Measurement of the ATLAS muon reconstruction efficiency in LHC-Run-2

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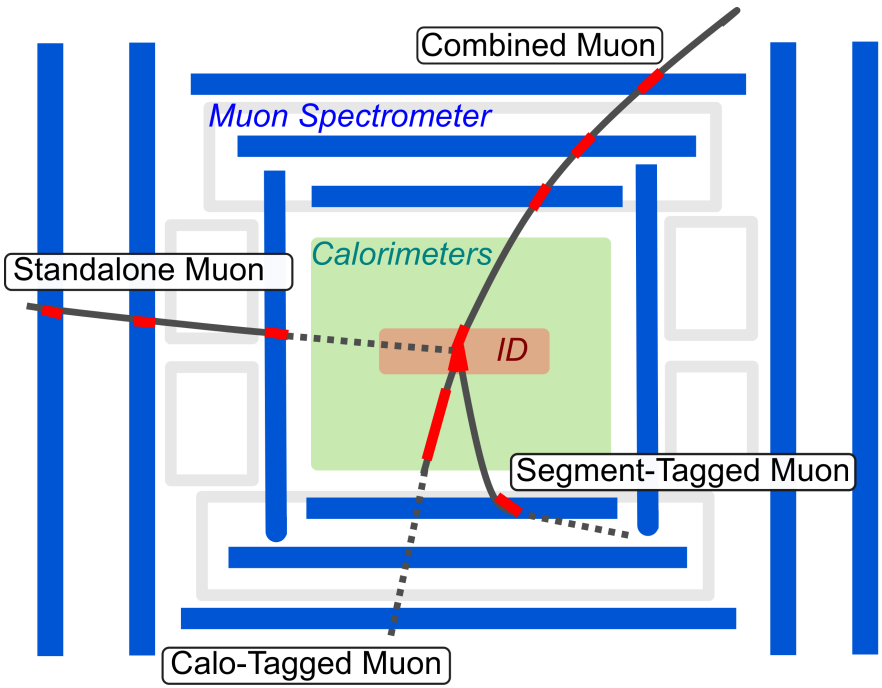
MAX-PLANCK-GESELLSCHAFT

Muon reconstruction at the ATLAS detector



- Combined muons (combine Inner Detector (ID) and Muon Spectrometer (MS) measurements)

$\rightarrow$ Standard method used in ATLAS

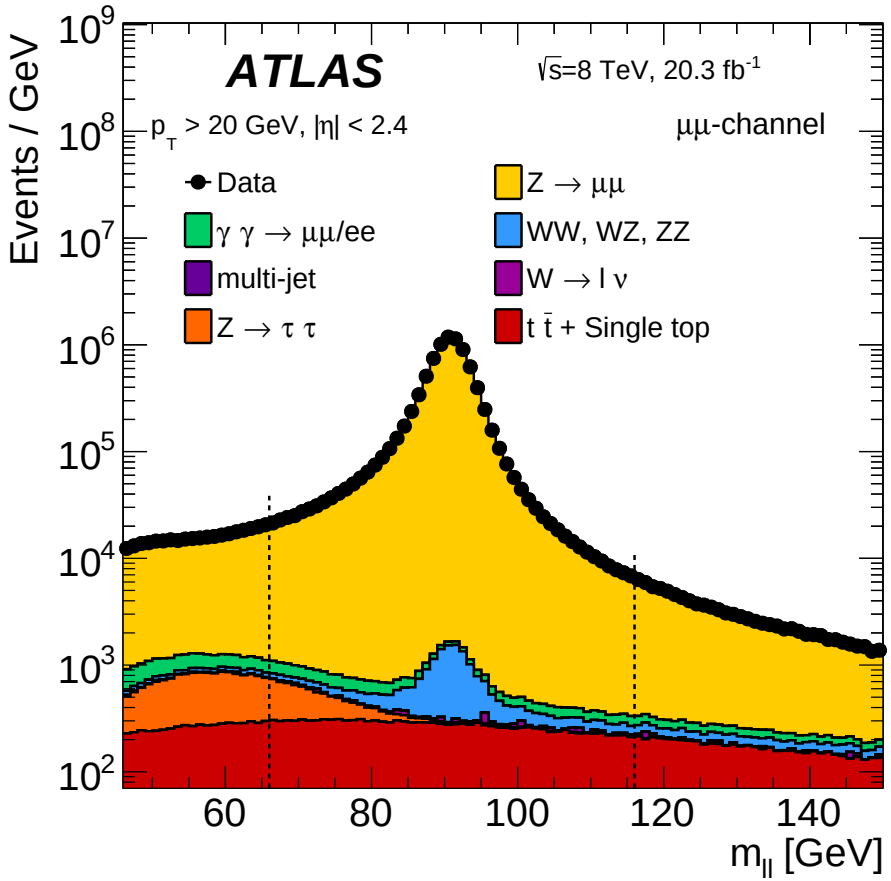
- Standalone muons: MS only (at high η, near to the beam axis)
- Calo-Tagged muons: ID tracks with additional small energy deposits in the calorimeter (at $\eta \approx 0$)
- Segment-Tagged muons: ID tracks combined with single segments of the MS (at low energies)

Motivation: How well does the reconstruction work?

