ATLAS Transition Radiation Tracker (TRT), from construction to installation.

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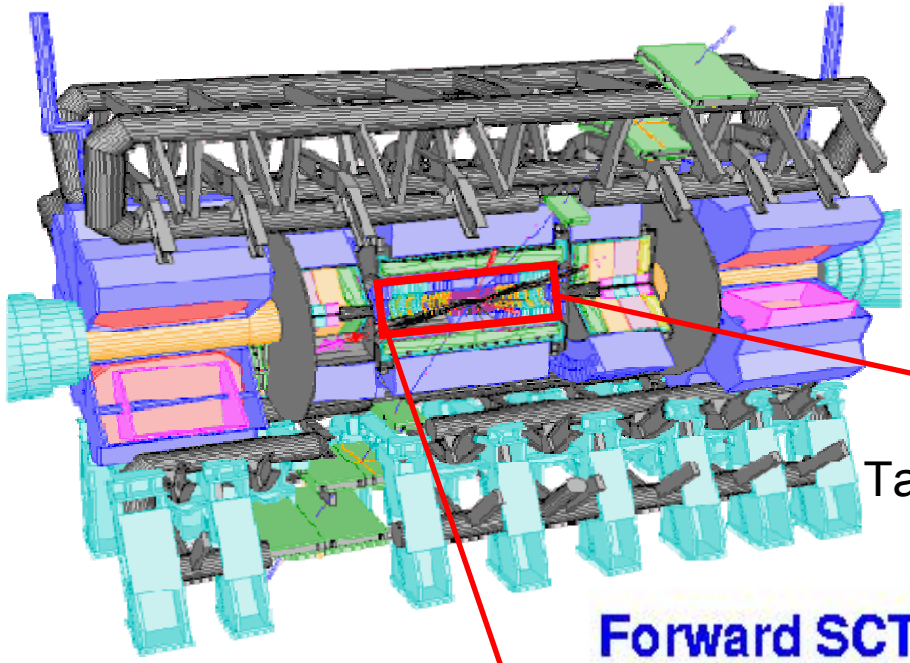
(On behalf of the ATLAS-TRT collaboration)

Outline

- TRT generalities :
  - Barrel
  - Endcaps
  - Front-end electronics
- Test and quality controls :
  - Front-end electronics
  - Services
- From 2004 to 2007 :
  - 2004 combined test beam
  - 2006 SCT (SemiConductor Tracker) and TRT combined cosmics – barrel
  - Installation of the barrel in the ATLAS cavern
  - 2006 SCT (SemiConductor Tracker) and TRT combined cosmics – endcaps
  - Progresses in the detector description.

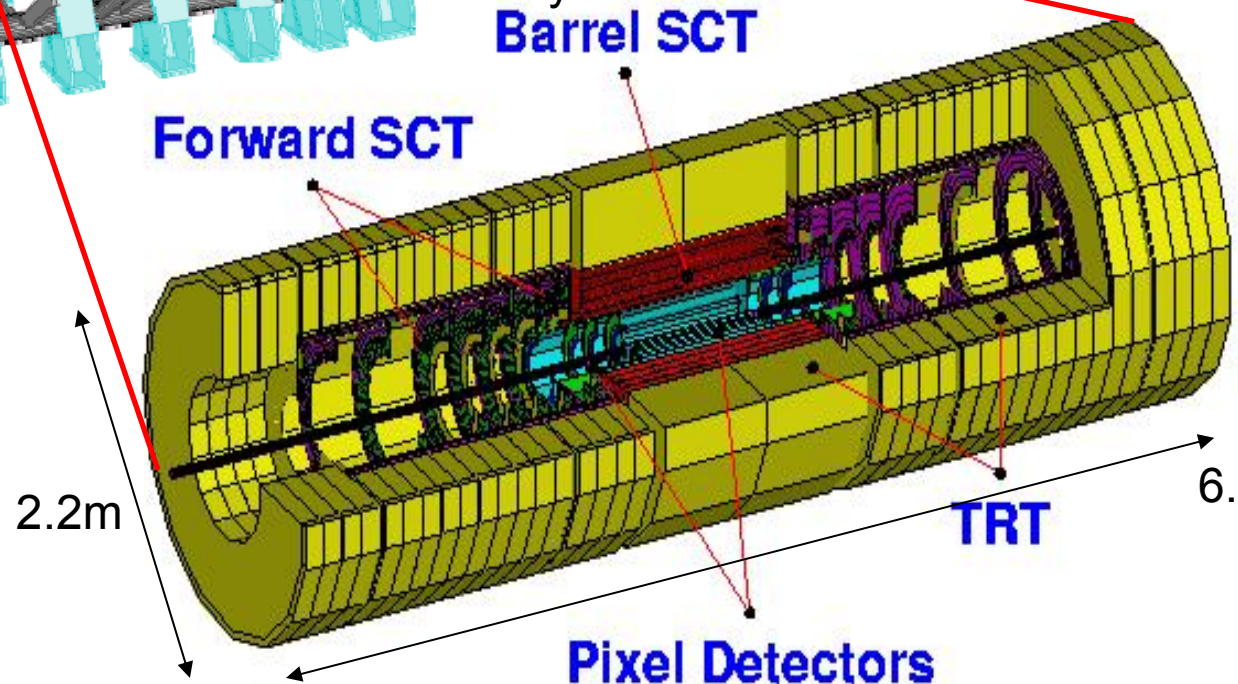
TRT in ATLAS



TRT :

- Tracking :
  - Solenoid magnet : 2T magnetic field
  - Active gas Xe(70%) - CO2 (27%) - O2 (3%)
  - High voltage ~ -1500V
- Particle Id : Transition radiations

Talk by Ewa Stanecka

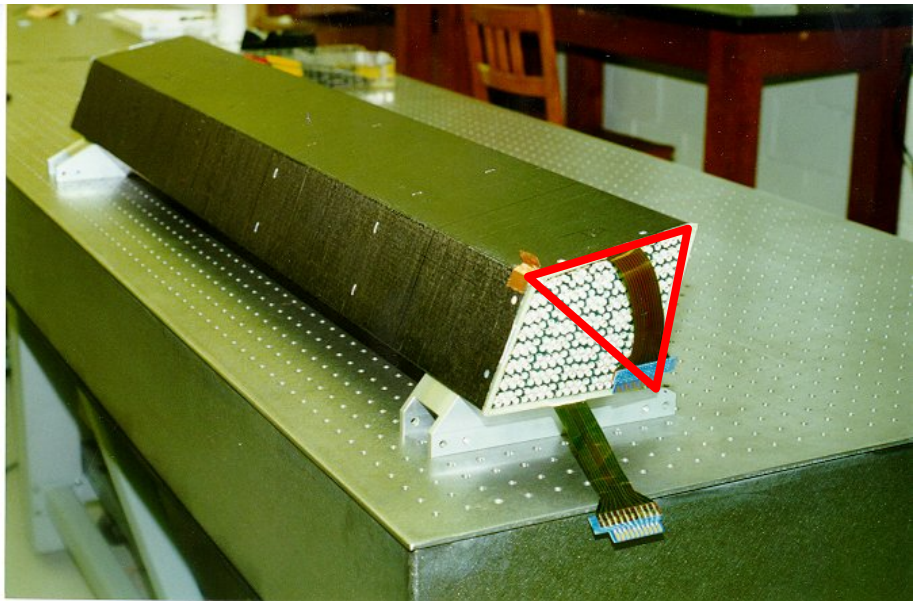


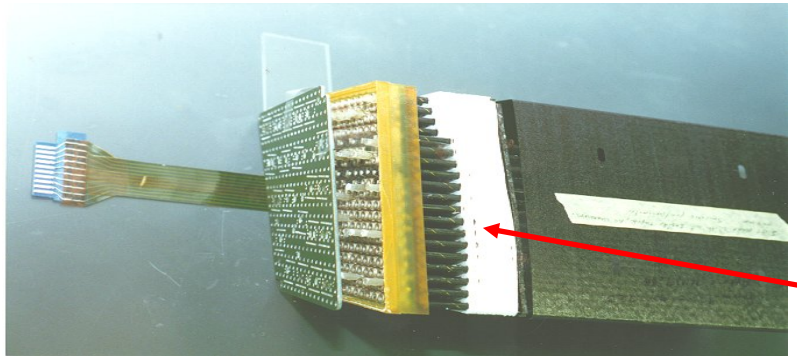
Talk by Mauro Donega

TRT - Barrel

The barrel detector :

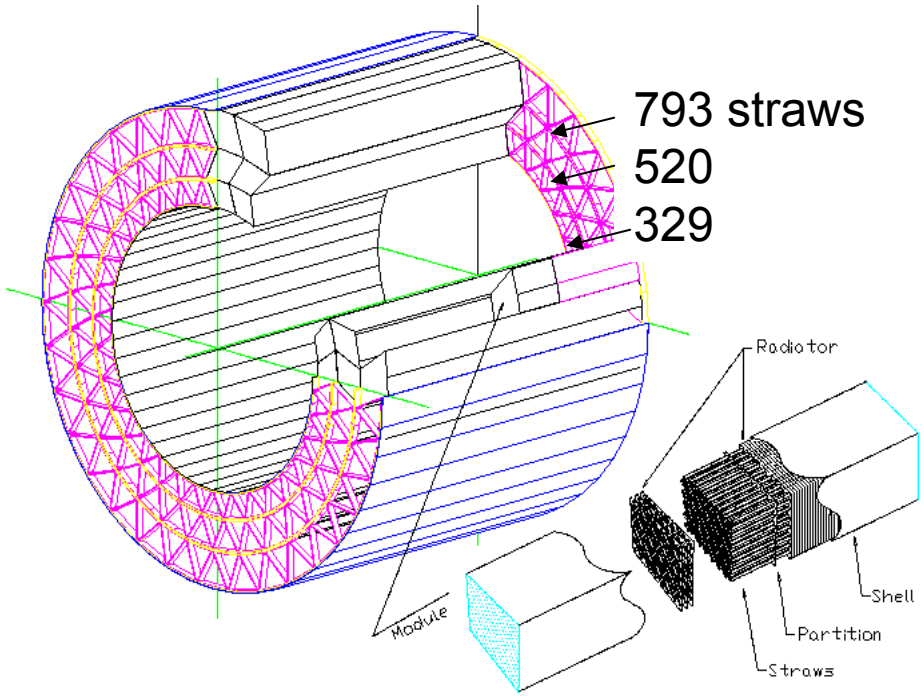
- 96 modules
- 1.5 m straws (Ø 4mm) parallel to the beam axis. The wires in the straws are electrically split in the middle. Each end of the straw is read out separately.
- 105088 channels



