Muon reconstruction and identification in the ATLAS experiment at LHC

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ATLAS
EXPERIMENT

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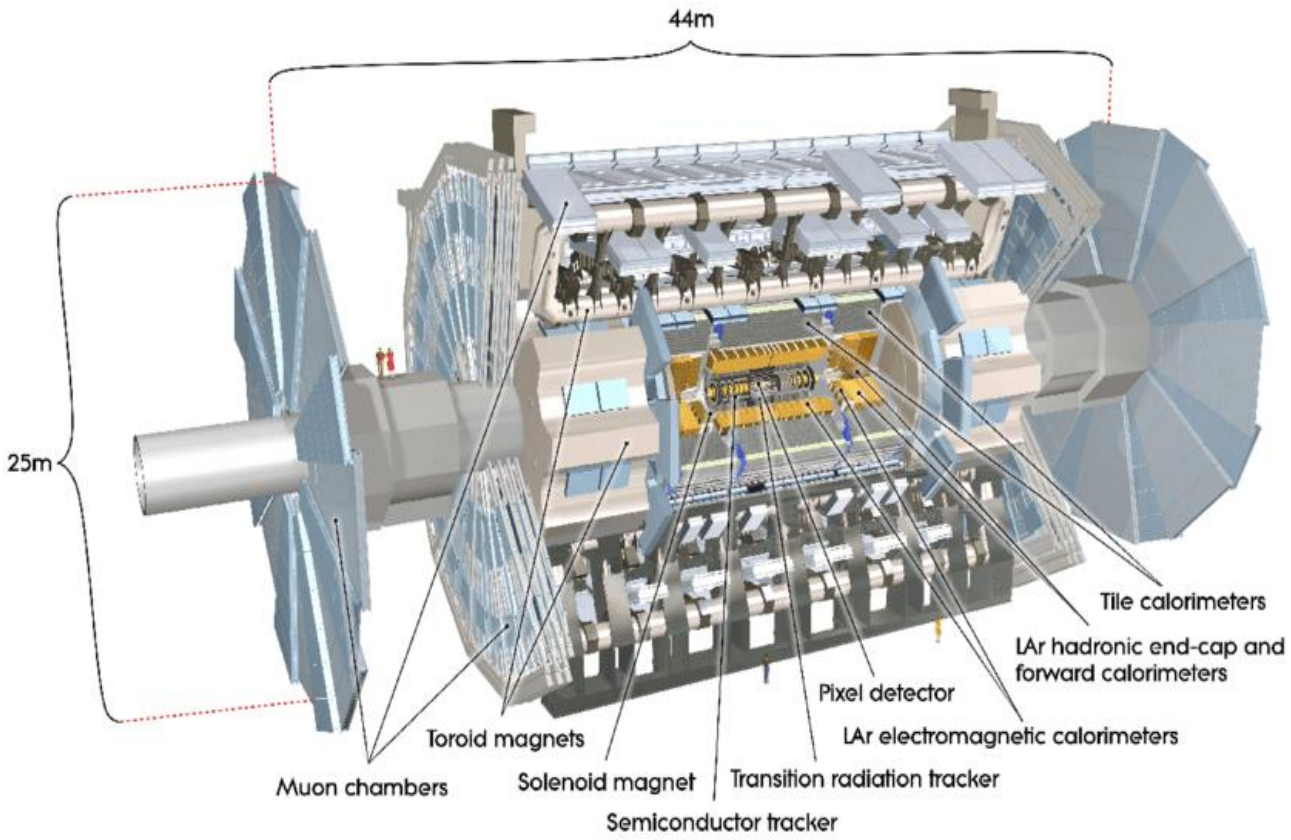
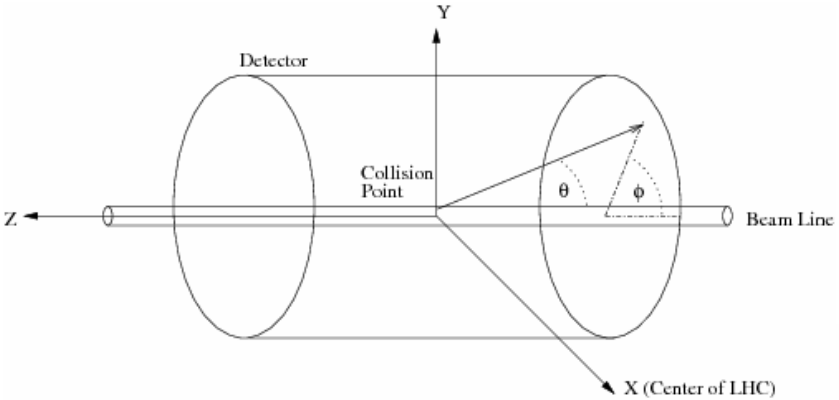
The ATLAS detector



