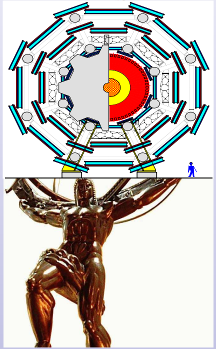
The Status of ATLAS Construction

Sandra Horvat
for the ATLAS Collaboration

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

LHC Days in Split • October 5-9, 2004, Croatia

The Status of ATLAS Muon Spectrometer



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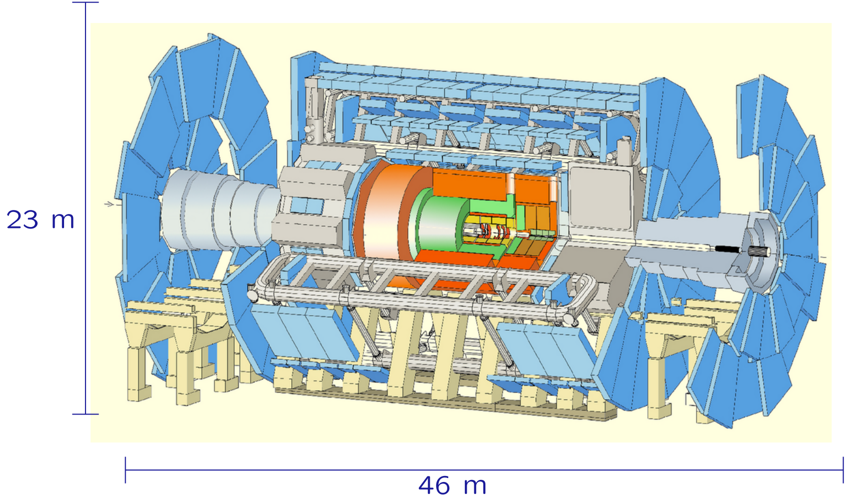
ATLAS Detector (A Toroidal LHC ApparatuS)

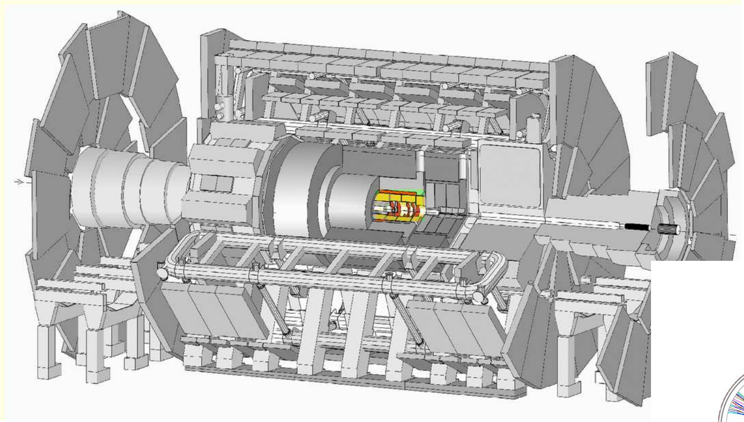
Multi-purpose detector for the widest range of physics at the LHC:

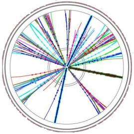


Almost the whole solid angle around the interaction point is covered.
Detector design is strongly influenced by the high interaction rates.

ATLAS Detector (A Toroidal LHC ApparatuS)

Multi-purpose detector for the widest range of physics at the LHC:



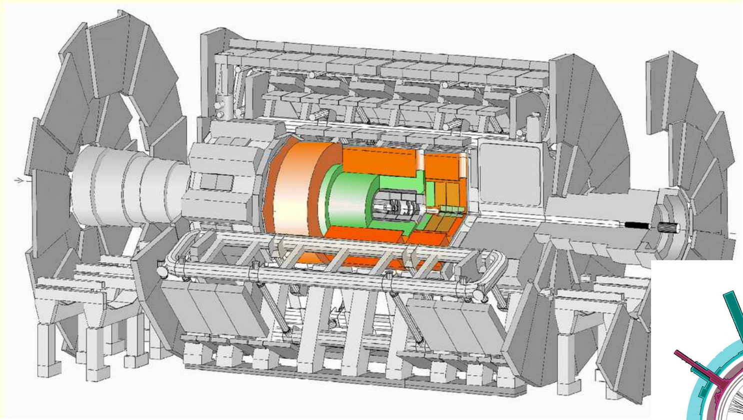


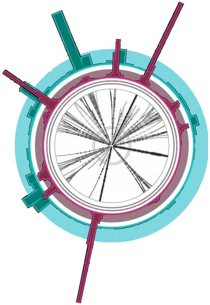
Inner Detector, in a solenoidal magnetic field of 2 T:

- tracking and momentum measurement of charged particles
- decay vertices close to the beam

ATLAS Detector (A Toroidal LHC ApparatuS)

Multi-purpose detector for the widest range of physics at the LHC:



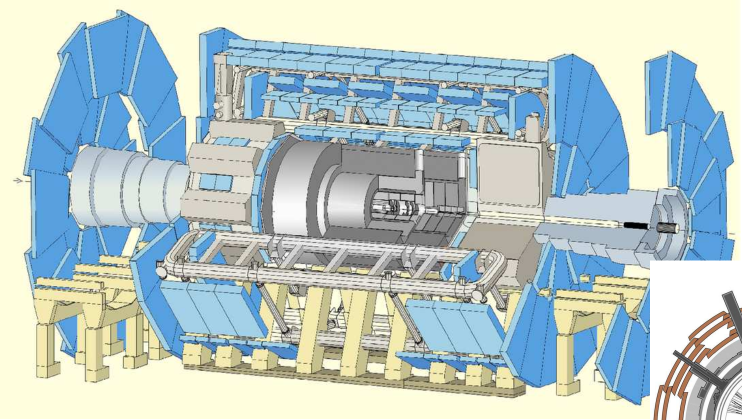


Electromagnetic and Hadronic Calorimeter:

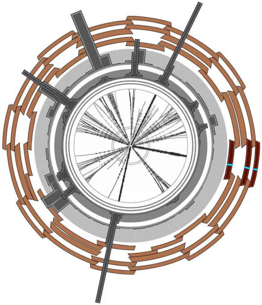
- energy and direction of e, γ and hadrons
- missing energy
- particle identification

ATLAS Detector (A Toroidal LHC ApparatuS)

Multi-purpose detector for the widest range of physics at the LHC:



Muon Spectrometer, in a toroidal mag. field of 0.3-1.2 T:



- stand-alone high-precision measurement of muon momenta

It's starting to grow...