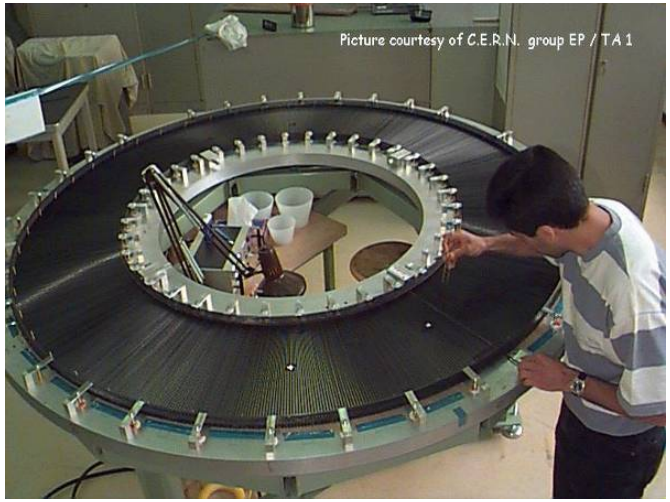


Radiator = polypropylene

96 modules = 32 x 3 different sizes

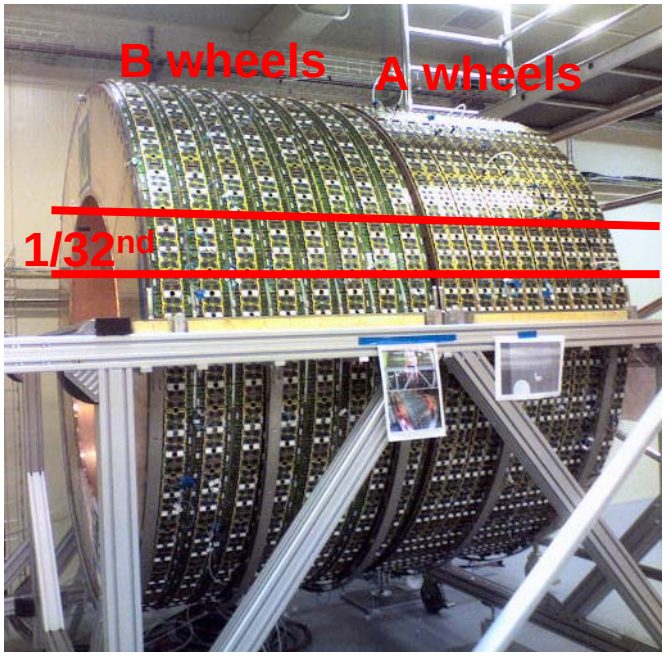


TRT - Endcaps



1 Endcap is constituted of :

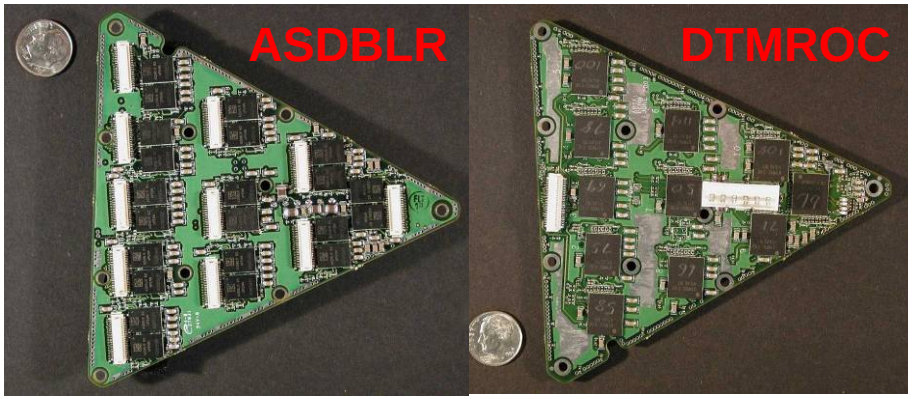
- 12 A wheels and 8 B wheels
- 122880 39cm long radial straws
- (640 digital + 1920 analog) front-end electronics boards
- 240 high voltage connectors and 720 HV lines
- 15360 fuses



Number of channels (2 endcaps) = 245760

TRT Front-End electronics

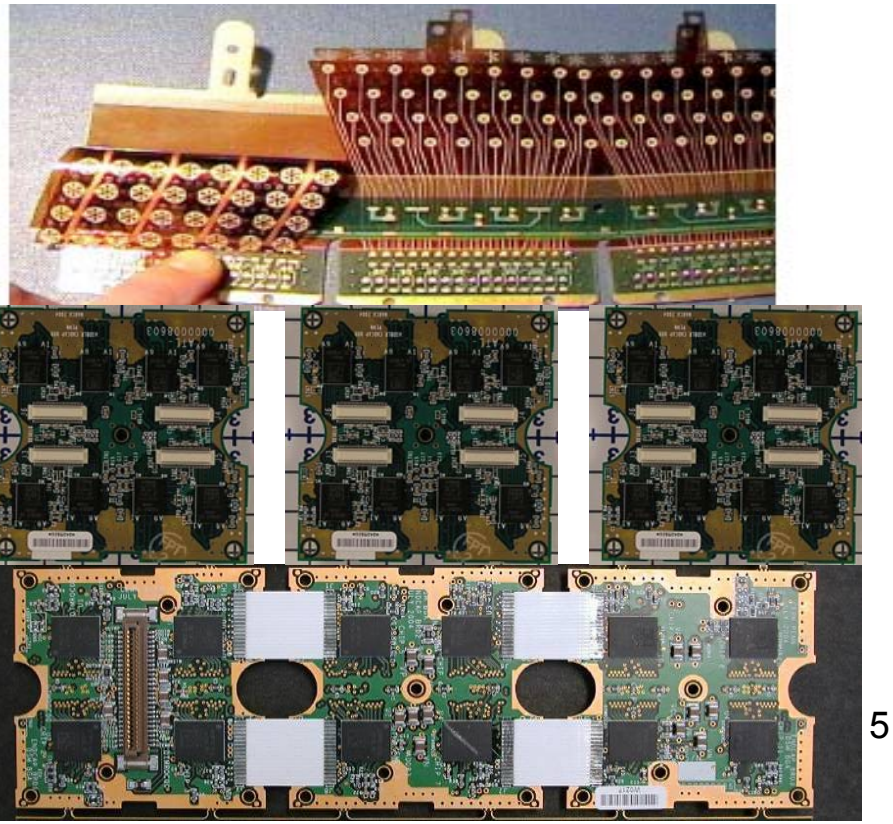
ASDBLR : **A**mplifier/**S**haper/**D**iscriminator/**B**ase **L**ine **R**estorer Integrated circuit
DTMROC : **D**rift **T**ime **M**easurement **R**ead**O**ut **C**hip



Barrel :
Digital and Analog Electronics
on the same board.

Endcaps, by 1/32nd of a wheel :

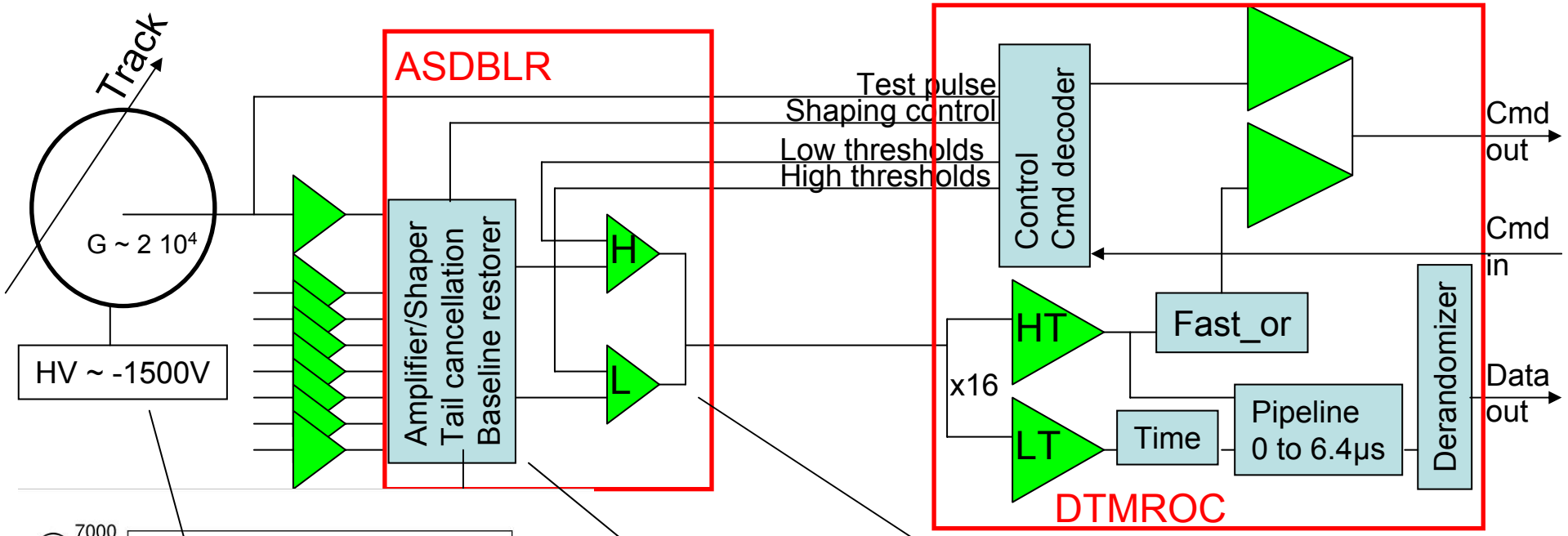
- 6 WEBs (Wheel Endcap Board) to connect straws to High Voltage and electronics

