Status of ATLAS

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On behalf of the ATLAS Collaboration

14th Lomonosov Conference on
Elementary Particle Physics

August 2009

Status of the ATLAS experiment

- The ATLAS experiment
  - The collaboration
  - The detector
  - Trigger, data acquisition, computing
- Performance results
  - Large sample of cosmic rays observed with the full detector in the cavern during Autumn 2008 and Summer 2009
  - Global operational experience including prompt calibration tasks and full offline processing to validate reconstruction with real data
  - Calibration and alignment studies - standalone, with cosmics and also with first beam in September 2008
- Achieved precision better than expected at this stage for “day 1”

The Collaboration

- ~2800 physicists, including 800 PhD students from
- 169 Institutions/Universities, 37 countries, 5 continents

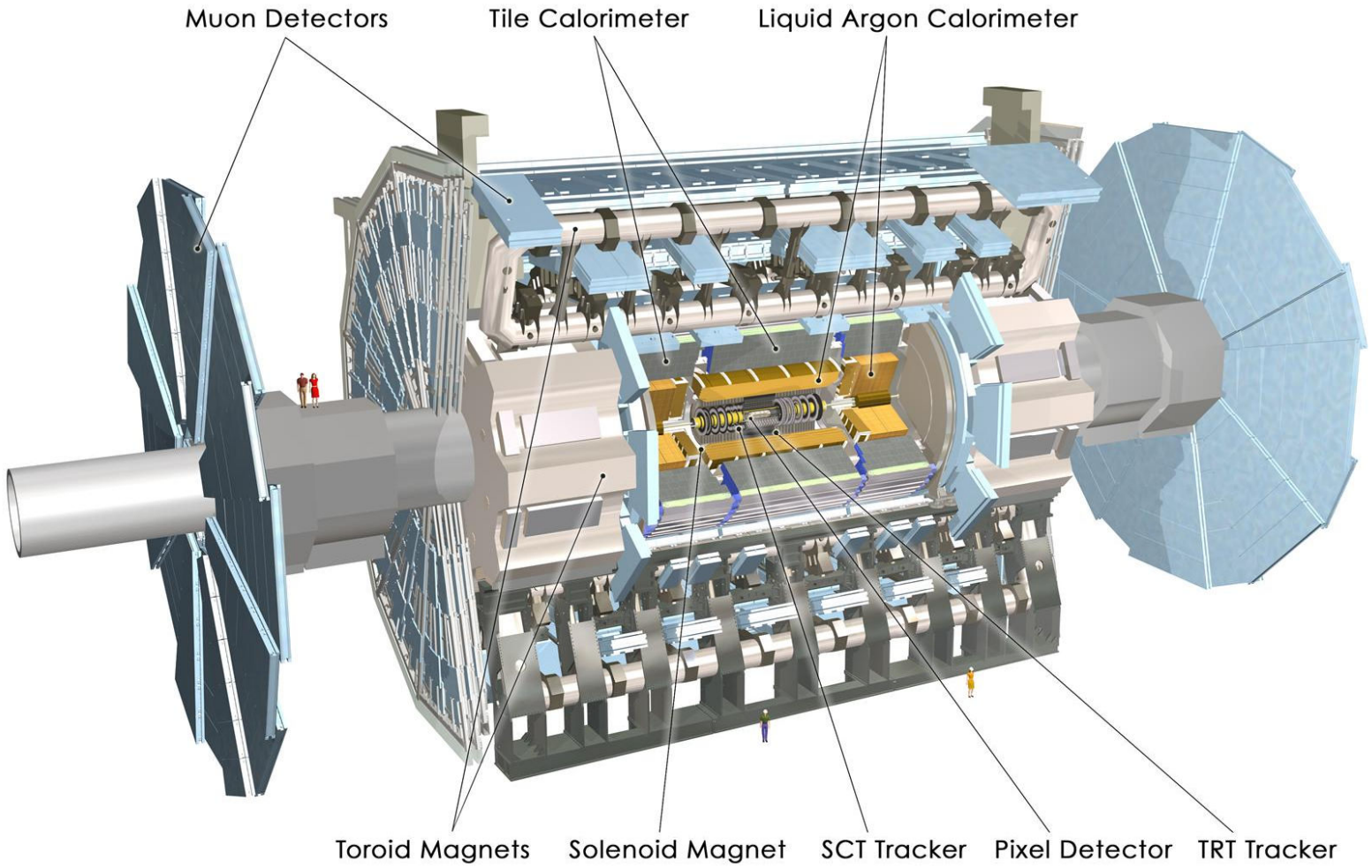
ATLAS Collaboration: 169 Institutions

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Brasil Cluster, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

ATLAS detector

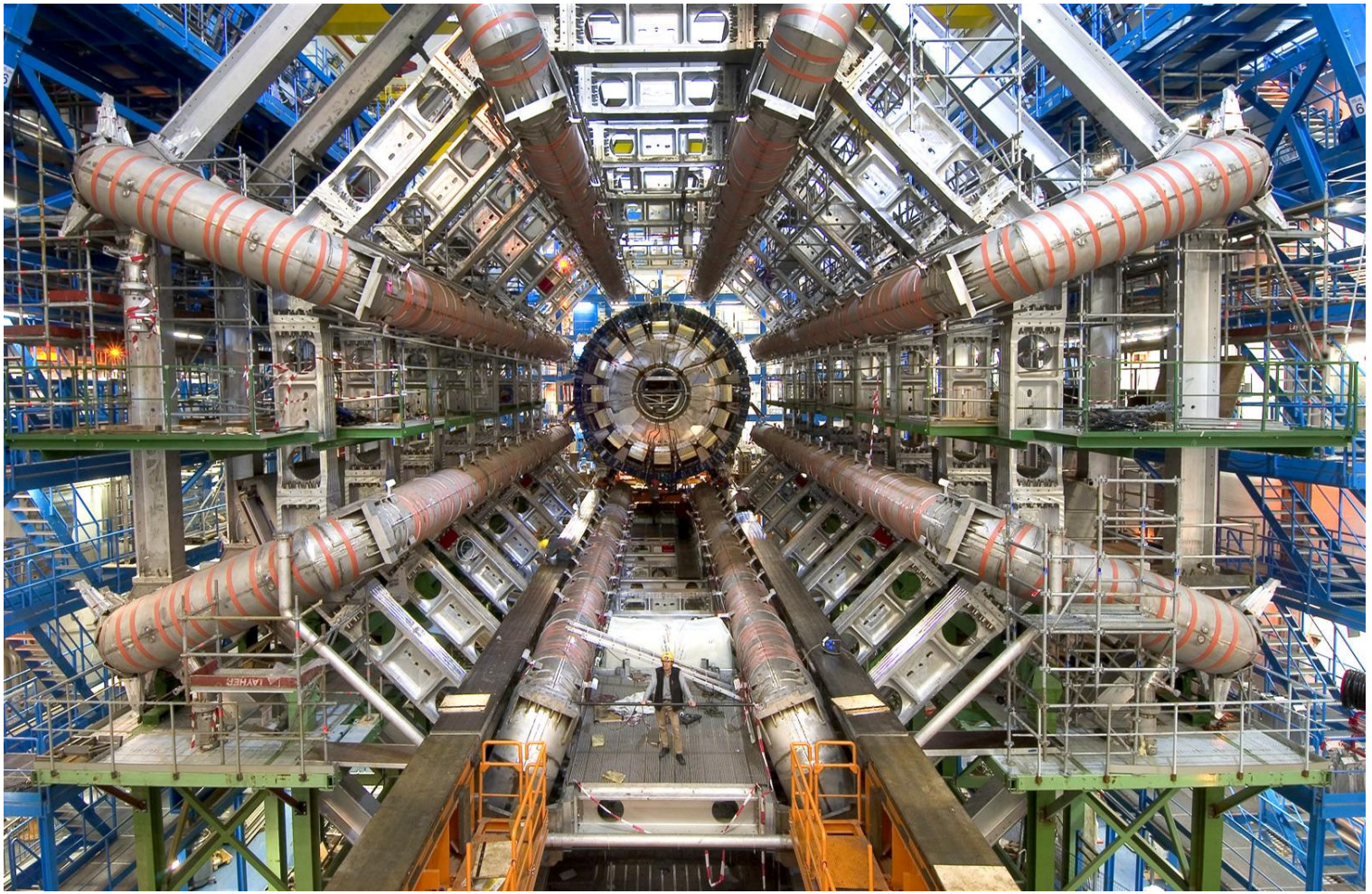
ATLAS detector

- 25m high, 44m long, total weight 7000 tonnes.



Magnet system

Barrel toroid (and barrel calorimeter)



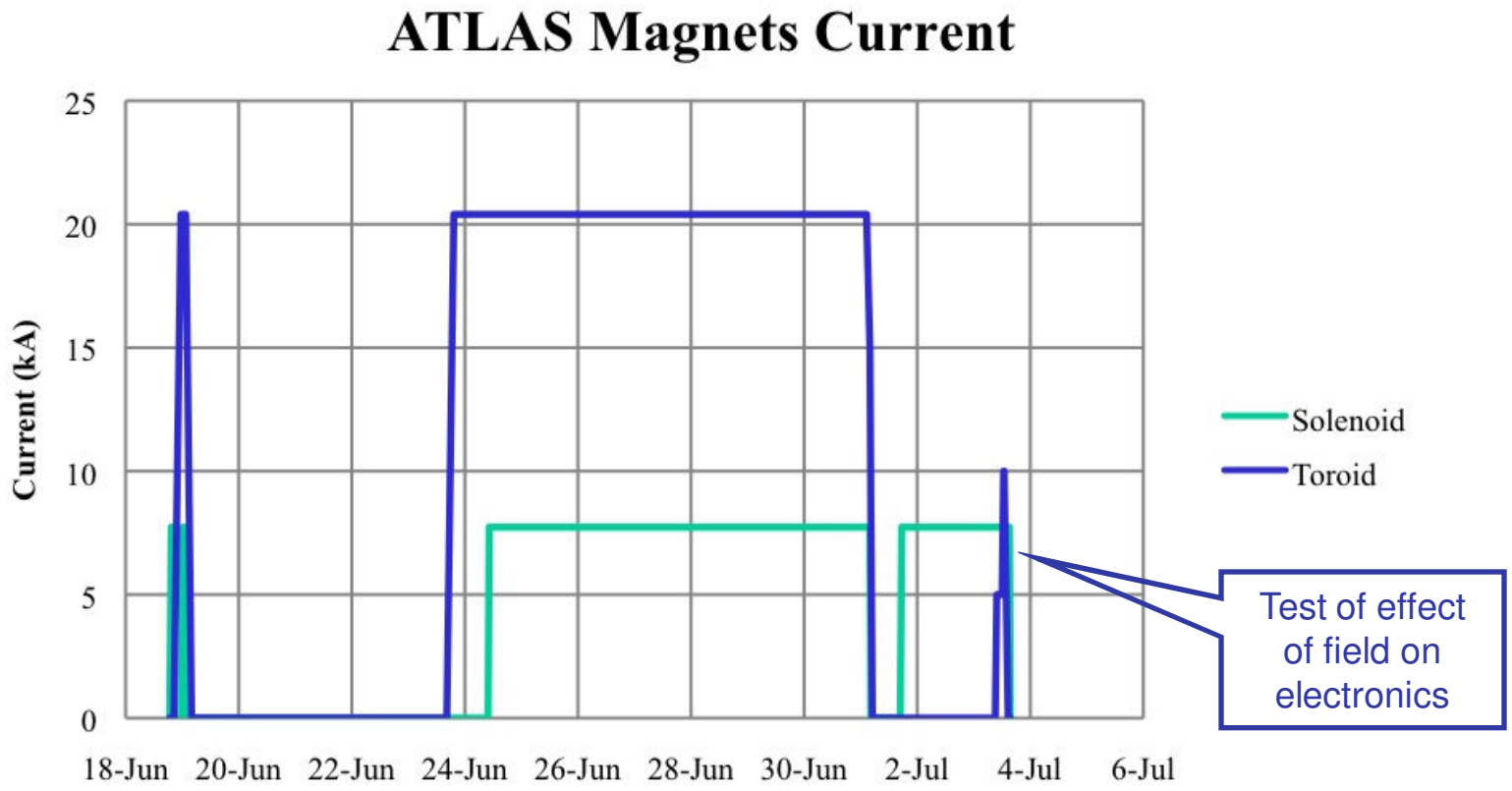
November 2005

Magnet system

- Solenoid
  - 5.8m long, 2.5m diameter.
  - I=7.7 kA, T=4.5 K
  - Uniform field 2 T
- Barrel toroid
  - 8 superconducting coils, each 25 m long, 5m wide, 100 tonnes.
  - I=20.5 kA, T=4.5 K
  - Typical field 0.5 T
- Endcap toroid (x2)
  - 8 coils in common cryostat
  - 11m diameter, 240 tonnes
  - I=20.5 kA, T=4.5 K
  - Typical field 1 T

Magnet system

- The full magnet system has operated for long periods since August 2008.

