Commissioning and operation of the ATLAS Pixel Detector

Joshua Moss, Ohio State University
on behalf of the ATLAS Collaboration

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Outline

Introduction

- The LHC and the ATLAS experiment at CERN
- The ATLAS Pixel Detector

Detector commissioning and operation

- Current status
- Operational safety
- Online Monitoring
- Beam backgrounds

Conclusions

The LHC at CERN

A proton-proton collider located on the France-Switzerland border outside of Geneva

- 27 km long ring previously housing LEP
- 1232 superconducting dipole magnets
- 7 TeV nominal beam energy
- $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ nominal luminosity
- 2808 proton bunches per beam
- 25 ns bunch spacing (40 Mhz)

Operating since Fall 2009

- First 900 GeV collisions – Nov 2009
- Began operations at 3.5 TeV – Feb 2010

Current operating parameters: beam energy= 3.5 TeV luminosity $\sim 0.5 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$

The ATLAS Experiment

ATLAS Pixel Detector

The Pixel Detector:

- 1442 mm long
 - 430 mm in diameter
 - 1.7 m² active area of silicon
 - 3 barrel layers – 1456 modules
 - 3 disks per endcap – 288 modules
 - ~80 million channels
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- Operates in 2 T solenoid magnetic field
 - 3 precision measurements points covering $|\eta| < 2.5$
 - $R\phi$ resolution $\sim 10 \mu\text{m}$
 - η resolution $\sim 115 \mu\text{m}$
 - Power consumption $\sim 15 \text{ kW}$

ATLAS Pixel Modules

Sensor:

- 250 μm thick silicon sensor
- n-doped bulk, n^+ pixels & p^+ backplane
- Pixels: 50 μm ($R\phi$) x 400 μm (η) nominal
 - Long, ganged, interganged pixels between chips
- Amplitude of the signal measured in the form of a Time-over-Threshold (ToT)
- Pixel by pixel threshold tuned to ~ 3500 e

Readout:

16 FEs bump bonded per module:

- DSM 0.25 μm CMOS
- Radiation hard up to $\text{NIEL-}10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$ fluence

MCC – module control chip

- Routes command and configuration data to individual FEs
- Aggregates data from chips for transmission to the off-detector readout drivers (RODs)

Services - Cooling

- Evaporative cooling system used to maintain a module temperature of less than -10°C
- Coolant – C_3F_8 , with $T = -25^{\circ}\text{C}$
- Cools both the Pixel Detector and the Semi-Conductor Tracker (SCT)
- 88 individual loops for the Pixel Detector
- Continuous operation for all of 2010 with very high efficiency $>95\%$
- Leak rate is currently 1.8 kg/day for both Pixel Detector and the SCT

Readout Links

- Information transferred to and from the detector over an 80 m optical link
 - 1 downlink per module, 1 uplink for L2, L1 and Disk, 2 uplinks for B-layer
- Trigger and configuration sent at 40 Mbit/s from the readout driver's Back of Crate (BOC) card
- Data is transferred from the detector at different rates depending on location

B-layer – 160 Mbit/s (2x80 Mbit/s)	Layer 1, Disks – 80 Mbit/s	Layer 2 – 40 Mbit/s
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- Each VCSEL array (both on-detector and off-detector) services 6 or 7 modules

Timeline

- 2006 – Detector construction
- May 2007 – Installation in ATLAS
- Sept 2008 – First cosmic events
- Oct 2008 – LHC incident
- Nov 2009 – First beam 450 GeV
- Dec 2009 – 900 GeV collisions , **Stable beams!**
- March 2010 – 7 TeV Collisions, **Stable beams!**
- September 2010 – 3.6 pb^{-1}