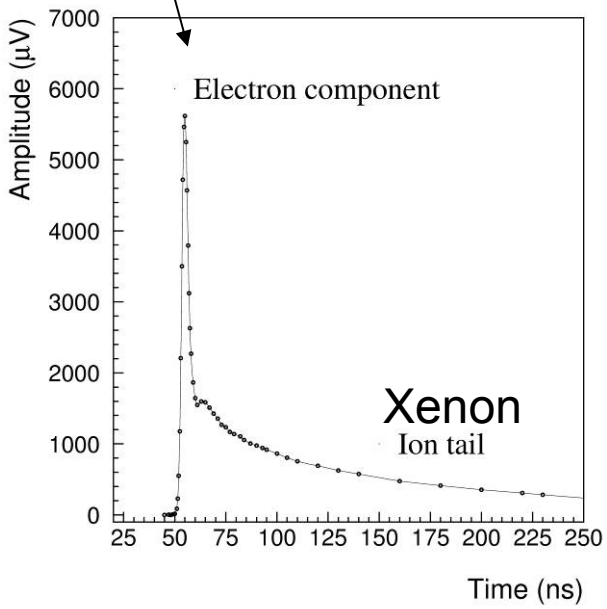


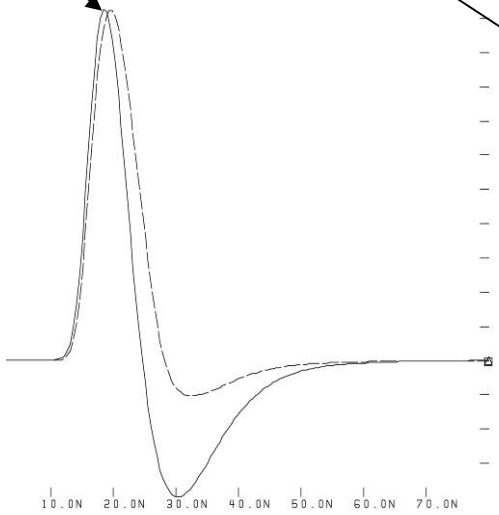
- 3 boards with 8 ASDBLR chips each
  (1 ASDBLR chip = 8 straws)

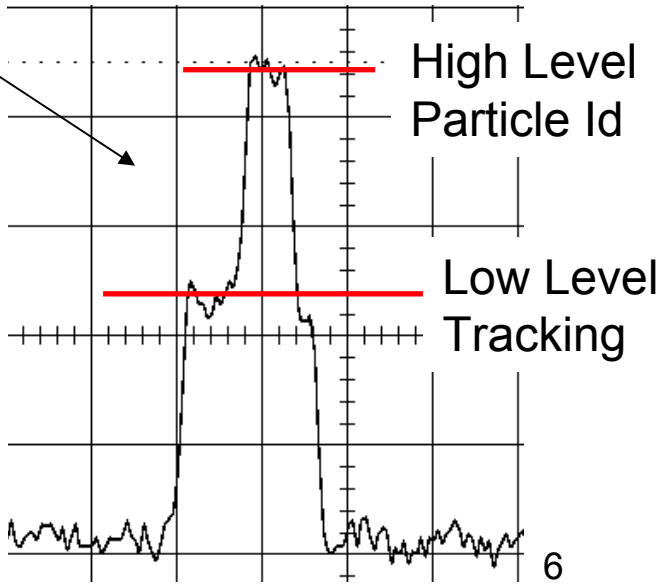
- 1 “triplet” with 3x4 DTMROC chips

TRT Front-end Electronics, cont'd



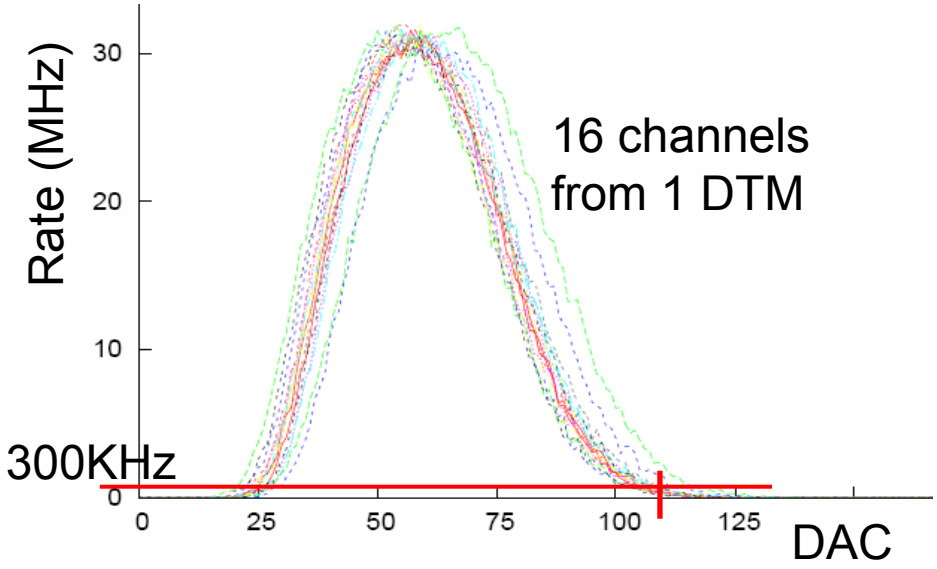


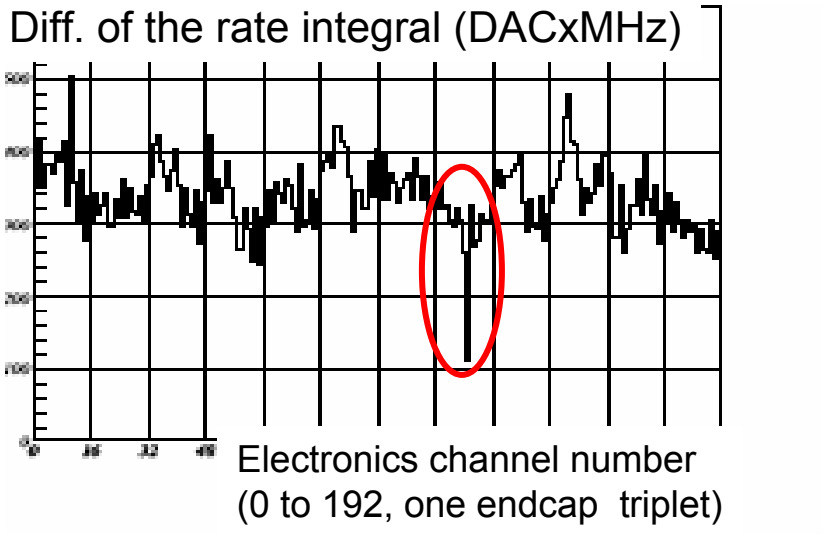


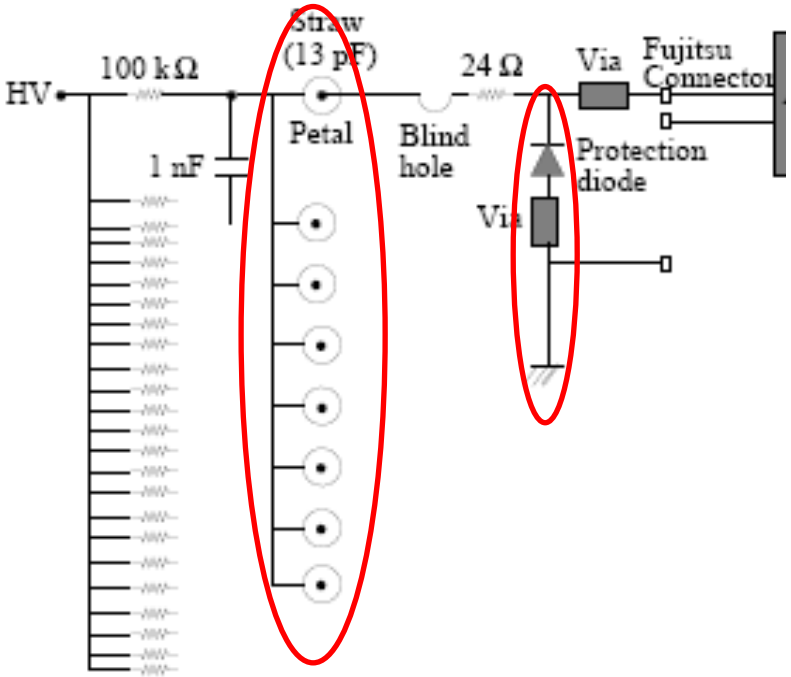


FE-Electronics – Quality Control - Noise

Noise rate (Low level) as a function of the threshold (DAC) :
300KHz rate (2.25% occupancy), and Integral of the noise is measured for each channel, first board un-connected then board connected







