Reconstruction Performance of the ATLAS Muon Detector

FRONTIER DETECTORS FOR FRONTIER PHYSICS, 13th Pisa Meeting on Advanced Detectors (2015)

Muon reconstruction in LHC Run-I: Performance measured in Inner Detector (ID) & Muon Spectrometer (MS) using Z→μμ, J/ψ→μμ, ϒ→μμ

Efficiency: ~ 99% over |η|<2.5 & p_T > 4 GeV
Momentum scale (MS+ID muons) known to ±0.05% for |η|<1, ±0.2% for |η|>2.3 (Z→μμ)
Di-muon mass resolution: low p_T = 1.2% (2%) & 2% (3%) at p_T≈100 GeV for |η|<1 (|η|>1).
Simulation reproduces data resolution within 3% to 10% depending on η and p_T.

Muon Types

Combined CB: ID + MS
Stand-Alone SA: MS only
Segment-Tagged ST: ID track extrapolated to MS segment
Calo-tagged: ID track associated with MIP-level dE/dX in calorimeter

Efficiency Measurement Method

Tag & Probe: two opposite charge, Δφ>2 (back to back) track-isolated muons in |η|<2.5 from Z, J/psi

Use both ID and MS to determine reconstruction efficiency.

MC Muon Momentum Correction

Corrections binned in (η,φ) regions of Det=ID or MS, where the momentum scale & resolution are ~uniform

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

g_m: normally distributed random variables (mean=0 width=1)

relative scale correction s_n
s_0: term to model the p_T–scale dependent difference data-MC in the momentum reconstruction due to energy loss in the calorimeter (→$s_0^{ID}=0$)
s_1: imperfect knowledge of B-field integral and detector radial dimension

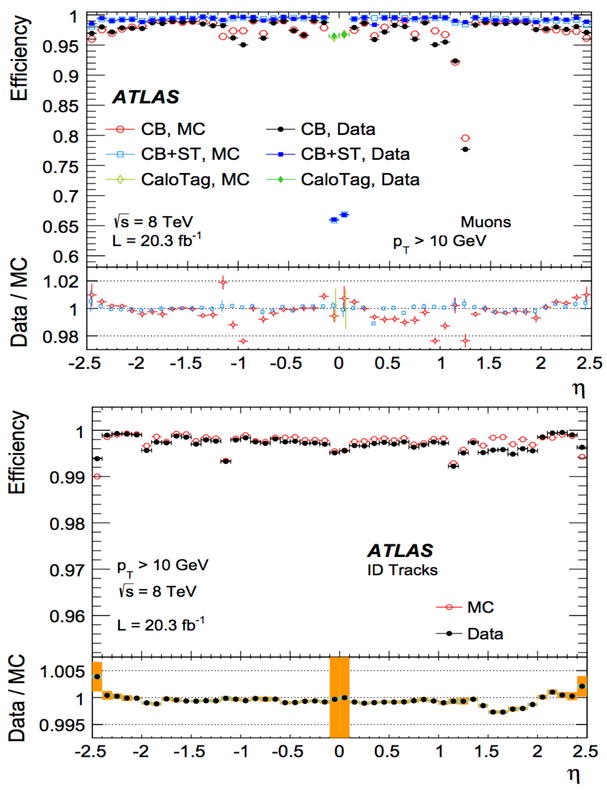
p_T-dependent momentum smearing Δr_m→ $\sigma(p_T)/p_T = r_0/p_T \oplus r_1 \oplus r_2 \bullet p_T$
components (summed in quadrature ✚)
r_0: from dE/dX fluctuations in the traversed material ($r_0^{ID}=0$)
r_1: from multiple scattering, local B-field inhomogeneity, local radial displacement
r_2: hit resolution, small misalignments

Total resolution smearing correction
(over 18 η detector regions p_T dependent)
ID<10% MS<15%

ID scale correction always < 0.1% with uncertainty ranging from 0.02% (|η|<1) to 0.2% (|η|>2.3)

MS scale correction ≤ 0.1% except in barrel large sectors (≈0.3%) and for 1.2<|η|<1.5 (-0.4%)

