Poster Session at the 2016 March LHCC meeting
CERN, Geneva (Switzerland), 2nd March 2016
https://indico.cern.ch/event/491582/

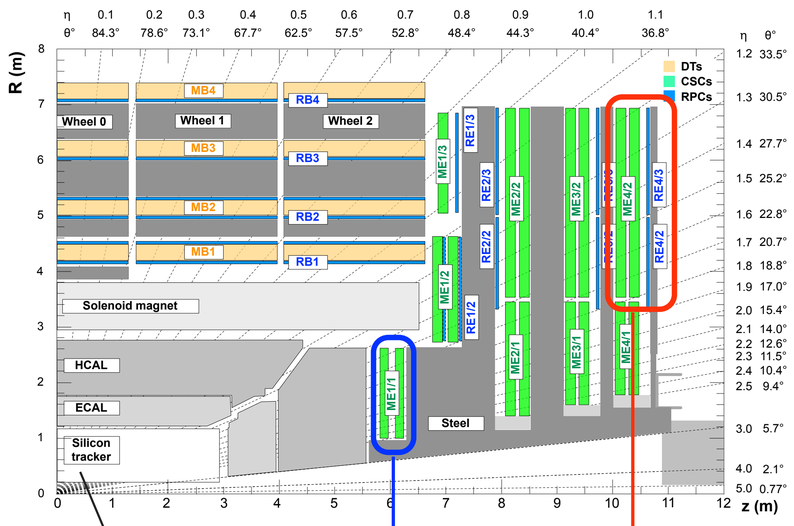
Muon reconstruction and identification efficiencies in CMS at $\sqrt{s}$ = 13 TeV

Leonardo Cristella (University & INFN of Bari), on behalf of the CMS Collaboration
leonardo.cristella@cern.ch

The Compact Muon Solenoid detector

Muons are measured in the **Muon System** and the **Inner Tracker**, providing two loosely correlated measurements.

The Muon system consists of three gaseous detectors:
Drift Tubes (DT) in the barrel ($|\eta| < 1.2$),
Cathode Strip Chambers (CSC) in the endcaps ($0.9 < |\eta| < 2.4$),
and **Resistive Plate Chambers** (RPC)
($|\eta| < 1.6$ for triggering and $|\eta| < 1.8$ for reconstruction).



Changes since Run-I:
- **CSC**: electronic upgrade
- **CSC**: 72 new chambers
- **RPC**: up to $|\eta| = 1.8$

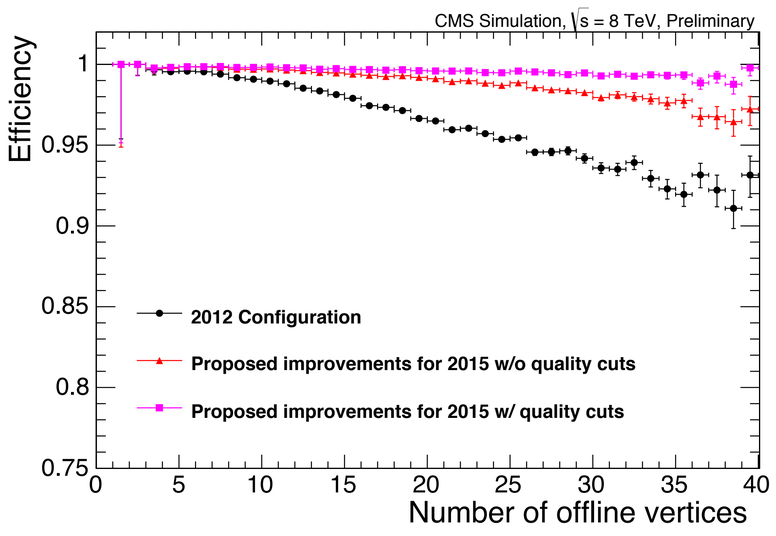
The inner tracker is located at the innermost part of the CMS, and covers a range of $|\eta| < 2.5$.
It consists of pixel detectors close to the interaction vertex and outer lavers of silicon strips.

L3 Improvements for Run-II

The HLT trigger level (see "Muon trigger efficiency section") can be divided into two software based reconstruction phases:

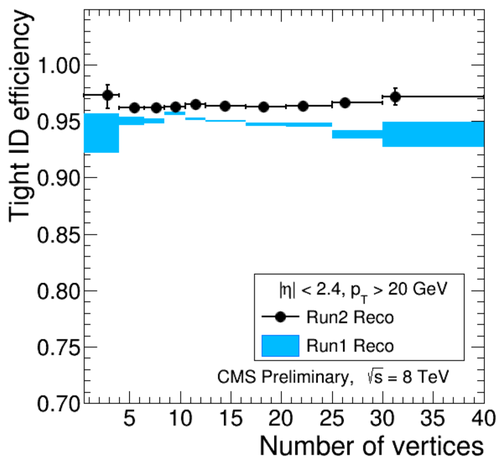
- **L2 Muon**: Track reconstructed using muon subdetectors.
- **L3 Muon**: Full track reconstructed using the inner silicon tracker and L2 muon.

