Physics objects from CMS: muons

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1 Introduction

The Compact Muon Solenoid (CMS) [1] is a multi-purpose detector designed to exploit the high discovery potential provided by the Large Hadron Collider (LHC). Muons are a distinctive signature for many of the most interesting physical processes at CMS.

The performance of muon reconstruction and identification in CMS has been studied on data collected in pp collisions at $\sqrt{s} = 7$ TeV at the LHC at CERN during 2010. During that period the experiment recorded a sample with an integrated luminosity of 40 pb^{-1}. We present measurements of muon reconstruction and trigger efficiencies, misidentification, and momentum scale and resolution [2].

2 Muon Reconstruction and Identification

In the standard CMS reconstruction for pp collisions, tracks are first reconstructed independently in the inner tracker (tracker track) and in the muon system (standalone-muon track). Based on these objects, two reconstruction approaches are used: *Global Muon reconstruction (outside-in)* and *Tracker Muon reconstruction (inside-out)*.

For the former case, for each standalone-muon track, a matching tracker track is found by comparing parameters of the two tracks propagated onto a common surface. A global-muon track is fitted combining hits from the tracker track and standalone-muon track, using the Kalman-filter technique; for the latter case, all tracker tracks with $p_T > 0.5$ GeV/c and total momentum $p > 2.5$ GeV/c are considered as possible muon candidates and are extrapolated to the muon system taking into account the magnetic field, the average expected energy losses, and multiple Coulomb scattering in the detector material, and matched to locally reconstructed segments in muon detectors.

The combination of different algorithms provides robust and efficient muon reconstruction. We study the performance of three basic muon identification algorithms: *Soft Muon selection*, which requires the candidate to be a Tracker Muon, with a tighter requirement on the matched muon segment; *Tight Muon selection*, for which the candidate must be a Global Muon with the χ^2/d.o.f. of the global-muon track fit less than 10, additional quality requirements for the track and transverse impact parameter $|d_{xy}| < 2$ mm with respect to the primary vertex; finally, the *Particle Flow Muon selection*, based on the CMS particle-flow [3] event reconstruction, which combines the information from all subdetectors to identify and reconstruct individually particles produced in the collision.

We present here data to simulation comparisons for an inclusive sample of intermediate and high-p_T muons collected with the single-muon trigger. In Figure 1 we show the distributions of transverse momentum and pseudorapidity for Tight Muons with $p_T > 20$ GeV/c, comparing data to Monte Carlo (MC) simulation (include the simulation of QCD processes, quarkonia production, electroweak processes such as W and Z boson production, non-resonant Drell-Yan processes, and top-pair production.), broken down into its different components. For momentum higher than 50

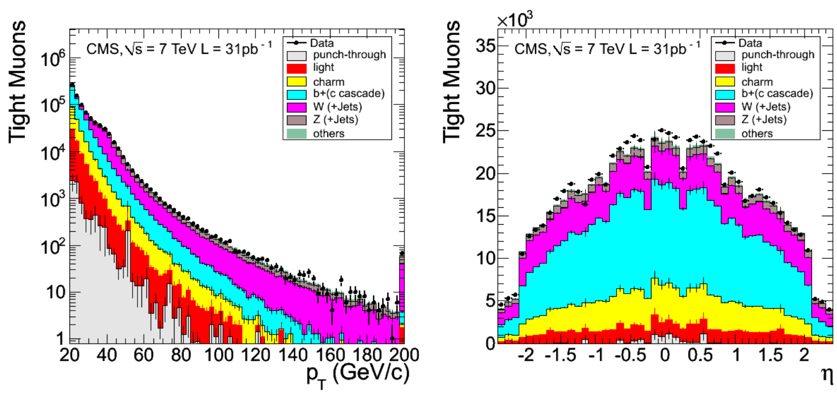

Figure 1: Distributions of transverse momentum (left) and pseudorapidity (right) for Tight Muons with $p_T > 20$ GeV/c, comparing data (points with error bars) to MC.

GeV/c, the leading processes are W and Z production, occasionally associated with hard jets. In this region, the data agree with the predictions within 10%. Given the known experimental and theoretical uncertainties, the agreement between the data and simulation is satisfactory over the entire momentum range of $p_T < 200$ GeV/c.

