CMS Tracker Performance

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Abstract

We are presenting the performance of the CMS pixel and strip silicon tracker with proton proton collision data at the LHC.

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1. The CMS Tracker

The CMS [3] silicon tracker [1] has been designed to provide precise hit measurements [2] in order to allow for very efficient tracking and vertex reconstruction in the dense environment of the proton-proton interactions at the LHC. It consists of 1440 pixel and 15148 strip modules, comprising 66 million pixels and 9.3 million strips. The pixel modules are arranged in three barrel layers and two discs on either side of the barrel, while the strip modules are arranged in 10 barrel layers, and three small and nine large discs on either side. The total coverage of the tracker in pseudo-rapidity is $|\eta| < 2.5$. The fraction of working channels is stably around 97%. While the pixel detector has virtually zero noise occupancy, the signal-to-noise ratio in the strips has been measured from clusters on tracks in collision data to be 18.4 in the inner barrel and 22.4 in the outer barrel modules. The pixel and strip trackers have been commissioned initially using cosmic ray muons [4, 5, 6]. Here we will present performance results measured with p-p collision data at 7TeV.

2. Hit Resolution

The resolution of the pixel detector is measured by selecting tracks with hits in all three pixel barrel layers and then redefine the track by using the curvature measurement from the full tracker and the position and angle as measured by the pixel hits in the first and third layer. Then the residual of the pixel hit on the second layer to the track is a measure of the pixel hit resolution. Figure 1a) shows the rϕ residual as measured with this method using high quality tracks with a pt> 12GeV. One can then translate the width of the residual distribution into the intrinsic resolution after unfolding it from the beam width. The result shown here at high pt where multiple scattering is negligible is a resolution of the transverse coordinate of 10.4μm. In Figure 1b) we show the dependence of the z resolution on the angle of the track. This measurement is performed for tracks with pt> 4GeV, and is compared to a monte carlo simulation.

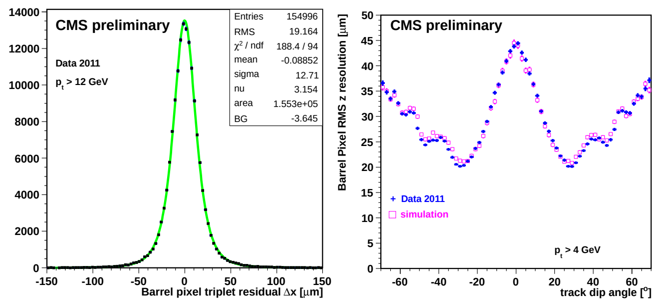

Figure 1: Pixel barrel hit resolution measurements in rϕ (a) and z (b).

In the strip tracker we measure the resolution in the barrel by using hits on tracks passing overlapping modules. We compare the difference in the measured and expected (from the track) hit position between the two hits. The width of this difference is a measure of the hit resolution. The resolution depends on the pitch of the silicon, which varies for different modules and layers, and the cluster size, larger clusters giving better resolution. The measured values range between 14μm (for 80μm sensor pitch) and 36μm (for 183μm pitch).

3. Hit Efficiency

The hit finding efficiency in the pixel detector is measured by using well reconstructed, isolated tracks with a pt> 1GeV, which originate from the primary vertex. Trajectories passing near the edges of sensors are excluded. Known bad modules are excluded as well from the analysis. The hit efficiency is calculated from the present and missing hits on and near the track (within 0.5mm of the predicted position). The average hit efficiency is measured to be 99%. It depends on the instantaneous luminosity, the trigger rate and the presence of beam background. Sources of inefficiency are readout errors in the frontend electronics and a limited internal buffer size of the readout chip. Figure 2a) shows the pixel hit efficiency for the three barrel layers and the four endcap discs. Figure 2b) shows the efficiency as a function of the instantaneous luminosity. It can be seen how the so-called dynamic inefficiency (due to the

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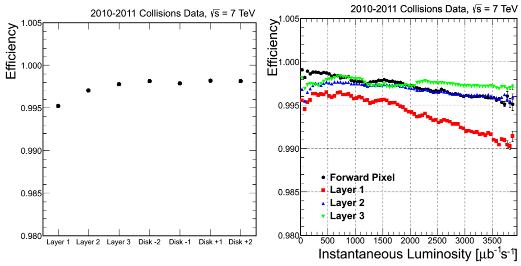

Figure 2: Pixel hit finding efficiency measurements for the individual barrel layers and endcap discs (a) and as a function of the instantaneous luminosity (b).

