



# CMS

Status of CMS\*

Ludwik Dobrzynski

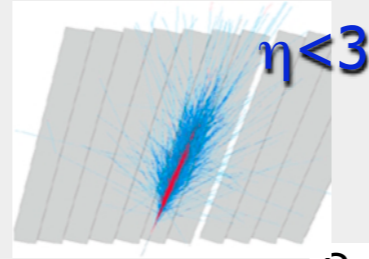
Laboratoire Leprince Ringuet, Palaiseau

Physics at LHC

Krakow July 4<sup>th</sup> 2006

\*slides courtesy of many people; particularly M. Della Negra, T. Virdee, D. Green, A. Ball, P. Sphicas, Ph. Bloch any many others

**SUPERCONDUCTING COIL**



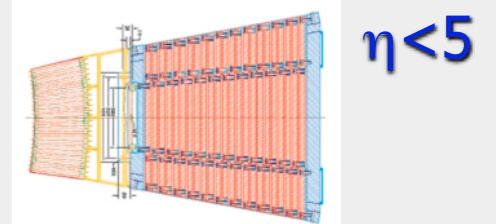
**CALORIMETERS**

**ECAL**

Scintillating PbWO<sub>4</sub> crystals

**HCAL**

Plastic scintillator/brass sandwich



**IRON YOKE**

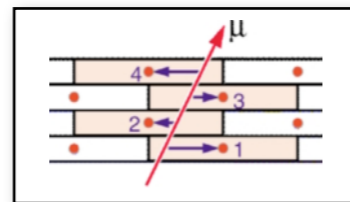
$\eta < 2.4$

**TRACKER**

Silicon Microstrips  
Pixels

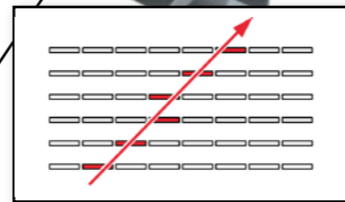
- Pixel Barrel
- Pixel Endcap
- Si Barrel
- Si Endcap
- MSGC Barrel
- MSGC Endcap

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



**MUON BARREL**

Drift Tube Chambers ( **DT** )

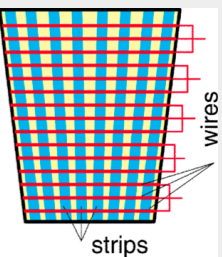



Resistive Plate Chambers ( **RPC** )

**MUON ENDCAPS**

Cathode Strip Chambers ( **CSC** )

Resistive Plate Chambers ( **RPC** )



- 
1. Robust and Redundant Muon system
  2. Best  $e/\gamma$  calorimeter consistent with 1.
  3. Efficient Tracker consistent with 1 + 2
  4. Hermetic calorimeter
  5. Affordable.



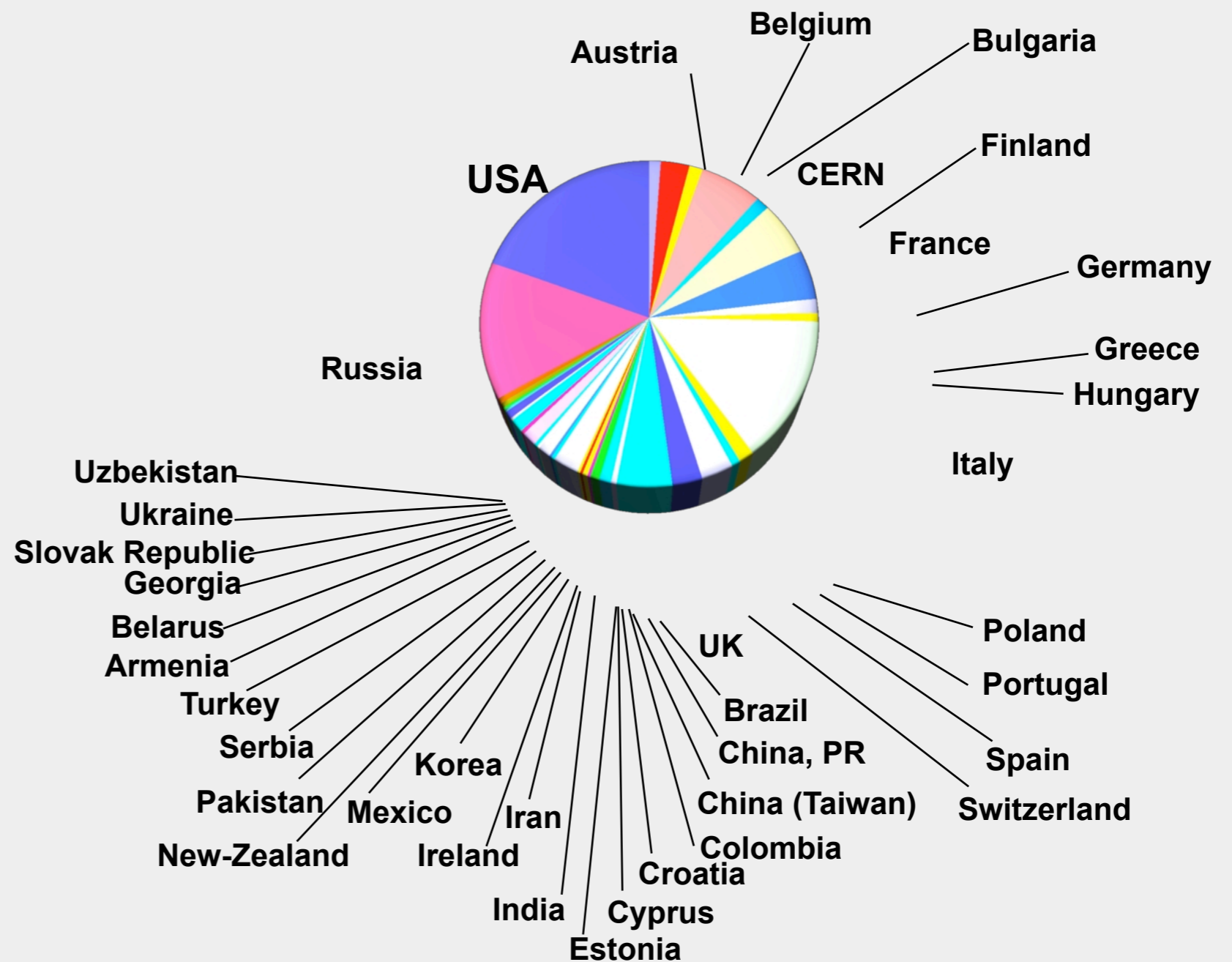
# The CMS Collaboration



	Institutions
<b>Member States</b>	<b>61</b>
<b>Non-Mem. States</b>	<b>64</b>
<b>USA</b>	<b>49</b>
<b>Total</b>	<b>174</b>

	Scientists
<b>Member States</b>	<b>1055</b>
<b>Non-Mem. States</b>	<b>428</b>
<b>USA</b>	<b>547</b>
<b>Total</b>	<b>2030</b>

Associated Institutes	
Number of Scientists	<b>46</b>
Number of Laboratories	<b>8</b>



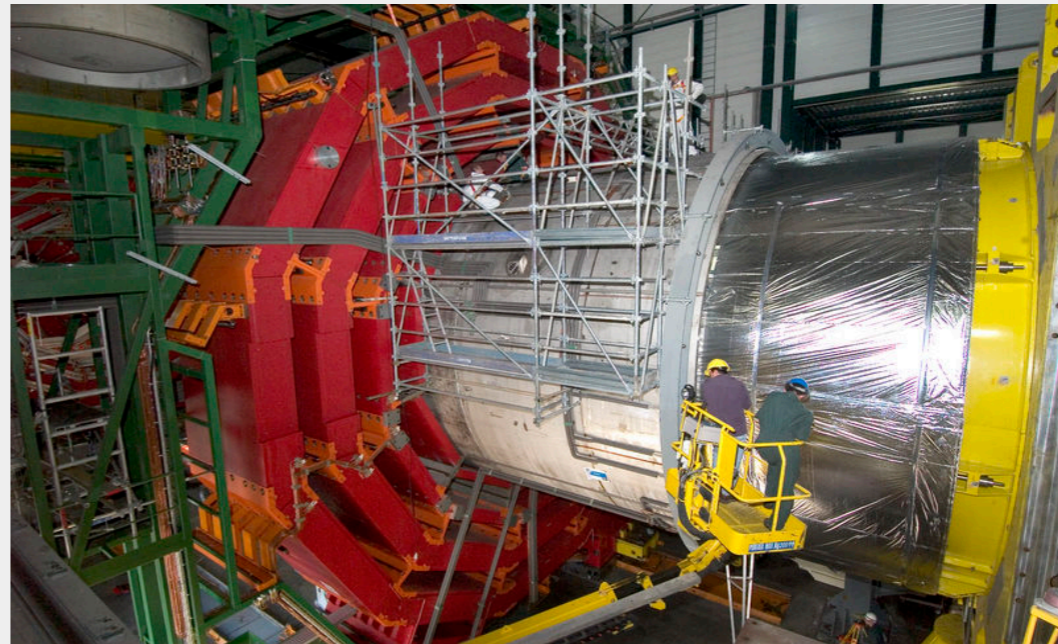
**2030 Scientific Authors, 38 Countries, 174 Institutions**



# Overview of CMS integration progress



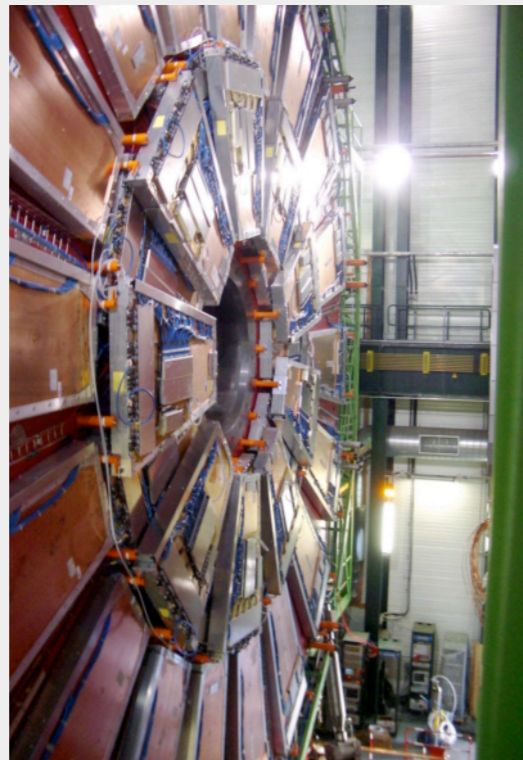
UXC will be ready  
for lowering 31  
August 06



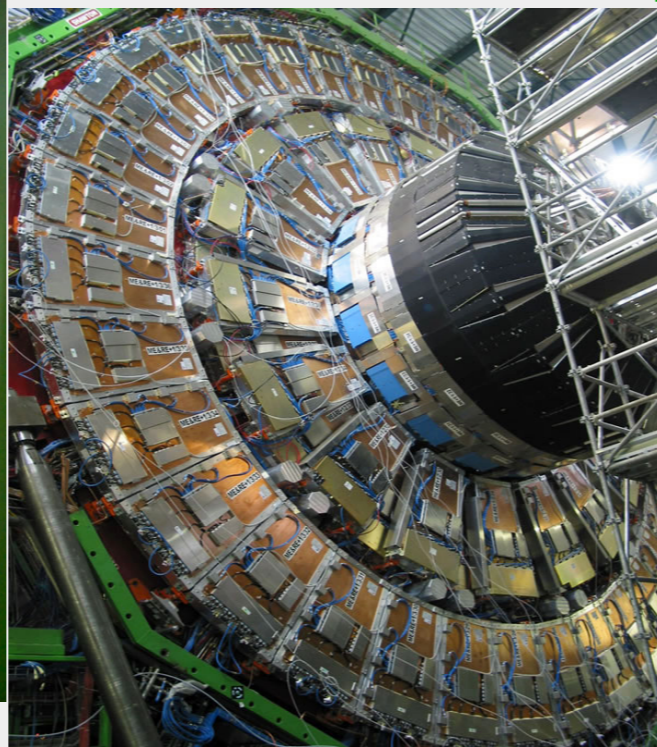
Coil inserted, 14. September



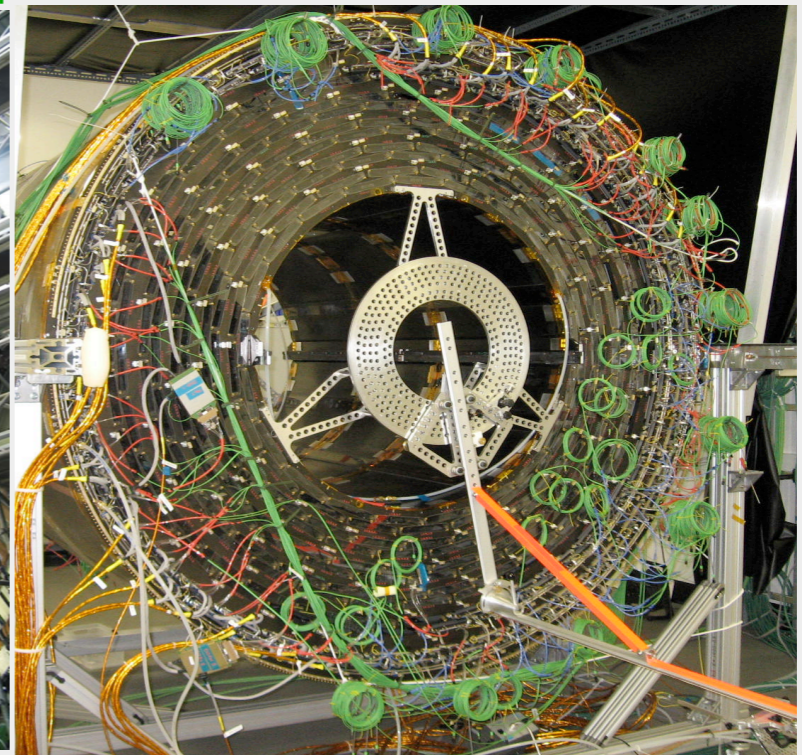
Cathode Strip chambers and yoke endcaps



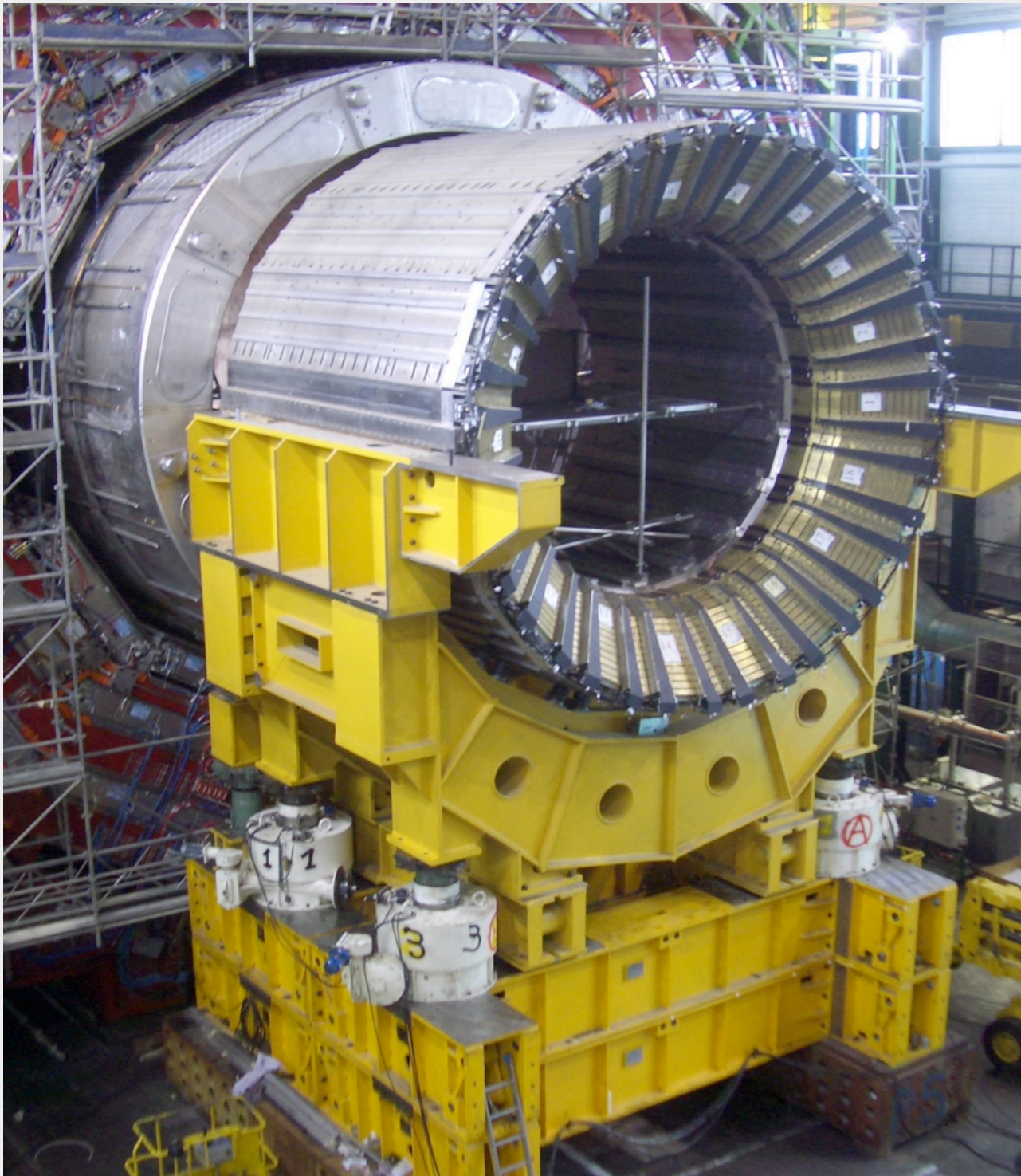
Hadronic calorimeter, endcap



Tracker, outer barrel

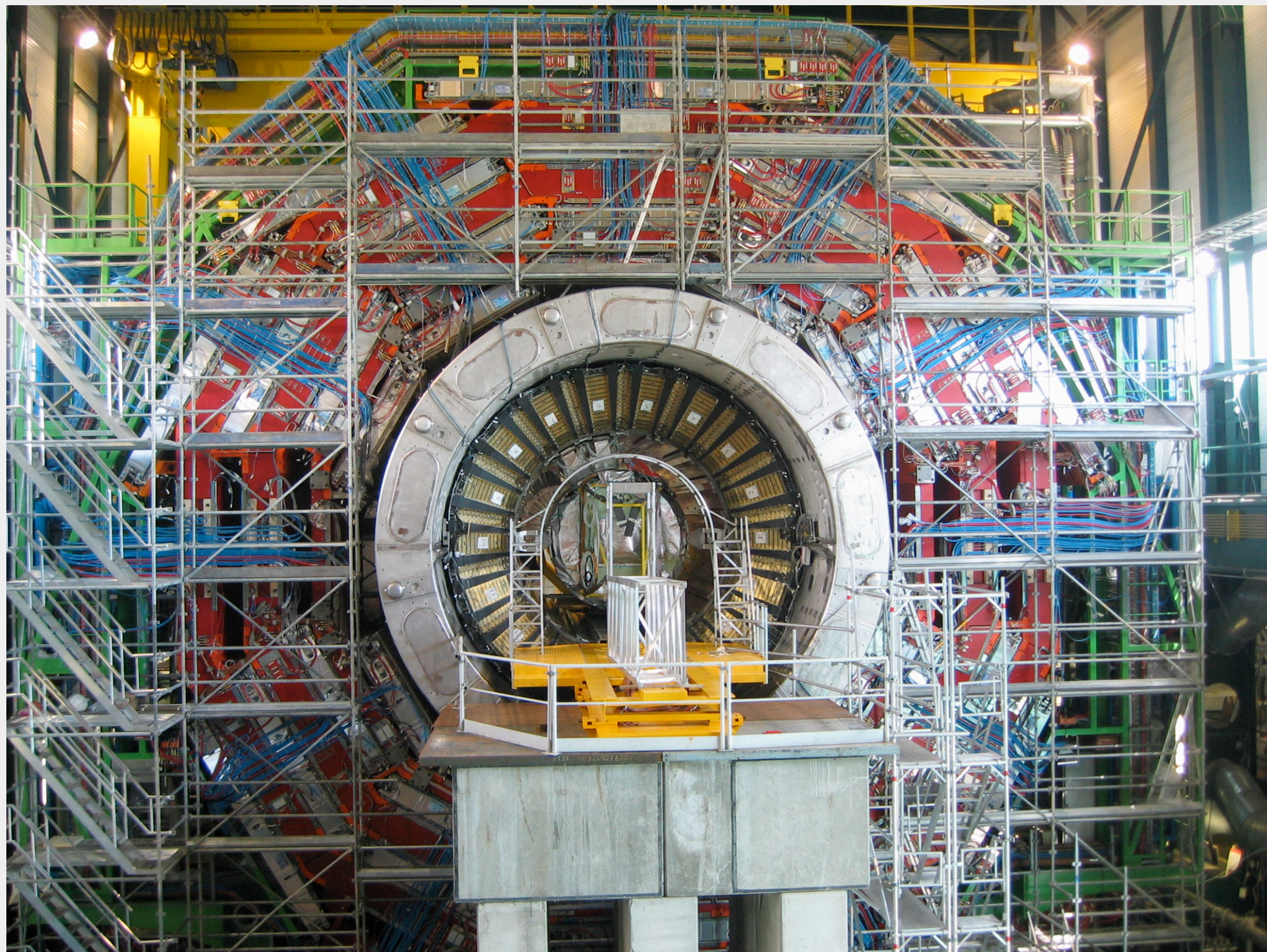


On critical path: ECAL crystal delivery (Barrel: Feb. 07, Endcaps: Jan. 08)  
Pixel installation for 2008 physics run.





# CMS in progress

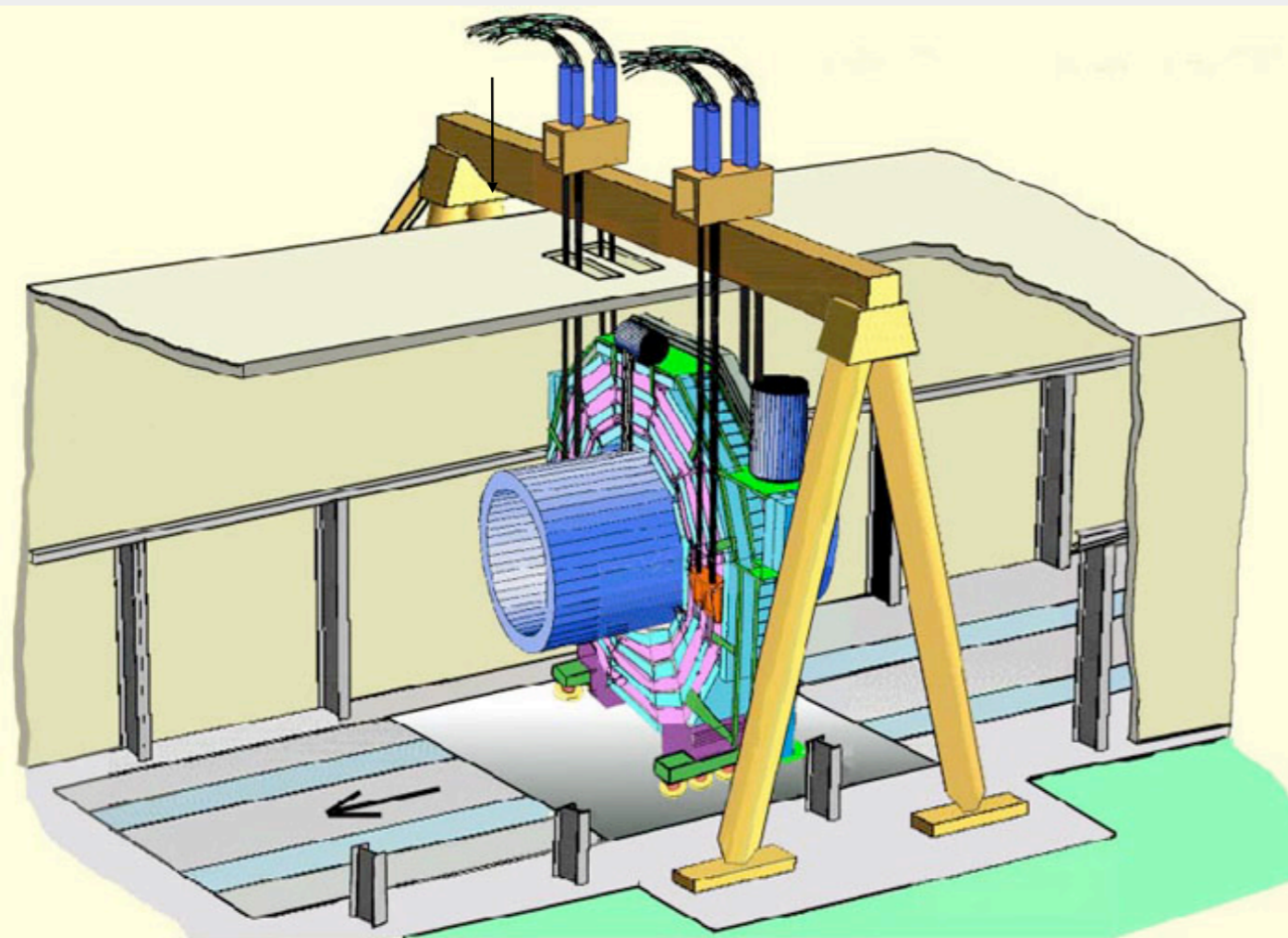




# Transfer CMS Underground in 2006



Gantry installed over PX56. load test in June and start HF lowering.



Start YB0 lowering (2000t): Nov 06







# From Design to a working detector MTCC



The Compact Muon Solenoid Experiment

## CMS Bulletin

CERN, CH-1211 GENEVA 23, Switzerland



Bulletins are available on  
CMS internal information server:

<http://cmsdoc.cern.ch/cms.html>

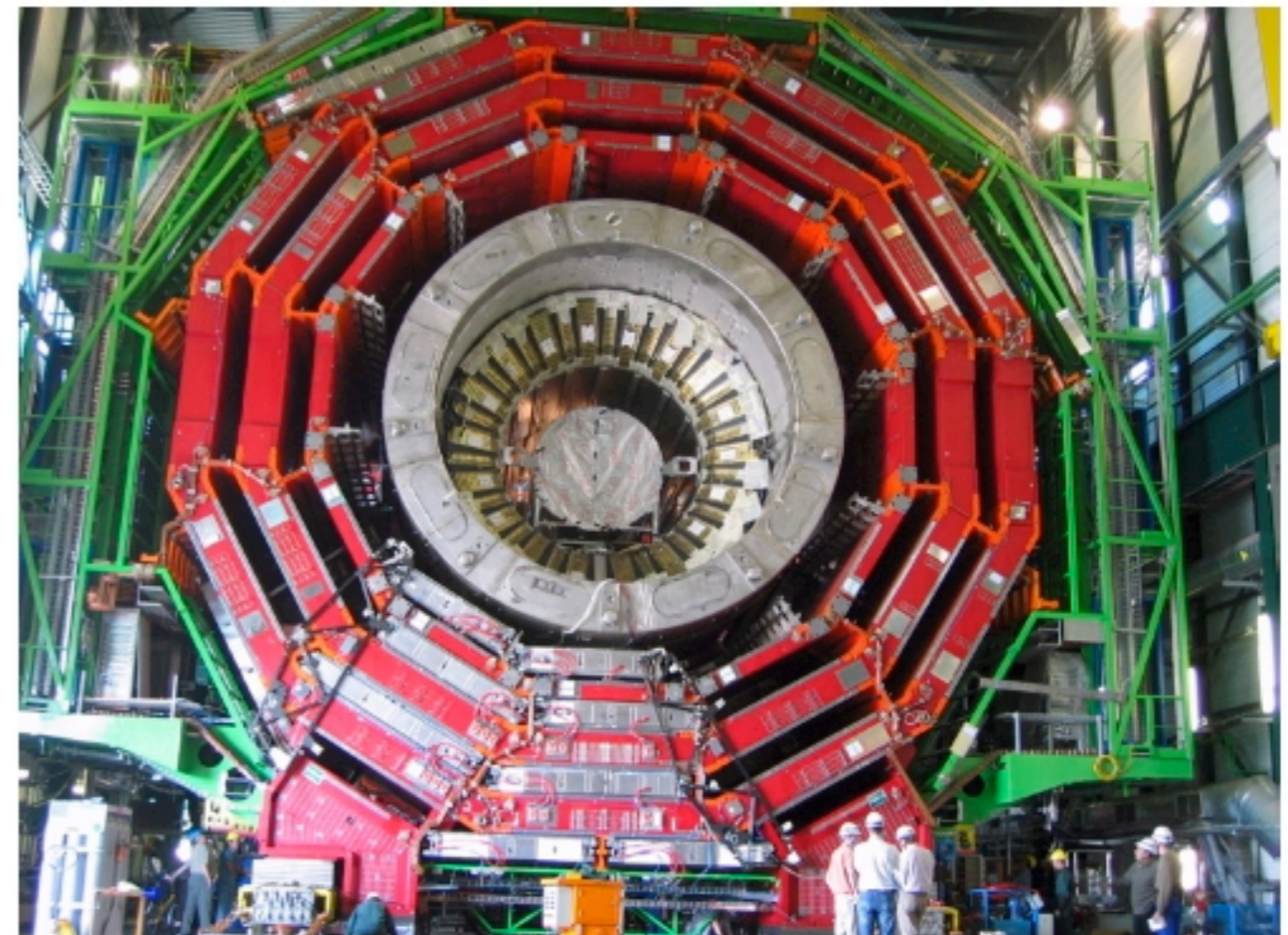
Number 06-02  
19 June 2006

## Getting Ready for Cosmics

# MTCC

*Magnet Test and Cosmic Challenge*

- ◆ *Installation validation*
- ◆ *Magnet Commissioning*
- ◆ *Cosmic Challenge*
- ◆ *Field Mapping*

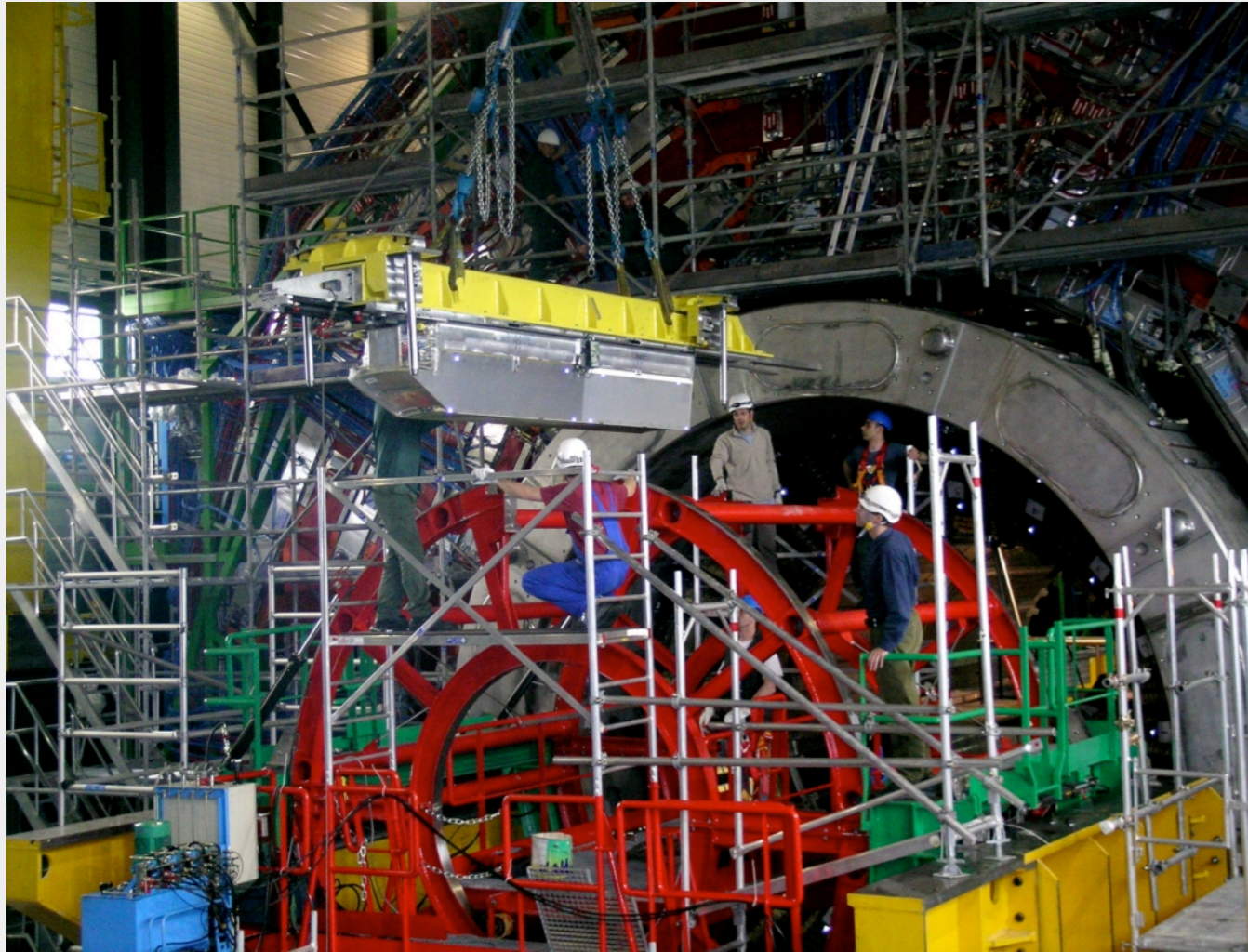


The CMS detector is being closed. The situation viewed from the -end (early last week) shows the YB-2 wheel (and YB-1) closed with the DT+RPC packages, the Barrel HCAL and the Tracker tube installed. Not visible are two SM modules installed at the +end, and the endcaps systems.



