CMS Construction Status and Commissioning Plans

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TeV4LHC Workshop, CERN,
28 April, 2005

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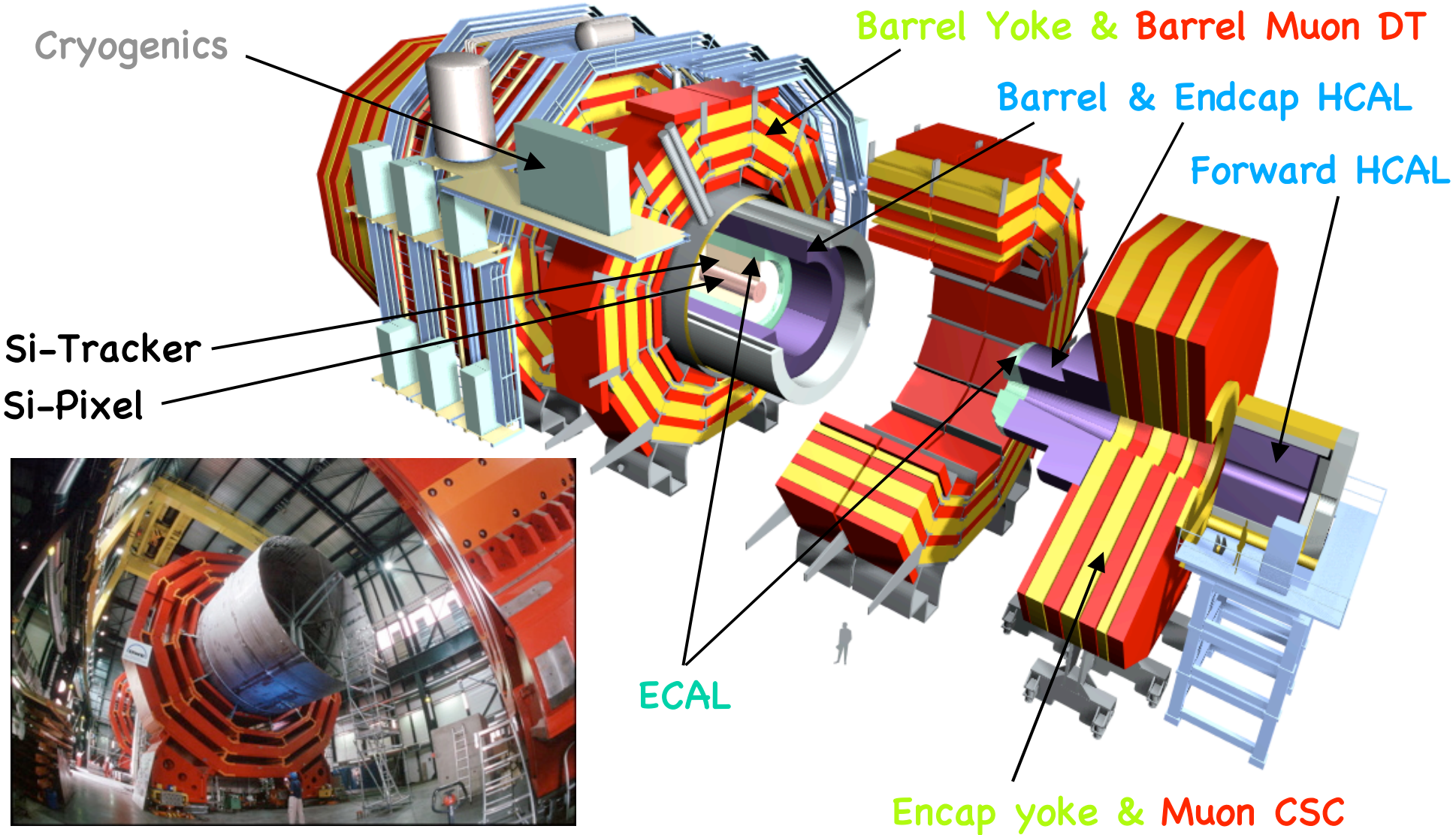
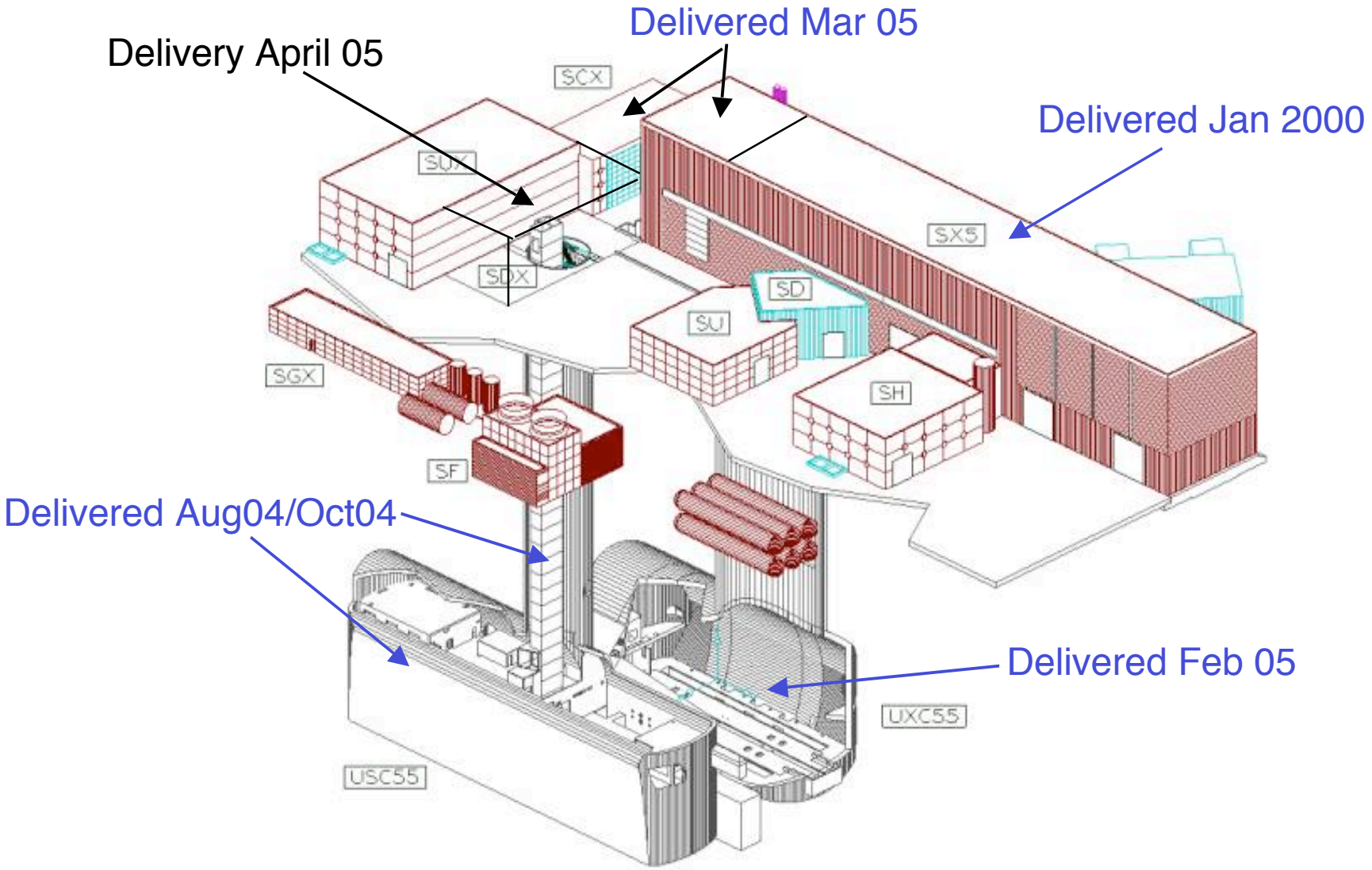
CERN/PH-CMG