- All precision measurements of processes with muons in the final state require the knowledge of the muon reconstruction efficiency
- Tune agreement between measured data and MC simulation by applying corrections to the MC

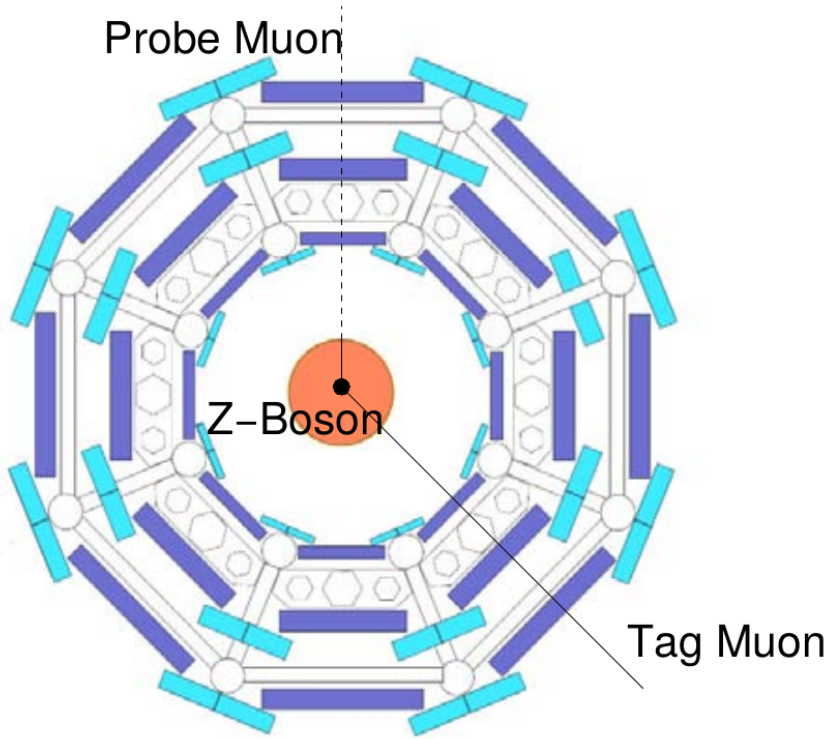
$\rightarrow$ Muon efficiency ϵ especially important for multi-lepton final states (e.g. integrated Z-boson cross section measurement, where $N_{\mathrm{events}} \sim \epsilon^2$)

CERN-PH-EP-2015-275



How to measure the muon reconstruction efficiency?

Example - Reconstruction efficiency for muons in the MS:



CERN-OPEN-2008-020

Select Z-decay by requiring
$81 < m_{\ell\ell} < 101$ GeV and $\Delta\phi_{\ell\ell} > 2$

- Use dimuon resonances where one muon is called *Tag*, the other one *Probe*
- MS efficiency is the probability that a *Probe* track measured in the ID is also reconstructed as a muon by the MS

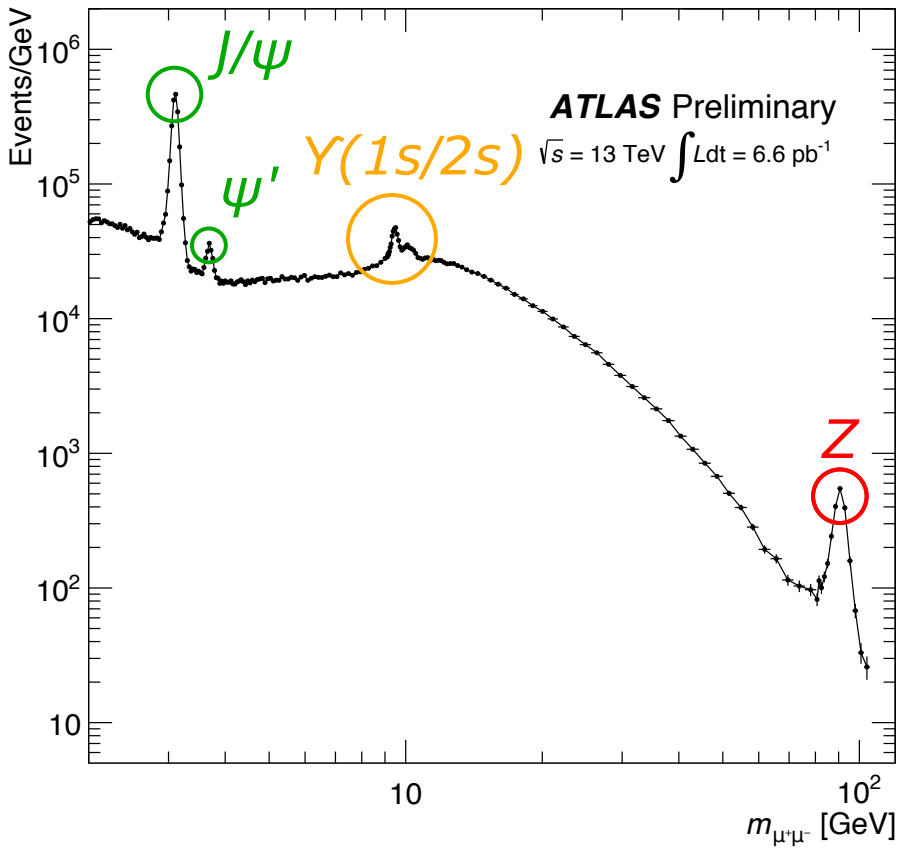
$\rightarrow$ Count number of ID tracks as *Probes*

$\rightarrow$ Try to match reconstructed MS muons to all the ID *Probes*

$\rightarrow$ Efficiency $\epsilon = \frac{N_{\text{matched Probes}}}{N_{\text{Probes}}}$

