The ATLAS Trigger
Commissioning with Cosmic-Rays

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on behalf of the
ATLAS Trigger Collaboration

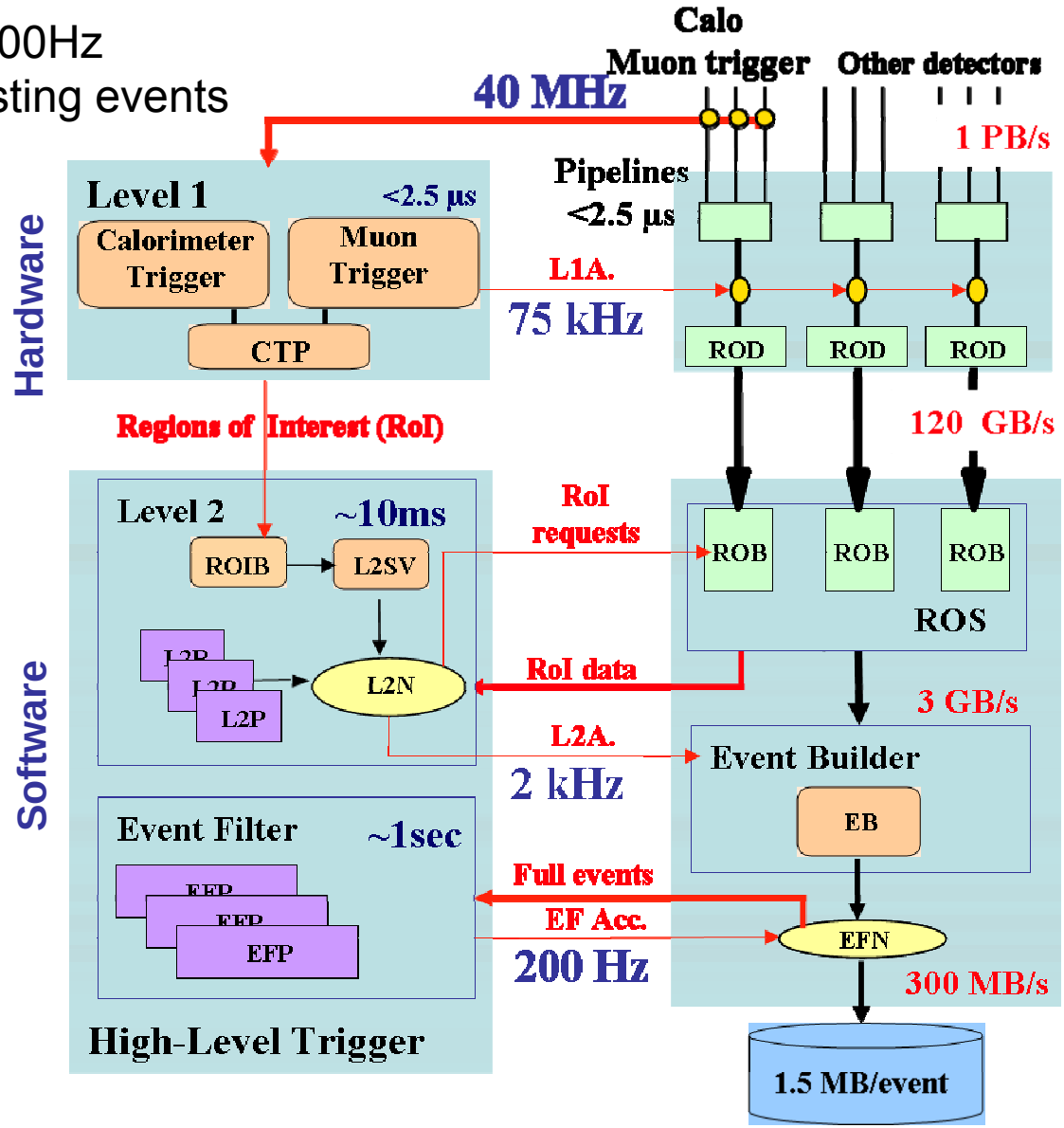
ATLAS Trigger and DAQ System

Reduce rate from 40 MHz to 200Hz while retaining the rare, interesting events

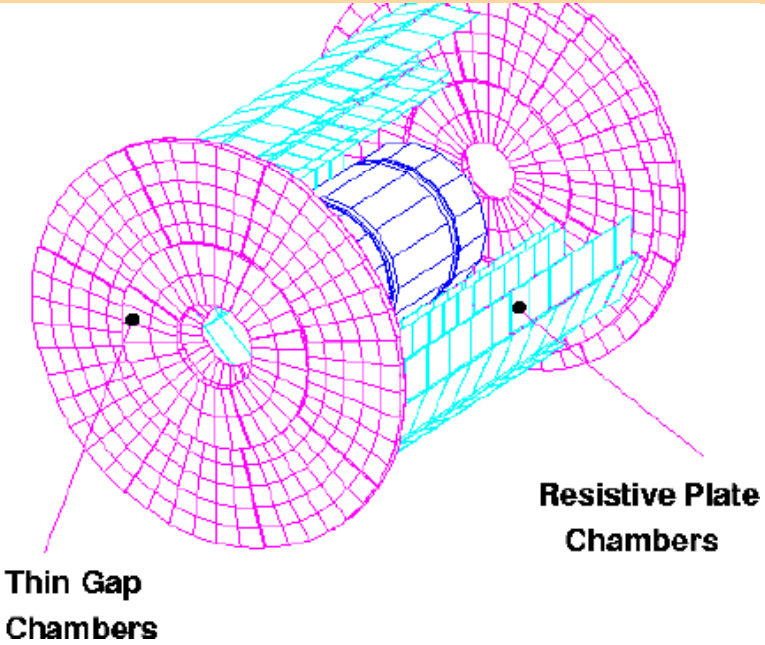
1) **Level 1** decision based on data from calorimeters and muon trigger chambers; synchronous at 40 MHz

