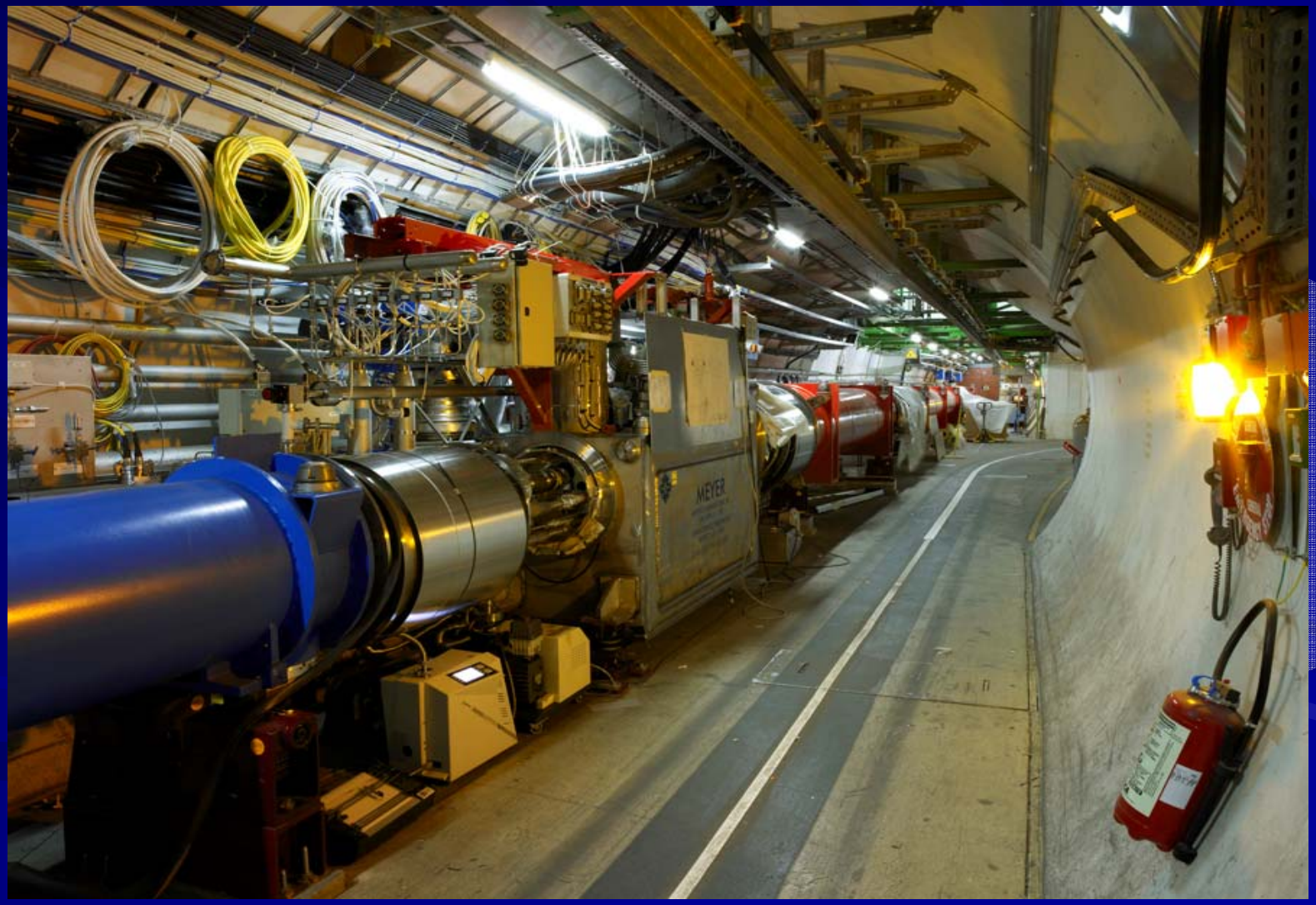
# The LHC Project

## Status Report to the LHC Physics Workshop, Cracow

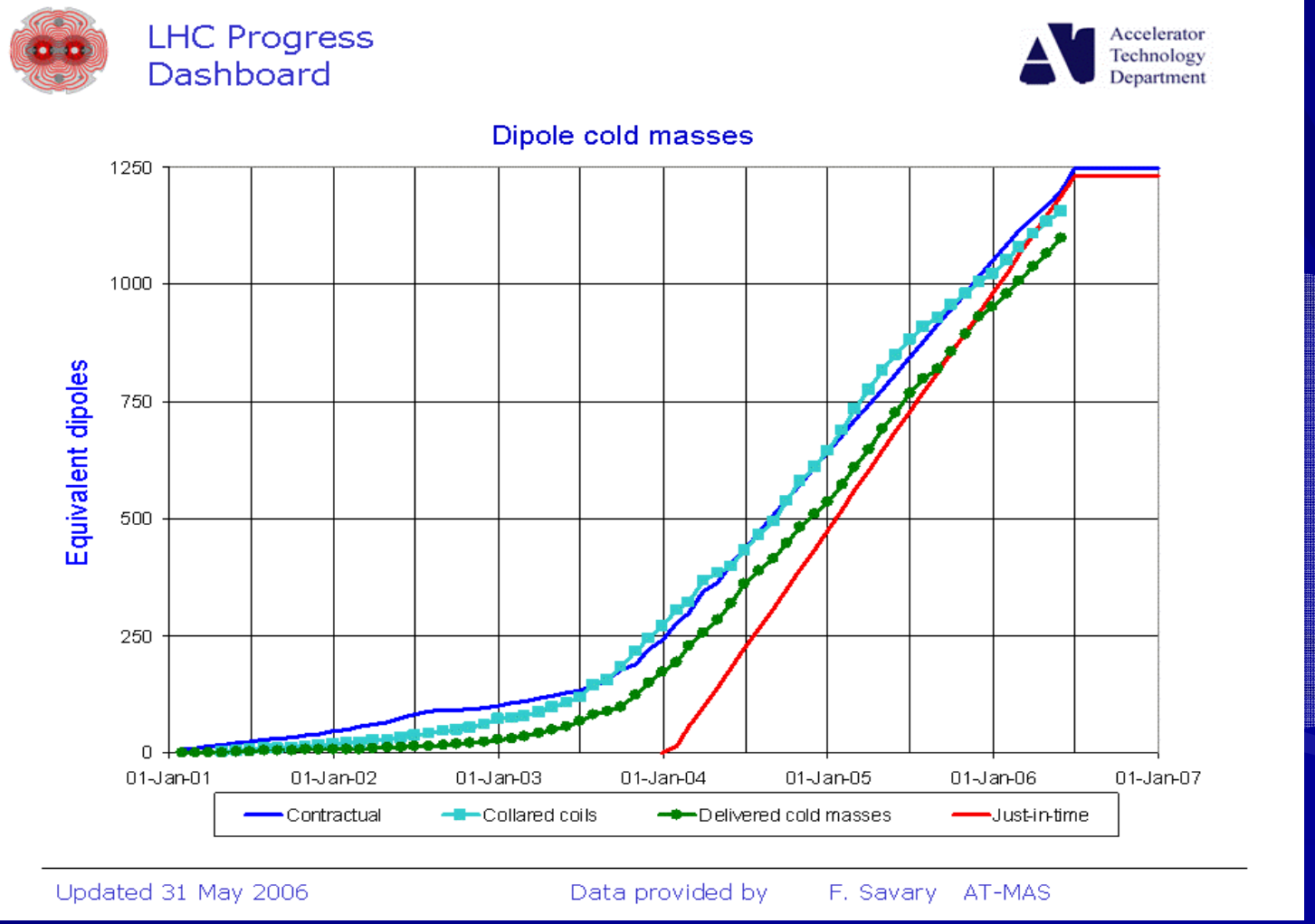
Jos Engelen

July 3, 2006

based on presentations to CERN Council (end of June 2006)
by Lyn Evans and Jos E.
(further input from Peter Jenni, Jim Virdee, Tatsuya Nakada, Juergen Schukraft, Ernst Radermacher, Les Robertson)


MEYER

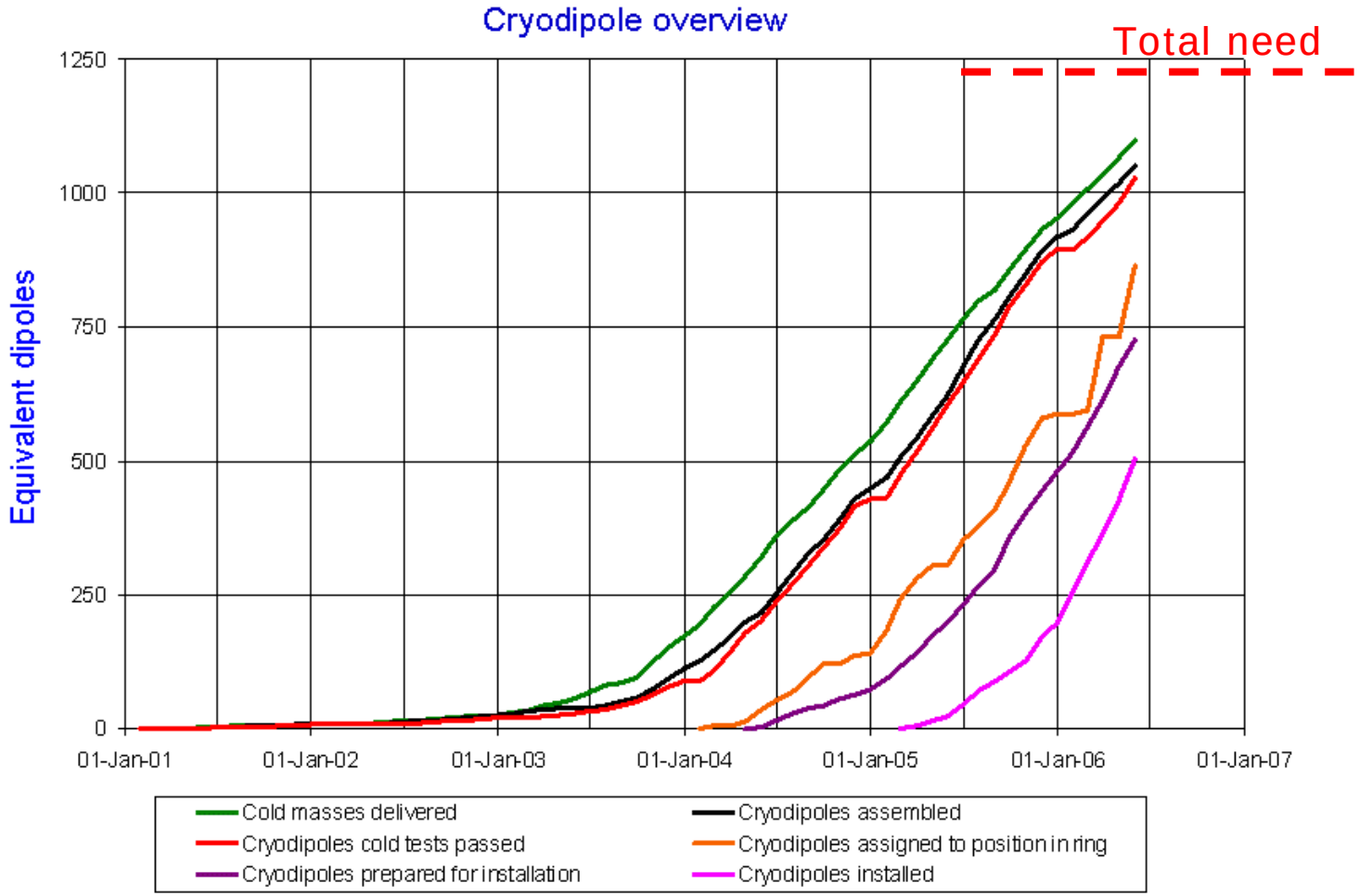
# Dipole cold masses



# Cryodipole Overview

LHC Progress Dashboard

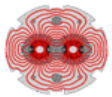
Accelerator Technology Department




Updated 31 May 2006

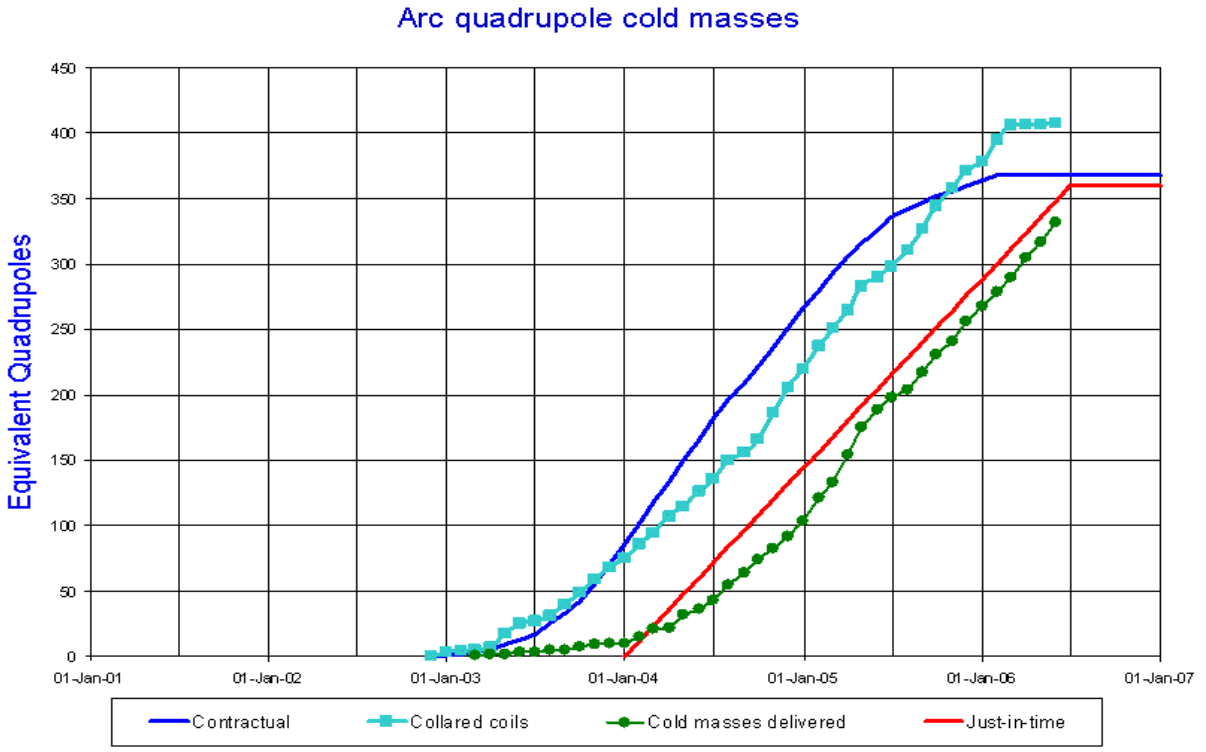
Data provided by D. Tommasini AT-MAS, L. Bottura AT-MTM

# Arc quadrupole cold masses

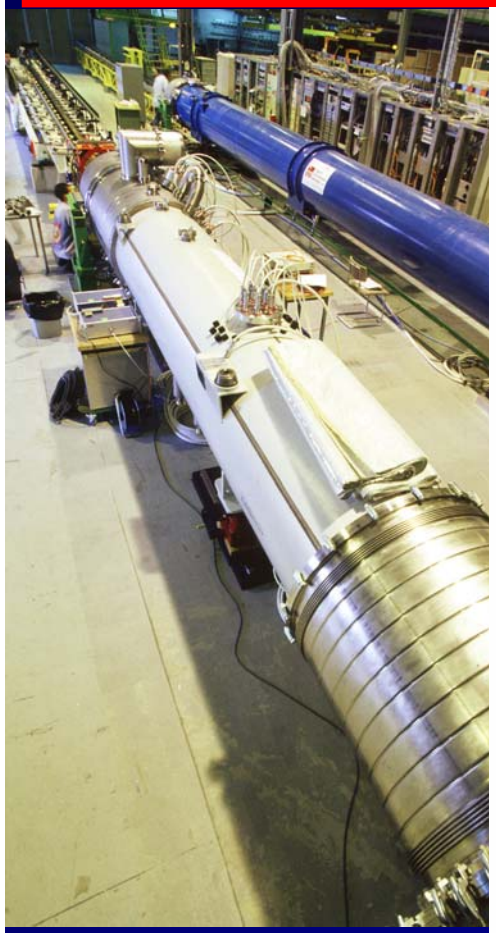


LHC Progress Dashboard

Accelerator Technology Department



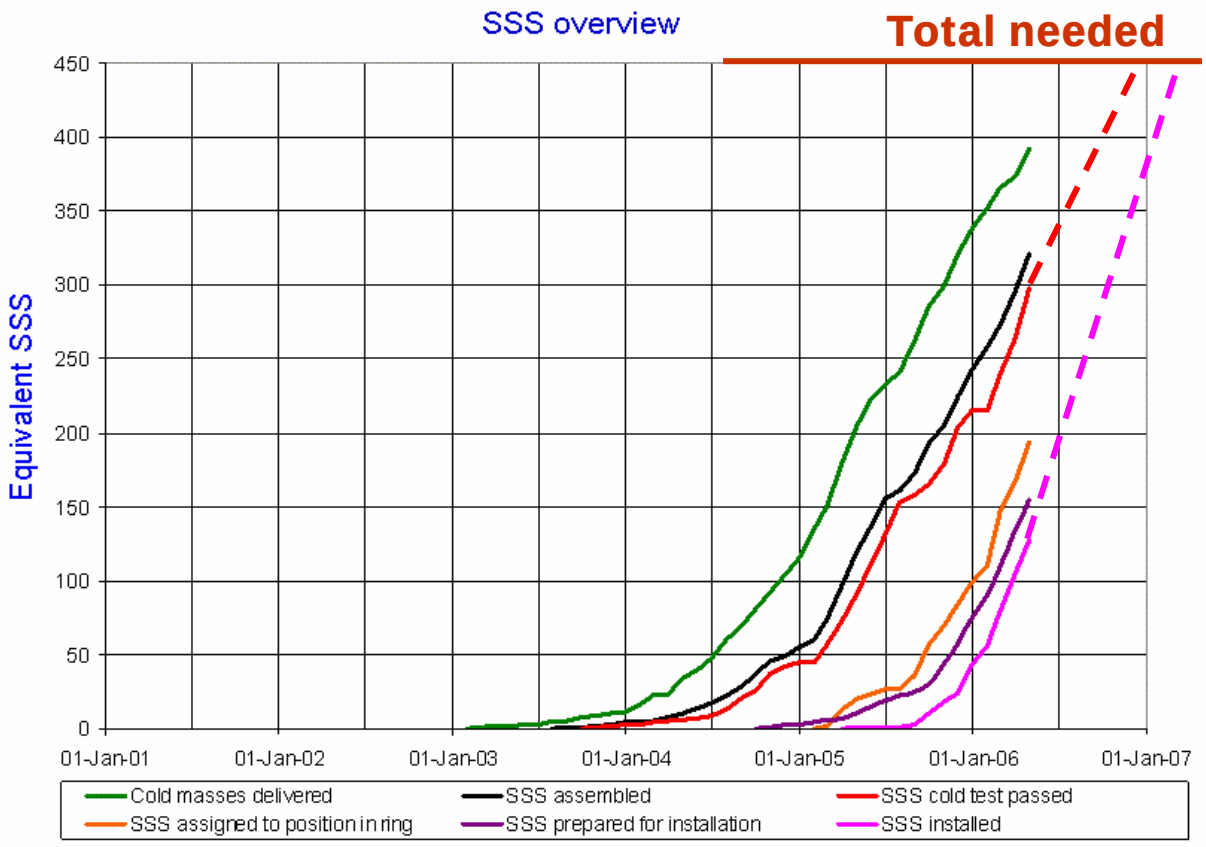

Updated 31 May 2006 Data provided by T. Tortschanoff AT-MAS



**SSS:**
**6–12 m, 8–19 t**
**SC: Nb-Ti**
**Gradient Quad : 223 T/m**

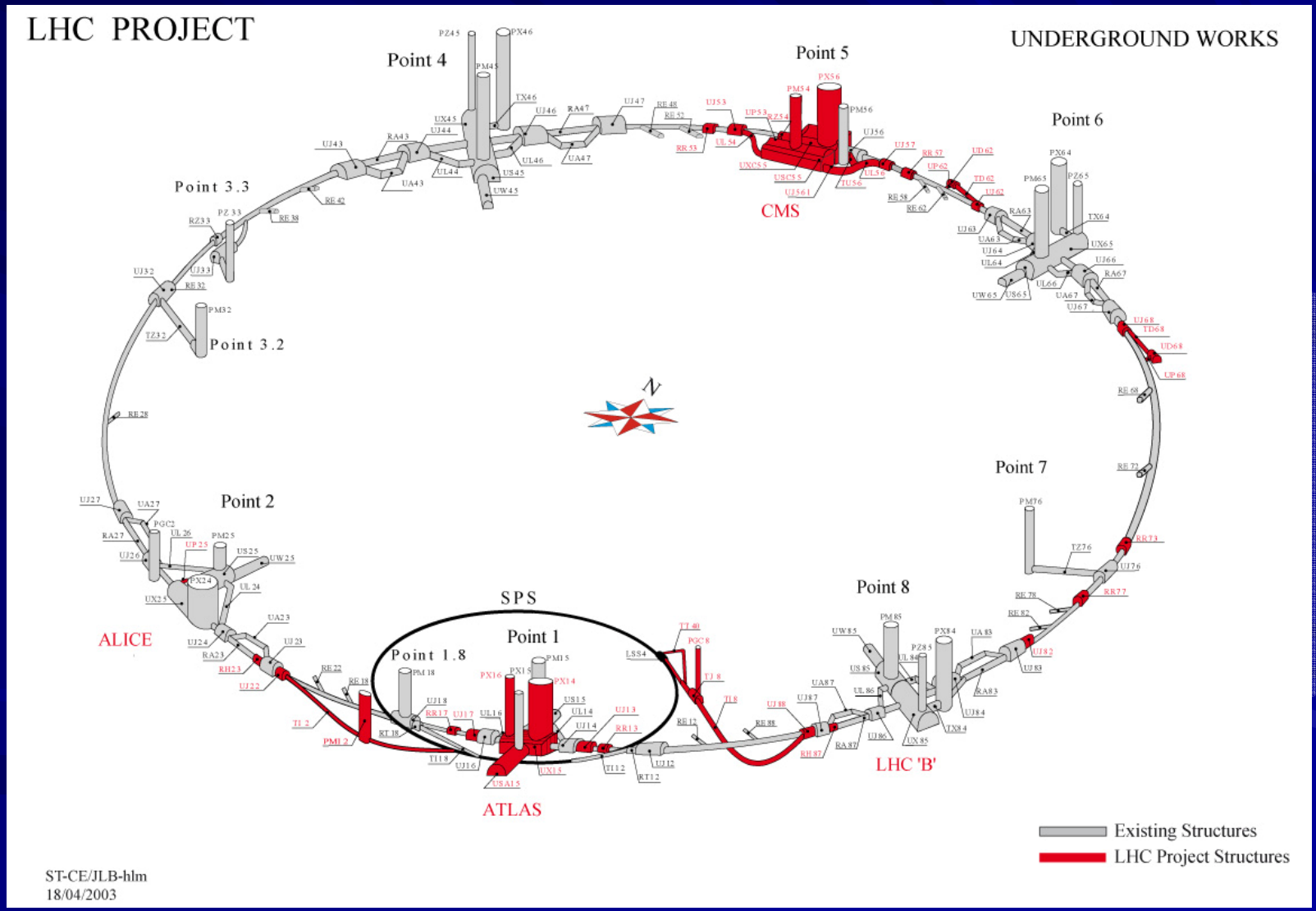
LHC Progress Dashboard

Accelerator Technology Department




Updated 30 Apr 2006

Data provided by M. Modena AT-MAS, L. Bottura AT-MTM


LHC PROJECT
UNDERGROUND WORKS
Point 4
Point 5
Point 6
Point 3.3
Point 3.2
Point 2
Point 7
Point 8
Point 1
Point 1.8
SPS
CMS
ALICE
ATLAS
LHC 'B'
N
ST-CE/JLB-hlm
18/04/2003
Existing Structures
LHC Project Structures