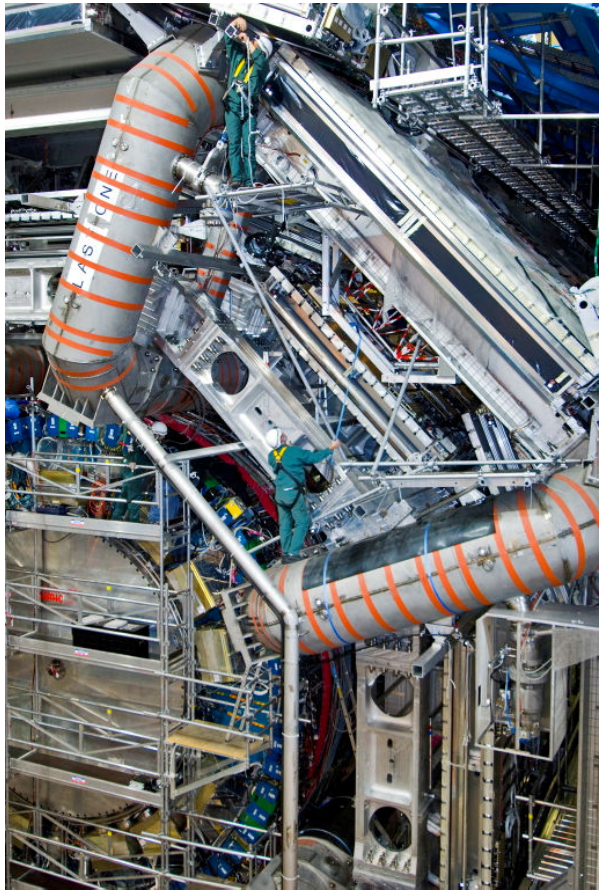


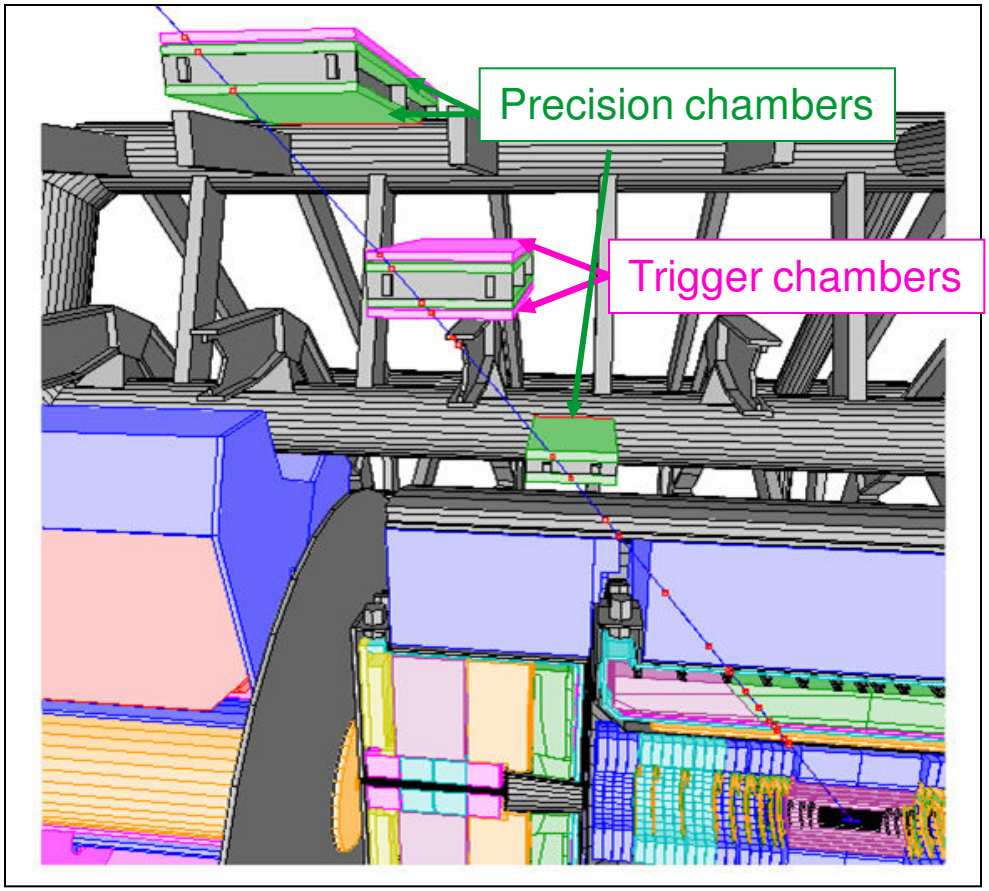
Jun-July 2009

Muon Spectrometer

Muon spectrometer - barrel

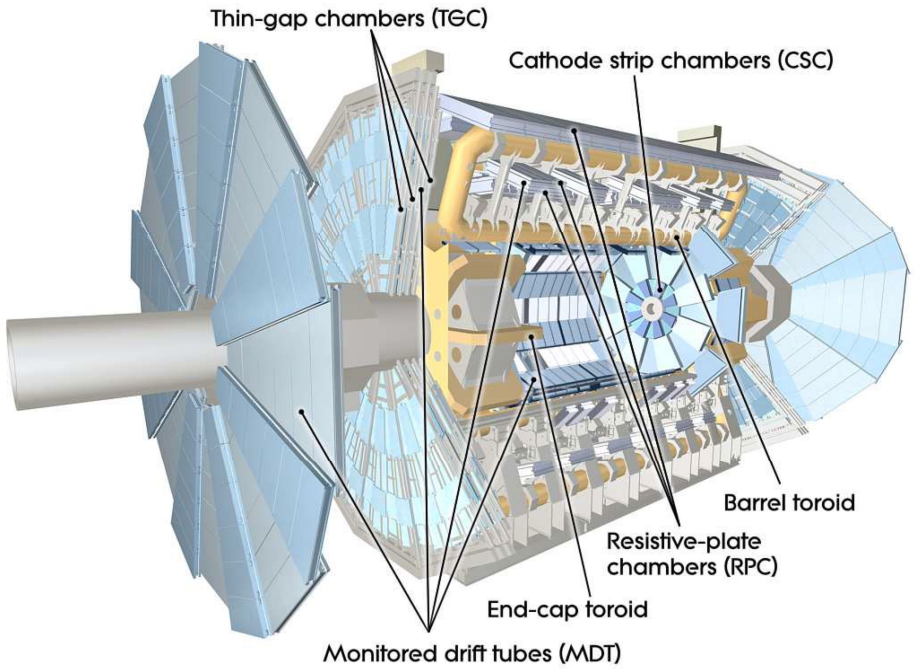
- Muon spectrometer provides trigger and momentum measurement. Momentum resolution <10% up to ~1 TeV
- Barrel toroid field alone $|\eta|<1.4$, overlap with end cap field $1.4<|\eta|<1.6$
- 700 barrel precision chambers (Monitored Drift Tubes)
- 600 barrel trigger chambers (Resistive Plate Chambers, $|\eta|<1.05$)

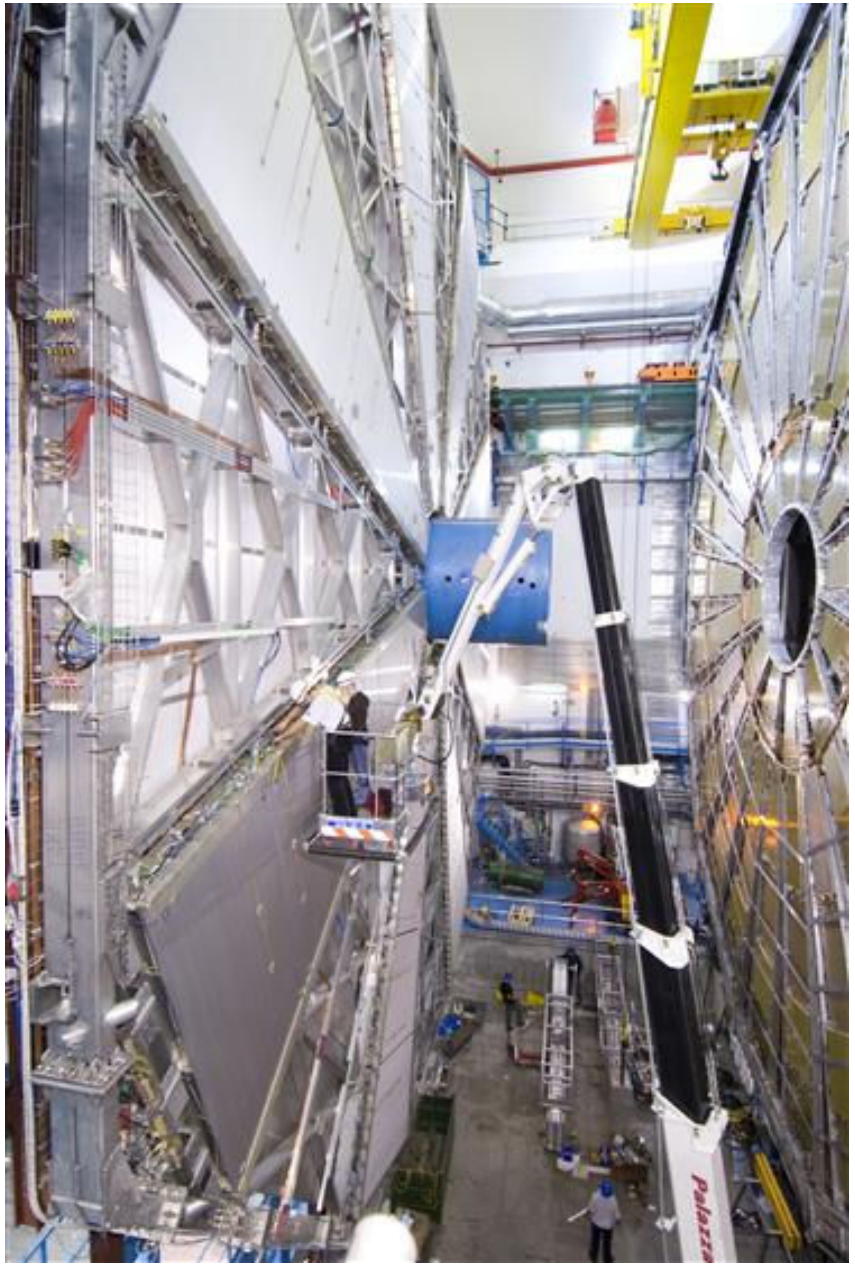




Forward muons

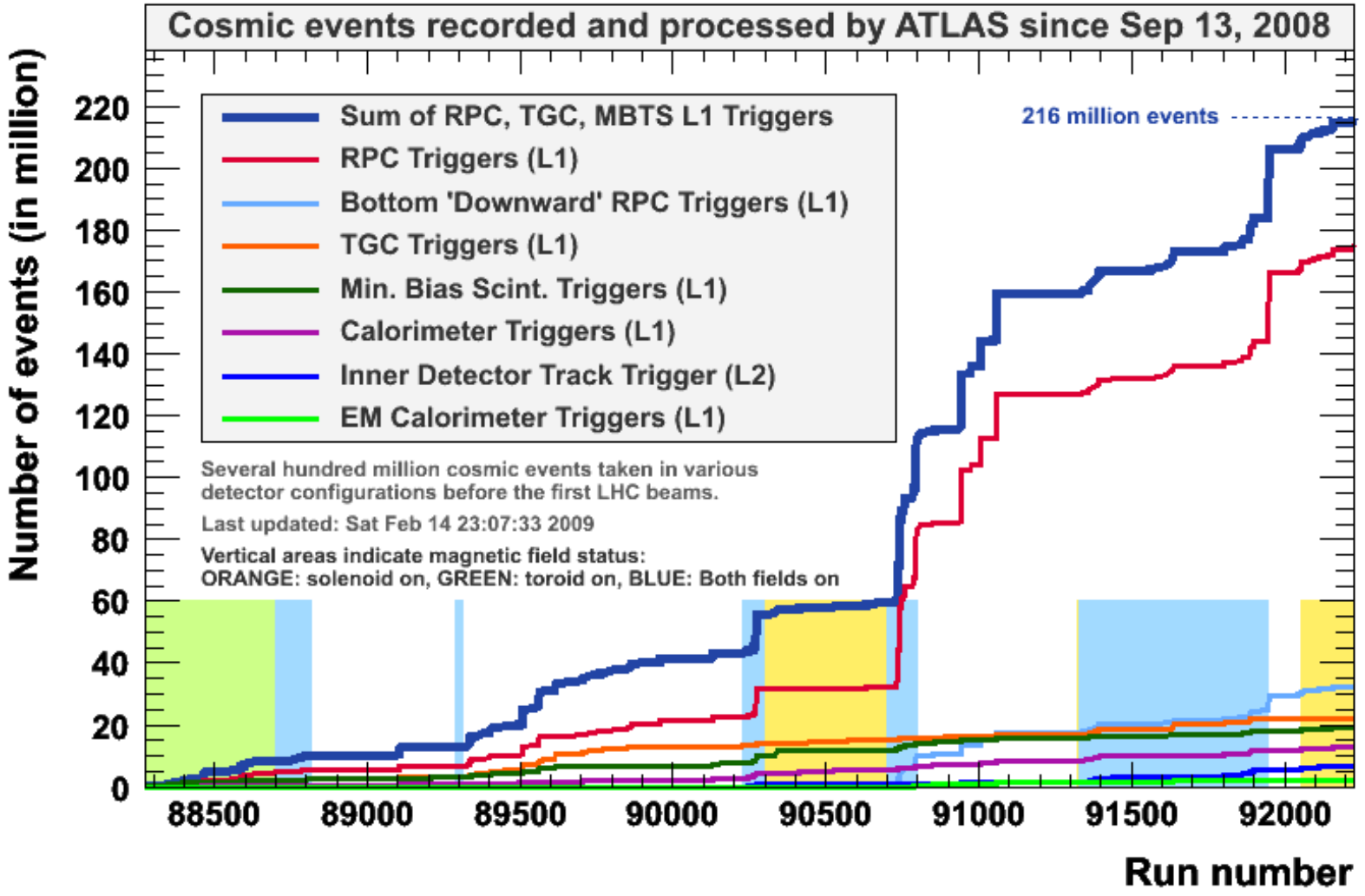
- 400 MDT chambers ($|\eta|<2.7$)
- 32 Cathode Strip Chambers ($2.0<|\eta|<2.7$)
- 3600 Thin Gap Chambers ($1.05<|\eta|<2.7$, 2.4 for trigger)

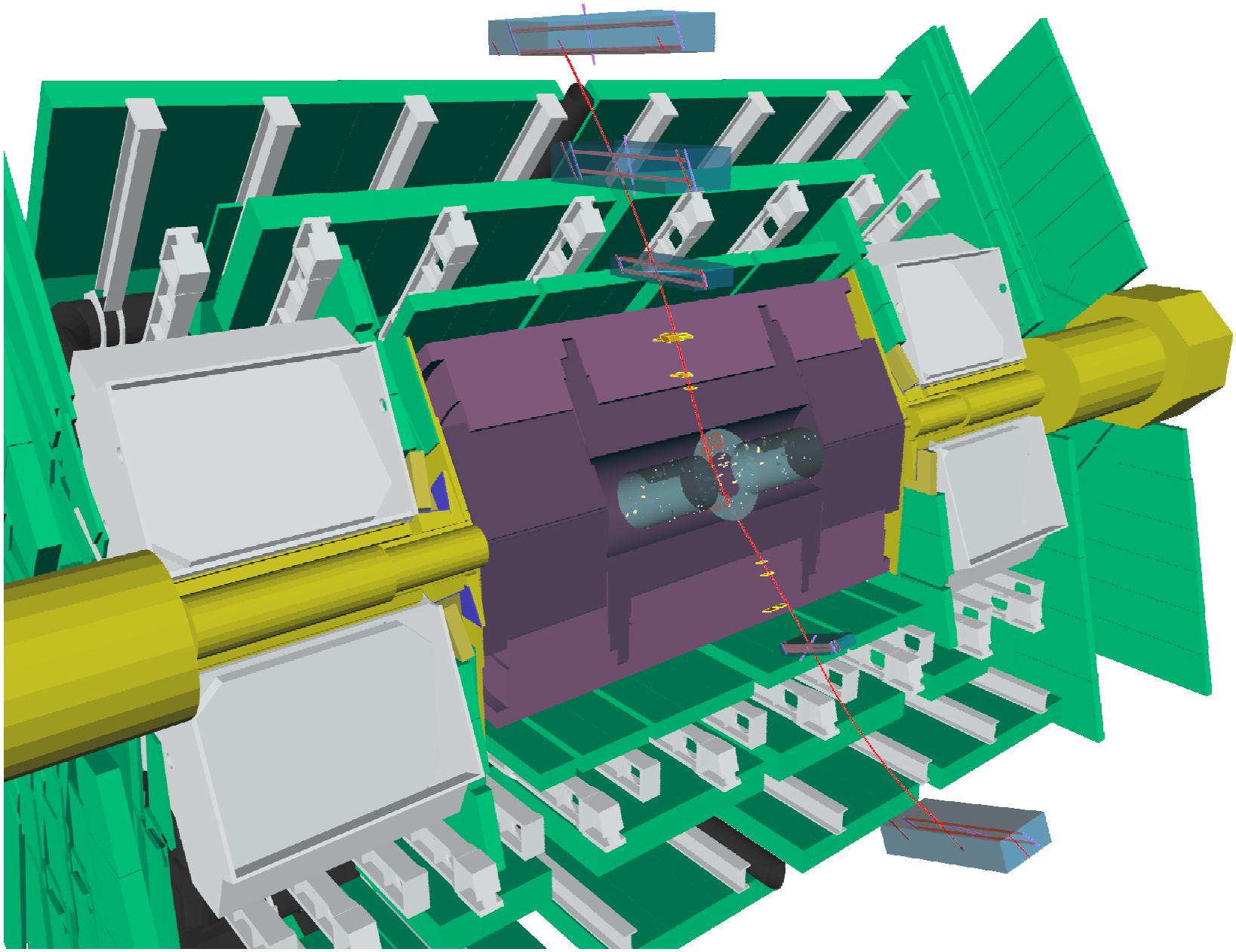




Cosmic ray events

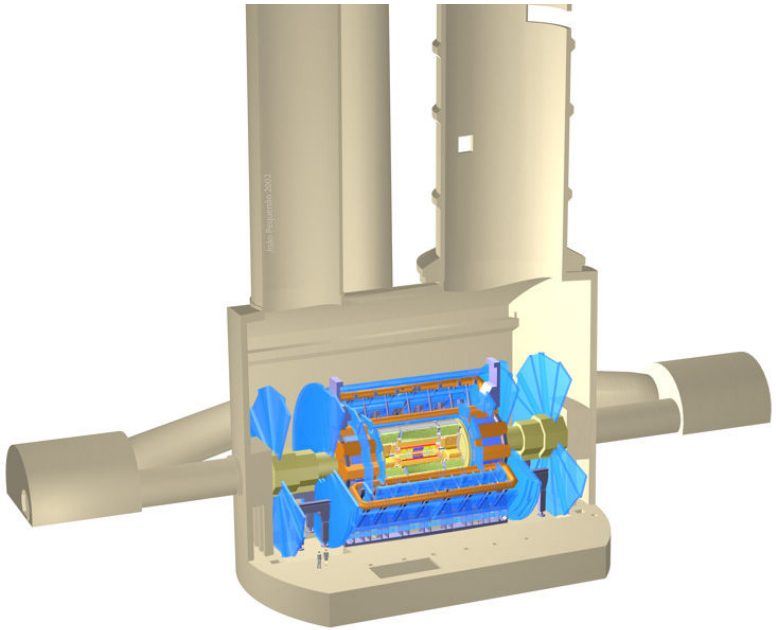
- Total of 216 million cosmic ray events in autumn 2008.
- Up to 700 Hz events in ATLAS. <1Hz in Pixel detector.

