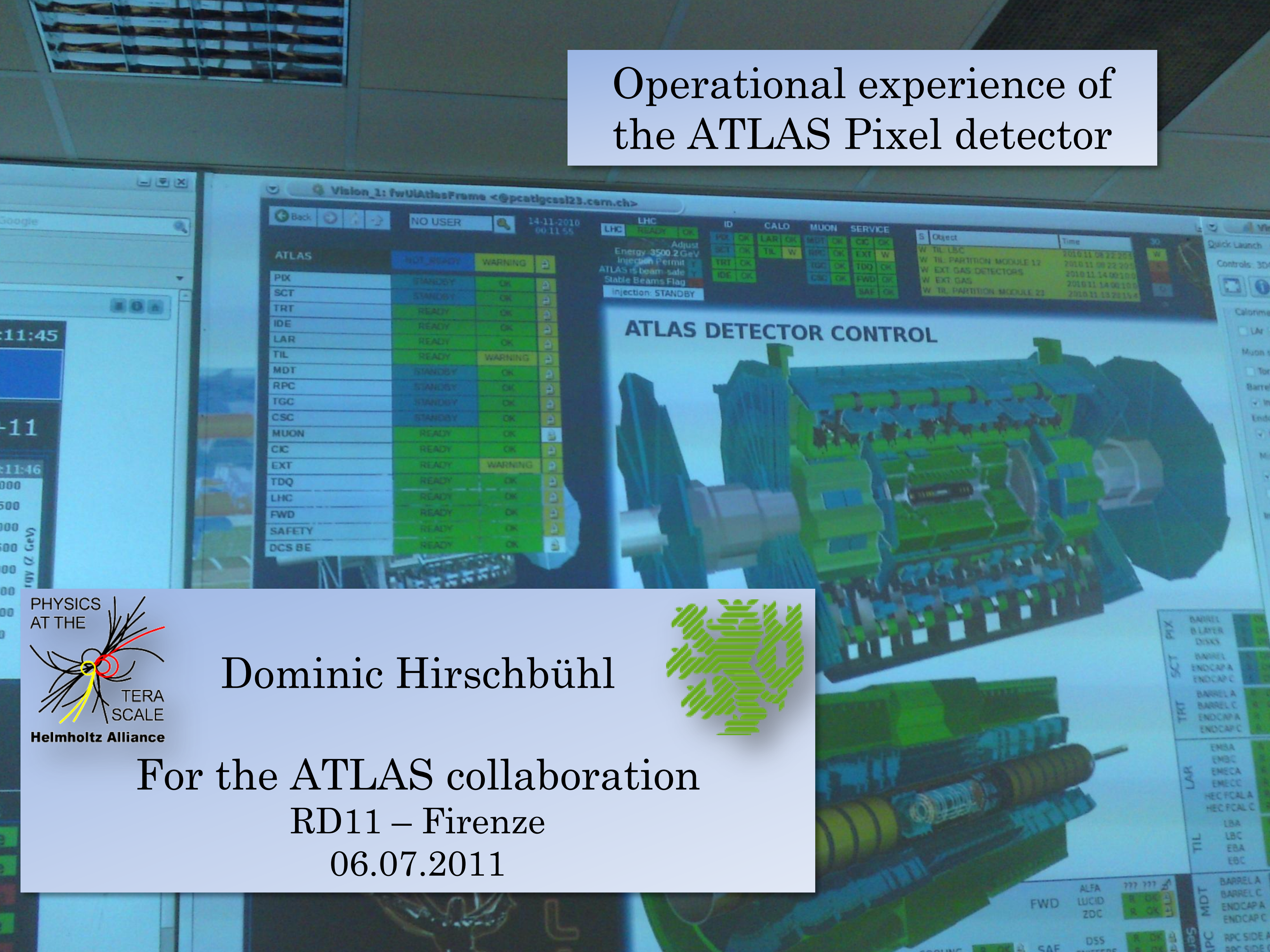


Operational experience of the ATLAS Pixel detector

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

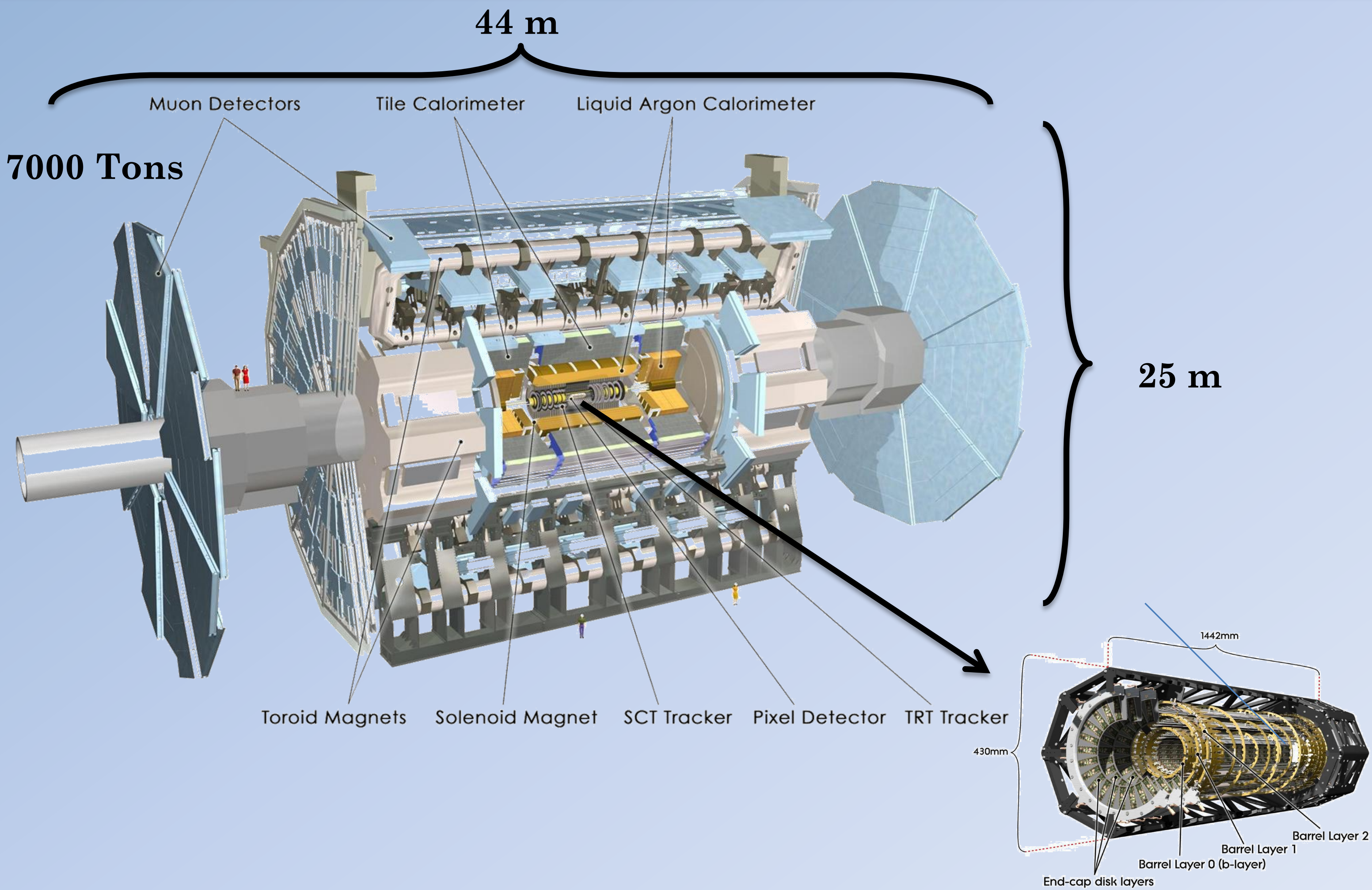
Dominic Hirschbühl

For the ATLAS collaboration

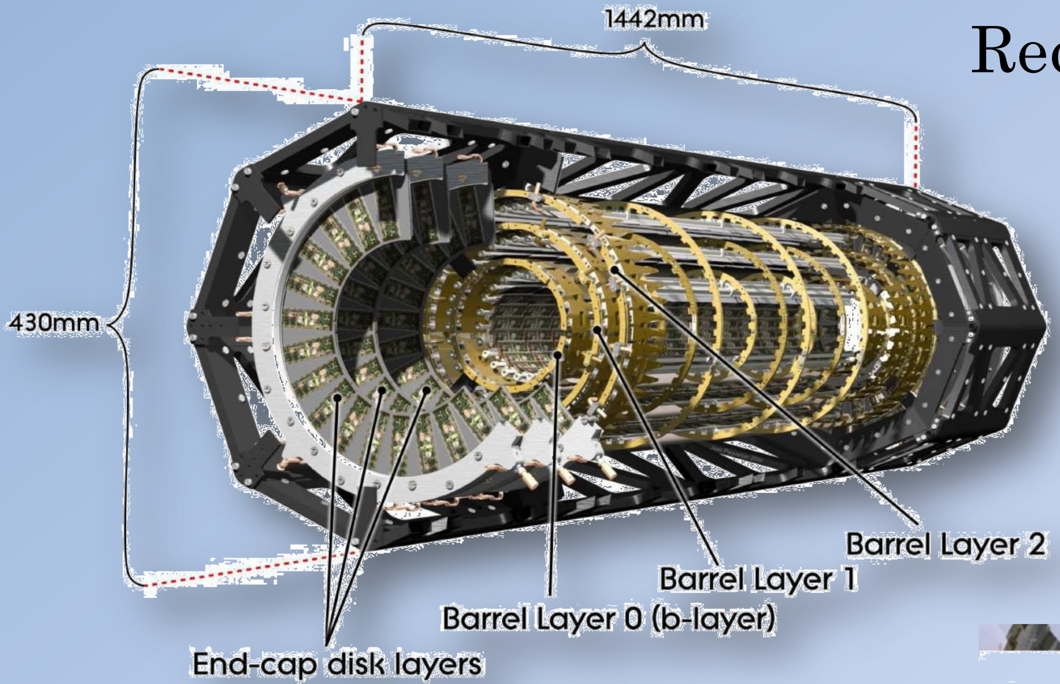
RD11 – Firenze

06.07.2011

The ATLAS detector



The ATLAS pixel detector

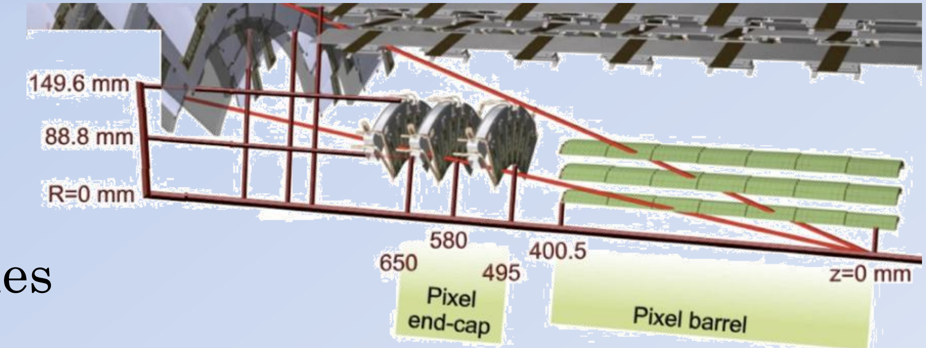


Requirements:

- Position resolution in rϕ-direction < 15 µm
- 3 track points for |η| < 2.5
- Time resolution < 25 ns
- Hit detection efficiency > 97%

Basic Properties:

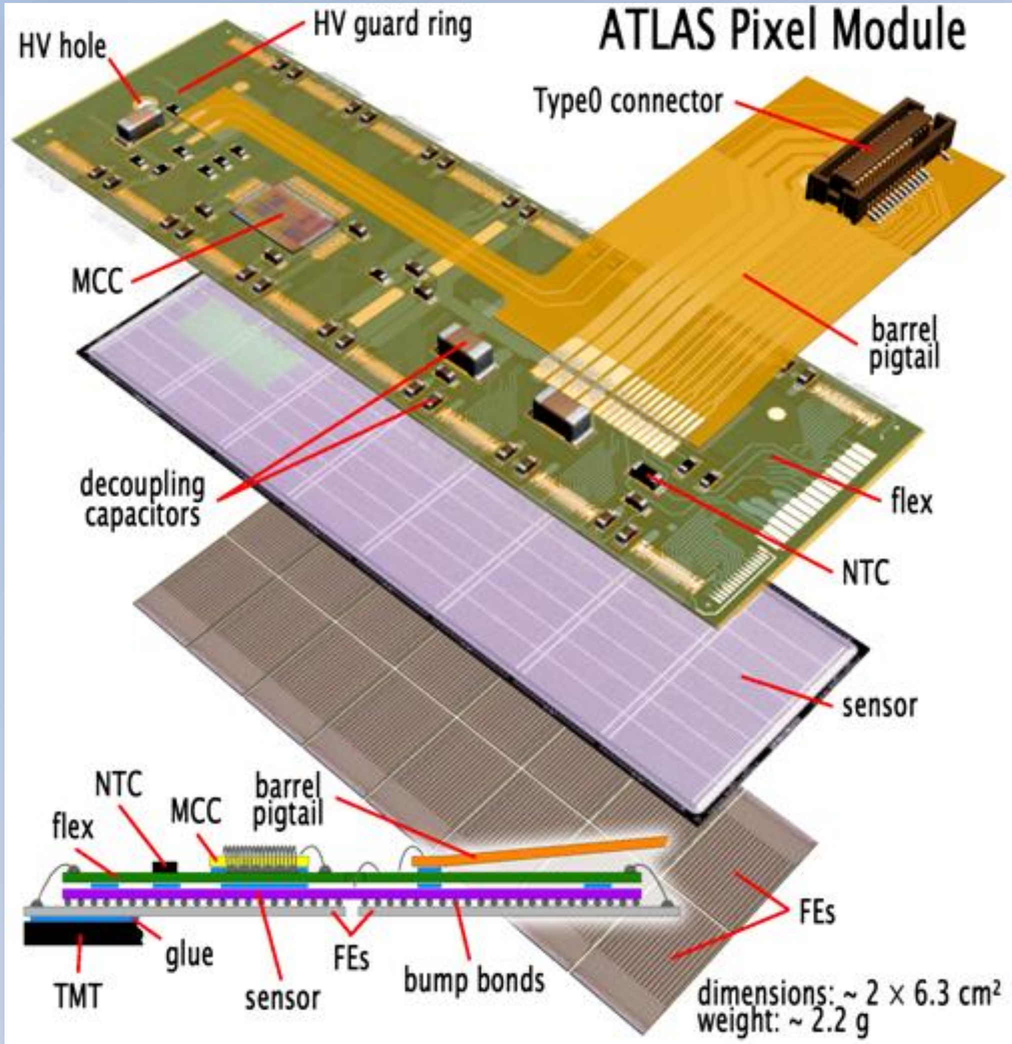
- 3 barrel layers: 1456 modules
- 3 disks per end-cap: 288 modules
- 80M readout channels
- Innermost layer at 50.5 mm
- Evaporative C_3F_8 cooling integrated in local support structures



