Commissioning the ATLAS Inner Detector Trigger

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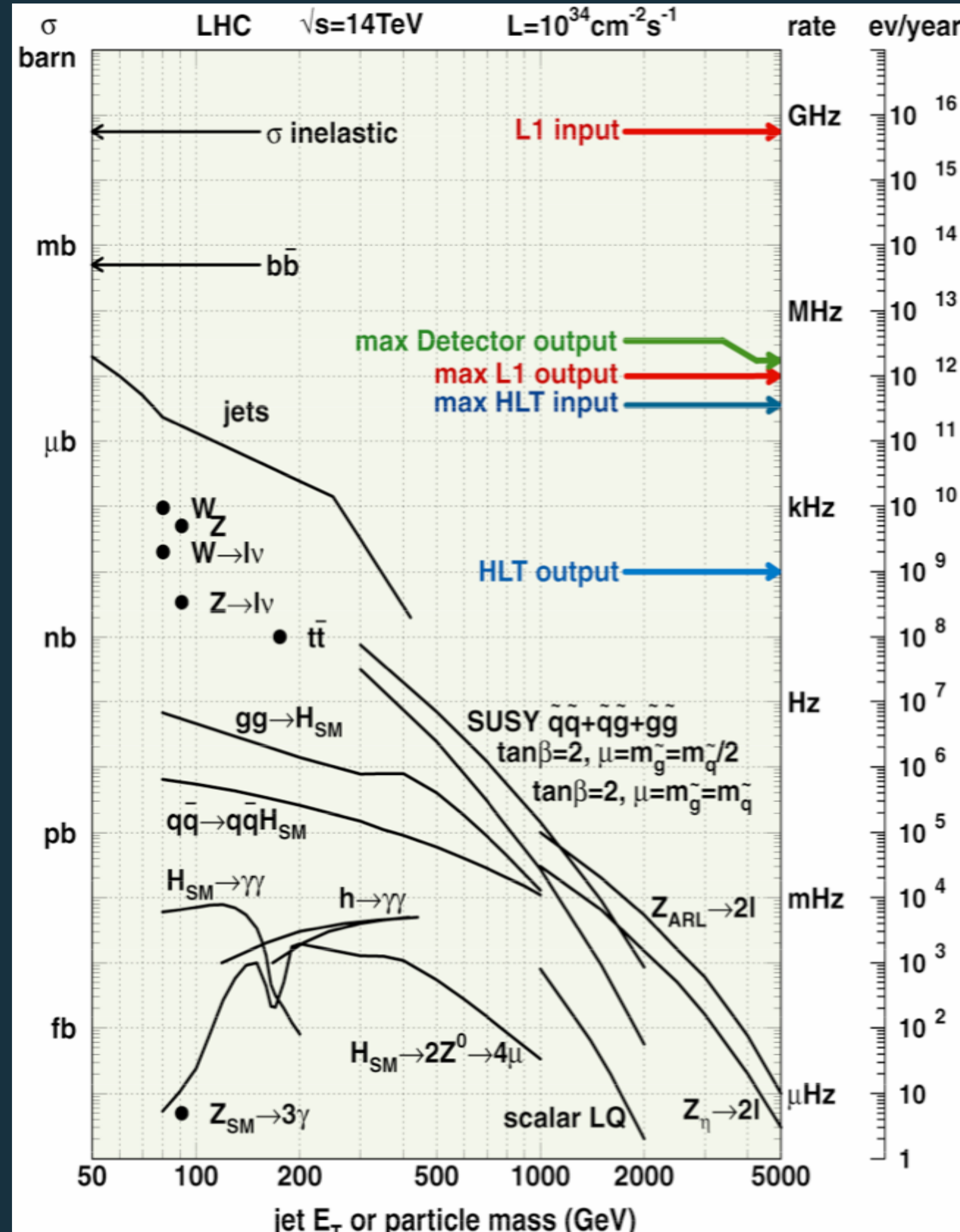
on behalf of the
ATLAS Collaboration

24th March 2009

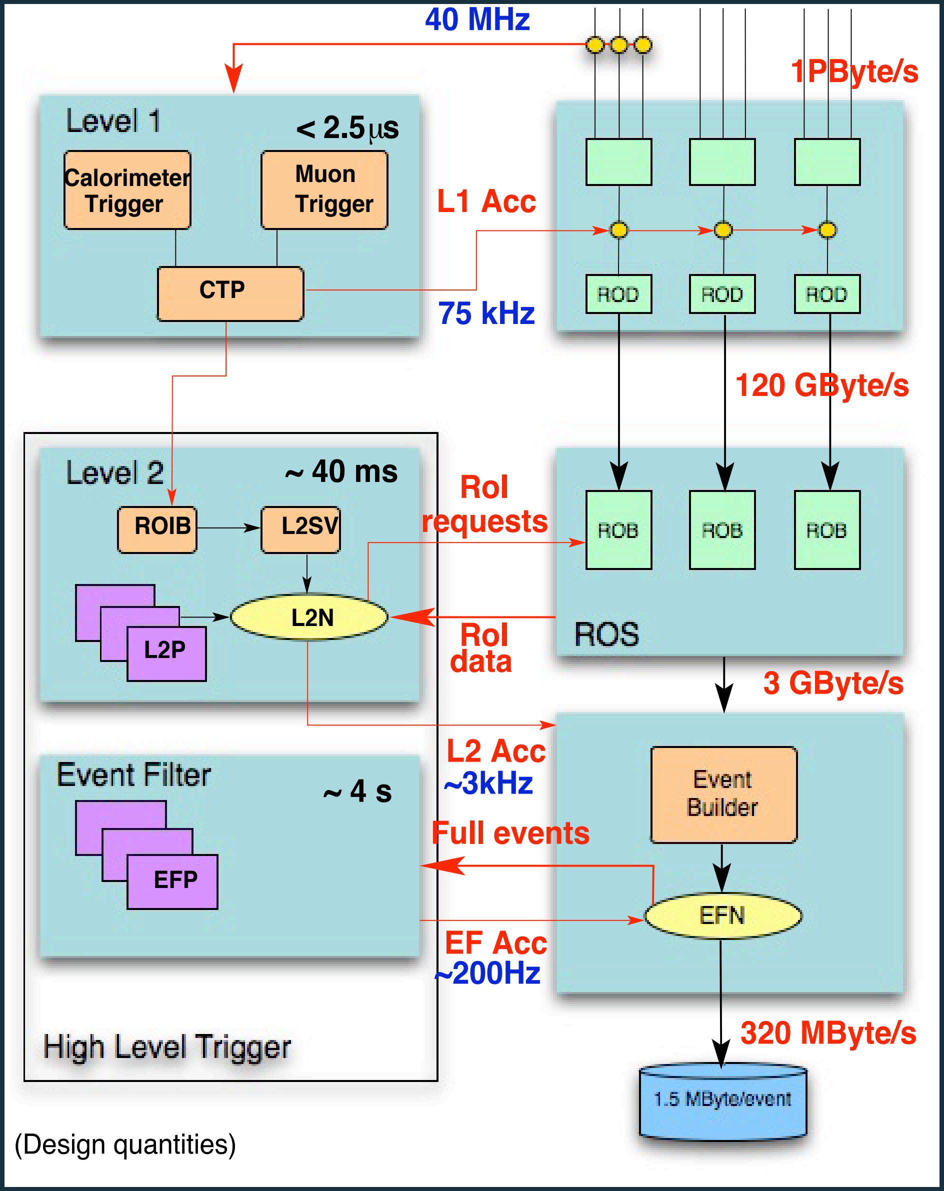
Preface

- LHC will take first collisions later in the year
- Bunch crossing every 25 ns – 40 MHz rate
  - Data storage capability ~200 Hz
  - Reduction of around 200000 to 1 required
- Between up to ~25 (soft) *pp* interactions per bunch crossing
  - Interesting high p_T interactions complicated by "pile-up"
- Almost all interesting signatures contain leptons or high momentum tracks
- To maximise the LHC physics potential we want to commission and understand the tracking in the Trigger as much as possible before collisions