HB+, sectors 5-8

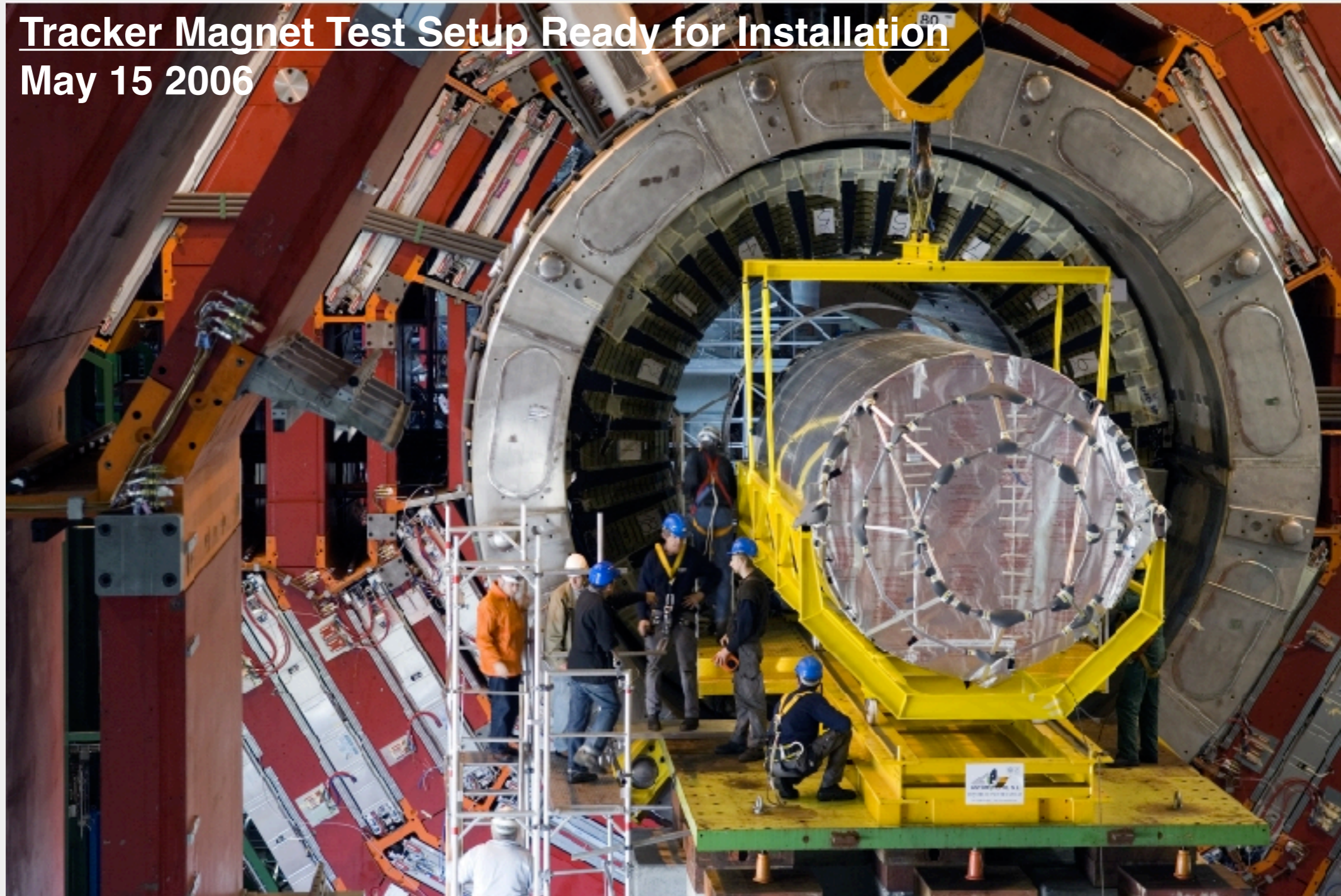
HB+, sectors 14-17



8-10 hours per supermodule

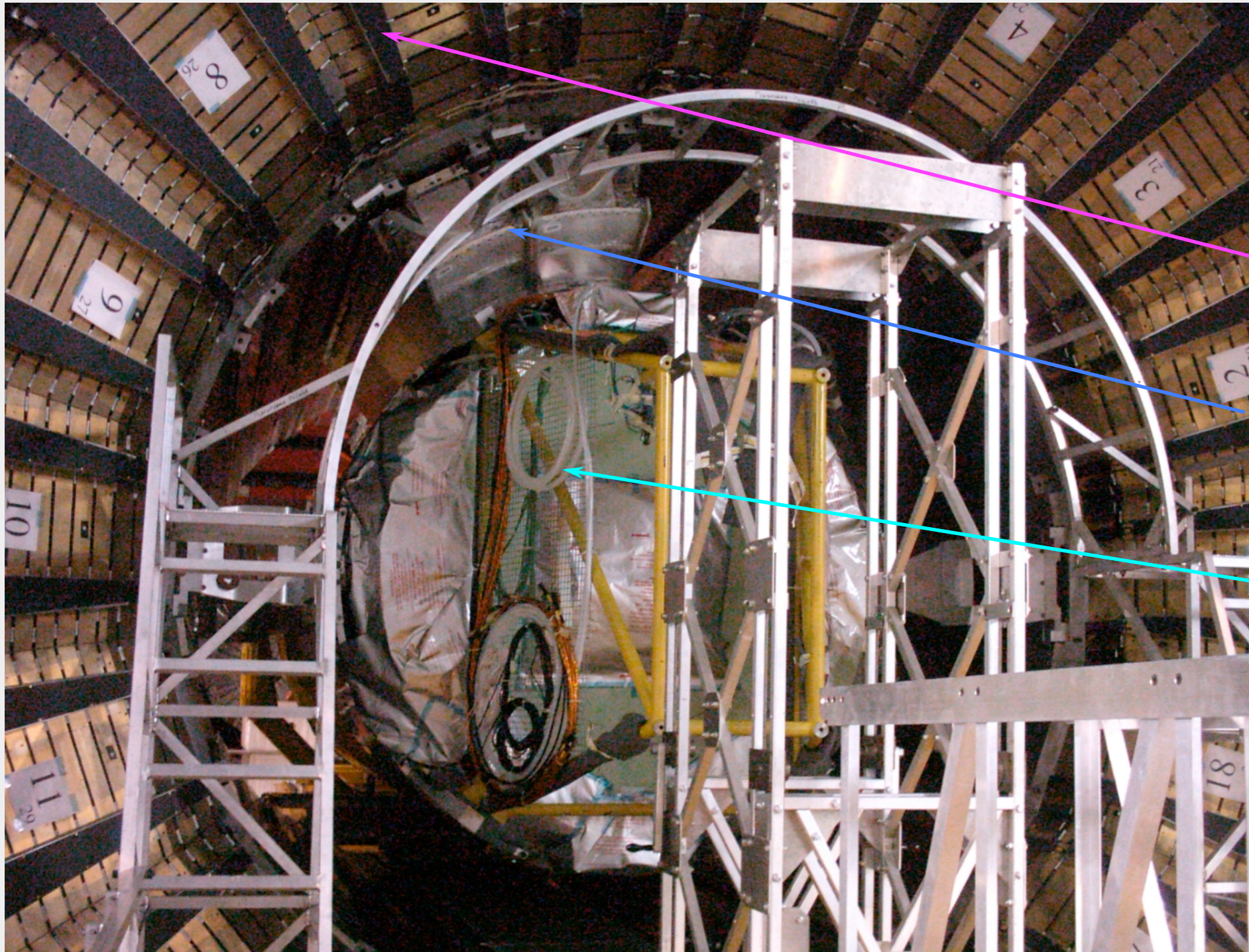


Tracker Magnet Test Setup Ready for Installation  
May 15 2006





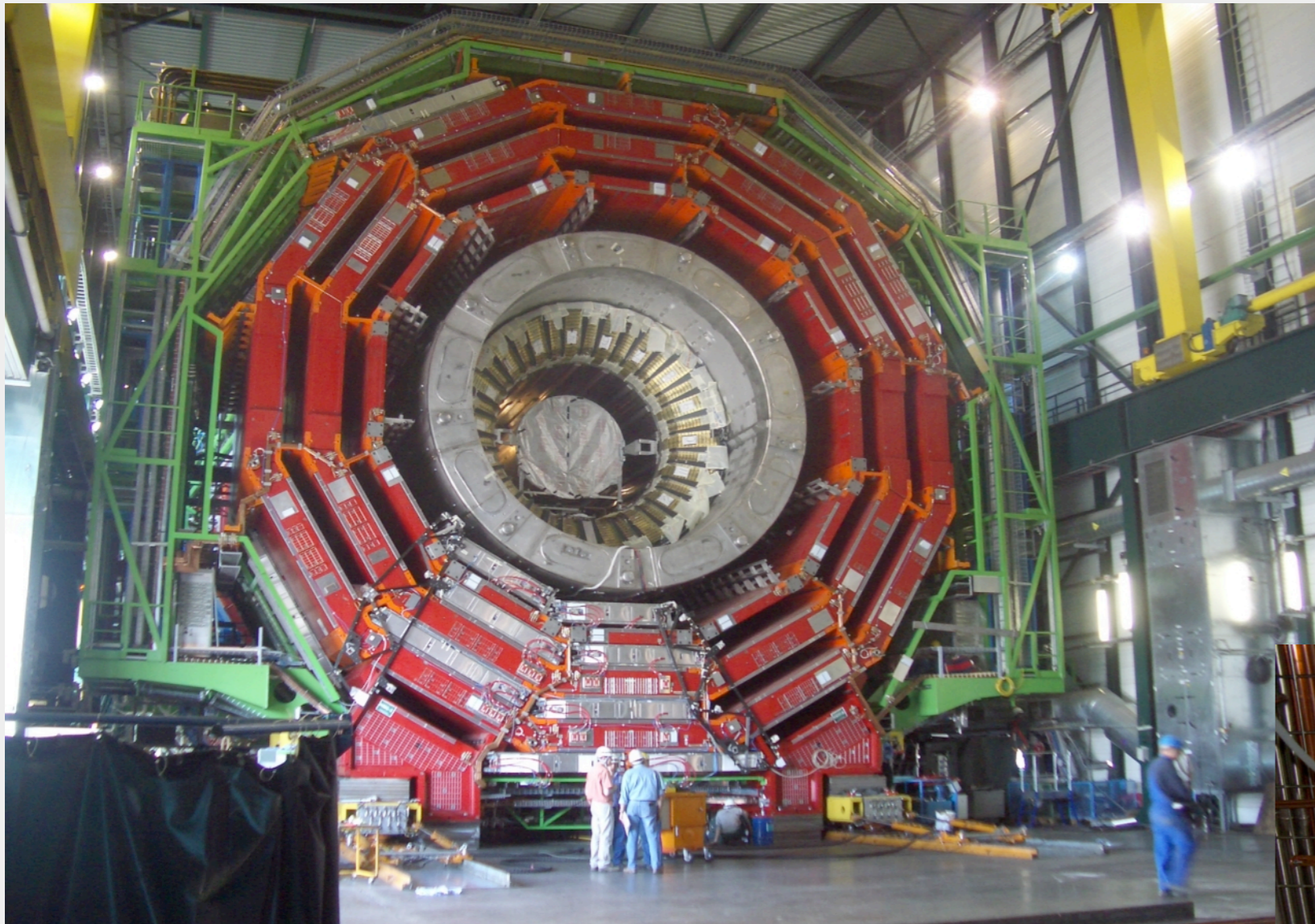
# MTCC detectors are inside yoke



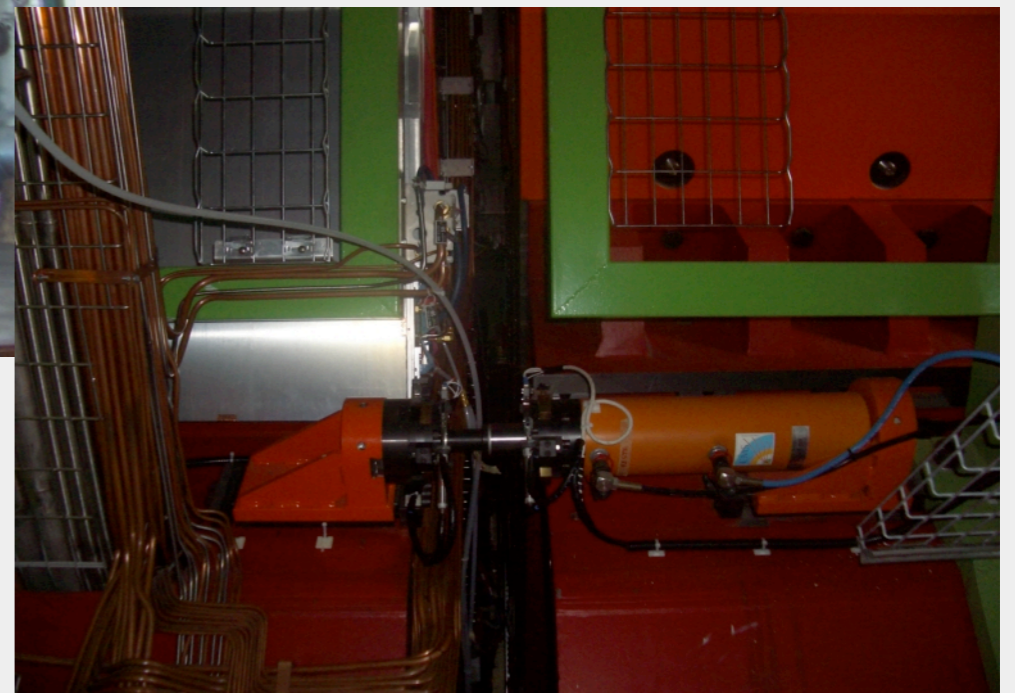
HCAL

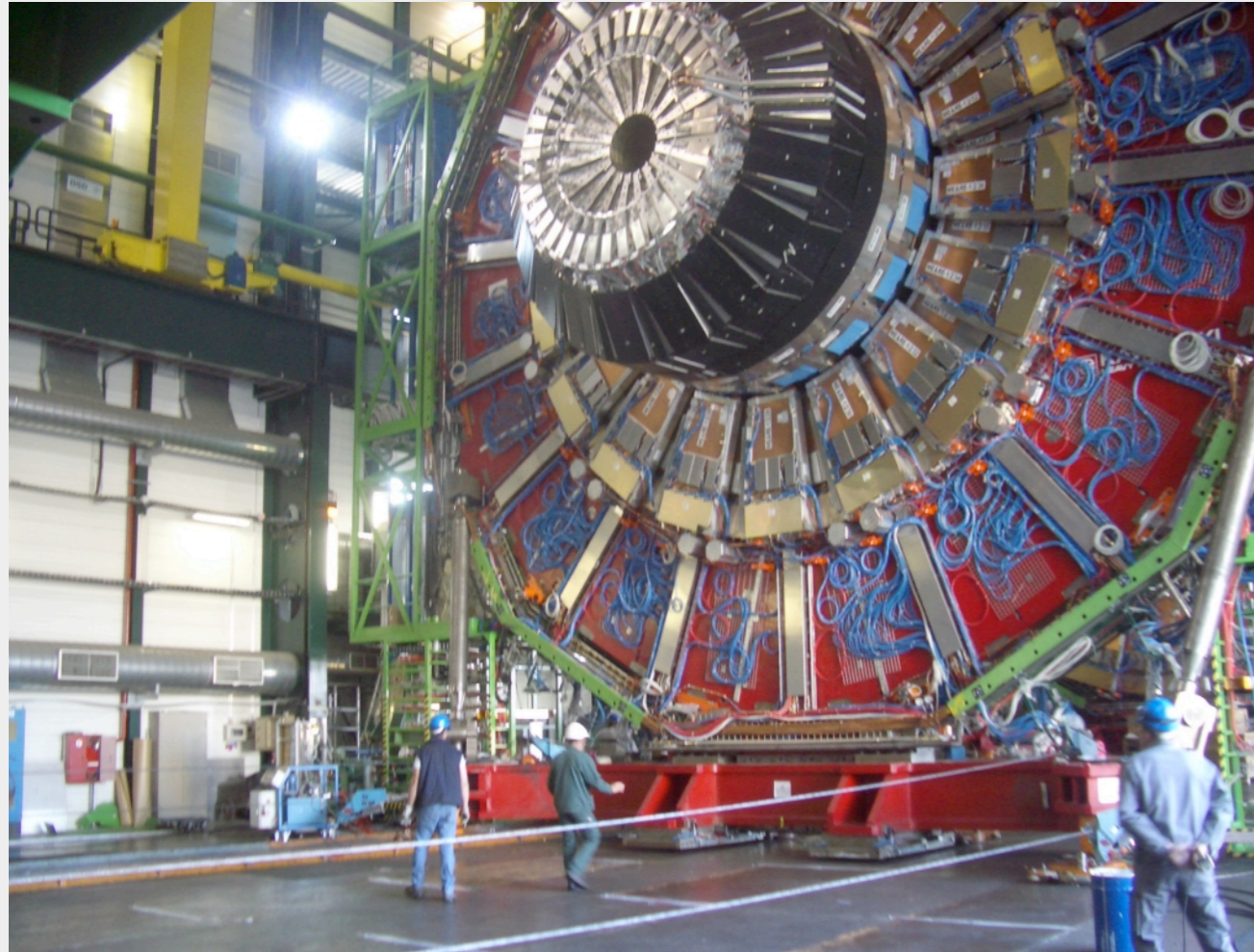
ECAL

Tracker

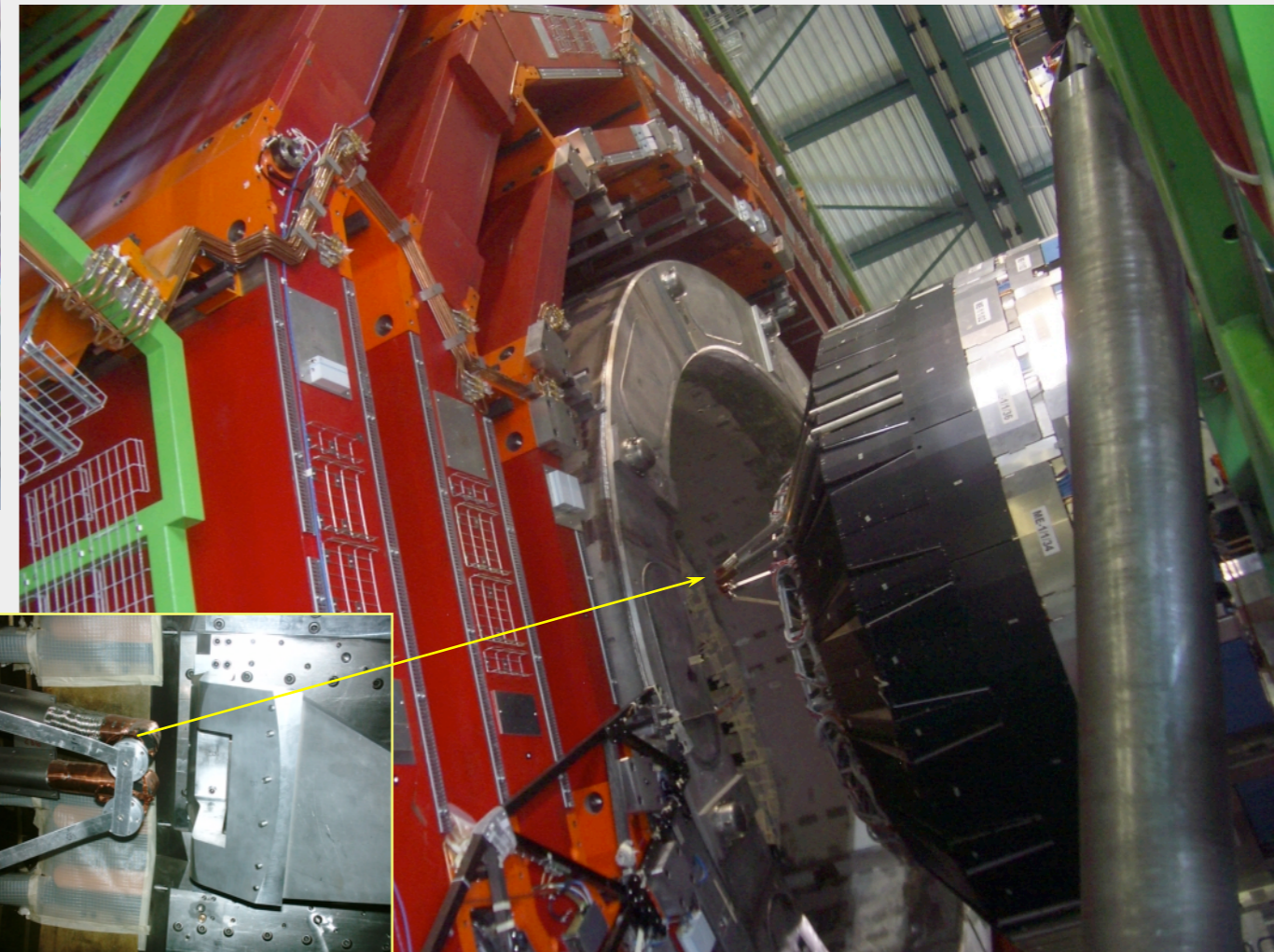


Both –end muon wheels are closed: airpads, grease pads + "proximity capture" hydraulic jacks

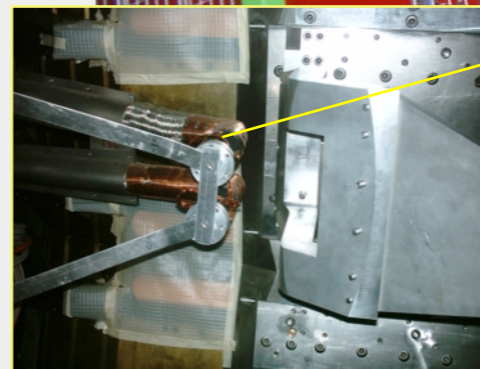


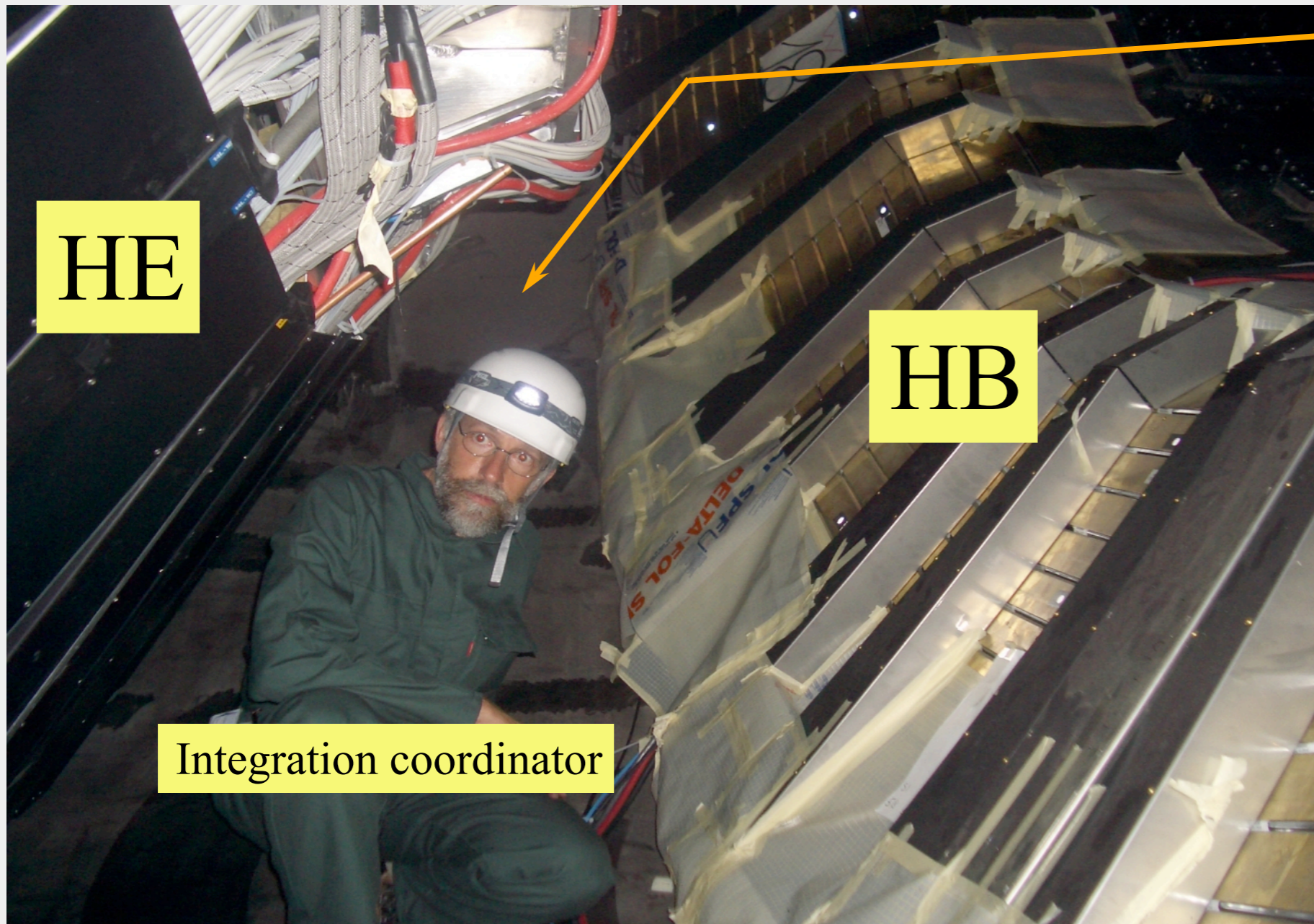


Heavier object, non-symmetric  
Lever arm insertion in vac-tank



Completion of RE1/3, ME1/3  
and RE 2/1, RE2/2 postponed until  
after field-mapping (MTCC phase 2)





HE

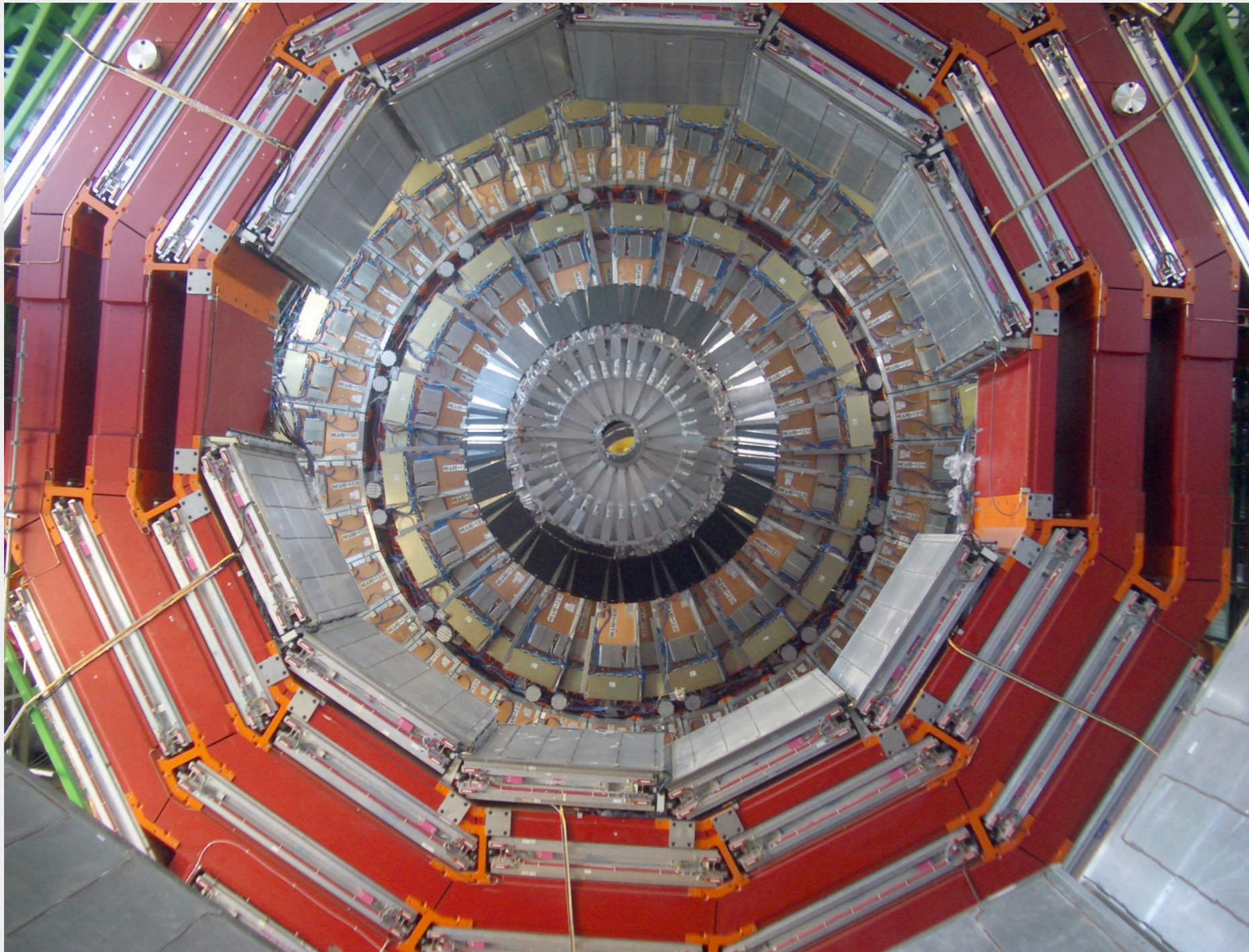
HB

Integration coordinator

53 degree gap  
~40mm when  
closed, field-off.

We will need people  
inside for YE+1 closing





After YB0+ surveyy

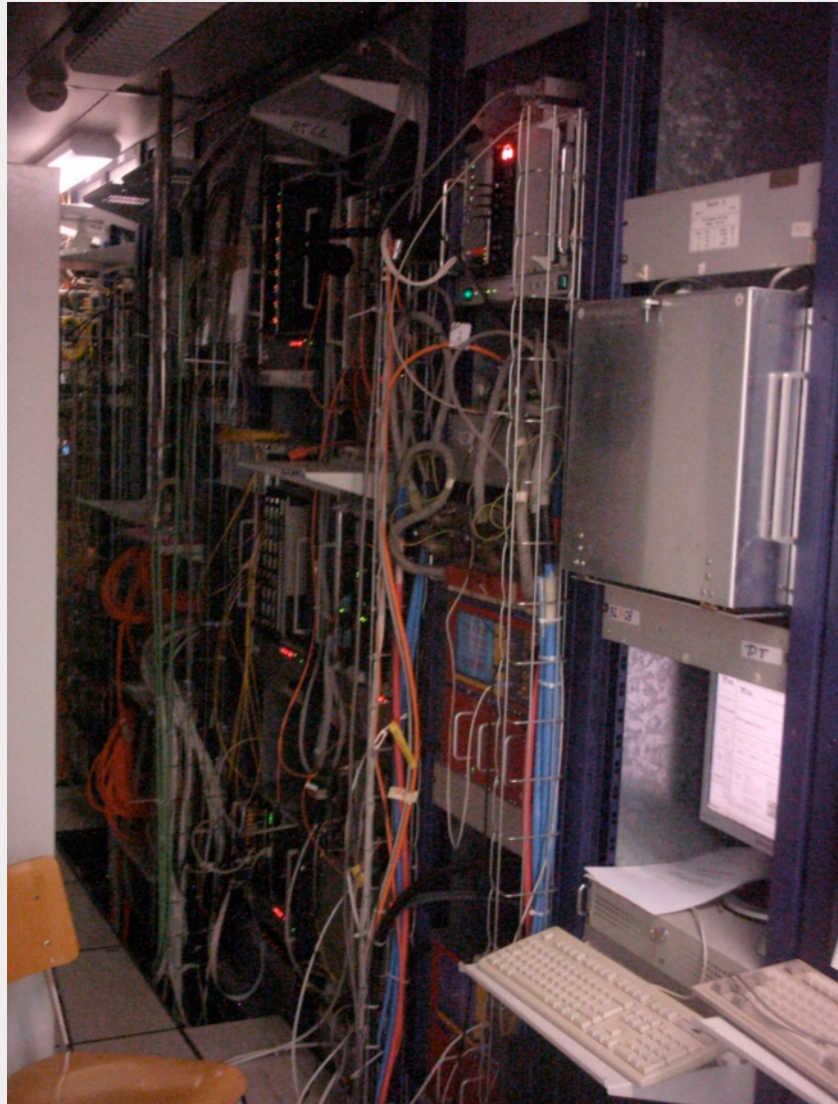
+ end muon wheels  
YB+1 and YB +2  
will be closed next

(allows final MTCC  
cabling to control  
barrack)

*endcaps should be  
closed by about 10  
Jul*



# MTCC Commissioning

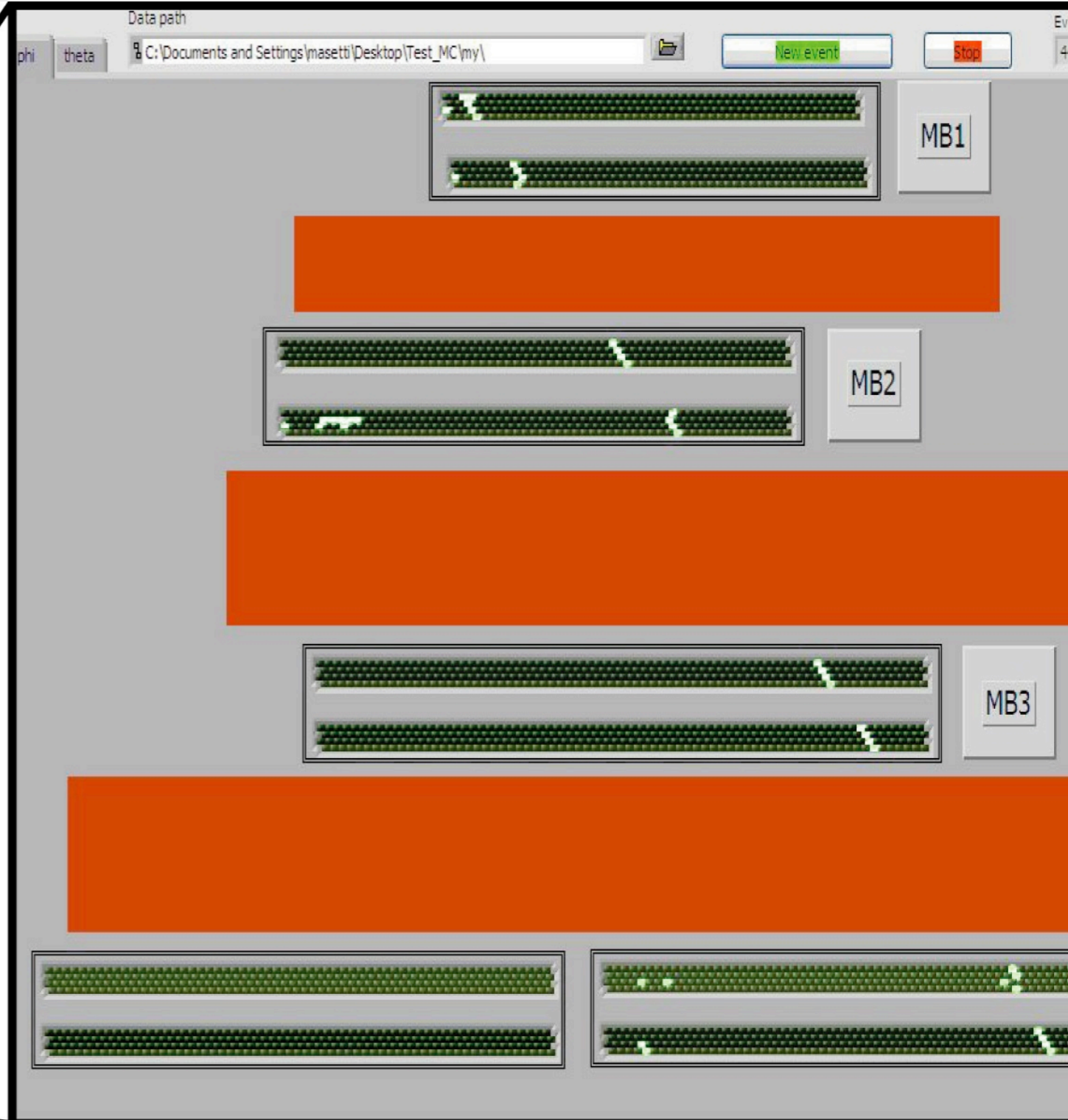
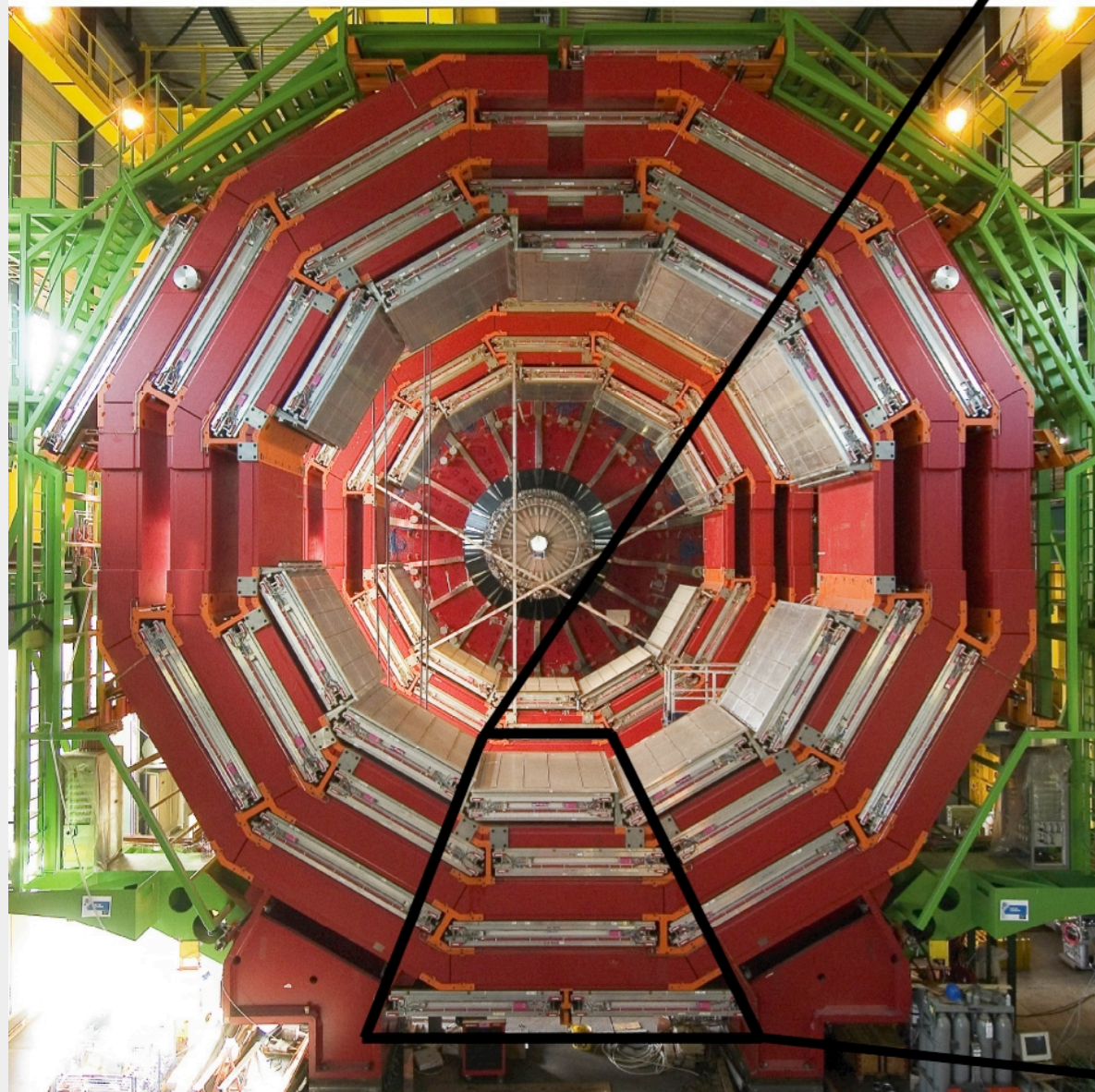


