ATLAS detector readiness for 2009/10 running

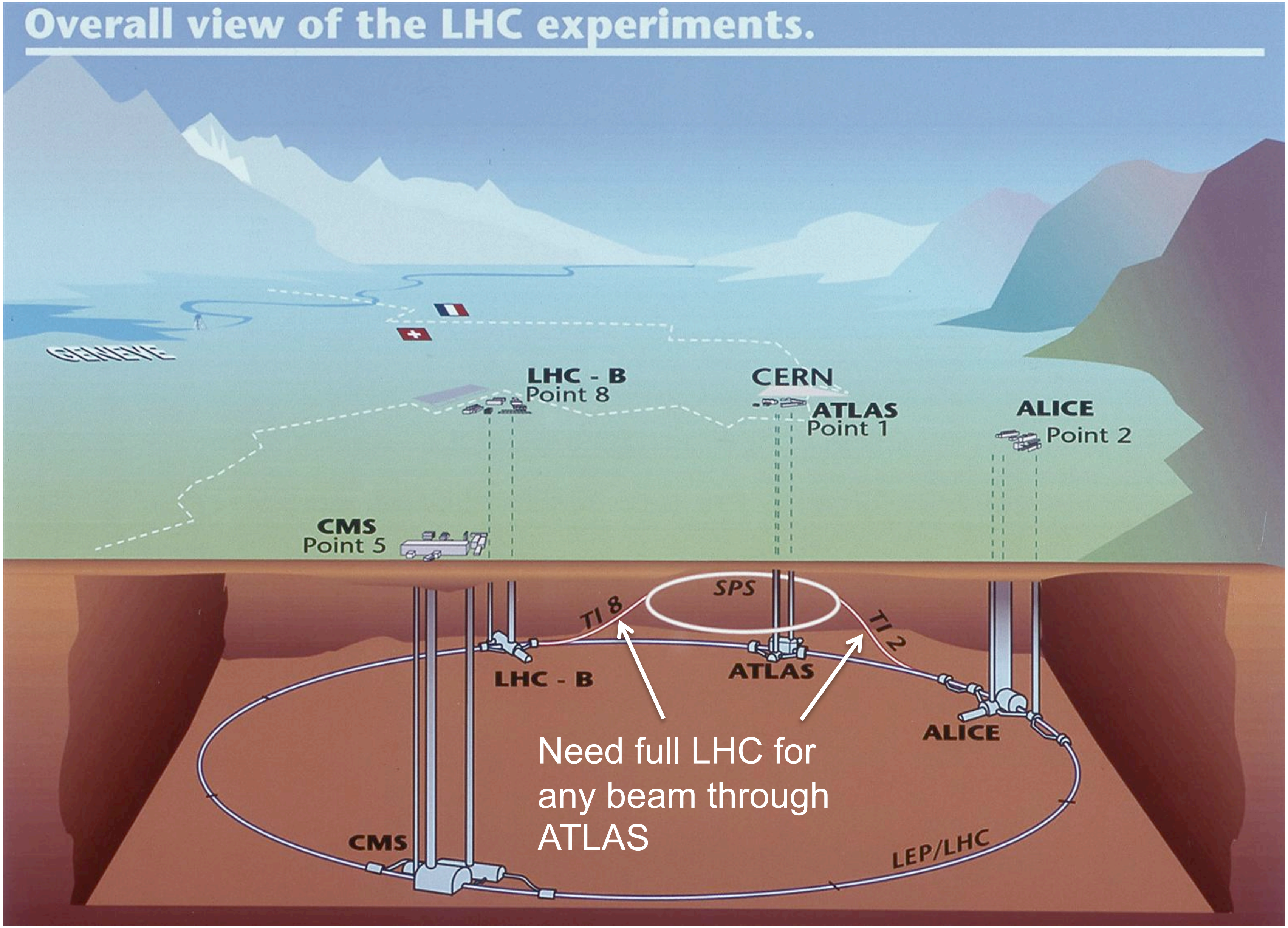
T. Wengler

Workshop on physics opportunities with the first LHC data
Berkeley, CA, 06 May 09

What (I hope) you will take away from this

- Foreseen running mode of the LHC and approximate data sample expected in 2009/10
- How much of ATLAS is operational
- How well does it work

The LHC complex



The 2009/10 LHC Run

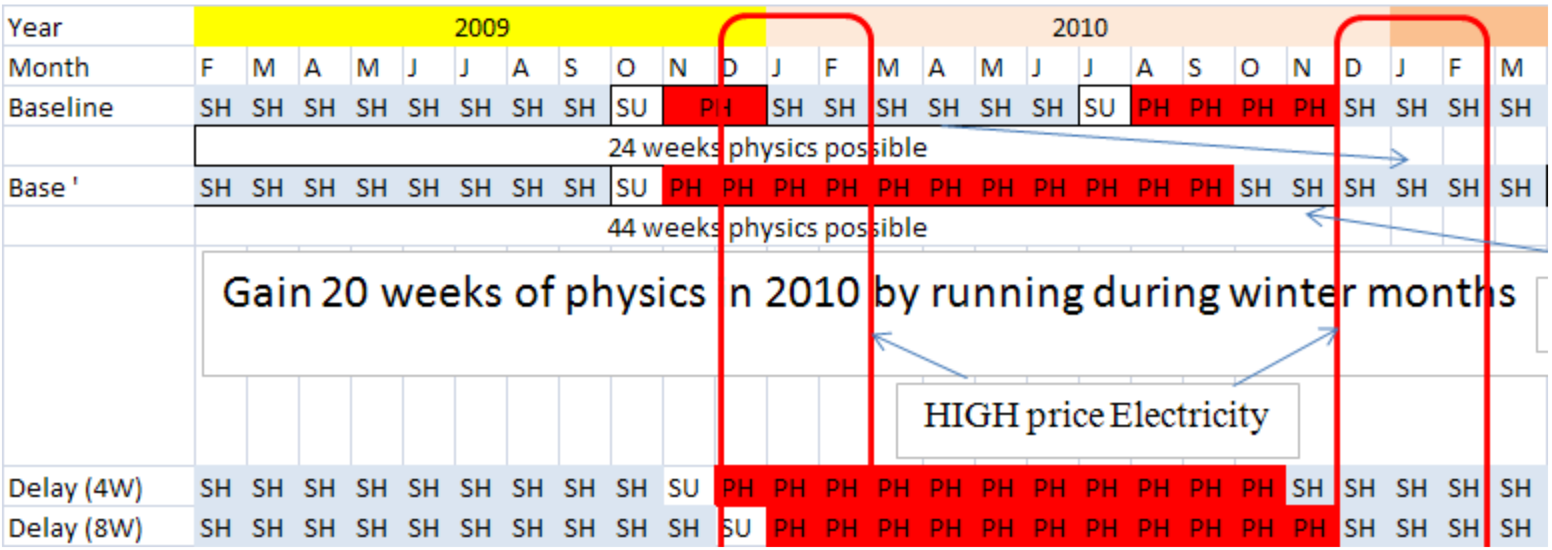
Year	2009											2010													
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH

Typical Run/Shutdown setup

Would leave little time for running in 2009

Delay may mean no running before autumn 2010!

The 2009/10 LHC Run



- Decisions taken
  - Physics run as soon as possible
  - Do not warm up all sectors
  - Top energy is 5 TeV (had been reached for all other sectors)
  - No winter shutdown 2009/10
- Consequences
  - 8 M Euro additional electricity cost
  - Gain 20 weeks of physics running
  - Further delays of a few weeks have small impact on physics 09/10
  - Enough data to compete with Tevatron in many areas by end of 2009/10 run

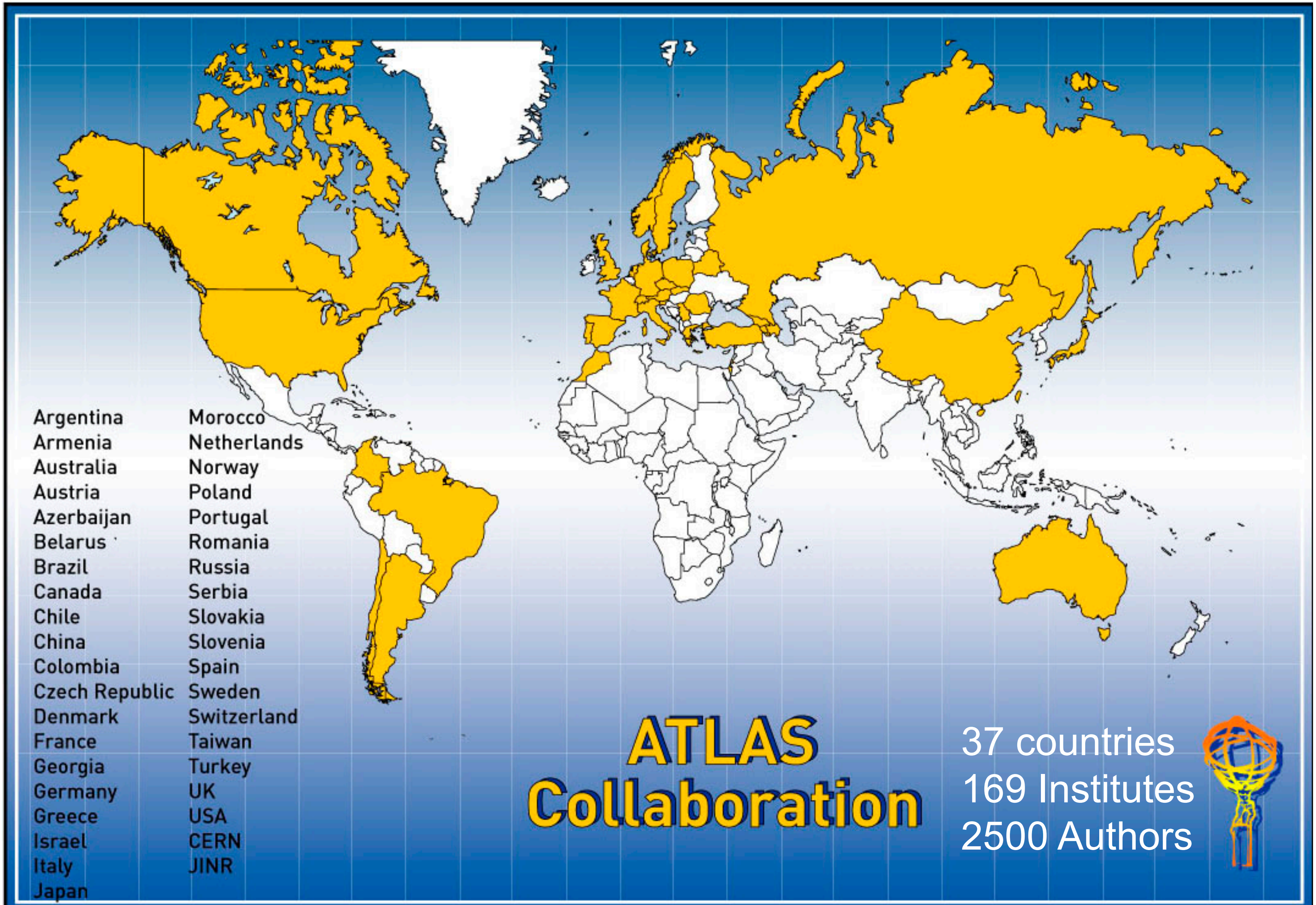
The 2009/10 data sample

- Beam energy
  - No intention of long running below 5 TeV/beam
  - Short collision run at injection energy 450 GeV/beam
  - Possibly stop along the way several times for machine commissioning
  - Reach 5 TeV/beam a.s.a.p.

- Data volume
  - Peak Luminosities from 5×10^{31} to 2×10^{32} $cm^{-2}s^{-1}$
  - First 100 days of operation ~ 100 pb^{-1}
  - Next 100 days of operation ~ 200 pb^{-1}

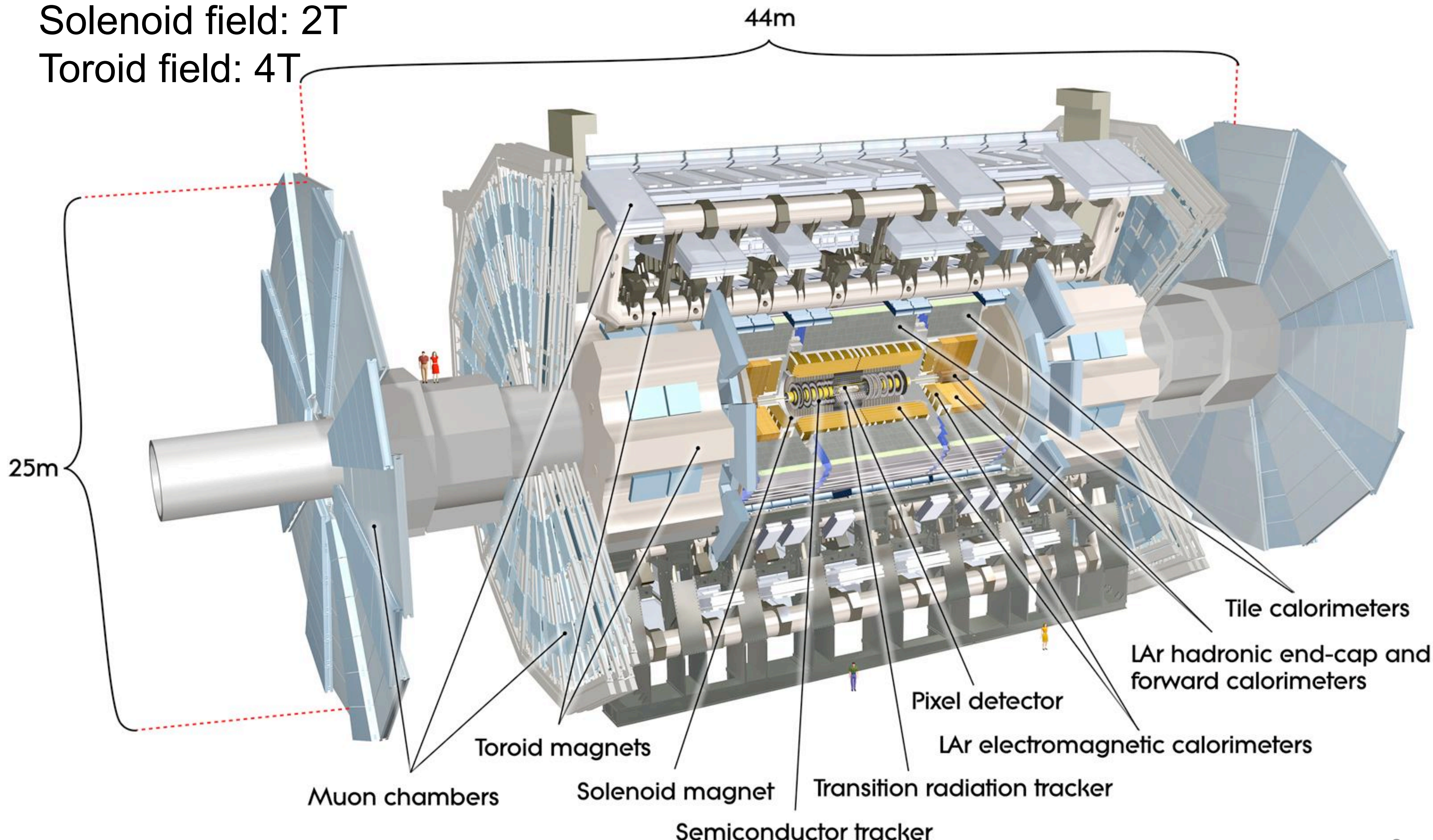
→ Large Uncertainties: somewhere between 100 – 500 pb^{-1} ?

