Commissioning of the ATLAS Transition Radiation Tracker With Cosmics Rays and Single Beam

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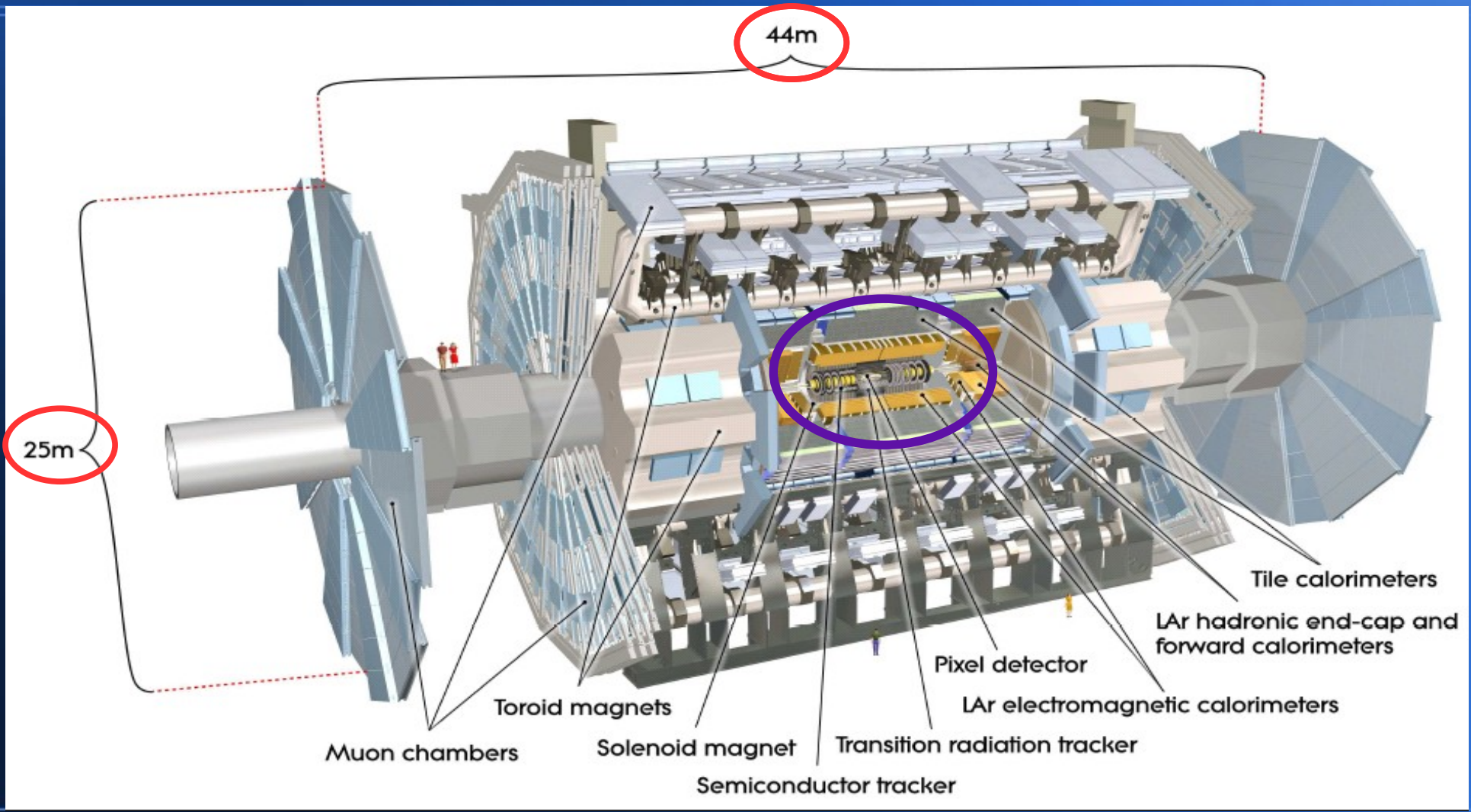
On behalf of the ATLAS Collaboration

11 ICATPP, Villa Olmo, Como, Italy October 5-8, 2009

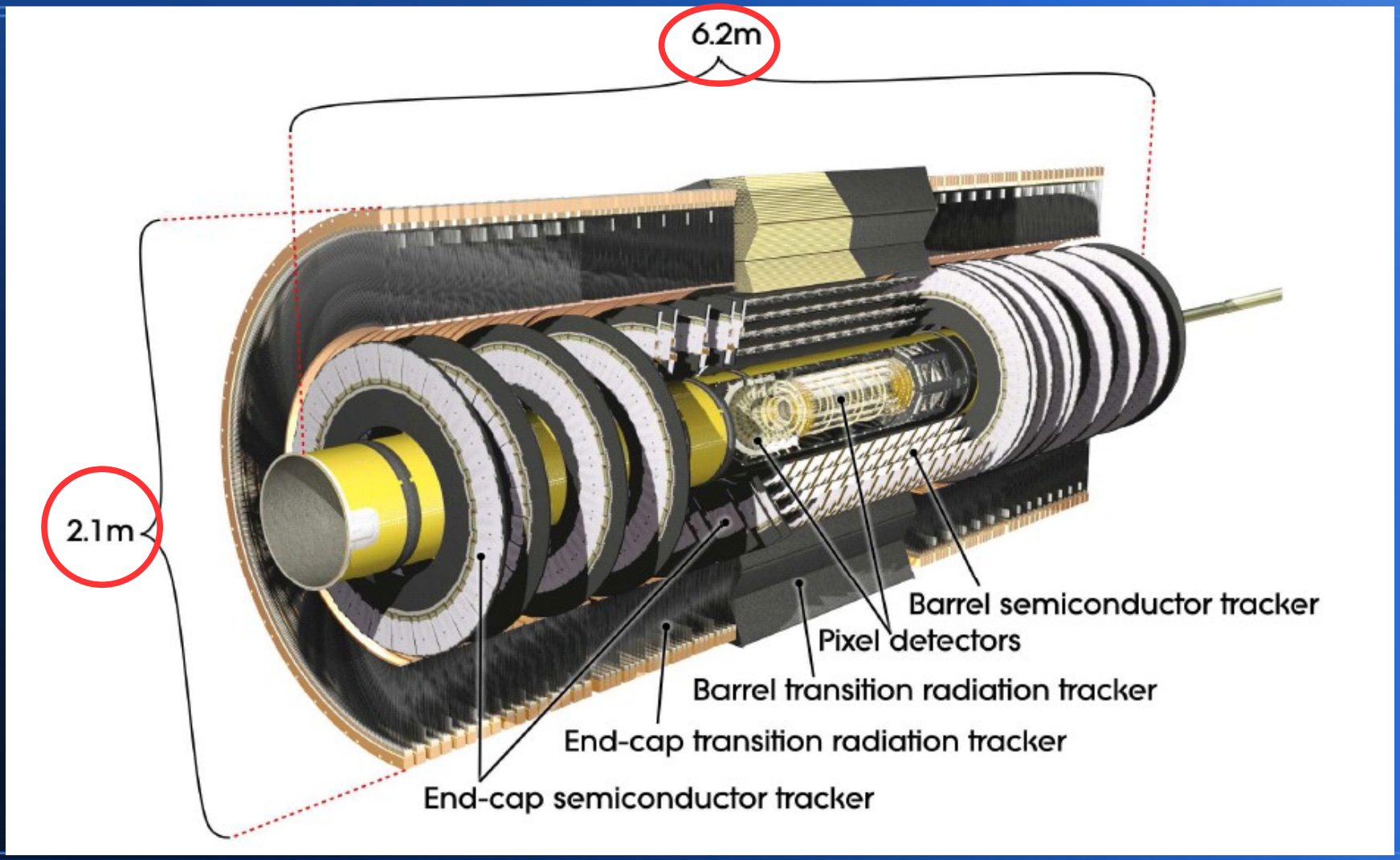
Outline

- Introduction to TRT
- Commissioning Phases
- Calibration
- TRT Cosmic Trigger
- Transition Radiation
- TRT Operation
- Summary

ATLAS Detector



ATLAS Inner Detector



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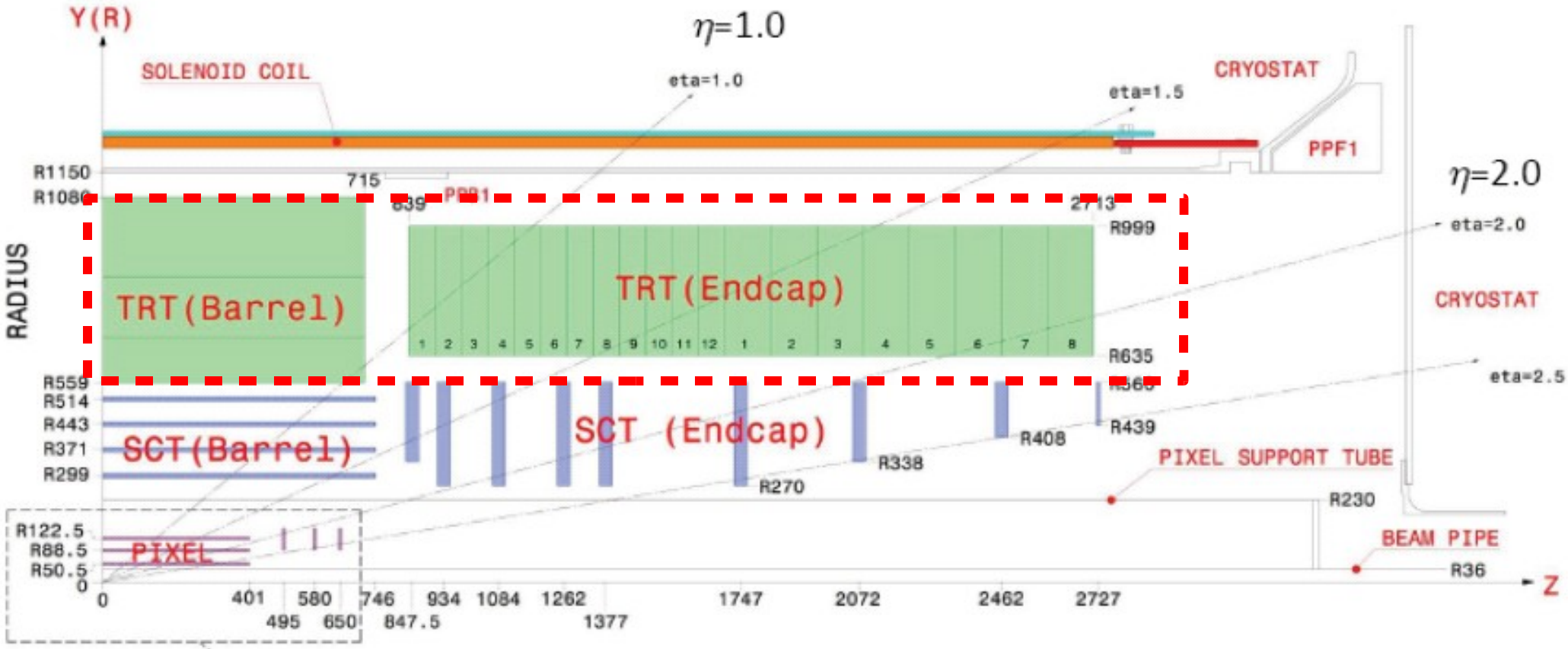
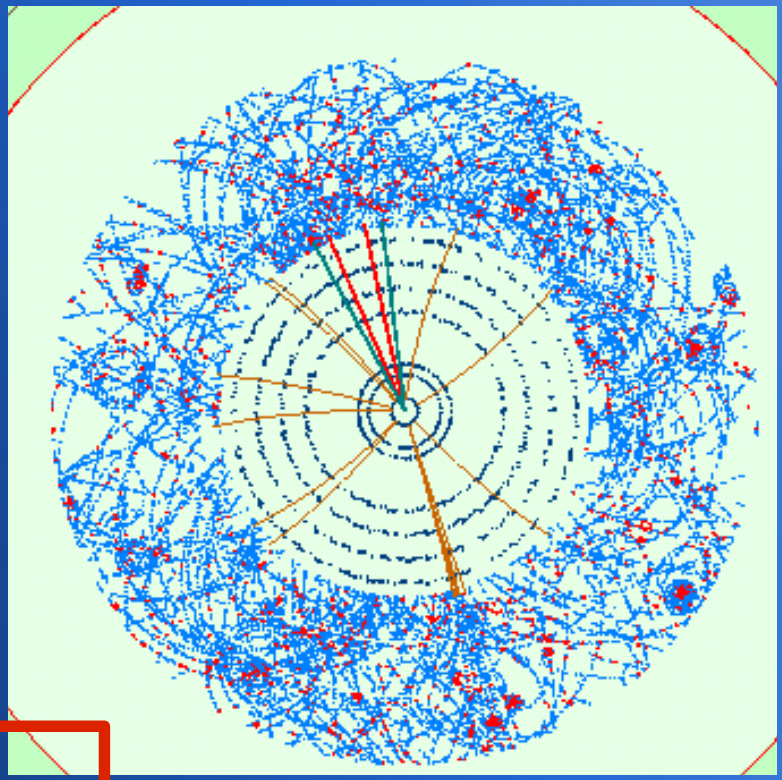


ATLAS Inner Detector Design

- Combination of high resolution detectors & continuous tracking elements
  - Fine granularity in the inner region
  - Limited number of Si layers (3+4)
    - Lower material budget (and cost)
- Large number of tracking points at high radius
  - Less material
  - Compensate the lower precision of points
  - Overall performance robust against possible sub-detector subpar performance
  - Improve detection of V^0 decays
  - Provide enhanced and robust pattern recognition
- TRT is also a transition radiation detector
  - Electron ID capability complementary to calorimeter



TRT Design Requirements

- Module design to avoid dead region
  - No projectivity in the barrel
  - 73 radial layers of straws in the barrel, 160 longitudinal layers in endcap.
  - Average of 30 hits per track in barrel

