Measurement of muon efficiencies for the $Z \to \tau\tau \to \mu\tau_{had}$ cross section measurement

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Introduction

$\Rightarrow$ GOAL: Measure the cross section of the $Z \to \tau\tau \to \mu\tau_{had}$ decay

$$\sigma = \frac{N - B}{A_Z C_Z L}$$

N data events, B background events, A_Z acceptance, C_Z efficiency of the selection and L integrated luminosity

- C_Z calculated from signal Monte Carlo $\to$ need of scale factors to correct Monte Carlo simulation with respect to data
- **Muon scale factors for reconstruction, isolation and trigger efficiencies derived from $Z \to \mu\mu$ data using the tag-and-probe method**

Muon selection for the Z$\rightarrow \tau\tau \rightarrow \mu\tau_{had}$ analysis

Track reconstruction in ATLAS is performed independently in the inner detector and muon spectrometer.

- ID tracks: tracks reconstructed in the Inner Detector. High efficiency and good momentum resolution
- MS tracks: tracks reconstructed in the Muon Spectrometer. High muon purity: only muons reach the spectrometer
- CB tracks: combination of tracks reconstructed in both detectors

Muon selection for the $Z \rightarrow \tau\tau$ analysis:

$\Rightarrow$ reconstruction: combined with $p_T \geq 15$ GeV, $|\eta| \leq 2.4$, $|z_0| < 10$ mm. Hits requirements on the ID associated track

$\Rightarrow$ isolation: use of transverse momentum and transverse energy of particles in $\Delta R < 0.40$ around the muon ($\sum p_T^{ID}/p_T < 0.06$ and $E_T/p_T < 0.06$)

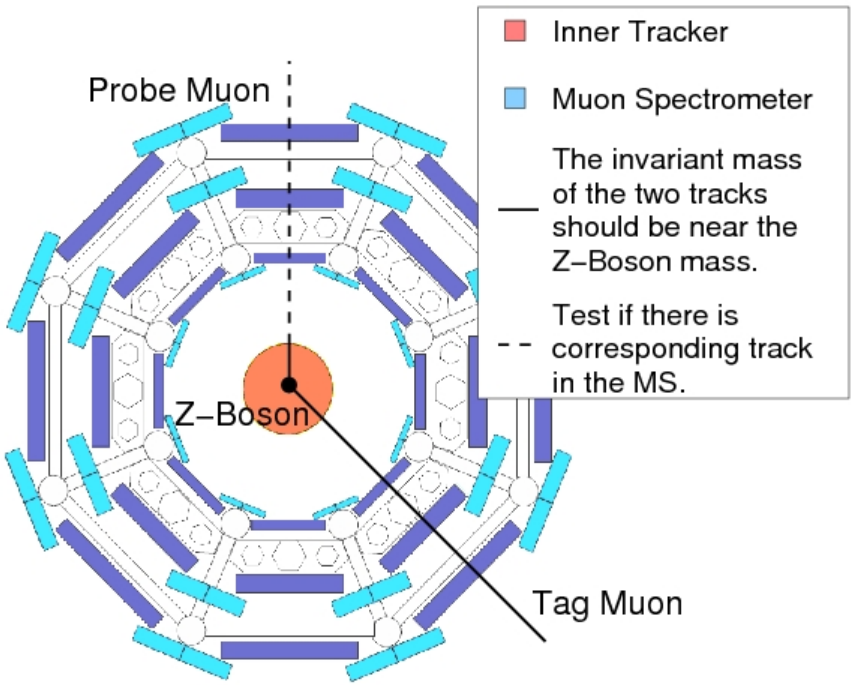
$\Rightarrow$ trigger: according to the data periods ($p_T > 10$ GeV for a small fraction of data and $p_T > 13$ GeV for remaining data)

Signal and background of the tag-and-probe method

- Goal: measure muon efficiency (reconstruction, isolation and trigger)
  - → combined reconstruction $\epsilon_{rec} = \epsilon_{id}\epsilon_{ms}\epsilon_{comb}$
  - → isolation ϵ_{iso}
  - → trigger $\epsilon_{trigger}$
- The method:
  - → select a clean sample of $Z \to \mu\mu$ events from data
  - → tight requirement on one muon (tag) and loose criteria on the second muon (probe)
  - → efficiency of muons measured with respect to the probe

Dataset	NNLO Cross Section [nb]
$Z \to \mu\mu$	0.99 ± 0.05
$Z \to \tau\tau$	0.99 ± 0.05
$W \to \mu\nu$	10.46 ± 0.52
$W \to \tau\nu$	10.46 ± 0.52
$b\bar{b}$	$73.9 \cdot 0.5$
$c\bar{c}$	$28.4 \cdot 0.5$
$t\bar{t}$	0.16 ± 0.01