The ATLAS collaboration



The ATLAS Detector

Solenoid field: 2T
Toroid field: 4T

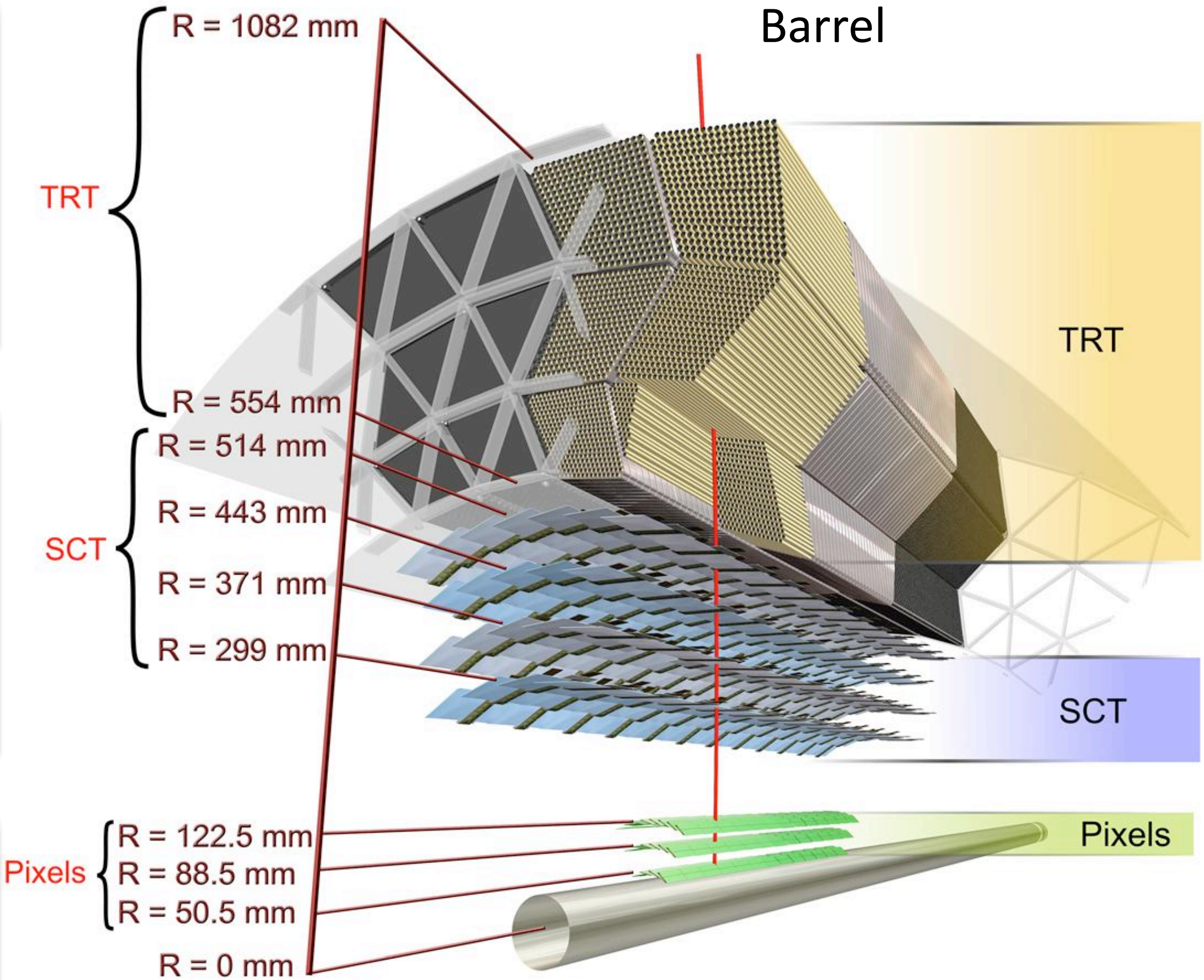


Inner Detector

- Straw tracker + Transition Radiation
- 4mm diameter straws with 35 μm anode wire
- Layers: 73 in Barrel (axial) 2x160 in Endcap (radial)

- 4(9) double layers in Barrel/Endcap
- 4088 modules, 6M chan., strips 80 μm
- Resolution 17 x 580 μm

- 3 layers in Barrel and Endcap
- Pixel size 50 x 400 μm
- Resolution 10 x110 μm
- 80 M channels

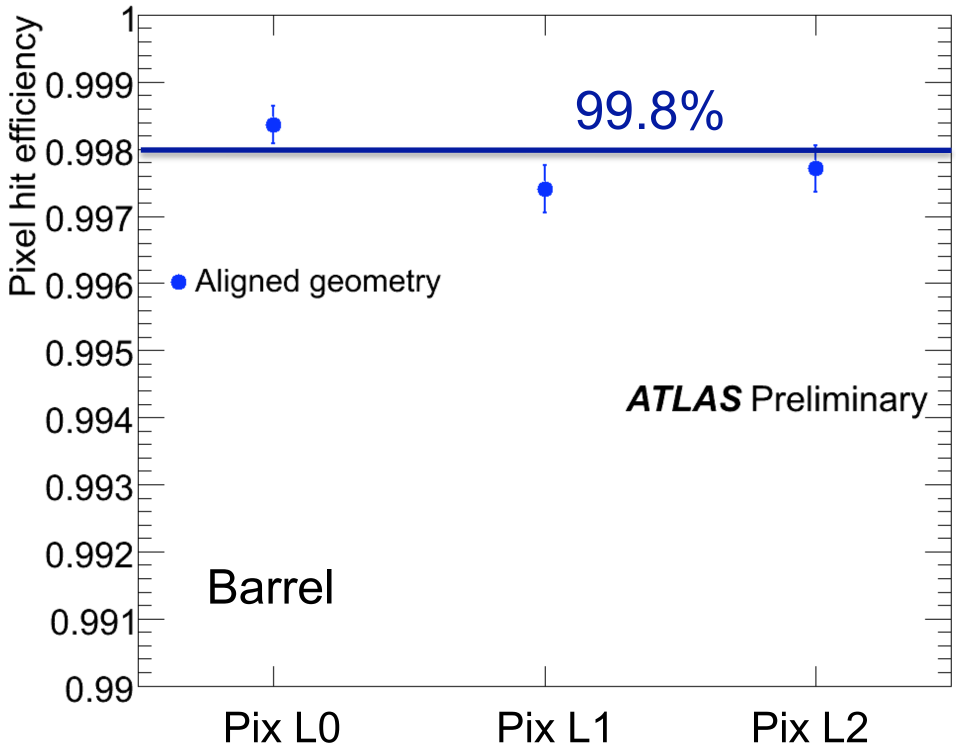


Inner Detector Status

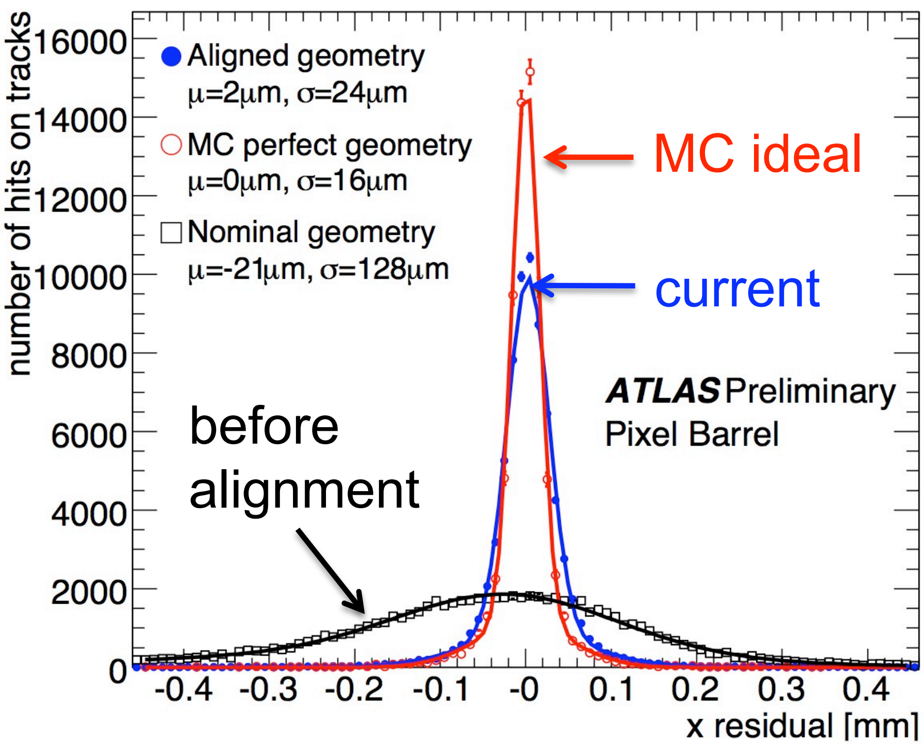
- Pixel
  - 80 Million channels, # of dead channels 1.6%
  - Hit efficiency ~ 99.8%
  - Noise occupancy ~10^{-10}
- SCT
  - 6 Million channels, > 99% of modules operational
  - Noise occupancy: Barrel: 4.4×10^{-5} ; Endcap: 5×10^{-5}
  - Hit efficiency > 99.5%
- TRT
  - e-π separation via Transition Radiation: $0.5 < E < 150$ GeV
  - 98% of the 52k channels operational
- Evaporative cooling (SCT/Pixel)
  - Problematic in 2008, much work ongoing to improve for 2009
  - Expected uptime 96%, rest partly planned stops outside collisions

Pixel Results

Pixel hit efficiency for the barrel layers (for active modules)



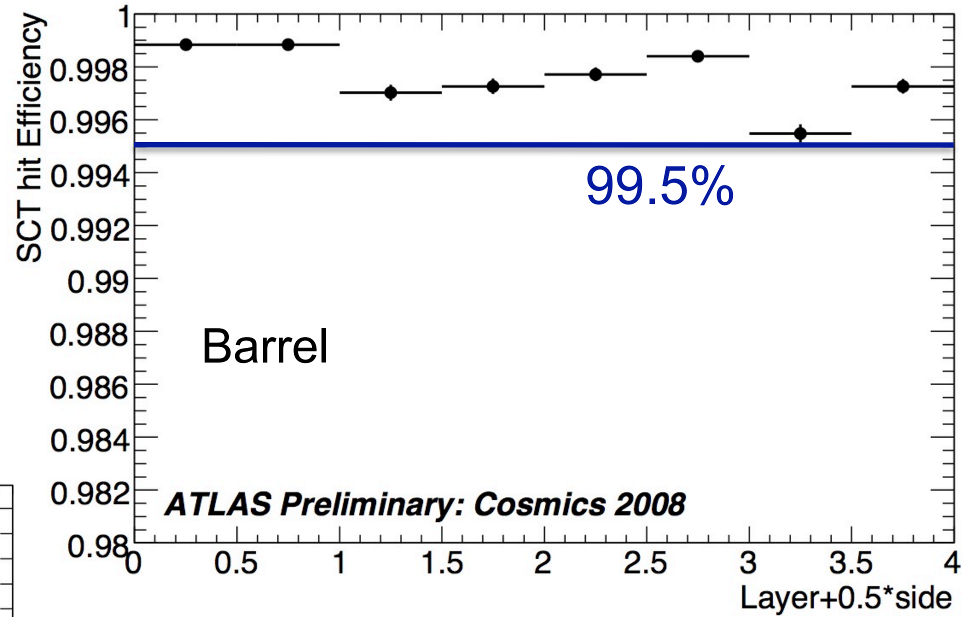
Track residuals for precision coordinate