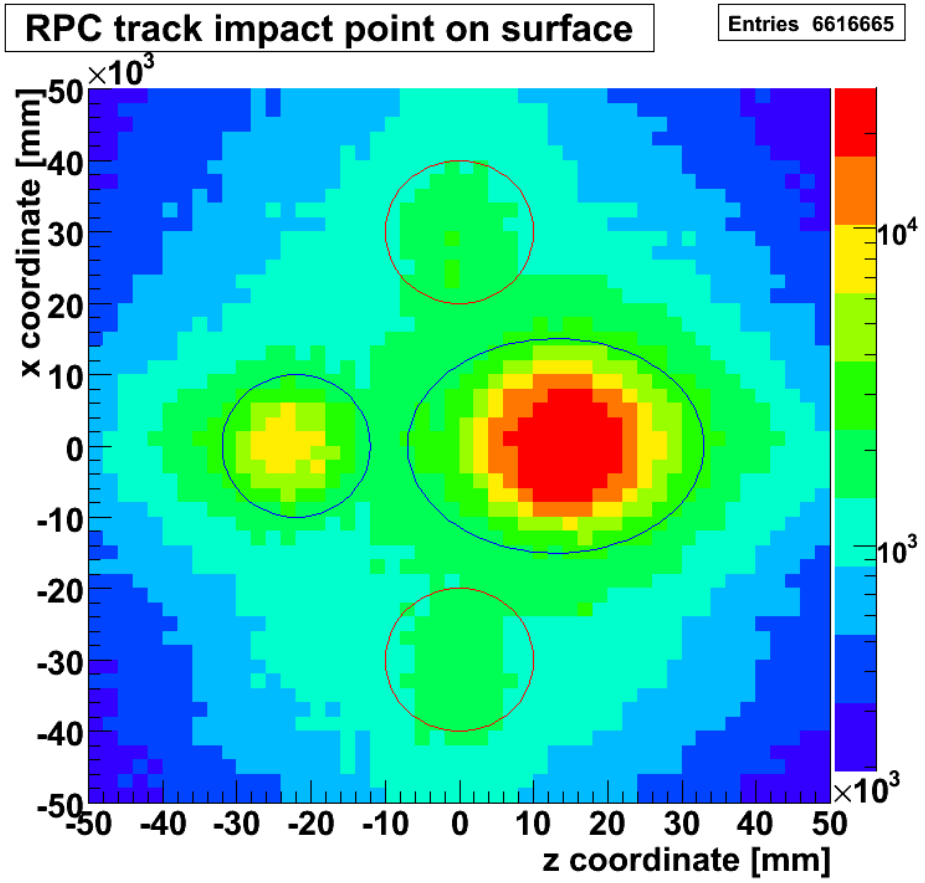




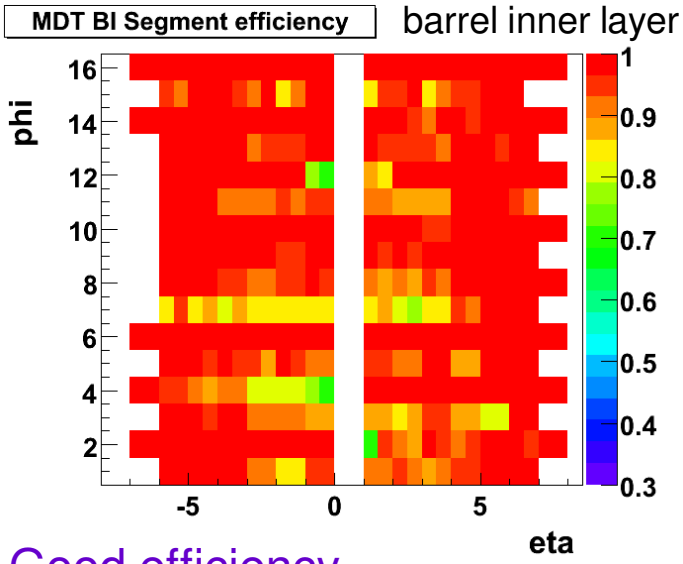
Cosmic muon map at surface

- RPC standalone muon tracks are projected to ground level (81m above centre of ATLAS)
- The two main access shafts and two smaller elevator shafts are visible



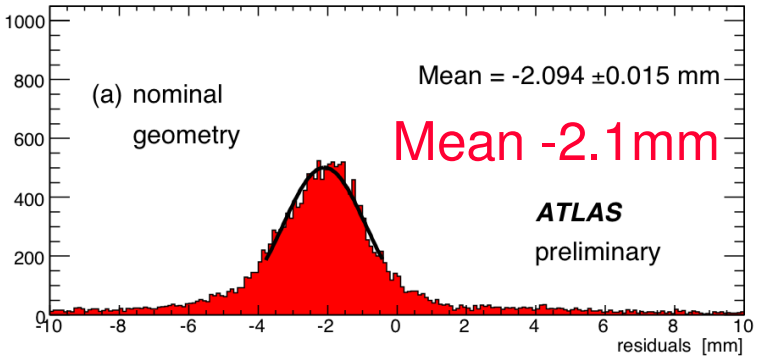


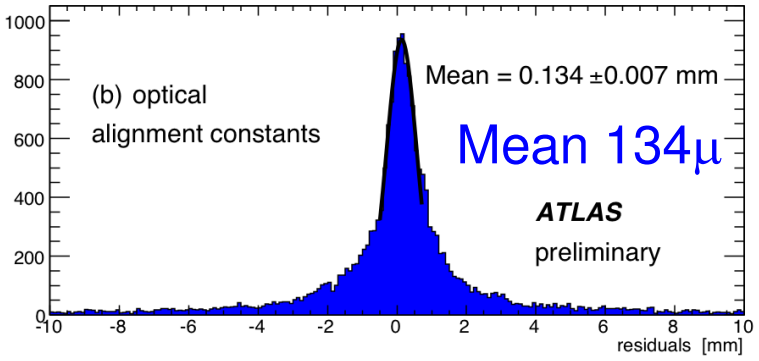
MDT performance

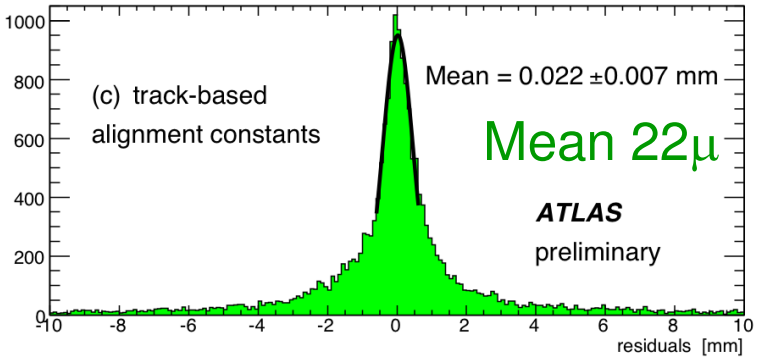


- Good efficiency
- Alignment with cosmic rays (no field, straight tracks):
  - Measure sagitta, in the middle barrel chamber, and in the precision plane. (Sagitta for 1 TeV muon is ~500μm)
  - Expected mean sagitta with good alignment is <30μ, to achieve 10% σ/p at 1 TeV.

Top sectors with no B field



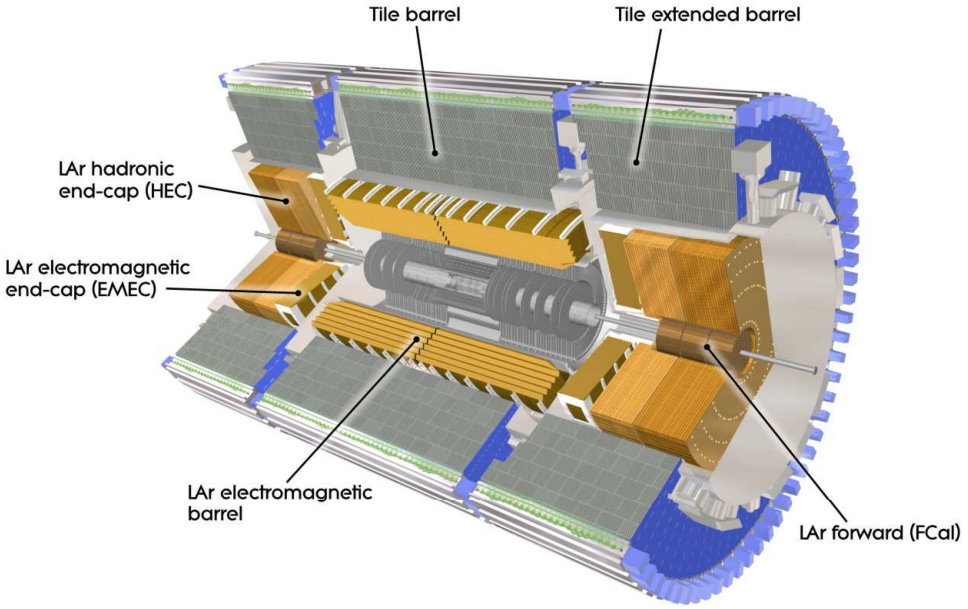


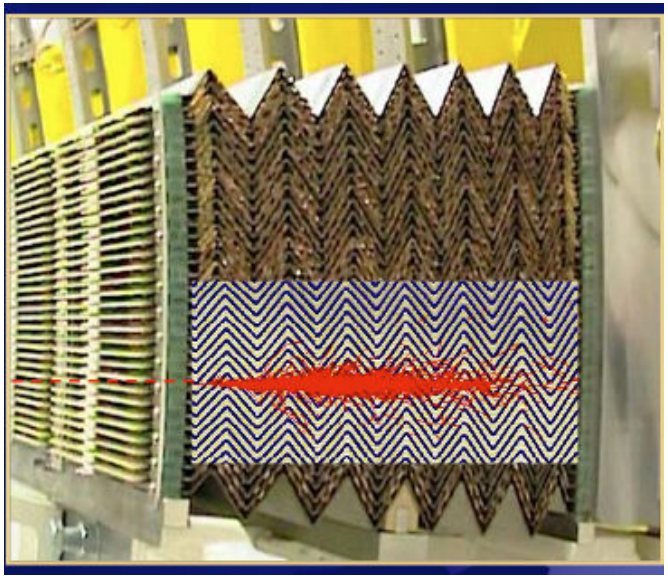


Calorimeters

Calorimeters

- Electromagnetic ($|\eta|<3.2$):
  - Pb-LAr Accordion
  - e/γ trigger, identification and measurement
    $\sigma/E \sim 10\%/\sqrt{E} \oplus 0.7\%$

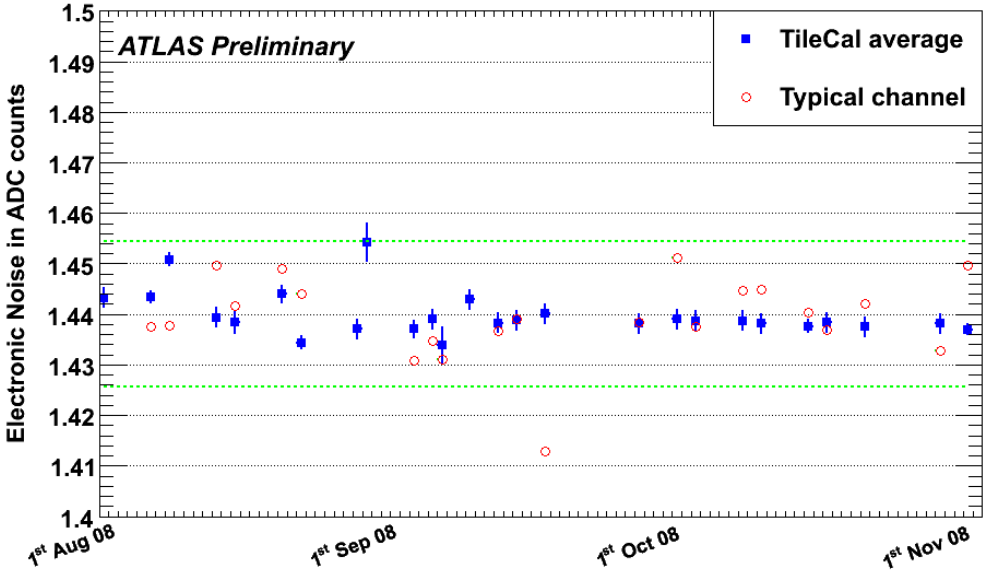


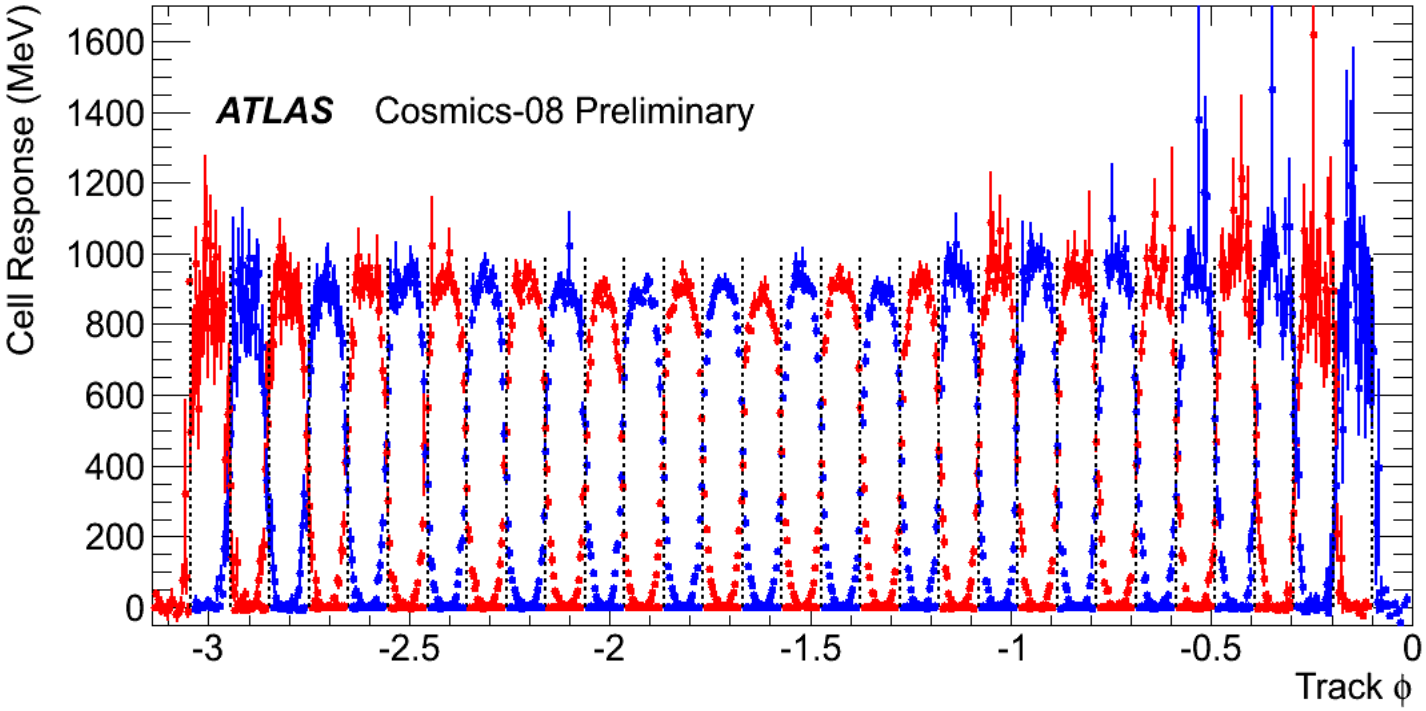


- Hadronic ($|\eta|<4.9$):
  - Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
  - Trigger, measure jets and missing E_T
    $\sigma/E \sim 50\%/\sqrt{E} \oplus 3\%$

