CMS

Compact Muon Solenoid

Status
Planning up to first beam
Risks

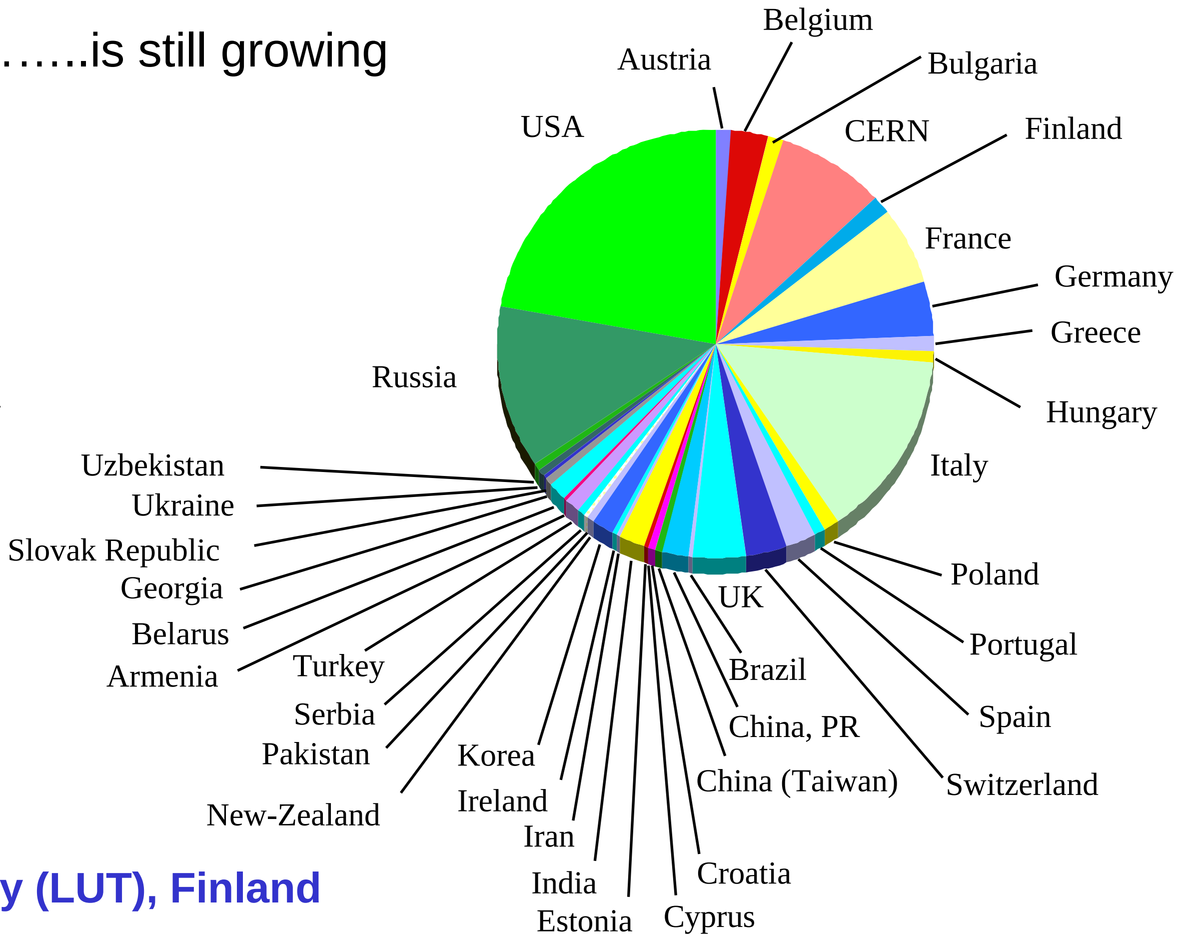
Austin Ball, Deputy Technical Coordinator

Physics at LHC
Vienna, July 2004

The CMS Collaboration

……..is still growing

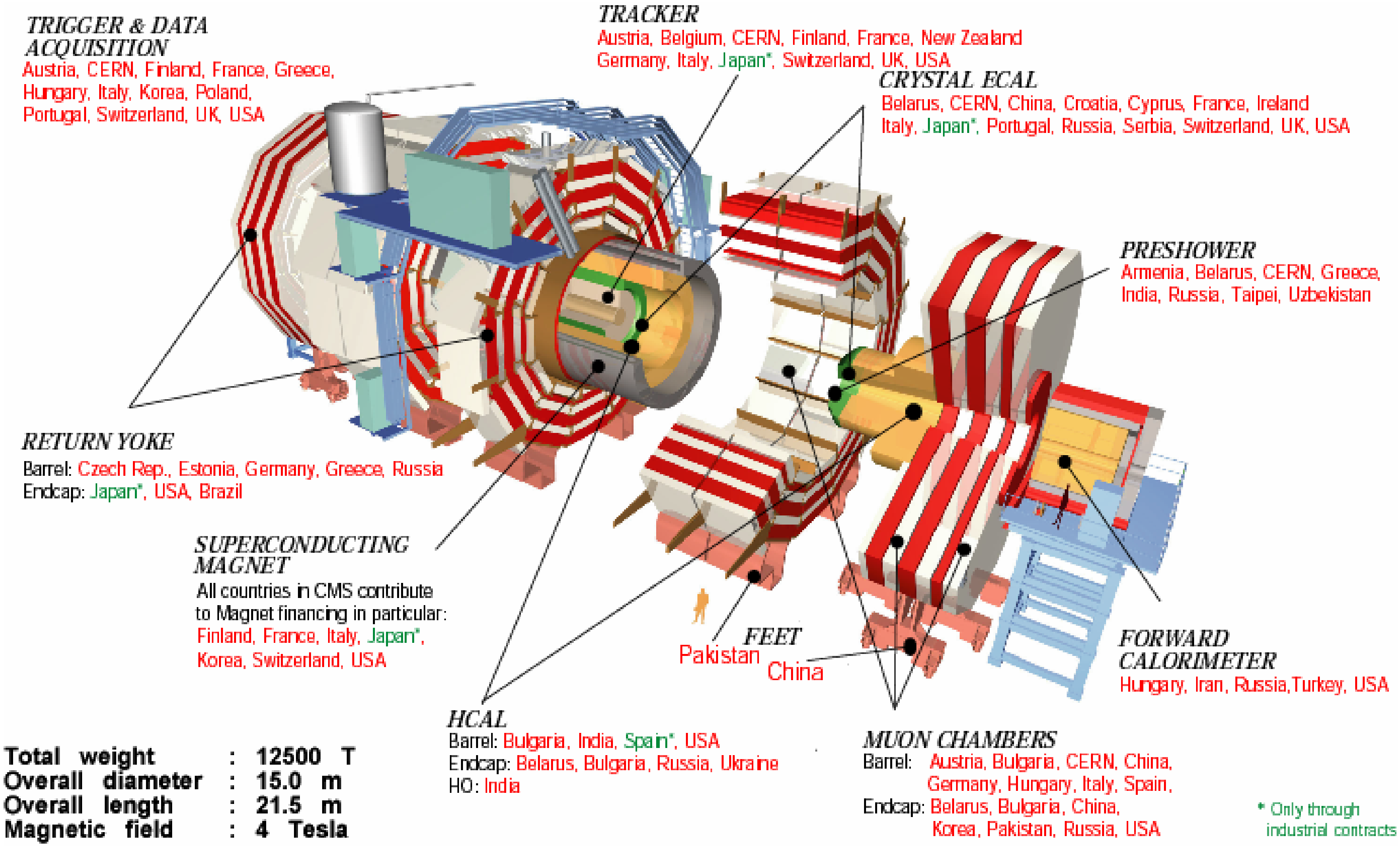
1976 Physicists and Engineers
36 Countries
153 Institutions
(+ 10 Associated Institutes with 76 scientists)



Approved in the last year

- Lappeenranta University of Technology (LUT), Finland
- Institute for Experimental Physics, Univ. of Hamburg
- Consortium of 4 Mexican Universities
- Brown University, Rhode Island, USA
- ELHEP – Inst. of Electronics of Warsaw Inst of Technology (Associate)

CMS: design & construction

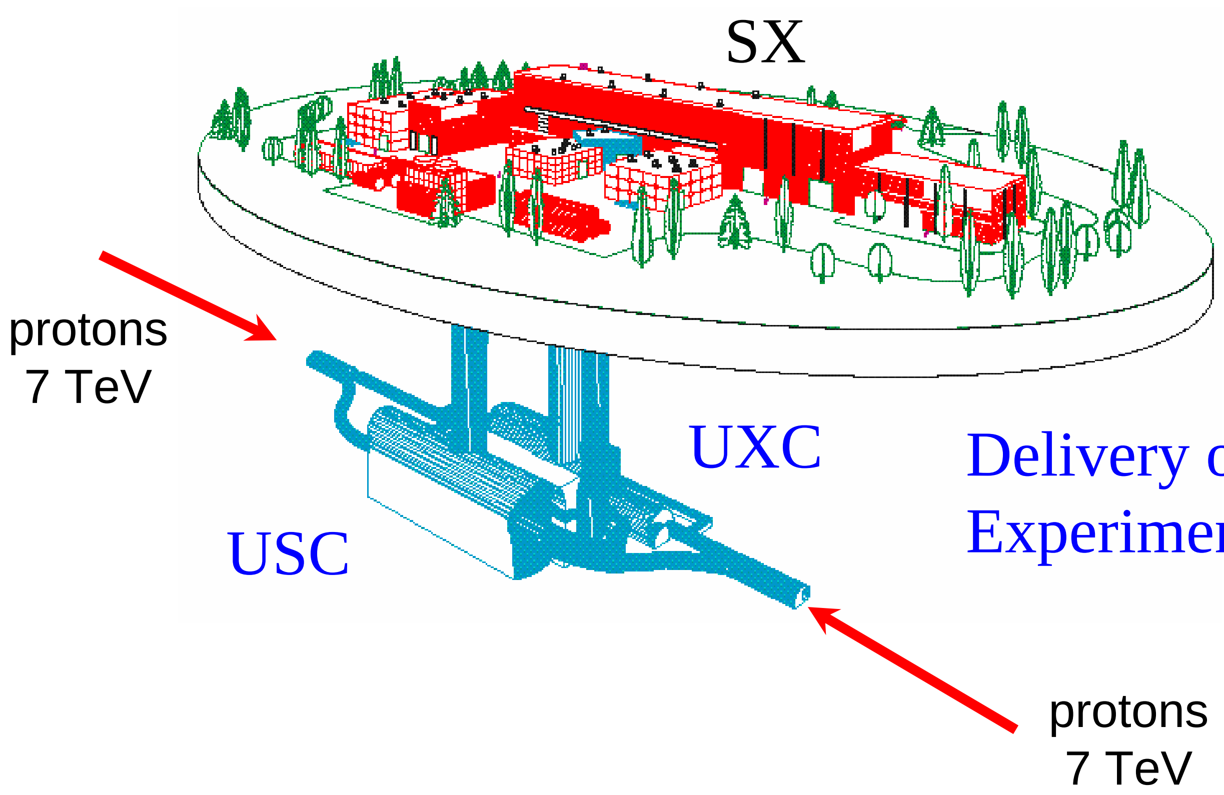


Total weight	:	**12500 T**
Overall diameter	:	**15.0 m**
Overall length	:	**21.5 m**
Magnetic field	:	**4 Tesla**

LHC point 5

Geologically difficult: overcome by exploiting modular design of CMS to partly pre-assemble and test on the surface, then lower as a few large modules

Surface assembly building SX was delivered on-time in early 2000
CMS assembly started in 2001.
Assembly & testing will continue in SX until early-06



Delivery of underground caverns in 2004
Experiment installation end 05 - Apr 07

Basic Mechanical Assembly Sequence

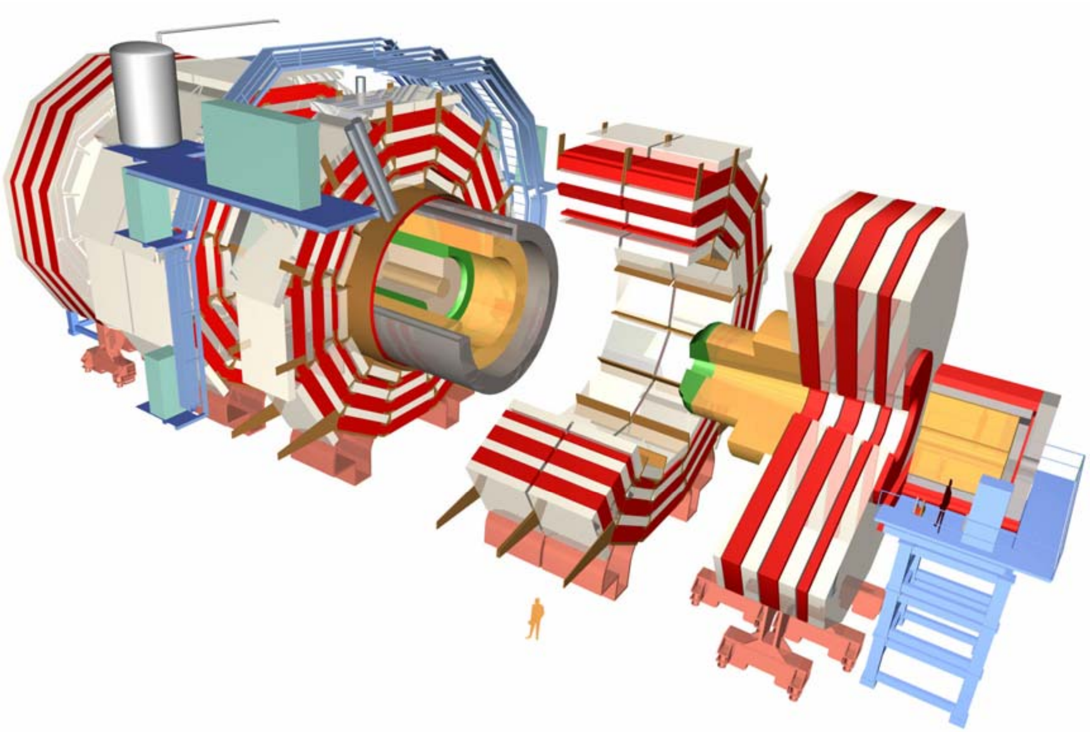
SURFACE : *proceeding independently of underground Civil Engineering*

*construct magnet barrel yoke & cable

* prepare solenoid vac tanks
* construct endcap yoke & cable
* assemble hadron calorimeters
* assemble coil & insert in vac tank
* insert HCAL inside coil
* insert part of ECAL barrel in HCAL
* install muon chambers (barrel+ec) in yoke

•**TEST MAGNET (Aug-Nov 2005)**

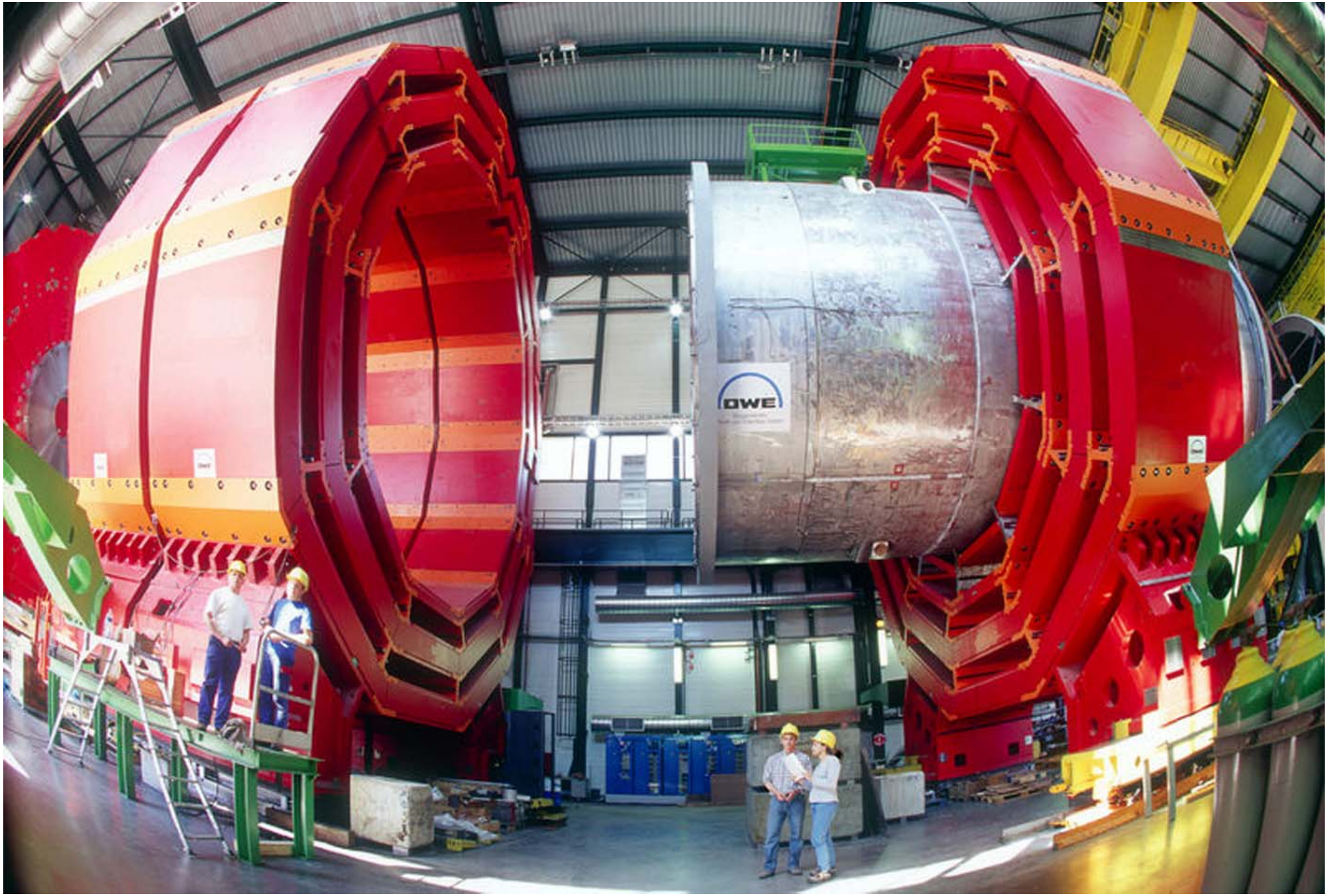
*separate elements and lower sequentially



UNDERGROUND:

* install remainder of ECAL barrel & cable
* install silicon strip tracker & cable
* install beampipe
* close experiment & commission for LHC pilot run in 2007.
* install ECAL endcaps and pixel tracker in 07-08 winter shutdown.
* close experiment and commission for first full year of physics.

