Challenges of ATLAS Operation

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on behalf of
ATLAS Collaboration

Who I am and What I will say

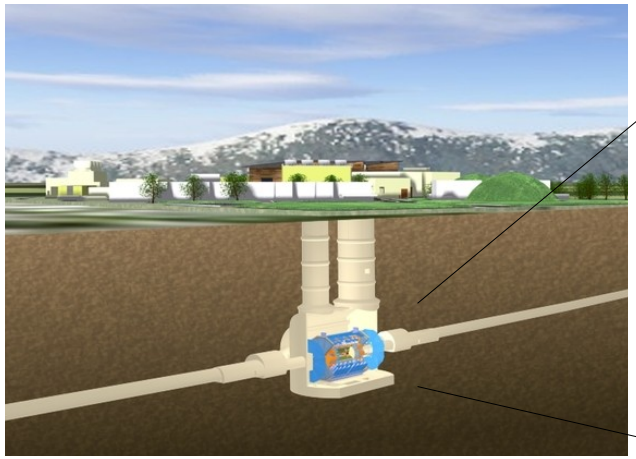
- Working in the ATLAS data-acquisition team since 2007
  - DAQ representative in the ATLAS Run Coordination group since 2011

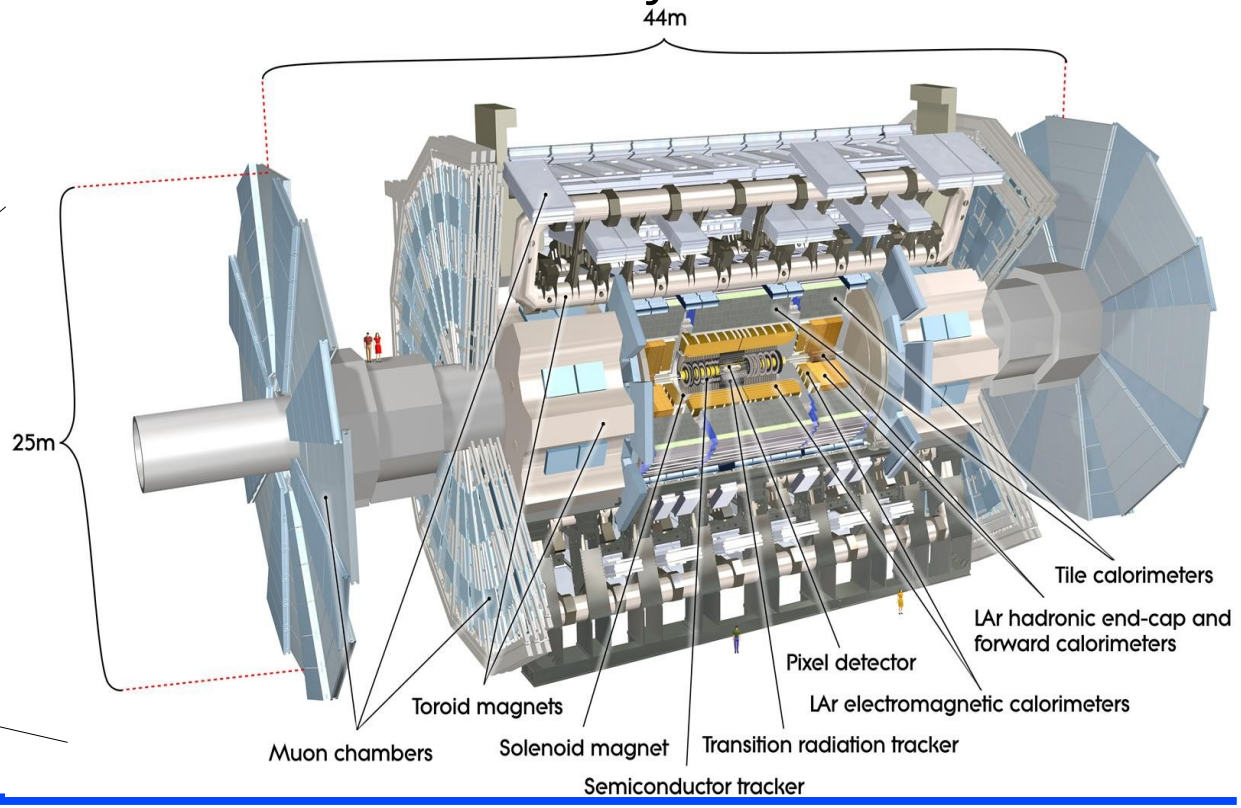
- Cannot cover all topics and aspects of ATLAS Operation in Run 1
- Biased view based on my experience
  - DAQ is strategic, central position to provide a wide overview

- Overview of Run 1
- Operation at 50 ns - Operation beyond design
- Automation and Operation Work-Flow
- Data Quality
- Toward Run 2

ATLAS Detector Operation

- Giant apparatus of extreme complexity
  - high-intensity magnetic fields (up to 4 T), cryogenic equipment, cooling and power demanding (several MW), human and equipment safety, …
- A primary, often unspoken, challenge is to keep the **ATLAS infrastructure** ticking
  - excellent work of the infrastructure teams in coordination with detector systems and common services like Detector Control System