2.1 Efficiency and Misidentification

We study exclusive samples of prompt muons, pions, kaons, and protons in data to determine the probability that such a particle is reconstructed and identified as a muon. The efficiency to reconstruct a muon in the inner tracker was measured previously [4] and found to be 99% or higher within the whole tracker acceptance, in good agreement with the expectation from simulations. We evaluate the efficiencies for different selection algorithms, already presented, for prompt muons, by applying a tag-and-probe technique to muons from J/Ψ and Z decays. Figure 2 shows the efficiency for the Soft Muon selection for muons with p_T up to 100 GeV/c. The tag-

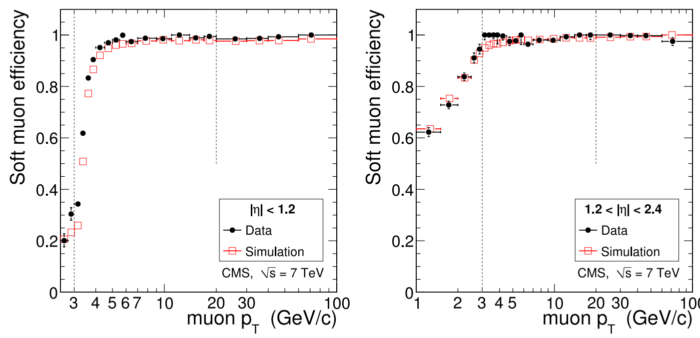

Figure 2: Tag-and-probe results for the muon efficiency reconstruction and identification Soft Muon selection in data compared to simulation.

and-probe results in data and in simulation agree within the statistical uncertainties of the measurement almost everywhere, with some discrepancies that are understood from a small difference in the widths of the track-to- segment pulls in data and in simulation. Identification efficiencies, for muons with p_T larger than a few GeV/c, are above 95% for all selections studied. Misidentification from pions, kaons and protons from resonances is also measured, being lower than 1% for the loosest selection and below 0.1% for the tightest. Concerning the trigger efficiencies, the plateau efficiencies are about 99% for the Level-1 trigger in the barrel region and for the High Level Trigger in the whole studied pseudorapidity range, for the Soft Muon selection.

3 Muon Momentum Scale and Resolution

The momentum scale and resolution of muons are studied using different approaches in the range $20 < p_T < 100$ GeV/c, where the momentum measurement is provided by the tracker. Figure 3 shows the comparison of muon transverse momentum resolution versus η obtained with two different method after correcting for biases in the momentum scale, for both data and simulation. The average bias in the muon momentum scale was measured with a precision of better than 0.2% and was found to be consistent with zero. The relative p_T resolution is between 1.3% to 2.0% for muons in the barrel and better than 6% in the endcaps, in good agreement with simulation

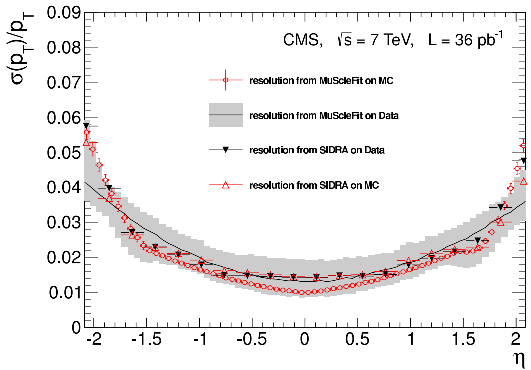

Figure 3: Relative transverse momentum resolution $\sigma(\mathrm{p_T})/\mathrm{p_T}$ in data and simulation measured with two different methods for muons produced in the decays of Z bosons and passing the Tight Muon selection.

4 Conclusions

The performance of muon reconstruction, identification, and triggering in CMS has been studied extensively using 40 pb^{-1} of data collected in pp collisions at $\sqrt{s} = 7$ TeV at the LHC in 2010. These data were used to study several representative muon selections, chosen as benchmarks covering a wide range of physics analysis needs.

Apart from the results summarized here, other studies were performed. For example, algorithms to identify cosmic and beam-halo backgrounds among collision events were developed and successfully used in physics analyses of 2010 data. At high momenta, the best measurement of muon $\mathrm{p_T}$ is obtained by selective use of information from the muon system in addition to that from the inner tracker, with $\mathrm{p_T}$ resolution better than 10% up 1 TeV/c. Also, the muon trigger efficiency for isolated muons is better than 90% over the full η range.

The good performance and detailed understanding of the muon reconstruction, identification, and triggering provides the necessary confidence in all elements of the chain from muon detection to muon analysis.

References

[1] CMS Collaboration, JINST 3 (2008) S08004

[2] CMS Collaboration, JINST 7 (2012) P10002

[3] CMS Collaboration, CMS-PAS-PFT-09-001, (2009).

[4] CMS Collaboration, CMS-PAS-TRK-10-002, (2010).