CMS

Compact Muon Solenoid

Challenges, Status, Prospects

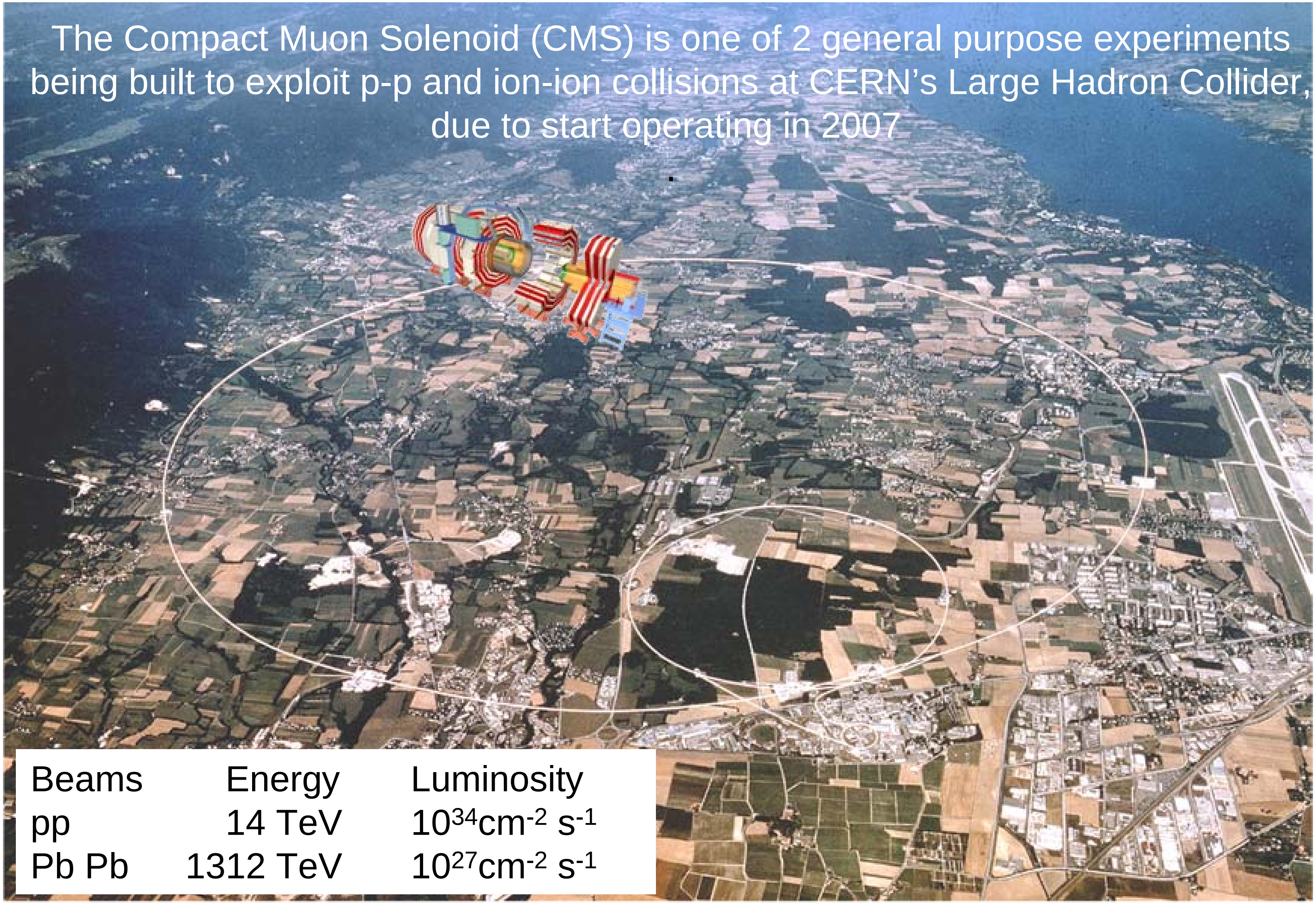
Austin Ball, Deputy Technical Coordinator

Workshop on Physics with LHC
Islamabad
16 Dec 2004

Objective & Challenges of the Experiment
Collaboration
Progress in Construction
Completing Construction for first LHC beam

CMS and LHC

The Compact Muon Solenoid (CMS) is one of 2 general purpose experiments being built to exploit p-p and ion-ion collisions at CERN's Large Hadron Collider, due to start operating in 2007



Beams	Energy	Luminosity
pp	14 TeV	$10^{34} cm^{-2} s^{-1}$
Pb Pb	1312 TeV	$10^{27} cm^{-2} s^{-1}$

Purpose of LHC experiments

Despite the phenomenal success of the "Standard Model" in describing the fundamental constituents of matter & the forces between them, many awkward and exciting questions remain

What is the origin of mass? (electroweak symmetry breaking)
Higgs mechanism?
New symmetry?
Extra dimensions?

What about gravity? Is "grand unification" with other forces possible?

Can a new particle explain "dark matter" which seems to pervade the universe?

Why does the Standard Model contain arbitrary features

Why does it give "nonsense" at very high energies

Do today's apparently elementary particles have substructure?

Is CP violation the origin of matter-antimatter asymmetry?

Does (did) the quark-gluon plasma exist?

Experiments and theory point to the LHC energy scale (~1TeV) to reveal answers.
LHC experiments will attack these questions; the general purpose experiments (CMS & ATLAS have been designed to particularly address electroweak symmetry breaking)

Benchmarks for physics performance

Physics objectives ––> performance requirements ––> technical design drivers

Principal benchmark: detection of Higgs boson, which would explain the origin of mass

easiest observed decay modes change with mass.

wide-ranging requirements for general purpose experiment

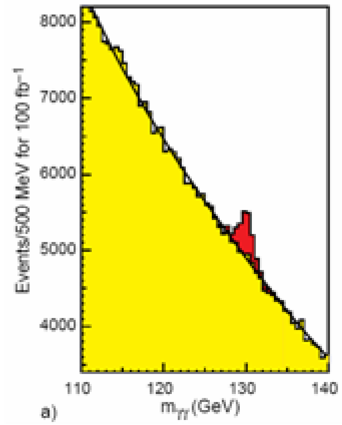
use "clean" (easy to detect) final states from Higgs decay

involve isolated photons and leptons

eg H ––> $\mu^+ \mu^- \mu^+ \mu^-$, H ––> $\gamma\gamma$,

narrow width in intermediate mass range

observed width dominated by instrumental resolution



Other benchmarks: reconstruction of new vector bosons from their leptonic decays

eg Z´ ––> $\mu^+ \mu^-$

: detection of supersymmetric particle decay chains ––> invisible particles

––> copious jets

detector design criteria

A. Efficient, hermetic **muon identification** with low contamination and good momentum resolution. di-muon mass resolution <1% at 100GeV/c^2.
charge determination for muons with momentum > 1 TeV/c^2.

B. Powerful **central tracking** system with good reconstruction of secondary vertices.
to detect the decays of long-lived b quarks & tau leptons

C. Highly granular, hermetic **electromagnetic calorimetry** with good energy resolution, di-photon mass resolution <1% at 100 GeV/c^2.

D. Highly granular and hermetic **hadron calorimetry** giving good resolution for measuring masses of hadron jet-pairs and for detecting and measuring transverse energy, thus deducing any "missing energy".

Criterion A : drives the overall physical design of the detector (magnet design)

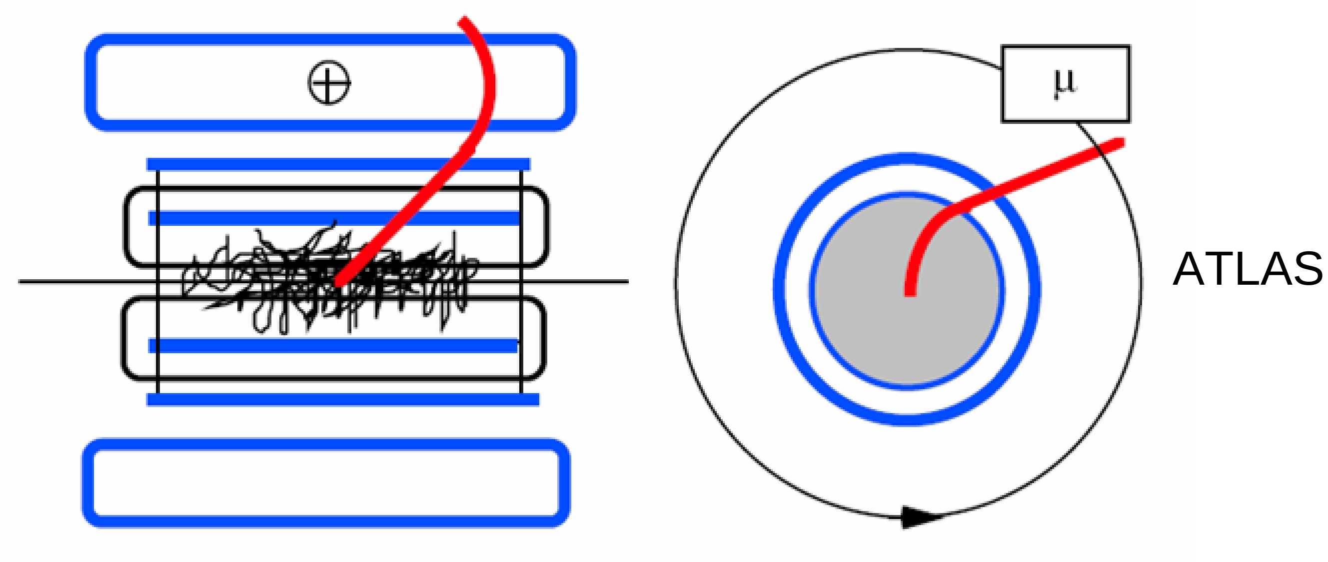
B,C: pose severe technological challenges when applied in the LHC environment.

D: poses an integration challenge

Magnet Systems: two options

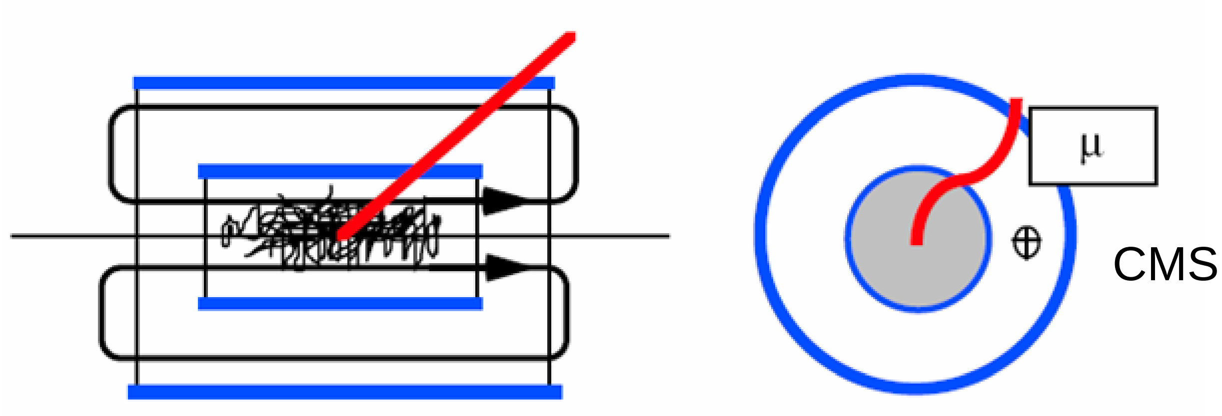
thin central tracking solenoid

outer air-core toroid

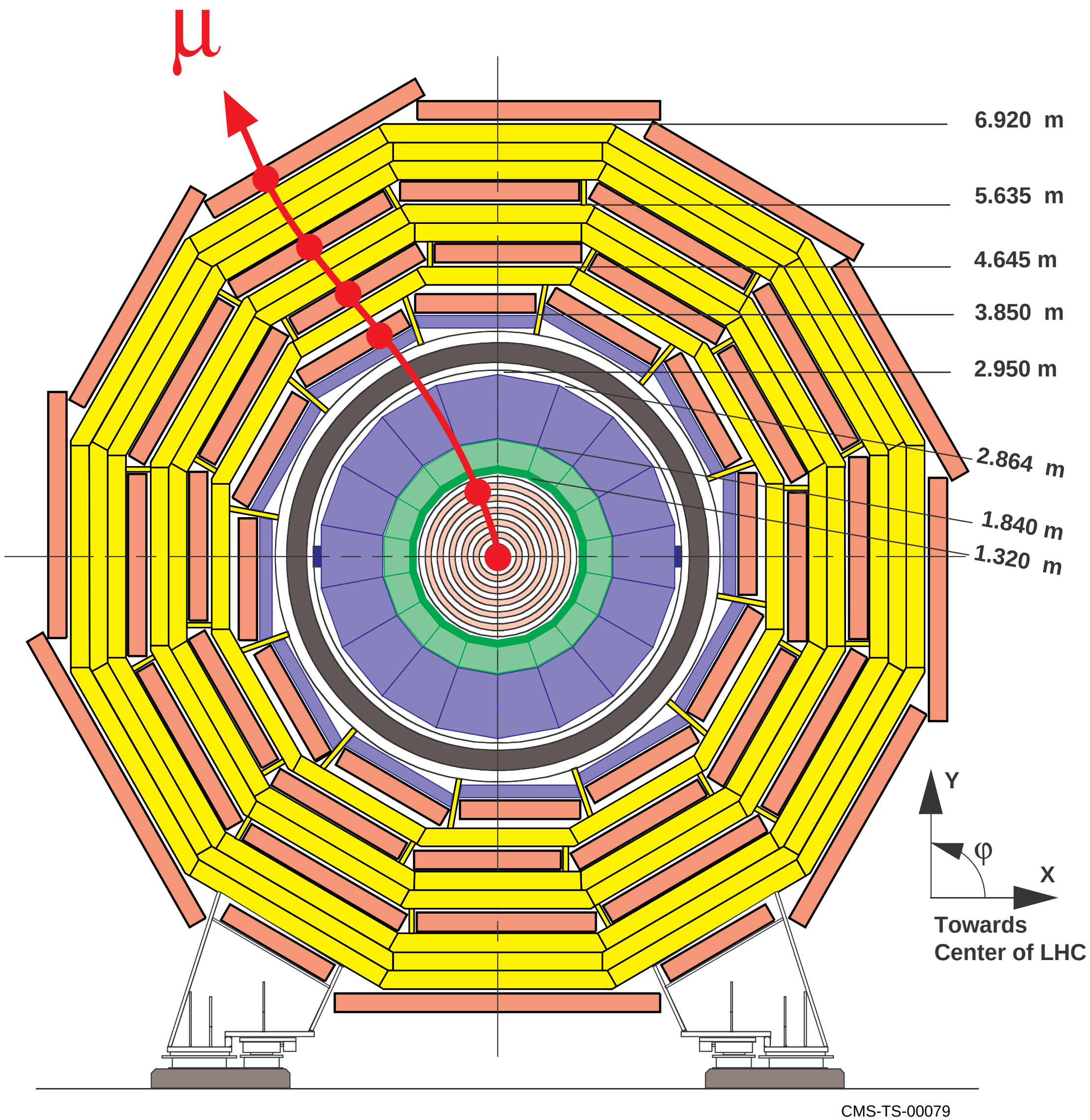


bending of track ~ BL^2

single long, large-bore,
high-field solenoid
with saturated return yoke



Compact Muon Solenoid (CMS)



Transverse View

Strong Field 4T

Compact design

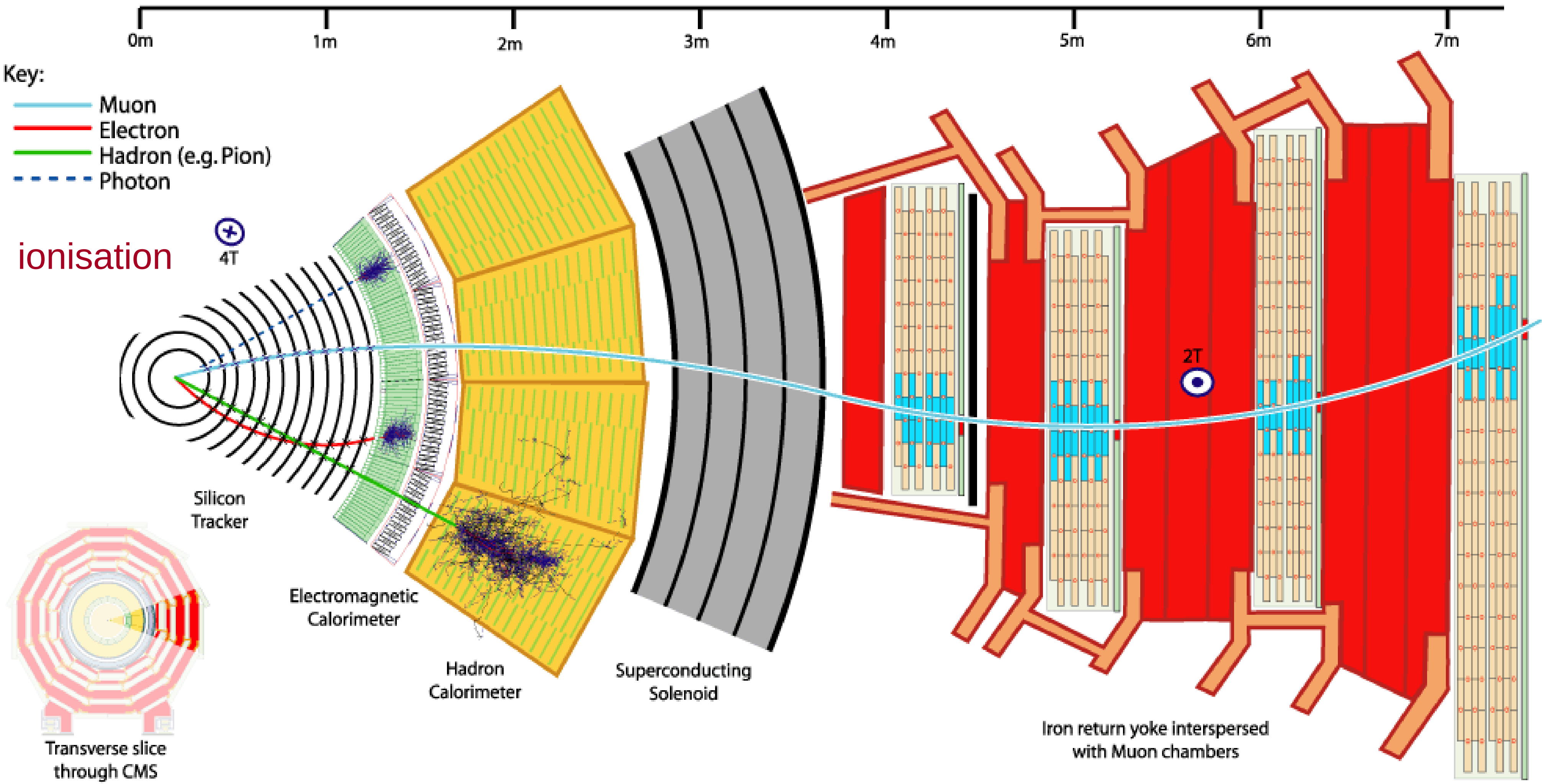
Solenoid for Muon P_t trigger in transverse plane

Redundancy: 4 muon stations with 32 r-phi measurements

$\Delta P_t/P_t \sim 5\%$ @1TeV for reasonable space resolution of muon chambers (200μm)

Slice through CMS detector barrel

solenoid field contains detectors for everything detectable except penetrating muons



ionisation

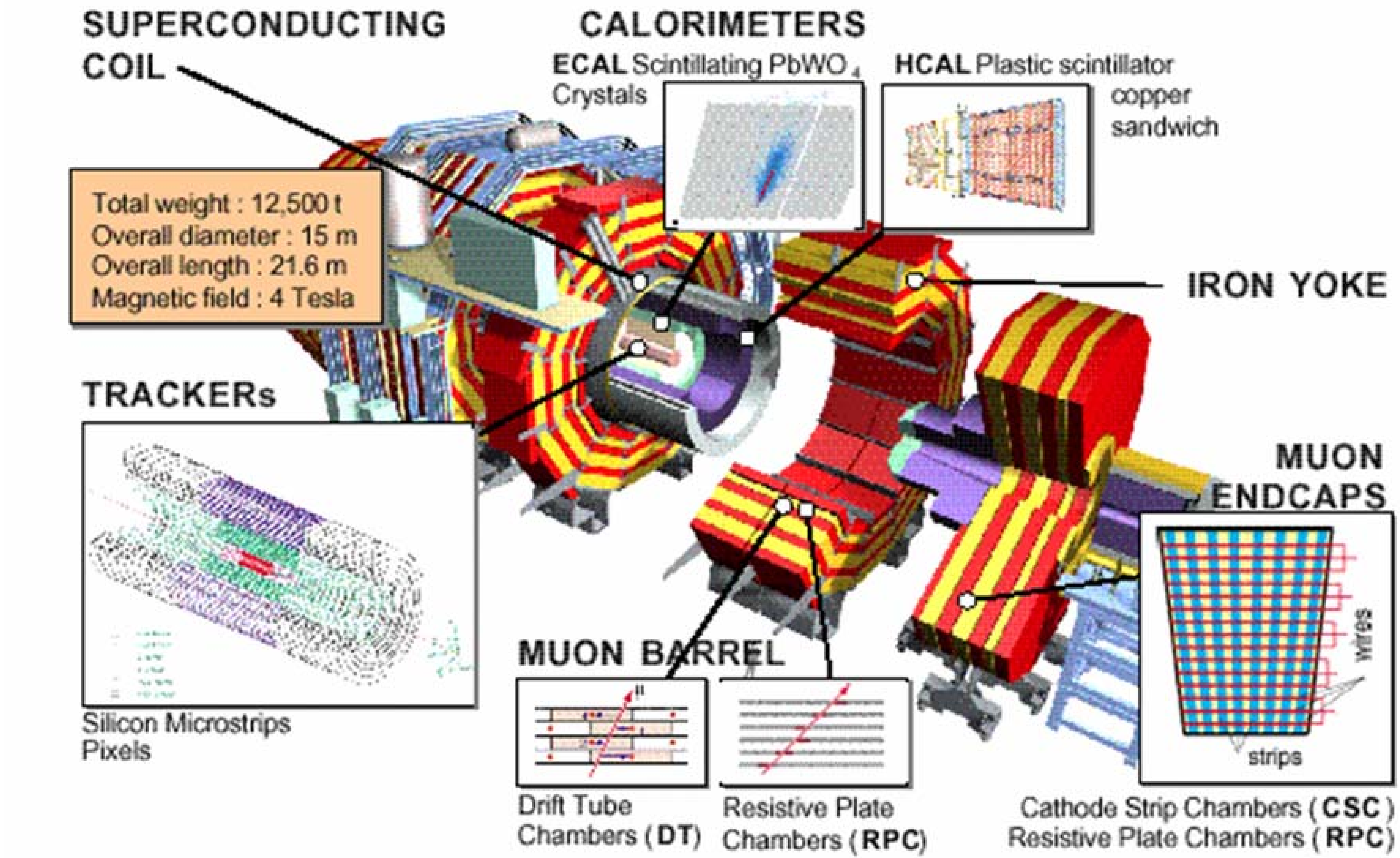
scintillation

magnetic bending

ionisation

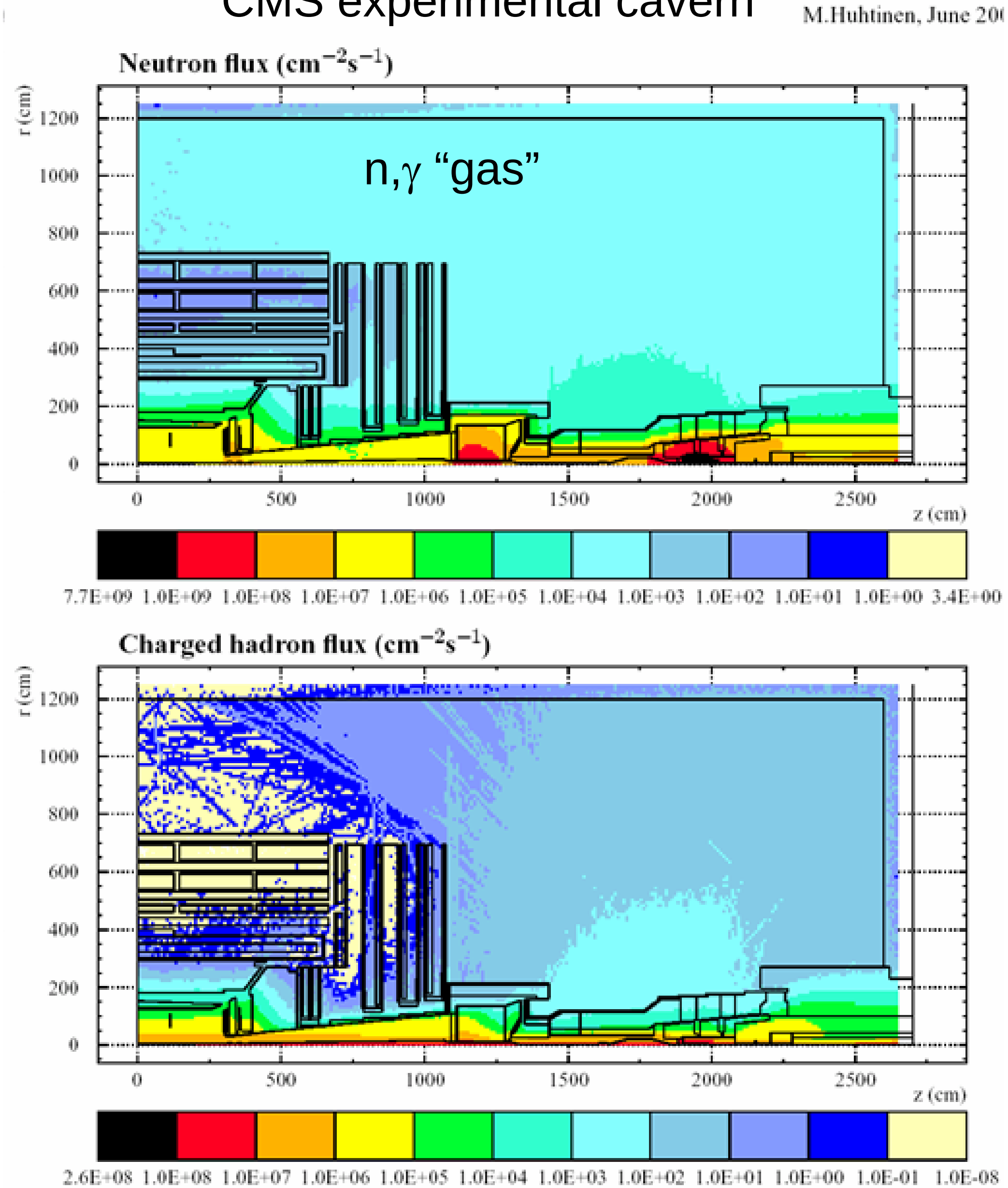
Engineering & technologies

modular design to simplify assembly and maintenance
minimise the number of different technologies and components



LHC environment is hostile

CMS experimental cavern



sensors
cables
structural materials
electronics,
power supplies & auxiliary systems

must survive:

the mixed radiation field
neutron (——> γ) + charged particles

important once design luminosity (collision rate) is reached
- say year 3 onwards

