Muon Trigger resolution studies on 2012 ATLAS data

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1. Introduction

The ATLAS [1] experiment has collected about 22 fb^{-1} of p-p collisions at a centre-of-mass energy of 8 TeV at the LHC (Large Hadron Collider) [2] during the so-called "Run-I" data taking period in 2012. Given the harsh detector environment produced by collisions of high energy protons at the LHC, events with muons in the final state are an important signature for many physics analyses.

ATLAS employs a multi-level trigger architecture that selects the events in three sequential steps of increasing complexity and accuracy. The Level-1 trigger is implemented with custom-built hardware to reduce the event rate from 40 MHz to 75 kHz with input from the calorimeter and muon detectors aiming to reject most background collisions in less than 2.5 μs. Then there are two software-based higher level triggers: the Level-2 (L2) and the Event Filter (EF), which refine the trigger decisions reducing the output rate down to about 400 Hz.

Muon trigger efficiencies and resolutions in all relevant ATLAS physics analyses are obtained directly from real data by means of the "Tag & Probe" method applied to events in which a Z boson decays into a muon-antimuon pair. The highest possible statistics is obtained thanks to the use of the muon stream, *i.e.* the subset of collected data in which at least one offline muon object is found in the event [3].

2. Muon event selection

Offline muon tracks reconstructed by the STACO algorithm are used as reference for muon trigger studies [4]. Information is used by hits in the Muon Spectrometer (MS) as well as in the Inner Detector (ID). A few minimal requests are applied to take into account trigger acceptance (pseudorapidity in the range $|\eta|$ <2.4) and following the prescriptions by the Muon Combined Performance group for *loose muons* [5]:

- $p_T > 2.5$ GeV, $p > 4$ GeV,
- number of PIXEL hits > 1, and at least 1 hit in the b-layer, number of SCT hits > 5 and no more than 2 holes of the track [1] in PIXEL and SCT detectors, (for $0.1 < |\eta| < 1.9$ the total number of hits has to be > 5 and the fraction of outlier hits to total hits < 0.9, for $|\eta| < 0.1$ or $|\eta| > 1.9$, if total hits are > 5, then the fraction of outlier hits to total hits is required to be < 0.9),
- $|z - z_{vtx}| < 10$ mm, where z_{vtx} is the z coordinate of the primary vertex in the event with >2 associated tracks within 150 mm of the interaction point position,

together with an adequate request on isolation (sum of p_T of tracks in a $\Delta R = 0.20$ cone [2] around the muon < 1.8 GeV.

After the muon preselection, di-muons coming from Z boson production are selected by asking for the following additional cuts:

- at least two muons with $p_T > 18$ GeV of opposite charge at a distance $\Delta R > 1$,
- di-muon invariant mass $m_{\mu\mu}$ such that $|m_{\mu\mu} - m_Z| < 15$ GeV.

Any of the two muon *candidates* defined above is considered if a trigger object is found in a $\Delta R = 0.1$ cone, firing any of the available unprescaled muon trigger thresholds.

3. Muon High Level Trigger resolution studies

Thanks to the Tag & Probe method, the momentum and position reconstruction of the trigger algorithms with respect to the offline reconstruction is assessed. The residual of the trigger-reconstructed p_T value with respect to the offline value is defined as

$$\delta_{p_T} = \frac{1/p_T^{trigger} - 1/p_T}{1/p_T}$$

where $p_T^{trigger}$ is the trigger reconstructed p_T value and p_T is that of the offline muon. The resolution was defined as the σ parameter obtained by fitting δ_{p_T} with a Gaussian function [6].

[1]A hole is considered here as an unassigned measurement which was expected to belong to a given track trajectory.
[2]In ATLAS the distance between two objects ΔR is defined as $\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$, where $\Delta\eta$ and $\Delta\varphi$ are the differences in η and in azimuthal angle φ, respectively.