Table: Signal and background processes for the tag and probe method



Tag and Probe definition

Tag Muon

- Combined muon from primary vertex
- $p_T \geq 20$ GeV, $|\eta| \leq 2.4$
- single muon trigger

ID Probe

- ID track
- $p_T \geq 15$ GeV, $|\eta| \leq 2.4$
- $|M_{tp} - M_Z| < 10$ GeV
- $\Delta\phi_{tp} > 2$
- loose isolation

MS Probe

- MS track
- $p_T \geq 15$ GeV, $|\eta| \leq 2.4$
- $|M_{tp} - M_Z| < 10$ GeV
- $\Delta\phi_{tp} > 2$
- loose isolation

CB Probe

- Combined track
- $p_T \geq 15$ GeV, $|\eta| \leq 2.4$
- $|M_{tp} - M_Z| < 10$ GeV
- $\Delta\phi_{tp} > 2$

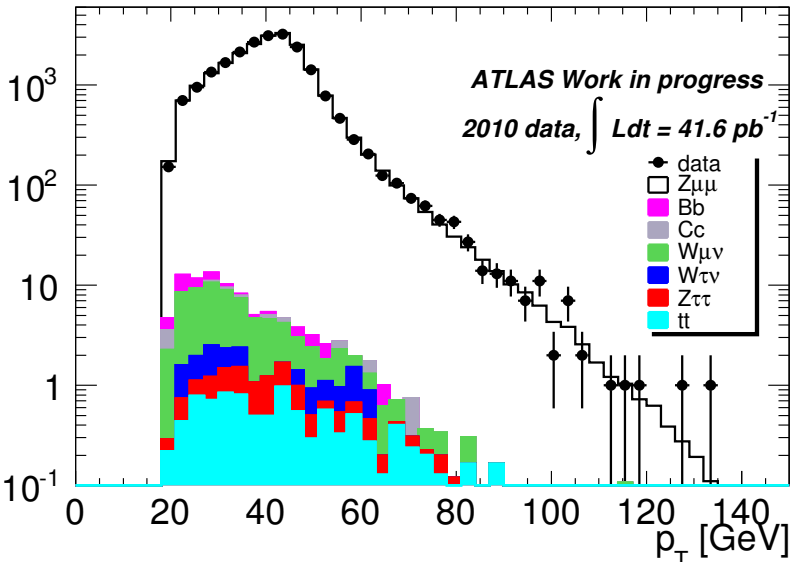
$\Rightarrow$ matching probeMS with the ID Track (ΔR < 0.05) to measure the ID reconstruction efficiency (ϵ_{id}). Not presented in this talk.

$\Rightarrow$ matching probeID with Muon (as defined for the $Z \rightarrow \tau\tau$ selection) in ΔR < 0.01 to measure the MS reconstruction efficiency together with the efficiency of the ID-MS matching for combined tracks ($\epsilon_{ms}\epsilon_{comb}$)

$\Rightarrow$ matching probeCB-Isolated Muon (as defined for the $Z \rightarrow \tau\tau$ selection) to measure the isolation efficiency

$\Rightarrow$ matching probeCB-Triggered Muon (as defined for the $Z \rightarrow \tau\tau$ selection) to measure the trigger efficiency

