ATLAS muon performance in first LHC run 2 data

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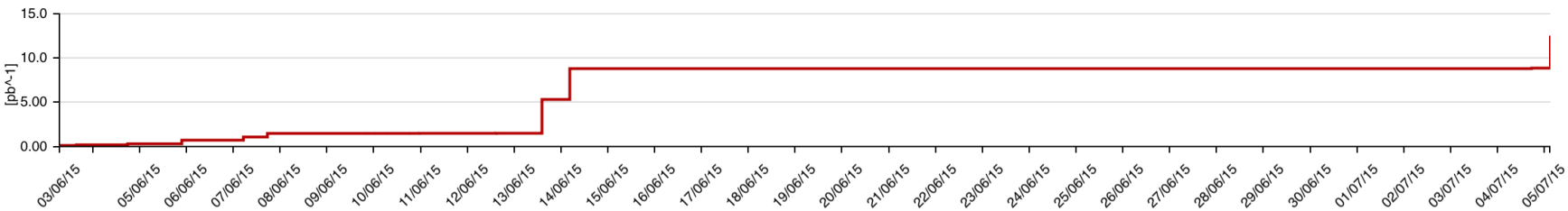
ATLAS run 2 started right now

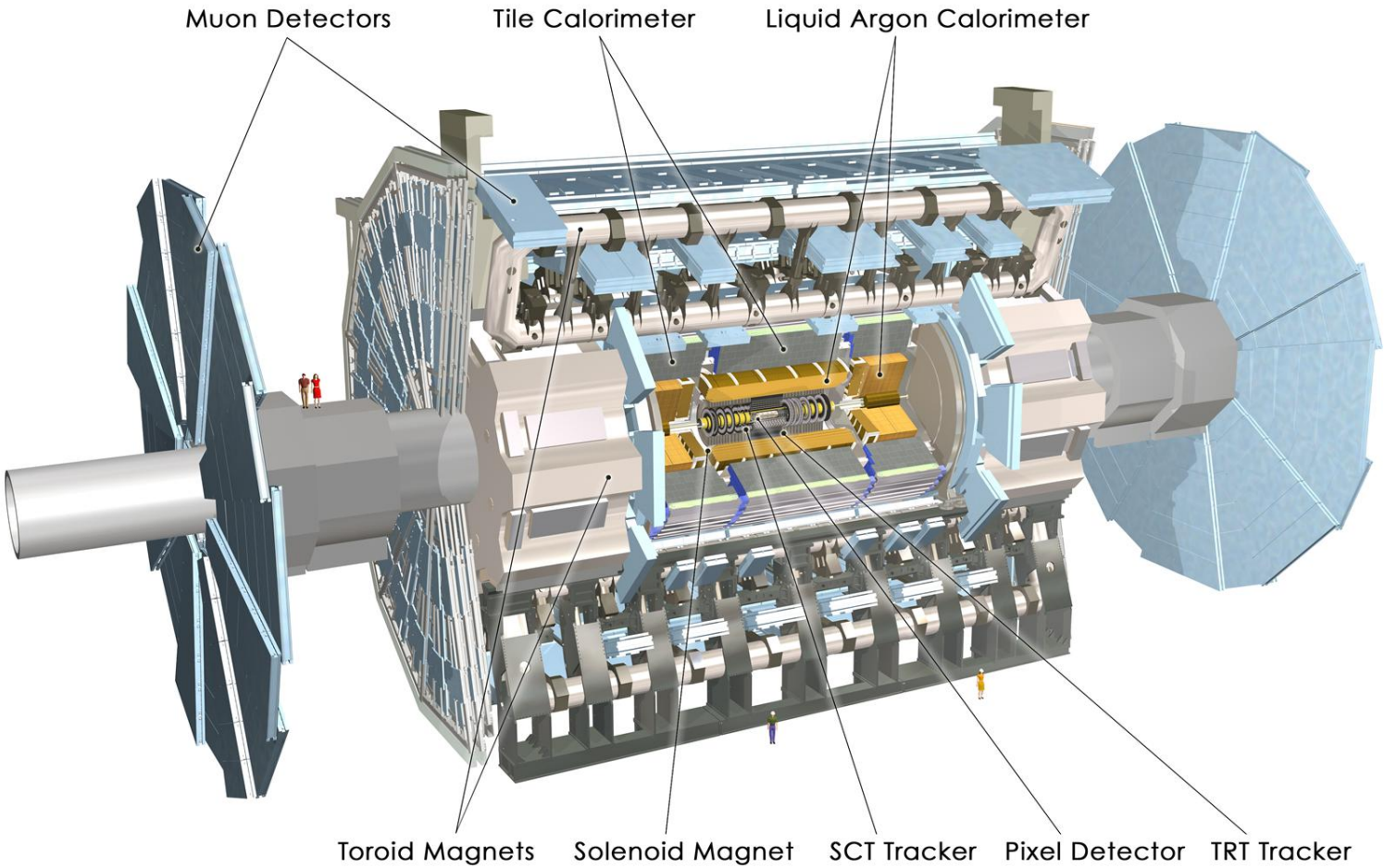
- LHC run 2 started on June 3rd, 2015
- ~ 20 hours of stable beams
- ~ 70 Mio. events recorded
- In total, 12.45pb^{-1} of ATLAS data recorded in 2015

