



CMS Detector

The Compact Muon Solenoid at the Large Hadron Collider

Jim Freeman

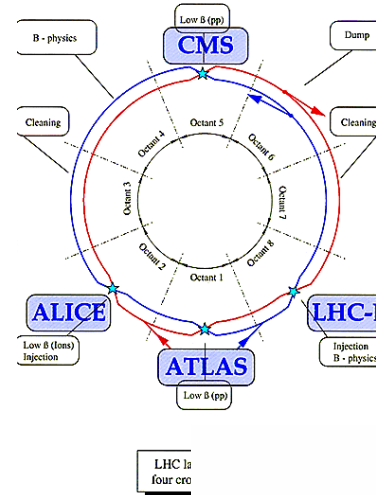
CMS 101



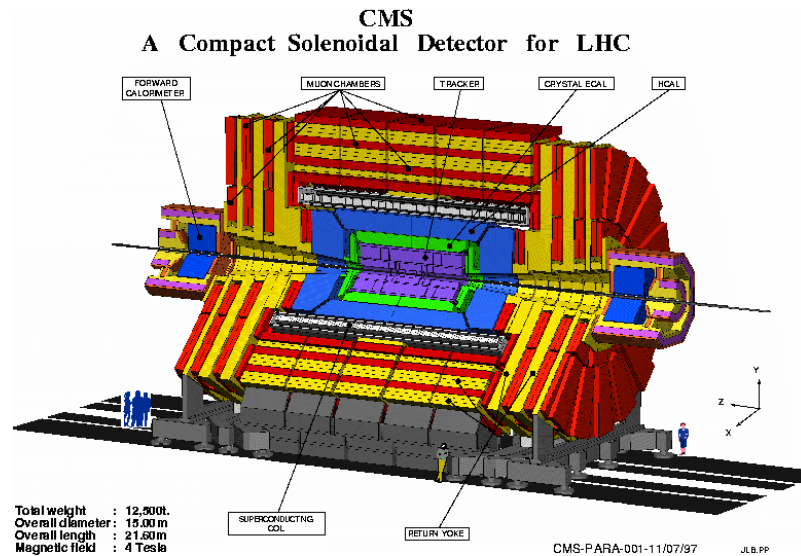
What and Where is CERN, LHC, CMS?



European Center for Nuclear Research (CERN)



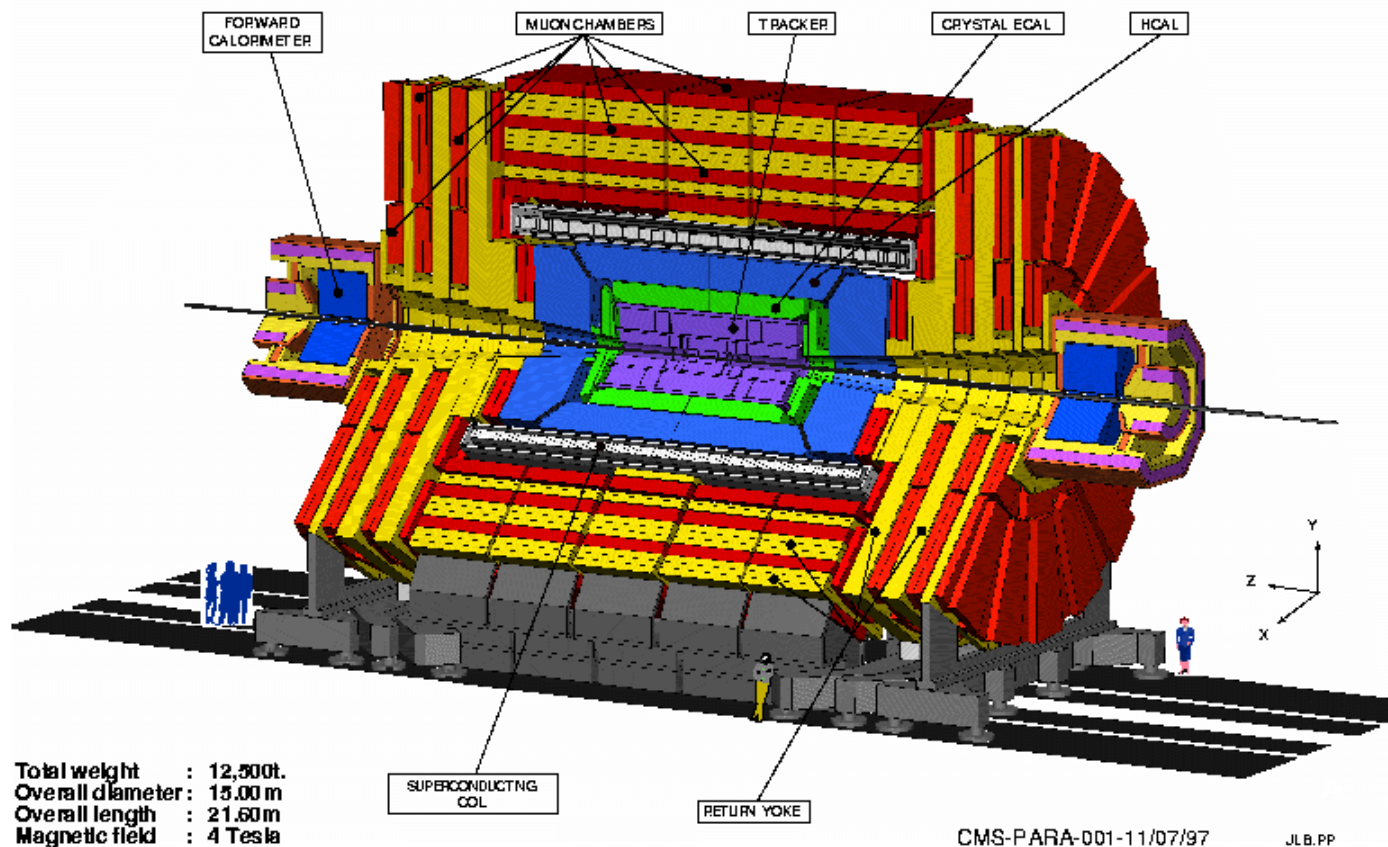
Large Hadron Collider (LHC)





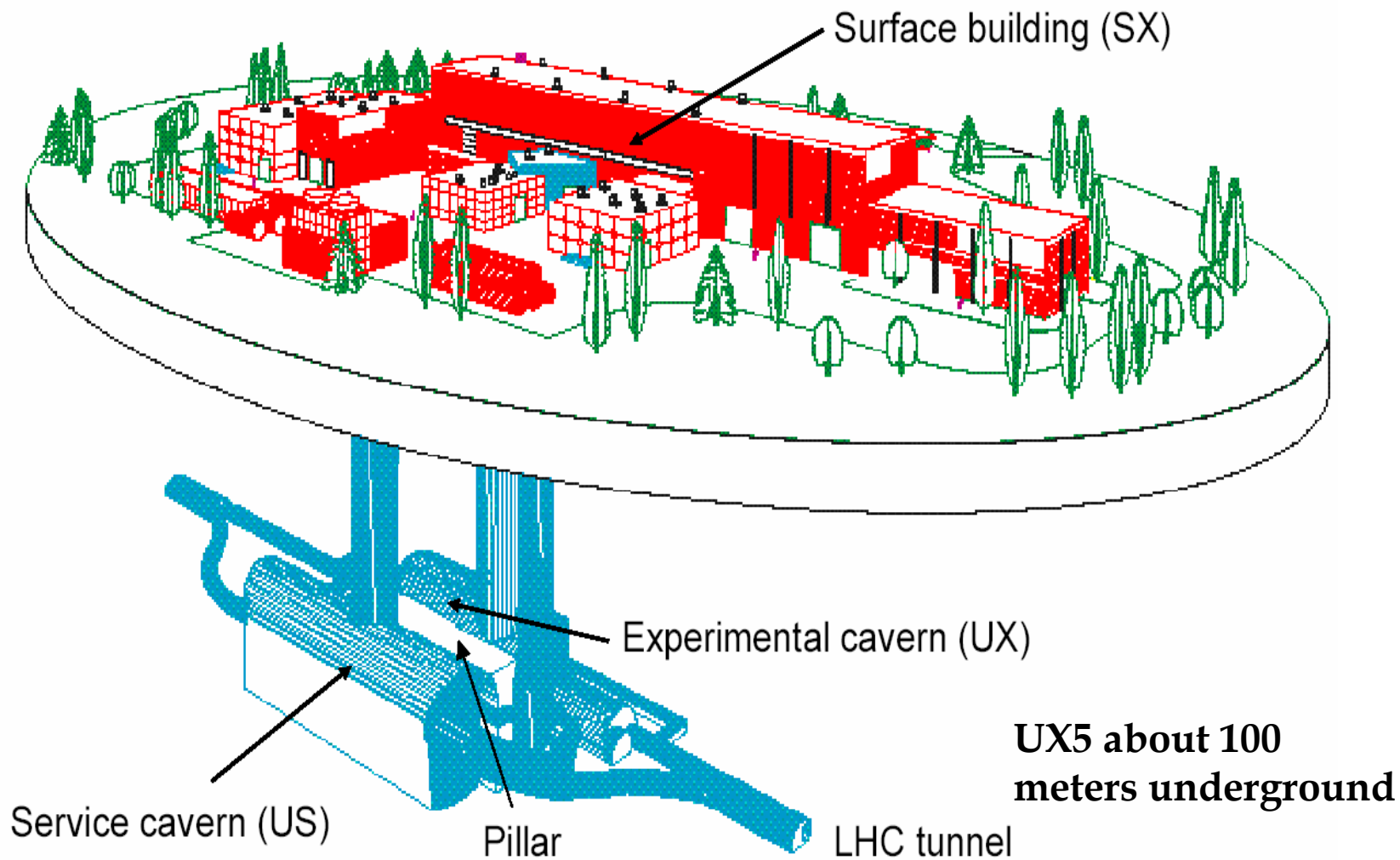
CMS Detector Subsystems

CMS A Compact Solenoidal Detector for LHC





CMS at LHC Point 5





Point 5 (a couple of years ago)





Civ Eng: SX5 and pit-head cover



LHC Point 5 - SX5 Extension - Bouchon Complete - 20 April 2004 - CERN TS-CE

UXC55 Feb 05





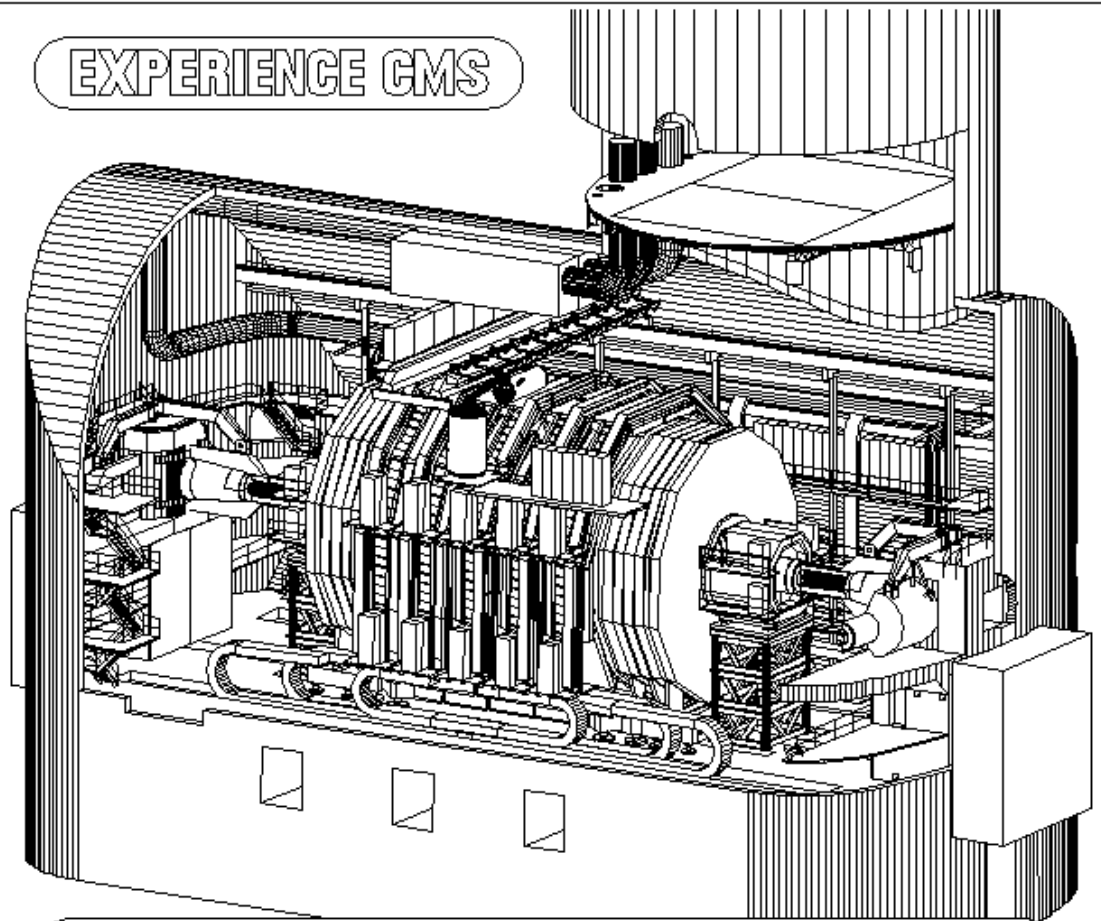
UXC55 Right Now





CMS in UX5

EXPERIENCE CMS



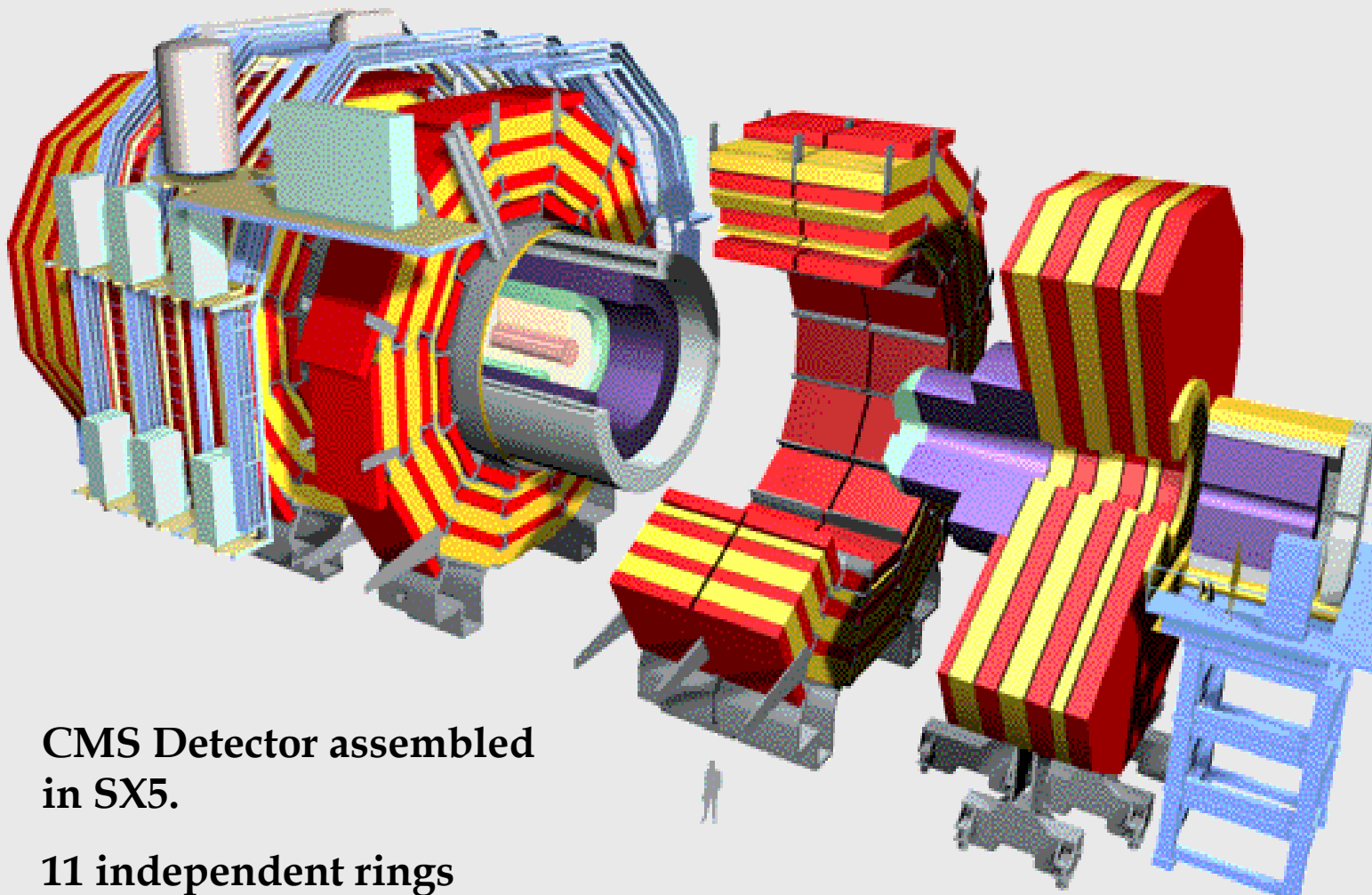
ENSEMBLE DU DETECTEUR DANS UX5

REMOVED BY LE 20 - OCTOBRE - 1997

CM4000B8PL



CMS in the Collision Hall

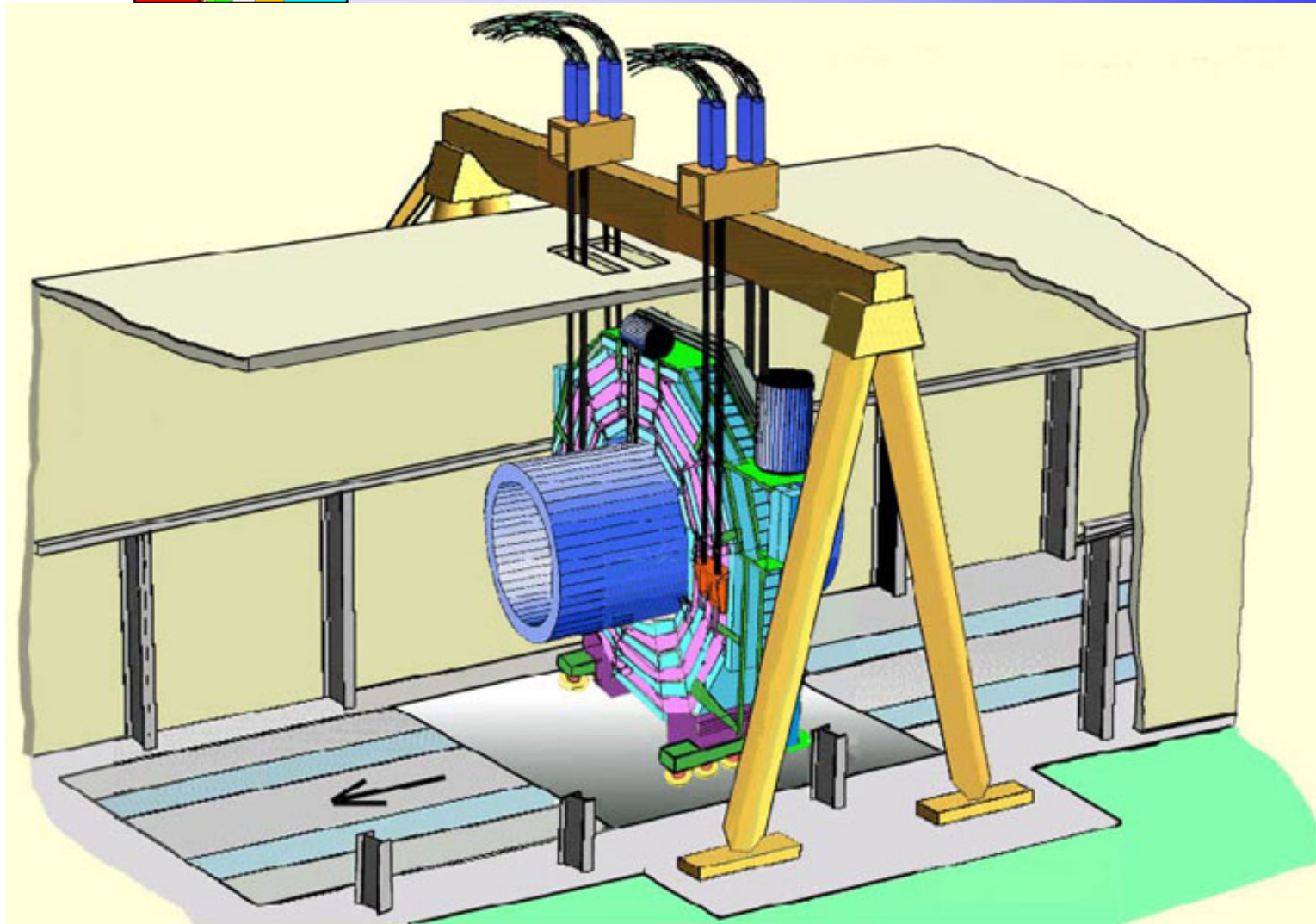


CMS Detector assembled
in SX5.

