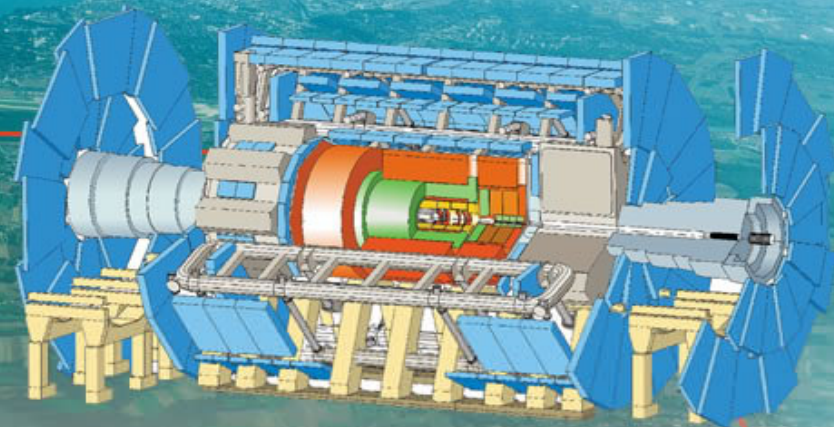
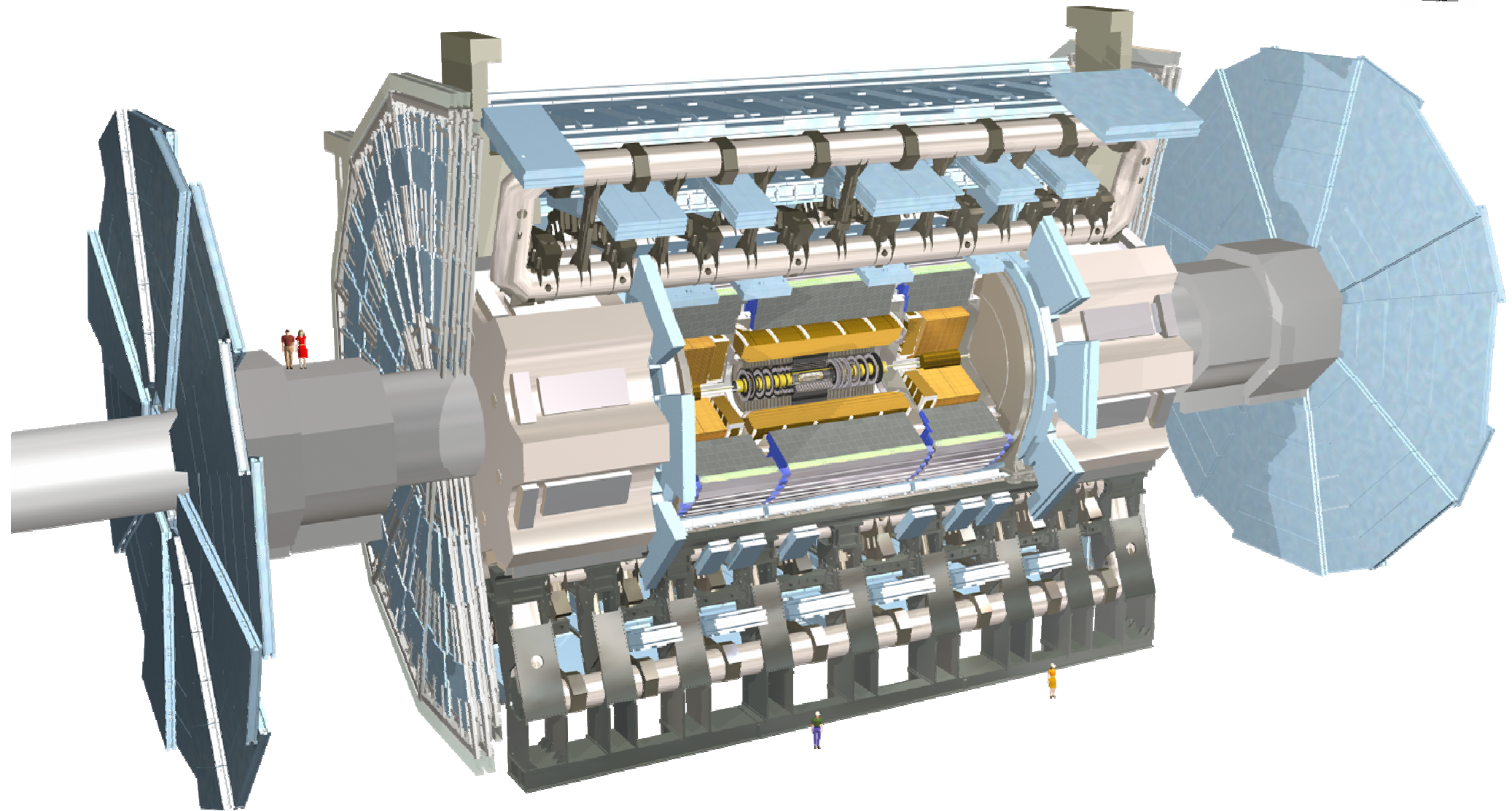


ATLAS (part II)

Marzio Nessi, CERN

NCP Islamabad, 18th November 2005





Magnets Project

Barrel Toroid + 2 End Cap Toroids + Central Solenoid
+ Cryogenics + Services

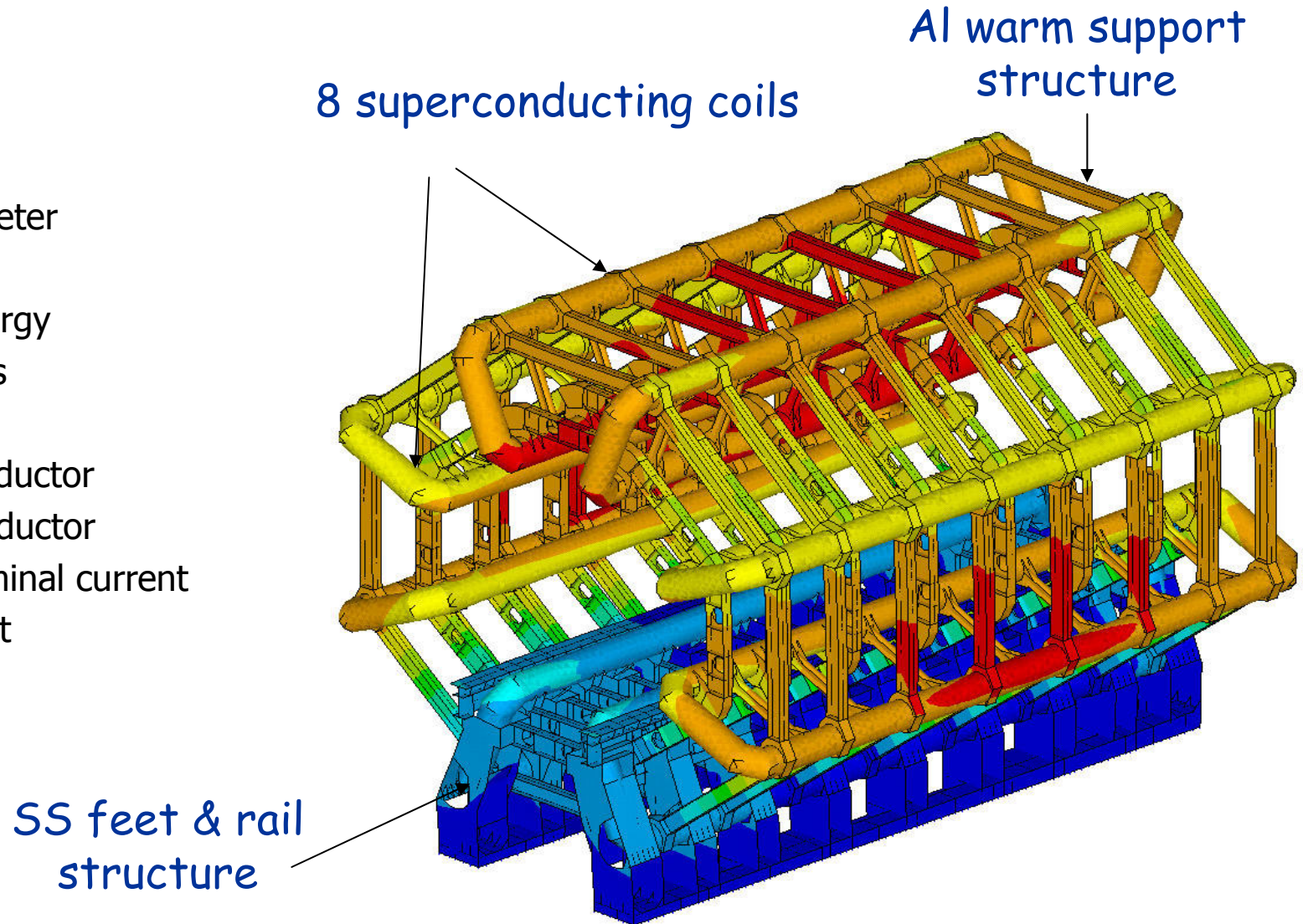
Production over 8 years, 1998-2005
Installation over 3 years, 2004-2006

ATLAS Barrel Toroid (BT)



BT Parameters:

- 25.3 m length
- 20.1 m outer diameter
- 8 coils
- 1.08 GJ stored energy
- 370 tons cold mass
- 830 tons weight
- 118 tons superconductor
- 56 km Al/NbTi conductor
- 20.5 kA @ 4 T nominal current
- 4.5 K working point



ATLAS BT: all components manufactured



56 km superconductor



16 / 16 Double Pancakes



8 / 8 Vacuum Vessels



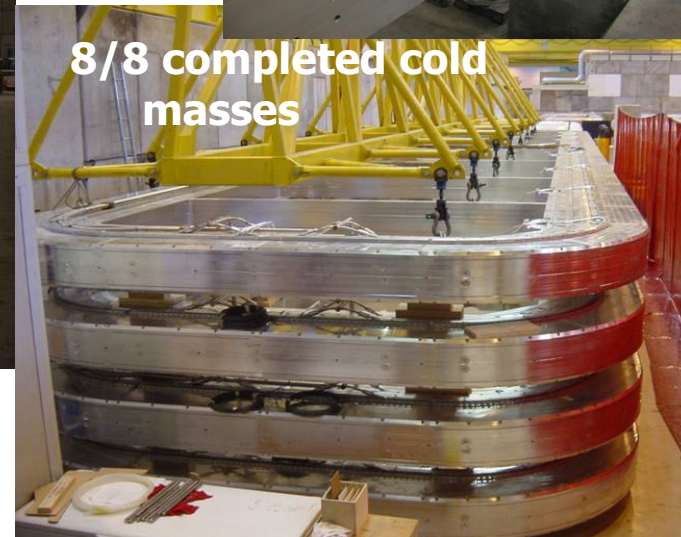
8 / 8 instrumented



8 / 8 Coil Casings



8 / 8 completed cold masses



ATLAS BT assembly problems



- ✓ For *~9 months* the heat shield has been ATLAS ' major problem, large delays in the delivery of components (N_2 cooling pipes welding problem,)
- ✓ Effective solution found in early 2004



This has generated 9 months of delay in the toroid installation and in ATLAS in general



Cold mass insertion in its vacuum vessel



Integration overview



- *Last coil was ready for installation in May '05*



BT1 and BT2 coils tested



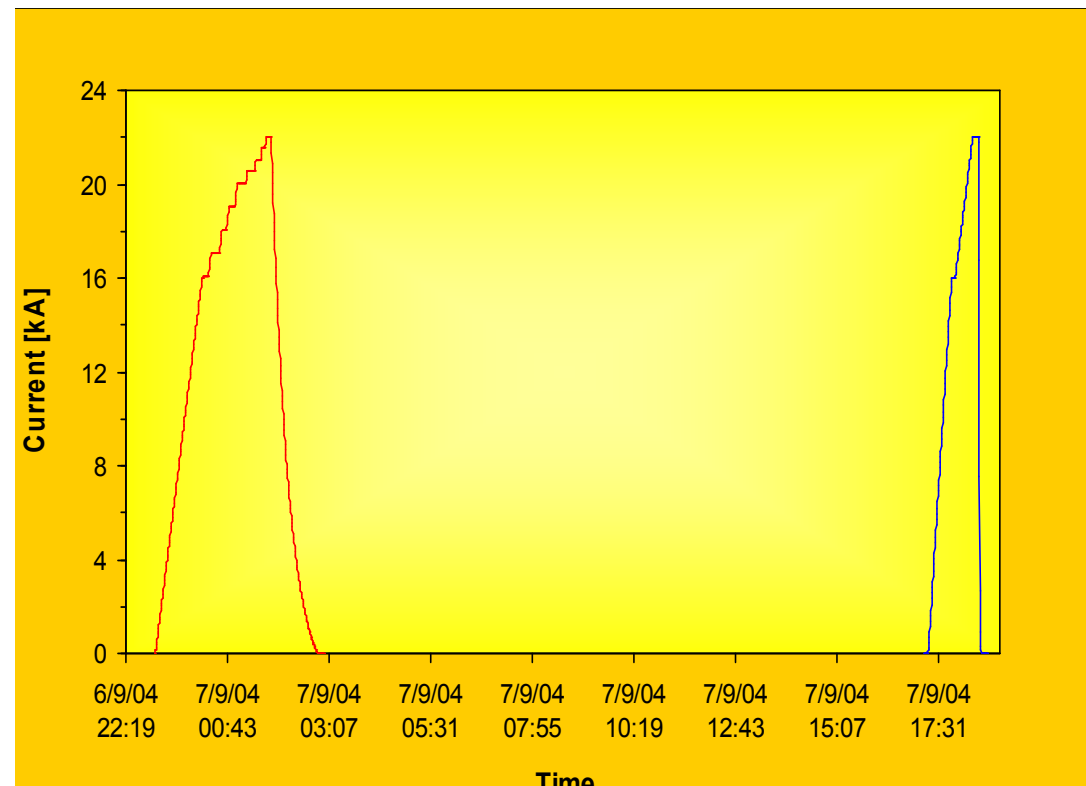
Coil 1

Coil 2

magnetic mirror

BT 1 & 2 Coil Test : Slow & Fast dumps

- *On 7 Sep '04 we charged the coil#1 twice up to 22 kA*
- *Slow dump (1hr normal ramp down without quench)*
- *Fast dump (2 minutes emergency ramp down with quench)*
- *Tested up to 22 kA (nominal 20.5 kA)*
- *Stability test of 8 hrs, all fine*
- *All coils have then been tested with the same procedure, all fine*



Preparing for installation

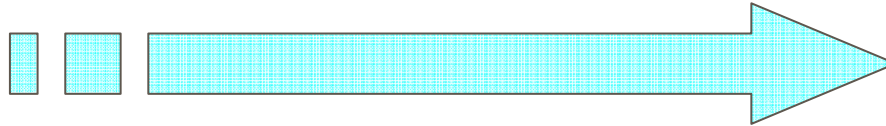


18/11/2005

BT Mechanical Assembly

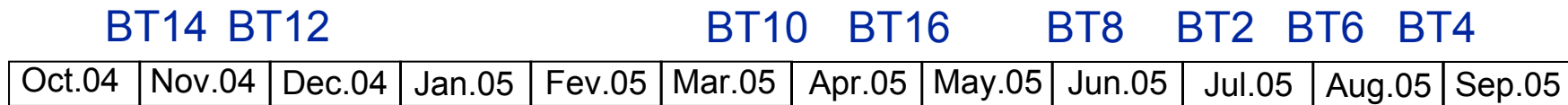


October 20th, 2004
**Transport of 1st
coil to point 1**



**September 28th, 2005
Release of BT**

Coil positioning



Lateral supports and central
platform installation

- ◆ Reinforcement of the manpower
- ◆ Work in parallel on both sides

BT Mechanical Assembly (2)



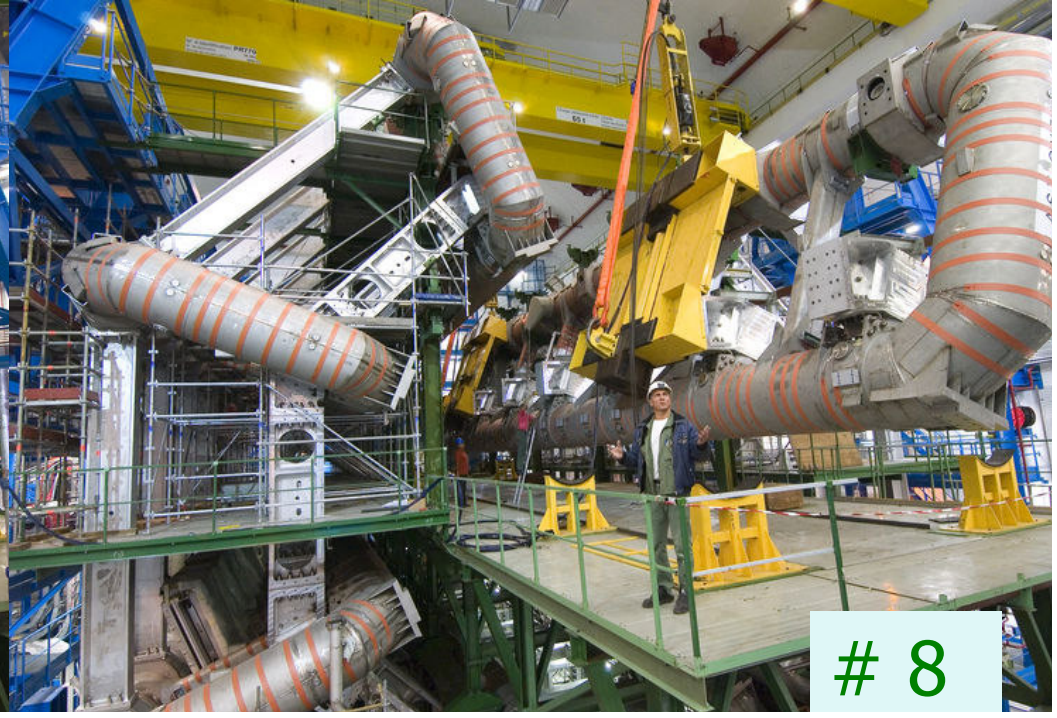
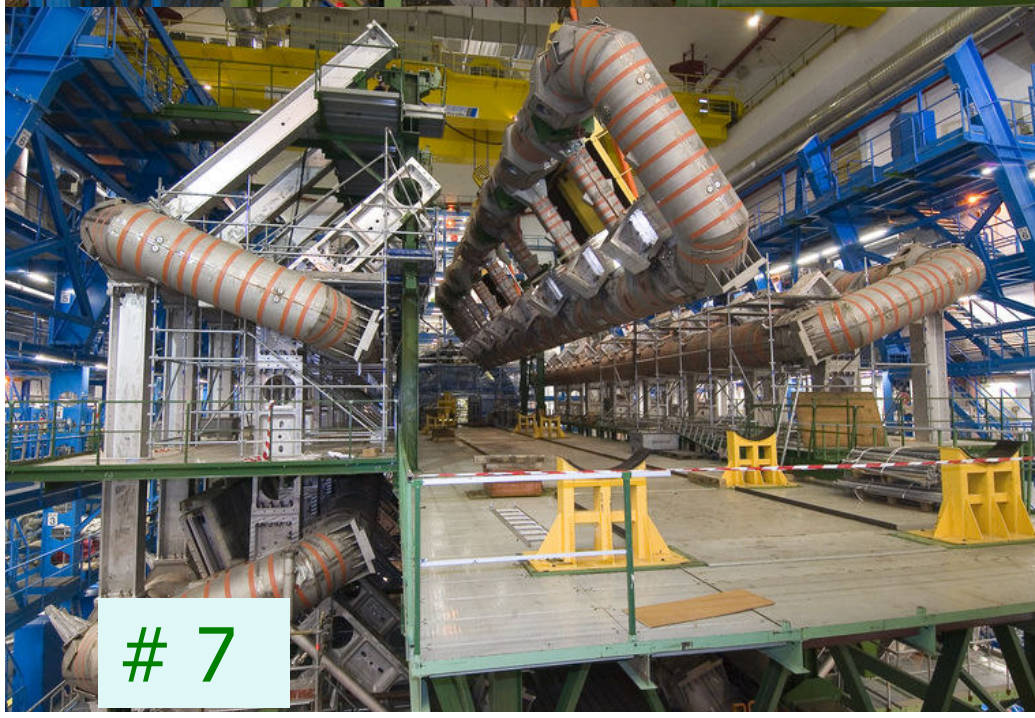
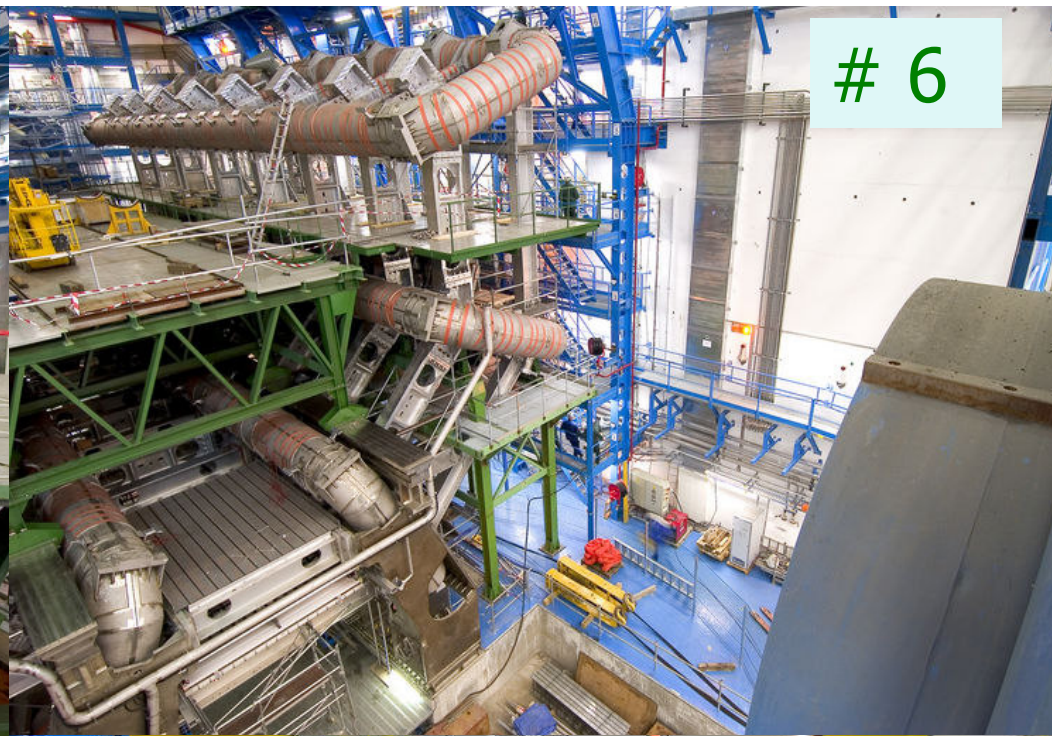
- ◆ Difficult but safe manipulations
- ◆ Use of 2 lifting frames
- ◆ Hydraulic winch with load capacity 190T (subcontracted)



BT Mechanical Assembly (3)



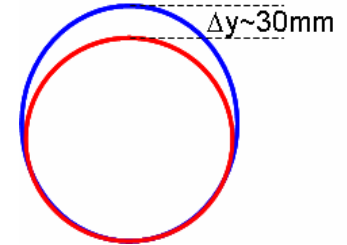
- ◆ First the lower 4 coils
- ◆ and a lot of temporary support structures



Coils positioning and release



- *Coils positioned on an ellipse, $DY(\text{vertical})=30\text{mm}$ to anticipate the sagging*
 - ✓ $DY = 24 \pm 6$ mm due to its own weight and the weight of the muon spectrometer (according to various FEA calculations)
- *Release of the hydraulic system and come to a circular shape*
 - ✓ Detailed procedure and control sheets
 - ✓ Many cross-checks before the operation
 - ✓ Re-tightening of all bolts
 - ✓ Checking of all bolt connections
- *Release by steps of 2 mm until the pressure ~ 0 bar*
(27th September '05)
 - ✓ Measured movements : $DY = 18$ mm ; $DX = 7$ mm
 - ✓ No increase of the tension in the bolts
 - ✓ Deformation < 1 mm at the level of the feet



Perfect and as calculated!

.... and finally



Mechanical assembly resources



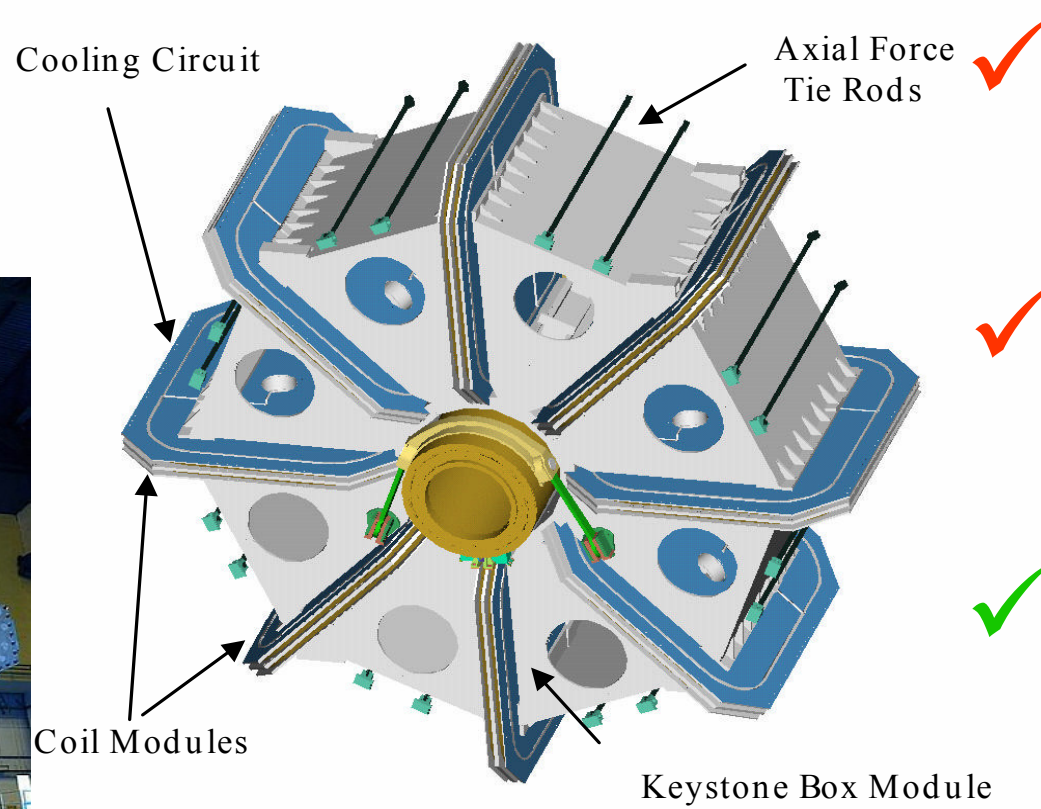
- ✓ Project executed with ATLAS technical personnel
 - ✓ Management : 2 project engineers + 2 designers
 - ✓ Mechanical installation : 3 team leaders + 13 technicians
(CERN, IHEP, JINR)
 - ✓ Tooling assembly and installation : JINR team (6 tech.)
 - ✓ Craning operations through CERN/TS/DBS contract
 - ✓ Winches operation subcontracted (firm Montalev)
 - ✓ Nearly 3000 bolts pre-loaded and ~ 1600 tons manipulated
- More than 35000 working hours,
no accidents**

BT next steps



- Step 1: Vacuum test of Coils and Cryoring starting Jan '05
- Step 2: Cool down to 4.8K in Jan-Mar '06, cleaning of the cavern from metallic objects
- Step 3: Field test in Apr-May '06, mostly overnight
- Step 4: Coils warming up May '06 and wait for the 2 end-cap toroids and full magnet test (Jan-Feb '07) for the final cool down

The End Cap Toroids



Engineering Design



Components Manufacturing



Integration at CERN



Installation in the PIT



Engineering & Monitoring @ RAL, NIKHEF

Integration work in bldg. 180

8 coils + 8 keystone boxes / cold mass

Coil winding



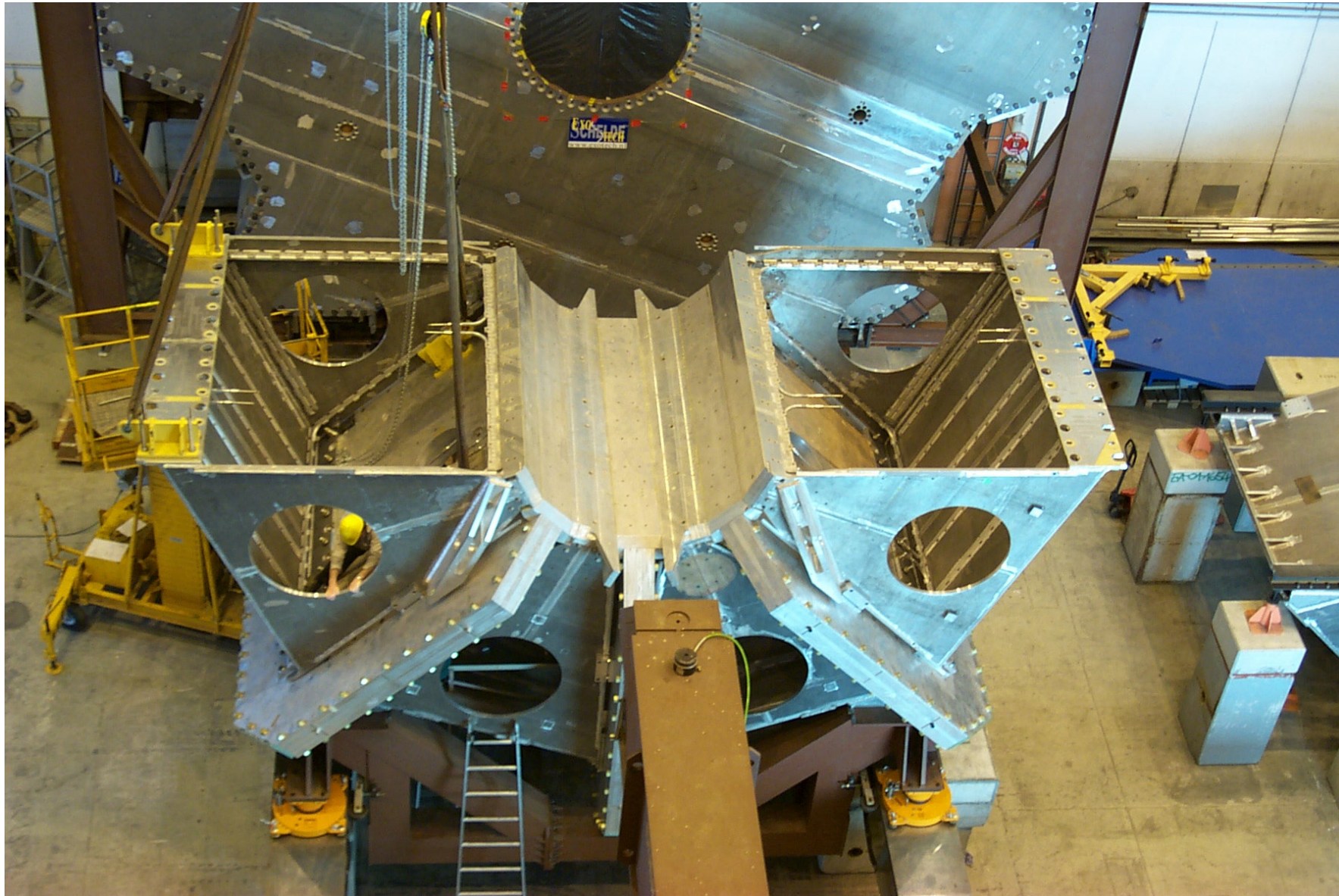
Coil impregnation



Wedges pre-assembly



1st half cold mass finished 3 Oct



18/11/2005

Marzio Nessi

Cold Mass integration



Work shows good progress though delayed due to a problem with the main manufacturer (~12 months)

ECT A:

First Cold Mass A is now being integrated on the rails in front of the cantilever and Vessel A

Will be inserted in the vessel in Nov '05

Ready for testing in Feb '06

80K test on surface (outside bldg. 180)

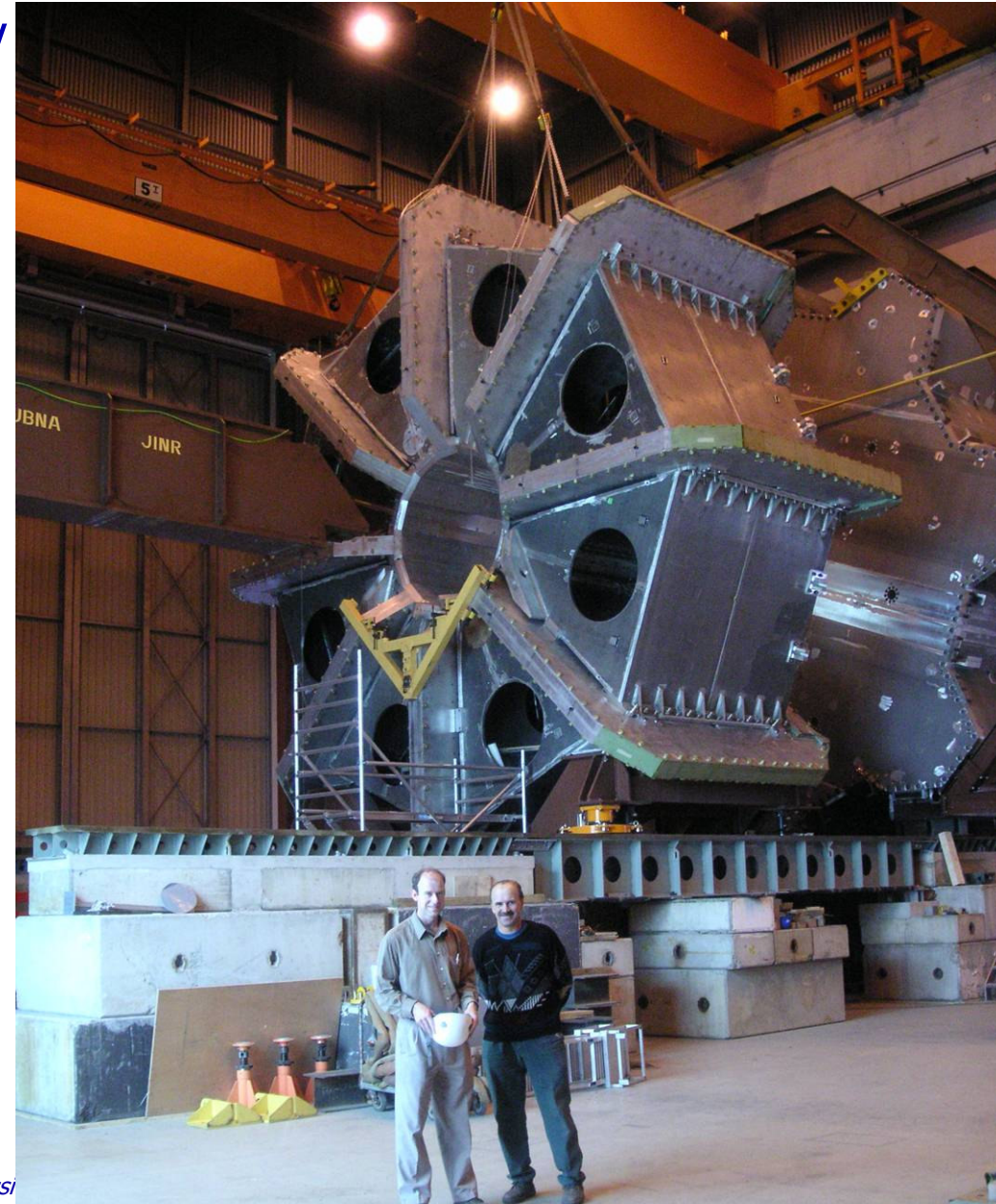
Then move to cavern in May '06

for 4 K test and installation (May '06)

ECT-C :

Follows with 3 months delay

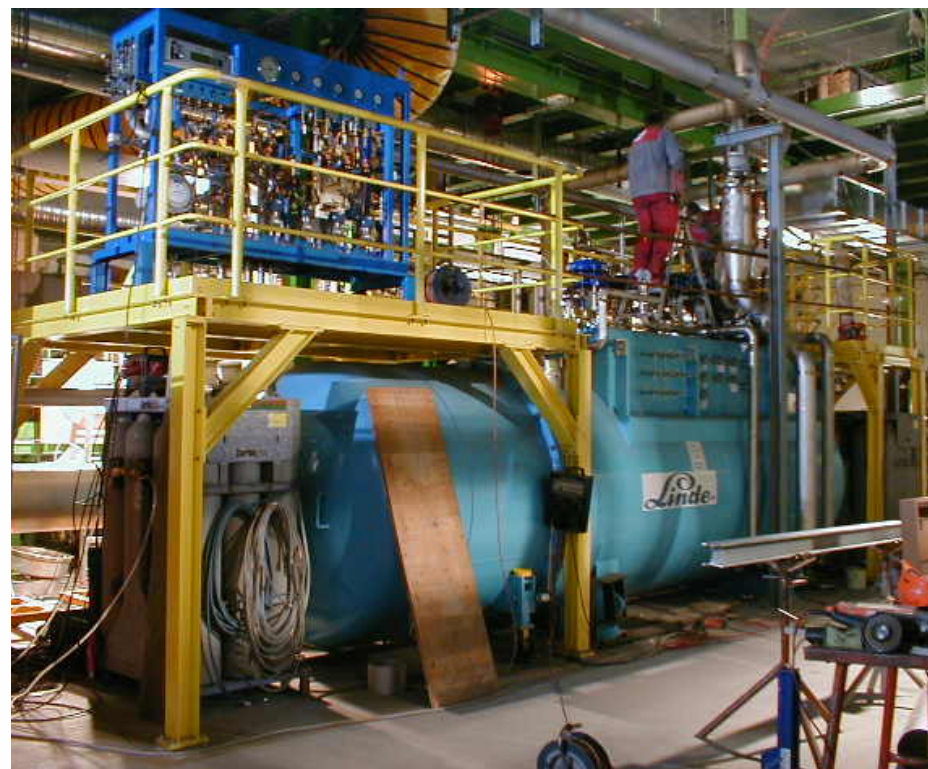
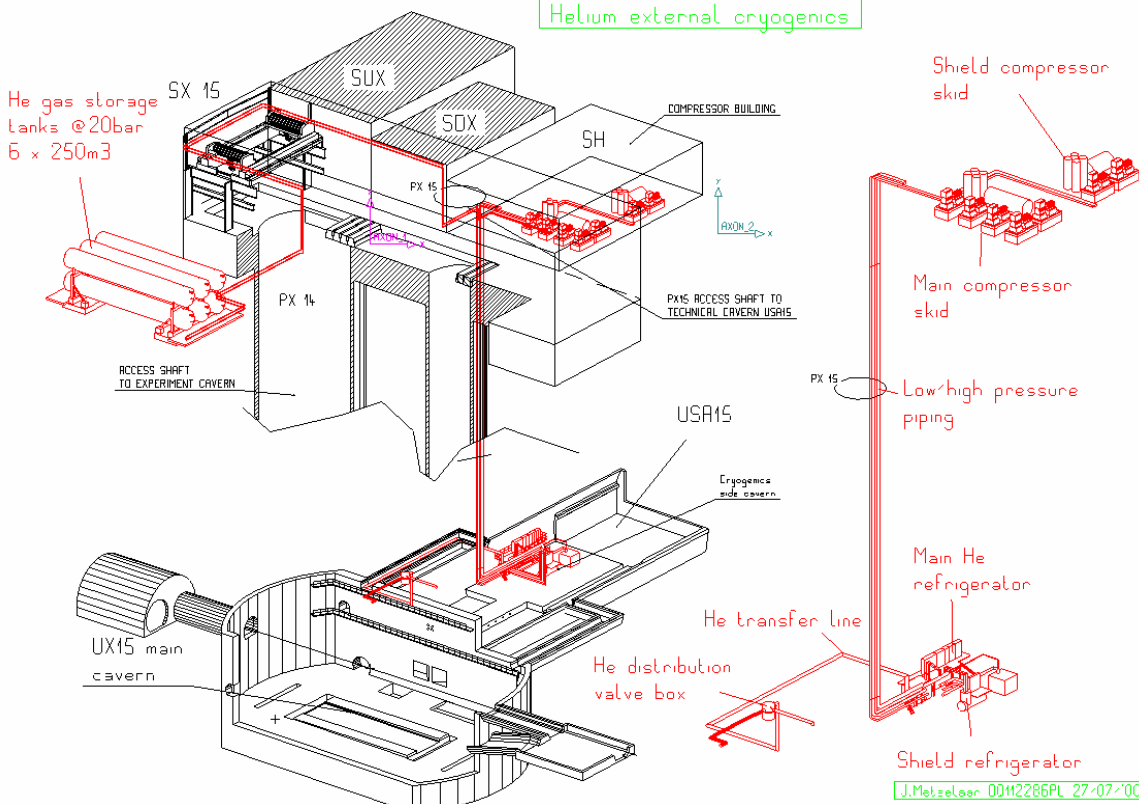
Ready for installation September '06