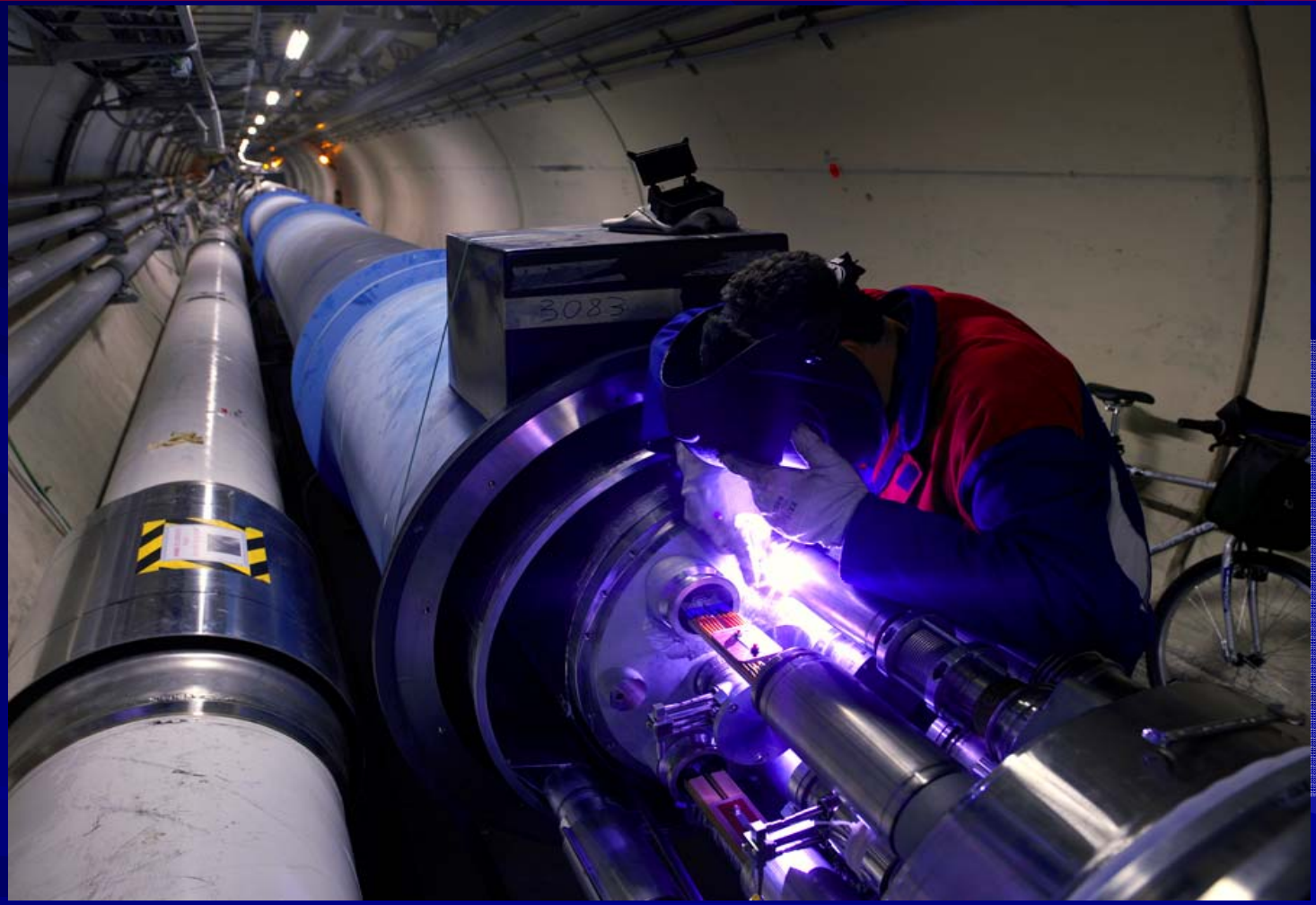
# Reporting - Installed magnets in LHC

| | R | | | | | L | | | | | Total | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cryo-magnets | | | DFB + others | Total | Cryo-magnets | | | DFB + others | Total | Cryo-magnets | | | DFB + others | Total |
| | Dipoles | SSS | LSS | | | Dipoles | SSS | LSS | | | Dipoles | SSS | LSS | | |
| Secteur 1-2 | | | | | **0** | | | | | **0** | 0 | 0 | 0 | 0 | **0** |
| Secteur 2-3 | | | | | **0** | | | | | **0** | 0 | 0 | 0 | 0 | **0** |
| Secteur 3-4 | 16 | 10 | | | **26** | 76 | 11 | | | **87** | 92 | 21 | 0 | 0 | **113** |
| Secteur 4-5 | 76 | 21 | | | **97** | 75 | 24 | | | **99** | 151 | 45 | 0 | 0 | **196** |
| Secteur 5-6 | | | | | **0** | 4 | 3 | | | **7** | 4 | 3 | 0 | 0 | **7** |
| Secteur 6-7 | | | | | **0** | | | | | **0** | 0 | 0 | 0 | 0 | **0** |
| Secteur 7-8 | 77 | 24 | | 1 | **102** | 77 | 27 | 8 | 4 | **116** | 154 | 51 | 8 | 5 | **218** |
| Secteur 8-1 | 77 | 26 | 6 | 3 | **112** | 77 | 23 | 4 | 1 | **105** | 154 | 49 | 10 | 4 | **217** |

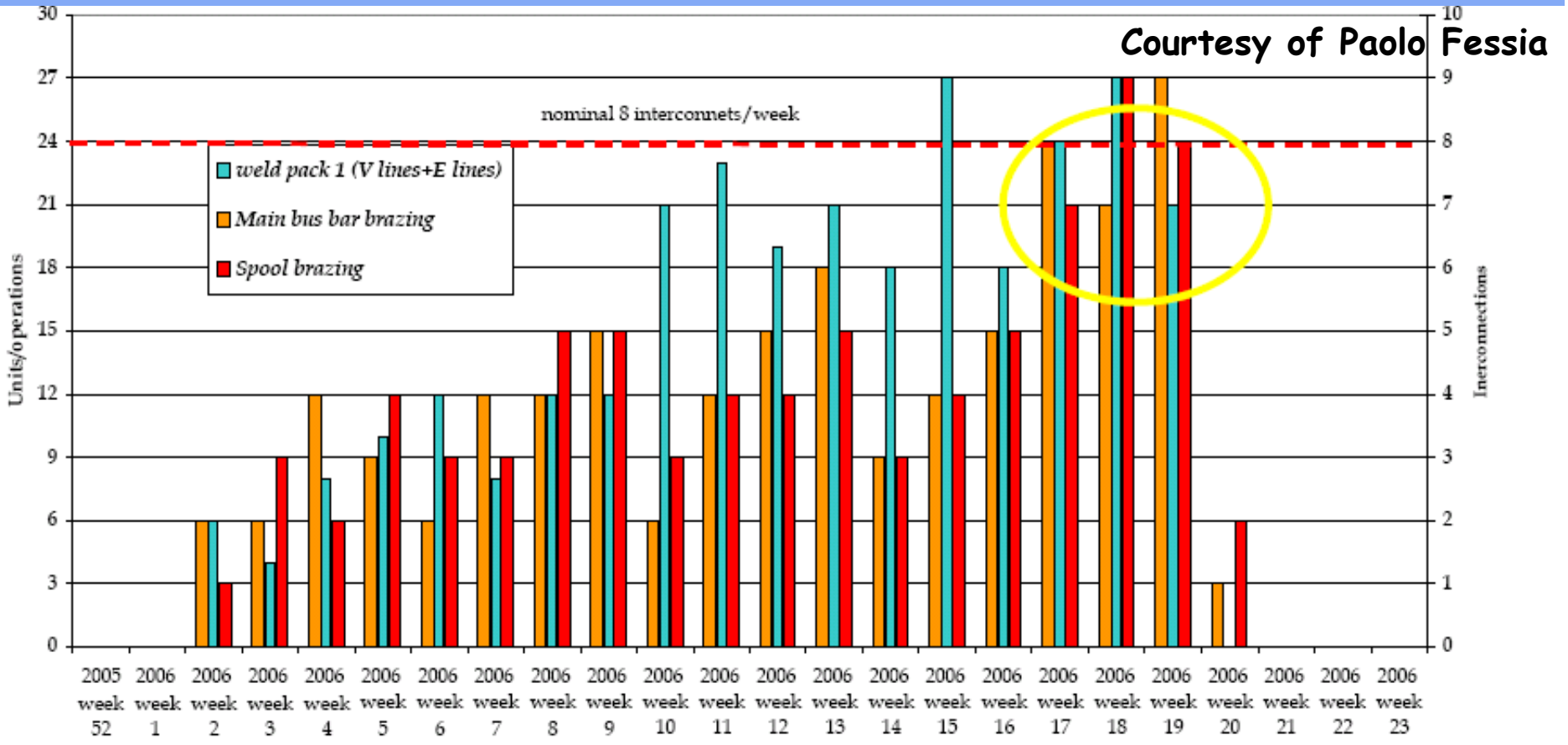
| | | | | | |
|---|---|---|---|---|---|
| LHC | 555 | 169 | 18 | 9 | **751** |
| Cryo-magnets | | | **742** | | |

Prepared by Pascal Ponsot TS-IC 14/06/2006 11:52

# Tunnel interconnect



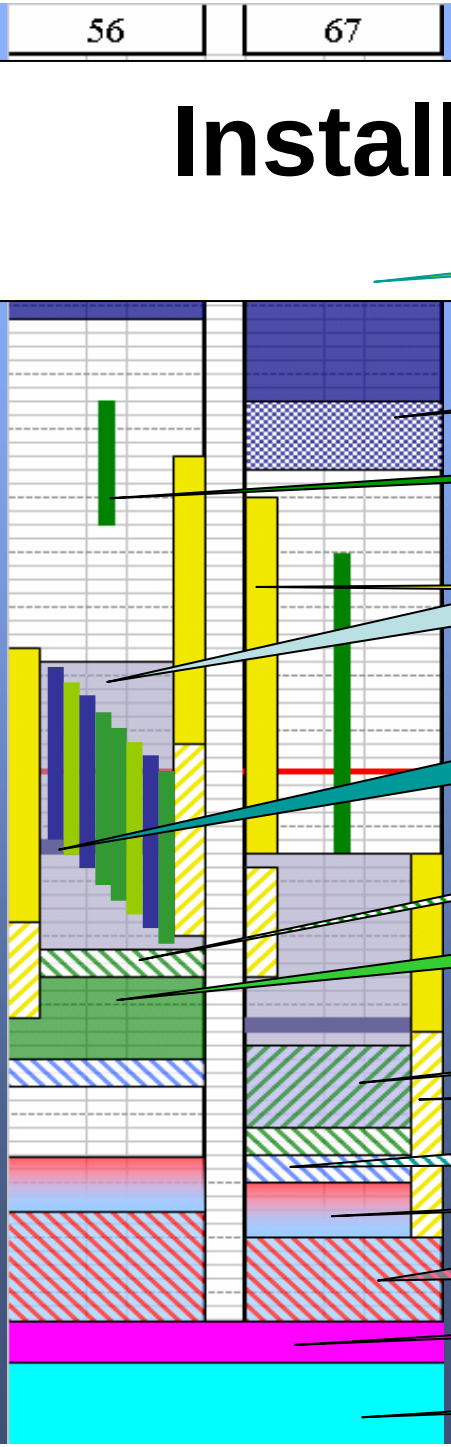
# Magnet interconnection Learning curve




## Interconnect rate of one team in sector 4-5

Since mid-May: 2 teams in 7-8 (6 days/wk) and 1 team in 8-1 (4 days/wk)

# Installation activities in a sector




QRL installation

QRL consolidation after pressure test

Cryo-magnet transport

Interconnection phase 1

LSS installation

End of 1st interconnect activity

Pressure test

Cryostat closure – Interconnect consolidation

Insulation // Interconnect phase 1

Beam pipes & bake-out

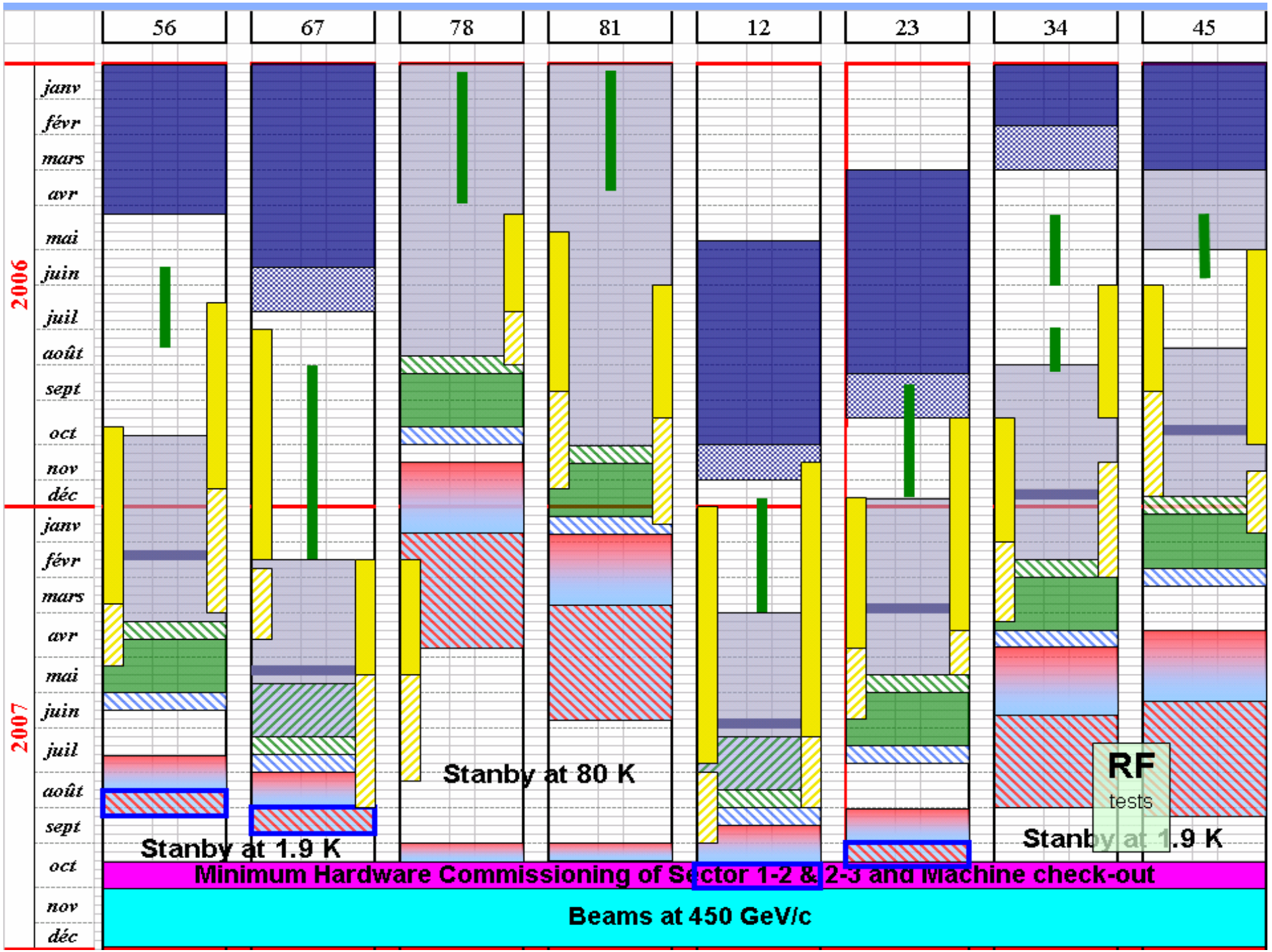
ELQA at warm

Cool-down

Power tests

Machine check-out

Beam at 450 GeV/C


56
67
78
81
12
23
34
45
2006
janv
févr
mars
avr
mai
juin
juil
août
sept
oct
nov
déc
2007
janv
févr
mars
avr
mai
juin
juil
août
sept
oct
nov
déc
Stanby at 1.9 K
Stanby at 80 K
RF
tests
Stanby at 1.9 K
Minimum Hardware Commissioning of Sector 1-2 & 2-3 and Machine check-out
Beams at 450 GeV/c

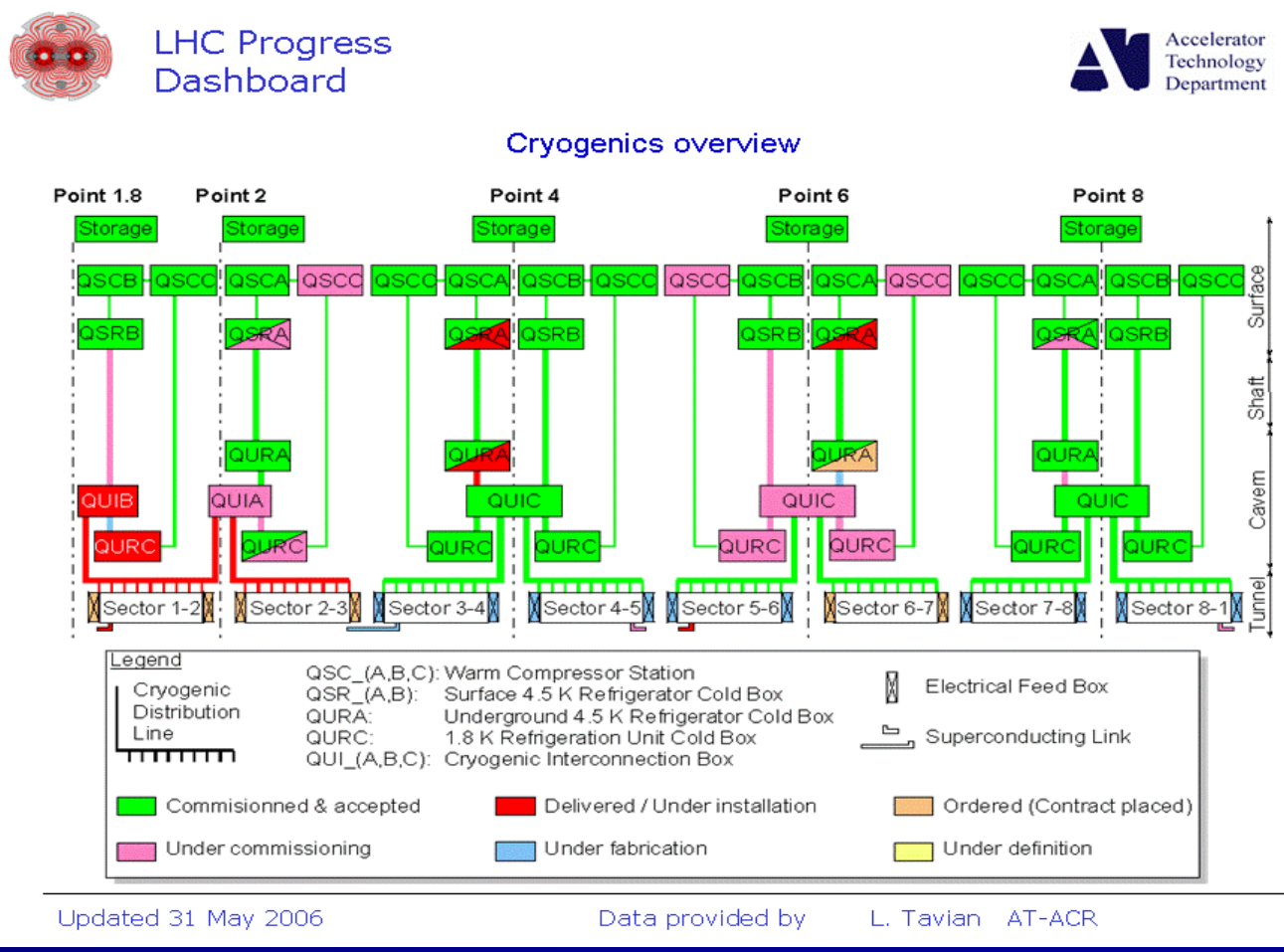
# Milestones

| | |
|---|---|
| Last magnet delivered | October 2006 |
| Last magnet tested | December 2006 |
| Last magnet installed | March 2007 |
| Machine closed | August 2007 |
| First collisions | November 2007 |

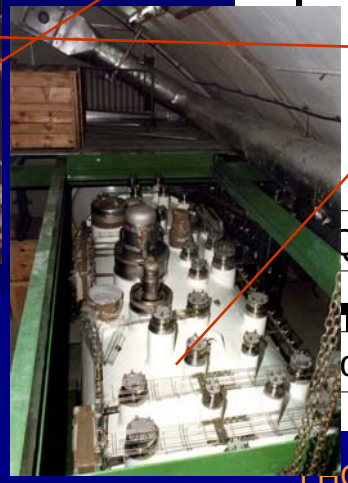
# Machine commissioning

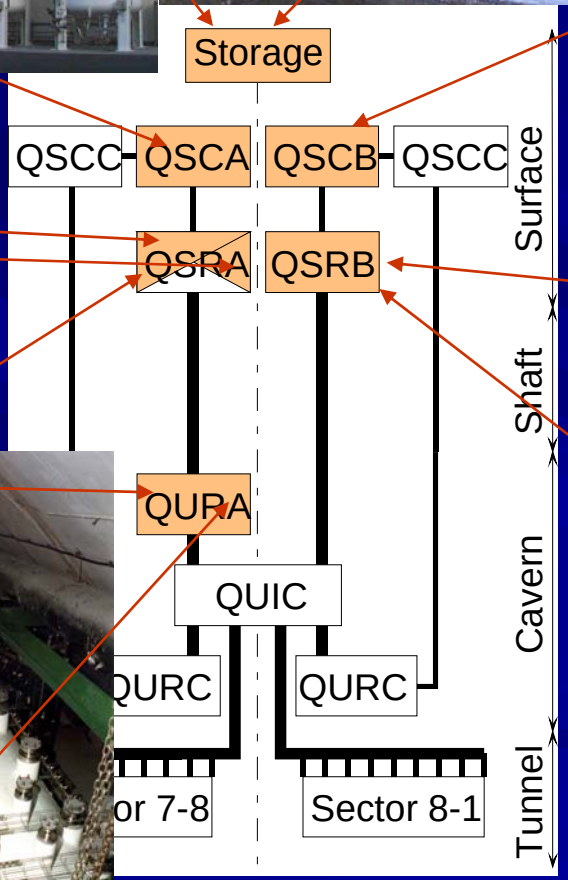
- Sectors 7-8 and 8-1 will be fully commissioned up to 7 TeV in 2006-2007. If we continue to commission the other sectors up to 7 TeV, we will not get circulating beam in 2007.
- The other sectors will be commissioned up to the field needed for de-Gaussing.
- Initial operation will be at 900 GeV (CM) with a static machine (no ramp, no squeeze) to debug machine and detectors.
- Full commissioning up to7 TeV will be done in the winter 2008 shutdown