11 independent rings



Heavy Lowering



Heavy lowering starts Feb 2006. 15 major lifts.



USC 55



**USC 55 for
readout
electronics,
trigger,
voltages,
services.
Accessible
during LHC
operation**



USC55 Ventilation System



Recent view



USC55 Relay Racks



USC55 Beneficial Occupancy (i.e. can install our crates) Feb 2005



SCX5 Control Room and Computer Farm



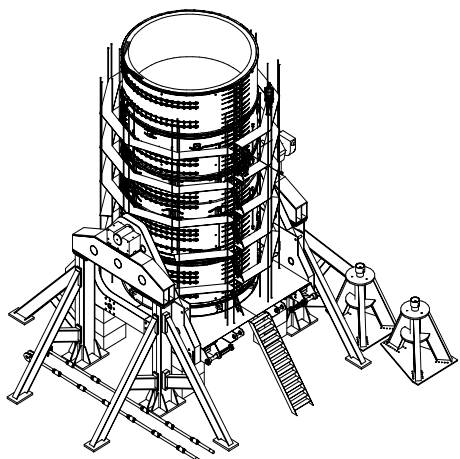


SCX5 Control Room

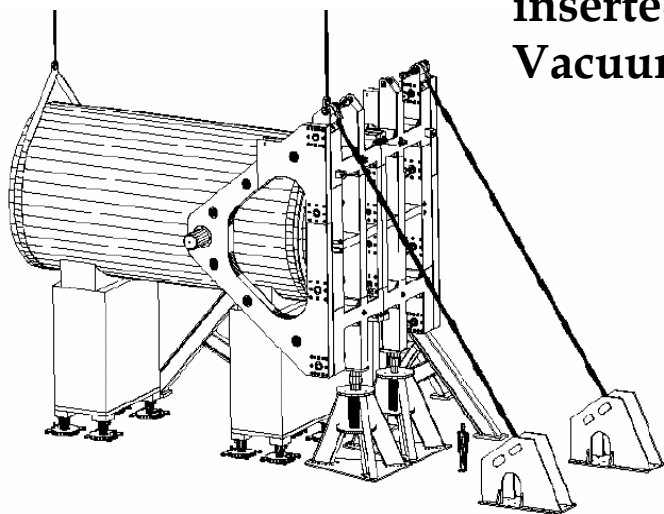




Magnet Coil Complete



Magnet coil built vertically



Rotated and inserted into outer Vacuum tank

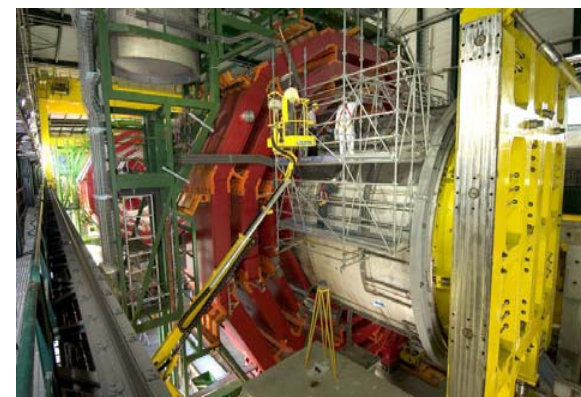


Yoke and Vacuum Tank





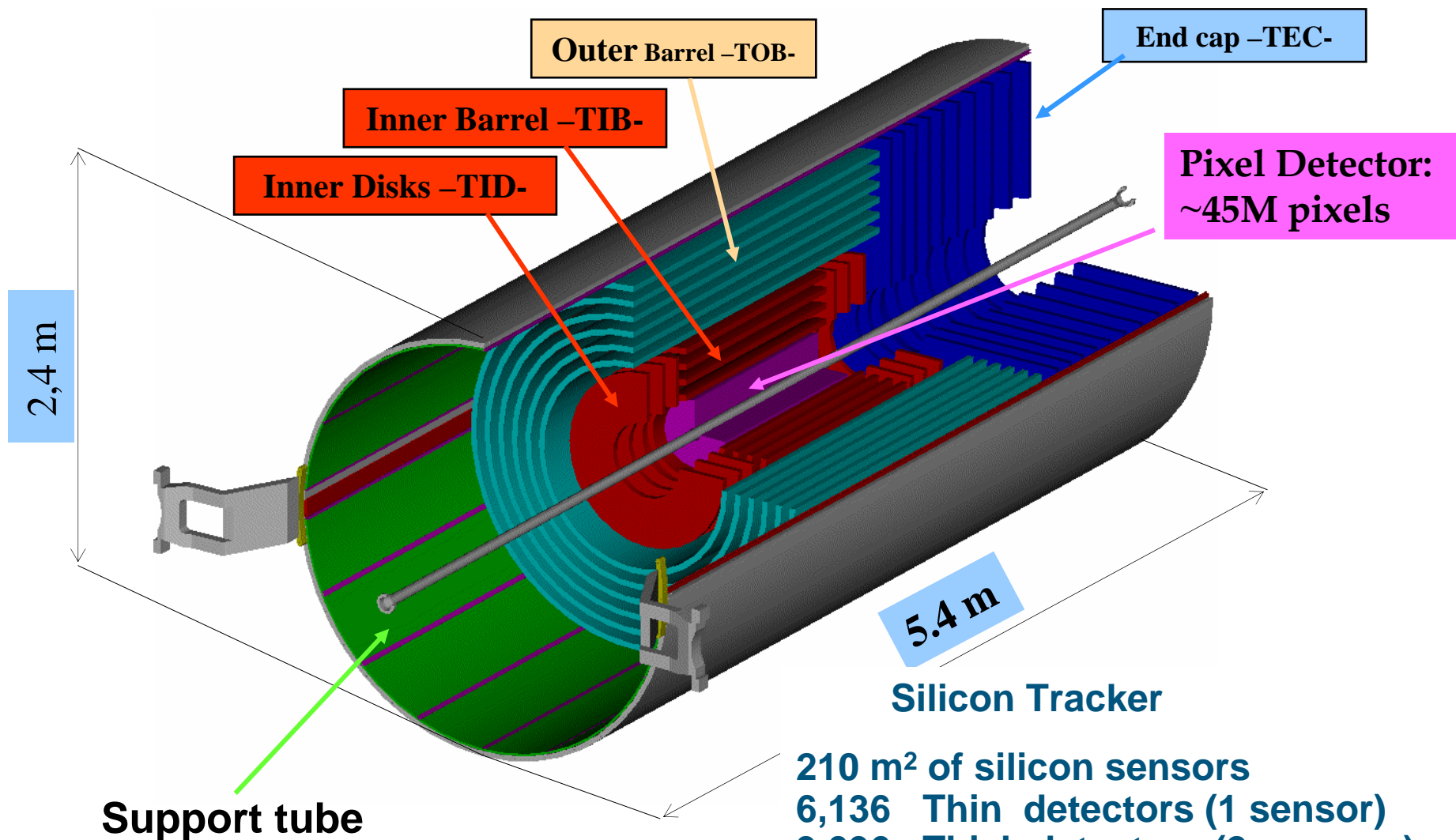
Coil Swiveling and Insertion



Happened in early September



CMS Tracker



210 m² of silicon sensors
6,136 Thin detectors (1 sensor)
9,096 Thick detectors (2 sensors)
10M channels



Tracker Inner Radius: Pixel Detector (44M Channels)

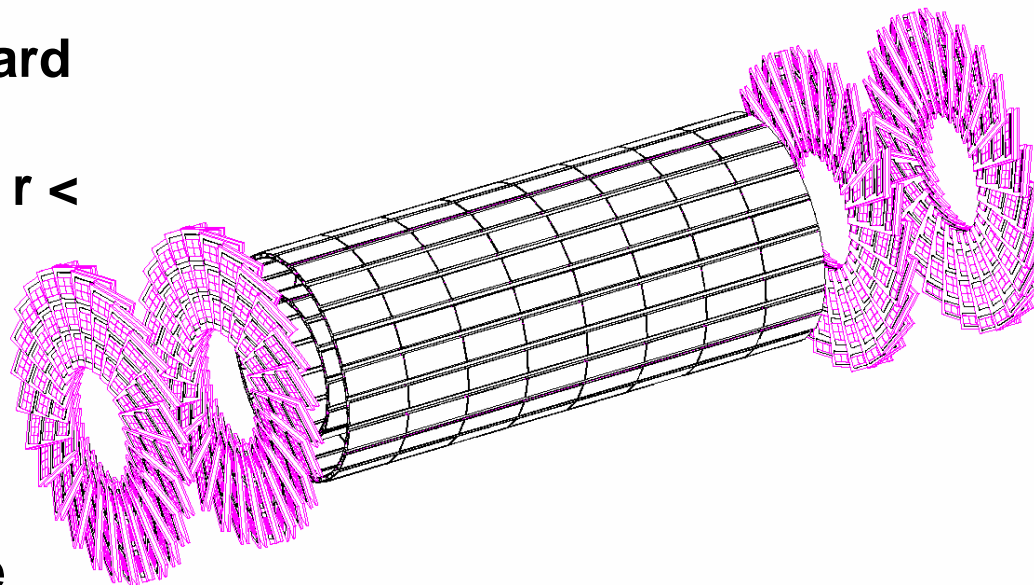
3 barrel layers

- $r = 4.1 - 4.6$ cm, $7.0 - 7.6$ cm, $9.9 - 10.4$ cm
- $\sim 32 \times 10^6$ pixels

2 pairs of Forward/Backward disks

- Radial coverage $6 < r < 15$ cm
- Average z position: 34.5 cm, 46.5 cm
- Per Disk: $\sim 3 \times 10^6$ pixels

⇒ 3 high resolution space points for $\eta < 2.2$



Pixel size: 150 mm x 100 mm driven by FE

Hit resolution:

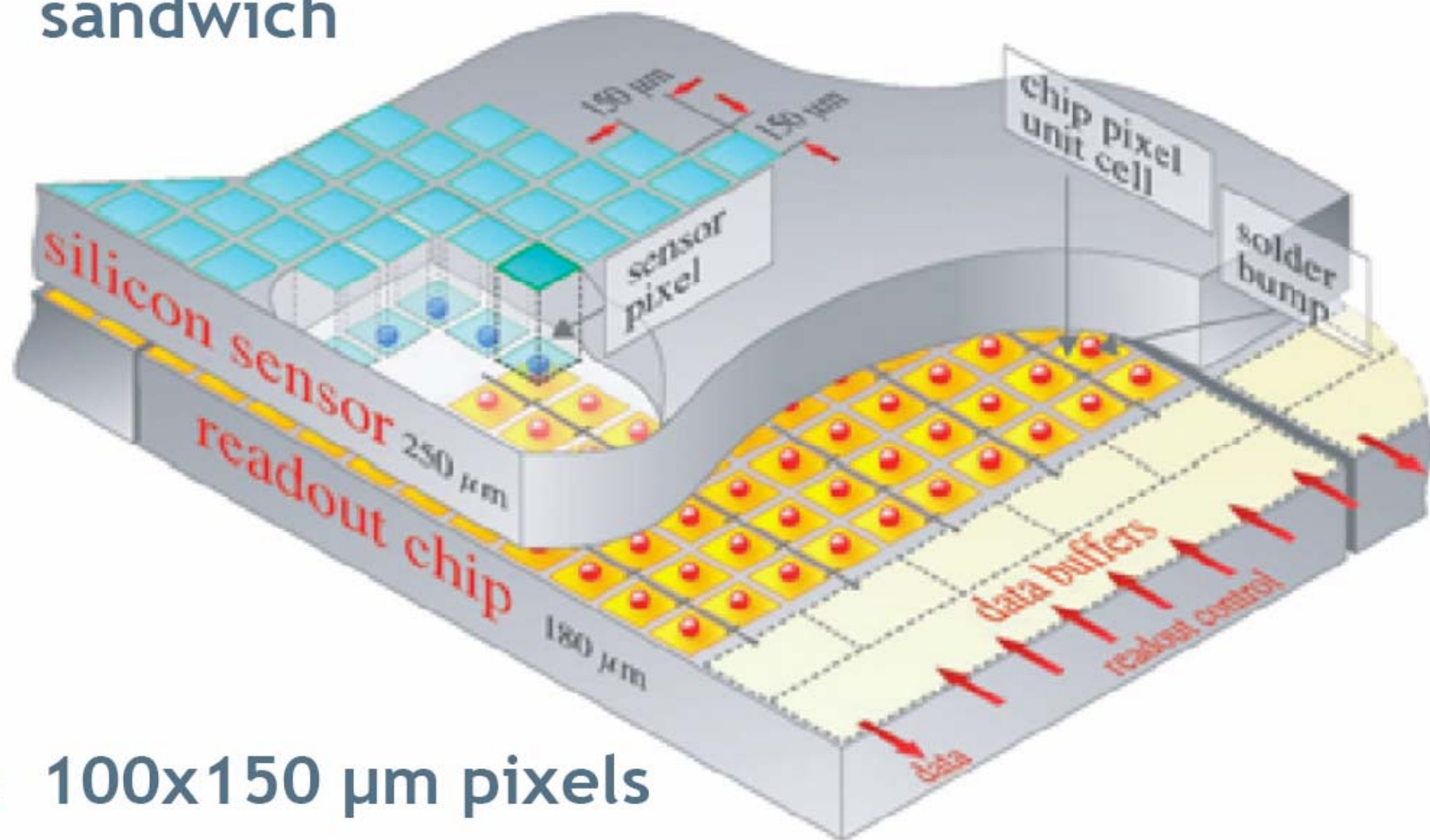
$r-\phi \sigma \sim 10 \mu\text{m}$

$r-z \sigma \sim 17 \mu\text{m}$



Sensor Construction

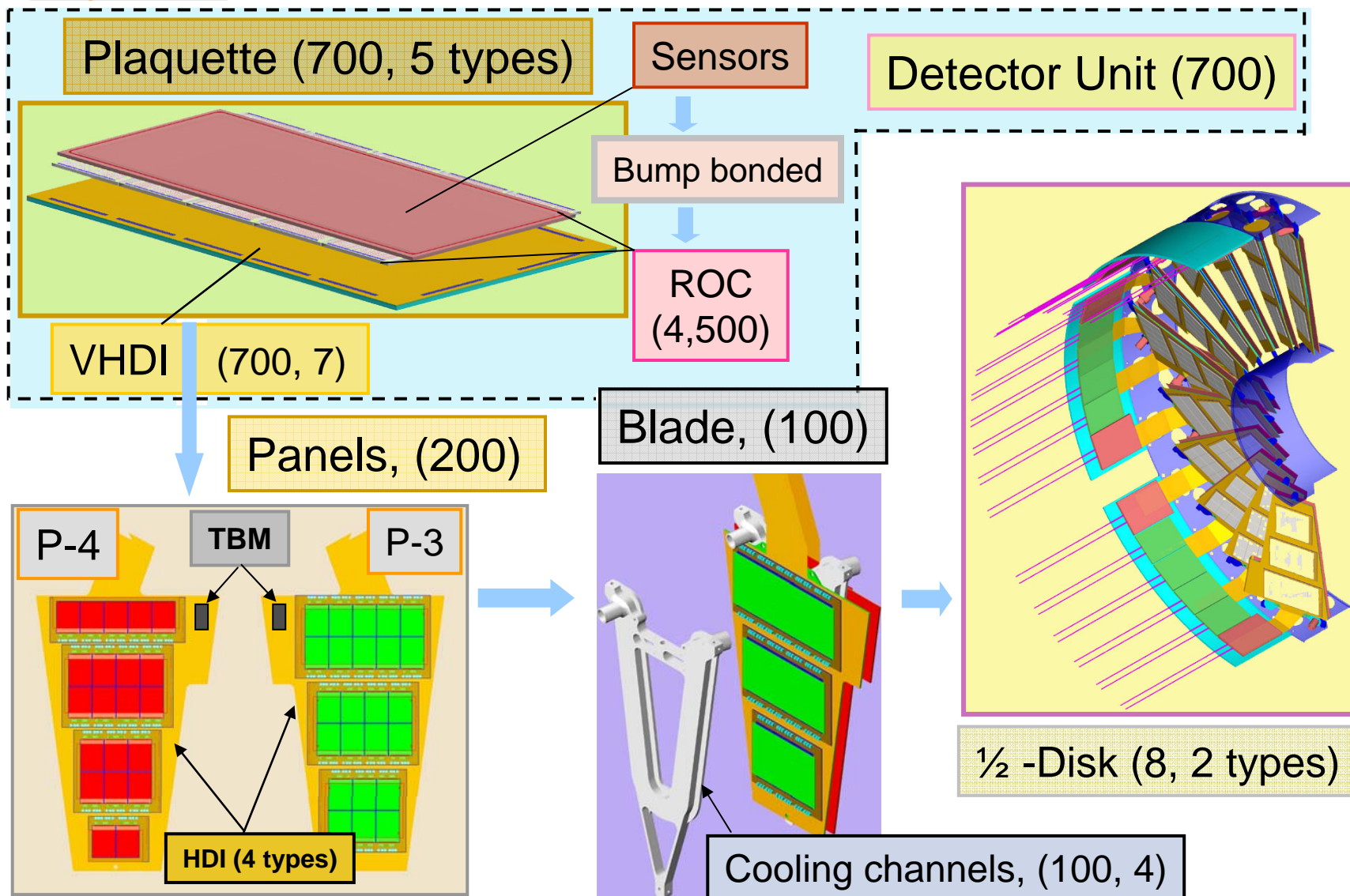
- ▶ bump-bonded sensor/readout chip sandwich