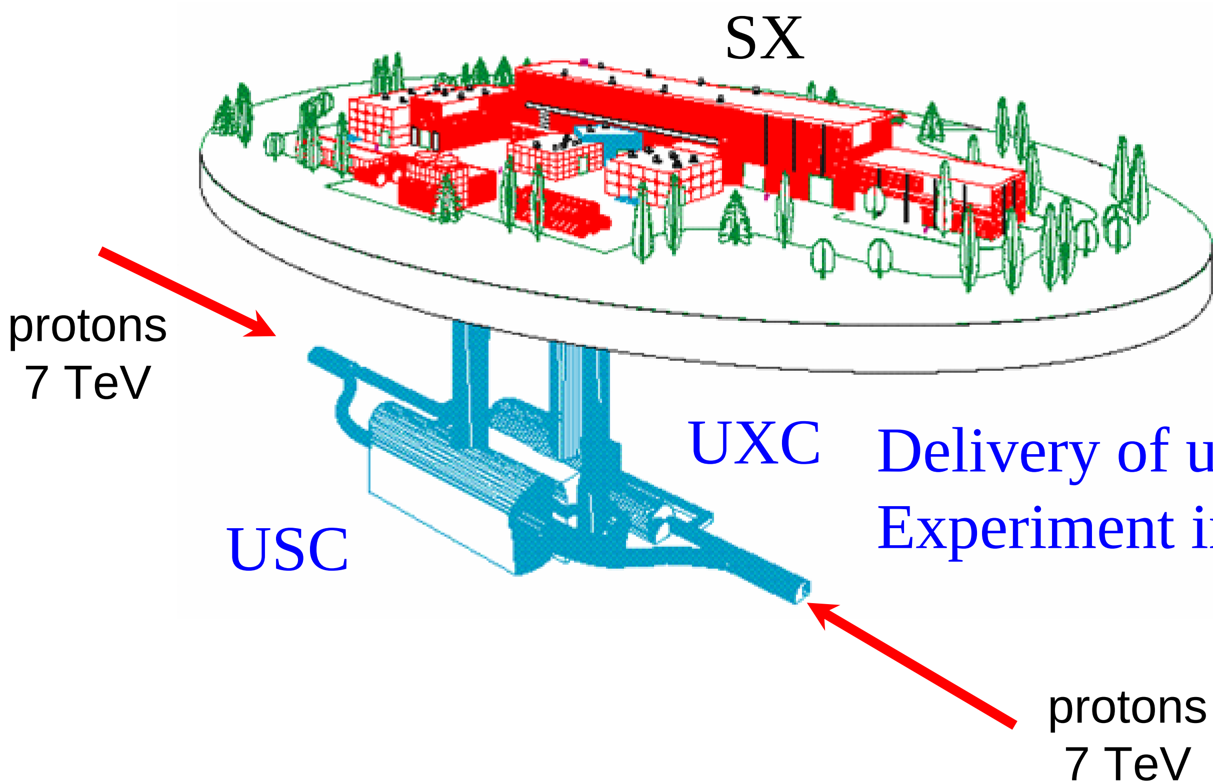
the solenoid field 4T

the external fringe field ~1-2 kG

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 and testing will continue in SX until mid-06



Delivery of underground caverns in 04/05
Experiment installation Jan 06 - Apr 07

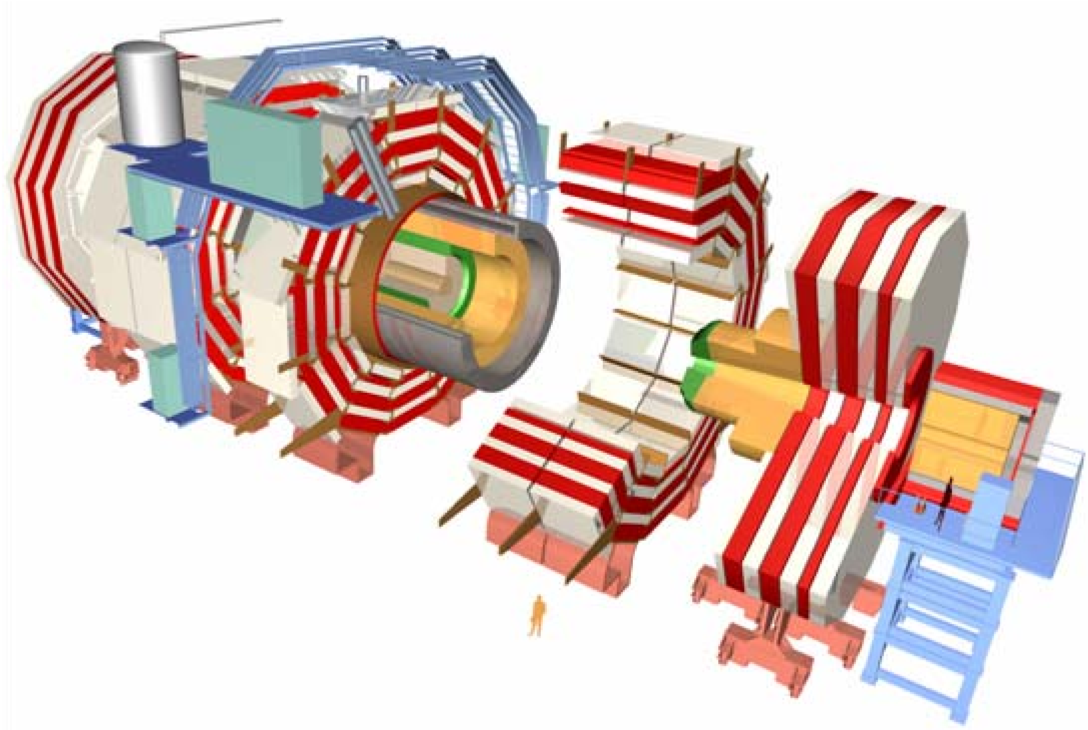
Basic Mechanical Assembly Sequence

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 (Oct 05-Jan 06)**

*separate elements and lower sequentially



UNDERGROUND:

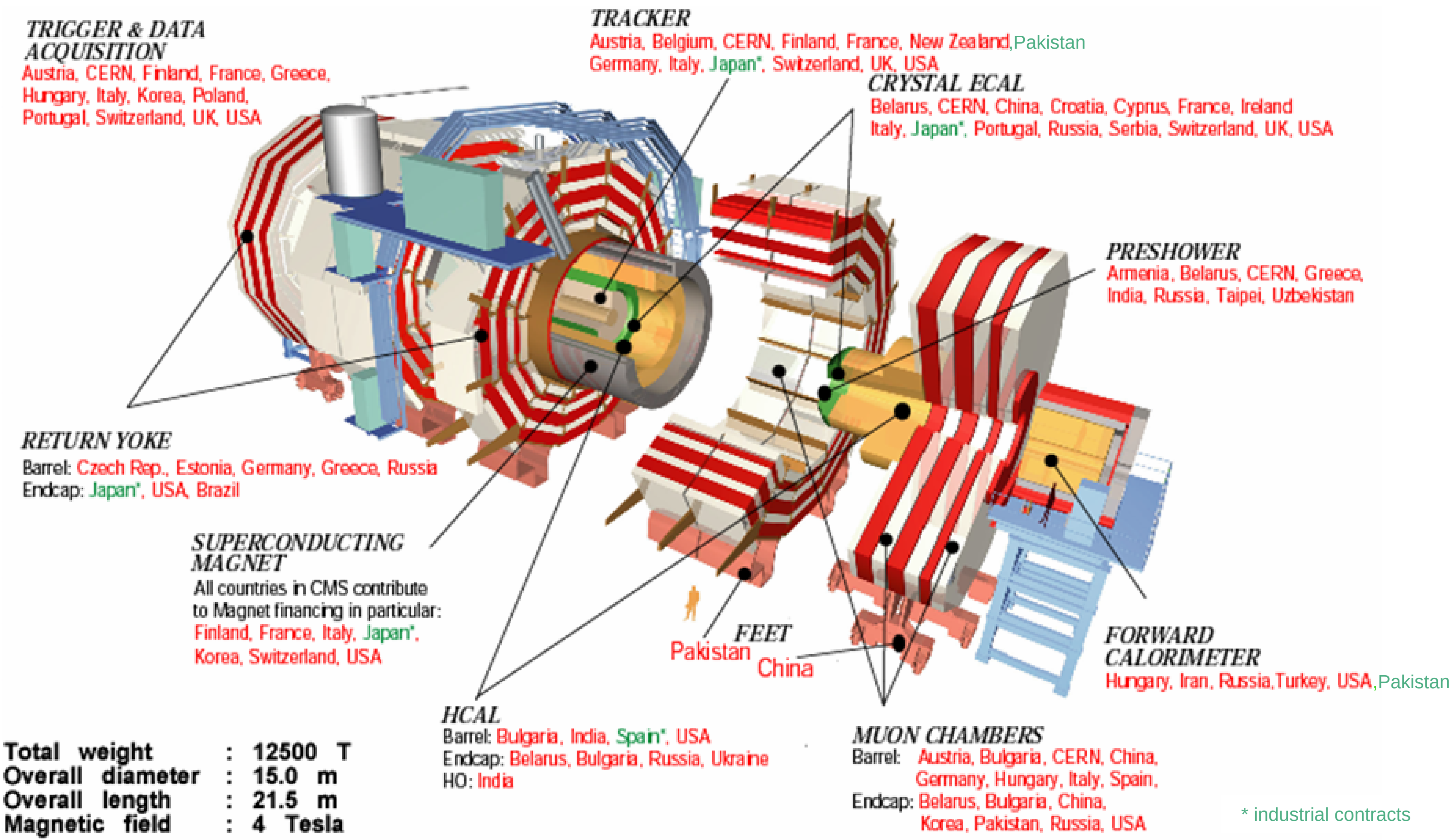
* install remainder of ECAL barrel & cable
* install silicon strip tracker & cable
* install beampipe

• **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.

Who does what in CMS?

> 2000 Physicists and Engineers, 36 Countries, 153 Institutions



CMS Funding (MoU) in kCHF

Funding Agencies	Contribution
Austria	4,500
Belgium	5,455
Bulgaria	440
CERN	98,700
China	4,815
Croatia	329
Cyprus	706
Estonia	106
Finland	5,870
France-CEA	7,287
France-IN2P3	21,700
Germany	19,709
Greece	5,000
Hungary	1,058
India	4,500
Iran	1,210

Italy	63'927
Korea	1'815
Pakistan	2'445
Poland	3'000
Portugal	2'300
RDMS-DMS	6'815
RDMS-Russia	14'251
Serbia	400
Spain	7'262
Switzerland-ETHZ	75'500
Switzerland-PSI	8'500
Switzerland-Universities	2'500
Taipei	2'740
Turkey	1'058
United Kingdom	10'018
USA-DOE + NSF	118'473
Total Funding	**502'390**

estimated cost of initial detector 517.3 MCHF. Cover 14.9 MCHF deficit mostly by DAQ staging

Additional substantial overcosts have arisen in ECAL crystal and Tracker sensor procurement

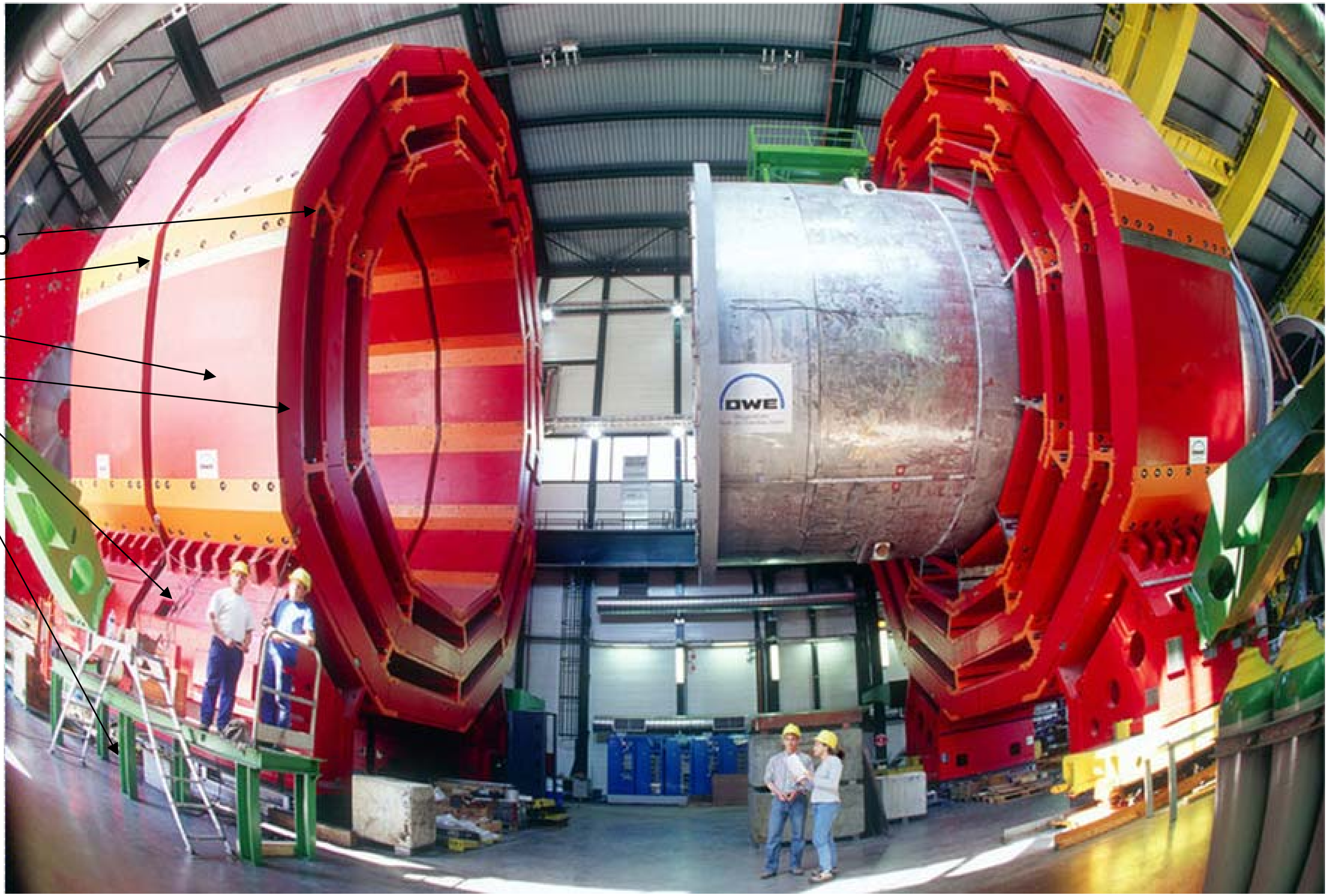
Surface assembly building SX5

view of SX5 after delivery in 2000

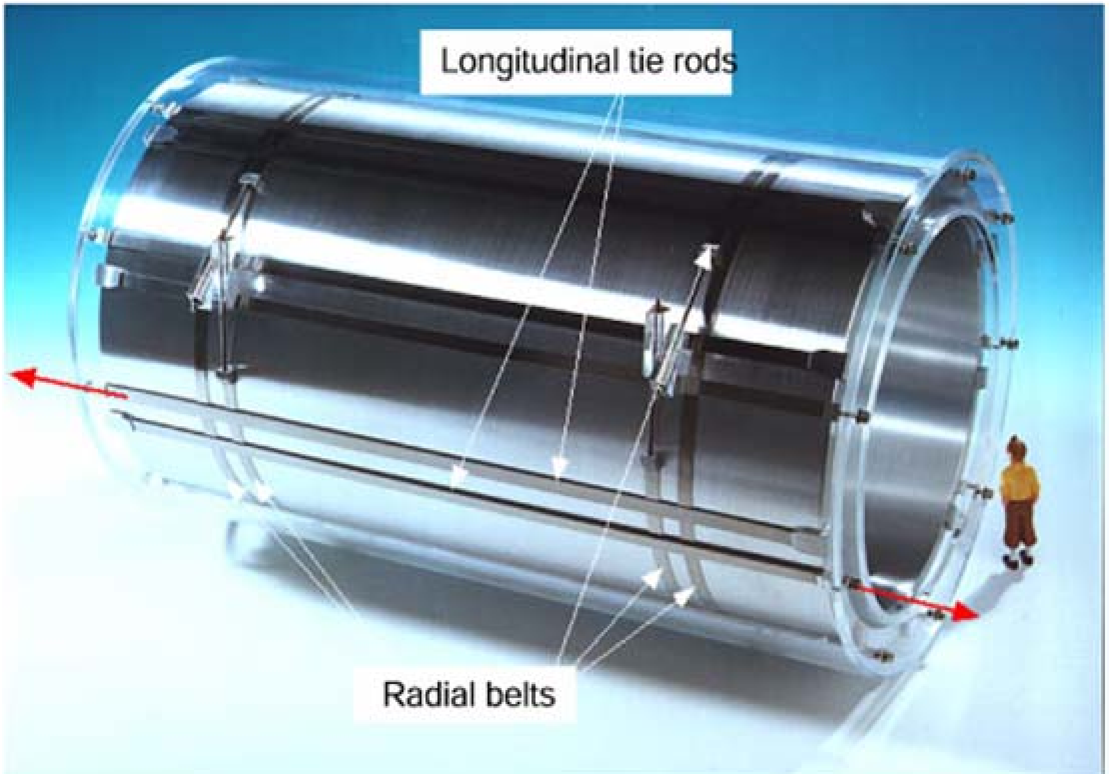
Pre-assembly of CMS in SX5 isolated from tricky underground Civ Eng.

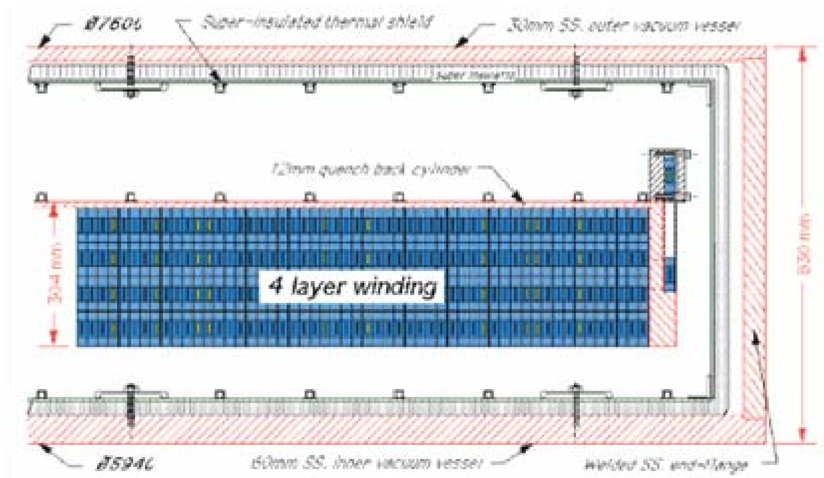
Yoke ready for coil and muon detectors:2003

Czech Rep
Estonia
Germany
Russia
Pakistan
Greece



Solenoid





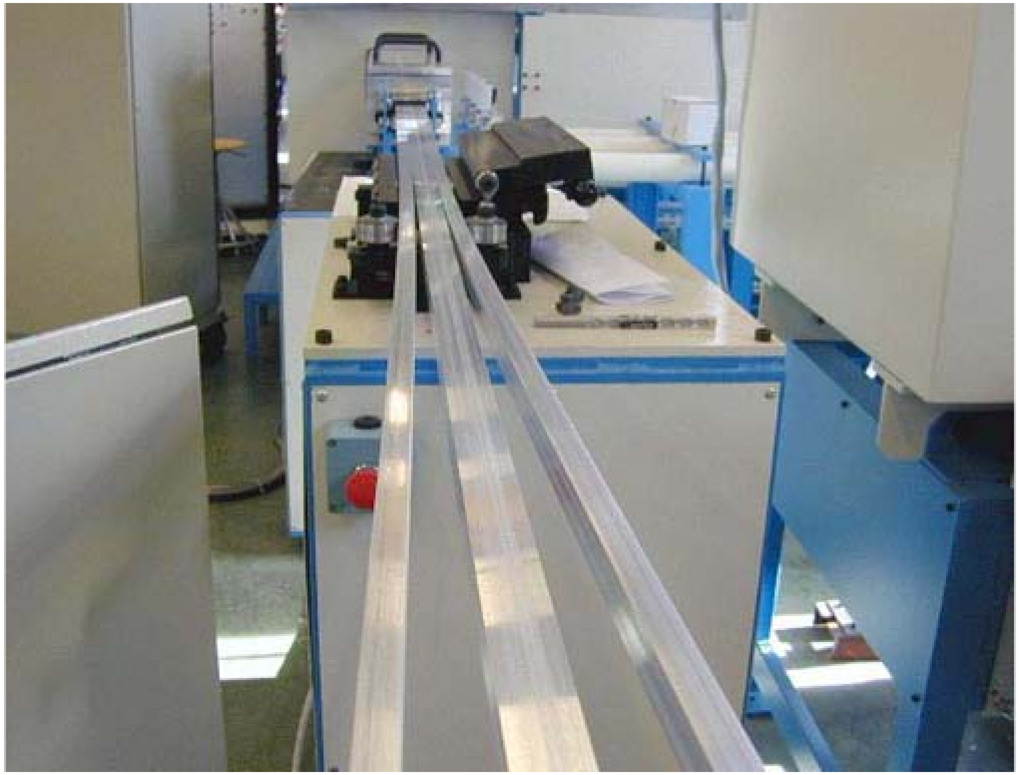
Design by CERN/CEA Saclay

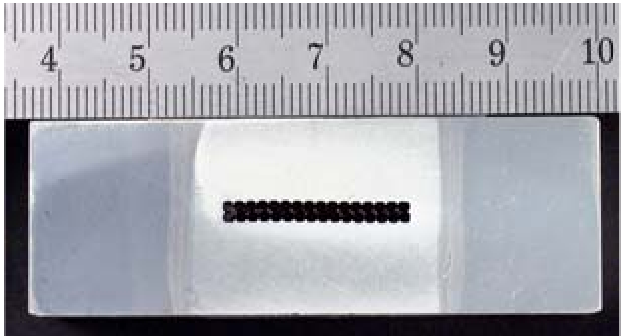
Magnetic length	12.5 m
Free bore diameter	6 m
Central magnetic induction	4 T
Nominal current	20 kA
Stored energy	2.7 GJ
Magnetic Radial Pressure	64 Atmospheres
Weight	220 t

SC Coil: reinforcement of conductor

Major Contracts for Coil

Superconducting Strands
 Outokumpu-Finland
Rutherford cable
 Brugg Kabelmetal-Switzerland (CH)
Pure Al Insert
 Sumitomo HI, Japan
Insert Extrusion
 Alcatel Suisse at Cortaillod, CH
Electron Beam Welding
 Techmeta, France
Winding
 Ansaldo, Italy
External Cryogenics
 Air Liquide, France



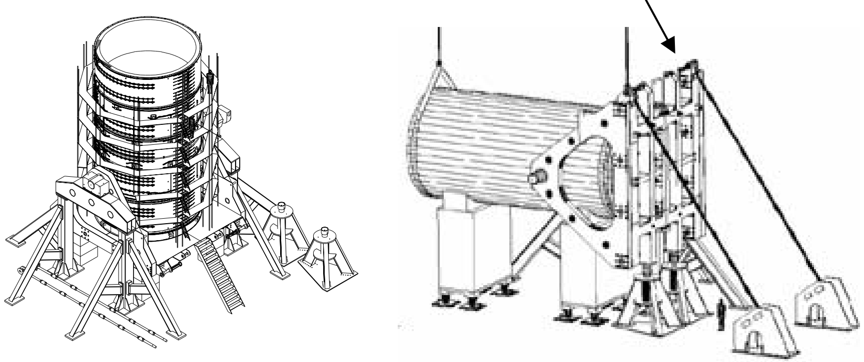


Coil: module 3 (of 5) delivered to CERN

on schedule to deliver last coil module by Jan 05

Magnet Test Oct 05-Jan 06

South Korea

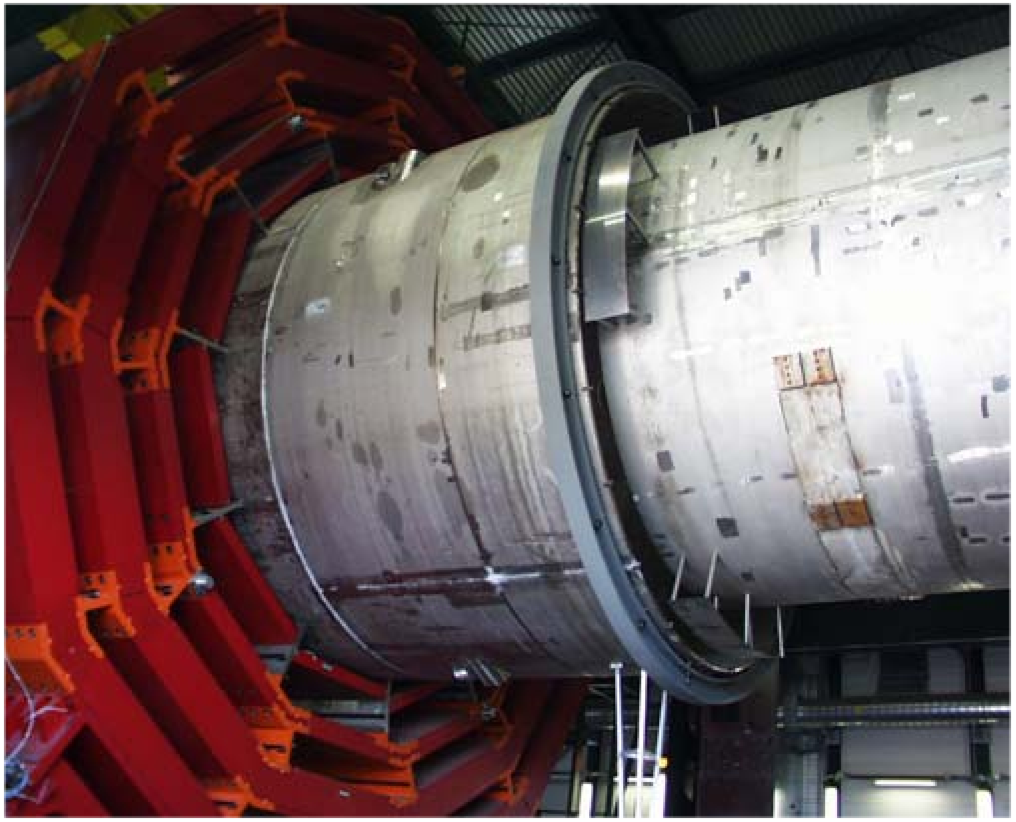


May-July 05, insert solenoid in YB0

swivelling test using inner vac tank

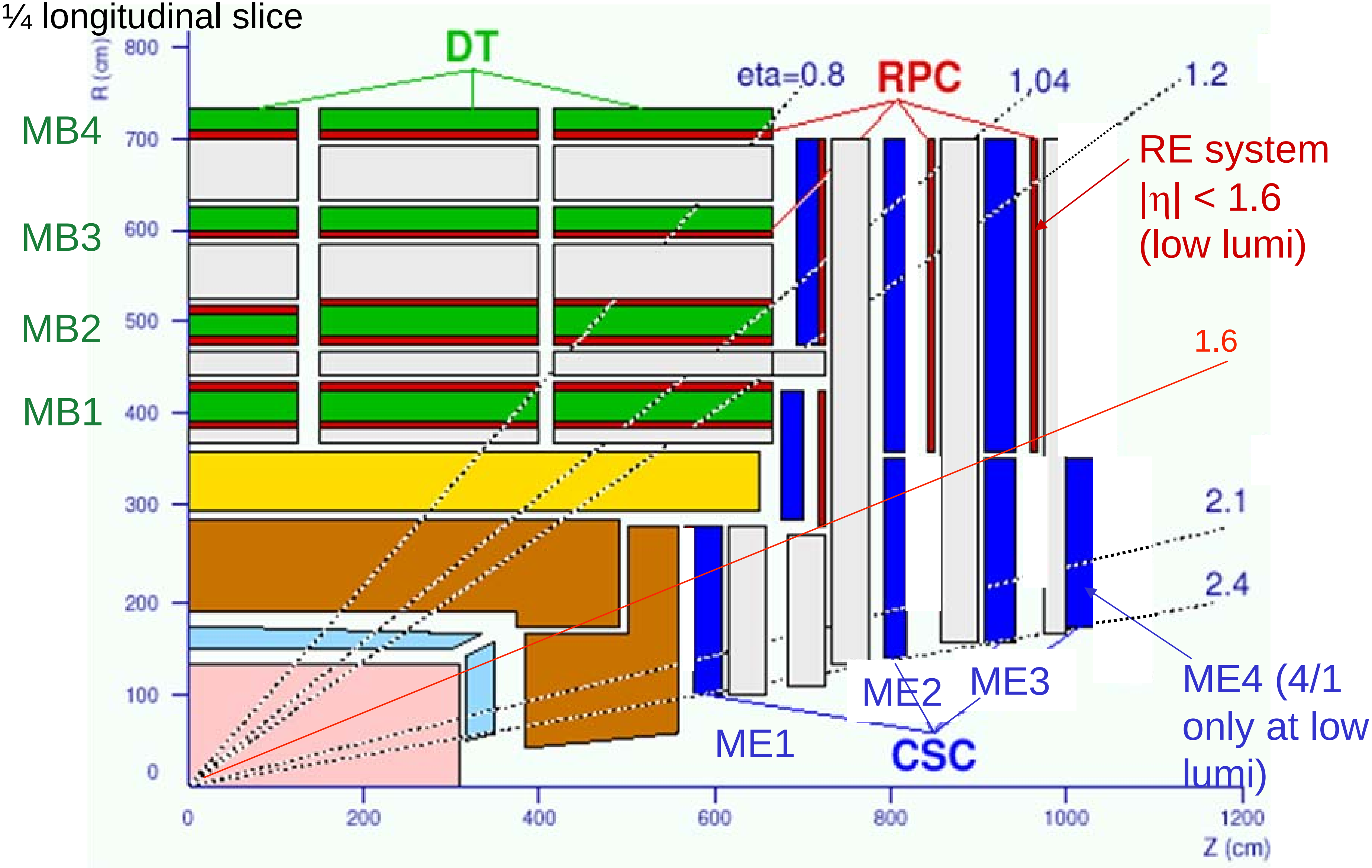
Yoke and coil assembly define the critical path for the work in the surface assembly building