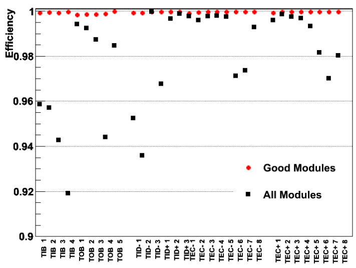

Figure 3: Strip hit finding efficiency measurements for the individual barrel layers and endcap discs.

limited buffer size) affects especially the innermost layer, which suffers from the largest occupancy.

In case of the strip tracker we measure the hit finding efficiency using tracks reconstructed with at least eight hits and not passing near the edges of sensors. The efficiency is calculated from the present and missing hits in the traversed modules. In order to avoid multiple scattering effects, a hit in the subsequent layer is required. Known bad modules are excluded. The average hit finding efficiency is measured to be 99% and is plotted for the individual barrel layers and endcap discs in Figure 3, where the red points represent all currently active modules, and the black points also include modules, which are known to have problems and thus are not used for physics analyses.

4. Tracking and Vertexing Performance

CMS uses an iterative tracking algorithm with subsequent steps picking up inefficiencies from previous steps. The main tracking algorithm is based on pixel seeds and uses a Kalman filter method for track finding. The track finding efficiency using muons from Z boson decays in pp collision data, and comparing them to results from monte carlo simulations, can be seen in Figure 4 as a function of the η of the muon.

Good primary vertex finding efficiency and resolution are essential to physics using the busy LHC collisions. The luminous region in CMS is roughly 5cm in z, containing an average of 8 (15) pp interactions for 2011 (2012) data taking conditions. The primary vertex finding algorithm consists of three steps: (i) selection of the tracks to be used; (ii) clustering of the tracks, meaning deciding which ones originate from the same interaction vertex; (iii) fitting the position of each vertex using its

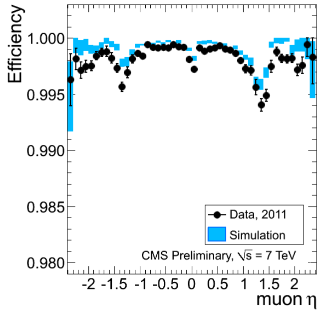

Figure 4: Track reconstruction efficiency versus η using muons from Z boson decays. Results from pp collision data are compared with a monte carlo simulation.

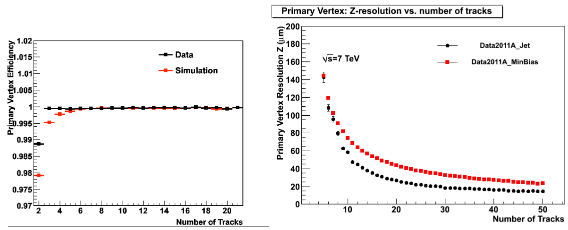

Figure 5: Vertex reconstruction efficiency in data and simulated events (a), vertex resolution for clean (MinBias) and busy (Jet) event environments (b) plotted as a function of the number of tracks used in the vertex reconstruction.

associated tracks. The measured efficiency and resolution of the primary vertex reconstruction are shown in Figure 5a) (efficiency) and b) (resolution) as a function of the number of tracks used for the reconstructed vertex. The efficiency in data is compared to that measured in simulated monte carlo events. Good agreement is found when requiring at least five good tracks in the vertex. The resolution is shown for two different types of events and can be seen to depend on the business and complexity of the event.

5. Conclusion

The CMS pixel and strip silicon tracker is working according to design specifications. Its excellent performance is key to the successful physics programme of CMS.

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