Tile calorimeter

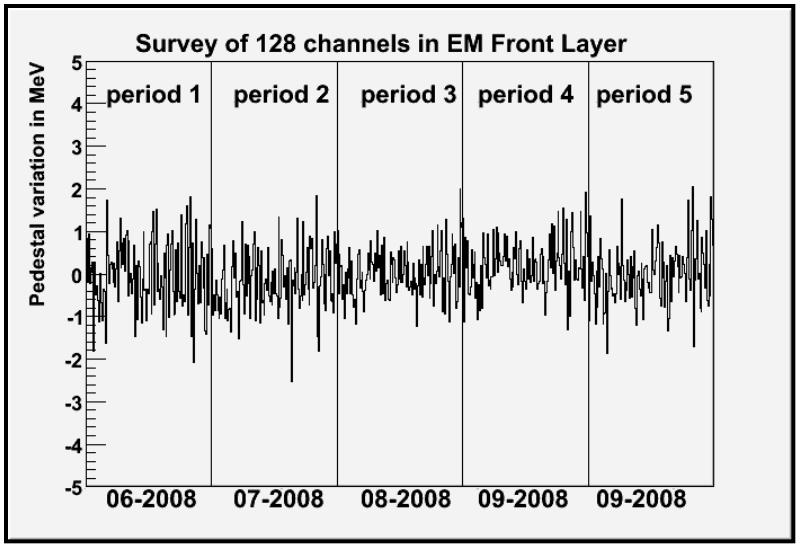
- Noise in random events is stable over months
- Cell uniformity from extrapolated ID track position in phi



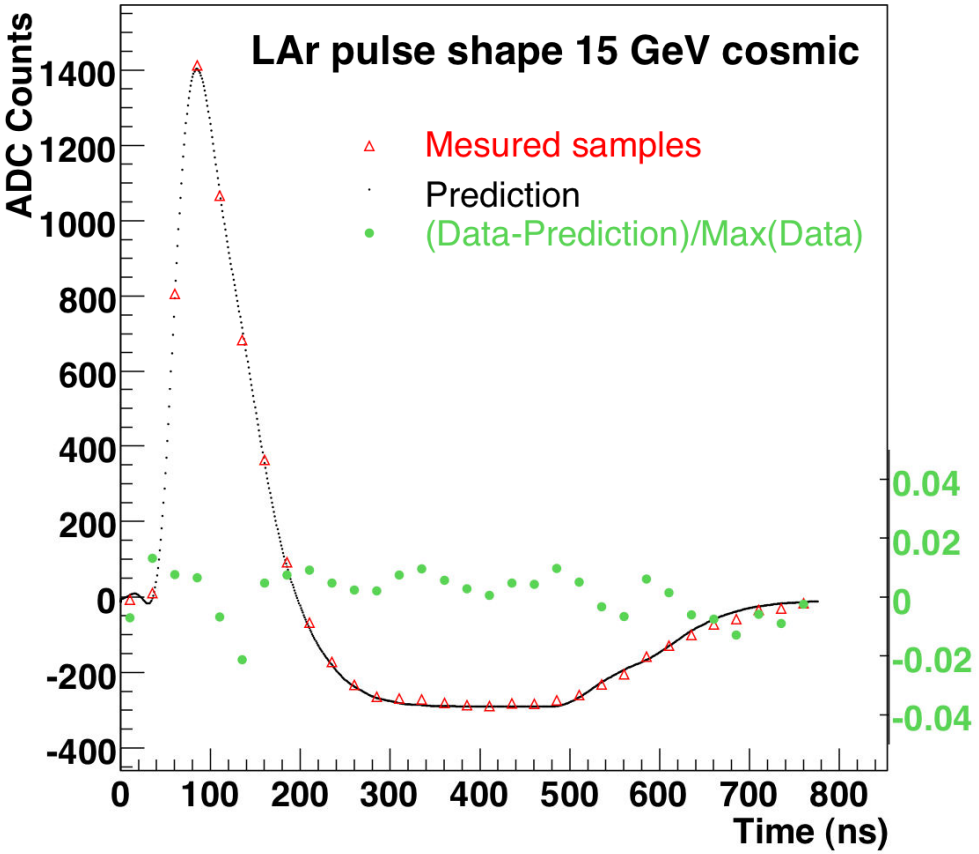


Liquid Argon calorimeter

- Checked uniformity of response and stability.
- Pulse shape distribution shows good agreement with prediction.



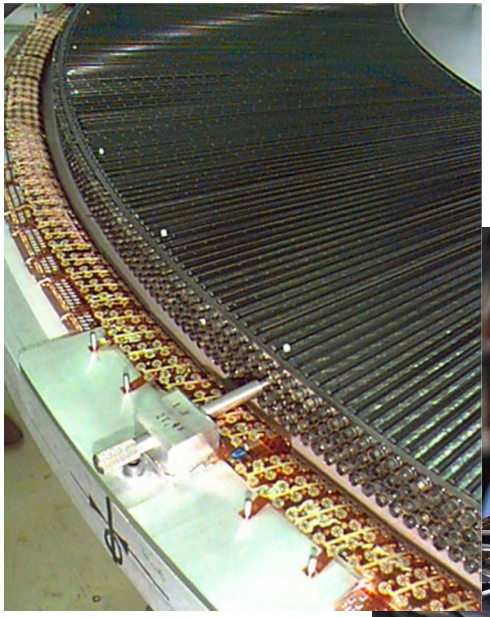
June to September 2008



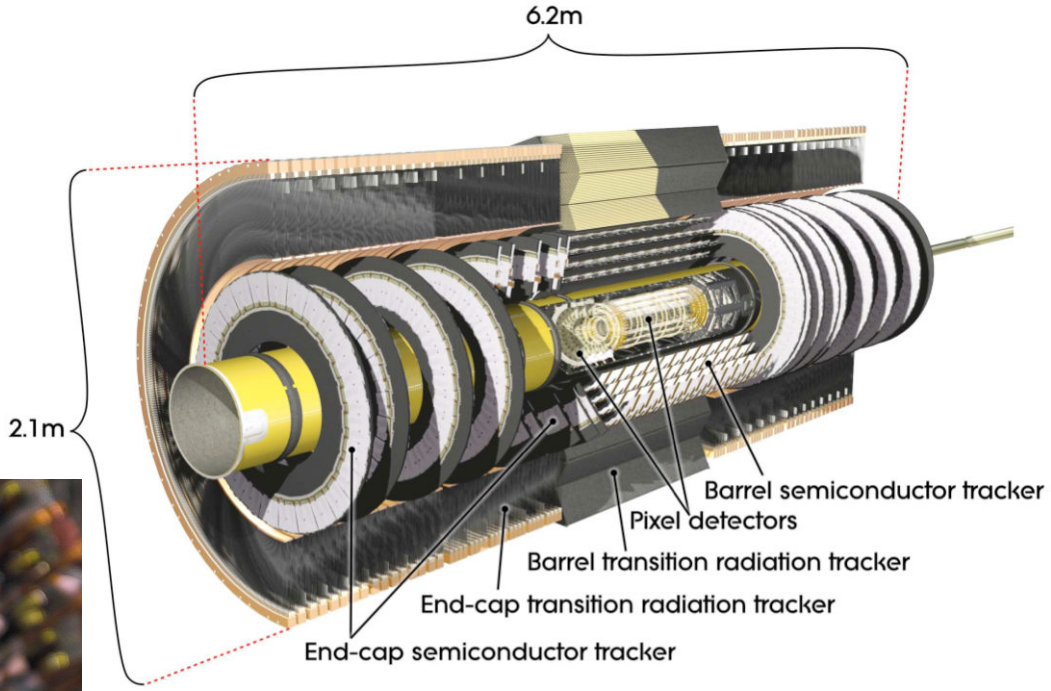
Inner Detector

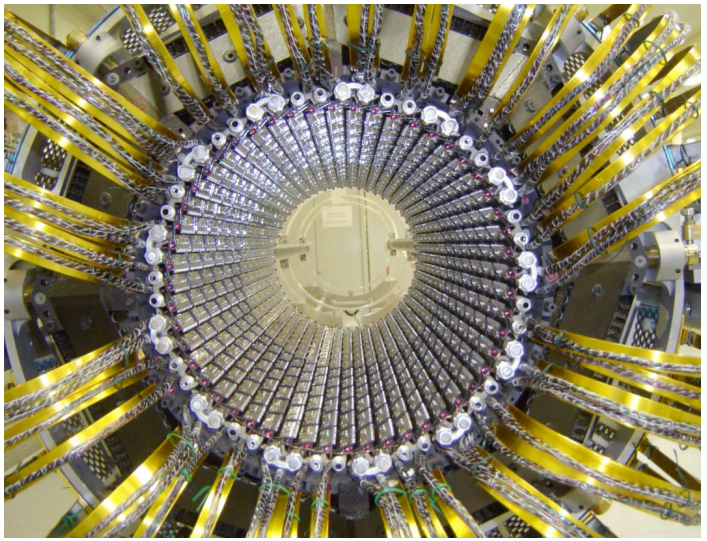
Inner detector

TRT EC straws+radiator foils



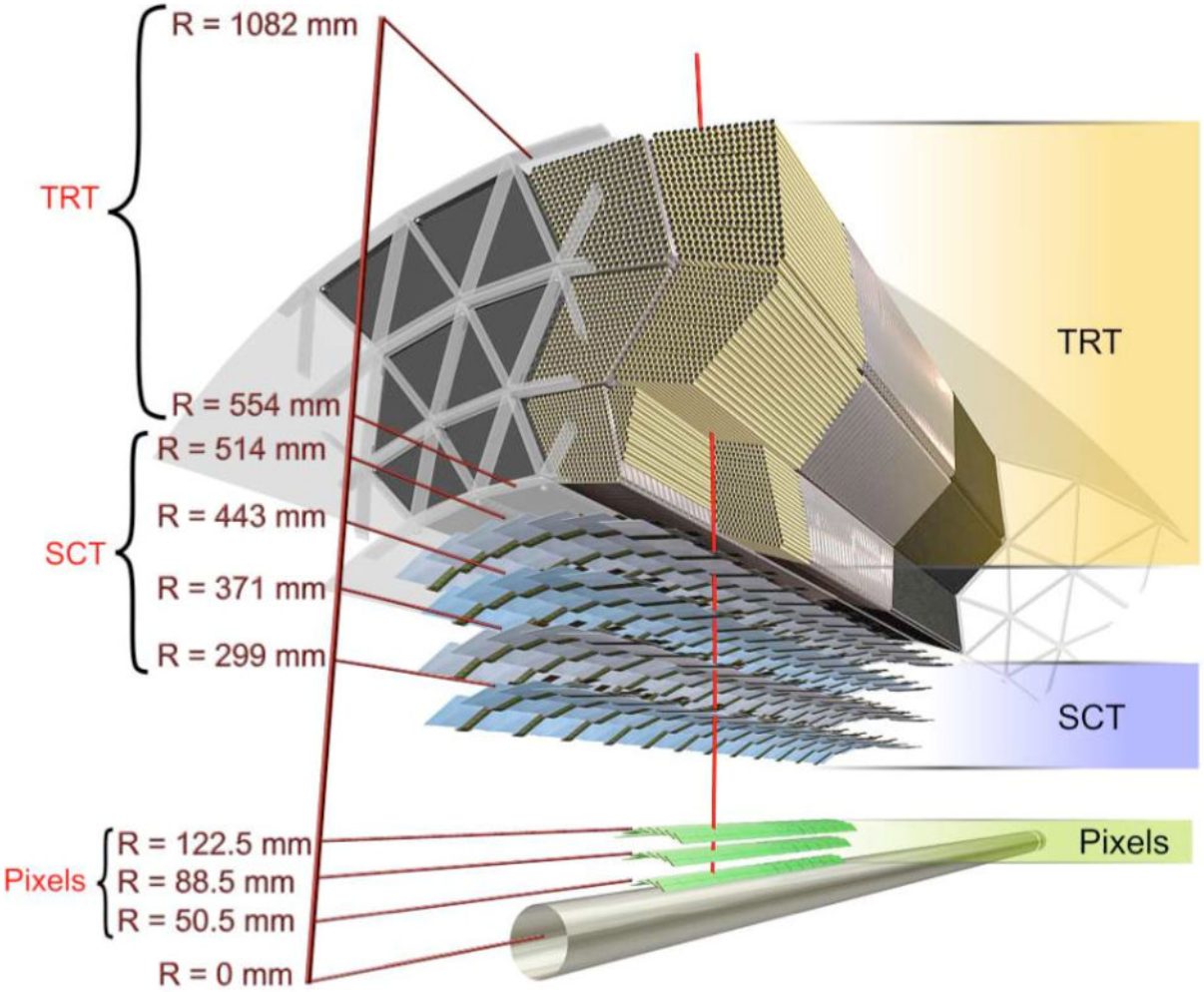
SCT barrel





Pixel barrel

Inner detector



Barrel track passes:

- 36 TRT straws
- 4x2 silicon strips
- 3 pixels

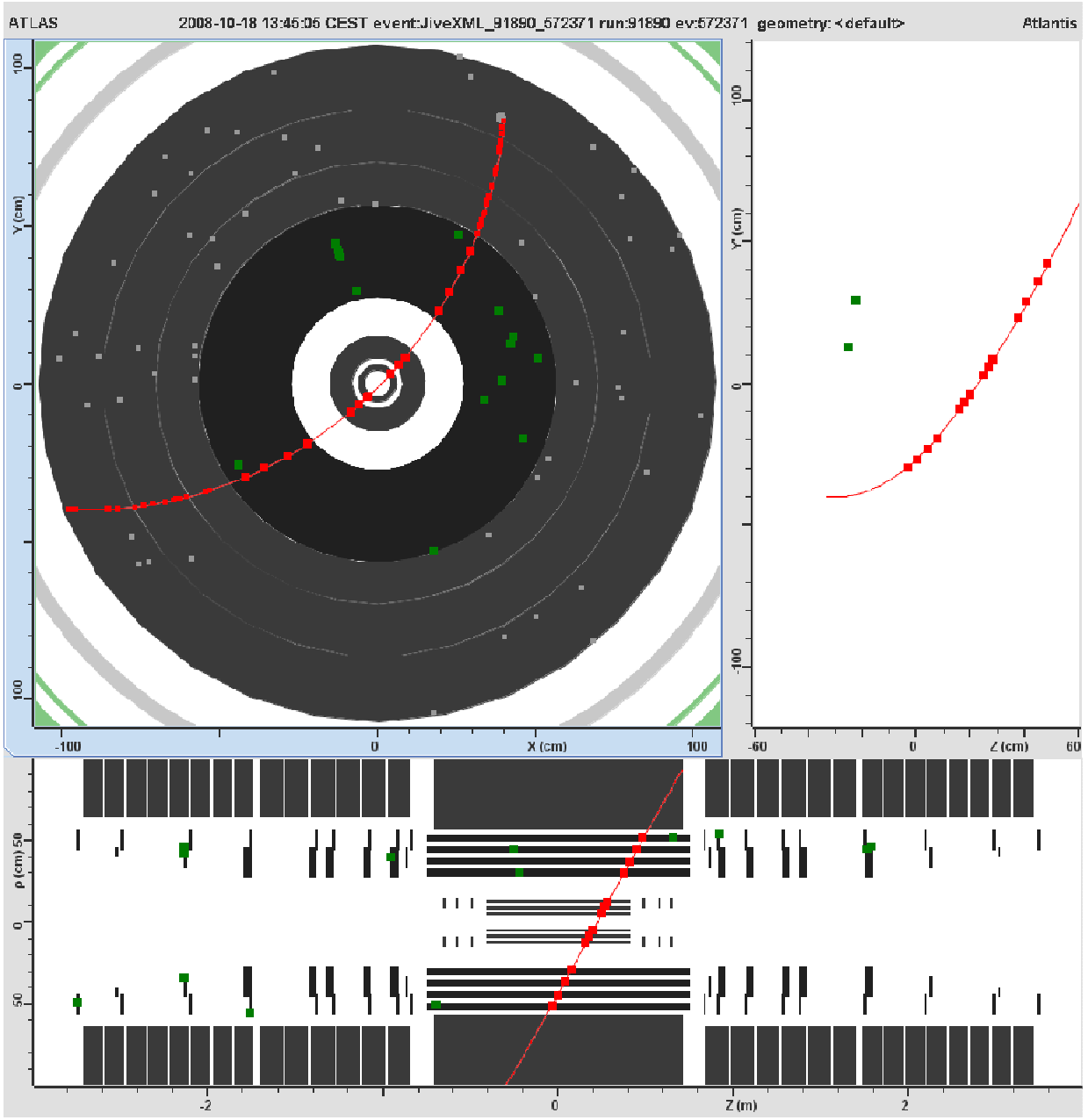
Total ID ($|\eta|<2.5$) has:

- TRT: 400k 4 mm straws
- SCT: 6.3M ~80μ strips, on 4088 modules with 40mrad stereo angle.
- 80M 50x400μ Pixels, on 1744 modules.