In the shadow of this, the barrel and endcap hadron calorimeter and muon detectors are being assembled and installed………



Muon System

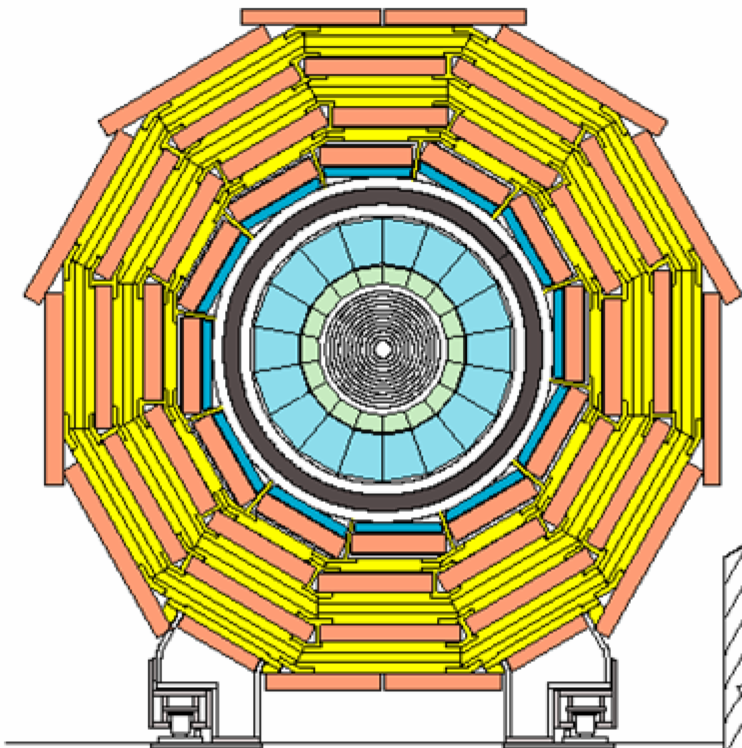
¼ longitudinal slice



Barrel muon system: Drift Tubes + RPC’s

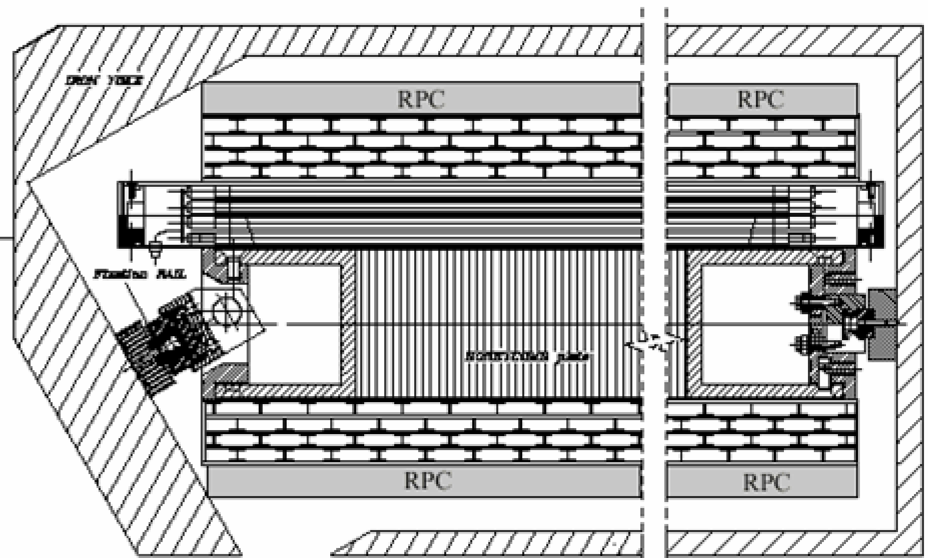
Bulgaria, Germany, Italy, Spain, Hungary, + Russia,China

Alignment system with link to Tracker: CERN, Portugal, Hungary, Pakistan



- **MB1,2,3= 8 ϕ-layers**
  + 4 θ-layers
- **MB4= 8 ϕ-layers**

- **250 chambers**
- **192 000 channels**



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

Barrel DT Chambers (MB1, 2, 3)

152/210 (60%) DT chambers produced for layers 1,2,3 in:

RWTH Aachen, Genmany,
CIEMAT, Madrid, Spain
INFN Legnaro, Italy

End production in 2005 (20 ch./year/site).

Installation delayed awaiting replacement of HV distribution boards which developed faults after 3000hrs.

Layer 4 production started in
Torino, Italy
limiting the installation of complete sectors and thus the cabling.

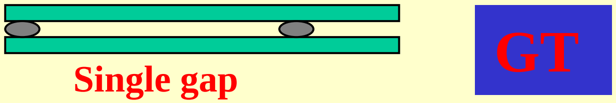
10% barrel mu DT+RPC chambers installed

27 chambers
installed on
YB+2

Finish installation
in yoke wheels +2+1, 0(part)
in late summer before magnet test

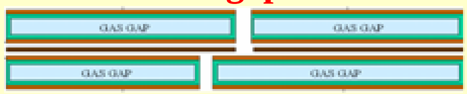
Installation in yoke wheels
-2,-1 and remainder of wheel 0
predominantly after magnet test.

Muon Barrel RPC's



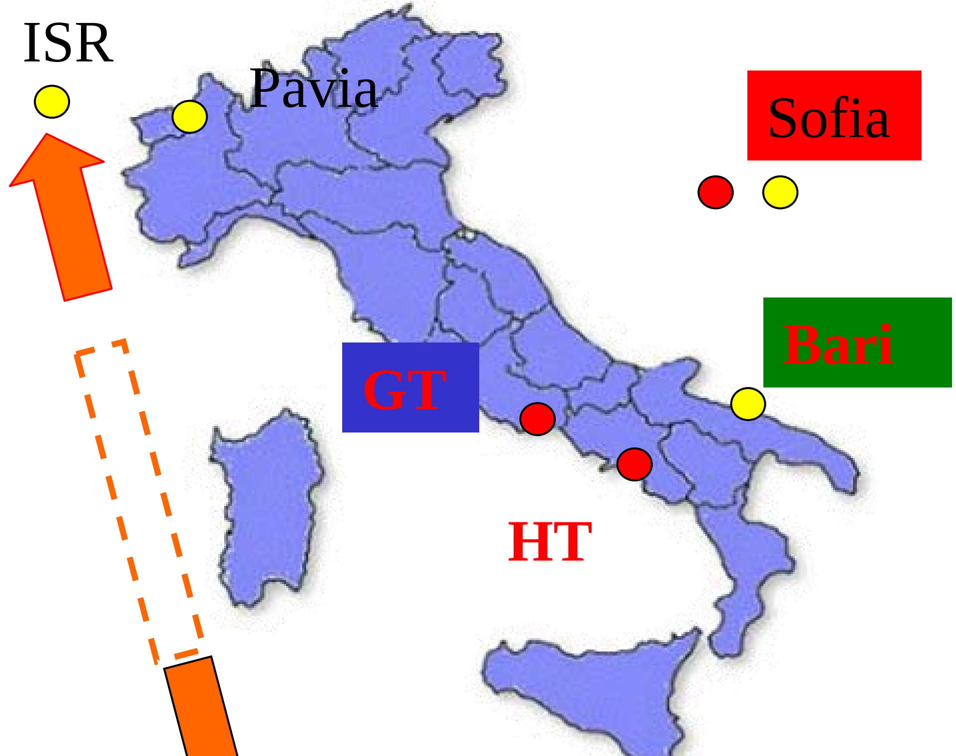
Single gap

Double gap



Chamber assembling sites

120 RB1 at HT
240 RB2 and RB4 at GT
120 RB3 in Sofia (& Bari)



Chamber test sites

RB1 in Pavia
RB2 & RB4 in Bari
RB3 in Sofia (& Bari)

Muon Barrel: RPCs

Single and double gap production on schedule

Gaps: ~ 75% complete: Planning assumes

2004 → 20 gaps/week

2005 → 25 gaps/week

20 % rejection

Bi-gaps: ~70% complete:Planning assumes

2004 → 8 bigaps/week

2005 → 10 bigaps/week

3 % rejection

Chambers: ~280/500 produced, rejection rate 1-2%

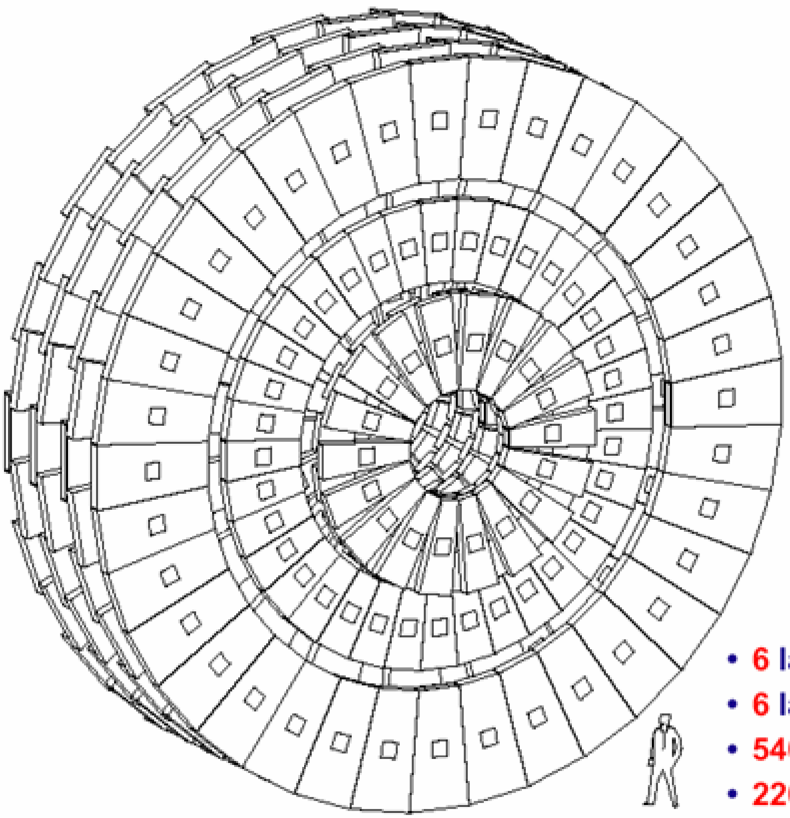
10 chambers /week total from 3 sites (GT,HT,Sofia)

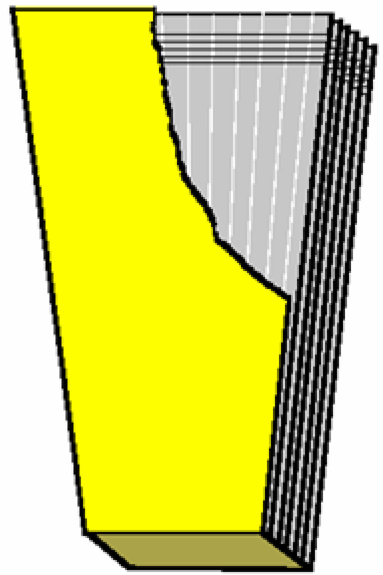
recovering from a 2 months delay from retrofit to remove incompatible materials by increasing testing throughput at Bari & Pavia

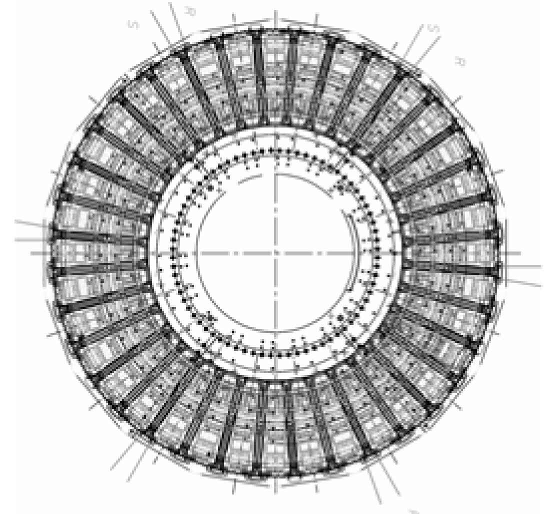
Endcap Muon System: CSCs & RPC's

CSC: China, Bulgaria, Belarus, Russia, USA

RPC: China, Korea,Pakistan (+CERN,Italy)







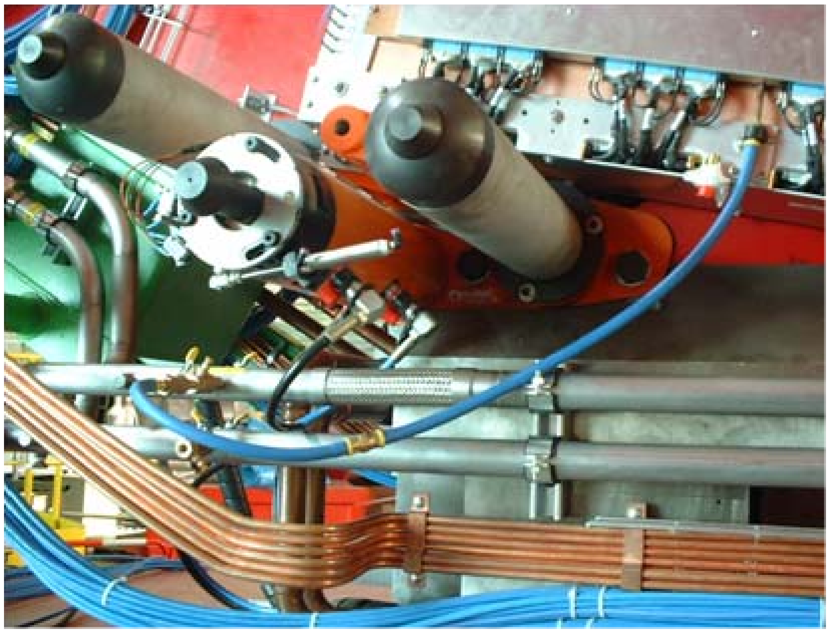
- 6 layers of radial strips / station
- 6 layers of tangential wires /station
- 540 chambers
- 220 000 anode strips
- 320 000 cathode wire groups

6 layers,
72 chambers
per layer
bi-gap structure
3 gaps per chamber
3 * 32 strips per cham

Installing CSC chambers

468 chambers needed
106% completed
99% tested
99% delivered to CERN
46% installed
29% commissioned

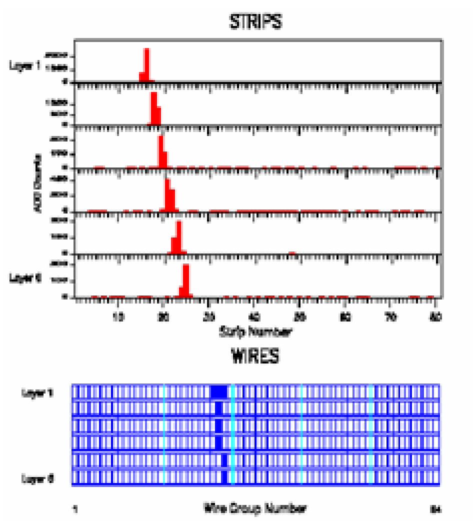
Services (gas,cooling) installation underestimated, but now well advanced



Commissioning of installed CSC chambers

First installed "CMS" subsystem to detect particles….

……. and to impress a president!



Goal now is to "configure and read out 18 chambers in various configurations, self-triggering on cosmics"

End-Cap RPC Gap & Chamber Assembly

KODEL

"Oiled" gas "gap" technology mastered in South Korea

RE1/2- & RE1/3- tested gaps sent from Korea to CERN

RE2/2- tested gaps sent to Pakistan

Readout strips & mechanical structures

Peking University, China to CERN & Pakistan

RE chamber assembly and test

Assembly and test site at CERN ISR.

20 RE1/2 + 20 RE1/3 assembled

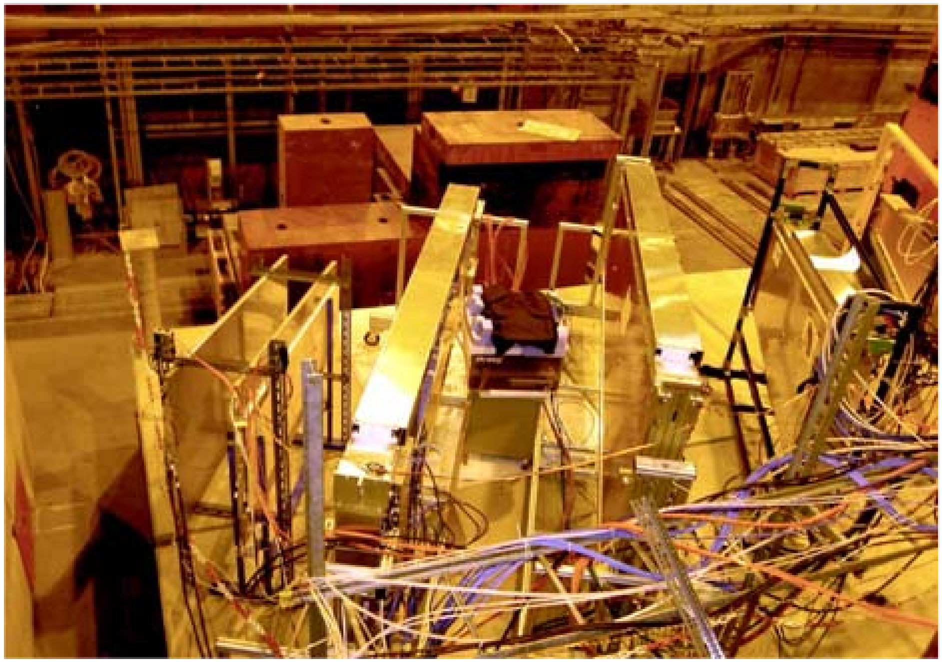
RE-1048	HALF(36): RE1/2 + & RE1/3+ ready for installation	Feb 05

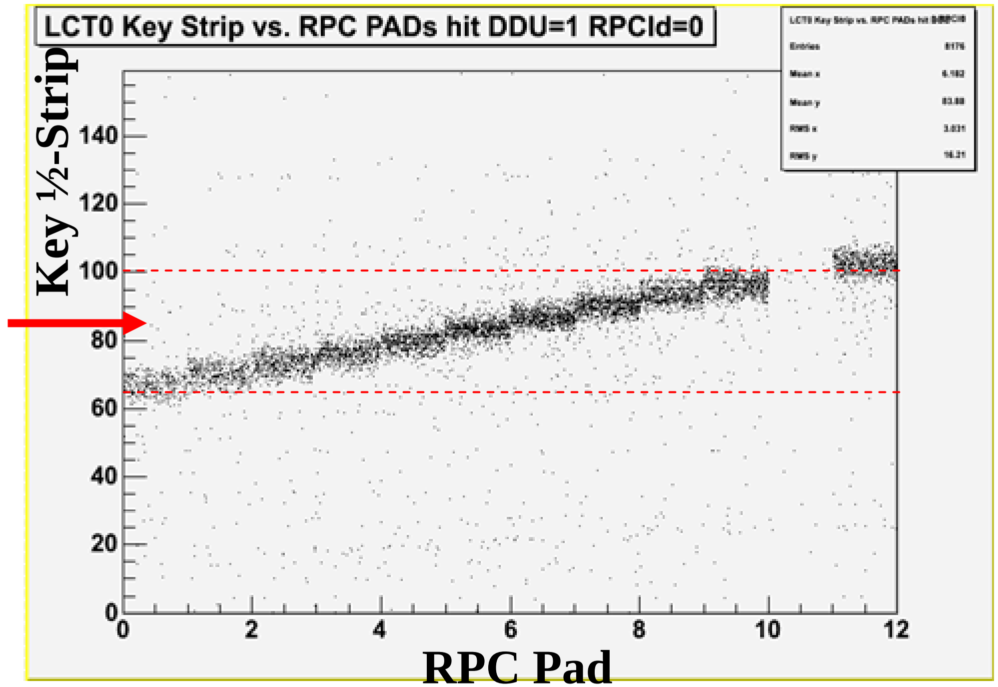
start 2'nd assembly site in Pakistan in 05

RE-1049	RE2, 3 installed on YE+	Sep 05

H2a test beam Oct 04: RE1 pads vs CSC strips

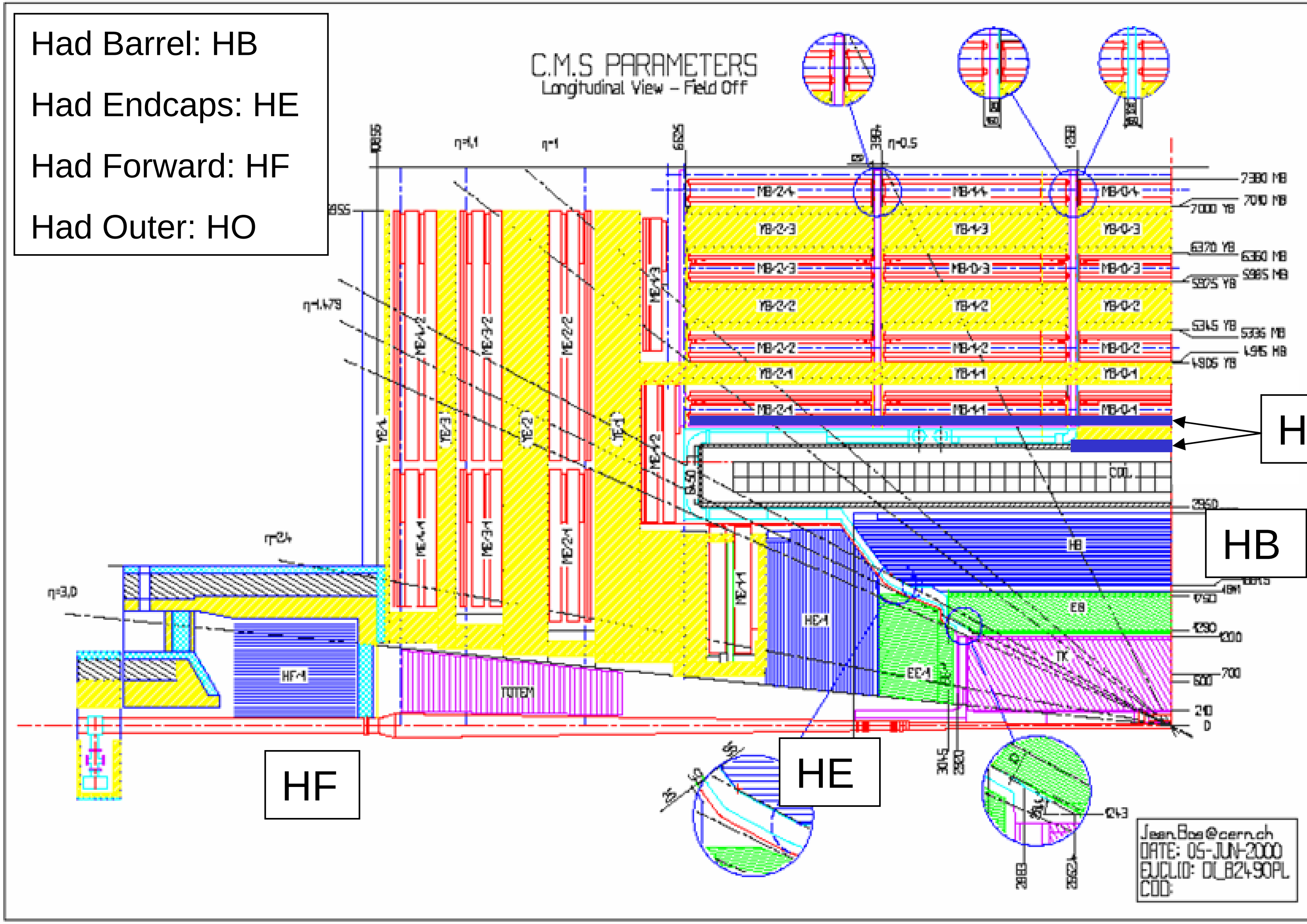
- Compare CSC *half-strips* to RE1 pads
- Good position agreement (one dead pad)
- Confirmation that RE1's can help pattern recognition in CSCs
- This is why the RE1's (mounted mated to the CSC's) are on the critical path





μ detector reception zone CERN ISR, Sept 04

Hadronic Calorimeter: HCAL



Hadron Calorimeter-Absorbers Complete

HO + thermal screen installation started.

