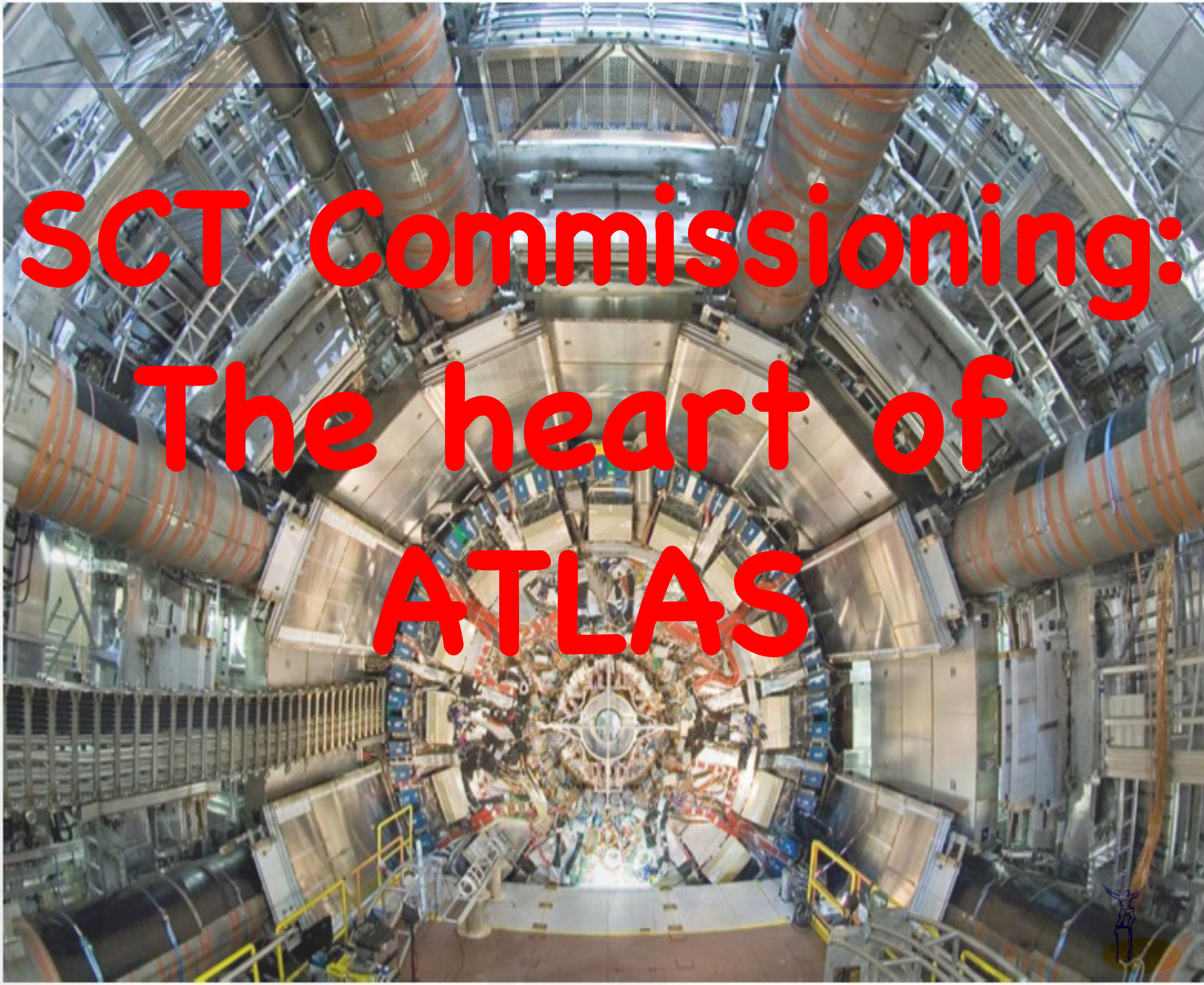


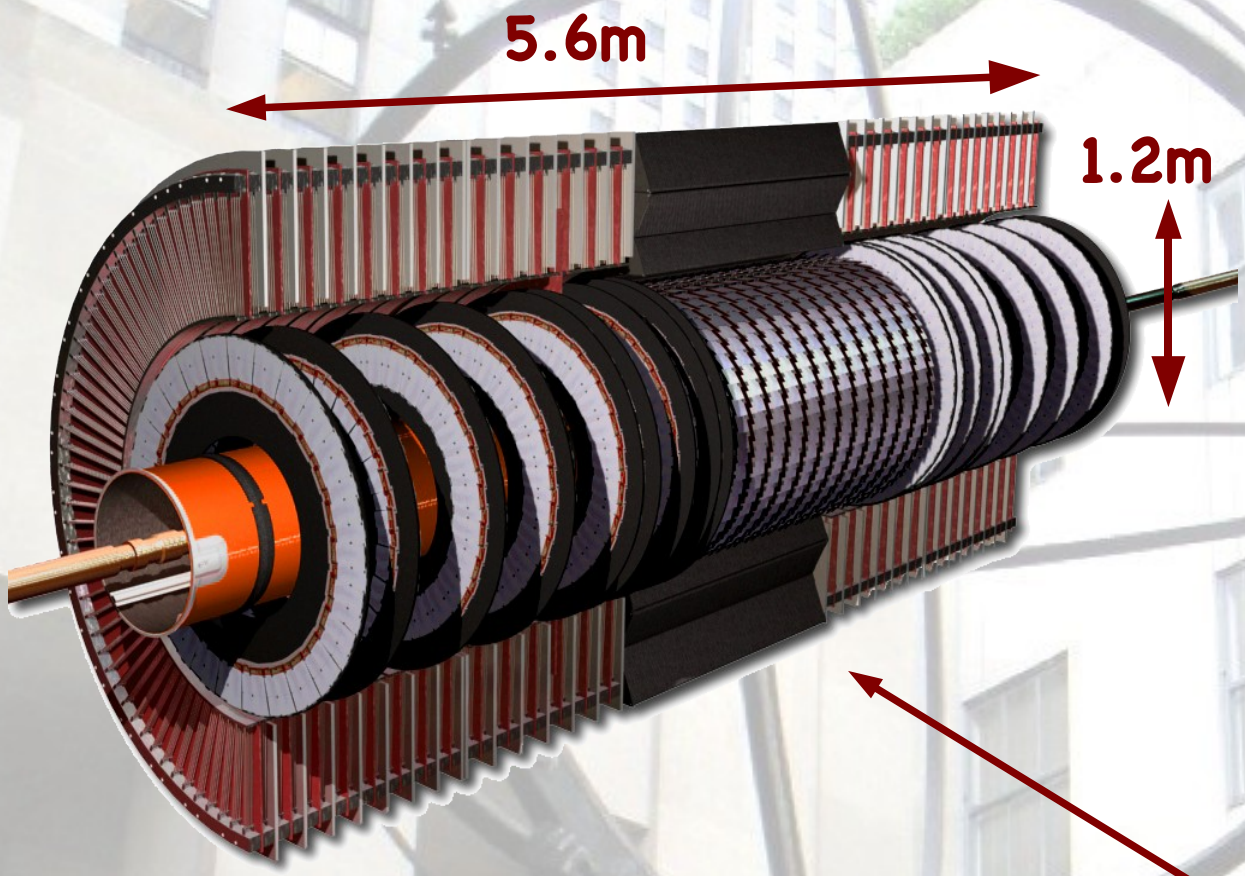
SCT Commissioning: The heart of ATLAS

Caroline Magrath
twepp2008 Naxos, Sep 15th-19th

Talk Overview

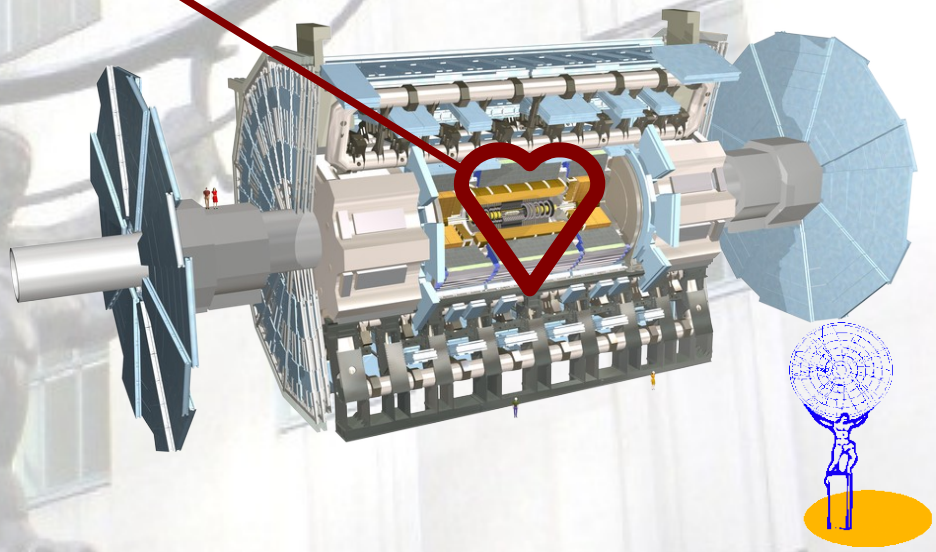
- What is the SCT?
- How does it work?
- Status of commissioning
- What tests are performed?
- Test results
- Cooling problems
- First cosmic data run
- Outlook

Semi-Conductor Tracker



- Barrel
- 4 cylindrical layers
- 2112 modules
- Coverage 0 < |η| <1.1-1.4

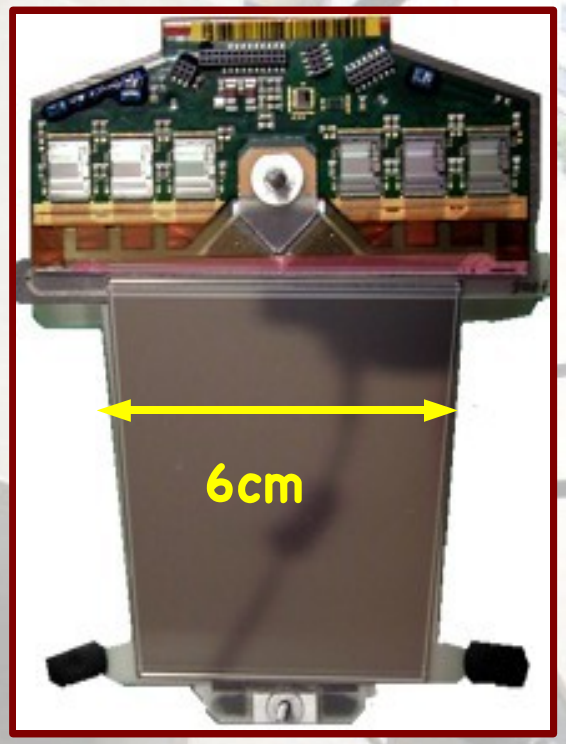
- End-Caps
- 18 discs
- 1976 modules
- Coverage 1.1-1.4 < |η| < 2.5



- 61 m^2 of silicon strip sensors
- 6.2 million readout channels
- Radiation hardness : 2 x 10^{14} 1- MeV neutron equivalent cm^{-2} (10 years LHC)

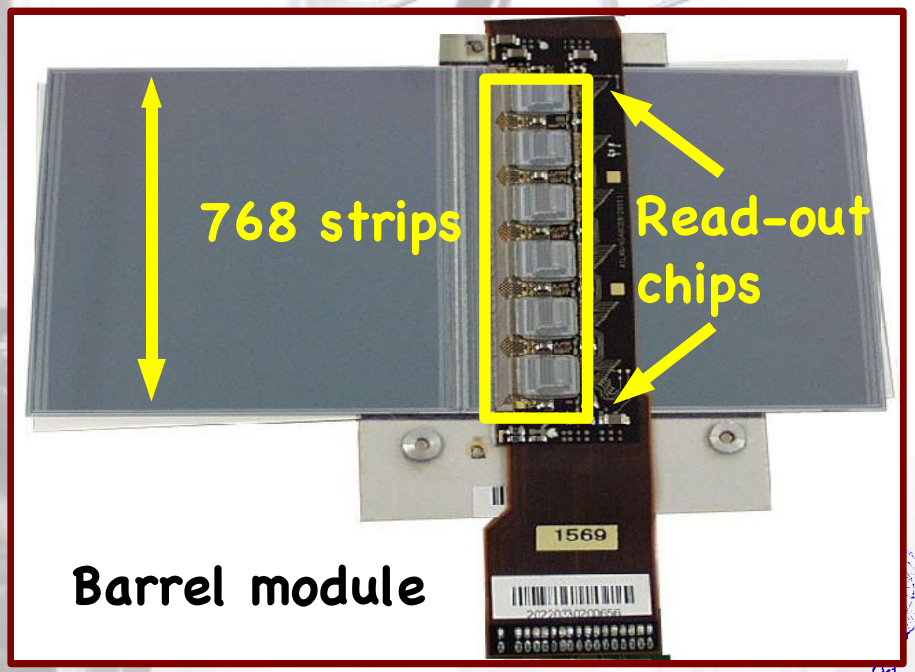
The SCT Modules

Endcap inner module

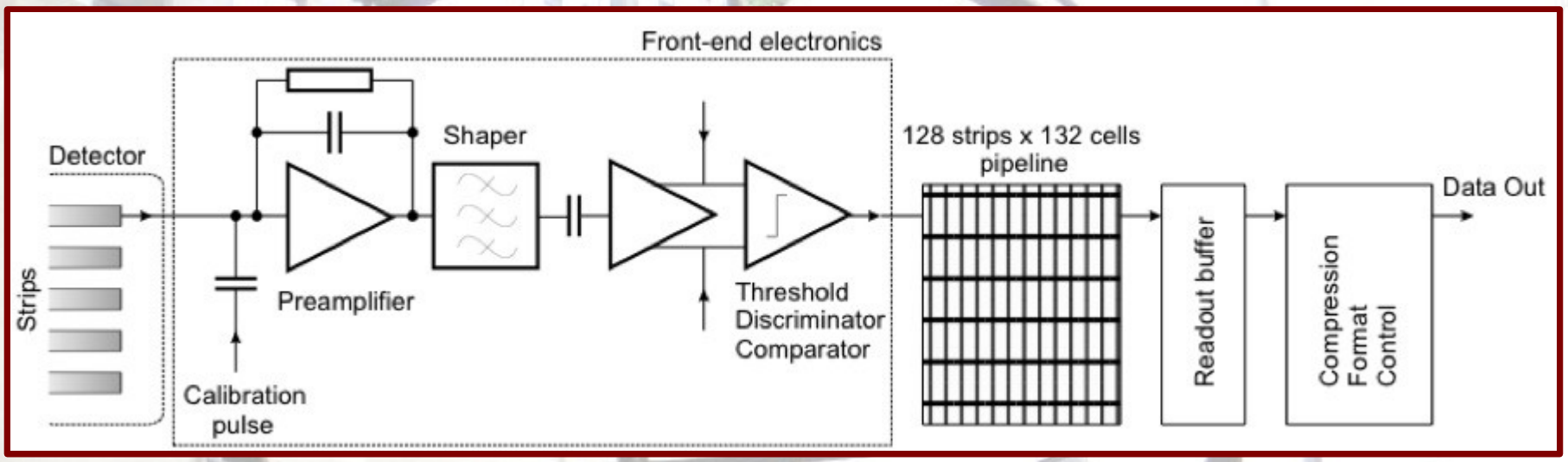


- Single-sided back-to-back p-on-n sensors
- 40 mrad stereo-angle
- 1536 channels per module
- 6 chips on each module side
- Binary read-out
- Optical communication

