Muon reconstruction performance during Run II

The CMS Collaboration

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Methods and samples

Methods:

- Efficiencies are calculated using the tag-and-probe method exploiting the Z $\rightarrow \mu^+\mu^-$ resonance
- Resolution is inferred by evaluating the features of the $\mu^+\mu^-$ invariant mass distribution in the Z mass peak

Data:

- Proton-proton collision data at $\sqrt{s} = 13$ TeV, corresponding to an integrated luminosity of 41.3 fb^{-1} (2017), and 59.8 fb^{-1} (2018)
- Events collected using single muon triggers

Monte Carlo simulations:

- Drell-Yan + jets LO sample (madgraph)
- Events are weighted to match the pile-up distribution of data

MUON IDENTIFICATION (ID)

More details can be found in JINST 13 (2018) no.06, P06015

- Loose muon ID: aims to identify prompt muons originating at the primary vertex, and muons from light and heavy flavor decays, as well as maintain a low rate of the misidentification of charged hadrons as muons. A loose muon is a muon selected by the PF algorithm that is also either a tracker or a global muon.
- Tight muon ID: aims to suppress muons from decay in flight and from hadronic punch-through. A tight muon is a loose muon with a tracker track that uses hits from at least six layers of the inner tracker including at least one pixel hit. The muon must be reconstructed as both a tracker muon and a global muon. The tracker muon must have segment matching in at least two of the muon stations. The global muon fit must have $\chi^2/ndof < 10$ and include at least one hit from the muon system. A tight muon must be compatible with the primary vertex, having a transverse impact parameter smaller than 0.2 cm and a longitudinal impact parameter smaller than 0.5 cm

TAG-AND-PROBE PARAMETERS

- Tag-and-probe method is used to extract efficiencies in Z$\rightarrow \mu^+\mu^-$ events

- Tag selection in 2017 (2018):
  - Tight ID muon with $p_T > 29$ (26) GeV
  - Tight PF isolation
  - Matched with single isolated trigger
- Probe selection:
  - Tracker muons with $p_T > 20$ GeV

- The invariant mass distribution for signal and background is fitted using the following functions:
  - signal: sum of 2 Voigtians
  - background: error function with an additional multiplicative exponential term at high $m_{\mu^+\mu^-}$
- Mass window: [70-130] GeV

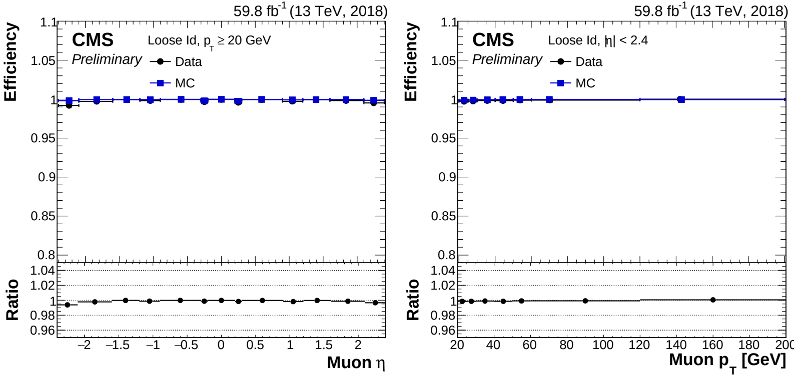
The plots shown include only statistical uncertainties. Quoted systematic uncertainties are estimated varying the isolation cut on the tag muon, with variations of the signal and background pdfs, and enlarging and reducing the mass window.

RESOLUTION MEASUREMENT

- Muon scale resolution are measured in the Z$\rightarrow \mu^+\mu^-$ mass resonance
- Di-muon events are required to have two muons passing the tight ID and isolation criteria
- $m_{\mu^+\mu^-}$ distribution is fitted to a Gaussian function convolved with the convolution of a Breit-Wigner and a Crystal-Ball
- Mean and standard deviation are evaluated
- Muons have been calibrated using the Rochester method
  - More information in EPJC V72, 10.2194 (2012)
- Uncertainties include systematic and statistical components