Belarus,
Bulgaria,
India,
Russia,
Ukraine,
USA

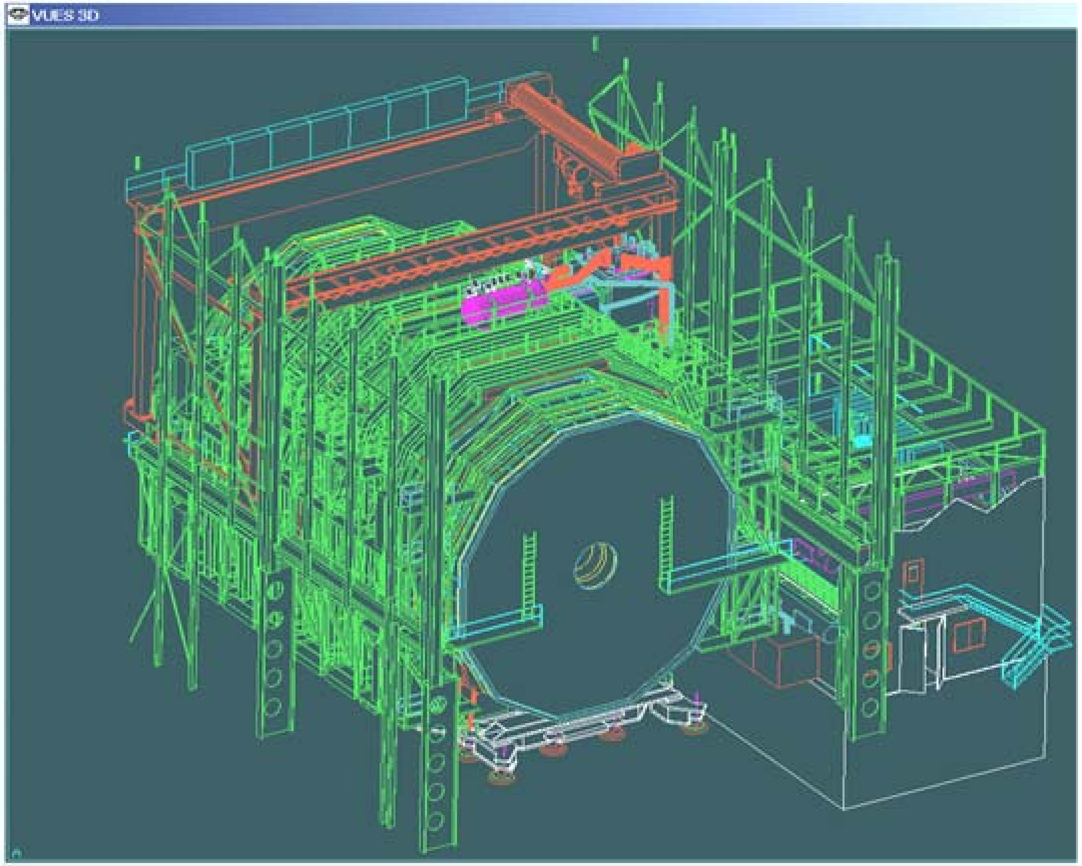
+ Spain
UK
Japan
Pakistan

Install electronic readout boxes. Start commissioning in early 2005

.

Magnet Test in SX5

CMS closed for magnet test in SX5 surface building: autumn 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.

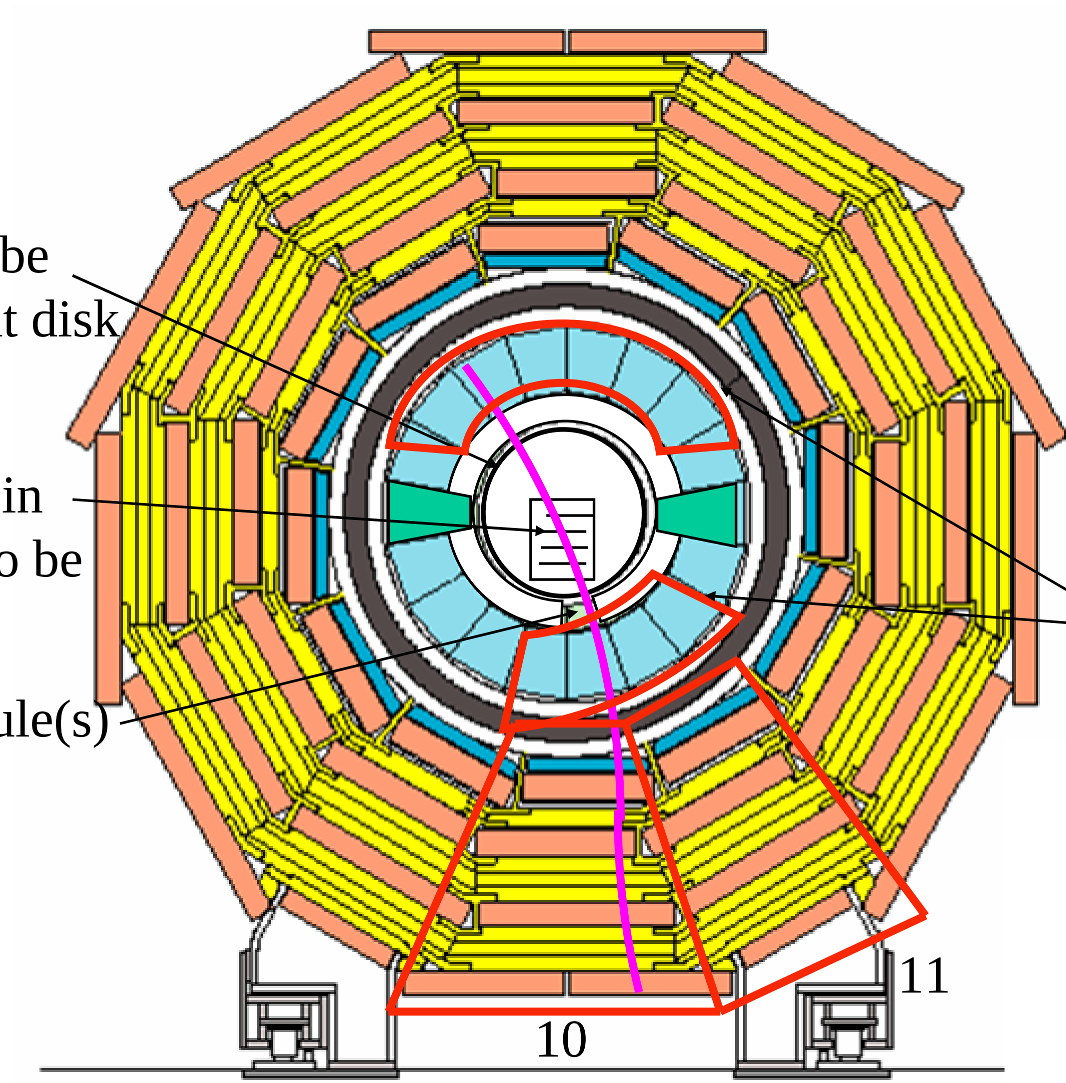
Test combined subdetectors in 20 degree slice(s) of CMS with magnet. Check noise. Record cosmics. Try out operation procedures for CMS. (24/7)

Magnet test: cosmic challenge:barrel

TK dummy tube with alignment disk & cables

TK (elements in dummy tube to be defined)

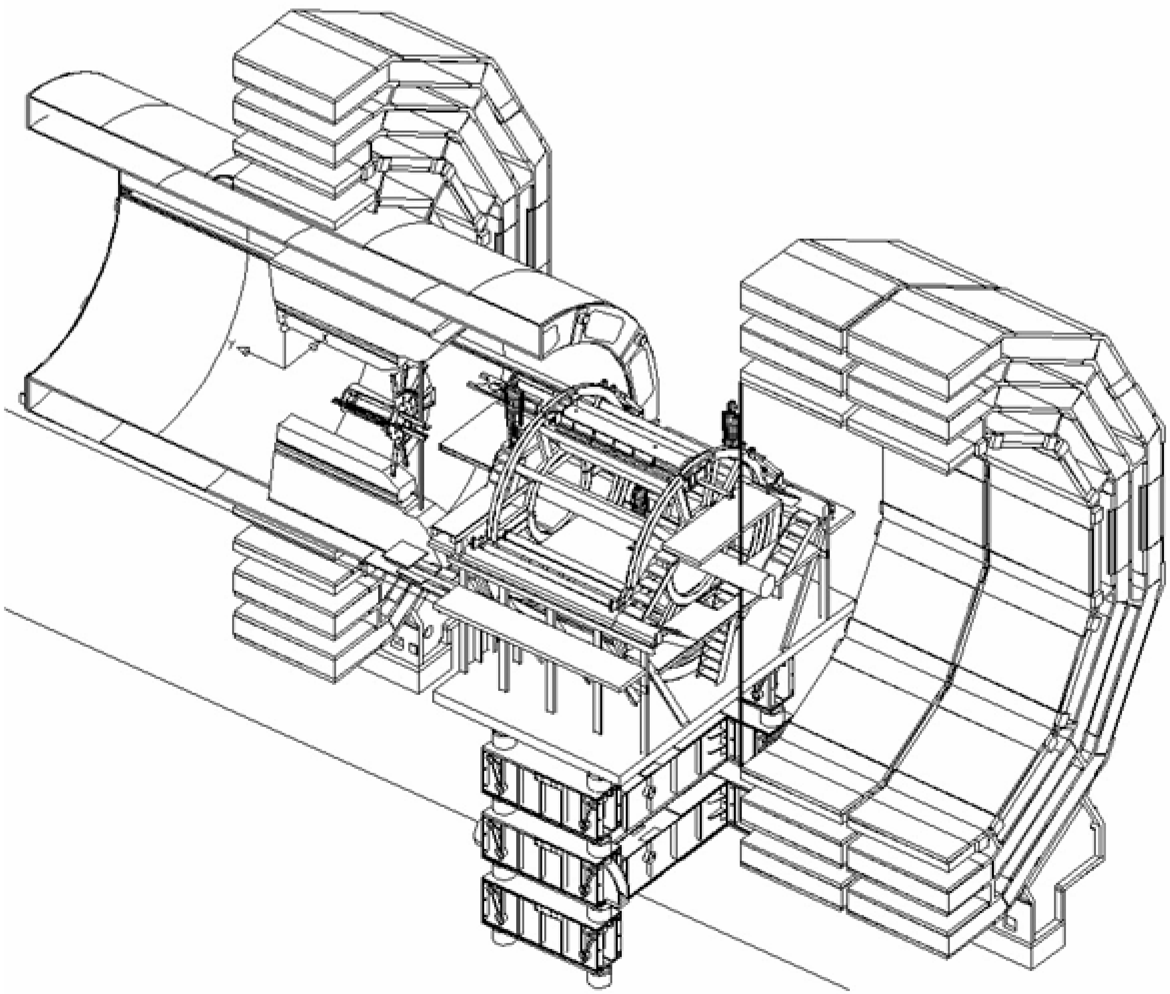
EB supermodule(s)



DT's in sector 10 of YB+2, YB+1 and CSC's of YE+1 lower 60 deg sector provide the principal triggers.

HB+ active sectors

ECAL barrel insertion



18 supermodules EB+ and up to 6 in EB- will be installed in HCAL in the surface building after the magnet test.

Crystals for 18 supermodules are already in hand at CERN

16 SM's are mechanically assembled (without electronics)

1'st final supermodule tested successfully this autumn (electronics completely revised in last 2 years)

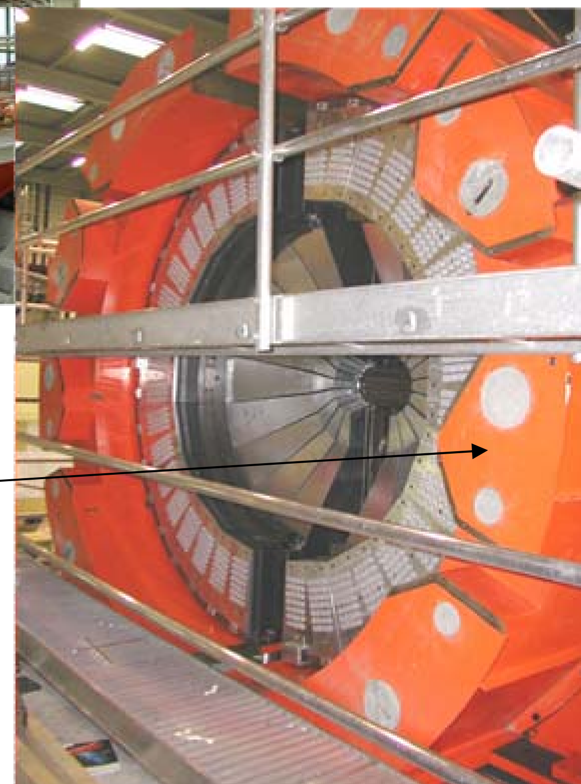
Electronic integration plans reviewed. Expect EB+ on time

Forward HCAL

Russia

Hungary

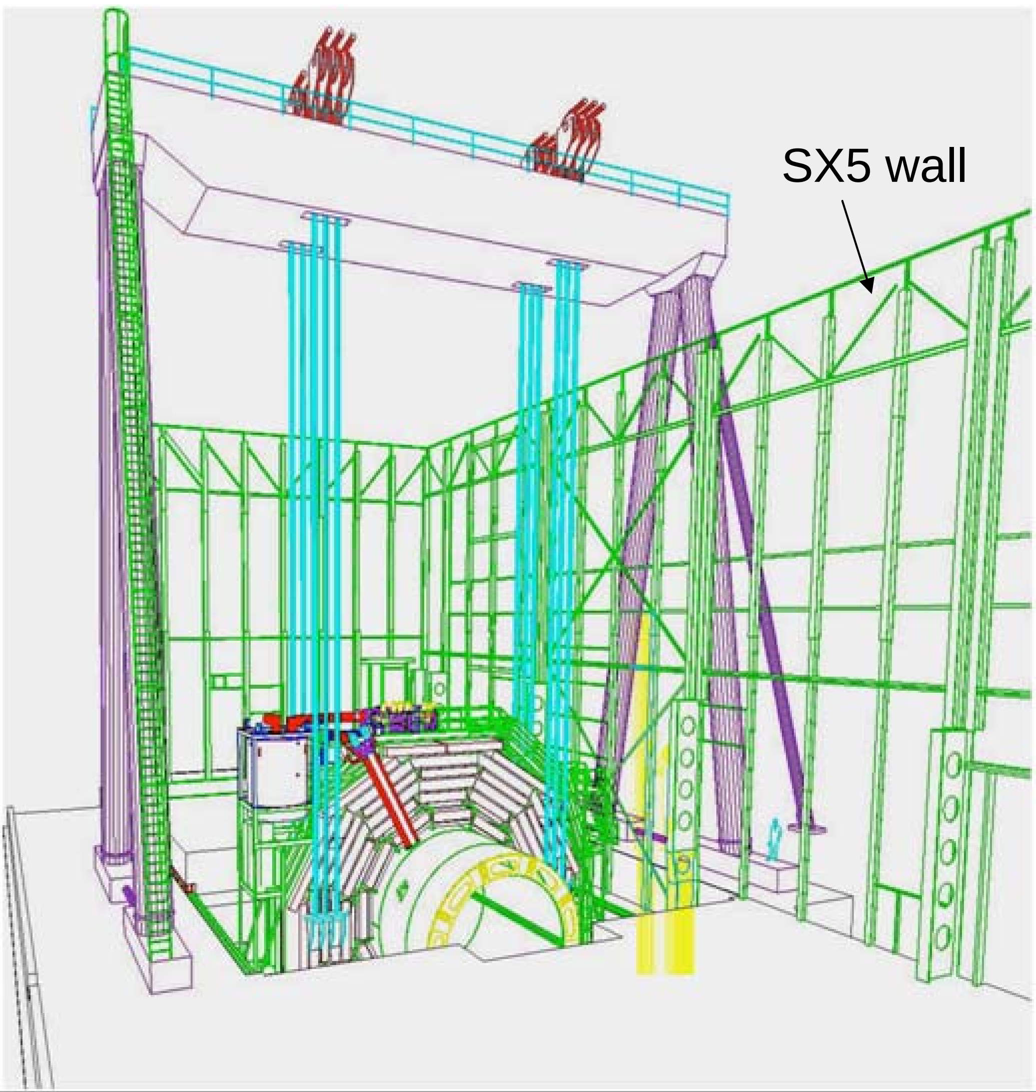
600,000 fibres installed in 18 months!!



Iran

Turkey, US

Heavy lowering



Heavy lowering starts early 2006, after magnet test

15 heavy lifts of about 1 week duration each.

Heaviest piece (central wheel + solenoid) 2000 tonnes.

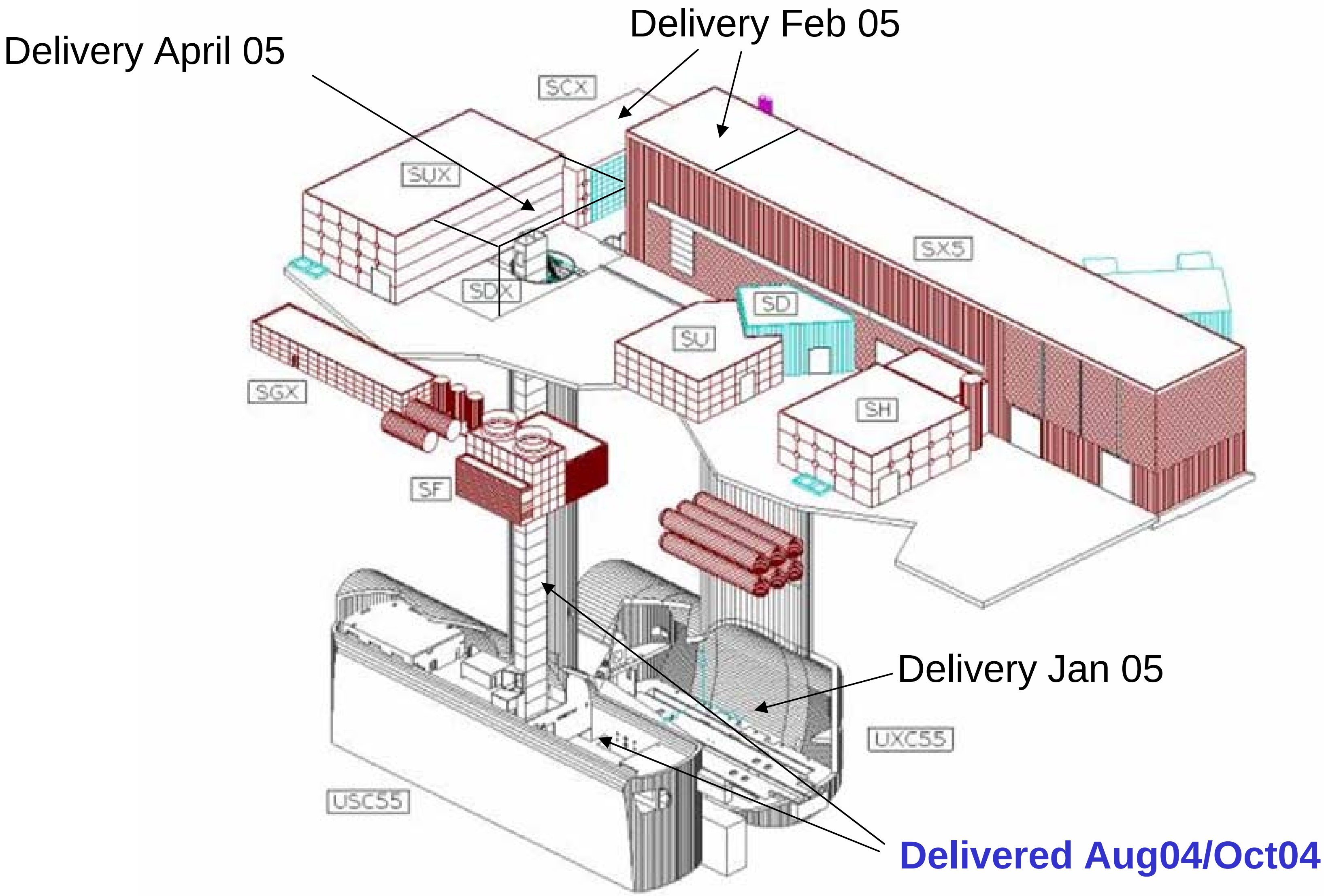
The cost of planned gantry idle time is reasonable: option to complete – z end on the surface, in parallel with critical path work on the +z end underground.

Contract awarded to VSL(CH)

worldwide experience in heavy lifting operations

cable winches for CMS will be similar to this

Civil Engineering for CMS



Civ Eng: SX5 and pit-head cover

-cover complete.
-closing system
tested.

- SX5 Jura wall removal next Spring to extend SX5 assembly building over the pit-head.

USC55 service cavern

USC55- Controls Ground Floor

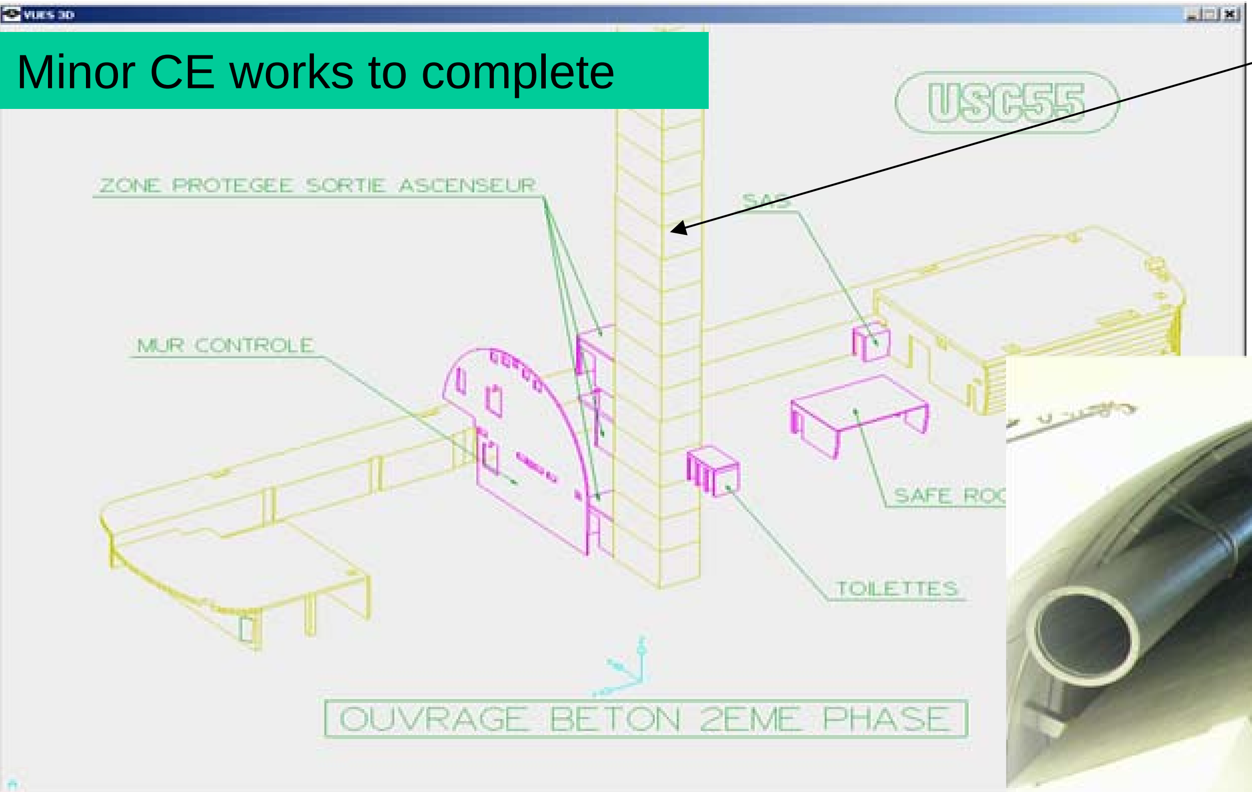
Delivered to CERN
after a big effort to recuperate
delays.
(3 shifts running underground with
up to 200 workers)

USC55- Controls First Floor

-delay accommodated in
schedule

USC55: good progress since delivery

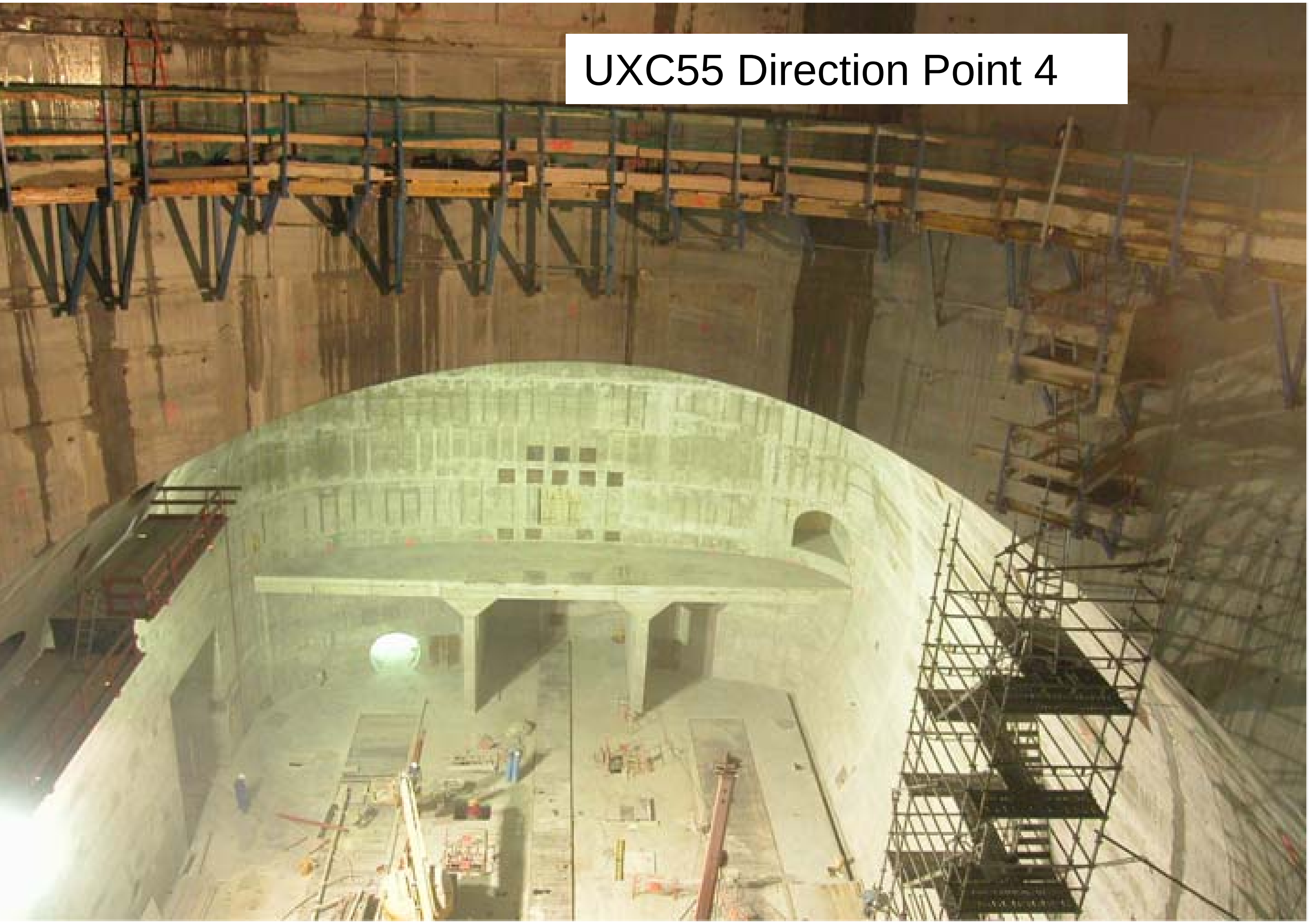
Minor CE works to complete



PM54 leaks repaired

lift modules, staircase, ventilation and services installed in the planned “10-week window”

