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Study of the performance of the ATLAS muon spectrometer

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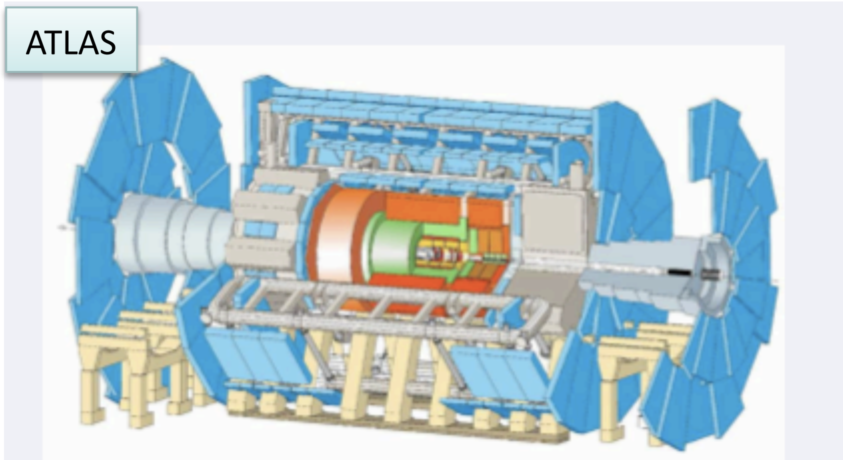
Detection of muons @ ATLAS

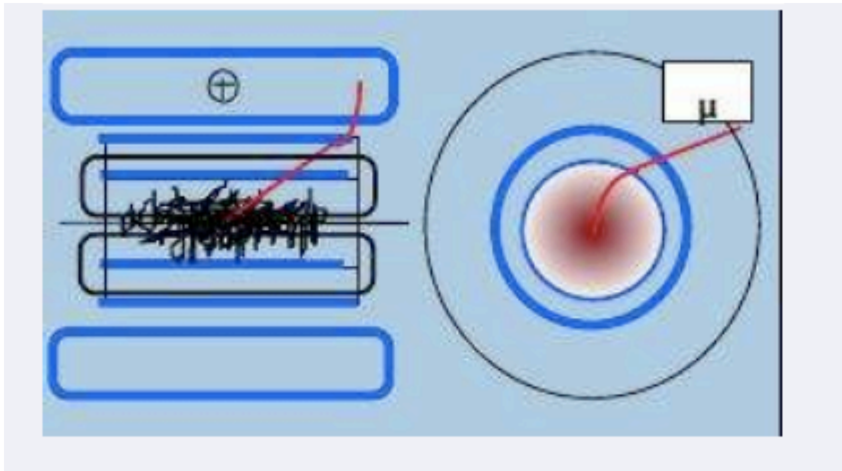
Muons @ LHC:

- probes of Standard Model processes: $Z \rightarrow \mu\mu$, $W \rightarrow \mu\nu$, $H \rightarrow \mu\mu\mu\mu$
- signature of phenomena beyond the Standard Model (Z′, W′, SUSY)



How muons are detected:

- filtering provided by the calorimeters
- tracking in B field for momentum measurement
- matching with Inner Detector (ID) to improve resolution and vertex capabilities



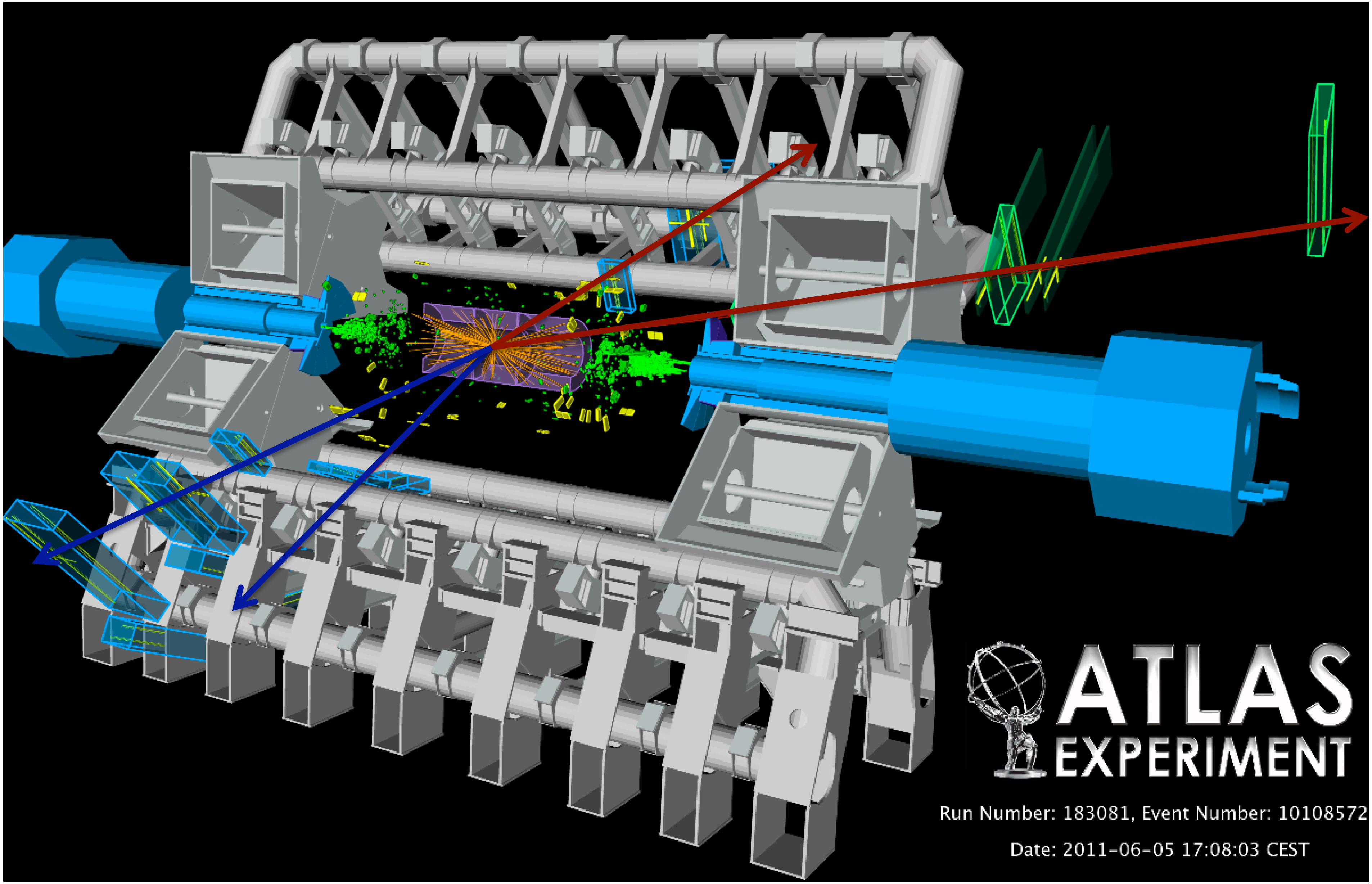
The ATLAS muon spectrometer (MS):

based on air-core toroid magnetic field:

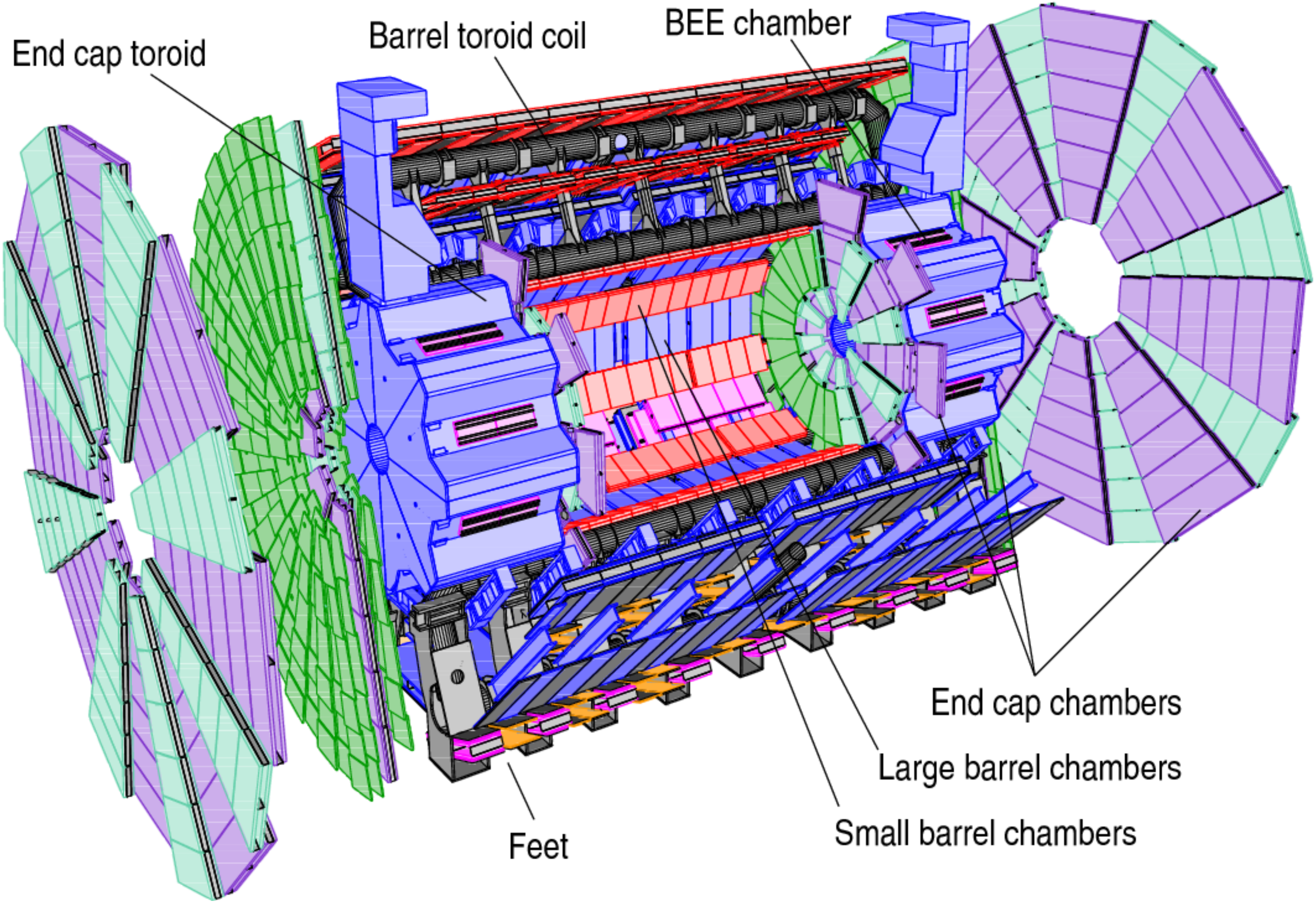
- Detects muons up to $|\eta| = 2.7$ (*)
- Triggers on muons (single and di-muon)
- Standalone operation + extrap. to vertex
- Combined mode with ID