http://run2-13tev.web.cern.ch



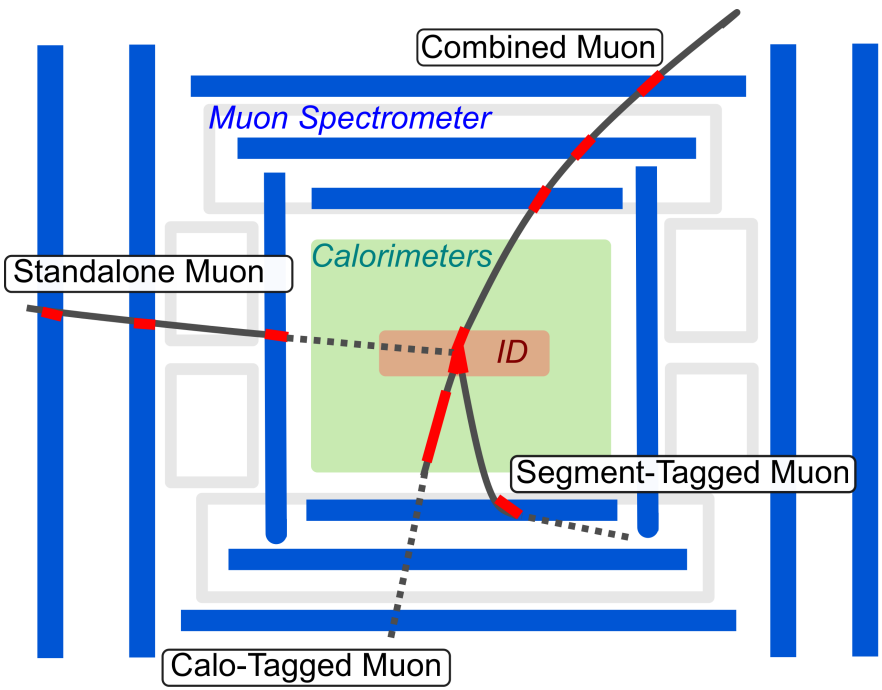
https://acc-stats.web.cern.ch/acc-stats/

Muon reconstruction at the ATLAS experiment



$\rightarrow$ Muon leaves curved track in the Inner Detector, small energy deposit in the calorimeters and curved track in the Muon Spectrometer