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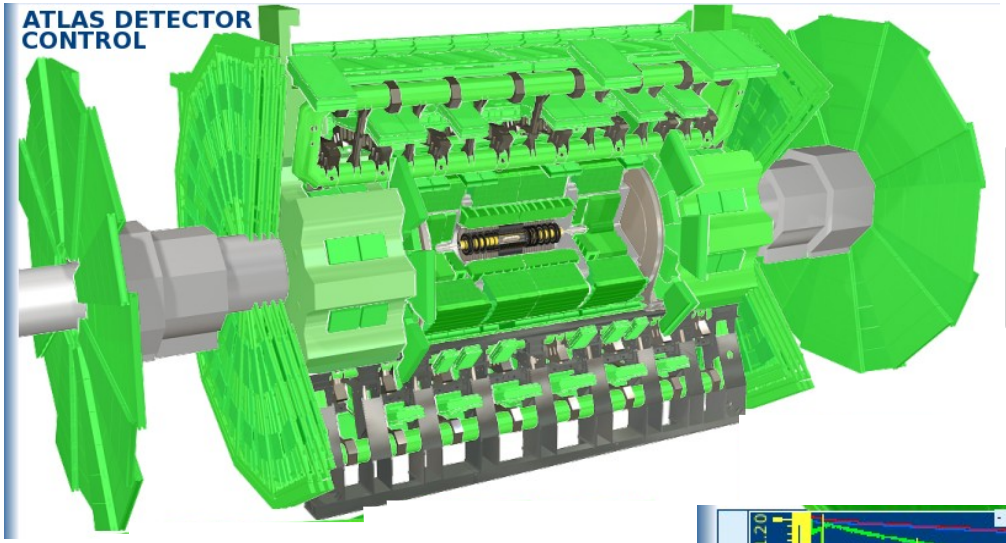
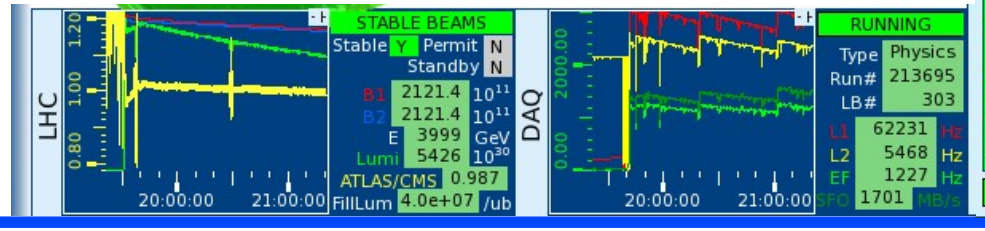
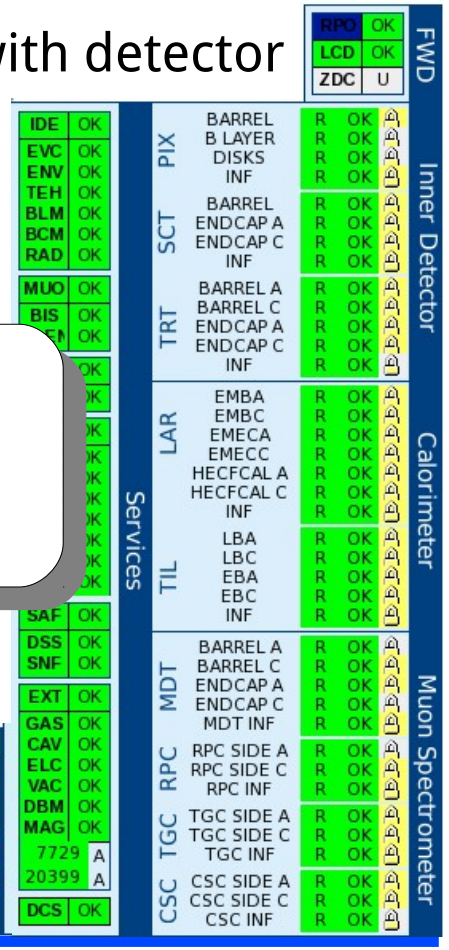


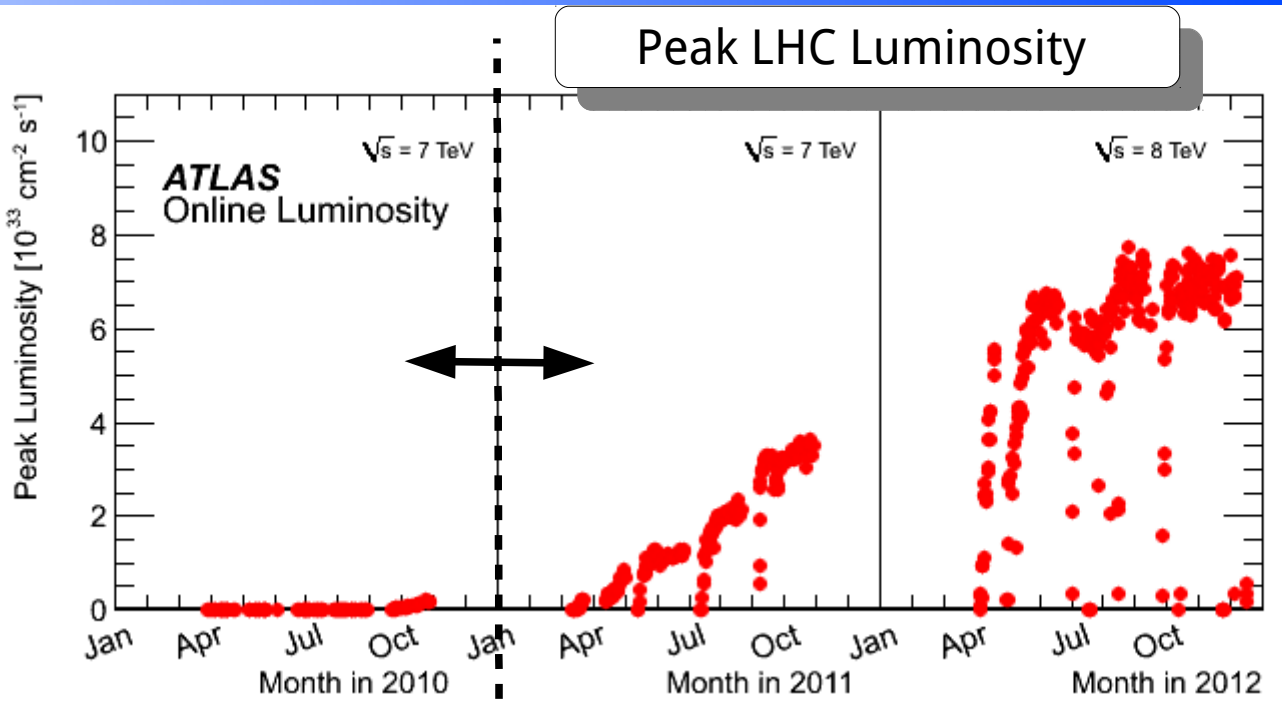
- >10^7 controlled and/or monitored parameters
- 6.6 GB/day of stored in condition database





Run 1 Overview

- Distinguish two major phases in Run 1
- 2010
  - establish **ATLAS detector**
  - establish operation routines
  - bring together many different communities
- 2011 – 2012
  - operation at and beyond design performance
    - **the pile-up challenge**
  - automation



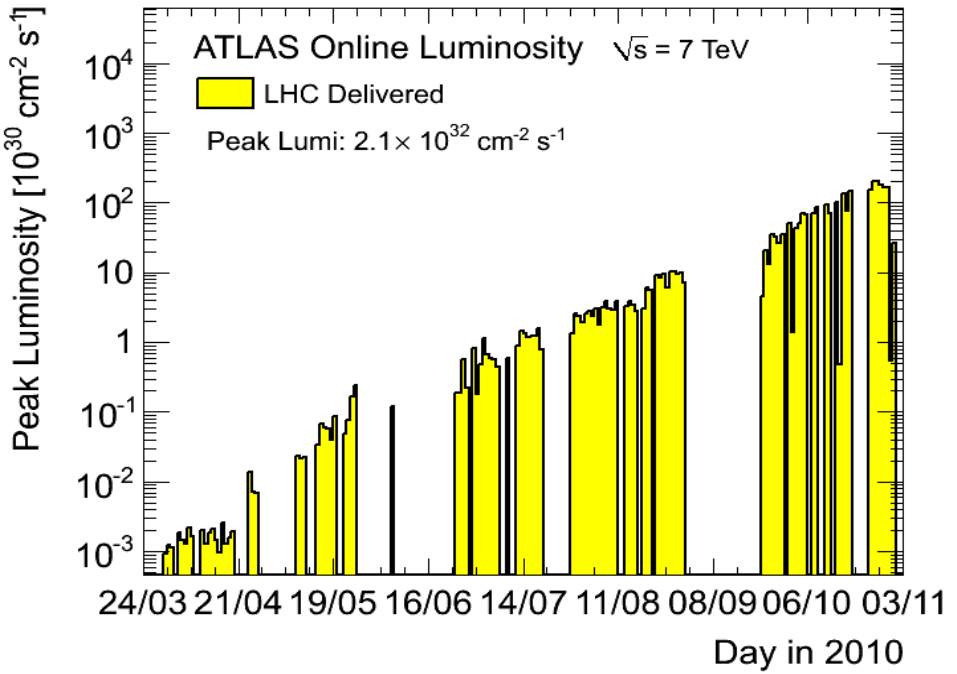
	Peak Luminosity (10^{33} cm^{-2}s^{-1})	Peak pile-up	Number of control room shifters
2010	0.2	4	14
2011	3.5	18	11
2012	7.7	35	9

