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

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on behalf of the CMS collaboration

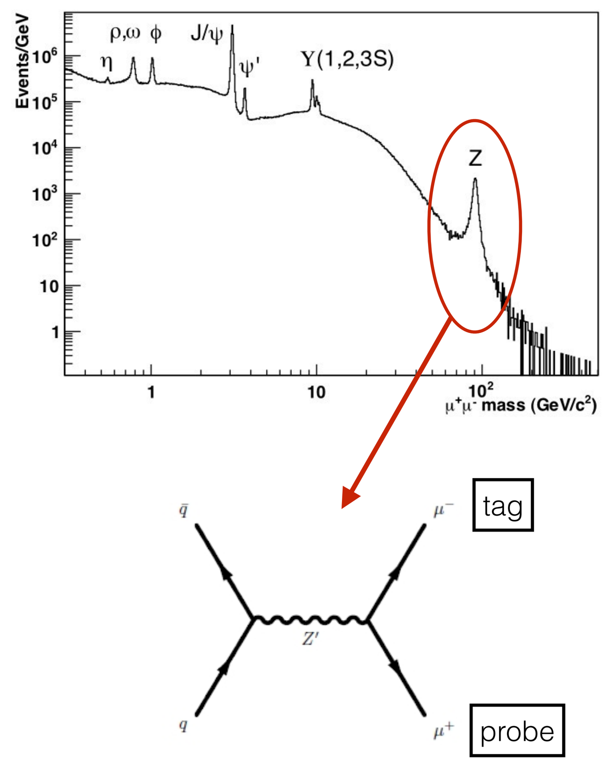
The Tag-and-Probe method (I)

- Total muon detection efficiency:

$$\varepsilon_{total} = \varepsilon_{trk} \times \varepsilon_{ID} \times \varepsilon_{ISO} \times \varepsilon_{trigger}$$

- *Tag & Probe* method: A known resonance is considered → in this case the invariant mass of two muons that come from Z. We name one muon as "tag" and the other as "probe"
    - "tag" muons: they pass very tight requirements of ID and ISO
    - "probe" muons: compatible tracks with the Z resonance
- The aim is to measure a certain ID or ISO efficiency over the "probe" muons as:

$$\varepsilon = \frac{N_{pass}}{N_{all}}$$



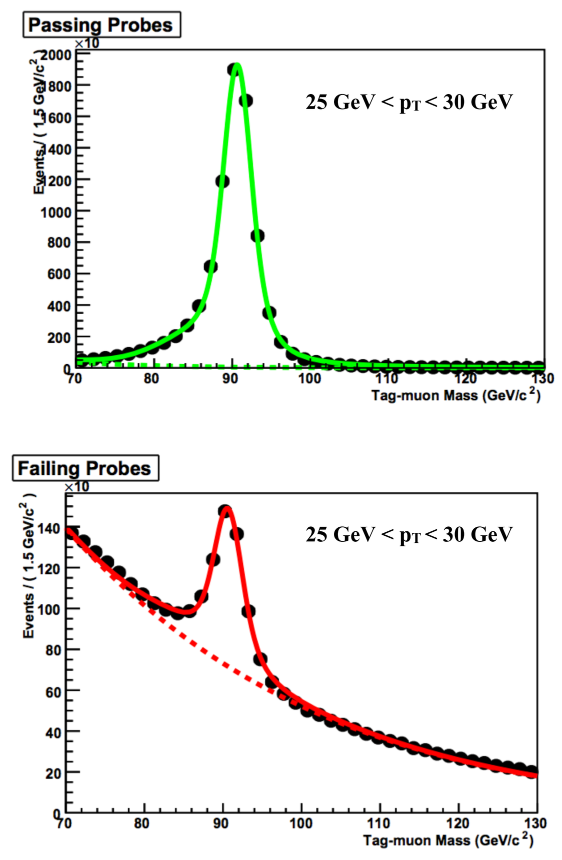
The Tag-and-Probe method (II)

