ATLAS Detector and Early Physics

- ATLAS Detector
- Performance and Status
- Early Physics
- Summary

Zhengguo Zhao

University of Science and Technology of China
Experiments at Large Hadron Collider
LHC—Factory for b, t-quarks, W, Z

\[ N = L \times \sigma(pp \rightarrow x) = 10^9 \text{ collision/s} \]

- Mostly low \( p_t \) events (soft) events. 20 inelastic (low-\( p_T \)) events ("minimum bias") produced simultaneously in the detectors at each bunch crossing \( \rightarrow \) pile-up
- Interesting high \( p_t \) events are rare
- New physics rate \( \sim 10^{-3-5} \) Hz \( \rightarrow \) event selection 1 in \( 10^{12-14} \)

Final object to be detected
- leptons (e, \( \mu \), \( \tau \))
- \( \gamma \)
- jets, light hadrons(\( \pi, p.. \))
- \( E_T \text{miss} \)
Challenge For Tracking $H \rightarrow ZZ \rightarrow 4\mu$
Challenge To The Detector

- **Fast response** (20-50 ns), otherwise too large pile-up.
  - integrate over 1-2 bunch crossings
  - pile-up of 25-50 minimum bias events
  → very challenging readout electronics

- **High granularity** to minimize probability that pile-up particles be in the same detector element as interesting object
  → large number of electronic channels, high cost

- **High radiation resistant**
  e.g. in forward calorimeters, up to $10^{17}$ n/cm$^2$ in 10 years of LHC operation

- **Good particle identification**

- **Good E, P resolution**
Main Design Choice

• Efficient tracking for lepton momentum measurement; enhance $e/\gamma$ identification; excellent $b$ tagging capability at low luminosity.

• Very good electromagnetic calorimeter for $e/\gamma$ identification, complemented by thick and hermetic hadronic calorimeter for jet and missing transverse energy measurement.

• Stand-alone and precise muon measurement over a wide polar angle range.
The ATLAS Detector

Solenoid field: 2T
Toroid field: 4T

Muon Detectors
Electromagnetic Calorimeters
Forward Calorimeters
End Cap Toroid

Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

Channels: ~ $10^8$
$\mathcal{L}_{\text{cable}}$: ~ 3000 km
Cost: 541 MCHF

~7000 tons

ATLAS superimposed to the 5 floors of building 40 at CERN
The dashed tracks are invisible to the detector.
### Particle Detection at ATLAS

<table>
<thead>
<tr>
<th>Particle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td>Track; energy deposit in ECAL</td>
</tr>
<tr>
<td>γ</td>
<td>No track, energy deposit in ECAL</td>
</tr>
<tr>
<td>μ</td>
<td>Track in both inner tracker and muon spectrometer</td>
</tr>
<tr>
<td>ν</td>
<td>No signal, only missing energy</td>
</tr>
<tr>
<td>q/g/τ</td>
<td>Hadronic jet, signal in all subdetector</td>
</tr>
<tr>
<td>b</td>
<td>Secondary vertex, signal in all subdetector</td>
</tr>
</tbody>
</table>
ATLAS Required Performance

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Required resolution</th>
<th>eta coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracking</td>
<td>$p_T/p_T = 0.05%p_T \oplus 1%$</td>
<td>2.5</td>
</tr>
<tr>
<td>EM calorimetry</td>
<td>$\sigma_E/E = 10%/\sqrt{E} \oplus 0.7%$</td>
<td>3.2</td>
</tr>
<tr>
<td>Hadronic calorimetry (jets)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrel and Endcap:</td>
<td>$\sigma_E/E = 50%/\sqrt{E} \oplus 3%$</td>
<td>3.2</td>
</tr>
<tr>
<td>Forward</td>
<td>$\sigma_E/E = 100%/\sqrt{E} \oplus 10%$</td>
<td>3.1–4.9</td>
</tr>
<tr>
<td>Muon spectrometer:</td>
<td>$\sigma_{p_T}/p_T = 10%$ (p_T=1 TeV)</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Calibration and reconstruction relies on MC, which needs to be validated by test beam and cosmic ray data -> improve the MC of the detector
Inner Detector

