The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

29 September 2009

Muon Reconstruction and Identification in CMS

Adam Everett for the CMS Collaboration

Abstract

We present the design strategies and status of the CMS muon reconstruction and identification identification software. Muon reconstruction and identification is accomplished through a variety of complementary algorithm strategies. The CMS muon reconstruction software is based on Kalman filter techniques and reconstructs muons in the standalone muon system, using information from all three types of muon detectors, and links the resulting muon tracks with tracks reconstructed in the silicon tracker. In addition, a muon identification algorithm has been developed which tries to identify muons with high efficiency while maintaining a low probability of misidentification. The muon identification algorithm is complementary by design to the muon reconstruction algorithm that starts track reconstruction in the muon detectors. The identification algorithm accepts reconstructed tracks from the inner tracker and attempts to quantify the muon compatibility for each track using associated calorimeter and muon detector hit information. The performance status is based on detailed detector simulations as well as initial studies using cosmic muon data.

Presented at *SUSY09: 17th International Conference On Supersymmetry And The Unification Of Fundamental Interactions*

Muon Reconstruction and Identification in CMS

A. Everett

Purdue University, West Lafayette, IN, 47906, USA

Abstract. We present the design strategies and status of the CMS muon reconstruction and identification software. Muon reconstruction and identification is accomplished through a variety of complementary algorithms. The CMS muon reconstruction software is based on a Kalman filter technique and reconstructs muons in the standalone muon system, using information from all three types of muon detectors, and links the resulting muon tracks with tracks reconstructed in the silicon tracker. In addition, a muon identification algorithm has been developed which tries to identify muons with high efficiency while maintaining a low probability of misidentification. The muon identification algorithm is complementary by design to the muon reconstruction algorithm that starts track reconstruction in the muon detectors. The identification algorithm accepts reconstructed tracks from the inner tracker and attempts to quantify the muon compatibility for each track using associated calorimeter and muon detector hit information. The performance status is based on detailed detector simulations as well as initial studies using cosmic muon data.

Keywords: Muon Reconstruction, Muon Identification

PACS: 13.38.-b, 14.60.Ef, 14.70.Pw

INTRODUCTION

Many scenarios beyond the Standard Model are expected to manifest themselves through modifications in the mass spectrum of high-mass dimuon pairs. For example, additional heavy neutral gauge bosons (Z') are predicted in several models ([1],[2],[5]), but there are no reliable theoretical predictions of the Z' mass scale. Current lower limits on the Z' mass are of the order of $600 - 900 \text{ GeV}/c^2$ [7], and the Large Hadron Collider (LHC) offers the opportunity to search for Z' bosons in a mass range larger than $1 \text{ TeV}/c^2$. Ways of distinguishing between different theoretical models involve measurement of the natural width and the forward-backward asymmetry, both of which require sufficiently good momentum resolution at high p_T to determine the sign of leptons. The detector requirements for CMS to meet these goals are:

- good muon identification and momentum resolution over a wide range of momenta and good dimuon mass resolution
- good charged particle momentum resolution and reconstruction efficiency in the inner tracker

MUON RECONSTRUCTION

Muon reconstruction, after local-pattern recognition, is performed in two stages: stand-alone reconstruction, and global reconstruction. Stand-alone muon reconstruction uses

FIGURE 1. Muon momentum resolution as a function of momentum and pseudorapidity. At low energy, the central tracker dominates. Information from both systems provides more precise measurement.

only information from the muon system, while global muon reconstruction uses also silicon tracker hits.

Stand-alone reconstruction starts with the track segments from the muon chambers obtained by the local reconstruction. The muon trajectories are built from the inside out using the Kalman-filter technique [8]. After the trajectory is built from the inner muon chambers to the outer muon chambers, a backward Kalman filter is applied, working from outside in, and the track parameters are defined at the innermost muon station. Finally, the track is extrapolated to the nominal interaction point and a vertex-constrained fit to the track parameters is performed.