- ▶ 100x150 μm pixels



Components of Forward Pix



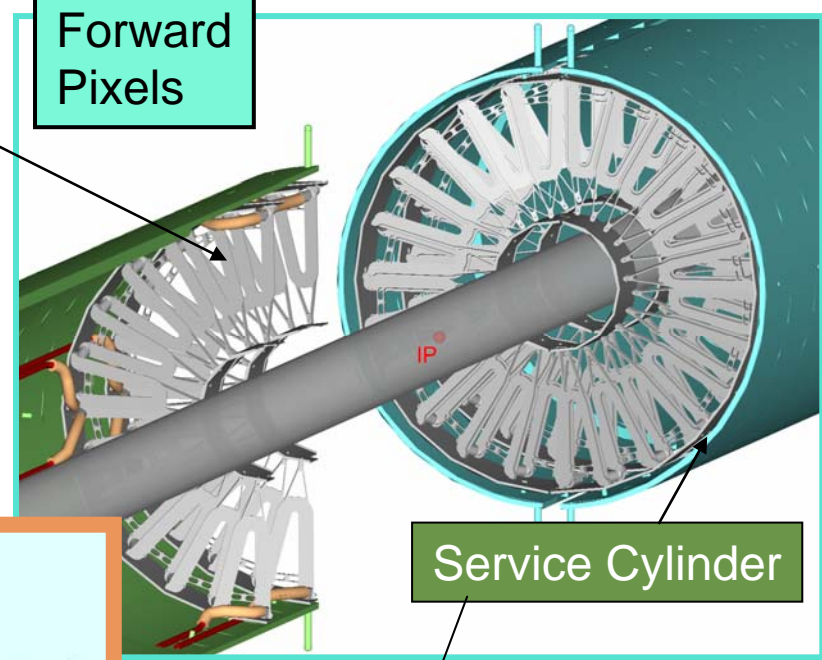
D:\cmelaga\www\6_assembly\blade.r.ppt



Forward Pixel Mechanics and Cooling

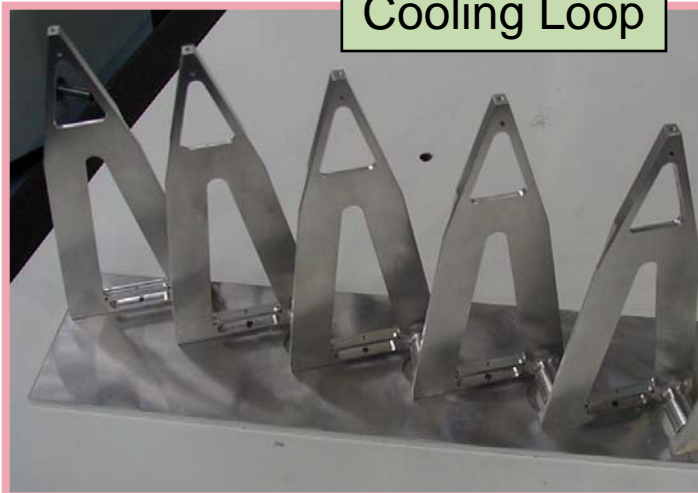


1/2 -Disks

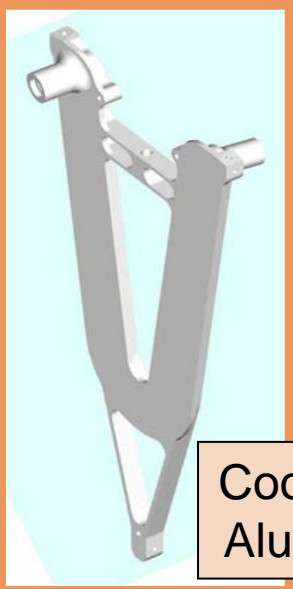


Forward Pixels

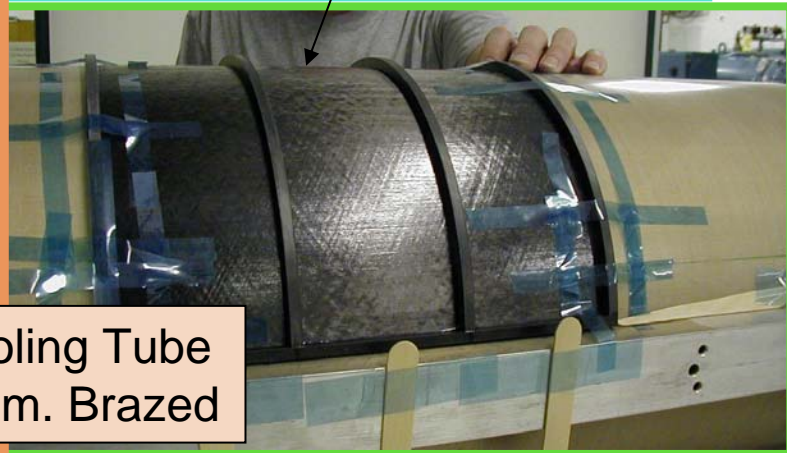
Service Cylinder



Prototype Cooling Loop



Cooling Tube Alum. Brazed





Forward pixel Detector (mockup with 3 disks)





The CMS Silicon Strip Tracker

Outer Barrel (TOB): 6 layers

- Thick sensors (500 μm)
- Long strips

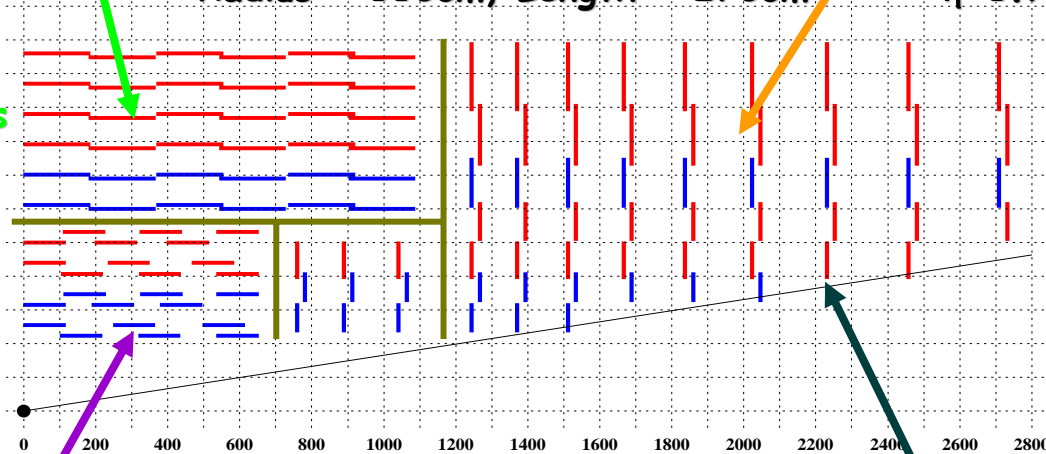
Endcap (TEC): 9 Disk pairs

- $r < 60$ cm thin sensors
- $r > 60$ cm thick sensors

Radius ~ 110 cm, Length ~ 270 cm $\eta \sim 1.7$

6 layers TOB

4 layers TIB



3 disks TID

9 disks TEC

Inner Disks (TIB): 3 Disk pairs

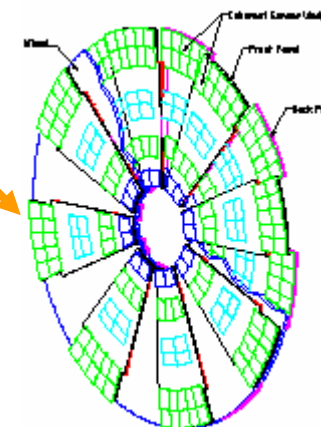
- Thin sensors

Inner Barrel (TIB): 4 layers

- Thin sensors (320 μm)
- Short strips

Strip length ranges from 10 cm in the inner layers to 20 cm in the outer layers.

Pitch ranges from 80 μm in the inner layers to near 200 μm in the outer layers



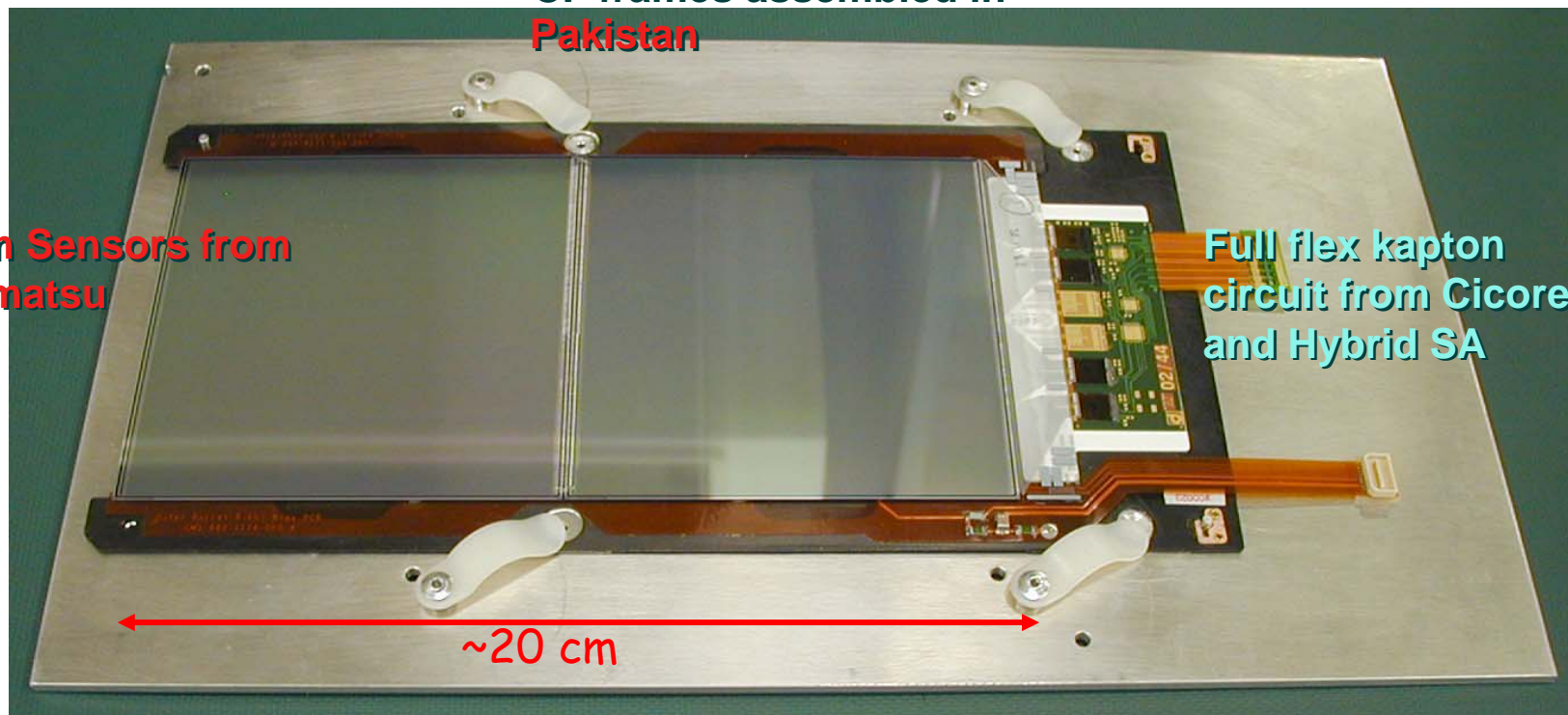


TOB Modules

CF frames assembled in
Pakistan

500 μm Sensors from
Hamamatsu

Full flex kapton
circuit from Cicorel
and Hybrid SA



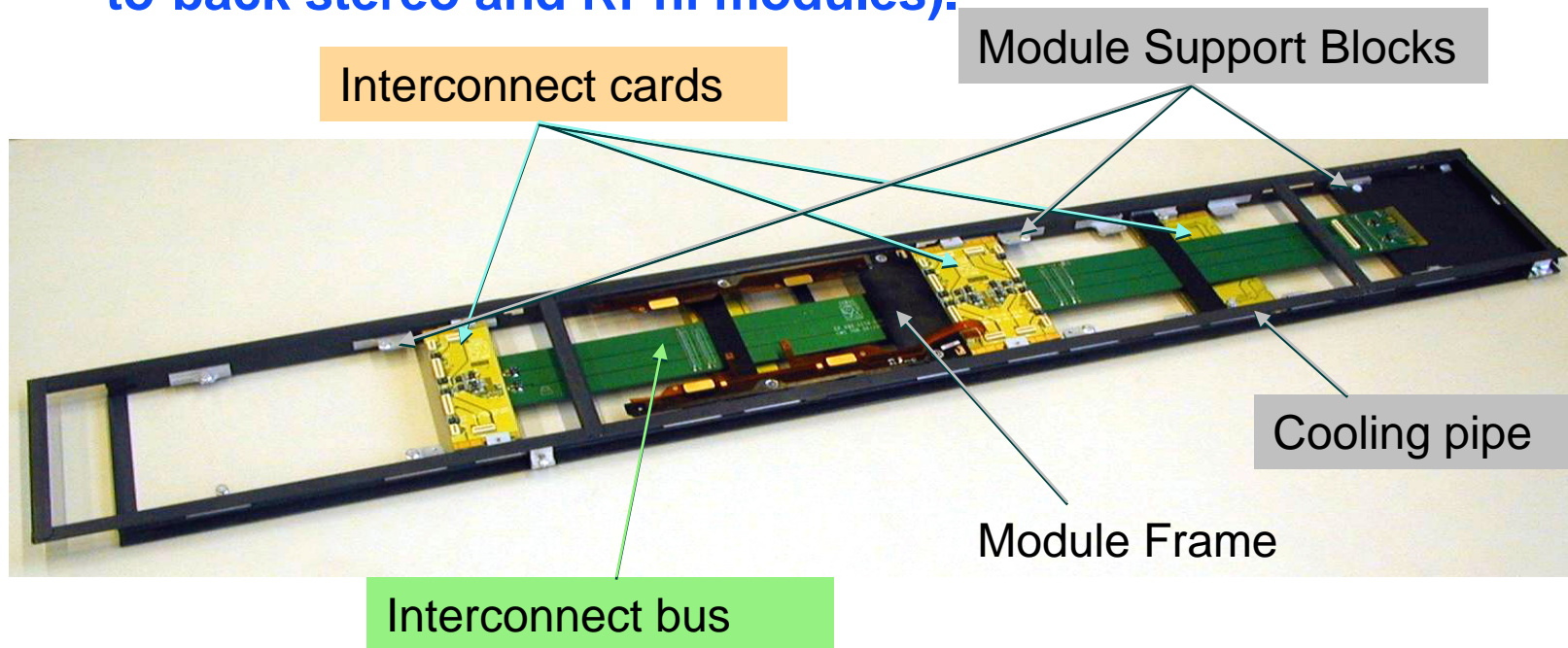
~5,600 Tracker Outer Barrel (TOB) modules

- To be assembled and tested at FNAL & UCSB



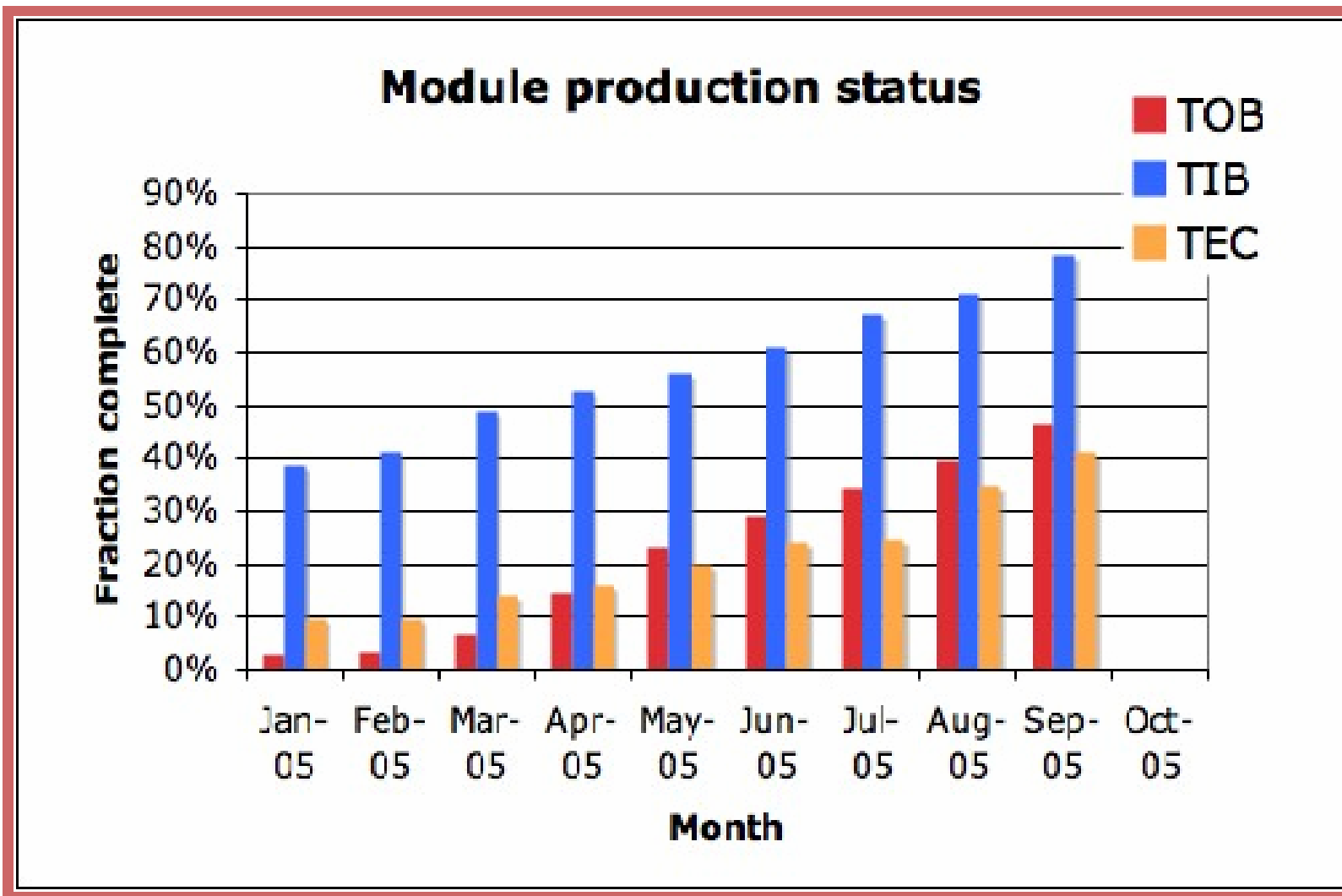
TOB Rods

- Rod assembly will be done in the SiDet Lab C clean room.
- We receive rods with interconnect buses and interconnect cards from CERN.
- A rod consists of 6 modules (12 for “double-sided” = back-to-back stereo and RPhi modules).