Tracking \(|\eta|<2.5\) \(B=2\,T\)

Momentum resolution: 
\[
\frac{\sigma}{p_{T}} \sim 3.4 \times 10^{-4} \, p_{T} \text{ (GeV)} + 0.015
\]

- Transition Radiation Tracker
- 4mm diameter straws with 35 \(\mu\)m anode wire
- Layers: 73 in Barrel (axial)
  2x160 in Endcap (radial)

- 4/9 double layers in Barrel/Endcap
- 4088 modules, 6M chan., strips 80 \(\mu\)m
- Resolution 17x580 \(\mu\)m

- 3 layers in Barrel and Endcap
- Pixel size 50 x 400 \(\mu\)m
- Resolution 10x110 \(\mu\)m
- 80 M channels
• SUSY studies
  Control the charge misidentification $\leq 1\%$

• $H \to 4l$
  Good track efficiency ($\geq 95\%$) with low track fake rate ($\leq 1\%$)

• Good $b$ tagging efficiency
  50% eff. with a rejection factor 100 (low luminosity)

• Enhance electron identification using the transition radiation

• Resolution: $\sigma_{p_T}/p_T=0.05\%+1\%$ cannot compete with ECAL nor
  muon spectrometer at high energies
Inner Detector Status

- **Pixel**
  - 80 M channels, 1.6% dead channel
  - Hit efficiency ~ 99.8%
  - Noise occupancy ~10^{-10}

- **SCT**
  - 6 M channels, dead channel < 1%
  - Noise occupancy: Barrel: 4.4 x 10^{-5 }; Endcap: 5 x 10^{-5}
  - Hit efficiency > 99.5%

- **TRT**
  - e-π separation via TRT: 0.5 < E < 150 GeV
  - 98% of the 52k channels operational
Pixel and SCT Cosmic Ray Results

For 2009/2010 running

- Very high efficiency: 99.8 for Pixel, 99.5% for SCT
- Good alignment available
Calorimeter System

- Cu-LAr structure
  - $1.5 < |\eta| < 3.2$
  - 4 longitudinal samples

- Pb-LAr accordion
  - 3 longitudinal samples $|\eta|<2.5$
  - Preshower $|\eta|<1.8$

- LAr hadronic end-cap (HEC)

- LAr electromagnetic end-cap (EMEC)

- Tile barrel

- Tile extended barrel

- W-LAr structure
  - 3 longitudinal samples
  - $3.2 < |\eta| < 4.9$

- LAr forward (FCal)

- Fe-Scintillating Tile structure
  - $|\eta| < 1.7$
Requirement to the calorimeter

Electromagnetic calorimeter
• Reconstruct \( e/\gamma \) from \( H, Z'/W' \) and b tagging
• \( H \rightarrow \gamma\gamma \) mass resolution 1%
• Jet rejection with inner detector: \( 10^5 \) and \( \varepsilon = 70\% \) for e;
  \( 10^3 \) and \( \varepsilon = 80\% \) for \( \gamma \) (include converted \( \gamma \))

Hadronic calorimeter
• Large coverage: good transverse missing energy (MET) resolution and tagging jets associated to the heavy Higgs production.
• Thickness: provide good MET resolution and limit punch through to the muon.
Calorimeter Status

• LAr calorimeter
  • Dead channels 0.02% (+0.9% from readout - being fixed)
  • Noisy channels 0.003%
  • Electronic calibration procedure is operational

• Tile calorimeter
  • Dead channels: < 1.4% (replaced during the shutdown)
  • Calibration system is operational (Cs source, laser, charge inj.)