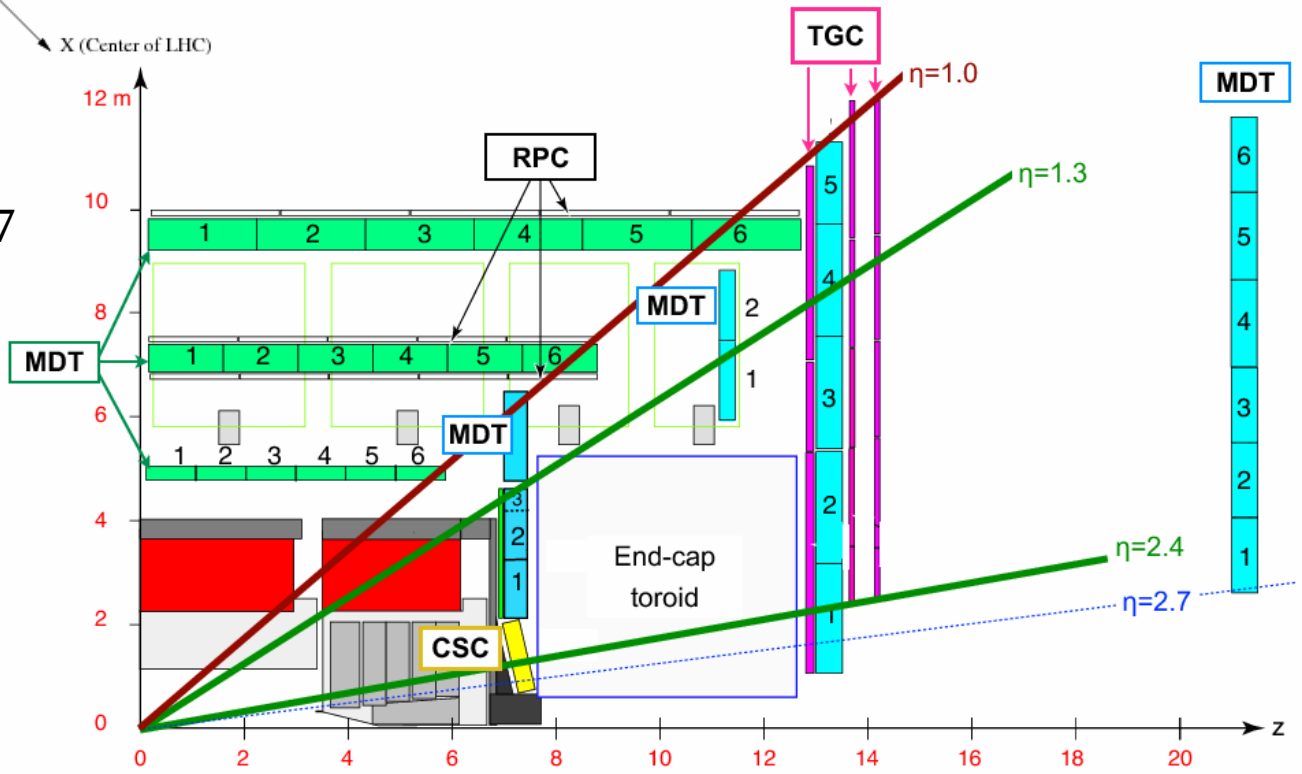
- Inner Detector (ID)
  - Pixel
  - SCT
  - TRT
- Inner solenoid
- Elettromagnetic Calorimeter (LAr)
- Hadronic Calorimeter (Tile)
- External toroids
- Muon Spectrometer

Muon Spectrometer (MS)



Pseudorapidity : $\eta = -\log(\tan {}^{\theta}/_{2})$
azimutal angle ϕ

Barrel : $|\eta| < 1.05$
End-Cap : $1.05 < |\eta| < 2.7$



- Precision Chambers:
  - MDT: $|\eta| < 2.7$
  - CSC : $2.4 < |\eta| < 2.7$
- Trigger Chambers
  - RPC: $|\eta| < 1.05$
  - TGC: $1.05 < |\eta| < 2.4$