## DT Trigger in MTCC



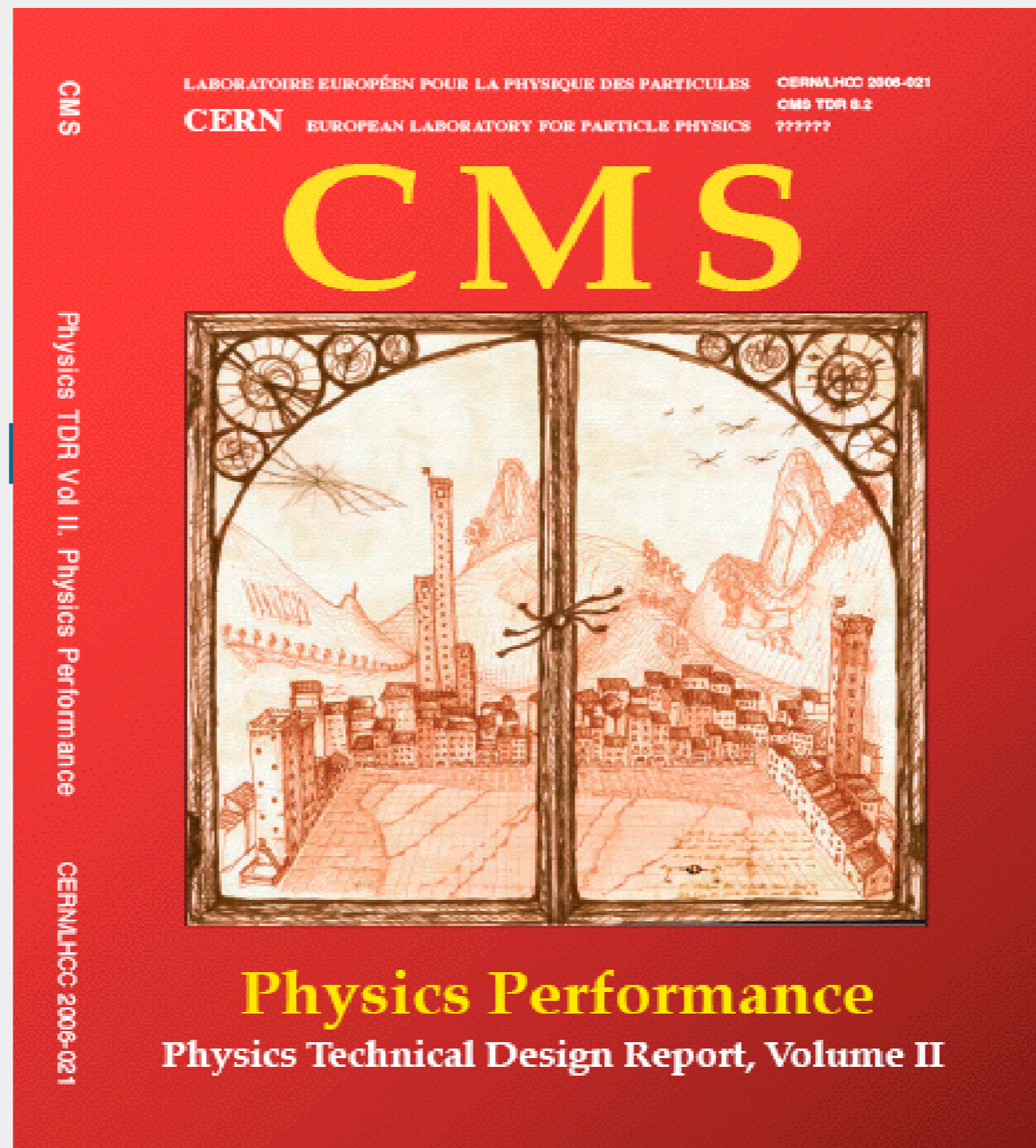
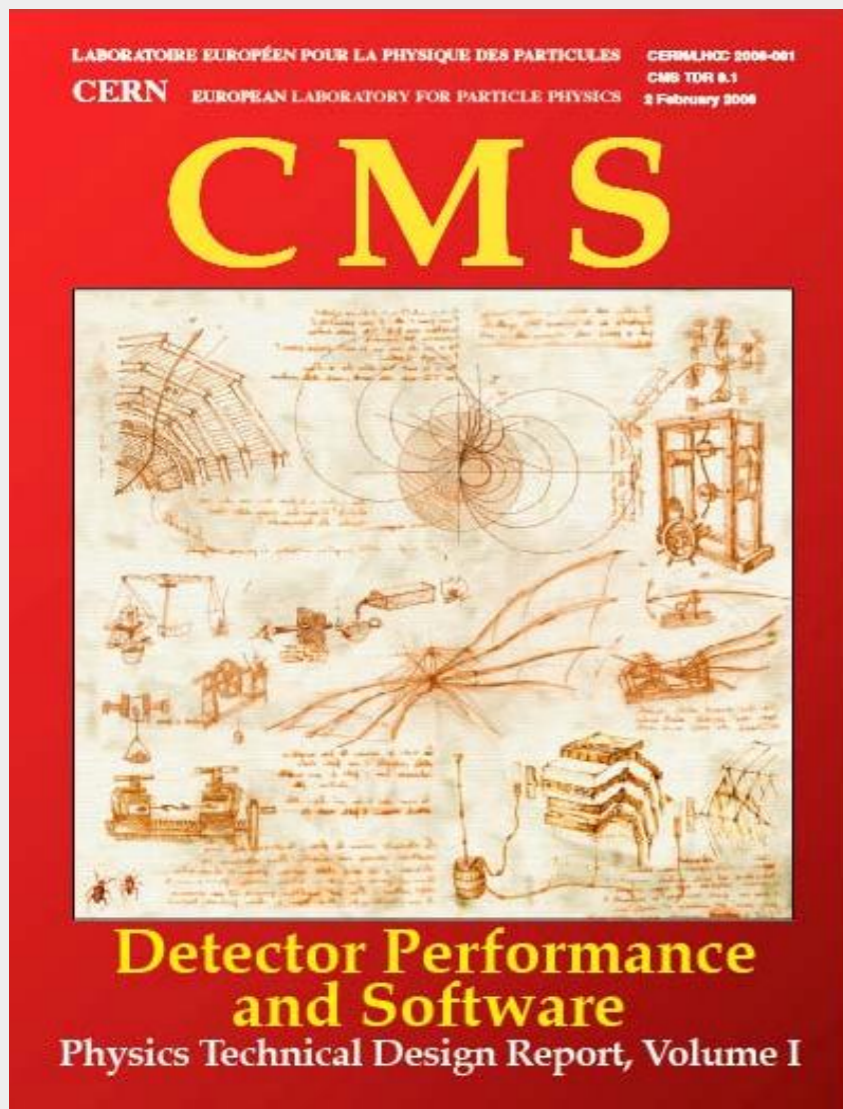


# Cosmics signal in muon chambers





# Physics at LHC with CMS



650 pages  
308 figures  
207 tables  
1.50 Kg

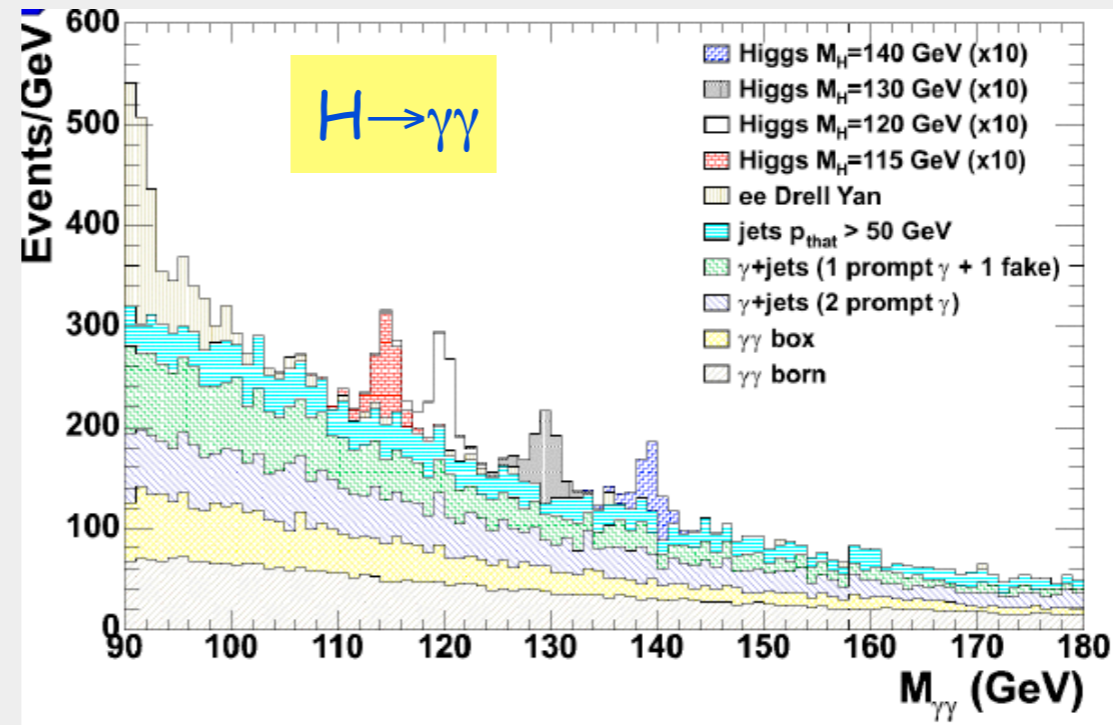
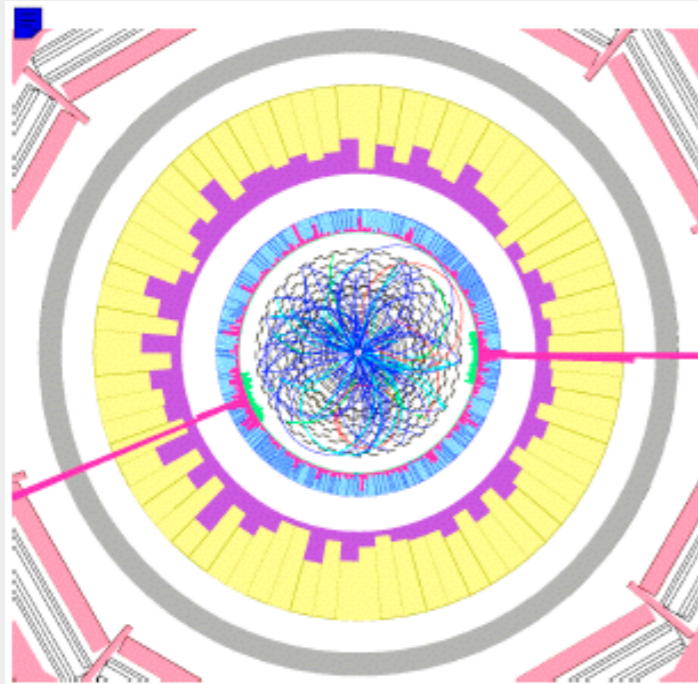
<http://cmsdoc.cern.ch/cms/cpt/tdr/>

CERN/LHCC 2006-001

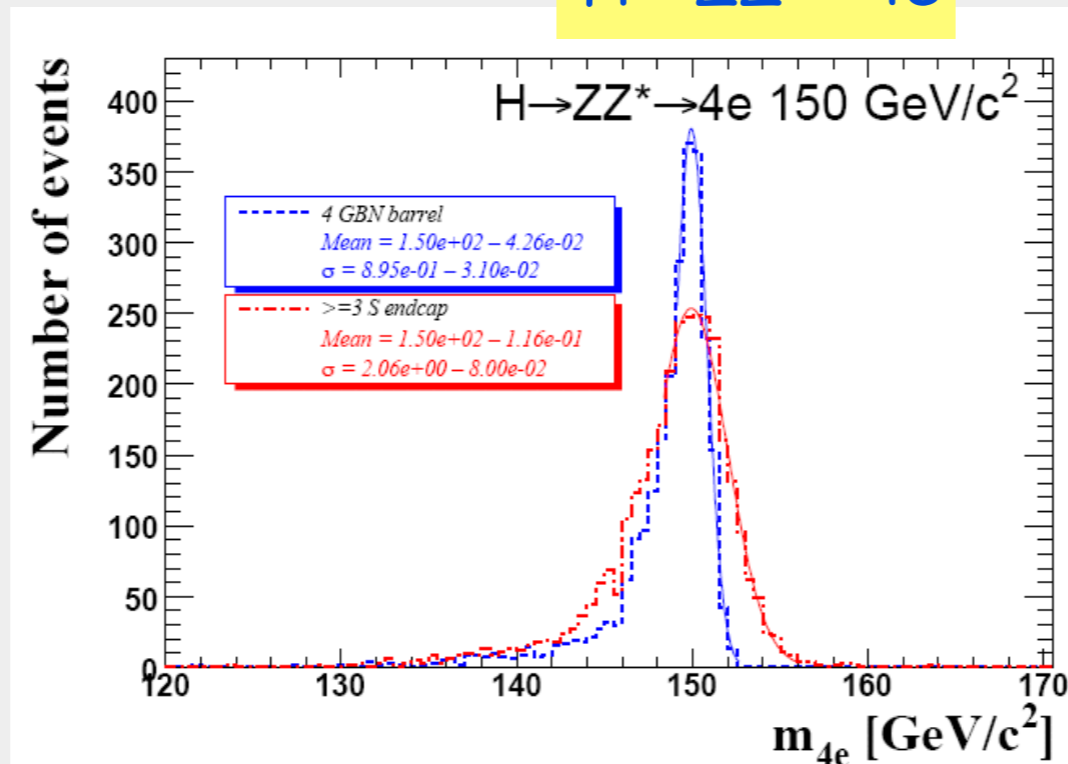
Published

CERN/LHCC 2006-021

Coming June 2006



$H \rightarrow ZZ \rightarrow 4e$



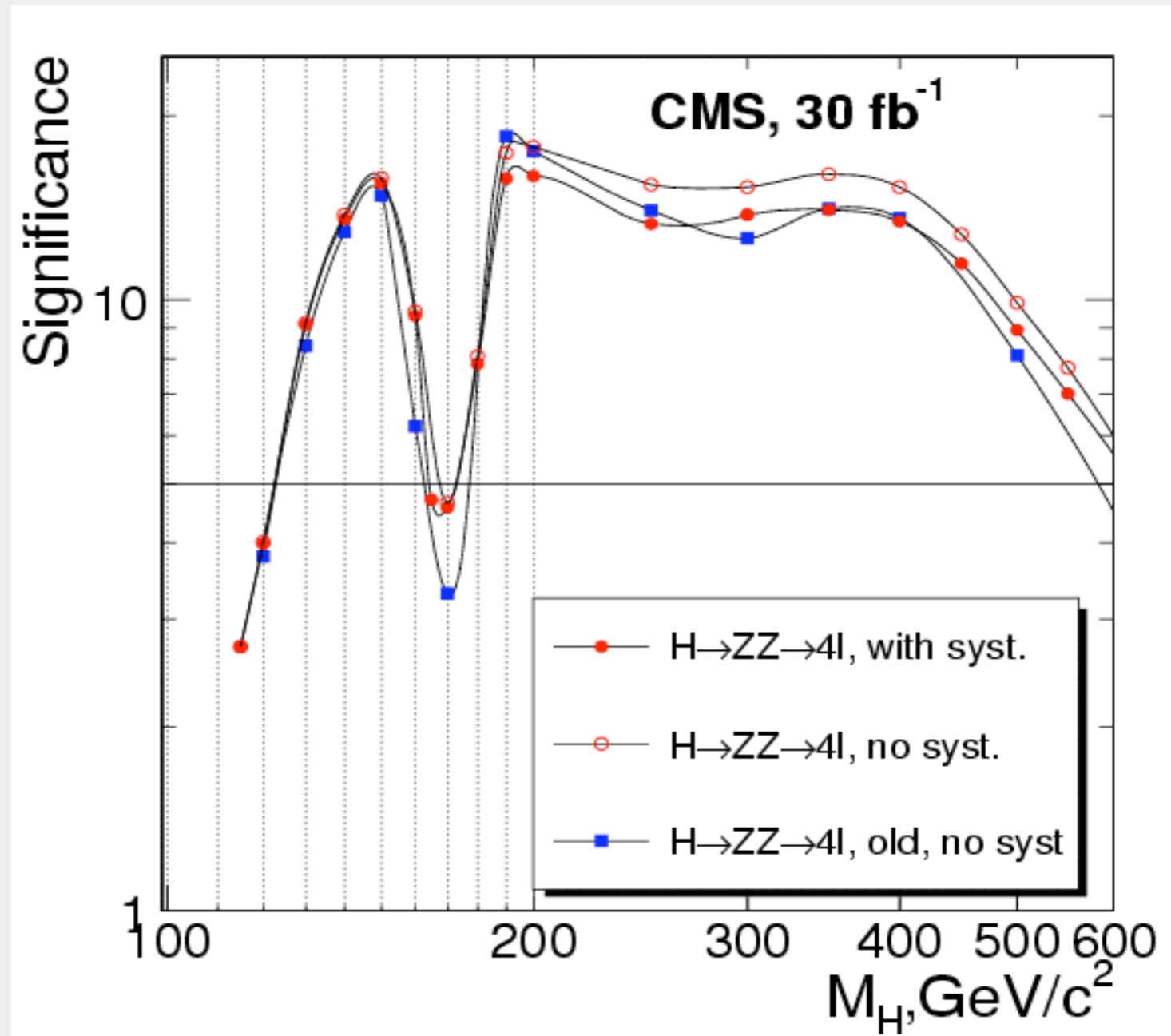
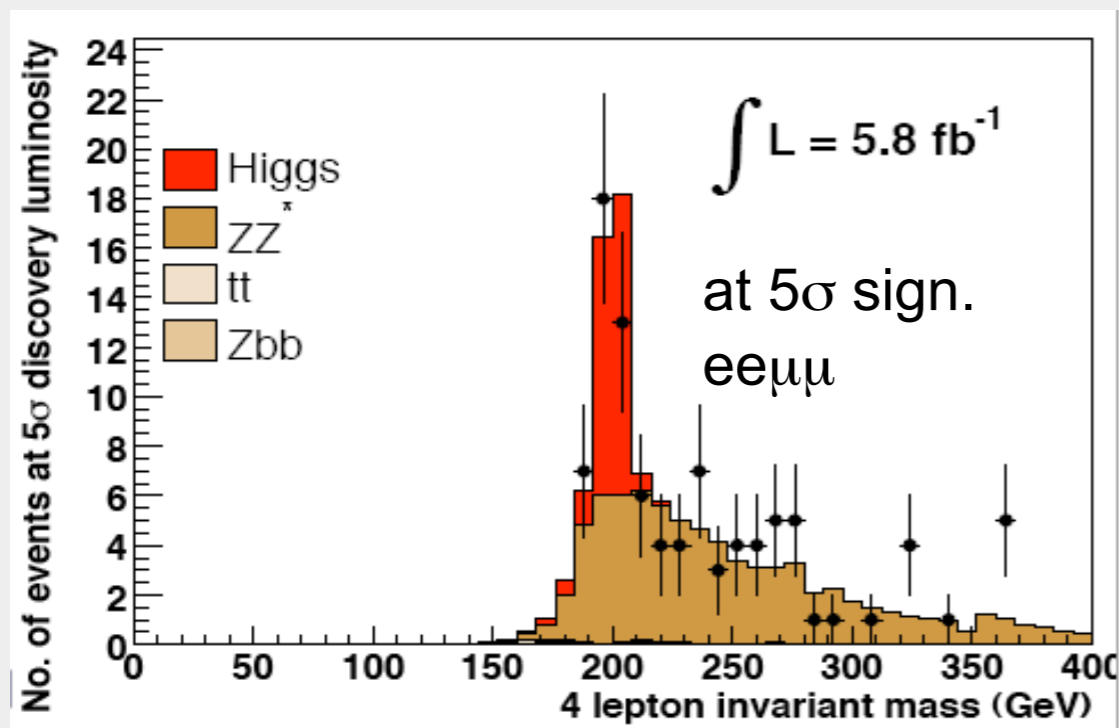
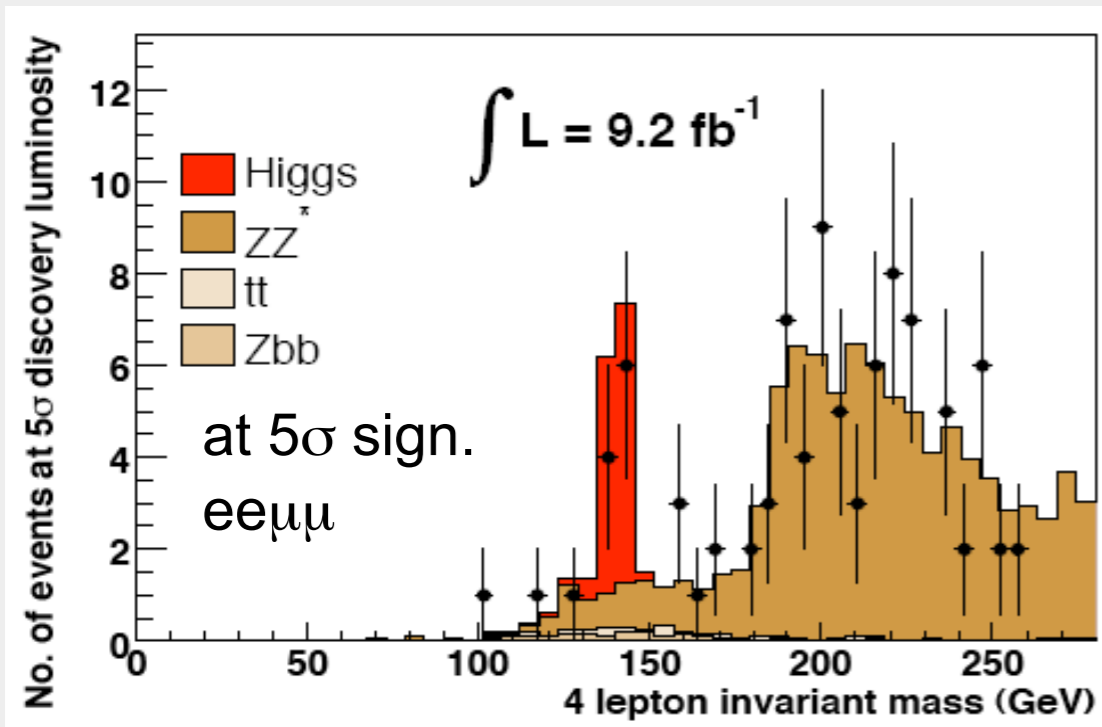
Mass measurements for two different samples of selected electrons



# Golden channel $H \rightarrow ZZ \rightarrow 4l$



**Signal significance: new vs old results; no big change**

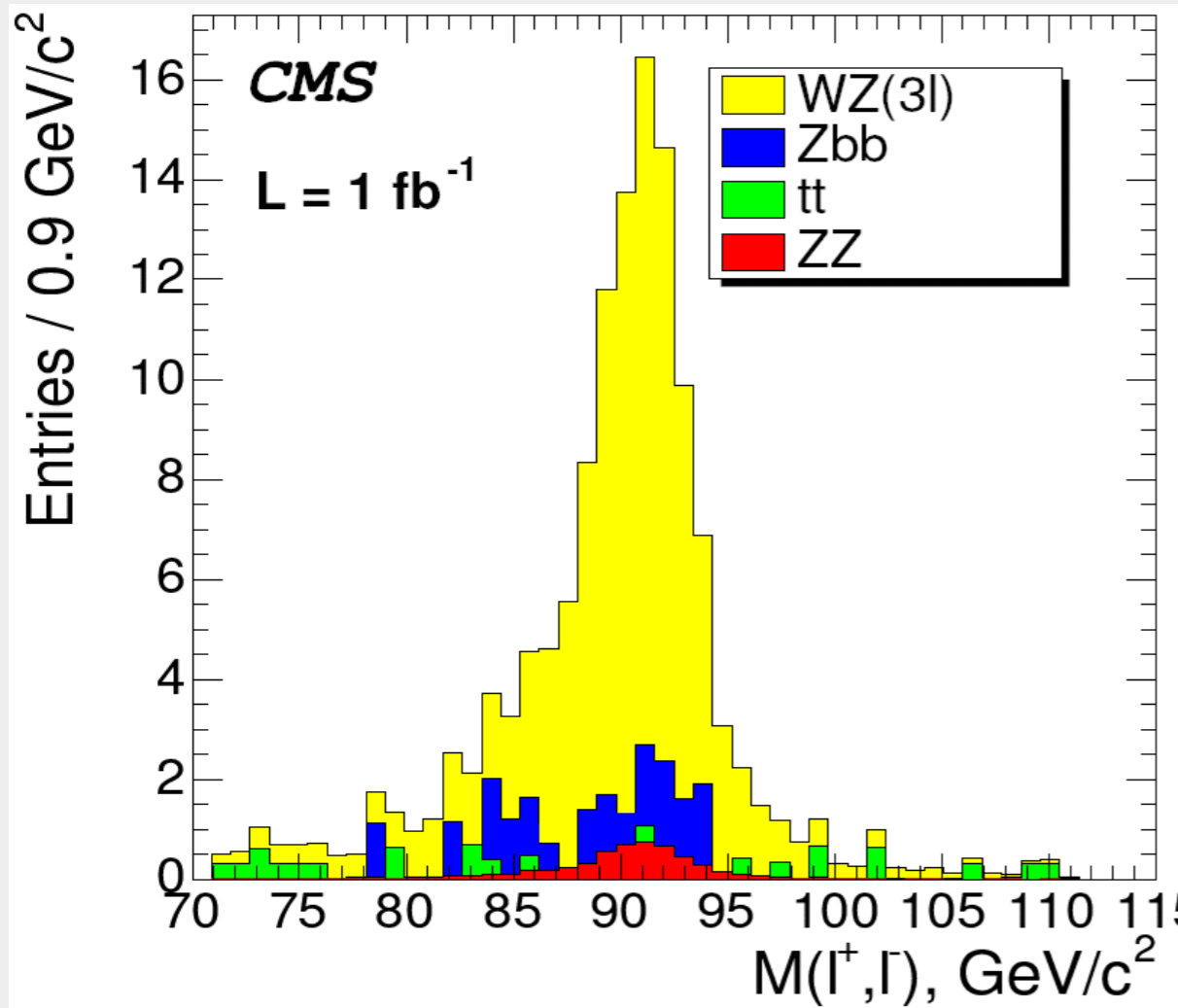




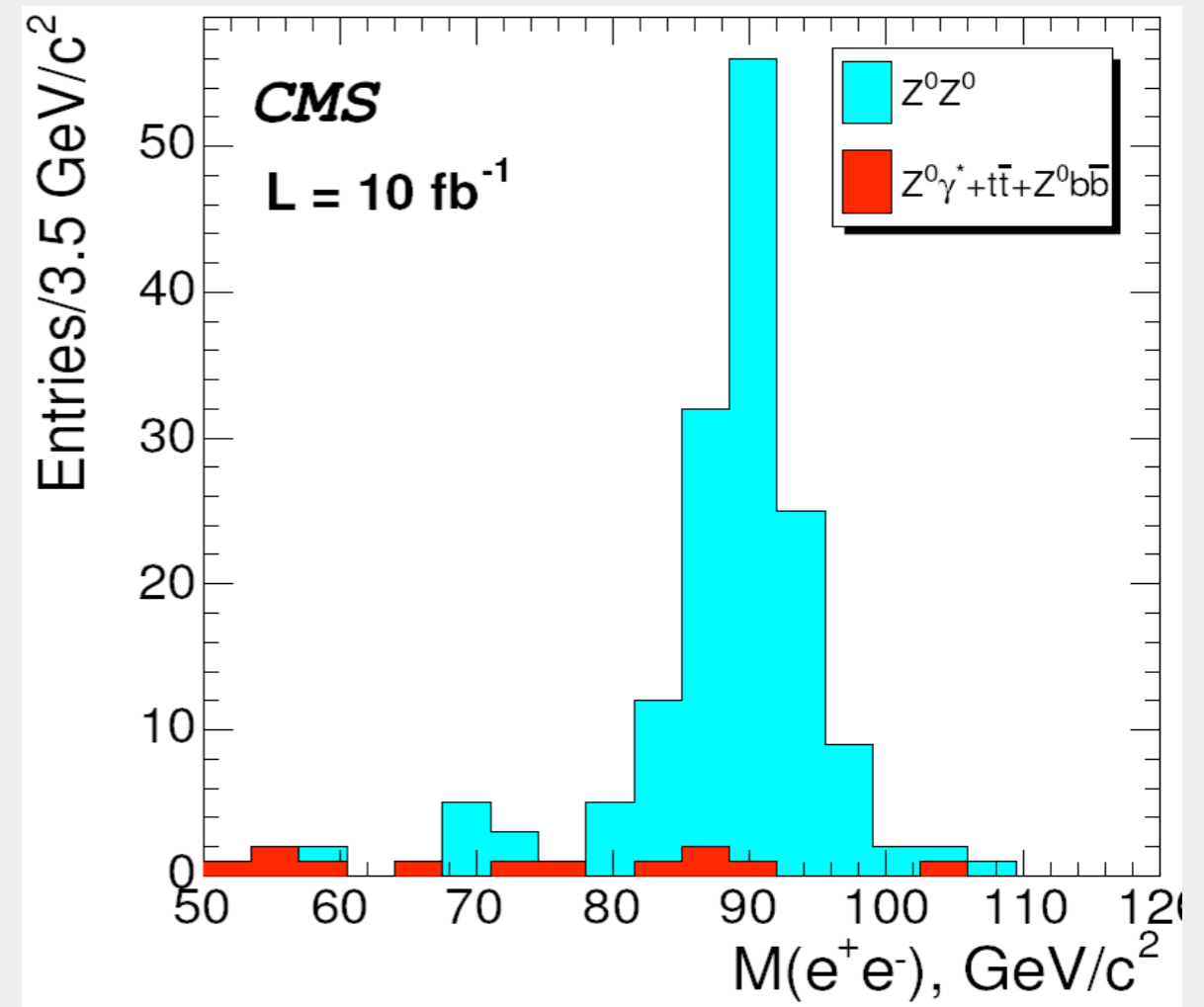
# Di-boson Production



▪  $WZ \rightarrow 3l + \nu$



▪  $ZZ \rightarrow 4e$



Observation of both processes possible with  $< 1 \text{ fb}^{-1}$

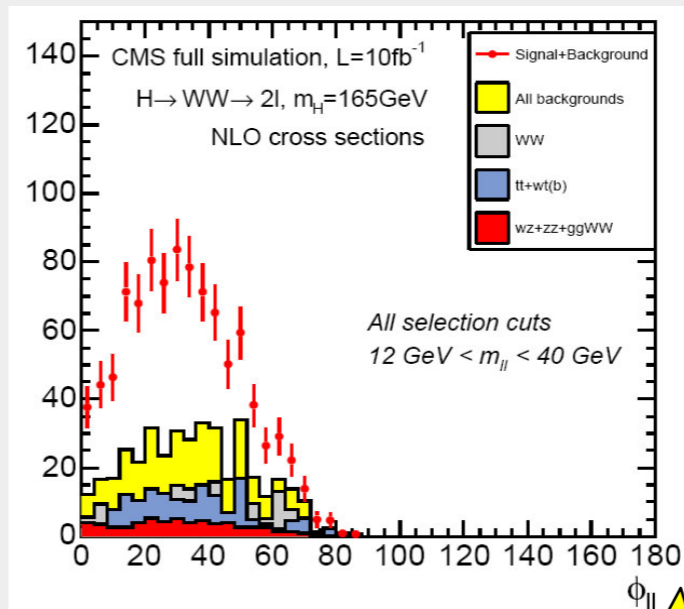


# Standard Model Higgs: $H \rightarrow WW \rightarrow 2l2\nu$

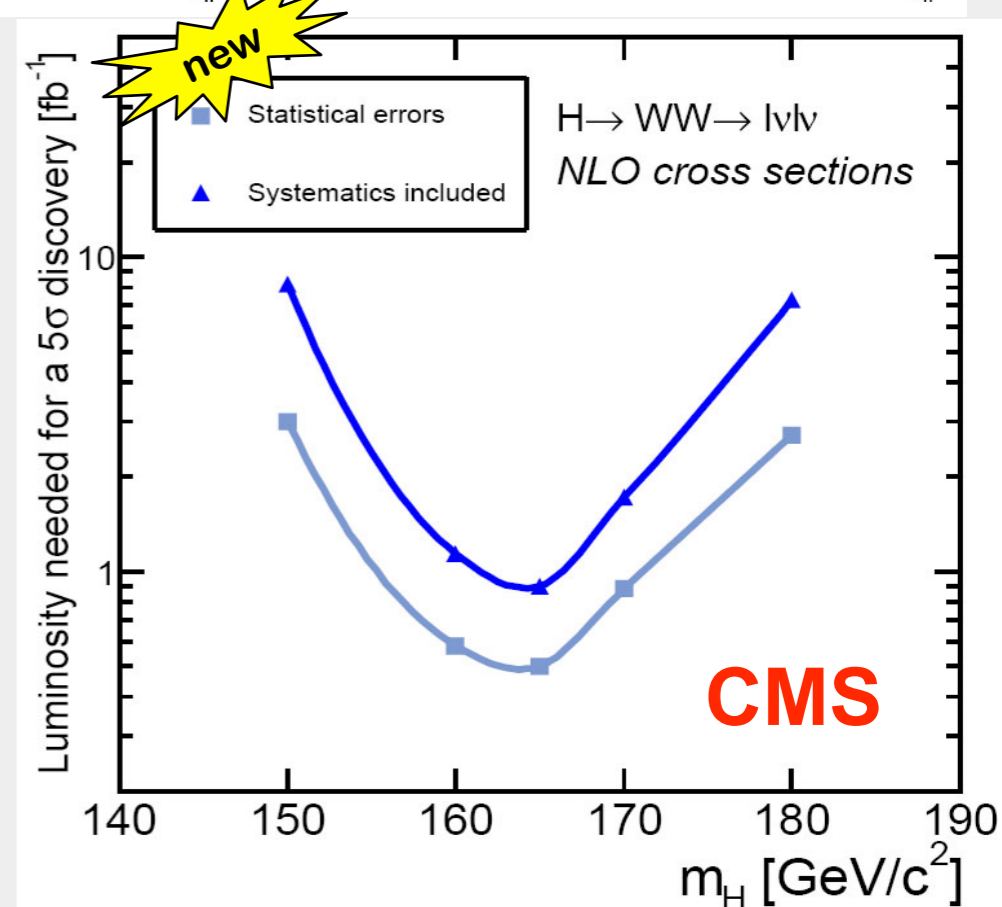
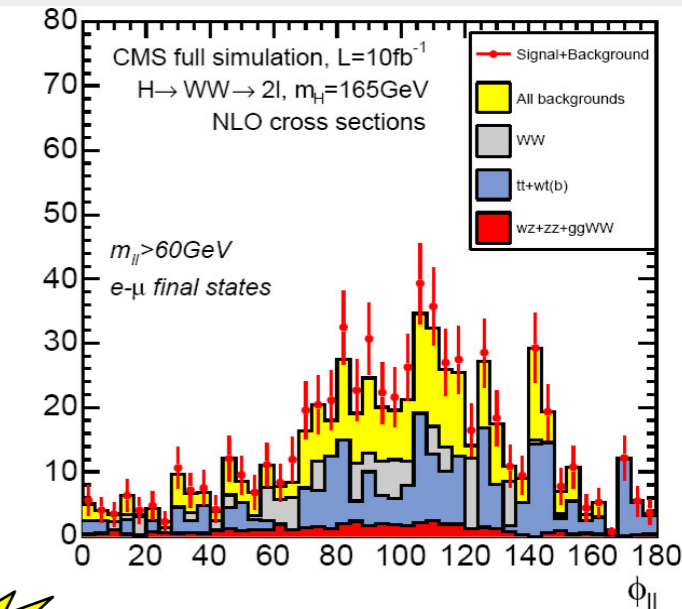


- **Backgrounds:**
  - $WW$ ,  $tt$ ,  $Wt(b)$ ,  $WZ$ ,  $ZZ$
  - $gg \rightarrow WW$  (box)
- **Analysis:**
  - $K_{\text{NLO}}(p_T^{WW})$
  - cuts:
    - $e/\mu$  kinematics, isolation, jet veto, MET
  - counting experiment, no peak
  - background from a control sample:
    - signal:  $12 < m_{ll} < 40$  GeV
    - control sample:  $m_{e\mu} > 60$  GeV
  - reduce syst. errors; pay stat. penalty
  - systematic errors are folded in

### Signal Region

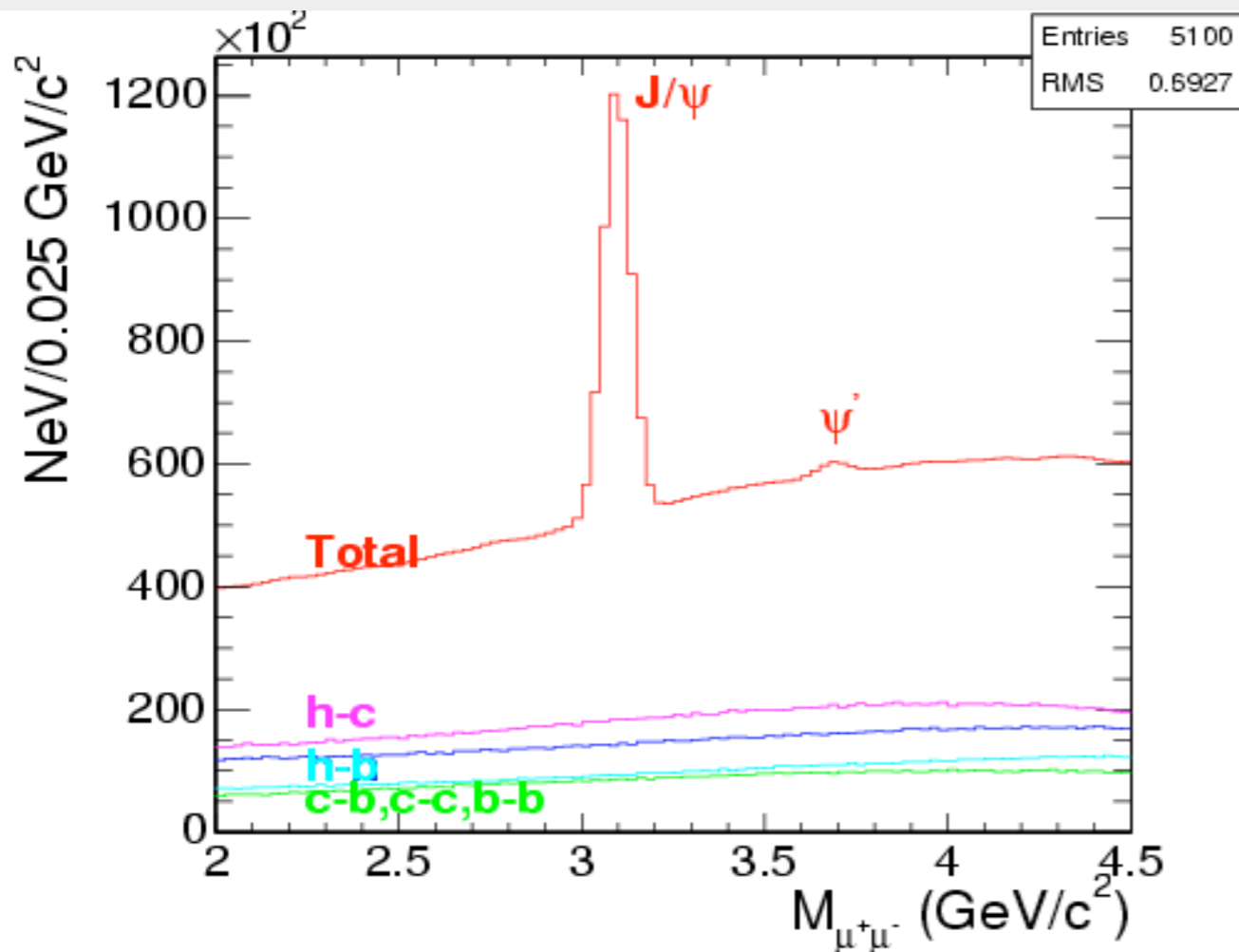


### Control Sample



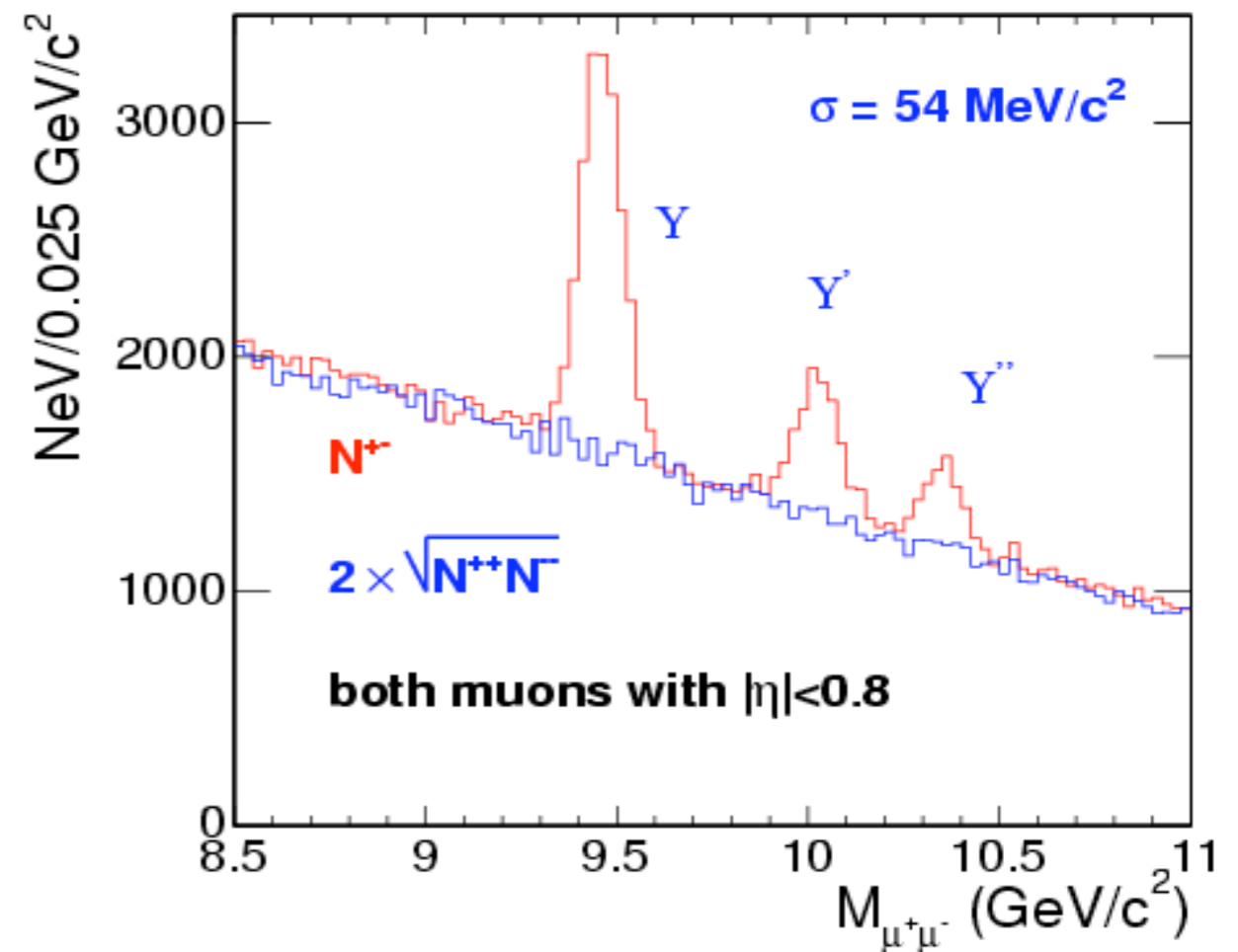


J/ψ  
 Full acceptance  
 Simulated background sources  
 Assume  $dN_{ch}/d\eta \sim 2500$



