MUON TRACK RECONSTRUCTION IN THE ATLAS EXPERIMENT

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INTRODUCTION TO ATLAS

ATLAS is a general purpose detector designed to record proton-proton collisions from the Large Hadron Collider (LHC). The LHC consists of two 27km circumference rings, accelerating proton beams to a combined energy of 14 TeV.

With dimensions of 46m by 25m and weighing 7000 tons, ATLAS is the largest particle physics detector ever built, yet must make extremely precise measurements (from ~10μm) very rapidly (there are collisions every 25ns). It consists of several sub-systems: the Inner Detector, which measures the trajectories of charged particles near the collision point; the Calorimeters, which measure the energies of charged and neutral deposition; and the Muon Spectrometer, which measures the trajectories of charged particles exiting the calorimeter. In addition, there are two magnet systems: an inner magnet producing a solenoidal field of 2T, and an outer magnet producing a toroidal field of ~0.5T.

The ATLAS collaboration itself is of impressive size: it is made up of over 1900 scientists, from 164 universities/laboratories and 25 countries.

OVERVIEW OF THE MUON SPECTROMETER

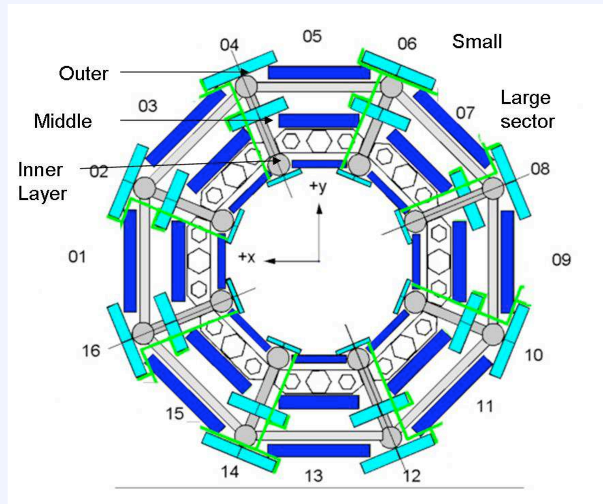
The Muon Spectrometer forms the outer layer of ATLAS, and is designed to detect tracks in the region $0<|\eta|<2.7$. It consists of a barrel section and two endcaps, all made up of three layers of chambers fitted around the toroidal magnets.

There are four types of technologies used:

- **Monitored Drift Tubes** (MDT);
- **Cathode Strips Chambers** (CSC);
- **Resistive Plate Chambers** (RPC);
- **Thin Gap Chambers** (TGC).

The **MDT**s are the primary source of measurements and have a precision of 80 μm per tube. However, they only measure the position in the bending plane (η) and not the position along the wire (the ϕ coordinate). In total, there are 339k tubes, spread over 1108 chambers.

The **CSC**s are used in forward regions ($2<|\eta|<2.7$) where their high rate capability and time resolution is vital. 32 chambers provide 30.7k channels with a resolution of about 60 μm in the bending (η) plane, and 5 mm in the transverse plane (ϕ).



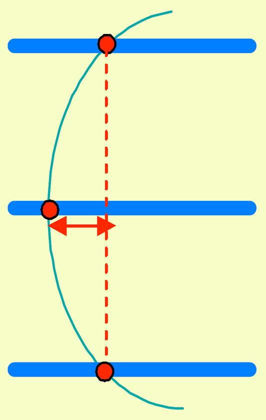
The Muon Spectrometer Barrel, showing the three layers of chambers, and the toroidal magnets.

The **RPC**s and **TGC**s have a faster response time, being designed primarily for the trigger. They provide a measurements of the η and ϕ coordinates for tracking, with a resolution of ~1cm each. There are 560 RPC and 2588 TGC chambers with 359k/318k channels respectively.

MUON RECONSTRUCTION

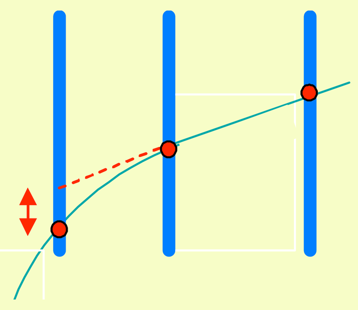
The purpose of the Muon Spectrometer is to measure the momentum and position of muons passing through its volume.

