The ATLAS Muon Spectrometer

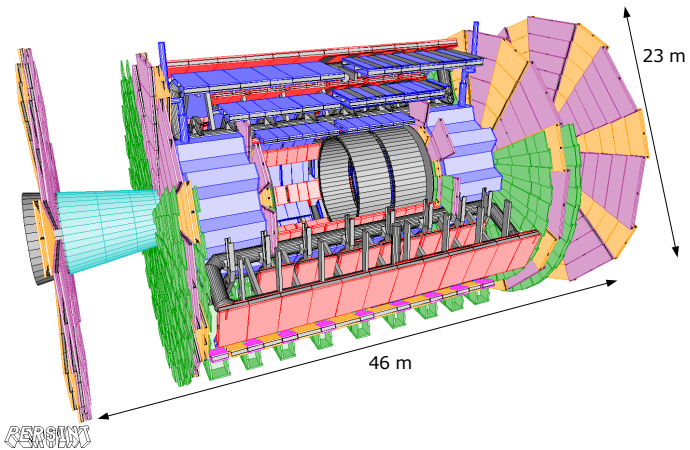
Sandra Horvat
for the ATLAS Muon Collaboration

Institut Ruđer Bošković, Zagreb
Max-Planck-Institut für Physik, Munich

LHC Days in Split • October 5-9, 2004

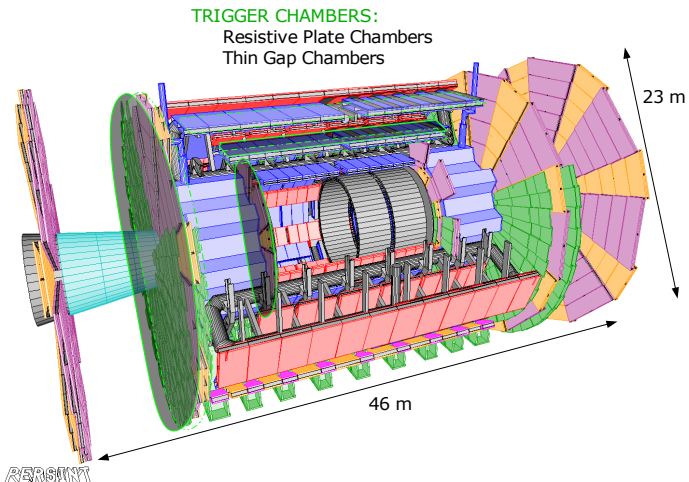
ATLAS Muon Spectrometer

- stand-alone muon momentum measurement
  in a toroidal air-core magnetic field of 0.3 - 1.2 T



ATLAS Muon Spectrometer

- stand-alone muon momentum measurement
  in a toroidal air-core magnetic field of 0.3 - 1.2 T



Fast response to muons (1-2 ns):

- bunch crossing identification

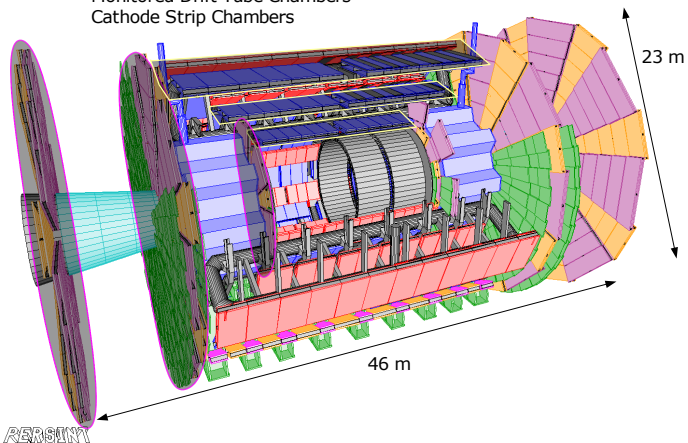
Rough position measurement (1 cm):

- region of interest
- low-p_T and high-p_T trigger

ATLAS Muon Spectrometer

- stand-alone muon momentum measurement
  in a toroidal air-core magnetic field of 0.3 - 1.2 T

