The ATLAS Project

Oliver Kortner, Advisory committee meeting, 29.03.2007

The ATLAS research group at MPI

Responsible director: Prof. S. Bethke.

4 project leaders: S .Kluth (Tier-2), H. Kroha (muon system), R. Nisius (inner detector), P. Schacht (calorimeter).

9 senior physicists: L. Andriček, T. Barillari, A. Kiryunin, S. Menke, H.-G. Moser, R. Richter, D. Salihagić, J. Schieck, H. von der Schmitt.

11 postdoctoral physicists: N. Benekos, J. Dubbert, N. Ghodbane, S. Horvat, O. Kortner, S. Kotov, F. Legger, S. Mohrdieck-Möck, G. Pospelov, J. Yuan, X. Zhuang.

12 doctoral students: A. Bangert, G. Dedes, T. Ehrich, T. Göttfert, M. Groh, R. Härtel, A. Jantsch, S. Kaiser, J. v.Loeben, S. Pataraia, E. Rauter, Ch. Valderanis.

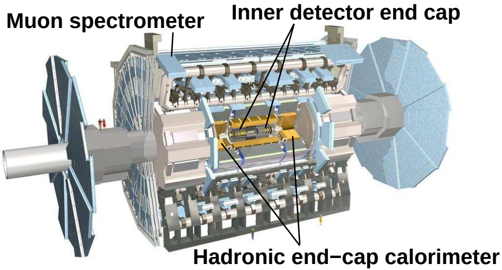
1 diploma student: J. Schmaler.

Up to 9 mechanical and electronics engineers

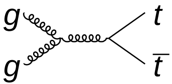
Up to 10 technicians + 20 technicians in the construction phase

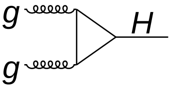
The ATLAS project at MPI

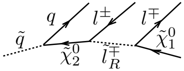
- Detector design and construction.
- Detector commissioning.
- Calibration and alignment software.



- Computing: Tier-2 centre in cooperation with LMU (see poster).
- Physics analysis.
  - Top-quark physics.
  - Higgs boson searches.
  - Search for supersymmetric particles.

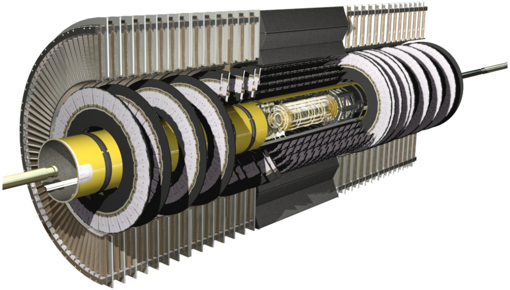






Construction of the ATLAS detector

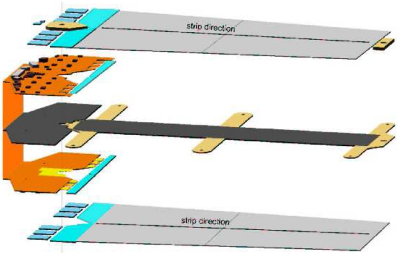
Construction of the inner detector



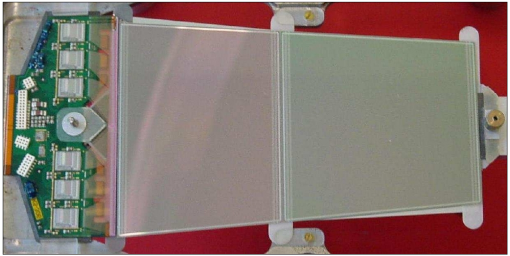
MPI envolvements

- Design of silicon pixel and strip sensors at our semiconductor laboratory.
- Contribution to the design of end-cap silicon strip modules (TPG spine).
- Construction of 18% of 2000 end-cap detector modules .

Parts of an end-cap module



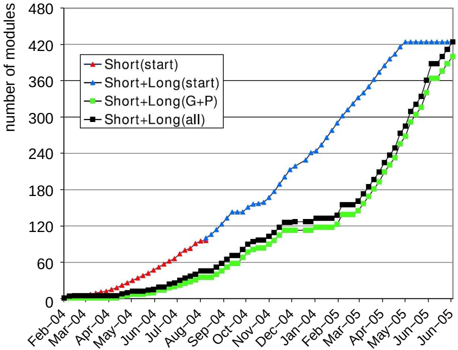
Assembled module



Mech. precision: 5 μm $\perp$, 10 μm $\parallel$ strip.

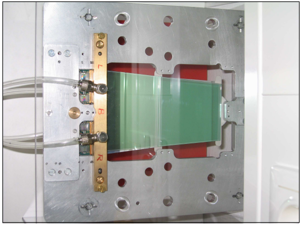
End-cap module assembly

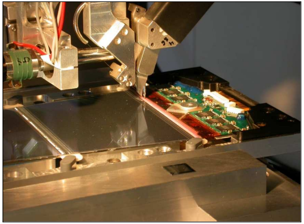
Production rate: ∼1 module/day.



Production done in June 2005.