~140-180 kevents/nominal year

Upsilon  
 Barrel only  
 Same-sign muon subtraction  
 Assume  $dN_{ch}/d\eta \sim 2500$



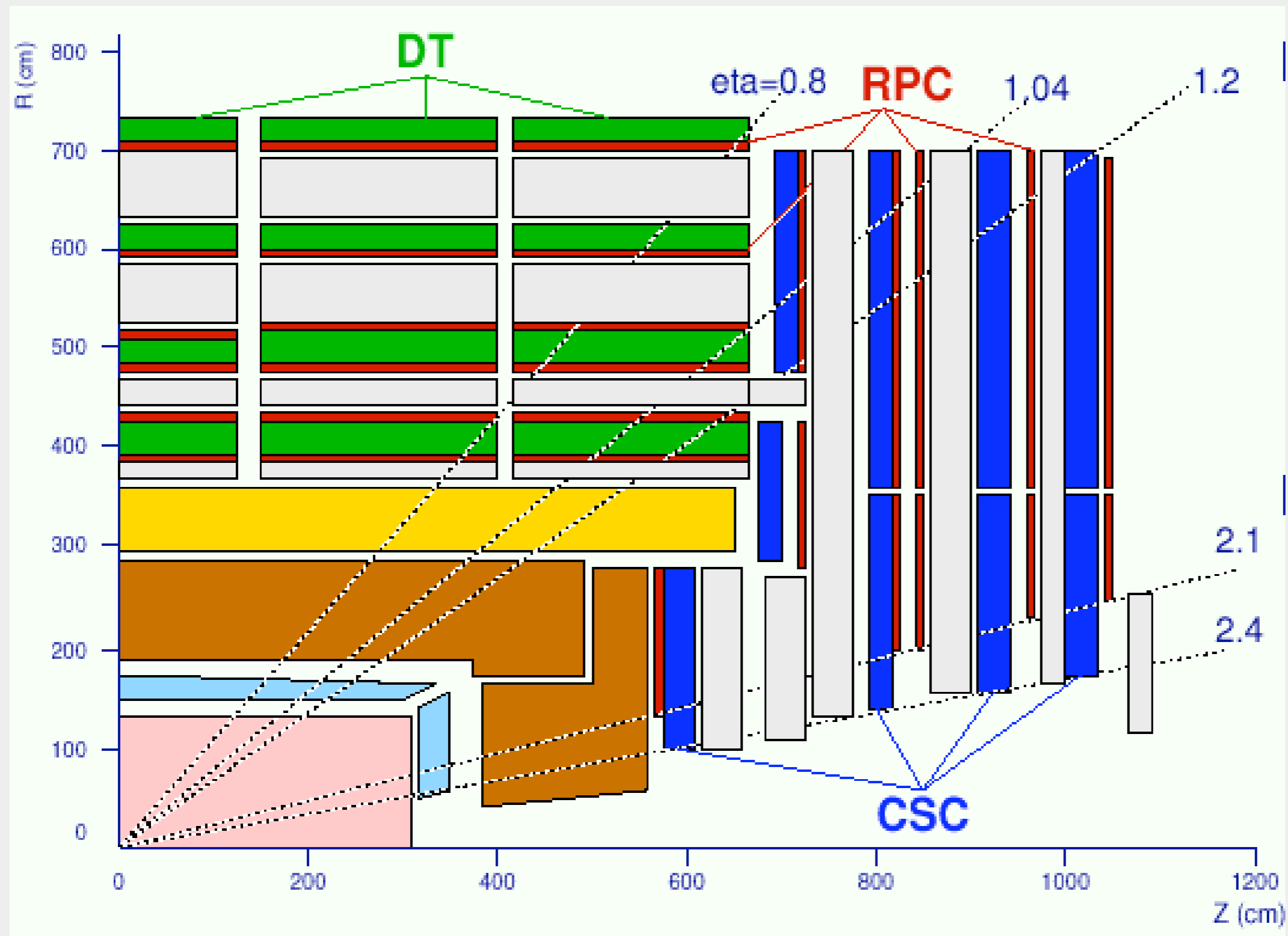
Y ~20-25 kevents/nominal year

Y' ~6-7 kevents

Y'' ~3-4 kevents

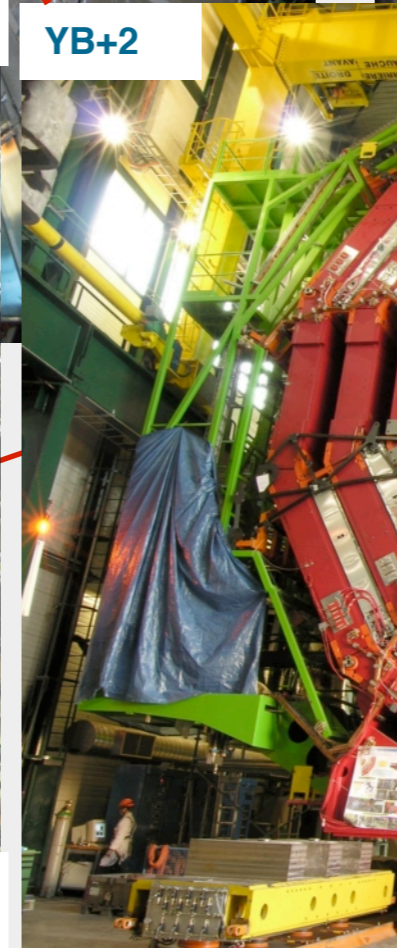
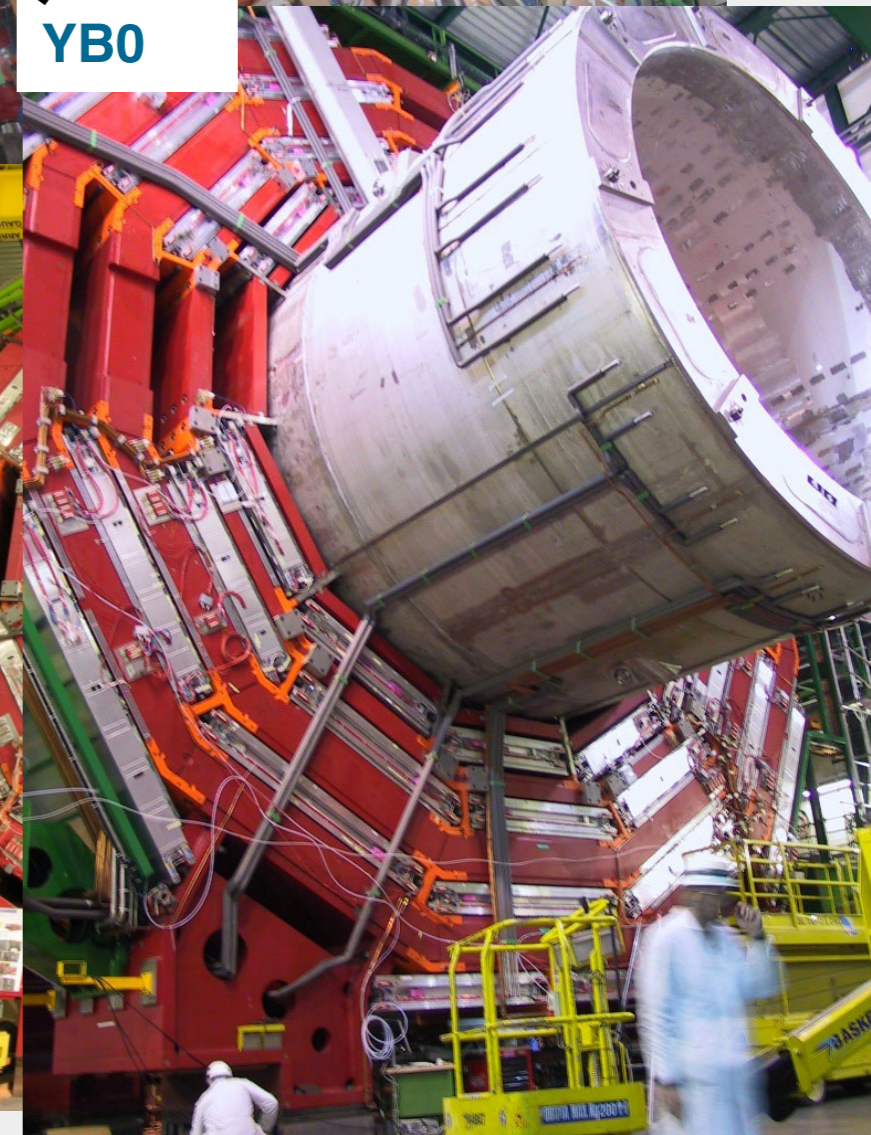
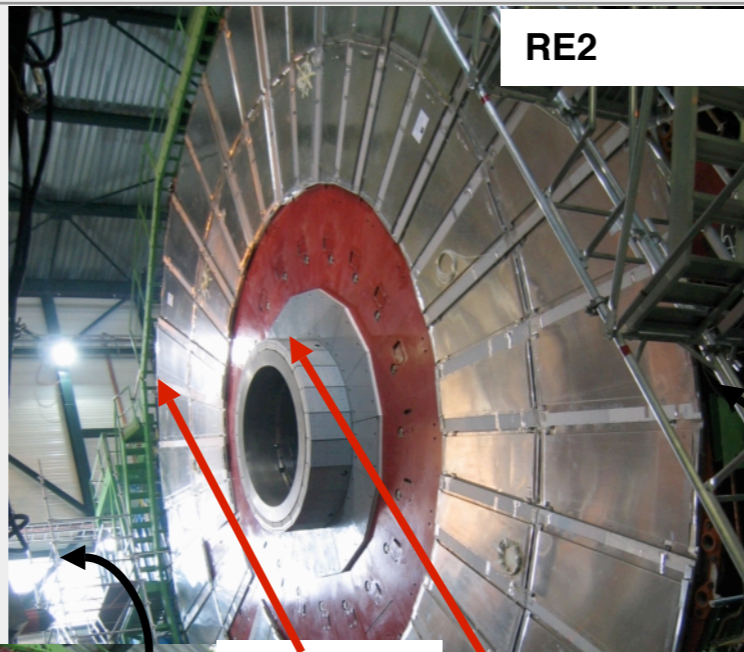
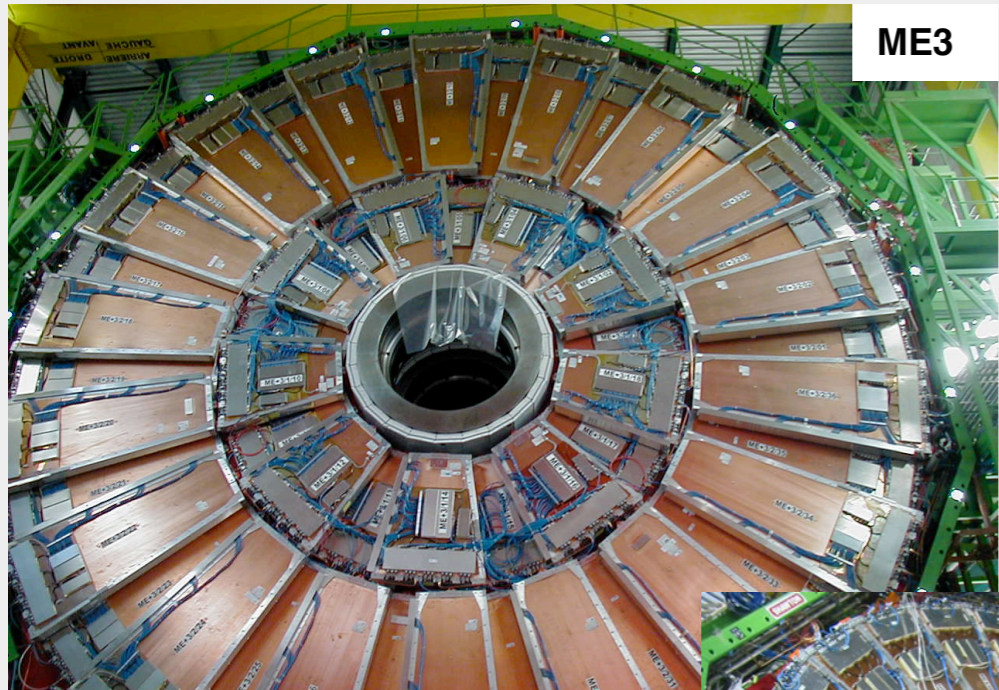


# CMS muon system





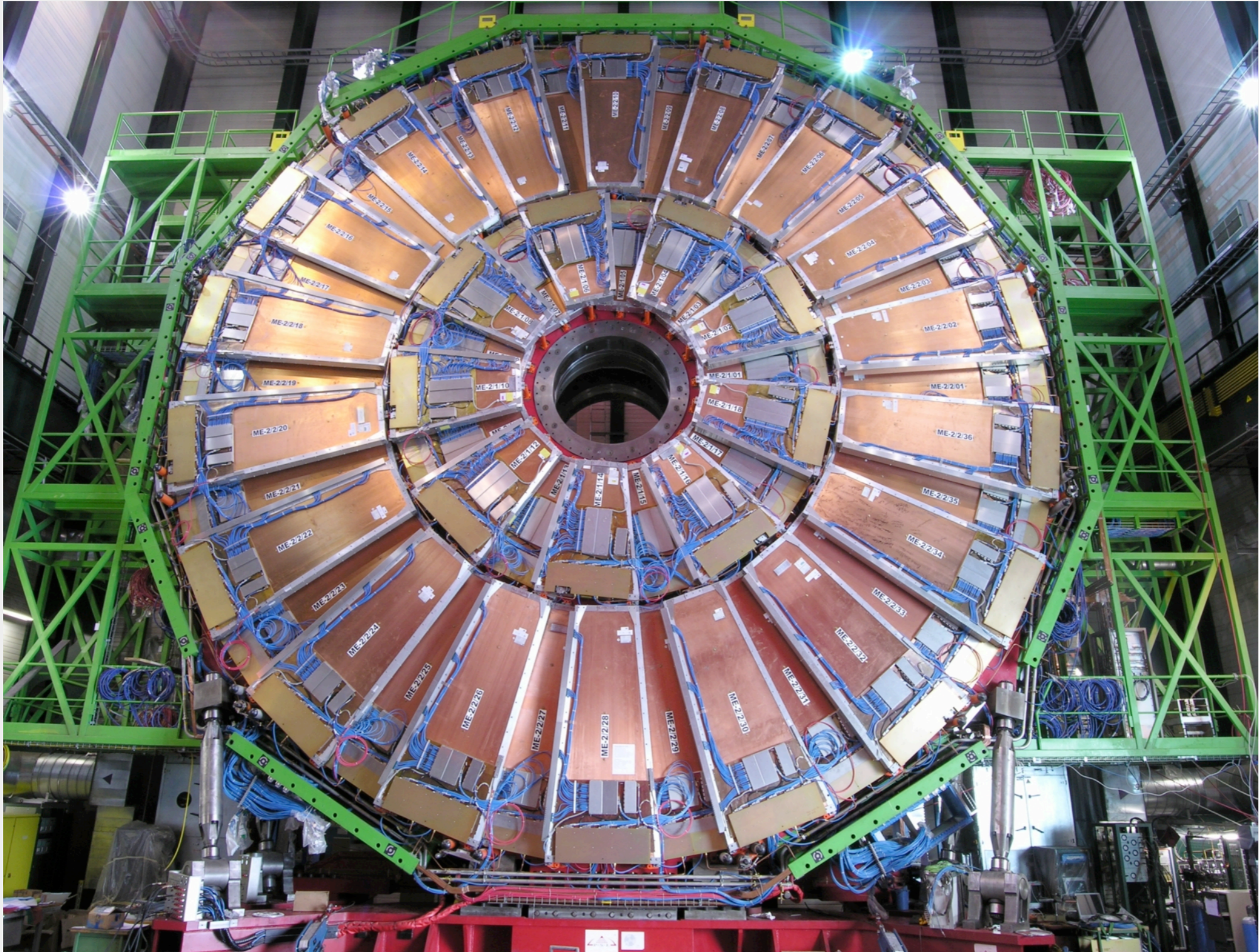
# Muons Installation and Commissioning



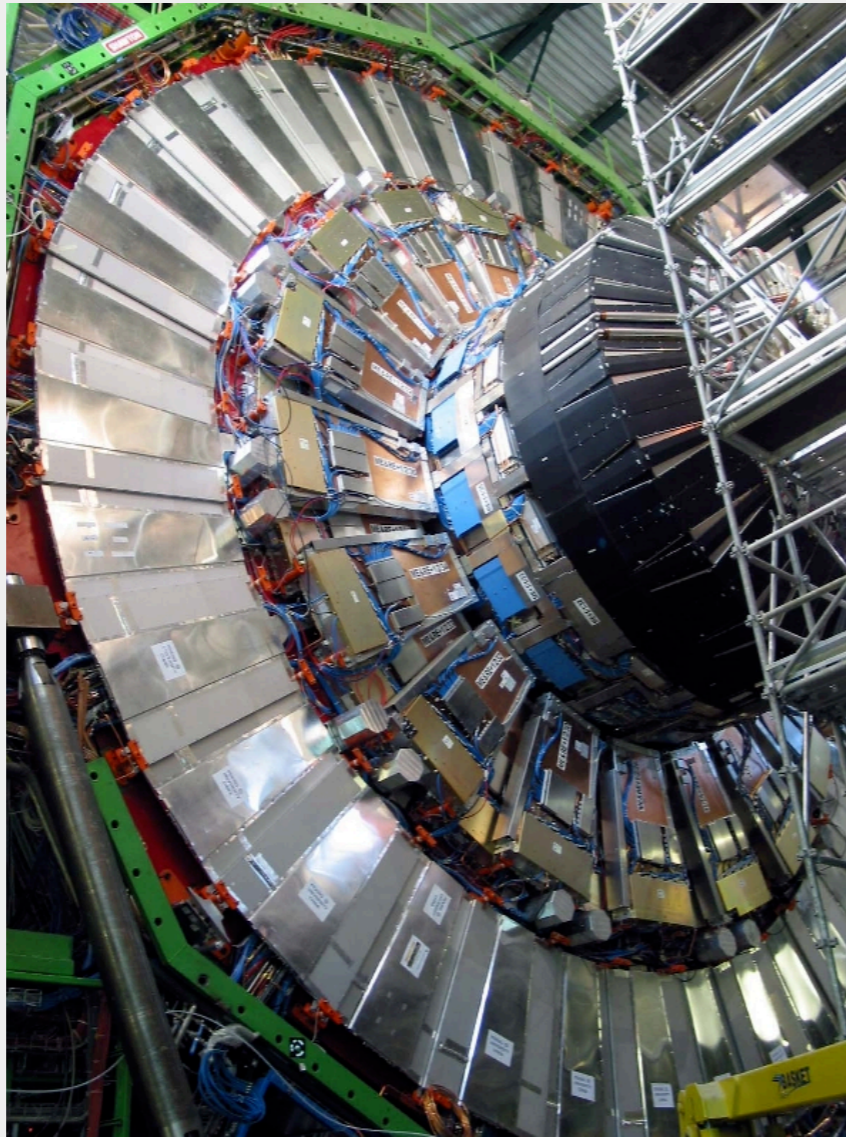
ME1R  
E1



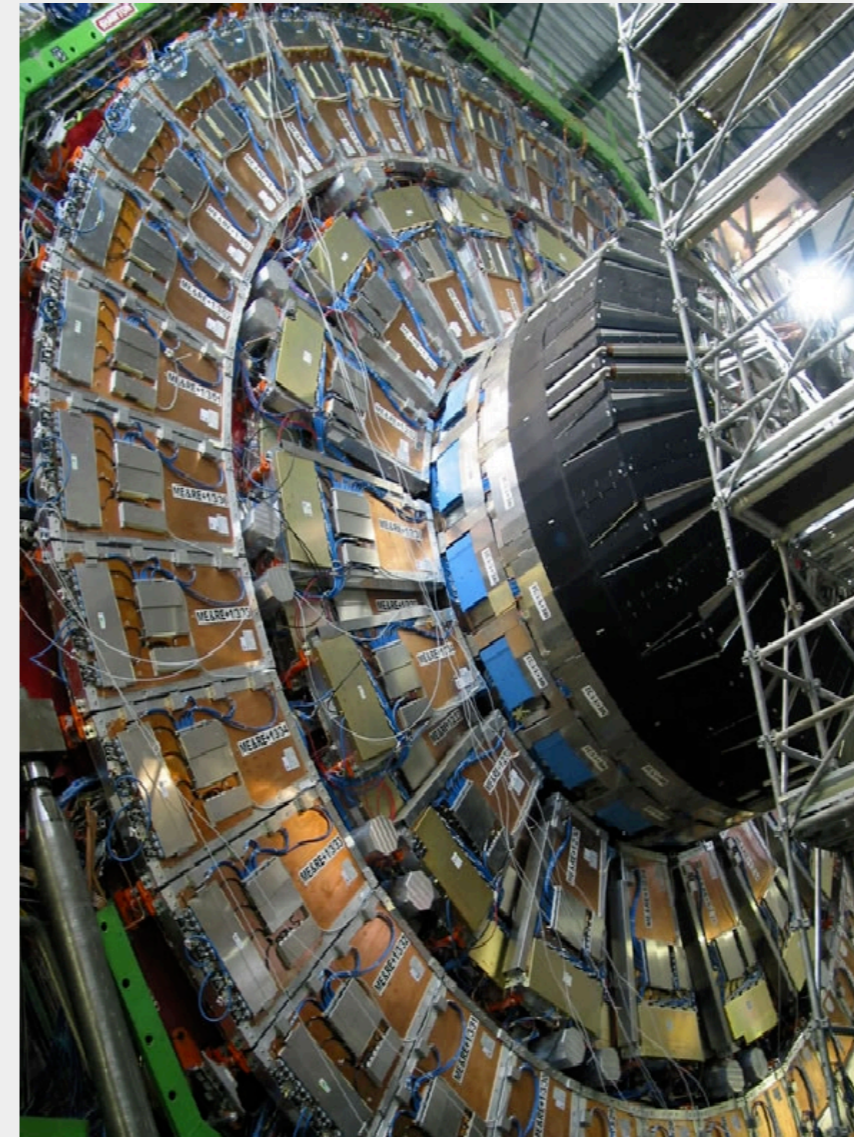
# Complete ME-2 Station



# EndCap muon chambers



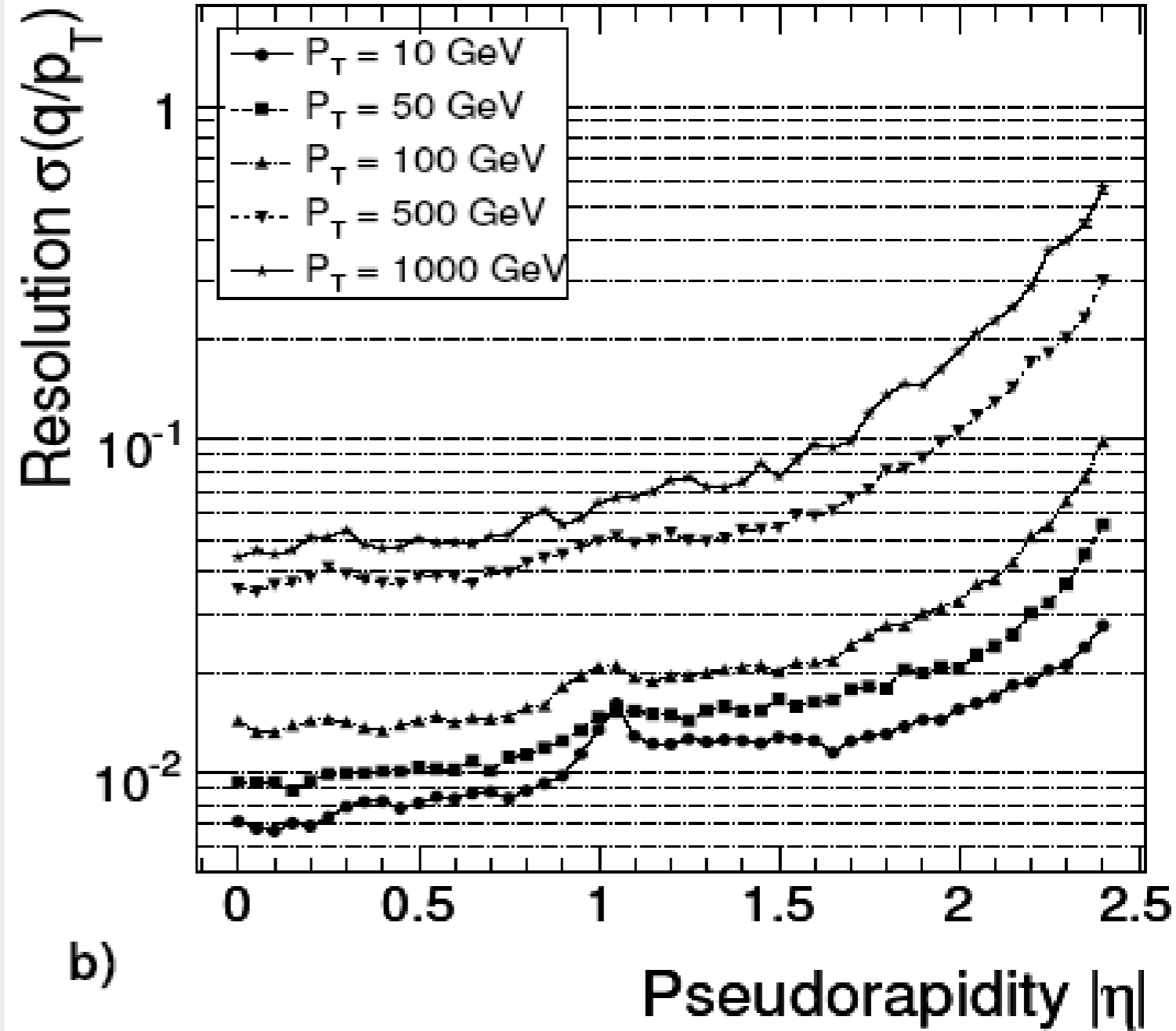
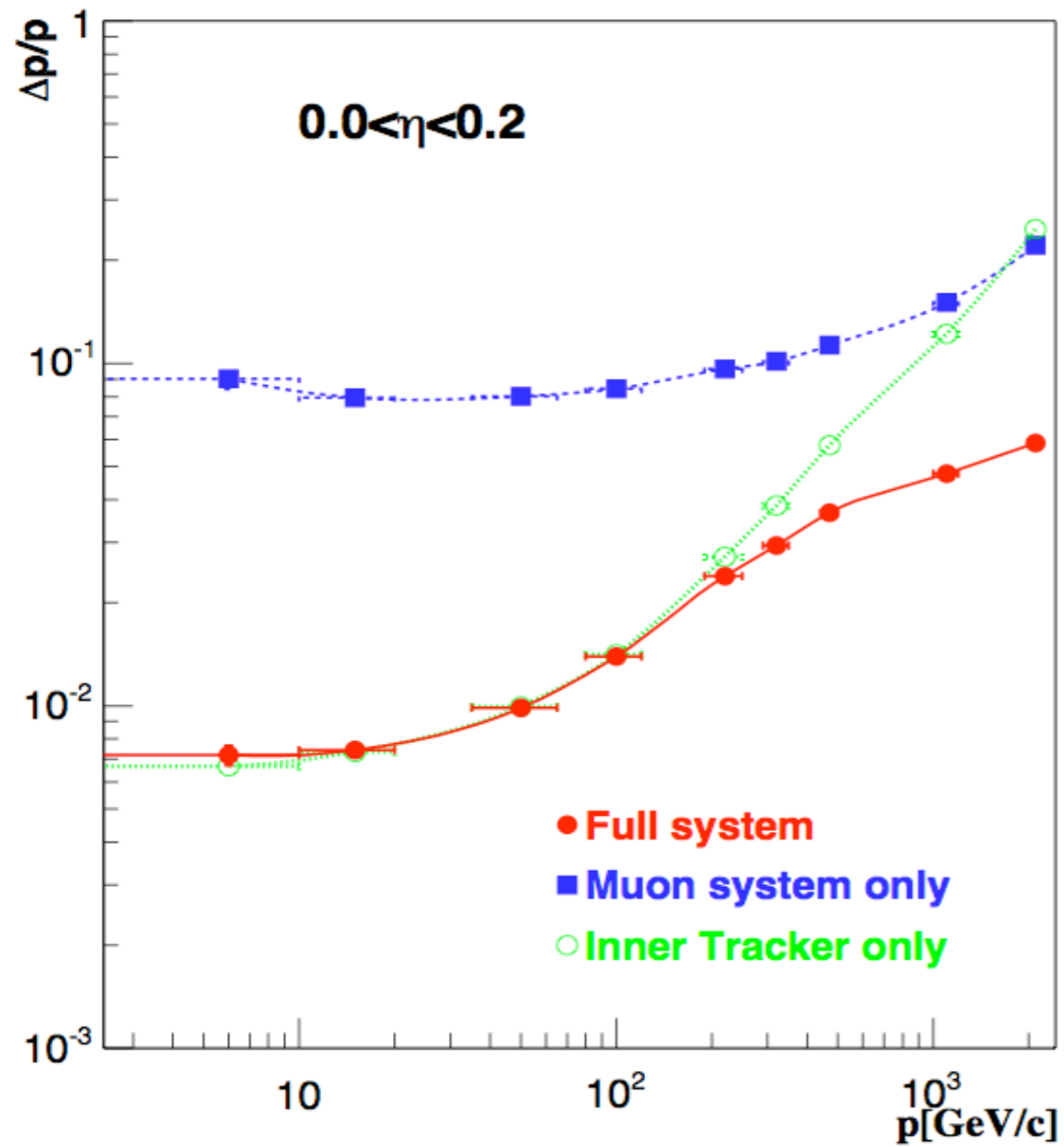
*YE+1 yoke equipped with CSC/ RPC packages (inner ring) and RE1/3 RPC's (outer ring).*



*The ME1/3 CSC's cover the RPC outer ring and hence complete the first muon station on YE+1.*



# Muon Reconstruction (Momentum Res.)



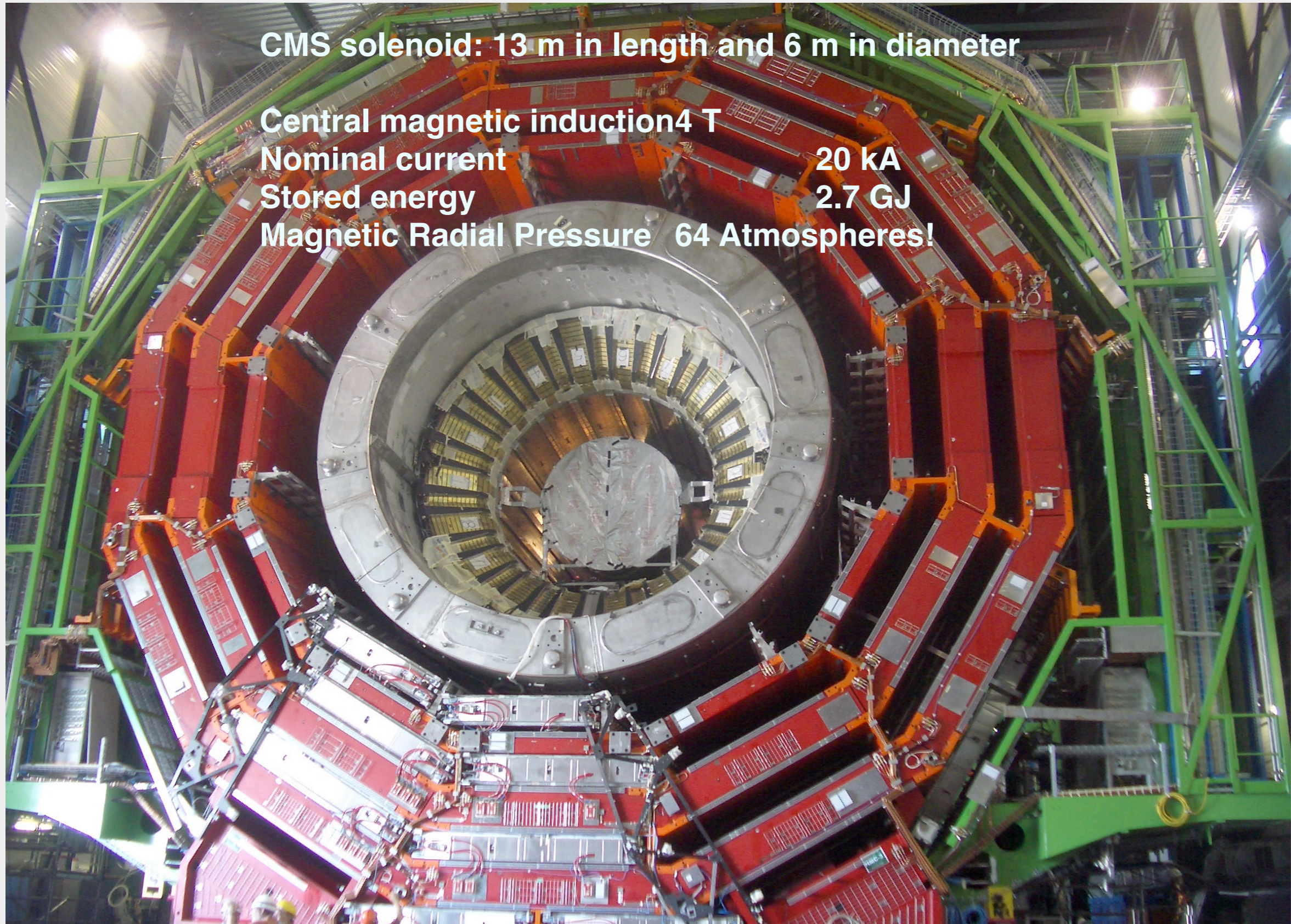


# Conclusions for muons

- ◆ Detector installation and commissioning almost complete (>90%)
- ◆ Peripheral Crate testing and installation well underway (50%) and will be completed before disk lowering
- ◆ Have been operating entire DAQ and trigger chains at SX5, combined operations with Global Trigger, DAQ, HCAL...
- ◆ ***Full MTCC setup is operational***



# CMS solenoid: in place and cold



CMS solenoid: 13 m in length and 6 m in diameter

Central magnetic induction 4 T

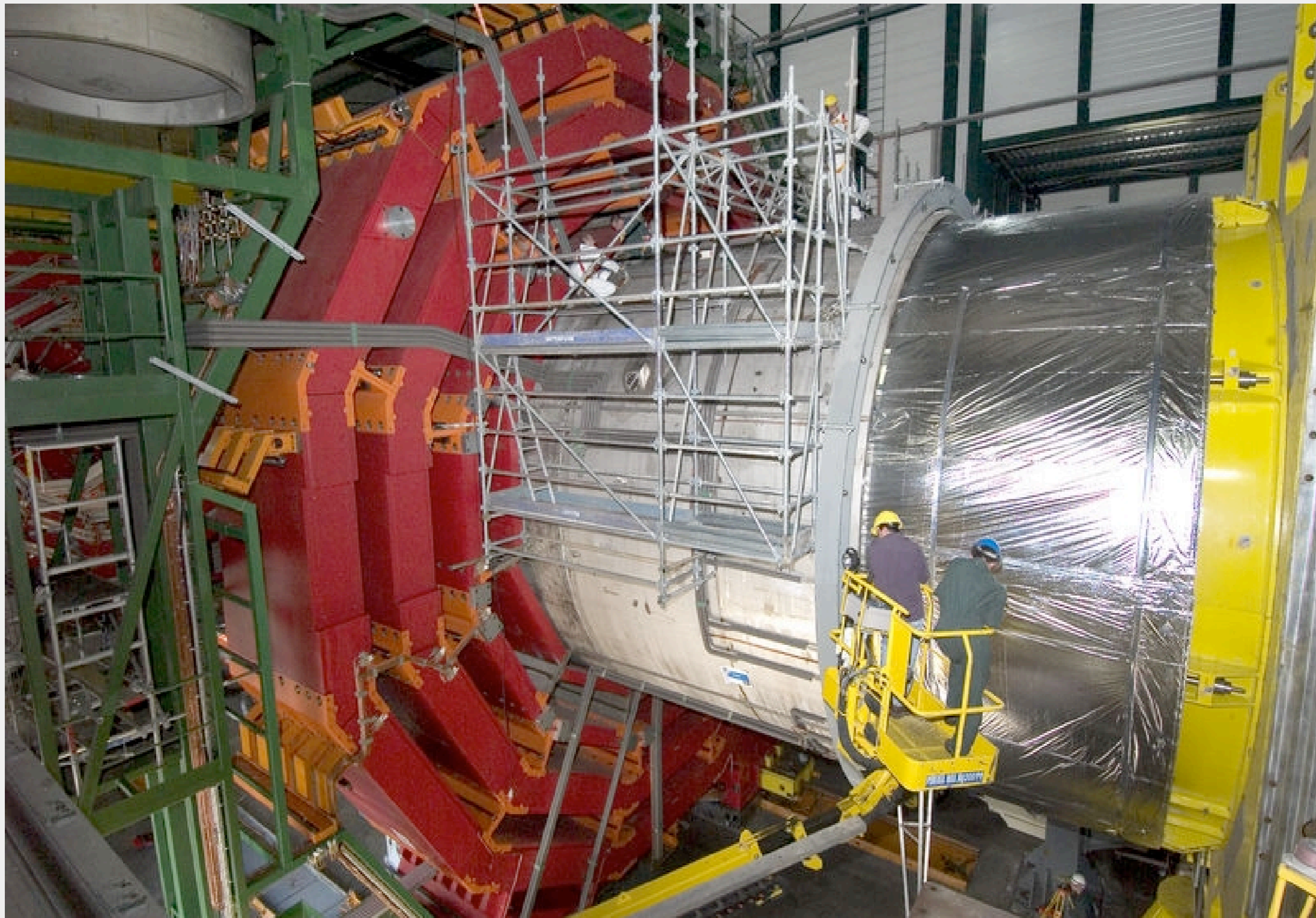
Nominal current 20 kA

Stored energy 2.7 GJ

Magnetic Radial Pressure 64 Atmospheres!



