Review of the Design Choices & Construction of the CMS Experiment

A. Hervé / CERN

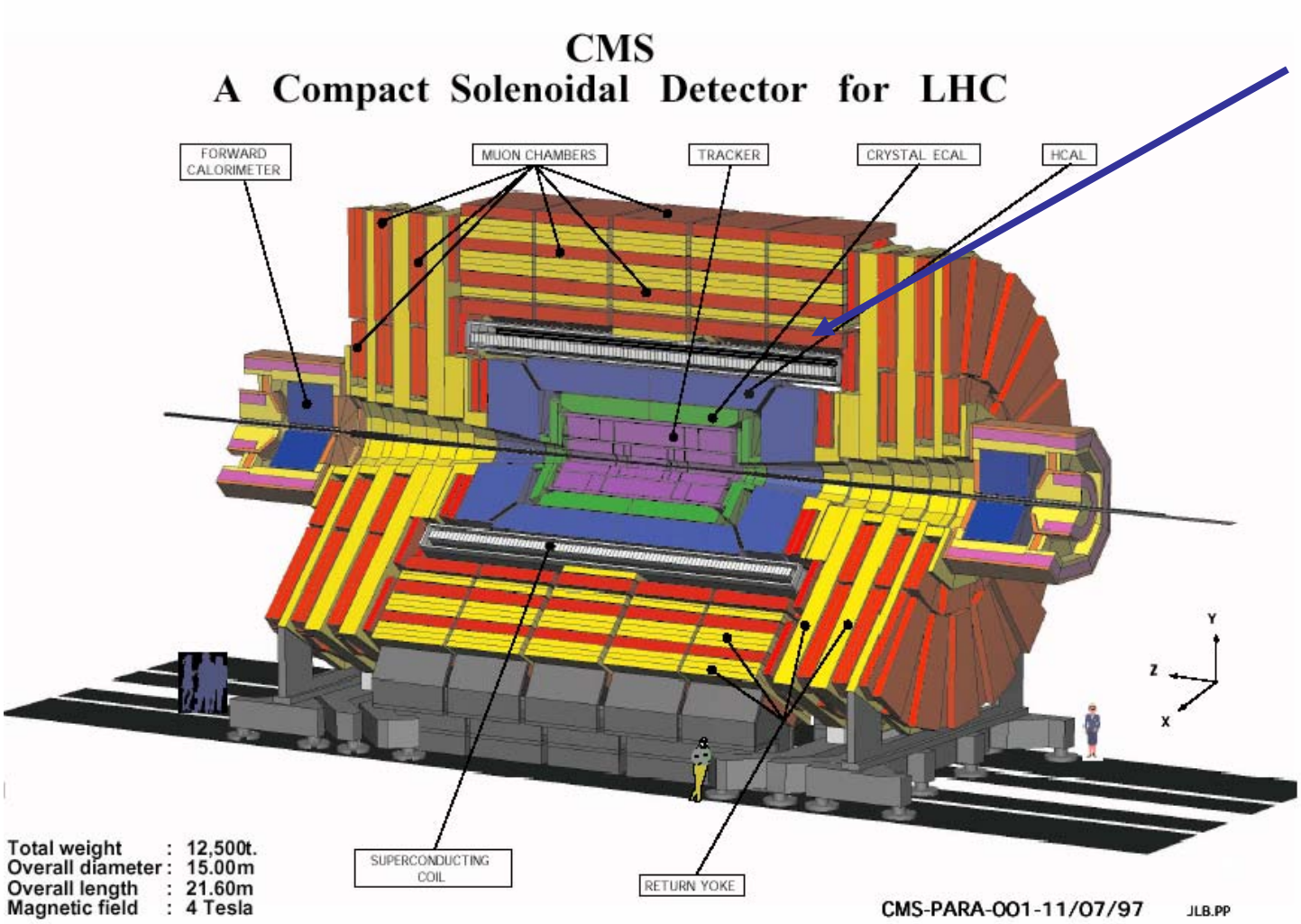
Content

- ***I will not touch on construction of sub-detectors but will concentrate on the general logistics for construction, installation and maintenance of CMS.***
- ***I will just mention the coil for its implication on the choice for constructing CMS on the surface.***
- ***I will not discuss the general principles of the integration project that would require a talk by itself.***
- ***I will show the recent events on CMS and status of installation.***
- ***I will mention, at the end, the relevance of the CMS concept and choices for new projects.***

Part-1

Concepts behind the design of the CMS Experiment

CMS Experiment
Fermilab is a strong collaborator



Based on Large SC Solenoid

6 m diameter

13 m long

Strong Field 4T

10’000-ton Instrumented Return Yoke

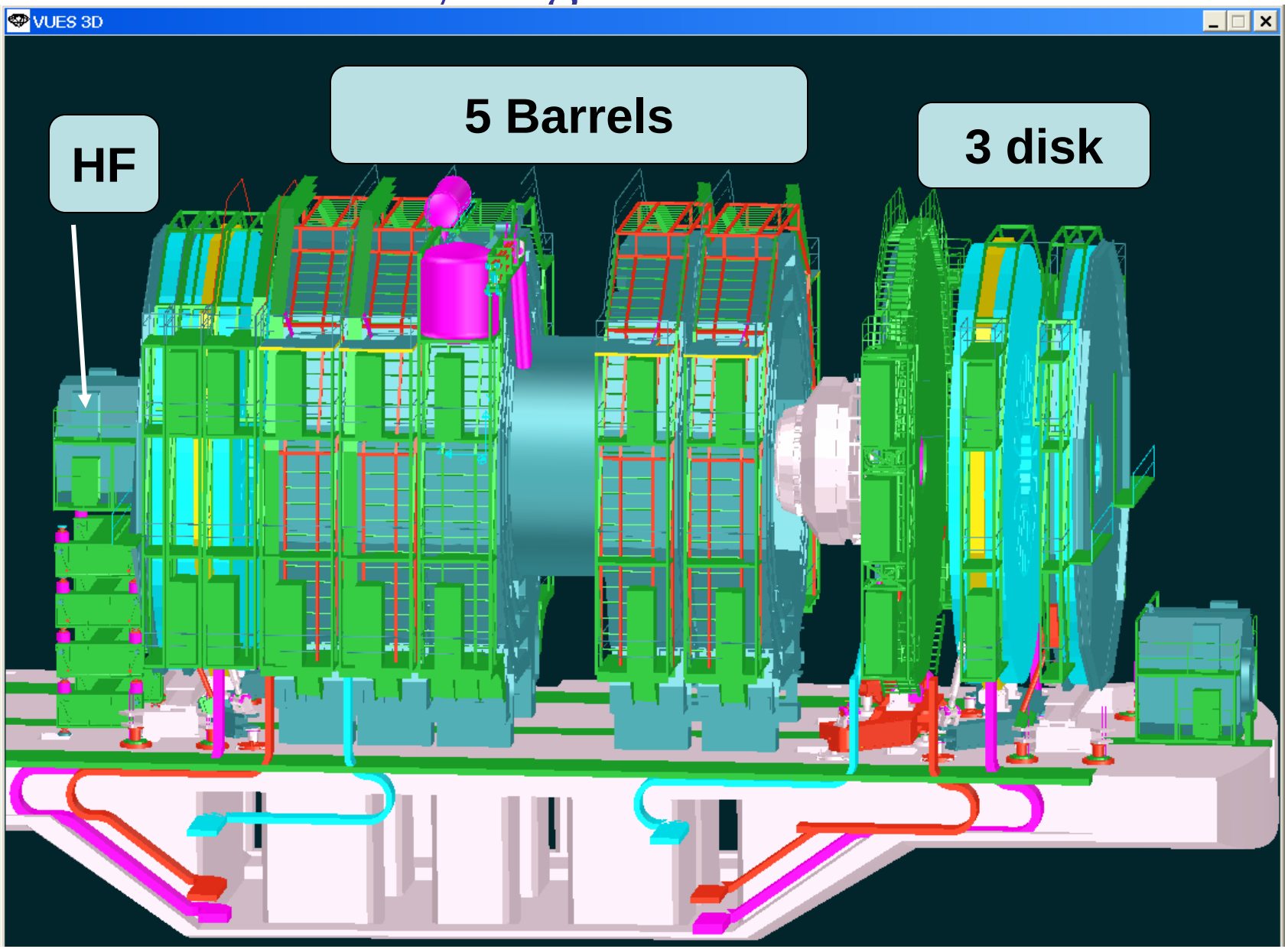
CMS Technical Design Principles from experience gained on LEP detectors

- ***Sub-detectors must be maintainable, that is detector can be opened in a reasonable time to give access to every one of them, including access to the main flanges of Tracker, ECAL and HCAL.***
- ***This opening scenario must be possible without decabling or removing services of any sub-detector, to allow fast re-commissioning before closing again the detector at the end of a shut-down.***
- ***The goal is to maximize maintenance time to get all sub-detectors operating at their optimum during the whole life of the experiment, not only at the start.***

Fermilab Seminar 31 August 2007

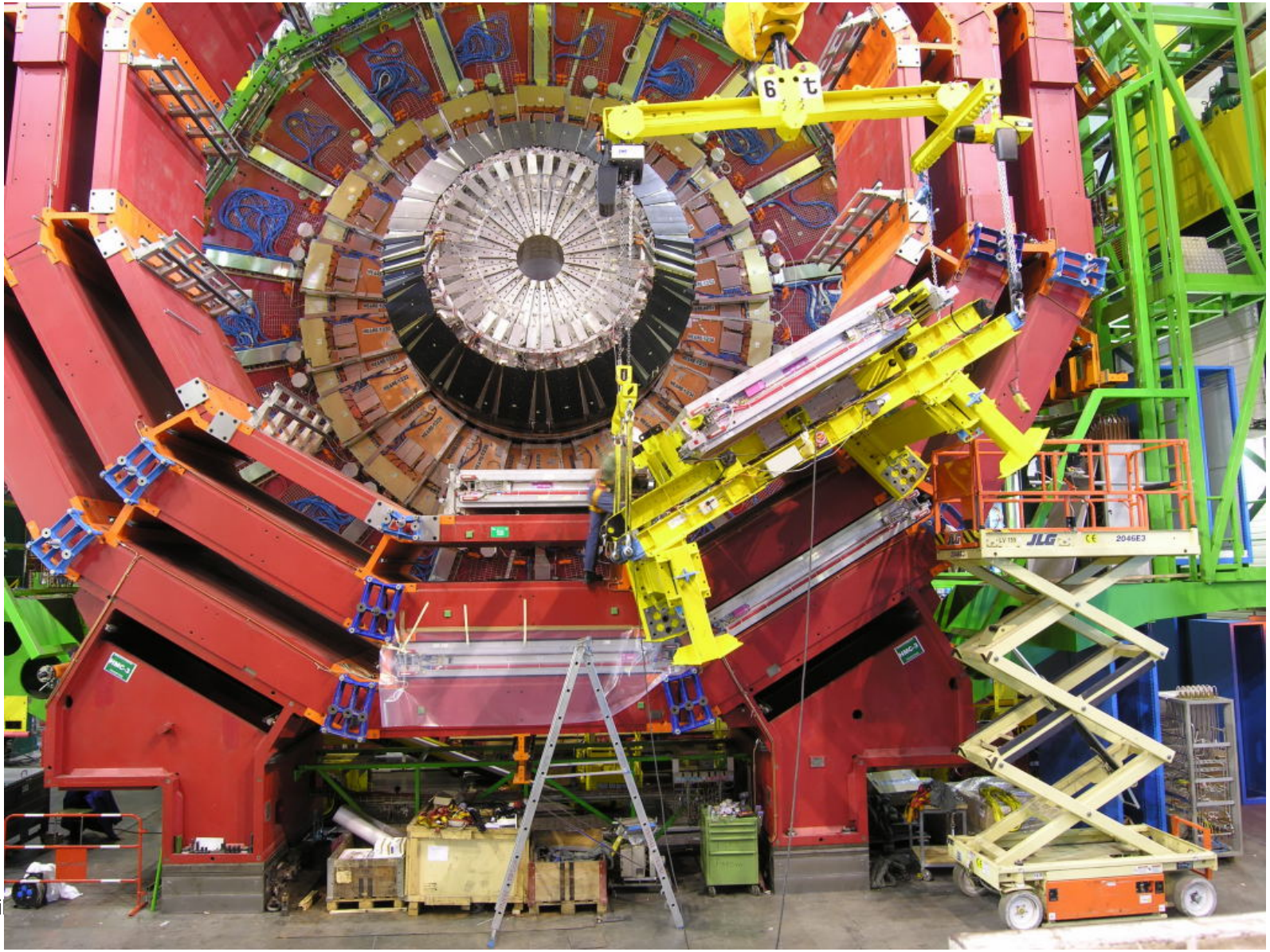
Sectioning the experiment and sub-detector installation with a view to maintenance

Large elements must be able to moved Connected by large cable chains



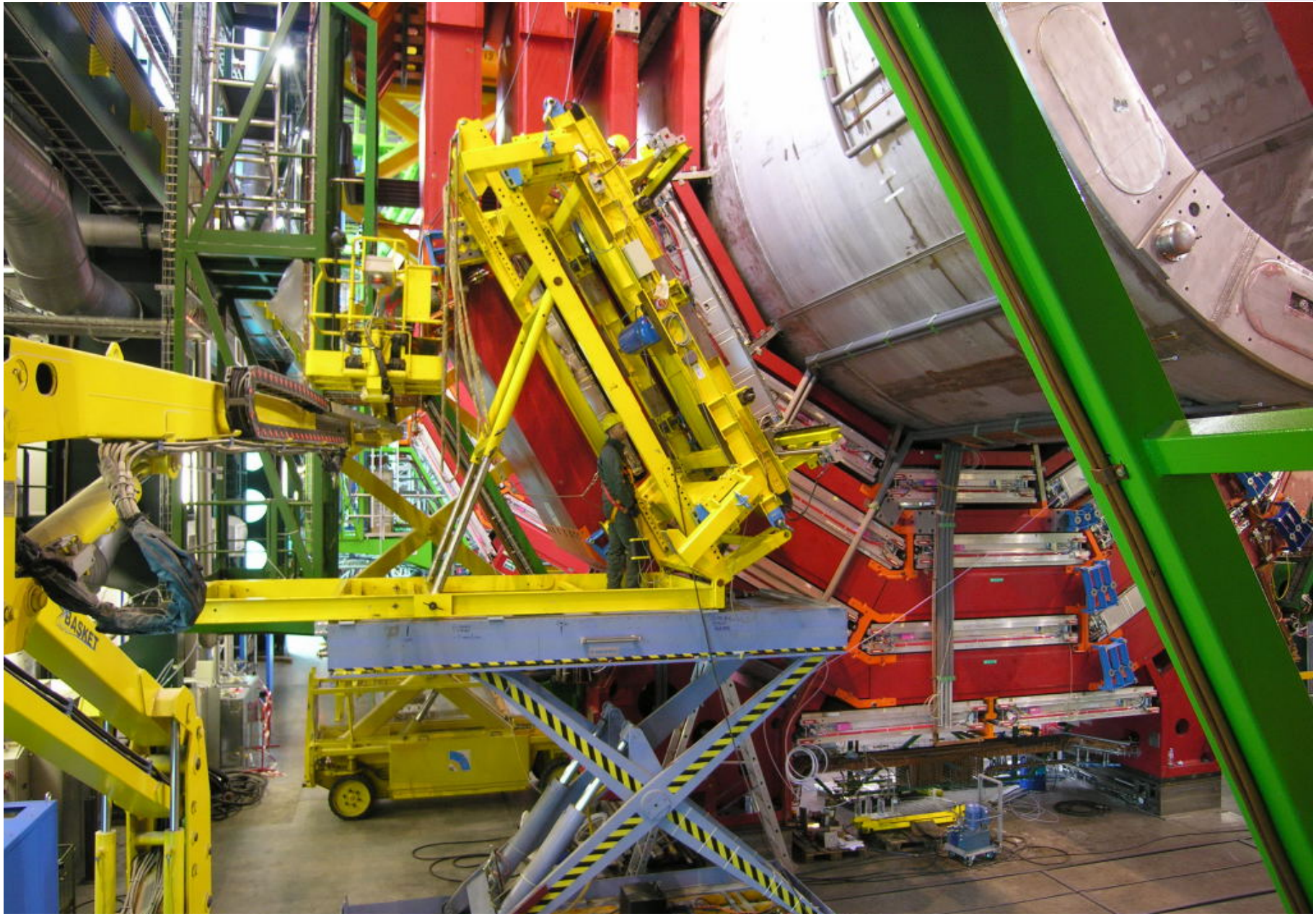
Installation of Muon Stations/RPC package in mobile wheel

Compatible with maintenance scenario



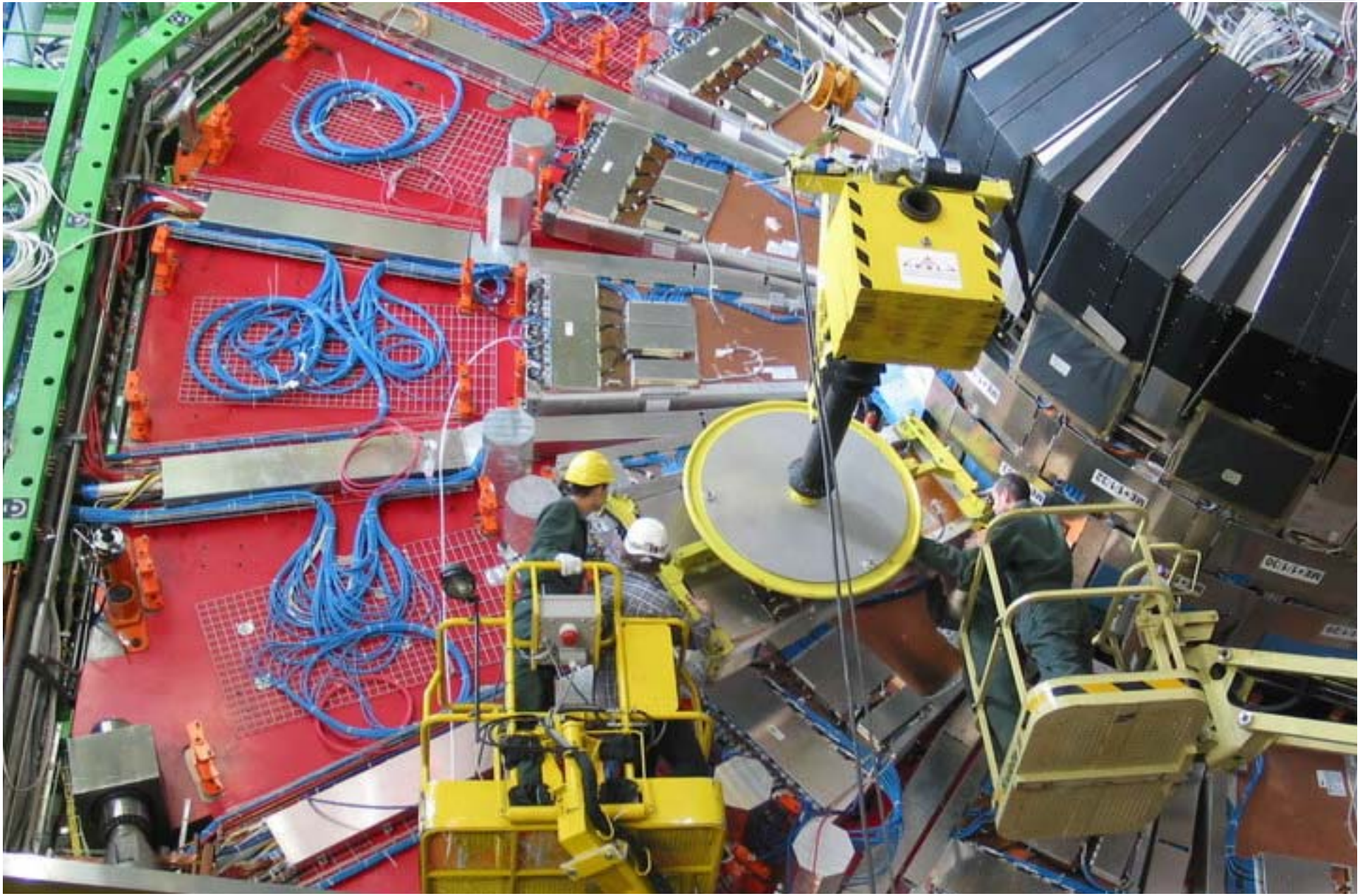
Installation of DT/RPC package in central wheel

Compatible with maintenance scenario



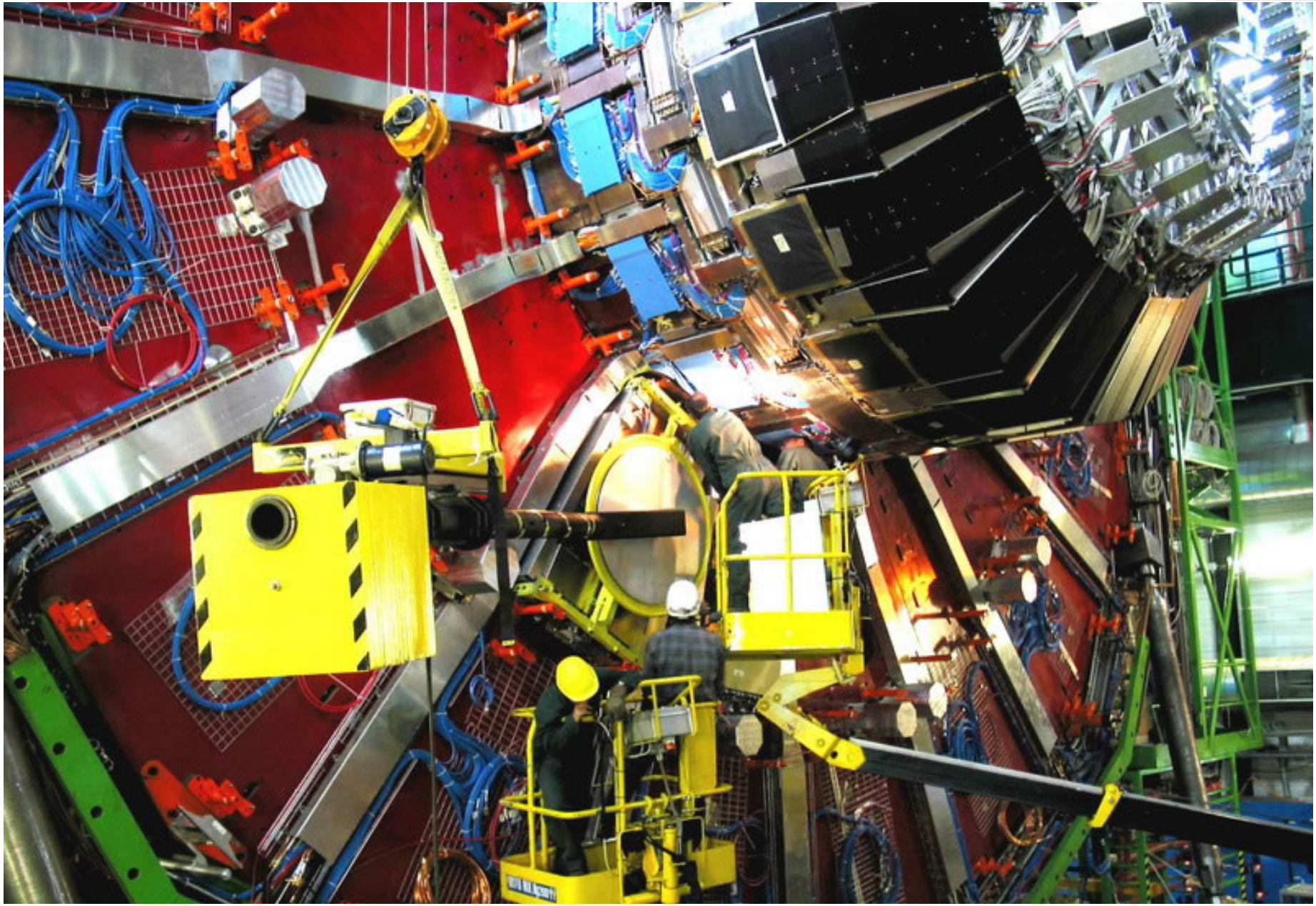
Installation of CSC/RPC package on first disk

Compatible with maintenance scenario



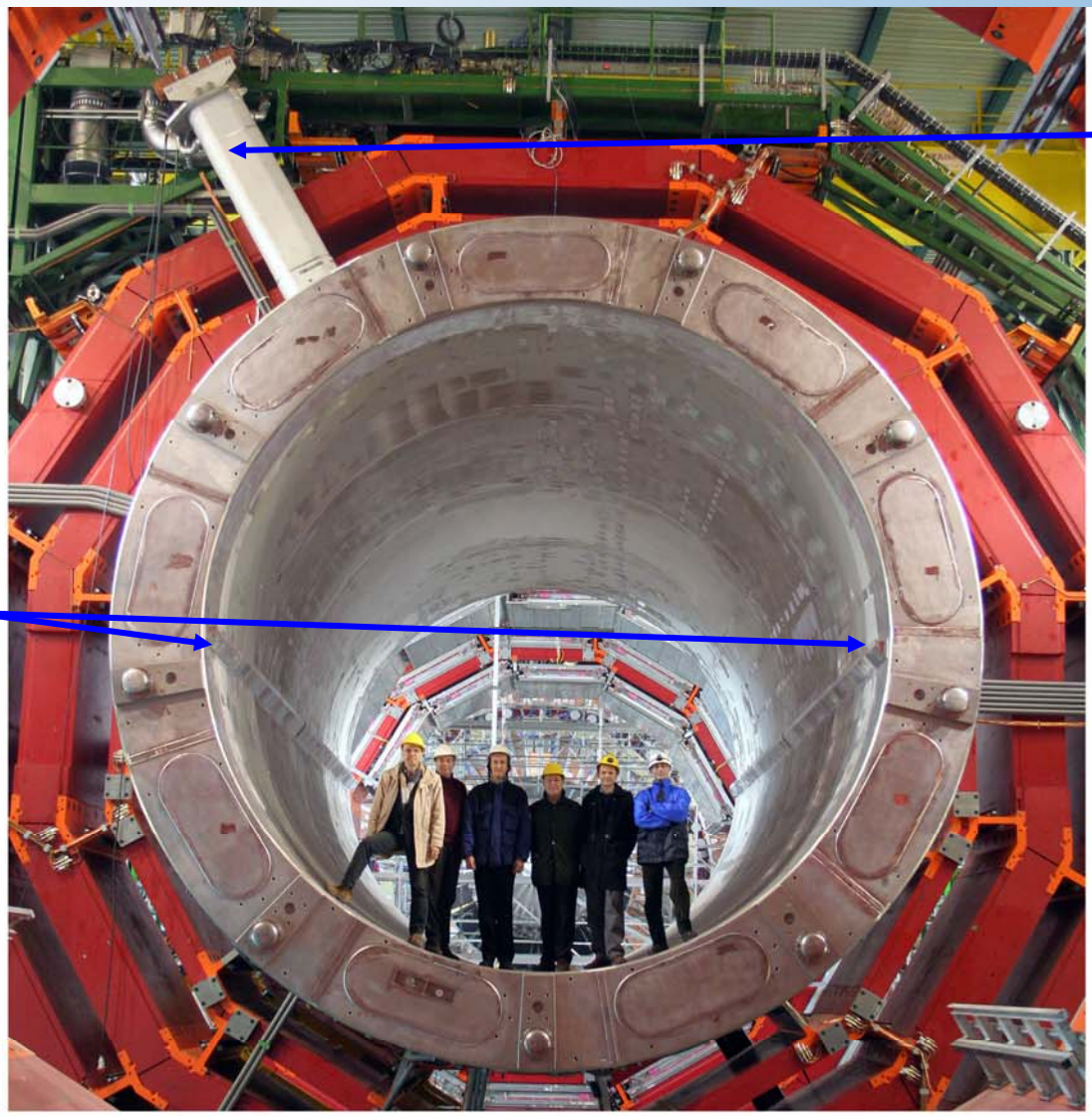
Installation of CSC/RPC package on first disk under nose

