ATLAS Commissioning and Physics with Early Data

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1. ATLAS status and commissioning pre-LHC startup
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1: Status and Commissioning pre-LHC Startup

A word on the LHC

- **Machine closure end of May; beam commissioning June 2008**
 - Currently in cooling down phase: cooling each sector to 1.9K takes ~8 weeks
 - Four commissioning phases
 - A: - establish first circulating beam → first 7TeV collisions (2 months)
 - pilot physics run (1 month) with luminosity $\sim 10^{31} \text{cm}^{-2} \text{s}^{-1}$
 - should deliver $\sim 3 \text{pb}^{-1}$ integrated luminosity
 - B: move to 75ns bunch spacing, up to 936 bunches/beam ($\sim 10^{32} \text{cm}^{-2} \text{s}^{-1}$)
 - C: move to 25ns bunch spacing ($\sim 10^{33} \text{cm}^{-2} \text{s}^{-1}$)
- <shutdown>
- towards full current ($10^{34} \text{cm}^{-2} \text{s}^{-1}$)

ATLAS Basics

25m diameter, 46m long, weighing 7000T, with 3000km of cables and 10^8 channels

Tracking ($|\eta| < 2.5$, $B=2T$):
 • Silicon pixels and strips
 • Transition Radiation Tracker

Calorimetry ($|\eta| < 5$)
 EM : Pb-LAr
 HAD: Fe/scintillator
 (central), Cu/W-LAr (fwd)

Muon spectrometer ($|\eta| < 2.7$, $B=4T$ max)
 Toroid magnet system with precision and trigger chambers

ATLAS Commissioning Activities

“Online”

1. Commissioning of individual subsystems in pit (almost finished)
2. Integration of subsystems into ATLAS trigger and DAQ system (on-going)

Several global commissioning runs using cosmic rays in 2007:

- operate the whole experiment
- achieve stable running for long periods
- exercise Trigger and DAQ (data flow, run control, configuration)
- operate control room as if data taking

Should not forget “Offline”

- **Full Dress Rehearsal (FDR):**
a “stress test” of the full data processing and analysis chain from point-1 to the end user

Global Commissioning Runs with Cosmics

Example event from August run:
cosmic through
Muon system (MDT),
Hadronic calorimeter (TileCal)
and
ID Tracking (TRT)

November run included:
- 1/4 of muon system
- 3/4 of EMC
- 2/4 of HCAL

Global Commissioning Runs with Cosmics

Phi-distribution of muons from **TRT tracking**, **calorimeter** and **muon spectrometer** combined, from November run:

- **higher level trigger** (software) operational
- **monitoring** of HLT operational
- detector performance understood

- Next run (March) will include SCT (inner detector silicon strip tracker) for first time

ATLAS will migrate to a different mode of running two months before beam closure (=three months before first 14TeV collisions)

- will reach continuous (24/7) running when beam closed
- truly global cosmic runs
- commissioning with beam halo and beam gas interactions

Part 2: Commissioning and physics with first data

The Road to Discovery

Step #1

- Understand / calibrate detector & trigger in situ using well-known processes
 - “Rediscover” Standard Model at 14TeV
- use well modelled “standard candles”: **W, Z, top:**

Channel	Events/ 100pb ⁻¹	Total Events from LEP/Tevatron	Leads to understanding of...
Z → ee, μμ	~10⁴	~10⁶ LEP ~10⁵ Tevatron	ECAL energy scale and uniformity Tracking alignment
W → ev, μν	~10⁵	~10⁴ LEP ~10⁶ Tevatron	ECAL energy scale Tracking alignment Constrain PDFs
tt → WbWb → μν+X	~10²	~10⁴ Tevatron	Jet scale from W → jj B tagging performance

Step #2

Understand backgrounds to New Physics,
e.g. tt and W/Z+ jets (omnipresent...)

Step #3

Look for New Physics potentially accessible in first year(s),
e.g. Z' → ee/μμ, SUSY, Higgs...?

Immediate New Territory...