Very high efficiency and good alignment available for 2009/10 running

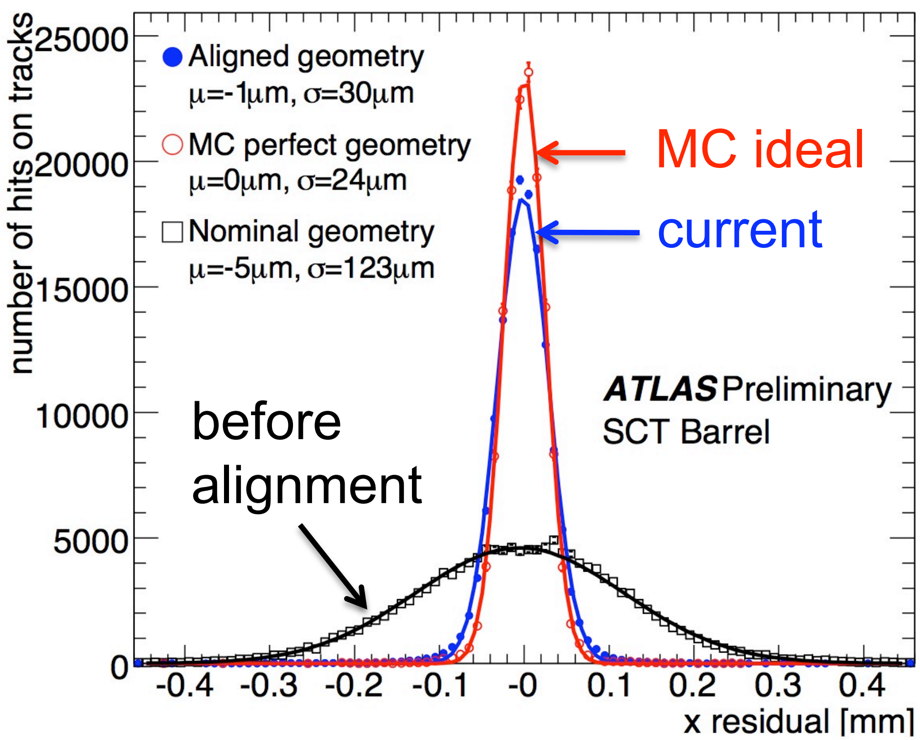
SCT Results

SCT hit efficiency for the barrel layers (for active modules) ⇨



Track residuals for precision coordinate

⇩

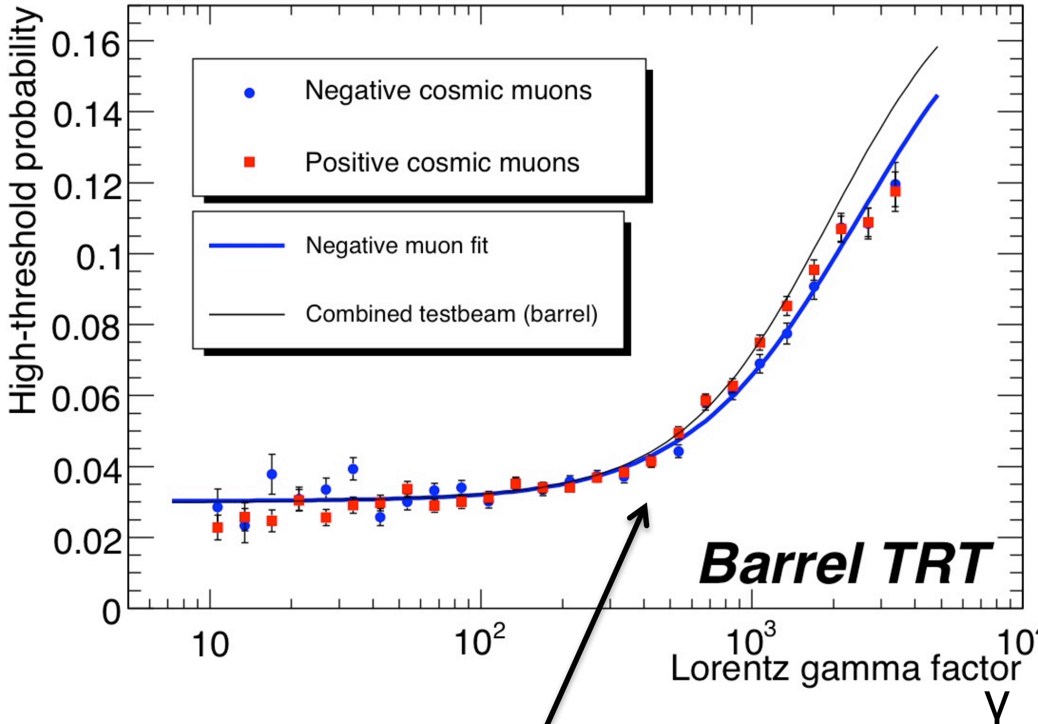


Very high efficiency and good alignment are available going into the 2009/10 running

Transition radiation in the TRT

Transition radiation (TR) photons generated by radiator foils (boundary of 2 materials with different dielectric constants)

Effect starts at $\gamma = (E/m) \approx 10^3$
➞ mostly for electron ID



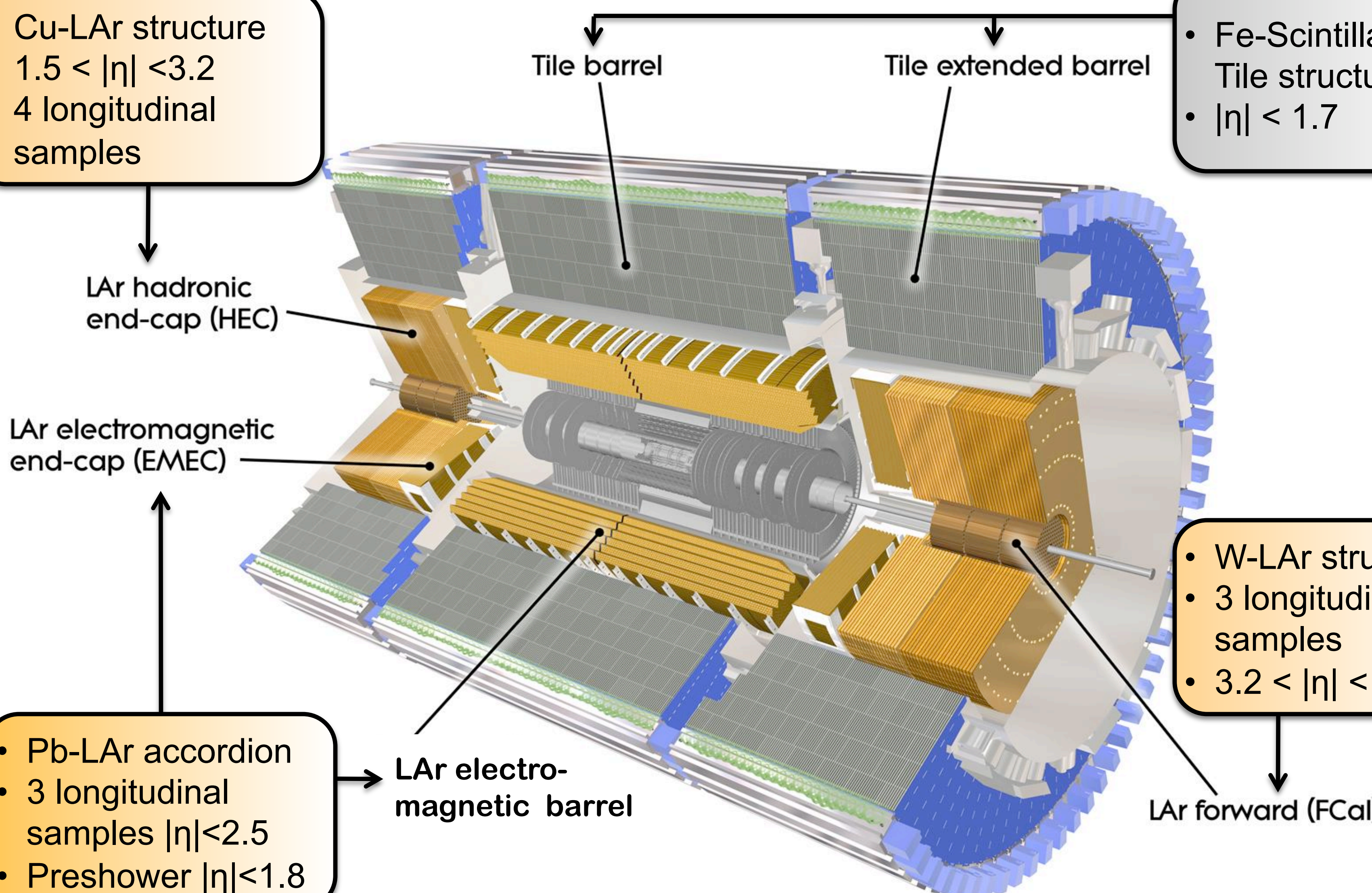
In the TRT, photons are absorbed in chamber gas
➞ large pulse
➞ passes high threshold

Turn-on of TR from cosmics at about $\gamma = 10^3$ as expected

Calorimeter system

- Cu-LAr structure
- 1.5 < |η| <3.2
- 4 longitudinal samples

- Fe-Scintillating Tile structure
- |η| < 1.7



- W-LAr structure
- 3 longitudinal samples
- 3.2 < |η| < 4.9

- Pb-LAr accordion
- 3 longitudinal samples |η|<2.5
- Preshower |η|<1.8

Calorimeter status

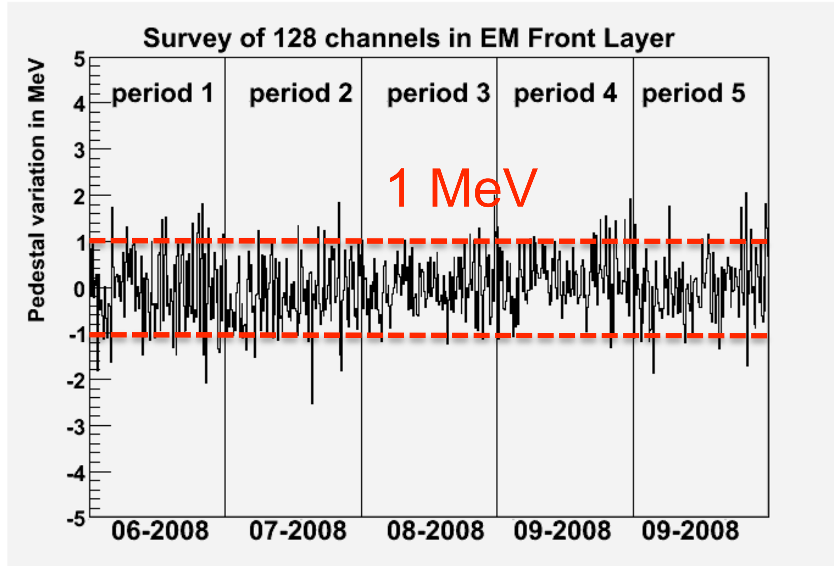
- LAr calorimeters
  - Dead channels 0.02% (+0.9% from readout – being fixed)
  - Noisy channels 0.003%
  - Electronic calibration procedure is operational

- Tile calorimeter
  - Dead channels: < 1.4% - to be repaired before end of shutdown
  - Calibration system is operational (Cs source, Laser, Charge inj.)

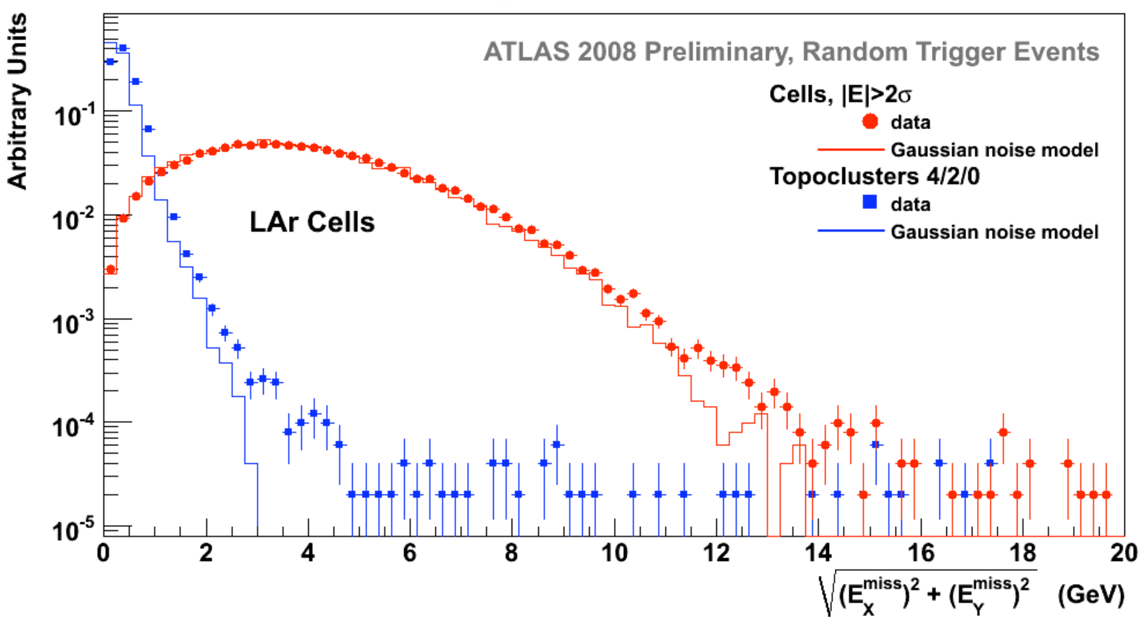
- L1 calorimeter trigger
  - Dead channels: <0.4% (+0.3% recoverable in shutdown) of 7200 analogue channels
  - Channels to channel noise suppression allows E_T=1GeV cut (aim: 0.5 GeV)

LAr Results

Pedestal stability for 128 channels of barrel EM strip (or front) layer over a 5 months period



$E_{T,miss}$ reconstruction on randomly triggered events using cells or topological clusters