PRECISION CHAMBERS:
Monitored Drift Tube Chambers
Cathode Strip Chambers

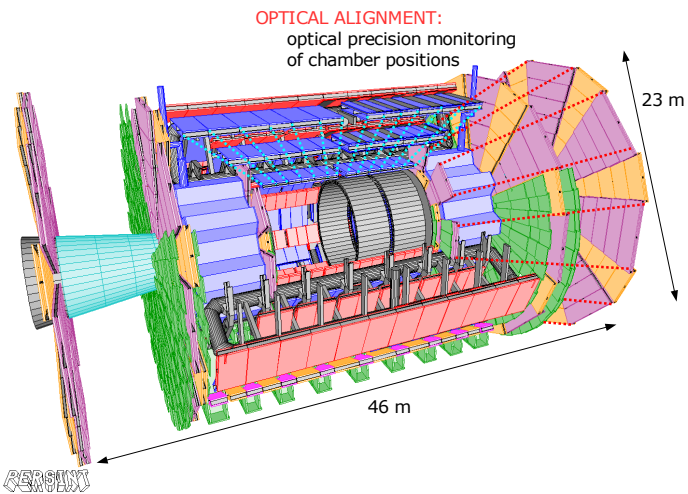


High position resolution (40 μm) in the direction of the track bending.

- high mechanical accuracy
- high spatial resolution in single cells

ATLAS Muon Spectrometer

- stand-alone muon momentum measurement
  in a toroidal air-core magnetic field of 0.3 - 1.2 T

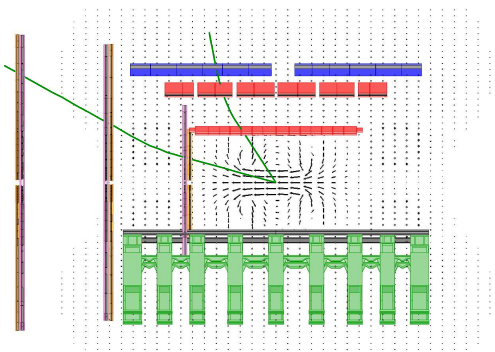


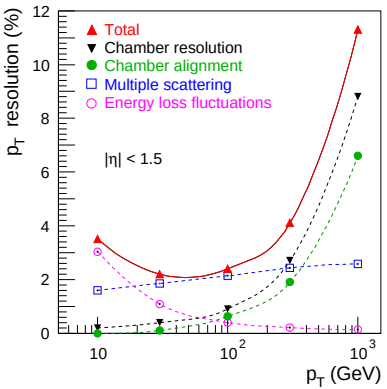
Measurement of the displacements due to the magnetic field and temperature changes.

- optical sensors on the lines-of-sight connecting chambers in all layers
- track bending corrections with 40 μm precision

Performance Goals

- track bending measured in 3 stations with resolution of 40 μm
- high muon p_T-resolution of 3-10% for $p_T = 6 - 1000\ GeV$





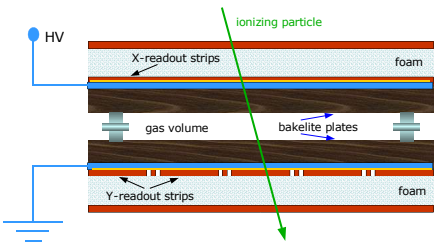
- stand-alone muon momentum measurement
- operation under high photon background irradiation

Production and Quality Assurance

Trigger Chamber Production

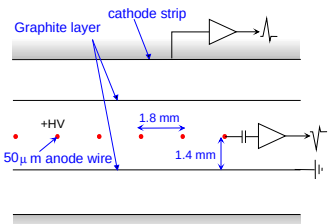
Resistive Plate Chambers, RPC

- 1116 chambers in the barrel region
- gas gap between 2 resistive plates, rectangular shape chambers



Thin Gap Chambers, TGC

- 1578 chambers in the end-cap region
- multiwire proportional chambers, trapezoidal shape

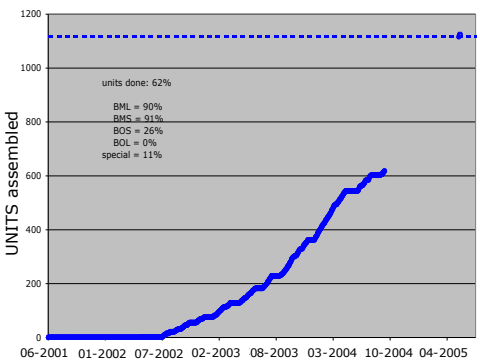


Trigger Chamber Production

Resistive Plate Chambers, RPC

- 1116 chambers in the barrel region
- 4 production sites, 50% produced
  completion expected in spring 2005

