The ATLAS barrel and end-cap SCT commissioning at CERN

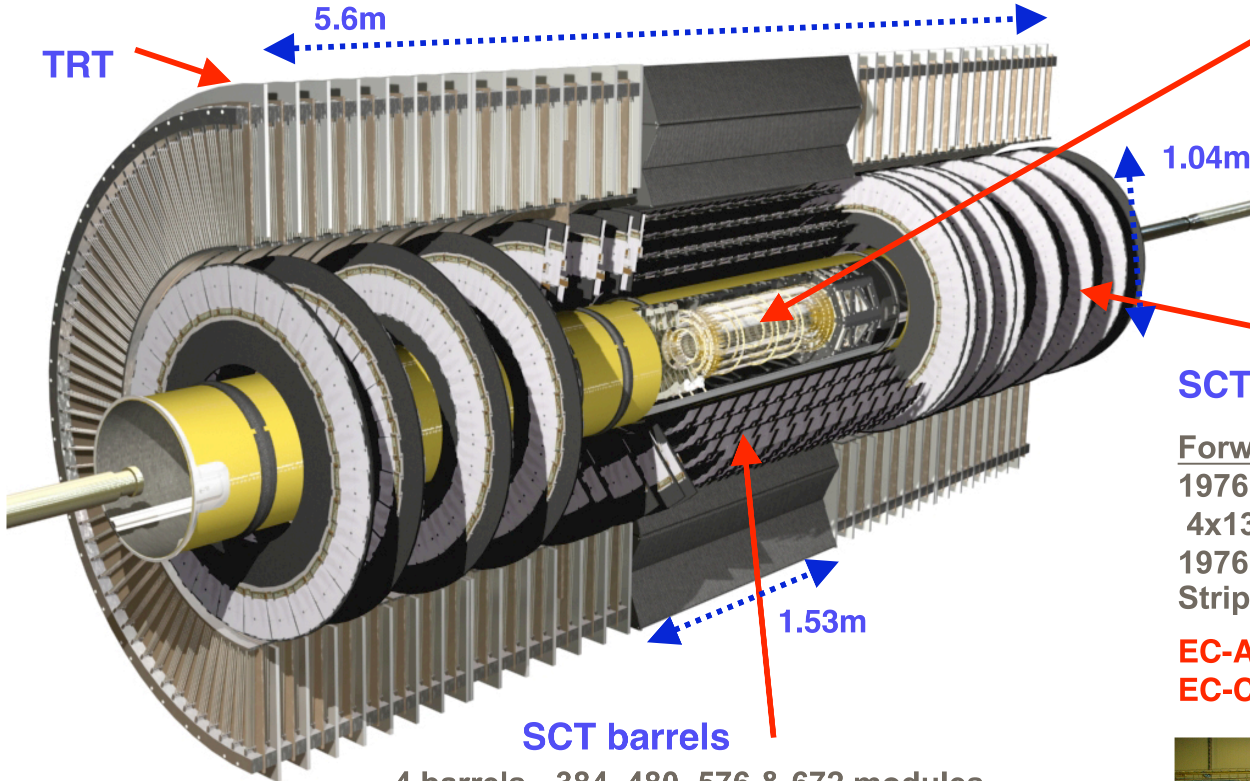
1. Goals of the SR1 commissioning
2. The SR1 assembly area and infrastructure
3. Barrel reception
    a) Individual barrel studies
4. Barrel integration and combined tests
    a) Barrel SCT integration steps - insertion into the TRT
    b) Combined studies of the SCT-TRT
    c) The barrel SCT-TRT in ATLAS and future steps
5. The SCT end-cap assemblies
    a) Individual EC-A and EC-C studies
    b) Integration into their thermal enclosure
    c) Future studies
6. Conclusions and next steps

A. Clark, SCT subsystem, ATLAS Collaboration

6th "Hiroshima" Symposium, Carmel, 11-15 September, 2006

(see other talks by M. Tyndel and U. Parzefall)

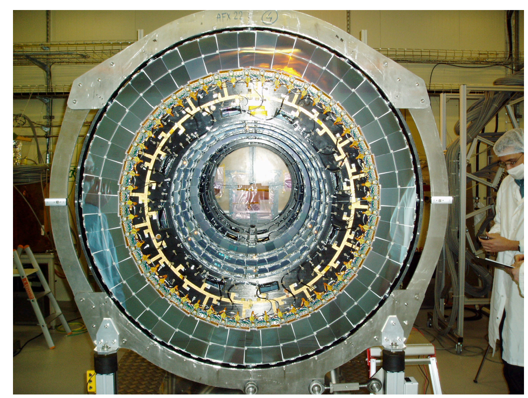
The ATLAS Inner Detector



SCT endcap disks

Forward (Endcap): 2 x 9 disks
1976 wedge-shaped modules
4x132, 4x92 and 1x52 Si modules.
1976 wedge-shaped modules
Strip pitch ~ 80μm.

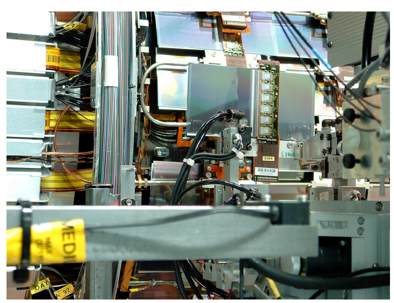
EC-A assembled NIKHEF ⇒ SR1
EC-C Liverpool ⇒ SR1



SCT barrels

4 barrels - 384, 480, 576 & 672 modules
Si modules. Each module has 4single-sided p-in-n detectors, ~ 64mm square
768 strips @ 80μm.

Barrels assembled in Oxford ⇒ SR1



1. Goals of the SR1 commissioning

Detector tests/ integration

Reception tests of barrels and end-caps

SCT standalone tests

- Online checks (eg. SCT characterization, pickup test,…)

Complete integration of barrels and EC

Combined noise and X-talk tests

- Common TDAQ readout of SCT and TRT
- Noise tests within SCT and on SCT from TRT
- Testing with the heater system and cooling operational
- Feedback of readout cycle to FE noise

Cosmic ray studies

Learning to operate the detector

Operation

- Run infrastructure requirements (e.g. detector cooling, PS, environmental)?
- Cooling performance
- Startup, operation, hardware monitoring procedures
- Monitoring

DAQ

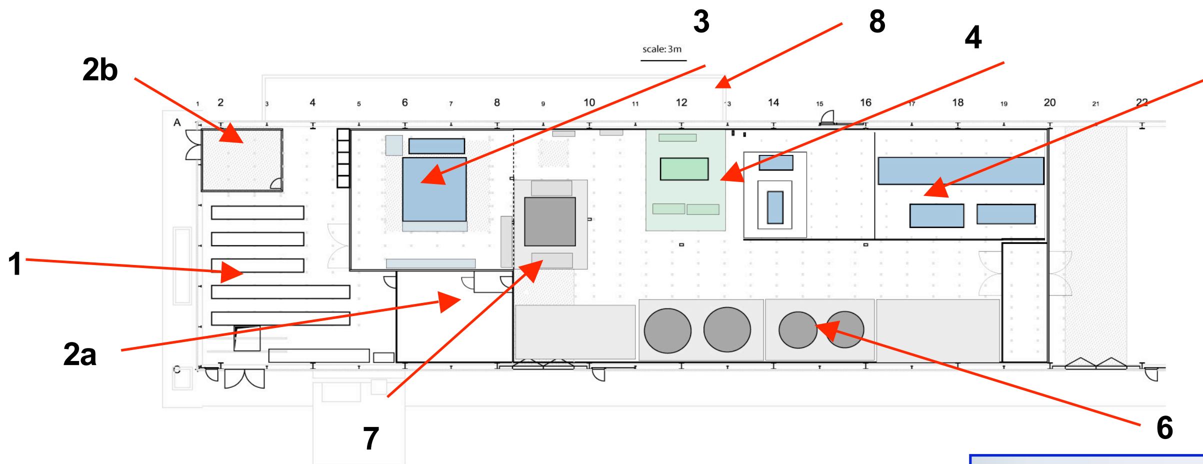
- Change standalone operation ⇒ combined readout
- Synchronization issues, data handling
- Tools for monitoring, detector timing, etc.

DCS

- Supply system *operation* and *stability* (PS, cooling, gas, environmental, …)
- Learning what needs to be improved & debugged (*e.g. C3F8 filters, reliability, safety …)*

Lead by H. Pernegger with R. Apsimon, T. Jones, N. Hessey + many others
AUS, CH, CZ, D, ES, JP, NO, NL, PL, SW, SLO, UK, US

2. The SR1 Cleanroom test facilty at CERN



600 m2 cleanroon

~ Class 2000

1: External area for electronics racks, LV+HV power, ROD readout (up to 55 racks)

2: Control room (2a), workshop (2b)

3: SCT test enclosure. Test ~ 700 modules ($\sim 10^6$ channels) simultaneously

4: Pixel assembly area (now expanded)