He external cryogenics

- ✓ Installation of He plants is completed, commissioning is ongoing
- ✓ Linde refrigerator (20 kW @ 40-80 K; 60kW with pre-cooling) for cooling down and maintaining thermal shield at 50-80K
- ✓ Air Liquide Helium liquefier (6 kW @ 4.5 K) to fill and maintain 11 kL in the storage dewar

Helium external cryogenics



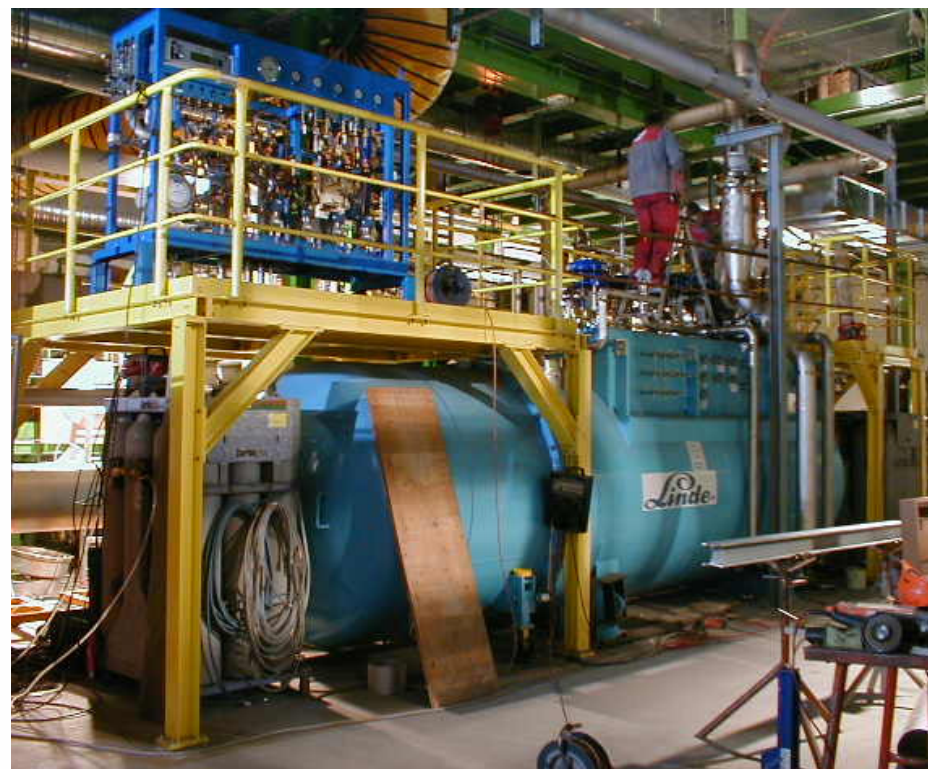
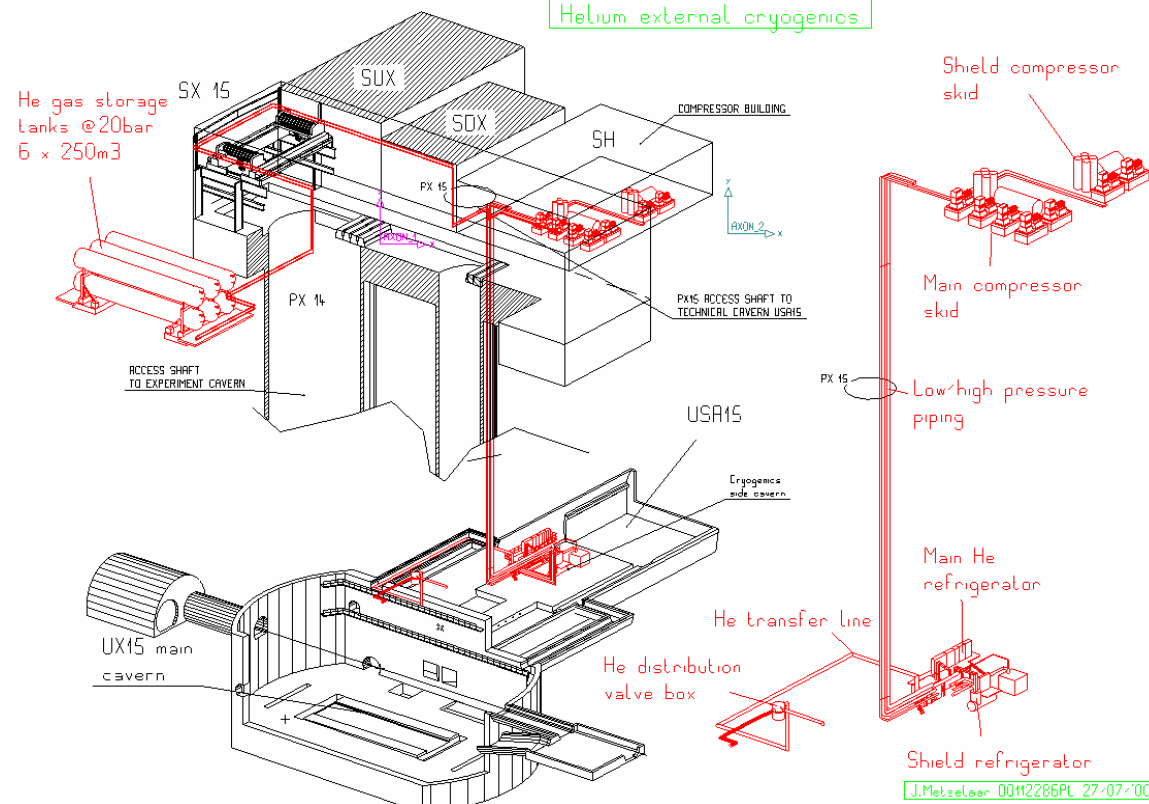
J.Melzelaar 00112266PL 27-07-00

Marzio Nessi

He external cryogenics

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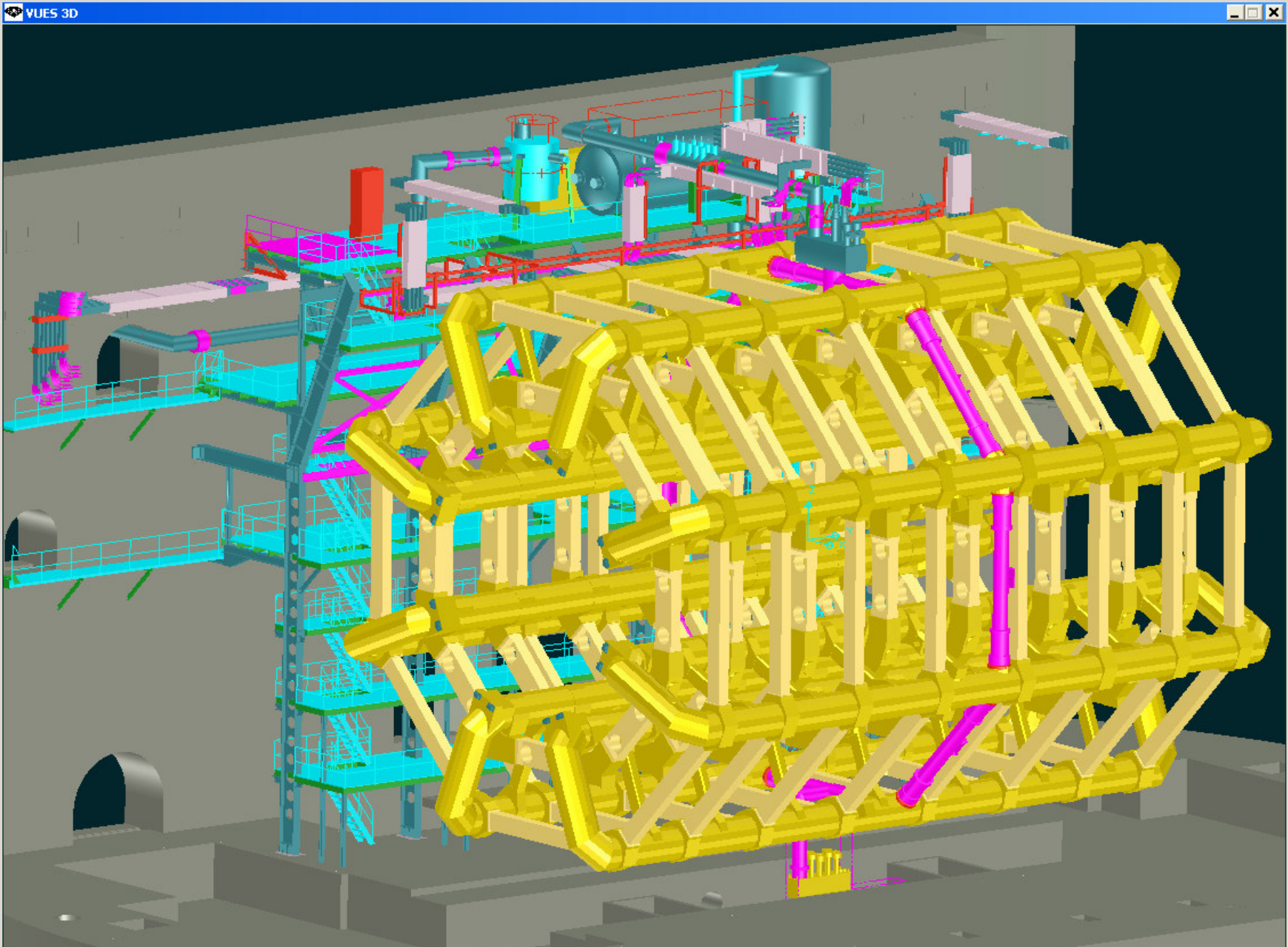
Helium external cryogenics



J.Melzeler-00112266PL 27-07-00

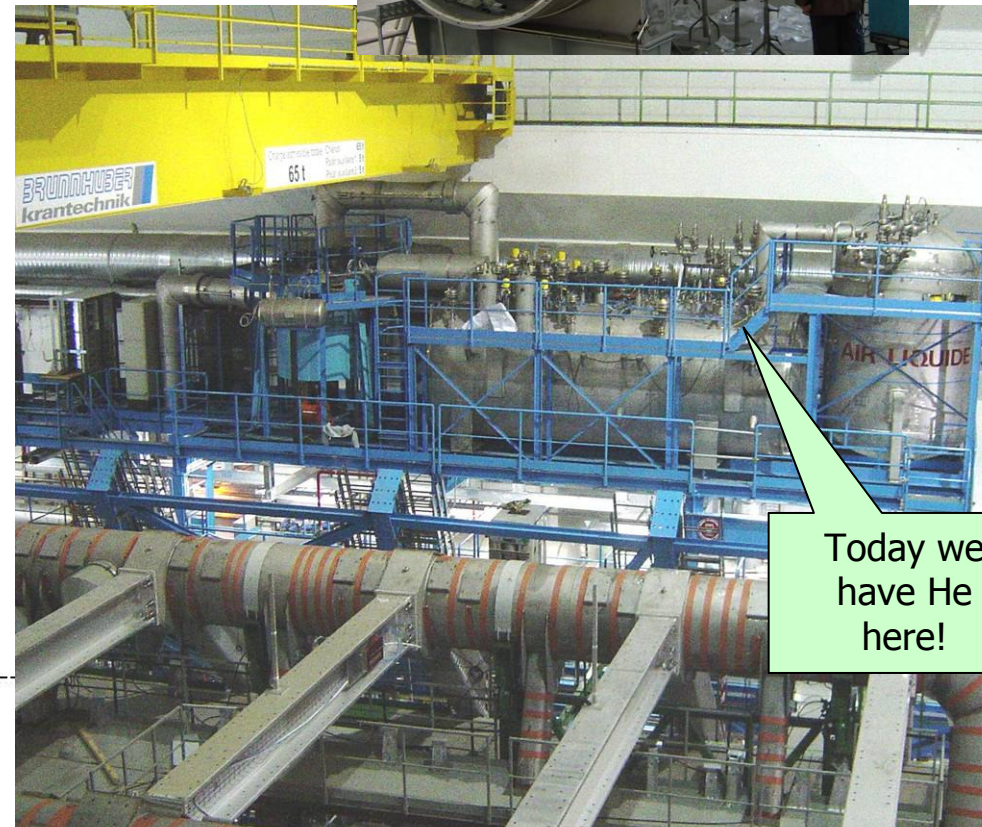
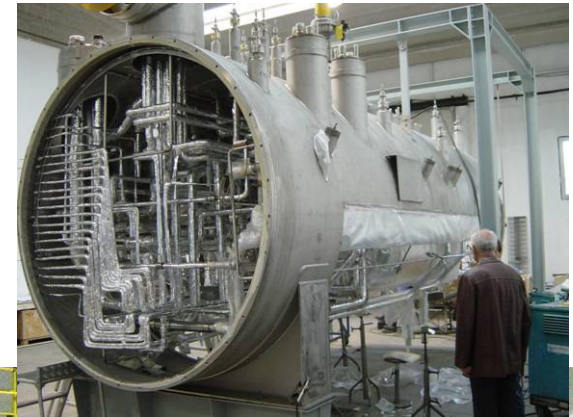
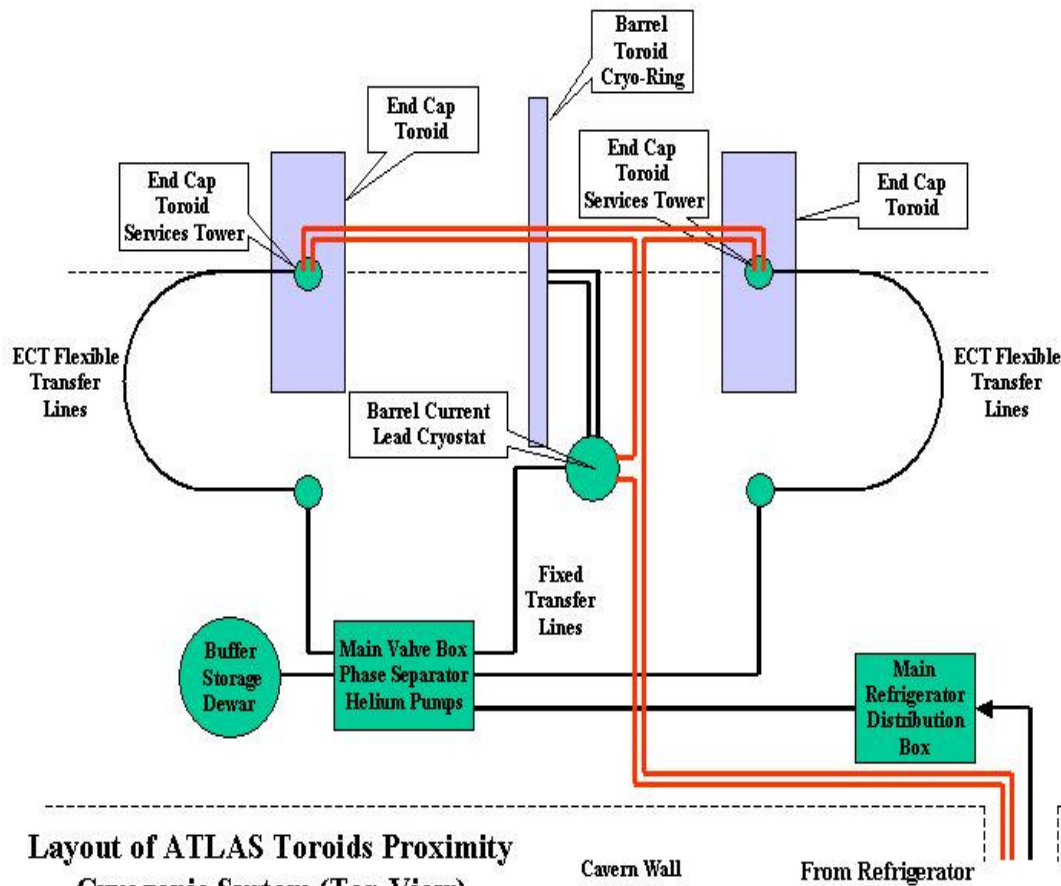
Marzio Nessi

Proximity services



Proximity cryogenics

- ✓ Coils conduction cooled by super critical He
- ✓ Circulation of 1.2 kg/s at 0.4 b by cold He pumps
- ✓ Valve box and dewar are already at 4.5K



Tracking Project

Pixels + SCT + TRT + services

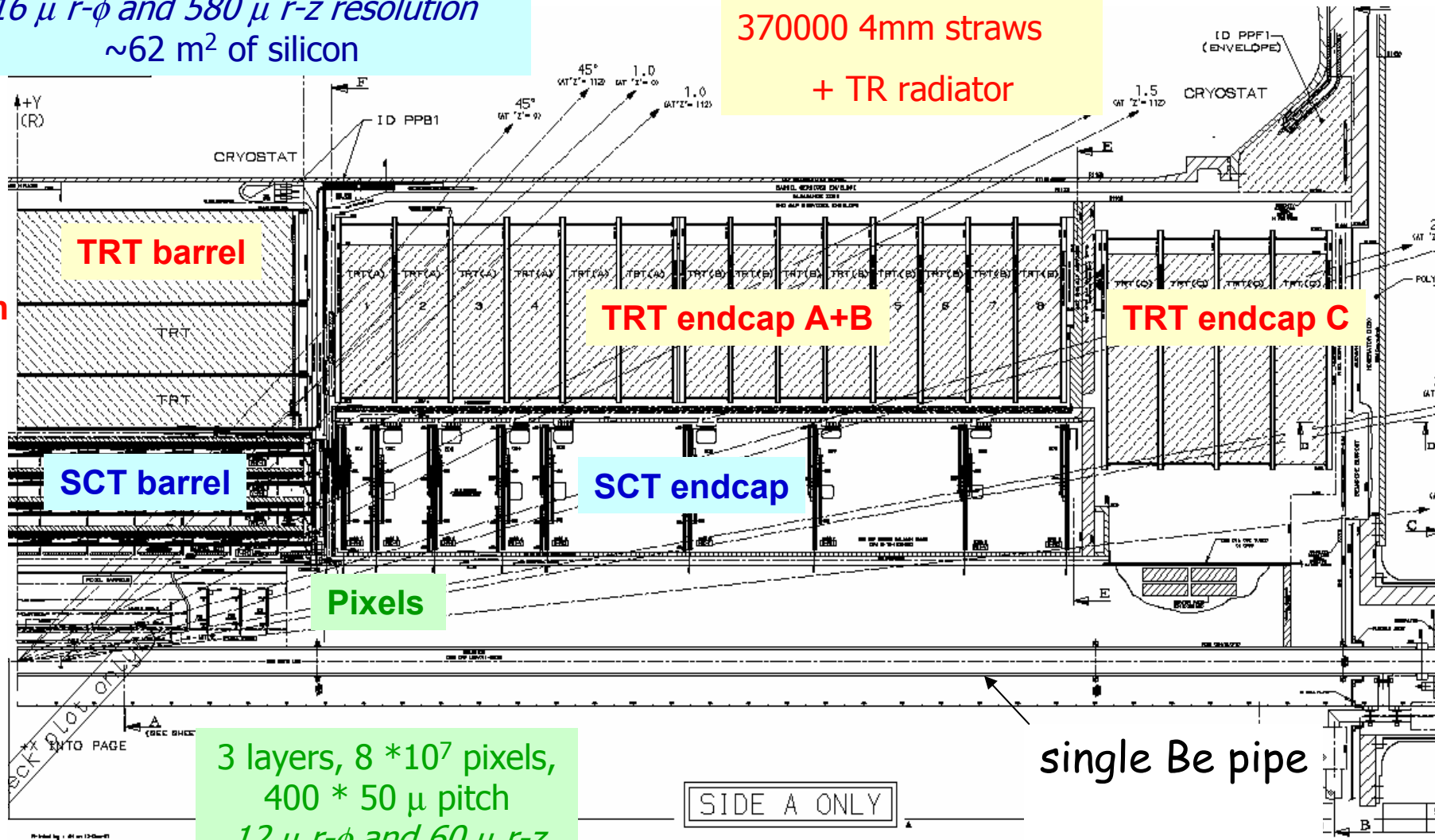
Production over 8 years, 1999-2006
Installation over 1.5 years, 2006-2007

Tracking detectors



SCT : 4088 modules, 80 μ pitch
 16 μ r - ϕ and 580 μ r - z resolution
 ~62 m² of silicon

370000 4mm straws
 + TR radiator



$r=55-105\text{cm}$

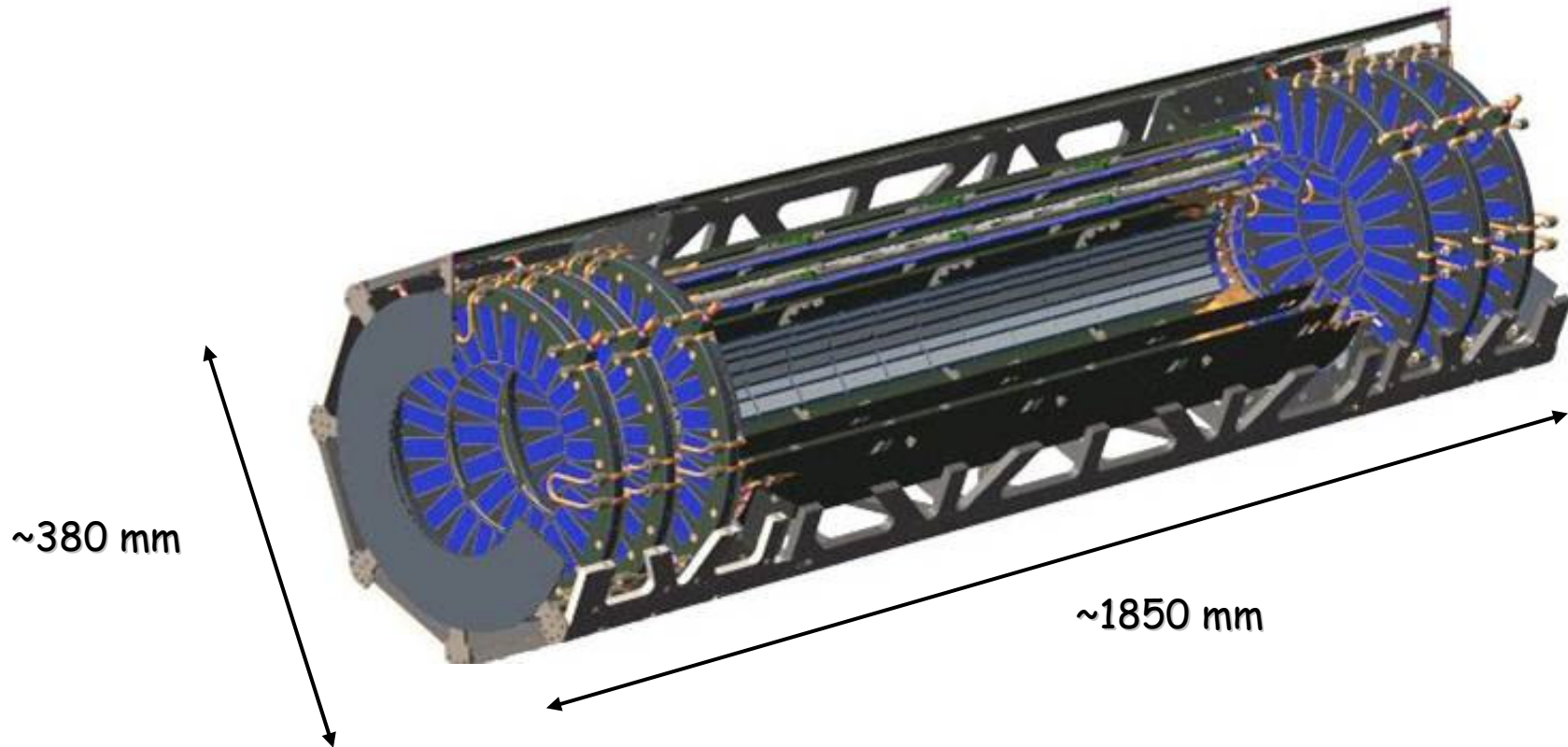
$r=30-52\text{cm}$

$r= 5-25\text{cm}$

3 layers, 8 * 10⁷ pixels,
 400 * 50 μ pitch
 12 μ r - ϕ and 60 μ r - z
 resolution

SIDE A ONLY

ATLAS pixels

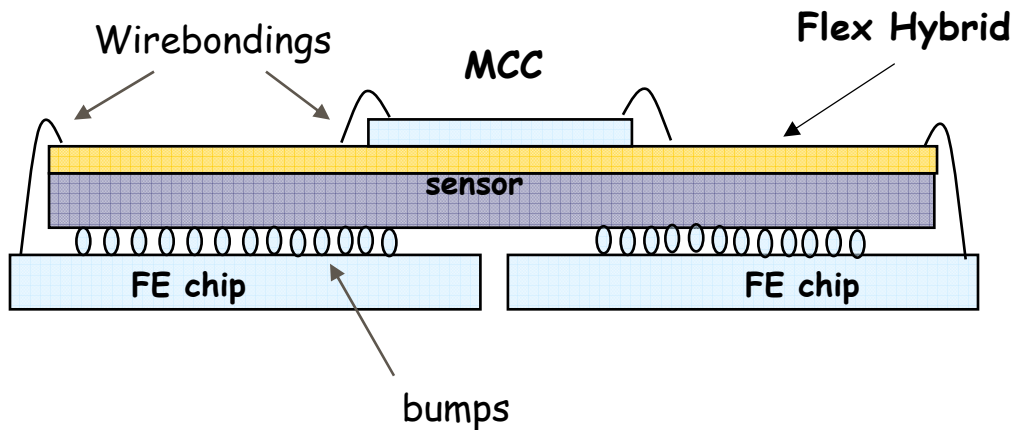


- ✓ ~1.7 m² of sensitive area with 67M (barrel) + 13M (disks) channels.
- ✓ n+ on n oxygenated sensors, 400μm x 50μm pixels.
- ✓ Total dose 50 Mrad on the middle layer in 10 years of LHC.

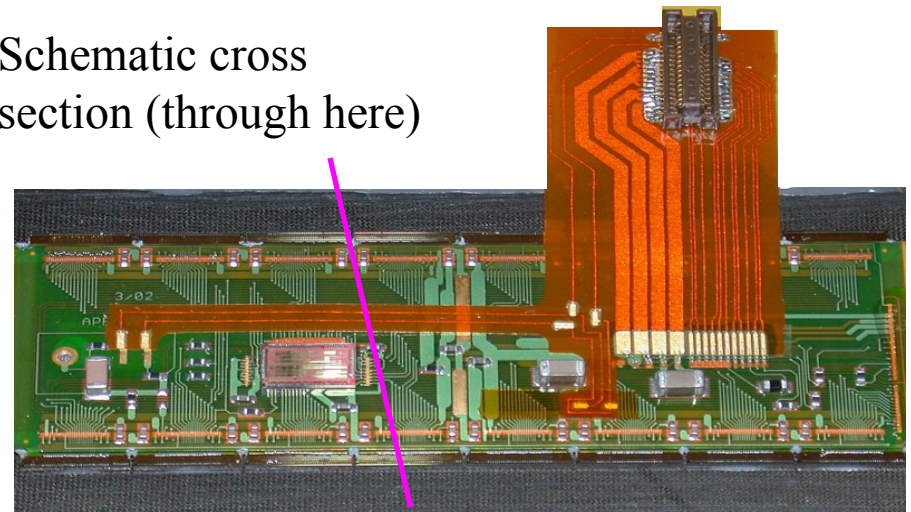
ATLAS pixels



- ✓ Modules are the basic building elements of the detector (1456 in the barrel, 288 in the end-caps).
- ✓ The sensitive area is read out by 16 FE chips which are controlled by a Module Controller Chip (MCC).
- ✓ A Flex-Hybrid circuit glued on the sensor backside provides the signal/power routing.
- ✓ A pigtail (barrel) + Al/Cu wire bundle connect flex hybrid to patch panels at either end of pixel detector. Pigtail is the only difference between barrel and disks modules.



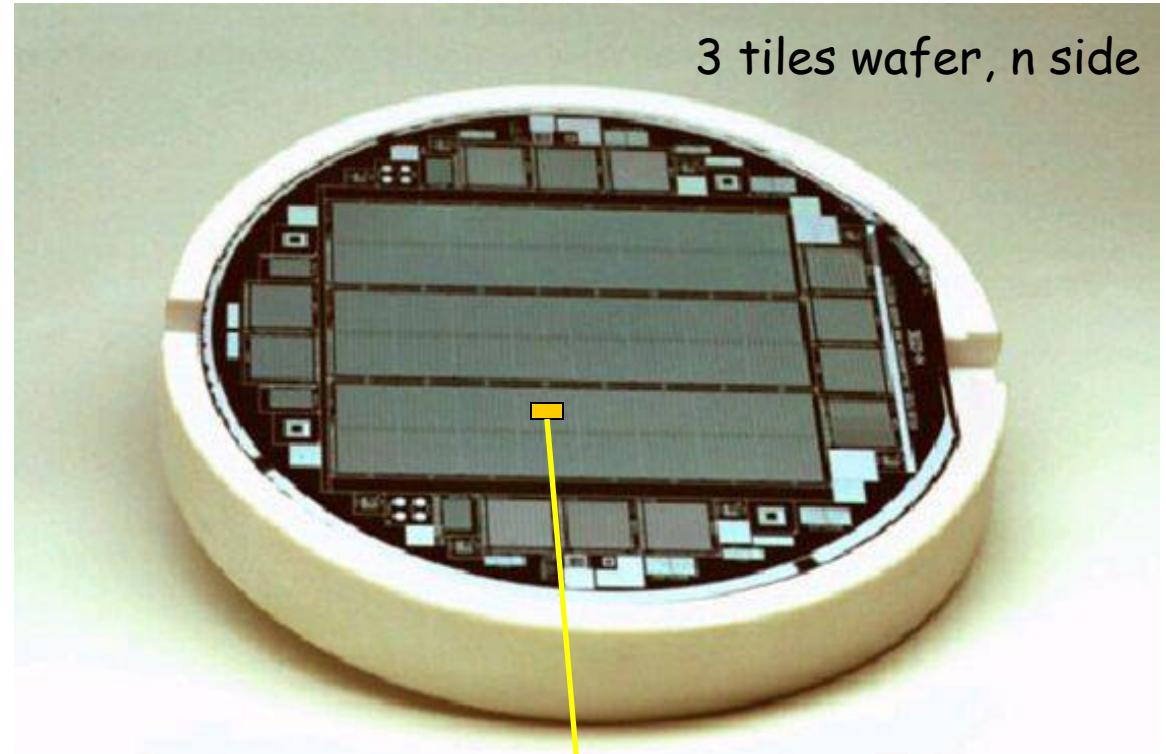
Schematic cross section (through here)



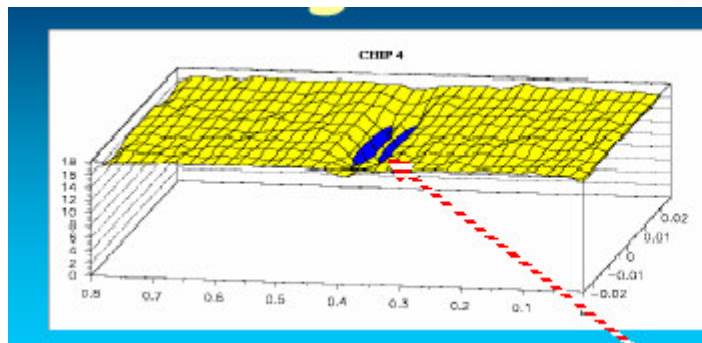
ATLAS pixels



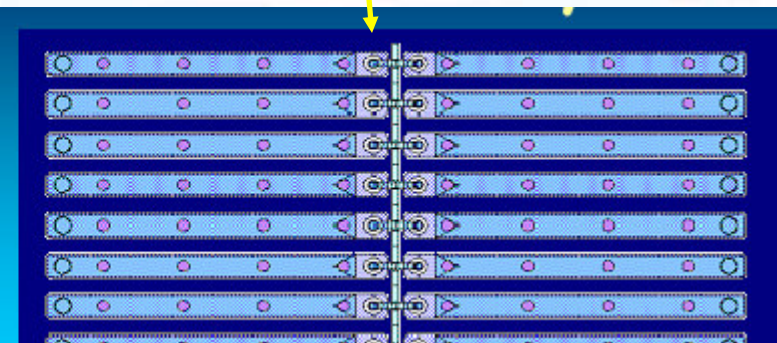
- Baseline design:
 - ✓ $n+$ pixel in n -bulk material:
 - ✓ Moderated p -spray isolation.
 - ✓ Bias grid to allow testing before module assembly.
 - ✓ Oxygenated silicon to improve radiation resistance and increase allowable time to room temperature (for repair/upgrades).
- Two vendors: Cis and Tesla



3 tiles wafer, n side



Charge collection efficiency (meas)

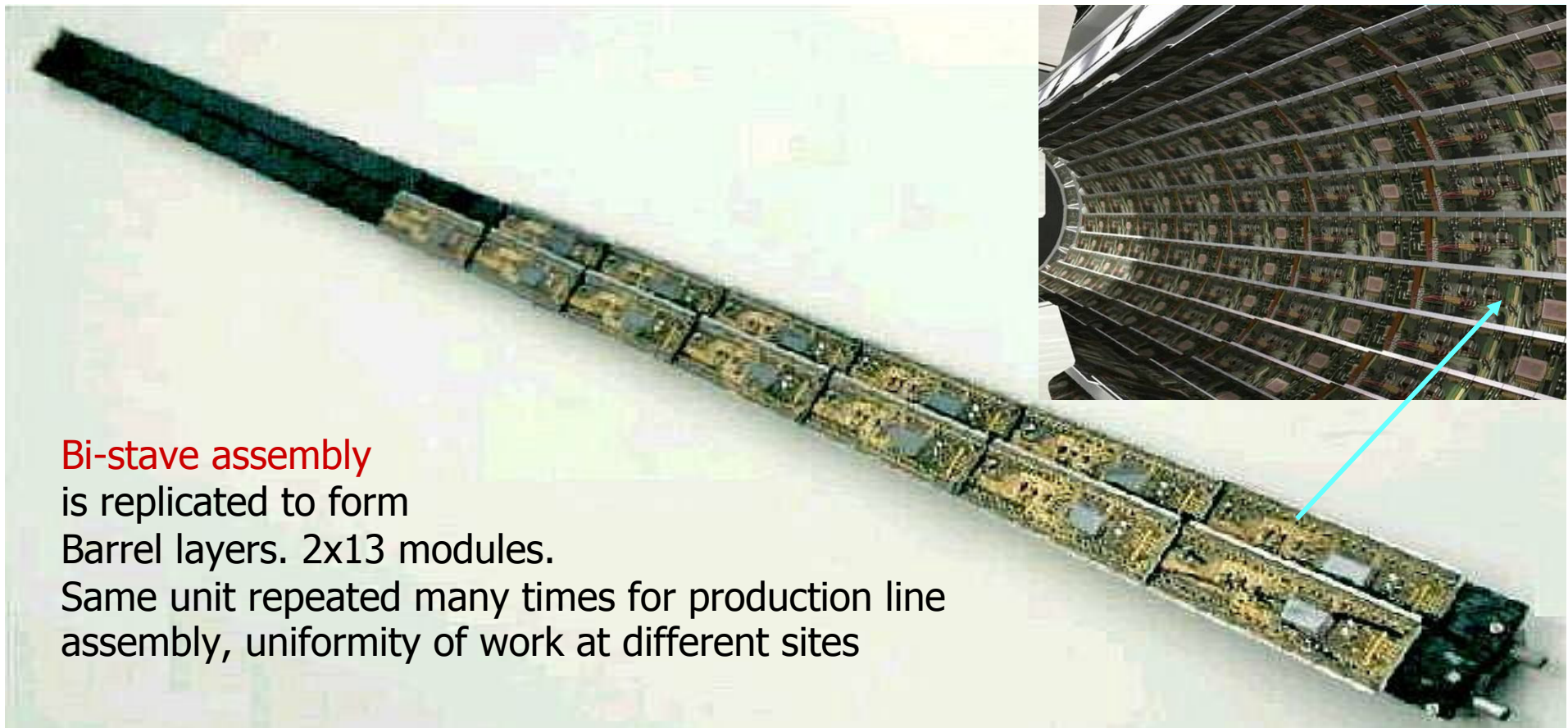


$n+$ implants and bias grid

ATLAS pixels staves



- ✓ Barrel staves and disk sectors are the local supports that hold and cool pixel modules (T sensors $<0^{\circ}\text{C}$).
- ✓ They are carbon-carbon structures to minimize material.
- ✓ The cooling fluid (C_3F_8) flows in thin Al tubes (0.2mm) both for staves and disks.