Muon reconstruction at the ATLAS detector



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

$\rightarrow$ Standard method used in ATLAS

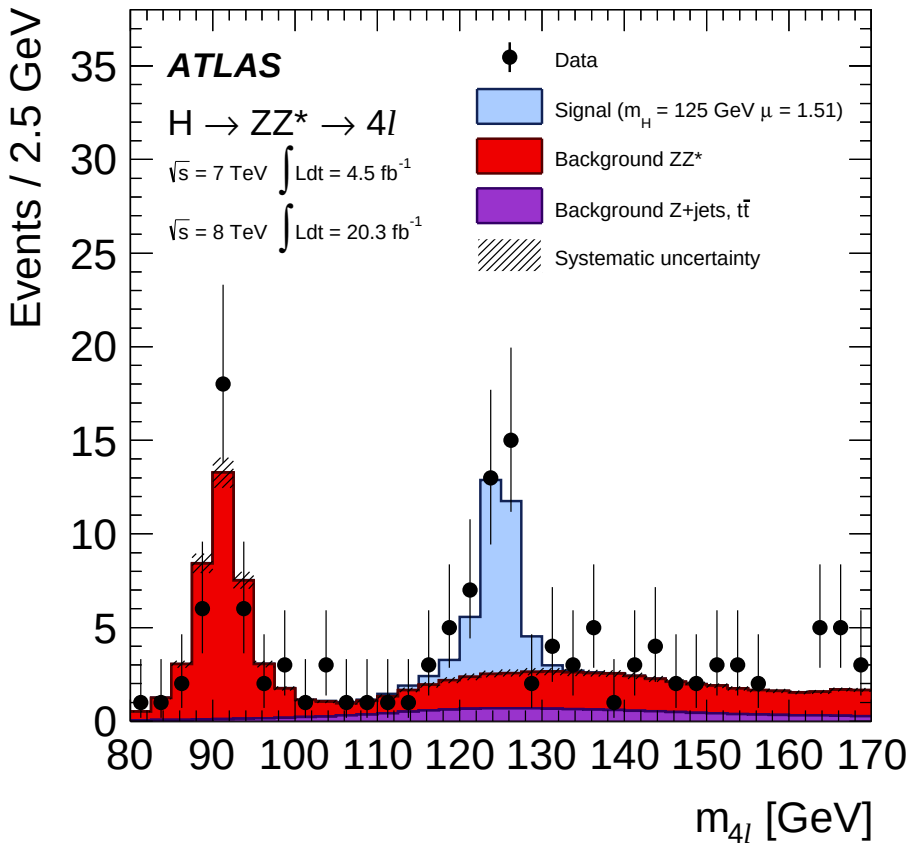
- Standalone muons: MS only (at high η, near to the beam axis)
- Calo-Tagged muons: ID tracks with additional small energy deposits in the calorimeter (at $\eta \approx 0$)
- Segment-Tagged muons: ID tracks combined with single segments of the MS (at low energies)

Motivation: How well does the reconstruction work?

- All cross section measurements of processes with muons in the final state require the knowledge of the muon reconstruction efficiency

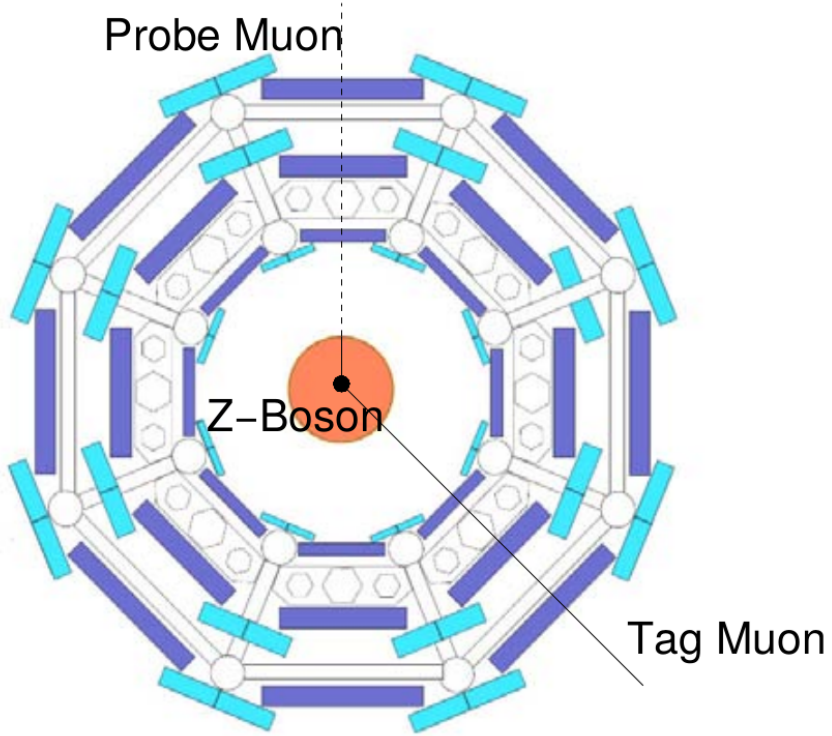
$\rightarrow$ Precise knowledge of the muon efficiency especially important for multi-lepton final states (e.g. $H \rightarrow 4\mu$, where $N_{\text{events}} \sim \epsilon^4$)