CMS Overview



Civil Engineering Status



CMS Assembly Sequence

Blue=done

Red=to be done

Surface

Construct barrel yoke & cable

Prepare solenoid vac tank

Construct endcap yoke & cable

Assemble hadron calorimeters

Install muon chambers in yoke

Assemble coil & insert in vac tank

Insert barrel HCAL inside coil

TEST MAGNET

Insert part of barrel ECAL in HCAL

Lower underground in big entities

2006

Underground

Prepare infrastructure in USC

Install shielding in UXC

Prepare infrastructure in UXC

Complete ECAL barrel & cable

Install Tracker and cable it

Install beam-pipe

Close experiment and commission

FIRST PHYSICS

Install ECAL endcap & pixel

Underground Service Cavern

USC55- Controls Ground Floor

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

USC55- Controls First Floor

delay accommodated in schedule by setting up an electronics pre-commissioning centre on the surface

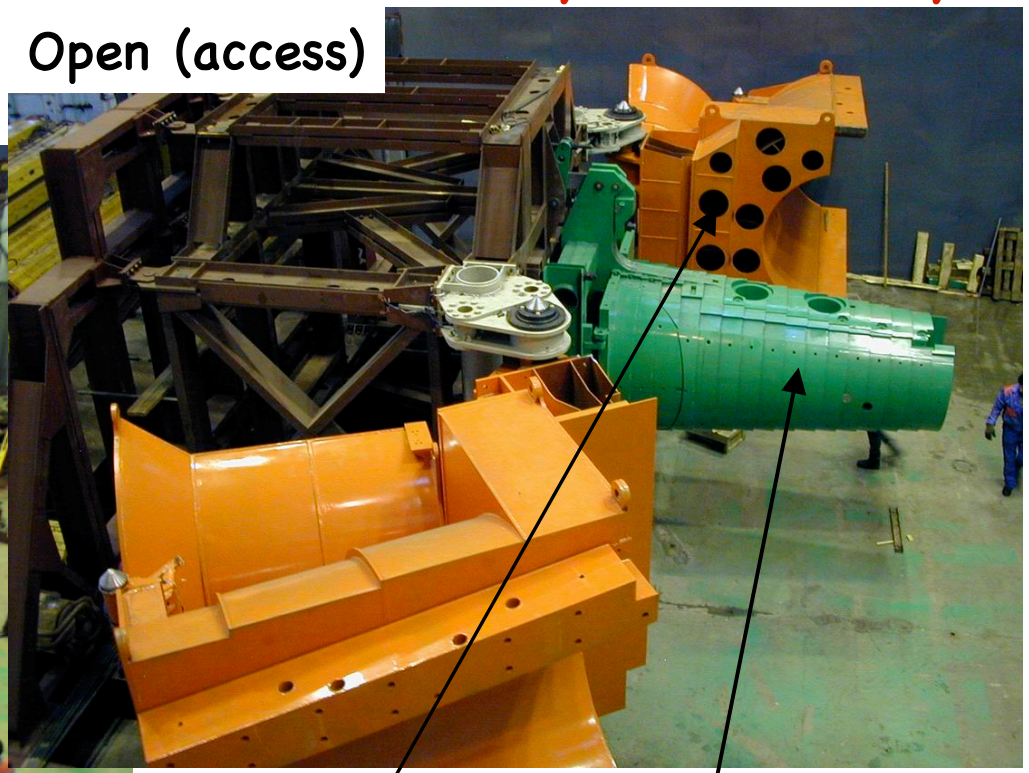
Experimental cavern (UXC)