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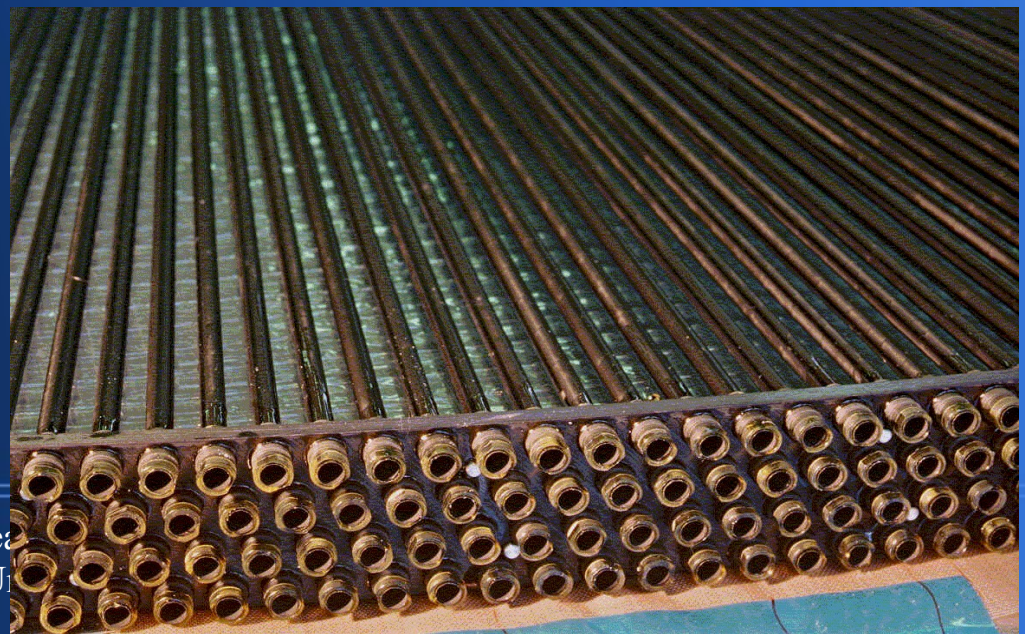

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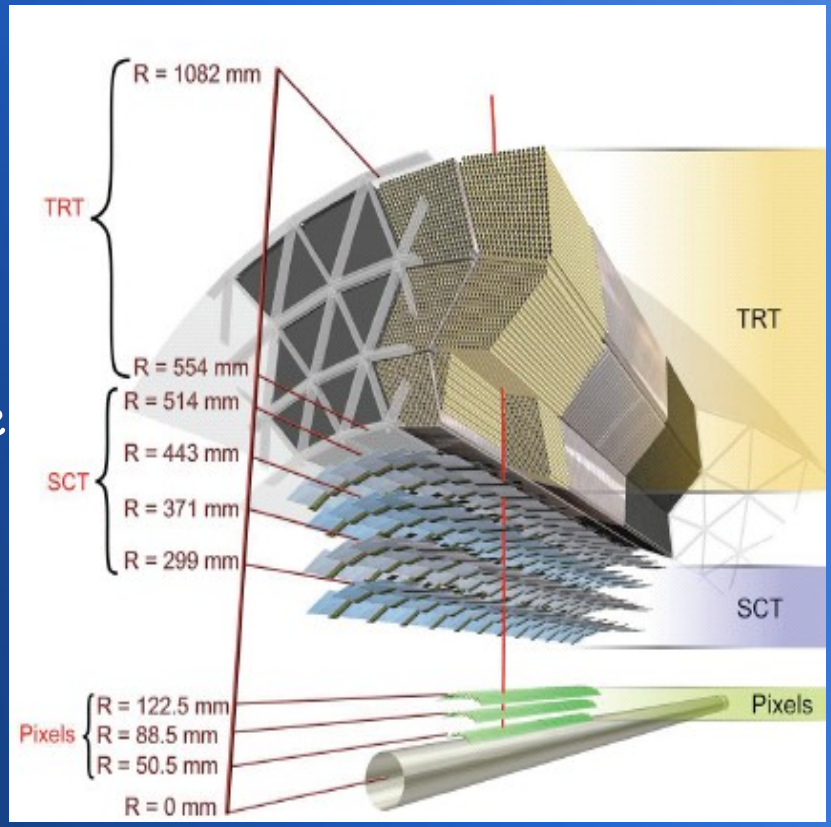
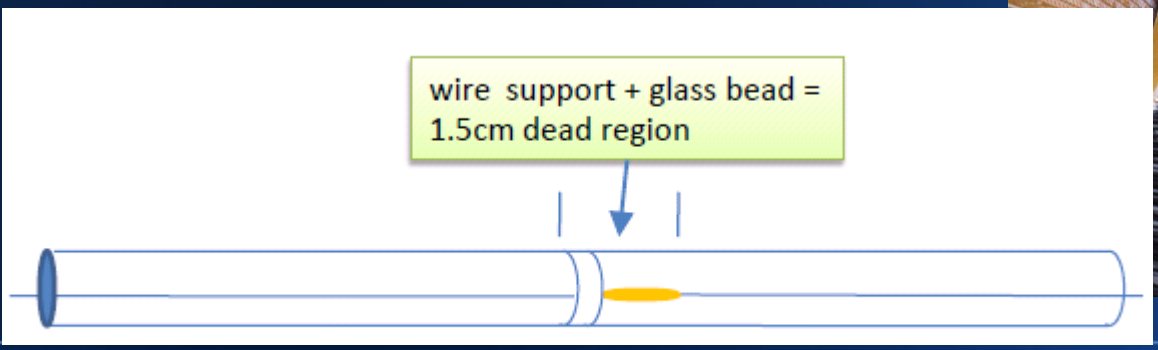
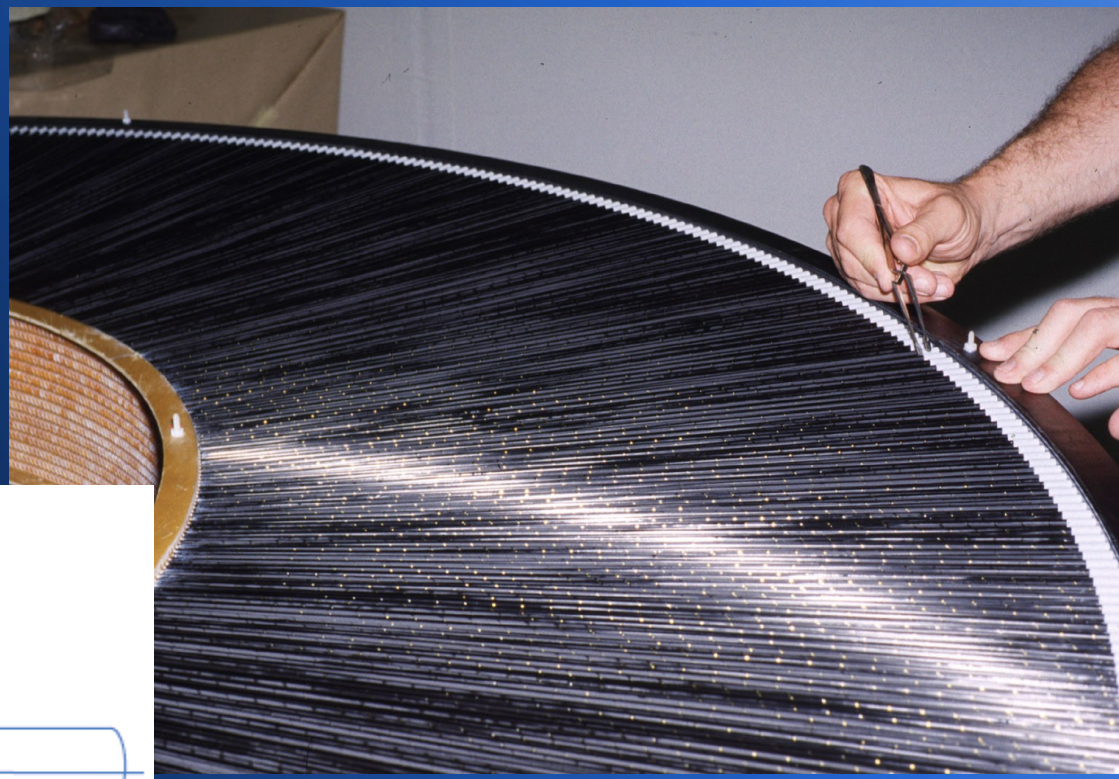
- Sensitive elements isolated to sustain high rate
  - Wires in individual gas envelopes (straws of 4 mm diameter)
- Straw spacing favors pattern recognition over transition radiation needs
  - Mean spacing ~ 7 mm in the barrel



TRT Design Requirements

- Wire length limited by occupancy at high luminosity
  - Wire active length ~ 71 cm in barrel and ~ 37 cm in endcap





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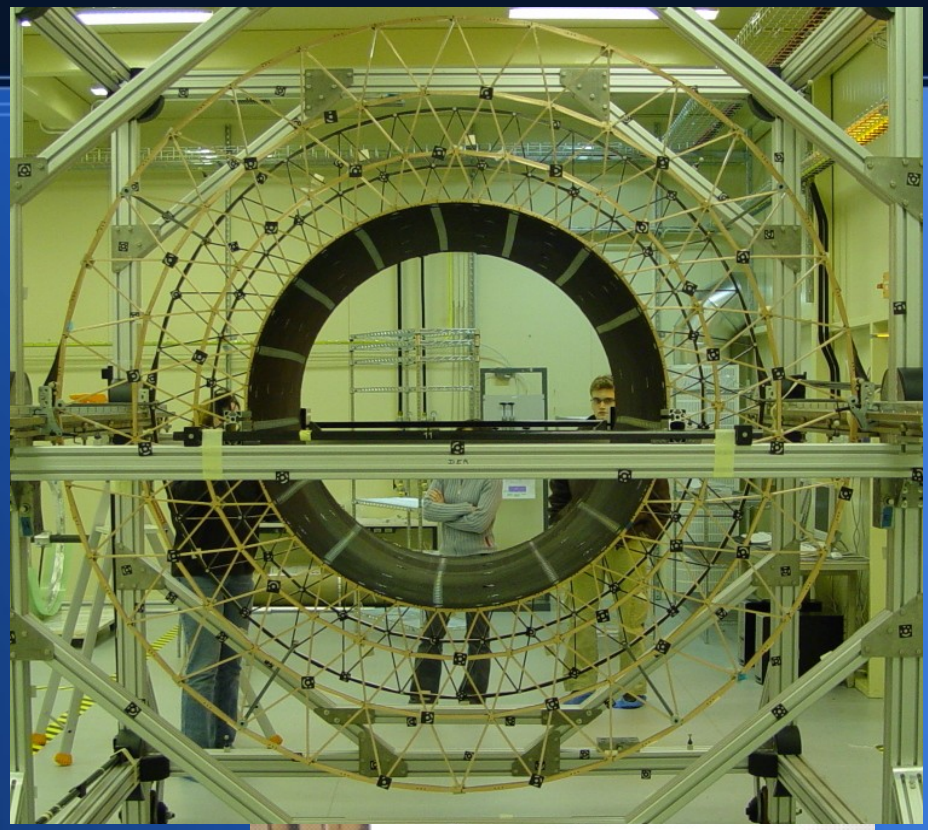
  - Carbon-fiber laminate 400 μm thick shell for barrel modules with maximum distortions < 40 μm
  - Barrel support structure displacements < 10 μm
    - Driven by the needs of silicon detectors



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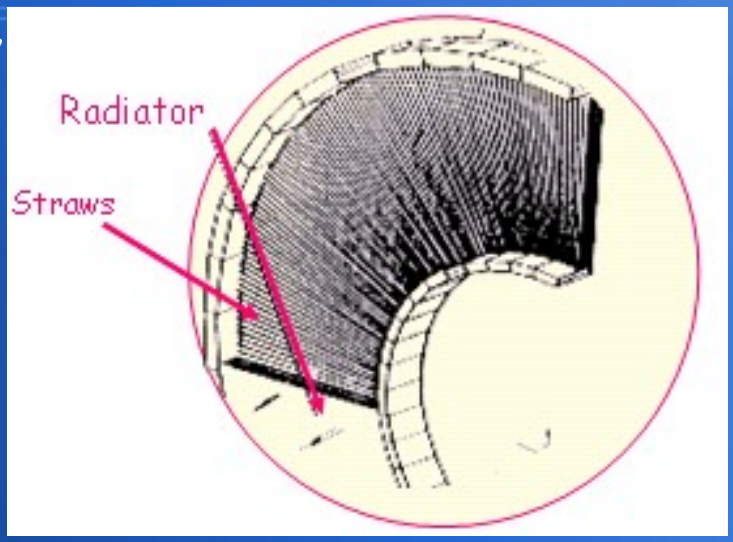
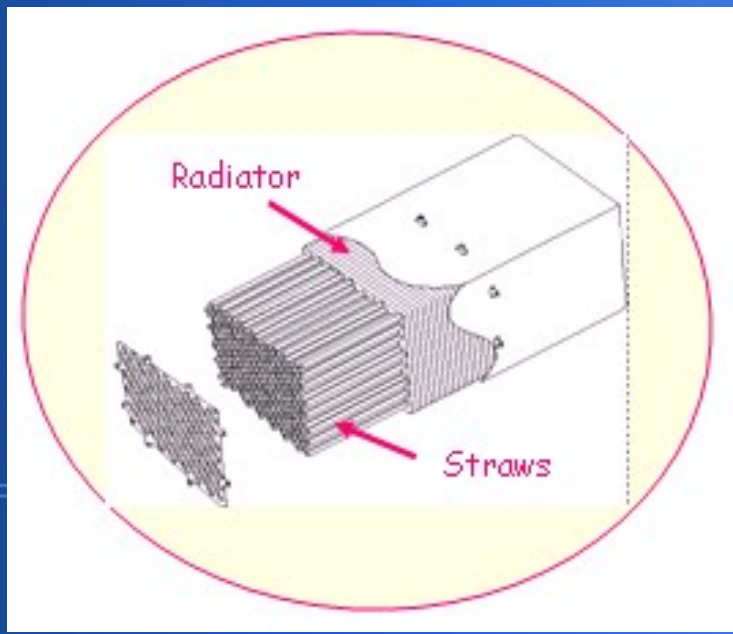
- Straws embedded in the radiator medium to maximize TR performance
  - Minimize the absorption of TR in the radiator itself