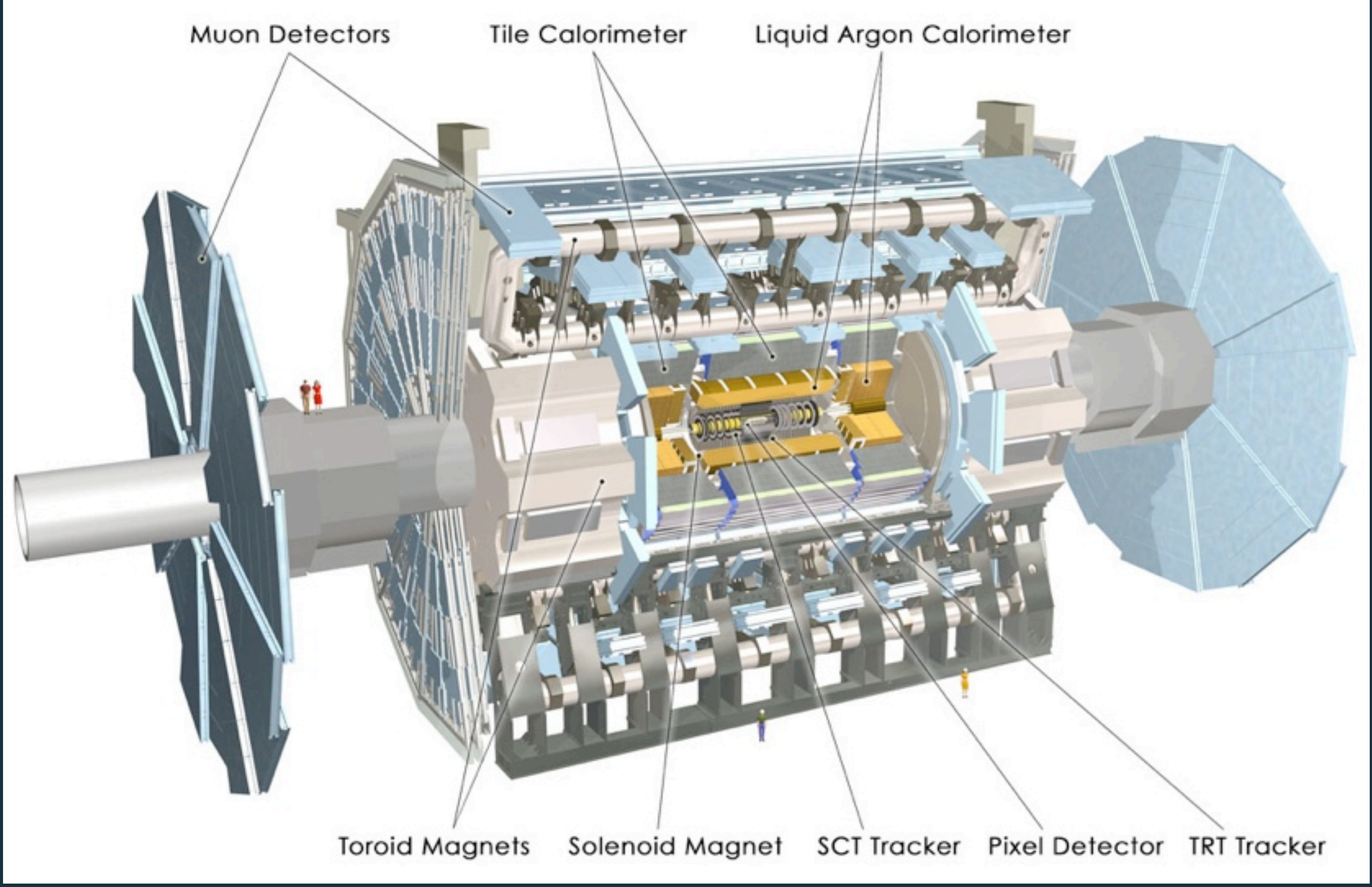


The ATLAS Trigger System

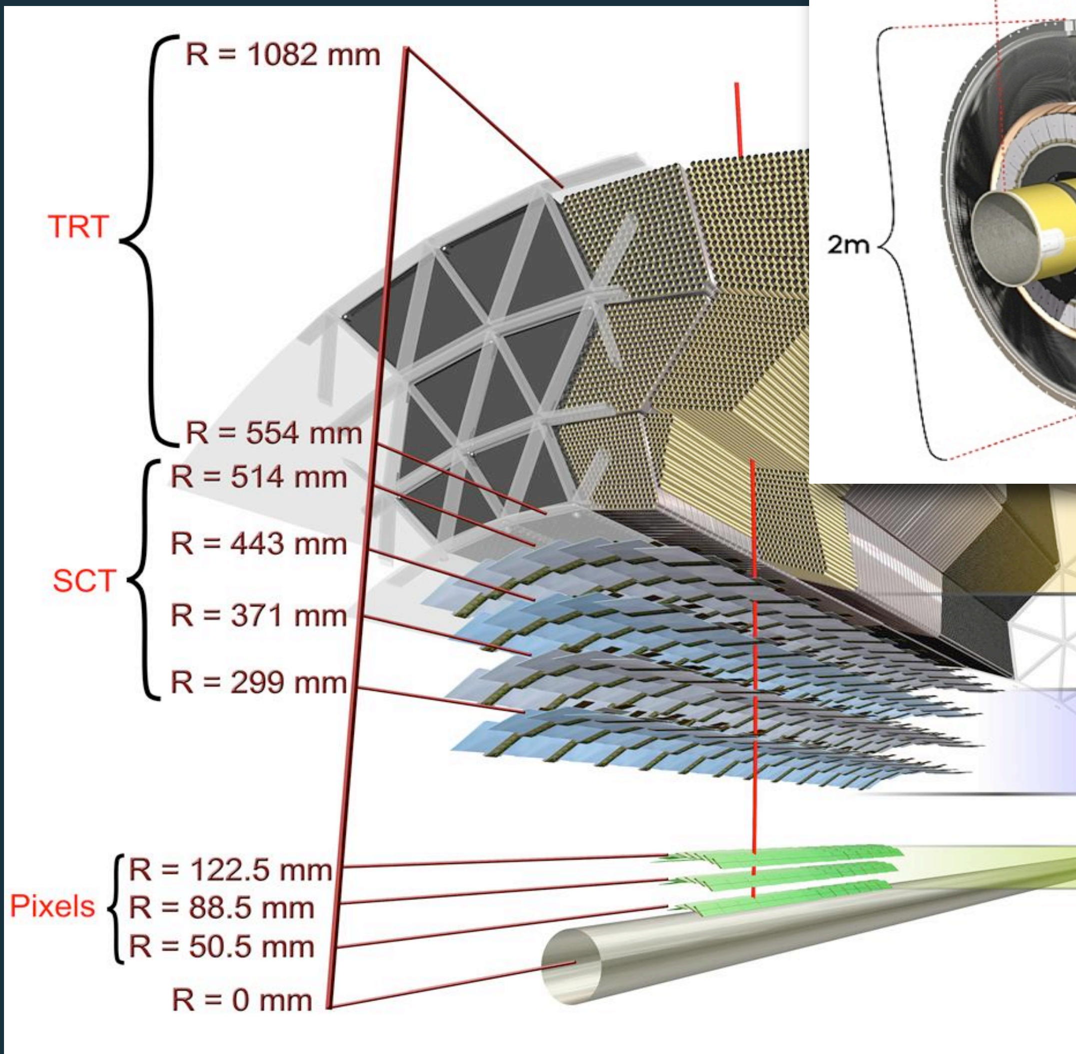
- Level 1
  - Hardware based, pipelined trigger, coarse granularity, largely Calorimeter and Muon system based.
  - 2.5 microsecond latency
- High Level Trigger - Level 2 and Event Filter
  - Software based, farms of commodity CPU's and ethernet
- Level 2
  - Seeded by Level 1 in Regions of Interest
  - Full detector granularity, all detector subsystems
- Event Filter
  - Seeded by Level 2
  - Access to complete event, reconstruction similar to Offline