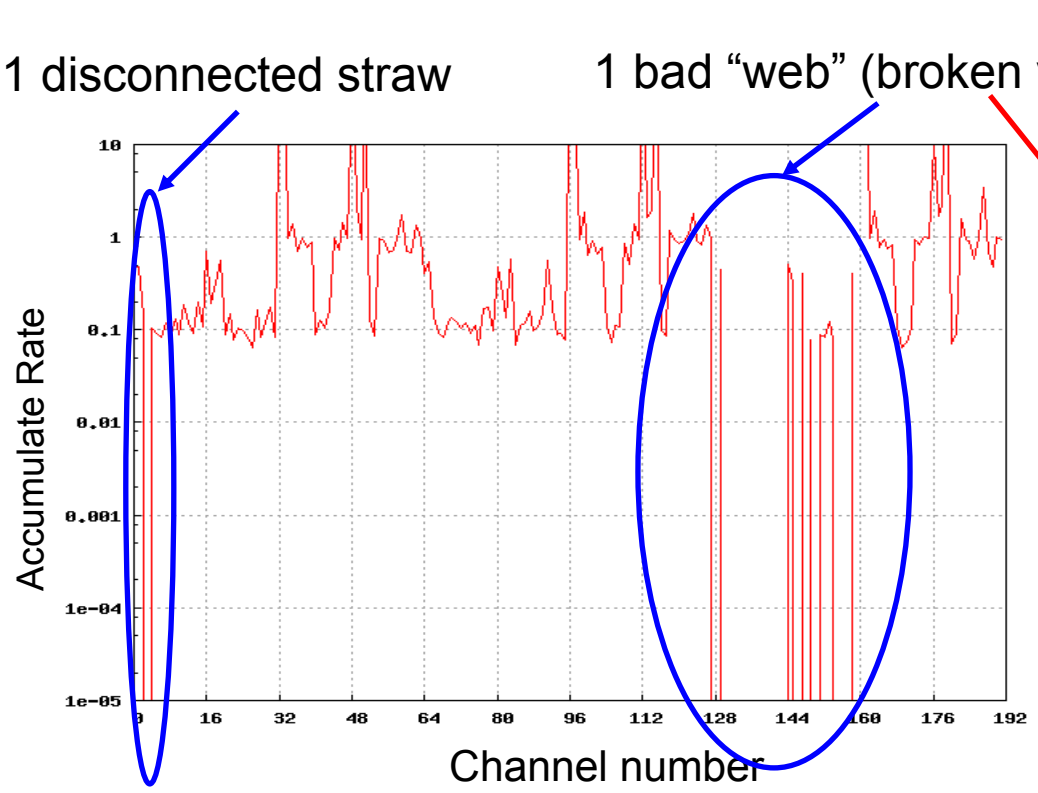
Bad channel found, check :
- capacitance
- diode voltage

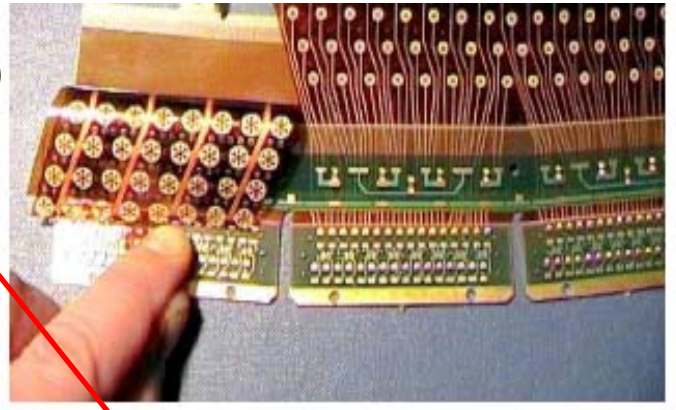
to identify the problem (electronics / detector ?)

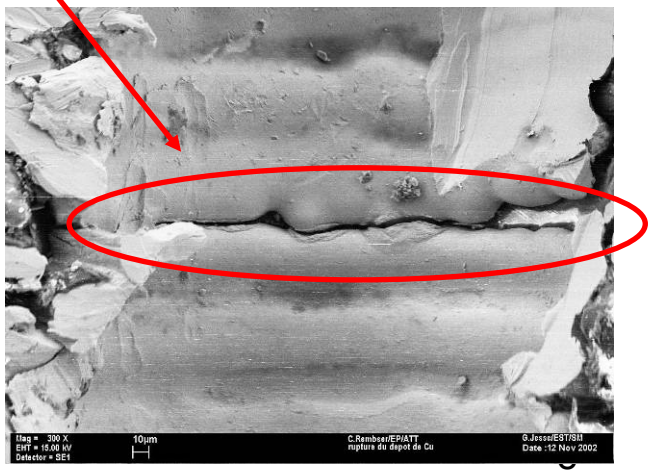
FE-Electronics – Quality Control – Accumulate Rate

Accumulate mode feature of the DTMROC :
Once High Level bit has been set, stay set until the relevant register bit is cleared.
Using different time gates, can compute an « accumulate rate »

- Active gas : Ar:CO_2
- High voltage : 1350V to 1450V



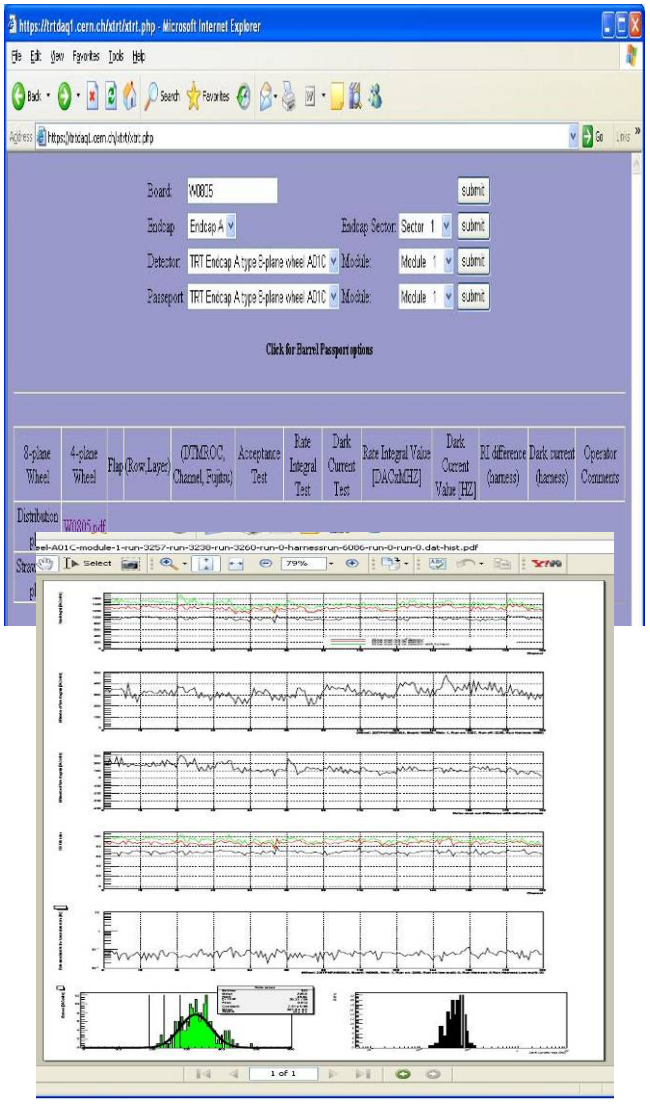




Other tests : timing (fine delay scan), test pulse on low and high gain.

FE electronics test - results

All the results are registered/accessible through a mysql database



Unusable channels :
- Mechanically disconnected
- Broken vias
- Dead electronics
- High Voltage problem (dead fuse)

Barrel :
Side A : 926 Unusable Channels.
Side C : 1050
Total : 1.9%
98.1% of the barrel is functional.

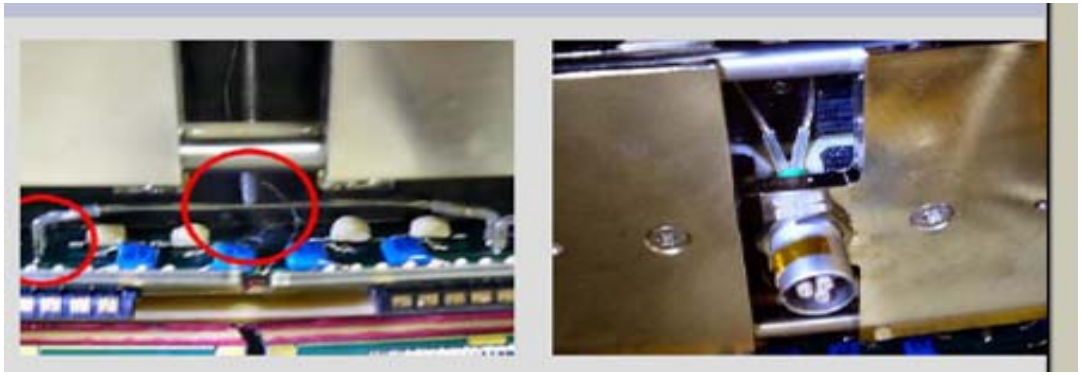
Endcap C : 954 : 0.78%
Endcap A : 522 : 0.42%
Total : 0.6%.
99.4% of the endcaps is functional.

99% of the detector is functional

(remember 350848 channels in total)

TRT endcap – tests of the services

- All HV lines, HV connectors, fuses & HV bridges (!) have been individually tested. (~10% rejection for HV lines, estimation of ~2 dead fuses/year, 2% of the HV bridges replaced)

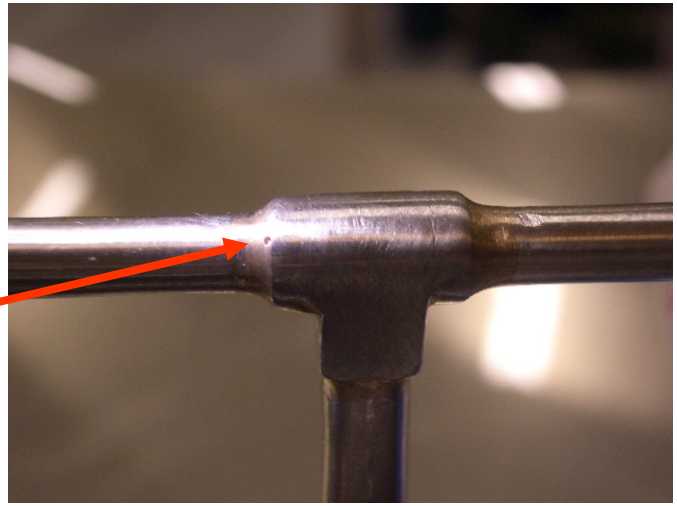


Absolutely needed, no access to high voltage after LHC start

- Piping for straw (CO2) cooling is leak tight (0.1l/h)
  → Pollution by environmental gas @ level of 0.05l/h