• L1 calorimeter trigger
  • Dead channels: < 0.4% of 7200 analogue channels
  • Channels to channel noise suppression allows $E_T=1\text{GeV}$ cut (aim: 0.5 GeV)
Muon Spectrometer

Requirements:

Trigger Chambers:
- $\text{MDTs}$ in the barrel and end-caps
- $\text{CSCs}$ at large rapidity for the innermost end-cap stations

Trigger chambers:
- $\text{RPCs}$ in the barrel
- $\text{TGCs}$ in the end-caps

Requirements:

$\text{Trigger Chambers:}$
- $P_T$ threshold 6 GeV

Rapidity range:
- $|\eta| \leq 2.7$

Track and $p$ measurement:
- $\sigma_{p_T}/p_T = 3\%$ at 100 GeV
- $10\%$ at 1 TeV

A crucial component to reach the required accuracy is the sophisticated alignment measurement and monitoring system.
Muon Spectrometer

Total MDT chambers: 1155   (371,232 tubes)
Total CSC chambers: 32     (67,000 channels)
Alignment sensor: ~10,000 channels
Tracking Sagitta resolution: 50 μm
Single wire resolution: 85 μm
Alignment precision: 40 μm

Large scale!
Large quantity!
High precision!
Requirements to the Ms

• Excellent stand-alone performance at high luminosity
  \( \sigma_{p_T}/p_T = 3\% \) at 100 GeV, 10\% at 1TeV

• Low momentum trigger capability at low luminosity
  \( P_t \) threshold 6 GeV

• Larger rapidity range
  2-6 Tm for \( |\eta|<1.3 \), 4-8 Tm 1.6<\( |\eta|<2.7 \)
# Muon System Status

<table>
<thead>
<tr>
<th>Precision chambers</th>
<th>Trigger chambers</th>
</tr>
</thead>
<tbody>
<tr>
<td>spatial resolution 35-40 µm</td>
<td>spatial resolution 5-10 mm</td>
</tr>
<tr>
<td>MDT (barrel/endcap)</td>
<td>time resolution &lt; 1 BC</td>
</tr>
<tr>
<td>- 99.8% of chambers operational</td>
<td>RPC (trigger chambers, barrel)</td>
</tr>
<tr>
<td>- Dead channels 0.2% (+0.5% recoverable)</td>
<td>- 95.5% operational (goal 2009: 98%)</td>
</tr>
<tr>
<td>CSC (small wheel)</td>
<td>- Dead strips &lt; 2%, hot strips &lt; 1%</td>
</tr>
<tr>
<td>- All chambers operational</td>
<td>TGC (trigger chambers, endcap)</td>
</tr>
<tr>
<td>- Dead channels 1.5%</td>
<td>- 99.8% of chambers operational</td>
</tr>
<tr>
<td>Optical alignment system (12232 sensors)</td>
<td>- Noisy channels &lt; 0.02%</td>
</tr>
<tr>
<td>- 99.7% (barrel), 99% (endcap) operational</td>
<td></td>
</tr>
</tbody>
</table>

**Muon system standalone resolution**  
\[ \Delta p_T/p_T < 10\% \text{ up to 1 TeV} \]
Muon Spectrometer

Momentum difference between ID and muon spectrometer (due to momentum loss in calorimeters)

Correlation endcap trigger (TGC) and precision (MDT) chambers

Muon tracking is working well standalone
Trigger, DAQ and Detector Control

**Trigger**

- LVL2
  - RoI Builder
  - L2 Supervisor
  - L2 N/work
  - L2 Proc Unit O(500) PCs
  - Event Filter
    - Processors O(1900) PCs
  - LVL2 acc = 2 kHz
  - Event Filter data = 1-2%

**Event Filter**

- Event Filter N/work
  - Event Builder
    - O(100) PCS
  - Event Builder Sub-Farm Input
  - O(100) PCS
  - Sub-Farm Output

**DAQ**

- Calo MuTrCh
  - Other detectors
- Lvl1 acc = 75 kHz
- RoI requests
- EFacc = ~0.2 kHz
- Fe Pipes
  - FE Pipelines
  - Read-Out Drivers 120 GB/s
  - Read-Out Links
  - Read-Out Buffers
  - Read-Out Sub-systems O(150 PCs)
  - LVL2 ~ 10 ms
  - ROIB
  - L2SV
  - L2P
  - L2N

