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Characterization of Detector Modules for the CMS Pixel Phase 1 Upgrade

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In high energy particle physics, accelerator- and detector-upgrades always go hand in hand. Along with an anticipated improvement of the Large Hadron Collider (LHC) to reach and exceed the luminosity of L = 2 x10ˆ34 cmˆ-2s ˆ-1 during Run 2 until 2023, a new pixel detector has been installed in the Compact Muon Solenoid (CMS) detector early 2017 to cope with the new conditions. This so-called Phase 1 Upgrade of the CMS pixel detector was built to operate at higher rates with increased tracking efficiency and vertex resolution. It features amongst others an additional detector layer, a new bi-phase CO2 cooling and new readout chips with on-chip digitization of the data stream.

The barrel detector consists of 1184 modules, each with a silicon sensor bump-bonded to sixteen readout chips, supported and coordinated by a high-density-interconnect. The innermost layer, exposed to the highest particle flux compared to all other parts in CMS, has a different design dedicated to cope with extreme data rates and radiation damage.

An intense performance investigation and optimization program has been performed in addition to the extended qualification and calibration procedure under controlled environments to ensure the module functionality after being installed into CMS.

This presentation summarizes the characterization results of module performance with focus on the new on-chip digitization of analog hit information that is mandatory for good position resolution and the module qualification results with focus on methods using module-internal calibration signals. This method allows extended characterizations on pixel level such as electronic noise and bump bond connectivity, optimization of operational parameters, calibrations, thermal stress resistances and sensor quality. “Lessons-learned”are shared regarding optimizations in detector manufacturing technologies based on feedbacks from characterization activities.

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