First public ATLAS run 2 results

Dimuon mass resonances are the standard candle for Tag&Probe measurements

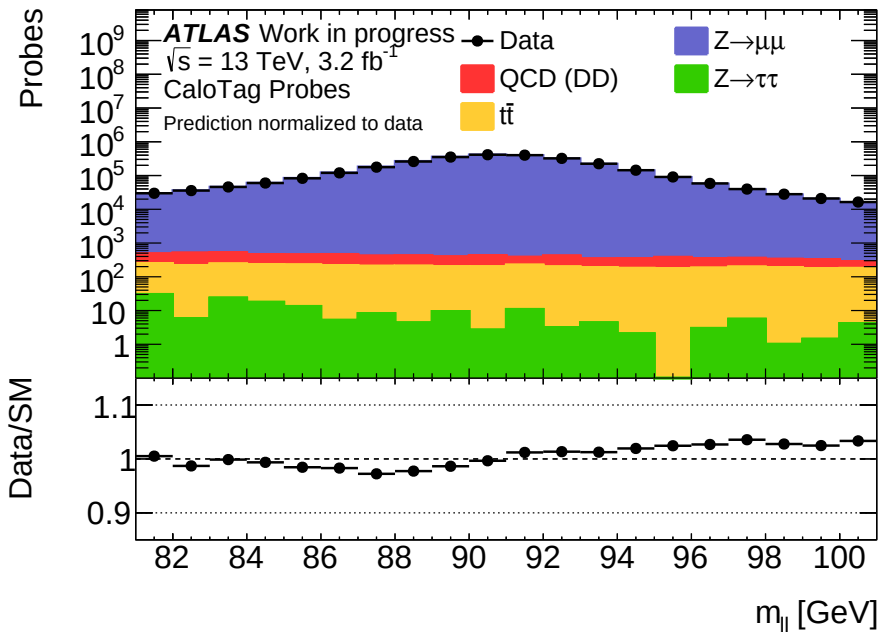


I.e. $Z \to \mu\mu$ and $J/\psi \to \mu\mu$ events profit from clear signature and good background suppression

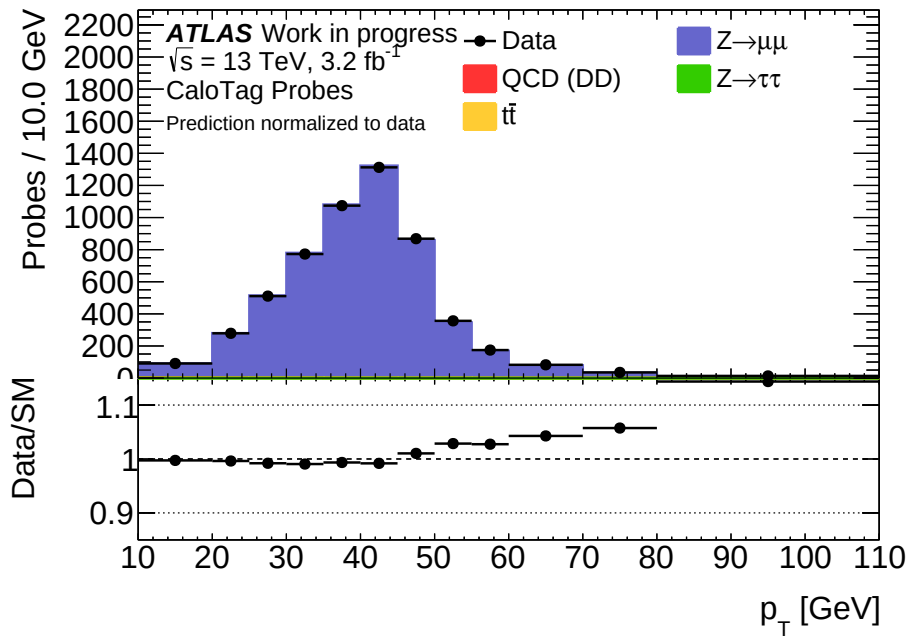
`https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/MUON-2015-001/`

Tag&Probe pairs after $Z \to \mu\mu$ selection

Invariant mass



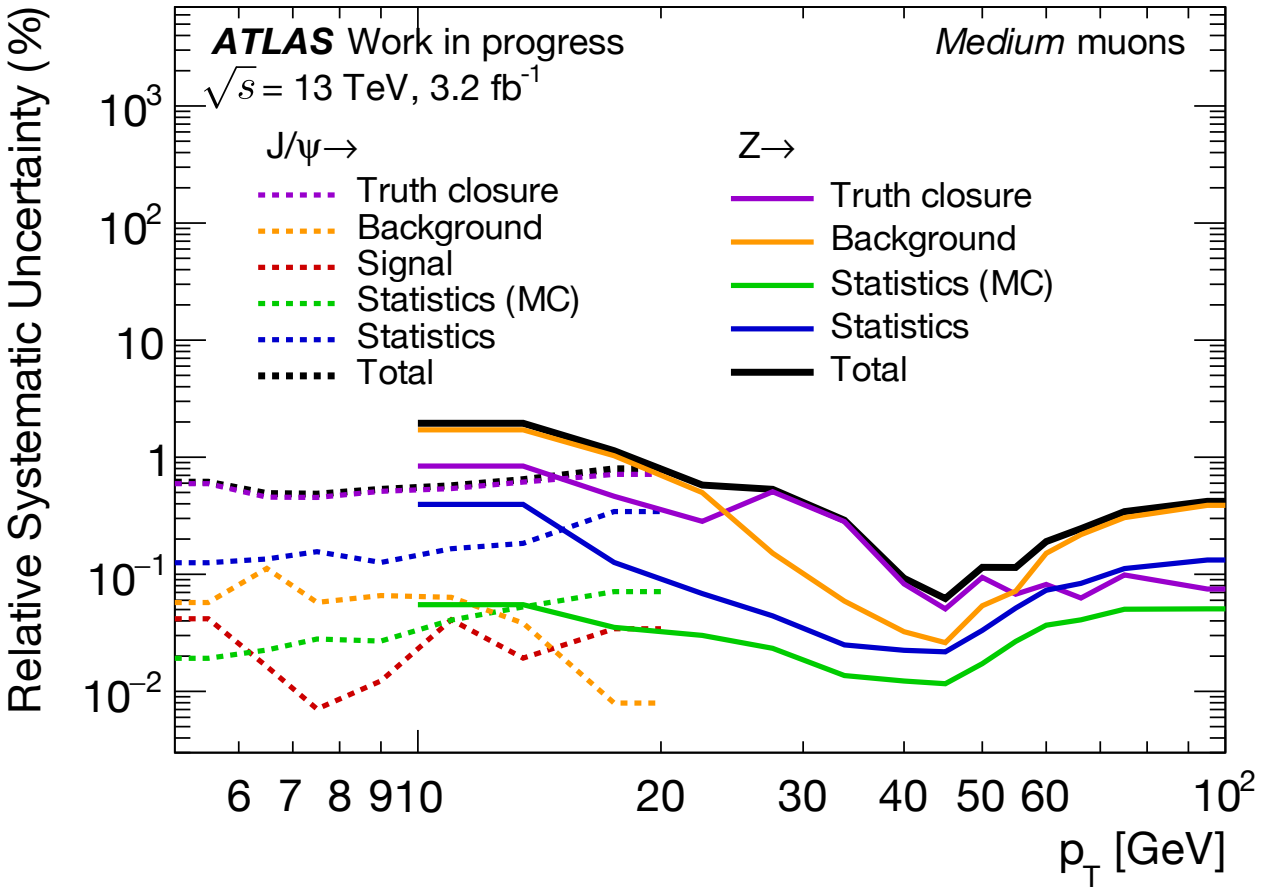
Transverse momentum of *probe* muon



$\sim 2.9 \times 10^6$ Tag&Probe pairs selected $\to$ Large signal to background ratio