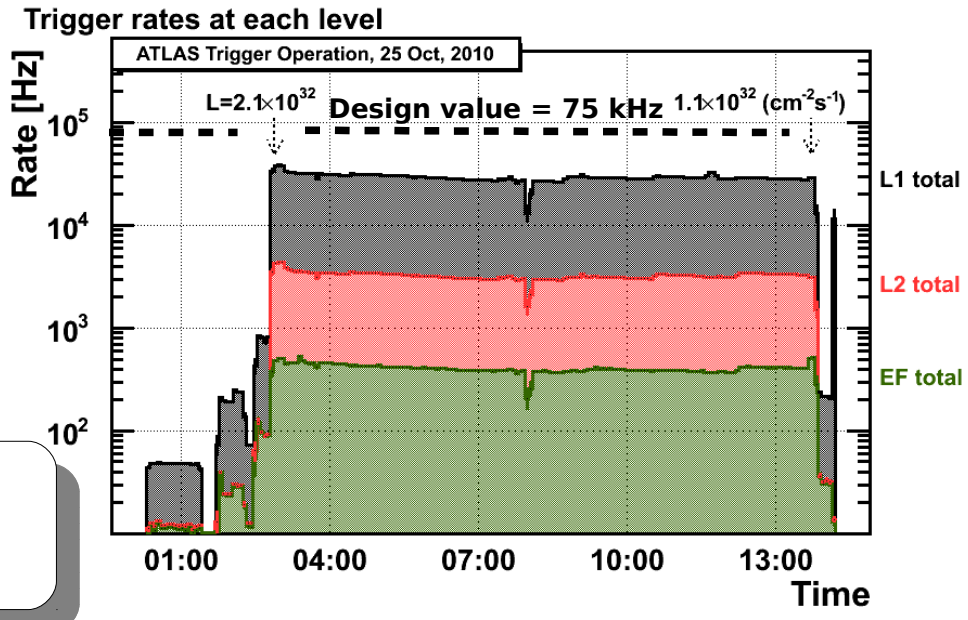
Run 1 Overview: 2010

	2010	Design
Peak L1 Rate (kHz)	<40	75
Peak Luminosity (10^{33} cm^{-2}s^{-1})	0.2	10
Peak pile-up	4	24

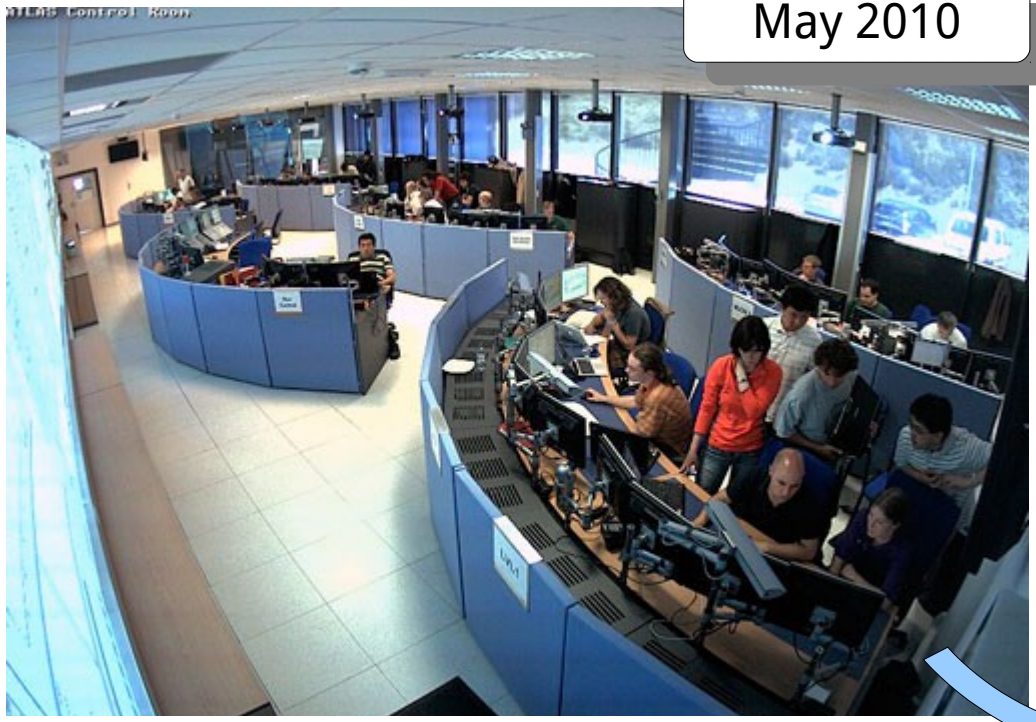
- LHC luminosity increased by 5 order of magnitude …
- L1 rate significantly lower than design one
- HLT rejection not needed until ~ 10^{29} cm^{-2}s^{-1}

Large margins for operation





What 2010 was about



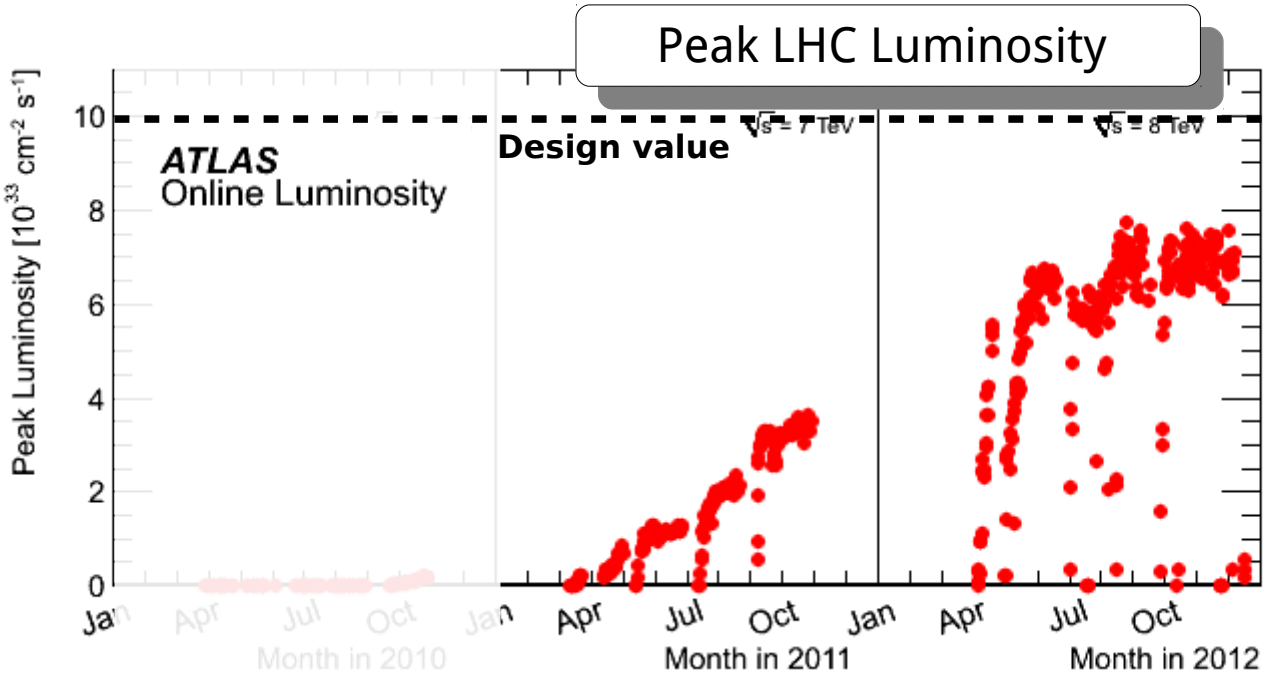
- Learn to operate ATLAS as a **unique team**
  - no just aggregation of individual detector systems
- Start the move from **expert operation to shift operation**

