ATLAS Detector Overview.

12th Pisa Meeting on Advanced Detectors, 10 May 2012

Christoph Rembser (CERN)

A brief word on the LHC

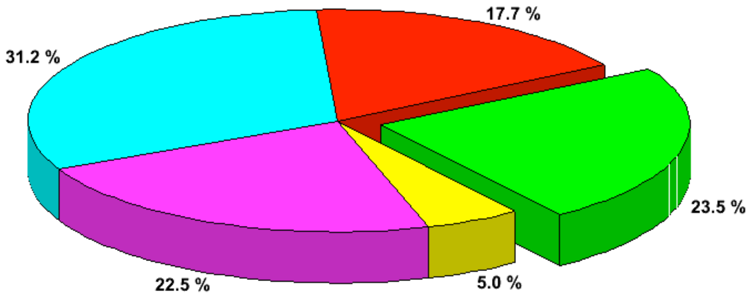
see https://lhc-statistics.web.cern.ch/LHC-Statistics/

2011: 3.5 TeV protons, 50ns bunch spacing

2011 LHC Efficiency: 740 Fills

- Access - No Beam
- Machine - Setup
- Beam In
- Ramp + Squeeze
- Stable Beams

Statistics for fills 1613 to 2353
Total Duration: 269 days, 07 h [13.03.11 to 07.12.11]
Time in Stable Beams: 63 days, 10 h

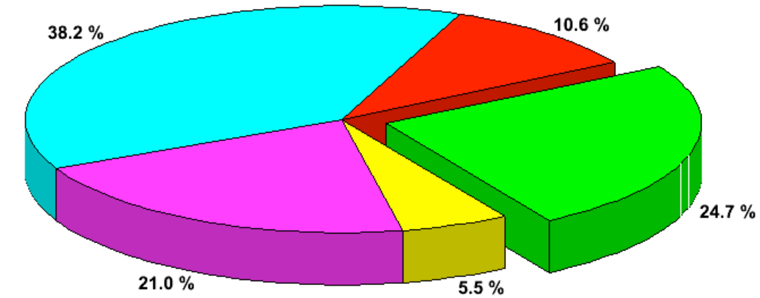


2012: 4 TeV protons, 50ns bunch spacing

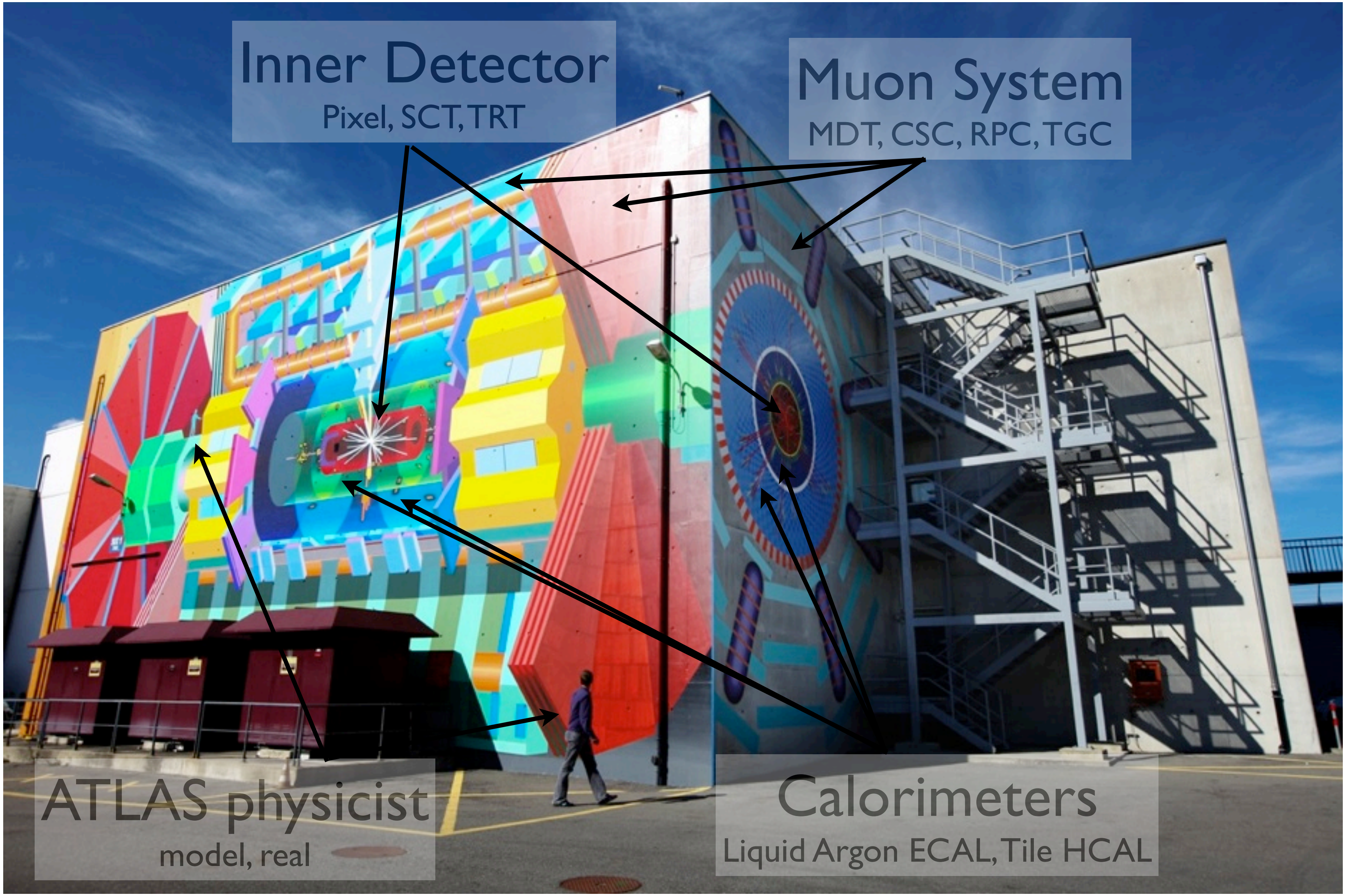
2012 LHC Efficiency: 204 Fills

- Access - No Beam
- Machine - Setup
- Beam In
- Ramp + Squeeze
- Stable Beams

Statistics for fills 2443 to 2647
Total Duration: 48 days, 18 h [01.04.12 to 20.05.12]
Time in Stable Beams: 12 days, 00 h



The ATLAS Detector



Hardware status (2011/2012)

Before shutdown 2011/2012...

Subdetector	# of Channels	Approximate Operational %
Pixels	80 M	96.4%
SCT Silicon Strip	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.8%
Tile Calorimeter	9800	96.2%
Hadronic endca LAr Calorimeter	5600	99.6%
Forward LAr Calorimeter	3500	99.8%
LVL1 Calo Trigger	7160	99.9%
LVL1 Muon RPC Trigger	370 k	99.0%
LVL1 Muon TGC Trigger	320 k	100.0%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	97.7%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	97.9%

...and after (11 May 2012)

Subdetector	# of Channels	Approximate Operational %
Pixels	80 M	95.9%
SCT Silicon Strip	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
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ATLAS detector in good shape for the 2012 run!

Detector readiness - activities shutdown 2011/2012

Example **Liquid-Argon calorimeter**:

- 10 front-end boards repaired and 12 new LVPS installed:

➡ bad channels decreased from 385/182468 to 106/182468 (0.06%)

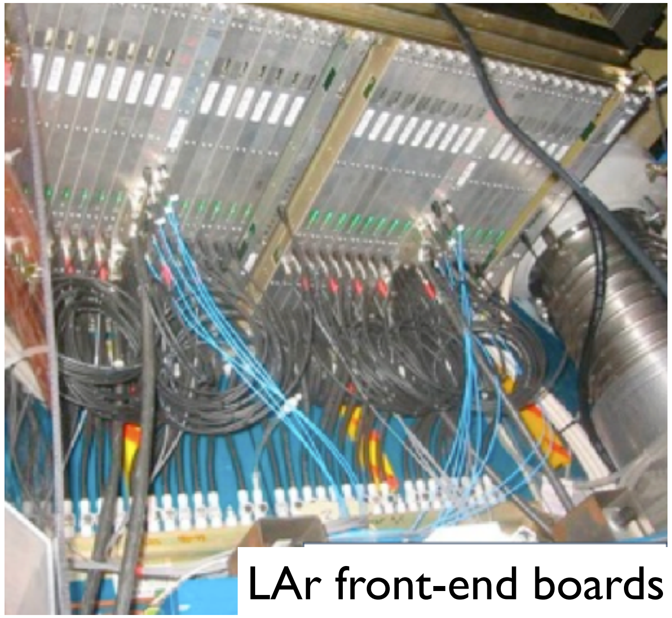
Example **Tile Hadronic calorimeter**:

- 45/256 on detector "drawers" opened for refurbishment
- 40/256 new low voltage power supplies replaced, reduce trip rates and noise

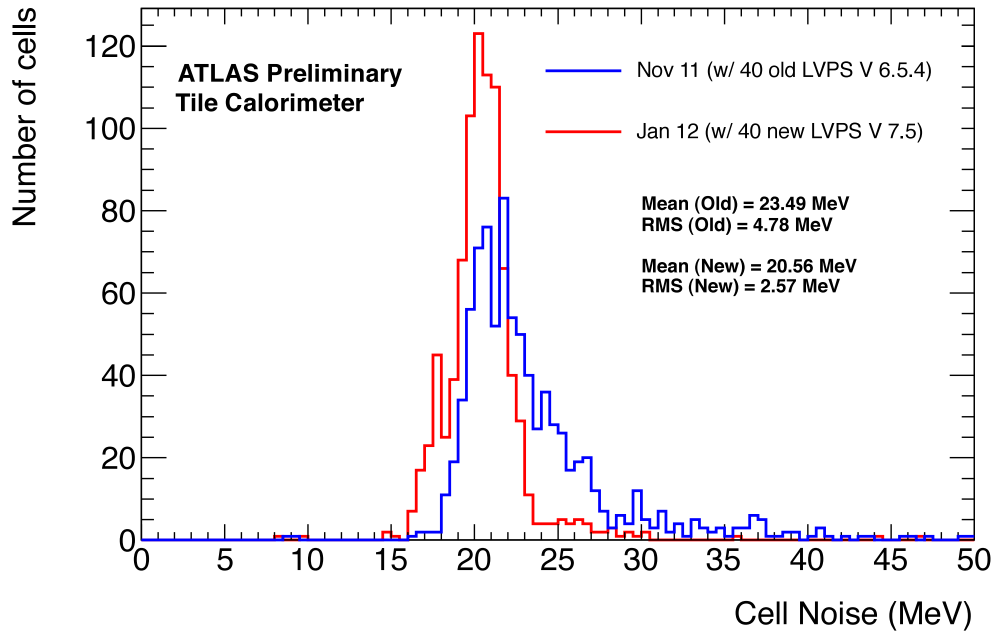
➡ bad cells: before shutdown 5% to 0.5% today

Example **infrastructure**:

- Cryogenics: NEW main compressor
- Maintenance cryogenics, gas, cooling, access systems and consolidation of the electrical system