February 1st, 2005

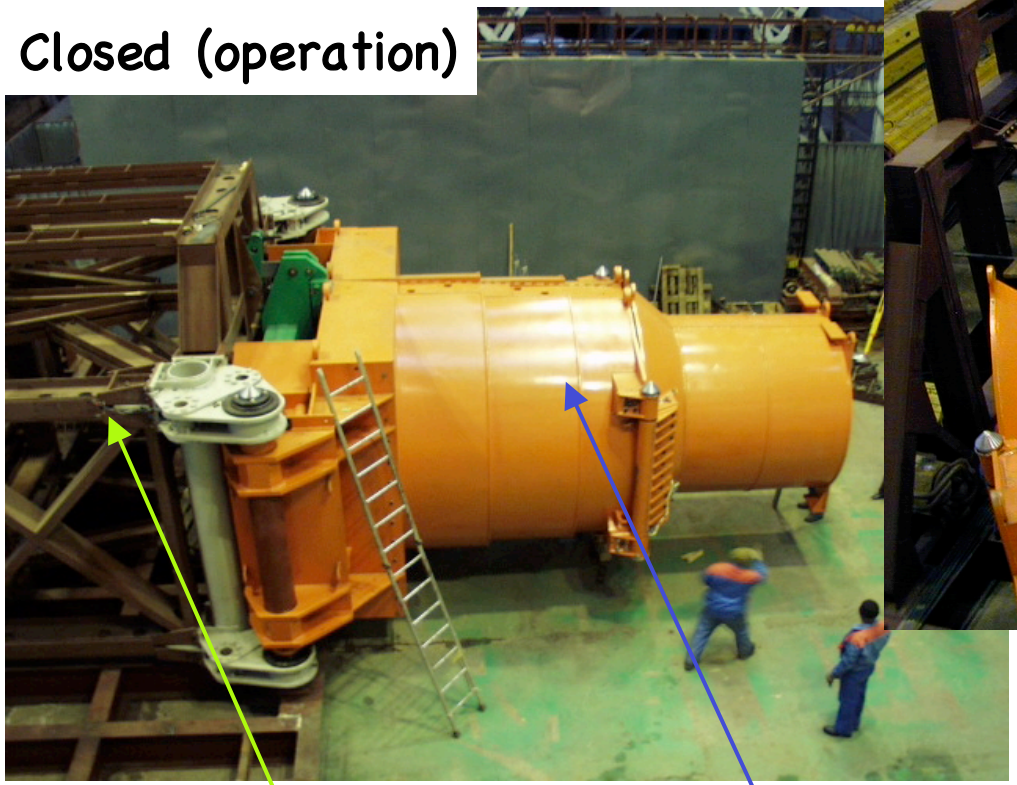
Radiation shielding

Forward shielding tested at Protvino – ready for delivery

Open (access)



Closed (operation)



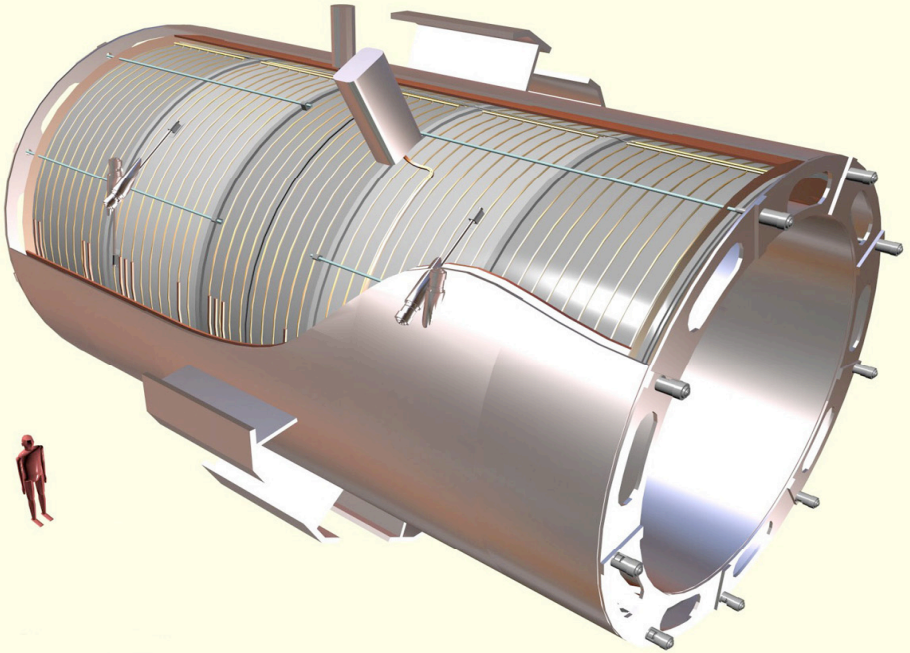
"Fixed iron nose"