5: Large space for 4-barrel assembly, EC-A, EC-C tests

6: TRT Endcap assembly and testing

7: TRT Barrel assembly and testing

8. Evaporative cooling plant

NIKHEF ⇒ SR1

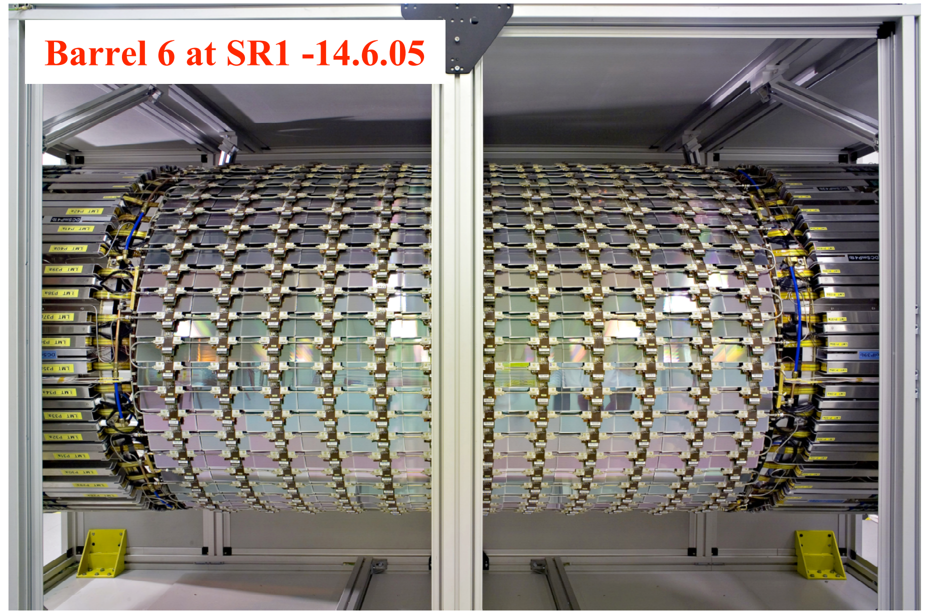
Transport - lesson - outstanding success

a) Environment controlled, air-sprung

b) Spring suspension, nested containers

c) Monitor *x,y & z* acceleration, temp, RH%, pressure

3a: Reception Tests at SR1 for each Barrel and End-cap

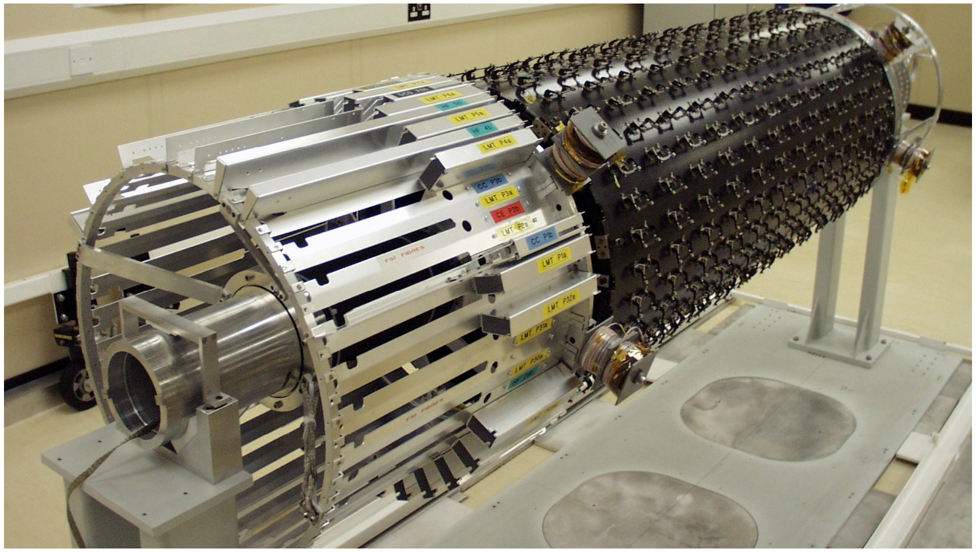


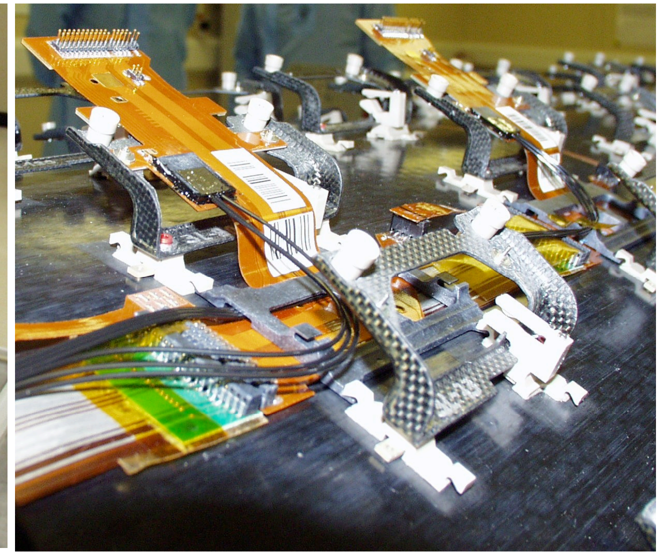
Item	Delivery	Reception tests
Barrel 6	6.2005	(Oxford)
Barrel 5	7.2005	CERN
Barrel 4	8.2005	(Oxford)
Barrel 3	1.2005	CERN
EC-A (NL)	21.4.06	22.06.06
EC-C (UK)	23.2.06	24.03.06

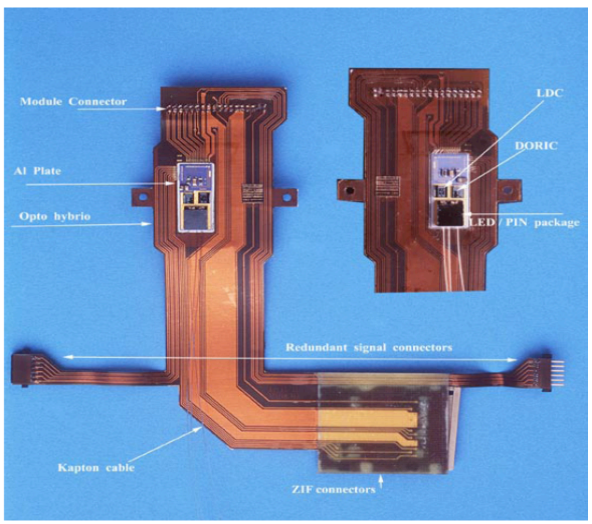
Reception tests include:

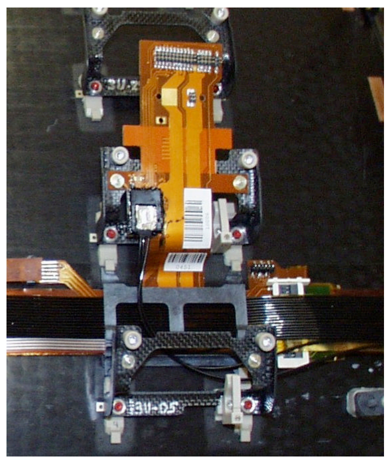
- Full visual inspection and photographic summary, check for component movement
- Leak test and repair of all cooling circuits
- Full "continuity check" of all modules
  - confirms module functionality (not analogue performance)
- Alignment check of all disks (forward)
- Limited cold tests - ~10^0C or -12^0C coolant at CERN, colder at assembly sites
- *Comparison with data at assembly site*

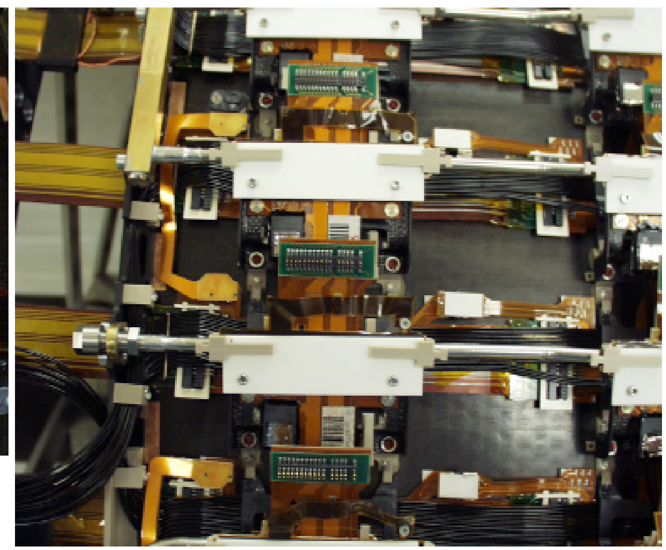
3b. Reception Tests at SR1 for each Barrel and End-cap







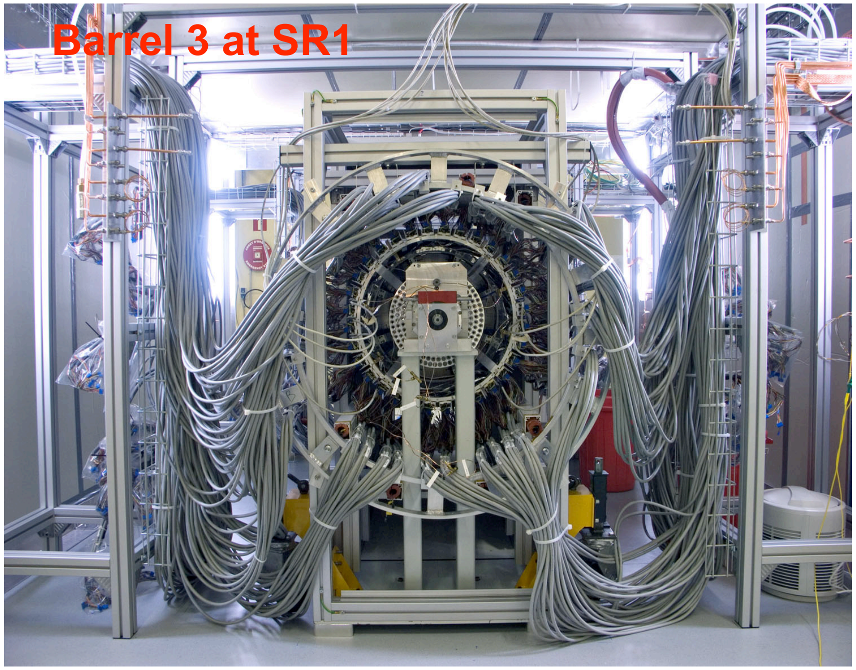




Example: Barrel services

- power services
- cooling
- optical readout
- DCS

3c. Individual Tests at SR1 for barrels 3 and 5



Infrastructure:

1. SR1 test enclosure
2. Evaporative cooling
3. HV +LV power and readout for 700 modules
4. 10^6 channels read out, dew point < - 40°C.
5. - "Final" Detector Control System (DCS)
   - "Final" detector readout, including full opto-readout
   - "Final" DAQ