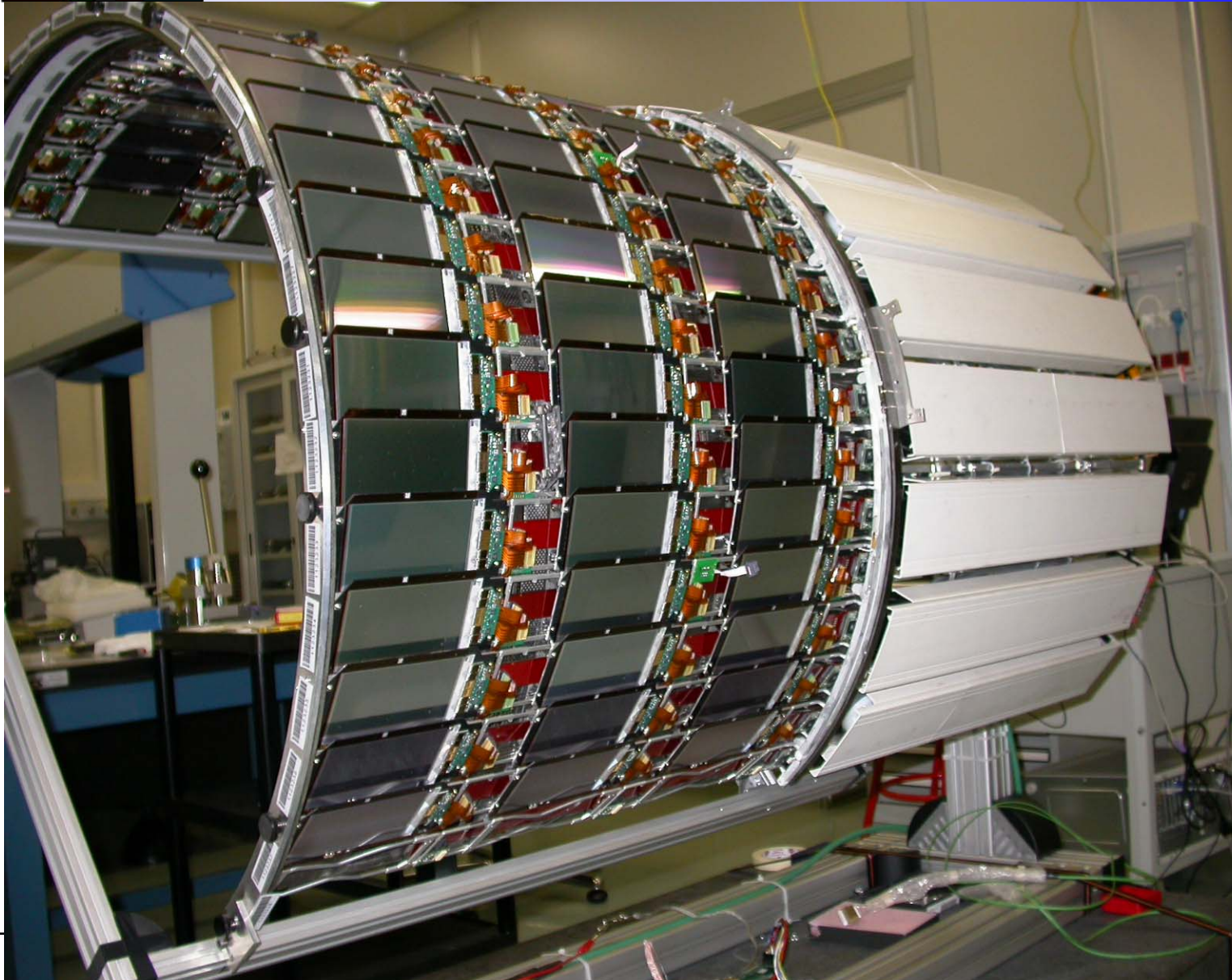


SiTrk Production Status



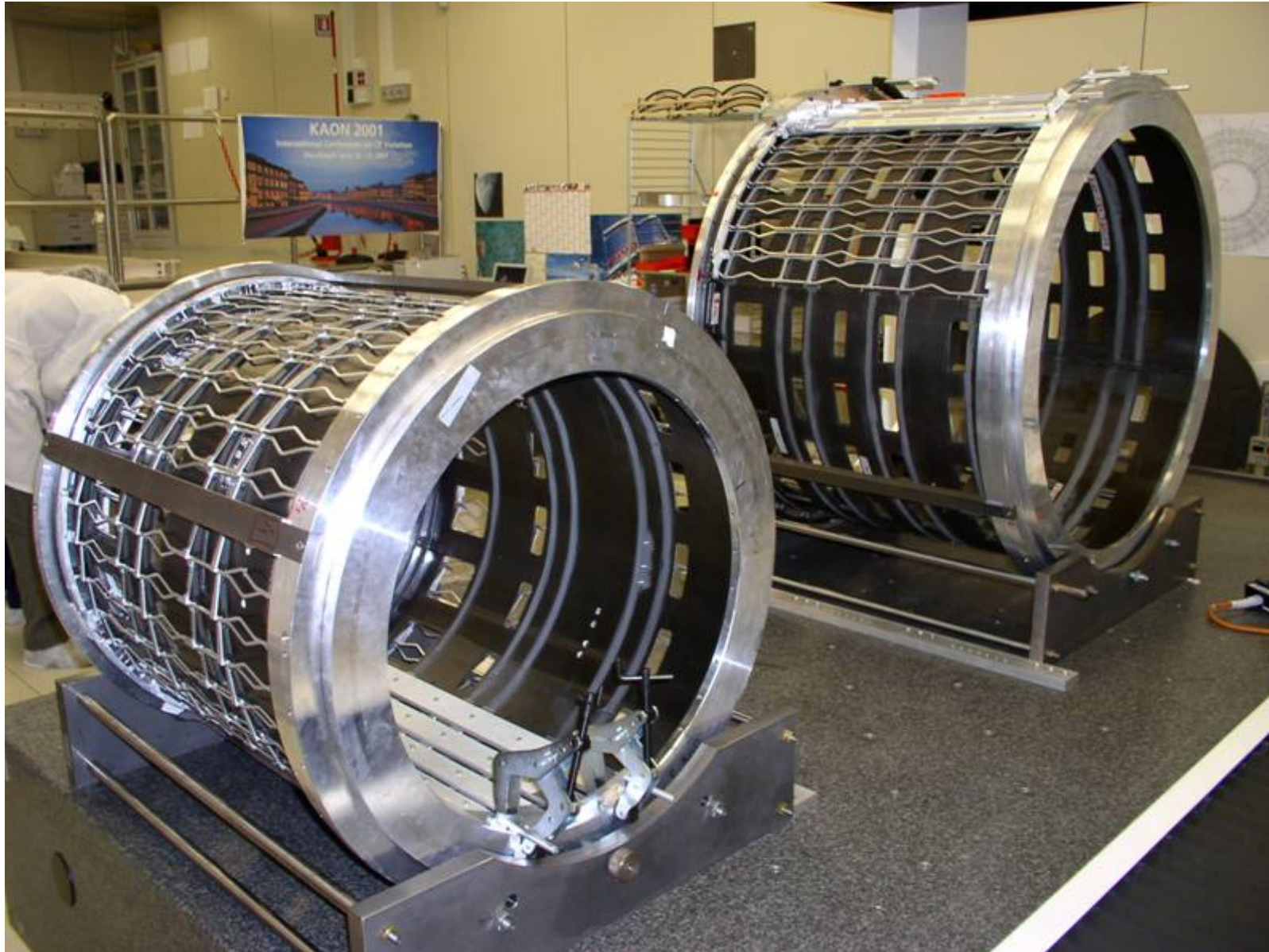


TIB Layer 3 at Florence





TIB Layers 2, 4 at Pisa





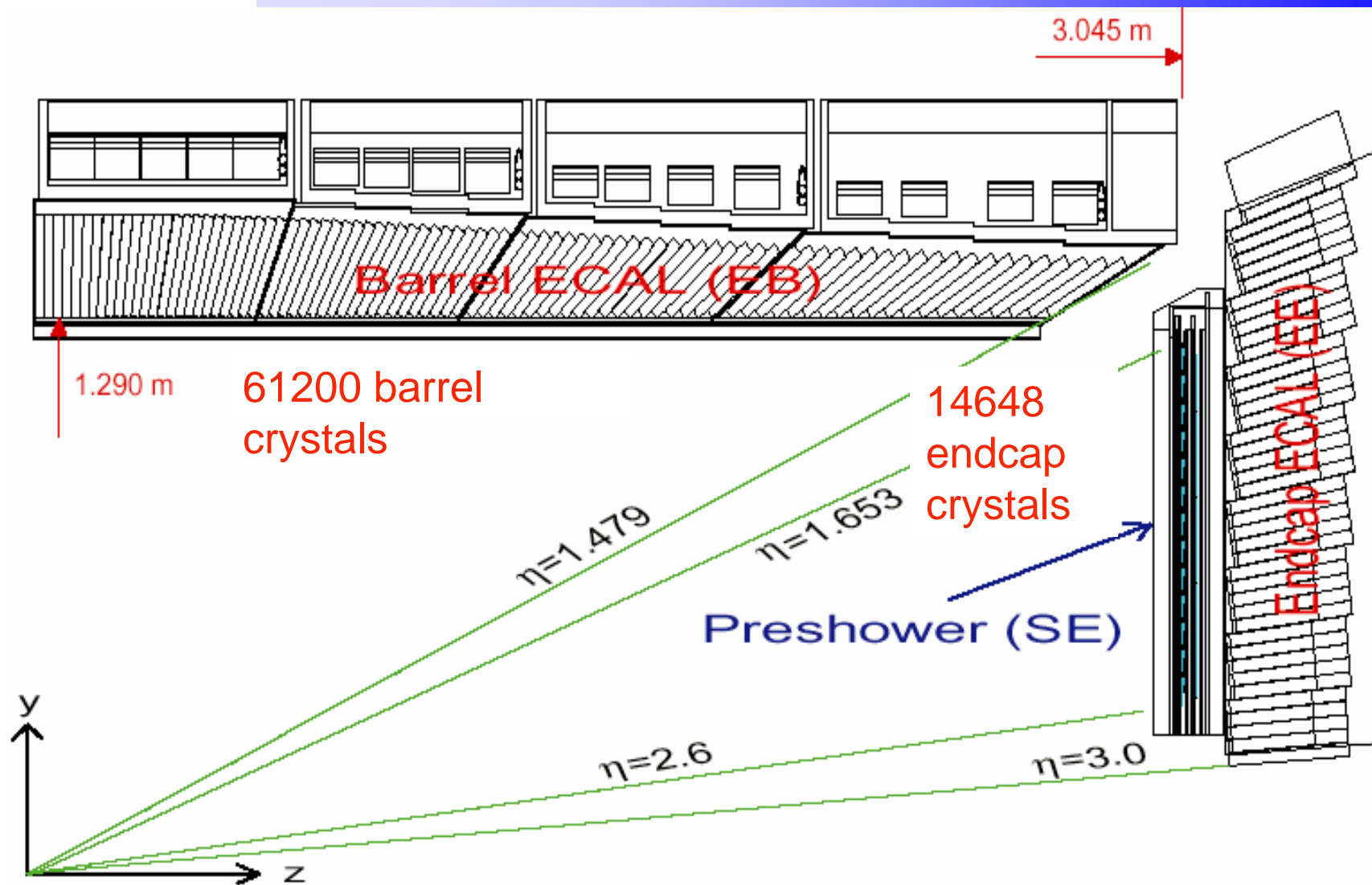
TOB Mechanical Structure

**TOB Structure
is now complete
at CERN**



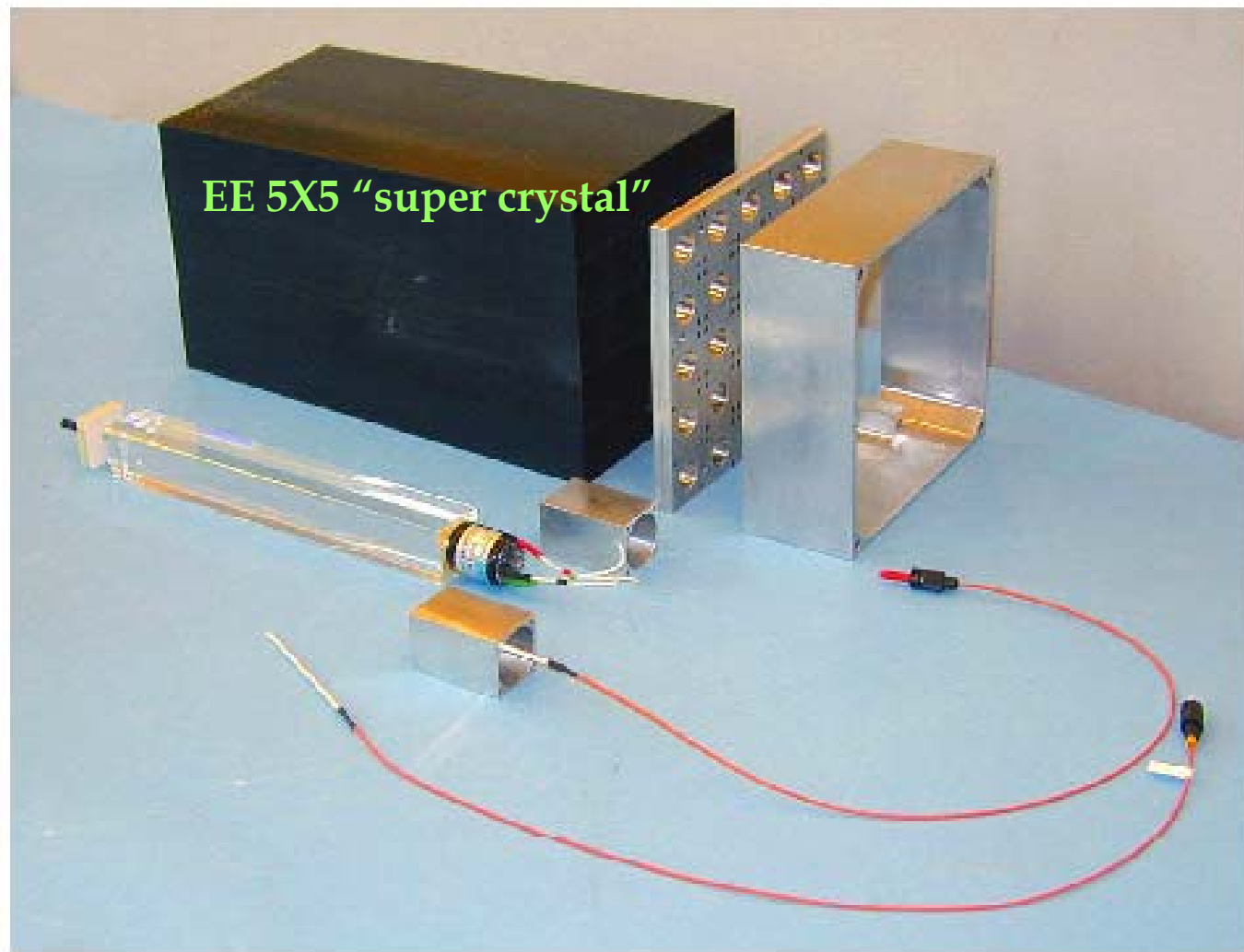


ECAL



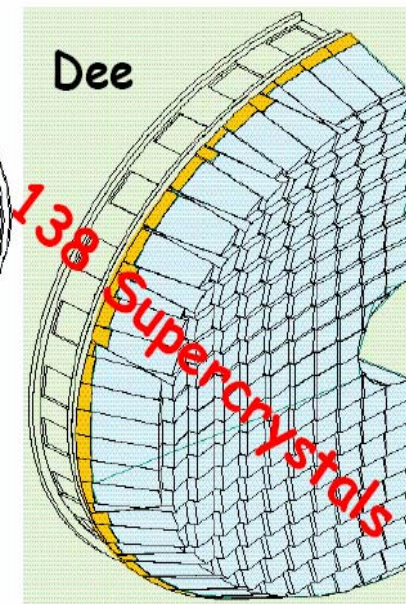
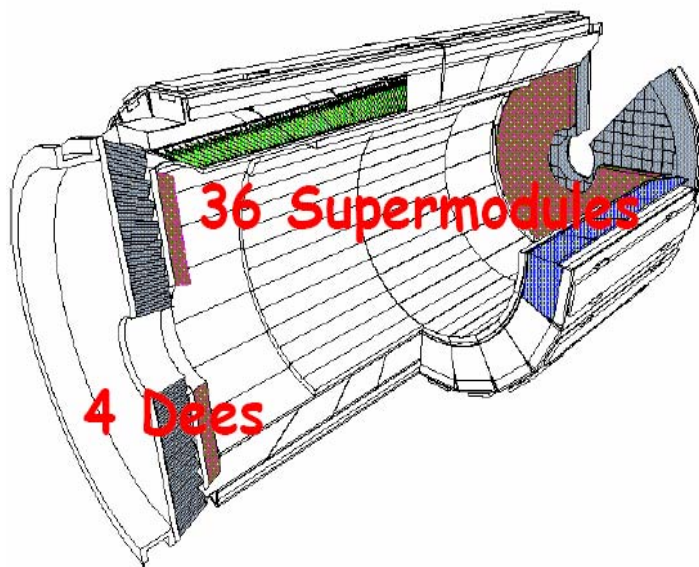
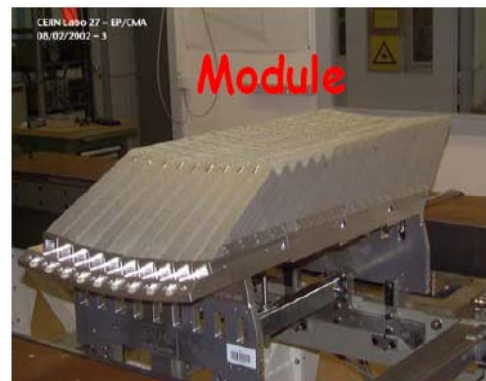


PbWO₄ Crystals for ECAL





ECAL



Barrel
61,200 PbWO_4 crystals
Readout with 122,400
APD's
Endcap
14684 crystals readout
with VPT's.

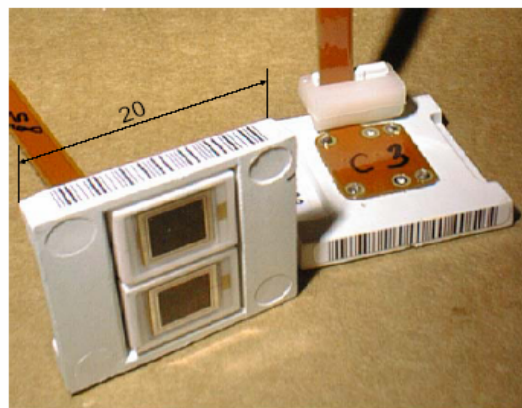


ECAL Optical Readout

4T B-field precludes use of PMT's..

Avalanche photodiodes in barrel.

*Two $5 \times 5 \text{ mm}^2$ APD's/crystal.
Gain – 50.
QE – 80% @ 420 nm.
Temp sensitivity – $-2.4\%/^{\circ}\text{C}$.*



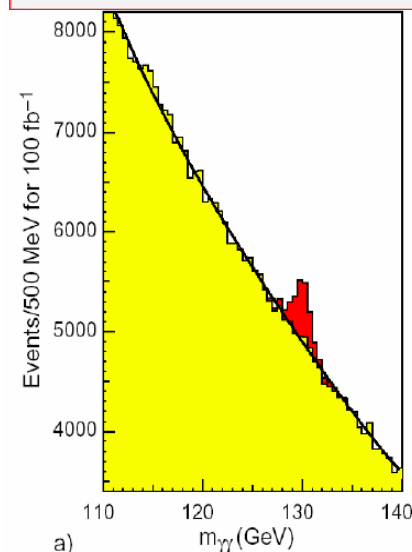
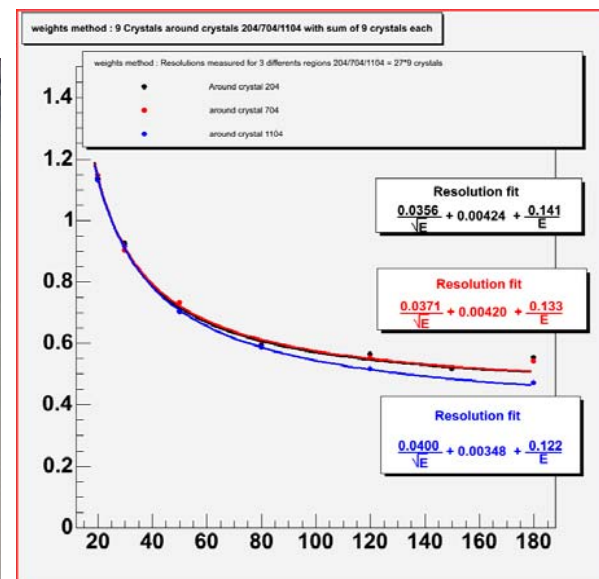
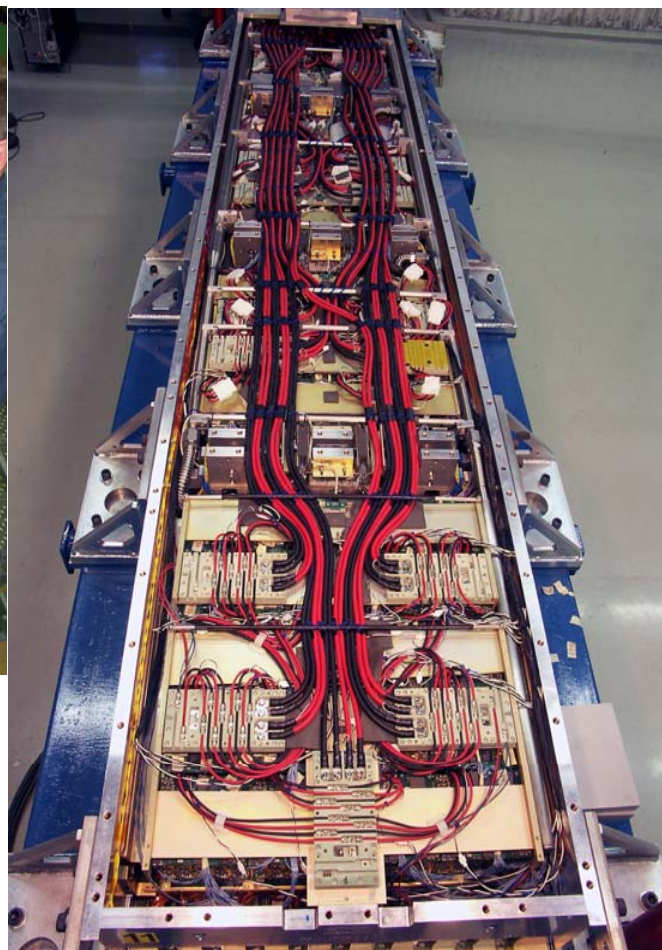
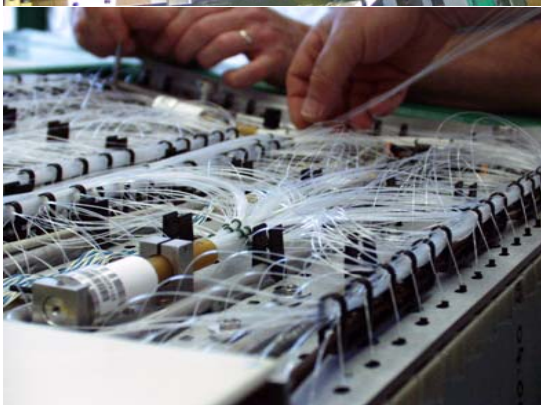
Vacuum Phototriodes in Endcap

*Gain – 10.
QE – 15% @ 420 nm.
Rad tolerance - $<10\%$ at 20 kGy.
Operates in high B – field.*





