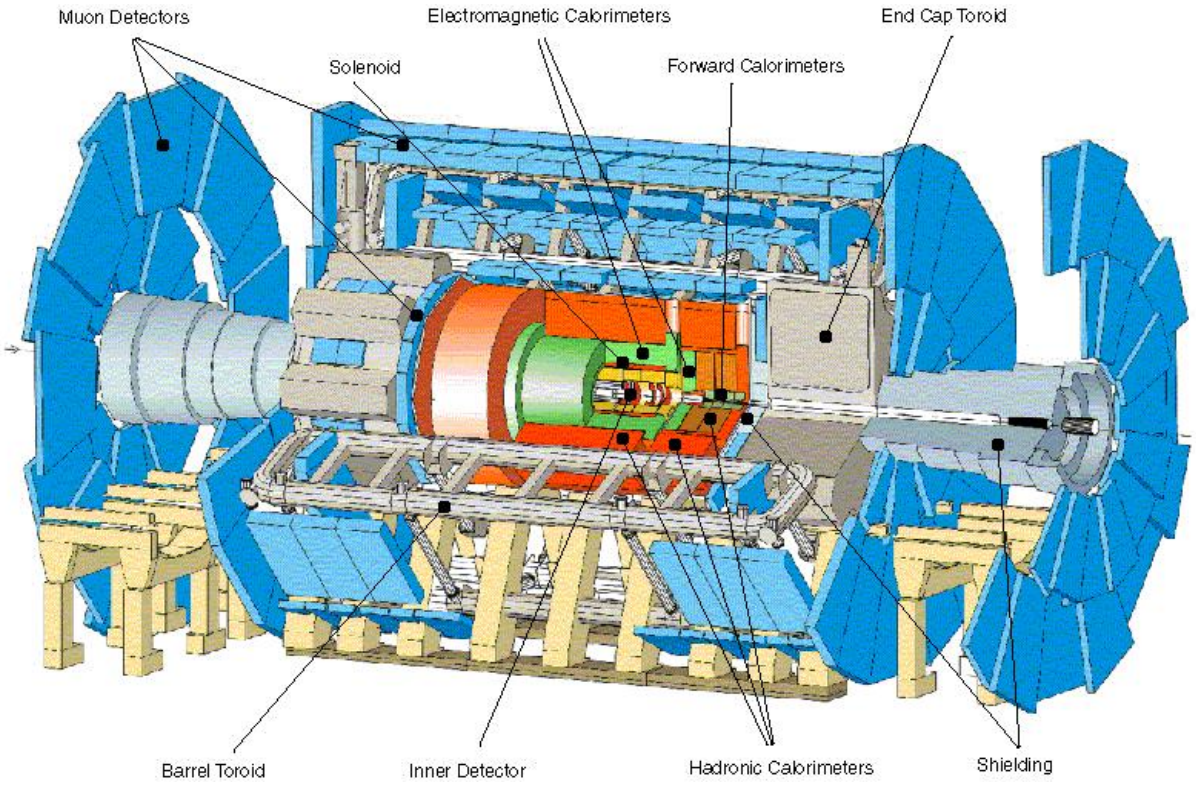


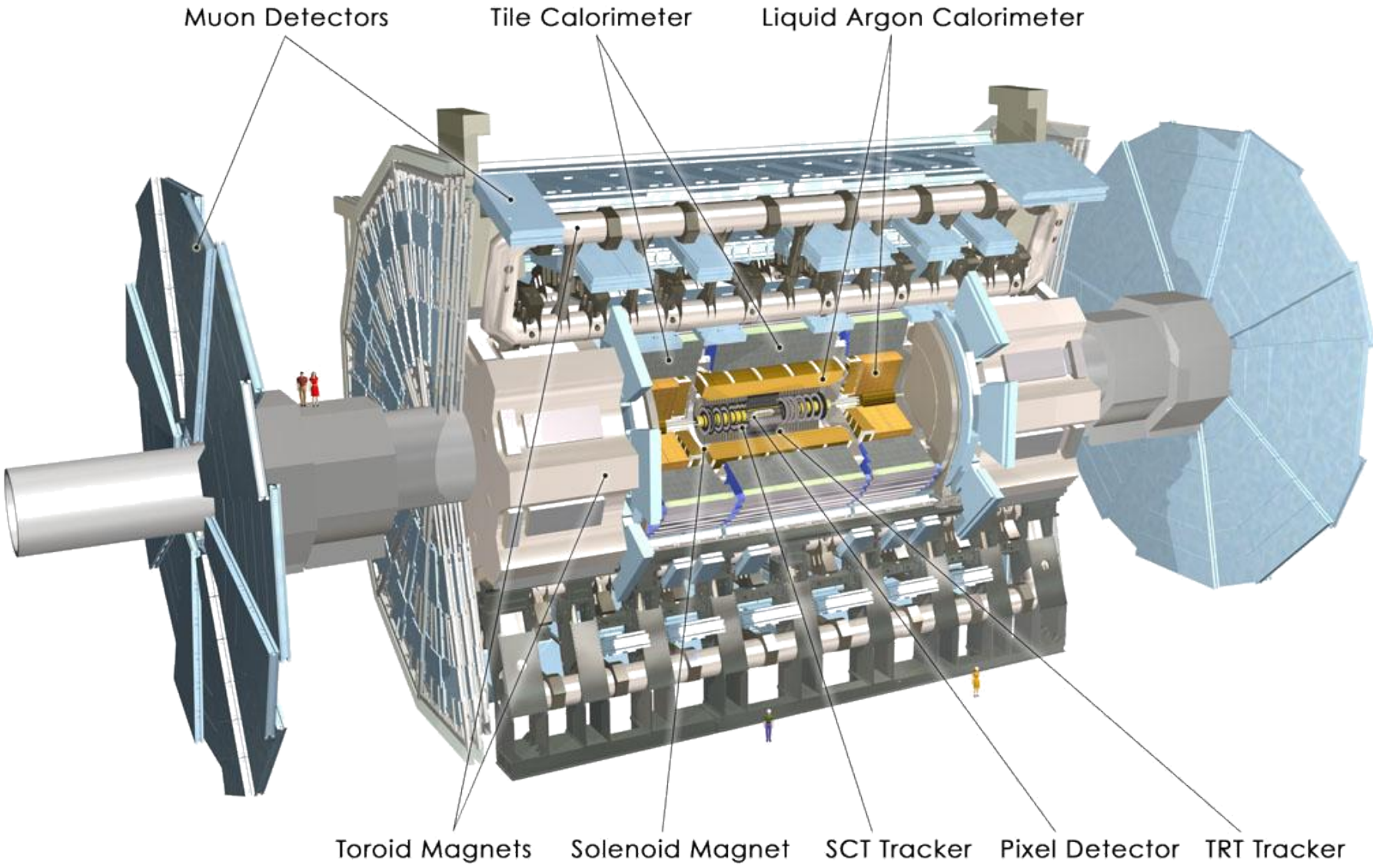
ATLAS Commissioning

Roberto Ferrari

Montecarlo Workshop

Frascati – 20 Febbraio 2008

ATLAS Detector



ATLAS Detector

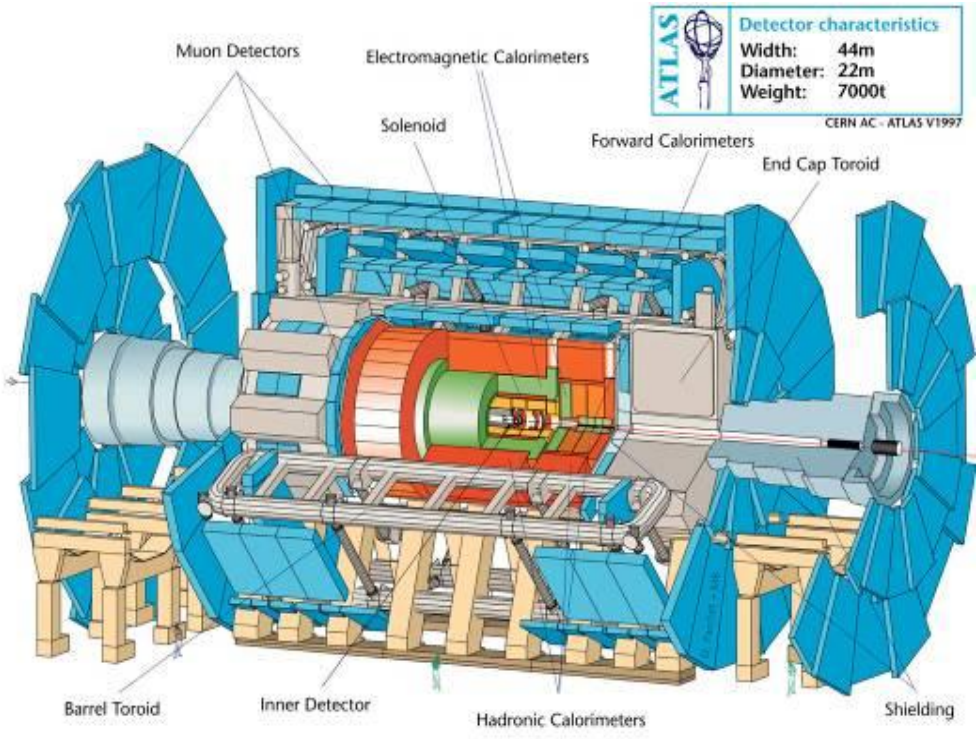
- 3 sottosistemi principali + sistema magnetico:
  - Sistema magnetico
    - Solenoide centrale
    - Toroidi barrel e endcap
  - Tracciatore Interno:
    - Pixel
    - Silicon Tracker (SCT)
    - Transition Radiation Tracker (TRT)
  - Calorimetria:
    - Calorimetro Elettromagnetico (LAr)
    - Calorimetro Adronico (Tile)
  - Spettrometro per Muoni:
    - Barrel
    - EndCap

Performance di progetto

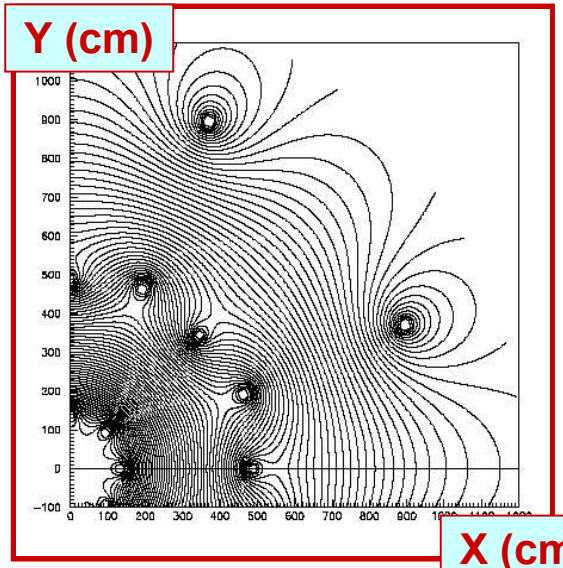
MAGNETS	4 magnets: 3 large air-core toroids (to minimize mult.scattering) 1 solenoid (B=2T) in inner cavity
TRACKER	Si pixel + strips TRD (straw tubes with radiator) → particle ID $\sigma/p_T \sim 5\times10^{-4}\ p_T\ (\mathrm{GeV}) \oplus 0.01$
EM CALO	Lead/Liquid Argon $\sigma/E \sim 10\%/\sqrt{E} + 0.007$
HAD CALO	Fe-scint. Tiles 10 λ $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$
MUON	Air core toroids,precision and trigger chambers $\sigma/p_T \sim 3$ % at 100 GeV,10% at 1 TeV, stand-alone

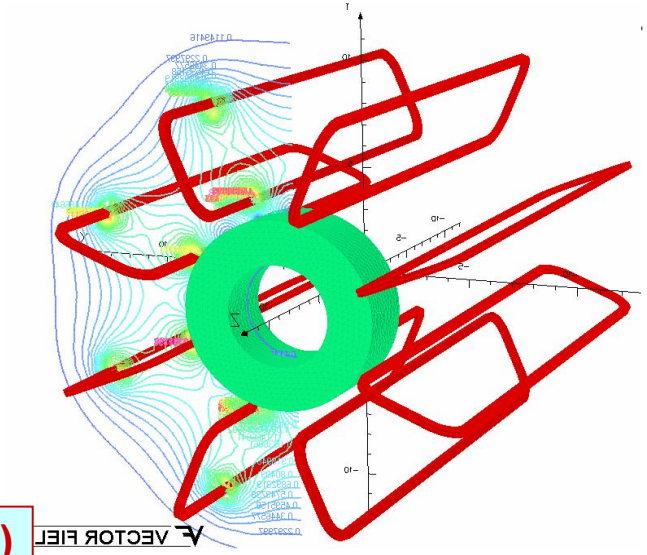
ATLAS superconducting magnets

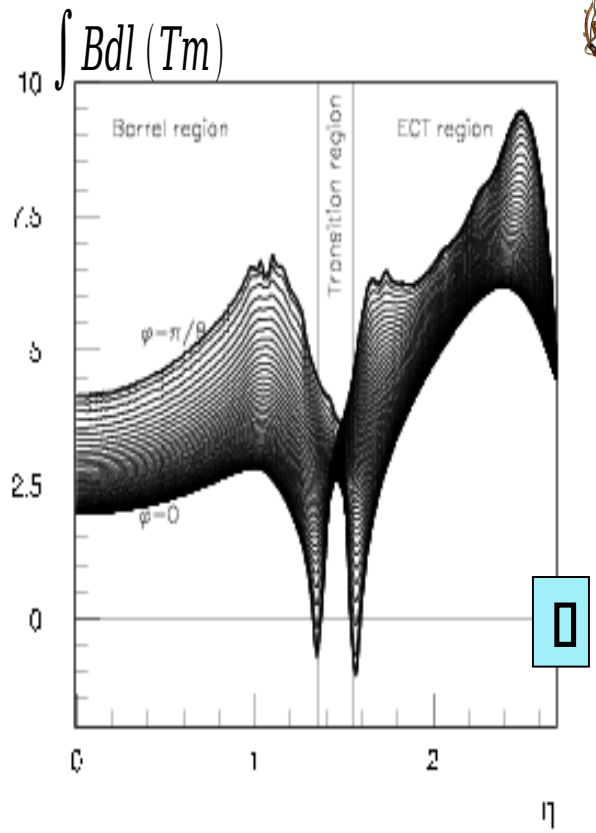
- Hybrid of 1 Central Solenoid, 1 Barrel and 2 End Cap Toroids
  - 2T magnetic field for inner detector (solenoid) and ~1T for the muon detectors (toroids)
  - 20 m diameter x 25 m long
  - 10000 m^3 field volume
  - 170 t superconductor
  - 700 t cold mass
  - 1320 t magnets
  - 7000 t detector
  - 90 km superconductor
  - 20.5 kA at 4.1 T
  - 1.6 GJ stored energy
  - 4.7 K conduction cooled
  - 9 yrs of construction 98-07



  - The largest system of toroids ever built !







❑ ATLAS Magnet System:

Central Solenoid
Barrel Toroid
End-cap Toroids

Central Solenoid

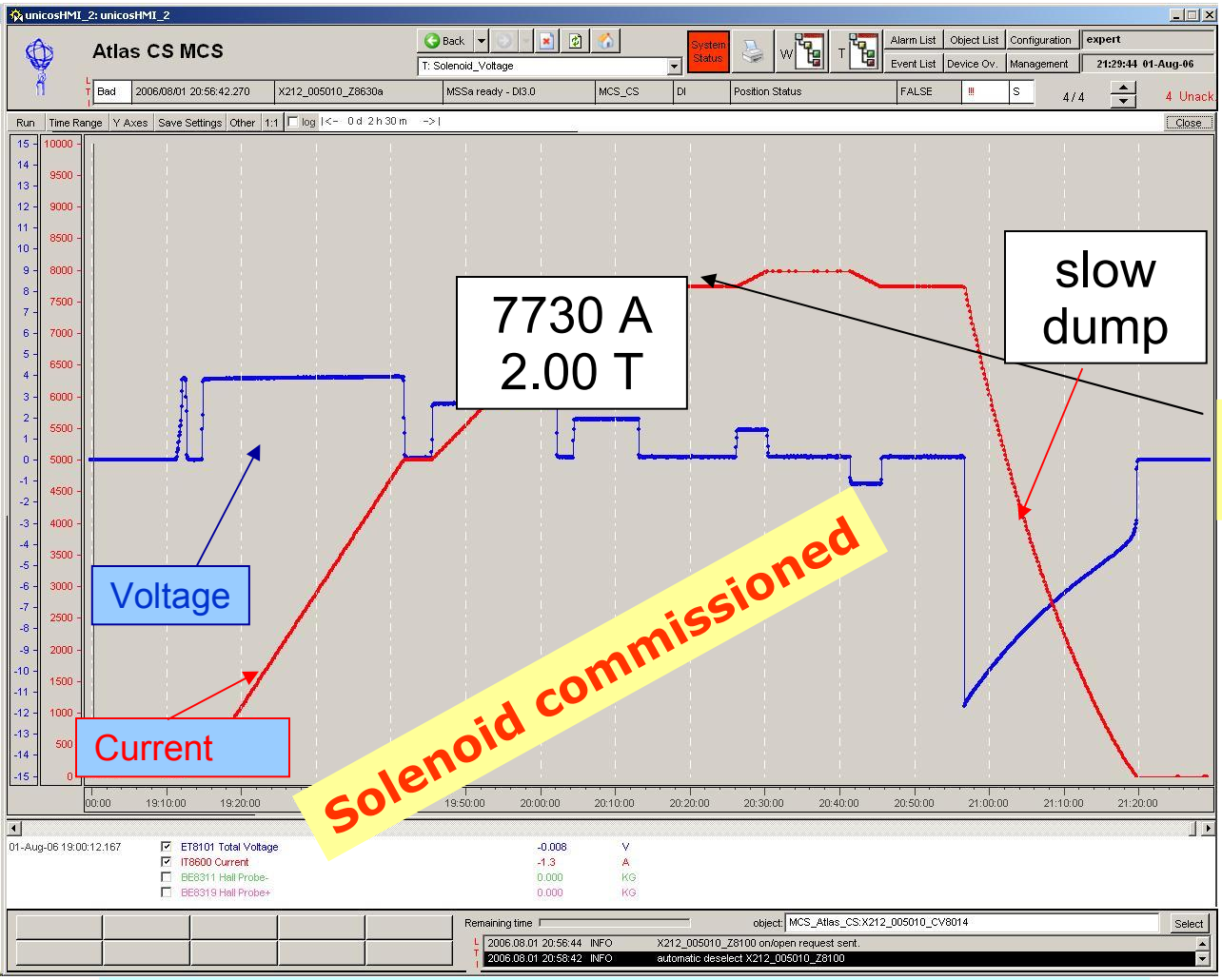
Provides 2T field with a stored energy of 38 MJ for the inner tracker

Integrated design within the barrel LAr em calorimeter cryostat

Minimize material before EM calorimeter

- **Inserted into the LAr cryostat in Feb. 2004**
- **Tested at full current (8 kA) in July 2004**

August 2006: Solenoid fully operational



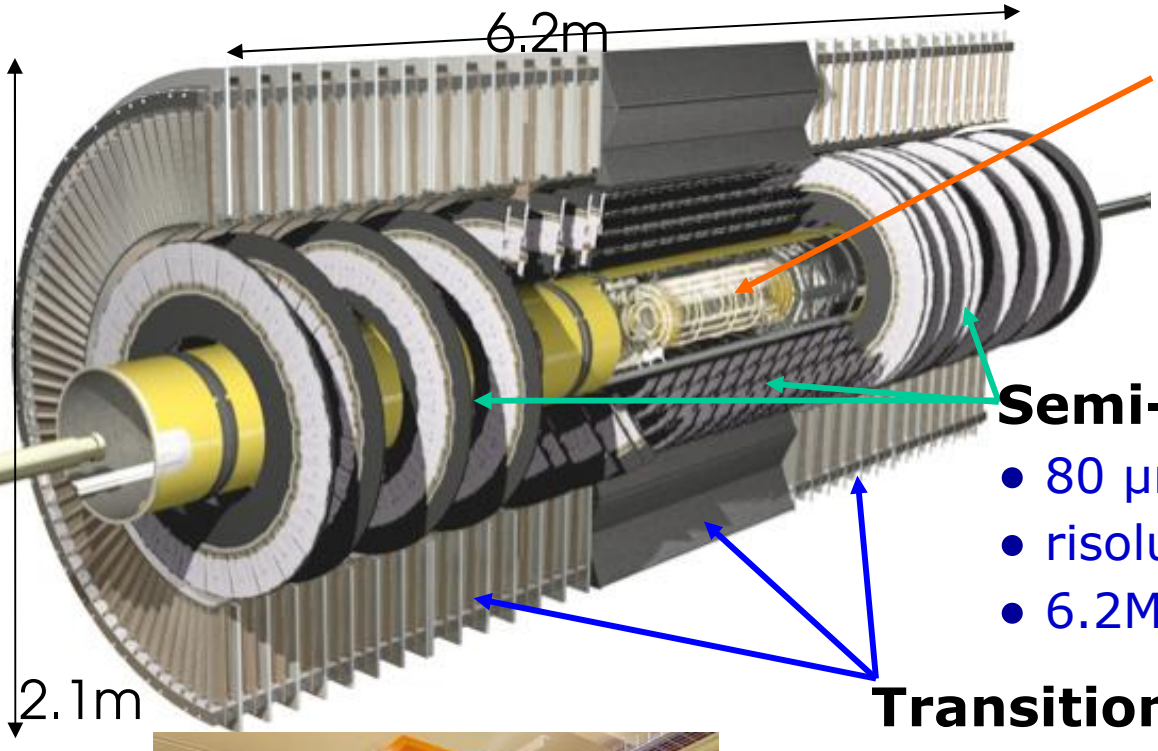
- **May 2006:**
  → **Cooled at 4 K**
- **July – August 2006:**
  → **fully commissioned *in-situ* up to 8.0 kA**

Operation current at 7.73 kA for 2.0 T field

Commissioning studies:

- **3 Fast Dump**
  Tmax = 100 K
- **Max. 8.0 kA (with iron)**

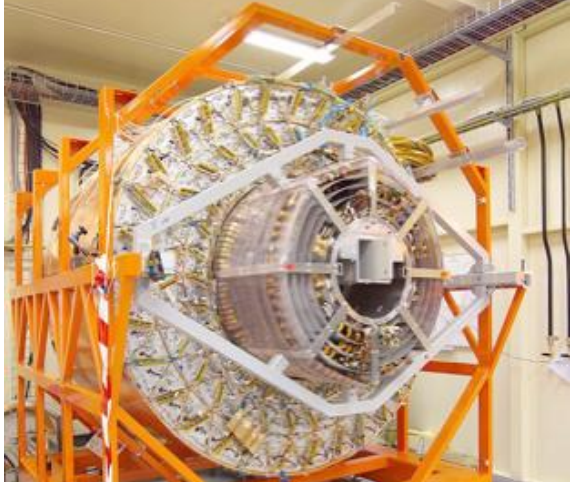
Tracciatore Interno



Pixel Detector
- 50 x 400 μm pixel
- risoluzione 12 x 100 μm
- 80M canali

Semi-Conductor Tracker (SCT)
- 80 μm pitch
- risoluzione 16 x 580 μm
- 6.2M canali

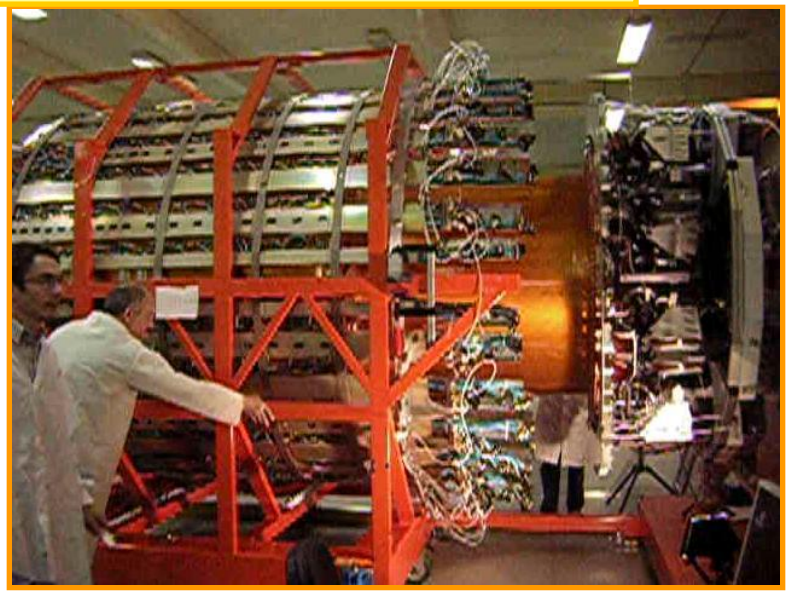
Transition Radiation Tracker (TRT)
- 4mm Ø straw, lunghe fino a 1.5m
- risoluzione 170 μm
- 298k canali

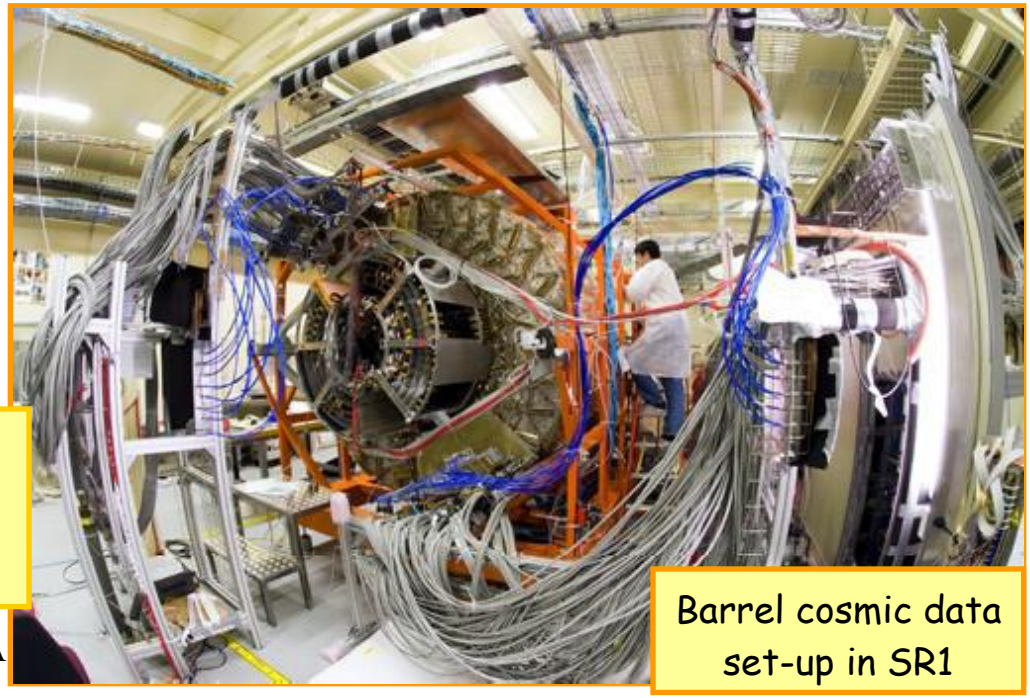


Integrazione SCT+TRT

barrel integration: february 2006

- endcapC september 2006
- endcapA november 2006





Cosmic data was taken at SR1 for the combined barrel and one of the combined endcaps,