# Cryogenics overview



# Infrastructure and refrigerators at 4.5 K

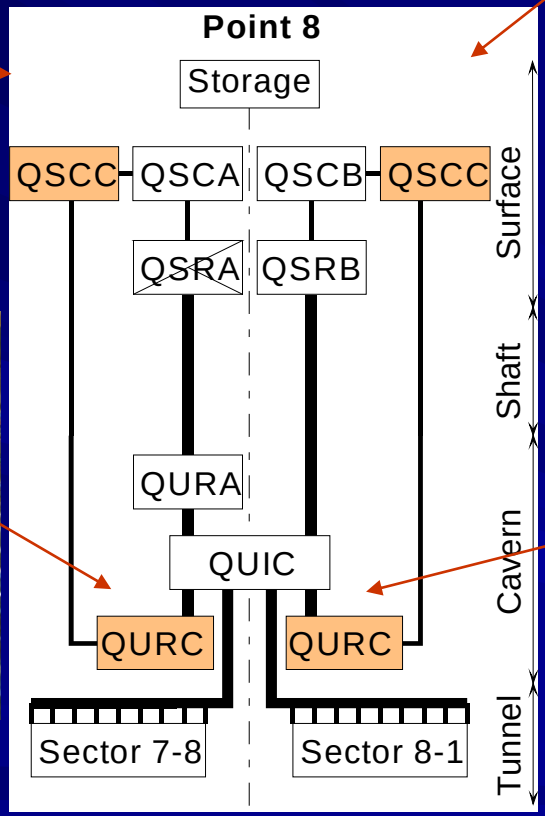




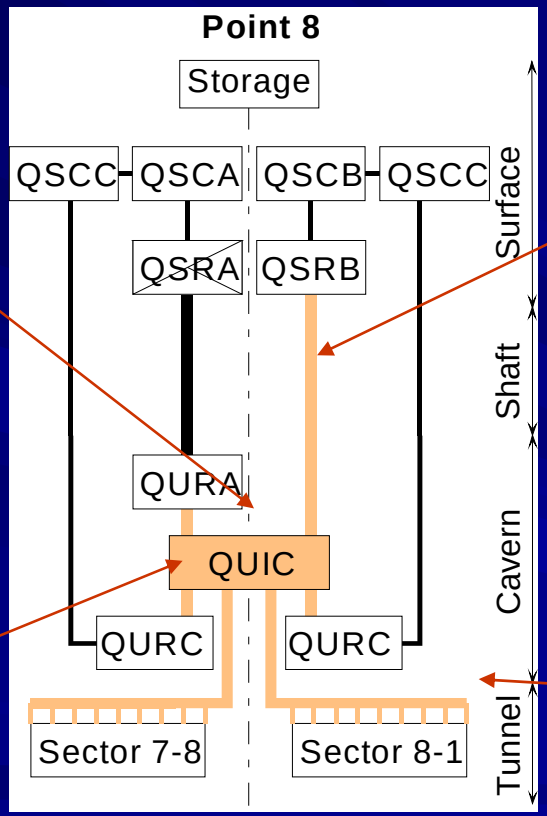
# Refrigeration units at 1.8 K

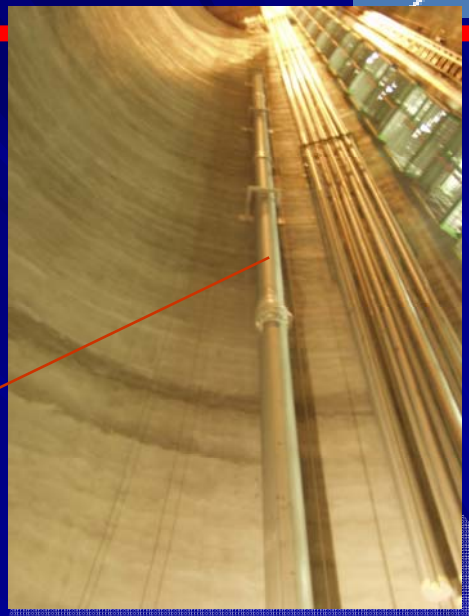
Air Liquide

IHI Linde




# Cryogenic distribution

# Distribution Feed Box

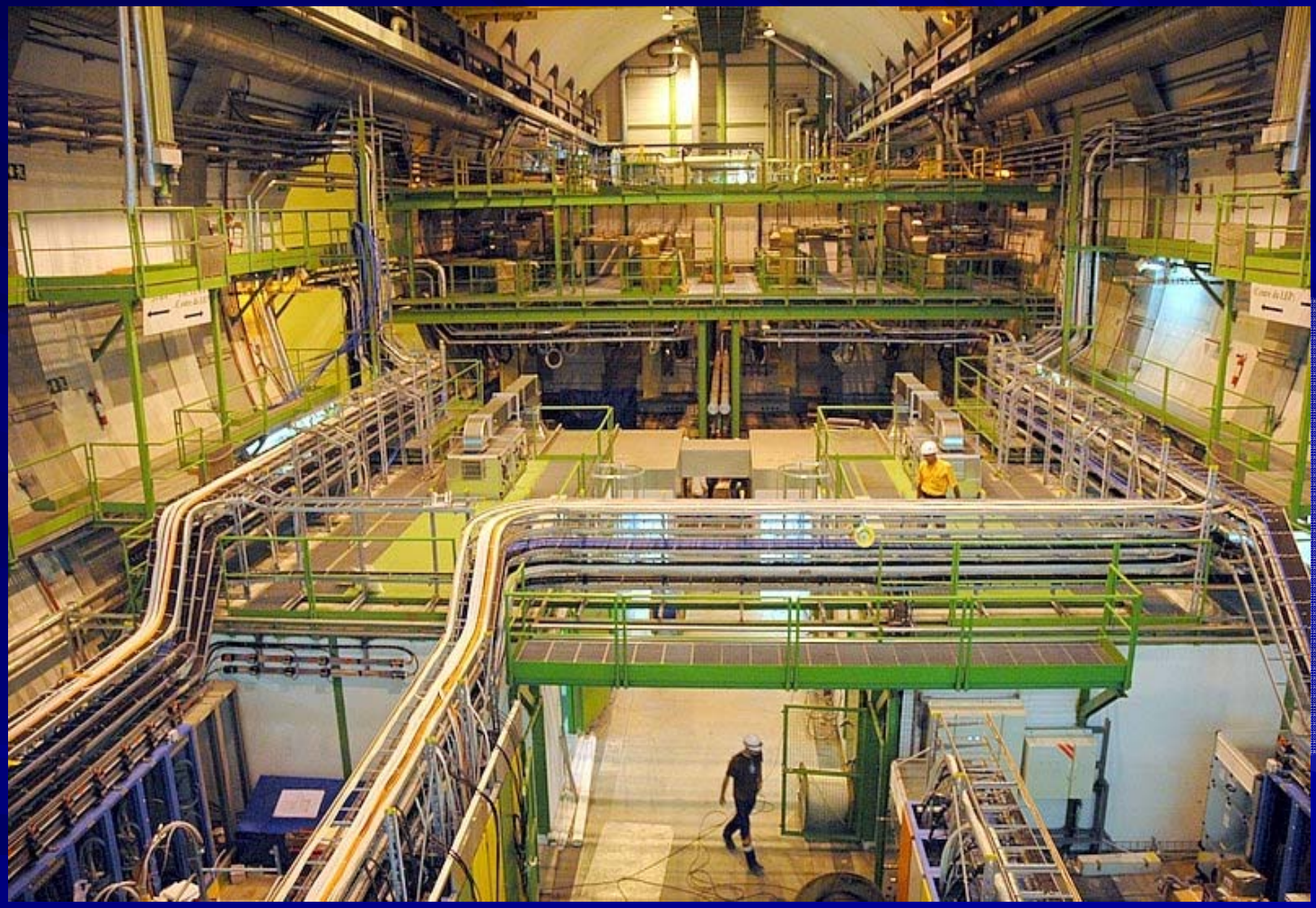
# Injection line TI8

# Injection Septum Magnets

# Kicker team

# Injection septum magnets

# RF infrastructure at Point 4



# Machine tunnel in RF region

# Cavity preparation

# 400 MHz Klystron

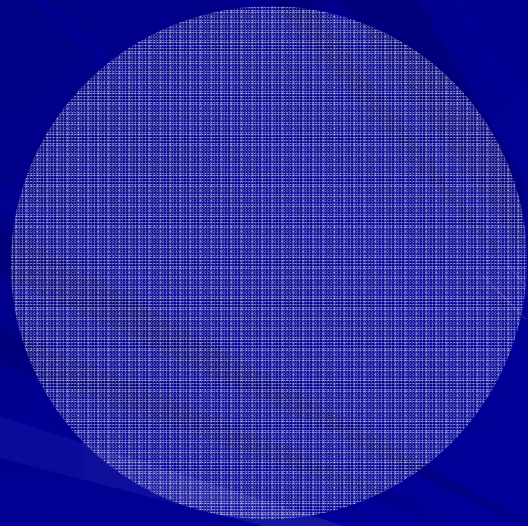
# Conclusions

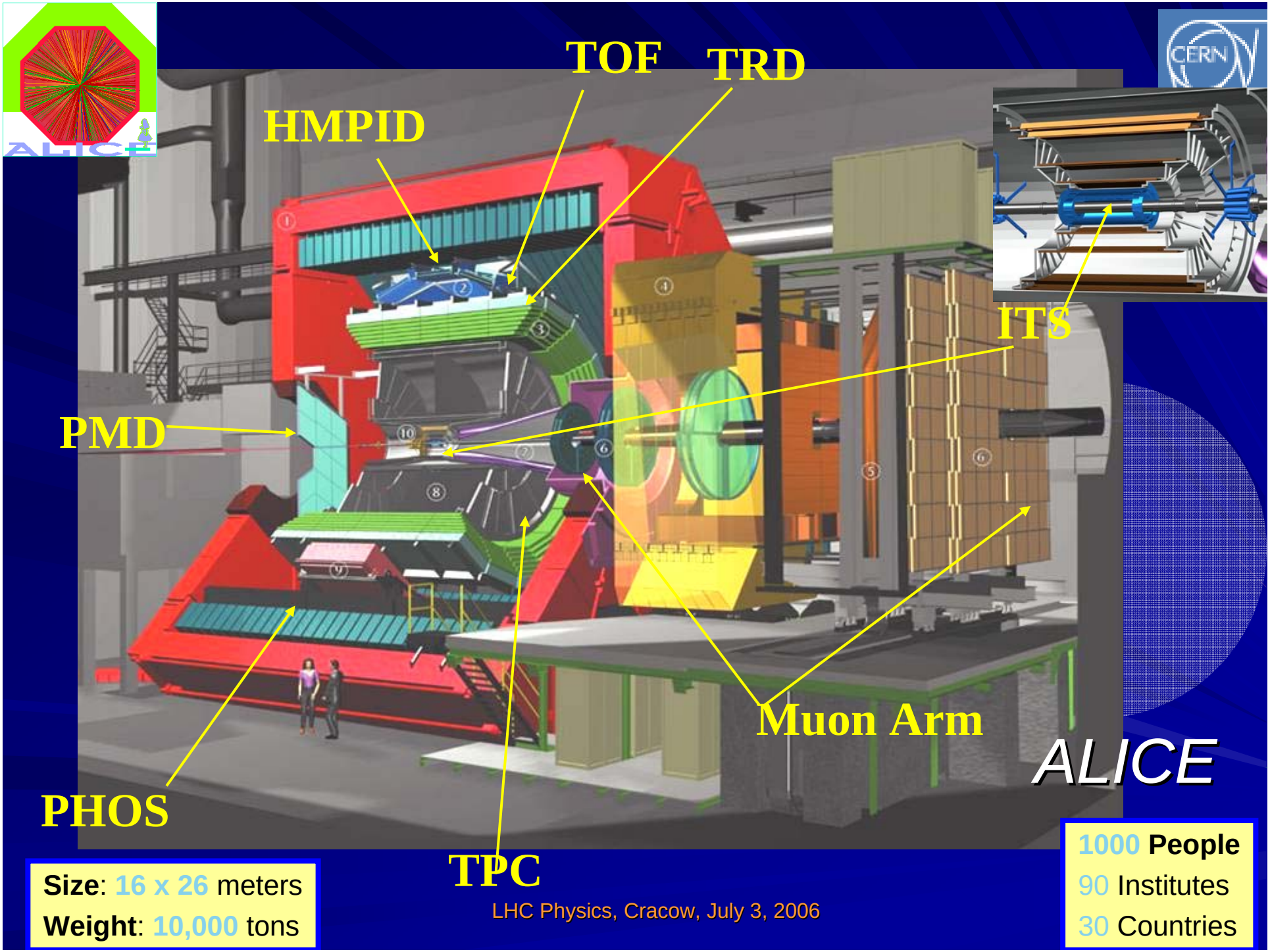
- We now have enough information to produce a consolidated plan for commissioning.

- Three quarters of the machine has been liberated for magnet installation and interconnect work is proceeding in 2 octants in parallel. Magnet installation is now steady at 25/wk . Installation will finish March 2007. The machine will be closed in August 2007.

- Every effort is being made to establish colliding beams before the end of 2007 at reduced energy. The full commissioning up to 7 TeV will be done during the 2008 winter shutdown ready for a Physics run at full energy in spring 2008.

# The Experiments



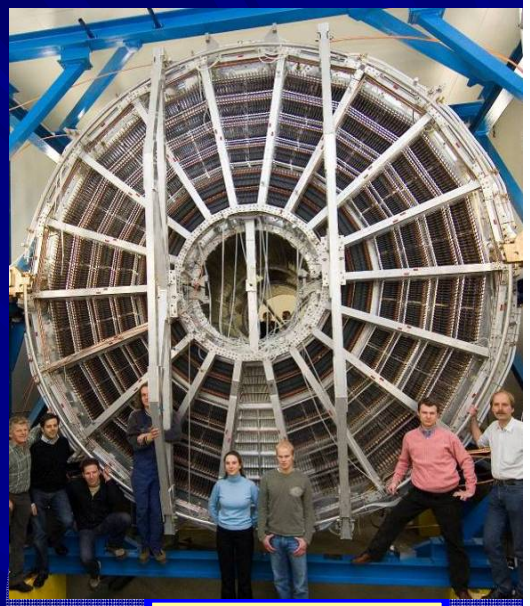

TOF
TRD
HMPID
ITS
PMD
Muon Arm
PHOS
TPC
ALICE
Size: 16 x 26 meters
Weight: 10,000 tons
1000 People
90 Institutes
30 Countries
LHC Physics, Cracow, July 3, 2006

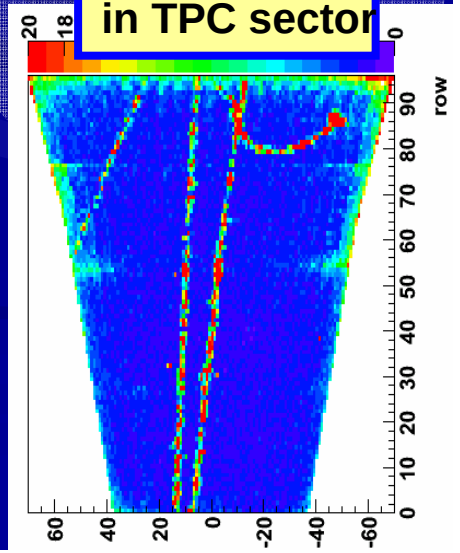
# Alice Status

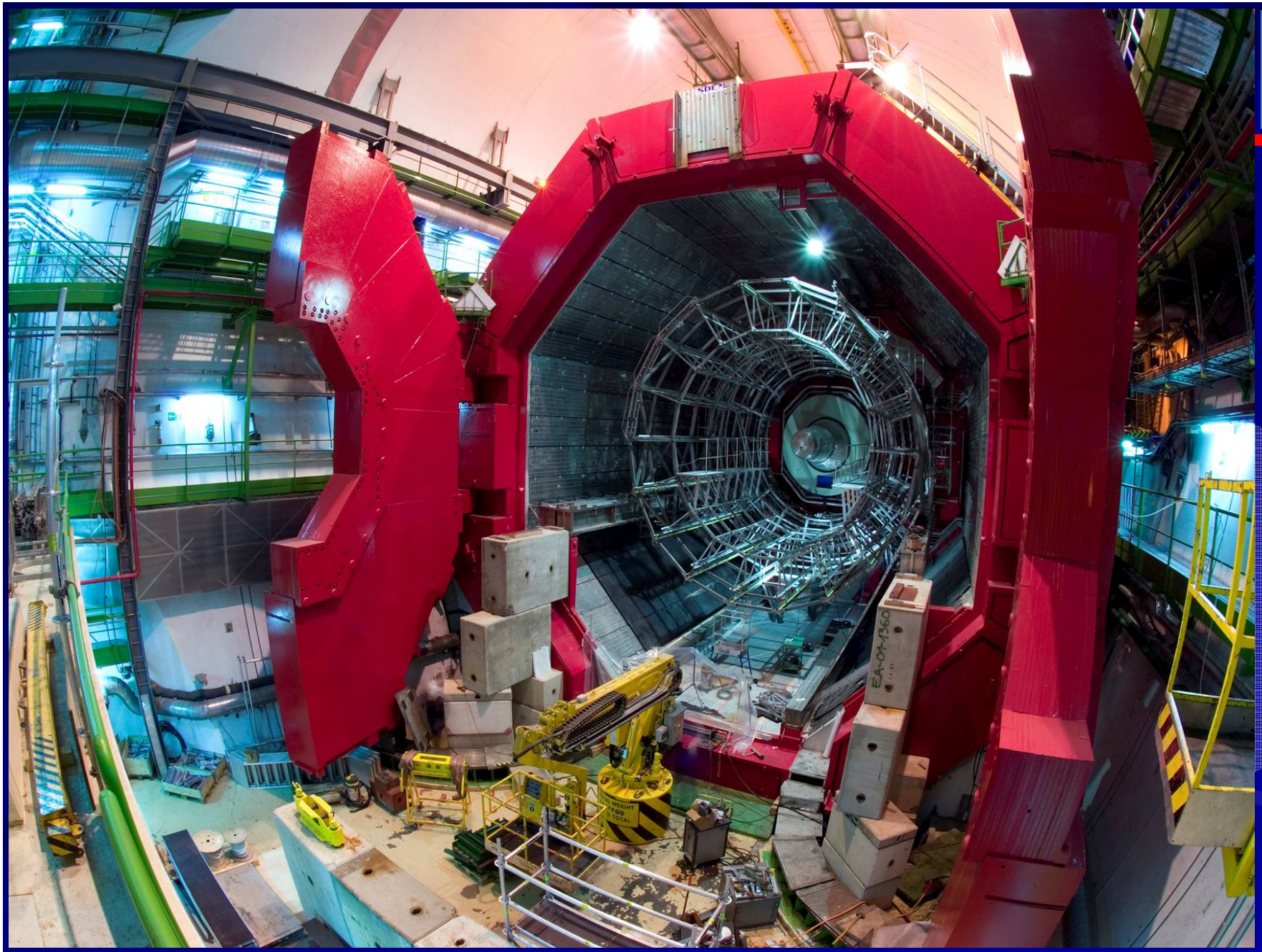
- Infrastructure (large structures, μ-absorbers, magnets,..)
  - installed and commissioned

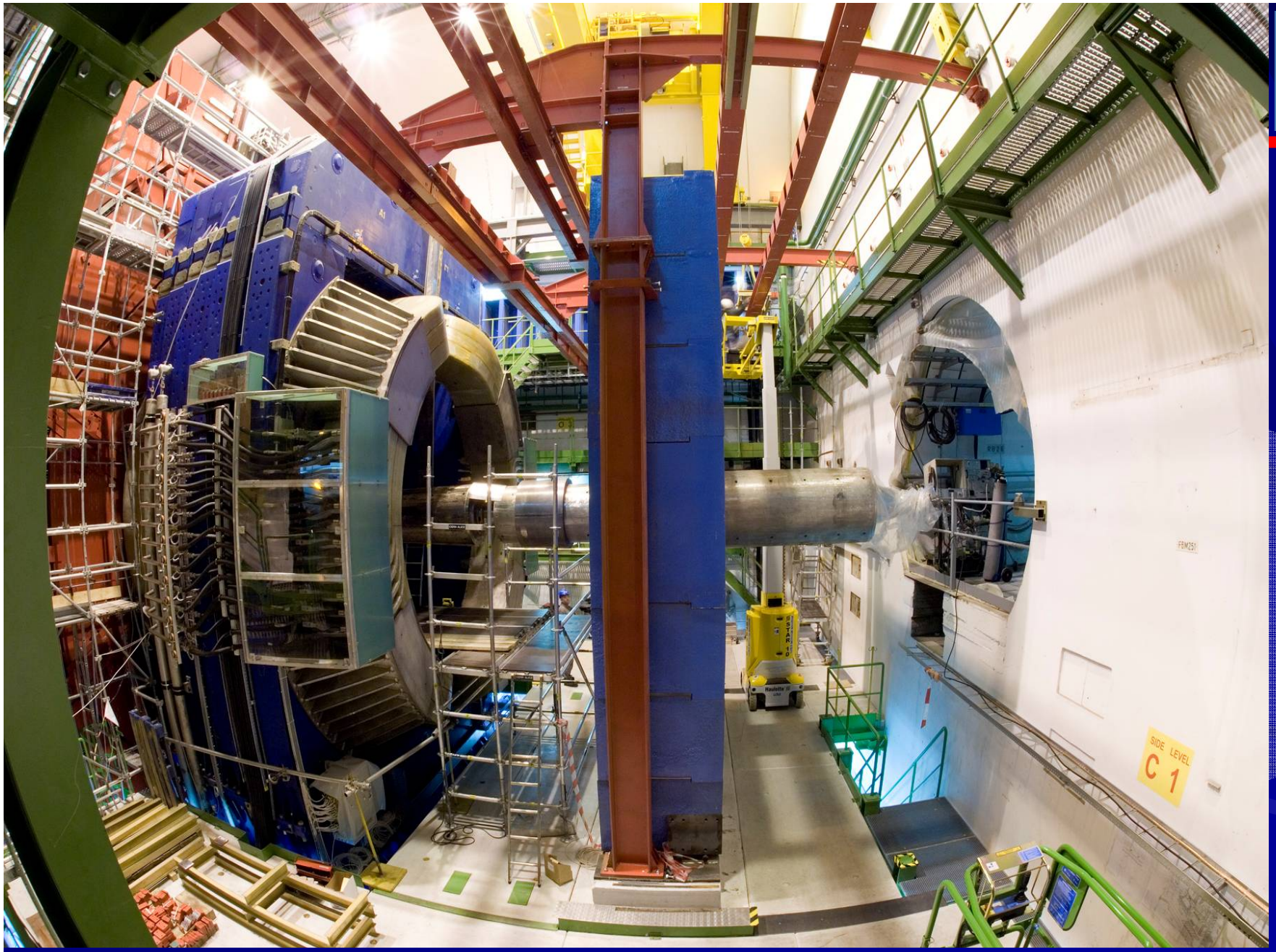
- Detector Construction
  - **completed:** TPC, HMPID, PHOS, ZDC, Muon trigger, cosmic trigger array
  - **nearing completion:** Muon tracking, TOF, TRD, ITS, forward (V0, T0, PMD, FMD)
    - **critical path: Silicon Vertex Detector (ITS)**