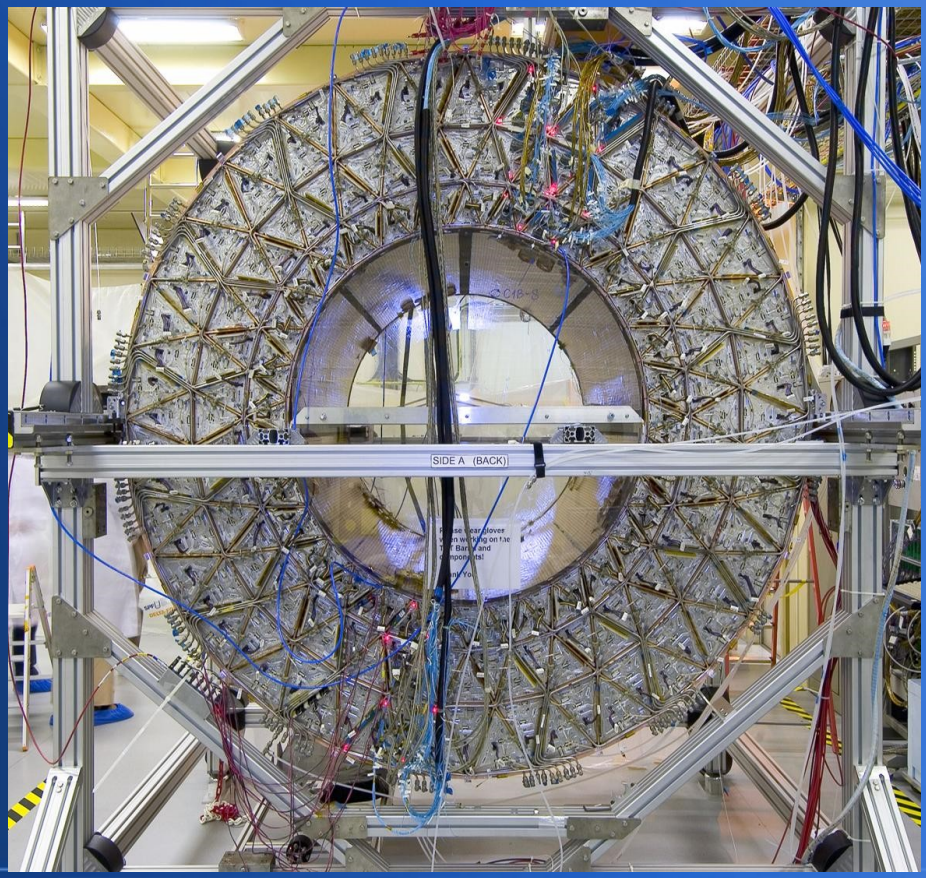
Andrea Bocci
Duke University

Quality Tests

- All detector components underwent qualification and acceptance tests to ensure reliable operation

- Material and individual elements not passing the stringent predetermined requirement were replaced or removed

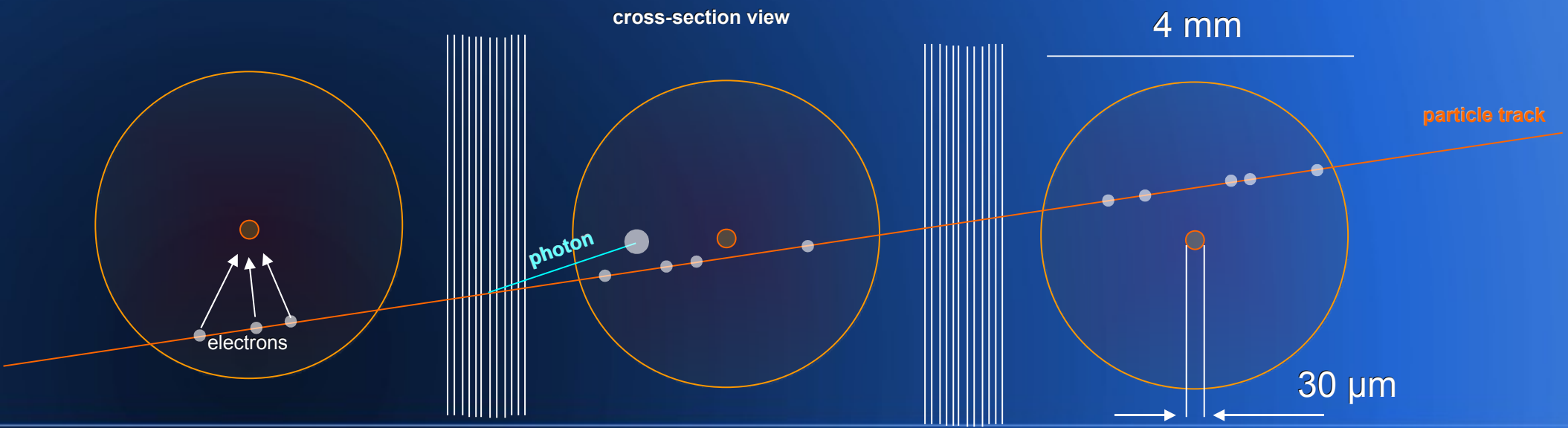
- Among other aspects the essential ones were:
  - Aging
  - HV stability
  - Straw straightness
  - Wire tension
  - Gas tightness
  - Wire offset w.r.t. Straw center < 400 μm



Detector Quality Enforcement

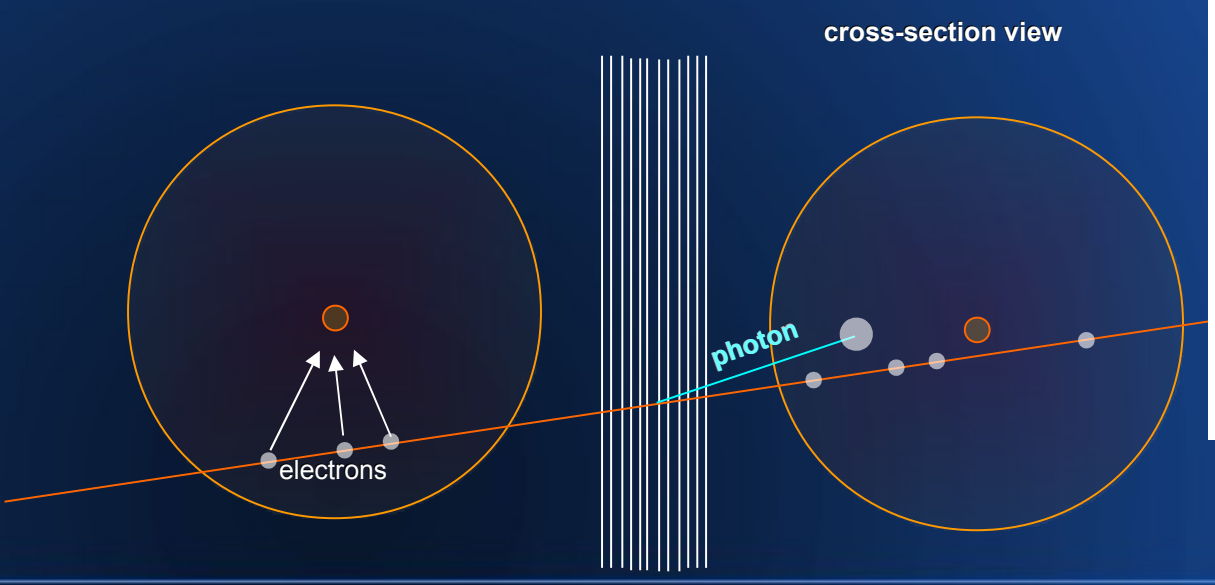
- After installation and commissioning the TRT has **98.2%** of working channels
- Permanently dead straws are also passed to the simulation
  - Signal generated in those straws is ignored
  - It improves the accuracy of the efficiency calculated by the MC
- During the offline calibration, a list of malfunctioning straws are produced each run
  - They are masked in reconstruction
  - Improves track selection, hole searches, etc...

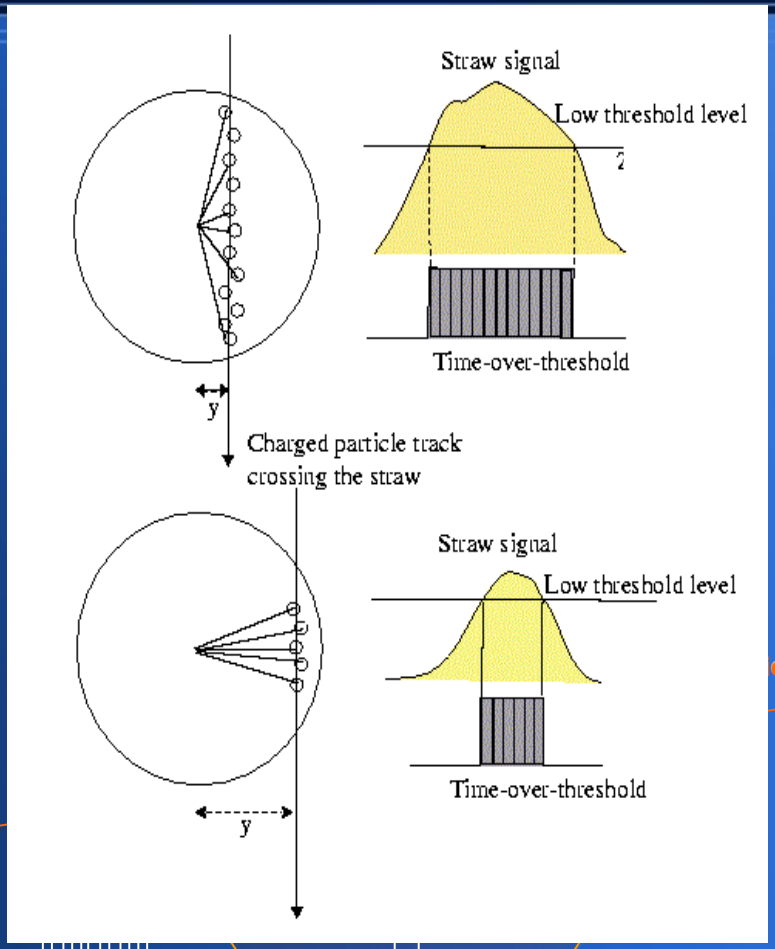
How TRT works



How TRT works

Drifted electrons from closest approach arrive first

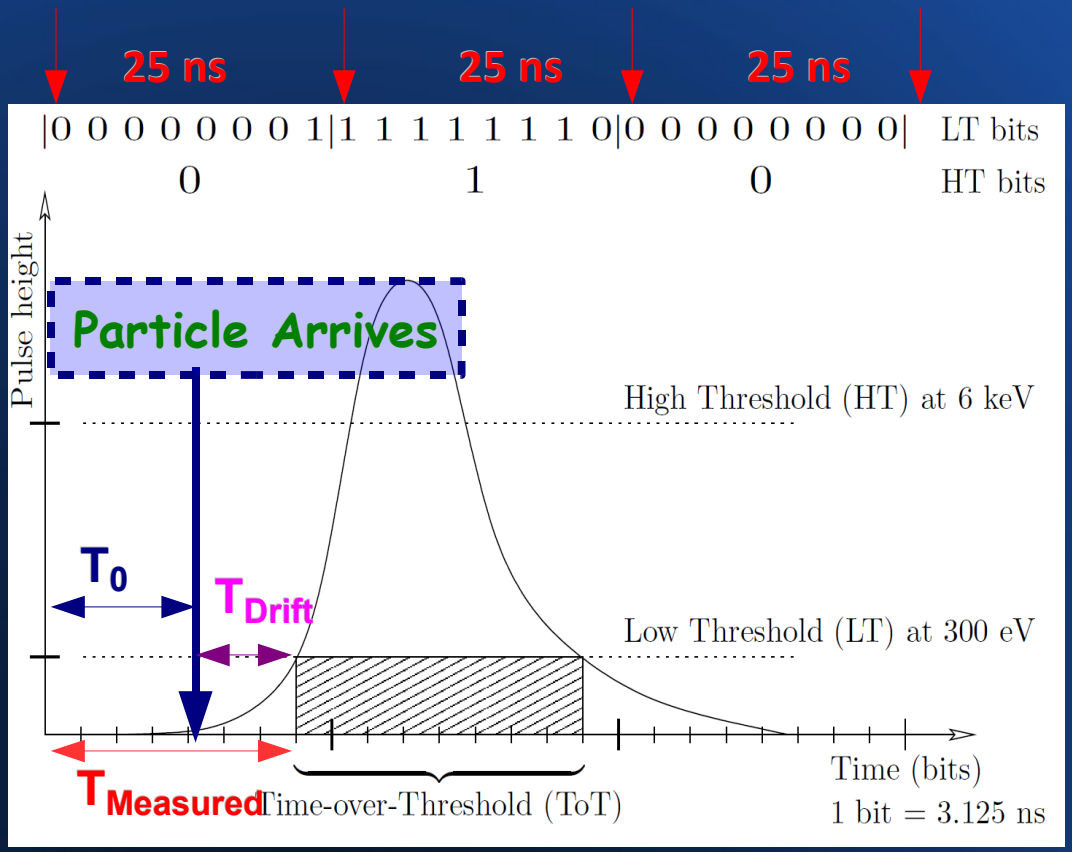




30 μm

Offline Calibrations

Signal spans over 3 Bunch Crossings



- T_0 is the arrival time of the particle w.r.t. LHC BC
  - It depends on time of flight, cable lengths, electronics delay, etc...
  - Different from every straw
  - May change from run to run

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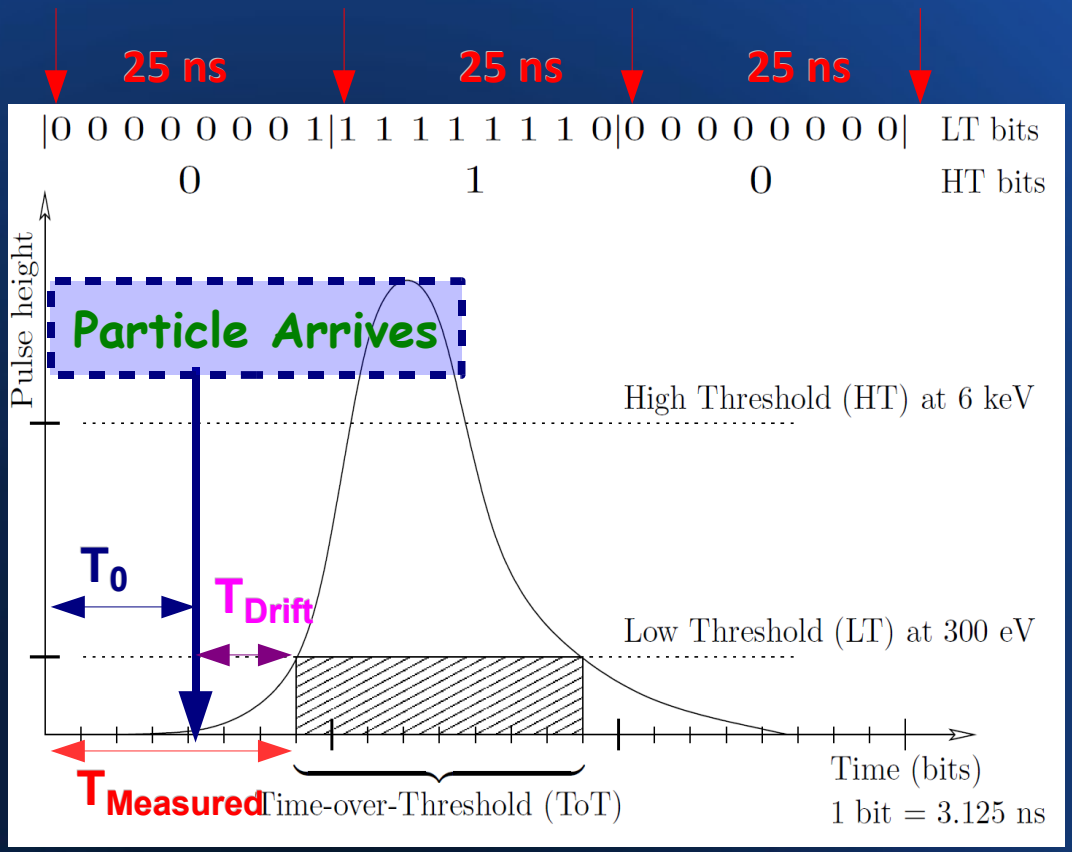