(*) $\eta = -\log \tan \frac{\theta}{2}$

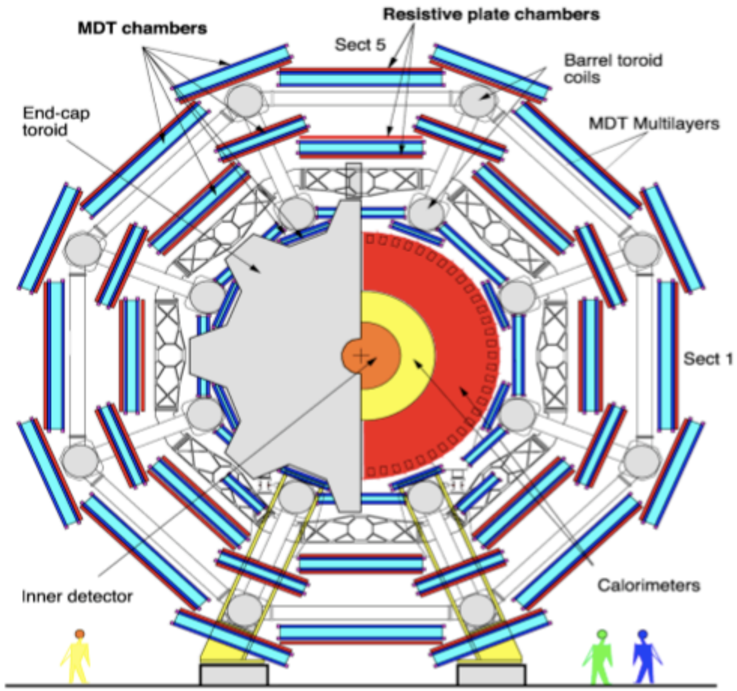
$ZZ^{(*)} \rightarrow \mu^+\mu^-\mu^+\mu^-$ event detected by ATLAS

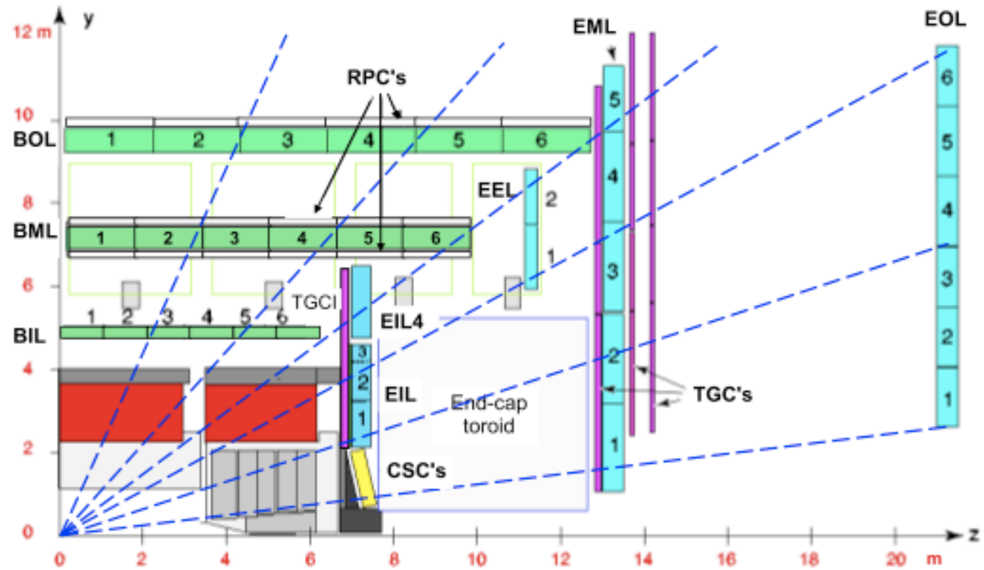


The ATLAS Muon Spectrometer - I



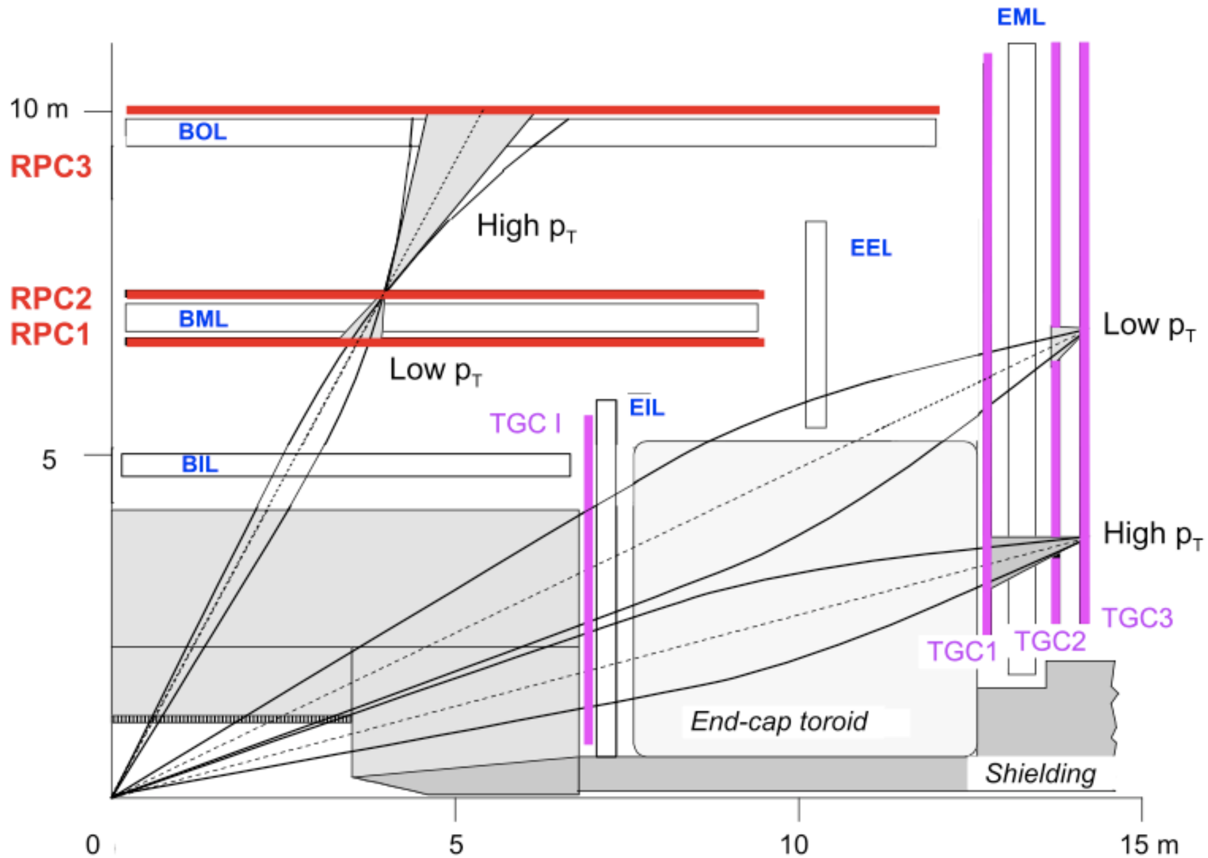
The ATLAS Muon Spectrometer - II





		Chamber resolution (RMS) in			Measurements/track		Number of	
Type	Function	z/R	ϕ	time	barrel	end-cap	chambers	channels
MDT	tracking	35 μm (z)	—	—	20	20	1088 (1150)	339k (354k)
CSC	tracking	40 μm (R)	5 mm	7 ns	—	4	32	30.7k
RPC	trigger	10 mm (z)	10 mm	1.5 ns	6	—	544 (606)	359k (373k)
TGC	trigger	2–6 mm (R)	3–7 mm	4 ns	—	9	3588	318k

ATLAS Muon Trigger concept



Level-1: hardware - based on RPC or TGC coincidences, with up to 6 p_T thresholds with full η coverage;
Level-2: software - using precision chambers with coarse granularity
Event-Filter: software - using quasi-offline track reconstruction

	rate
L1	<10kHz
L2	<1kHz
EF	<100Hz

ATLAS Muon Tracking concept

A muon tracks can be:

*"**standalone**"* based on MS

*"**combined**"* btw MS and ID

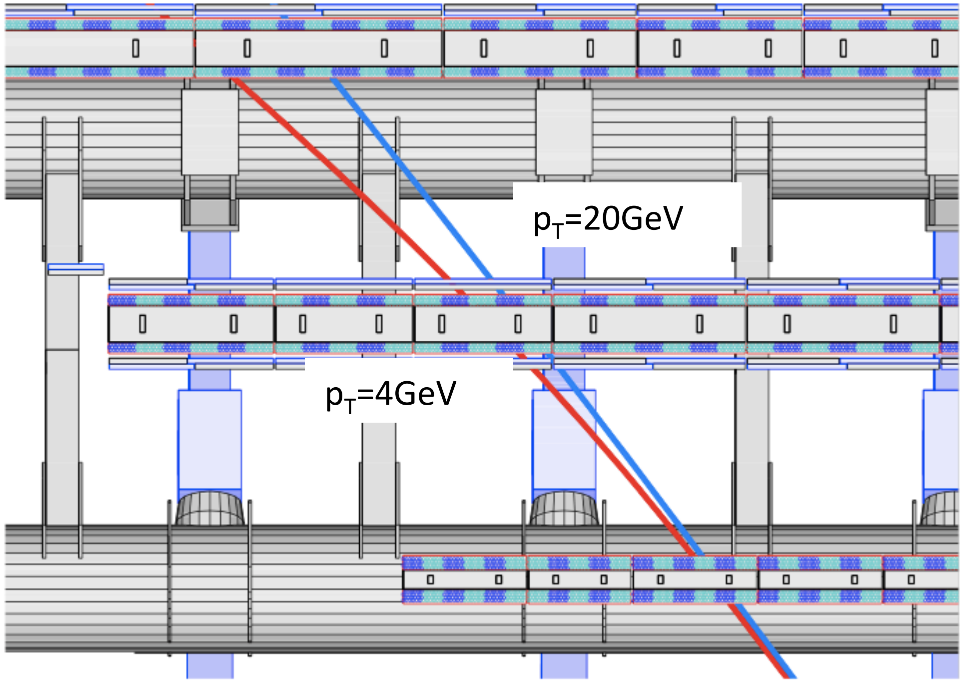
*"**tagged**"* ID + MS tag

Tagged muons allow to recover "geometrical" inefficiencies

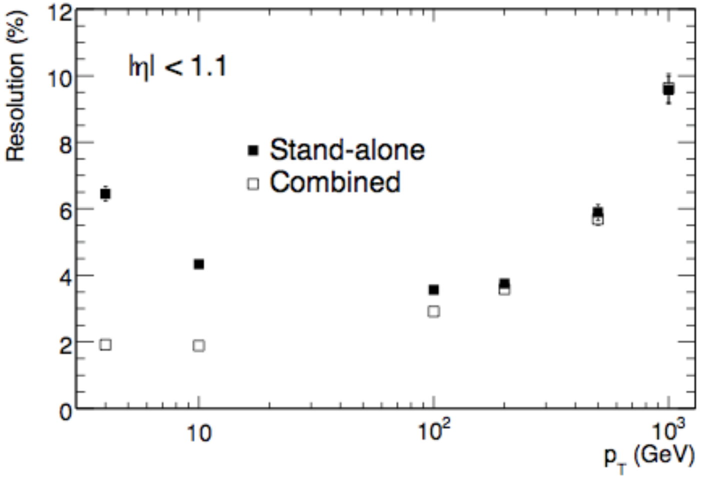
The combined momentum resolution is dominated by

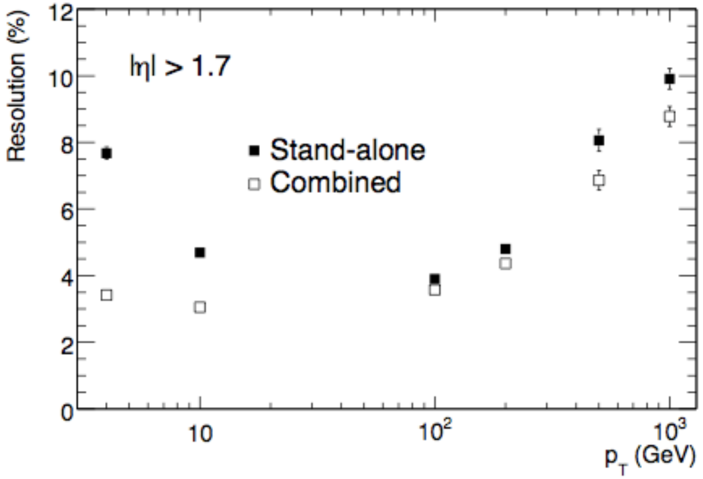
ID @ low p_T

MS @ high p_T



Design p_T resolutions: standalone and combined (G.Aad et al., JINST 3,:S08003,2008)





Measurement of the muon performance

The muon detection performance are continuously monitored during collision data-taking

→ **Data Quality** Assessment and continuous Detector **Calibration** (see M.Iodice talk in this session)

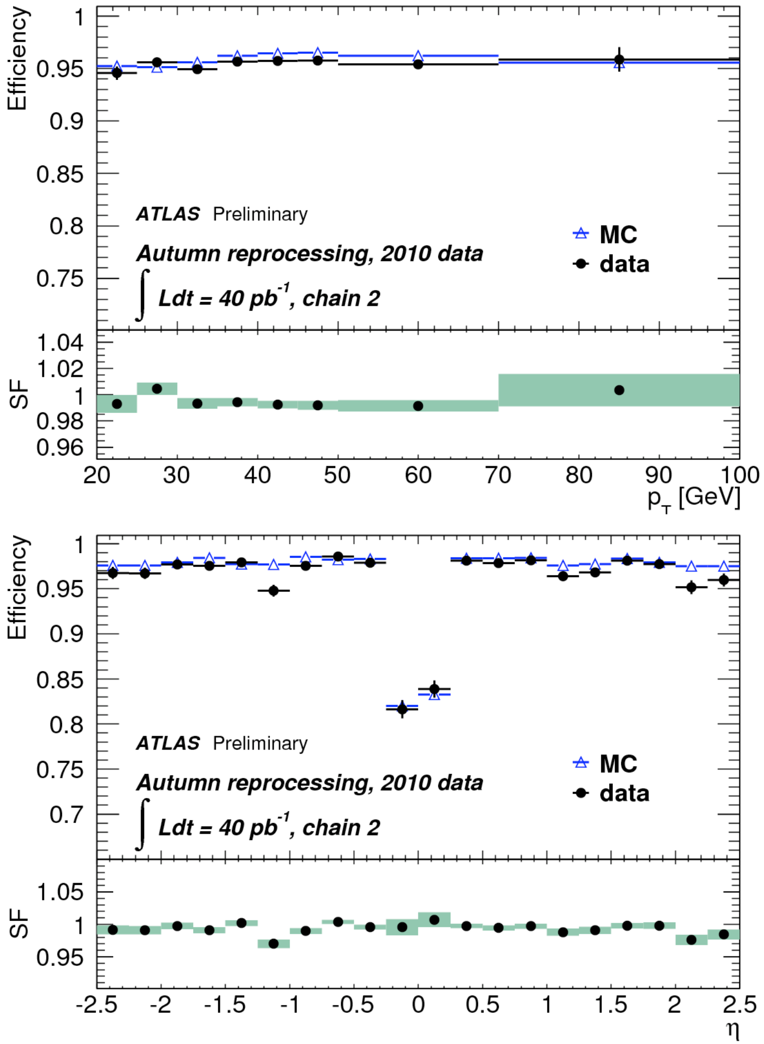
→ Tag & Probe method to determine **reconstruction and trigger efficiencies**, based on J/ψ and Z resonances

→ Resonance mass peaks and ID vs. MS comparisons to determine **resolution and momentum scale**

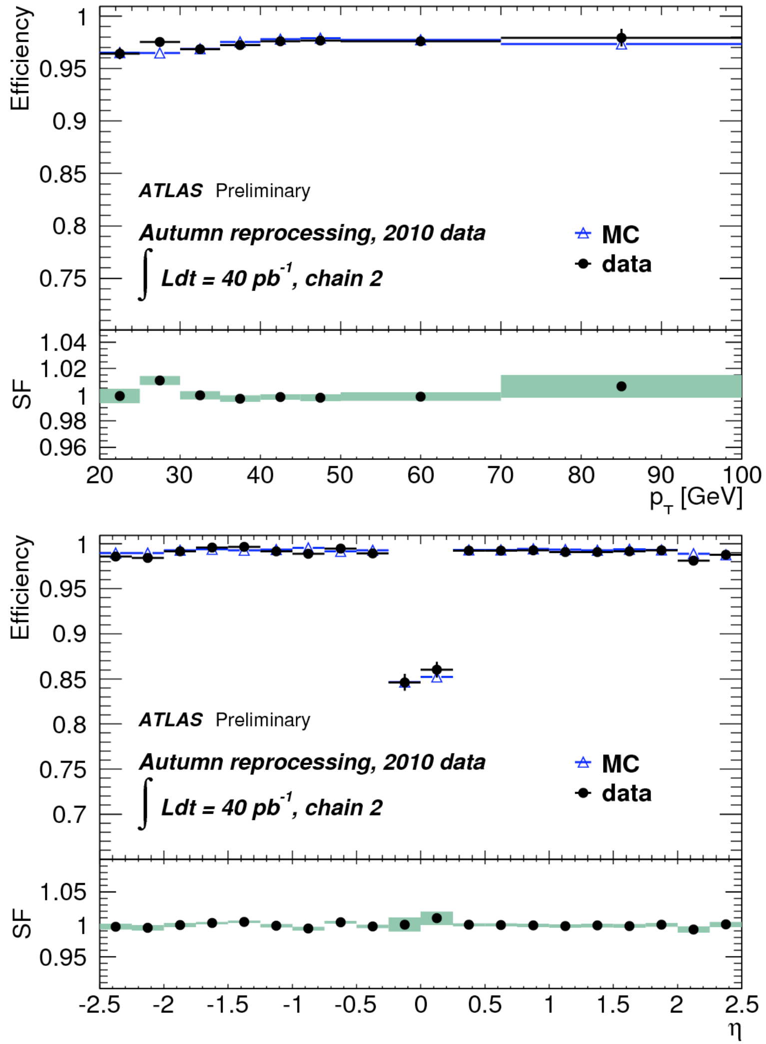
→ Special runs with toroid off and solenoid on to determine **alignment**