Muon ID efficiencies with the 2018 dataset

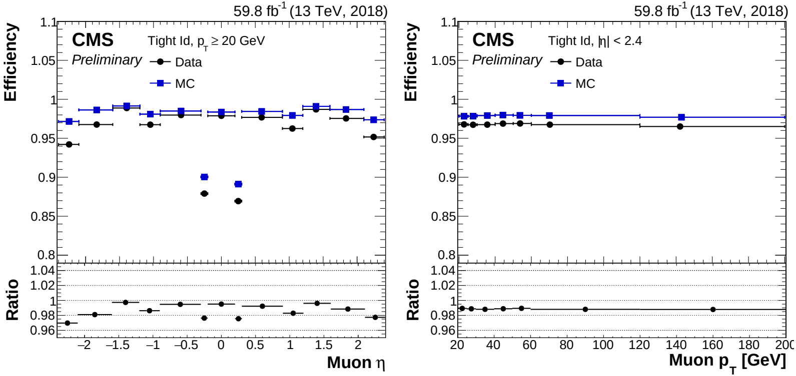
LOOSE ID EFFICIENCIES VS p_T, η



Loose lepton ID efficiency as a function of η and p_T for 2018 data and MC. The denominator is tracker muons with $p_T > 20$ GeV. No dependency with respect to the number of primary vertices was observed.

Average scale factor is 0.998. Systematic uncertainties are smaller than $< 0.2\%$.

TIGHT ID EFFICIENCIES VS p_T, η

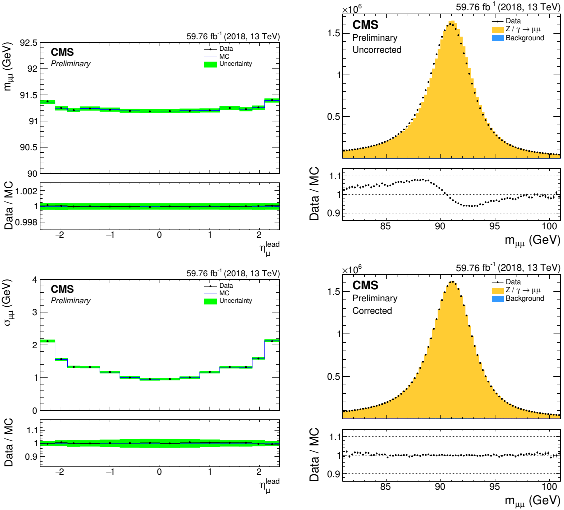


Tight lepton ID efficiency as a function of η and p_T for 2018 data and MC. The denominator is tracker muons with $p_T > 20$ GeV. No dependency with respect to the number of primary vertices was observed.

Average scale factor is 0.98. Systematic uncertainties are smaller than $< 0.5\%$.

Muon resolution in Run 2

MUON RESOLUTION IN 2018

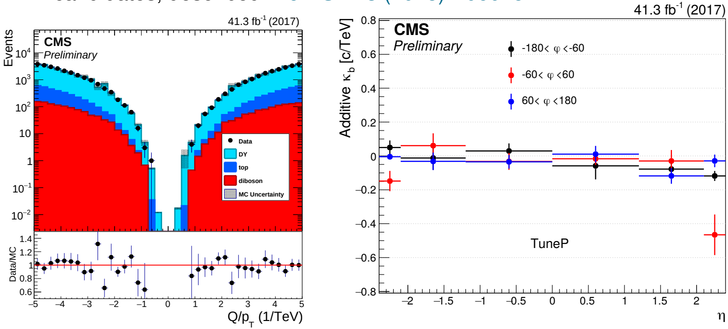


Resolution measured in $Z \to \mu^+\mu^-$ events in the 2018 dataset. Top and bottom left plots show the mean and the standard deviation of the $m_{\mu^+\mu^-}$ resonance peak obtained fitting the distribution to the convolution of a Gaussian with a Breit-Wigner and a Crystal-Ball. Uncertainties incorporate systematic uncertainties from the Rochester method.

Plots in the right shows the data / Monte Carlo comparison of the $m_{\mu^+\mu^-}$ distribution before (top) and after (bottom) applying the scale corrections given by the Rochester method.

Energy scale in high energy muons

- Energy scale corrections for high energy muons are estimated using events with two muons with $p_T > 200$ GeV, using the Generalized Endpoint method (JINST 13 (2018) P06015)
- Custom identification and momentum assignment criteria are applied to the muon candidates, described in JINST 13 (2018) P06015



(Left) Distribution of muon curvature in data and Monte Carlo in $Z \rightarrow \mu^+\mu^-$ events. (Right) additive correction to the muon curvature ($\kappa \rightarrow \kappa + \kappa_b$) as a function of η and ϕ. κ_b is injected as an additive correction to curvature in Monte Carlo simulations, and its value is chosen such that the χ^2 of the comparison between data and Monte Carlo is minimized. Additive corrections are consistent with those obtained with the Rochester method.