# Coil has been inserted on 14 Sept.





# Inner Vacuum Tank insertion on 2 November

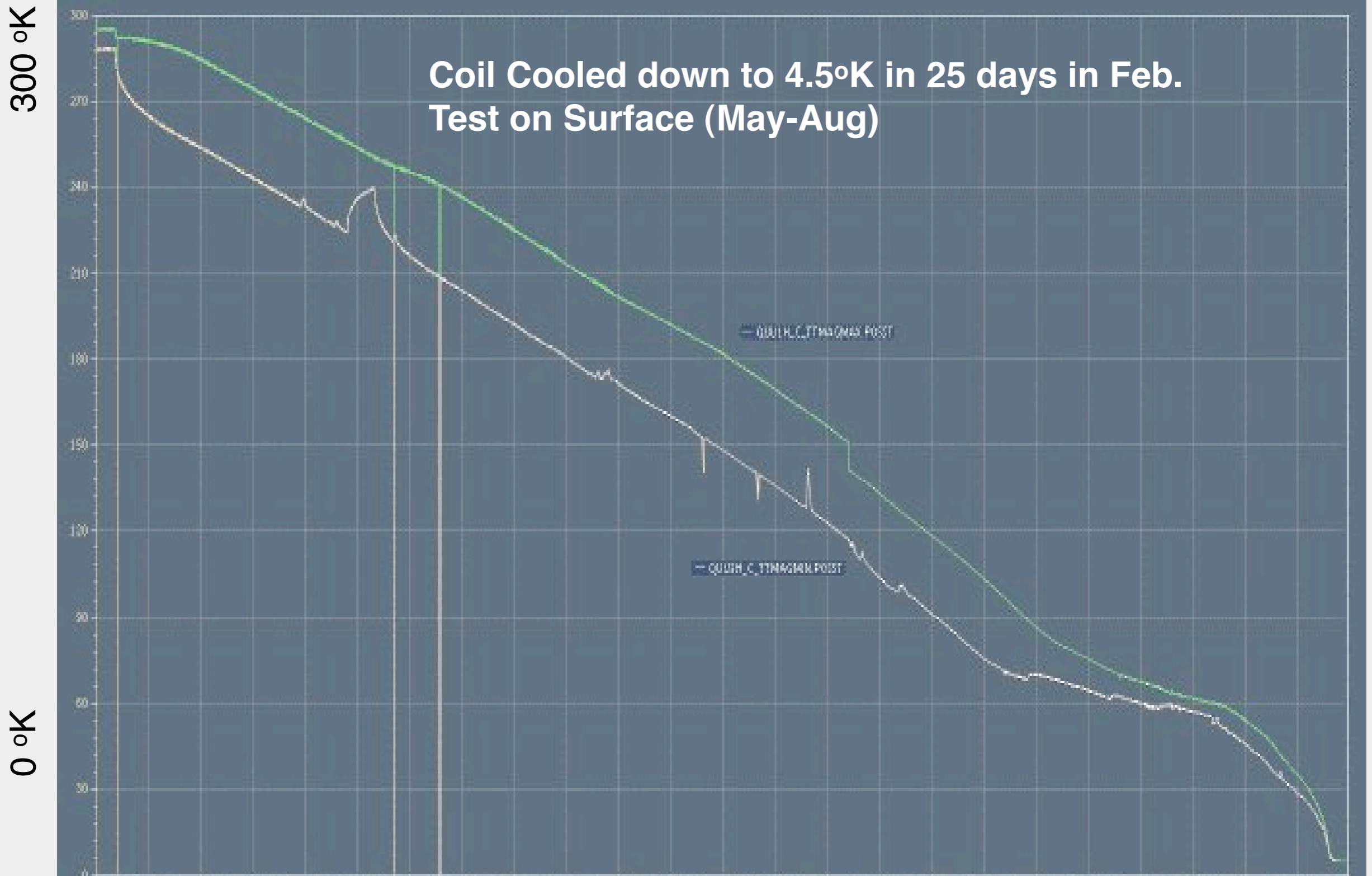
15:15:43 2-NOV-2005





# CMS Solenoid

Coil Cooled down to 4.5°K in 25 days in Feb.  
Test on Surface (May-Aug)



Feb 1

Feb. 28<sup>th</sup>



# CMS hadron calorimeter



## HB+ insertion complete on 3 April



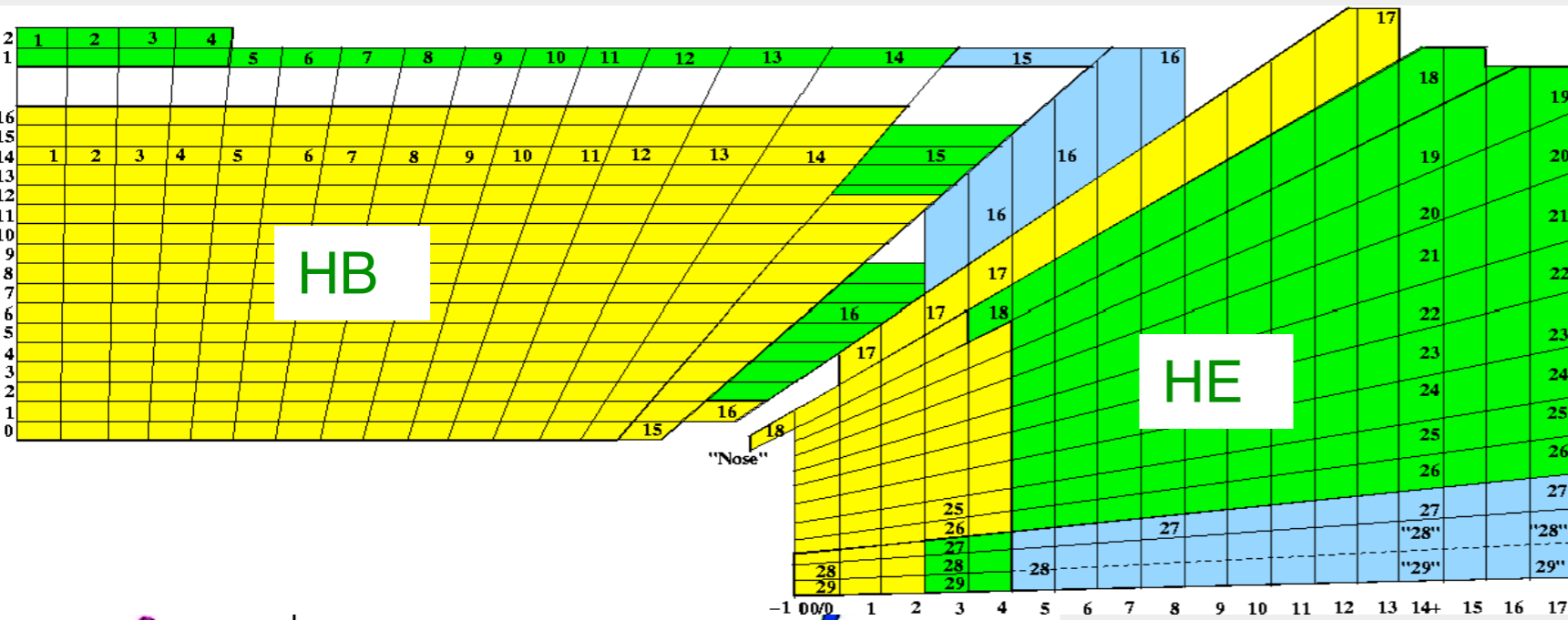
**CMS: HF**

*Both have been source calibrated*

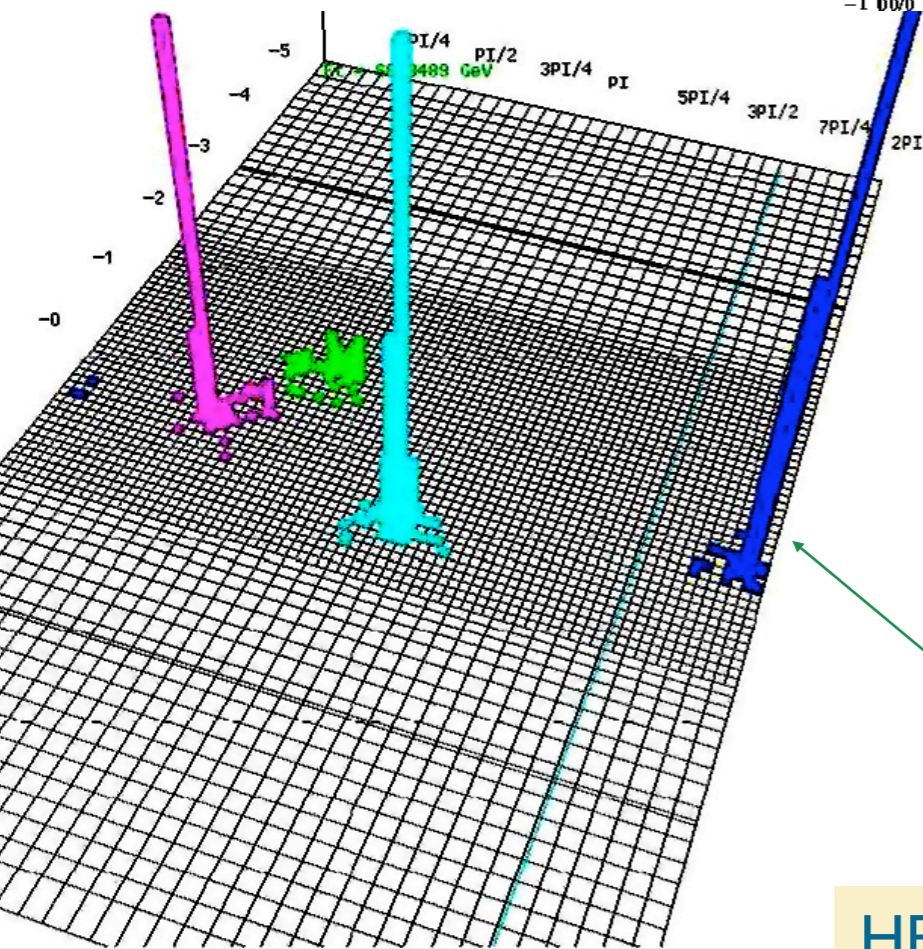
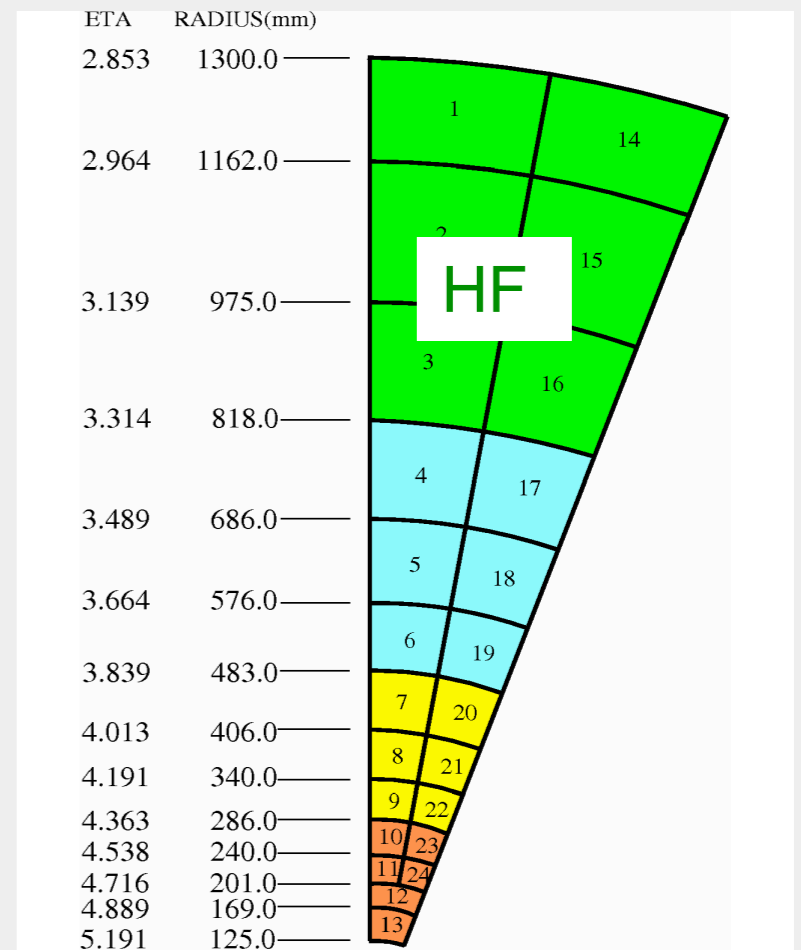
**Lower HF+ in July**



# HCAL Segmentation and Coverage



HF:  $3 < |\eta| < 5$   
 $\Delta\phi \times \Delta\eta = 10^\circ \times 13 \eta$   
 towers

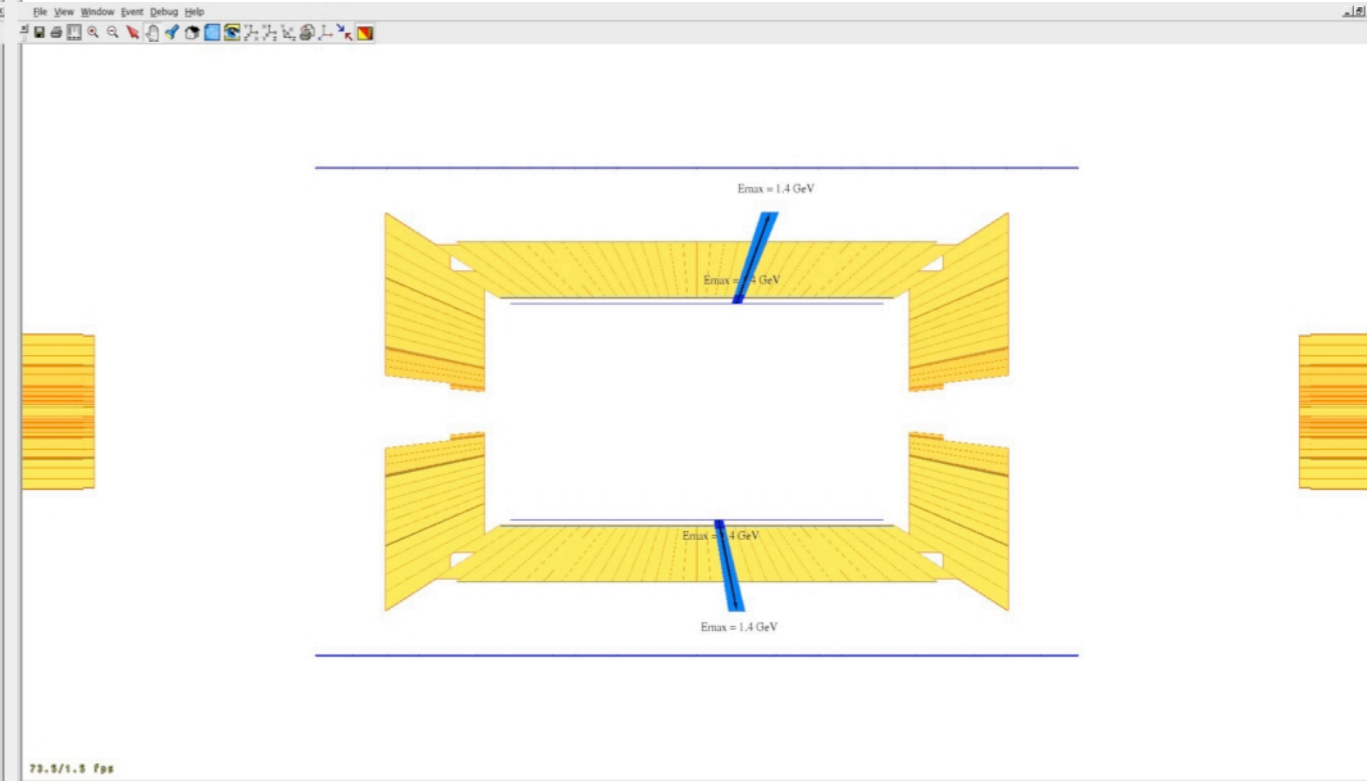
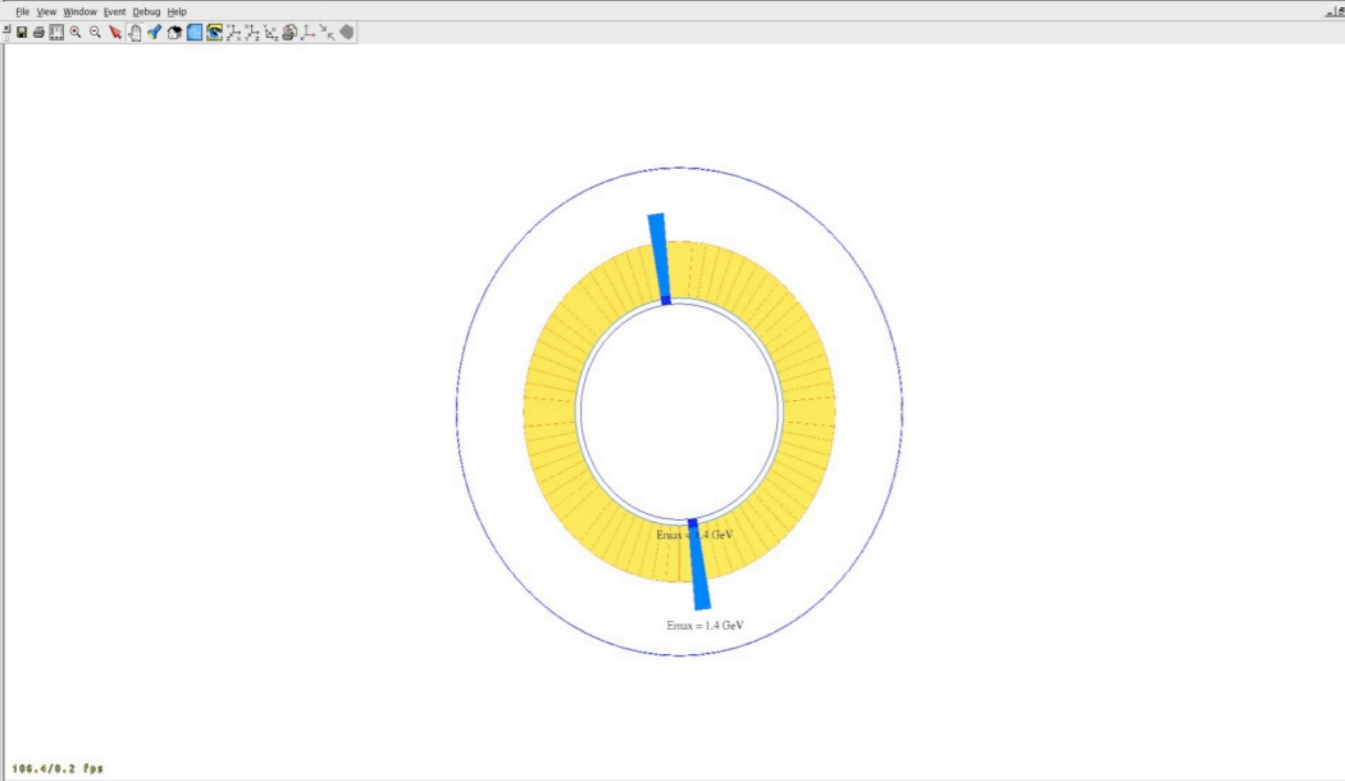
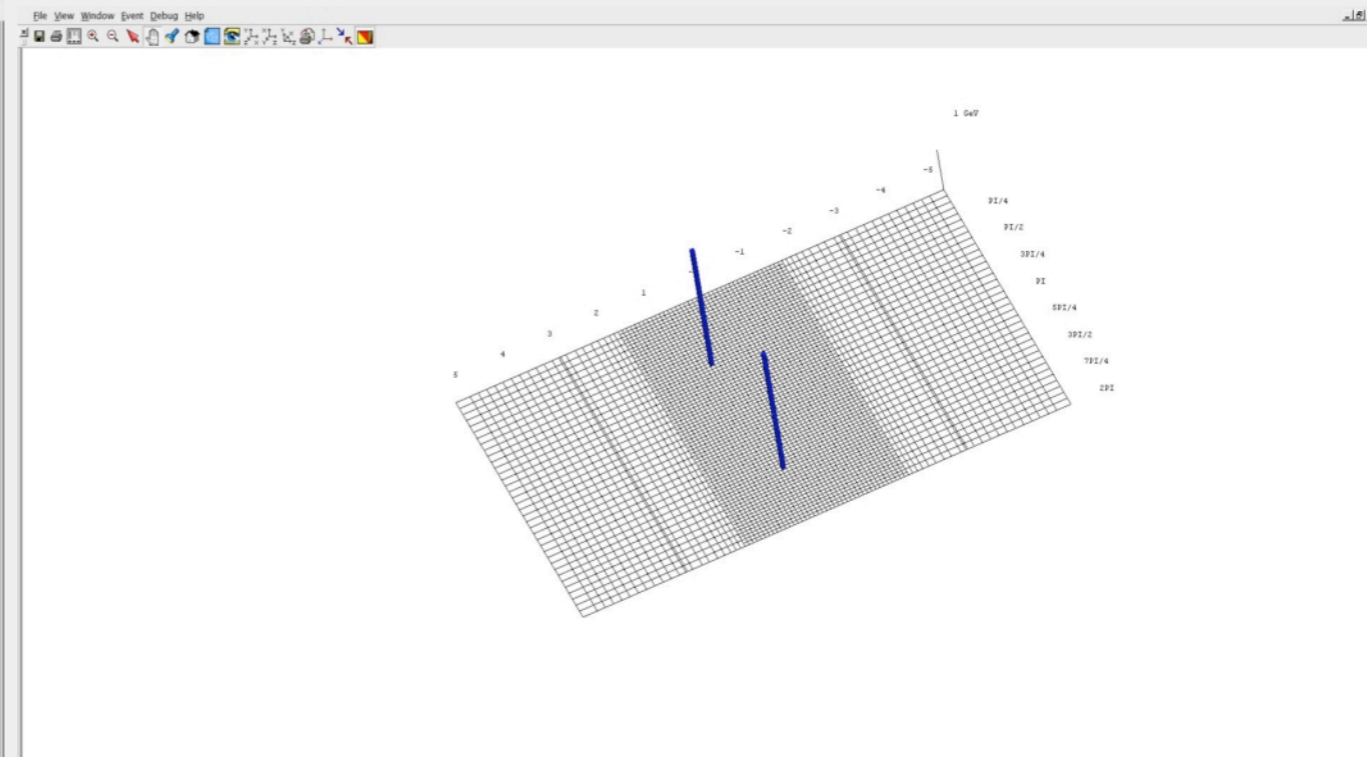
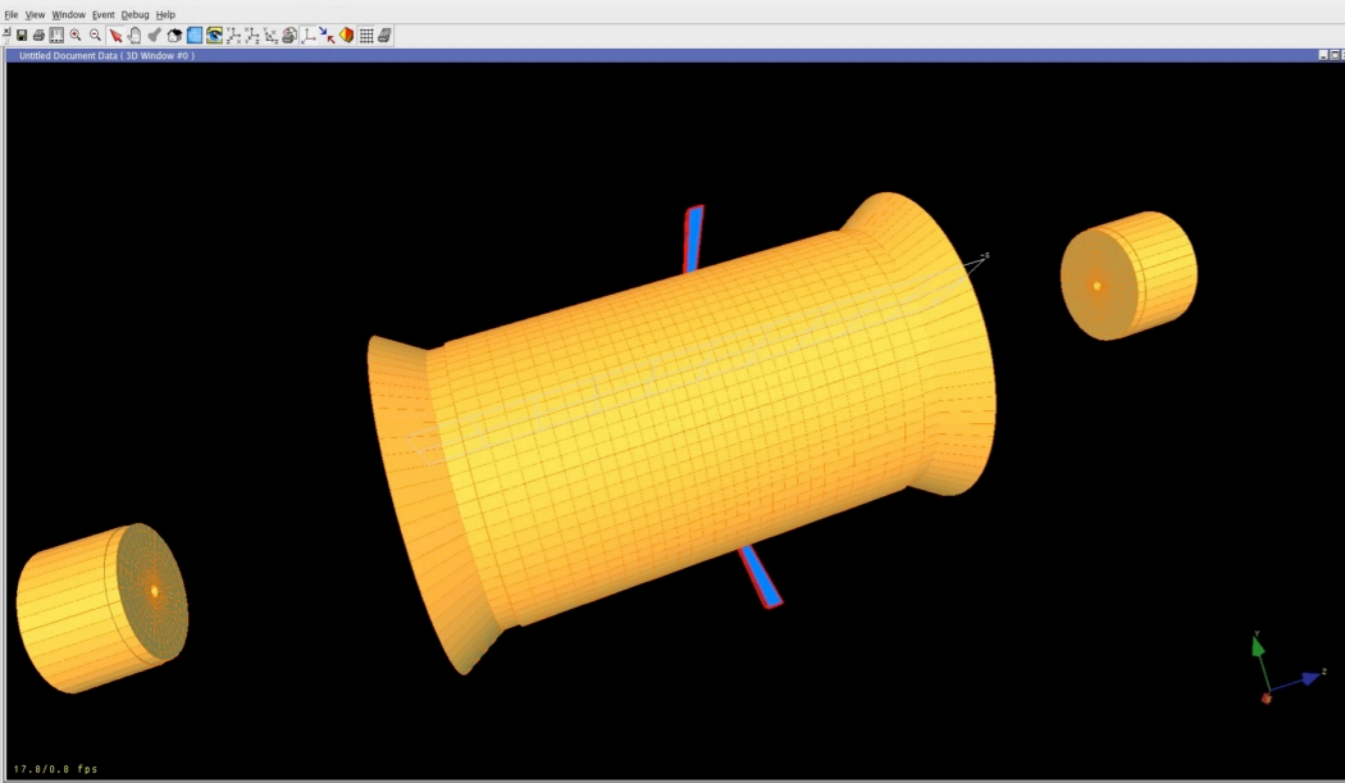


HB:  $|\eta| < 1.3$   
 HE:  $1.3 < |\eta| < 3$   
 HF:  $3 < |\eta| < 5$   
 Very Fine Granularity:  
 $\Delta\phi \times \Delta\eta = 0.087 \times 0.087$  for  $|\eta| < 1.7$

HB & HF: Brass Absorber and Scintillating tiles. HO: Scintillator "catcher". HF: Iron and Quartz fibers

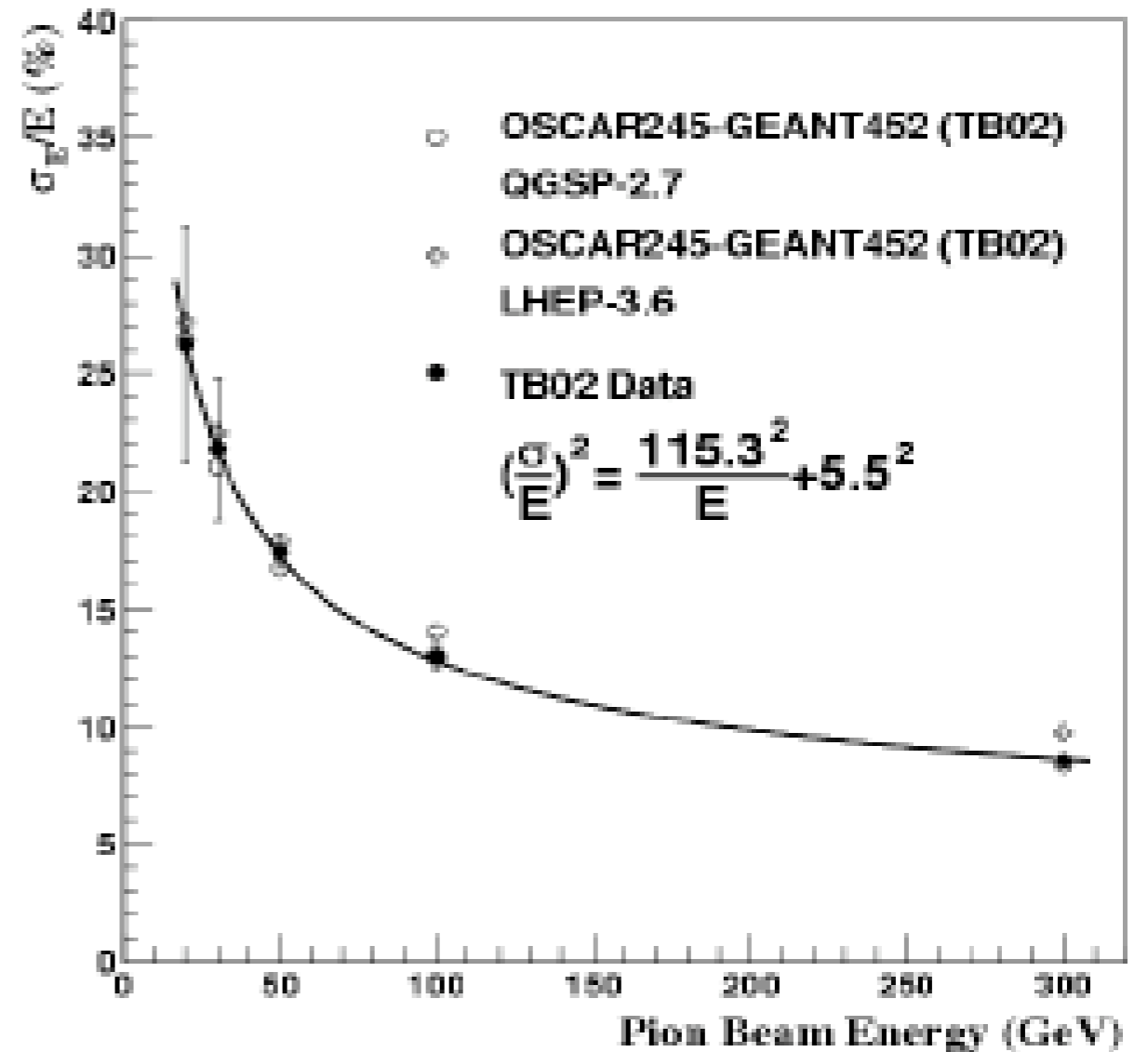
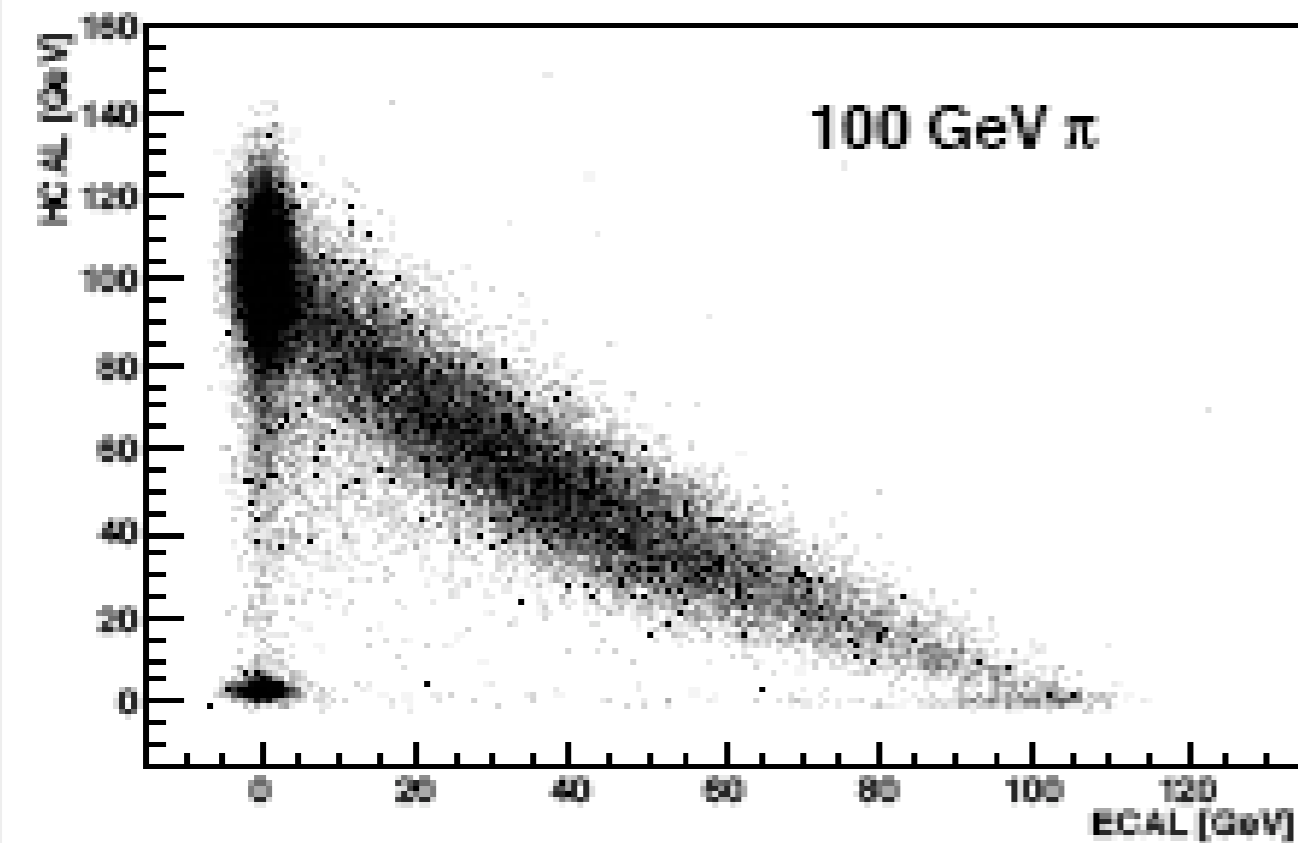


