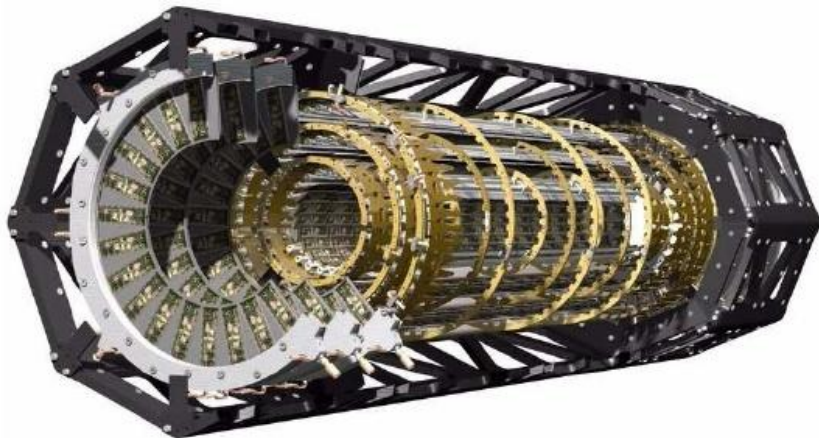




# Commissioning and Operation of the ATLAS Pixel Detector



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on behalf of the ATLAS Collaboration

Pixel 2010  
Grindelwald, Switzerland  
6 September 2010



# 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

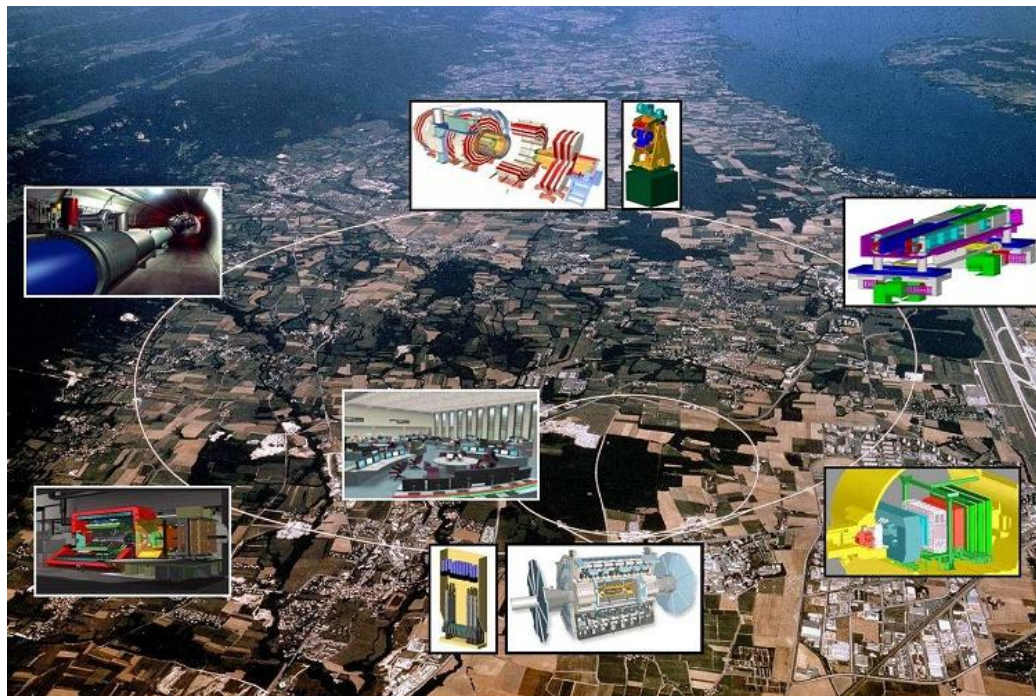
# The LHC at CERN

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)