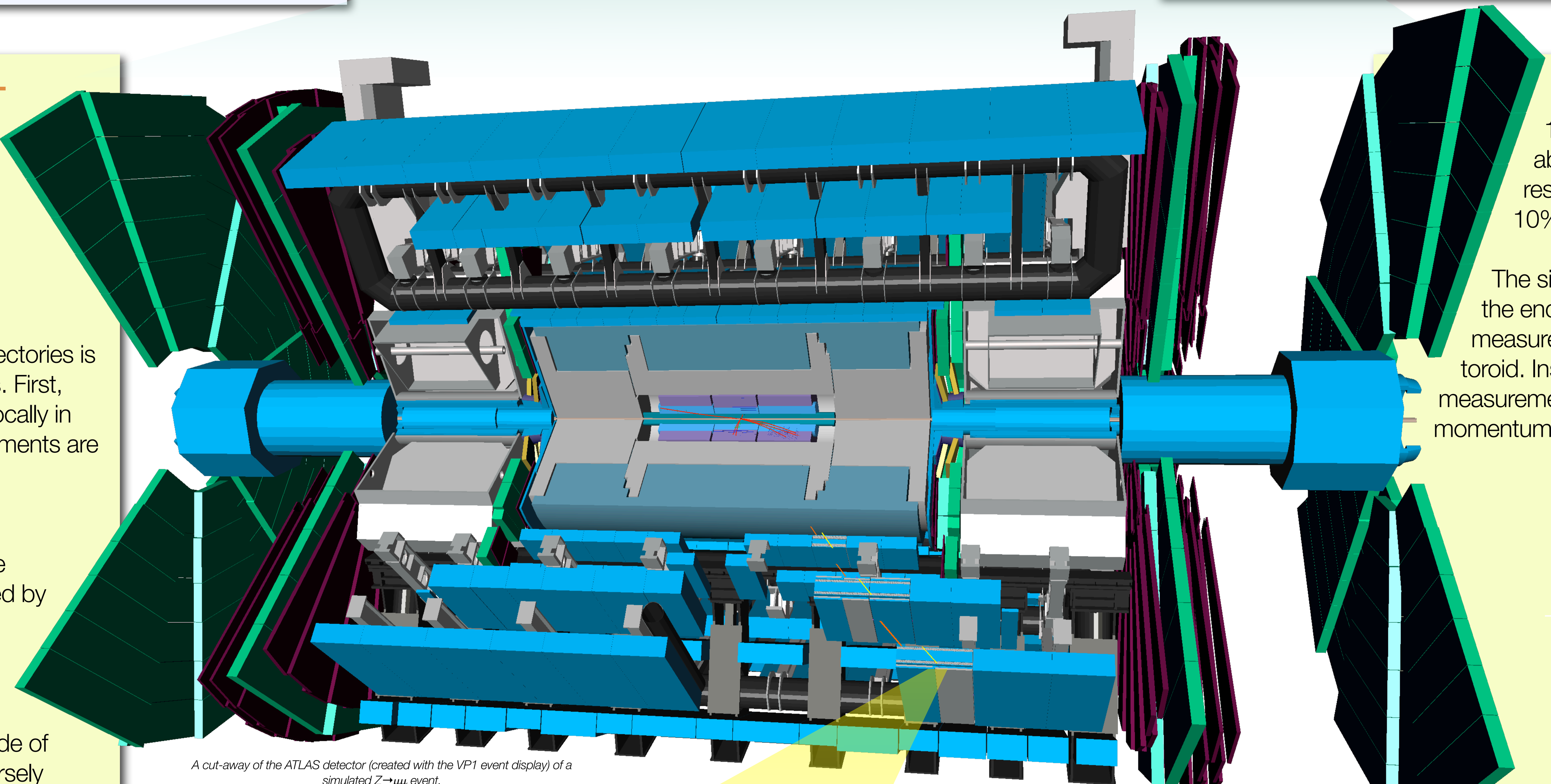
The reconstruction of the muon trajectories is performed in two consecutive steps. First, track segments are reconstructed locally in individual chambers, then track segments are combined to form track candidates.