Data-driven (DD) QCD background estimate with same-charge muon events, irreducible backgrounds ($t\bar{t}$, $Z \to \tau\tau$) are taken from MC simulation

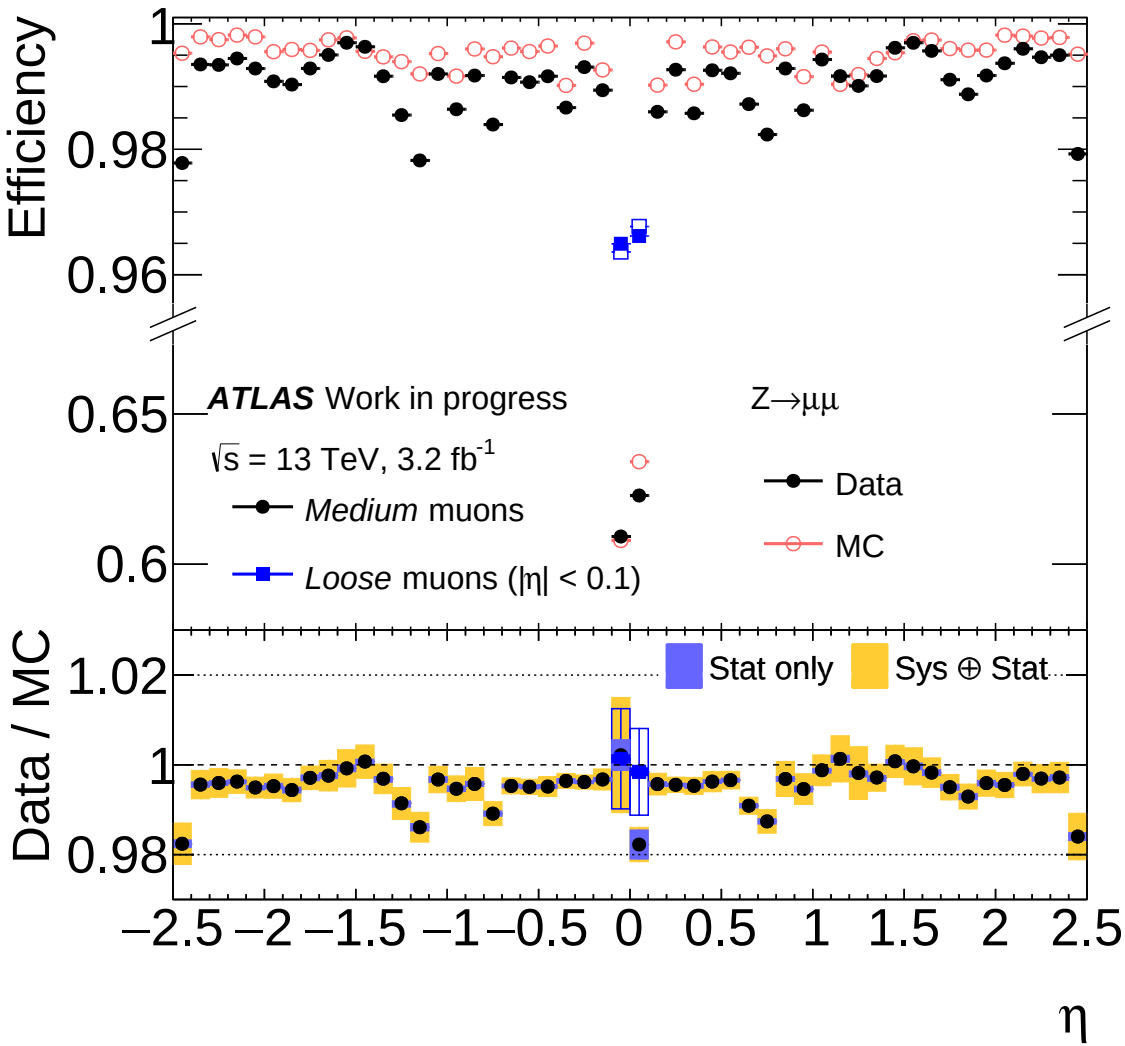
$J/\psi \to \mu\mu$ and $Z \to \mu\mu$ systematics evaluation



$\to$ Very small systematic uncertainties ($< 1\%$-level)