- Trend continued in following years
- By 2011, **ordinary operation handled by shifters**
  - large **pool of experts** ready to intervene
    - ~ 20 primary on-call phones just for on-line operation (+ infrastructure, service piquet, off-line facilities, ...)

	Number of control room shifters
2010	14
2011	11
2012	9

Run 1 Overview: 2011 - 2012

- Smoother and smaller changes in luminosity delivery than in 2010
  - 0.2 → 7.7 10^{33} cm^{-2} s^{-1}
- **Entered the region of demanding operational requirements**



Operation @50 ns

Exceeded many (interrelated) design parameters

	Peak Luminosity (10^{33} $cm^{-2}s^{-1}$)	Peak pile-up	Number of control room shifters
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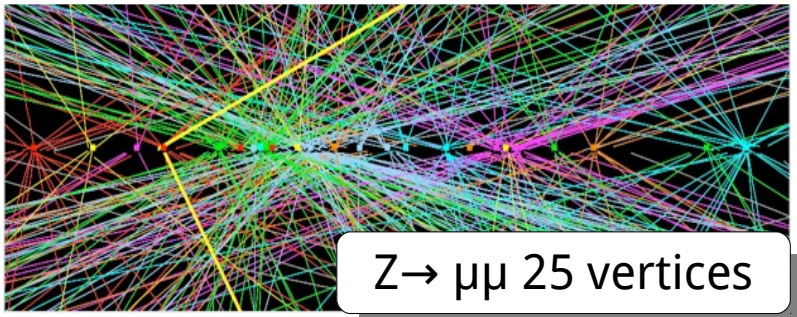
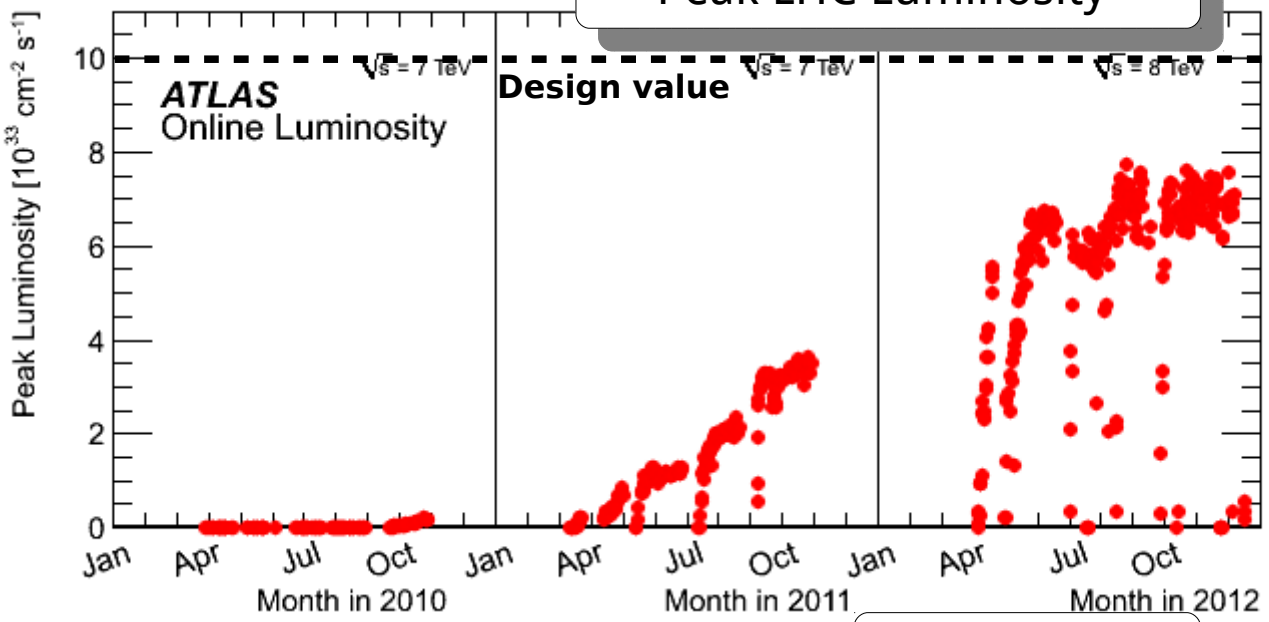
Effects of 50 ns operation

- Operation at high pile-up has (non-linear) effects at all levels
  - trigger rates
  - on-line and off-line processing times
  - data rates
  - reconstruction and simulation
  - …