Compatible with maintenance scenario



Supporting the inner detectors from vactank

Inner vactank supports the 1000-tonne Hadronic Barrel and 200-ton Electromagnetic barrel on 2 rails imbedded in the shell

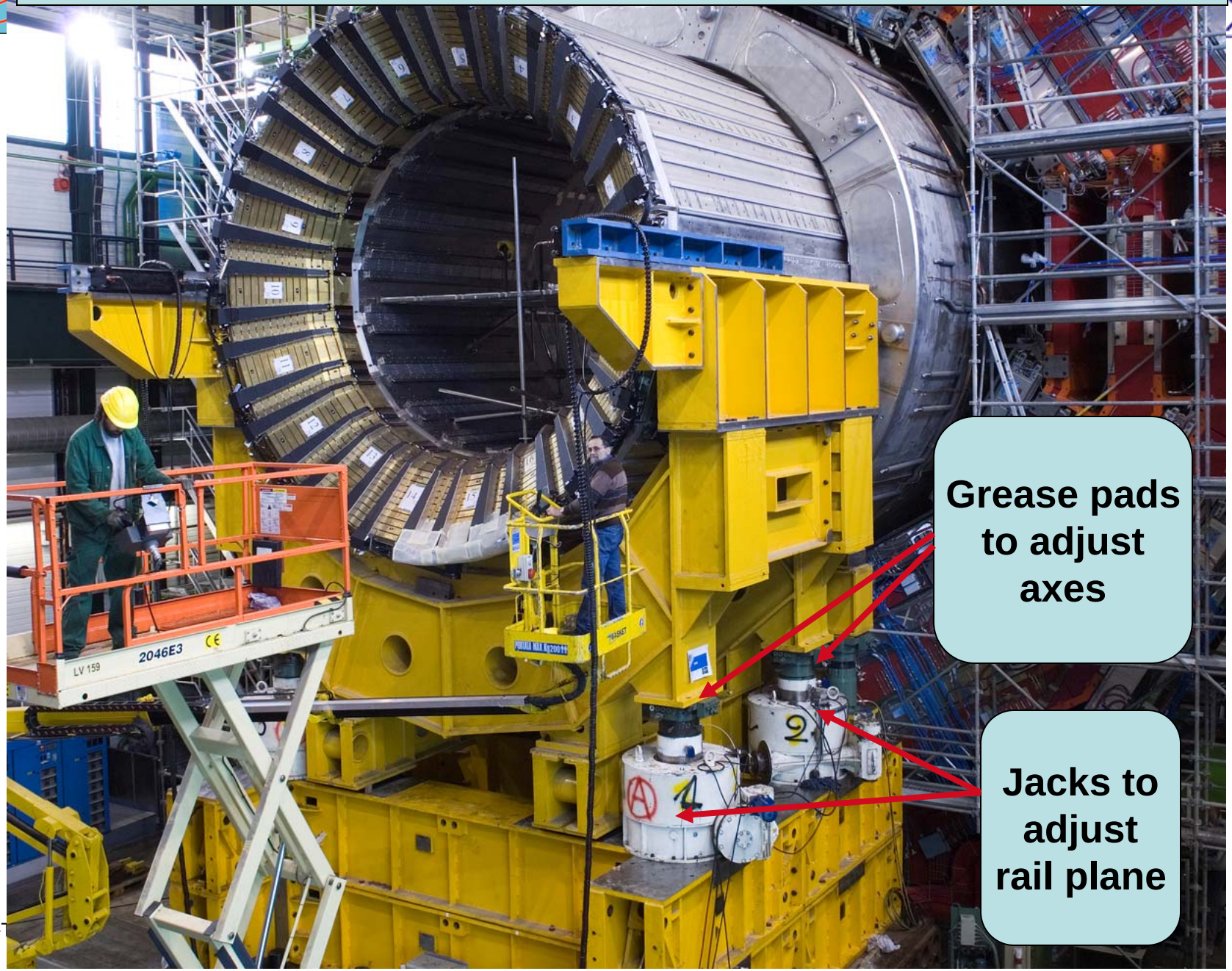


Penetration for current leads and pumping

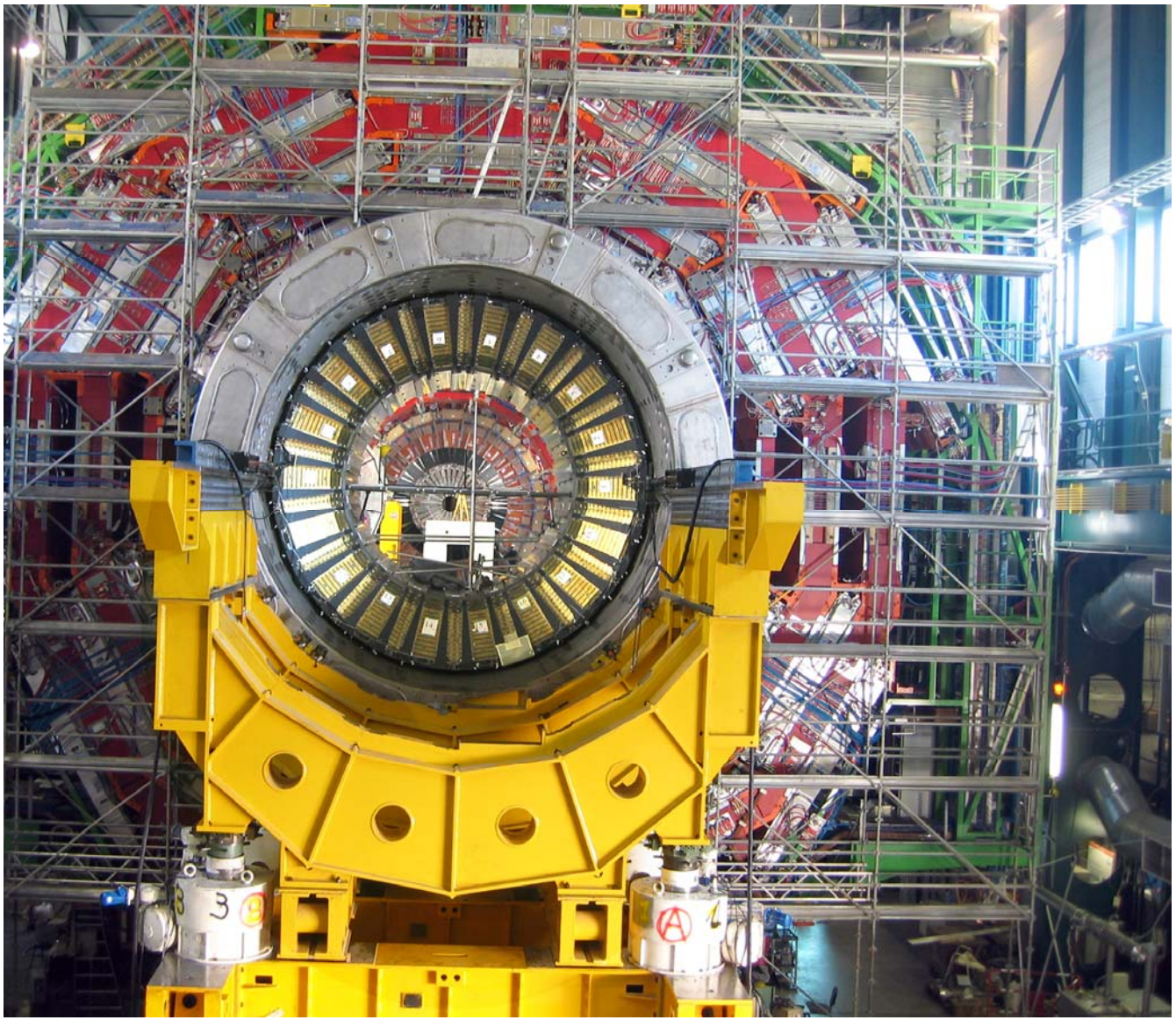
There is another one for cryogenics vertical on opposite side of YB0

January 2006: End of the CMS Magnet Manufacturing

HB Insertion inside inner vacuum tank on surface



HCAL Barrel inserted to load Vactank

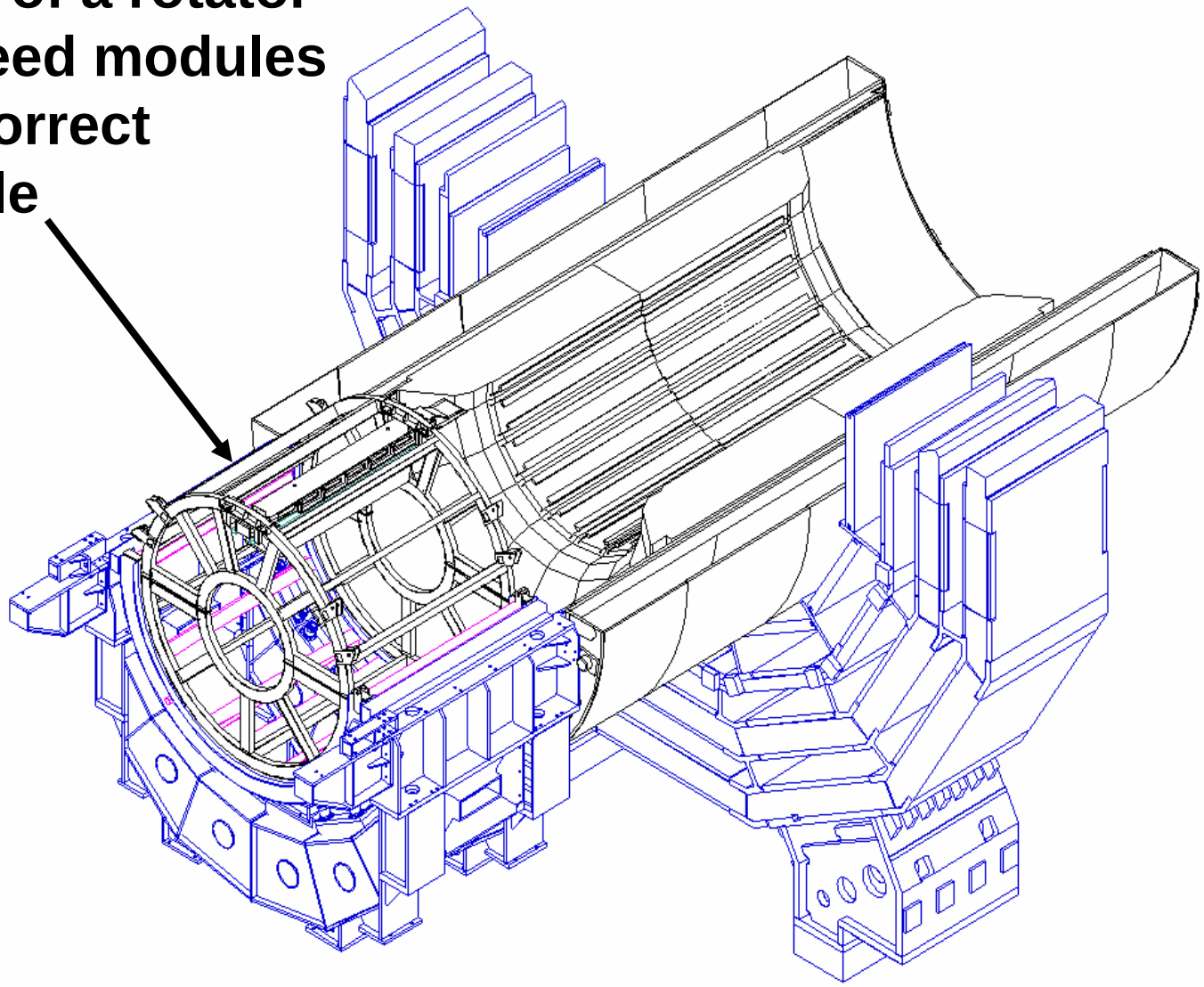


Precise survey to determine shimming and corrections to be applied for final installation underground

Installation of EB modules inside HB

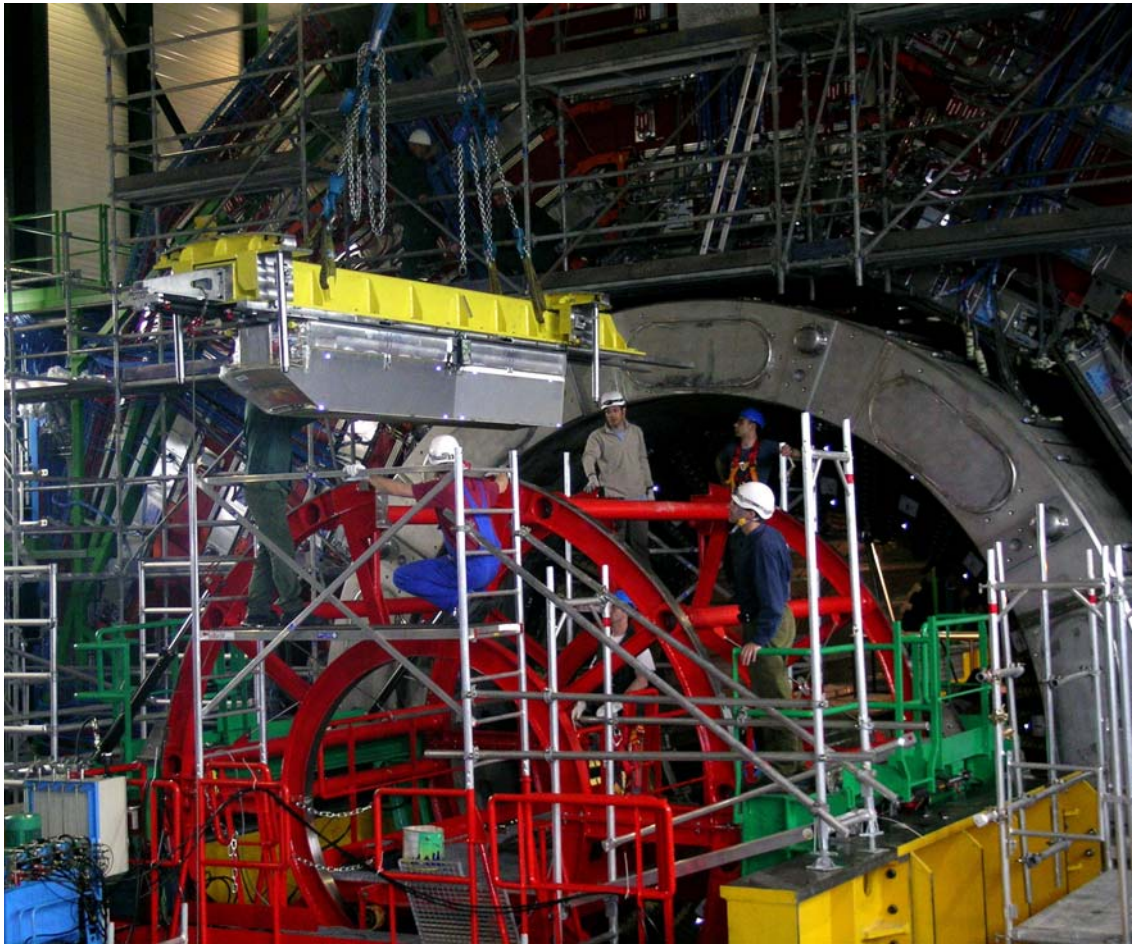
Compatible with maintenance scenario

Use of a rotator to feed modules at correct angle



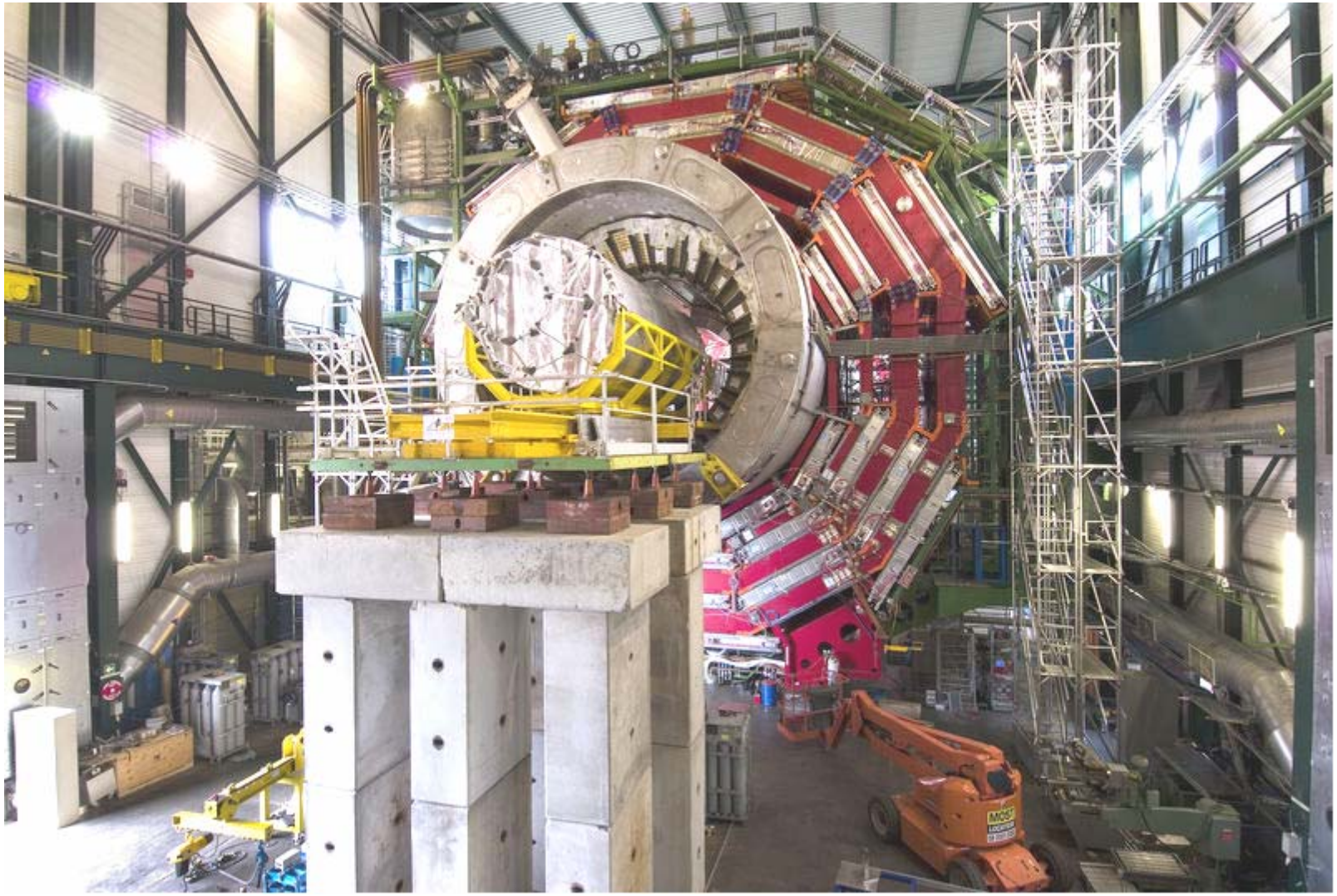
Installation of two EB modules inside HB

For testing on the surface



Installation of dummy Tracker inside HB

Compatible with maintenance scenario



Eiffel Tower to pull Tracker through EB

Compatible with maintenance scenario

Construction of the the Yoke, Coil and HCAL in the Surface Hall

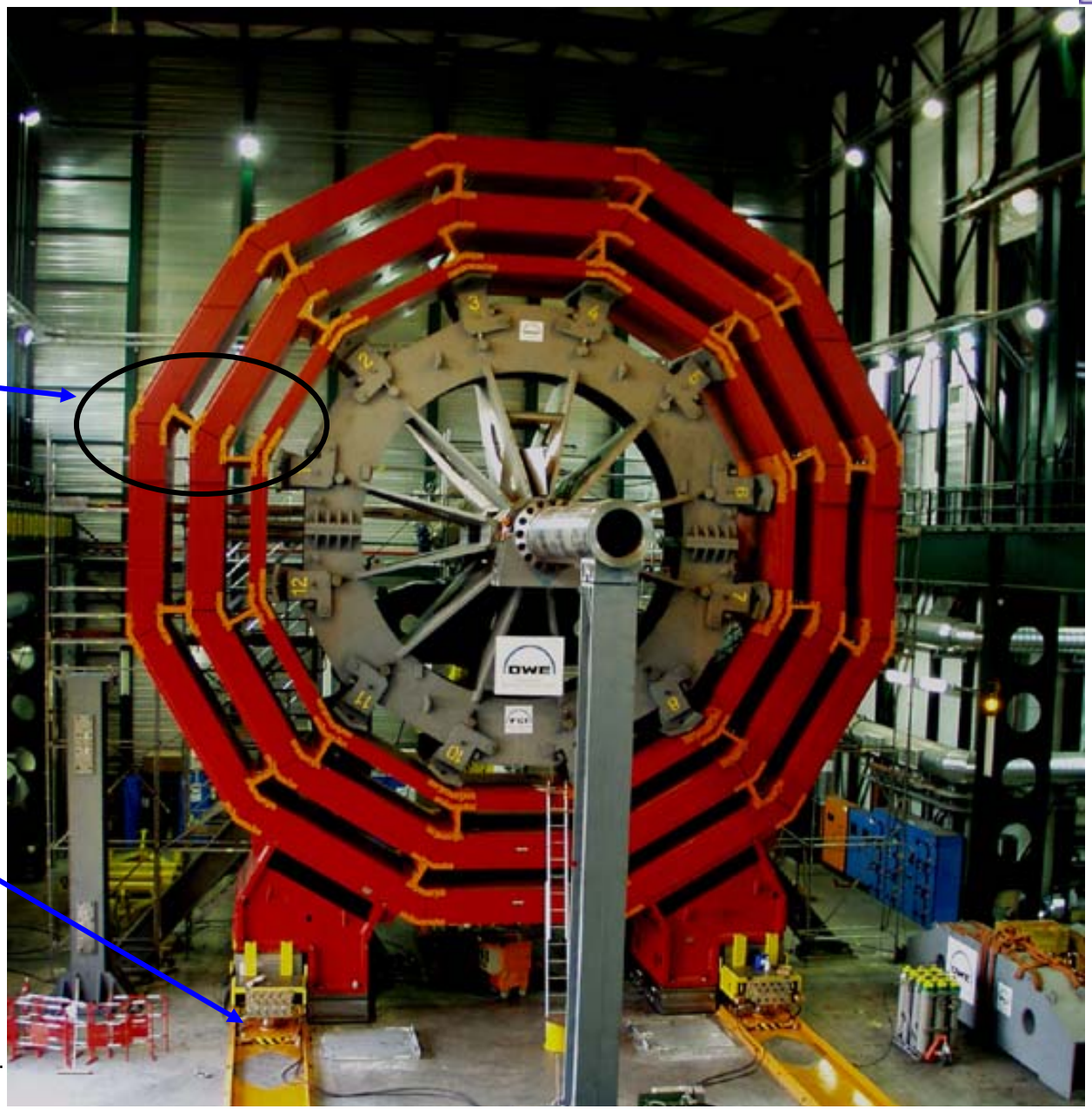
Construction of Surface Hall Sept. 1999 delivered mid 2000

Point 5 - SX5 gantry crane installation - September 17, 1999 - CERN ST-CE

Construction of yoke wheels started beginning of 2000 using a precise jig

Effort has been made not to align dead zones

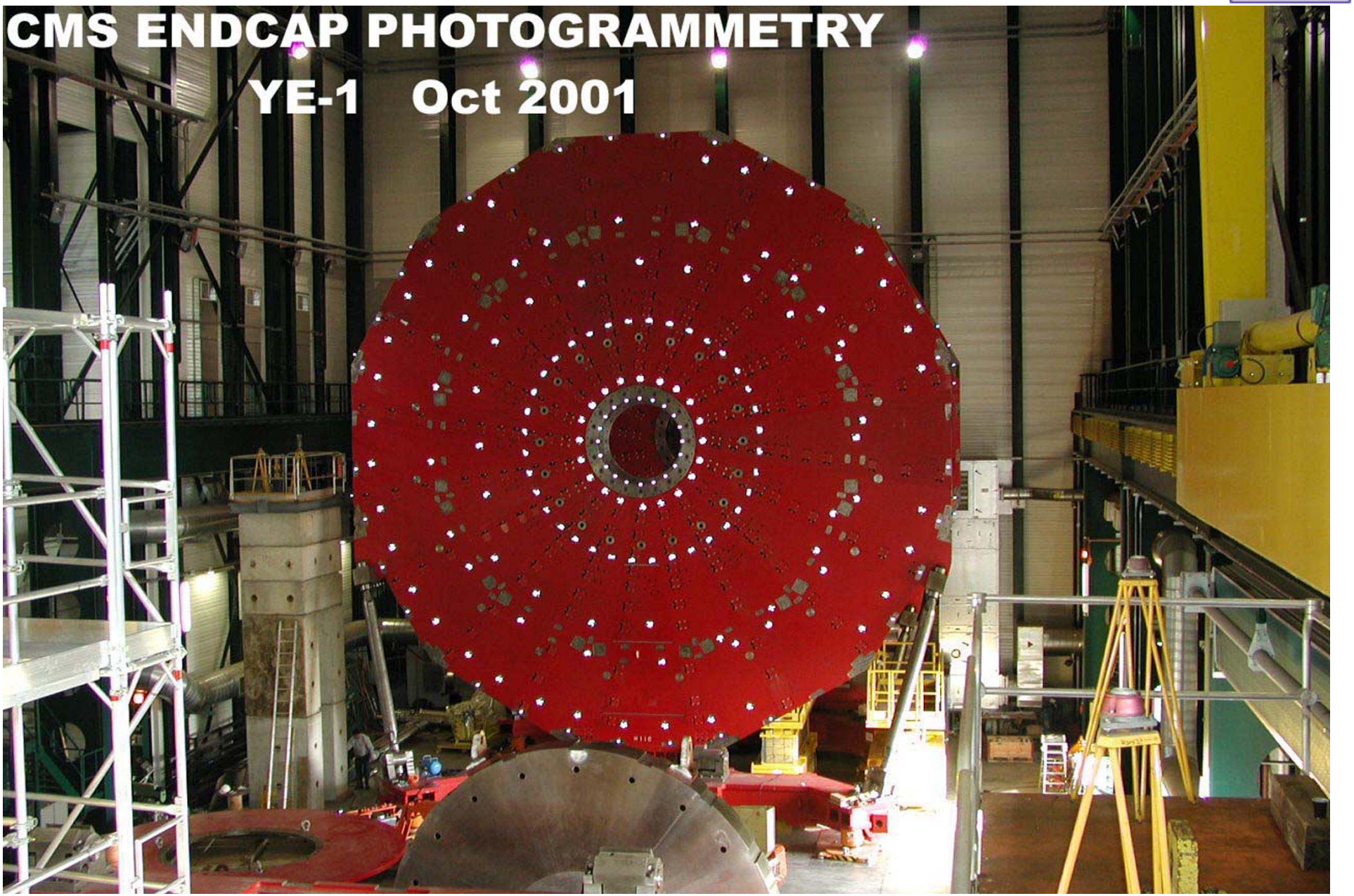
Air pads



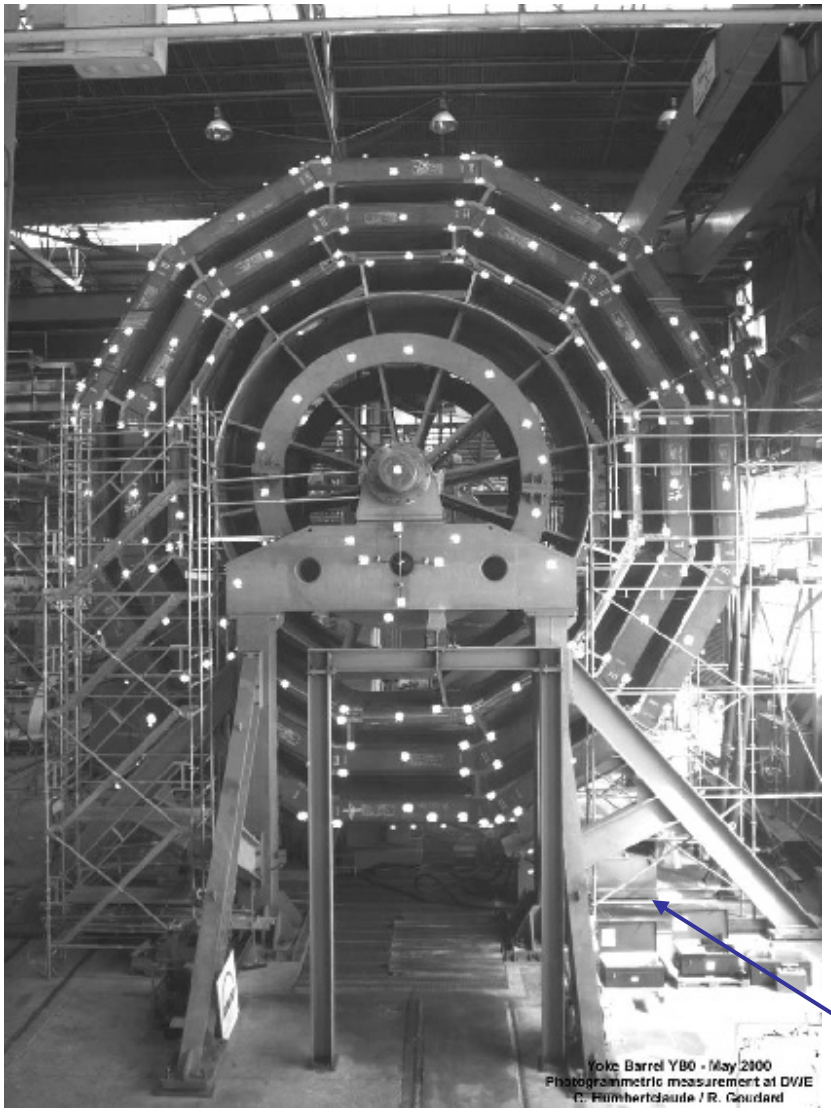
Construction of Outer vacuum tank imbedded in the central wheel