The ATLAS pixel module

Sensor

- 250 µm thick n-on-n Si sensor
- 47232 (328 x 144) Pixels (46080 read channels)
- Typical pixel size 50 x 400 µm (50 x 600 µm pixels in gaps between FE chips)
- Bias voltage 150 – 600 V



Readout

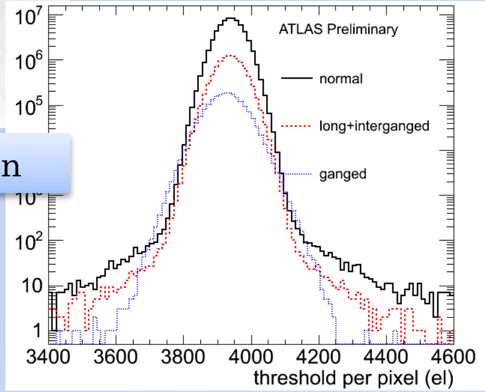
- 16 FE Chips with 2880 pixels each
- Pulse height measured by means of Time-over-Threshold
- Zero suppression in the FE chips, MCC chip builds module event
- Data transfer 40-160 MHz depending on layer

Timeline

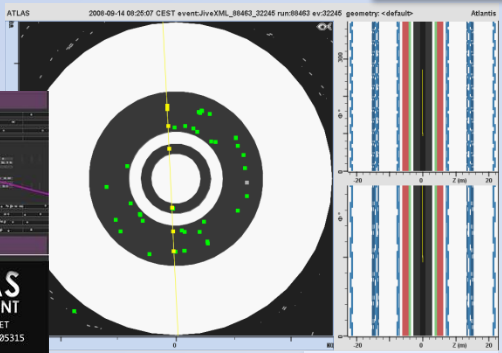
- May 2007 – Installation in ATLAS
- Sept 2008 – First cosmic events
- Oct 2008 – LHC incident

- Nov 2009 – First beam 450 GeV
- Dec 2009 – 0.9 TeV and 2.36 TeV collisions
- March 2010 – 7 TeV Collisions
- End 2010 – Heavy Ions
- May 2011 – Luminosity 10^{33} cm^{-2} s^{-1}