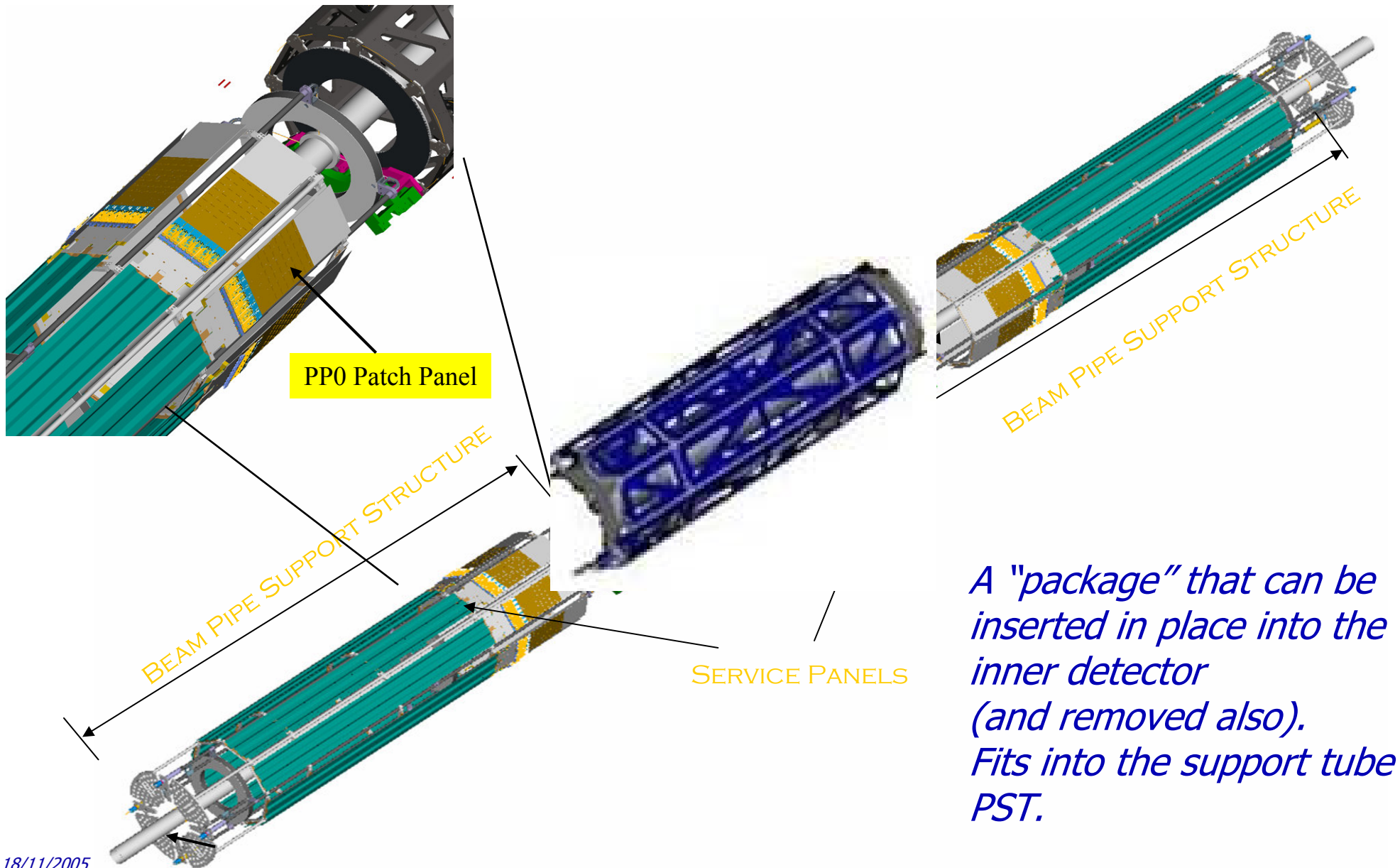
Bi-stave assembly

is replicated to form

Barrel layers. 2x13 modules.

Same unit repeated many times for production line assembly, uniformity of work at different sites

ATLAS pixels assembly

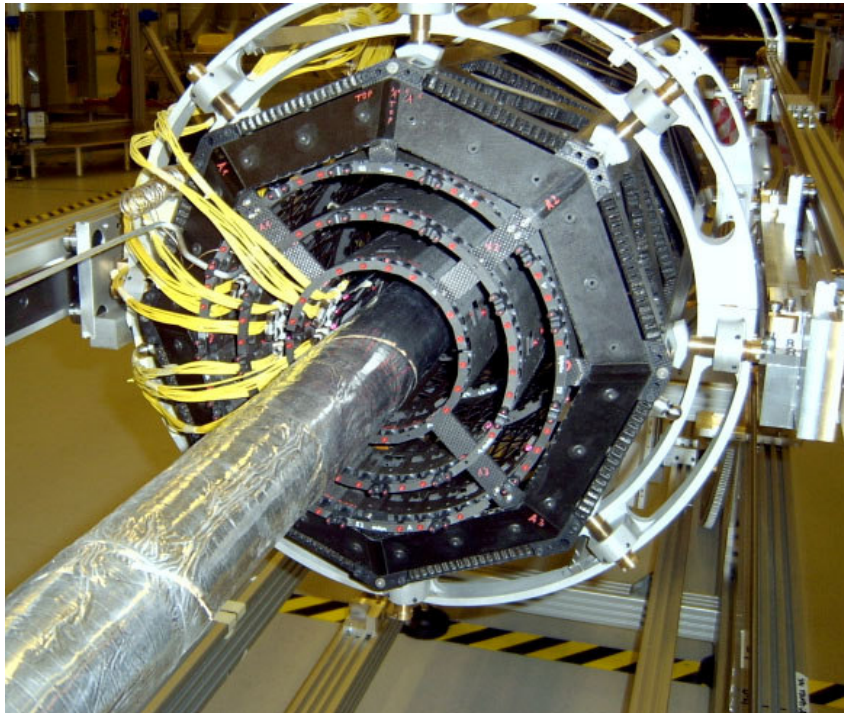


A "package" that can be inserted in place into the inner detector (and removed also). Fits into the support tube PST.

ATLAS pixels assembly



- ✓ Setup to carry out bi-stave assembly and testing of staves
- ✓ Assembly tools installed for bi-stave to CF-structure mounting
- ✓ Carried out a full dry-assembly of all support structures and tested assembly procedure of Pixel detector with dummy beam pipe
- ✓ Started in Mar 05 and will complete by Oct 2006



Integration and Testing Tool

Today we are stopped by some corrosion problems of the primary stave cooling pipes (major rework needed)

The SCT (SemiConductor Tracker)

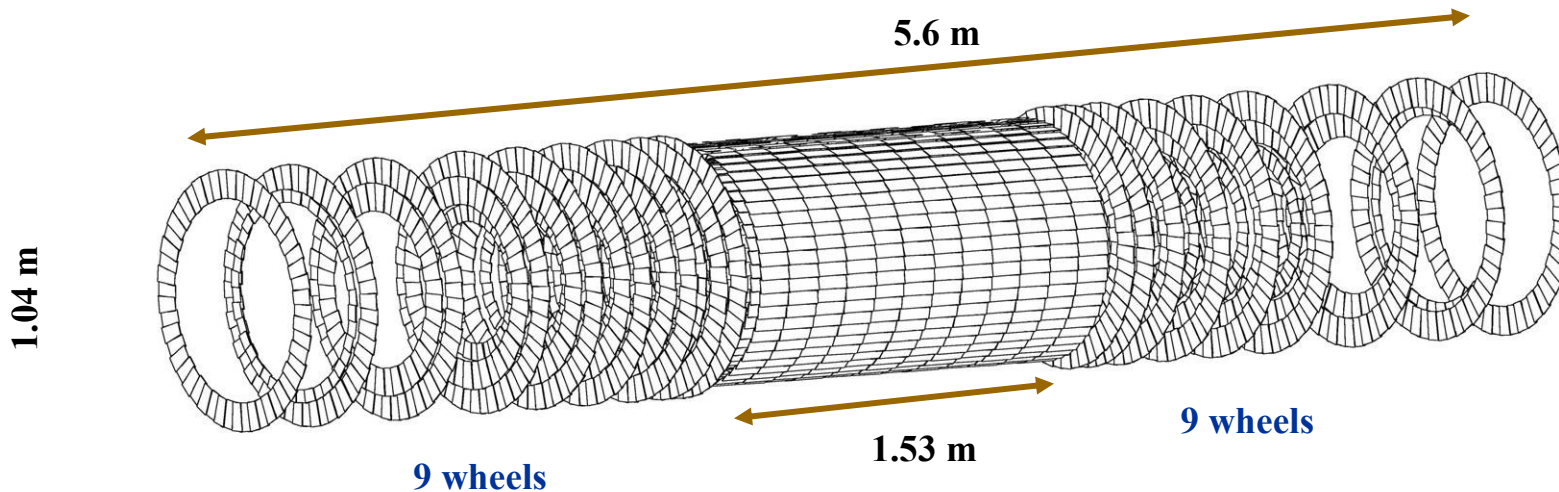


Two Endcaps

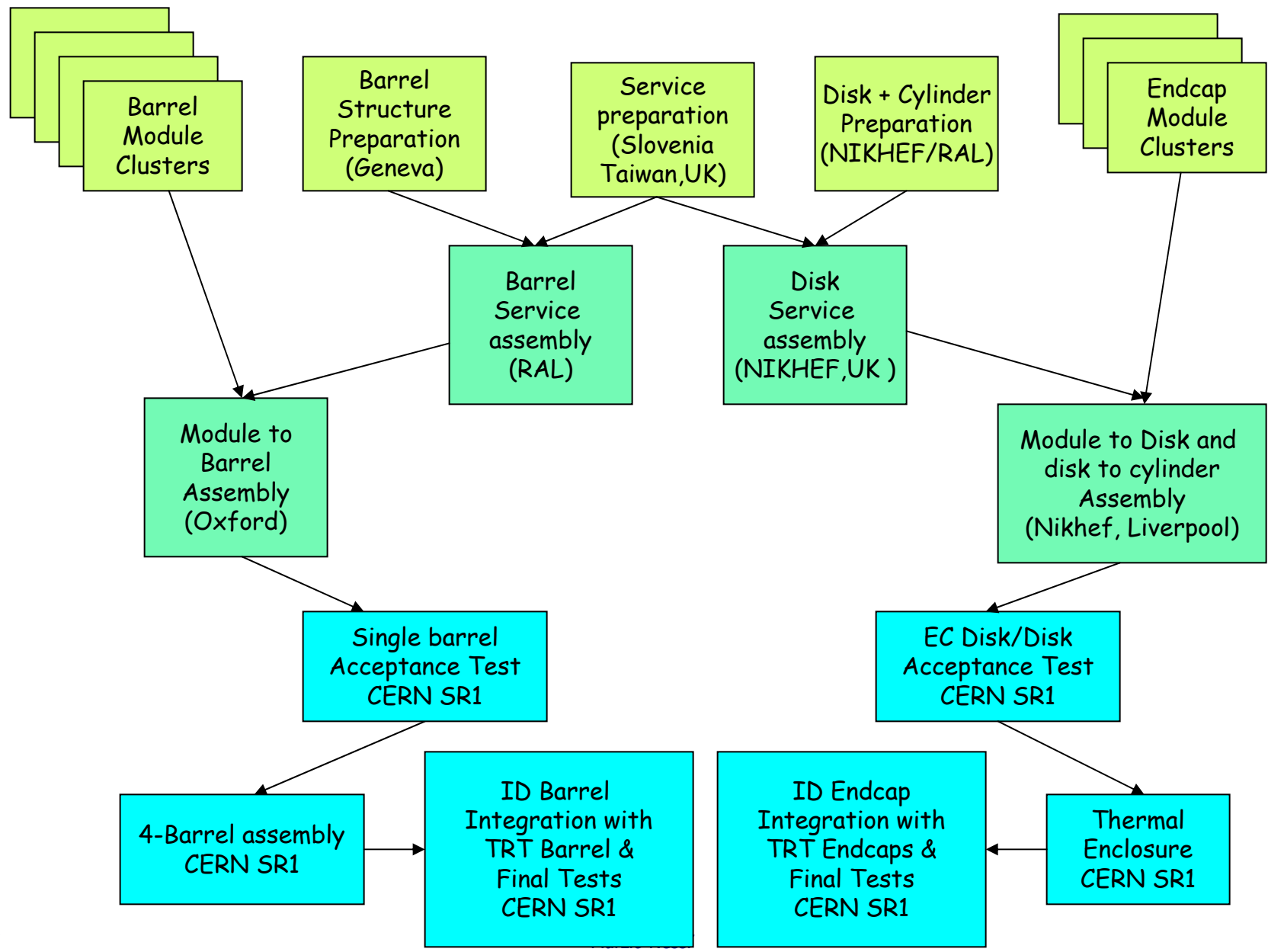
4-Layer Barrel

~34.4 m² of silicon
~3.2 × 10⁶ channels
2112 barrel modules (1 type)
Space point resolution:
 $r\phi \sim 16\mu\text{m} / Z \sim 580\mu\text{m}$
Coverage:
 $|\eta| < 1.1 \text{ to } 1.4 / 300\text{mm} < r < 520\text{mm}$

~26.7 m² of silicon
~3.0 × 10⁶ channels
1976 endcap modules (4 types)
Space point resolution:
 $r\phi \sim 16\mu\text{m} / R \sim 580\mu\text{m}$
Coverage:
 $1.1 \text{ to } 1.4 < |\eta| < 2.5$



Production flow chart



The barrel module

1. 4 Sensors

280 microns thick p-n
Strip length 12cm
Pitch 80 μ m

2. 3rd Mounting point

3. Hybrid & Binary Readout chips

Flex circuit with 12 x ABCD chips.

7. Overlaps

Overlap in ϕ and Z to adjacent modules

8. Stereo angle

Upper or lower detector pairs rotated by 40 mRad

4. Be Facing & Central TPG

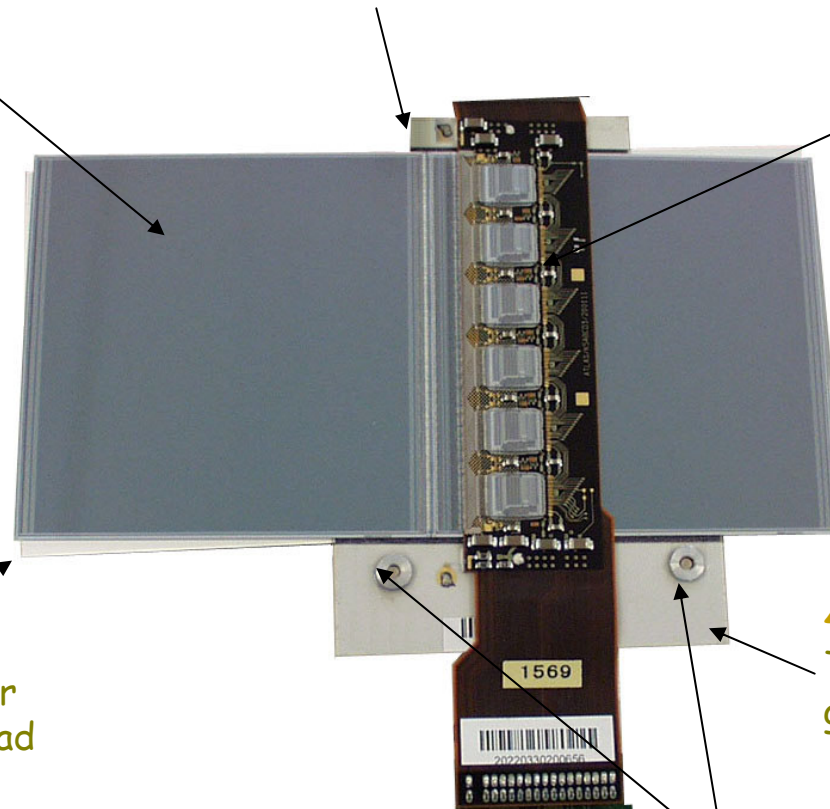
TPG (thermal pyrolytic graphite) plate for sensor cooling

6. Connector

Power & Data

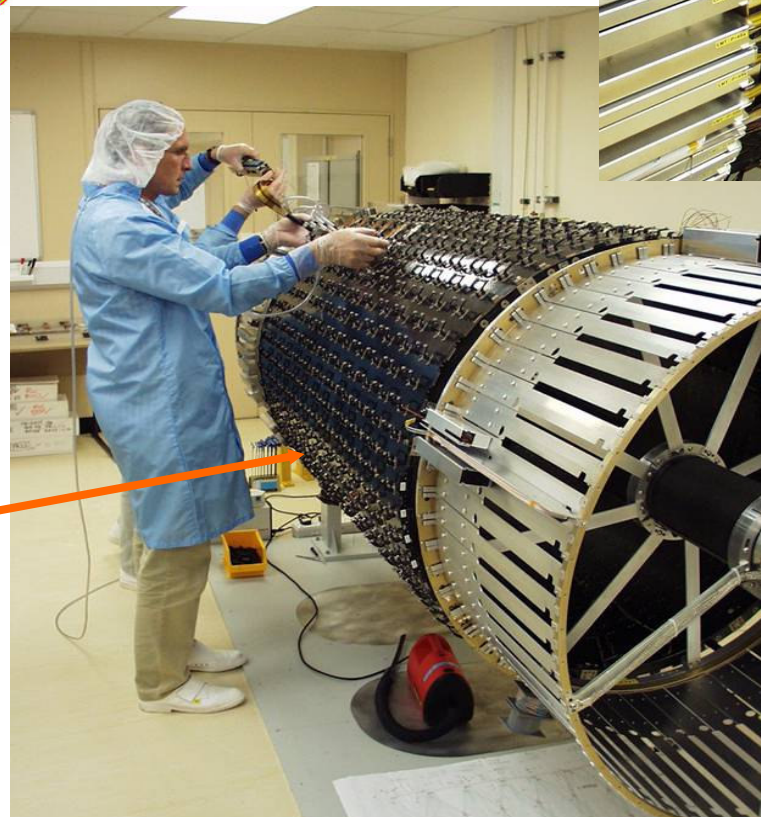
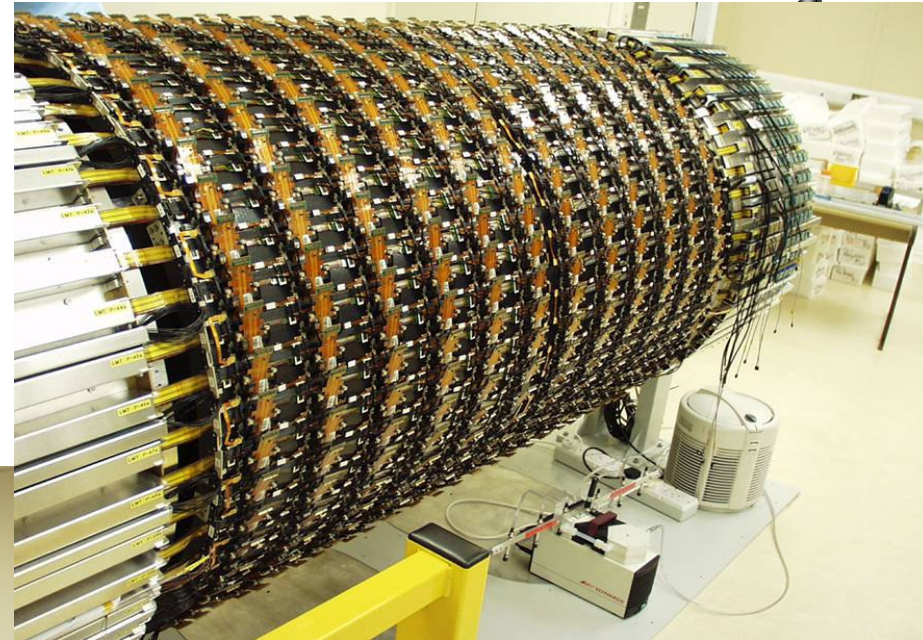
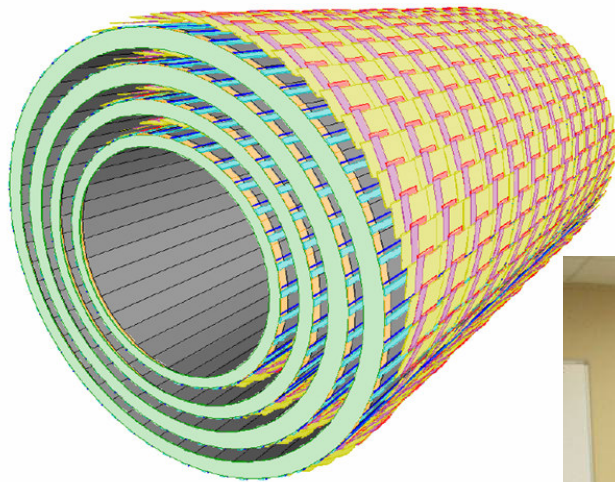
5. Module support & Location Holes

fix to brackets, one hole & one slot

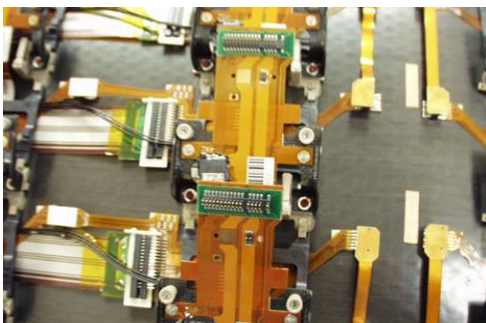


ATLAS barrel SCT

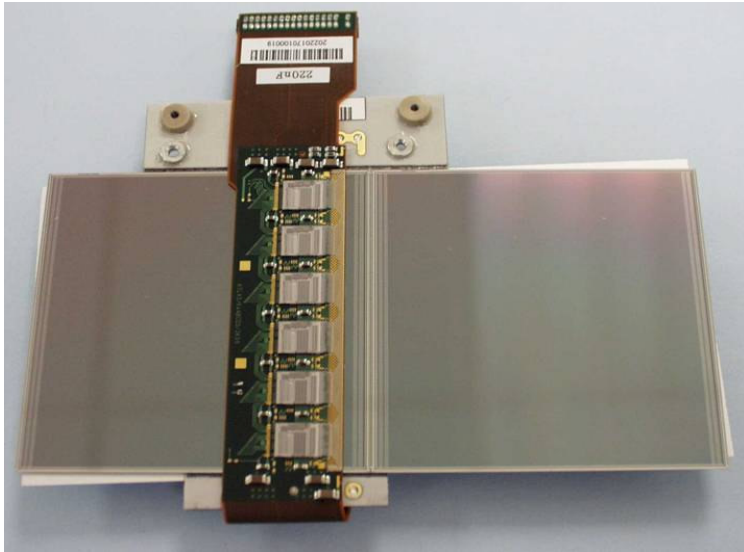
4 cylinders mechanically constructed and being assembled with services



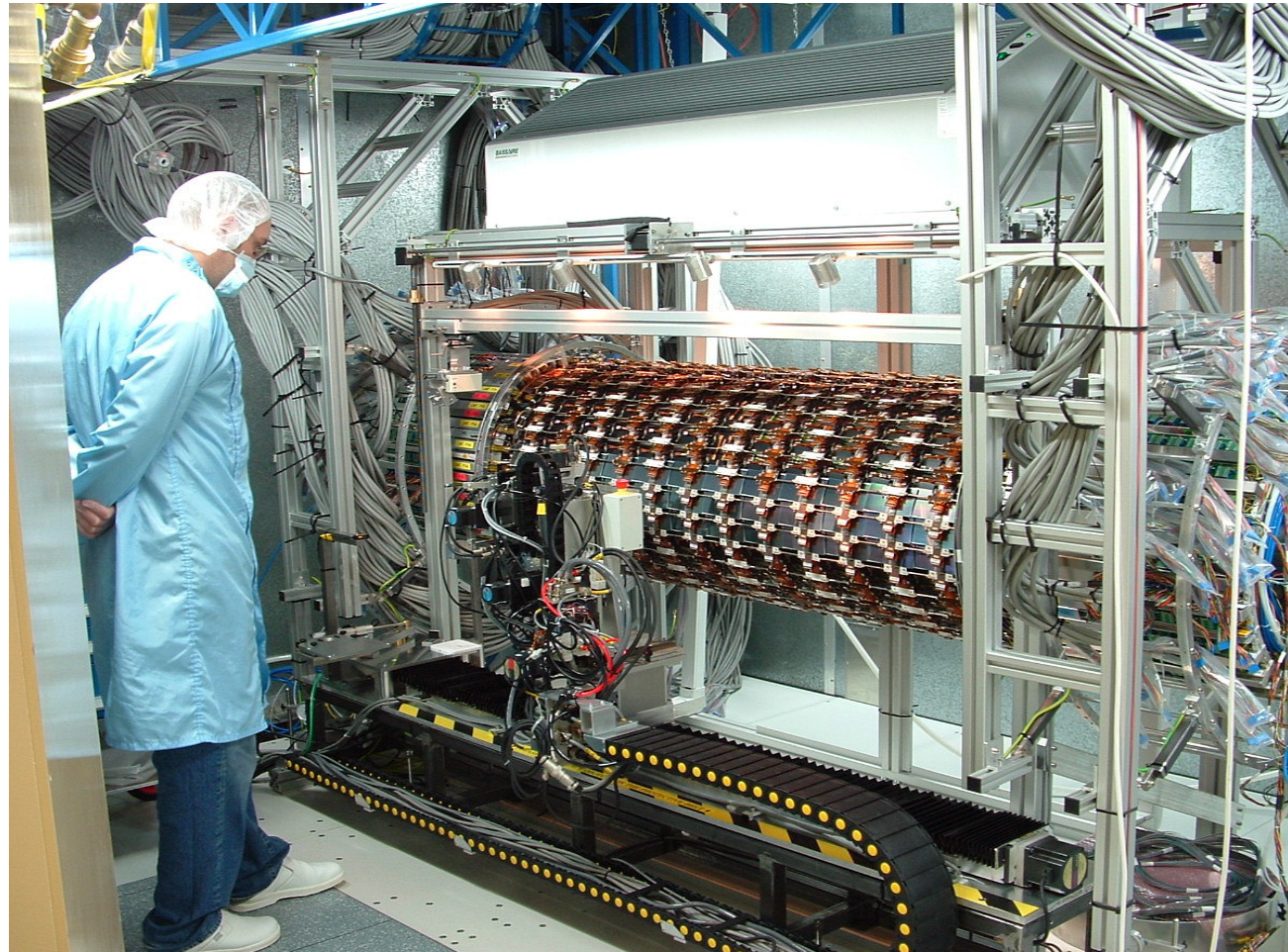
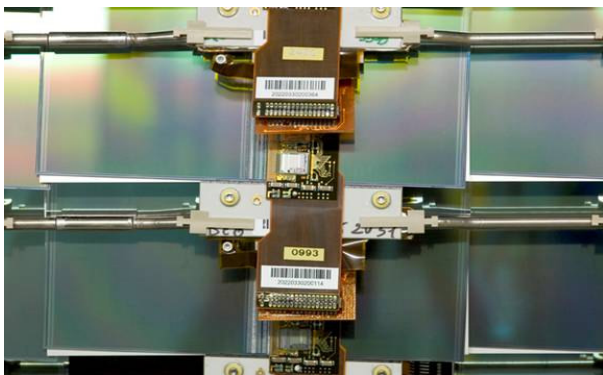
cylinders ready with all services mounted on it



ATLAS barrel SCT



All sensors procured, all modules have been produced (final yield > 90%). Sensor alignment and position tolerance typically $\pm 5 \mu\text{m}$



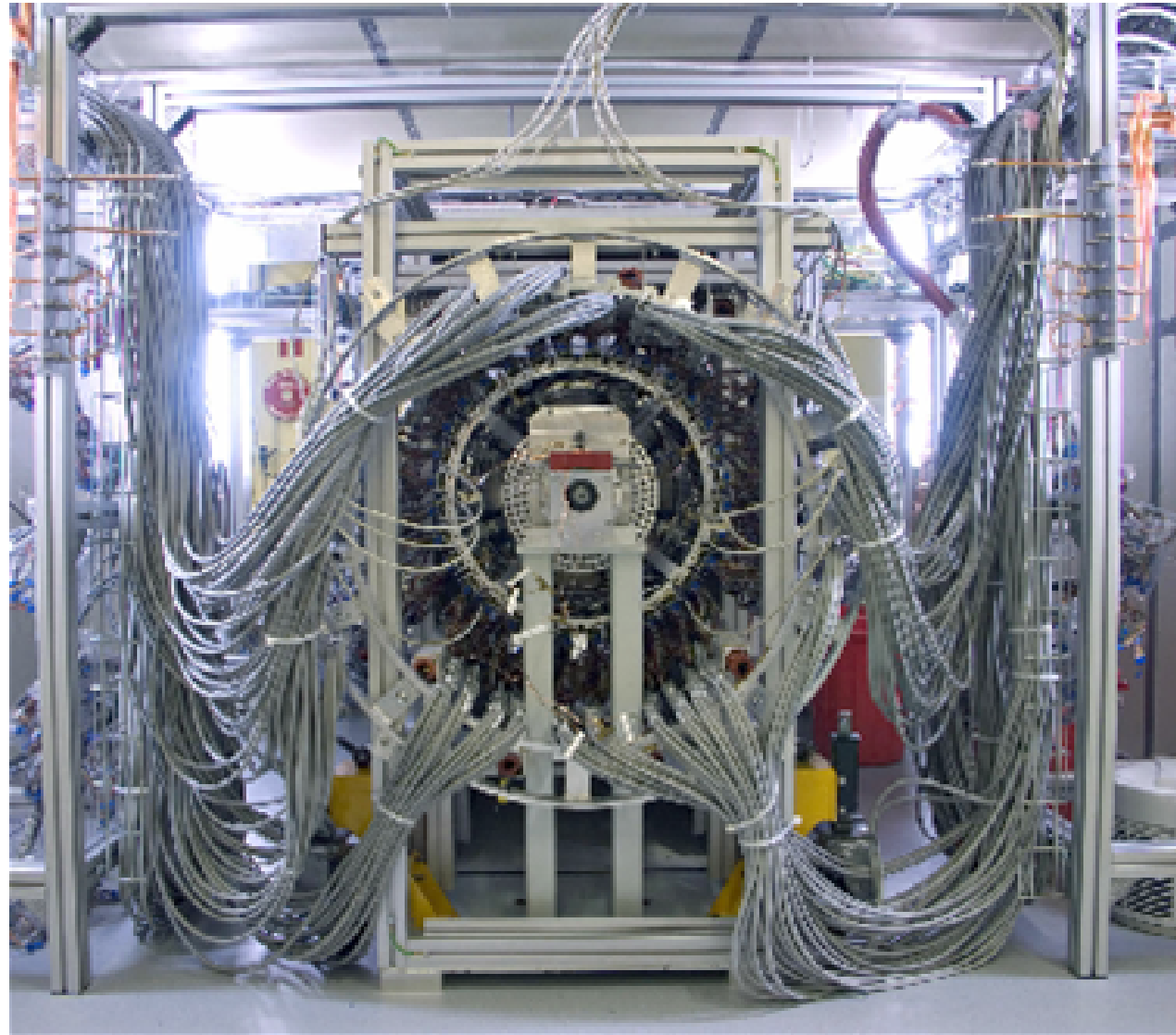
Macro-assembly of the modules on the support cylinder using a dedicated robot. All 4 barrels assembled and now at CERN

SCT barrel acceptance tests

SCT acceptance tests
(each barrel was fully tested)

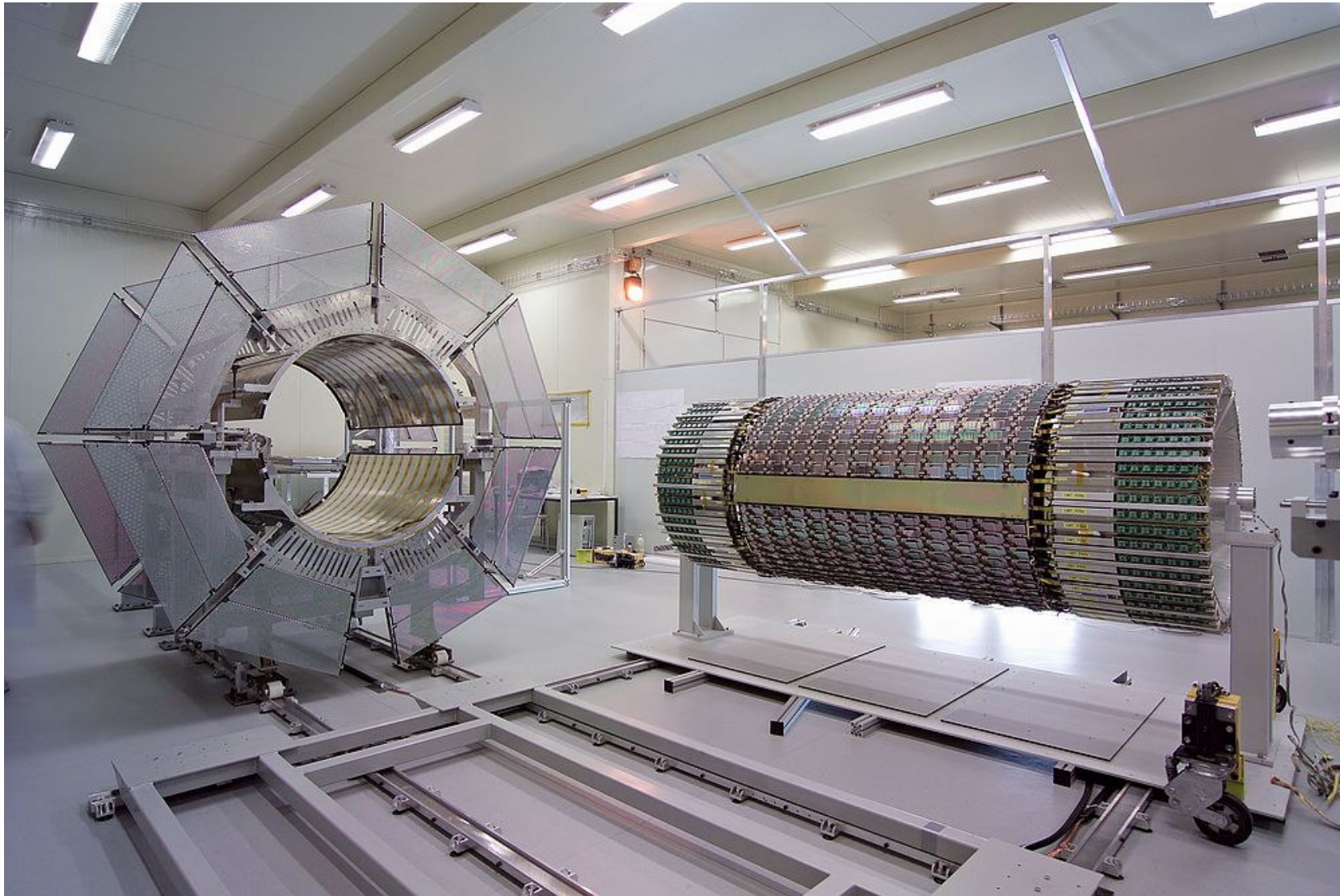
Barrel	Total Channels	Total Defects
3	589824	1483
4	737280	841
5	884736	1818
6	1032192	5720
Total	3244032	9862

**Total of 99.7% of all channels
fully functional**



SCT barrel during acceptance test

SCT barrel assembly

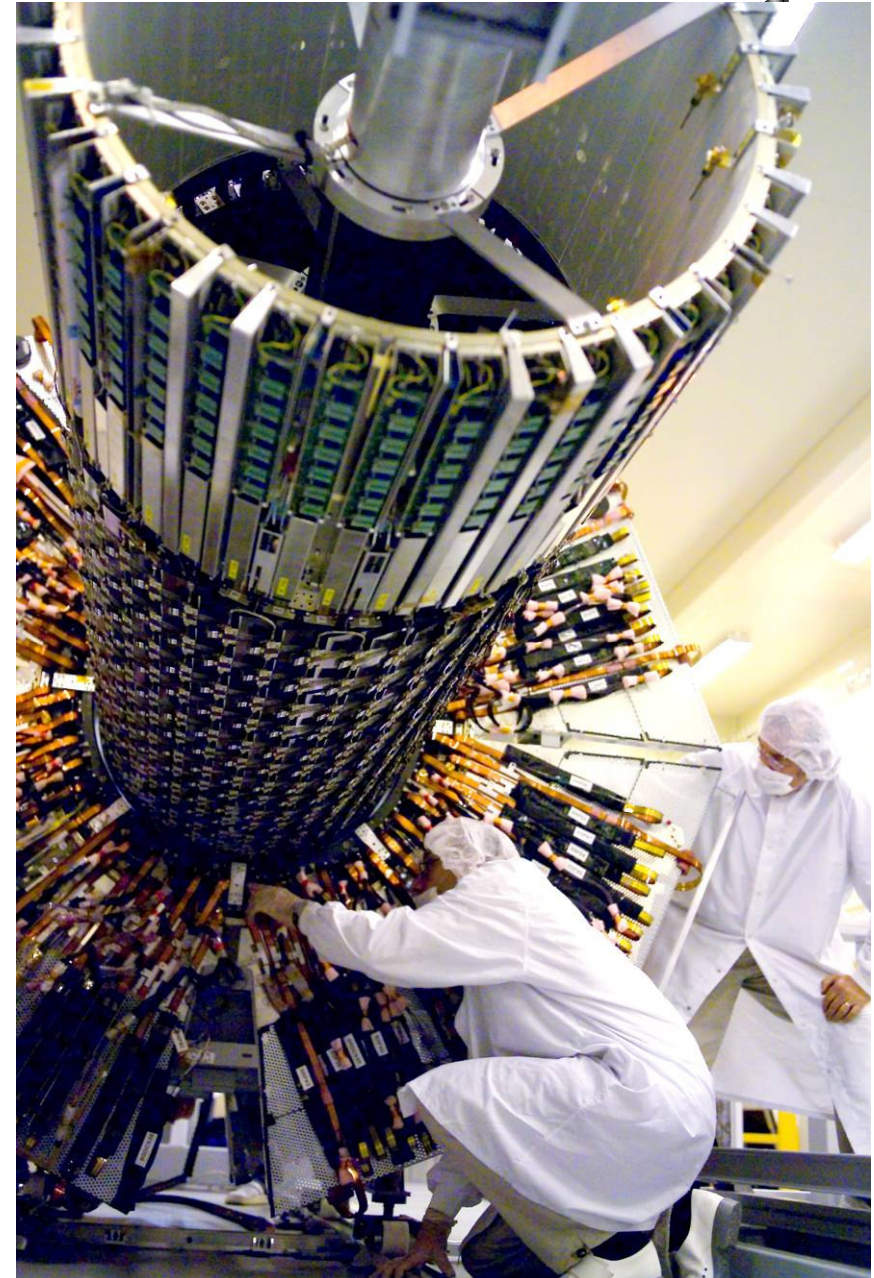
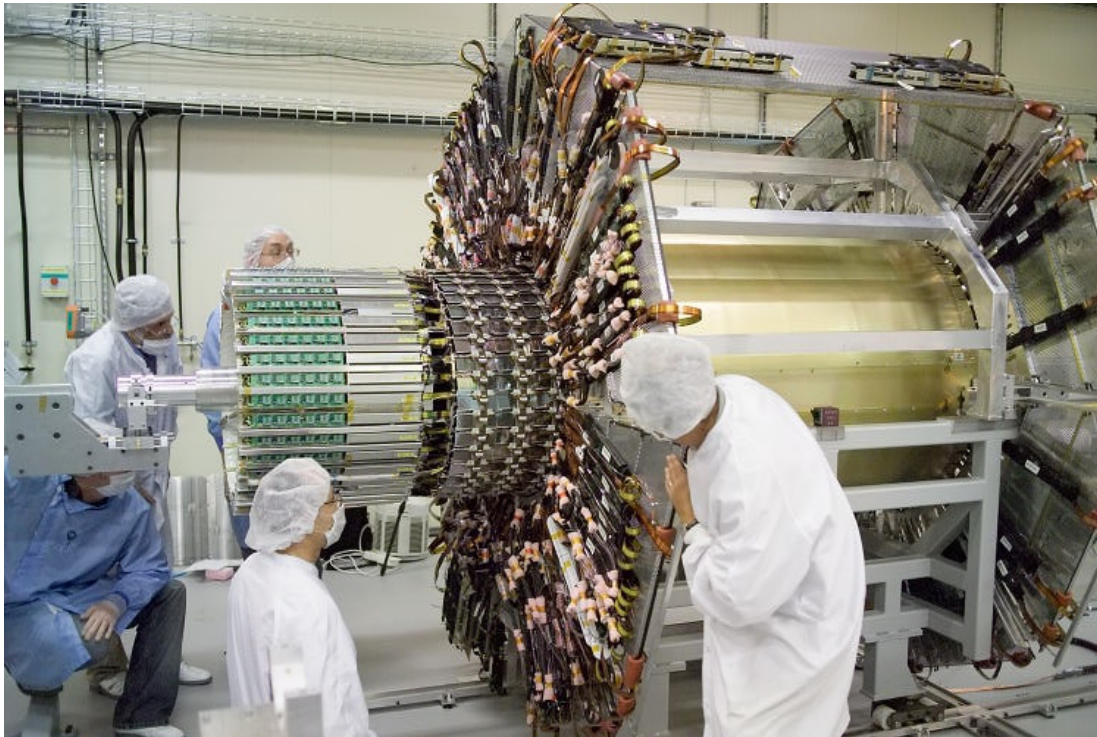