The global muon reconstruction consists in extending the muon trajectories to include hits in the silicon tracker. Starting from a stand-alone reconstructed muon, the muon trajectory state on the inner surface of the muon detector is compared to the trajectory state of tracker tracks propagated to the same surface. Tracker tracks that are found to be compatible in momentum, position, and direction with the stand-alone muon are selected as candidates for global muon reconstruction. The hits from the matched tracker system and muon system pairs are merged into one hit collection and refitted to form a global muon track. The resultant global tracks are then checked for ambiguity and quality to choose, at most, one global muon track per stand-alone muon.

RECONSTRUCTION PERFORMANCE

Fig. 1 shows the momentum resolution as a function of particle momentum, in bins of pseudorapidity, for the tracker system alone, the muon system alone, and the combined tracker and muon system. The momentum resolution of the muon system alone is shown to be larger than the momentum resolution of the silicon tracker alone up to momentums of about 1 TeV/c and 5 TeV/c in the central and forward regions of the detector respectively. Using all information from both systems, the tracker dominates momentum measurements below several hundred GeV/c, but both systems are essential to resolve nearly straight TeV-scale muons. Consequently, the resolution of low-momentum tracks

FIGURE 2. Stand-alone muon q/p_T resolution for (a) ideal (b) startup and (c) long-term understanding of alignment. The peaks in the stand-alone muone resolution reflect the structure of the muon detector.

FIGURE 3. Global muon q/p_T resolution for (a) ideal (b) startup and (c) long-term understanding of alignment. The peaks that were evident in the stand-alone muone resolution are suppressed in the global muon.

depends strictly on the quality of tracker alignment, while muon alignment and inter-alignment between the two systems is necessary to resolve highly energetic muons.

To properly reconstruct muons, the positions and orientations of all elements in the silicon tracker and the muon system need to be well-known relative to one another. Misalignment, by which we mean an incorrect assumption about the geometry of the detectors, causes errors in the direction and curvature of reconstructed tracks, both of which have a degrading effect on reconstructed masses. Figs. 2 and 3 show the momentum resolution for the stand-alone and global muon reconstruction with different alignment scenarios. The results were obtained using simulated single-muon samples. The first alignment scenario, *ideal*, represents the reconstruction with an ideal detector. The second alignment scenario, *startup*, represents the reconstruction with the expected uncertainty of the detector alignment at the start of data taking. The third alignment scenario, *long-term*, describes the situation when all alignment procedures have enough data to obtain a full set of alignment constants.

FIGURE 4. The effect of alignment on the dimuon mass spectra and resolution help indicate the discovery potential for dimuons at startup and after data collection.

Physics Potential

Fig. 4 shows the dimuon reconstruction efficiency and invariant mass resolution for various physics channels assuming different detector misalignment scenarios. The efficiencies shown are offline reconstruction efficiencies obtained from events having two muons within the muon detector acceptance.

ACKNOWLEDGMENTS

We thank the technical and administrative staff at CERN and other CMS Institutes, and acknowledge support from: CERN; DOE and NSF (USA).

REFERENCES

1. M. Cvetič, and P. Langacker, *Phys. Rev.* **D54**, 3570–3579 (1996), hep-ph/9511378.
2. M. Cvetič, and P. Langacker, *Mod. Phys. Lett.* **A11**, 1247–1262 (1996), hep-ph/9602424.
3. A. Leike, *Phys. Rept.* **317**, 143–250 (1999), hep-ph/9805494.
4. C. T. Hill, and E. H. Simmons, *Phys. Rept.* **381**, 235–402 (2003), hep-ph/0203079.
5. T. Han, H. E. Logan, B. McElrath, and L.-T. Wang, *Phys. Rev.* **D67**, 095004 (2003), hep-ph/0301040.
6. L. Randall, and R. Sundrum, *Phys. Rev. Lett.* **83**, 3370–3373 (1999), hep-ph/9905221.
7. S. Eidelman, et al., *Phys. Lett.* **B592**, 1 (2004).
8. R. Fruhwirth, *Nucl. Instrum. Meth.* **A262**, 444–450 (1987).