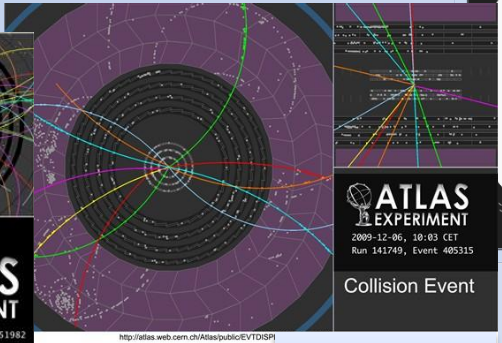

Installation



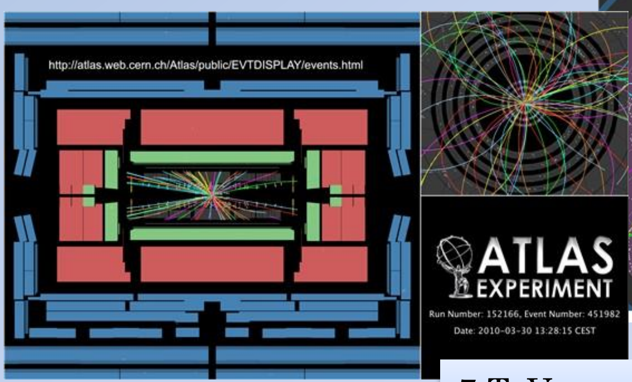
Calibration



Cosmics



900 GeV Collisions

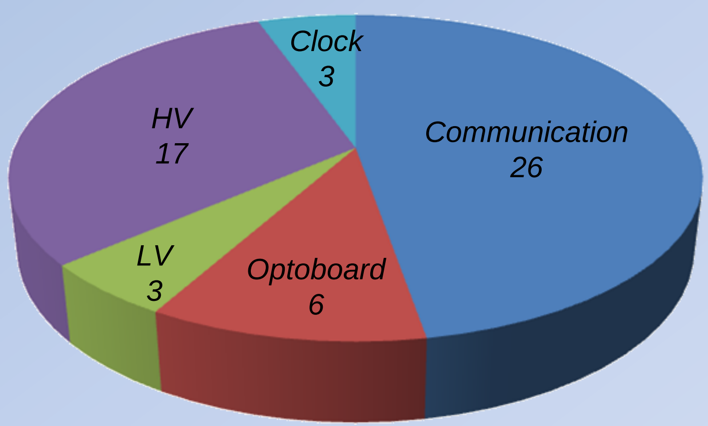


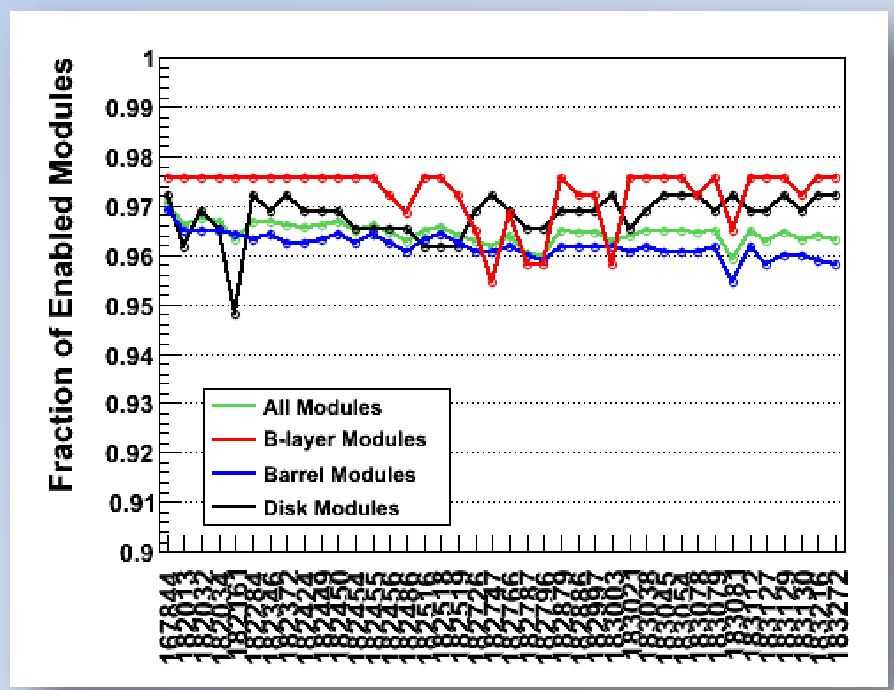
7 TeV Collisions

Detector status

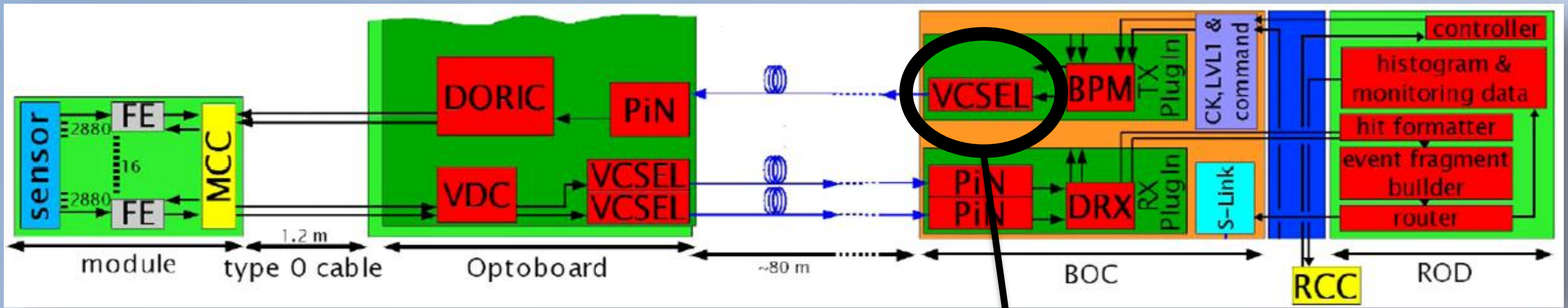
- 96.8% of the detector active in data taking
  - 55 Modules disabled (3.2%)
    (6 modules due to a single opto-board failure)
  - 47 FE chips disabled (0.16%)
  - In particular failures are linked to thermal cycles
    - Possibly always keep cooling ON
    - If cooling goes off use two step temperature adjustment procedure to cool down the modules

Disabled modules by failure type:



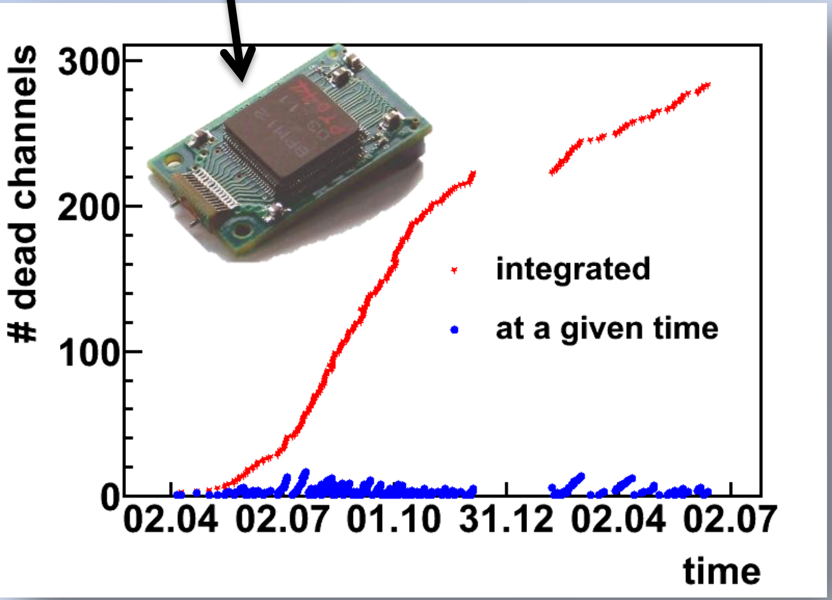


TX status



- Still main operational problem
  → needs ~4 hours of no physics to exchange dead ones.
- Death rate ~ 2-3 / week
- Most probable cause: Humidity