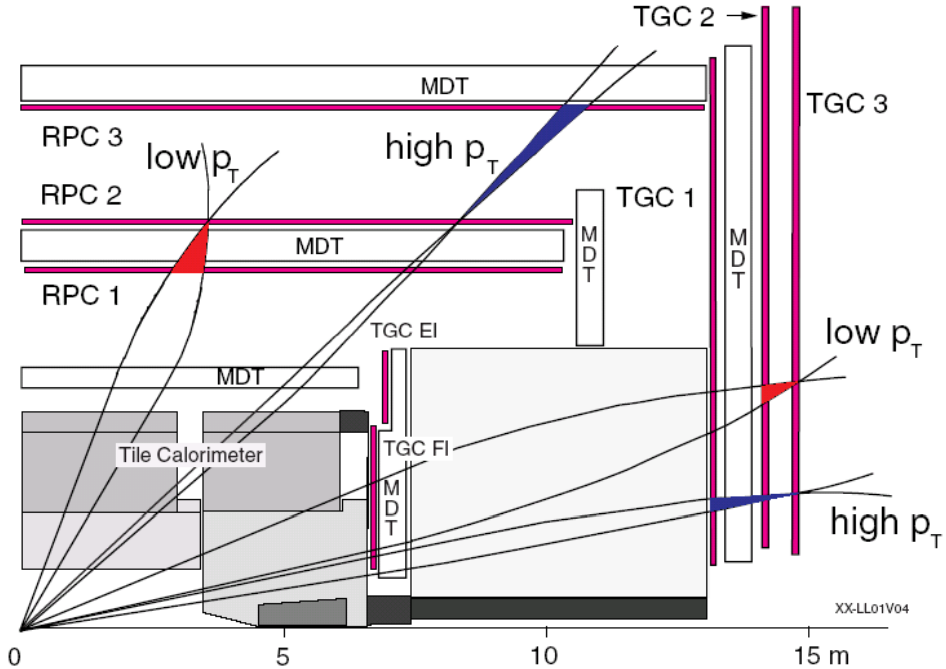
2) **Level 2** uses Regions of Interest identified by Level-1 (< 10% of full event) with full granularity from all detectors

3) **Event Filter** has access to full event and can perform more refined event reconstruction



ATLAS Level-1 Muon Trigger





- Dedicated muon chambers with good timing resolution
  - Barrel: Resistive Plate Chambers (RPC)
  - Endcaps: Thin Gap Chambers (TGCs)
- Local track finding on-detector, candidate multiplicity calculation off-detector

- Looking for coincidences in chamber layers within programmable *roads* (road width related to momentum)
- 6 programmable coincidence windows determine momentum threshold (using B-field deflection)
- For cosmic rays open up the coincidence windows as much as possible

Combined Cosmic run in June 2007

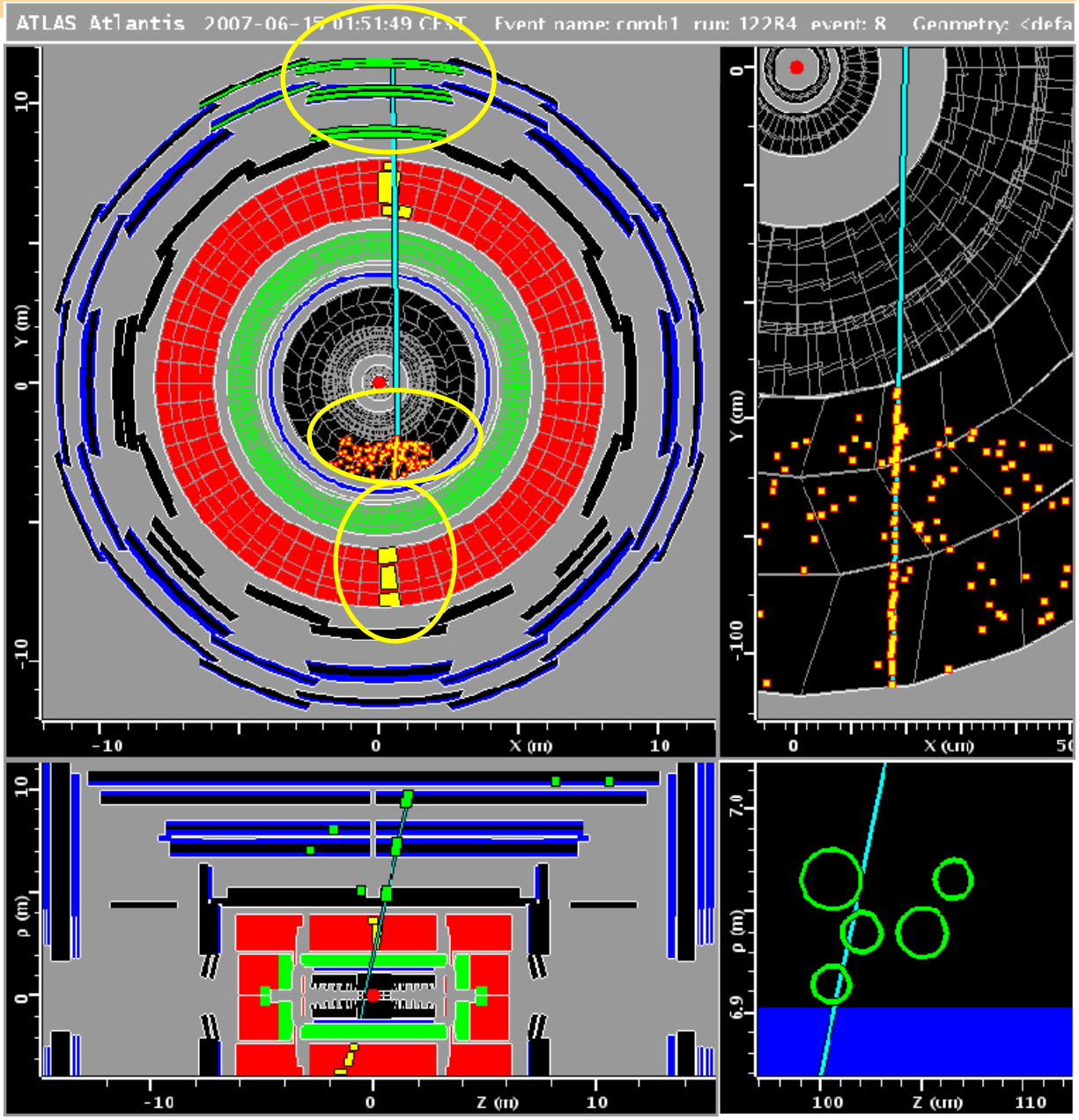
In June we had a 14 day combined cosmic run. Ran with no magnetic field. Included following systems:

Muons – RPC (~1/32) **,**
MDT (~1/16),
TGC (~1/36)

Calorimeters –
EM (LAr)(~50%) **&**
Hadronic (Tile) (~75%)

Tracking – Transition Radiation Tracker (TRT)
(~6/32 of the barrel of the final system)