- Detector Installation
  - **precomissioning** of all detectors **on surface,** started
  - **Installation:**
    - **Muon Spectrometer:** June 06 to March 07
    - **Central Barrel:** Sept. 06 to April 07
  - **Installation after summer 2007**: parts of TRD, TOF, PHOS



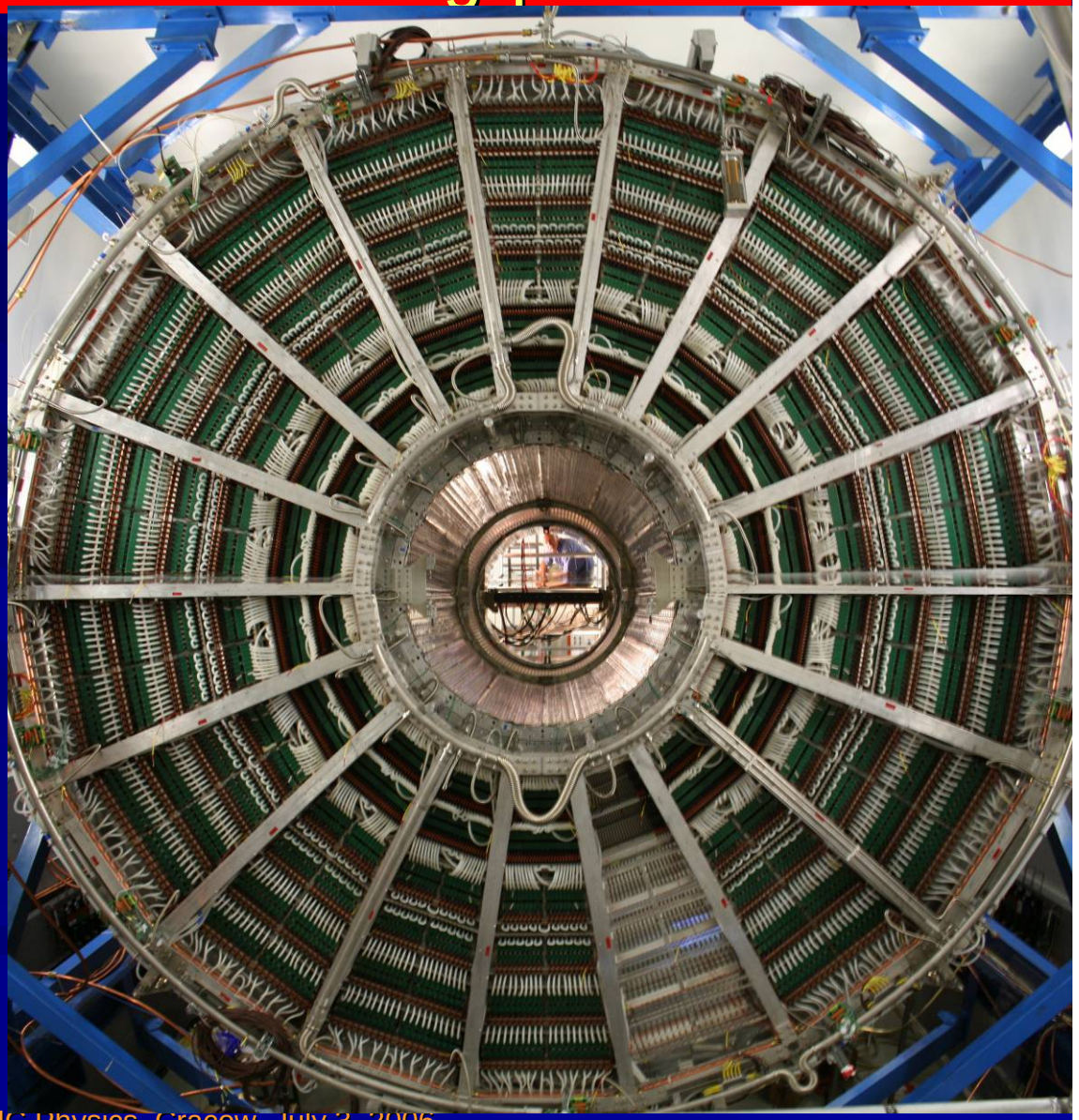





SIDE LEVEL
C 1

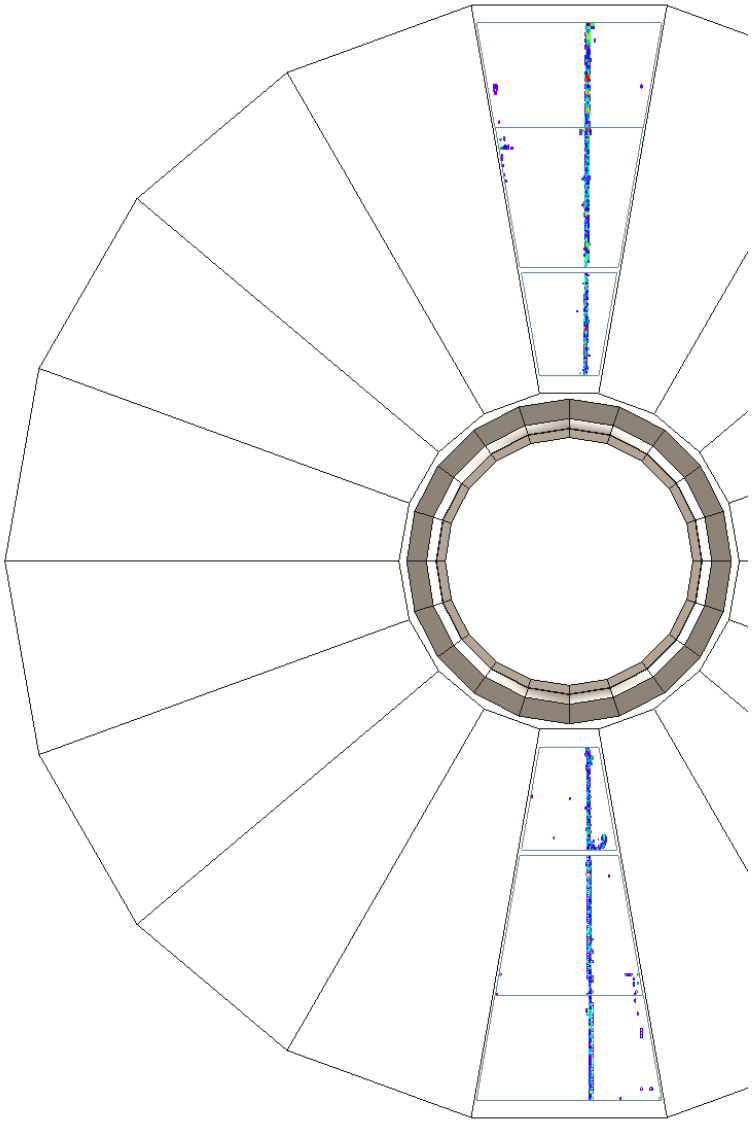
# The ALICE TPC has entered the commissioning phase

- 2006/Q1: Frontend electronics installation
  - 72 readout chambers
  - 4356 FEE cards
  - 557,568 channels
  - up to 1000 time bins each
- Pre-commissioning above ground since May
  - Gas system: 95 $m^3$ $Ne/CO_2/N_2$ (90/10/5), now few ppm $O_2$
  - 2 sectors at a time
  - Full data chain
  - Cosmics tracks
  - Laser tracks
  - Noise $\sigma$ ~ 0.7 ADC cts
- Move to cavern in fall

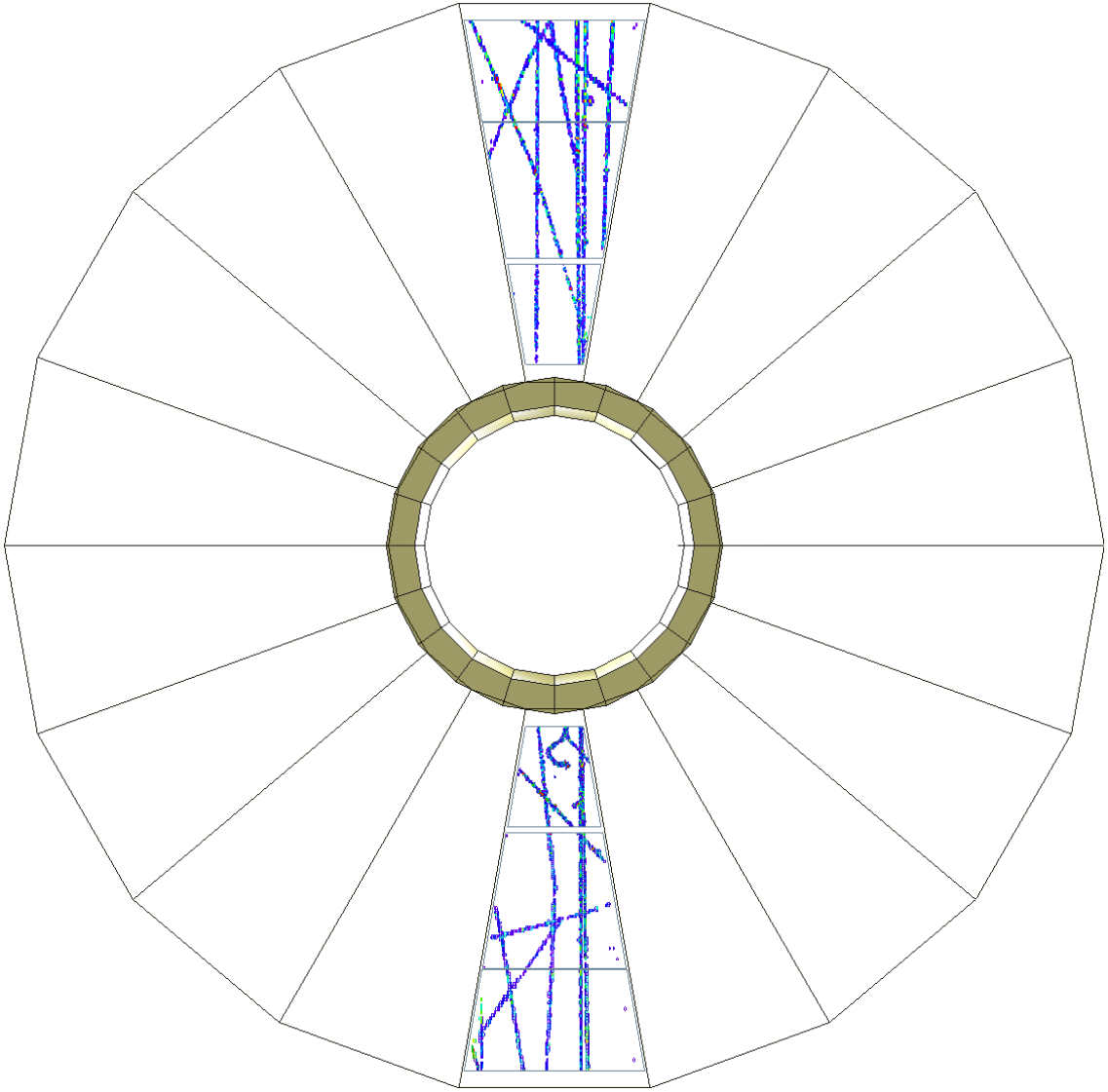


# First tracks in the TPC, projection view

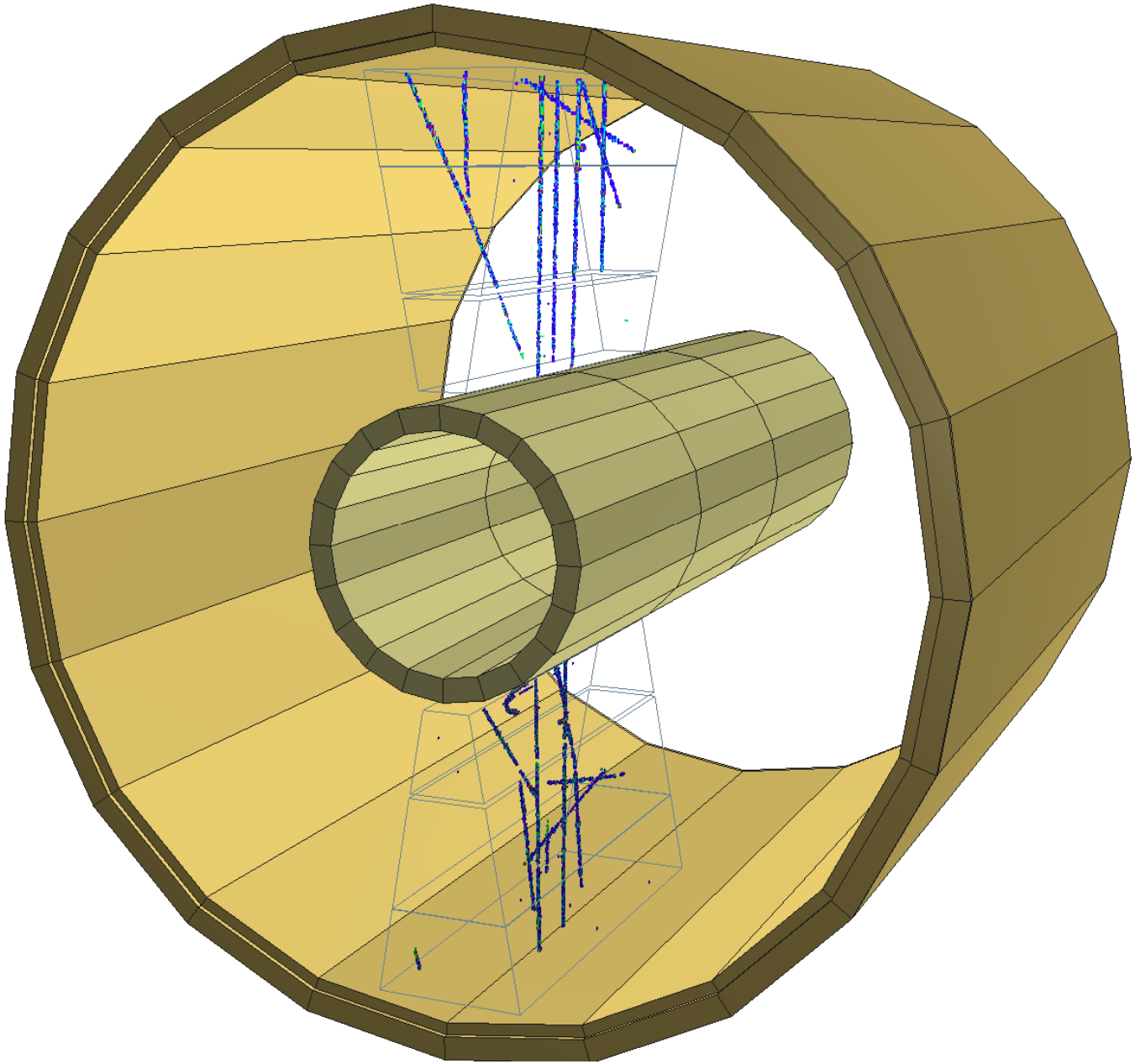
isolated track



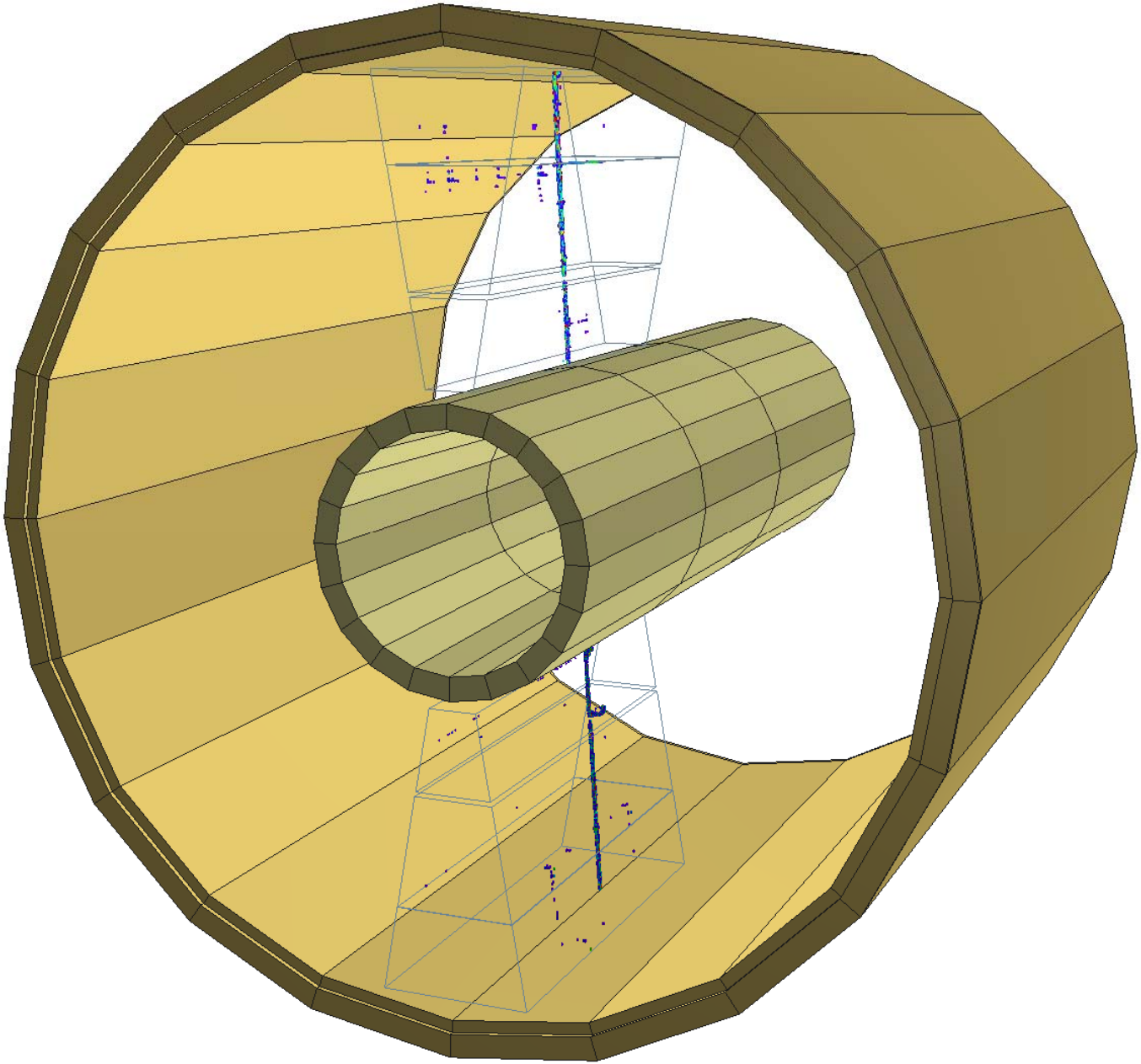
cosmic shower



# 3D view of shower event



# 3D view of single track



# Alice Installation Planning

Phase 2 until mid-Oct. 2006
- install services
- start installation of tracking and trigger chambers for Muon Spectrometer
- PHOS module, 2 TOF modules, TRD module

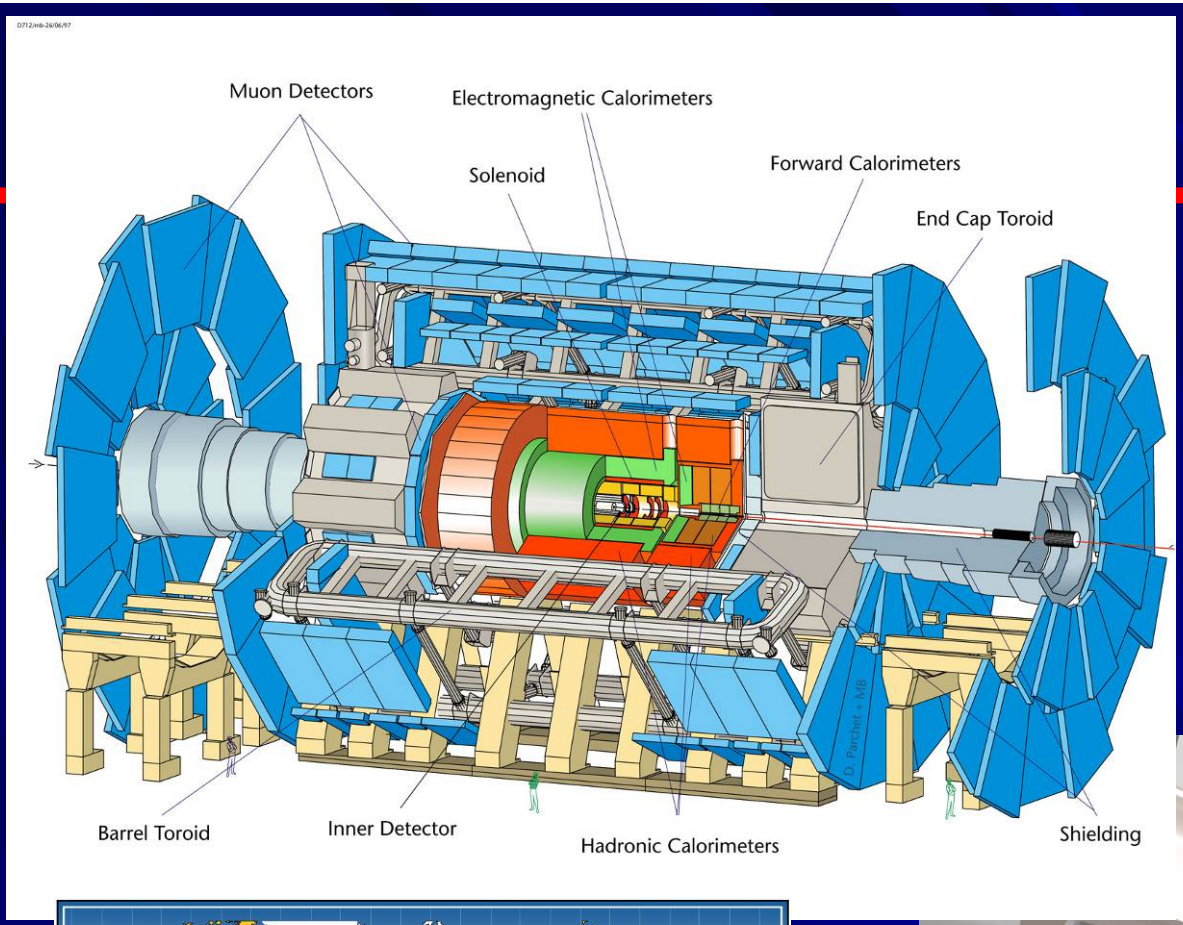
Phase 3 mid-Oct 2006 to mid-April 2007
- TPC, ITS
- Central Be- Vacuum Chamber
- Forward Detectors on C-side