Basic Electronic Tests

- Establish Communication, optimise Opto settings

Digital Electronic Tests

- Verify Communication

Analogue Electronic Tests

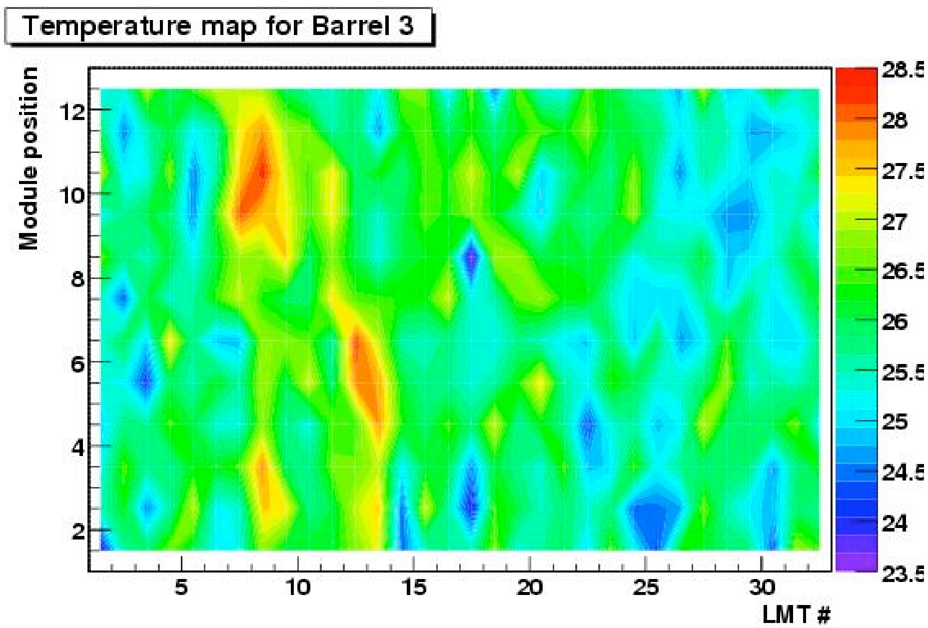
- Measure Gain, Offset, Noise, Noise Occupancy
- Look for Time Structure
- Detect excess noise possibly related to high frequency, synchronous triggers

Module supply and sensor currents (an issue)

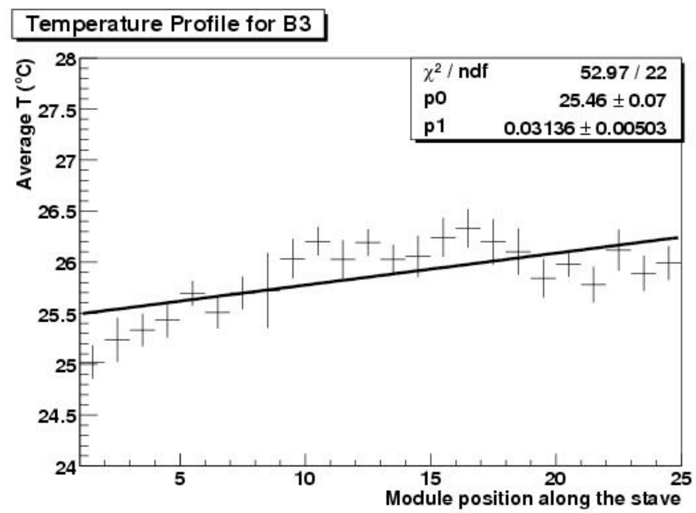
Module temperatures and other DCS monitoring

3d. Individual Tests at SR1 for barrels 3 and 5.

Test of individual cooling loops - DCS

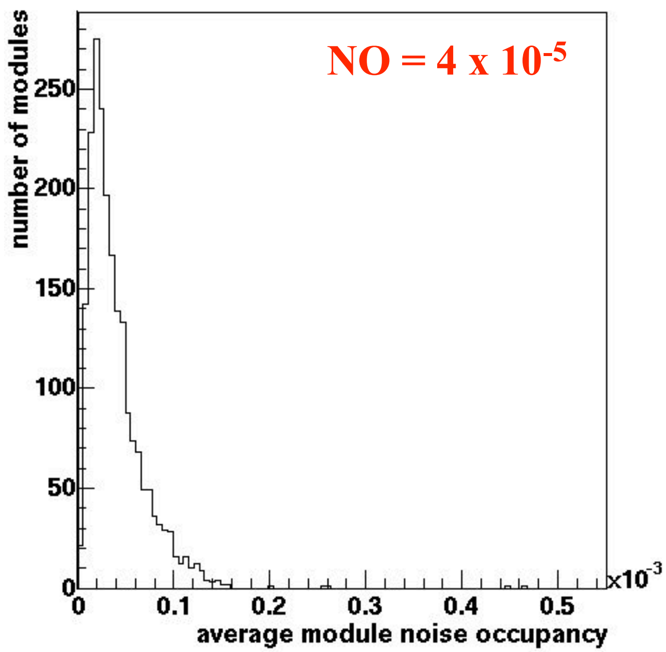


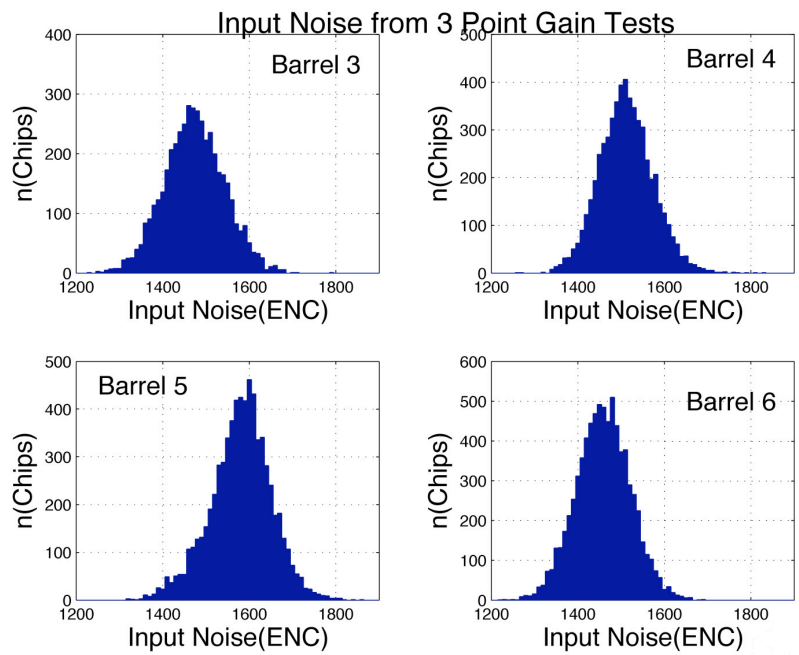
2-d map of mean module temperatures for B3



B3 temperature profile along stave from entry to exit averaged over all staves.

3e. Individual Tests at SR1 for barrels 3 and 5.





Barrel	Total Channels	Not bonded	Dead	Not Reachable	Part bonded	Noisy	Other	Total Defects
3	589824	180	357	384	91	460	11	1483
4	737280	55	245	256	16	242	27	841
5	884736	173	770	256	97	492	30	1818
6	1032192	385	2513	640	197	1936	49	5720
Total	3244032	793	3885	1536	401	3130	117	9862

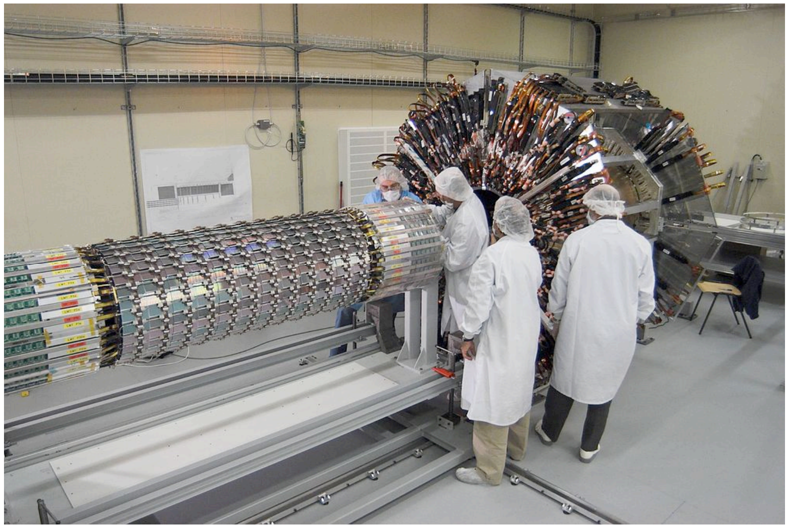
99.8% working channels

4a. 4-barrel integration

B6 ⇒ thermal enclosure - 22.7.05

B5 ⇒ B6 + thermal enclosure - 12.8.05

B4 ⇒ B5 + B6 + thermal enclosure - 06.9.05 (not shown)



B3 ⇒ B4-6 + thermal enclosure - 20.09.2005

Started after Barrel 6 tests

4b. 4-barrel integration

Service time dominated by service handling

~ 10% inserting

~ 60% moving services and cooling capillaries at end of barrels - risks+ lessons

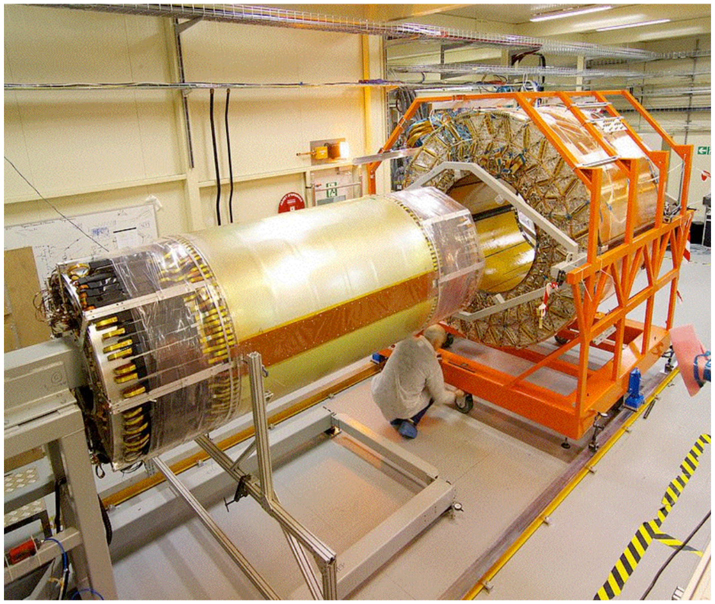
~ 30% sealing thermal enclosure bulkheads