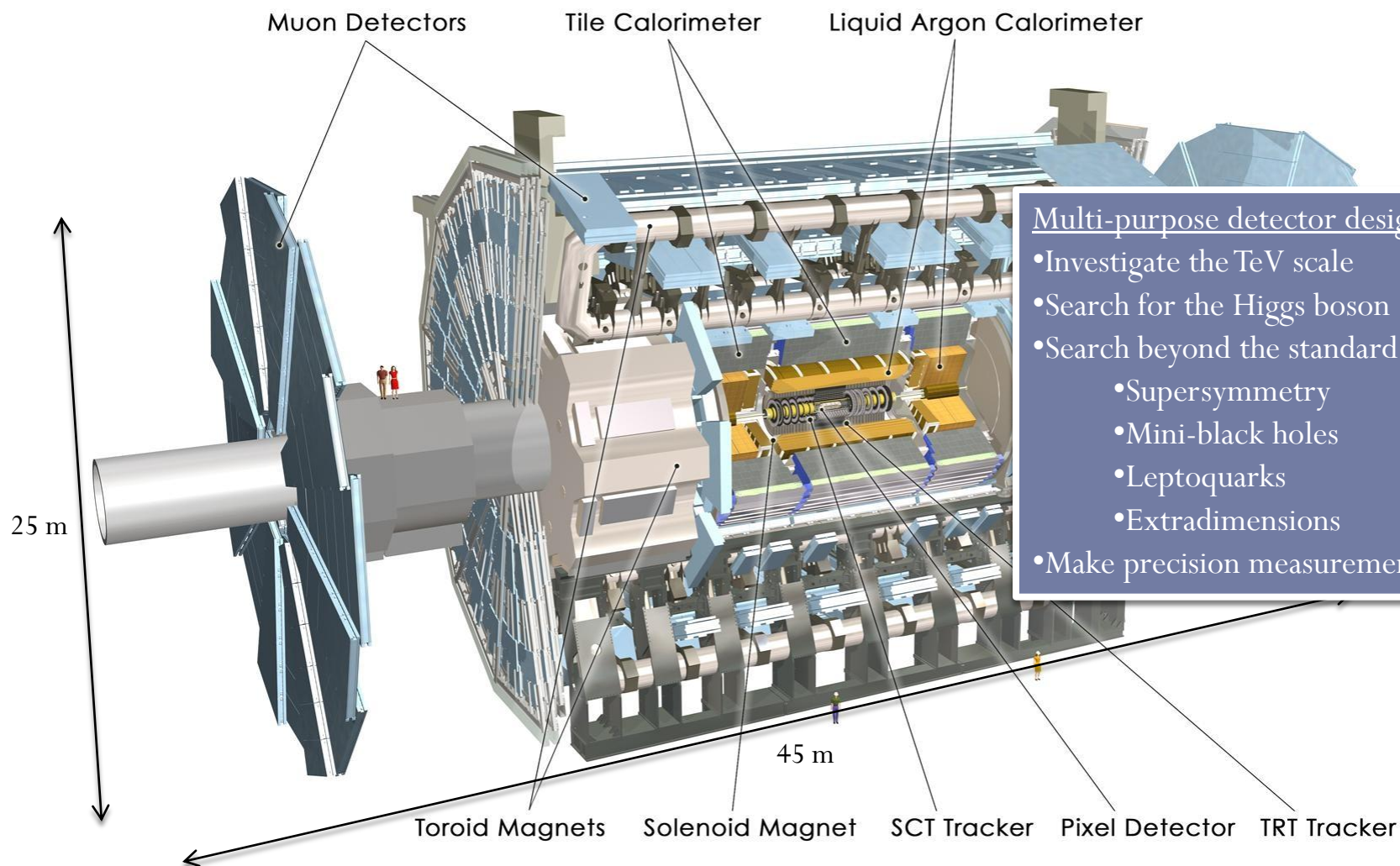
Operating since Fall 2009

- 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



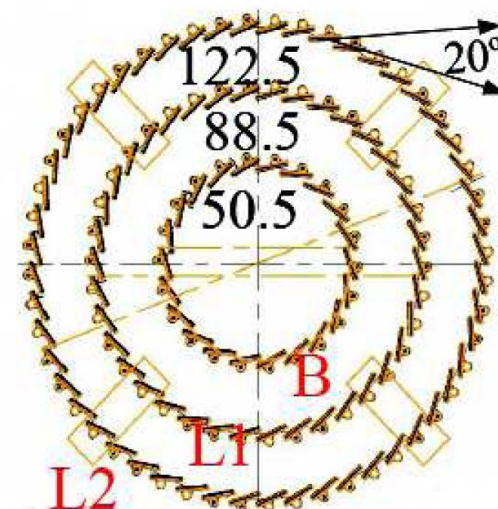
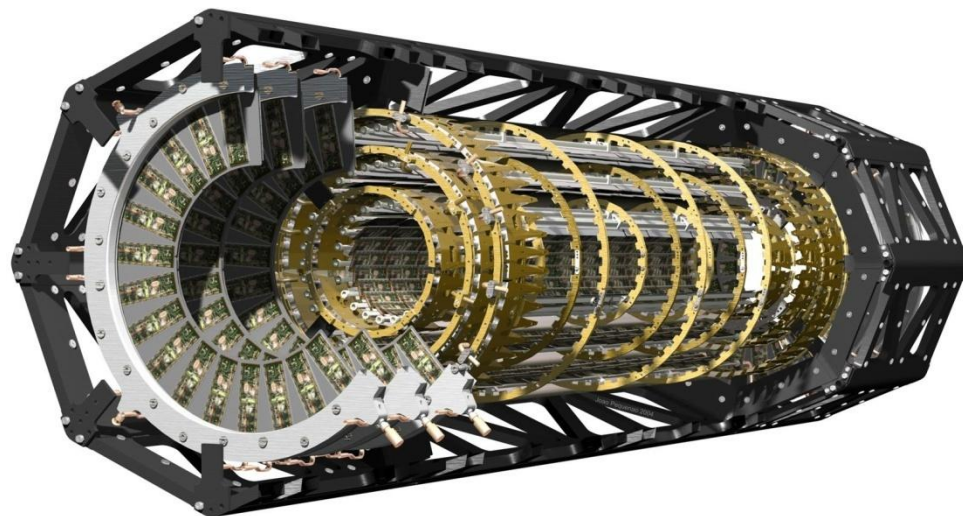
Multi-purpose detector designed to:

- Investigate the TeV scale
- Search for the Higgs boson
- Search beyond the standard model
  - Supersymmetry
  - Mini-black holes
  - Leptoquarks
  - Extradimensions
- Make precision measurements of SM

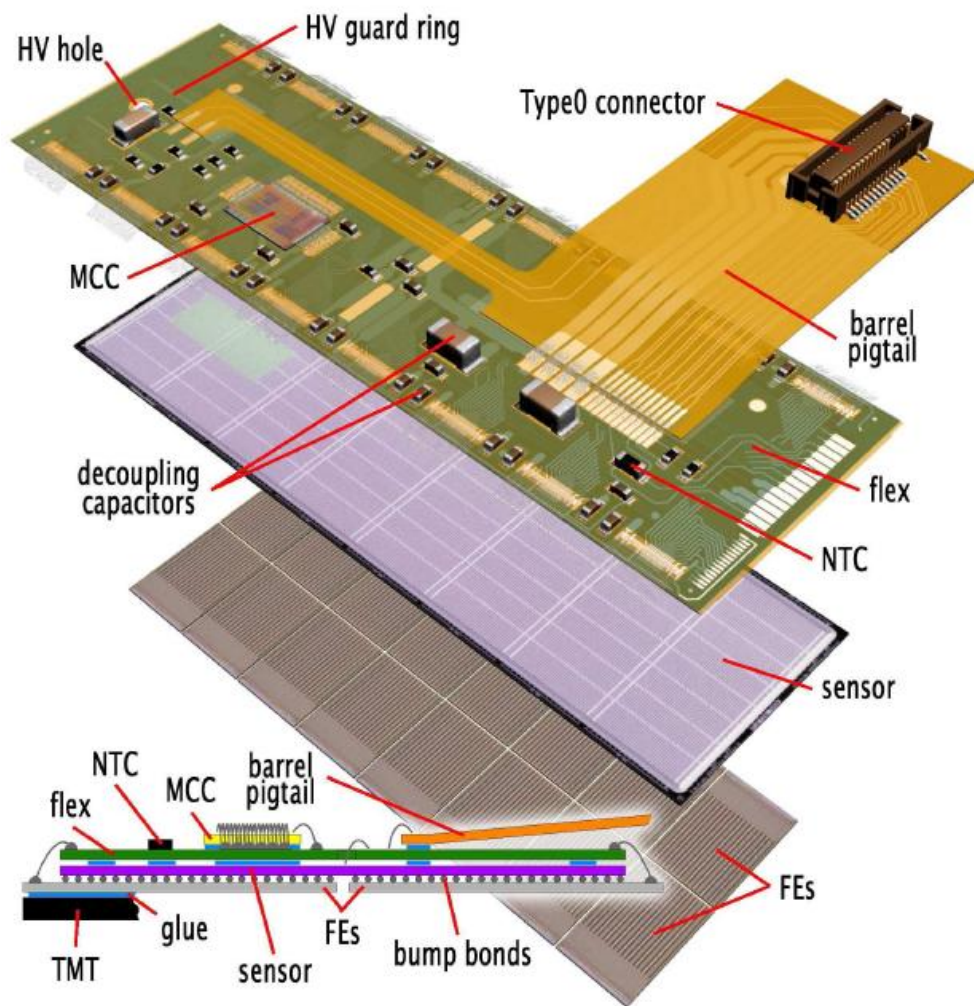
# ATLAS Pixel Detector

## The Pixel Detector:

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



# ATLAS Pixel Modules



## Sensor:

- 250  $\mu\text{m}$  thick silicon sensor
- n-doped bulk,  $n^+$  pixels &  $p^+$  backplane
- Pixels: 50  $\mu\text{m}$  ( $R\phi$ ) x 400  $\mu\text{m}$  ( $\eta$ ) 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  $\sim 3500$  e