Physics with muon

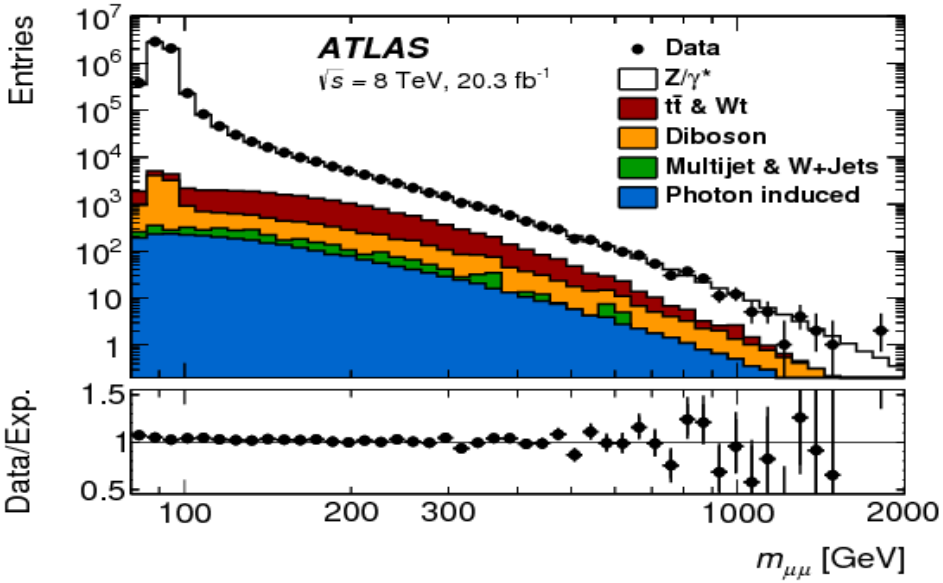
- $J/\psi \rightarrow \mu\mu$ ⟹ $P_t \sim 5 - 20\ GeV$
- Precision EW measures
- Higgs Physics

  } $P_t \sim 50\ GeV$
- BSM searches ⟹ $P_t \sim 1 - 3\ TeV$

Target:

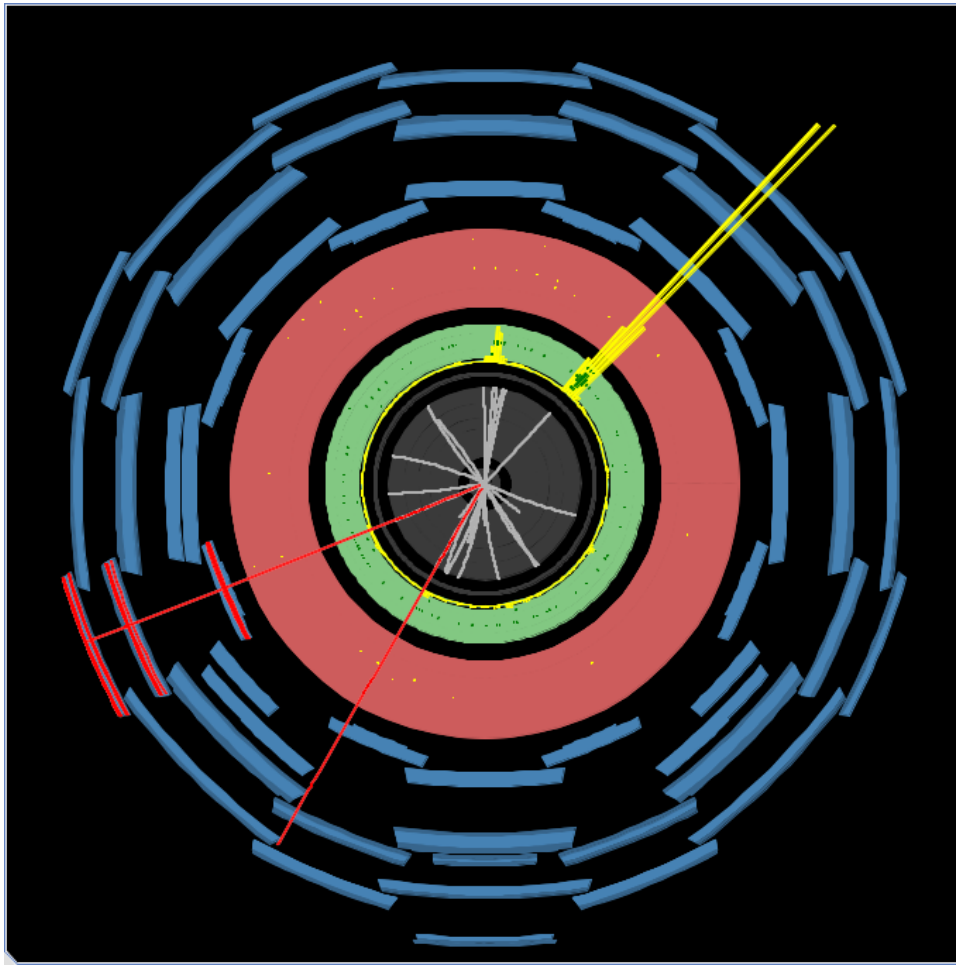
⊙ Robust muon reconstruction for different pT regions