Barrel Yoke ready for coil and μ detectors

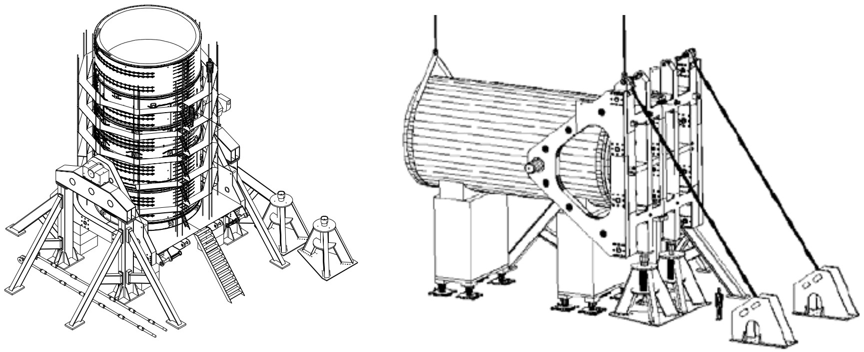


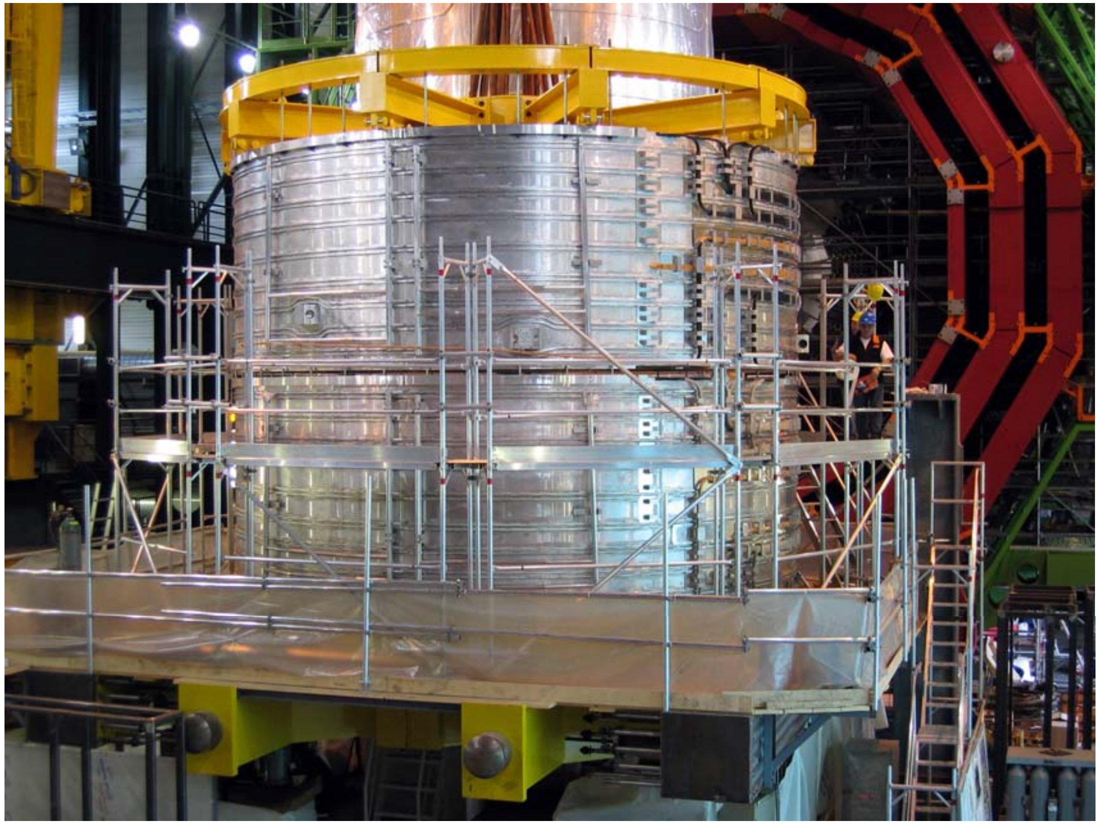
Coil: module 2 (of 5) delivered to CERN

-on schedule to deliver last coil module by Oct 04
- power supply and cryo system will be ready

Magnet Test in surface building

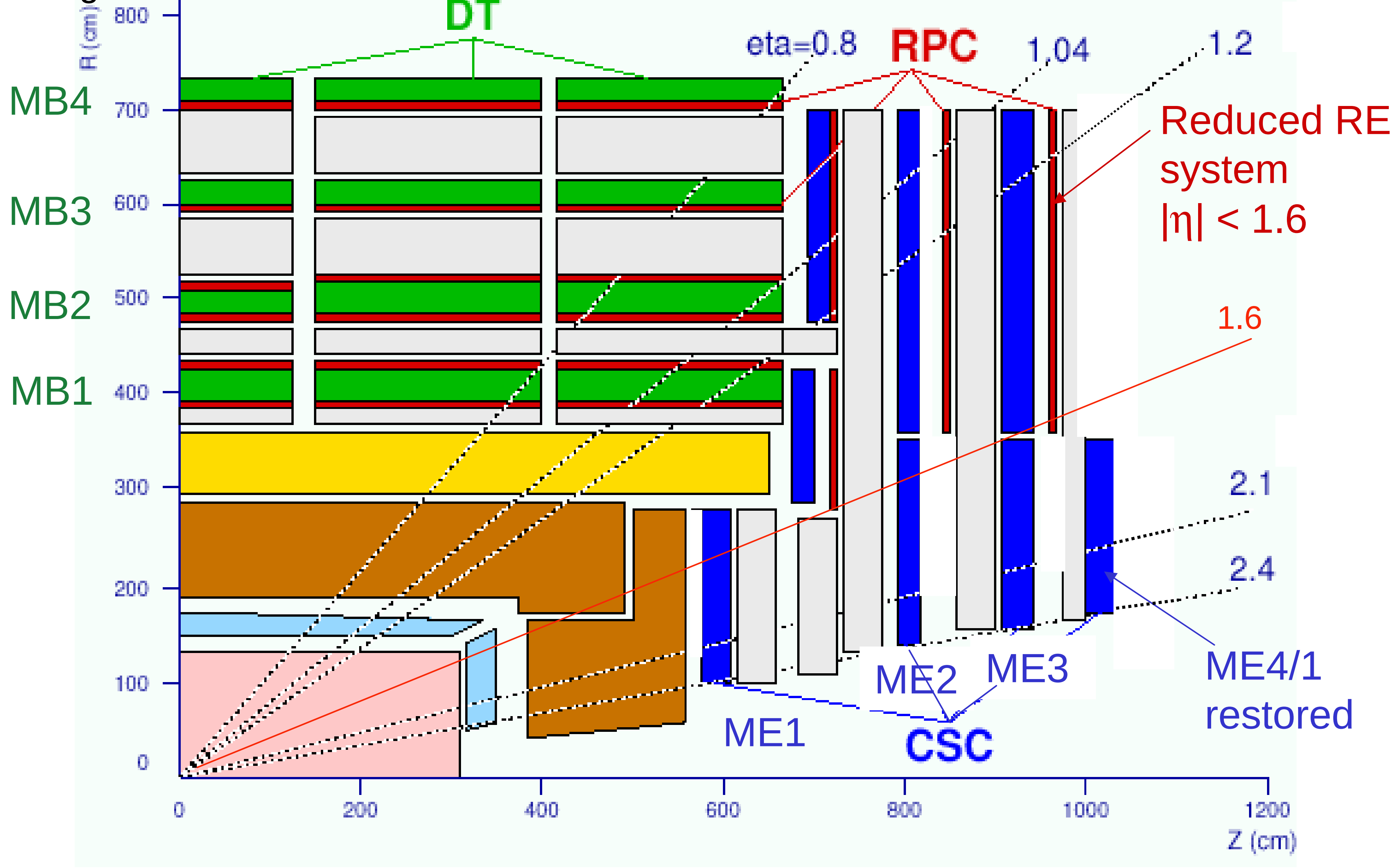
Aug-Nov 2005





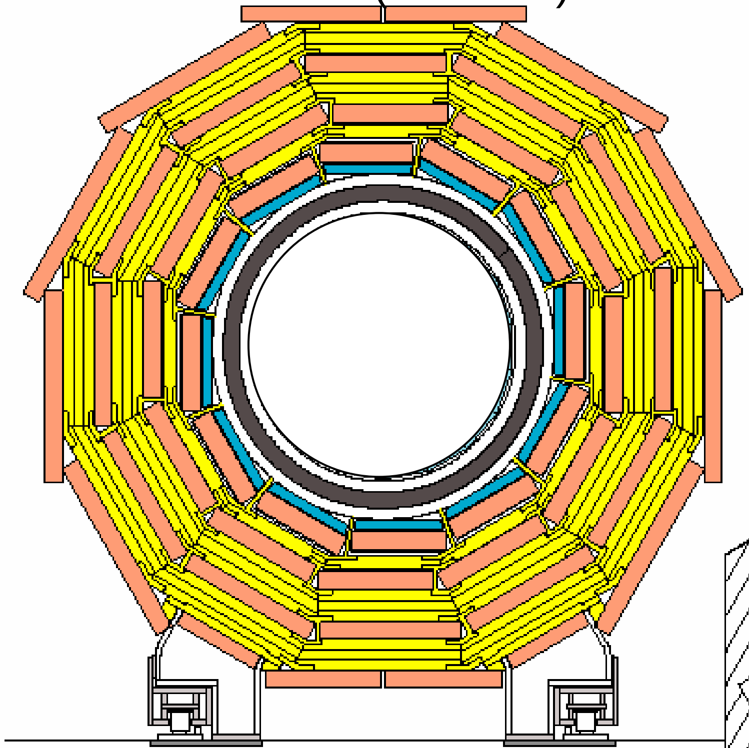
Muon System

¼ longitudinal slice



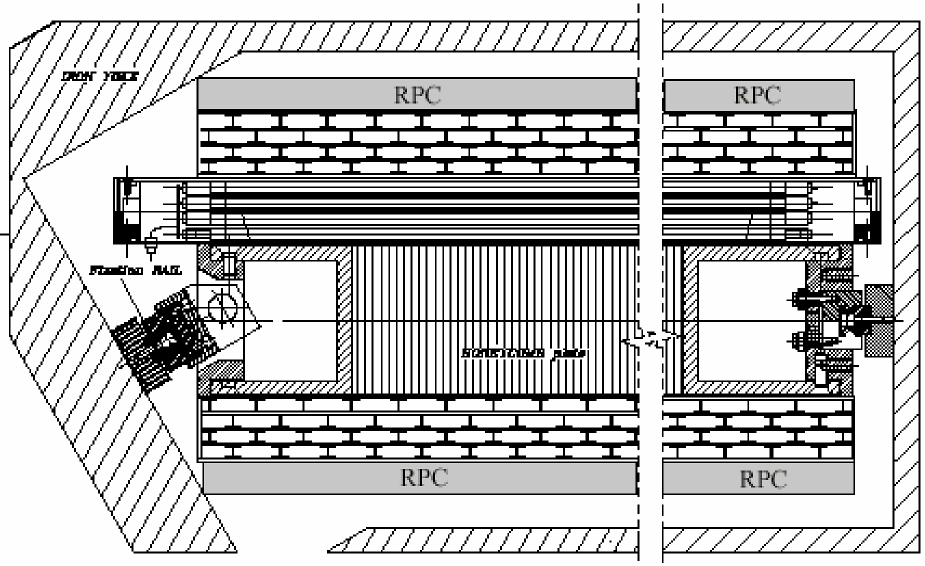
Barrel muon system: Drift Tubes + RPC's

12 sectors/wheel (5 wheels): all but horizontal sectors can be installed on surface



- DT 1,2,3= 8 ϕ-layers
  + 4 θ-layers
- DT 4 = 8 ϕ-layers

- 250 chambers
- 192 000 channels



DT
- wire pitch = 4.2 cm
- max. drift time = 380 ns

RPC
- double-gap type, sandwiching DT's in layers 1,2, single in layers 3,4

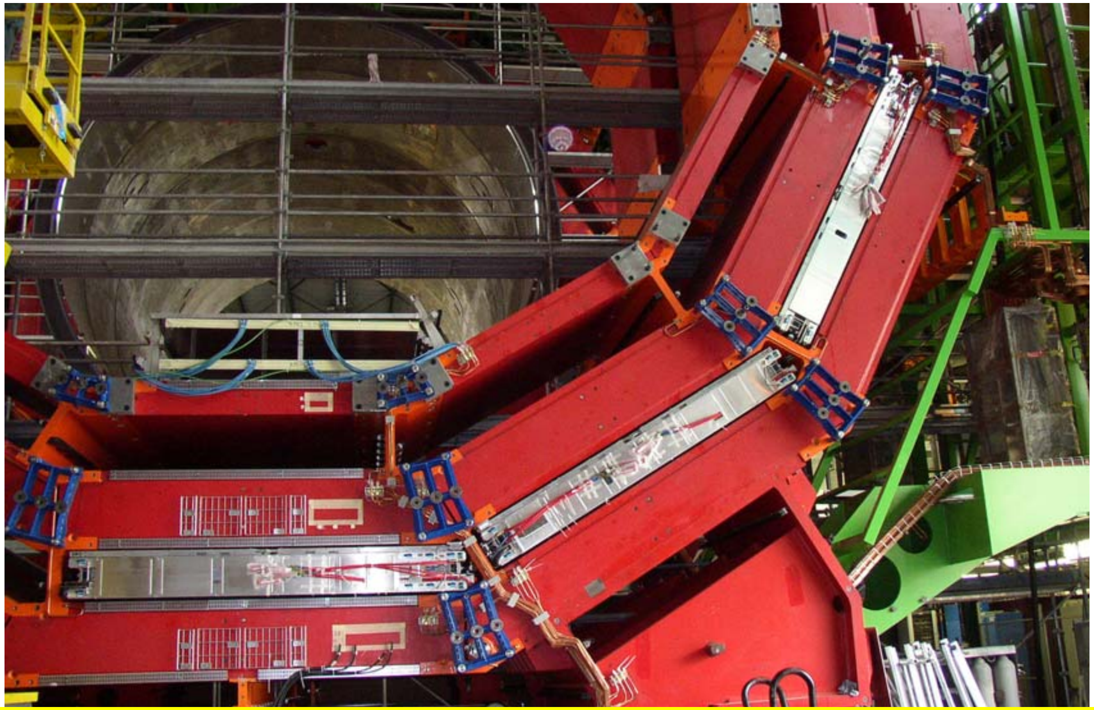
Muon Barrel: DT Chambers

Robotic gantries in Legnaro, Italy

126/210 (60%) DT chambers produced.
End production around mid 2005
(20 ch./year/site).

Installation started last week (delayed to replace HV distribution boards which developed faults after 3000hrs operation).

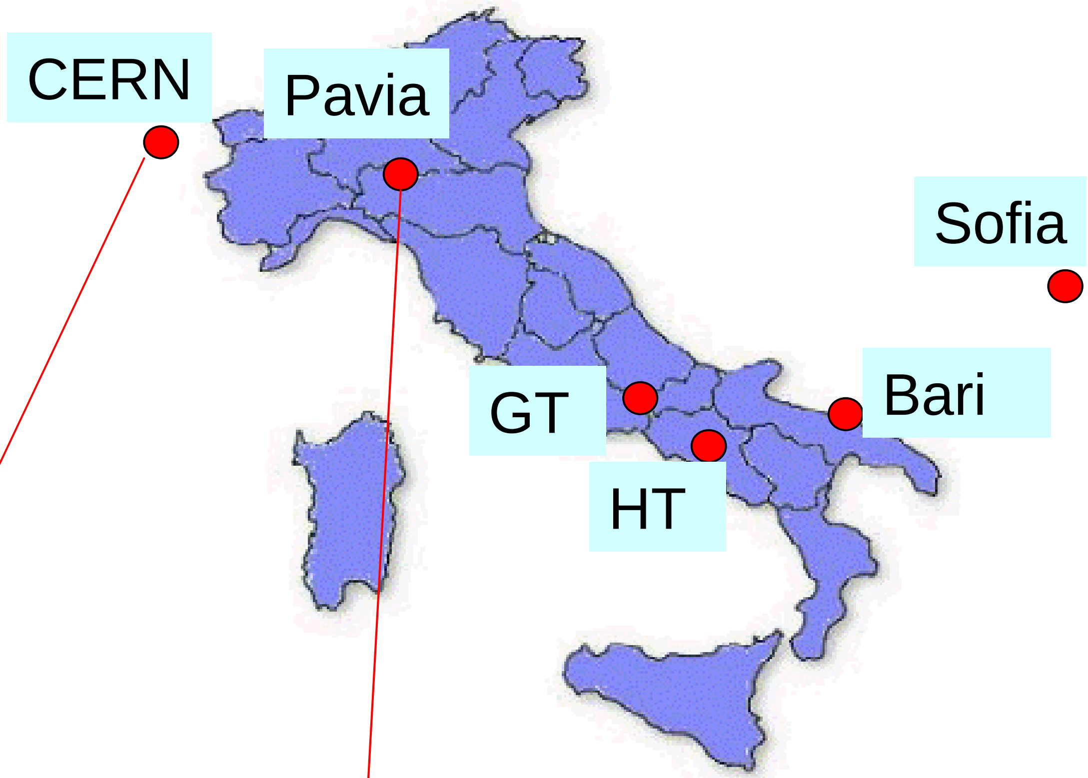
115 chambers at CERN for survey, “fitting-out” and test.