Expect $\sigma/p_T \sim 3.4\times10^{-4}\ p_T(\text{GeV}) \oplus 0.015$

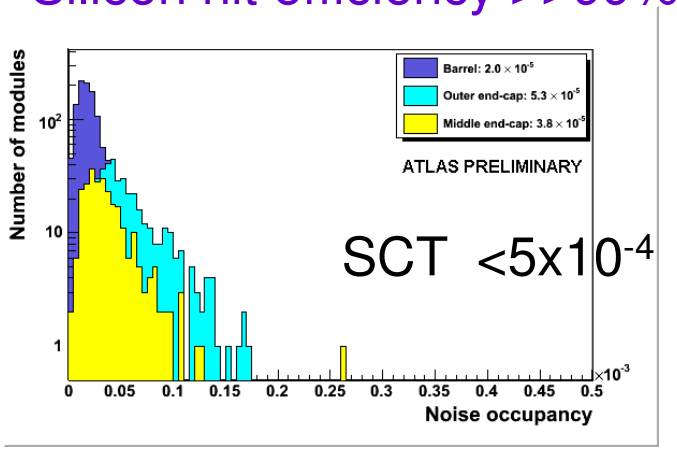
ID Cosmic ray track

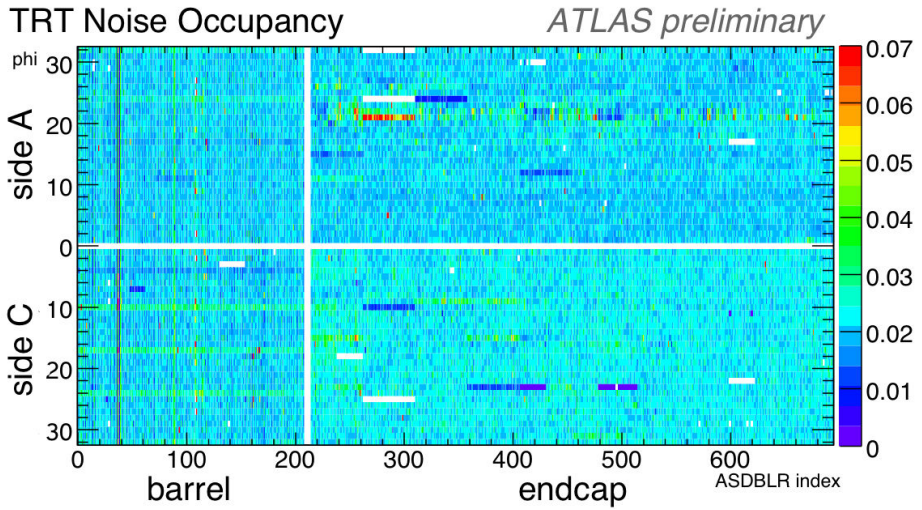
Out of 216 M total cosmic ray events, 7.6 M through ID, 420k with at least one pixel hit

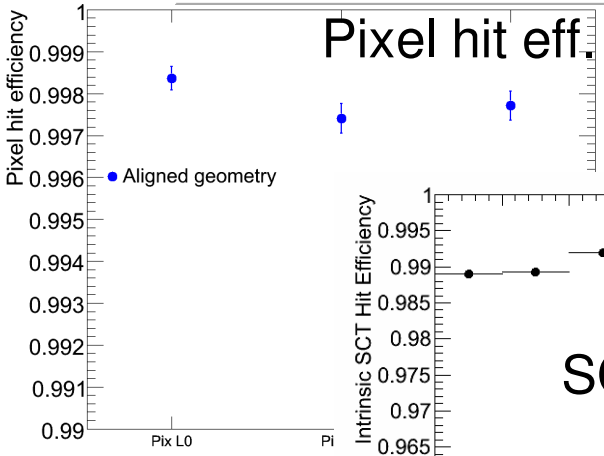


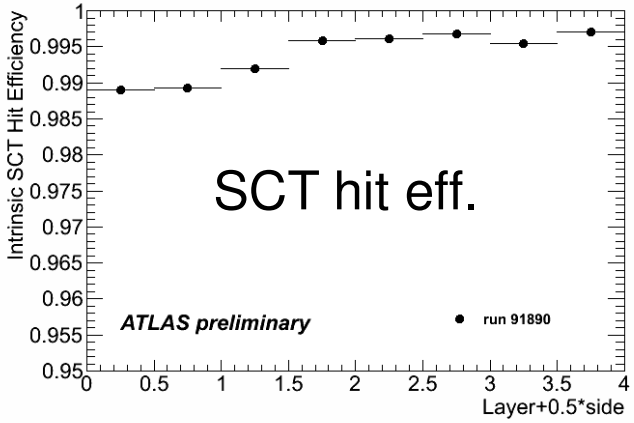
ID noise occupancy and hit efficiency

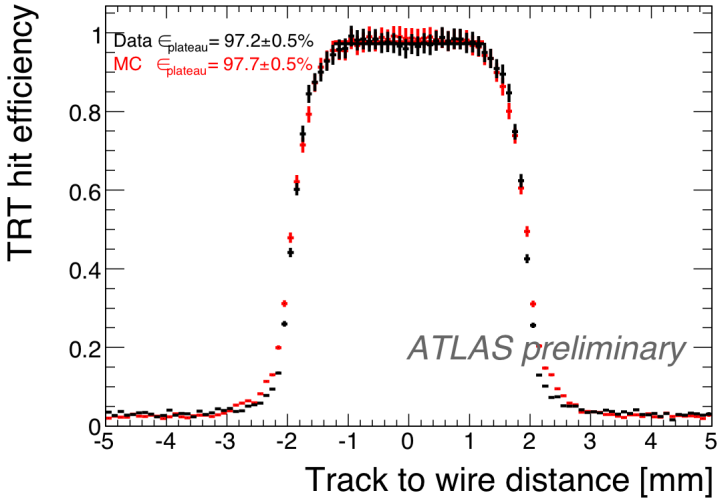
- Pixel noise occupancy < 10^{-9}, SCT < $5x10^{-4}$, TRT set to 2%.
- Silicon hit efficiency >>99%, TRT >97%



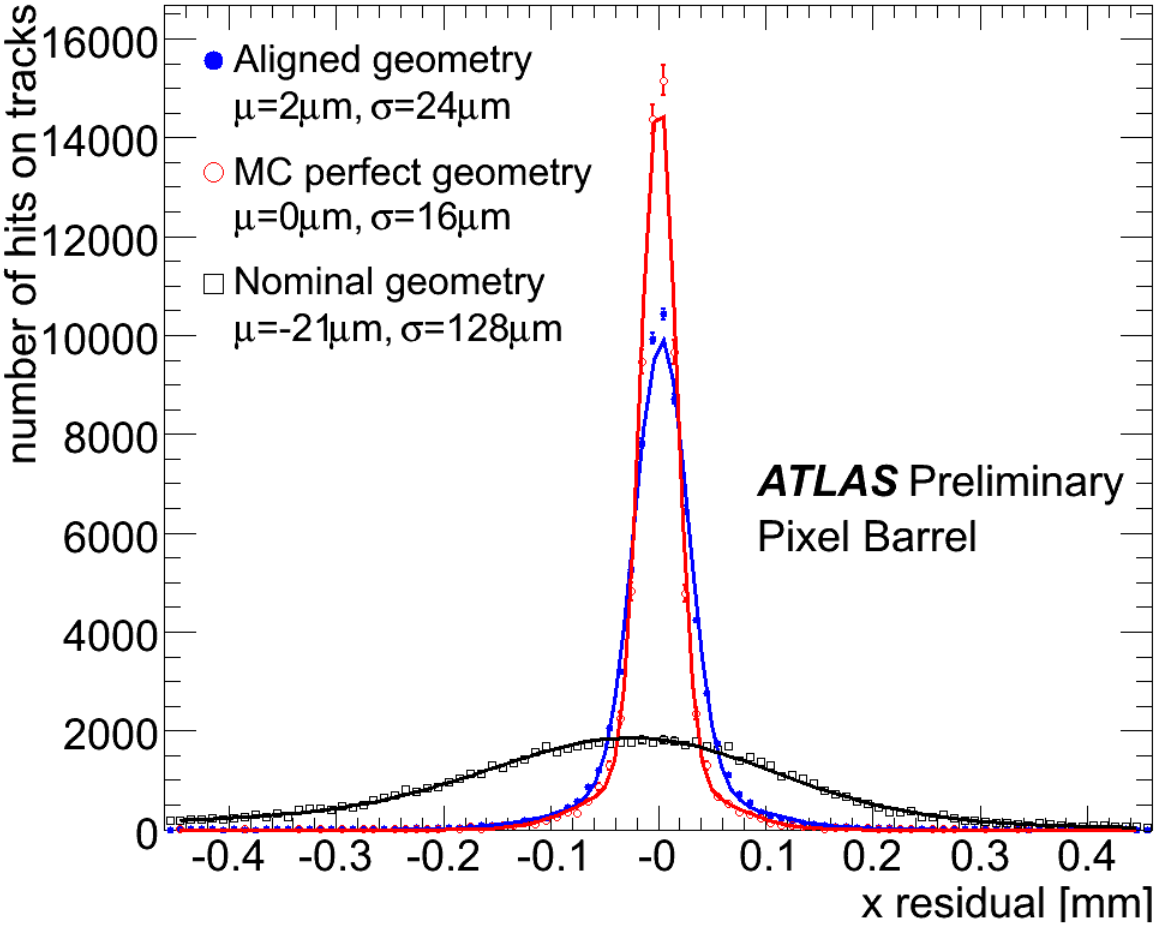






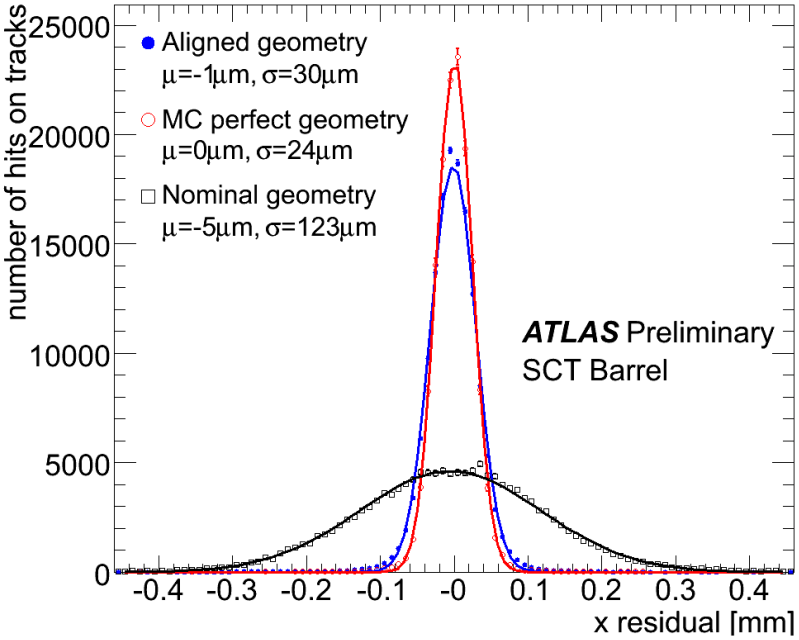


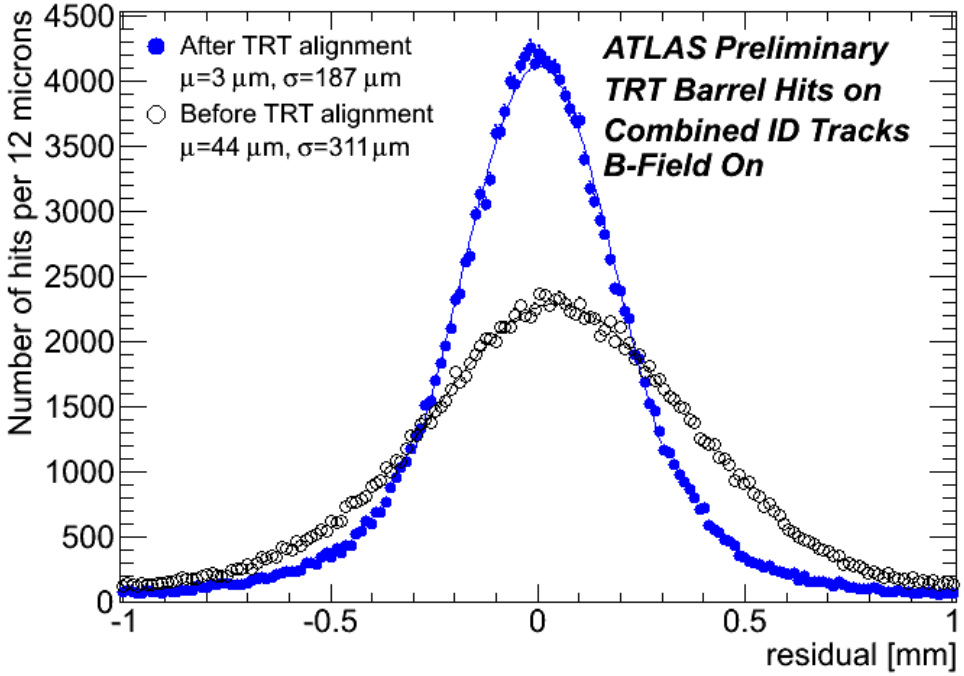
ID Alignment with cosmic ray tracks



- Pixel x resolution: perfect 16 μ, achieved 24 μ
- Pixel y resolution: perfect 127 μ, achieved 131 μ