UXC55: delay risk now low



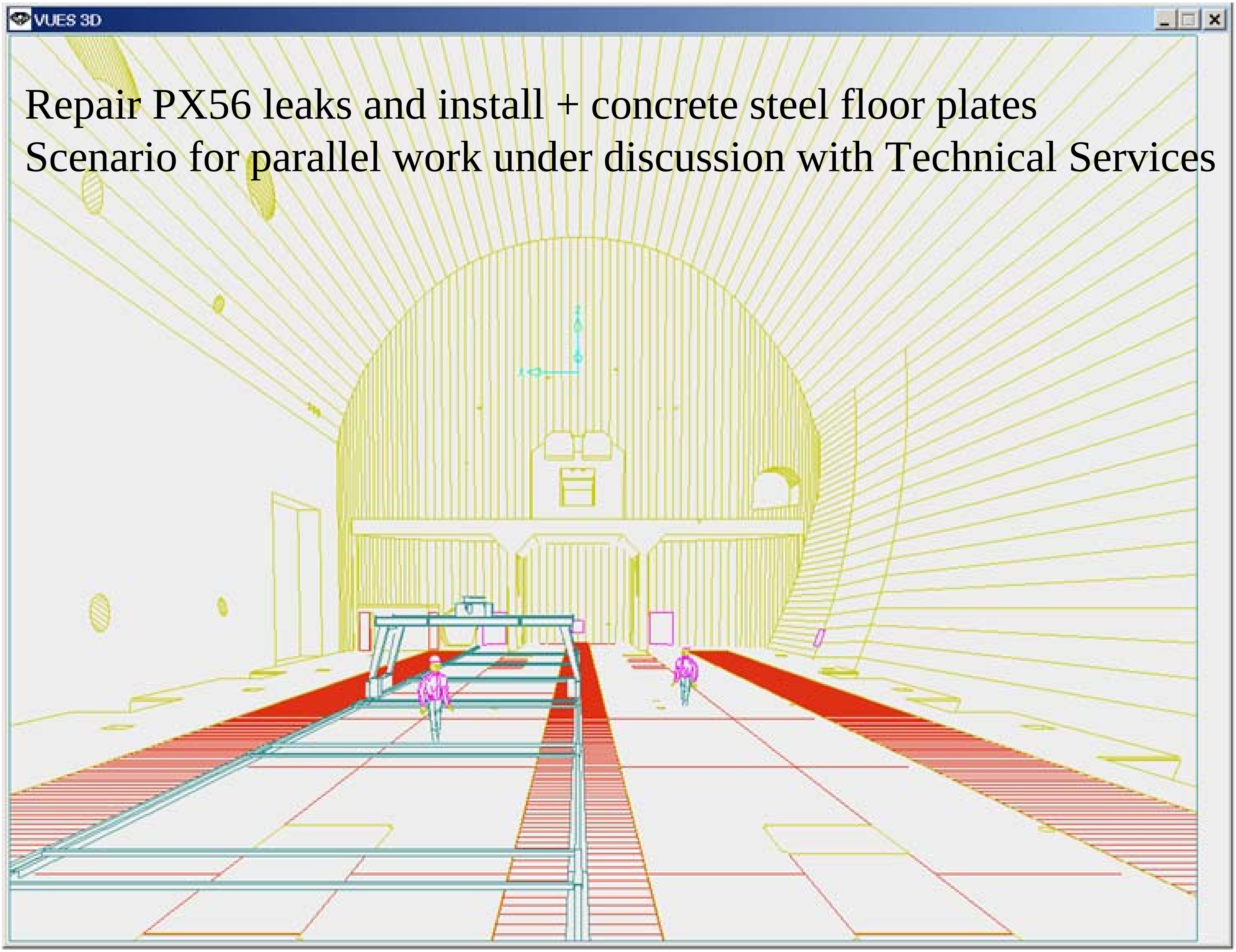
Delivery estimate:
mid-January 2005

-additional 3 month delay accommodated in planning, leading to "start of heavy lowering" in Feb 2006, in step with completion of the magnet testing on the surface

UXC Feb-May 05

Repair PX56 leaks and install + concrete steel floor plates

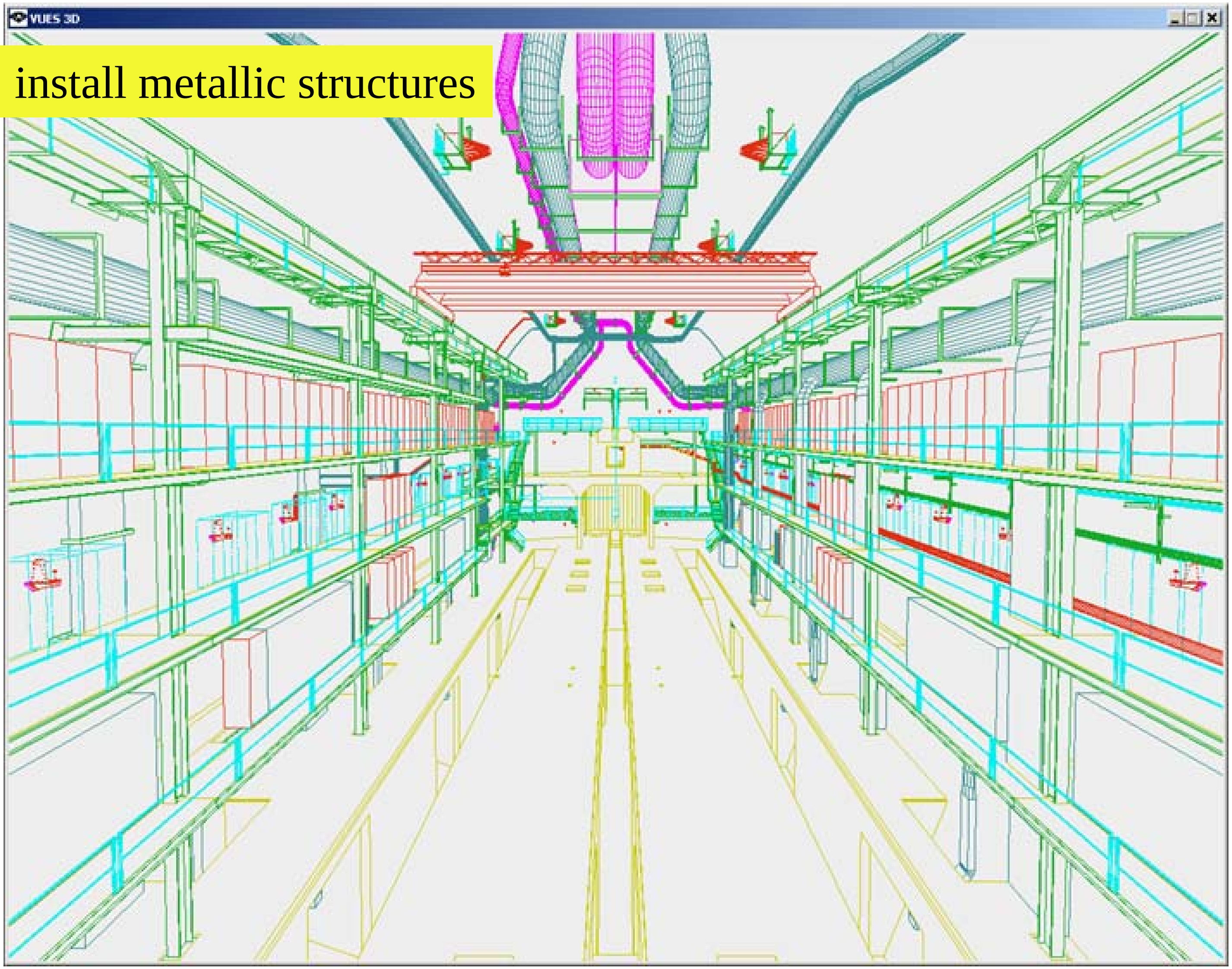
Scenario for parallel work under discussion with Technical Services



UXC Jan-March 05.

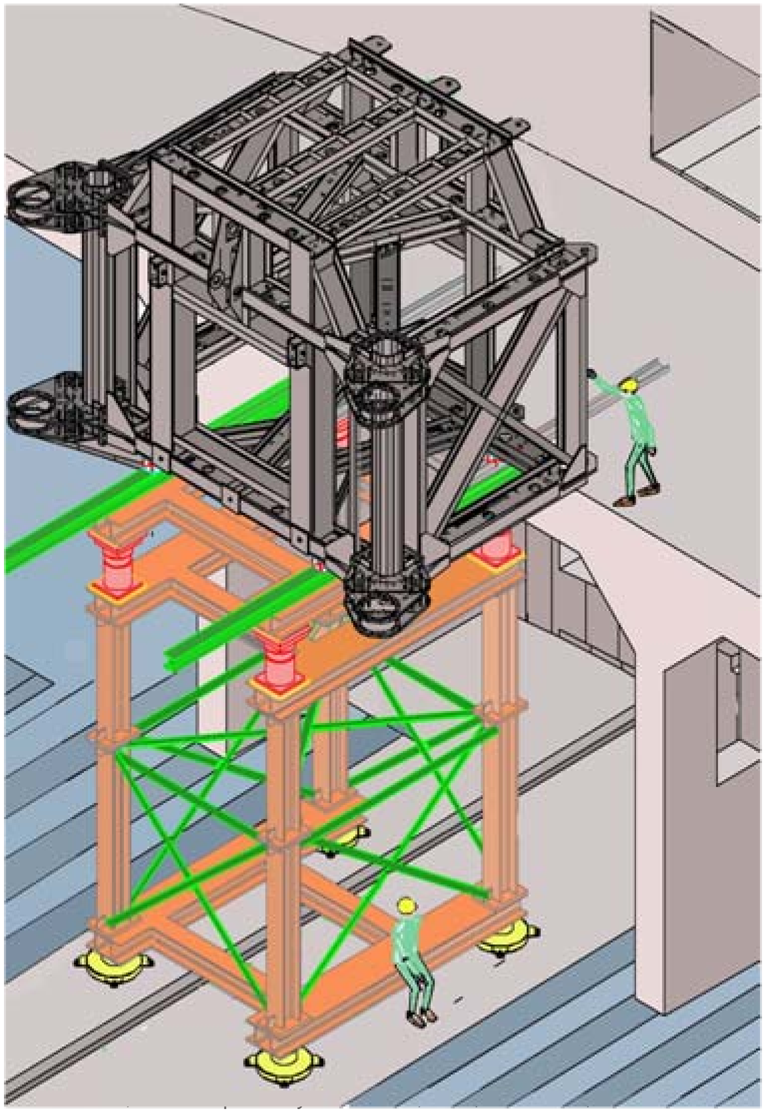
Survey UXC floor,
install mechanical jacks
& drives for HF- and HF+.

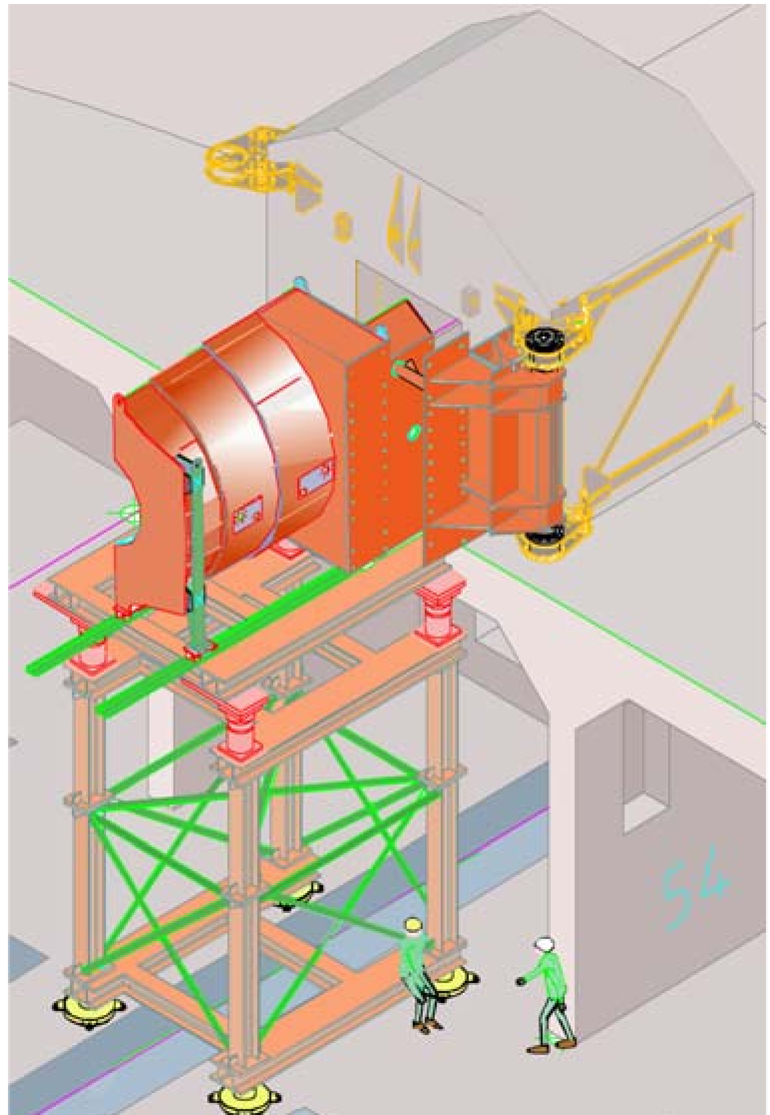
UXC May-June 05



Jun-Sep Install Forward Shielding

CERN, Russia





Forward Shielding

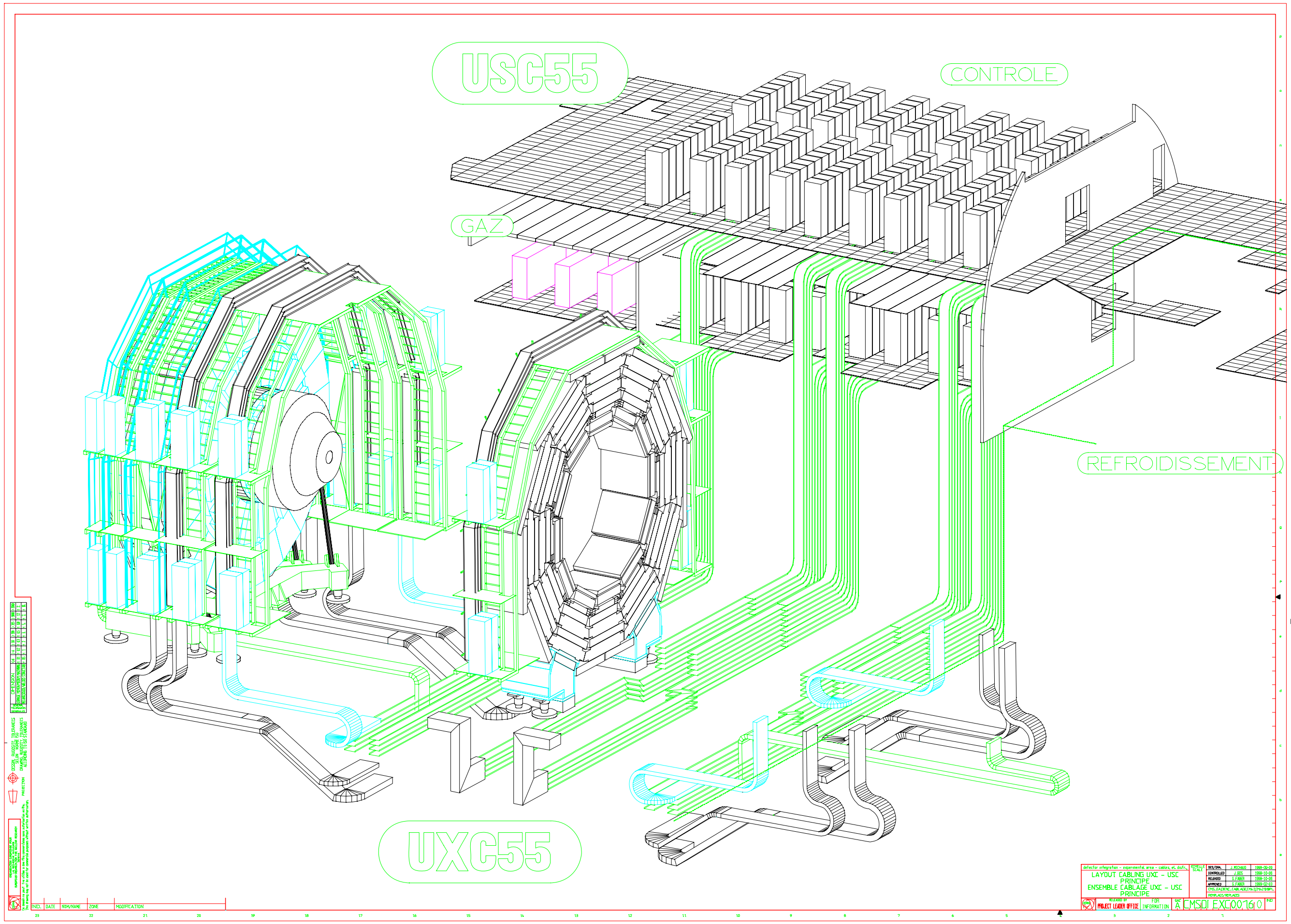
+z blockhouse & FIN at
Protvino, Russia

Rotating shielding
en route to Protvino

will be available at CERN on time

v34.1: lowering & cabling major elements

snapshot during – end lowering: working on YB-2



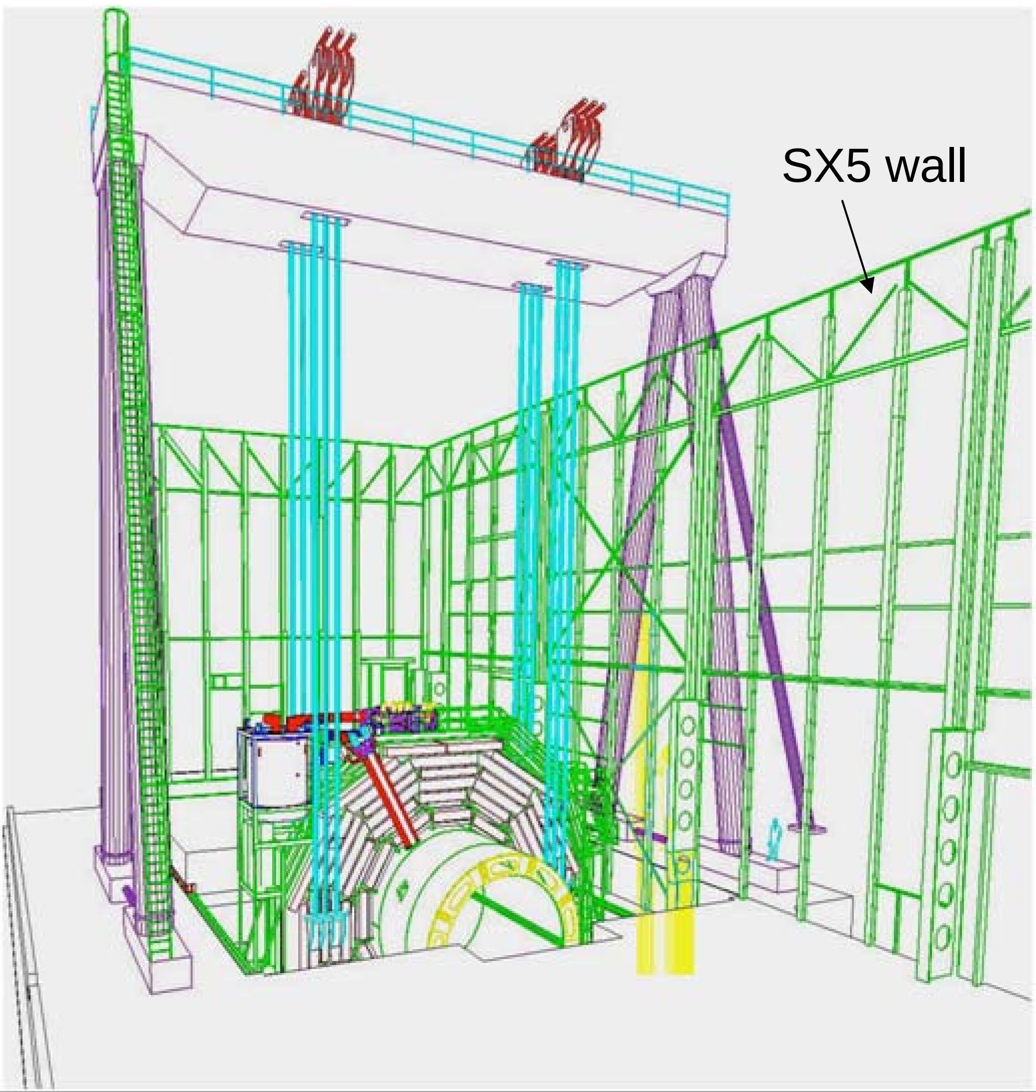
Cable chains will be installed and pre-cabled to patch panels from autumn 2005

HFs, YE1 disks and YB wheels are pre-cabled and tested on the surface.

Contract allows lowering to be suspended, allowing time to connect + end elements just after they are lowered. (μ barrel chambers blocked by lowering gear will also be installed then)
Work on -end elements for 3-4 months after mag. test

Aim: Lower elements when complete and ready to connect to USC

Heavy lowering



Heavy lowering starts early 2006, after magnet test

15 heavy lifts of about 1 week duration each.

Heaviest piece (central wheel + solenoid) 2000 tonnes.

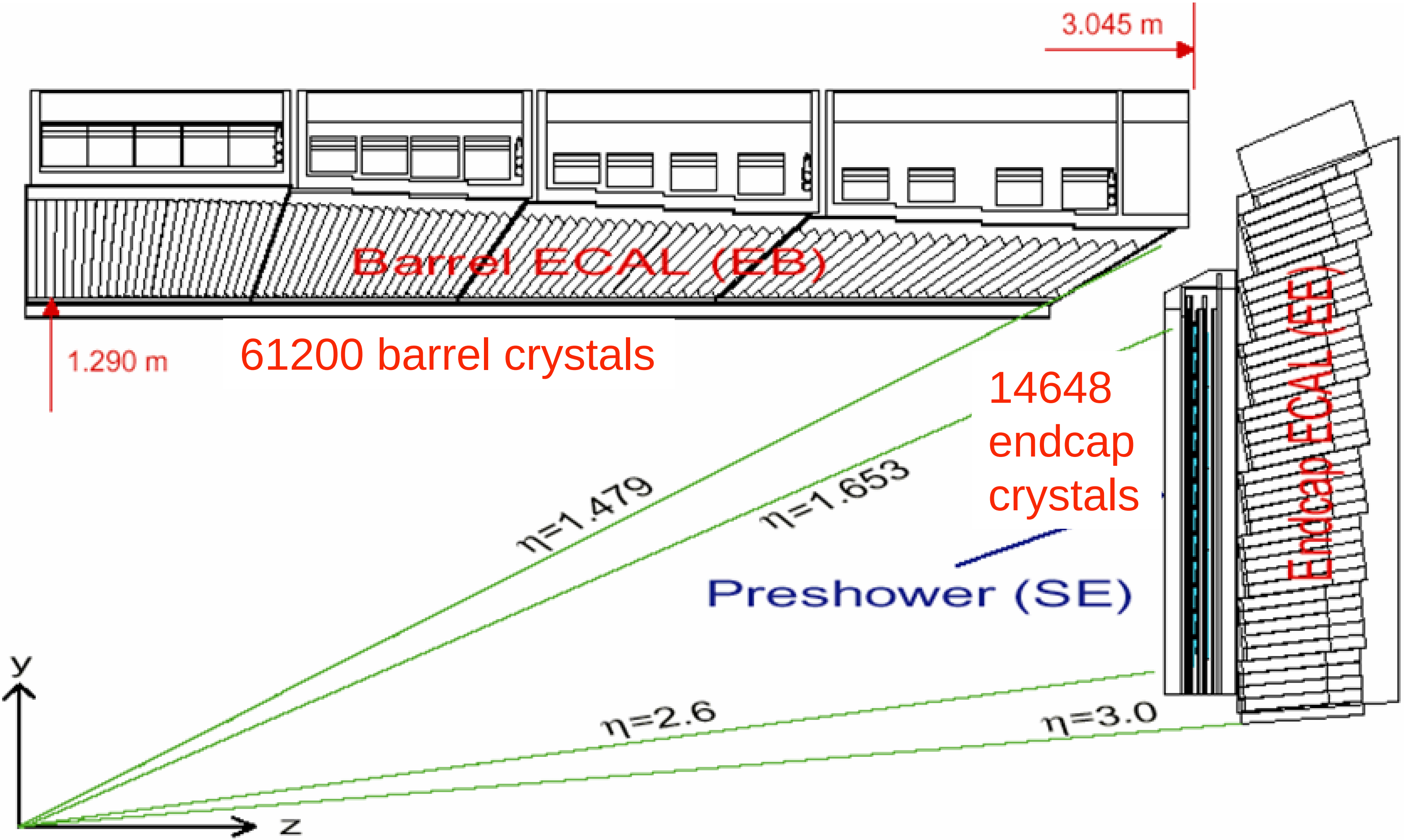
The cost of planned gantry idle time is reasonable: option to complete – z end on the surface, in parallel with critical path work on the +z end underground.