ATLAS cavern: May 2002.

- Cavern: May 2002.
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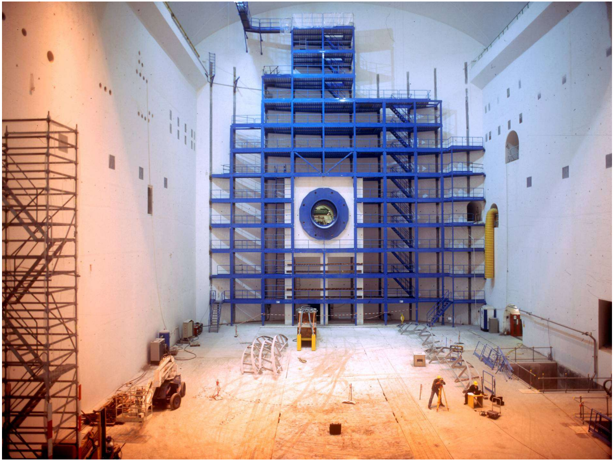
It's starting to grow...

ATLAS cavern: Aug 2003.



- Cavern: May 2002.
- Infrastructure: Sep 2003.
-
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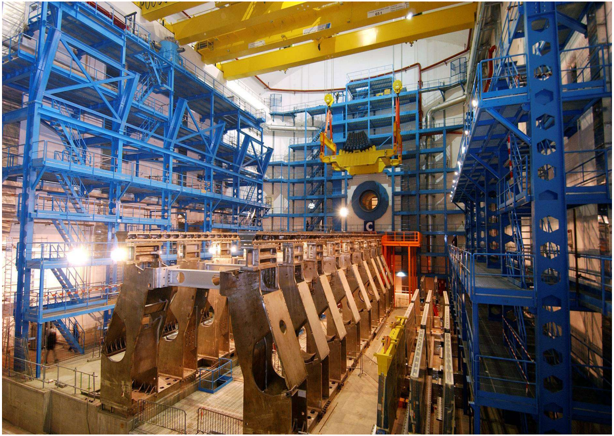
-

It's starting to grow...

ATLAS cavern: Mar 2004.



- Cavern: May 2002.
- Infrastructure: Sep 2003.
- Feet structure: Feb 2004.

It's starting to grow...

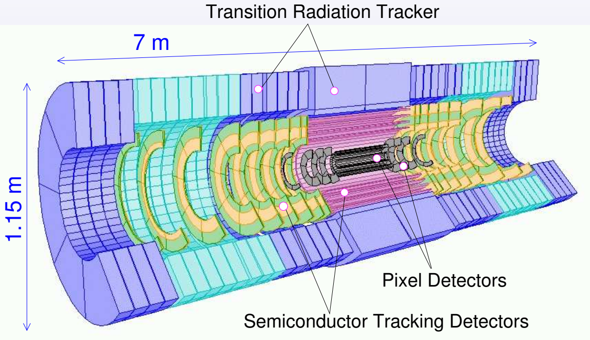
ATLAS cavern: Jul 2004.

- Cavern: May 2002.
- Infrastructure: Sep 2003.
- Feet structure: Feb 2004.
- Barrel calorimeter: Jan 2005.
- Barrel toroid: Oct 2005.
- Barrel Muon: Dec 2005.
- End-cap calorim.: Aug 2006.
- Inner detector: Sep 2006.
- End-cap toroid: Oct 2006.
- Beam vacuum: Nov 2006.
- End-cap muon: Feb 2007.
- Shielding: Feb 2007.

Commissioning of most subdetectors during 2006.

Ready for the beam: March 2007.

Inner Detector



Requirements:

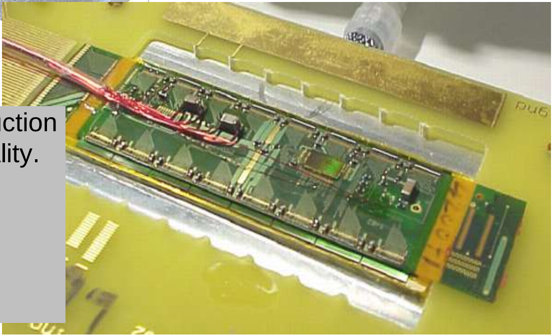
- momentum resolution of 10% (at 100 GeV) to 50% (at 500 GeV)
- decay vertex position resolution of $\sim 20\ \mu m$

Major challenges:

- high occupancy requires high granularity (in space and time)
- severe radiation rates (3×10^{14} proton/cm^2/year)

Pixel Detectors

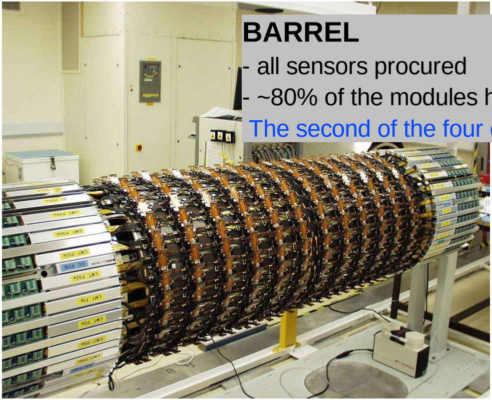
The support structures have been delivered.



60% of the sensor production complete, with good quality.

The module production has just started, full production rate still to be proven.