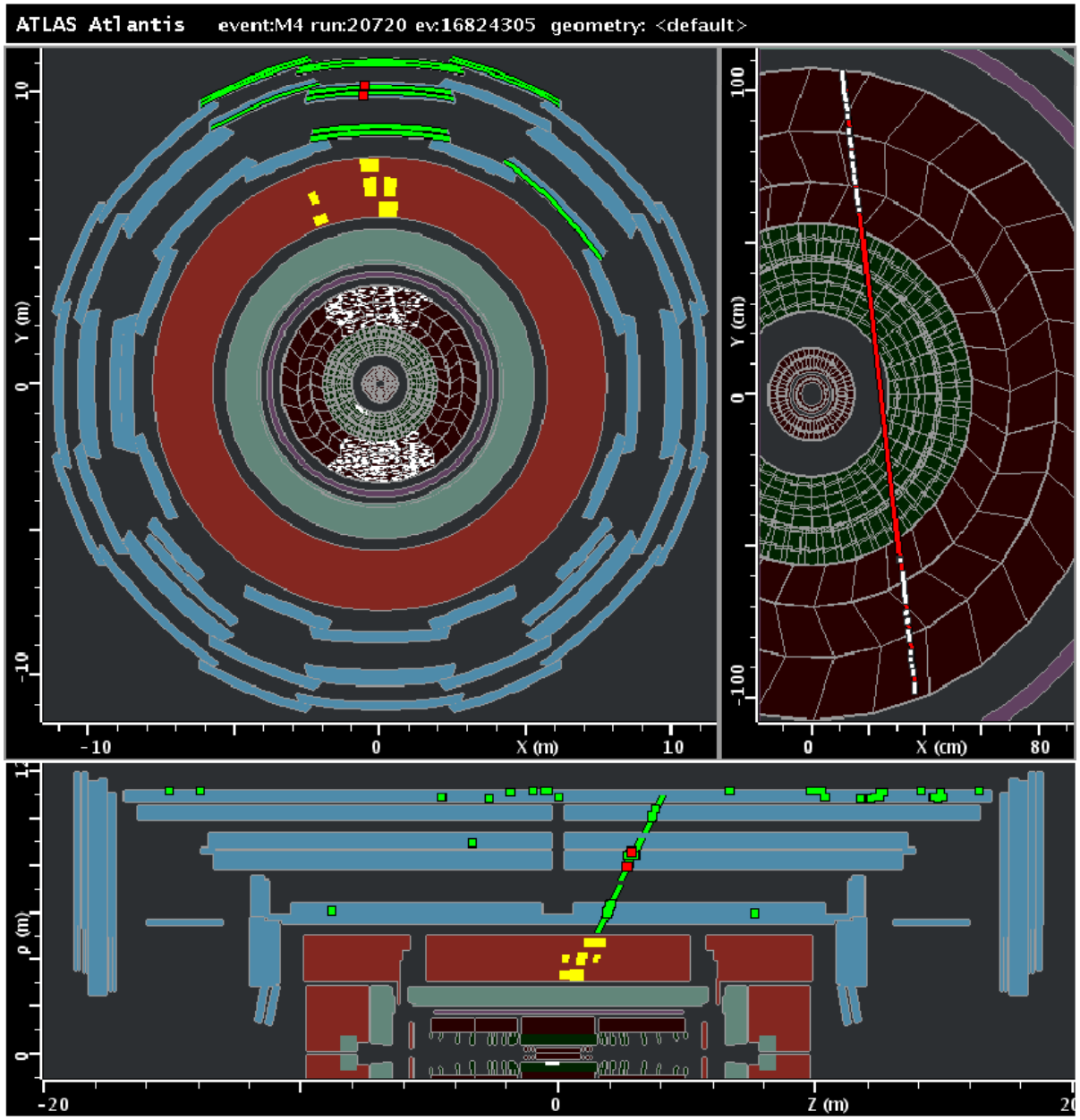
Only systems missing are the Silicon strips and pixels and the muon system CSCs



Combined Cosmic run from last week

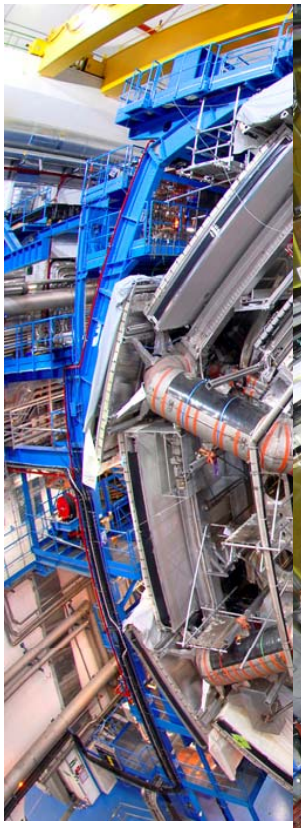
Latest combined cosmic run was last week – same systems present as in June but with greater coverage

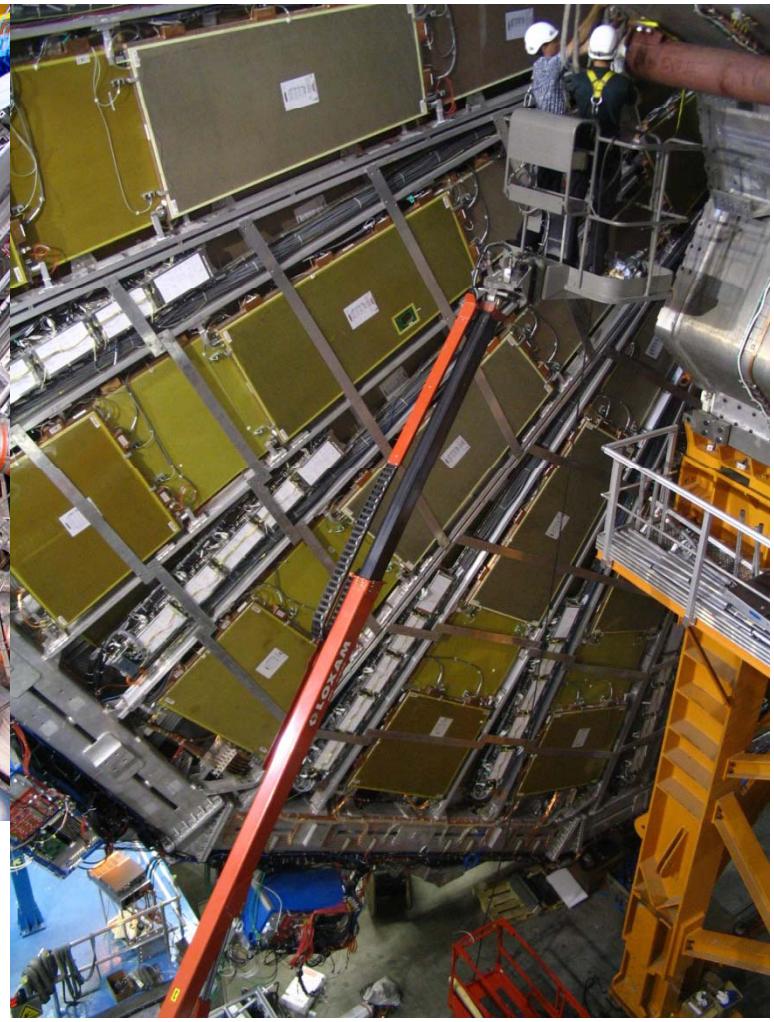
Hot of the press!!



