Muon identification performance of the ATLAS experiment

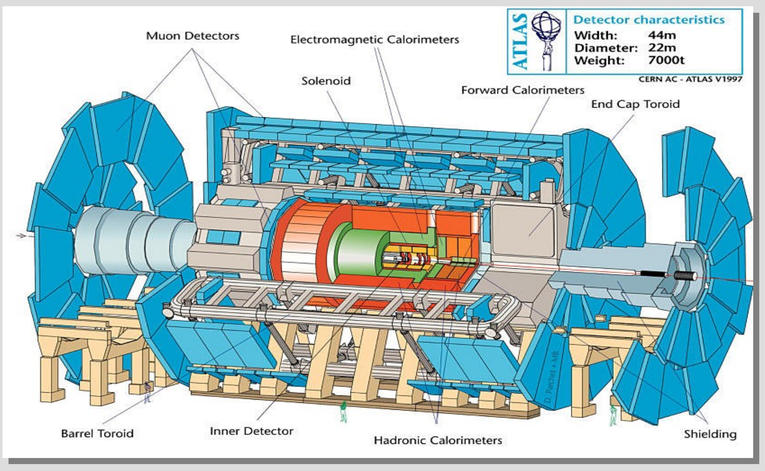
Why the muons?

Muons are key to some of the most important physics results published by the ATLAS experiment at the LHC. These results include the discovery of the Higgs boson and the measurement of its properties, the precise measurement of Standard Model processes and searches for physics beyond the Standard Model. Reconstruction efficiency has been measured for the ATLAS muon spectrometer, by exploiting J/ψ and Z decays for different classes of reconstructed muons. Results are compared with the Monte Carlo simulation.

The ATLAS detector

Two of the ATLAS sub-detector systems have a key role in the muon identification and momentum measurement:

- The Inner Detector (ID): the ID measures the muon track close to the interaction point, providing accurate measurements of the track parameters inside an axial magnetic field of 2 T. The ID is composed of three subdetectors: the silicon pixel (Pixel), the semiconductor tracker (SCT) and the transition radiation tracker (TRT). It measures tracks up to $|\eta|<2.5$.
- The Muon Spectrometer (MS): the MS measures muons up to $|\eta|<2.7$ and consist of a barrel ($|\eta|< 1.05$) and two endcap sections ($1.05 <|\eta|< 2.7$). It is designed to provide momentum measurements with a relative resolution better than 3% over a wide p_T range and up to 10% at p_T about 1 TeV.



Muon reconstruction and identification

Four muon types are defined depending on which subdetectors are used in reconstruction:

- Combined (CB): track reconstruction is performed independently in the ID and MS;
- Segment-tagged (ST): a track in the ID is classified as a muon if, once extrapolated to the MS, it is associated with at least one local track segment in the MDT or CSC chambers;
- Calorimeter-tagged (CT): a track in the ID is identified as a muon if it can be matched to an energy deposit in the calorimeter compatible with a minimum-ionizing particle;
- Extrapolated (ME): the muon trajectory is reconstructed based only on the MS track and a loose requirement on compatibility with originating from the IP.

Four muon identification selections are provided to address the specific needs of different physics analyses:

- Loose: maximize efficiency → good for multi-lepton analysis. All muon types are used;
- Medium: minimize systematics uncertainties. Only CB and ME tracks are used;
- Tight: maximize purity. Only CB with hits in at least two stations in MS and with Medium criteria are used;
- High p_T: maximize momentum resolution for high-p_T tracks (>100 GeV).