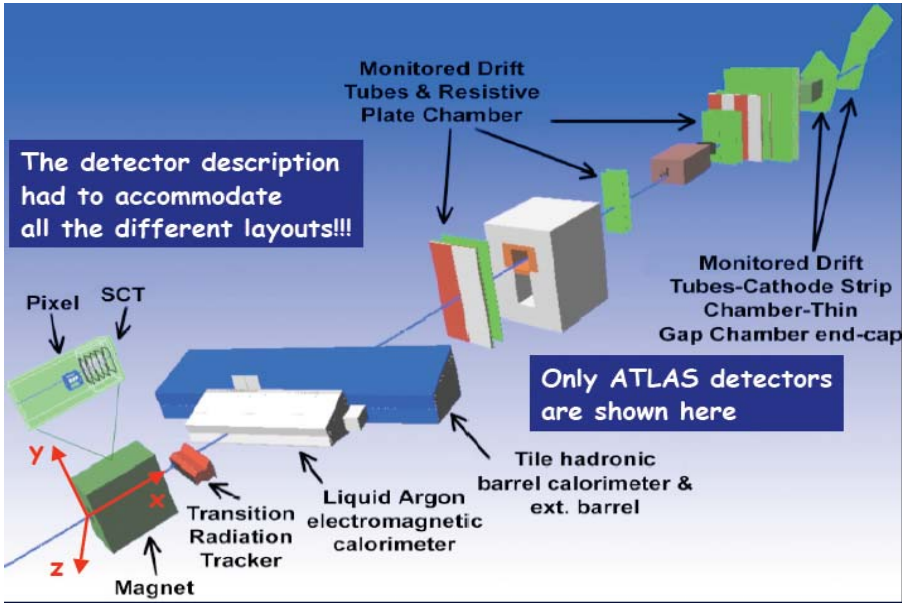
- Piping for electronics cooling (C_6F_{14}) and heat exchanger (1km piping, 880 Swagelok connectors) are leak tight :

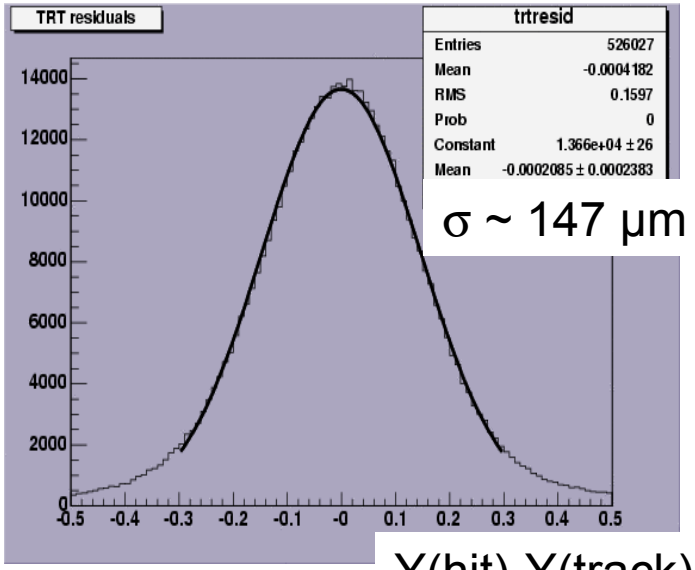
  – Very low leak : 12 liters/year (2 endcaps) (well within specifications)
  – Leak smaller than a tiny leak through this single hole in a brazed joint!



- Temperature sensors have been calibrated and all the cooling circuit have been checked (Temp. measurement using dedicated Detector Control System (DCS) software.)

2004 combined test beam

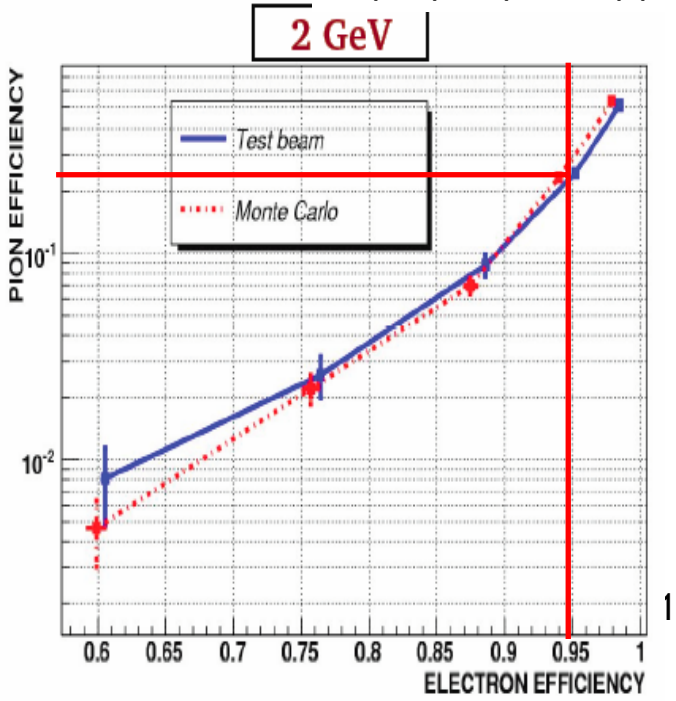




First time a full “slice” of ATLAS was tested
Very useful exercise for the common DAQ

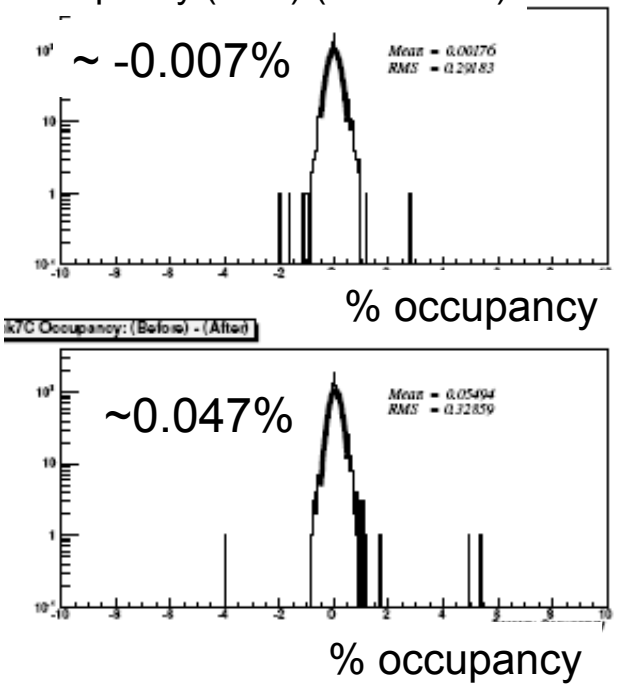
A lot of results from the Inner detector concerning track reconstruction, alignment, particle Id.

Only PRELIMINARY (2005) results shown here



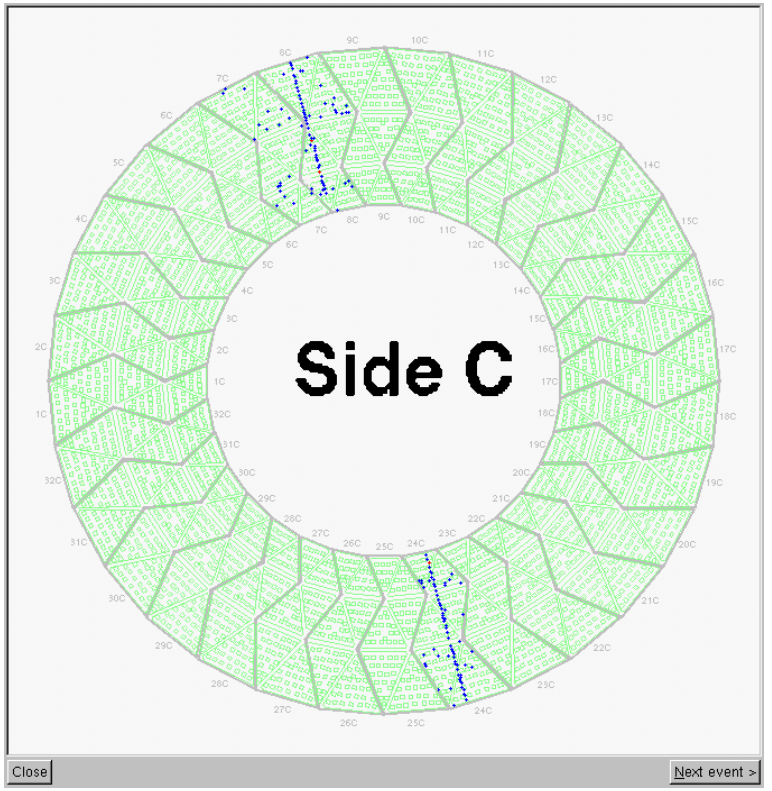
Barrel SCT+TRT combined tests (cosmics – Ar:CO_2 gas)

Occupancy (TRT)-(SCT+TRT)

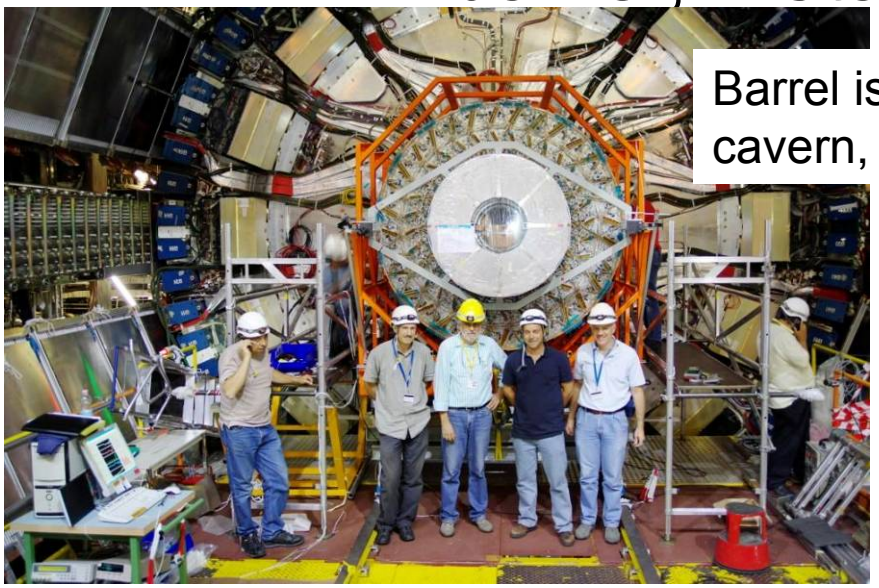


- No effect of the SCT running/readout on the TRT noise.
  - Noise changed by ~ ±0.05% on 0.5% occupancy
- No effect of running the SCT heater as well.
  (SCT operate @ -7°C, TRT @ 20°C)

Common DAQ & offline track reconstruction works well. A nice example of a cosmics, using an online/offline TRTviewer.