SCT and TRT alignment

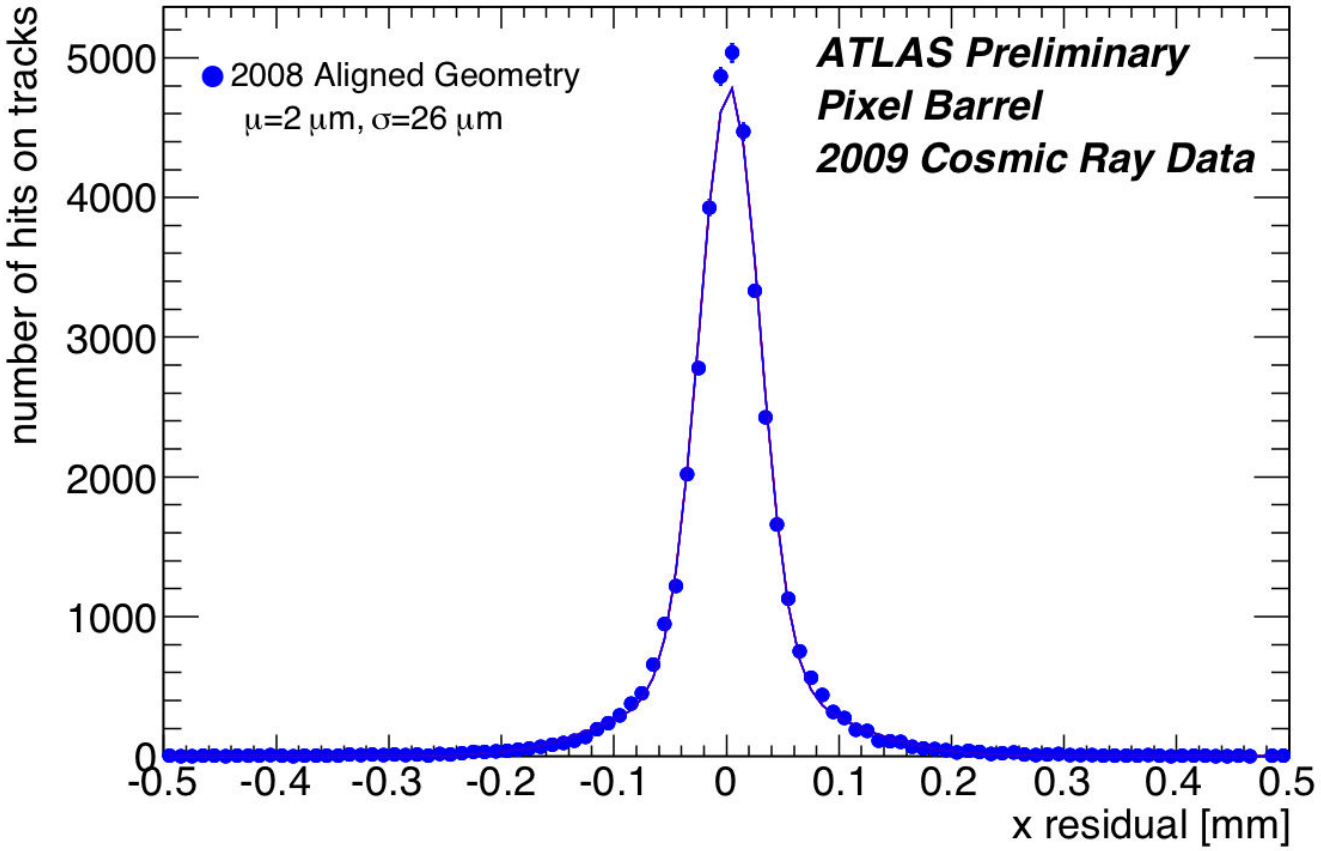




- SCT residuals resolution: perfect 24 μ, achieved 30 μ
- TRT stand-alone alignment and alignment with full ID tracks are in good agreement

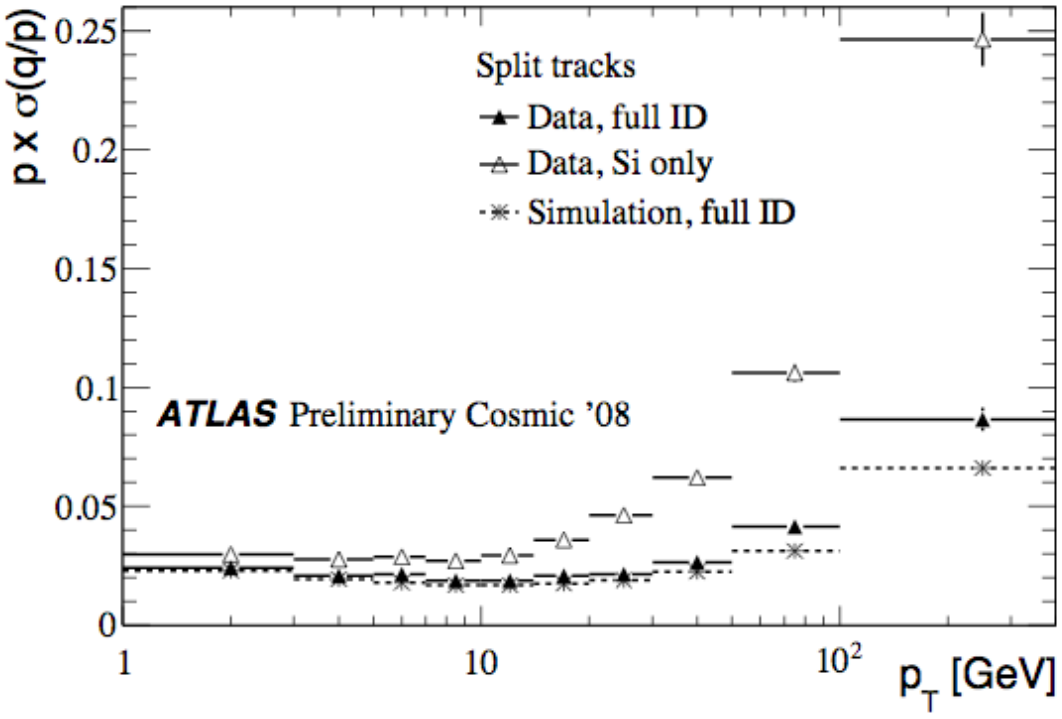
Alignment stable 2008 to 2009

- 93 million events recorded between June 22 and July 5, 2009.
- Pixel x alignment using 2008 constants directly for 2009 sample
- Resolution only increases from 24 to 26 μ – detector very stable



ID track reconstructcion

- Split cosmic tracks which pass through the whole ID into upper and lower hemisphere and refit two tracks.
- Direct measurement of track resolutions

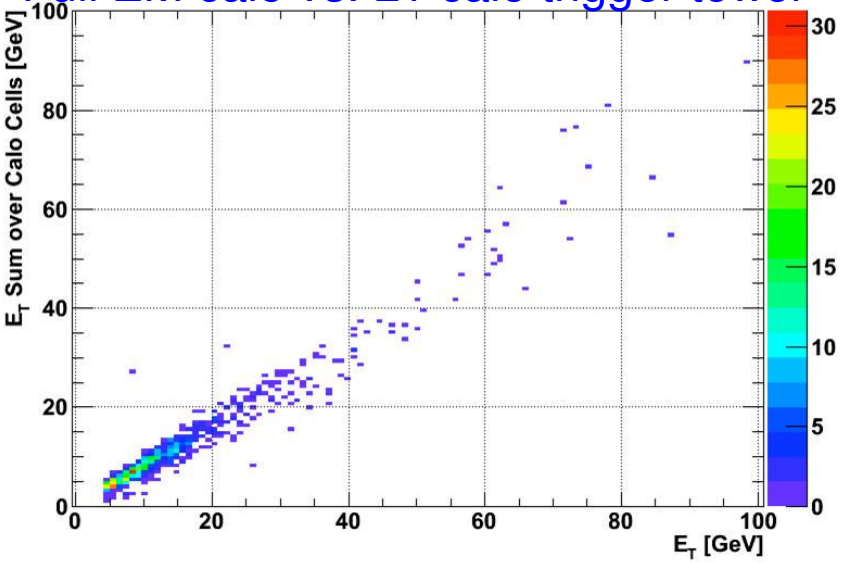


Trigger

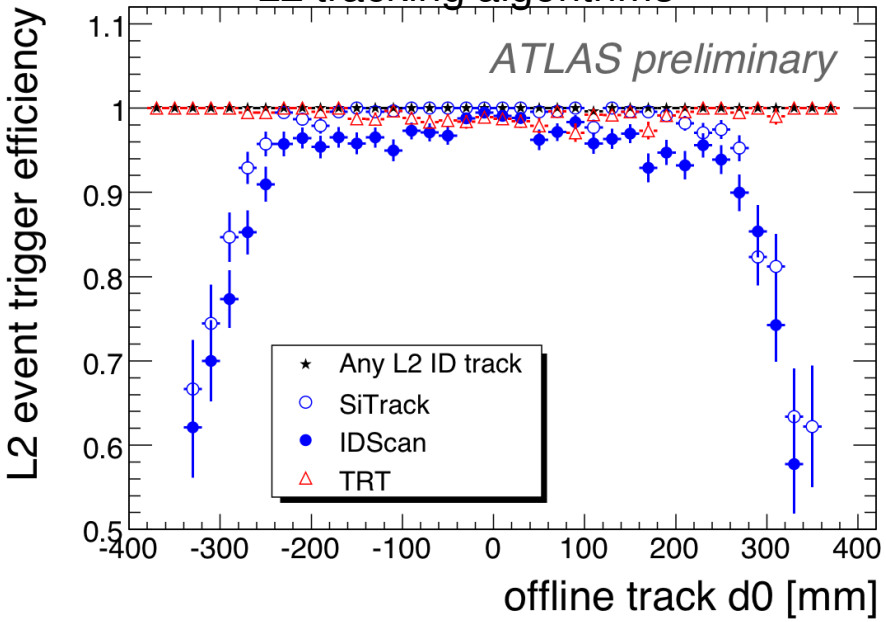
Trigger

- For pp data, 3-level trigger reduces the event rate from 40 MHz to ~200 Hz
- All levels were tested with cosmic rays
- Tracking algorithms adjusted for geometry

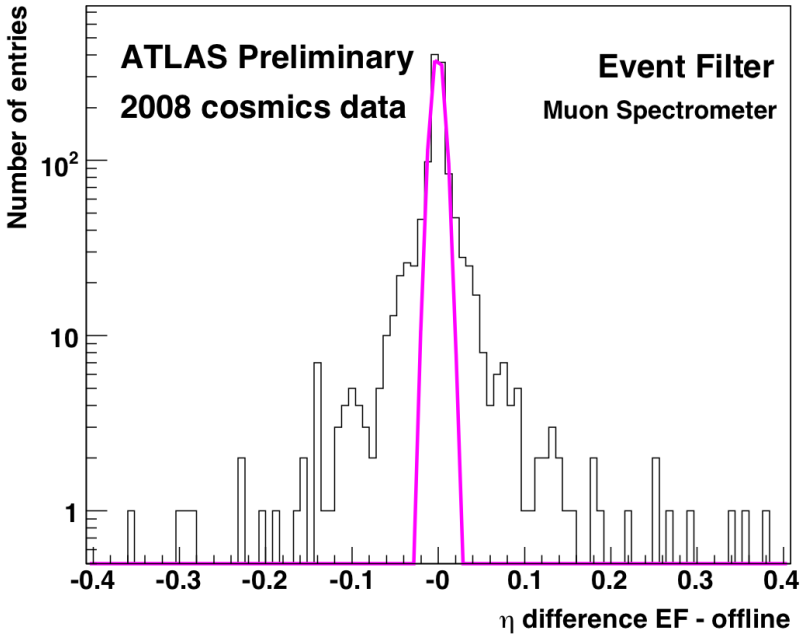
Full EM calo vs. L1 calo trigger tower



L2 tracking algorithms



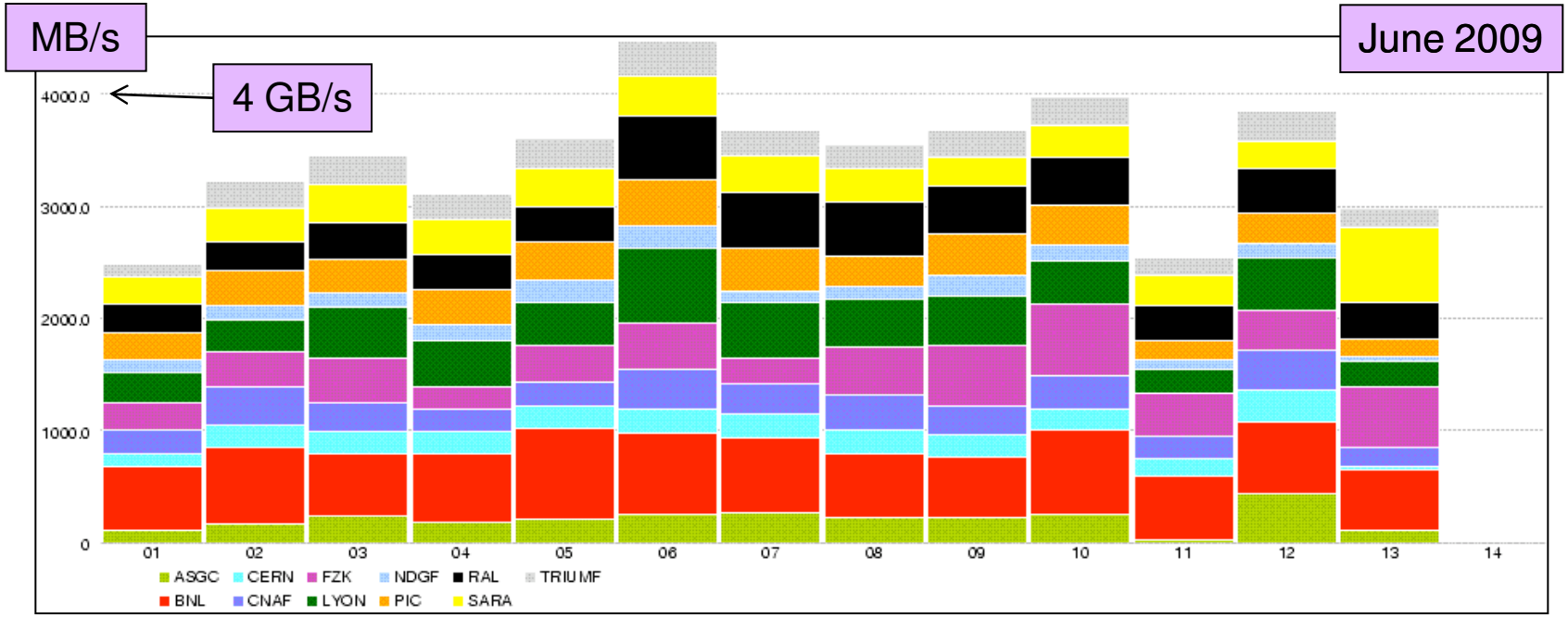
Event filter - offline reco.



Computing

Computing infrastructure & operation

- Cosmic ray data from 2008 have been reprocessed twice with improved calibrations or additional algorithms. Monte Carlo production running in parallel.
- Higher than nominal data transfer (Tier0 to Tier-1s and between Tier-1s) sustained over 2 weeks (1-2GB/s at LHC).



Overall performance

ATLAS efficiency

- Running efficiency ~83% for simulated LHC fills in Jun-Jul 2009
- Single hit efficiencies of each detector layer excellent for operational parts, but what fraction will be operational?