Construction of 600mm thick endcap disk

Construction of 600mm thick endcap disk
Generally all pieces have been carefully surveyed



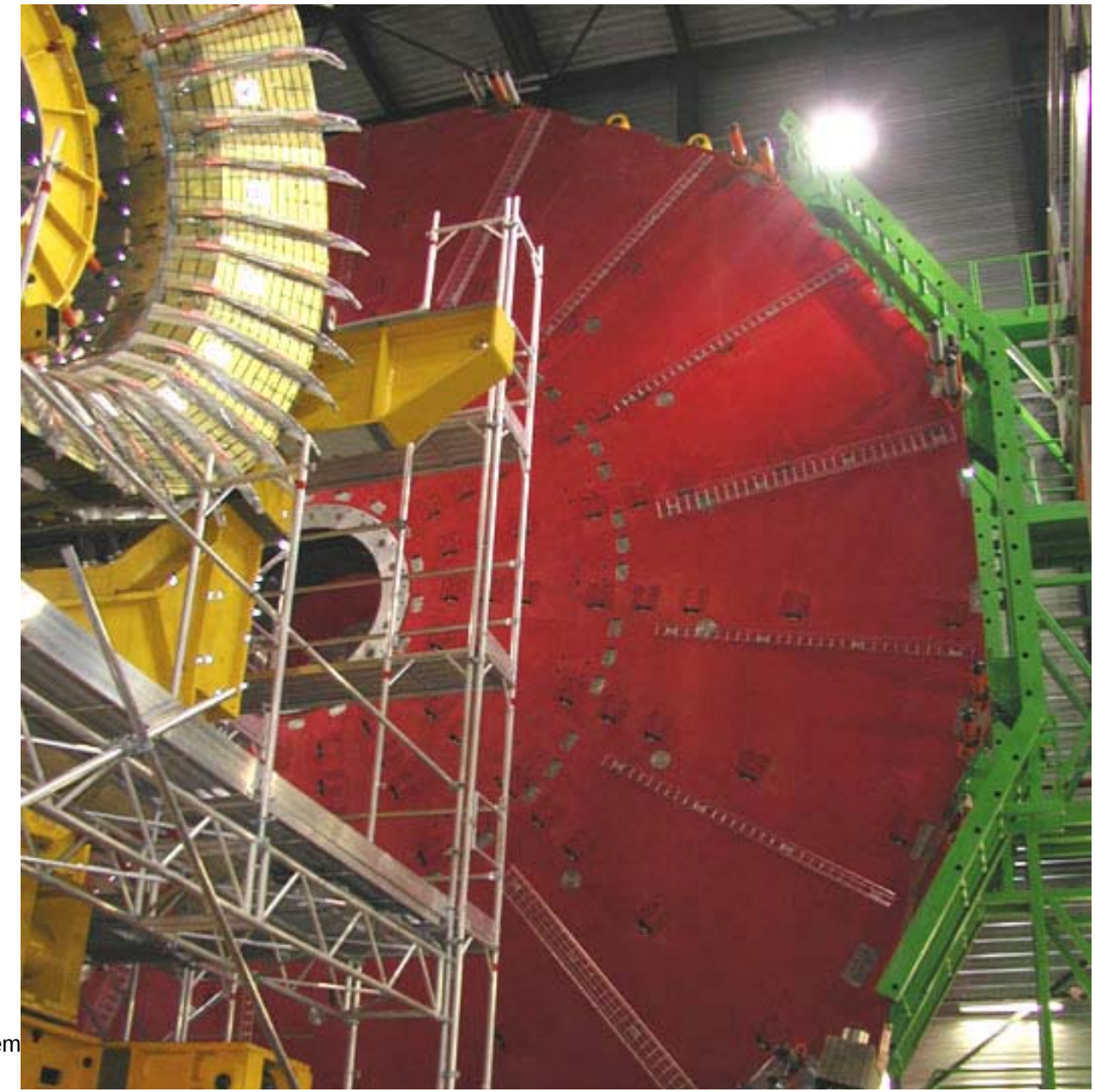
Also during blank assy at manufacturers..



In Germany

In Japan

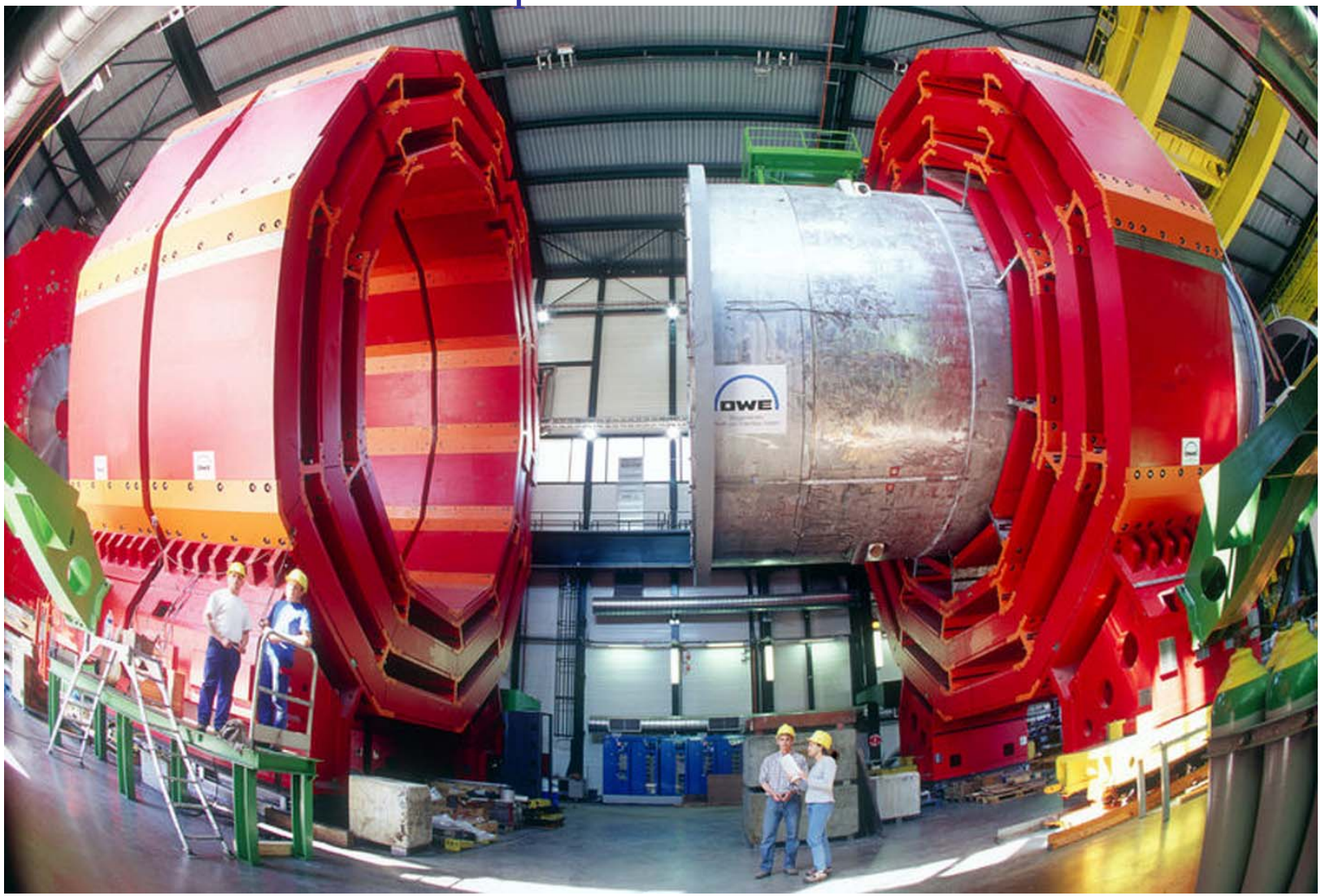
Each yoke element has been equipped with metallic structures to support local racks and services



In the mean time the two 500-ton HBs have been assembled directly at beam height

HB Barrels have been parked in alcoves on the side of the building not to eat space

The Yoke has been completed in 2003 to be ready to accept the cold mass



All these activities have been carried out in the surface hall

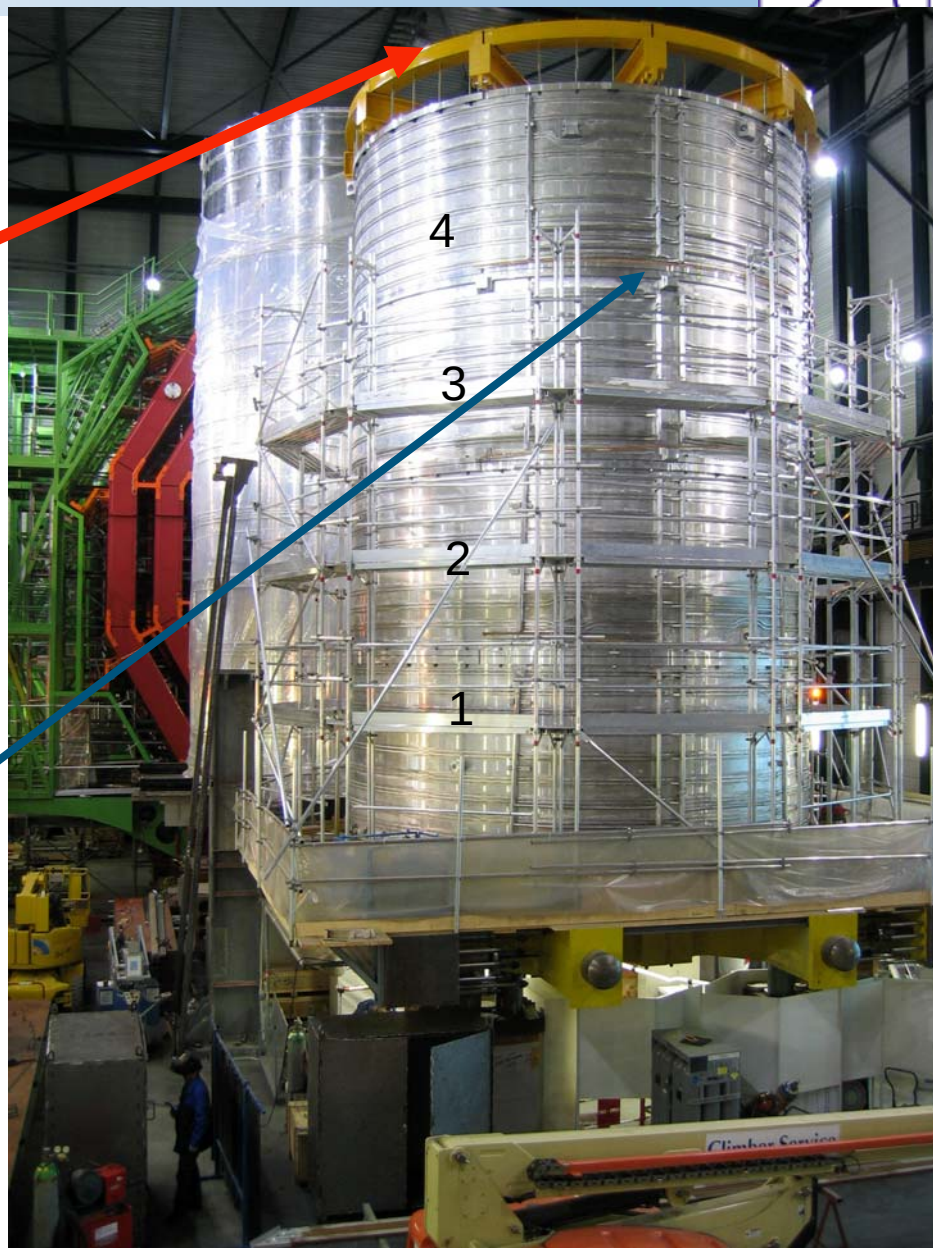
view of SX5 after delivery in Oct. 2000

Pre-assembly of CMS in SX5 has isolated us from tricky underground Civil Engin. and schedule pressures

Why Construct CMS on the Surface ?

- ***As seen at LEP, installation work takes 50% more time in a deep underground area for questions of access, limited space, superposed work areas and related safety precautions.***
- ***CMS has from the start requested an assembly on the surface followed by transfer of FULLY COMMISSIONED large detector elements (up to 2000 tons) by heavy lifting means.***
- ***It was also argued, and I think this has been demonstrated, that the length of the underground cavern would be insufficient to carry out such a construction work in a reasonable time.***
- ***Another important argument was that all delicate or risky operations, coil test, HB insertion, EB insertion, Tracker insertion, closing of detector etc. can be carried at least once on the surface and corrections made before final operations underground.***

The coil has been assembled with vertical axis



This allows a very precise coupling

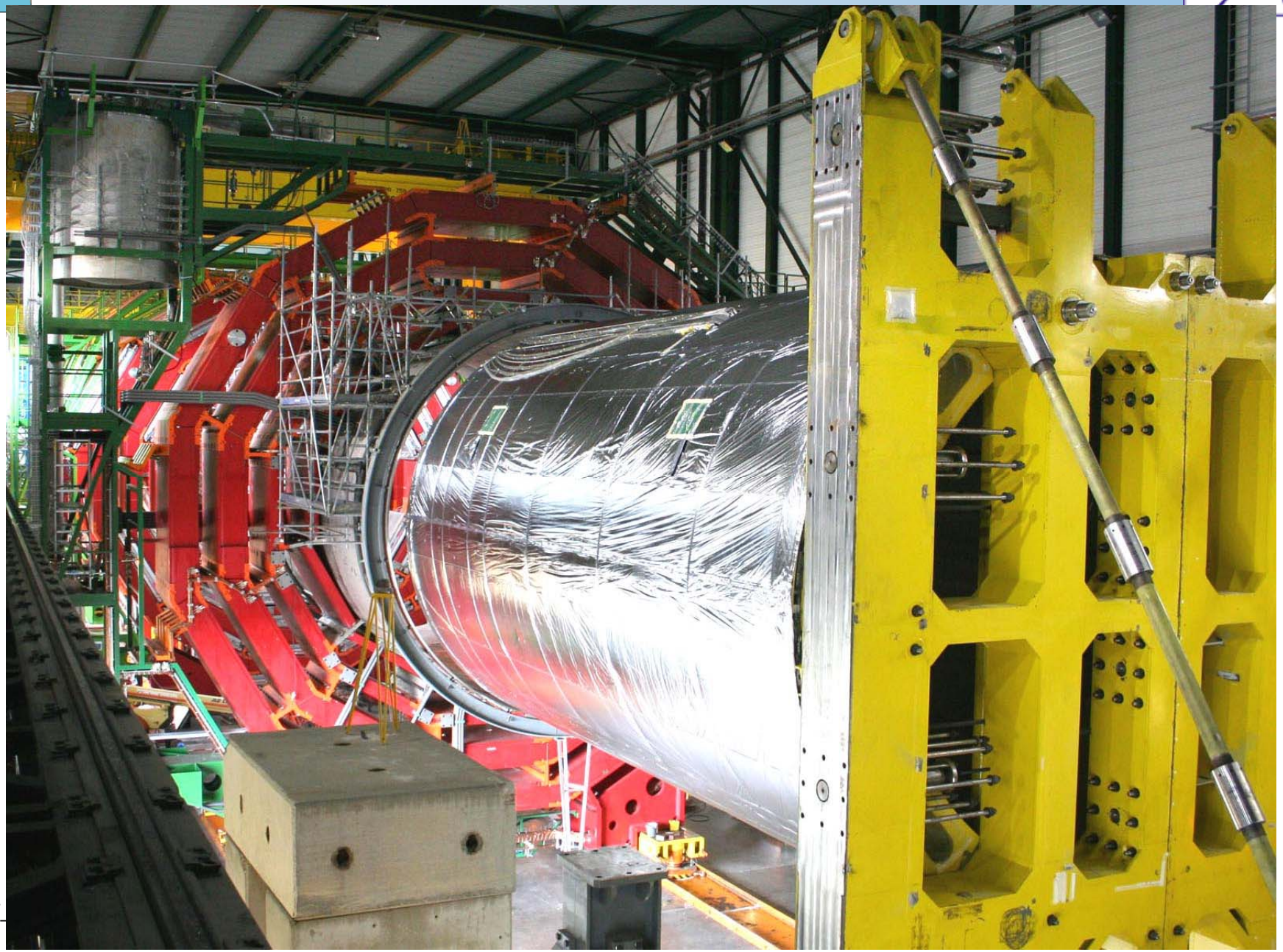
But the 220-ton coil has to be inserted inside the vacuum vessel with horizontal axis!

Coil swiveling requests large tooling

The 220 ton cold mass was rotated in 15 min

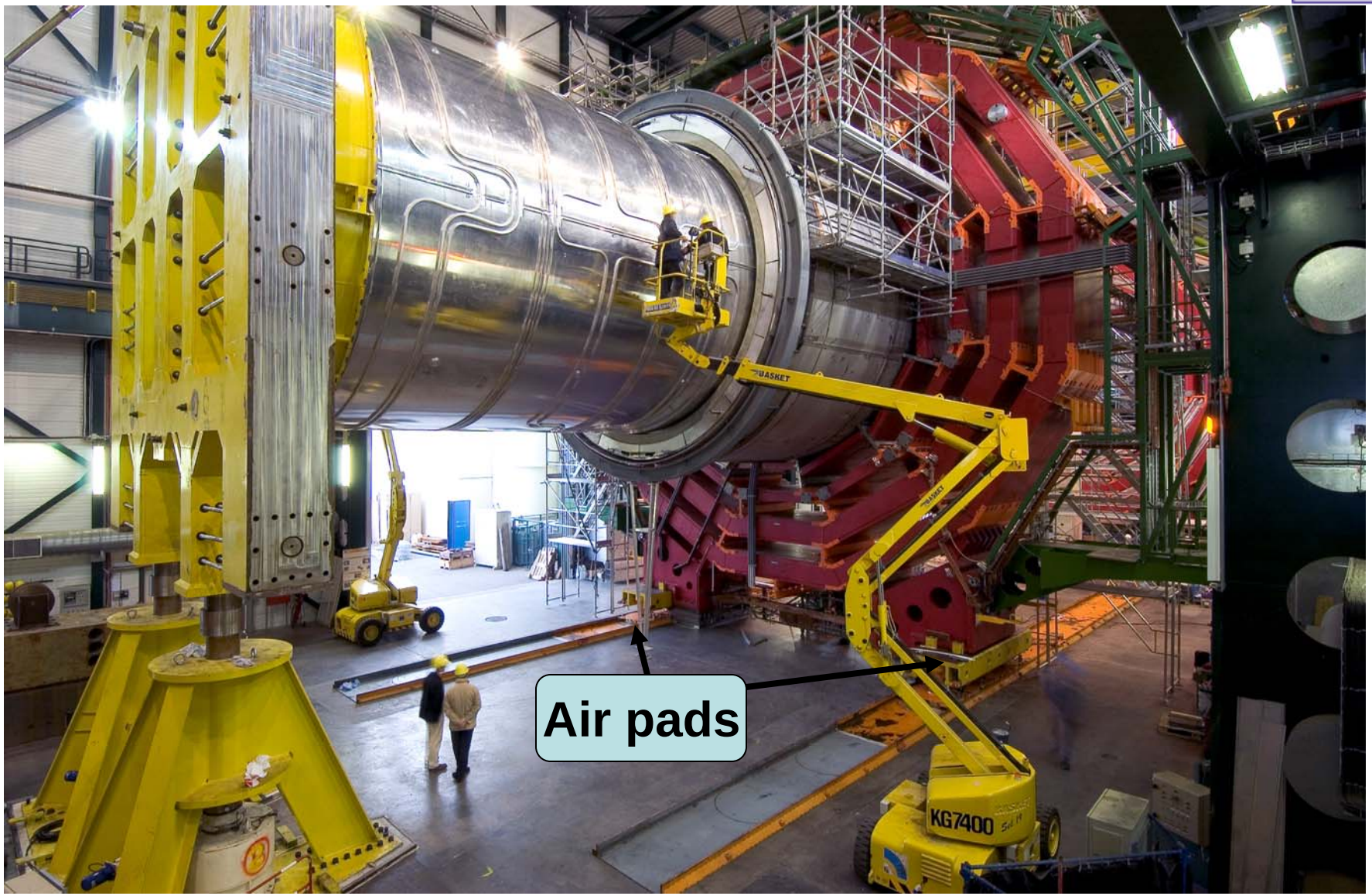
The coil is maneuvered cantilevered from one end

Sept. 2005: ready to insert!

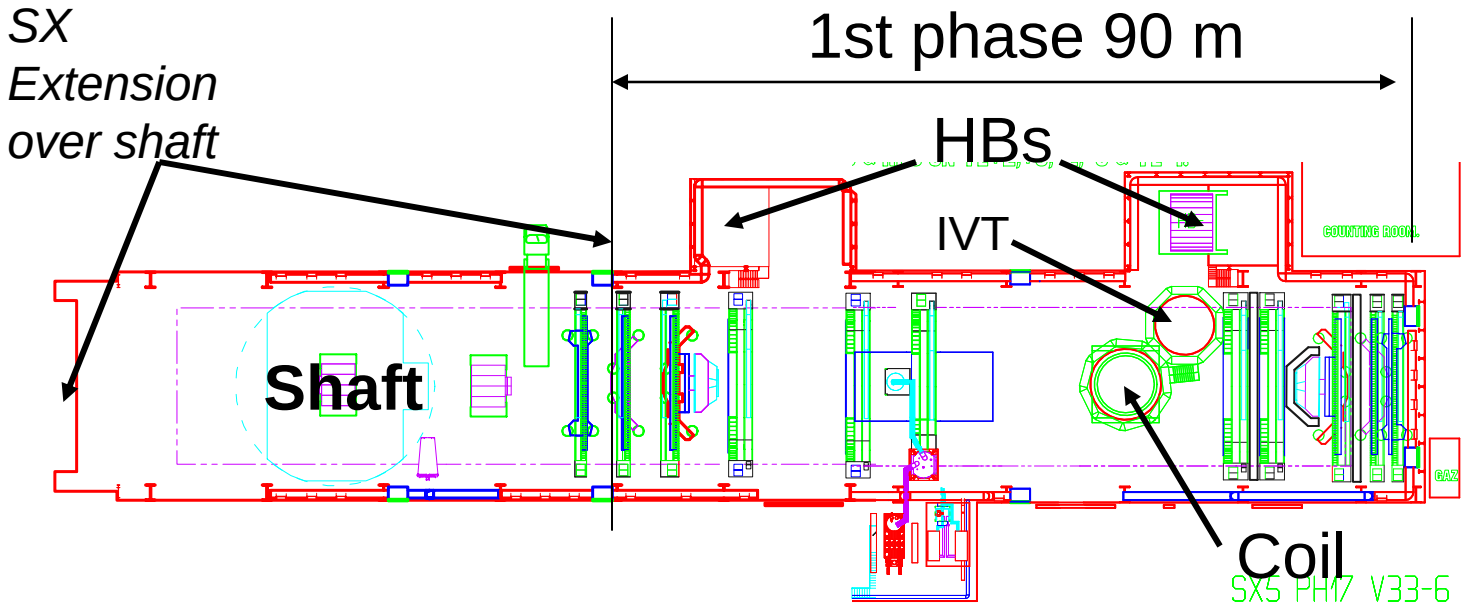


Moving YB0 with VacTank over the Coil

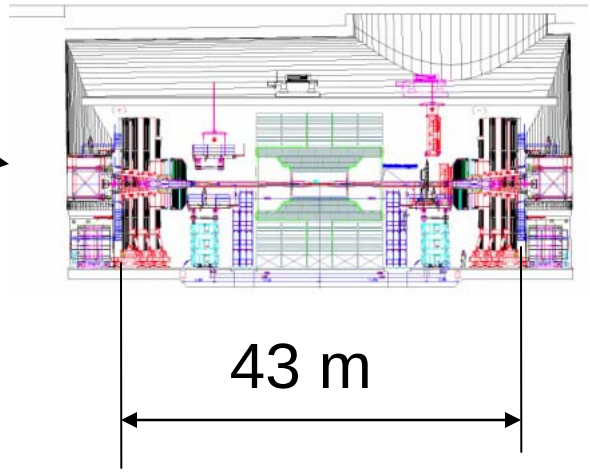
Inner VacTank/Screen Insertion in Sept 2005
These operations require a free length of 30 m min.



Coil swiveling in Surface Hall August 05



Underground hall Detector fully open



Same scale!