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Need Calibration

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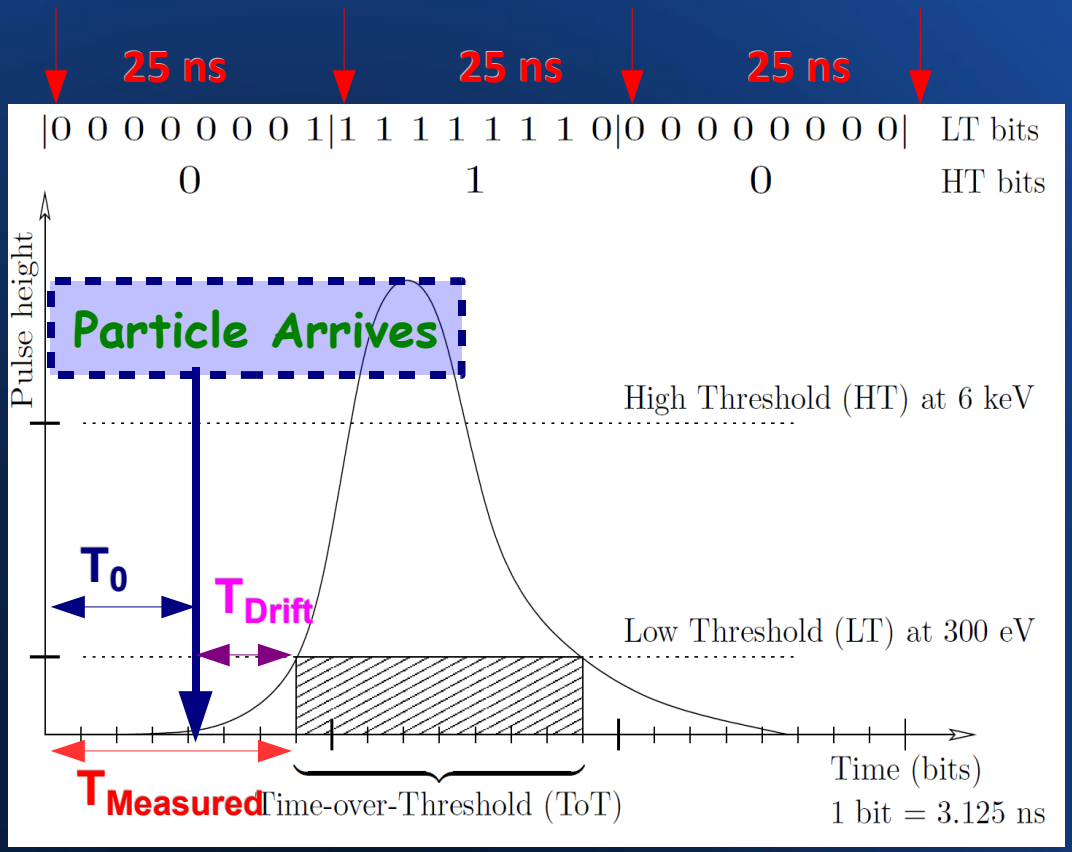
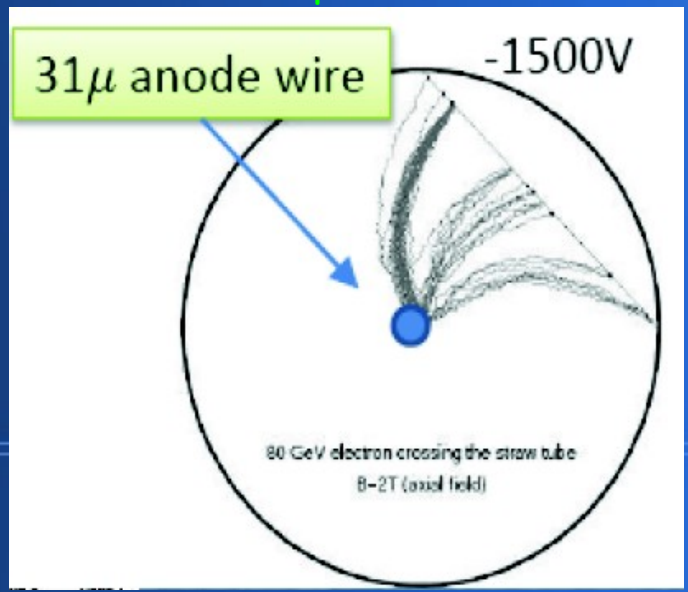


- T_{Drift} is the drift time of the first ionized electrons
  - It depends on the position along the straw, gas density, threshold setting,...
  - Need to be converted in distance with a proper R-t relation (drift radius)
  - R-t relation is straw dependent and time dependent



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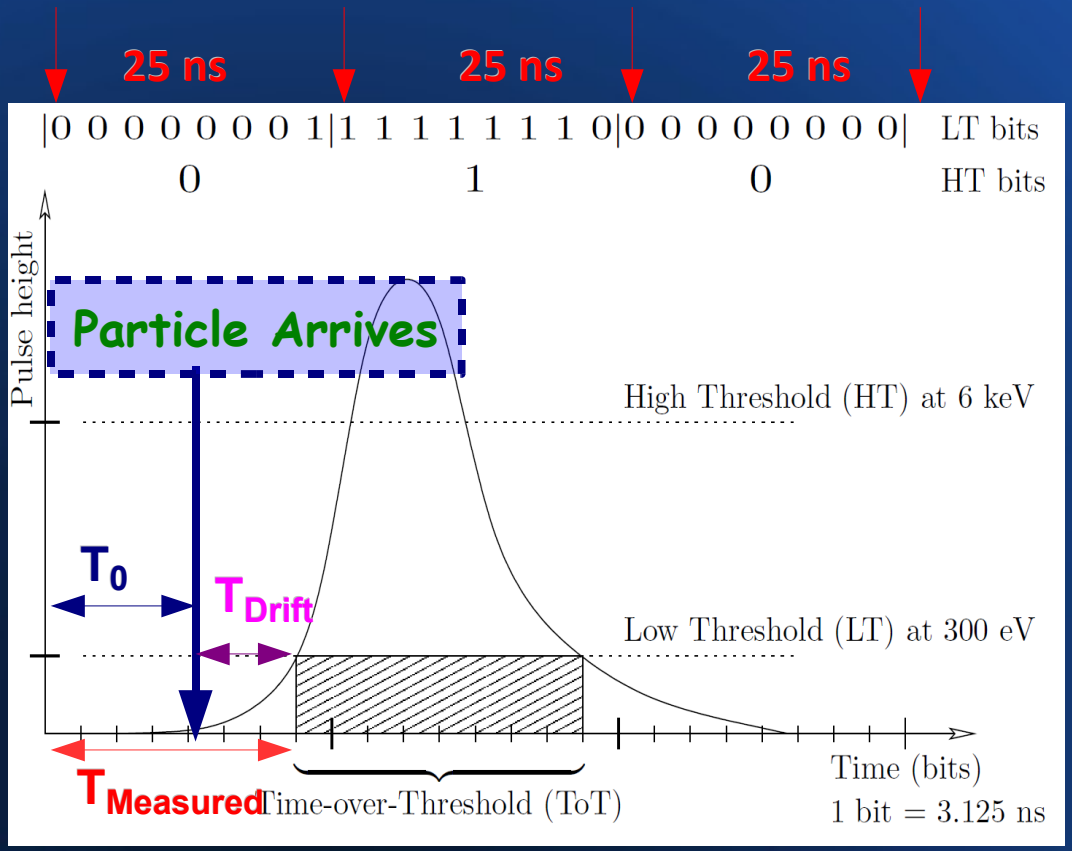

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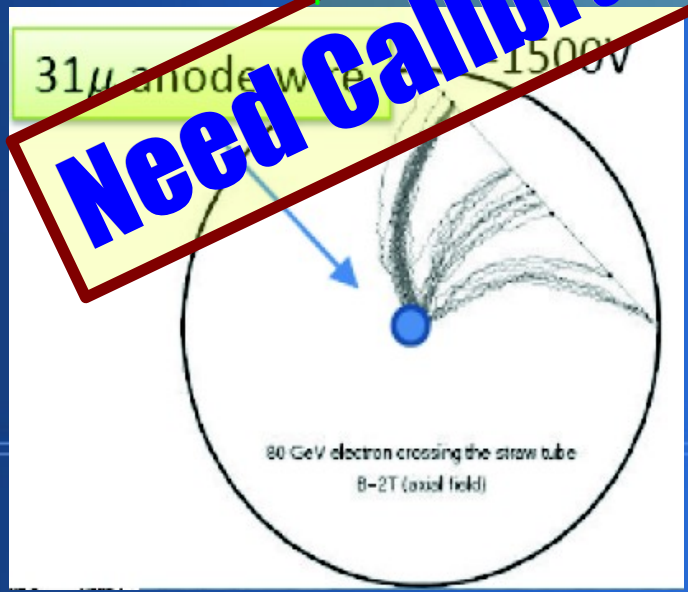

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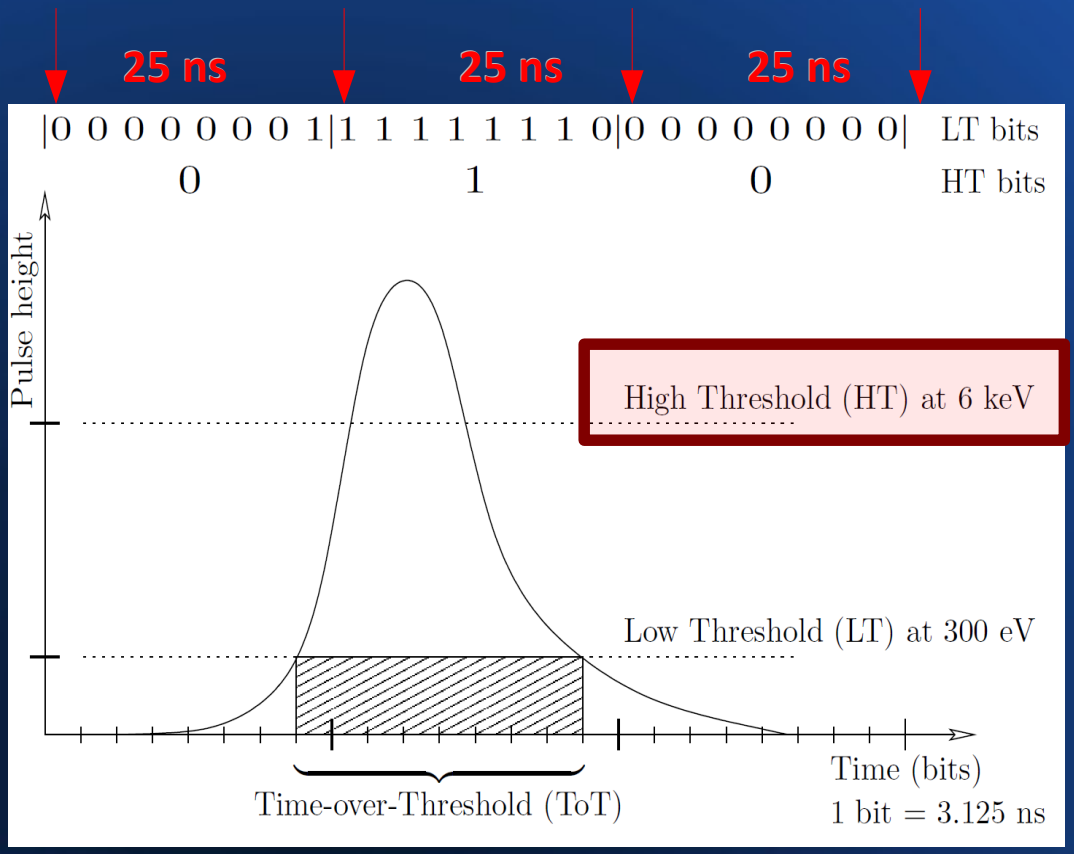

- TR photons increase the collected charge
  - Information used for e/π separation
    - Tracks with high number of HT hits more likely electrons
  - Rejection power optimal in a narrow range of threshold values
    - Correlated with TR energy, property of the gas, etc...
  - Crucial to maintain the optimal HT setting stable and uniform across the detector

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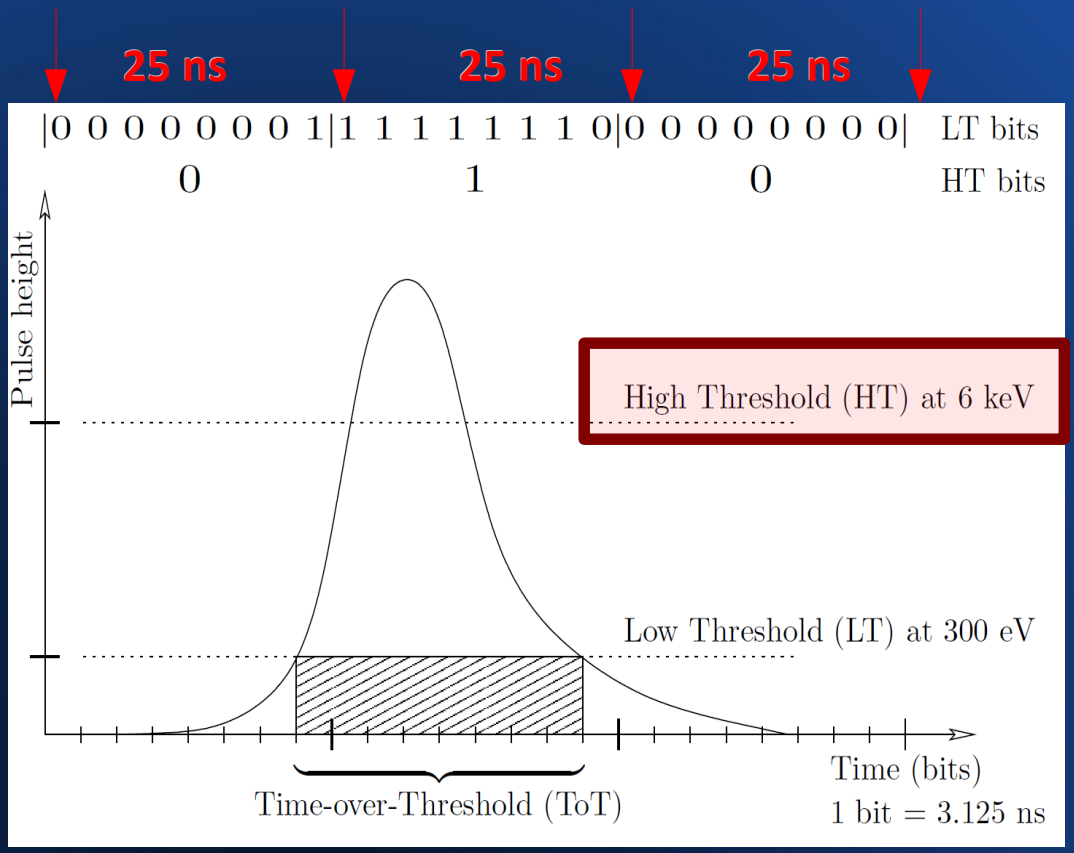