## Readout:

16 FEs bump bonded per module:

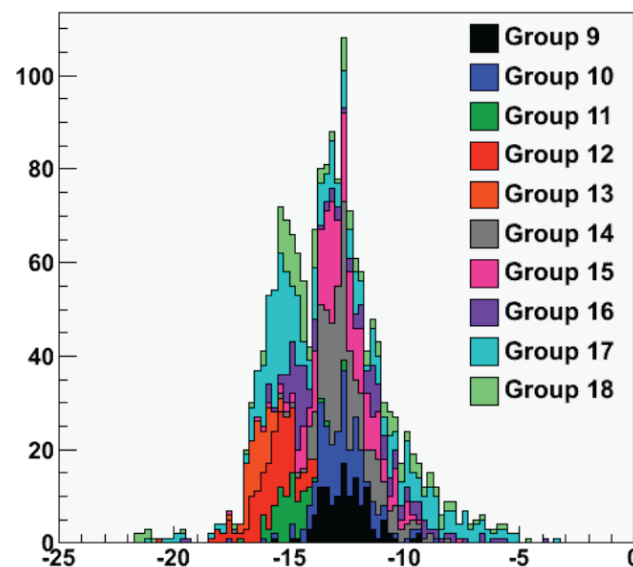
- DSM 0.25  $\mu\text{m}$  CMOS
- Radiation hard up to  $\text{NIEL} \cdot 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$  fluence

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

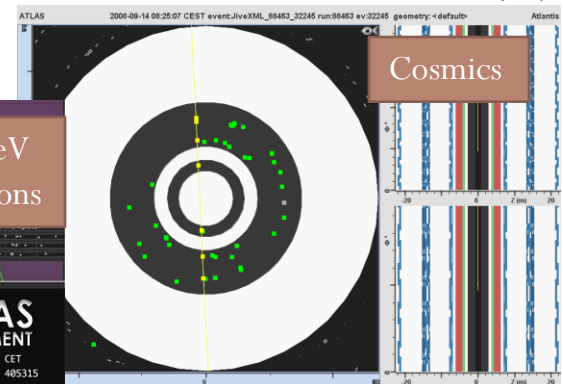
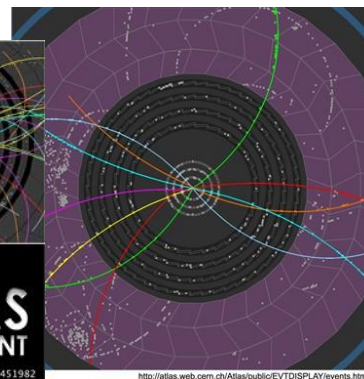
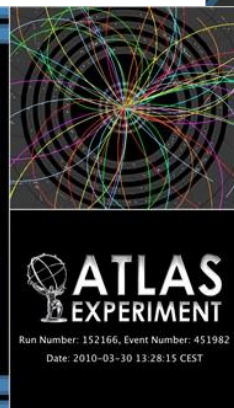
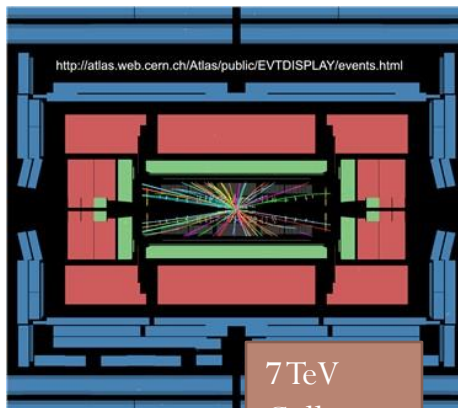
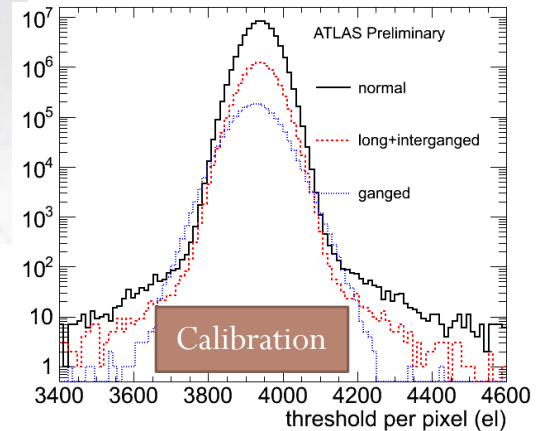
- Evaporative cooling system used to maintain a module temperature of less than  $-10^{\circ}\text{C}$
- Coolant –  $\text{C}_3\text{F}_8$ , with  $T = -25^{\circ}\text{C}$
- Cools both the Pixel Detector and the Semi-Conductor Tracker (SCT)
- 88 individual loops for the Pixel Detector
- Continuous operation for all of 2010 with very high efficiency  $>95\%$
- Leak rate is currently 1.8 kg/day for both Pixel Detector and the SCT





# 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 – 7TeV Collisions, **Stable beams!**
- September 2010 –  $3.6 \text{ pb}^{-1}$

