Performance and Operation of the CMS Phase 1 Pixel Detector

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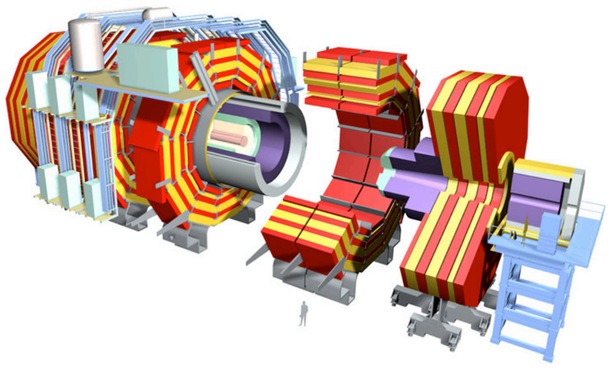
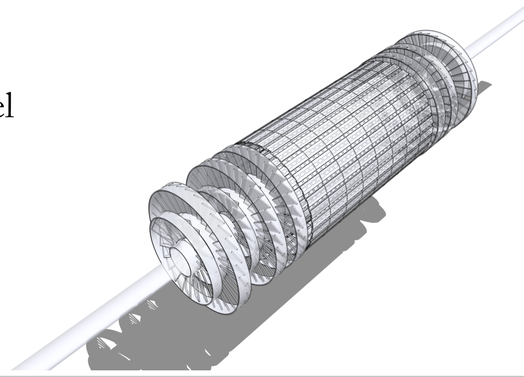


The CMS Phase 1 Pixel Detector

The CMS detector is a multipurpose detector at the CERN LHC. The silicon pixel detector is closest to the proton-proton interaction point and provides high-precision tracking information. The original pixel detector has been replaced with an upgraded system (Phase 1) during winter 2016/17 to maintain the excellent track reconstruction performance of CMS at higher luminosities (up to $2.5 \times 10^{34} cm^{-2} s^{-1}$ during LHC Run 2+3).



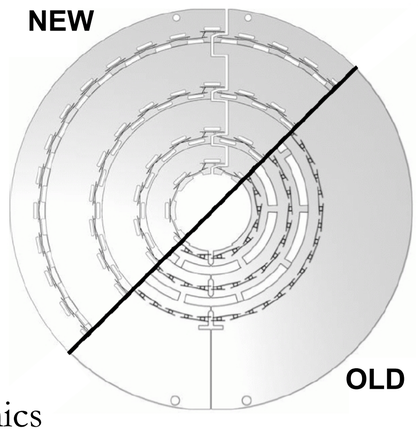
Main Improvements

Robustness
- Additional barrel layer and endcap disk

Vertex resolution
- Innermost layer and disks closer to beam

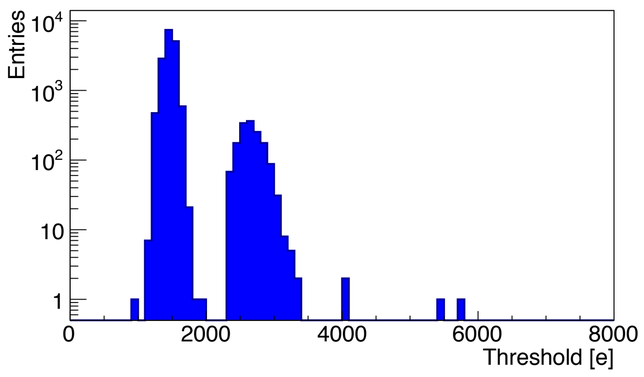
Efficiency
- Faster readout electronics

Materiel budget
- CO_2 cooling and lightweight CFK mechanics



Performance during first year of data-taking

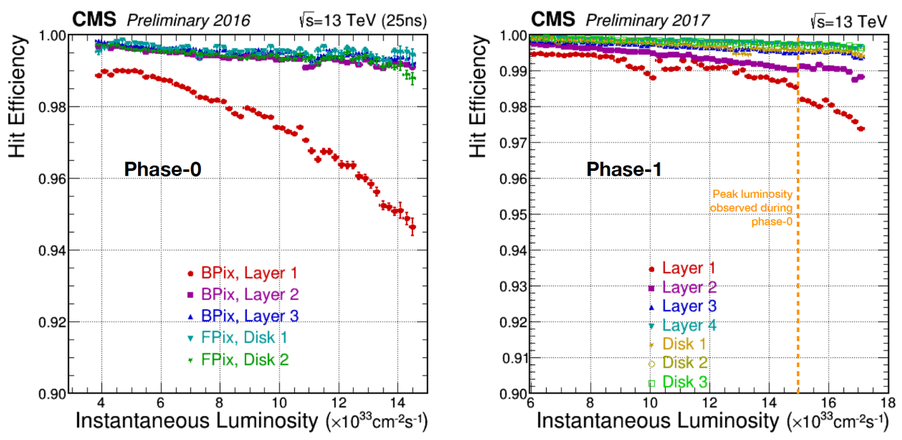
Threshold and Noise



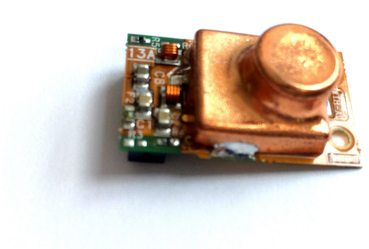
- Mean threshold of 1800e with noise of ~150e for outer barrel layers and endcap disks
- Mean threshold of 2600e for innermost barrel layer (different readout chip)