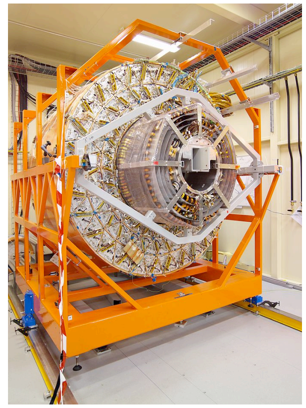
Barrel ends assy	Days	
Mount final Interlinks (in parallel)	1	
Remove kapton tape from LMTs (200mm)	2	2
Check harness pairs are correct	0.5	2.5
Label each harness pair	0	2.5
Check & label the R/O fibre bunches	0.5	3
Checkrouting of DCS wire bunches	0	3
Check & label capillaries	0.5	3.5
Seal LMTs into grommets	5	8.5
Mount central part of bulkhead	0.5	9
JST crimps heater cables (in parallel)	2	
Seal opt. fibers into grommets	2	11
Seal DCS wires	1.5	12.5
Set capillaries to HEX models	1	13.5
Seal capillaries into grommets	1	14.5
Bend & insulate capillaries	2	16.5
Mount exhaust spiders	2	18.5
Leak test cooling spiders	2	20.5
Mount N2 supply /exhaust pipes	0.5	21
Mount and seal rear part of bulkhead	1	22
Mount additional TE ext. Temp DCS sensors	1	23

	Days	
Mount pixel supports	0.5	23.5
Mount handling points	0.5	24
Survey barrel ends	1	25
Try Pixel master jig	1	26
Take footprint of Pixel supports	3	29
Mount ITE/seal penetrations	1	30
Mount, connect Cooling Ref Disc (CRD)	2	32
Mount and seal end covers	1	33
Sub Total	33	
Test the Thermal Enclosure	2	35
	)	
Prepare SCT for insertion		
Mount the reinforcement rings	0.5	35.5
Mount the ISSS	1	36.5
Arrange services for insertion	5	41.5
Check envelope	0.5	42
Dismount service support wheel	0.5	42.5
Prepare cradle for "travel"	0.5	43
Sub Total	8	
Total	43	

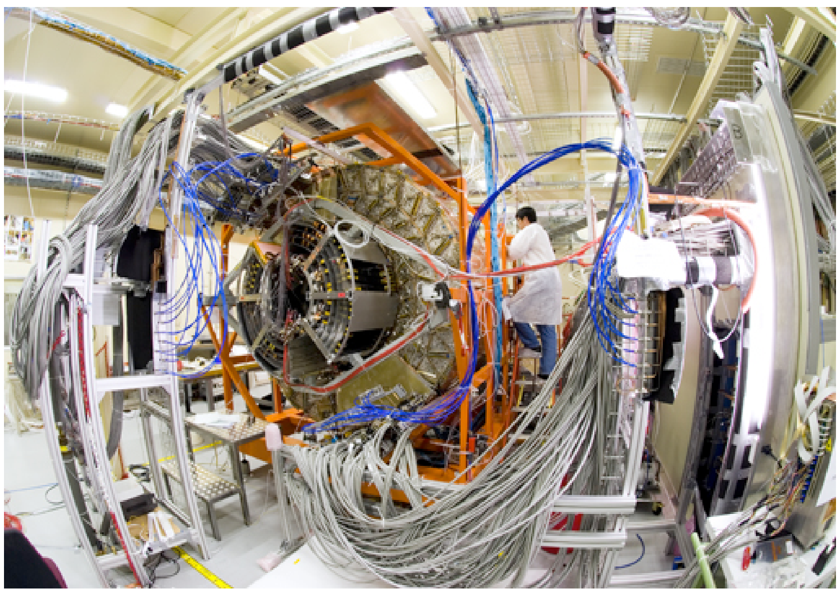
(from R. Apsimon / H. Pernegger)

4c. Integrating the SCT and TRT barrels - 17.02.2006





Integration and cabling for combined tests of SCT and TRT (next slide)



Detector connection:

- TRT power, readout cables, gas/cooling
- Heat spreader between SCT , TRT services
- Fold out SCT services +connection + leak test (LMT->Cooling->fibres)

Cleanliness:

- Fibres and capillaries

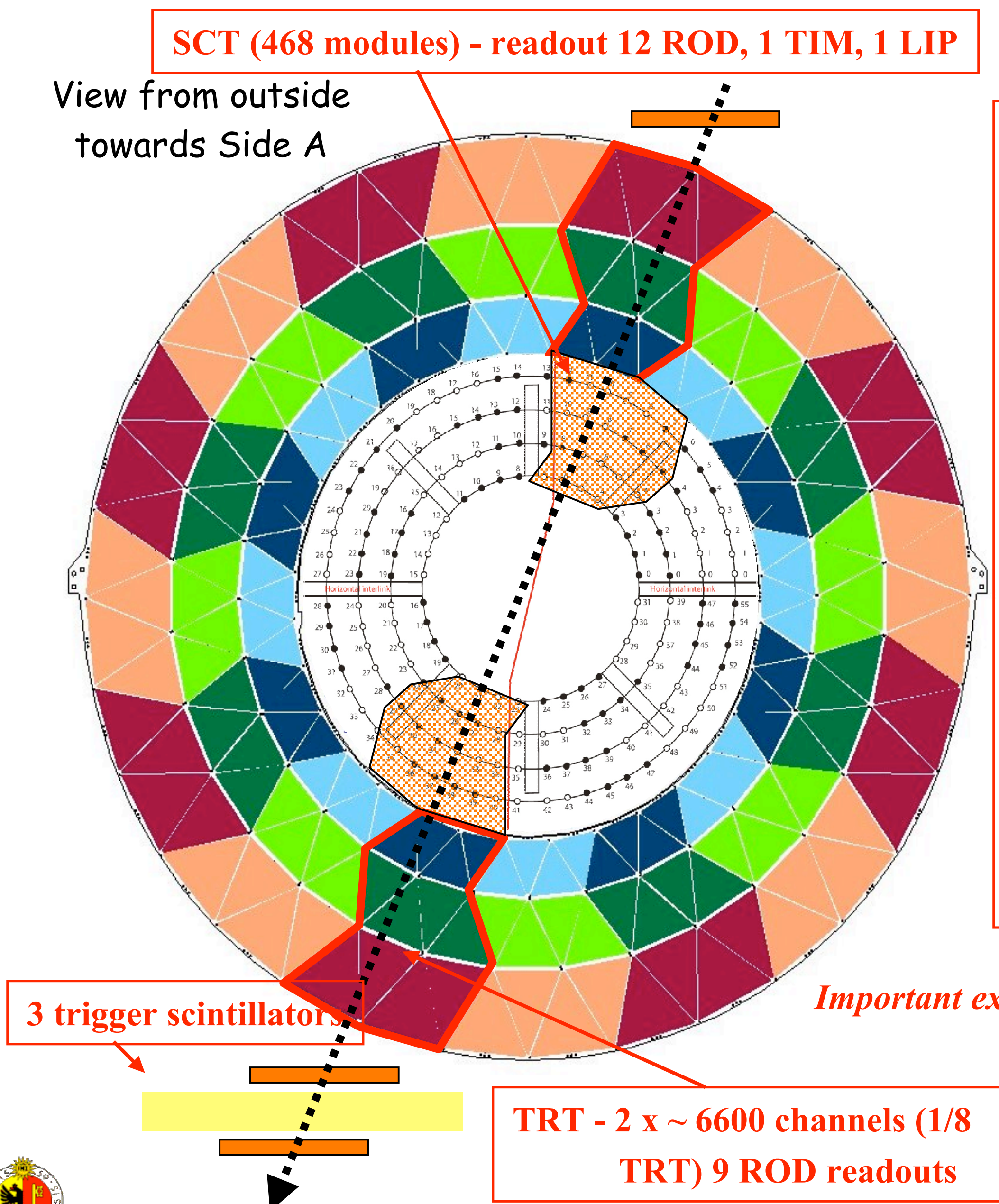
Reliability:

- 4 of 88 harnesses required repair

Time: ~ 5 weeks for 1/8 TRT + 1/4 SCT

- Including time to resolve minor problems

4d. Combined barrel SCT+TRT test - *goals*



Operation:

- Experience of detector operation
- Test detector supply systems
- Development of standalone & combined monitoring tools
- Commission and test combined readout and trigger
- Commission offline SW chain

Detector performance:

- Test 4 SCT barrels together
- Operation with TRT
- Grounding for SCT and TRT
- Synchronous operation
- X-talk and noise

Collect cosmics for efficiency & tracking studies

Important experience for preparation for pit installation
(discuss only SCT aspects)

