The ATLAS Detector

Status and results from Cosmic Rays

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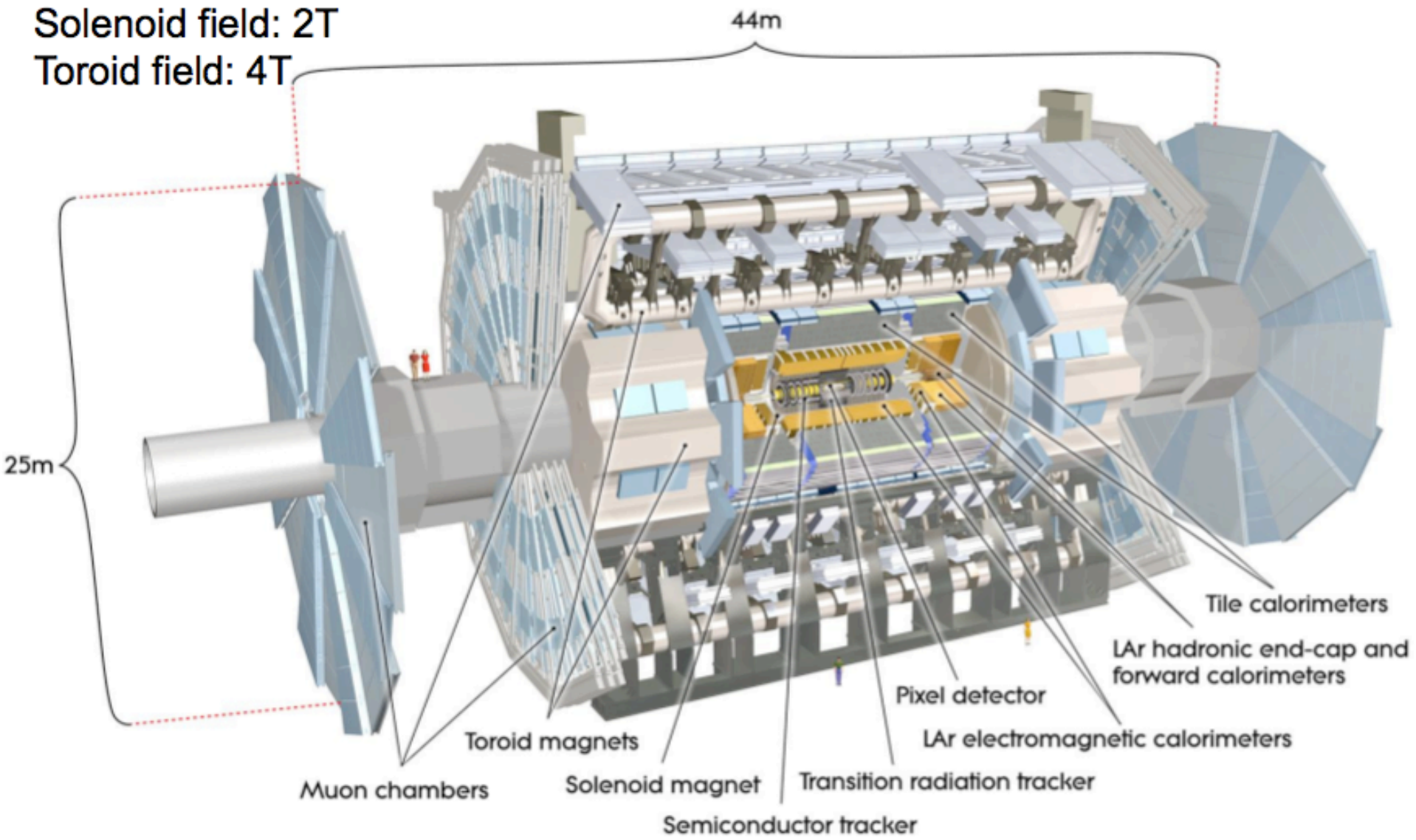
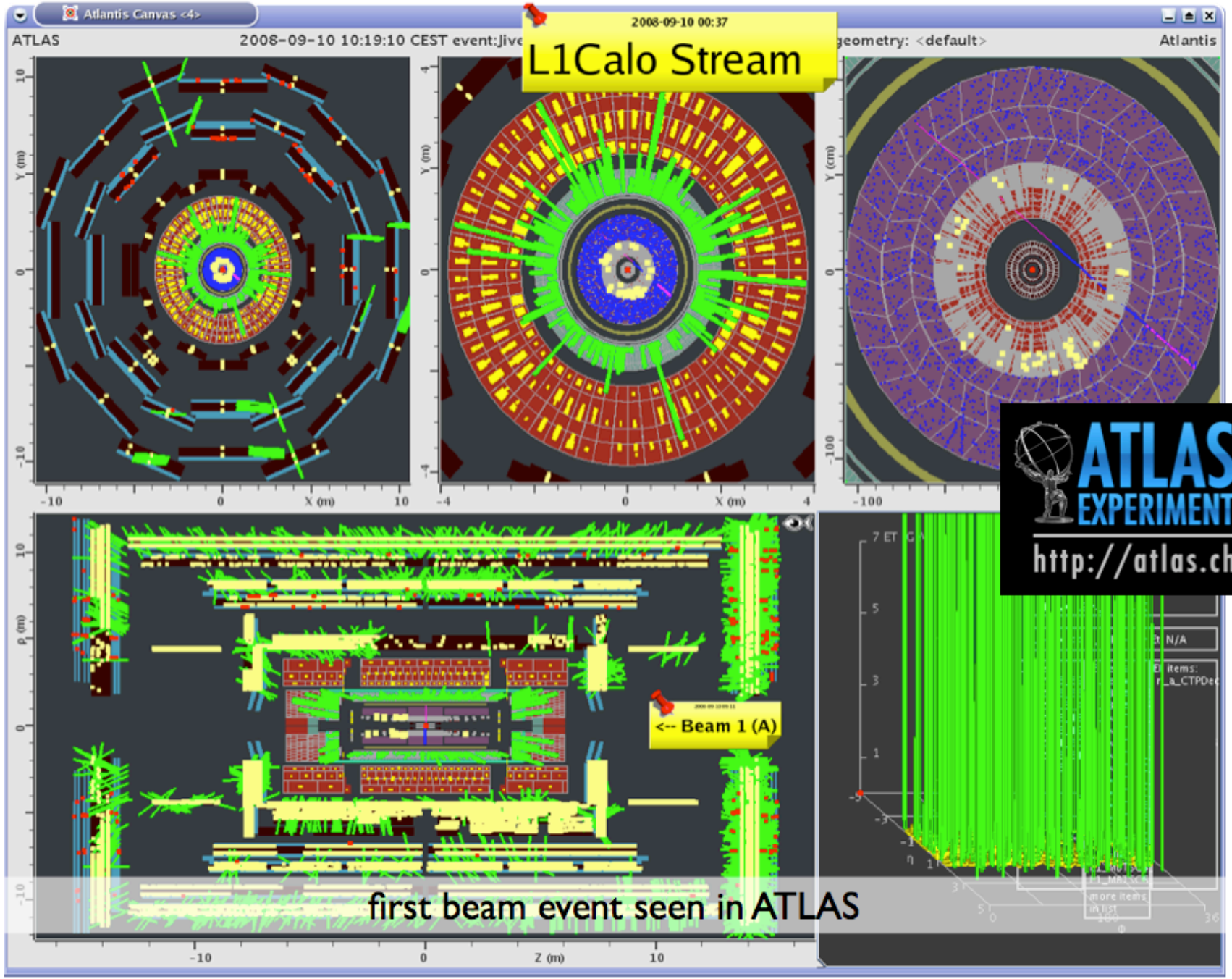
On Behalf of the ATLAS Collaboration