Outermost ATLAS SCT barrel cylinder before insertion into the thermal enclosure

SCT barrel assembly



Insertion of the 3rd cylinder (out of the four) into the barrel SCT

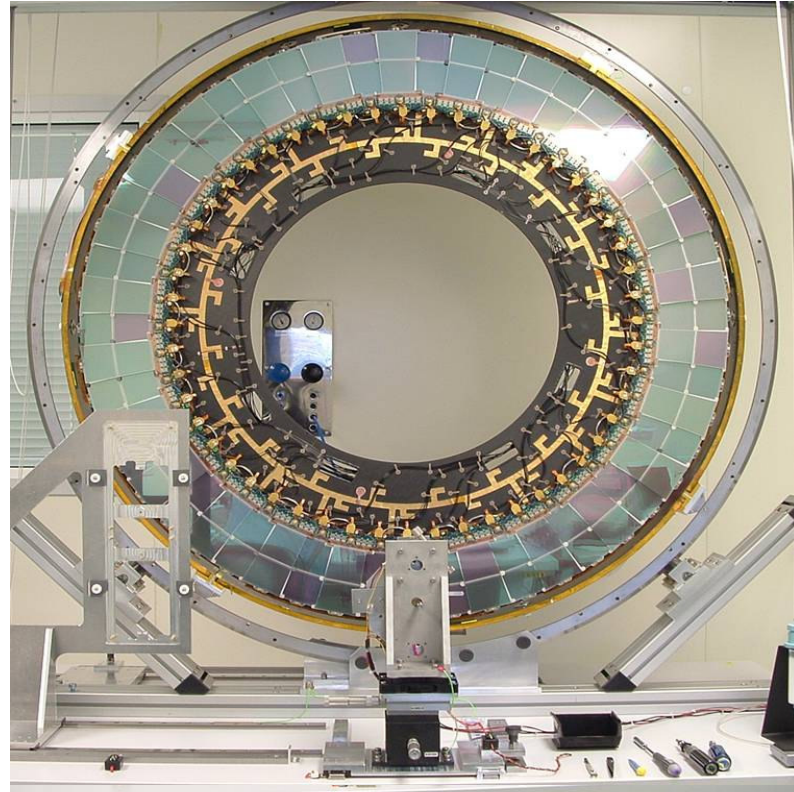


ATLAS SCT disks assembly



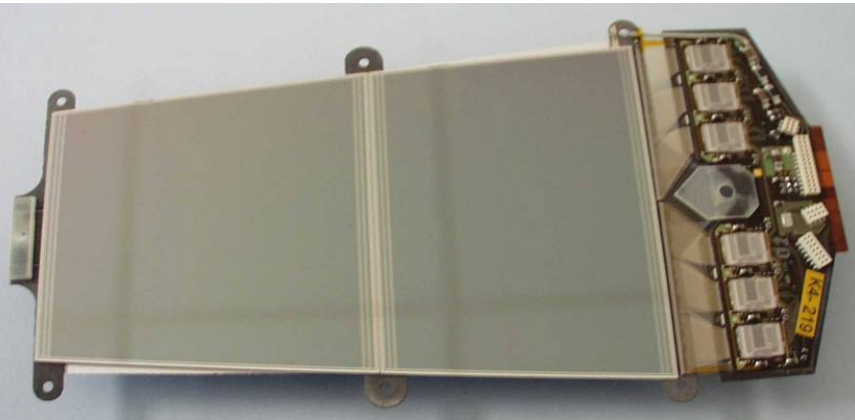
All sensors procured (two producers). Some characteristics of the modules built from the second producer are not stable and appear to depend on the environment and operating history

Decision was taken to replace a few of them, buying more from the first producer. Done!



The support disks preparation is in full swing, and 60% have been completed and tested

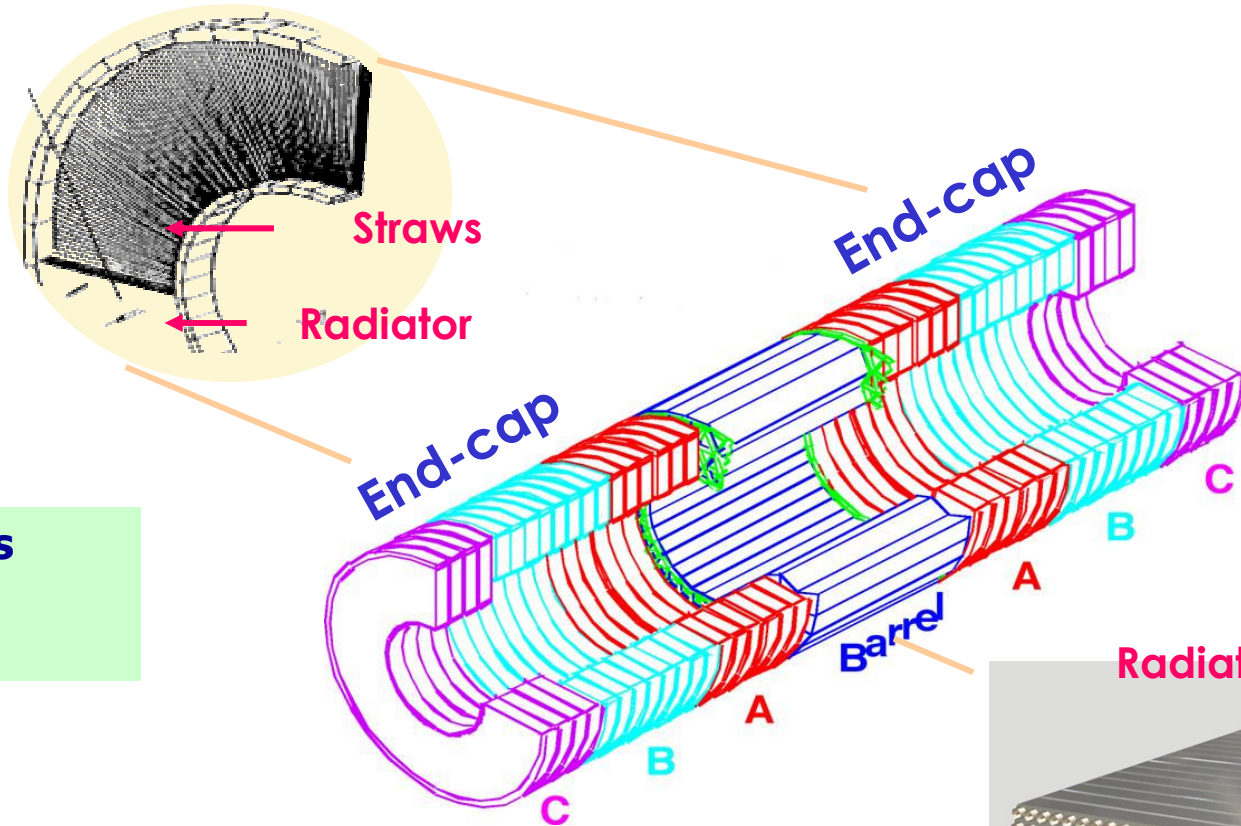
Both end-cap side-C and A are being assembled. The current end-cap side-A disk assembly schedule is on the critical path, point of view integration and installation.



All modules produced

Some hybrid production problems (delamination) have slowed down the final production, but solved.

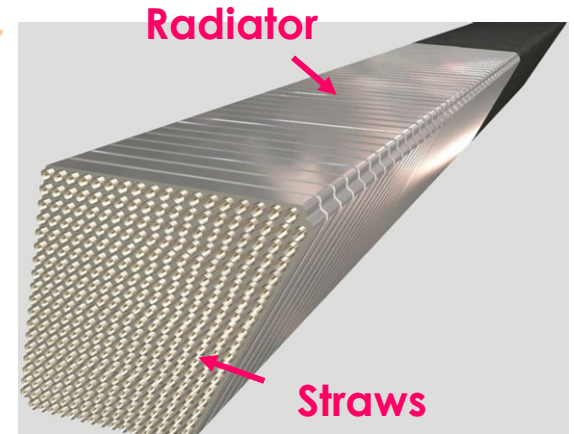
The TRT (Transition Radiation Tracker)



The gas mixture is Xe/CO₂/O₂ in a 70/27/3

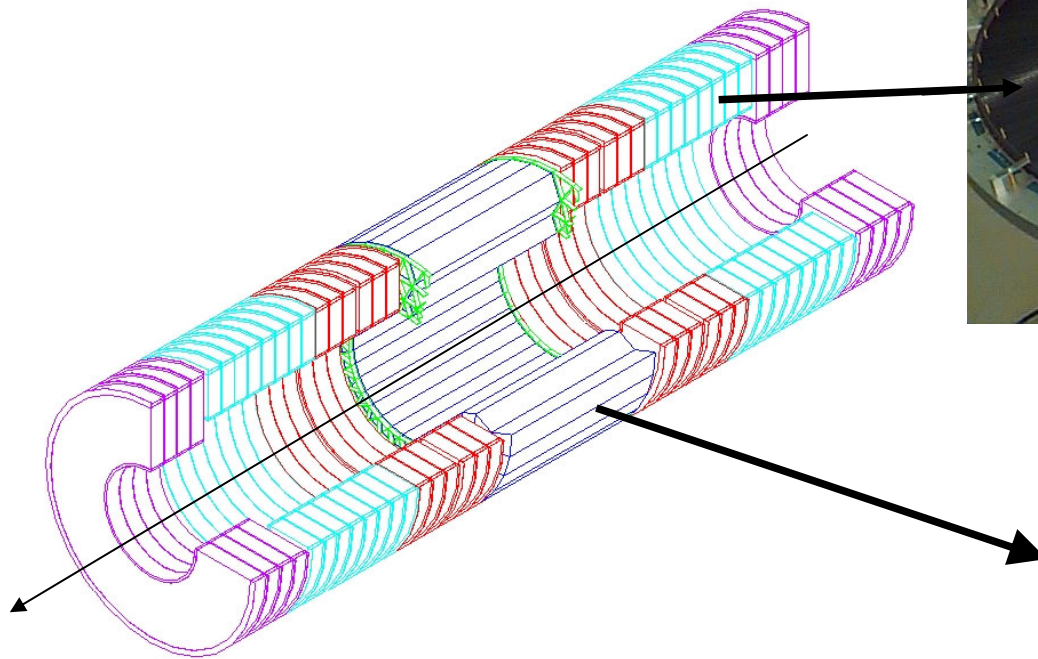
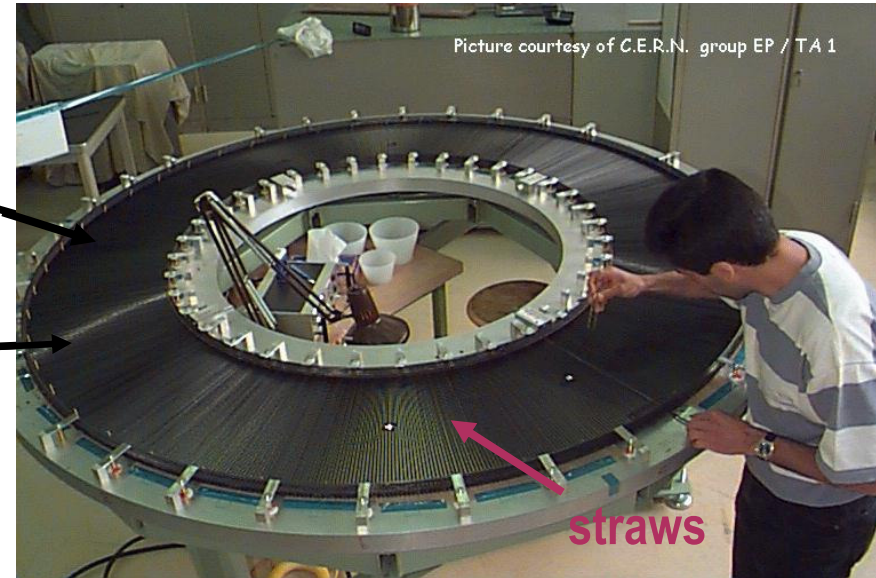


4 mm diameter kapton straws

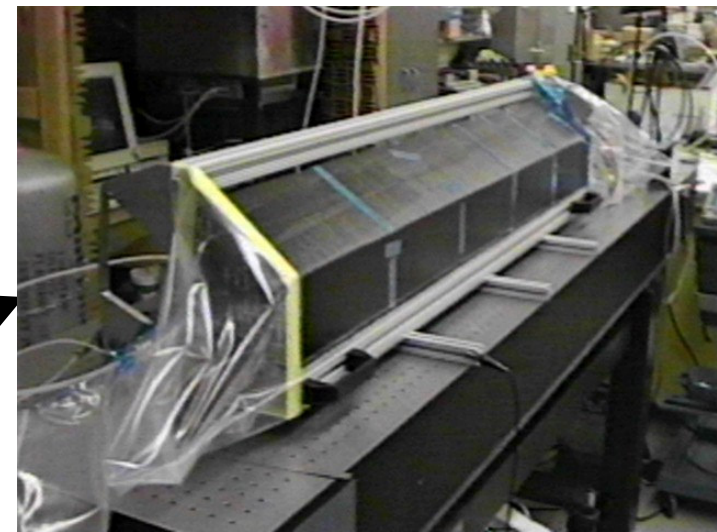


The TRT (Transition Radiation Tracker)

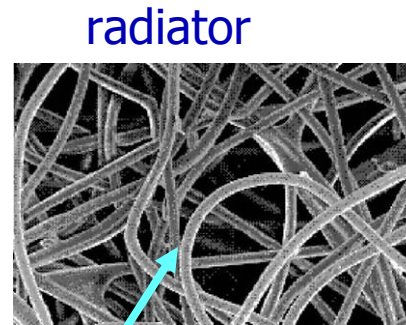
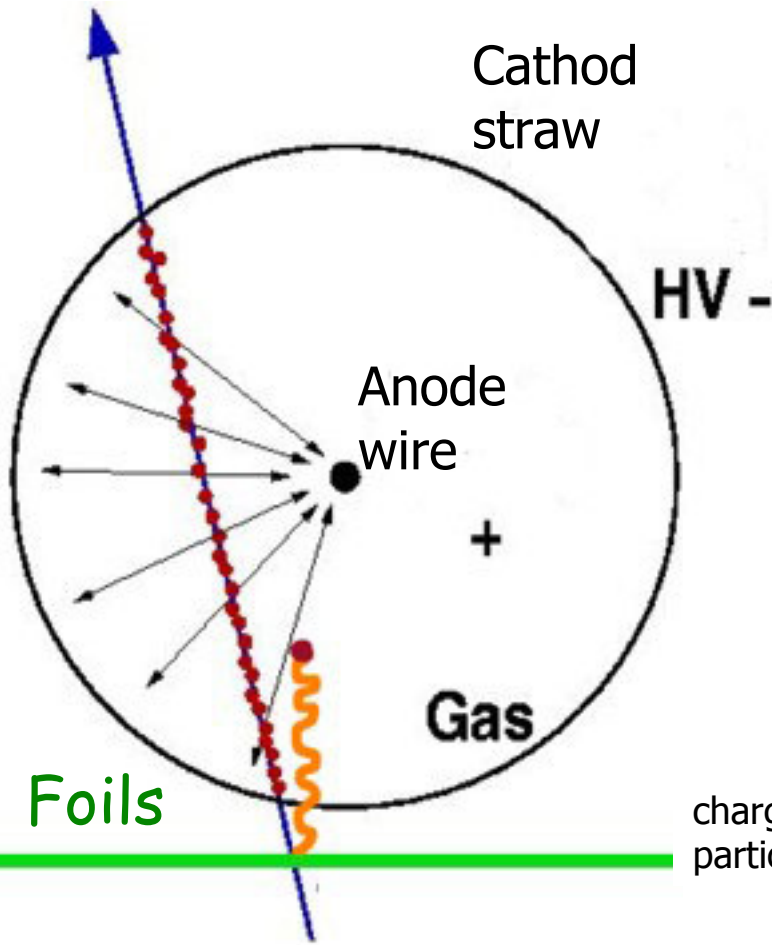
Endcap (~ 320000 straws)
radial from beam axis



Barrel (~ 100000 straws)
parallel to beam axis

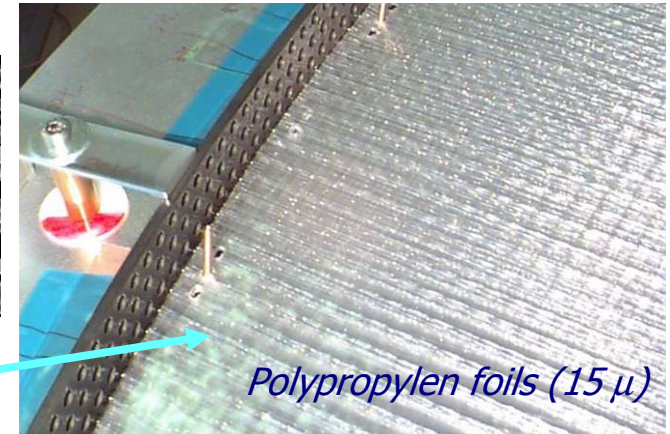


The TRT (Transition Radiation Tracker)



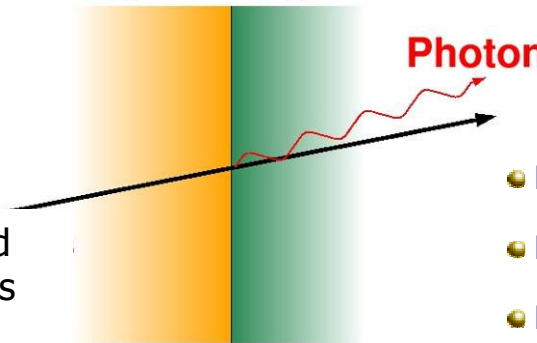
radiator

Barrel end-cap



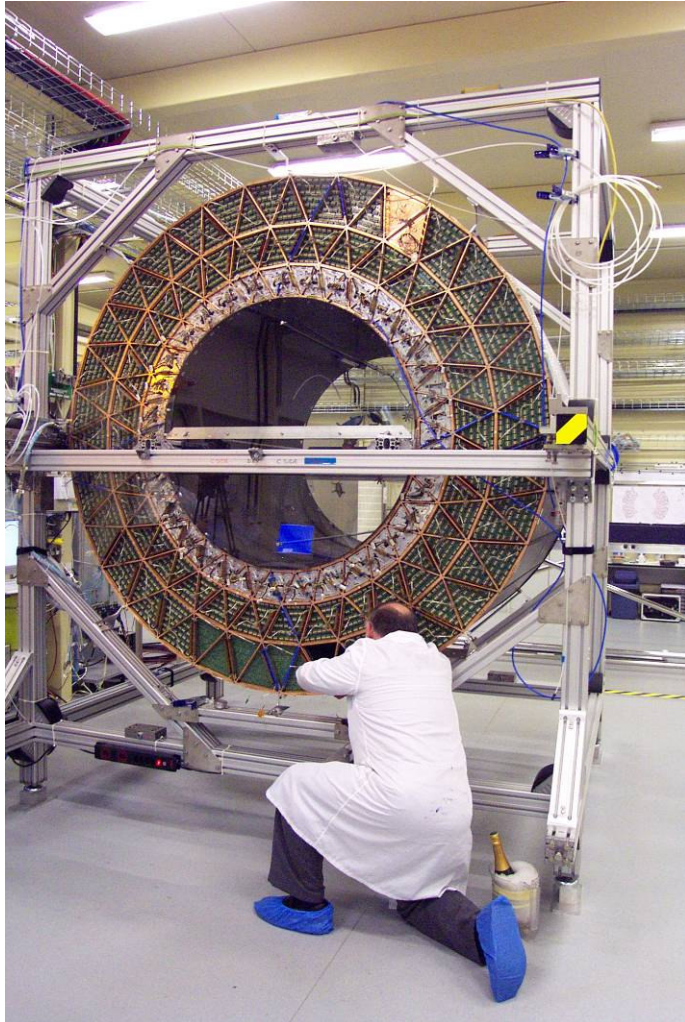
Polypropylen foils (15 μ)

$$\epsilon_1, \omega_1 < \epsilon_2, \omega_2$$



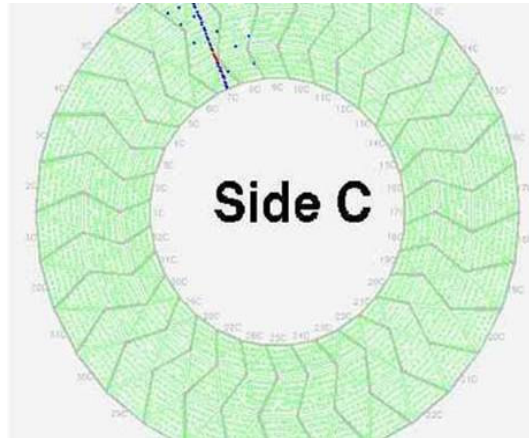
- Different dielectric constants
- Photon energy $\sim (\epsilon_1 - \epsilon_2)$
- Many transition to enhance probability
- Photon energy (x-rays): 10-30keV
- Xe gas as good X-rays absorber

Two examples of cosmic rays registered in the barrel TRT

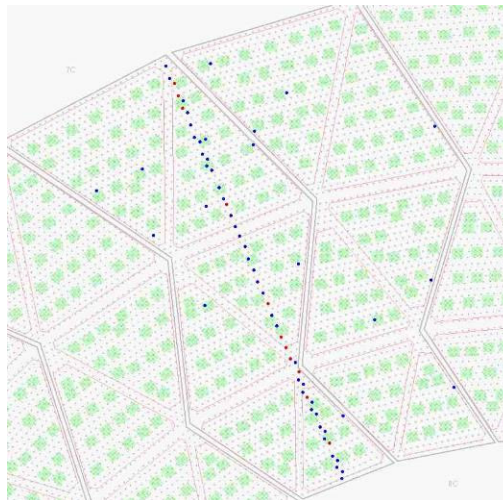
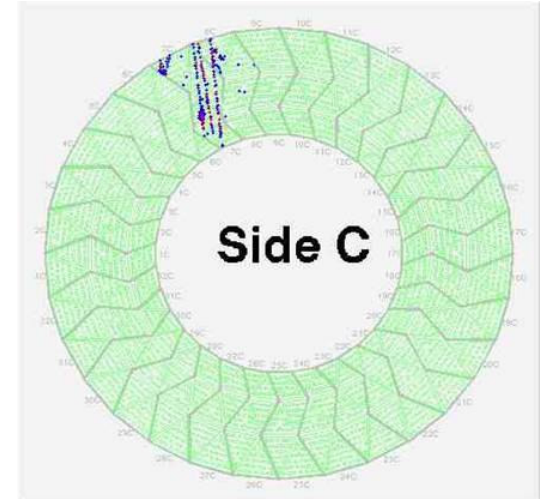


Barrel TRT during insertion of the last modules (February 2005)

Example 1



Example 2

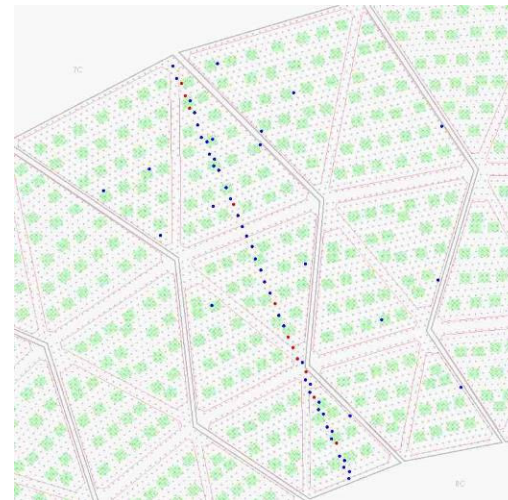
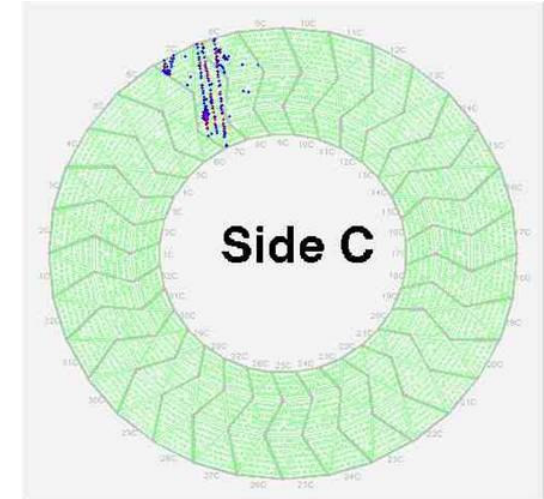
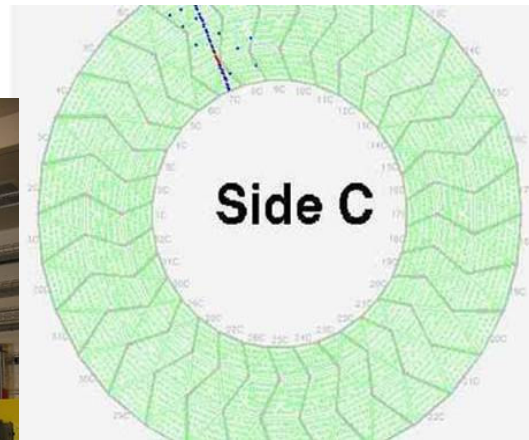


Two examples of cosmic rays registered in the barrel TRT

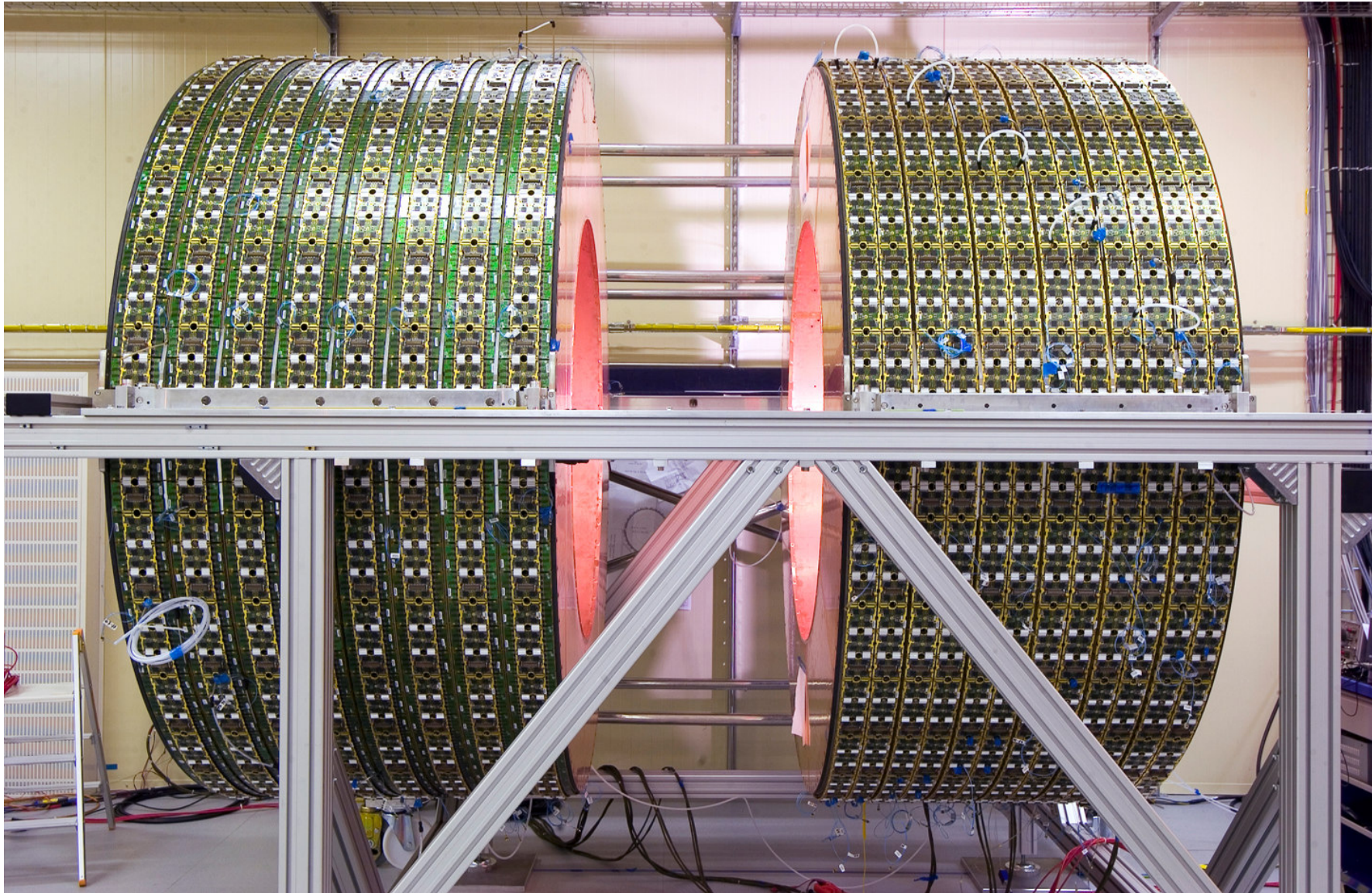


Example 1

Example 2



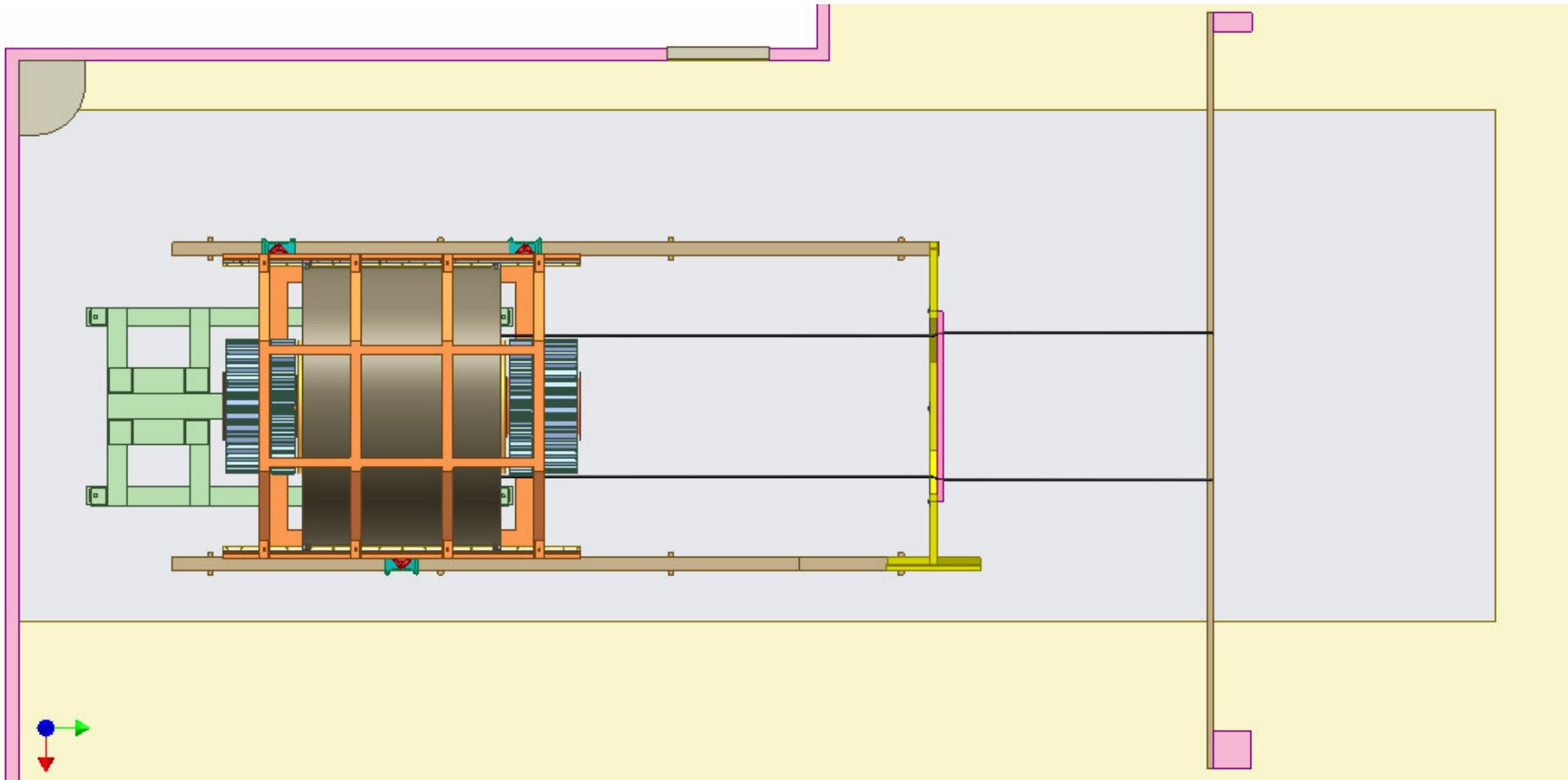
First end-cap wheel assembled



Next step

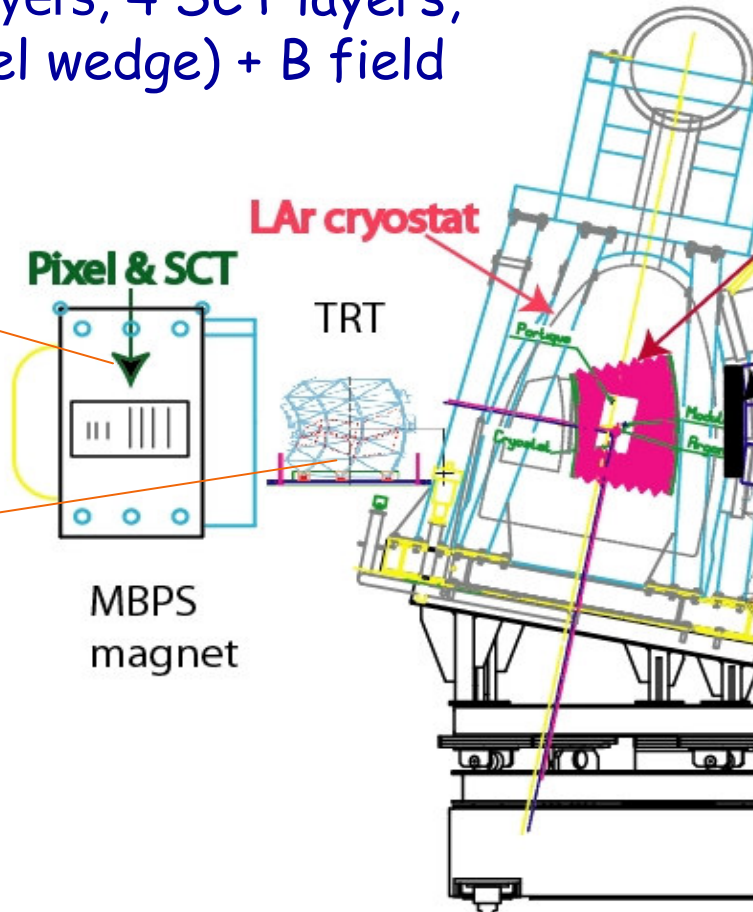
Insertion of SCT to TRT

- ✓ *Based on cantilever tool which holds SCT while TRT is "rolled over"*
- ✓ *Same method for Barrel and Endcaps but different tools*
- ✓ *Barrel Dec 05, Endcap March '06 (EC C) and ~June '06 (EC A)*



ATLAS ID combined test beam

Full barrel slice simulated in
the H8 SPS beam line
(3 pixel layers, 4 SCT layers,
TRT barrel wedge) + B field