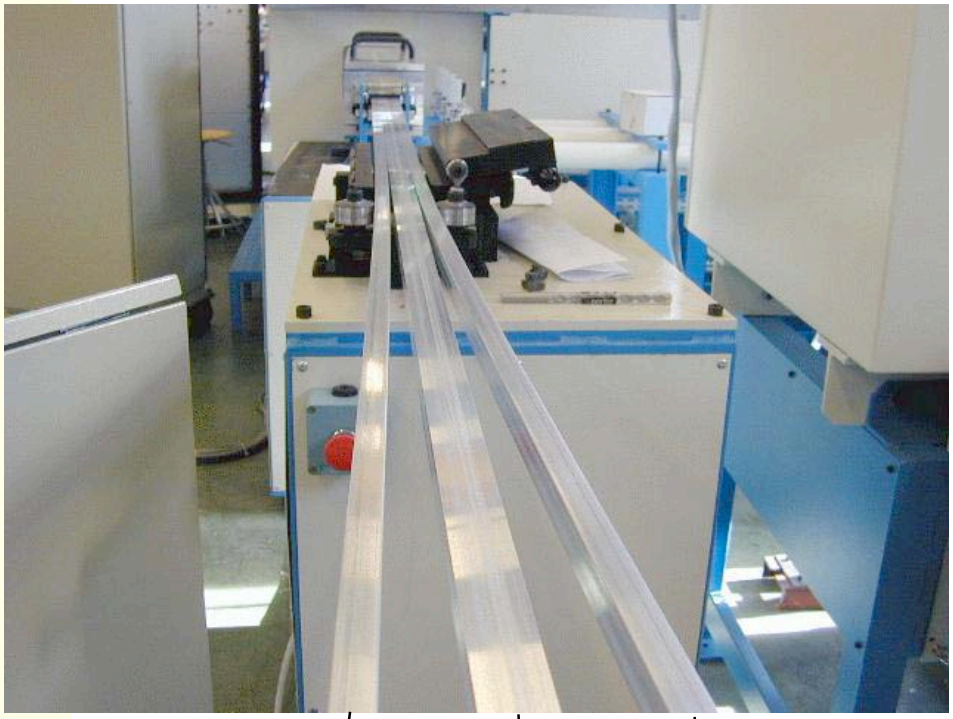
Holes for concrete filling

"Rotating shielding"

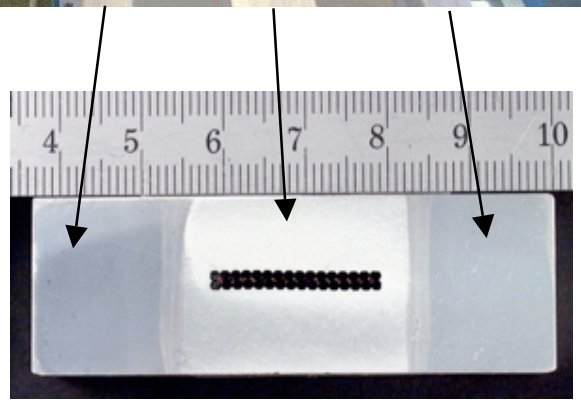
"block house" steel frame

The CMS Magnet Coil



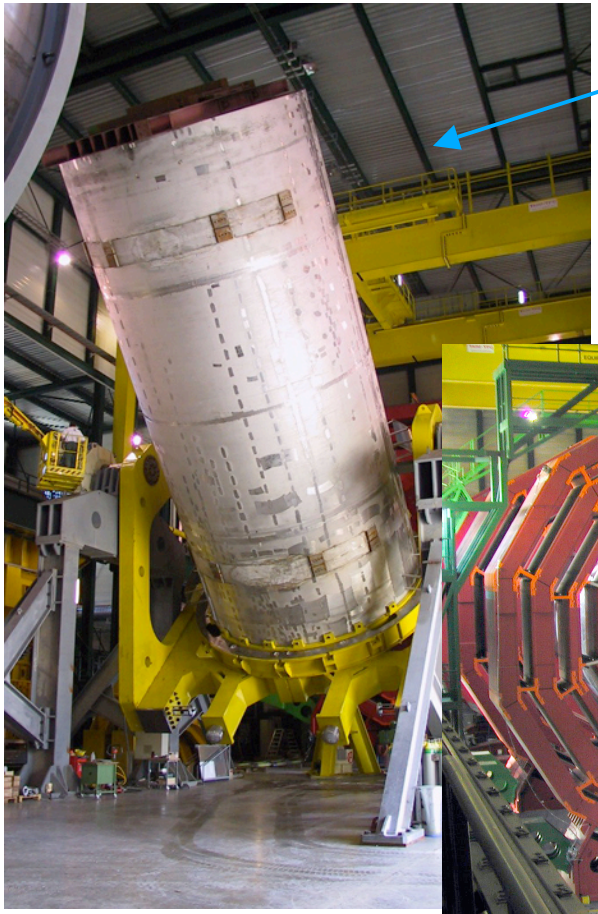


Magnetic length	12.5 m
Free bore diameter	6 m
Central magnetic induction	4 T
Nominal current	20 kA
Stored energy	2.7 GJ
Magnetic Radial Pressure	64 Atmospheres
Weight	220 t