- Sensor cooled at -10 deg C using C_3F_8 coolant.
- Up to 500 Volt bias voltage
- Power consumption : 5.6 W/module (10 W after 10 years of LHC)



Front-end



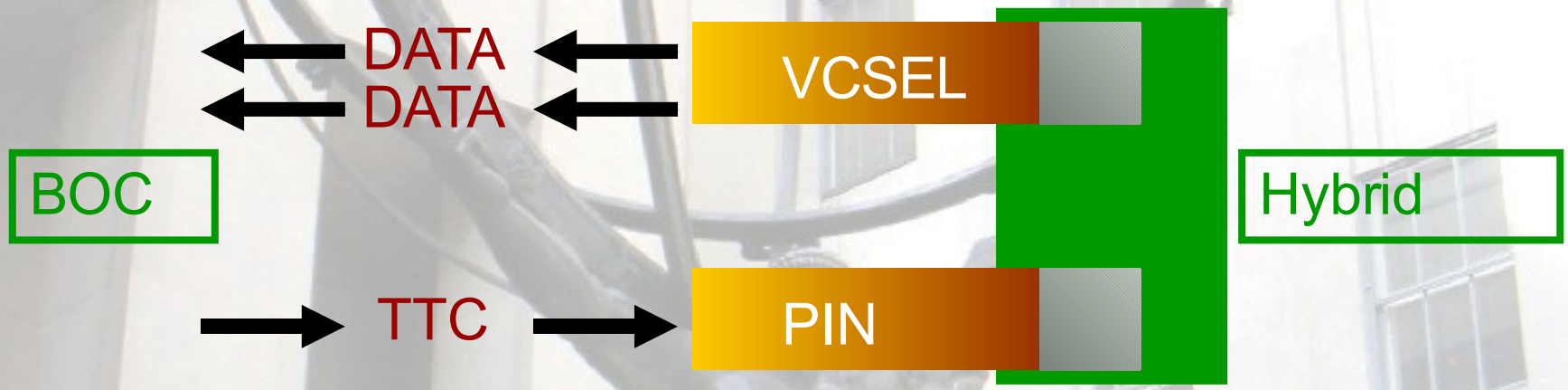
- Signal induces current on strip
- Current on strip integrated at pre-amplifier and voltage output
- Signal shaped and noise filtered
- Signal voltage compared to a pre-set threshold voltage
- Hit '0' or '1' returned and stored in a pipeline
- Data compression logic
- Charge injection circuitry (calibration)

Optical Communication

- 4088 Clock and Command links
  -1 p-i-n diode for timing, trigger and control signals
  - If signal fails, neighbouring module will provide signal.

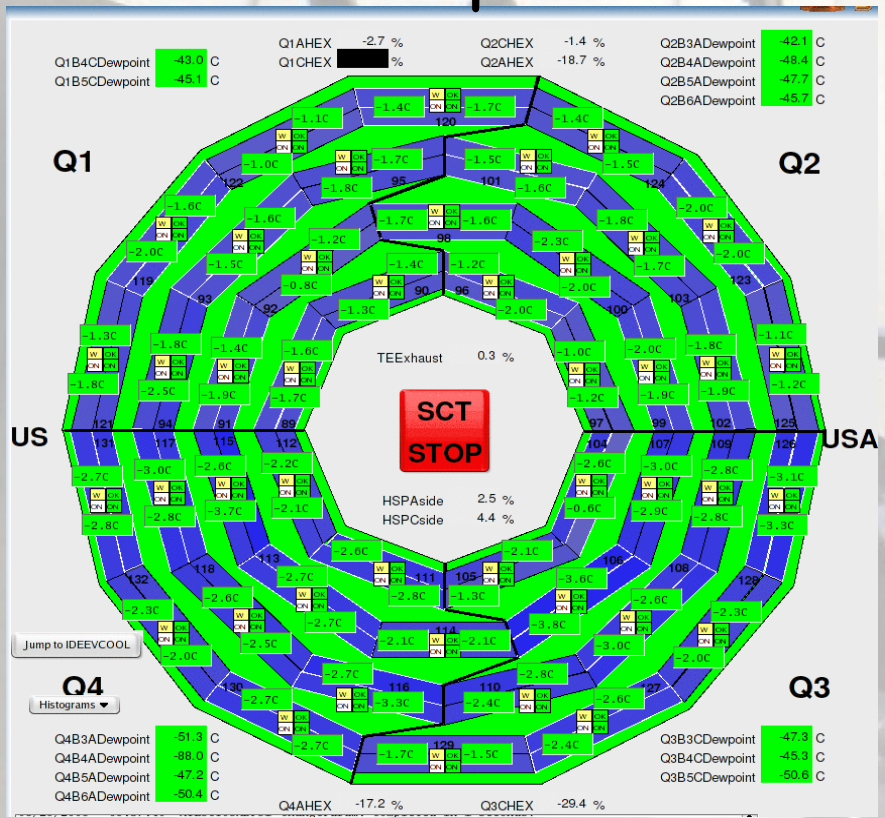
- 8176 Data links
  -2 VCSELs for reading data from both sides of module -
  - Redundancy in case of one link failing

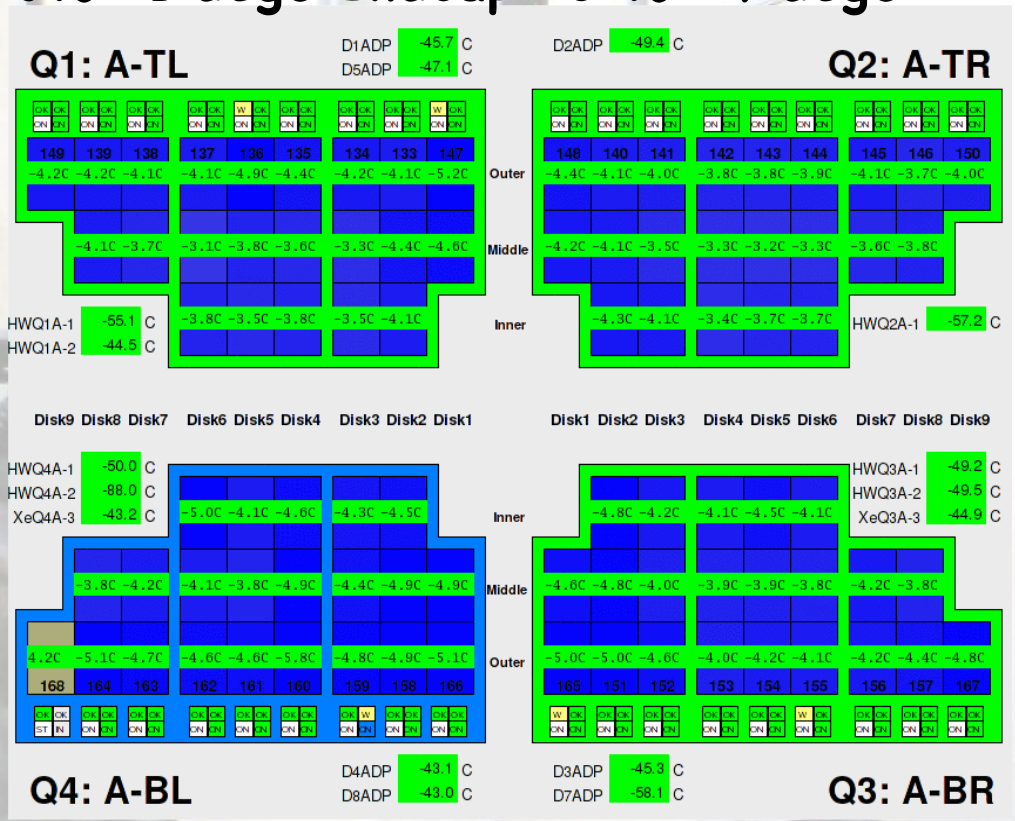
- Off detector electronics sends and receives data via back of crate cards (BOC)



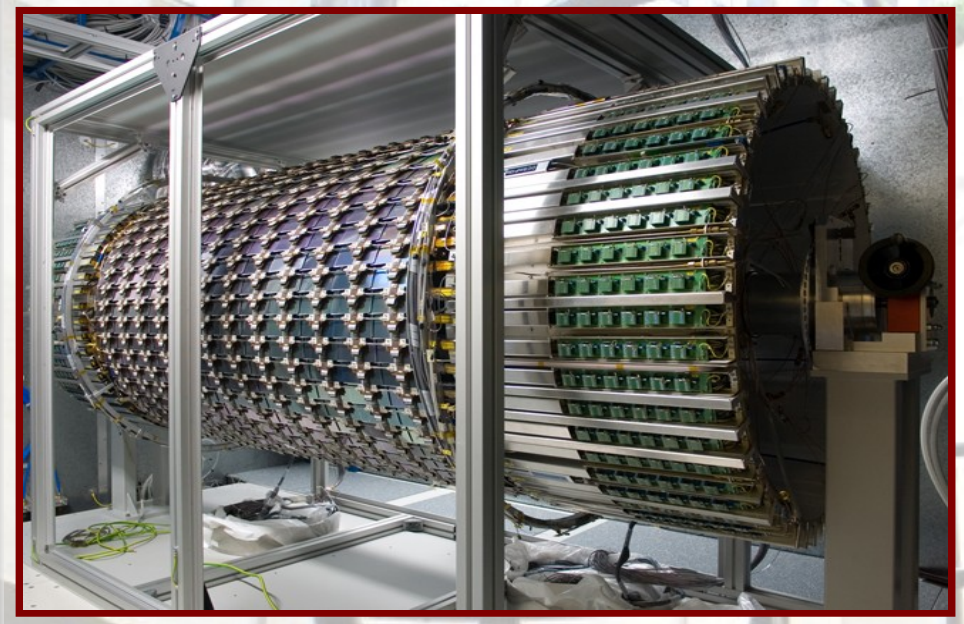
Inner Detector Cooling

- C_3F_8 Evaporative cooling system (Pixels +SCT)
- Fluid is evaporated through cooling loops.
- Any remaining fluid is boiled away by heaters in the exhausts of cooling lines
- Temperature of gas raised above cavern dewpoint to avoid condensation)
- Gas condensed and liquid recovered
- Current Status: Cold!!
- With modules powered: Barrel -3to -1 degC Endcap -5 to -4 degC