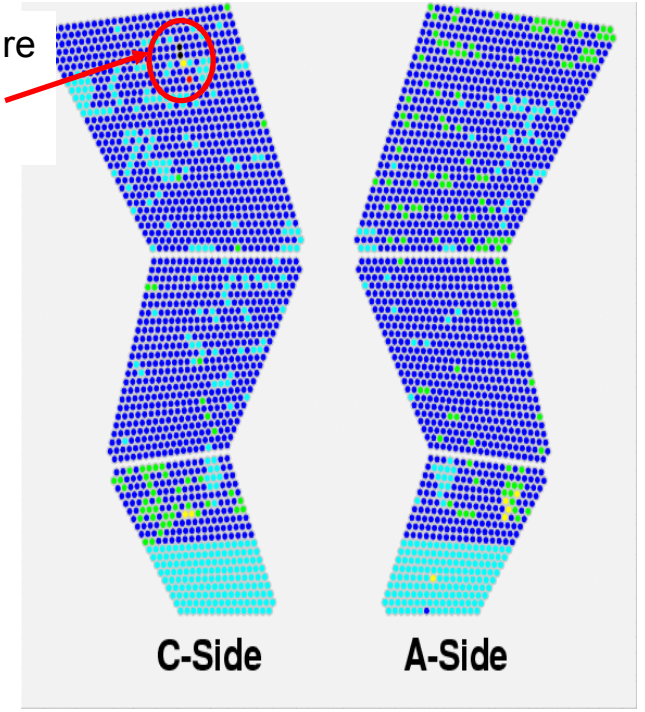
TRT barrel, installed in the ATLAS pit



Barrel is inserted in the calorimeter in the ATLAS cavern, all services are connected

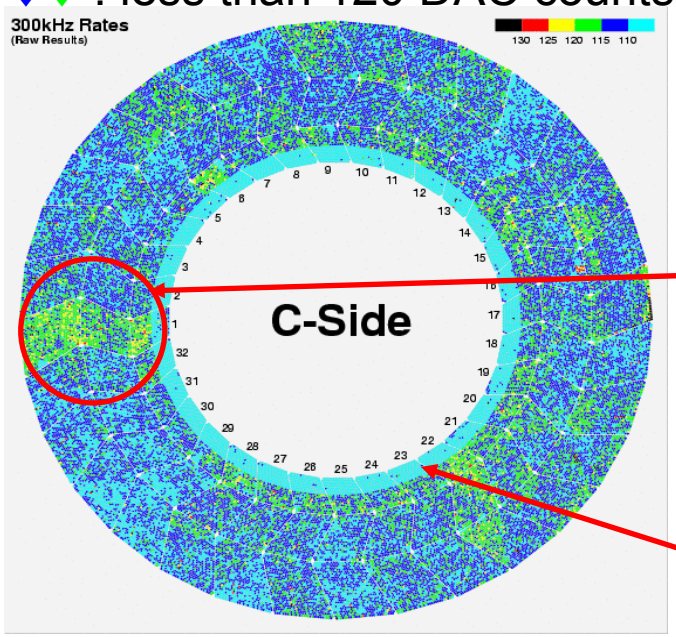
Average thres(300KHz) per 1/32nd

Known board feature (noise due to hole in ground plane)



"Map" of the threshold corresponding to 300KHz

♦ ♦ : less than 120 DAC counts

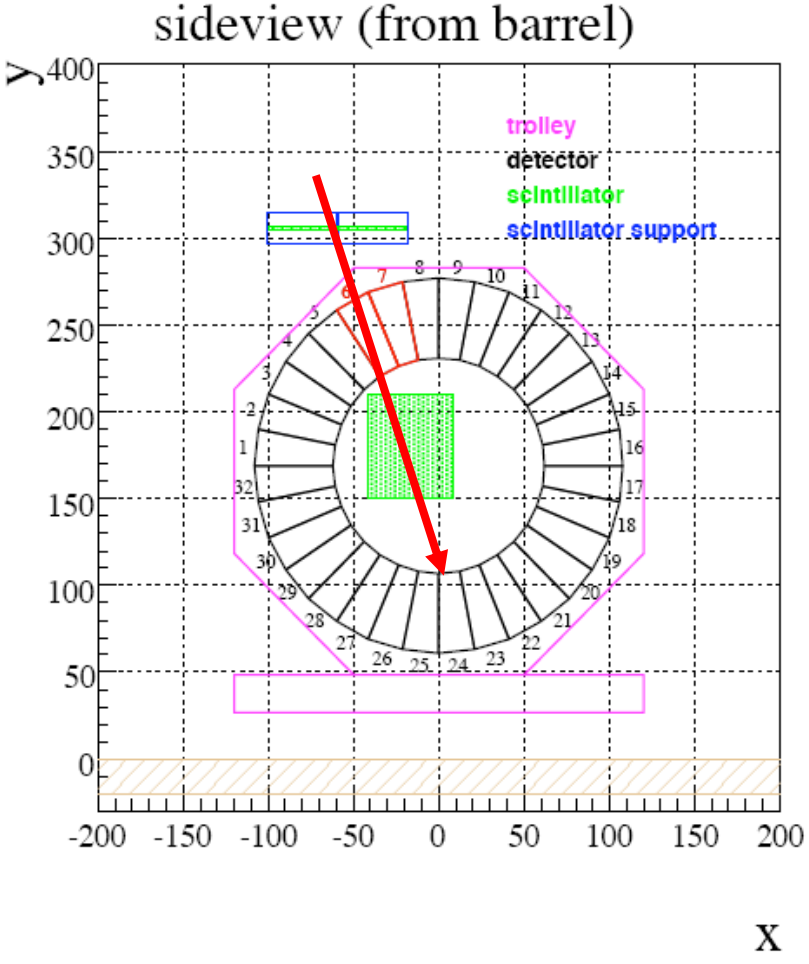


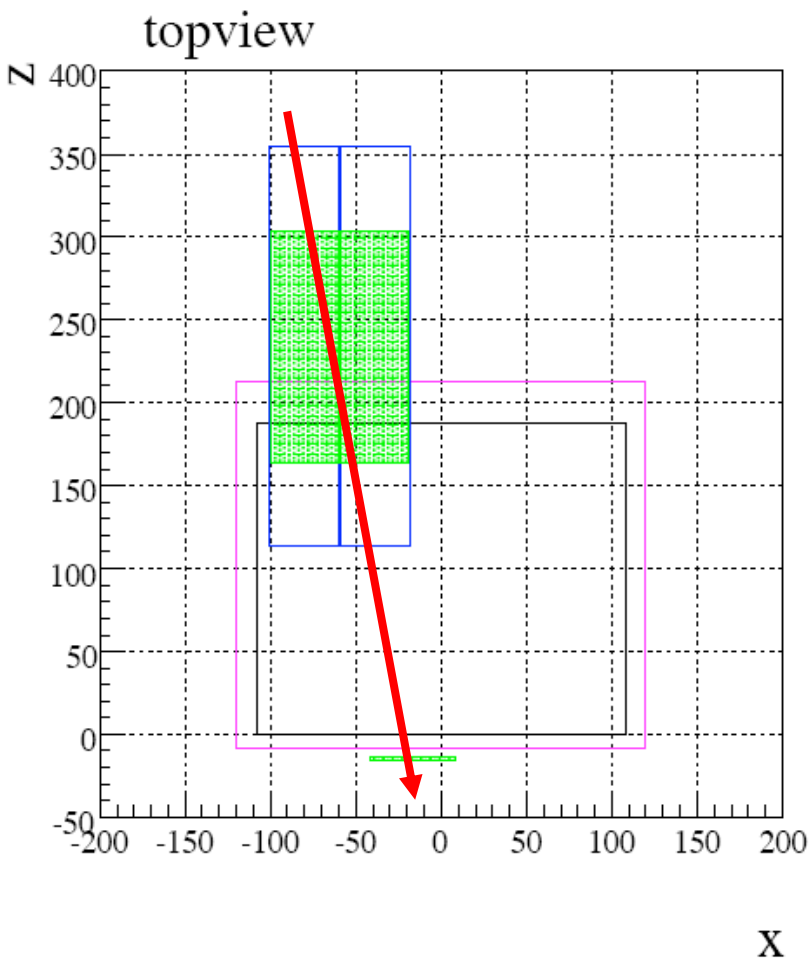
Voltage/ground corrections limitation

The first straws are shorter straws :