- TR photons increase the collected charge
  - Information used for e/π separation
    - Tracks with high number of HT hits more likely electrons
  - Rejection power optimal in small range of threshold values
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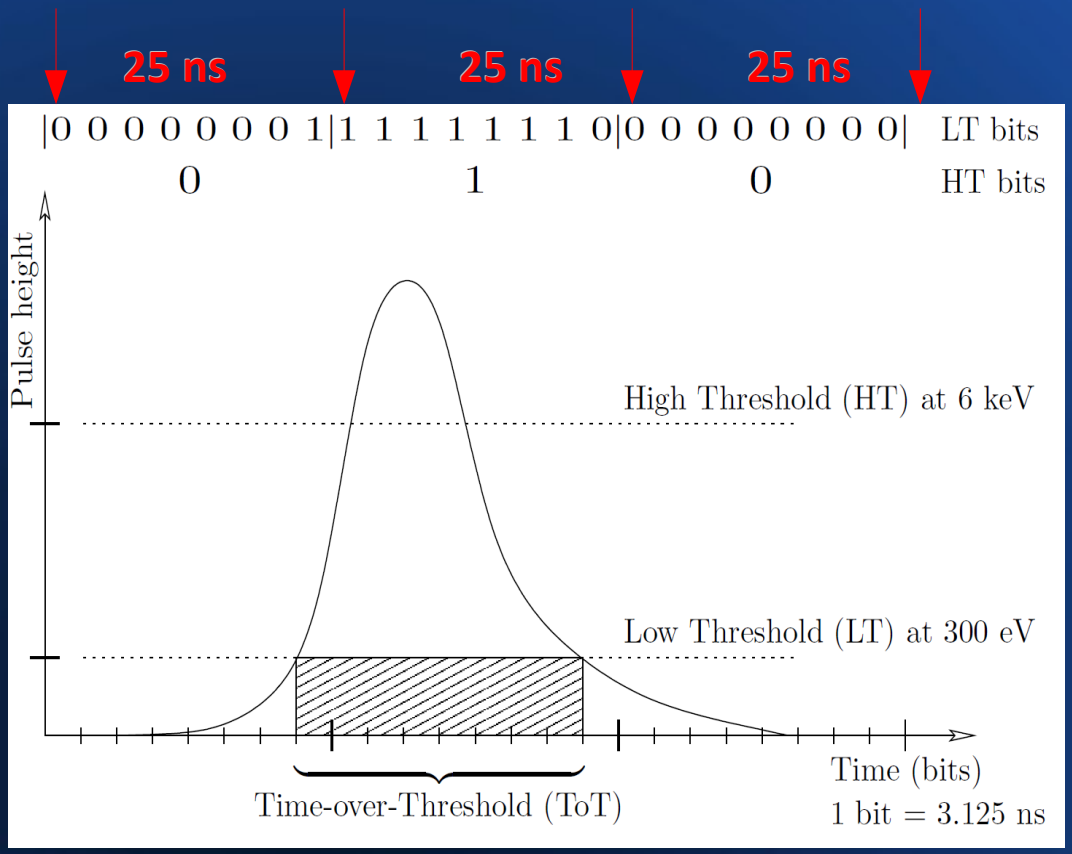
Need Calibration

Offline Calibrations

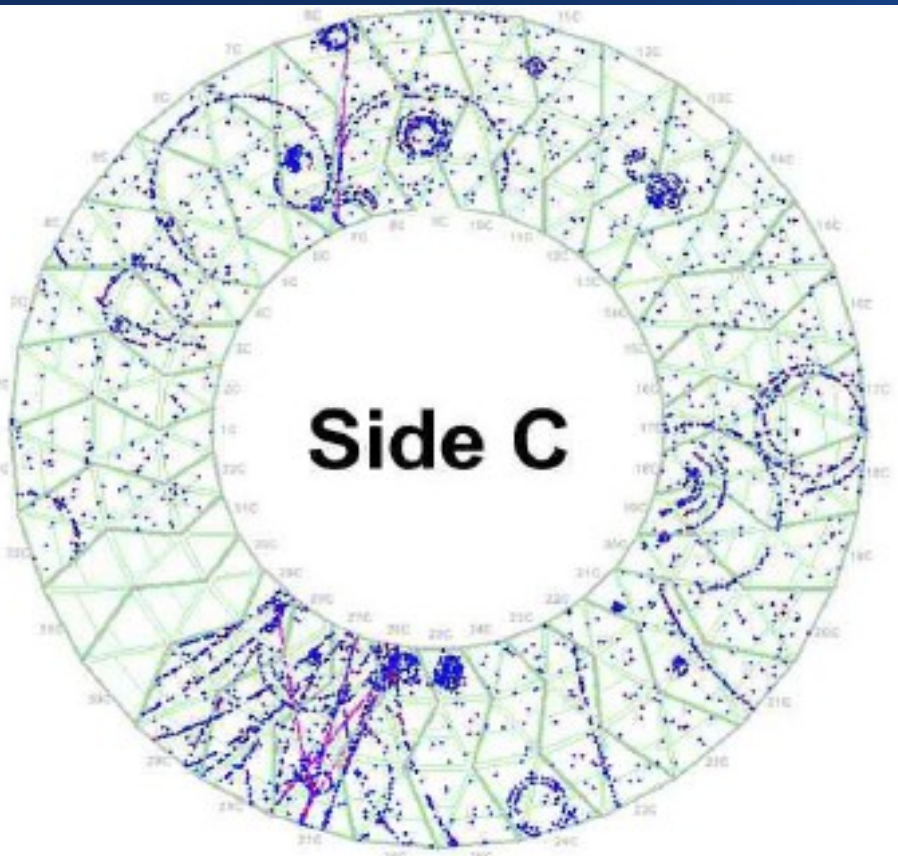
Signal spans over 3 Bunch Crossings

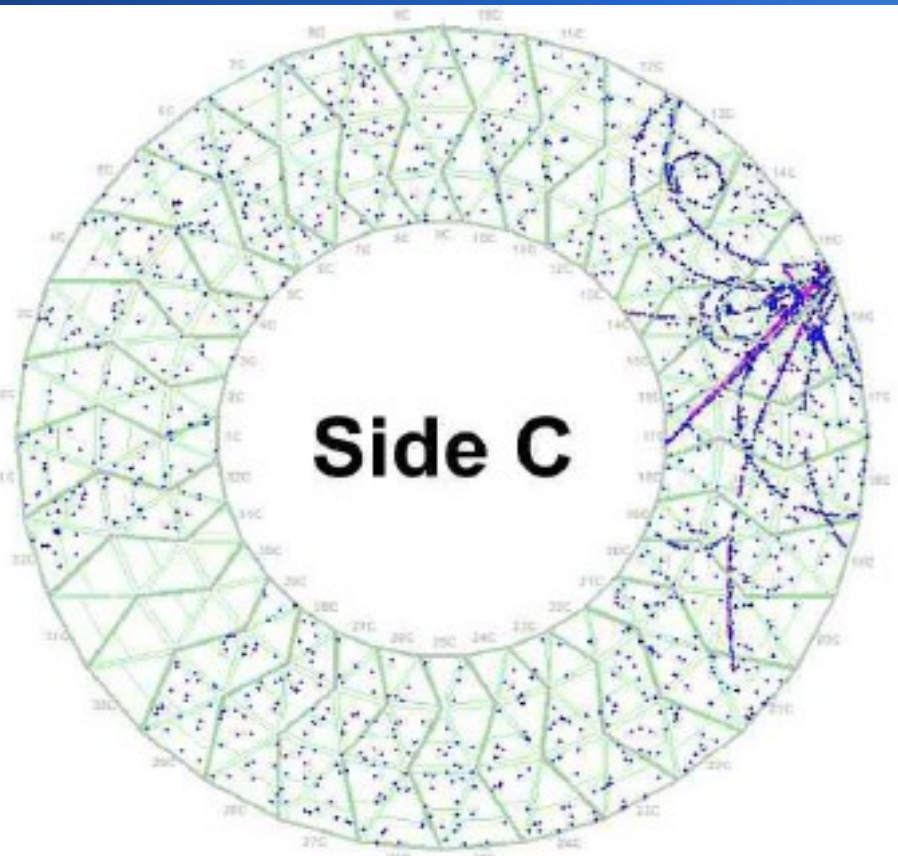


- All offline calibrations implemented and extensively tested
  - All the TRT calibrations comply with the ATLAS 24-hour scheme
  - Use of dedicated priority data stream
  - Fast reaction to change constants if necessary
  - Ready to be used before the reconstruction of the rest of the data
  - Test during cosmic runs provided real condition to stress the procedure
  - Calibration adjusted while taking data

Timeline

- May 2007: Insertion of last Endcap
- Sep07-Sep08: Various Milestone Cosmic Runs
  - Integration of various part of TRT operation





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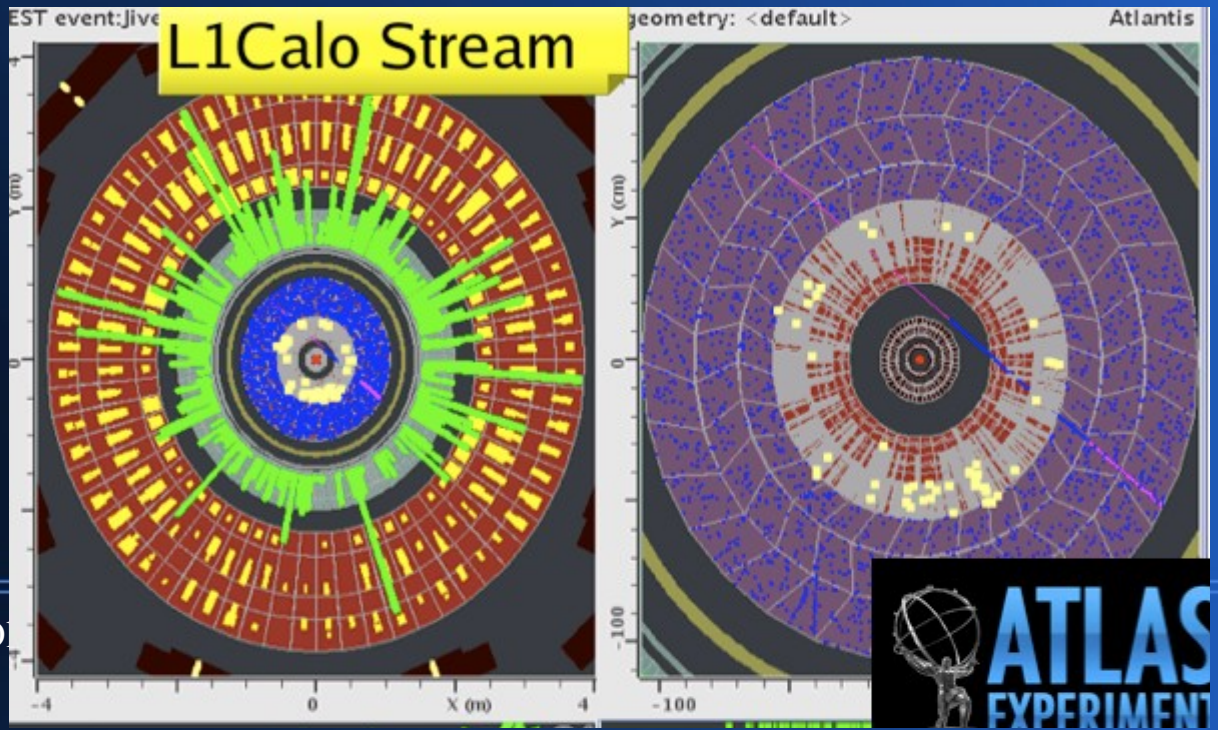
- September 10th 2008: **FIRST BEAM !!**



