The CMS Pixel Detector for the High Luminosity LHC

Antonio Cassese (antonio.cassese@cern.ch), INFN - Firenze, on behalf of the CMS Collaboration

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The present CMS tracker cannot sustain the foreseen radiation levels and data rates and has to be completely replaced.

High Luminosity LHC

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LHC (after 2010)</th>
<th>HL-LHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_{vtx} ) [TeV]</td>
<td>7 ± 34</td>
<td>7 ± 75 × 10^{34}</td>
</tr>
<tr>
<td>( \mathcal{L} ) [cm^{-2} \cdot s^{-1}]</td>
<td>&lt; 50 = 60</td>
<td>160 = 200</td>
</tr>
<tr>
<td>( \mathcal{T} ) [fb^{-1}]</td>
<td>300</td>
<td>3000 + 4500</td>
</tr>
</tbody>
</table>

Resulting in:

- Dose & fluence 10x higher
- 750 kHz L1 rate
- 12.5 μs L1 latency

The CMS HL Pixel Detector

- High radiation tolerance:
  - \( 2.3 \times 10^{34} \) n/cm², fluence
  - 1.2 Grad, TID
- Improve tracks separation:
  - High granularity
  - Low material budget
- High bandwidth (up to 3.5 GHz/cm² occupancy)
- Extend tracking coverage (|\( \eta \)| ≤ 4)
- Stringent space constraints
  - Thin planar n-in-p and 3D silicon sensors
  - Operation at 20°C
- Innovative power scheme

CMS Read Out Chip (CROC)

- CMS chip size (16.8×21.6 mm², 336×432 cells)
- 65 nm CMOS technology
- Dead time ≤1% @3.2 GHz/cm²
- 1 Grad TID resistant
- Stringent space constraints
  - High hit and trigger rate (up to 4×1.28 Gb/s output links)
  - Serial powering capabilities

Serial powering

- Consecutive modules use the same current
- Current is shared in parallel between:
  - ROCs in the same module (2 or 4)
  - Analog and Digital domain on ROC
  - Shunt-LOD:
    - ROC IP block for serial powering support
    - On chip solution
    - Low mass, radiation hard, no extra ASIC
    - Equivalent to a resistor in series with a voltage source (\( R_{over} \), \( V_{over} \))

- 2 cell readout chip of the CMS Inner Tracker for HL-LHC - Michael Grippo

Services

- Portcards:
  - 3 LGGBT
  - 3 VTRX+
  - 1 bPOL12V DC/DC converter
  - 1 bPOL2V5 DC/DC converter
- Powering:
  - Low voltage power with serial powering scheme over 576 chains
  - High voltage distributed in parallel to modules in each serial chain
  - ~ 350 pre-heaters meeded by cooling

Mechanical structure

- Simple mechanics:
  - Can be removed for maintenance
  - Barrel splits in half at \( z = 0 \)
  - Disks with planar geometry
- Light Carbon Fiber structures with embedded cooling pipes
- Features a two-phase -35°C CO₂ cooling system
  - 1.8 mm OD stainless steel pipes
  - 168 cooling loops
  - 60kW power budget

Contacts

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Sensors

- 25×100 μm² pixel cells
- 50–50 μm² bump bond pads
- Extensive R&D program
- Irradiations and test beams (CERN, Fermilab, Desy, FNAL)
- Simulations for geometry optimization
- Thin planar n-in-p sensors:
  - > 150 μm thickness
  - Bitten implant, no punch-through bias dot
  - Hit efficiency > 99% (after \( 2 \times 10^{14} \) n/cm²)
- 3D pixel sensors on Barrel layer:
  - Lower high voltage power consumption
  - Stable hit resolution up to \( 10^{4} \) n/cm²

Poster:
- Study of irradiated 3D pixel sensors from CNM – Clara Lasaosa García
- Characterization of irradiated passive CMOS sensors for tracking in HEP experiments – Franz Glessgen
- Performance of highly irradiated FBK 3D and planar pixel detectors – Rudy Ceccarelli

Poster:
- The CMS Tracker for the High Luminosity LHC – Alessandro Rossi