Reconstruction Efficiencies: high p_T muons

Combined muons only



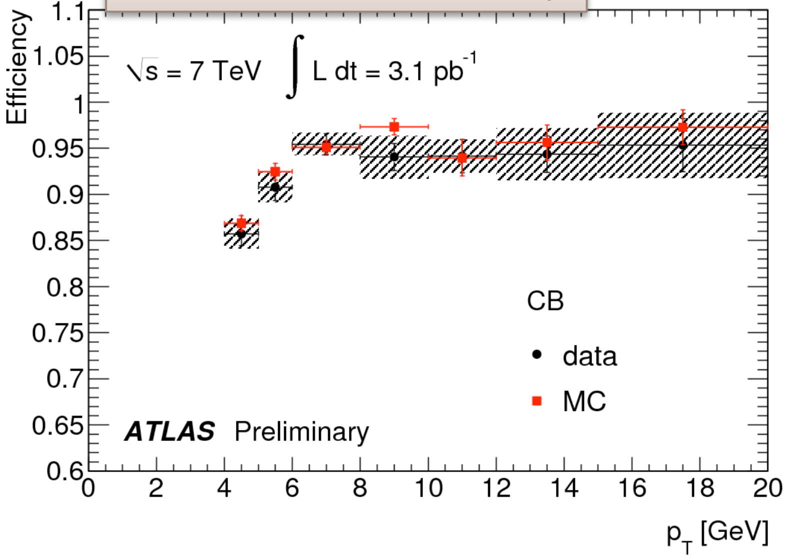
Combined + tagged muons



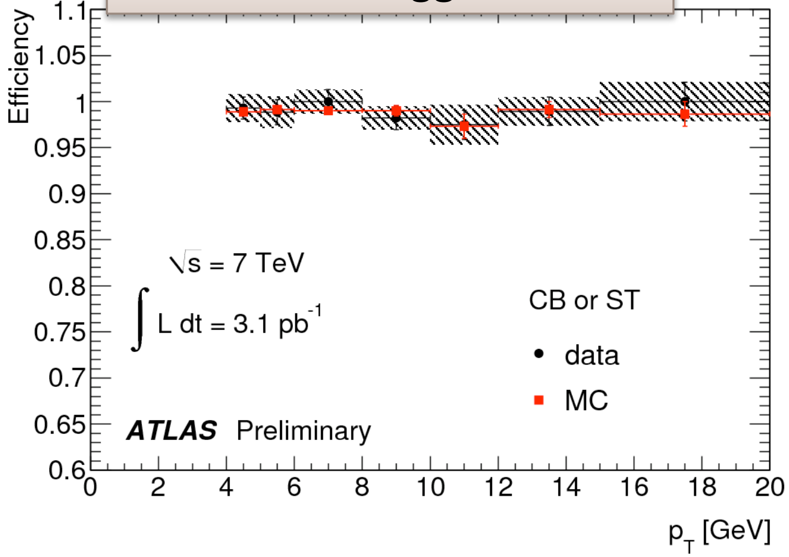
Measurements based on Tag&Probe using the Z resonance
→ high efficiency and good data-MC agreeement.

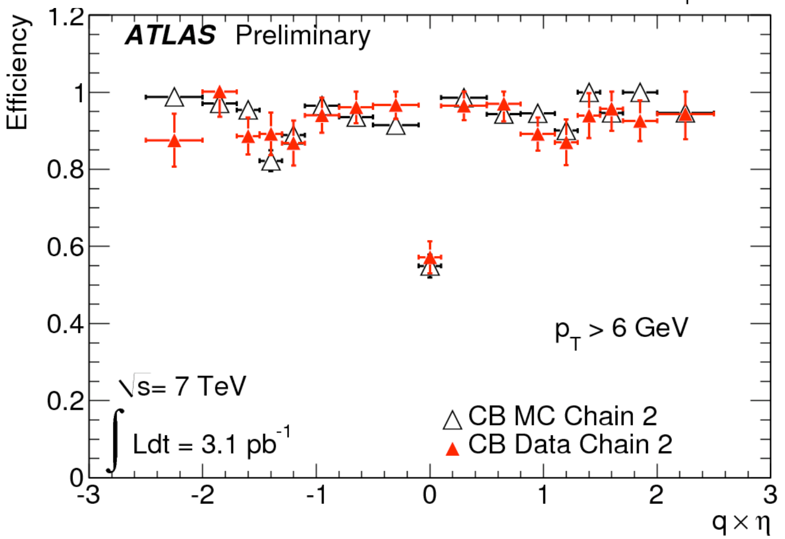
Reconstruction Efficiencies: low p_T muons

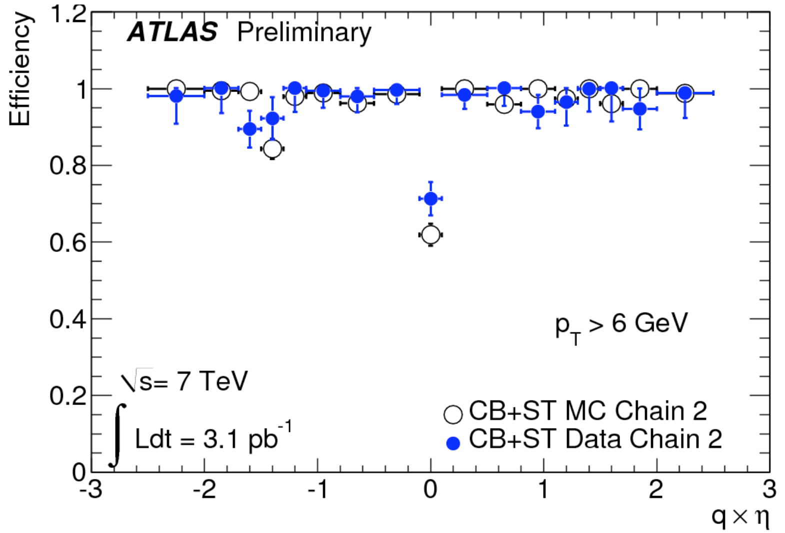
Combined muons only



Combined + tagged muons



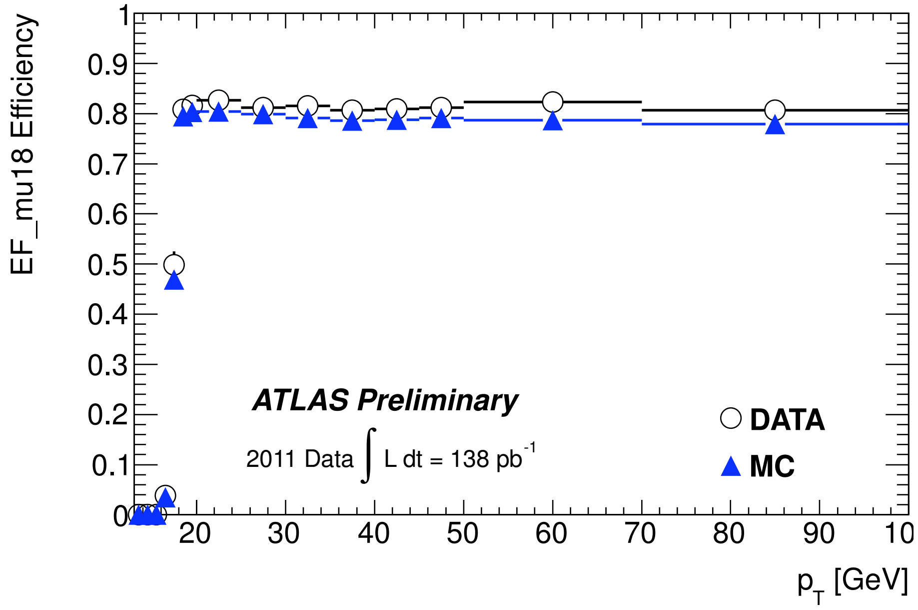


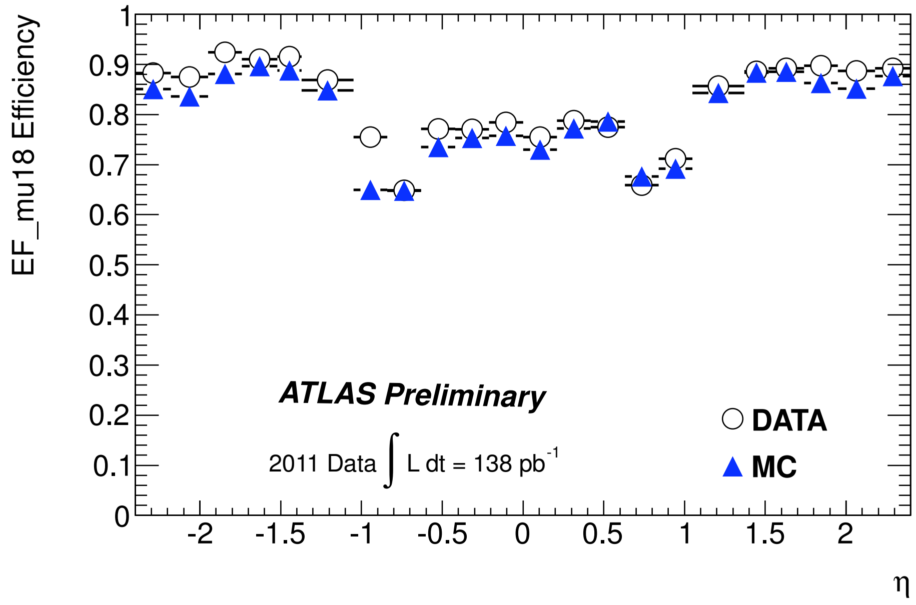


The measurements are based on Tag&Probe using the J/ψ resonance
→ high efficiency for $p_T > 6$ GeV and good data-MC agreeement.

