Hard Muon Reconstruction in CMS/LHC

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Introduction

Studies with hard muons[1] at the Compact Muon Solenoid (CMS) [1] experiment on Large Hadron Collider (LHC) constructing at CERN can lead to new physical phenomena discoveries and also be a tool for testing of reconstruction algorithms on their efficiency and a precision of measurements. Two of CMS physical aims are the searching of new TeV-mass resonances in dimuon channel [2] and the testing of Standard Model prediction for the Drell-Yan continuum up to TeV energy scale.

Muon trajectories in CMS will be reconstructed both in the Tracker located around interaction point and in the Muon system which is placed after the Calorimeter system. The Muon system should provide a high efficiency of muon trajectory reconstruction with a high spatial resolution under conditions of heavy background. The precision of measurements in the muon system plays a leading role in achieving of the required resolution on transverse momentum and mass reconstruction for the processes with hard muons. To avoid systematic errors in Drell-Yan process cross-section measurements, it is necessary to achieve a very high efficiency of hard muon reconstruction, even at the cost of increasing of statistical errors (it is a question of LHC operation time only).

Hard muon reconstruction — single muons

As it is mentioned above, hard muon reconstruction can be a tool for testing of reconstruction algorithms. Offline muon reconstruction in CMS consists of 3 stages: local, standalone (in muon system only) and global (in full tracking system).

Local reconstruction is mainly a pattern recognition of track-segments in local muon detectors (drift tubes in the barrel region and cathode strip chambers (CSC) in the endcap region of the CMS setup). The essential part of hard muon hits in CSCs will be contaminated by electromagnetic secondaries entering a muon detector from a calorimeter or iron yoke and delta-electrons produced by a muon passing through the material of a muon detector. As a result, we obtain the degradation of CSC track-segment building efficiency. For the first we tried to improve the situation by tuning track-segment building parameters. Currently in accordance with our work on Dubna prototype beam test data [3] we propose to do the 2^{nd} pass for CSC track-segment building with the more wide thresholds for contaminated muon data [4].

On Figs. 1–2 the residuals for reconstructed transverse momentum defined as

$$\Delta P_T/P_T = [1/P_T(reconstructed) - 1/P_T(generated)] \cdot P_T(generated) \qquad (1)$$

are presented for 1 TeV single muons in endcap region obtained with CMS standard and modified software. As it can be seen, the inefficiency for standalone reconstruction in the muon system is decreased from 3.7 to 0.6% and for global reconstruction — from 6.0 to

[1] hard muons — the muons with high transverse momenta from several hundred GeV up to TeV region

4.1%. The modified algorithm of CSC track-segment building is now implemented in the official release of CMS software.

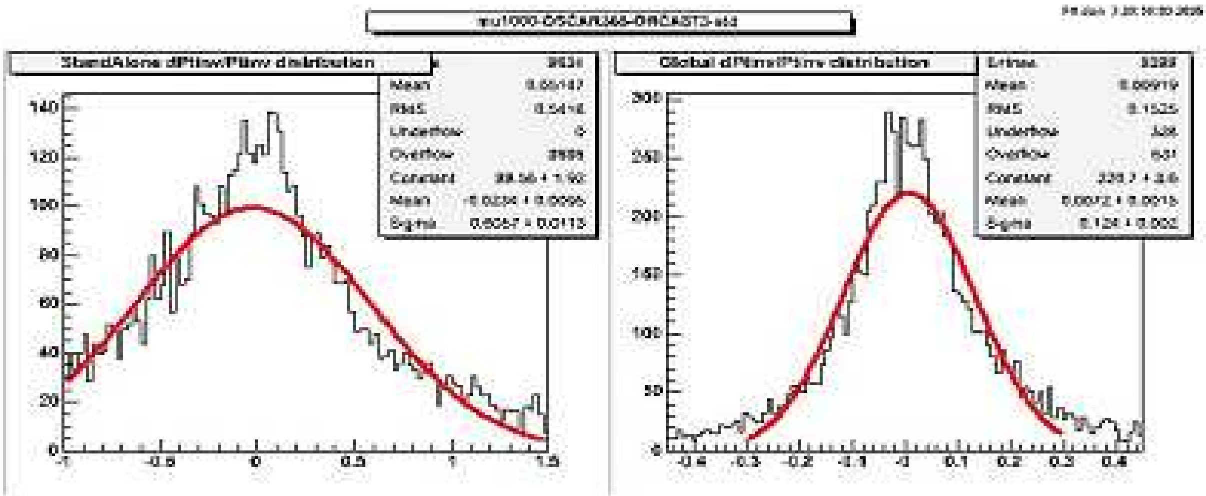

Fig. 1: $1/P_T$ residual distributions for standalone (left) and global (right) 1 TeV single muon reconstruction in pseudorapidity $\eta = 1.3 - 2.3$ region (10 000 events; standard CMS software): efficiency for standalone reconstruction is 96.3%, for global reconstruction — 94.0%.