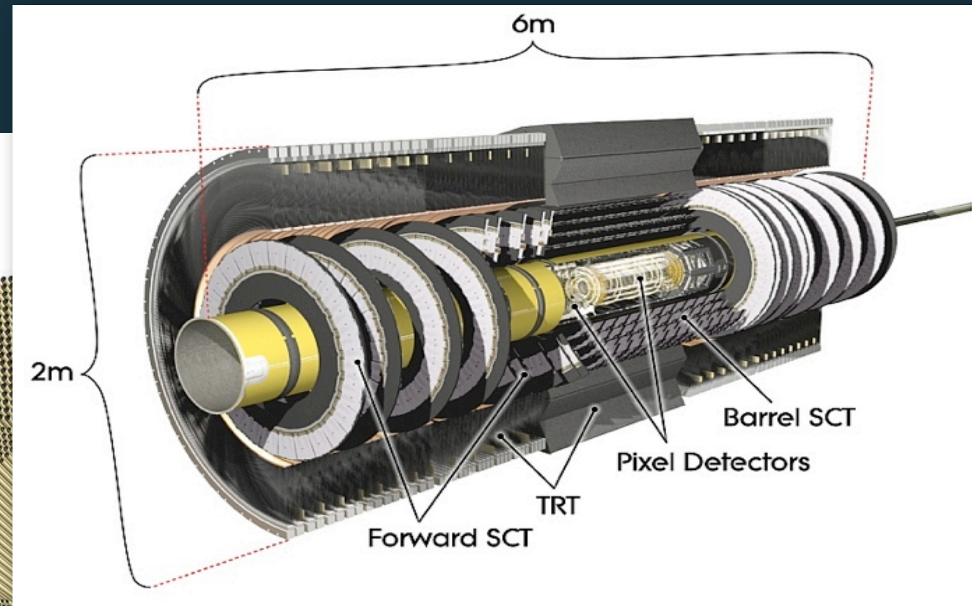


The ATLAS Detector



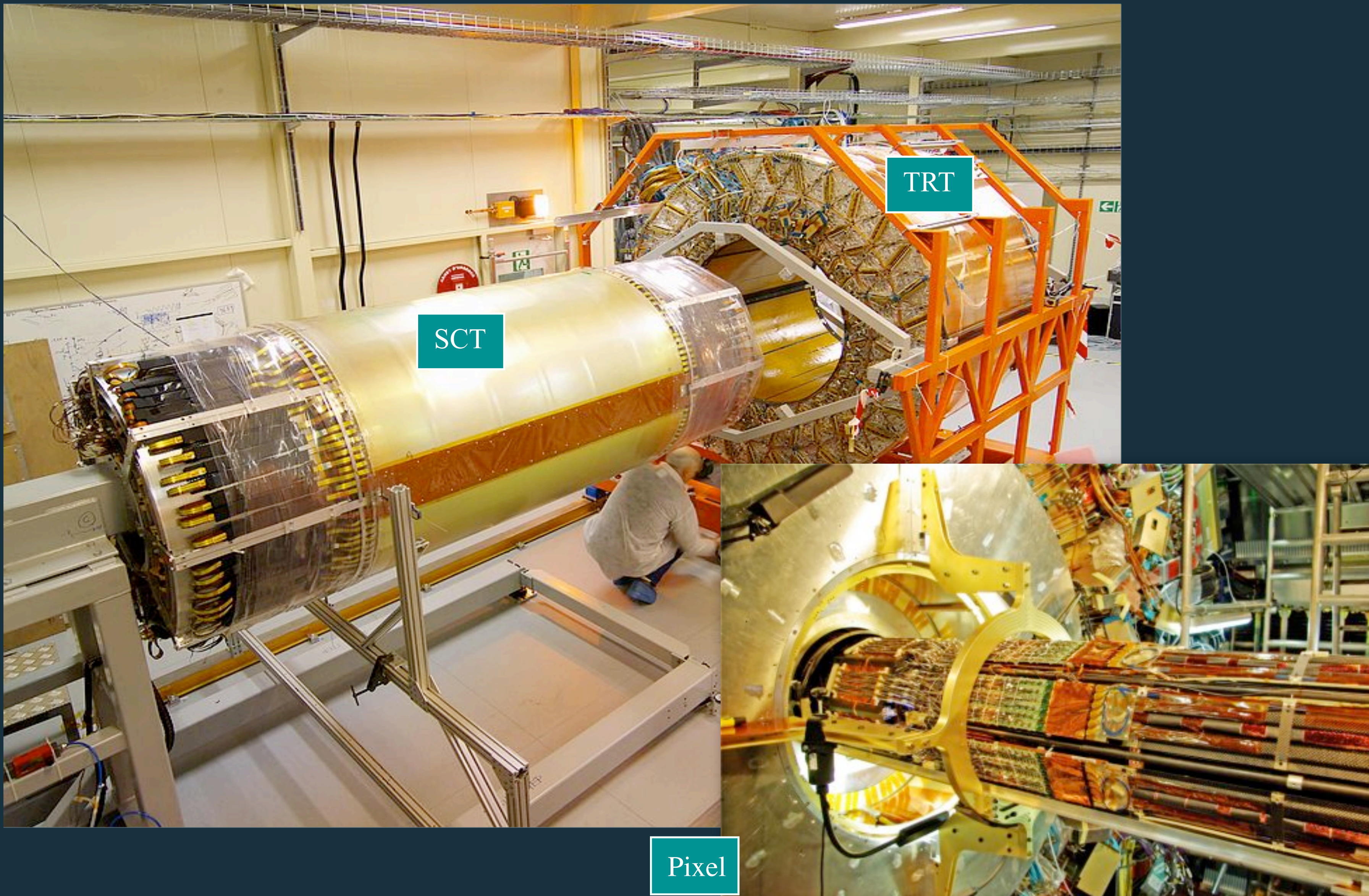
The Inner Detector





- Transition Radiation Tracker (TRT)
  - Radius 2 mm straw tubes
- Silicon Central Tracker (SCT)
  - 80 μm pitch Silicon strip detectors, 40 mrad stereo
- Pixel Detector
  - Silicon pixel detector 50×400 μm pixels

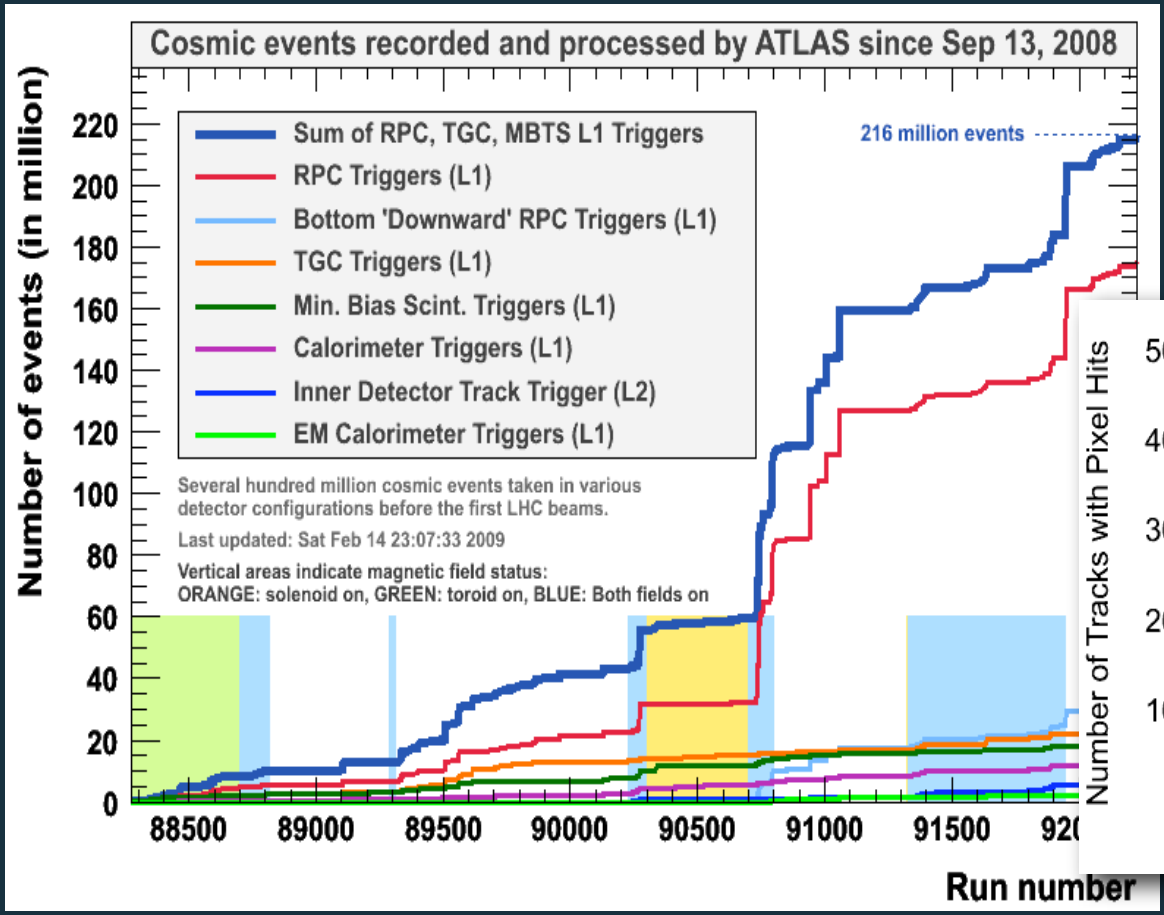
The Inner Detector

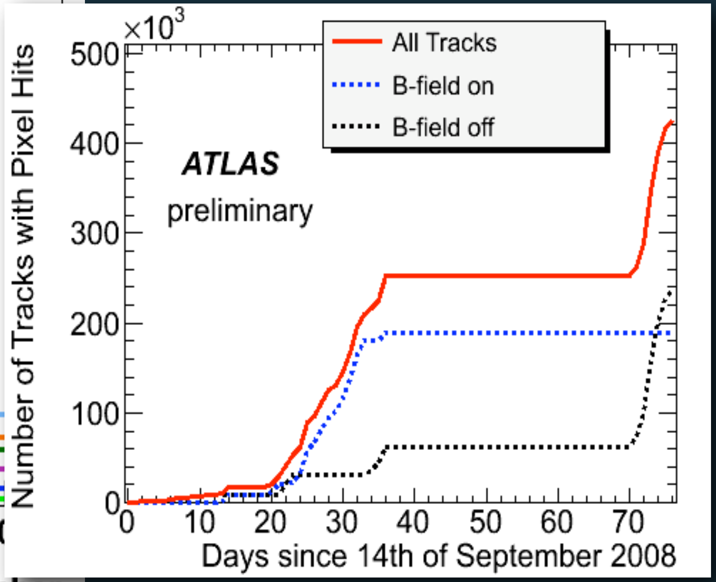


Commissioning

- We want to commission the High Level Trigger system and the reconstruction algorithms to be ready for collisions as much as possible before actual collision data taking
- Event Steering, Event Streaming, monitoring frameworks,
  - Technical runs - Monte Carlo data injected in to DAQ and HLT system
  - Cosmic ray muons - see talks by Alessandro Di Mattia and Andrea Ventura
- Commissioning the Inner Detector Tracking algorithms
  - Cosmic muons - different event topology, but realistic detector alignment, noise occupancy and data realistic data preparation
- To study algorithm efficiency, need orthogonal or passthrough triggers
  - Muon triggers, Level 1 from hits in muon trigger chambers - Pass through HLT with large prescale - unbiased by HLT, but lower efficiency for Inner Detector tracks
  - Level 1 Fast-OR from the TRT - improved purity for Inner Detector tracks
- For alignment studies, want to maximise number of high momentum tracks with (as much as possible) uniform detector illumination
  - Select good Inner Detector tracks using the High Level Trigger
  - HLT Inner Detector Cosmic stream - any L1 trigger also with Inner Detector track from tracking HLT - biased by HLT selection