CMS Magnet Status

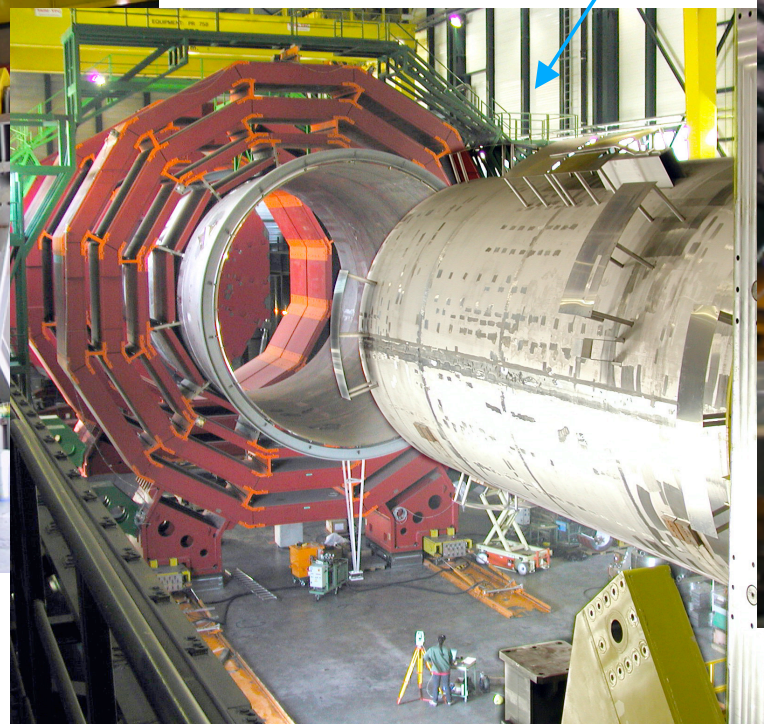
Cold mass of CMS coil complete



Swiveling and

Insertion tests

With dummy coil



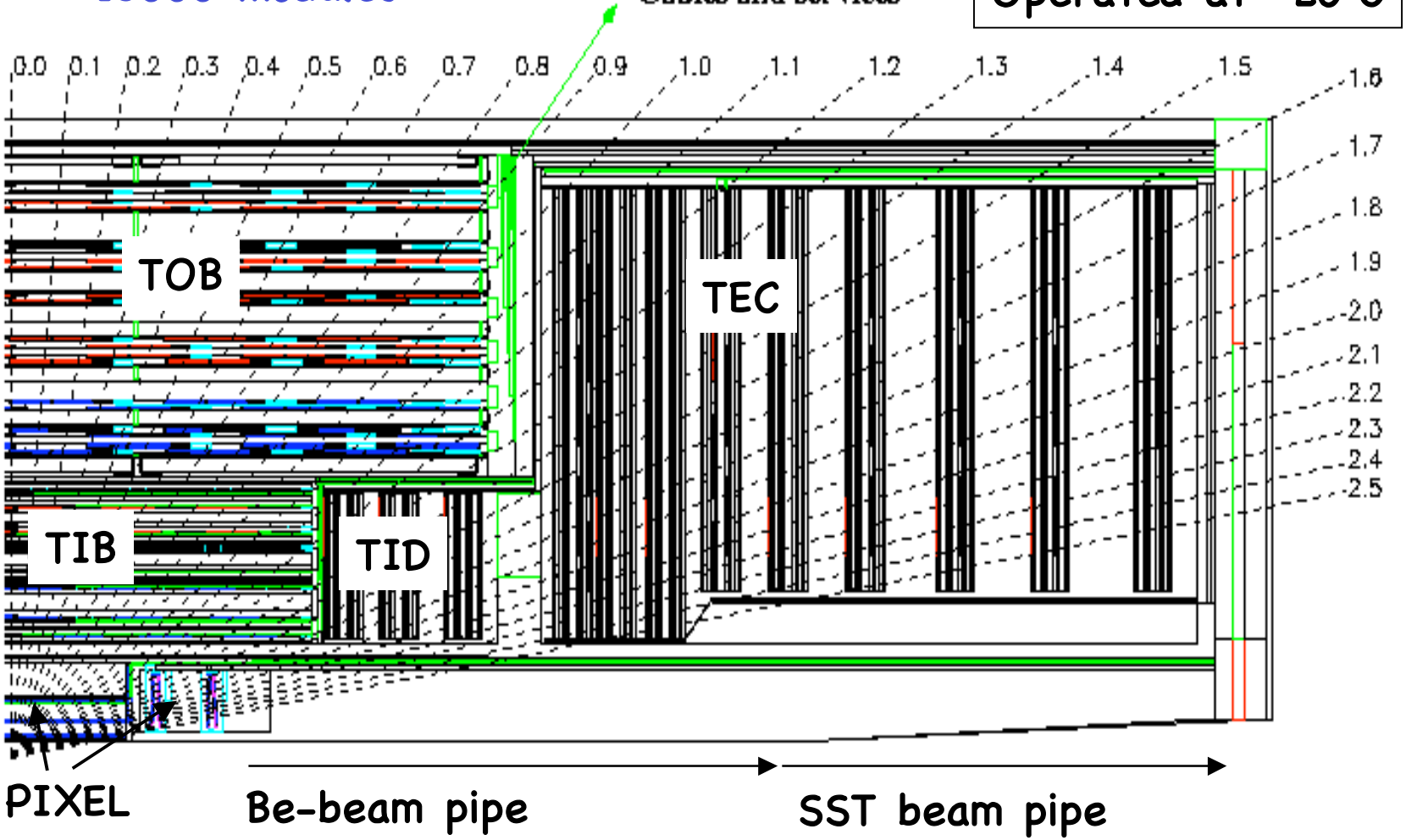
Silicon Tracker

210 m² Si strip sensors

15000 modules

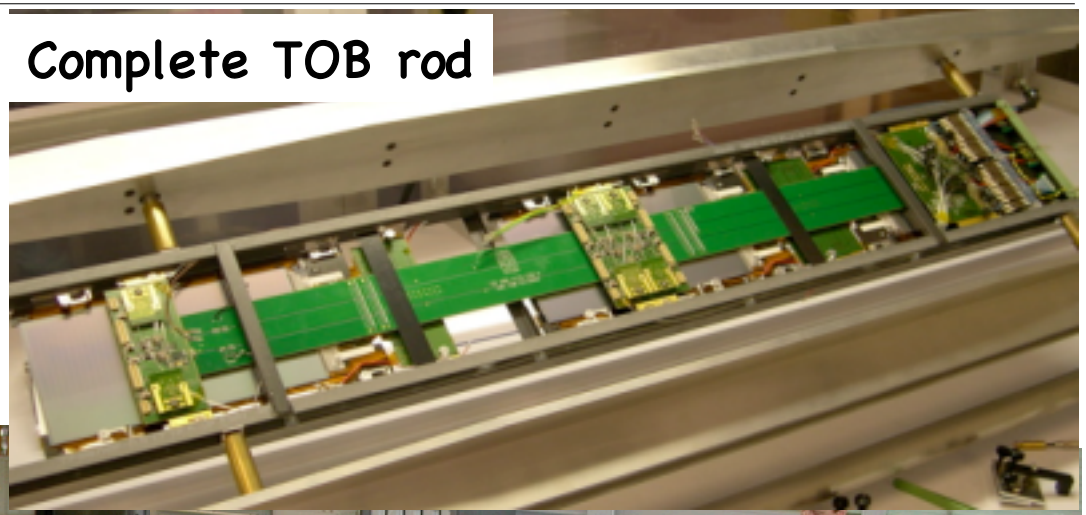
9.65 Million channels (+66M in Pixel)