Level-1 Barrel & Endcap Muon Trigger

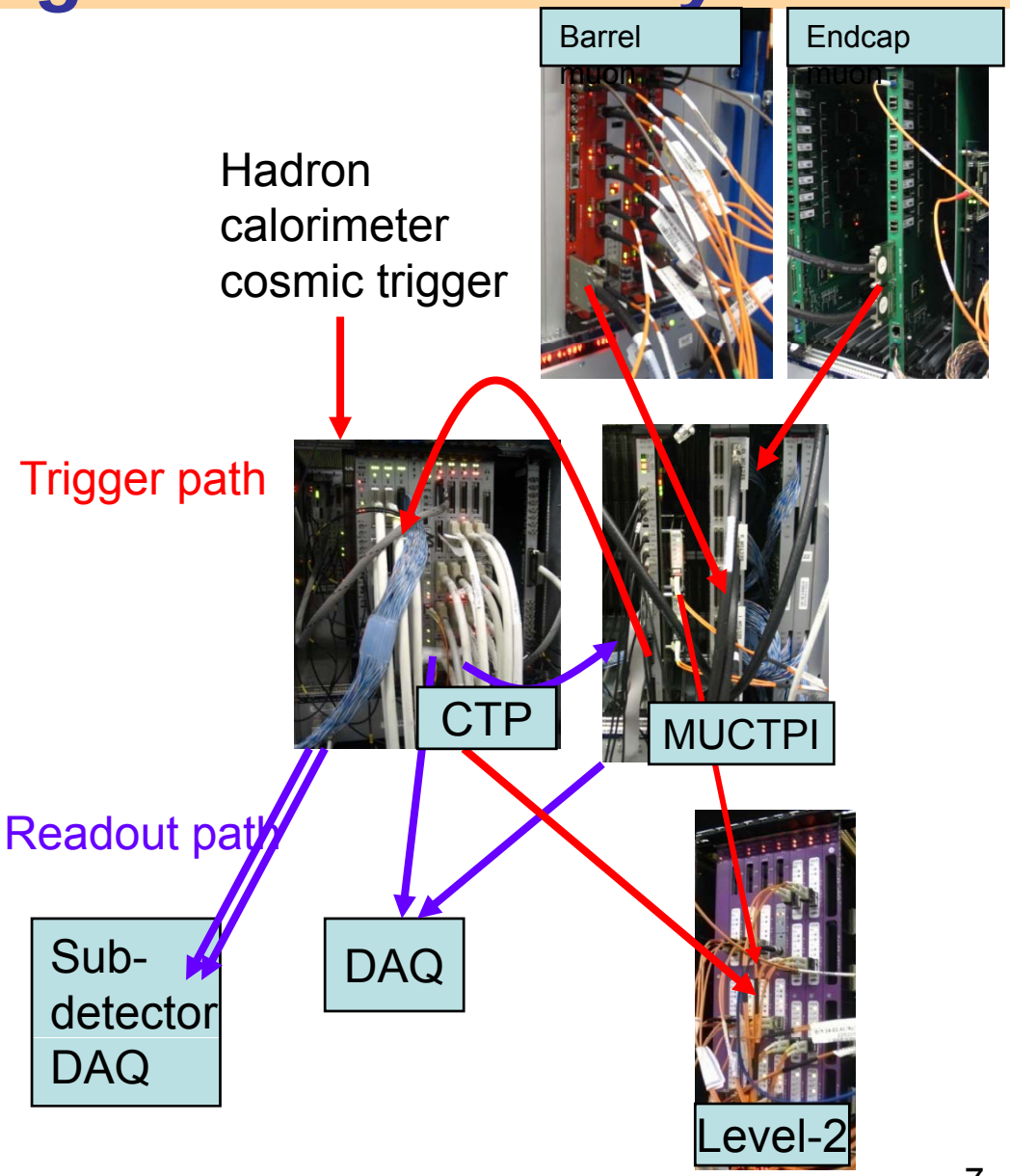
- Most chambers installed and being commissioned
- Cosmic ray commissioning in June 2007: top sector barrel & 2 sectors endcap provided cosmic ray trigger to Muon Interface and Central Trigger Processor through final trigger chain
  - Rate (barrel): 120 Hz
  - Rate (endcap): few Hz
- Rates consistent with expectation from simulation
- Measured trigger latencies as expected





Setup of the Level-1 trigger during commissioning with cosmic rays

- Muon interface (MUCTPI) & Central trigger:
  - crates with close to final boards installed
- Central Trigger inputs:
  - Muon interface (MUCTPI):
    - Barrel (RPC): 120Hz
    - Endcap (TGC): few Hz
  - Temp. hadron calorimeter cosmics (sub-Hz)
- LVL1 Calorimeter coming online now



HLT algorithms for Cosmic rays

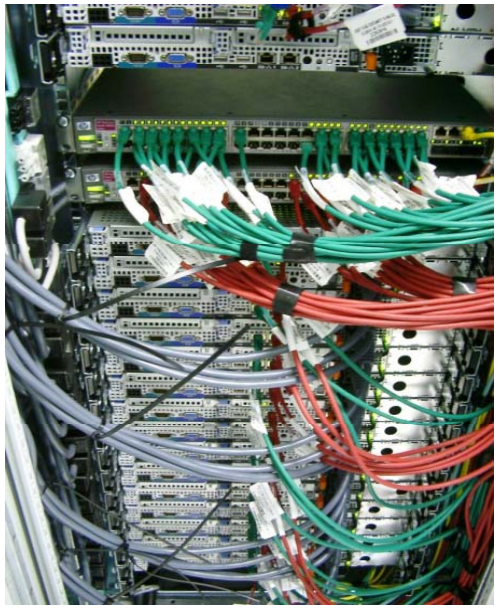
Algorithm description	Level	Status
Dedicated cosmic algorithm using muon systems	LVL2	Run online in June & August
Modified physics algorithm using calorimeters	LVL2 & EF	LVL2 part using LAr run online in June, Full algorithm run in August
Modified physics algorithm to identify muons in Tile Cal	LVL2	Run online in August
Modified physics tracking algorithm using TRT	LVL2	Run online in August
Dedicated algorithm using muons and TRT	EF	Run online in August
Modified physics tracking algorithm(s) using silicon	LVL2	Tested on simulation & standalone cosmic run on surface

- Algorithms open up the RoI from LVL1 to look at the whole detector (as the cosmic muons are not pointing to interaction point)
- The algorithms are run in forced accept mode so no event rejection
- All algorithms tested using simulated cosmic rays
  - see talk by H. Hadavand for details of cosmic simulation at ATLAS