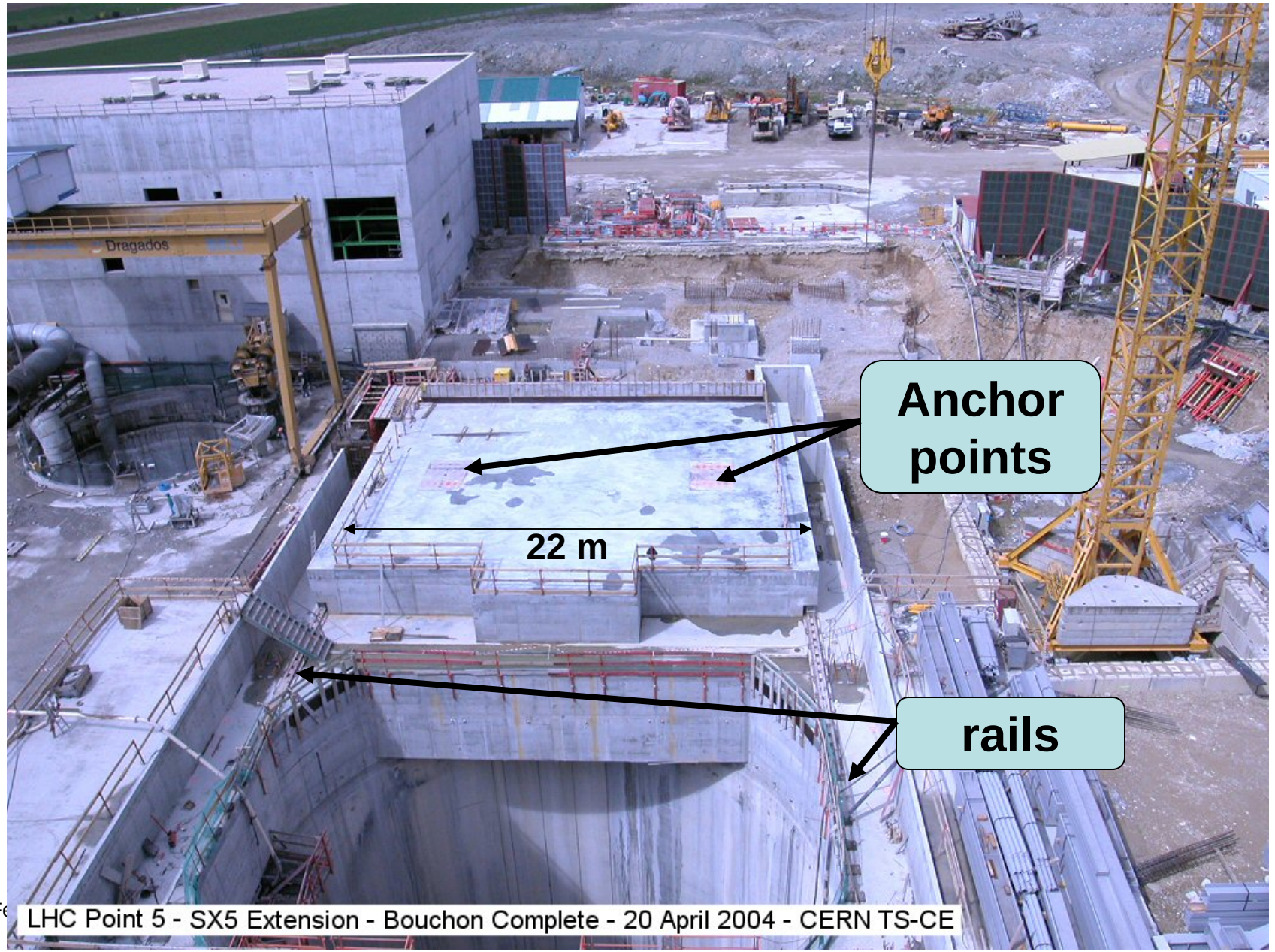
This justifies the surface assembly

- These heavy construction activities cannot be done in a reasonable time, safely, in the underground hall.

- A much longer and wider underground hall, equipped with two 80-ton cranes, would be needed, and more time….

Completing the Civil Engineering Testing of Magnet and Detectors Preparation for Transfer Underground

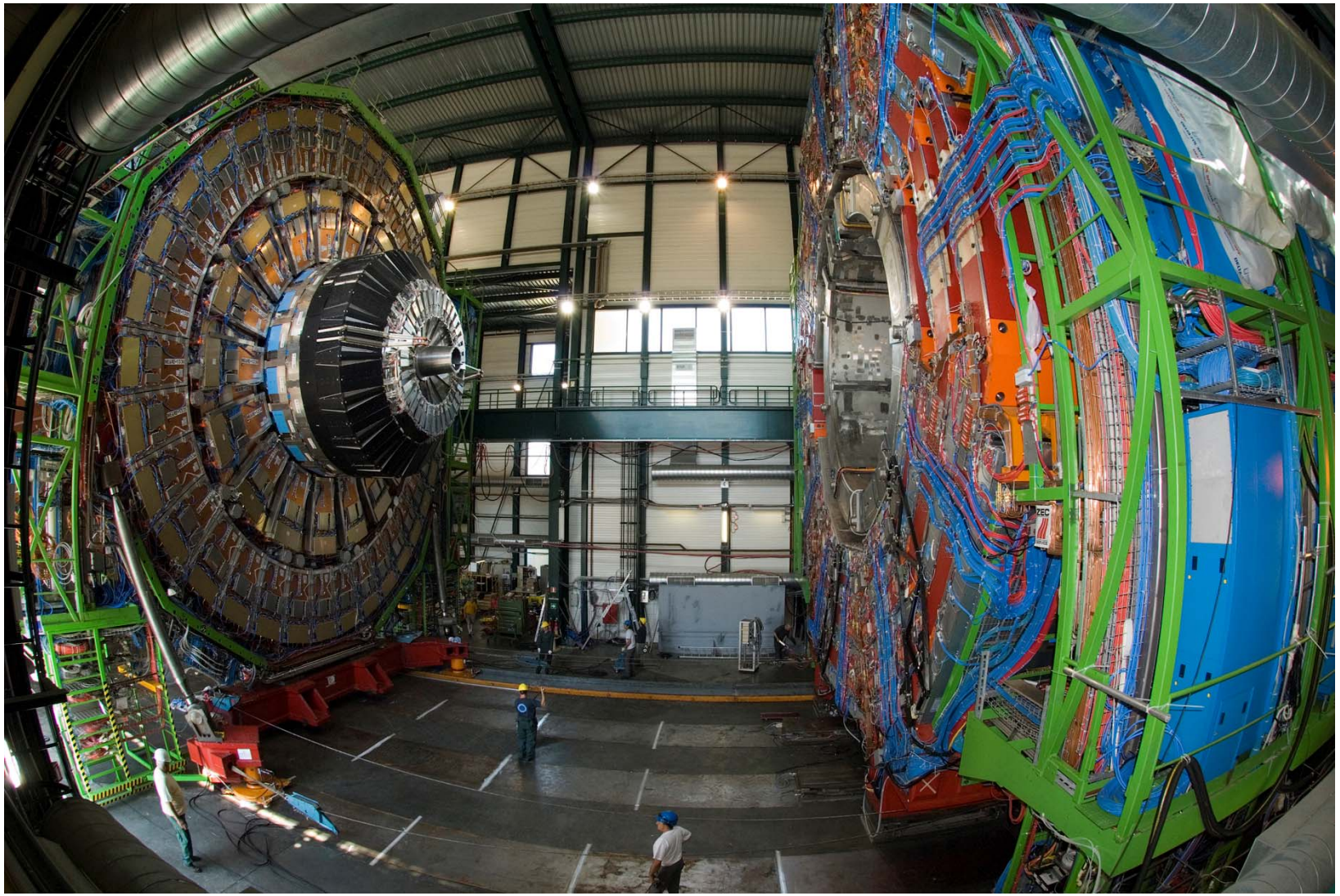
Construction of Main Plug on side of Shaft Apr. 04
Used as radiation protection and lifting platform



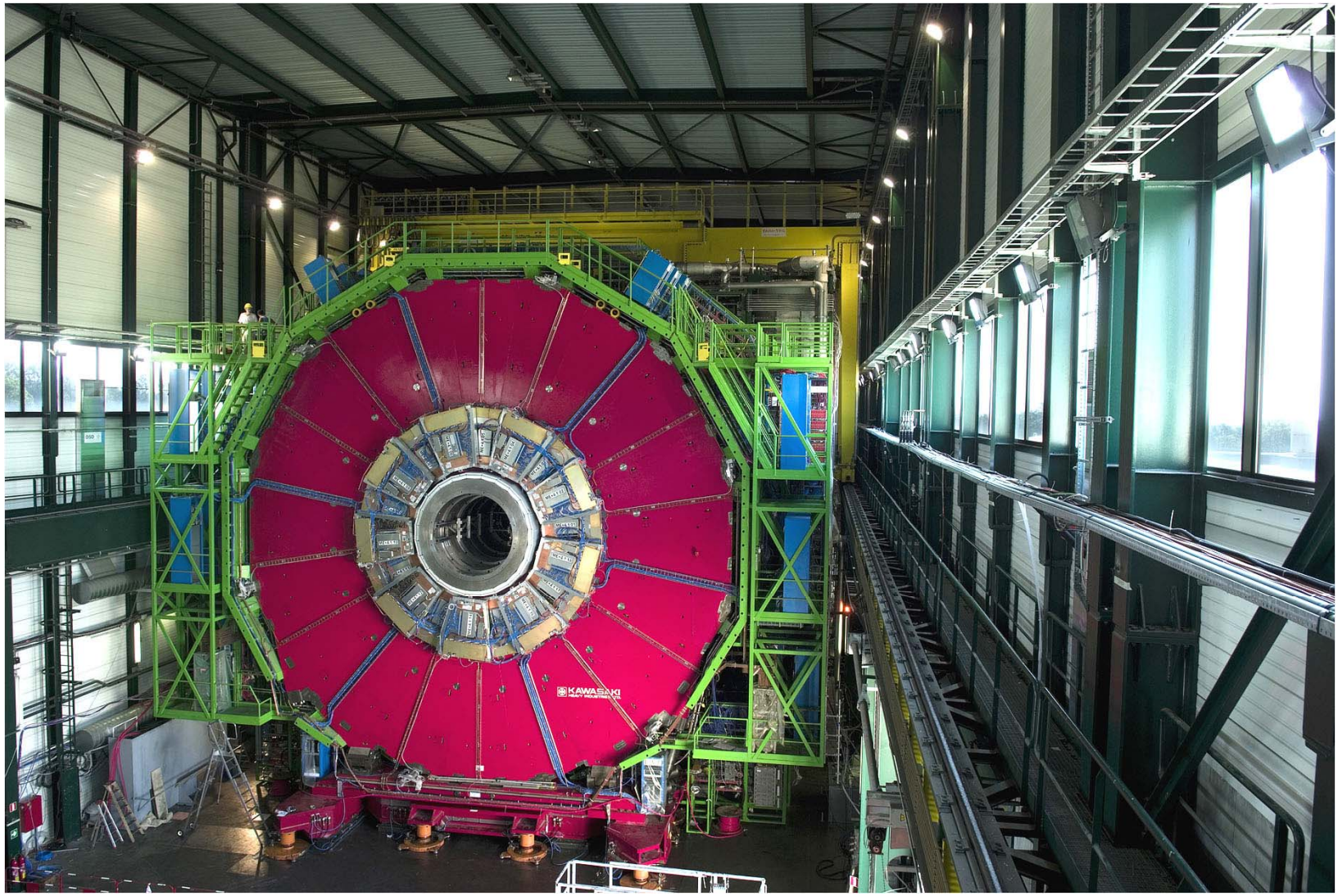
Construction of Surface Hall Extension Jul. 2004

The plug has been tested using a 2500 ton dead load

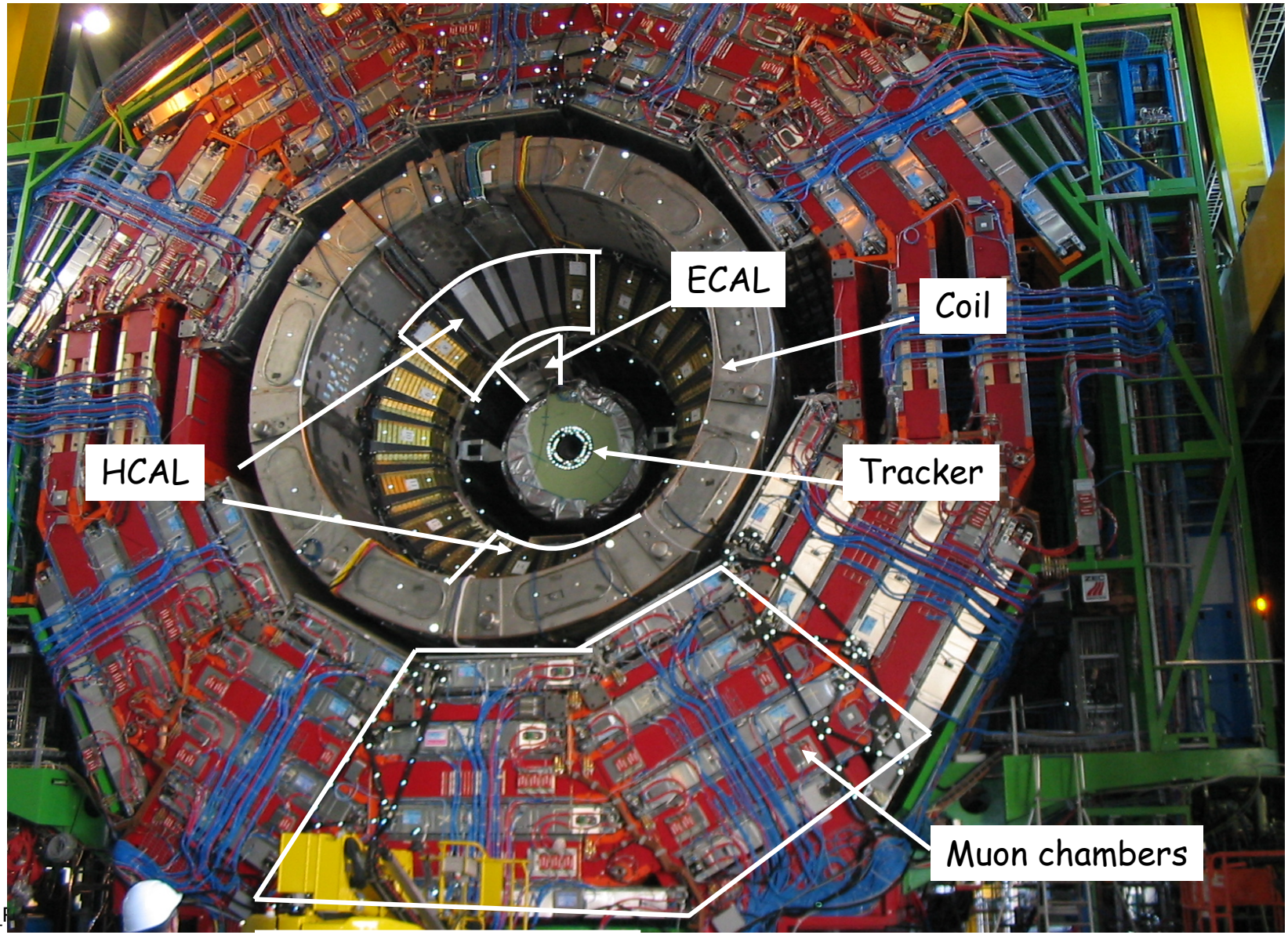
Survey has constantly ensured an alignment of Elements of ≠ 1-2 mm wrt the ideal axis



CMS Closed mid-July 2006
4T reached on 22 August 2006



A slice of all sub-detectors has been fully commissioned using cosmics

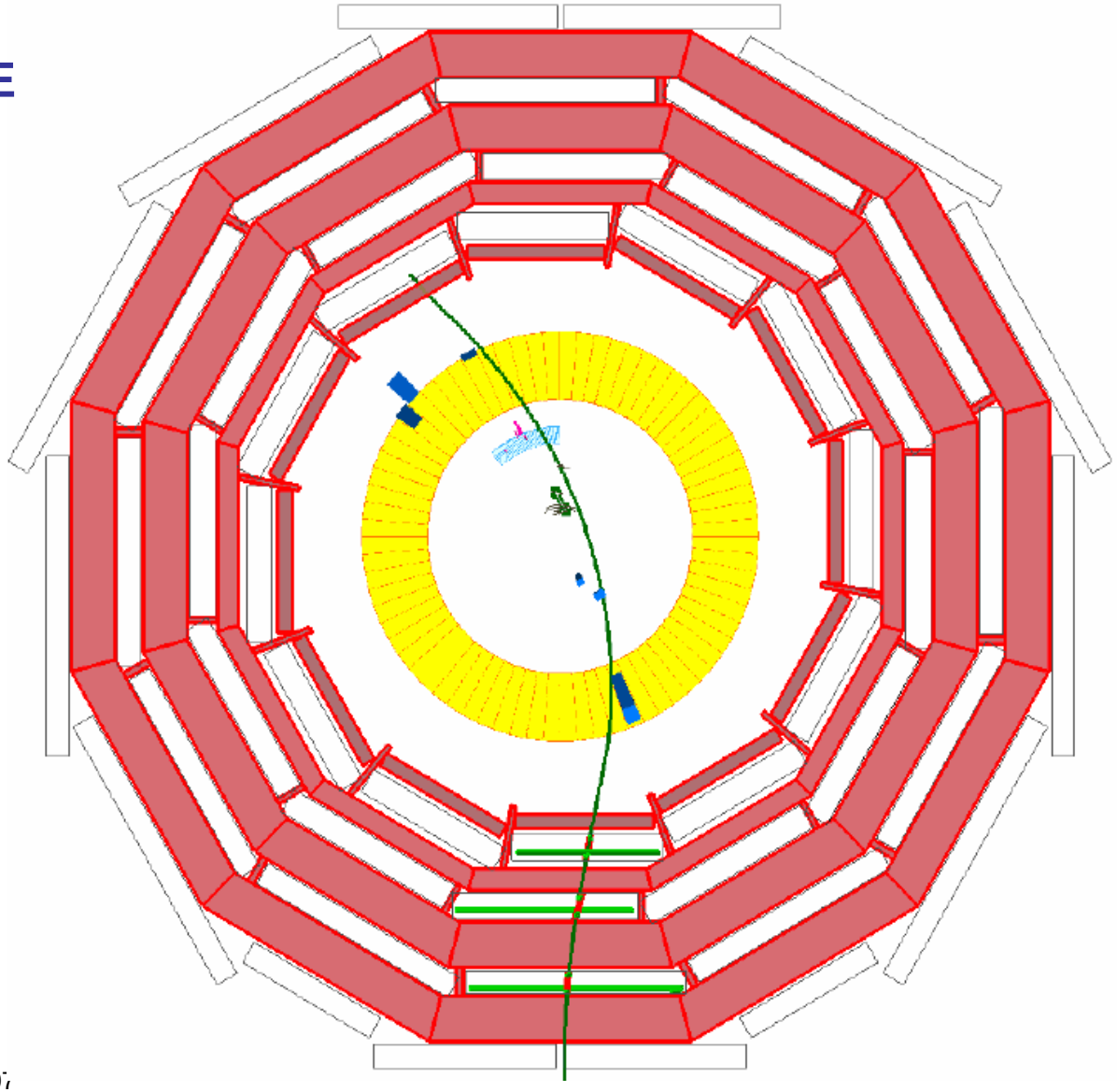


Commissioning: CMS - Cosmics Event

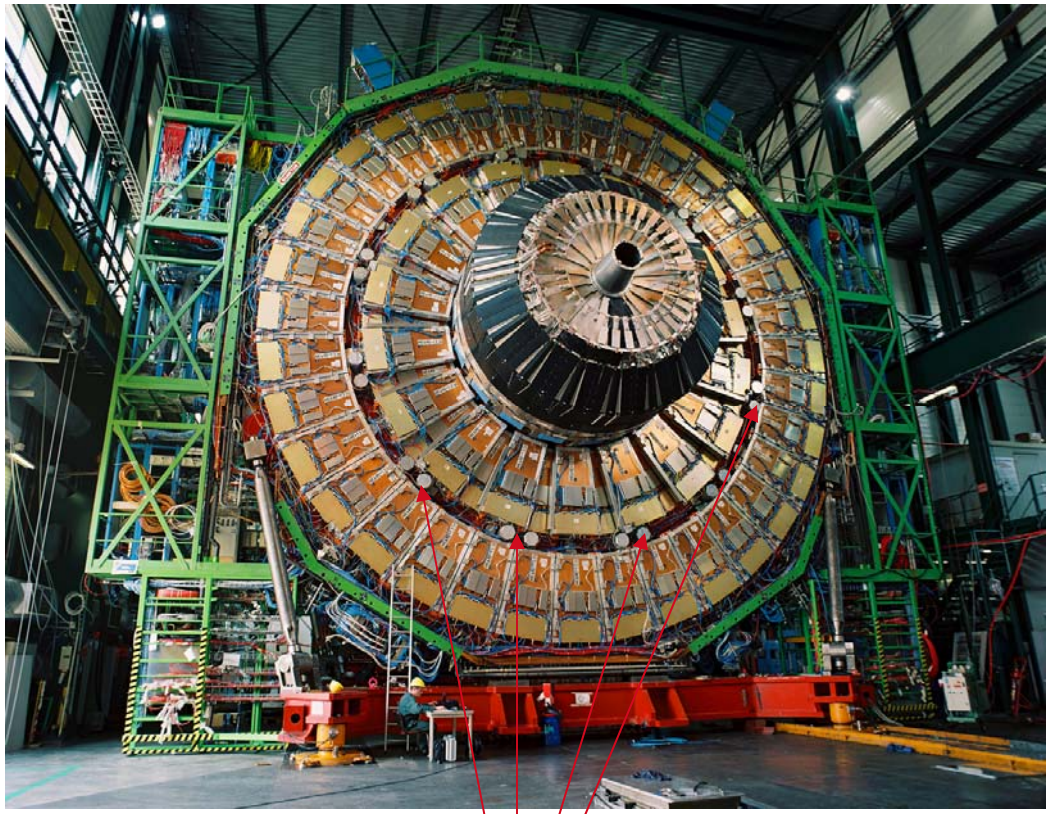
CERN PRESS RELEASE
13 September 2006

Mammoth CMS magnet reaches full-field at CERN

Tests show CMS detector will be ready for data



Elements fully commissioned ready to be lowered (for example YE+1)



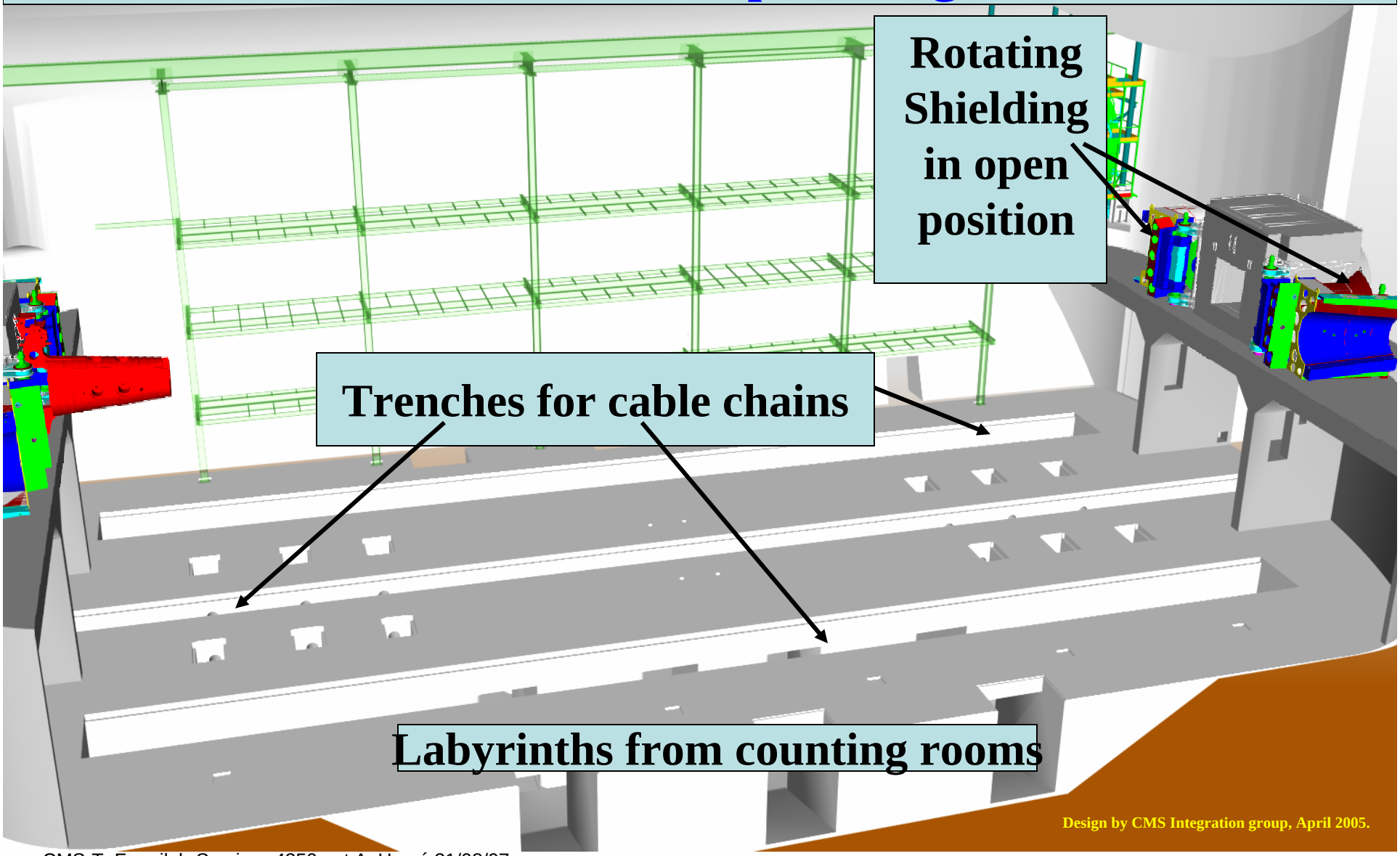
Z-stops resist the 10’000-ton attraction magnetic force

Elements are fully cabled to local racks.
All services, gas and water cooling pipes are there.
Subdetectors have been commissioned.
Once below they can be connected to the umbilical cables going to the counting rooms through the cable chains.