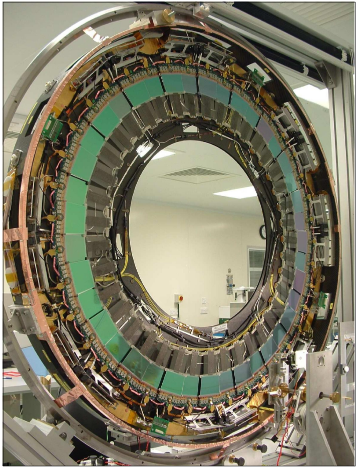
Module production





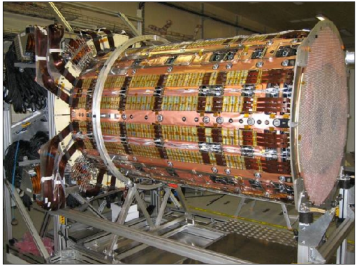
Assembly of the inner detector

First end-cap disk



July 2005

Completed end cap



December 2005

Fully assembled end cap

February 2006

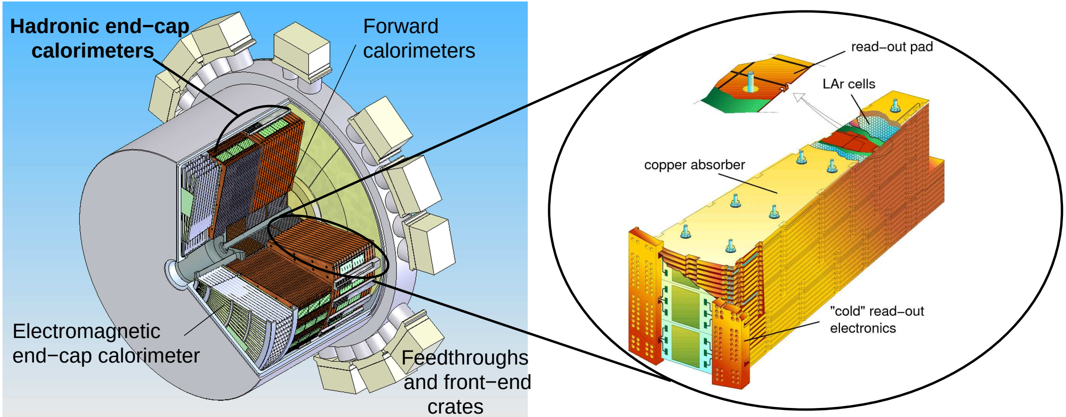
Number of dead channels <0.1%!

Insertion of the inner detector barrel into ATLAS

Next steps

- Insertion of the inner detector end caps halted due to problems with heaters in the cooling system.
- June 2007: Insertion of the pixel detector.

Construction of the hadronic end-cap calorimeter



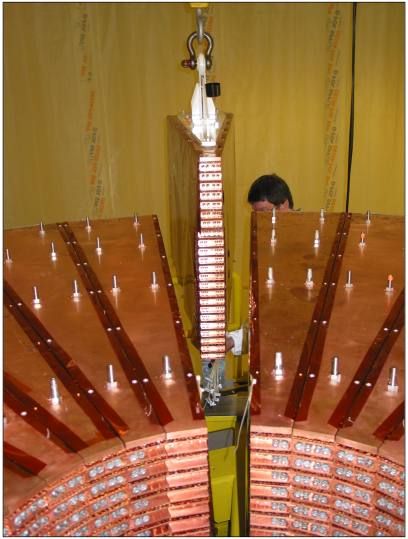
MPI contributions

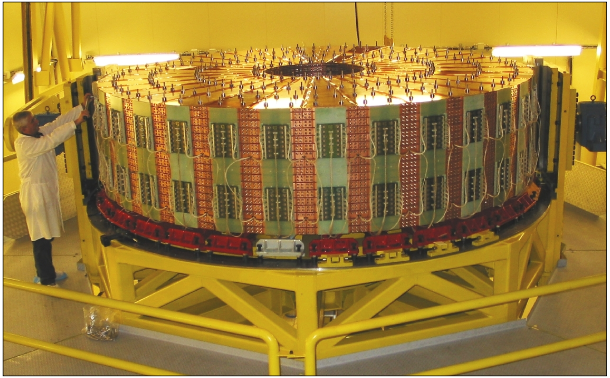
- Design and construction of the hadronic end-cap calorimeter.
- Design and production of the cold electronics.
- Read-out and detector control system.

ATLAS LAr calorimeter project leader: H. Oberlack.