Phase 4 mid-April to mid-July 2007
- 10 TOF modules, 2 TRD Modules,
- Forward detectors on A-side
- complete Muon spectrometer installation

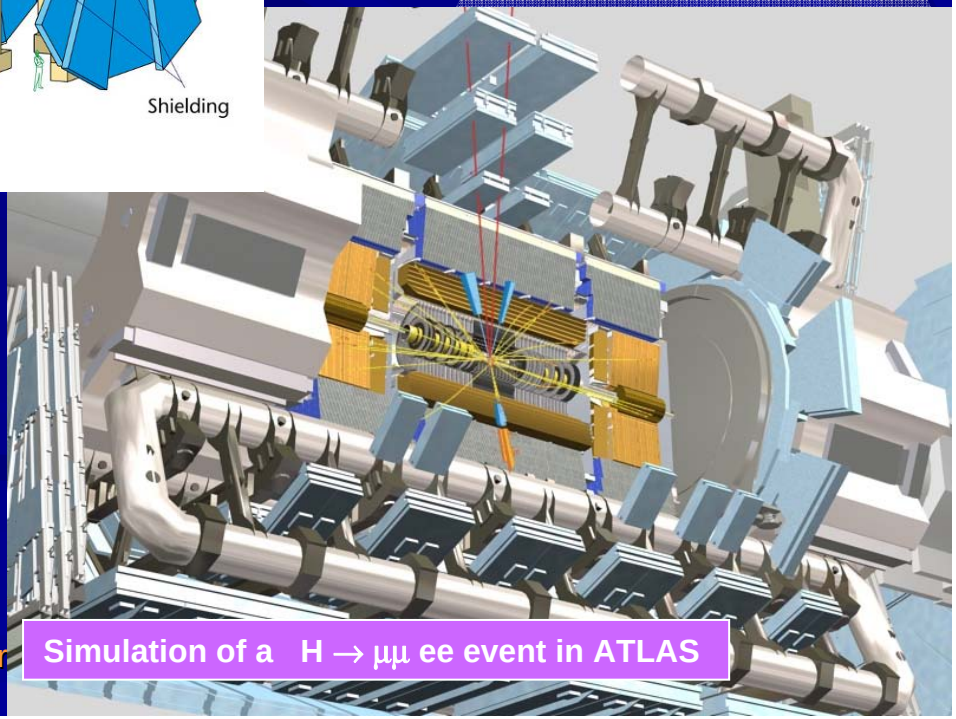
Beam line closed : mid July 2007

Global Commissioning starts
- without magnets: mid-July 2007
- with magnets August 2007

# ATLAS




***Construction status: on track for collisions towards the end of 2007***

**Simulation of a $H \rightarrow \mu\mu$ ee event in ATLAS**

# Inner Detector

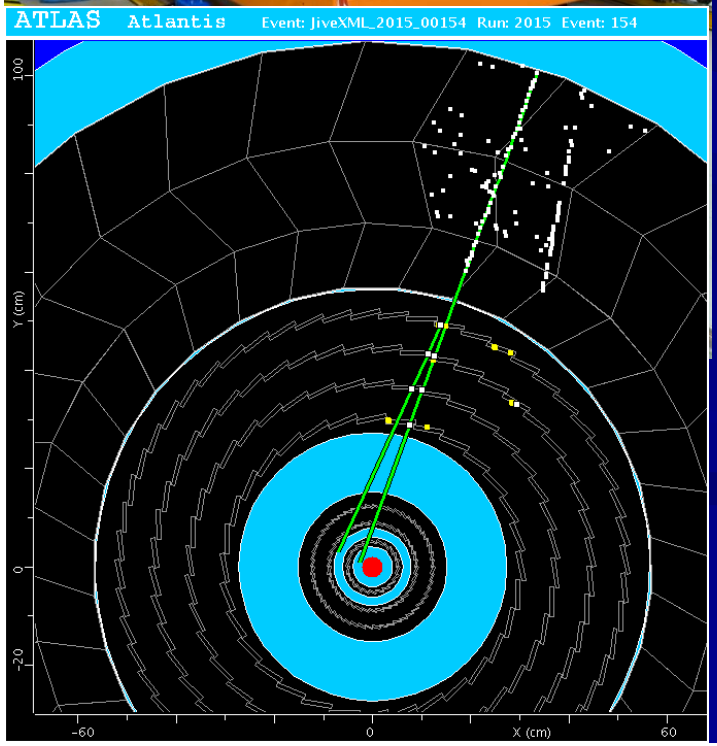
**Pixel detector: recovery from cooling pipe leaks in the barrel proceeding according to schedule, but a new problem is encountered with faulty low-mass cables for the barrel**

**Silicon tracker (SCT): full system preassembled**

**Transition Radiation Tracker (TRT): services Integration on fully preassembled system is being finalized**

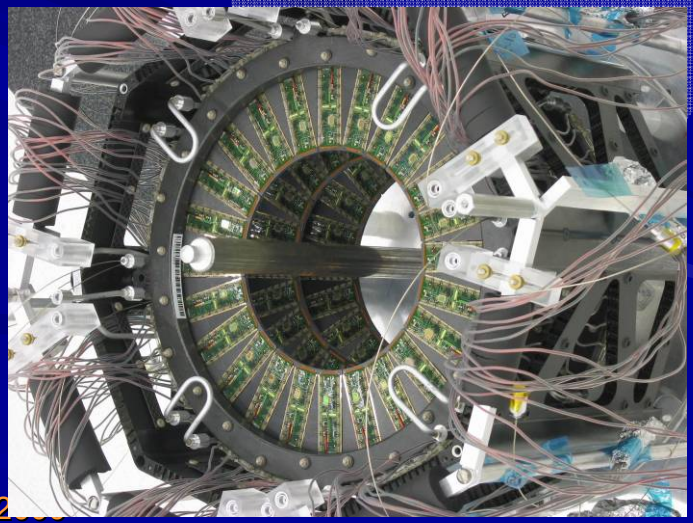
**→ Installation of the complete system on time for August 07, but with schedule risks for the Pixels**

**Complete, assembled barrel TRT and SCT**




**Cosmic rays recorded in barrel TRT and SCT in the surface building clean room SR1**

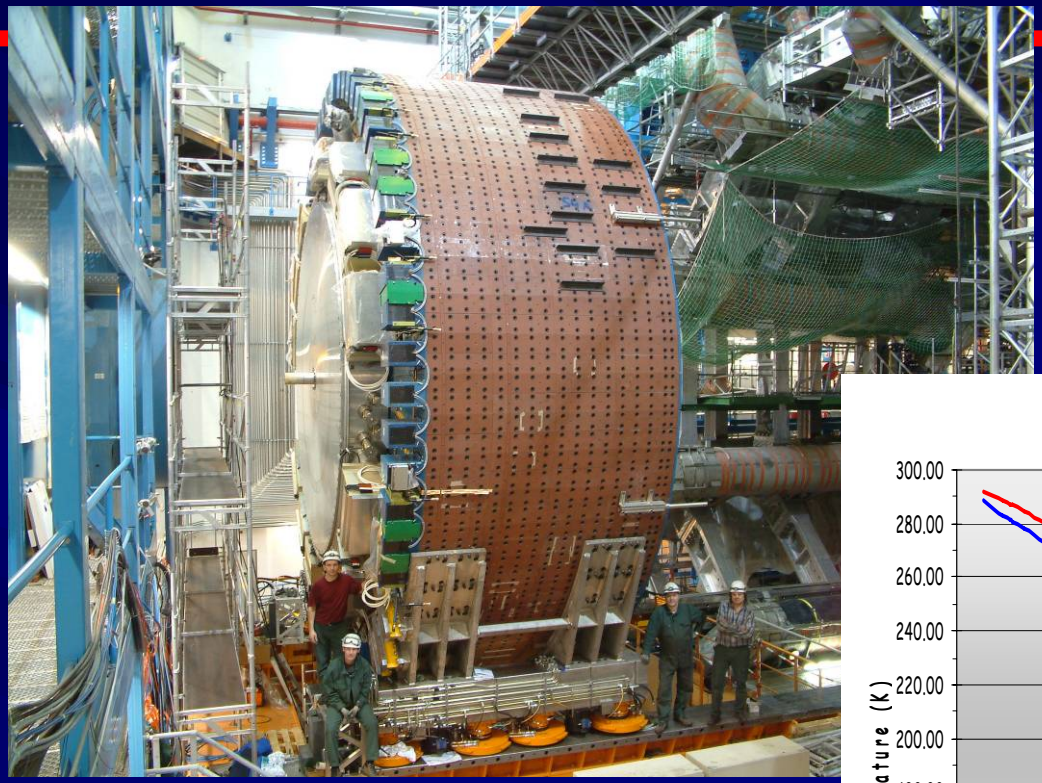
**Complete, integrated Pixel end-cap with 6.6 M channels at CERN**



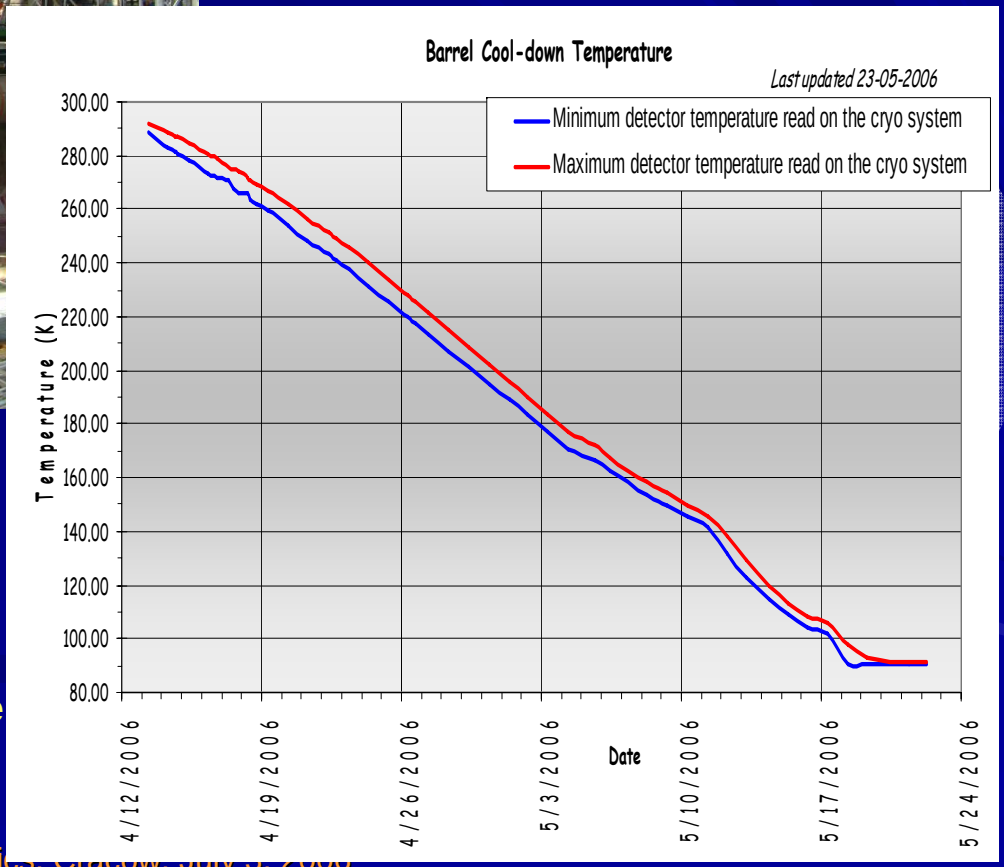
# Calorimeters

All three calorimeter cylinders are installed in the underground cavern, and the gradual commissioning of them has started

→ The full calorimeter system is expected to be operational spring 07



Complete end-cap calorimeter cylinder (LAr and Tiles) just before insertion into the barrel toroid region (access position)




Cool-down history of barrel LAr EM calorimeter *in situ* at the centre of the ATLAS detector

Since early June filled with LAr

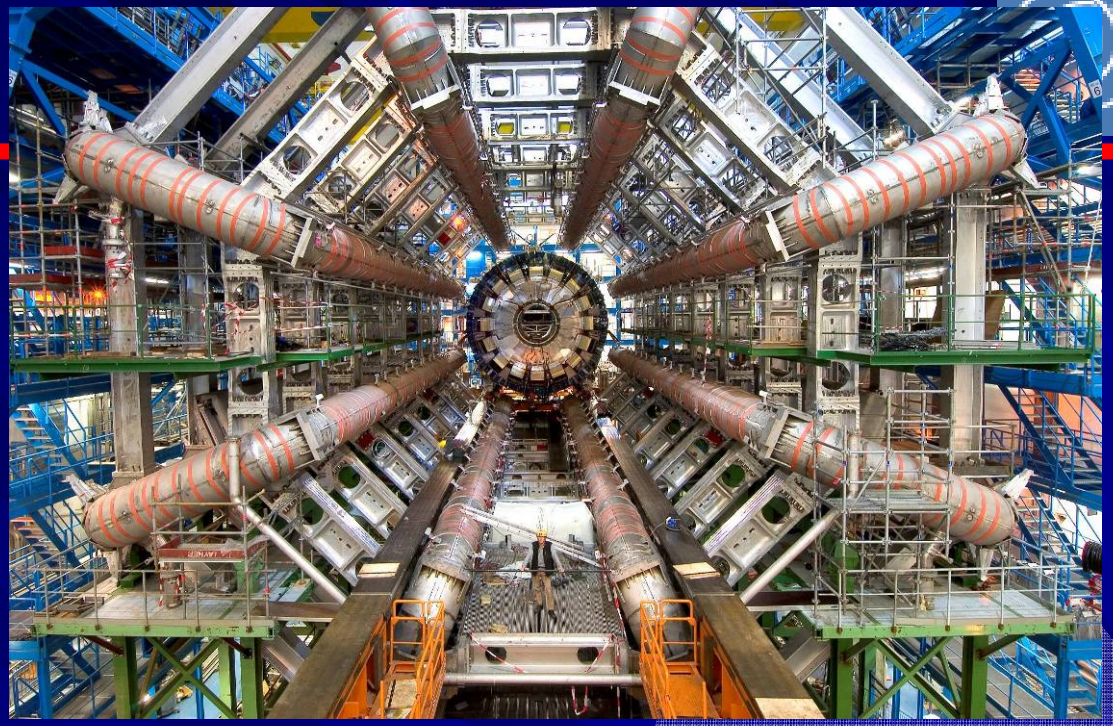
# Magnet System

The Barrel Toroid is installed, and is being pumped down, followed by full excitation tests in July/Aug 06

The End-Cap Toroids are in the final integration phase, on time for the cavern (end of 2006)

The solenoid has been tested already *in situ* at reduced current, awaiting the closure of the calo end-caps

→ The full magnet system is on time to be operational in spring 07



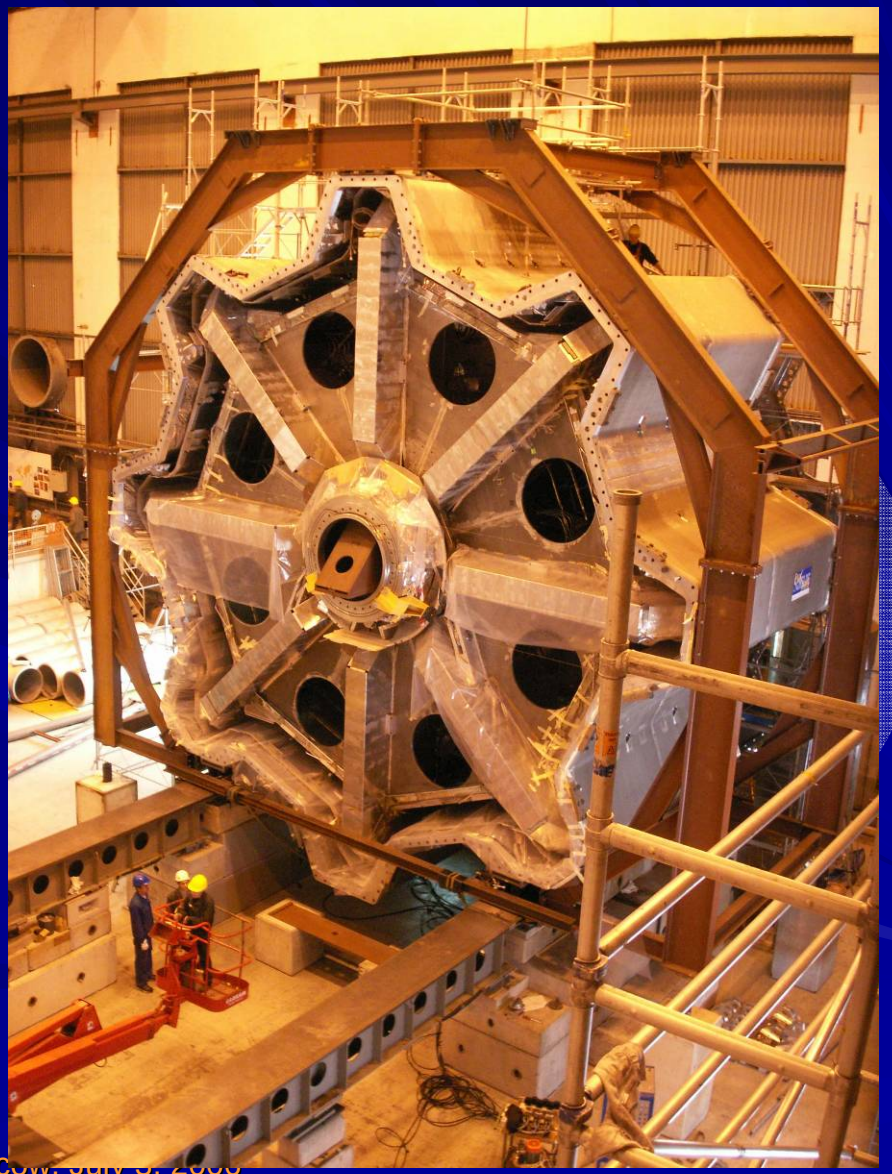
Barrel Toroid before insertion of the barrel calorimeter on 4th November 2005

# Muon Chambers

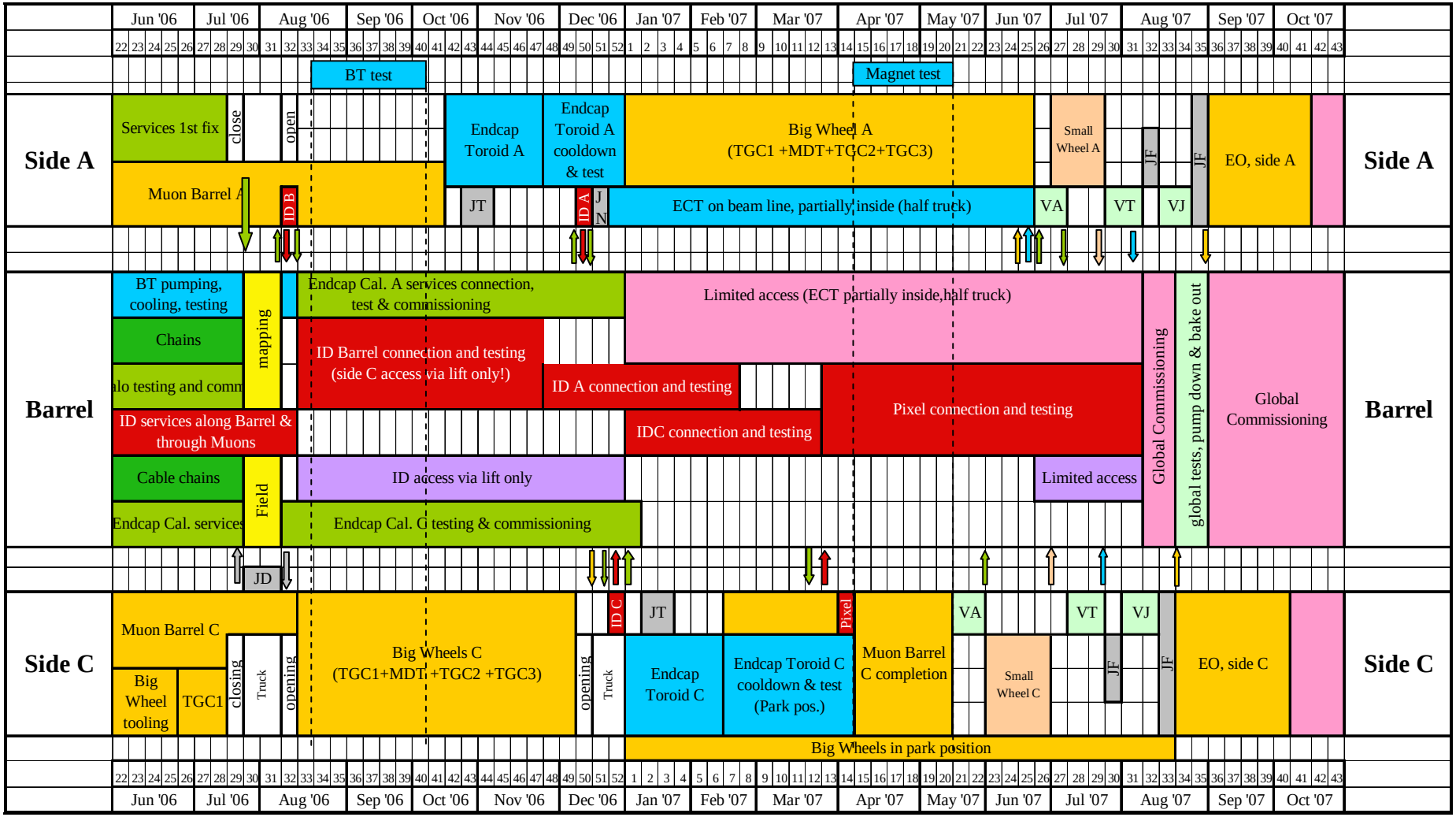
All chambers are built, installation in the barrel region is in full swing (complete before end 2006), and end-cap sectors are being pre-assembled in Hall 180 (on the critical path for installation by summer 2007)