The ATLAS Collaboration

2500 scientists from almost 200 universities and labs in 37 countries

The ATLAS Detector

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2008-09-10 00:37
L1Calo Stream
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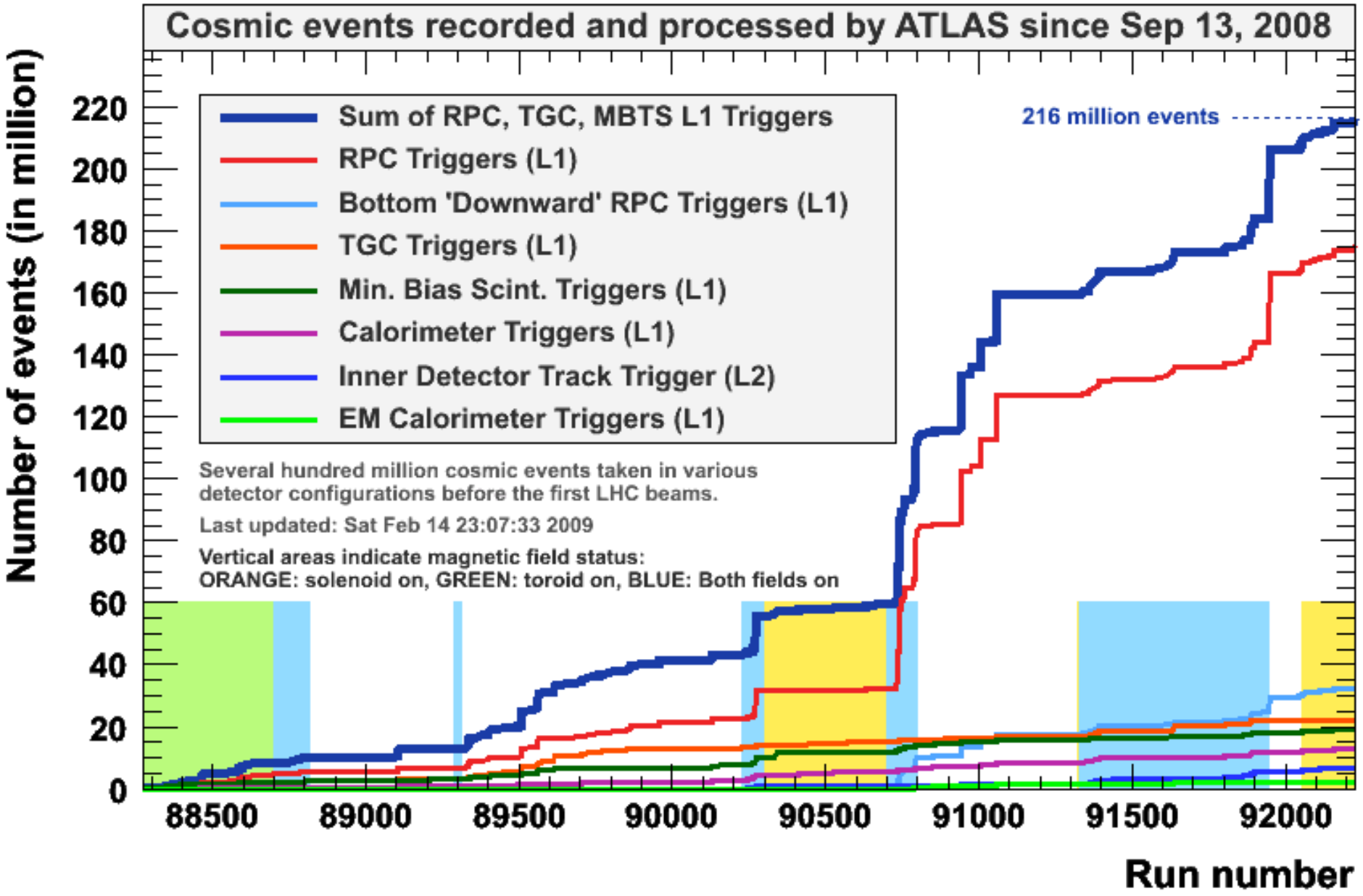
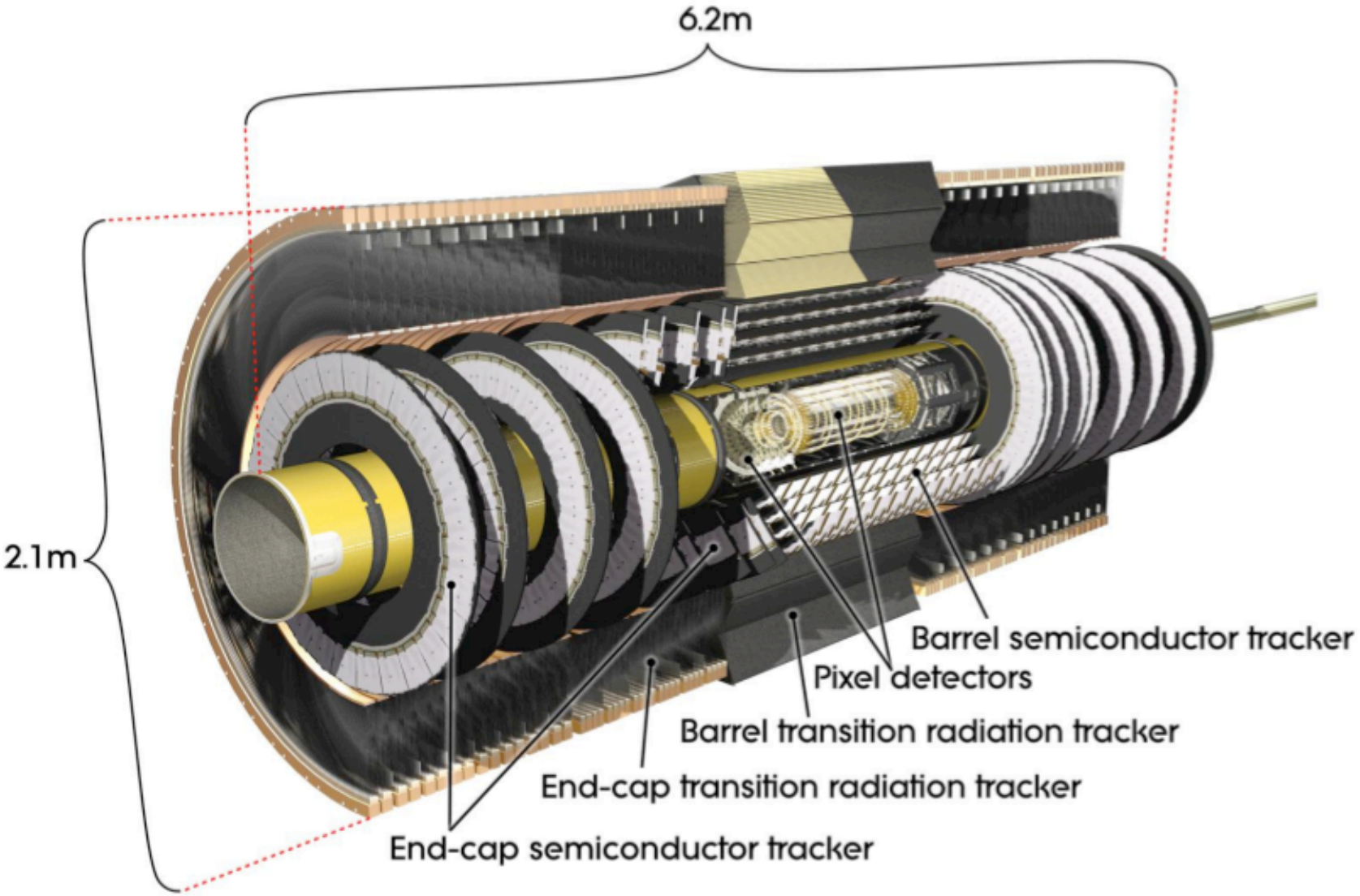
Atlantis
ATLAS EXPERIMENT
http://atlas.ch
<-- Beam 1 (A)
first beam event seen in ATLAS