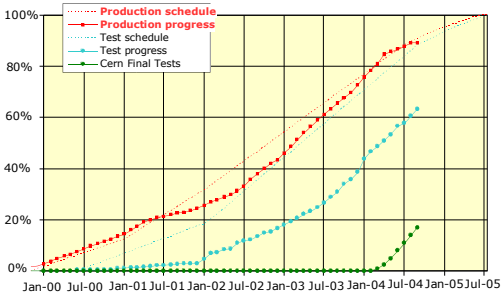
RPC UNITS PRODUCTION



Thin Gap Chambers, TGC

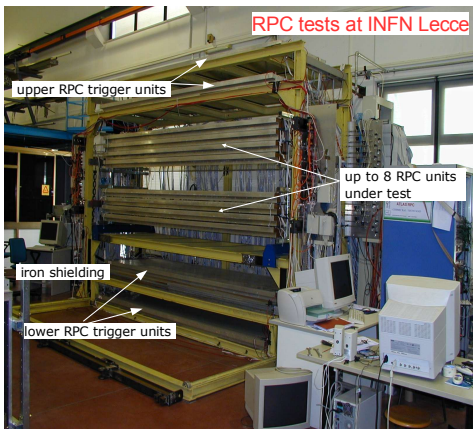
- 1578 chambers in the end-cap region
- 3 production sites, 90% produced
  completion in July 2005

TGC production & test status

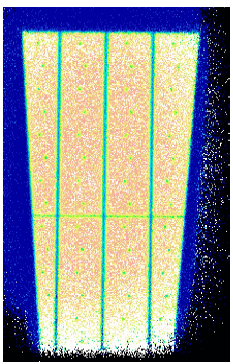


Trigger Chamber Quality Assurance

Each chamber tested for efficiency and noise with cosmic muon rays:



- efficiency map for one TGC unit



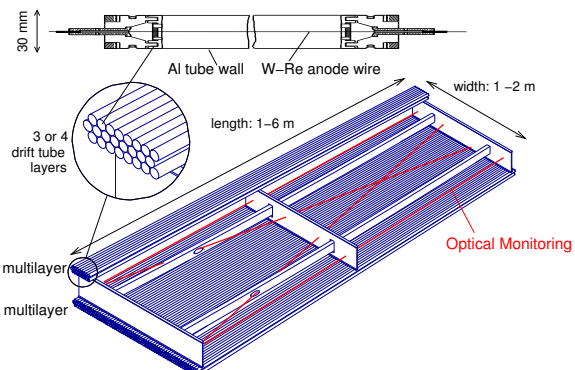
- average efficiency of 98% for RPC and 95% for TGC is achieved.

Additional tests of the long term stability and of the operation under high irradiation rates show a reliable performance.

Precision Chamber Production

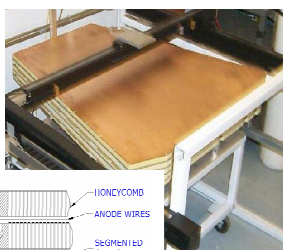
Monitored Drift Tube Chambers

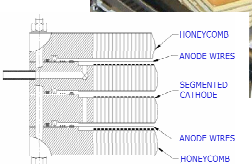
- 1200 chambers covering 99.9% of the total spectrometer area
- layers of cylindrical drift tubes with anode wires positioned in the chamber with a 20 μm precision



Cathode Strip Chambers, CSC

- 64 chambers in the two innermost end-cap disks (regions of highest background irradiation)
- multiwire proportional chambers, trapezoidal shape



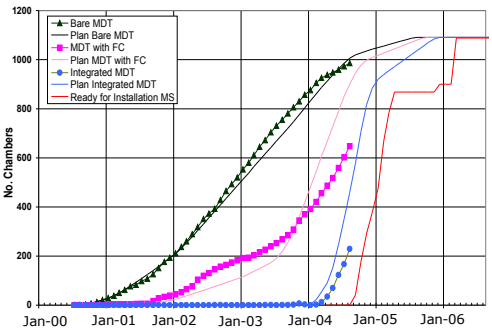


Precision Chamber Production

Monitored Drift Tube Chambers

- 1200 chambers covering 99.9% of the total spectrometer area
- 13 production sites, 85% produced