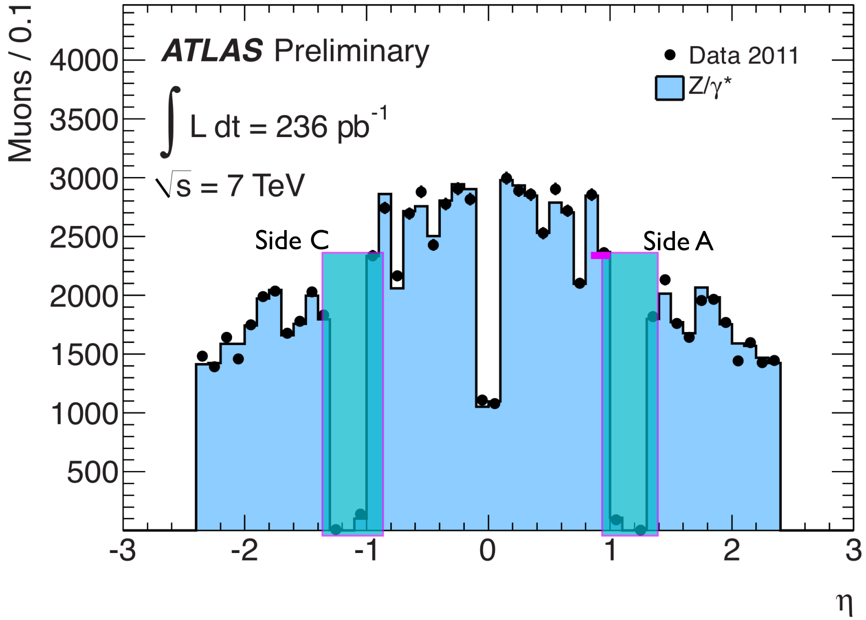
LAr front-end boards

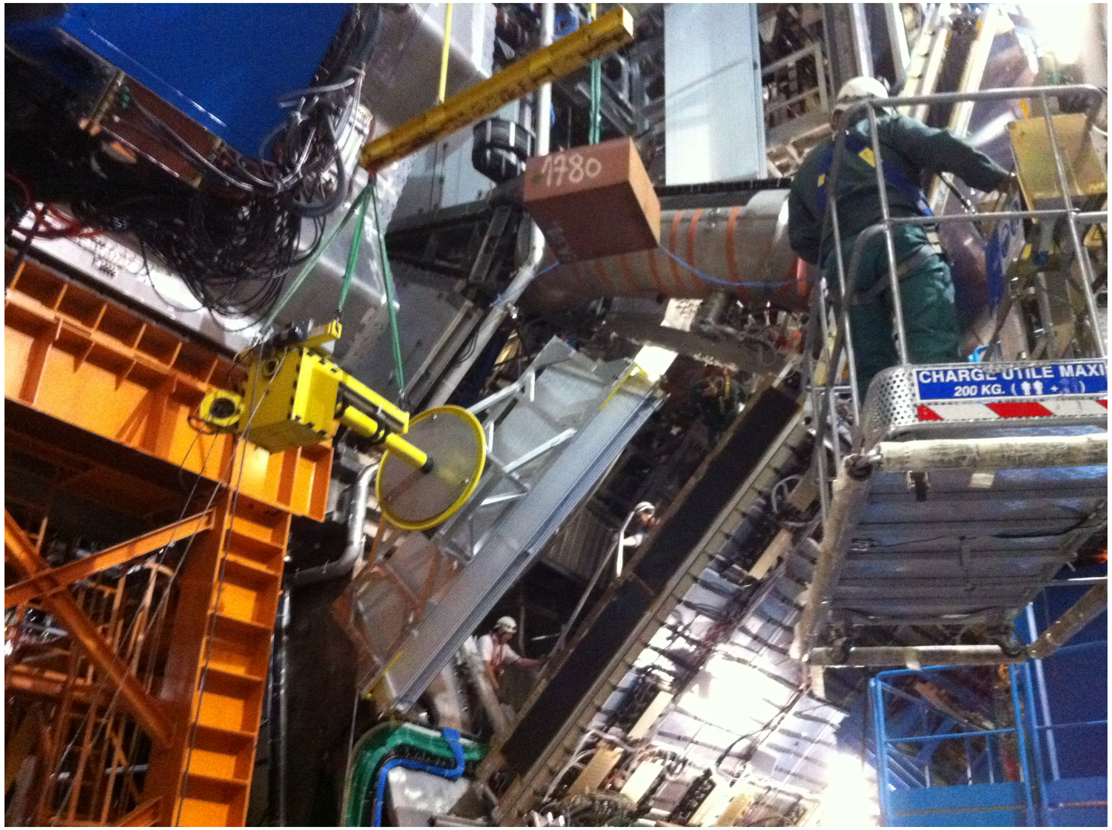


Detector readiness - activities shutdown 2011/2012

Muon Spectrometer:

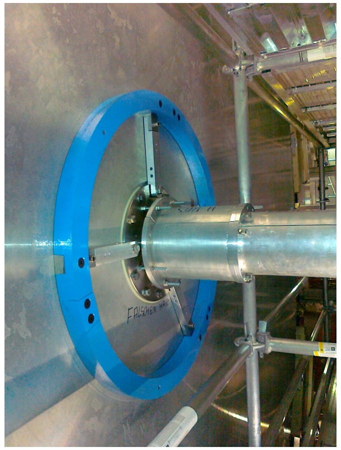
- Installation MDT EE (precision MS tracking at $|\eta|$~1.2):
  - ➡ Side C: completed, 31 modules
  - ➡ Side A: 5 EELs (completion 2013)

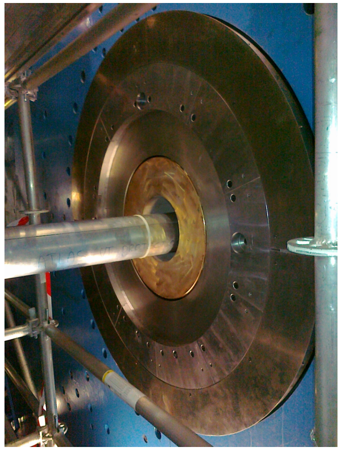




New shielding at |Z|~ 7 m:

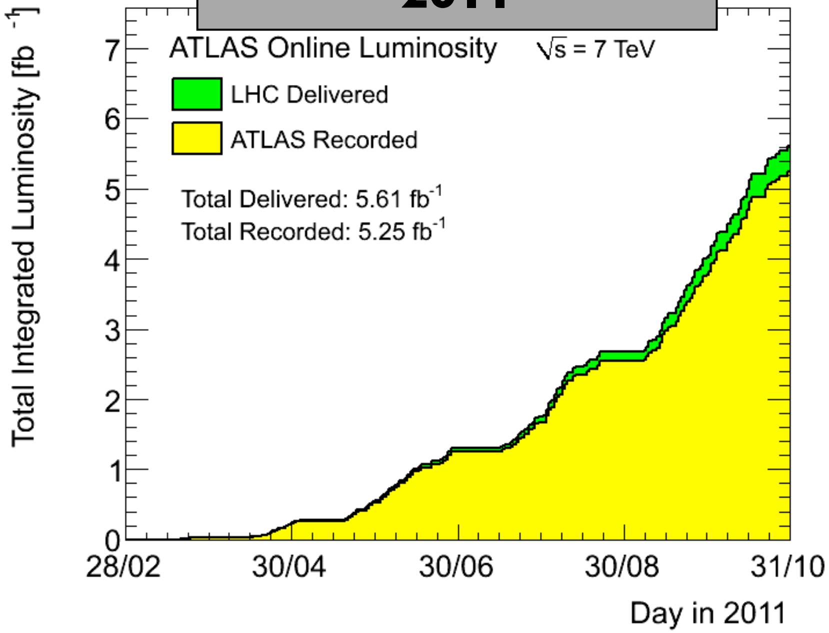
- reduction of large plume of photons in Muon Spectrometer

