Operational experience of the ATLAS Pixel Detector

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Introduction

ATLAS Pixel Detector is situated at the heart of the ATLAS apparatus operating at the Large Hadron Collider. Operational conditions require radiation hardness of 500 kGy or total fluence equivalent of 10^{15} 1 MeV $n_{eq}cm^{-2}$ for the innermost layer. Among the major challenges is fast signal readout and hit identification, detector should be able to distinguish between hits in following bunch crossings with time interval 25 ns. Since the commissioning in 2008 and massive data-taking campaign started in March 2010 the detector successfully participates in the reconstruction of tracks, vertices and tagging of short-lived particles. After more than one year of LHC running at high luminosity, more than $1 fb^{-1}$ of collisions was recorded and significant operational experience was acquired.

Atlas Pixel Detector – present state

- 3 layers in barrel and each endcap
- 1744 identical modules total with 80×10^6 channels
- Submerged in 2T magnetic field
- Operating temperature $-13^\circ C$ (evaporative C_3F_8 cooling)
- 3 track points down to $|\eta|=2.5$
- IP resolution 15 μm in R_ϕ , 100 μm in Z
- Hit detection efficiency 99%
- Time resolution < 25 ns

A candidate Z boson event in the di-muon decay with 11 reconstructed vertices.

An event with one of the first K_s candidates.

Residual distributions, the widths are close to the Monte Carlo simulations for a perfectly aligned detector.

ATLAS pixel module sensor and FE electronics

- 250 μm thick n^+ -on- n Si sensor
- $50 \times 400 \mu m^2$ pixel size
- 47232 (328×144) Pixels (46080 read out)
- Bias voltage 150 – 600 V

- Each module contains 16 FE Chips with 2880 pixels each
- Pulse height is measured by Time-over-Threshold
- Module Control Chip distributes commands and builds event from FE chips.

- Now operating at 3500 e- threshold with 0.1% of pixels masked (hit rate $> 10^5$)
- Threshold dispersion after tuning $\sim 40 e^-$
- Noise for normal pixels $\sim 170 e^-$

Pixel measurements

Lorentz angle measurements of $E \times B$ drift.

Minimal cluster size is reached for particles coming at a Lorentz angle w.r.t. the sensor plane. Measured value of 211.3 ± 1.5 mrad is close to the expected value of 225 mrad.

Expected dependence of the Lorentz angle on the mobility measured on modules with different temperature (-0.78 ± 0.18) mrad/K, expected: -0.74 mrad/K

dE/dx determined by ToT for different tracks. Pion Kaon, proton and deuteron bands are clearly seen.

Comparison of cluster properties for non-colliding vs. colliding bunches.

Charge sharing in between pixels improves the resolution. Impact on local residuals is remarkable.

X vs. Y of reconstructed secondary vertices (excluded vertices from $\gamma/K_s/\Delta$).

The AI cooling pipe, carbon fiber stave and the sensitive part of the sensor are well visible in both data (lower) and simulation (upper).

Data taking efficiency

- Pixel data taking efficiency 99.8%
- Dead time is significantly reduced by automation of on/off switching procedure

Inner Tracking Detectors			Calorimeters			Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	FWD	Tile	MDT	RPC	CSC	TGC	Solenoid
99.8	99.5	100	89.3	92.7	94.3	99.5	100	99.5	100	99.9	98.5
99.9	99.5	100	89.3	92.7	94.3	99.5	100	99.5	100	99.9	98.5

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at $\sqrt{s}=7$ TeV between March 13th and June 6th (in %). The inefficiencies in the LAr calorimeter will partially be recovered in the future. The magnets were not operational for a 3-day period at the start of the data taking.

Detection efficiency

96.8% of the pixels are operational in data taking. The fraction of disabled modules increased from 2.1% at start-up to 3.2% in 3 years of operation.

- Out of 1744 modules:
- 55 Modules disabled (3.2%)
- 47 FE chips disabled (0.16%)
- Failures are mostly linked to thermal cycles.

Inactive fraction per layer:

- B-layer 3.1 %
- Layer 1 1.4 %
- Layer 2 4.6 %
- Endcap A 2.8 %
- Endcap C 2.8 %

Layer (readout)	Occ. Hits/pixel/BC
B-layer (160 MHz)	1.5×10^{-4}
Layer 1 (80 MHz)	0.7×10^{-4}
Disks (80 MHz)	0.55×10^{-4}
Layer 2 (40 MHz)	0.45×10^{-4}

Typical module occupancies during data taking at luminosities $\sim 10^{33} cm^{-2} s^{-1}$

Pixel detector noise occupancies between runs.

Efficiency of a hit-to-track association.

Summary

Atlas Pixel Detector has been tuned and operates with 99.8% efficiency, 96.8% of pixels fully participating in the data taking. Since commissioned, the Pixel Detector demonstrated stability of operational parameters. Requirements on hit detection efficiency, track and vertex reconstruction precision and low noise occupancy rate have been met. Data obtained by the Pixel Detector contributed significantly to the quality of physics results. Gathered experience with the Pixel Detector demonstrates operational readiness for further data-taking periods and increasing luminosity.