Finish 10/12 of installation, all wheels, on surface.

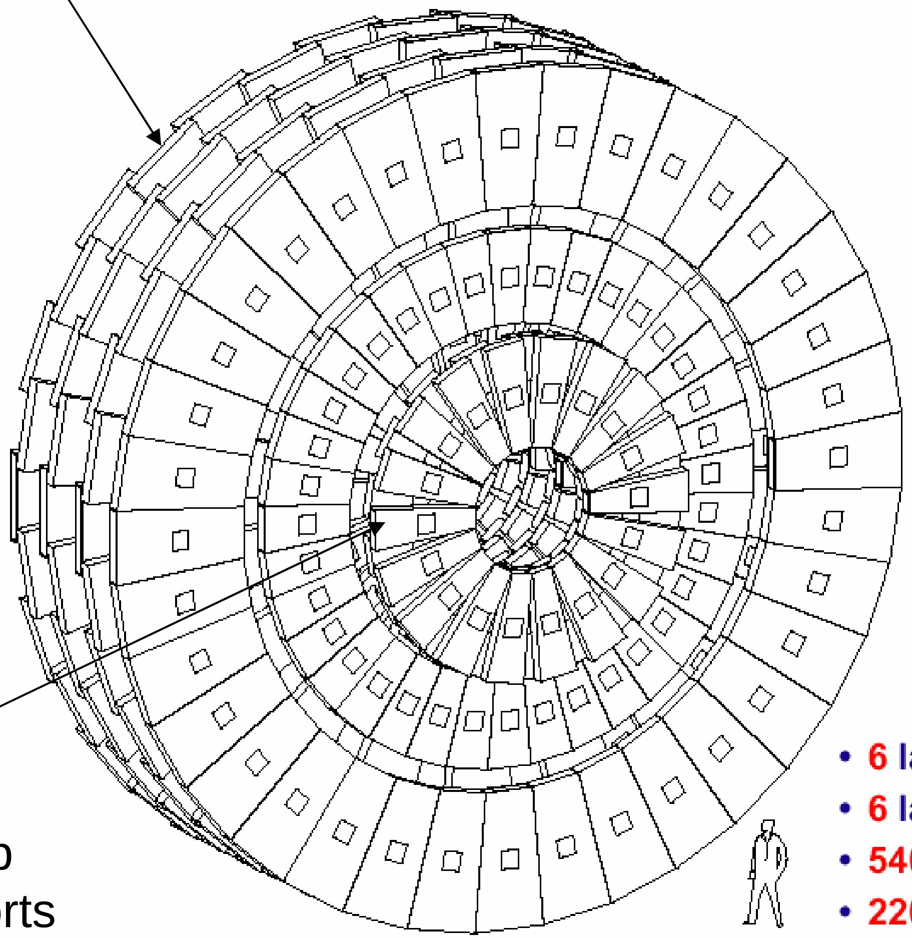
Muon Barrel: RPCs

- All 6 sites are in operation
- Gap production is on schedule
- Chamber production delayed by 2.5 months (retrofits to solve material compatibility problems)

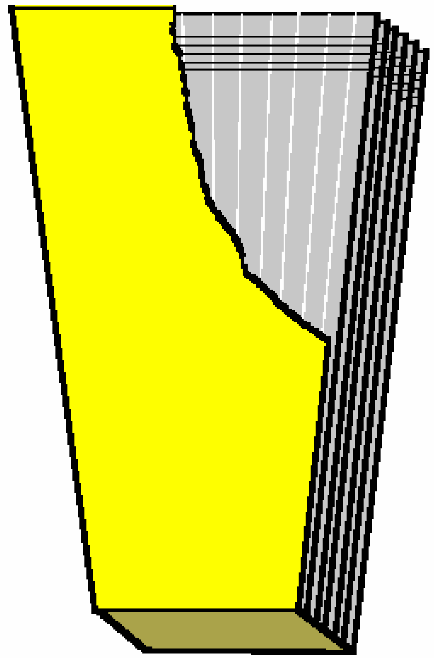


Endcap Muon System: CSCs

outer section of 4'th station staged



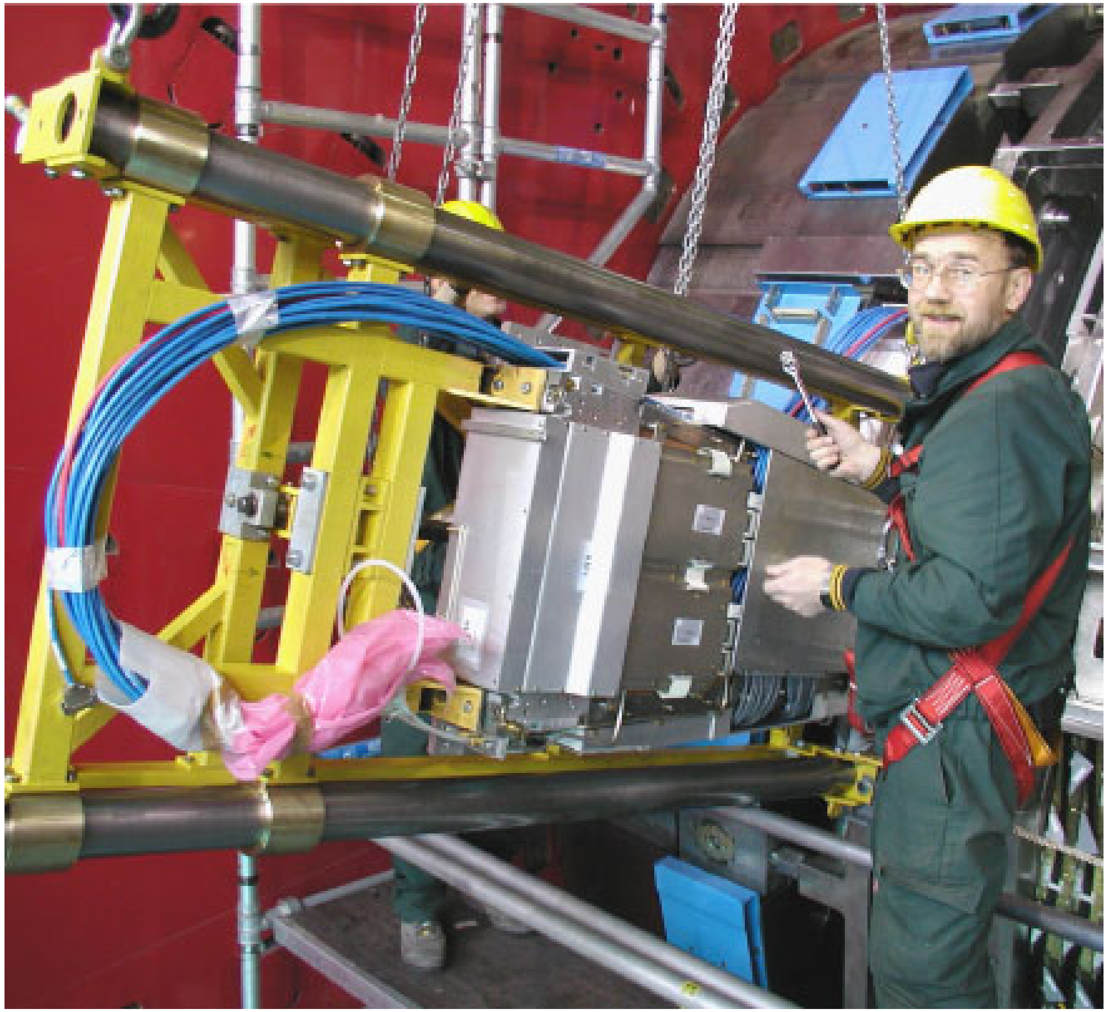
special design "ME1/1" CSC's inserted in endcap calorimeter supports



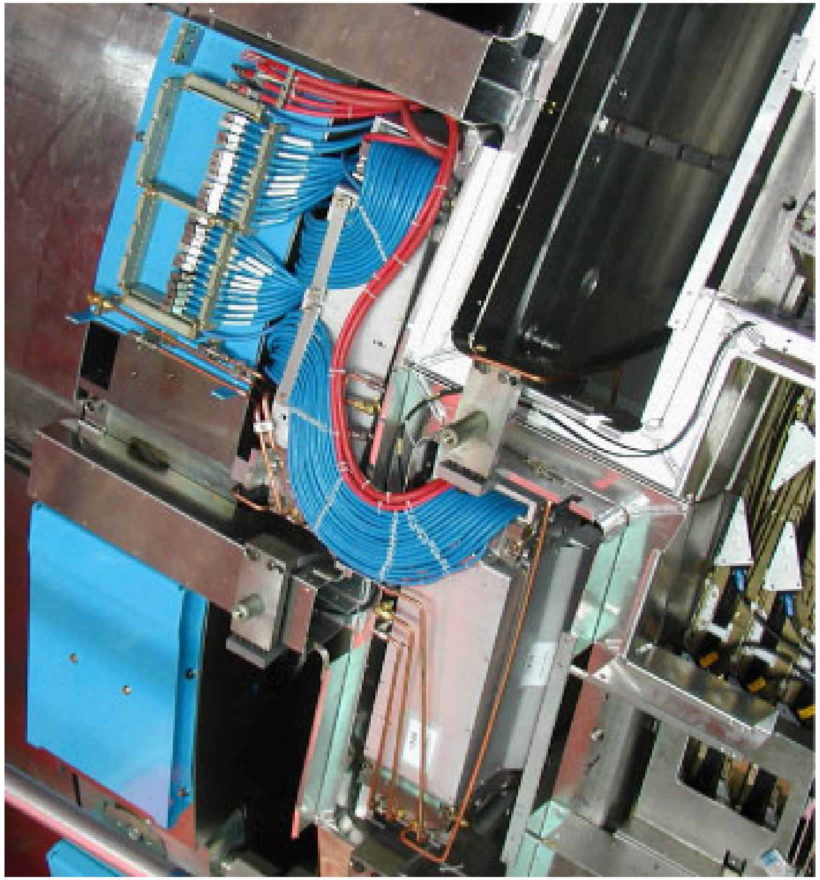
- 6 layers of radial strips / station
- 6 layers of tangential wires /station
- 540 chambers
- 220 000 anode strips
- 320 000 cathode wire groups

1'st endcap μ layer (ME1/1) Installation

ME1/1 Trial Installation



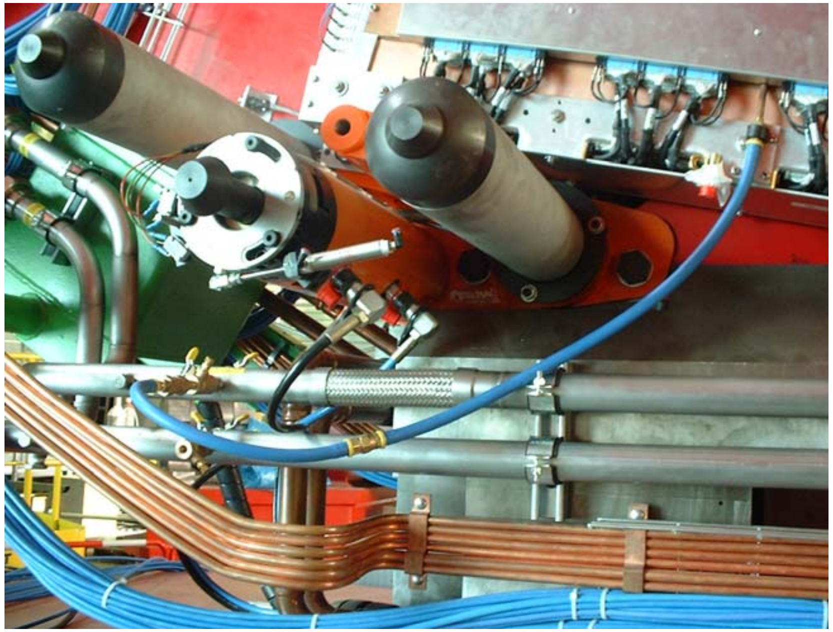
2 CSCs with ME1/1 cables and services up to the patch panel were successfully installed on YE+1



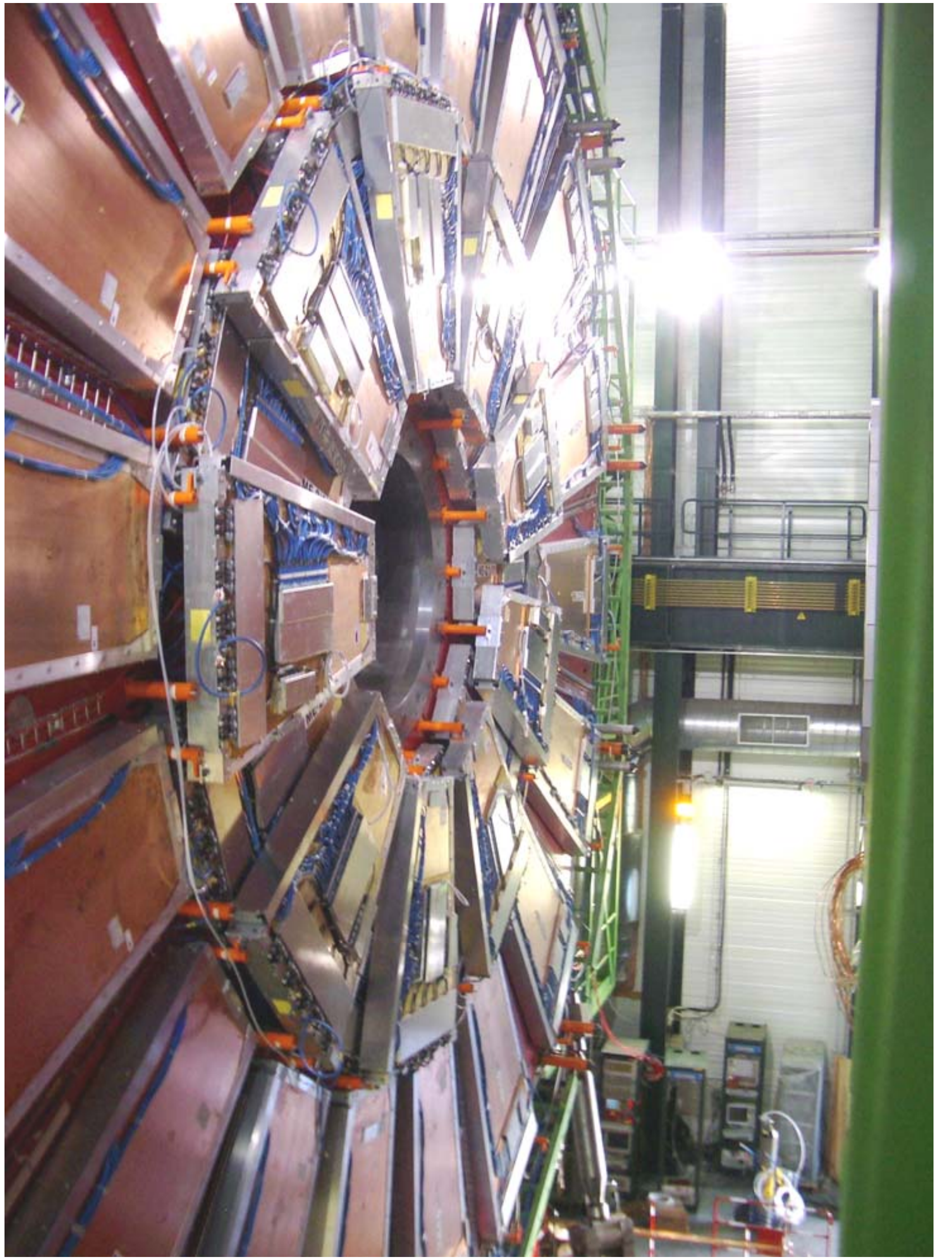
Standard CSC chamber installation

468 chambers needed
construction ~ complete
79% tested
65% delivered to CERN
25% installed

Services (gas,cooling) installation
underestimated, but now well advanced

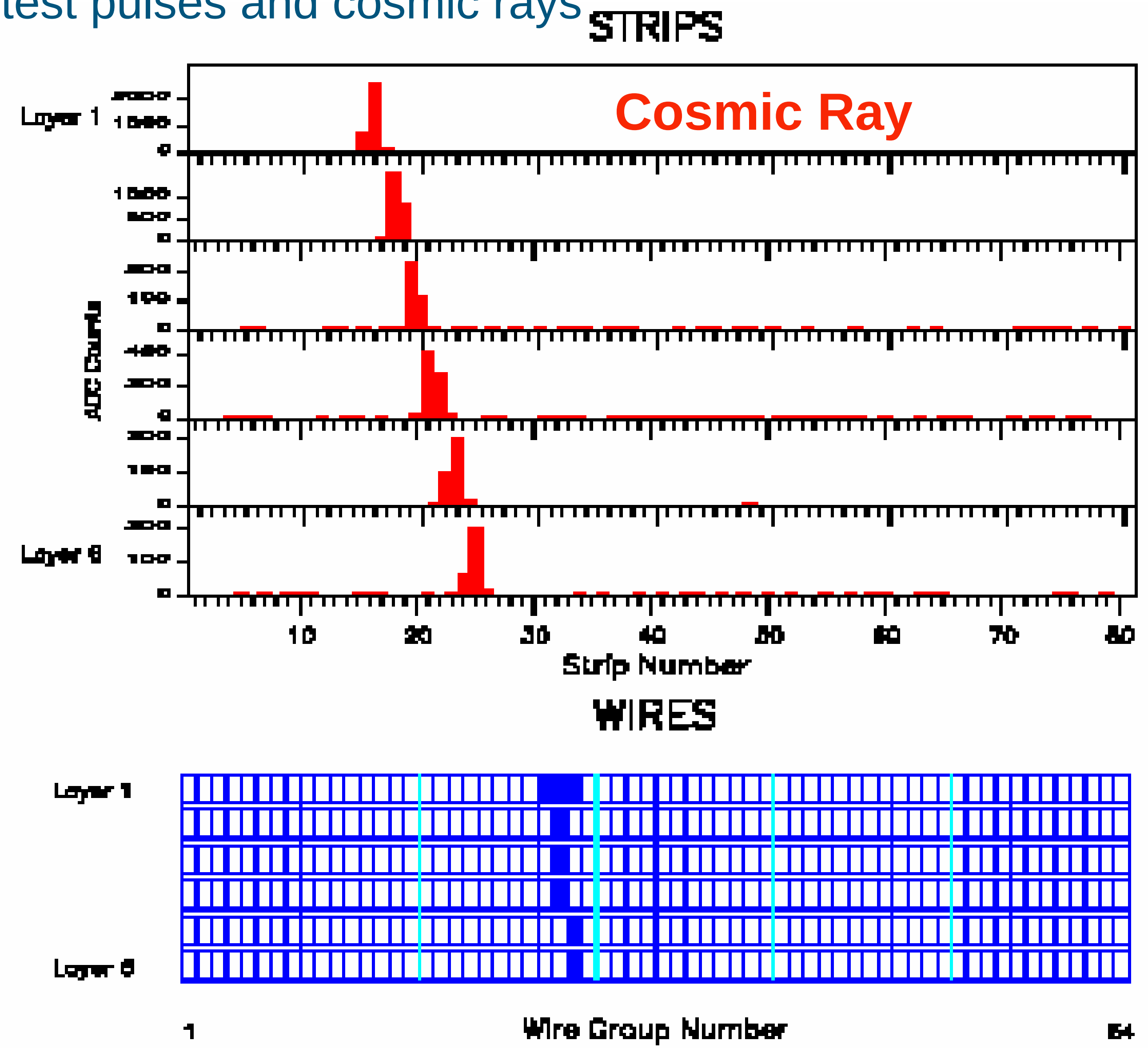


Finish CSC installation on surface



Commissioning of installed CSCs

using test pulses and cosmic rays



First particles detected by installed "CMS" subsystem!!