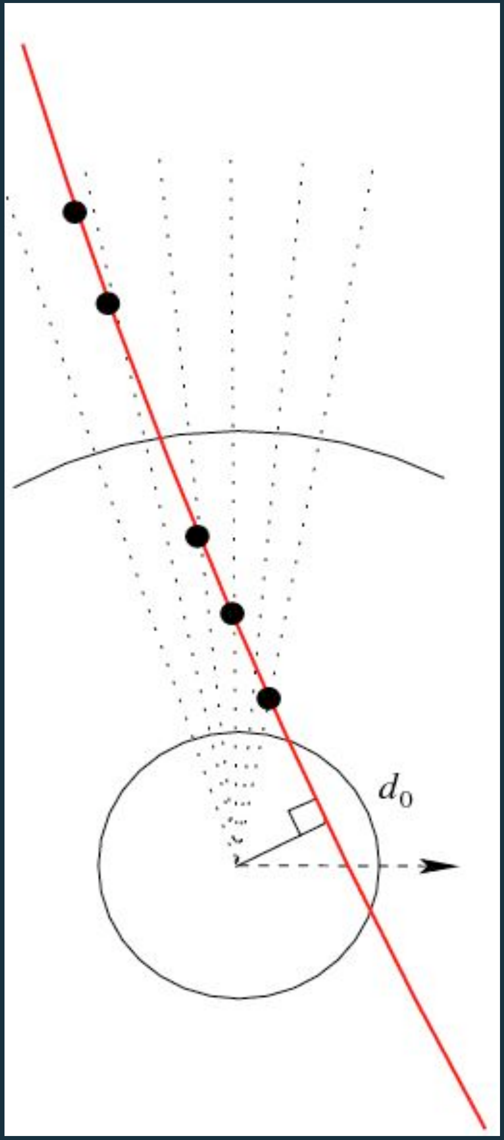
Collected Cosmic Data

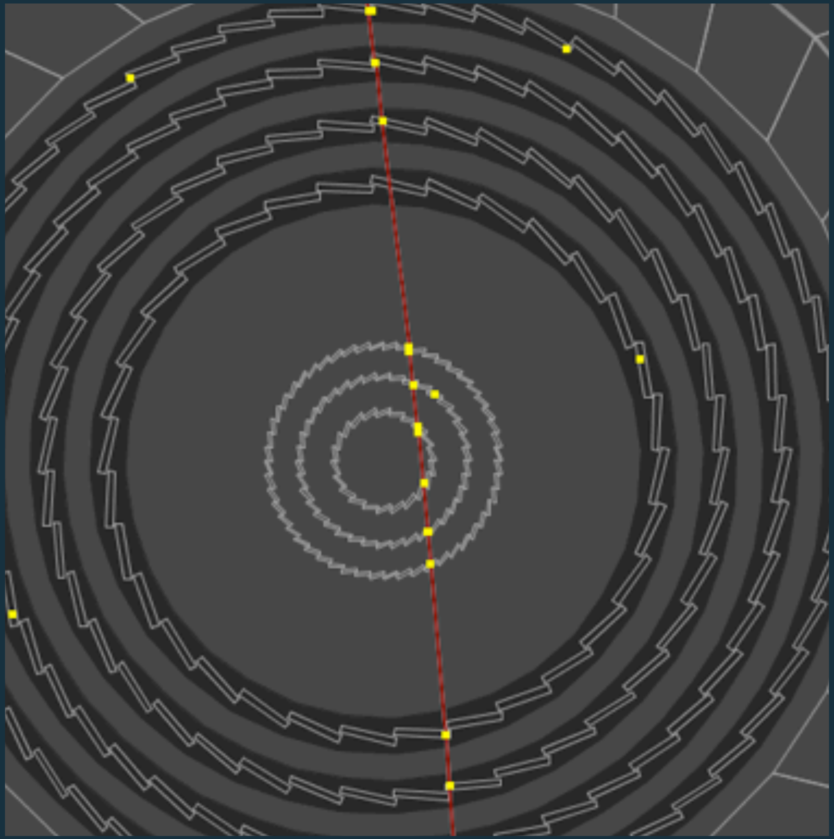




- From September to December 2008, extended Combined Inner Detector Cosmic run where the HLT tracking has been exercised - concentrate on results from this run.
- Currently greater than 300 million events collected.

Comic Muon Reconstruction



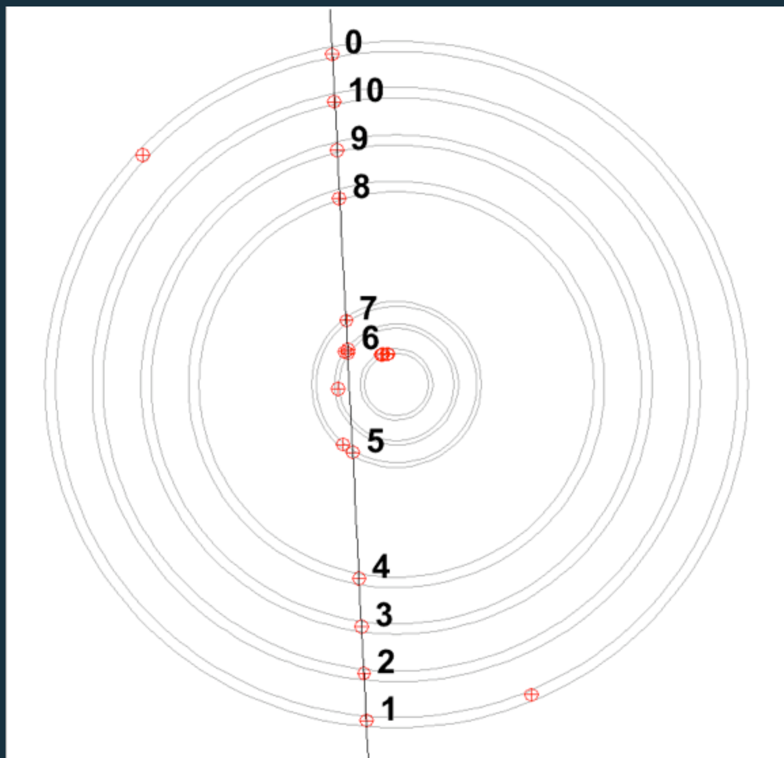


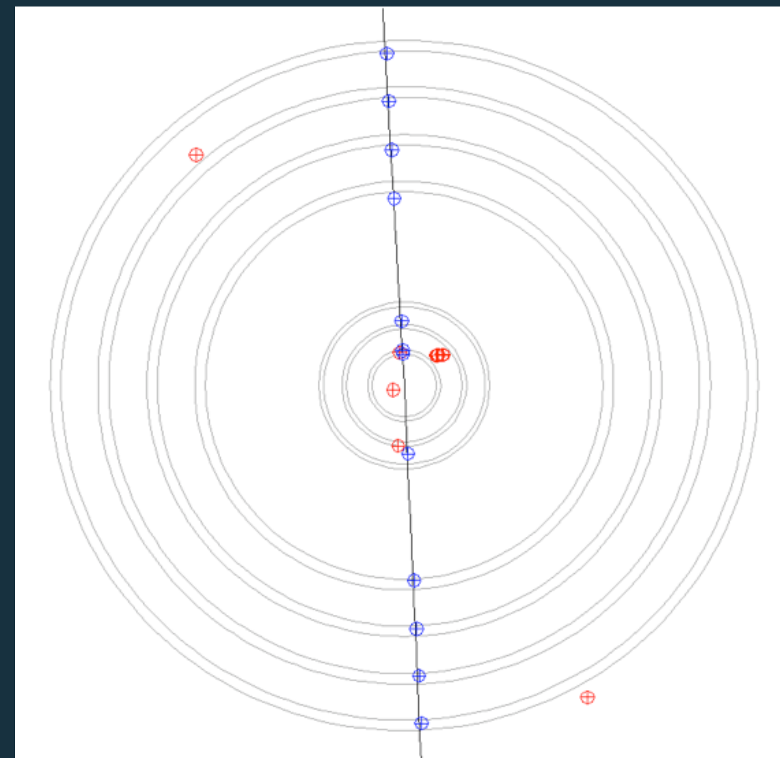
- Cosmic muons have characteristic up-down tracks.
- Can have very large impact parameter with respect to the nominal beamline
  - Level 2 Trigger algorithms are optimised for collisions - outward going tracks originating from the beamline, with a small impact parameter.