**Dataflow**

- LVL2 acc = 2 kHz
- EFacc = ~0.2 kHz
- EF requests
- ~4 GB/s
- ~ 300 MB/s
- Sub-Farm Output
- Event Filter N/work
- Event Builder O(100) PCS
- Event Builder N/work
- Dataflow Manager
- Event Building N/work
- Sub-Far Input
- Event Builder N/work O(100) PCS

**Other detectors**

- Lvl1 acc = 75 kHz
- Lvl1 acc = 2 kHz
- RoI data = 1-2%
- ~ 300 MB/s
- 40 MHz
- 2.5 µs
- 2.5 µs

---

- RoI Builder L2 Supervisor
- L2 N/work L2 Proc Unit O(500) PCs
- Event Filter Processors O(1900) PCs
## Present Detector Status

<table>
<thead>
<tr>
<th>Sub-detector</th>
<th>Number of channels</th>
<th>Operational fraction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixels</td>
<td>80 M</td>
<td>98.5</td>
</tr>
<tr>
<td>SCT Silicon Strips</td>
<td>6 M</td>
<td>99.5</td>
</tr>
<tr>
<td>TRT Transition Radiation Tracker</td>
<td>350 k</td>
<td>98.2</td>
</tr>
<tr>
<td>LAr EM Calorimeter</td>
<td>170 k</td>
<td>99.1</td>
</tr>
<tr>
<td>Tile Calorimeter</td>
<td>9800</td>
<td>99.5</td>
</tr>
<tr>
<td>Hadronic endcap LAr calo</td>
<td>5600</td>
<td>99.9</td>
</tr>
<tr>
<td>Forward LAr calorimeter</td>
<td>3500</td>
<td>100</td>
</tr>
<tr>
<td>MDT Muon Drift Tubes</td>
<td>350 k</td>
<td>99.3</td>
</tr>
<tr>
<td>CSC Cathode Strip Chambers</td>
<td>31 k</td>
<td>98.4</td>
</tr>
<tr>
<td>RPC Barrel Muon Trigger</td>
<td>370 k</td>
<td>~95.5 (aim &gt;98.5)</td>
</tr>
<tr>
<td>TGC Endcap Muon Trigger</td>
<td>320 k</td>
<td>99.8</td>
</tr>
</tbody>
</table>
Concerns

- Long-term reliability of some components
  - LV power supplies of LAr and Tile calorimeters;
  - Liquid-Argon readout optical links;
- Inner detector cooling.

Back-up solutions being prepared for installation in future shut-down.
## Expected number of events

<table>
<thead>
<tr>
<th>Channels</th>
<th>Number of events after selection ((\sqrt{s} = 10\text{ TeV}, 100\text{ pb}^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(J/\psi \to \mu\mu)</td>
<td>(10^6) ((7 \times 10^4) at 7 TeV)</td>
</tr>
<tr>
<td>(\Upsilon \to \mu\mu)</td>
<td>(5 \times 10^4) ((5 \times 10^3) at 7 TeV)</td>
</tr>
<tr>
<td>(W \to \mu\nu)</td>
<td>(3 \times 10^5)</td>
</tr>
<tr>
<td>(Z \to \mu\mu)</td>
<td>(3 \times 10^4)</td>
</tr>
<tr>
<td>(t\bar{t}b\rightarrow WbWb\rightarrow \mu\nu+X)</td>
<td>800</td>
</tr>
<tr>
<td>QCD jets ((p_T &gt; 1\text{ TeV}))</td>
<td>500</td>
</tr>
<tr>
<td>WW/WZ</td>
<td>50/10</td>
</tr>
</tbody>
</table>
ATLAS Physics Road Map

10 pb\(^{-1}\)
- Initial detector & trigger synchronisation, commissioning, calibration & alignment, material.
- Rediscover SM processes: jet, lepton rate, Z, W.