Cosmic Ray Data Collection in ATLAS



The ATLAS Inner Detector

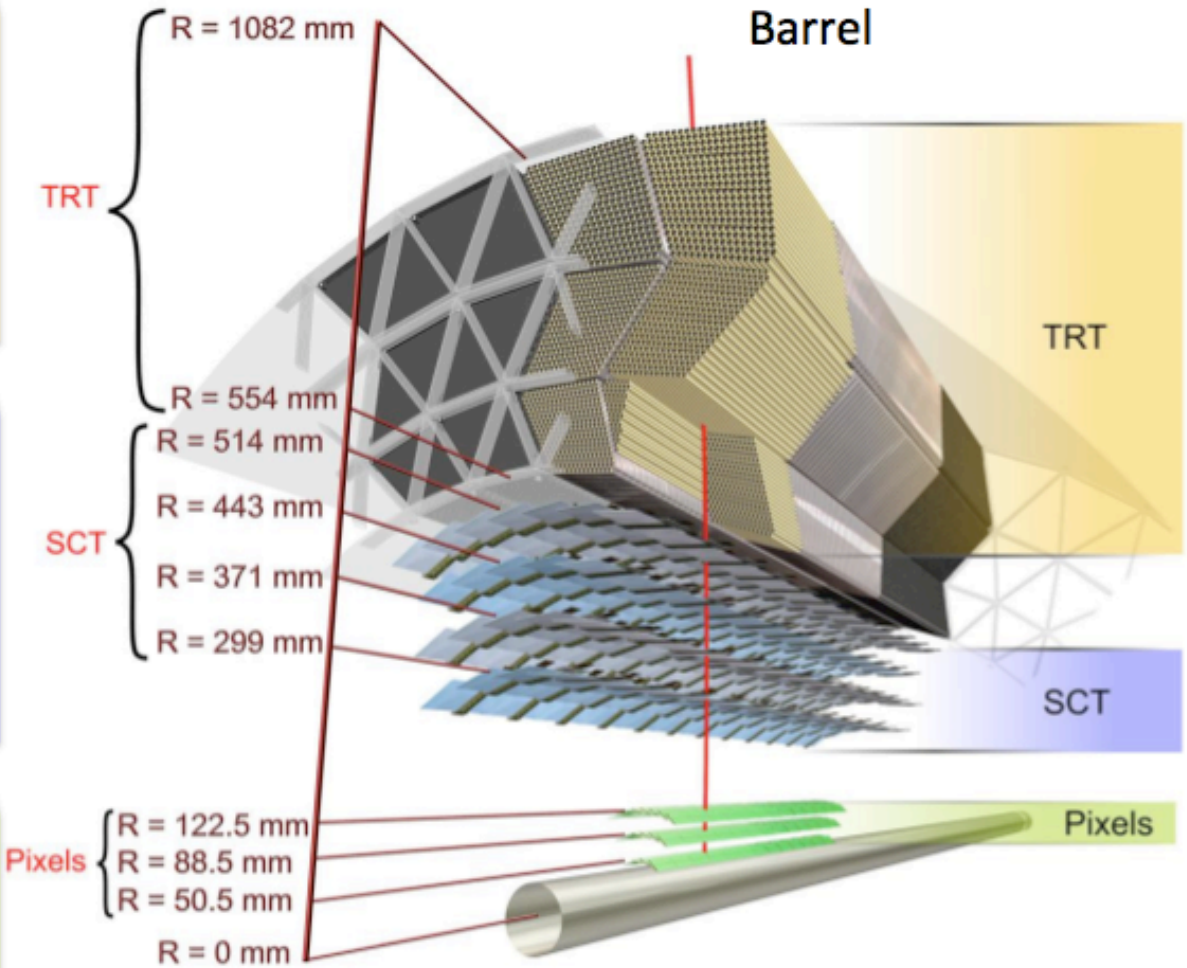


The ATLAS Inner Detector

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

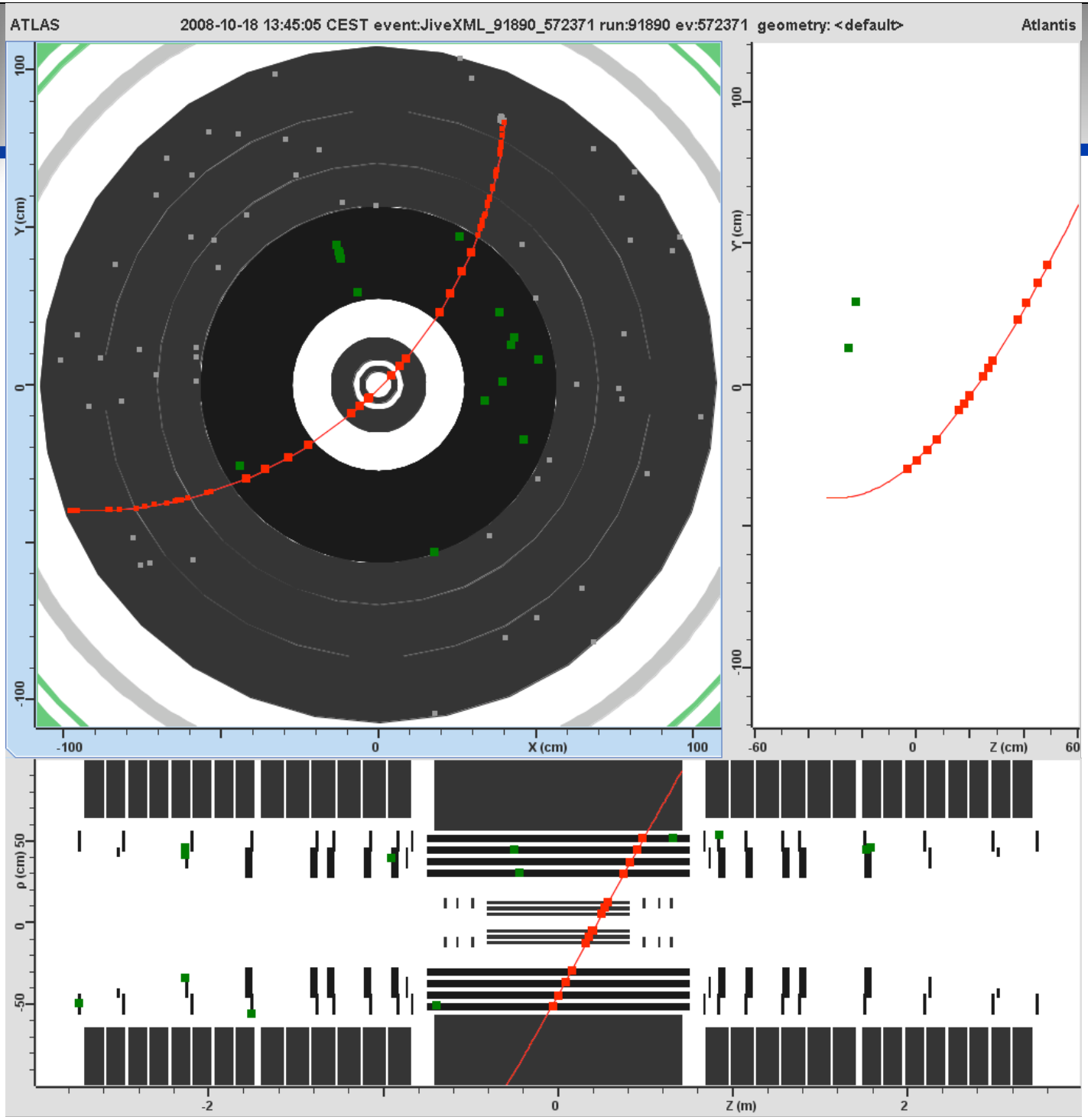
- 4(9) double layers in Barrel/Endcap
- 4088 modules, 6M chan., strips 80 μm
- Resolution 17 x 580 μm

- 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 x 10^{-5} ; Endcap: 5 x 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