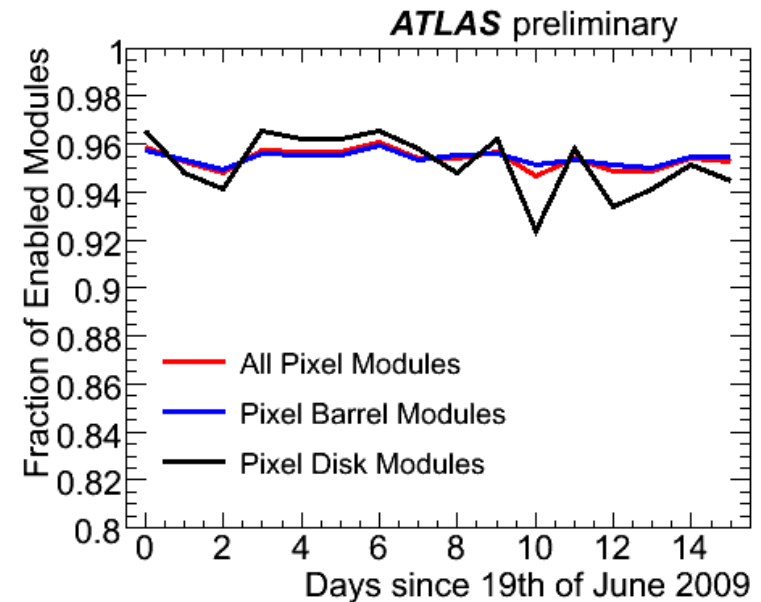




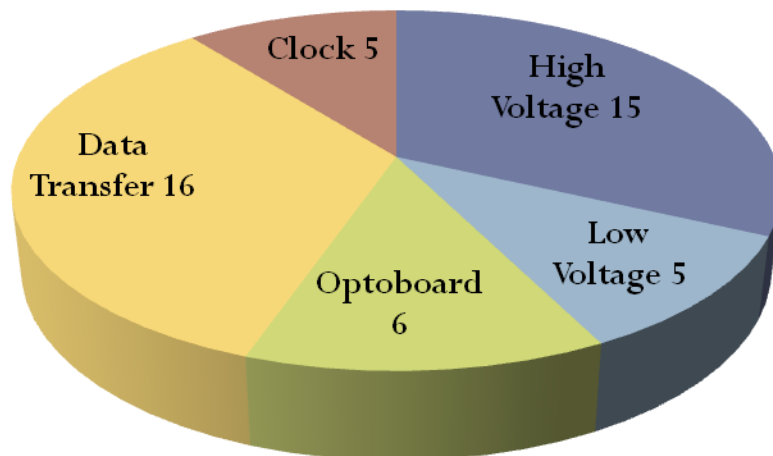
# Current Status of the Pixel Detector



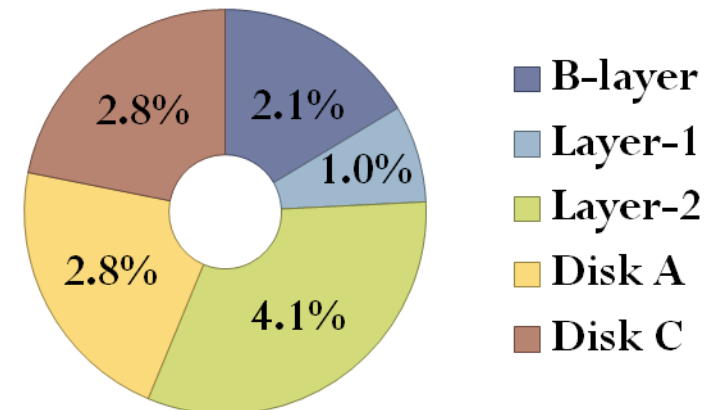
- 1697 of 1744 modules are active in data-taking
  - 47 module disabled (2.7%)
- 27860 of 27904 front end chips are enabled
  - 44 FEs disabled (0.16%)
- 271 of 272 optoboards are included in operations
  - 6 or 7 modules per optoboard



## Disabled Modules by Failure Type

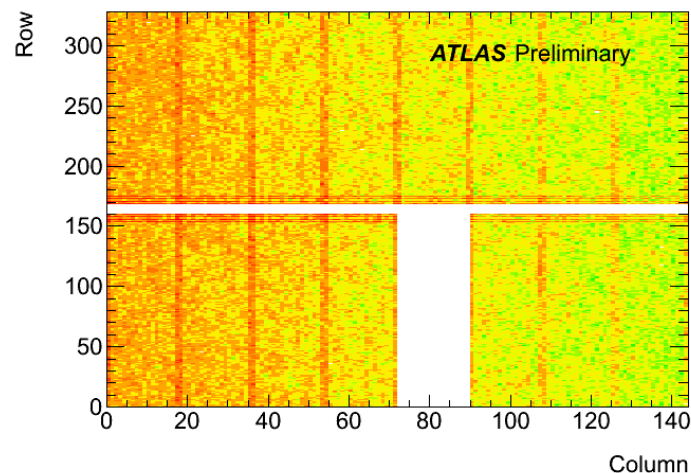
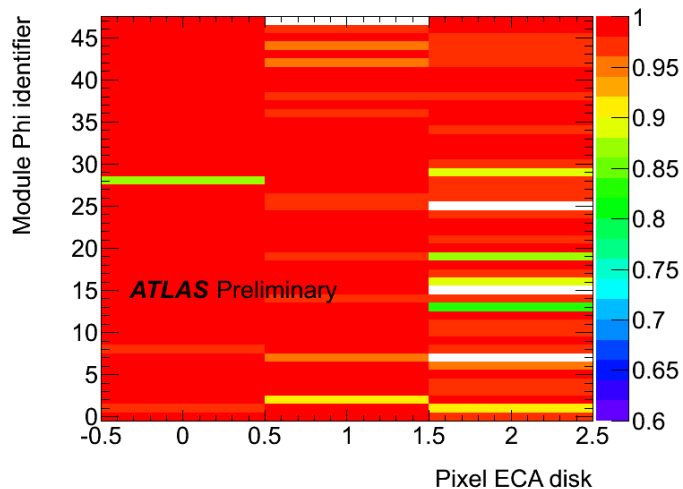


## Inactive fraction per layer

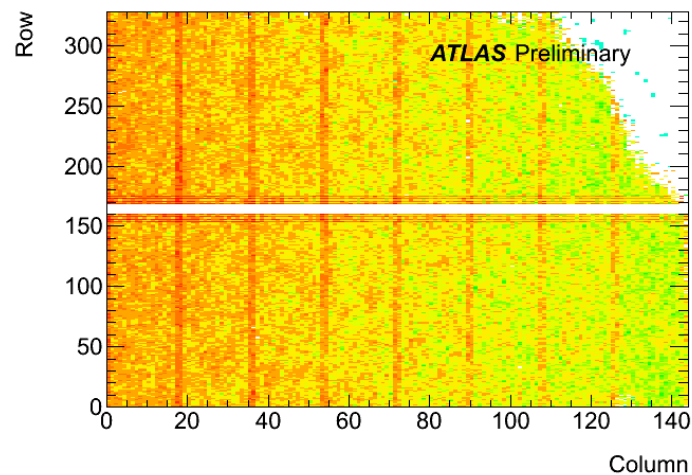
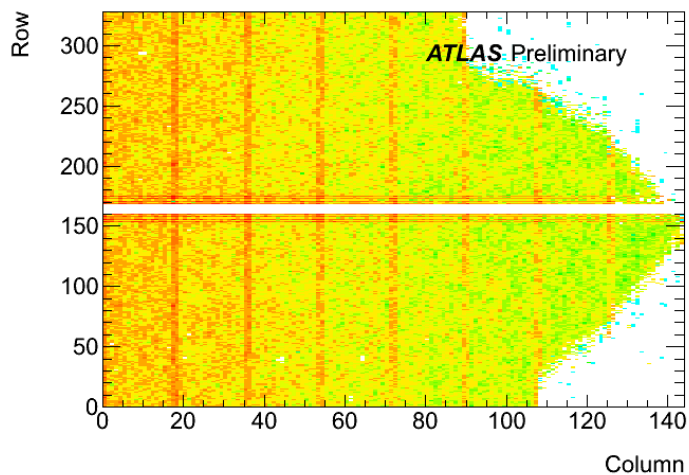