Installation of barrel muon chambers

# First End-Cap Toroid cold mass just before and after insertion into the vacuum vessel

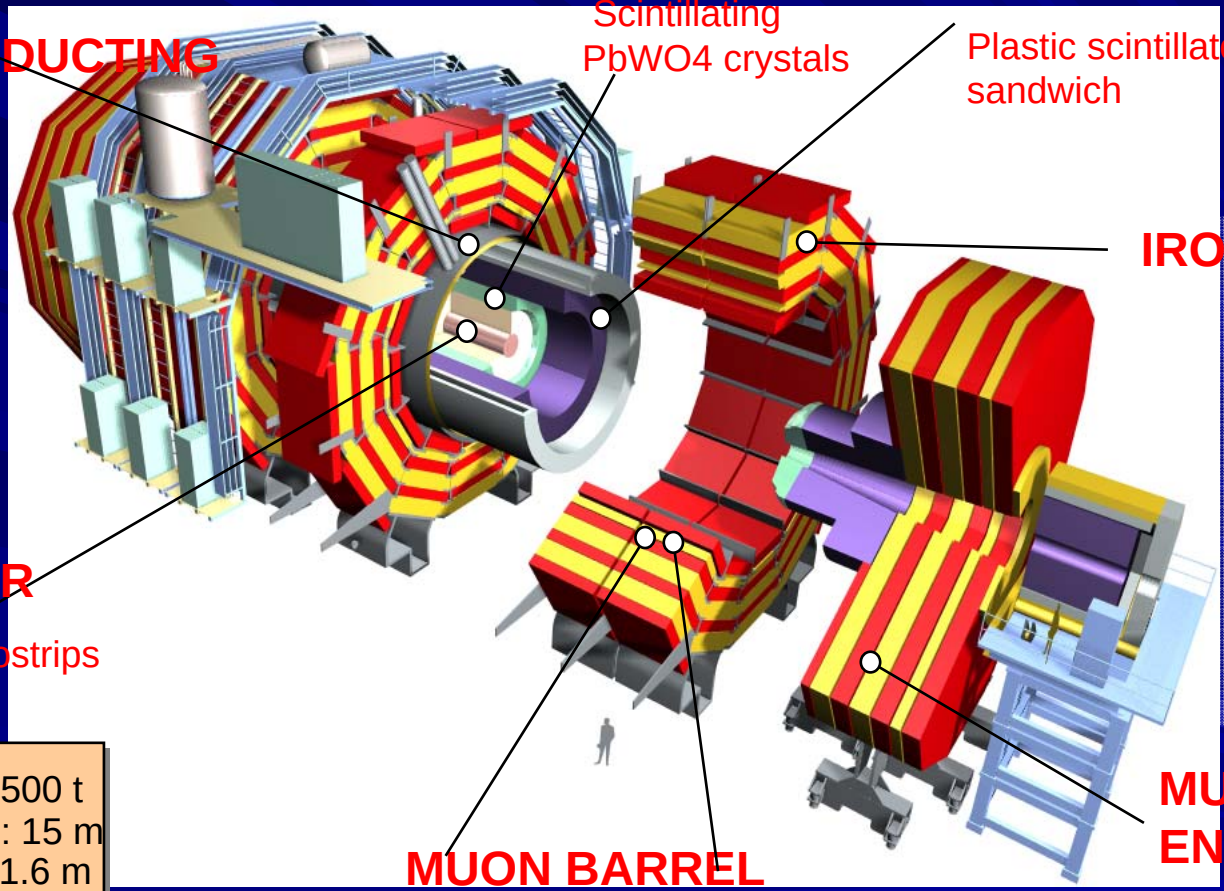


# ATLAS Installation Schedule Version 8.0




- Beam pipe in place end of August 2007
- Restricted access to complete end-wall muon chambers and global commissioning until mid-Oct 2007
- Ready for collisions from mid-October 2007

# The CMS Detector



**CALORIMETERS**

**ECAL**
Scintillating PbWO4 crystals

**HCAL**
Plastic scintillator/brass sandwich

**SUPERCONDUCTING COIL**

**IRON YOKE**

**TRACKER**
Silicon Microstrips
Pixels

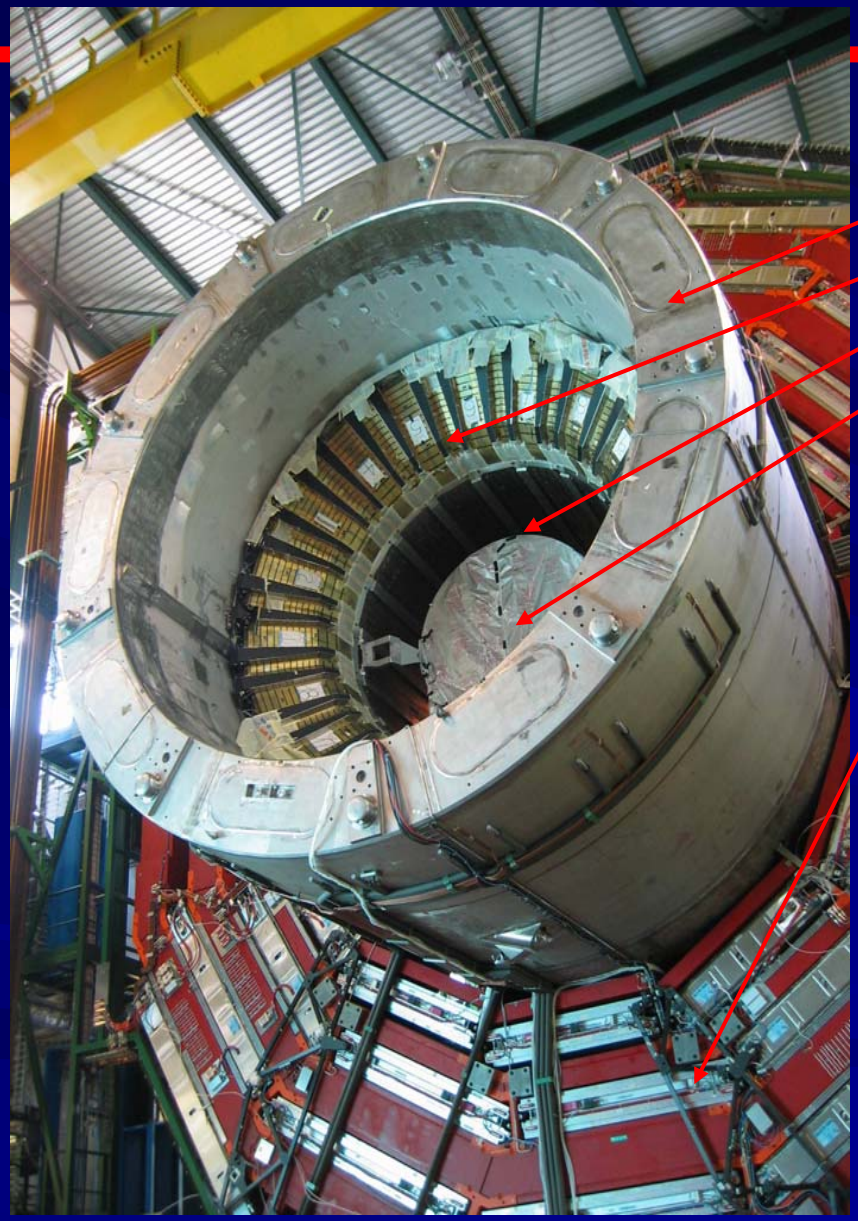
**MUON ENDCAPS**

**MUON BARREL**
Drift Tube Chambers
Resistive Plate Chambers
Cathode Strip Chambers
Resistive Plate Chambers

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

3 g/cm$^3$

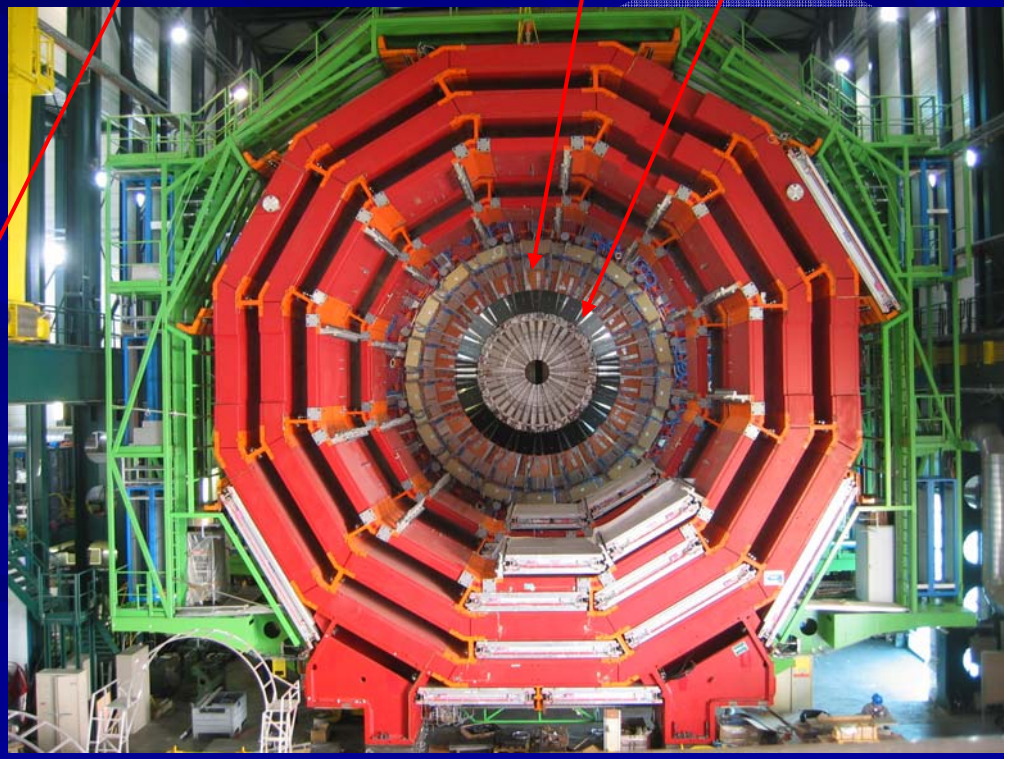
# CMS Assembly at Point 5 for Slice Test



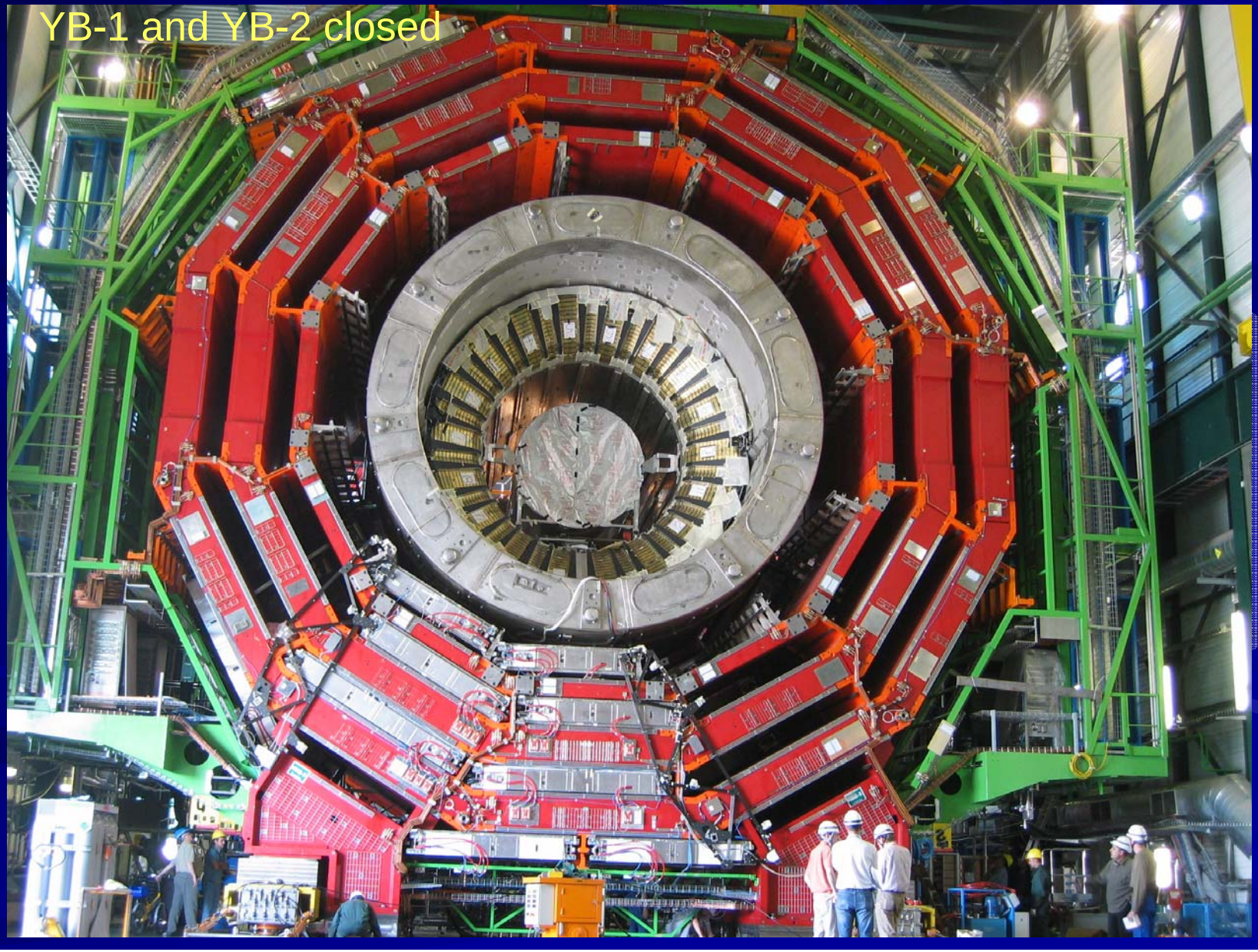
Magnet Test and Detector Test - Jul-Aug06

Solenoid is cold
HB inserted in coil
2 ECAL SM
Tracker Components
DT + RPCs

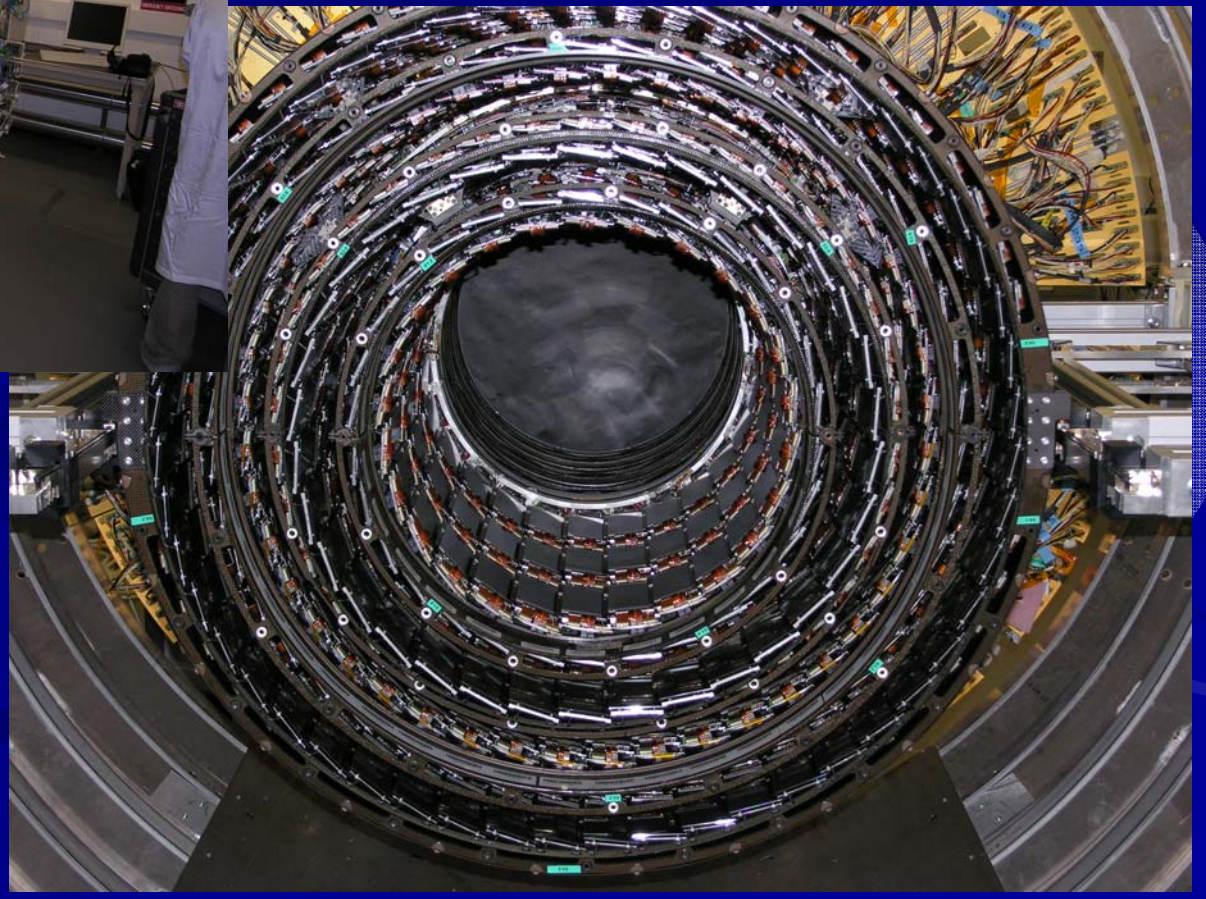
HCAL Endcap
CSCs



# CMS Closing for Magnet Test



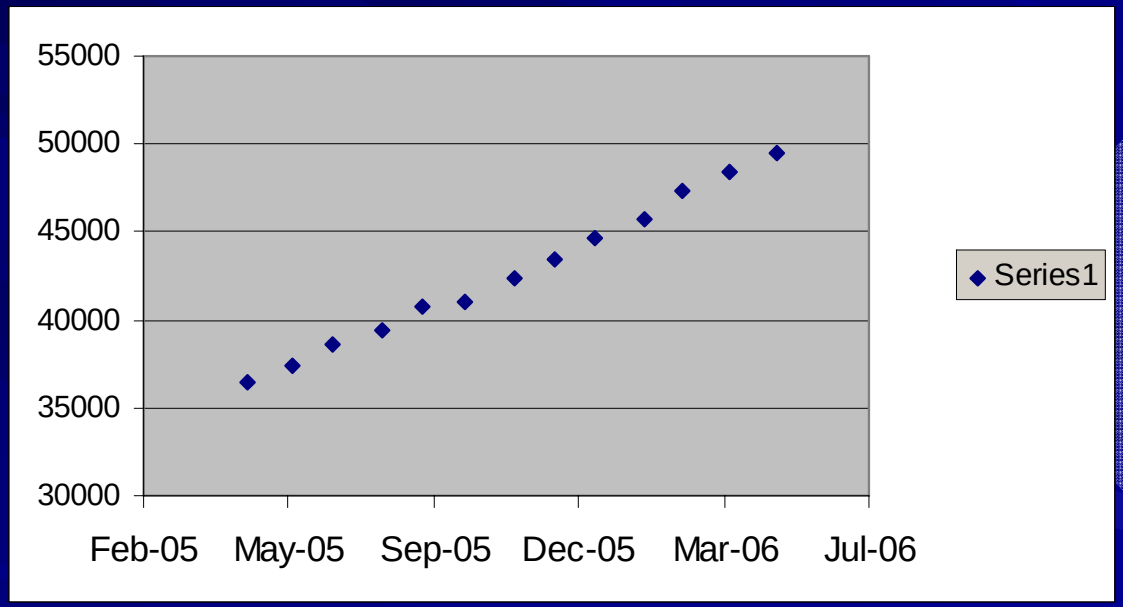
# Tracker Inner Barrel (TIB/TID+) in TIF at CERN



# Crystals Production and ECAL Schedule

**Crystals delivery determines ECAL Critical Path.**

- Last ECAL Barrel crystal delivered February 2007.
- Last ECAL Endcap crystal delivered January 2008.
- Plan is to have ECAL BARREL completed for the pilot run in 2007 and to install ECAL ENDCAP and pre-shower for the first physics run in 2008.




EB Crystal Production in Russia: > 50,000 usable crystals (80%).

# CMS: Construction Progress


The 4 Tesla s.c. coil is now cold, at liquid He temperature 4.5K.

Tracker assembly progressing well. All parts (~220 $m^2$ of Si sensors) expected to be installed in Support Tube (by end06) for final commissioning and then transport to Point 5. TIB/TID+ Delivered to CERN on 14 June

83% of barrel crystals delivered. 27/36 bare Supermodules (1700 xtals) assembled. First half barrel integrated with electronics. Instal 30 SM into HB before lowering. Endcap ECAL will be installed for 2008 physics run.

Over 3 out of 5 wheels worth of DT/RPC packages installed. > 90% of CSCs installed on endcap disks. Half of endcap RPCs installed.

Commissioning with cosmics of large sub-parts (systems tests) has started. Cosmics have been recorded for all sub-detectors: TK, ECAL, HCAL and Muon system. Test a full slice of CMS in July-Sep 06.

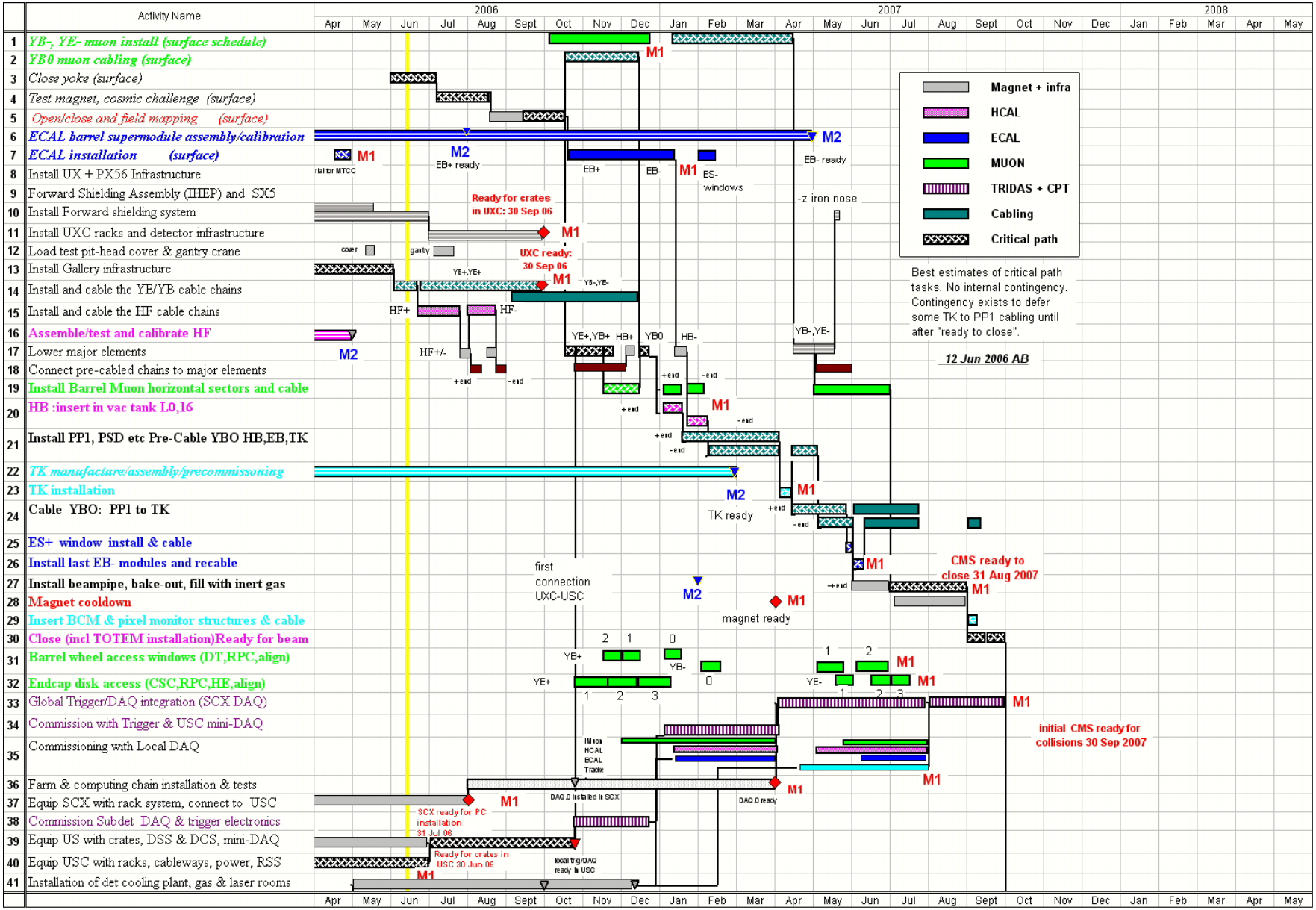
Start lowering disks and wheels in Oct06.