In the barrel the momentum of the tracks is measured by determining the deviation (sagitta) of the trajectory from a straight line. The magnitude of the sagitta is inversely proportional to the momentum of the muon. At 1 TeV the average sagitta is about 500 μm. The design resolution at this momentum is 10% (50 μm).

The situation is slightly different in the endcaps as no position measurement is available inside the toroid. Instead a point-angle measurement is used to determine the momentum.



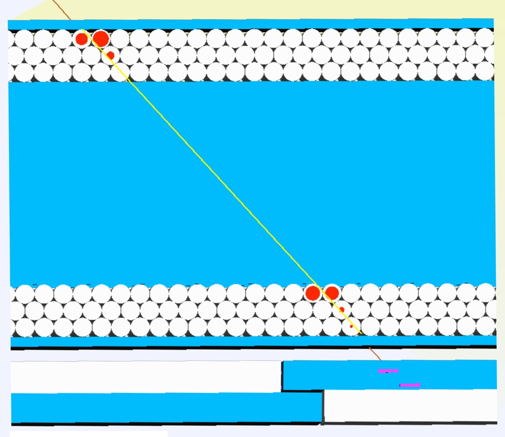


A cut-away of the ATLAS detector (created with the VP1 event display) of a simulated $Z \rightarrow \mu\mu$ event.
Inner Detector tracks are shown (in the centre) in red, whilst the reconstructed muon track is orange. The segments used to create the muon track are shown in yellow and are projected on to the ends of their respective muon chambers.

LOCAL TRACK SEGMENT RECONSTRUCTION

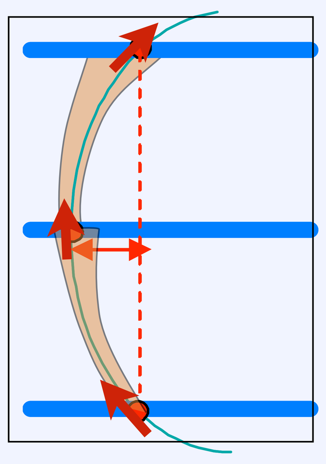
The MDT and CSC detectors provide 4 to 8 η measurements per chamber. In the first stage of the pattern recognition, they are used as independent tracking detectors to reconstruct the local trajectory of muons. Within the chamber the trajectories of the muons can be described by a straight line which simplifies the pattern recognition. Track segments are formed from the MDT/CSC η measurements and associated measurements from the RPC/TGC.

These reconstructed track segments measure the position of the muon in the bending plane (η) with a precision of 40 μm. In addition the MDT chambers measure the track angle in the bending plane with a precision of about 0.3 mrad.



A slice through a barrel chamber, showing the reconstructed segment (yellow), the track (orange) and the measurements used to create them (red and purple). The red measurements are "drift circles" from the MDTs, whilst the purple are RPC strips.

GLOBAL TRACK RECONSTRUCTION

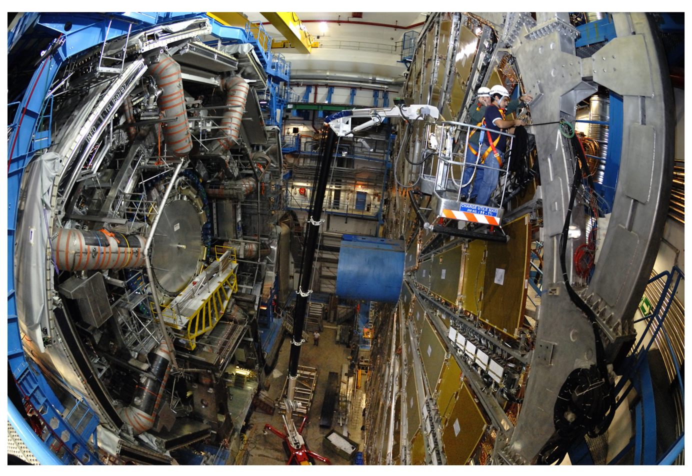


The locally reconstructed track segments are used as seeds for the global track finding. Segments found in the outer chambers are combined with segments from the inner layers of the spectrometer. A track fit is used to combine segments into a track candidate. The procedure is repeated until the innermost station of the spectrometer is reached and at this stage, the track candidate is refitted (taking into account multiple scattering and energy loss) to obtain the final parameters of the track in the Muon Spectrometer.