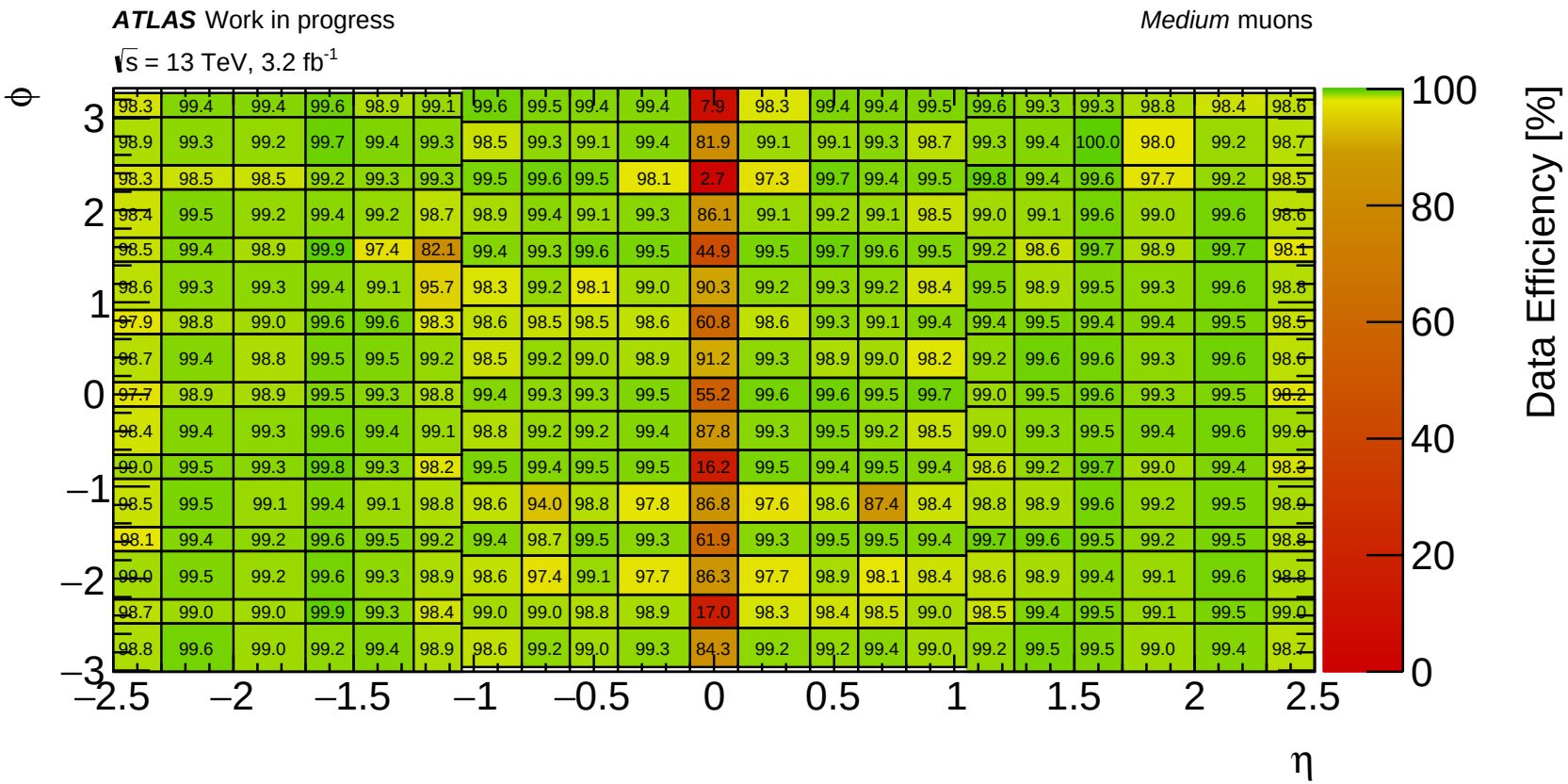
$J/\psi \to \mu\mu$ measurement more precise for probe muon $p_T < 20$ GeV

$Z \to \mu^+\mu^-$ reconstruction efficiencies vs. η



Loose muons increase reconstruction efficiencies in $\eta \sim 0$ region

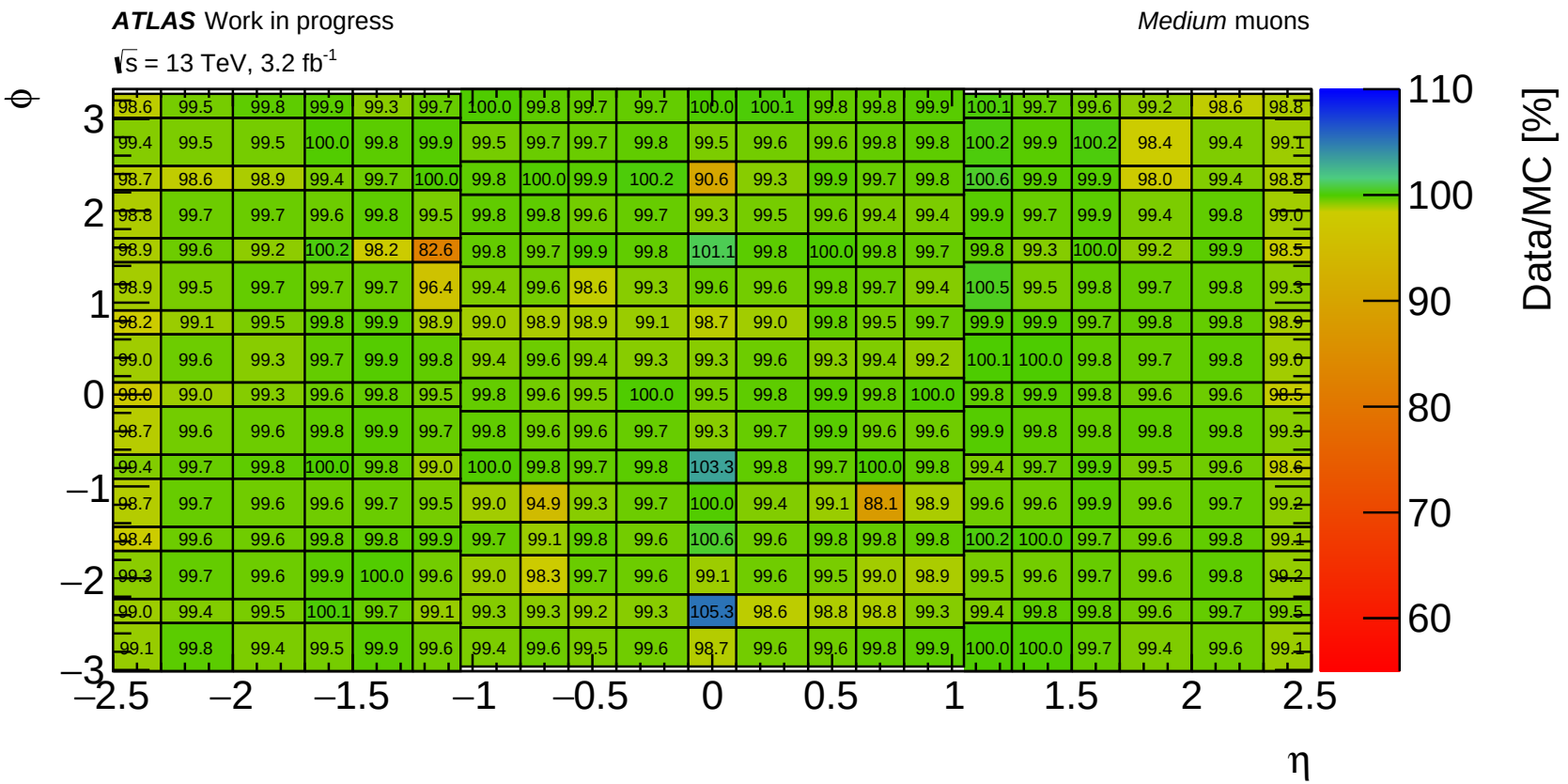
$Z \to \mu^+\mu^-$ reconstruction efficiencies for *Medium* muons