Beam pipe in place by 31 Aug 2007 and ready to close for pilot physics run.

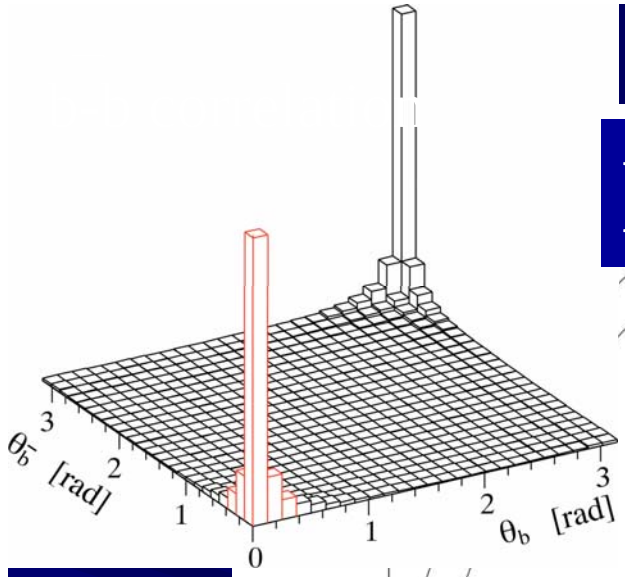
# CMS Schedule v35 (Draft)

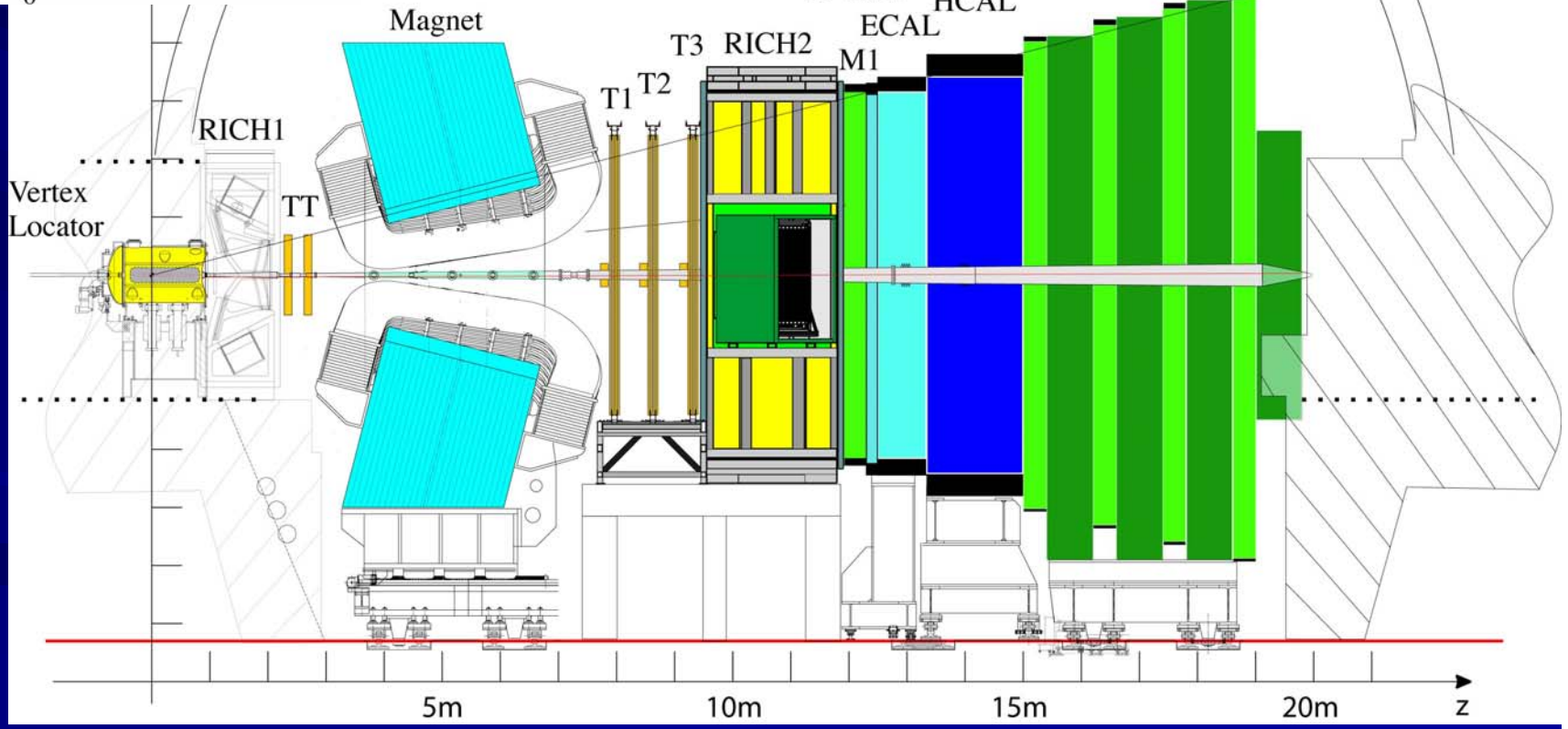
| | |
|---|---|
| Magnet closed: | 9 Jul 06 |
| Magnet test/cosmic challenge: | Jul 06 - Sep 06 |
| Magnetic field mapping | Sep06 - Oct 06 |
| EB+ installation | Oct 06 - Jan 07 |
| USC ready for crates: | Jul 06 |
| Install and cable YE/YB cable chains (+z) | Jun 06 - Sep 06 |
| Start HF lowering: | July 06 |
| YE3+ lowering start | Oct 06 |
| UXC ready for crates | Oct 06 |
| First connection to USC | Oct 06 |
| YB0 lowering | Dec 06 |
| Tracker installation | Apr 07 |
| ECAL/Tracker cabling | Jan-Jun 07 |
| Heavy lowering complete | May 07 |
| Beam Pipe baked out/CMS Ready to Close | 31 Aug 07 |

# CMS Schedule v35 (Draft)

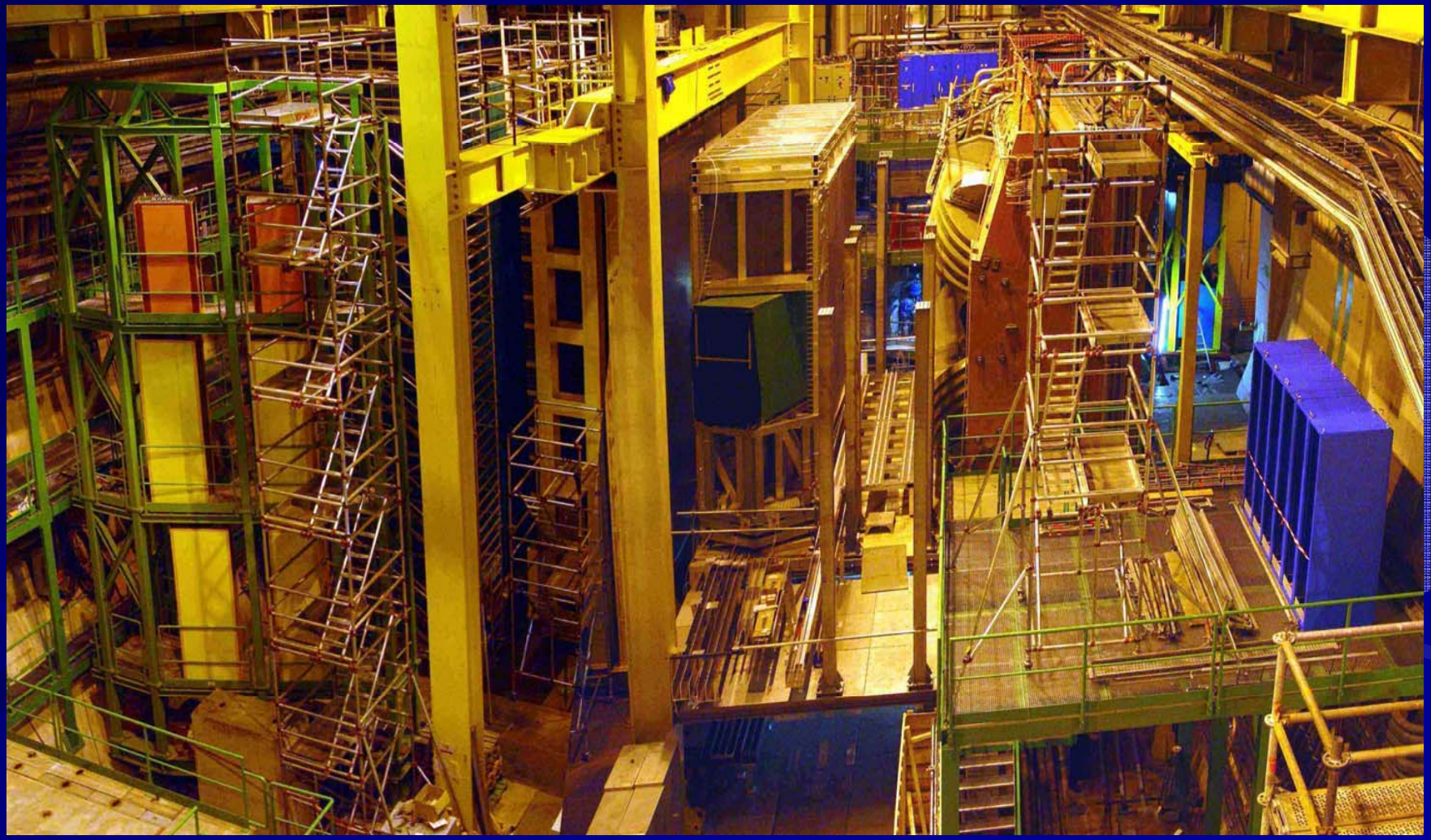


# LHCb detector at IP8



# LHCb pit



# LHCb experiment status

**Magnet:** commissioned, B field measurement completed

**VELO:** Vertex Locator
vacuum tank installed, sensor module production started

**Outer Tracker:**
module construction completed, support structure being installed

**Silicon Tracker:** Inner Tracker and Trigger Tracker
Si ladder production and support structure construction in progress

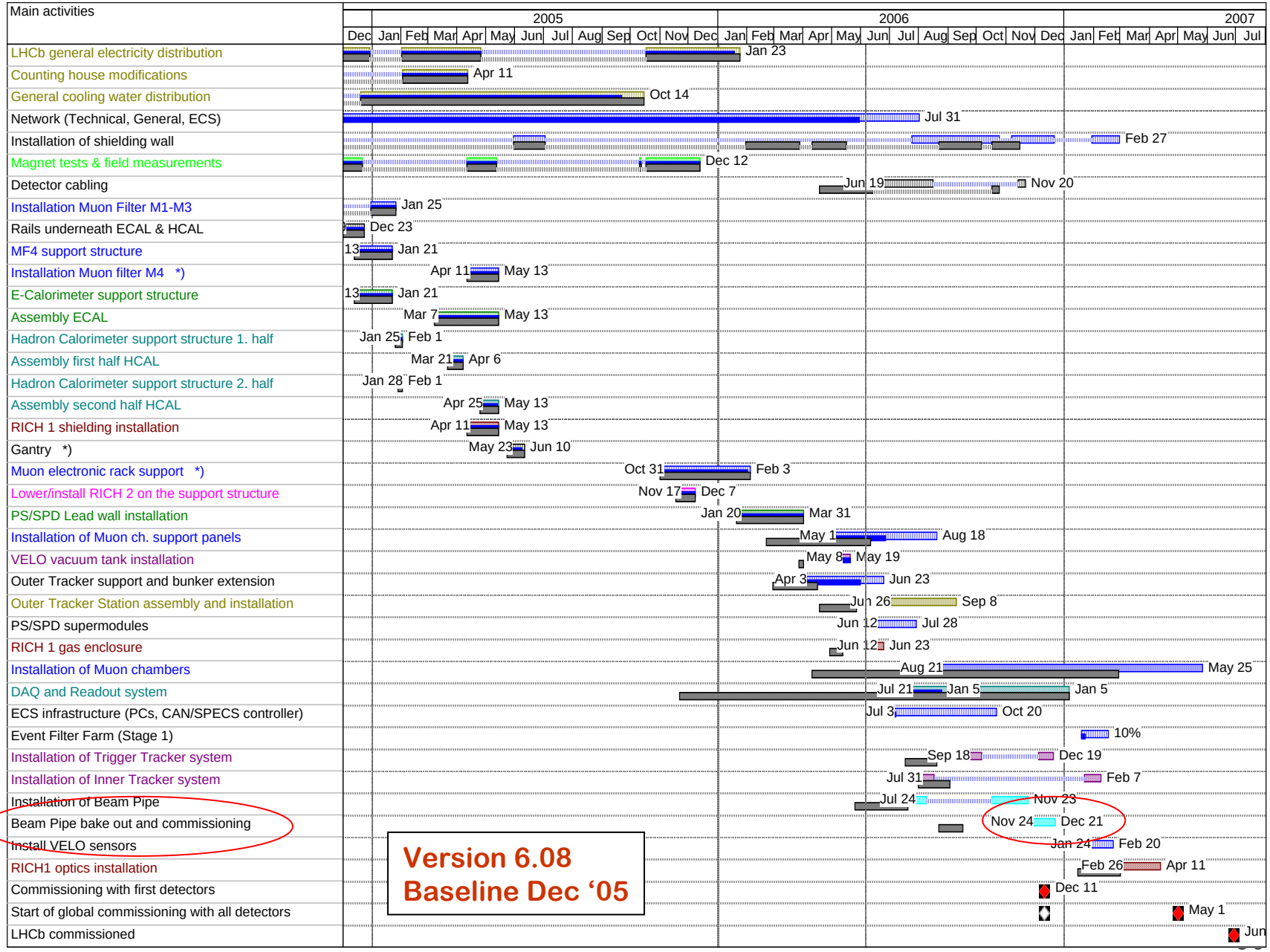
**RICH:** RICH2 mechanics installed, RICH1 shielding box installed

**Calorimeters:**
Ecal and Hcal modules installed, Preshower ready for installation

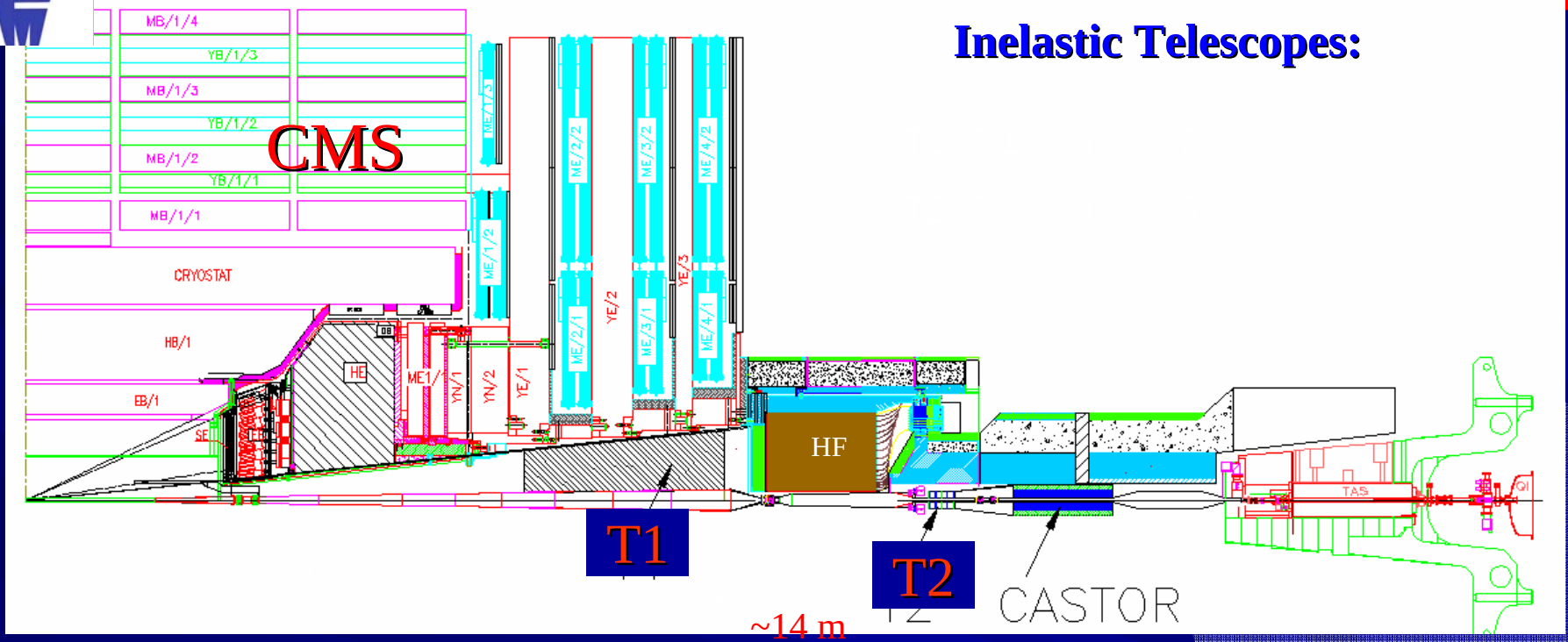
**Muon:**
chamber production progressing, infrastructure in preparation

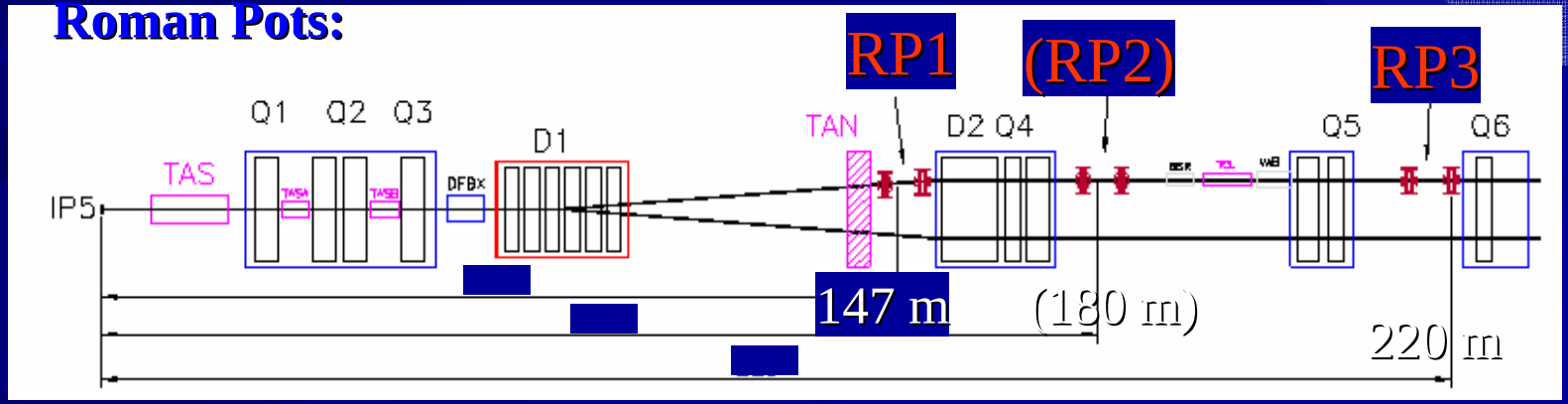
**Trigger:**
Level-0 electronics production about to start

Plan to be ready for the first beam collisions


Main activities
2005
2006
2007
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
LHCb general electricity distribution
Jan 23
Counting house modifications
Apr 11
General cooling water distribution
Oct 14
Network (Technical, General, ECS)
Jul 31
Installation of shielding wall
Feb 27
Magnet tests & field measurements
Dec 12
Detector cabling
Jun 19
Nov 20
Installation Muon Filter M1-M3
Jan 25
Rails underneath ECAL & HCAL
Dec 23
MF4 support structure
13
Jan 21
Installation Muon filter M4 *)
Apr 11
May 13
E-Calorimeter support structure
13
Jan 21
Assembly ECAL
Mar 7
May 13
Hadron Calorimeter support structure 1. half
Jan 25
Feb 1
Assembly first half HCAL
Mar 21
Apr 6
Hadron Calorimeter support structure 2. half
Jan 28
Feb 1
Assembly second half HCAL
Apr 25
May 13
RICH 1 shielding installation
Apr 11
May 13
Gantry *)
May 23
Jun 10
Muon electronic rack support *)
Oct 31
Feb 3
Lower/install RICH 2 on the support structure
Nov 17
Dec 7
PS/SPD Lead wall installation
Jan 20
Mar 31
Installation of Muon ch. support panels
May 1
Aug 18
VELO vacuum tank installation
May 8
May 19
Outer Tracker support and bunker extension
Apr 3
Jun 23
Outer Tracker Station assembly and installation
Jun 26
Sep 8
PS/SPD supermodules
Jun 12
Jul 28
RICH 1 gas enclosure
Jun 12
Jun 23
Installation of Muon chambers
Aug 21
May 25
DAQ and Readout system
Jul 21
Jan 5
Jan 5
ECS infrastructure (PCs, CAN/SPECS controller)
Jul 3
Oct 20
Event Filter Farm (Stage 1)
10%
Installation of Trigger Tracker system
Sep 18
Dec 19
Installation of Inner Tracker system
Jul 31
Feb 7
Installation of Beam Pipe
Jul 24
Nov 23
Beam Pipe bake out and commissioning
Nov 24
Dec 21
Install VELO sensors
Jan 24
Feb 20
RICH1 optics installation
Feb 26
Apr 11
Commissioning with first detectors
Dec 11
Start of global commissioning with all detectors
May 1
LHCb commissioned
Jun
Version 6.08
Baseline Dec '05