Phys. Rev. D 91, 012006 (2015)



How to measure the muon reconstruction efficiency?

Example - Reconstruction efficiency for muons in the MS:



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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*

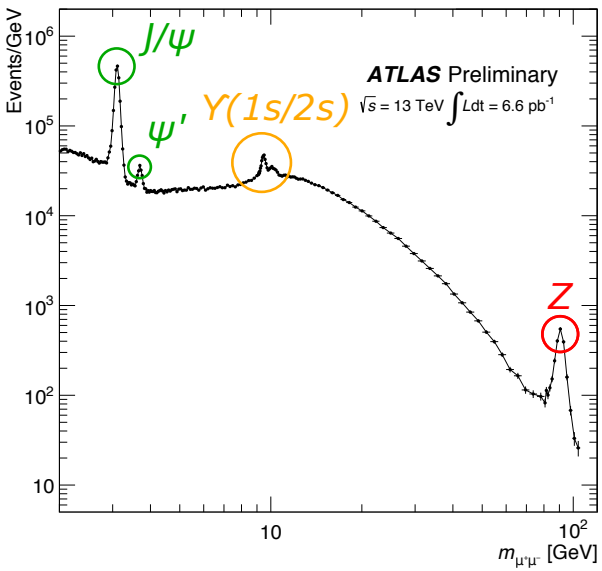
$\rightarrow$ MS efficiency is the probability that a *Probe* track measured in the ID is also reconstructed as a muon by the MS