Results: reconstruction efficiency

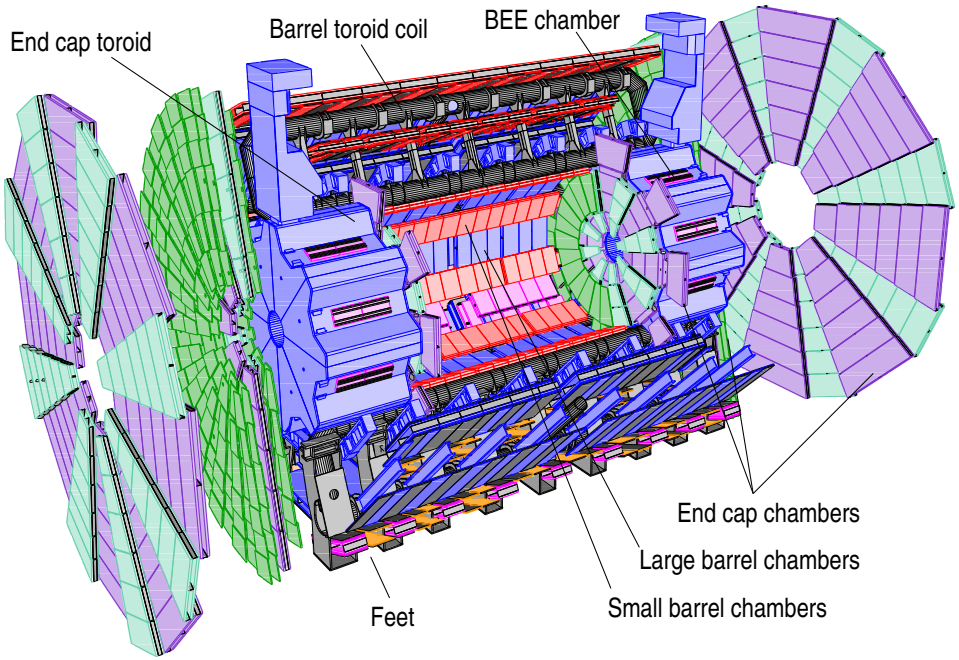


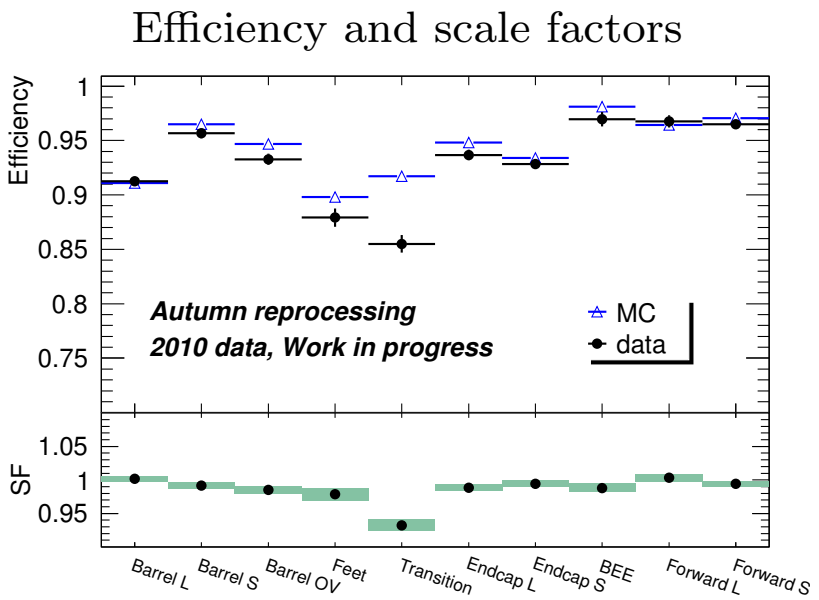
Dataset	Number probes
$Z \to \mu\mu$	23811
$Z \to \tau\tau$	6
$W \to \mu\nu$	49
$W \to \tau\nu$	7
$b\bar{b}$	14
$c\bar{c}$	5
$t\bar{t}$	10

Table: Signal and background processes for the tag-and-probe method

- Background less than 1%, present only at low p_T
- Dominant background is $W \to \mu\nu$.

Results: reconstruction efficiency





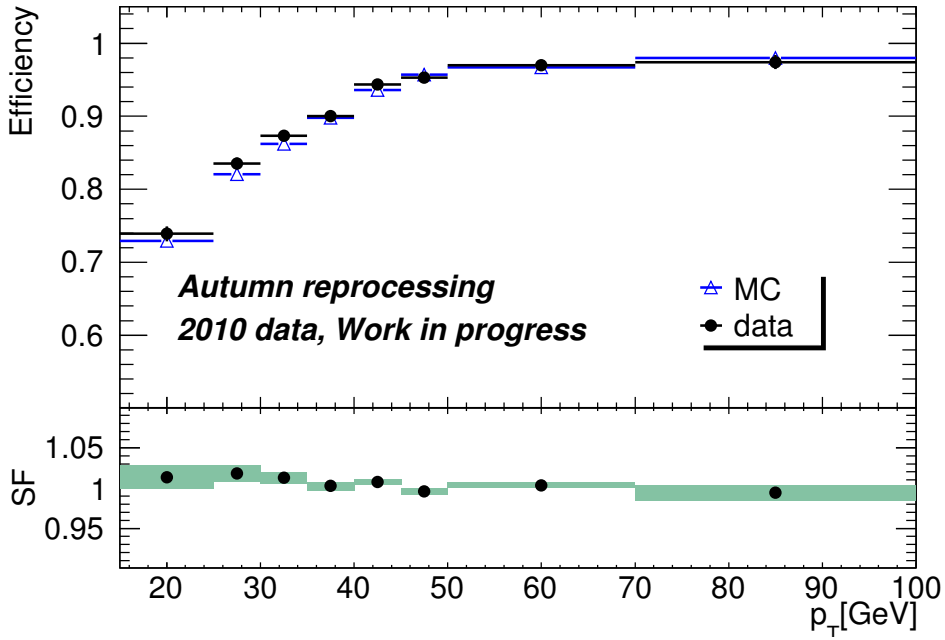
- Inefficiency in the endcap-barrel transition region and in the feet: missing chambers and not perfect alignment
- Scale factor 0.95 in the transition region: Monte Carlo simulation does not reproduce very well the asymmetric magnetic field and misalignment