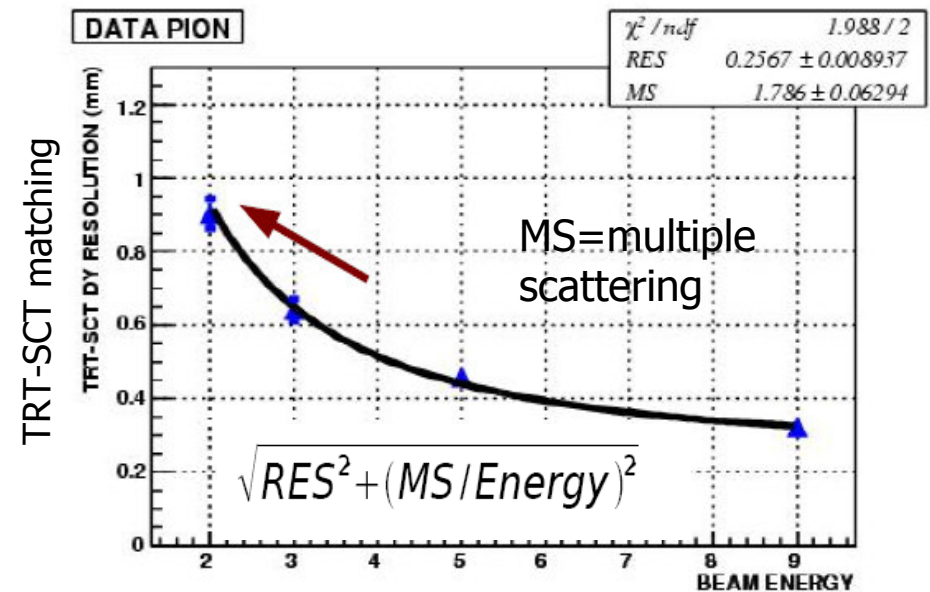
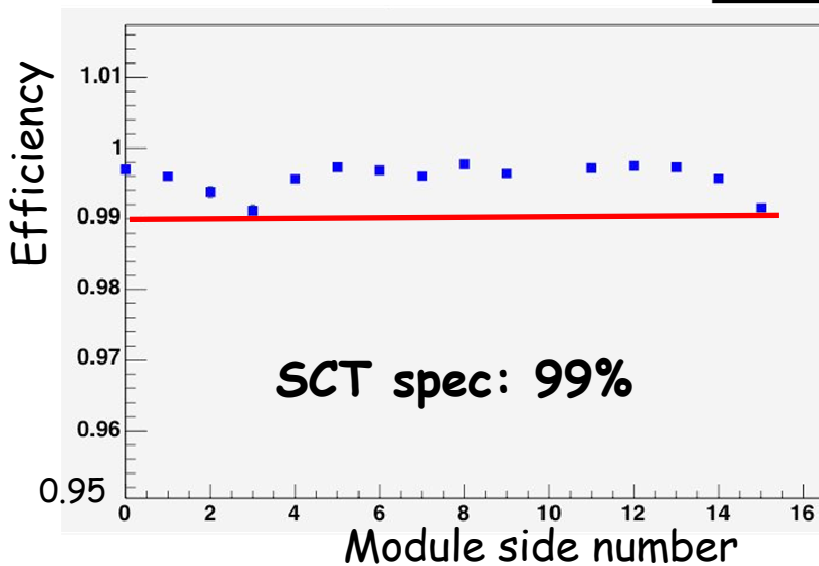
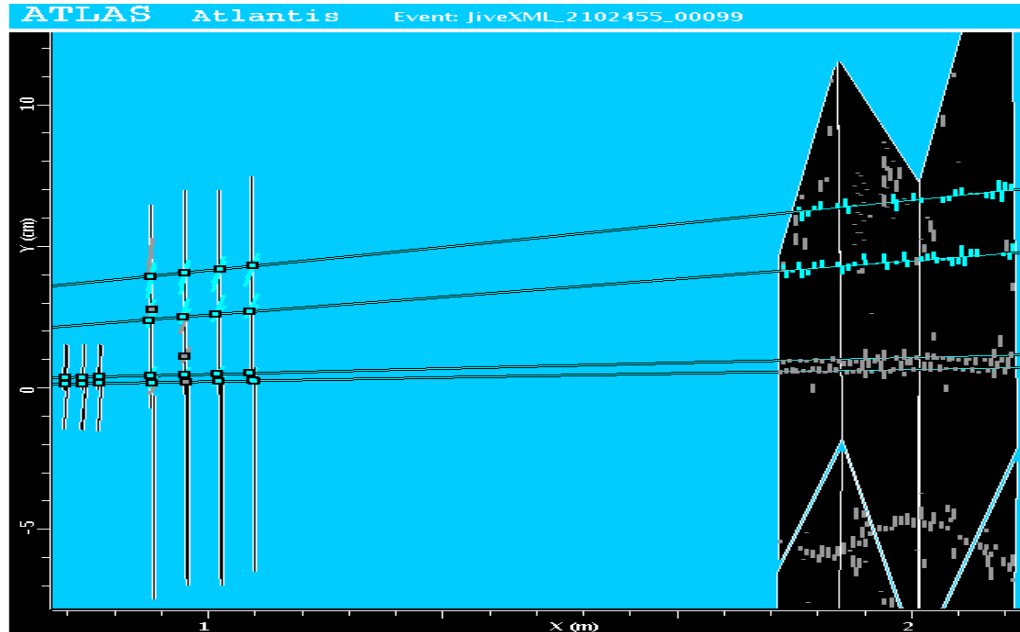
ID barrel full slice

ID combined test beam

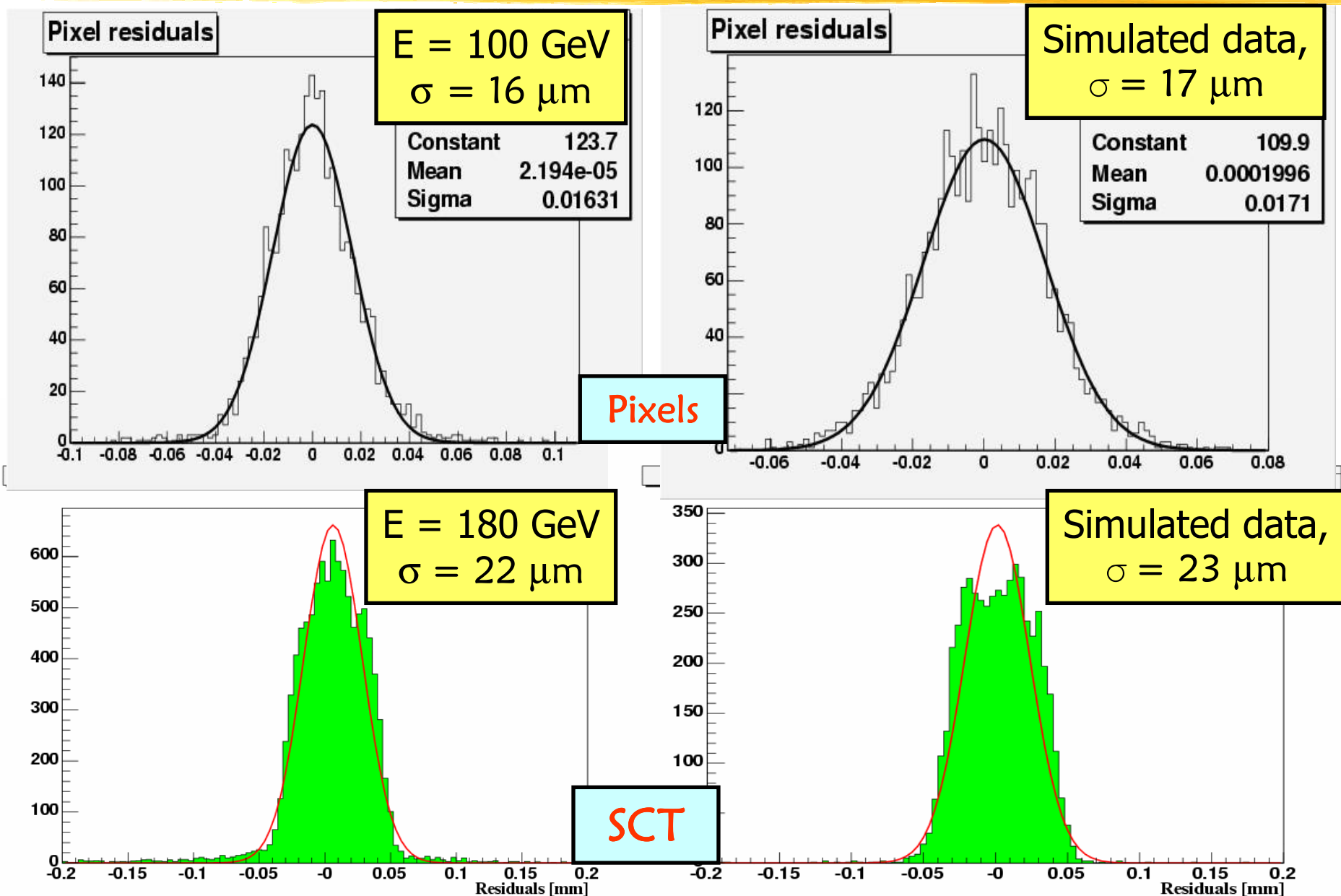


The (ID-part) setup

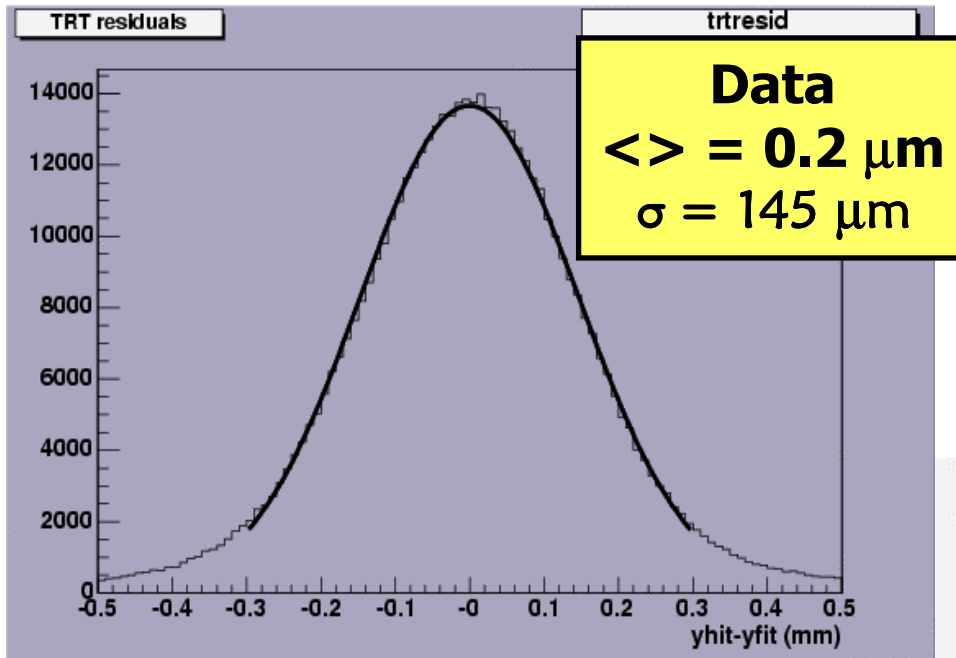
- ✓ 3 pixel layer
- ✓ 4 SCT layer
- ✓ TRT barrel stack



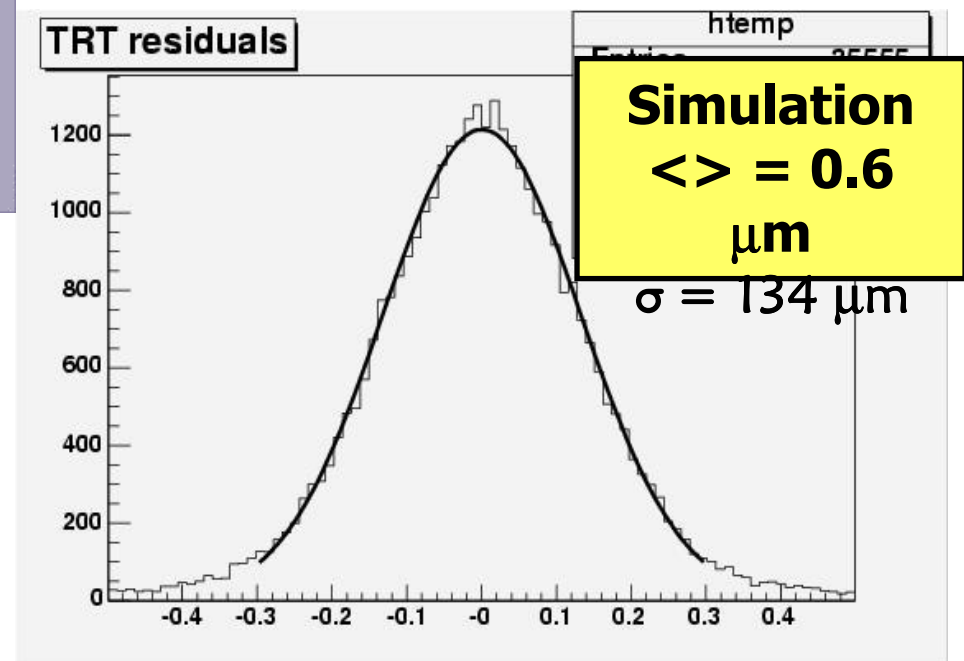
Pixel + SCT tracking resolution



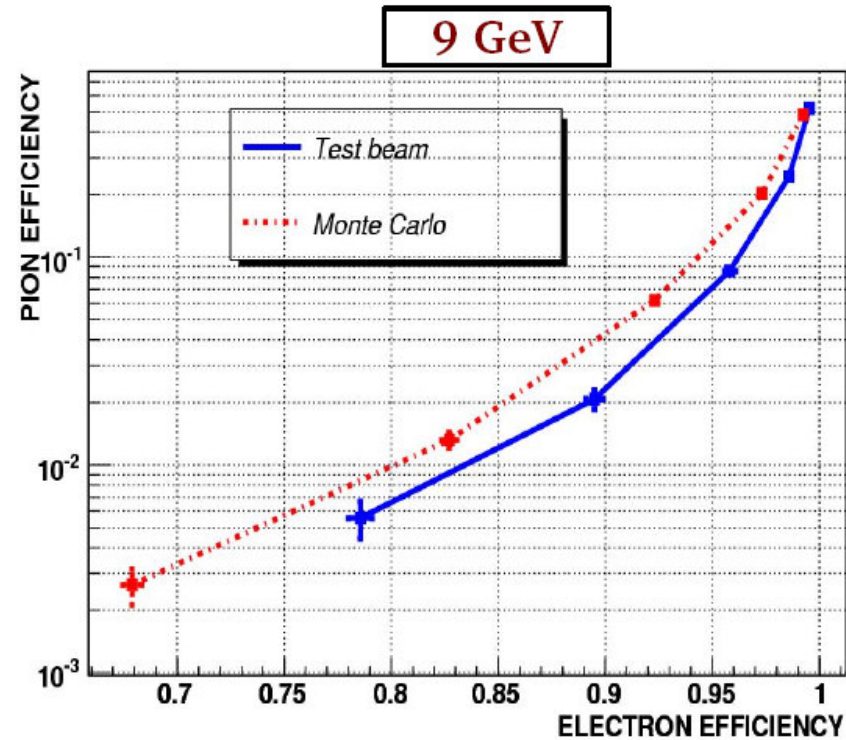
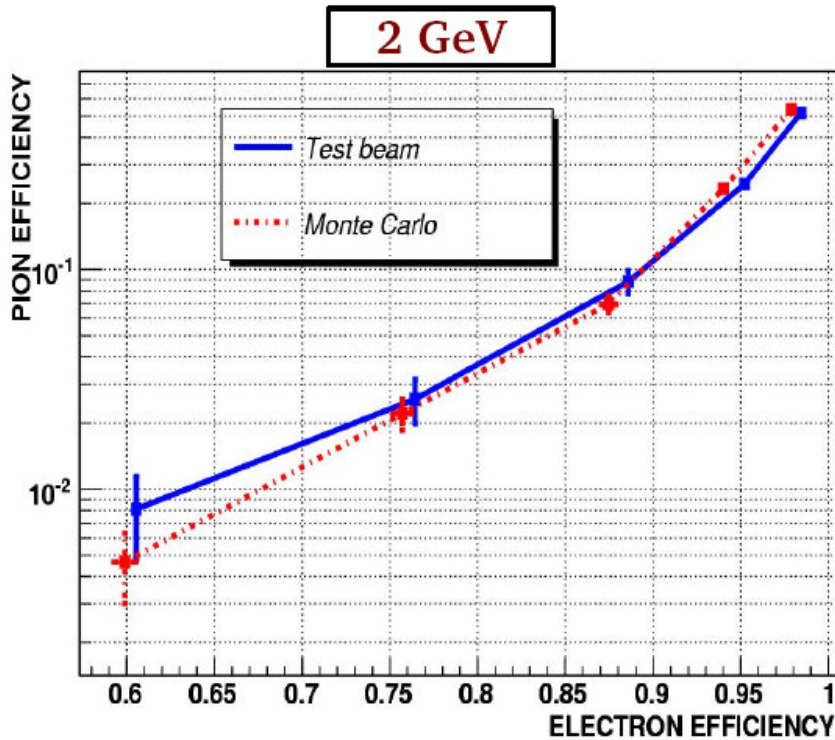
TRT tracking resolution



$E_\pi = 100 \text{ GeV}$



TRT e/π separation



- ✓ e/π samples selected with Cherenkov + LAr
- ✓ Curves obtained by a cut on the "fraction of TR hits"
- ✓ Good agreement data/simulation at 2 GeV
- ✓ At 9 GeV rejection better in data than in simulation

Tracking summary



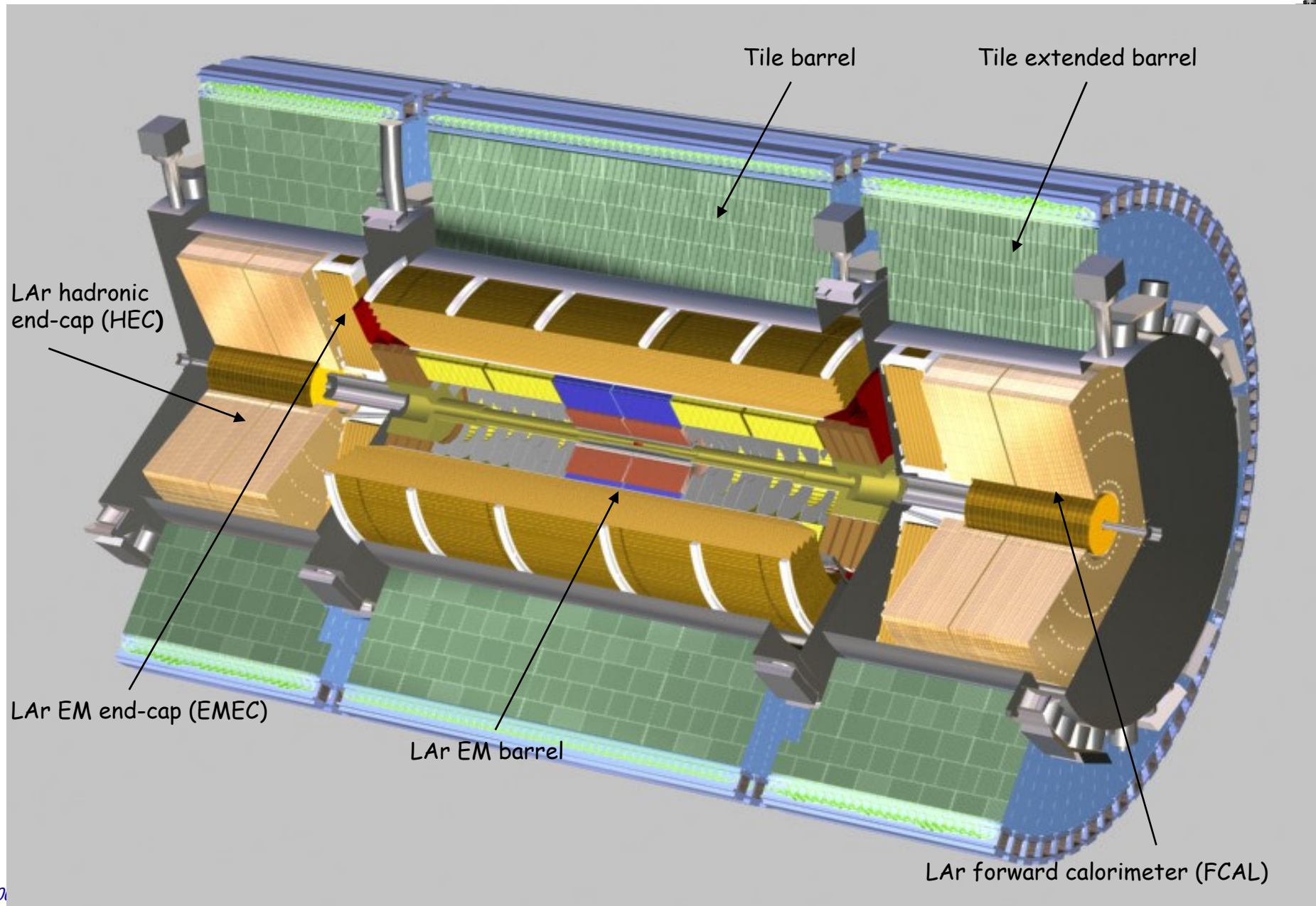
- ✓ Components production is in full swing and reaching the end (Si modules production, rad-hard front-end electronics,...). All sensors production done.
- ✓ The SCT detector has started the final instrumentation of the cylinders and the forward disks. The barrel is ready for integration inside the TRT.
- ✓ The TRT has recovered all old construction problems (delamination, gas ...). The barrel TRT is ready, 1 end-cap too. A problem of cooling tubes corrosion is the next problem to solve.
- ✓ The overall integration work is ongoing with a ready-for-installation milestone of the barrel ID for May '06. The barrel is the first system to be integrated.
- ✓ The pixel project was running well, advancing modules production. It is now delayed by a nasty cooling tubes corrosion problem. Technical solutions have been found to allow installation in early 2007.
- ✓ Underground the main issue is the installation of all ID services and cables. The cooling pipes have been installed in situ, next is the cabling campaign foreseen for end 2005

Calorimeters Project

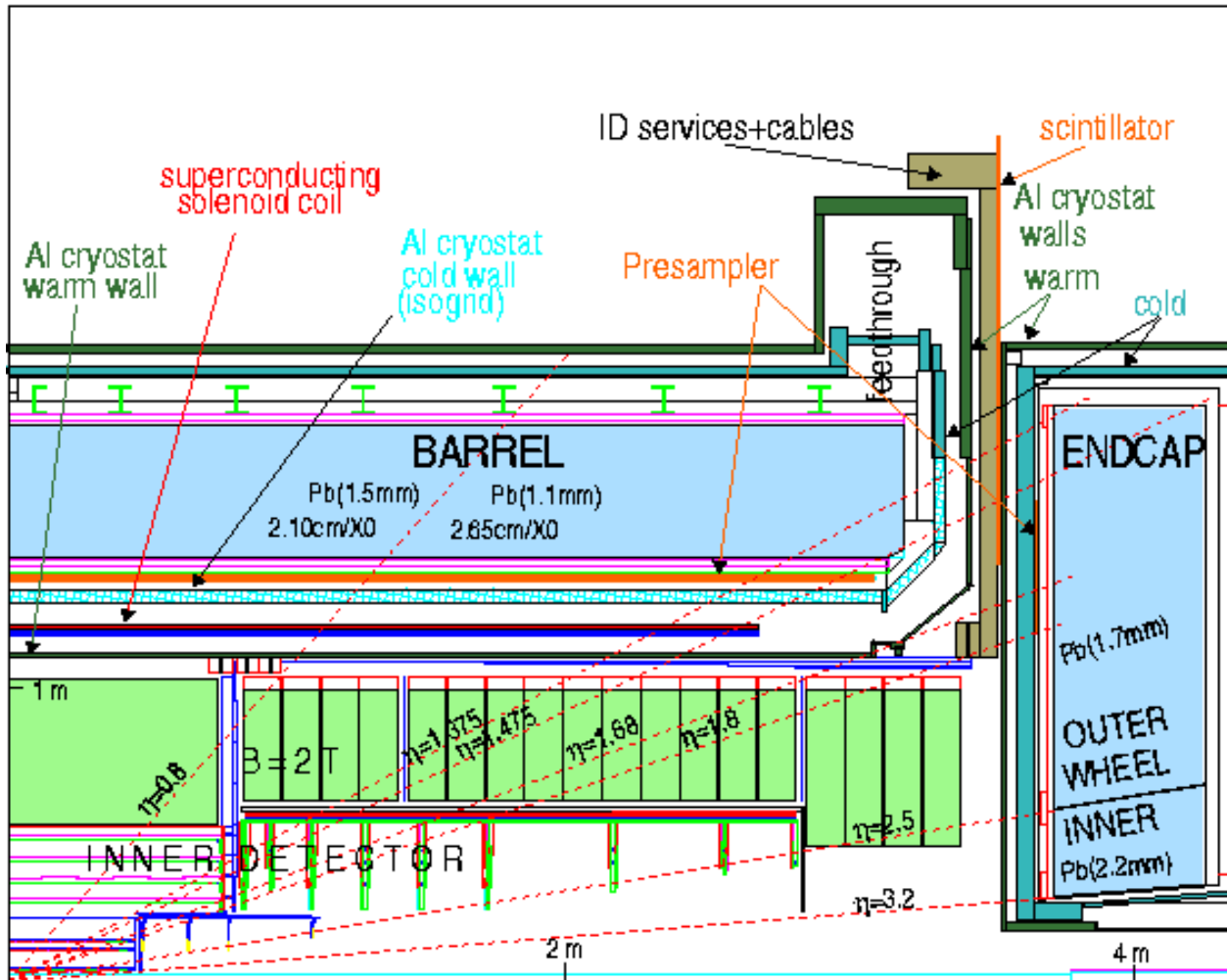
EM LAr + HAD LAr + LAr forward + HAD Tiles +
cryogenics + services

Production over 10 years, 1996-2005
Installation over 3 years, 2004-2006

ATLAS Calorimetry ($|\eta| < 5$)



ATLAS LAr EM Calorimetry



$$\sigma / E \sim 10\% / \sqrt{E}$$

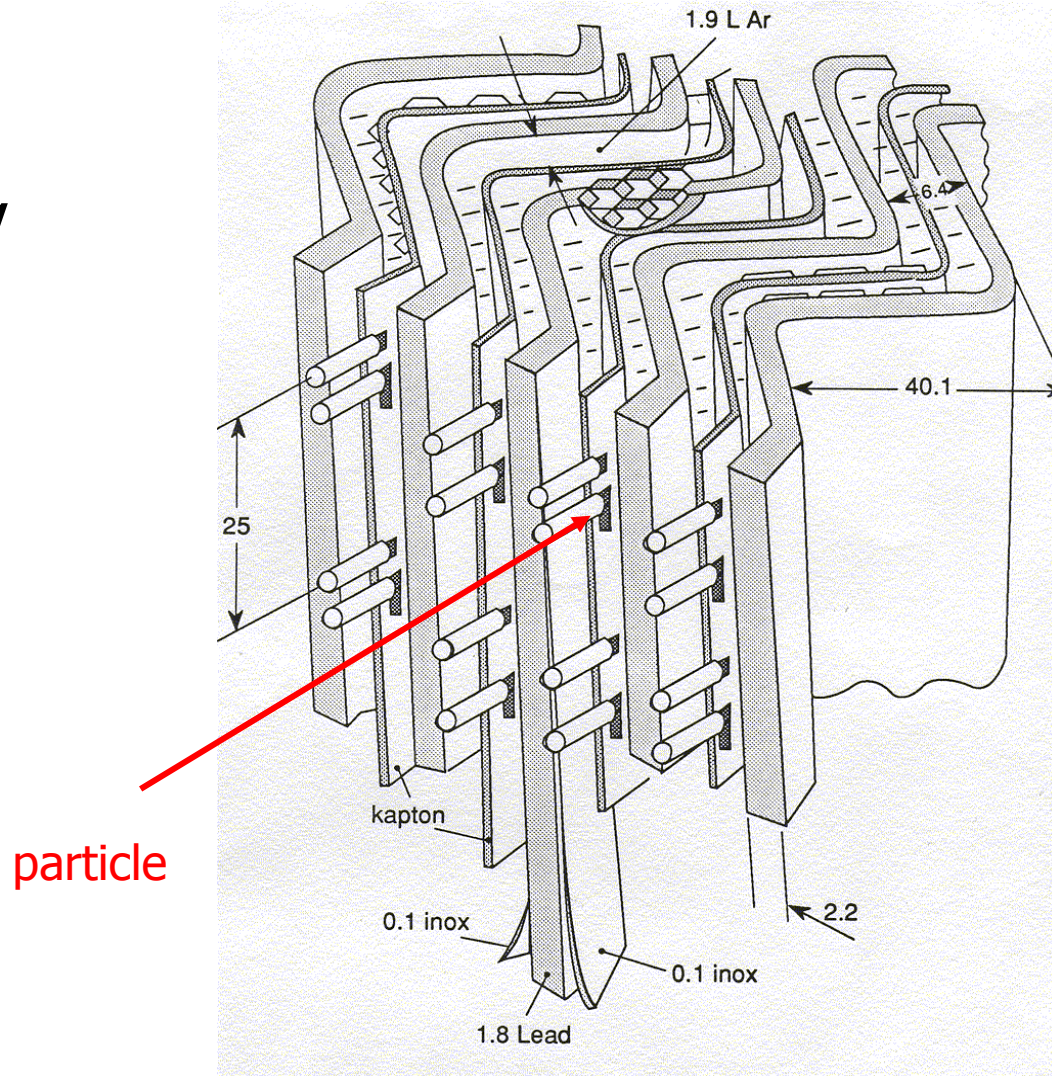
$$c \sim 0.8\%$$

- ✓ LAr ionization chamber, with fast signal shaping
- ✓ Pb as absorber
 $X_0 \text{ eff} = 2.2 \text{ cm}$
- ✓ Sampling fraction
 $\sim 0.25 @ \eta < 0.8$
- ✓ 3 longitudinal samples + preshower

ATLAS LAr EM Calorimetry



45° sampling



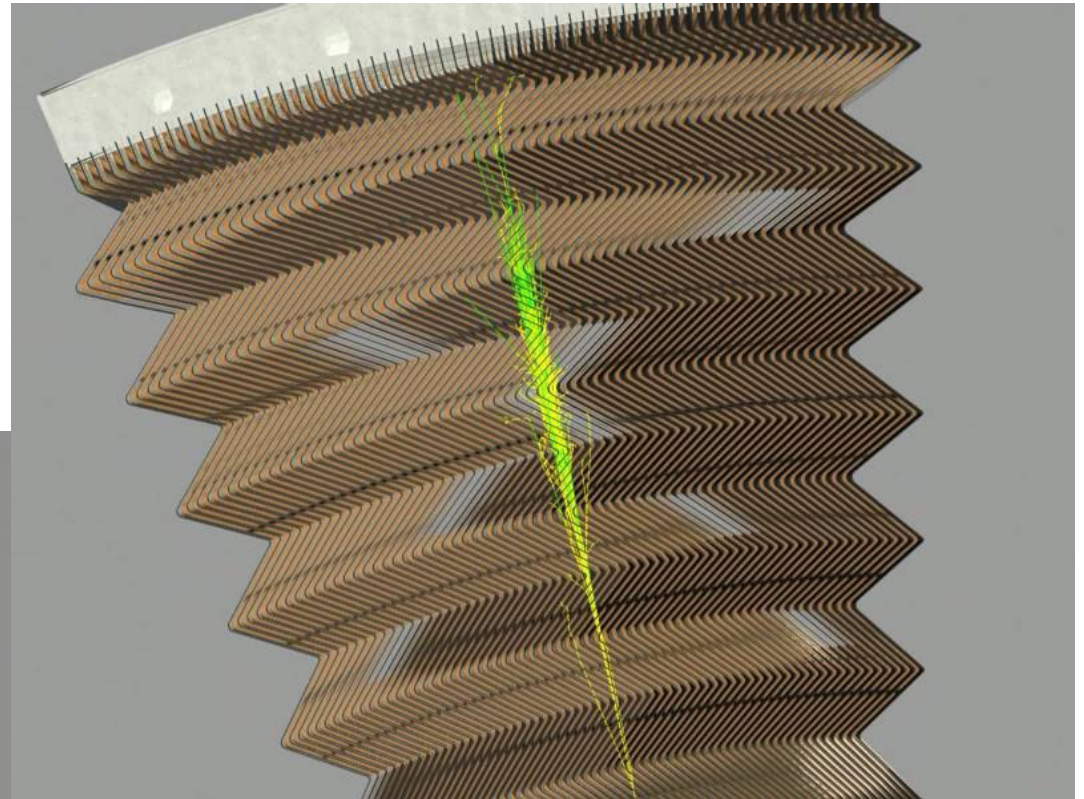
ATLAS LAr EM Calorimetry



readout panel

LAr gap

absorber panel
(Fe-Pb+Fe)



accordion geometry

ATLAS LAr EM Calorimetry



- 1024 accordion absorber plates
- 16 identical modules
- $\eta < 1.7$

Completely stacked series LAr EM barrel module at Saclay



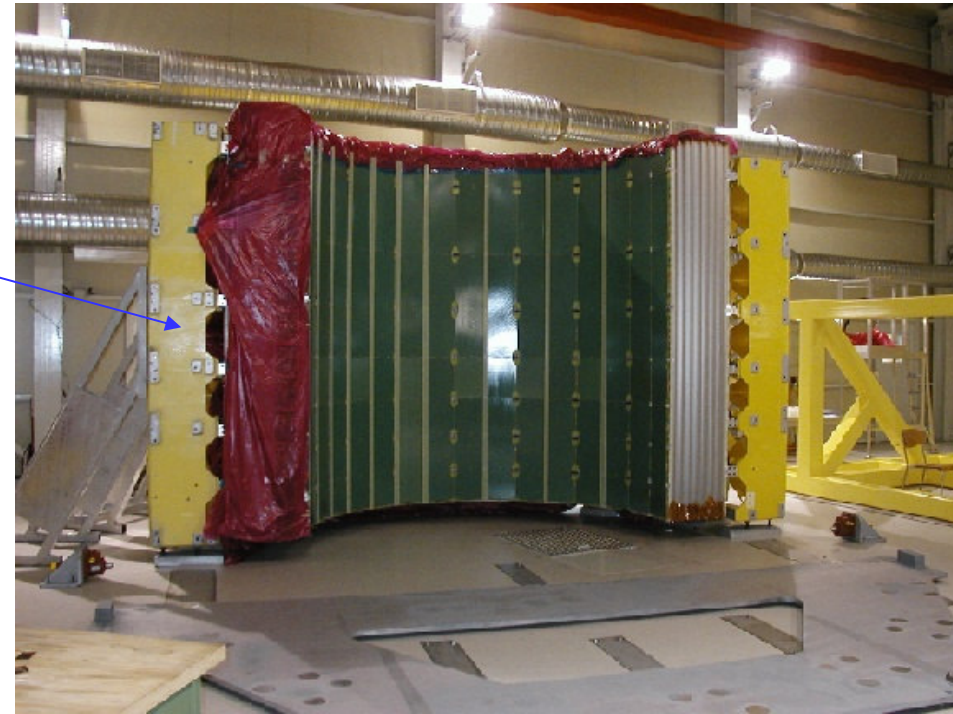
- Inner + Outer wheel
- 768 (256) accordion absorbers/wheel
- 8 identical modules/wheel
- $1.375 < \eta < 3.2$

Series LAr EM end-cap module during stacking at CPPM Marseille

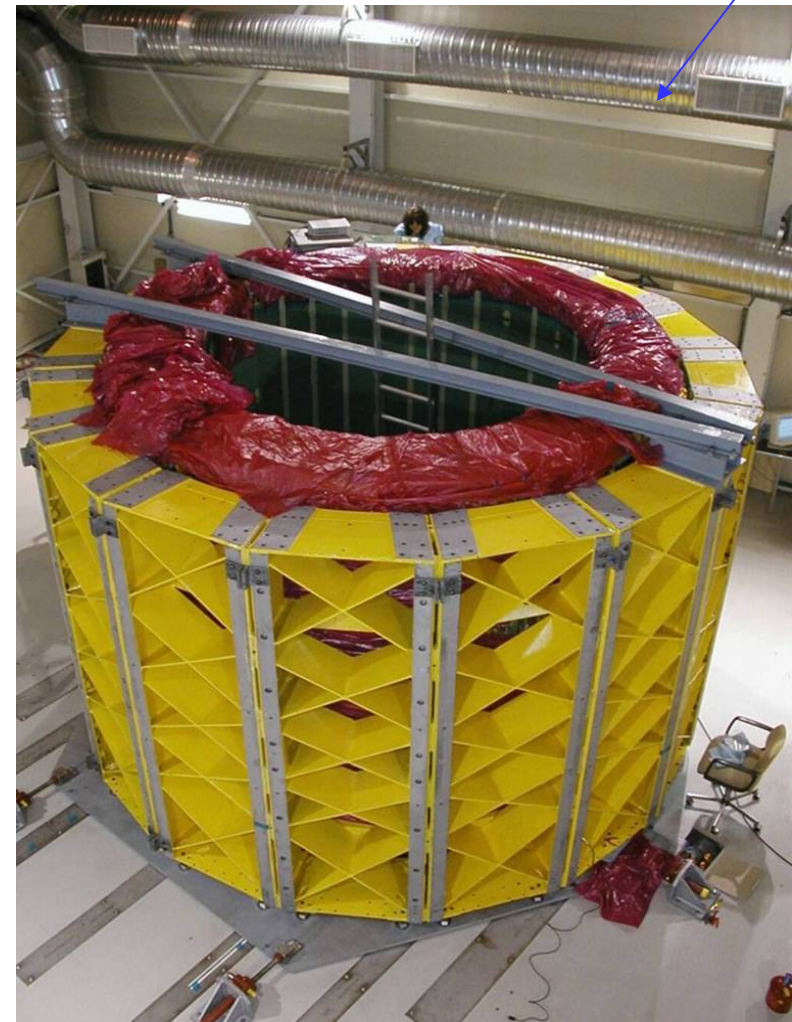
ATLAS LAr EM Calorimetry



LAr EM barrel assembly in the vertical position. Second wheel 50% done.