# Inefficiencies on Modules

Hit efficiency of Disk modules in Endcap A



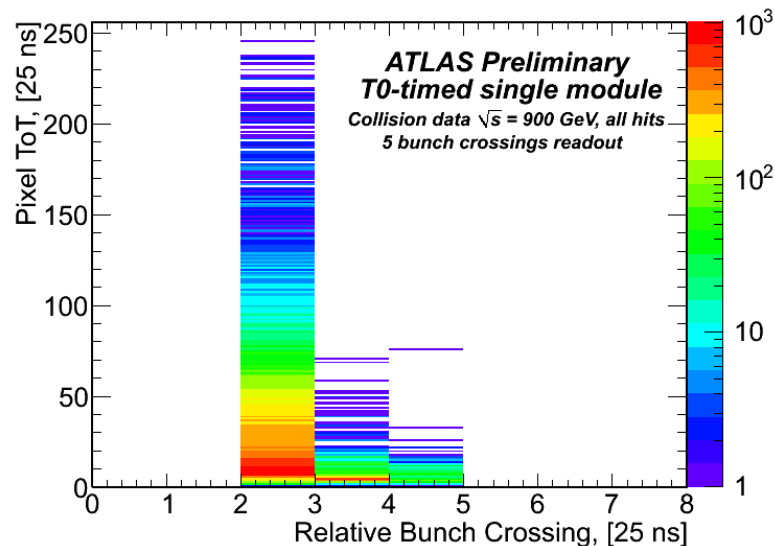
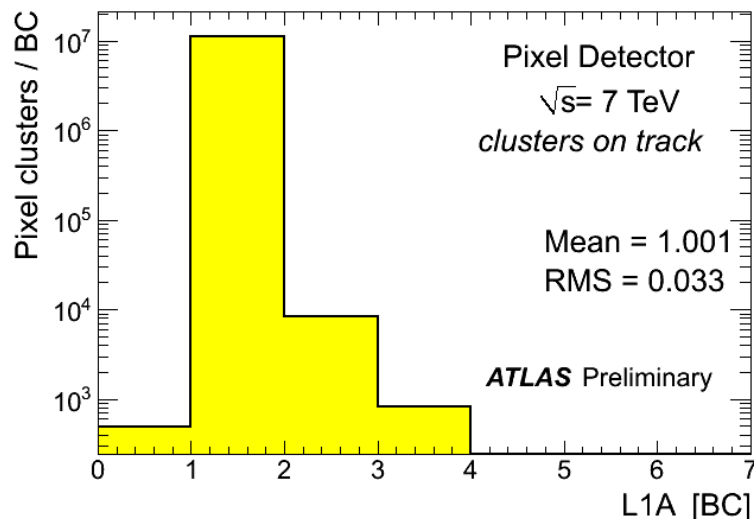
Occupancy plots for 3 modules with smallest efficiency



# 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



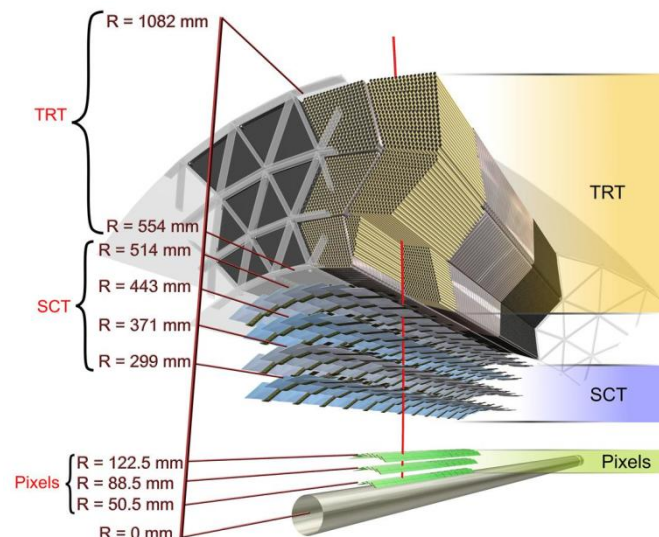
# Pixel Operations

## Detector safety:

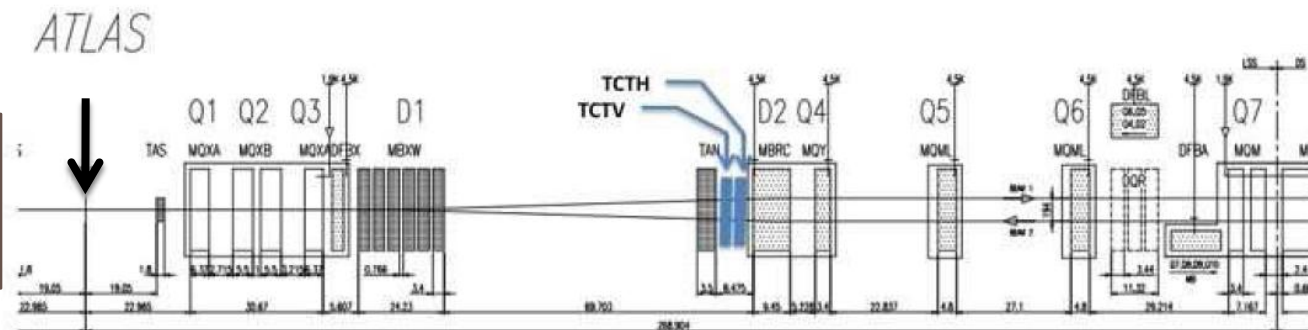
- Until “STABLE BEAMS” are declared by the LHC, the HV for the modules is off. This can be bypassed for calibration periods.

## Warm start procedure:

- Module configuration is performed at the start of a run
  - Without HV, modules are noisy and can block the DAQ
- To reduce noise, FE preamplifiers are killed when HV is off
- When LHC declares STABLE BEAMS:
  - Checks of beam conditions and collimator positions are made
  - HV is ramped up
  - Preamplifiers are enabled