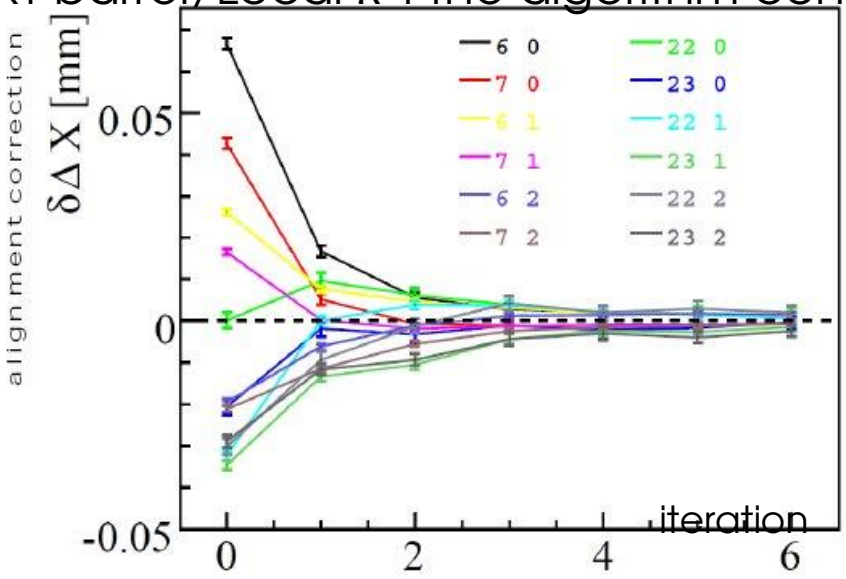
Barrel cosmic data set-up in SR1

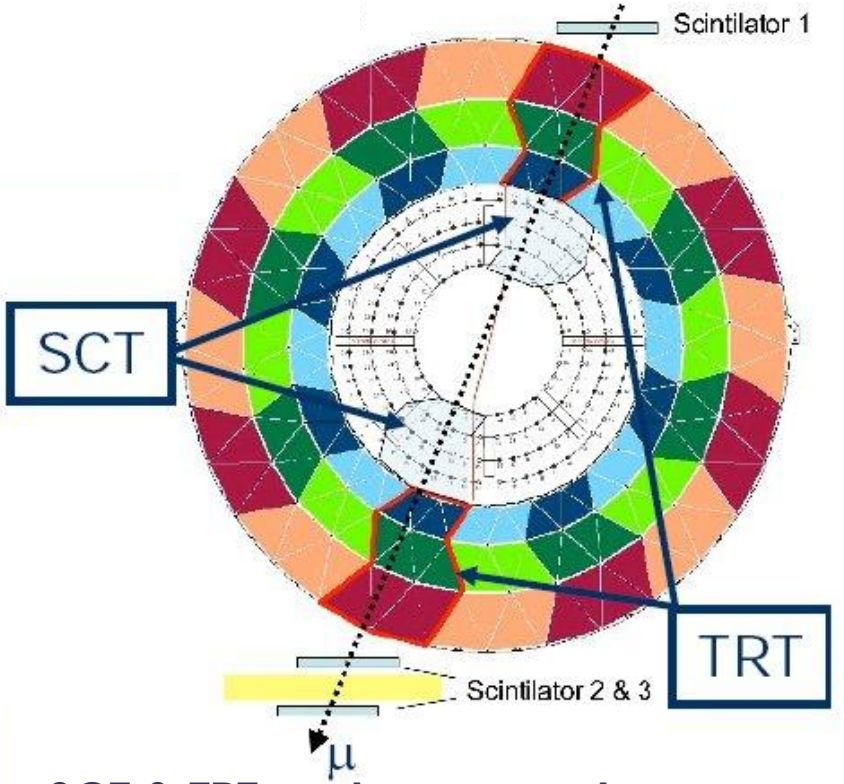
SCT/TRT Cosmics Test on Surface

2006 combined SCT & TRT barrel cosmic run:

- **22% SCT, 13% TRT barrel**
- **No B-field**
- **~400k events**

TRT barrel, Local χ^2: the algorithm converges



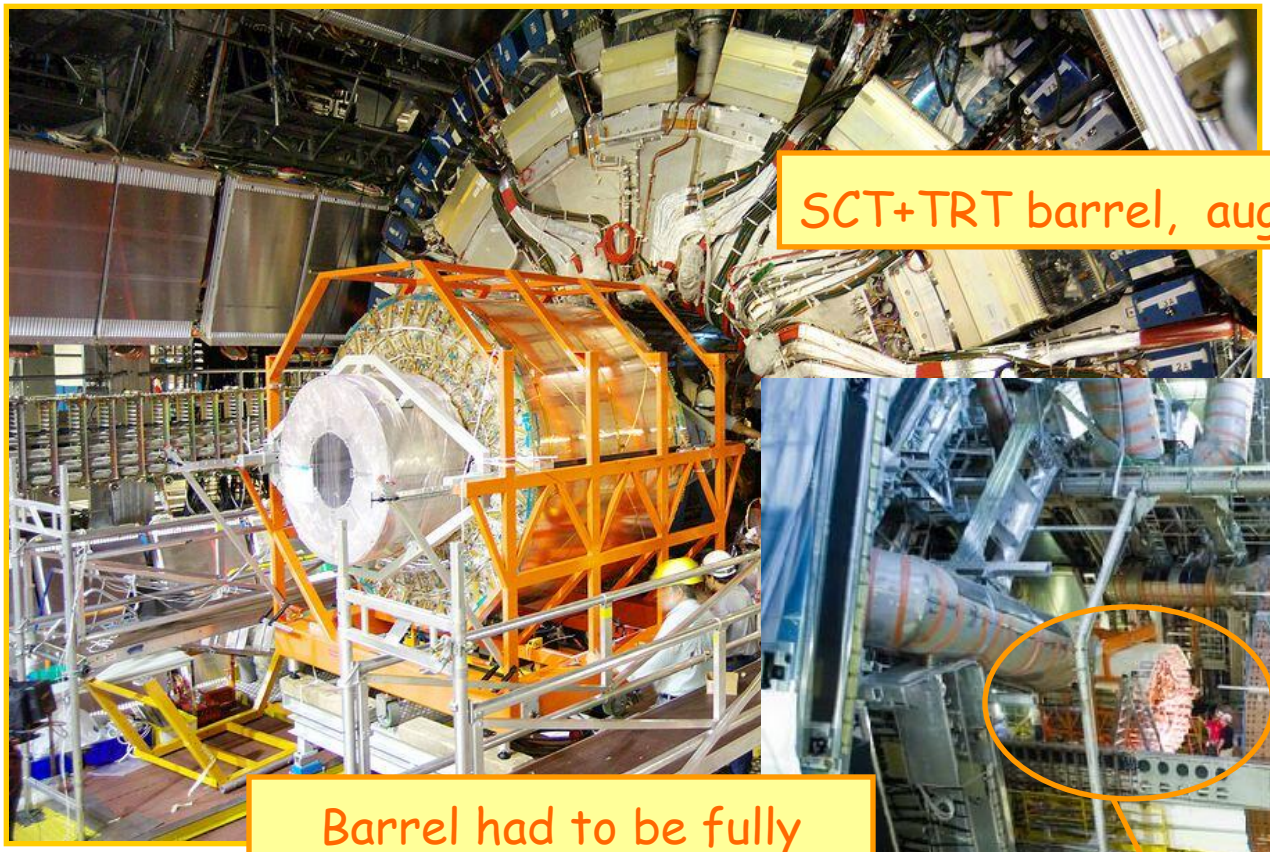


SCT & TRT endcap cosmic run:

Validation of survey data:

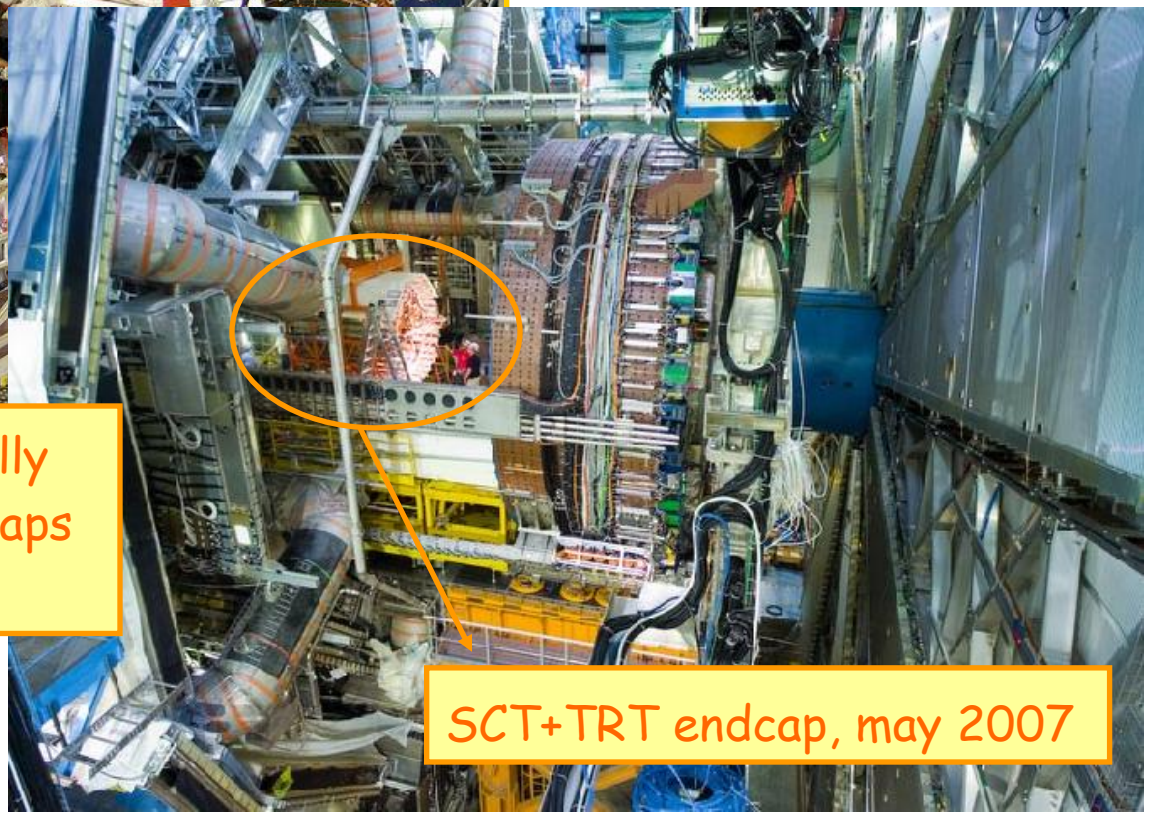
- **Usage of SCT survey information improves residuals by 10-20%**

Installazione SCT/TRT



SCT+TRT barrel, august 2006

Barrel had to be fully tested before end-caps could be installed!



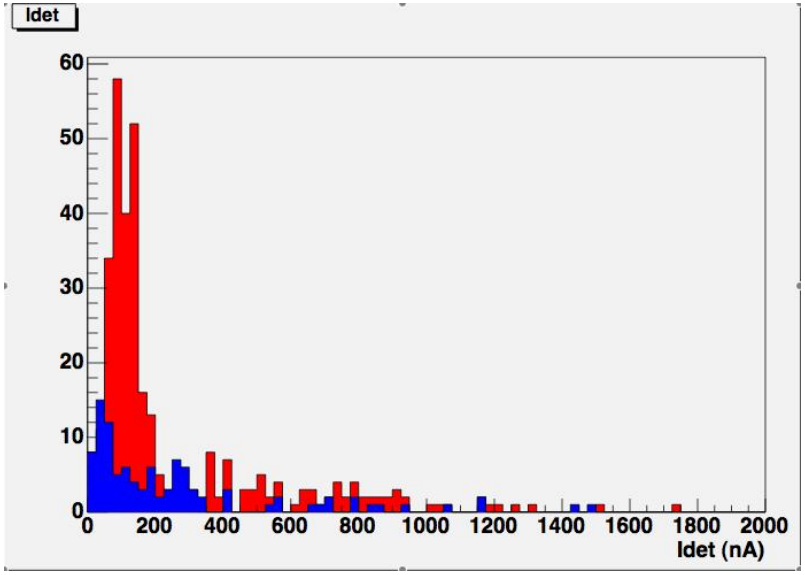
SCT+TRT endcap, may 2007

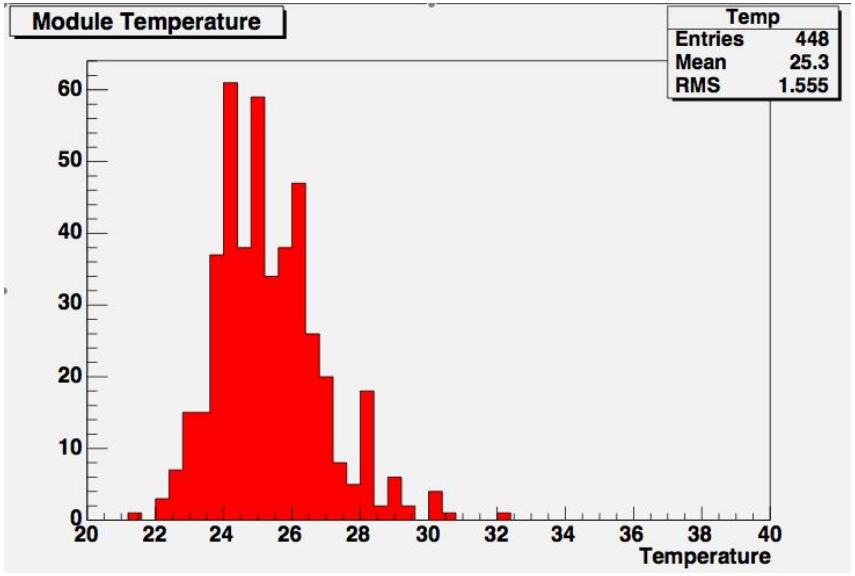
SCT (EndCap-A) Performance

Bias Current

Measured at 150V

All modules below 2μA





Module Temperature

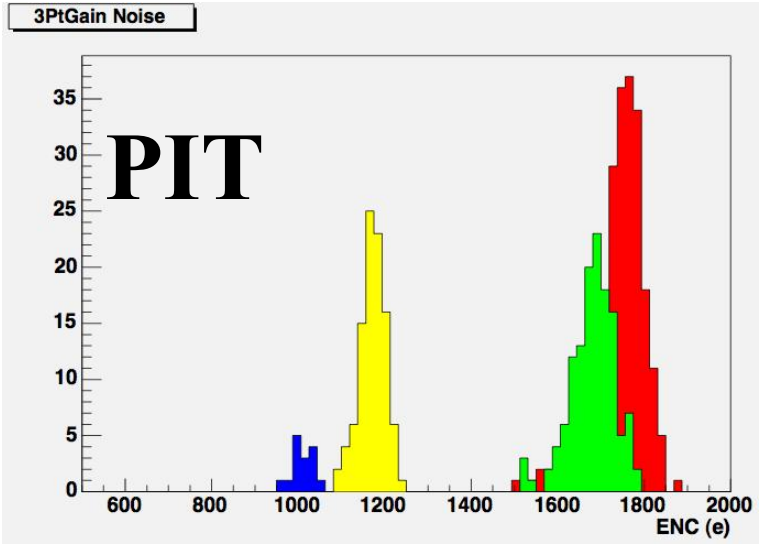
Average Temp = 25.3±1.5°C

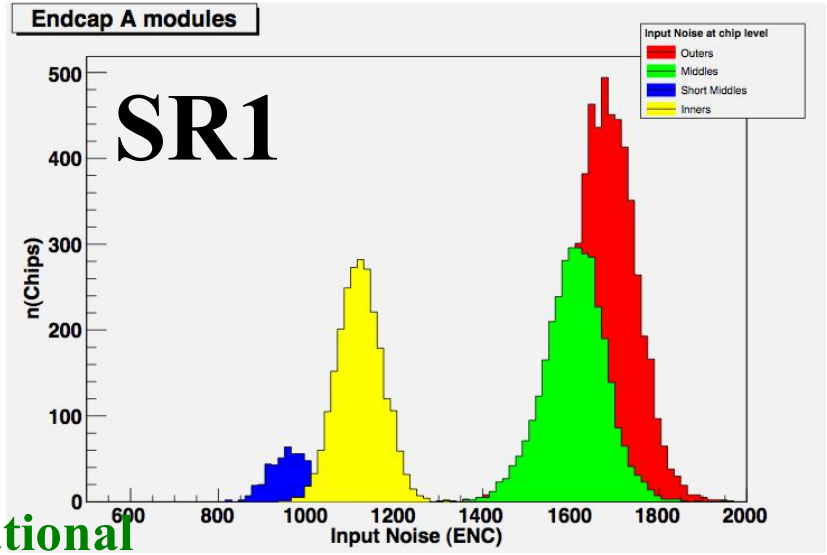
Uniform across detector

No hotter areas

SCT (EndCap-A) Noise

- **Pit Temperature = 25°C**
  - Outers: 1753 e
  - Middles: 1681 e
  - Inners: 1172 e
  - Short Middles: 1009
- **SR1 Temperature = 15°C**
  - Outers: 1675 e
  - Middles: 1609 e
  - Inners: 1121 e
  - Short Middles: 960 e
- Data agree with temperature difference

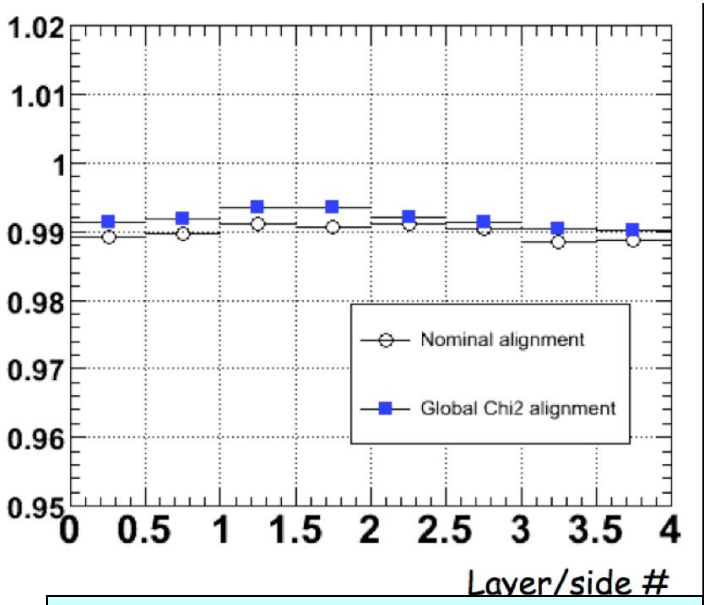




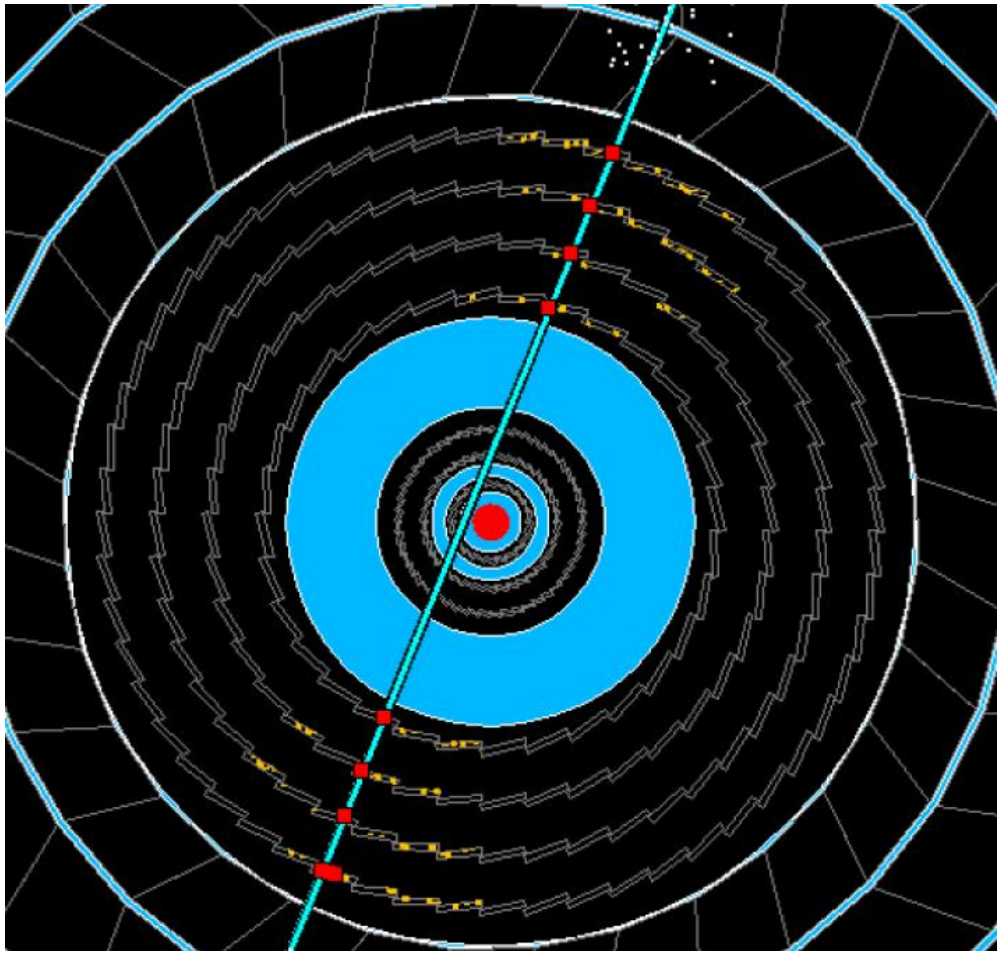
No Increase in noise when Barrel Operational

SCT Tracking with Cosmics

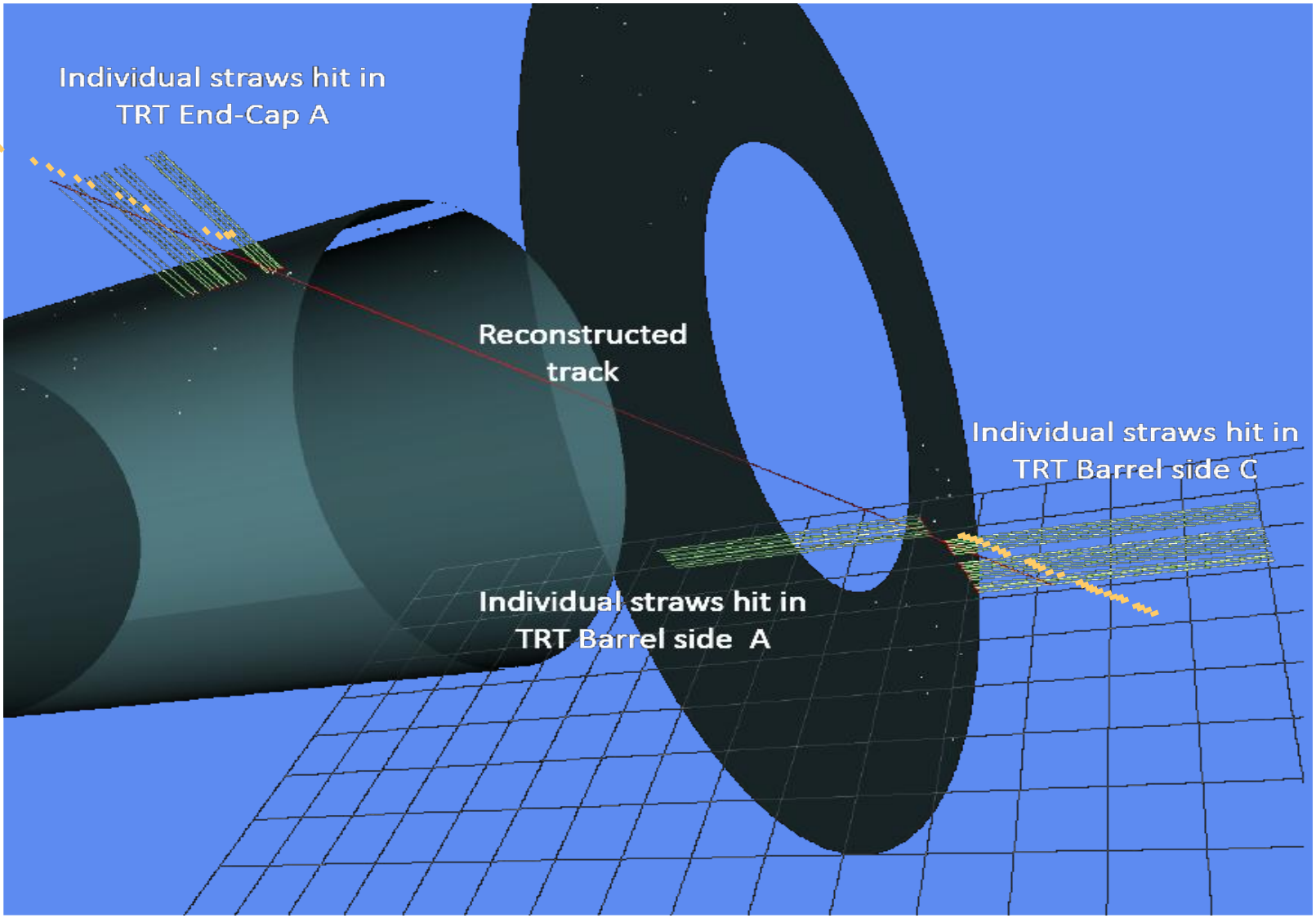
~9 million triggers taken in 'physics' mode, including ~450k cosmics triggers