Construction phases

2002-2003: Wheel assembly at CERN



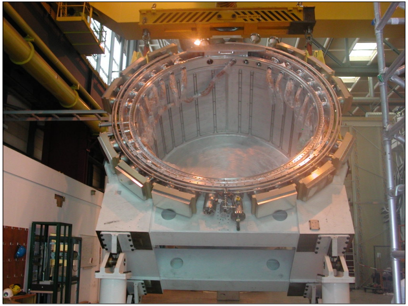


Construction phases

2003-2004: Insertion into the cryostat at CERN

Rotating the wheel

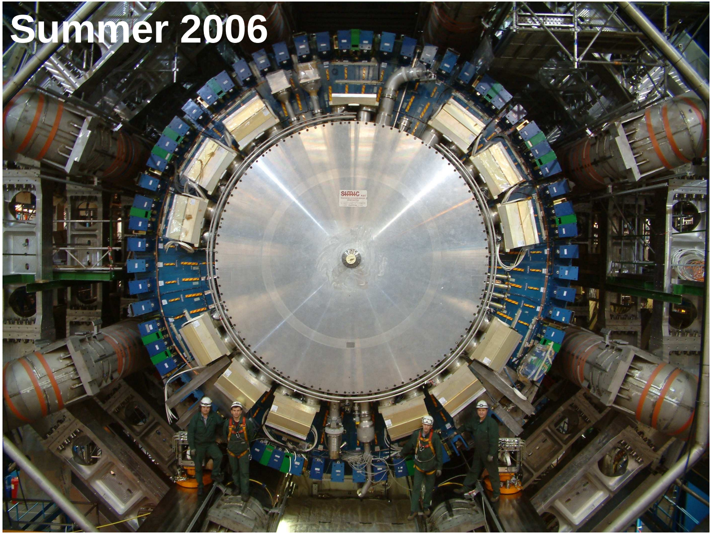
The end-cap cryostat



Closed cryostat

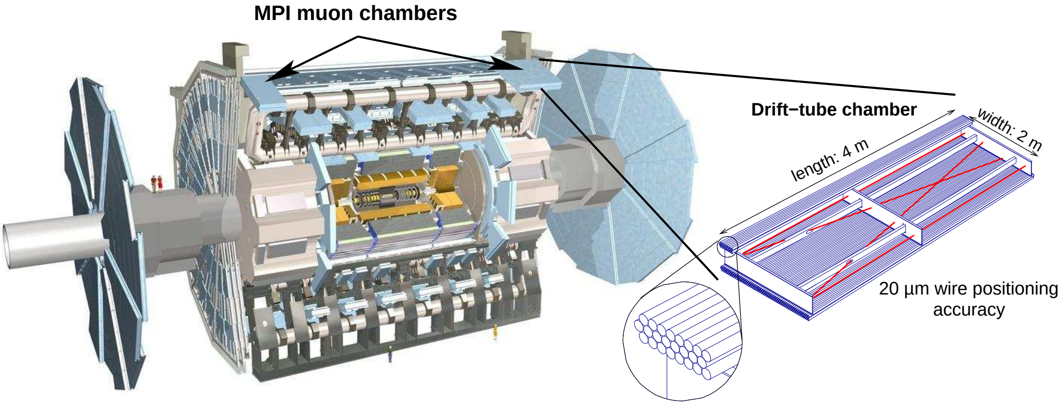
2005: Cold commissioning

End-cap calorimeter in final position



Next steps

- March 2007: Final cool-down of end cap C, cold commissioning of end cap A in situ (tested before in construction hall).
- June 2007: cold commissioning of end cap C.

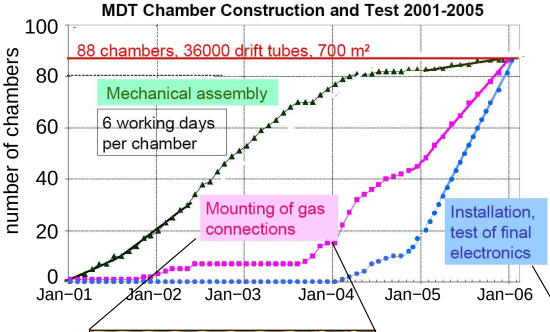


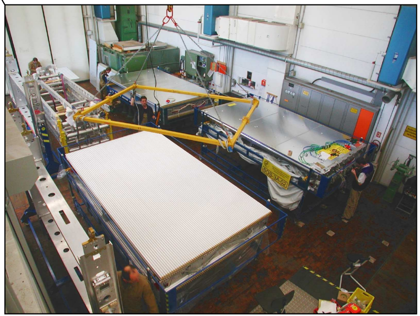
MPI contributions

- Design of the muon drift-tube (MDT) chambers.
- Production of 88 (10%) muon drift-tube chambers.
- High-voltage system.
- Design of the optical alignment system.

ATLAS muon electronics and finance coordinator: R. Richter.

Construction of muon chambers





Construction finished January 2006.

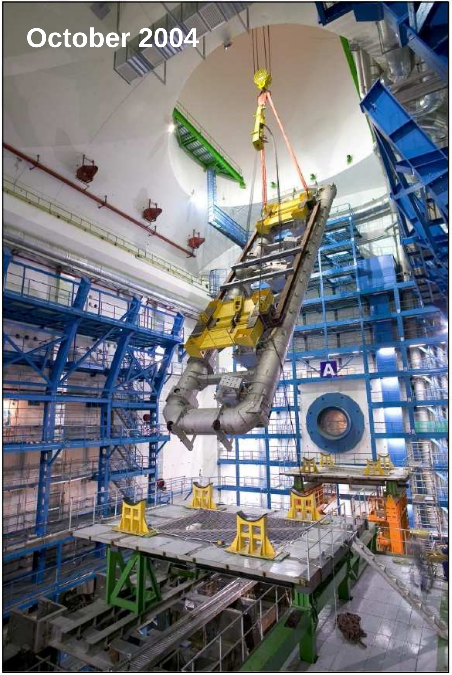
Chamber integration at CERN

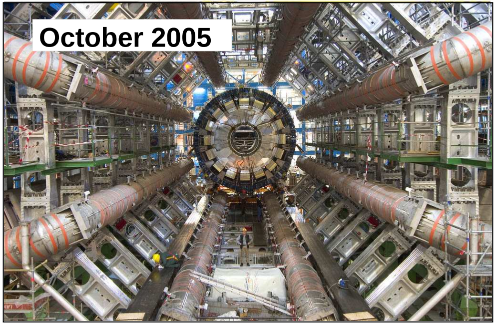
June 2005-February 2006: Integration of drift-tube and trigger chambers