Trigger Efficiencies

Trigger efficiencies are evaluated using the Tag&Probe method on the Z with respect to combined tracks ➔ **ε (Trigger / reconstruction)**
Results of the measurement for the single muon trigger with threshold = **18 GeV**





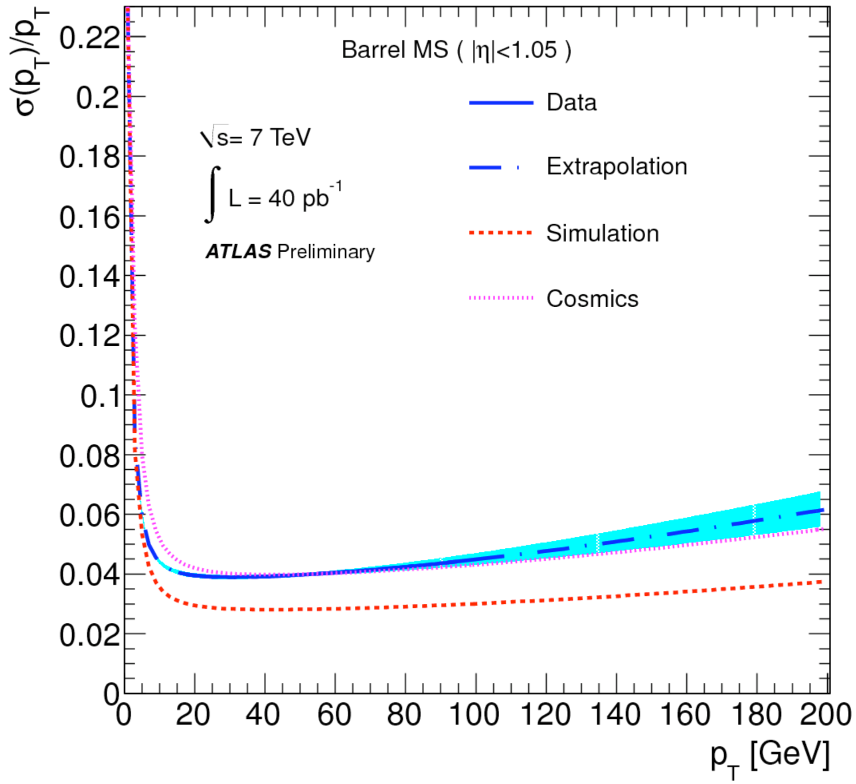
The 80% efficiency at the plateau is due to regions with limited acceptance (clearly identified in the η distribution)

Muon Spectrometer Resolution: 2010 data

MS momentum resolution as a function of p_T for Barrel and Endcap constrained by $Z \rightarrow \mu\mu$ line-shape and by ID vs. MS measurement from $W \rightarrow \mu\nu$ events.

$$\frac{\sigma(p_T)}{p_T} = \frac{p_0^{MS}}{p_T} \oplus p_1^{MS} \oplus p_2^{MS} p_T$$

$p_0^{MS} \rightarrow$ energy loss
$p_1^{MS} \rightarrow$ multiple scattering
$p_2^{MS} \rightarrow$ hit resolution (calib. + alignm.)



Improvement expected with new software release based on new alignments

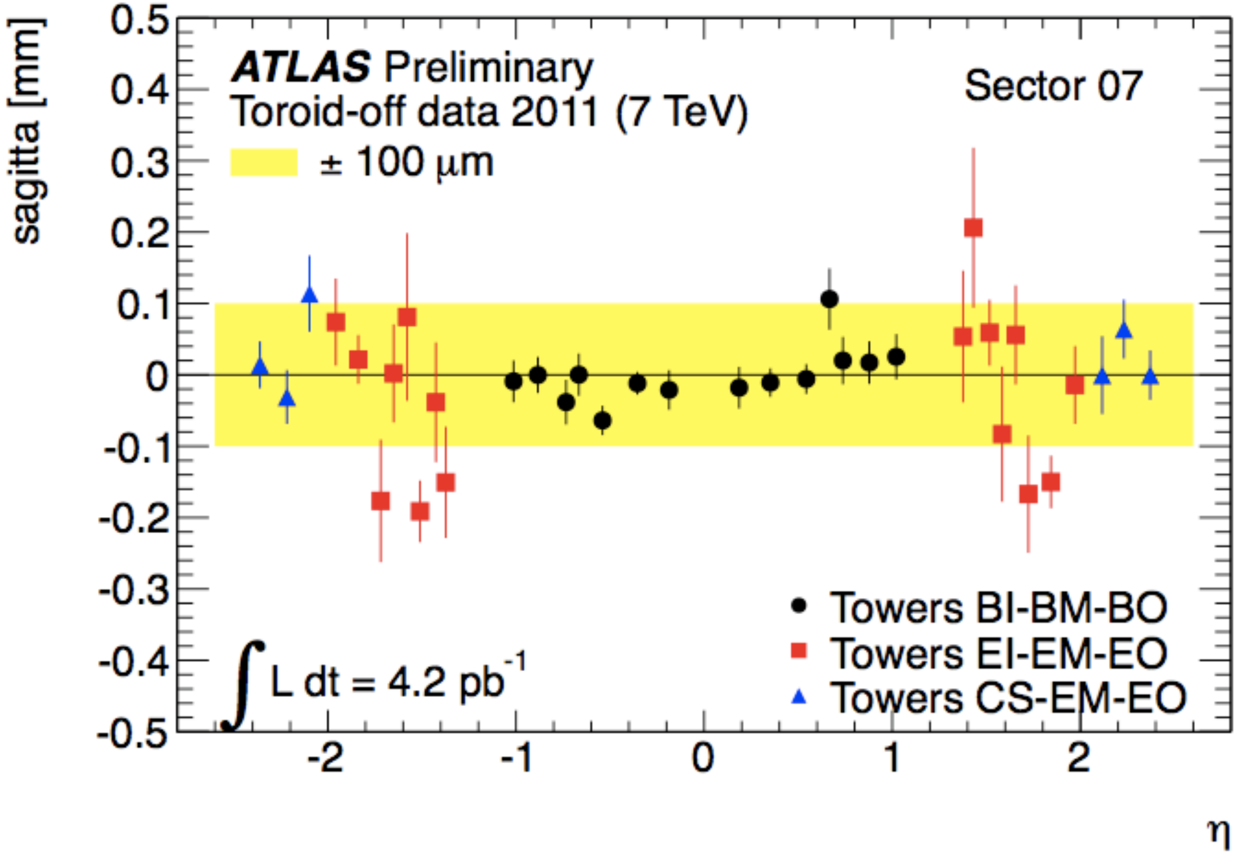
Chamber alignment from toroid off data

Alignment is based on:

(1) Optical sensors on all chambers

(2) Intercalibration using straight tracks (toroid off data) with high momentum

The goal is < 50 μm all over the detector (very challenging goal)



2011 data show an alignment within 50 μm (barrel) and 100 μm (endcap)

New alignment runs are expected to reduce the spread on endcap to 50 μm.

Conclusions and Outlook

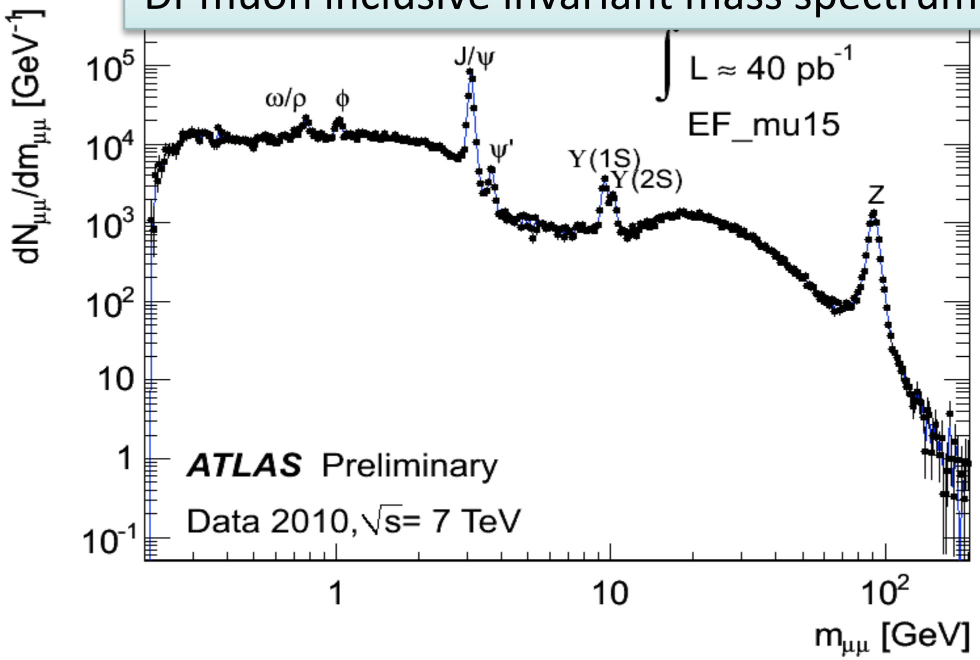
Many physics results from ATLAS are based on muon detection:

→ Trigger and Reconstruction efficiencies match well the design performance;

→ Momentum resolution of ID and MS approaching design values;