HLT algorithms for Cosmic rays

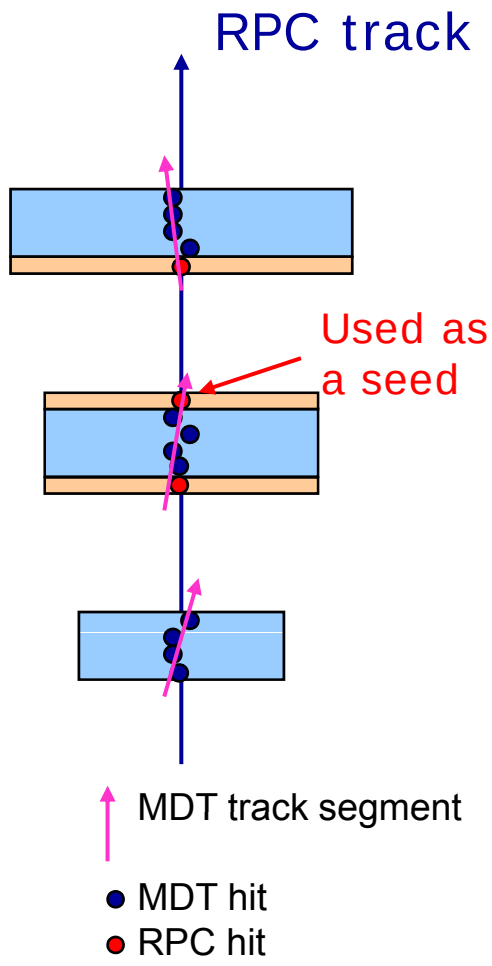
- Running these algorithms extremely useful for testing nearly the whole trigger chain
- Tests
  - Muon systems -> LVL1 interface
  - Input to LVL2 (using ROI mechanism)
  - Distribution of LVL1 trigger and timing signals (LVL1A, clock & busy)
  - HLT configuration (see talk by J. Stelzer)
  - HLT Steering (see talk by S. George)
- The HLT was run on a subset (~4%) of the final hardware
  - LVL2 running on 20 XPU machines

(see talk by B. Gorini for more on hardware used)



Dedicated Muon HLT algorithm

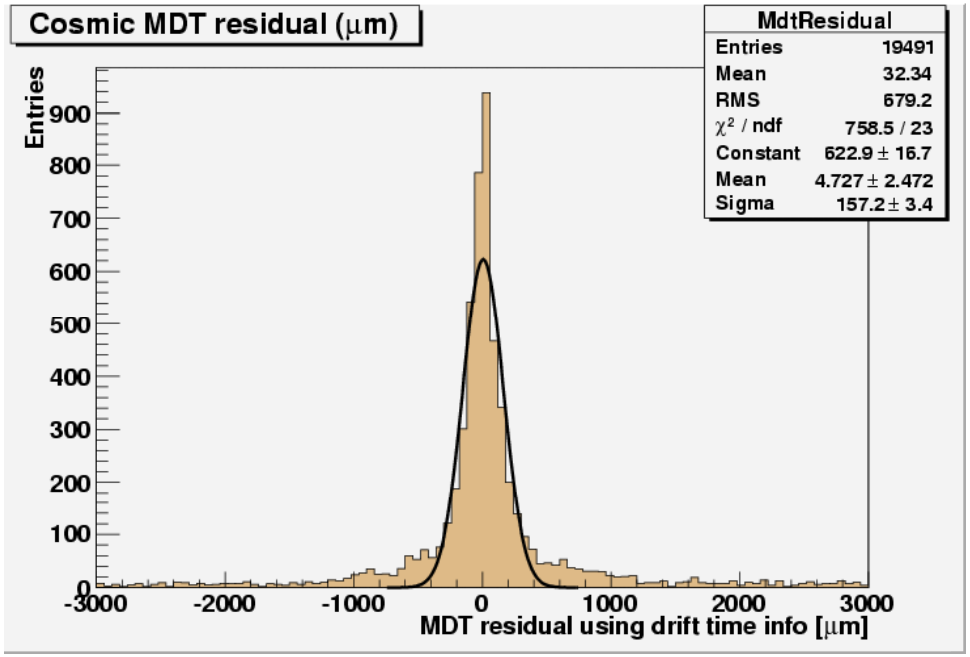
- Form RPC track
  - Uses RPC hits from middle RPC station as seed
  - Finds RPC hits in inner & outer layers to form straight line RPC track around seed hit
  - Straight line fit of RPC hits to find associated MDT hits
- MDT pattern recognition -> MDT Track segments
  - Find MDT hits in region around the extrapolated RPC track
  - Local straight line fit of MDT hits in each chamber (drift time not used)
  - Check number of MDT hits and compatibility of track direction with RPC track
- Possibility to use MDT timing to estimate direction of cosmic ray muon



Dedicated Muon HLT algorithm

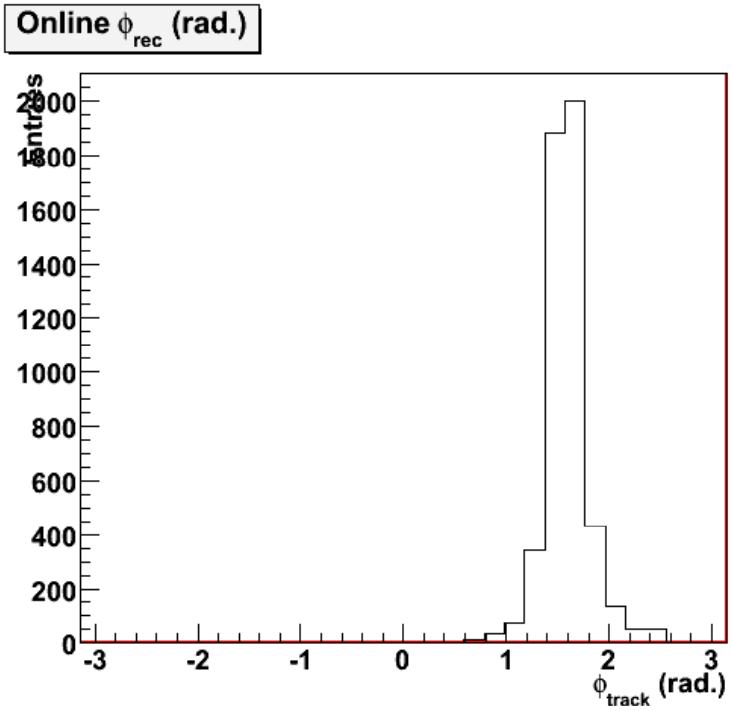
Plots produced online by the HLT algorithm during the June & Aug. cosmic ray run

Algorithm selects ~80% of events selected by LVL1 – consistent with simulation



Resolution of MDT track wrt RPC track. RMS 1.8cm consistent with expectation as MDT is uncalibrated

Resolution improves to 0.16mm if we use a fit to the MDT drift time (LVL2 algorithm to do this but not run online yet)