Semiconductor Tracking Detectors



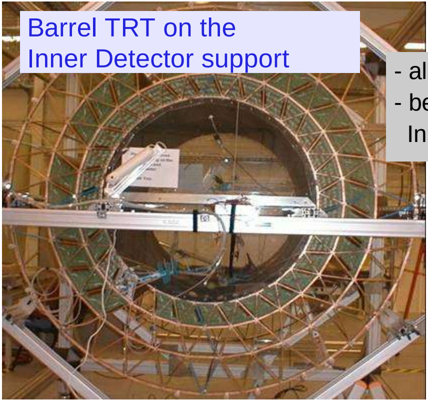
BARREL
- all sensors procured
- ~80% of the modules have been produced

The second of the four cylinders is just being assembled.

END-CAP
- all sensors procured
- module production now started, after a slow start-up (> 15 %)

The current end-cap disk assembly started, is on the critical path.

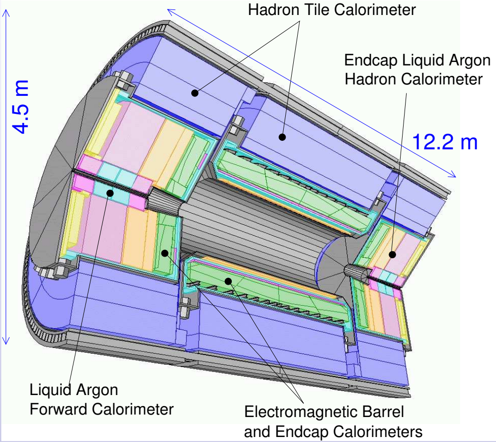
Transition Radiation Tracker



- all barrel modules are made and at CERN
- being mounted on the barrel
  Inner Detector support structure

- construction of the forward wheels
  started, on the crytical path

Calorimeters



Requirements:

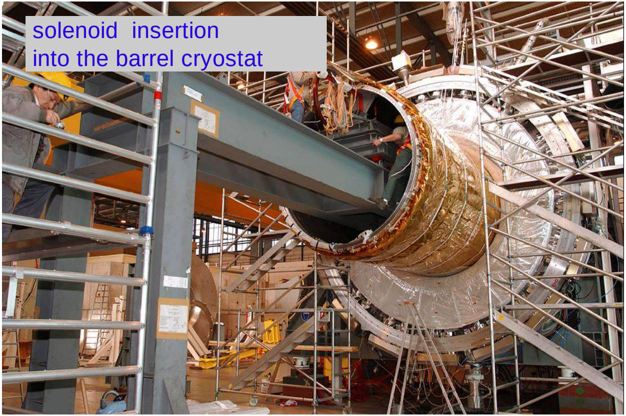
- high energy resolution

  jets: $50\%/\sqrt{E} \oplus 3\%$; electrons: $10\%/\sqrt{E} \oplus 0.7\%$
- uniform response

Major challenges:

- high occupancy requires fast response
- long-term stability of the electronics, radiation hardness

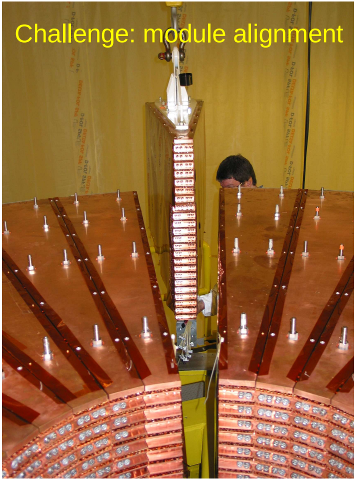
Barrel Calorimeter

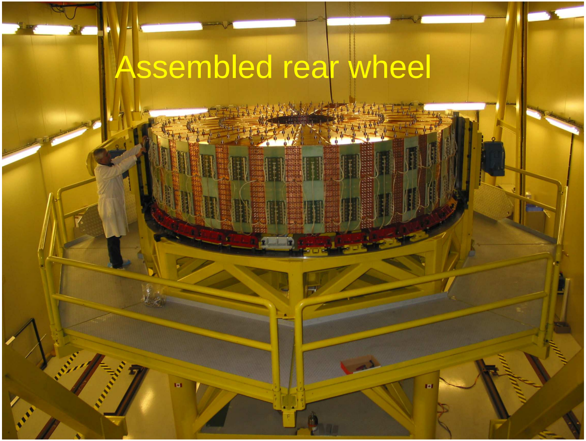


- barrels are ready for installation, will be lowered in the cavern by end ’ 04
- barrel EM calorimeter and the solenoid have been cooled at the surface and succesfully passed the final electrical test
- cryostat is warmed up again, will be transported into cavern Oct '04
- the front-end electronics mass production has started, all radiation-hard chips are in hand

End-Cap Wheels Assembly

All end-cap modules are assembled and mounted into wheels.

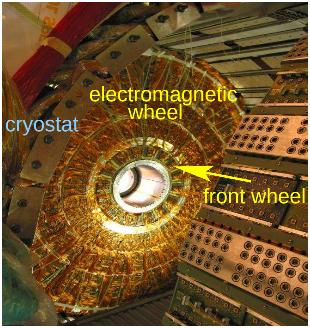


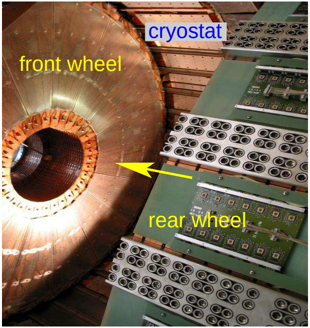


End-Cap Calorimeters

The liquid-argon wheels are all assembled.
One end-cap inserted into cryostat and tested with very good results.
Second end-cap integration in a well advanced stage.