End-Cap RPC Gap & Chamber Assembly

K
O
D
E
L

“Gap” assembly
South Korea

Assembly and test line for 1’st station (on critical path) ready at CERN.
Preseries of 3 chambers assembled.

Mass assembly starting now, gaps arrived from Korea to be inserted in mechanical structures from Peking University, already at CERN.

2’nd line starting in Pakistan later this year

Install (with CSC) on surface

Hadronic Calorimeter: HCAL

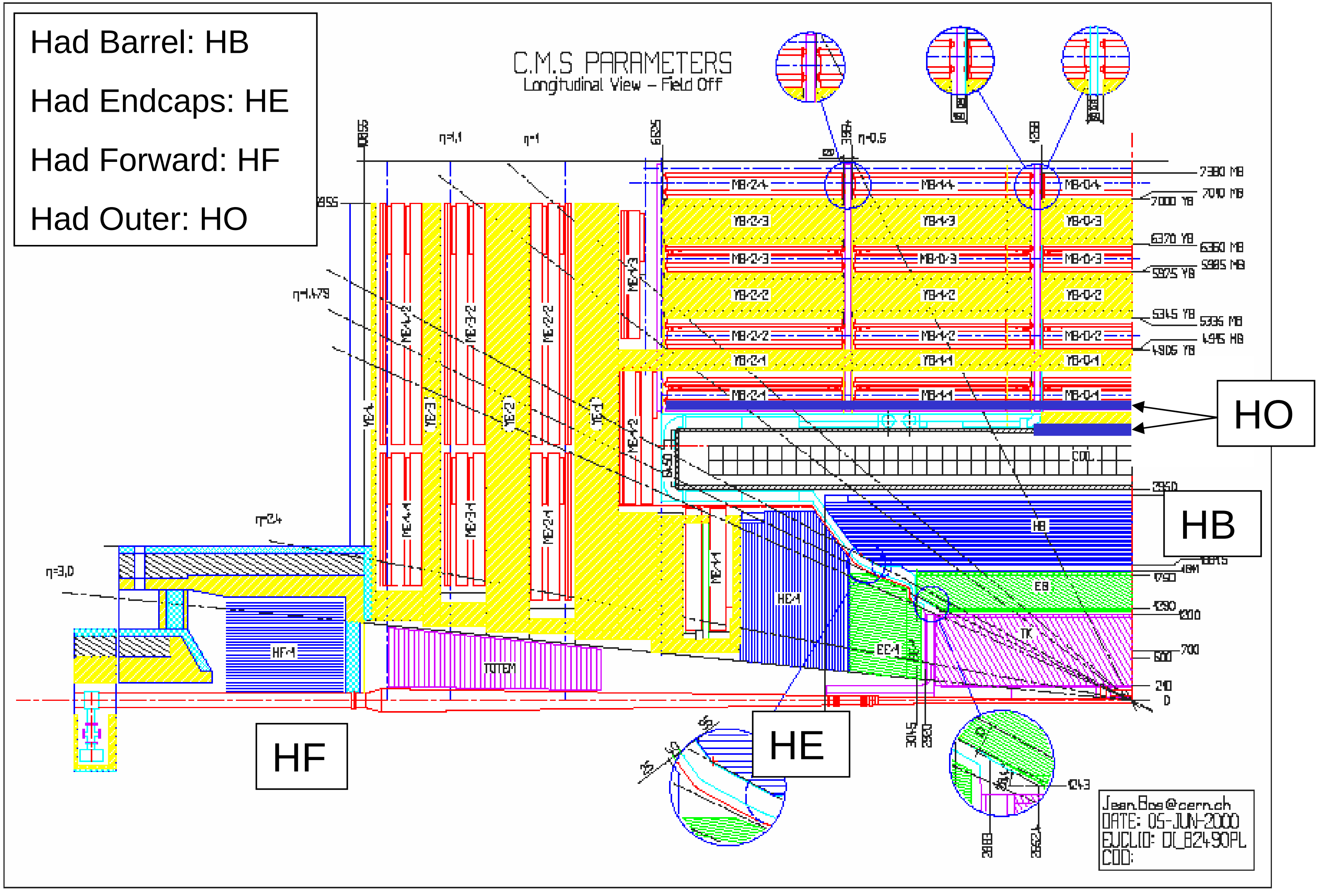
¼ longitudinal slice

Had Barrel: HB

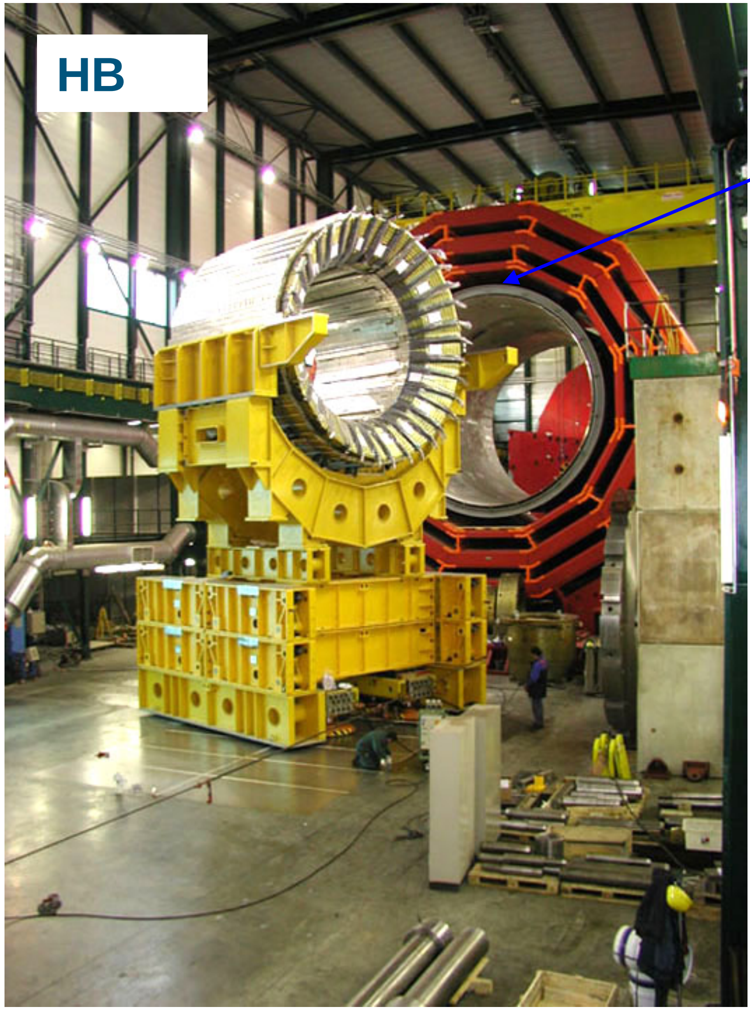
Had Endcaps: HE

Had Forward: HF

Had Outer: HO

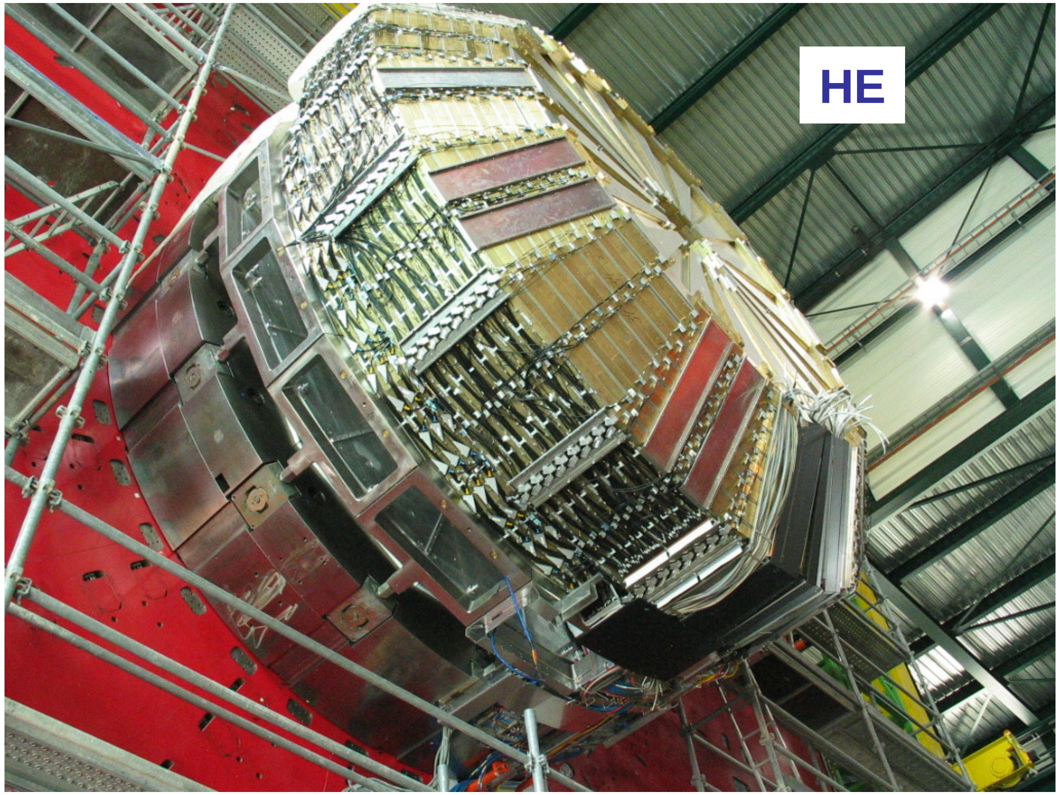


Hadron Calorimeter-Absorbers Complete



HB and HE absorbers are complete with scintillator layers

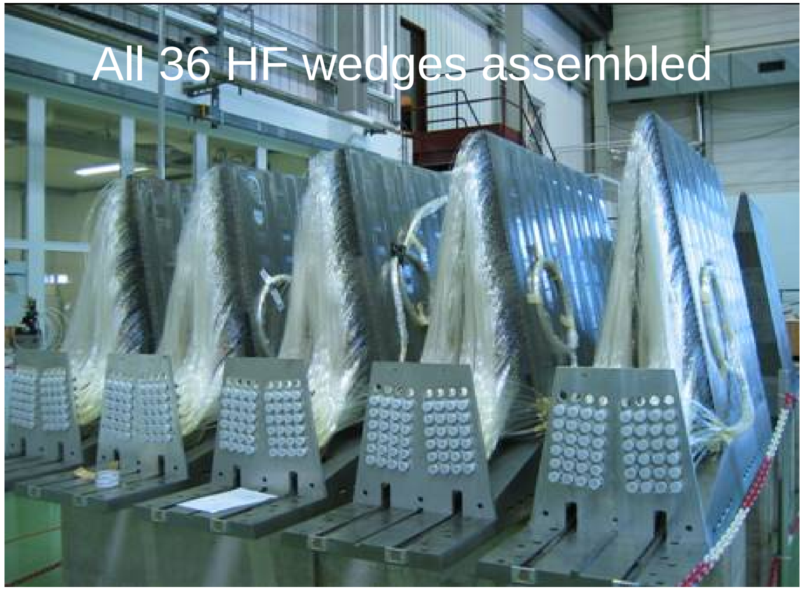
HO to be inserted into thermal screens this summer



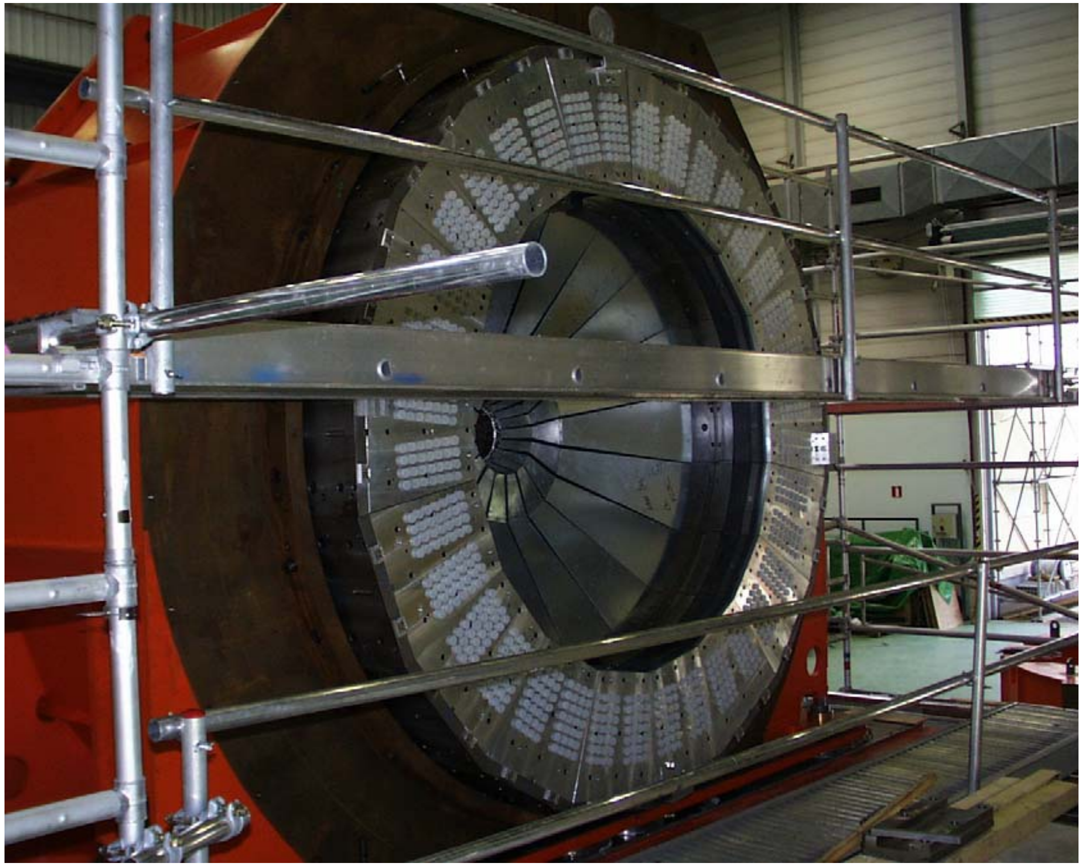
Install electronic readout boxes & start cabling & commissioning in Autumn 2004.
(including a full calibration using wire-driven sources).

Insert HB in yoke for magnet test and close endcaps, July-Aug 2005.

