Status of ATLAS

Howard Gordon (for the ATLAS Collaboration)
BNL
Special Thanks to Peter Jenni, Mike Tuts, Manuella Vincter, Alex Grillo, Frank Taylor, Abe Seiden, Michael Ernst, Dirk Zervas and others...
ATLAS Collaboration
(STATUS OCT. 2008)

37 Countries
169 Institutions
2340 Scientific Authors total
(1817 with a PhD, for M&O share)

U.S.: 480 Scientific Authors
395 with Ph.D 22%
150 Graduate Students

U.S. ATLAS People at CERN (full time)

- 19 Professors
- 21 Scientists
- 76 Post Docs
- 76 Graduate Students
- 36 Professionals
- 4 Technicians
- 232 Total
ATLAS Strengths:
1) Stand alone $\mu$ system; 2) Highly segmented calorimeter: $\gamma$ pointing

ATLAS superimposed to the 5 floors of building 4C

24 m

45 m

7000 Tons

Muon Detectors, Tile Calorimeter, Liquid Argon Calorimeter, Toroid Magnets, Solenoid Magnet, SCT Tracker, Pixel Detector, TRT Tracker
The Underground Cavern at Point-1 for the ATLAS Detector

Length = 55 m
Width = 32 m
Height = 35 m
ATLAS installation:
Status before closing April 2008
(ATLAS is now closed and looks different)
First Single Beam seen in ATLAS Sept. 10, 2008
The very first beam-splash event from the LHC in ATLAS on 10:19, 10th September 2008

Online display

Pixels were off on purpose

Offline display
Typical Cosmic Ray Event in ATLAS

- Reconstruction in good shape for different magnet and detector configurations
  - Solenoid only field needs final validation
  - Conditions are continuously updated

Atlantis Event Display
Cosmic run 90272
Full magnetic field
All systems in (except CSC)
Another Cosmic Ray Event
Integration of the U.S. into ATLAS

- The U.S. integrated into almost all systems of ATLAS:
  - Inner Tracker: Pixels, Silicon Strips, Transition Radiation Tracker
  - Liquid Argon
  - TileCal
  - Muon
  - Trigger/Data Aquisition
  - Technical Coordination
  - Computing (Jim Shank)
  - Physics Analysis
U.S. Leadership Positions in ATLAS

- Andy Lankford (UC Irvine): Deputy Spokesperson starting 3/1/09
- Bob Stanek (ANL): TileCal System Leader
- Kevin Einsweiler (LBNL): Pixel System Leader
- Mike Tuts (Columbia): Executive Board
- Tom LeCompte (ANL) Deputy Physics Coordinator (will be PC 6/1/09)
- Ketevi Assamagan (BNL): Higgs Convener
- Peter Steinberg (BNL): Heavy Ion Convener (NP)
- David Quarrie (LBNL): Software Project Leader
- Jim Shank (Boston): ATLAS Distributed Computing Project Co-leader
ATLAS Status

- All systems are working well except the readout of the Cathode Strip Chambers (U.S. responsibility)
- Magnet Systems (10 toroid coils and solenoid) are working well
- The software and computing systems are working and would have been ready for collisions
- Commissioning with cosmic rays is still in progress and more refined calibration and alignment of the detector is in progress
- ATLAS has defined a shutdown schedule for maintenance and repairs starting soon being ready for collisions 3/31/09
US ATLAS ORGANIZATION CHART