Finally, the parameters of the muon at the collision point are obtained by combining the Muon Spectrometer track with an associated Inner Detector track and calorimeter measurements (again taking into account energy loss, etc.).

The software is modular, with several different approaches being developed for each step of the reconstruction chain.

Group photo taken during the event celebrating the completion of the installation of all sectors of the ATLAS Big Wheel in the cavern. [Sep. 2007]



An endcap wheel of the Muon Spectrometer in the ATLAS cavern.
[October 2006]

"Big Wheel" endcap muon MDT sector

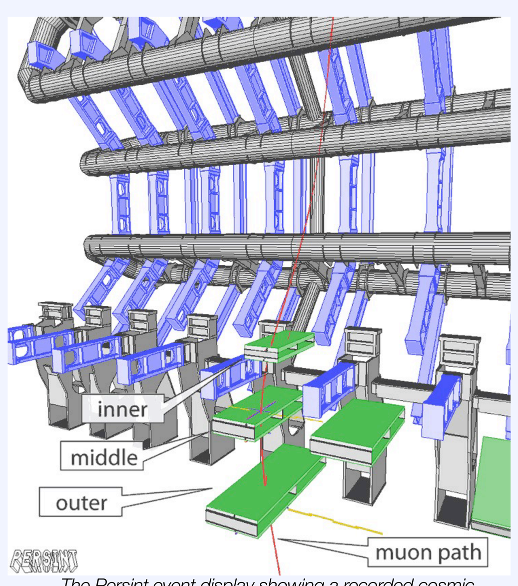
Installation of a barrel chamber

COMMISSIONING

ATLAS is currently being commissioned: 98% of barrel stations are installed and the endcaps are also well advanced.

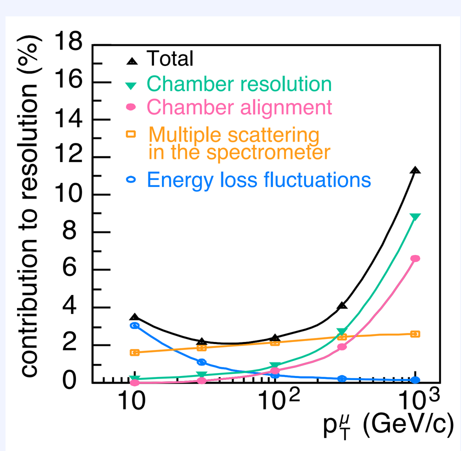
As part of this process, there have been several periods of data-taking and the full software chain has been used to reconstruct these cosmic ray muons. The figure to the right shows a reconstructed muon track curving in the magnetic field of the barrel toroid.

The recording of cosmic data will continue right up to first collisions and will continue to be used to integrate and test ATLAS software.



The Persint event display showing a recorded cosmic ray event. For clarity, only the active muon stations (and some of the toroidal magnets) are shown.

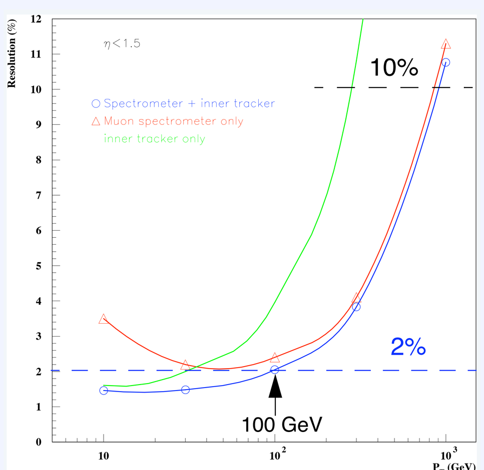
PERFORMANCE



Momentum resolution of the barrel Muon Spectrometer in stand-alone mode.

The Muon Spectrometer is vital to the ATLAS physics program since the muon track momentum resolution is dominated by the Muon Spectrometer at high momentum.

The track finding efficiency is about 90% for $5<p_T<20$ GeV/c and >96% for $p_T>20$ GeV/c at a fake rate<0.5%.



Momentum resolution as a function of transverse momentum.
(ATLAS Muon Spectrometer TDR, CERN/LHCC 97–22)