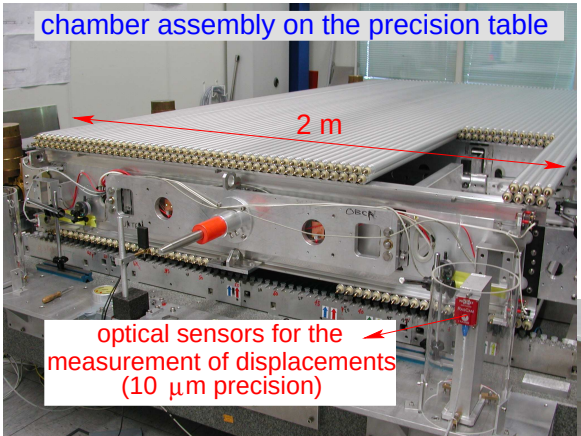
MDT Chamber Production



Cathode Strip Chambers, CSC

- 64 chambers in the two innermost end-cap disks (regions of highest background irradiation)
- all chambers produced

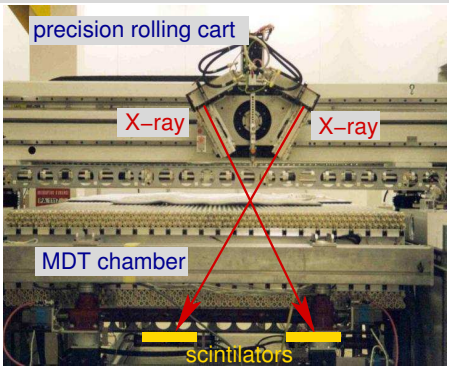
MDT Chamber Assembly



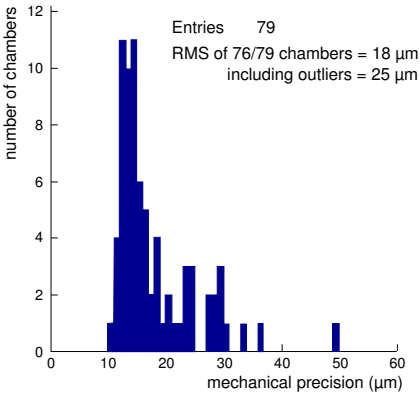
Micrometer precision of the chamber positioning and optical monitoring of drift tube positions.

MDT Chamber Quality Assurance

Measurement of wire positions with an X-ray Tomograph at CERN (for 10% of chambers from each production site):



measurement of the intensity along the chamber

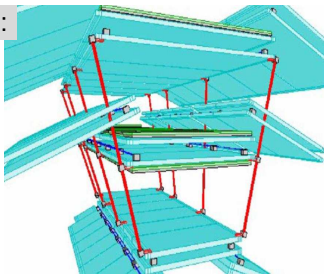


The response to muons (noise, efficiency, resolution) is measured in each chamber at cosmic ray test benches.

Alignment System

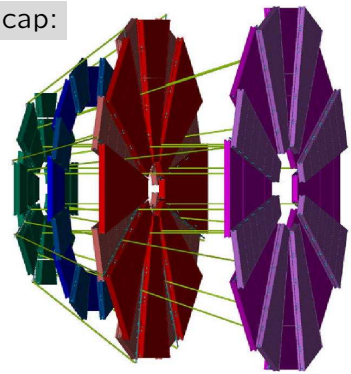
Based on the (light source / lens / CCD)-systems positioned along the alignment lines of sight:

Barrel:



- ∼2500 sensors for alignment of chambers within one layer
  40% produced and calibrated
- ∼128 sensors for alignment between the three layers
  production to start 2005

End-cap:

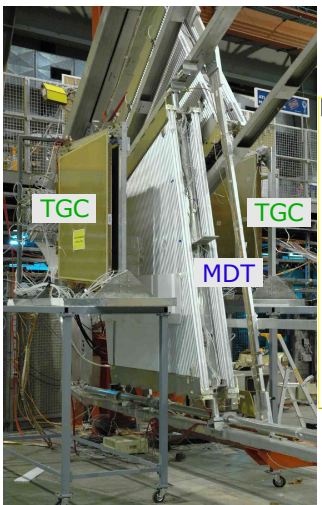


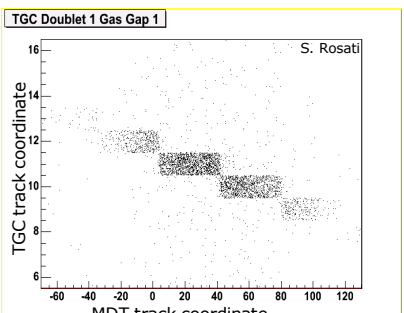
- ∼3000 sensors for alignment of chambers within and between the disks
  40% produced, 20% calibrated