← electromagnetic ← front hadronic ← rear hadronic ← forward



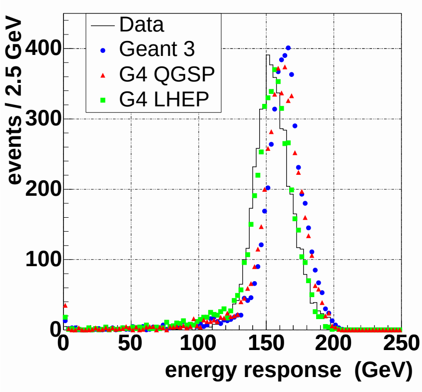


End-Cap Calorimeter Performance

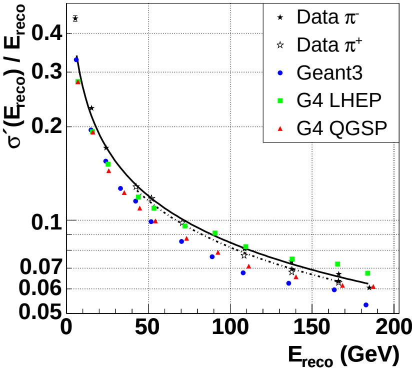
Years of tests with muon, pion and electron beams allow for the

- development of the algorithms for the energy measurement
- tuning of the simulation models to the experimental data

Calorimeter response to 200 GeV pions:

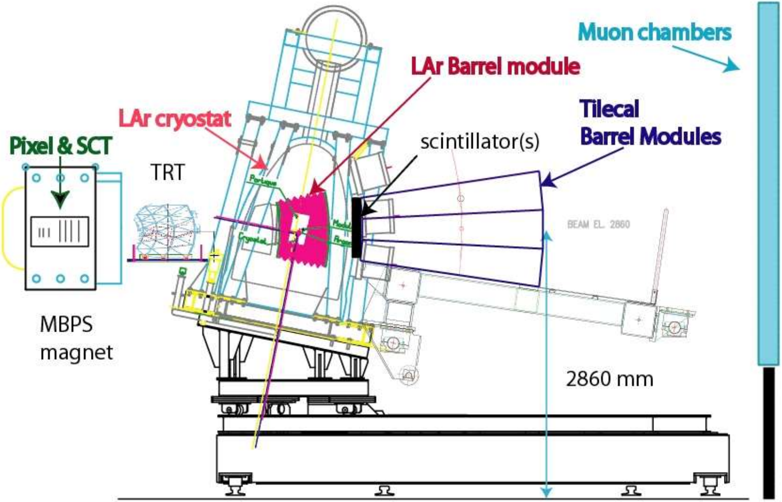


Calorimeter energy resolution:

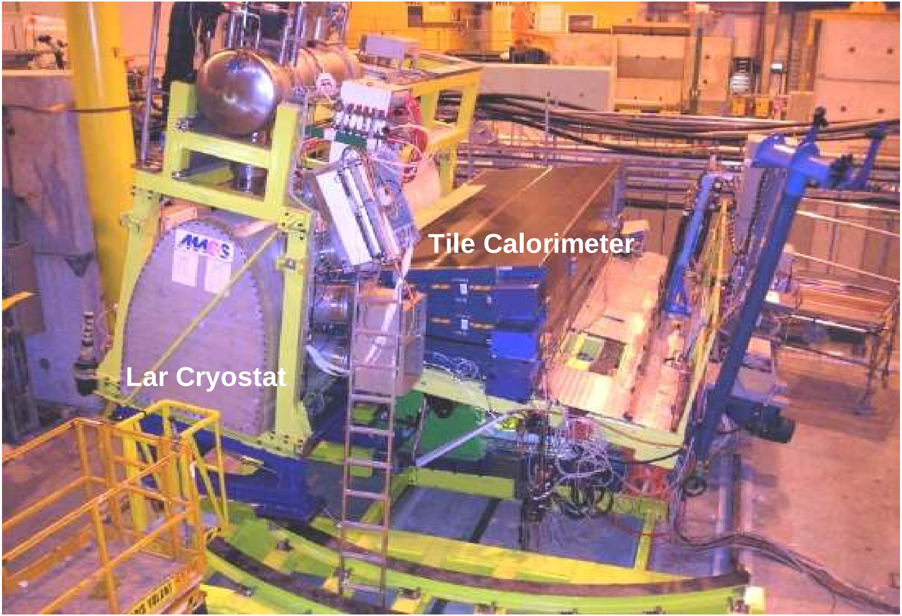


Combined Test Beam

The combined test beam of all ATLAS subsystems runs 2004 in the CERN SPS H8 and H6 beam lines (1 to 300 GeV/c).



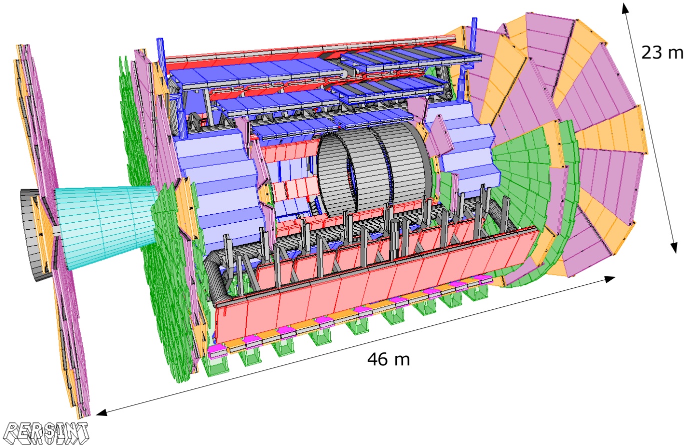
Combined Test Beam



MUON SPECTROMETER

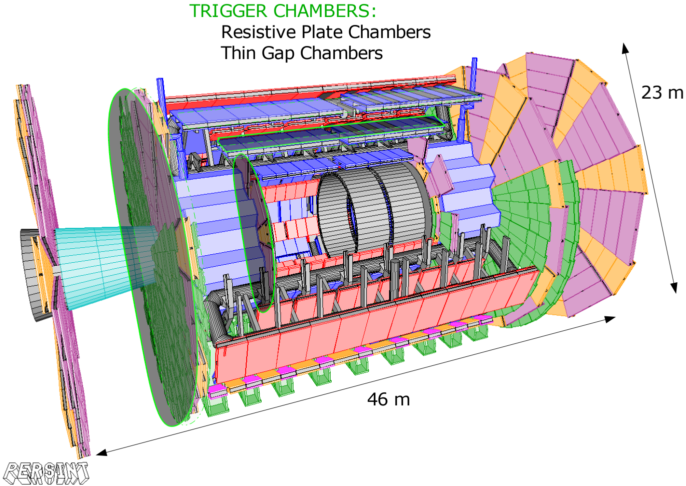
ATLAS Muon Spectrometer

- 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):