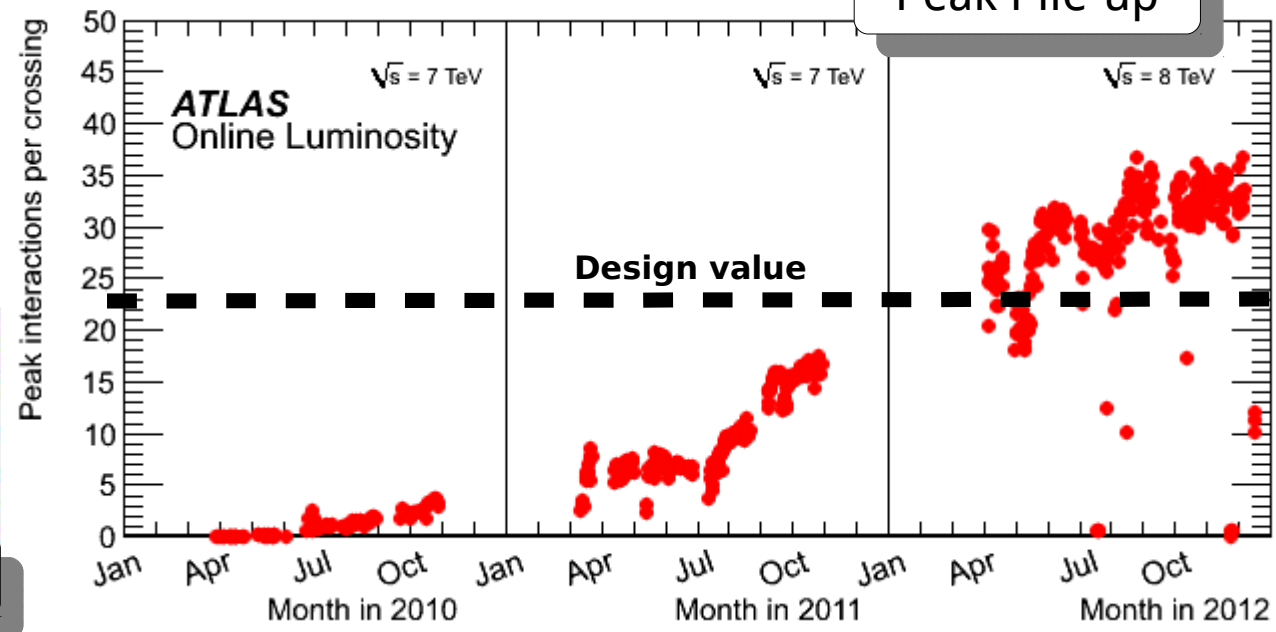


Z→ μμ 25 vertices

Peak LHC Luminosity

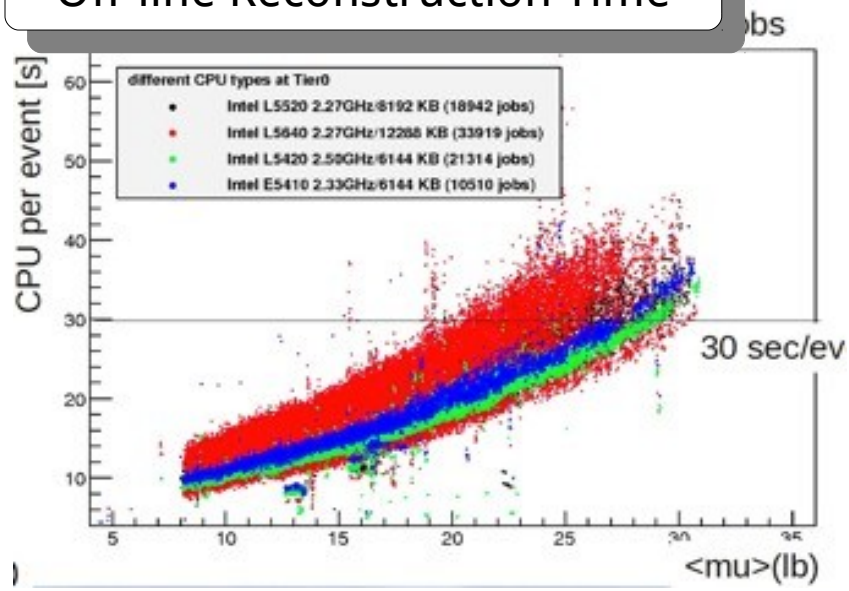


Peak Pile-up

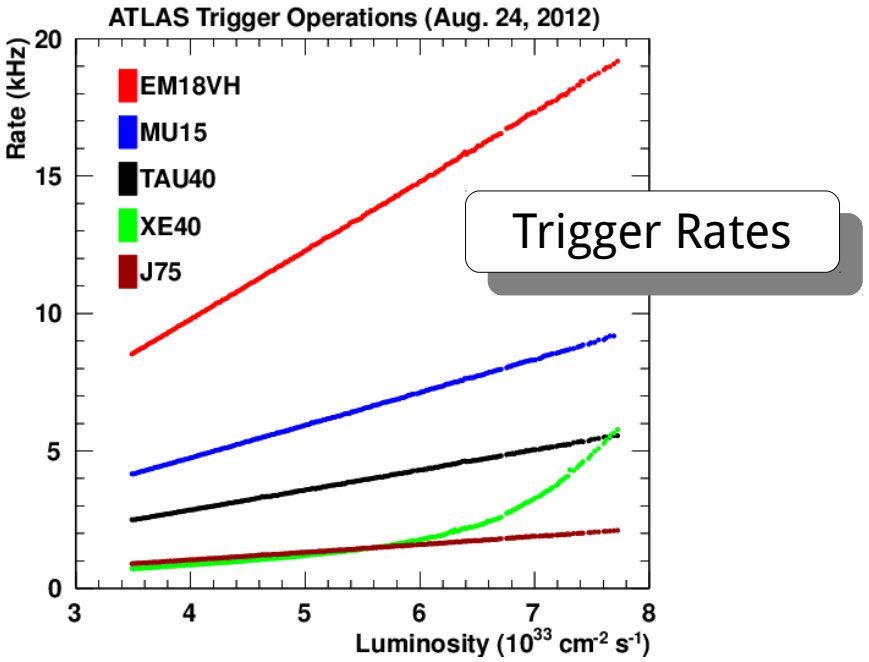


Effects of 50 ns operation

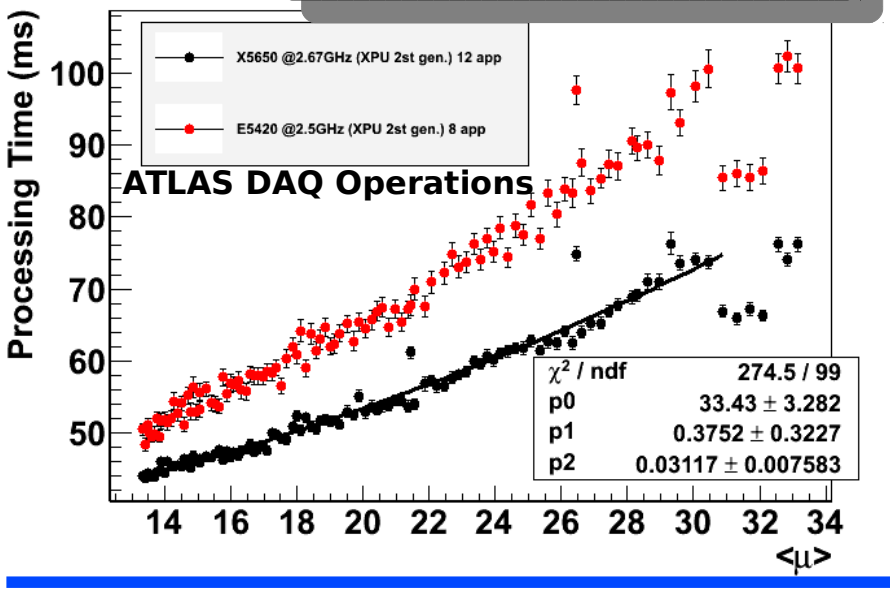
Off-line Reconstruction Time



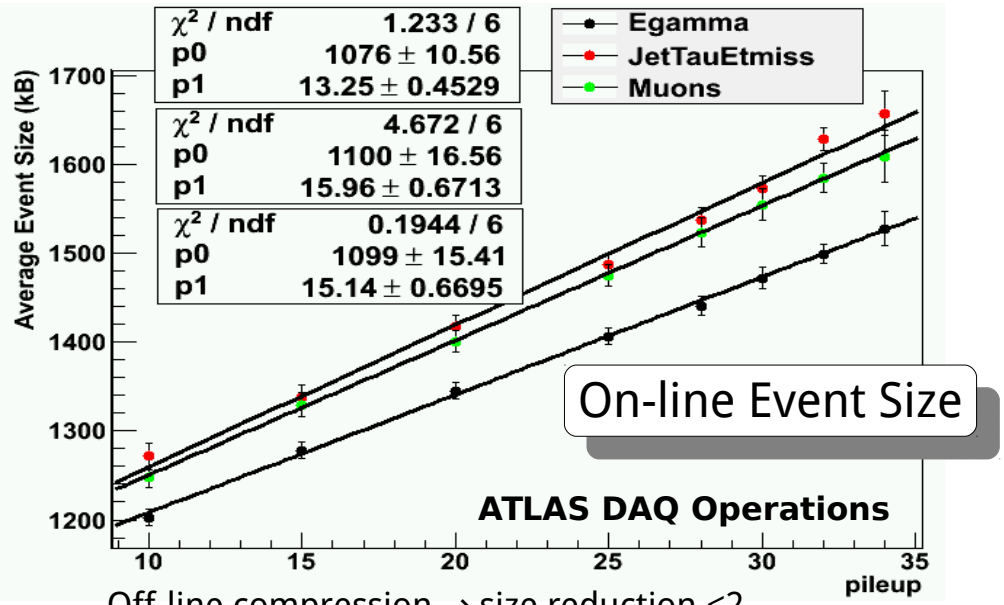
Trigger Rates



On-line Processing Time



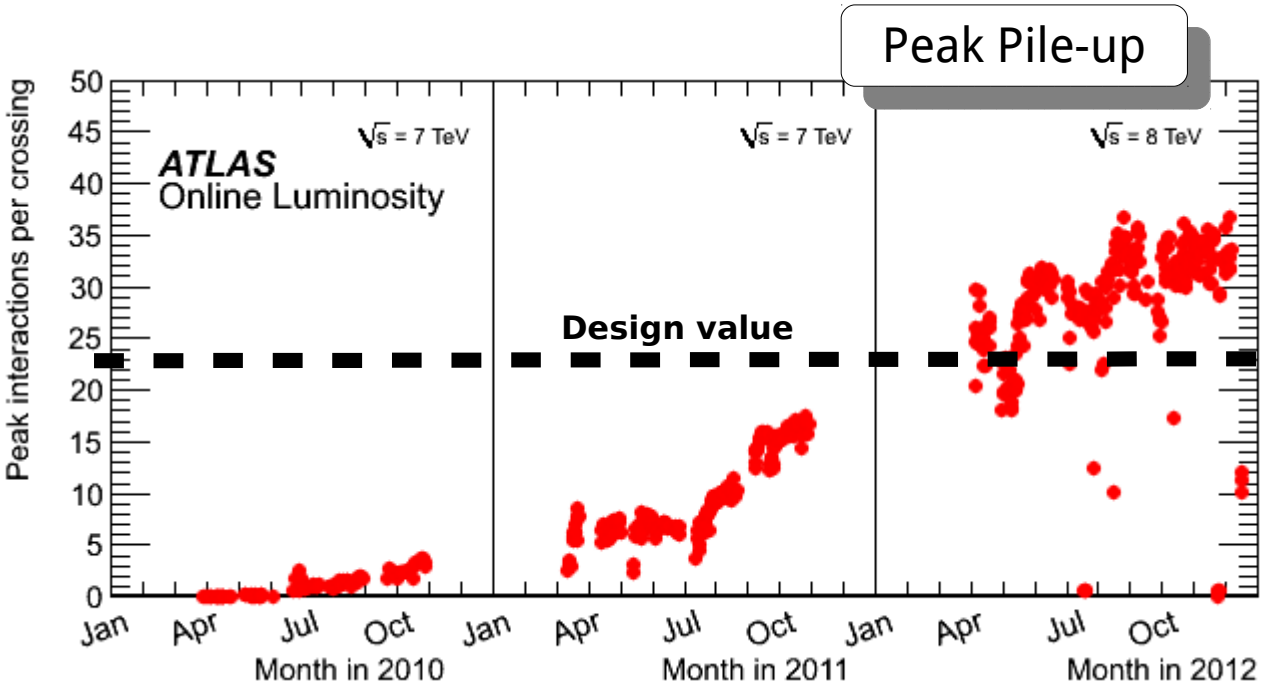
On-line Event Size

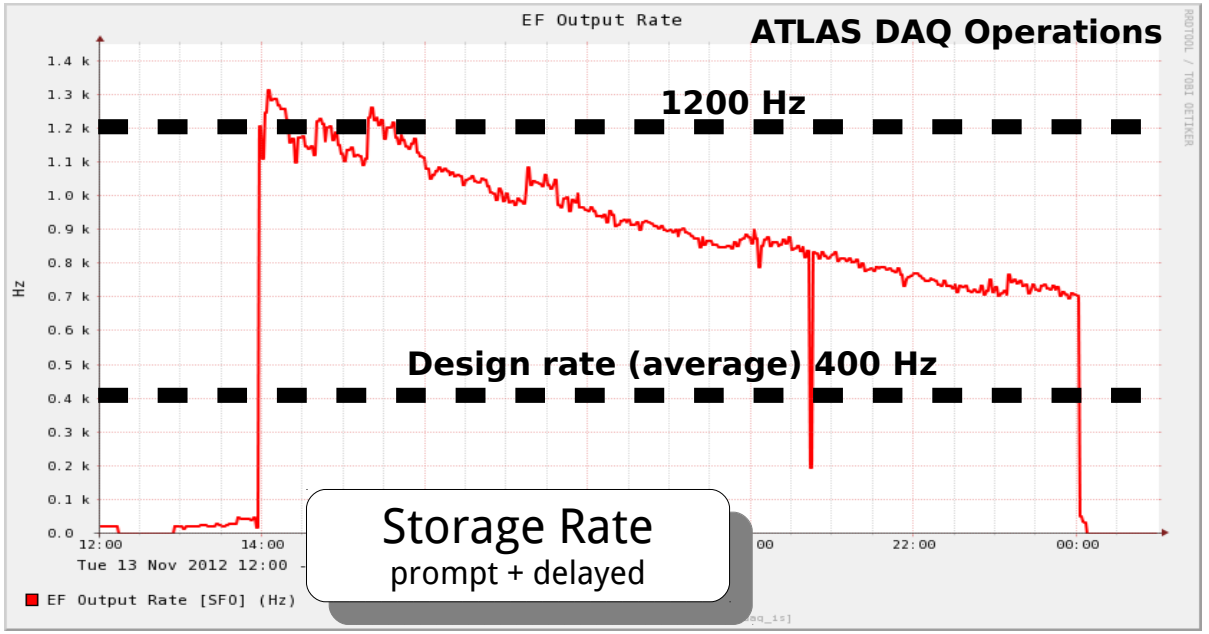


Off-line compression → size reduction ≤2

Dealing of 50 ns operation

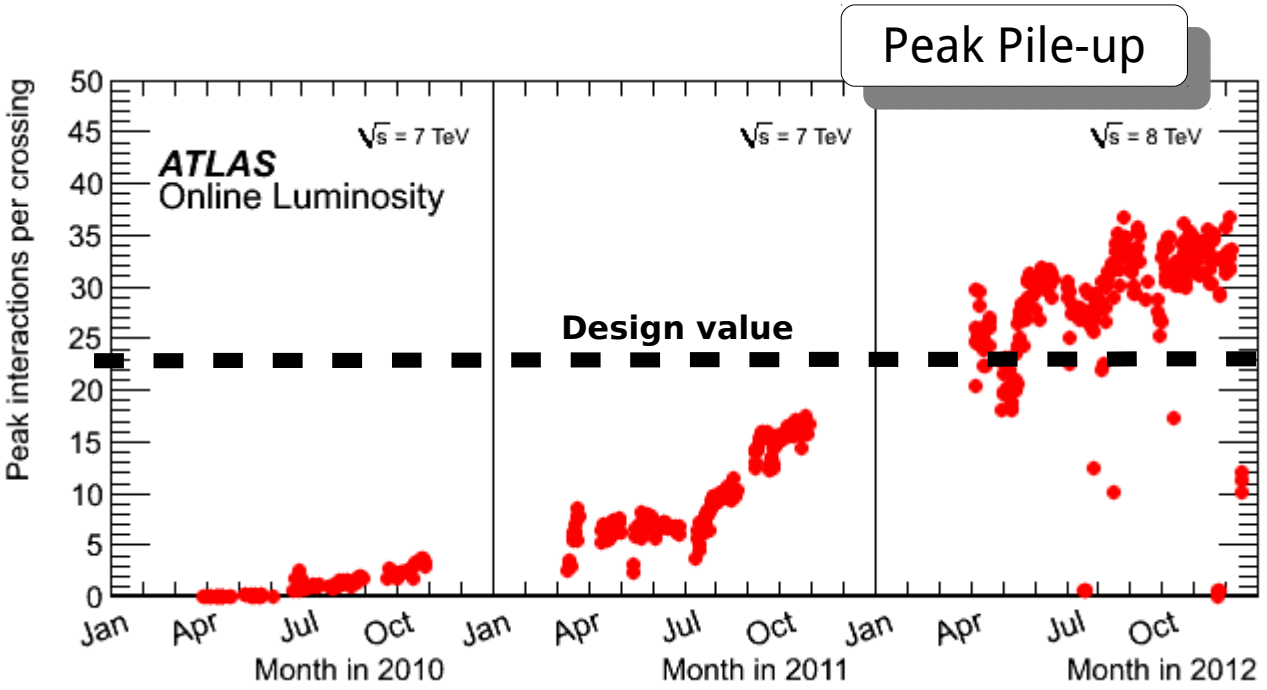
- In many areas, dealt with 50 ns operation
  - using the built-in **operational margins**
    - e.g. allocated readout bandwidth