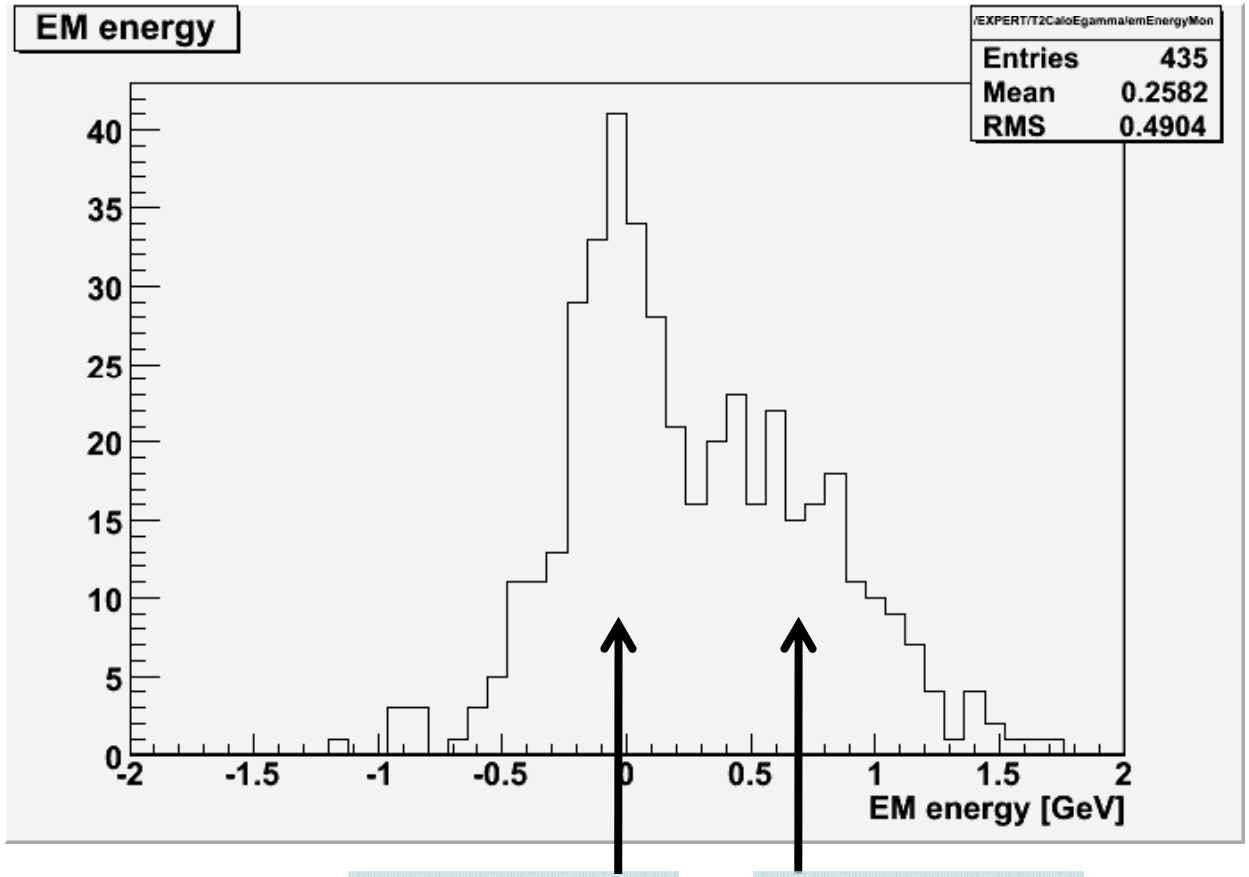


Phi of muon candidates. Corresponds to the top part of the detector where the muon system was being readout

LAr Calorimeter algorithm

Plot produced online by the HLT algorithm during the June cosmic ray run

Algorithm finds total EM energy in 0.07 x 0.125 $\Delta\eta \times \Delta\varphi$ region centered on the highest energy cell