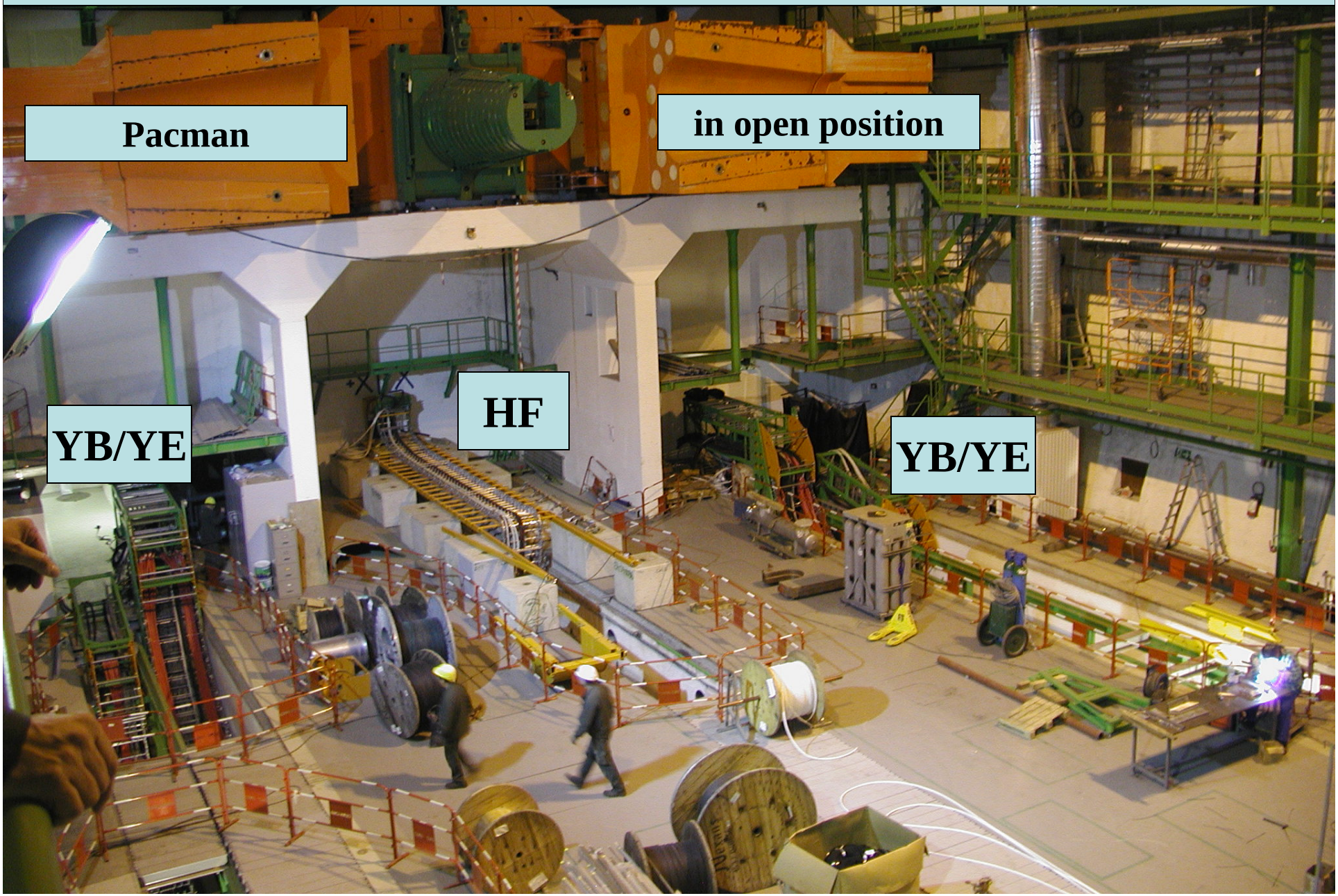
Part-2

Transfer of the CMS Experiment Underground

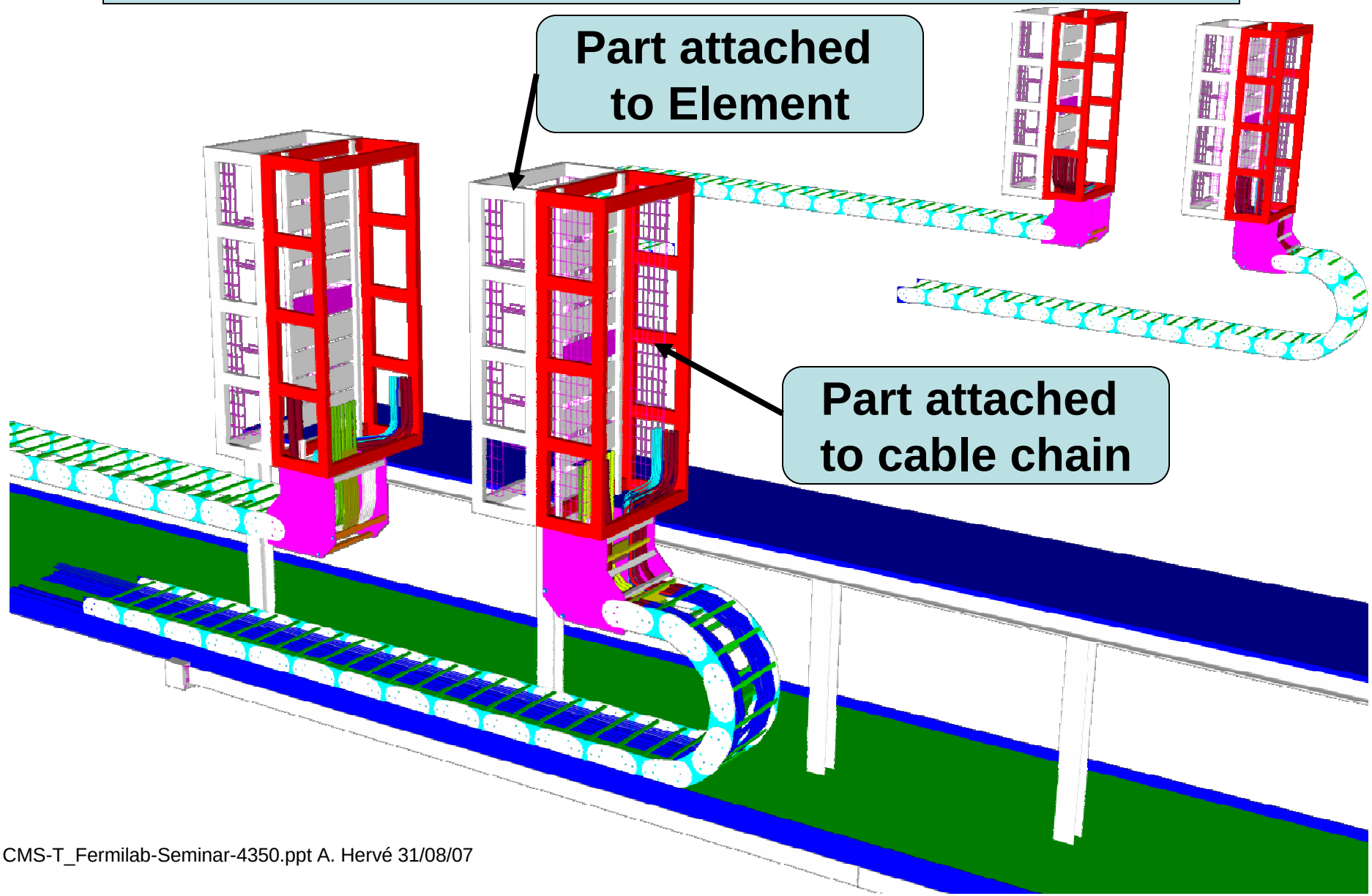
UX5 before receiving Elements
The cave below is used as dispatching center for cables



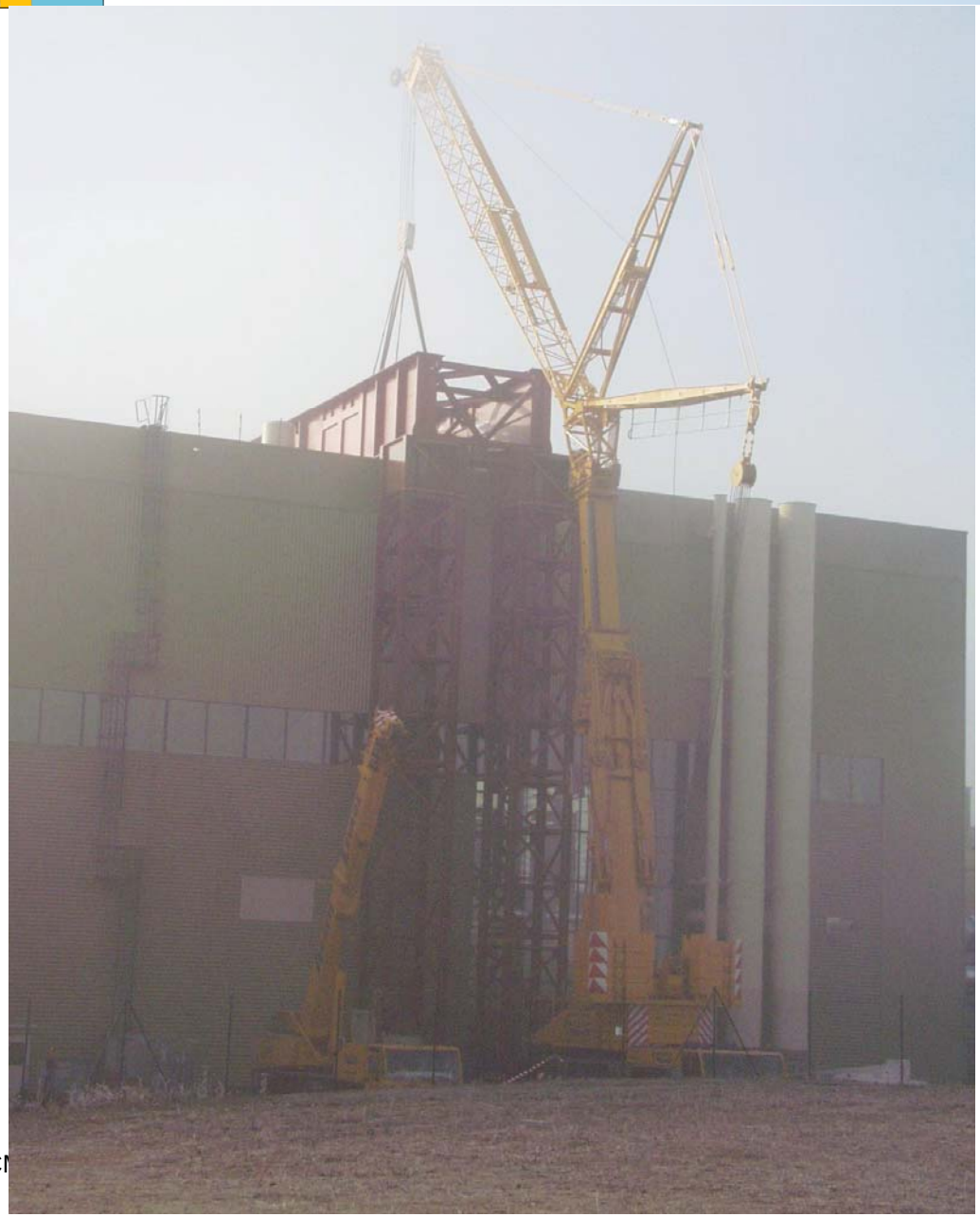
Situation of cable chains before lowering Elements



How cable chains are connected to pre-cabled Elements



Installation of the 2000-ton Gantry

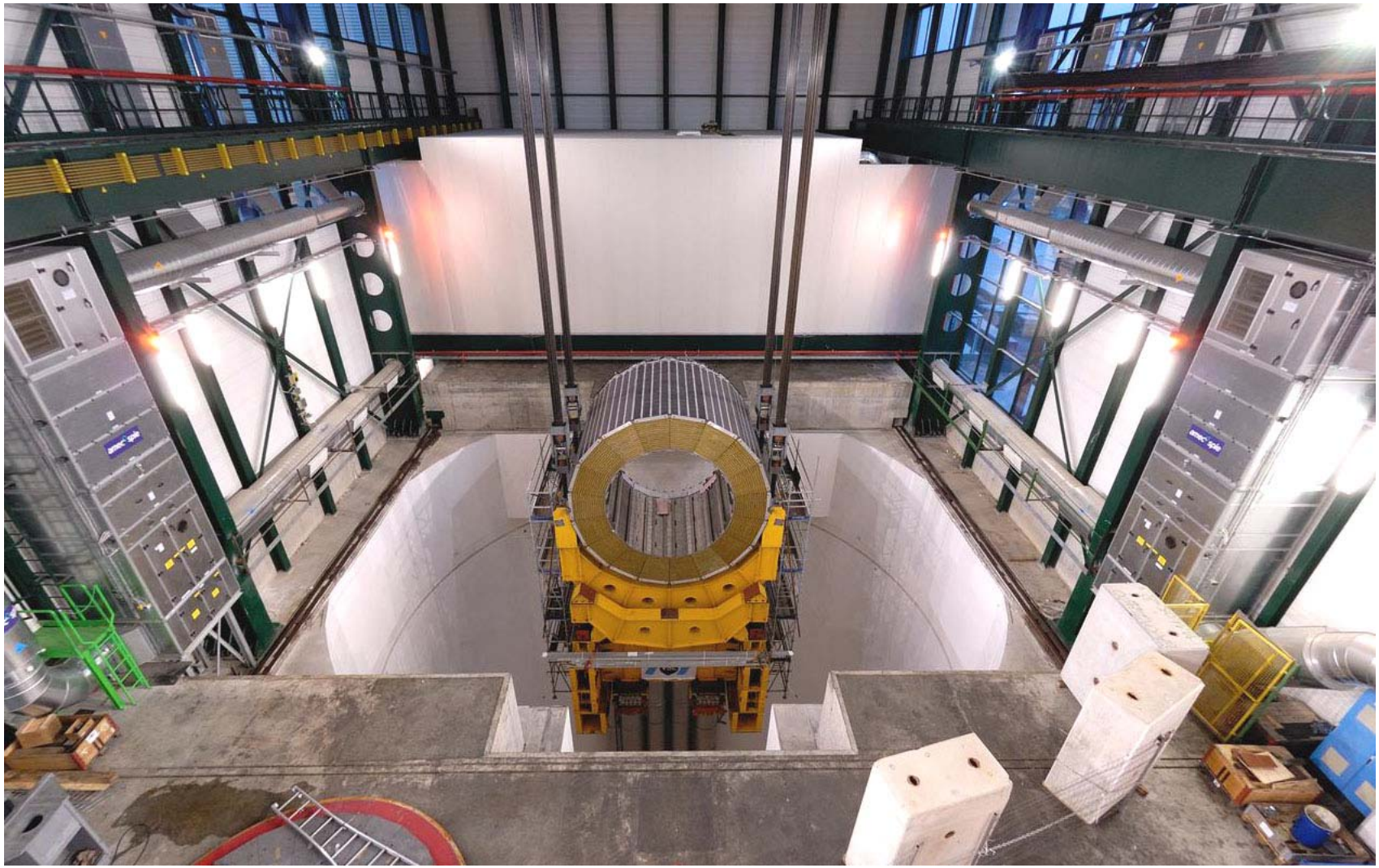


The gantry has been tested statically at 125% of the nominal load, that is at 2’500 tons using the plug as dead weight

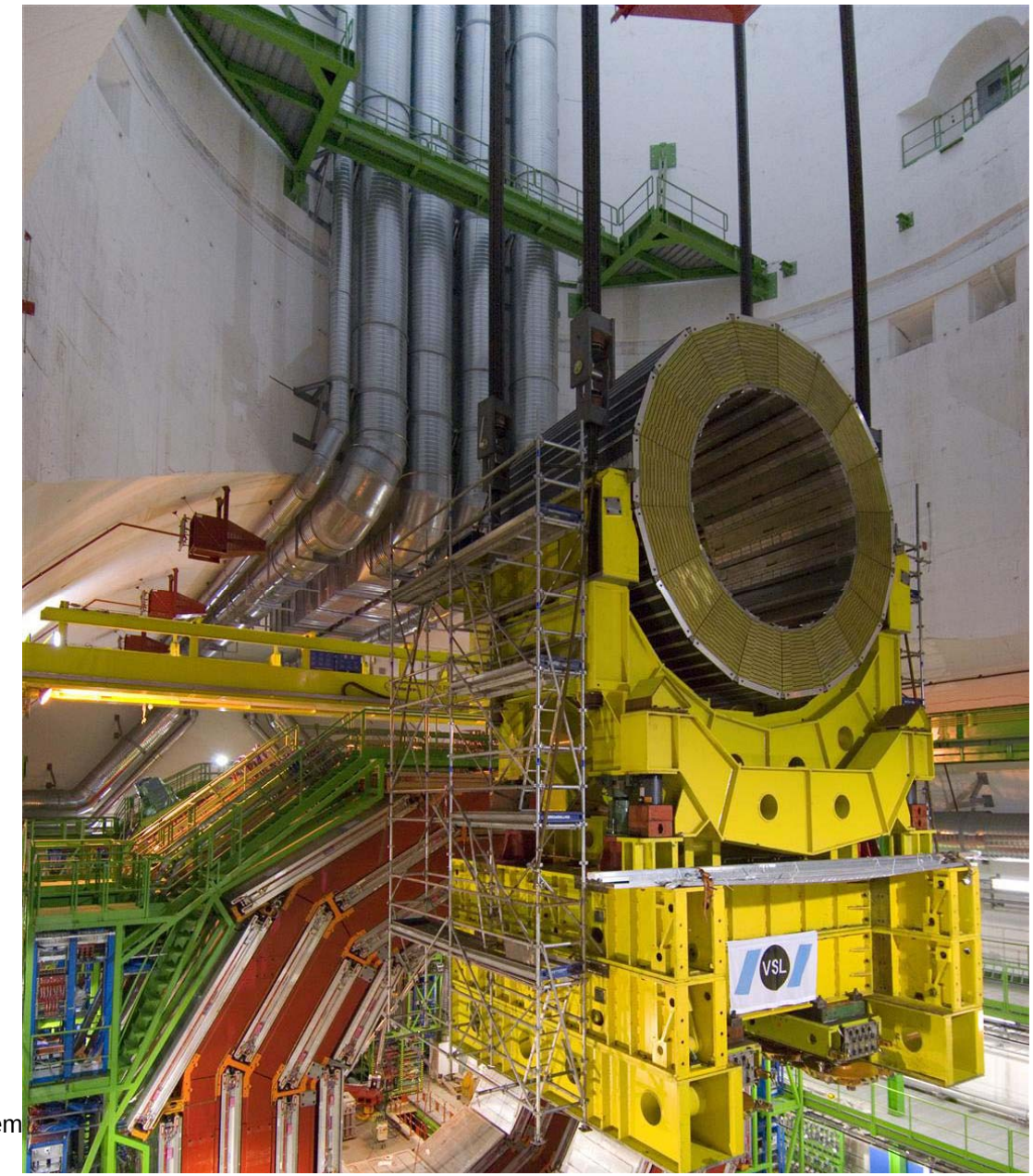
350-t HF 100 m below at the bottom of the shaft

First heavy lift with the 350-ton Hadronic Forward Calorimeters Nov. 06

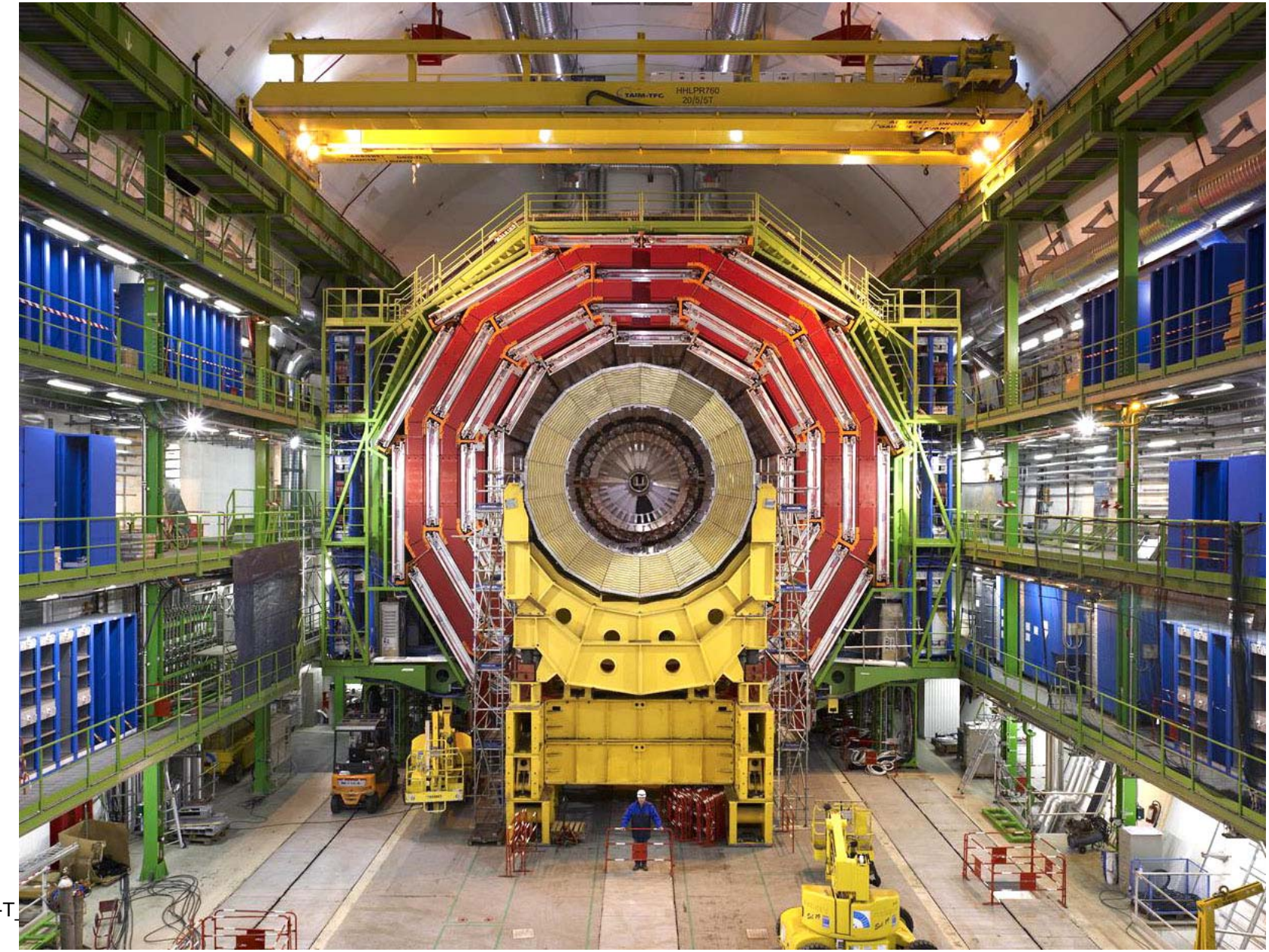
500-t HB beginning the descent



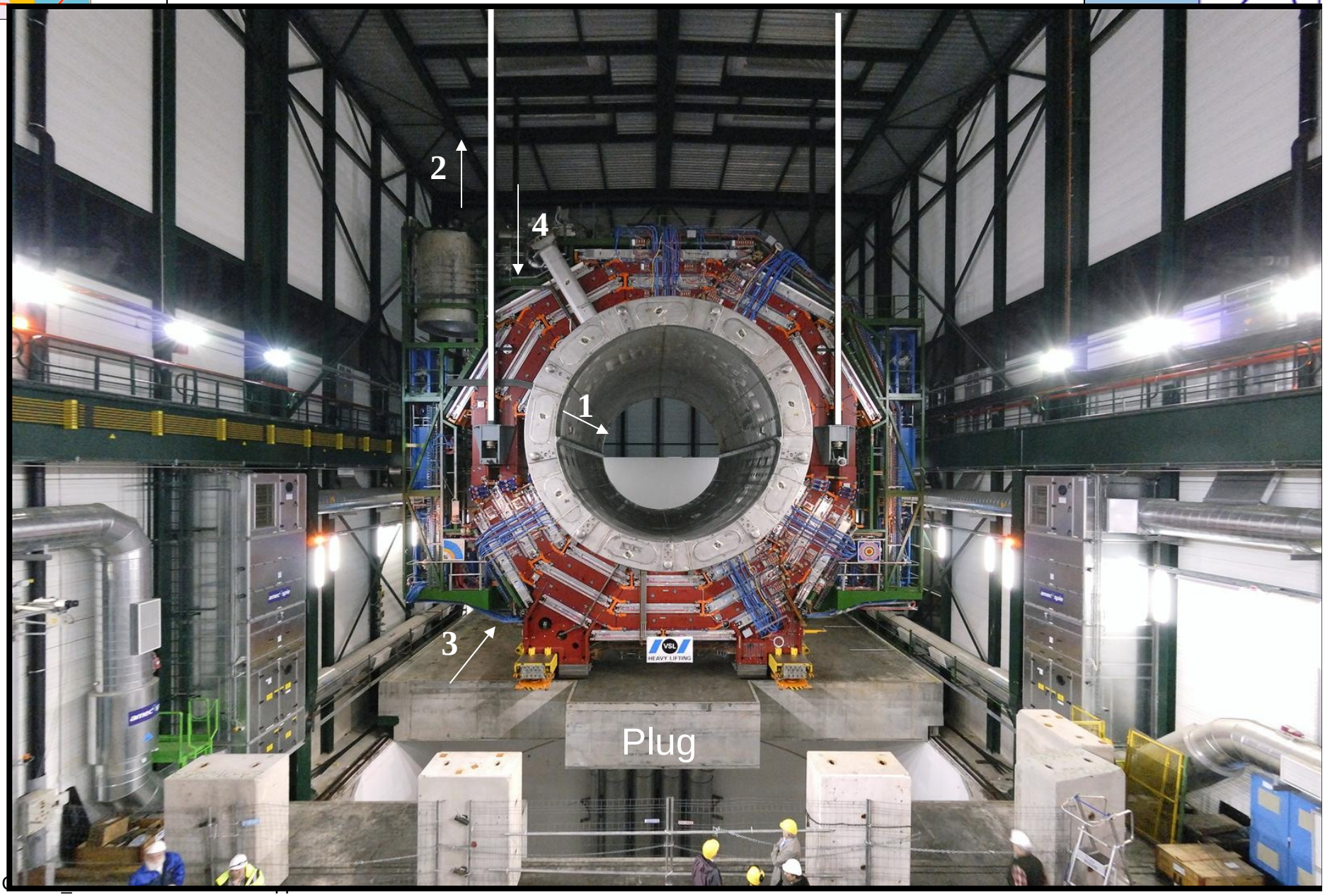
500-t HB 10 hours later after a 100 m trip