  - exploiting systems **scalability**
    - e.g. on-line storage system extension





Dealing of 50 ns operation

- In many areas, dealt with 50 ns operation
  - using the built-in **operational margins**
    - e.g. allocated readout bandwith
  - exploiting system **scalability**
    - e.g. on-line storage system extension
- Other areas required a completely **different approach**

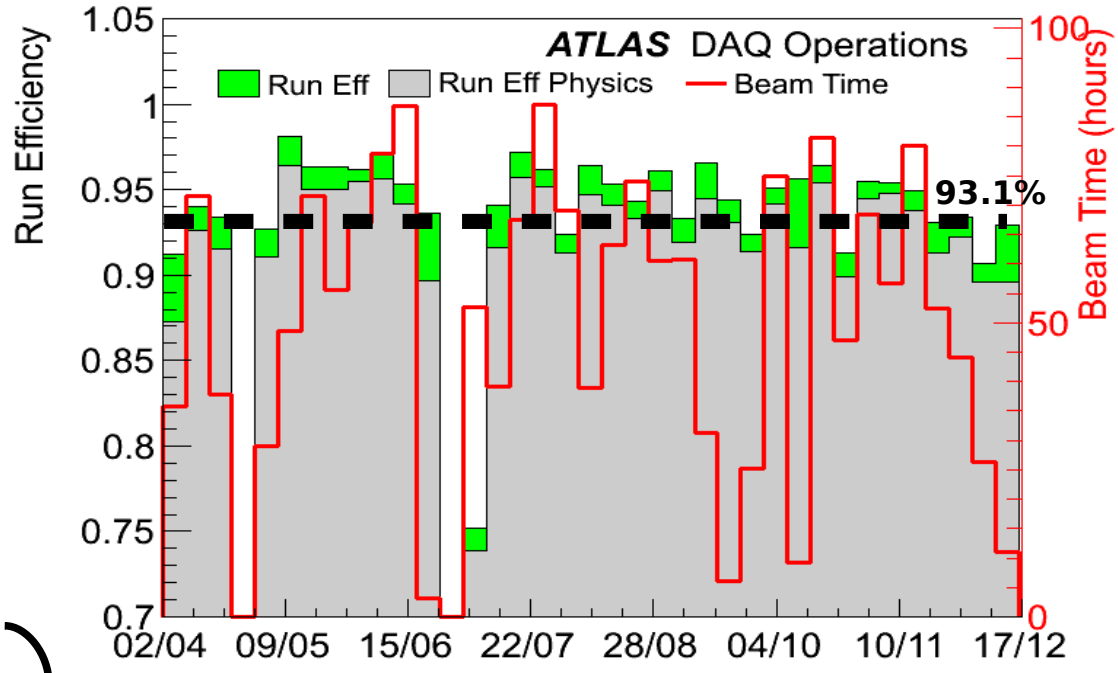


detector stability, fault and de-synchronization rates, overflows, ...

Automate procedures

- **Automated recovery procedures** turned out to be very valuable
  - major contribution to the high ATLAS uptime in Run1
  - concentrated effort from all communities