→ Notice smaller ϕ-dependant reconstruction efficiencies for *Medium* muons in $\eta \sim 0$ region due to missing MS coverage

$Z \to \mu\mu$ reconstruction scale factors for *Medium* muons

$$\text{Efficiency scale factor} := \frac{\text{Data efficiency}}{\text{MC efficiency}}$$



→ Investigated and understood origin of local inefficiencies

Close collaboration and feedback for detector operation

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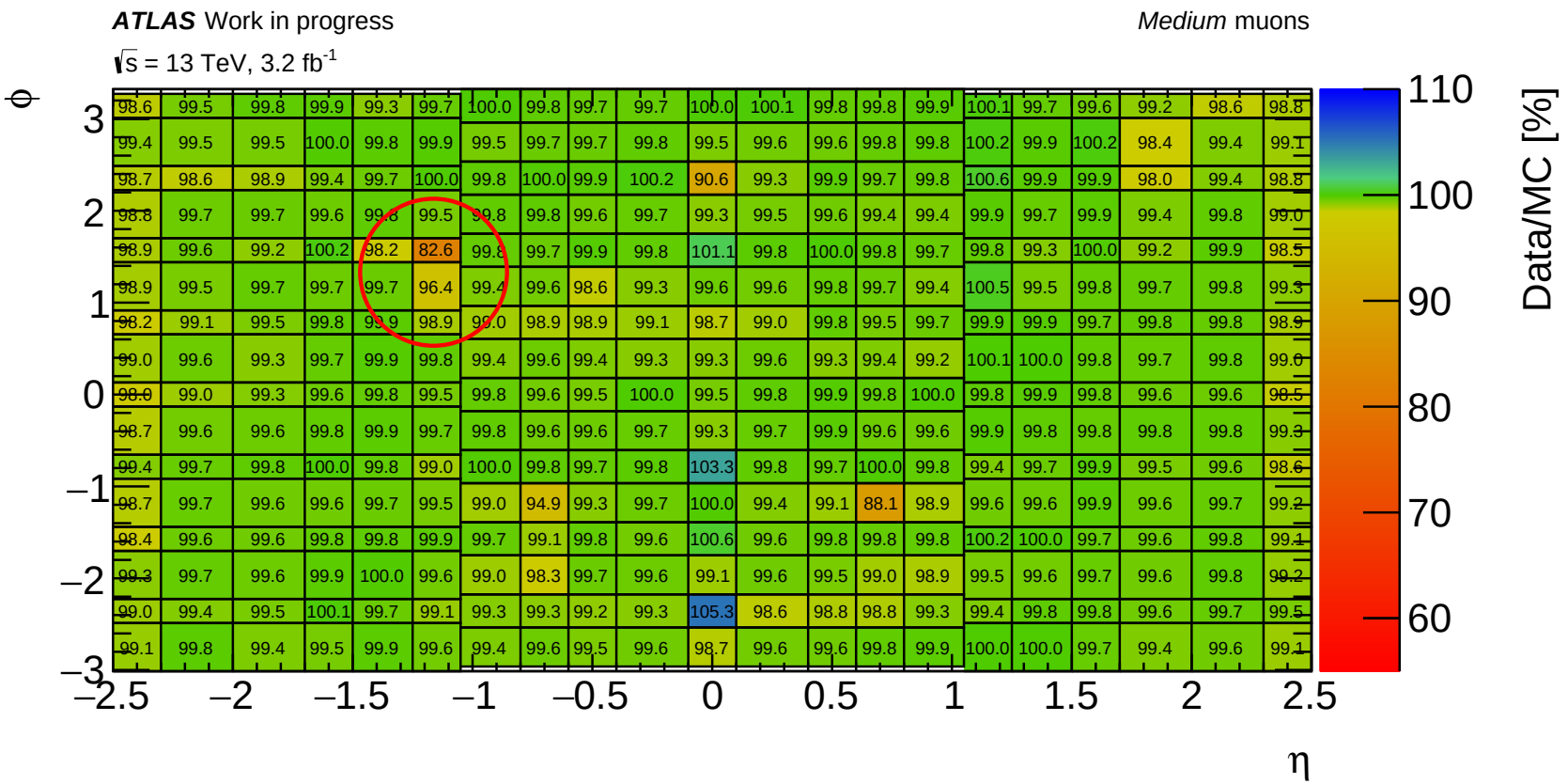