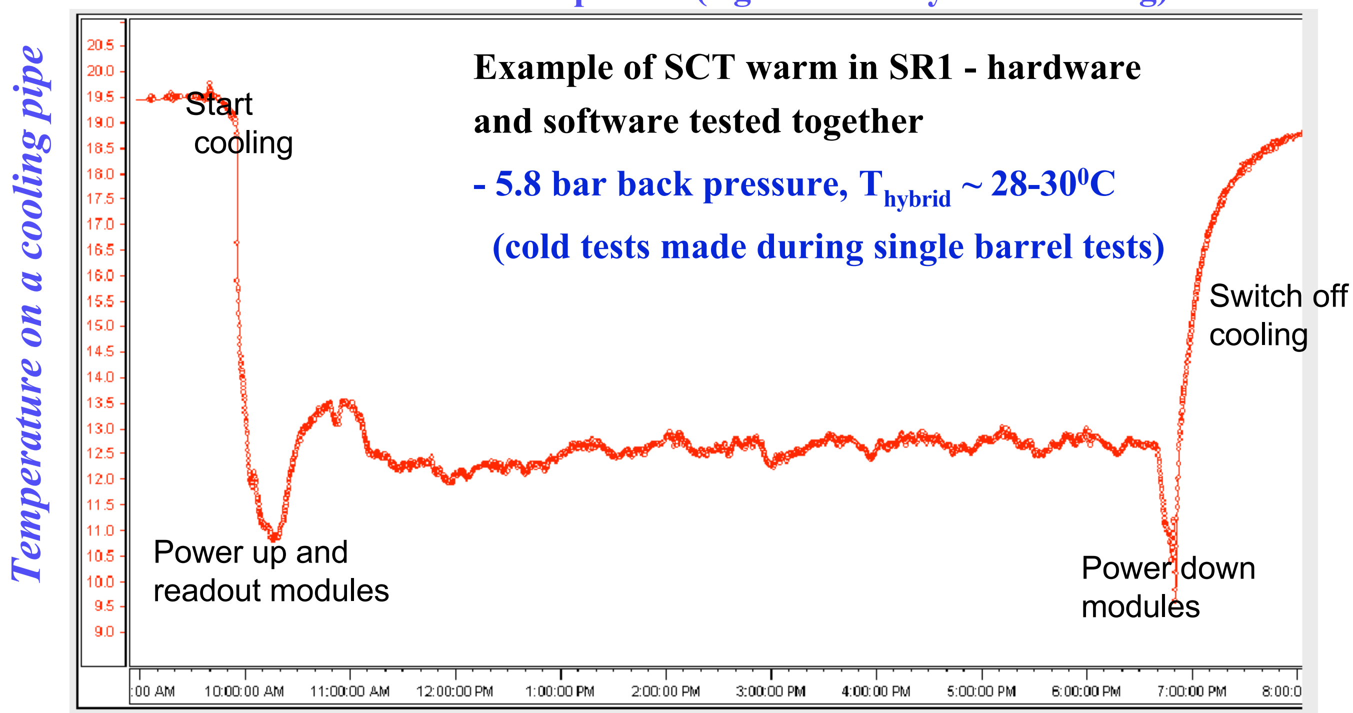
4e. Combined barrel SCT+TRT test - DCS issues

DCS crucial to reliable and safe operation - an essential test bed

- Cooling system monitoring
- Environmental monitoring
- PS control and monitoring
- Interlock safety system

→ Startup procedure defined
→ Implementation of FSM and latest PVSS ongoing
→ Database issues - DCS configuration, conditions - much to do
→ Archiving into COOL (read by Athena)
→ Learn what needs to be improved (e.g. mandatory filter cooling)

Significant experience and improvements made - both control and monitor functions



4f. Combined barrel SCT+TRT test - DAQ

Multi-ROD Crate (not yet multiple crates)

- TRT uses RodCrateDaq
- SCT uses SCTDAQ)

DAQ event building

SCT uses Slink based readout

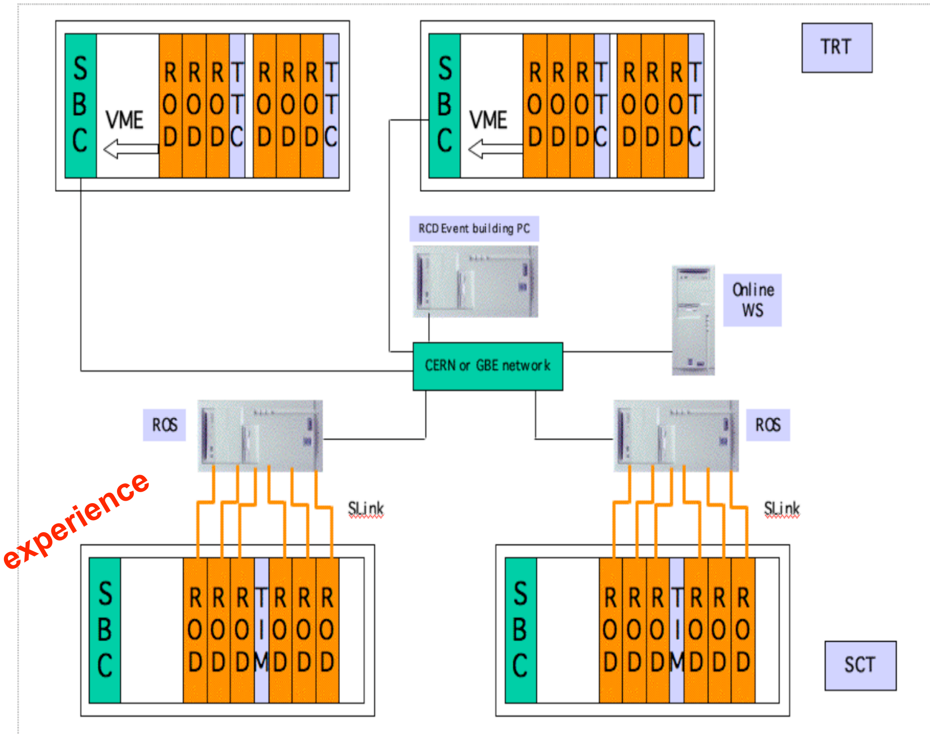
- 12 ROD/BOCs in 1ROD crate)
- 3 FILARs (12 Slink channels) in 1 ROS

TRT uses VME-ethernet based readout

- 2 ROD Crates: 6&3 RODS inside

Exercised full functionality of calibration and data collection

ongoing - much experience



Issues include

- Synchronisation
- Monitoring
- Start of run issues (data base)

Transition	SCT	TRT	Monitor
Boot	O(1min)	O(10sec)	O(1.5min)
Configure	O(2min)	O(10sec)	O(2min)
Start	O(10sec)	O(10sec)	O(30sec)

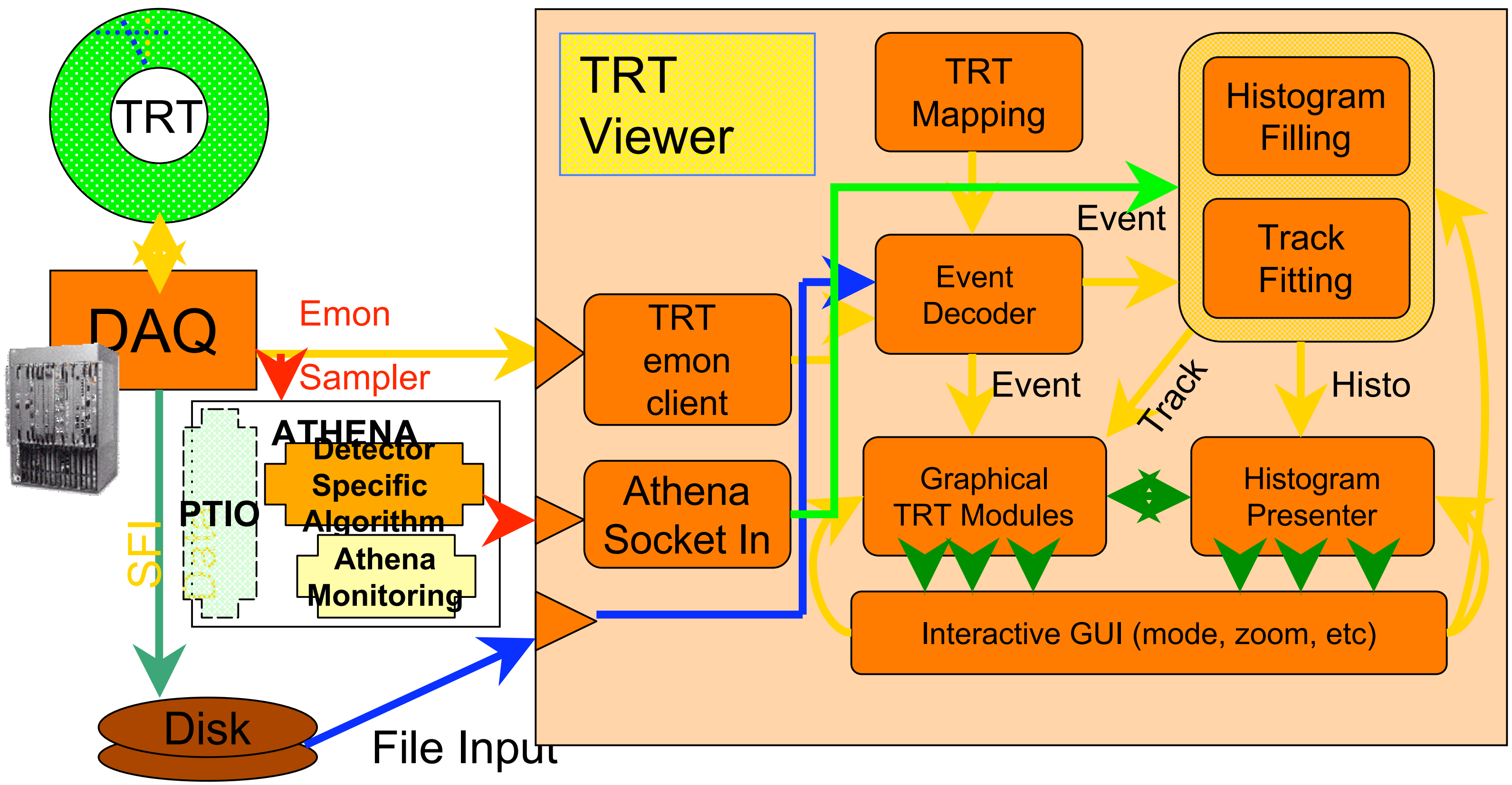
e.g. start of run timing

Data base issues important

- SCT and TRT conditions data bases
- SCT and TRT configuration data bases
- Start of run issues
- Reliability