ATLAS
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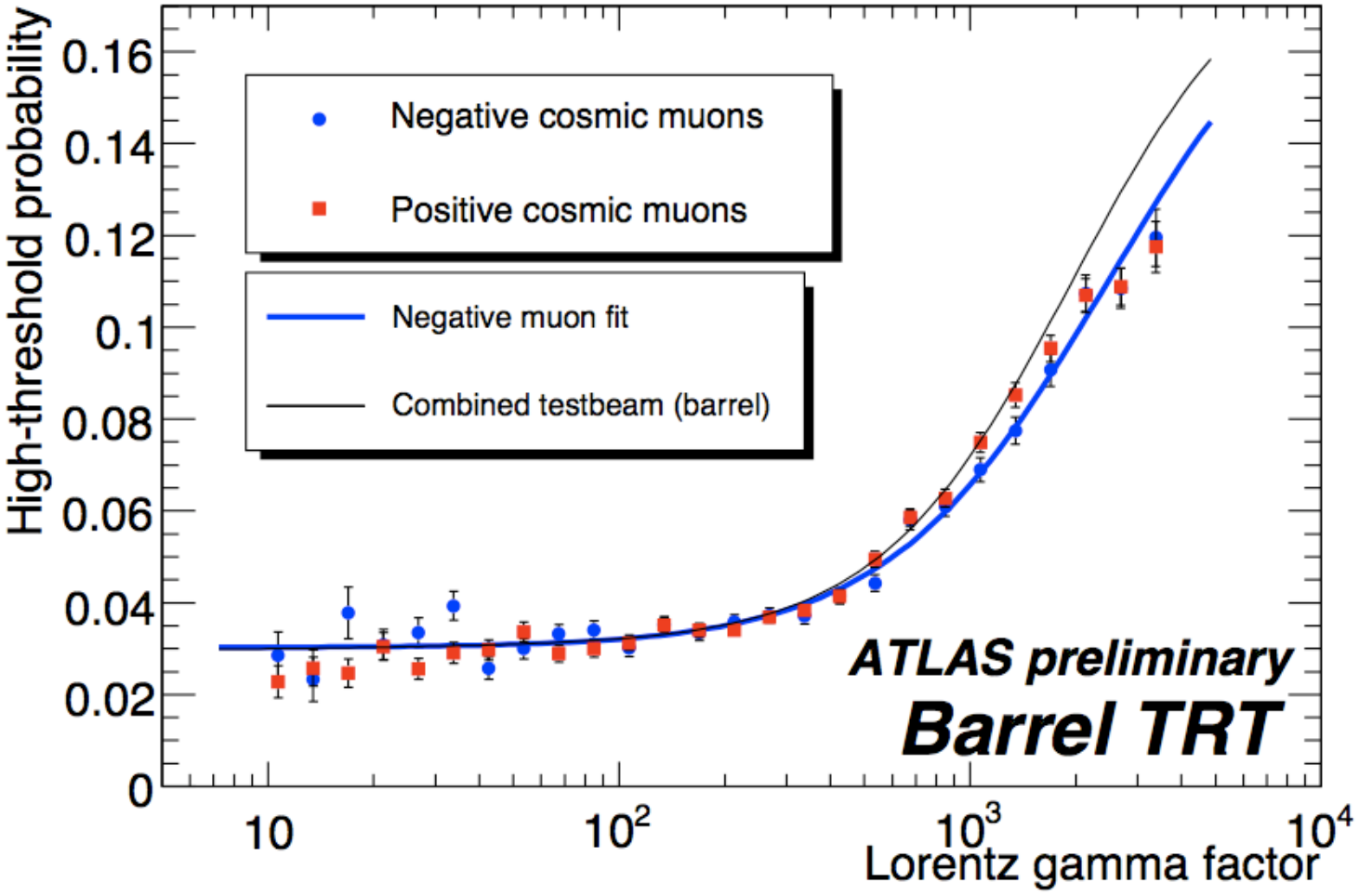
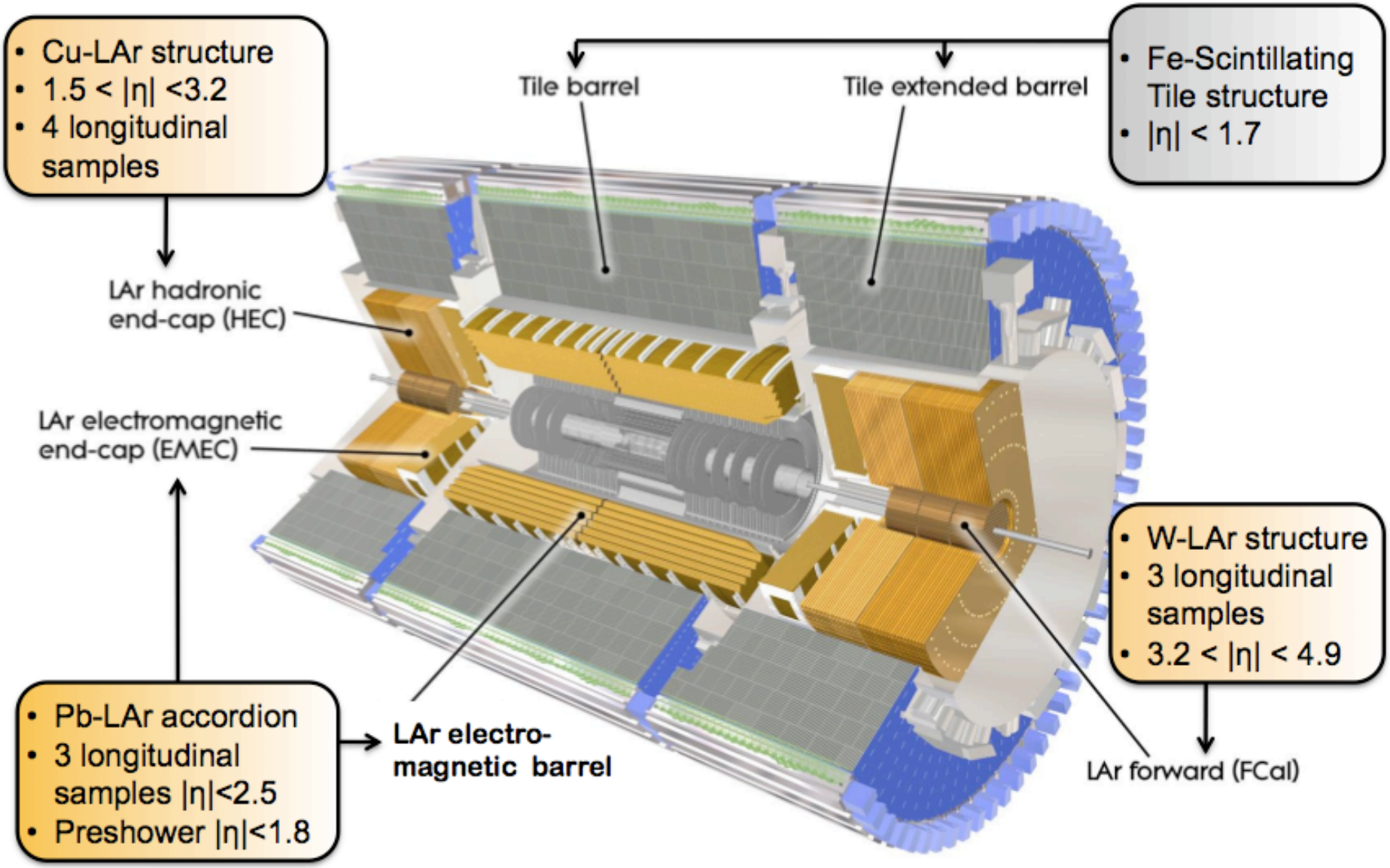
Atlantis
Y (cm)
X (cm)
Z (cm)
ρ (cm)
Z (m)