# Cosmic's in HCAL at SX5





# ECAL + HCAL Energy Resolution

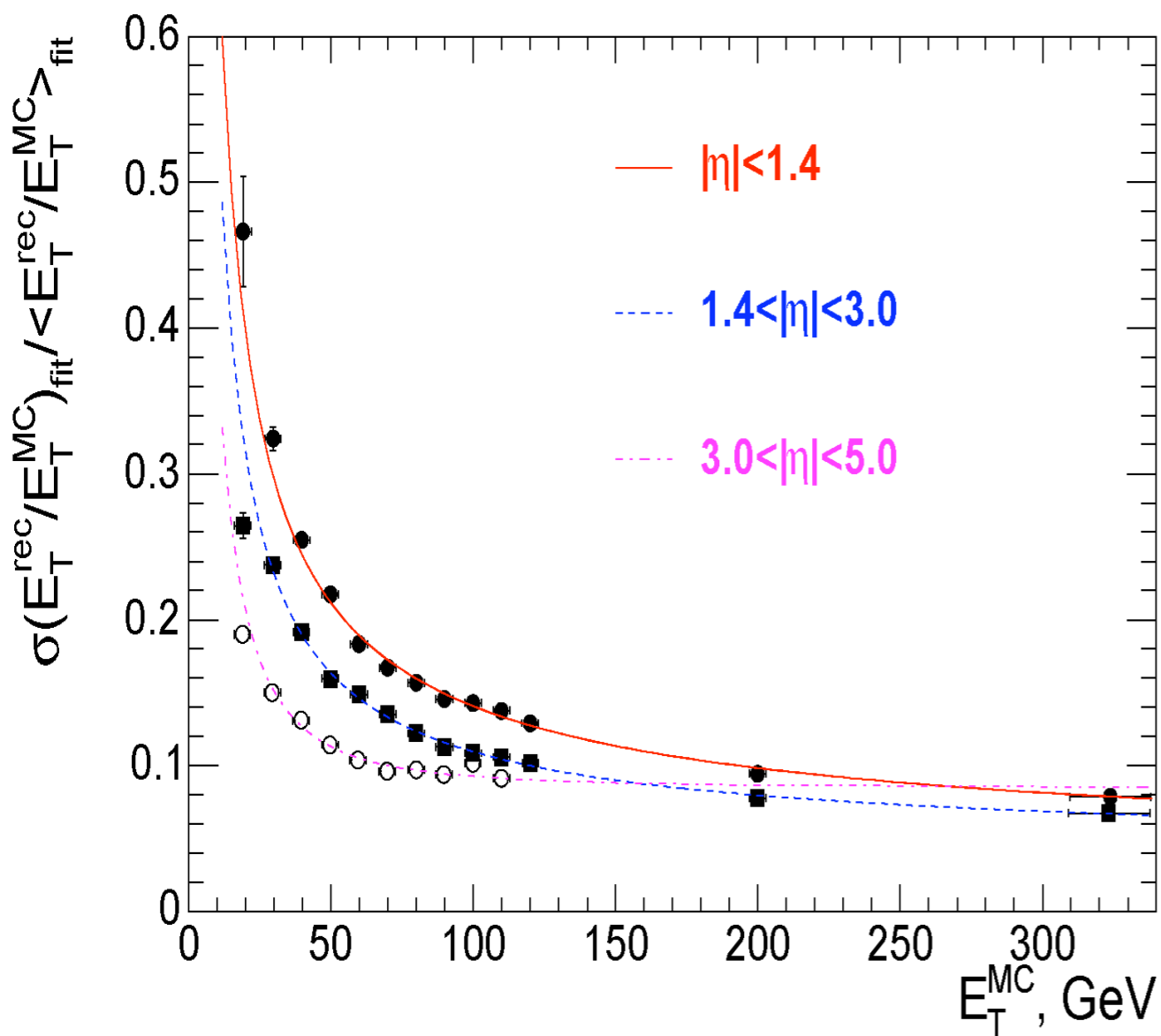


Combined Test ECAL SM + HCAL  
Wedge in Summer 06

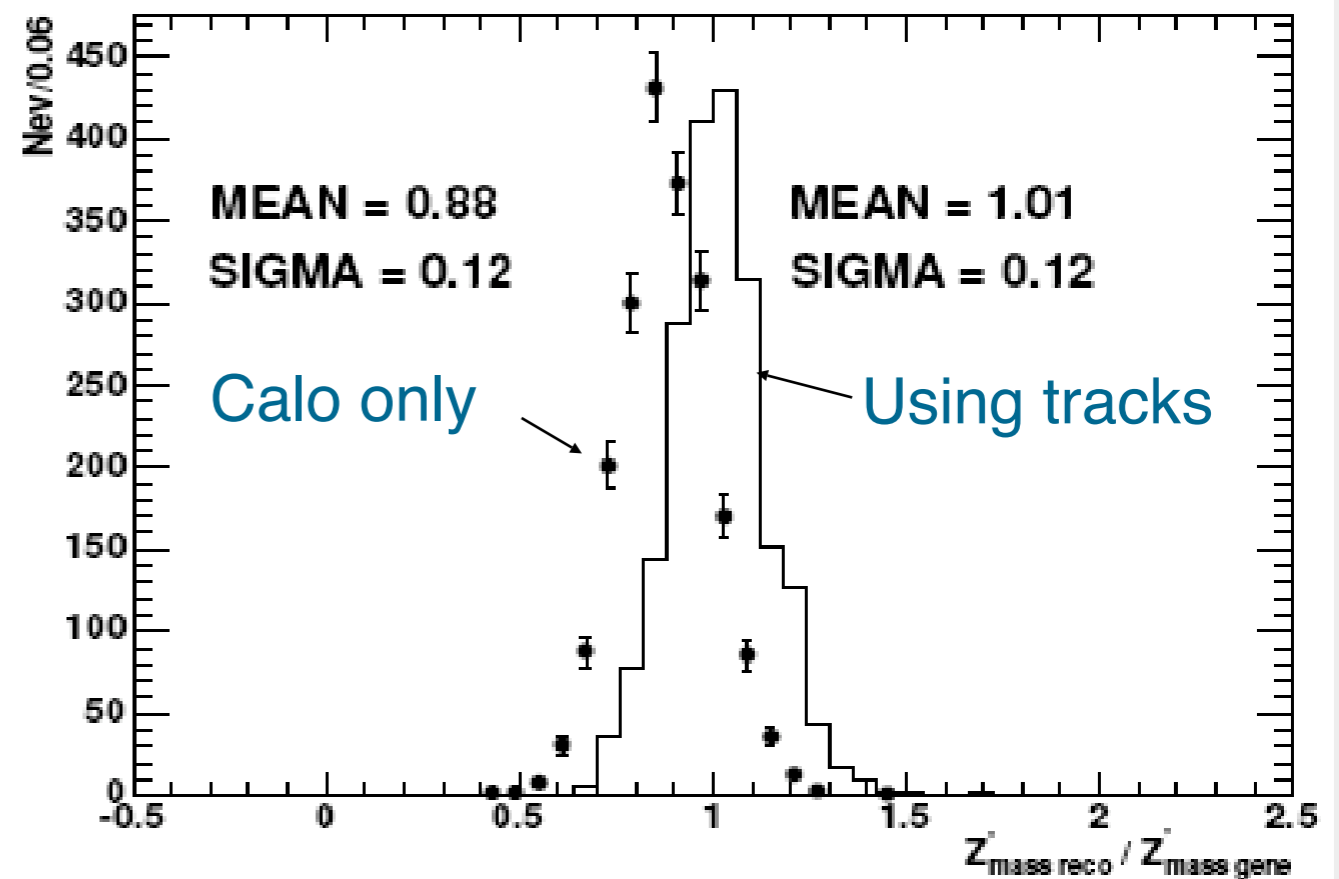


# Jet Reconstruction and Resolutions

## Jet $E_T$ resolution

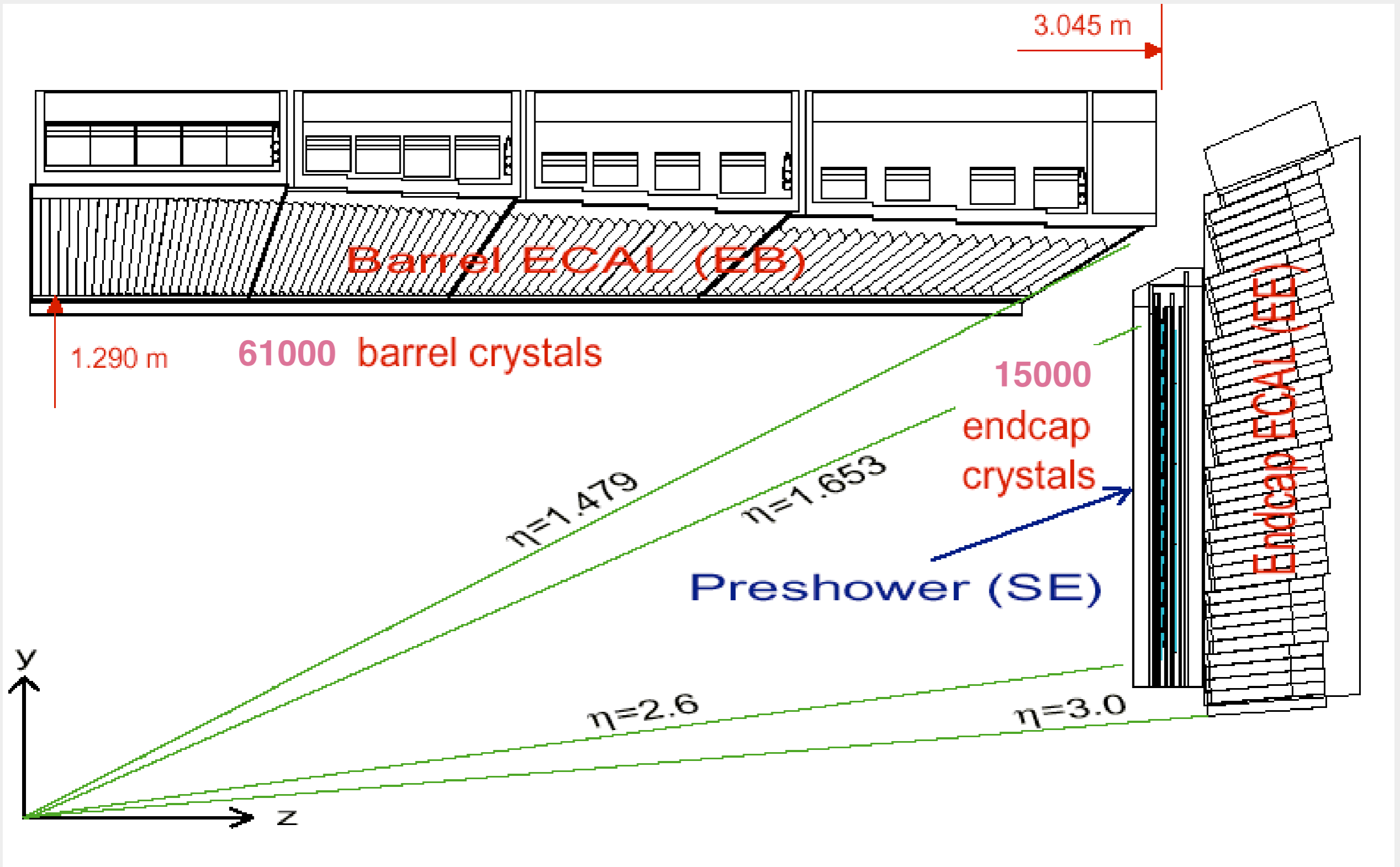


## $M_{jj}$ resolution at 120 GeV



$M_{jj}$  resolution  $\leq 15\%$







# ECAL integration Progress



SM 21

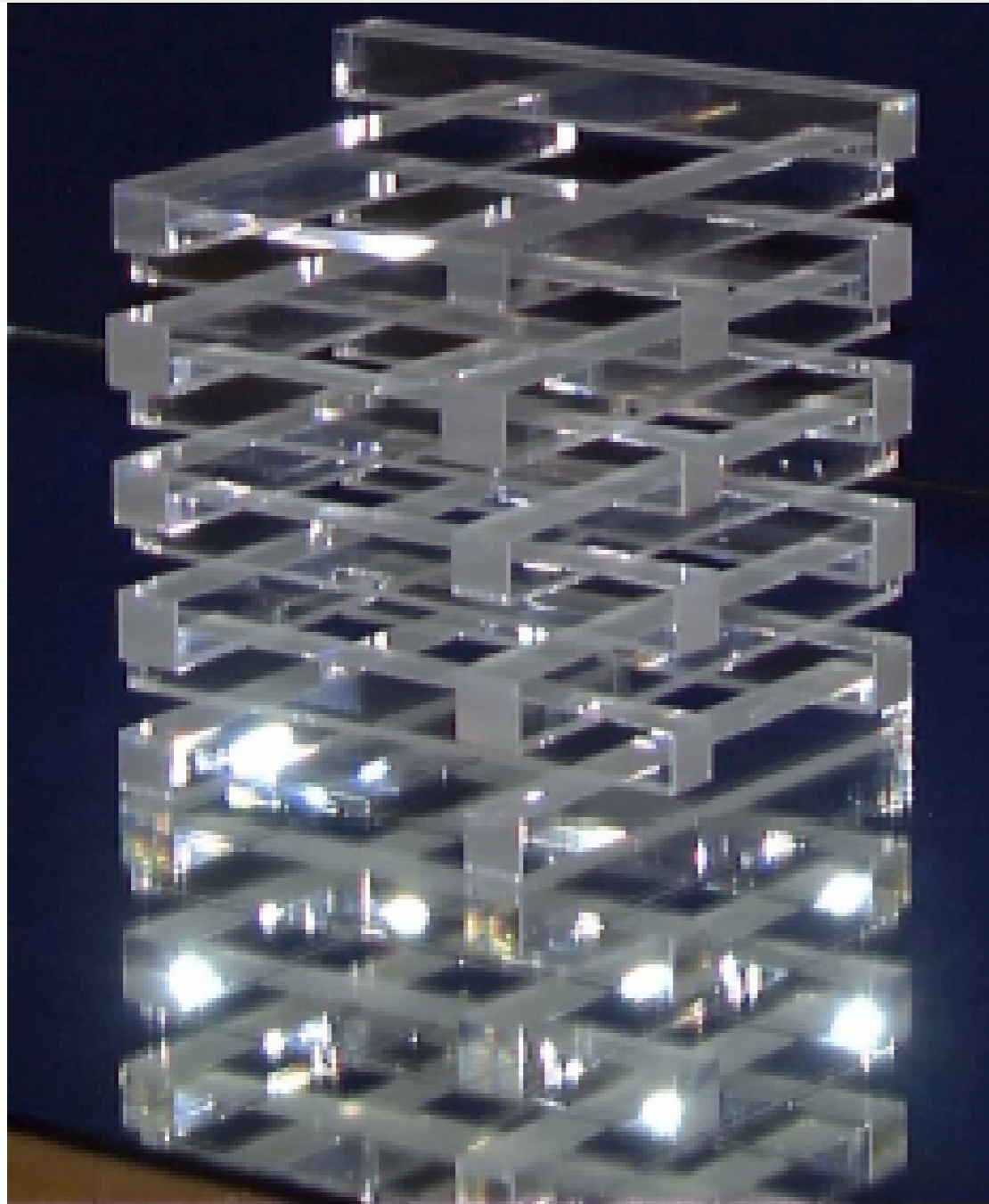
SM 13

SM 17

SM 19



# Status of ECAL



79% of crystals delivered (49,000).

Barrel: 36 Supermodules with 1700 crystals.



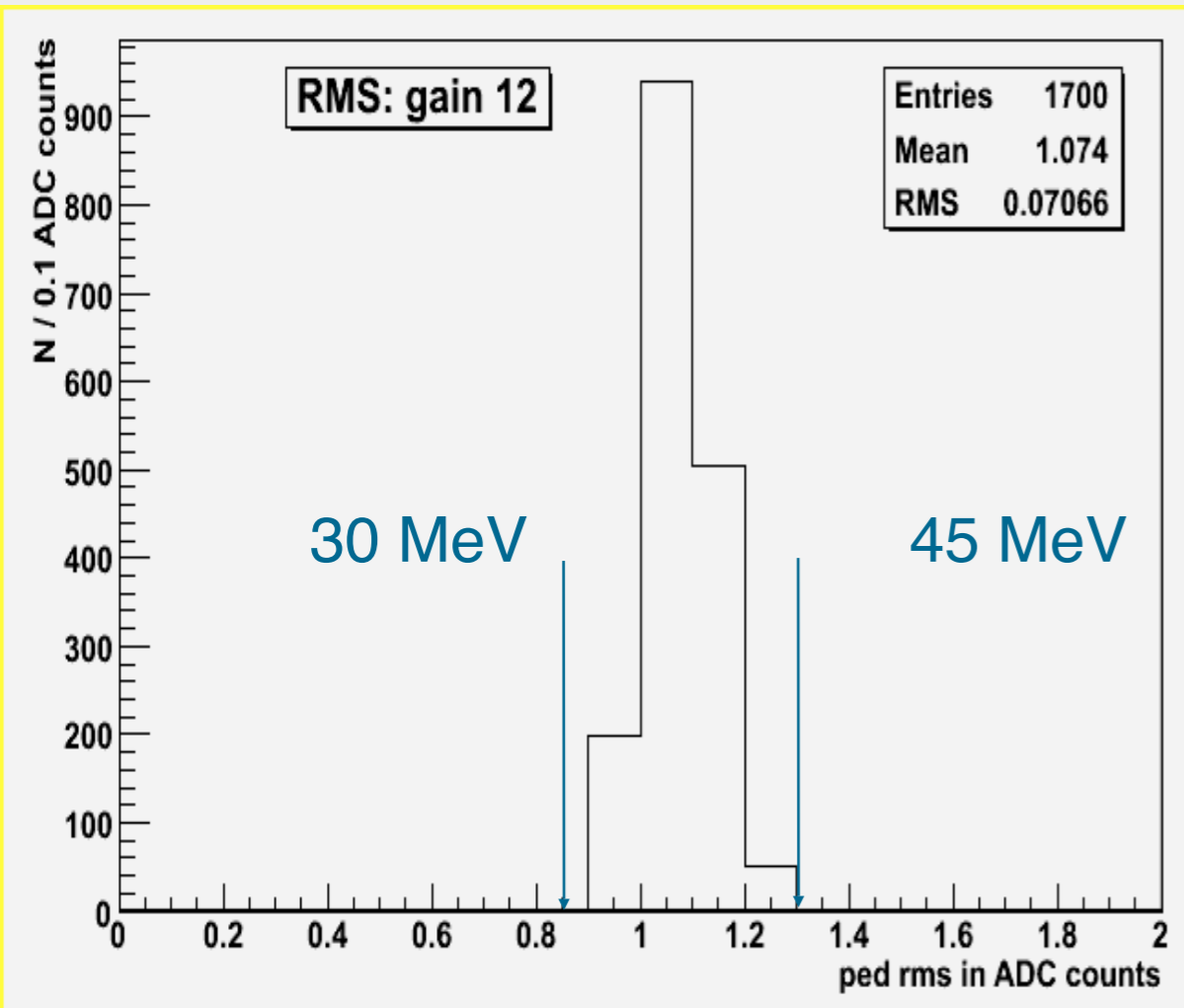
26/36 bare SM assembled.

- **20/36 Supermodules (SM) integrated.**
- Every integrated Supermodule is pre-calibrated with cosmic rays for  $\sim 1$  week.
- 3% absolute calibration achievable with cosmics.

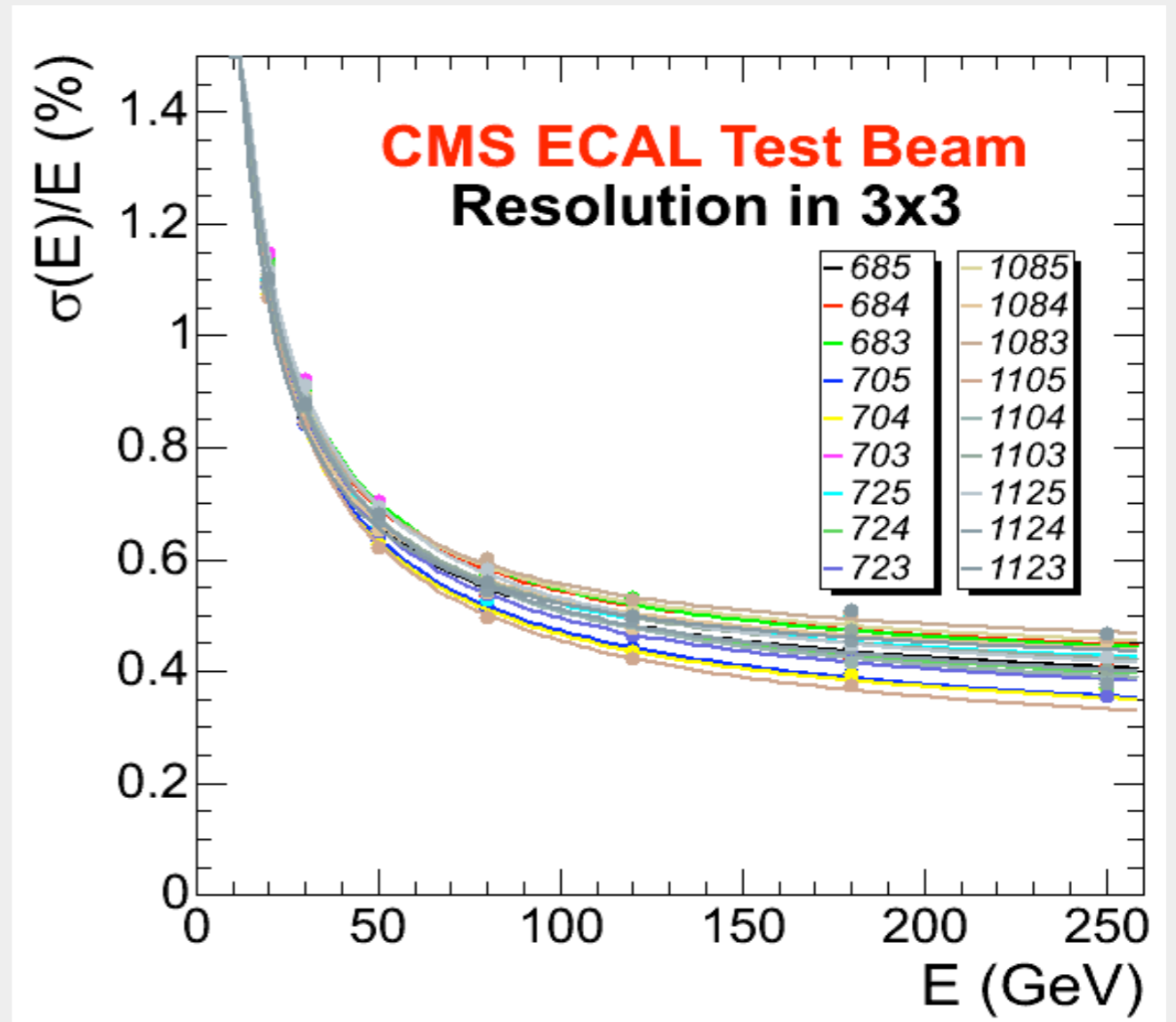
**On critical path: ECAL crystal delivery (Barrel: Feb. 07, Endcaps: Jan. 08)**



# ECAL performance



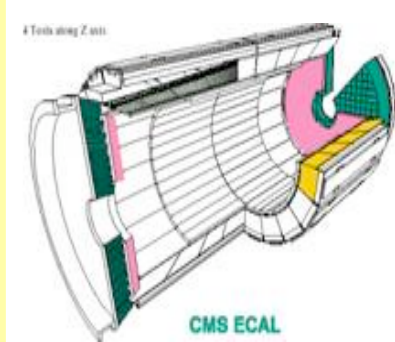
Noise distribution of the 1700 channels of SM13



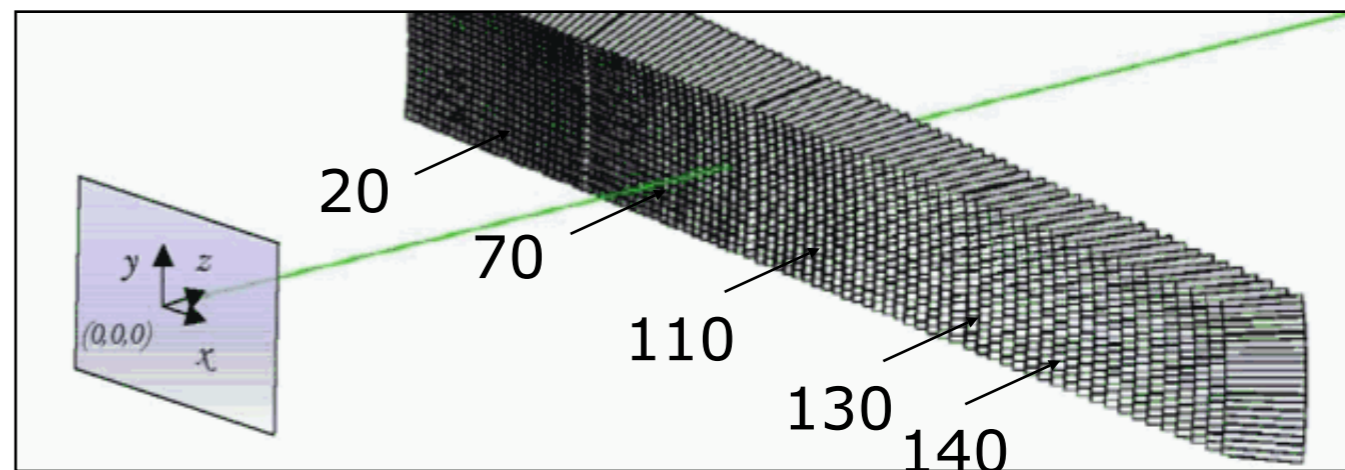
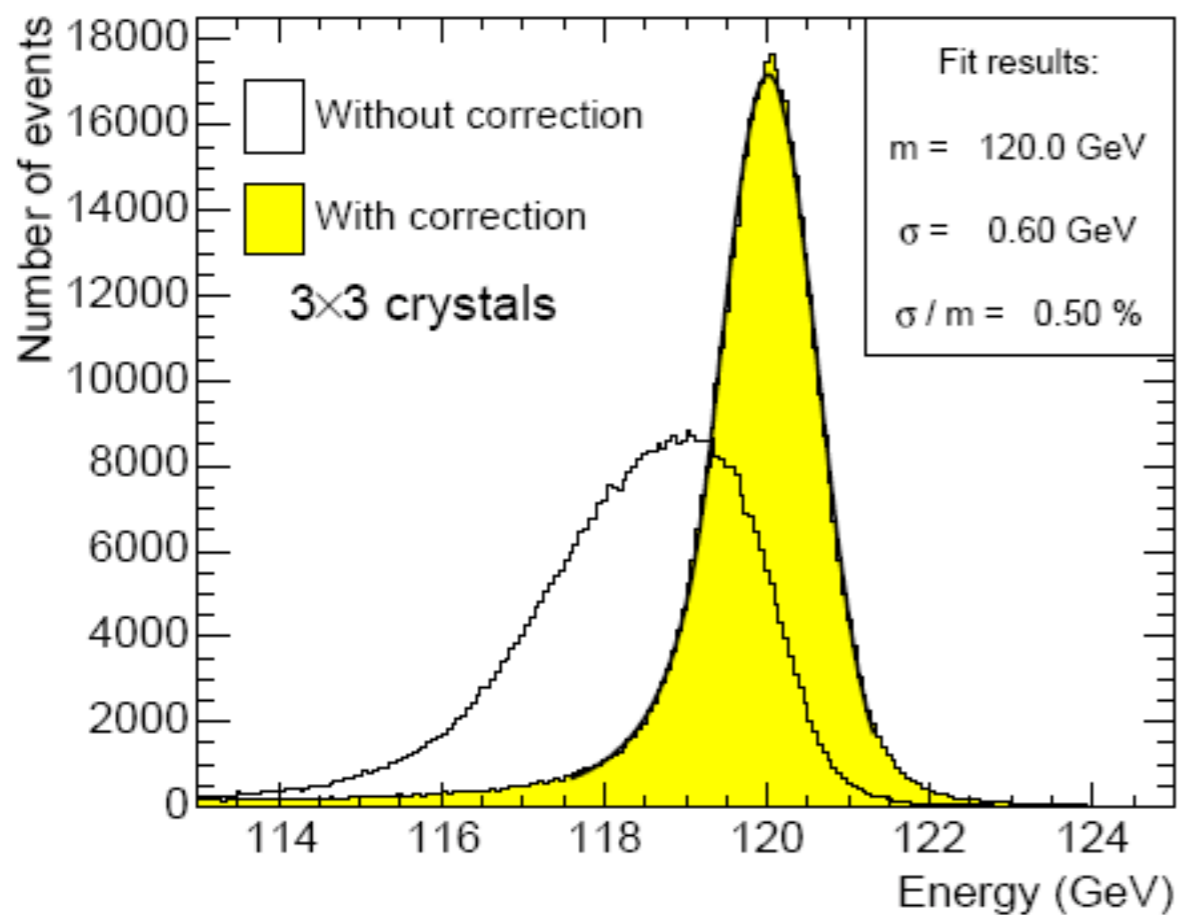
Energy resolution: 2004 test beam 18 crystals



# Uniformity



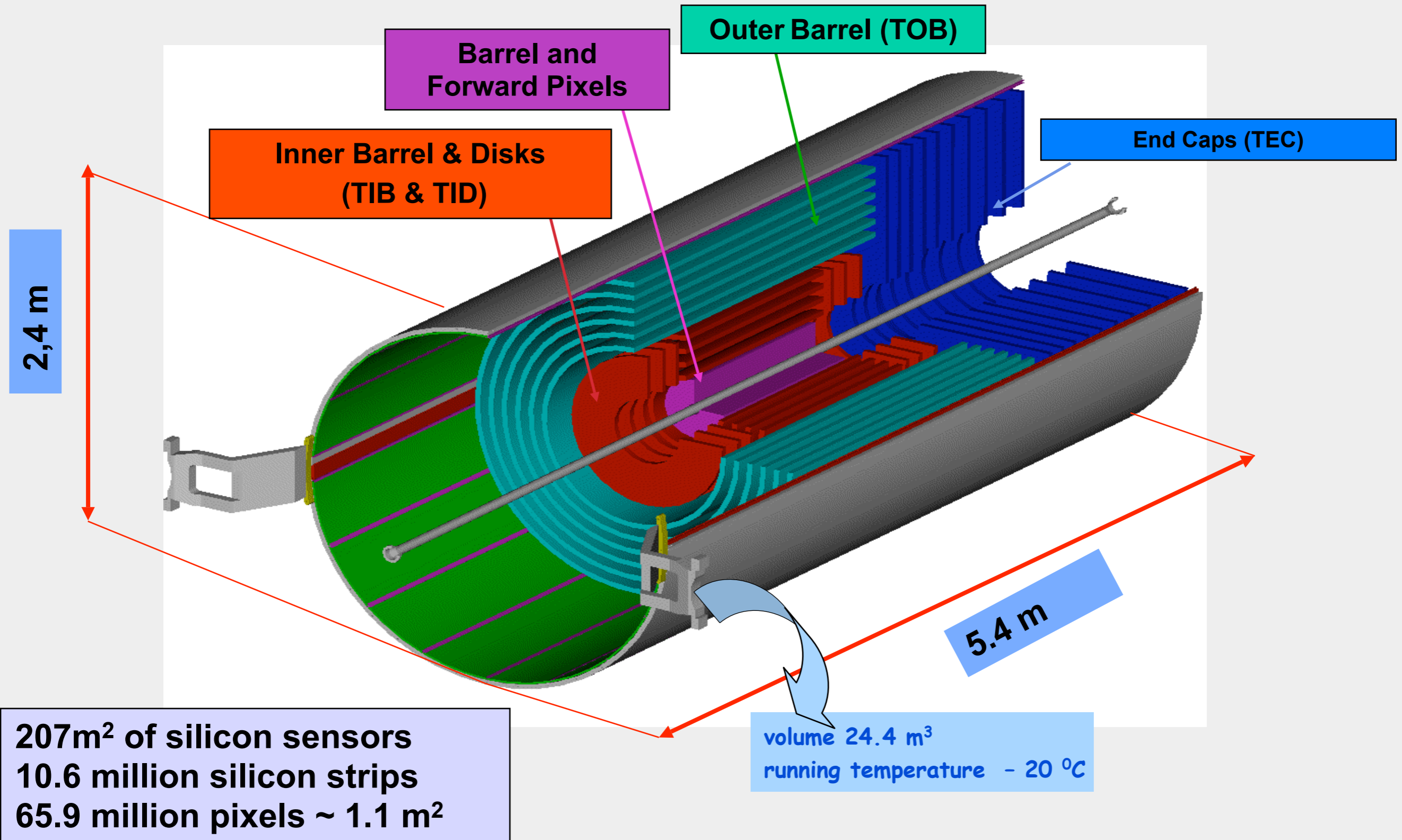
How well can we sum different part of the calorimeter together?



⇒ 2004 performance → 0.50% energy resolution at 120 GeV



2 Super modules inserted 27 April for magnet test



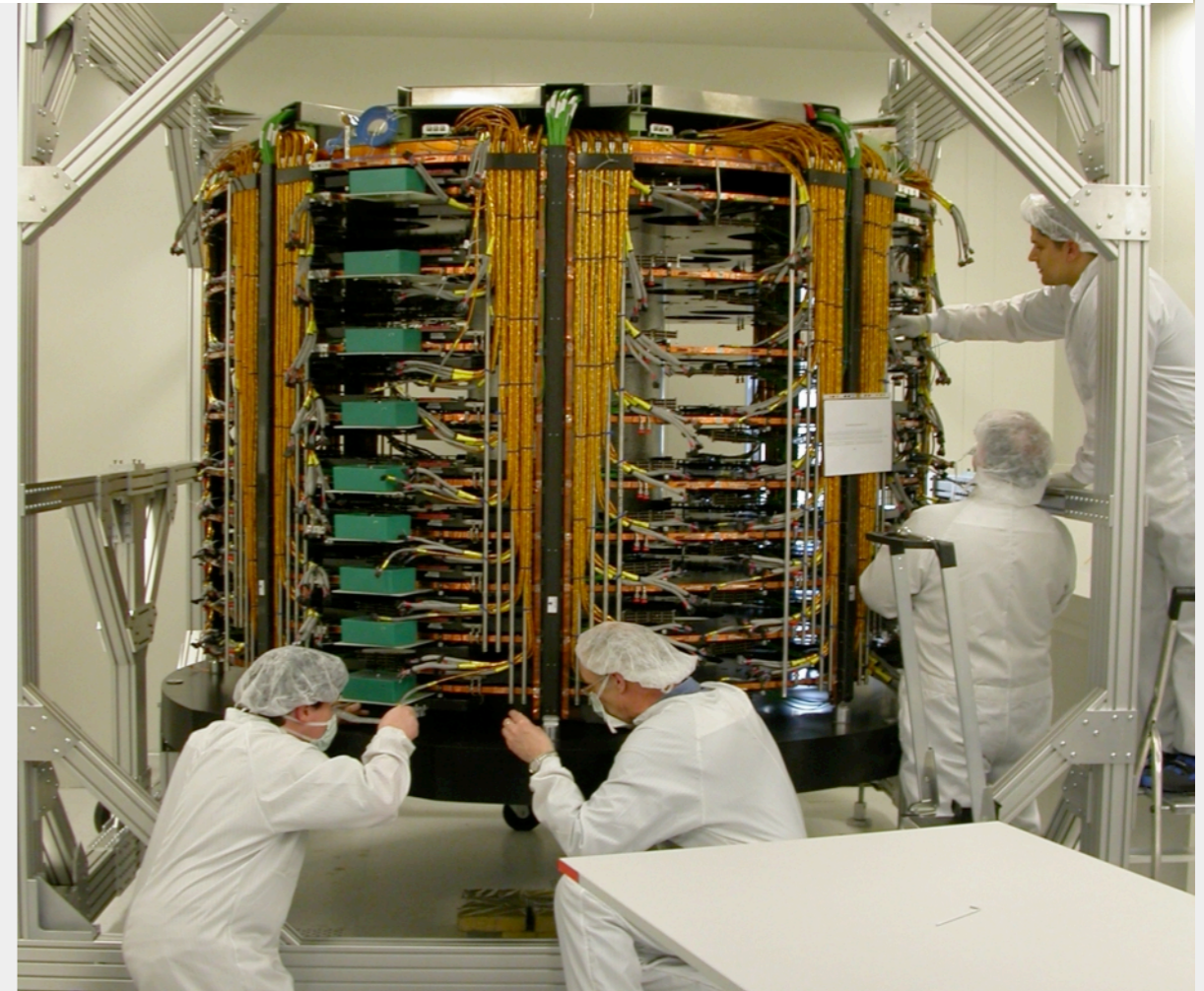
## TEC- at CERN

27 petals integrated  
qualification in progress



## TEC+ at Aachen

72 petals integrated  
Several sectors qualified



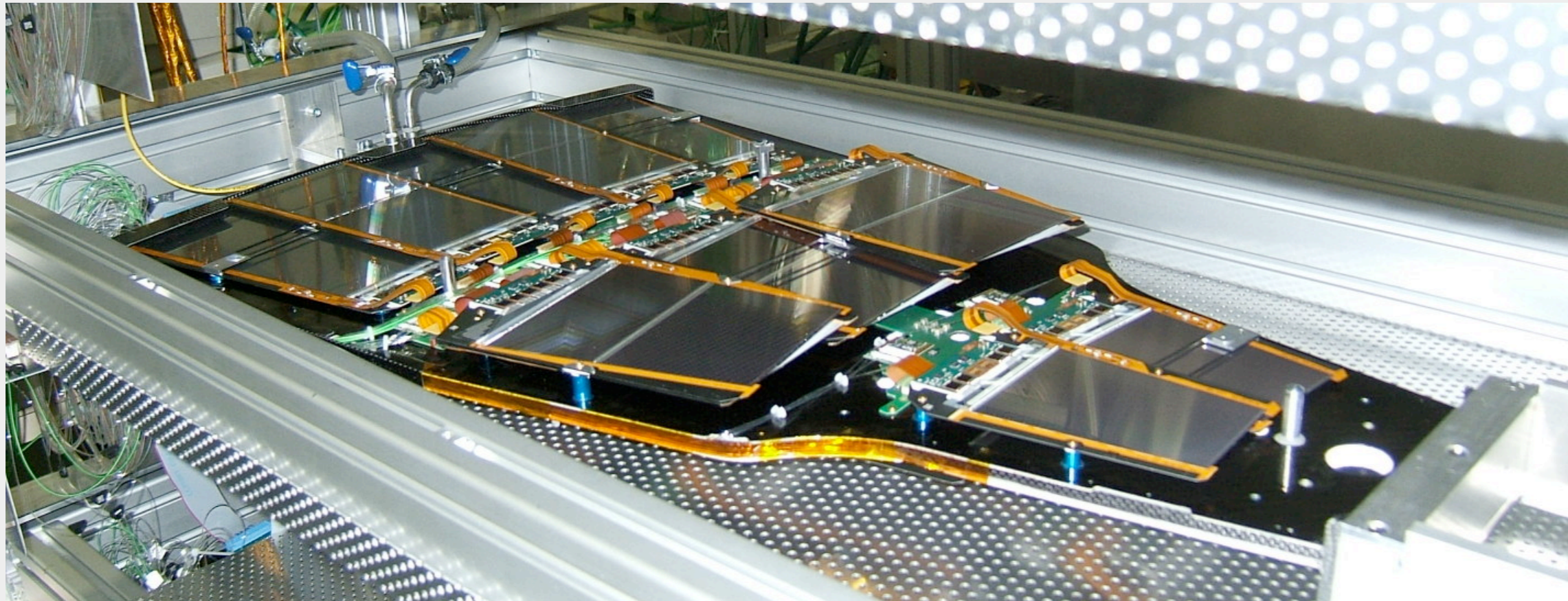
- Each TEC is made of 9 disks (144 petals).
- TEC+ complete: Sep06, TEC- complete: Nov06
- TIB, TOB and TEC all inside tube in Nov06.





