Data driven muon identification efficiency measurement at low transverse momenta with the 2011 ATLAS data

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The muon offline reconstruction efficiency is a basic performance measurement which is used by all physics analyses with one or more muons in the final states. The general analysis strategy in ATLAS accounts for mismodeling of the reconstruction algorithm performance by scaling the simulation prediction on an event by event basis by a factor defined as the ratio between the efficiency measured in data and the efficiency measured in Monte Carlo by applying the same method used to extract the efficiency in data. The scaling factor must, therefore, be measured over a grid of $\mathrm{p_T} \times \eta$ in order to closely follow the detector and reconstruction algorithm features.

In spite of the typical high $\mathrm{p_T}$ regime of the program of physics measurements and searches at LHC, there are many analyses which benefit from a large acceptance for muons of low transverse momentum. In addition to the heavy flavor measurements, the Higgs search in the di-boson final states, WW and ZZ has been an important client of these performance measurements. The gauge boson decays to lepton provide a clean signature, which however suffer of a limited statistics in the scenarios of a light Higgs boson, which decay more often in $\mathrm{b\bar{b}}$ and $\tau\bar{\tau}$ pairs and to a lower rate in boson pairs. As a consequence the ability of relying on a well understood lepton efficiency at low $\mathrm{p_T}$ allows to lower the $\mathrm{p_T}$ selection threshold and to increase the acceptance for the signal.

The measurement of the muon reconstruction efficiency is extracted from data using standard physics candles which are the decay of the Z boson to the di-muon final state, which allows to probe the muon reconstruction efficiency at intermediate $\mathrm{p_T}$ values ($\mathrm{p_T} \sim 45\mathrm{GeV}$), and the $J/\Psi \rightarrow \mu\mu$ decay which provides a large sample of relatively low transverse momentum muons. In both cases, the procedure applied to derive the reconstruction efficiency in data is the so-called "tag and probe" method. Here we concentrate on the low transverse momentum efficiency measurements. The procedure and the measurements obtained with the 2010 data are described in details in [1]. The full results on 35 pb^{-1} of data are described in [2]. This document has later been used as one of the basic contribution to the preparation of a paper, currently in the process of being submitted for publication, which collects the ATLAS Muon Spectrometer performance studies with the 2010 data. In the analysis described in [2] it was shown that calorimeter tagged muons, can be used as a very clean alternative sample of probes to the standard selection consisting of tracks reconstructed in the Inner Detector. Calorimeter tagged muons are ID tracks whose extrapolation to the calorimeter satisfy some requirements corresponding to the pattern of energy deposition expected for a minimum ionizing particle. The scale factor measured as the fraction of calo-tagged muon probes which is reconstructed in the muon spectrometer was found in good agreement with the scale factor measured as the fraction of ID track probes reconstructed as muon. This observation is clearly useful because it allows to perform a measurement affected by a very limited statistical and systematic error arising from the small background in the probe sample.

Two categories of muons are reconstructed in ATLAS using the Muon Spectrometer data: Combined (CB) muons, that require the reconstruction of consistent tracks in the MS and in the ID, and Segment tagged (ST) muons, that give additional efficiency as they can recover muons, typically of low p_T, which did not cross enough precision chambers to allow an independent momentum measurement in the MS. The two classes of muons are implemented in two different reconstruction chains, hereafter referred as chain 1 (Staco) and chain 2 (MuId).

The analysis strategy has been applied for the determination of the muon reconstruction efficiency at low transverse momentum in the 2011 data, with minor modifications related to the different data taking conditions, listed below:

- data are split into two periods because a 4% difference in efficiency was discovered between data taken before September 2011 (Periods B-K) and data taken after September 2011 (Periods L-M);

- use of calorimeter-tagged inner detector probes as the baseline (and accordingly, the use of the linear background as baseline);

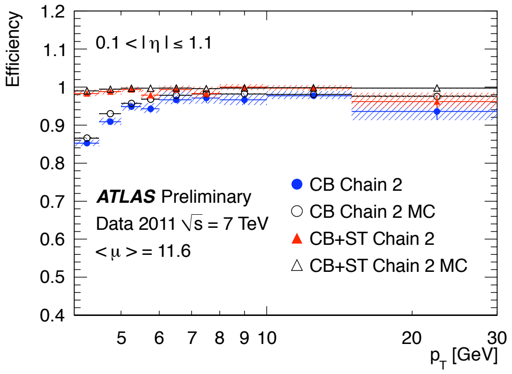

Figure 1. Reconstruction efficiency for chain 2 combined (CB) and combined + segment tagged (CB +ST) muons using calorimeter-tagged (calo-tagged) tracks as probes for 2011 collision data from September through October. The solid error bars represent the statistical uncertainty and the hashed error bands represent the total uncertainty (systematic + statistical uncertainties added in quadrature). The systematic uncertainties are calculated by finding the maximal positive and negative variation from the baseline efficiency of different fitting methods that vary the signal shape, the background shape, and the fitted populations. In addition, a constant systematic is applied to account for pileup and run conditions.

- use of EF_mu6_Trk_Jpsi as primary trigger (as opposed to single muon triggers used in 2010); This is a J/Ψ trigger where one of the two muons is not biased by a single muon trigger or by standard muon reconstruction algorithms and is therefore suitable to select a probe sample; EF_mu18, a single muon trigger with threshold on the muon p_T equal to 18 GeV was also used to increase statistics and to allow a sampling of events from all run periods.

The full set of results released by the Collaboration for this analysis can be found at [3]. A few example plots are reported in figures 1 and 2.

REFERENCES

1. The ATLAS Collaboration, ATLAS-CONF-2011-021 (https://cdsweb.cern.ch/record/1336750).
2. G. Chiodini, N. Orlando, and S. Spagnolo, ATL-COM-MUON-2011-032 and ATLAS-CONF-2012-125 (https://cds.cern.ch/record/1474642).
3. W. Spearman, G. Chiodini, S. Spagnolo *et al.* ATL-COM-MUON-2012-013.

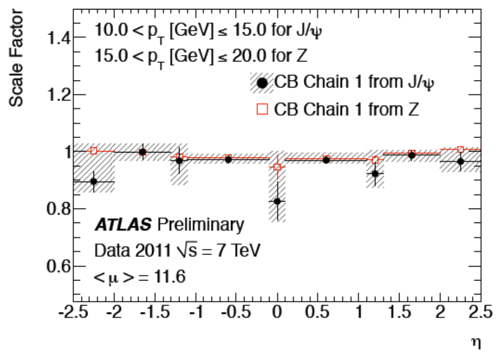

Figure 2. The plot shows the chain 1 combined (CB) muon efficiency scale factors using calorimeter tagged (calo-tagged) inner detector tracks as probes for the p_T range: 10 GeV 15 GeV. The scale factors are calculated by dividing the data efficiency by the MC efficiency and adding the statistical errors in quadrature. The error bars represent the statistical uncertainty while the error bands represent the statistical and systematic uncertainties added in quadrature. The systematic uncertainties are calculated by finding the maximal positive and negative variation from the baseline scale factor for different fitting methods that vary the signal shape, the background shape, and the fitted populations. Also, a systematic is applied to account for running conditions and pileup. The Z scale factors also use calo-tagged probes and are for the $15 < p_T(\mathrm{GeV}) < 20$ region. Both the J/Ψ and Z measurement span the 2011 collision data from September through October. The error bars on the Z scale factors represent only the statistical error.