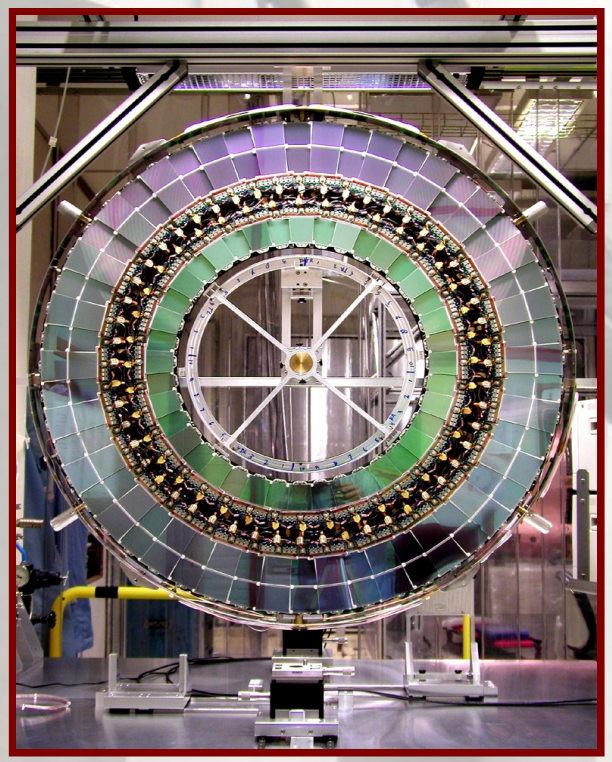


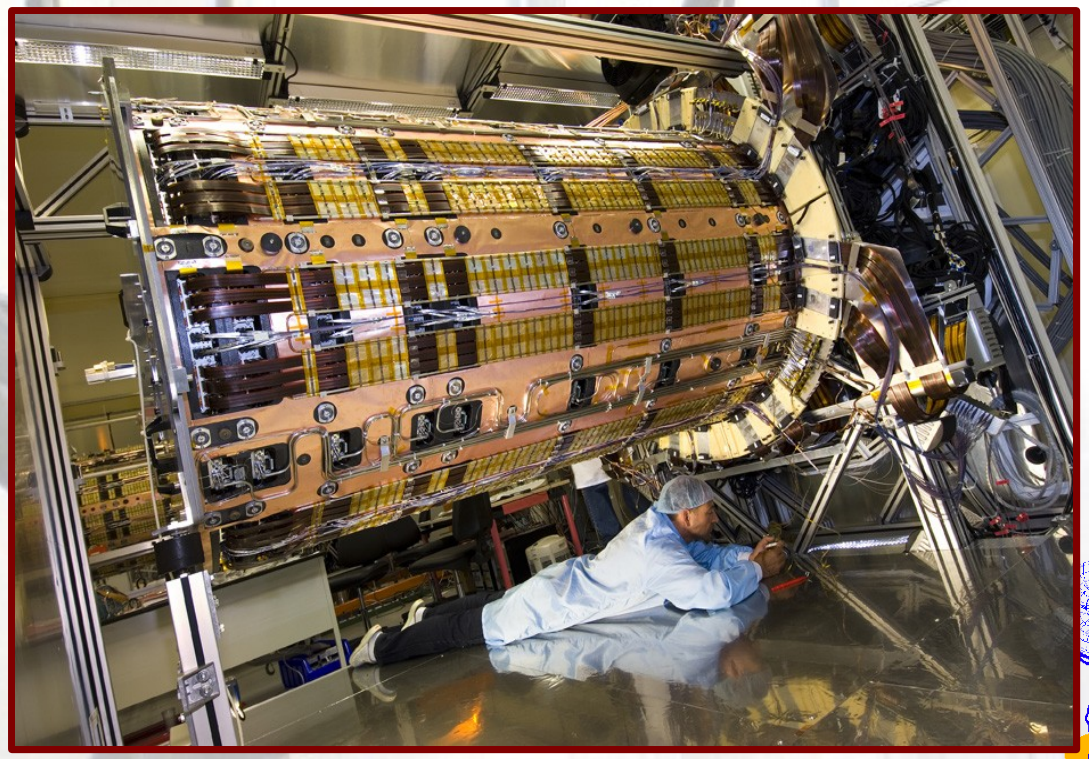


Macro Assembly

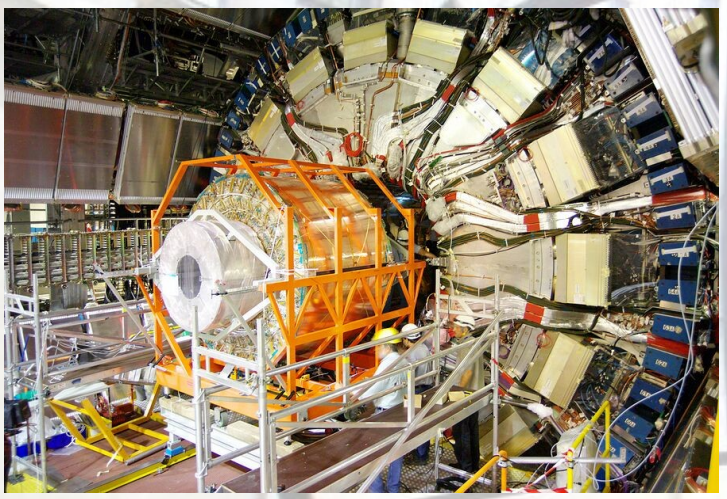


- 3 Assembly sites
- Oxford: 4 barrels
- NIKHEF: Endcap A
- Liverpool: Endcap C

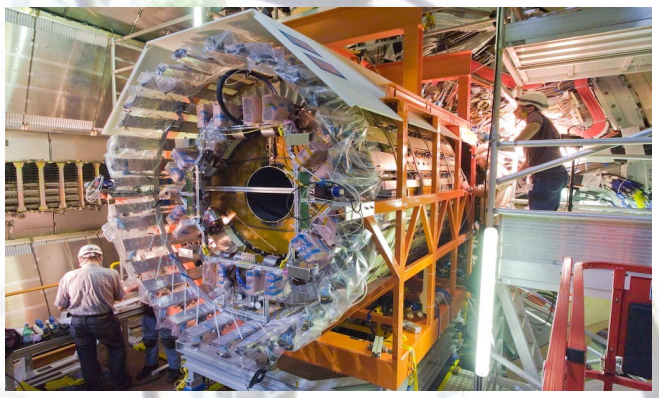




ATLAS Integration Timeline



Barrel in pit



Endcaps in pit

Connections complete

Cooling failure

aug

may

jun

18th apr

may

2 0 0 6 2 0 0 7 2 0 0 8

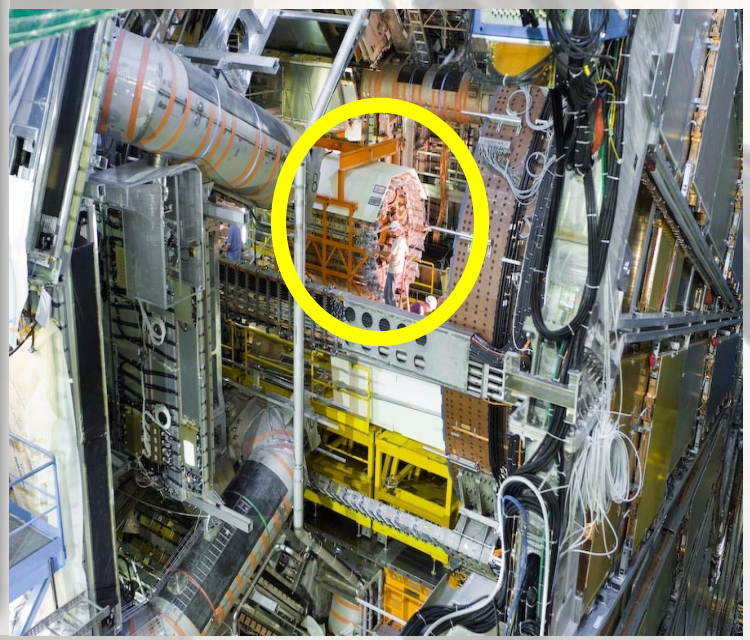
jun

Cooling problems

24th apr

Pixels in pit

ID sealed

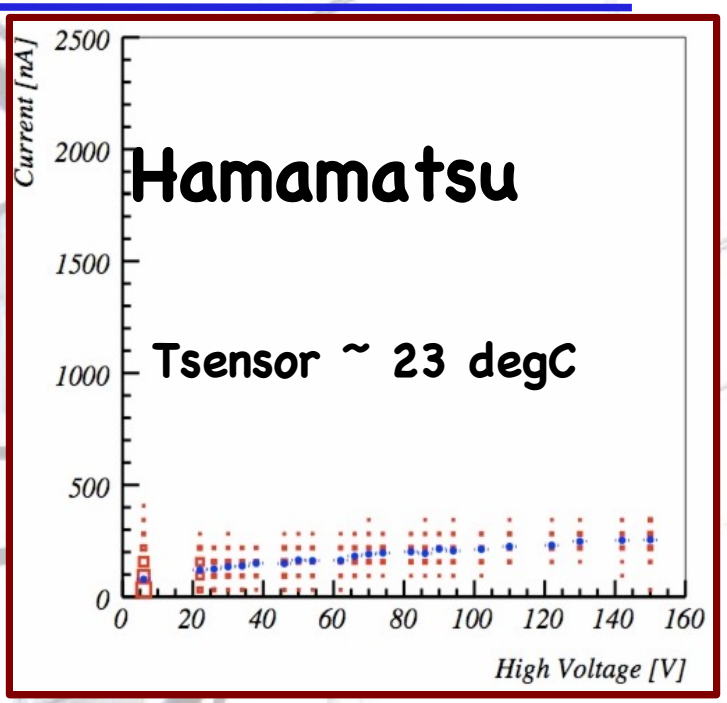


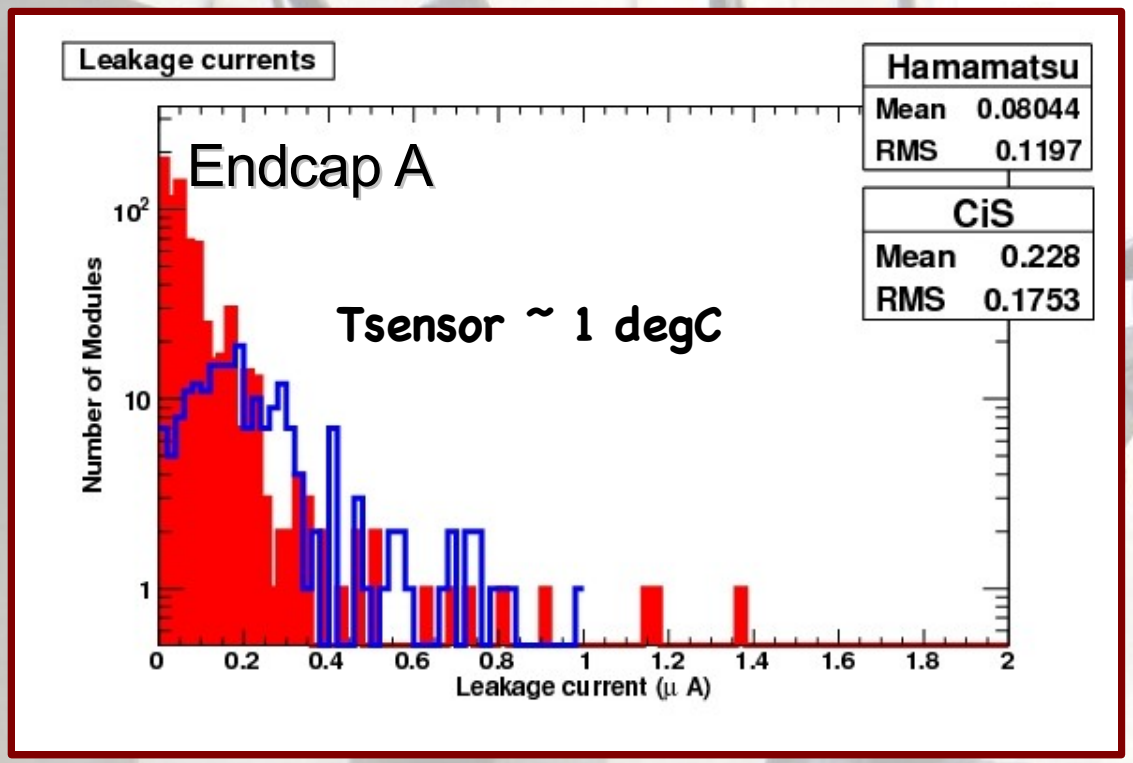
Commissioning Tests

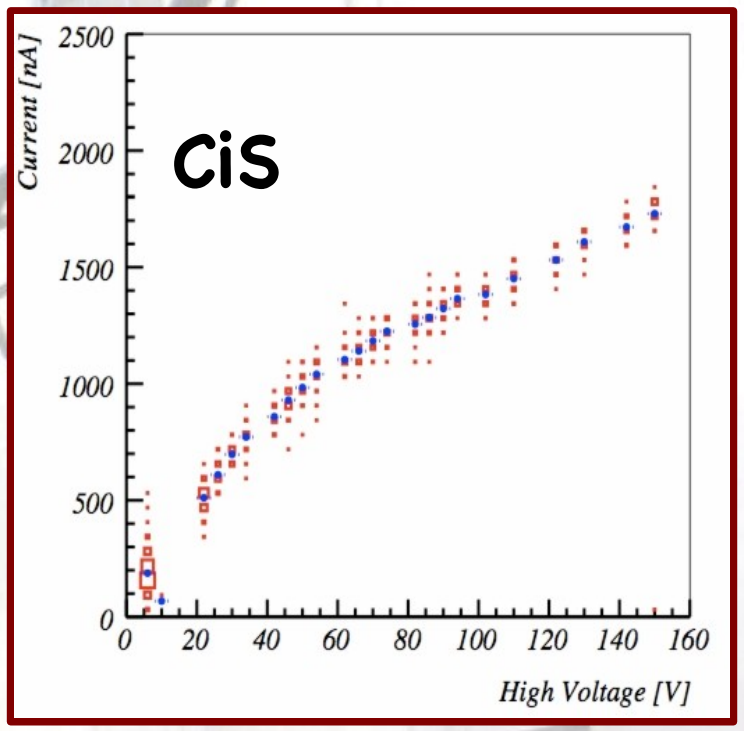
- Electrical Connections
  - Check LV arrives at modules: Vdd, Vcc, Ipin, Ivcsel
  - HV current scan
  - Check temperature readings
- Optical Connections
  - P-i-n diode current measurement:
  - Light from data fibre measured at BOC
  - Ensures good fibre connections and correct mapping in place
- Calibration Tests
  - Digital and Analogue functionality of front-end tested
- Cosmic Tests
  - Milestone 6 run: Global commissioning run with ATLAS sub-detectors