US. ATLAS Research Program Organization as of July 14, 2008

Program Office
BNL/Columbia
H. Gordon

Program Manager
M. Tuts
Deputy: H. Gordon

Executive Committee
M. Tuts, Chair

Institutional Board
A. Goshaw
Convener

Maintenance and Operations
Computing

4 X
Upgrade R&D
A. Seiden
UC-Santa Cruz

3.1 Silicon
A. Grillo
UC-Santa Cruz

3.2 TRT
H. Ogren
Indiana

3.3 Liquid Argon
R. Stroynowski
SMU

3.4 Tilecal
L. Price
ANL

3.5 MUON
F. Taylor
MIT

3.6 Trigger/DAQ
A. Lankford
UC Irvine

3.7 Common Projects
M. Tuts

3.8 Education
M. Barnett
LBNL

3.10 Technical Coordination
D. Lissauer
BNL

3.9 Physics Support & Computing
T. Hinchliffe
LBNL

2.3 Facilities Manager
M. Ernst
BNL

2.2 Software and Analysis Support Manager
S. Rajagopalan
BNL

2.4 Communication
Kevin Einsweiler and Erik Anderson inspecting the ATLAS pixel detector just before it is inserted into its final location.
3.1 SILICON PROGRESS

- **US Institutions:** Columbia, Iowa State, Iowa, Berkeley/LBNL, New Mexico, Ohio State, Oklahoma, UC Santa Cruz, UT Dallas, Wisconsin

- Retrofit of evaporative cooling system heaters complete and operating in Pixel and SCT detectors. However work will continue during the shutdown.

- First cosmic runs with pixels: mid-September!

  - 7 pixel hits and 16 SCT hits: one hit in every layer!

  **Initial alignment of SCT and pixel with cosmic rays:**

3.1 Silicon Operations

Cosmic Ray Track through TRT, SCT and Pixels

SCT Noise Occupancy
No interference from TRT or Pixels

Spec limit ≤ 510-4
Off scale right

Pixel Alignment Studies
Difference in closest approach to beam line

Track Efficiency of SCT Barrel
Red “reference” points from run with early calibration
Barrel TRT and SCT
3.2 TRT PROGRESS

- **US Institutions**: Duke, Hampton, Indiana, Penn, Yale
- Inner Detector integration is completed
  - Cosmic runs have been very successful
  - Timing, voltage, delay scans routine; stable operation
  - Monitoring tools improved with experience (histograms, forensic tools both on-line and off-line)
  - Active gas recirculation system tested with Ar (M8), was switched to Xe in September 2008
  - Cosmic rays from Endcap C through Barrel to Endcap A
U.S. Barrel Liquid Argon Cryostat and Signal Feedthroughs for Barrel and EndCap
We also had our share of problems
3.3 LAR CALORIMETER

PROGRESS

- **US Institutions:** Arizona, BNL, Columbia, Pittsburgh, Stony Brook, SMU
- All 183,296 channels are being readout
- **Electromagnetic (EM)**
  - < 0.1% single dead channels
  - No dead HV regions
  - A few percent of channels with HV lower than nominal (corrected in DSP)
- **Forward Calorimeter (FCal)**
  - 1.7% channels require some correction
  - Two $\Delta \phi = 0.2$ regions with bad HV lines (require additional corrections)
- **Hadronic End-Cap (HEC)**
  - <0.1% dead channels uniformly distributed
Extended Barrel TileCal
3.4 TILE CAL PROGRESS

- U.S. Institutions: ANL/NIU, Chicago, MSU, UTA, UIUC
- Calorimeter working well after hardware commissioning
  - Including modification of all LV power supplies and refurbishment of all readout drawers
  - All drawers powered by both LV and HV
    - LBC34 in special mode for HV
  - Only 20 cells (of 5000) are not usable for physics now
  - Still significant list of “lesser” problems for attention in shutdown
- No problems with front-end electronics and power supplies during magnetic field testing
  - PMT gains appear stable
  - ~1.5% increase in the tiles’ light response when solenoid field is on
Calorimeter performance

- Energy reconstruction
  - LAr EM: Reconstruct E with 3x3 calorimeter cells, comparison to Landau
    - energy $\eta$ dependence agreement, though there is a 5% systematic uncertainty on the MC prediction
  - Tile: energy deposited by $\mu$ vs. $\eta$, normalised by distance traveled in tile
    - energy scale&uniformity tested to 2-3%