Figure 1 shows the p_T resolutions of EF standalone (*i.e.* MS only) and combined (*i.e.* MS + ID) algorithms in the barrel and endcap regions, respectively. The p_T resolution is about 2% and 5% for EF combined and standalone algorithms, and the data and MC agreement is reasonably good in the barrel, with discrepancies of order $< 10\%$ in the endcap regions. Similar results can be obtained for L2. Inhomogeneities in the endcap resolution plot are due to the non-uniform MS geometry over the entire $|\eta| >$1.05 range.

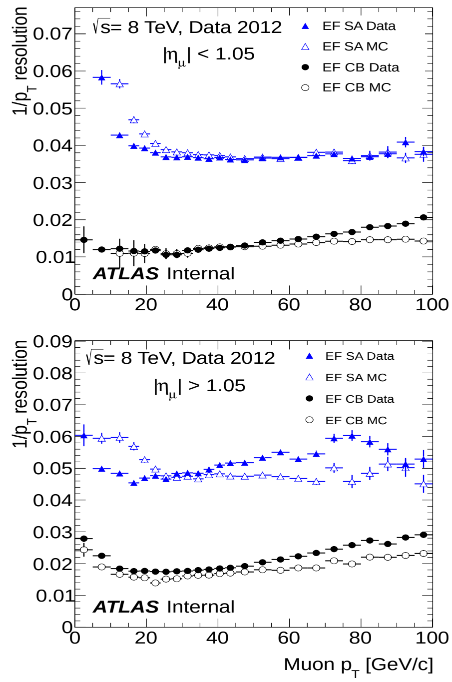

Figure 1. Resolution on muon EF $1/p_T$ as a functions of p_T in barrel (top) and in endcaps (bottom) for standalone MS (triangles) and MS+ID combined (circles) tracks, separately shown for real data (filled symbols) and Monte Carlo simulation (empty symbols).

The agreement

Spatial resolutions on η and on φ are examined by means of the residuals:

$$\delta\eta = \eta^{trigger} - \eta$$

and

$$\delta\varphi = \varphi^{trigger} - \varphi$$

In Figures 2 and 3 the resolution on η are shown for L2 and EF algorithms, separately for data and for Monte Carlo, over a wide muon p_T range, up to 100 GeV. Similarly, in Figures 4 and 5 resolutions on φ are shown.

In all cases, it is apparent that the η and φ distributions are in good (and in some cases excellent) agreement between data and Monte Carlo.

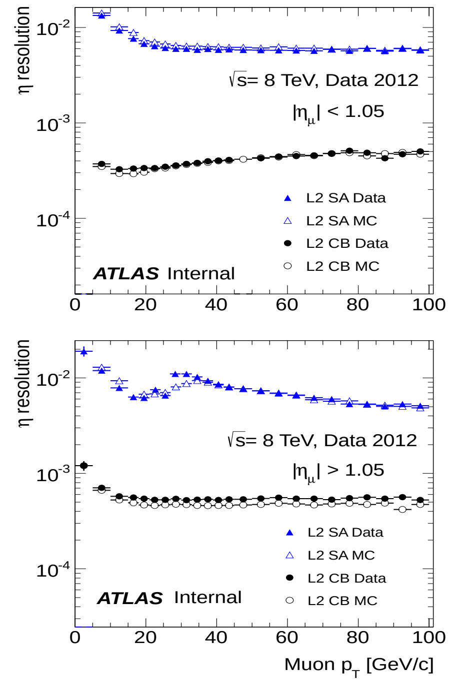

Figure 2. Resolution on muon L2 pseudorapidity η as a functions of p_T in barrel (top) and in endcaps (bottom) for standalone MS (triangles) and MS+ID combined (circles) tracks, separately shown for real data (filled symbols) and Monte Carlo simulation (empty symbols).

For the combined algorithms, spatial resolutions are better than 10^{-3}, and improve as the muon p_T increases. Thus, the trigger-offline matching requirements, which are performed by using ΔR distance for instance for efficiency measurement with Z Tag & Probe as $\Delta R < 0.1$, can be said as sufficiently wide compared to the η and φ resolutions.