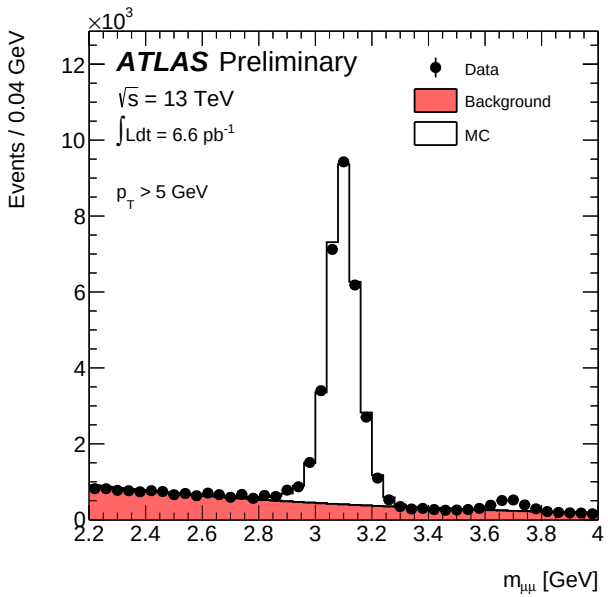
First public ATLAS run 2 results

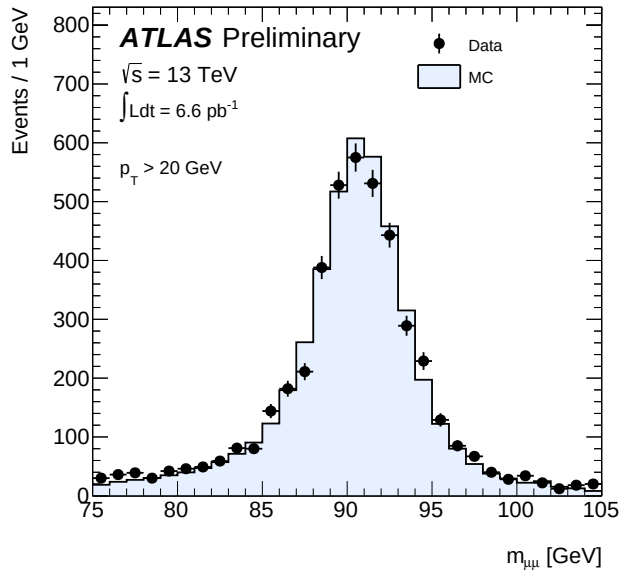
Dimuon mass resonances

$J/\psi \to \mu\mu$ mass peak

$Z \to \mu\mu$ mass peak





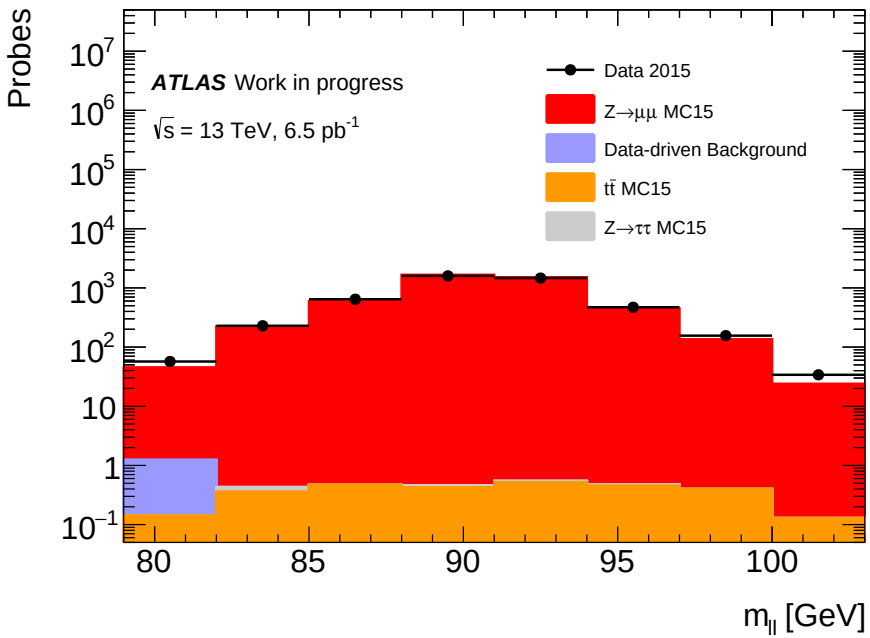


`https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/MUON-2015-001/`

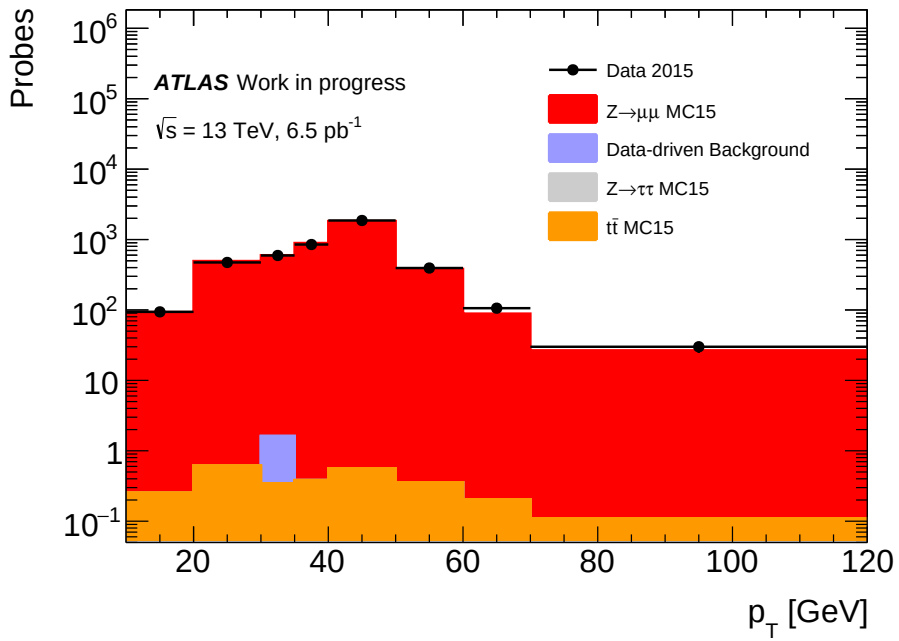
$\to$ Use dimuon events, i.e. $Z \to \mu\mu$ (cleaner signature) for Tag&Probe analysis