100 pb\(^{-1}\)
- Understand SUSY and Higgs background from SM.
- More accurate alignment & EM/Jet/ETmiss calibration.
- Early discoveries.

1 fb\(^{-1}\)
- Higgs discovery sensitivity (MH=130~500 GeV).
- Explore SUSY to m ~ TeV.
- SM precision measurements.
Status of the ATLAS Experiment

Kerstin Jon-And, Stockholm University, on behalf of the ATLAS Collaboration
The SM Early Signals: $J/\psi$, $\Upsilon$, $W$, $Z$

- Muon Spectrometer and ID alignment
- ECAL calibration, $E$ and $p$ scale of full detector
- Lepton trigger and reconstruction efficiency
The first Top Quarks from ATLAS

\[ \ttbar \rightarrow bW \ bW \rightarrow bl\nu \ bjj \]

- For \( \mu \) channel, expect 600 and 1600 events at 7 and 10 GeV
- Expected uncertainty of cross section < 20% (+luminosity uncertainty)
- Contain lepton, jets, b-jets and \( E_T^{\text{miss}} \), background to all searches
$Z' \rightarrow ll$ with mass $\sim 1$ TeV

Sensitivity beyond Tevatron limits with 200 pb$^{-1}$ and $\sqrt{s} \geq 7$ TeV (100 pb$^{-1}$ at 10 TeV)
SUSY Particles

- Huge production cross-section for the production of $\tilde{q}, \tilde{g}, \tilde{g}$ for $M_{\text{susy}} \sim 1 \text{ TeV}$
- Expect 1 event/5 days at $L = 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$
- Final states: lepton+multi-jet+missing $E_T$
Jets + $E_T^{\text{miss}}$: highest reach

- ATLAS discovery reach beyond Tevatron expected exclusion ($\sim 400$ GeV) with 200 pb$^{-1}$ for $\sqrt{s} \geq 7$ TeV
- Crucial to understand backgrounds, fake missing transverse energy and jet energy
- LHC reach: $m(\tilde{q}, \tilde{g}) \sim 3$ TeV

$\mathbf{m_{\text{SUSY}}} \sim 750$ GeV with 200 pb$^{-1}$ at $\sqrt{s} = 10$ TeV
Conclusion

• The ATLAS detector is in good shape and ready to take colliding data for exciting physics.

• Dead channels is on the level of 1-2%.

• Cosmics ray and single beam data shows good detector performance.

• Computing and software have proven to be able to handle the massive data for world wide distribution.

• ATLAS upgrade activity has been going on for 3-4 years: pixel, forward muon, low voltage power supplies..... (RD51 has done three years test beam).
Let’s cross our finger and hope that

• LHC could ramp up its energy and luminosity smoothly

• Detectors could commission with long term stability, good performance and a reasonable age.

• LHC experiments will then be the frontier of high energy physics in the next 10 year and beyond.
Early Physics (~100 pb\(^{-1}\))

- Without understanding the detector performance and data quality, hardly one can go for publication with convincing results. Needs time to understand stand such a complicated giant.

- First tuning of MC (minimum-bias, underlying event, \(tt\), \(W/Z+jets\), jets,\(\ldots\))

- Measure particle multiplicity in minimum bias (a few hours of data taking \(\ldots\))

- Measure QCD jet cross-section to \(\sim 30\%\)? (~103 events with ET \((j) > 1\ \text{TeV})

- \(Z\), \(W\) are standard candles to reply on. \text{Xsec}(10\%), mass, width.

- Establish diboson (WW, WZ\(\ldots\)) events and measure \text{Xsec}

- Observe top signal with \(\sim 30\ \text{pb}^{-1}\)

- Measure \(tt\ xsec\). to 20\% and m(top) to 10 GeV?

- Improve knowledge of PDF (low-x gluons \(!\)) with \(W/Z\)?

And if nature is favoring us:

- Discover SUSY up to gluino masses of \(\sim 1.3\ \text{TeV}\)?

- Discover a \(Z'\) up to masses of \(\sim 1.3\ \text{TeV}\)?