Results: Electrical Tests

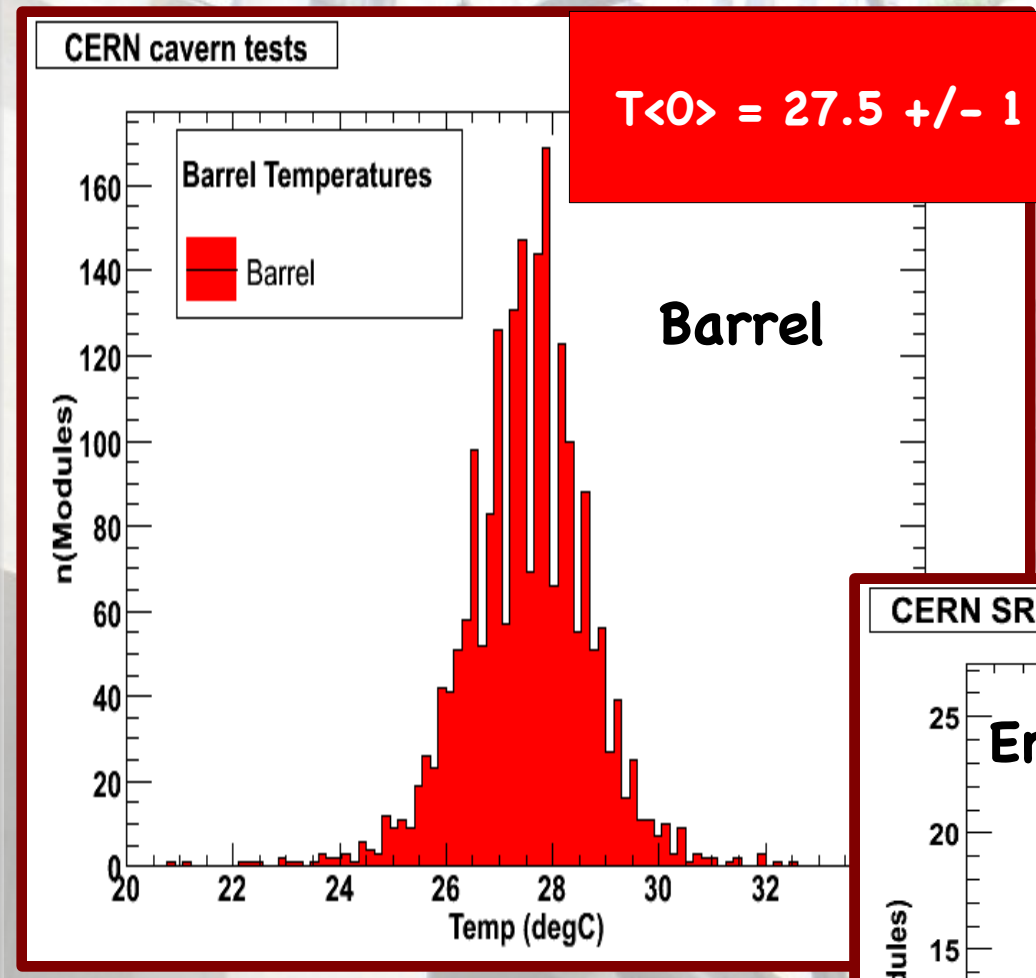
- I V scan measured in 10V steps from 0 -150V
- Multiple current measurements recorded for each voltage step.
- Two manufacturers of module sensor:
  - Hamamatsu: Field plate geometry
  - CiS: Aluminium strip narrower than p-implant
- Non-field plate geometry, higher surface currents







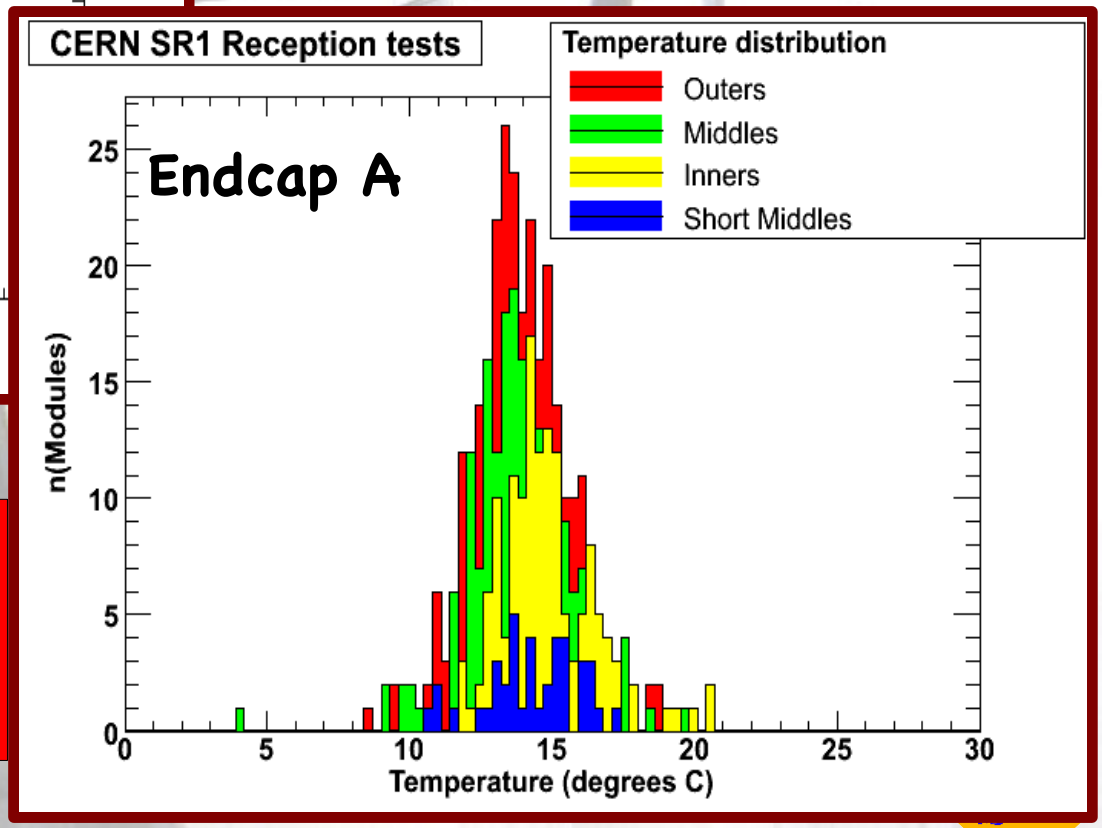
Module Temperatures



T<0> = 27.5 +/- 1 degC (6bar)

Barrel

- Uniformity of temperatures
- No Hot regions

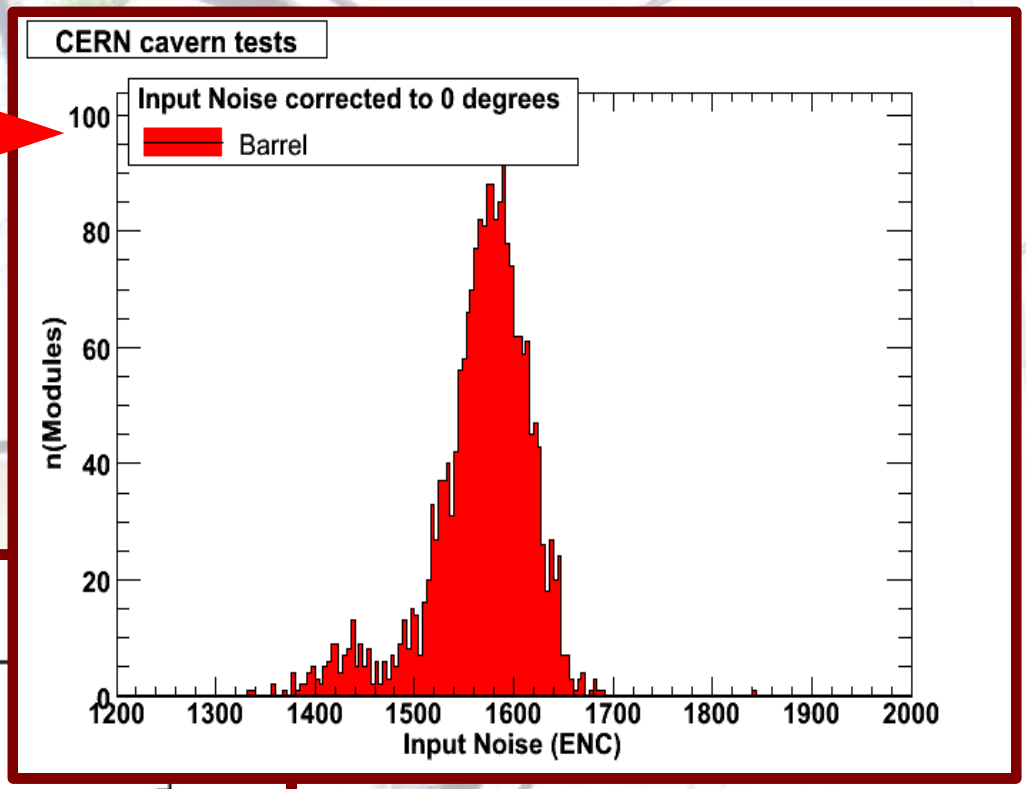


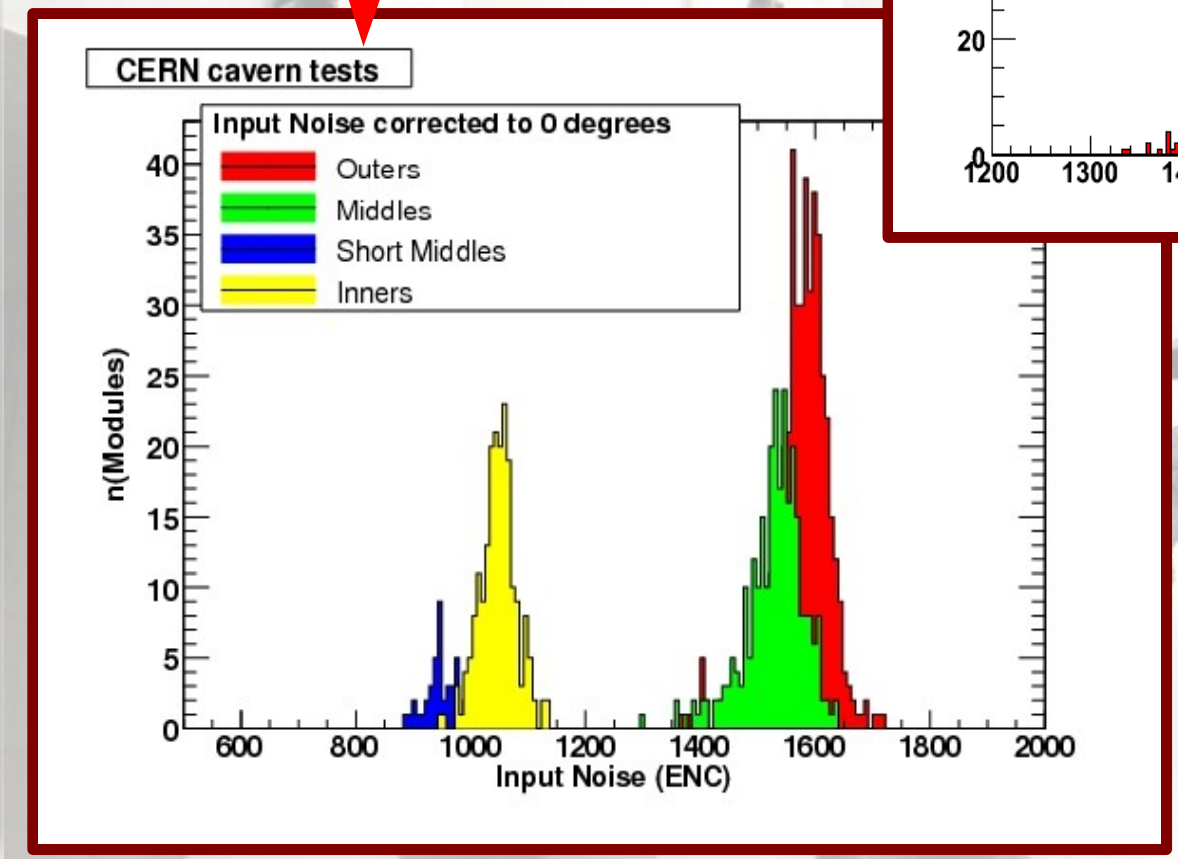
Outers/Middles :
T<0> = 14 +/- 2 degC (2bar)
ShortMiddles/Inners:
T<0> = 15 +/- 2 deg C (2bar)

Input Noise

Barrel Modules

Endcap A modules



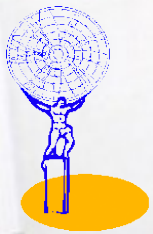


- Noise as expected
- Different strip lengths mean different noise groups for endcap modules
- Endcap C similar results

Percentage of functional channels for 2008 (hardware)

- Endcap C suffered from 2 leaks and a heater power cable short -
  - Loop 204: disk 9 Q4 operates well at 3b BP
  - Loop 186: disk 9 Q2, 13 modules lost
  - Loop 183: disk 1 Q1, 23 modules lost (heater short)

	Barrel	Endcap A	Endcap C
Total number of modules	2112	988	988
Modules not functional (powering problem)	3	0	1
Modules not cooled in 2008	0	0	36
Individual dead strips [%]	0.2	0.3	0.3
Chips lost through redundancy readout	13	0	0
Fraction of functional channels [%]	99.61	99.70	95.96



Cooling Problems

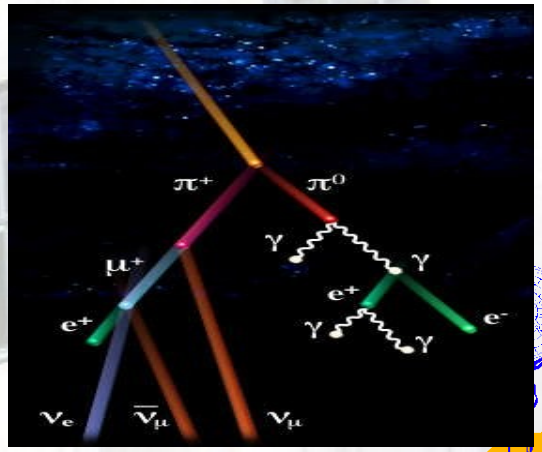
- Feb 2007 heaters failed (barrel commissioning)
- Moisture getting into connector, so sleeves were retrofitted
- They failed once more in May 2007
- Heaters moved to more serviceable area, involving more pipe work!
- Heater completely re-designed. No problems so far

THEN.....