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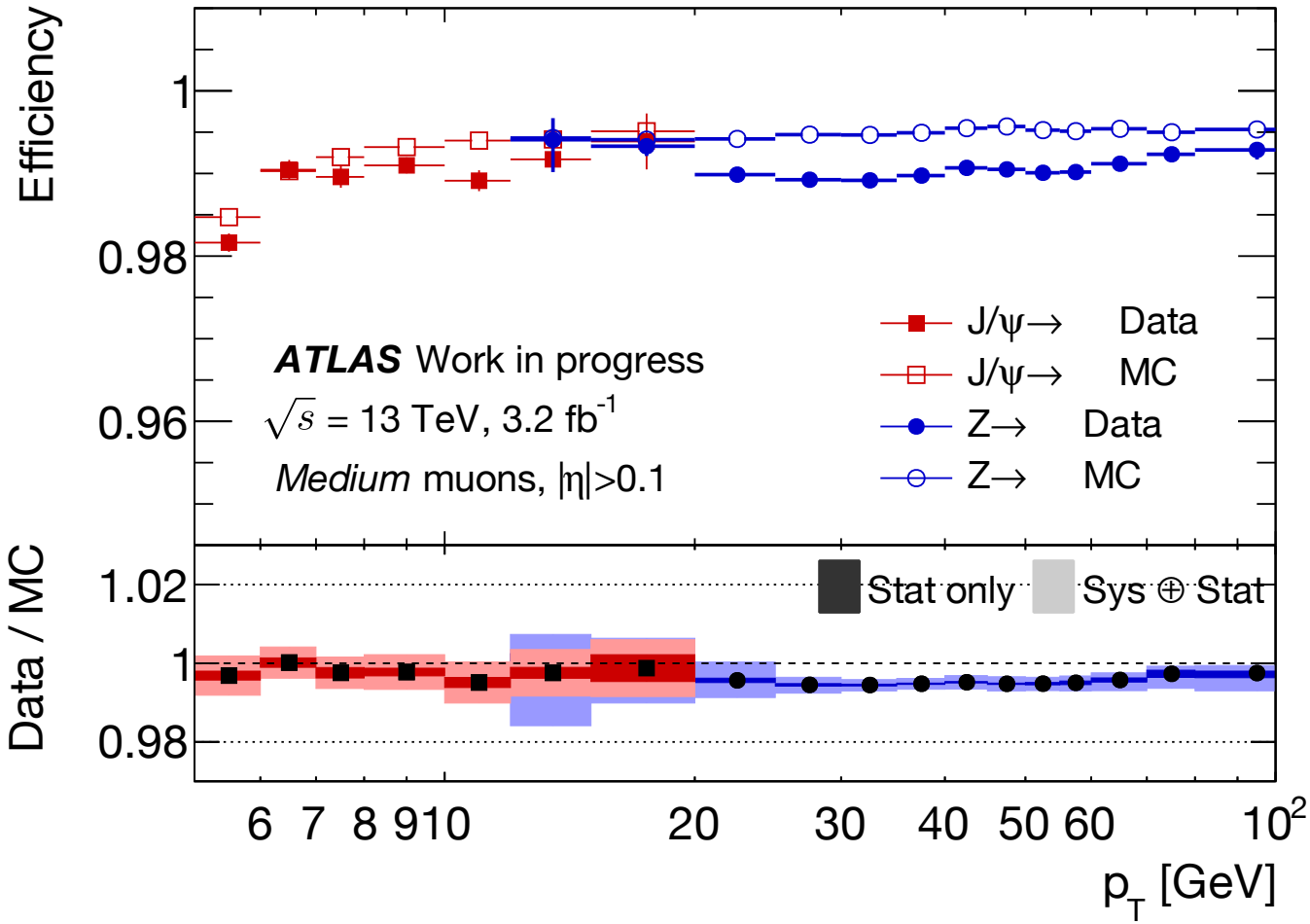
Close collaboration and feedback for detector operation

Combined $J/\psi \to \mu\mu$ and $Z \to \mu\mu$ measurement

Muon reconstruction efficiency as a function of p_T for $0.1 < |\eta| < 2.5$



$\to$ Very good agreement of $J/\psi \to \mu\mu$ and $Z \to \mu\mu$ results

Summary

Tag&Probe measurement of muon reconstruction efficiencies in ATLAS

- Muon reconstruction efficiencies around 99%
- Tiny systematic uncertainties ($< 1\%$)
- Very high granularity of measurement in η-ϕ
- Very good agreement of $J/\psi \to \mu\mu$ and $Z \to \mu\mu$ results

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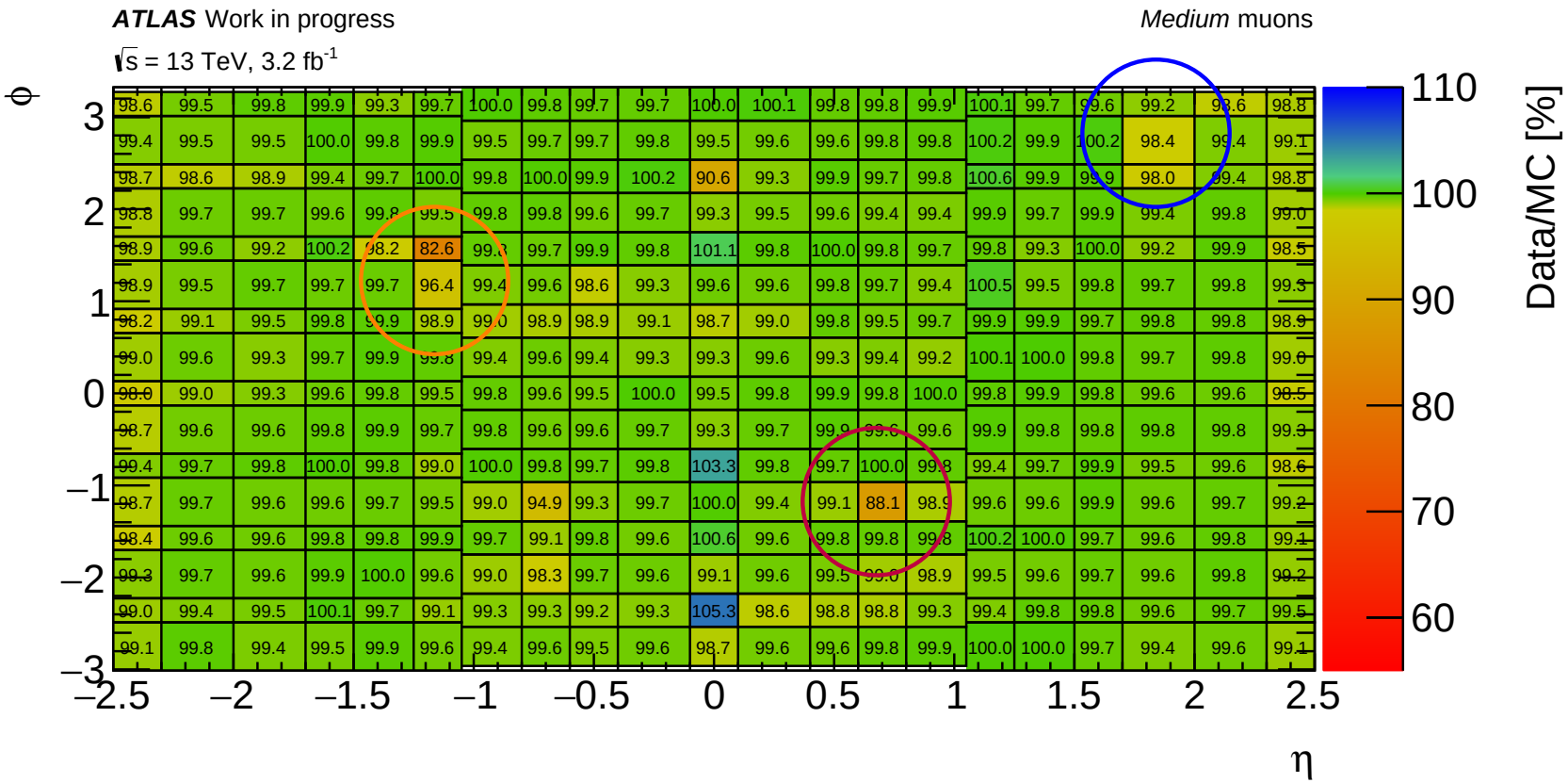
Thanks for your attention!

