Track Reconstruction with the CMS Tracking Detector

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With proton-proton collision energy of 14 TeV at luminosity of $10^{34}\text{cm}^{-2}\text{s}^{-1}$, the LHC environment poses challenges for the tracking system and for the tracking software. The system must reconstruct charged particles from the primary collision in the presence of up to 20 underlying events. CMS has built an all-silicon tracking system consisting of an inner pixel detector (1 m^2 active area) and an outer strip detector (200 m^2) with over 70 million readout channels. The CMS software has to master the dense track environment and also take into account multiple scattering due to the large amount of material (0.5 X_0 on average). With 13 layers crossed on average, 0.7 % to 5 % transverse momentum resolution is achievable. An overview of the tracking system and the tracking software will be given. Both general and specialized tracking algorithms covering, for example, muon reconstruction will be discussed.

1. CMS Tracker design and Hit Reconstruction

The CMS tracking detector has been presented by other authors at this conference [1] and is shown in figure 1. Although the original design [2] includes two types of sensor technology, the CMS tracker is fully based [3] on silicon sensors. At innermost radiuses less than 10.2 cm, there are three pixel barrel layers and two pixel disks are located in each end cap at longitudinal distance from the interaction region less than 50 cm. The 1 m^2 active area consists of about 66 millions 100×150 μm pixels. Single pixels signals are clusterized and cluster position is calculated from the cluster edge: single hit resolution ranges 15 to 30 μm. Pixel resolution is expected to degrade by a factor of two due to the high particle fluence at the LHC. However, the pixel detector high granularity yields a low occupancy, even at high luminosity.

There are ten barrel layers of strip sensors up to a radius of 1.1 m, four layers of which are double sided and mounted with a stereo angle (5.7°) to provide 3D measurement points. There are 12 strip disks in each end cap up to a longituinal distance of 2.75 m; Disk partially consists of double sided stereo sensors. 40 % of the 200 m^2 active area of strip detector provides 3D measurement points. Strip signals are clusterized and cluster position is either calculates from the edges or as the centroid depending on the cluster size. Single point strip resolution ranges from 8 to 64 μm.

The tracker is embedded in a homogeneous solenoidal magnetic fiel of 4 Tesla that bends the trajectory of charge particles.

Figure 1. Sketch of the CMS Tracker Detector

2. Track Reconstruction Resolution

Track parameter are fitted and smoothed on sets of reconstructed hits using the Kalman fitting method. The effect of material (see figure 2) concentrated in the thin layer of silicon is taken into account in this procedure. Combined to single point measurement uncertainty, CMS track reconstruction reaches fine resolution as shown in figure 2. Transverse and longitudinal impact parameter resolution ranges from 10 to 100 μm and 20 μm to 1 mm respectively, depending on track momentum and pseudo rapidity.

Figure 2. Amount of material in the CMS tracker volume and muon transverse momentum resolution.

3. Pattern Recognition

Pattern recognition consists on gahtering sets of reconstructed hits consistent with the path of a charge particle and is initiated by during a seeding phase.

3.1. Trajectory Seeding

3.1.1. Hit doublet

A pair of hits in the tracker combined with an interaction region constraint determine initial track parameters. High efficiency is achived by searching for hits pairs in redundant pair of trakcer layers. The purity of such set of trajectory seeds is low. Pixel pairs, strip pairs and mixed pairs are used and allow for the reconstruction of tracks with vertex further out than the pixel detector volume.

3.1.2. Pixel Triplet

Pixel triplets are constructed from pixel pairs for which a consistent hit is found on one of the outtermost pixel layer. In the baseline, pixel triplet is optimized for transverse momentum greater than 1 GeV, and specialized algorithm allow for triplet recosntruction at lower transerse momenta. Pixel doublet and triplet efficiency is shown in figure 3

Figure 3. Reconstruction efficiency for pixel hit doublet and triplet.

3.2. TrajectoryBuilding

In the baseline, there are two pattern recognition algorithms: the combinatorial track finder and the road search algorithm.

3.2.1. Combinatorial track finder (CTF)

The CTF algorithm, starting from consecutive hit pair or triplet, combines compatible measurements based on the Kalman trajectory filtering method.

3.2.2. Road Search Algorithm (RS)

The RS algorithm search for compatible measurements with precalculated set of detector modules based on trajectory seed computed from transverse curvature assumption and pair of hits distant to provide sufficient lever arm.

3.3. Alternative Algorithm

Dedicated algorithms are used out of the track reconstruction baseline due to computing power limitations. Gaussian sum filter (GSF) algorithm provides non gaussian modeling of energy loss and is dedicated to electron. The deterministic annealing filter (DAF) and multi track finder (MTF) algorithms let tracks compete with each other for consistent hits and are dedicated to track reconstruction in jets.

4. Tracker Alignment

5. Tracker Related High Level Trigger

REFERENCES

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3. CMS Physics TDR, Volume I, 2006.