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

Invariant mass



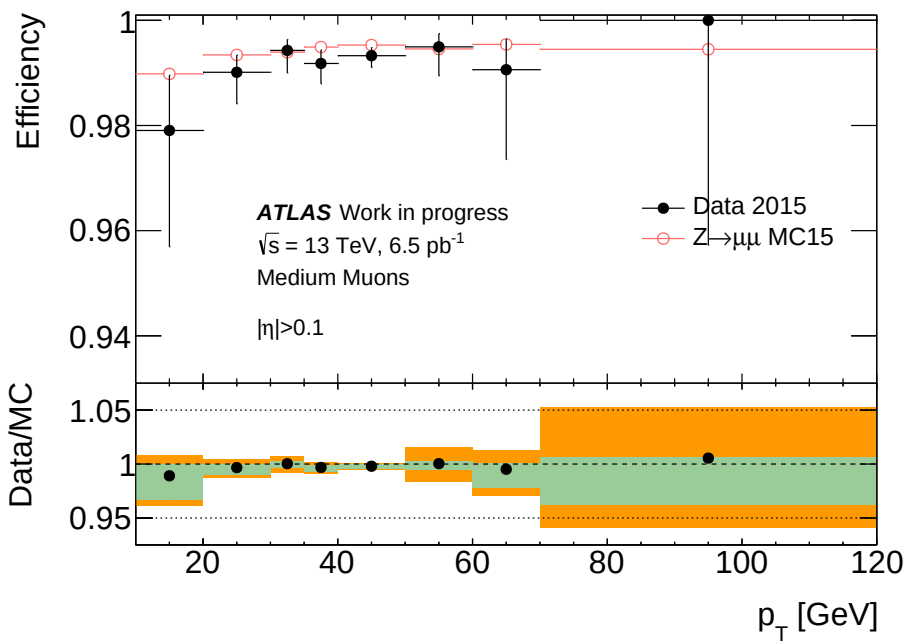
Transverse momentum of *probe* muon

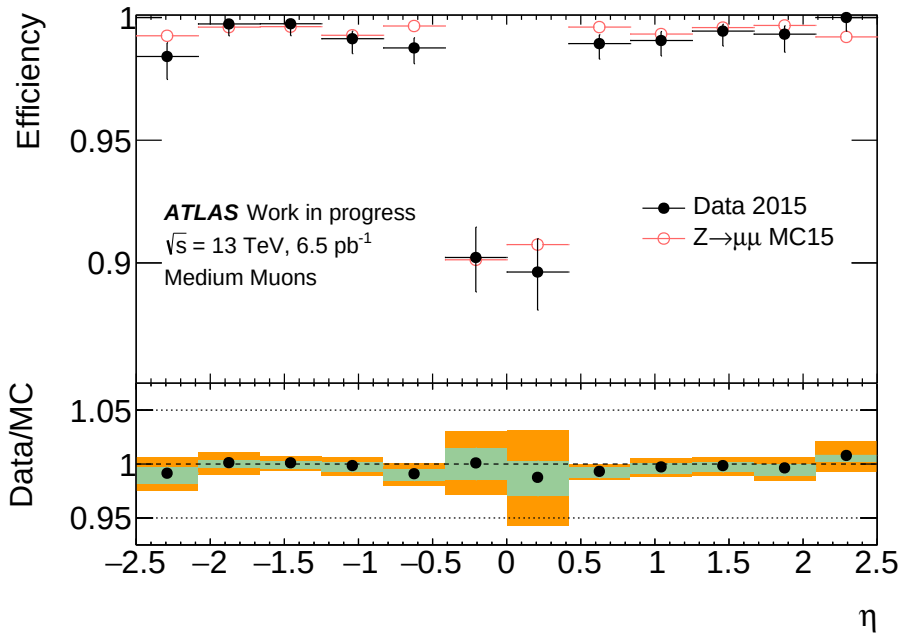


~ 4400 Tag&Probe pairs selected $\to$ Large signal to background ratio

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

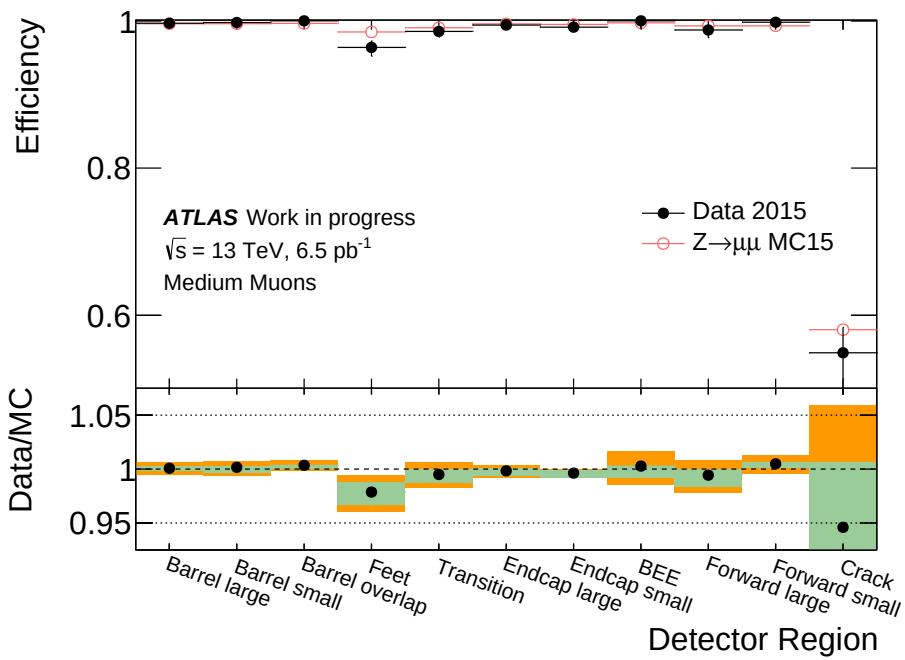
Muon reconstruction efficiency results from $Z \to \mu\mu$ decays





$\to$ Percent-level precision with only 6.5pb^{-1} of data

Providing reconstruction efficiencies to physics analyses



- MC samples get corrected using ratio between efficiency in data and MC simulation to correct for deviations from the real detector behaviour

→ Providing run 2 data-based efficiencies is crucial prerequisit for all real physics analyses with lepton final states

→ Already high statistical accuracy

Summary

- First ATLAS run 2 measurements
- Already very precise muon efficiency determination from the first 6.5pb^{-1} of run 2 data

$\rightarrow$ In agreement with ATLAS run 1 results

Outlook - Near-term plans for run 2

July

- 50 ns bunch-crossing rate
- Detector performance
- SM cross-section measurements: W, Z, J/ψ

August

- 25 ns bunch-crossing rate
- Black holes ≤ 5 TeV (ATL-PHYS-PUB-2009-074)
- SM cross-section measurements: $t\bar{t}$