- Prepared for surprises
Accelerator chain of CERN (operating or approved projects)
Main Components of the LHC Accelerator

- **Power converts**: power the magnets?
- **Beam dump**: get rid of the beam, in an emergency, or at the end of a fill
- **Magnets**: bending, focusing, steering...
- **Radio frequency cavity (RF)**
- **Cryogenics**: keep the magnets cold
- **Vacuum**: the beam has to travel in a very good vacuum
- **Collimators**: catching particles before they catch the magnets
- **Current leads**: feeding the current from warm into the cold mass of the magnets
LAr Results

Pedestal stability for 128 channels of barrel EM strip (or front) layer over a 5 months period

\[ E_{T,\text{miss}} \] reconstruction on randomly triggered events using cells or topological clusters

Very good stability and understanding of reconstruction and noise behaviour
# Luminosity Ramp Up

<table>
<thead>
<tr>
<th>Luminosity 1 mon run</th>
<th>Int. Lumi. (1/fb)</th>
<th>Interest proc. (with e, μ, γ)</th>
<th>X-section</th>
<th>Events for calibration and measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{29}$</td>
<td>0.00001 (100 nb⁻¹)</td>
<td>$W\rightarrow\mu\nu, \text{ev(DY)}$ $J/\psi, \gamma\rightarrow\mu\mu, \text{ee}$</td>
<td>$\sigma_{\mu\nu} \sim 20\text{nb}$ $\sim 800 J/\psi, \sim 100 \gamma$</td>
<td>Detecte 1000 $\mu$ ($W\rightarrow\mu\nu$) Detect 800 $J/\psi$, Detect 100 $\gamma$</td>
</tr>
<tr>
<td>$10^{30}$</td>
<td>0.001 (1 pb⁻¹)</td>
<td>$Z\rightarrow\mu\mu, \text{ee}$ $ttbar$</td>
<td>$\sigma_{\mu\mu} \sim 2\text{nb}$ $\sigma_{tt} \sim 750\text{pb}$</td>
<td>Detect 1500 $\mu\mu$ from $Z$ Detect 800 $tt$</td>
</tr>
<tr>
<td>$10^{31}$</td>
<td>0.01 (10 pb⁻¹)</td>
<td>$Z+\text{jet}$ $\gamma\gamma, W\gamma, Z\gamma$</td>
<td>$\sigma_{q\mu\mu} \sim 40\text{pb}$ $\sigma_{\gamma\gamma} \sim 24\text{pb}$</td>
<td>400 $Z$jet events,JE cali. 250 $\gamma\gamma$ with $M&gt;60\text{ GeV}$</td>
</tr>
<tr>
<td>$10^{32}$</td>
<td>0.1 (100 pb⁻¹)</td>
<td>$WZ$, $WW$, $Z+\text{n jets}$</td>
<td>$\sigma_{e\mu} \sim 2.4\text{pb}$</td>
<td>$\sim 50 \text{ e}\mu$ from $WW$ selection $\sim 10$ trilepton events ($WZ$)</td>
</tr>
<tr>
<td>$10^{33}$</td>
<td>1.0 (10M $W\rightarrow l\nu$) (1M $Z \rightarrow ll$) Understand detect $\sim 2%$</td>
<td>$ZZ\rightarrow 4l$, $ll\nu\nu$ $H \rightarrow WW$? $W' \rightarrow e/\mu \nu$? $Z' \rightarrow ee, \mu\mu$? SUSY?</td>
<td>$\sigma_{4l} \sim 0.08\text{pb}$</td>
<td>$\sim 11 ZZ\rightarrow 4l$, 10 $ZZ\rightarrow ll\nu\nu$ Searches: Single $\mu$, $M_T &gt; 1\text{ TeV}$ dilepton mass $&gt; 1\text{ TeV}$ Higgs $\rightarrow WW$ ($\sim 165\text{ GeV}$) SUSY $\rightarrow$ multi-leptons</td>
</tr>
</tbody>
</table>
Tile results

Muon dE/dz from horizontal muons during single beam running

Tile calorimeter noise measured during first beam period

Low noise, uniform response, well understood calibration
W, Z Cross Section Measurement

Theoretical predictions on the single W and Z production cross-sections, calculated at NNLO with a precision of 1%.

