Muon reconstruction performance in the ATLAS experiment

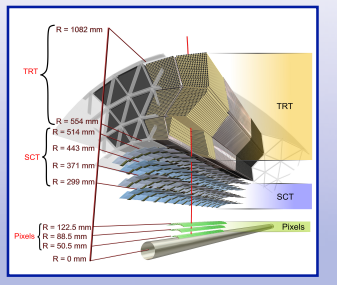
Daniele Capriotti, on behalf of the ATLAS Collaboration

Abstract – Measurements of the muon reconstruction efficiency as well as the muon momentum resolution have been carried out with LHC collision data recorded by the ATLAS experiment. A comparison of the results with Monte-Carlo prediction is given.

ATLAS Inner Detector

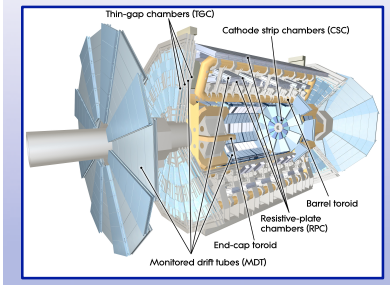
The Inner Detector measures tracks up to $|\eta| < 2.5$ exploiting the three types of detector operated in a solenoidal magnetic field of 2 T:

- ✓ silicon pixel detector closest to the interaction point,
- ✓ silicon strip detector (SCT) surrounding the pixel detector,
- ✓ transition radiation straw tube tracker (TRT) covering $|\eta| < 2.0$.



ATLAS Muon Spectrometer

The Muon Spectrometer consists of three large air-core superconducting toroidal magnetic systems providing a field of approximately 0.5 T:



- ✓ hits in three layers of precision drift tube (MDT) chambers for $|\eta| < 2$ and two layers of MDT chambers in combination with one layer of cathode strip chambers (CSC) at $2.0 < |\eta| < 2.7$ to measure the muon trajectory.
- ✓ Three layers of resistive plate chambers (RPC) in the barrel ($|\eta| < 1.05$) and three layers of thin gap chambers (TGC) in the endcaps ($1.05 < |\eta| < 2.4$) provide the muon trigger and also measure the muon trajectory in the non-bending plane.

Muon Reconstruction in ATLAS

- ✓ **Muon Spectrometer** (**MS**) tracks are entirely reconstructed in the MS, from trigger chambers hits and segments reconstructed in the precision chambers. The track is then extrapolated to interaction point and the momentum is corrected for the energy loss due to the material crossed before reaching the MS.
- ✓ **Calorimeter Muon** tracks are Inner Detector tracks identified as muons if the calorimeter deposit is compatible with a minimum ionizing particle.
- ✓ **Combined muon** (**CB**) tracks result from the combination of MS and ID measurements by a statistical combination or a refit of the entire track. Energy losses in the calorimeter are taken into account using parametrization and possibly calorimeter measurements.
- ✓ **Segment tagged muons** (**ST**) are based on the ID measurement. The muon is identified if at least one segment in MS matches with the ID track.

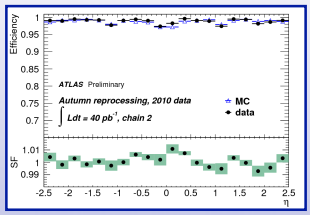
Muon Recontruction Efficiency

Muon reconstruction is performed by the Inner Detector and Muon Spectrometer. The efficiency of combined muons is defined as $\varepsilon = \varepsilon_{ID}\varepsilon_{MS}\varepsilon_{comb}$. The different contributions are estimated with the Z tag-and-probe method.

Tag-and-probe selection

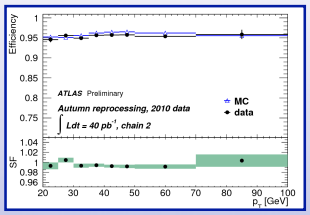
- ✓ Selection of a clean sample of Z decays.
- ✓ Reconstruction efficiency calculated of inner detector (ID), combined (CB) and segment tag (ST) tracks.
- ✓ Efficiencies calculated as a function of eta and p_T
  - ⇒ η dependence of the efficiency according to the different detector regions,
  - ⇒ no p_T dependence of the efficiency (confirmed by J/ψ analysis at low p_T).
- ✓ Data-MonteCarlo agreement evaluated by means of scale factors (applied as corrections to MonteCarlo predictions in many physics analysis).

ID efficiency



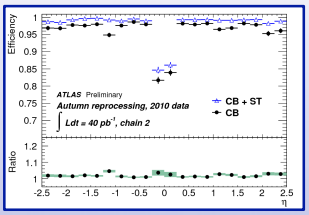
- ✓ Efficiency (ε_{ID}) calculated with respect to MS tracks.
- ✓ Hit quality criteria applied.
- ✓ Data efficiency 0.991 ± 0.001.
- ✓ Good data-MonteCarlo agreement: scale factors within 1%.

CB efficiency



- ✓ Efficiency ($\varepsilon_{MS}\varepsilon_{comb}$) is calculated with respect to ID tracks.
- ✓ Flat p_T distribution.
- ✓ Data efficiency 0.958 ± 0.001.
- ✓ Good data-MonteCarlo agreement: scale factors within 1%.

ST efficiency



- ✓ Efficiency calculated with respect to ID tracks.
- ✓ Gain in efficiency in transition region and $\eta \approx 0$ (dead material).
- ✓ Data efficiency 0.980 ± 0.001.

Muon Momentum Resolution

The momentum resolution is extracted from the width of the di-muon mass in Z decays and from the momentum measurement in single muon events given by the ID and MS.

- Resolution studied separately for ID and MS, in 4 η regions.
- Combined fit: dimuon invariant mass width and momentum difference measured in ID and MS as input.
- Alignment constraint for the resolution measurement.

MS resolution:

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

ID resolution:

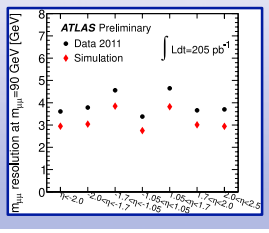
$$\frac{\sigma(p)}{p} = p_1^{ID} \oplus p_2^{ID} p_T$$

p_0(TeV) energy loss in the calorimeter, p_1 multiple scattering, p_2 (TeV^{-1}) resolution term.

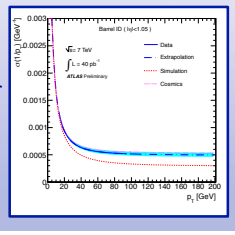
Results (for Barrel)

	p_0 (TeV^{-1})	p_1 (%)	p_2 (TeV^{-1})
MS	0.23 ± 0.01	3.75 ± 0.10	0.24 ± 0.04
ID		1.60 ± 0.32	0.49 ± 0.04

Resolution contribution to the relative di-muon invariant mass width, measured by the MS. Data (circles) and simulation (open triangles) as a function of η regions.



Resolution curve $\sigma(1/p_T)$ from the fitted parameter values of the Inner Detector in collision data and simulation as a function of the muon p_T.



Good agreement after MonteCarlo smearing correction.