Assembly hall at CERN

Integration muon station

Barrel toroid installation

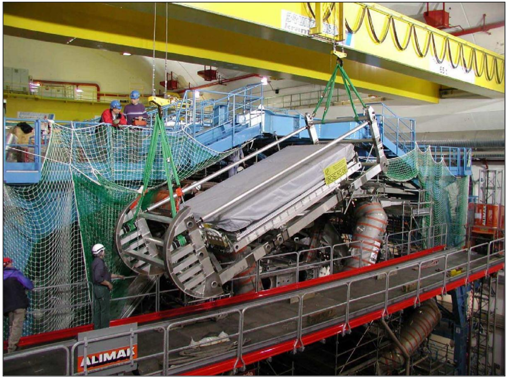




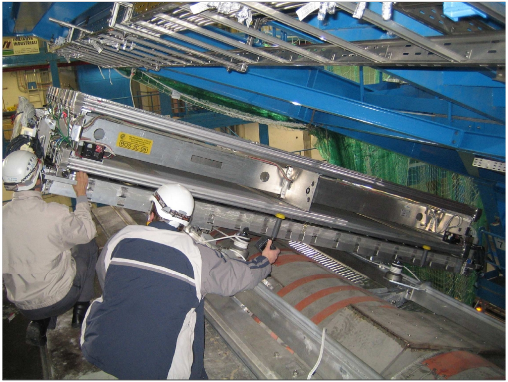
Installation of muon stations

February 2006-July 2006: Installation of MPI muon chambers

Mounting the chambers

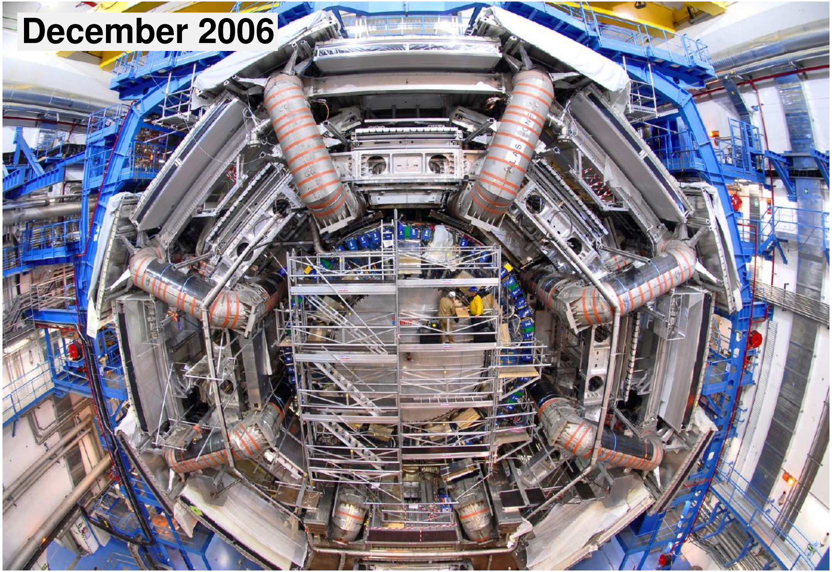


Positioning the chambers



<0.1% dead channels after installation!

Completed barrel muon spectrometer

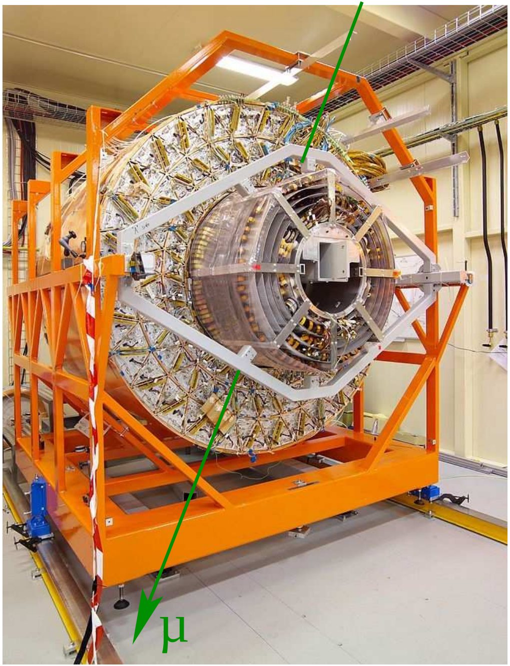


Next steps

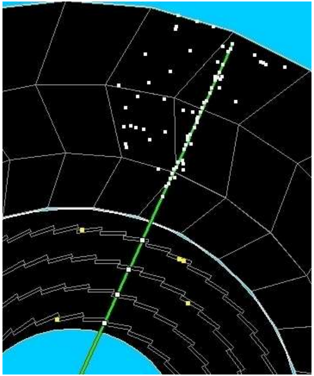
- Until July 2007: Completion of the end-cap muon spectrometer.
- June 2007 and August 2007: Installation of the end-cap toroid.

Commissioning of the ATLAS detector

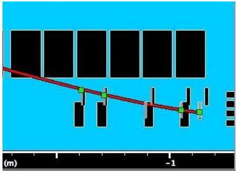
Cosmic-ray test of the assembled inner detector