Operated at -20°C



Tracker Outer Barrel (TOB)

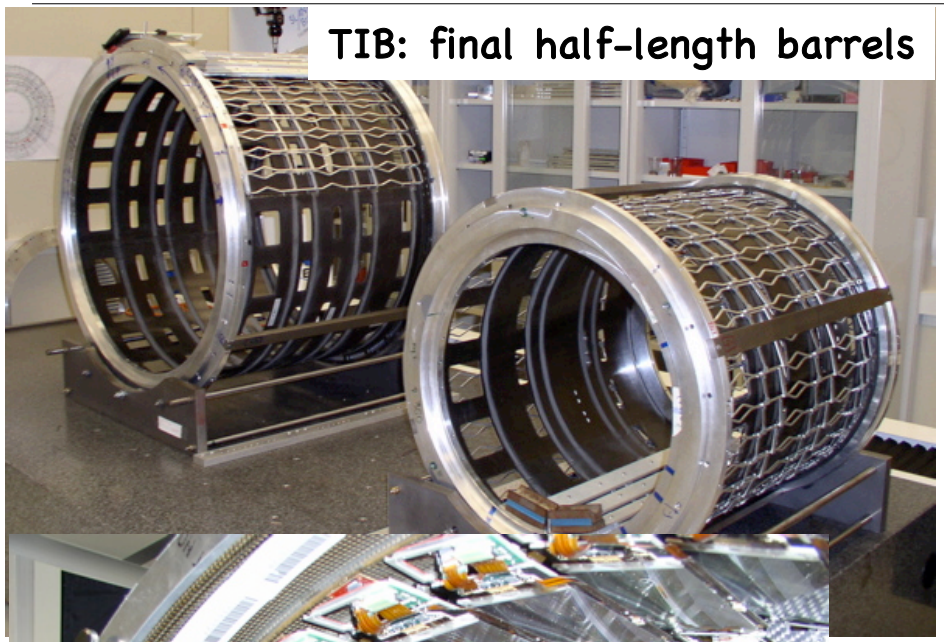
Complete TOB rod



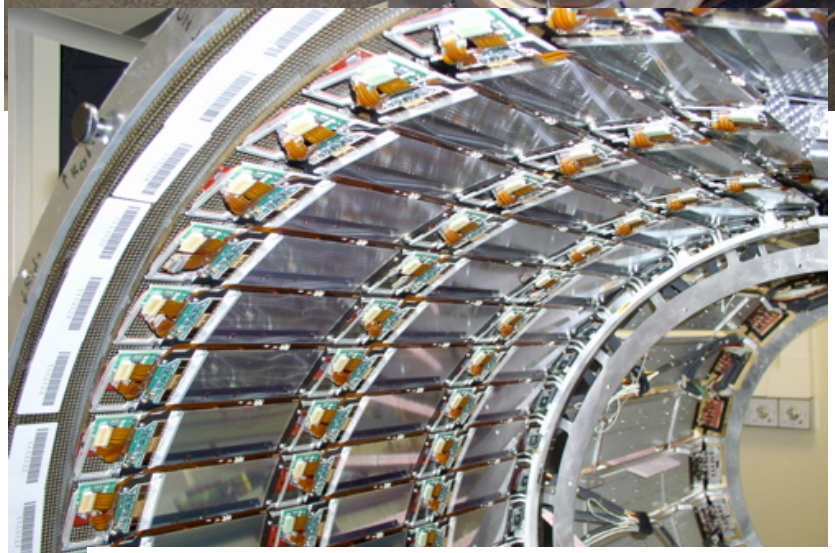
TOB disk

TOB "wheel" assembly (this week!)

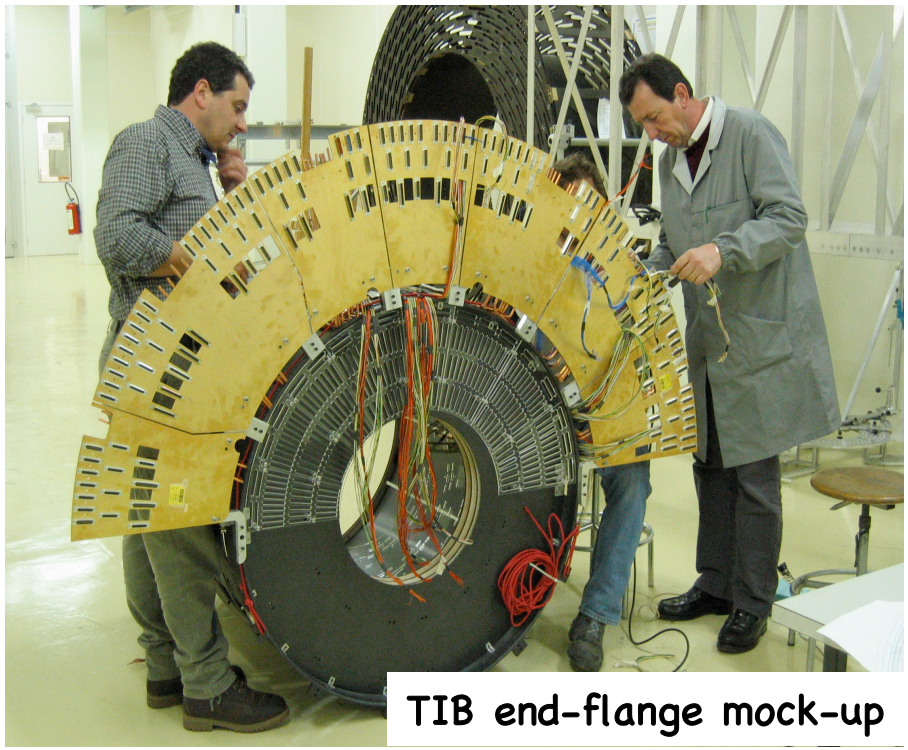
Tracker Innner Barrel (TIB)



