Test Beam Results with 3D Silicon Strip Detectors

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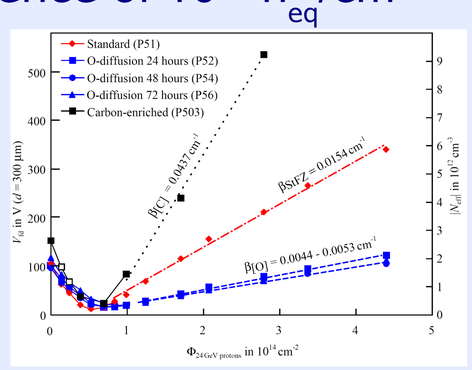
Motivation: More Radiation Hardness Needed...

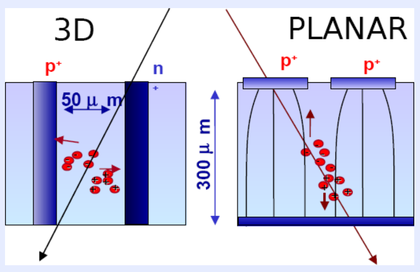
- Upgrade of the LHC (~2018): super LHC (sLHC), peak luminosity increased tenfold ($L=10^{35}\ s^{-1}\ cm^{-2}$)
  → Extremely high track density, severe radiation damage especially for the silicon tracking detectors
- ATLAS: current SCT (SemiConductor Tracker, silicon strip detector) designed for fluence of $10^{14}\ n_{eq}/cm^2$
  → For the sLHC: inner strip sensors must withstand $10^{15}\ n_{eq}/cm^2$ (factor of 10!)
- Main effects of radiation damage in silicon:
  - Voltage to achieve full depletion of the sensor increases
  - Trapping increases: free charge carriers get trapped at crystal defects
- Possible solutions: radiation harder material (e.g. oxygen enriched, p-type silicon), modified geometry (3D, see below)



[A. Ruzin, NIMA 447 (2000)]

3D Detectors

- Idea: decoupling of detector thickness and charge collection distance
- Columnar electrodes etched into the wafer

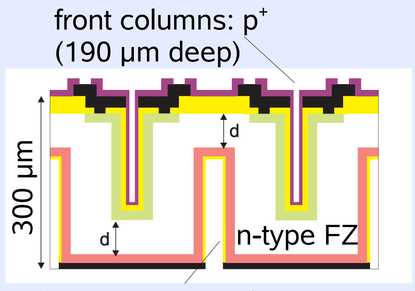


Advantages:
- Lower depletion voltage
- Less affected by trapping

→ Effects of radiation damage reduced

But: fabrication challenging!

- Process simplification: 3D DDTC detectors
  - DDTC: double sided, double type columns - columns not etched through the sensor completely
  - Device under test: microstrip detector, 100 µm pitch; fabricated by FBK-IRST, Trento (Italy)



[A. Zoboli, NIMA, in press]

Test Beam

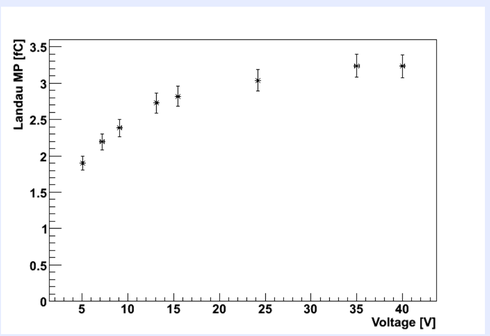
- July 2008: test beam at the CERN SPS, H2 beamline (225 GeV/c muons)
- Silicon Beam Telescope (SiBT, provided by the university of Helsinki): delivering track position with a resolution of ~4 µm

- Readout: APV25 chip (CMS tracker)
- Purpose: position resolved studies of the detector behaviour (charge collection, efficiency ...) in a realistic environment

Test Beam Results

- Key questions:
  - Does the collected charge correspond to the value expected for 300 µm silicon (~3.5 fC)?
  - Is the charge collection and the efficiency uniform?

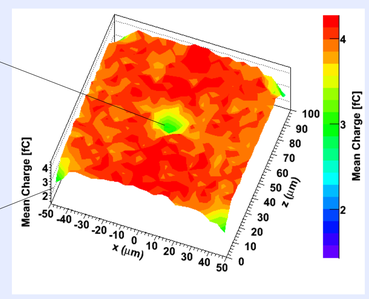
- Signal (Landau MP) for bias voltages from 5 V to 40 V
  - Max. collected charge: ~3.2 fC
  - Close to expectation, 10% loss due to asynchronous beam
  - S/N: ~15

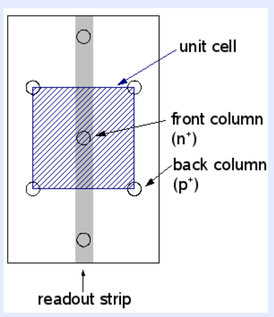


- Mean value (not Landau MP!) of collected charge mapped onto a 2D unit cell, 3-strip-clusters: uniformly distributed, hollow columns visible

front column

back column

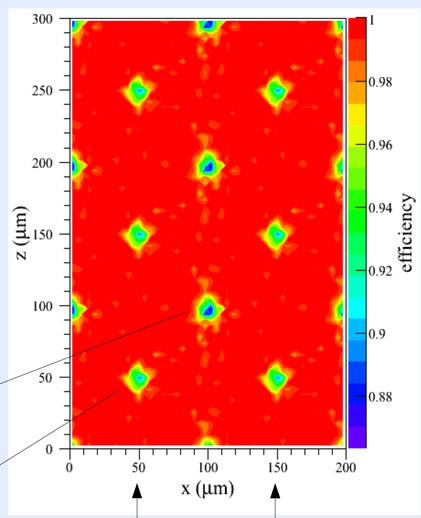




- 2D efficiency for a cut S/N > 5 (Q > 1 fC)
  - Entire sensor mapped onto a unit cell, then plotted six times
  - Efficiency homogenous, lower efficiency only in hollow columns
  - Overall efficiency: 99%

back column

front column



Conclusion and Outlook

- Test beam results show: 3D DDTC detectors meet the expectations concerning spatially resolved charge collection and efficiency
- Plan for summer 2009: perform another test beam with planar and 3D DDTC strip detectors (irradiated and unirradiated)
  → Direct comparison of the radiation hardness of both detector types