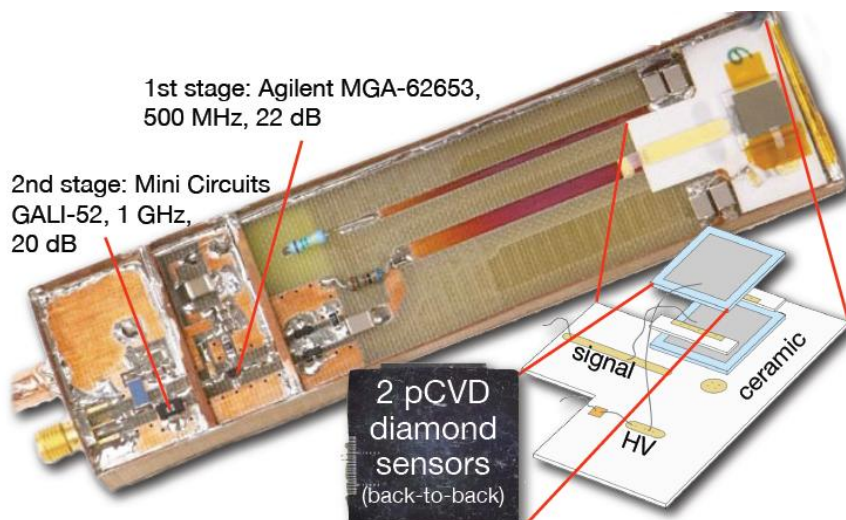
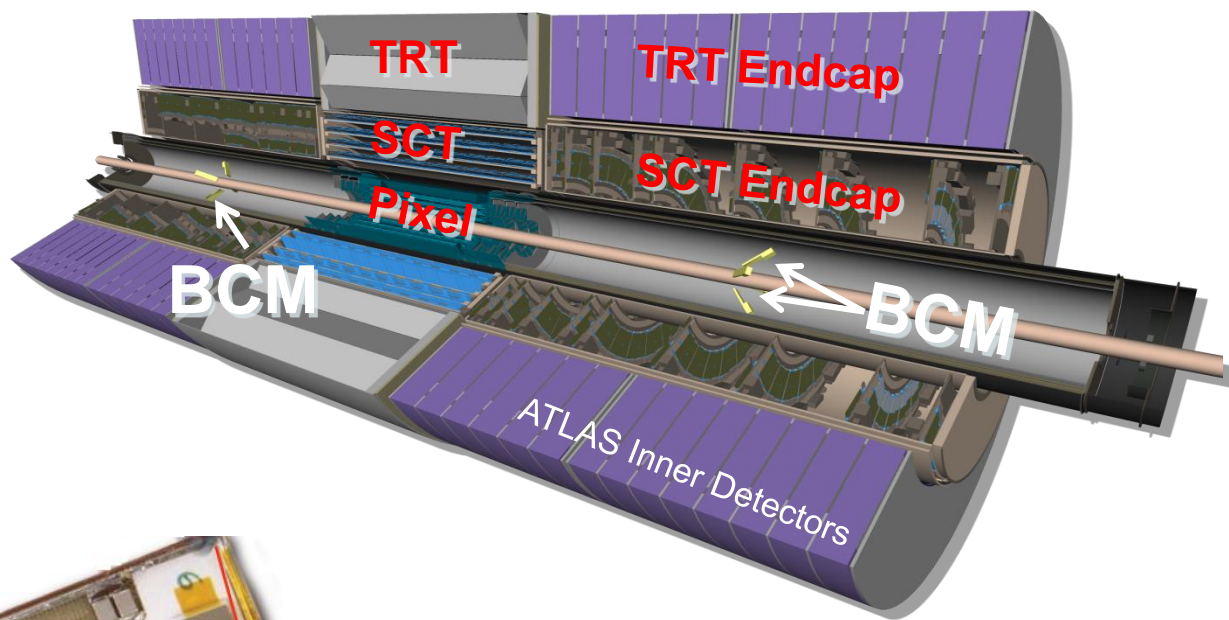


Collimators and Magnets near ATLAS interaction point



# Beam Conditions Monitor

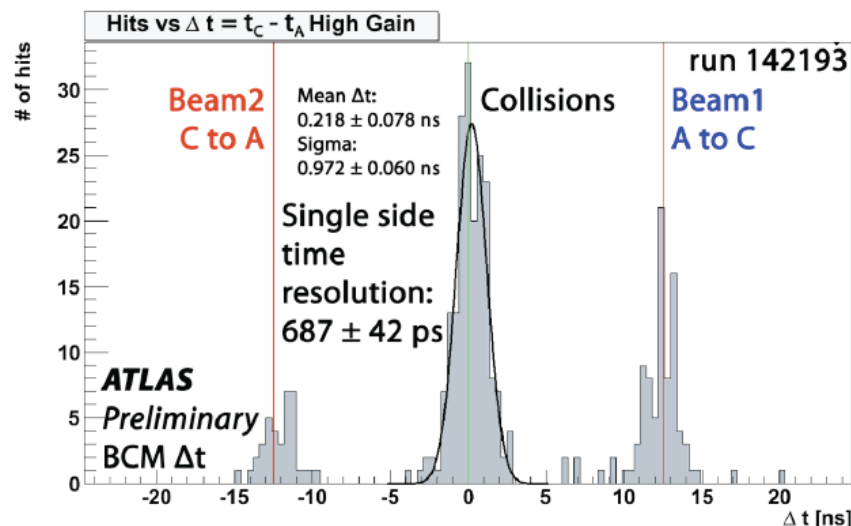
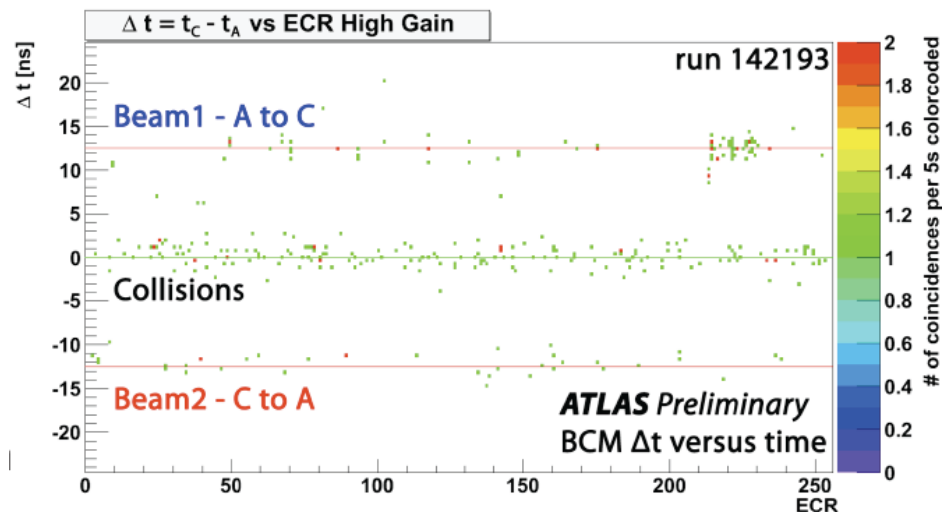
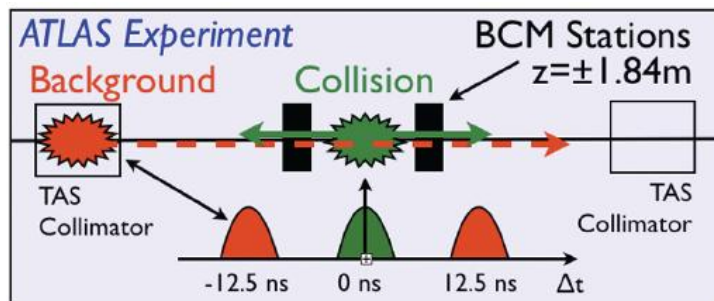
- Two 4-module stations symmetrically positioned at  $z = \pm 1840$  mm around IP
- Radially positioned at  $r = 55$  mm
- Mounted at  $45^\circ$  w.r.t. the beam pipe, giving 41% increased signal
- Provides protection against single turn and multi-turn losses in the LHC