HLT Tracking for Cosmics

- Three algorithms for the ID Cosmic Stream used during the cosmic runs…
  - SiTrack - Silicon hit lookup table based algorithm with extension to include TRT hits
    - Using seed hits, extend tracks candidates using lookup table to identify likely location of additional hits consistent with tracks
  - IDScan - Silicon hit histogramming based algorithm allowing extension of tracks to TRT
    - Finds likely z position of vertex and identifies potential tracks consistent with this vertex by clustering silicon hits in η - ϕ and $1/p_T$ - ϕ space
  - TRT Segment Finder
    - Special cosmic algorithm for the TRT barrel, finds tracks using only TRT hits, uses wrapped offline algorithm but restricted to the regions $\pi/2 \pm \pi/4$ and $-\pi/2 \pm \pi/4$
- All algorithms highly configurable, both silicon algorithms optimised for collisions and tracks with a small impact parameter with respect to the beamline
- Event Filter tracking - Offline algorithm. For Combined Cosmic Run, running in evaluation mode near end, performance studies still ongoing - will concentrate on the Level 2 algorithms

Dealing with Large Impact Parameter

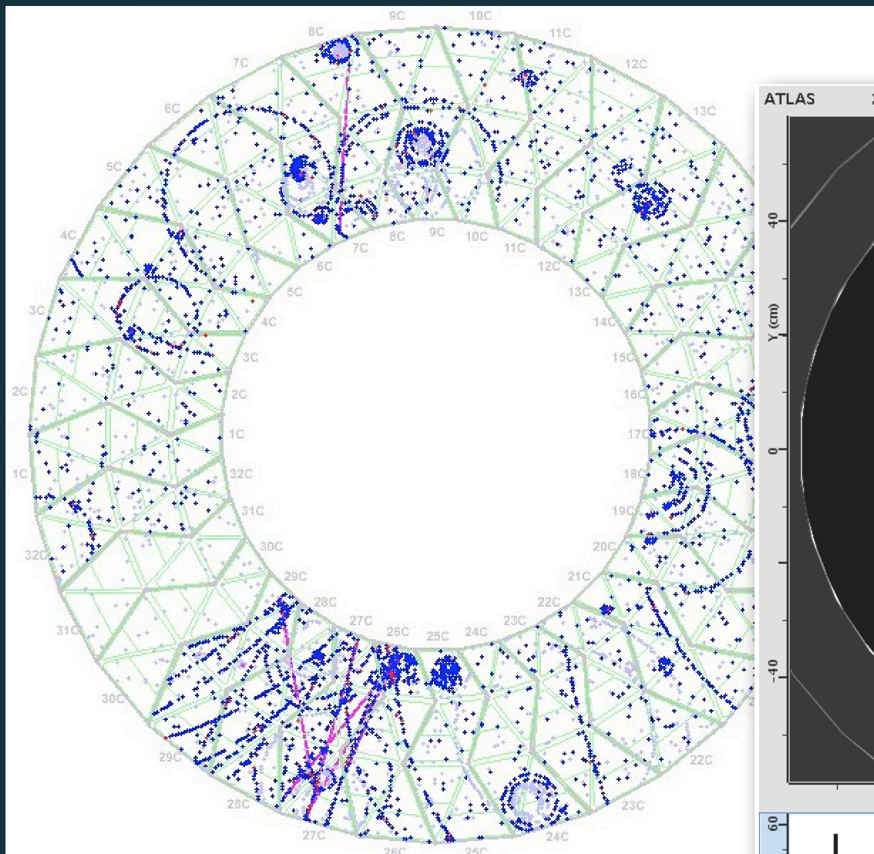


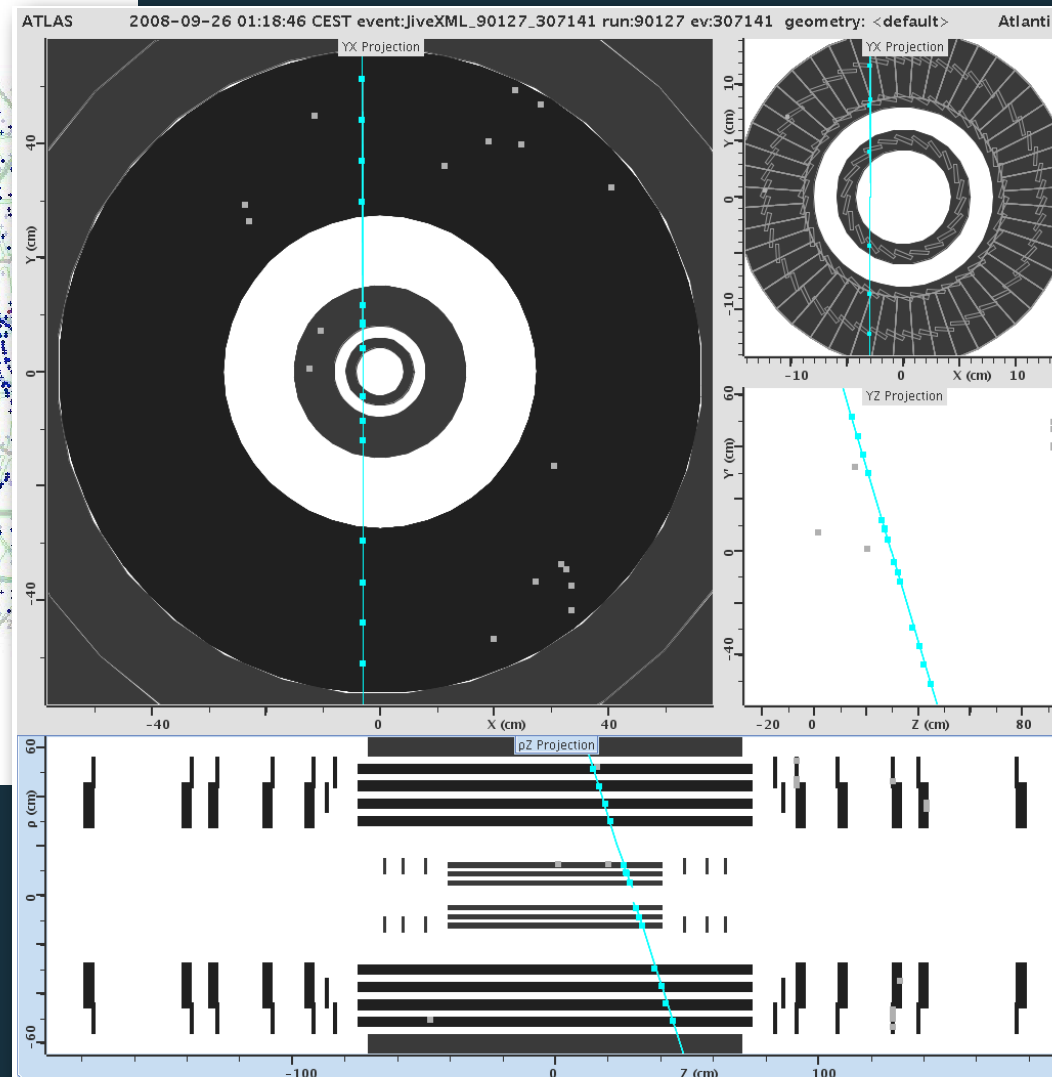


- IDScan uses collision algorithm with a barrel preprocessing stage to shift the coordinate frame
  - Tracks still originate from origin - constrained by efficiency of the shift, but allows exercise of algorithm nearer to collision mode