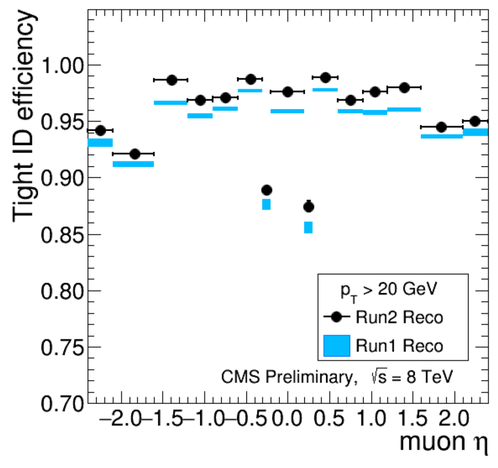
The L3 reconstruction uses an algorithm called **Cascade** in which three algorithms are run in sequence, two of which start the tracking reconstruction from the outside of the tracker inwards and one which starts inside outwards. If a full track is successfully created from the L2 muon then the sequence stops and subsequent algorithms are not run. **Quality filters on the tracker tracks** used as part of the reconstruction were introduced for Run-II. The choice of the estimator in assigning hits to tracker tracks was also changed from using a η-ϕ window to a χ^2 measurement. The changes provide higher efficiencies with respect to the higher amounts of pileup expected in Run-II.



Muon reconstruction improvements

The reconstruction efficiency has improved with respect to Run-I thanks to two additional muon-specific tracking iterations. An outside-in iteration, starting from the muon system, recovers the missing tracker tracks. An inside-out iteration re-reconstructs the muon tagged tracks with loser requirements to improve the hit collection efficiency.





Tight ID efficiency
Particle identified as a muon by the Particle-Flow event reconstruction. Global muon track, including hits in the inner tracking system and in the muon detectors. Requirements on number of hits, global track χ^2, impact parameters.

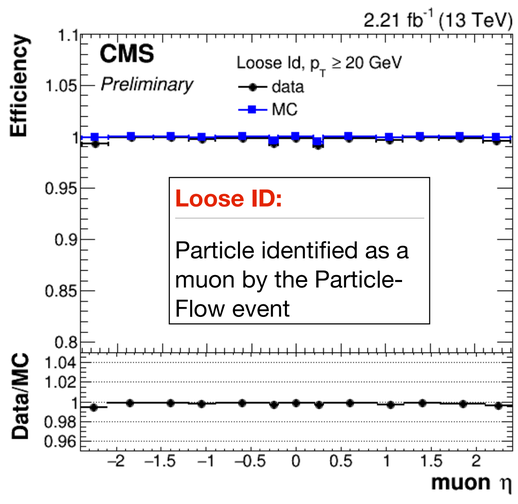
Data: on a Z → μμ subsample recorded on the last part of the 2012 run. Estimated performance using a Tag and Probe method. Improvements for tightly identified muons are of the order of 1-2%.
The **Run-II** reconstruction recovers a mild pileup dependence present in Run-I.

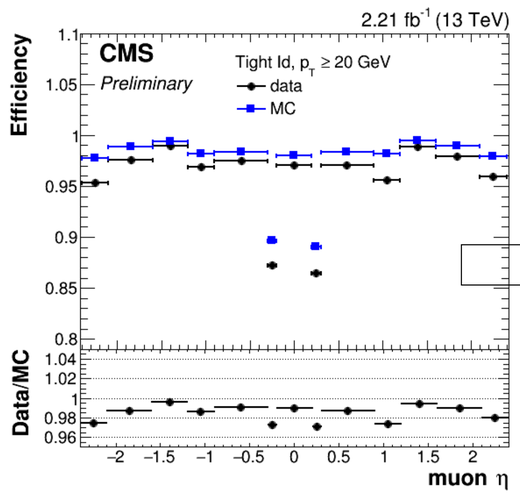
Muon reconstruction and identification efficiency (Tag and Probe method)

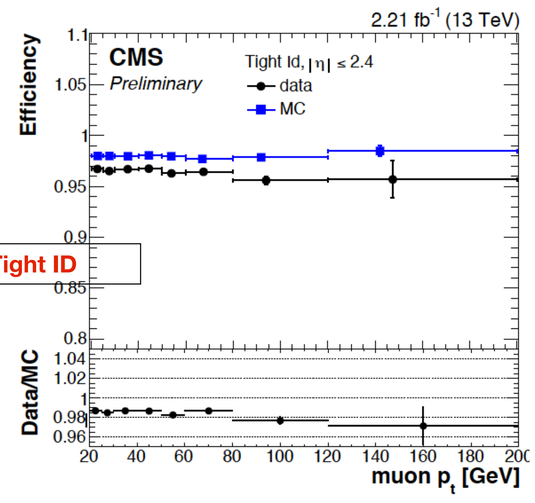
Tag and Probe is a data driven technique to perform efficiency estimation. To build the Z resonance a muon pair is reconstructed, which consists of:

- **Tag: muon triggering the event passing a tight selection**
- **Probe: muon or track used for the efficiency measurement**