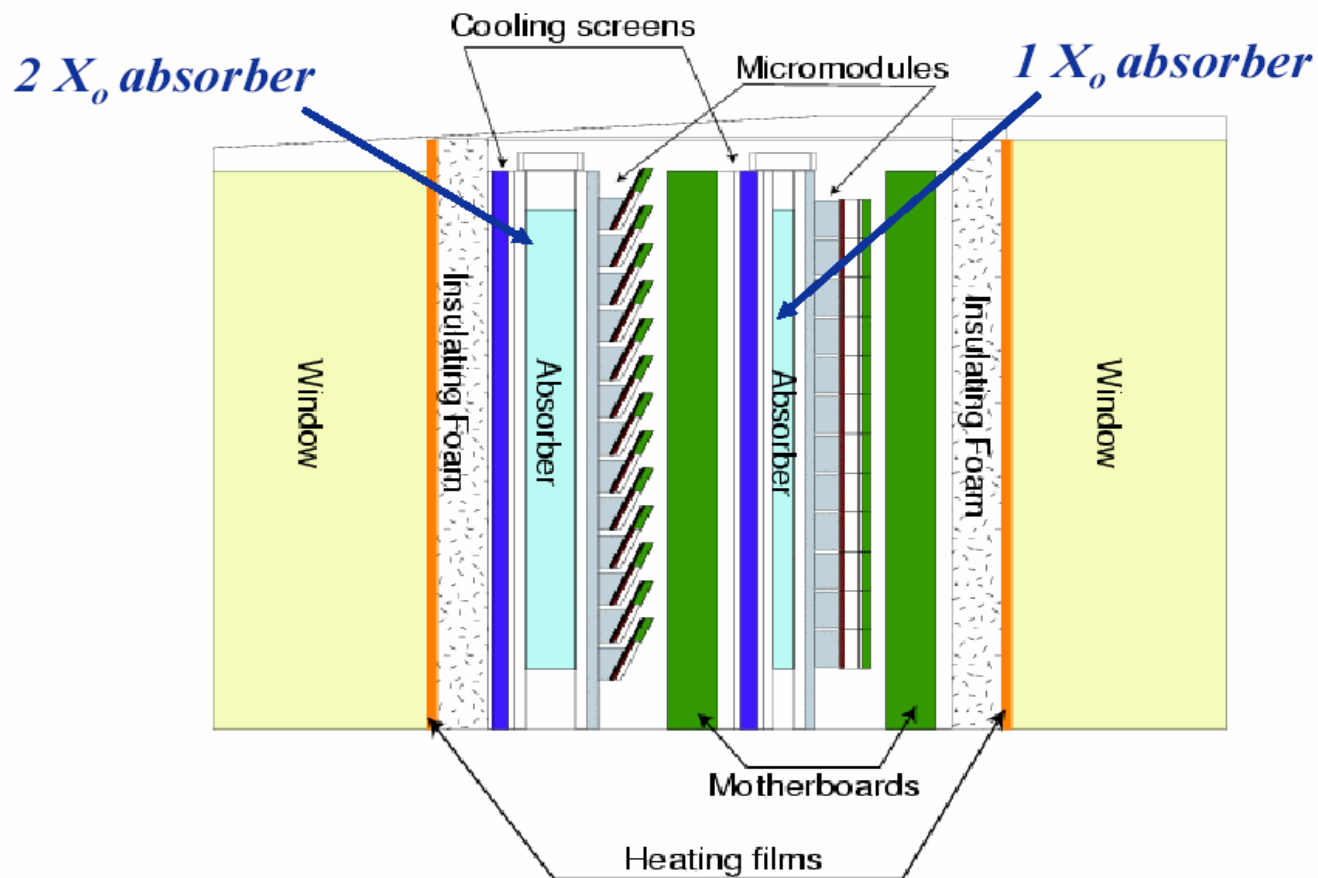
The first Crystal Supermodule tested in the beam





EndCap Preshower Detector

Two-layer silicon preshower detector placed in front of the endcap calorimeters

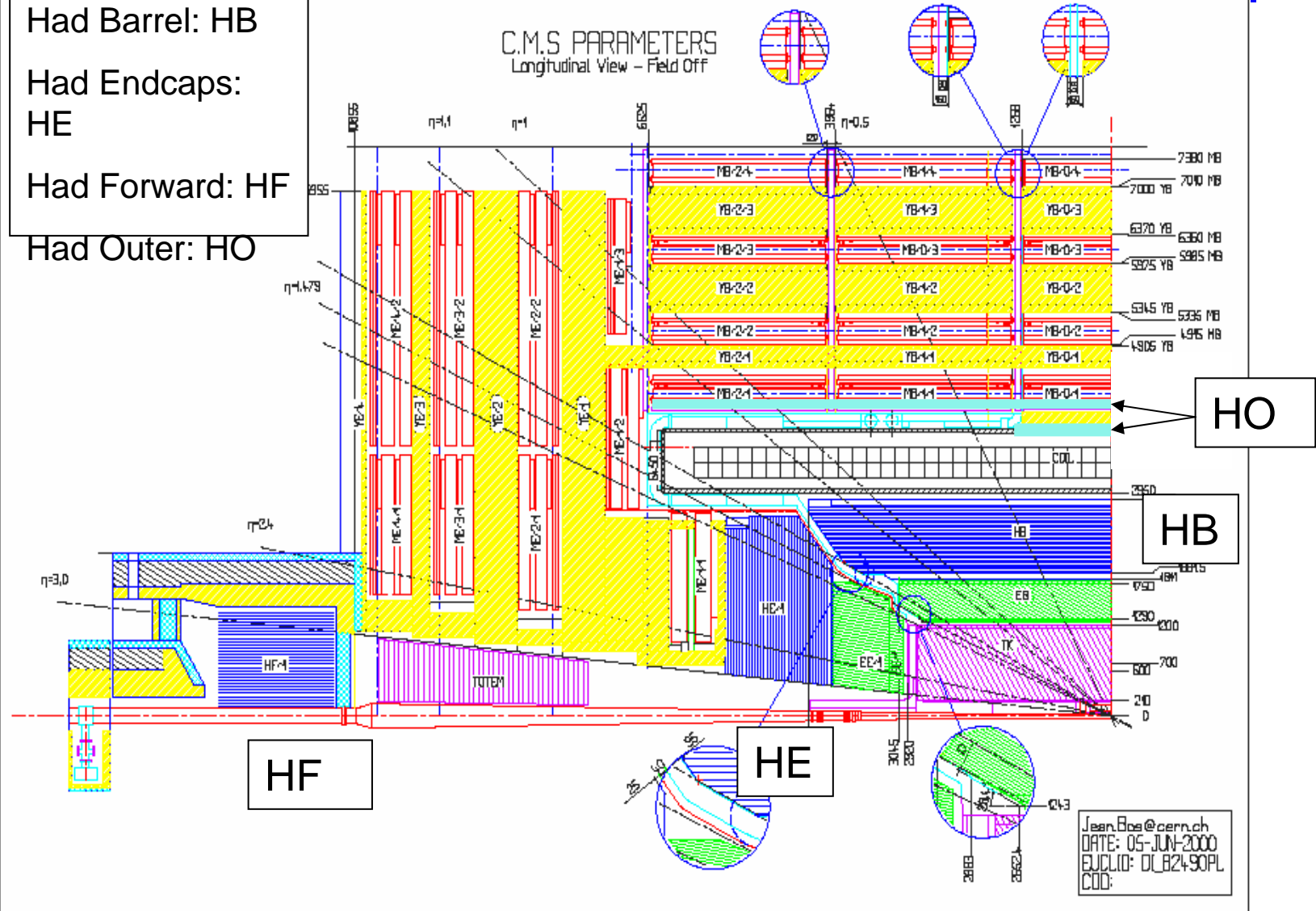


2mm silicon strips to separate γ 's from π^0 's and for vertex identification.



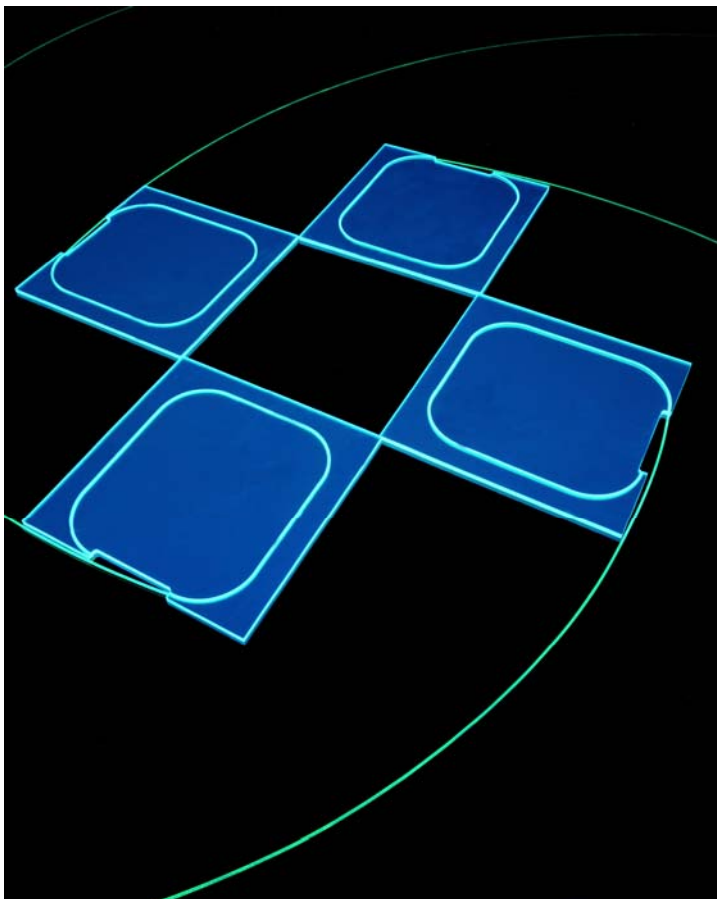
HCAL

- Had Barrel: HB
- Had Endcaps: HE
- Had Forward: HF
- Had Outer: HO





Central Hadron Calorimeter HB, HE, HO



**Scintillator +
Wavelength
Shifter Readout**



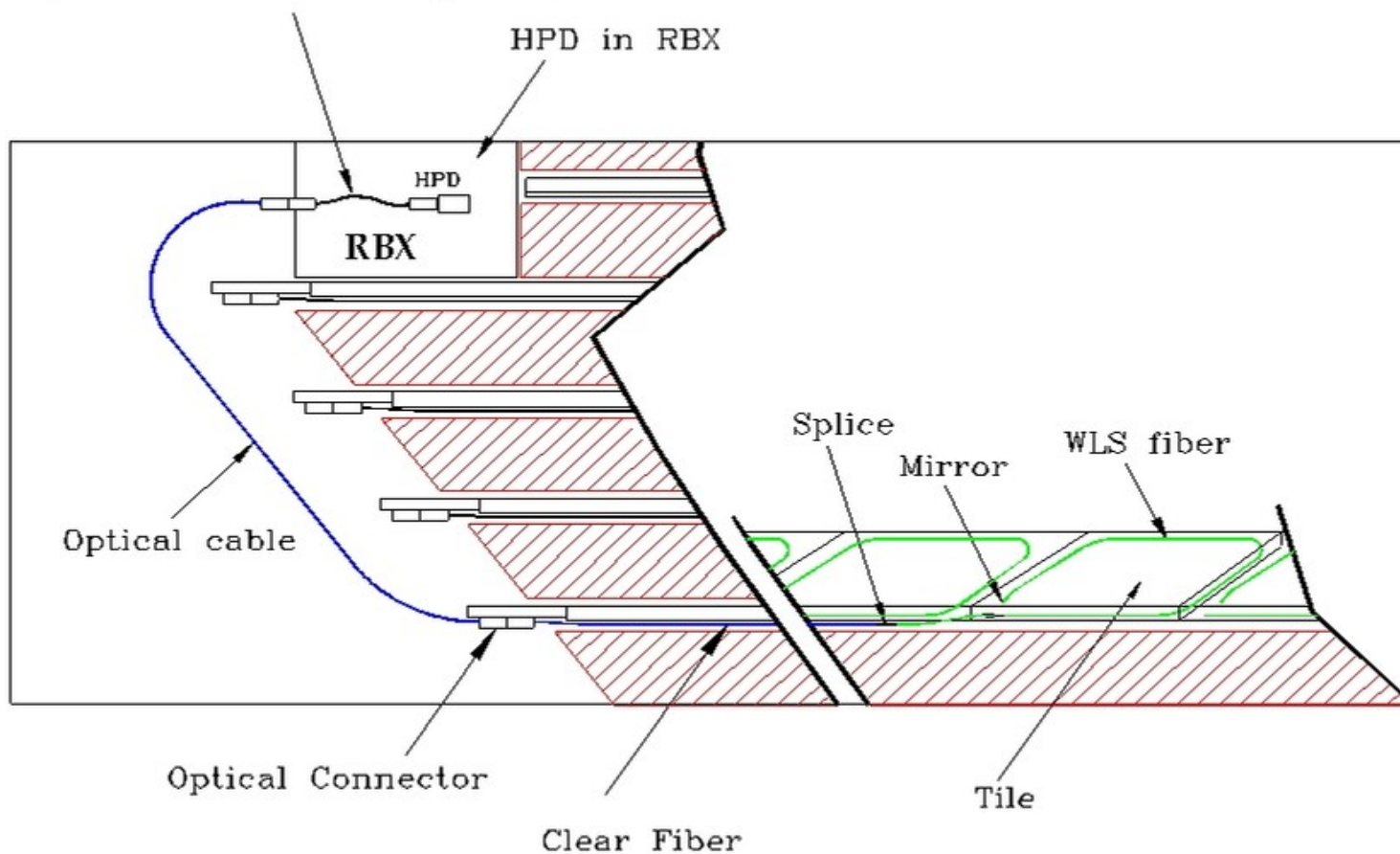
**Inserting scintillator into HB
wedge**



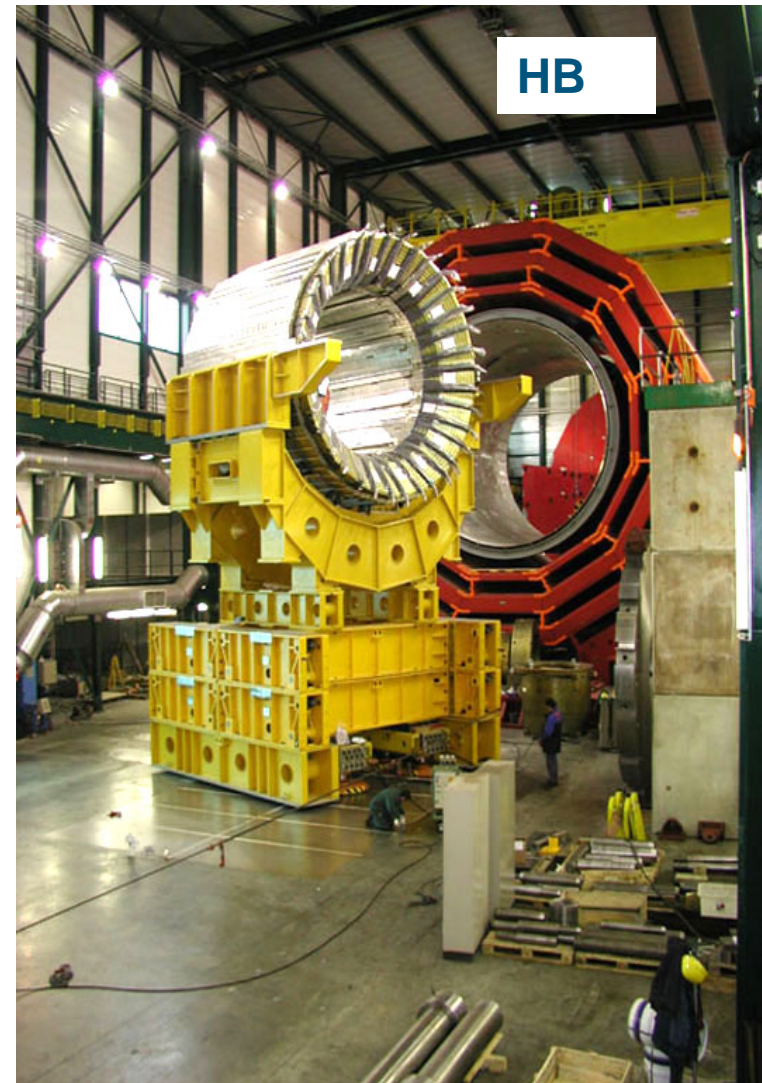
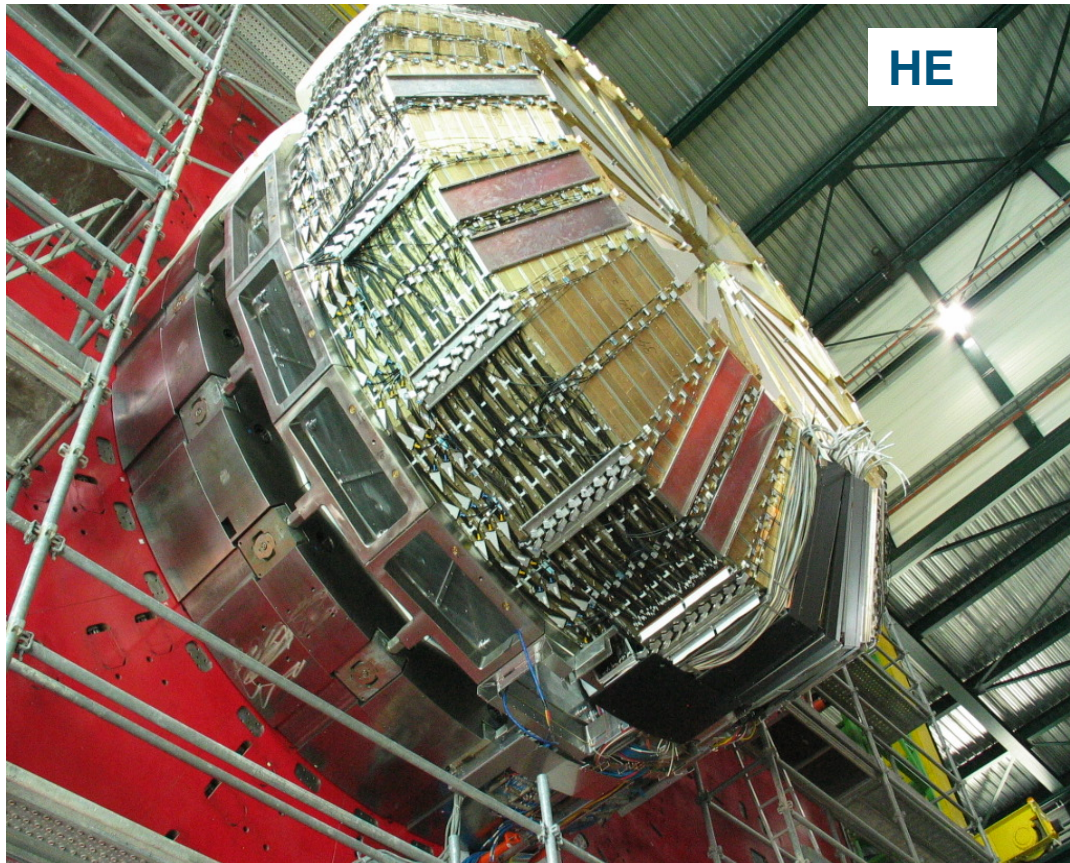
Optical Design for HCAL