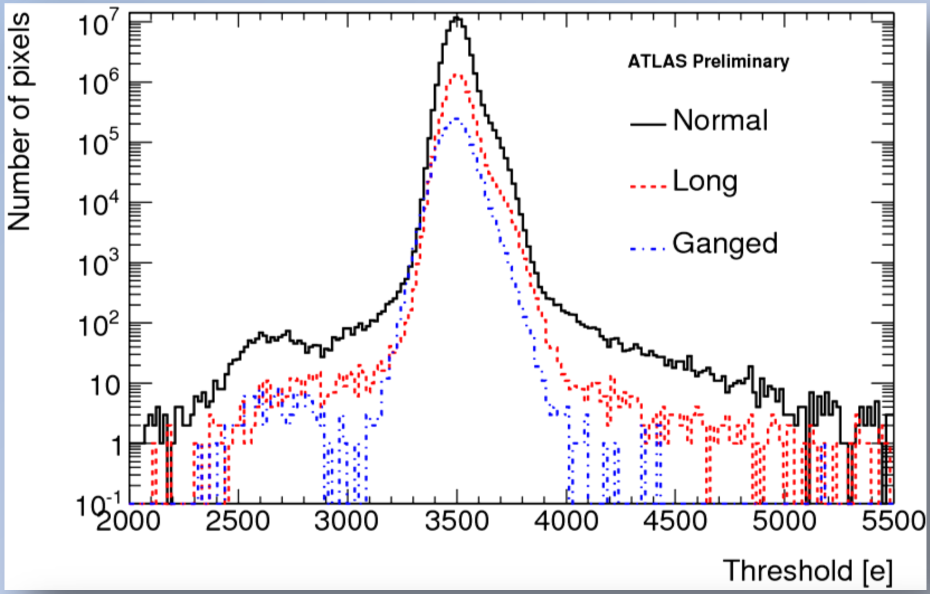
- Flush racks with dry air
- Installed first plugins with different lasers

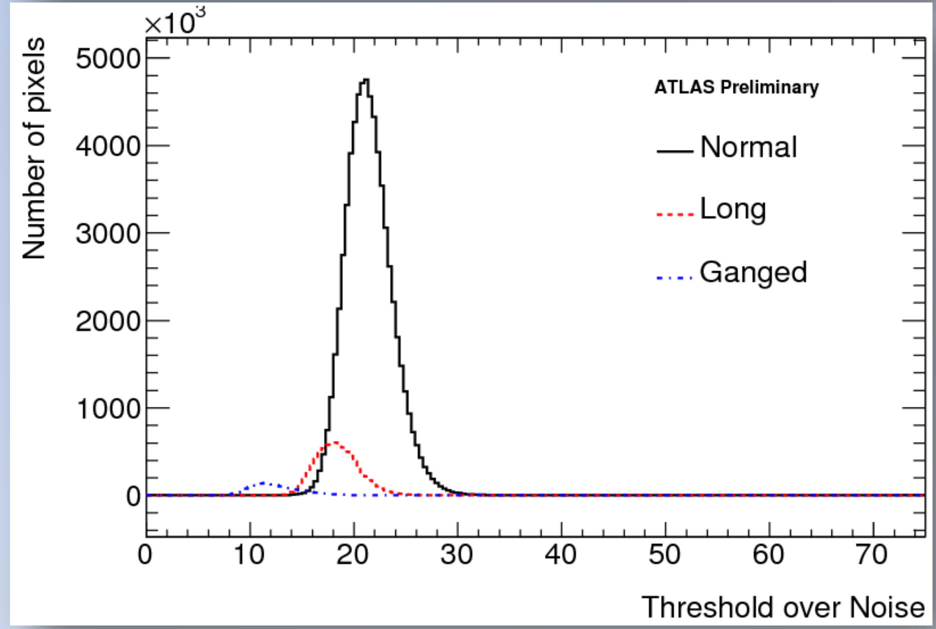


Operation parameters

- Threshold setting: 3500 e
  - Typical dispersion: 40 e
  - Noise for normal pixels ~170 e, higher in ganged pixels (~300 e) due to higher load capacitance

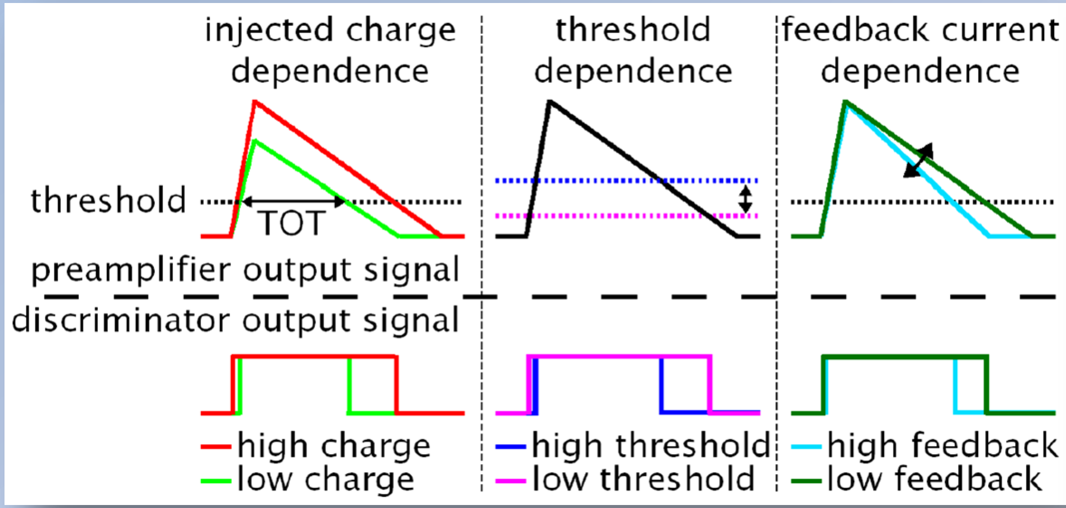
- Fraction of masked pixel ~ 0.1%
- 1 BC readout
- Readout speed
  - B-layer: 160 MHz
  - Layer 1: 80 MHz
  - Disks: 80 MHz
  - Layer 2: 40 MHz

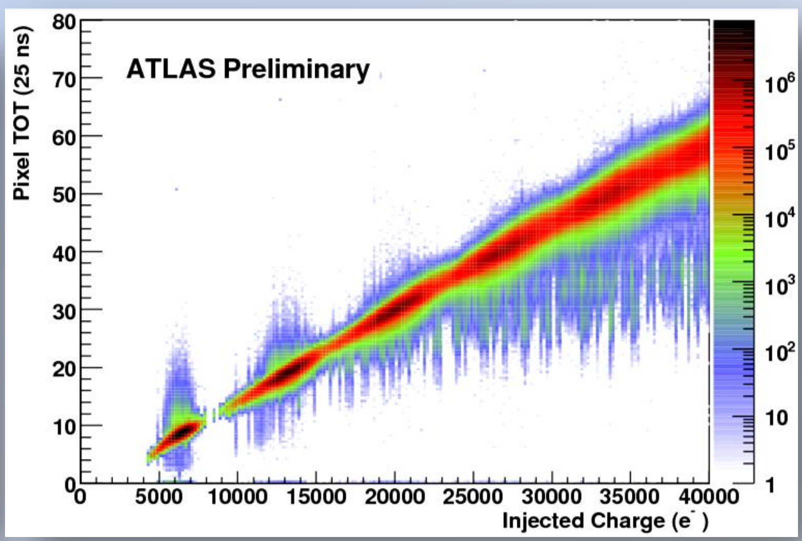




Time-over-threshold

- Time-over-threshold (ToT, length of discriminator signal) depends on:
  - deposited charge
  - discriminator threshold
  - feedback current
- Information of the ToT (in units of 25 ns) is read out together with the hit information → measurement of the deposited charge
- Time-over-threshold tuned pixel by pixel to 30 BC @ 20ke