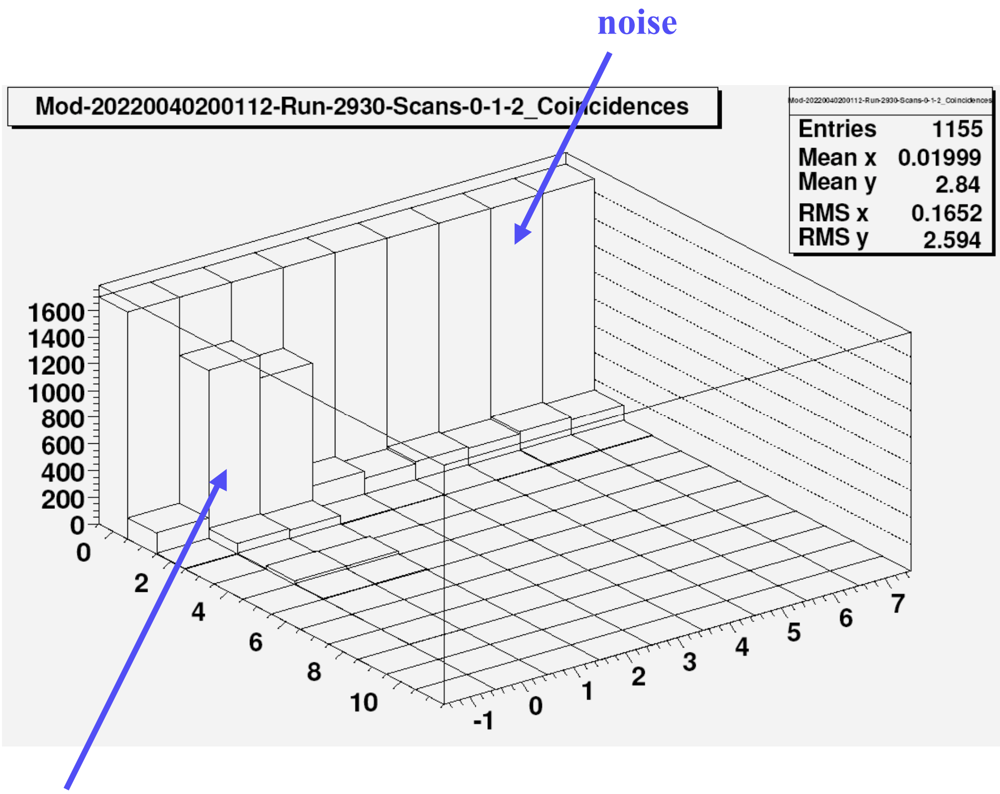
4g. Combined barrel SCT+TRT test - monitoring

Detector specific histograms + 1) monitor synchronization of LVL1 and BC IDs of different detectors
2) monitor hits for any track collection, calculate residuals etc
3) monitors matching of TRT and SCT segments



Developed for TRT, SCT also inserted

4h. Combined barrel SCT+TRT test - module timing with cosmics



Timing coincidence between module sides for each module
(BOC Tx coarse scan (32 bcos)

4i. Combined barrel SCT+TRT test - SCT noise

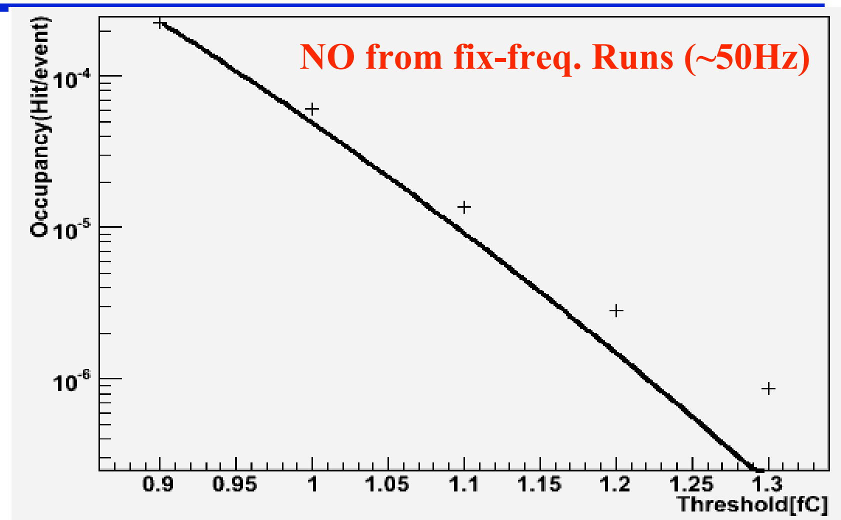
- First full test after 4-barrel assembly
- Number of extra defects found in tested sectors):
  - 4 interrupted LMT lines - repaired
  - 3 of 468 modules with opto anomalies (redundancy, no channels lost)
  - 2 non-readable FE chips (dead Vcsel?)

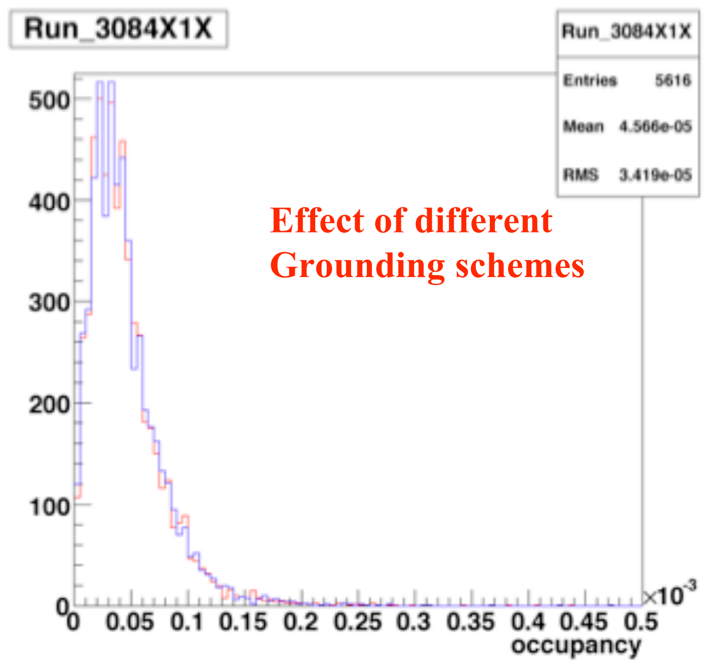
- Functional channels ~ 99.8% (+0.03%)

- Noise threshold and occupancy scans made:
  - with/without TRT
  - as function of trigger rate
  - with/without cooling and heaters
  - with different grounding schemes
  - effect of noise in adjacent time slots
  - Possible common mode effects

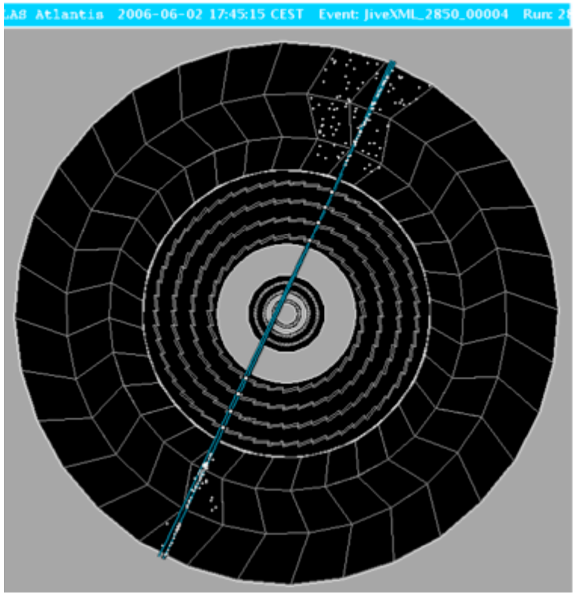
- No evidence of increased noise in any tests

Run 3102	Top	Bot
B3	4.56e-5	4.14e-5
B4	3.41e-5	4.03e-5
B5	4.17e-5	4.27e-5
B6	6.63e-5	4.95e-5