Muon Reconstruction Efficiency

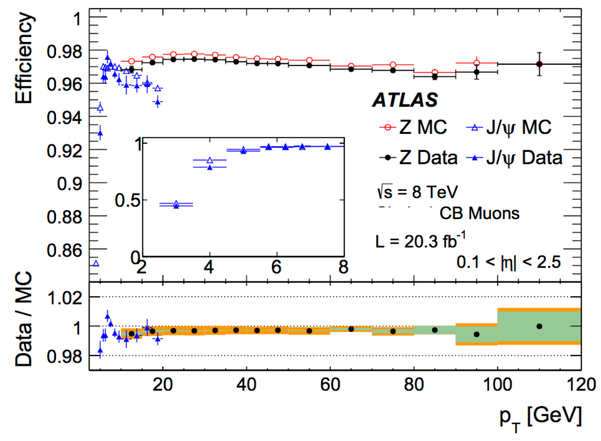


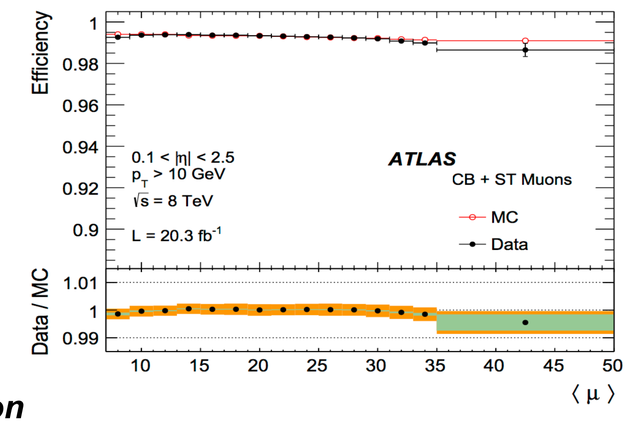
Left: Z-tag: CB isolated muon at p_T>24 GeV triggering the event, Z-probe: muon with p_T>10 GeV CB/SA for ε(CB/SA | ID) or CaloTag ε(CB/ST | MS).
Includes backgrounds:Z→ττ, t-tbar, W(→μ+ν) + jets

Right-top: low p_T from J/ψ→μμ acquired with single muon or muon at p_T>6 GeV + ID-track at p_T>3.5 GeV triggers, with invariant mass in 2.7-3.5 GeV

Right-Bottom: reconstruction efficiency vs <#inelastic collisions>/bunch crossing