TRT Results from Cosmics

Turn on of transition radiation from Muons



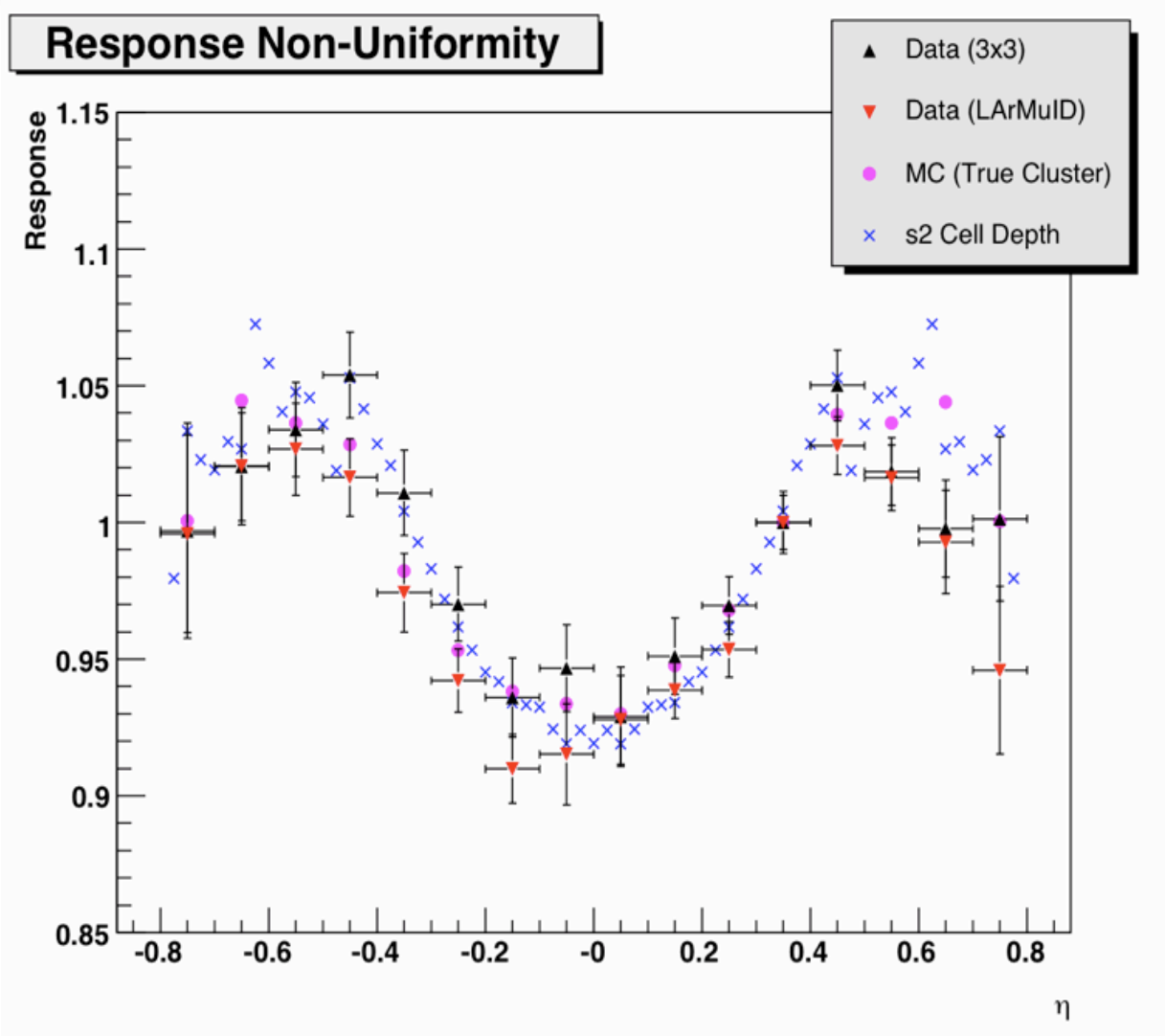
The ATLAS Calorimeter System



Calorimeter Status

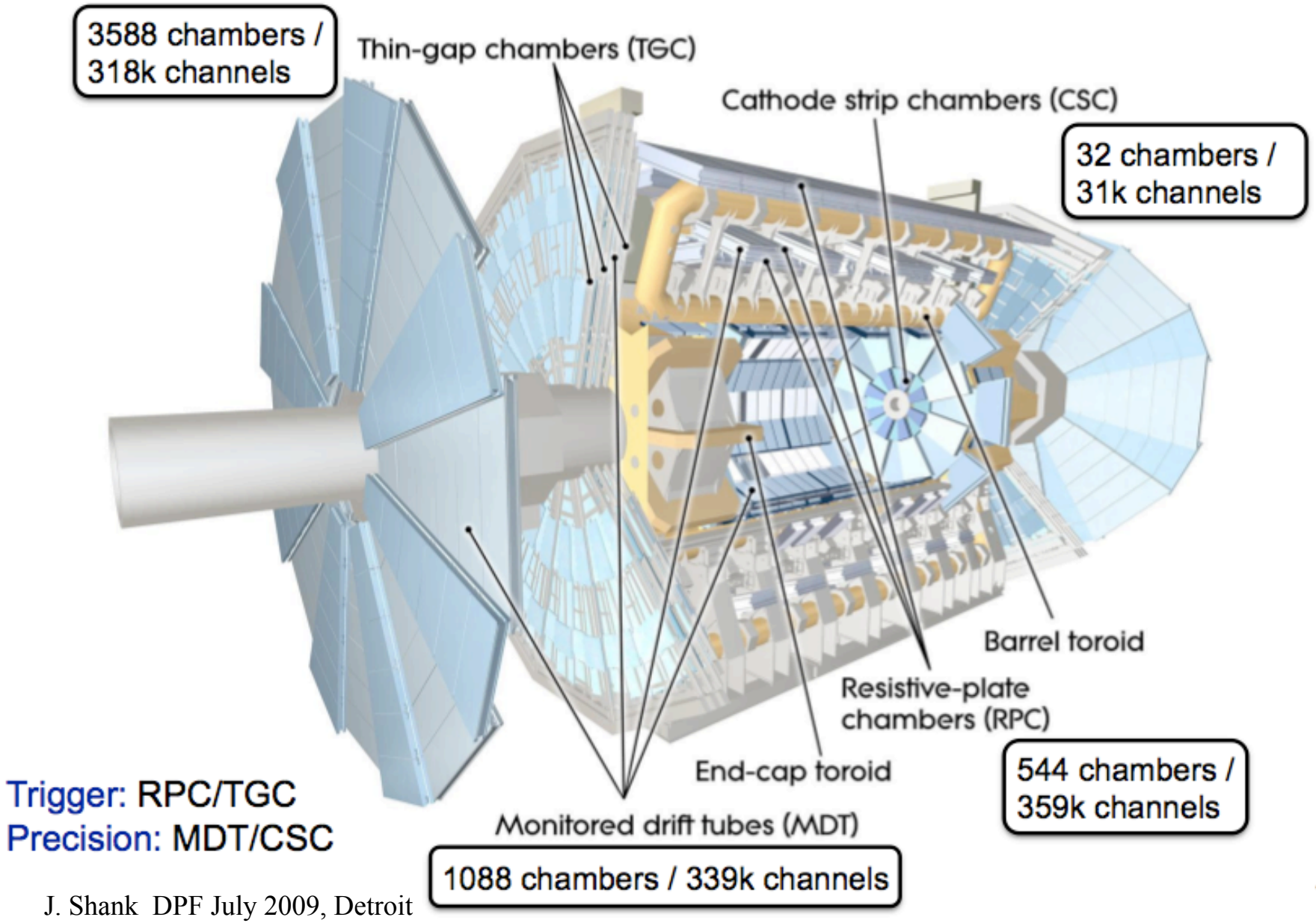
- LAr Calorimeters
  - Dead channels 0.02 % (+0.9% from readout being fixed)
  - Noisy channel 0.003%
  - Electronic calibration procedure is operational
- Tile Calorimeter
  - Dead channels 0.4% (reparable at next shutdown)
  - Calibration system is operational (Cs source, Laser, Charge inj.)
- L1 Calorimeter Trigger
  - Dead channels < 0.4% (+0.3% recoverable) of 7200 analogue channels
  - Channel to channel noise suppression allows E_T=1GeV cut (aim is 0.5 GeV)

LaR Cosmic results



Three cluster MPV curves are shown - the LArMuID and 3x3 cluster algorithms applied to real cosmic data, and the true cluster from the cosmic simulation. The curves have been normalized to the point at eta between 0.3 and 0.4. Also shown is the second sampling cell depth. The MPV value clearly tracks the cell depth as one would expect for a minimum ionizing particle - the uniformity of the response agrees with simulation at the level of 2%.

The ATLAS Muon Spectrometer



Muon Spectrometer Status

- **Precision Chambers**

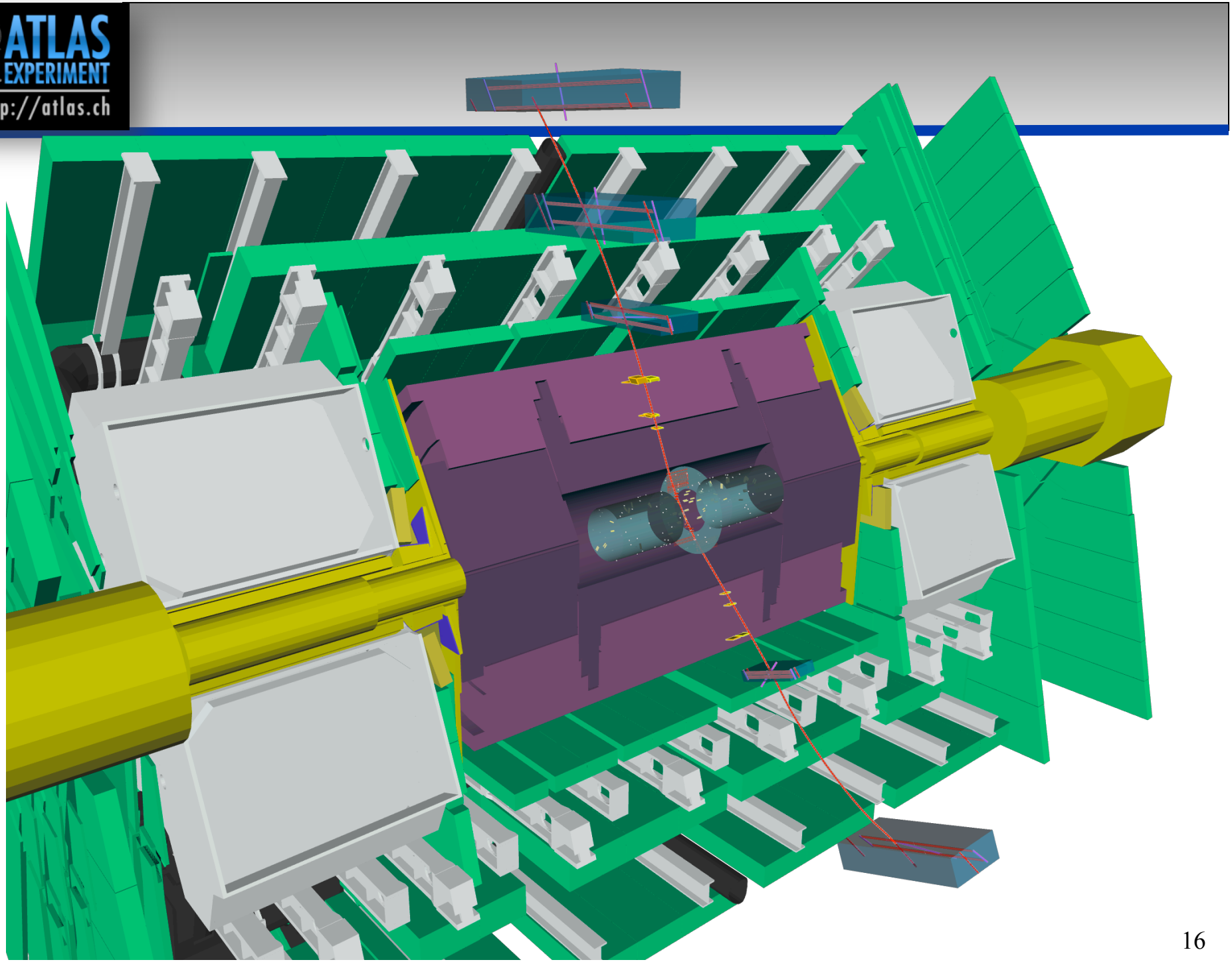
  Spatial resolution 35-40 μm
  - MDT (barrel/endcap)
    - 99.3% channels operational
    - Dead channels (0.2%)
    - 0.5% recoverable
  - CSC (small wheel)
    - 1.5% dead channels
  - Optical Alignment System (12232 channels) (30 μm)
    - 99.7% operational in barrel
    - 99% Operational in endcap