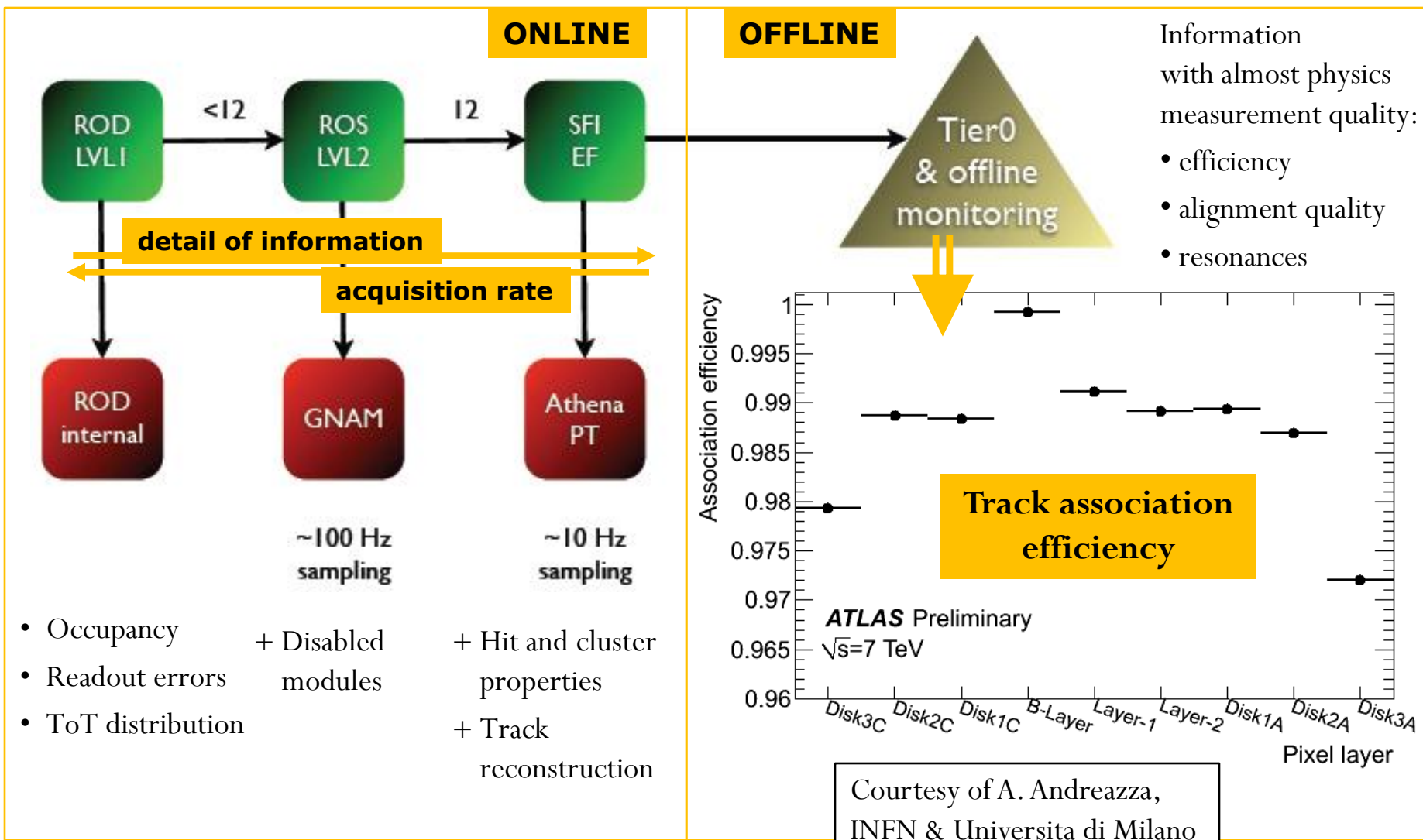
- Modules consist of two 10 mm x 10 mm pCVD diamonds, 500  $\mu$ m thick
- Nominally biased at 1000 V
- Signal is split to provide 2 thresholds per module: high and low gain

# 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 – Monitoring





# 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 :

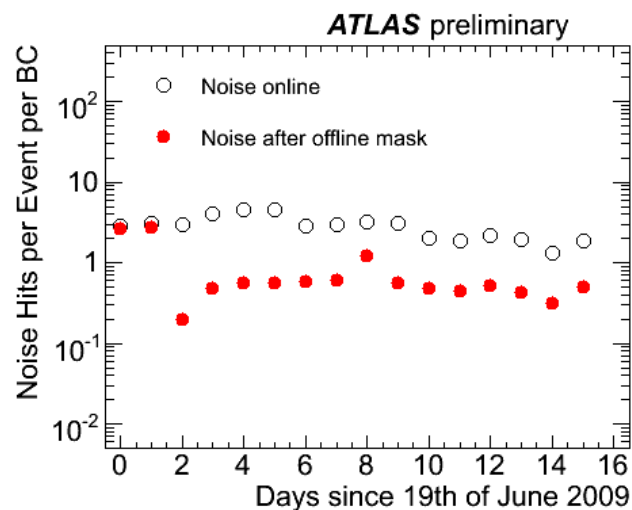
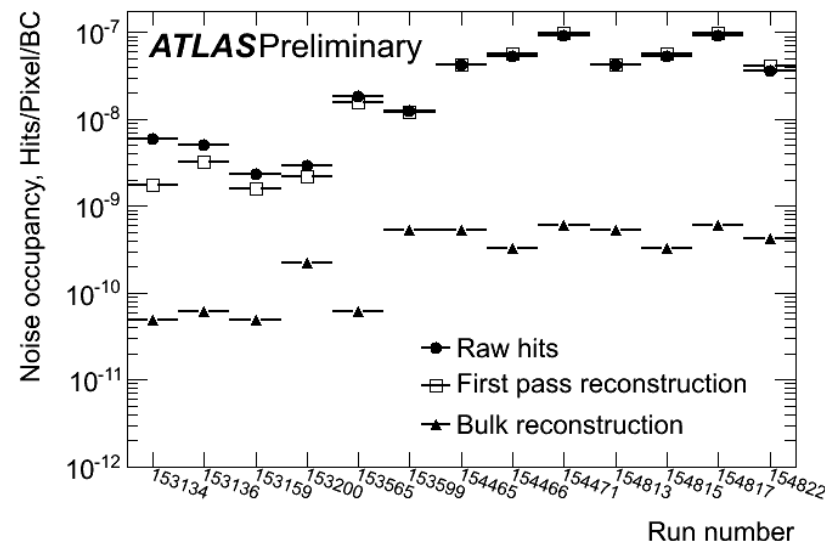
B-layer  $3 \times 10^{-5}$