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- May 2007: Insertion of last Endcap
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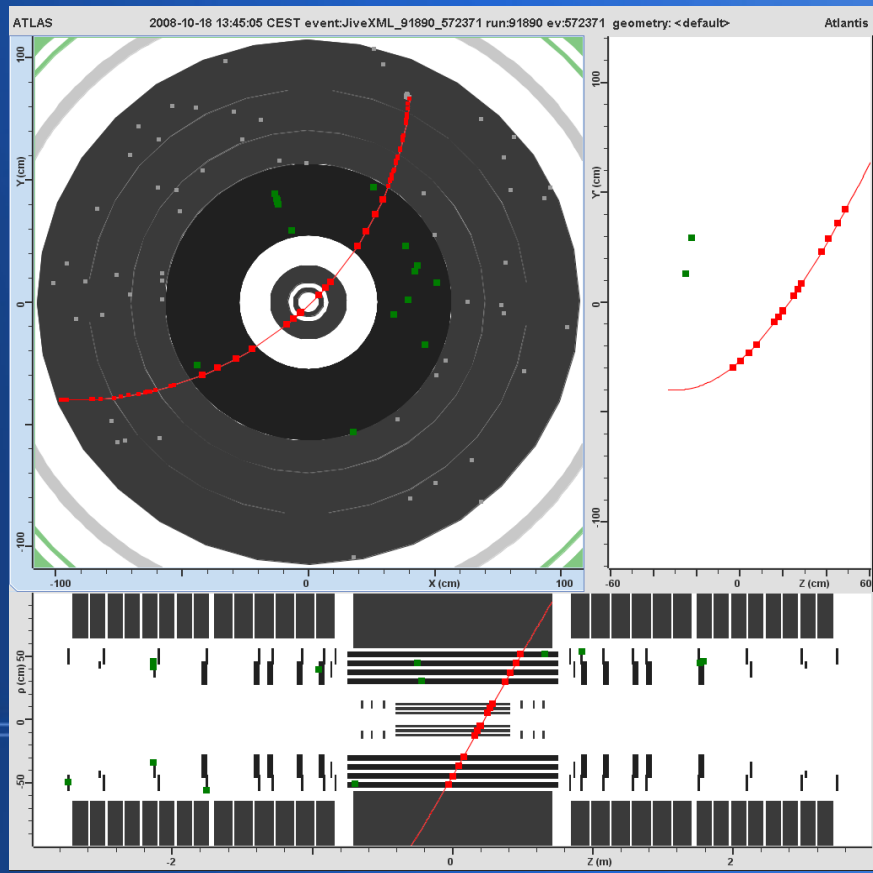
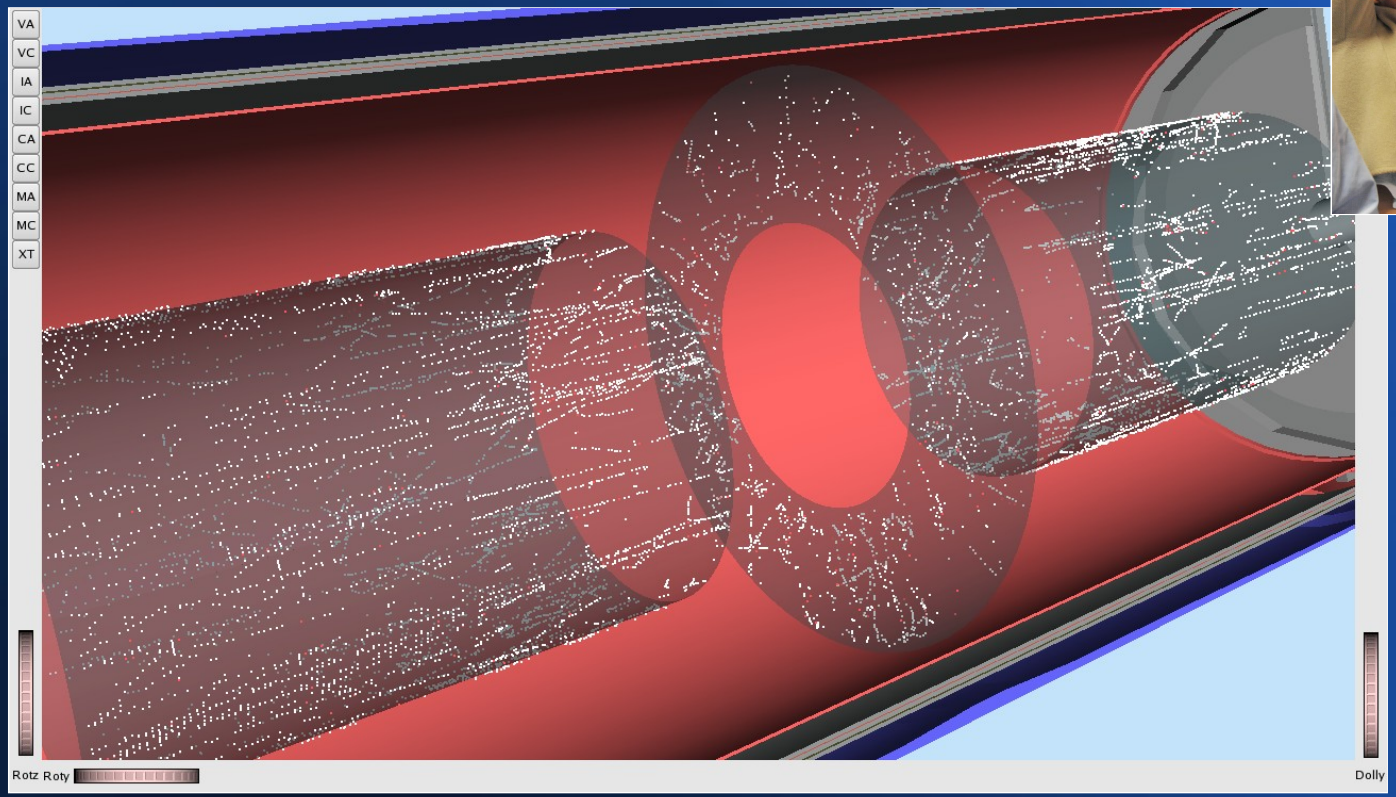
  - Integration of various part of TRT operation
- September 10th 2008: **FIRST BEAM !!**
- Fall 2008: Combined Cosmics Runs
  - Bfield On and Off. Xenon gas
- Spring/Summer 2009: More Combined Runs
  - Used Argon gas
- October 2009: ATLAS 24/7 Operation



First Beam

Beam Helo Event in TRT



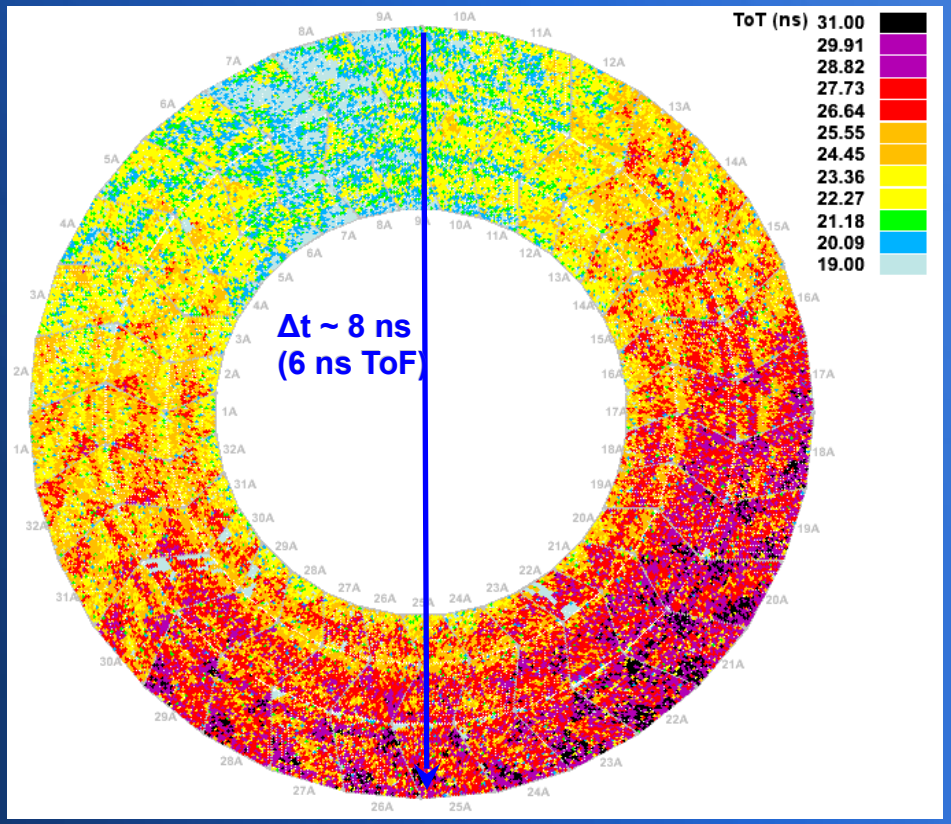
First Beam

Beam Splash Events

Rough estimate: 10-100 hits per straw

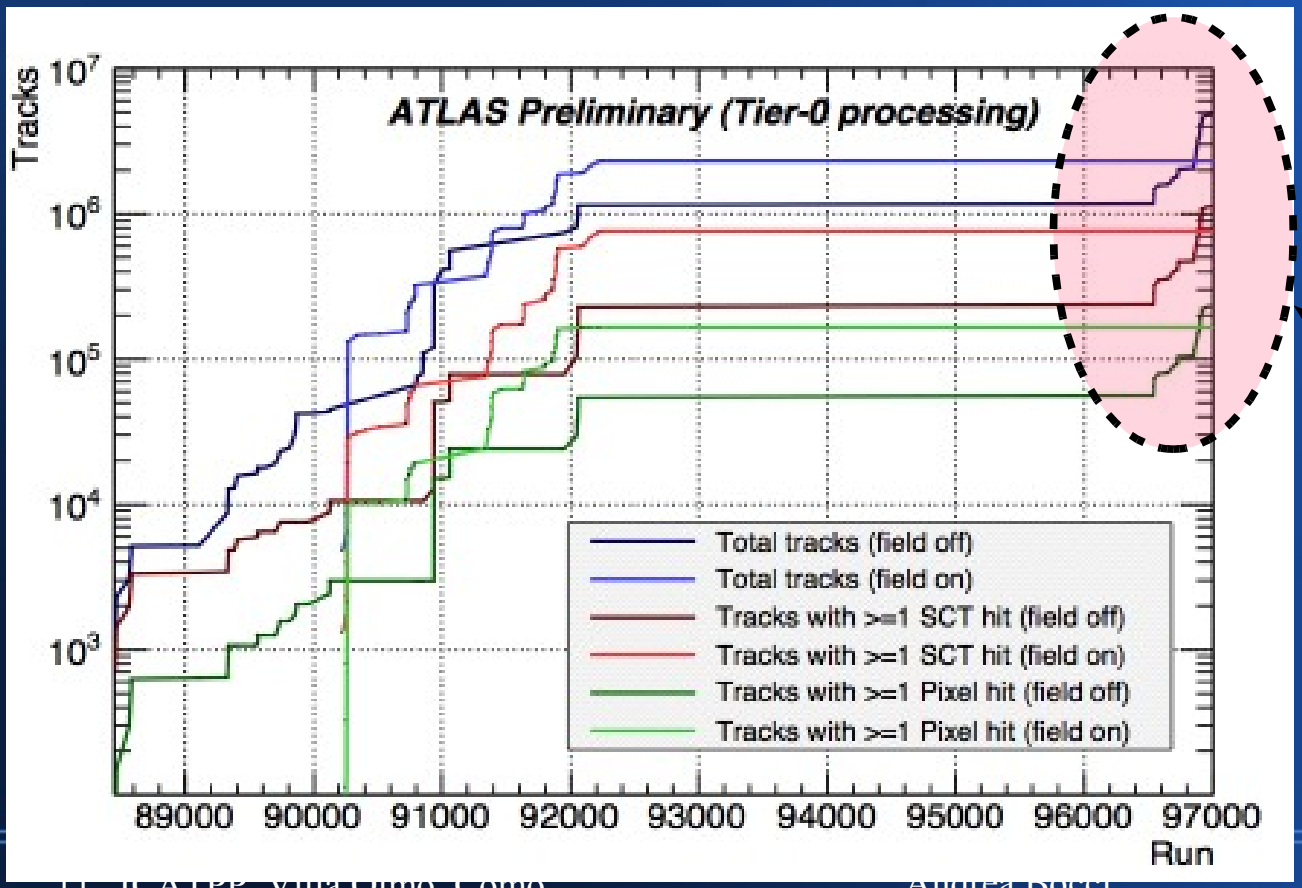
Unique opportunity to time the whole detector at once with one event!

It saves months of work with cosmics !



Cosmic Runs 2008

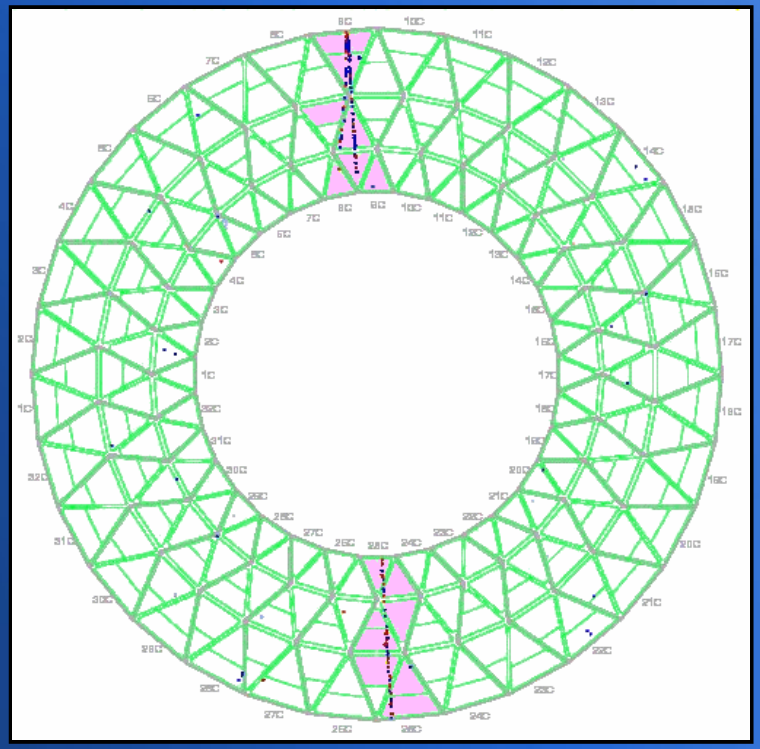
Few millions track collected in the Fall 2008
(see C. Shmitt plenary talk on Wed.)



Statistics doubled in one week when using a dedicated L1 TRT trigger

TRT L1 Fast-OR Trigger

- Employed after the LHC accident and originally developed for timing purpose
  - Became the most efficient way to collect cosmics in the Inner Detector
- Main Features:
  - High threshold lowered to less than half its value
    - Low threshold too sensitive to noise for trigger purpose
    - Low threshold not affected, tracking reconstruction proceeds as normal
    - Trade TR capability in favor of high rate
      - Couldn't use anyway TR with Ar
    - Efficiency extremely high



