Muon Trigger resolution studies on 2015 ATLAS data

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1. Introduction

The analysis shown here is based on data taken with the ATLAS [1] detector, collected from June to November 2015, corresponding to about 4 fb^{-1} of proton-proton collisions occurring at a centre-of-mass energy of 13 TeV at the LHC [2] (Large Hadron Collider).

Already during the successful *Run I* data taking phase at $\sqrt{s} = 8$ TeV the ATLAS muon trigger [3,4] had shown a very good performance [5] in terms of high efficiencies (both at Level-1 [3] and at the High Level Trigger, or HLT [4]), adequate rates, good resolution and reduced fake track probability.

The increased centre-of-mass energy of 13 TeV during the so-called *Run II* has required an even more performing muon trigger system, capable to operate with increased pile-up conditions due to an instant luminosity as high as 5.22 $\times 10^{33} cm^{-2} s^{-1}$.

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2. Selection cuts

The muon trigger resolution study is realized on events selected from the muon stream (*physics_Muons*) in which a $Z \to \mu\mu$ decay is observed.

Muon tracks reconstructed by the "MuidCo" offline algorithm have been used as reference. These tracks have been required to satisfy specific quality cuts in order to suppress fake tracks:

- $p_T > 2$ GeV,
- $|\eta| < 2.4$,
- number of holes in PIXEL and in SCT < 3,
- number of PIXEL hits and number of crossed dead PIXEL sensors > 0,
- number of SCT hits and number of crossed dead SCT sensors > 4,
- being n := number of TRT hits plus number of TRT outliers, n > 5 and number of TRT outliers $<$ than 90% of n,
- *medium quality* working point [6] tracks, that means:
  - significance of the ratio between track charge and track momentum < 7,
  - either number of precision layers hits $= 1$ and number of precision layers holes < 2 in $|\eta| < 0.1$ or number of precision layers hits > 1,
- *gradient isolation* working point [7] tracks,

where p_T is the transverse momentum, η is the pseudorapidity, PIXEL, SCT and TRT are specific technologies of the ATLAS Inner Detector.

Any of the offline reconstructed muons selected in this way has been taken into account in the resolution computation if a HLT track was found in the event within $\Delta R < 0.1$.

3. Resolution of muon Event Filter algorithms

The muon HLT algorithms considered in this study are: *MuidSA* and *MuidCo*. While the first one performs track reconstruction only in the Muon Spectrometer extrapolating back to the beam line in order to determine the track parameters of the muon at the interaction point, the second one combines the independent measurements from the Inner Detector and Muon Spectrometer to reconstruct a combined muon.

For each algorithm, the parameters p_T, η and φ are extracted and compared to the ones of the corresponding offline muon reference in order to evaluate residuals, which are defined, for the different variables, as:

- $\delta_{p_T} = \frac{1/p_T^{\text{trigger}} - 1/p_T^{\text{offline}}}{1/p_T^{\text{offline}}}$;
- $\delta_{phi} = \varphi^{\text{trigger}} - \varphi^{\text{offline}}$;
- $\delta_{eta} = \eta^{\text{trigger}} - \eta^{\text{offline}}$.

The residuals are fitted in two steps with Gaussian functions:

- the first fit is done with the mean and RMS values as initial values for Gaussian function parameters in a range defined as [mean$-1\cdot$RMS;mean$+1\cdot$RMS];

- two more fits are done imposing, as initial values, the mean and sigma parameter values obtained in the first fit, choosing two different fit ranges:

  A) [mean−1.5·sigma;mean+1.5·sigma]

  B) [mean−2·sigma;mean+2·sigma]

Then the resolution is defined as the average of the sigma parameters obtained with fits A and B and the resolution error includes the (statistical) errors provided by the two fits plus a possible (systematic) error contribution evaluated by adding in quadrature the semidifference between the two sigma parameters.

In Figures 1, 2 and 3, respectively, the p_T, η and φ resolution for MuidCo and MuidSA algorithms is shown as a function of the muon offline p_T, separately for barrel region ($|\eta| < 1.05$) and for the endcap regions ($1.05 < |\eta| < 2.4$).

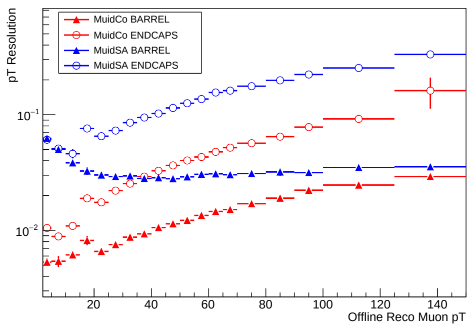

Figure 1. Transverse momentum resolution with respect to offline as a function of p_T for MuidCo and MuidSA algorithms, separately for barrel and endcap regions.

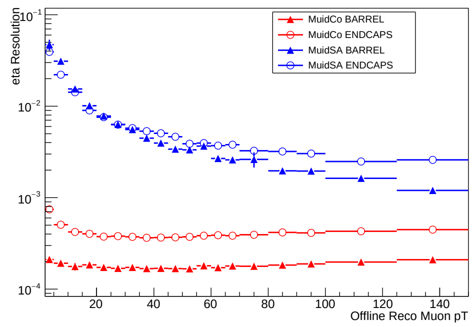

Figure 2. Spatial η resolution with respect to offline as a function of muon offline tranverse momentum.

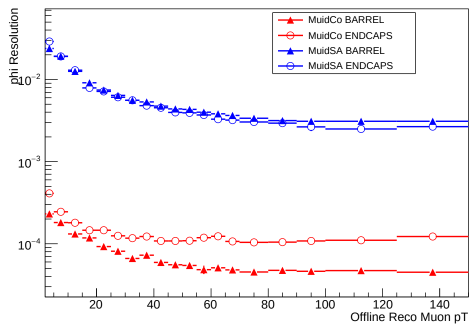

Figure 3. Spatial φ resolution with respect to offline as a function of muon offline tranverse momentum.

In general, the MuidCo algorithm shows better performance than MuidSA, since it takes advantage of the combination of Muon Spectrometer and Inner Detector information to improve the resolution with respect to the *MS only* algorithm. This improvement is even more evident (by at least one order of magnitude) in the case of the η and the φ thanks to the excellent accuracy allowed by the Inner Detector. In addition, better reconstruction performance can be observed in the barrel region with respect to the endcap regions for the MuidCo algorithm, both for p_T and spatial resolution. For MuidSA algorithm this difference in barrel and endcaps performance is true only for p_T resolution, while the spatial resolution seems to be coherent over the whole detector.

A comparison between the present results and those obtained with the statistics collected in 2012 [5] puts in evidence a general improvement for MuidSA spatial resolutions and a possible improvement for MuidCo spatial resolution in the range with $p_T < 50$ GeV. For what concerns the p_T resolution, a significant improvement is observed in the barrel region, while the resolution is generally deteriorated (by up to a factor of 2) in the endcaps, which can be partially explained with track reconstruction problems due to the increased average muon energies in the *Run II* with respect to the *Run I* [5].

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