⊙ High efficiency and purity, excellent resolution and momentum scale



(CERN-EP-2016-079)

Muon Reconstruction -I



Steps:

1. Muon reconstruction is first performed indipendently in the ID ($|\eta| < 2.5$) and MS ($|\eta| < 2.7$)
2. The information from individual subdetectors is combined to form the muon track

Muon Reconstruction -II

Different kind of muons:

- Combined (CB) → a combined track is formed with a global refit that uses the hits from both ID and MS

- Segment-tagged (ST) → a track in ID is classificated as a muon if , once extrapolated to the MS it is associated with at least one local segment in the precision chambers

- Calorimeter-tagged (CT) → a track in ID is identified with a muon, if it can be matched to an energy deposit in Ecal compatible with a MIP

- Extrapolated (ME) → the muon track is reconstructed using only the MS and a loose requirement on compatibility with the IP, taking into account the energy deposit in the calorimeter

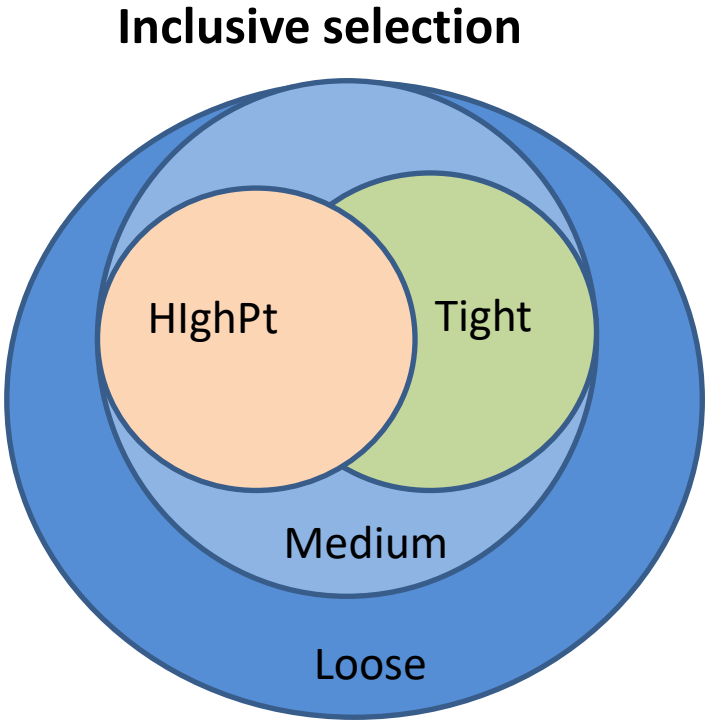
Muon Identification -I

Muon quality identification is performed using these discriminating variables:

- $\frac{q/p_{ID} - q/p_{MS}}{\sigma q/p} \rightarrow q/p$ significance
- $\frac{Pt_{ID} - Pt_{MS}}{Pt_{CB}} \rightarrow \rho'$
- Number of hits and number of precision layers

Muon Identification -II

- Medium → only CB and ME muon
  number of hits ≥ 3
  number of precision layer ≥ 2
  $^{q}/_{p}\, significance < 7$
- Loose → all muon types are used
  same requirements of medium
- Tight → only CB are used
  same requirement of medium
  2-dimensional cut in the ρ' and $^{q}/_{p}$ significance
- High-Pt → muon have to pass the medium selection
  number of precision layer $= 3$
  vetoed chambers