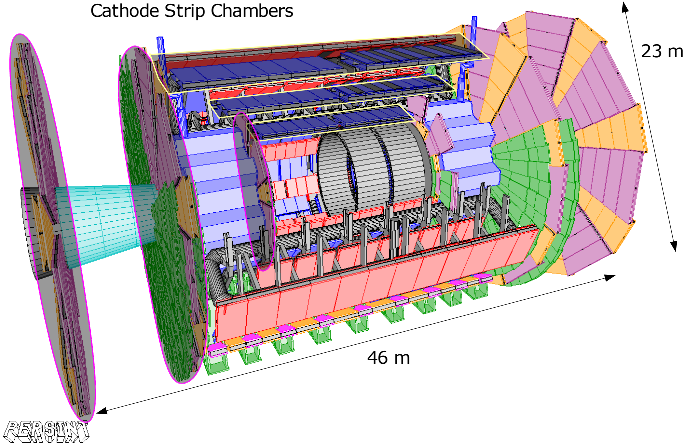
- region of interest
- low-p_T and high-p_T trigger

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



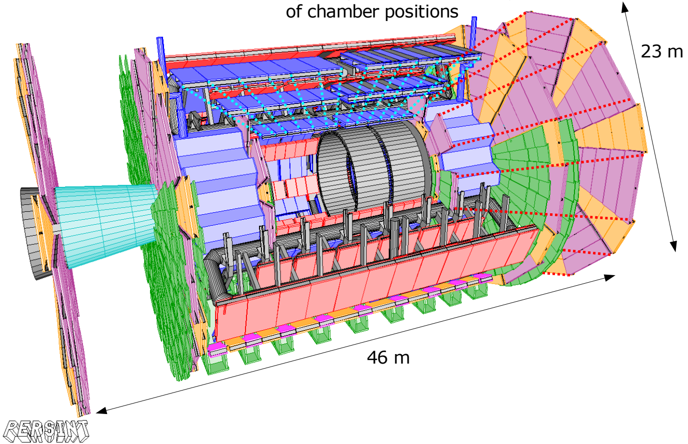
High position resolution (40 μm) in the direction of the track bending.

- 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

OPTICAL ALIGNMENT:
optical precision monitoring of chamber positions

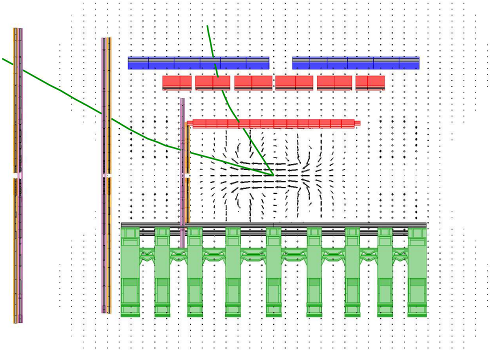


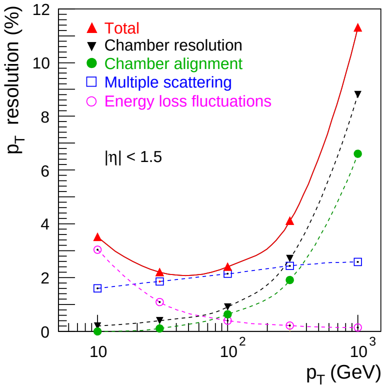
Measurement of the displacements due to the magnetic field and temperature changes.

- 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 $p_T = 6 - 1000\ GeV$





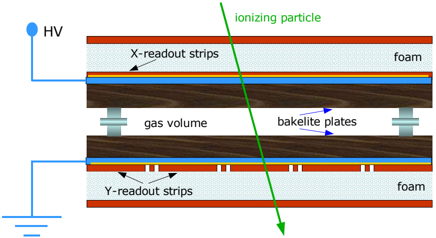
- stand-alone muon momentum measurement
- operation under high photon background irradiation

Chamber Production and Quality Assurance

Trigger Chamber Production

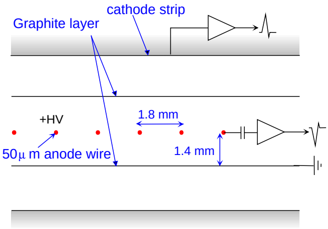
Resistive Plate Chambers, RPC

- 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



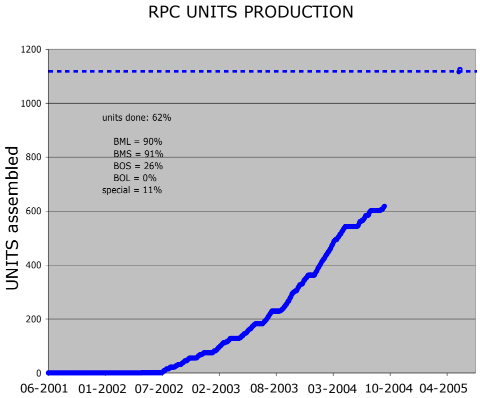
Trigger Chamber Production

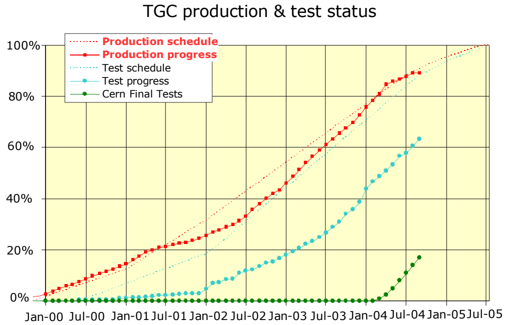
Resistive Plate Chambers, RPC

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

Thin Gap Chambers, TGC

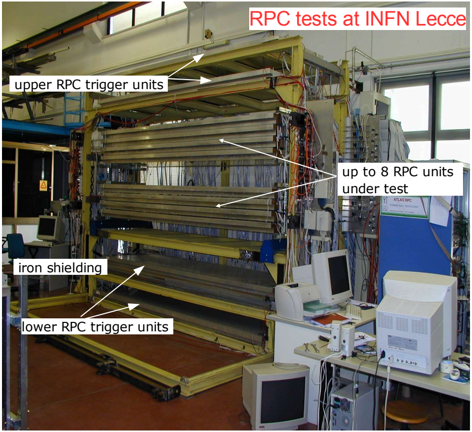
- 1578 chambers in the end-cap region
- 3 production sites, 90% produced
  completion in July 2005



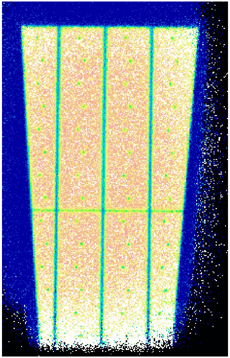


Trigger Chamber Quality Assurance

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.