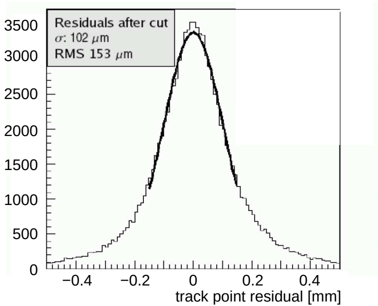


Cosmic muon in the barrel

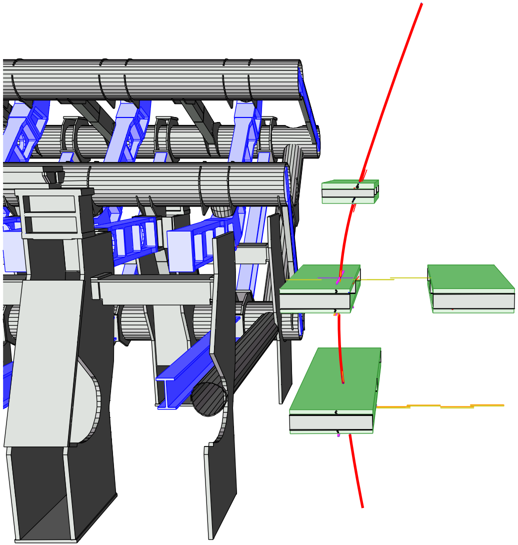


Muon in the end cap



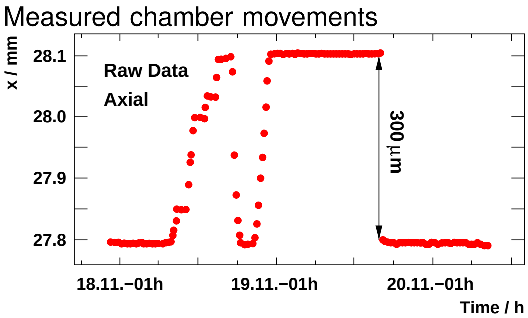


Full system test of the muon spectrometer

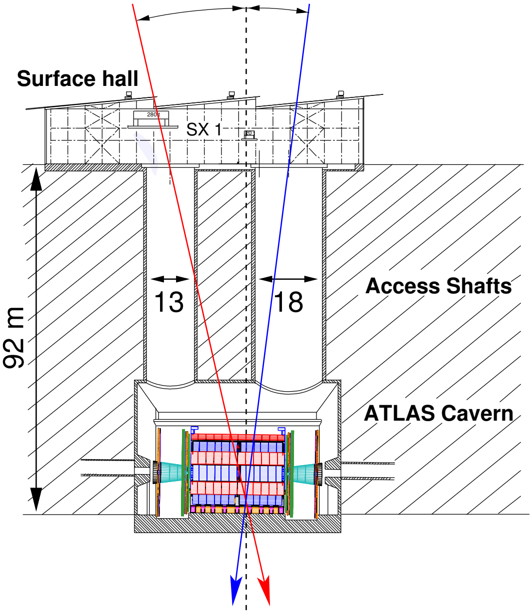


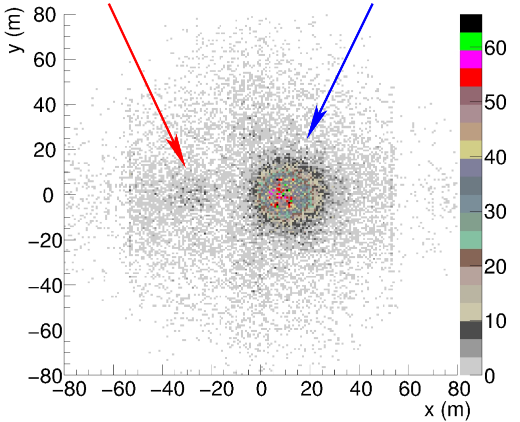
First system test 18./19.11.2006

- Barrel toroid at full field.
- Muon stations.
- Low- and high-p_T trigger.
- Muon barrel alignment.



Commissioning of the muon spectrometer with cosmics





Muon tomography of the rock formation above the ATLAS cavern.

LHC and ATLAS schedule

LHC milestones:

- August 2007: Closing of the LHC beam pipe.
- November, December 2007: Commissioning towards 450 GeV.
- December 2007: 1 week of pp collisions at $\sqrt{s} = 900\ GeV$ and $L = 10^{29}$ cm^{-2} s^{-1}.
- January – June 2008: Commissioning towards 7 TeV.
- July 2008: Start of operation at $\sqrt{s} = 14$ TeV.

Next ATLAS steps:

- Until June 2007: Computing system commissioning and physics analysis preparation.
- Until December 2007: Commissioning with cosmics.
- December 2007: Commissioning with data from pp collisions at $\sqrt{s}$=900 GeV.
- July – December 2008: Start of physics with pp collisions at $\sqrt{s}$=14 TeV.

Contributions to ATLAS data analysis

Data analysis projects at MPI

Alignment with tracks

- Inner detector.
- Muon spectrometer.
- ⋆ ATLAS inner detector alignment coordinator: J. Schieck.

Calibration

- Hadronic calibration.
- Muon spectrometer.
- ⋆ ATLAS hadronic calibration & test-beam coordinator: P. Schacht.

Reconstruction

- Calorimeter clusters.
- Jets.
- Muons.
- ⋆ ATLAS muon reconstruction coordinator: O. Kortner.

Monte-Carlo validation

- Calorimeter.
- Muon spectrometer.
- ⋆ ATLAS muon simulation coordinator: N. Benekos.

Data analysis tools

- ⋆ ATLAS data analysis tools coordinator: S. Menke.
- ⋆ ATLAS muon data quality coordinator: J. Dubbert.

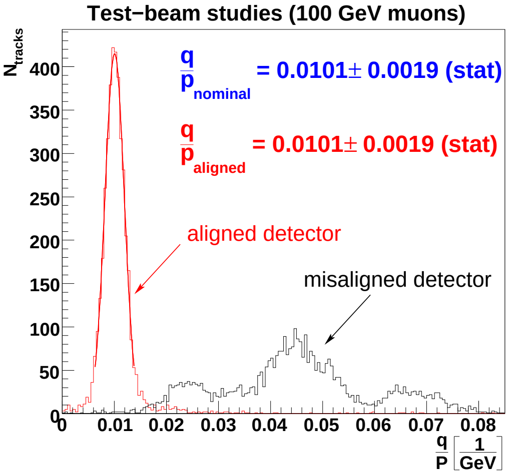
Core software

- ⋆ ATLAS databases project leader: H. von der Schmitt.

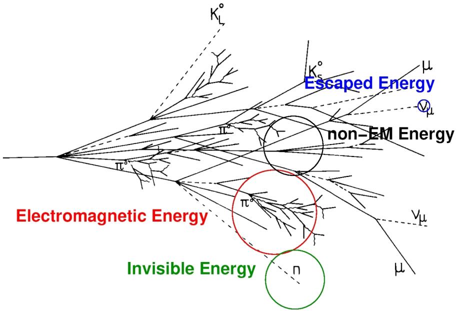
Alignment of the inner detector

Concept

- Iterative determination of misalignment from track residuals.
- Algorithm developed on Monte-Carlo.
- Algorithm applied on test-beam and commissioning data.



Correct momentum measurement with expected resolution after alignment of the test-beam set-up!



