Commissioning of the ATLAS Pixel Detector

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The ATLAS Pixel Detector

**MOTIVATION**

Decay length ~mm ⊗ semiconductor technology
2D spatial tracking information @ LHC beam pipe ⊗ silicon pixel detector,
(50x400)μm² x 200μm

**ATLAS:** 3 Barrel layers (r = 5, 9, 12 cm) + 2 End-Caps each with 3 Disks

촉 3 space points for |η| < 2.5 with resolution 16μm (Rφ) and 115μm in η
Performance Requirements

High multiplicity tracking detector:
\[
\sim 1200 \text{ tracks per bunch crossing @ } 10^{34} \text{ cm}^{-2}\text{s}^{-1} \Rightarrow \text{high granularity (80 million channels!)}
\]

High impact parameter resolution:
\[
\sim 12 \mu\text{m vertex resolution – secondary vertex reconstruction}
\]

Low interaction length:
\[
\sim 10\% \chi_0
\]

High radiation dose tolerance:
\[
> 50 \text{ Mrad}
\]

High time resolution:
\[
40 \text{ MHz bunch crossing rate; single bunch crossing resolution, up to 16 consecutive bunch crossing readout}
\]
**Readout Chain: The Module**

**Module** - The building block of the detector

1 Module = 46080 pixels
Pixel Detector = 1744 Modules ≈ 80 million pixels

**Front End**

- Array of analog cells directly coupled with the pixels via bump bonding.
- Digital readout interfacing the chip to the rest of the DAQ.
- End-of-Column buffers to compensate LVL1 latency (up to 255 BC).

PP0 connection

Sensor tile

Bump bonds

Wire bonds

16 FE chips

BOC

TX

RX

S-Link

ROD

L1A

SBC

ROBIN

S-link
OptoBoard
Rad-hard optical transmitters, receivers and an encoder/decoder to transmit clock and serial commands over a single optical fiber.
Electrical to optical signal conversion (for ground decoupling and noise immunity).

ROD
9U VME board.
Trigger distribution to the modules
Hits extraction from the modules
Calibration control

BOC: Back Of Crate, optical components

Optimize detector response ➔ calibrate readout electronics, tune on-line and store results
**The Module Tuning**

**Motivation:** Mean energy loss in pixels changes in time due to irradiation.

**Calibration source:** Directly inject charge by applying a voltage step ($V_{Cal}$) to a calibrated capacitor embedded in each FE chip. No sensor involved (except dedicated scans).

**Calibration procedures:** Many! Vary $V_{Cal}$ and determine distribution for
- discriminator threshold
- noise (slope of signal rise)
- Time-Over-Threshold (ToT) indirect charge deposit measurement
- ...

for all pixels in modules.

![Graph showing ToT (Q_target) distribution and noise per pixel (el)](image)
The Optical Communication Tuning

Tune link between on-detector Optoboards and off-detector Back-Of-Crate cards:

2. Laser transmission power for the Optoboard (ViSet)

3. Threshold at the BOC

4. Delays at the BOC

Send known patterns and look for the error free region

Find optimal values for individual module by varying the three parameters.

Threshold, delay & ViSet tuning strategies

- most stable ViSet strategy
- threshold & delay readjust strategy
The software challenge

The Pixel Detector configuration requires a huge amount of information (# channels x # configuration parameters).

Pixel Database Server

- handles configuration quickly and efficiently
- caching mechanism

The calibration procedures produce a huge amount of histograms, both on-line and off-line.

Must analyse data on-line to decide which modules need to be disabled during data taking.

Efficient on-line histogram dispatching system, Pixel Histogram Server, uses multi-threaded and distributed software.
The Pixel Detector Commissioning

July 2007

Jan-Apr 2008 Sign Off

- Test light transmission to and from detector
- Test of the analog and digital low voltage supplies
- Check the high voltage and the bump connectivity
- Cooling Plant commissioning
First Results

Sept, 14th - First Cosmic Track!

Event with 7 Pixel hits and 16 SCT hits
Trigger provided by muon chambers and calorimeters
Modules disabled for Data Taking

- 1744
- 1743
- 1701
- 1667
- 1663

1 short clock Vdd

12 module current
6 high voltage
21 TX
3 not configurable

34 Bad Output

81/1744
4.5% disabled

WILL IMPROVE!

- Noisy pixel mask created offline and applied online
- Noisy pixels are defined as having $\geq 10^{-5}$ hits/event
- ~5000 pixels masked 0.006% of the detector
Masking the noisy pixels

Without the noise mask

With the noise mask
ATLAS cosmic run 90272

- Run with all subdetectors
- 15h 42min
- Solenoid on
- # tracks with pixel hits: 3387
- Track rate ~ 62mHz

MIP peak @ TOT = 30

Noise peak @ TOT = 5
backup
Noise mask

occupancy: L2_B06_S2_C6_M6C

h_global_module_noisy_pixel_1e-05

Entries 635
Mean 6.205
RMS 17.46

noisy pixel per module
Nel **silicio**:  
- la perdita di energia media è 1.66 MeV g$^{-1}$ cm$^2$,  
- la densità vale 2.33 g cm$^{-3}$,  
quindi la perdita di energia equivale a 390 eV μm.  
Sono necessari 3.6eV per generare una coppia elettrone-lacuna, quindi, al passaggio di una MIP, sono prodotte in media 110 coppie per μm.  
Poiché i sensori di ATLAS sono spessi 200 μm:  
- **1 MIP = 20000 coppie elettrone-lacuna**