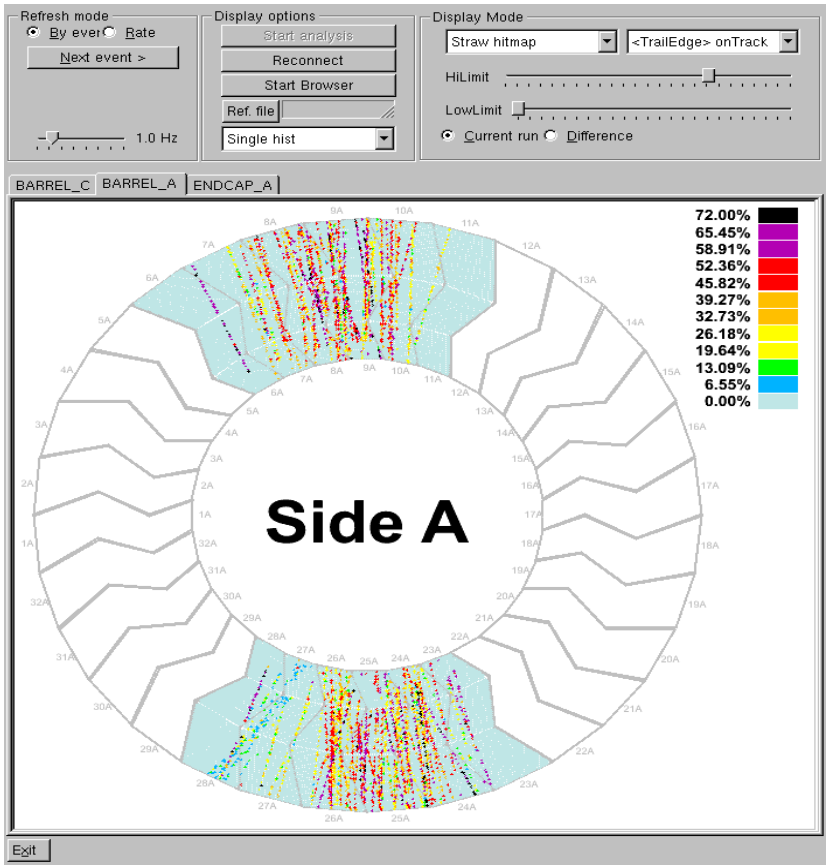
SCT Hit Efficiency after alignment >99%



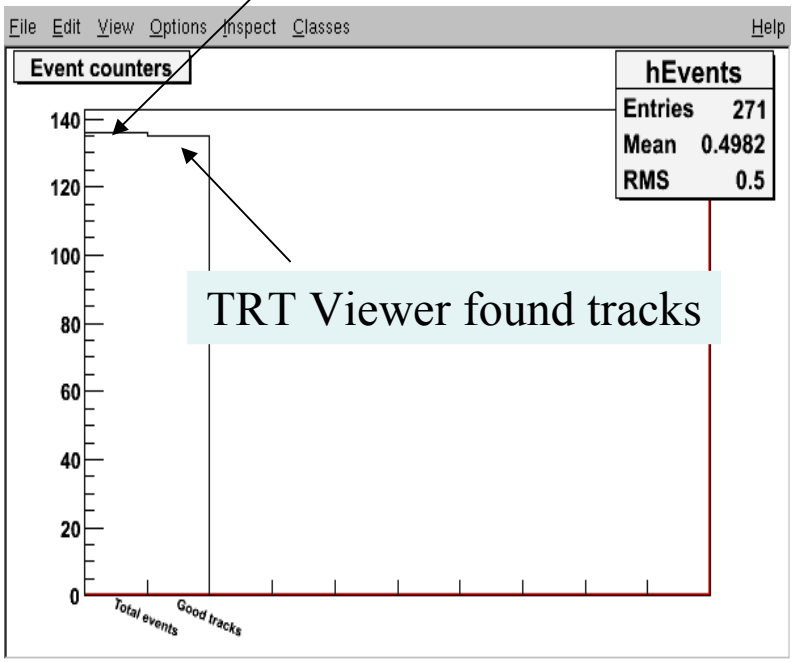
TRT in Milestone Week 5 (1)



TRT in Milestone Week 5 (2)



Events with L2 tracks

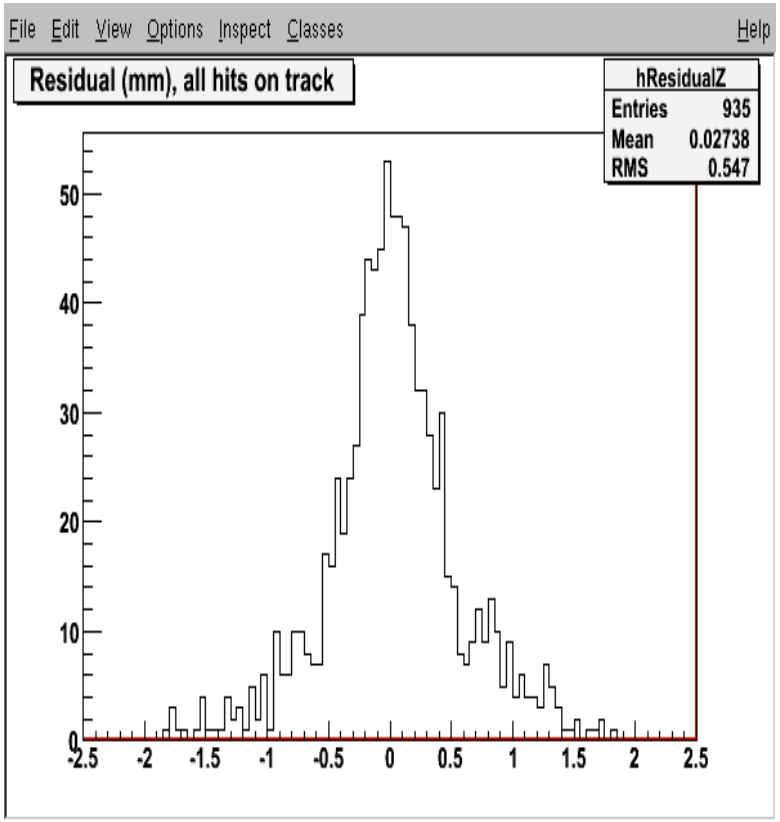


- **Efficiency of the L2 tracks with respect to TRTViewer monitoring**

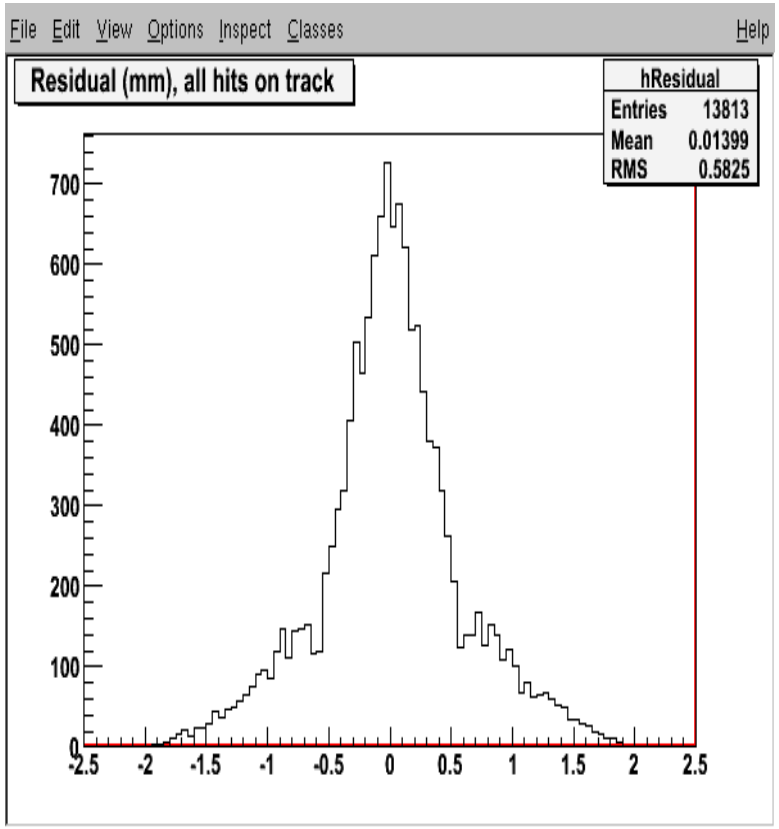
Trigger from scintillation counter (2ns jitter) and tile calorimeter

TRT in Milestone Week 5 (3)

One stack.



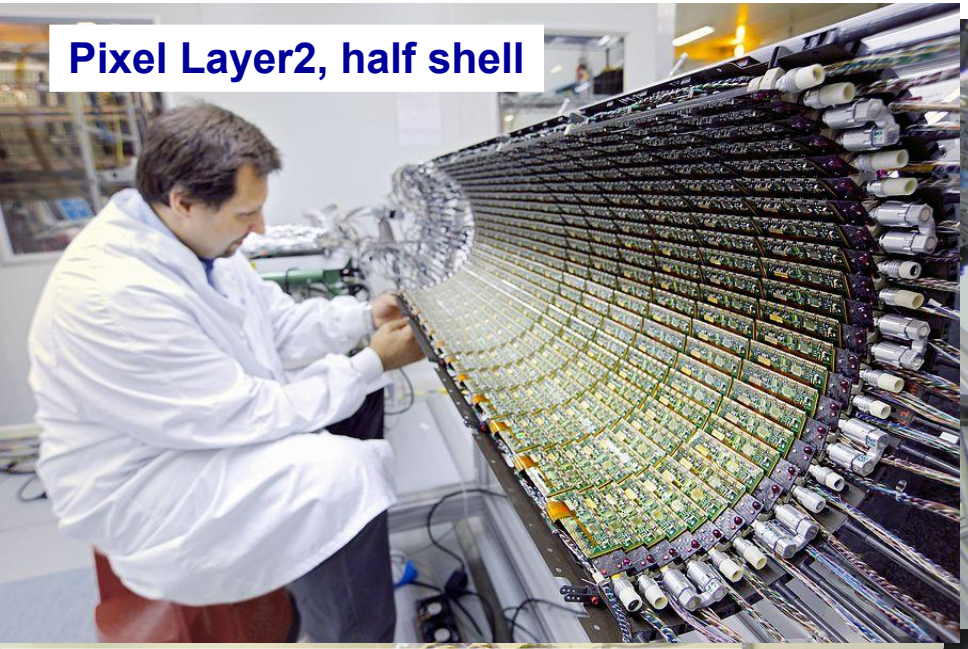
All stacks

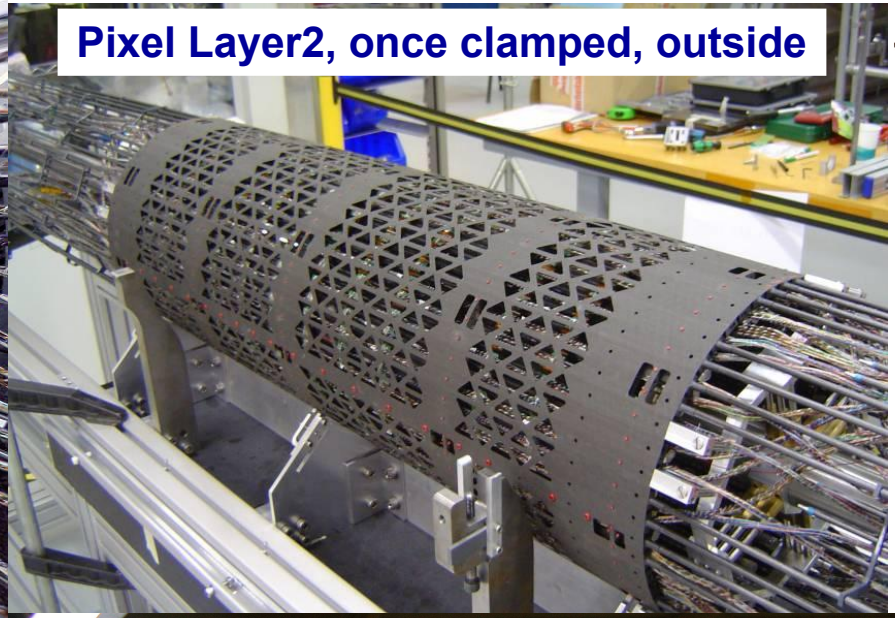


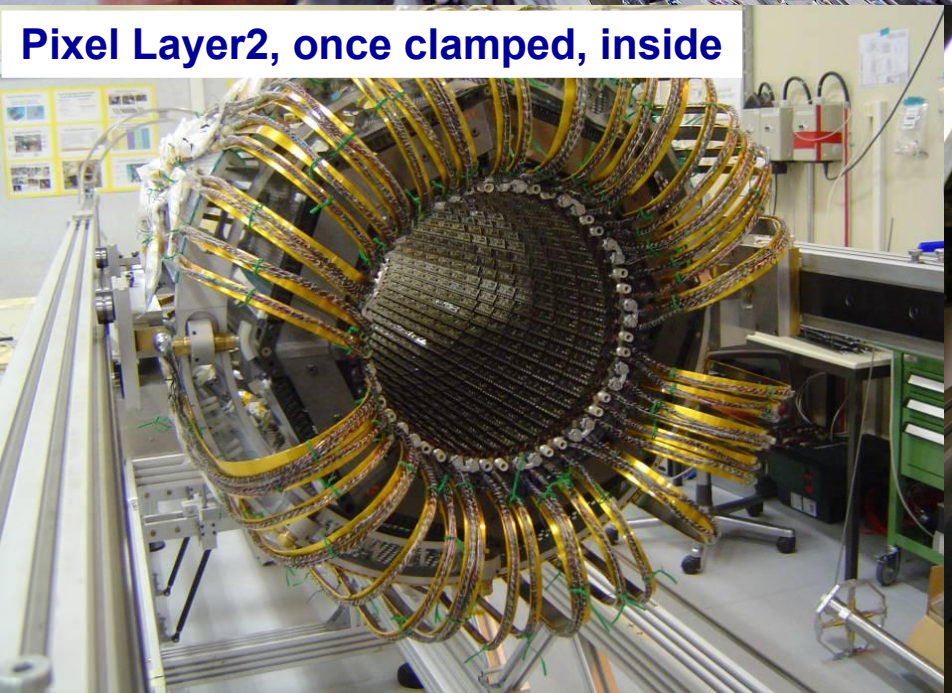
$\sigma \sim 300\ \mu m$. Expected $\sim 220\ \mu m$

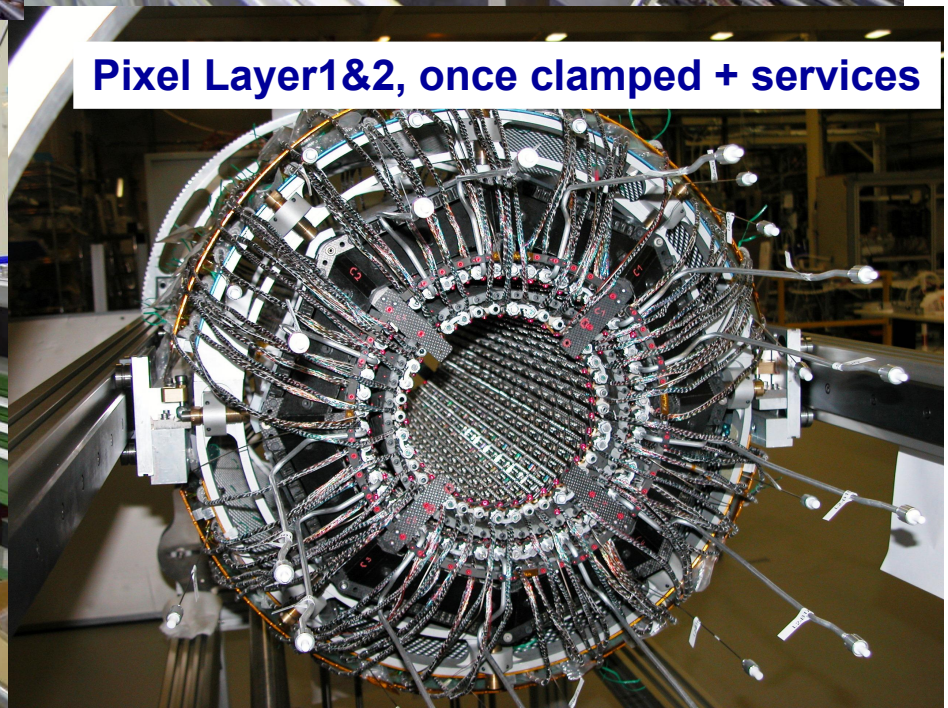
Possibly due to threshold/Gas Gain issue (ArC02 gas)

L1 and L2 Pixel Assembly

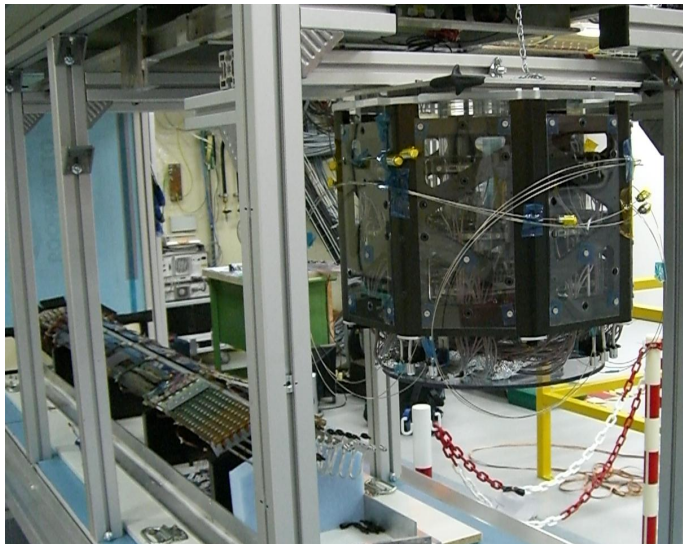








Pixel Cosmics Test on Surface

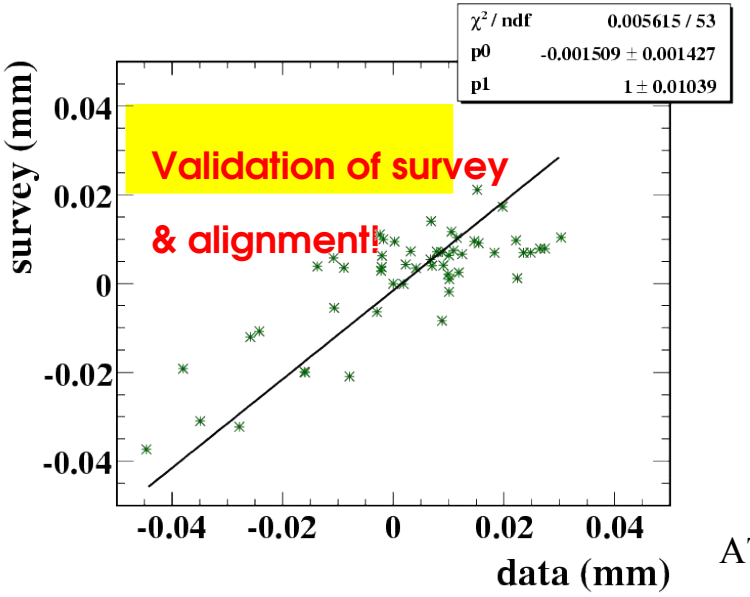


Test of one full Endcap

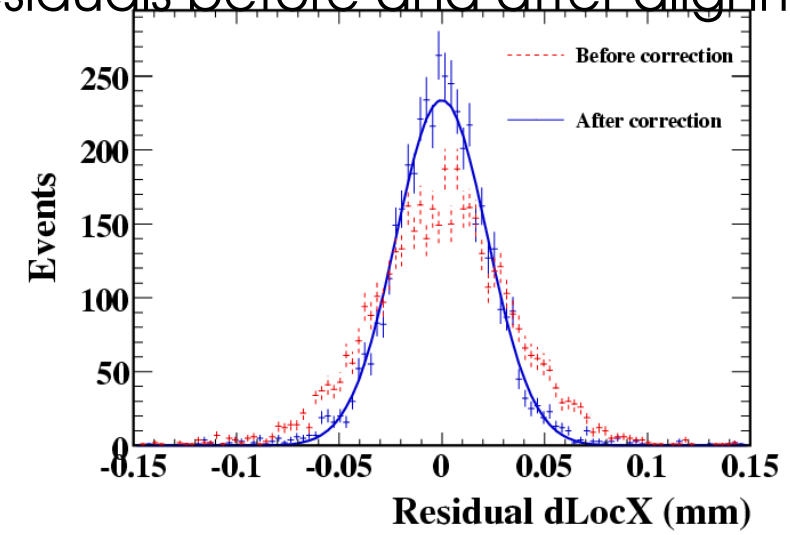
~150k cosmic tracks

Noise occupancy below 1E-8

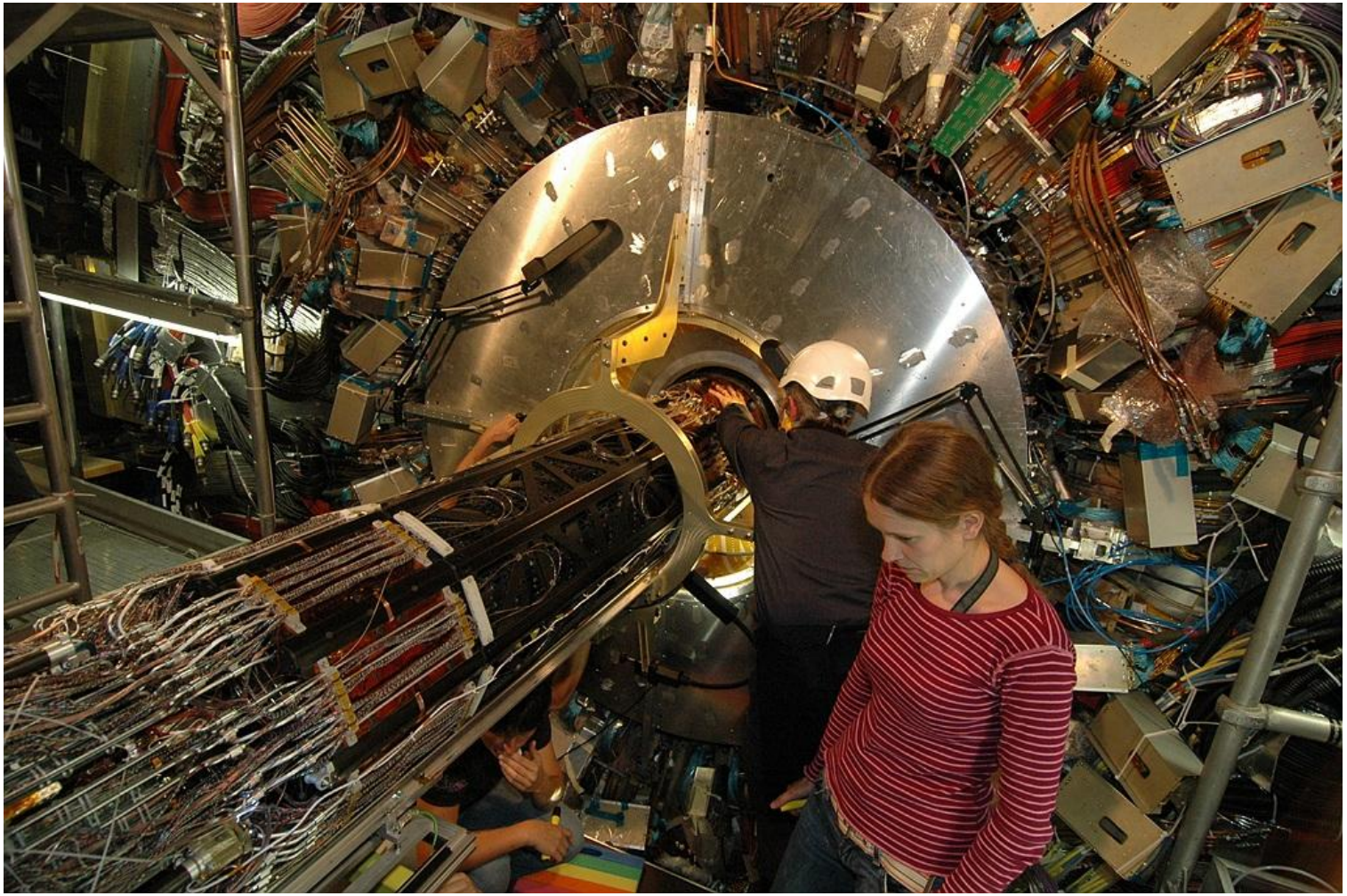
< 1% bad channels



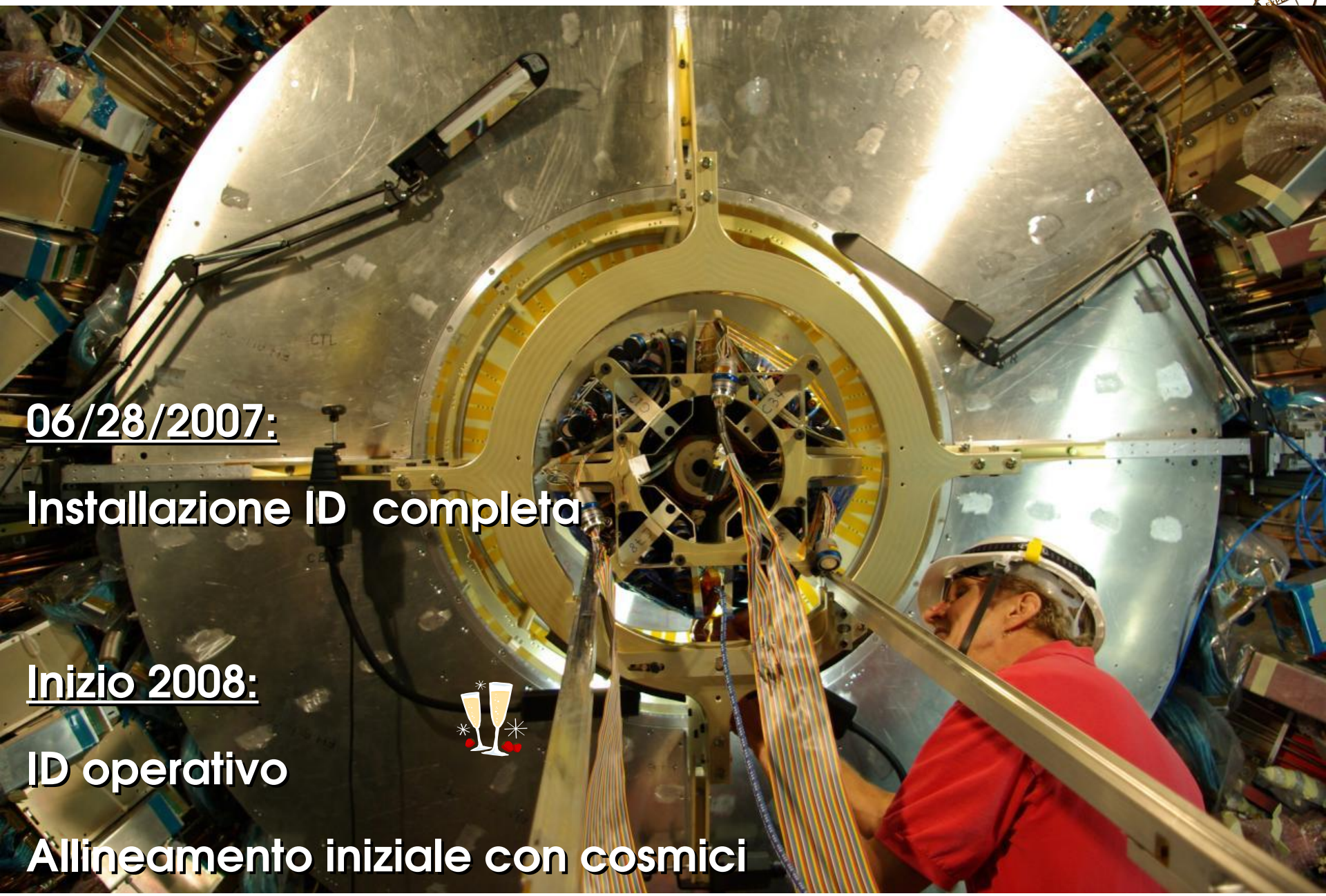
Residuals before and after alignment:



Installazione Pixel



Inserimento nell'ID il 26 giugno 2007



06/28/2007:

Installazione ID completa

Inizio 2008:

ID operativo

Allineamento iniziale con cosmici

Stato Tracciatore

- Rivelatori completamente installati da giugno 2007
- TRT e SCT cablati e commissionati
- Cablaggio Pixel iniziato il 5 febbraio
  - Termine previsto per inizi aprile
  - Certificazione prevista per fine aprile
  - Catena di lettura DAQ completamente testata (generazione di pattern casuali nella elettronica di lettura)
- Canali morti/rumorosi < 1%

… some concern

- Sorgente principale di preoccupazione (e di ritardo):
  - corrosioni e rotture a connessioni nel circuito di raffreddamento
    - ==> elementi critici (“evaporative heaters”) già sostituiti e spostati in zone meglio accessibili

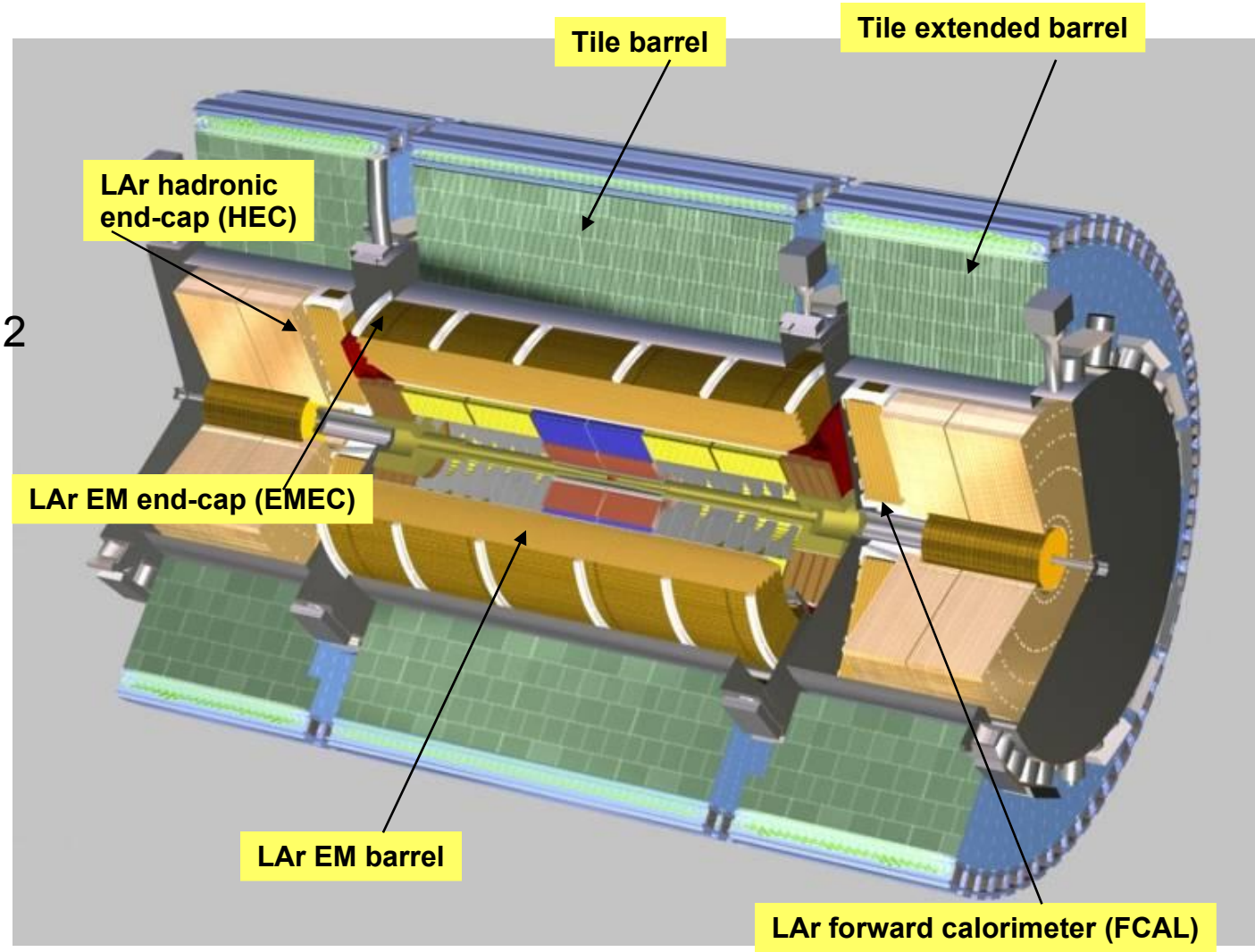
Calorimetri a LAr e a Tile

ECAL:

Accordion Pb/LAr
Barrel: $|\eta|<1.475$
Endcap: $1.375<|\eta|<3.2$

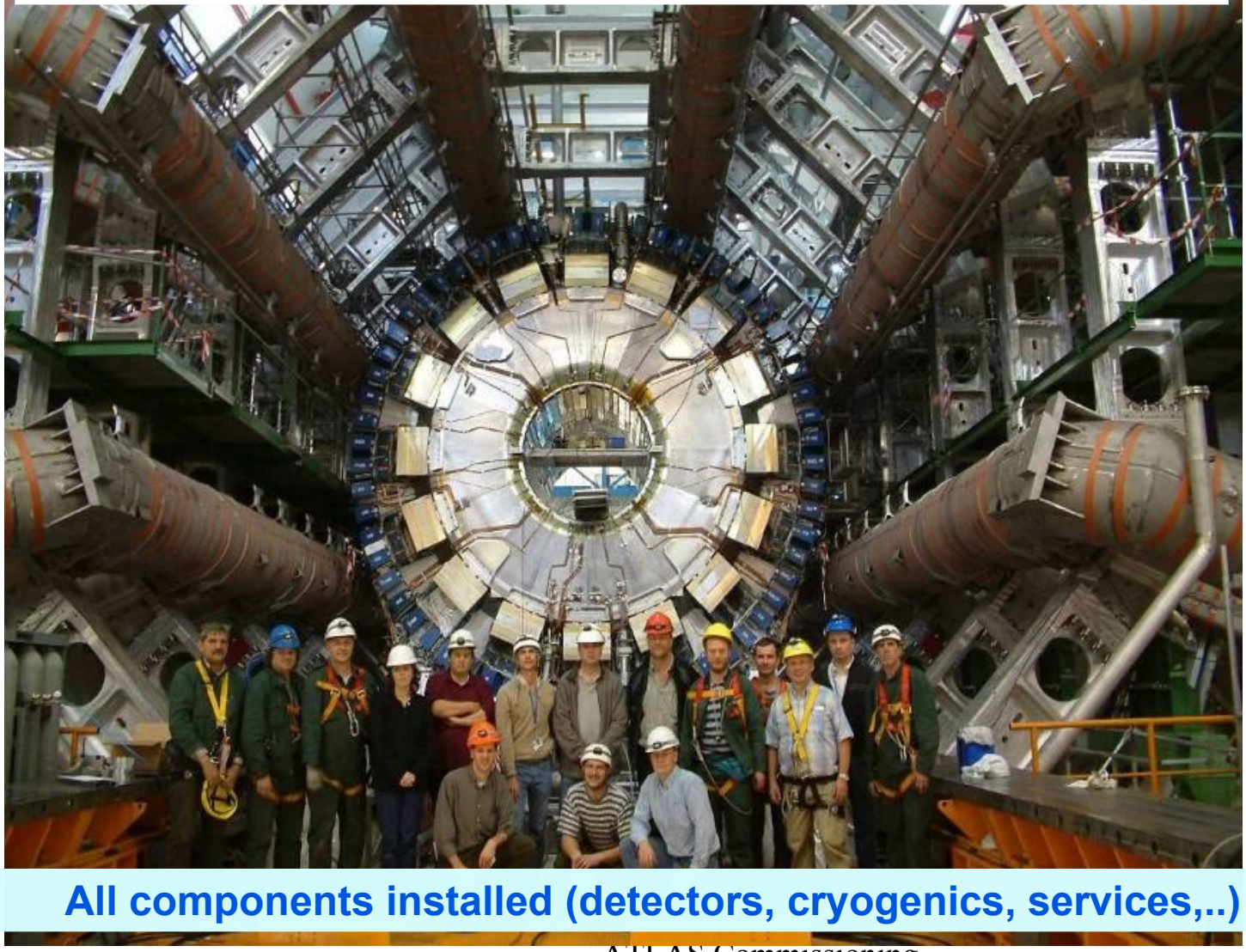
HCAL:

Tile: Fe/Scintillator
$|\eta|<1.7$
HEC: Cu/LAr
$1.5<|\eta|<3.2$
FCAL: Cu/W/LAr
$3.1<|\eta|<4.9$



Barrel Calorimeters (LAr + Tiles)

November 4th 2005: moved to the center of ATLAS



All components installed (detectors, cryogenics, services,..)

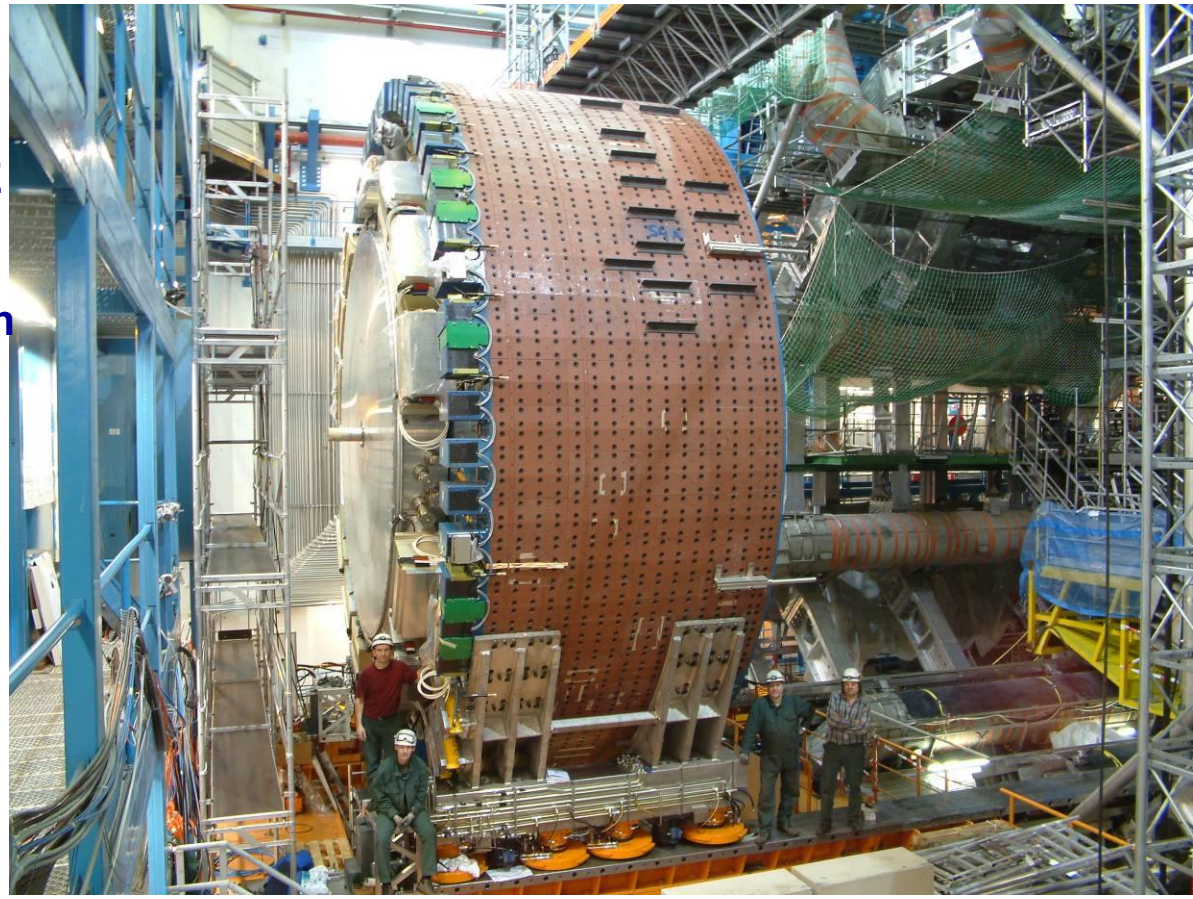
End-Caps LAr and Tile Calorimeters

End-cap Side C : assembled in the cavern by January 2006
End-cap Side A : assembled in May 2006

Main end-cap LAr activities:

EC-A:
- Since August 06 installation of FE electronics
- November 2006 start cool down
- February 2007 start cold operation

EC-C:
- Since April 06 installation of FE electronics,
- February 2007 start cool down
- April 2007 start cold operation



Completed end-cap calorimeter side C, just before insertion

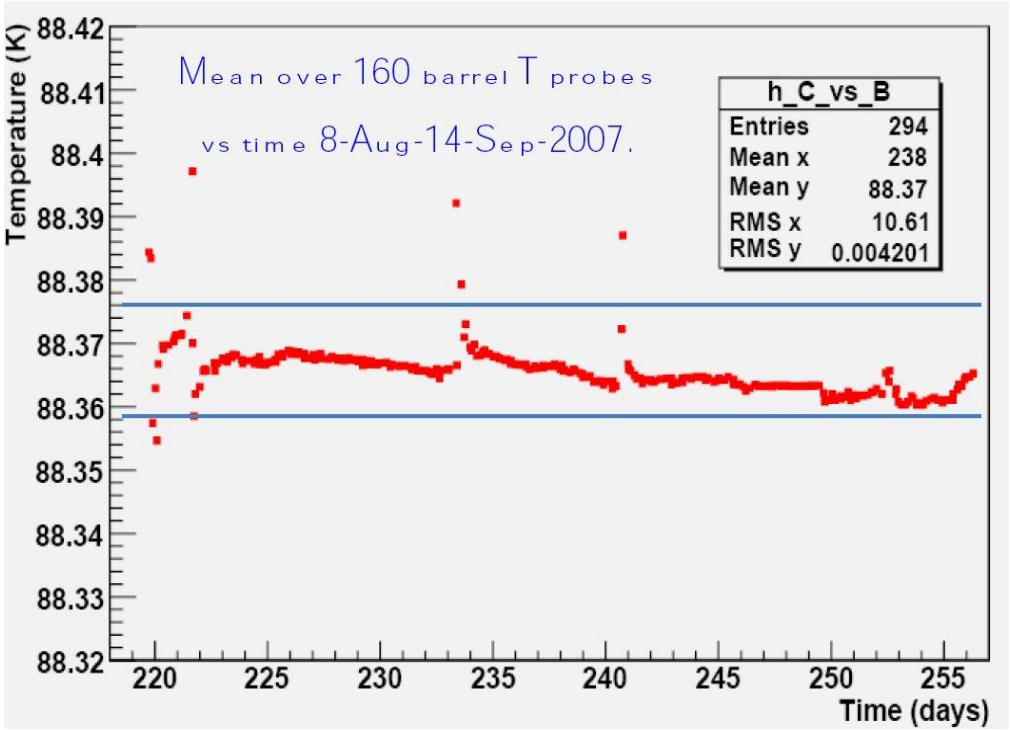
Lar Status

All cryostats filled and operated continuously for several months

Liquid purity stable and well below 0.5 ppm

Calorimeter Temperature very stable, average within +-10 mK.

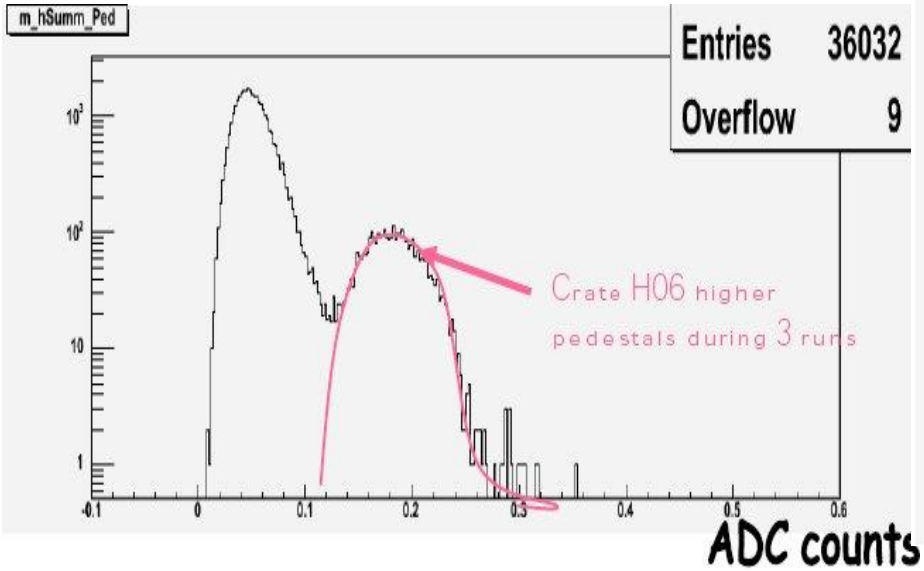
All back-end electronics available in the readout

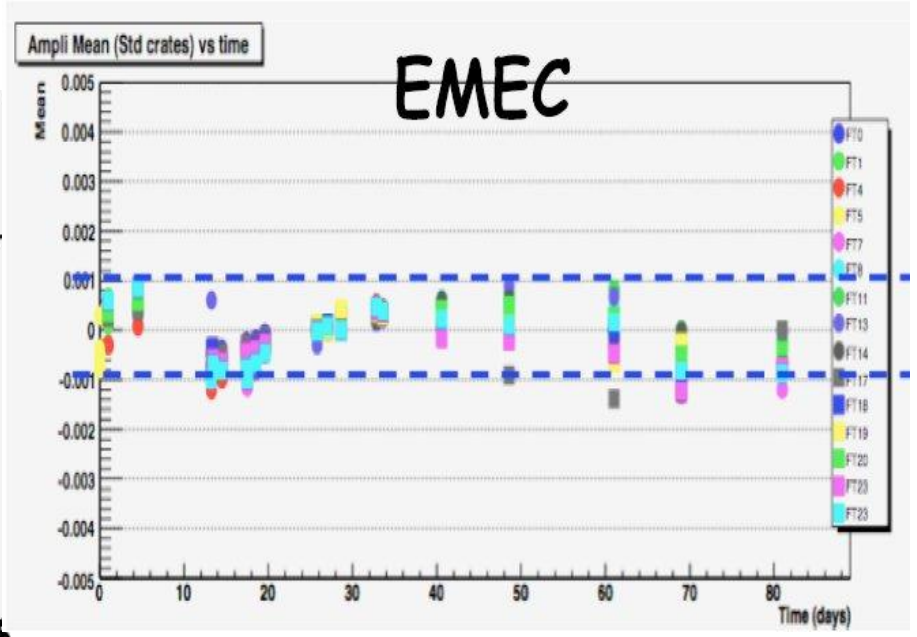


Lar Commissioning

- **Pedestal (noise) stability within ~0.05 ADC**
- **Calibration pulse stability < 1%**

- Pedestal variation over 4 months

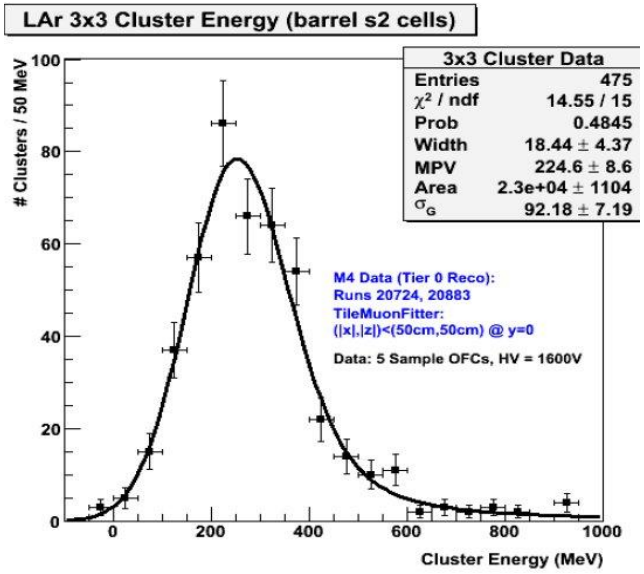




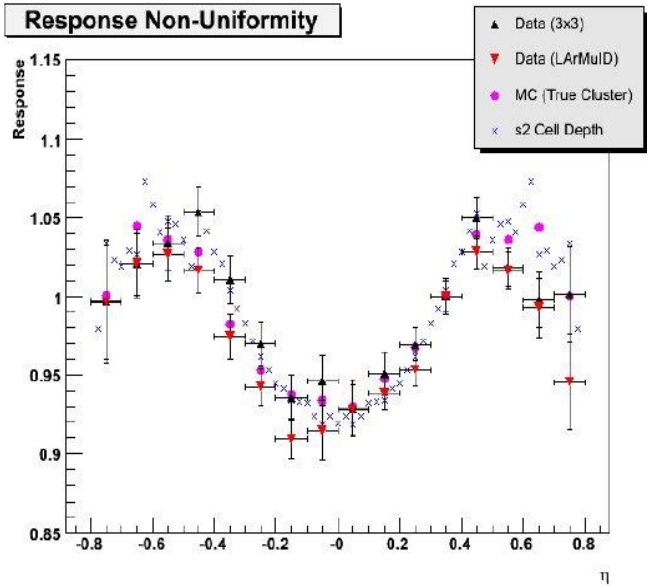
LAr Commissioning with Cosmics

- **Data taking on week-ends and M. weeks**
- **Rate: 15 ev/min, Tile triggered**
- **About 500k events registered since Aug 06**

- **Optimize timing, intercalibration, uniformity**



- Most probable value vs η



Desaster

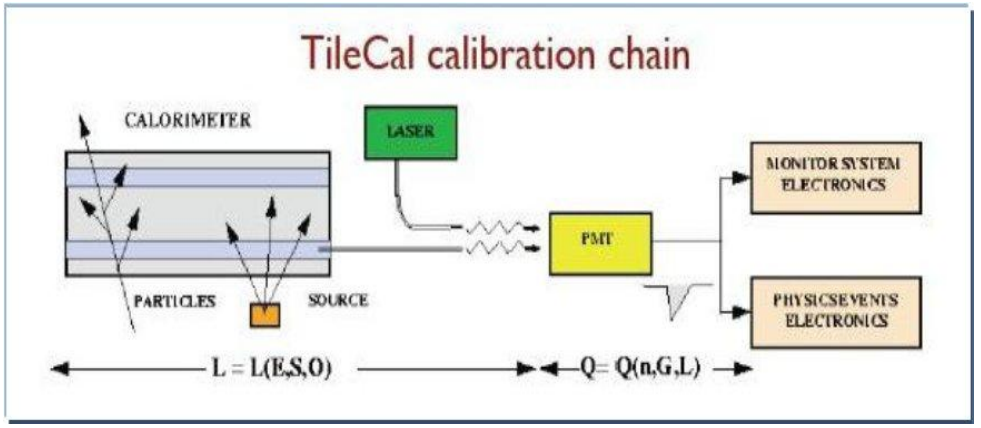
Nov: EC Toroid destroys cryoline of LAr End-cap C

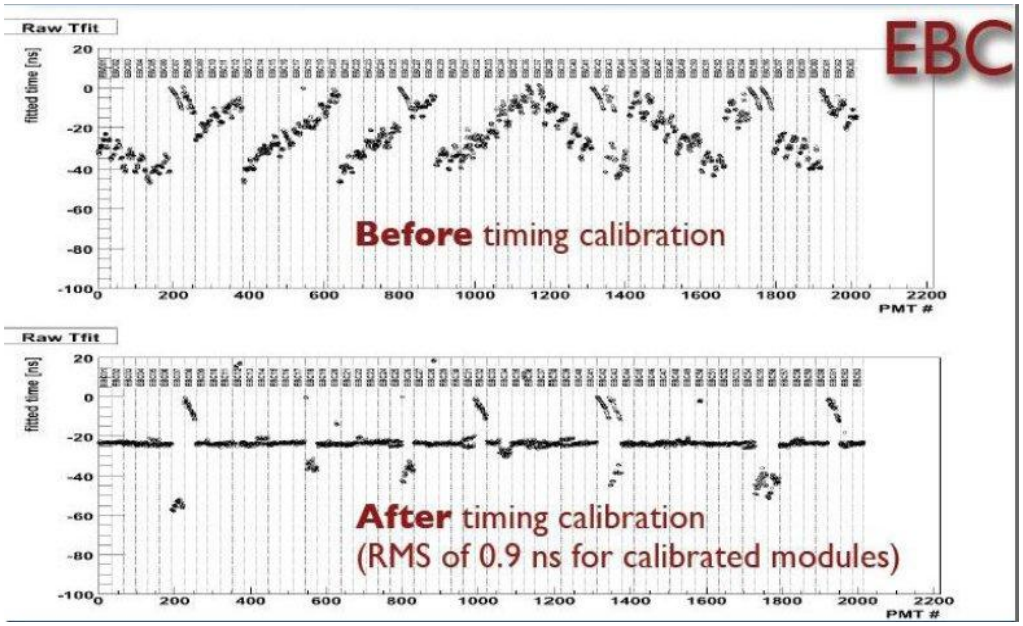
Formation of bellows in place on cryoline of LAr End-cap C

