The upgrade of the CMS pixel detector for LHC Phase1

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1 Introduction

After a little over one year of operation, the LHC is operating smoothly and delivering luminosities up to 10^{33} cm^{-2}s^{-1}, while the CMS detector is performing very well collecting over 380 pb^{-1} of data. However, data-taking will continue for many years to come, and one of the main goals for the coming years is to reach and pass the design luminosity of 10^{34} cm^{-2}s^{-1}. As the accelerator reaches new frontiers, CMS needs to operate reliably in the new environment: this means improved radiation hardness and better handling of large occupancy events resulting from high pileup. This calls for an upgrade of the CMS experiment, including a new pixel detector. Along with these improvements, better and newer solutions to reduce the amount of material in the inner part of the detector and improve its electronics and cooling will be pursued. To accomplish all of these tasks a new pixel detector has been designed with lighter supports, a CO_2 cooling system and a full 4 hits-per-track coverage up to pseudorapidities of 2.5.

2 Current design and future challenges

The current CMS design [1] was developed more than twenty years ago and was meant to handle the LHC design luminosity of 10^{34} cm^{-2}s^{-1}. The experiment is divided into many sub-detectors: the innermost is the tracker featuring an inner silicon pixel detector and an outer silicon strip detector that guarantee good spatial resolution to measure vertices and the momentum of charged particles.

The current pixel detector consists of a central barrel divided into three layers and two endcaps divided into two disks, giving a good 3 hits-per-track coverage, and making it a good device for tracking and b-jet tagging purposes.

The pixel detector is the closest to the interaction point and therefore the most subject to radiation damage and for this reason its replacement, after a long period of operation, was already foreseen.

The average number of interactions per crossing (pileup) dramatically increases with the luminosity and it goes rapidly from 25 (design luminosity) to 50-100 according to the extrapolation for the High-Luminosity phase of the LHC (HL-LHC). This results in data loss in the innermost pixels due to readout chip limitations and higher track fake rates due to the large number of hits from pileup.

3 Phase1 upgrade design and simulation results

The new pixel detector [2] aims to maintain the current good performance of the CMS tracker in the new environment that will be produced by the HL-LHC interactions.

In order to reduce the number of fake tracks, an extra barrel layer and an extra disk per side have been added to the current design, so the number of hits per track will increase in order to provide better tracking and b-jet tagging performance in the high pileup scenario that CMS will face in the future.

We have performed simulations of the capabilities of the new detector and results are available in the Technical Proposal [2]. In Figure 1 are shown the tracking efficiency and fakerate for the HL-LHC; the new design will be able to provide almost the same performance as the tracker today, while the current detector will not only suffer high pileup but also inefficiency due to data loss and radiation damage.

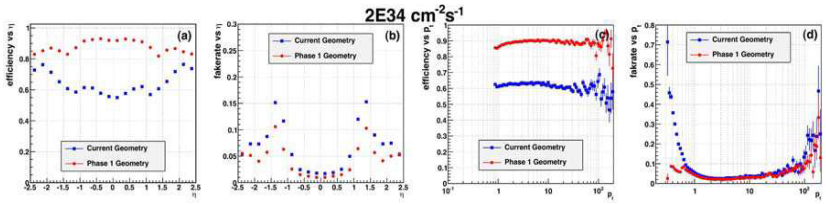

Figure 1: Tracking efficiency vs eta (left) and pt (right) for the current geometry (blue squares) and the proposed upgrade (red circles), for $t\bar{t}$ events at $\sqrt{s} = 14$ TeV and luminosity of 2×10^{34} cm^{-2}s^{-1}

References

[1] The CMS Collaboration, The Tracker Project: Technical Design Report, **CERN/LHCC 98-006**, CMS TDR 005 (1998).

[2] The CMS Collaboration, Technical Proposal for the Upgrade of the CMS detector through 2020, **CERN/LHCC 2011-006**, CMS-UG-TP-1 (2011).