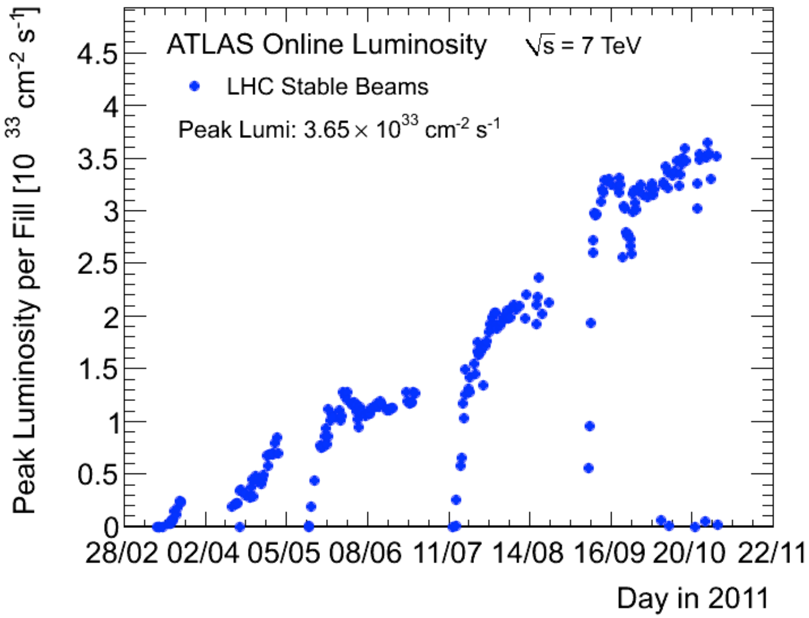




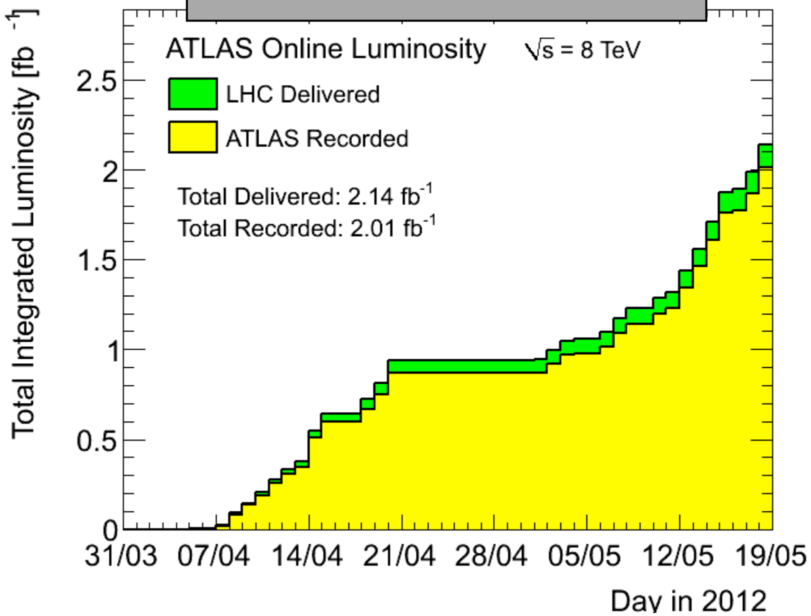
Luminosities at ATLAS

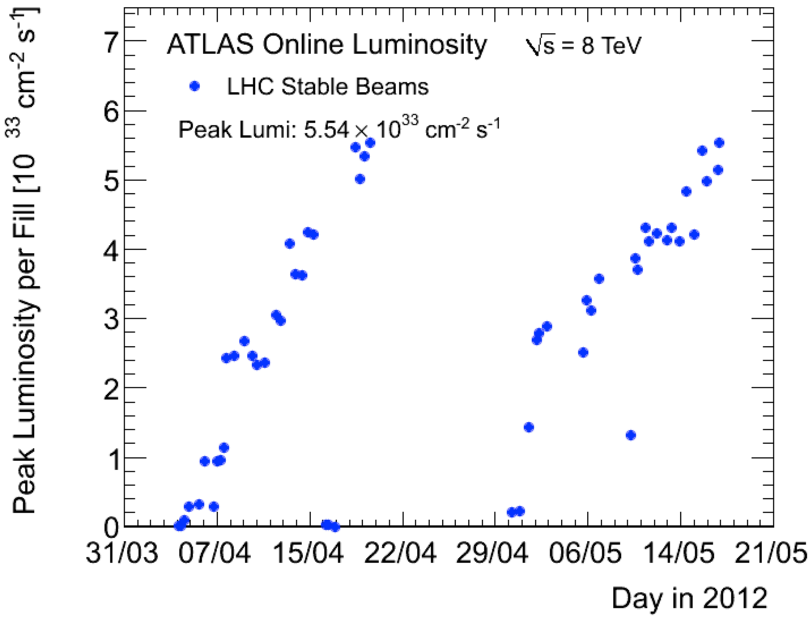
2011





2012



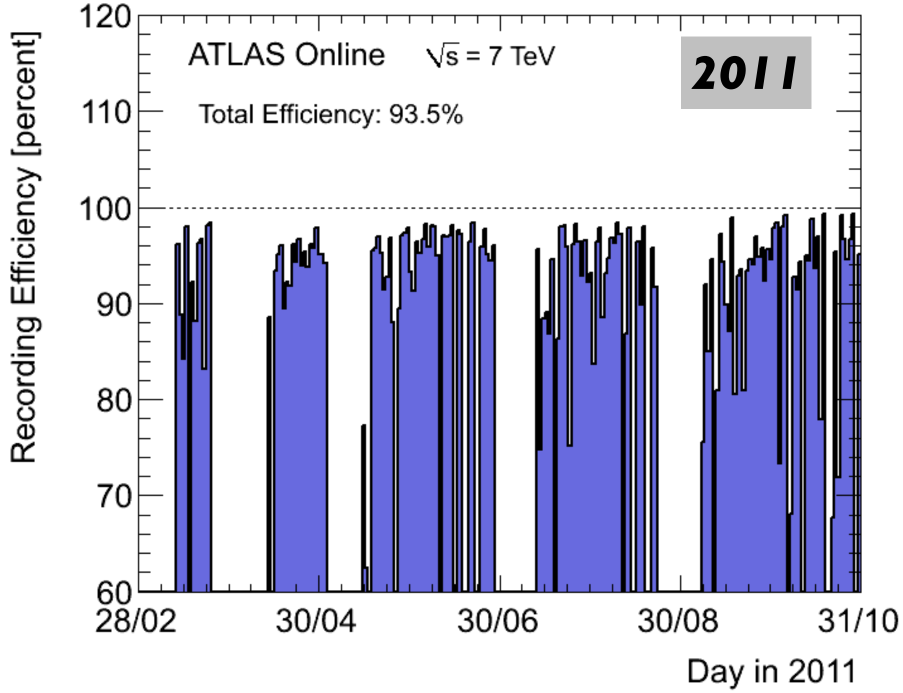


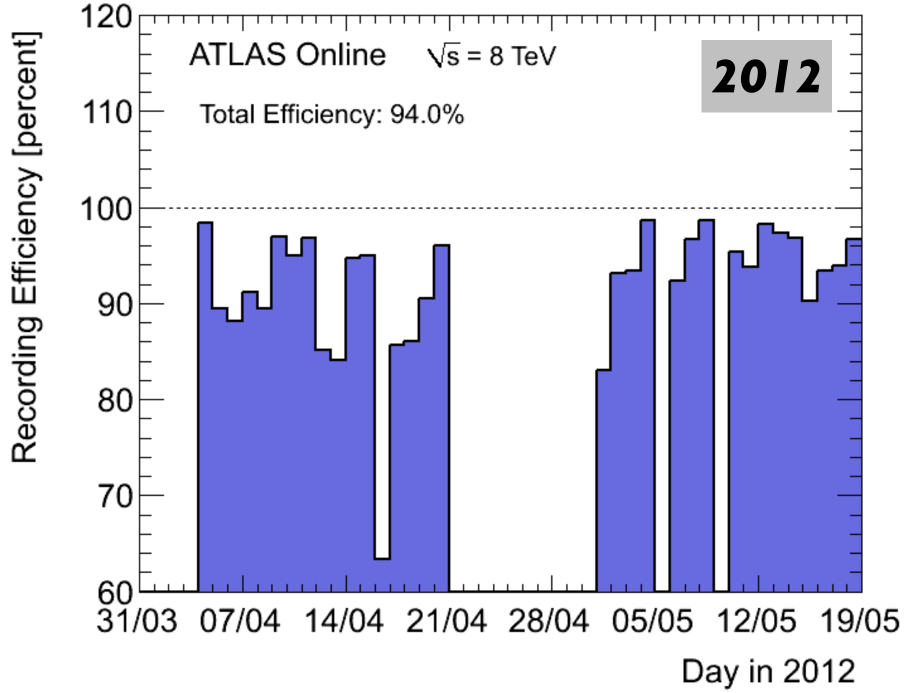
Data taking efficiency

- Recording efficiency accounts for:
  - ➡ DAQ deadtime and Trigger, DAQ problems;
  - ➡ Start-of-fill preparations (ramp-up of detectors after reaching stable beams)

Cause	Inefficiency
Dead time	1.0
Warm-start	1.2
DAQ Actions	1.2
Equipment Failure (incl. Human Resp.)	2.8

Losses in 2011





- Recording efficiency kept high over the year despite increase in data-taking rates
- Data quality efficiency accounts for detector-specific problems

➡ Some can be recovered/narrowed through reprocessing

Data quality 2011

- Close to 100% detector uptime and good quality data during stable beams in 2011 for nearly all subdetectors
  - ➡ LAr calorimeter suffered from noise bursts/HV trips, recovered to 97.5% after 2011 summer data-reprocessing campaign

ATLAS 2011 p–p run													
Inner Tracking			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.6	99.2	97.5	99.2	99.5	99.2	99.4	98.8	99.4	99.1	99.8	99.3

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 October 30th (in %), after the summer 2011 reprocessing campaign

Same performance reached for heavy ion runs in 2011

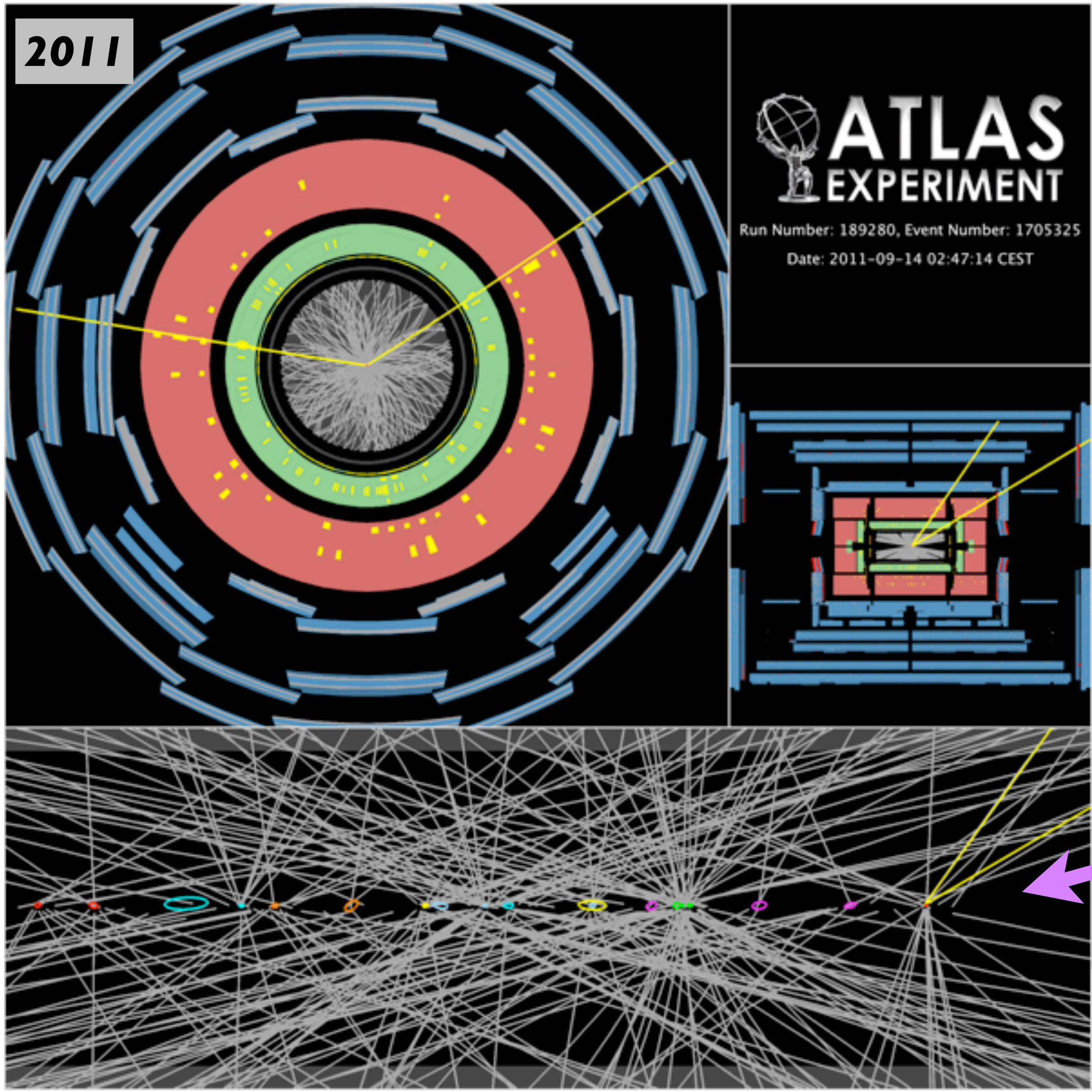
- Near 100% quality also for Trigger (jet online reconstruction most affected by LAr noise)

L1			HLT						
Muon	Calo	CTP	electron	photon	muon	tau	jet	b-jet	missing E_T
99.0	100	99.8	99.3	99.3	100	99.9	98.6	99.9	99.3

Luminosity weighted relative relative fraction of good trigger data quality delivery during 2011 stable beams in pp collisions at √s=7 TeV between 13 March and 30 October (in %).

Overall, about 90% of recorded collisions are available for physics analysis

Challenge: pile-up



50 ns bunch spacing (25 ns design) with higher than nominal bunch charges pushed in-time pile-up past expectations

A challenge for

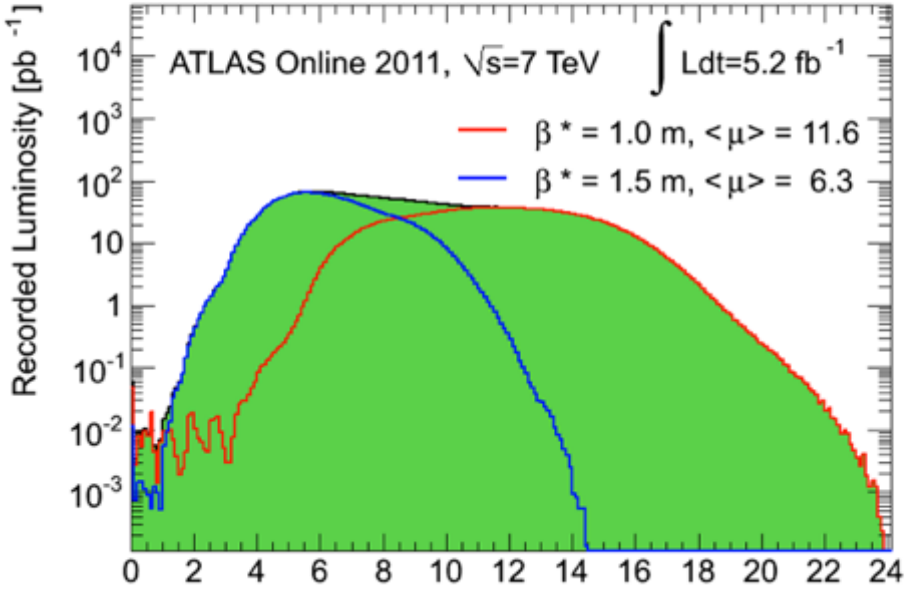
- ➡ Tracking and vertexing
- ➡ Trigger
- ➡ Lepton isolation
- ➡ Jet energy scale/resolution
- ➡ Missing transverse energy reconstruction
- ➡ Reconstruction CPU time

zoom to interaction region (few cm)

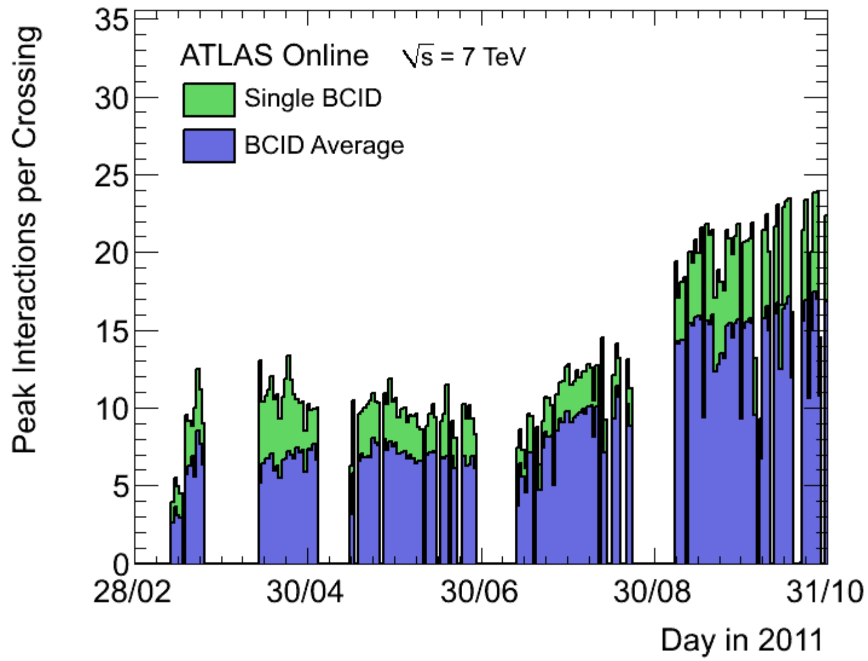
$Z \rightarrow \mu\mu$, 20 reconstructed vertices, recorded September 2011

Multiple interactions per bunch-crossing (2011)