TIB: final half-length barrels



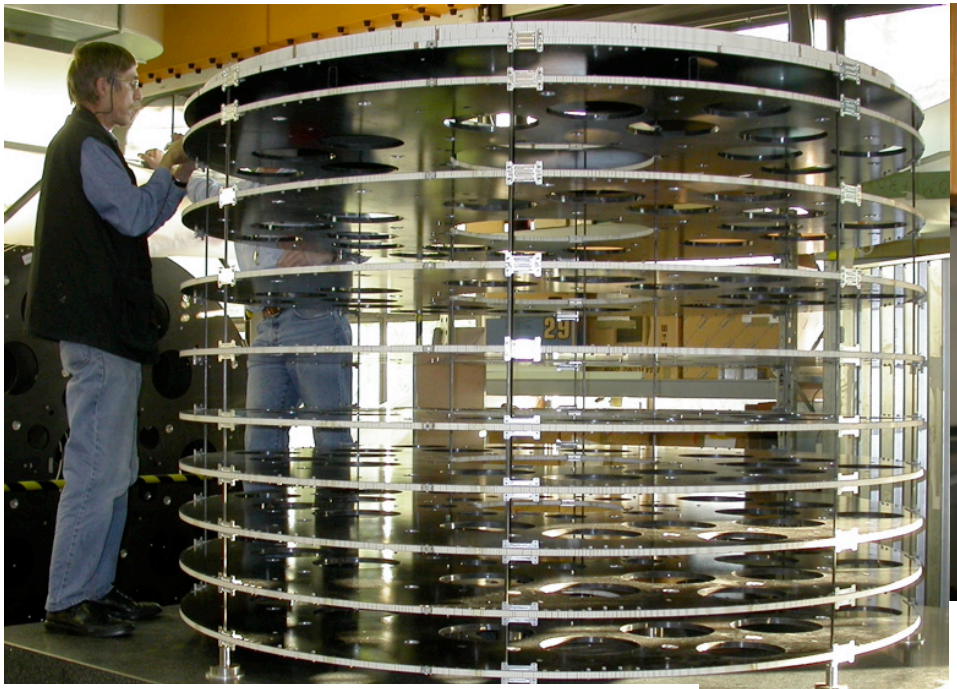
TIB shell with all modules installed



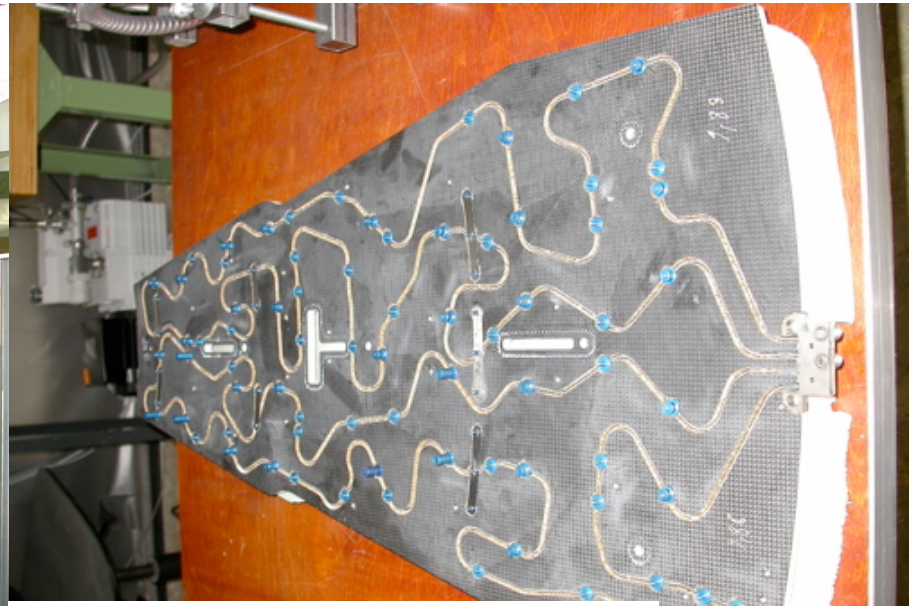
TIB end-flange mock-up

Expect delivery of
complete TIB/TID
at CERN by end 2005

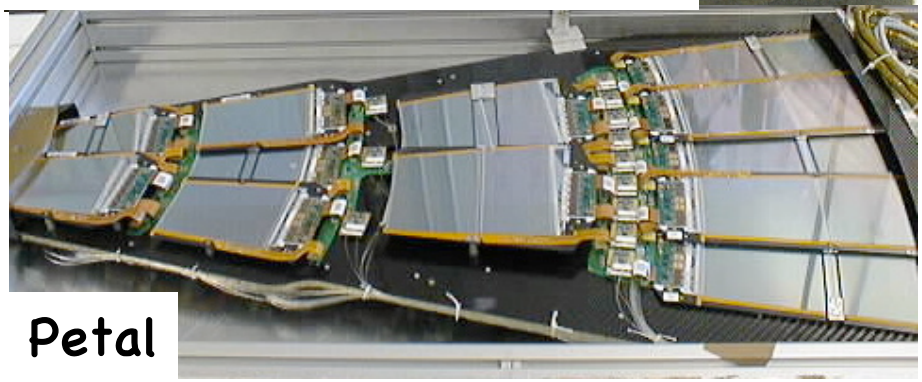
Tracker Endcap (TEC)