Forward HCAL (HF)



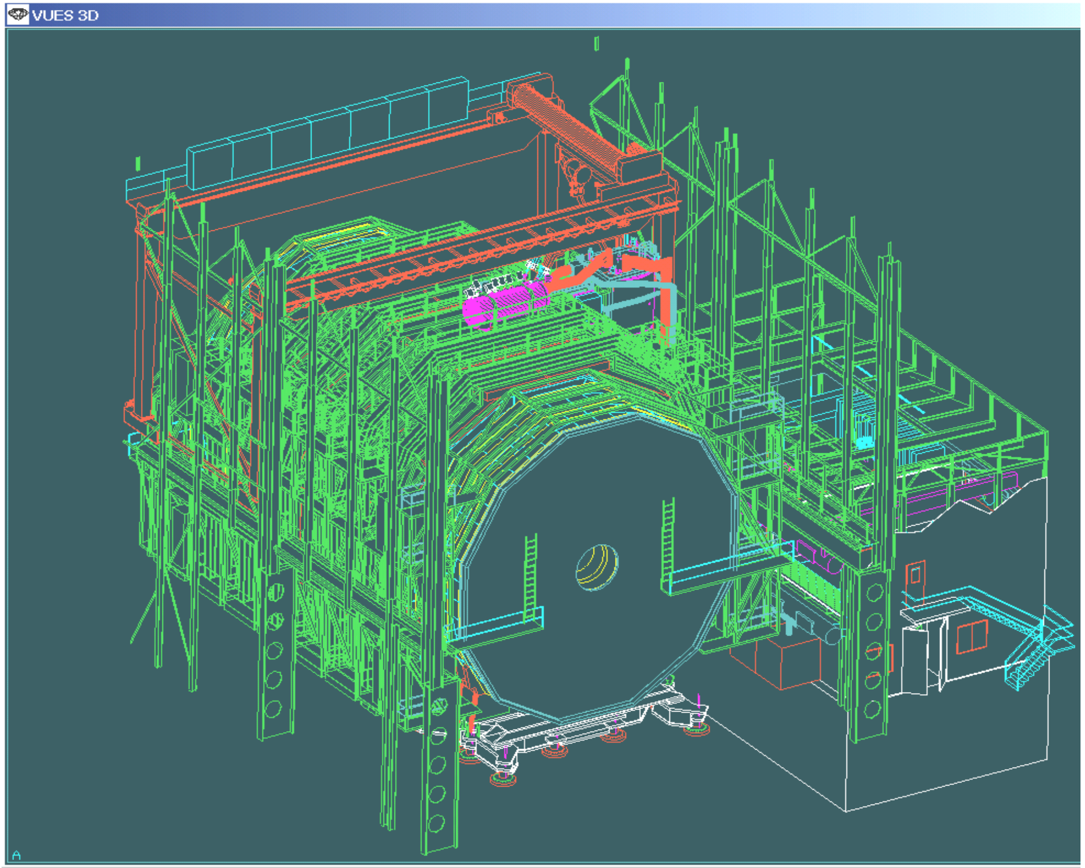
First (HF+) forward calorimeter assembled inside forward cylindrical shielding on adjustment table



First detectors to be lowered underground: Nov 05

Magnet Test in SX5

CMS closed for magnet test in SX5 surface building: Aug 05



Check functionality of :
magnet, including cooling, power supply and control system.

Map the magnetic field.

Check closure tolerances, movement under field and muon alignment system (endcap + barrel + link to Tracker).

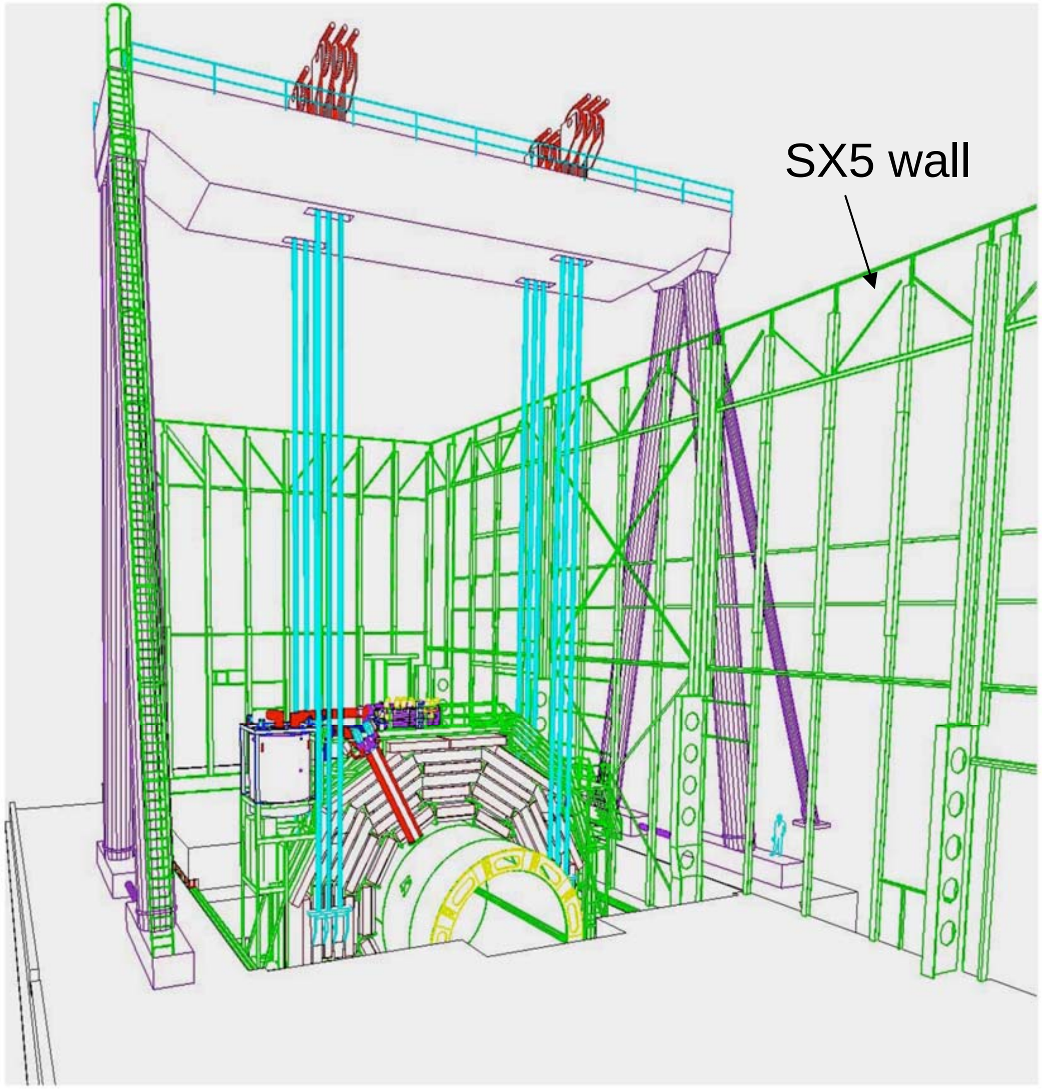
Check field tolerance of yoke mounted components.

Check installation & cabling of :
ECAL/HCAL/Tracker[dummy] inside coil, including cabling test.

Test combined subdetectors in 20 degree slice(s) of CMS with magnet. Try out operation procedures for CMS. (24/7 running).

Heavy lowering

Heavy lowering starts end 2005.



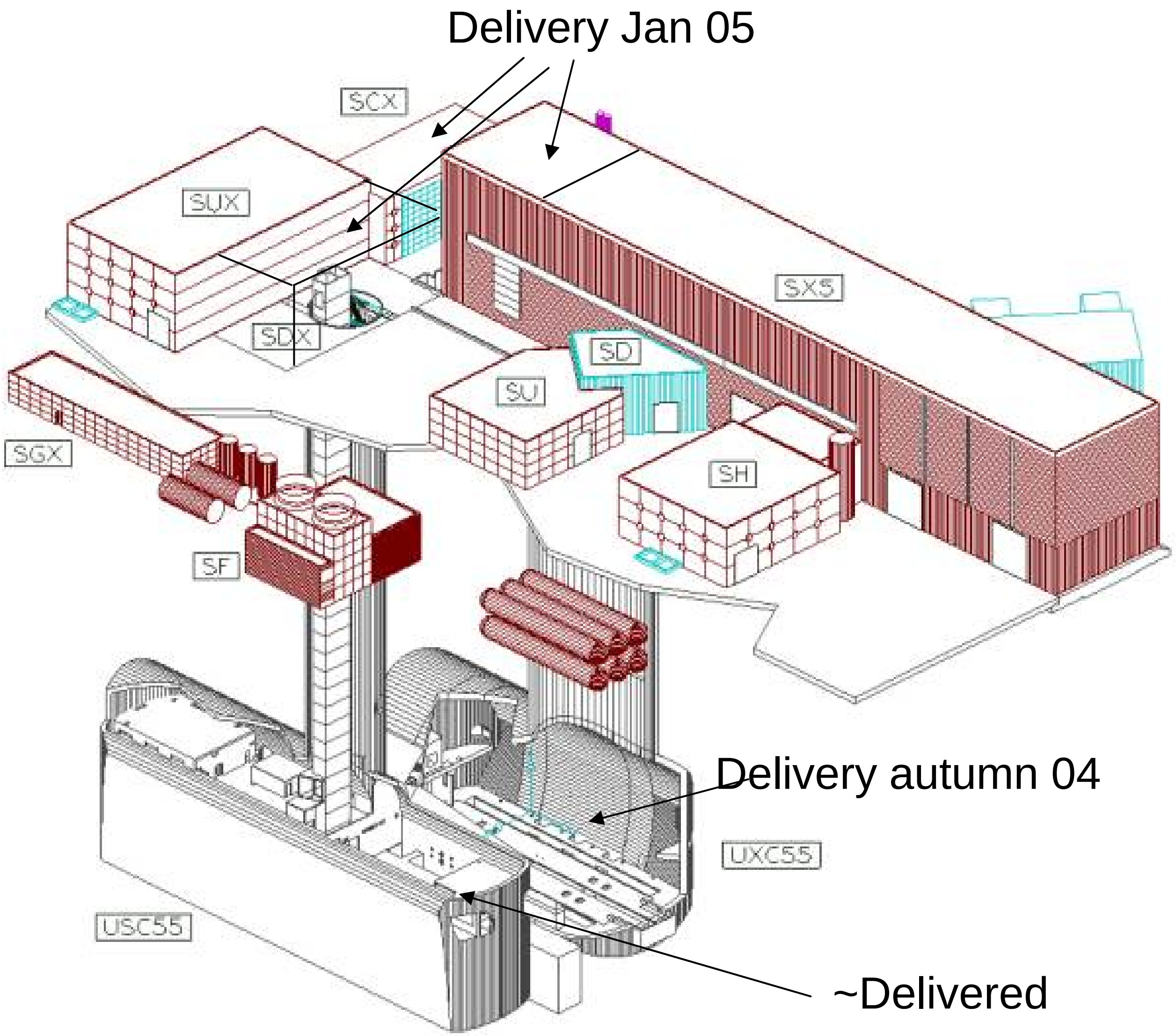
15 heavy lifts of about 1 week duration each.

Heaviest piece (central wheel + solenoid) 2000 tonnes.

2 lowest bids are within the budget foreseen (including insurance).

The cost of planned gantry idle time is reasonable: option to complete – z end on the surface, in parallel with critical path work on the +z end underground.

Civil Engineering for CMS



USC 55

Delivered to CERN after a big effort to recuperate delays.
(3 shifts running underground with up to 200 workers)

Net delay ~6 weeks

-trying to accommodated delays in schedule.

Aiming to be ready for installation of off-detector electronics crates in July 2005.

UXC55

Still working on crown concreting.

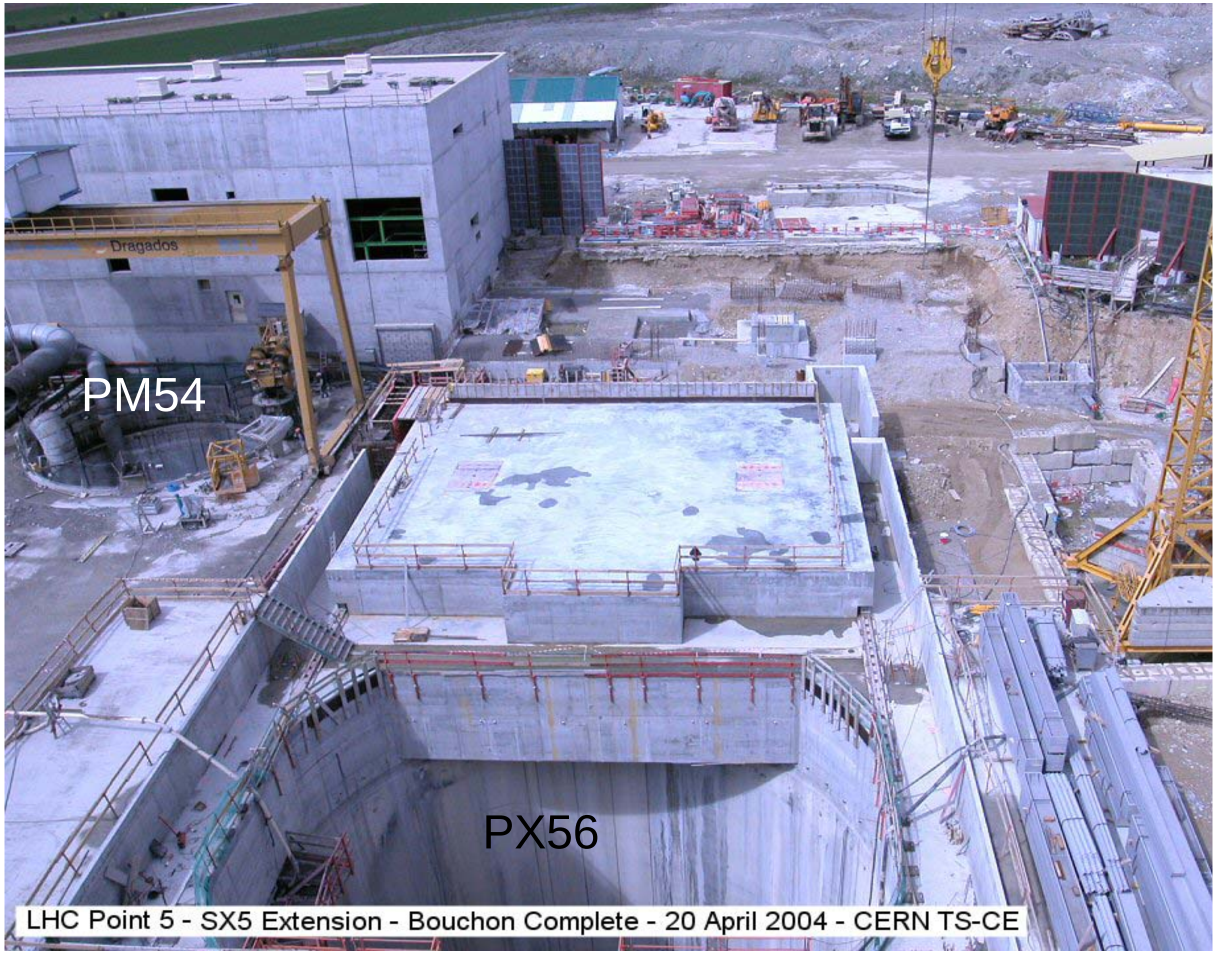
Delivery estimate:
Autumn 2004: still subject to uncertainty

"start of heavy lowering"
(ie ready for experiment)
~ end 2005.

ready for near-detector electronics, power supplies etc ~ April 06

Civ Eng: SX5 and pit-head cover

SX5 Jura endwall removal summer 04, pillars in place to extend SX5 over PX56

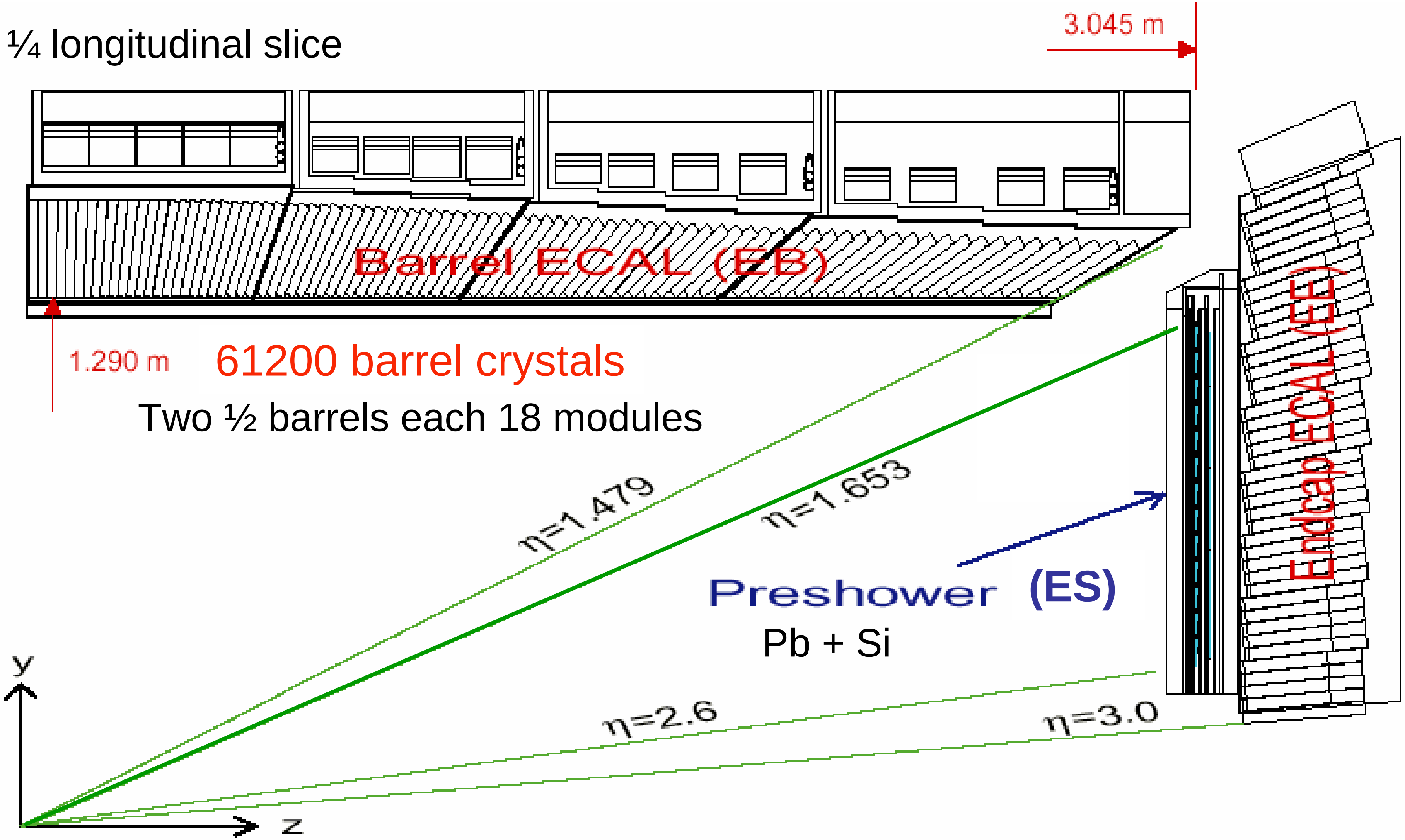


Pit-head cover 1m moving trial completed successfully

awaiting completion of reinforcement in UXC joint to PX56 before closing for first time (imminent)