Plus side stacked waiting for the central barrel

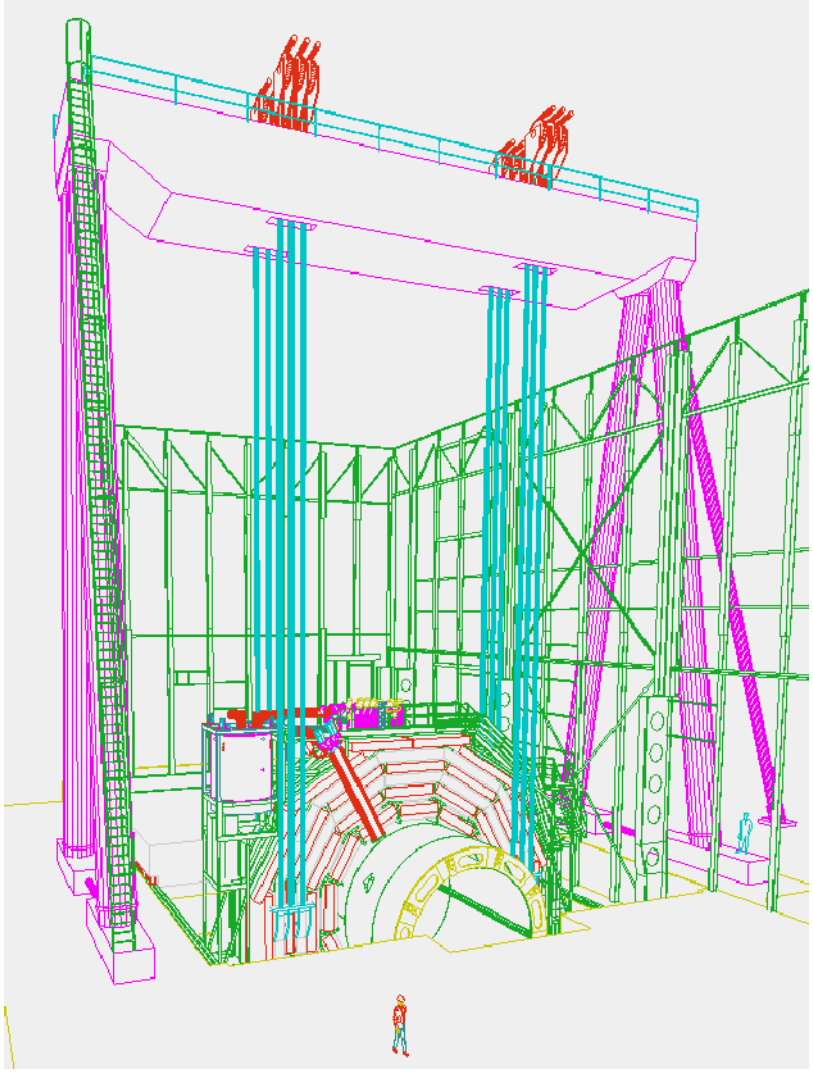


Opening the plug under the 2000-ton load

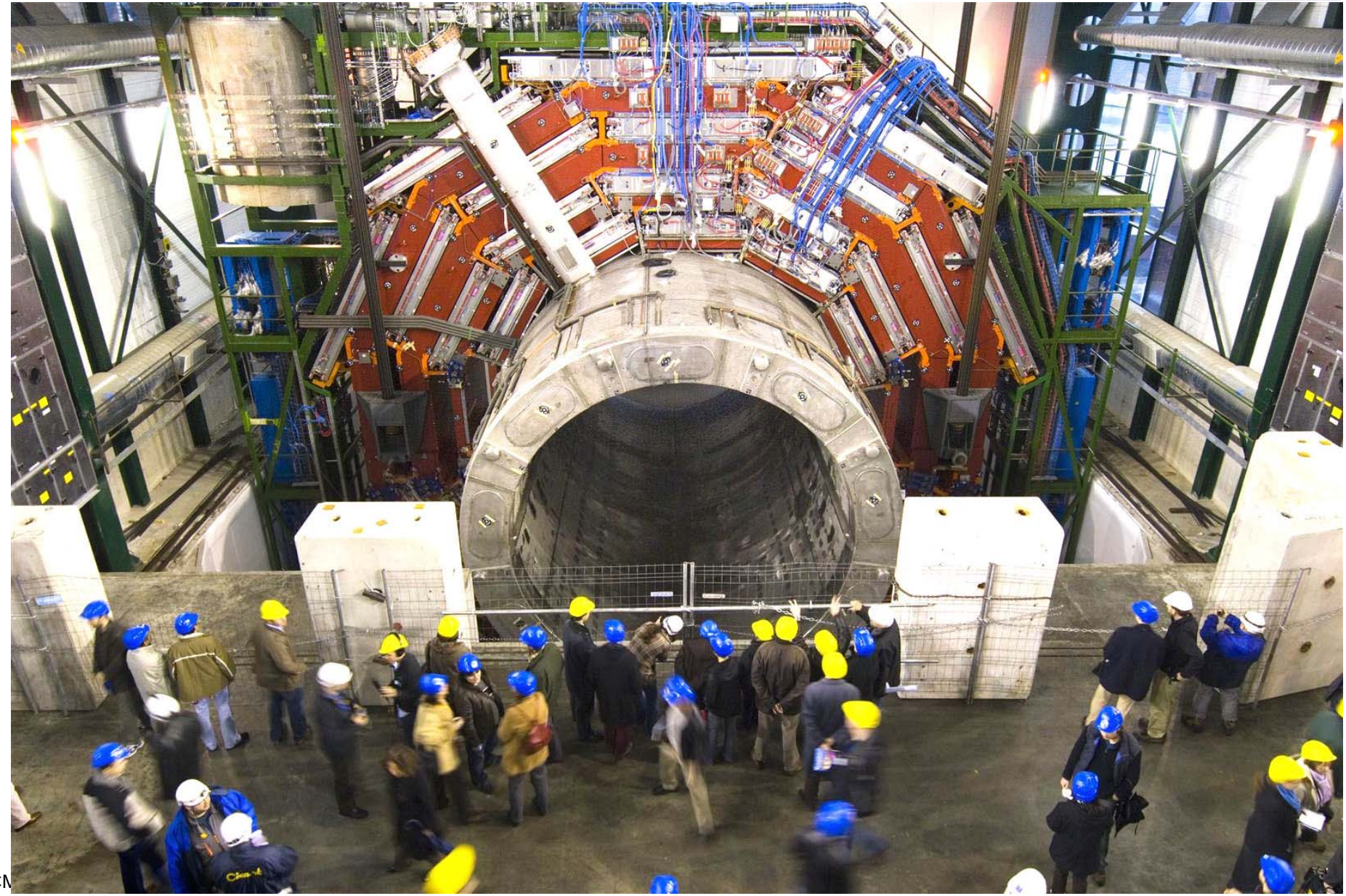


Lowering of the CMS detector into UXC55
Total of 15 loads from 350 to 2000 tons

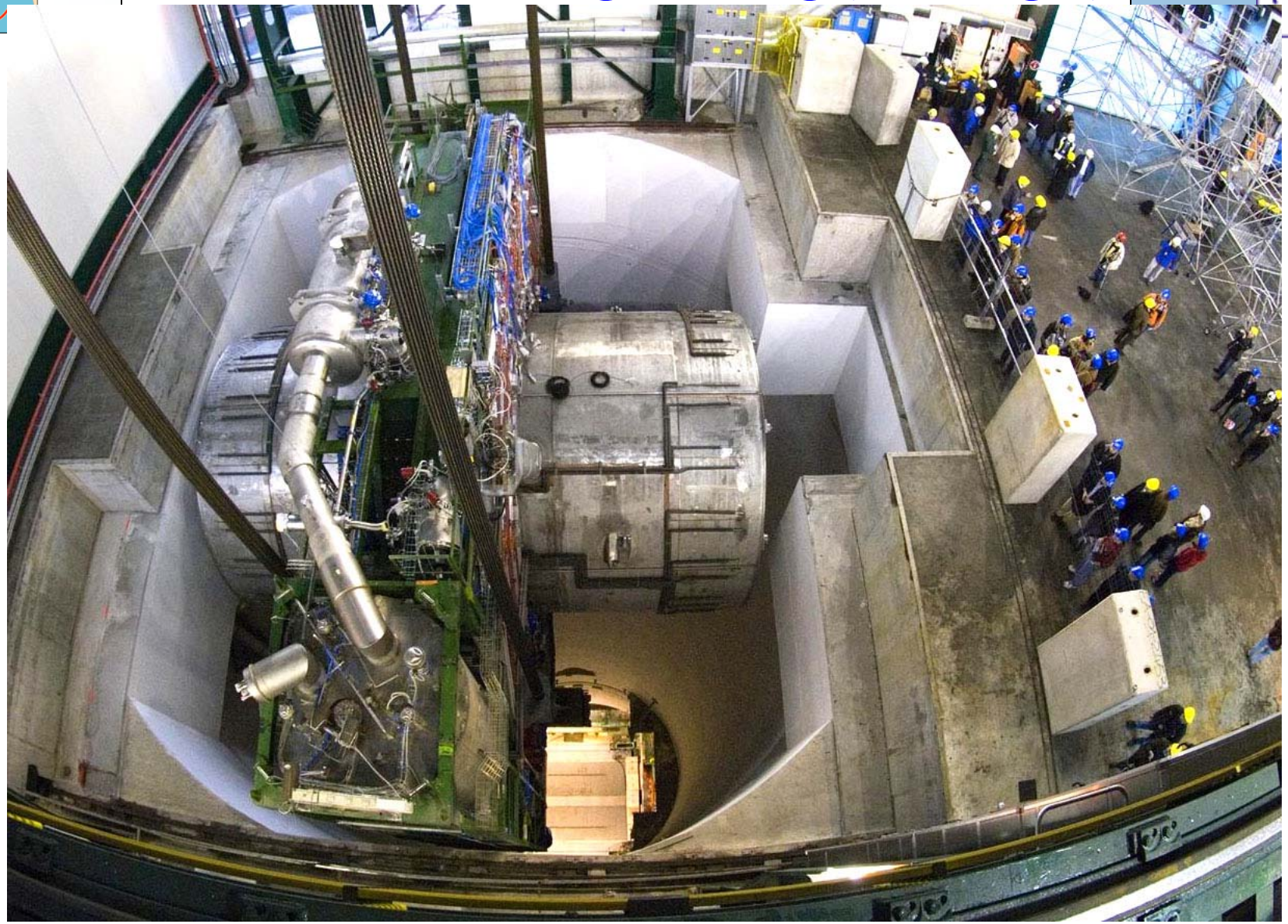
For public relations, we used for a long time, this view of YB0 disappearing in the shaft….



28 Feb. 07-YB0 at the Beginning of Descent



2000-t YB0 Crossing the Plug (2” margin)

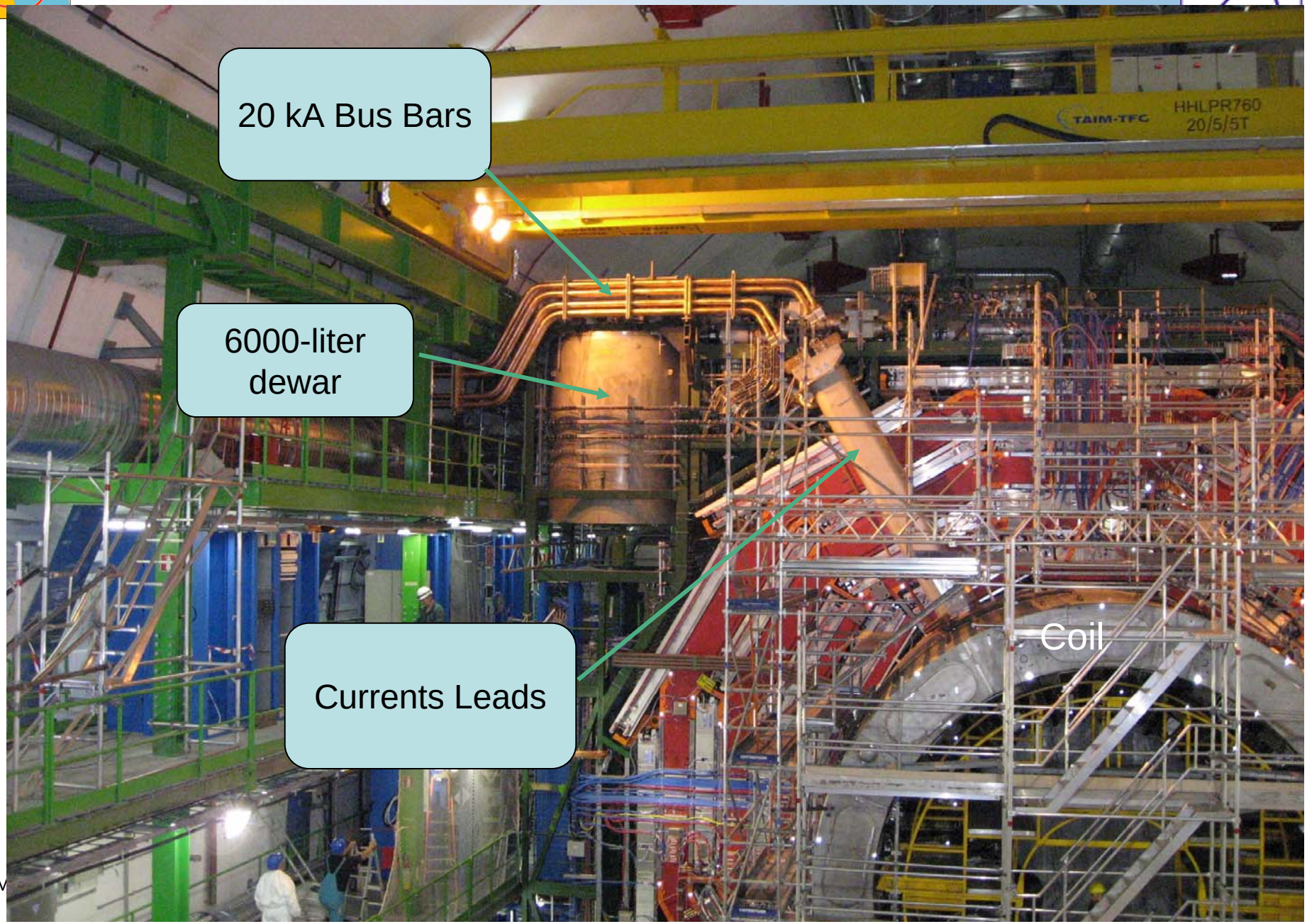


2000-t YB0 with Coil arriving underground

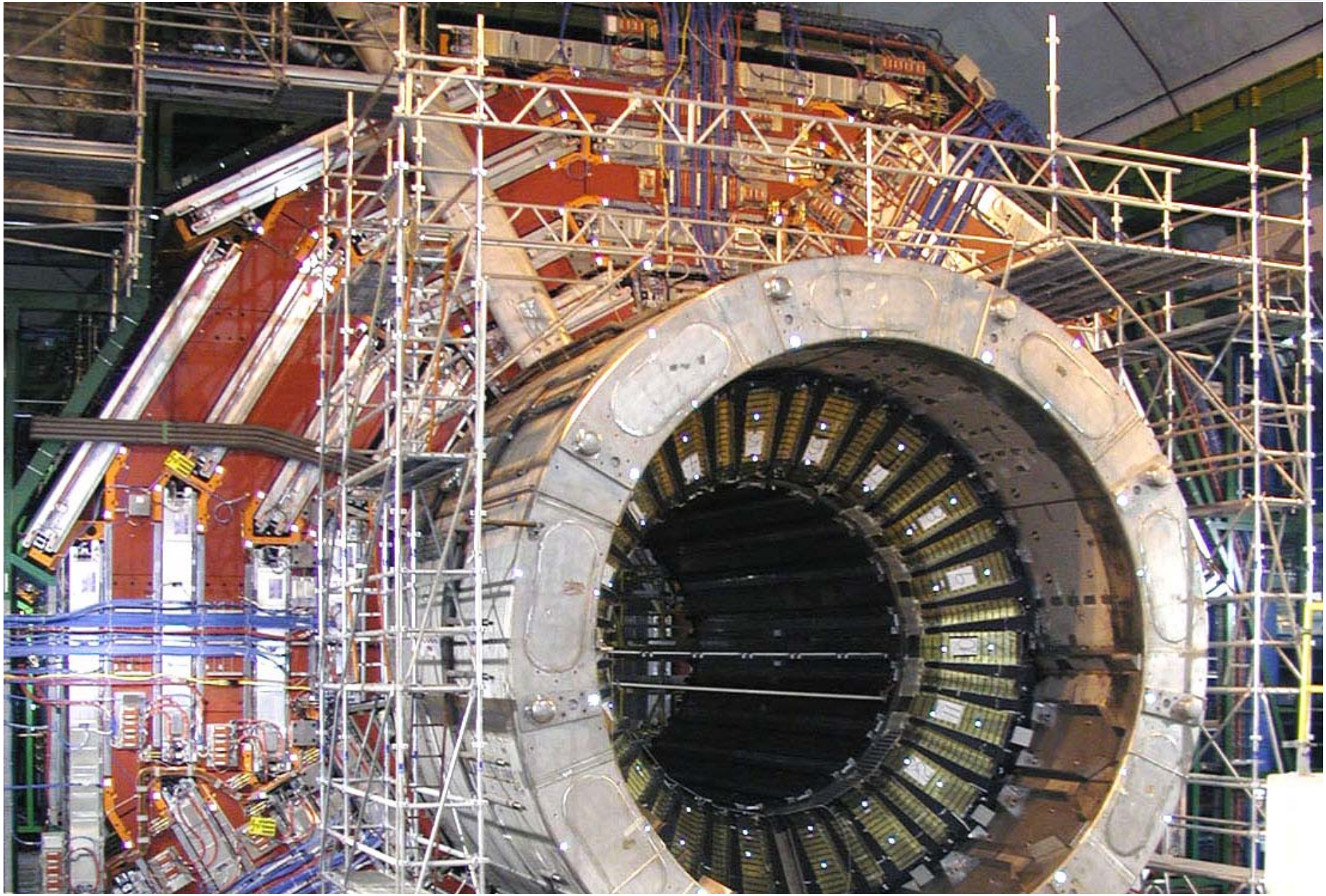
1800-t Endcap Disk with Calorimetric Nose

We had quite a good press coverage at the occasion of these heavy operations!