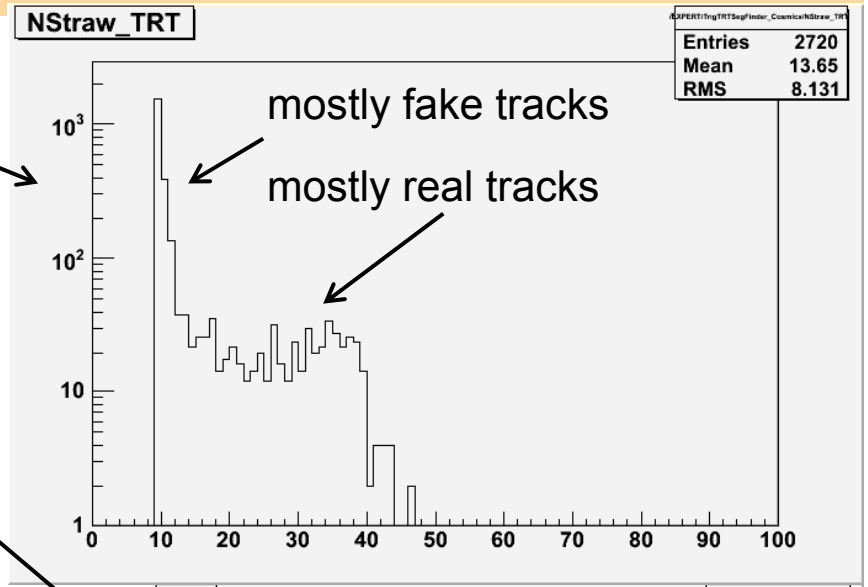
Calorimeter Noise

Cosmic signal ~700MeV

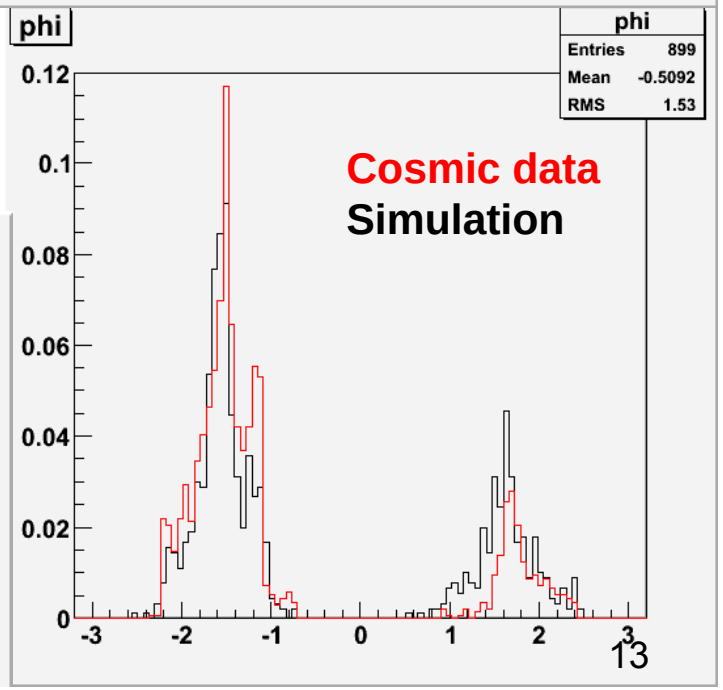
HLT TRT tracking algorithms

Run online in last weeks August cosmic run

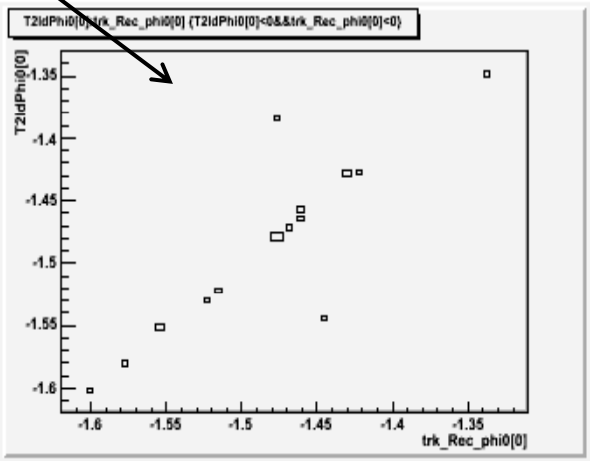
Number of TRT hits on the HLT track

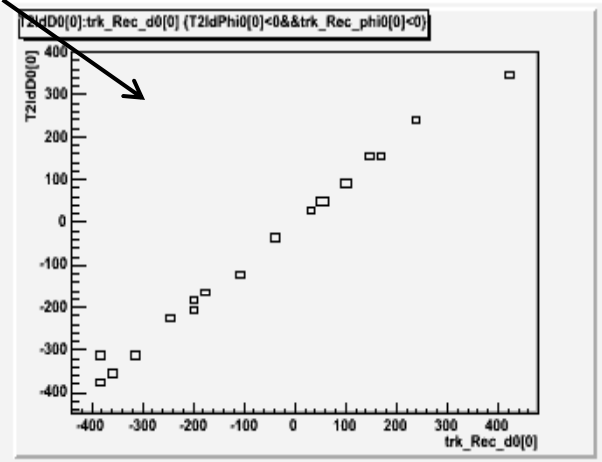


Phi distribution of HLT tracks (rad)
(+ve phi track in top of detector,
-ve phi track in bottom of detector)



Comparison between the HLT track (y-axis) and the corresponding offline tracks (x-axis) :
Phi0 of track (rad), impact parameter of track (mm)





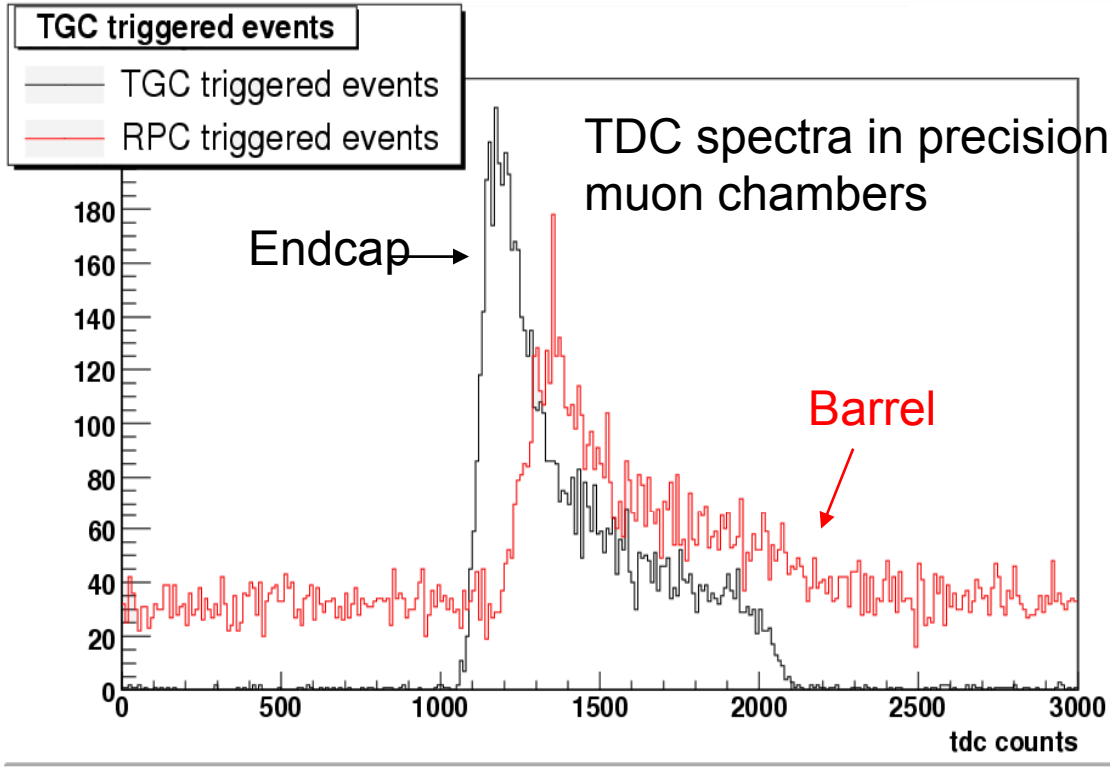
Cosmic triggers in the future

- Cosmic rays are not only useful for detector commissioning but can also be very useful during physics runs
  - Alignment (especially for constraining alignment parameters which are insensitive to tracks coming from interaction point)
  - Calibrations
- We must have a good strategy for collecting adequate amount of cosmic data to do this
  - Looking at the possibility of triggering on cosmic rays in the long-gap (2.75μs of each 89μs orbit (3%) when there are no bunches in the machine)
- The cosmic HLT algorithms being developed for commissioning can be very useful for this

Summary

- ATLAS trigger system is based on data from the calorimeters and dedicated muon chambers at LVL1 and all detector systems in the HLT
- It reduces the event rate of initially 40 MHz to less than 200 Hz
- Significant parts of the ATLAS trigger system are already installed at the experimental site
- Regular combined cosmic-ray commissioning runs are undertaken with a substantial fraction of the ATLAS detector
- These runs have tested many parts of the ATLAS trigger chain
- Dedicated cosmic HLT algorithms have run online for the first time in the June & August combined cosmic ray runs
  - Useful for providing a sample of cosmic rays but more importantly for testing the trigger chain and setup
- ATLAS trigger is well on track to be fully operational for the first collisions in summer 2008