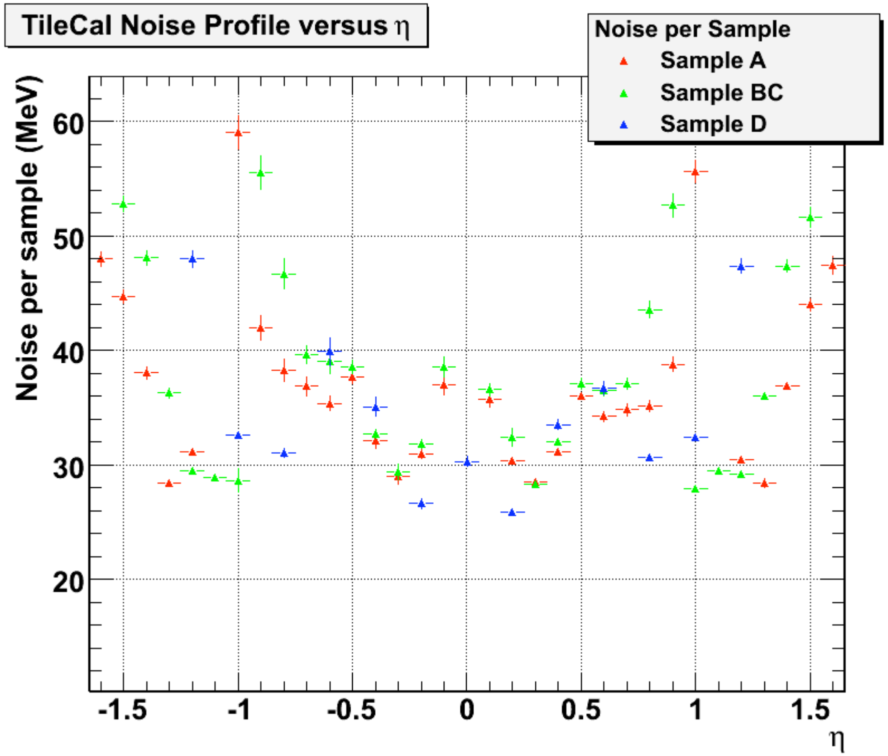


Very good stability and understanding of reconstruction and noise behaviour

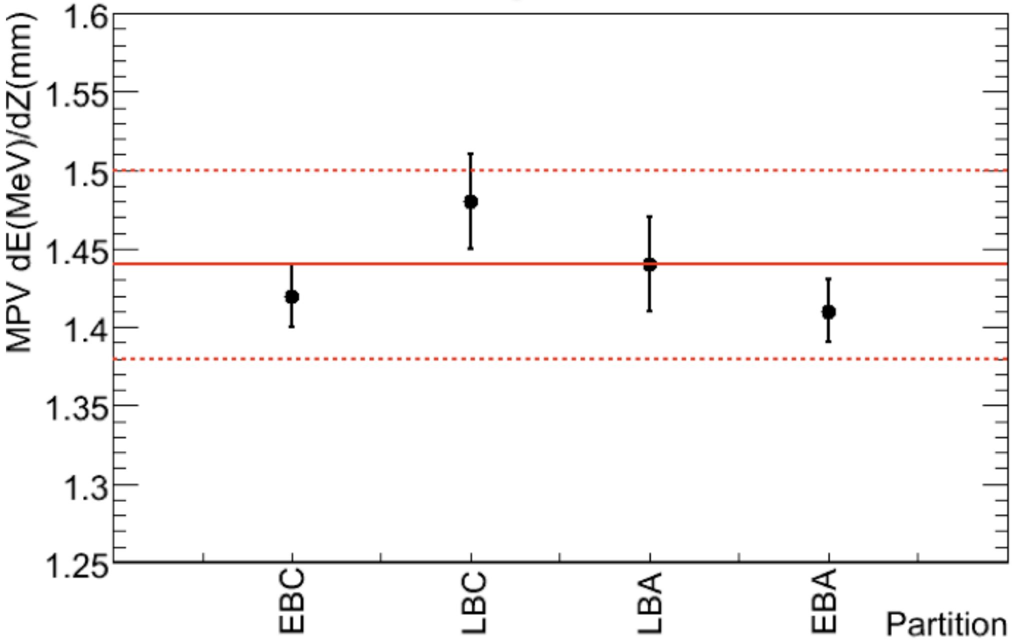
Tile results

Tile calorimeter noise measured during first beam period

(results compatible with those obtained in cosmic running)



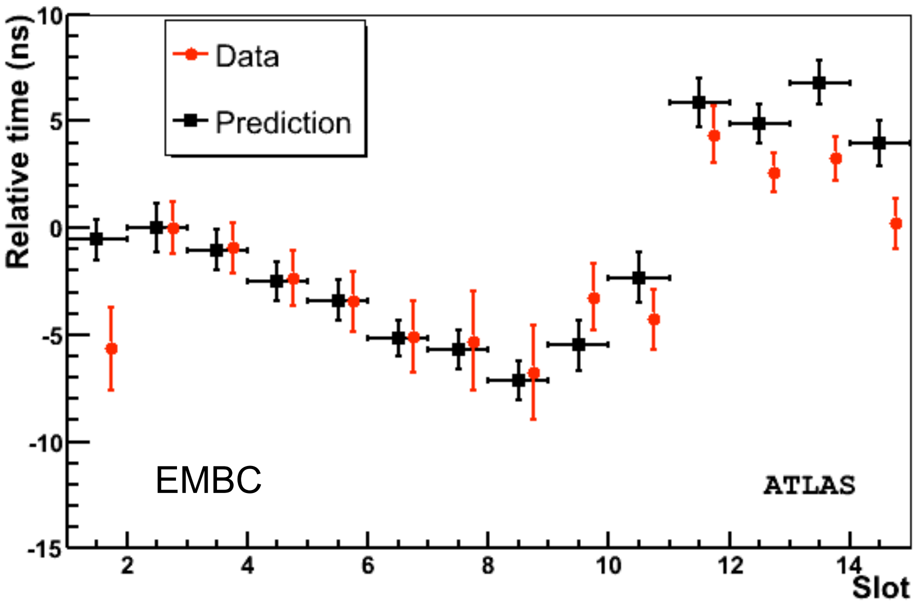
Muon dE/dz from horizontal muons during single beam running

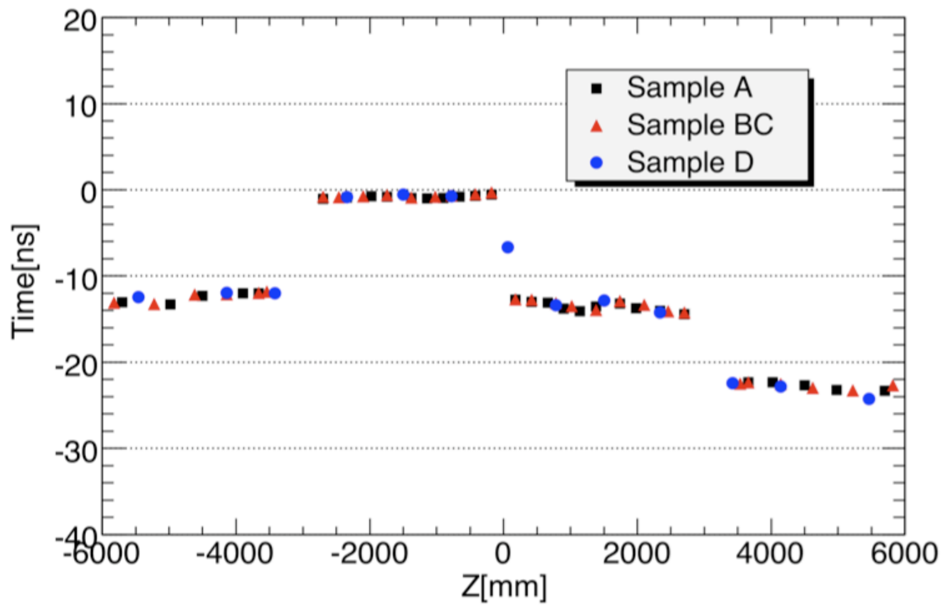


Low noise, uniform response, well understood calibration

Calorimeter timing with beam events

Checks on calorimeter signal timing using horizontal muons and hadrons
(halo muons or beam splash events)

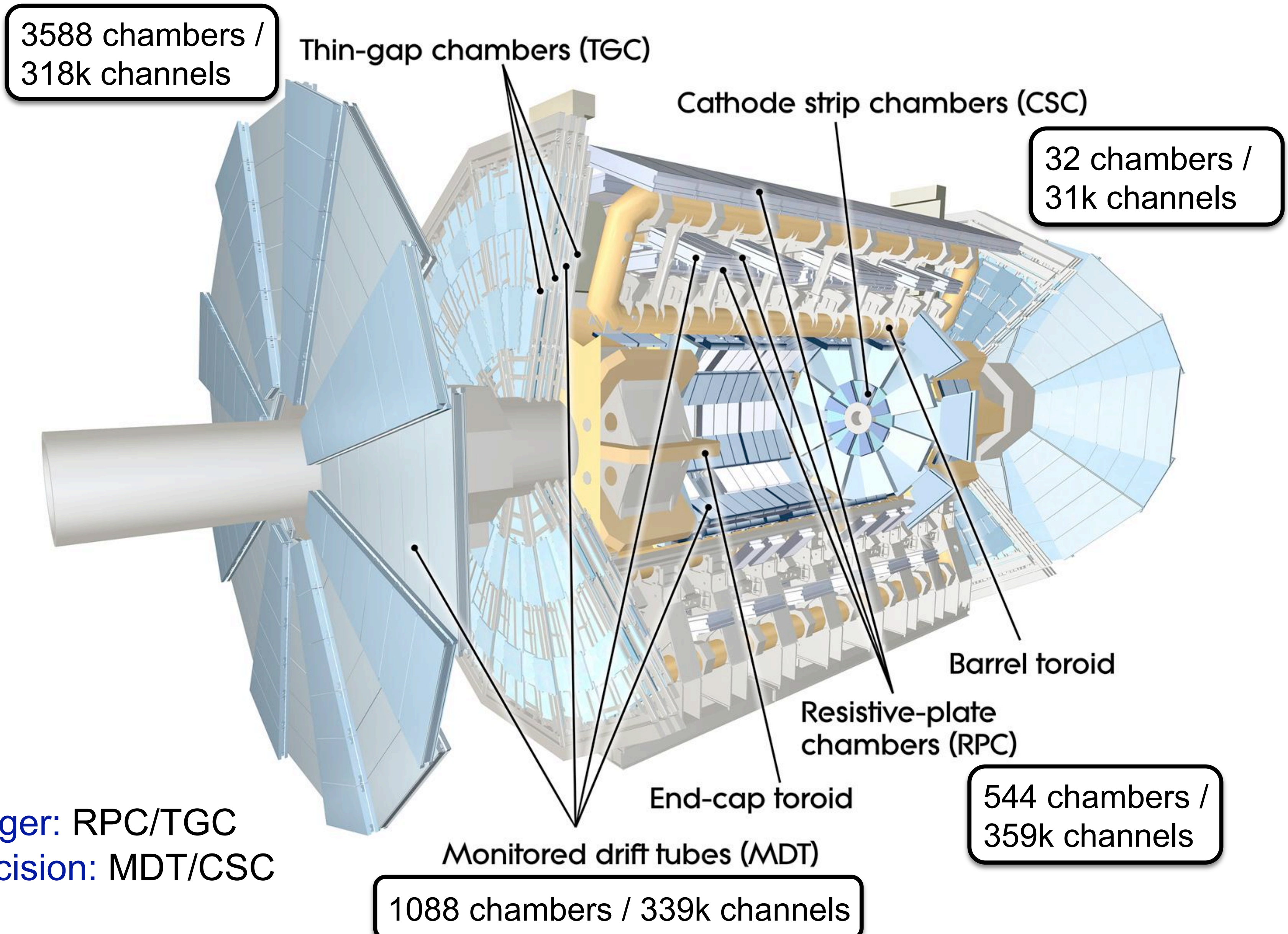




LAr physics vs calibration pulse timing
- Obtain timing from calibration pulses
- Predict signal timing (TOF, cables)
- Agreement mostly better than 2 ns for the whole LAr calorimeter

Tile signal timing
- Obtain timing from calibration pulses
- Dispersion within partition < 2ns
- Inter-partition differences (< 1BC) adjusted using this data

Muon system



Trigger: RPC/TGC
Precision: MDT/CSC

Muon system status

Precision chambers

spatial resolution 35-40 μm

- MDT (barrel/endcap)
  - 99.8% of chambers operational
  - Dead channels 0.2% (+0.5% recoverable)
- CSC (small wheel)
  - All chambers operational
  - Dead channels 1.5%
- Optical alignment system (12232 sensors)
  - 99.7% (barrel), 99% (endcap) operational

Trigger chambers

spatial resolution 5-10 mm

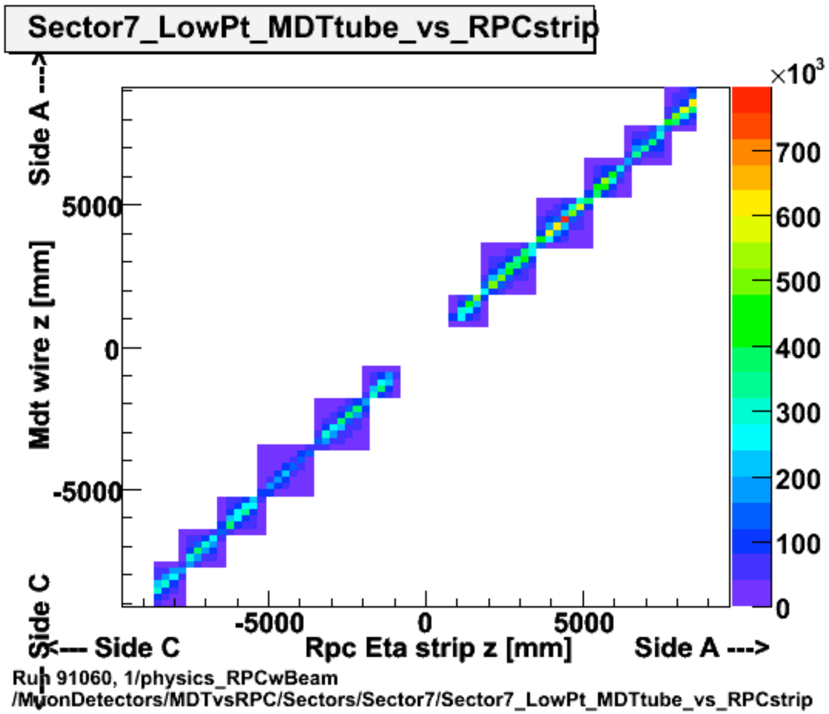
time resolution < 1 BC

- RPC (trigger chambers, barrel)
  - 70% operational (goal 2009: 98%)
  - Dead strips < 2%, hot strips < 1%
- TGC (trigger chambers, endcap)
  - 99.8% of chambers operational
  - Noisy channels < 0.02%

Muon system standalone resolution

$\Delta p_T/p_T < 10\%$ up to 1 TeV

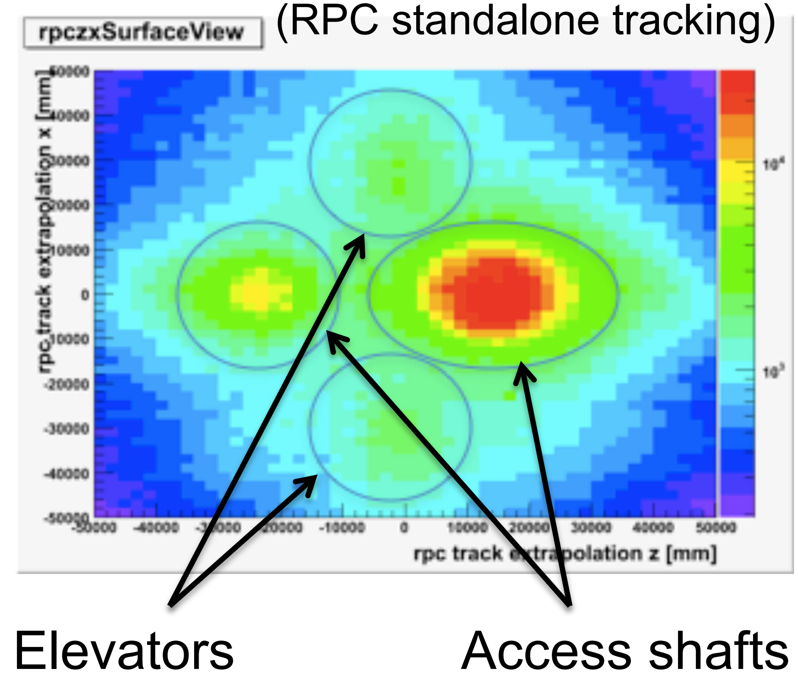
Muon spectrometer



Very good correlation between RPC (trigger chambers) and MDT (precision chambers) hits