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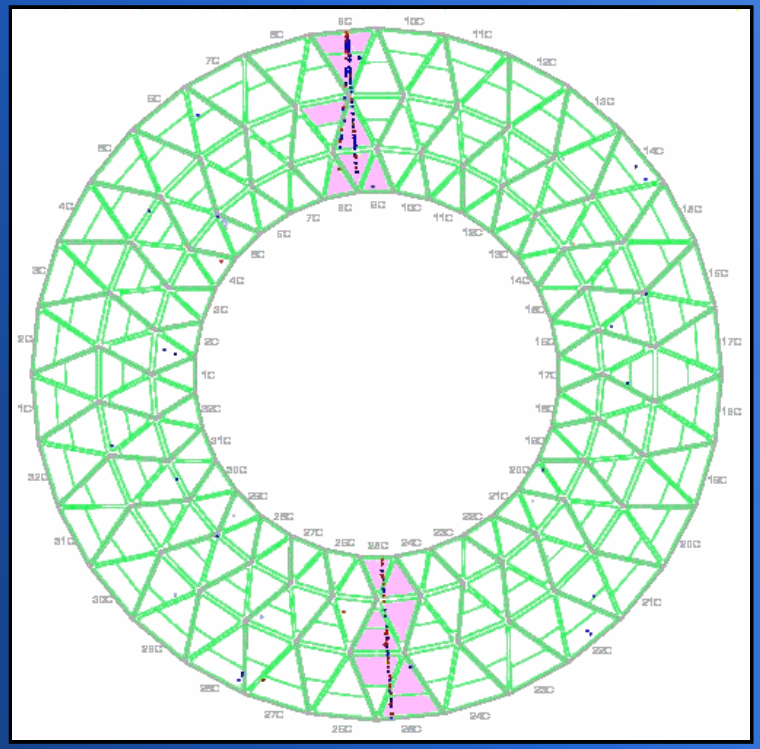
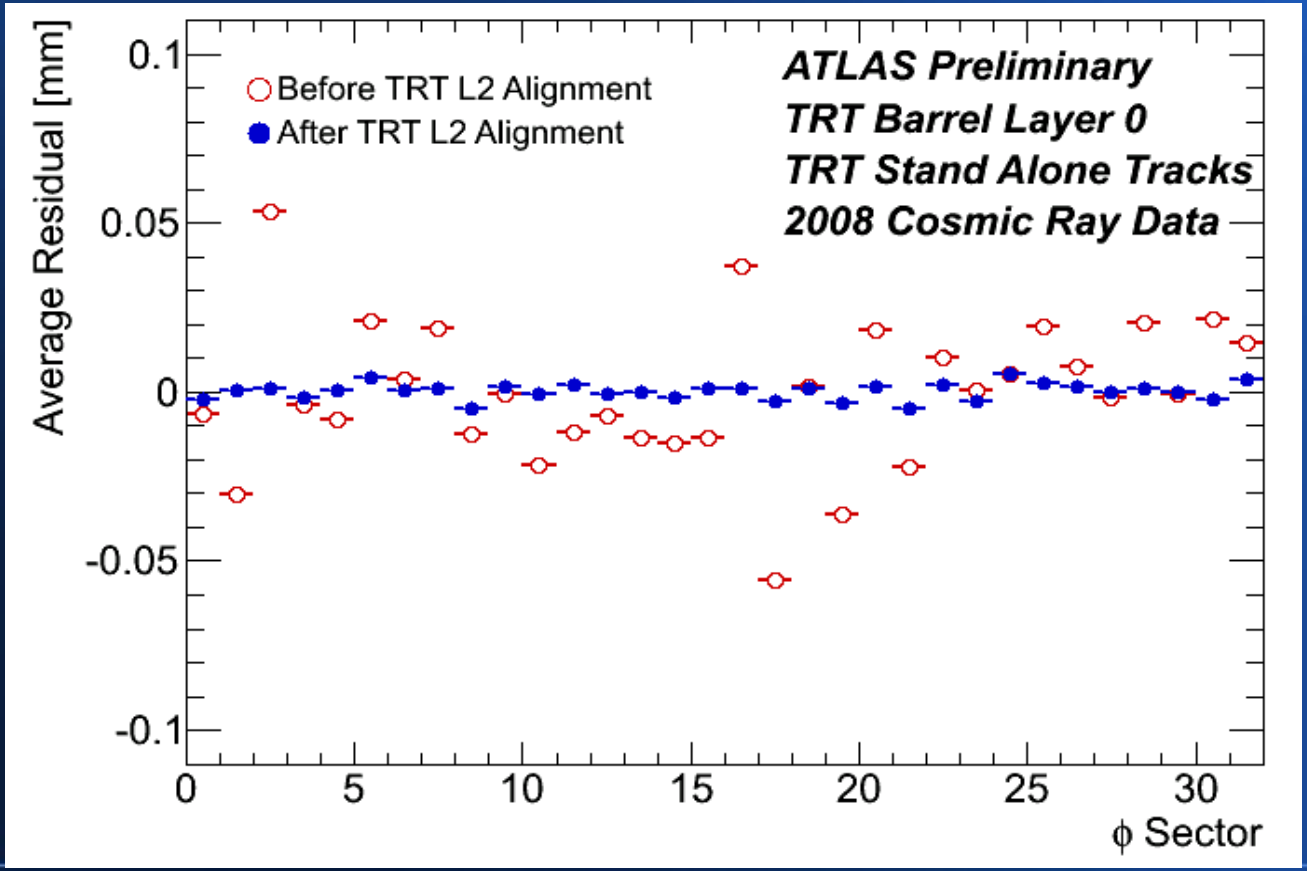
  - Became the most efficient way to collect cosmics in the Inner Detector
- Main Features:
  - High threshold lowered to less than half its value
  - HT signals are "Or-ed" in a group of 16 straws
  - A positive signal from 4 consecutive groups fire the trigger
  - Reached a rate of ~ 9.3Hz in the Inner Detector
  - No plan to use this trigger for collisions
    - Trigger line "borrowed" from Front End electronic monitoring



TRT Alignment

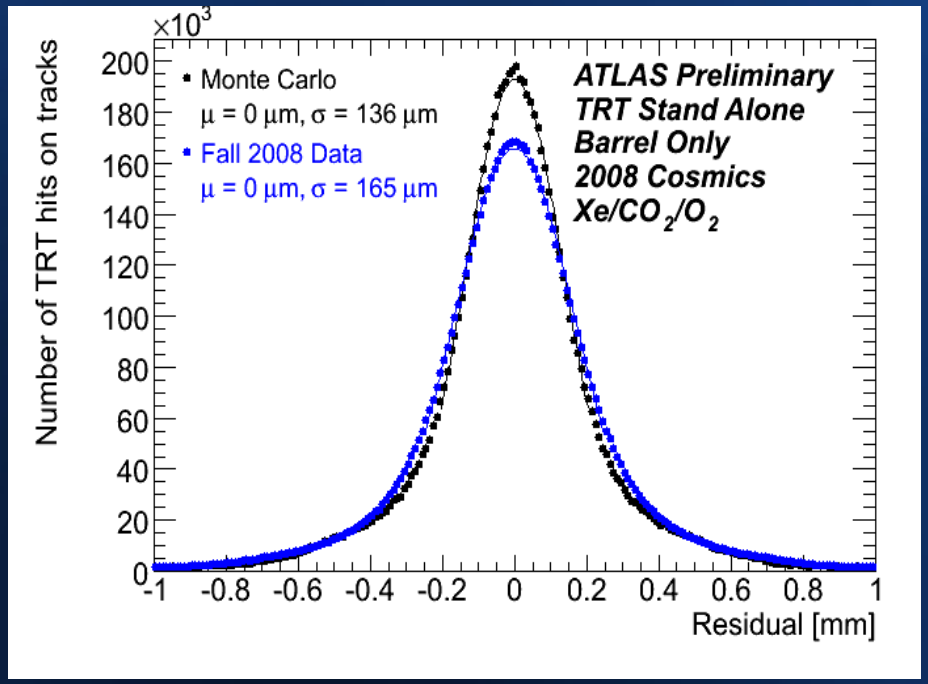
Alignment of TRT modules fully integrated in the ID framework
(see previous talk)

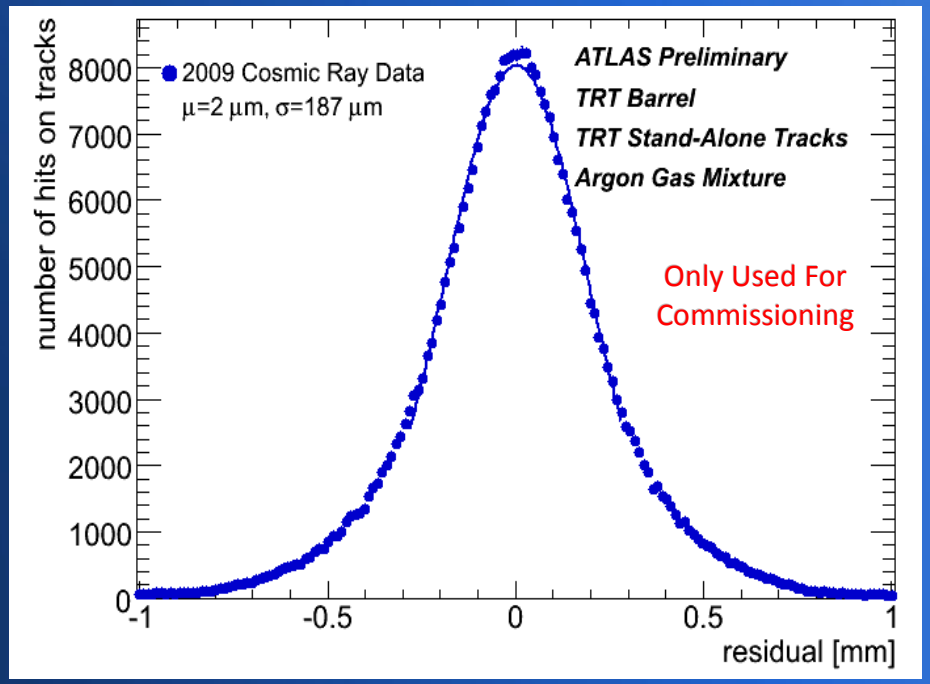


Expected precision of the module position after construction (~ 100 μm)

TRT Resolution

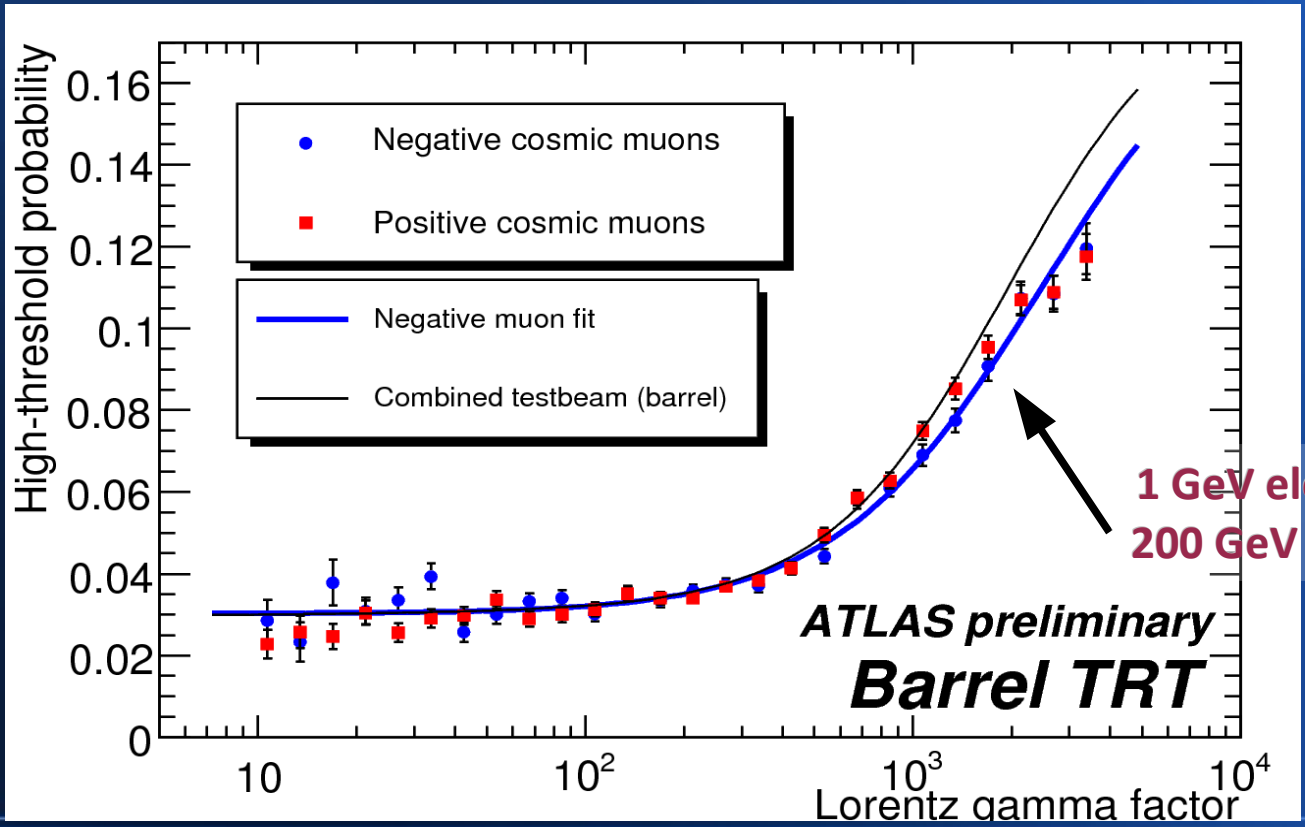
- TRT residual width is a convolution of several different factors
  - Intrinsic resolution, calibration, alignment, tracking performance, timing, etc…
  - Huge improvement from its initial value (although still not at the expected value)
    - Result of a lot of work in all aspects of the offline reconstruction





Test of TR with Cosmics

With Xe operation and before switching on the TRT trigger, TR capability were tested with cosmics



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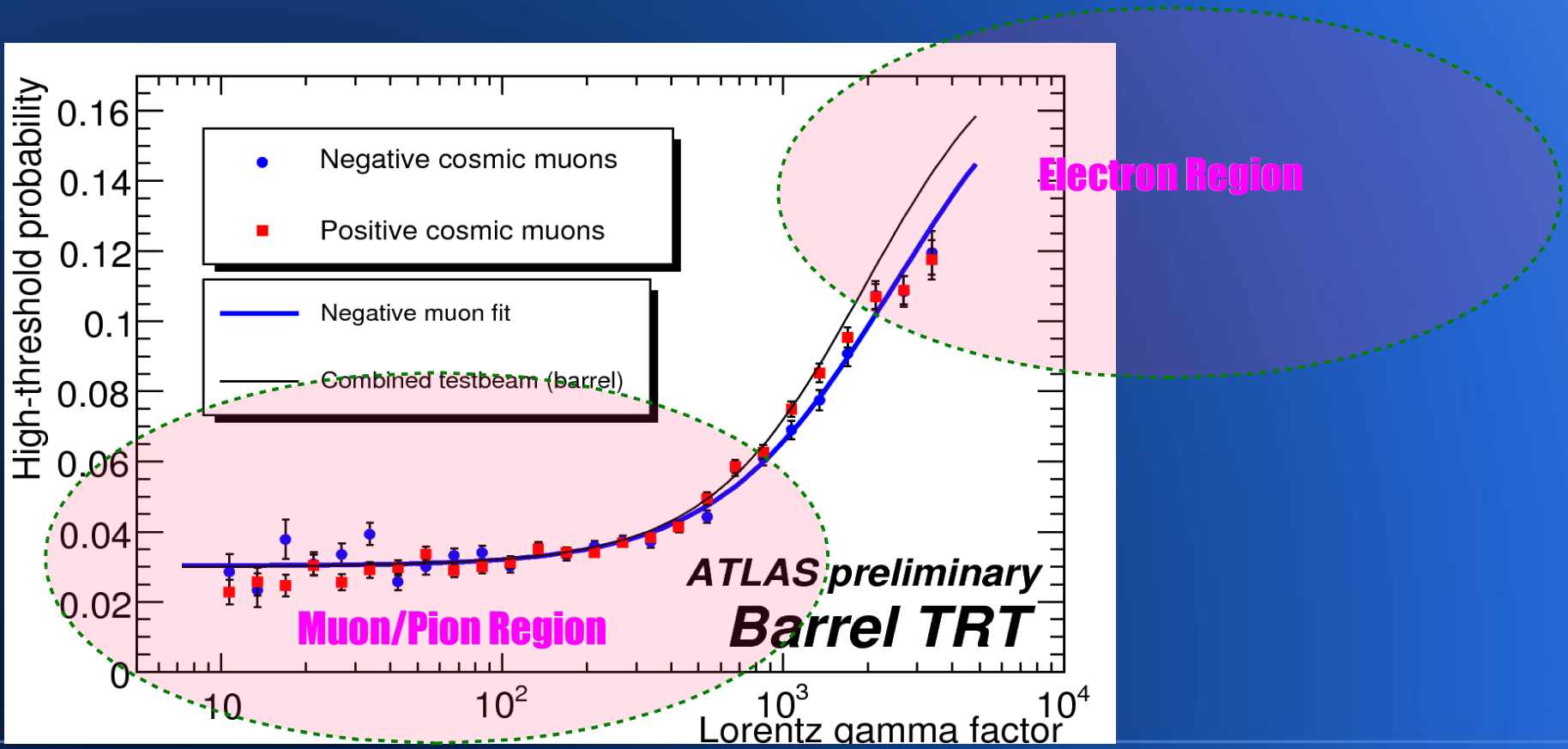