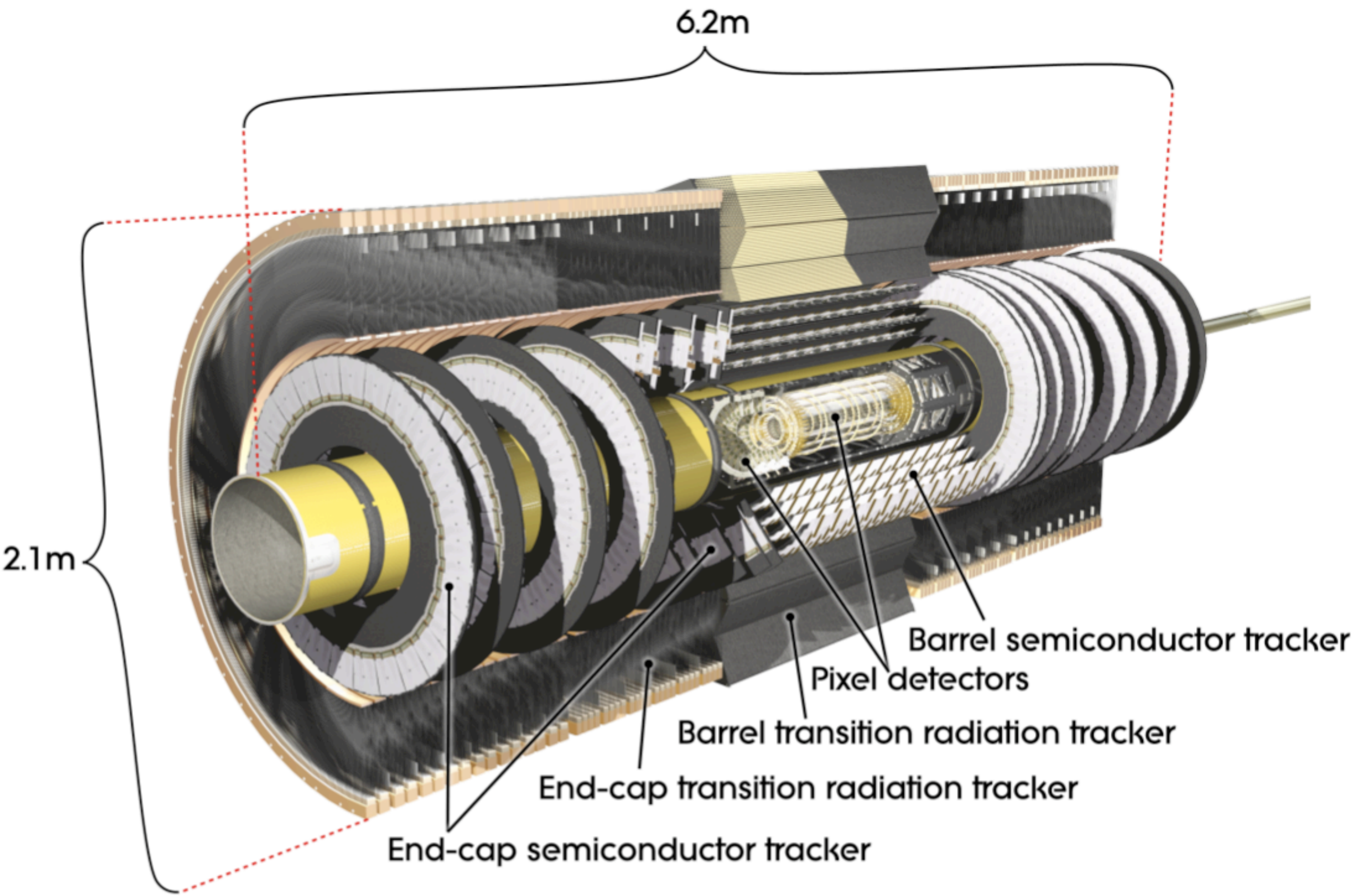
→ Work in progress to define the optimal alignment all over the detector.

Di-muon inclusive invariant mass spectrum

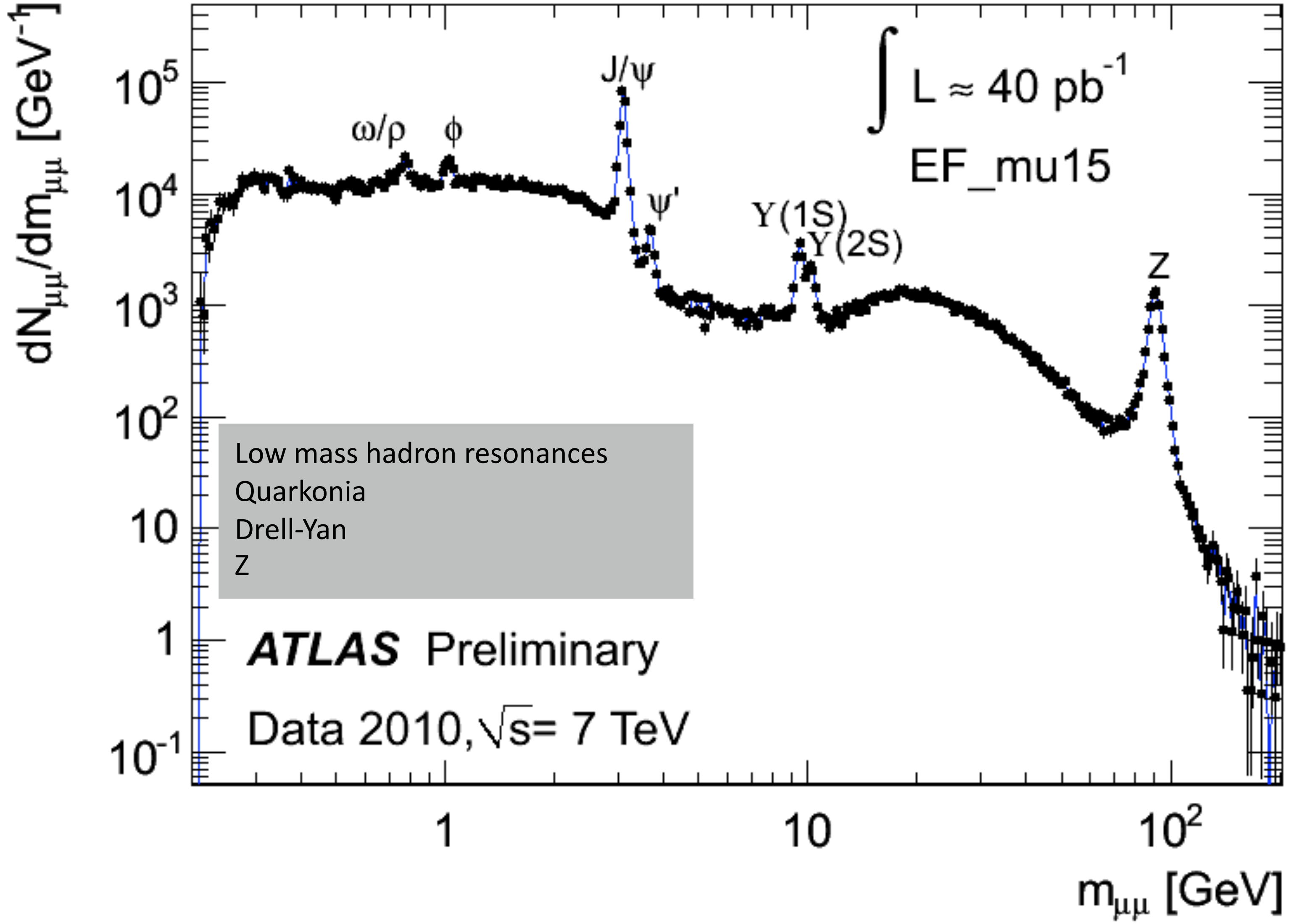


Backup

The ATLAS Inner Detector



Dimuon invariant mass spectrum

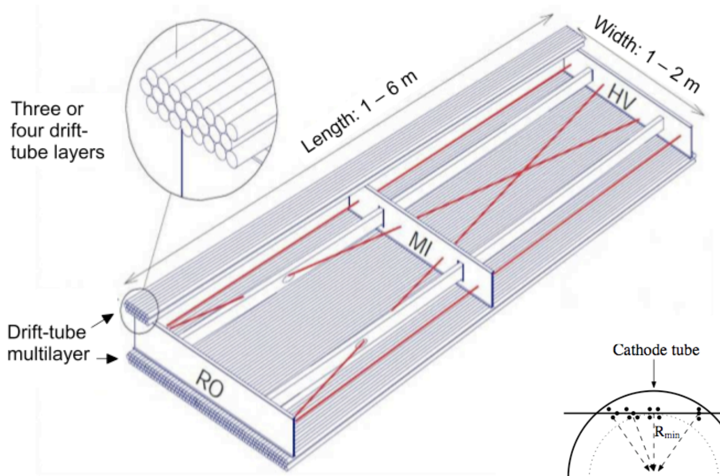


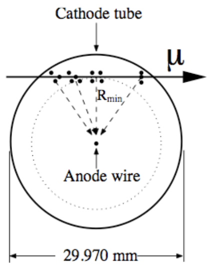
Low mass hadron resonances
Quarkonia
Drell-Yan
Z

ATLAS muon spectrometer technologies

Precision chambers

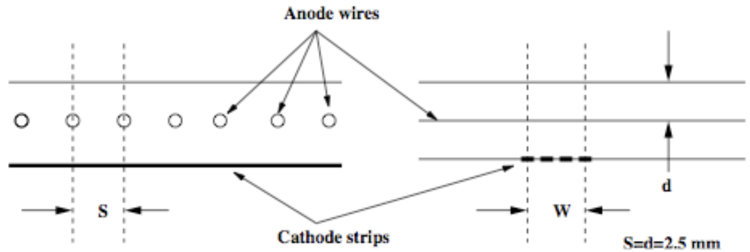
(1) Monitored Drift Tubes (MDT)





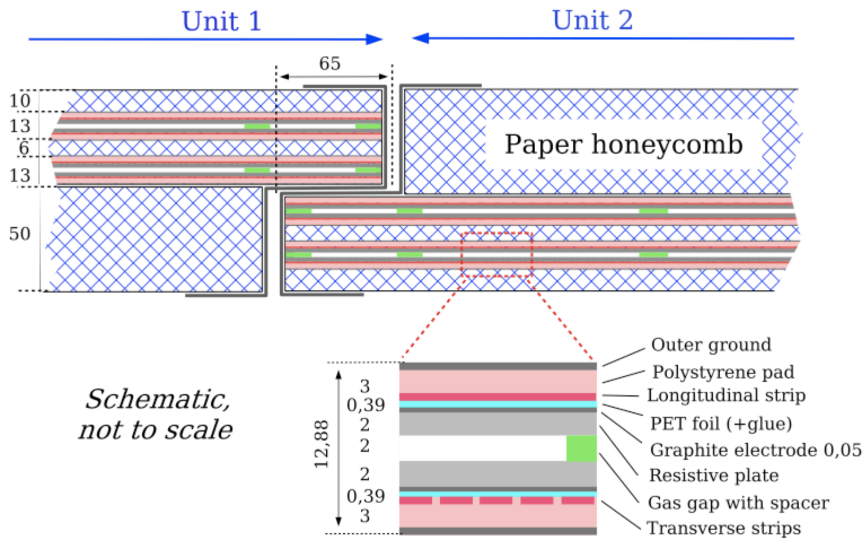
High-pressure drift tubes
$\sigma(R)\approx 100\mu m$, $T_{drift}\approx 700ns$