Electromagnetic Calorimeter

¼ longitudinal slice



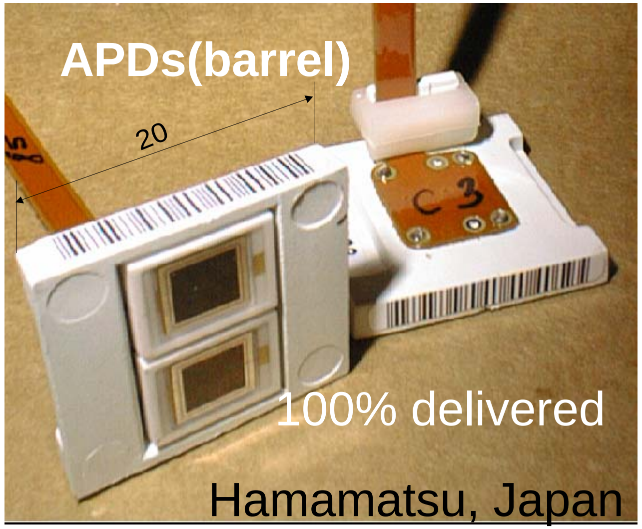
14648 endcap crystals

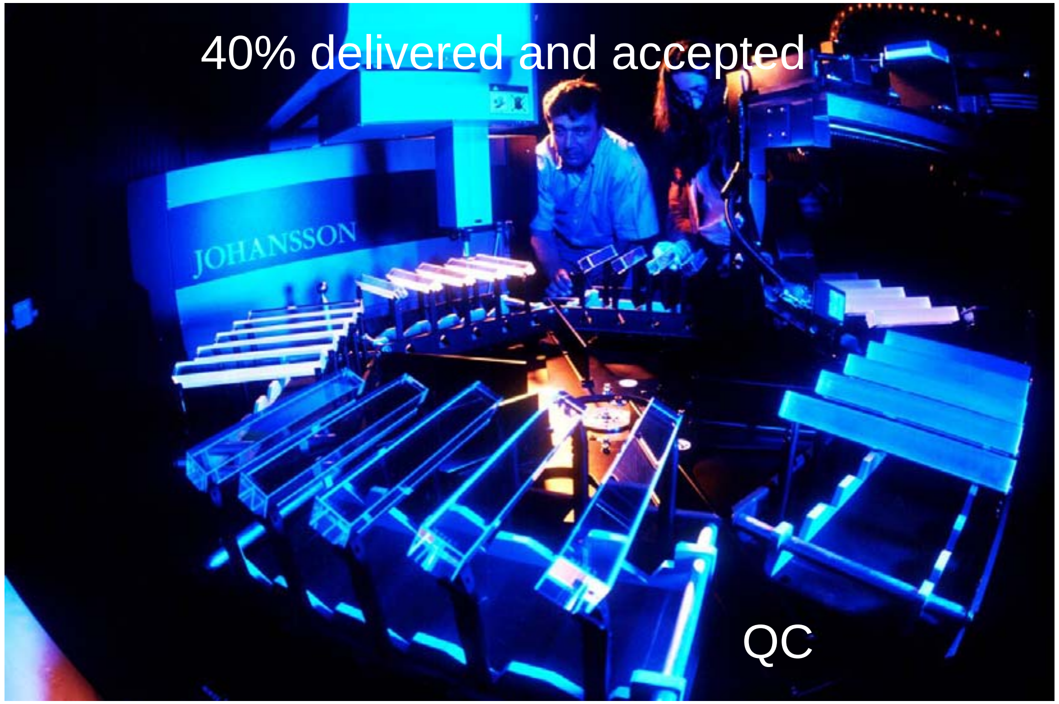
2 "dees"

per end

Installation EB	: on surface after magnet test: (at least 1'st ½ barrel)
	: underground: remainder of second ½ barrel (2006)
EE	: underground, in 07-08 winter shutdown

ECAL crystals+transducers





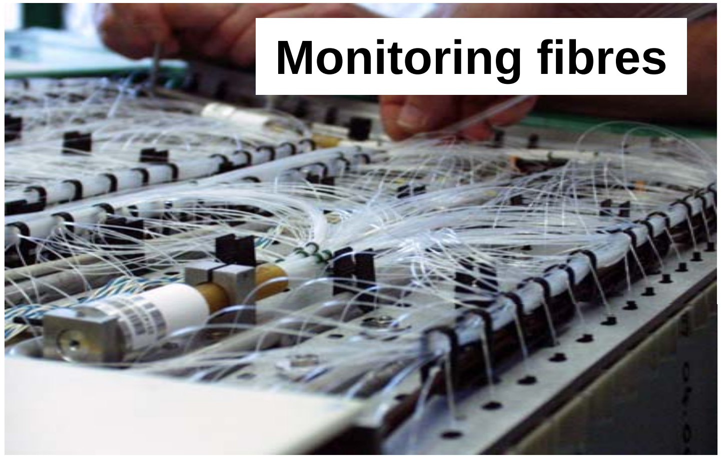
Supermodule Assembly

Assembly hall

13/36 bare SM's assembled

SM with Cooling System

Monitoring fibres



First SM in test-beam this autumn

ECAL: risks to schedule

- Unexpected demands from sole qualified crystal supplier earlier this year:
  Substantial increase in unit price + reduction in production rate
  (1000 barrel crystals/month: 1 crystal per boule).
  Production stopped for 2.5 months during re-negotiations

- Interim Agreement now in place
  (oversight includes Russian labs and government)
  - production restarted in April: 152 ovens now in operation
  - 1400 crystals produced & delivered in May and first half of June
  - production rate of 1200/month from Oct. 04 agreed (still 1 crystal per boule)
  - current contracts will end in June 2005
  - 20k barrel crystals still needed by June 2006

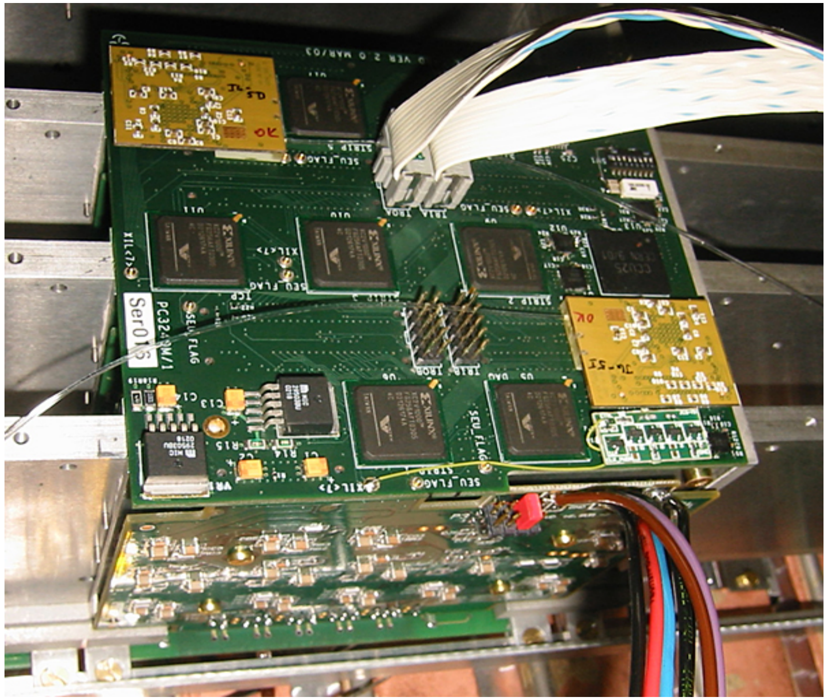
  ⇒Good progress in qualifying 2 alternative suppliers
  ⇒Tender for remainder of barrel and endcap to be launched in next few weeks.

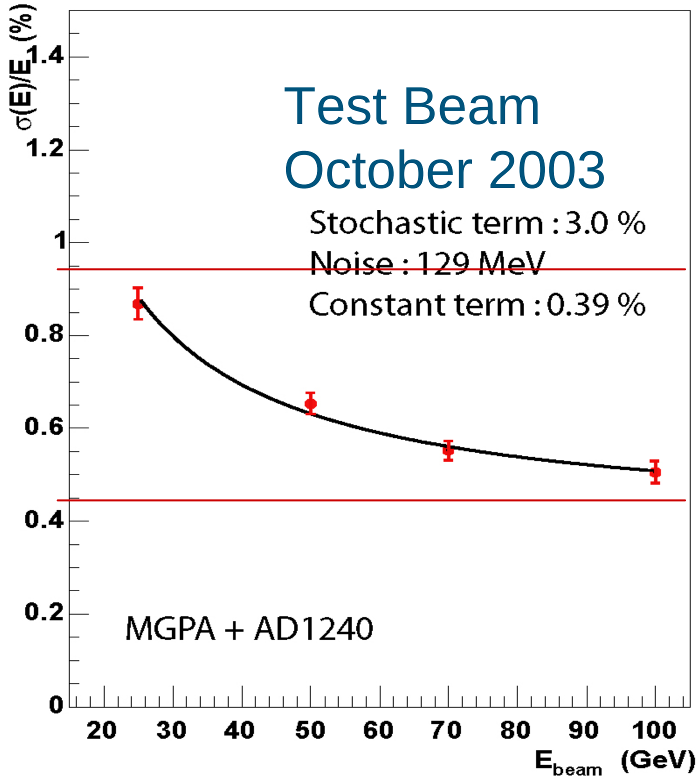
⇒ Arrangements for funding remaining purchases being discussed with agencies:
⇒ Strong support from CERN and agencies for completing barrel for end 06 and endcap for end 07.
⇒Provision for late installation of a few/36 barrel supermodules, as necessary.

ECAL: Front-End Electronics

Re-design in 0.25 μm electronics has been very successful!

25 channels ECAL Trigger Tower





ΔE/E

1%

0.5%

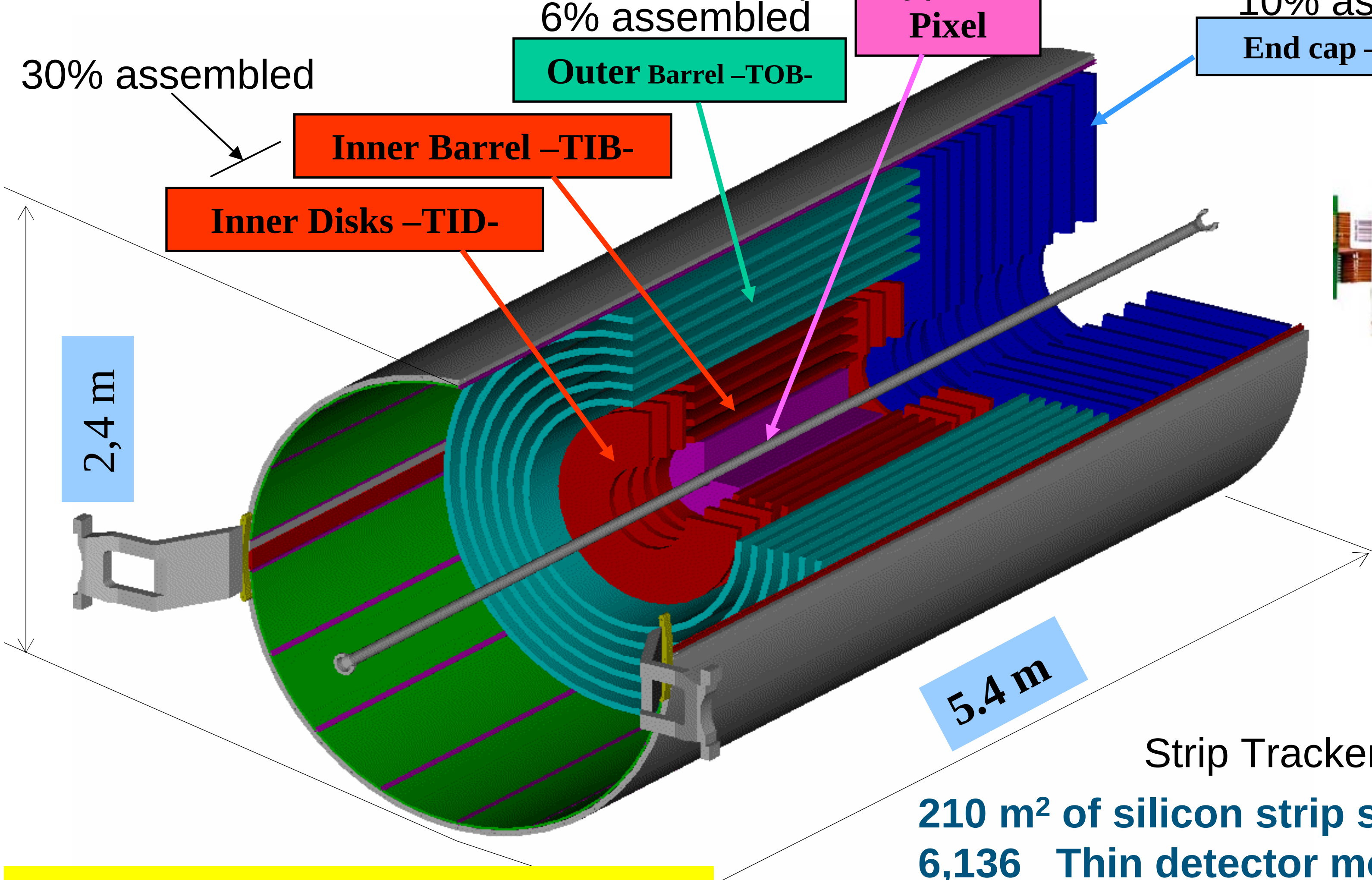
Developed four new chips in 0.25μm technology over the last 18 months

Engineering run for ASICs (4 chips) successful (enough for 3 SMs)

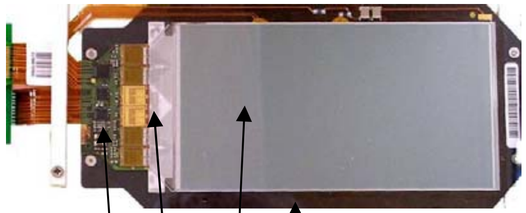
Launched full production of ASICs (ADC, MGPA, other will follow soon) .

Fully equipped SuperModule in beam-test by the end of autumn 04.

Tracker



strip Tracker module



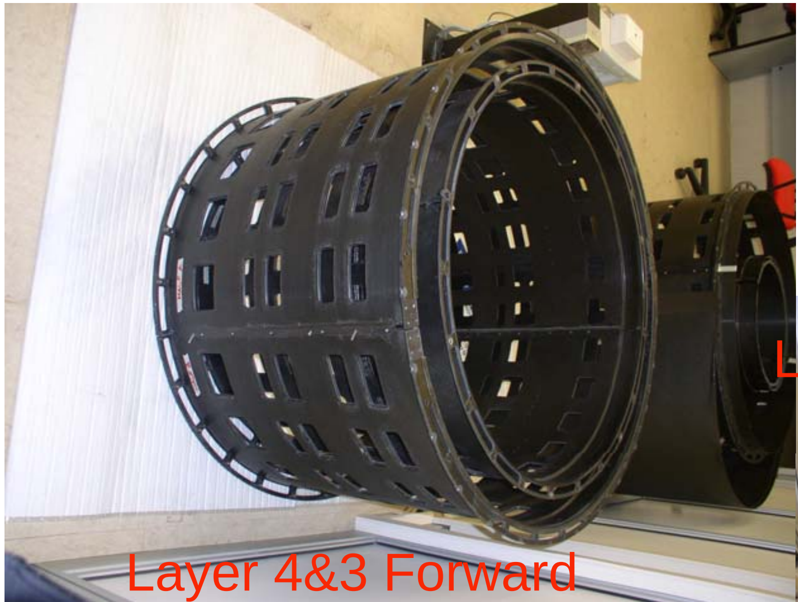
Strip Tracker

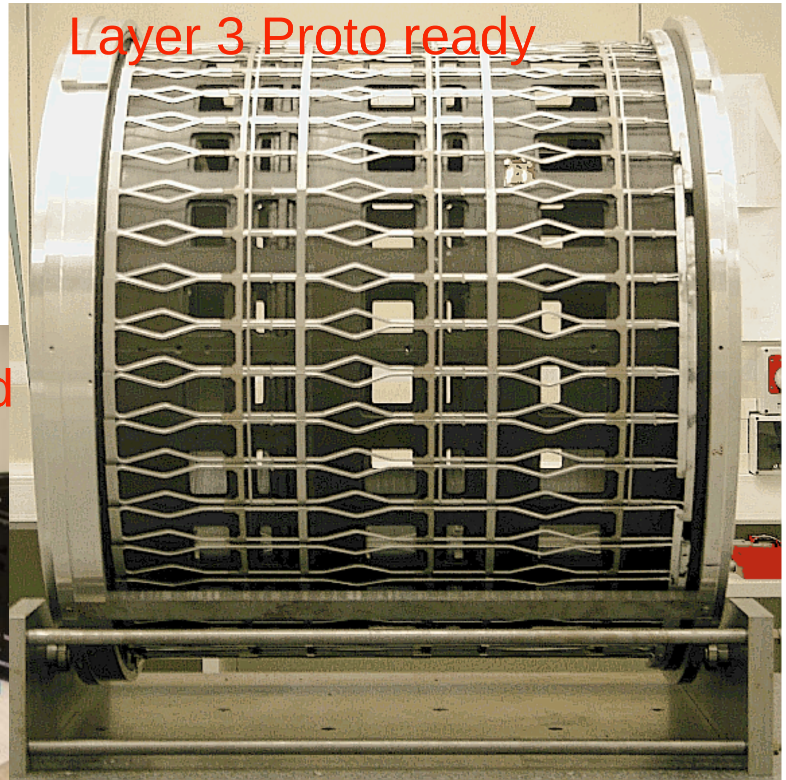
210 m² of silicon strip sensors
6,136 Thin detector modules (1 sensor)
9,096 Thick detector modules (2 sensors)
15,000 modules, 25M wire bonds
9,648,128 electronics channels

Re-design in 2001
Homogeneous Si technology
Ready for Installation target: May 06

TIB Mechanics (Pisa): 4 Layers

All TIB support layers completed: L1, L2, L3 and L4 (F/B).
Surveyed TIB layers: L1B and L4F/B.
Layer 3 Proto: ready for module integration.