- Capabilities (e.g.)
  - raise (high-) voltages upon safe beam declaration
  - temporary exclude/reconfigure/include individual (group of) readout channels
  - re-synchronize (group of) channels
  - reconfigure and re-synchronize complete sub-detectors



93.1% time-based efficiency

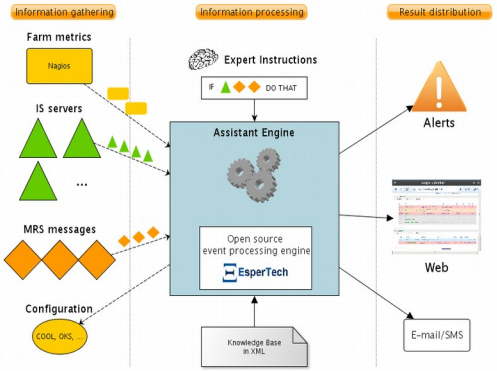
No need to stop a run for any of these

	Time-based Efficiency (%)
2010	93
2011	93.4
2012	93.1

Operation work-flow

New inefficiency or data-defect source

Understand occurrence and signature



Prompt and automatic condition detection

Permanent fix or automated recovery

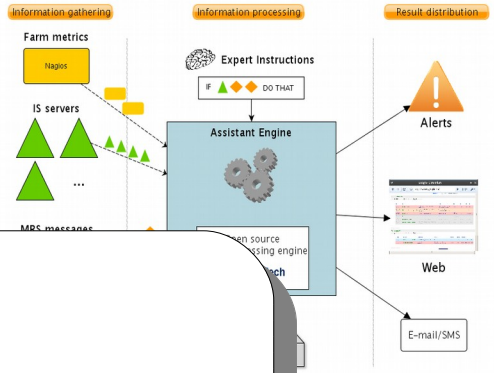
Shifter and/or expert recovery procedure