X-ray of the ATLAS cavern with cosmic muons

(RPC standalone tracking)

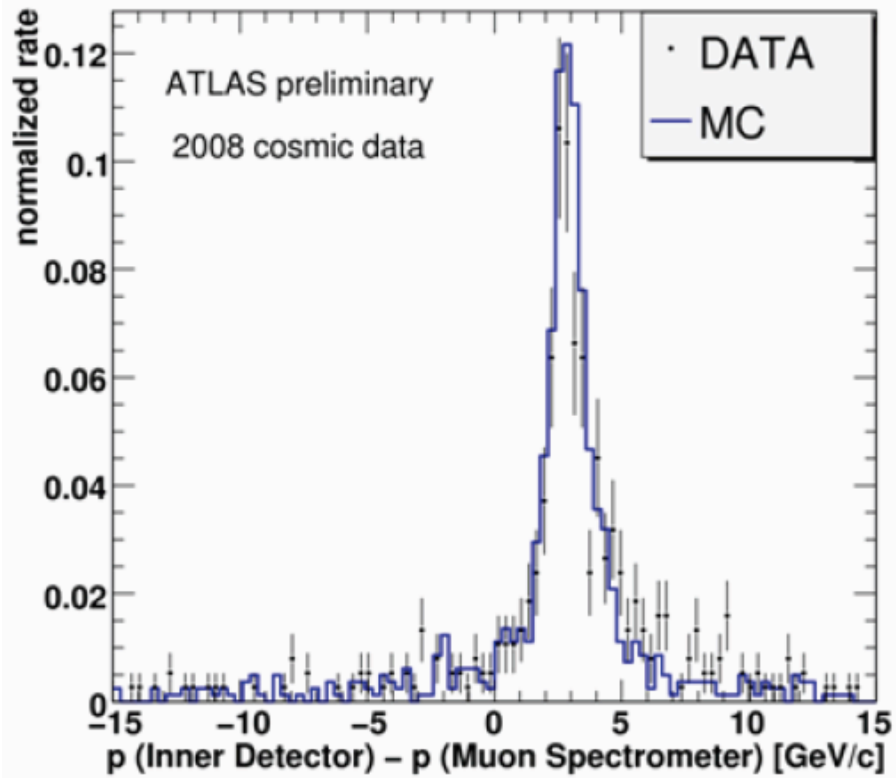


Optical alignment system

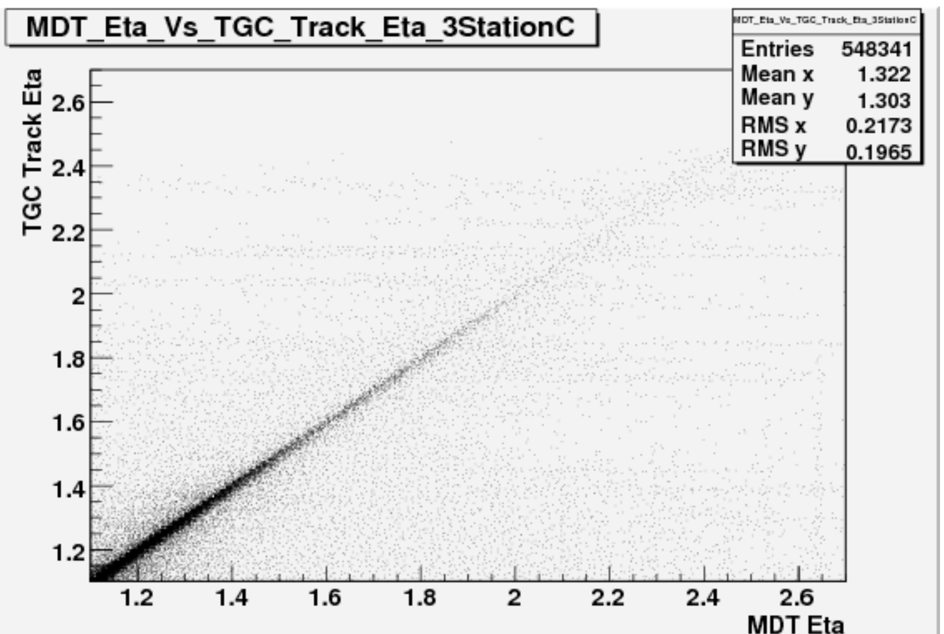
- Dead channels < 1%
- End-cap: 40 μm → o.k.
- Barrel: 250 μm → in progress

Muon spectrometer cont.

Momentum difference between ID and lower muon spectrometer
(due to momentum loss in calorimeters) ⇨

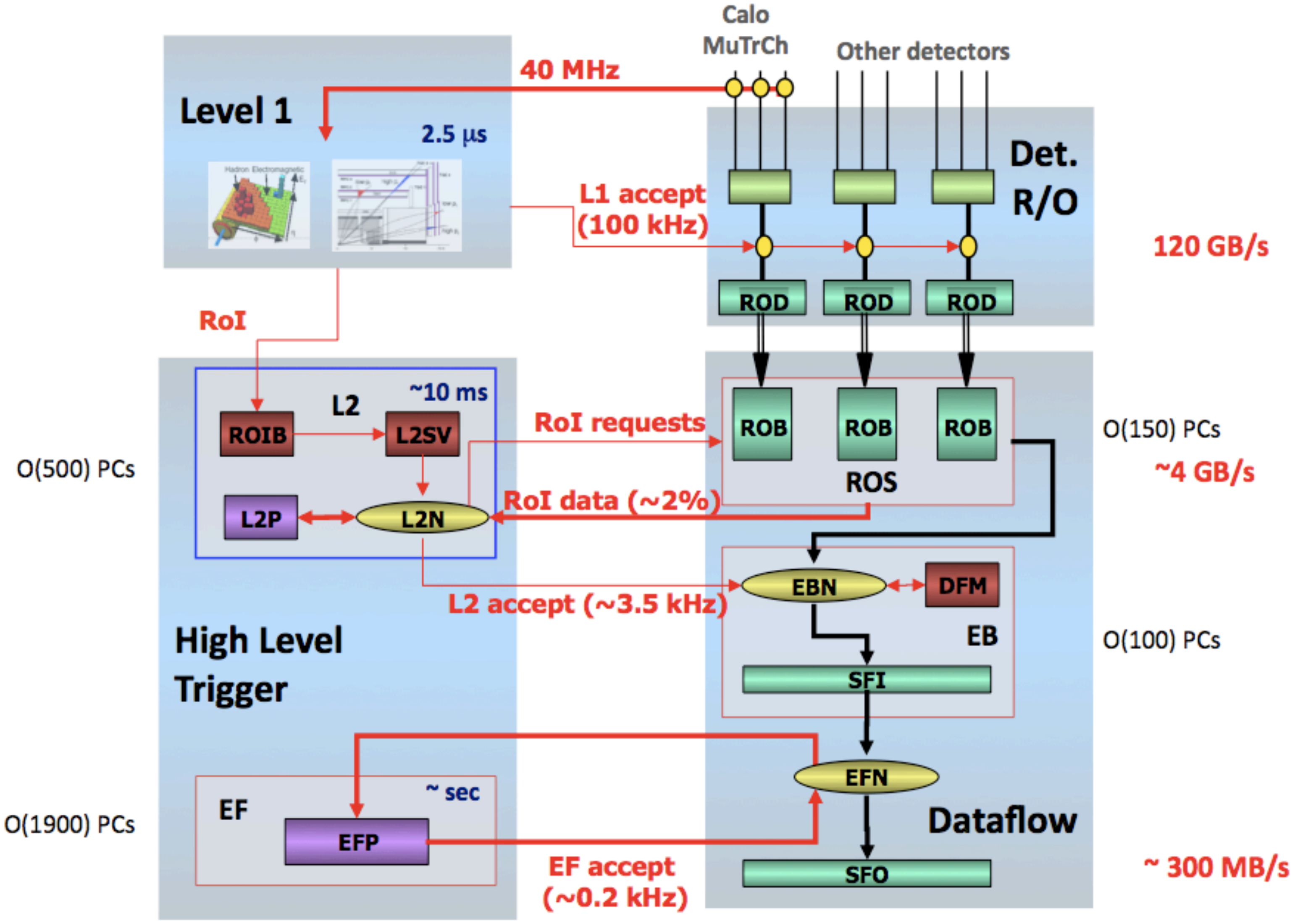


Correlation endcap trigger (TGC) and precision (MDT) chambers ⇩



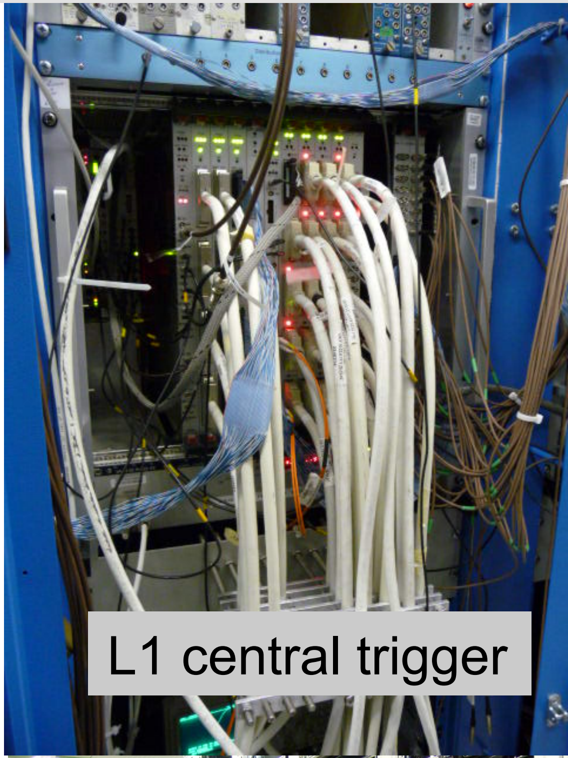
Muon tracking is working well standalone and in conjunction with ID

Trigger and DAQ

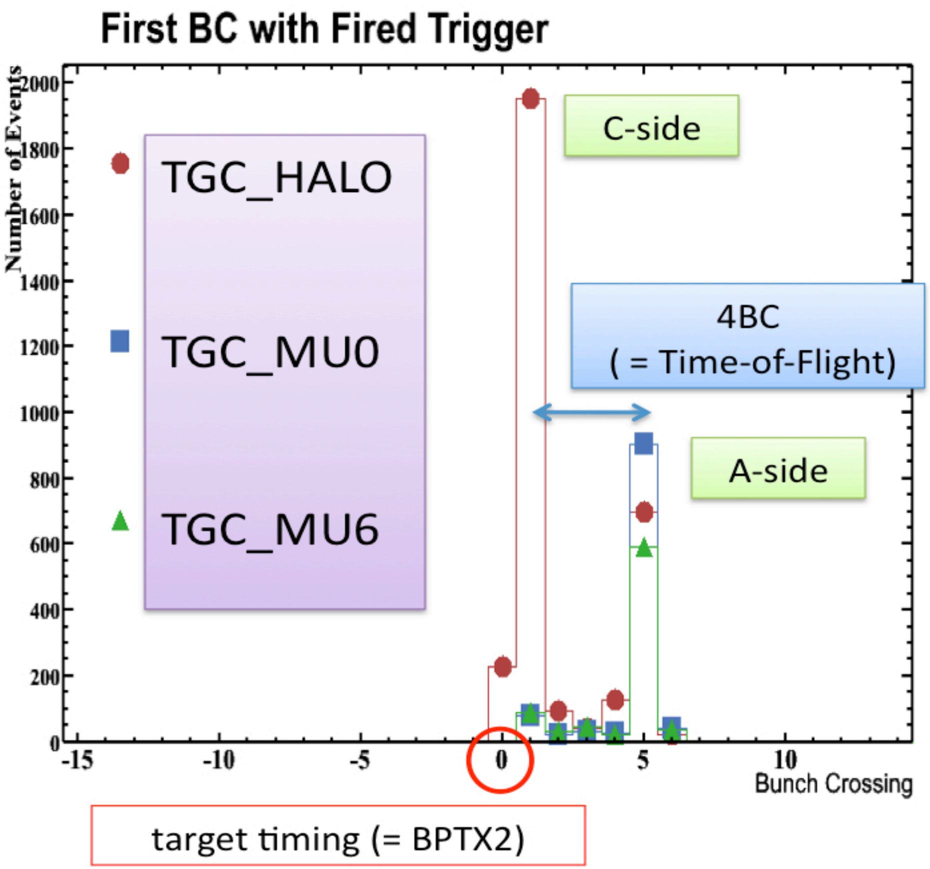


TDAQ status

- DAQ (ROS, EB, SFO)
  - 100% of final system available
  - Delivered 2x design rate of event throughput with 5 SFOs
- First level trigger (L1)
  - System completely installed
  - Rate with full system tested up to 40kHz
  - Fine timing in progress
- High level trigger (L2 + Event Filter)
  - ~850 nodes in 27 racks (8 cores@2.5GHz)
  - Capable to handle 50% of 75 kHz input rate currently
  - Final system 500 L2 + 1800 EF nodes
  - Flexible node assignment L2 ←→ EF to react to run situations

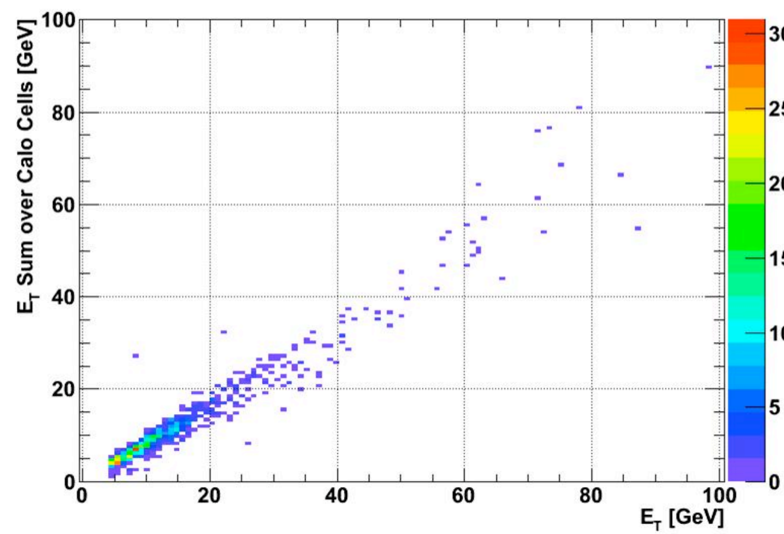


L1 Trigger results



Muon endcap (TGC) trigger timing from beam data

- Difference in endcap timing due to expected difference in ToF
- Timing good to ~1BC (narrow peaks)