Contract awarded to VSL

worldwide experience,
notably large roof structures

Cable jacks for CMS will be based on this principle

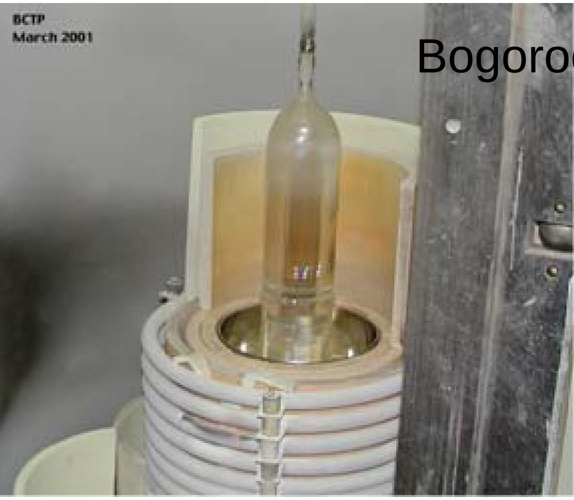
ECAL



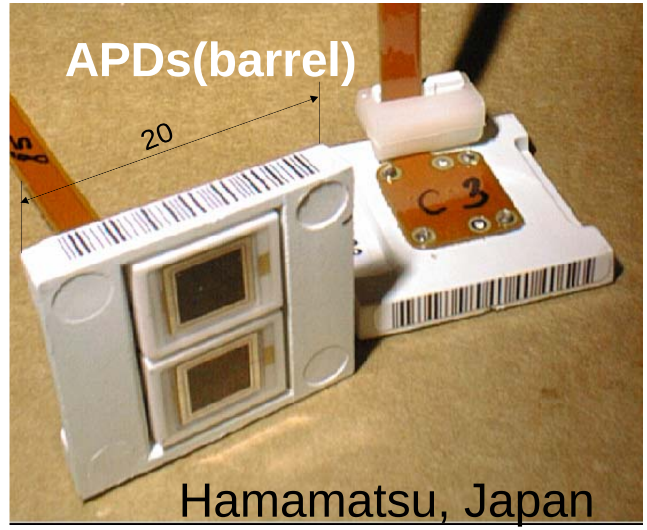
CERN
China
Croatia
Cyprus
France
Ireland
Italy
Portugal
Russia
Serbia
Switzerland
UK
USA
Japan

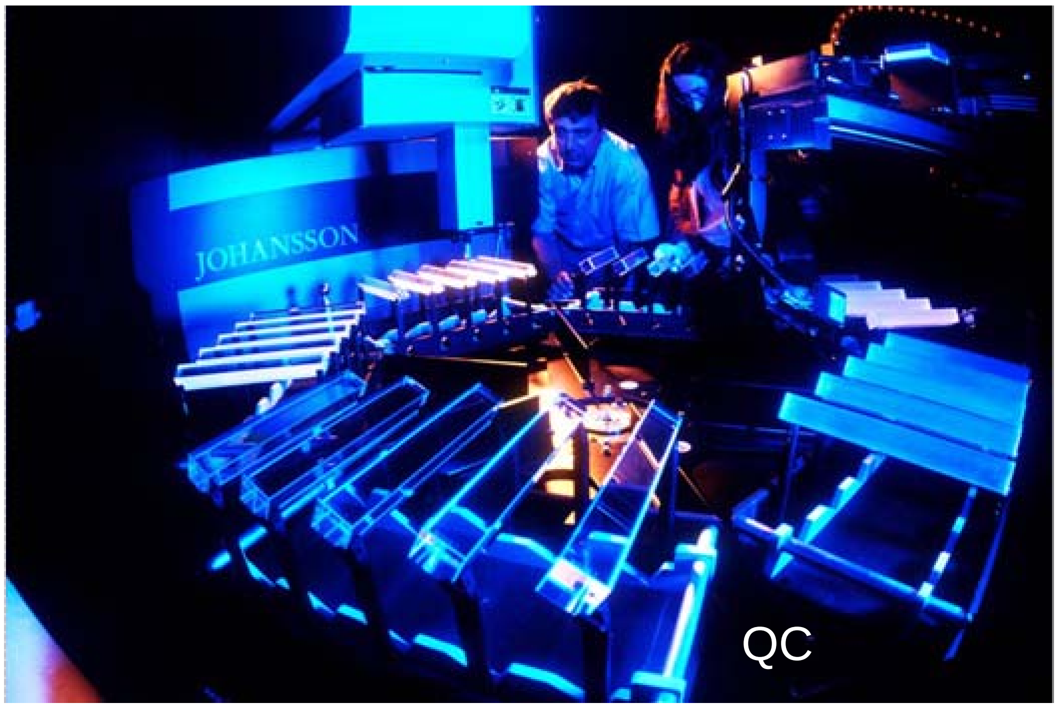
high resolution, small inhomogeneities (0.5%)
operates in 4T magnetic field
dense crystal to measure electromagnetic shower in minimum thickness of cylinder

ECAL crystals+transducers



Bogoroditsk, Russia





Supermodule Assembly

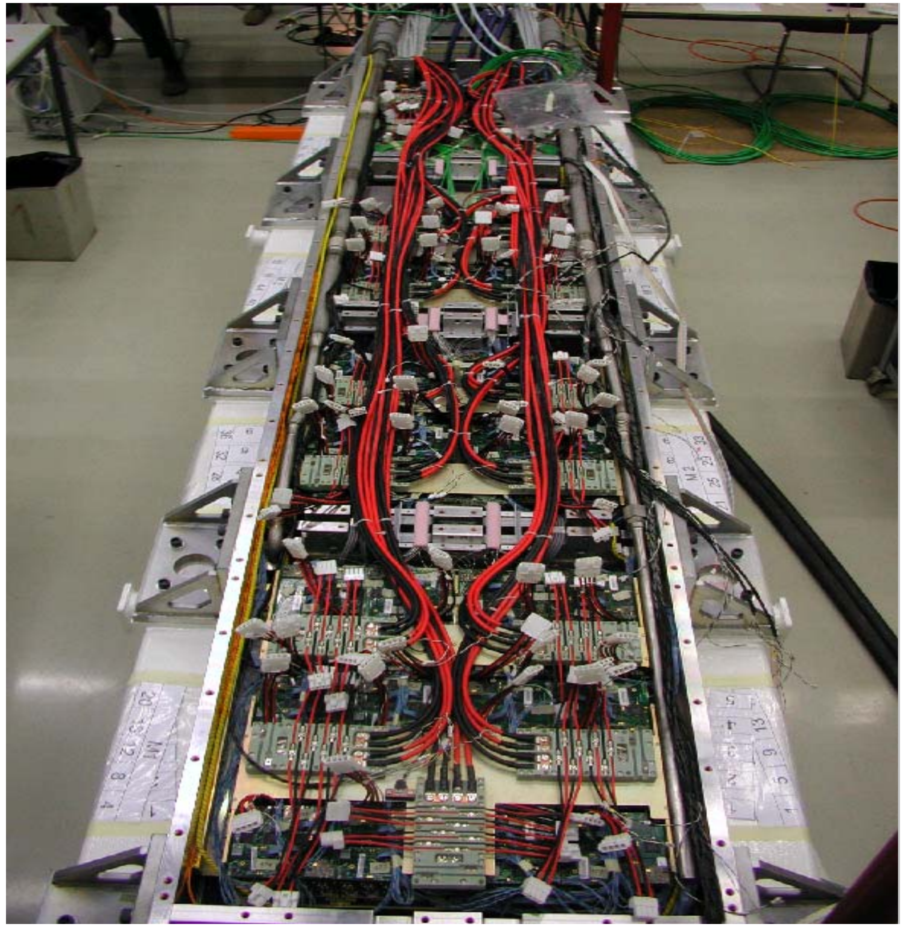
32k (50%) out of 62k barrel crystals delivered.However will soon be limited by crystal delivery.
(see “risks to schedule”)

16 ‘bareSupermodules assembled (out of 36 + 1 spare). The 18th ‘bare’ Supermodule (completion of the first half Barrel) is planned for early Spring

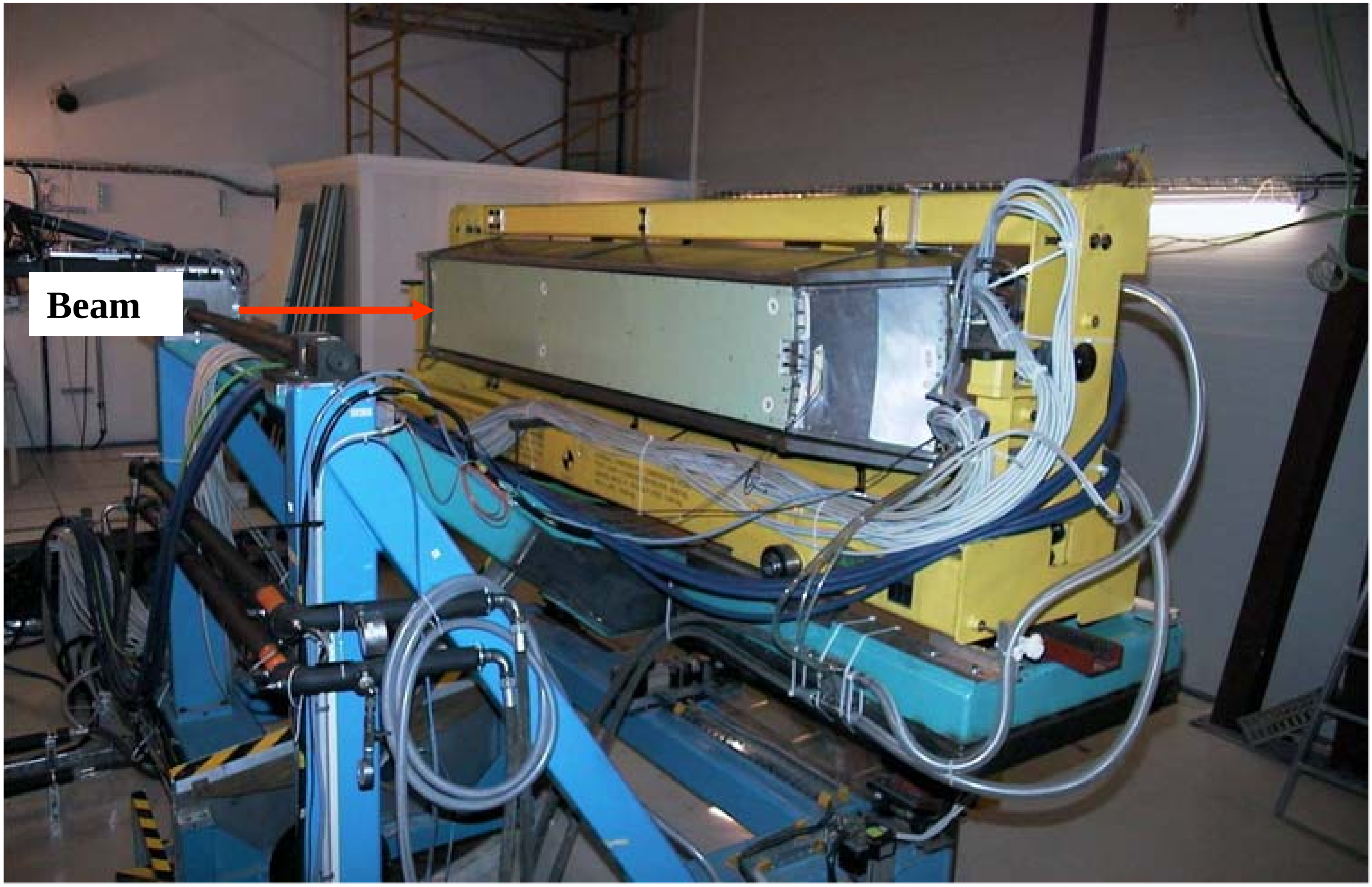
Electronics integration

Testing

Tidying



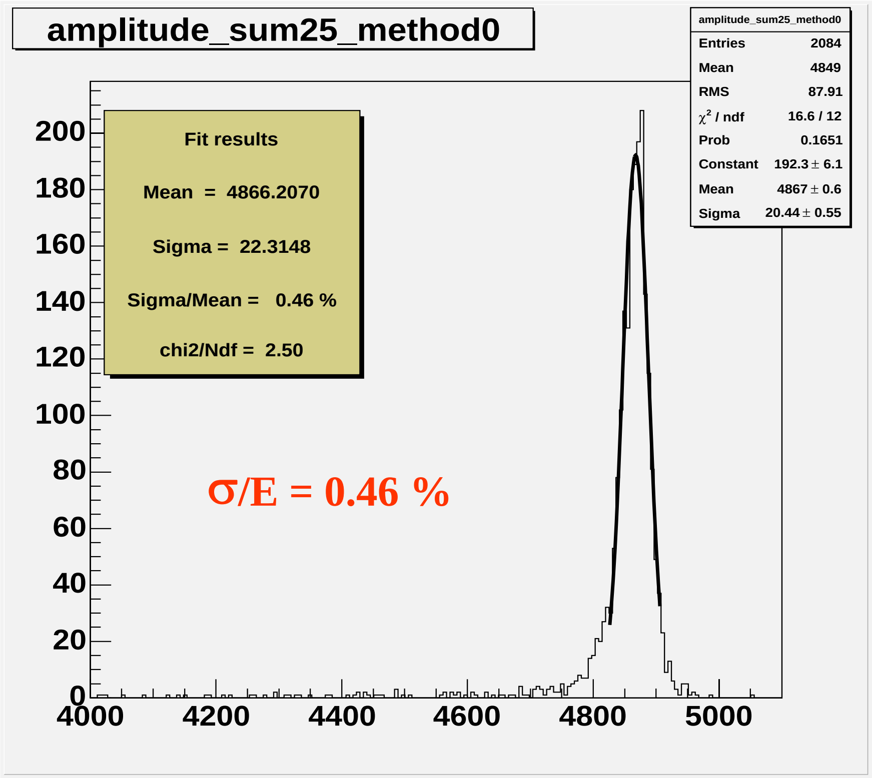
SM was moved to H4 on October 5th



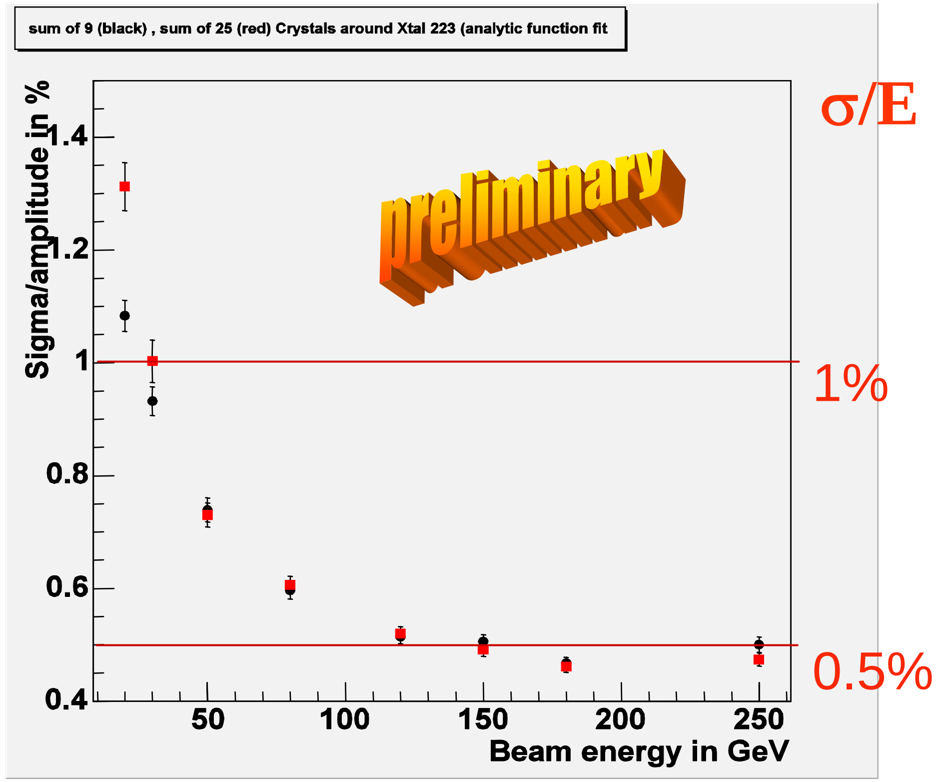
SM10 test beam results with electrons

- **Noise 40 MeV per channel**
- **No correlated noise**

Electronics performance



Xtal 223, 180 GeV, sum of 25 crystals



Xtal 223, sum of 9 (black) and 25 (red)

excellent resolution!

Risks to schedule: ECAL

Intended rate of crystal delivery not reached, due to poor yield of advanced process with more than 1 crystal produced per boule.

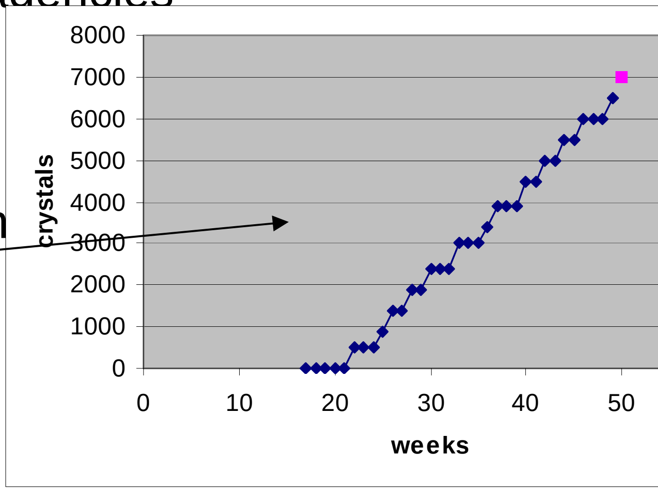
Serious dispute with sole qualified manufacturer earlier this year

3 months of production were lost while contracts were re-negotiated

Endcaps not affordable at new price

Action: -CMS + CERN management and CMS major funding agencies supportive in negotiations and unexpected over-costs. Russian labs and government involved.

- production re-started, steady at ~1200 xtals per month
- 31400 barrel crystals now in hand (>50%)
- contracts in place for a further 10,000



-negotiating with/qualifying alternative suppliers.

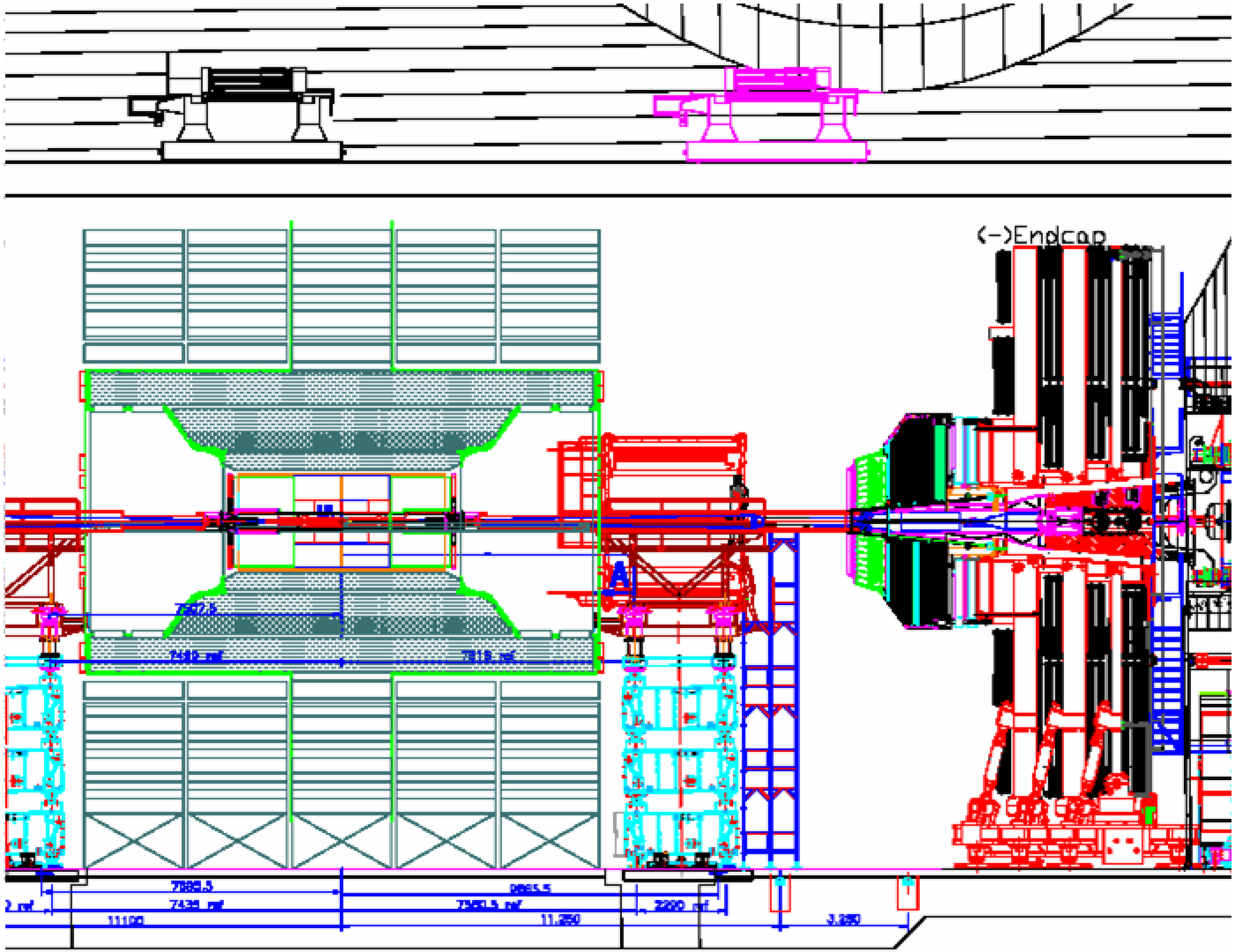
-tender for remaining crystals complete, contract for remainder of barrel in Q1 2005

-substantial overcost to complete endcaps (being discussed with funding agencies)

-provision made for installing last elements of ECAL in 07-08 winter shutdown

Schedule: endgame EB-

Tracker installation determines the last certain date to install EB- supermodules.



probably 3 campaigns

-on surface

-before tracker insertion

then

Mount dummy bulkheads

Tracker insertion

EB/TK cabling

beampipe insertion

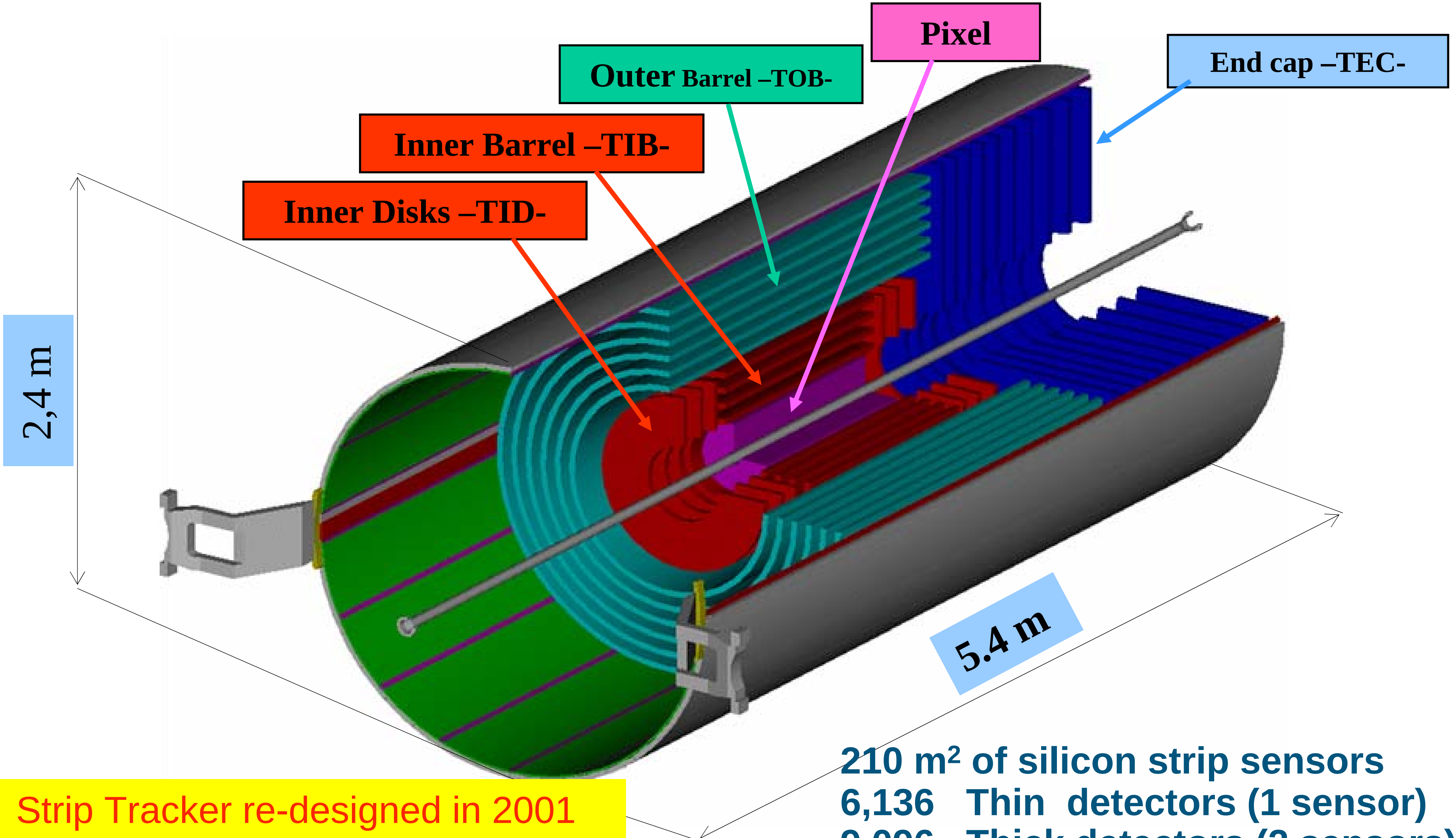
close CMS.

replace dummies by supermodules after EB/TK cabling or after BP insertion

(EB- limited by crystal delivery from suppliers)

Tracker: pixels and strips

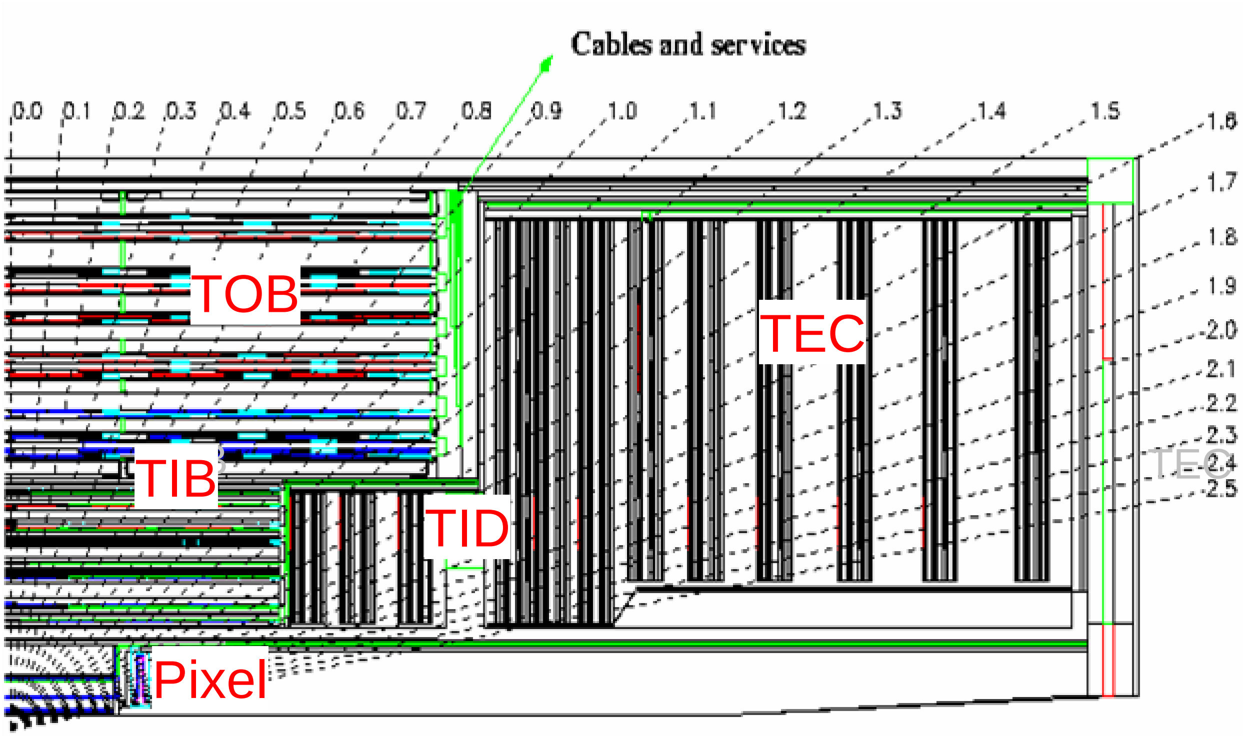
67 million pixels



Strip Tracker re-designed in 2001
- single homogeneous Si technology

210 m^2 of silicon strip sensors
6,136 Thin detectors (1 sensor)
9,096 Thick detectors (2 sensors)
9,648,128 electronics channels

Silicon Strip Tracker



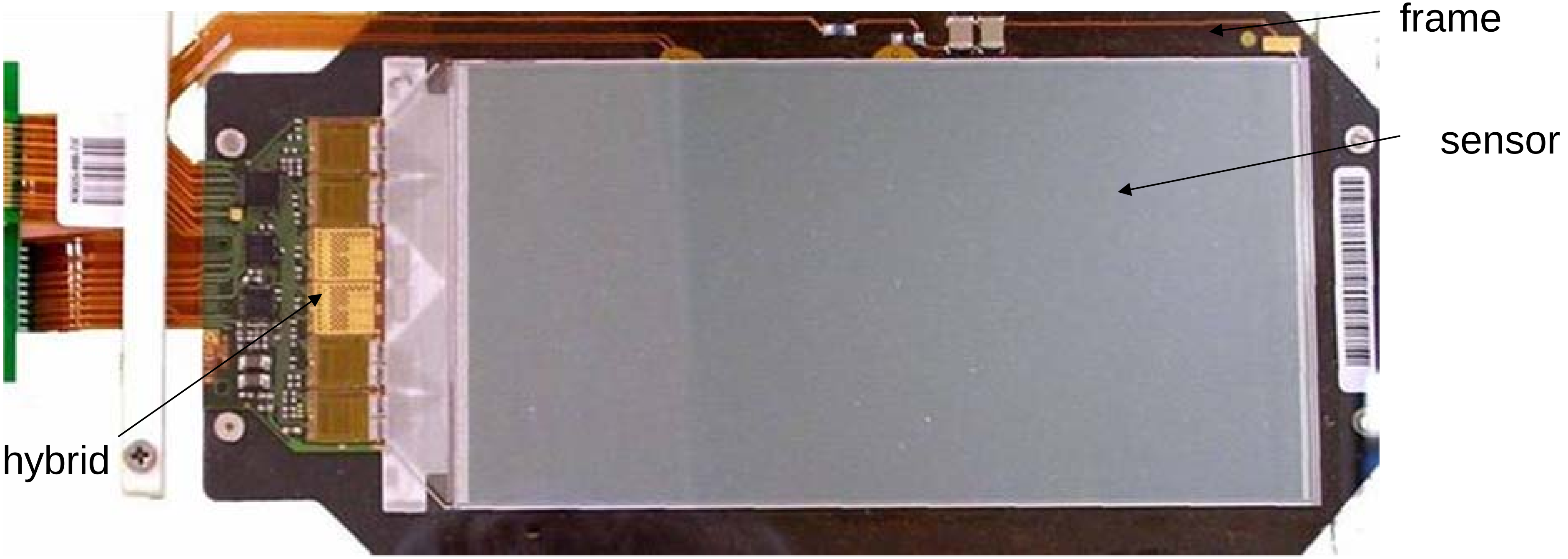
Precise module location on carbon fibre support structures