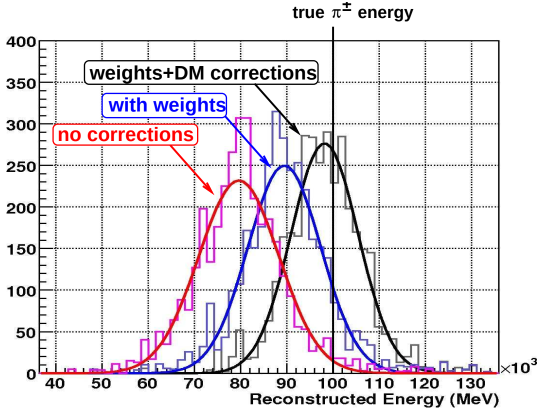
Goal of hadronic calibration

- Correct treatment of EM and non-EM deposits.
- Correction for invisible energy deposits of hadrons and for energy losses in uninstrumented ("dead") material.

Concept

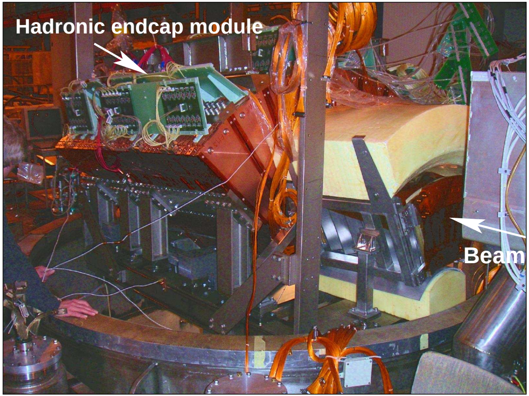
- Reconstruct calorimeter clusters in 3D to distiguish EM from non-EM deposits.
- Apply appropiate weights to measured energy depositions.
- Correct for invisible energy and dead material.

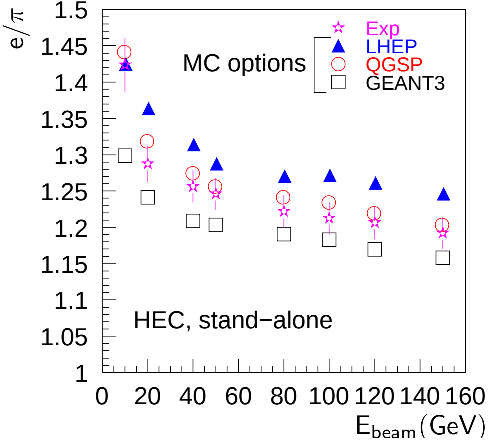
Weights and corrections derived from MC simulations verified with test-beam data.



MPI driving validation of hadronic Monte-Carlo simulations with test-beam data.

2004: HEC-EMEC-FCAL beam test





Muon reconstruction at high rates

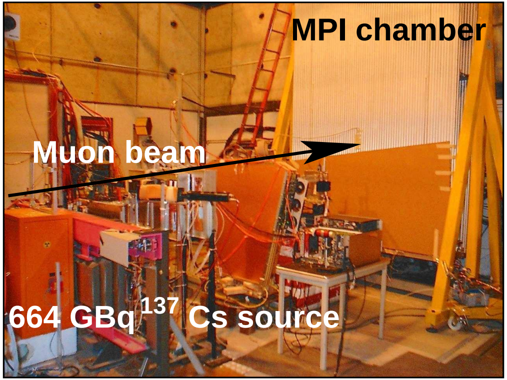
Challenging environment

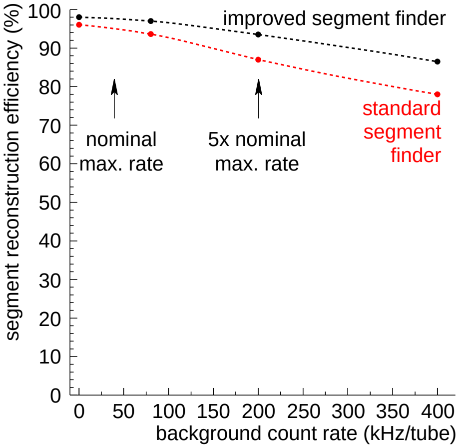
- High n-γ background $\Rightarrow$ high occupancy (up to 15%).

MPI driving high-rate test-beam programme

- Measurement of the high-rate capability of the MDT chambers.
- Development of improved track-reconstruction algorithms.

Gamma Irradiation Facility at CERN





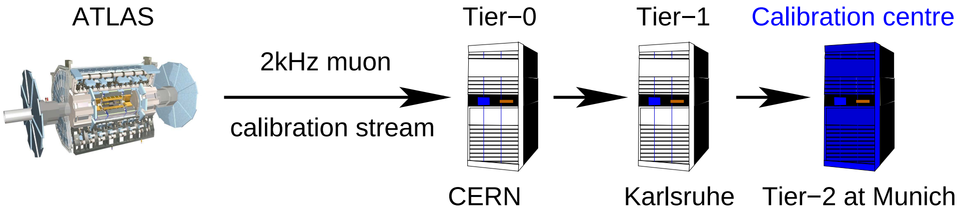
Calibration of the muon spectrometer

Calibration task

- Determination of the space-to-drift-time relationships of all muon chambers with 20 μm accuracy.
- Frequency: once a day for all 1200 chambers.

→ 2 kHz muon rate ($\gg 100$ Hz high level trigger rate)!

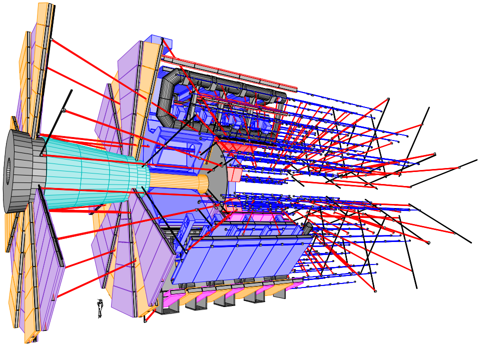
⇒ Special calibration data stream with processing outside CERN in calibration centres in Michigan, Munich, and Rome.



Calibration centre

- 100 CPUs and 5 TB disk space.
- Operation time: 24 hours/day during ATLAS data taking.

Alignment of the muon spectrometer



Optical alignment system with 30 μm accuracy (~5000 light rays).