(2) Cathode Strip Chambers (CSC)
Operation in high rate environment
$\sigma(R)\approx 60\mu m T_{drift}\approx 20ns$

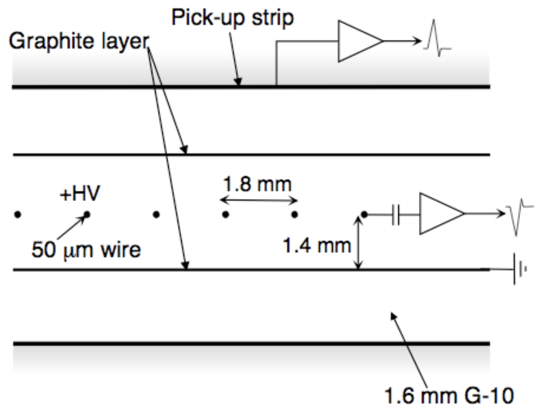


Trigger chambers

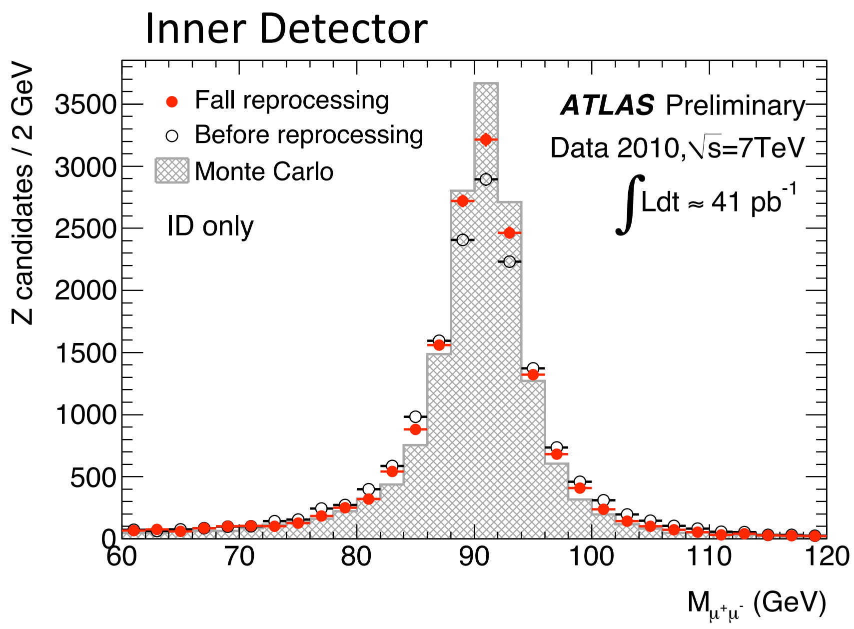
(1) Resistive Plate Chambers (RPC)

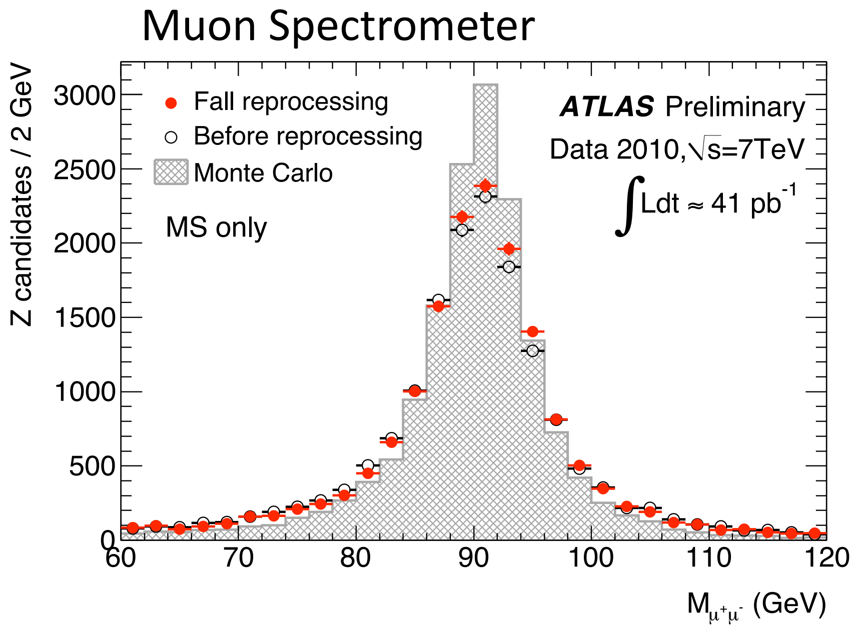


(2) Thin Gap Chambers

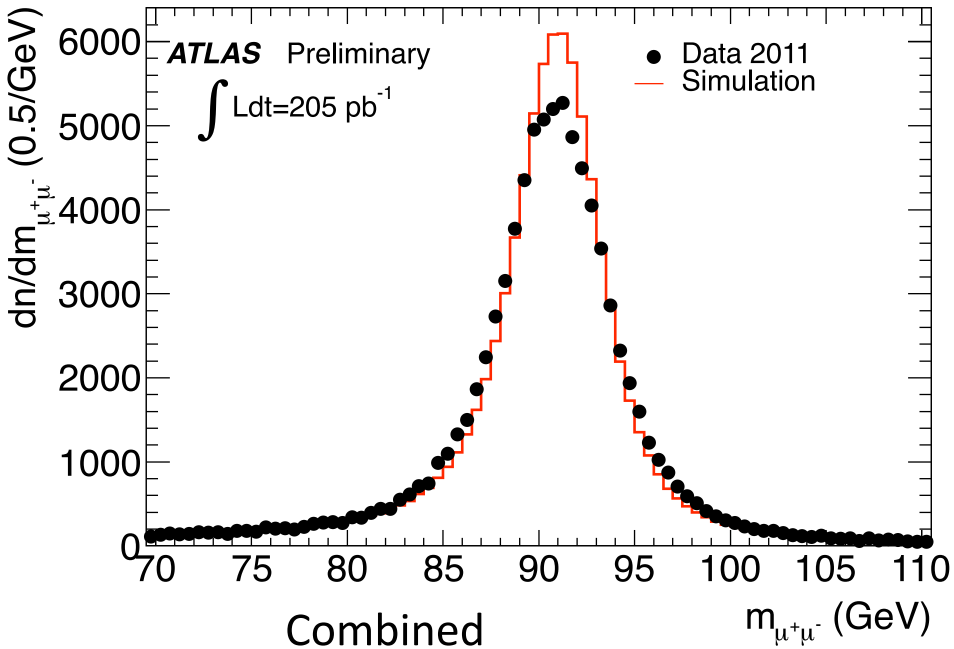


Z mass resolution after alignment (2010 data)

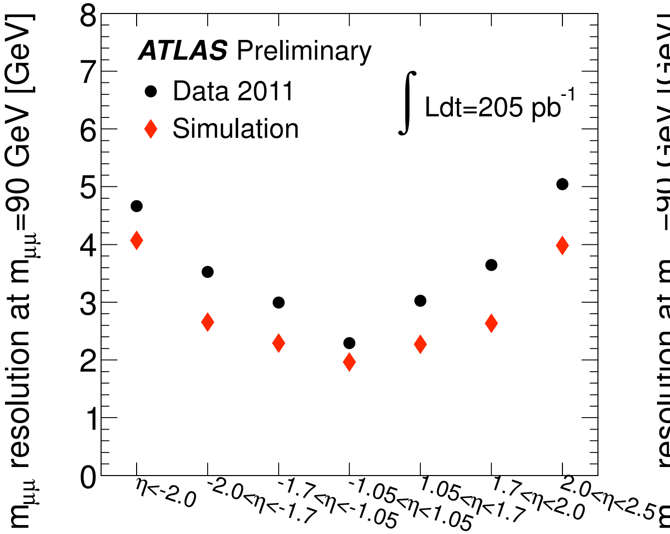




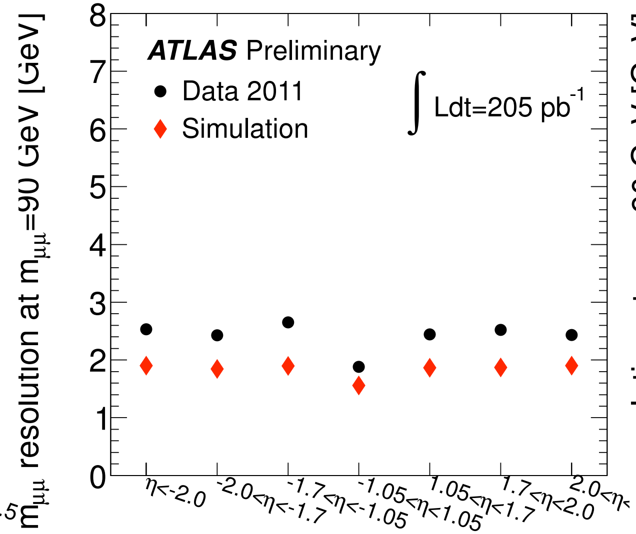
Z invariant mass resolution: comparison with MC results based on perfect alignment