4j. Combined barrel SCT+TRT test - cosmic tracks

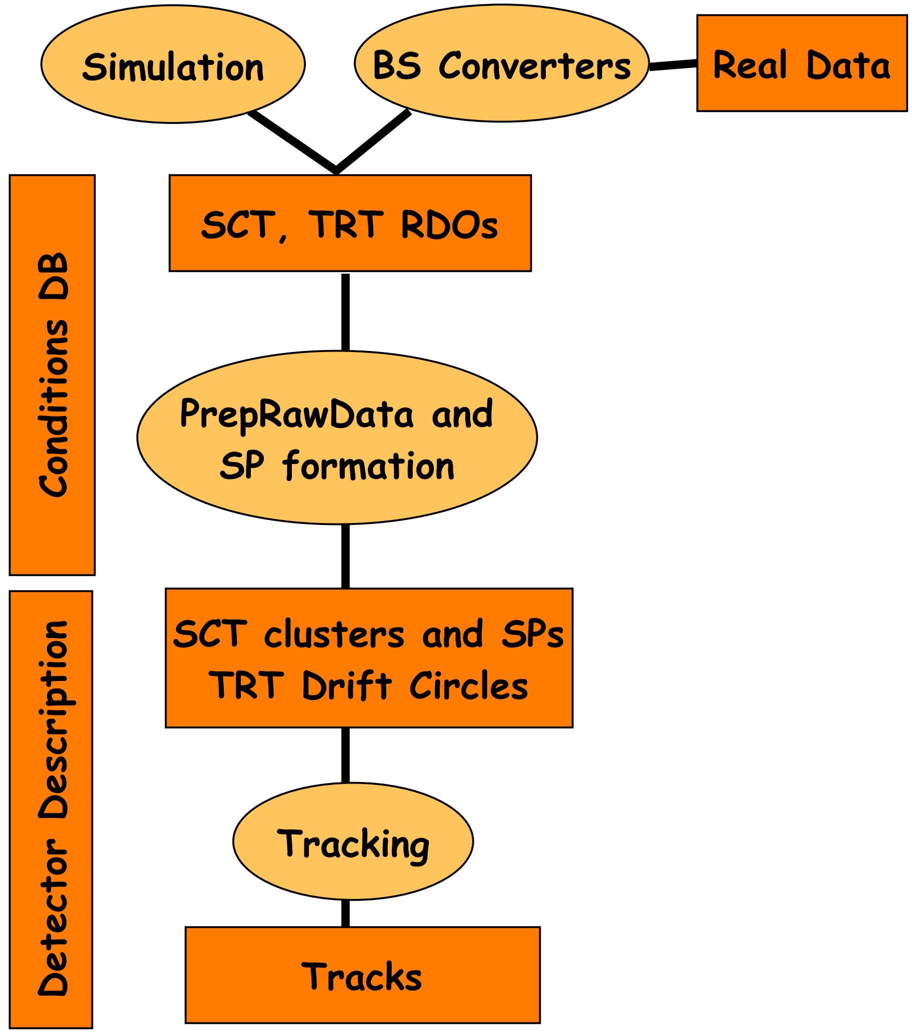


~ 450K events recorded

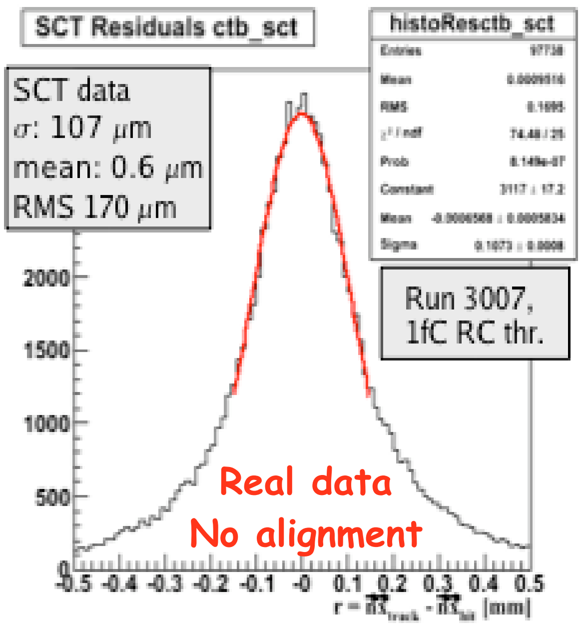
Full ID reconstruction chain tested with cosmics

- **Final data decoding in place**
- **Tracking with no vertex constraint**
- **Extensive use of information from ConDB**
- **Fixes in SCT detector description done**

Cosmic simulation also available

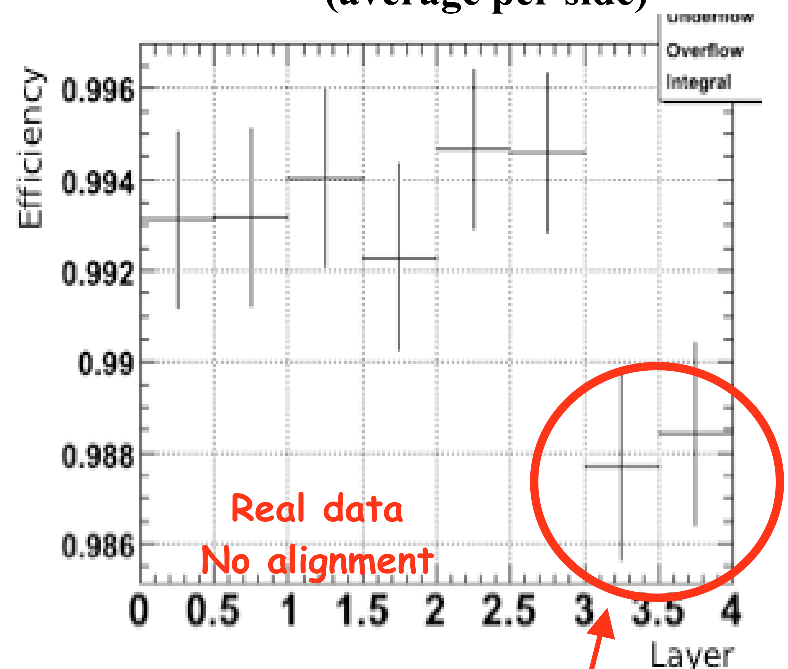


4k. Combined barrel SCT+TRT test - SCT performance



Preliminary

SCT efficiency per layer (average per side)



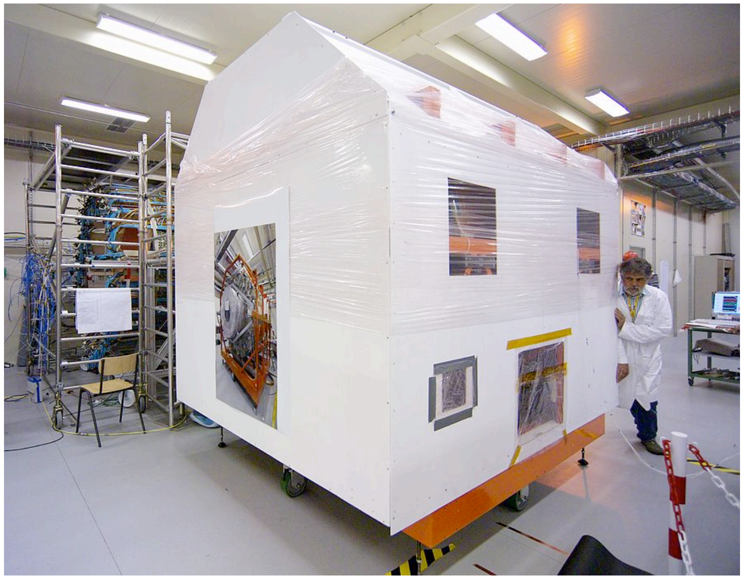
Simulation:
- **Perfect alignment: μ~0μm ⇒ σ=55 μm**

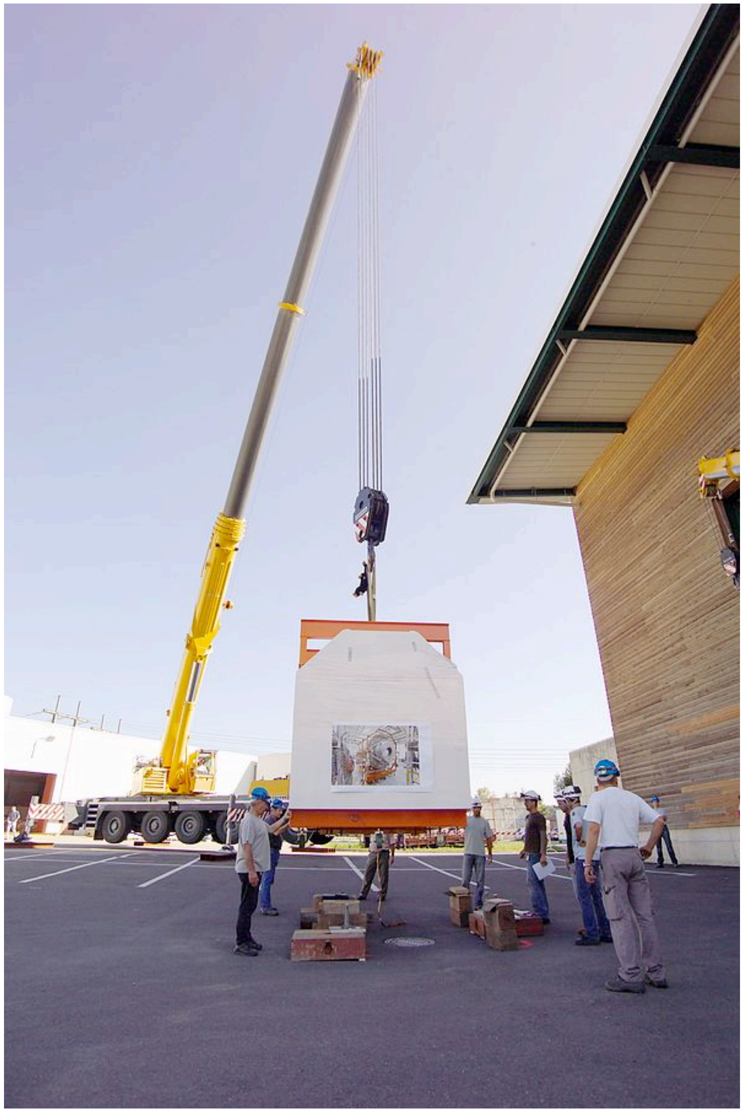
Expected precision:
modules: 100μm (rϕ, z), 500 μm)
Barrels: 100 μm (rϕ, z and R)

- **Overall efficiency > 99% (in spec)**
- **Resolution better than obtained with the expected level of misalignment**
- **Alignment studies ongoing - promising results**

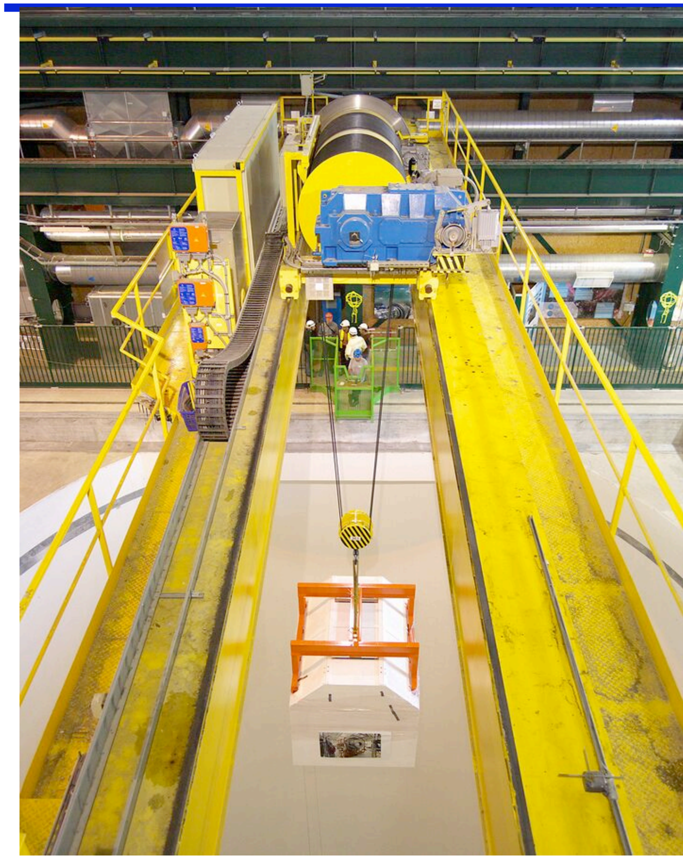
Cabling problem in some modules of outer layer