Reconstruction Efficiency -I

Measured with tag-and-probe method

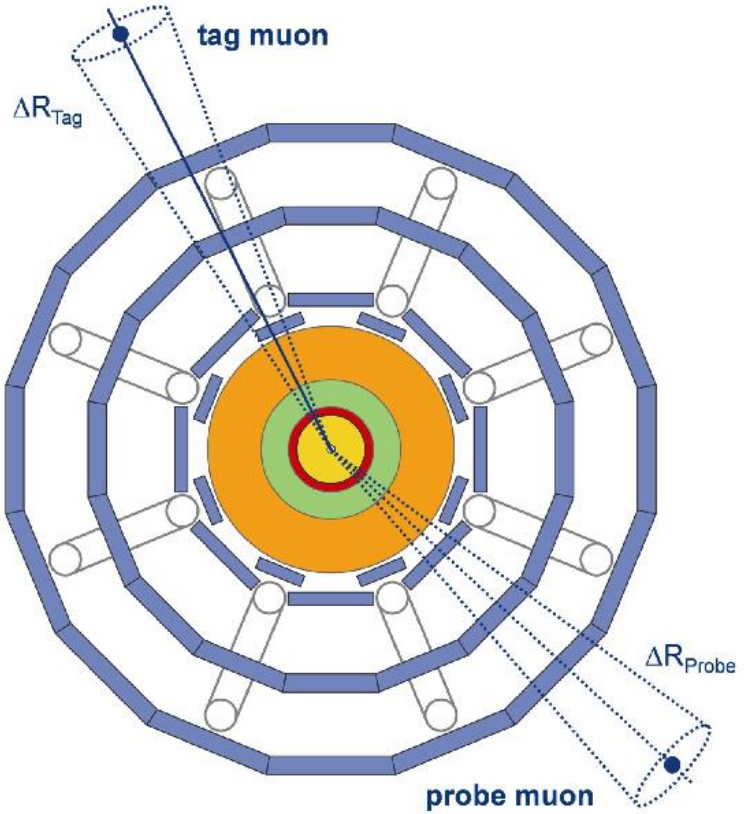
The method is based on the selection of almost pure samples ${}^{J}/_{\psi} \rightarrow \mu\mu$ and $Z \rightarrow \mu\mu$ events

Tag muon must pass the medium selection

$\Delta R_{probe} = 0.05$ is the cone radius showed in the picture -> $\sqrt{\Delta\eta^2 + \Delta\phi^2}$

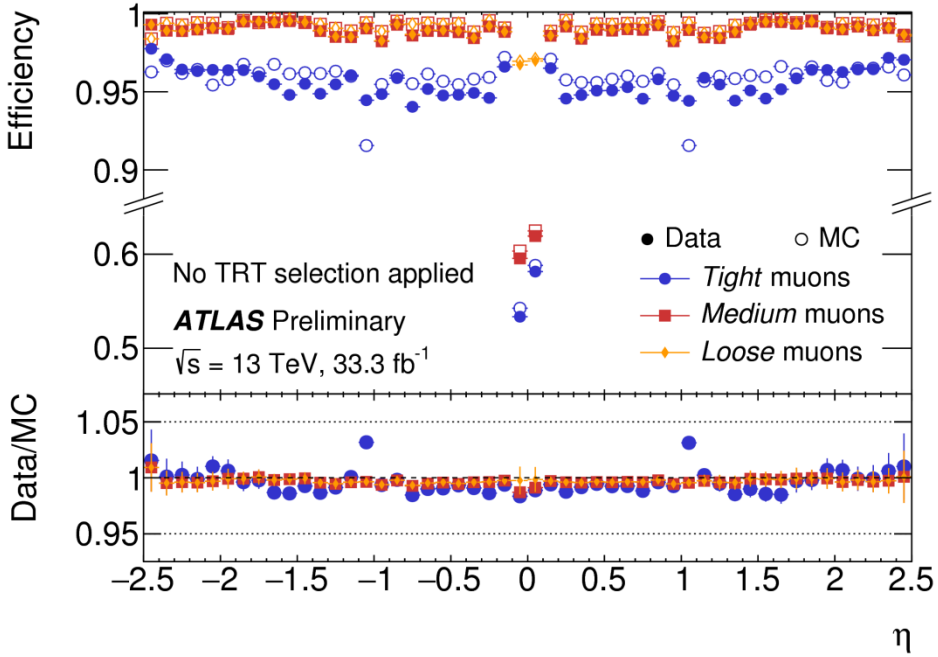
The scaling factor (SF) define the agreement between data and MC efficiency:

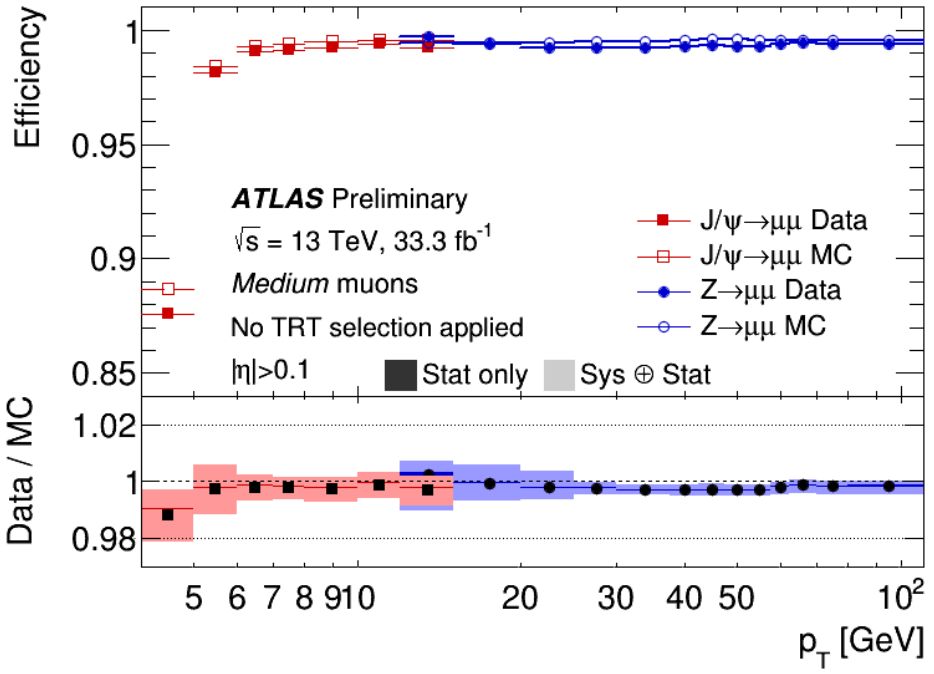
$$SF = \frac{\epsilon^{data}}{\epsilon^{MC}}$$



Reconstruction Efficiency -II

Reconstruction efficiency as a function of η (left) and Pt (right) measured for different muon identifications





Momentum calibration -I

$J/\psi \rightarrow \mu\mu$ and $Z \rightarrow \mu\mu$ samples are used to calibrate the momentum

very useful to measure the Higgs mass

MC P_t will be corrected using several parameters ($s_0, s_1, \Delta r_0, \Delta r_1, \Delta r_2$) estimated with a fit using the following:

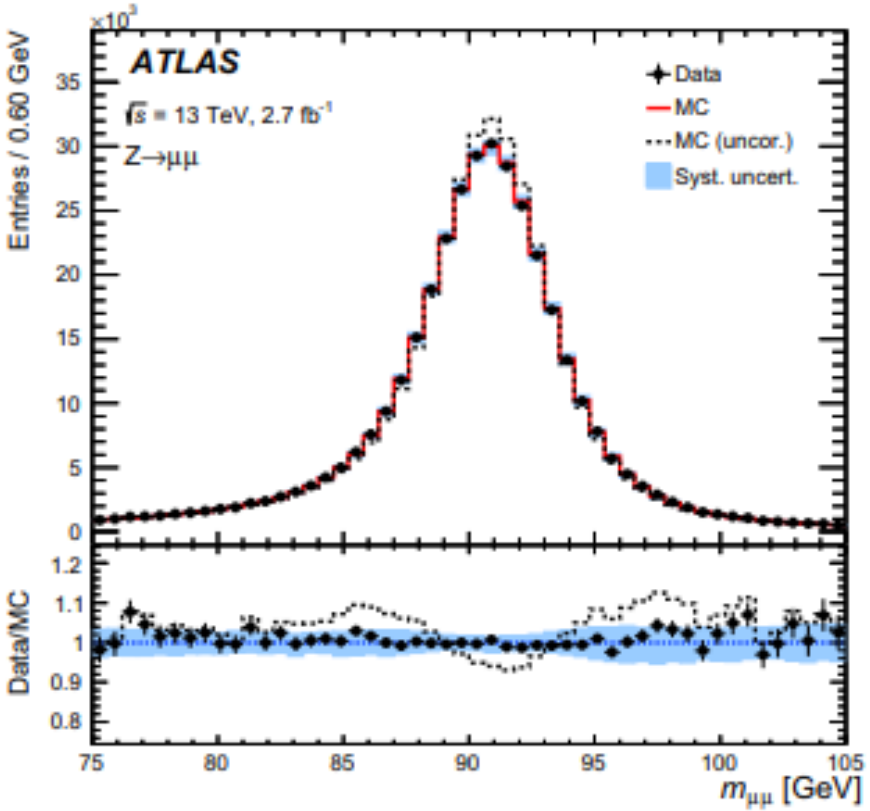
$$P_t^{Cor} = \frac{P_t^{MC} + \sum_{n=0}^{1} s_n(\eta,\phi)(P_t^{MC})^n}{1 + \sum_{m=0}^{2} \Delta r_m(\eta,\phi)(P_t^{MC})^{m-1} g_m}$$