Performance Tests with Muon Beams at CERN

Test with a 25 ns beam structure

- TGC chambers tested together with the MDT chambers and their alignment
- 25 ns beam intervals corresponding to the LHC bunch crossing intervals

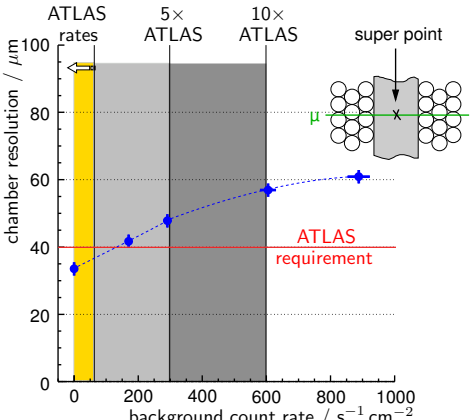


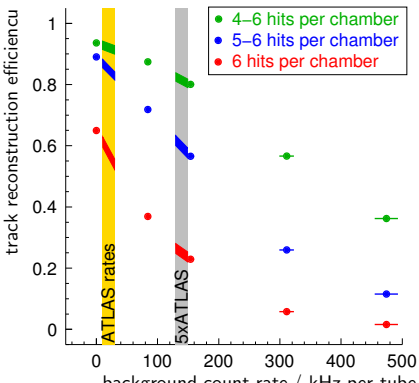


99.5% trigger efficiency with respect to muon tracks

Performance under High γ-Irradiation

Test of the MDT-chamber response to muons under influence of high background rates:



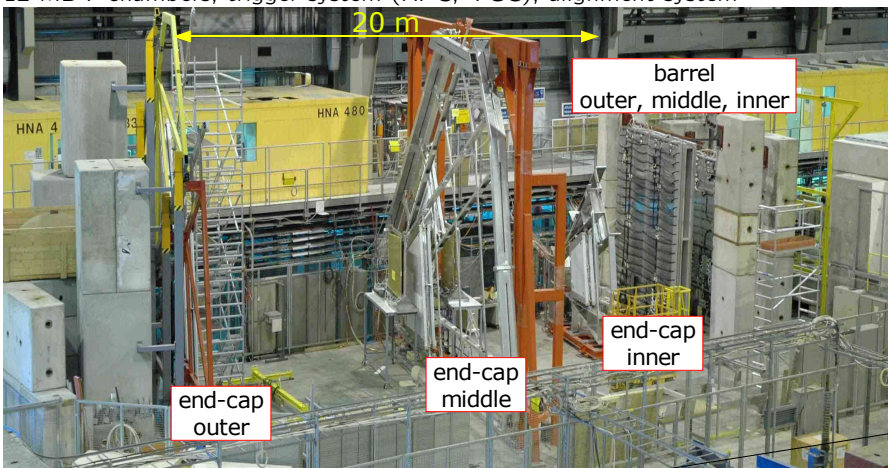


- performance within the requirements even under the high background rates

Myon System Test

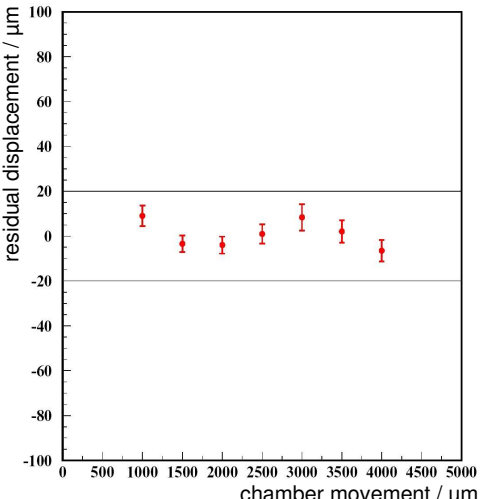
Full system test with one ATLAS end-cap and one barrel sector:

12 MDT chambers, trigger system (RPC, TGC), alignment system



- chamber installation with ATLAS like tools
- performance of the data acquisition system
- test of the barrel and the end-cap alignment system