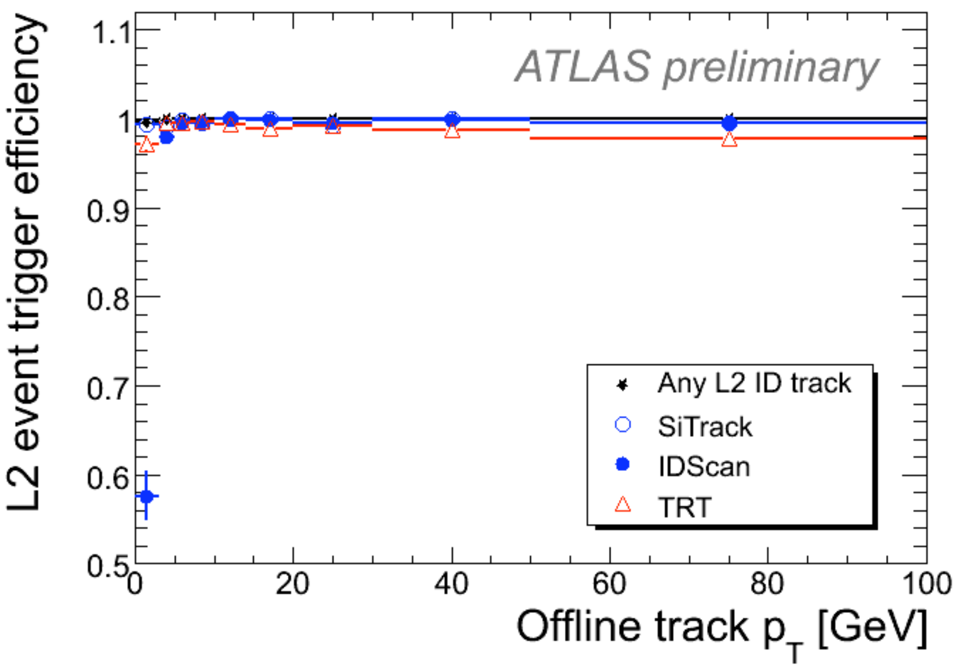


L1Calo trigger tower (x) vs. calorimeter full readout (y), Spread will decrease with full calibration

HLT results

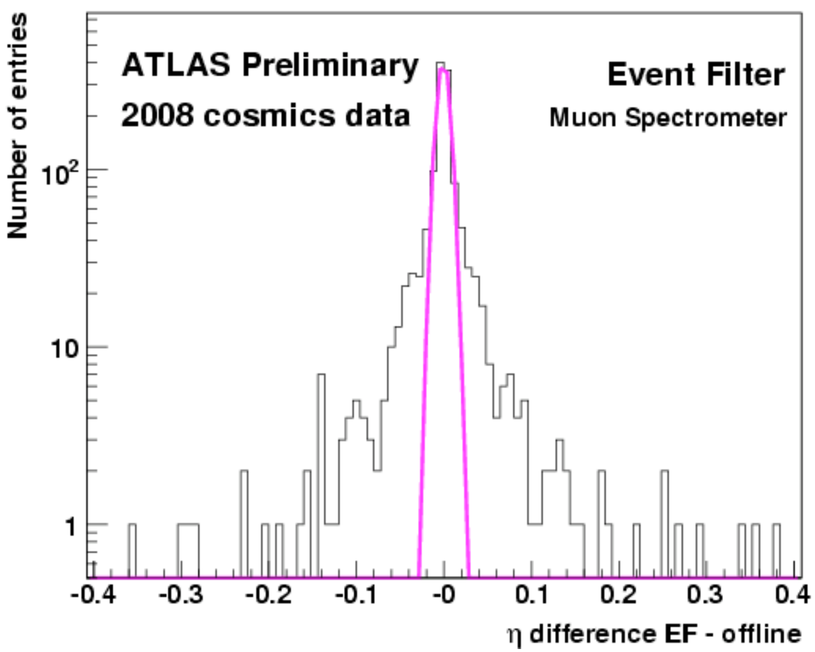
L2 track trigger efficiency

- Inner detector tracks
- Relative to offline reconstructed tracks, using one arm of through going cosmic ray track as reference



Muon trigger vs muon reconstructed

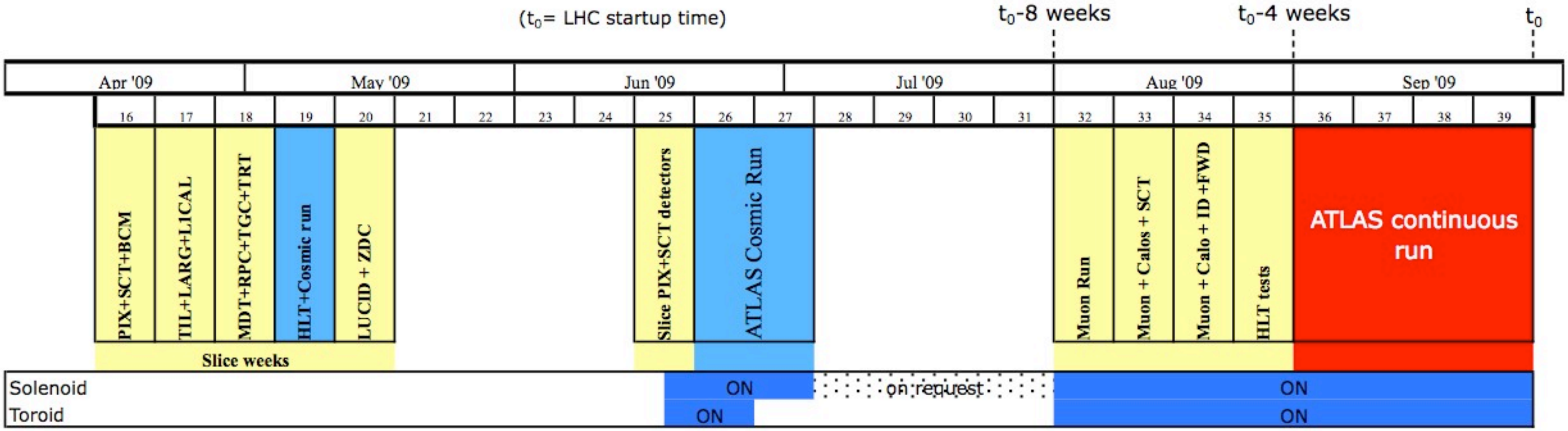
- Event filter muon track compared to offline reconstructed muon (in η)
- Tails due to slightly different configuration online vs offline



Width of fitted Gaussian = 0.007

Ongoing (re-)commissioning

Run Plan over the next few months (version 1.4):



Very intense programme of:

- Confirming repairs, recoveries, improvements
- Bringing in some remaining components
- Achieve smooth running before beam later this year

Conclusions

- ATLAS will enter the 2009/10 running period with:
  - Very few dead channels – only about 1% not functional
  - Low and well understood noise
  - Much progress in calibration and alignment

→ With of course the ultimate test still to come …

- Tremendous amount of work is still ongoing to:
  - finish the shutdown work
  - Re-assemble ATLAS into a smoothly running experiment in time for the beam

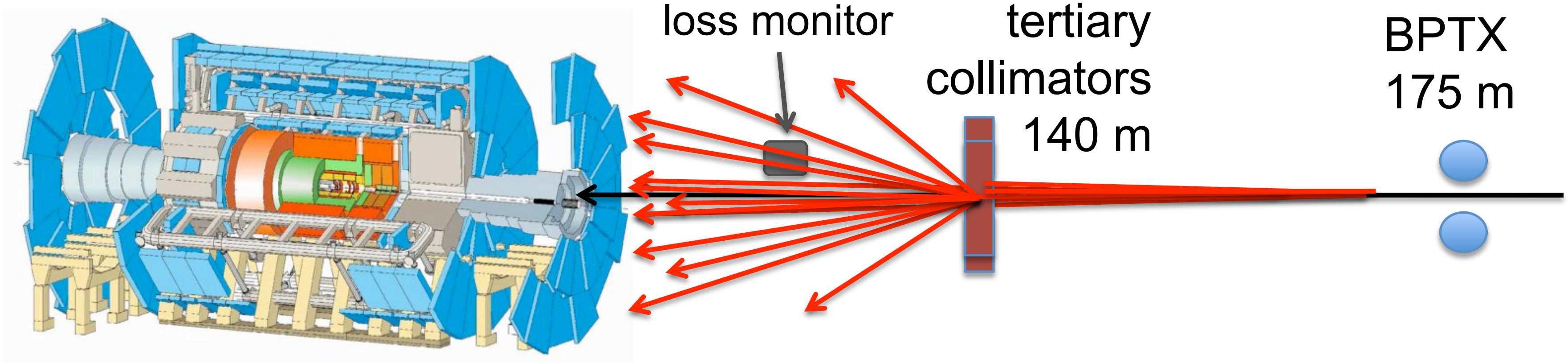
Additional Slides

ATLAS required performance

Detector component	Required resolution	η coverage	
		Measurement	Trigger
Tracking	$\sigma_{p_T}/p_T = 0.05\%\ p_T \oplus 1\%$	± 2.5	
EM calorimetry	$\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$	± 3.2	± 2.5
Hadronic calorimetry (jets)			
barrel and end-cap	$\sigma_E/E = 50\%/\sqrt{E} \oplus 3\%$	± 3.2	± 3.2
forward	$\sigma_E/E = 100\%/\sqrt{E} \oplus 10\%$	$3.1 < \lvert\eta\rvert < 4.9$	$3.1 < \lvert\eta\rvert < 4.9$
Muon spectrometer	σ_{p_T}/p_T=10% at $p_T = 1$ TeV	± 2.7	± 2.4

Table 1. General performance goals of the ATLAS detector. Note that, for high-p_T muons, the muon-spectrometer performance is independent of the inner-detector system. The units for E and p_T are in GeV.

Going into beam op. Sep 10th



ATLAS was ready for first beam:

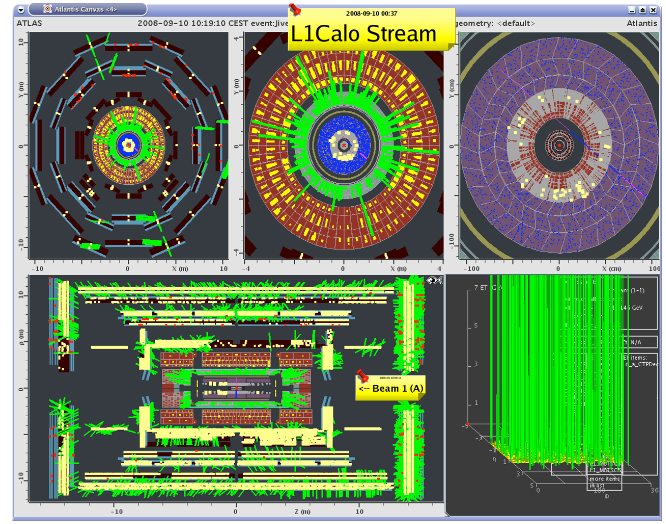
- Muon system (MDT, RPC, TGC) on at reduced HV
- LAr (-FCAL HV), Tile on
- TRT on, SCT reduced HV, Pixel off
- BCM, LUCID, MinBias Scint. (MBTS), Beam pickups (BPTX)
- L1 trigger processor, DAQ up and running, HLT available (but used for streaming only)

LHC start-up scenario:

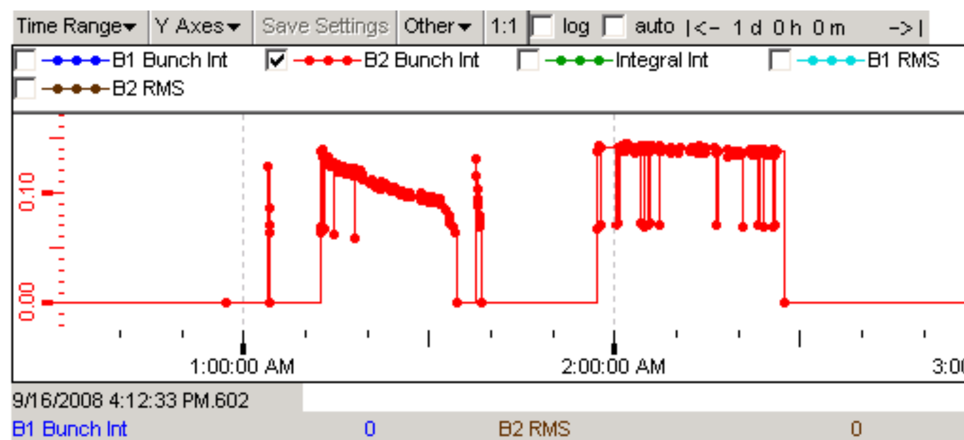
- Go step-by-step, stopping beam on collimators, re-align with centre
- Open collimator, keep going
- Last collimator before beam through ATLAS – tertiary collimators (protection of triplets)
- **Splash** event from these collimators for each beam shot with collimator closed

Strategy for first beam / first signals

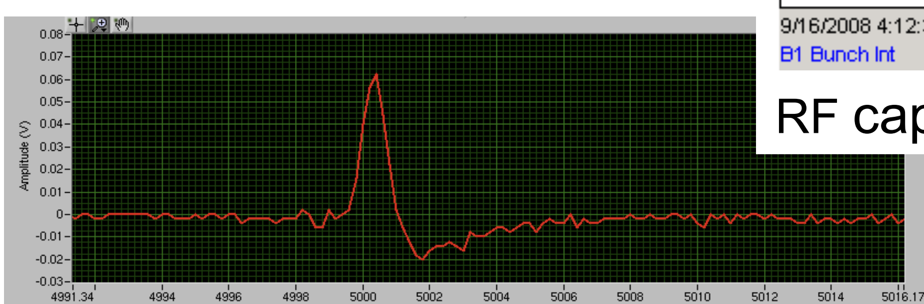
- Splash events are first
  - only 10 shots expected – not enough time to set up BPTX
  - Rely on small radius triggers with well defined cosmics timing (L1Calo + MBTS)
  - **Catch the first events!**