Operation and procedures
- Detector calibration after installation and during technical stops
- Fraction of active channels of 95.7%
- Periodic power-cycling/resets/programming to mitigate SEU effects

Performance
- Resolution of about 10(30)um in the transverse(longitudinal) direction
- Dynamic inefficiency at high inst. luminosity significantly reduced



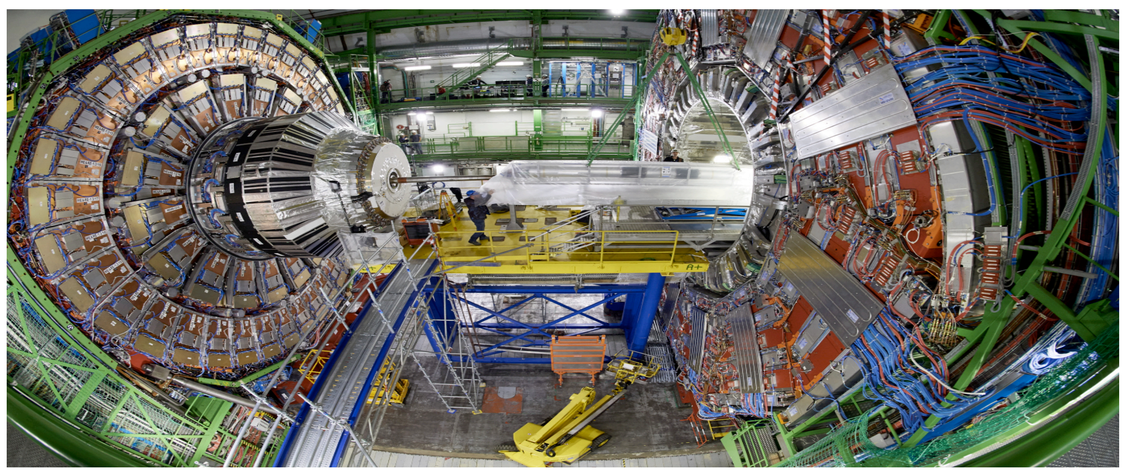
DCDC converter issue



- 1184 DCDC converters used for powering
- Components started failing during last two months of operation (67 converters)
- Detector extracted for repair at the end of 2017
- Failure traced to FEAST2 chip, cause still under investigation

Consolidation work during LHC shutdown

Detector Extraction
- Mechanical design allows for pixel detector installation and extraction with beampipe in place
- Repair work and testing in cleanroom at surface (about 3 weeks)

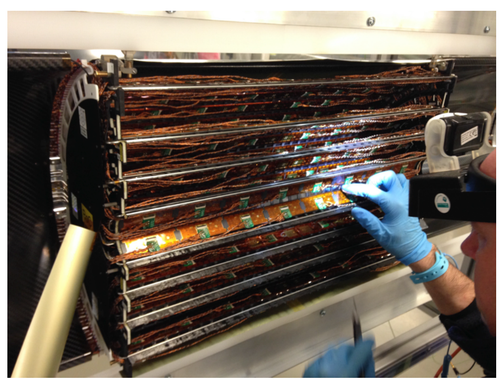


Replacement of DCDC converters
- All 1184 DCDC converters replaced

Replacement of Layer 1 modules
- Collateral damage of pixel detector modules attached to faulty converters
- Extent of damage correlated with amount of sensor leakage current
- Accessible modules in innermost layer replaced and tested

Other repairs
- Issues with individual power and readout groups (4%) resolved by improving connections or component replacement

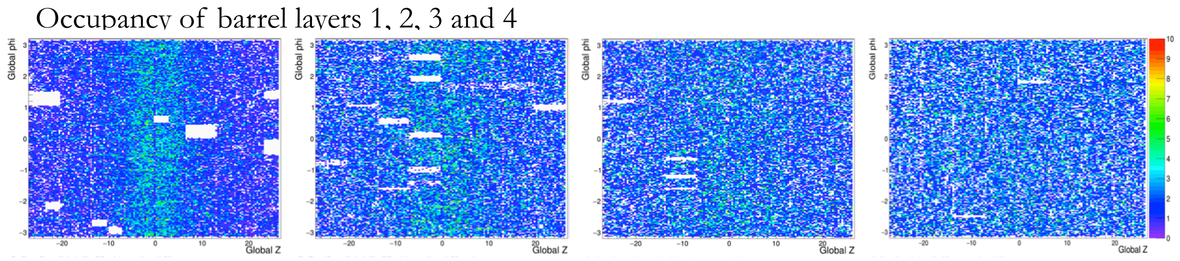
+ Testing and calibrations



Performance during early 2018 collision data-taking

- Detector successfully re-installed in February 2018
- Ready to record first collisions of 2018 with working fraction of 97.8%
- Performance of DCDC converters closely monitored and preventive measures put in place to mitigate potential losses

Occupancy of barrel layers 1, 2, 3 and 4



Conclusion

The CMS Phase 1 pixel detector delivered high-quality data during its first year of operation. An issue with the DCDC converter chips, required an unforeseen intervention in winter 2017/18. Despite the limited time available before the start of the next LHC run, all repair work was completed and the detector is again taking data. Detailed investigations of the DCDC converter issue are ongoing and are crucial in view of many future LHC detector upgrade projects.