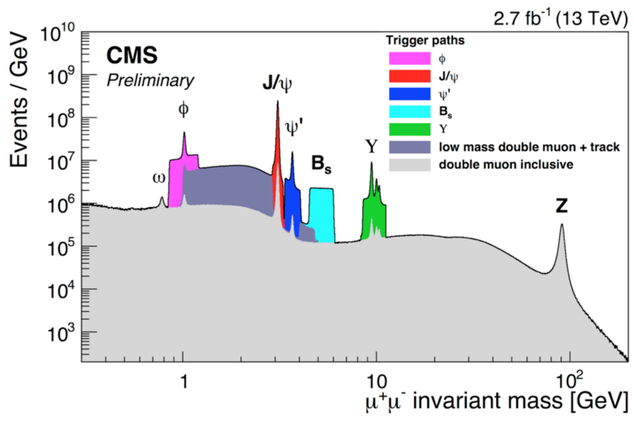
The background is removed by performing a fit to the dimuon invariant mass distribution simultaneously on the probes passing and failing the selection under study.







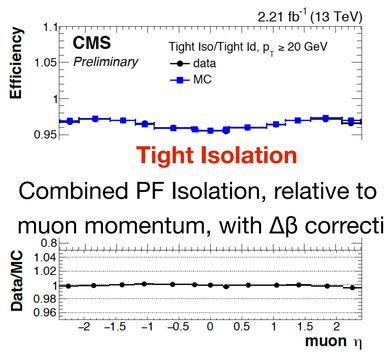
The dimuon invariant mass spectrum



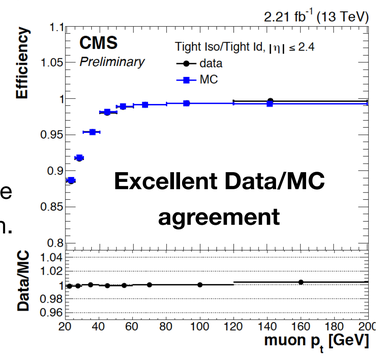
The dimuon mass distribution collected with various dimuon triggers shows the CMS capability to reconstruct and resolve several dimuon resonances.

Muon isolation performance

Isolation: How the muon is isolated with respect to other particle next to its trajectory ? Computed by summing all particles in a $\Delta R = (\Delta\eta^2 + \Delta\phi^2)^{1/2}$ cone around the muon.



Tight Isolation
Combined PF Isolation, relative to the muon momentum, with Δβ correction.



Muon trigger efficiency

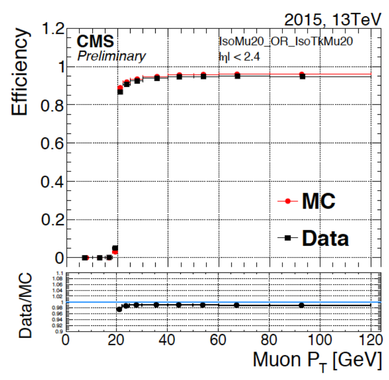
The Muon triggers consists of the **Level-1** and **HLT** trigger levels

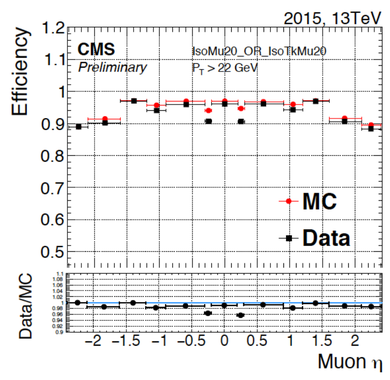
- **Level-1**: hardware-based, use information of the muon system exclusively.
- **HLT**: software based, combines informations from muon system, calorimeter and inner tracker.

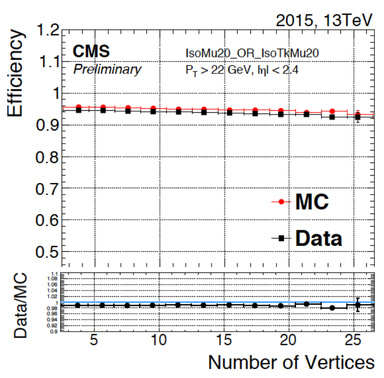
Computation of isolation for single muon HLT triggers was updated with respect to 2012 configuration. Isolation computation strategy was updated, from single isolation cut combing tracker and calorimeter information, to sequential isolation cuts, tuned independently for tracker and calorimeter components. This results in a better rate-rejection vs efficiency trade-off.

Single muon triggers:

- An additional algorithm identifying muons at HLT by matching extrapolated tracks with segments in the muon chambers was deployed in parallel to the one exploiting L2/L3 reconstruction.
- Isolation improvement allowed to keep single muon thresholds similar to Run-I







References:
CMS Collaboration, *"Muon Reconstruction and Identification Improvements for Run-2 and First Results with 2015 Run Data."*, CMS-DP-2015-015, CERN-CMS-DP-2015-015.
CMS Collaboration, *"Selected Heavy Flavor distributions from CMS with first 13 TeV data"*, CMS-DP-2015-018 ; CERN-CMS-DP-2015-018.