Common Technology for HB, HE, HO

Layer to Tower Decoding Fiber

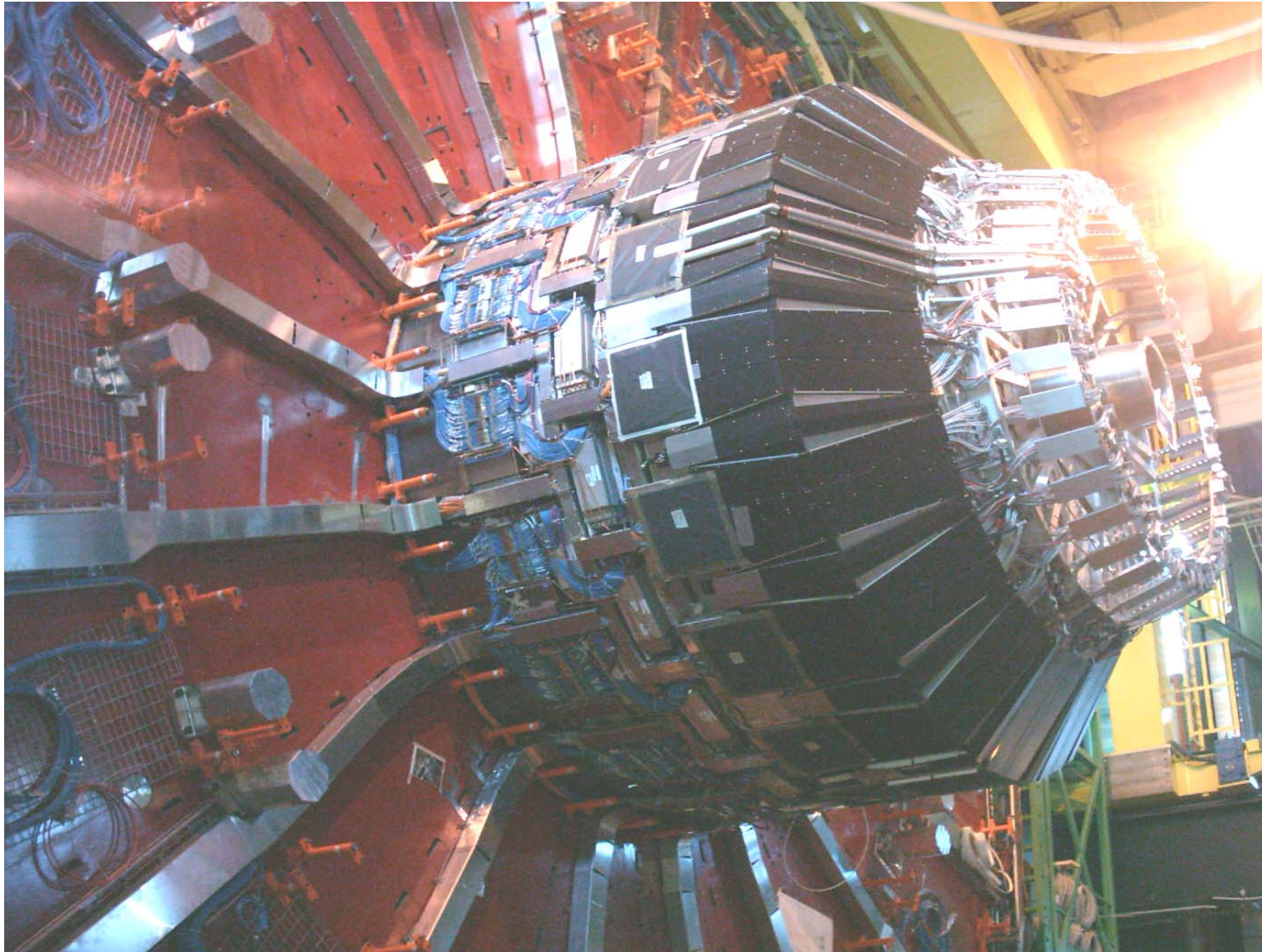


HCAL-Absorbers Complete



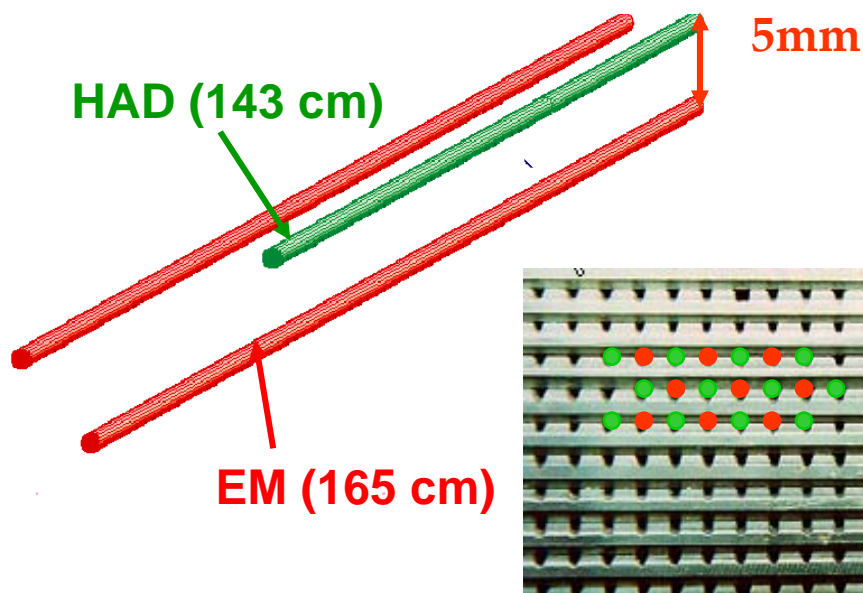


HE Right Now





Forward Hadron Calorimeter: HF



To cope with high radiation levels (>1 Grad accumulated in 10 years) the active part is Quartz fibers: the energy measured through the Cerenkov light generated by shower particles.

ETA	RADIUS		
2.866	1300.0		
2.918	1234.2	1 *	14 *
2.976	1162.0		
3.064	1065.4	2 *	15 *
3.152	975.0		
3.240	893.3	3	16
3.327	818.0		
3.503	686.0	4	17
3.677	576.0	5	18
3.853	483.0	6	19
4.027	406.0	7	20
4.204	340.0	8	21
4.377	286.0	9	22
4.552	240.0	10	23
4.730	201.0	11	24
4.903	169.0	12	
5.205	125.0	13	

Iron calorimeter
Covers $5 > \eta > 3$
Total of 1728 towers, i.e.
2 x 432 towers for EM and HAD
 $\eta \times \phi$ segmentation (0.175 x 0.175)



HF Status

HF are first Items to be lowered in May 2006

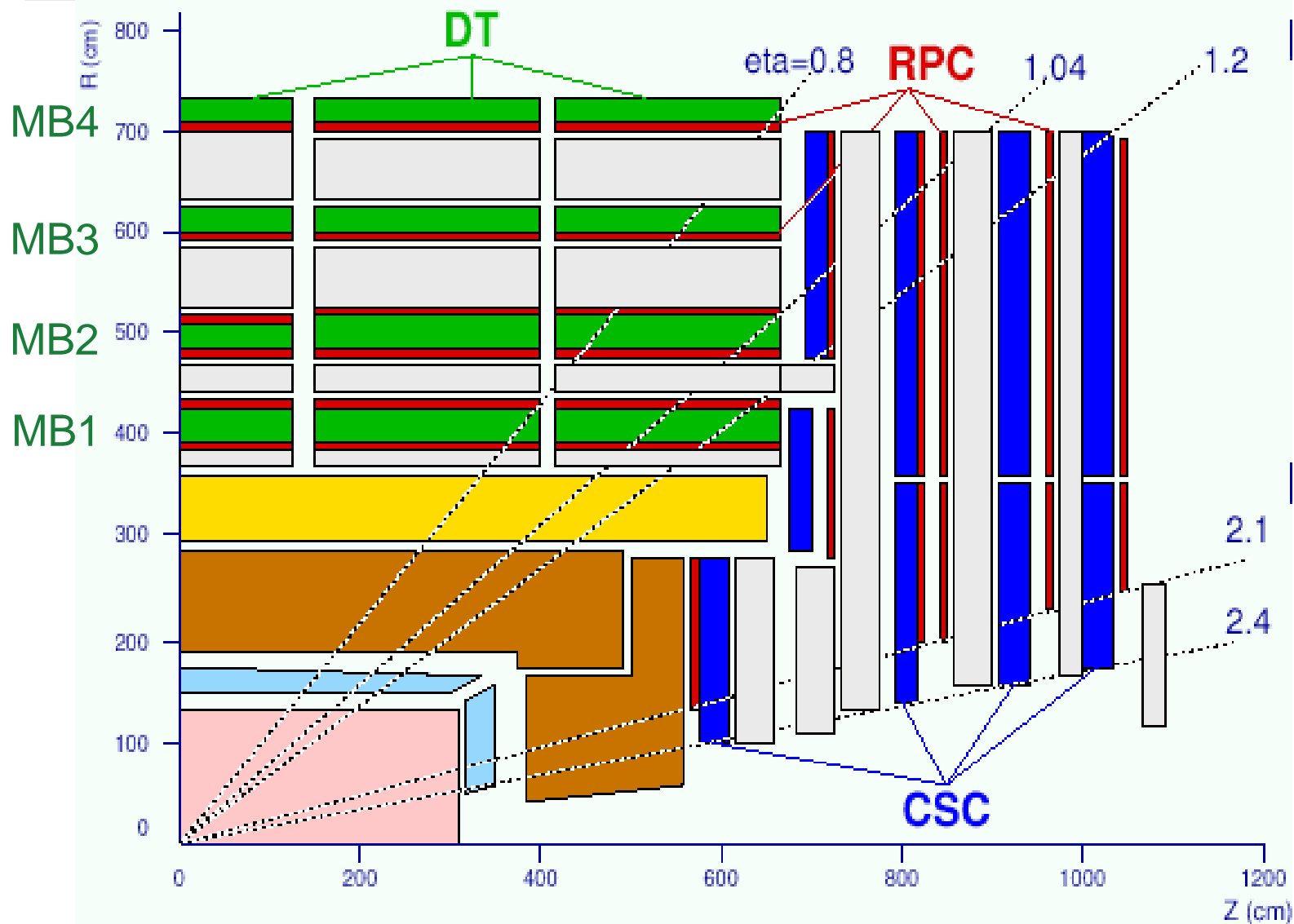
Individual wedges

Both ends assembled in Bat 186



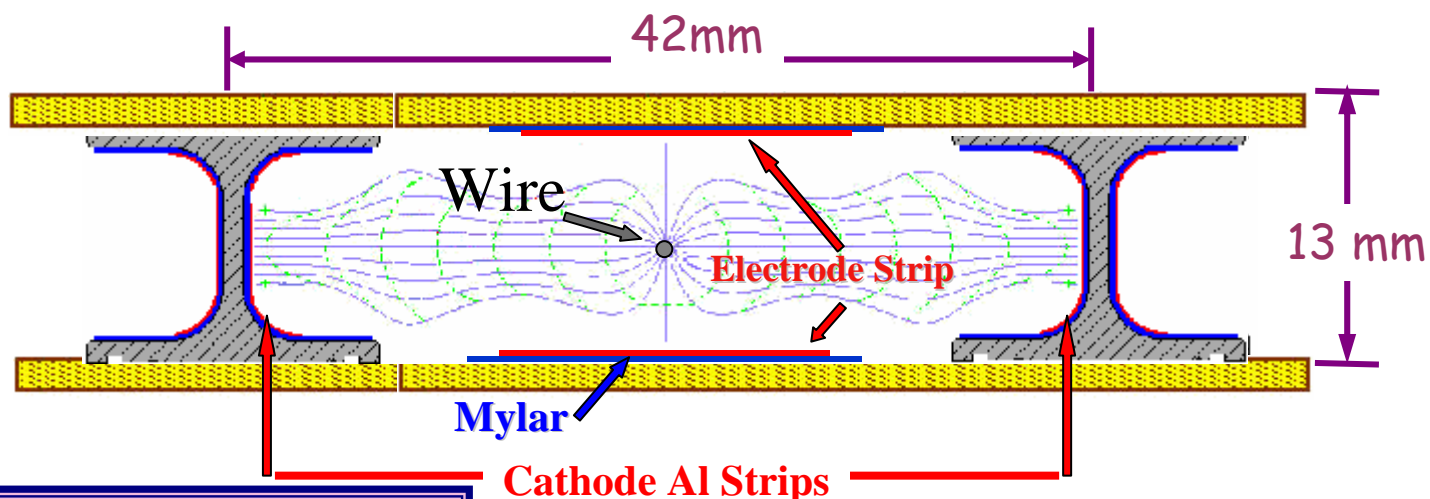


Muon System





Barrel Muon DT



GAS: Ar/CO₂ (85/15)

HV: Wires 3600 V

Strips 1800 V

I-beams -1200 V

T_{max}: < 400 ns

Drift Velocity : ~ 55μm/ns

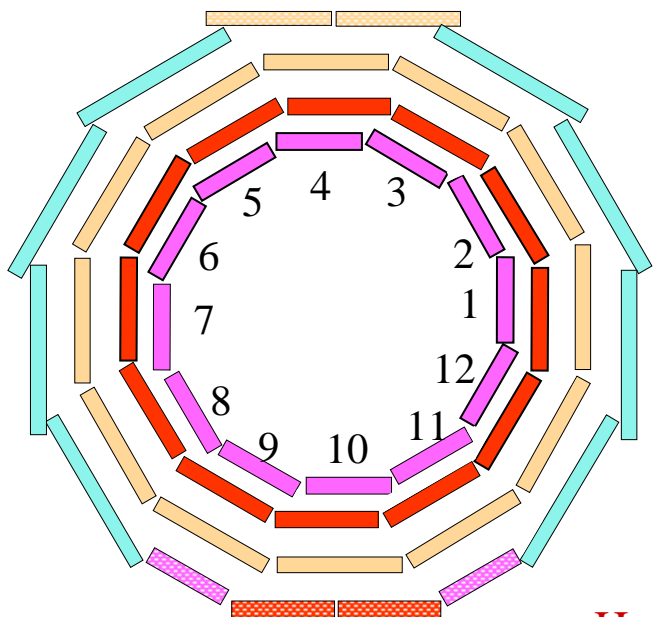
Single Wire

Resolution : < 300 μm

➔ 100μm Φ
150μm θ

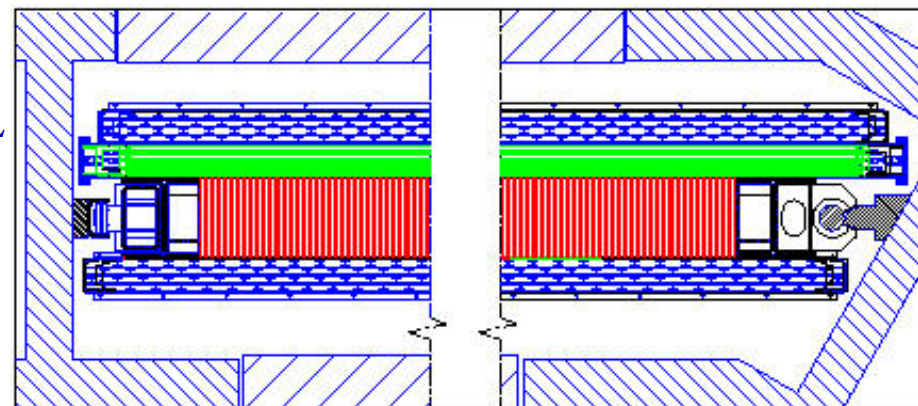


Barrel Muon DT

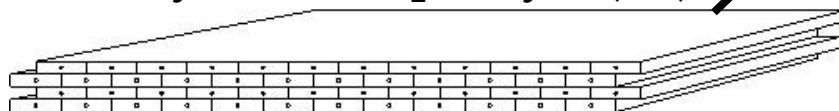


	60 MB1	3SL	2 RPC	~2.0 x 2.54 m ²	960kg
	60 MB2	3SL	2 RPC	~2.5 x 2.54 m ²	1200kg
	60 MB3	3SL	1 RPC	~3.0 x 2.54 m ²	1300kg
	40 MB4	2SL	1 RPC	~4.2 x 2.54 m ²	1800kg
	10 MB1	2SL	1 RPC		
	10 MB2	2SL	1 RPC		
	10 MB3	2SL	1 RPC		

Φ SL
 Θ SL
 Honeycomb
 Φ SL



4 layers = 1 Superlayer (SL)



The Barrel Muon system comprises 250 chambers for 5 wheels:
 Total 1700 SqM. Each Chamber has 2*4 Φ and 1*4 Θ layers