Cryoline of LAr End-cap C successfully repaired

Tile Hadronic Calorimeter

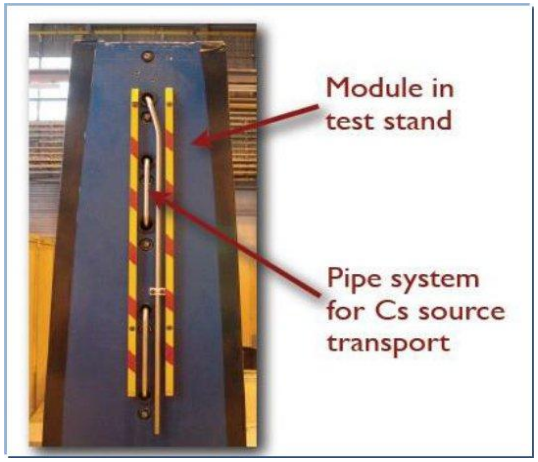
- **Commissioning with laser:**
  - **pulse all PMT at the same time**
  - **test full readout chain**
  - **equalize arrival time**
- **Charge injection:**
  - **inter calibrate electronics chain**

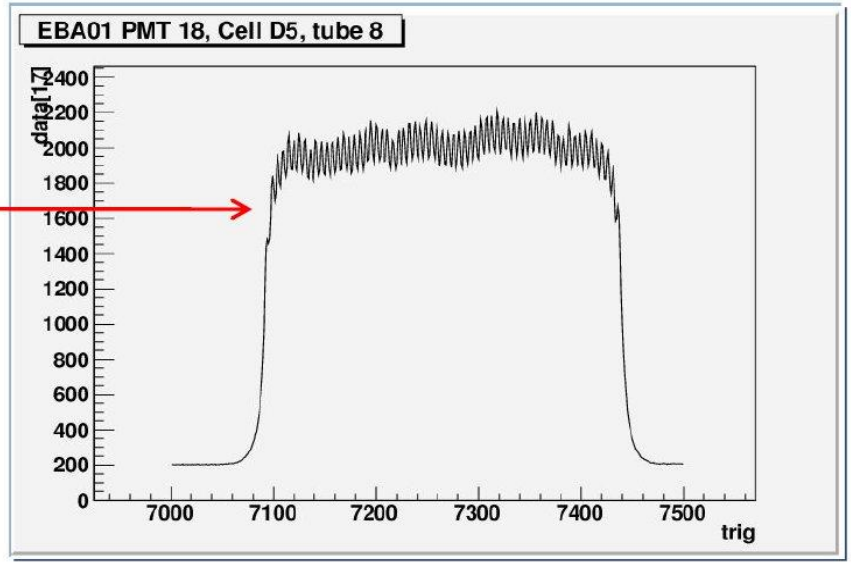




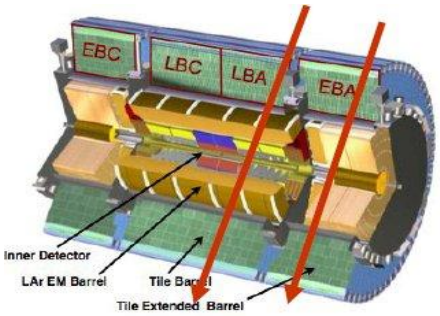
Tile Commissioning with Source

- **Hydraulically moved Cs source of ~10 mCi**
- **Dedicated calibration run, with source traversing each one of 463k tiles**
- **Tune HV setting and inter-calibrate response of each readout channel**

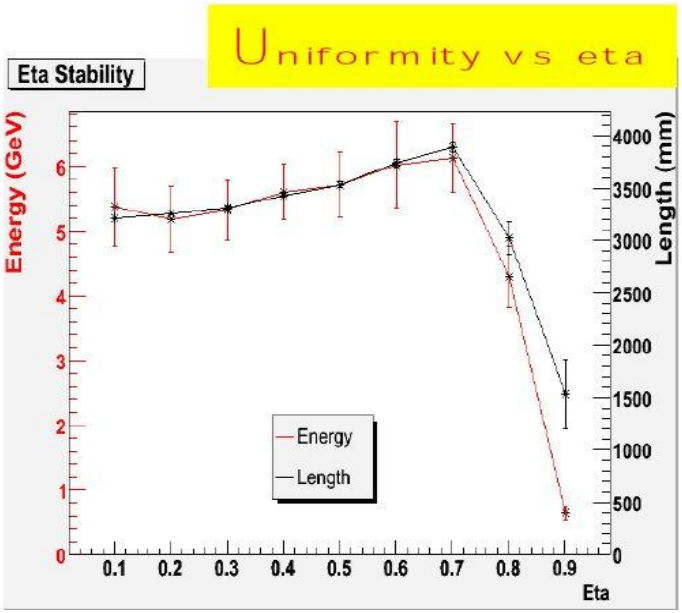




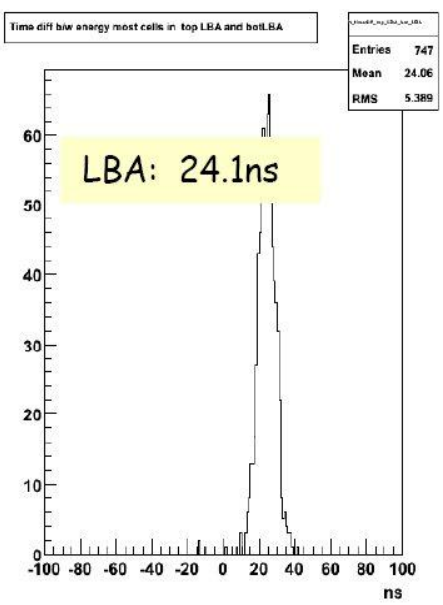
Tile Commissioning with Cosmics

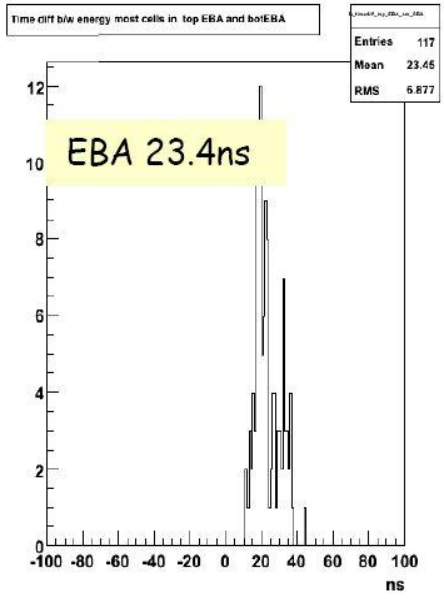


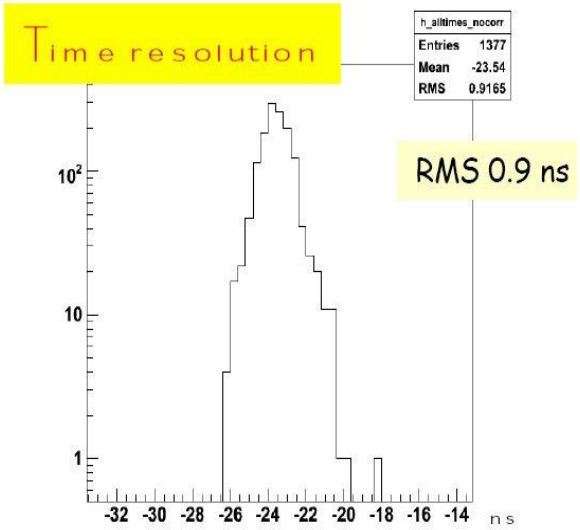
- **Energy deposition**



- **Time of flight measurements**

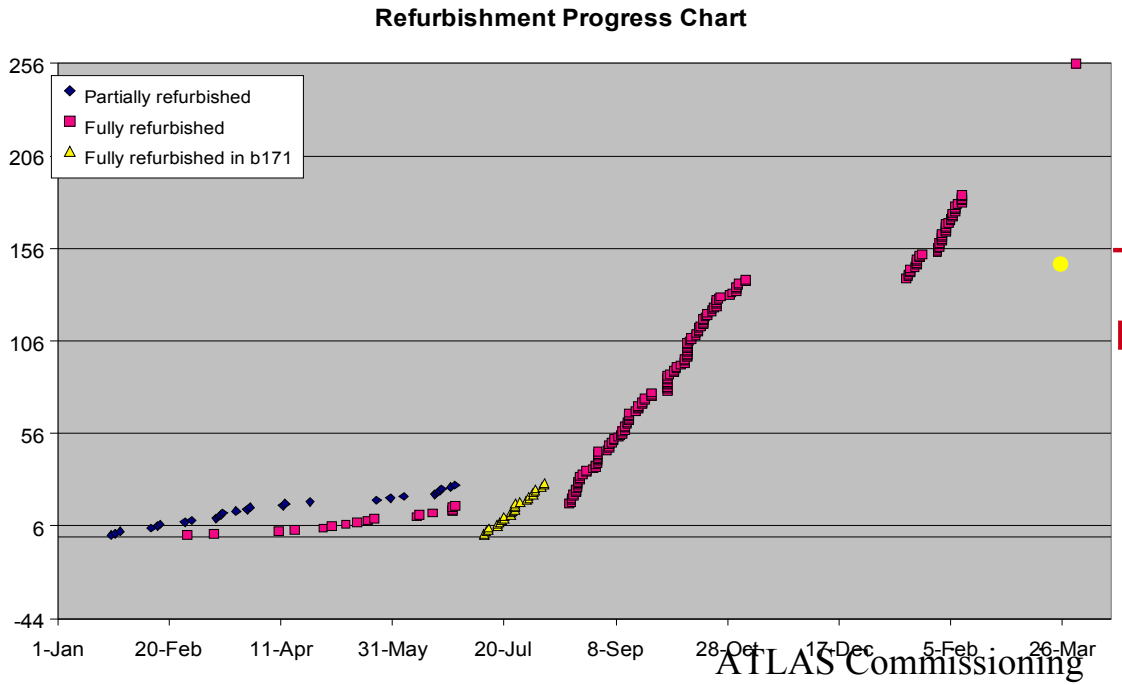






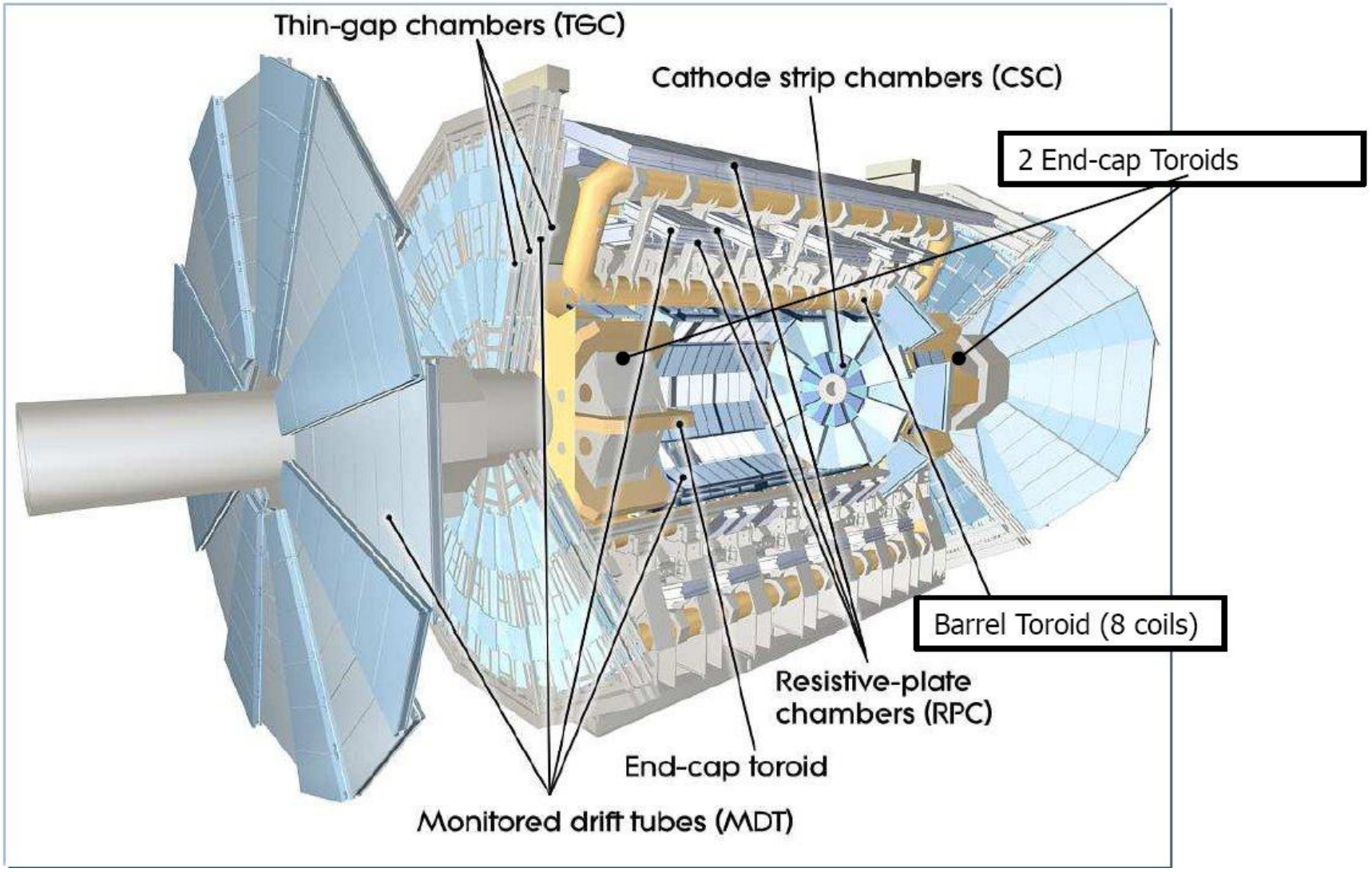
Some more minor fun …

- Both for Lar and Tile, several components needed retrofitting/refurbishing:
  - High voltage power supplies
  - Low voltage power supplies (MTBF still an issue for LAr: looking for backup solution)
  - Front end electronic board (work on going)



Tile Drawers refurbishing

Spettrometro a muoni



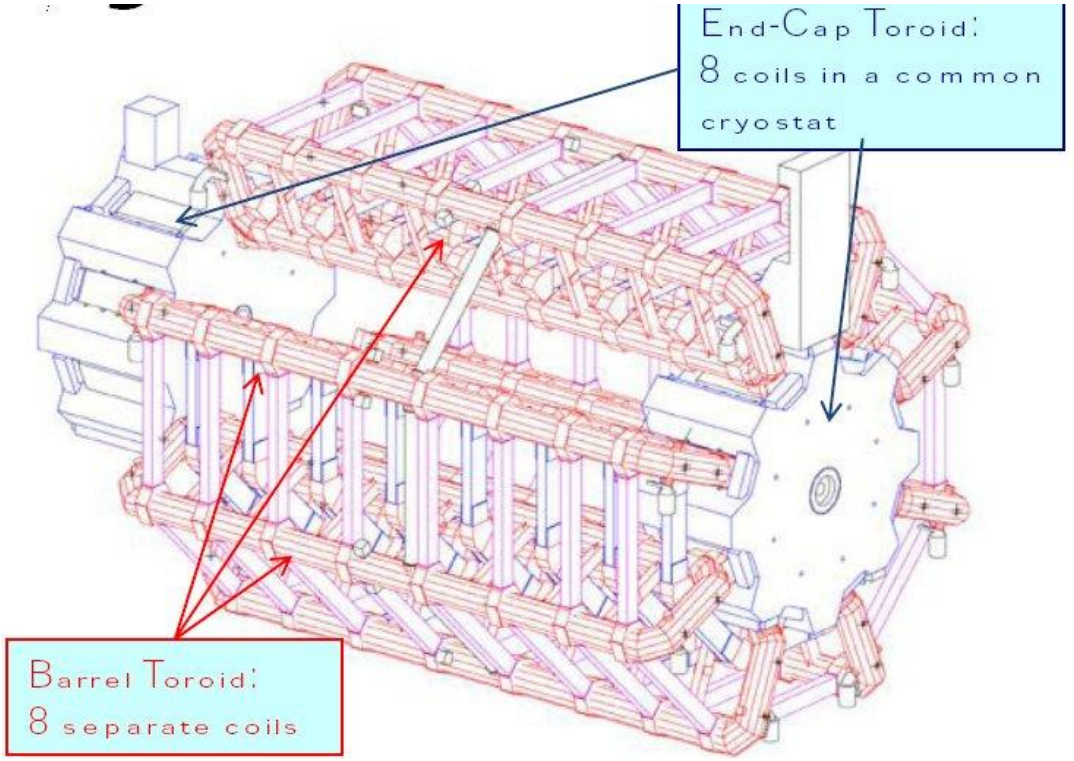
Toroidal Magnetic Field

Large volume air core system: strong bending powel with minimal multiple scattering

Barrel toroid tested at 20.5 kA

End-caps tested at

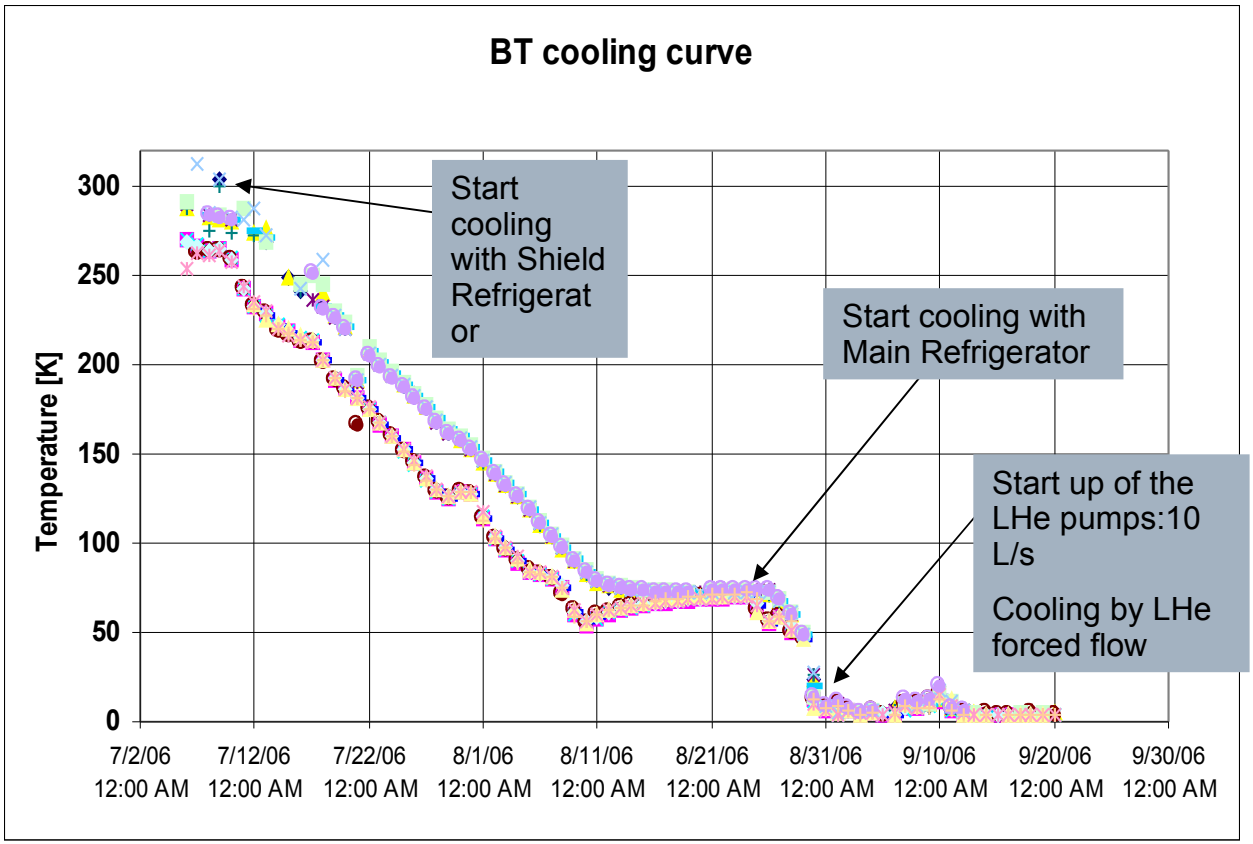
10 kA (not in final position)



Barrel Magnet Toroid cooling down

- **All magnet services connected and operational** (vacuum, power, cryogenic)
  - Vacuum < 5 10^{-5}mbar reached
- **Started on 3 July, takes 5 weeks nominally**
- **Finally cooled down at 4.7K on 30th August**

….



Barrel Magnet Toroid tests

- **Phase I (27 Sep - 14 Oct) : 0-300A**

  Cleaning: Large platforms removed

  - **Test of toroid inductance, resistances, fine tuning of coil cooling, identification of quench heaters etc.**
  - **Check of cabling, identification of all sensors**

  -> OK

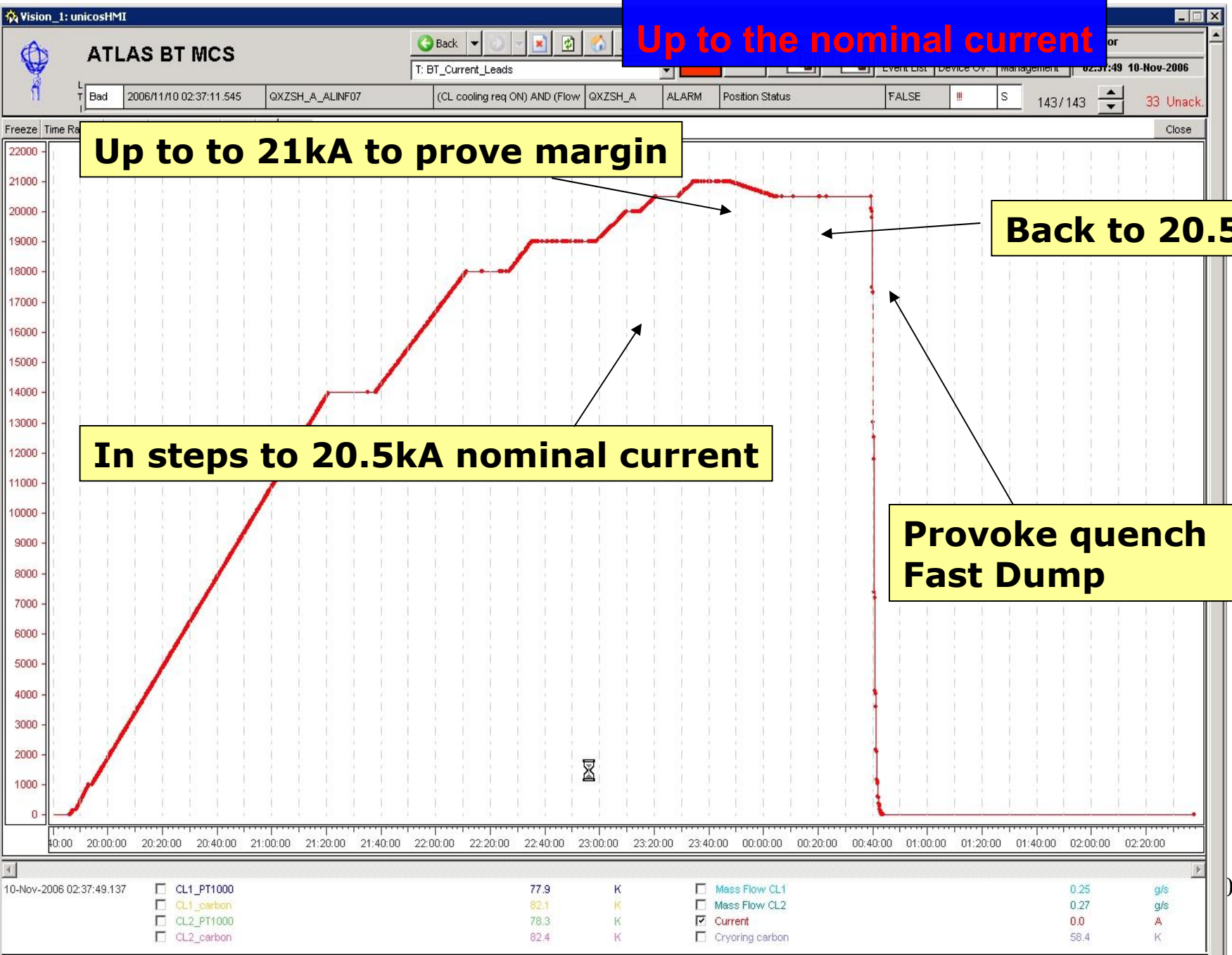
- **Phase II (16 Oct - 26 Oct) : 1-5kA**
- **Cleaning: Detector area, completely**
  - **Magnet Safety test : 3h test duration at 20kA of the power circuit, toroid not connected**
  - **The 8 BT coils are powered in series on 1 power supply**
  - **Power supply adjustments, slow and fast dumps, quench heater tests, check of coil mechanics**
    - ***Fast dump tests: first 25 October***
  - **First readings of mechanical sensors, tie rods, fixed points**

  -> OK

Phase III 5-21 kA

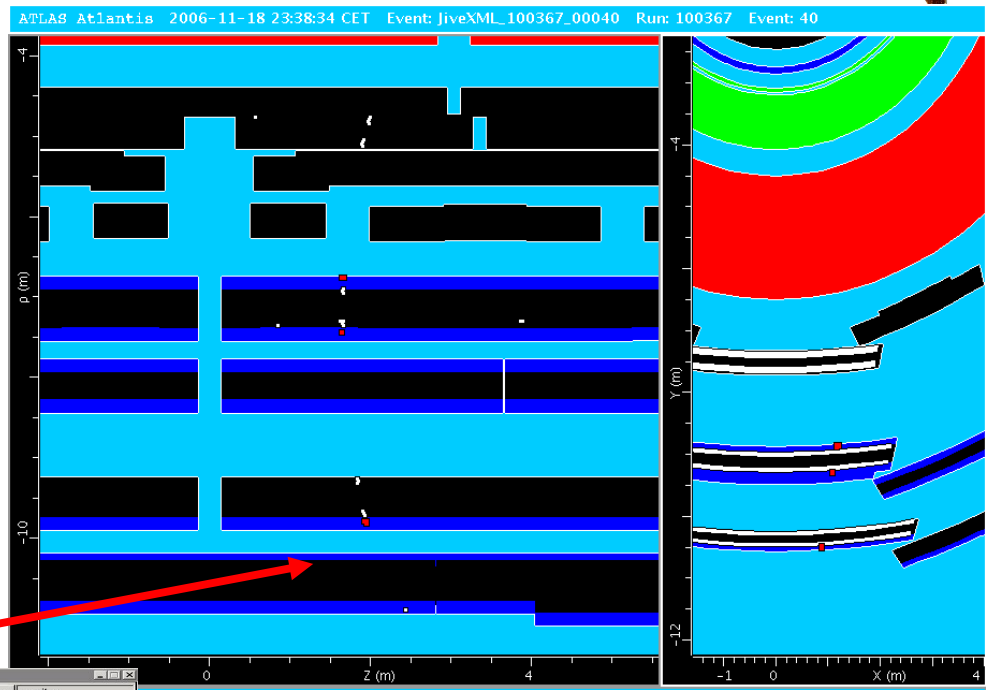
9-10 November 2006:

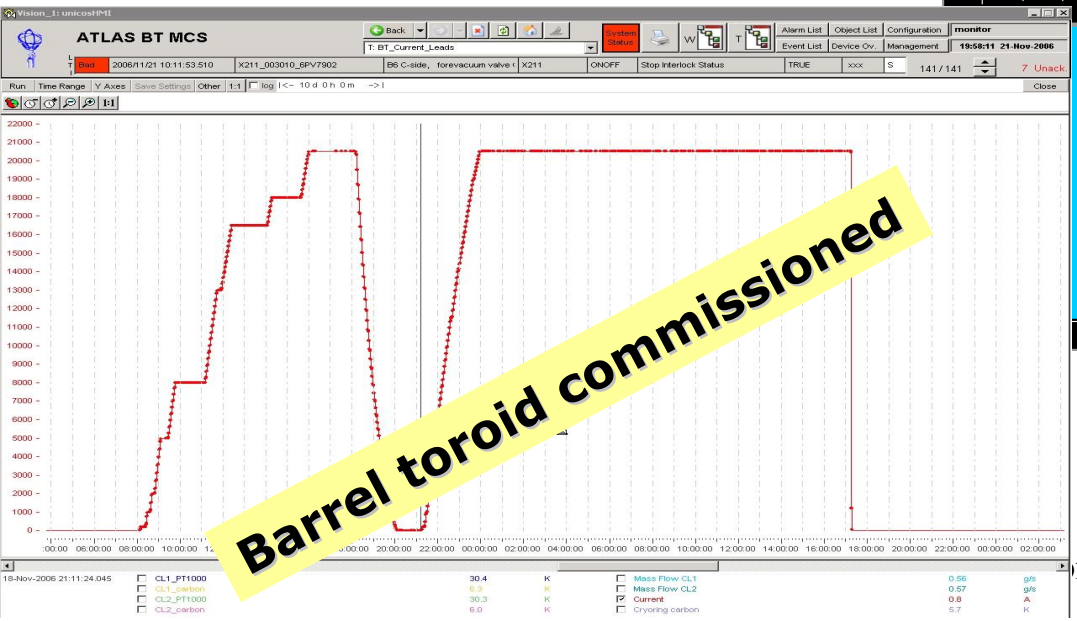
Up to the nominal current

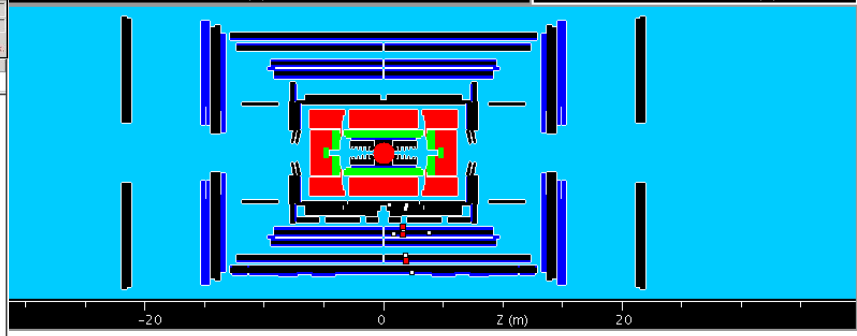


18-19 November: 24 h test of Toroid Barrel

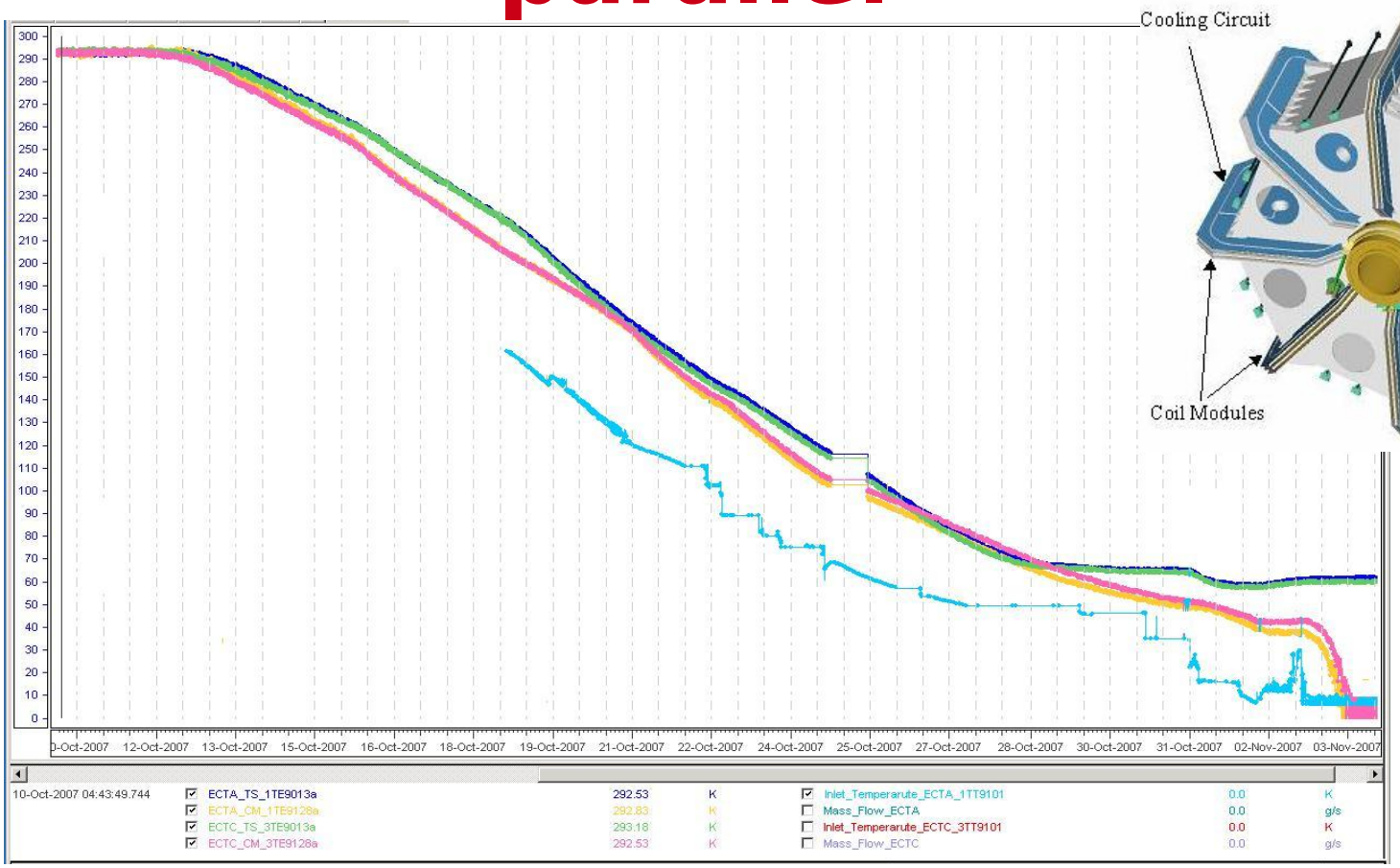
- Cosmic ray data taking with muon sector 13
  - 1M events collected
- The first track with magnet on triggered by the RPCs!!

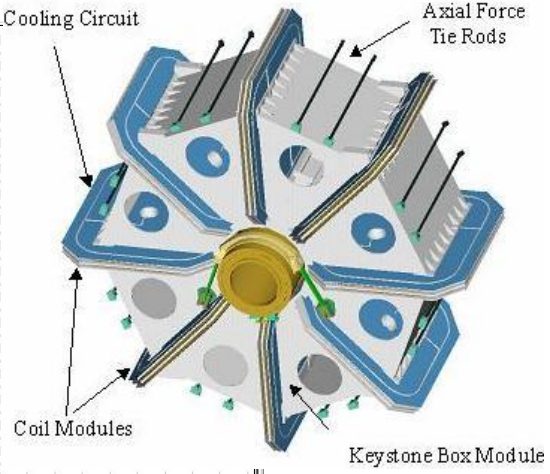






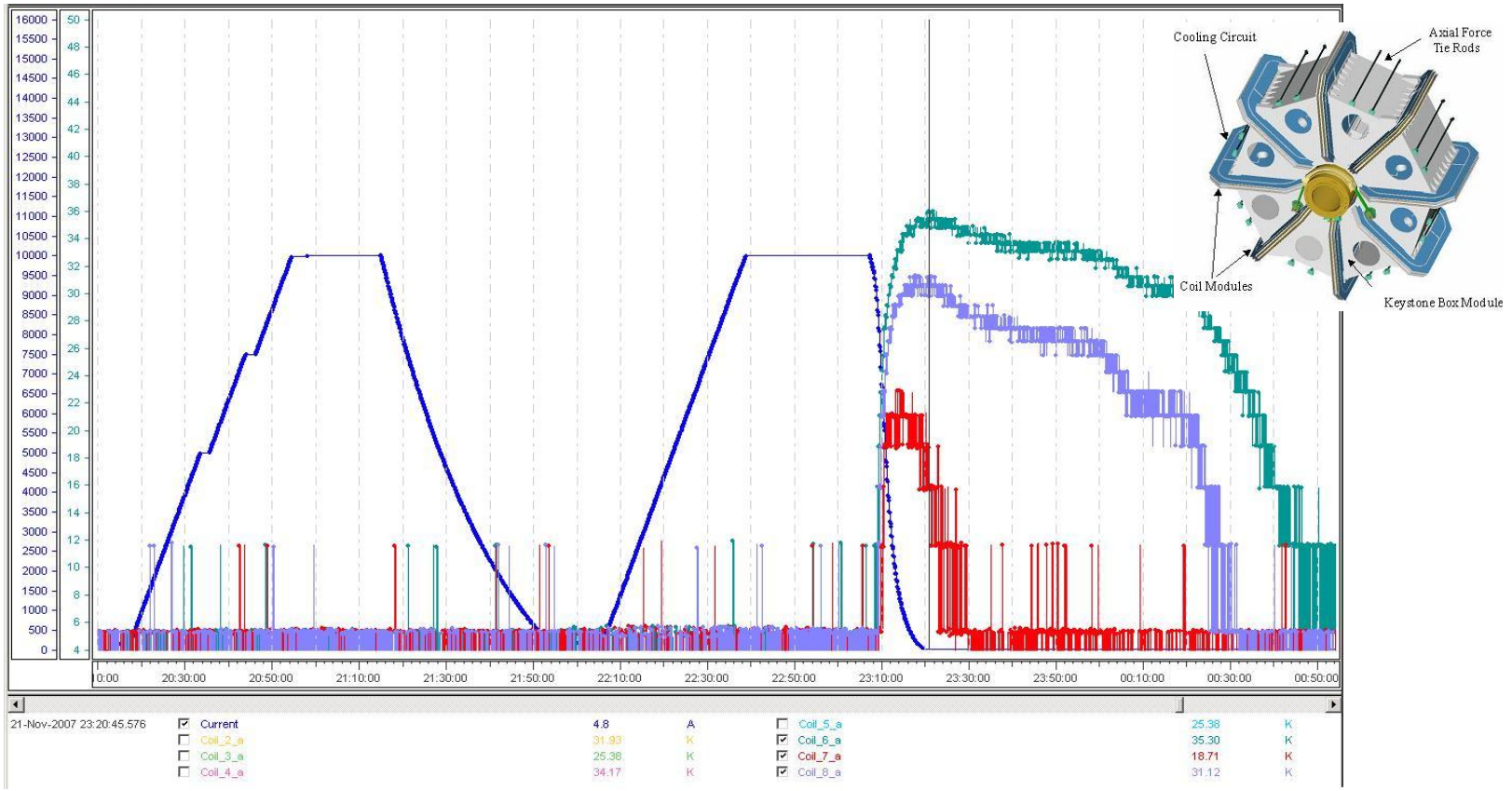
ECT-A&C cooling down in parallel





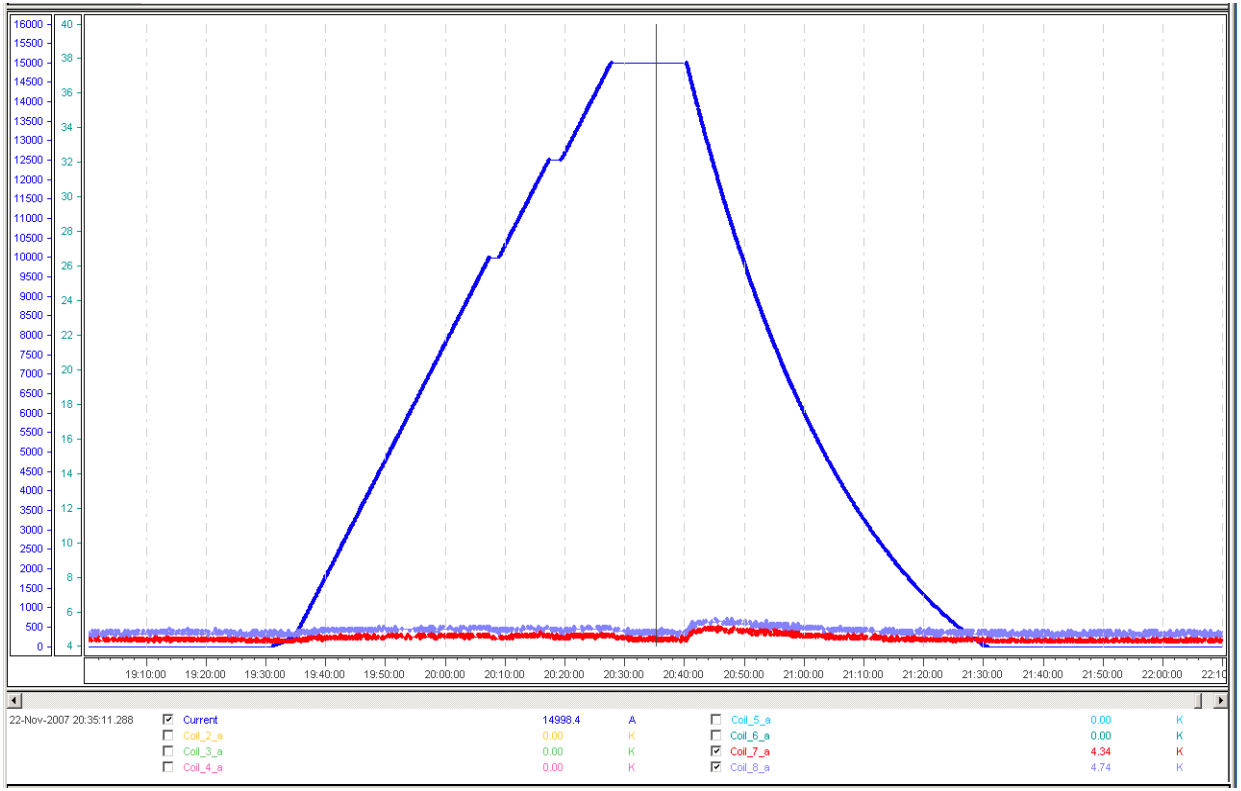
- First cool down of ECT A&C in parallel completed within 5 weeks
- No problems: thermal shield runs at 50-60 K, cold mass at 4.6 K

10 kA Slow and Fast Dump



- 0-10-SD and 0-10-FD by quench detector
- T_max cold mass ~35 K, T_conductor ~50 K
- All coils do not quench simultaneously, delays to be checked at 21kA

ECT-C: 15 kA and surprise…..



- Toroid behaved fine and past 15 kA!
- At 14.8 kA toroid moved unexpectedly towards TC/ECC and a slow dump was manually triggered, what happened?

Test configuration and forces

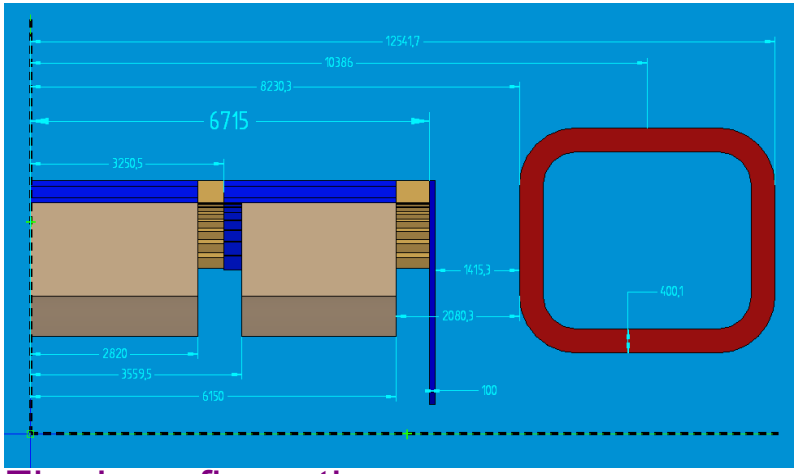
Configuration

- ECT tested in provisional position to allow repair access to ID
- Much smaller gap to iron in TC
- This position was considered safe, expected friction force >68 t (0.2x340t)

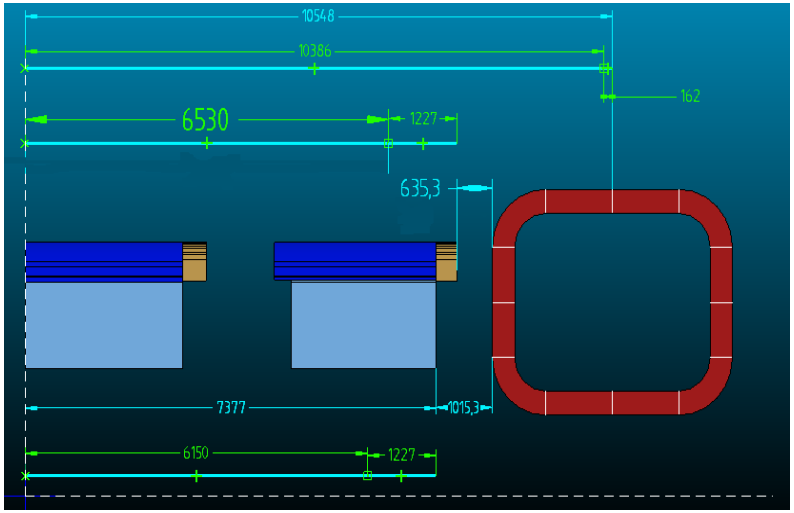
Forces at 15 and 21 kA?

- Measured ~20 t
- Calculated ~20 t at 15kA
- and 40 t at 21kA , so << 70 t safe!
- Still not understood why it moved

Tests >10kA postponed to final configuration in May 08



Final configuration

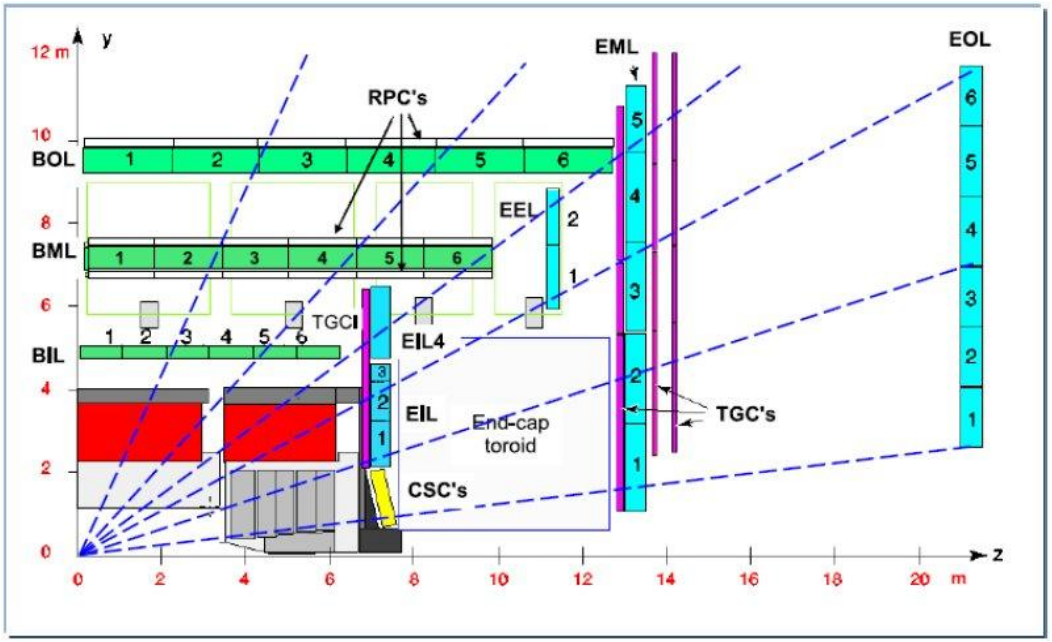


Test configuration

Muon Chambers

The high momentum resolution is achieved with 3 layers of high precision tracking chambers arranged in 3 cylindrical layers (barrel) or perpendicular to the beam (end cap wheels).

Trigger chambers make part of the LVL1 trigger in ATLAS providing BC identification, muon pT triggers selection and second coordinate information



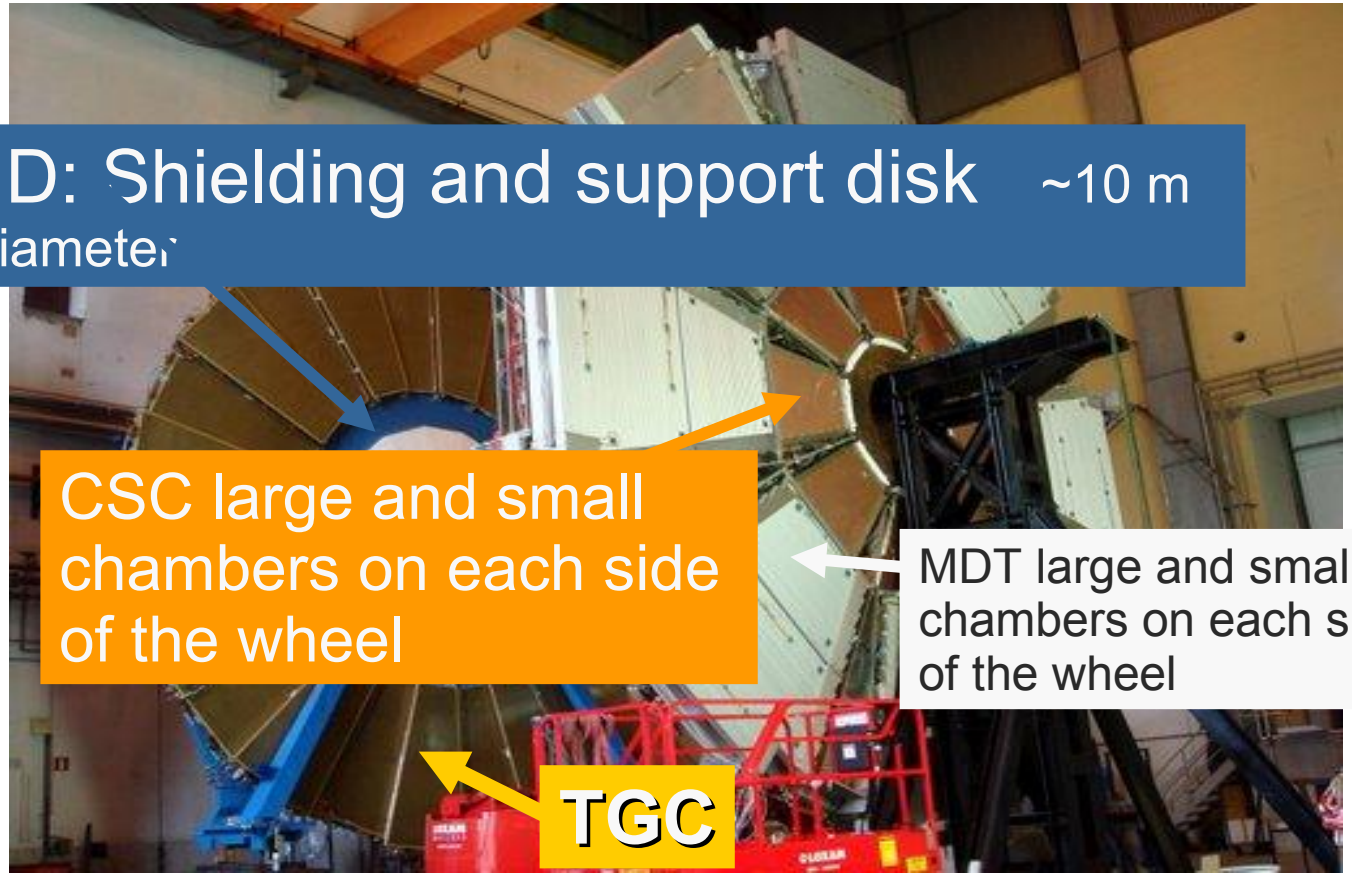
	Function	Resolution (RMS) in z/R	Resolution (RMS) in ϕ	Resolution (RMS) in time	Chambers	Channels	Coverage
MDT	Tracking	35 μm (z)	-		1108	339k	|η| <2.7
CSC	Tracking	40 μm (R)	5 mm	7 ns	32	31K	2.0 < |η| <2.7
RPC	Trigger	10 mm (z)	10 mm	1.5 ns	544	359k	|η| <1.05
TGC	Trigger	2-6 mm (R)	3-7 mm	4 ns	3588	318k	1.05<|η|<2.7 (2.4 for trigger)

MDT Installation

Barrel: 701/704 stations installed, 96% precisely positioned; commissioning on-going