With 50 pb$^{-1}$ of data, ATLAS allows to measure the cross section to a precision of 5% (luminosity is not included).

W, Z cross section ratio

\[
\text{BR}(W \rightarrow \mu \nu) = R \left( \frac{\sigma(pp \rightarrow WX)}{\sigma(pp \rightarrow ZX)} \right) \text{BR}(Z \rightarrow \mu^+ \mu^-)_{\text{LEP}}
\]

\[
\Gamma_W = \left( \frac{1}{R} \right) \left( \frac{\sigma(pp \rightarrow WX)}{\sigma(pp \rightarrow ZX)} \right) \text{BR}(Z \rightarrow l^+ l^-)_{\text{LEP}} \Gamma(W \rightarrow l \nu)_{\text{LEP}}
\]
Studying the spectrum in the lowmass region can help to improve the PDF precision.
W leptonic decay and the PDF's

Observing the lepton asymmetry instead of the lepton distribution one can reduce the uncertainty inside each PDF set (less than 4%) and maintain the spread between the different sets.
Minimum Bias Events

- Minimum bias particle density drives detector global occupancy even at « low » $L=10^{33}\text{cm}^{-2}\text{s}^{-1}$
- Uncertainties up to 30% from extrapolation from lower energies
- Can be measured in a few days, but should always be kept in mind when defining startup scenarios (occupancies, rates....)
Top Quark Mass

- Reconstructed in $tt \rightarrow W(l\nu)bW(qq)b$
  - Most important background: $W+4$ jets
- Selection without b tag at the beginning
- Isolated lepton with $P_T > 20$ GeV
- Exactly 4 jets ($\Delta R=0.4$) with $P_T > 40$ GeV
- $W$ and top peaks visible with 30 pb$^{-1}$
- With b tag: $\sigma(M_{\text{top}}) \sim 0.8$ GeV with 150 pb$^{-1}$
Search for High Mass Dilepton Resonance

Search for $Z' \rightarrow e^+e^-/\mu^+\mu^-$
Higgs Search

- $m_H > 150 \text{ GeV}$ could be visible in 2008
- Lower masses $5\sigma @ 30 \text{ fb}^{-1}$ need more luminosity

*ATLAS graph showing signal significance versus $m_H$ (GeV) with 5$\sigma$ significance at 3 fb$^{-1}$ and 30 fb$^{-1}$.
## ATLAS and CMS Resolution Performance

<table>
<thead>
<tr>
<th></th>
<th>ATLAS</th>
<th>CMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tracker</strong></td>
<td>Si pixels, strips + TRT (pid) (\sigma/p_T \approx 5 \times 10^{-4} p_T \oplus 0.01)</td>
<td>Si pixels, strips (\sigma/p_T \approx 1.5 \times 10^{-4} p_T \oplus 0.005)</td>
</tr>
<tr>
<td><strong>EM calorimeter</strong></td>
<td>Pb + LAr (\sigma/E \approx 10%/\sqrt{E} \oplus 0.007)</td>
<td>PbWO(_4) crystals (\sigma/E \approx 2-5%/\sqrt{E} \oplus 0.005)</td>
</tr>
<tr>
<td><strong>Hadronic calorimeter</strong></td>
<td>Fe+scintillator / Cu + Lar (\sigma/E \approx 50%/\sqrt{E} \oplus 0.03)</td>
<td>Cu+scintillator (\sigma/E \approx 100%/\sqrt{E} \oplus 0.05)</td>
</tr>
<tr>
<td><strong>Combined Muons (ID+MS)</strong></td>
<td>2%@50GeV to 10%@1TeV</td>
<td>1%@50GeV to 5%@1TeV</td>
</tr>
</tbody>
</table>
LAr and Tile Calorimeters

