Scale Factors for Muon Trigger Efficiency on 2012 ATLAS data

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1. Introduction

The ATLAS experiment [1] has been collecting about 22 fb^{-1} of proton-proton collisions at a centre-of-mass energy of 8 TeV at the LHC (Large Hadron Collider) [2] during the 2012 data taking period, recording in the last summer the highest instant luminosity ever reached at particle accelerator ($7.73 \cdot 10^{33}$ cm^{-2} s^{-1}).

The ATLAS trigger system is designed to select events by identifying muons, electrons, taus, photons, jets and B hadron candidates, as well as using event-based signatures, such as missing transverse energy. The trigger is structured in a three-level scheme, with the goal to reduce the event rate from the design bunch-crossing rate of 40 MHz to a final average rate of about 400 Hz. After a first level based on custom electronics with input from the calorimeter and muon detectors aiming to reject most background collisions in less than 2.5 μs, two levels of software-based triggers (LVL2 and Event Filter) follow.

In continuity with the 2011 data taking, the muon trigger has been initially configured with *EF_mu24_tight* as lowest unprescaled threshold, seeded by the high-p_T *L1_MU11* at first level (corresponding to a 3-station coincidence in the Muon Spectrometer) and optimized to reject muons with $p_T < 24$ GeV at Event Filter. The continue increase of LHC luminosity during the whole 2012 (from April to December) has imposed a large number of quick adaptations to the ATLAS trigger menu, which has reflected in a subdivision of the data taking in separate periods (labelled with the letters from A to L). Since period C, the high rate reached by *EF_mu24_tight* has overcome the bandwidth limit allowed by the data acquisition (DAQ) system, so a new threshold (*EF_mu24i_tight*) has been defined as lowest unprescaled, where the “i” stands for an isolation requirement imposed at LVL2 to reduce the rate at an acceptable value.

Muon trigger efficiencies in analyses are obtained directly from real data by means of the “Tag & Probe” method applied to events in which a Z boson decay into $\mu\mu$ is selected. The highest available statistics is selected 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. Event selection

Offline muon tracks reconstructed by the STACO algorithm are used to estimate trigger efficiencies for all the single muon thresholds of interest. 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* [4]:

- $p_T > 2.5$ 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.

Once the muon preselection is performed, dimuons coming from Z boson production are selected by applying 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 as a *tag muon* if a trigger object is found in a $\Delta R = 0.15$ cone, firing the

[1]A hole is defined 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.

EF_mu24_tight trigger. Finally, a given trigger threshold is called *efficient* on the other muon (*probe muon*) in case a trigger object is present within $\Delta R < 0.20$ from the probe muon.

3. Muon Event Filter efficiencies

In Figure 1 the efficiencies at the Event Filter are separately represented for barrel ($|\eta| < 1.05$) and for endcap regions ($1.05 < |\eta| < 2.4$) in case of the *EF_mu24i_tight*: in particular, the first two periods of the 2012 data taking are considered, denominated A and B. While results obtained agree in the endcap regions, a $\sim 5\%$ efficiency loss is observed in the barrel over the entire p_T range. At the time in which this loss was observed (April 2012), it was investigated and understood to be due to problems in the configuration of the first level: after solving these issues, the efficiency of *EF_mu24i_tight* was brought again to the plateau values regularly observed until the end of 2011 data taking.

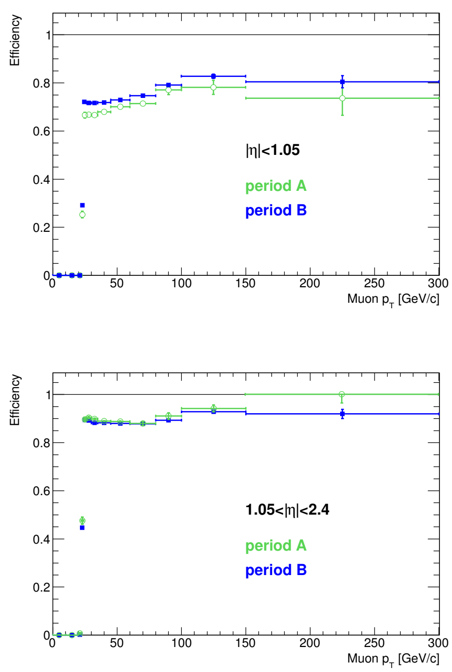

Figure 1. Efficiency vs. p_T for *EF_mu24i_tight* in the barrel region (top) and in endcaps (bottom), for 2012 data in period A (empty green circles) and in period B (filled blue squares).

In general, the large difference in the efficiency plateau values between barrel and endcaps is mostly due to the different L1 trigger acceptance of the Muon Spectrometer.

In order to study *EF_mu24i_tight* trigger on Monte Carlo samples for any physics analysis containing muons in the final state, suitable muon trigger scale factors have to be computed, defined in each p_T, η or φ bin as the ratio between the efficiency obtained on real data and the one obtained on $Z \to \mu\mu$ simulated events.

In both cases muon trigger efficiencies are obtained by means of the "Tag & Probe" method. The muon trigger scale factors for

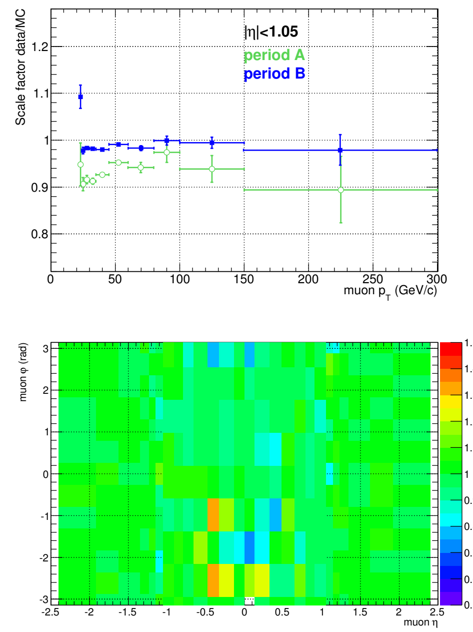

Figure 2. Muon trigger scale factors as functions of p_T for *EF_mu24i_tight* in barrel (top) for period A (empty green circles) and in period B (filled blue squares), and as a function of η and φ in period B (bottom).

EF_mu24i_tight are shown in Figure 2 for the barrel region (periods A and B superimposed) and in the whole η-φ plane[3] in period B. They are observed to be generally close to 1 except for some critical regions in the barrel, for instance around $\varphi \simeq -\pi/2$, where the feet of the Muon Spectrometer are installed. A more detailed survey on muon trigger scale factors for the other periods and with respect to other variables can be found in [5].

REFERENCES

1. ATLAS Collaboration, JINST 3 S08003 (2008).
2. L. Evans and P. Bryant, LHC Machine, JINST 3 S08001 (2008).

[3]Scale factors as functions of η and φ are obtained after having required a muon p_T larger than the nominal threshold multiplied by 1.1 (*i.e.* $p_T >$26.6 GeV in the case of *EF_mu24i_tight*).

3. ATLAS Collaboration, Performance of the ATLAS Trigger in 2010 running at the LHC, Eur. Phys. J. C 72 (2012) 1849.
4. http://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/MCPAnalysisGuidelinesData2012
5. http://twiki.cern.ch/twiki/bin/viewauth/Atlas/MuonTrigger PhysicsTriggerRecommendations2012