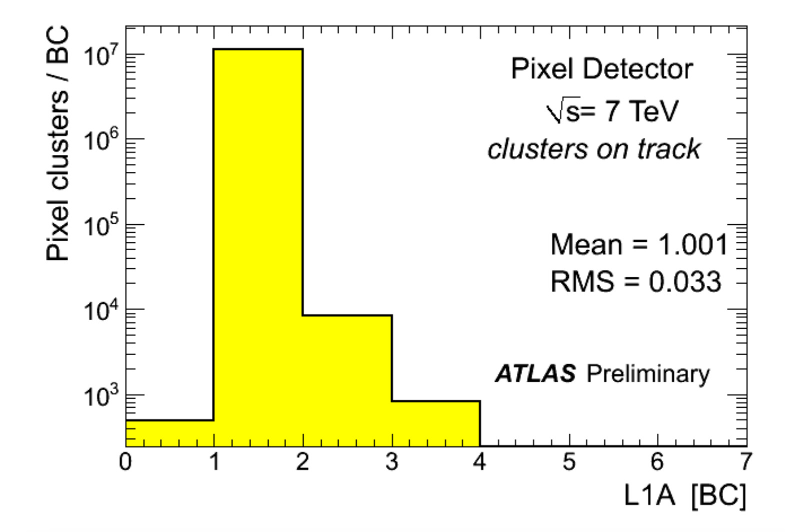


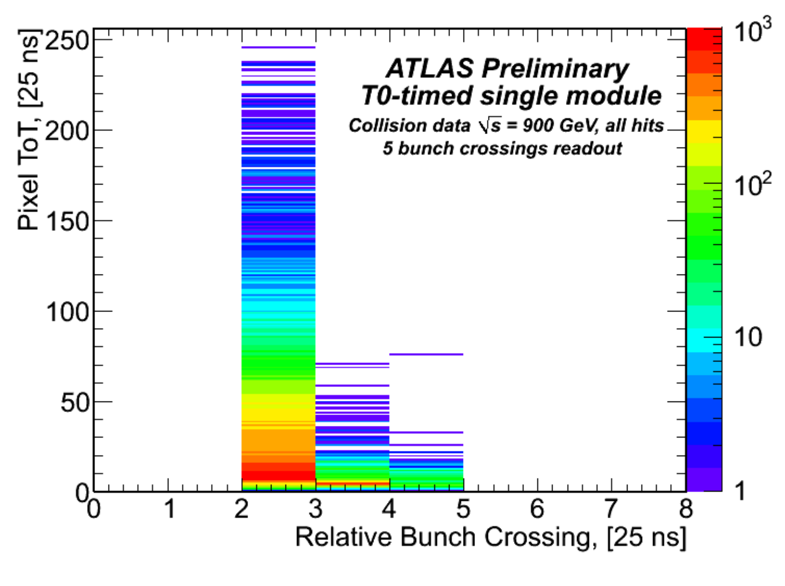


Readout window

- For each trigger received, the module can read out up to 16 consecutive 25 ns buckets (Bunch crossings – BC)
- Timewalk effect due to risetime of the preamplifier can shift low amplitude (ToT) hits into next time bucket
- To compensate for timewalk, low charge hits can be written twice
  - Original timestamp
  - Previous BC timestamp

Cosmics 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
September 2010	1 BC readout





Timing : Homogenity and Stability

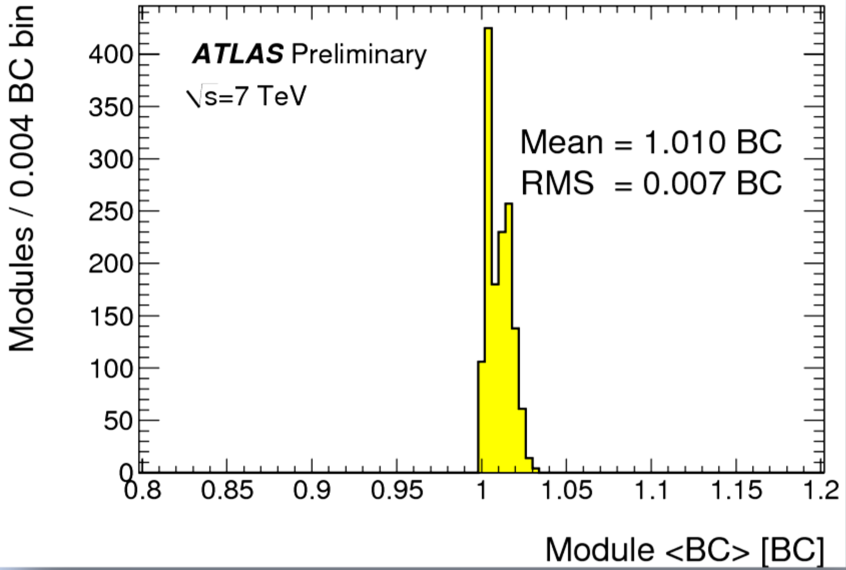
Several steps for adjustment of timing:

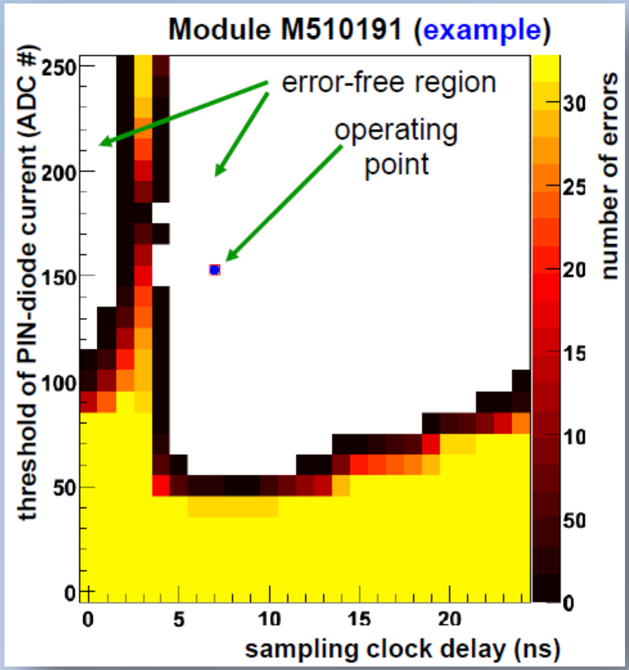
Trigger delays: from cosmic ray data

Cable lengths: values measured during installation

Final adjustment: timing scans with collisions

After all adjustments: module-to-module dispersion: 0.007 BC (corresponds to 0.17 ns)

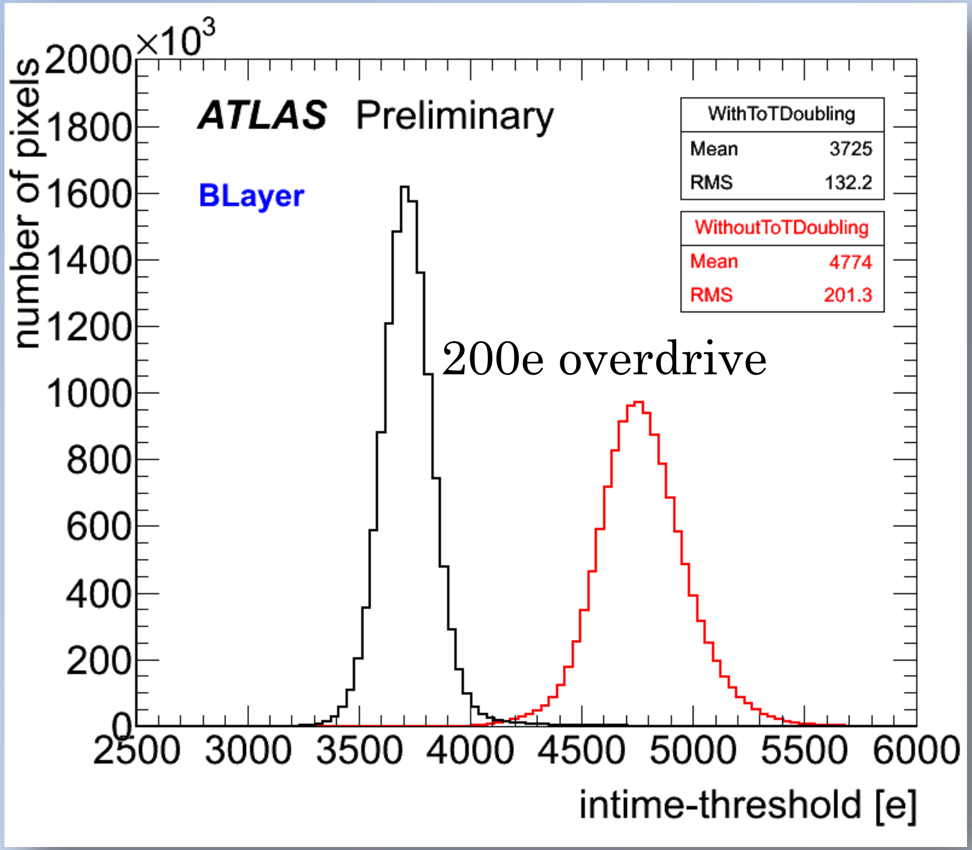




- Stability can be measured from stability of delay edge in Rx-scan.
- For most modules maximum delay band position changes ≤ 2 ns

In-time threshold

- Hits with lower charge suffer time-walk
- This leads to an "In-time threshold" higher than the discriminator threshold for a hit detection "in time"
- At 3500 e threshold:
  - 4800 e for normal pixels, BUT…
- Time-walk can be compensated for by on-chip hit doubling (using ToT information)
  - Using the hit doubling the in-time threshold is 3700 e
  - Overdrive of only 200 e