End-caps: installation of small wheels on-going

Small Wheels

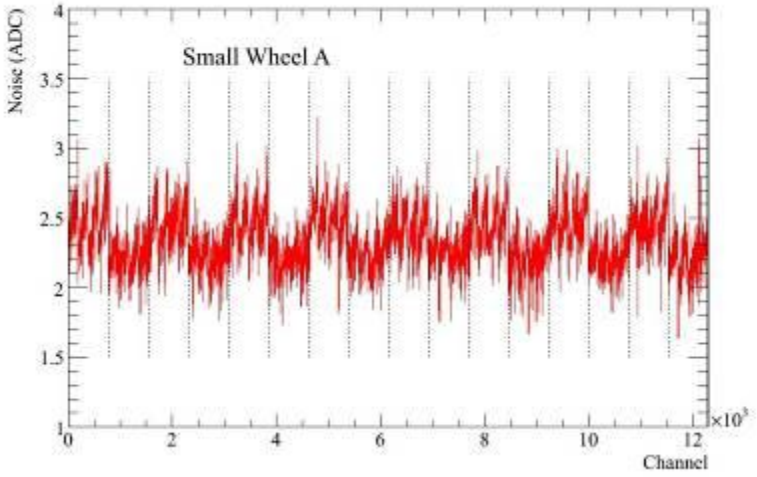


Small Wheels Test

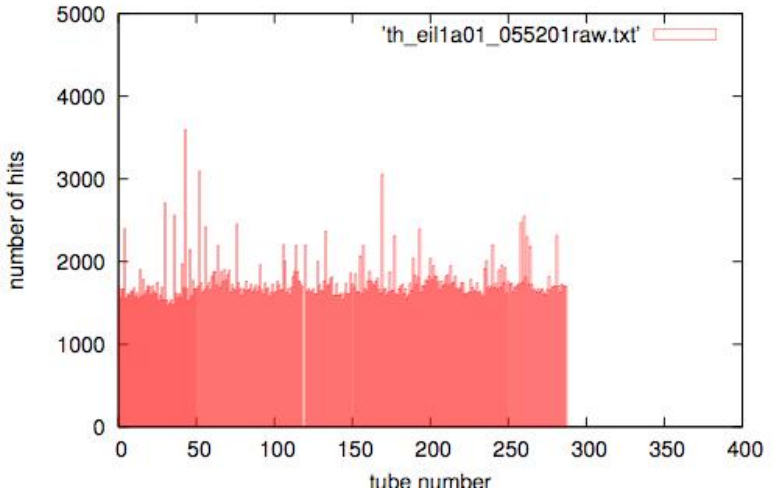
All detectors working correctly at nominal voltage

Dead channels: CSC&TGC → 0.06% MDT → 0.03%

CSC noise



MDT tube occupancy



GAS: none has gas leaks

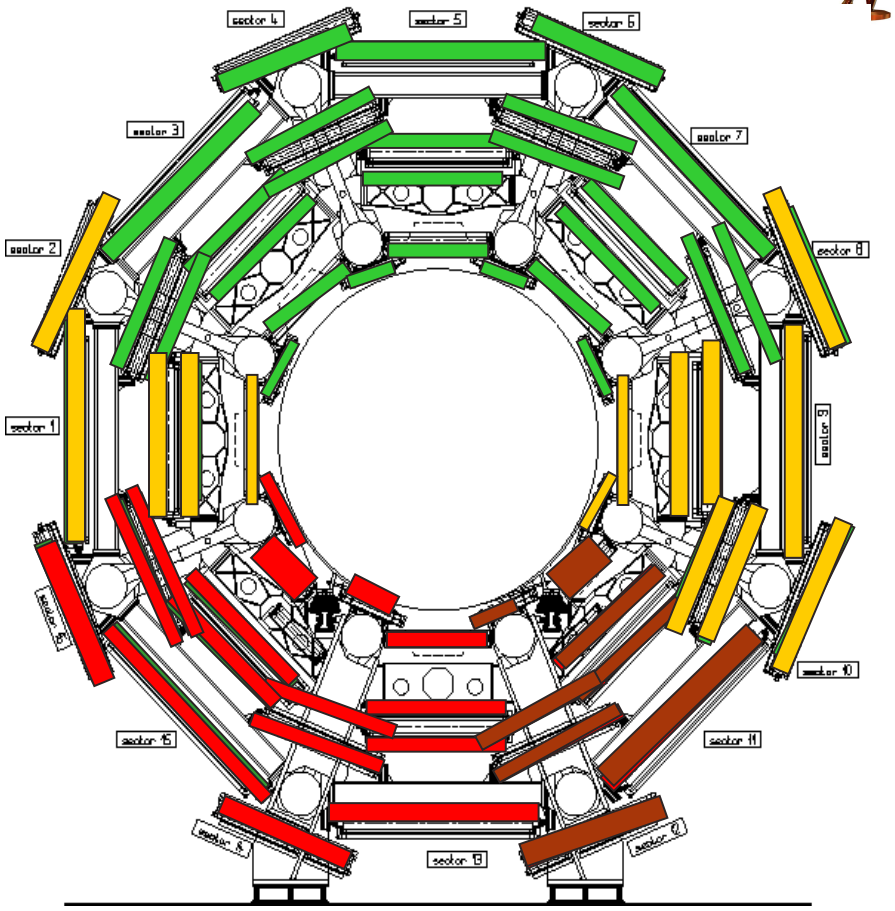
TGC <0.1 mb in 5 min at twice the working pressure


Friderici
Friderici
44
S


CH
184
LOXAM
0844 844 801
LOXAM

Barrel Commissioning: Sectors

- MDT:
  - Sectors from 3 to 8 Commissioned with Cosmic rays
  - Sectors 1-2 & 9-10 noise test (missing HV-PS's)
  - Sectors 11-12 under test
  - Many problems found and solved



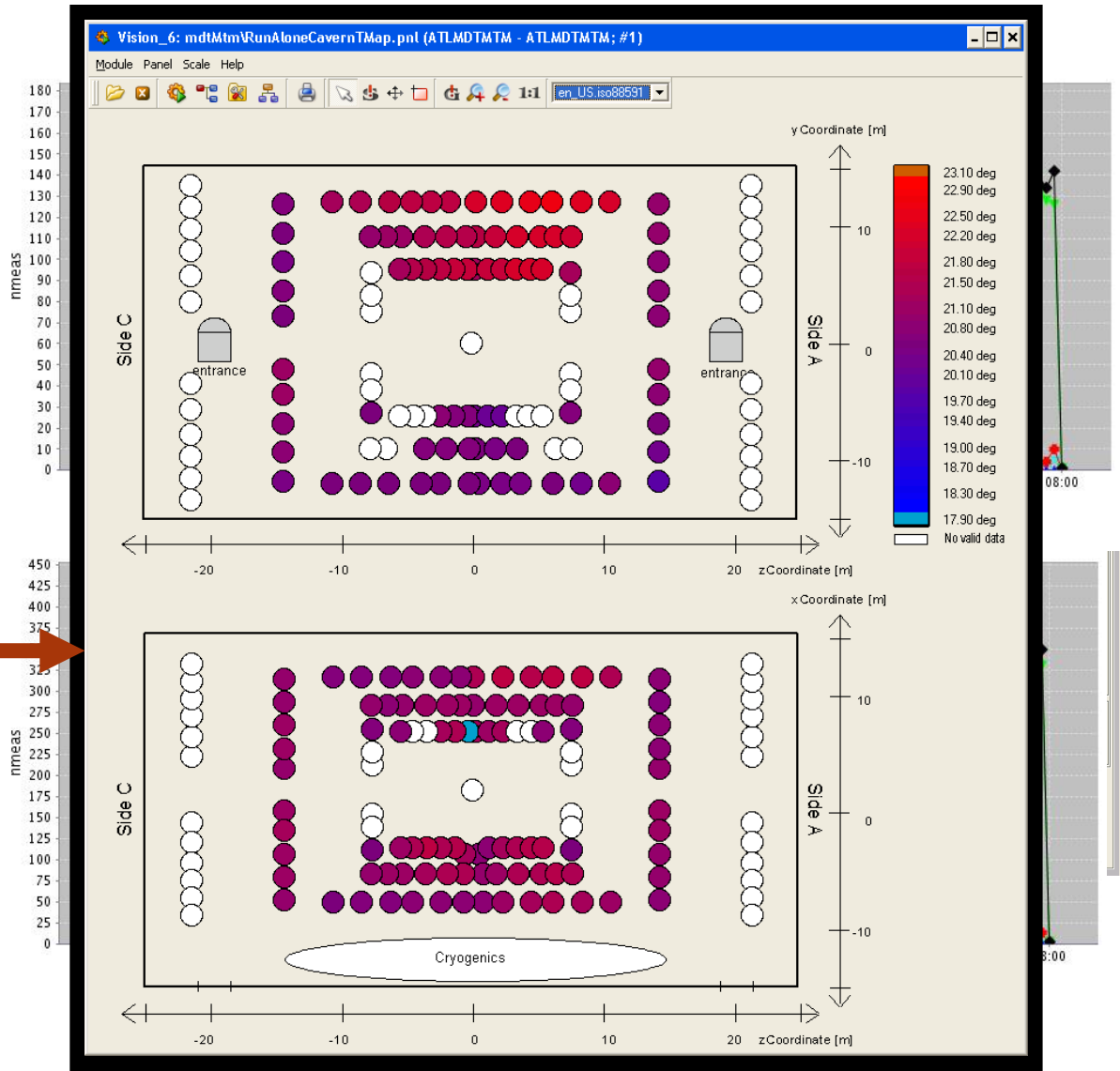
- *List of remaining problems*
  - *% Dead tubes less than 1‰*
  - *Some noisy wires mainly on BOS*
  - *# HV trips: 2*
  - *# Gas leaks: 18 yet unfixed leaks*

Mean Occupancy < 0.1%

MDT DCS

- DCS: All systems in advanced state, but not all yet integrated in Central DCS.

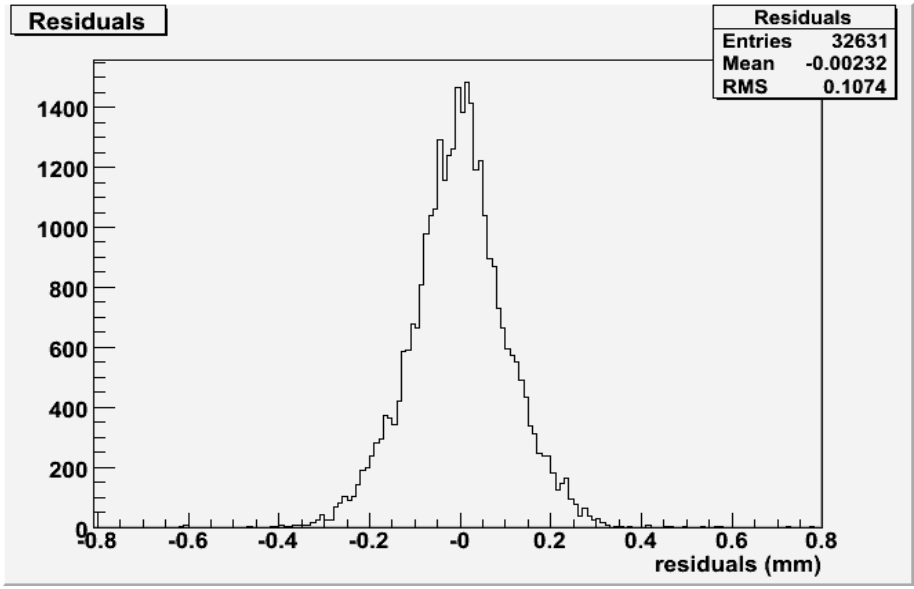
- *HV/LV + monitoring of FE electronics T and V*
- *Alignment*
- *B-field*
- *T-sensors*
- *Gas*
- *Initialization*



Barrel/EC Commissioning: Calibration Stream

- The Muon Calibration Data Stream provides large samples of muon data extracted before LVL2 decision (Only data in Region Of Interest).

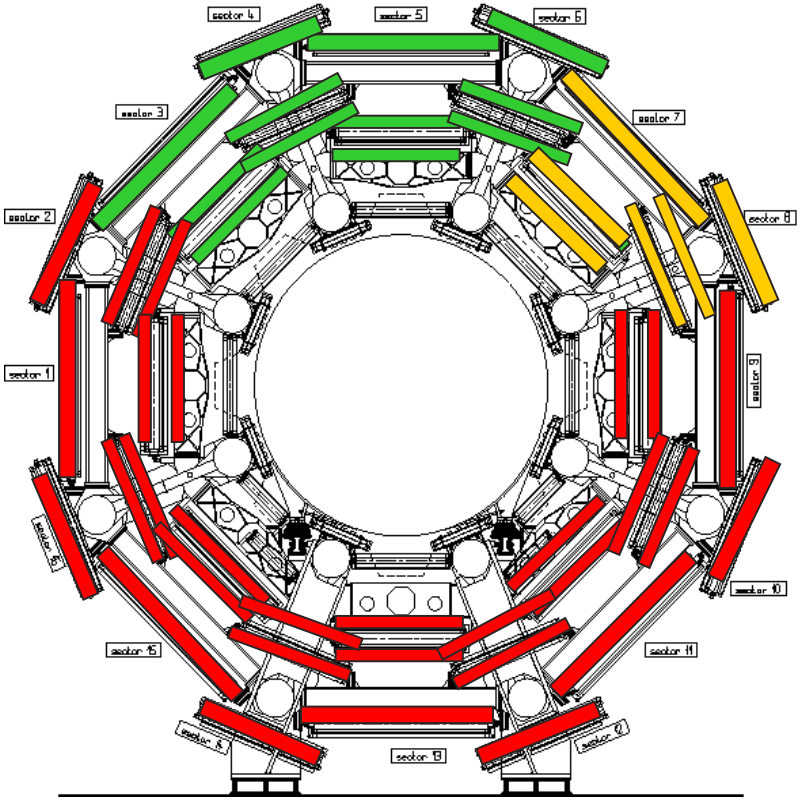
MDT Residuals after calibration



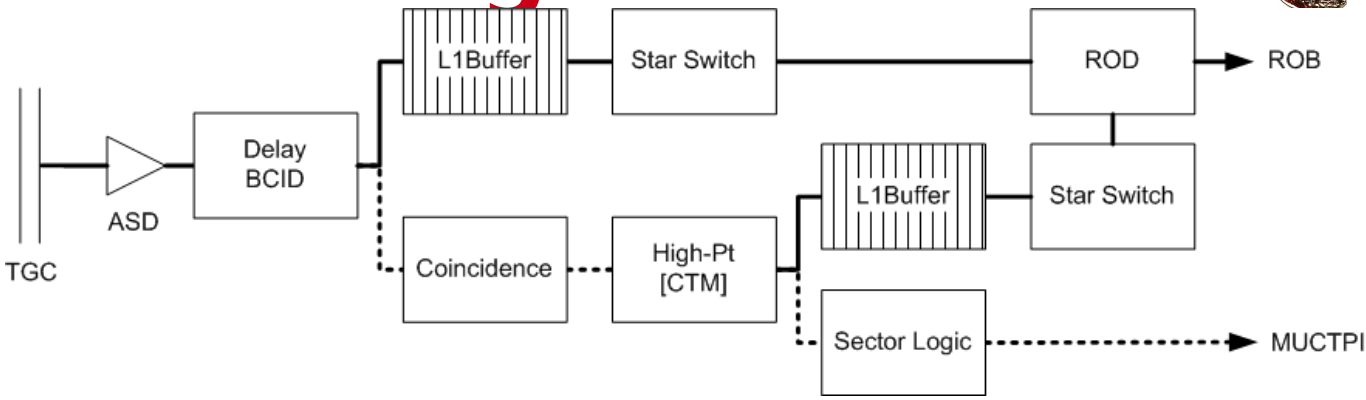
- During Milestone Week 4:
  - Calibration Stream emulated offline, data sent (offline) to Tier2
- During Dec. muon run:
  - Calibration stream extracted online from LVL2

Barrel Commissioning: RPC sector commissioning

- Sectors 3-6 commissioned up to Cosmic rays:
  - Dead strips= 0.2%
  - Disconnected gaps for HV problems 0.6%
  - Disconnected gaps for Gas Leak 0.2%
  - Noisy channels: few units
  - Average Noise 0.4 Hz/cm^2
  - LVL1 Timing-In
- Sector 7 & 8 under Cosmic ray test now

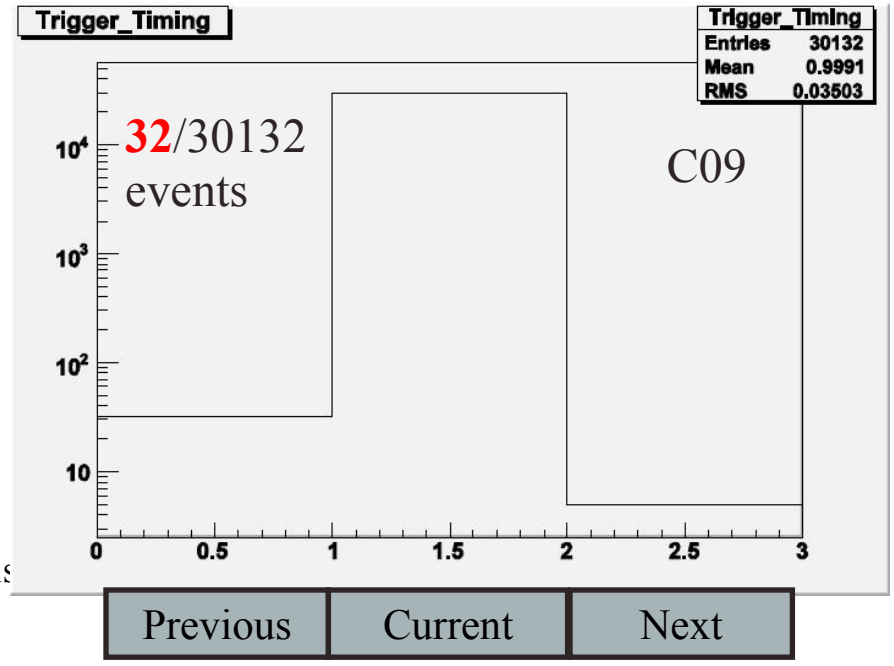


EC commissioning: TGC results



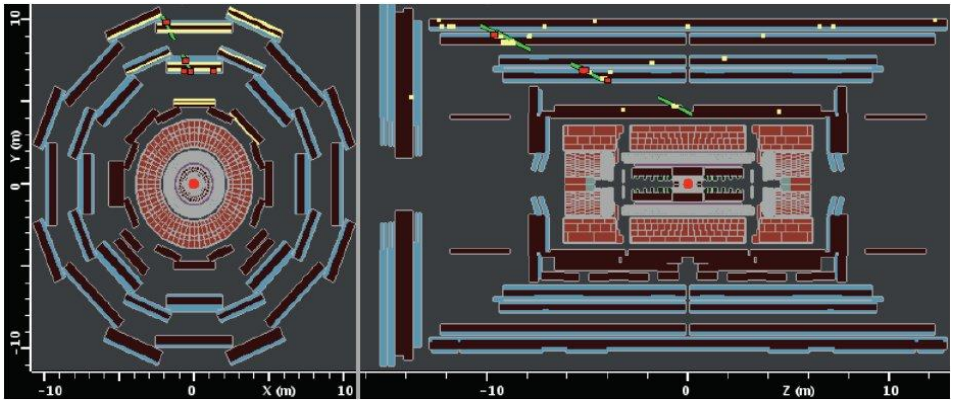
- Both trigger & read-out paths working
  - Fibre length measured for each sector

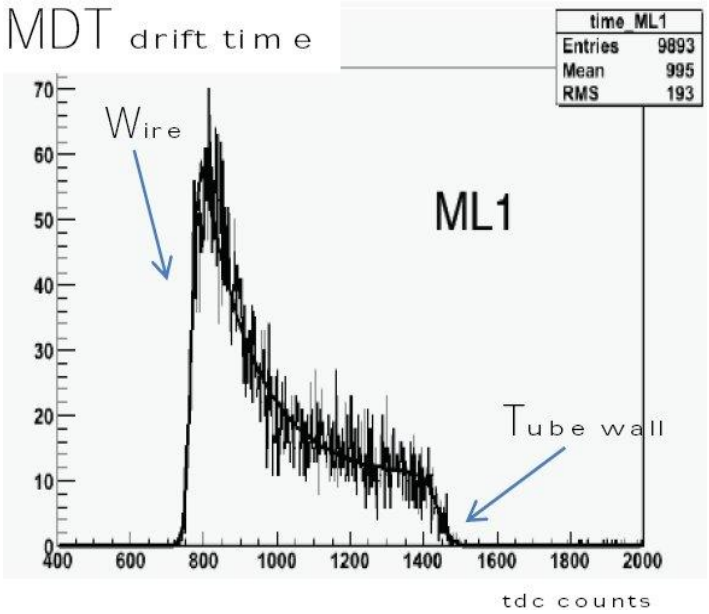
- Trigger Latency measured: 86-90 clk
  - Most data recorded in the Current Bunch Crossing: Trigger timed-in

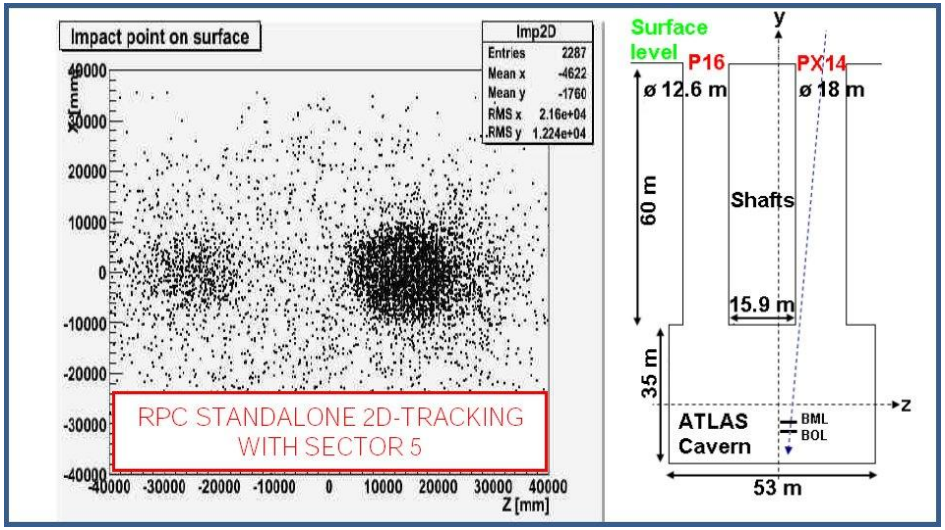


Commissioning with Cosmics

- Trigger by top RPC sectors
  - rate ~200 Hz
- Cosmics rays acquired on
  - 10/16 MDT sectors
  - 4-6/16 RPC sectors
- Bad/Dead channels < 0.5%







… sofferenze

- *General common issue: availability of (CAEN) power supplies*
- MDT Barrel and EC:
  - EOL chambers commissioning
- RPC & Muon Level 1 Trigger
  - Commissioning speed
  - Gas leaks
  - Gas system commissioning
- TGC
  - Access problems
  - Gas system commissioning

TDAQ Commissioning

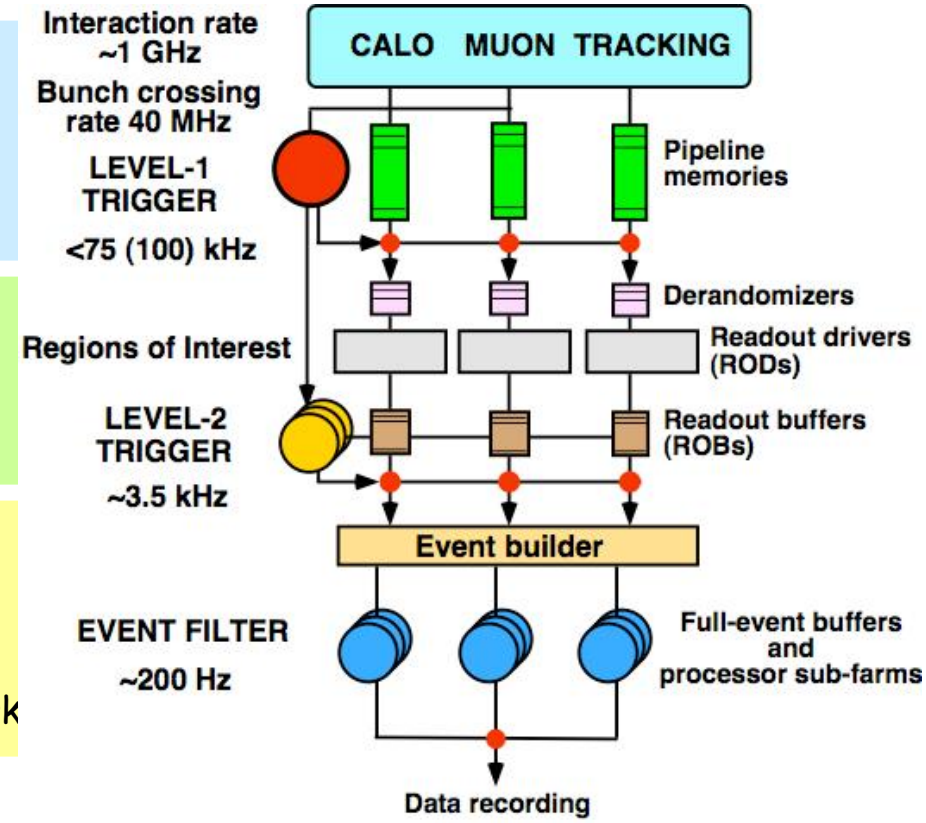
- Level-1 Trigger
- HLT infrastructure
- DAQ infrastructure
- DAQ software
- Commissioning (Technical) Runs

Trigger/DAQ architecture

Level-1 Trigger
Custom Pipelined Hardware

Region of Interest Builder
Custom Hardware

High-Level Trigger
Large PC farm
High data bandwidth
Dedicated 'Data' Network



Detector Front End Electronics
(Detector responsibility)
Detector RODs

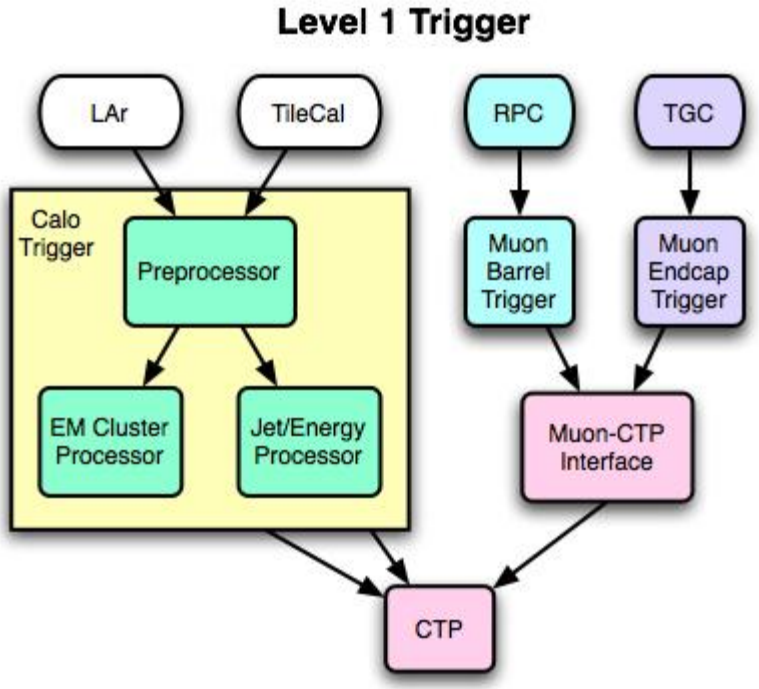
Readout System
Custom built buffers in ROS PC farm