- As the selected events may not come from the resonance → There could be a bias in the efficiency measurement
    - To avoid this we do a simultaneous fit to the signal (Z peak) and the background → A wider mass range (for instance 70-130 GeV) has to be considered in order to be able to fit the background properly.
    - The total probes sample is split considering whether the muons pass (**Passing probes**) or do not pass (**Failling probes**) the ID / ISO working point that we want to measure.
    - The fit is done for the passing probes, for the failling probes and for all probes. Then the efficiency is computed as:

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

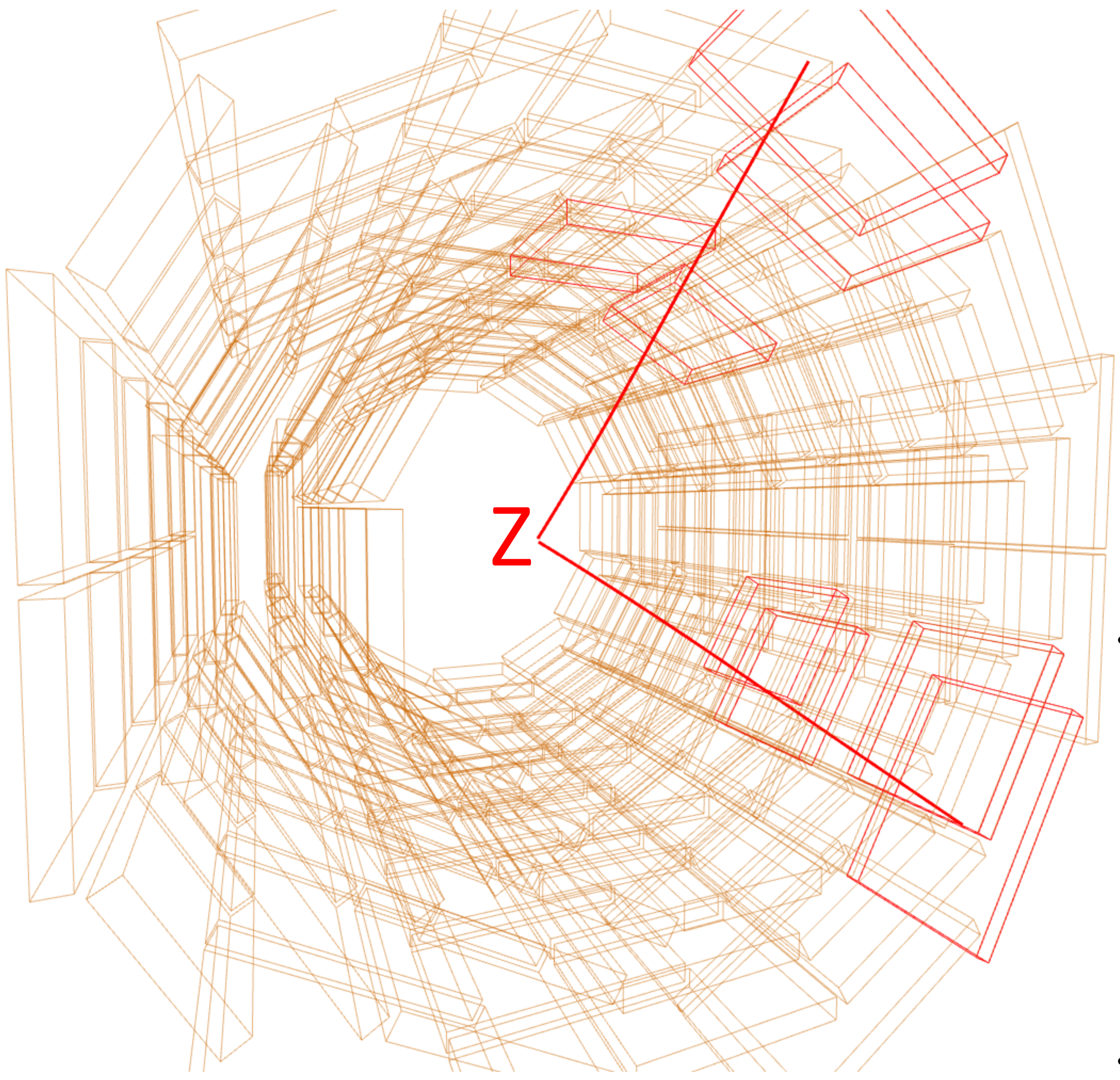
The same procedure is followed for simulation