- Start timing in Beam Pickups (our timing reference) rapidly to trigger on through-going beam
  - First signal seen in ATLAS
  - **Multi-turns!**

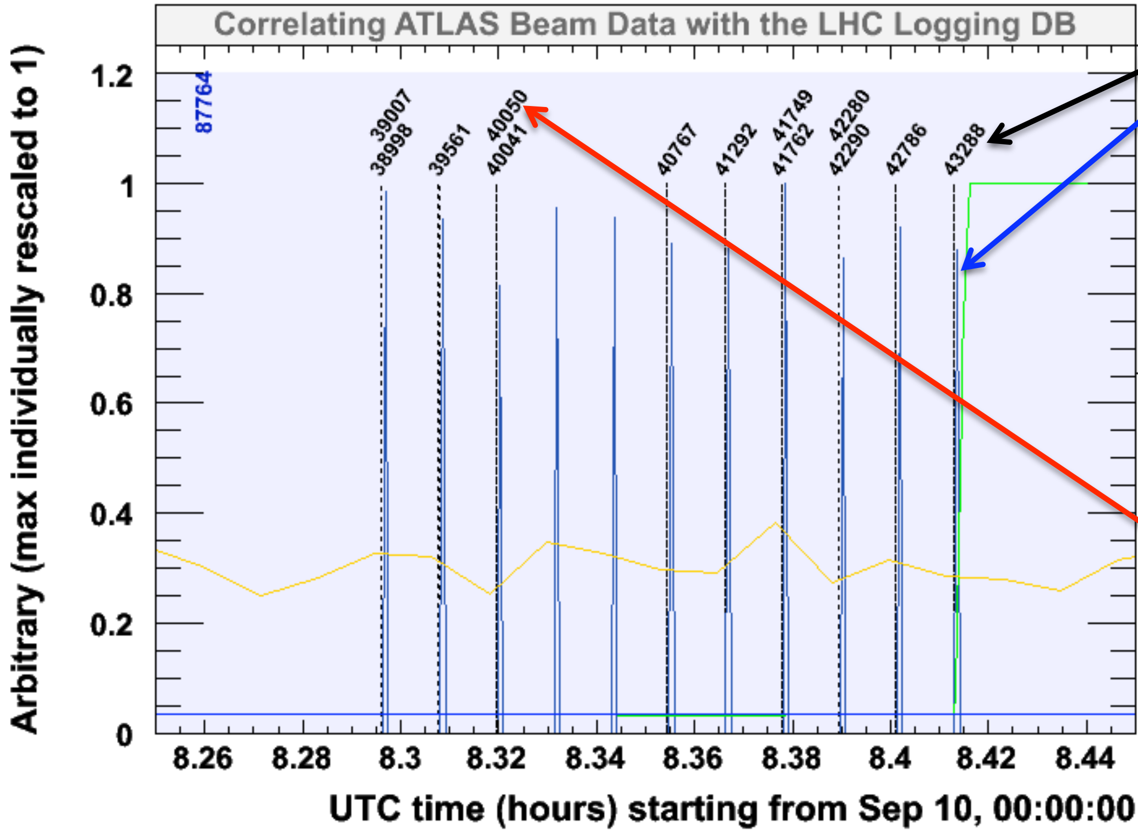


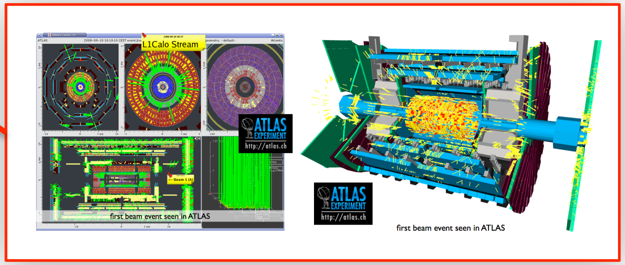
RF captured beam for > 20 min on day 2!



Worked out nicely, with very stable data taking

The first events – did we get them?





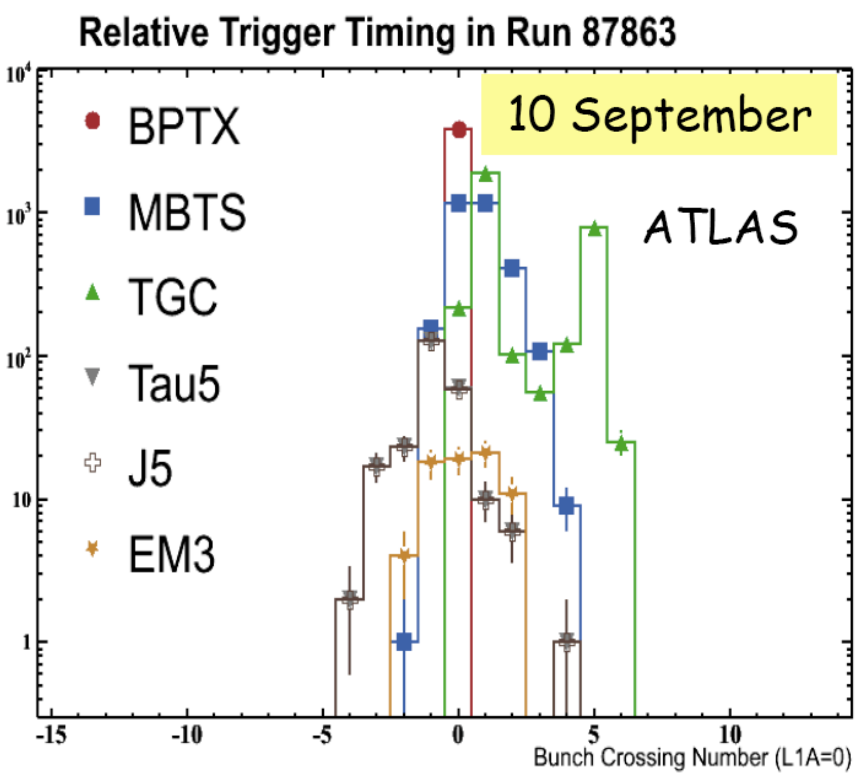
“First beam event seen in ATLAS”
(not quite !)

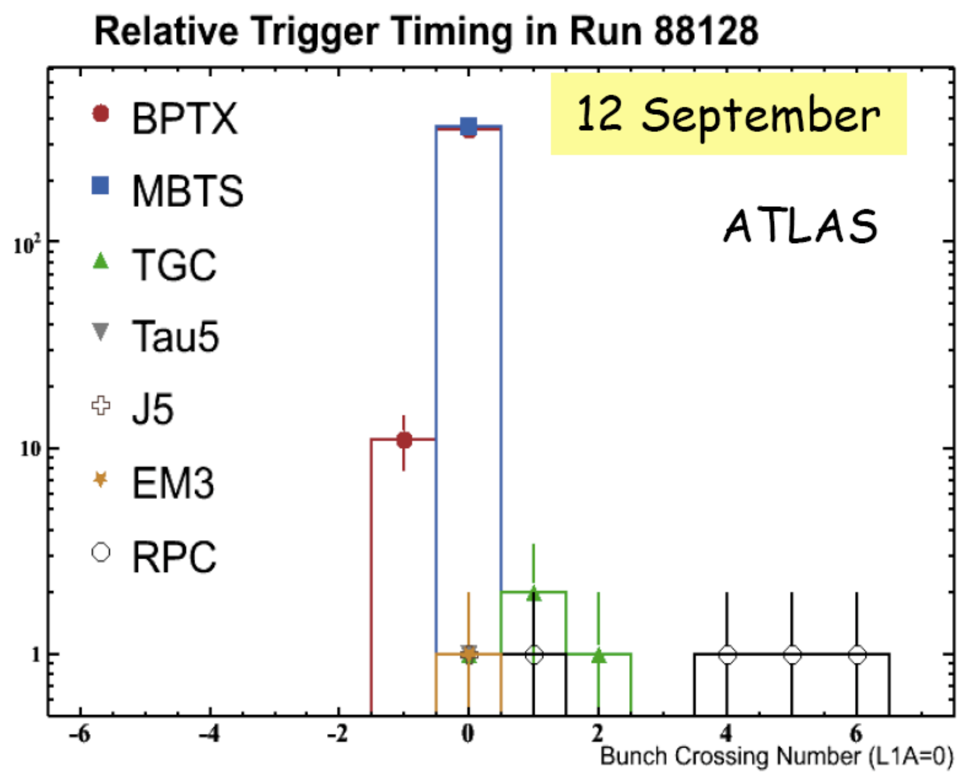
Zoom into the first beam ‘splash’ activity with beam-1 closed collimator, recorded in run 87764.

Of 11 beam ‘splashes’ (solid-blue), 9 have been triggered (ATLAS events are dashed-black, the event numbers are indicated).

Timing of the trigger inputs

Intense programme of timing adjustments of trigger inputs

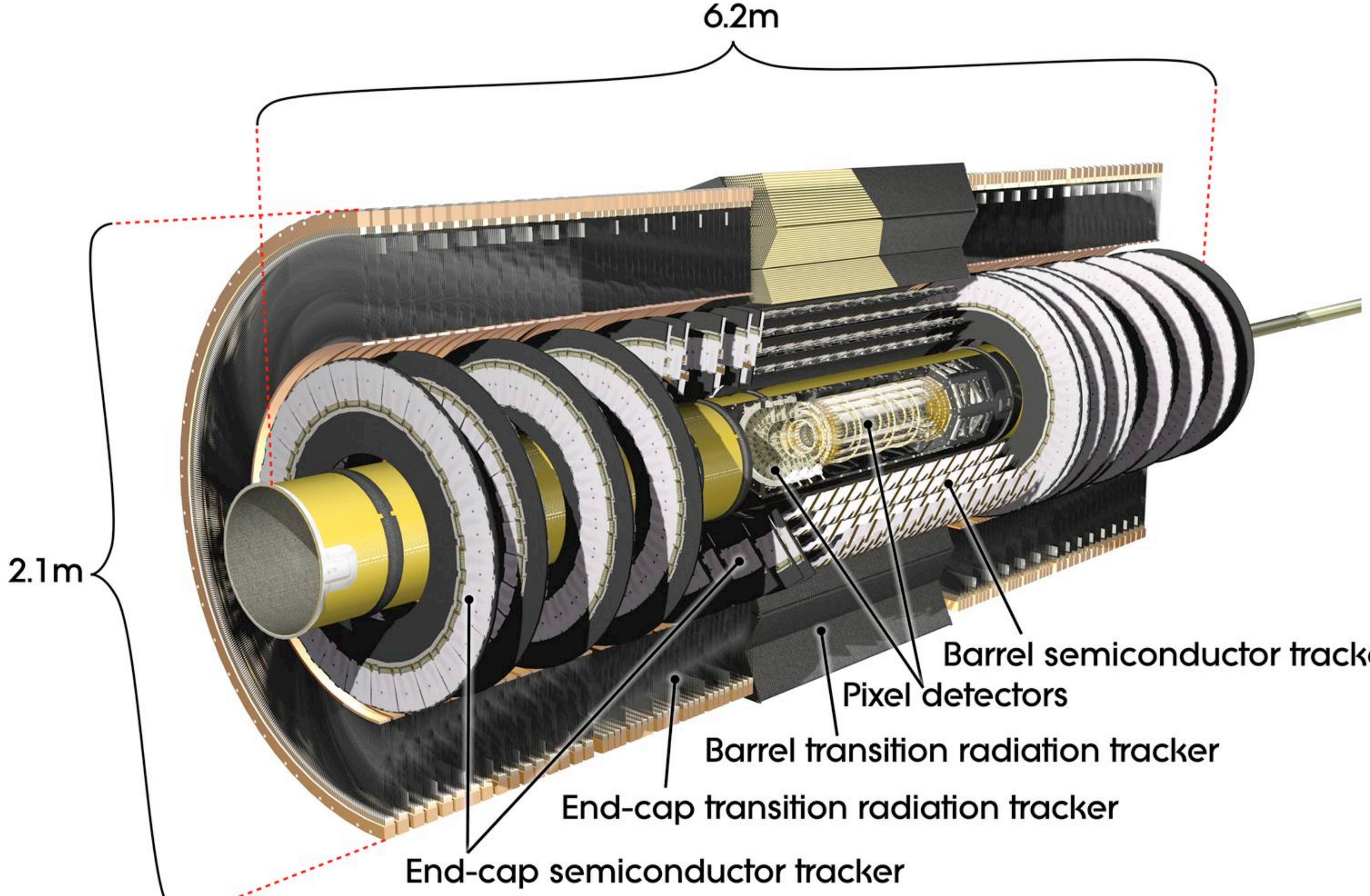




1 BC = 25 ns

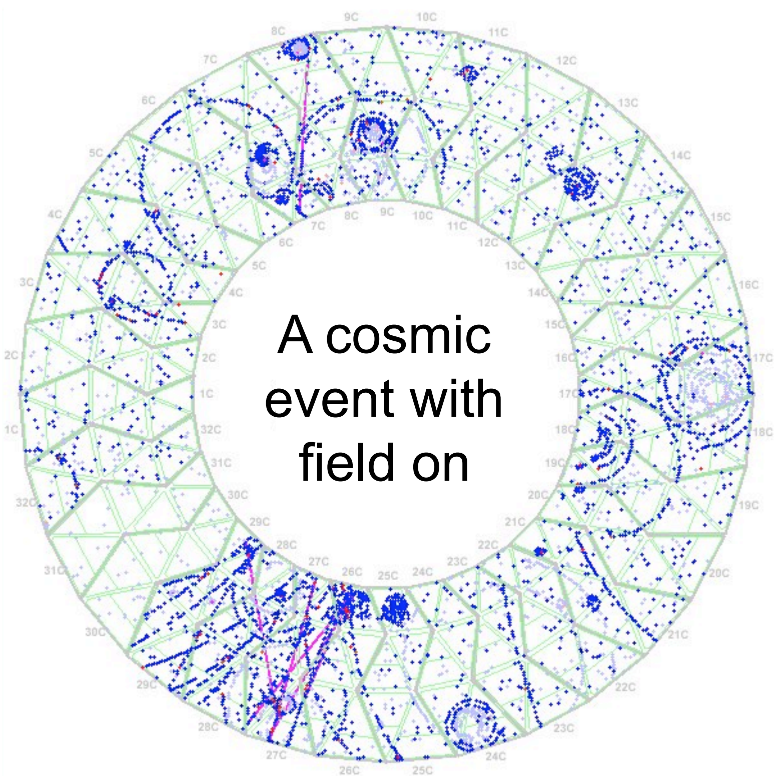
Only about 30 hours of
(any kind of) beam in 2008 …

