PROCEEDINGS OF SCIENCE

Muon Identification and Isolation efficiencies on Run II data with the CMS experiment

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The performance of muon identification and isolation efficiencies in CMS has been studied on data collected in proton-proton collisions at 13 TeV at the LHC on the full 2016 dataset. The efficiencies have been computed with the tag-and-probe method, in different periods of data taking. Results obtained using data are compared with Monte-Carlo predictions.

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1. Introduction: the Tag-and-Probe method

The identification (ID) and isolation (ISO) muon efficiencies in CMS experiment are estimated by using the Tag-and-Probe method [1], whose performance is described in this section.

The Tag-and-Probe method is a very common procedure for measuring efficiencies in High Enery Physics. First, a well known resonance is considered, in this case two muons that come from the Z boson peak are selected. Then, one muon is named as "Tag" and the other as "Probe" for both data and simulation.

The "Tag" muons pass very tight requirements of ID and ISO, while the "Probe" muons correspond to compatible tracks with the Z boson resonance. The aim is to measure a certain ID or ISO efficiency over the "Probe" muons.

Since the selected events may not come from the resonance, there could be a bias in the efficiency measurement. To avoid this, a simultaneous fir to the signal (Z peak) and the background is performed (as shown in Figure 1), and in order to be able to fit the background properly, a wide mass range (for instance 70-130 GeV) has to be considered.

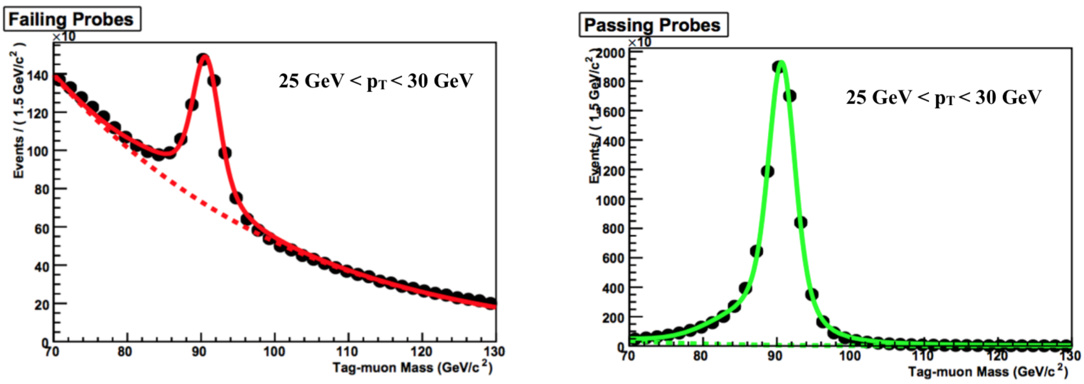

Figure 1: Failing (left plot) and Passing probes (right plot) fits examples for *Tight ID* working point, $25 < p_T < 30$ GeV bin.

At the end of this proccess, the total probe sample is split considering whether the mons pass (Passing Probes) or do not mass (Failing Probes) the ID or ISO working point that we want to measure. The fit is done independently for both the Passing Probes and the Failling Probes, and finally the efficiency is computed as:

$$\varepsilon = \frac{passing\ probes}{passing\ probes + failling\ probes} \tag{1}$$

One thing to remark is that if we want to measure the efficiency as function of one kinematic variable, this proccess will have to be repeated for each variable bin.

2. Data / Monte-Carlo samples, fitting parameters, and event selection

The details on the Data and Monte-Carlo samples used in this study, on the fitting parameters that are set for the Tag-and-Probe method, and on the chosen event selection are described in this section.

The efficiency is computed for several working points based on quality requirements on the muon ID and ISO (more details in [1]). In particular, the two most used working points in CMS are the *Tight muon ID*, and the *Tight muon ISO*:

- *Tight muon ID* aims at suppressing muons from decay in flight and from hadronic punch-through.
- *Tight muon ISO* removes muons with a *relative isolation* above 0.15. The *relative muon isolation* is defined as the sum of the energy relative to the muon transverse momentum (p_T) inside a cone of radius $\Delta R = (\Delta\varphi^2 + \Delta\eta^2)^{1/2}$ centered on the muon direction, where φ corresponds to the azimuthal angle and η to the pseudorapidity.

The systematic uncertainty on the measurements can be evaluated by varying the “Tag” muon definition, the fit functions, the number of mass bins, or the mass range where the fits are performed. The impact of the variations on top of the efficiencies is in most of the cases less than 0.5%.