Coil will be Recommissioned in Spring 08



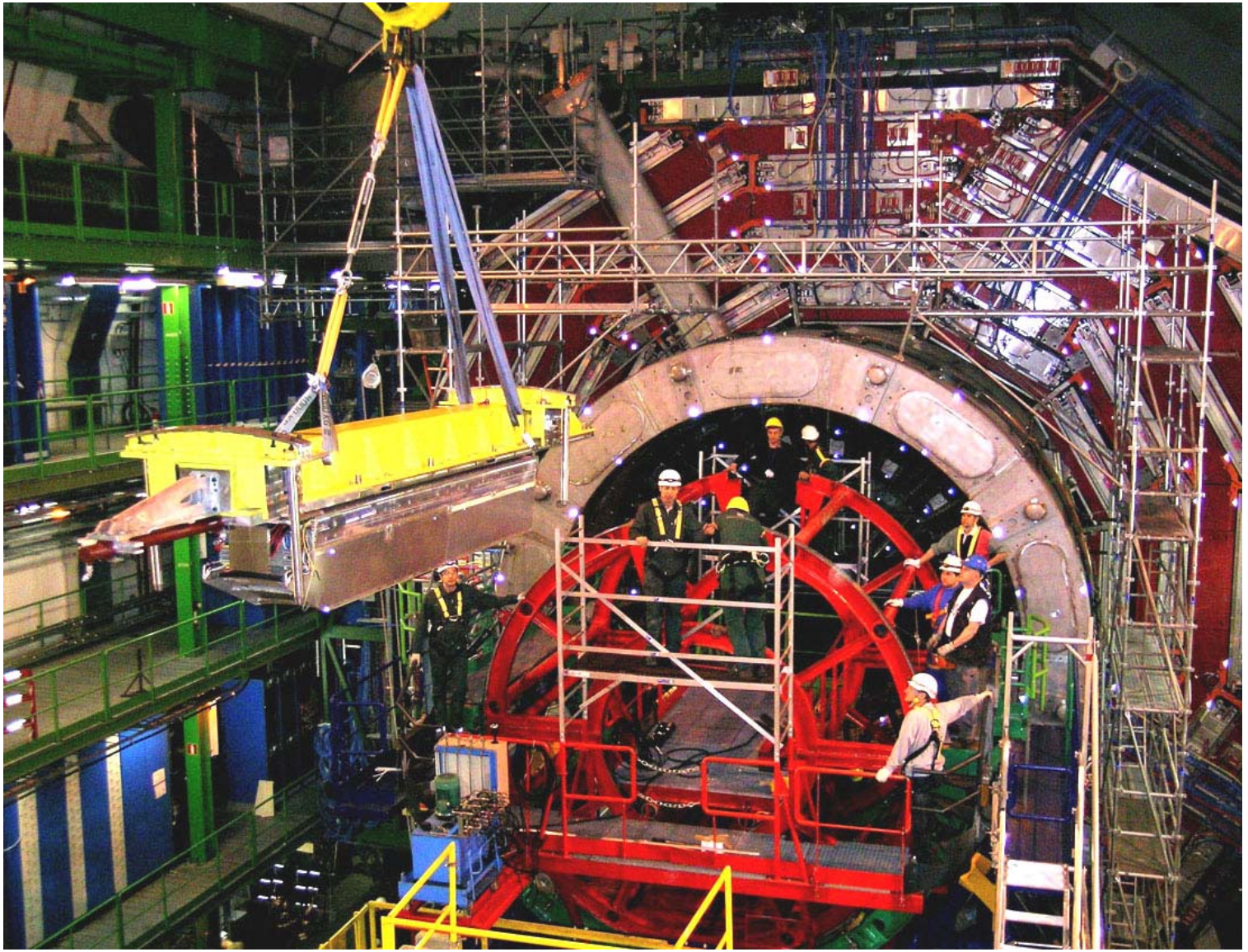
HB inside Vacuum Tank



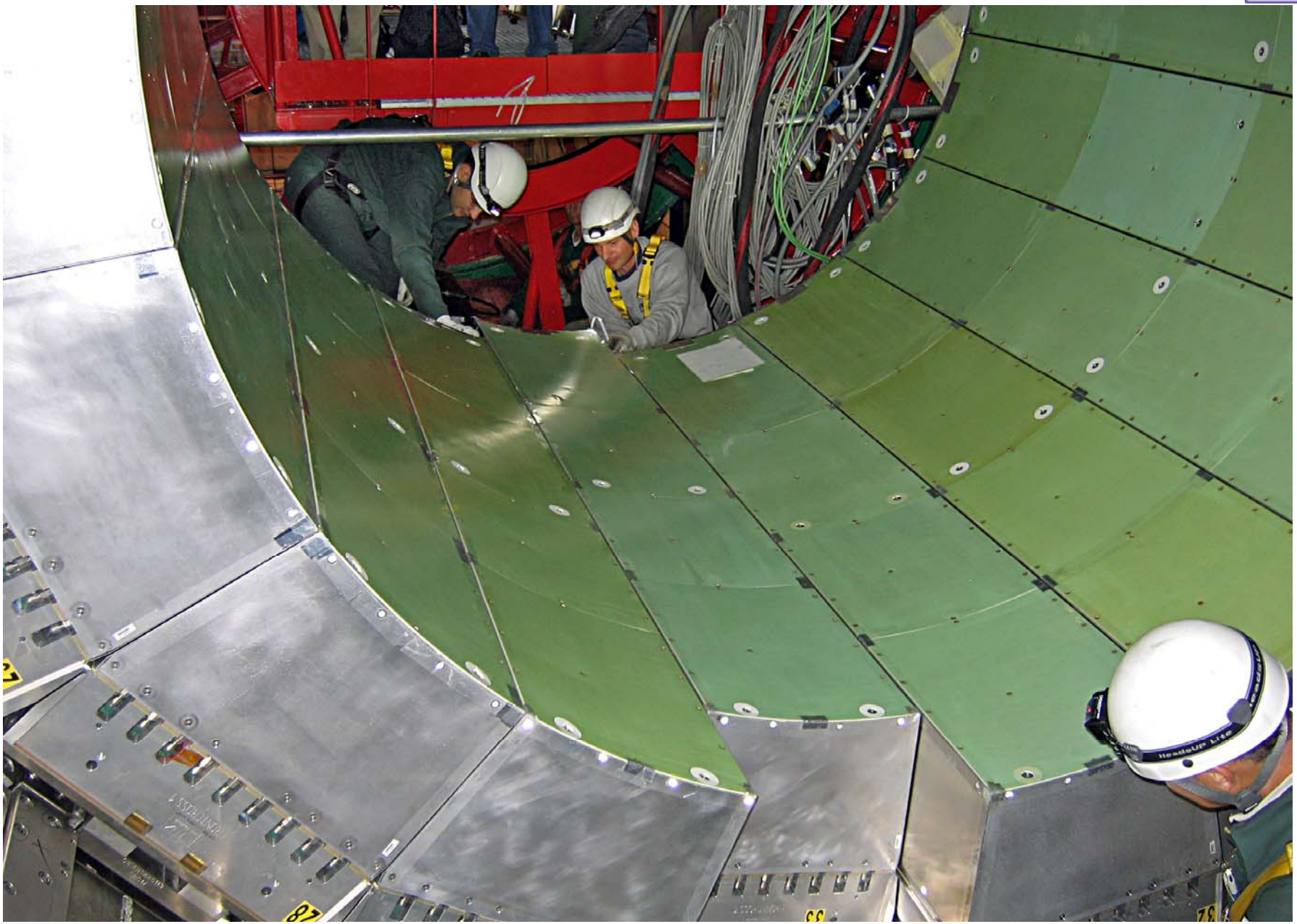
Positioning of HB and fit are perfect

Largely due to the test installation on the surface and later corrections

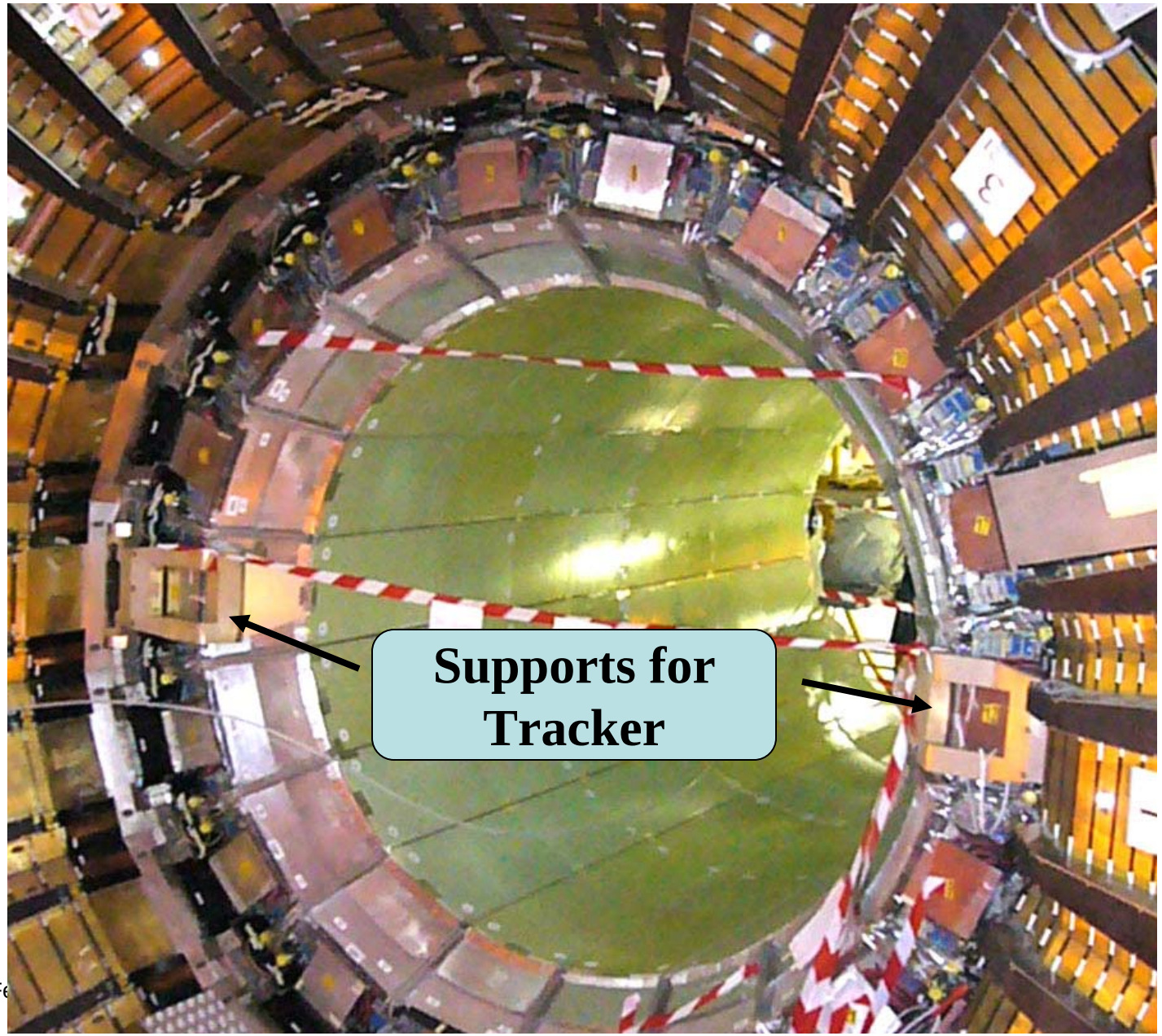
EB module with insertion tooling



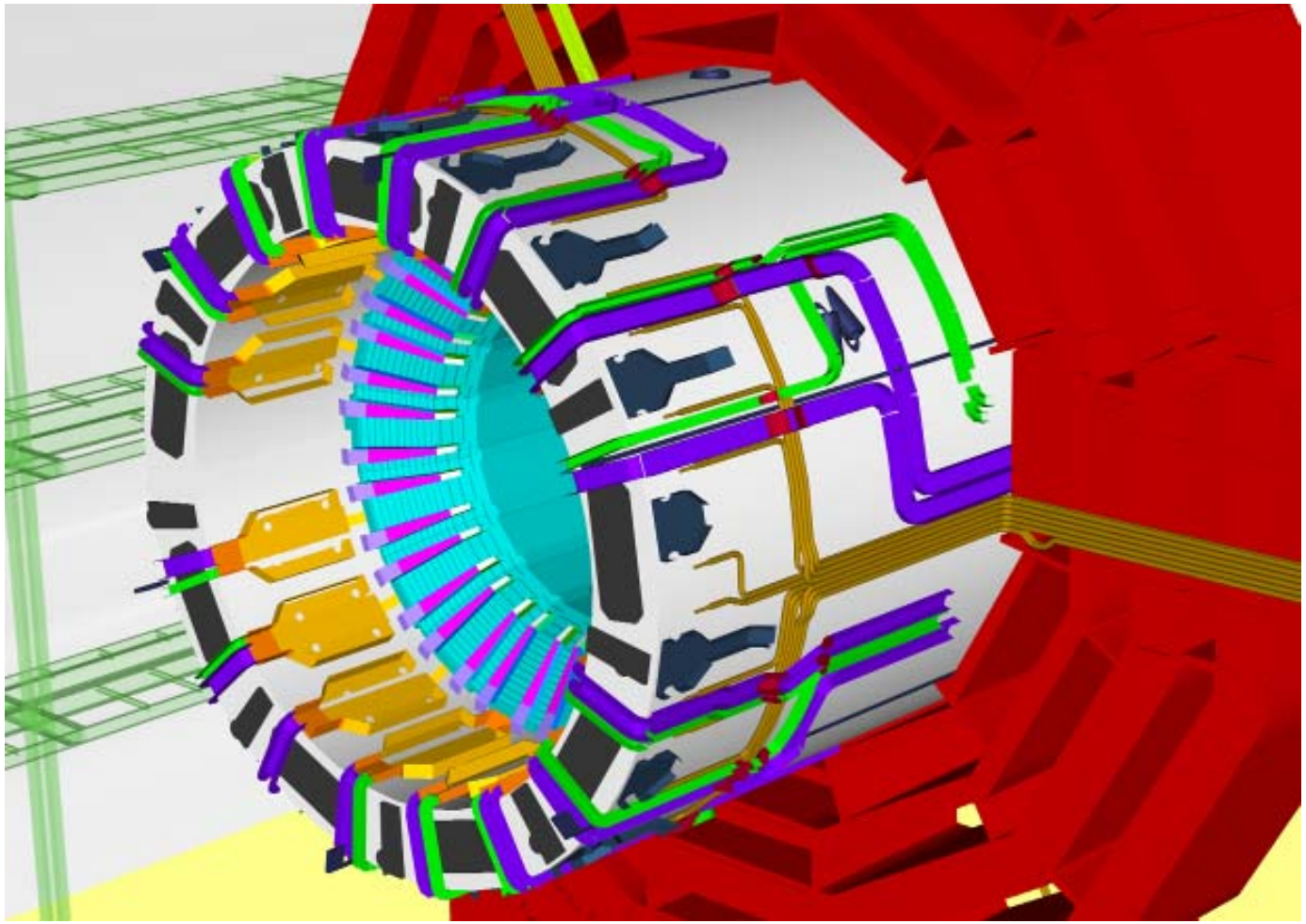
Installation of last EB module on +



Installation of EB Completed



Today: Cabling of Tracker, HB and EB over Vacuum Tank



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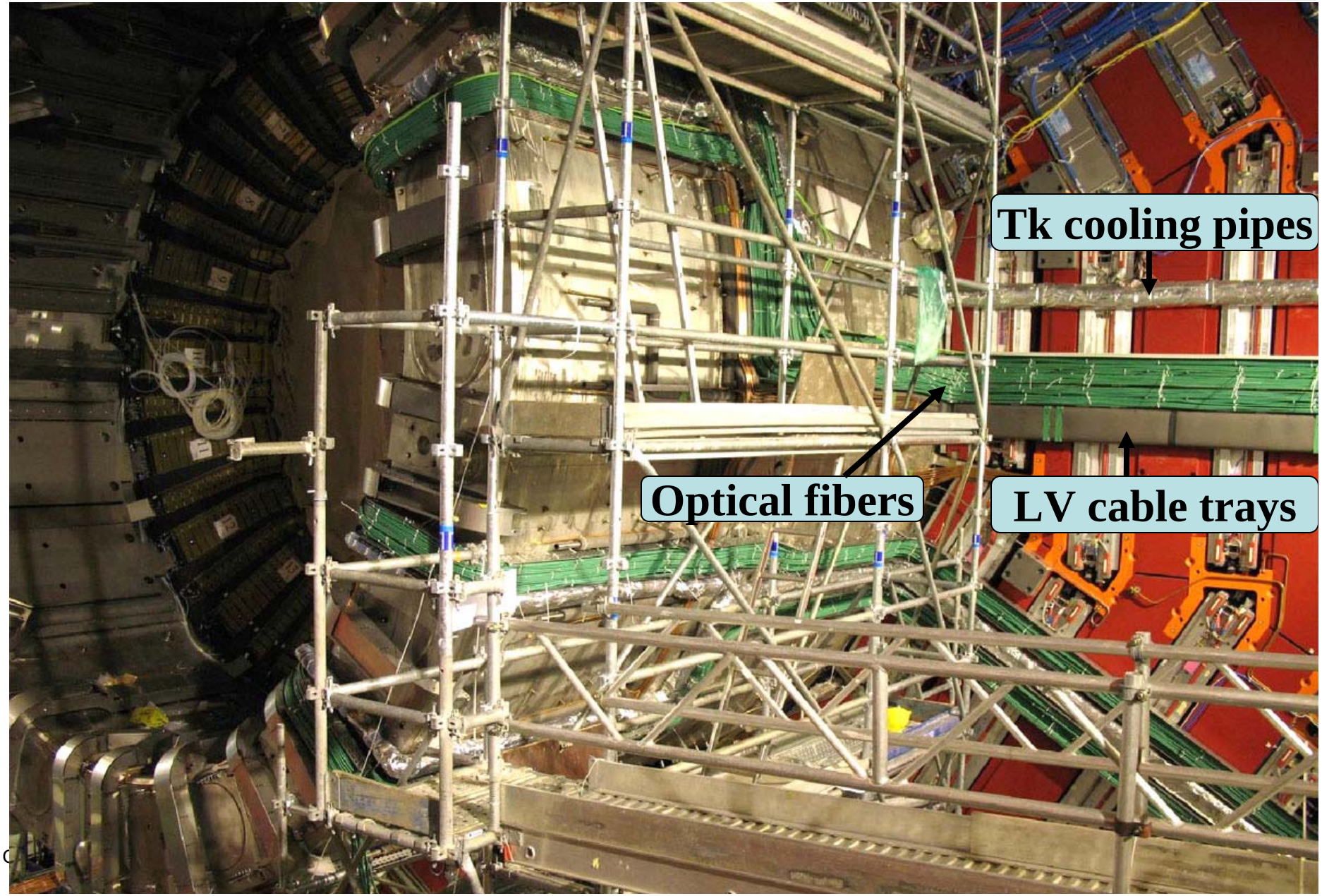
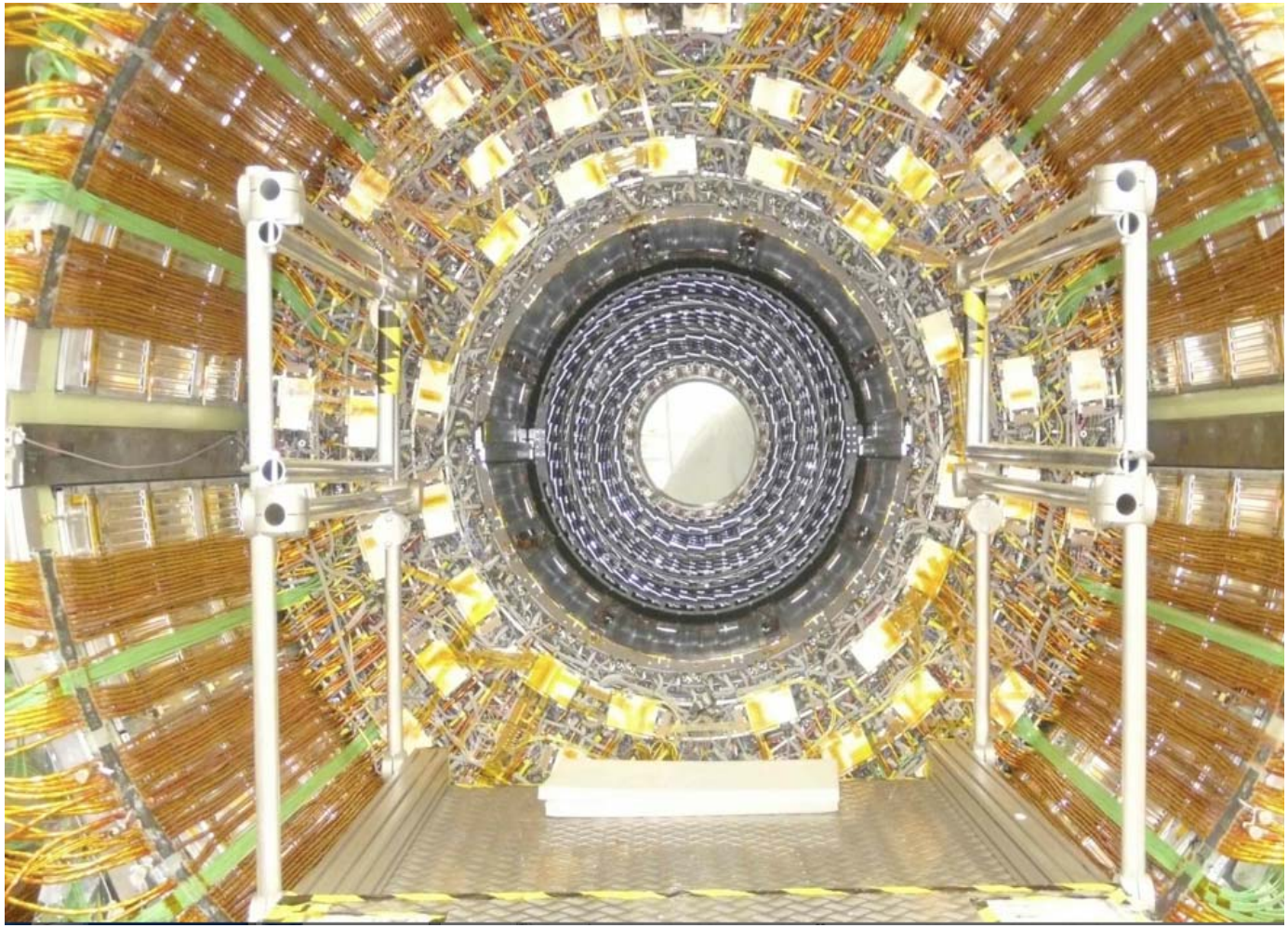


In parallel: Completion of Tracker in Bldg 186

TIB + inserted into TOB +

seen from the - End

TOB - Complete

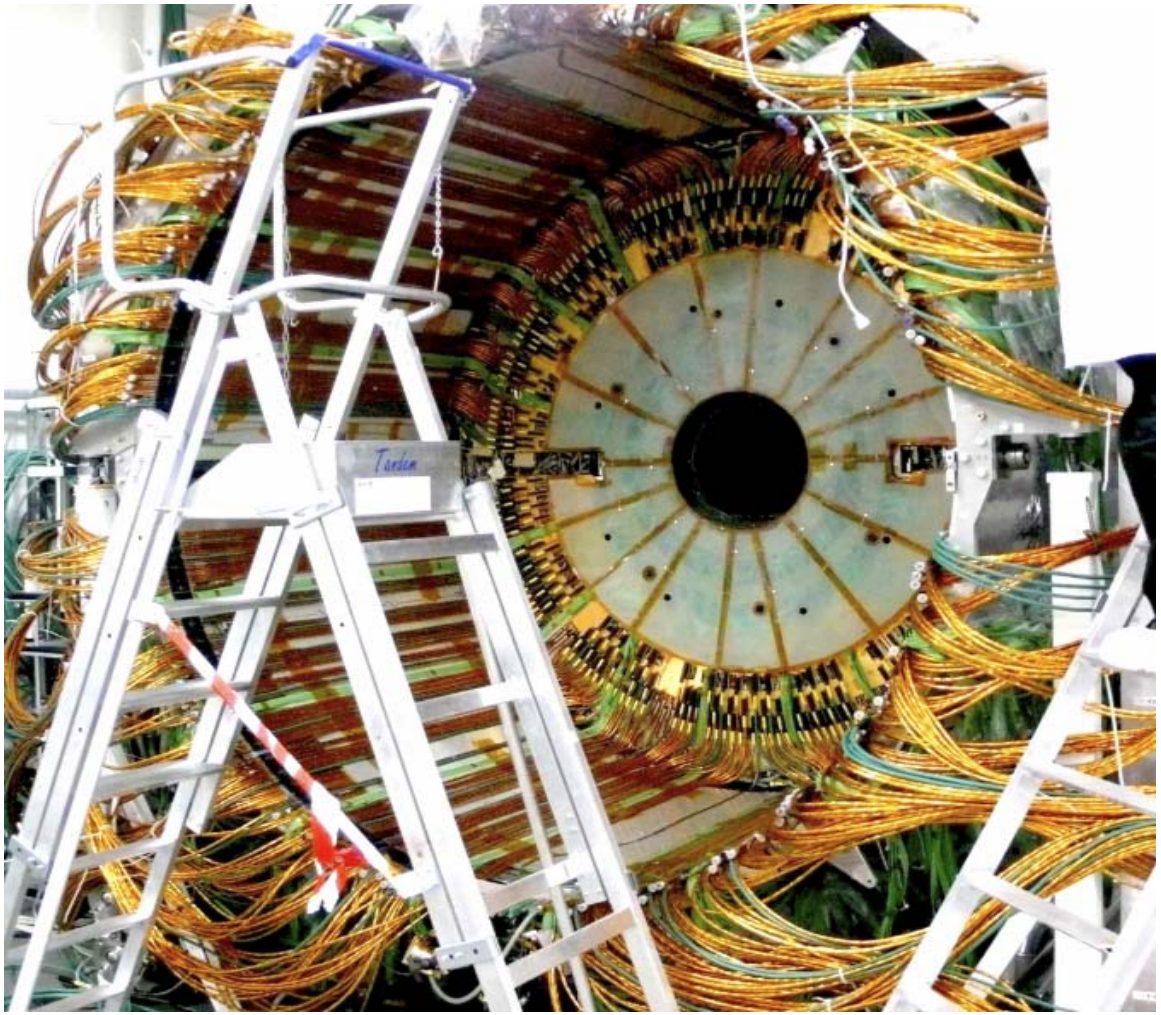


In parallel: Completion of Tracker in Bldg 186

TEC - Ready for insertion into the TST

In parallel: Completion of Tracker in Bldg 186

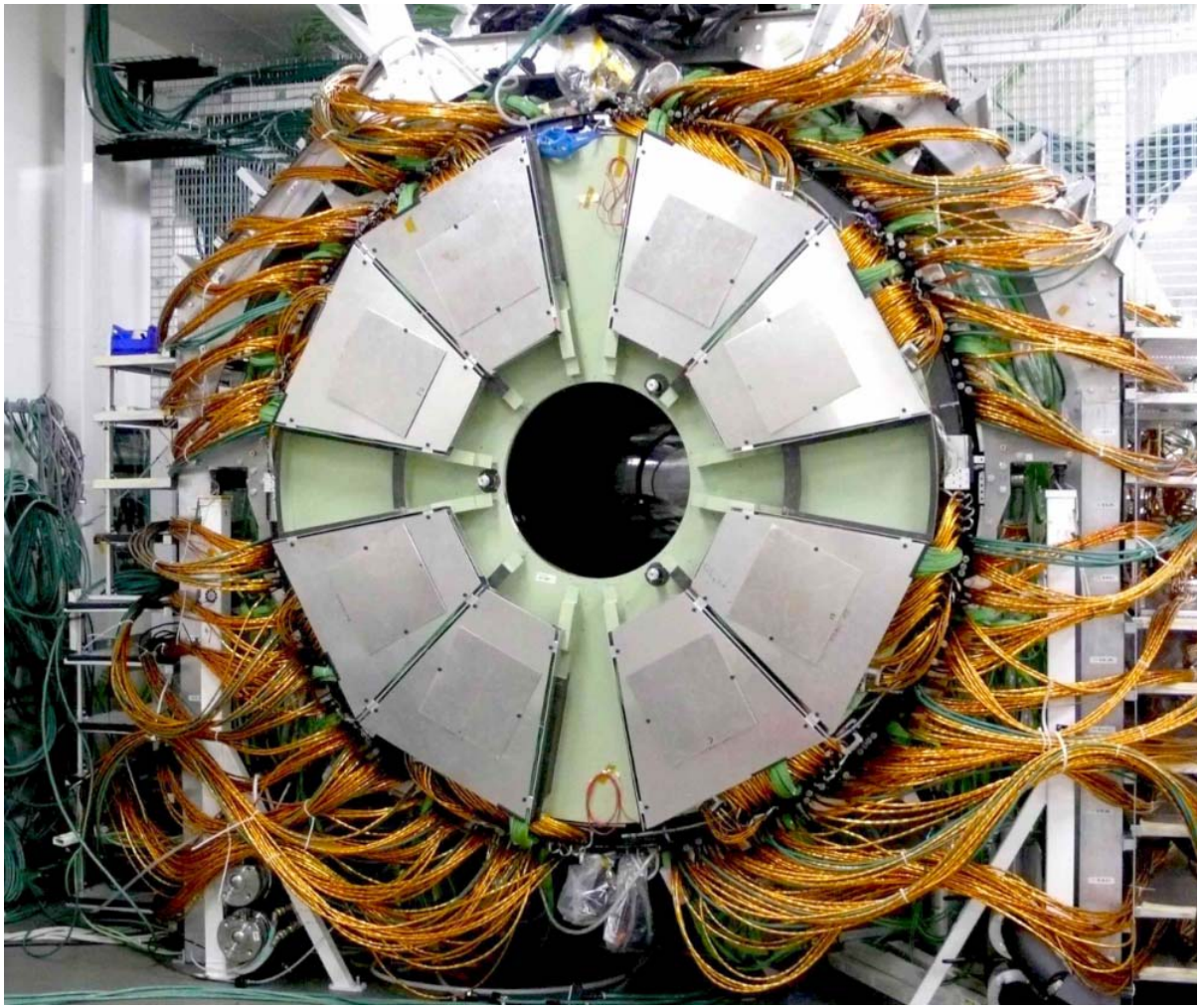
- End of TST is Prepared for TEC-
TIB - has been inserted and services dressed along TST



In parallel: Completion of Tracker in Bldg 186

TEC - is Installed in TST
seen from the - End

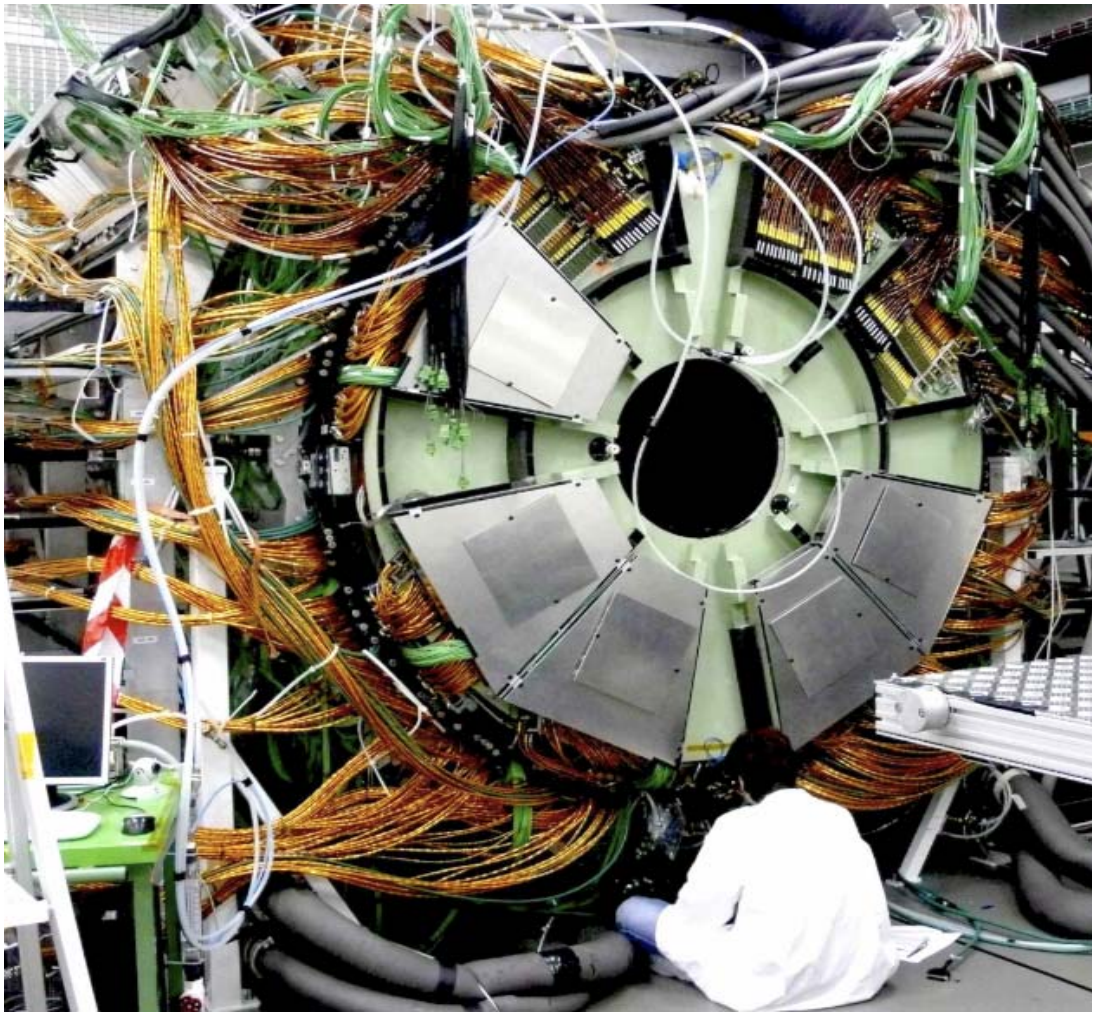
21 March 2007



In parallel: Completion of Tracker in Bldg 186

TEC + seen from the + End

Taking Cosmic Triggers and Preparing the Thermal Screen to run Cold



Tracker Completed and Commissioned

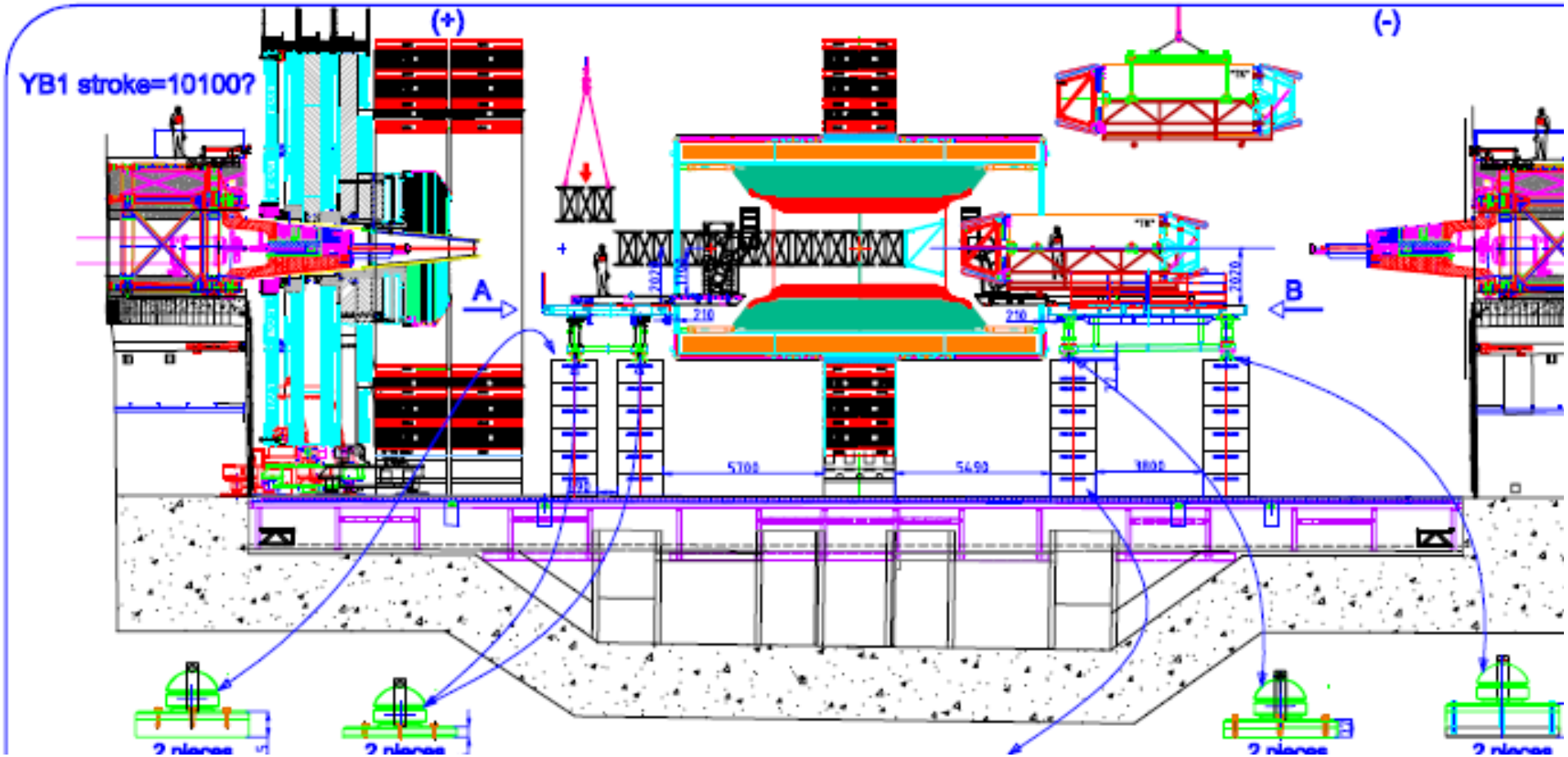
Tracker in dry air tent for cold running
Dew point < -14C