- **Trigger Chambers**

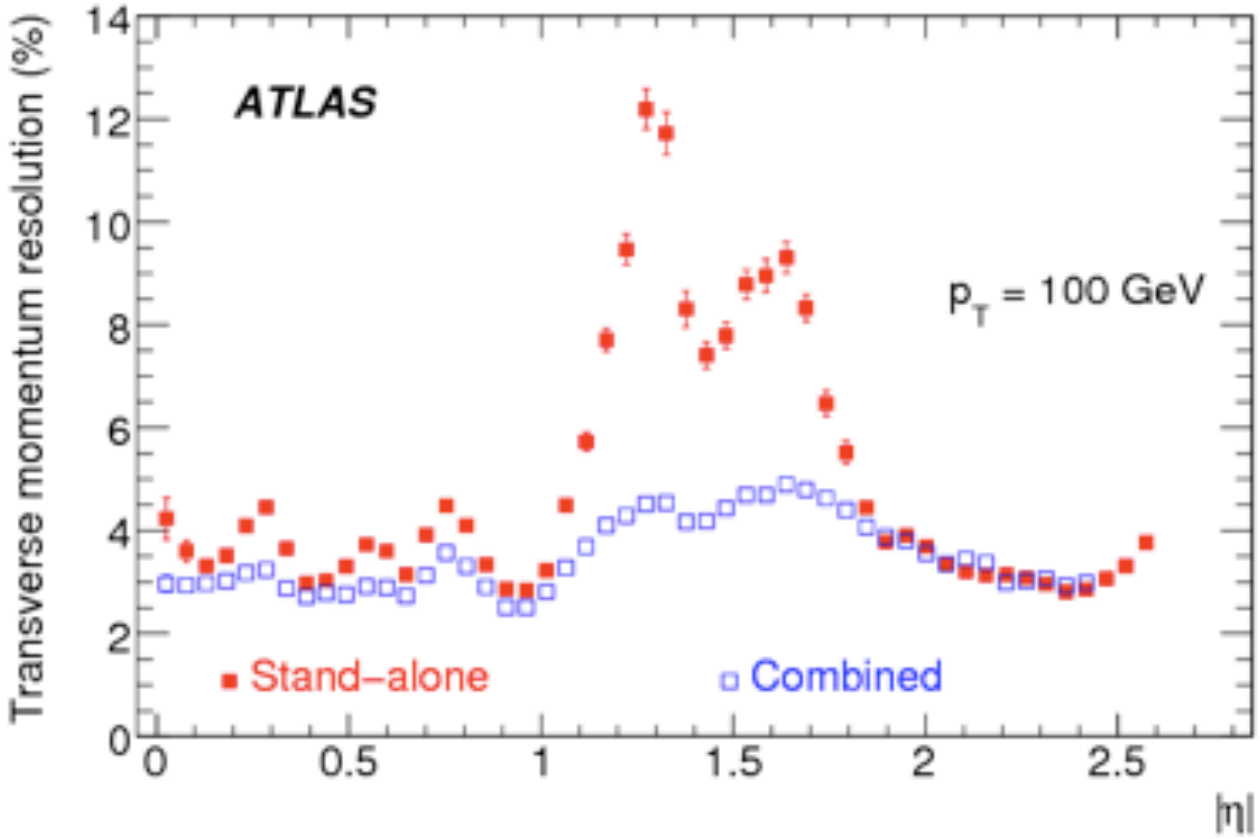
  Spatial resolution 5-10 mm

  Time resolution < 25 ns
  - RPC barrel 95.5% operational (goal: 98.5%)
    - Dead strips < 2%
    - Hot strips < 1%
  - TGC endcap
    - 99.8% operational
    - Noisy channels < 0.02%

Muon System stand alone resolution
$\Delta P_T/P_T$ < 10% up to 1 TeV


ATLAS
EXPERIMENT
http://atlas.ch

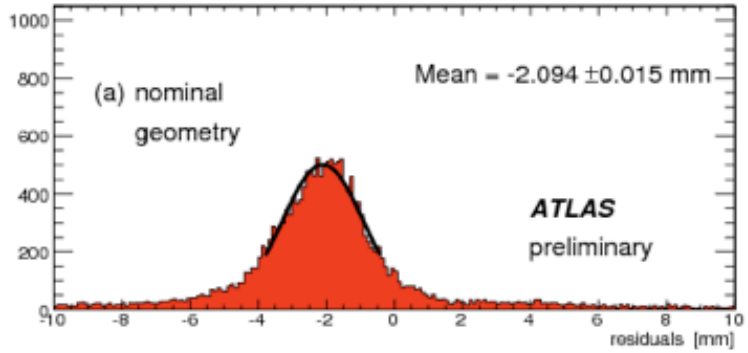
Muon Spectrometer Performance

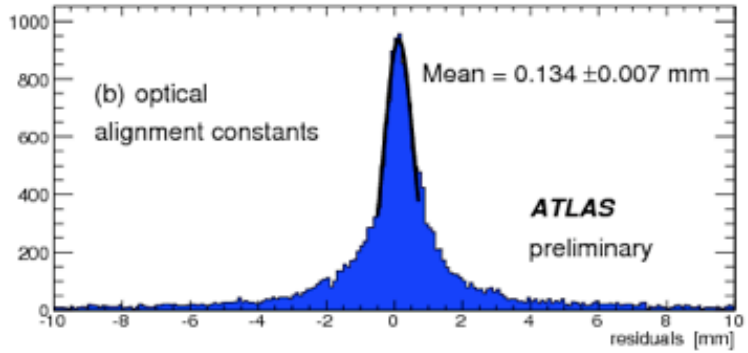


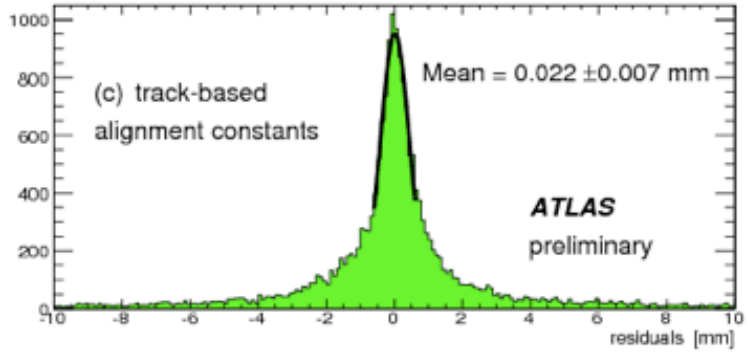
- stand-alone = muon reconstructed with the muon spectrometer stand alone; the muon momentum is corrected for the energy loss in the calorimeters by the expected energy loss;
- combined = muon reconstructed with the muon spectrometer and the inner detector;

Cosmic Ray Performance in the Muon Spectrometer

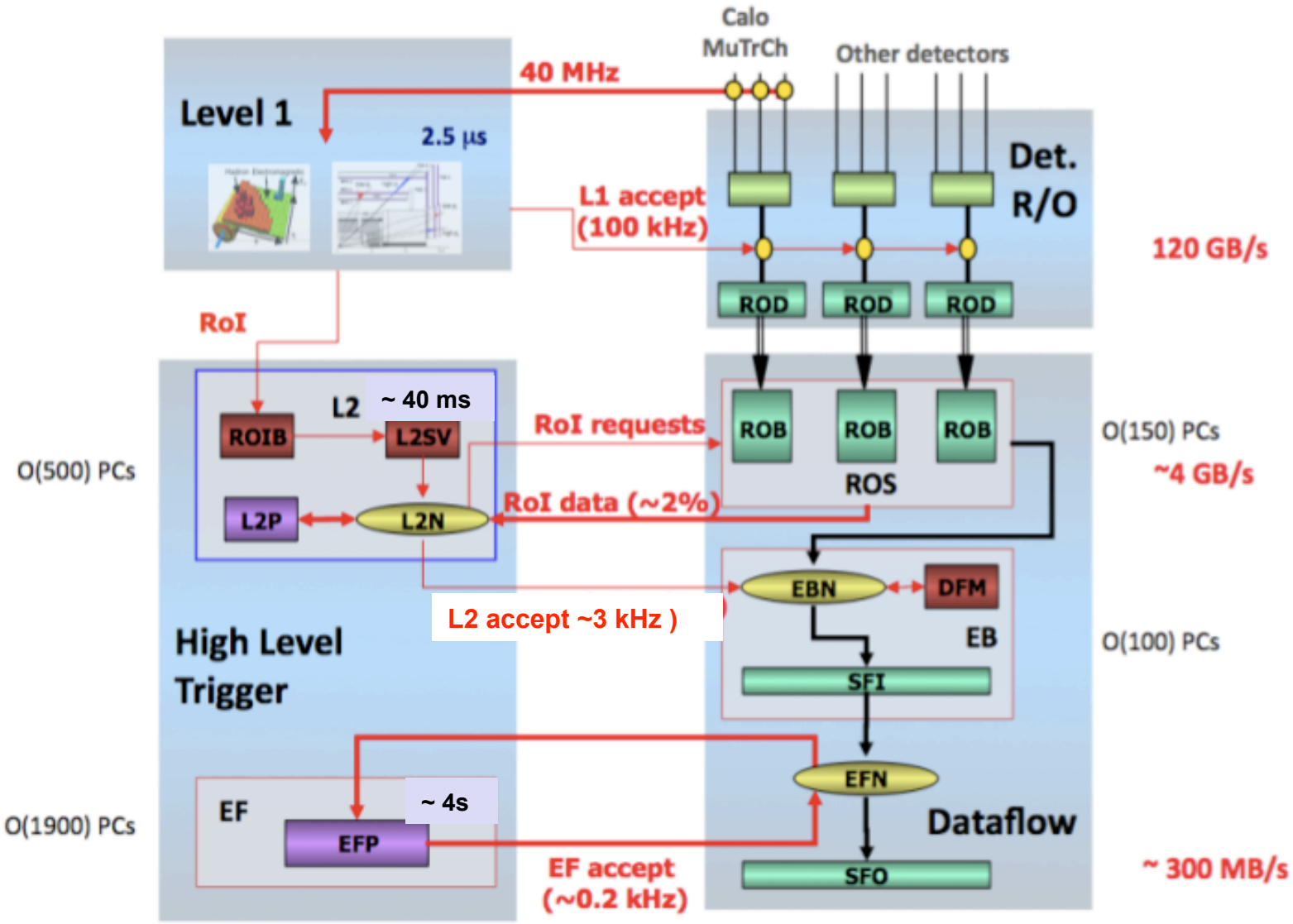
- Isolated Track Residuals
- Residuals corrected by Optical Alignment
- Residuals correct by track-based alignment