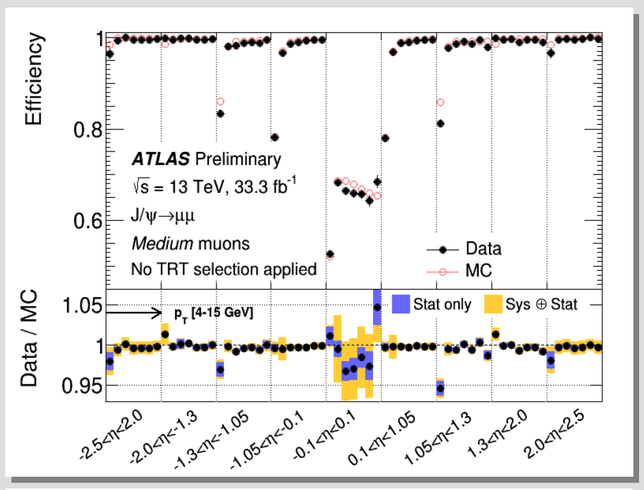
Muon reconstruction efficiency

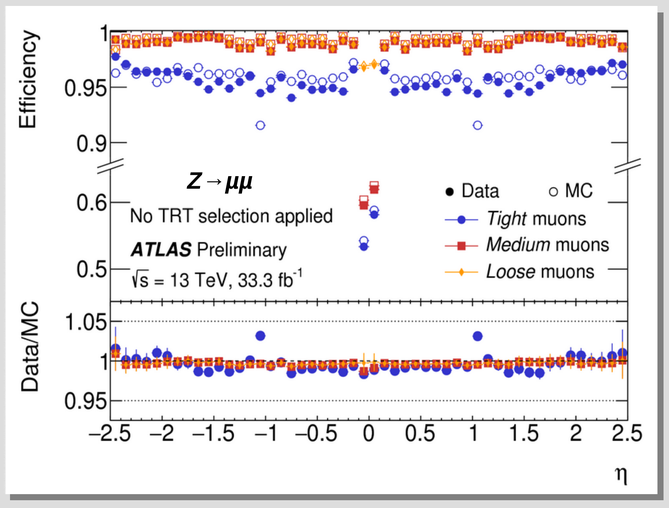
The muon reconstruction efficiency is obtained with the Tag&Probe method. The method is based on the selection of an almost pure muon sample from $J/\psi \rightarrow \mu\mu$ or $Z \rightarrow \mu\mu$ events, requiring:

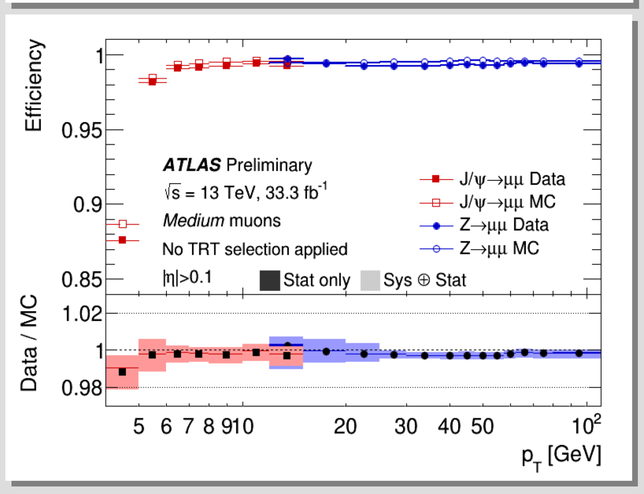
- one leg of the decay (tag) to be identified to be identified as a Medium (or Tight etc.) muon that fires the trigger;
- the second leg (probe) reconstructed by the ID independently from the MS.

The level of agreement between the measured efficiency ϵ^{Data} and the efficiency in the simulation ϵ^{MC} is expressed as "*Efficiency Scale Factor*":

$$SF = \frac{\epsilon^{Data}}{\epsilon^{MC}}$$



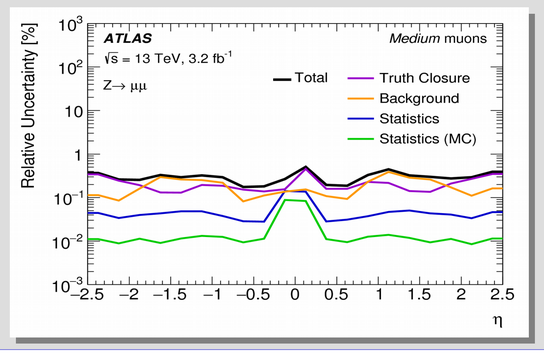


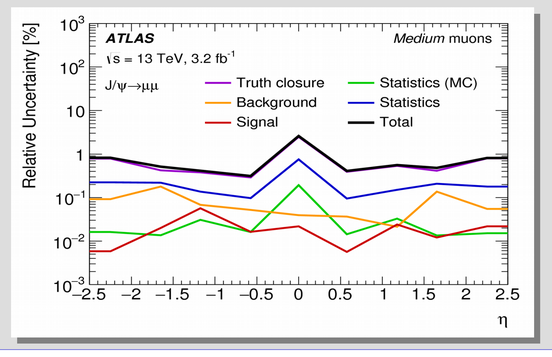


Systematic uncertainties estimation

$Z \rightarrow \mu\mu$: estimated with a simulation-based approach and assuming the background to be charge-symmetric.

$J/\Psi \rightarrow \mu\mu$: estimated by changing the function used in the fit to model the background, replacing the 1st-order pol with a exp function.





Ref:

Muon reconstruction performance of the ATLAS detector in proton–proton collision data at √s=13 TeV;
Eur. Phys. J. C 76 (2016) 292

Maurizio De Santis (INFN & University of Rome Tor Vergata) on behalf of the ATLAS collaboration

New Phenomena at the TeV Scale With Top Quarks
NPTEV-TQP2020
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 648723

ATLAS EXPERIMENT