statistical uncertainty
statistical + systematic uncertainties

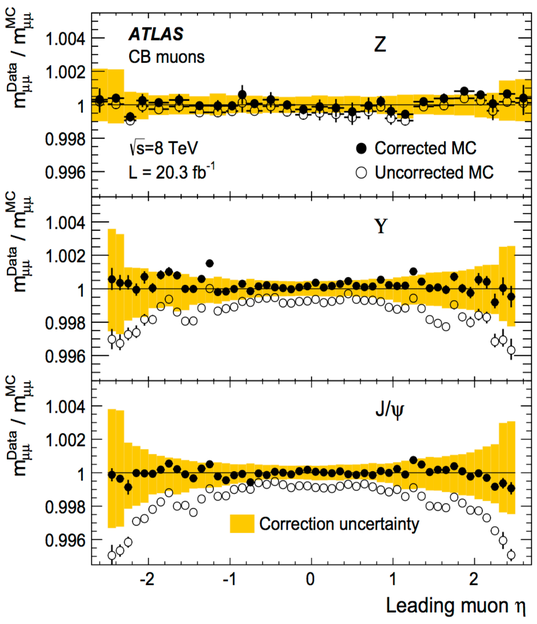


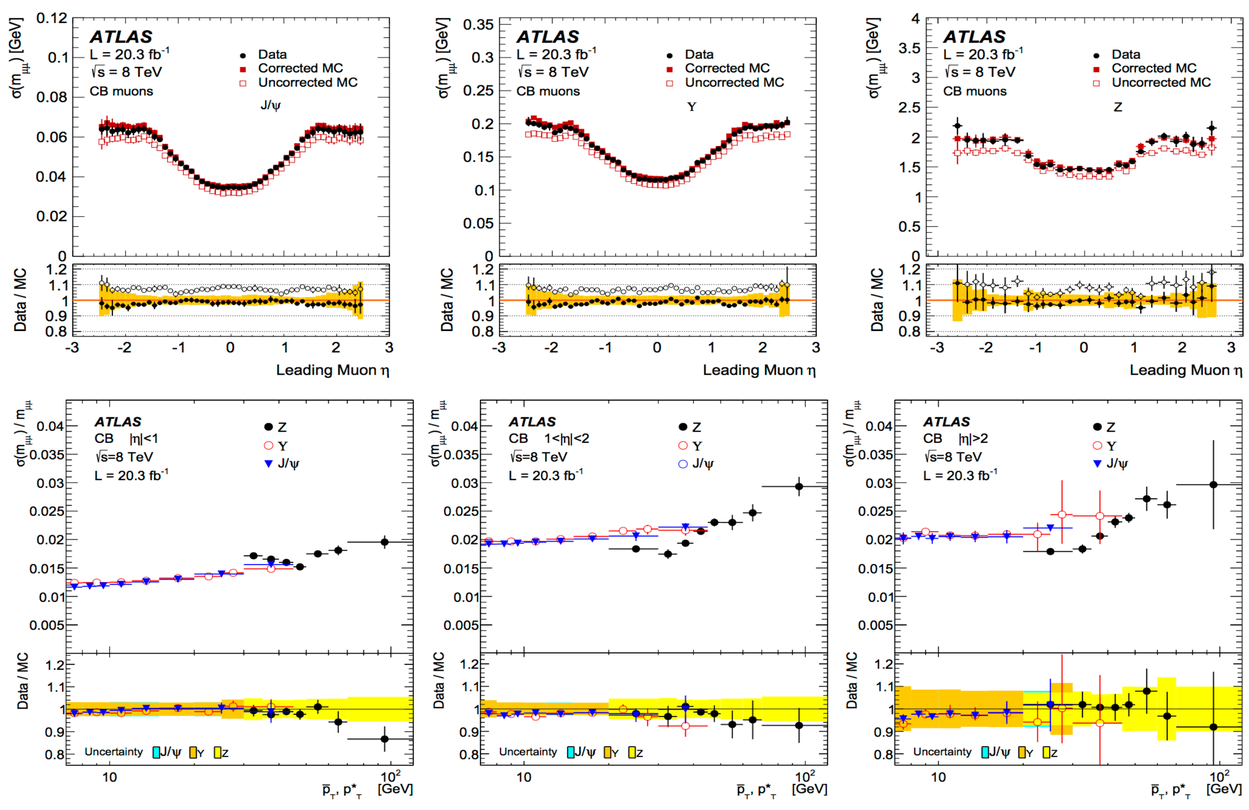


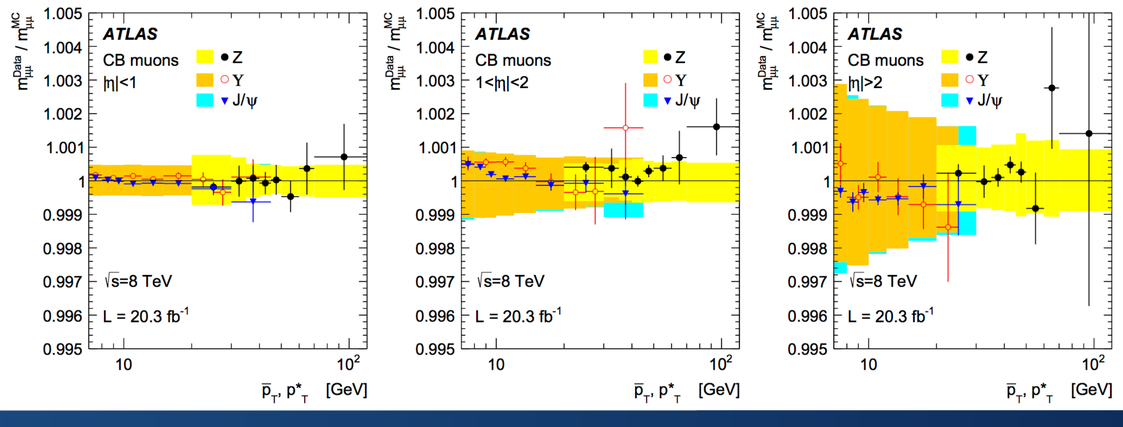
Data distributions are well predicted by the MC simulation
→ scale factors =ε(Data)/ε(MC) ≈ 1 in each (η,φ) regions
→ no significant p_T dependence

Di-Muon Mass Scale and Resolution

The corrected MC agrees within the scale systematics: ≈0.035% for |η|<1 up to 0.2% for |η|>2 for Z→μμ







CB muons di-muon invariant mass resolution is well reproduced by the corrected MC within the uncertainty of the corrections
|η|<1 $\sigma(m_{\mu\mu})/m_{\mu\mu}$ ≈ 1.2% (2.0%) at p_T<10 (≈100) GeV
|η|>1 $\sigma(m_{\mu\mu})/m_{\mu\mu}$ ≈ 2% (3%) at p_T<10 (≈100) GeV

Neglecting angular effects the invariant mass resolution is related to the momentum resolution of the two muons (for p_T balanced events) by $\sigma(m_{\mu\mu})/m_{\mu\mu} \approx 1/\sqrt{2} \bullet \sigma(p)/p$ ➔
σ(p)/p ~1.7% (|η|<1) to 4% at large η and p_T=100 GeV

Claudio Ferretti, for the ATLAS Collaboration