![Graphs and images related to calorimeter performance]
Calo/trigger performance

- Correlation between energy as measured in calorimeter and as seen in L1 trigger
- Impact of air showers as sources of non-IP jets: reduced though timing cuts

\[ E_T = \sqrt{\sum E_{T,x}^2 + \sum E_{T,y}^2} \]
Muon EndCap MDT and CSC Chambers
All US-made components are commissioned

- Have taken extensive cosmic ray data with both the RPC barrel trigger and the TGC endcap trigger
  - Data are useful for hardware operational tests as well as refinement of software and calibration
- Alignment system operational – azimuthal & polar
  - Design resolution is being approached
    - 45 to 50 μm vs. design 40 μm
- System operated well during the beam splash tests in September
  - But CSCs did not participate due to ROD rate and stability problem

Status of ATLAS Muon System – October 2008
High Level Trigger Farm
3.6 TDAQ M&O

- **US Institutions**: UCI, MSU, ANL, Wisconsin, BNL, NYU, Arlington, Oregon, SLAC
- **Hardware**
  - Install/ commission
- **DAQ/HLT Software**
  - Integration/ test
- **Trigger Selection & Algorithms**
  - Testing/ refinement
- **Data Quality Monitoring**
  - Improved tools for maintenance & operation
- **Currently in intense commissioning and support of detector commissioning**

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**Hardware**

- Event Filter (EF)
  - ~500 ~1900 dual-CPU nodes
- Event Builder (SFIs)
  - ~100 ~10 Event rate ~ 200 Hz
- Data storage
  - Local Storage (SFOs)
  - EventFilter (EF)
  - LVL2 farm

**Software**

- LVL2 DataFlow Manager (DFM)
- pROS stores LVL2 output
- Gigabit Ethernet

**Schematic of TDAQ system**

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- **First-level trigger**
  - ATLAS Detector (UX15)
  - Timing Trigger Control (TTC)
  - Dedicated links
  - 1600 Read-Out Links
  - VME

- **Data Quality Monitoring**
  - Improved tools for maintenance & operation

- **Currently in intense commissioning and support of detector commissioning**

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**DAQ/HLT Software**

- Integration/ test

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**US Institutions**

- UCI, MSU, ANL, Wisconsin, BNL, NYU, Arlington, Oregon, SLAC
We have a detailed plan for the maintenance work to be completed before being ready for beam collisions next spring.

<table>
<thead>
<tr>
<th>Side C</th>
<th>Side A</th>
<th>Barrel</th>
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</thead>
<tbody>
<tr>
<td>BW-EQ, Lucid in commission mode</td>
<td>BW-EQ, Lucid in commission mode</td>
<td>SW-TGC-A commissioning</td>
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<tr>
<td>BW-C open for fibers repair</td>
<td>JF to surface</td>
<td>open barrel C</td>
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<tr>
<td>no n-pentane</td>
<td>ECT-C out</td>
<td>Calos C electronics repair</td>
</tr>
<tr>
<td>Lucid + EO fix</td>
<td>JF to surface</td>
<td>close barrel C</td>
</tr>
<tr>
<td>BW-C in garage position, no n-pentane</td>
<td>ECT-C in</td>
<td>Commissioning of individual systems</td>
</tr>
<tr>
<td>Forward C in commissioning mode</td>
<td>JF in</td>
<td>Fix barrel muon chambers + SW TGC</td>
</tr>
</tbody>
</table>

**Magnets**
- Toroids on
- Magnets off + yearly maintenance
- Magnets on

**HS**
- restricted access
- repairs / maintenance activities
- restricted access
An Example of Work in Technical Coordination

New NBL Position

Nominal Beam Axis - real beam 3 mm.