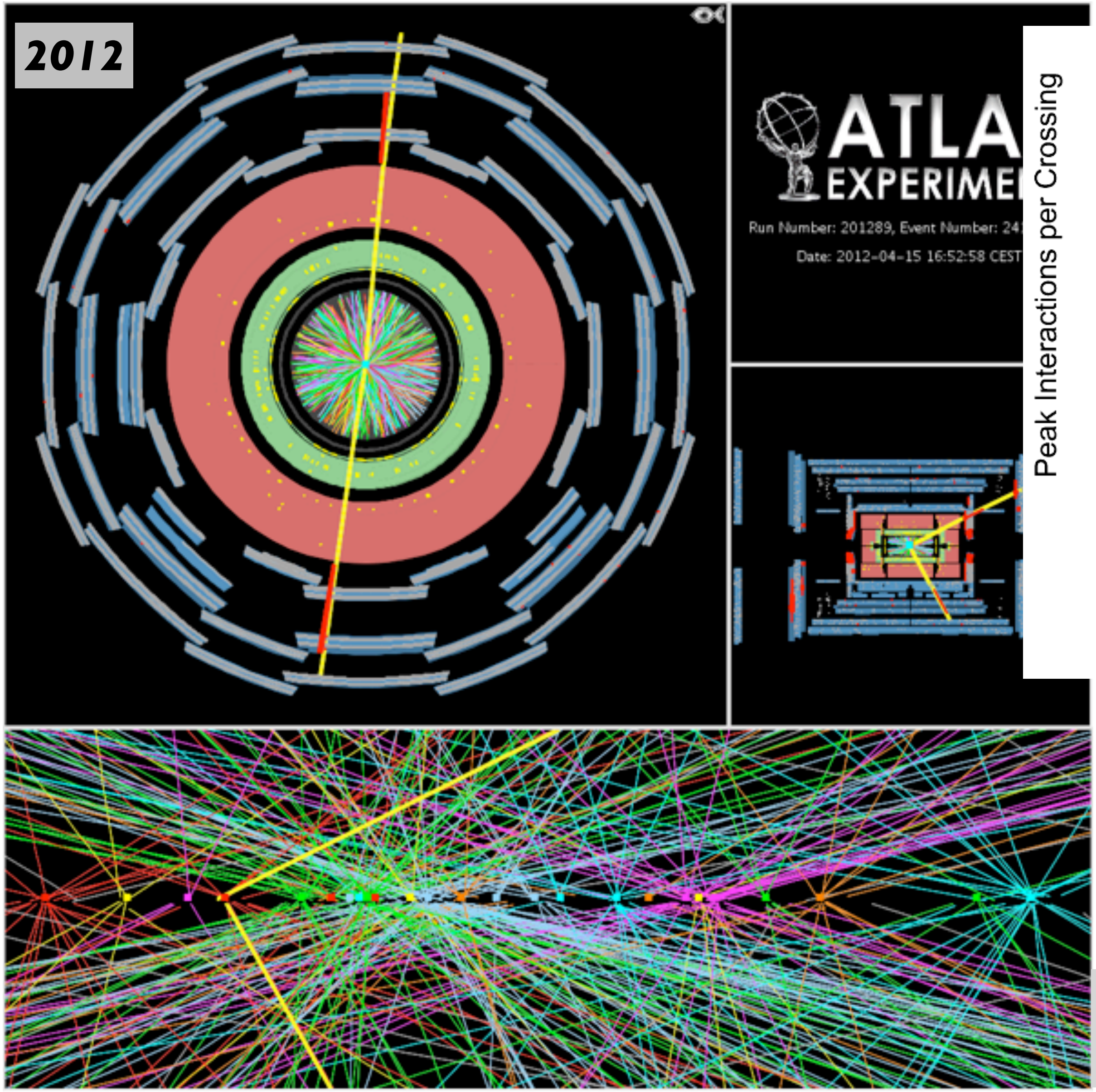
- In September 2011, beam spot size was reduced through smaller β-function at the IP:
  $$\beta^* = 1.5\ \text{m} \rightarrow 1\ \text{m}$$
- Mean number of interactions increased from <μ> = 6 to 12 (average) over the year

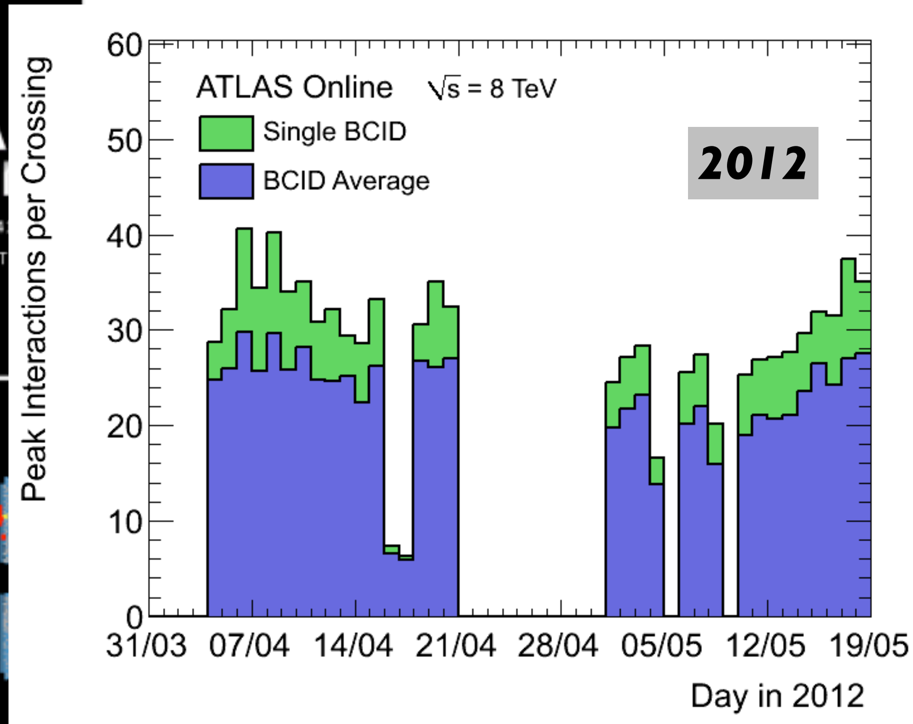


- Peak interactions per crossing exceeding 16 for beam average
- Peaking at 24 for individual bunches
  - ➡ equal to number of interactions per bunch crossing expected by the design LHC parameters



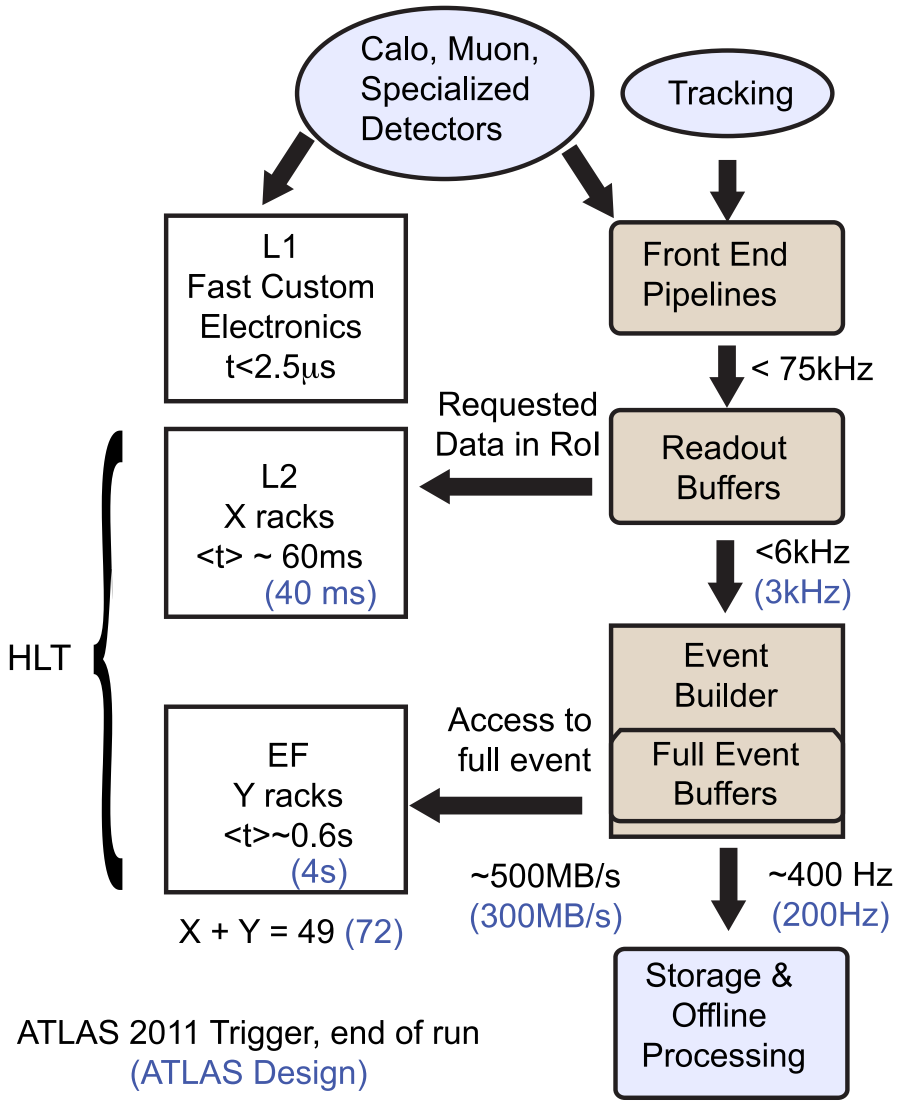
High pile-up 2012





Z →μμ, 25 reconstructed vertices, recorded April 2012

ATLAS trigger and DAQ



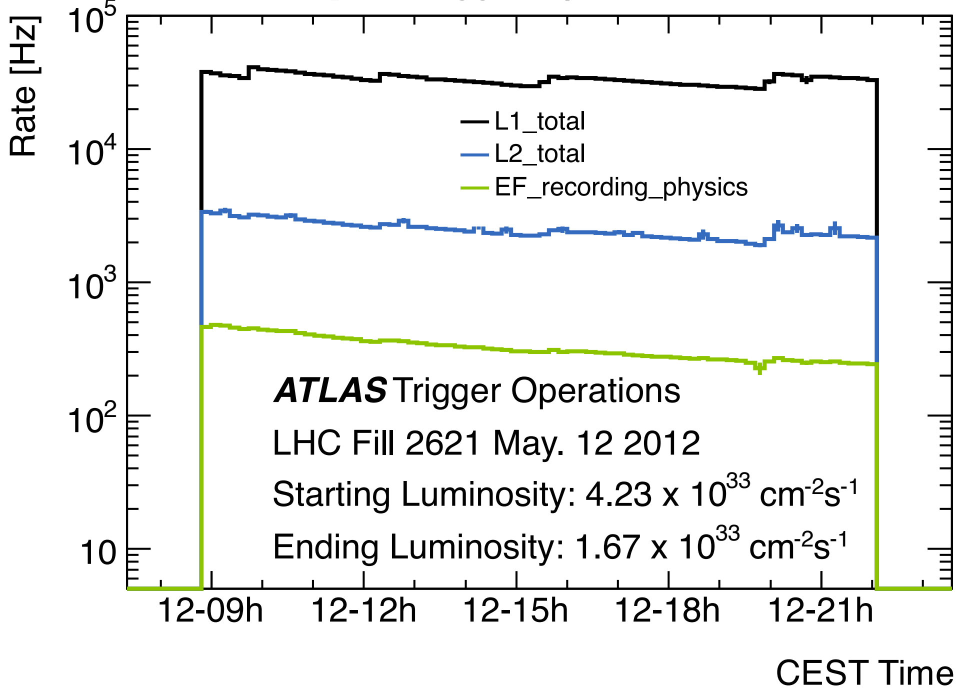
ATLAS 2011 Trigger, end of run
(ATLAS Design)

arXiv:1110.1530

DAQ readout rate significantly beyond design (lower thresholds)

- Expect that system is adequate for 2012 run

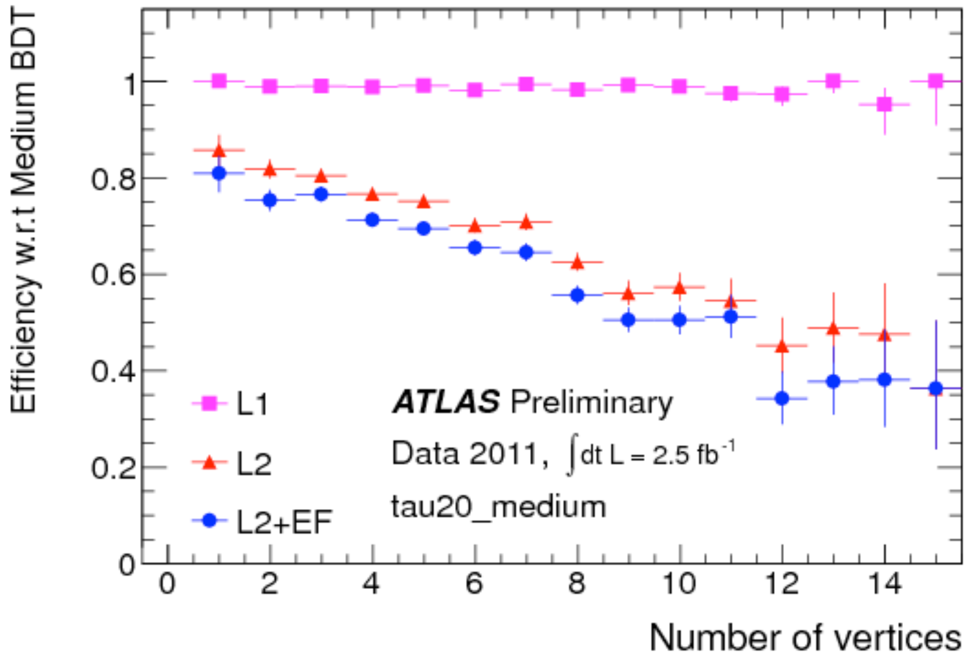
***Example** trigger operation **2012**:*