- If we want to measure the efficiency as function of one kinematic variable, this process will have to be repeated for each variable bin



Data / Monte-Carlo samples and event selection

- Data sample:
    - Collision data at 13 TeV and 25 ns bunch spacing. Luminosity: 36 fb^{-1}
- Monte-Carlo sample:
    - Drell-Yan + Jets sample generated with M5_aMC@NLO at LO
    - Re-weighting is applied to match the pileup distribution in data
- Fitting parameters:
    - Mass window: [70-130 GeV] for ID, [77-130 GeV] for ISO
    - Functions:
        - For ID as function of pT → Signal: sum of two voigtians; Background: product of failling exponential and error function
        - Else → Signal: sum of two voigtians. Background: Exponential

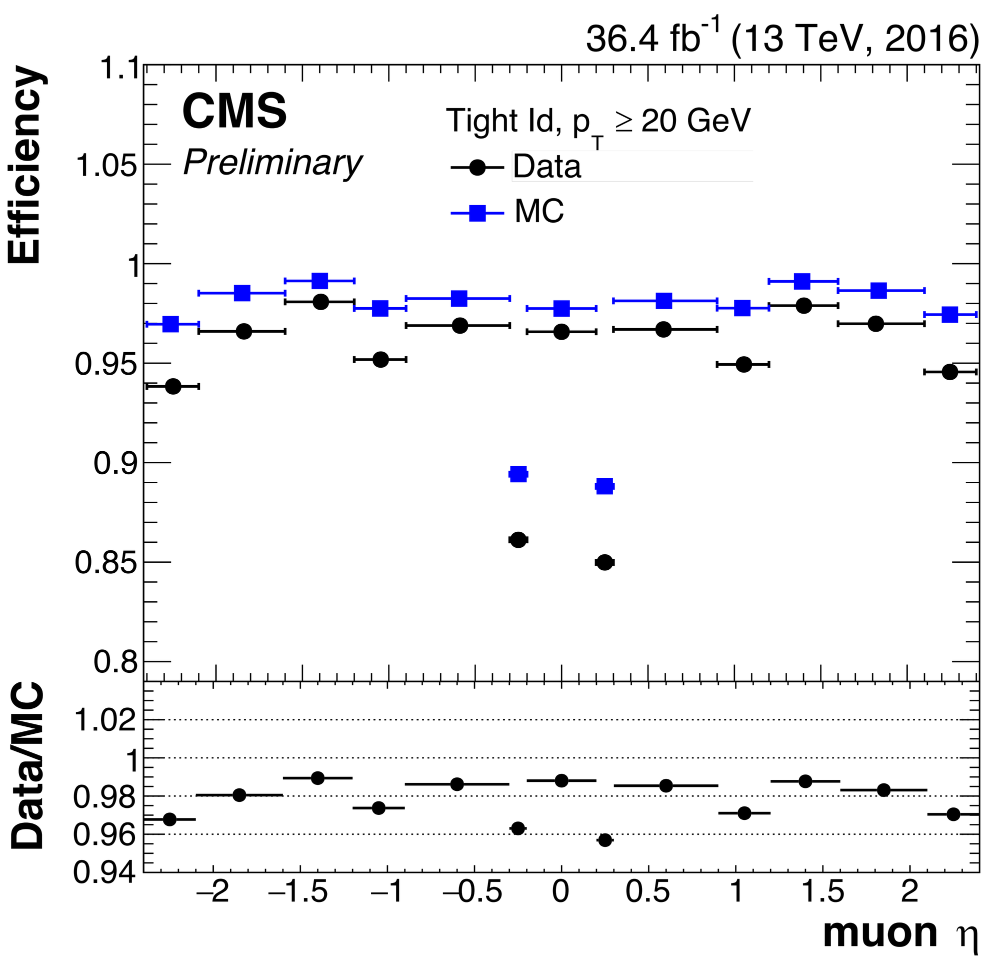


- **Probe muon selection**:
    - For ID efficiencies:
        - Compatible tracks with the Z resonance
        - $p_T > 20$ GeV
    - For ISO efficiencies:
        - Pass a required ID working point
        - $p_T > 20$ GeV
- **Tag muon selection**:
    - Tight muon identification
    - SingleMuon $p_T > 24$ trigger that includes a relative isolation requirement (Iso < 0.15)
    - $p_T > 26$ GeV
    - Relative Isolation(ΔR=0.4) < 0.2