# Tracker End Cap (TEC): Petals

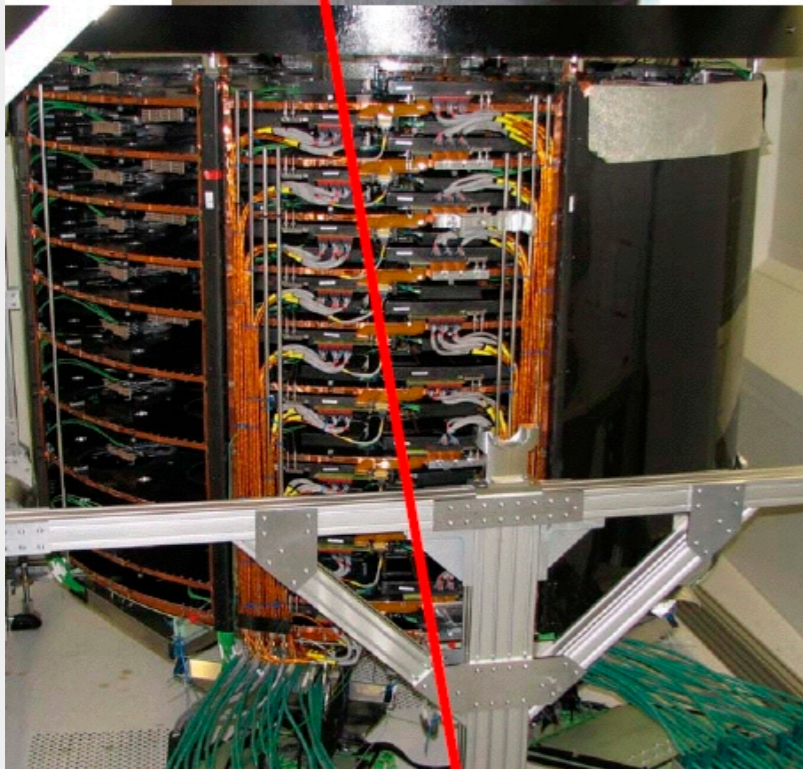
*Germany, France, Belgium...*



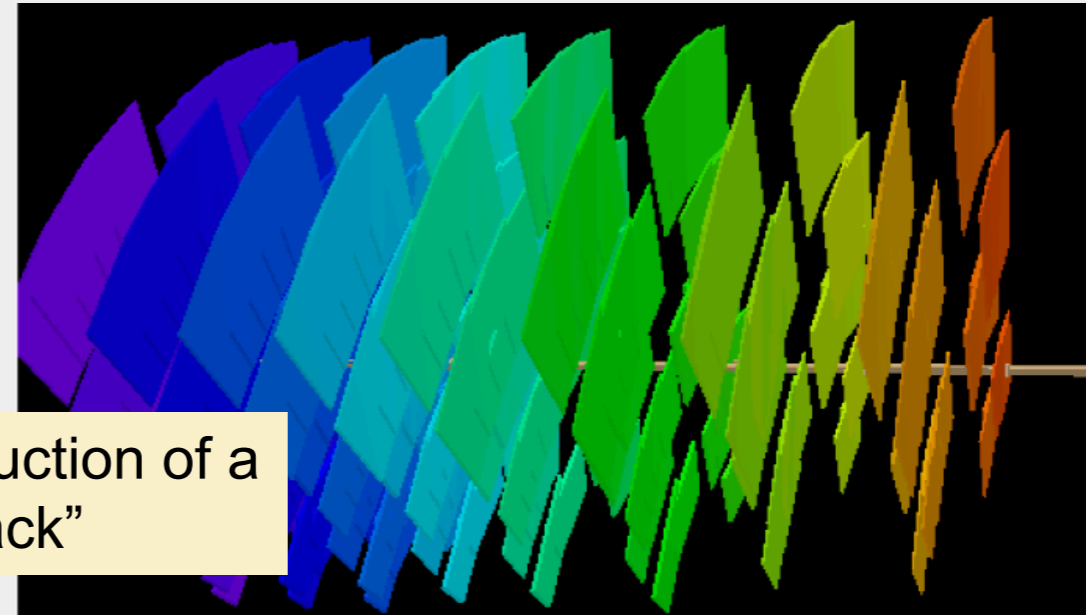
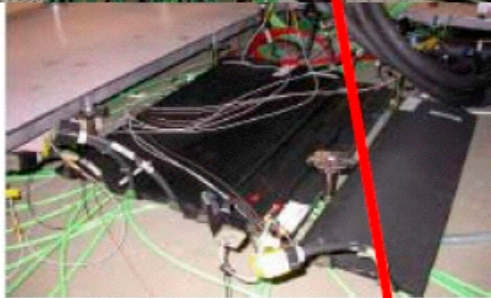
Today : 190 petals/300 (63%) ;  
petals produced at a rate of 10 petals/week (Fr, Ge, Be).



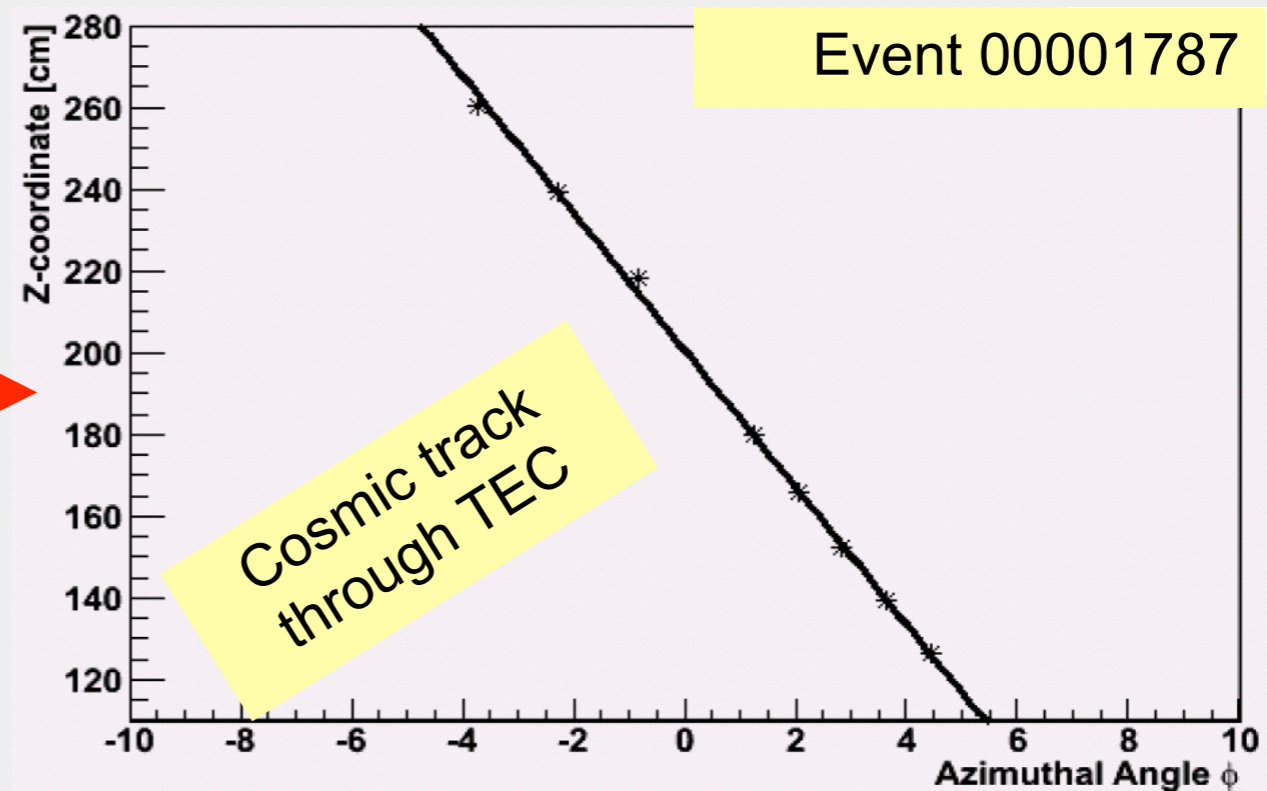
Scintillator panels above and below for triggering



Tracker Endcap (TEC)

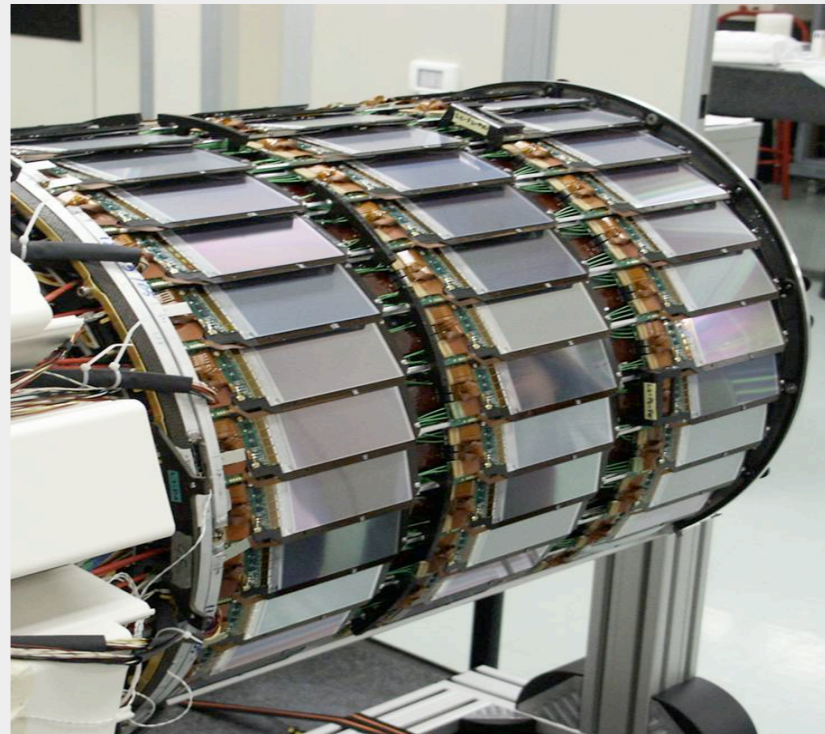
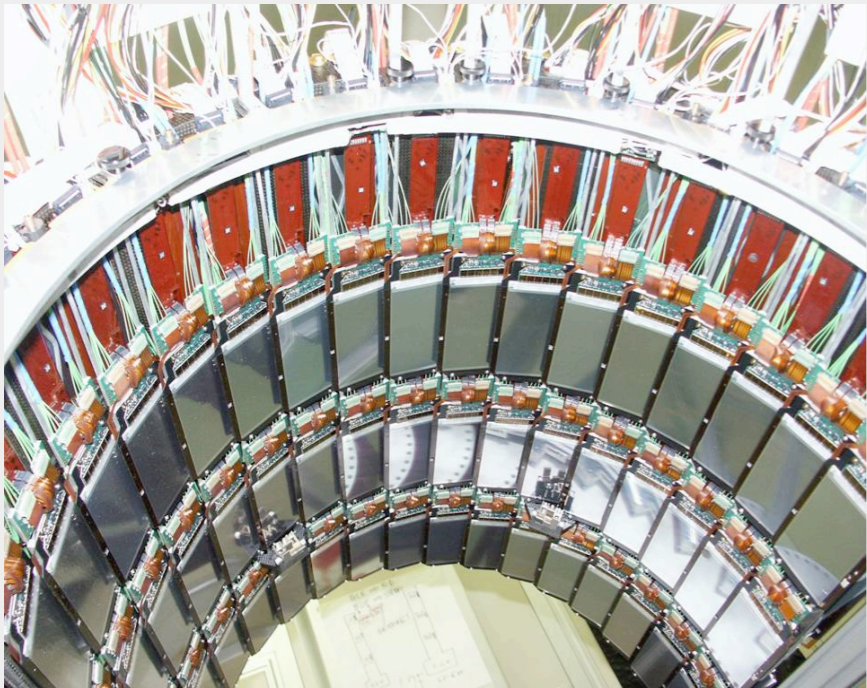
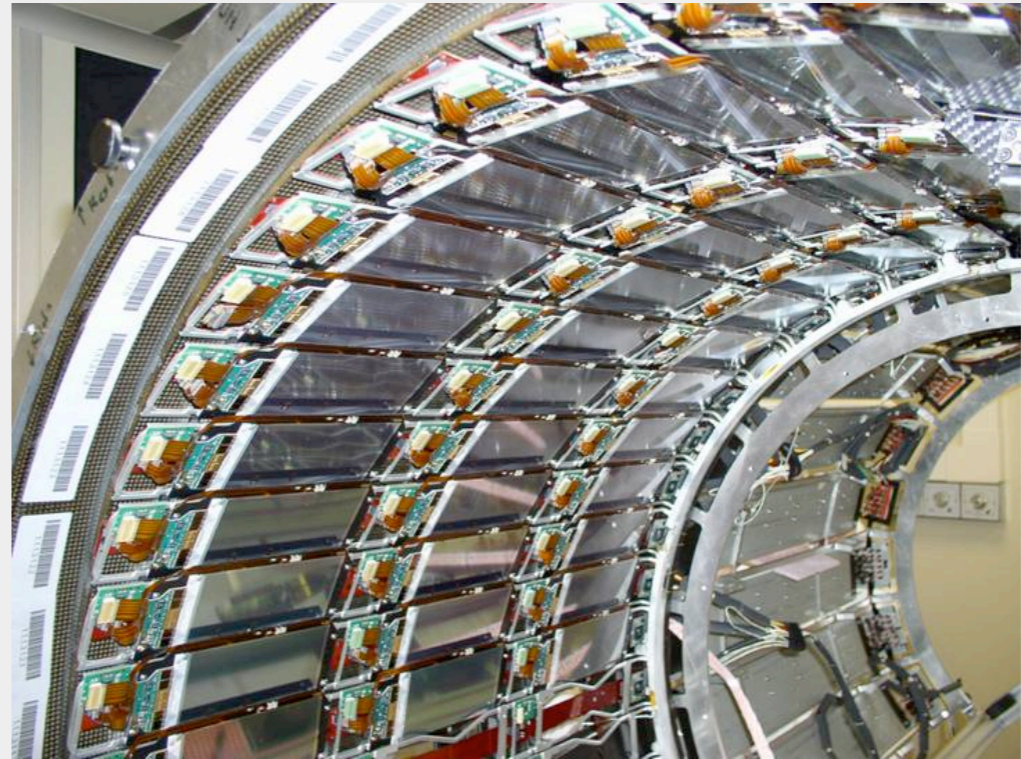
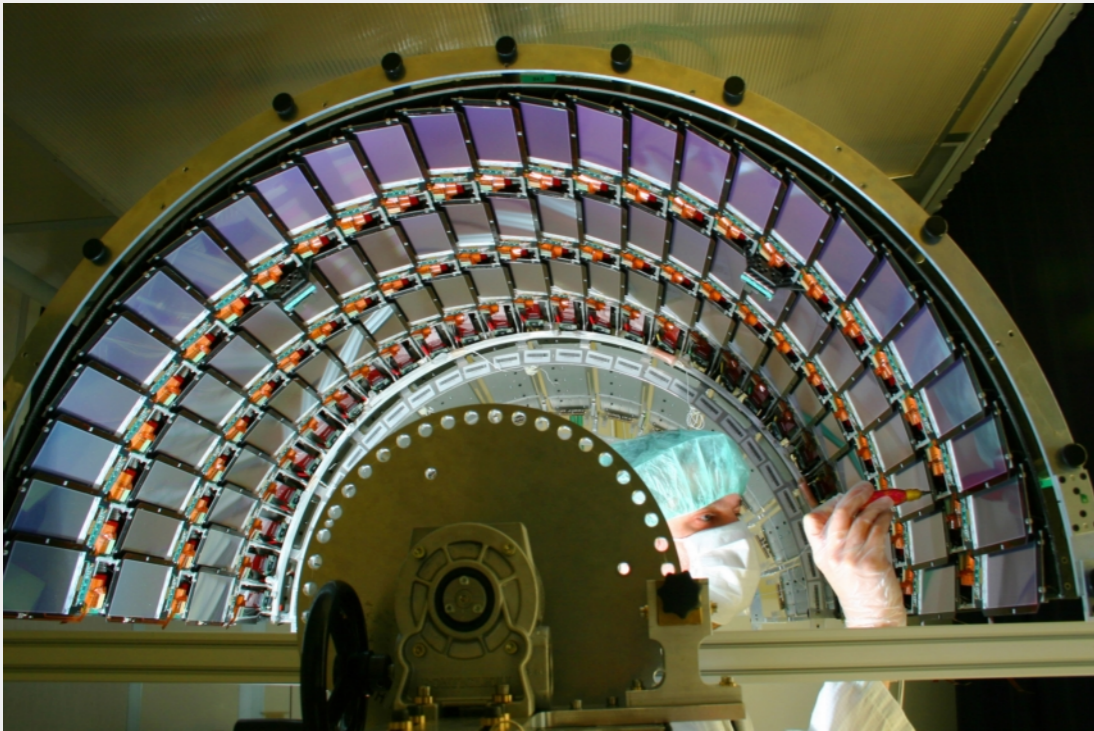


Reconstruction of a "Laser track"





# Integration of the TIB Layers (Pisa and Florence)

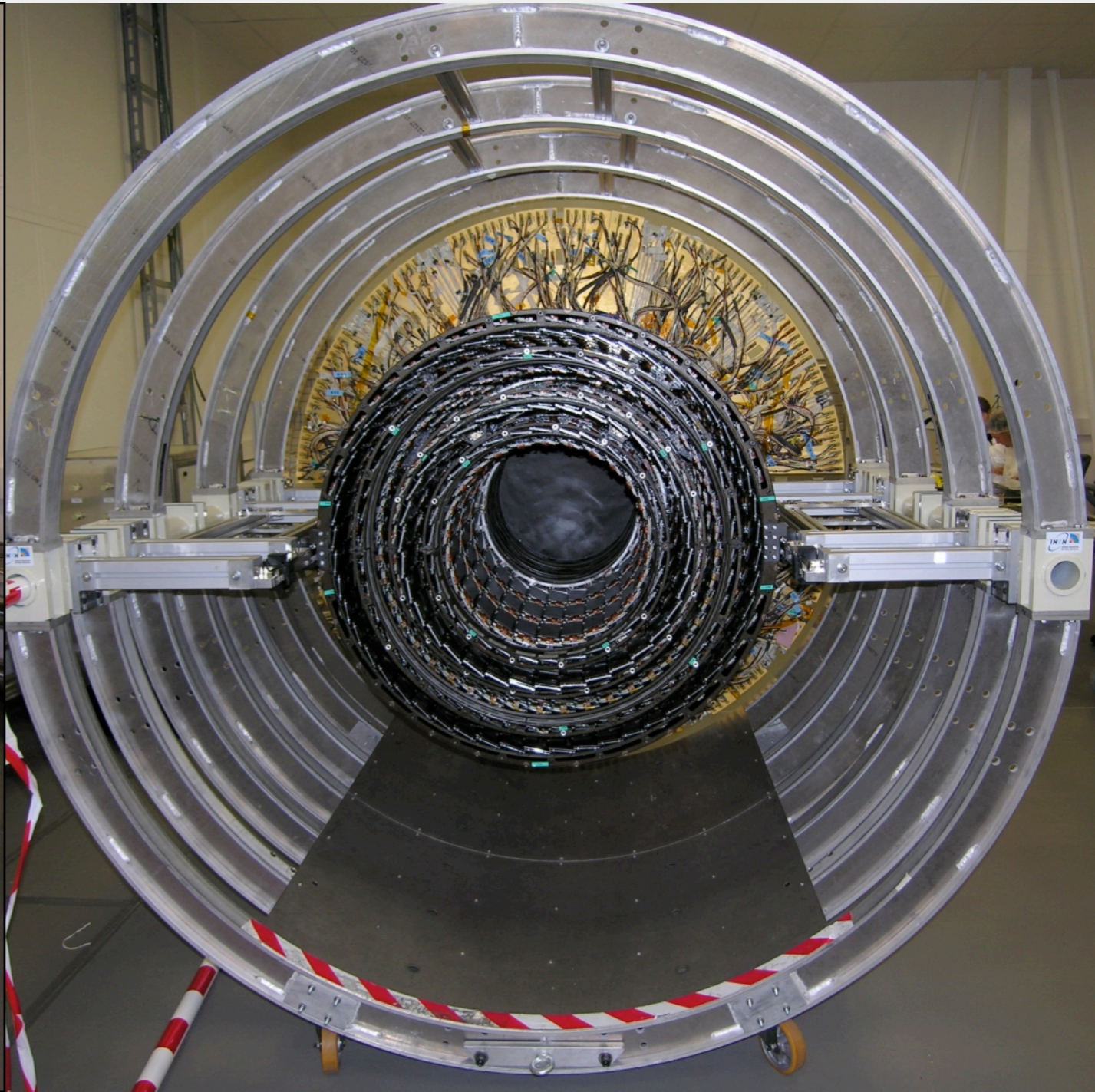
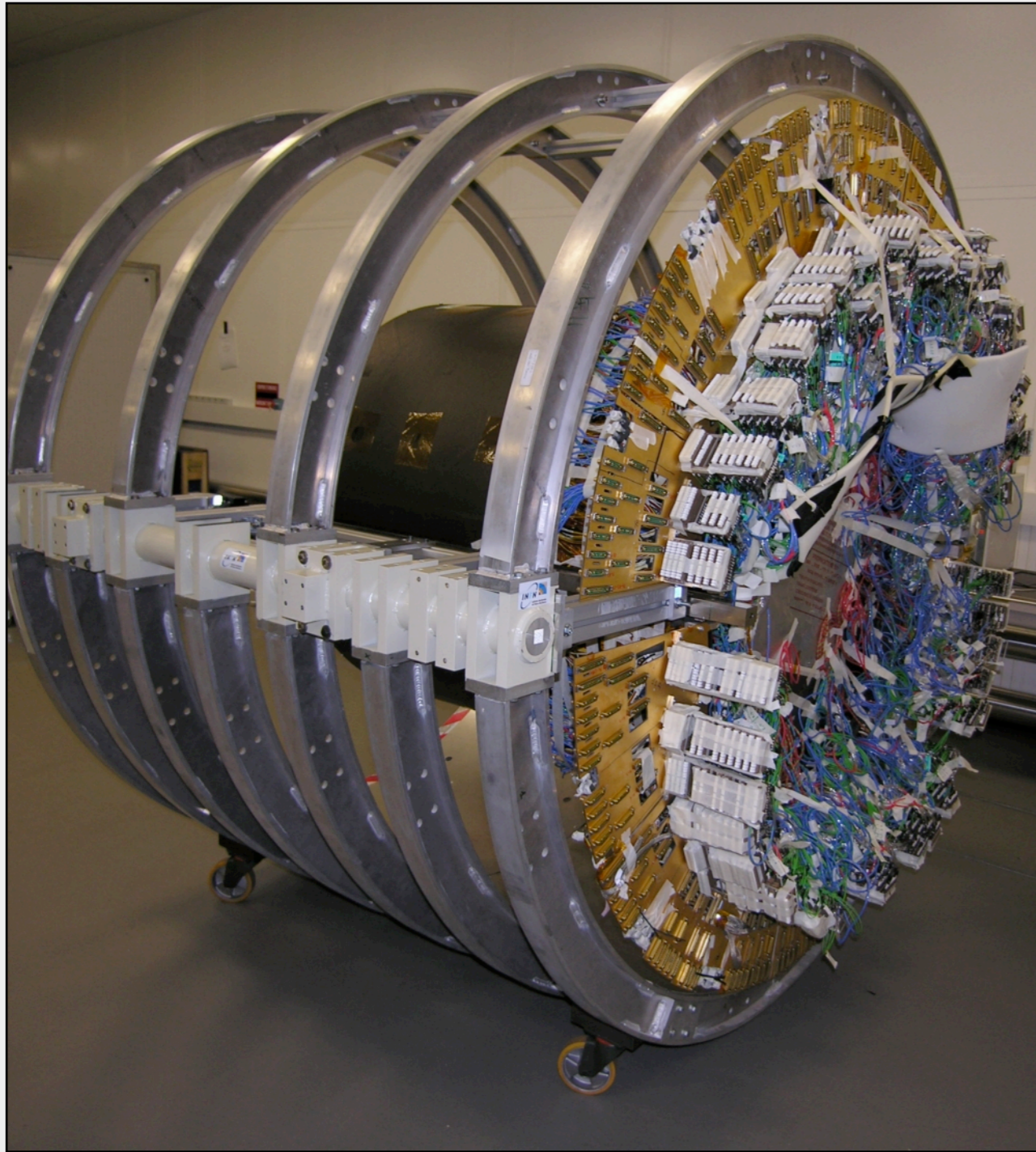


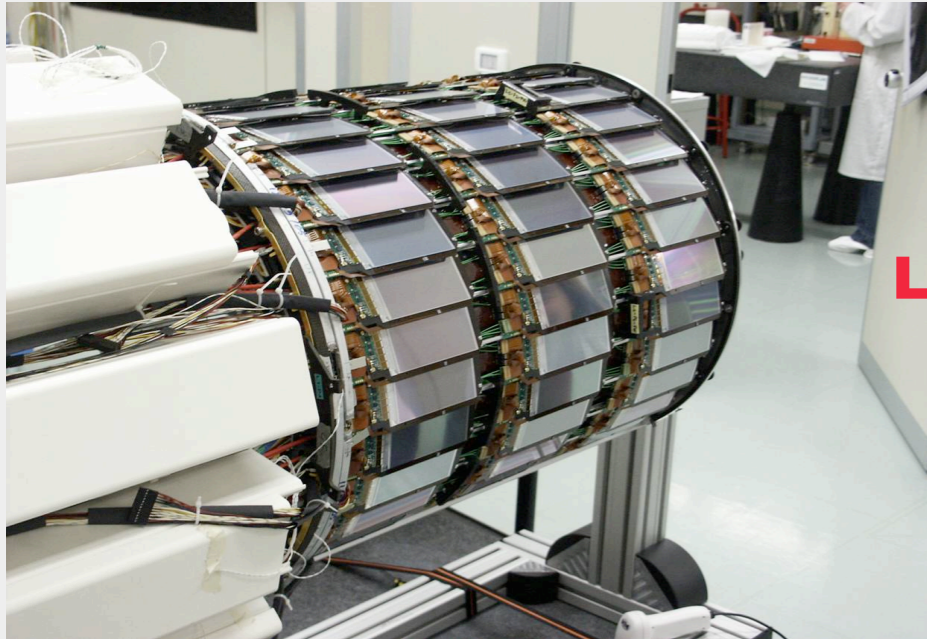
Completed by the end of April



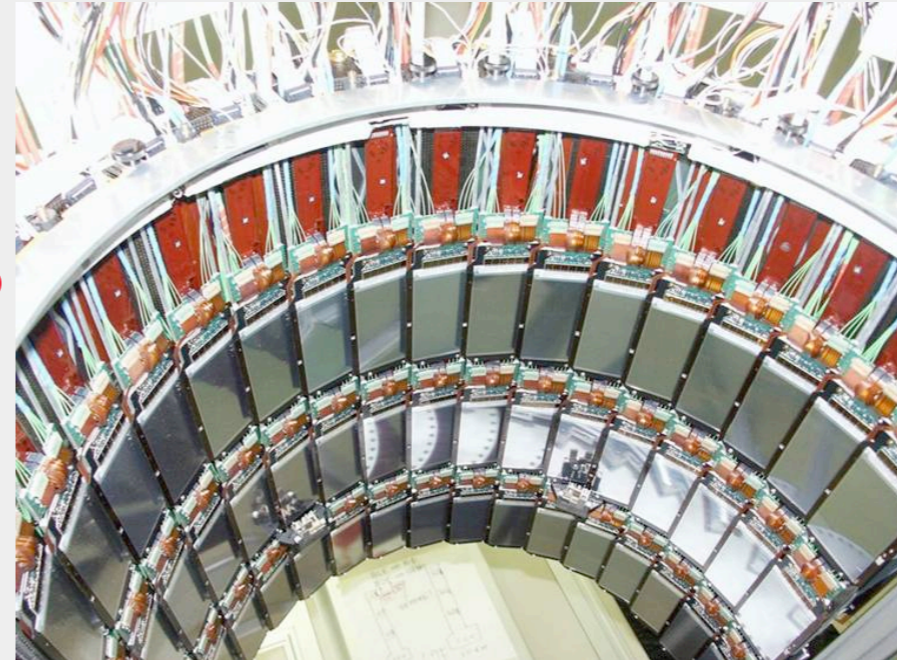
# Preparation for the transport and arrival at Cern



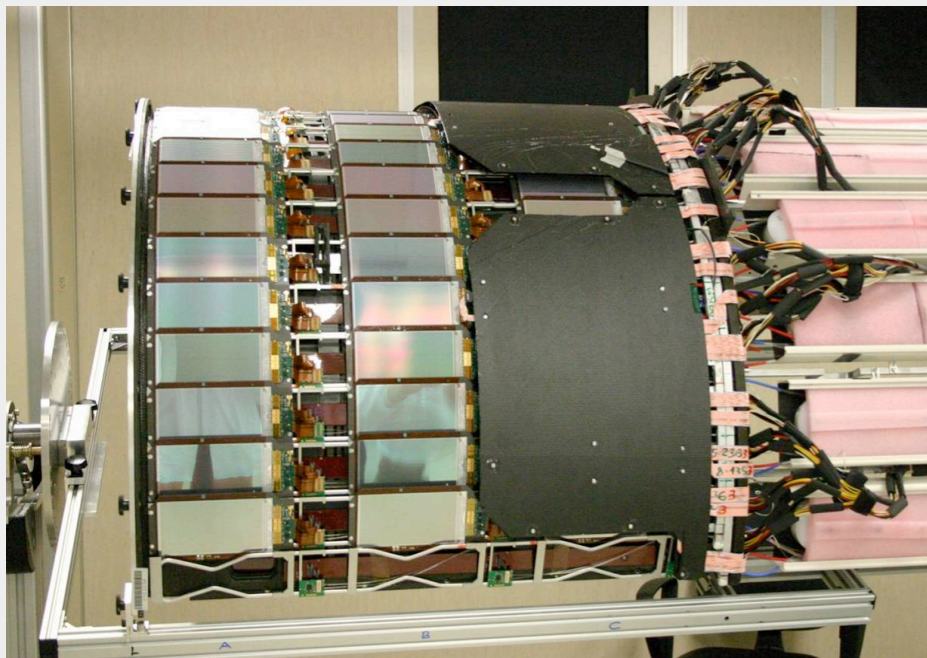




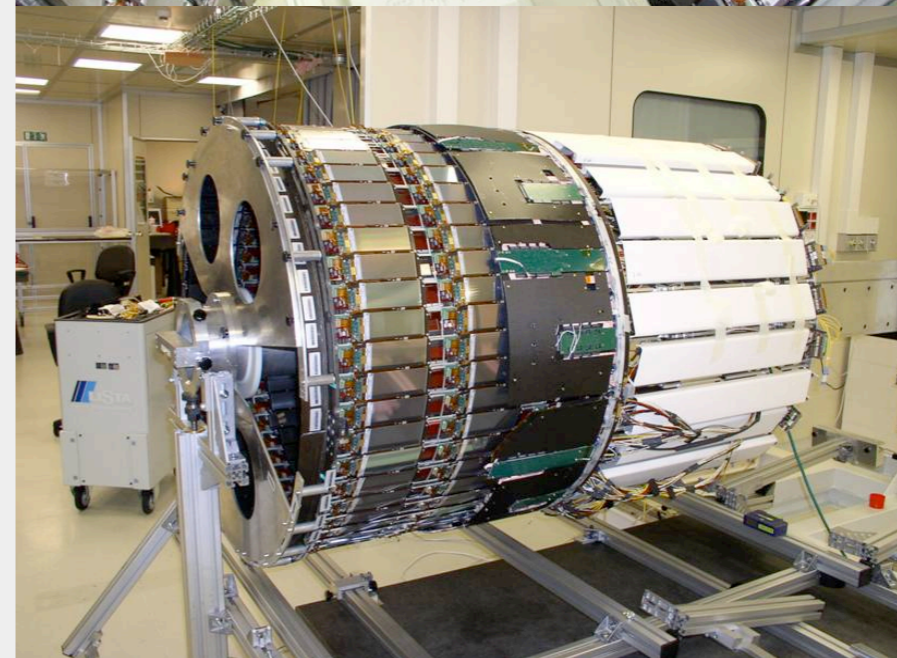
**Layer 1 Stereo**



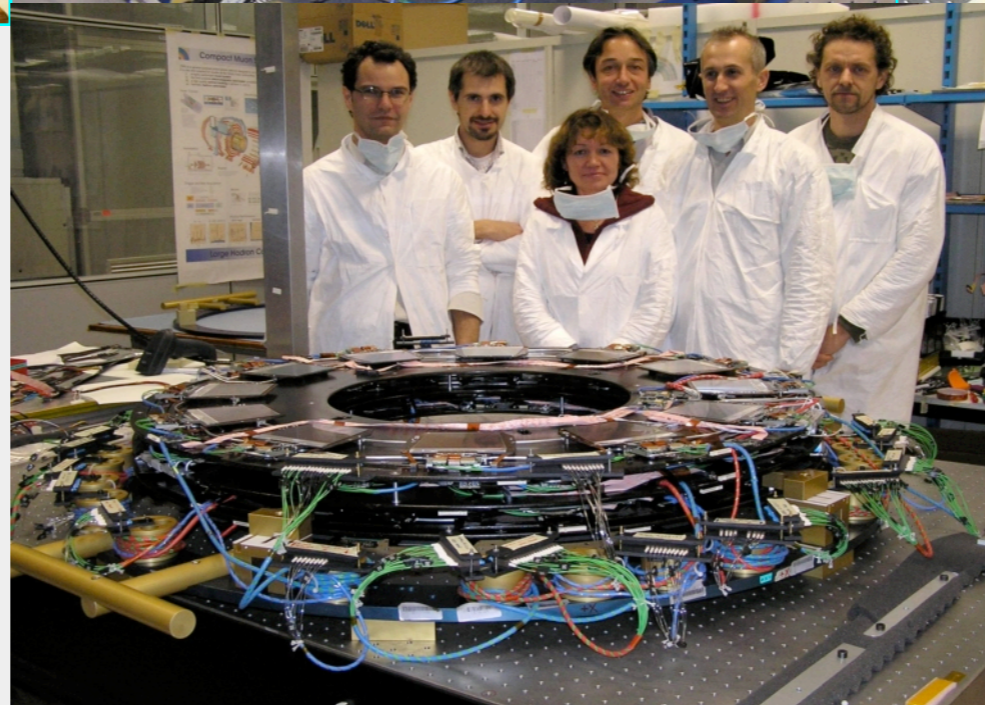
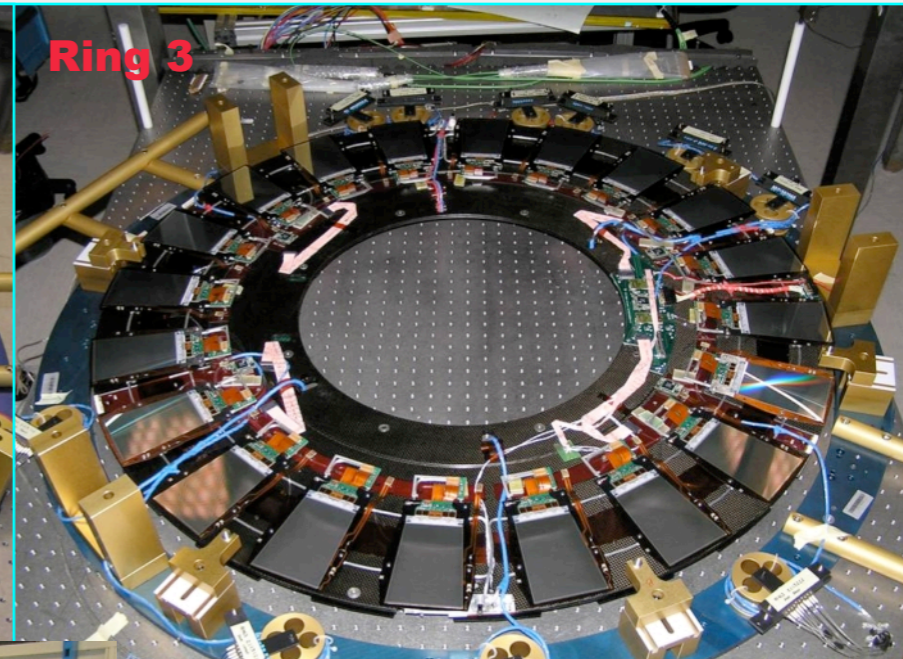
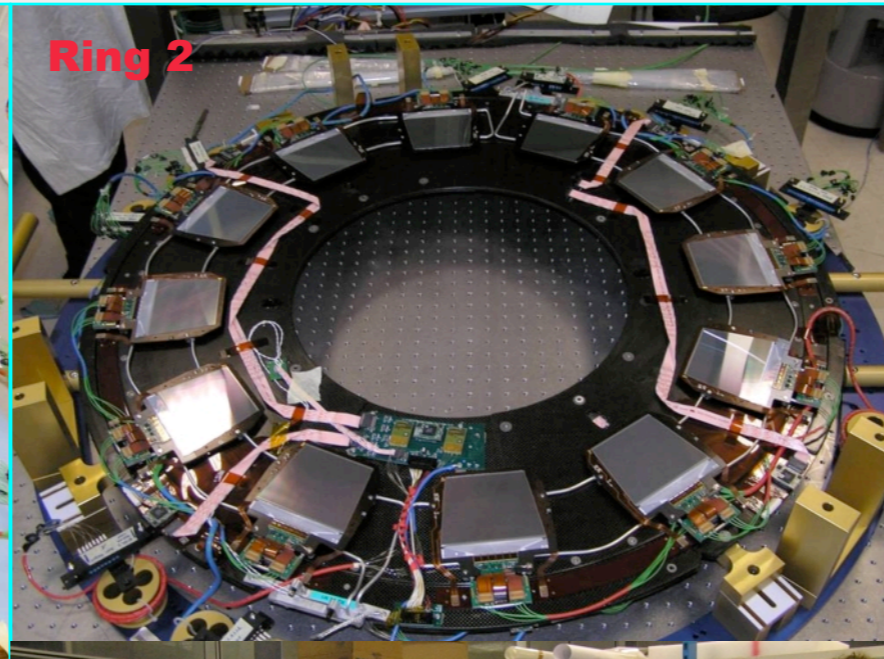
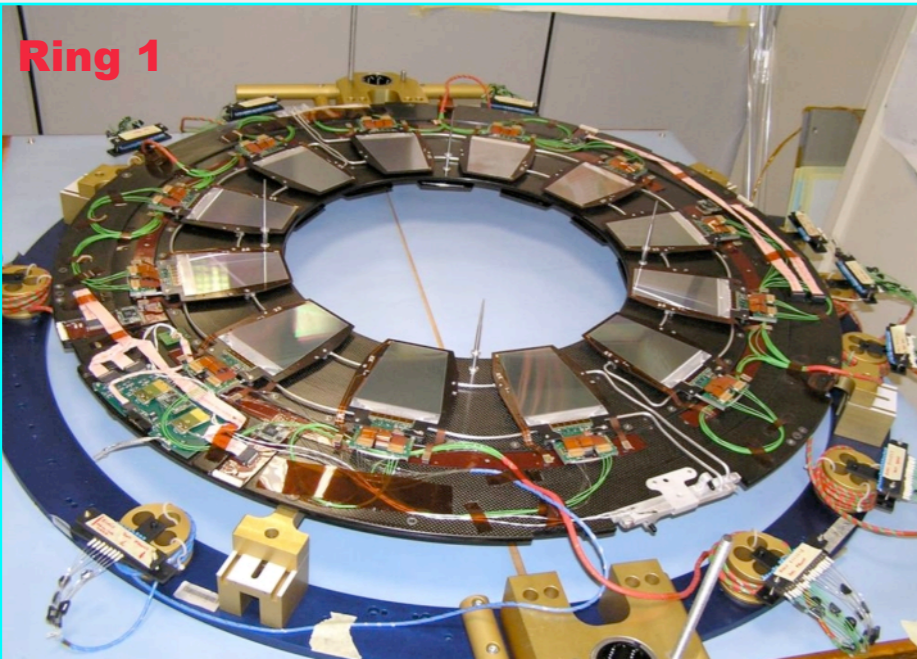
**Layer 2 Stereo**