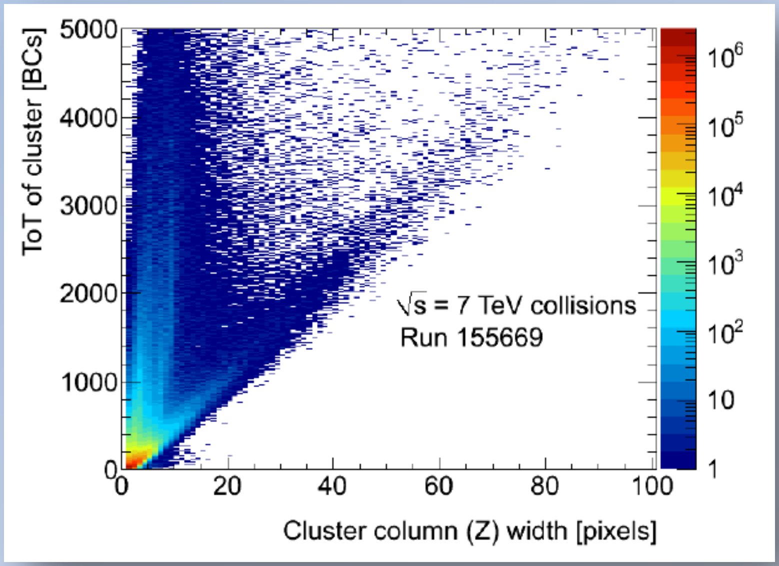


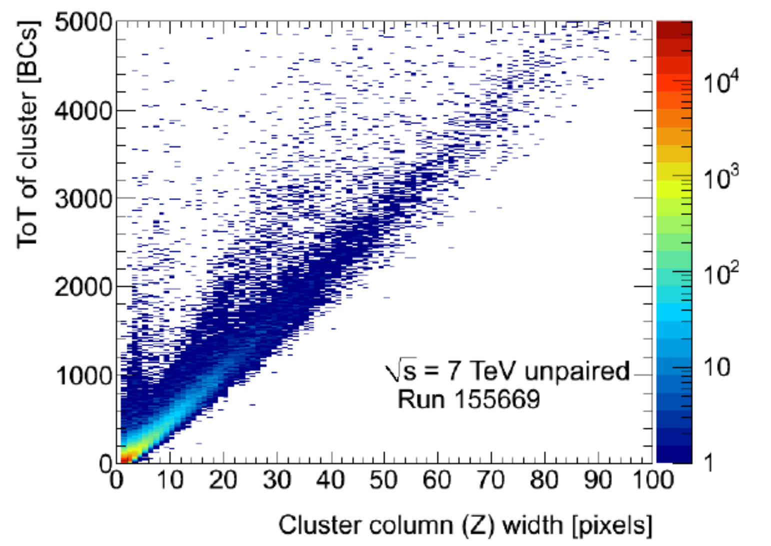
Background effects

- Last year we suffered from background, unexpectedly high because of vacuum issues in the warm regions around IP1
- We managed with a new firmware of the off-detector electronics to solve the problems, so far
- We do not have buffer problems to date and we are still using half speed for emptying the FE buffers

Typical module occupancies for luminosities ~10^{33} cm^{-2} s^{-1}

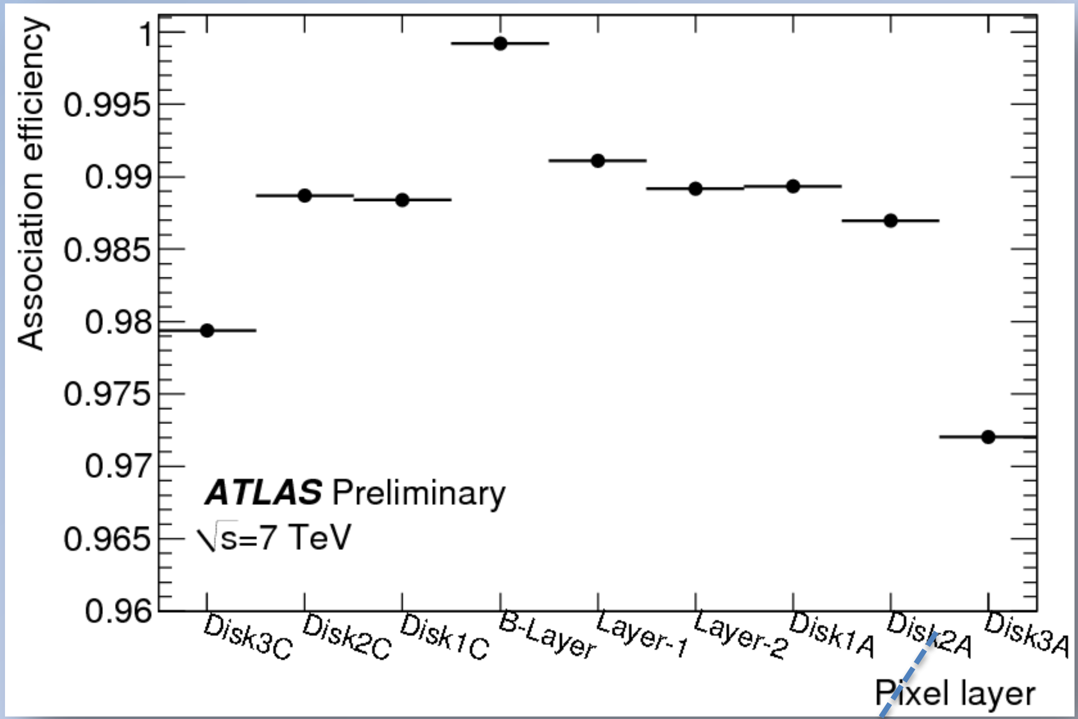
B-layer: 1.5 x 10-4 hits/pixel/BC
Layer 1: 0.7 x 10-4 hits/pixel/BC
Disks: 0.55 x 10-4 hits/pixel/BC
Layer 2: 0.45 x 10-4 hits/pixel/BC

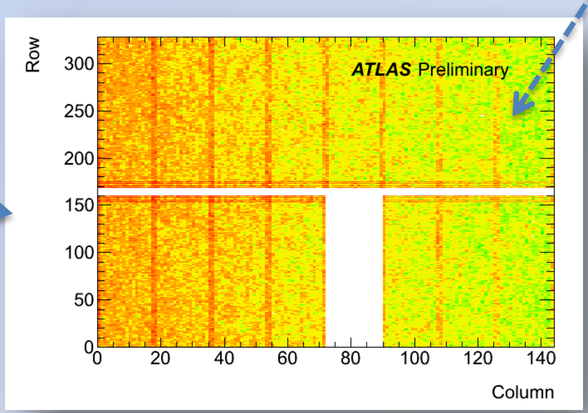




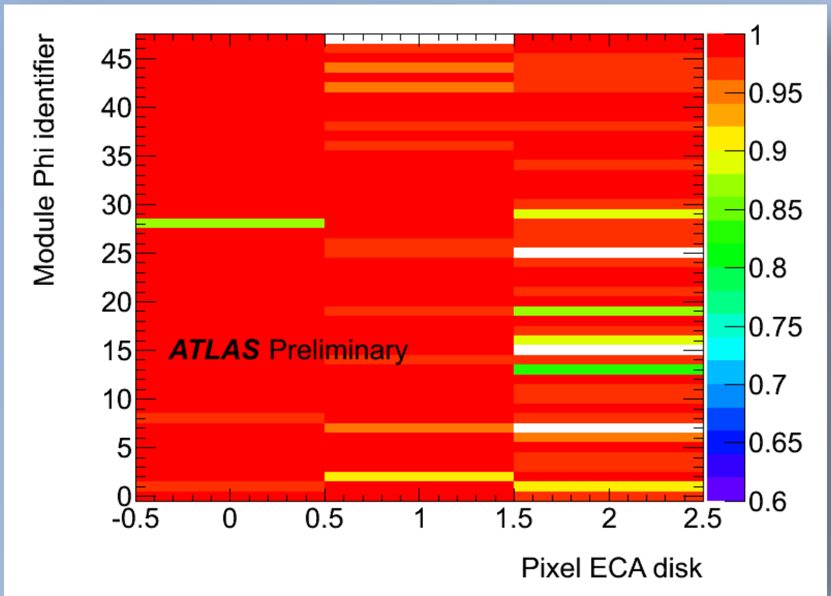
Hit-to-Track Association Efficiency

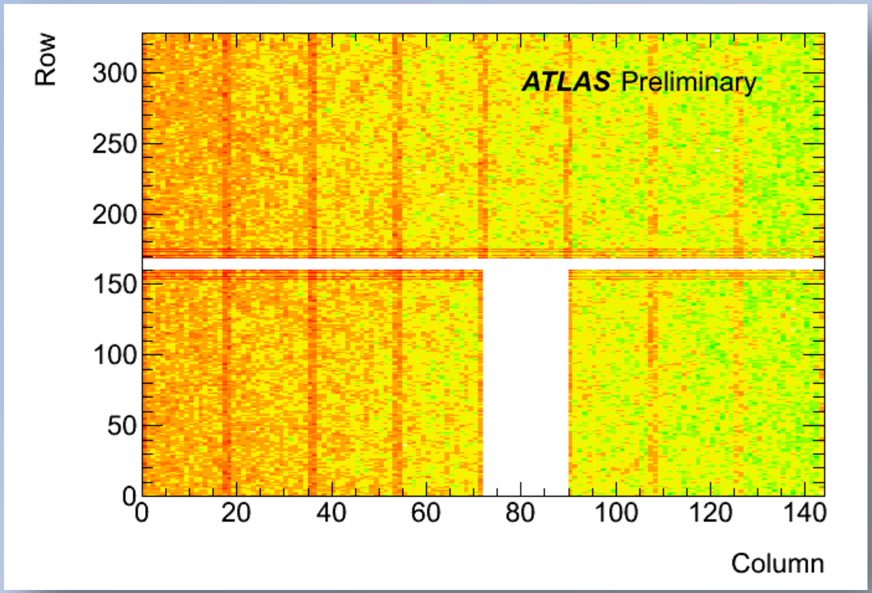
- Hit-to-track association efficiency for the different parts of the detector
- Disabled modules have been excluded, dead regions not
- Full efficiency of the B-layer due to track selection)
- Efficiency ~99% for nearly all parts
  - Slightly lower efficiency in the outermost discs due to individual modules