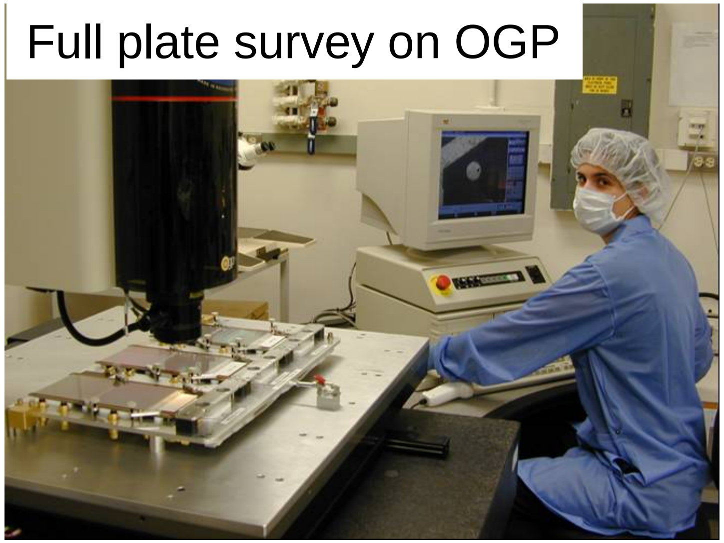




TOB Module Production (UCSB, FNAL)

UCSB Gantry Team at work

Full plate survey on OGP



Demonstrated peak capacity of 15 modules/day

UCSB:	Jan 26 to Feb 9 (10 days)	150 modules
FNAL:	Feb 23 to Mar 8 (10 days)	150 modules

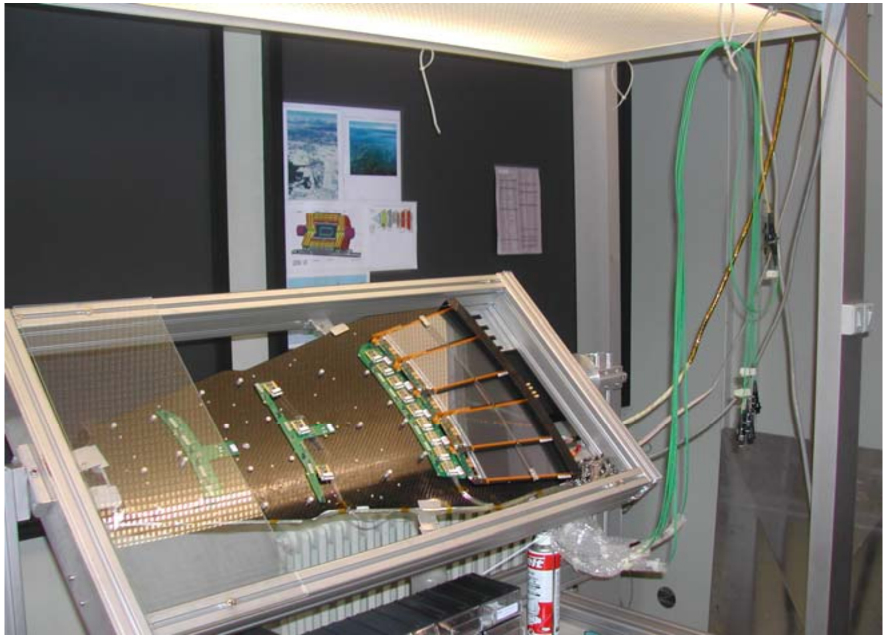
Using best thick sensors from STM.

1 day production: 15 modules
curing under vacuum

TEC Petal Integration and Test

TEC modules assembly:
Lyon, Brussels and US

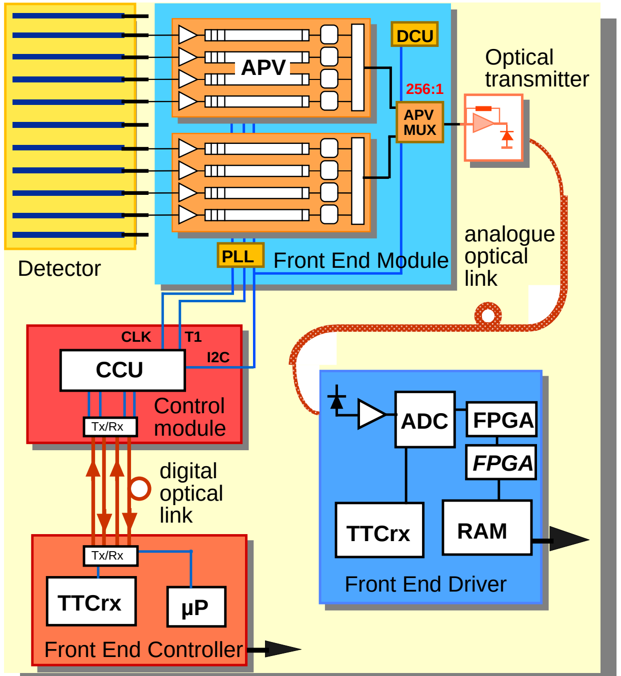
Petal Integration in Lyon



Karlsruhe: Petal Long-Term Test

Tracker: Electronics Status

- Components
  - production approaching completion
  - procuring spares
- Off-detector electronics
  - FED & FEC development complete
    - substantial software development
  - Power supplies
    - prototyping successful
    - tender action almost complete
- ESRs completed
- Emphasis now shifting to system implementation
  - many system and lab tests
  - Grounding and shielding



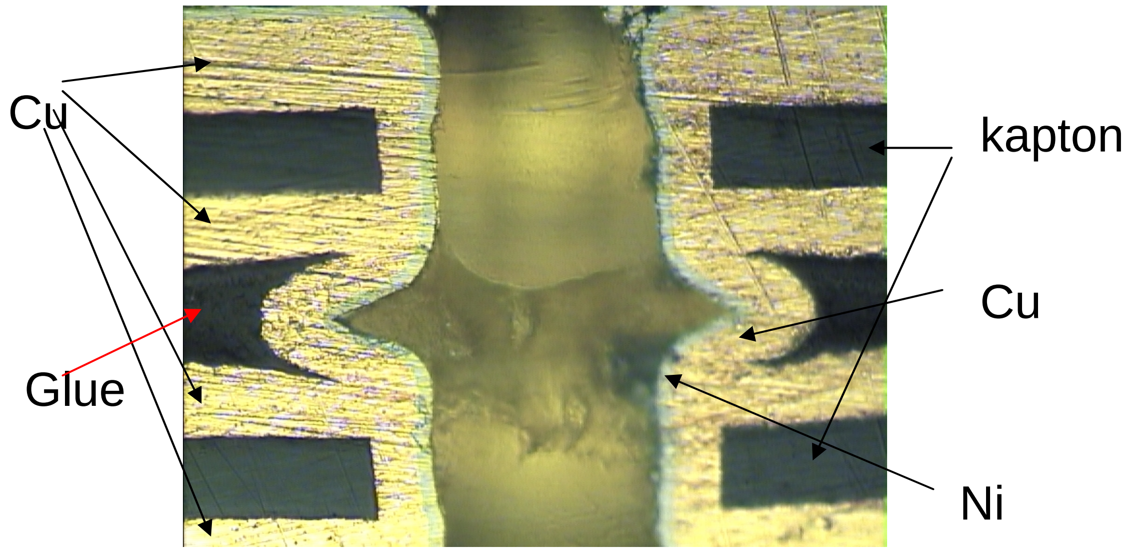
Risks to schedule: Si strip Tracker

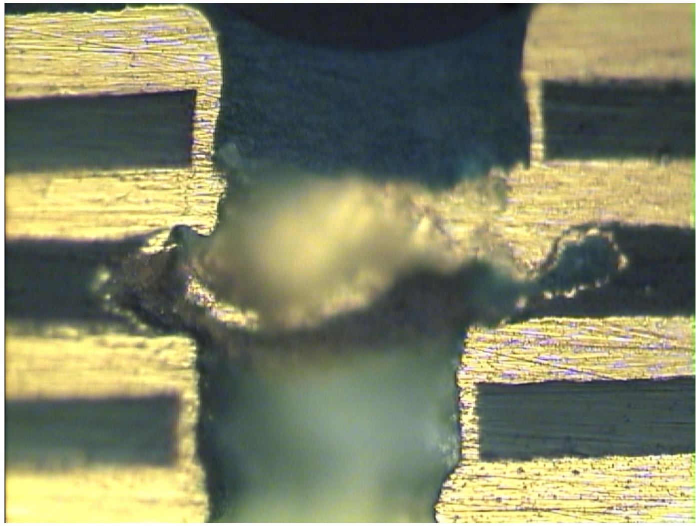
• Sensors from 1 of 2 suppliers out of spec or unpredictable long-term performance.

Resources diverted to quality checks: Module mass production delayed.

Action: Alter division of order between suppliers

• Hybrids have suffered a succession of generic faults: latest is “weak” vias

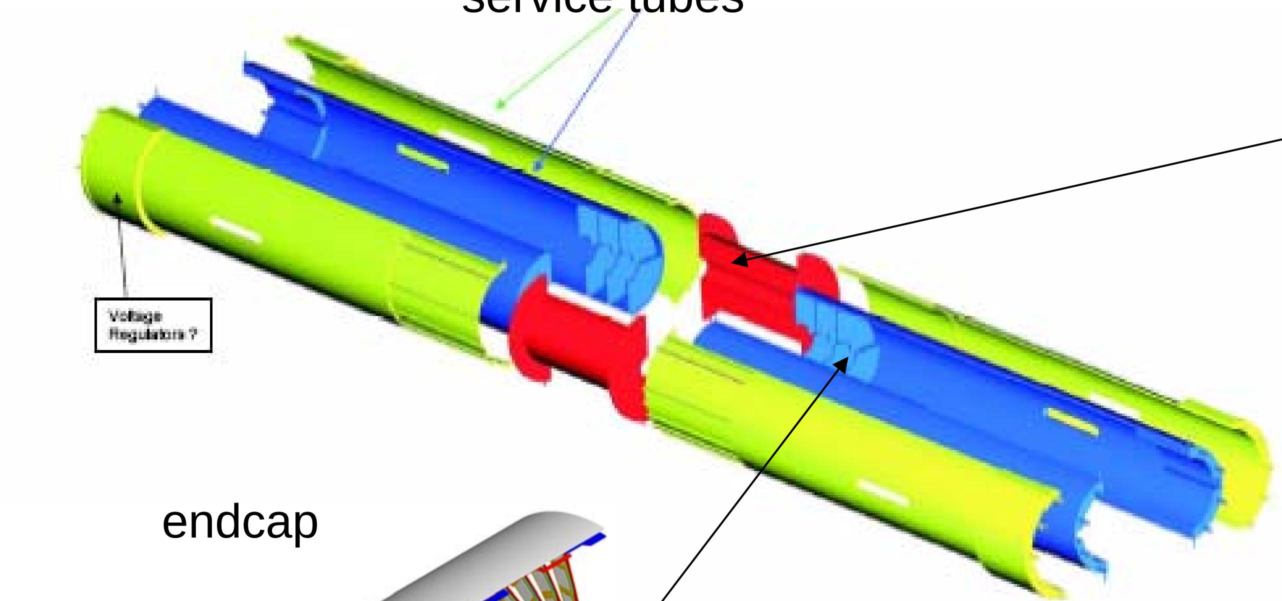




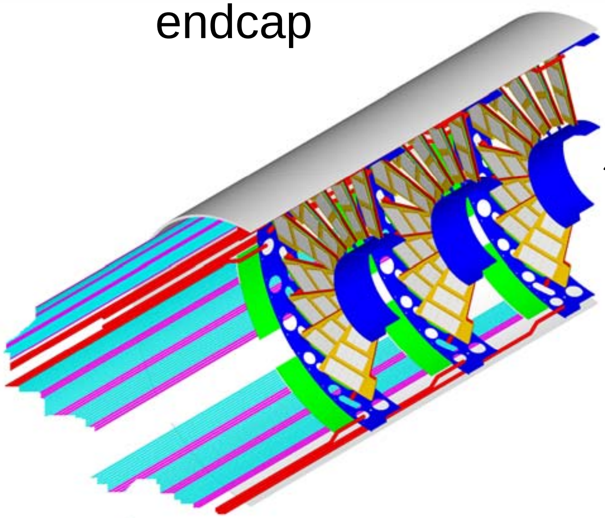
Faulty laser drill tuning and ignored QC indications. Value added before detection
Module mass production slowed or delayed: No contingency left in delivery schedule.
Needs very high throughput of automated gantries to achieve delivery target.
risk of similar late-identified fault absorbing a lot of added value
Action: provision for pre-cabling Tracker to allow later delivery on critical path
(invert 2 task bars on the Gantt chart)

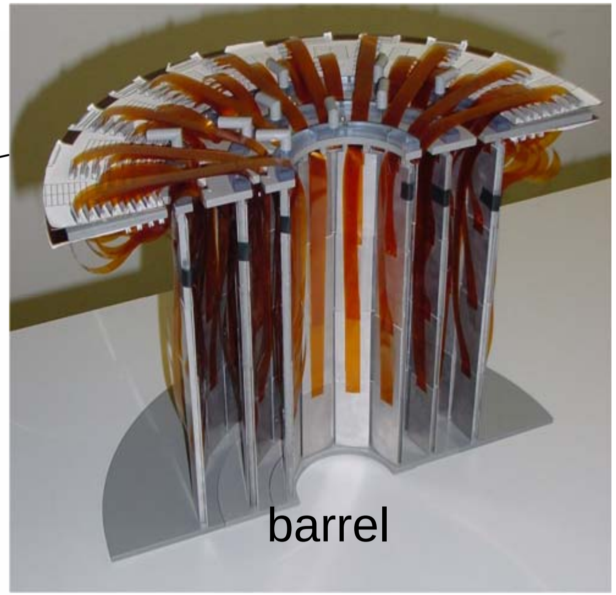
Pixel Tracker

service tubes



endcap





barrel

720 modules

12032 chips

50M channels

672 modules,
2-10 chips per module
4320 chips
18M channels

current plan is to install after pilot run
to minimise beam accident risks

Pixel Module Assembly Line

Vacuum system and mobile microscope

Glue underfill
(3b)

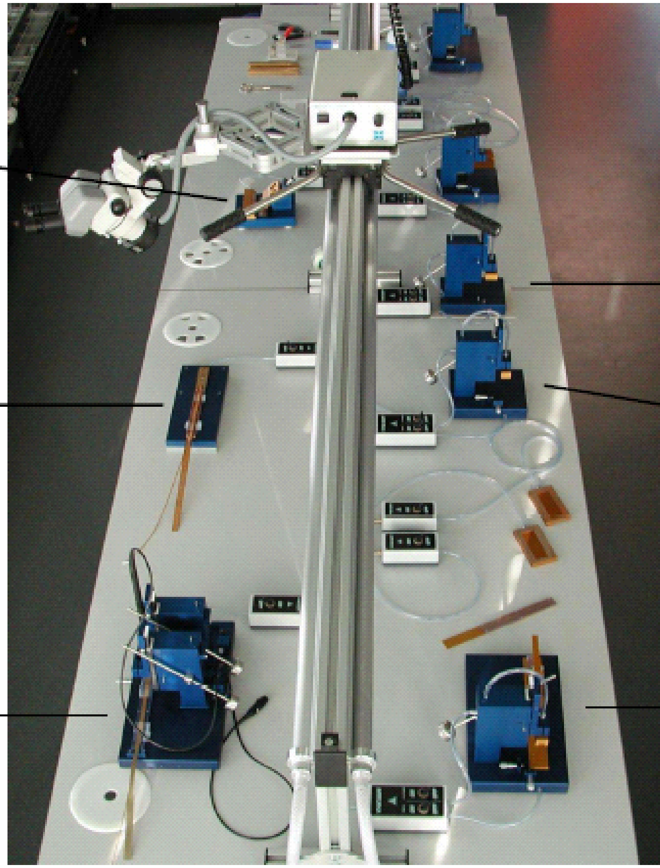
Glue application for Baseplate & Sensor

Mounting on Module Grip & adding TBM ...
(4,6,7)

