ATLAS Experiment at the LHC

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- Introduction to ATLAS
- Physics motivation
- ATLAS Combined Test beam
- Commissioning
- Summary
Multi purpose particle detector
(coverage up to $|\eta|=5$, $L=10^{34}$ cm$^{-2}$s$^{-1}$)

**ATLAS: A Toroidal Lhc ApparatuS**

**Tracking** ($|\eta|<2.5$, $B=2T$):
- Si pixels and strips
- Transition Radiation Detector (e/$\pi$ separation)

**Calorimetry** ($|\eta|<4.9$):
- LAr EM Calo: ($|\eta|<3.2$)
- HAD Calo: ($|\eta|<4.9$)
- scintillator-Tile (barrel), LAr (fwd)

**Muon Spectrometer** ($|\eta|<2.7$):
- Air-core toroids ($B\sim 0.5T$) with muon chambers

**Dimensions**:
- Diameter: 25 m
- Barrel toroid length: 26 m
- Length: 46 m
- Overall weight: 7000 Tons

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Scale of ATLAS

- ATLAS superimposed to the 5 floors of building 40
- Atlas assembled 92 m below ground at CERN
Event rate

- At high luminosity event rate ~ 1GHz
- Space between two bunches is 25ns~7.5m
- On average 23 minimum bias inelastic event low $p_T$ events per bunch crossing of 25ns

Pile up: $H \rightarrow ZZ \rightarrow 4\mu$

Reconstructed tracks with $p_T > 25$ GeV

Reconstructed tracks for $p_T > 25$ GeV
Status (Atlas Cavern)

- Installation of Barrel Toroids will finish next month (Aug 05)
- LAr and Tile Barrel Calorimeters are in the pit
Basic Detector Components

- Photons
- $e^\pm$
- Muons
- $\pi^\pm$, $p$
- Neutrons

Diagram showing basic detector components:

- Innermost Layer
- Tracking detector
- Electromagnetic calorimeter
- Hadronic calorimeter
- Muon chambers
- Outermost Layer
The Inner Detector (ID) has three sub-systems:

- **Pixels** \((0.8 \times 10^8\) channels)
- **Silicon Tracker (SCT)** \((6 \times 10^6\) channels)
- **Transition Radiation Tracker (TRT)** \((4 \times 10^5\) channels)

- Precision Tracking: Pixel and SCT
- Continuous Tracking and e identification: TRT
- ID inside 2 Tesla solenoid field
The Muon Spectrometer is instrumented with precision chambers and fast trigger chambers.

**Precision chambers:**
- MDTs in the barrel and end-caps
- CSCs at large rapidity for the innermost end-cap stations

**Trigger chambers:**
- RPCs in the barrel
- TGCs in the end-caps
Physics Motivation (i)

- What gives particle mass?
  - The missing piece of the SM is the Higgs (H)
  - Breaks electroweak symmetry
  - Generates masses of particles
- Higgs properties predicted—except its mass
  - From LEP direct search: $M_H > 114.4$ GeV
  - From Electroweak fit of the SM: $M_H < 260$ GeV
  - $M_H < 1.2$ TeV else WW scattering violates unitarity
- If SM is correct and there is Higgs then it can be observed at the LHC(ATLAS/CMS)

The LHC experiments have to cover From the LEP limit up to the TeV scale
Standard Model Higgs Production At LHC

Excluded by LEP


Direct: Gluon Fusion

Associated Production (tt or bb): Small σ

Associated Production (W or Z): Small σ

Vector Boson Fusion (VBF): Distinct Final State

σ(pp → H+X)

√s = 14 TeV

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Standard Model Higgs Decay

Search Channel depends on $M_H$

- Low mass range $\sim 2M_Z$
  - $H \rightarrow \gamma\gamma$: smallest BR but better resolution
  - $H \rightarrow b\bar{b}$: good BR but poor resolution (15%)

- Intermediate mass
  - $H \rightarrow WW^*, ZZ^*$, useful at $M_H > 125\text{GeV}$
  - For $M_H > 2M_Z$
    - $W$ decays to jets or lepton + neutrino

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Overall View of the SM Higgs

- 5σ observation is possible for 30 fb⁻¹ (in first year(s) at low luminosity operation)
- Observation of all channels important to extract convincing signal in first year