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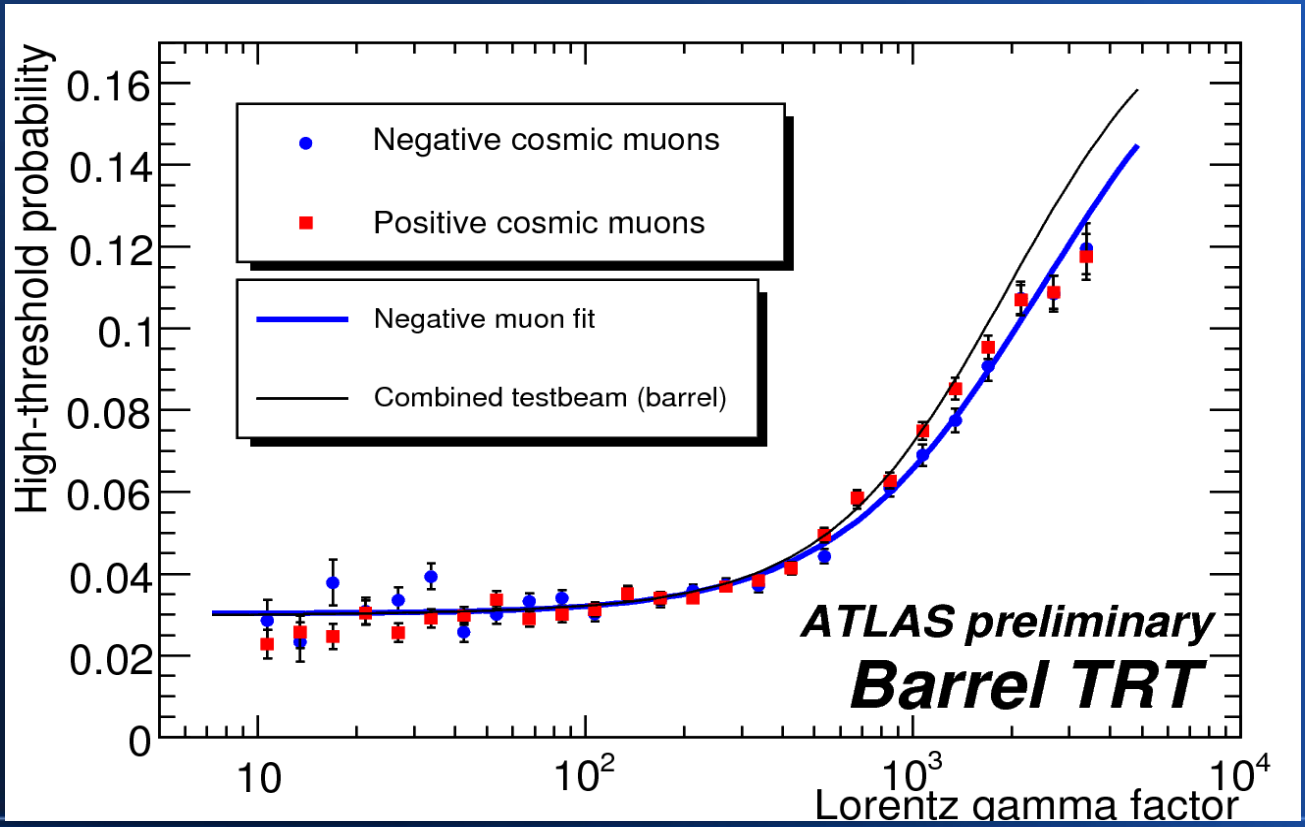
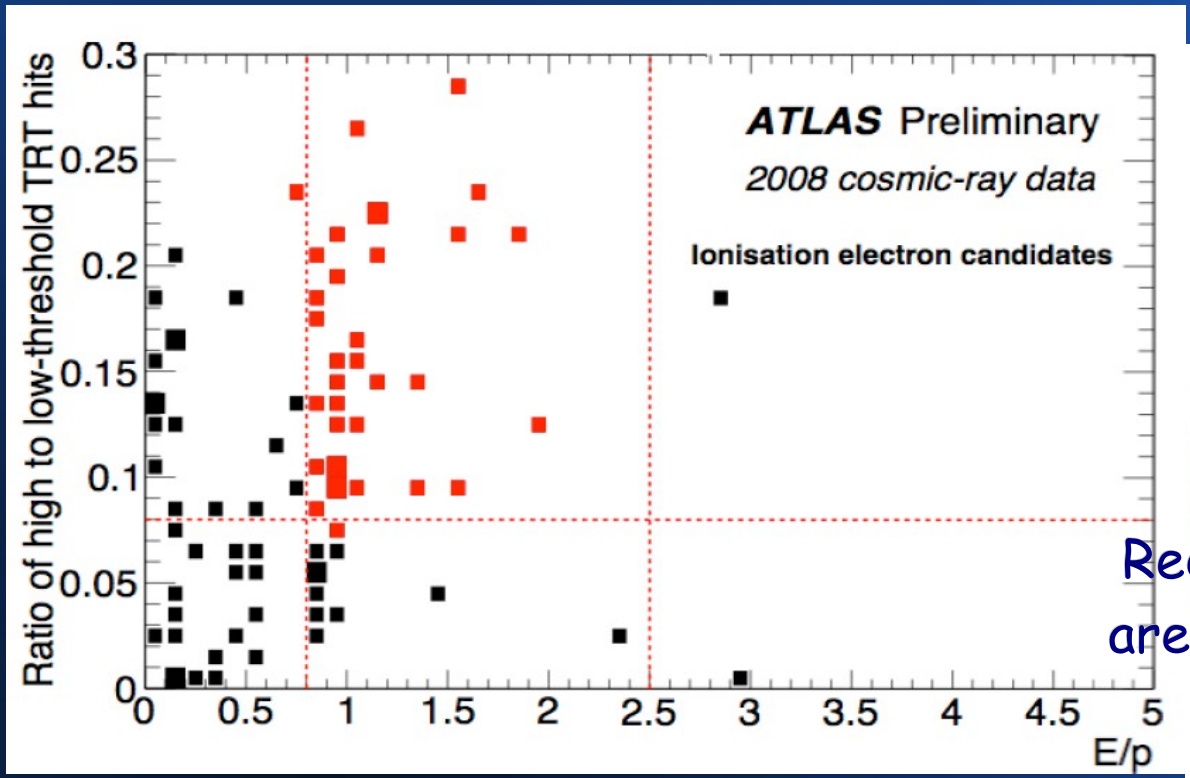


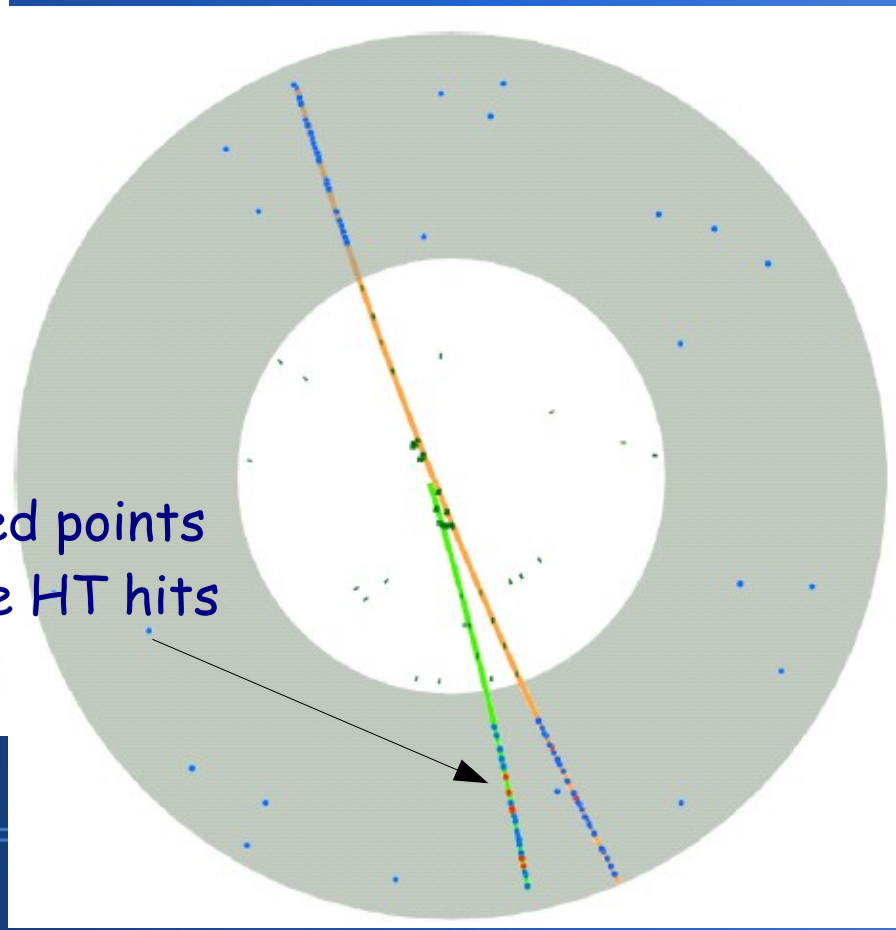
Turn-on of the TR curve at the right place

For the electron plateau we need collisions

First Electron in ATLAS

Nevertheless TR capability essential in the identification of the first electrons in ATLAS
(more on C. Schmitt plenary session talk on Wed.)





TRT Operation Commissioning

- All aspects of the TRT Operation have been continuously tested and improved, both with cosmics and standalone runs

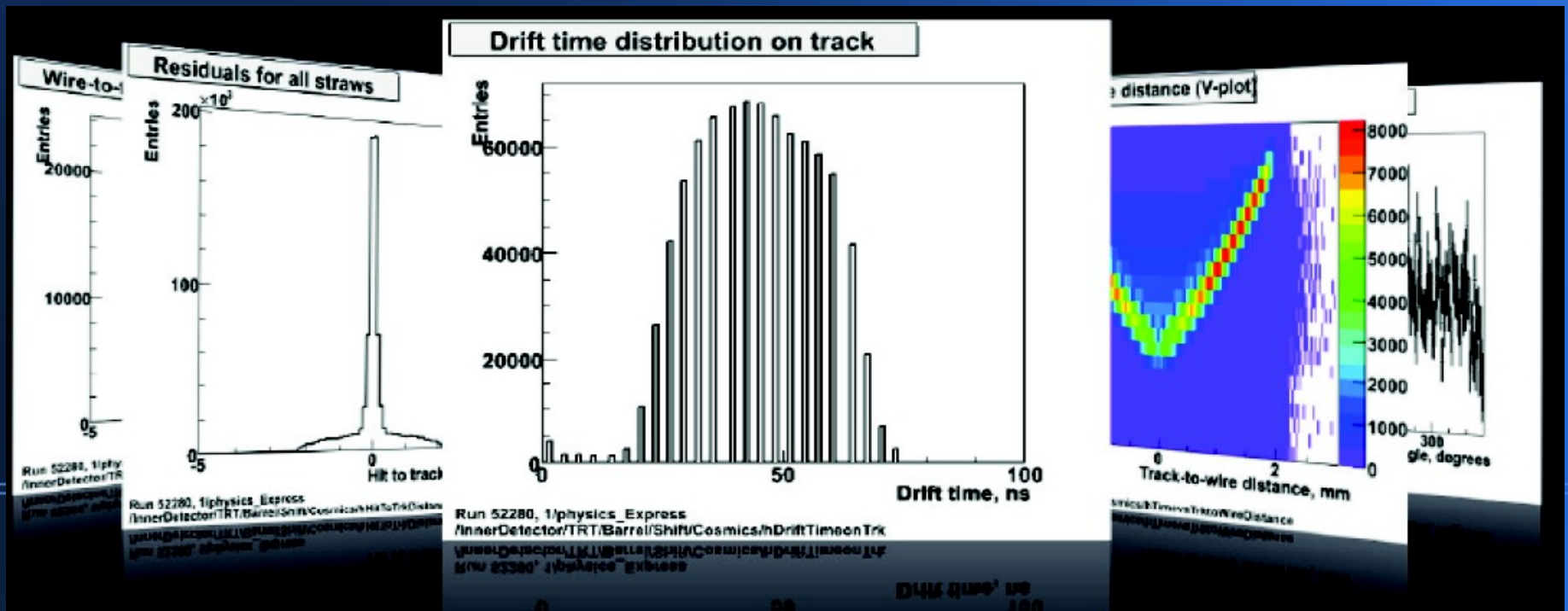
- Some highlights:
  - Low voltage and noise equalization
    - It assures uniformity of low threshold setting
  - High rate readout tests, with and without data compression mode
  - Integration of services in the monitoring system (DCS)
    - Powerful framework fully tested to assess the detector condition during data taking and to flag the quality of data collected
  - Implementation and testing of a "stop-less recovery system"
    - Huge saving of "collision time" avoiding the stop and restart of the run

TRT Operation Commissioning

- Some highlights (cont.):
  - Procedure to resync of the clock
    - Loss may occur when ATLAS switches from reference clock to TRT clock
    - Other clock problems like jump in clock phase, interruptions, ...
  - Continuous improvement of the gas system
    - Xenon is very expensive, leak reduced to ~ 0.15 l/h
      - One of the best system in ATLAS!
    - Recuperation system in production
    - Xenon filled again the TRT straws this week
  - Temperature stabilization and monitoring
    - TRT operates at room temperature but Silicon is cold!
    - Gain drop by 2.5% for each deg C
    - For large gradient (~ 20C) loss of particle identification capability

TRT Operation Commissioning

- Some highlights (cont.):
  - Monitoring framework in place to monitor the Data Quality and the DAQ
    - A subset of data analyzed in almost real-time to control the data quality
    - Very first look at what is actually recorded
    - More sophisticated reconstructed quantities are monitored offline
    - Fully automated checks support visual inspection by human shifter



Summary

- After the end of construction the TRT has gone through several years of commissioning work
- All aspects of operation and commissioning were tested in real data taking condition with the 2008/9 cosmics run (and few days of beam)
- The huge amount of tracks collected has been used to test the performance in situ of the TRT detector
- 24/7 operation of the detector starting next week
- We are ready, again, to record the first collisions (and the following ones in the next decade)

Backup