September

- $\sim 3 - 5\text{fb}^{-1}$
- SUSY strong production: $\sim 3\sigma$ discovery potential: $m_{\tilde{g}} \leq 1.5$ TeV, $m_{\tilde{b}} \leq 730$ GeV, $m_{\tilde{t}} \leq 900$ GeV ATL-PHYS-PUB-2015-005
- RPV SUSY $\rightarrow 4\ell$ (run 1 results: Phys. Rev. D 90)
- Z' with $m_{Z'} \leq 3$ TeV

Outlook - Longer-term plans for run 2

October

- Higgs $\rightarrow ZZ^*$ rediscovery

January '16

- Higgs properties (CP) & couplings

April '16

- Significant increase in integrated luminosity
- $t\bar{t}H$
- $H \rightarrow b\bar{b}$

2017

- SUSY electroweak production
- SUSY displaced vertices (run 1 results: arXiv:1504.05162)
- Generic Dark matter

2018

- $\sim 300\text{fb}^{-1}$
- $HZ \rightarrow Z+$invisible (arXiv:1309.7925)
- High-statistics analyses

Backup: $Z \to \mu\mu$ event selection

Tag muon:

- Has to fullfill the event trigger requirements
- Has to be a well reconstructed muon (isolated and $p_{\mathrm{T}} > 28$ GeV)

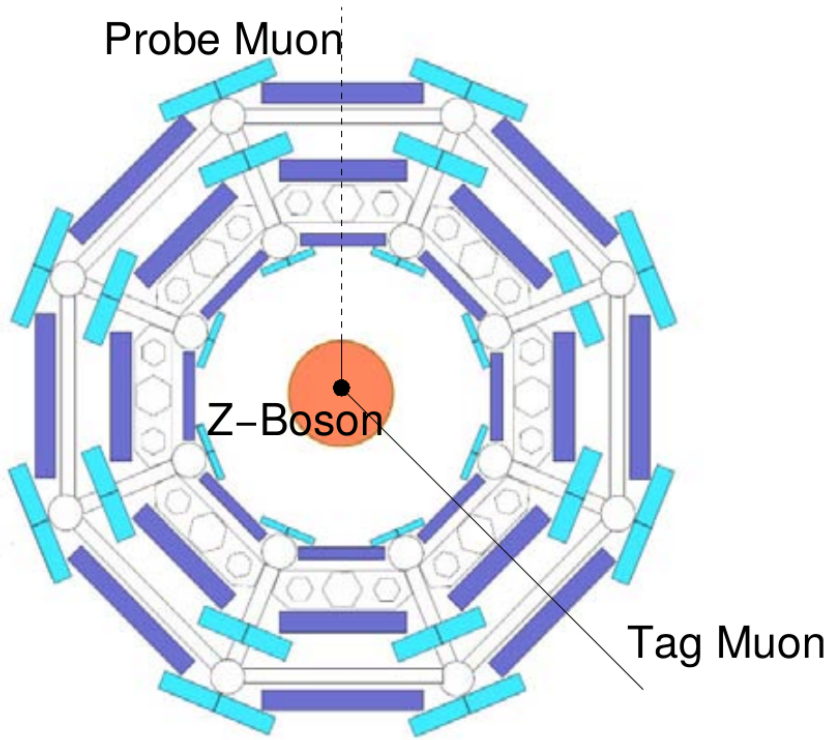
Probe muon:

- $p_{\mathrm{T}} > 10$ GeV
- Has to fullfill the requirements for the respective muon type for which the efficiency shall be computed

Tag&Probe-pair:

- 81 GeV$< m_{ll} < 101$ GeV
- $\Delta\phi_{ll} > 2$

How to measure the muon reconstruction efficiency?



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Example:

- Efficiency to reconstruct a muon of the type μ_{type}:
  $\epsilon(\mu_{\text{type}}) = \epsilon(\mu_{\text{type}}|\text{ID}) \cdot \epsilon(\text{ID})$
  $\approx \epsilon(\mu_{\text{type}}|\text{ID}) \cdot \epsilon(\text{ID}|\text{MS})$
- Idea: In order to measure $\epsilon(\mu_{\text{type}}|\text{ID})$, ID tracks are used as probes and matched to muons of the type μ_{type}

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