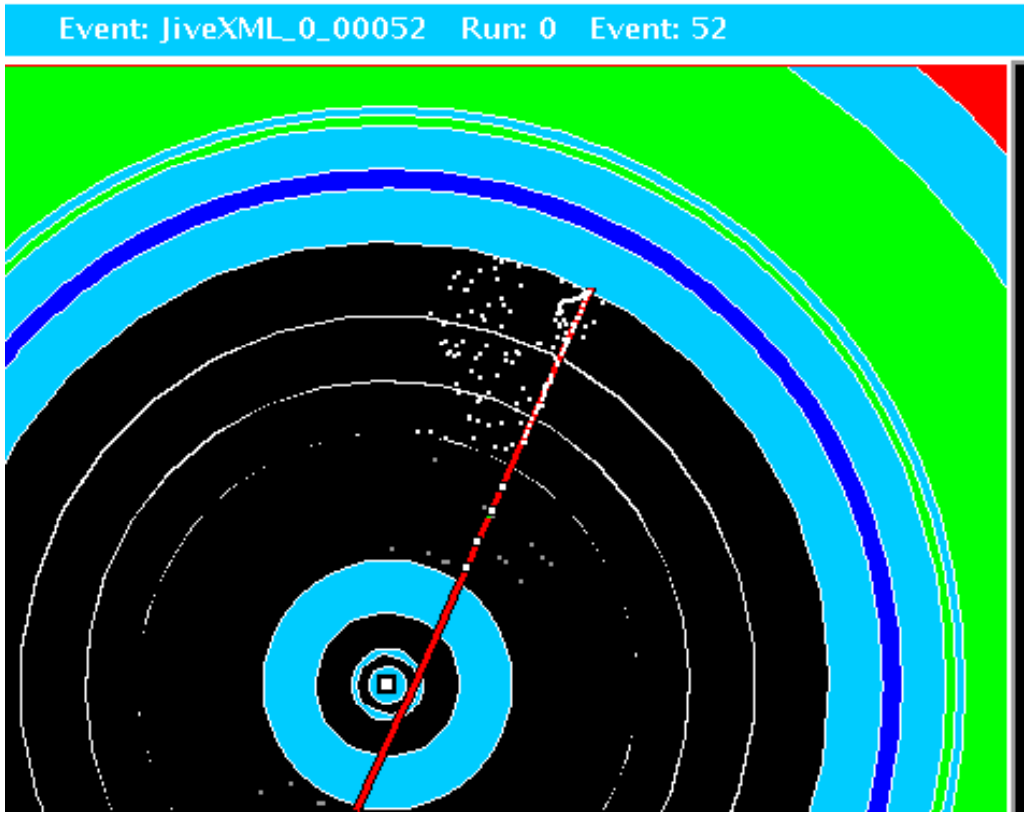
Muon confirmation in the precision muon chambers



- Both, endcap- and barrel-triggered events have hits in the precision muon chambers with characteristic muon TDC spectrum
- Trigger from barrel reaches the precision muon chamber front-end electronics 130ns sooner than from endcap, as expected

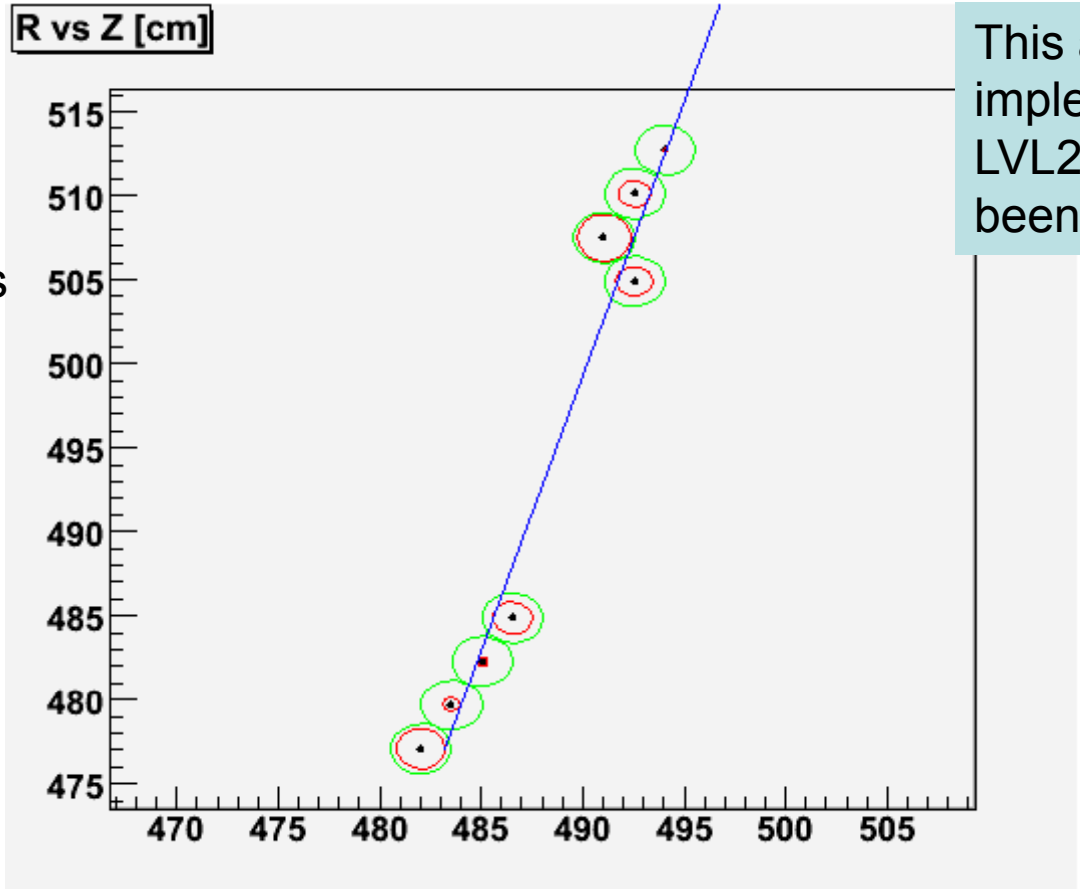
LVL2 Silicon Tracking algorithms

- Two LVL2 Silicon tracking algorithms were run online in special standalone cosmic runs on the surface with ~1/4 of the Silicon strips and TRT barrel phi coverage
- These runs were triggered with standalone scintillators
- LVL2 tracking finds tracks with d0 < 30cm
- Hope to test in next combined cosmic run (in mid October)



MDT Drift time algorithm

-Green are MDT tubes
-Black are tube centres
-Red are drift circles at best t0
-Blue is best track



This algorithm is implemented at LVL2 but hasn't been run online yet

- By choosing a t0 for the event one can calculate the residual between the track and the Drift Circle in the MDT
- Stepping through all possible (reasonable) t0's one can minimize the sum of the residuals to get the best t0 and improve the positional information (resolution improves from 1.8cm -> 0.16mm)