Results: isolation efficiency

- Isolation of muons needed to reject QCD events: $\sum p_T^{ID}/p_T < 0.06$ and $E_T/p_T < 0.06$

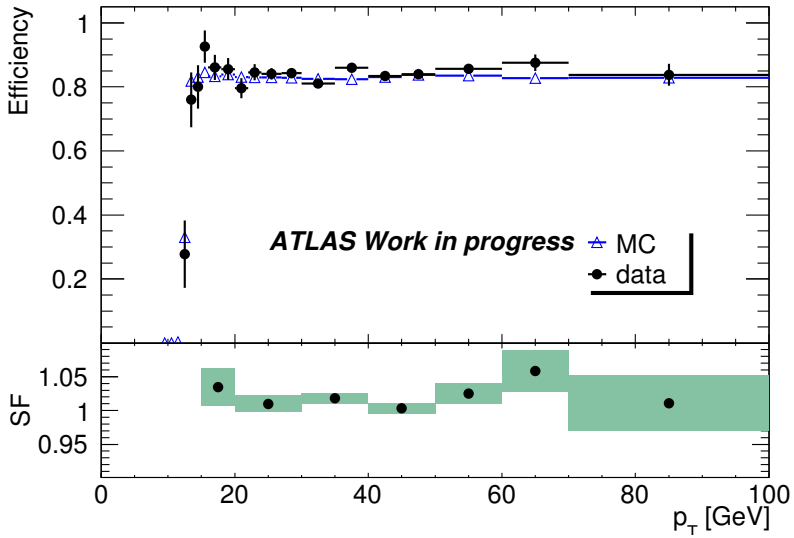
Dataset	Number probes
$Z \to \mu\mu$	23927
$Z \to \tau\tau$	2
$W \to \mu\nu$	4
$W \to \tau\nu$	< 0.4
$b\bar{b}$	23
$c\bar{c}$	3
$t\bar{t}$	6

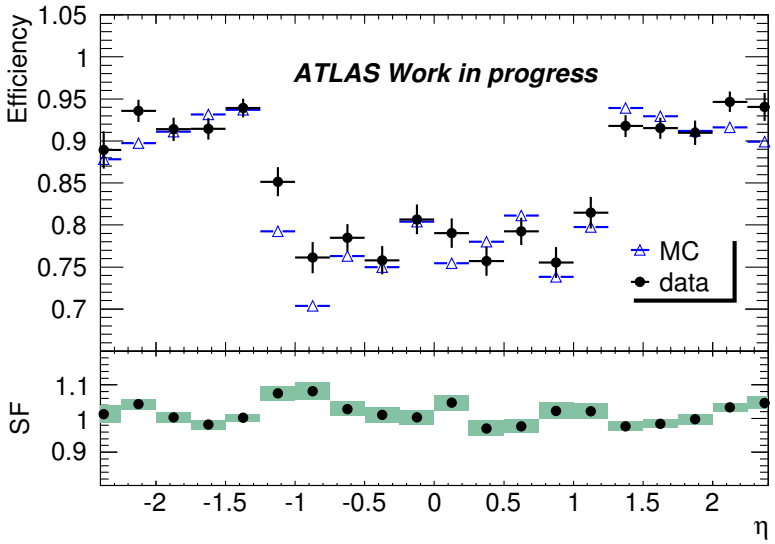
Table: Signal and background processes for the tag and probe method



- Background to $Z \to \mu\mu$ sample additionally reduced ($< 0.2\%$) by the request of 2 combined muons
- Monte Carlo simulation reproduces very well the efficiency curve calculated from data

Results: trigger efficiency





- Trigger threshold: $p_T > 13$ GeV at event filter
- Efficiency: ≈ 0.95 in end-cap (full coverage) and ≈ 0.80 in barrel (not fully covered)
- Scale factors: flat p_T distribution, more pronounced fluctuations on η
- η dependent scale factors will be used for the cross section measurement

Conclusion

- A_Z and C_Z factors for $Z \to \tau\tau \to \mu\tau_{had}$ cross section measurement obtained by Monte Carlo simulation
- Selection efficiency depends on reconstruction, isolation and trigger muon efficiencies, measured on data with $Z \to \mu\mu$ events
- The study presented shows good agreement between data and Monte Carlo simulation for muon efficiencies: scale factors calculated to take into account differences