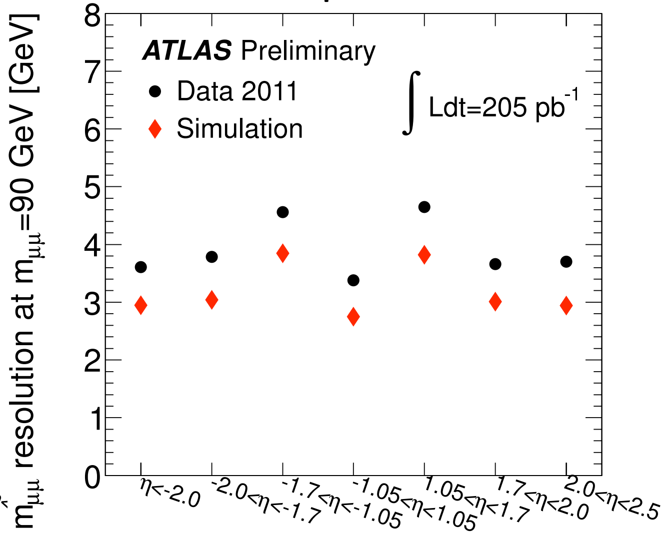
Inner Detector



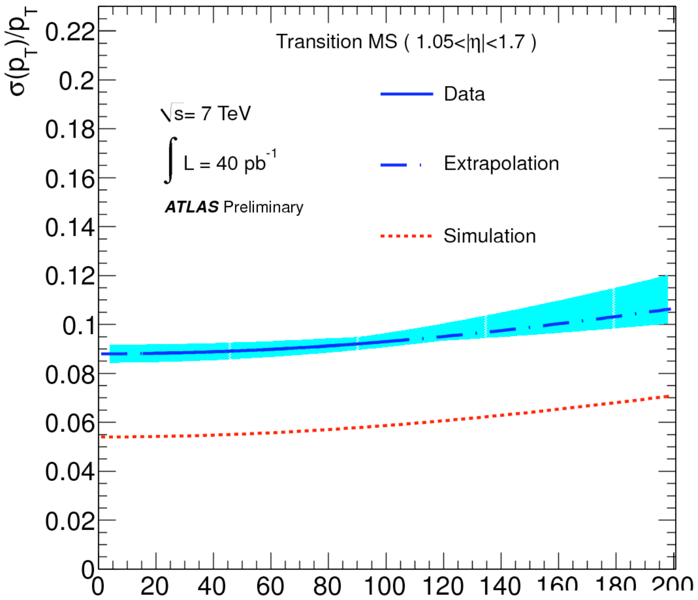
Combined

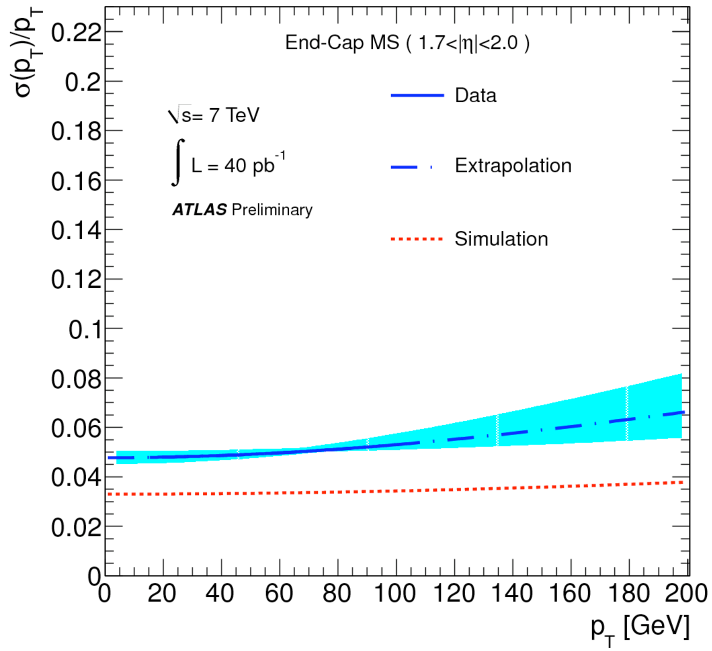


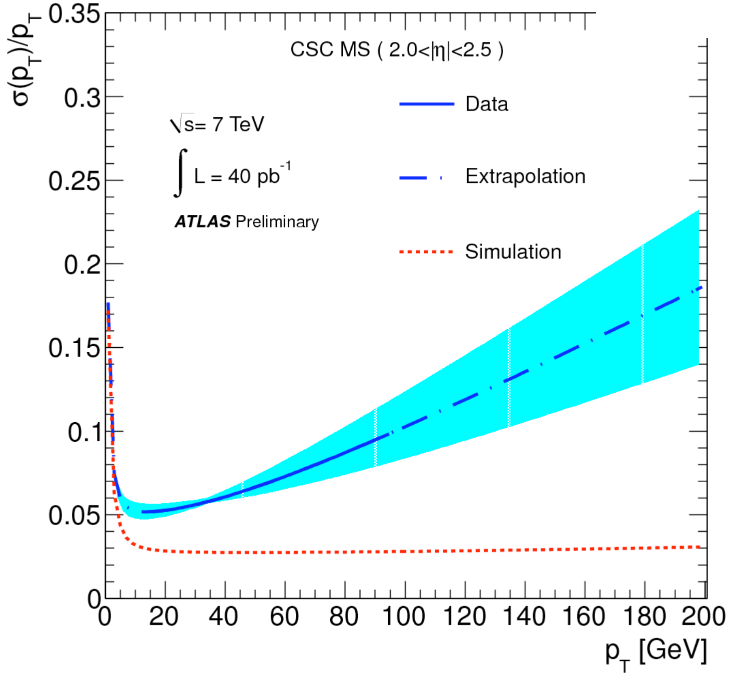
Muon Spectrometer



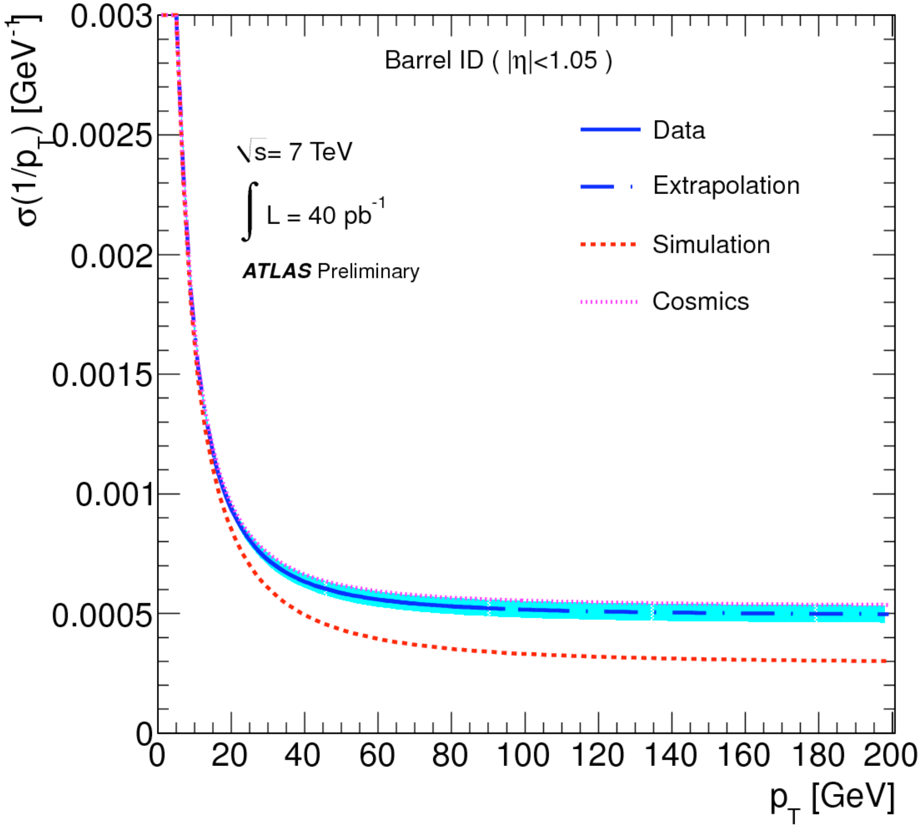
Muon Spectrometer Resolution: 2010 data

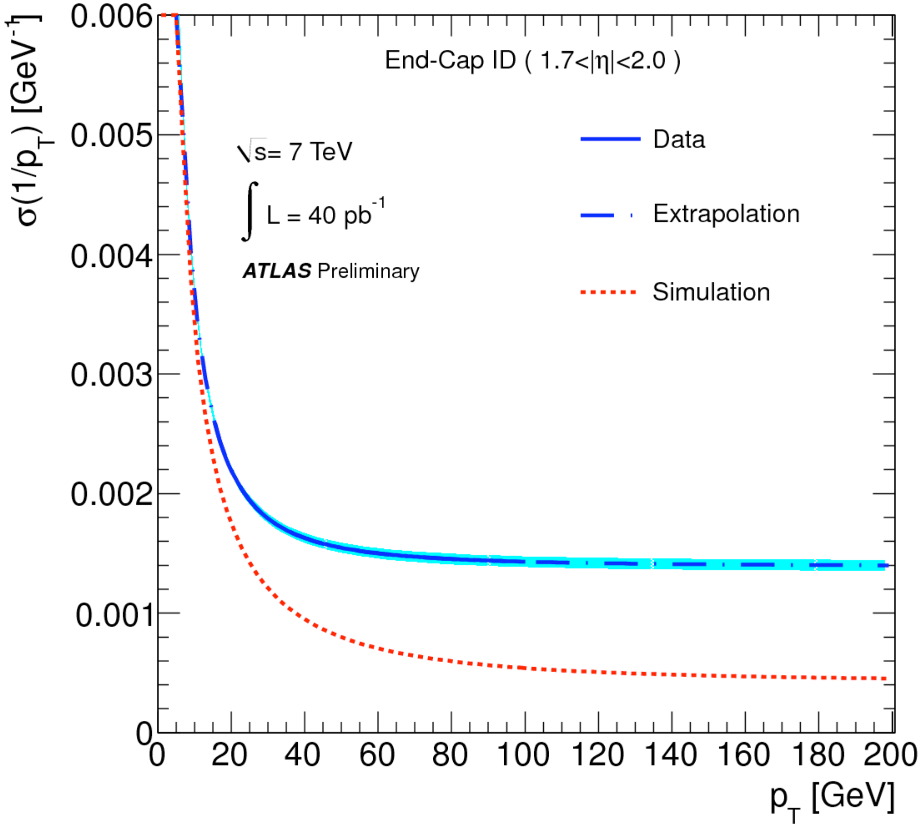






Inner Detector Resolution: 2010 data





Sagitta measurements of straight tracks in toroid off data:
Comparison between use of nominal geometry and
aligned geometry.