Installation

7 TeV
Collisions

900 GeV
Collisions

ATLAS
EXPERIMENT
2009-12-06, 10:03 CET
Run 141749, Event 405315
Collision Event

Cosmics

Current Status of the Pixel Detector

- 1697 of 1744 modules are active in data-taking
 - 47 module disabled (2.7%)
- 27860 of 27904 front end chips are enabled
 - 44 FEs disabled (0.16%)
- 271 of 272 optoboards are included in operations
 - 6 or 7 modules per optoboard

Disabled Modules by Failure Type

Inactive fraction per layer

Inefficiencies on Modules

Hit efficiency of Disk modules in Endcap A

Occupancy plots for 3 modules with smallest efficiency

Readout Window

- For each trigger received, the module can read out up to 16 consecutive 25 ns buckets (Bunch Crossings – BC)
- Timewalk effect due to the risetime of the preamplifier can shift low amplitude (ToT) hits into the next time bucket
- Goal is to eventually run with 1BC readout
- To compensate for timewalk, low charge hits can be written twice – first with original timestamp, then with the previous BC timestamp

Comics in 2008 – 8 BC readout
First collisions 2009 – 5 BC readout
May 2010 – 4 BC readout
July 2010 – 3 BC readout
August 2010 – 2 BC readout

Beam Conditions Monitor

- Two 4-module stations symmetrically positioned at $z = \pm 1840$ mm around IP
- Radially positioned at $r = 55$ mm
- Mounted at 45° w.r.t. the beam pipe, giving 41% increased signal
- Provides protection against single turn and multi-turn losses in the LHC

- Modules consist of two 10 mm x 10 mm pCVD diamonds, 500 μ m thick
- Nominally biased at 1000 V
- Signal is split to provide 2 thresholds per module: high and low gain

Beam Conditions

- 390 ps timing resolution allows for time of flight discrimination between background events and collision events
- Useful in determining the beam conditions prior to switching on the Pixel Detector
- Can protect ATLAS from dangerous conditions by triggering beam aborts

Pixel Operations – Online Monitoring

Courtesy of A. Andreazza,
INFN & Universita di Milano

Noise Masks and Module Occupancy

- Dedicated runs are taken with a random trigger and no beam to measure the noise occupancy
- Noisy pixels are masked online at the level of 10^{-5}
 - Individual pixels are disabled → not read out
 - Online noise is reduced below 10^{-7}
- Offline noise mask applied for data reconstruction
 - Created run by run
 - Applied during the “prompt calibration loop”
- ~80k pixels disabled for the online noise mask
 - Out of 80M total channels, ~ 0.01%

Typical module occupancies :

B-layer 3×10^{-5}

Layer-1 1×10^{-5}

Layer-2 0.8×10^{-5}

Disks 1×10^{-5}

7 TeV collisions

Beam Background Studies

- Events with large numbers of hits per module can cause blocking of the DAQ due to the long readout time from the event size.
- High occupancy events can originate from beam gas and beam halo events which impact the Pixel Detector parallel to the beam pipe (z-direction)
- Studying the colliding (paired) and the non-colliding (unpaired) bunches, the characteristics of the clusters from beam backgrounds can be investigated.

Data-Taking Efficiency

Integrated Luminosity

Peak Luminosity

- Weekly improvements in peak and integrated luminosity delivered by the LHC
- Losses in data-taking efficiency dominated by the “warm start” procedure

Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
97.7	96.4	100	94.4	98.7	99.3	99.2	98.5	98.3	98.6	98.3

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at $\sqrt{s}=7$ TeV between March 30th and August 14th (in %)

Pixel efficiency for data-taking is 97.7%

Conclusions

- The ATLAS Pixel Detector is performing very well
- 97.3% of pixel modules are included in data-taking
- The data-taking efficiency is currently at 97.7%
- Calibration procedures and data-taking preparations are now routine (see talk by M. Keil)
- Offline alignment and analysis are producing good results and are continually being improved (see talk by L. Dell'Asta)
- Our understanding of the detector and operational procedures continue to improve experience

We are looking forward to increased luminosity from the LHC this fall and on into 2011!