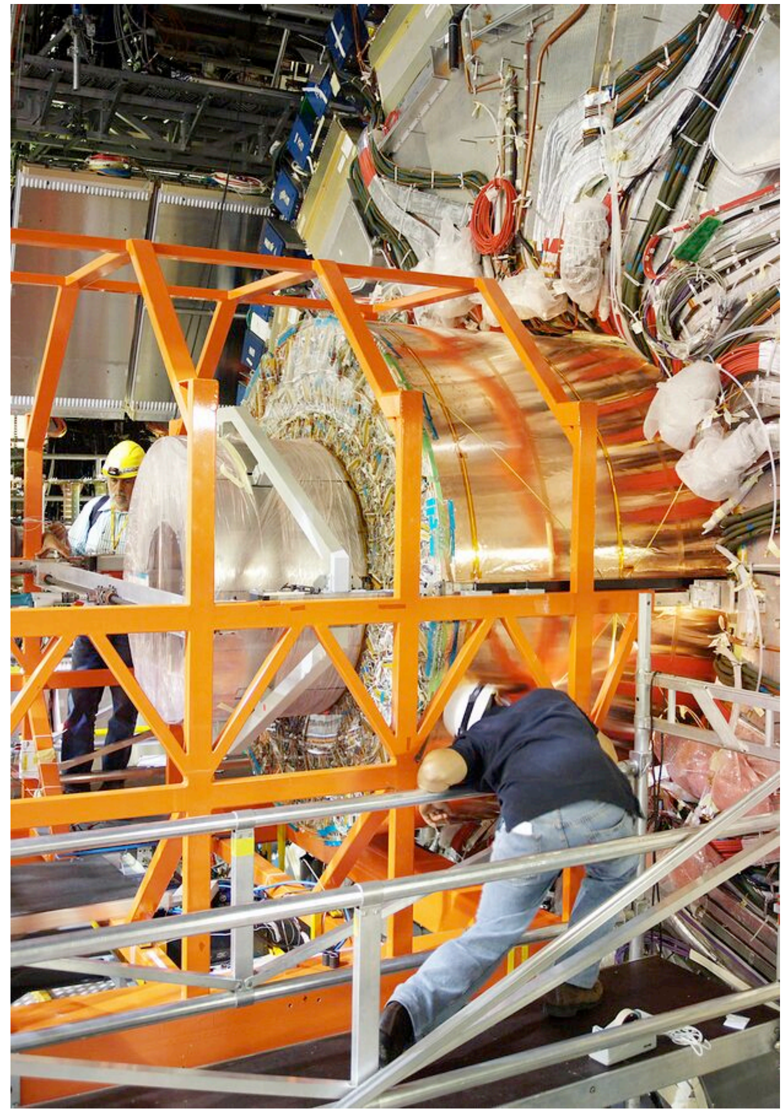
4I. Installation of ID - 24-25.08.2005





4m. Installation of ID - 24-25.08.2005





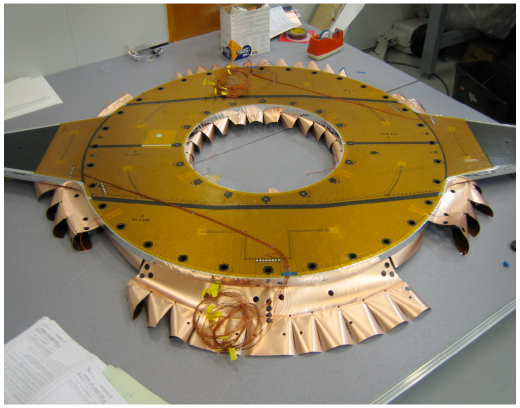
Next challenges: - service connection,
- repeat noise studies
- cosmic studies
- understanding/operation

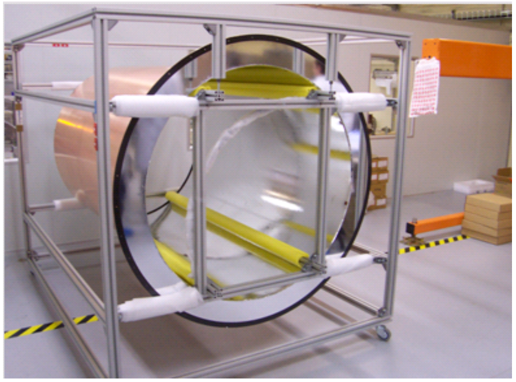
5a: End Cap: EC-A and EC-C integration and studies

A. Arrival and Reception Tests

B. Final Assembly Stage

- Preparing and fitting Rear Support
- Transfer to cantilever stand
- Move to integration position
- Fit Inner Thermal Enclosure (ITE)
- Seal ITE and fit front membranes
- Complete services feed through area
- Transfer weight of EC to stand
- Fit Outer Thermal Enclosure (OTE) including heaters etc.





C. Testing inside Thermal Enclosure

D. Integration with TRT

E. Combined Testing with TRT

5b: End Cap: EC-A and EC-C integration and studies

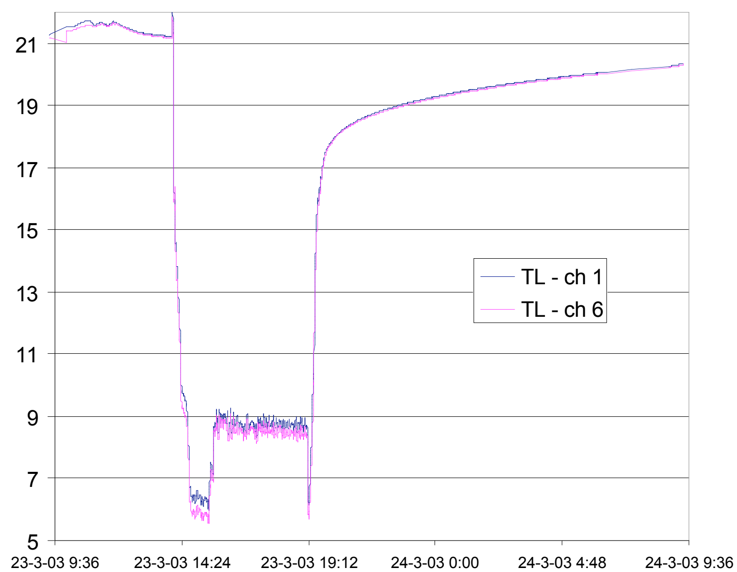
	Task	EC-C	EC-A
A.	Arrival and Reception Tests	23rd Feb (Lvpl)	21st Apr (Nikhef)
B.	Final Assembly Stage	done	done / ongoing
	- Preparing and fitting Rear Support		
	- Transfer to cantilever stand		
	(- Investigation of electrical problems)		
	- Move to integration position		
	- Fit Inner Thermal Enclosure (ITE)		
	- Seal ITE and fit front membranes		
	- Complete services feed through area		
	- Transfer weight of EC to stand		
	- Fit Outer Thermal Enclosure (OTE)		
C.	Testing inside Thermal Enclosure	ongoing-1st results	
-	Leak tightness, octant with cooling		
D.	Integration with TRT - ~5 weeks	mid-Sept (28.09.06)	~ mid-Oct
E.	Combined Testing with TRT	mid-Oct	~ mid-Nov

ATLAS

5c: End Cap: EC-A and EC-C - reception tests

- Comparison of digital and analog tests with assembly lab
  - Noise
  - Gain
  - Offset
  - Nmask, pipeline, bypass etc.
  - Bad channels
  - Module currents, high voltage behavior
    (CIS modules in general OK up to ~250V)
- Performance was seen to be the same as before shipping:

EC-C, disk 3, quadrant 1



Unlike EC-C, EC-A had all modules tested cold during the reception tests:

6: Conclusions and Outlook

Conclusions:

- Work continuing
- Many small problems found, but no accidents, no show-stoppers
- Enormous task ahead and operation in pit next major challenge

Outlook Barrel SCT

- Expect ~35 days to cable TRT and ~75 days to cable SCT in pit
- To be followed by full continuity tests, cooling tests
- Then full functionality tests on all SCT modules ("warm"?) from ~01.07
- To be followed by cosmic ray studies - ID then ID+CAL

Outlook Endcap SCT - EC-A and EC-C

- Integration SCT-TRT
  - → EC-C 09.06 - 10.06
  - → EC-A 10.06 - 11.06
- Combined SCT-TRT tests
  - EC-C mid 10.06 - end 12.06
  - → EC-A mid 11.06 - end 01.07
  - → Tests will be made in parallel using independent setups
  - → Will use 1/4 of SCT, 1/12 of TRT
- Expect transfer to pit from ~end 01.07 with functional tests from ~04.07

Backup Slide- List of observed anomalies

- **DAQ**
  - **SCT opto setting needed more frequent adjustment then expected**
  - **3 channels return “000” hits occasionally**
  - **Desynchronizations in sub-detector readout**
- **DCS and supply systems**
  - **Hardwired interlock system implemented for TRT in SR after cooling incident + modified TRT DCS software for better reliability**
  - **Reading from humidity sensors on SCT barrels too high**
  - **Remote access to DCS system not ideal in SR**
- **Cooling system**
  - **One capillary suddenly blocked - cleared, but points out necessity of filters and (during connection) clean environment**
  - **Also observed some (still unexplained) flow differences**
  - **1 inlet regulator failed - replaced**
  - **PLC module for back pressure sensor failed - replaced**
  - **Compressor engine needed additional fan to have adequate cooling**
  - **Few occasions when high “chilled” water temperatures prevented C3F8 cooling operation**

(courtesy H. Pernegger)

Backup Slide - backplane resistance

- **Glue composition:**
  - Endcap - Tra-Duct 129-4
  - Barrel - Eotite p-10228
- **Resistance of ~2000 endcap modules and ~ 600 barrel modules checked**
  - No bias connections have lost
  - Barrel modules appear more affected than endcap modules
  - No clear evidence of environmental influence
  - Over period May-July 06, no evidence of deterioration
- **Module performance is not affected by high R in early running**
- **Remedial action on all or some modules?**
  - Evidence that sustained biasing at 350V cures most modules
  - Evidence that forward biasing (~100 μA) cures most modules
  - Small number of modules not fully cured by either of these operations
- ***Post-irradiation, there will naturally be a high current, so will it be self-curing?***
- **The cause of the high R is not fully established**