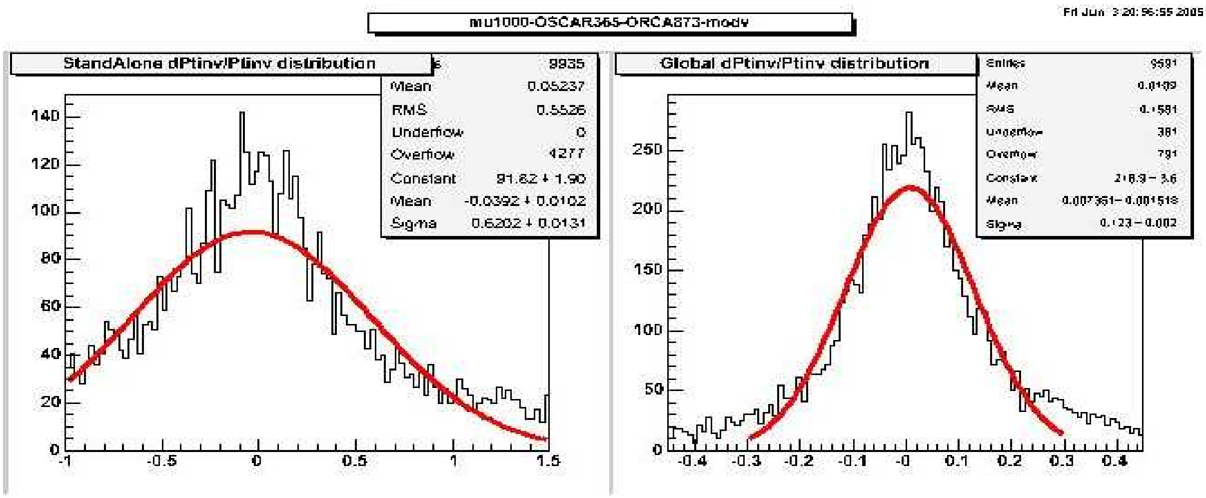

Fig. 2: $1/P_T$ residual distributions for standalone (left) and global (right) 1 TeV single muon reconstruction in pseudorapidity $\eta = 1.3 - 2.3$ region (10 000 events; modified CMS software): efficiency for standalone reconstruction is 99.4%, for global reconstruction — 95.9%.

Hard muon reconstruction — dimuons

The global reconstruction efficiency $\epsilon = 96\%$ obtained for 1 TeV single muons (see Fig. 2, right) allows to estimate the expected dimuon reconstruction efficiency as ϵ^2, i.e.$\cong$ 93%. However with the usage of the standard CMS offline software it resulted the efficiency of 75% only. This result is certainly crucial not only for dimuons but for multi-muon events, e.g. for the process of Higgs $\rightarrow$ 4 muons. As it was reported at the CMS collaboration meetings [5], this contradiction was resolved by the modification of the trajectory seed generator algorithm which is the first step of standalone muon reconstruction stage. This algorithm is based on track-segments resulted from a local reconstruction stage and has been improved by getting track-segments compatible in the $(\eta, \phi) = +/-(0.2, 0.1)$ — window. The results for Drell-Yan dimuon efficiency are presented on Fig. 3 by dotted and dashed lines for standard and modified algorithms correspondently. These modifications are implemented in the official release of CMS software also.

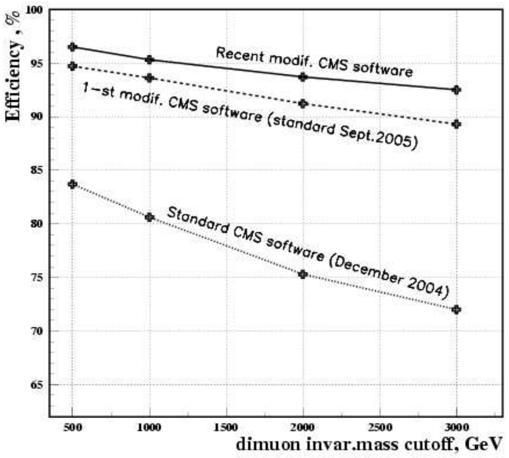

Fig. 3: Drell-Yan dimuon reconstruction efficiency in standard and modified CMS software for samples with mass cutoffs 0.5, 1, 2 and 3 TeV.

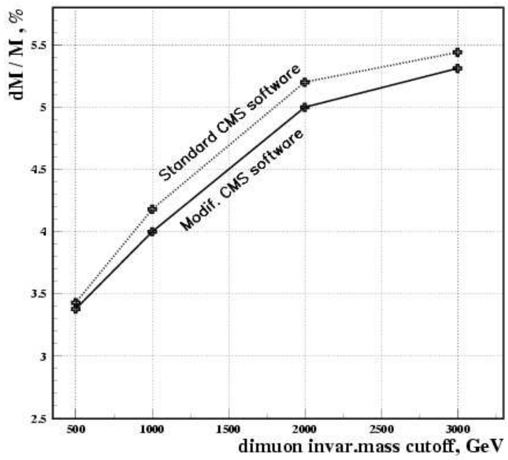

Fig. 4: Drell-Yan dimuon reconstructed mass resolution in standard and modified CMS software for the same samples as on Fig. 3.

Recently it was proposed [6] to use the global positions of track-segments as the additional condition for trajectory seeds composing. In the standard CMS code a seed is formed from track-segments close to the direction. This modification leads to the further increasing of dimuon reconstruction efficiency (solid line on Fig. 3). The modifications proposed improve the resolution for dimuon invariant mass in TeV mass region (Fig. 4).

Conclusions

A significant progress has been achieved in efficiency and transverse momentum reconstruction for hard single muons in CMS software: up to $P_T = 1$ TeV the efficiency of reconstruction remains not less than 96% and P_T-resolution stays less than 8%.

Drell-Yan dimuon reconstructed invariant mass resolution in 0.5–3 TeV region is 3.4–5.3% and after the new modifications a high efficiency of dimuon events reconstruction has been obtained (92.5–96.5%).

These improvements have been achieved by the modifications implemented in the CMS software for track-segment building in CSCs and for muon trajectory seed generator.

References

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