LAr EM end-cap wheel during assembly



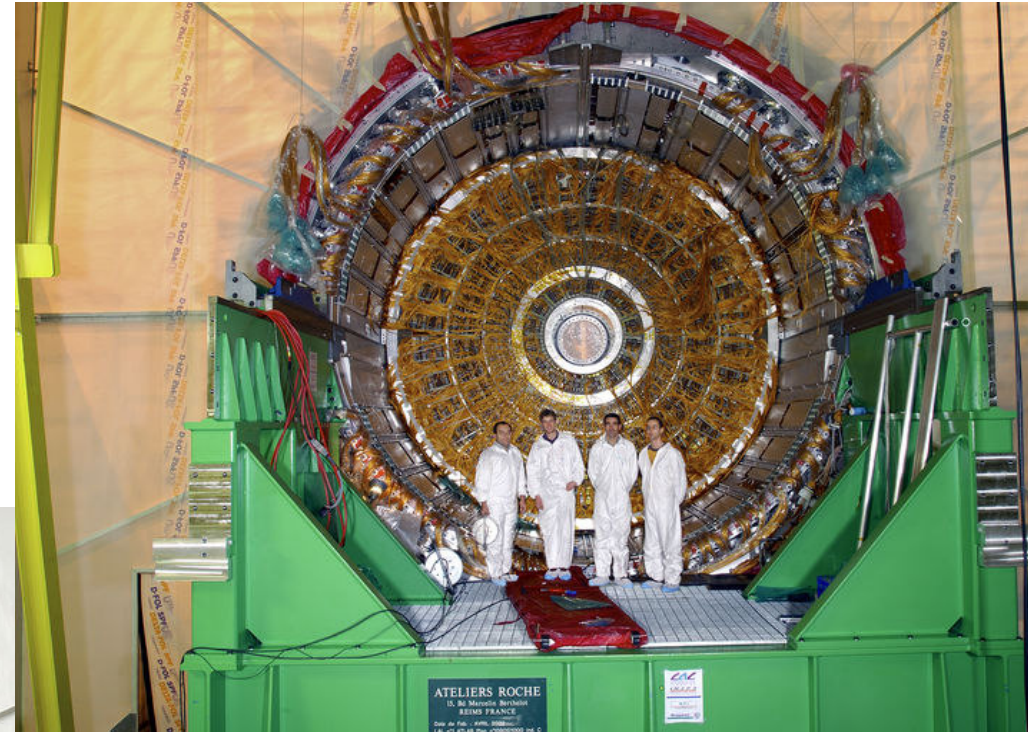
ATLAS LAr EM Calorimetry



The barrel EM calorimeter is installed in the cryostat, and after insertion of the solenoid, the cold vessel has been closed and welded

The warm vessel has been closed as well, the detector has been cooled down

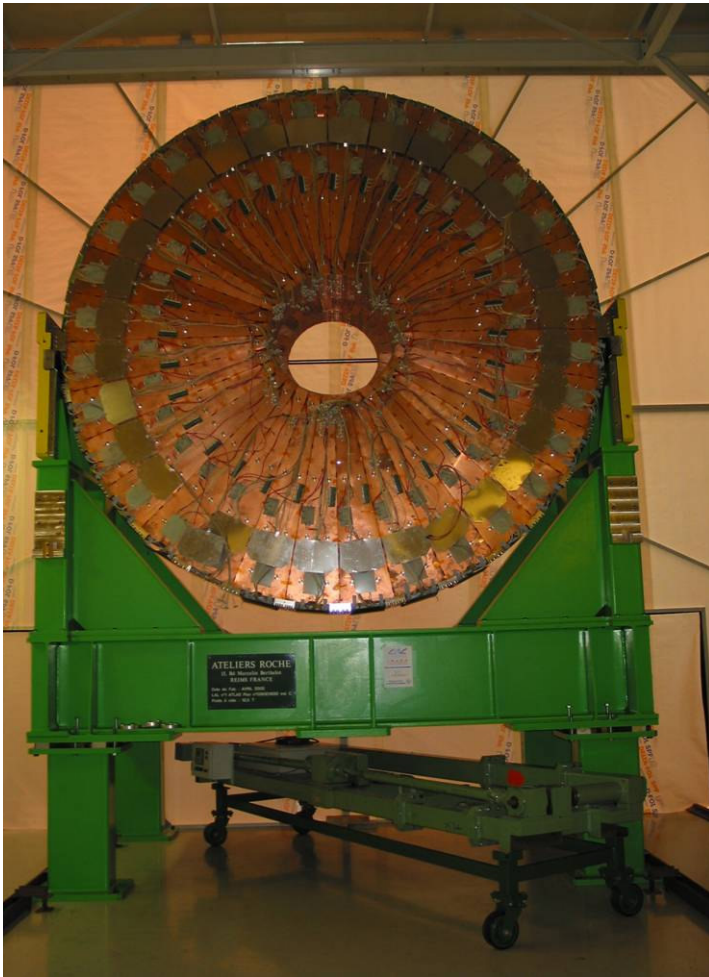
The final cold tests of the barrel EM have been done over summer 2004 with excellent results!



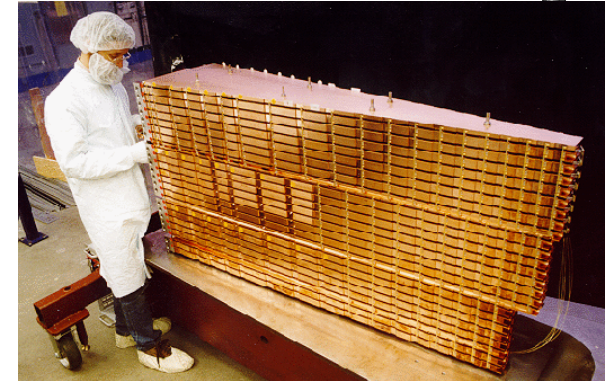
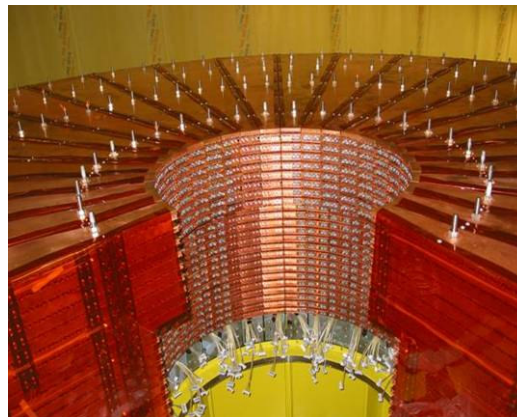
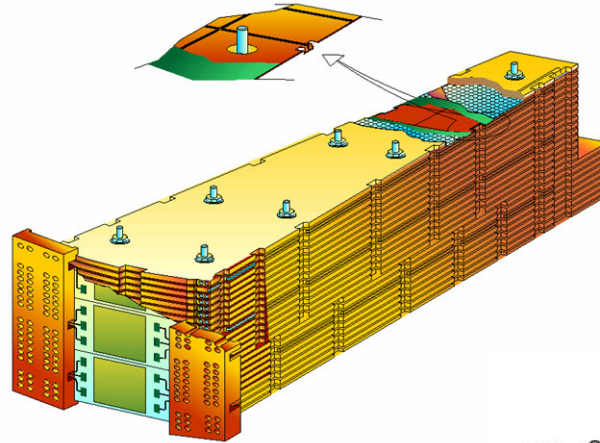
The first of the two LAr end-cap EM calorimeter wheels inserted in the cryostat (for side C)

The second wheel has been completed as well and inserted into the side-A cryostat

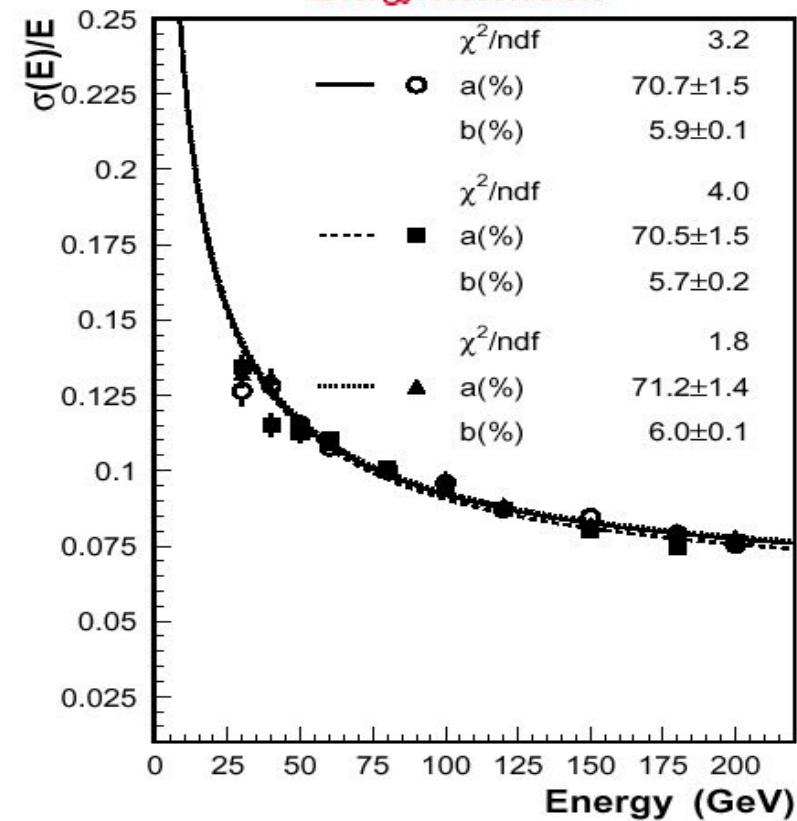
LAr Hadronic



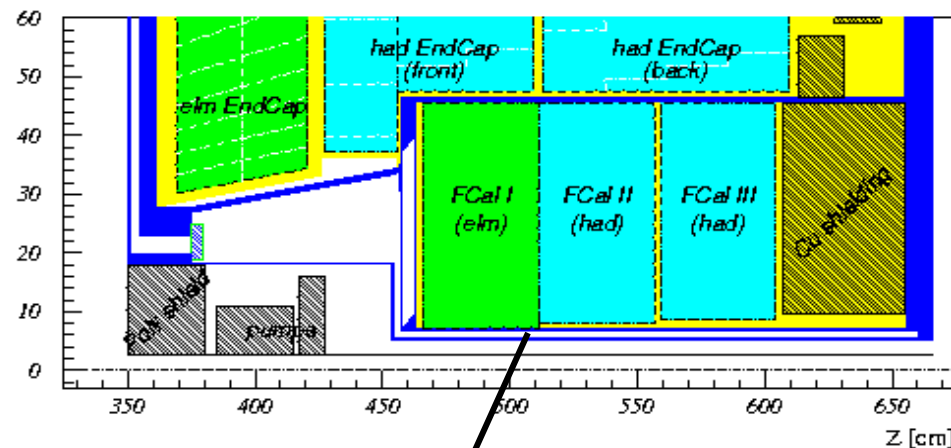
4 wheels fully assembled @ CERN



Testbeam Results: Pions Energy Resolution



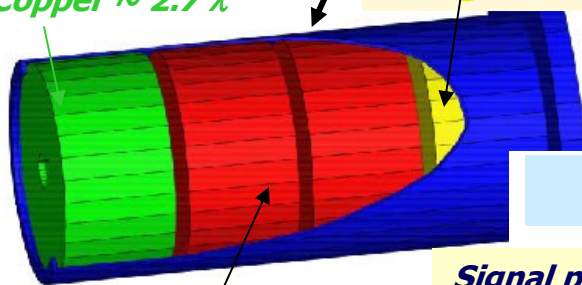
Forward Calorimetry



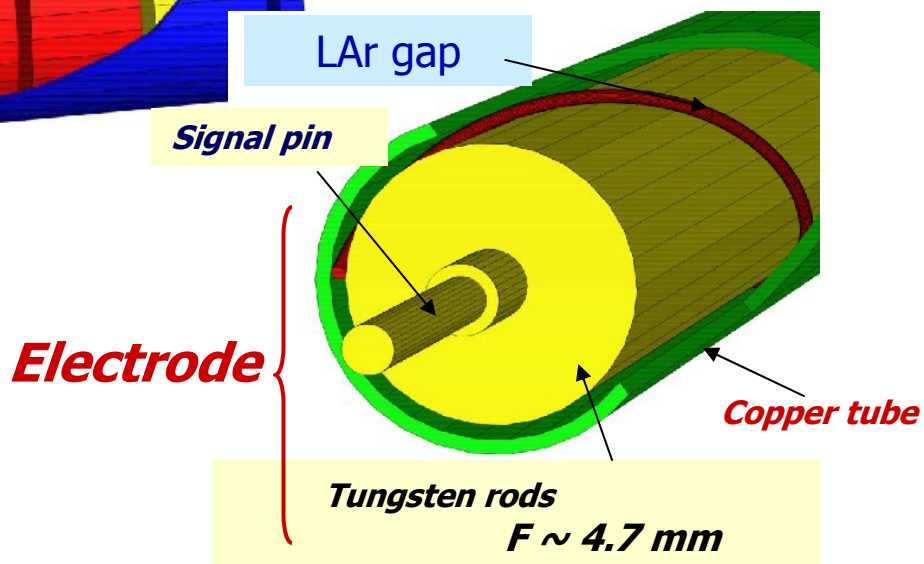
FCal2 and 3 assembly; insertion of tungsten slugs

FCal1 : EM made of Copper $\sim 2.7 \lambda$

FCal3 : mostly tungsten $\sim 3.6 \lambda$



FCal2 : mostly tungsten $\sim 3.7 \lambda$



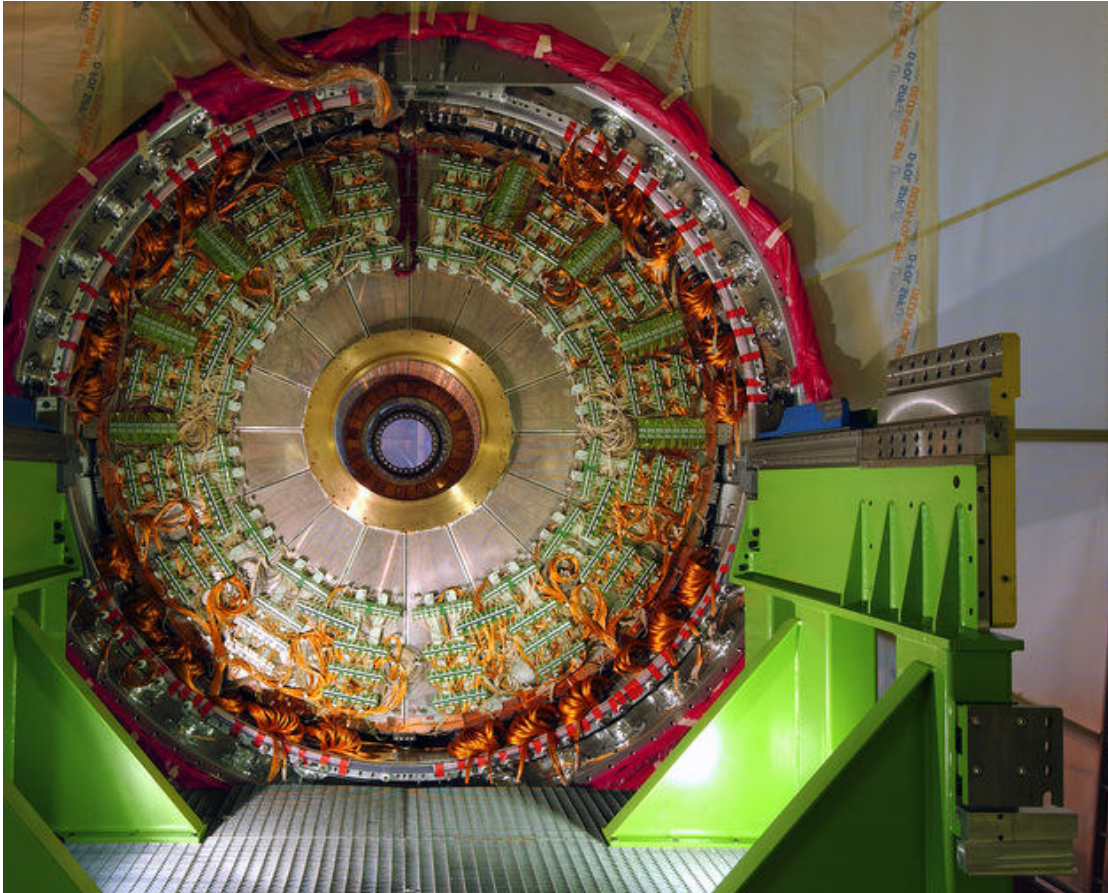
FCal1 copper matrix stacking

LAr Hadronic & Forward Calorimetry

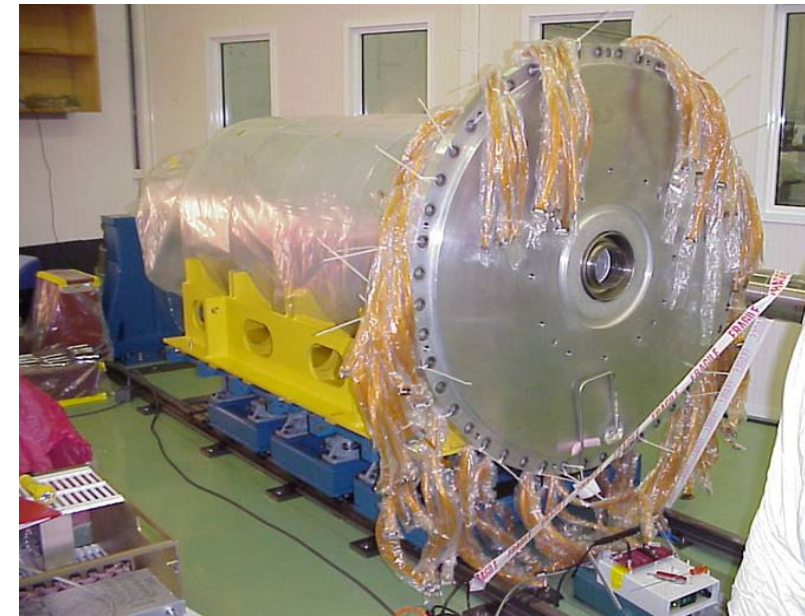


The LAr hadronic end-cap (HEC) wheels are all assembled, and were inserted in the cryostat (side A & C) and tested with very good results

The LAr forward calorimeters (FCAL) are integrated and cold-tested as well.

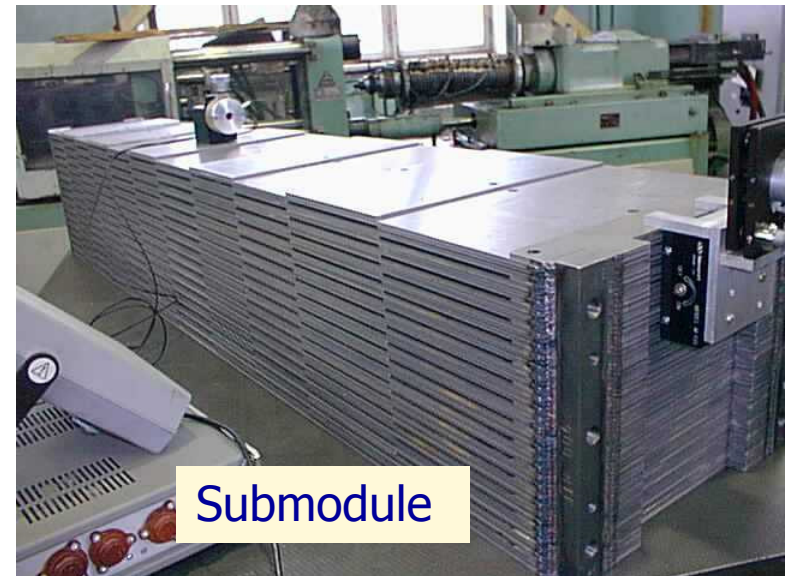
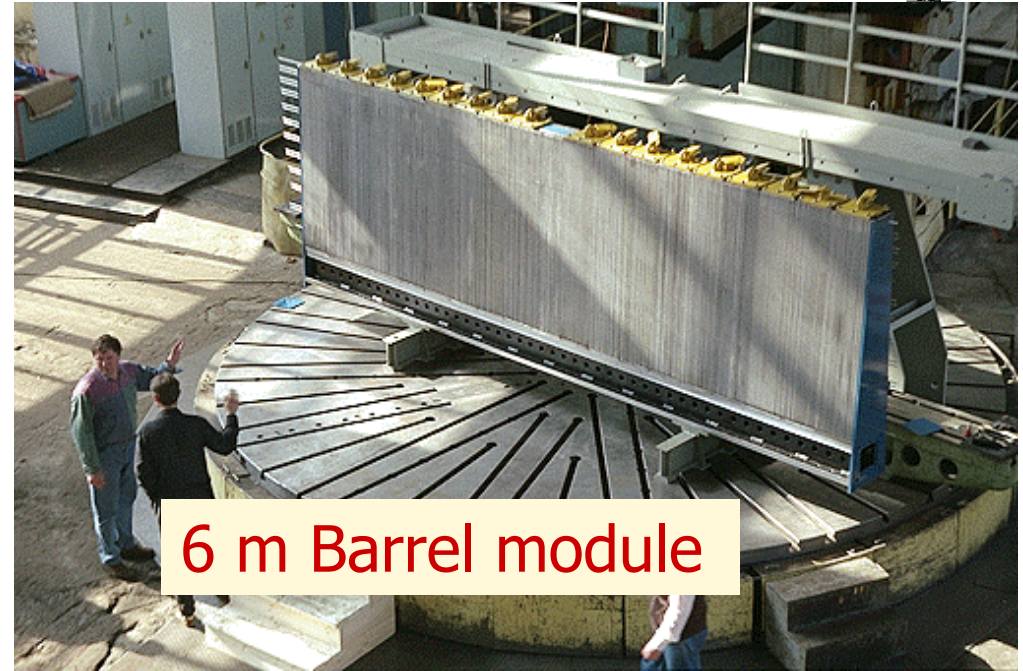
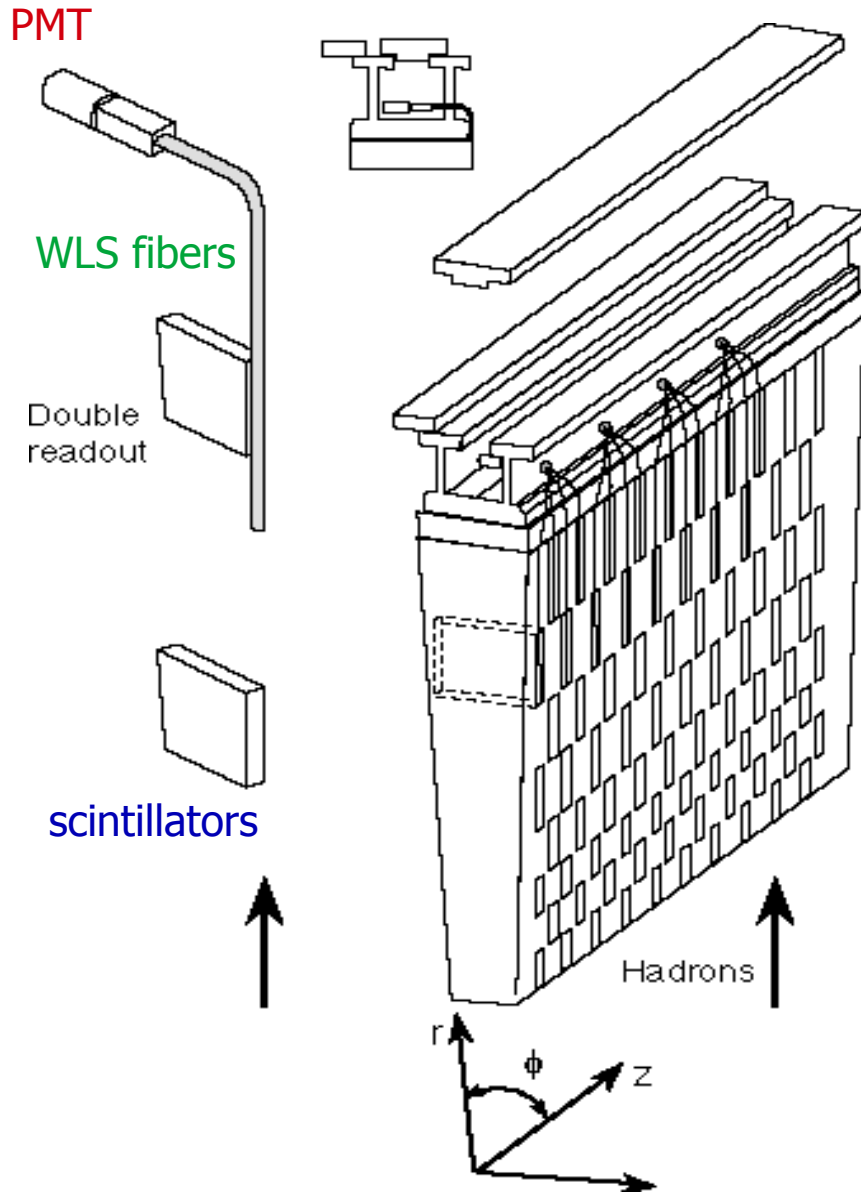


Back view of the HEC wheels in cryostat side-C



Integrated FCAL ready for insertion

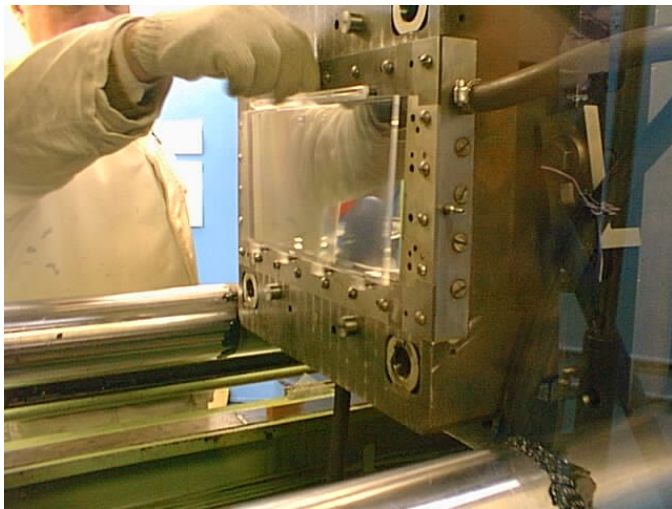
ATLAS Tile Calorimeter



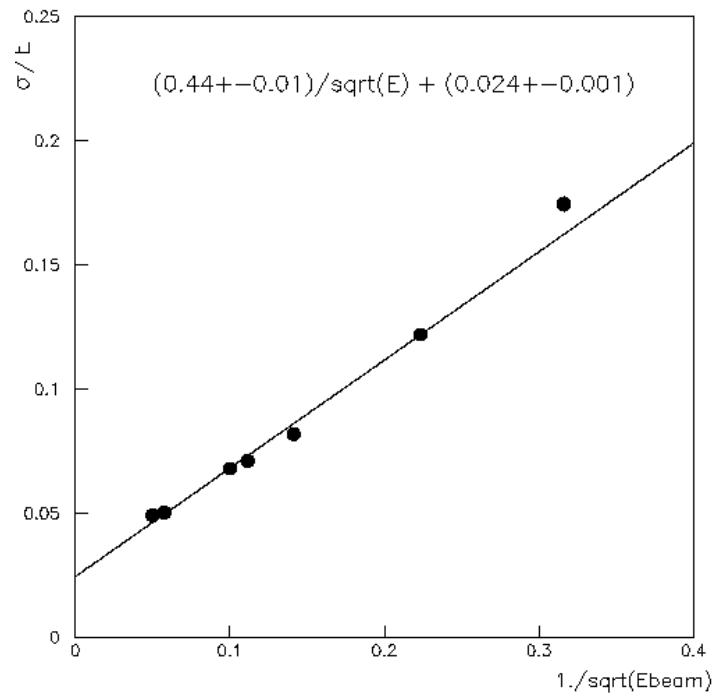
ATLAS Tile Calorimeter



~ 3000 tons of hadronic calorimeter: iron absorber, active material scintillator (60 tons) read-out by WLS green fibers (1100 Km). Acts also as return yoke for inner solenoid



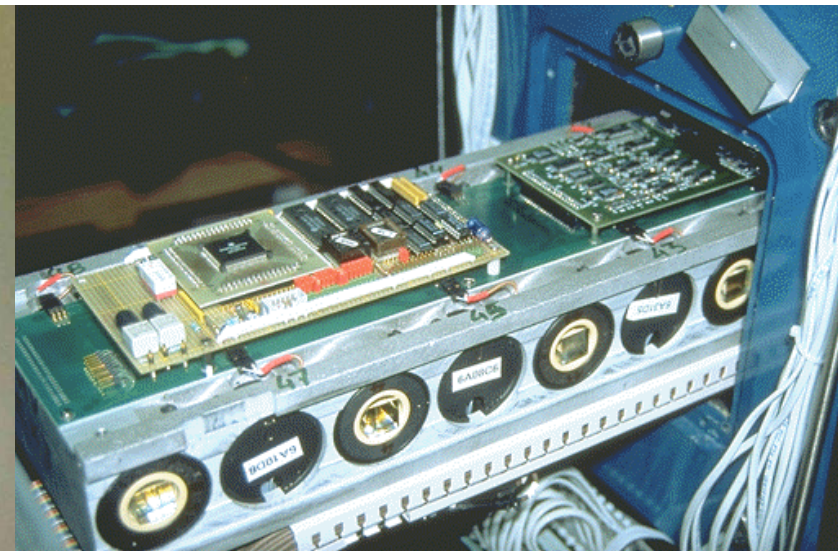
Marzio Nessi



ATLAS Tile Calorimeter

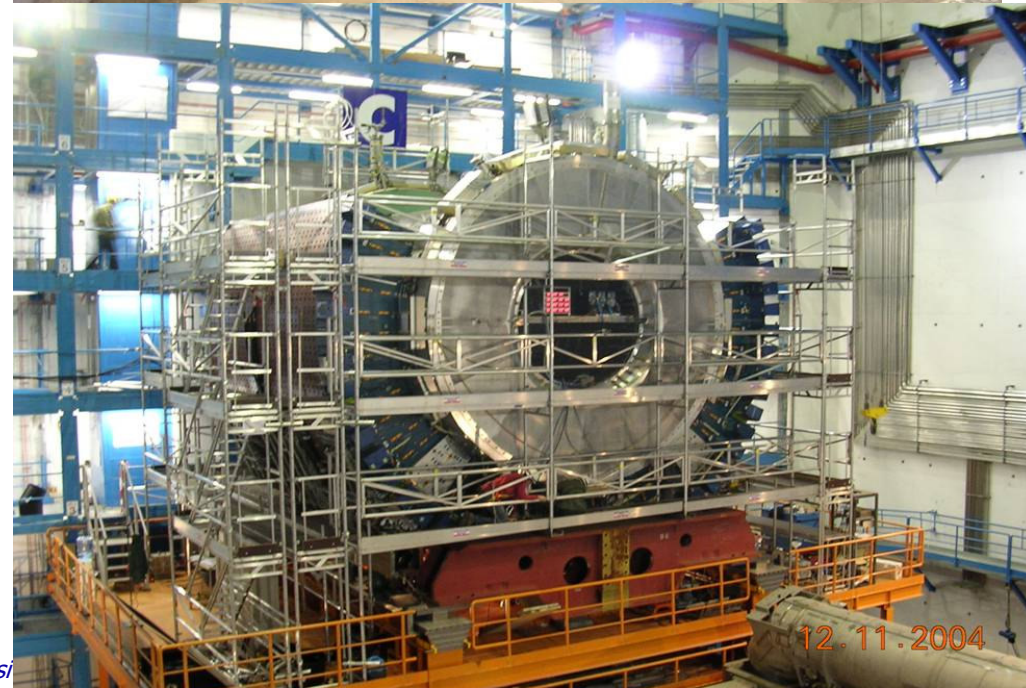


Modules construction and optical instrumentation has been completed since a few years, and in the meantime the pre-assembly and disassembly on the surface of the first extended barrel (EB) cylinder as well as of the barrel have been completed, the second EB has gone through the same procedure



The electronics components are fabricated, the 'drawer' system with all on-detector circuits is now installed in all modules going underground.

Barrel Tile Calorimeter lowering



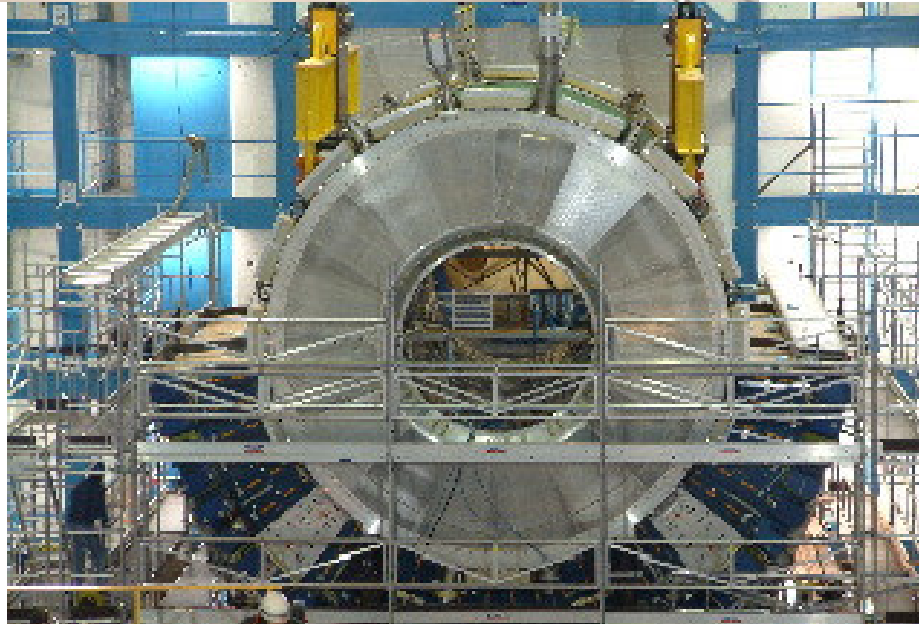
18/11/2005

Marzio Nessi

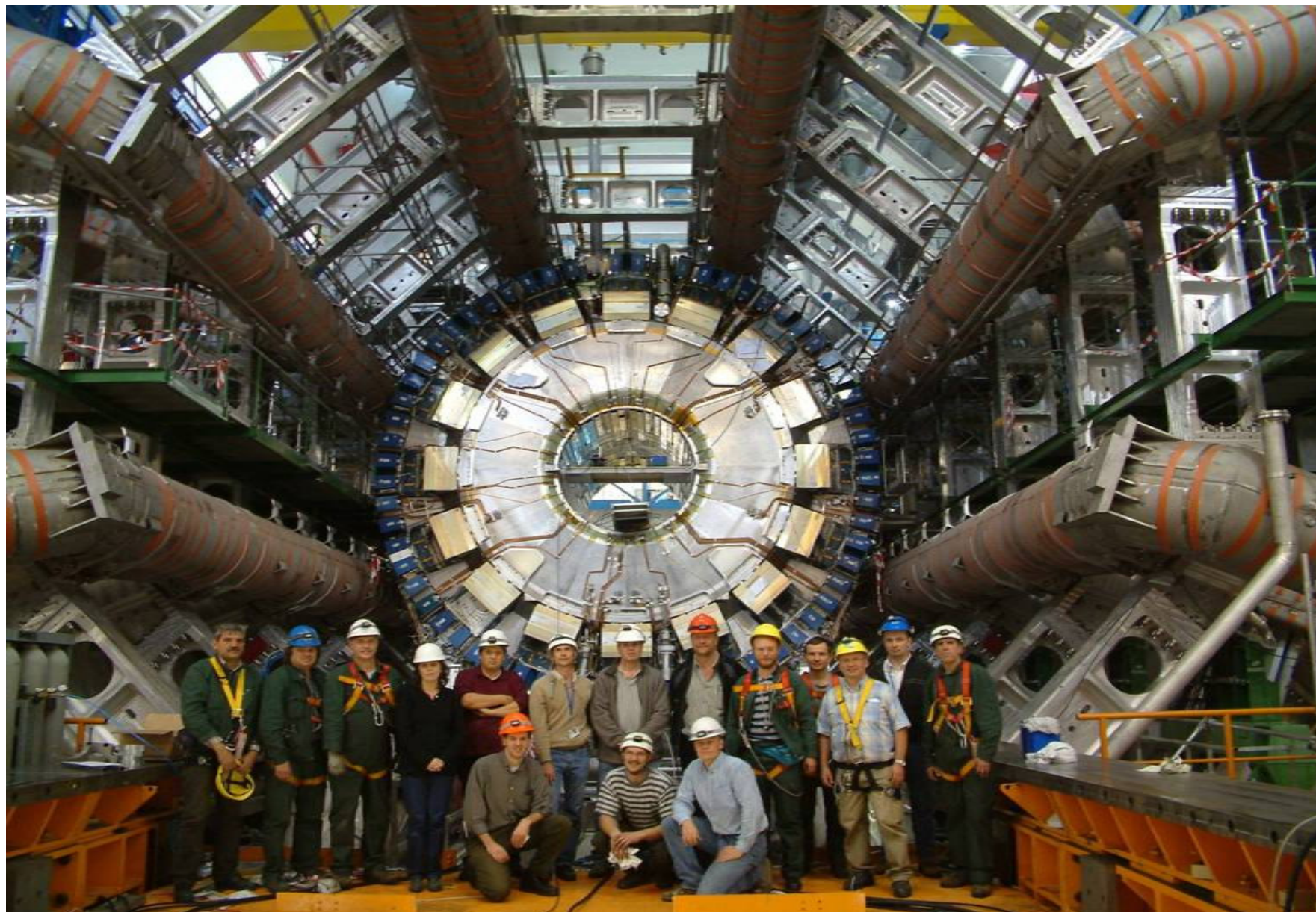
Barrel LAr Calorimeter lowering



170 tons assembly



Barrel Calorimeter positioning at $z=0$

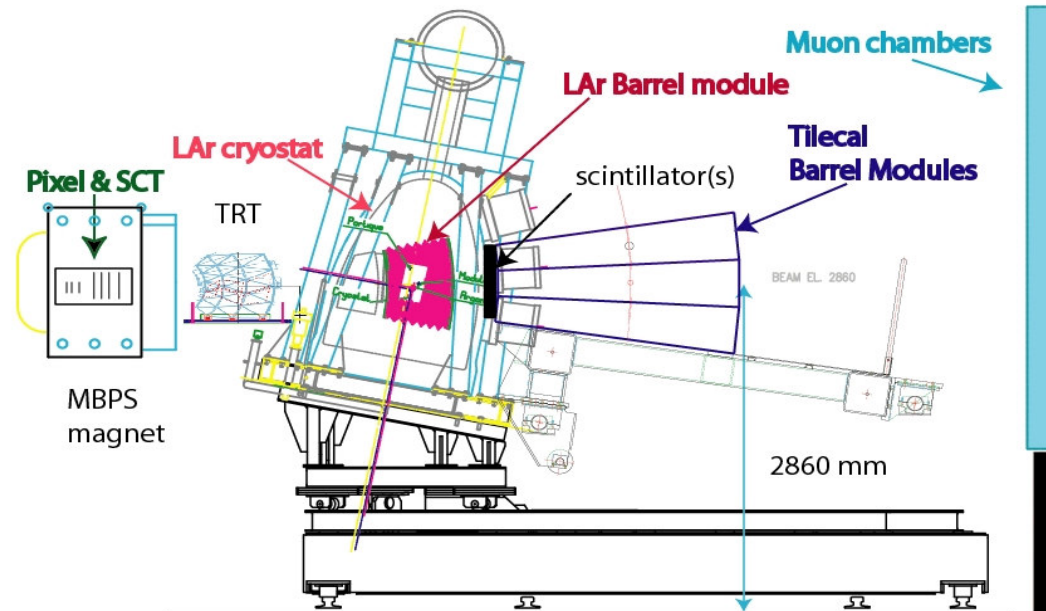
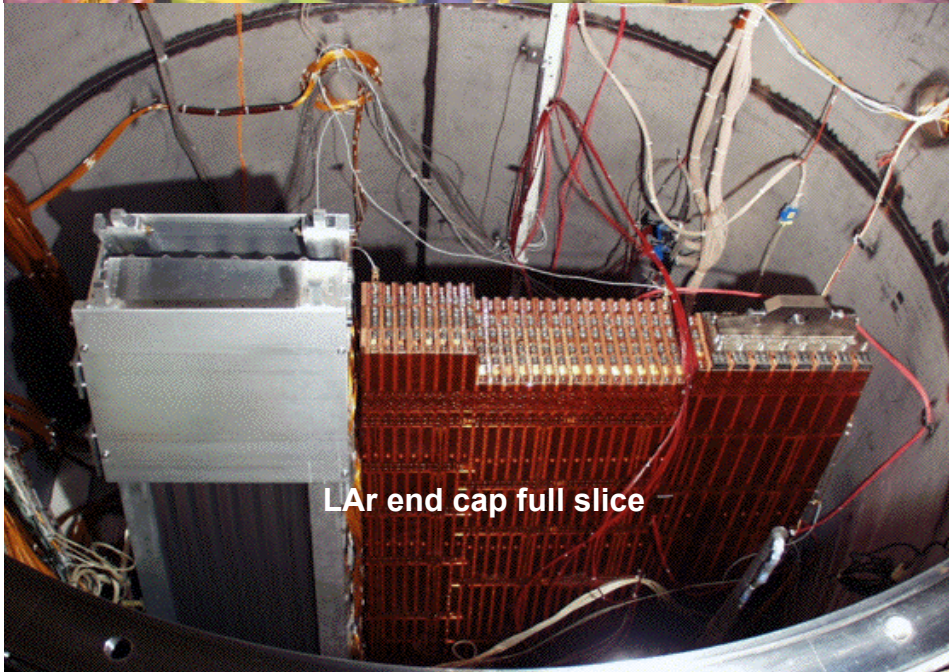
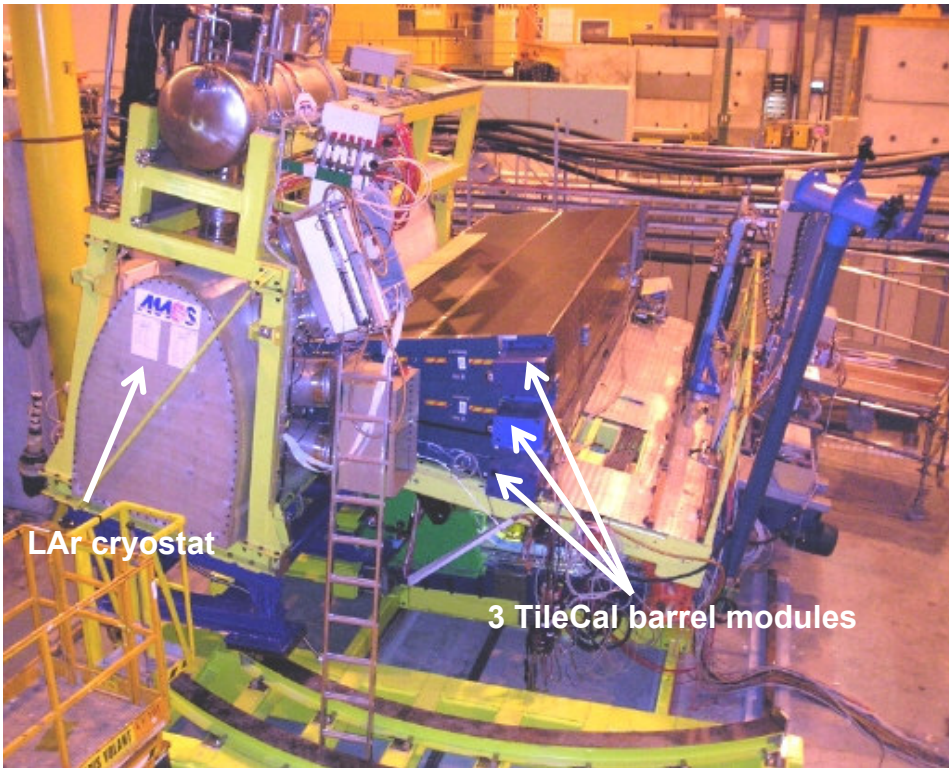


18/11/2005

Marzio Nessi

Combined test beam

The combined test beam runs 2004 in the CERN SPS H8 and H6 beam lines are just finished (1 to 300 GeV/c).