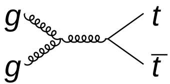
- Concept by MPI.
- Optical alignment accuracy confirmed by test-beam measurements.

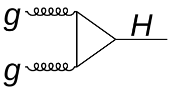
Alignment with tracks

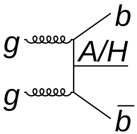
- Algorithm for alignment with curved tracks developed by MPI.
- Needed rate of 2 kHz provided by the calibration stream!

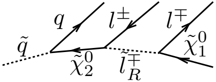
Preparation of the physics analysis

The following physics analyses are prepared at the MPI:

- 

Top-quark physics.
- 

Search for the standard model Higgs boson.
- 

Search for supersymmetric Higgs bosons.
- 

Search for supersymmetric particles.

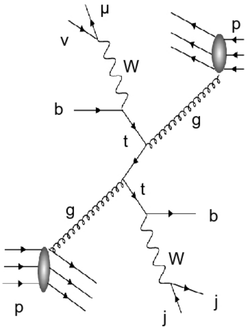
Top-quark physics

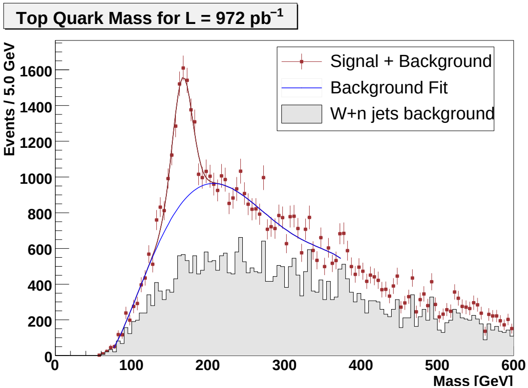
Main aspects

- Precision measurement of m_t and $\sigma(pp \to t\bar{t})$.
- $t\bar{t}$ for detector commissioning and calibration.
- $t\bar{t}$ main background for all searches.

Present focus

- Top-quark mass and cross-section measurements with early LHC data in the semileptonic final state.

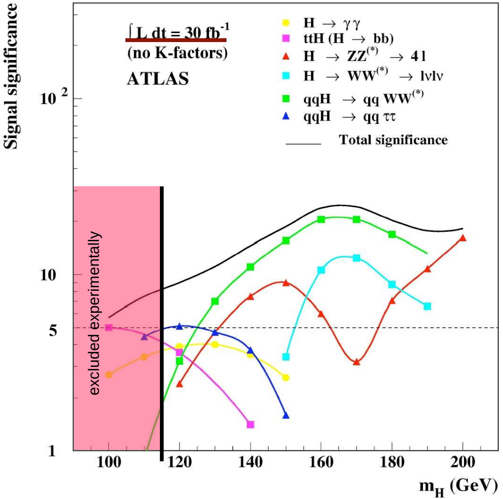




German top physics co-coordinator: S. Menke.

Search for the Higgs boson

Standard model Higgs for 3 years of LHC



$m_H > 180$ GeV

Golden channel: $H \rightarrow ZZ \rightarrow 4\ell$.

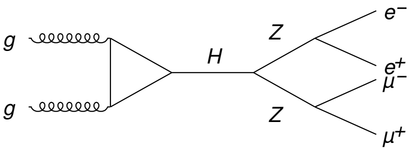
$m_H < 180$ GeV

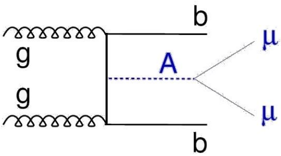
- Favoured by precision electroweak data.
- Combination of different decay channel necessary:
  - $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$.
  - $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$.
  - $qqH \rightarrow qq\tau\tau$.
  - $H \rightarrow \gamma\gamma$.
  - $ttH \rightarrow ttbb$.

MSSM Higgs boson searches at MPI

- $A/H \rightarrow \mu^+\mu^-$, $\tau^+\tau^-$.
- $H^\pm \rightarrow \tau\nu$.

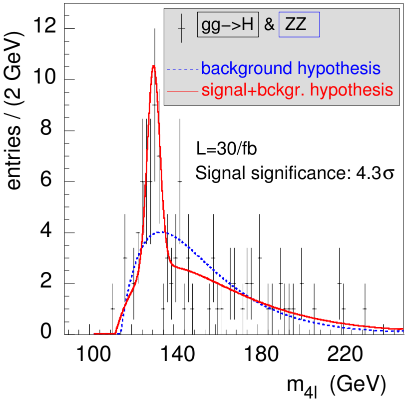
Higgs searches in leptonic final states



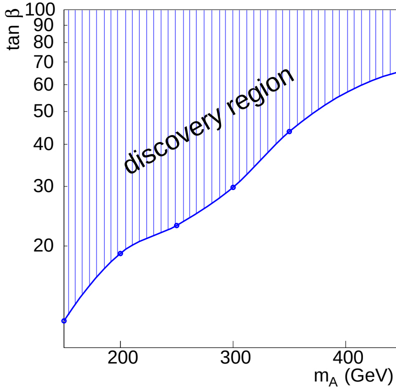


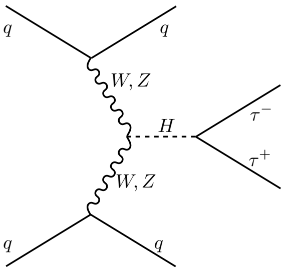
Searches require high lepton identification efficiency and momentum resolution.