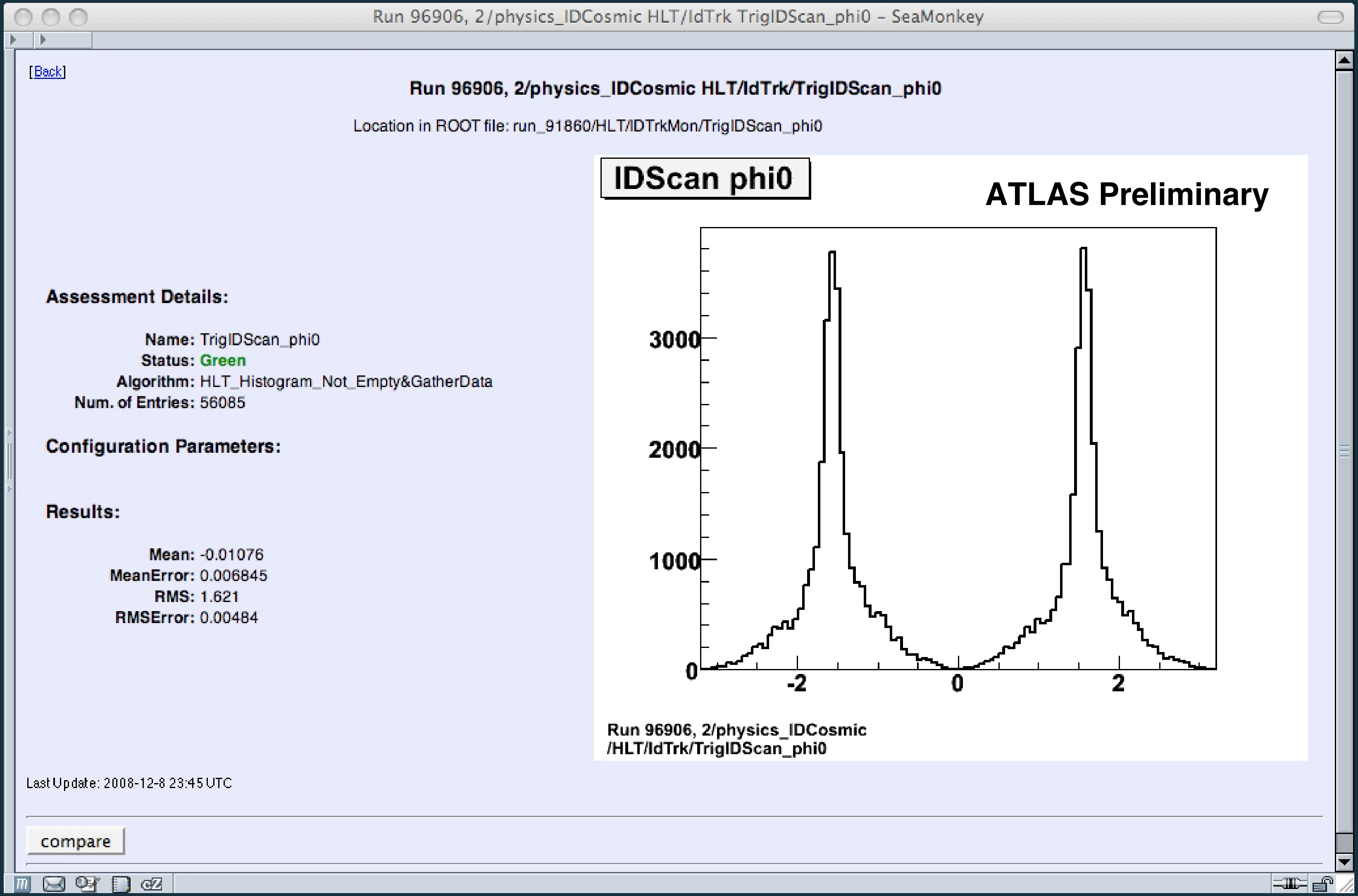
- SiTrack can also run on shifted spacepoints, but in addition it allows track seeds to originate anywhere in the detector and relaxes the track pointing constraint

Trigger Reconstruction



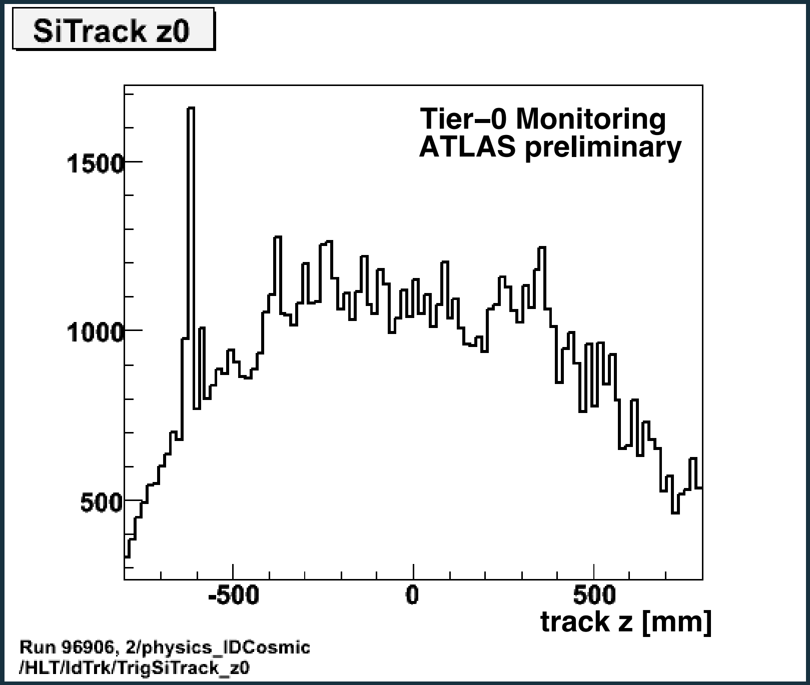


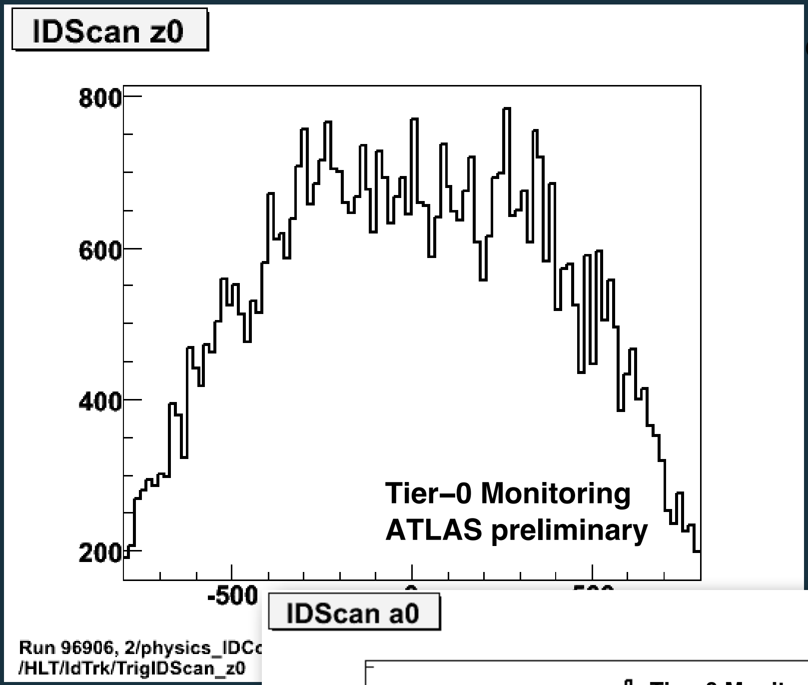
Monitoring

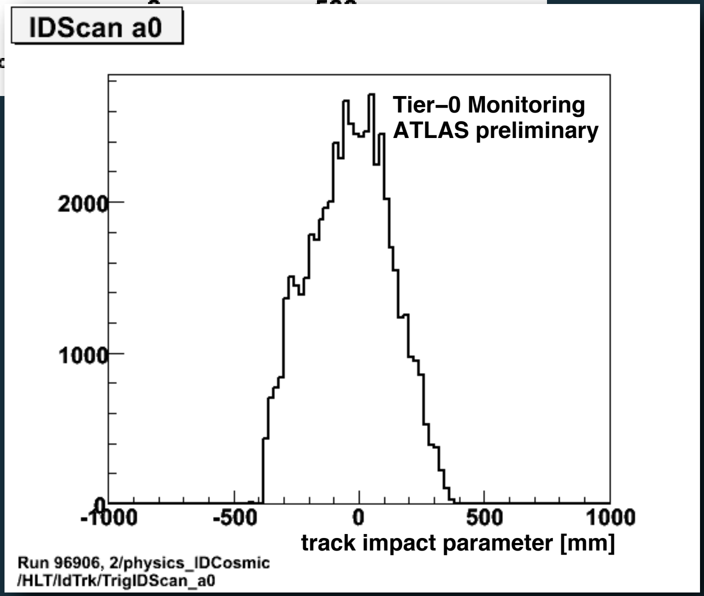


- Trigger performance monitored both offline and online (see talk by Alina Corso-Radu)

Monitoring



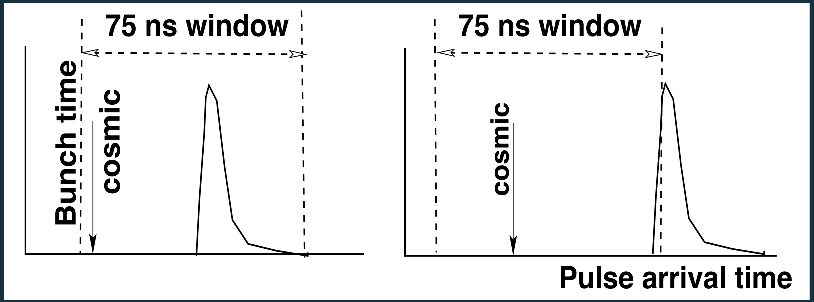


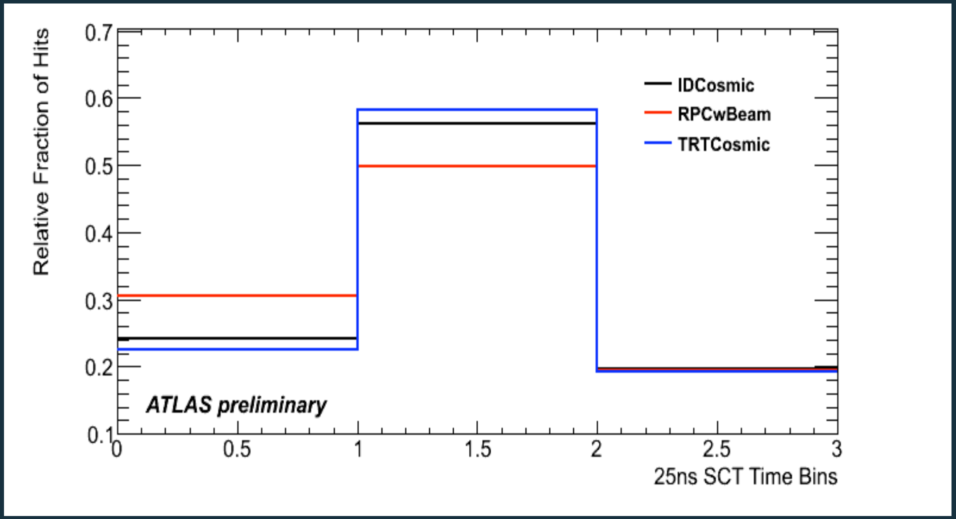


- Example of additional fake tracks due to noisy detector module
- Monitoring allows routine, fast diagnosis of problems which might otherwise affect trigger performance
- Additional module masking implemented online with dynamic noise suppression