Alignment System Performance



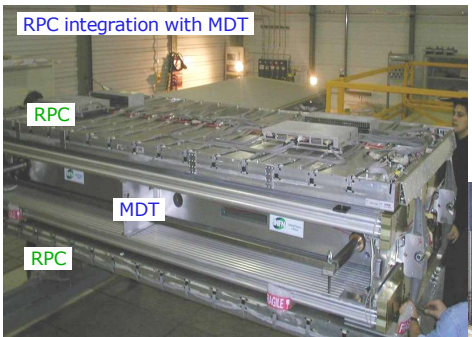
- absolute chamber positions are calculated from the reconstructed straight muon tracks
- optical alignment system independently measures the chambers movements

The accuracy of the alignment system is better than 20 μm.

Chamber Integration and Installation in ATLAS

Integration and Commissioning

- chambers from different production sites are shipped to CERN
- precision and trigger chambers are integrated into common assemblies
- final commissioning (functionality) test before installation into ATLAS

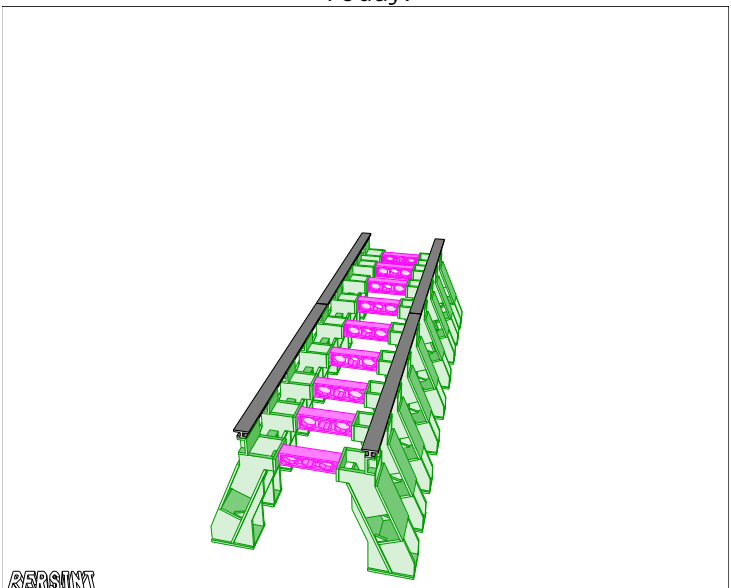


The preparations are starting to ramp up.
~20% chambers integrated

Installation into ATLAS

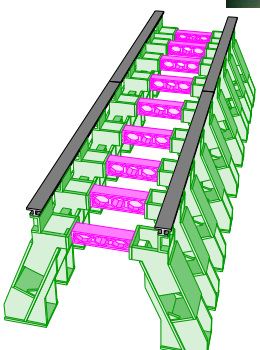
Installation into ATLAS

Today:



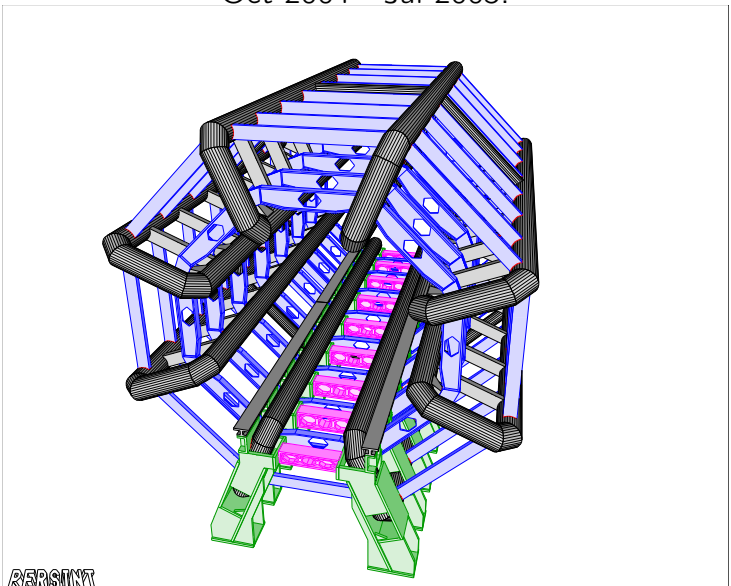
Installation into ATLAS

Today:



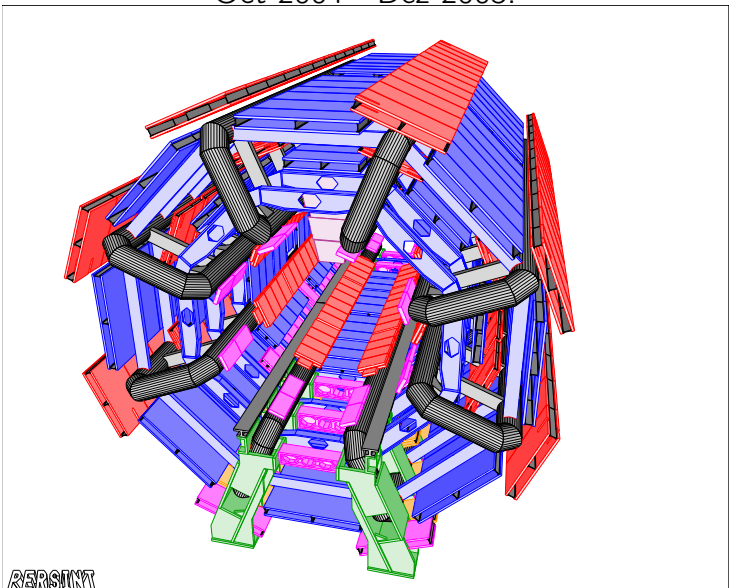
Installation into ATLAS

Oct 2004 - Jul 2005:



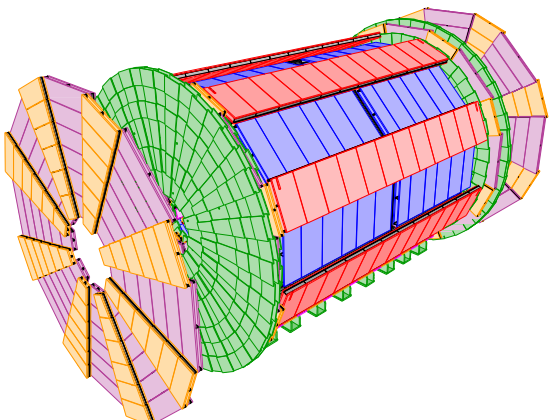
Installation into ATLAS

Oct 2004 - Dez 2005:



Installation into ATLAS

Finished Feb 2007; first physics run Mid 2007.

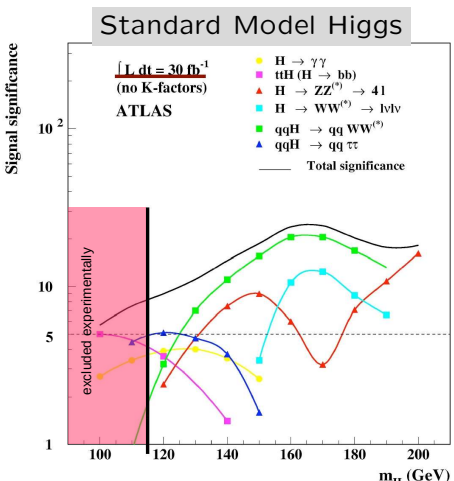


Commissioning of the spectrometer with cosmics muons during the whole installation period.

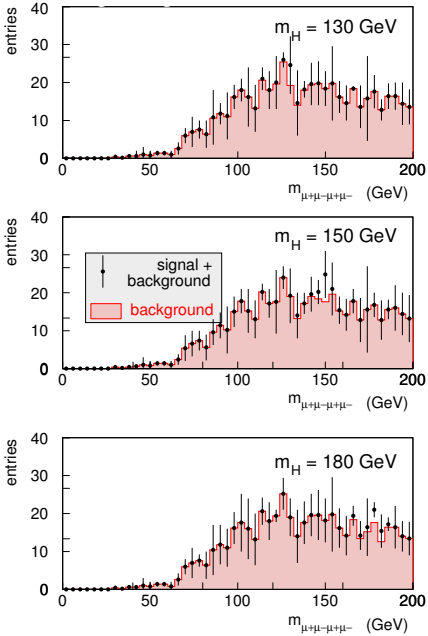
Physics Potential

Physics Spectra

- precision tests of the Standard Model:
  $t \to b\mu\nu$, $W \to \mu\nu$, $Z \to \mu\mu$
- search for the Standard Model Higgs boson:
  $H \to WW^{(*)}$, $H \to ZZ^{(*)}$
- search for the extensions or alternatives to the Standard Model:
  $H/A \to \mu\mu$, $H/A \to \tau\tau$
  supersymmetric particles
  extra dimensions



$H \to ZZ^* \to \mu^+\mu^-\mu^+\mu^-$ at 30 fb^{-1}



Full detector simulation of the signal and background processes is performed.