Hadronic end-cap (HEC)
- Cu-Lar structure
- $1.5 < |\eta| < 3.2$
- 4 longitudinal samples

LAr EMEC
- Pb-LAr accordion
- 3 longitudinal samples $|\eta|<2.5$
- Preshower $|\eta|<1.8$

LAr forward calorimeter (FCAL)
Transition radiation (TR) photons generated by radiator foils (boundary of 2 materials with different dielectric constants)
Effect starts at $\gamma = (E/m) \approx 10^3$ ➞ mostly for electron ID

In the TRT, photons are absorbed in chamber gas ➞ large pulse ➞ passes high threshold

Turn-on of TR from cosmics at about $\gamma=10^3$ as expected
**Forward Muon Spectrometer**

**Big wheels** (and end-wall wheels): 400 MDT precision chambers and 3600 TGC (Thin Gap Chambers) trigger chambers

**Small wheels:** 32 CSC (Cathode Strip Chambers) precision chambers

Level-2 Trigger: RoI. e/γ, μ, jet, .. Full granularity in RoI.


High Level Trigger (HLT): Event Building.

Interaction rate ~1 GHz, Bunch crossing rate 40 MHz. LEVEL-1 TRIGGER <75 (100) kHz.

Region of Interest: LEVEL-2 TRIGGER ~3.5 kHz.

Event builder: Full-event buffers and processor sub-farms. Data recording.

DAQ software: Control, configuration, Monitoring on Control Network.

300 MByte/s to Computer Center. ~3 Pbytes stored year.
Muon (shower) energy measured with full calorimeter readout

vs

energy measured in trigger towers 
($\eta \times \phi = 0.1 \times 0.1$)

by level-one calorimeter trigger.

With initial calibration (final calibration will reduce the spread)
The 2009/10 LHC Run

- **Decisions taken**
  - Top energy is 5 TeV (had been reached for all other sectors)
  - No winter shutdown 2009/10

- **Consequences**
  - Enough data to compete with Tevatron in many areas by end of 2009/10 run
Machine layout

LHC PROJECT

Main dipoles: 1232
Arc quadrupoles: 392
Correctors: 4846
Insertions: 158

6628 sc magnets

UNDERGROUND WORKS
Combined Test Beam (~O(1%) Coverage)

- All ATLAS sub-detectors (and LVL1 trigger) integrated and run together with common DAQ and monitoring, “final” electronics, slow-control, etc.
- Data analyzed with common ATLAS software.
- Gained lot of global operation experience during ~ 6 month run.

- B field: 0-.4 T
- e^+, π^+: 1- 250 GeV
- μ^+, π^+, p up to 350 GeV
- γ: 20-100 GeV
- ~ 9x10^7 events collected
Sagitta resolution vs momentum

Two contributions:
1. Intrinsic resolution
2. Multiple scattering

Disentangled by fitting with:
$$\sigma = \sqrt{P_1^2 + \left(\frac{P_2}{P}\right)^2}$$

Intrinsic resolution \(\sim 50 \, \mu m\)

MDT fit residuals to data

\(\sigma = 61 \, \mu m\)

Preliminary
Energy Resolution from EM Test Beam

Barrel

Data ($\eta=0.48$)

$\sigma_{\sqrt{E}} = a/\sqrt{E} + c + n/E$

For every tested points:

<table>
<thead>
<tr>
<th></th>
<th>Barrel</th>
<th>End-cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>$&lt;10%$</td>
<td>$&lt;12.5%$</td>
</tr>
<tr>
<td>$c$</td>
<td>$&lt;0.4%$</td>
<td>$&lt;0.5%$</td>
</tr>
</tbody>
</table>

- Within specifications
- Good agreement with MC

End-cap

$\eta=1.9 \cdot \text{Data}$

$\sigma_{\sqrt{E}}$ ($\%$)

$\circ \text{MC}$

$a = 10.35\% \pm 0.05$

$c = 0.27\% \pm 0.02$