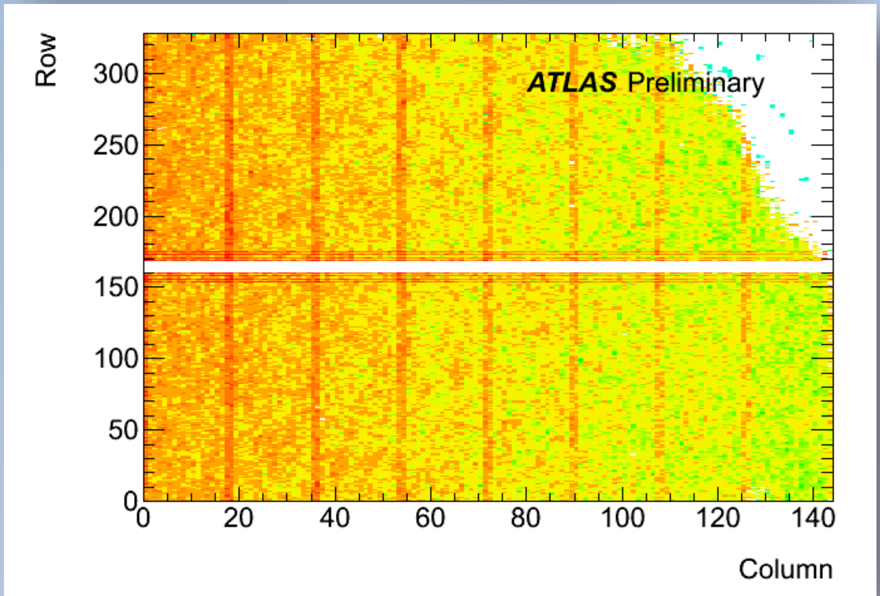


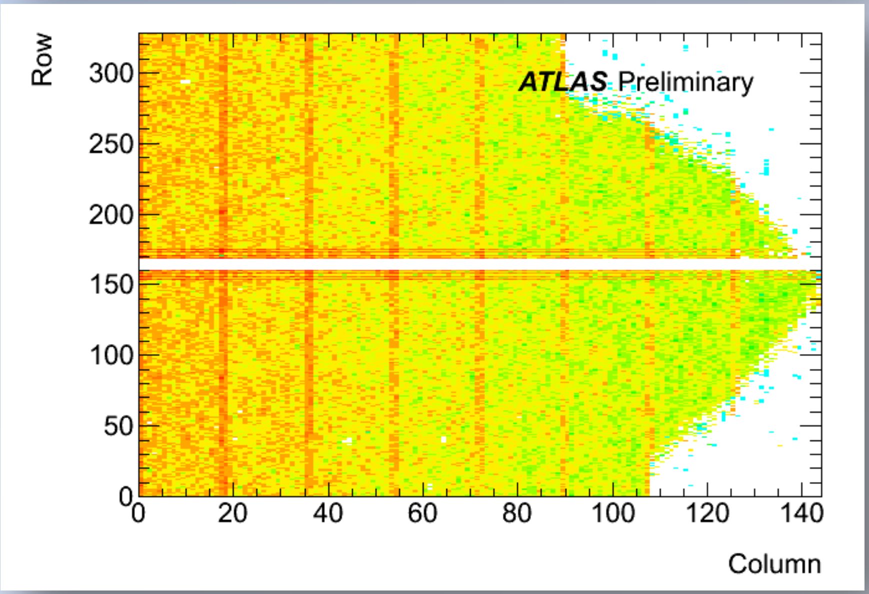


Inefficiencies



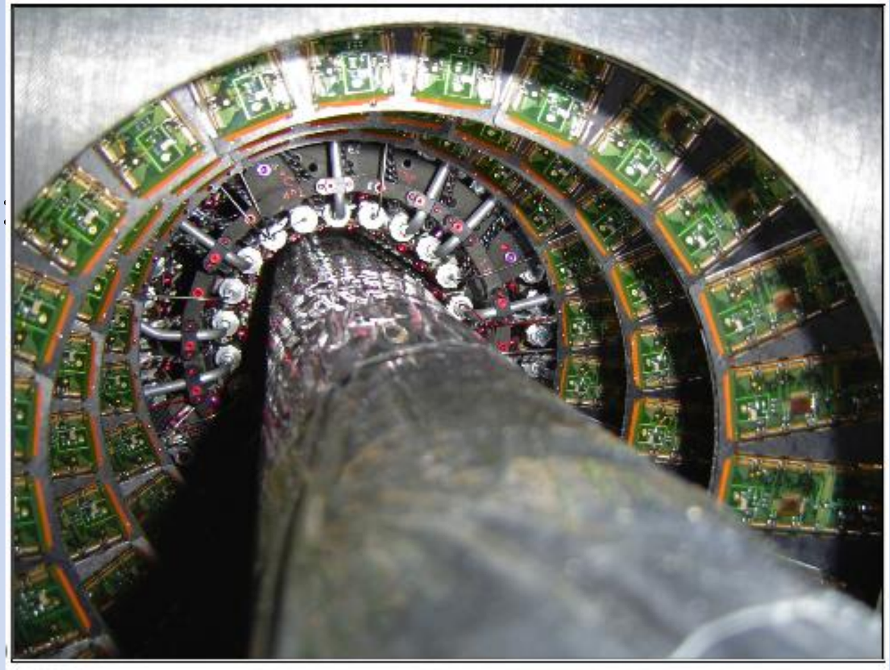






Operations

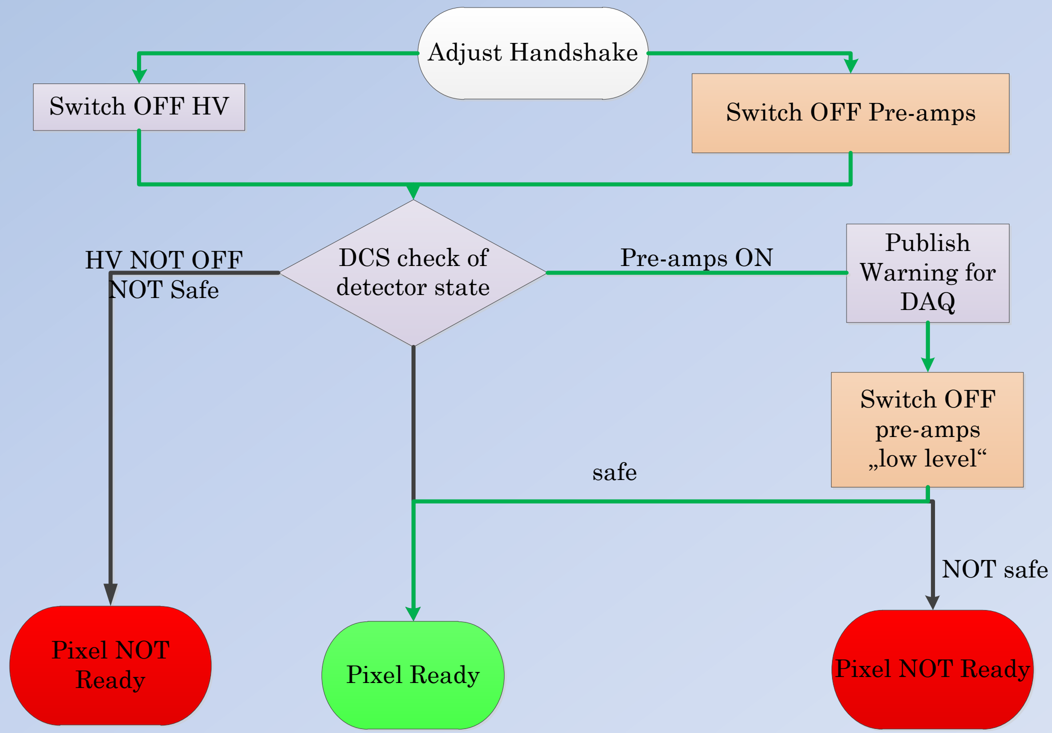
- Detector safety:
  - Until STABLE BEAMS are declared by the LHC, the HV for the modules is off.
- Warm start procedure:
  - Module configuration is performed at the start of the a run
  - Without HV, modules are noisy and can block the DAQ
  - To reduce noise FE preamplifiers are killed
- When LHC declares STABLE BEAMS:
  - Checks of beam conditions and collimator positions
  - HV is ramped up
  - Preamplifiers are enables