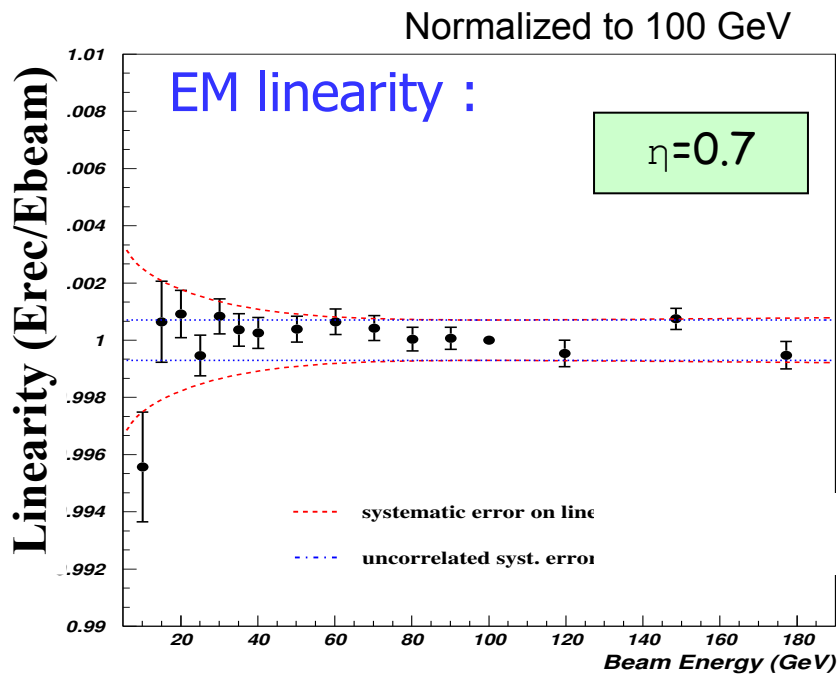
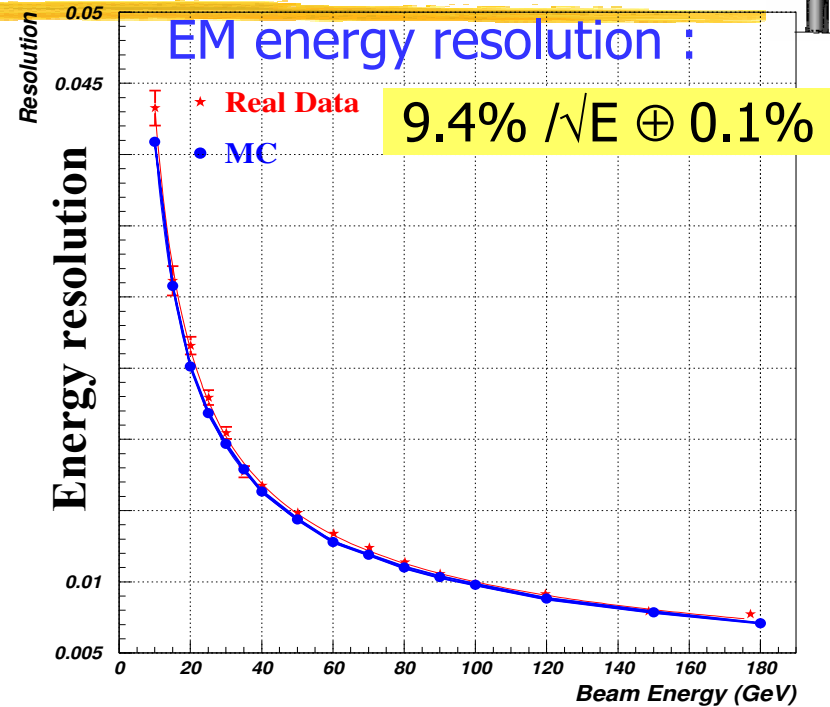


LAr Calorimetry test beam performance

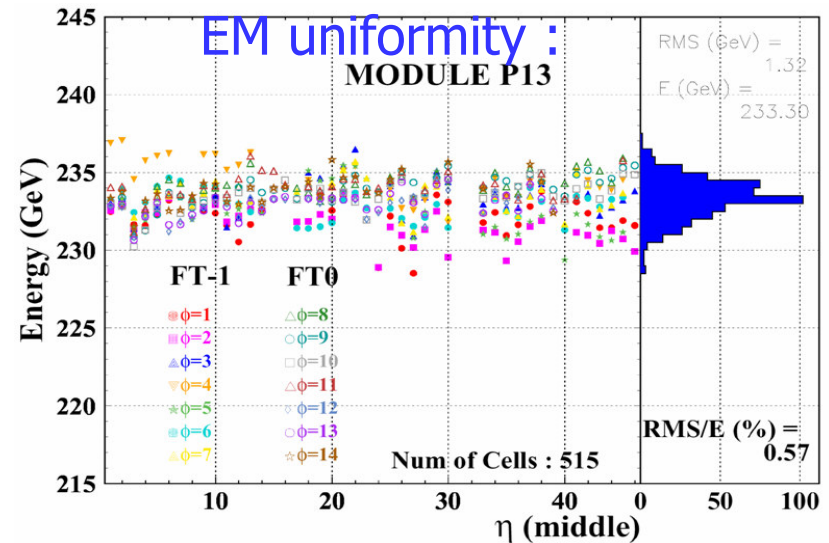


Test beam runs of series modules:

- EMB finished in 2002. 4 / 32 modules tested.
- EMEC finished in 2002. 3 / 16 modules tested.
- HEC finished in 2001. 24 / 128 modules tested.
- FCAL beam calibration in 2003. 3 / 6 modules.



Detector linear within $\pm 0.25\%$ ($\pm 0.1\%$)
 for $E > 10$ (40) GeV



Impact on Higgs mass resolution



Simulations, $m_H = 130$ GeV

✓ $H \rightarrow \gamma\gamma$

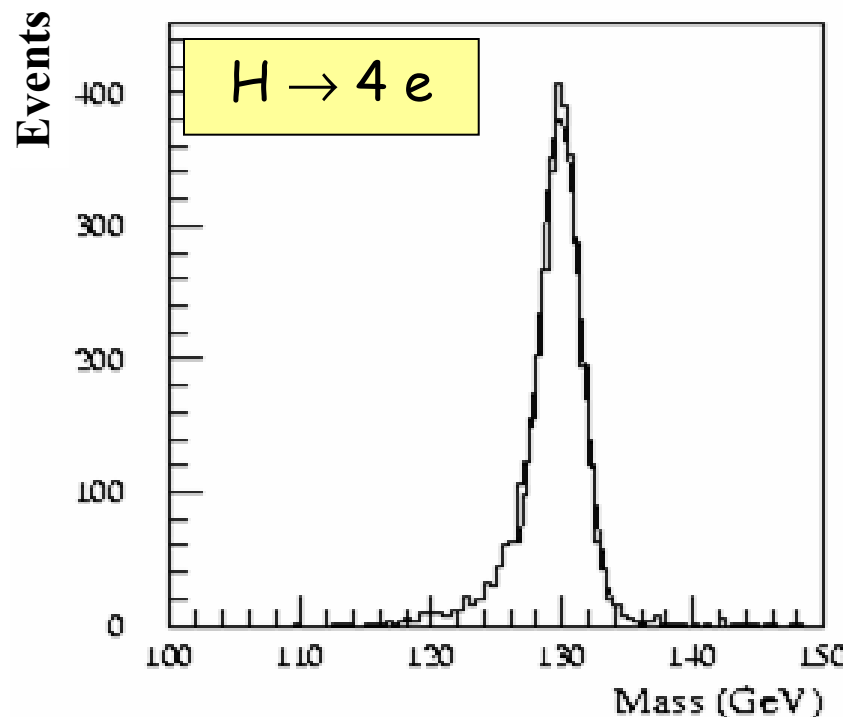
Resolution: 1% (low luminosity)
1.2% (high luminosity)

Acceptance: 80% within $\pm 1.4 \sigma$

✓ $H \rightarrow 4e$

Resolution: 1.2% (low luminosity)
1.4% (high luminosity)

Acceptance: 84% within $\pm 2 \sigma$



Calorimetry summary



- ✓ All ATLAS calorimeters are in the final assembly phase. The barrels are installed underground at $Z=0$ ready for final commissioning
- ✓ The 2 T Solenoid is integrated inside the LAr cryostat, it has been surveyed and tested, performances are excellent
- ✓ The front-end electronics is fully in production, 30% installed on the barrel, all rad-hard chips are in hand
- ✓ Substantial test beam efforts done, design performance demonstrated
- ✓ A major step has been the final cold test of the LAr barrel before the underground installation
- ✓ We have turned on the barrel Tiles to cosmics in mid '05 and the barrel LAr will be on cosmics by spring of '06
- ✓ Both end-caps are ready for installation underground. The first end-cap was just lowered. We expect end '06 all calorimeters to be fully operational and debugged.

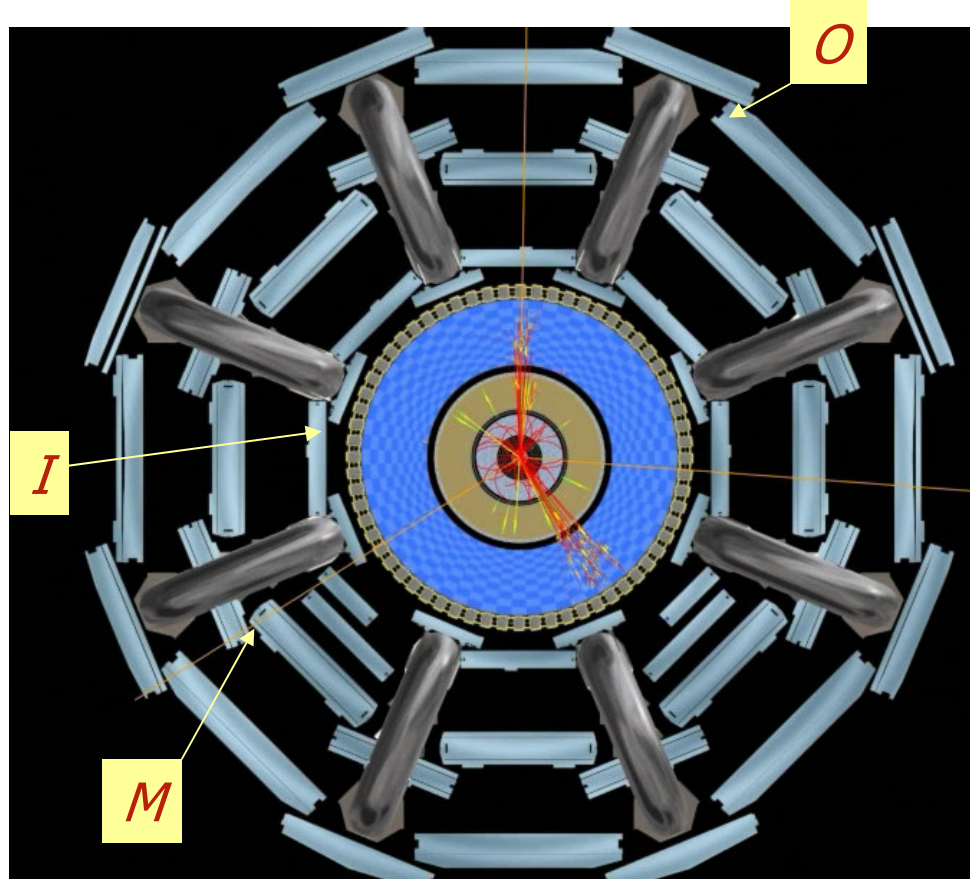
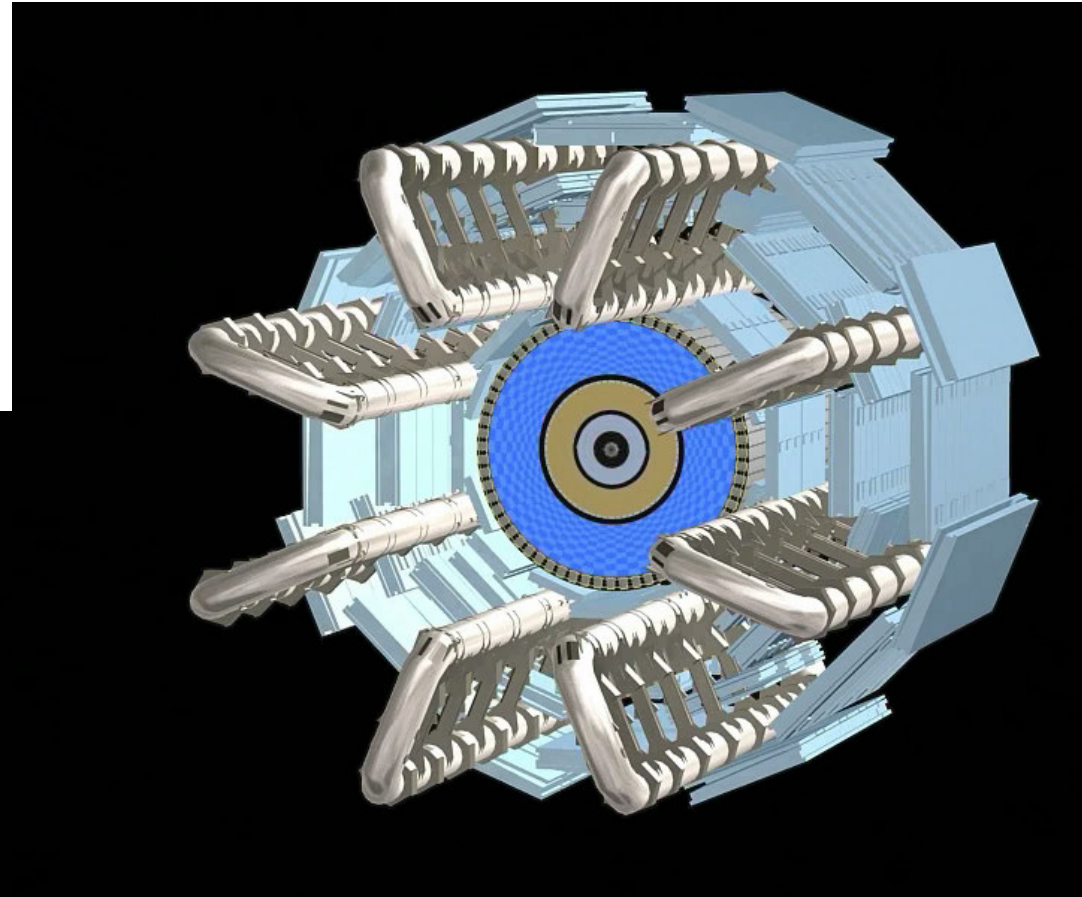
Muon Spectrometer Project

Barrel precision and trigger chambers + small and big wheels in the forward + alignment

Production over 8 years, 1998-2005
Installation over 3 years, 2005-2007

The muon spectrometer (barrel)

Barrel: precision and trigger chambers in 3 layers:
I (inner) - M (middle)
O(outer)



2 technologies:

MDT - Monitored Drift Tubes (layers: *I,O,M*)

RPC - Resistive Plate Chambers (trigger)
(layers *M+M,O*)

The muon spectrometer



Barrel station:

Two MDT layers (2 x 3 planes)

Two (M-layer), One (O-layer) RPC chambers

MDT

RPC

RPC

The muon spectrometer (MDT)

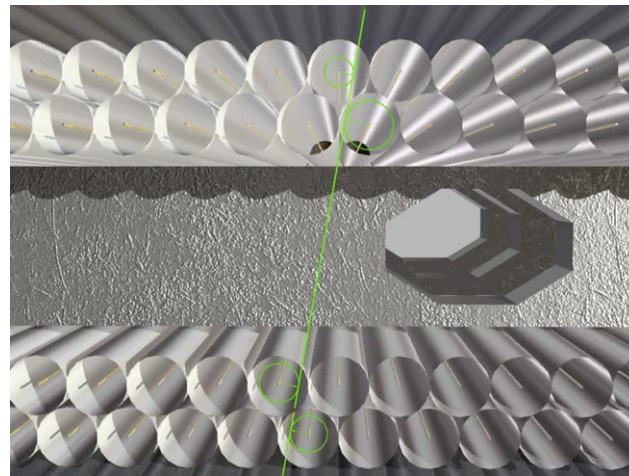
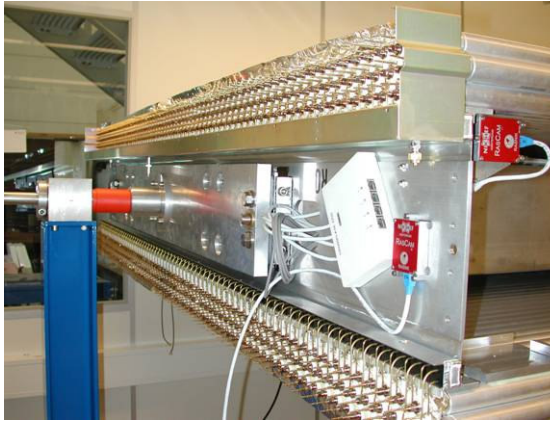


30 mm ϕ high precision Al tubes

Wire ϕ 50 μ m

Operating pressure 3 bar

Gas : Ar/CO₂; HV : 3270 V



3 layers of tubes
(4 layers inner ch.)

3(4) layers of tubes
(wire position 20 μ m)

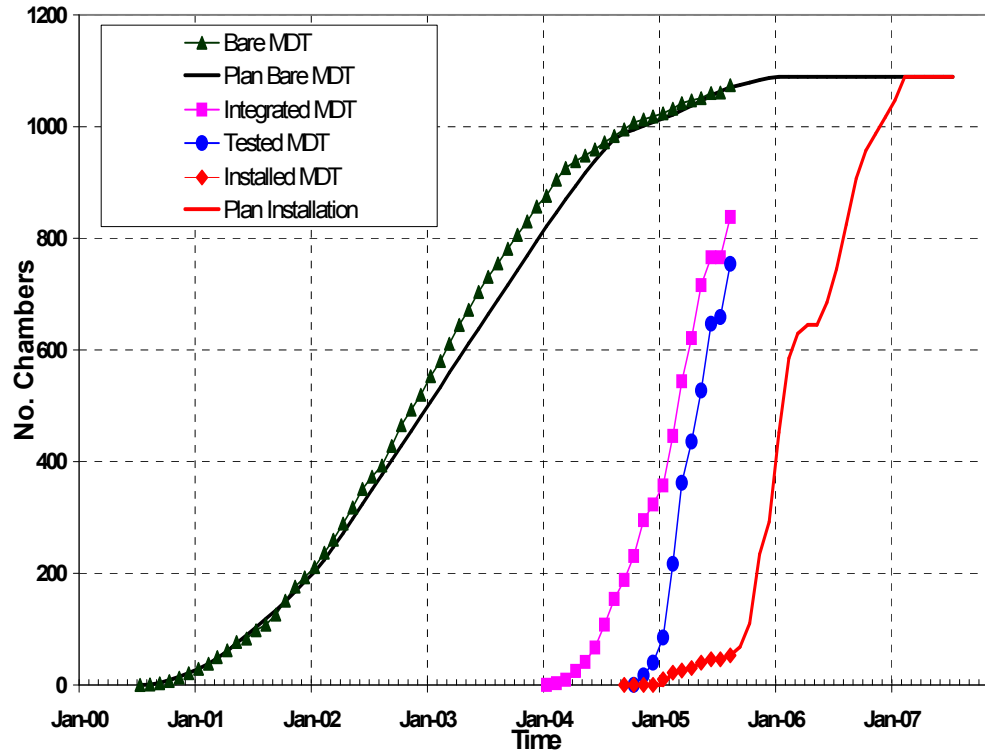
Single wire resolution 80 μ m

1091 MDT chambers needed, \sim 5500 m², construction in 18 ATLAS Labs.

The muon spectrometer (MDT)



MDT Chamber Production (wo EE)



Production status October 2005



All chambers tested on cosmics. All production plants monitored with a X-rays Tomograph (chambers sampling). All stations tested on cosmics, just before installation

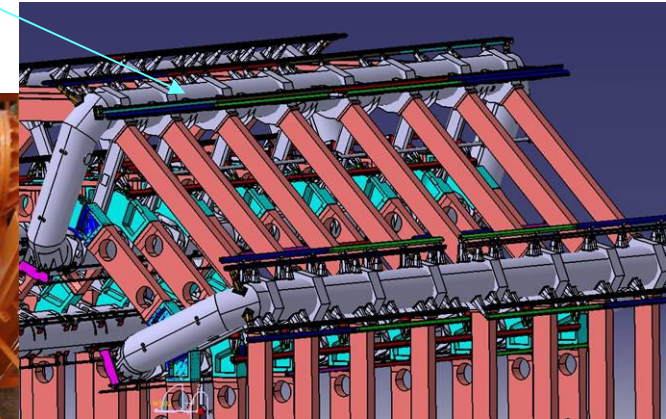
The muon spectrometer (barrel assembly)



~ 85 stations installed during magnet assembly (most difficult and inaccessible locations)

Main installation campaign between December-April 2006

Stations sliding on pre-assembled rails from the extremities



The muon spectrometer (trigger)

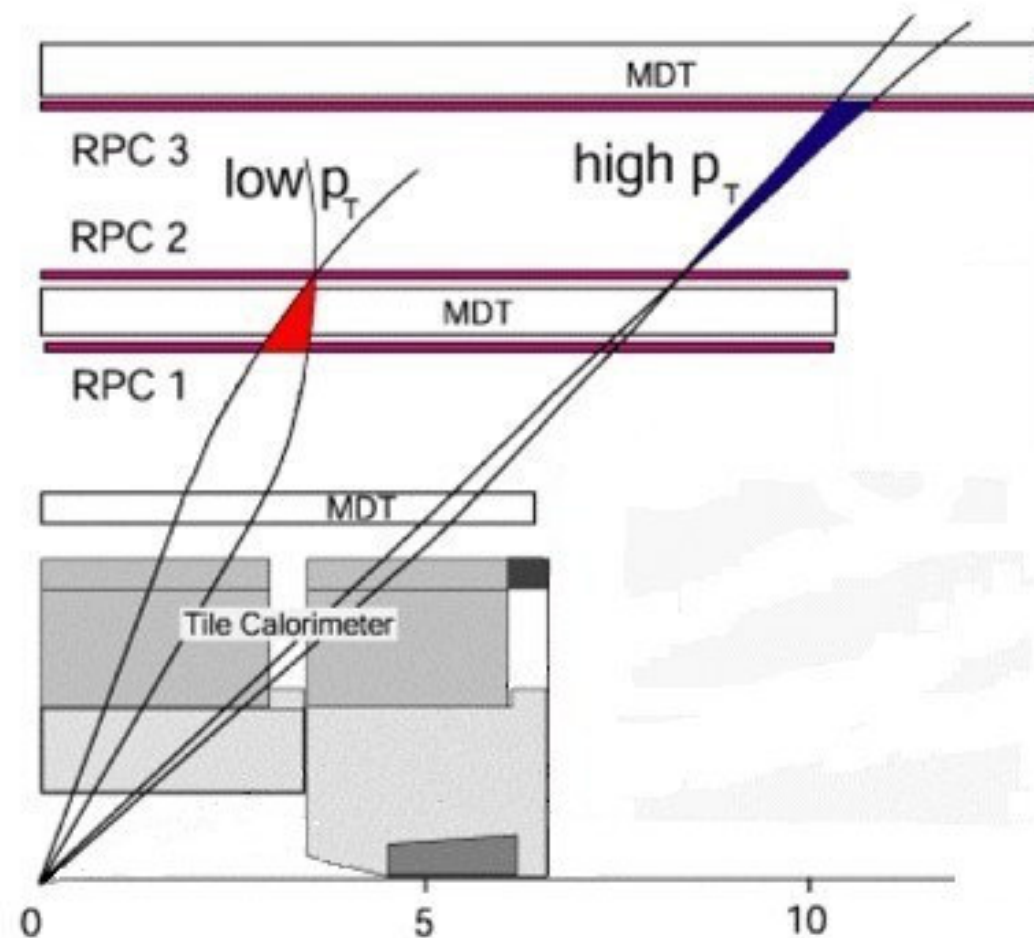


Low p_T trigger:

- at least 3 out 4 track hits in RPC1 and RPC2
- $p_T > 6$ GeV
- progr. coincidence matrix + pipeline

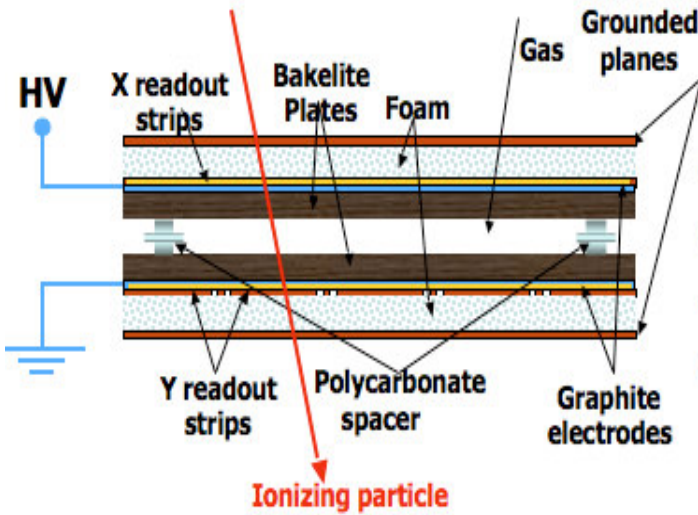
High p_T trigger:

- low p_T and at least 1 track hit in RPC3
- $p_T > 20$ GeV
- progr. coincidence matrix + pipeline

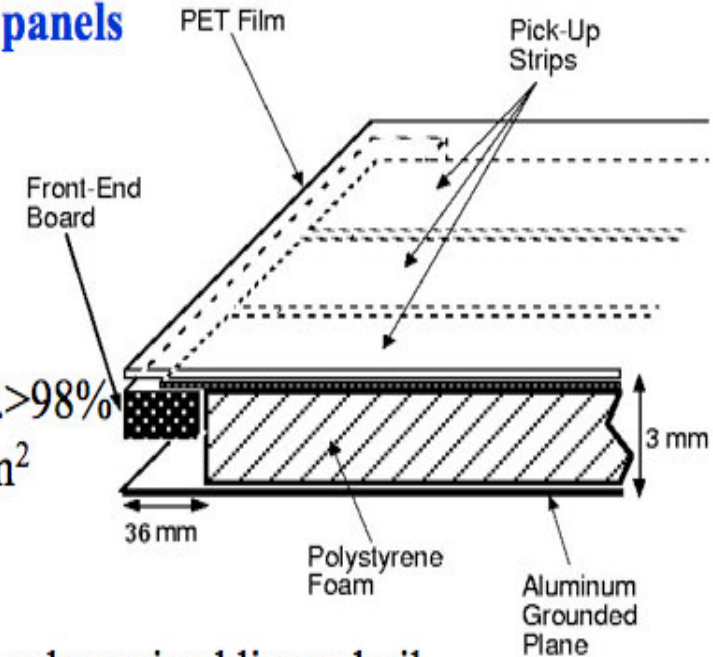


Trigger chambers (RPC) rate capability required ~ 1 kHz/cm²

The muon spectrometer (RPC)



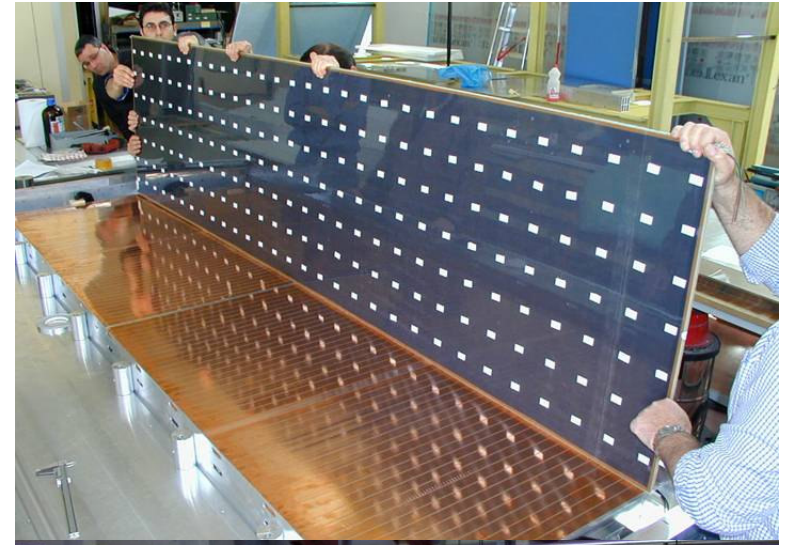
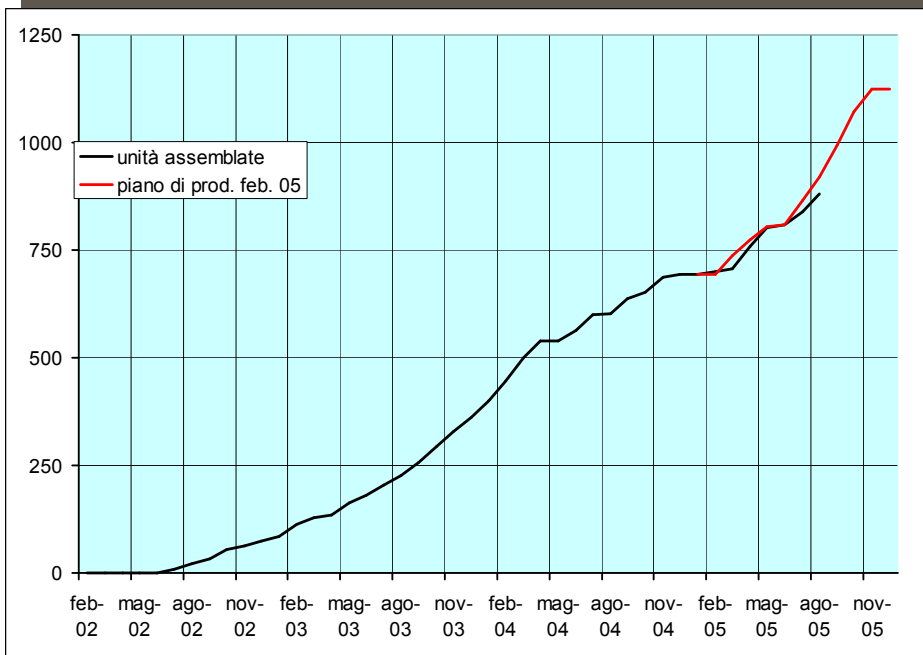
Readout panels layout



- Saturated avalanche regime.
- Bunch crossing ID (TW ~ ns).
- XY measurement (~ 1 cm).
- Rate Capability ~1 kHz/cm²@Eff.>98%
- Gap volume size from 1.72x0.75m² up to 2.96x1.2m².

- Electrodes: graphite layer+ 2 mm thick bakelite ($\rho \sim 1 \div 4 \times 10^{10} \Omega \text{cm}$) + polymerized linseed oil.
- Gap gas: $d = 2 \text{ mm}$, $\text{C}_2\text{H}_2\text{F}_4(94.7\%)\text{C}_4\text{H}_{10}(5\%)\text{SF}_6(0.3\%)$, $\text{HV} \sim 10 \text{ KV}$ ($E_{\text{gas}} \sim 5 \text{ KV/mm}$)
- Readout panels: X and Y copper strip (pitch ~3 cm).