Toroid Axis
Barrel Toroid EC Toroid
Magnetic Axis Aligned.
Barrel - Nominal beam +6 mm from Survey

Tile Calorimeter Barrel +/- 1 mm to Solenoid Axis

Solenoid Axis

EM Calorimeter +/- 2 mm to Solenoid

Solenoid Axis to nominal beam 2 mm

TRT SCT +/- 1

Pixel Tube - Pixel +/- 1 Beam Pipe

EC Calorimeter EM, HEC, Forward +/- 1.5

BW +/- 8

JD/SW +/- 5

EO +/- 5

ATLAS is still “Dynamic” – need to keep monitoring. Interact with the Machine. Stability after movement (Open/Close)
2.1 ANALYSIS SUPPORT (RECENT ACTIVITIES)

- Weekly U.S. Physics meeting focusing on data analysis of Cosmic and FDR (1 and 2).
- Many Jamborees at the three Analysis Support Centers
  - Six single Jamborees with average of 27 participants each
  - One dual jamboree (joint ANL-BNL) : 42 participants
    - Positive feedback on all jamborees
  - 3-way jamboree was held on September 9-12.
    - Focused on preparing for remote analysis with real data.
- Second Annual American Physics Workshop
  - Simon Frasier University, Burnaby, BC, Canada, June 16-18, 2008
  - Focus on early physics and tools to extract first results
  - Very productive tutorial on final day.
- Latin American Computing Workshop
  - 3-day workshop, March 2008, Buenos Aires
  - Several Americans (with NSF support), including students participated and conducted a series of tutorials, lectures to support our Latin American colleagues.
U.S. ATLAS Tier 2 Sites Empowered by Open Science Grid

- Great Lakes Tier-2
- North East Tier-2
- Mid-West Tier-2
- South West Tier-2
- Western Tier-2 (DOE)
- U.S. ATLAS Tier-1

Local Tier 3 computing supported by The Core Research Program
**ATLAS Data Replication Performance**

Transfer performance for ATLAS Cosmic Data Replication from CERN to all ATLAS Tier-1 & Calib. sites

Data at a rate of >500MB/s

The maximum rate observed so far for transfers between CERN and the ATLAS Tier-1 sites is 3,500 Megabytes per second

Upgrade R&D

- **Active Silicon work**
  - Inner Pixel layer (b) inserted into the beam pipe (~2013)
  - The eventual complete replacement of the Inner Detector – all silicon (no TRT) (~2017)
  - Pixels, Strip staves, electronics, optical links
- **Also lots of progress on Liquid Argon Electronics** which is >x10 more radiation hard
Pixel Readout Chip Development

- A chip called FE-I4 is being developed in 130nm CMOS for ATLAS pixel upgrades. Results were presented at TWEPP08 and Pixel2008 conferences. Collaboration of designers from 5 institutes (LBNL + 4 European).
- Main advances of FE-I4:
  - 4x larger pixel array size to reduce material overhead and module assembly cost (2cm x 1.9cm chip size).
  - Smaller pixels (62% of present) and reduced analog precision (4x faster ADC) to function with >99% efficiency at higher track occupancies
  - Lower current consumption per unit area thanks to greatly increased digital functionality inside the pixel chip
    - FE-I3 data storage = 1.5 bits/pixel, FE-I4 = 40 bits/smaller pixel
  - First HEP on-chip x2 DC-DC power converter included in design.
- A suite of 3 test chips were fabricated in FY08 (5% scale pixel array, LVDS chip, SEU register chip).
  - First irradiations already performed (LANL, CERN). Good results so far, provides basis for FEI4.
- Analog layout close to final. Digital design in progress.
- Target final design review March 09, full wafer engineering run Summer 09.
3-D Pixel Detector Development

- Focus on production scaling and industrialization.
- Productions at SINTEF (European collaborator driven and funded) and Stanford.
- Technology development in parallel (irradiation, modeling, operation of assemblies). A number of runs have been completed and several planned for next year.