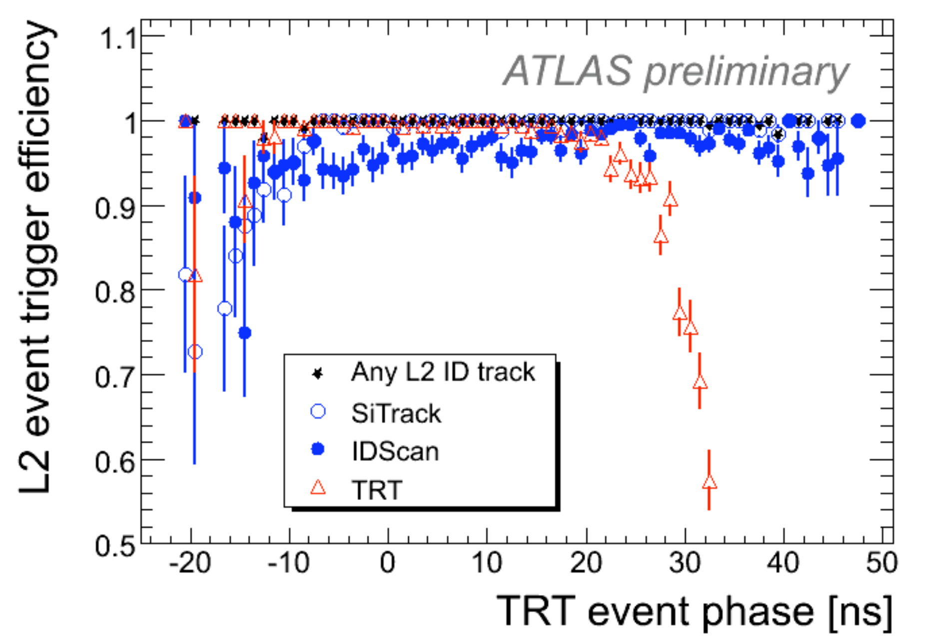
Event Timing

- For cosmic running, the Pixel detector reads out 8 successive bunch crossings
- The SCT reads out 3 - timing adjusted so that most hits arrive in the central bunch crossing.

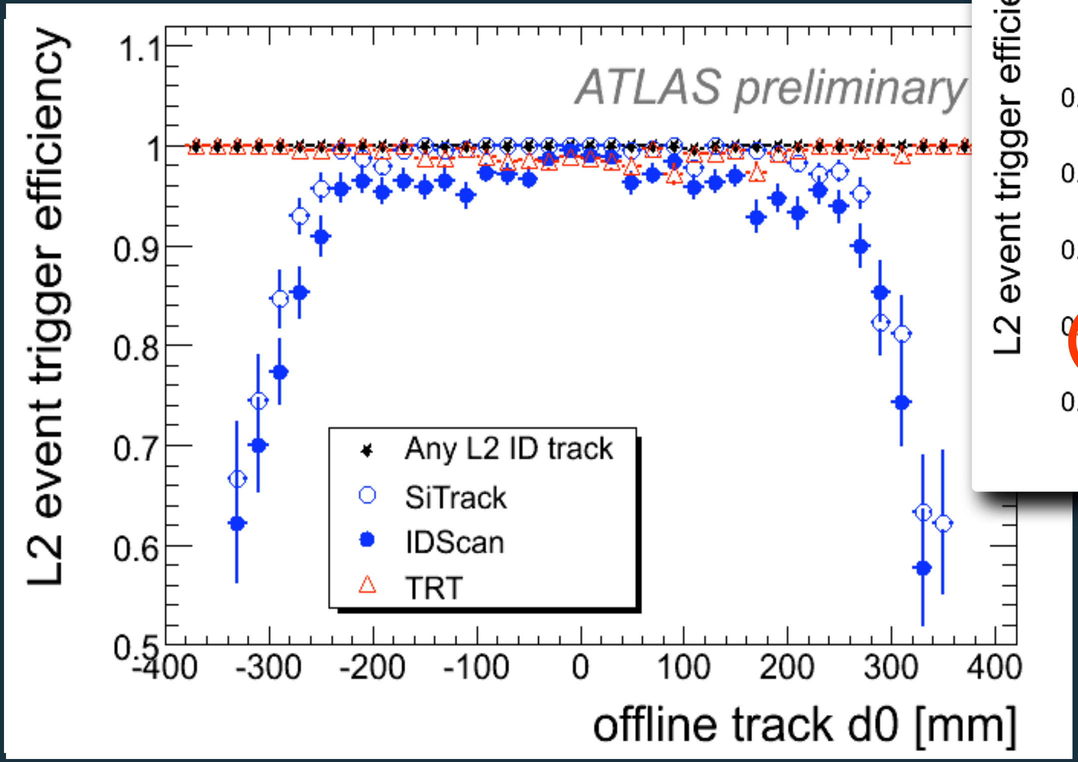


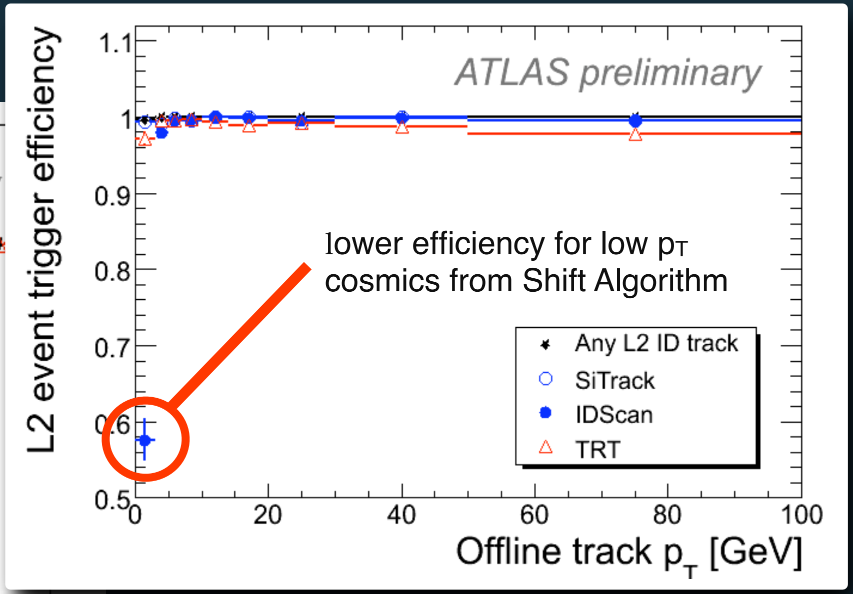


- Events with Offline track with at least 3 Silicon hits in both the upper and lower halves of the detector
- For the TRT hits must come within a specified time window, the Event Phase (EP) is the global time with respect to the nominal bunch crossing time.
- For times >25 ns the efficiency starts to fall as hits are outside time window