![Graph showing signal significance vs. m_H (GeV/c²)]
Physics Motivation (ii)

- SUSY search at LHC
  - unification matter-forces/fermions-bosons is beautiful
  - allows incorporation of gravity
  - allows unification of forces at GUT scale
  - provides candidate for cold dark matter
  - not ruled out by present data
  - predicts light Higgs as favored by data

- Exotics: extra dimension, black holes production...
Testing the detector, Combined Test Beam (2004)
The ATLAS Combined Test Beam

Full “vertical slice” of ATLAS tested on CERN H8 beam line May-November 2004

For first time, all ATLAS sub-detectors integrated and run together with common DAQ, “final” electronics, slow-control, etc. Gained lot of global operation experience during ~ 6 month run. Common ATLAS software used to analyze the data

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~ 90 million events collected
~ 4.5 TB of data:
\[ e^\pm, \pi^\pm \rightarrow 250 \text{ GeV} \]
\[ \mu^\pm, \pi^\pm, p \rightarrow \text{up to 350 GeV} \]
\[ \gamma \rightarrow \sim 30 \text{ GeV} \]
\[ \text{B-field} = 0 \rightarrow 1.4 \text{ T} \]
Validating detector simulation at the CTB

**Pixel residuals**

- **E = 100 GeV**
  - $\sigma = 16 \mu m$
  - Constant: 123.7
  - Mean: 2.194e-05
  - Sigma: 0.01631

- **Simulated data, $\sigma = 17 \mu m$**
  - Constant: 109.9
  - Mean: 0.0001996
  - Sigma: 0.0171

**SCT**

- **E = 180 GeV**
  - $\sigma = 22 \mu m$

- **Simulated data, $\sigma = 23 \mu m$**
Detector calibration using CTB data

Application of dead/noisy straws data

- From the CTB data maps of dead/noisy straws are created
- Algorithms are in place to register maps in the database
- During the reconstruction straw status is read from the Condition database
- Bad channels are masked, hence not used in reconstruction chain

TRT straw global Y

180GeV electrons without magnetic field

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Nest Step: Atlas Commissioning
ATLAS Commissioning with “physics data”

- **Step 1**: Cosmics run: end 2006-March 2007
  - commissioning at sub-detector level has started
  - here “physics data” are cosmic muons
  - Good for the calibration and alignment of detector
  - Atlas has already started recording cosmic muons!
    - For now TileCalo, article in Nature on 14 July 2005: http://www.nature.com/nphys/journal/vaop/nprelaunch/full/nphys005.html

- **Step 2**: Only one beam in the machine: April-May 2007?
  - here “physics data” are beam-halo muons and beam-gas events

- **Step 3**: First pp collisions: prepare the trigger and the detector

- **Step 4**: Commissioning of physics (e.g. understand backgrounds to discovery channels) can start ...
ATLAS Commissioning

~ 5 million cosmic muons enter the cavern in 15 minutes

First cosmic event in Atlas

Tower energies: ~2.5 GeV
Contribution from our group

- **Hardware:**
  - Provided opto links for Pixel, SCT, LAr and Tile (In fact we are giving “light” to Atlas!)
  - LMT for the SCT

- **Software:**
  - One of our colleague is Atlas software release coordinator
  - Taking care of smooth and useful release builds
  - Provided monitoring software for the TRT and global ID level inside Athena framework
    - Useful for debugging detector, spotting dead/noisy channels, studying correlations among sub-detectors…..

- **Grid:**
  - To deal with the enormous amount of data (Atlas ~ 1PB per year) produced by the LHC, Grid is essential
  - Our group is taking active part in the development, deployment and testing of the Grid (releases)
  - Contributed actively to DC1 and DC2
  - After all we are **Tier1!!** (the only one in Asia so far)
  - You can access/process LHC data while sitting at home institute (Great chance for new people to join and take part in the LHC analysis)
Summary

- ATLAS offers a wealth of physics
- ATLAS sub-detectors have passed extensive period of construction, R&D, Testbeam
- ATLAS commissioning has started on sub-detector level
- The whole ATLAS commissioning in 2006-2007
- We are looking forward to first p-p collision in summer 2007