4μ invariant mass after the trigger selection of muons: signal is hidden below the background of

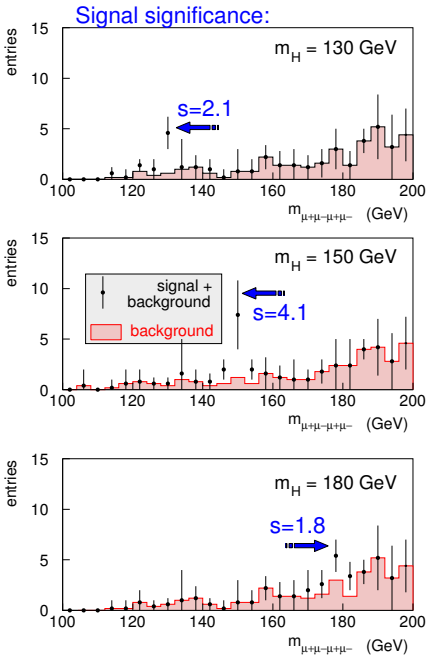
$q\bar{q}, gg \to Zb\bar{b} \to \mu\mu b\bar{b}$

$q\bar{q}, gg \to t\bar{t} \to WbW\bar{b}$

$q\bar{q}, gg \to ZZ^{(*)}, Z\gamma^* \to 4\mu$

$q\bar{q}, gg \to ZZ^{(*)}, Z\gamma^* \to 2\mu 2\tau.$

$H \rightarrow ZZ^* \rightarrow \mu^+\mu^-\mu^+\mu^-$ at 30 fb^{-1}



4μ invariant mass after the trigger selection of muons and the selection cryteria requiring:

- no jet around the muon
- $m_{\mu^+\mu^-}$ peaks around the Z-resonance
- common vertex of four muons

After 3 years of ATLAS operation at a low luminosity, the signal significance is 2 - 4σ.

Combination with decay channels into electrons provides the 5σ significance needed for the discovery.

Summary

Production of the instrumentation for the ATLAS muon spectrometer is well under way and soon to be finished.
Extensive quality assurance tests are performed for all components.
The results of the performance studies in the muon beam and under high irradiation rates are within the designed goals.

The accent is now put on the final commissioning of the chambers and the preparation for the installation into ATLAS.
Installation into ATLAS starts within the next month.

During the installation, the spectrometer will be commissioned with cosmic rays long before the first physics run.

Simulation of physics processes is important for a good understanding of the detector performance and of the physics potential.

Summary

Production of the instrumentation for the ATLAS muon spectrometer is well under way and soon to be finished.
Extensive quality assurance tests are performed for all components.
The results of the performance studies in the muon beam and under high irradiation rates are within the designed goals.

The accent is now put on the final commissioning of the chambers and the preparation for the installation into ATLAS.
Installation into ATLAS starts within the next month.

During the installation, the spectrometer will be commissioned with cosmic rays long before the first physics run.

Simulation of physics processes is important for a good understanding of the detector performance and of the physics potential.

Summary

Production of the instrumentation for the ATLAS muon spectrometer is well under way and soon to be finished.
Extensive quality assurance tests are performed for all components.
The results of the performance studies in the muon beam and under high irradiation rates are within the designed goals.

The accent is now put on the final commissioning of the chambers and the preparation for the installation into ATLAS.
Installation into ATLAS starts within the next month.

During the installation, the spectrometer will be commissioned with cosmic rays long before the first physics run.

Simulation of physics processes is important for a good understanding of the detector performance and of the physics potential.

Summary

Production of the instrumentation for the ATLAS muon spectrometer is well under way and soon to be finished.
Extensive quality assurance tests are performed for all components.
The results of the performance studies in the muon beam and under high irradiation rates are within the designed goals.

The accent is now put on the final commissioning of the chambers and the preparation for the installation into ATLAS.
Installation into ATLAS starts within the next month.

During the installation, the spectrometer will be commissioned with cosmic rays long before the first physics run.

Simulation of physics processes is important for a good understanding of the detector performance and of the physics potential.