- March 2008, 3 ID compressors failed catastrophically!
- Magnetic couplers slipped during cooling start up (they drive crank which performs compression)
- 100 kg C_3F_8 lost, 900 kg contaminated
- Fortunately only cooling plant affected, not detector.
- Huge clean up operation. New parts built, replacement pipework needed
- Filters put in pipes and recovery tank made to avoid any future losses.
- Sensors to detect slipping of couplers.

Commissioning with cosmics

- In between both cooling problems, we actually managed to have a very successful week of commissioning the barrel detector using cosmics!!!
- Cosmics are a useful method for testing detector performance
- Entire readout chain of ATLAS and its sub-detectors can be tested
- Investigation into any cross talk between modules and noise as a result of synchronous SCT/TRT running.
- First look at detector alignment and tracking using real data.
- Results: -Event Displays
  -Basic Alignment
  -Noise occupancy

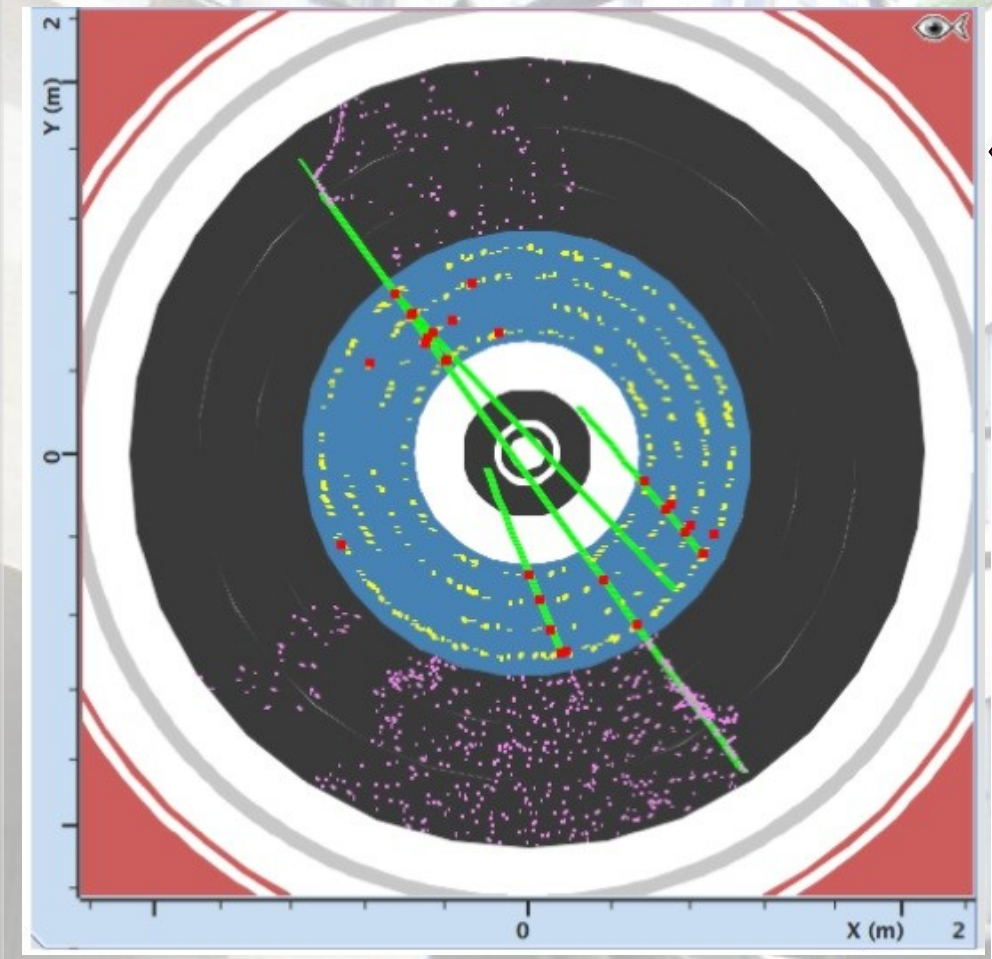


Milestone 6

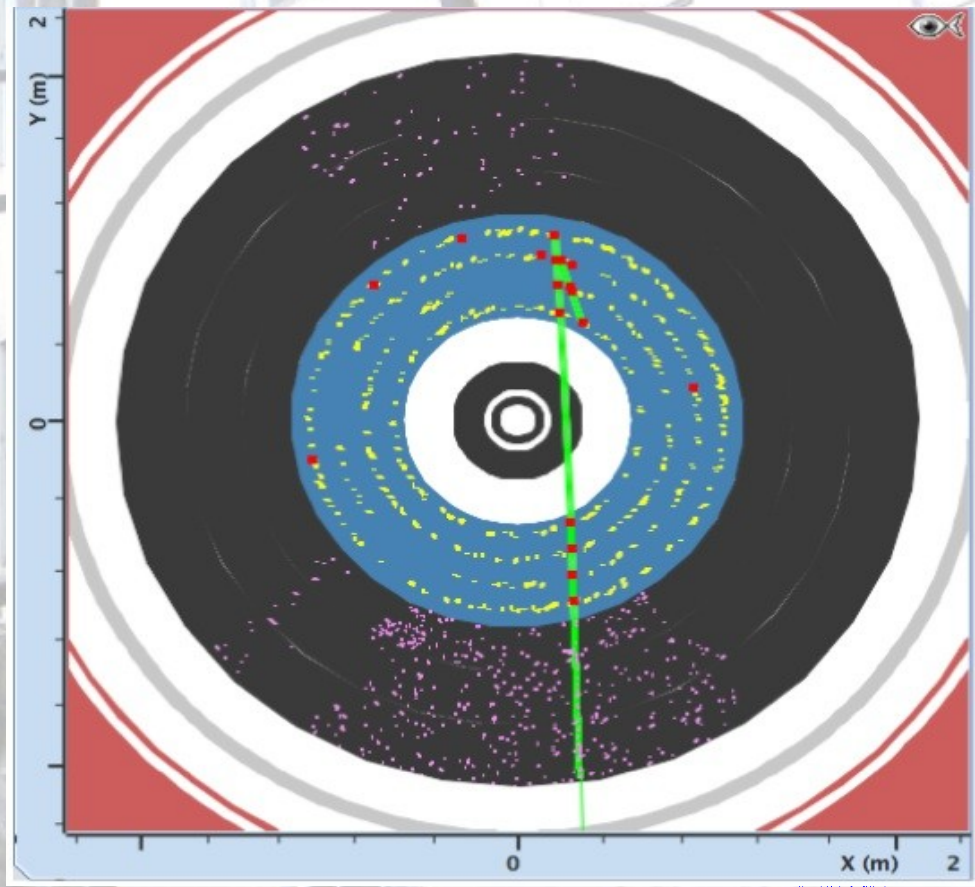
- First ATLAS milestone run for SCT
- Beginning of March for one week (1st-9th)
- First steps towards global commissioning
- Number of successful runs with tracks in SCT and TRT
- Most of SCT Barrel read out (1965 modules) 3/8 TRT read out.
- Final ATLAS reconstruction software implemented

43719: SCT, TRT, Tile,LAr, TGC,MDT,CTP,RPC,TDAQ,HLT,LVL1
3241 Any Track Events | 1270 SCT Tracks | 1183 SCT+TRT tracks
-timed in, 1fC threshold, < 1Hz cosmic trigger (Tile trigger and ID scintillator combination)

Event Displays



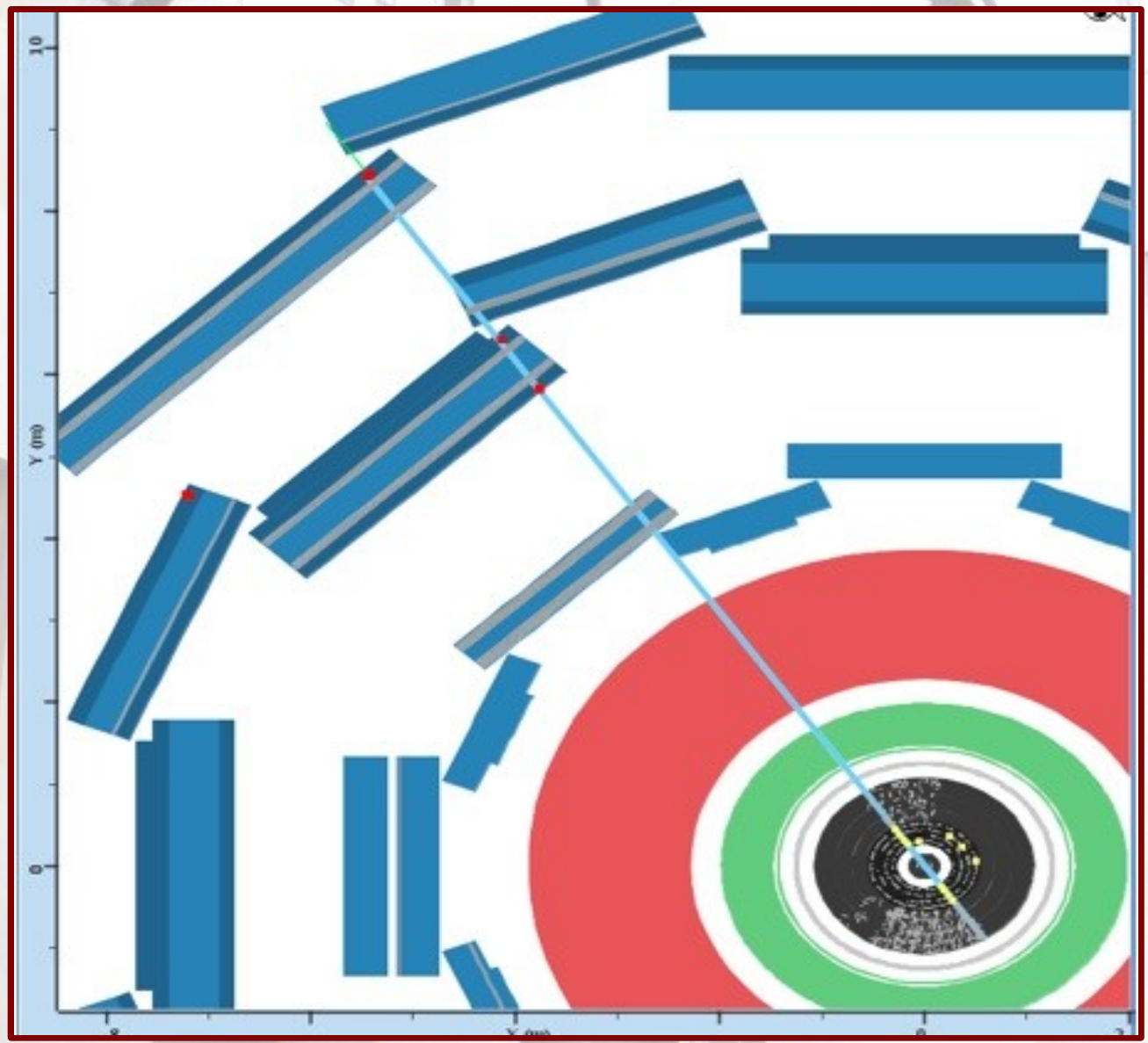
Event with 4 tracks through SCT!!!!



Nice track going through upper and lower parts!!

First combined track in ATLAS

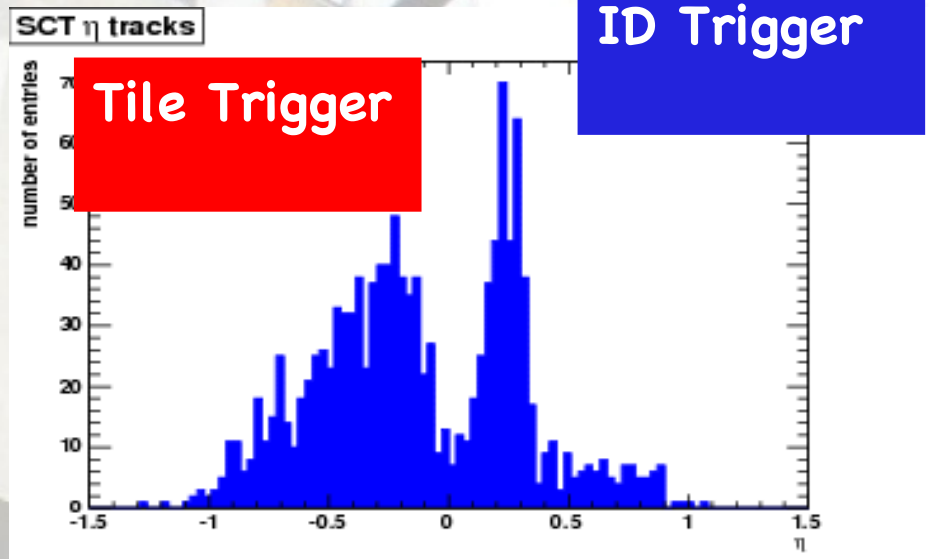
Muons through to SCT!!!