Layer-1  $1 \times 10^{-5}$

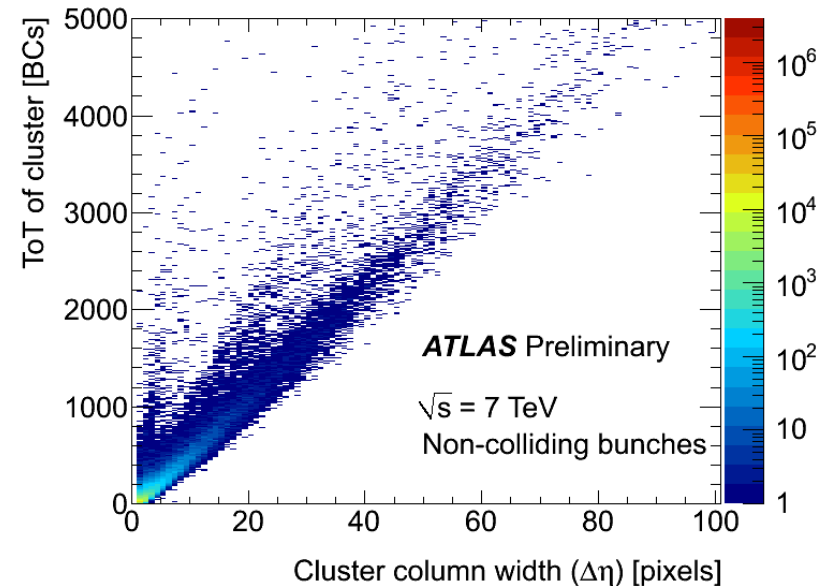
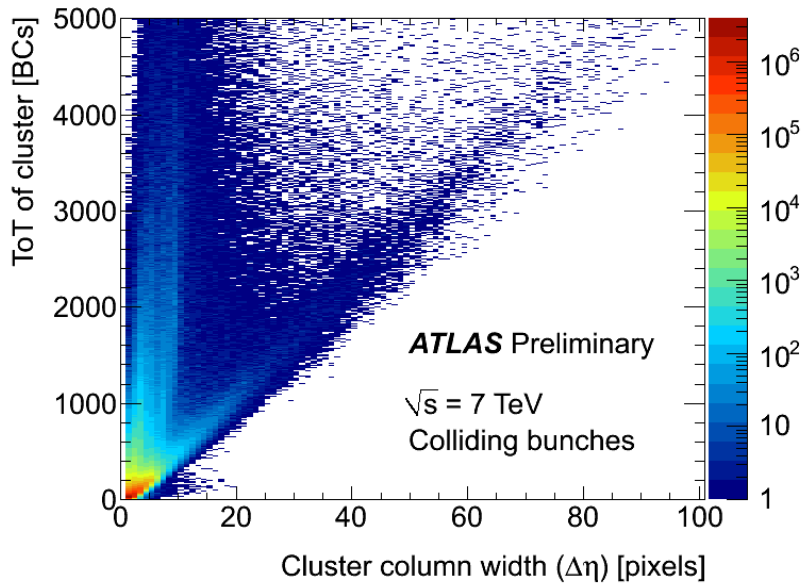
Layer-2  $0.8 \times 10^{-5}$

Disks  $1 \times 10^{-5}$

7 TeV collisions



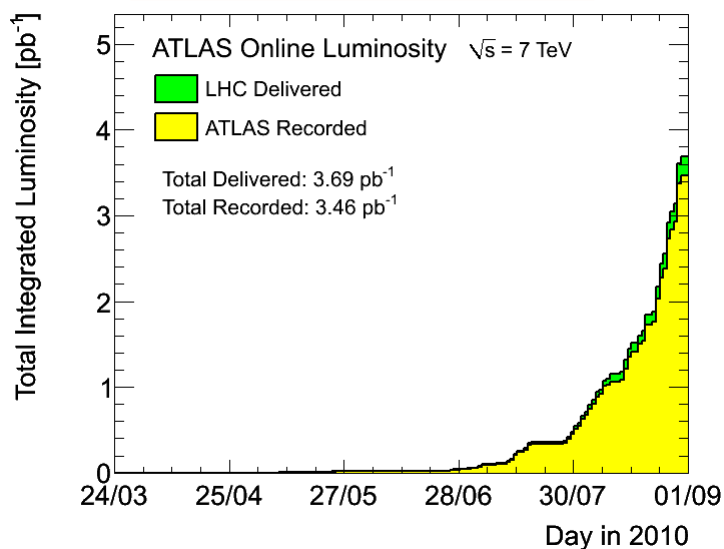
# Beam Background Studies



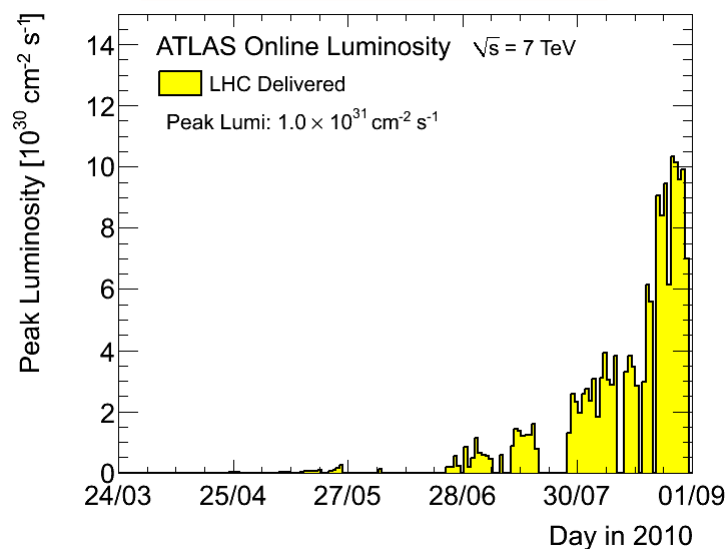
- Events with large numbers of hits per module can cause blocking of the DAQ due to the long readout time from the event size.
- High occupancy events can originate from beam gas and beam halo events which impact the Pixel Detector parallel to the beam pipe (z-direction)
- Studying the colliding (paired) 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 Pixel Detector 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 30<sup>th</sup> and August 14<sup>th</sup> (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 with experience

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