The ATLAS Trigger/DAQ System



Trigger/DAQ 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

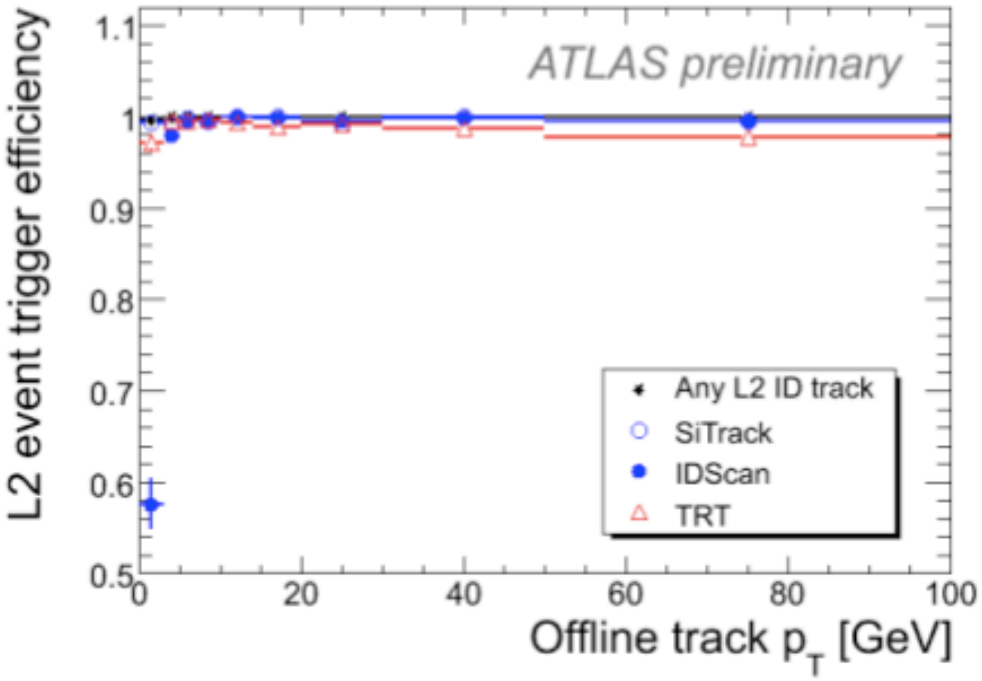
High Level Trigger Cosmics Results

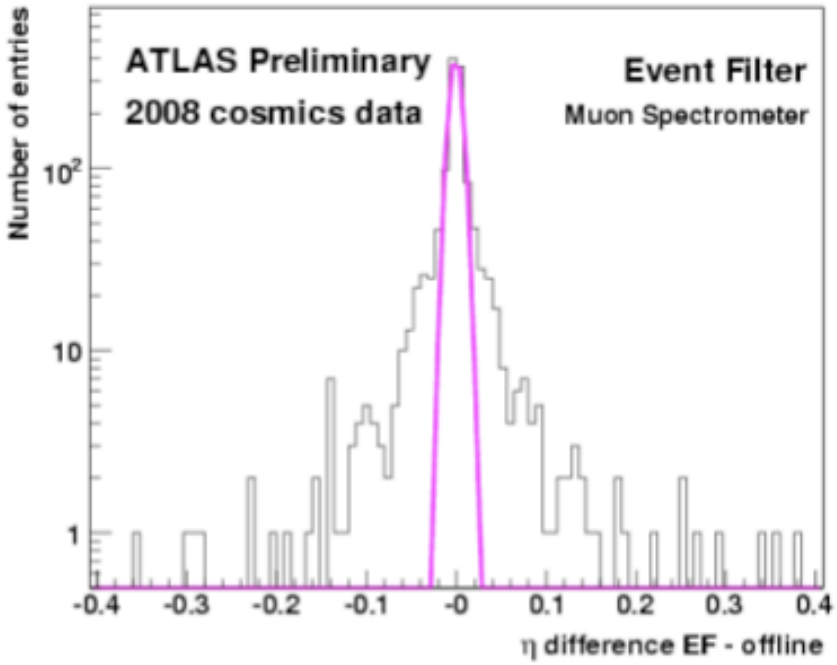
L2 track trigger efficiency

- 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



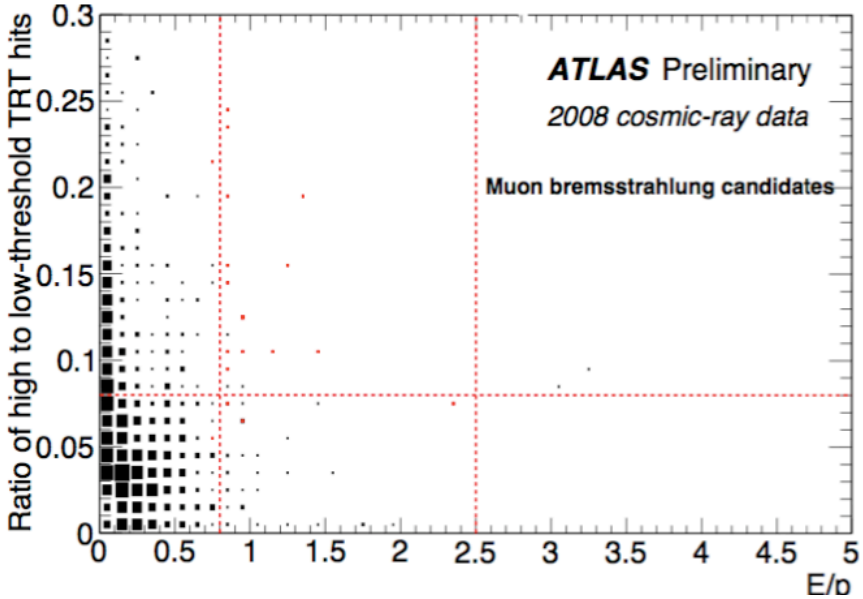


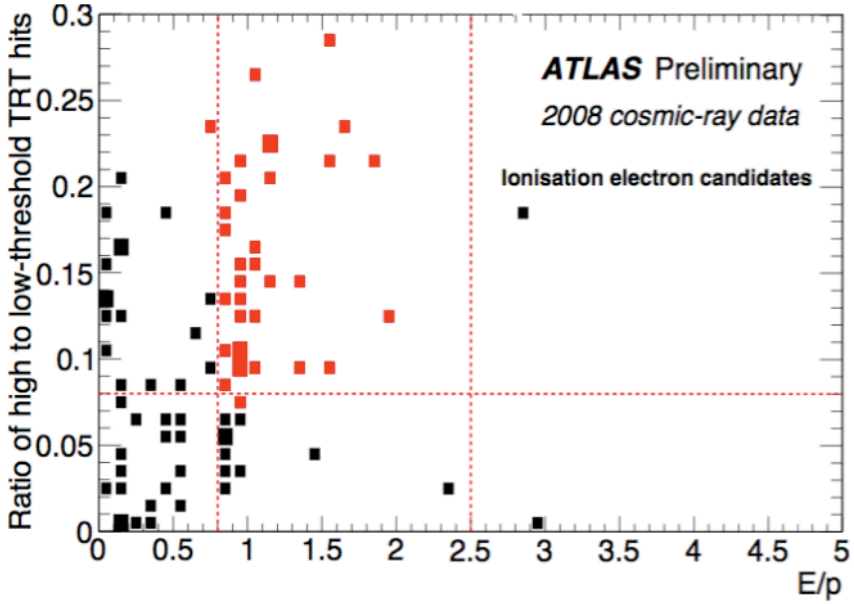
Width of fitted Gaussian = 0.007

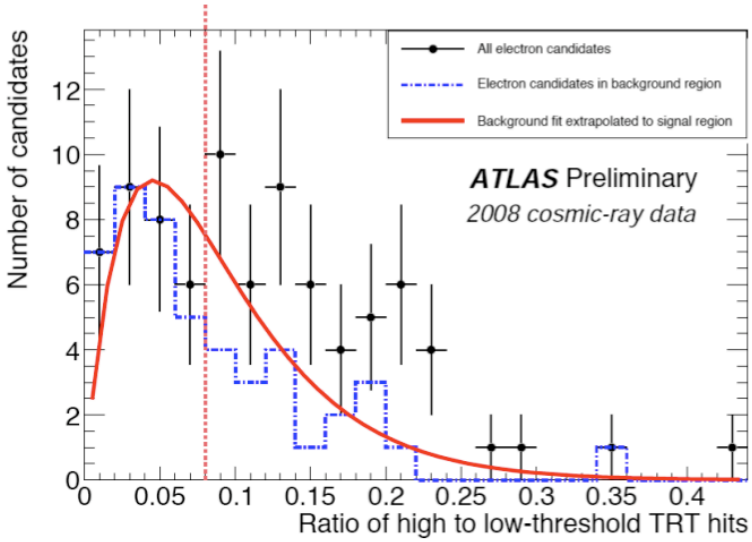
Combined Cosmic Ray Results: Electrons

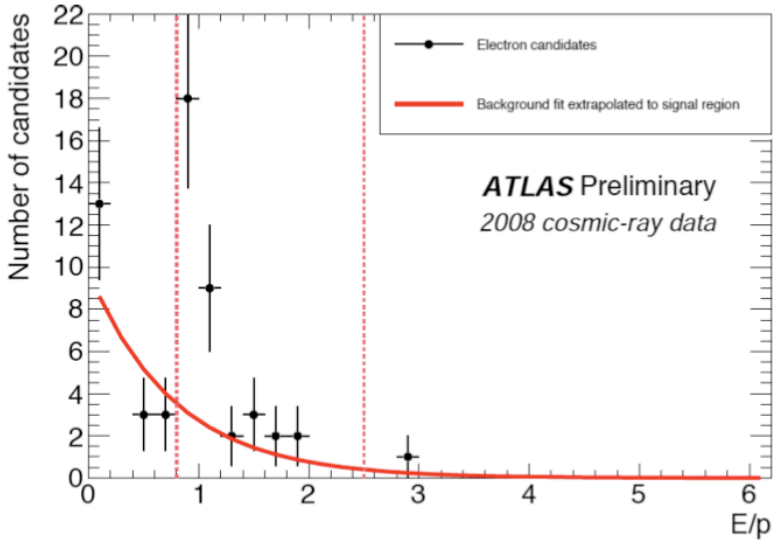
- Input for analysis: 3.5M events with High Level Trigger track candidate reconstructed in Inner Detector (ID)
- Filter for E_T>3 GeV, loose track matching => 11k evts.
- Electrons cuts: lateral shower shapes in 1st,2nd layer
- Track cluster matching in ϕ, >25 hits in TRT
- Remaining events split into:
  - 1229 muon brem. Candidates
    - Only one track reconstructed in the barrel ID
  - 85 ionization electron candidates
    - >2 tracks reconstructed in the barrel ID
- Results on next slide…

Electrons in Cosmic Rays









ATLAS Distributed Computing

- ATLAS will produce many Petabytes of data over the next 1.5 years
- This data is distributed world wide in order to get enough resources to perform the required analysis.
- The Computing Model
  - Tier 0 computing center at CERN.
    - First pass reprocessing to produce Event Summary Data (ESD) and Analysis Object Data (AOD).
    - Raw data stored on tape at CERN
  - Ten Tier 1 centers around the world
    - Each get a fraction of the raw data such that there are 2 full copies around the world
    - Re-processing occurs at T1 centers producing refined ESD and AOD
  - ~ 65 Tier 2 centers around the world
    - Get copies of some ESD and AOD
    - Physicists do analysis at T2 centers
- Fully automated system, moves data, performs Monte Carlo simulation, re-processing and physics analysis
  - This system has been repeatedly tested to ensure the computing fabric is ready for data

Conclusion

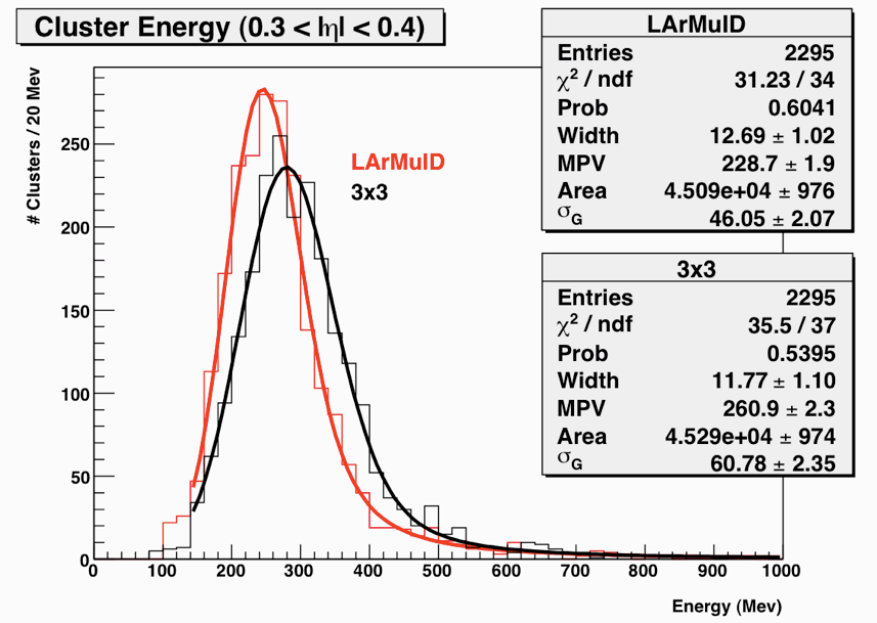
- ATLAS is ready for collision data!
- Very few dead or hot channels, low noise.
- There has been much progress on understanding the detector through studying cosmic rays.
  - A lot more progress can be made with collisions of any energy
- Poised to make discoveries quickly when high energy collisions occur.

Backup Material

Energy Distribution in the LAr

- This plot shows the cluster energy distribution for two different cluster algorithms, both of which are restricted to cells of the second sampling layer. The clusters are taken from events which satisfy a loose projectivity requirement determined from Tile calorimeter information. The clusters shown in this figure have centers in the eta region from 0.3 to 0.4. The LArMuID algorithm is a variable size algorithm - only cells above a given threshold are added to the cluster. The 3x3 cluster is fixed in size. Both cluster energy distribution have been fit with a Landau convoluted with a Gaussian. The most probable value (MPV) of the LArMuID algorithm is less than that of the 3x3 distribution as a result of a bias from only including cells with energy above a certain threshold. The 3x3 cluster is sufficiently large to capture all the relevant energy in these pseudo-projective events, and the fitted