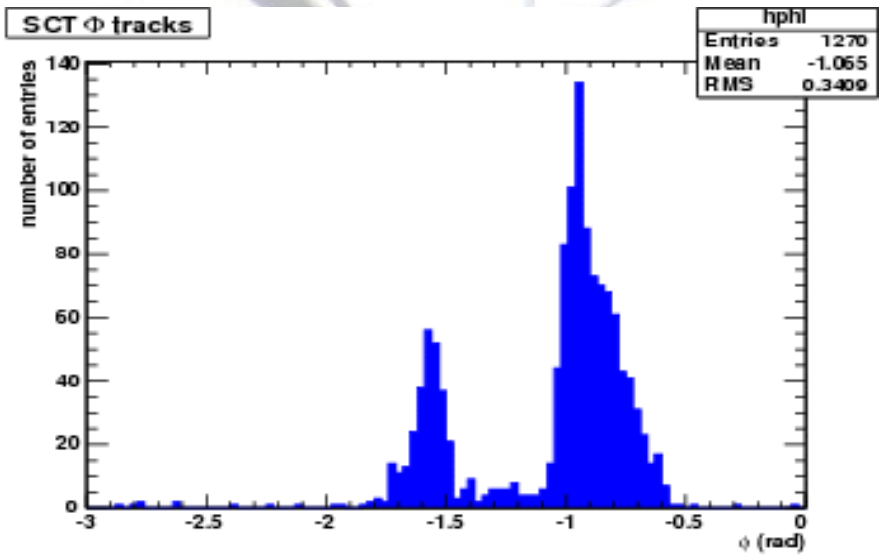


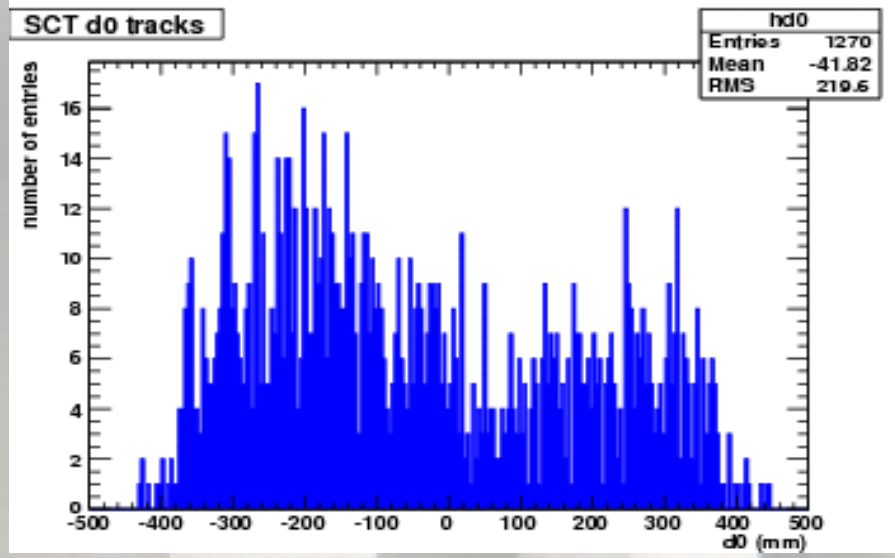
Track parameters

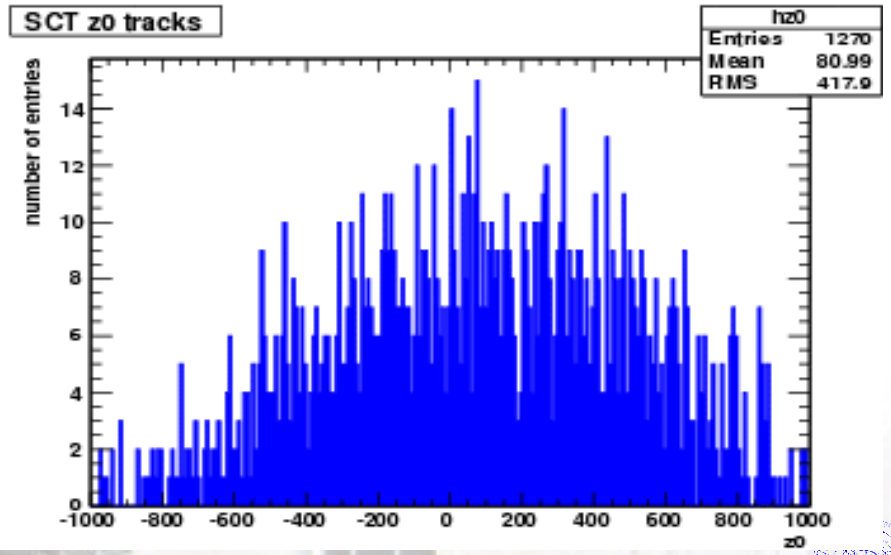
Tile Trigger

ID Trigger

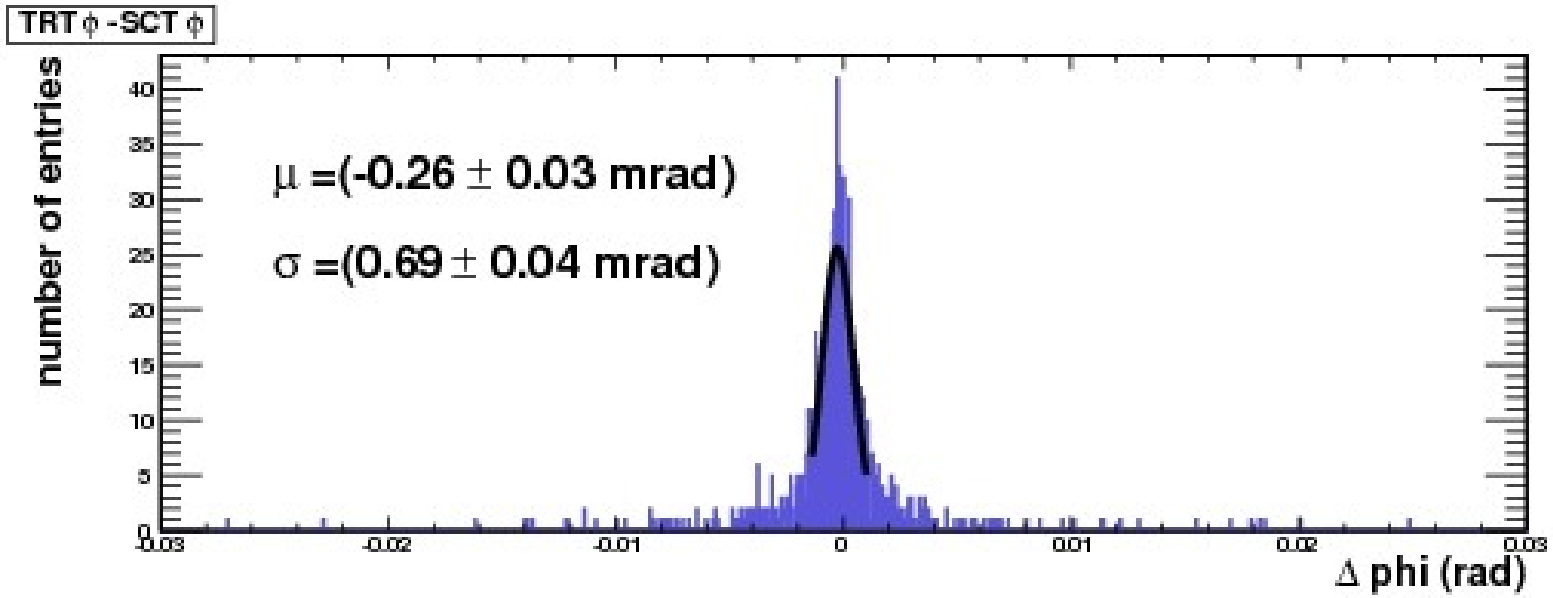


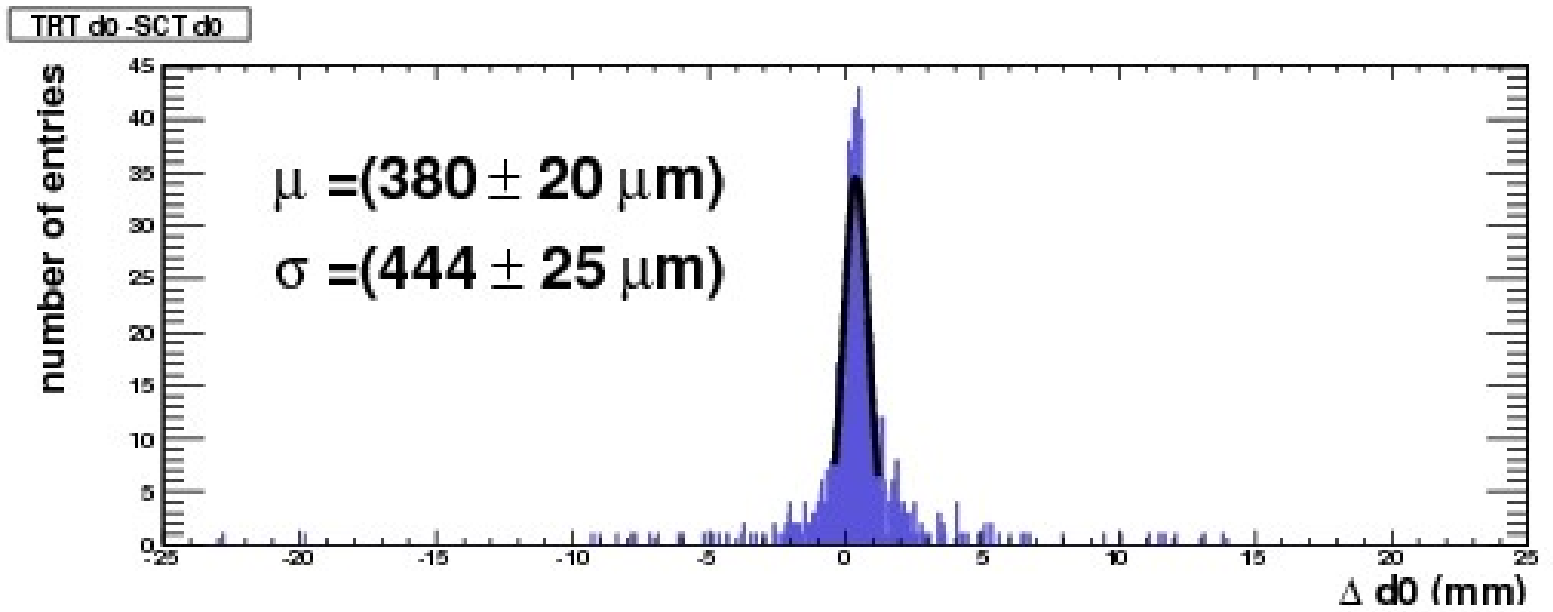






Very basic alignment

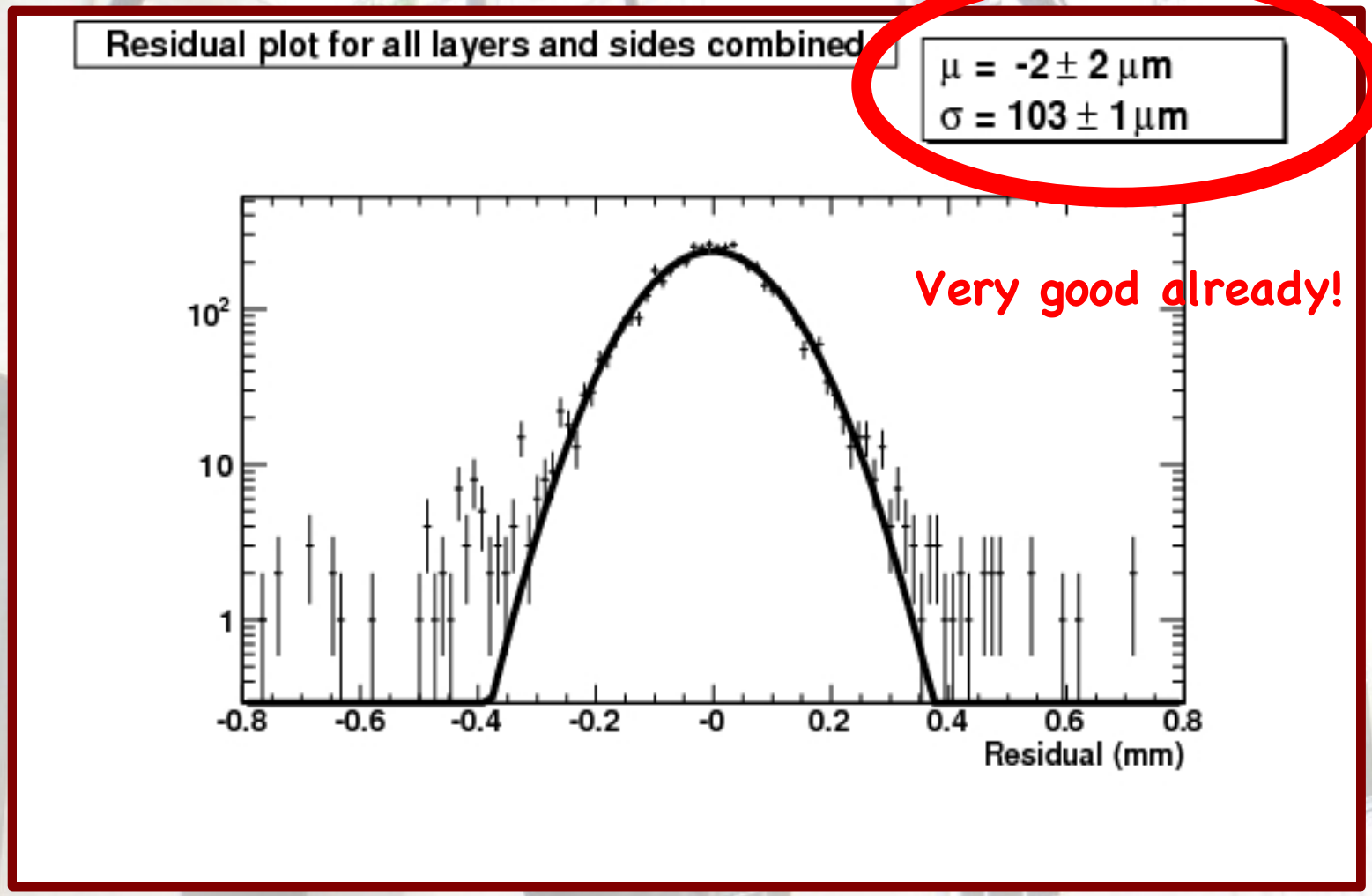




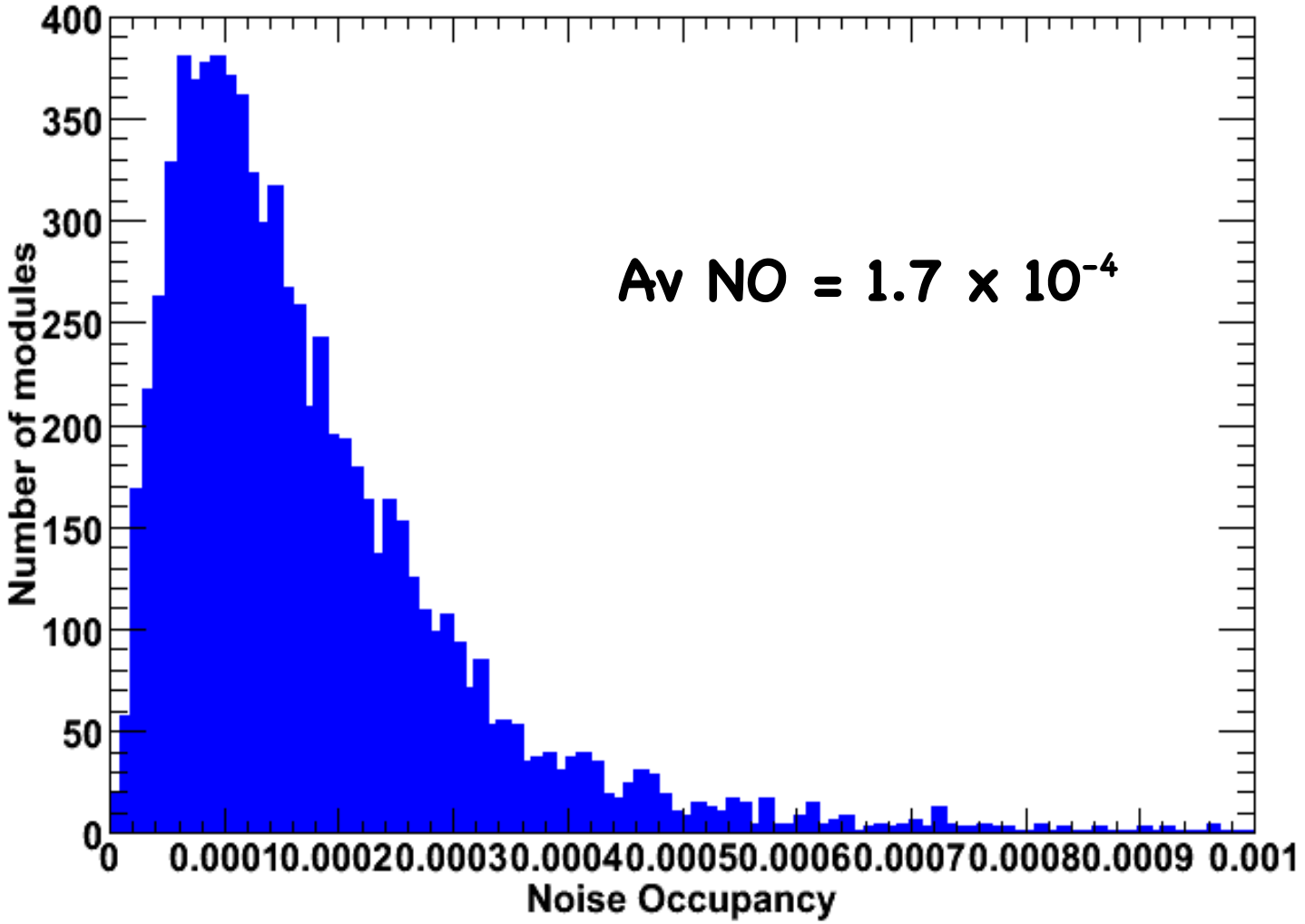
Track residuals

Residual = X_track - X_local

(Plane perpendicular to strips)



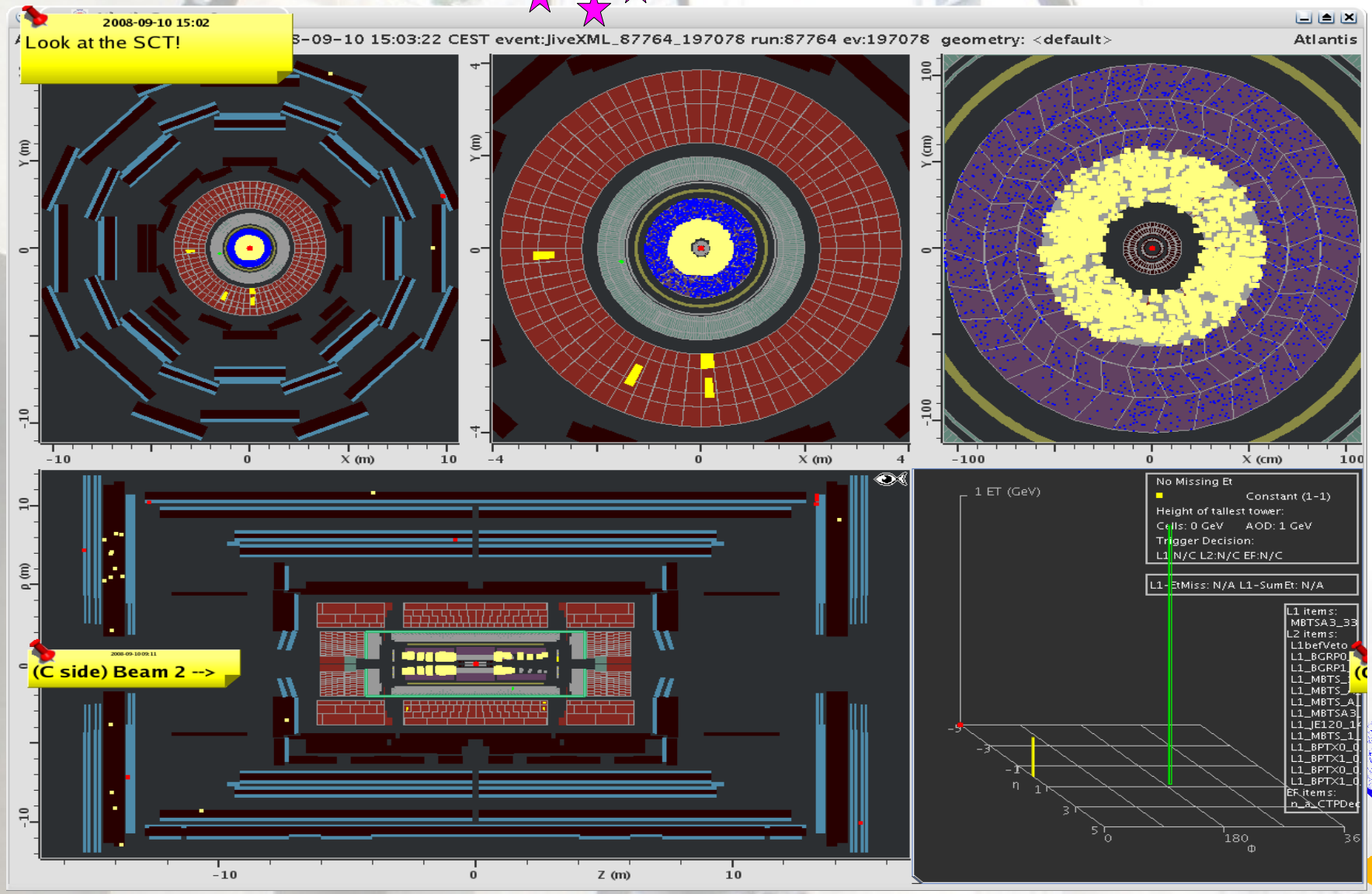
Noise Occupancy



Average noise occupancy better than requirement of 5 x 10^{-4}!

The excitement of the LHC switch on: September 10th

- Only endcaps on, 20V bias (too much charge deposited along barrel strips, so they were kept out of config)
- Both endcaps completely lit up with beam halo muons!!!