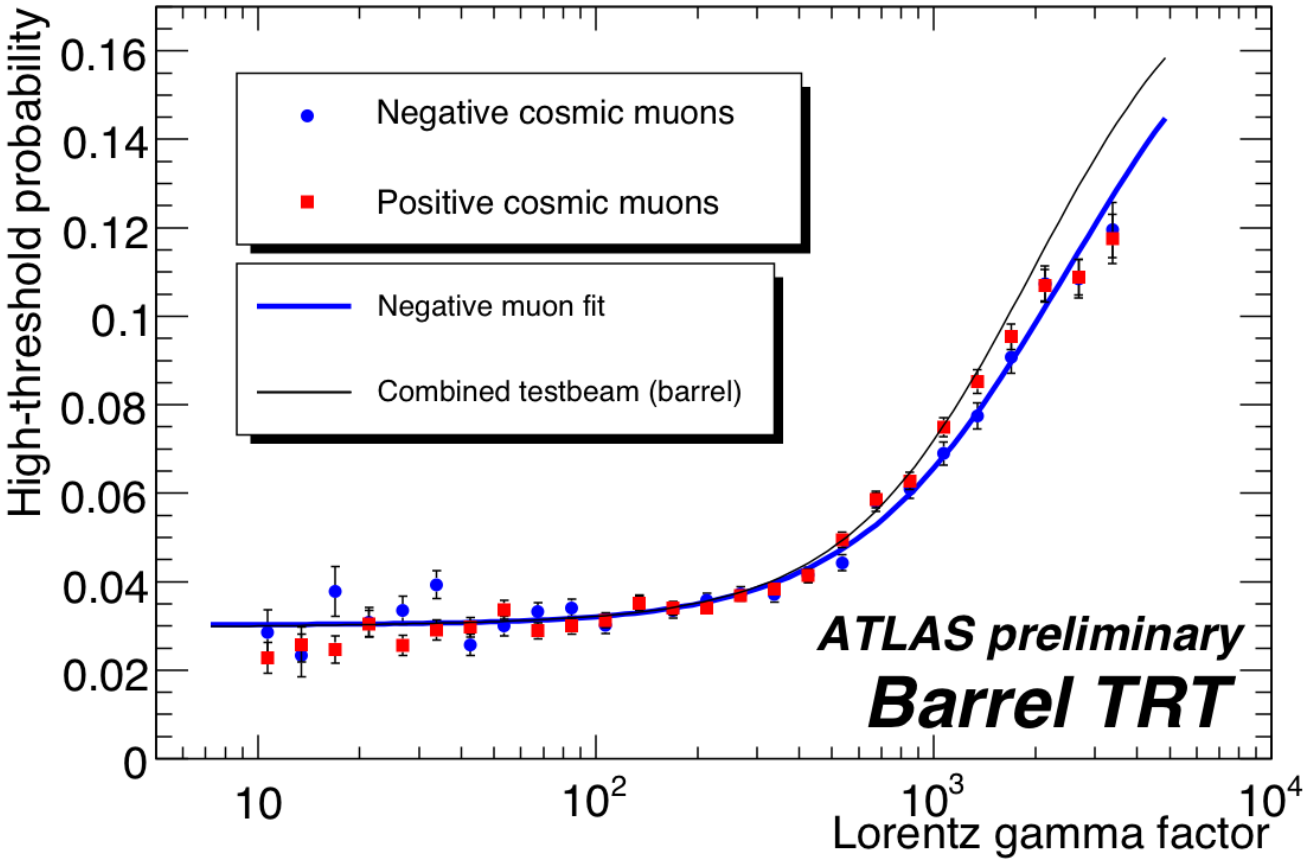
Sub-detector	Number of channels	Operational fraction (%)
Pixel	80 M	98.5
SCT silicon strips	6.3 M	99.5
TRT transition radiation tracker	350 k	98.2
LAr EM calorimeter	170 k	99.1
Tile calorimeter	9800	99.5
Hadronic endcap LAr calorimeter	5600	99.9
Forward LAr calorimeter	3500	100
MDT muon drift tubes	350 k	99.3
CSC muon endcap	31 k	98.4
RPC barrel muon trigger	370 k	~95.5 (aim >98.5)
TGC endcap muon trigger	320 k	99.8

Work in progress

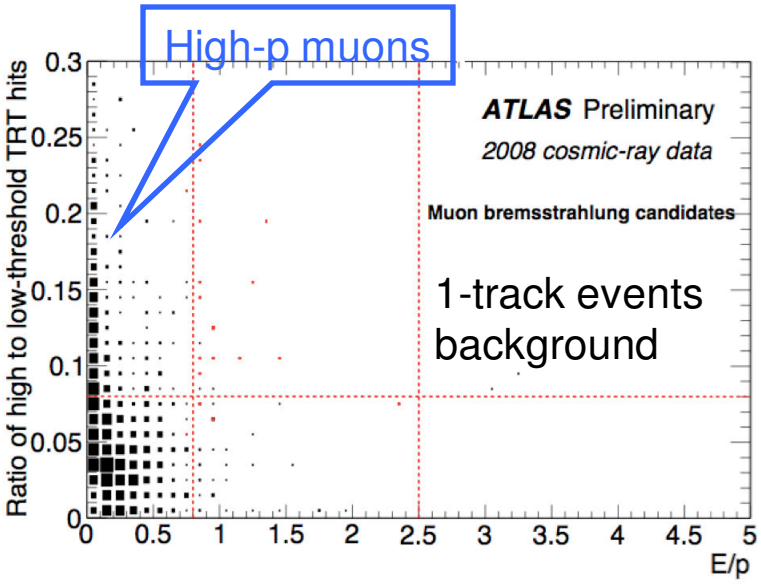
- Consolidation work has been done on the detector during the shutdown, eg.
  - Installation of more “EE” muon chambers to improve the coverage in the forward region (missing chambers are not included in the assessment of “operational fraction”)
  - Hardware fixes and more robust synchronisation for RPC
  - Refurbishment of LAr and Tile power supplies
  - Optical transmitters of LAr, SCT and Pixel
  - Inner detector evaporative cooling plant and distribution racks
- Concerns about long term reliability of some of these parts, and replacement solutions are being studied for installation in a future long shutdown.
- Continuous improvements to operational procedures.

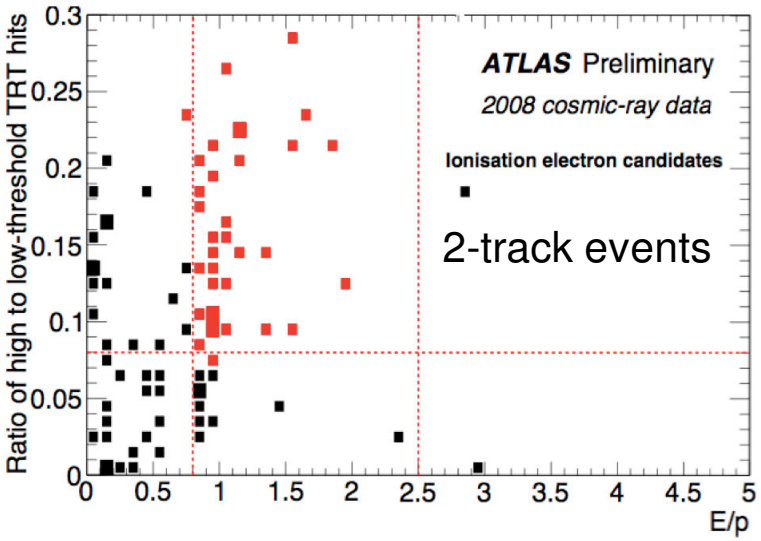
Transition radiation

- TRT will be used for e/π separation.
- Highest energy cosmic rays also produce transition radiation (increased chance of high threshold hits).

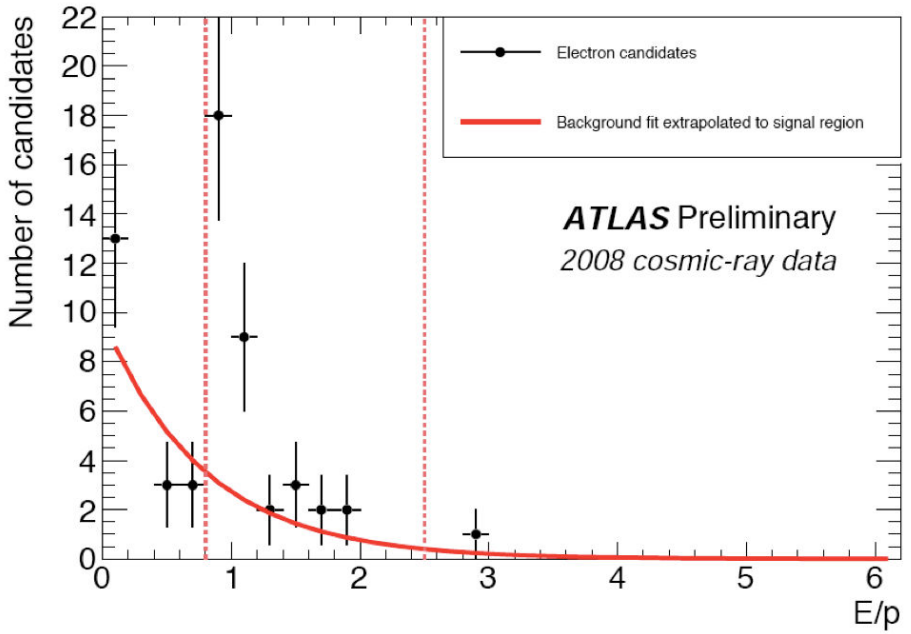


First electrons seen in ATLAS

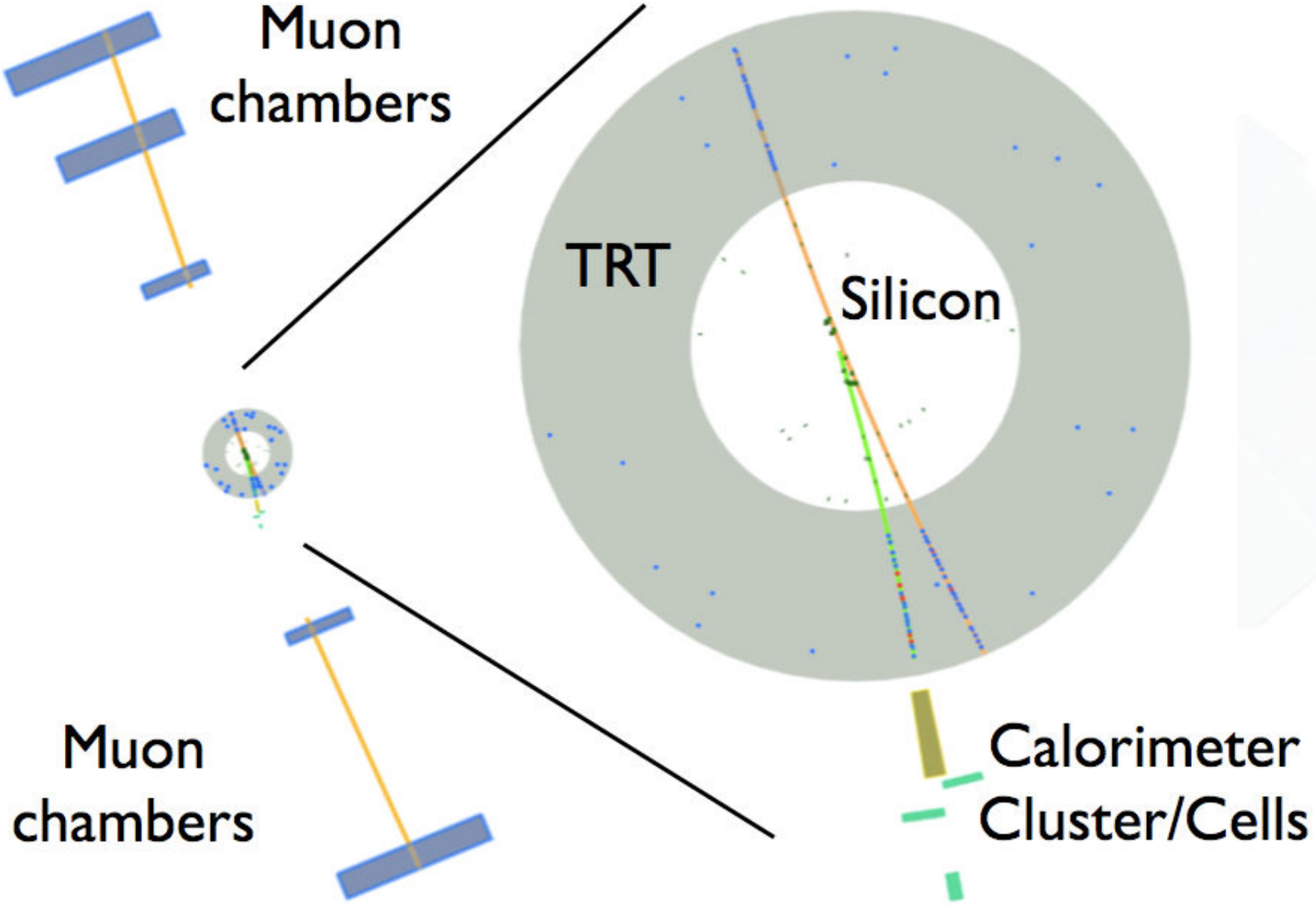




- Electrons produced by ionization (δ-rays)
- Require loose association between track and EM cluster with E>3 GeV
- Resulting samples:
  - electron "signal": events with 2 tracks
  - background: events with 1 track (γ – Bremsstrahlung by muons)
- Select on TRT signal and E/p ratio