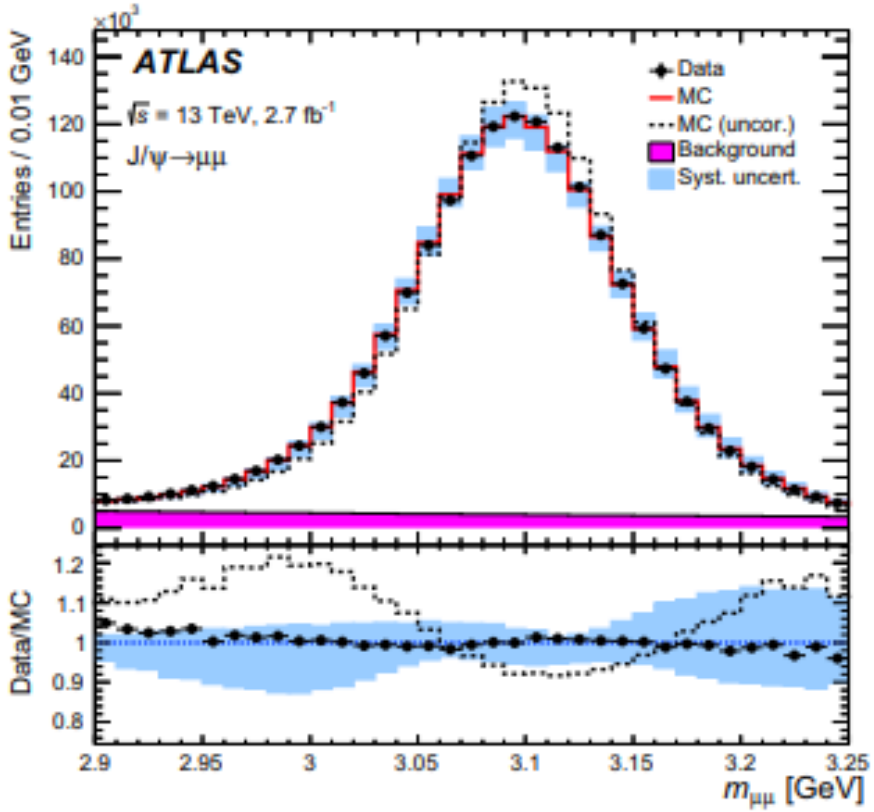
Where the following parameters takes into account of:

- $s_0 \rightarrow$ the inaccuracy of the energy loss from IP to MS
- $s_1 \rightarrow$ the innacuracy of the description of magnetic field
- $\Delta r_m \rightarrow$ describes the momentum resolution smearing