Minimum bias events: not well modelled at LHC energies

- Multiplicity of charged particles at $\eta = 0$, as a function of centre-of-mass energy: *extrapolating existing measurements to the LHC energies reveals differences of around 50% between the different models*

- A sample of $\sim 10^4$ events represents sufficient statistics to measure the charged particle multiplicity with enough precision to discriminate between different models: *in principle possible with a few hours' worth of data*

- (Min. bias events will also play an important role in the trigger commissioning)

New Territory: QCD Jets

High cross-sections

($\sim 100 \text{ events}/10 \text{ pb}^{-1}$ for $E_T > 1 \text{ TeV}$)

- rapidly probe QCD on a new scale
- high E_T region sensitive to new physics
- background to $\sim$ all searches: accurate reconstruction and calibration is essential

Main error on jets cross-section is from jet energy scale

- 10% initially from test beam studies
→ 1% from data (γ/Z +jet, $W \rightarrow jj$ in $t\bar{t}$)

First Peaks and Detector Calibration

After all cuts expect ~ 600 $Z \rightarrow \mu\mu/ee$ events per pb⁻¹, per channel

Muon channel used for alignment of muon spectrometer and ID tracker, plus trigger and reconstruction efficiencies

Electron channel used to calibrate the lepton energy scale, using the Z mass constraint, measure trigger and reconstruction efficiencies and calibrate the ECAL uniformity:

- Expect initial, residual long range non-uniformities at level of 1-2%
- Around 10^5 $Z \rightarrow ee$ events should be sufficient to reach the goal response uniformity of $\sim 0.7\%$

With 100pb⁻¹ the Z cross section should be measured to around 10%, dominated by the uncertainty on the luminosity

Top Signal

After all cuts expect ~ 500 events per 100pb^{-1} in the lepton plus jets channel ($t\bar{t} \rightarrow b\bar{\nu} bjj$)

Signal can be observed with simple analysis without b-tagging

Error on cross-section is $\sim 20\%$, dominated by luminosity and jet energy scale

NB: same events are used to calibrate the light-jet energy scale using the W mass constraint ($M_W = M_{jj} \cdot K^2$ where K = jet energy scale factor)

Early Surprises?

A very narrow Z' resonance decaying to e^+e^- is predicted in a “Higgsless” extension to the SM

For $M_{Z'} \sim 1\text{TeV}$ this would be a very early discovery (ultimate reach is 5TeV with 300fb^{-1})
(Could also be a graviton candidate but would need much more data to distinguish)

Mass/TeV	Selected Events/fb ⁻¹	$\int L$ for Discovery
1	~ 160	$\sim 70\text{pb}^{-1}$
1.5	~ 30	$\sim 300\text{pb}^{-1}$
2	~ 7	$\sim 1.5\text{fb}^{-1}$

Looking Ahead... SUSY?

For squarks and gluinos with $M \sim 1 \text{ TeV}$, hints of a signal can already show up with 100 pb^{-1}

...but...

will need $\sim \text{fb}^{-1}$ of data to understand the backgrounds which could fake this:

- W/Z + jets with $Z \rightarrow \nu\nu$, $W \rightarrow \tau\nu$; $t\bar{t}$
- QCD multijet events with fake E_T^{miss} (calorimeter resolution, cracks, ...)
- cosmics, beam-halo, detector problems overlapped with high- p_T triggers...

Finally, A Word on the Higgs...

Higgs discovery will require $\sim \text{fb}^{-1}$ of well understood data, with a light Higgs being the most difficult to observe: final word in 2010?

Low mass region most difficult: need to combine many channels (e.g. $H \rightarrow \gamma\gamma$, $qqH \rightarrow qq\tau\tau$)

$\leq 1 \text{ fb}^{-1}$ for 95% C.L. exclusion
 $\leq 5 \text{ fb}^{-1}$ for 5σ discovery

Outlook

ATLAS readiness:

- ATLAS is ~100% installed in the cavern
- Next few months will see remaining subsystems integrated into global TDAQ
- *Will reach 24/7 operation with cosmics when beam pipe closed – ready and waiting for collisions!*

First Physics:

- First 14TeV collisions during summer 2008
- Some immediate discoveries to be made on the nature of pp collisions at 14TeV
- Well understood W, Z, top will be the first “rediscoveries” allowing the detector to be commissioned, calibrated and generally understood – hardware, trigger, offline reconstruction...
- *The first steps on the road to discovery in 2008*