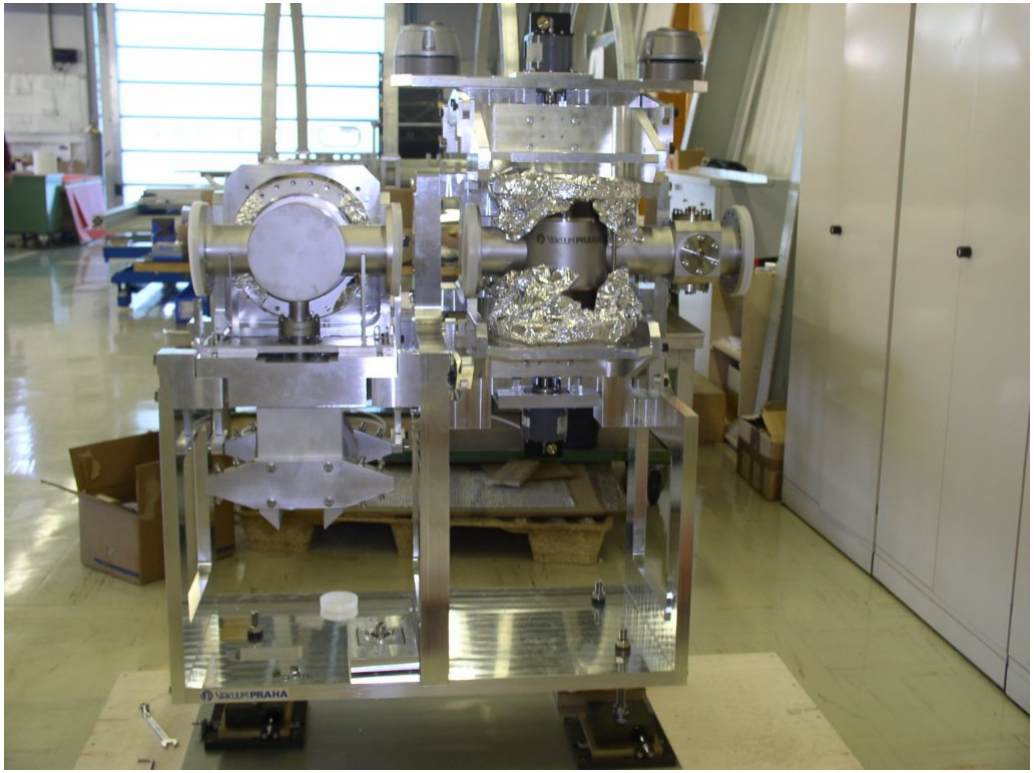
# TOTEM


Inelastic Telescopes:
CMS
MB/1/4
YB/1/3
MB/1/3
YB/1/2
MB/1/2
YB/1/1
MB/1/1
CRYOSTAT
HB/1
EB/1
HE
ME1/1
YN/1
YN/2
YE/1
ME/1/2
ME/2/2
ME/2/1
YE/2
ME/3/2
ME/3/1
YE/3
ME/4/2
ME/4/1
HF
TAS
T1
T2
CASTOR
~14 m


Roman Pots:
RP1
(RP2)
RP3
(RP4)
Q1
Q2
Q3
D1
TAS
IP5
DFBX
TAN
D2 Q4
Q5
Q6
147 m
(180 m)
220 m
?
(420 m)

# The TOTEM Roman Pot Project

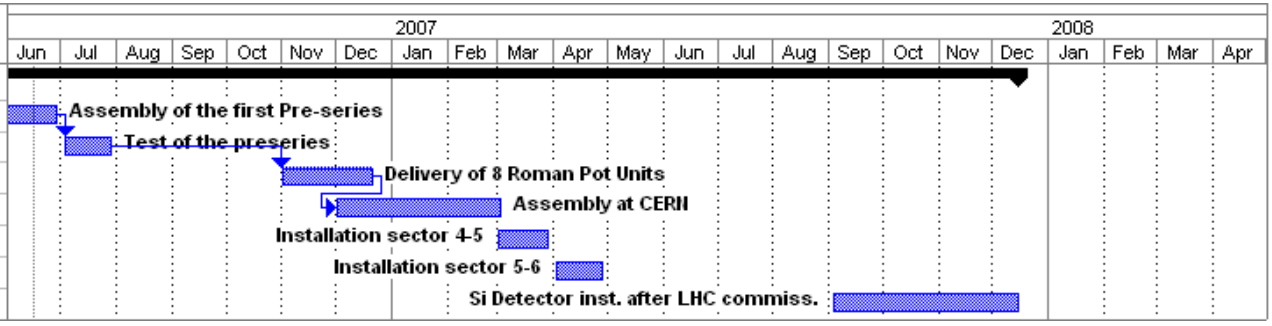
TOTEM
http://totem.web.cern.ch/Totem/



First Roman Pot (partly assembled)

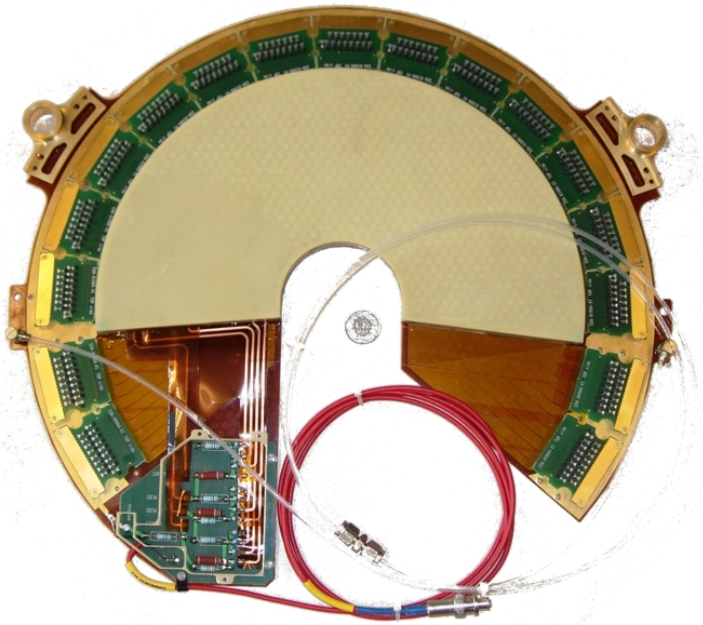
- First Roman Pot delivered and partly assembled.
- Once window is mounted, final vacuum, motor and RF tests in July.
- Order for mass production of 8 Roman pots will be submitted in July to Czech company.
- Complete delivery end of 2006.
- 40 final edgeless Si detectors delivered. Excellent quality.
- VFAT chip production submitted, expected end of August.
- Test in test beam in autumn 2006 and in 2007.

| ID | Task Name |
|---|---|
| 1 | **Roman Pot Project** |
| 2 | Assembly of the first Pre-series |
| 3 | Test of the preseries |
| 4 | Delivery of 8 Roman Pot Units |
| 5 | Assembly at CERN |
| 6 | Installation sector 4-5 |
| 7 | Installation sector 5-6 |
| 8 | Si Detector inst. after LHC commiss. |



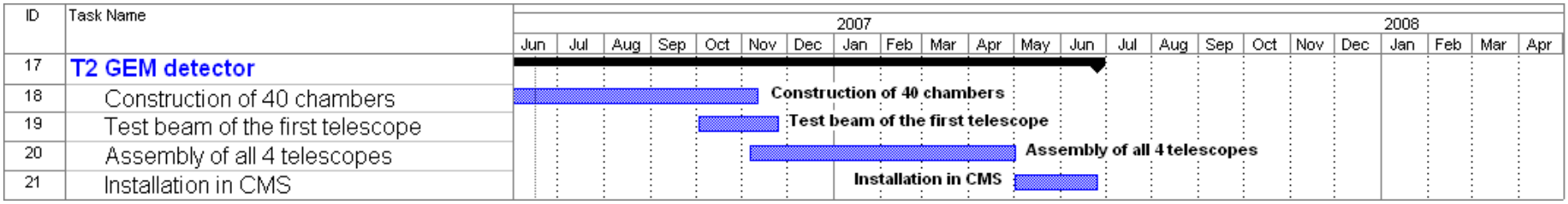
# The TOTEM T2 (GEM) detector

TOTEM
http://totem.web.cern.ch/Totem/



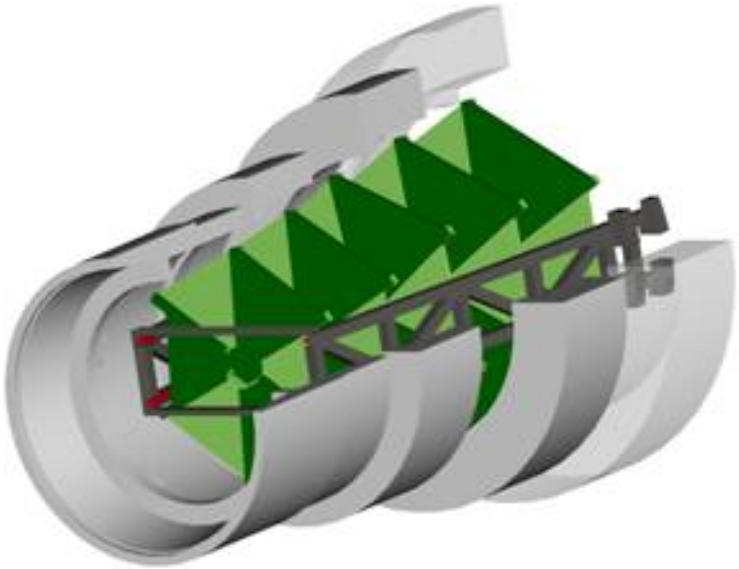
Final GEM chamber

- High quality GEM production line installed in laboratory of HIP Helsinki.
- 10 GEM chambers from a total of 40 already produced in this lab.
- Total production should be finished by end of 2006.
- Once VFAT chip delivered 10 GEM chambers to be tested in test beam in autumn.
- Assembled telescopes to be commissioned in test beam in 2007.



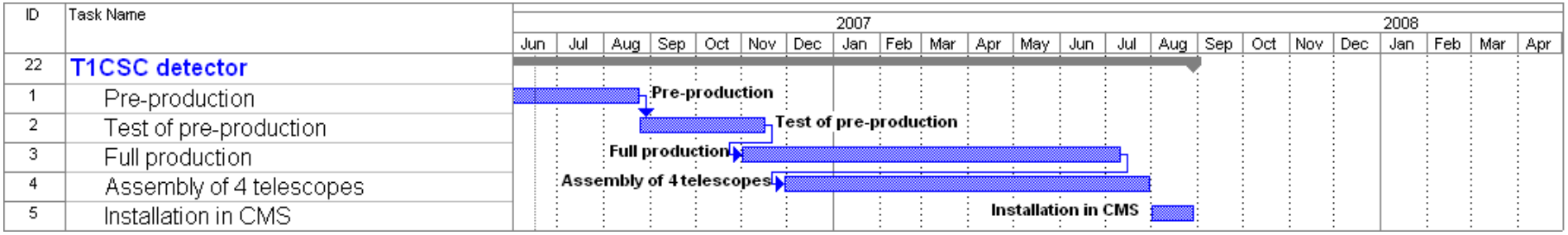
# The TOTEM T1 (CSC) detector

TOTEM
http://totem.web.cern.ch/Totem/



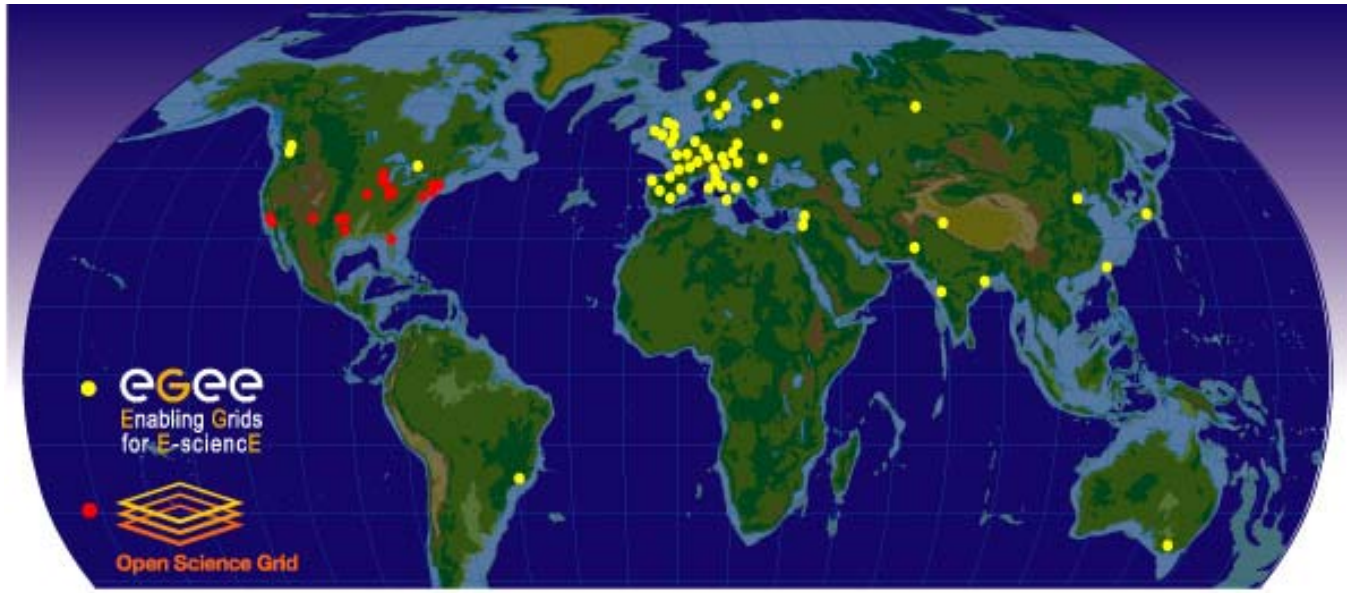
The T1 detector in the CMS end-cap

- Preproduction of 4 CSC chambers started at Gatchina (St. Petersburg), delivery foreseen in summer.
- After test in test beam mass production will start.
- All chambers should be delivered in June 2007.
- Complete assembled telescopes to be commissioned in test beam in 2007.
- Supporting structure has been successfully mounted in CMS end-cap.



# Interoperation between Grid Infrastructures

- Good progress EGEE-OSG interoperability
- Cross job submission – in use by CMS
- Integrating basic operation – 4th workshop at CERN 19-20 June



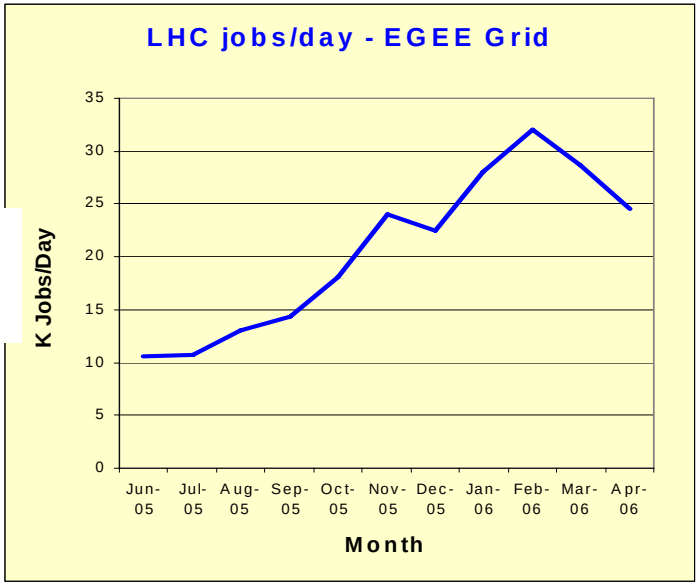

*A map of the worldwide LCG infrastructure operated by EGEE and OSG.*

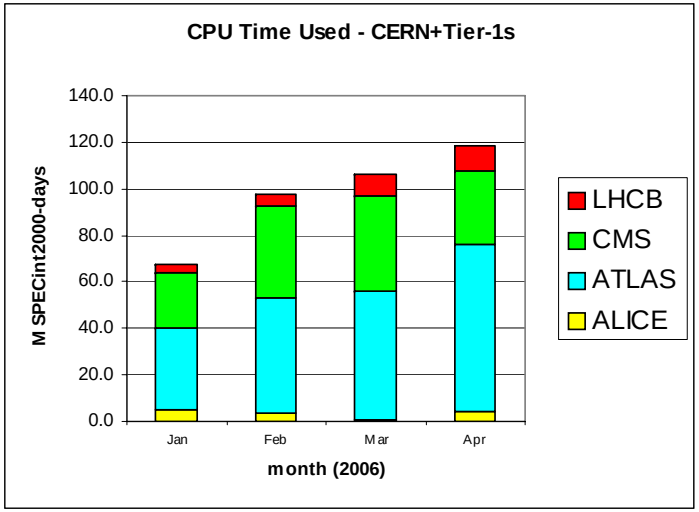
- Early technical studies on integration with Nordic countries

les.robertson@cern.ch

# Steady increase in grid usage

**More than 30K LHC jobs/day on the EGEE Grid**

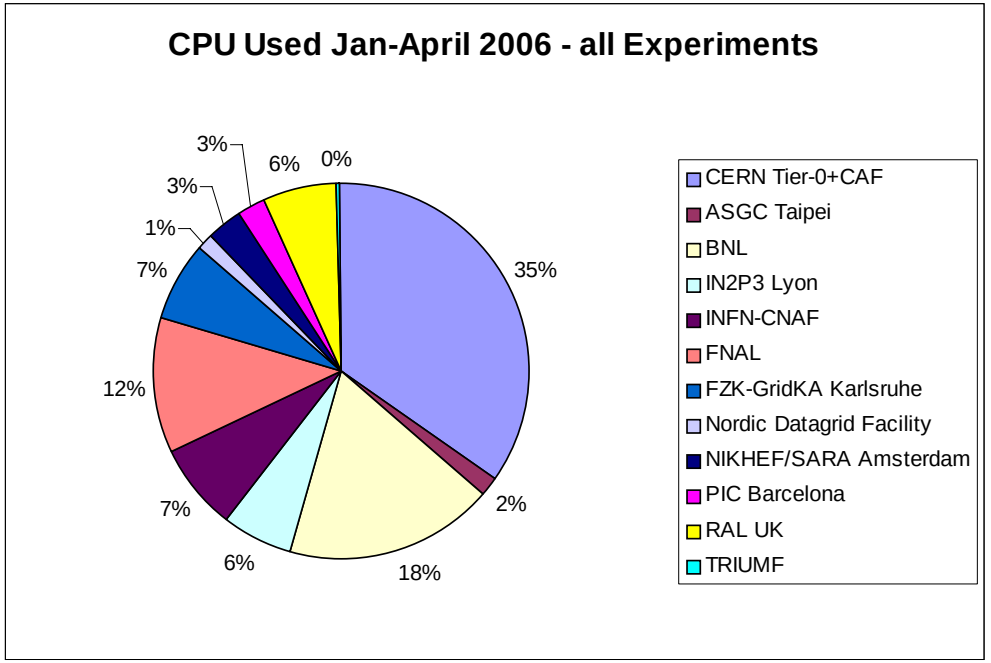


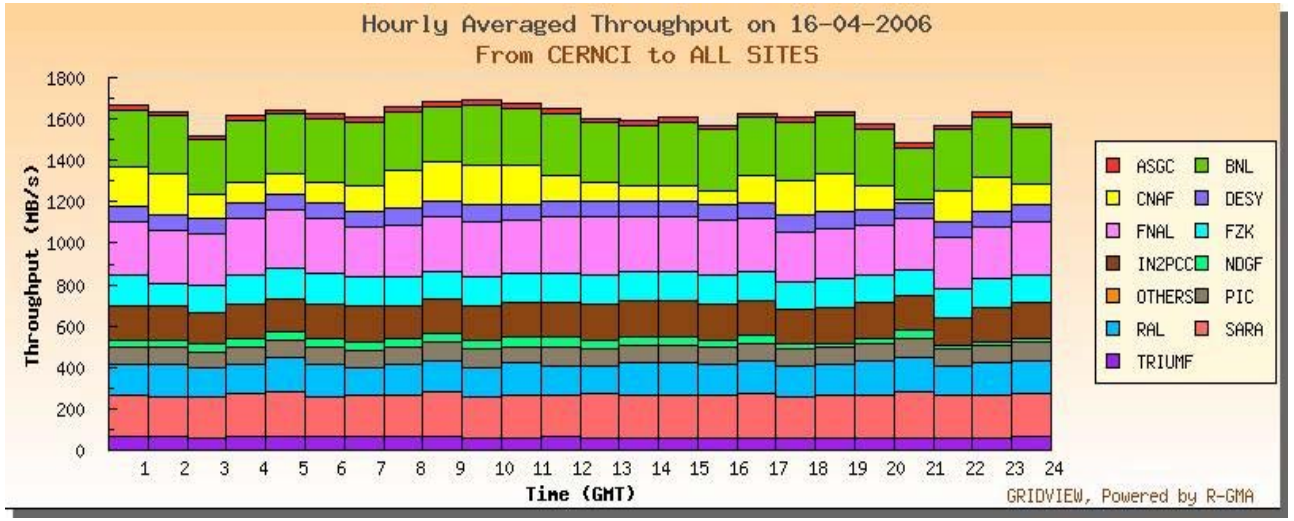

## CPU Usage - CERN+Tier-1s EGEE + OSG

- 120 K processor-days/month
- 65% outside of CERN

**➔only 7% of usable capacity at CERN+Tier-1s in first full year of LHC**
**Challenging ramp-up!**



# Data Distribution Tests Tier-0→Tier-1s




CERN → disk at Tier-1s

July 2005 – 600 MB/sec

January 2006 – 1 GB/sec

April 2006 – 1.6 GB/sec

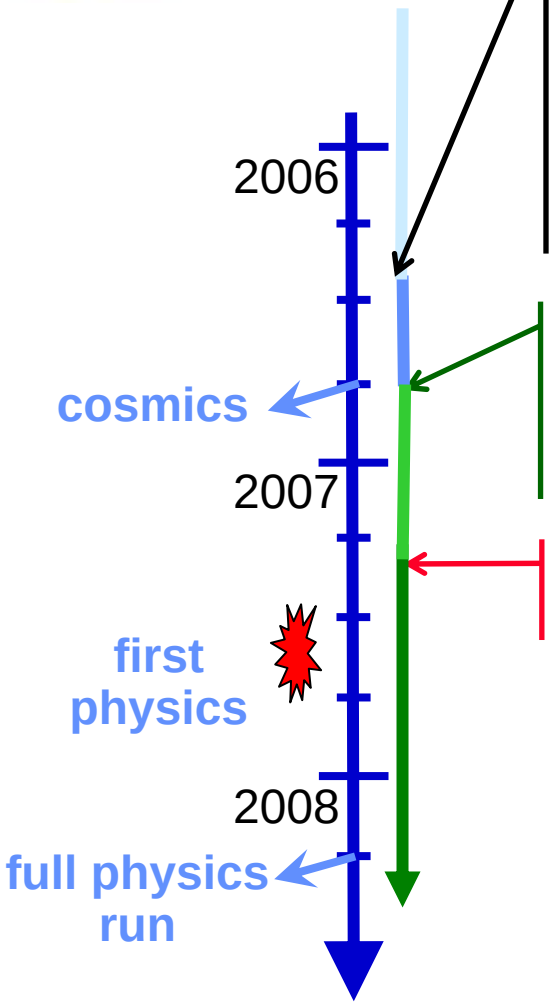
== nominal data rate when LHC running

More work needed to build a stable service

Target for end September 2006 – 1.6 GB/sec to tape at Tier-1s

les.robertson@cern.ch

# LCG Service Deadlines




**Service Challenge 4 –**
**Stable service opened on 2 June 06**
**New middleware package – gLite 3.0**
**– merger of LCG and EGEE middleware**
**First major experiment test – ATLAS**
**– starts 19 June**

**LHC Service in operation – *1 Oct 06***
over following six months ramp up to full operational capacity & performance

**LHC service commissioned – *1 Apr 07***

les.robertson@cern.ch

# MoU Signature Status

**Signed**

- China
- France
- Germany
- Italy
- India
- Japan
- Netherlands
- Pakistan
- Romania
- Taiwan
- UK
- US-ATLAS
- US-CMS

**Pending**

- Australia
- Canada
- Czech Republic
- Nordic Countries
- Poland
- Portugal
- Russia
- Spain
- Switzerland
- Ukraine

**In discussion**

- Belgium

les.robertson@cern.ch

# Conclusions

The LHC experiments continue to make wonderful progress towards completing initial detectors, ready for beam in Q4 2007.

The Worldwide LHC Computing Grid service is being developed according to plan.