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<td>SINTEF</td>
<td>Stanford</td>
<td>Stanford</td>
<td>SINTEF</td>
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<td>3D</td>
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<tr>
<td>Number of wafers</td>
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<td>25</td>
<td>8</td>
<td>6</td>
<td>25</td>
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<tr>
<td>Number FE-I3 tiles /w</td>
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<td>54</td>
<td>12</td>
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<td>39</td>
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<tr>
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<td>&gt;10</td>
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<tr>
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<td>2</td>
<td>&gt;2</td>
<td>2</td>
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<tr>
<td>Yield</td>
<td>50%</td>
<td>8%*</td>
<td></td>
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<tr>
<td>Modules produced/expected</td>
<td>/20</td>
<td>10/10</td>
<td></td>
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<tr>
<td>Bump bonding facility</td>
<td>Stanford</td>
<td>IZM</td>
<td>Stanford</td>
<td>Stanford/IZM</td>
<td>IZM</td>
</tr>
</tbody>
</table>
3-D Silicon Pixel Detector Irradiation Results

Recent irradiation results. 4E, 3E, 2E refer to number of columns connected to one electronics channel.

Device simulation results.

We are planning for an Upgraded Detector since CERN has approved a Phase 1 upgrade to the LHC – This will allow an increase in Physics Reach of ~30%

- New injectors + IR upgrade phase 2 Decision 2011
- ATLAS silicon strips begin to degrade at 700 fb⁻¹ and pixels at 300 fb⁻¹
- Early operation
- Linac4 + IR upgrade phase 1
- Collimation phase 2

- 300 fb⁻¹ ~ 3 years at 10^{34} – nominal program
- 700 fb⁻¹ ~ data accumulated until 2016
- 1700 fb⁻¹ ~700 + 5 years at 3x10^{34} Phase 1
- 3000 fb⁻¹ ~5 years at 10^{35} – Phase 2
For ATLAS we would completely replace the Inner Detector, and upgrade the Trigger/DAQ and FCAL.

Units are cm.
Expected performance: $E_T\text{miss}$

$E_T\text{miss}$ at EM energy scale $\sim 30\%$
refined with
- muons
- electrons
- jets
$E_T\text{miss}$ scale $\sim 5\%$
$E_T\text{miss}$ resolution $0.57\sqrt{E}$
First check: $Z\rightarrow\tau\tau$
energy scale $2\%$
Standard model: top quark

The LHC top quark factory
→ semi-leptonic top quark events
no b-tagging used

First physics:
• 100 pb$^{-1}$ clear signal even with QCD bg x2
• signal purity for the muon/electron channel 80%

100 pb$^{-1}$: 508 signal events (muon channel)

$\Delta\sigma/\sigma = 7\%$ (stat) $\pm 15\%$ (syst) $\pm 3\%$ (pdf) $\pm 5\%$ (lumi)
New physics: Supersymmetry

Large cross sections for gluinos and squarks:
- multi-jet + large $E_T$miss (+leptons)
- necessitates understanding of all components

Define effective mass:
- sum of jet $p_T$ and $E_T$miss
- require one lepton
- less statistics, but cleaner

Sensitivity:
- 10pb$^{-1}$ $\sim$ 400GeV sensitivity=TeVatron
- 1 fb$^{-1}$ $\sim$ 1.5TeV (all jets)
- 1 fb$^{-1}$ $\sim$ 1TeV (1lepton + jets)
Physics Prospects

• We would benefit from the full 14 TeV
  ♦ Prospects are that the LHC will still start up at <=10 TeV

• Still the prospects for some high cross section discovery in the first year or two is high: Supersymmetry, Extra Dimensions, Micro Black Holes

• The potential for the discovery of the Higgs boson is still very high over the full mass range (as opposed to a narrow range at the Tevatron) – but it will take several years of data taking.

• We are really looking forward to the collisions hopefully next spring and the start of the physics discoveries.

• I did not have time today – but we also have an extremely effective program for Heavy Ion Collisions and are planning for some DOE NP support.