Momentum calibration -II

- Plot of data, MC and MC after the corrections





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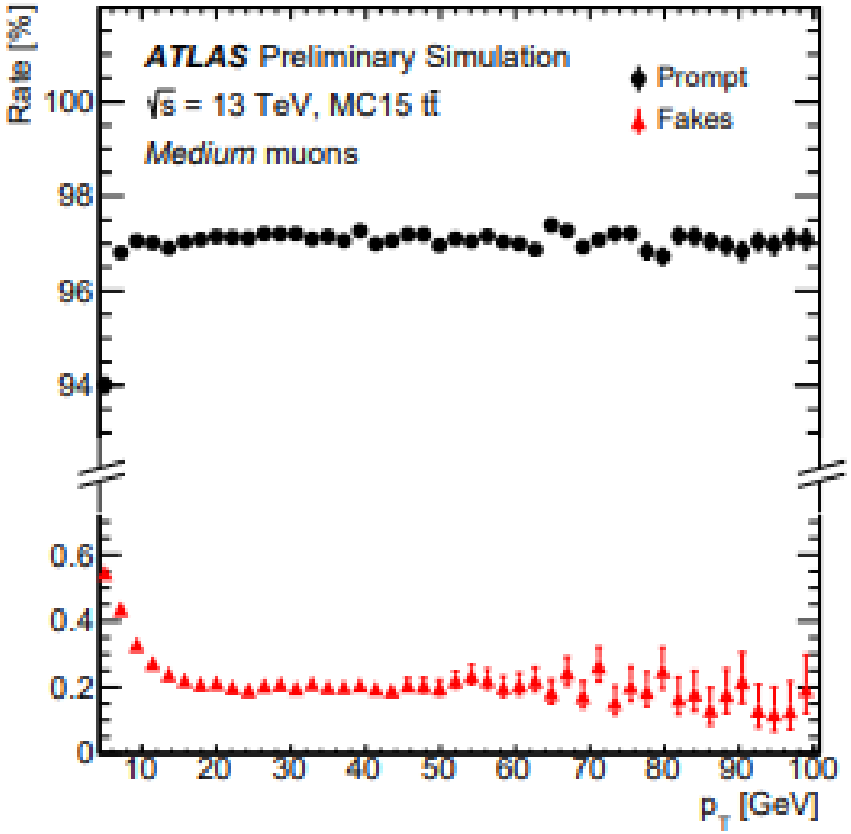
Conclusions

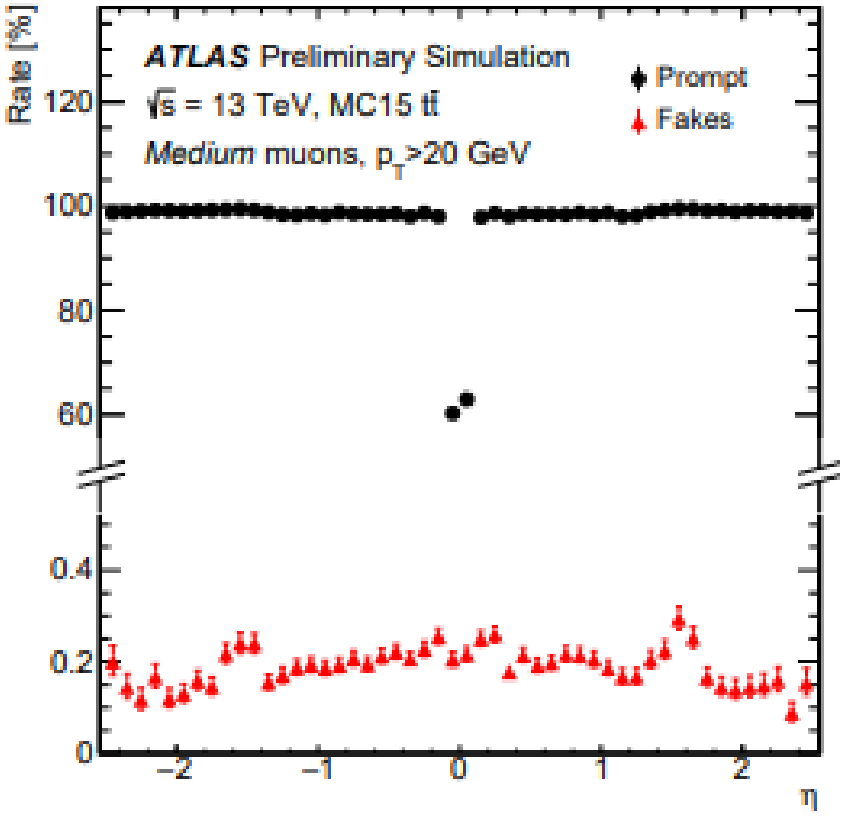
- Muon objects are used in most of the analyses at ATLAS
- Several algorithms developed to ensure robust and high efficient reconstruction and identification of muons
- Efficiency close to 99% within acceptance
- In situ techniques for the measurement of the muon reconstruction efficiency, momentum scale and resolution using J/ψ, and $Z \longrightarrow \mu\mu$
- Correction factor estimated to remove residual discrepancies of data and simulation
- Next studies $\longrightarrow$ try to optimize the compromise among efficiency and resolution for high pt muon (TeV), that can be used for BSM searches

backup

Reconstruction Efficiency -III

- Rate of prompt and fake muon as a funcion of P_t η





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