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6. ATLAS Collaboration, *Performance of the ATLAS muon trigger in pp collisions at* $\sqrt{s}$*=8 TeV*, ATL-COM-DAQ-2013-147, submitted to Eur. Phys. J. C.

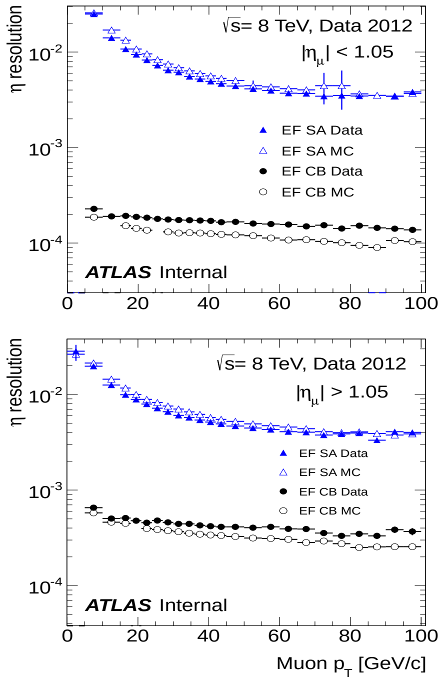

Figure 3. Resolution on muon EF pseudorapidity η as a functions of p_T in barrel (top) and in endcaps (bottom) for standalone MS (triangles) and MS+ID combined (circles) tracks, separately shown for real data (filled symbols) and Monte Carlo simulation (empty symbols).

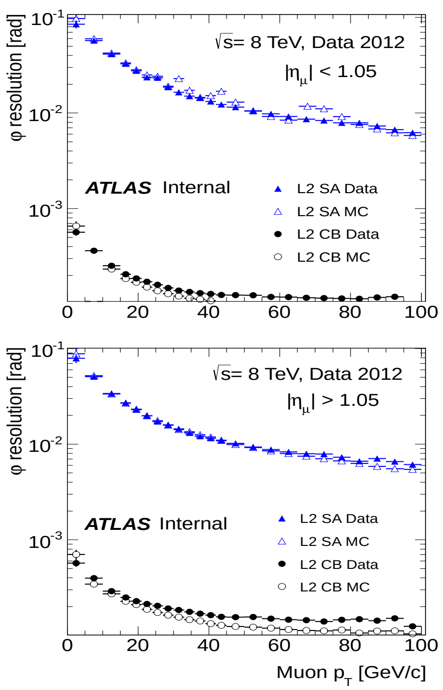

Figure 4. Resolution on muon L2 azimuthal angle φ as a functions of p_T in barrel (top) and in endcaps (bottom) for standalone MS (triangles) and MS+ID combined (circles) tracks, separately shown for real data (filled symbols) and Monte Carlo simulation (empty symbols).

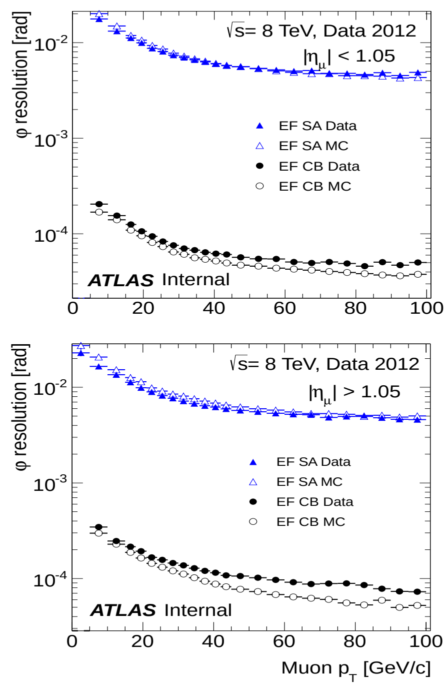

Figure 5. Resolution on muon EF azimuthal angle φ as a functions of p_T in barrel (top) and in endcaps (bottom) for standalone MS (triangles) and MS+ID combined (circles) tracks, separately shown for real data (filled symbols) and Monte Carlo simulation (empty symbols).