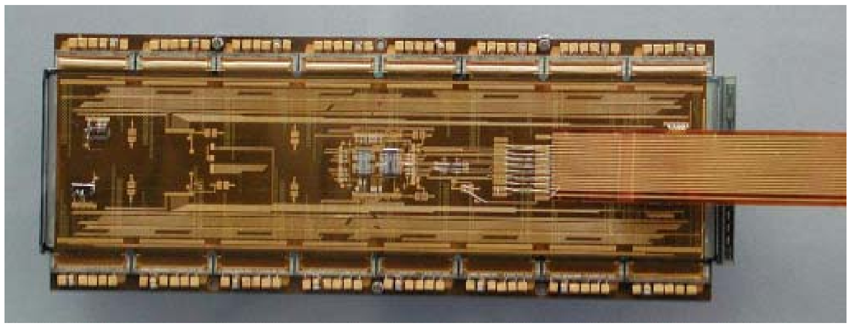
Baseplate – Sensor
(3a)

HDI equipping (cables)
(5)

HDI – Sensor & Mounting on Module Grip
(8)



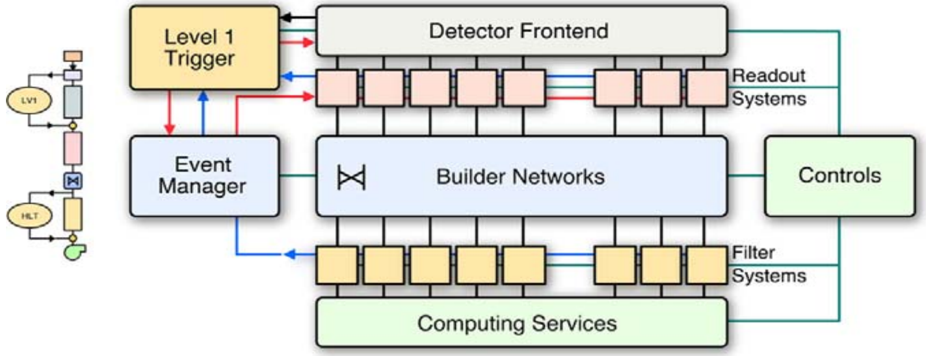
Pixel system on-course for 3+2 layers ready for installation in 2007



prototype module

CMS Trigger and DAQ

Principle

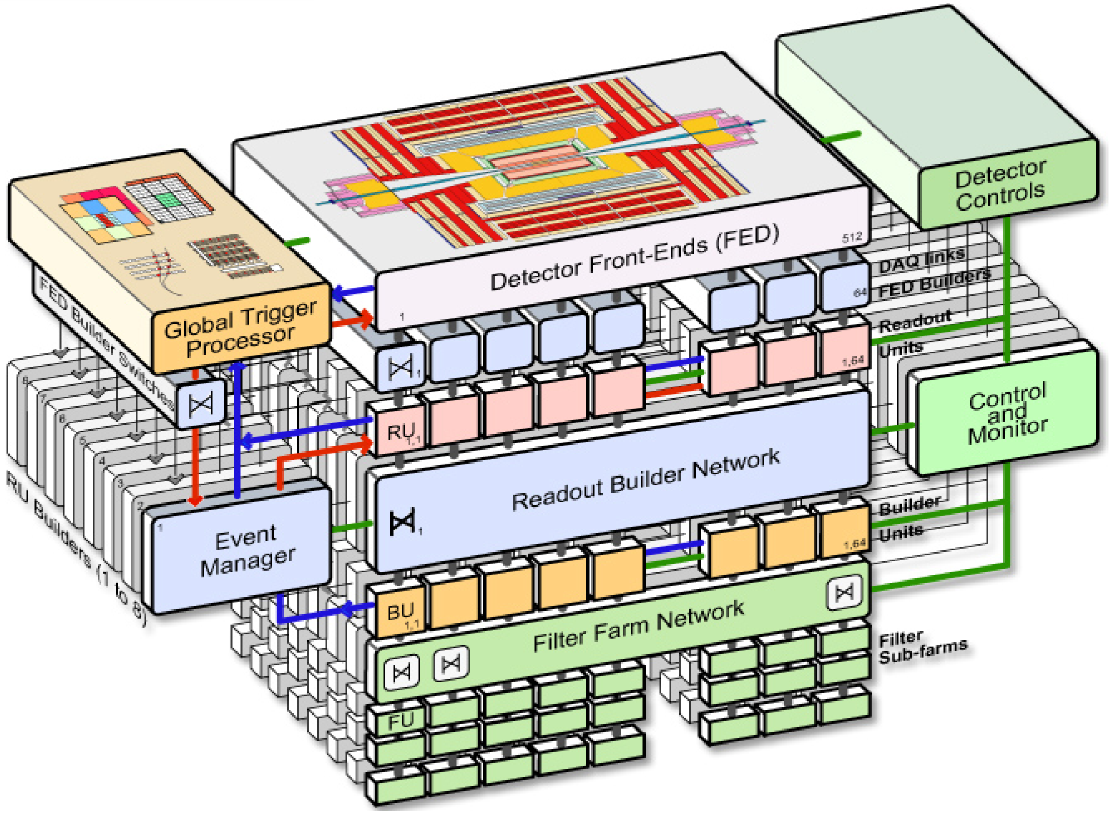


Implementation

40 MHz

100kHz

100Hz



Fully scalable:
8 x (12.5 kHz DAQ units)

Plan to install 4 units for LHC start-up

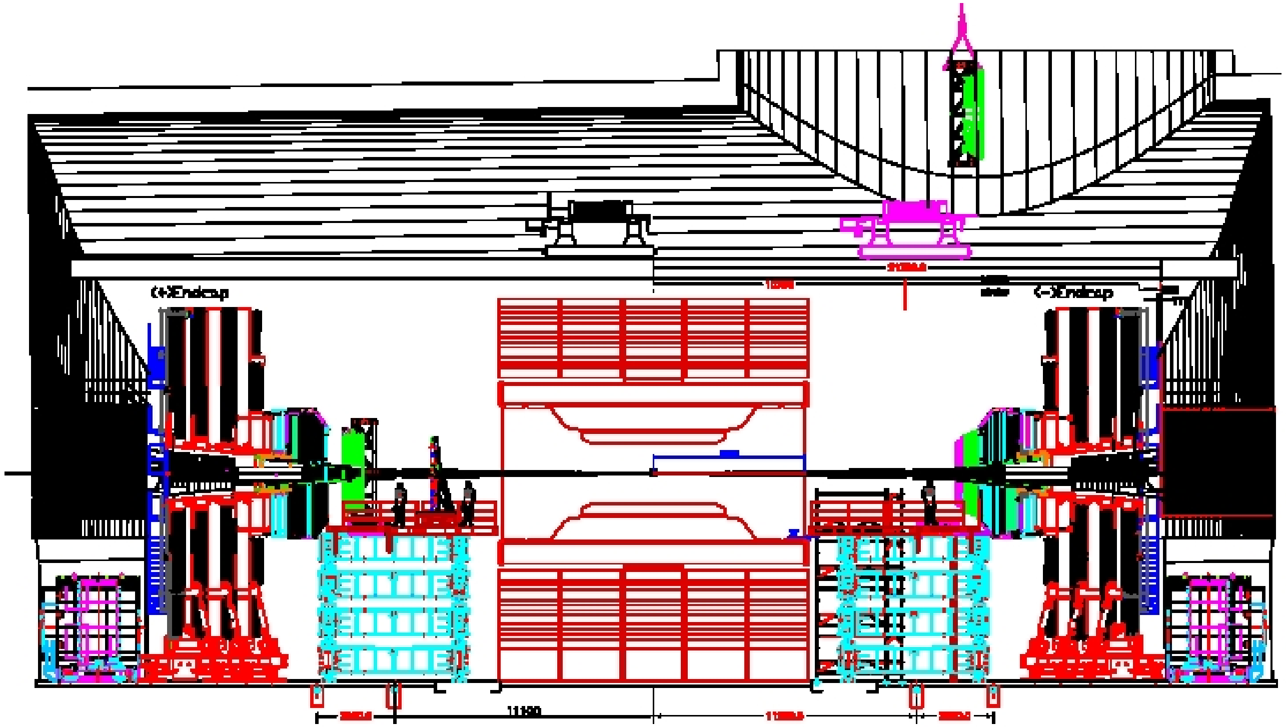
Trigger & DAQ

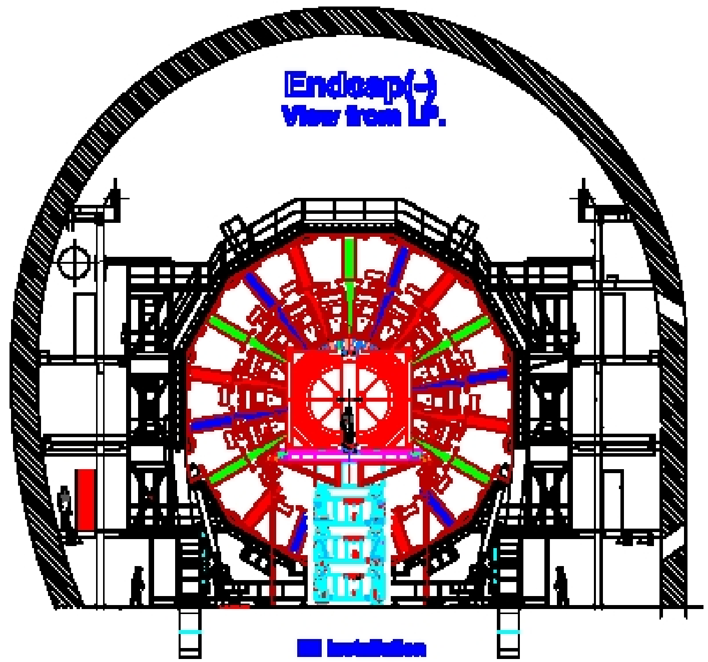
large effort in the last year to validate the DAQ architecture using prototype modules and emulators

1:8 scale DAQ system (preseries)installed at Point 5, implementing almost final functionality and nominal performance

“Ready to close” : April 07

“universal” EB/TK/Beampipe EE/ES installation platforms being designed for an efficient endgame





In this configuration, (barrel closed) we can continue to work (eg last EB- installation) and be ready to close at short notice

April 07 configuration

"Initial Detector" minus both electromagnetic endcaps (crystal ECAL+ pre-shower)
(unable to be installed by then due to: overall delays to critical path (Coil, Civ Eng.)
currently estimated crystal delivery profile)

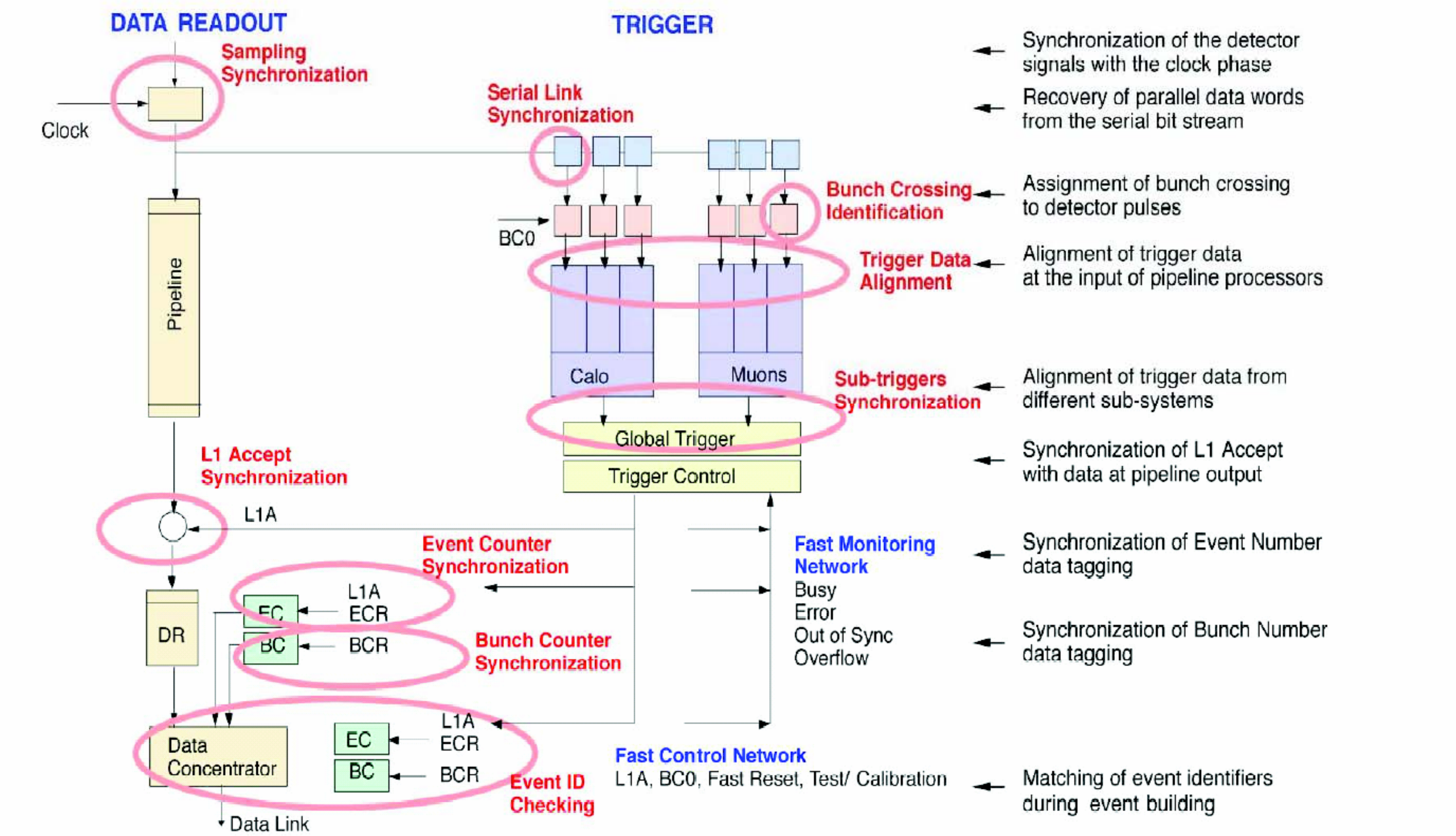
The **initial detector** has several officially staged items, notably:
- ME4/2 muon station (4'th endcap layer,low eta part CSC + RPC)
- all high eta forward RPC's,
- 3'rd endcap pixel layer,
- 50% of the DAQ online farm.

preferred strategy (at present) is not to expose the pixel tracker to the risk of damage from first beams in 2007 ...but rather to install it after the pilot run in the 2007/2008 winter shutdown.
- to be reviewed in 2006 once the LHC start-up plan is better understood.

Commissioning

CMS has started holding "Run Meetings" to identify strategies for commissioning & potential pitfalls

synchronisation during trigger/DAQ system integration may be the trickiest issue



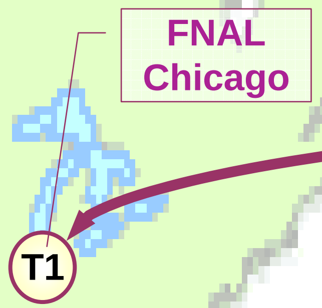
DC04 Data Challenge

T1 centres in DC04

- Pull data from T0 to T1 and store
- Make data available to PRS
- Demonstrate quasi-realtime "fake" analysis of DST's

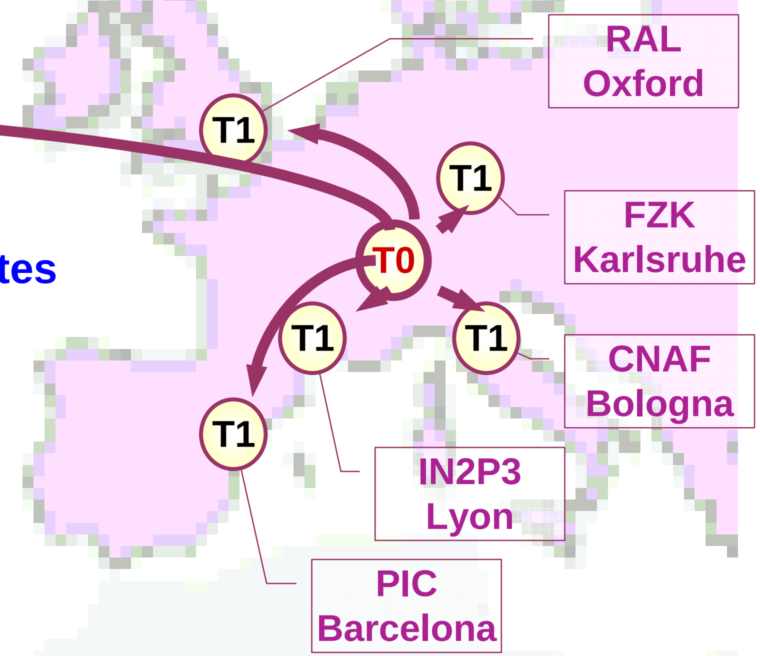
T0 at CERN in DC04

- 25 Hz input event rate
- Reconstruct quasi-realtime
- Events filtered into streams
- Record raw data and DST
- Distribute raw data and DST to T1's



T2 centres in DC04

- Pre-challenge production at > 30 sites
- Modest tests of DST analysis



•DC04 demonstrated that the system *can* work…
…at least for for well controlled data flow / analysis, and for a few expert users

•Next challenge: make it useable by non-experts & demonstrate that the performance scales acceptably

Conclusion

• CMS sub-detector construction and experiment assembly is proceeding well

-many problems have been overcome

-on course towards closing for magnet test in SX5 in late summer 2005, with hadron calorimetry, endcap muons and most of barrel muons installed and tested.

•The underground schedule target is to have CMS "ready to close" in April 2007 with the initial configuration complete apart from

-the endcap electromagnetic calorimeters

-the pixel tracker (by choice)

these detectors will be installed during the winter 2007-8

•Civil Engineering, ECAL crystal delivery and Tracker module assembly still present risks to this schedule…contingencies are being worked on.