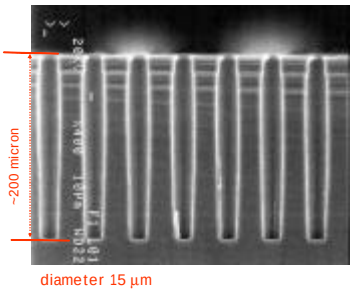
- **>5000 electrons for a p-type mini-strip detector measured after $8 \cdot 10^{15} cm^{-2}$ with fast LHC readout!**



3D detectors

- **Radiation hard due to geometry**
- **Fast signal readout**





More details: http://cern.ch/rd50/