Example for trigger in 2012

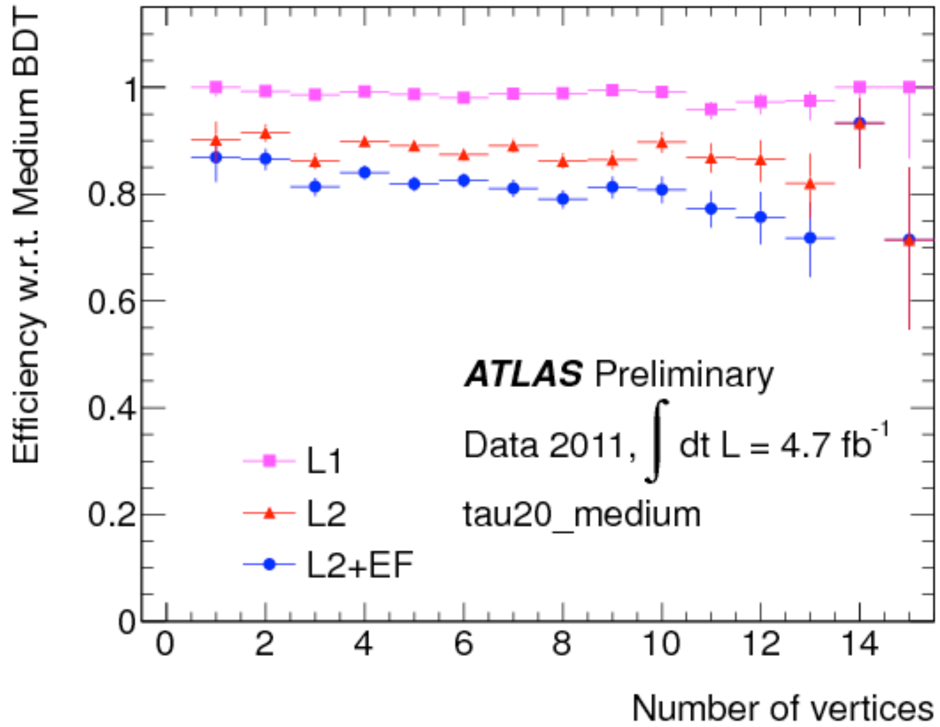
- Level-1 menu: defined at L= $8x10^{33}$ $cm^{-2}s^{-1}$ (8 TeV) for 75kHz with (~10KHz contingency)
- Level-2:
  - ➡**Pile-up insensitive selections for tau and e implemented in Level-2**

Example tau trigger: *efficiency with respect to the offline identified tau candidates as a function of number of vertices measured in **2011**...*



*... and as **expected for 2012***

(the τ trigger is rerun on 2011 dataset from unbiased Z → ττ → μh events,
μ trigger is used to collect Z → ττ → μh data).

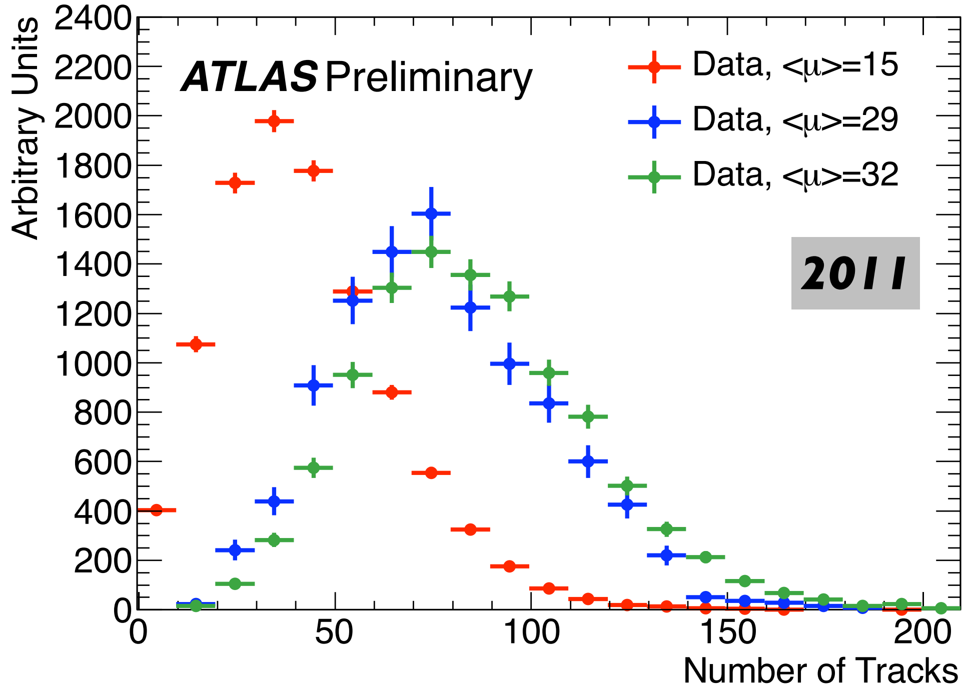


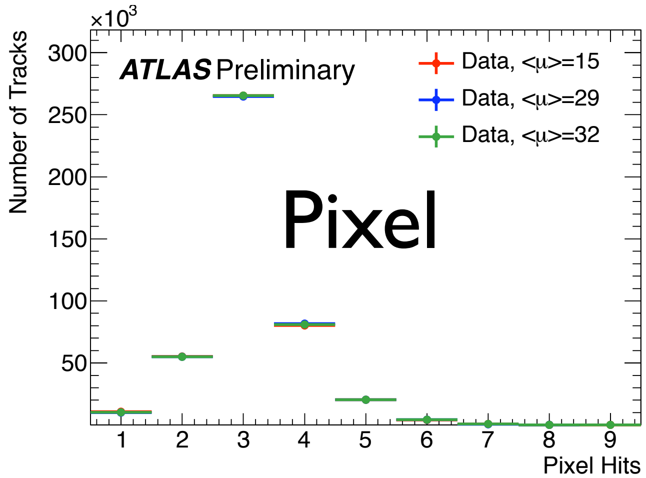
Tracking at high pile-up (μ~30)

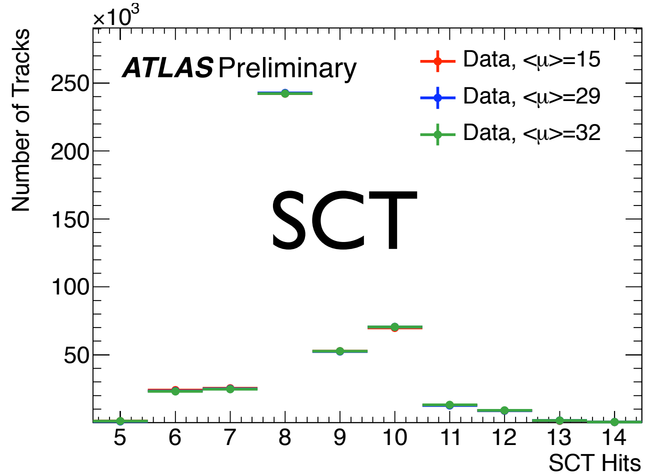
- Comparison of tracks in random events between normal running and special high μ run (2011)

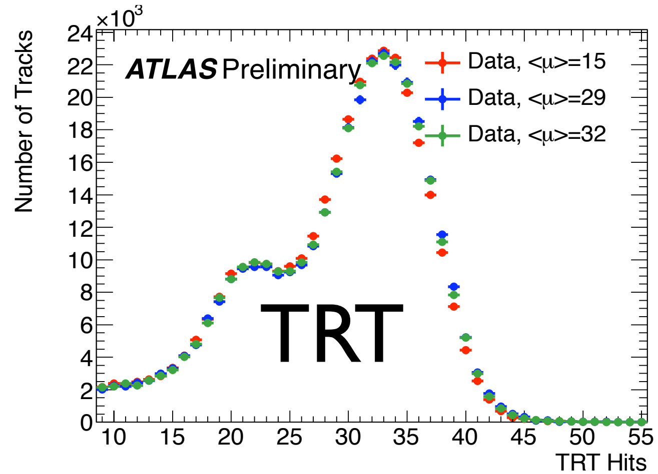
➡ Number of hits on tracks are constant even at pile-up of 30

  - but fakes will increase...

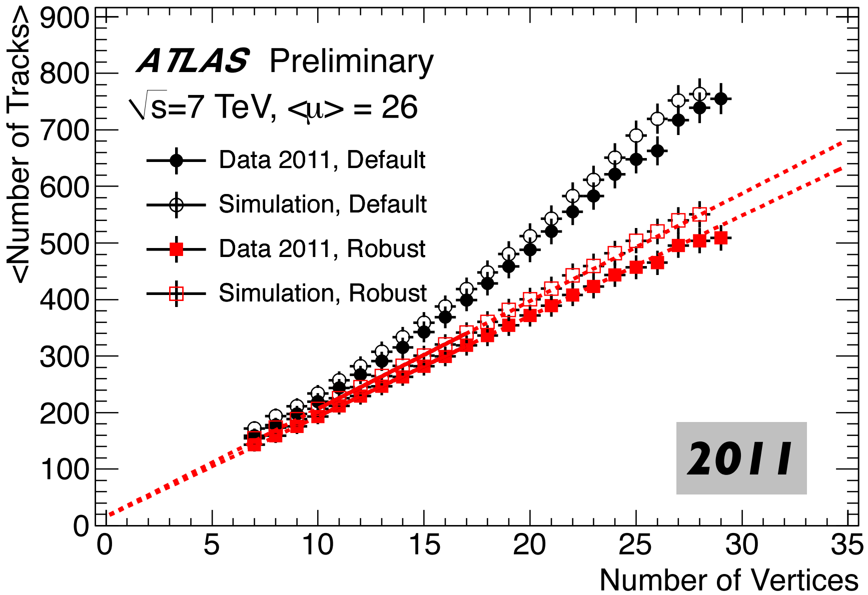






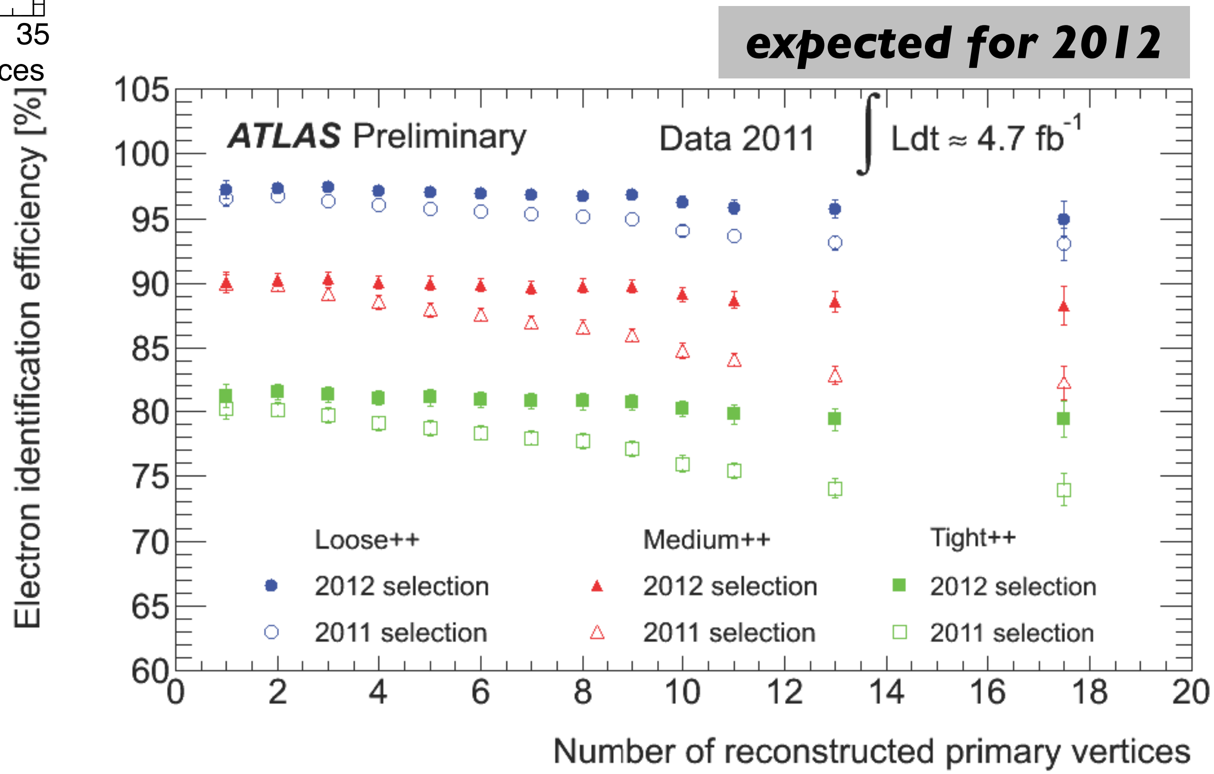


Tracking tuning for 2012



- Strong reduction of combinatorial "fake" tracks caused by pile-up by applying "robust" cuts (only small efficiency loss)...

... leads to improved electron identification efficiency almost independent of the number of vertices.



Transition Radiation Tracker at 25 / 50ns

Transition Radiation Tracker (TRT):

- gaseous detector with ~300000 drift tubes
- maximum drift time in 2mm tube:~40 ns
- highest TRT occupancy at high <μ> (approaches 60% @<μ> > 40)

Note: occupancy determined over 75ns readout window!