→ lower capacitance → lower noise

Endcap SCT+TRT combined tests. (cosmics)
TRIGGER SETUP - 2

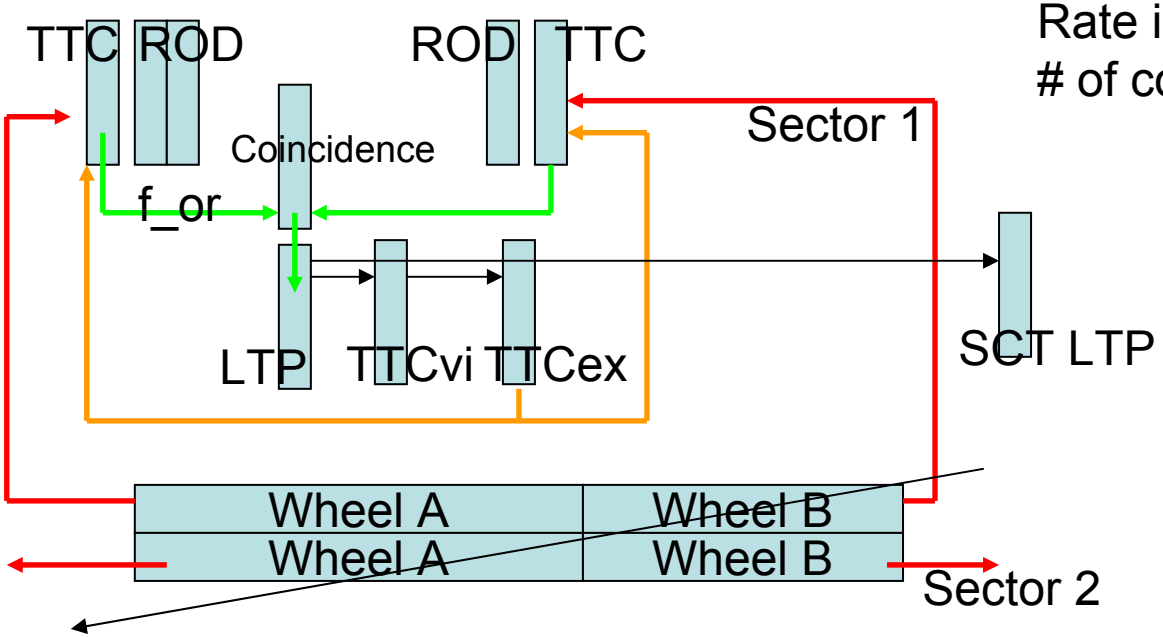




160k events on disk, ~4 days of running (24h/24h)
Trigger rate : good agreement MC (0.67Hz) / data (0.7Hz)
Number of combined SCT+TRT tracks ~35k

Endcap SCT+TRT combined tests. (cosmics)
TRIGGER SETUP - 1

- TRT FE-Board trigger :
  high threshold set @ 45 DAC counts / ~1KeV
  Cut on multiplicity @ least 3 wheels per A or B sectors
- Fast_or on TTC TP_out to coincidence unit, A || B.
  (Not shown, then : Sector 1 || Sector 2)
- L1A

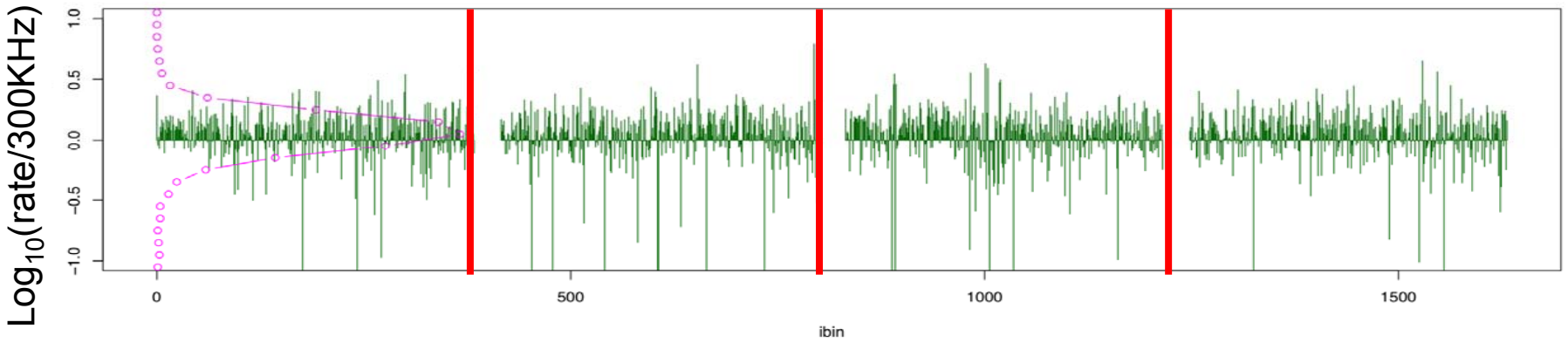


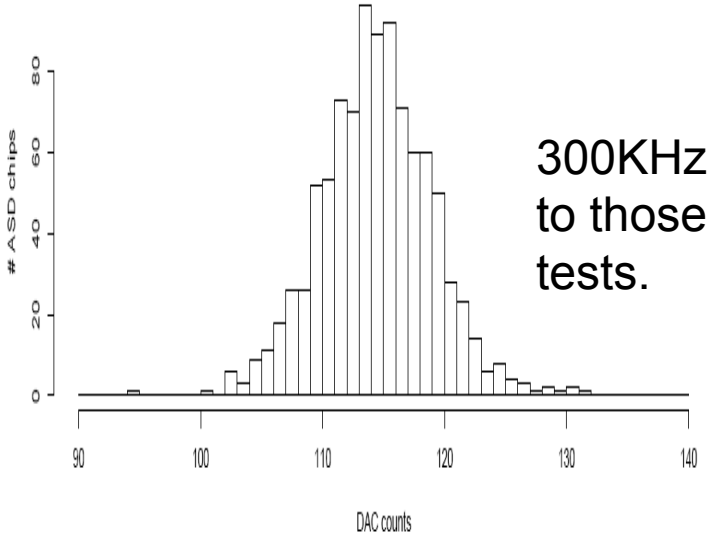
2.5M events on disk
~2.5 days of running (24h/24h)
Rate is ~25Hz
# of combined SCT+TRT tracks:100k

Endcap SCT+TRT combined tests : Rate Equalization

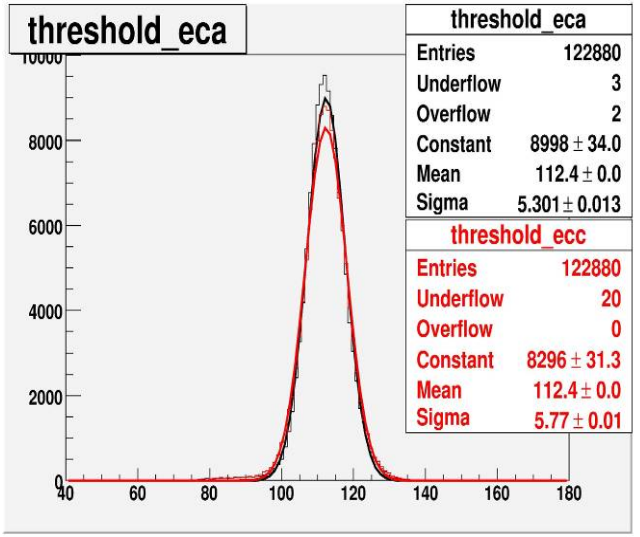
- Go from INDIVIDUAL 300KHz threshold to the threshold to be set for each asdblr (8 straws). Iterating, using the fact that : threshold α exp (Noise Rate/bandwidth)^2

1 ROD = 4 slots = 8 FE boards x 12 DTM x 16 straws = 1536 straws



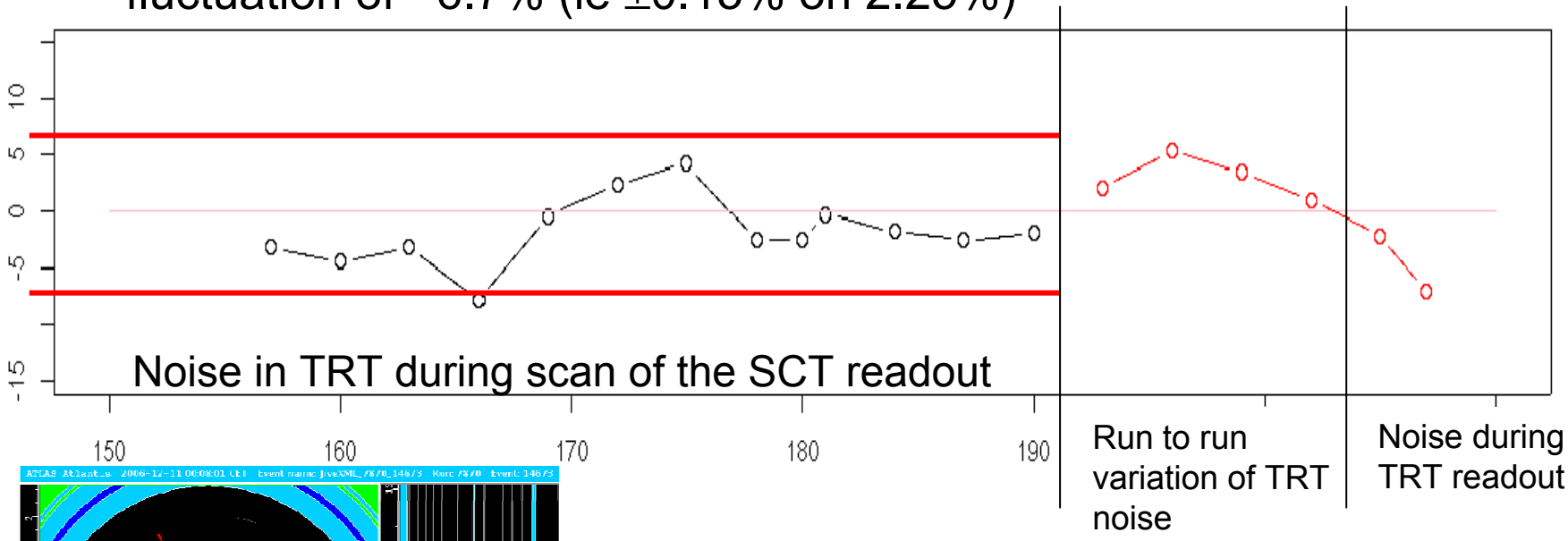


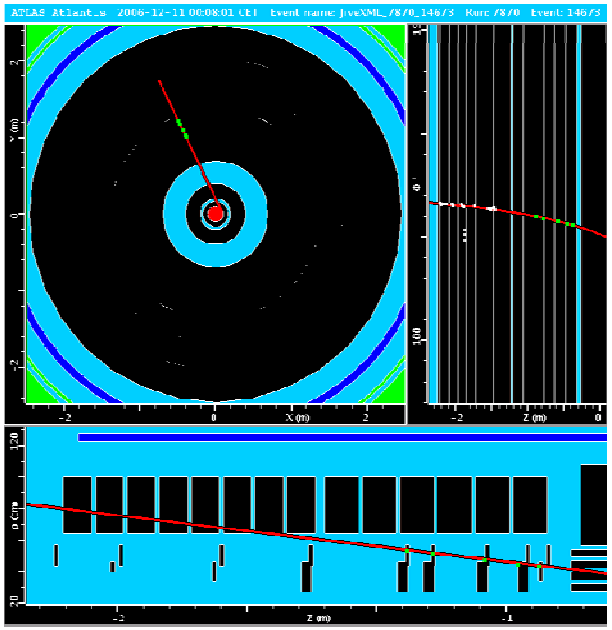
300KHz thresholds similar to those from the electronics tests.