5M triggers taken at +15, +1,-5 and -15C

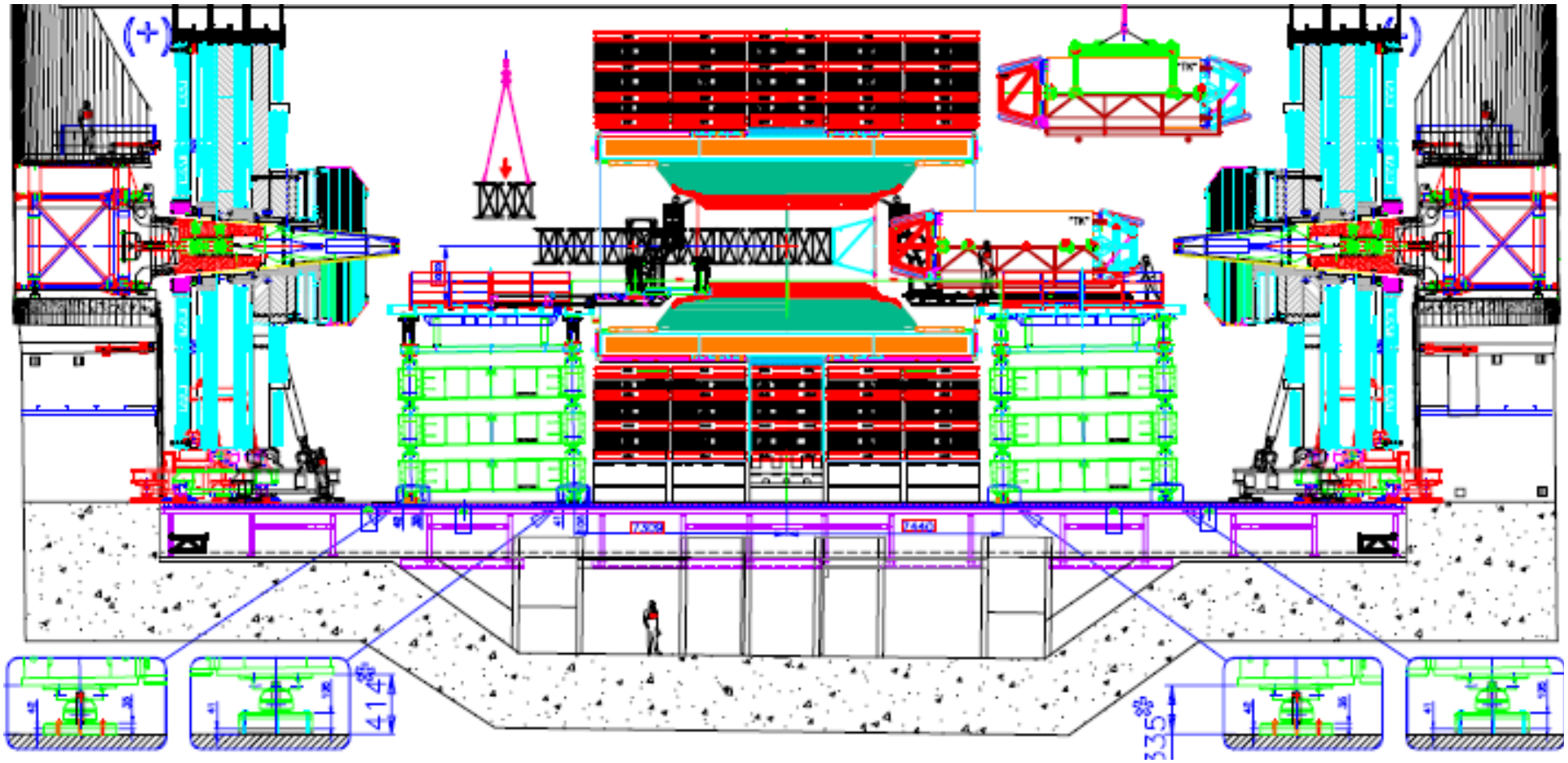
Part-3

Operations to come
&
Conclusions

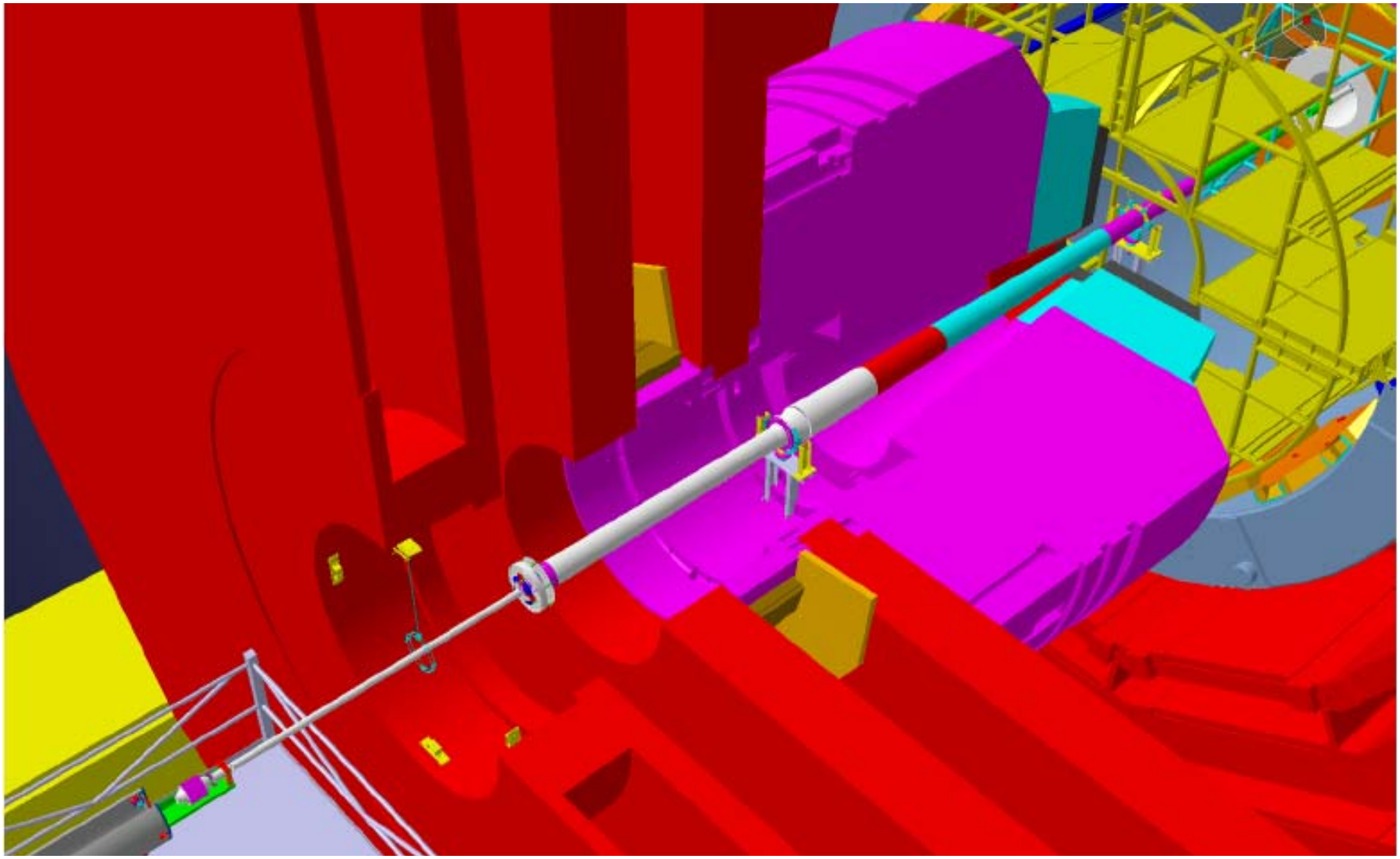
Tracker to be installed end October 07



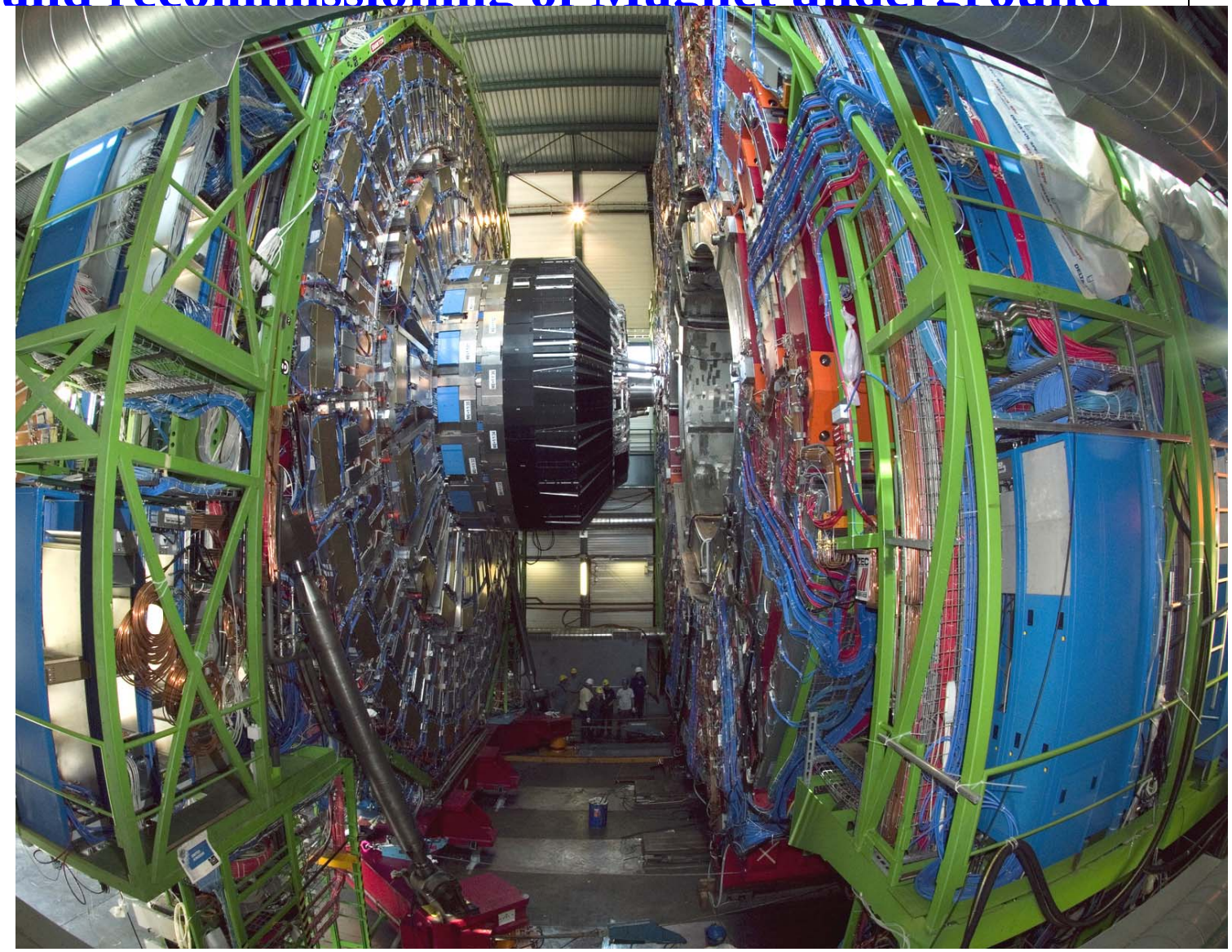
Installation scenario is compatible with Tracker ultimate maintenance (removal)



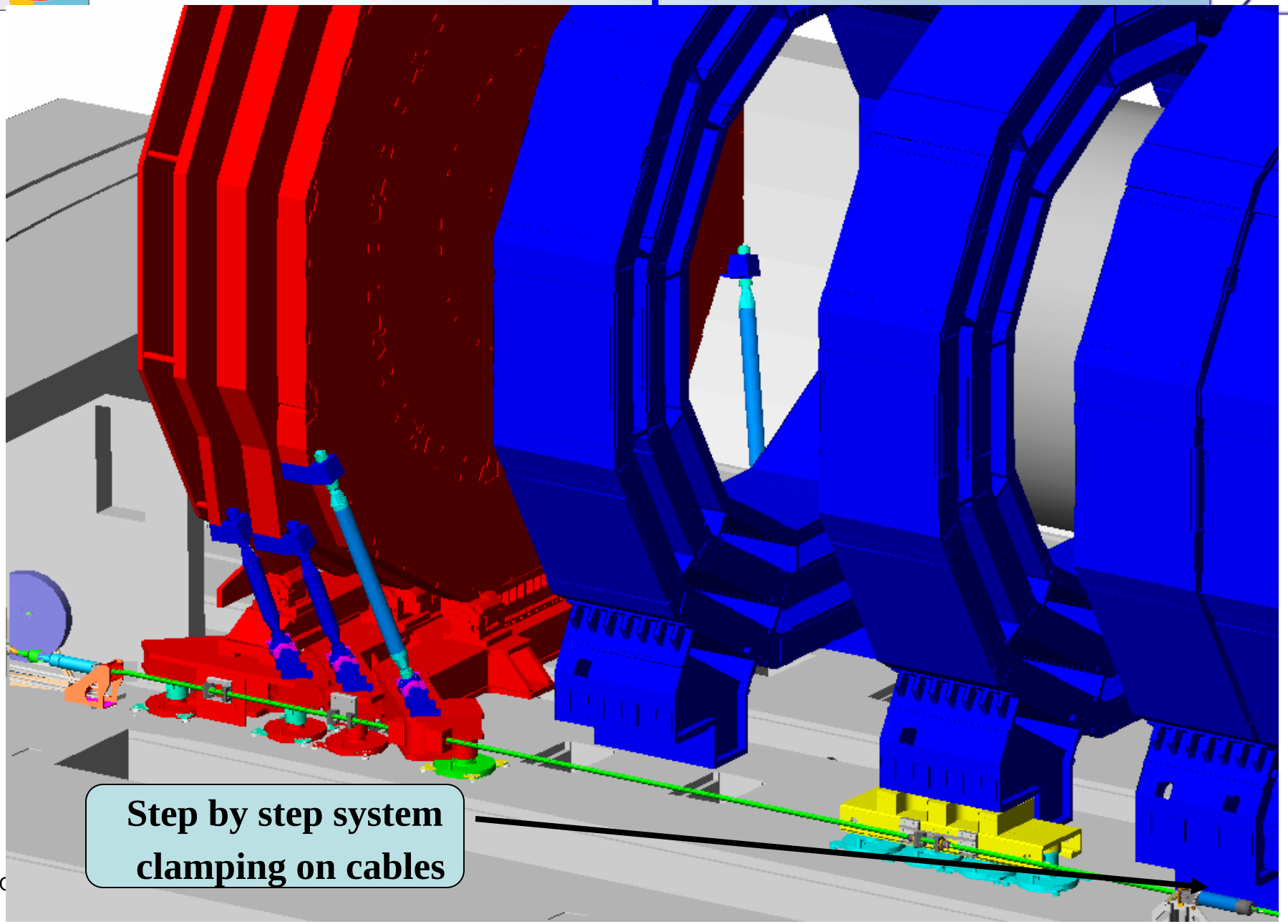
Then installation of beam pipe will proceed



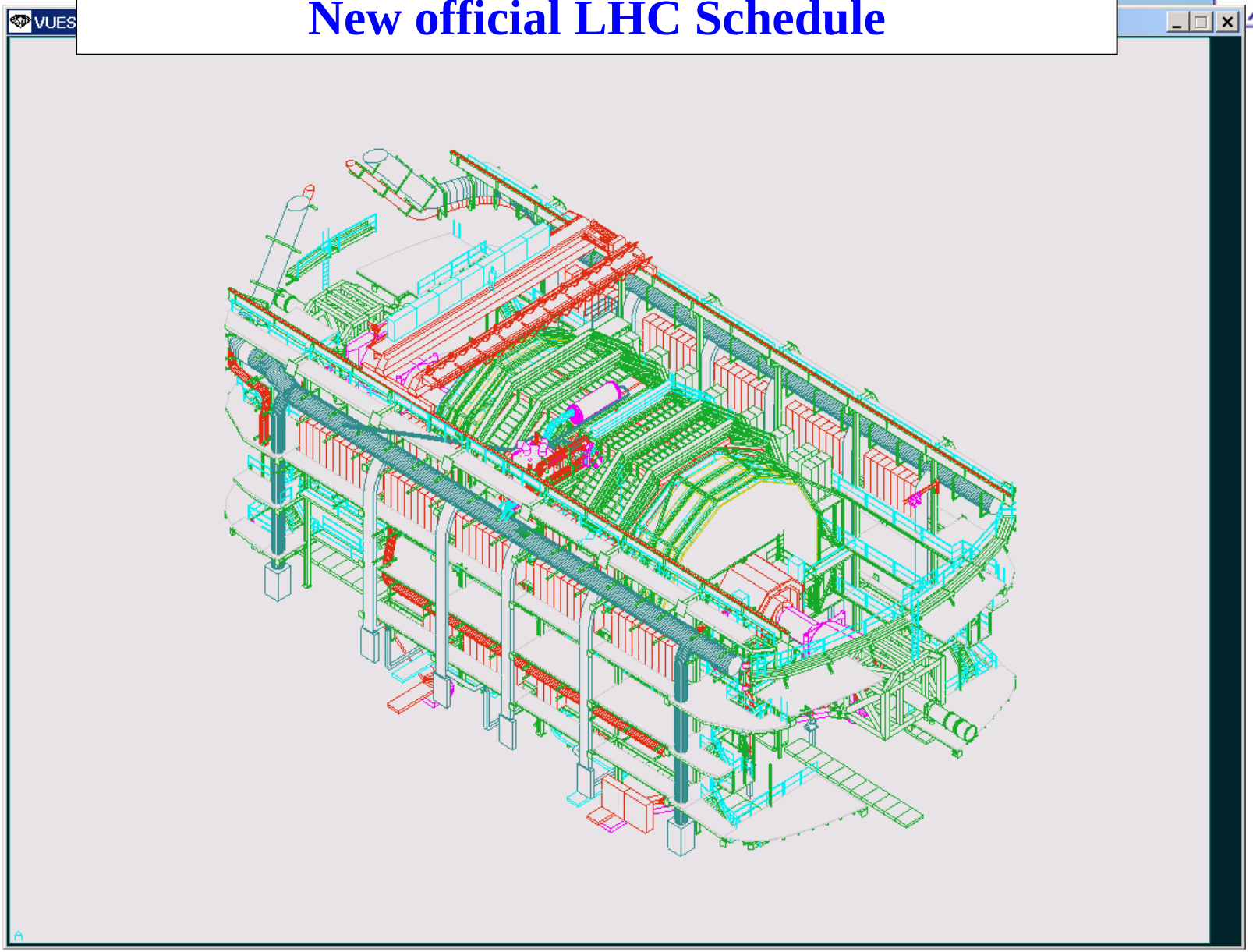
Expected closure of the endcaps in March and recommissioning of Magnet underground



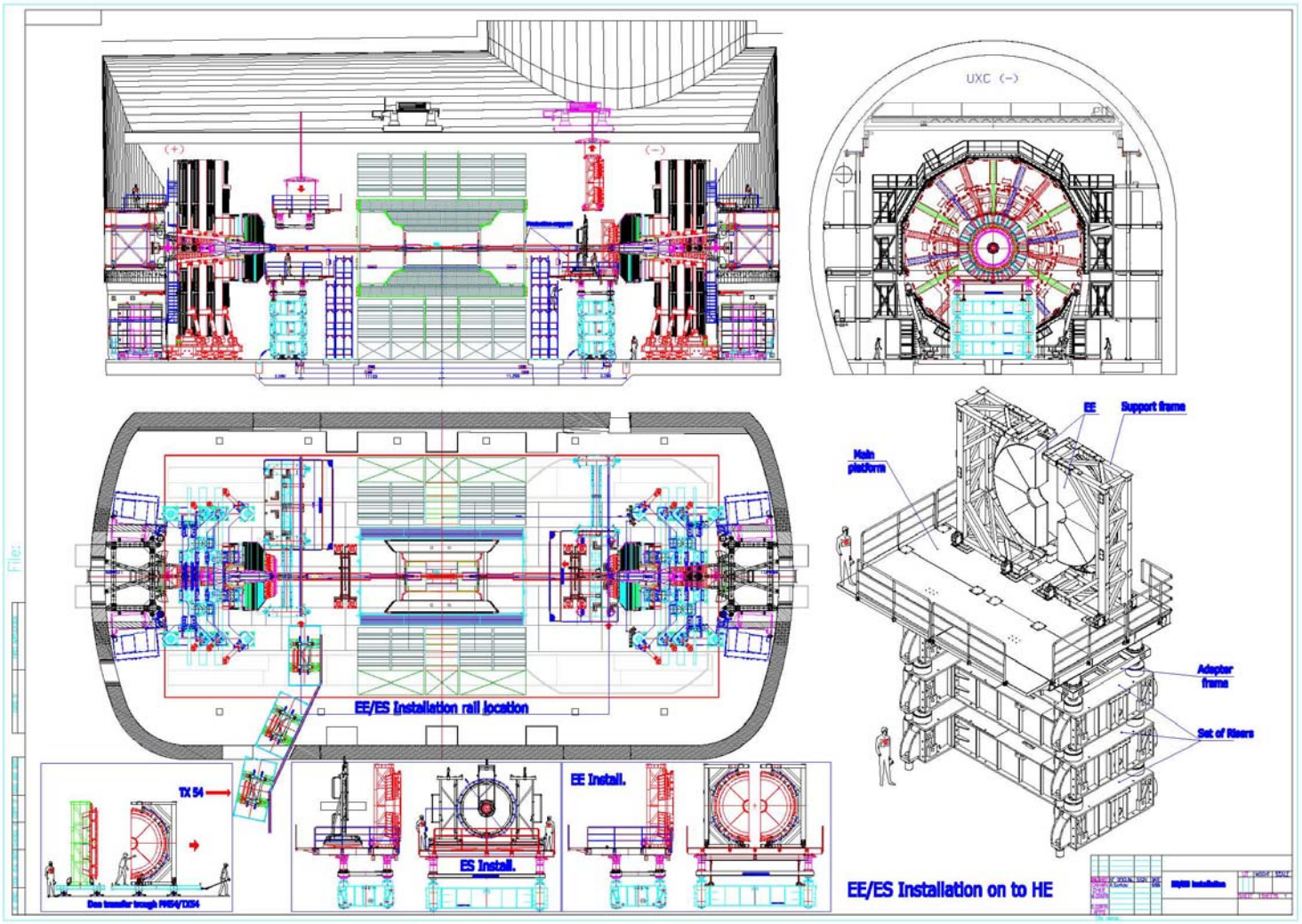
Movement Underground on a 1.24% slope has been practiced !



CMS will be ready to take first beam in May 08
New official LHC Schedule



If needed installation of last EE during the first Shut-down



Ecal End-cap installation inside UXC55.

During Shut-downs maintenance will be easy!

10 m space for access can be shared at best on each side.

Conclusions

Conclusions

- **We have been able to maintain the principles adopted in 1991/1992 without any compromising.**

- **The end of CMS installation, Tracker, re-commisioning of magnet & final commissioning, is in good hand to be completed to take first beam in very good condition in May 08.**

- **The general architecture will allow an efficient maintenance as all sub-detectors can be easily accessed during a shut-down.**

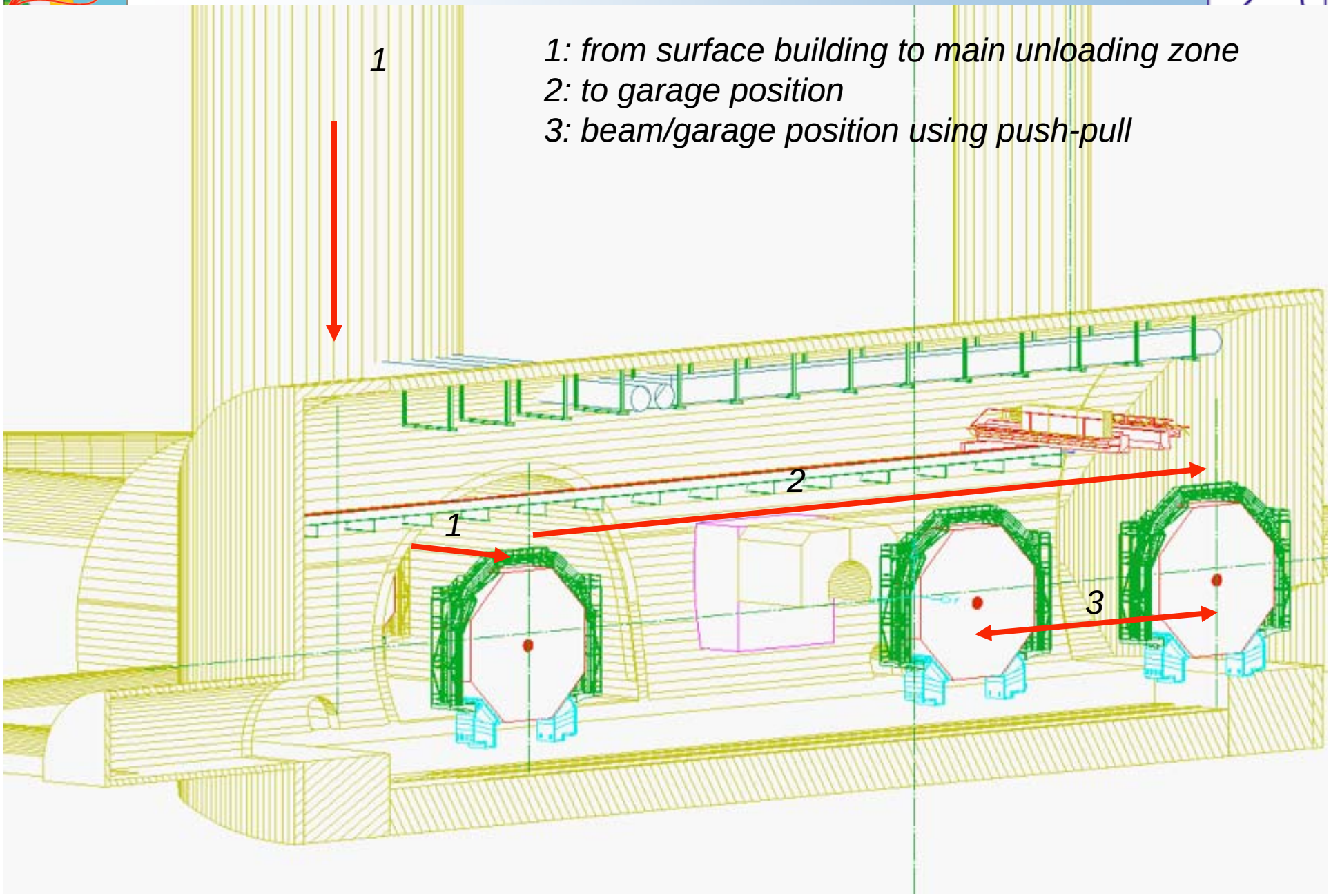
Conclusions

• **The scenario of constructing on the surface followed by transfer underground looks still to us like the best solution for a detector like CMS.**

• **This option is looked at very carefully by ILC which is considering a scenario 'à la CMS'.**

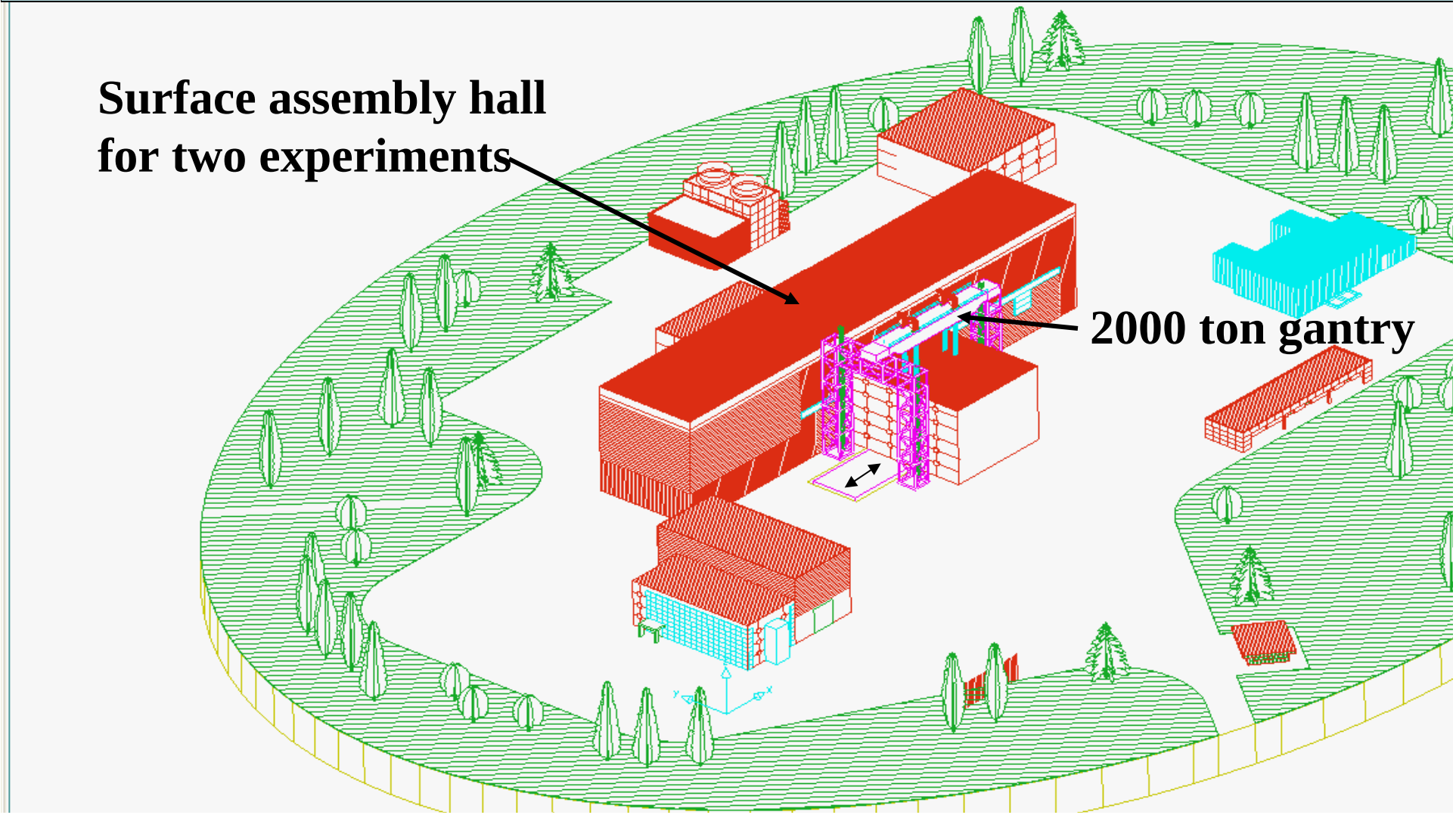
Movements of Experiment B for ILC

1: from surface building to main unloading zone
2: to garage position
3: beam/garage position using push-pull



VUES 3D

One possible arrangement of an ILC experimental area for surface assembly scenario



Thank You!