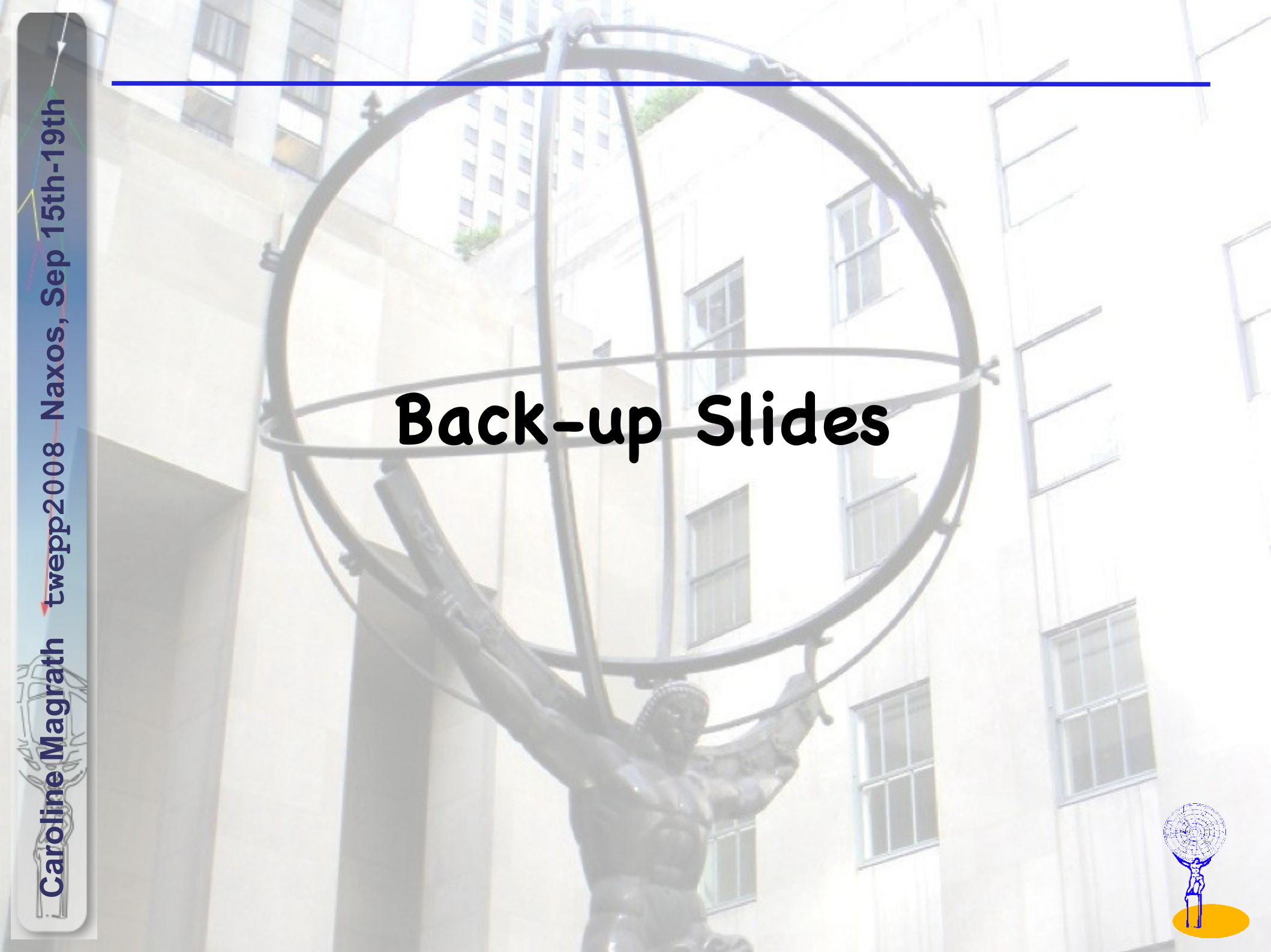
Outlook

- Barrels and Endcaps successfully installed in ATLAS cavern
- Have been extensively tested and signed off.
- Cooling problems have limited the actual commissioning period of the SCT detector.
  - New heater connectors working well, no sign off problem returning.
  - Cooling plant has new measures in place to prevent compressor burn out in future.
  - Pixel b-layer was cooled sufficiently during ATLAS beam-pipe bakeout, with the centre of the beam reaching 220 degC.
- Have had a very successful global commissioning with cosmics during milestone 6.
- first beam circulated in LHC ring at 450 GeV!!!
- Endcaps glowed with beam halo muons on September 10th

Very exciting times lie ahead!