**Layer 3**



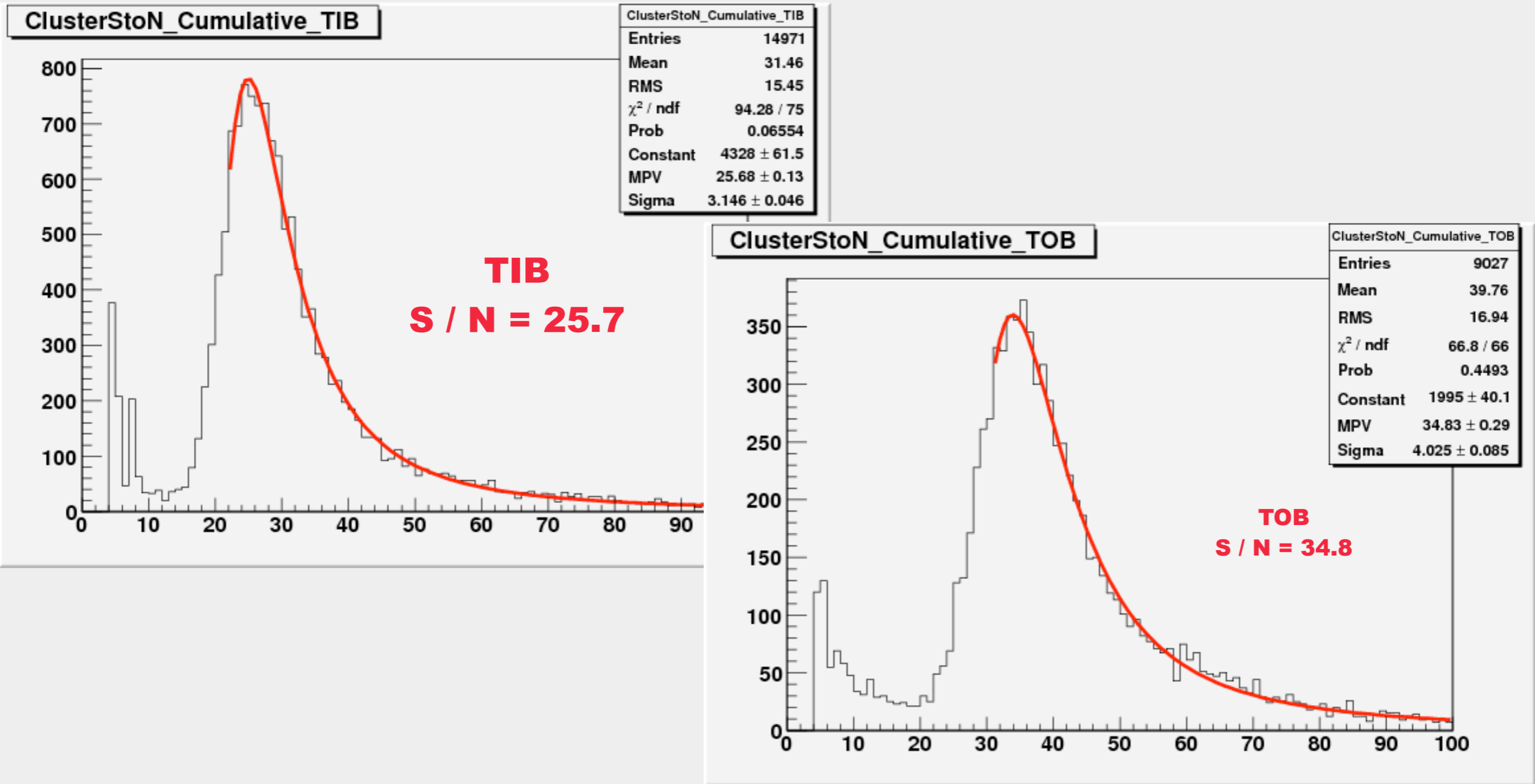
**Layer 4**



**All Three Rings Coupled  
Together  
to form TID +**

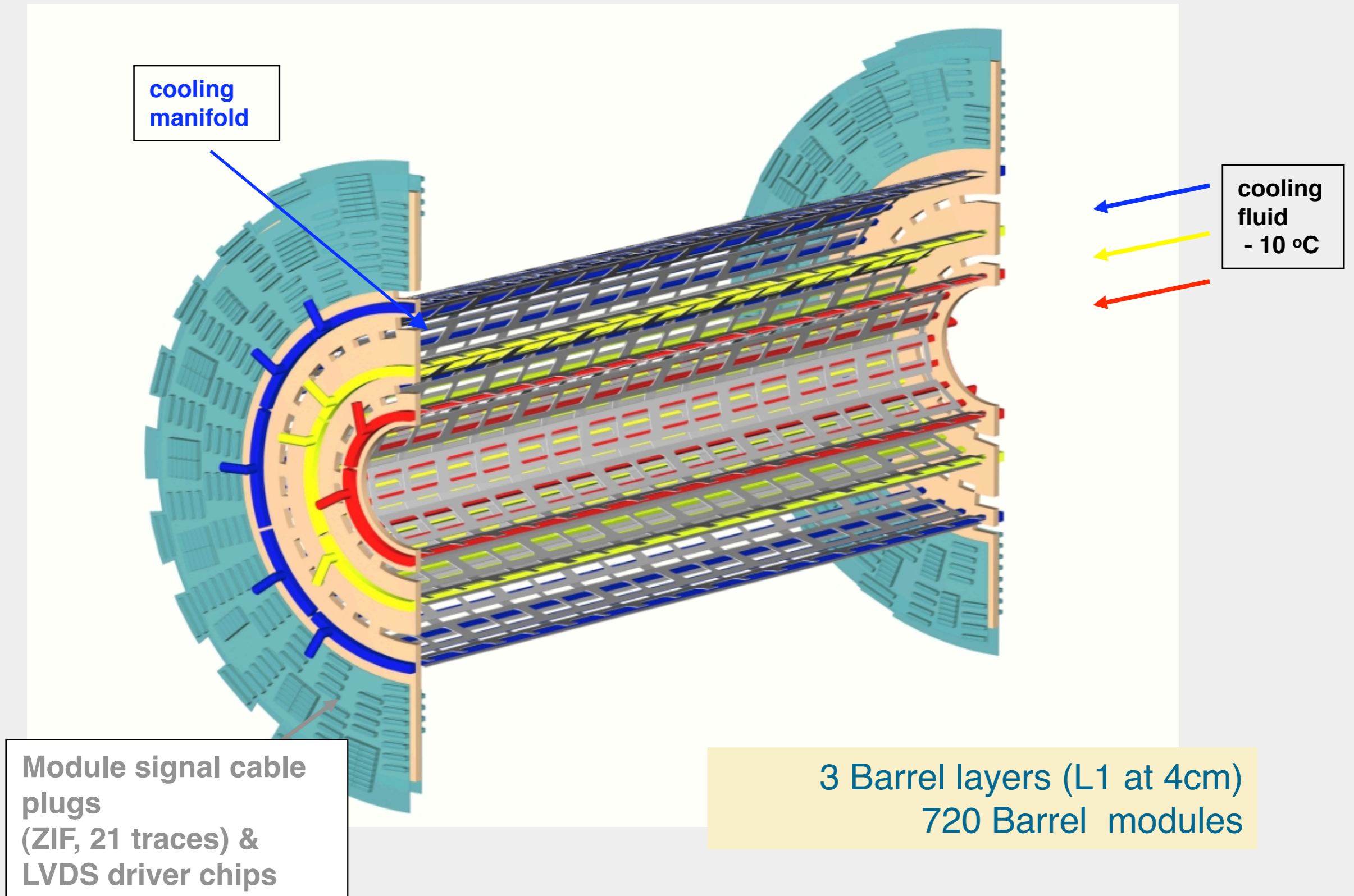


# Cosmics Test of MTCC Tracker in B 186

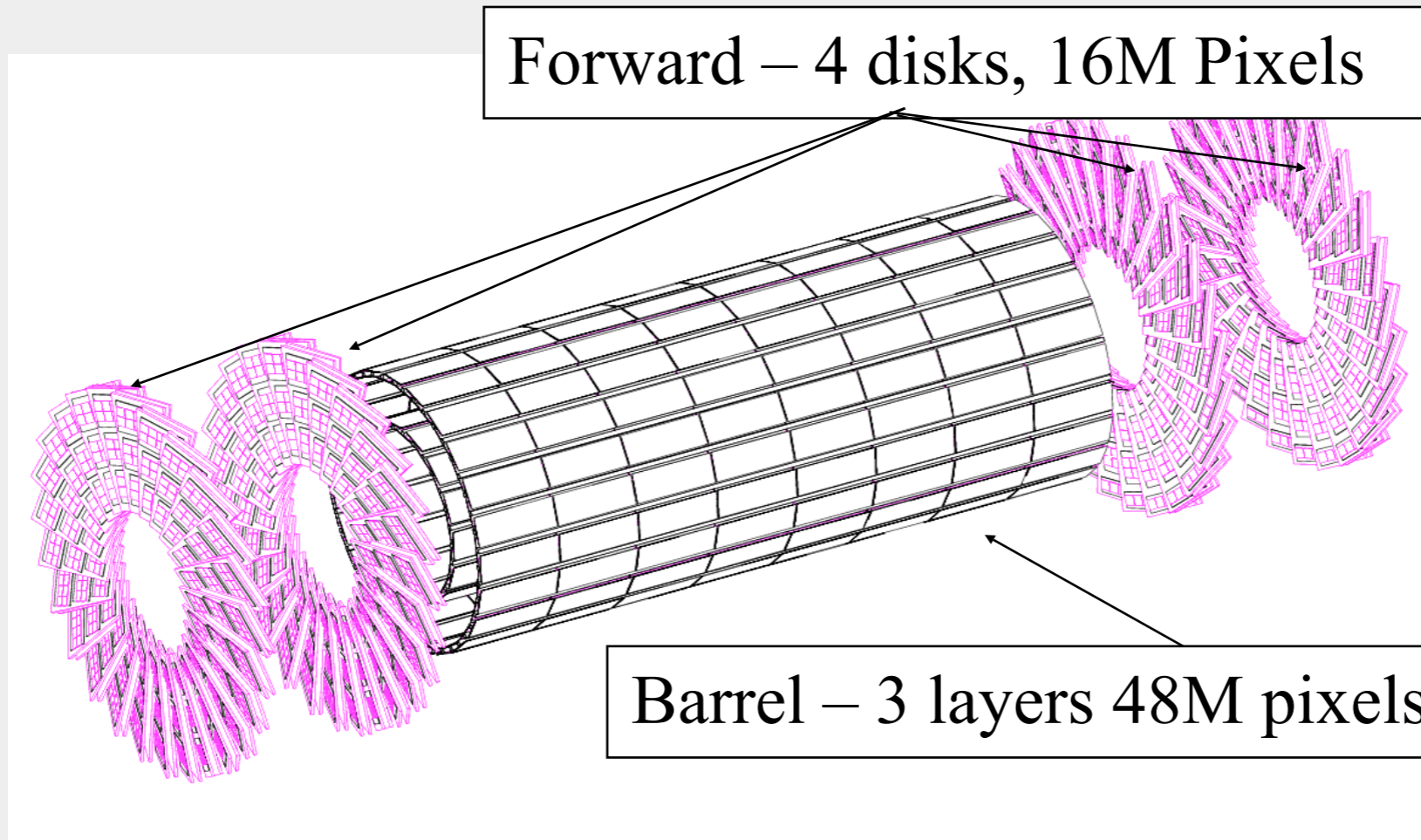




## Barrel Mechanics



# Pixels Design



Forward – 4 disks, 16M Pixels

Barrel – 3 layers 48M pixels

LAYERS: R = 4.3cm 7.2cm 11.0 cm → Area Barrel = 0.78 m<sup>2</sup>

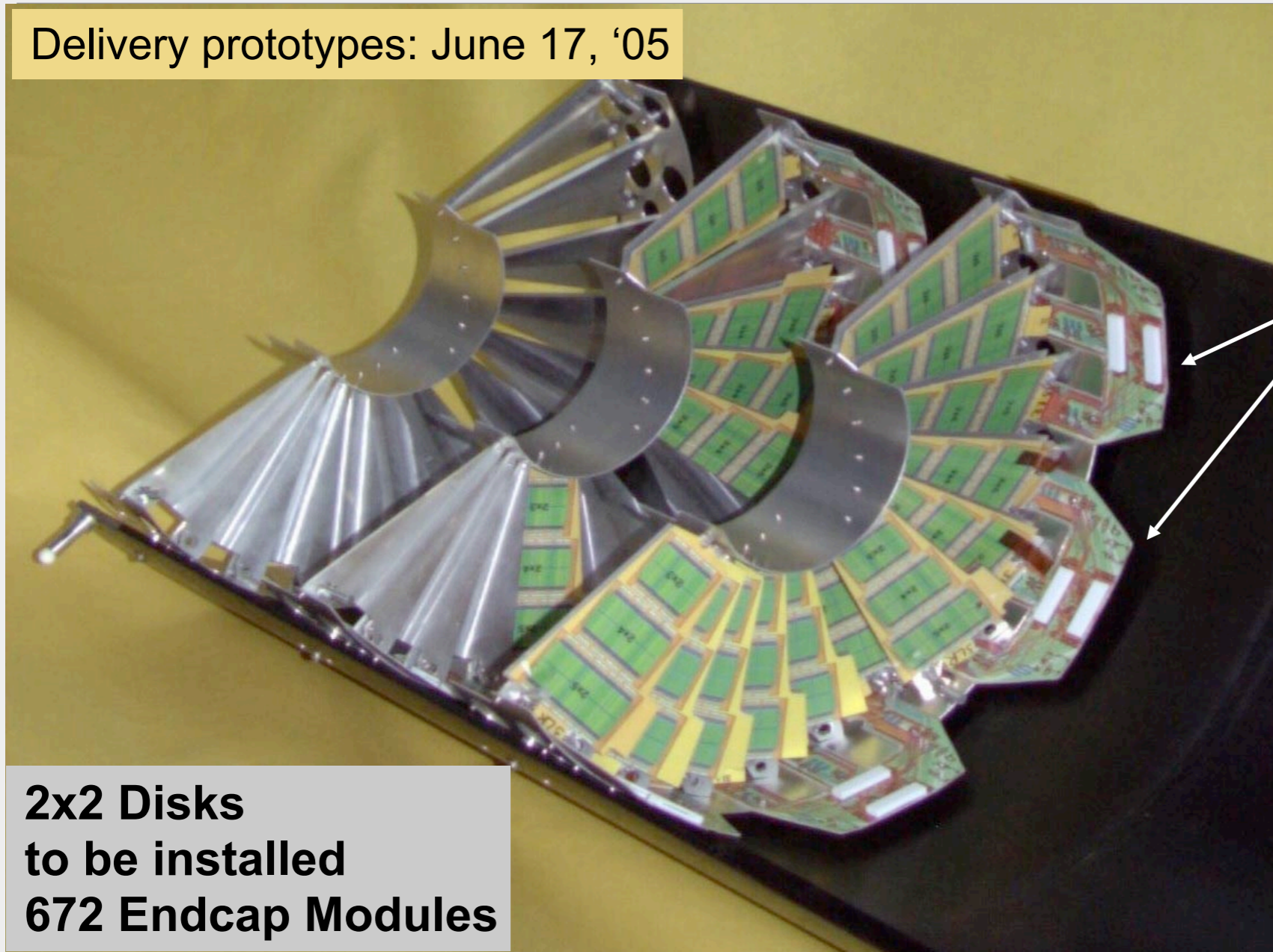
Disk = 0.28 m<sup>2</sup>

Total ~ 1.1 m<sup>2</sup>



# Forward Pixels

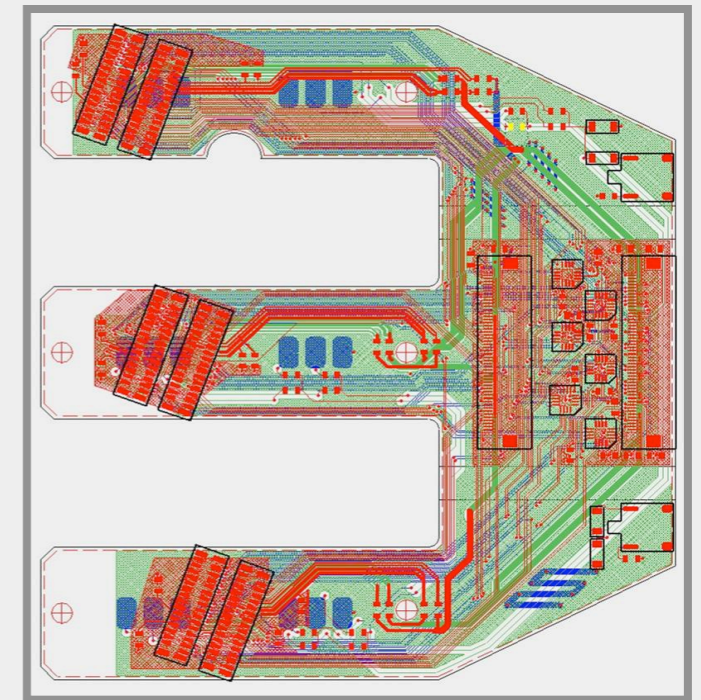
Delivery prototypes: June 17, '05



**2x2 Disks  
to be installed  
672 Endcap Modules**

Service Cylinder

Adapter Board



## Pixels Status

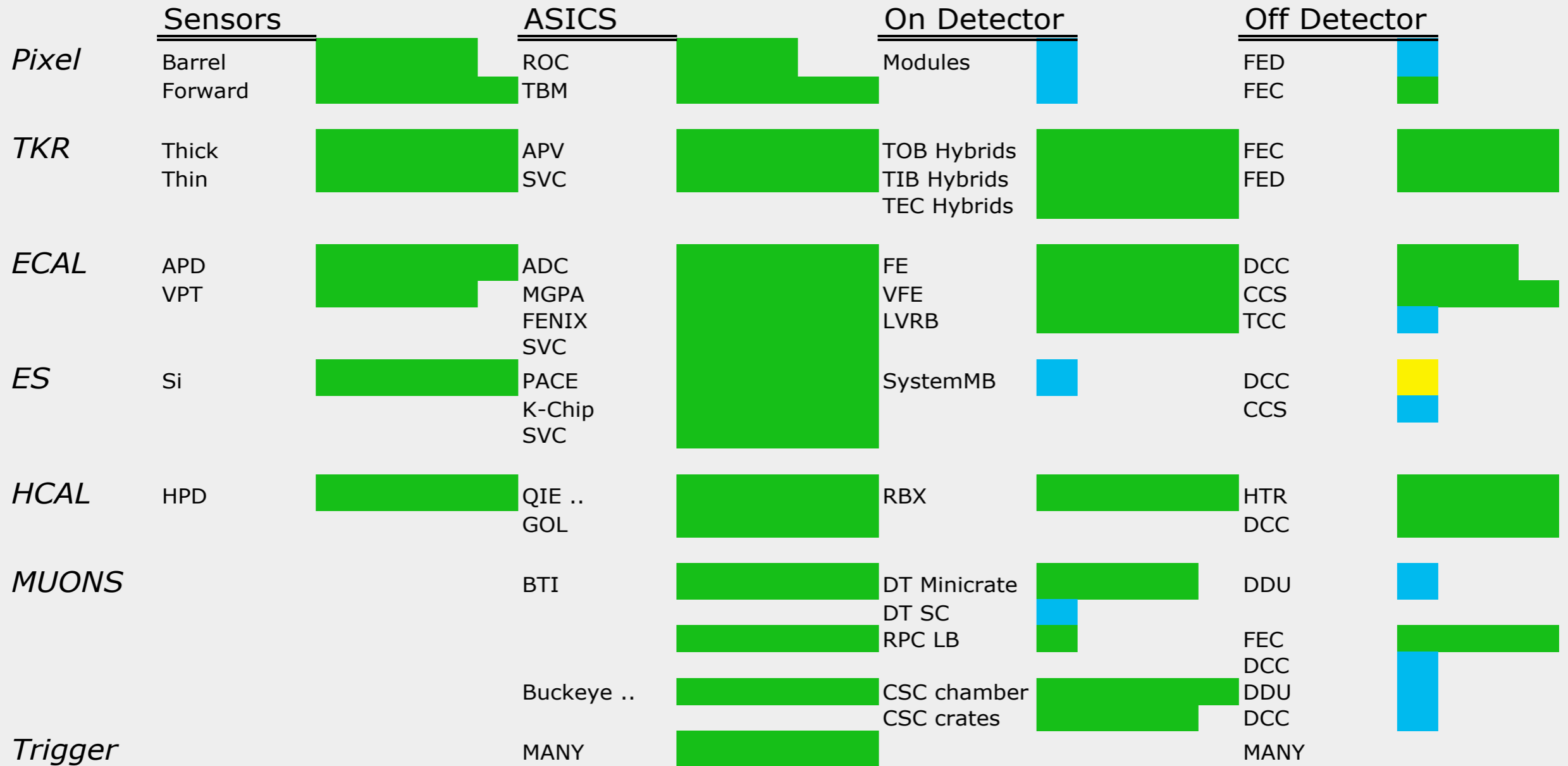
- Readout chip successful
- Pre-production runs completed
- Construction will take 1 year
- Installation for the '08 LHC physics run!



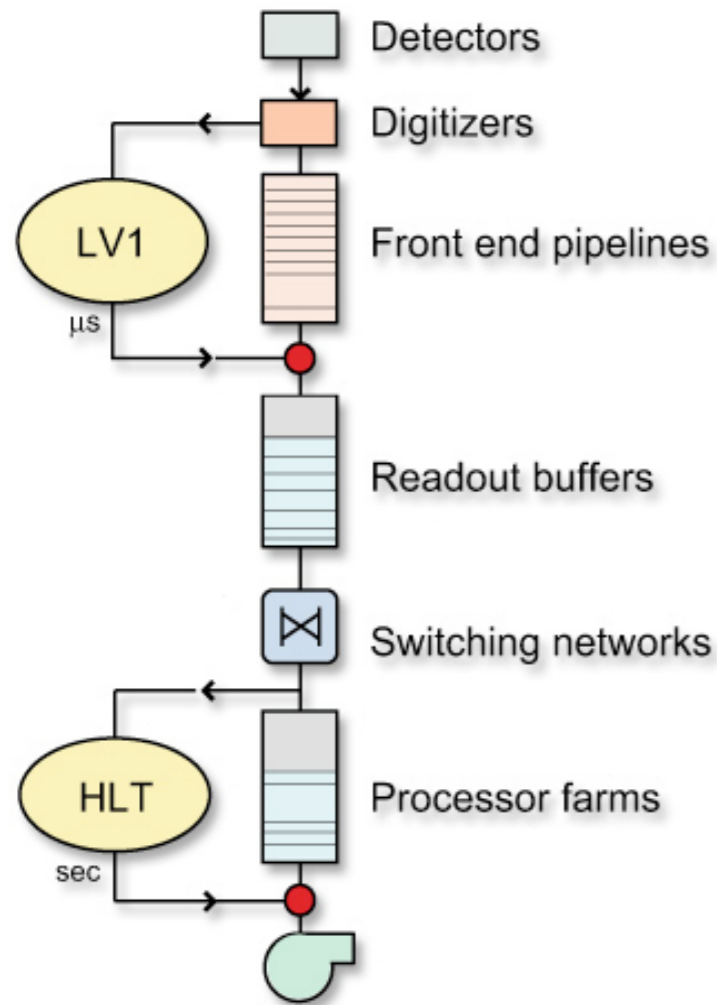
# CMS electronics



## Electronics Status: June 2006



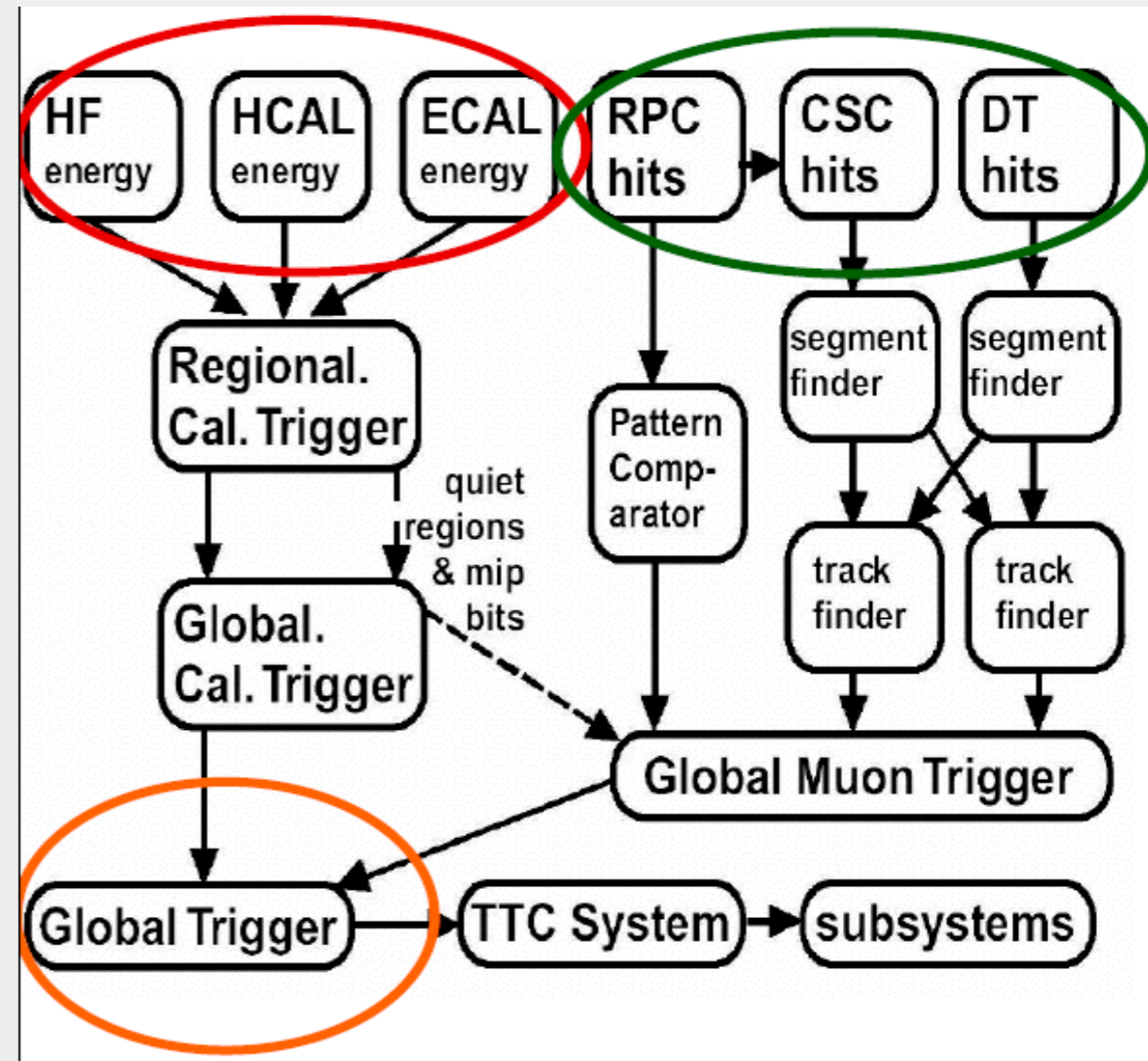




**40 MHz**  
 Clock driven  
 Custom processors

**100 kHz**  
 Event driven  
 PC network  
 Totally software

**100 Hz**  
 To mass storage



## two trigger levels

Level-1 ( $\sim\mu\text{s}$ ) 40 MHz  
 High-Level (ms-sec) 100 kHz  
 Event Size  $\sim 10^6$  Bytes



# Integration test DTTF - GMT in 904

## Integration Tested:

Test data - PHTF - WS -  
BS - DCC - S-link -  
DAQ-readout  
Test data - PHTF -  
ETTF - WS

Detector - Minicrate  
Sector Collector -  
PHTF - WS - BS - LTC  
- TTCci - DCC - S-link -  
DAQ-readout

Test data - PHTF - WS -  
BS - GMT





# Integration test CSC - GMT in 904

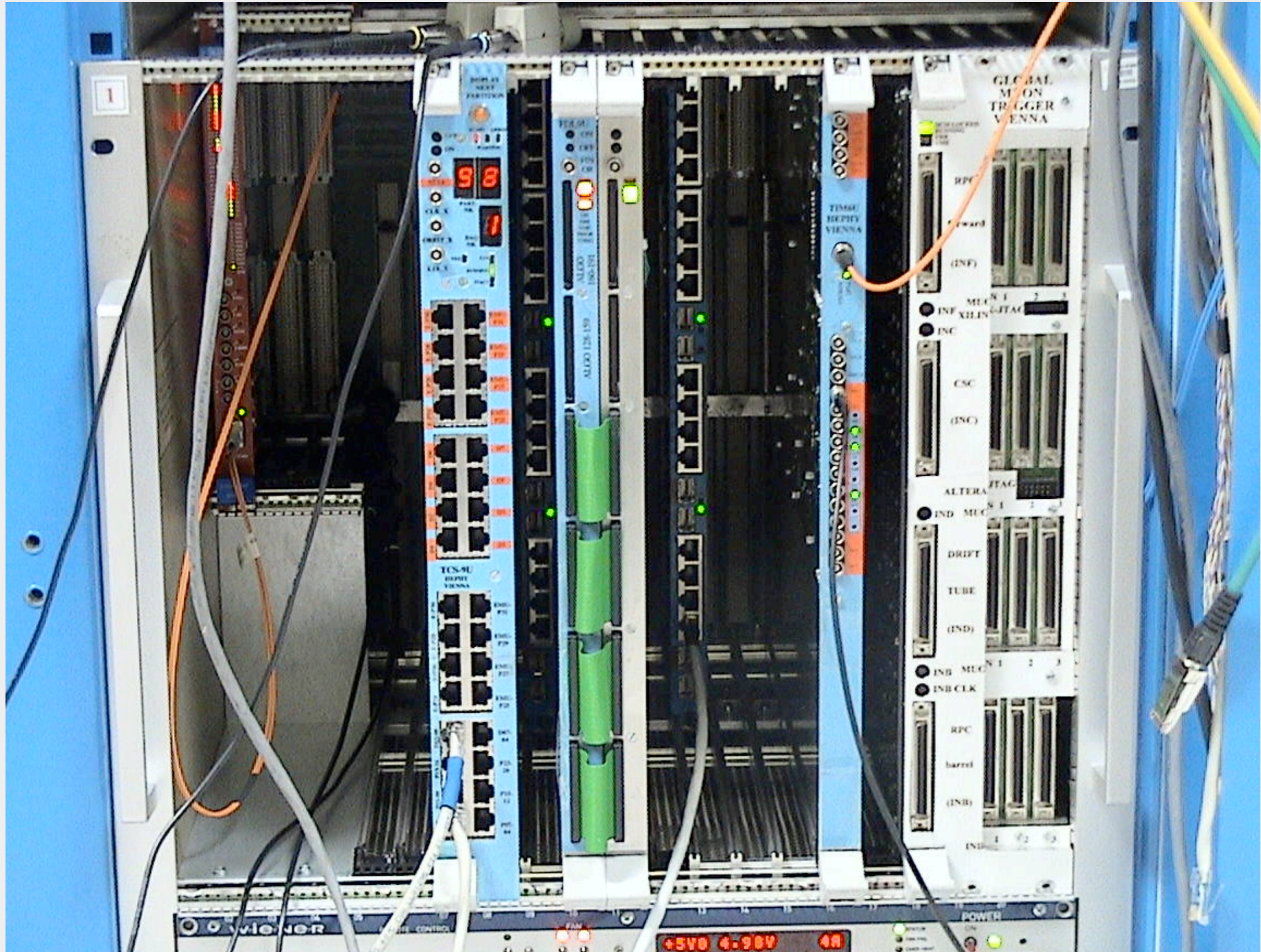
**Integration  
Tested:**

**Test data -  
PHTF - CSC**

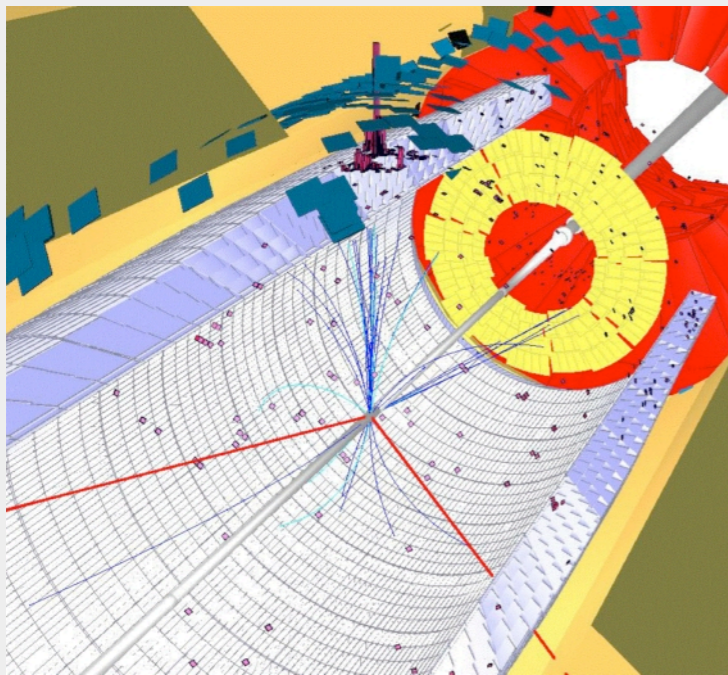




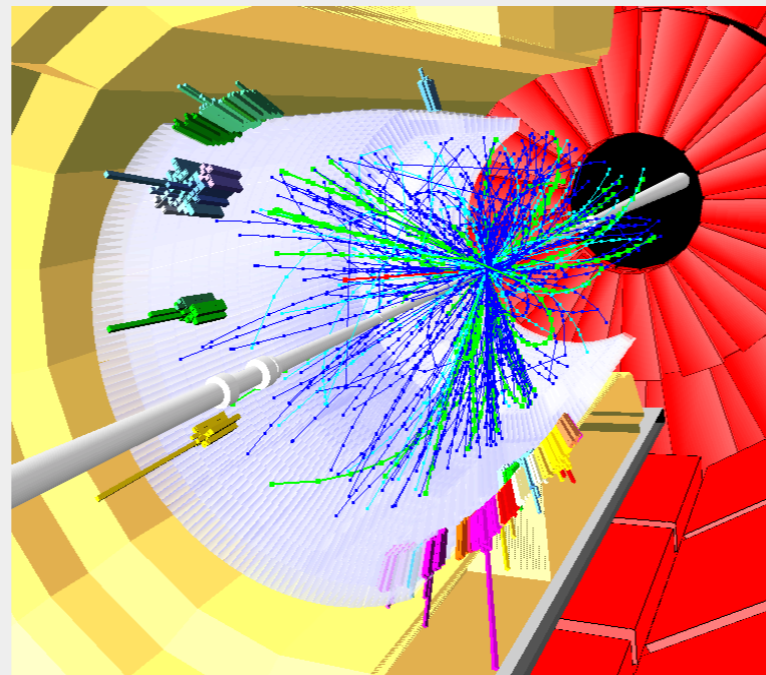
# Global Trigger crate in 904 (Vienna)



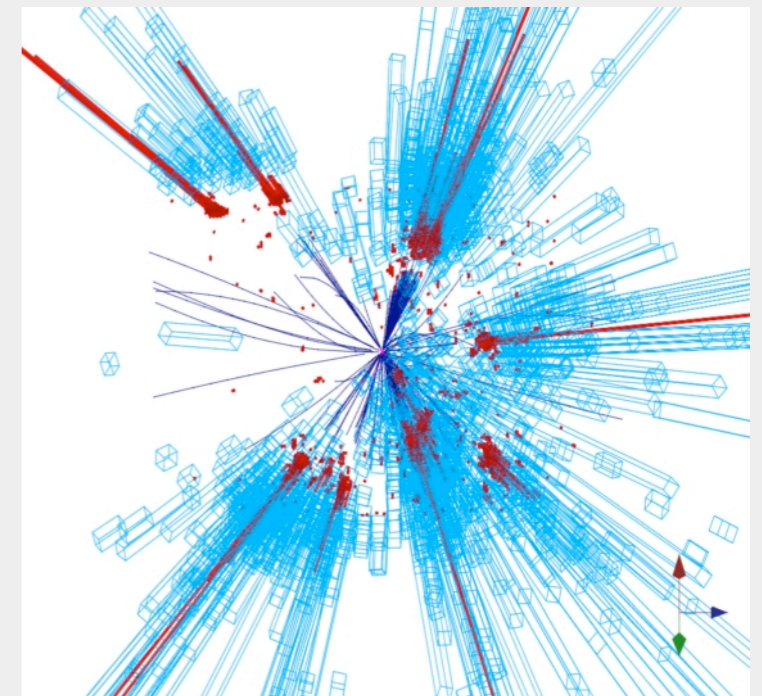
- *The Physics TDR is now finished for CMS*
- *Next objectives: MTCC, CSA06 and preparing for the physics commissioning and first data.*
- *Have to maximalize experience & training for the real thing in 2007*
- *An ambitious program ahead for the next 14 months*



SUSY events (LM4 point: leptons, missing  $E_T$ )



SUSY events (LM1 point: jets missing  $E_T$ )



Micro-Black Hole



# CMS is rapidly coming together!



- *Major progress, particularly in this past year*

- *Beam tube baked out on 31st August 2007*

- *CMS ready for collisions at injection energy*

- *Rendez-vous at the next “Physics at LHC”  
with first collision results*



# LHC Luminosity Profile : prospective