- The efficiency is computed for several working points based on quality requirements on the muon ID and ISO (more details in **arXiv:1804.04528**)
    - *Tight muon ID* aims to suppress muons from decay in flight and from hadronic punch-through
    - *Relative muon Isolation*: sum of the energy relative to the muon p_T in a geometrical cone ΔR surrounding it
        - *Tight muon ISO*: relative isolation (ΔR=0.4) < 0.15
- The systematic uncertainty effect 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 %

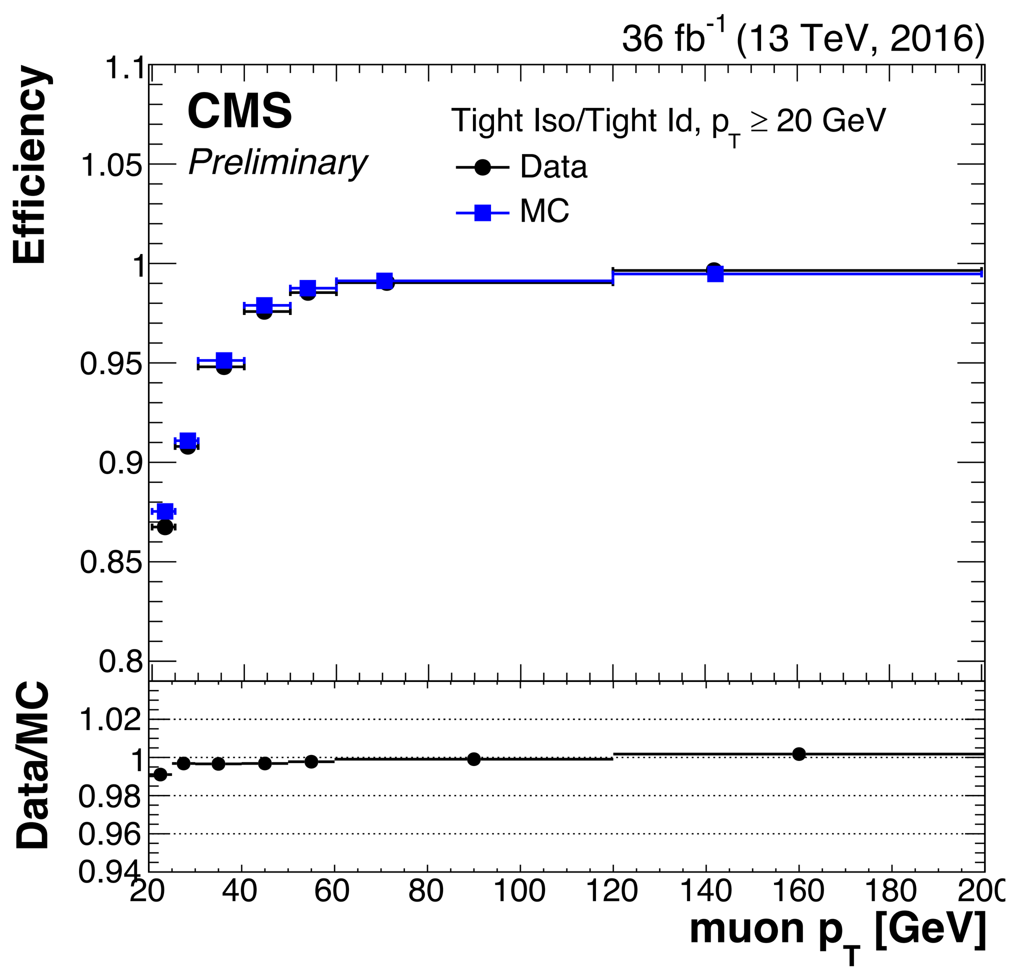
Results

Tight ID vs η



Denominator: Compatible tracks

Tight ISO vs p_T



Denominator: Tight ID

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%

The Sixth Annual Large Hadron Collider Physics conference (LHCP2018), 4 – 9 June, Bologna