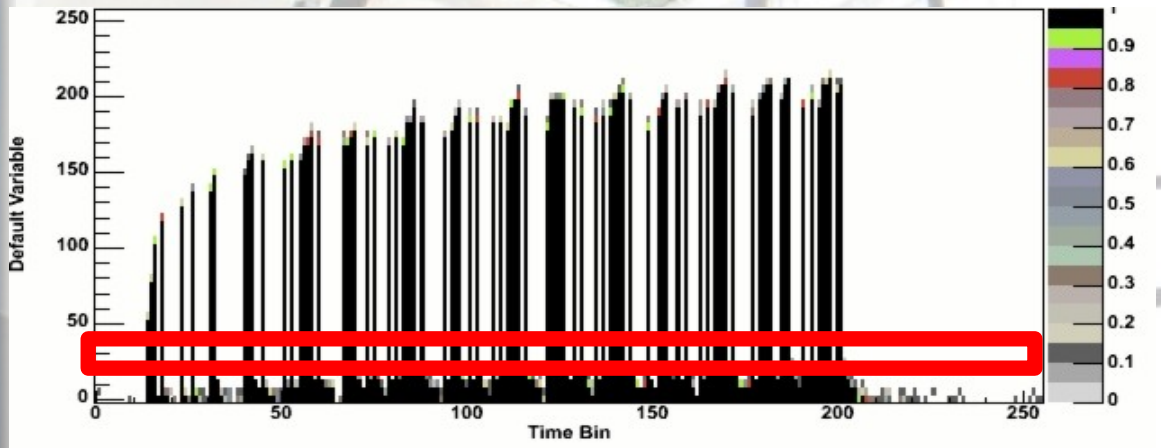
SCT is eagerly awaiting its first proton-proton collisions!!!

Back-up Slides



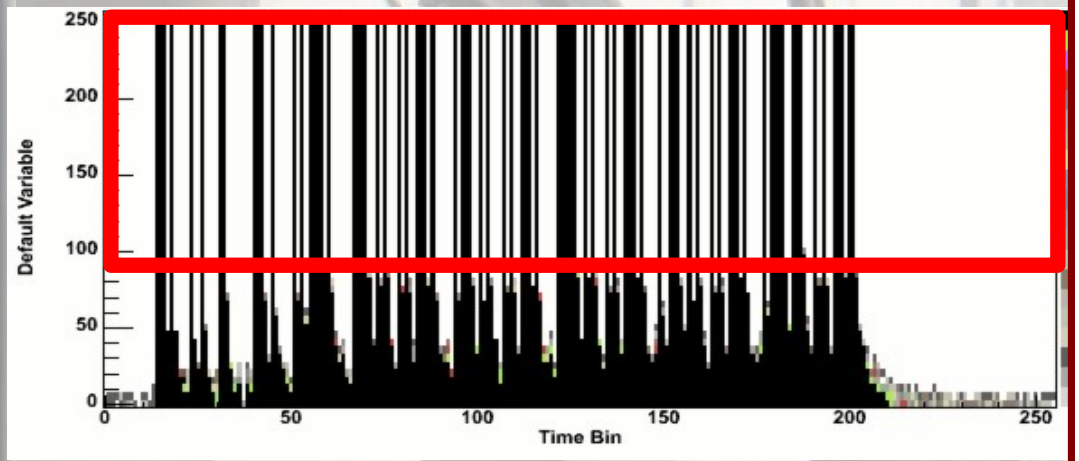
RX links: Off detector

- Need to set the correct optical threshold at the BOC for each link (all 8176 of them!!)
- This determines the threshold for a hit to be registered



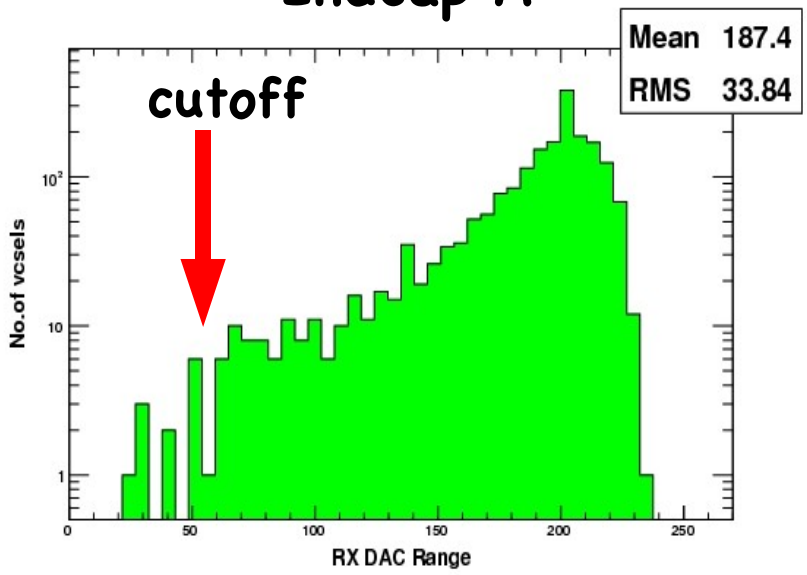
- Pattern of '1's sent and returned by module to BOC
- Threshold is varied from 0-255 DAC steps.
- Several patterns of 1's over a time period are sent.
- Working range determined
- Best threshold set

RX Working regions



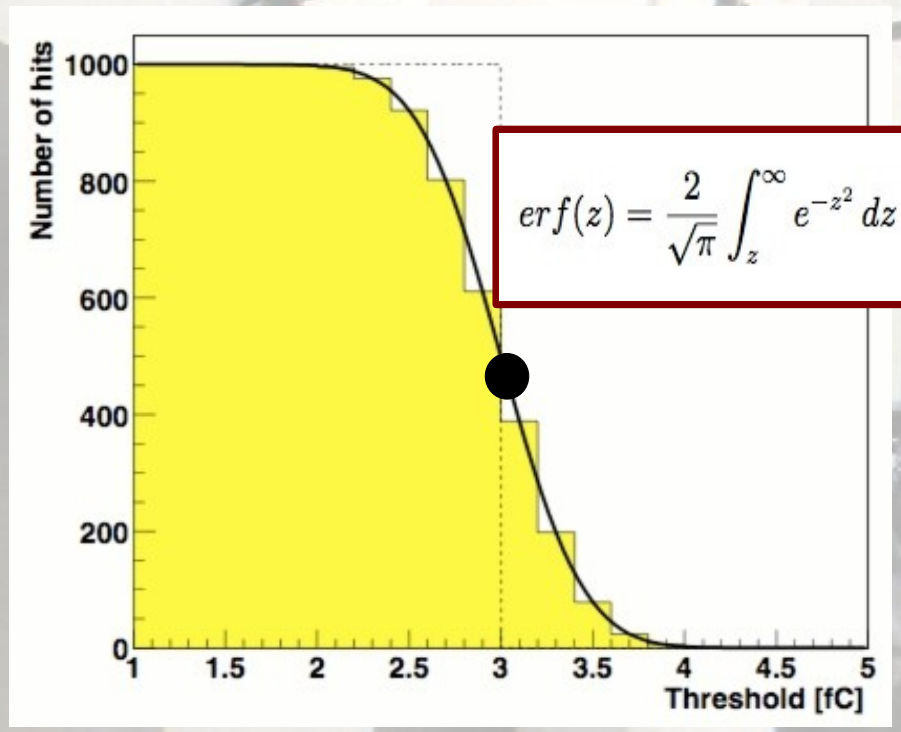
- All modules return data
- Some need to be read out redundantly.

Endcap A

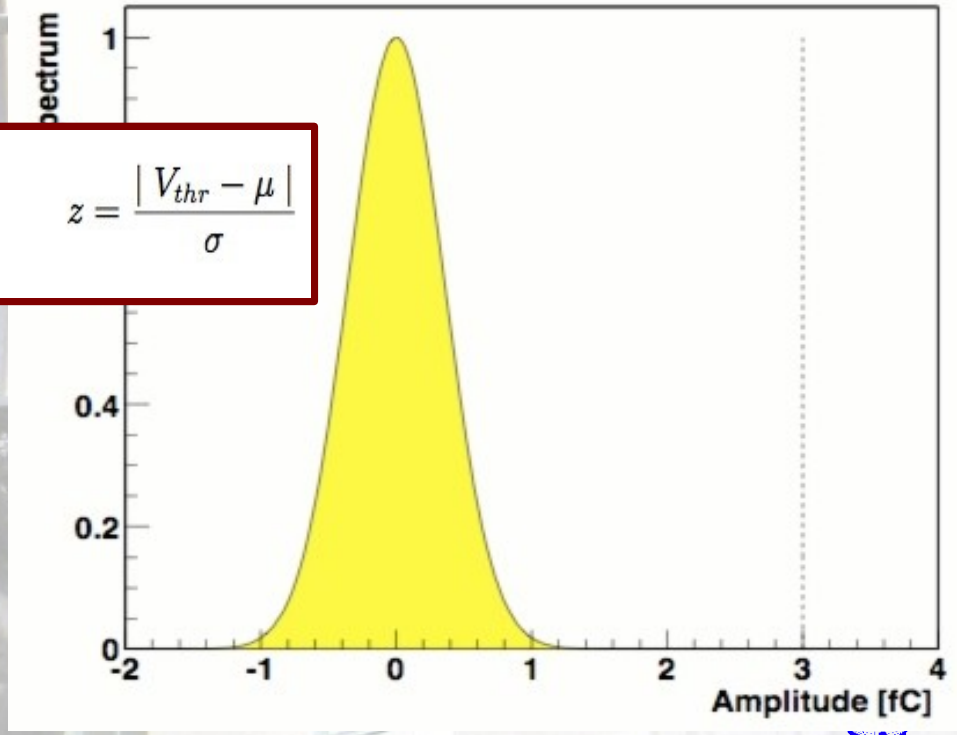


Calibration Tests

- Want to measure the noise of each channel (defective channels found)
- 3Pt Gain test- 3 charges injected: 1.5, 2.0, 2.5 fC.
- 1000 triggers are sent to module and hit threshold varied
- Occupancy counted for each theshold
- S-curve fitted with complementary error function:VT50 & output noise of the amplifier is extracted
- Linear fit applied to 50% occupancy points, gain is the slope of this fit
- Input noise calculated from output noise over gain.

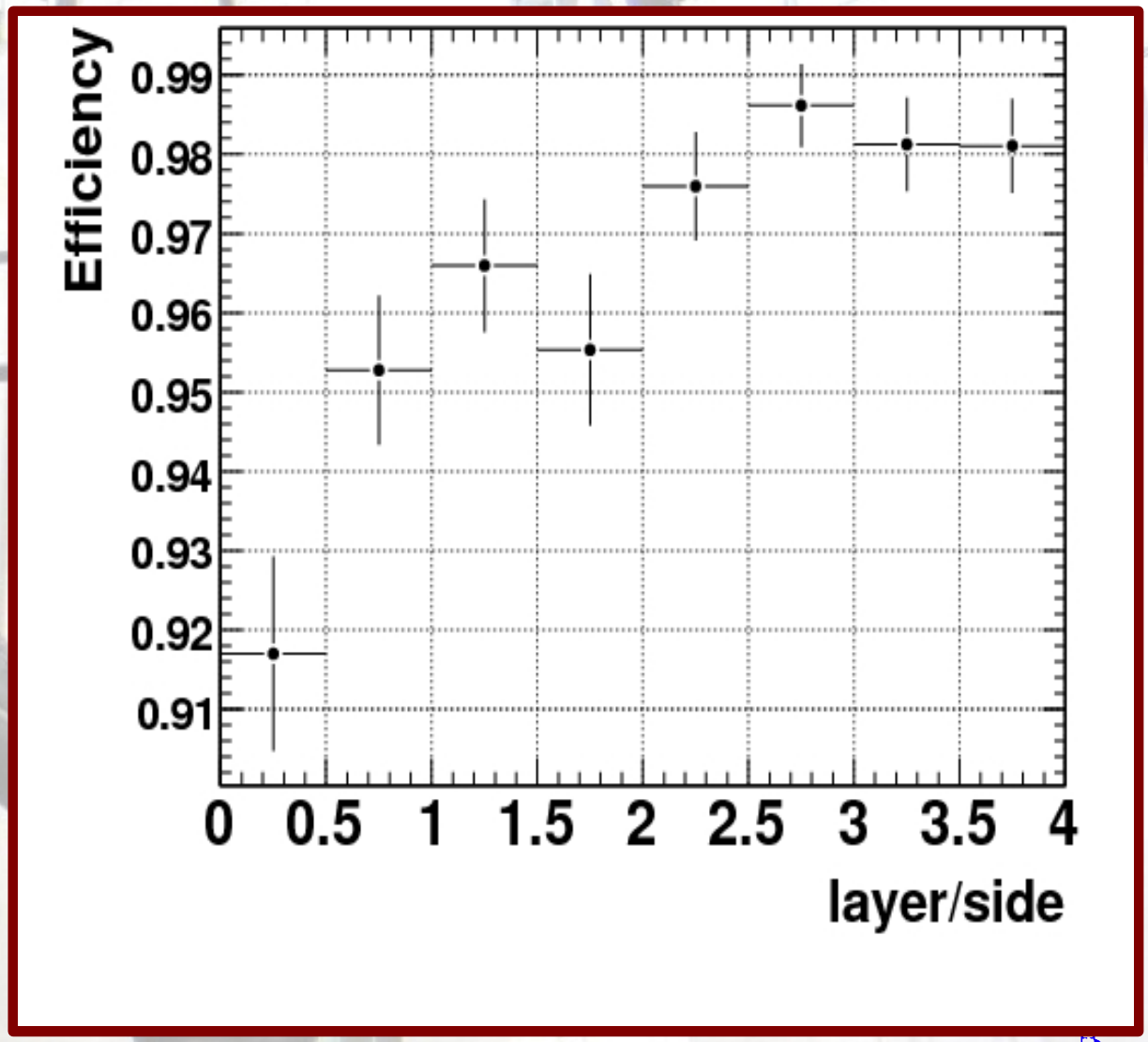


$$erf(z) = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-z^2} dz \qquad z = \frac{|V_{thr} - \mu|}{\sigma}$$



Hit Efficiency = Number of Hits / Number hits expected

- Known defects not considered
- No access to conditions DB during run
- Detector not aligned
- Efficiency will improve once the above are implemented



NO calculation

$$NO = \frac{1}{N_{Events}} \sum_{Events} \frac{\left(Tot_{Hits} - Tot_{sps}\right)}{\left(N_{strips} - Tot_{sps}\right)}$$