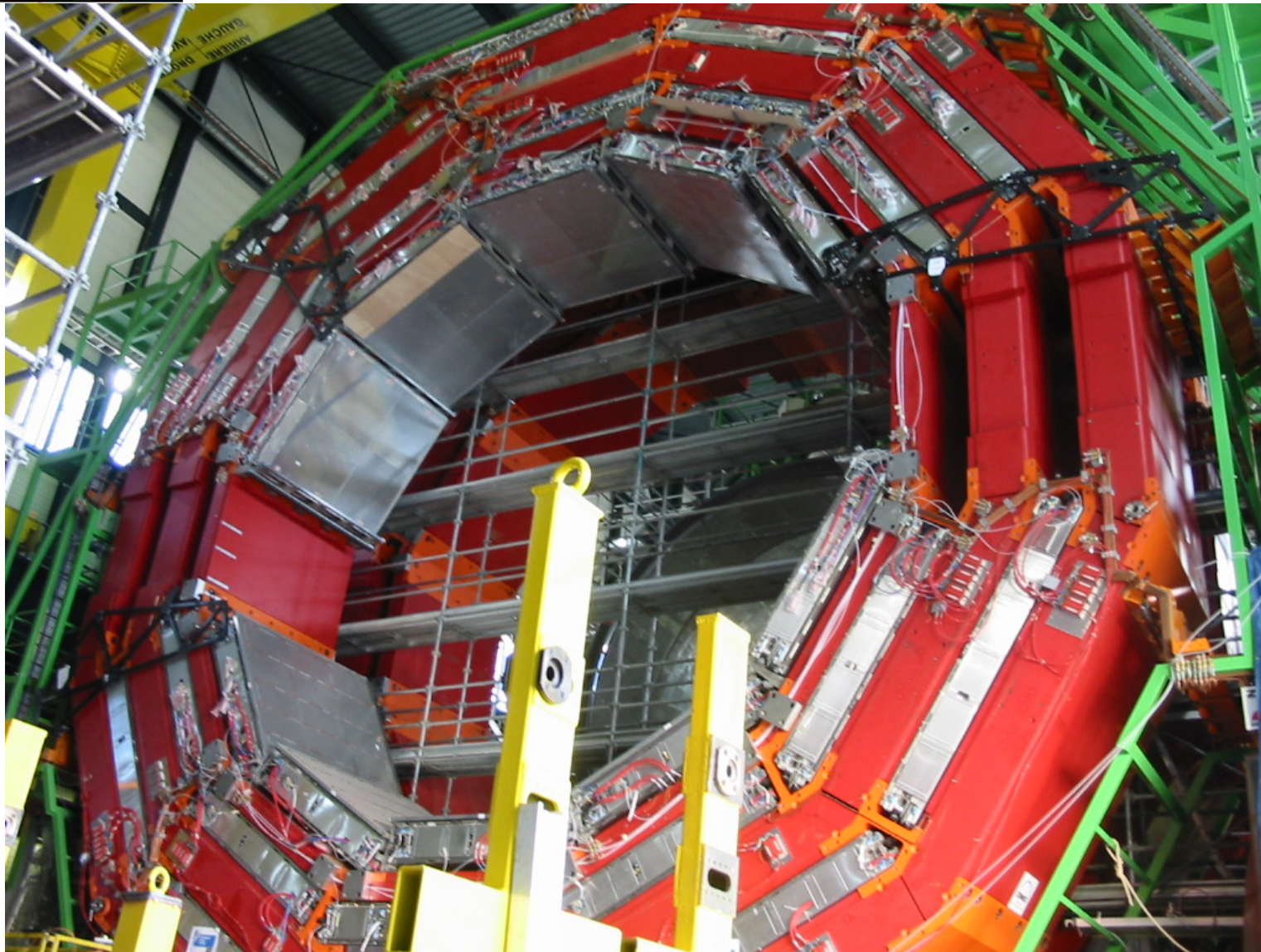


Installation of DT chambers





Installation of DT chambers YB+2



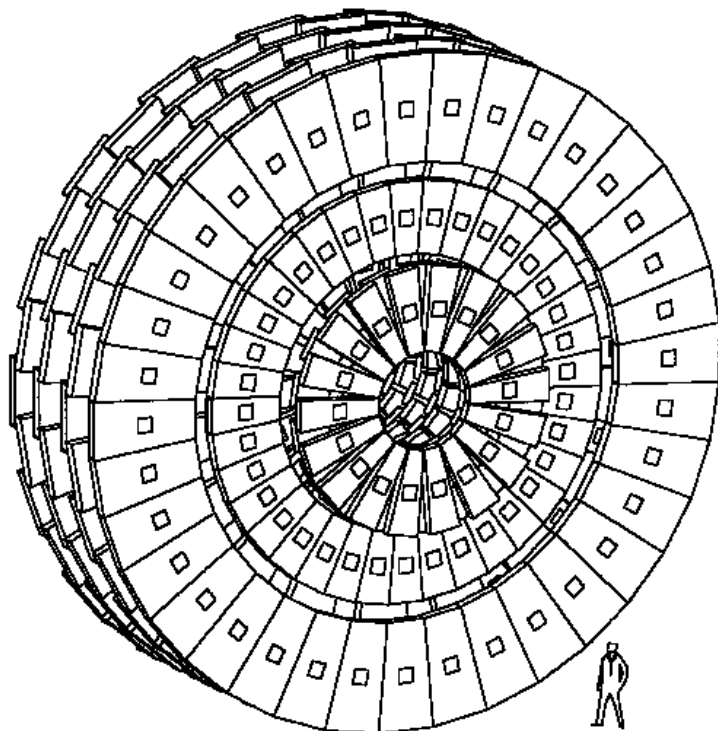


Endcap Muon CSC

468 Cathode Strip Chambers

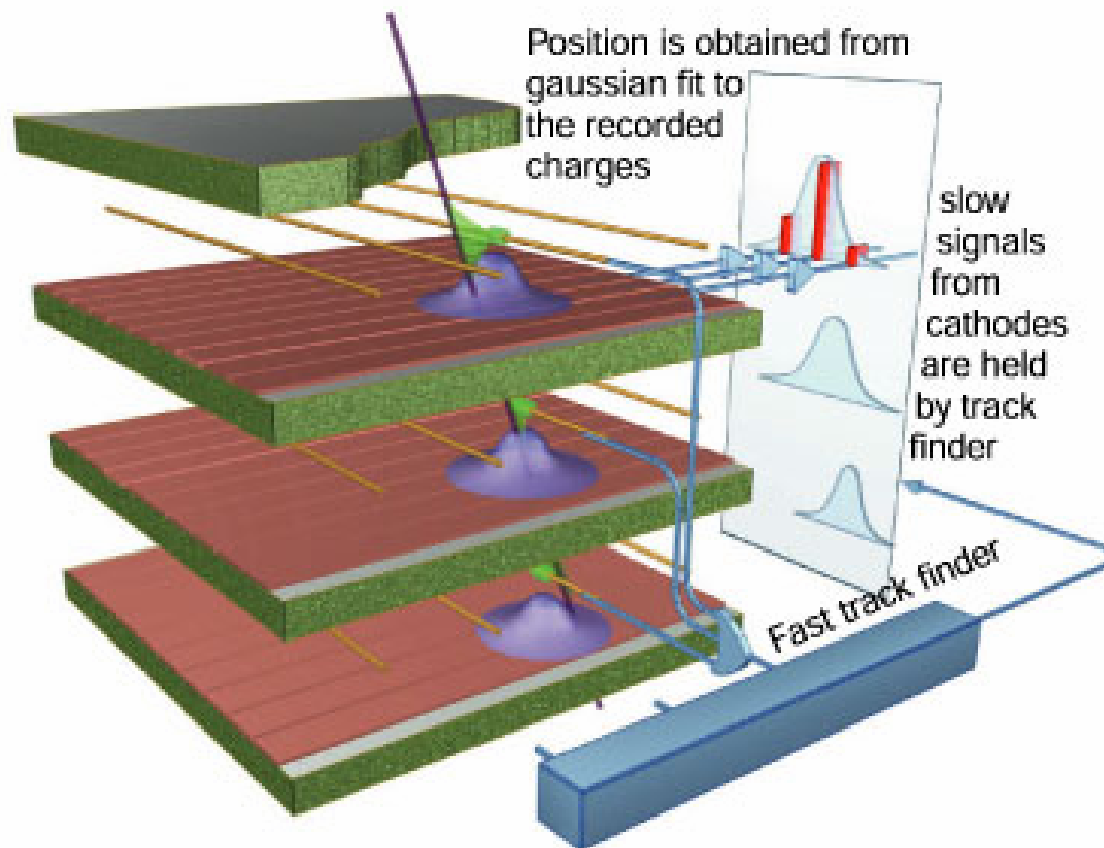
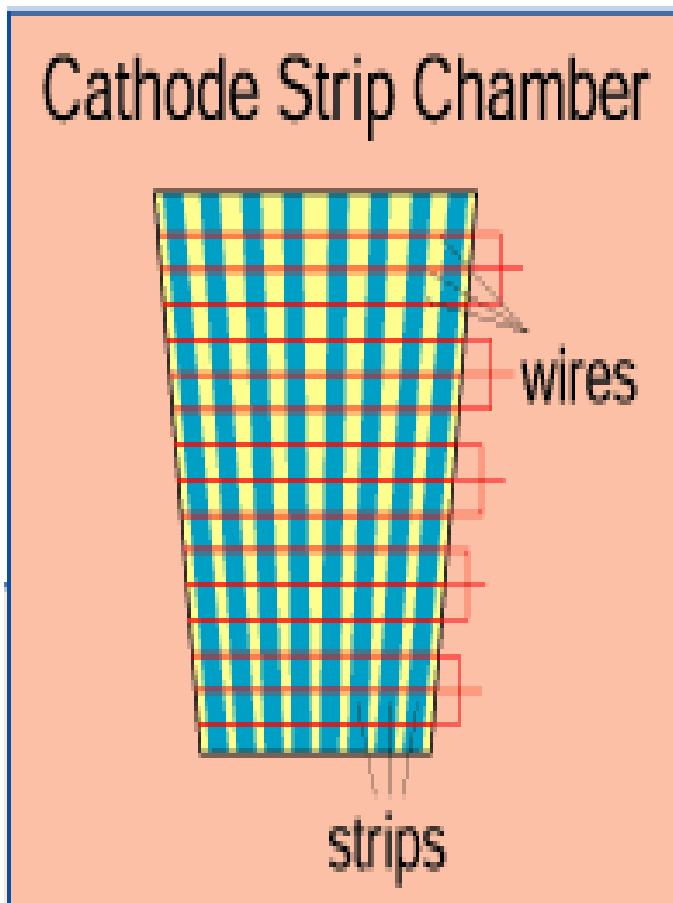
~2,000,000 wires

~6,000 m² sensitive area





CMS End Cap CSC



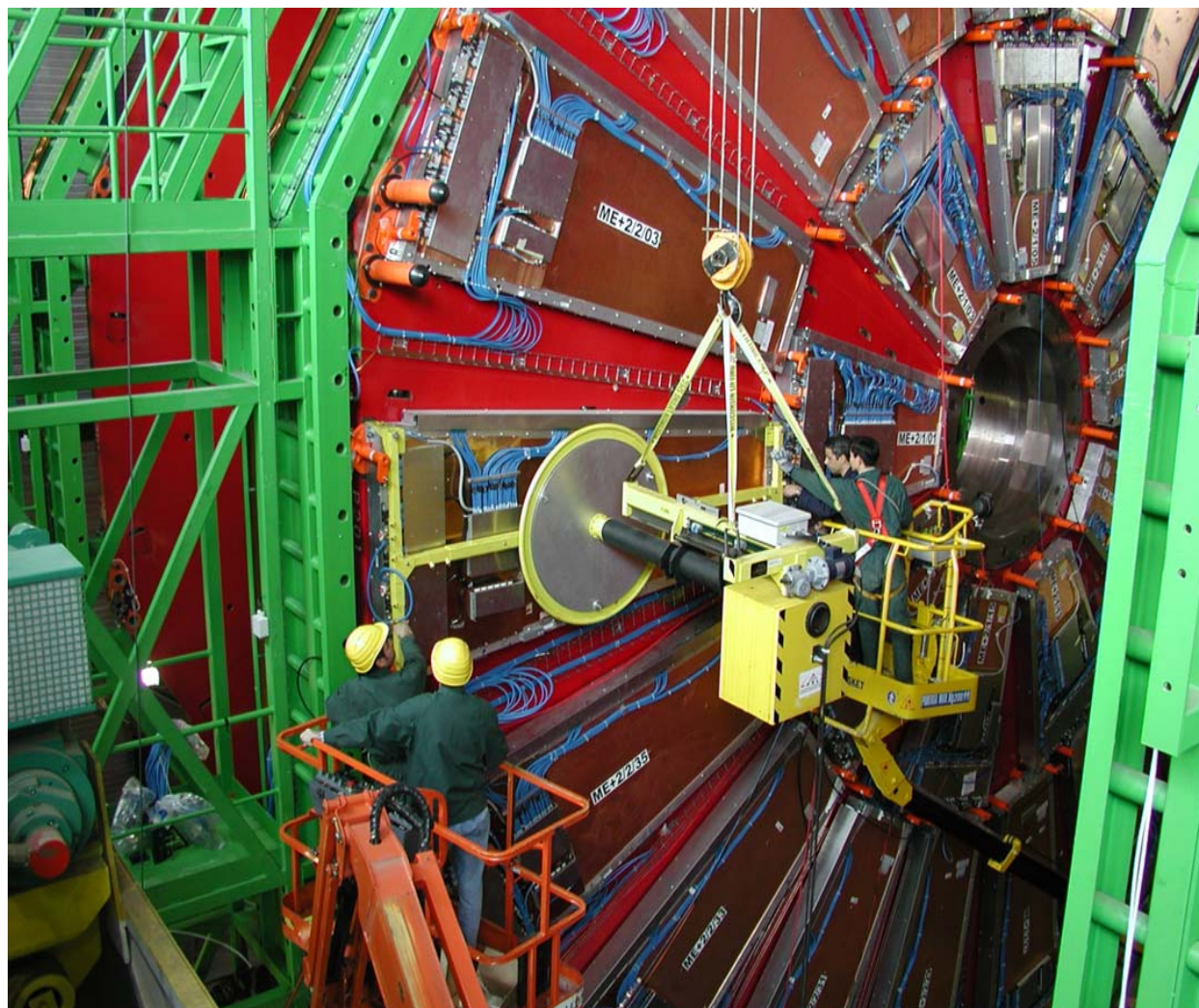
6 layers in each chamber

Position resolution ~ 50 microns (from strips)
Timing resolution better than 25ns (from wires)



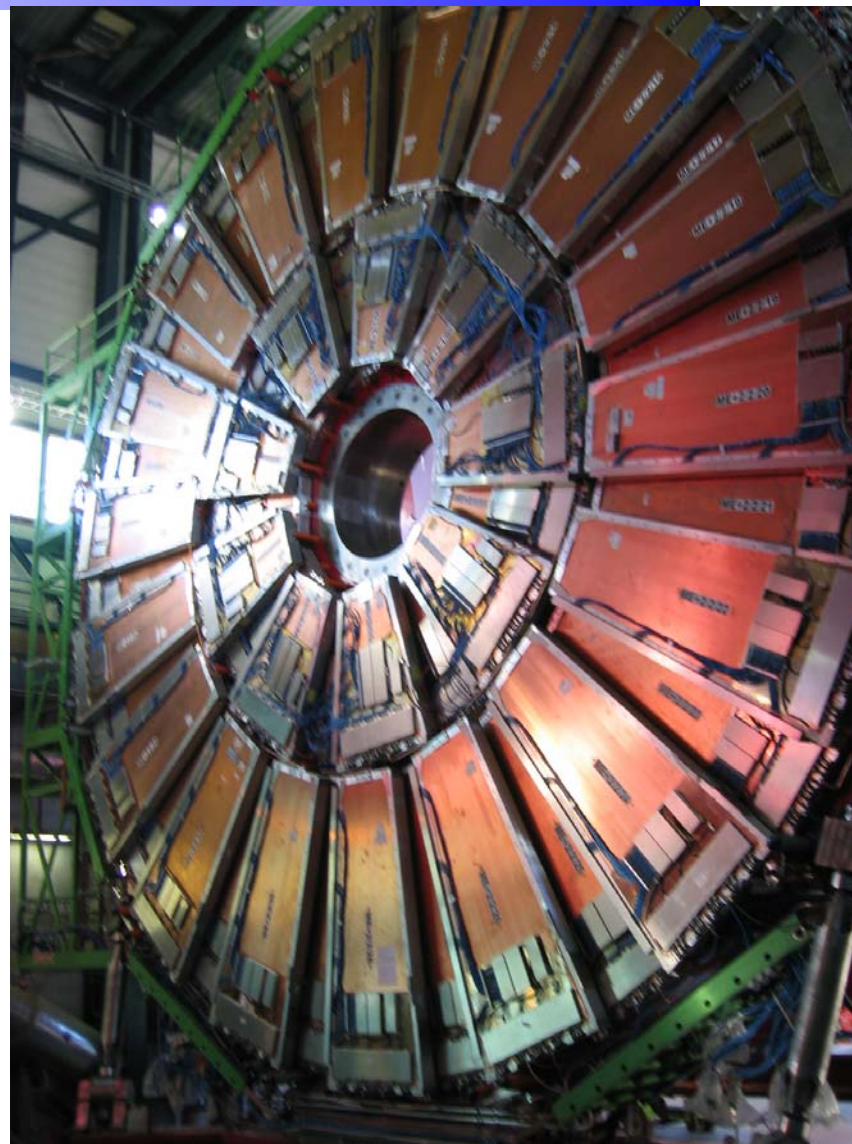
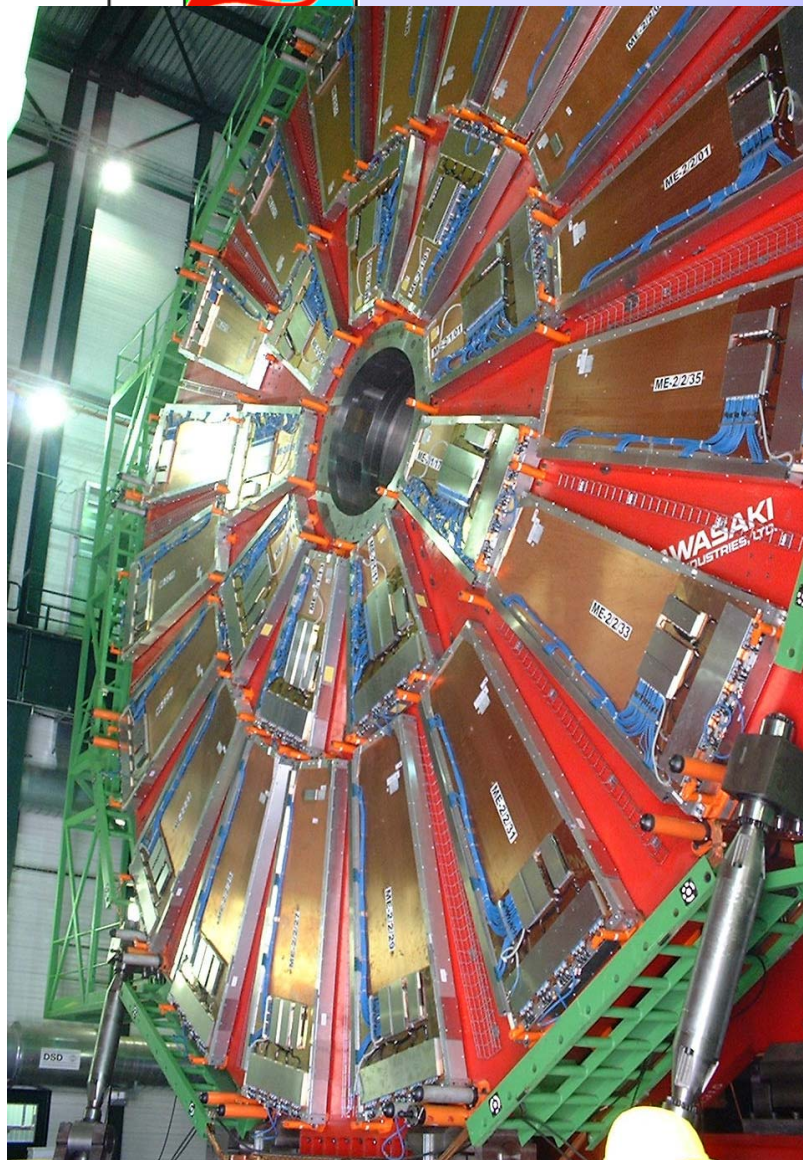
Endcap CSC Installation

468 chambers needed
100% tested and at CERN
67% installed
65% commissioned



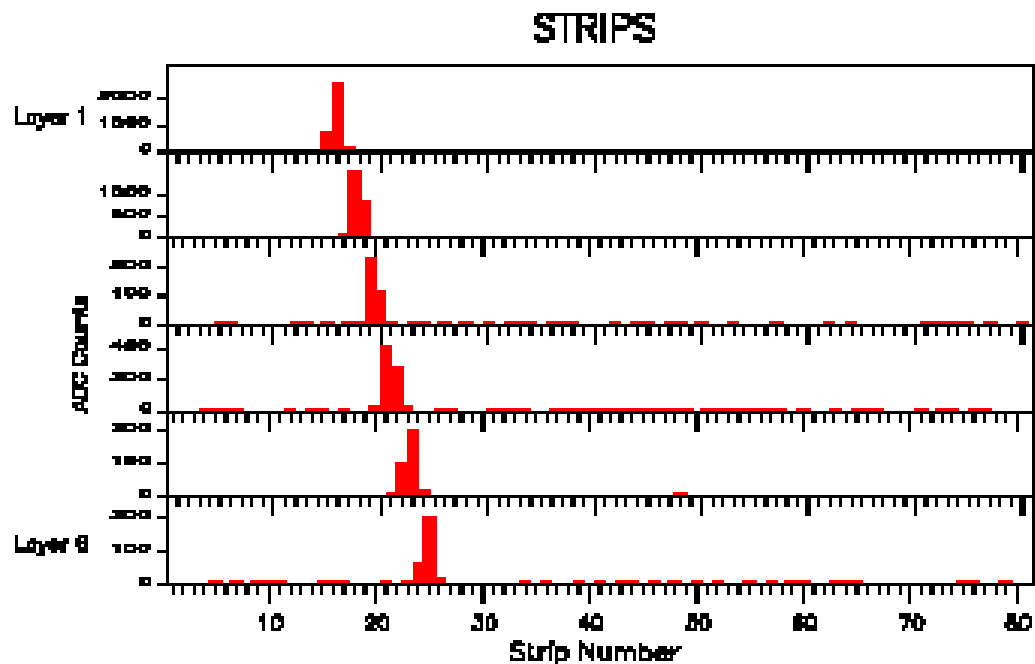


CSC on YE

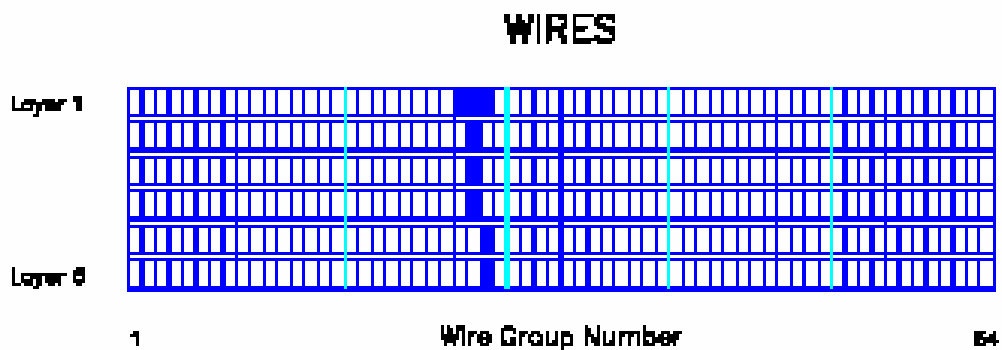




First Muon seen by CMS



**Single muon track
in one CSC**





RPC

Resistive Plate Chamber (Used for CMS Muon Triggers)

Item	CMS Requirements
Time Resolution	$\leq 3 \text{ ns}$
Efficiency	$\geq 95 \%$
Rate Capability	$\geq 1 \text{ kHz/cm}^2$
Intrinsic Noise Rate	$\leq 15 \text{ Hz/cm}^2$
Streamer Probability	$\leq 10 \%$
HV Plateau	$\geq 300 \text{ V}$



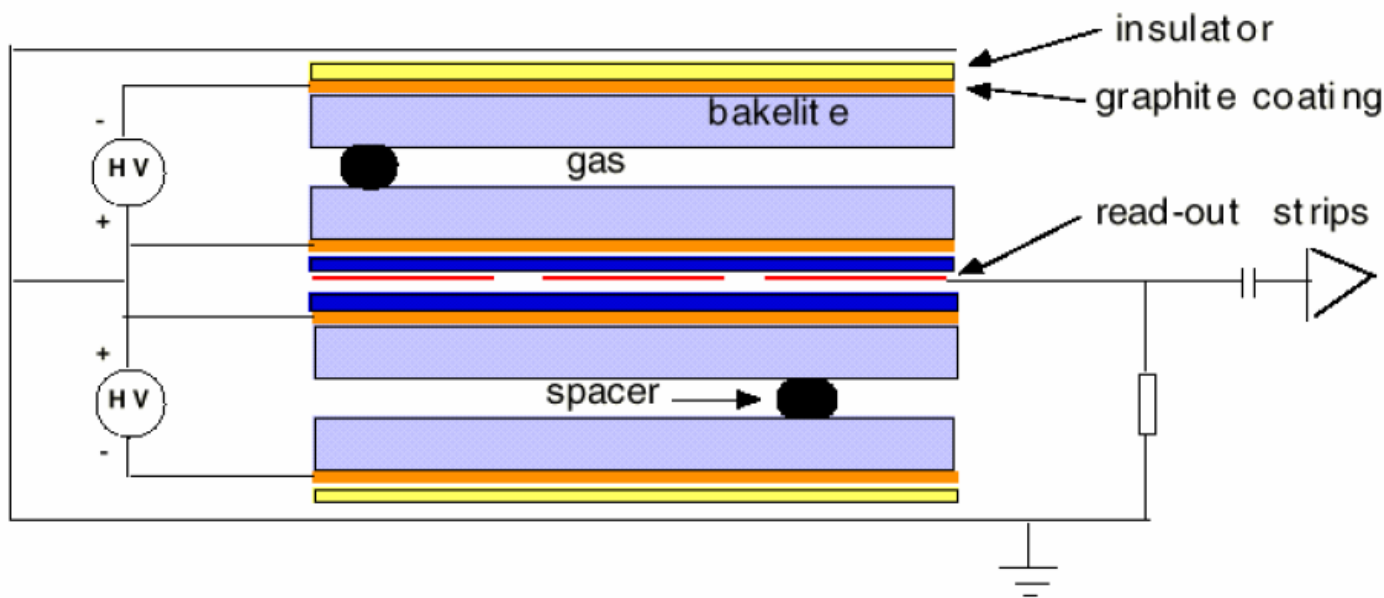
RPC

Dedicated trigger detector, with fast timing response

Basic functions:

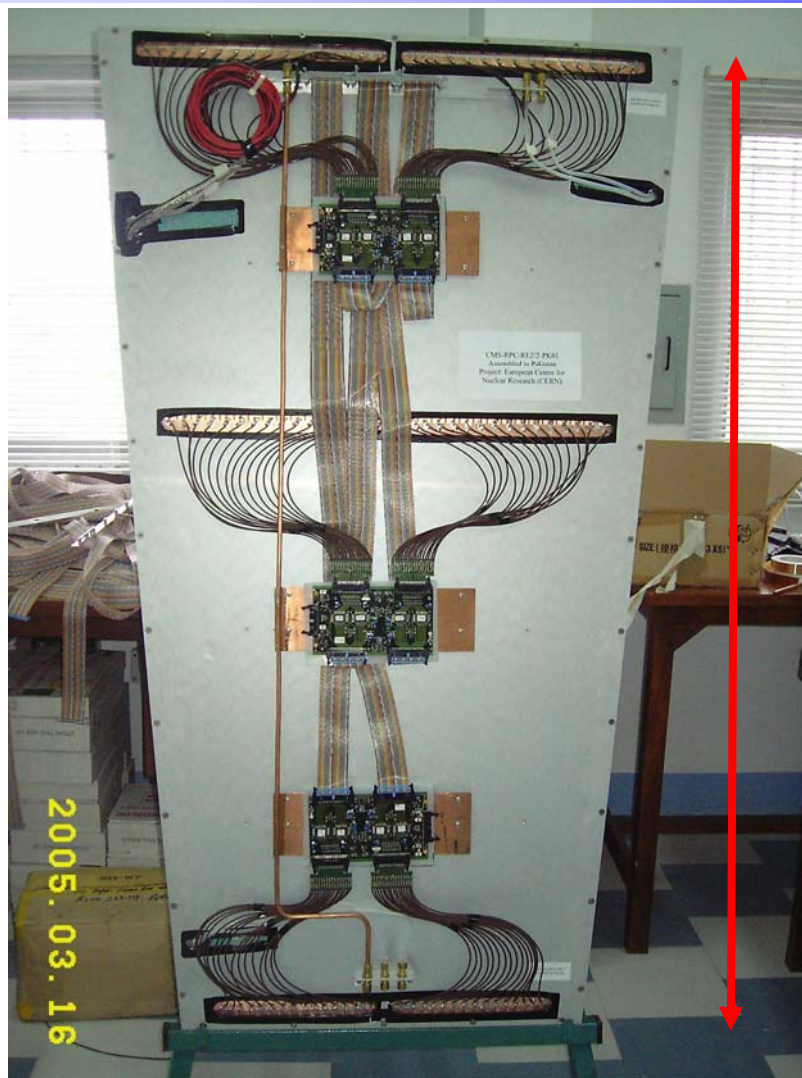
- identify candidate muon track
- assignment of bunch crossing to the candidate track(s)
- estimate their transverse momenta

An RPC module is made self-supporting, mounted outside the muon chambers (barrel and endcap) to match the active area of the tracking chambers





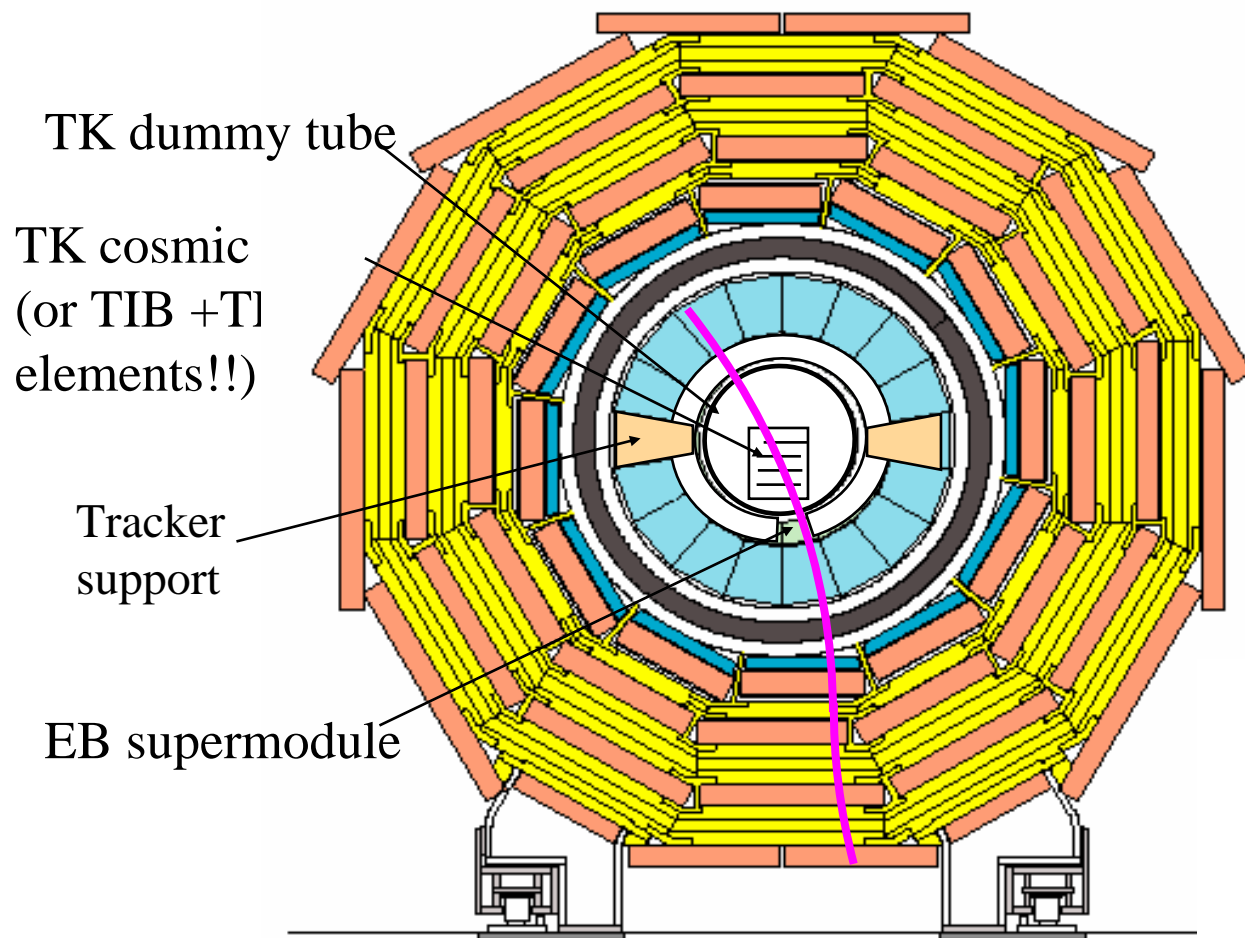
Endcap RPC



3.2 m



Magnet test: “cosmic challenge” Feb 06



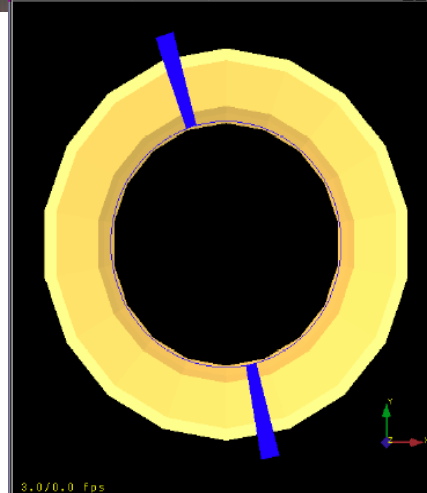
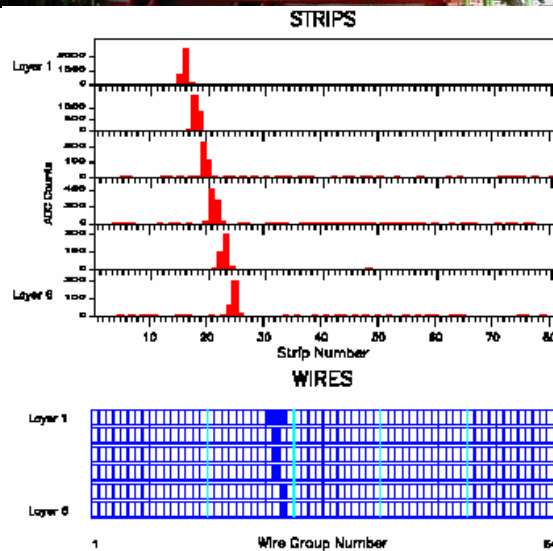
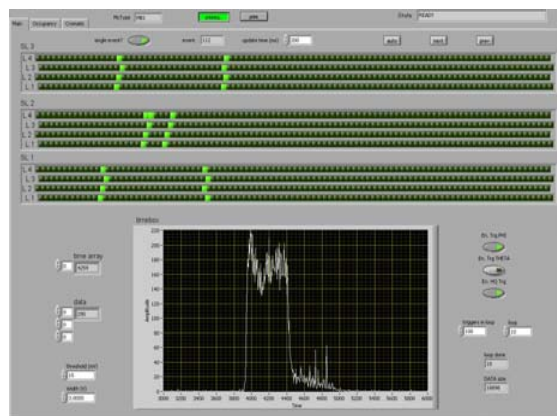
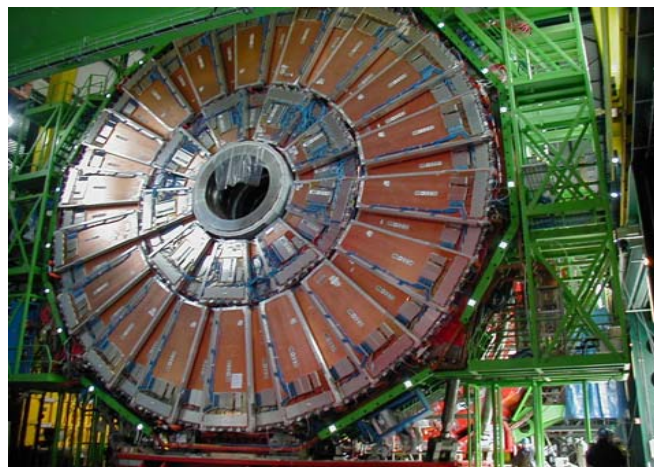
ambitious integration test:

issues:

- compatibility with basic programme of tests
- special installations
- muon, rpc, hcal, ecal, trk detectors
- cabling & services (esp LV)
- controls and safety
- trigger
- off-det electronics
- DAQ & Run Control
- DAQ integration requires:
 - local DAQ (over VME)
 - FED Slink
- Common trigger (ad-hoc with LTC?)
 - databases
 - data-structure/storage
 - analysis software etc etc etc



Commissioning CMS with Cosmics (Right now)





LPC Involvement with Vertical Slice

Remote Operations Center (ROC) to analyze calibration runs, alignment.

Starts in December

Large scale magnet test starts in Feb?

Other LPC Involvement?

Data Quality Monitoring:

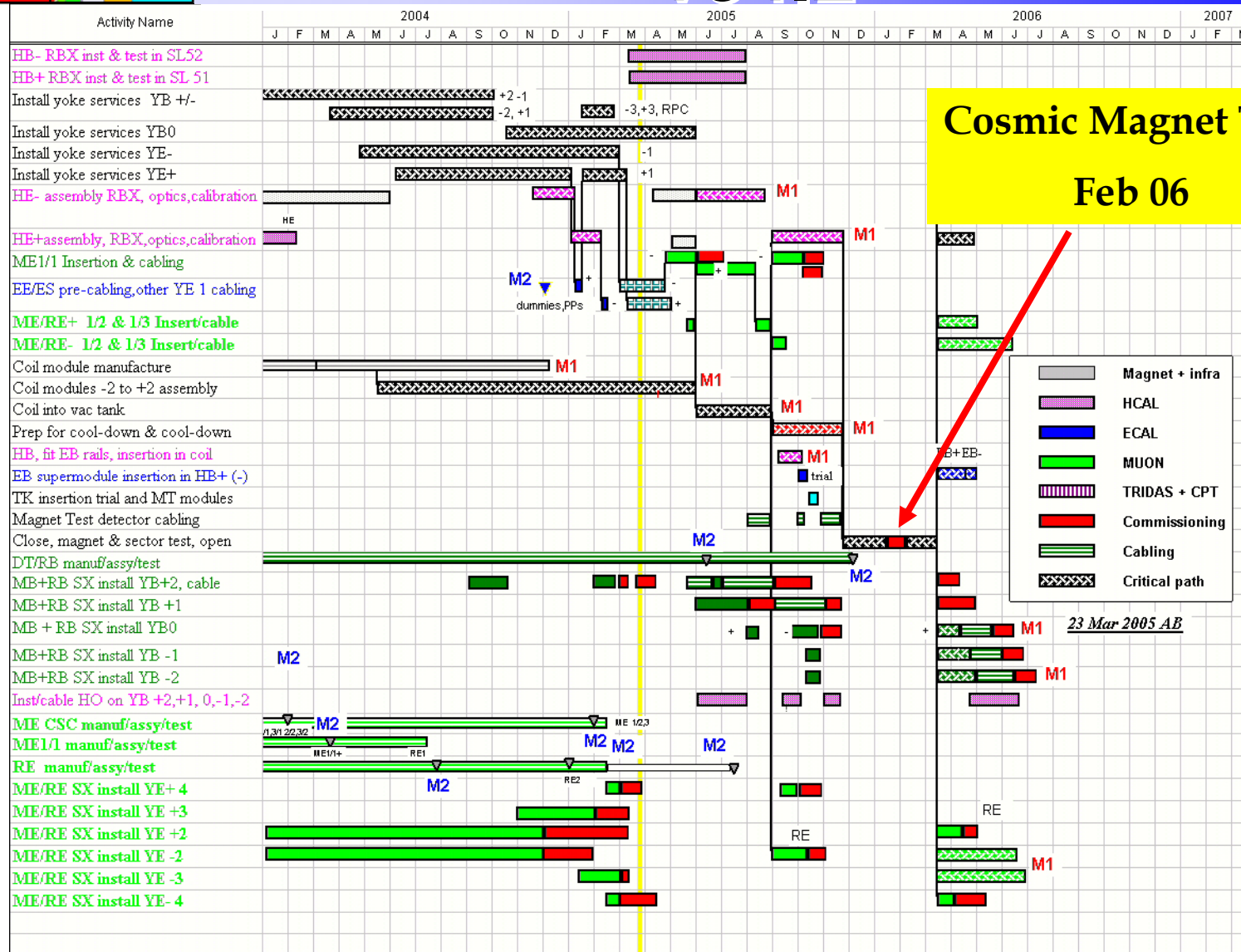
HCAL has person at LPC for this

High Level event filtering

“offline analysis”



SX schedule, draft revision v34.2



Cosmic Magnet Test
Feb 06

- Magnet + infra
- HCAL
- ECAL
- MUON
- TRIDAS + CPT
- Commissioning
- Cabling
- Critical path

23 Mar 2005 AB

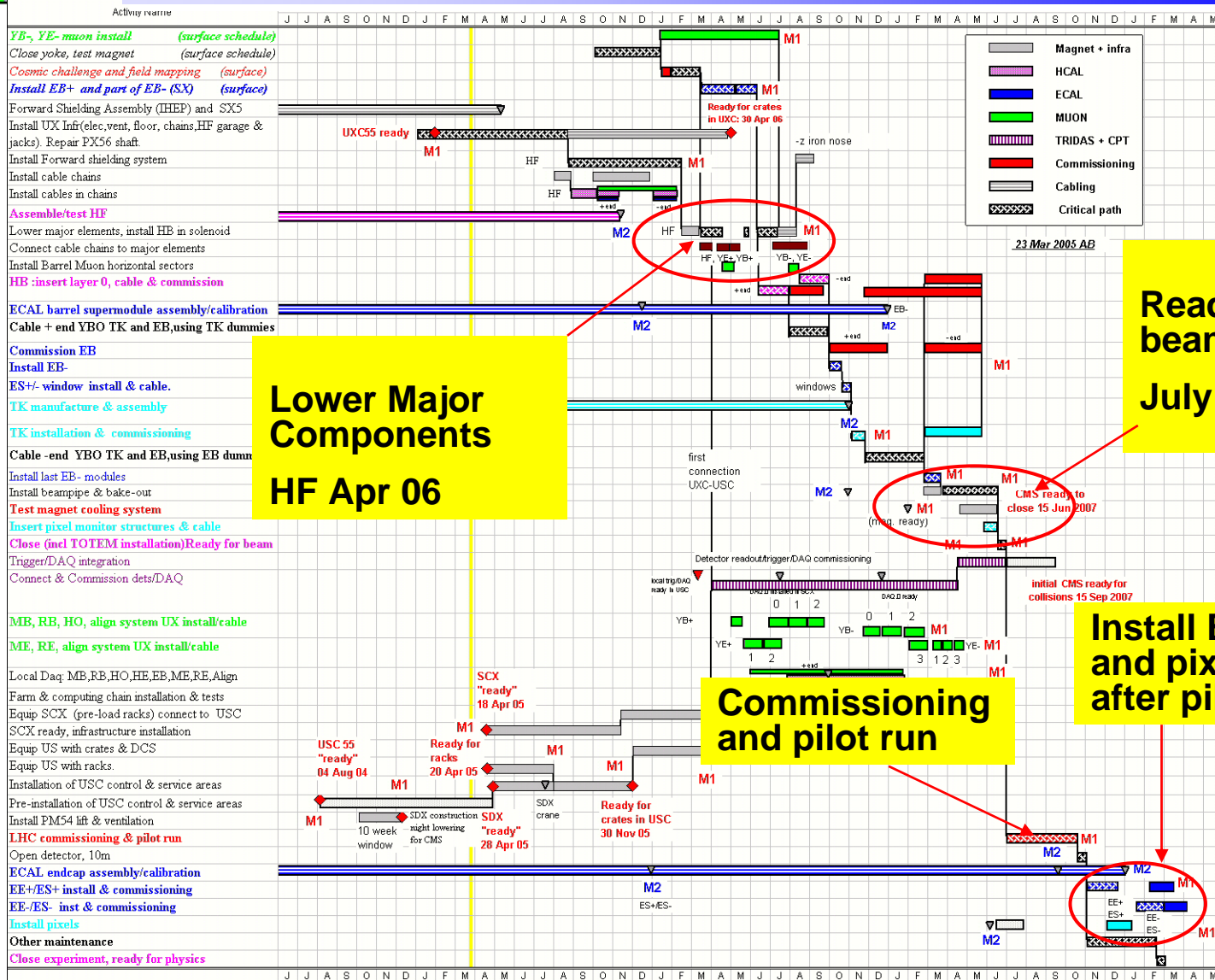


V34.2 UX Assembly (+6W)

2005

2006

2007



Lower Major Components
HF Apr 06

Ready for beam
July 2007

Commissioning and pilot run

Install EE/SE and pixels
after pilot run



Some Reference Talks

Pixel Detector

<http://agenda.cern.ch/askArchive.php?base=agenda&categ=a054217&id=a054217s1t1/transparencies>

Tracker

<http://eps2003.physik.rwth-aachen.de/data/talks/parallel/14Detectors/14Tricomi.ppt>

ECAL

<http://agenda.cern.ch/askArchive.php?base=agenda&categ=a035690&id=a035690s9t1%2Fmoreinfo%2FCamporesi.ppt>

HCAL

<http://uscms.fnal.gov/users/freeman/Elba%20Talk%20May%202024.ppt>

Muon

<http://eps2003.physik.rwth-aachen.de/data/talks/parallel/14Detectors/14Cerrada02.ppt>