Endcap SCT+TRT combined tests.

- No changes in occupancy bigger than the expected run to run fluctuation of ~6.7% (ie ±0.15% on 2.25%)





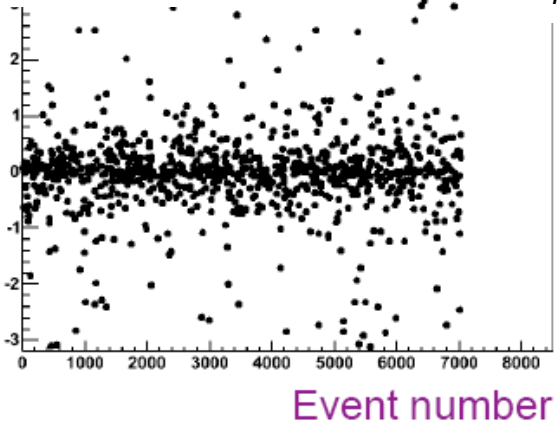
Combined DAQ
Online monitoring
Offline reconstruction work well

An example of ONLINE track reconstructed using the ATLAS ATHENA+ATLANTIS standard software

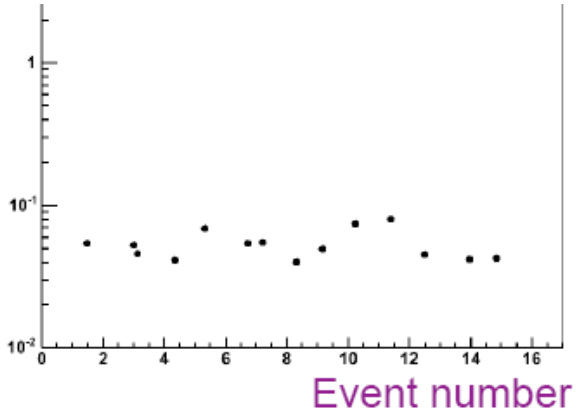
Endcap SCT+TRT combined tests.
ONLINE Monitoring

No sign of desynchronization between SCT/TRT endcaps

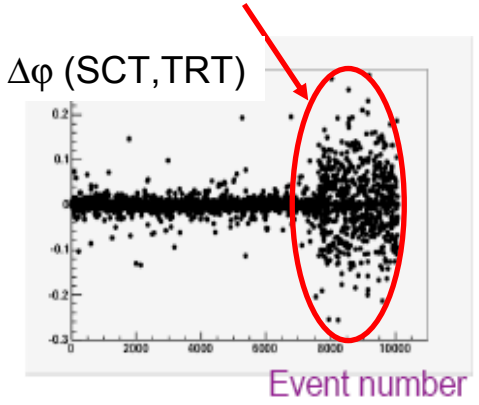
Δφ (SCT,TRT) track segment

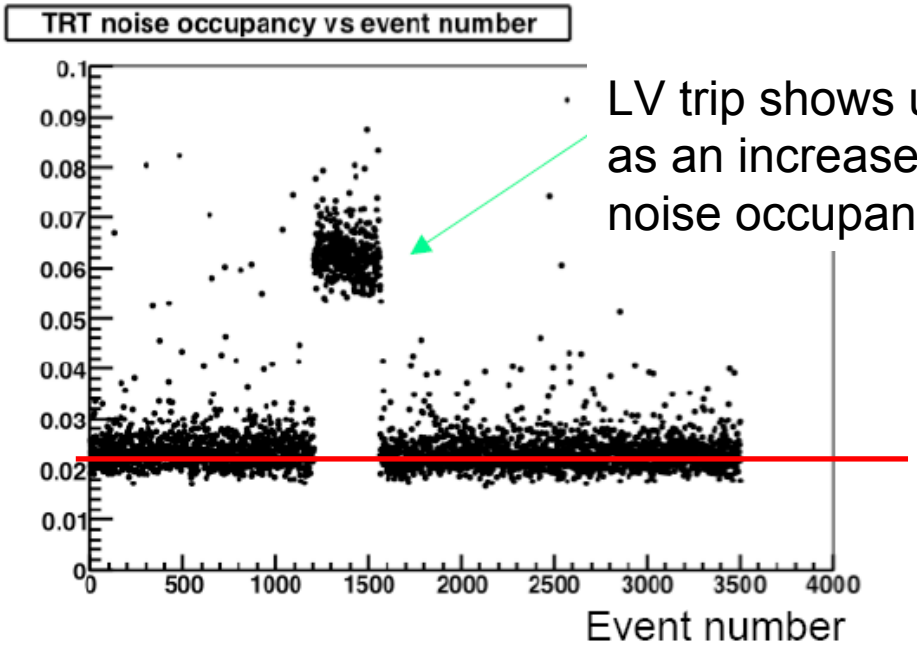


combined (SCT,TRT) tracks/500 events



Example of a lost of synch.on a barrel run



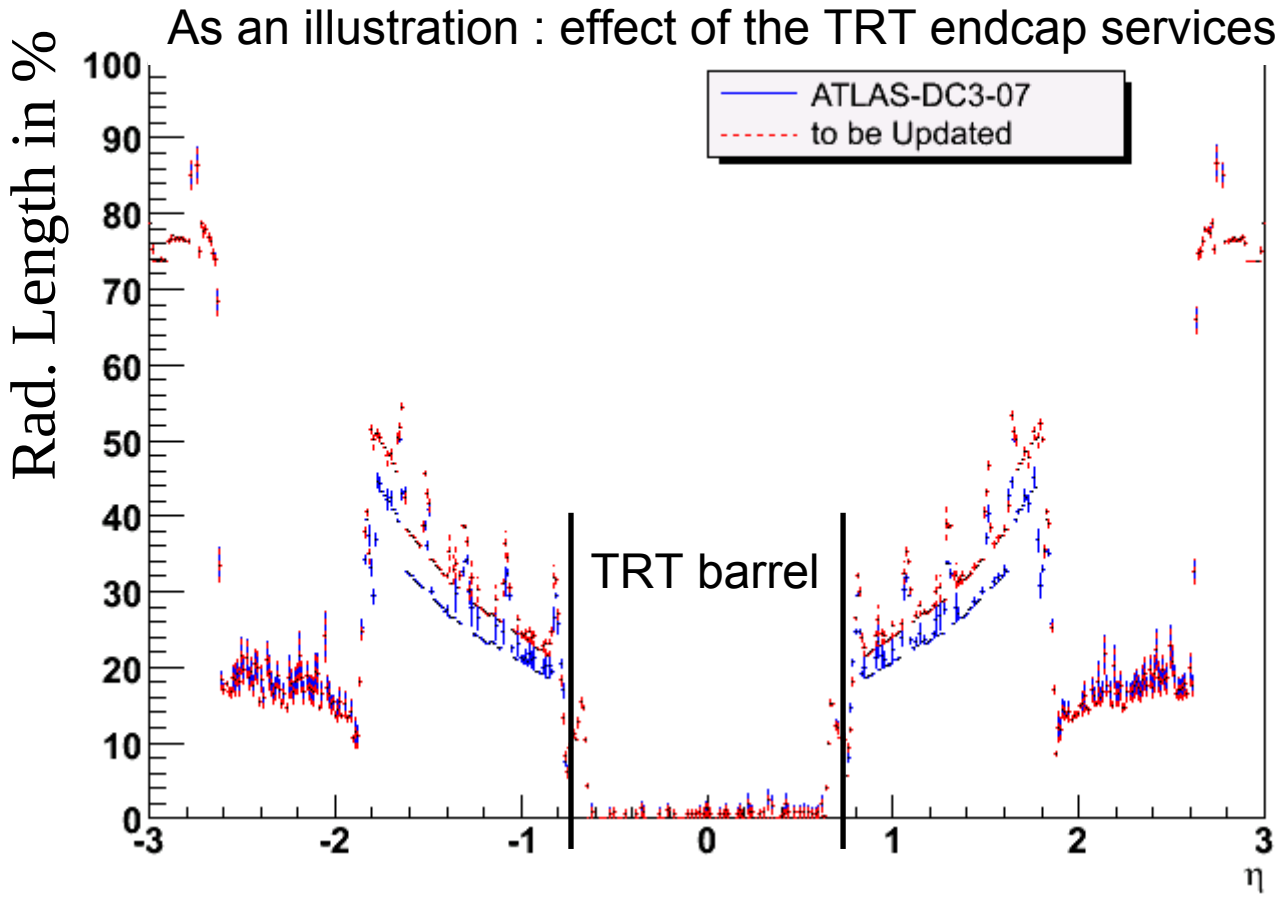


LV trip shows up as an increase in noise occupancy

Occupancy is 2 ~ 2.2% (depending of phi sector)
Setting was 2.25%

TRT detector simulation

- Big effort in 2005-2006 to get Geant4 description of the detector “as installed”
- Geometry and material of the TRT have been updated in the simulation
  - Radiation length is 4.49% (was 2.89%) (A wheels) and 3.56% (was 2.19%) (B wheels)



Conclusions

- Construction of the TRT now finished. Quite a success : 99% of the detector is functional!
- Successful combined test of TRT+SCT (for the barrel and for one endcap) on surface (noise study, cosmics, test beam)
- Successful installation of the TRT - barrel in the ATLAS cavern.
- Installation of the TRT- endcaps is going on.
- Test and installation of the back-end electronics are progressing.
- Strong software activities in parallel : online & offline monitoring, track reconstruction, “as installed” detector simulation…
- Next : commissioning of the TRT, and combined run of SCT+TRT in the cavern.