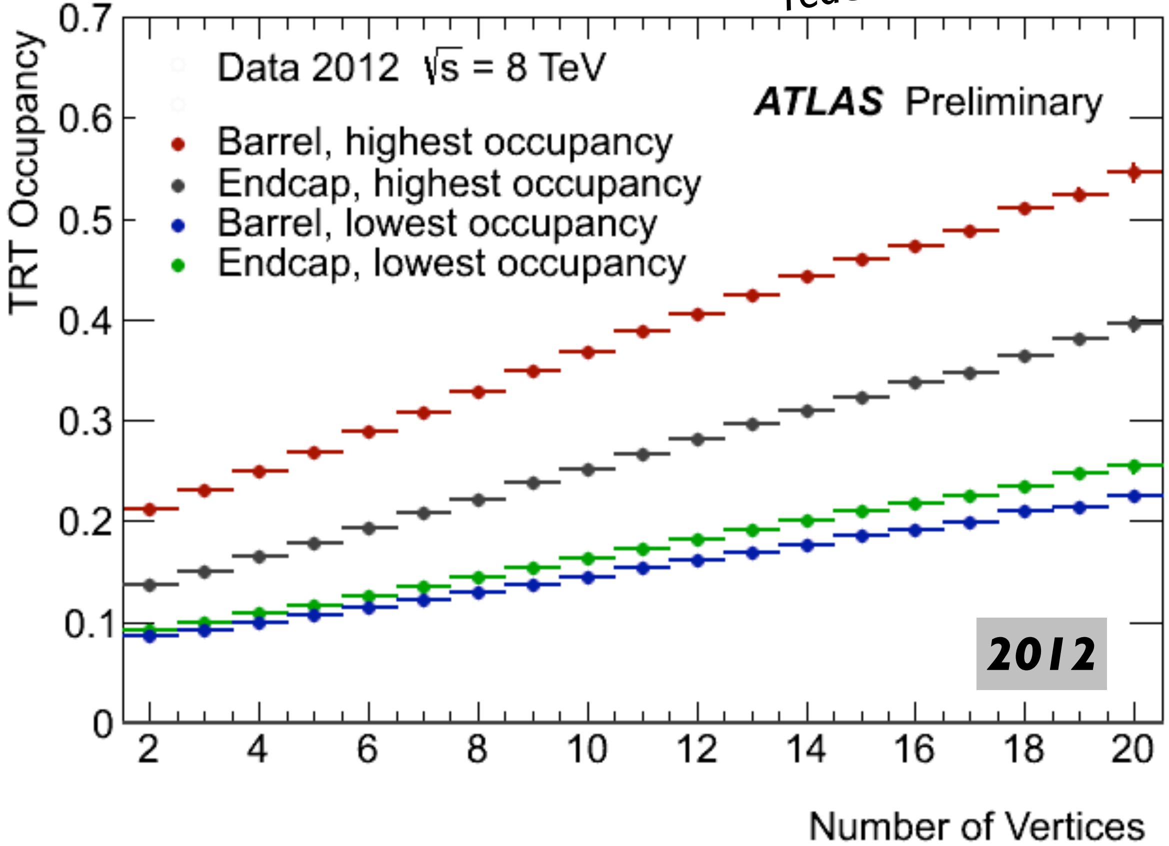
TRT designed to operate at 25 ns bunch spacing

➡ timing information of single hits (leading edge) is measured with a precision better than 1 ns;

➡ no loss of information for tracking even at high occupancy;

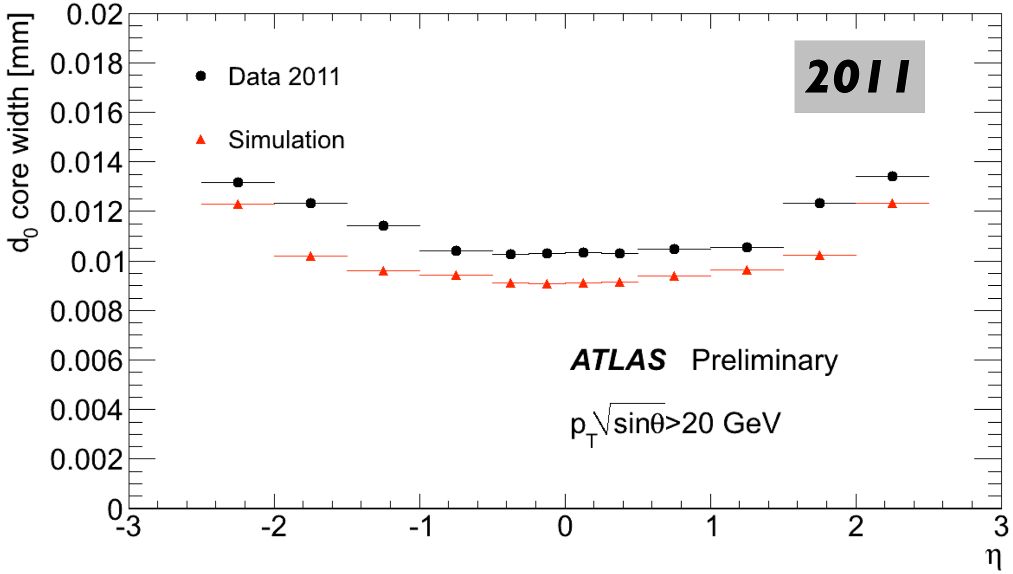
➡ trailing edge information (max. 40ns late) of a hit is used for particle ID;

➡ minimal (<5%) impact on particle ID in case timing cuts on hits are required for very high <μ>.

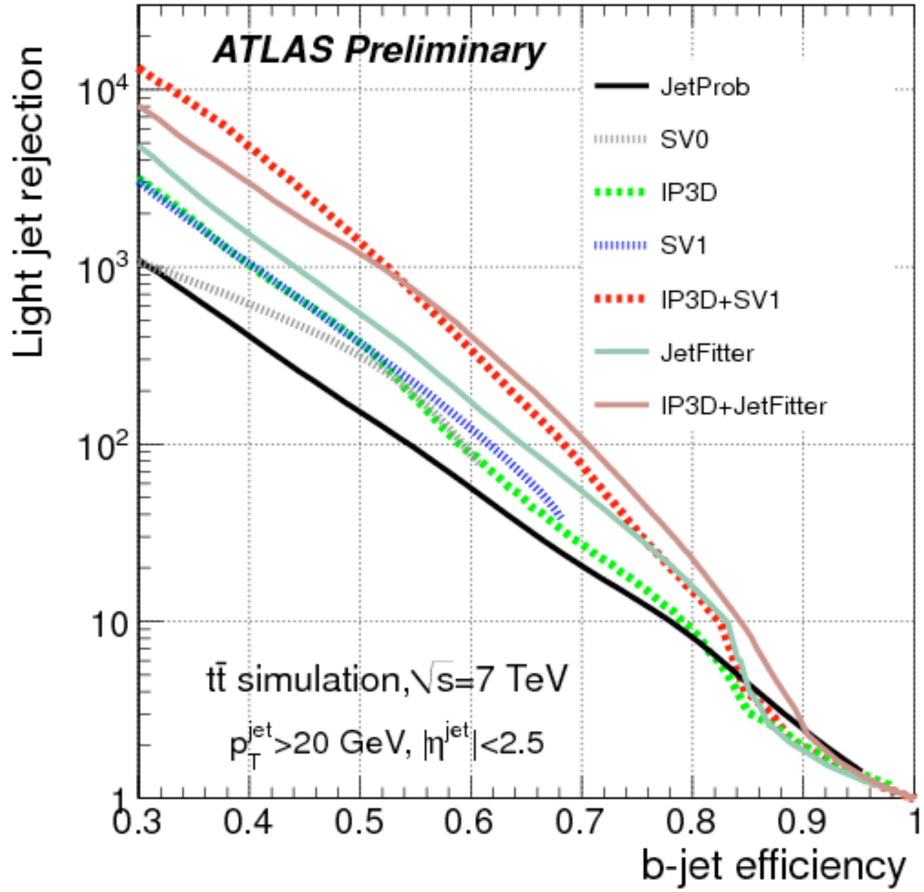


Impact parameter resolution and b-tagging performance

d0 core width for data and simulation as function of η for tracks with pT√(sinθ) > 20 GeV.



Light-jet rejection as function of the b-jet tagging efficiency for early tagging algorithms (JetProb and SV0) and for the highperformance algorithms
(based on simulated top-antitop events)

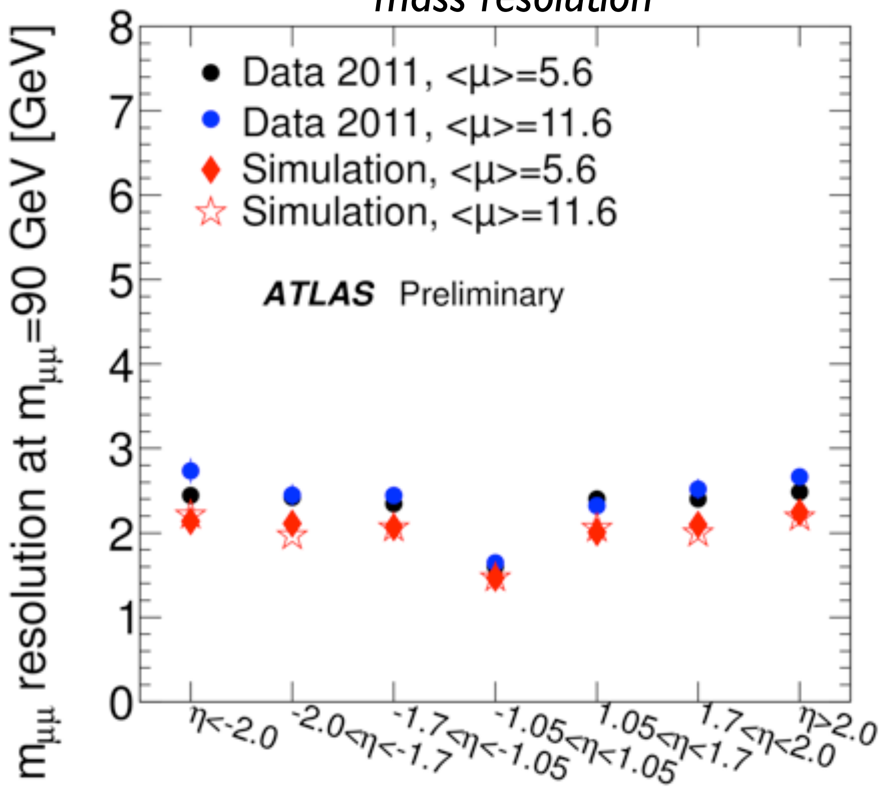


➙ **Good tracking and vertexing performance**

Muon performance

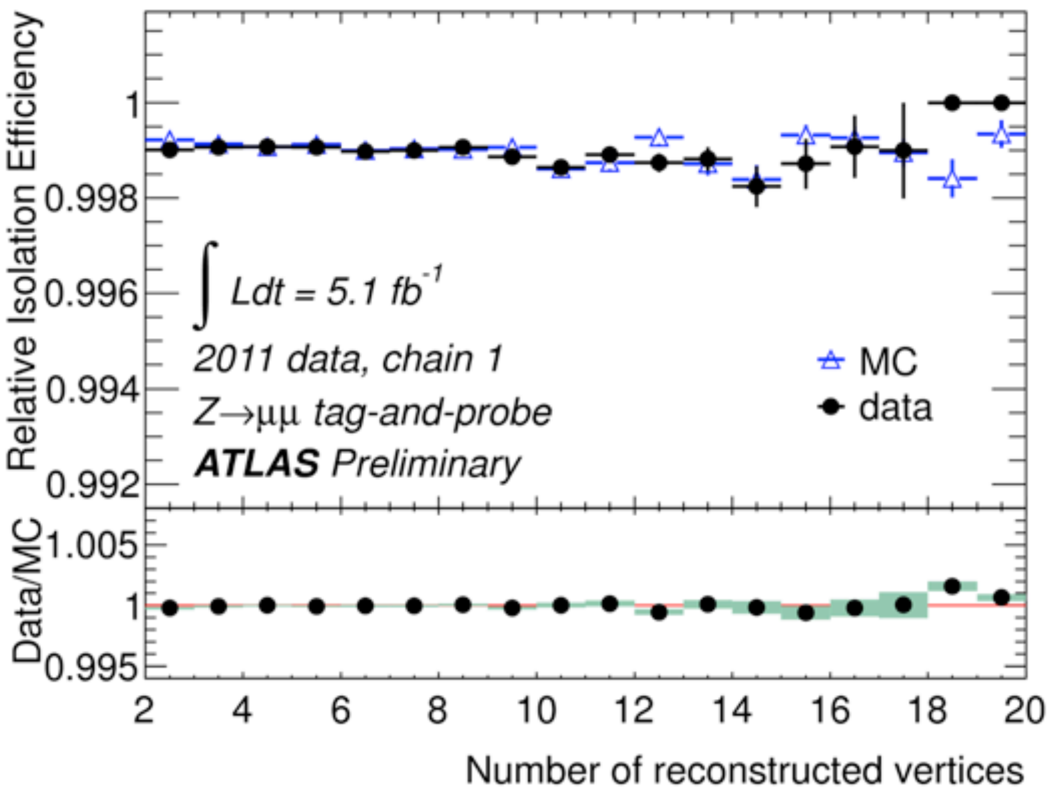
High pile-up performance for H➙ZZ➙ 4l like selections:

Muon / ID combined tracking mass resolution



2011

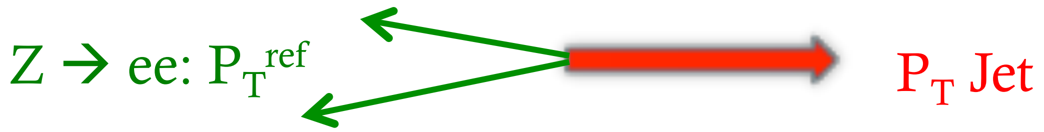
Muon spectrometer

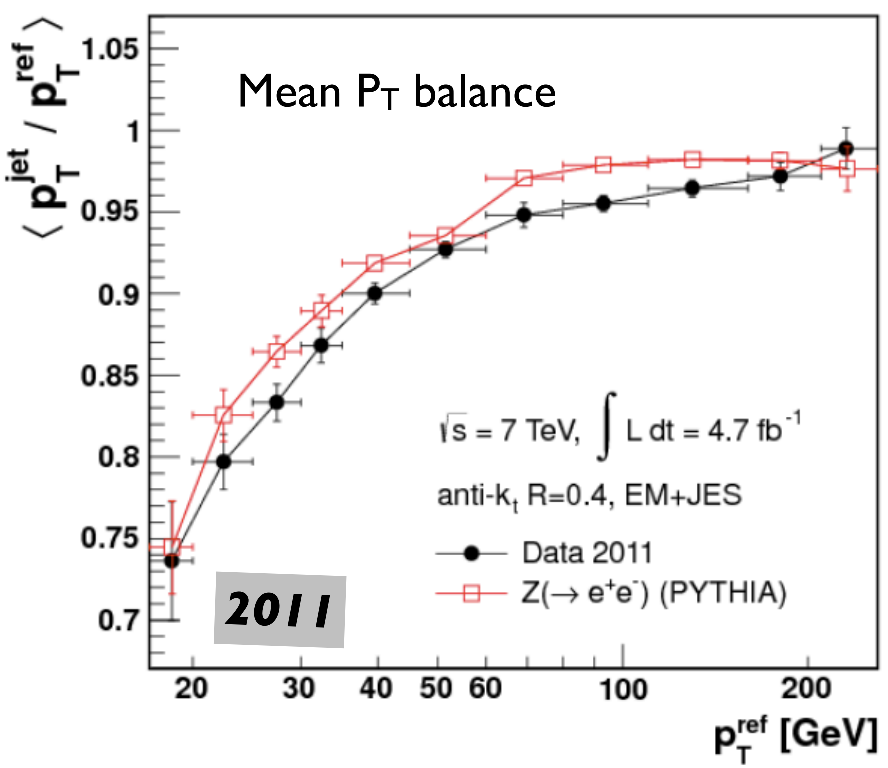


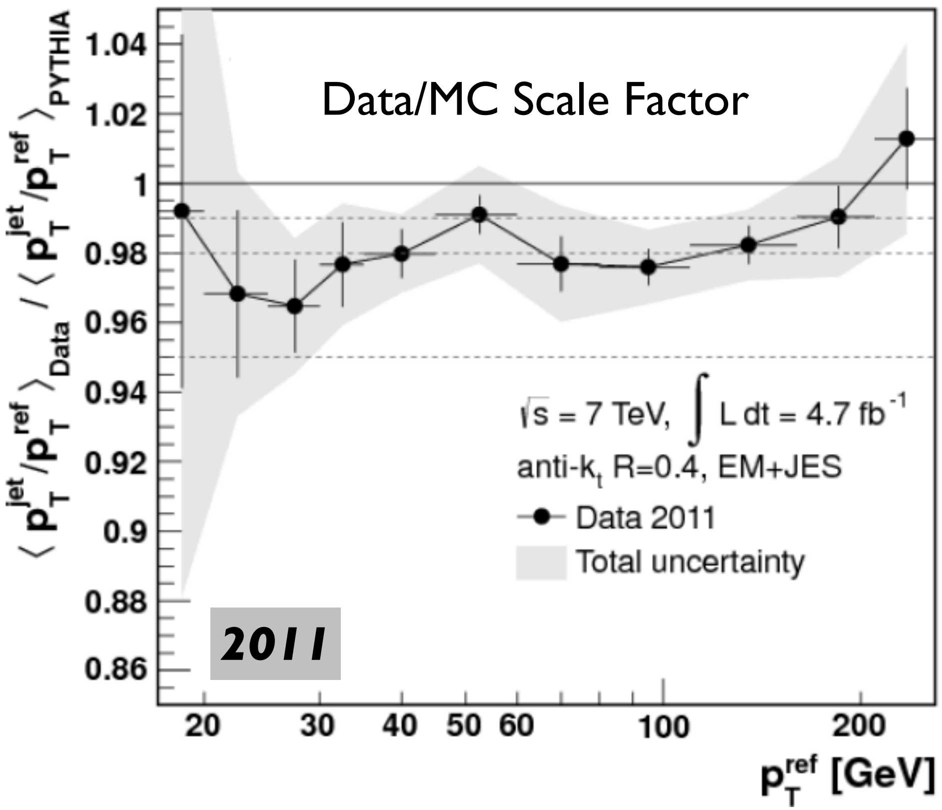
Clean and controlled muon spectrometer performance, even in high pile-up environment.

Jet energy scale performance

Understanding detector performance basic ingredient of all physics analyses,
Jet Energy Scale is one of the main systematics of precision measurements and searches





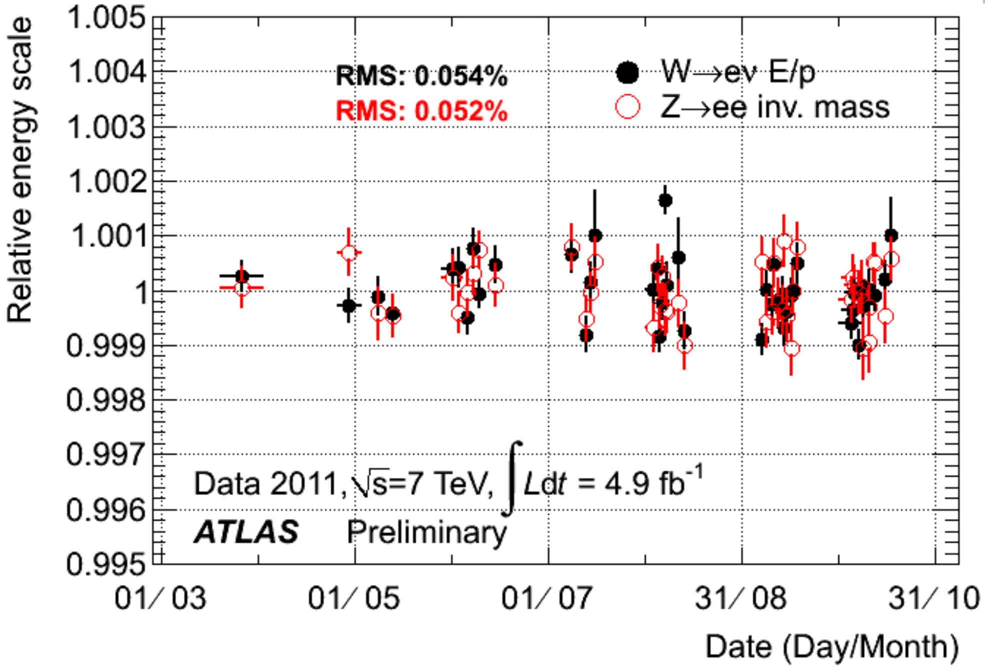


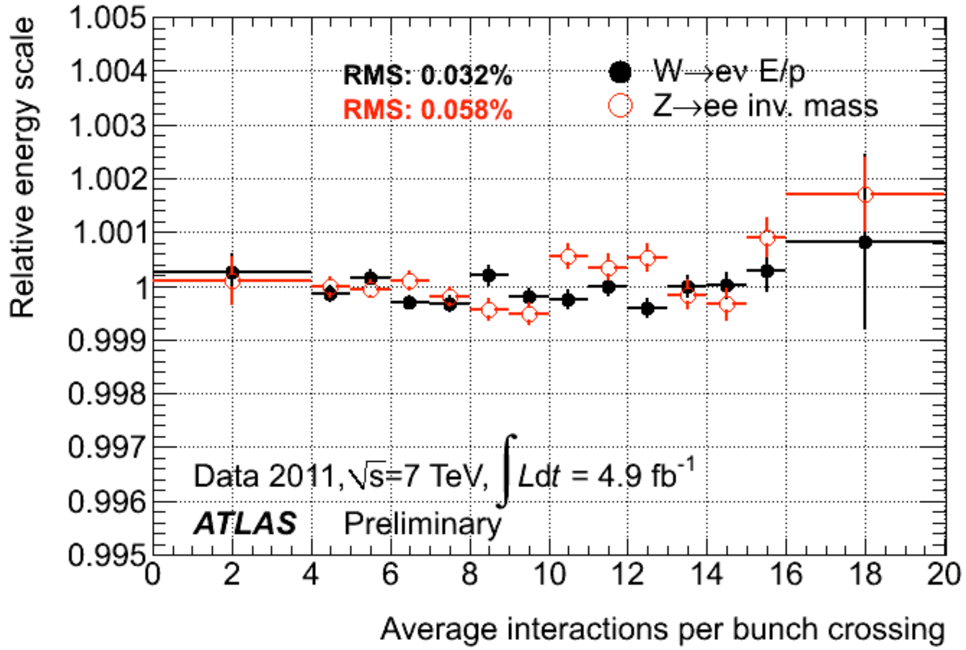
- Data/MC *in situ* Jet Energy Scale determined with **2% accuracy above 25 GeV** and constrains JES uncertainty down to 15 GeV

e/γ energy scale stability

- Electromagnetic calorimeter energy scale studied as a function of time and pile-up conditions using Z ➙ ee mass scale and E/p from W ➙ eν events

2011





Good stability of the electron energy response with time and pile-up.

Conclusions

- The excellent performance of the LHC allowed ATLAS to collect a substantial data set in 2011.
- The hard work of the ATLAS collaborators resulted in high data quality, high efficiency and a well understood detector.
- The 2012 run started successfully. Detectors, trigger, data acquisition, event reconstruction, computing and analysis are meeting the challenge of the increased luminosity and the increased pile-up.

➡ **Looking forward to collect more data and to find new physics!**

More ATLAS talks & posters at this meeting

Atlas talks

Enjoy!