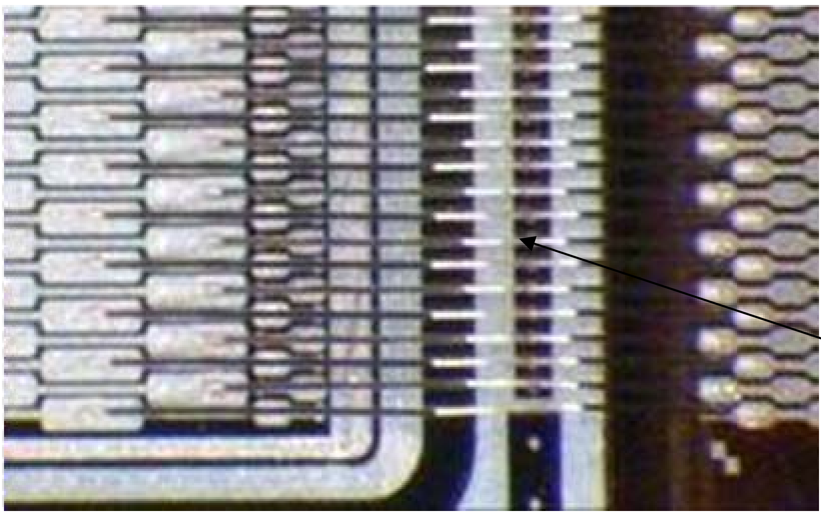
Current status: TIB/TID : 50% assembled
TOB : 6% assembled
TEC : 10% assembled

Austria, Belgium, CERN, Finland, France, Germany, Italy, Switzerland, UK,USA
Japan

Assembly for TOB and TEC delayed due to faults & quality issues (industrial suppliers))

Tracker: silicon strip modules





15'000 modules

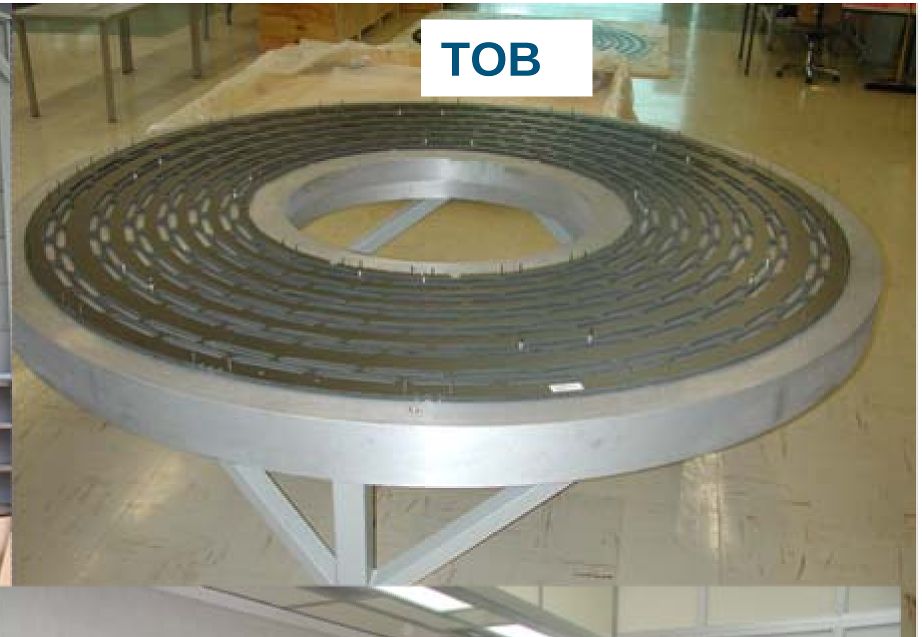
15'000 hybrids

Aim for reliable, high yield industrial hybrid fabrication and assembly

25,000,000 Bonds

Automated module assembly

Silicon Tracker: All CF structures delivered



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

TOB:rods

Rods (Helsinki) cabled at CERN by Pakistani colleagues

Frames assembled in Pakistan

Source scan of completed rods delivered to CERN

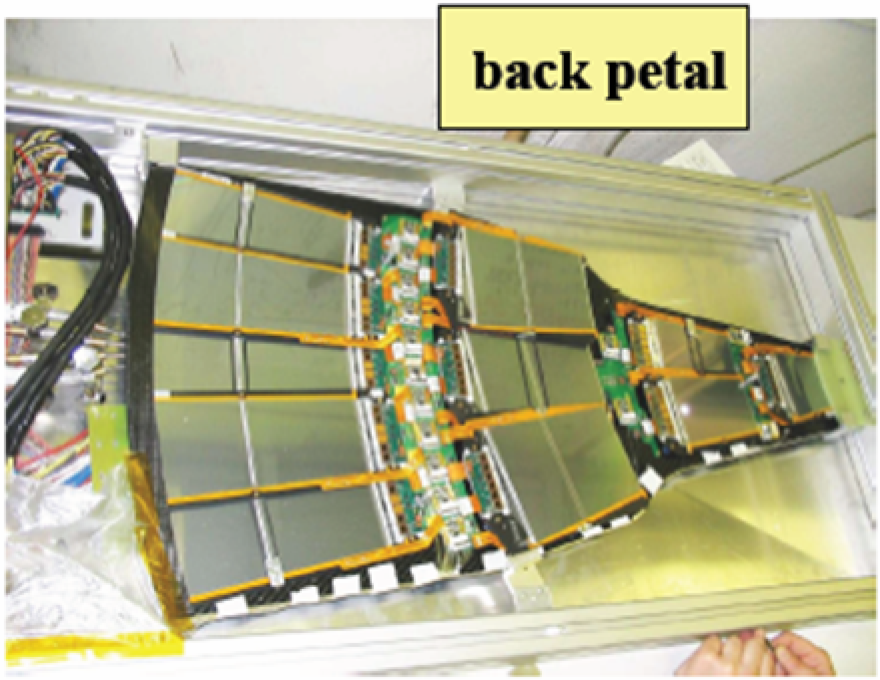
TEC Petal Integration and Test

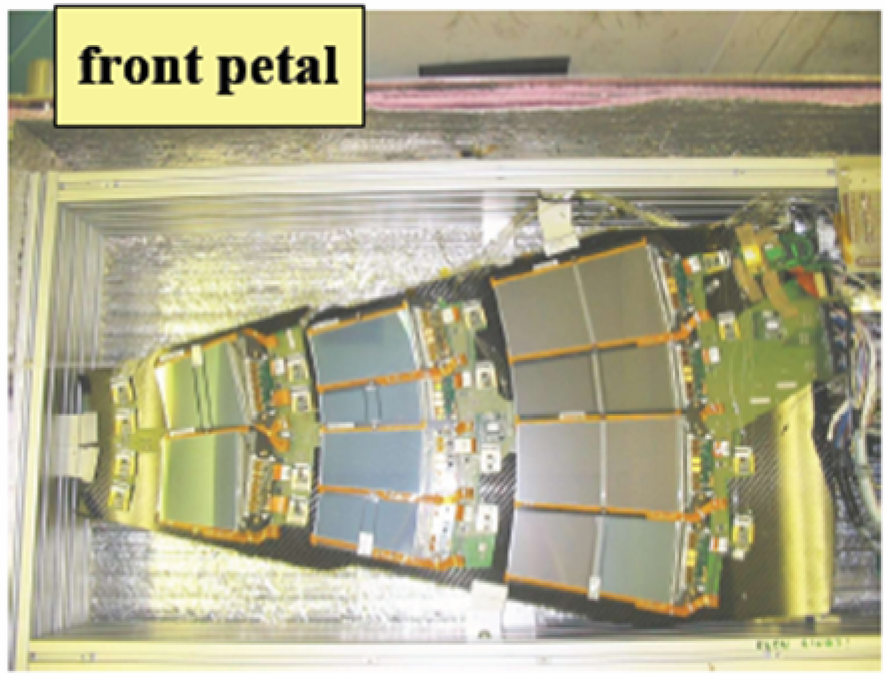
TEC modules assembly: Lyon, Brussels and US

Petal Integration

Aachen

Lyon





Risks to schedule: Si strip Tracker

Silicon strip Tracker:

Sensors from 1 of 2 suppliers either out of spec or proved to have unpredictable long-term performance.

-Large resources needed for quality checks

-Module mass production delayed

Action: Increased fraction of order moved to reliable supplier

Some contractual issues + cost overrun remain but little technical risk

Hybrids suffered a succession of generic faults, discovered late and after incorporation into modules.

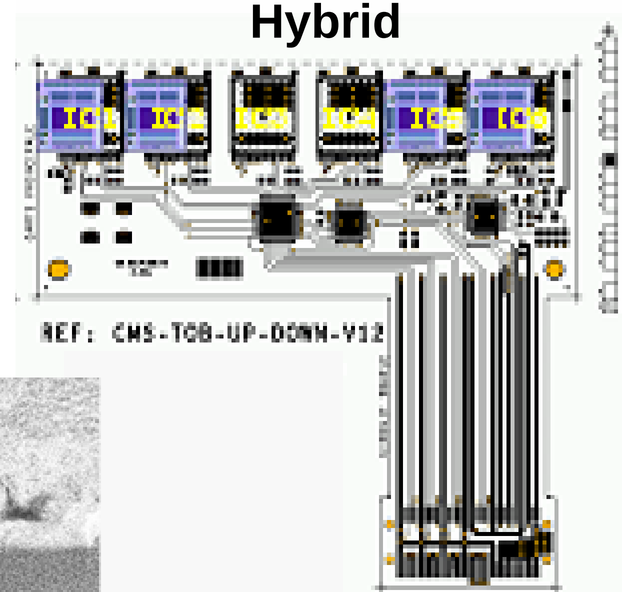
-wastage of sensors

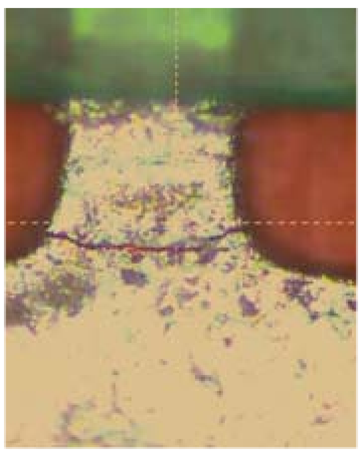
-successive halts in module production

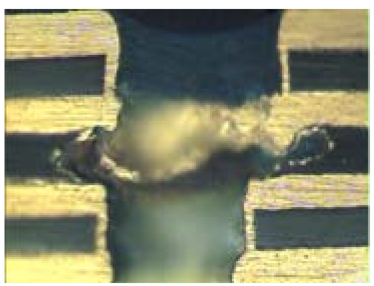
Action: minor re-design and improved QA/QC

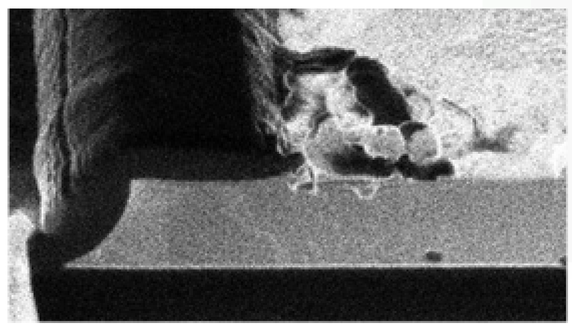
- production re-started
- module production re-start in Jan 05
- 20 months to complete Tracker

Hybrid



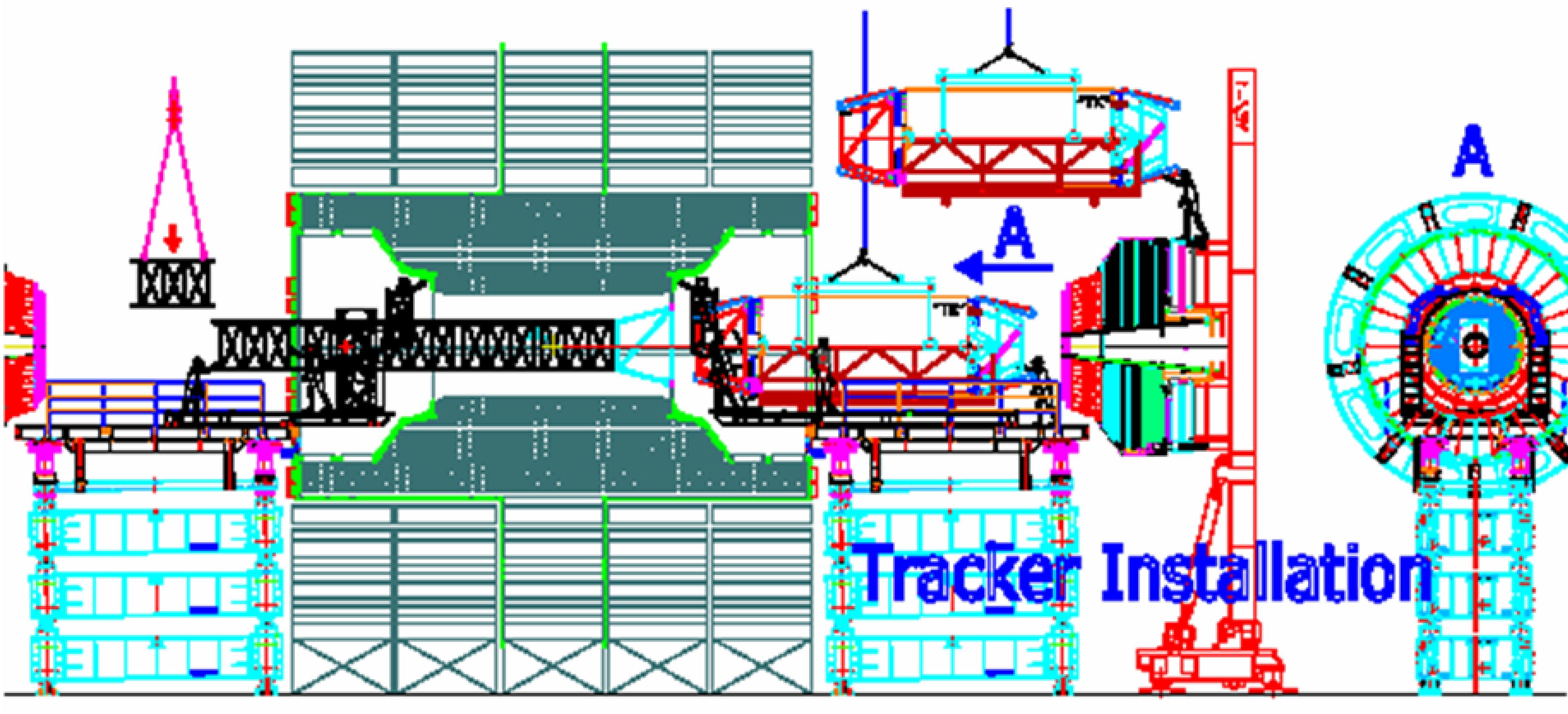






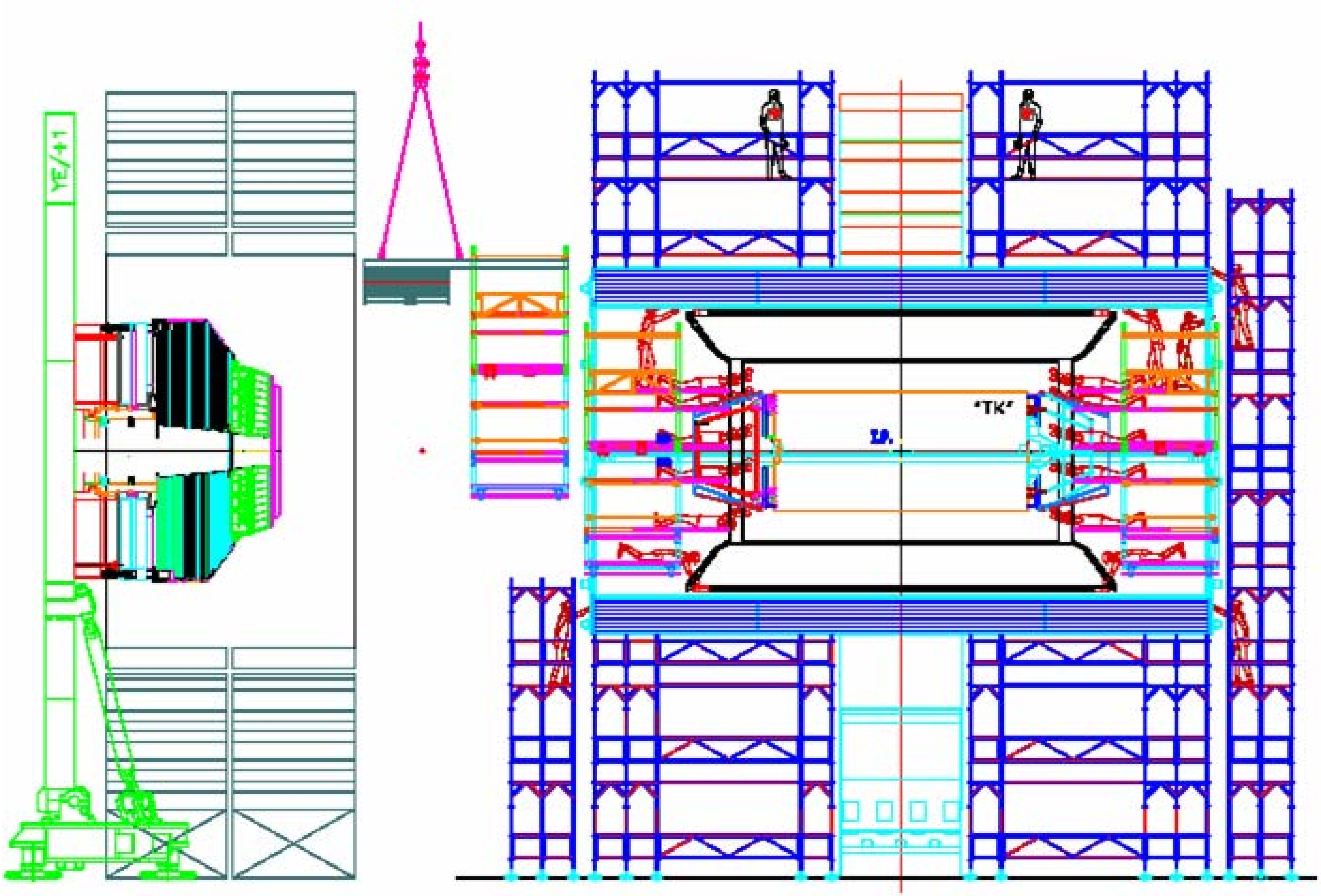
Tracker insertion

Working to make the Tracker schedule robust.
(Fall-back option to omit some elements from the initial detector for the pilot run?)
“drop-dead” date for insertion depending on time for YB0- cabling and beampipe installation.



Cabling of detectors inside solenoid

Complex problem. Must facilitate maintenance, EB supermodule replacement etc
3 months allocated: Dummy patch panels will allow pre-cabling before TK insertion

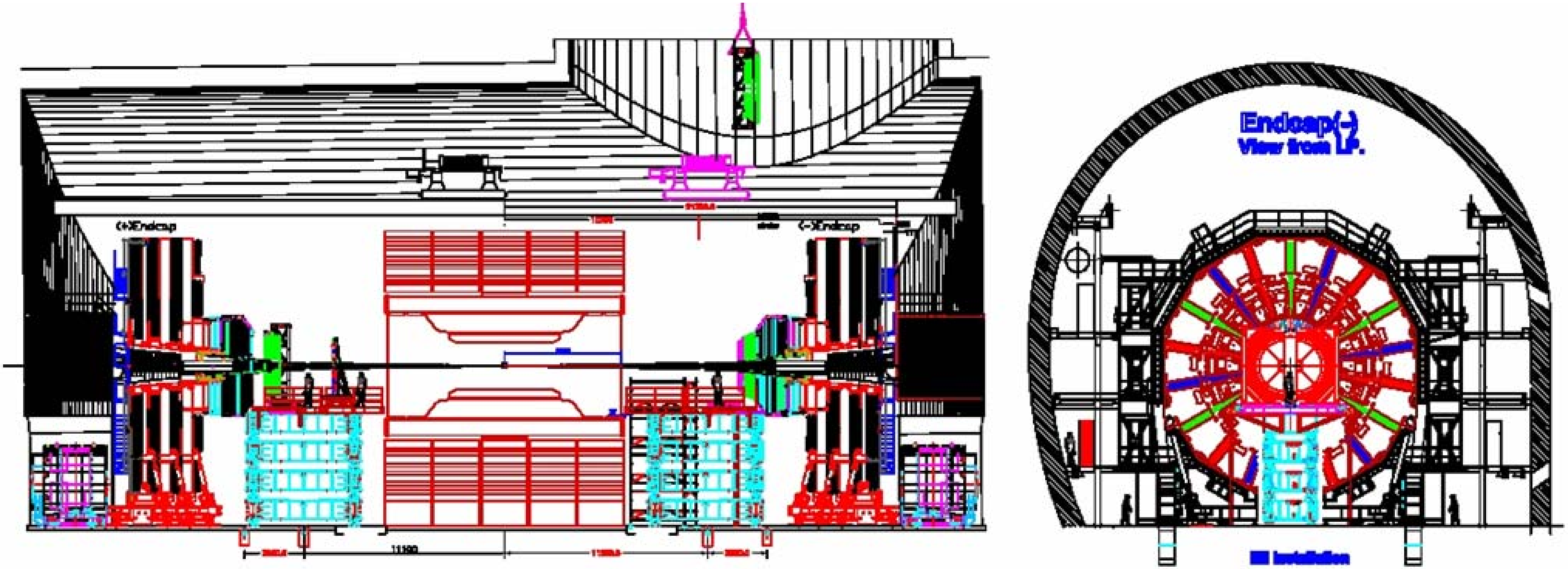


Install beampipe, then "ready to close"

EB/TK/Beampipe EE/ES installation platforms being designed for an efficient endgame.

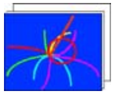
Beampipe installation schedule under discussion with vac group (3 mo allocated)

Beampipe EDR 25 Jan 05: authorise construction of remaining sections.

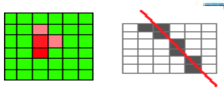


In this configuration, (barrel closed) we can continue to work and be "ready to close" at short (~2weeks?) notice

Trigger, Data Acquisition and Software



40 MHz
COLLISION RATE

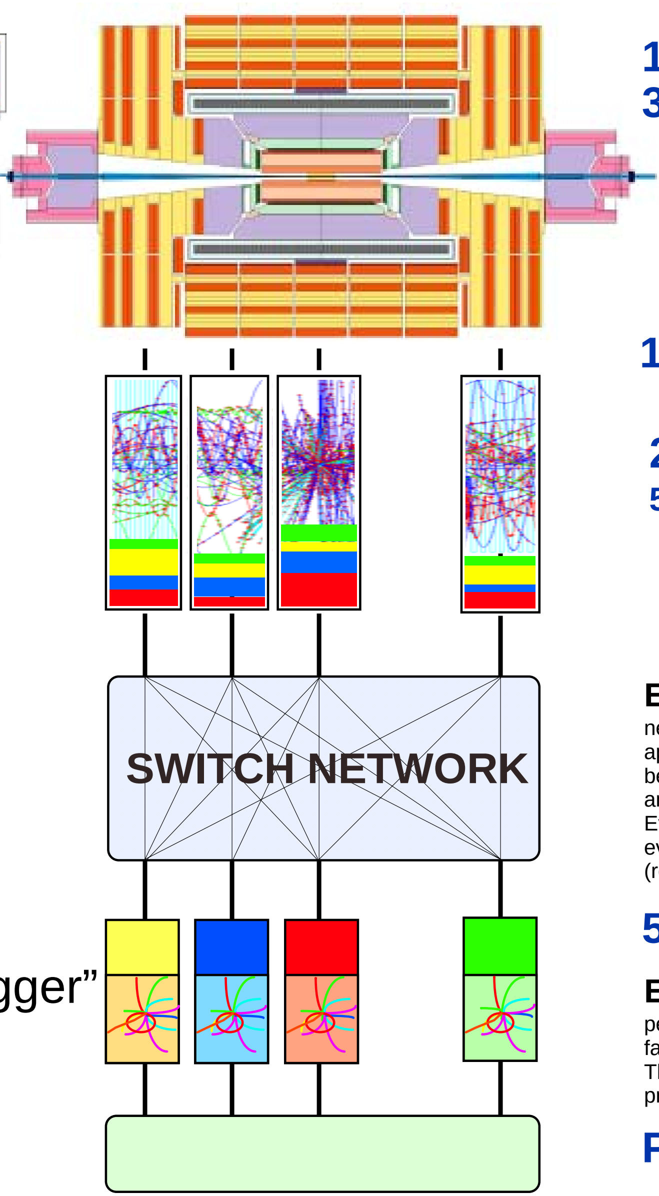


100 kHz
LEVEL-1 TRIGGER

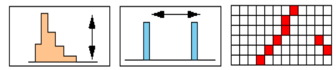
1 Terabit/s
(50000 DATA CHANNELS)

500 Gigabit/s

"High Level Trigger"
(software)



16 Million channels
3 Gigacell buffers



1 Megabyte EVENT DATA

200 Gigabyte BUFFERS
500 Readout memories

EVENT BUILDER. A large switching network (512+512 ports) with a total throughput of approximately 500 Gbit/s forms the interconnection between the sources (Readout Dual Port Memory) and the destinations (switch to Farm Interface). The Event Manager collects the status and request of event filters and distributes event building commands (read/clear) to RDPMs