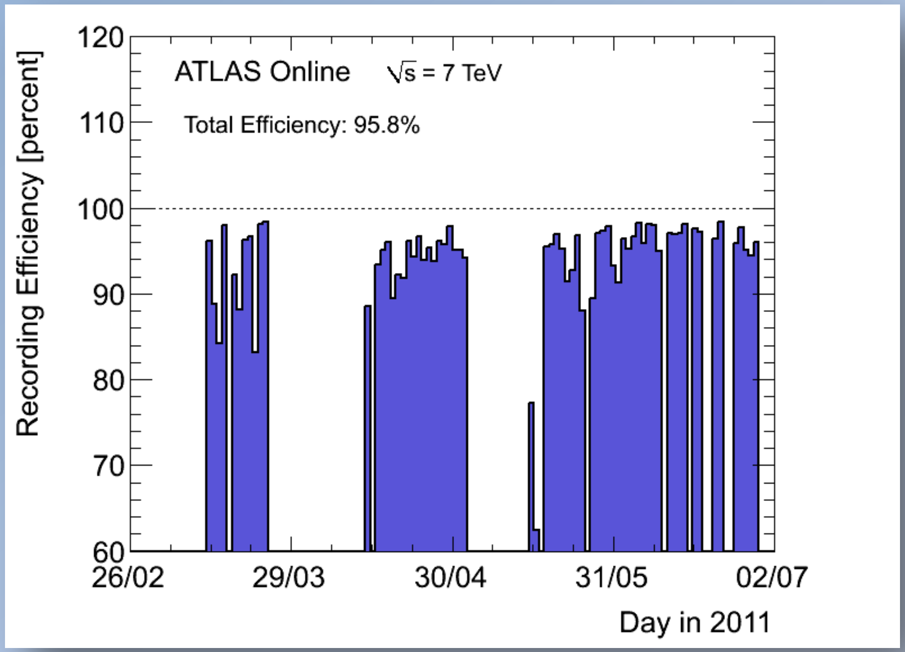
Operations

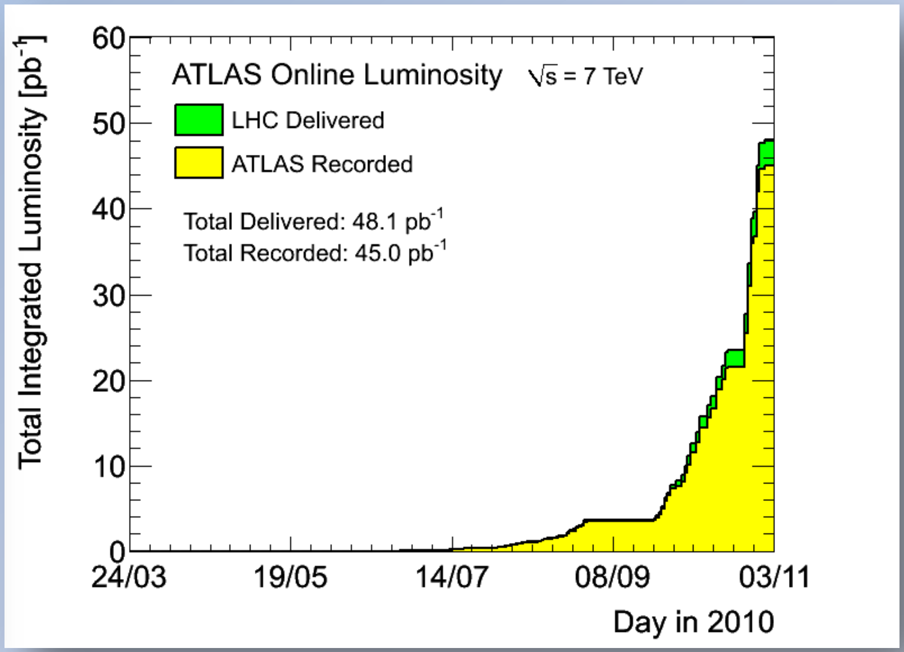
Move to more and more automatized operations

- Detect busies already on the ROD
- Automatic warm stop
  - Complication due to HV and pre-amplifiers
  - Experienced also already a lot of special cases
- Next step is top implement this also for switch ON.



Data taking efficiency





Pixel data taking efficiency **99.8%!**

Mainly dominated by switch-on time.

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.5	100	89.3	92.7	94.3	99.5	100	99.5	100	99.9	98.5	97.9

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at √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.

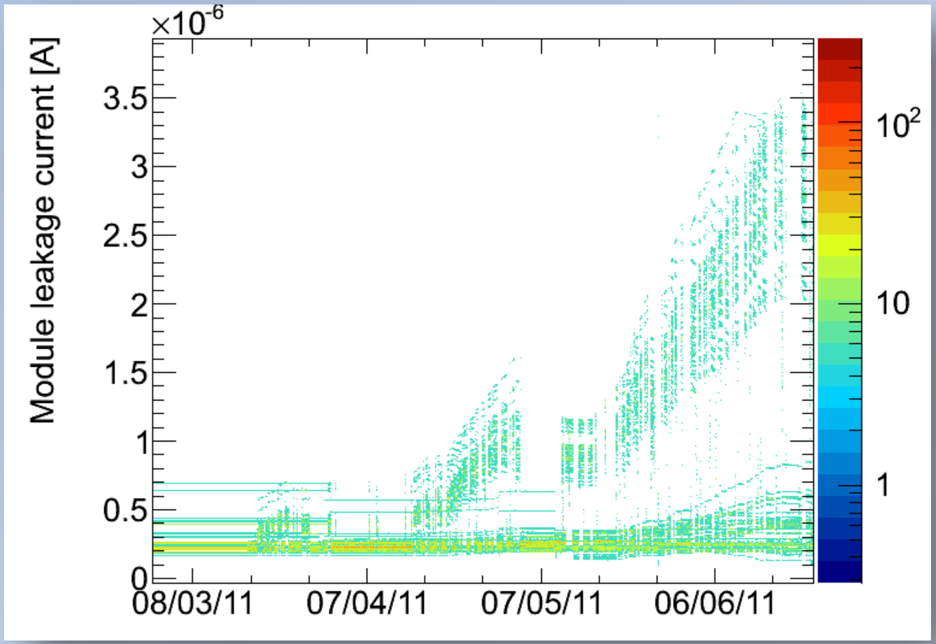
Radiation damage

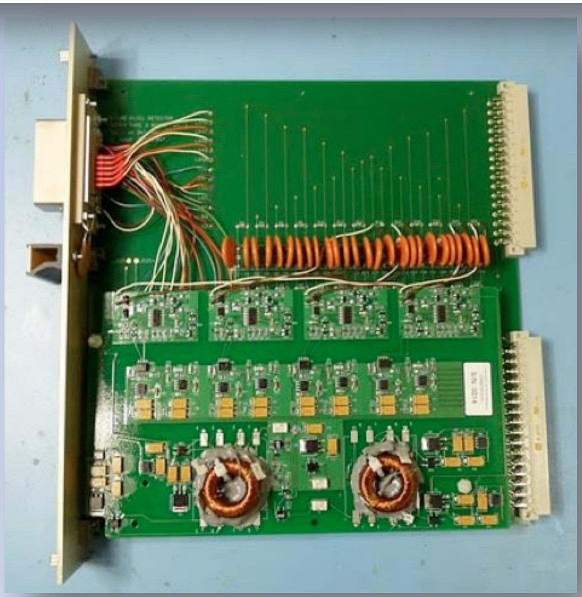
- Latest depletion voltage scans indicate a clear decrease of the depletion voltage in the B-layer

- Clear increase in leakage current measured by:
  Current measurement boards
  - 56 boards installed on b-layer modules
  - More planned to be installed
  - Precision: approaching ~10 nA.

  Power supplies per half-stave of 6 or 7 modules :
  - Precision: ~ 80nA

More details in Stephen Gibson's talk





Conclusions

- The ATLAS Pixel Detector has been calibrated and tuned to a stable working point
  - 3500 e threshold
  - Time over Threshold of 30 BC for 20 ke charge
- Performance at this working point is good
  - Threshold Dispersion ~ 40 e, average noise ~ 170 e
  - Efficiency 98% - 99%
  - Online noise occupancy O(10^{-8})
- Detector operations very stable
  - Tx failures major issues
  - More and more automatization
- Now preparing next steps:
  - Use the available calibration measurements to monitor detector properties over time
    (leakage current, depletion voltage, bump connectivity)
  - Going to a complete automatic switch-on and off procedure to face the shift crew reduction and increase data taking efficiency