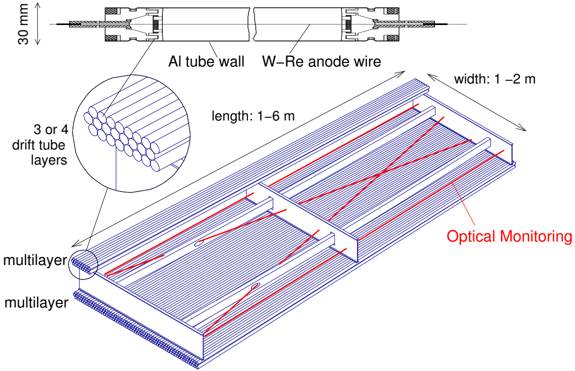
Precision Chamber Production

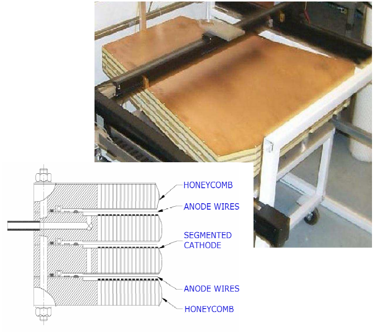
Monitored Drift Tube Chambers

- 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



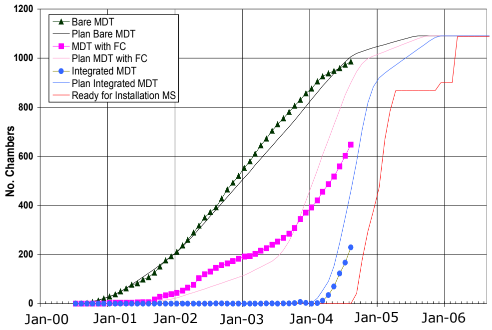


Precision Chamber Production

Monitored Drift Tube Chambers

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

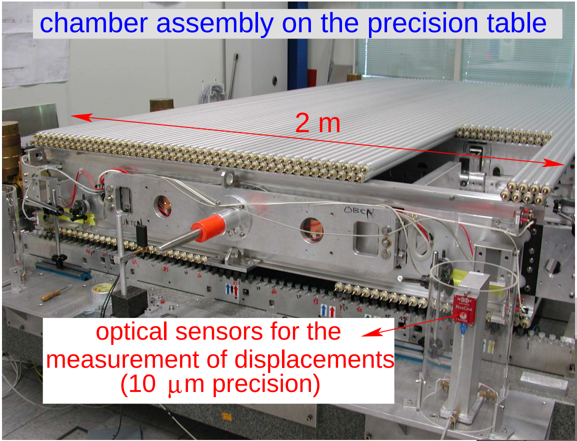
MDT Chamber Production



Cathode Strip Chambers, CSC

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

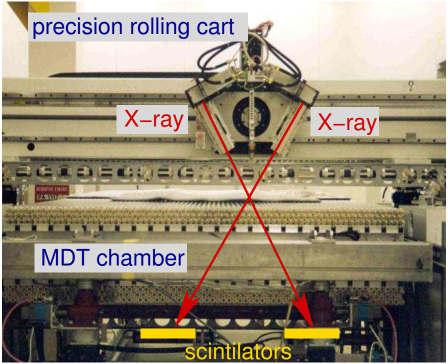
MDT Chamber Assembly



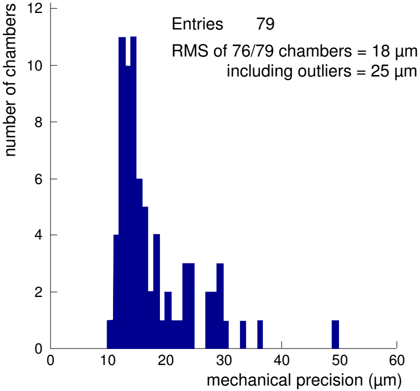
Micrometer precision
of the chamber positioning
and optical monitoring
of drift tube positions.

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

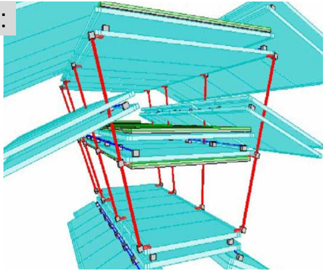


The response to muons (noise, efficiency, resolution) is measured in each chamber at cosmic ray test benches.

Alignment System

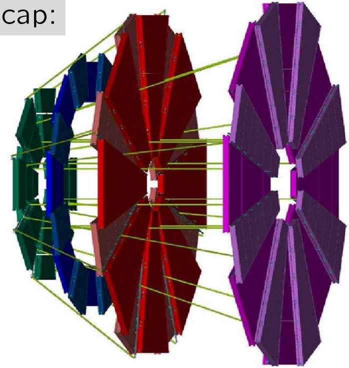
Based on the (light source / lens / CCD)-systems positioned along the alignment lines of sight:

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:

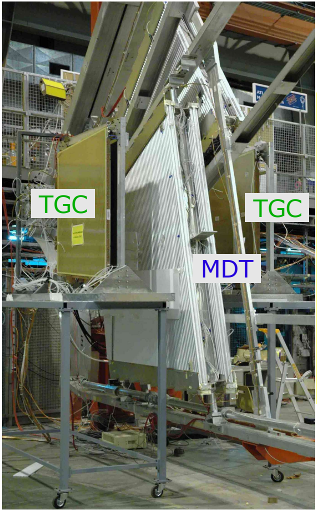


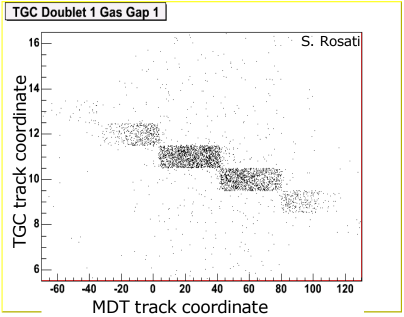
- ∼3000 sensors for alignment of chambers within and between the disks
  40% produced, 20% calibrated