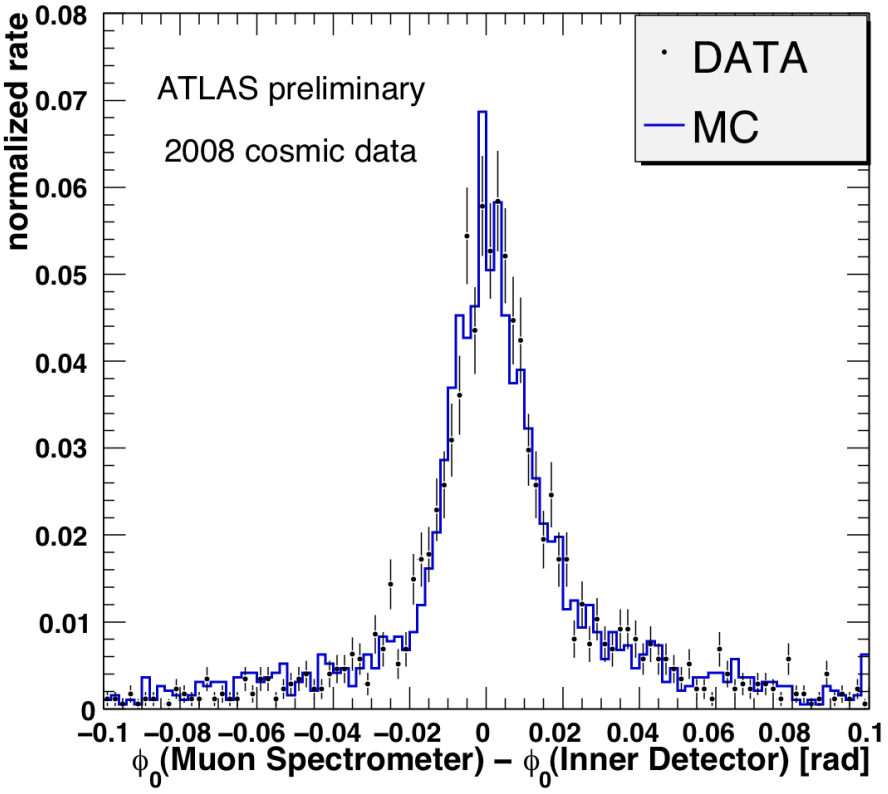


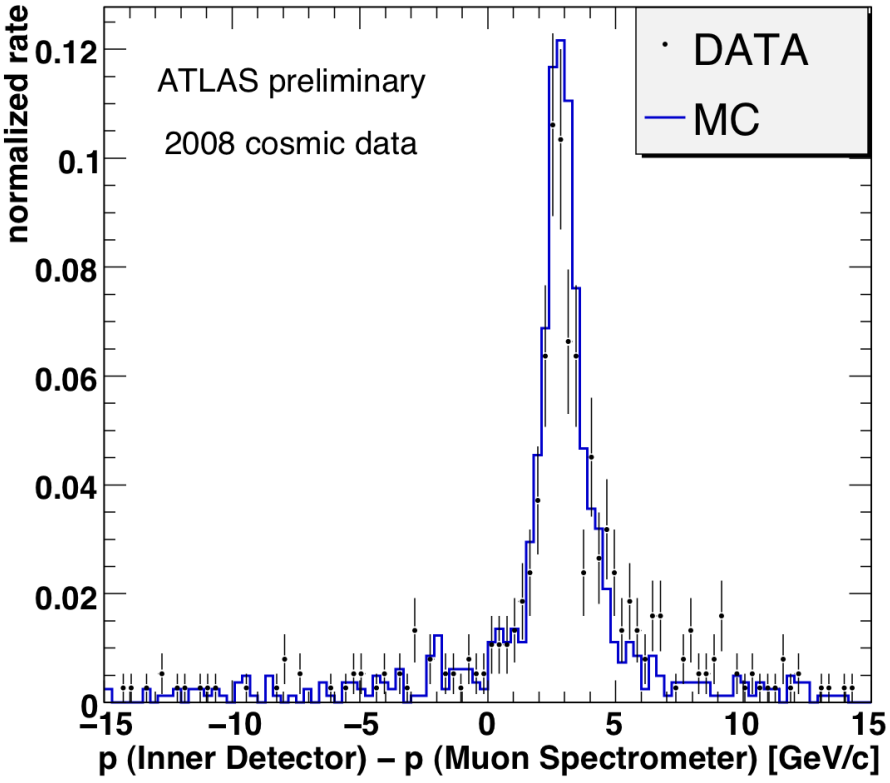
Event display of an electron candidate



Combined muons

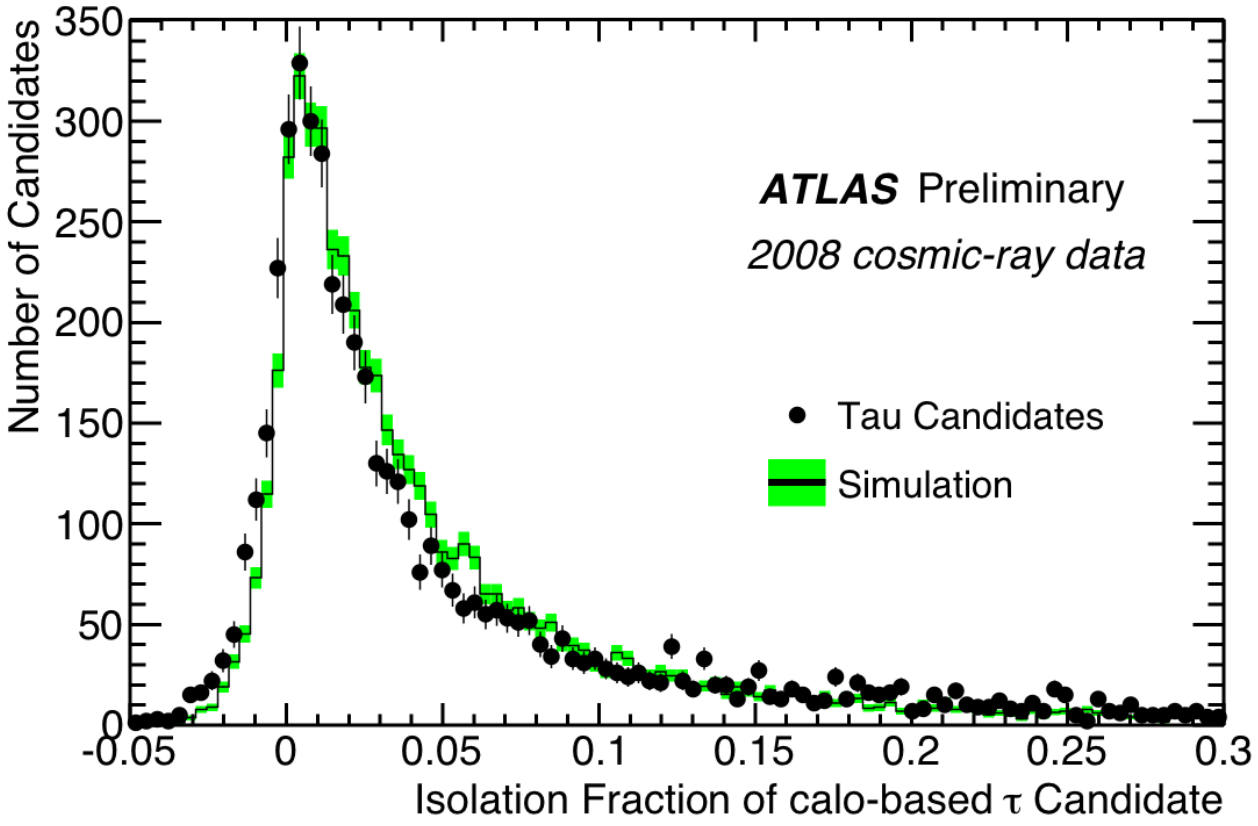
- Good agreement between track parameters measured in ID and MS, eg. Delta phi.
- Difference in momentum between ID and lower MS track is about 3 GeV - as expected from Monte Carlo





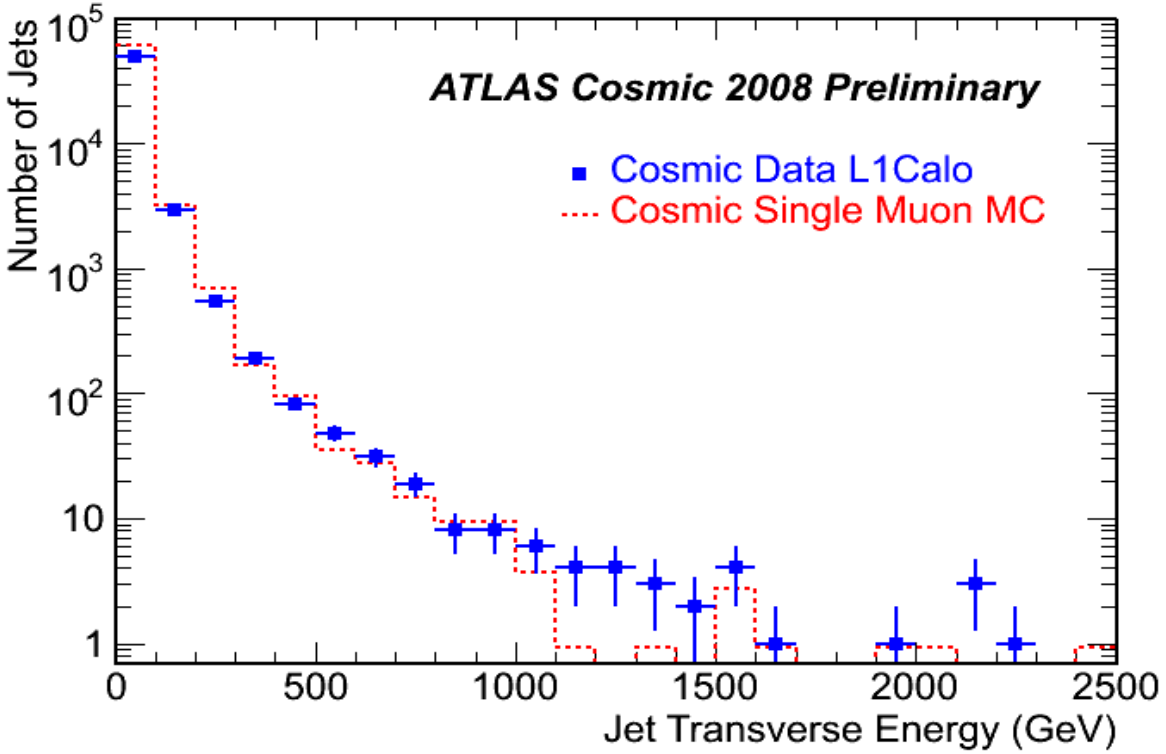
Taus

- Check data-MC agreement of tau id. variables, eg. fraction of energy in a cone slice $0.1<\Delta r<0.2$ compared to the total energy in a cone $\Delta r<0.4$. (These are cosmic muons - not real taus).



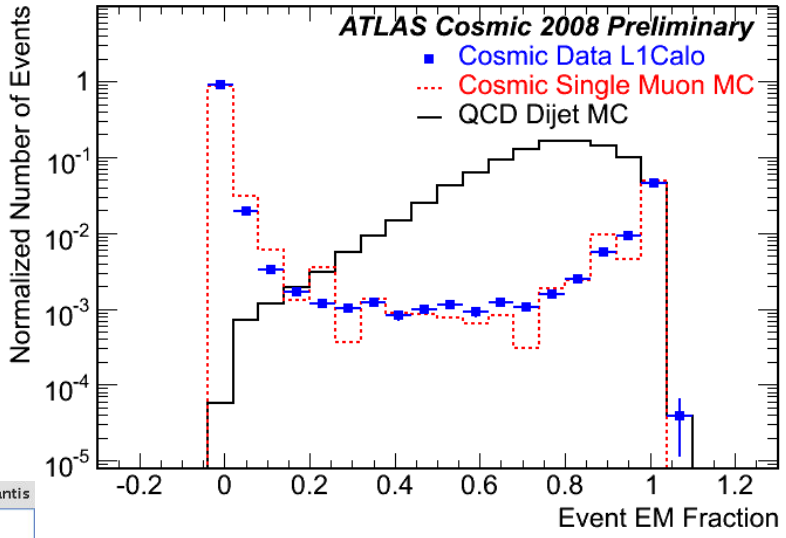
Jets

- Jet transverse energy distribution for events triggered by the calorimeter trigger, compared to Monte Carlo
- There are limited MC statistics at high E_T, and air showers are not modelled.

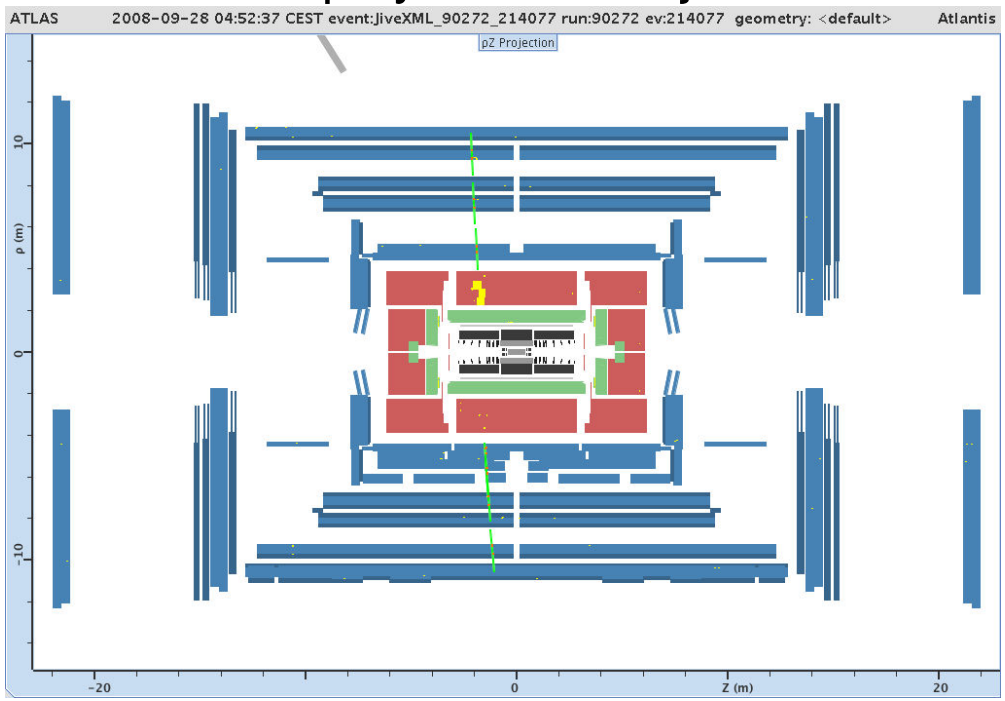


Jets

- The EM fraction in jets from cosmic rays tends to be low (or peaks at 1) compared to QCD jets.

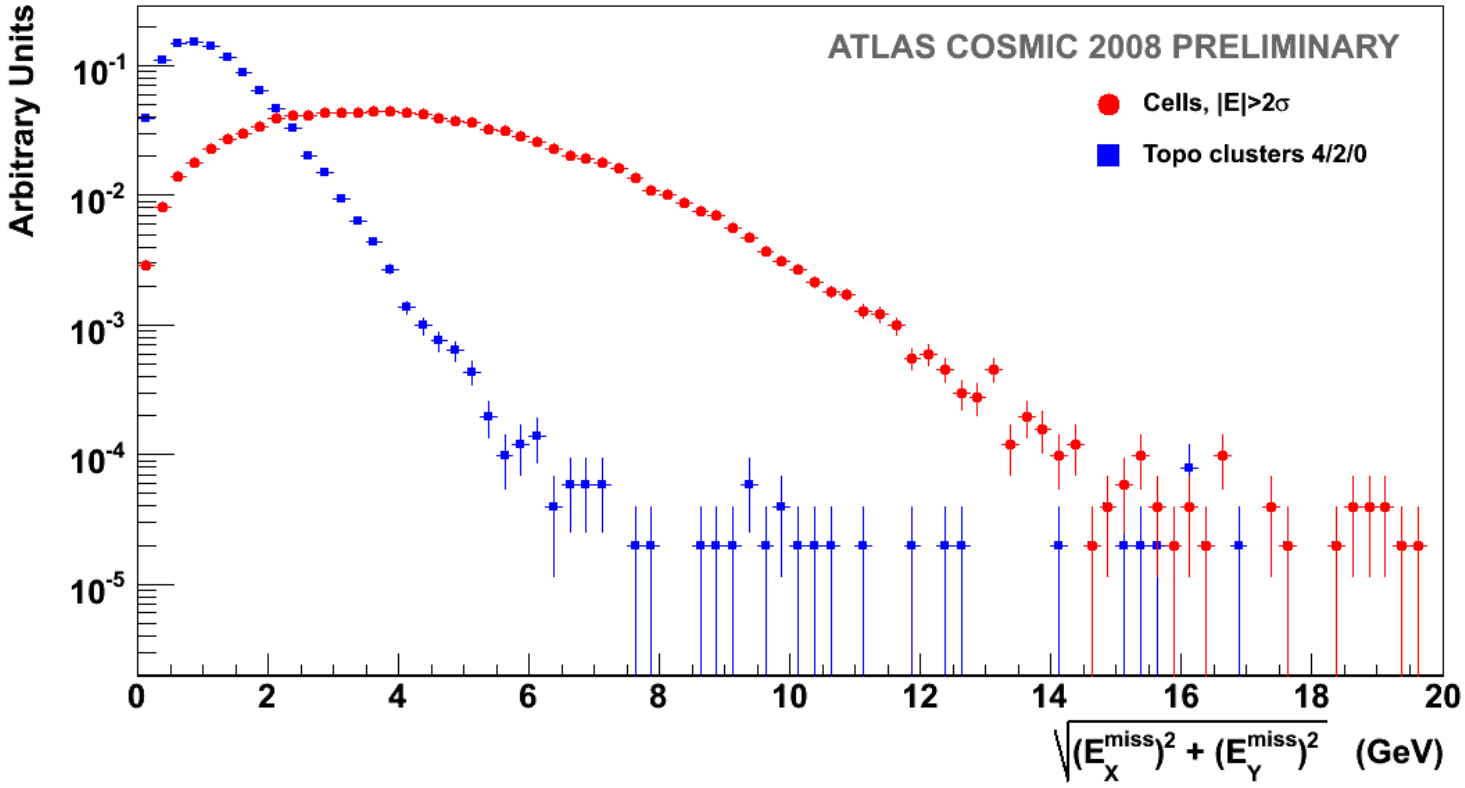


Event display of a 1TeV jet.



Missing energy

- Study missing E_T in randomly triggered events
- Noise suppression using clusters instead of individual cells



Conclusions

- ATLAS has used the LHC delay to assess the detector performance with cosmic rays.
  - Efficiency and noise are within specification, and >99% of channels are working for most systems.
  - Overall data taking efficiency was ~ 83% during the last cosmics week (1-6 July 2009).
  - First detector alignment is better than expected for day 1
  - Algorithms and performance for e, μ, τ, jets, missing E_T have been exercised.

ATLAS is ready for pp data