  Gaussian width variable is consistent with the non-correlated noise of 9 cells.



Details of upper plots on slide 23

Ratio of high to low-threshold TRT hits versus E/p, where E is measured in the EM calorimeter and p in the inner detector, for bremsstrahlung and ionisation candidates.

The red boxes correspond to candidates satisfying additional cuts defined for standard tight high-p_T electron identification in ATLAS at $\eta \sim 0$. These cuts are p_T and η-dependent and the ones applied to most of the events are illustrated by the dashed red lines in slides 3 and 4: $0.8 < E/p < 2.5$ and high to low-threshold TRT hit ratio > 0.08 (indicating the detection of transition radiation produced only by relativistic particles).

Most of the events in the muon bremsstrahlung sample have small E/p and few high-threshold TRT hits (only muons above 100 GeV momentum are expected to produce transition radiation). The events with low E/p and high TRT ratio contain a large fraction of muons with combined momentum measured in the muon spectrometer and ID above 100 GeV. Only 19 of the 1229 events satisfy the signal criteria.

In contrast, in the electron ionisation sample, a large fraction of events, 36 out of a total of 85, satisfy the signal criteria. These events are interpreted as high-energy δ-rays produced in the inner detector volume by the incoming cosmic muons.

Details of lower plots on slide 23

Distribution of the ratio of the high to low-threshold TRT hits for the 85 ionisation electron candidates (black) and for the 49 candidates failing the final signal criteria (blue).

The red curve is the projection of a 2d binned maximum likelihood fit to the 2d plot on slide 4, excluding the signal candidates. The shape of the projected distributions is obtained from the muon bremsstrahlung sample, but the parameters are fitted using the ionisation sample. This fit is used as one of the methods to estimate the background contamination to the signal.

A clear excess of events with a large ratio of high to low-threshold TRT hits is observed, indicating the presence of an electron signal.

Distribution of the energy to momentum ratio, E/p, for the electron candidates of slide 4, after applying the cut indicated on the ratio of high to low-threshold TRT hits. The red curve shows the background, estimated as explained in slide 5 and projected on the E/p distribution. The background under the signal is estimated to be (8.7 ± 3.1) events, using this first method described on slide 5.

A clear accumulation of signal events around E/p = 1 is observed, as expected for electrons.

A second independent method to estimate the background uses the measured ratio of negatively to positively charged muons coupled to the fact that the electron ionisation signal should contain no positrons:
- the μ^-/μ^+ ratio obtained from the muon bremsstrahlung sample is ~ 0.70
- out of the 36 signal candidates, four have a positive charge, leading to an expectation of (6.8 ± 3.4) background events in the signal sample, in good agreement with the estimate from the first method.

The final sample consists of the 32 candidates with measured negative charge.