- Minimize impact of data-taking inefficiencies
- Learn from experience
- Continuously update procedures and documentation

Operation work-flow

New inefficiency or data-defect source

Understand occurrence



utomatic
tection

Knowledge base at end of Run 1

- ~30 automatic recovery procedures
- ~100 automatic condition detection and alerting rules

Permanent fix or automated recovery

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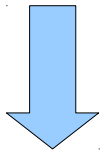
Not just Quantity, but Quality

- Recording a lot of data is not sufficient
  - ultimately data must be usable for physics measurements
- Automated procedures and shift crew must be aware of physics implications
- **Data quality framework** complemented the data-taking automation and operation



Maximize the
Quantity x Quality

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	95.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.9%
Tile calorimeter	9800	98.3%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	100%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	96.0%
RPC Barrel Muon Chambers	370 k	97.1%
TGC Endcap Muon Chambers	320 k	98.2%

ATLAS p-p run: April-December 2012

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.1	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5

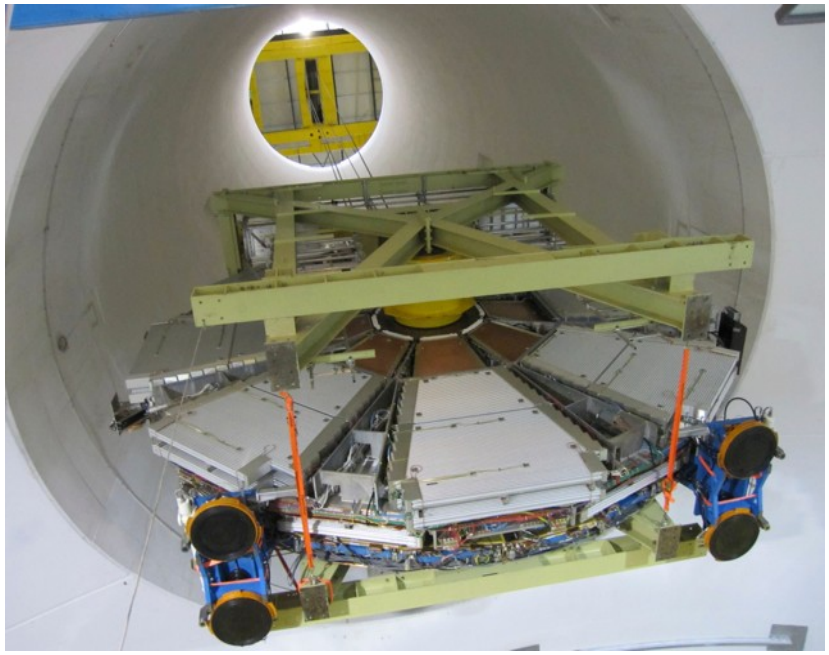
All good for physics: 95.5%

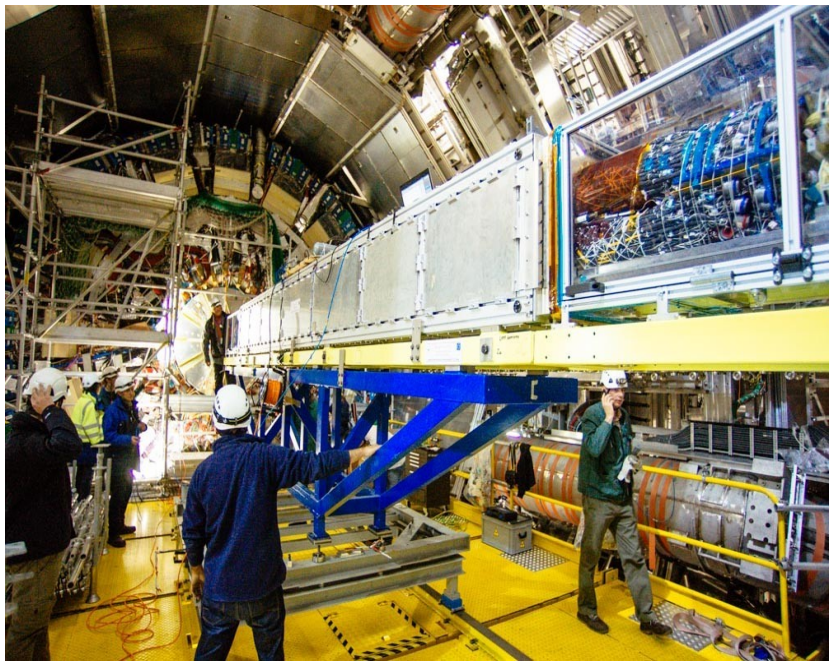
Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}$=8 TeV between April 4th and December 6th (in %) – corresponding to 21.3 fb^{-1} of recorded data.

In preparation for Run 2

- Long Shutdown 1: consolidation and maintenance of ATLAS infrastructure, detector and services
  - > 250 work packages
  - ranging from
    - beam pipe replacement and magnet cryogenics consolidation
  - to
    - Trigger & Offline code optimization, DAQ evolution and L1 trigger improvements and extension
  - via
    - new Pixel layer, gas leaks and power supply repairs

Operational experience from Run 1
considered at all levels





Milestone Weeks

- ATLAS operation restarted in **February 2014**
- Combined integration and cosmic data-taking session every ~6 weeks
- Incrementally exercise ATLAS operation
  - from L1 trigger to Tier-0 data processing
    - complemented by Data Challenge '14 → ensure readiness of off-line software and distributed computing
  - integrate new detectors, consolidated systems, ...
  - **form new experts:** new students and post-docs

Milestone Weeks

- ATLAS Control Room very lively again
- LHC luminosity ramp-up after LS1 expected to be very fast
  - beat Run 1 peak luminosity after few weeks of physics operation
- (Hopefully) We have learnt how to empty our control room as quickly
  - preserving a **high Quantity x Quality product**

Outlook

Run 1 was **extremely successful**

Very broad and rich **Physics measurements,** culminating with the Higgs discovery

Likewise for the definition and evolution of an overall **ATLAS operation culture & model**

Interventions and improvements at all levels in the Long Shutdown period driven by the **Run 1 experience**

Run 1 experience provides **solid base** for the **Run 2 Challenges**

Peak Lumi $1.6 \cdot 10^{34}$ $cm^{-2}s^{-1}$ – Pile-up 43
L1 Rate 100 kHz – Avg Output Rate 1 kHz
Reduced Shift Crew ≤8