2.1 Data and Monte-Carlo samples

For data, the full 2016 dataset is considered, corresponding to CMS collision data at 13 TeV and 25 ns bunch spacing, with a total luminosity of 36 fb^{-1}. Concerting the Monte-Carlo simulation, a Drell-Yan plus Jets sample generated with MadGraph5_aMC@NLO [2] has been used, for which an event re-weighting has been applied in order to match the pileup distribution in data.

2.2 Fitting parameters

The considered mass window is 70-130 GeV for ID efficiencies and 77-130 GeV for ISO efficiencies. The reason why the ID one is wider is because the amount of background is much larger for ID efficiencies than for ISO efficiencies, and then fitting the background properly is so important in the ID case.

About the fitting functions, for ID measurements as function of the transverse muon momentum the signal is fitted by the sum of two Voigtians, while the background is fitted by a product of an exponential function and an error function. In other cases the background is simply fitted by an exponential function.

2.3 Event selection

“Tag” muons are required to pass the *Tight muon ID*, a single muon trigger that includes a p_T > 24 GeV cut and a *relative isolation* requirement below 0.40, a selection on transverse momentum greater than 26 GeV, and finally a *relative isolation* below 0.2.

For ID efficiencies the “Probe” muons are required to be have p_T > 20 GeV, while for ISO efficiencies they have to pass a certain ID working point and p_T > 20 GeV.

3. Results

The efficiency measurements for *Tight muon ID* as function of the muon pseudorapidity η, and for *Tight muon ISO* as function of the muon p T are shown in Figure 2 (more plots in [2]).

The global efficiencies for all the studied muon working points are registered in Table 1.

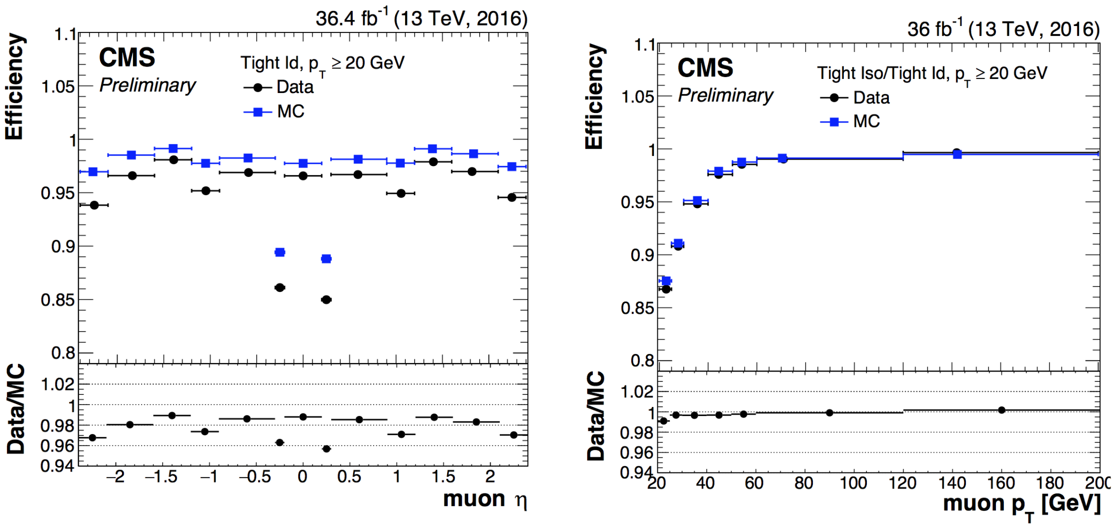

Figure 2: Efficiency measurements for *Tight muon ID* working point as function of muon η on the left, and for *Tight muon ISO* working point on top of Tight muon working point on the right. Data is plotted in dark and Monte-Carlo simulation in blue. The ratio between data and simulation is placed at the bottom.

Working Point	Global efficiency
Loose ID	~ 99%
Medium ID	~ 97%
Tight ID	~ 96%
High-p_T ID	~ 96%
Loose ISO / Loose ID	~ 99%
Loose ISO / Medium ID	~ 99%
Loose ISO / Tight ID	~ 99%
Loose Trk ISO / High-p_T ID	~ 98%
TIght ISO / Medium ID	~ 96%
Tight ISO / Tight ID	~ 96%

Table 1: Global efficiency summary for all the studied working points.

References

[1] The CMS collaboration, *Performance of the CMS muon detector reconstruction with proton-proton collisions at 13 TeV*, 2018 *JINST* 13 P06015 [arXiv:1804.04528]

[2] J. Alwall, R. Frederix et al, *The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations*, JHEP 07 (2014) 079 [arXiv:1405.0301]

[3] The CMS collaboration, Muon Identification and Isolation efficiency on full 2016 dataset, CMS-DP-20017/007