- Francesca Pastore: ***Upgrade project and plans for the ATLAS detector and trigger***
- Didier Ferrere: ***Overview of the ATLAS Insertable B-Layer (IBL) Project***
- Frank Seifert: ***Upgrade plans for the ATLAS Calorimeters***

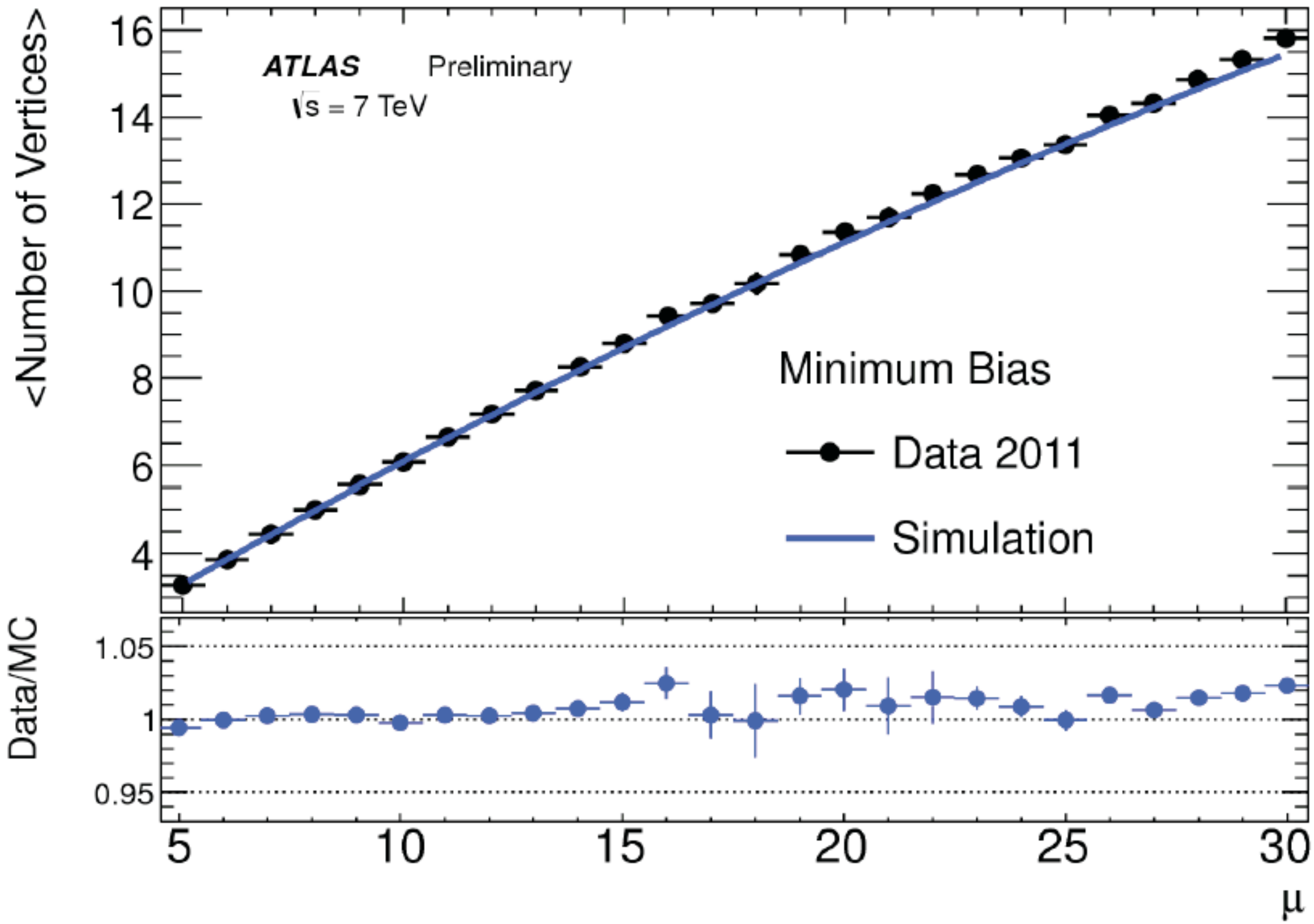
ATLAS posters

- Sofia Maria Consonni: ***Tracking and Calorimeter Performance for Tau Reconstruction at ATLAS***
- Lucy Anne Kogan ***Determination of the jet energy scale uncertainty***
- Federico Meloni: ***Track and vertex reconstruction in the ATLAS Experiment***
- Karoline Elfriede Selbach: ***Neural network based cluster creation in the ATLAS silicon pixel detector***
- Mario Sousa: ***Single hadron response measurements in ATLAS***
- Mark Cooke: ***Monitoring radiation damage in the ATLAS Pixel Detector***
- Andrea Favareto: ***Status of the ATLAS Pixel Detector at the LHC***
- Peter Lundgaard Rosendahl: ***ATLAS Silicon Microstrip Tracker Operation and Performance***
- Jonathan Stahlman: ***Advanced Alignment of the ATLAS Inner Detector***
- Ludovica Aperio Bella: ***Status of the Atlas Liquid Argon Calorimeter and its Performance after two years of LHC operation***
- Margret Fincke-Keeler: ***Upgrade plans for ATLAS Forward Calorimetry for the HL-LHC***
- Steffen Staerz: ***Upgraded readout electronics for the ATLAS LAr Calorimeter at the High Luminosity LHC***
- Fernando Carrio Argos: ***Upgrade for the ATLAS Tile Calorimeter readout electronics at the High Luminosity LHC***
- Yesenia Hernandez Jimenez: ***The ATLAS Tile Calorimeter performance at LHC***
- Evelin Meoni: ***Performances of the signal reconstruction in the ATLAS Hadronic Tile Calorimeter***
- Djamal Boumediene: ***Calibration and Monitoring systems for the ATLAS Tile Hadron Calorimeter***
- Antonio Sidoti: ***The ATLAS trigger system: performance and evolution***
- Matthew Tamsett: ***Performance of the ATLAS jet trigger***
- Andres Jorge Tanasijczuk: ***The ATLAS hadronic tau trigger***
- Guido Volpi: ***A Fast Hardware Tracker for the ATLAS Trigger System***

Spare slides

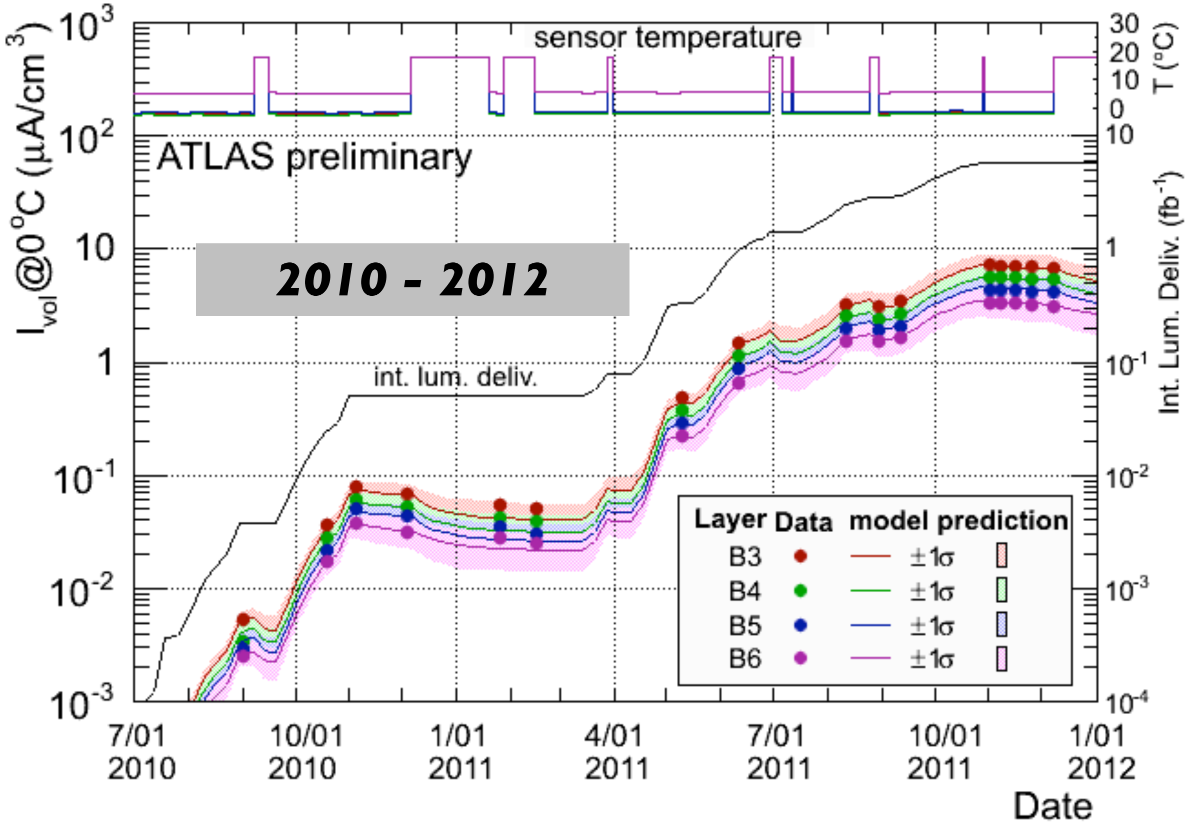
Reconstructed vertices vs interactions per bunch crossing

Average number of reconstructed primary vertices as a function of average number of pp interactions per bunch crossing measured for the data of 2011.



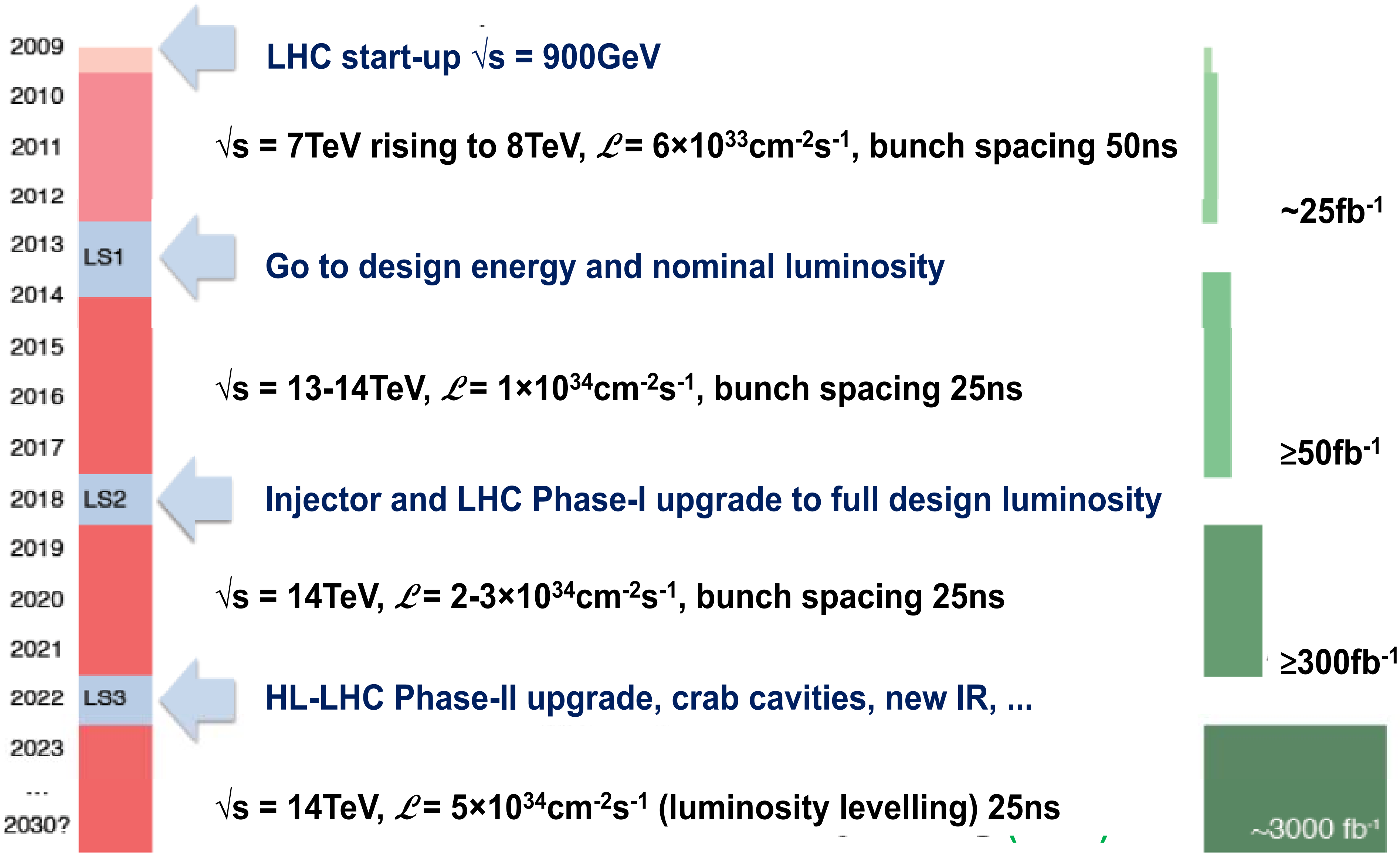
Radiation damages seen?

- Example: Silicon strip detector SCT
  - ➡ Radiation damage indicated by leakage current it is exactly along the lines of the predictions. Change in depletion voltage for the SCT is very small, everywhere less than 10V.



Detectors are behaving as expected.
No advanced ageing observed.

LHC Schedule assumption



Phase-0 (Installation 2013/2014)

Major Improvements to Physics Capabilities

- ➡ New insertable pixel b-layer (IBL) (drives shutdown schedule)
- ➡ Finish the installation of the EE muon chambers staged in 2003 +additional chambers in the feet (new electronics) and elevators region
- ➡ New small Be pipe

Consolidation and maintenance to preserve present performance

- ➡ New Aluminum beam pipes to prevent activation problem and reduce BG
- ➡ New pixel services (nSQP) (pending decision by mid 2012)
- ➡ New evaporative cooling plant for Pixel and SCT + IBL CO_2 cooling plant
- ➡ Replace all calorimeter Low Voltage Power Supplies
- ➡ Exchange all broken TGCs where possible
- ➡ Consolidate part of the LUCID system
- ➡ Upgrade the magnets cryogenics with a new spare main compressor and decouple toroid and solenoid cryogenics
- ➡ Add specific neutron shielding (behind end-cap toroid, USA15)
- ➡ Revisit the entire electricity supply network (UPS,…)
- ➡ Repairs and maintenance work in general
- ➡ Preparations for Phase I upgrade (moveable b-pipe, AFP prototypes,…)
- ➡ MBTS removal and possible replacement

Tracking: improve event reconstruction time

For 2012: in addition to improved tracking performance
➙ ~30% CPU reduction in track reconstruction at μ~30 was achieved