BACKUP

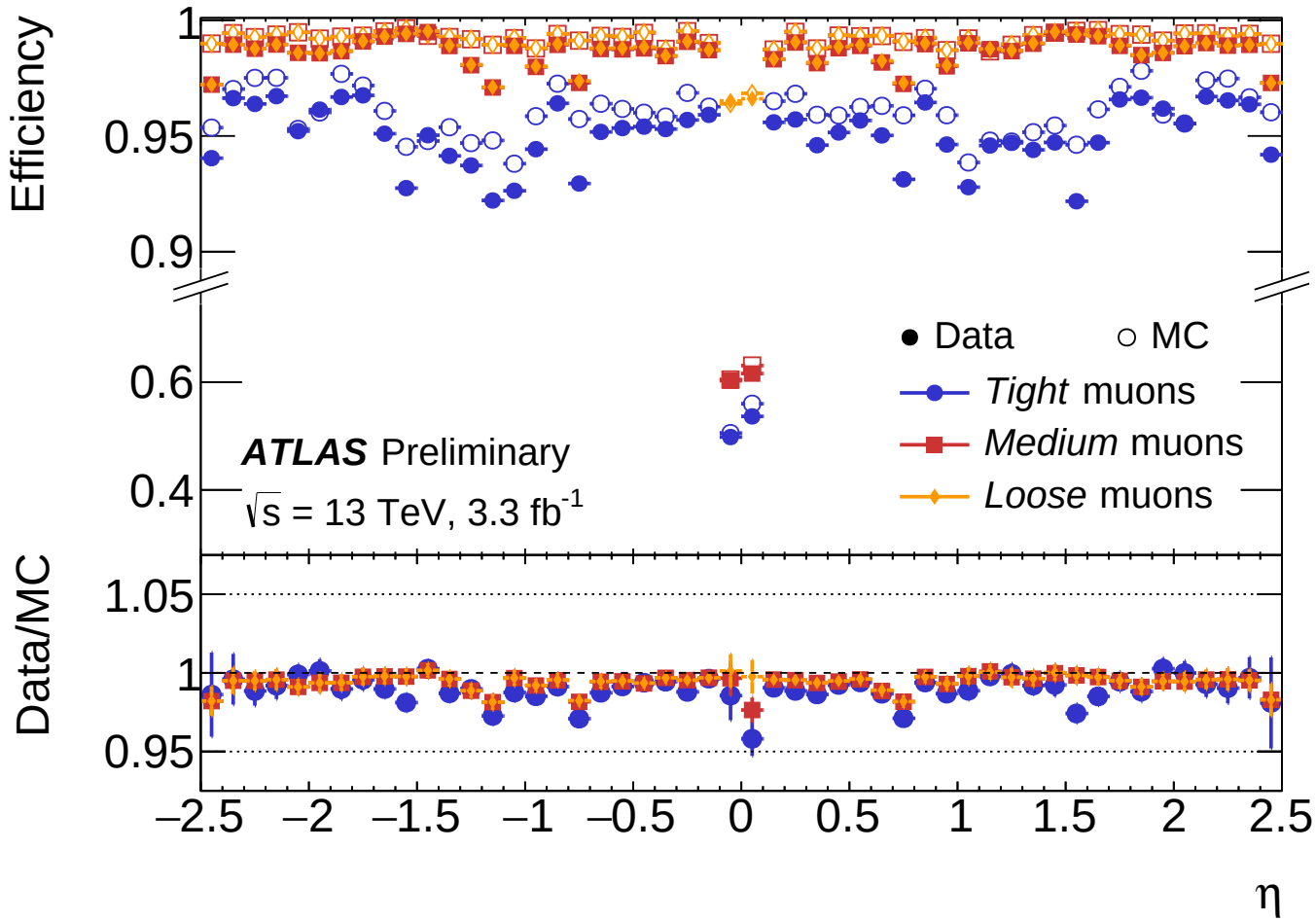
Backup

Locally resolved $Z \rightarrow \mu\mu$ reconstruction inefficiencies



Backup

$Z \to \mu\mu$ reconstruction efficiencies for different ATLAS muon *Working Points*



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/MUON-2015-004/index.html