Event Building
More PC farms on 'data' network

DAQ software – control, configuration, monitoring (control network)

Level-1 Trigger System

- Three major systems
  - Calorimeter Trigger
  - Muon Trigger
  - Central Trigger Processor (CTP)
- Other triggers and signals also integrated by CTP
  - Minimum bias
  - Luminosity triggers
  - Beam Pick-up
- CTP distributes all timing information, (avaliable since 2006, now fully installed)

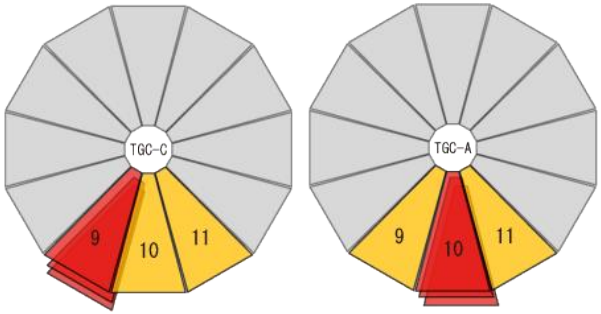


Level-1 Muon/Calorimeter Trigger

- Calorimeter trigger installation completed in December 2007
- Muon trigger essentially complete
  - on-detector electronics power supply and gas issues
  - commissioning done sector-by-sector

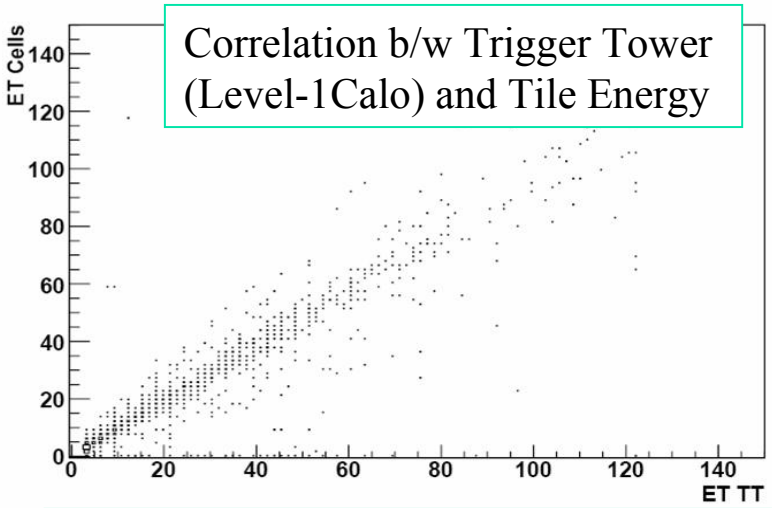
Level-1 Trigger Commissioning

- Calorimeter trigger signals need thorough testing before access disappears
  - About half tested so far
- Muon trigger commissioning sector by sector

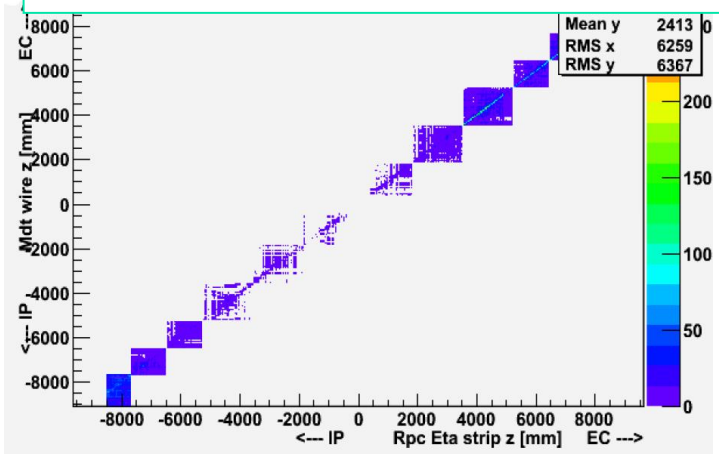


- Timing needs to be addressed

Correlation b/w Trigger Tower (Level-1Calo) and Tile Energy



Correlation b/w hits in RPC and MDT

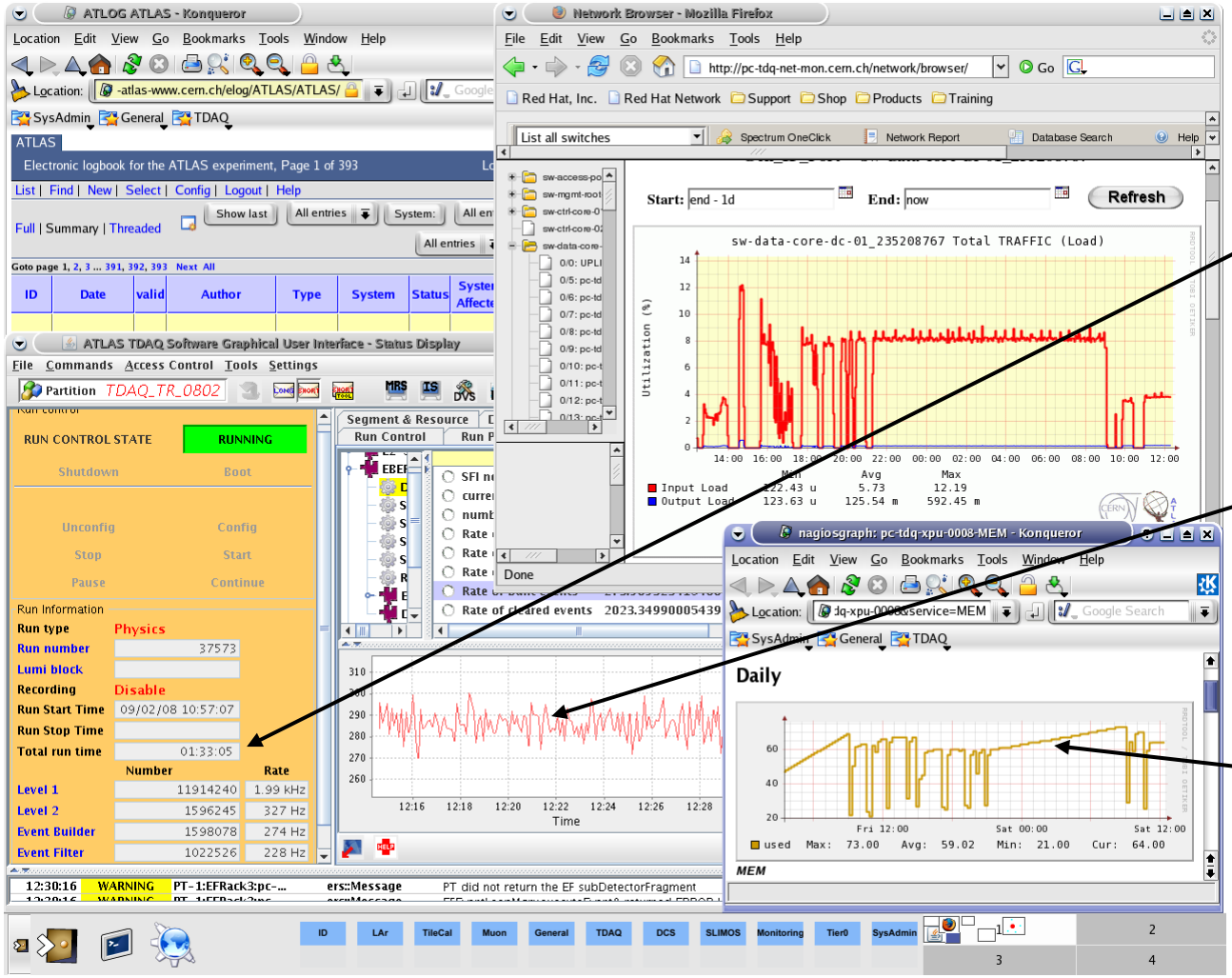


Technical Runs

- Inject Montecarlo event fragments in the readout buffer
- Send level-1 trigger information to the system
- Data acquisition and monitoring ~ as in real time

- Software validation
- Hardware commissioning
- Configuration issue
- Debugging
- Scaling issue

Technical Run Display



1.5 hour running time

stable trigger rate

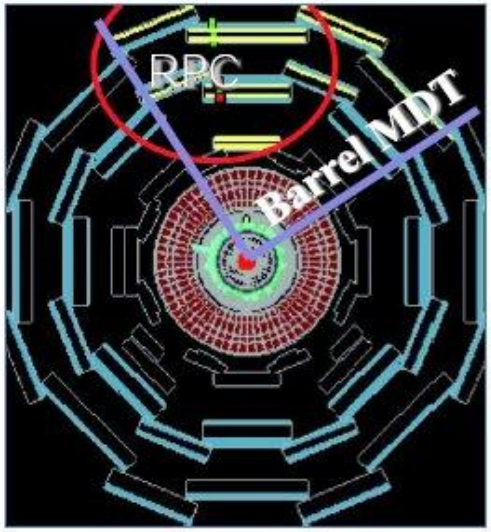
memory leak spotted

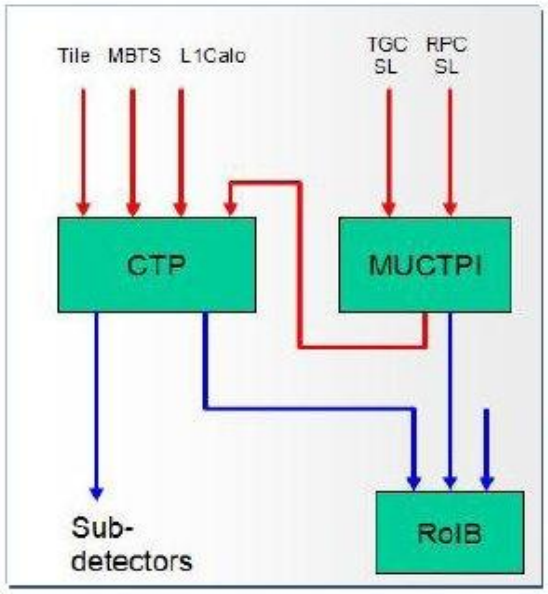
ATLAS Integration

- Combined mode running:
  - Milestone #N Weeks every 6-8 Weels
  - M5 in November 07, M6 scheduled for March 08
- Goal:
  - Software and hardware integration
  - Cosmic data taking
  - Monitoring
  - Timing

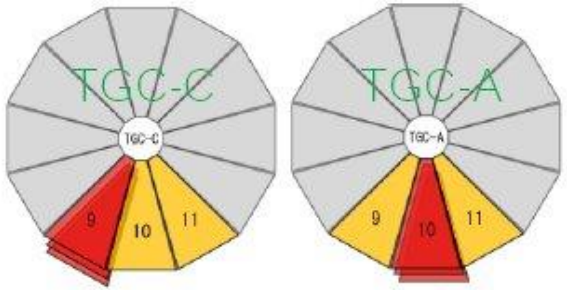
M5 combined run

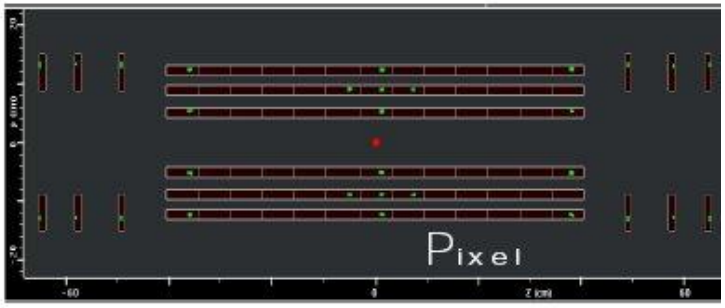
- RPC (12.5%): Sectors 5,6
- MDT (~25%): barrel sectors 3-6, 16EIL4 chambers
- TGC: 5/36 stations with final setup in read out and trigger on each side (~14%). First operation on A-side
- Tile: ~55%; LAr: 68%-87%
- Pixel: Readout only, no TRT (but M4 and M5.x in Dec)



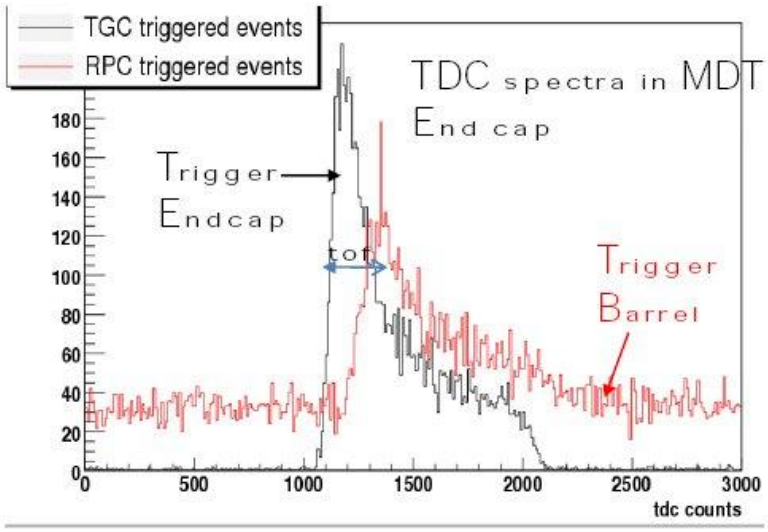


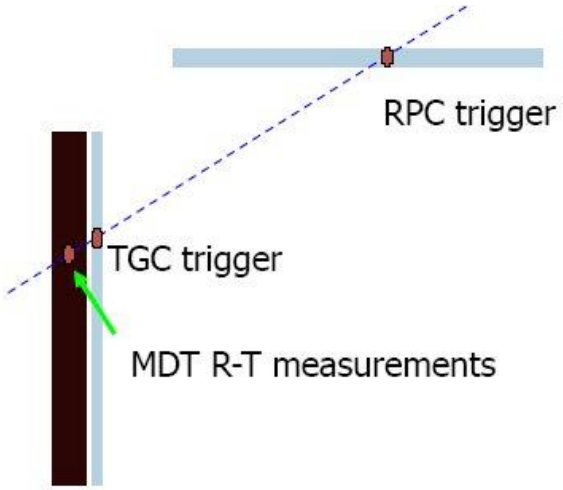
- ✓ Cosmic trigger:
  - Tile: sub-Hz
  - RPC: few tens Hz
  - TGC: few Hz
  - L1Calo: sub-Hz
  - MBTS: sub-Hz
- ✓ Technical triggers:
  - random, fixed frequency from CTP



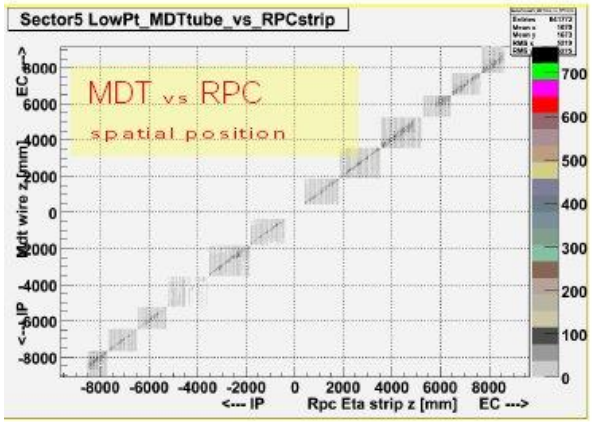


M5 Achievements

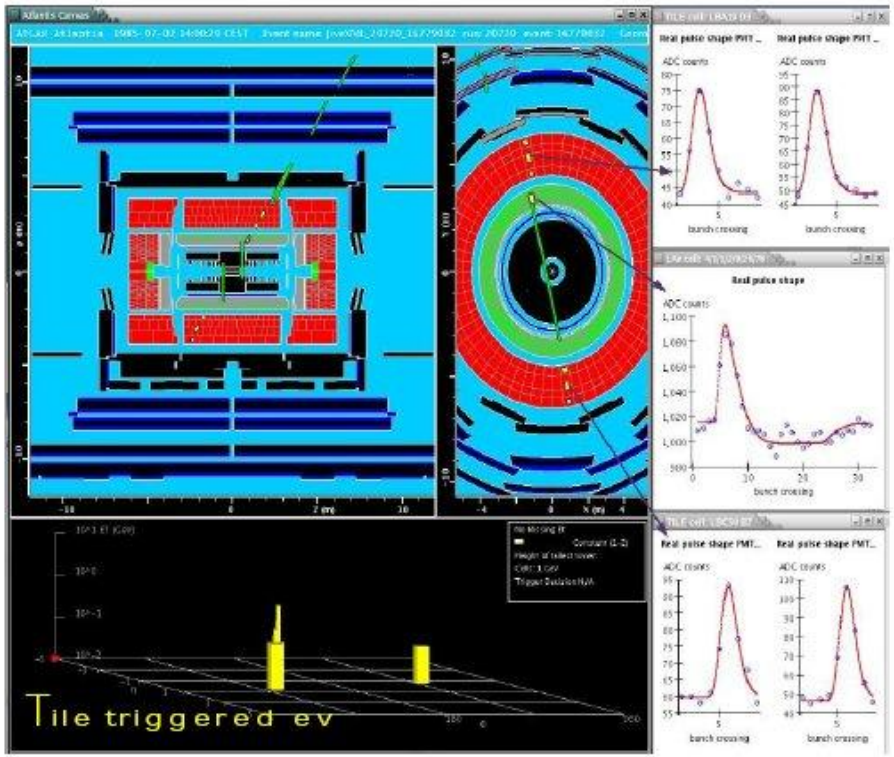




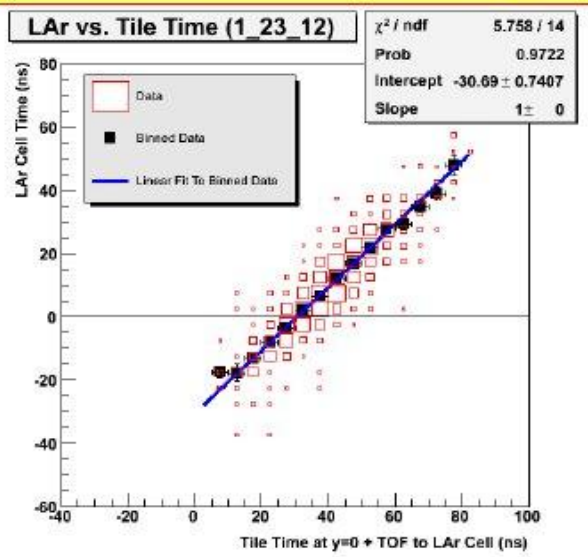
- End-cap MDT show hits for both RPC and TGC trigger
- Different T0 is as expected



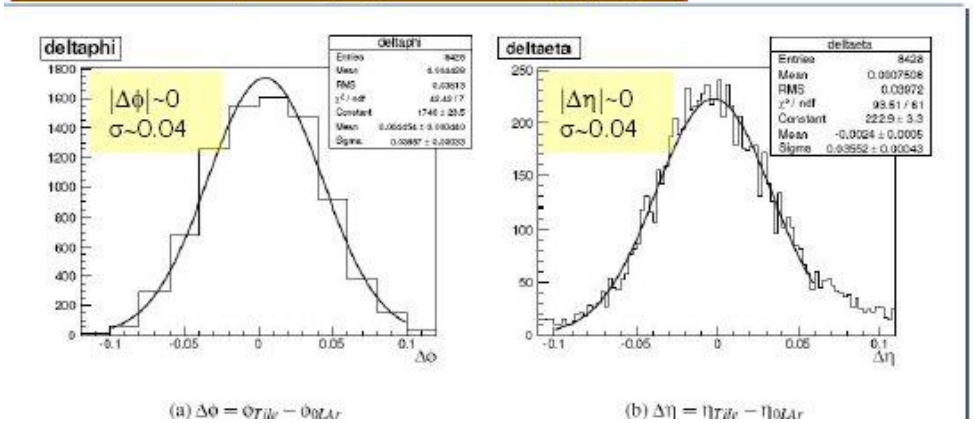
LAr and Tile cosmics

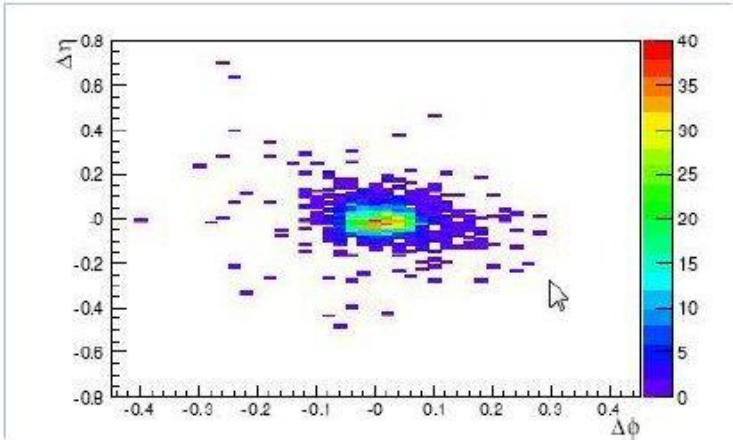


Correlation TileTime vs LArgTime



Correlation Tile(ϕ,η) and LArg(ϕ,η)





Since some time now the ATLAS Control Room is a major centre of actions

This has of course increasingly been so, and the ACR soon will be staffed permanently when full-time shift presence starts

Non e' finita:

- Full Dress Reharsal: realtime tests of hardware, software, databases, storage media, networks, data flow, data integrity and quality checks, calibrations, etc

"FDR-1 run was a difficult success—data were played through and are now at Tier1 and Tier2 sites:

Finding problems was the goal; most were overcome

For FDR-2 expect basics to run more smoothly"

Prossimo futuro …

Schedule linked to beam pipe closure (T0)

Detector: ~ 5-6 weeks before T0 start closure to final position: close ID, move back calorimeters (-3m), install Small Wheels, position ECT, test magnet system, shielding

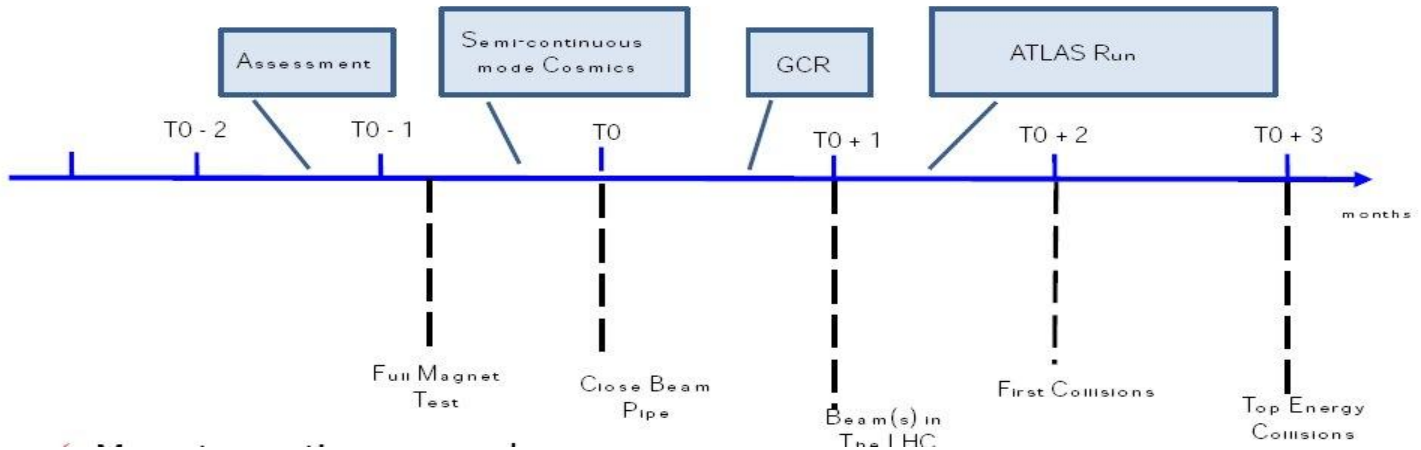
Operation:

- Keep current mode global commissioning along two lines up to T0-2 months
  - Periodic (~ 2 months) global commissioning (Mx) weeks for integration, operation, training, cosmic runs
  - System dedicated periods (few days/system) for addressing specific issues
- Move to continuous mode starting at T0-2 months

Commissioning Feb/Mar 08

Month	Date	System	Requirements, remarks	CS	Parallel
February	4-8	DAQ/HLT	Technical Run	yes	FDR, SCT
	9-10				TRT, SCT
	11-13	Tile	Calibration Triggers	yes	SCT; TRT; 13/2 11:00 DAQ/HLT 24h
	14-15	Tile	R/O debugging	Yes	TRT; TDAQ 24h up to 14/1 at 11:00
	16-17				TRT
	18-20	TRT+SCT	Scintillator trigger	Yes	
	21-24	L1Calo, Tile, LAr	Calorimetry days Lar may join if possible	Yes	TDAQ 24h period 20-2. TBC wrt ID progress
	25/2-2/3	Muons+TRT	TRT "comes in" when ready "at times"	Yes	TDAQ 24h period 27-28 Dedicated to HLT
March			RPC pointing trigger needed by TRT (wish)		
	3-10	M6			

… T0



Move to continuous mode

- [T0 -2 to T0 -1] Assessment month: Check system stability, controls, Data Quality/monitoring.
- [T0 -1 to T0] Semi-continuous Global Cosmic Run (GCR) and problematic detector out for debug.
- [T0 to T0 + 1] Global Cosmic Run; start 24/7
- [T0 + 1 to T0 + 3] ATLAS Run: commissioning with beams, global run with beam/cosmics, timing, 24/7 operation

Conclusioni

Molte attivita' in parallelo per commissioning di rivelatori, sistemi di controllo, trigger, data acquisition, monitoring, ricostruzione

Sottorivelatori vicini alla fine delle attivita' di commissioning individuale

Milestone Week Mx fondamentali per la transizione all' ”ATLAS mode”

Raggi cosmici forniscono il modo migliore di calibrare il rivelatore e il sistema di trigger