Trigger Event Efficiency

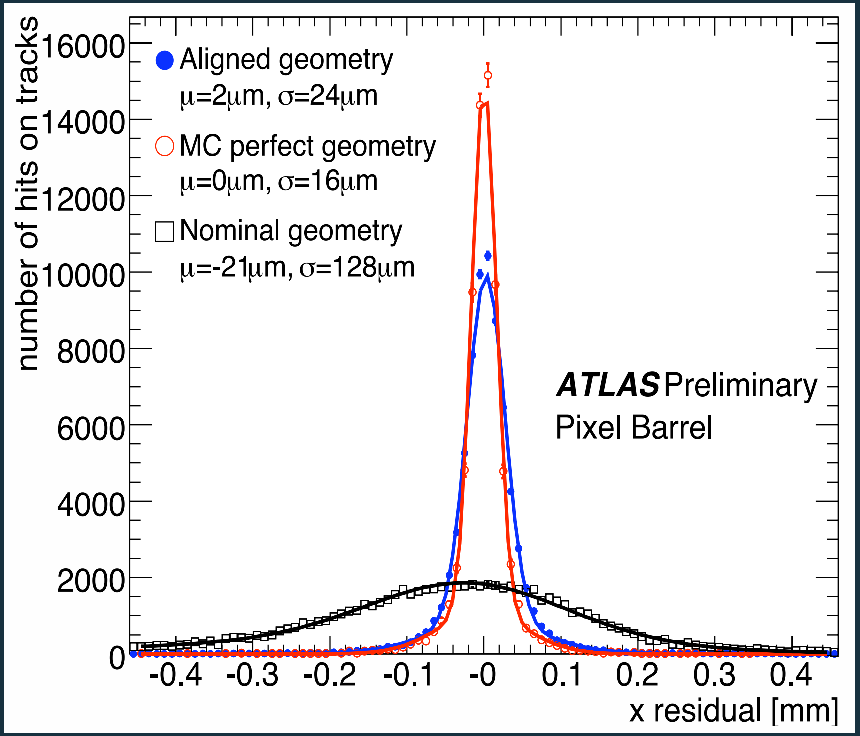


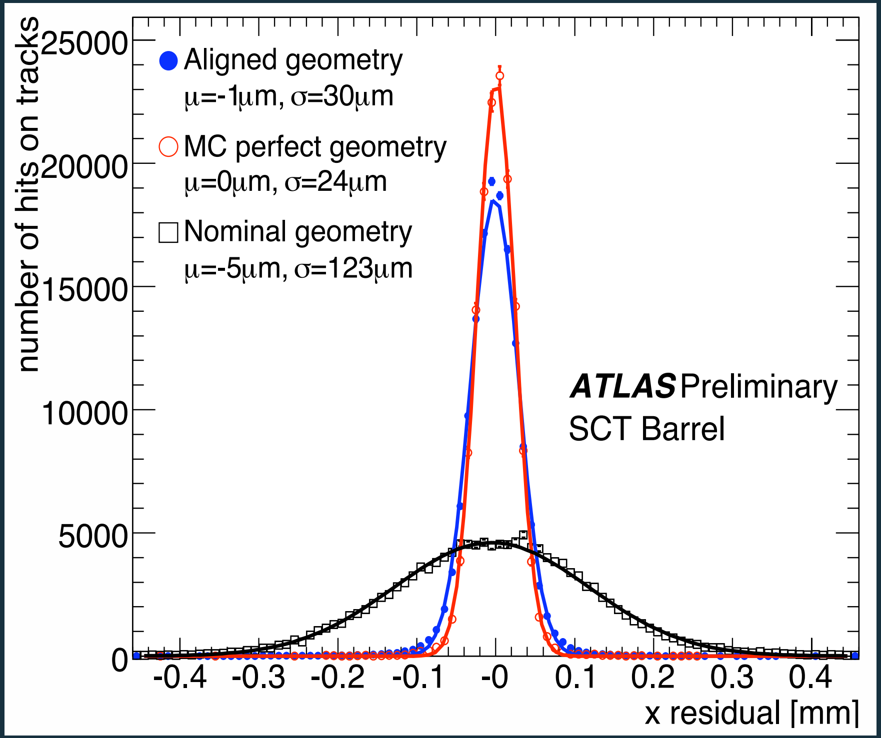


- Efficiency for selecting events with Offline track with at least 3 Silicon hits in both the upper and lower halves of the detector, and the TRT event phase in range -10 to 25 ns

- Si Algorithms approximately flat efficiency >90% for events where the cosmic track passes within the inner radius of the SCT
  - SiTrack slightly higher efficiency than IDScan, but larger rate of fake, low p_T tracks
- TRT efficiency extends beyond Silicon algorithm acceptance, but with larger rate of fake tracks
- Efficiency for OR of all three algorithms ~99% - good for alignment studies

Detector Alignment

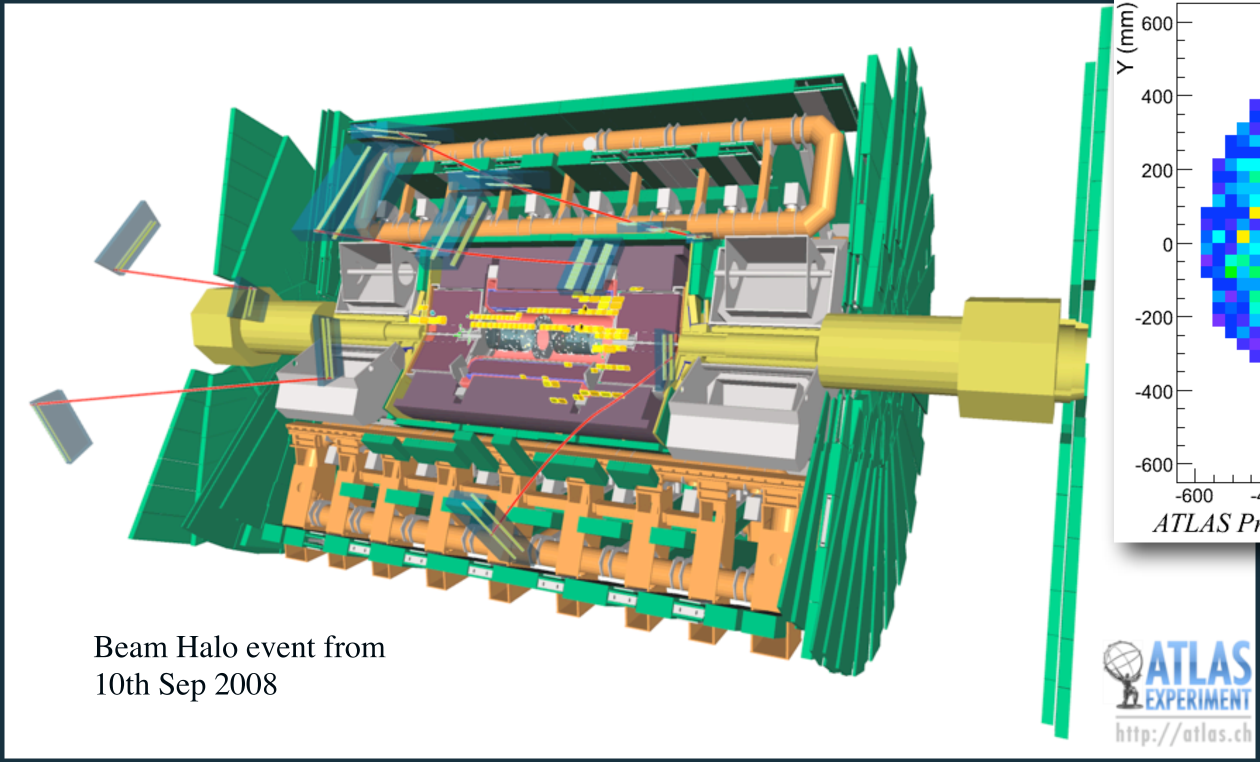




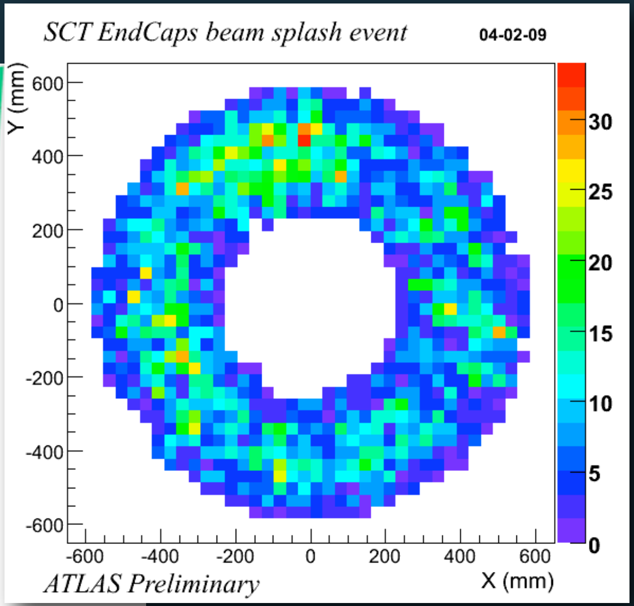
- Large statistics from Inner Detector Cosmic Stream allow significant improvement in detector alignment in Barrel Region
    - Pixel spacial resolution improves from ~130 μm to near optimal 24 μm, similar improvement for SCT
- In turn, alignment improves resolutions and trigger performance

The Future - Commissioning with Beam

- Cosmic muons are good for aligning detector elements at $\phi = \pm\pi/2$, not so good for modules at $\phi = 0$ and π or in the endcaps



Beam Halo event from
10th Sep 2008



- Will want to exercise trigger as much as possible with first beam. Even single beam will provide tracks from beam-gas interactions and beam halo muons, although at lower angles of incidence
  - Good for end cap alignment, track reconstruction at low angles
  - Maybe not so good for detectors - backgrounds not well understood at this stage

Summary and Outlook

- Tracking in the ATLAS HLT is essential to achieve the physics goals of the LHC

- The Level 2 Inner Detector Trigger has been routinely operated during cosmic running and commissioning is progressing well
  - Over 300 million cosmics collected, over 400000 with Pixel spacepoints
  - Improved understanding of the detector and trigger with REAL data, timing, alignment, noise occupancy...

- Event Filter tracking used for end of cosmic run, performance studies underway

- The Inner Detector Trigger will be ready for first beam, emphasis will be on stable and SAFE running
  - Pixel detector off
  - SCT with reduced bias voltage

- ATLAS will see its first collisions later this year, the Inner Detector Trigger Commissioning is well advanced and will be ready to rise to this challenge