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

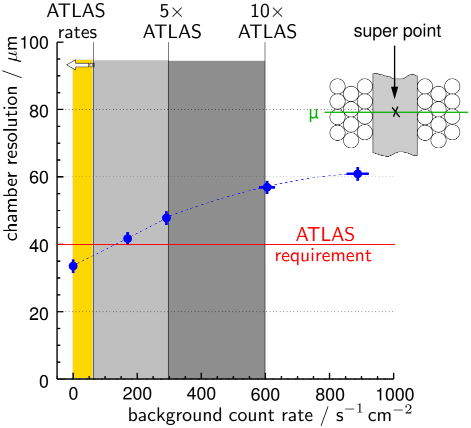


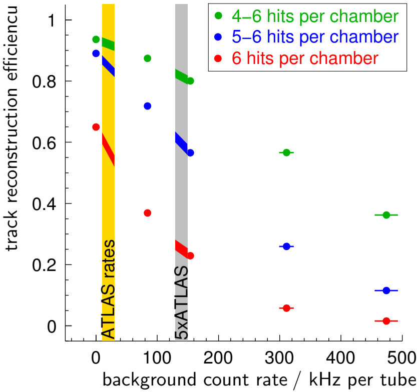


99.5% trigger efficiency with respect to muon tracks

Performance under High γ-Irradiation

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



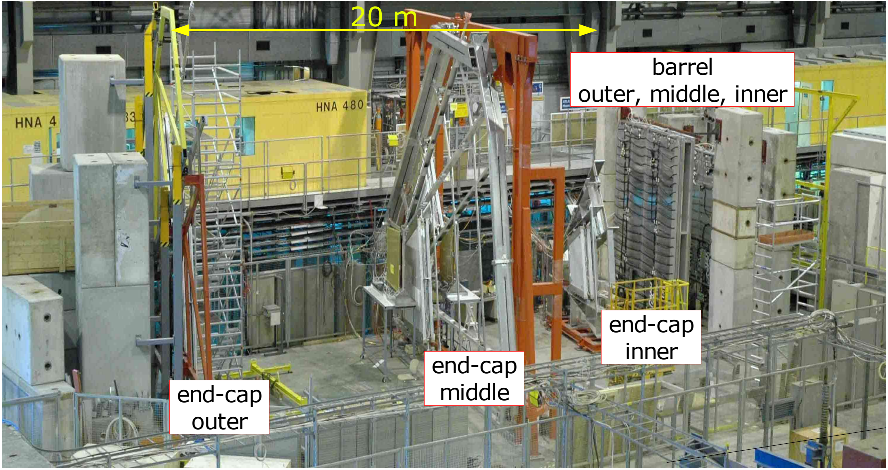


- performance within the requirements even under the high background rates

Myon System Test

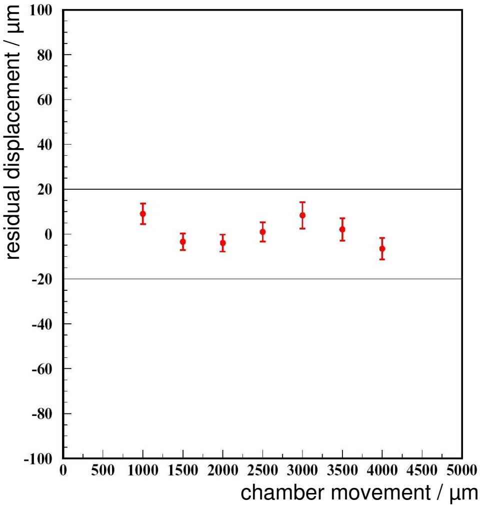
Full system test with one ATLAS end-cap and one barrel sector:

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



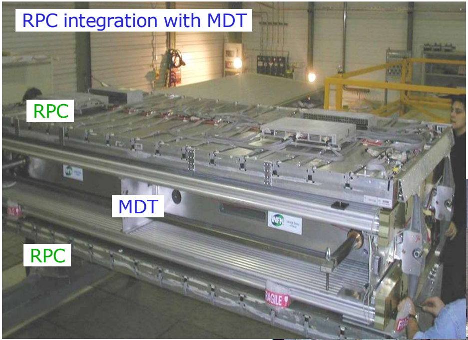
- absolute chamber positions are calculated from the reconstructed straight muon tracks
- optical alignment system independently measures the chambers movements

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

Chamber Integration and Installation in ATLAS

Integration and Commissioning

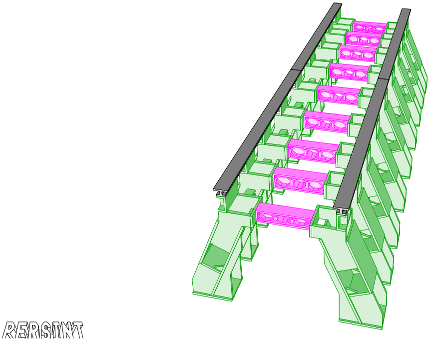
- chambers from different production sites are shipped to CERN
- precision and trigger chambers are integrated into common assemblies
- final commissioning (functionality) test before installation into ATLAS



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

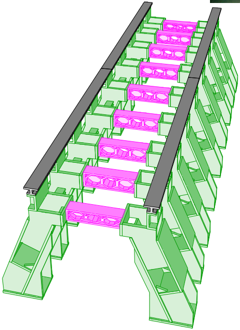
Installation into ATLAS

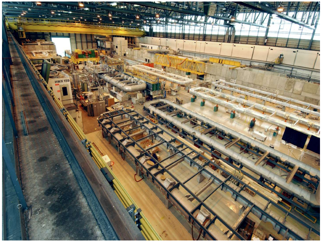
Today:



Installation into ATLAS

Today:

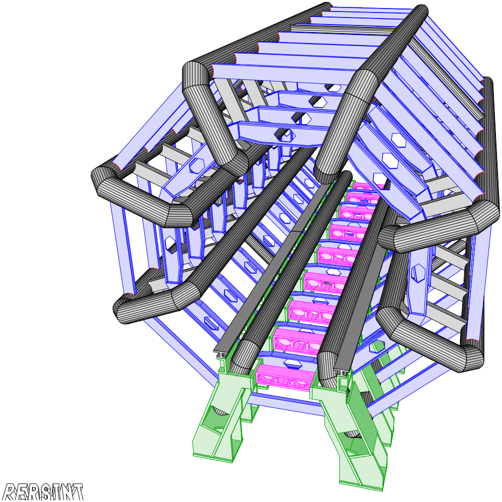




PERSINT

Installation into ATLAS

Oct 2004 - Jul 2005:



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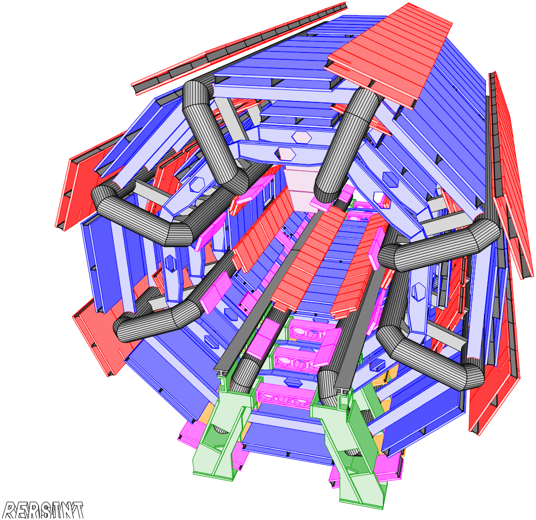
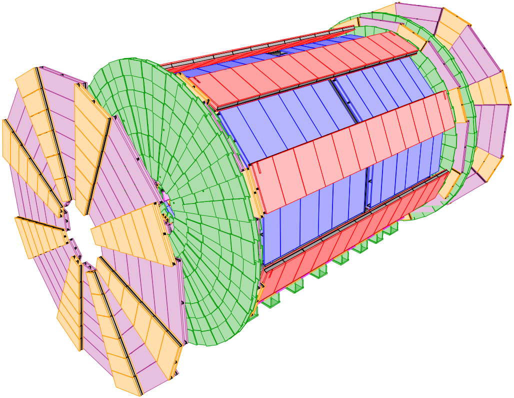
Oct 2004 - Dez 2005:



Installation into ATLAS

Finished Feb 2007; first physics run Mid 2007.



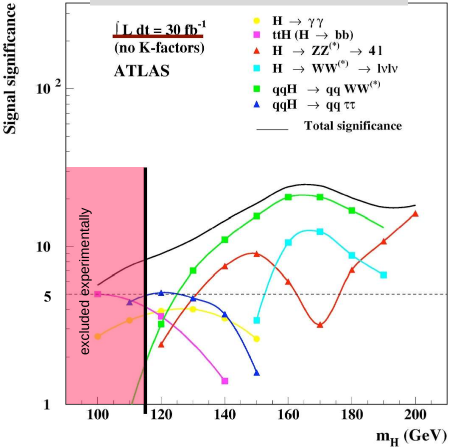
Commissioning of the spectrometer with cosmics muons during the whole installation period.

Physics Potential

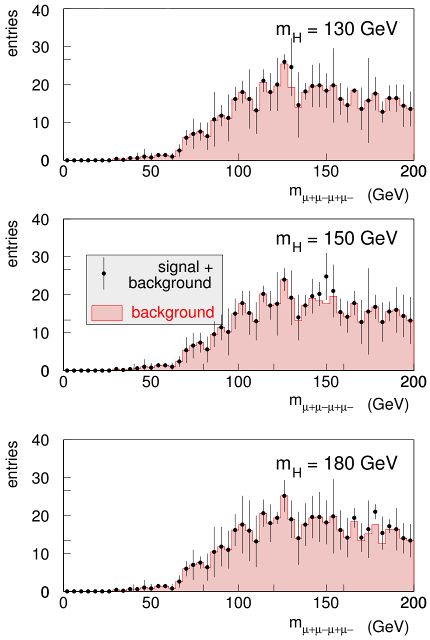
Physics Spectra

- 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

Standard Model Higgs



$H \rightarrow ZZ^* \rightarrow \mu^+\mu^-\mu^+\mu^-$ 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

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

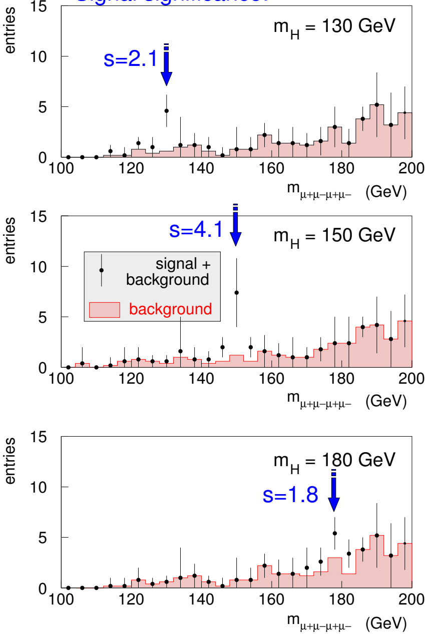
$q\bar{q}, gg \rightarrow t\bar{t} \rightarrow WbW\bar{b}$

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

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

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

Signal significance:



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 most of the instrumentation for the ATLAS detector is well under way and soon to be finished.
The results of the quality assurance and performance tests are within the designed goals.

The integration work for the inner detector has started;
the barrel TRT are first to be installed into ATLAS in early 2006.
All calorimeters are in the final assembly phase;
the barrels will be installed by the end of 2004.
The installation of the barrel muon spectrometer starts by the end of this month.

During the installation, the detector 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.

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