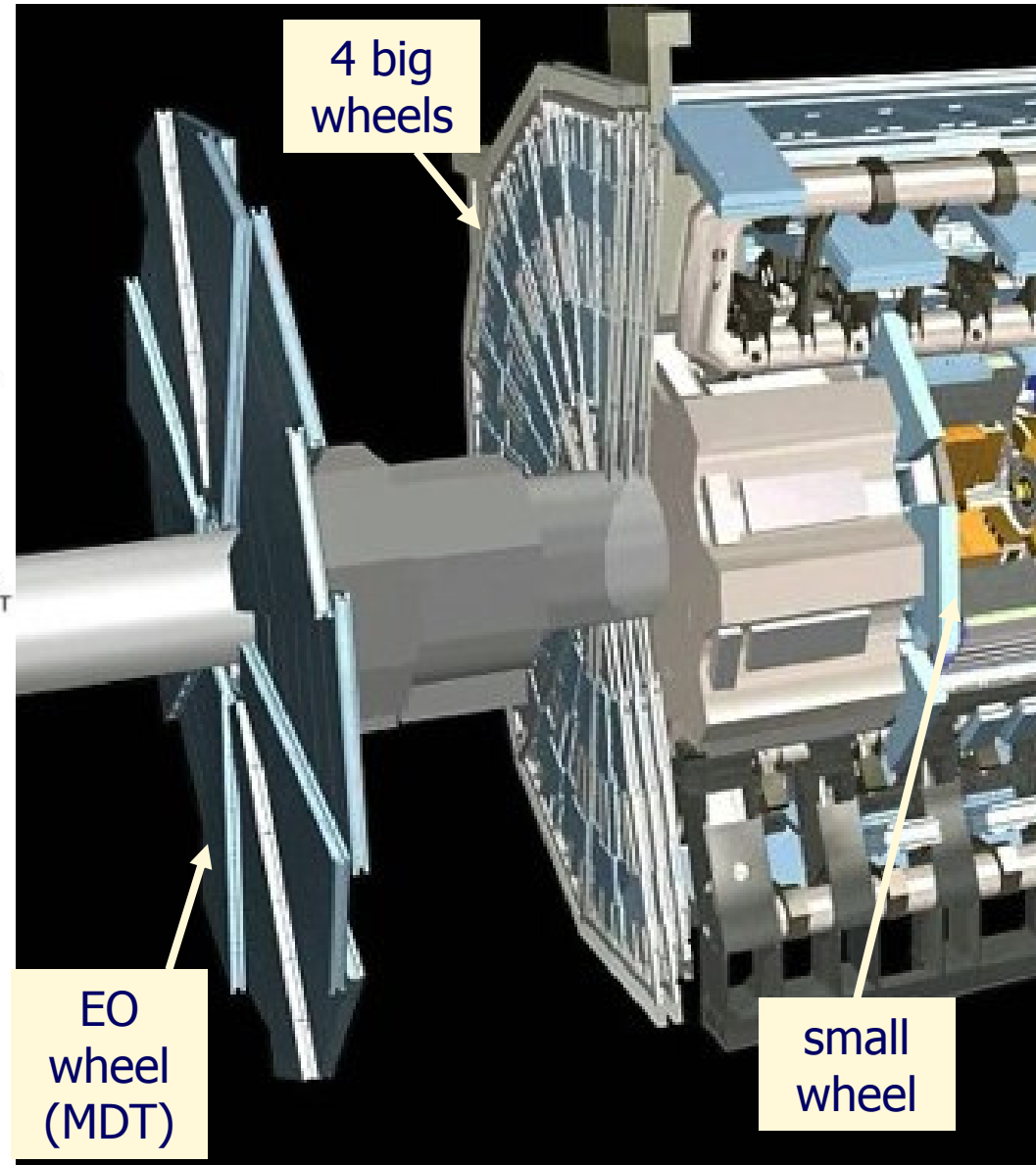
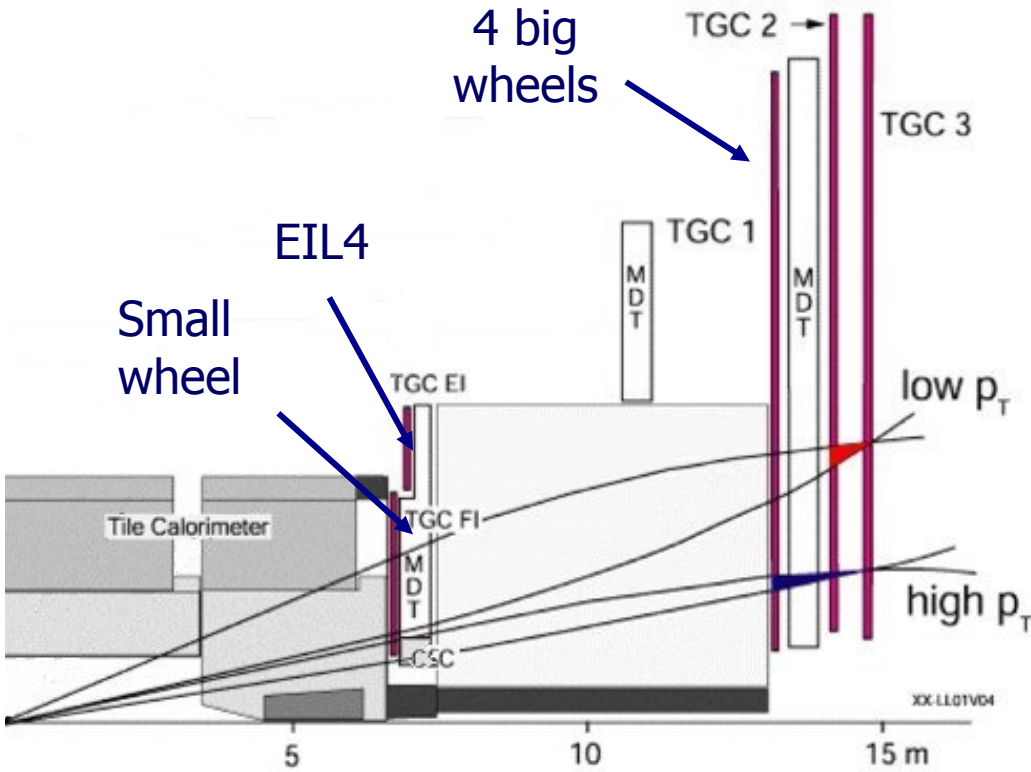
The muon spectrometer (RPC)



Last 20% construction affected by some problems of material availability, repairs, delamination ... should finish in end 2005

1136 RPC chambers needed, $\sim 3650 \text{ m}^2$, construction in 5 ATLAS Labs.

The muon spectrometer (forward)



3 technologies:

MDT - Monitored Drift Tubes

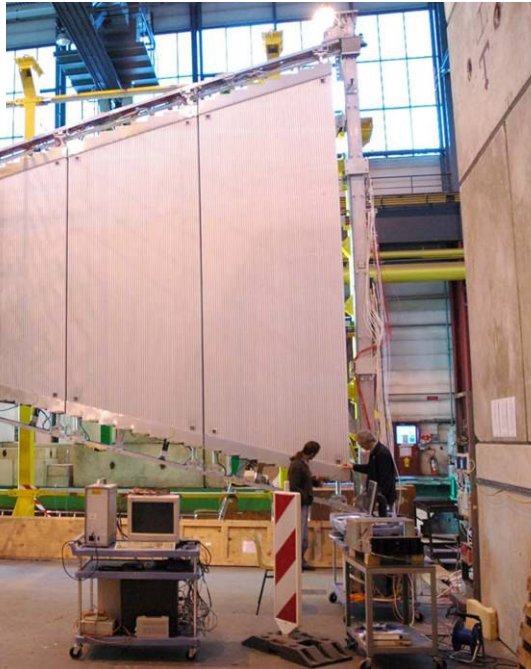
CSC - Cathod Strip Chambers ($|\eta| > 2$, sm. Wheel)

TGC - Thin Gap Chambers (trigger)

The muon spectrometer (Big Wheels)



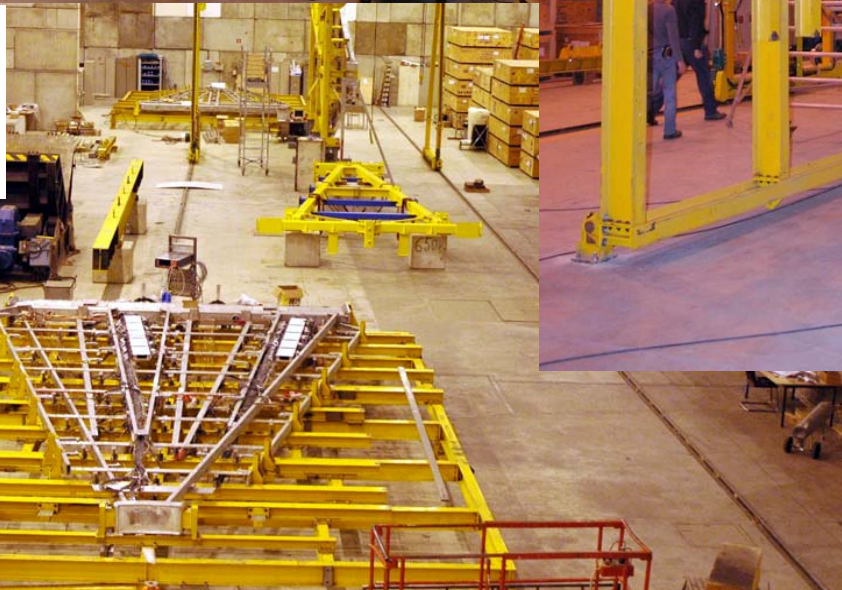
MDT wheel sector



TGC1 wheels sectors



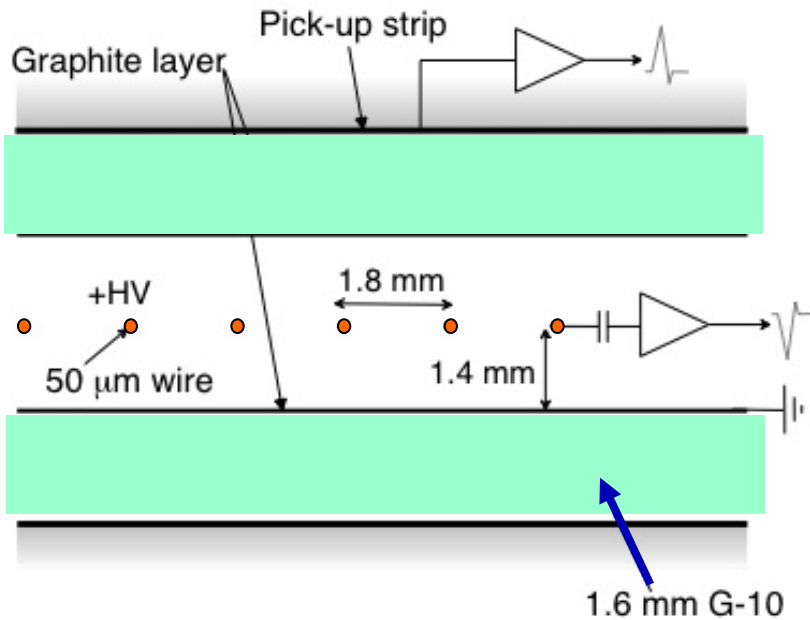
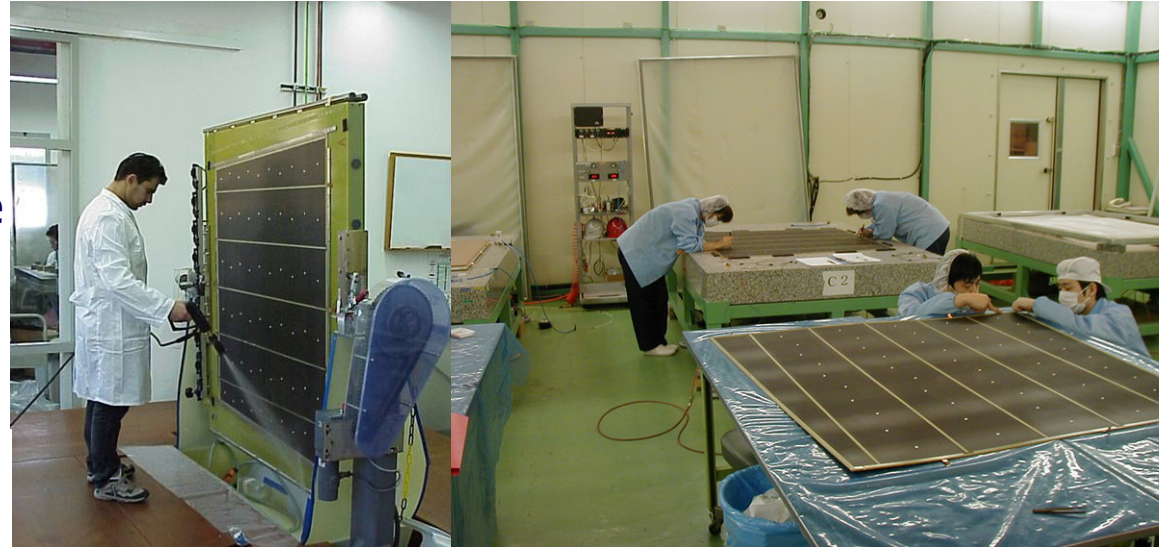
Wheels assembly @ CERN



EIL4

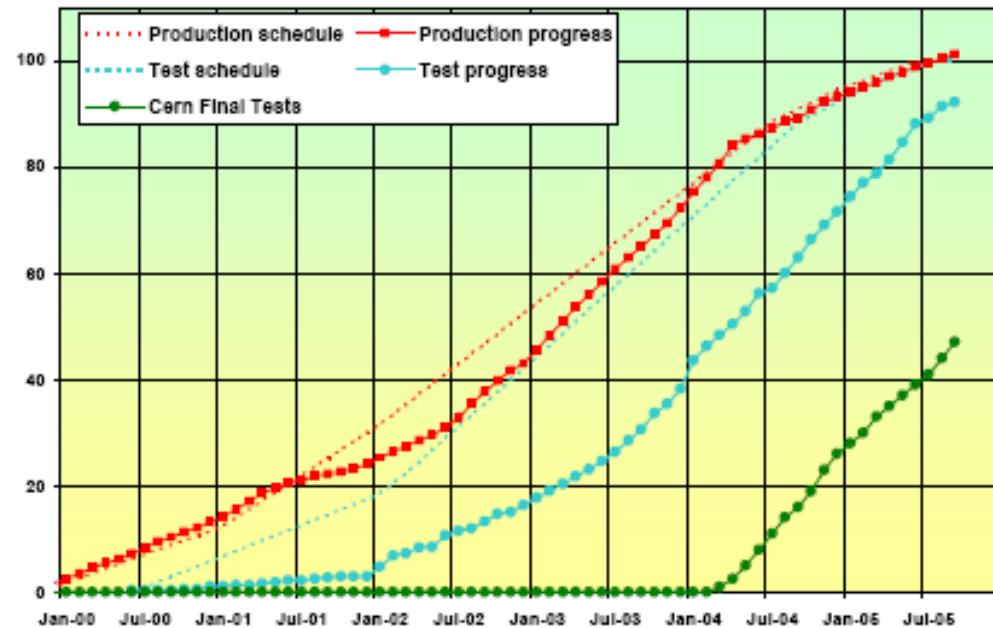
The muon spectrometer (TGC)

- Proportional chambers operating with a very thin gap, small drift time
- Wire signal for trigger, cathode signal for trigger and second coordinate (high rate, < 25 ns)
- Gas CO₂ + n-pentane, 3.1 KV

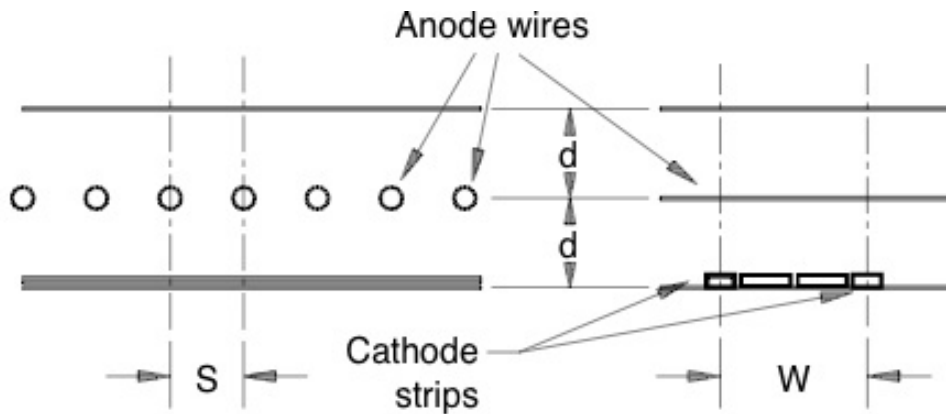


1584*2 TGC chambers needed, ~ 2900 m², construction in 5 ATLAS Labs.

TGC production & test: schedule and progress

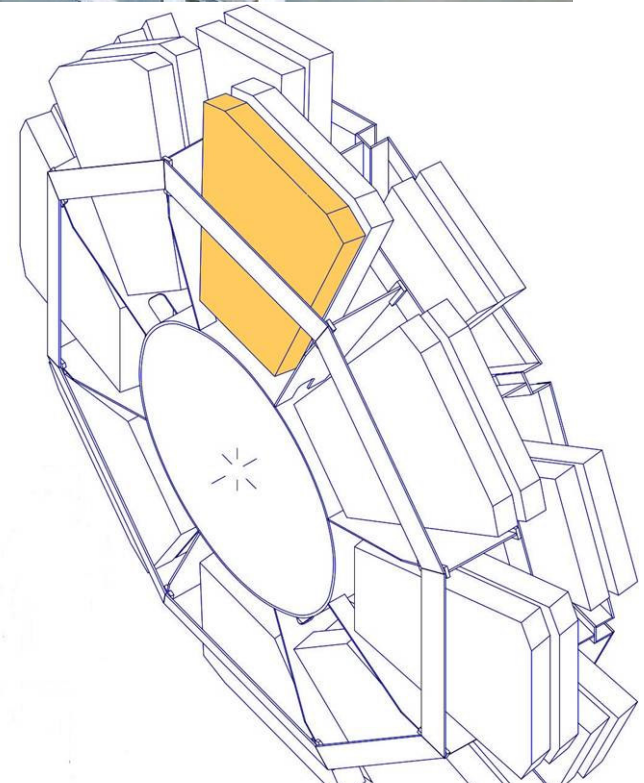


The muon spectrometer (CSC)

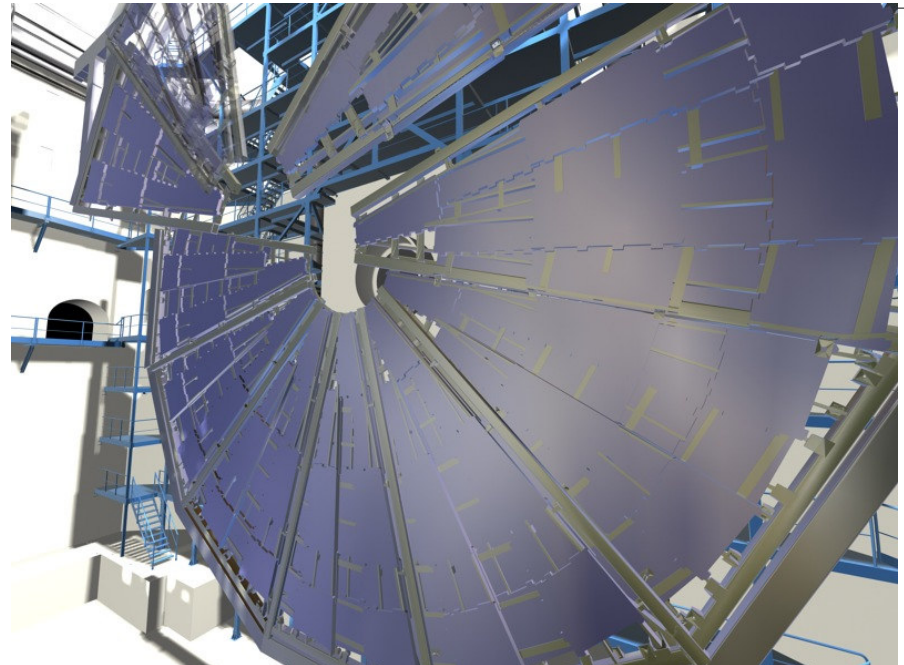
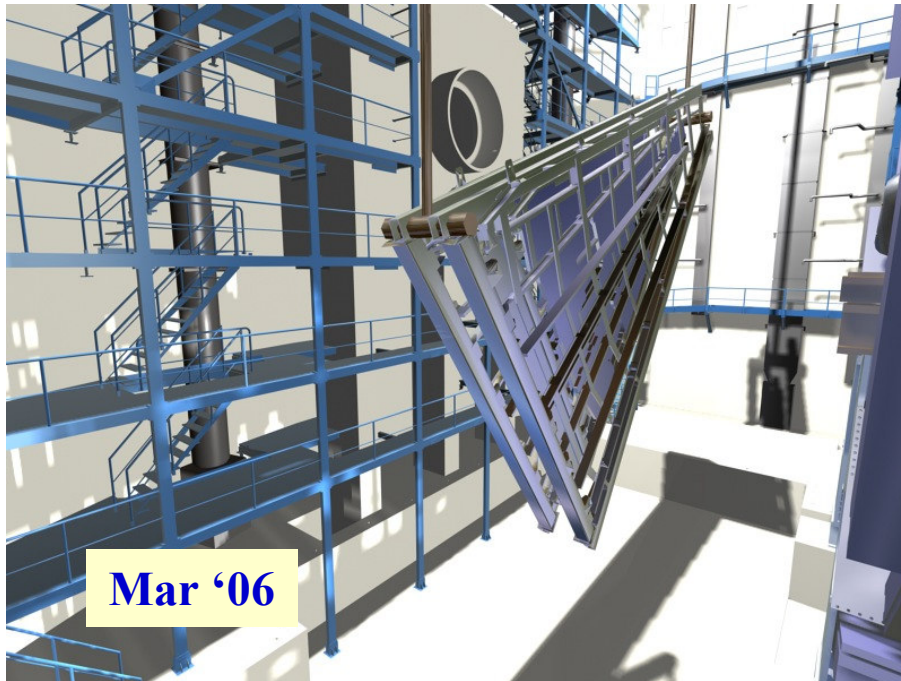


- Multiwire Proportional Chambers operating with $d=s=2.54$ mm , wire=0.015 mm
- Time resolution <7 ns, $W \sim 5$ mm, hit resolution ~ 60 μ
- Gas Ar/CO₂/CF₄, 2.6 KV
- All chambers constructed

32 CSC chambers needed, ~ 27 m²,
construction in 2 ATLAS Labs.

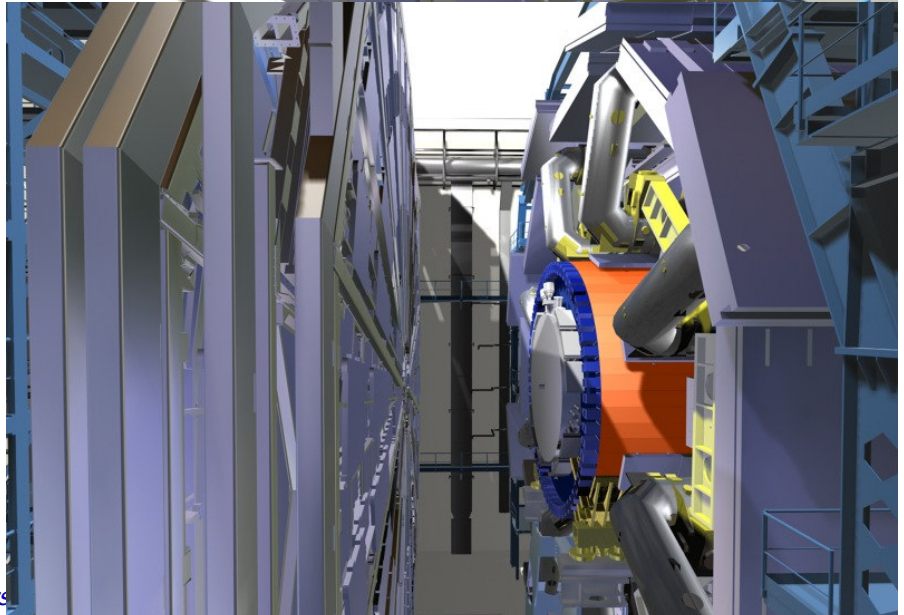


The muon spectrometer (wheels installation)

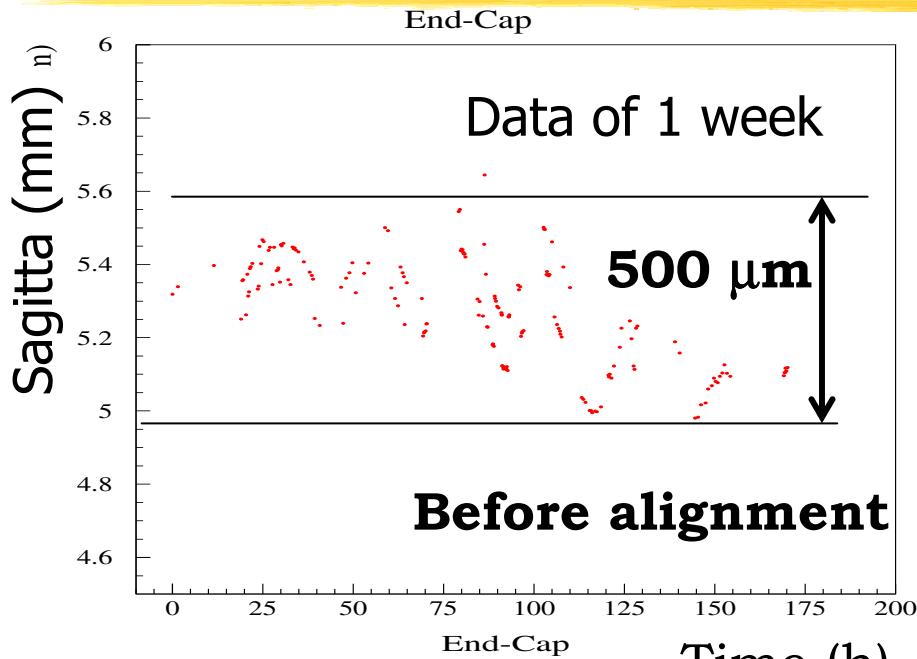


4 wheels on each side, 24 m diameter

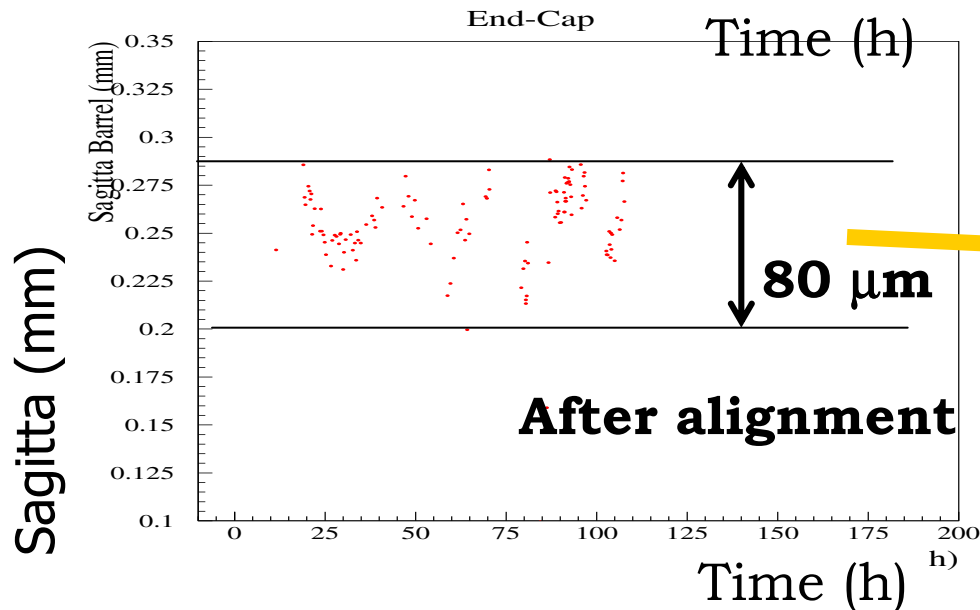
- ✓ installation in octants
- ✓ each octant is instrumented and tested on the surface
- ✓ the production of the mechanical wheels has started, installation in the ATLAS cavern in March '06



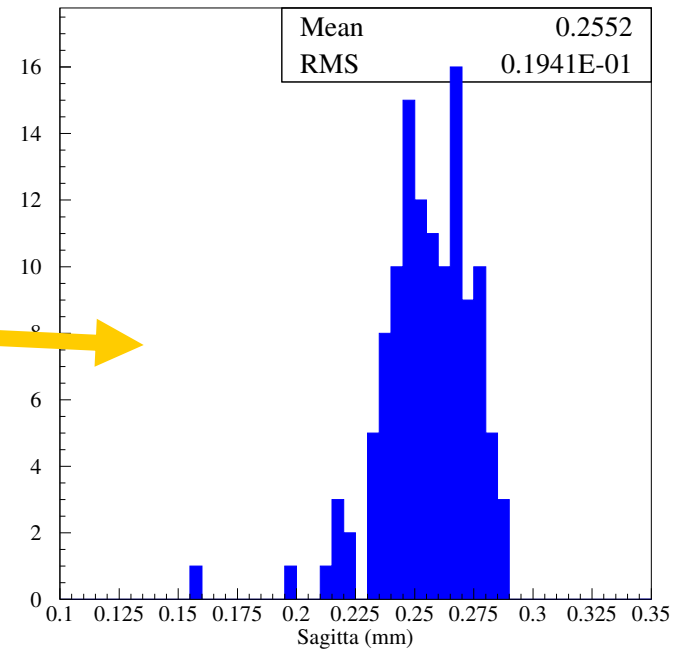
Test beam : Alignment with optical alignment system



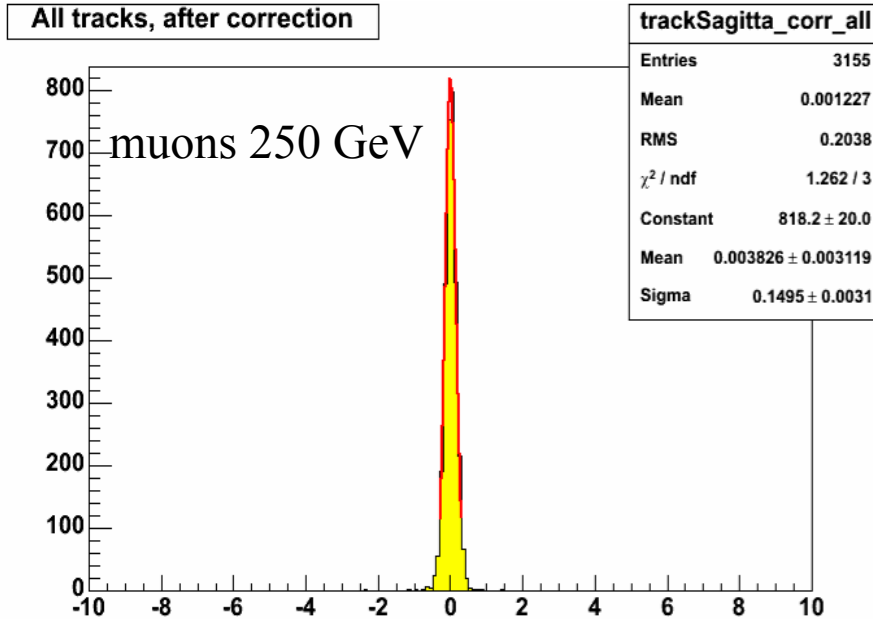
Sagitta stability:
19 μm dispersion of sagitta



RMS 19 μm

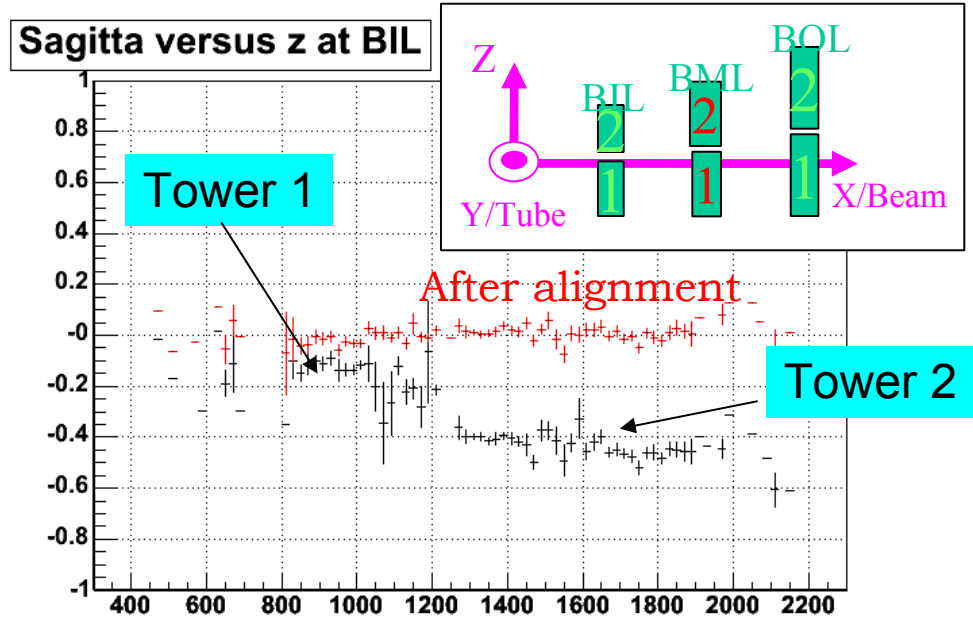


Test beam :Alignment with straight tracks

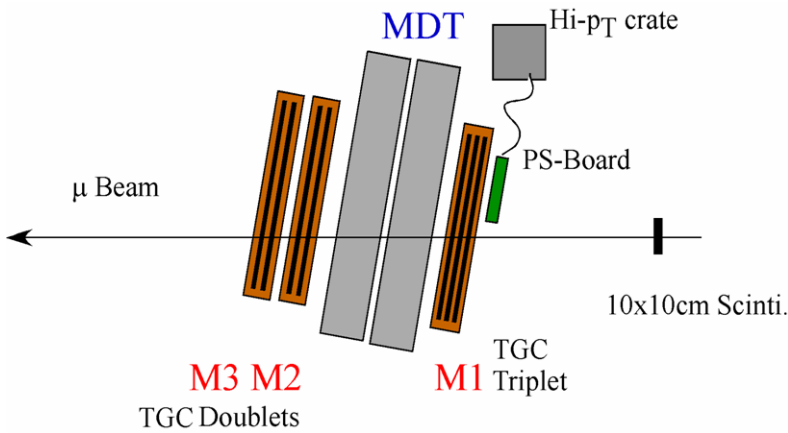


After alignment:
 Sagitta mean value: $4 \mu\text{m}$
 Statistical error on alignment: $3 \mu\text{m}$

Relative alignment of two towers using tracks in the overlap region achieved



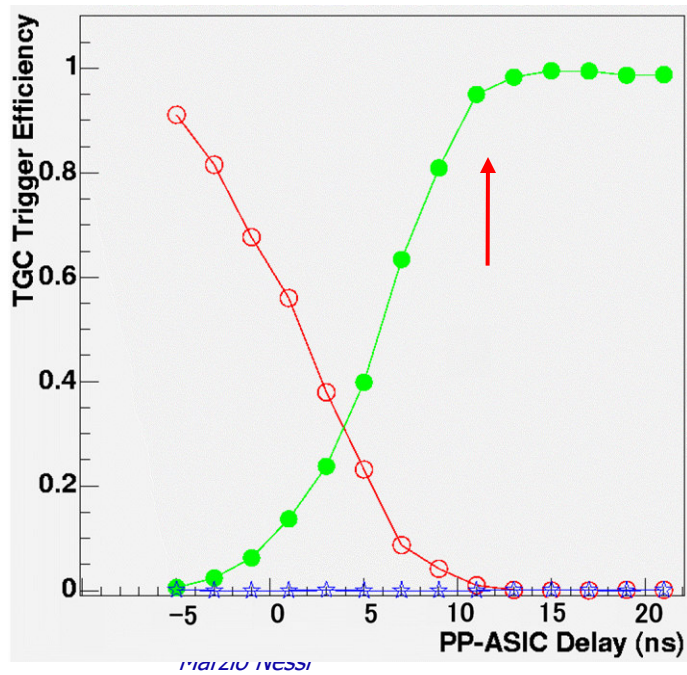
Test beam : TGC muon LVL1 efficiency



7 layers of TGC in 3 stations
 Full chain of trigger/readout electronics for a part of “forward region”

- ✓ All on-board ASICs have full functionality
- ✓ DAQ including DCS in RCD framework
- ✓ 25ns bunched Muons triggered with 10x10 scintillators to measure High-Pt trigger efficiency

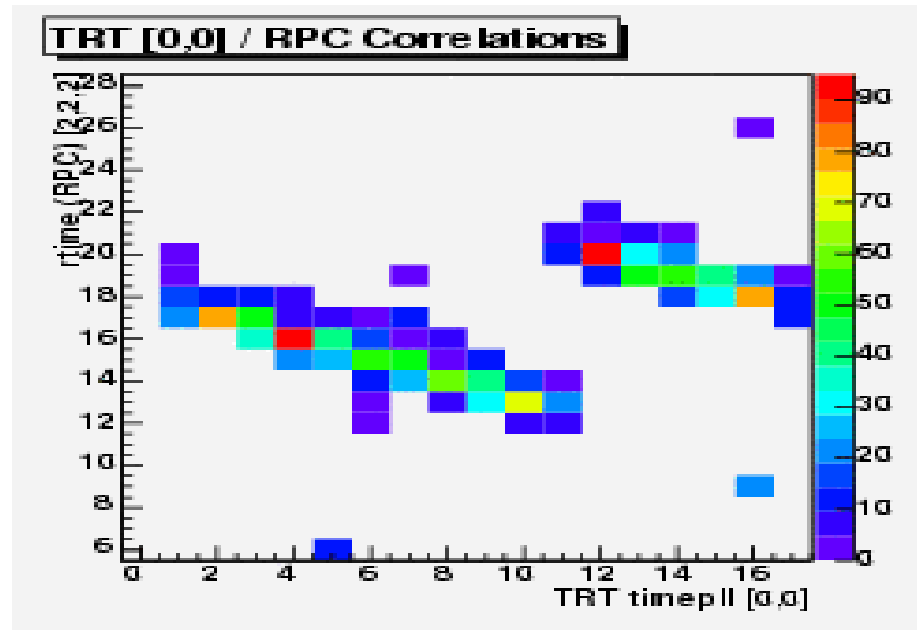
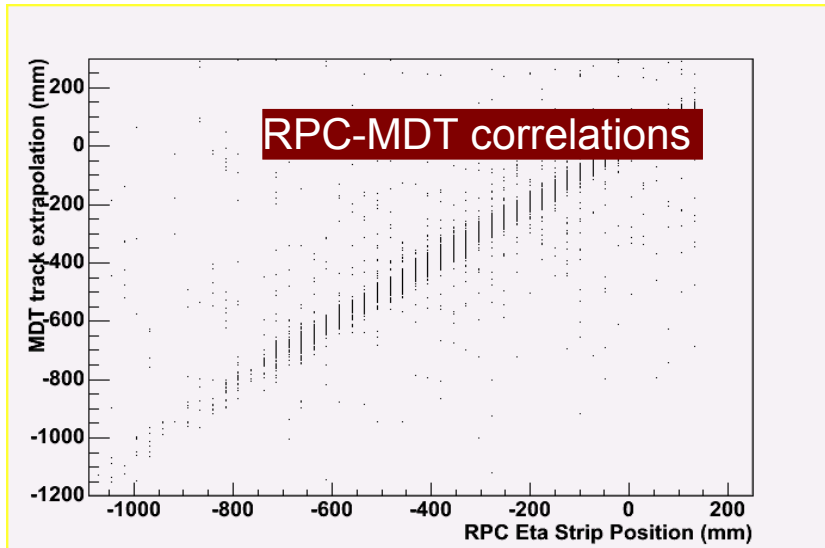
Adjust Delay/Gate Width parameters
 maximize Trigger efficiency and BCID performance



98% trigger efficiency
 ~1% spurious 10x10
 ~1% tracks out of phase

● Triggered Bunch
 ★ Next Bunch
 ○ Previous Bunch

Test beam :RPC muon trigger efficiency



- ✓ Region-of-Interest trigger information successfully transmitted
- ✓ RPC running in self-triggering mode
- ✓ RPC+MDT+TGC combined run show good (trigger and readout) synchronization
 - ✓ Full integration with all sub-detectors using Muon+Calo Trigger sent by CTP(central trigger processor)
 - ✓ BC identification tested after transmission to CTP : Efficiency capability at CTP level using RPC trigger = 99.5%
 - ✓ First test of Muon Barrel off-detector trigger slice: Trigger Efficiency preliminary measurement = 99.4%

Muon Spectrometer Summary



- ✓ All chamber production centers are near to completion of their production, 1-2 months to go !
- ✓ The less advanced chambers in production are the RPCs. Intensive aging tests under irradiation (GIF facility at CERN) have been performed with good results. By end December all RPCs should be produced.
- ✓ The assembly on surface of the big wheels has started, ready for installation milestone, spring '06.
- ✓ The assembly and testing of barrel stations (2 RPCs + 1 MDT) has started. This is in the next 4-5 months on the critical path, until all barrel chambers are installed.
- ✓ Underground installation has started: 15% done, soon the standard installation and commissioning will start. We expect the barrel muon spectrometer to be on cosmics by mid '06

Summary



- ✓ 95% of the production of all detectors and infrastructure is done, just few specific items are in their final production process, mainly because of unexpected technical problems
- ✓ Underground all infrastructure, barrel magnets and barrel calorimeters are installed and in their final commissioning phase. We plan to turn on the barrel magnetic field in spring '06
- ✓ The next major step is the installation in situ of all proximity services (cables, pipes, cryogenics)
- ✓ An important test beam effort has shown that what we are installing is fully within the design requirements
- ✓ We have still 20 months of hard and detailed work to get the ATLAS detector ready for beam: 20 very difficult, but very exciting months! Slowly ATLAS is turning into a real experiment, ready for great discoveries!!!