Inner Detector



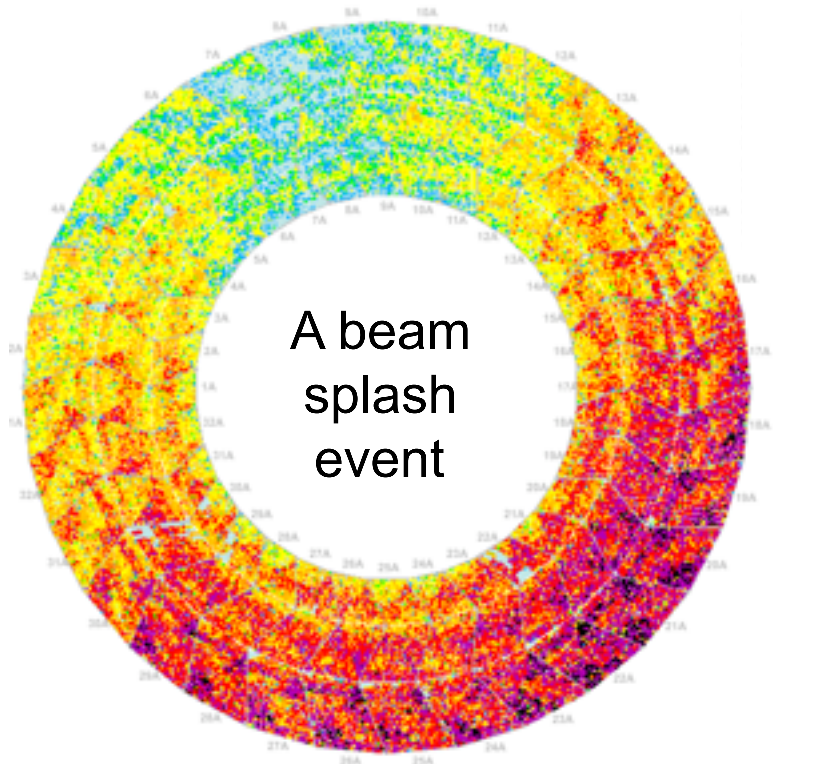
The TRT as …

Bubble chamber



Occupancy ~ 1%

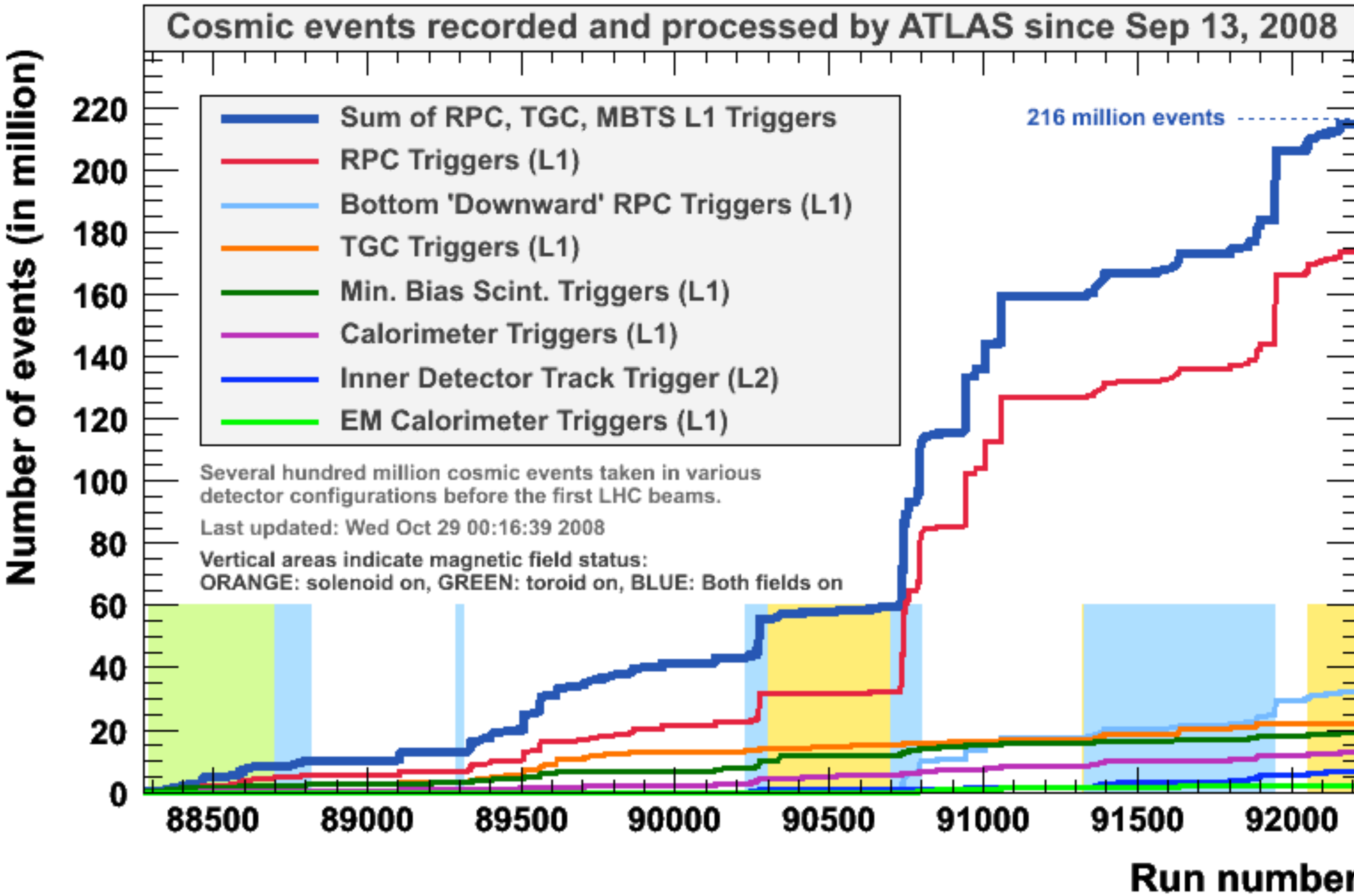
Fixed target detector



Time over threshold, imbalance due to timing setup for cosmics

Data overview

ATLAS then went into a sustained cosmic-ray data taking campaign



Calibration and alignment

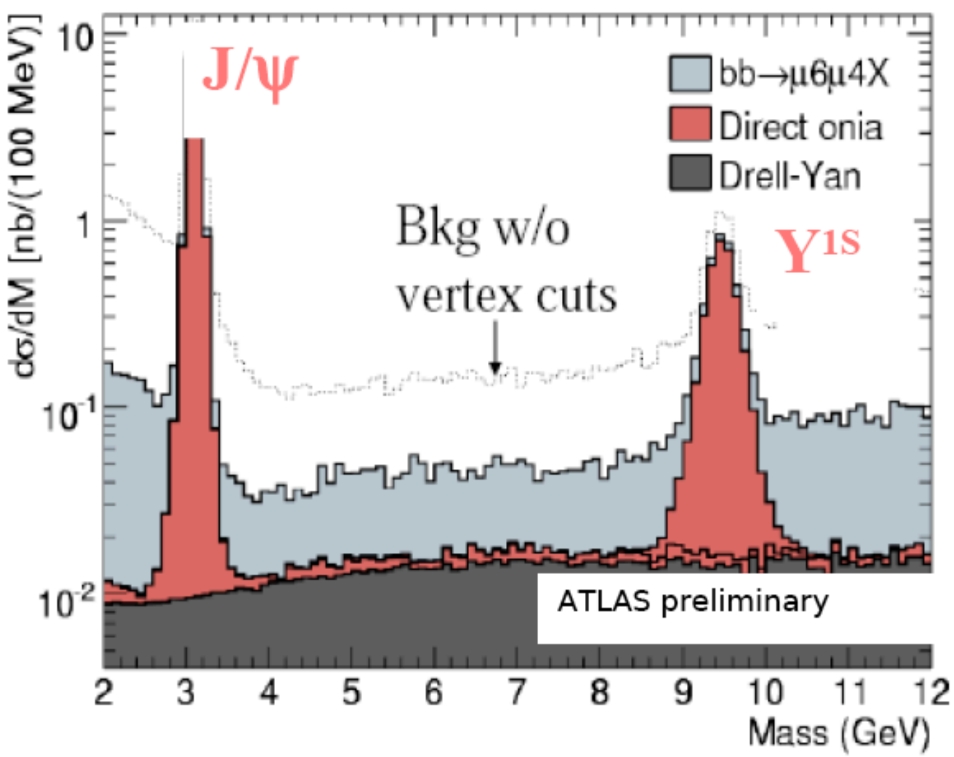
Initial values from

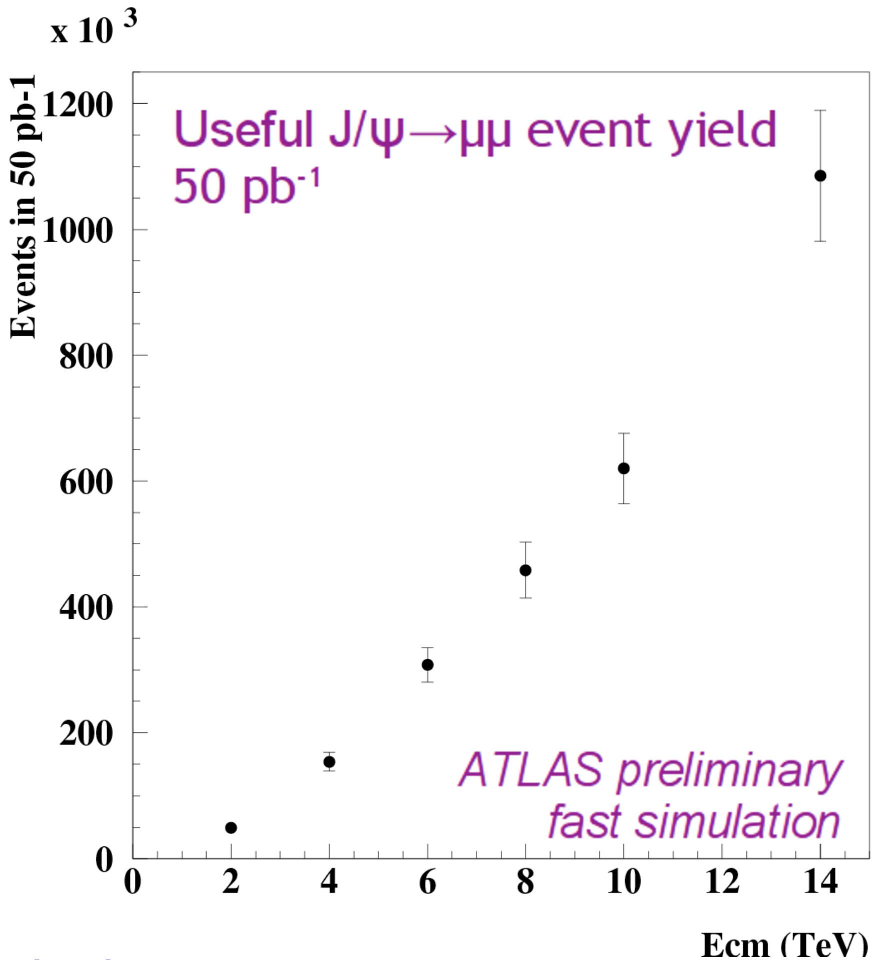
- test beam data
- calibration and alignment systems
- analysis of cosmic ray data

	Initial	Ultimate	Samples
e/γ E scale	~2%	0.1%	$Z \to ee$, J/ψ, π^0
e/γ uniformity	1-4%	0.5%	$Z \to ee$
jet E scale	5-10%	~1-2%	$W \to jj$ in tt, γ/Z+jets
tracking alignment	10-100μm	<10 μm	tracks, $Z \to \mu\mu$
muon alignment	?	30 μm	inclusive μ, $Z \to \mu\mu$

From the first collision data will be used to improve the detector performance with standard samples [iterative].

Example: J/ψ

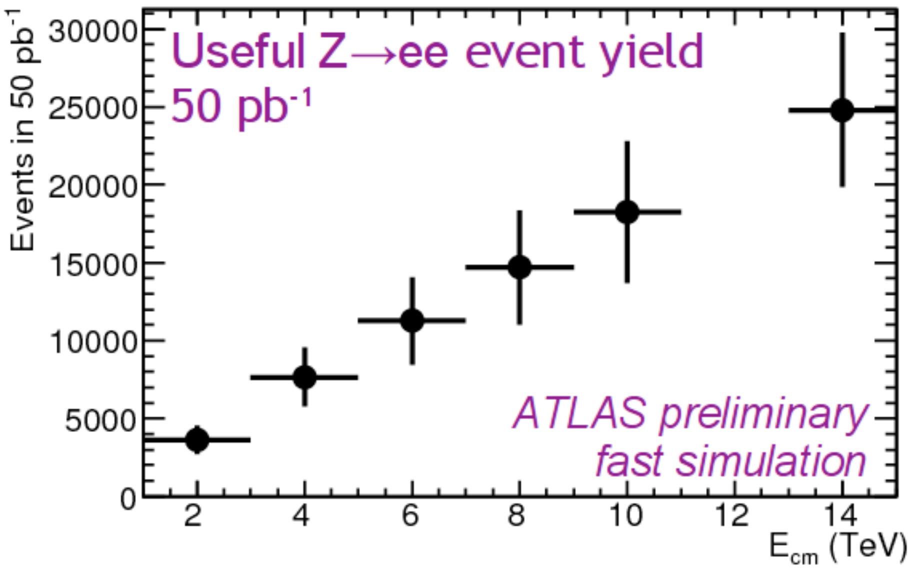




- Important standard candle for commissioning
- Huge statistics fast, especially in μμ channel
  - Easy to select, muon chamber, inner detector tracking alignment

Example: Z→ ee

- Clean sample of di-electron events
  - e/γ uniformity
  - e/γ energy scale



After a short period of running large calibration samples will be available to start improving the detector performance