5 TeraIPS

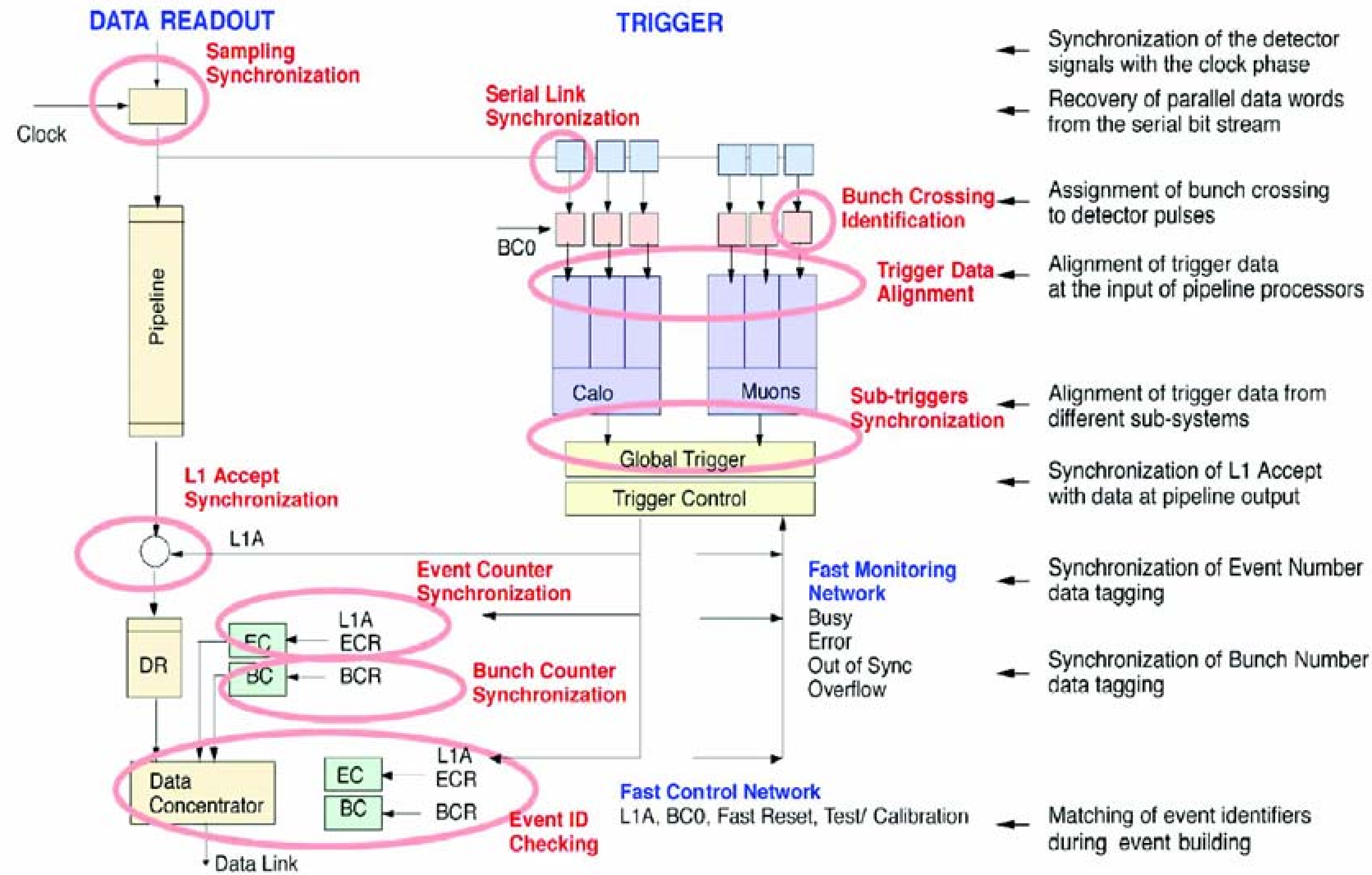
EVENT FILTER. It consists of a set of high performance commercial processors organized into many farms convenient for on-line and off-line applications. The farm architecture is such that a single CPU processes one event

Petabyte ARCHIVE

Austria
Finland
France
Greece
Hungary
Italy
Korea
Poland
Portugal
Switzerland
UK
USA

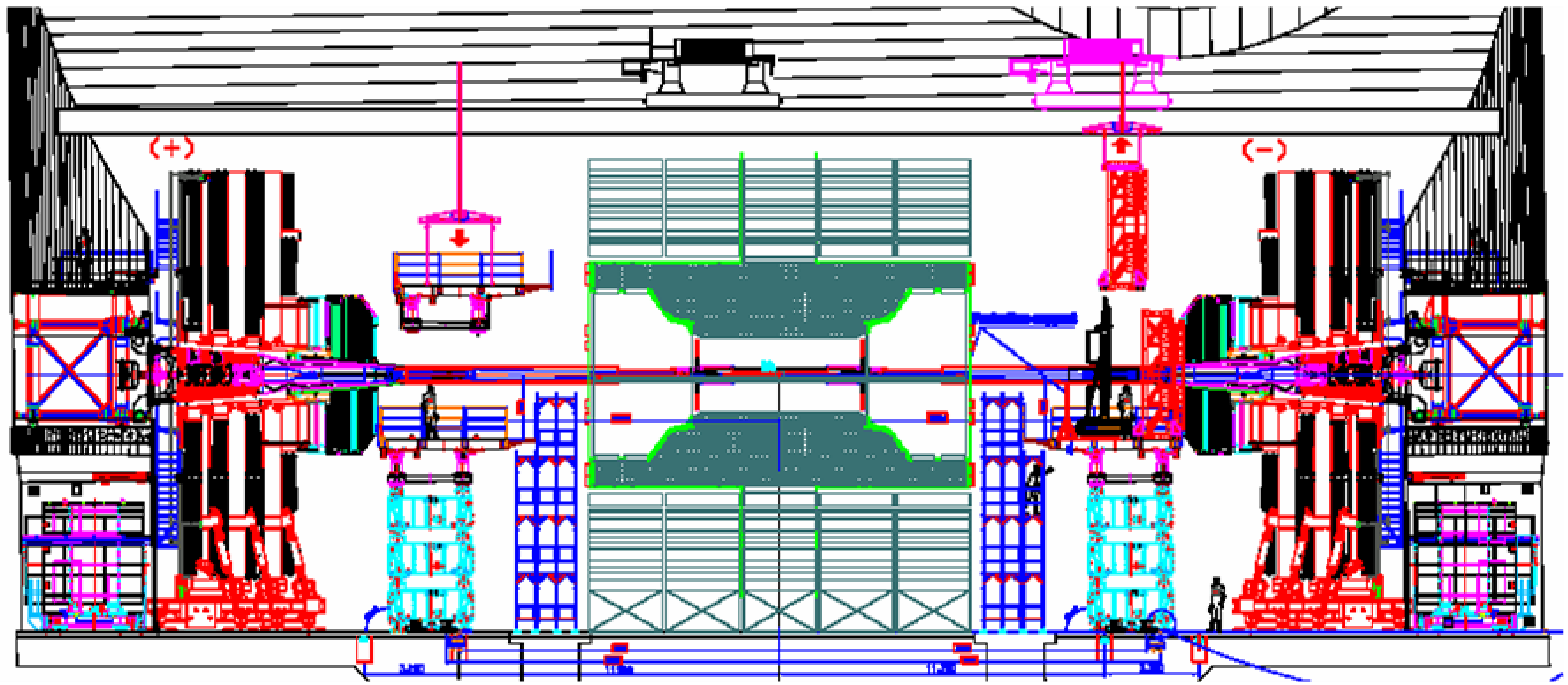
Commissioning : Synchronisation

the trickiest part of trigger/DAQ system integration



First shutdown

Fall-back scenarios with elements missing imply greater activity in 1’st shutdown
Aim: Emerge from first shutdown with “low luminosity detector”



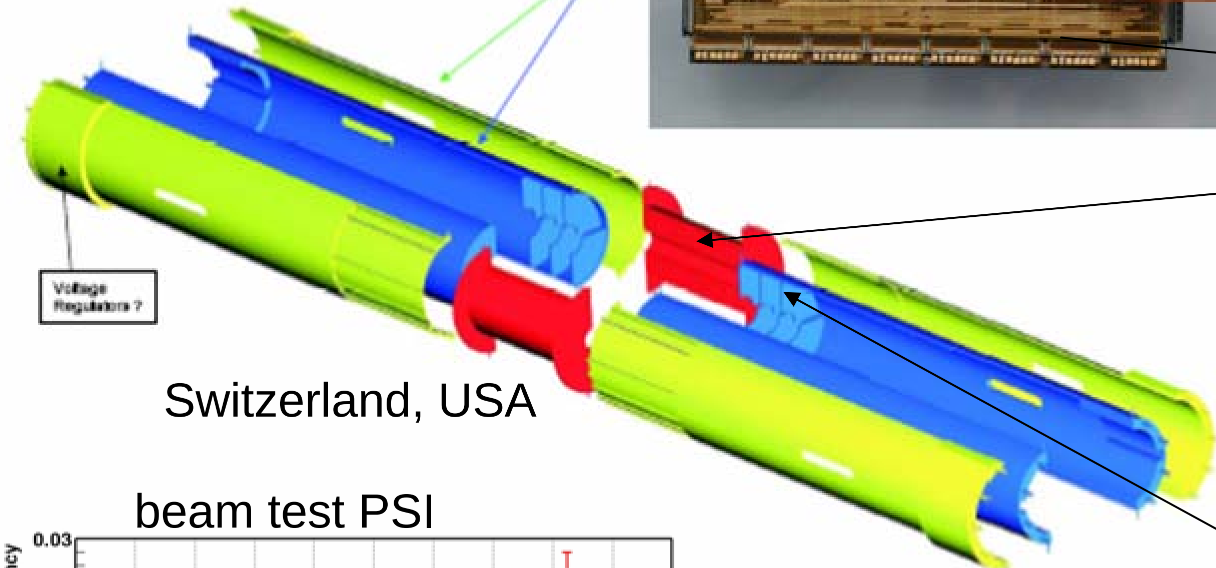
Mounting EE Back Flange on HE+1

Dummy flanges and patch panels are ready.

Install in Jan 05 to permit EE/ES pre-cabling.

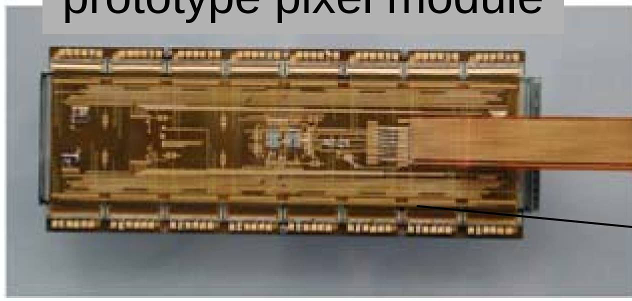
Pixel Tracker

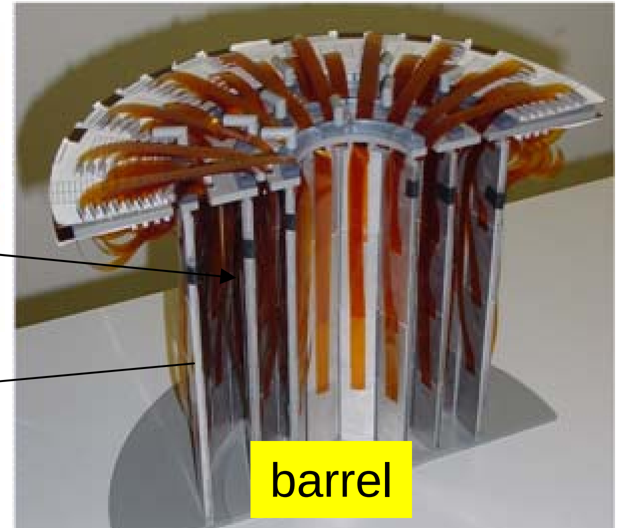
service tubes



Switzerland, USA

prototype pixel module



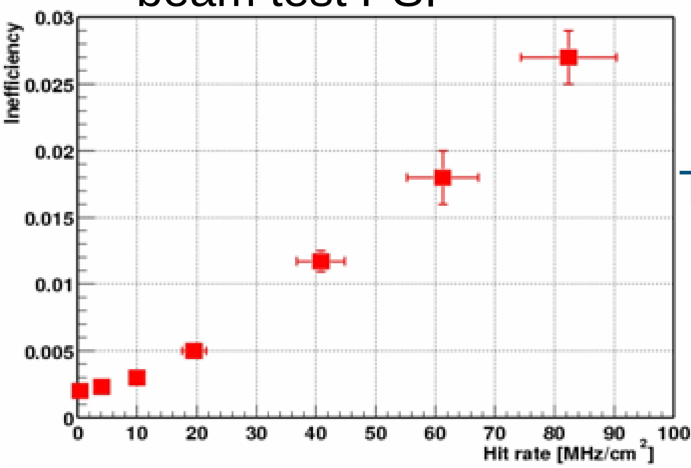


assembly at PSI, Switzerland

720 modules, 50M channels

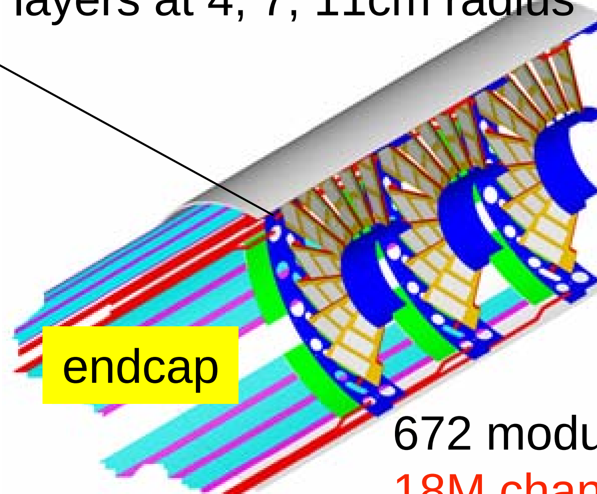
layers at 4, 7, 11cm radius

beam test PSI



Track rate of 25MHz/cm^2
(LHC @ r = 4cm)

Data Loss ~ 0.8%

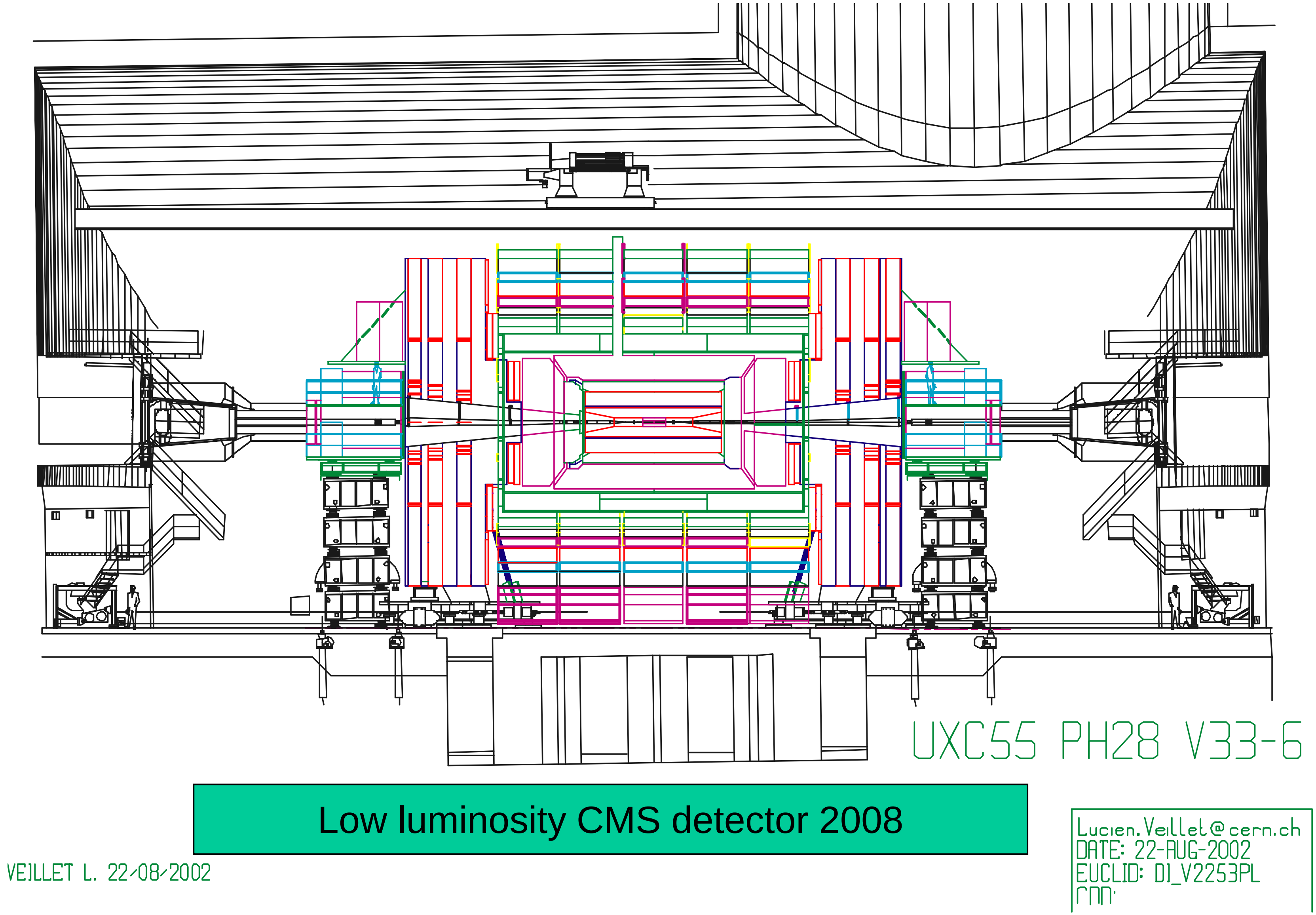


672 modules

18M channels

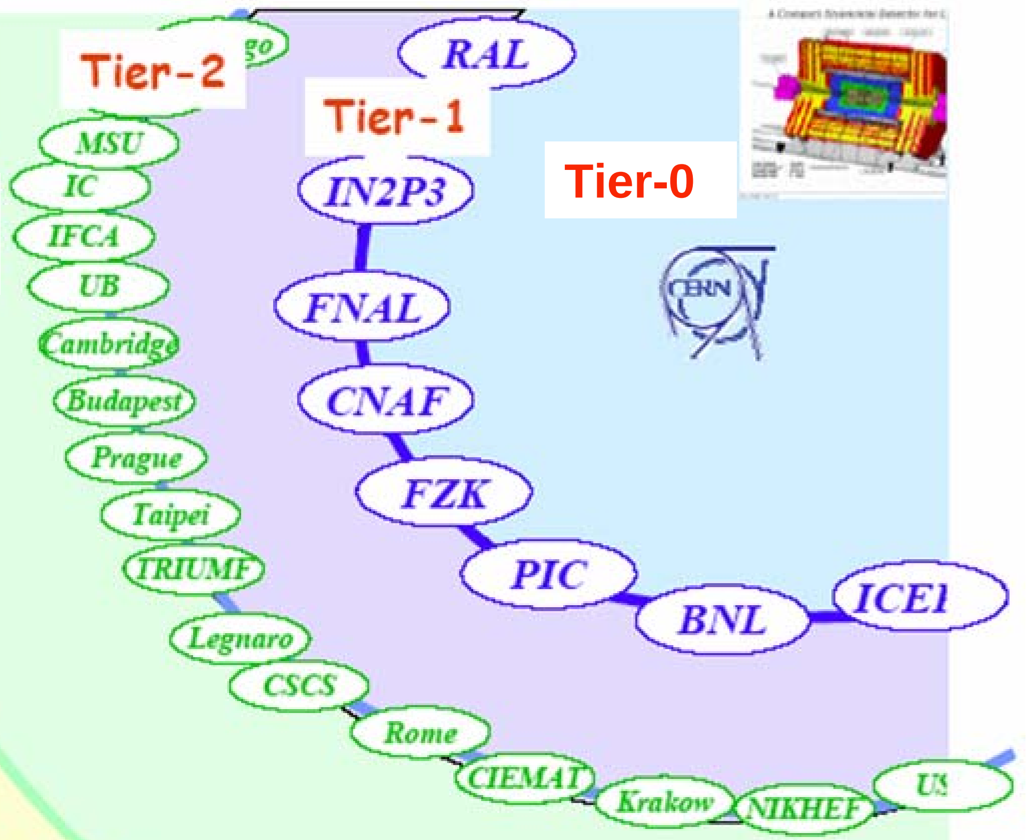
assembly in US

2008: CMS closed for beam



Low luminosity CMS detector 2008

LHC Grid Computing



- **Tier-0 –**
  - Filter → raw data
  - Reconstruction → summary data
  - Record raw data and DST
  - Distribute raw and DST to Tier-1
- **Tier-1 –**
  - "inline" to data acquisition process
  - Permanent storage and management of CMS data
  - Data-heavy analysis
  - Re-processing raw → ESD
  - National, regional support
- **Tier-2**
  - Simulation, digitisation, reconstruction of simulated data
  - General end-user analysis for local communities or physics groups

CMS produces 40 Million events/s
Select and Store 100 events/s
100 Mbyte/event
10^{17} byte/year = 100 Pbyte/year
(1 year = 10^{7} s)

DPS June 04

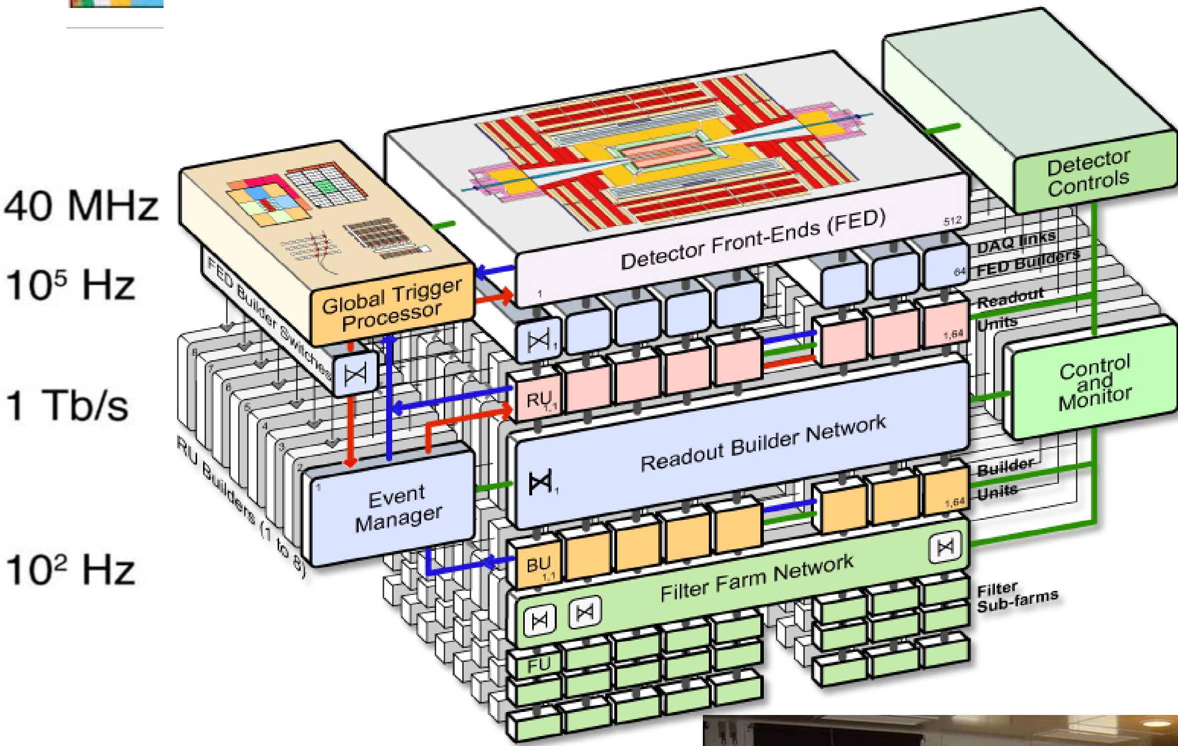
Conclusion

- **CMS is being constructed on a schedule targetted at:**
  - **Completing an Initial CMS Detector without ECAL Endcaps. “ready to close” from April 07, and ready to exploit the first LHC beams (“pilot run”) later that year.**
  - **Completing ECAL & installing pixels in winter shutdown 2007/2008 so as to have a Low Luminosity Detector ready for first the first physics runs.**

- Progress is generally very good. Concerns, risks and cost over-runs are being addressed.

- Pakistani groups are active in CMS (Magnet, RPC, Tracker)
  - the endcap RPC project is progressing well after many delays.
    the contribution of Pakistan will be crucial to success in the next year
  - opportunities exist to take responsibility for new CMS deliverables.

CMS Trigger and DAQ



Fully scalable system

8 x (12.5 kHz DAQ units) start in 2007 with 2 to 4 only

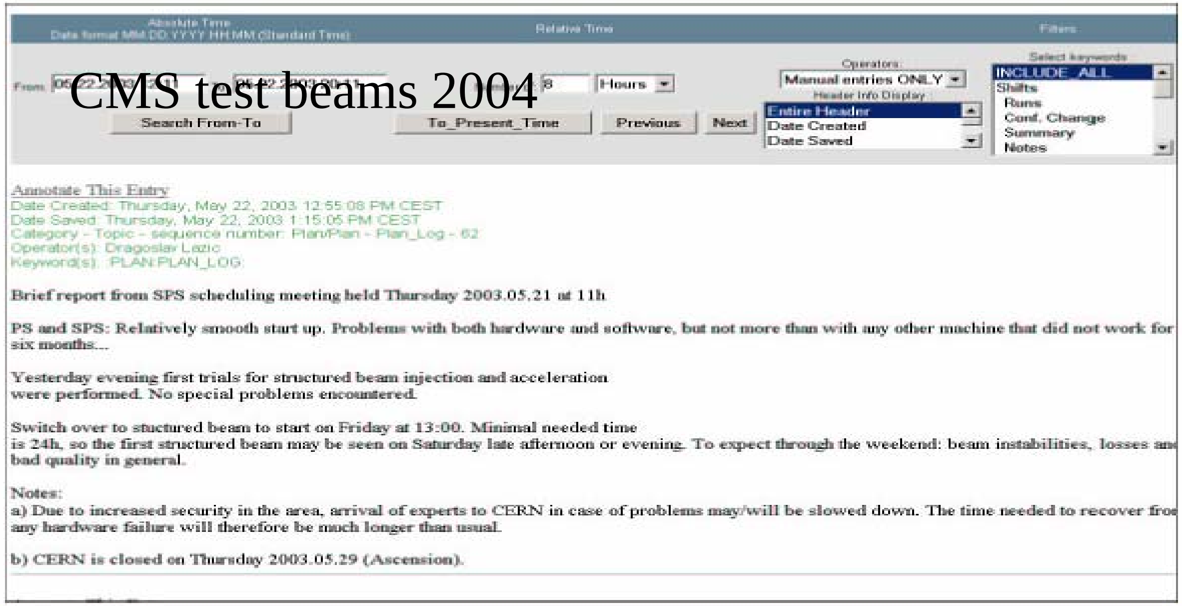
large effort in the last 18 months to validate the architecture using prototype modules and emulators

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

Remote Participation

tests are going on to evaluate the best way to use "virtual control rooms" around the world to assist in the commissioning

CMS test beams 2004



Absolute Time
Date format MM.DD.YYYY HH.MM (Standard Time)
Relative Time
Filters
Operators:
Manual entries ONLY
Header Info Display
Select keywords
INCLUDE_ALL
Shifts
Runs
Conf. Change
Summary
Notes
From
Hours
Search From-To
To_Present_Time
Previous
Next
Entire Header
Date Created
Date Saved

Annotate This Entry
Date Created: Thursday, May 22, 2003 12:55:08 PM CEST
Date Saved: Thursday, May 22, 2003 1:15:05 PM CEST
Category - Topic - sequence number: Plan/Plan - Plan_Log - 62
Operator(s): Dragoslav Lazic
Keyword(s): PLAN:PLAN_LOG

Brief report from SPS scheduling meeting held Thursday 2003.05.21 at 11h

PS and SPS: Relatively smooth start up. Problems with both hardware and software, but not more than with any other machine that did not work for six months...

Yesterday evening first trials for structured beam injection and acceleration were performed. No special problems encountered.

Switch over to stuctured beam to start on Friday at 13:00. Minimal needed time is 24h, so the first structured beam may be seen on Saturday late afternoon or evening. To expect through the weekend: beam instabilities, losses an bad quality in general.

Notes:
a) Due to increased security in the area, arrival of experts to CERN in case of problems may/will be slowed down. The time needed to recover fro any hardware failure will therefore be much longer than usual.

b) CERN is closed on Thursday 2003.05.29 (Ascension).

We have new tools for tb2004 There are 2 webcams and a good Polycom system. There is an e-log which allow remote parties to follow