$m_{4\ell}$ for $m_H = 130$ GeV, 30 fb^{-1}

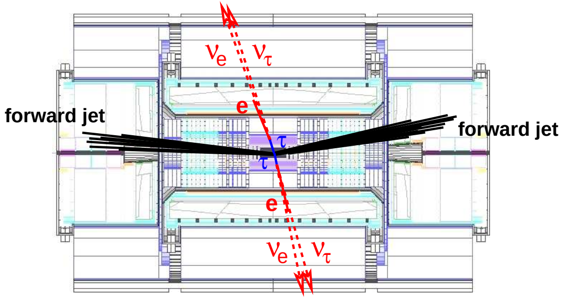


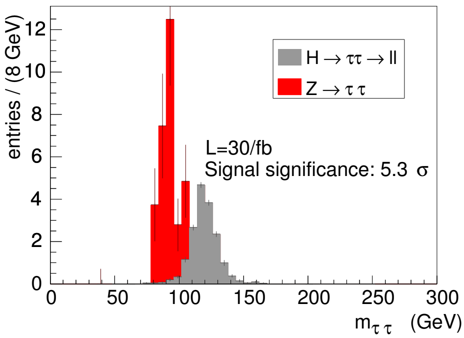
$A \to \mu^+\mu^-$ for 30 fb^{-1}





m_H=120 GeV

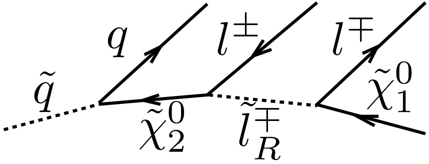




Work focus at MPI:

- Optimization of forward jet reconstruction.
- Optimization of τ identification.

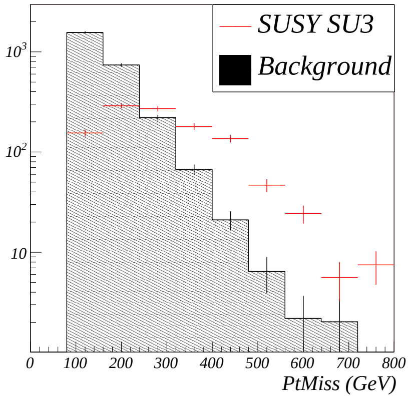
Inclusive search for supersymmetric particles



SUSY signature

- High jet multiplicity.
- Large missing energy.
- n high-p_T leptons.

1 lepton. MC scaled up to 1/fb.



m_0=100 GeV, $m_{1/2}$=300 GeV, A_0=-300 GeV,

$\tan\beta = 6, \ \mu < 0$

Work focus at MPI

- Inclusive searches with 0, 1, 2 leptons in the final state.
- Determination of background from data.
- Speed up the simulation to obtain large background samples ("fast shower").

R&D for SLHC

2015: LHC luminosity upgrade to ∼10 times higher luminosity → SLHC.

Consequences of SLHC for ATLAS

- More radiation toleranat all silicon inner detector with finer segmentation.
- New more radiation hard calorimeter electronics, new forward calorimeter.
- More radiation hard electronics, higher bandwidth, new chambers in the hottest regions of the muon spectrometer.

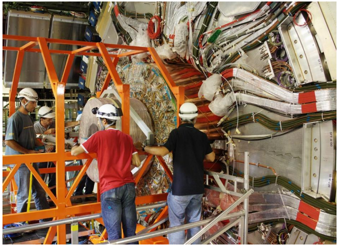
R&D programme at MPI

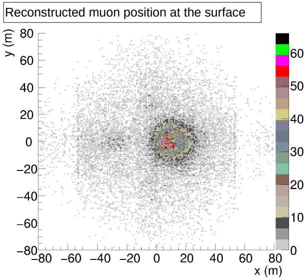
- Inner detector. Thin pixel sensors, novel interconnection proccess, 3D integration of electronics.
- Hadronic end-cap calorimeter. Radiation-hard cold read-out electronics.
- Muon spectrometer. Radiation-hard read-out electronics, selective read-out, muon chambers with increased high-rate capabilty.

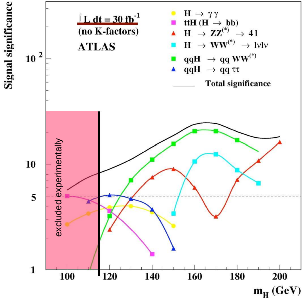
Significant contributions of the MPI group to:

- the design and the construction of the ATLAS detector,
- the commissioning of the ATLAS detector,
- software for the alignment and calibration,
- reconstruction software,
- preparation of physics analyses.

We are well prepared for the start-up of the LHC.

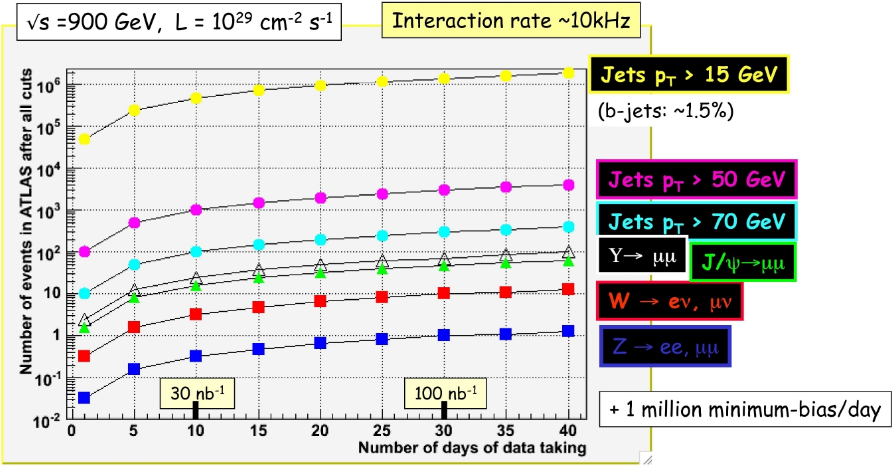






R&D for SLHC has started.

Plans for the 900 GeV run



Plan: Use 900 GeV data for commissioning.

Control distribution to be compared with previous experiments:

- Jet rates and multiplicities.
- Inclusive muon spectra.

Event rates at the LHC