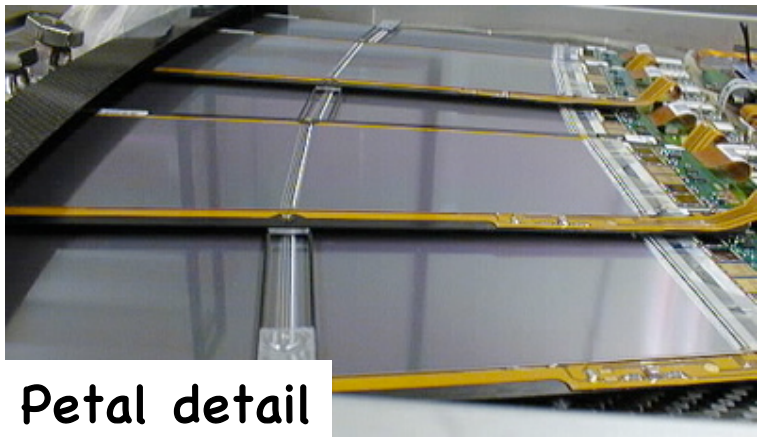
Disks of one complete TEC



Cooling pipe within petal

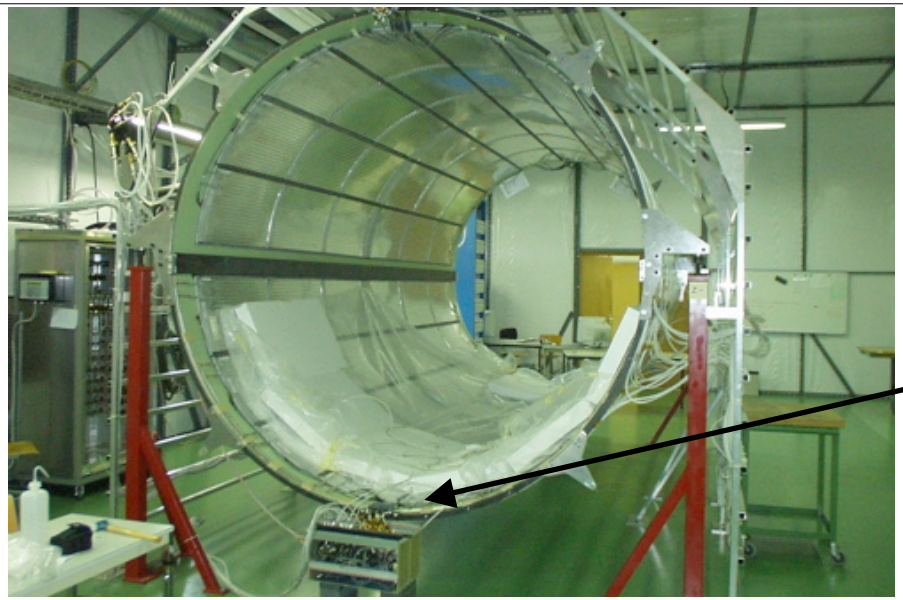


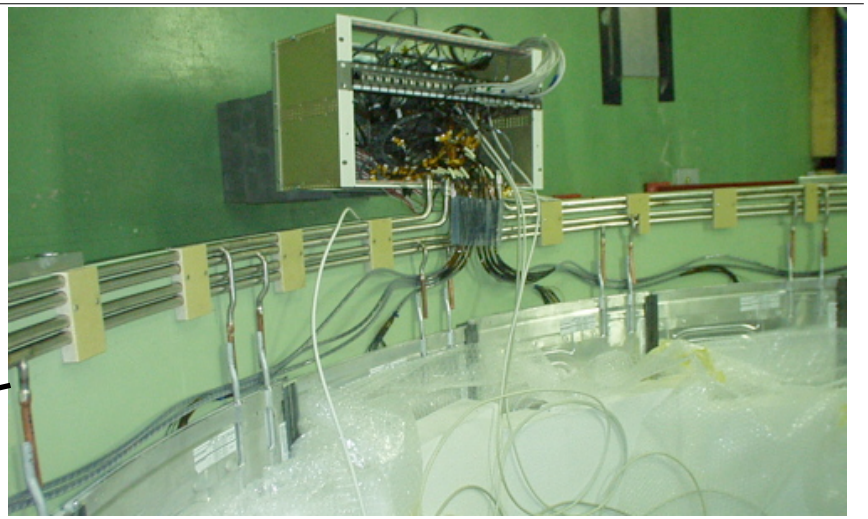
Petal



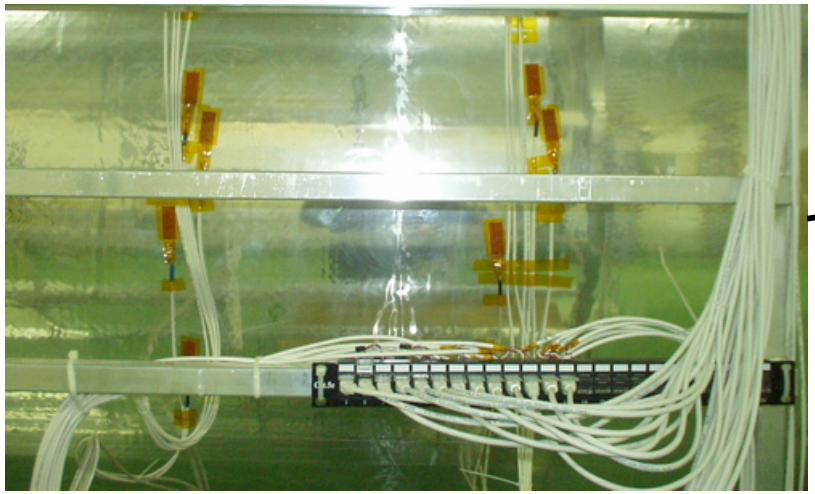
Petal detail

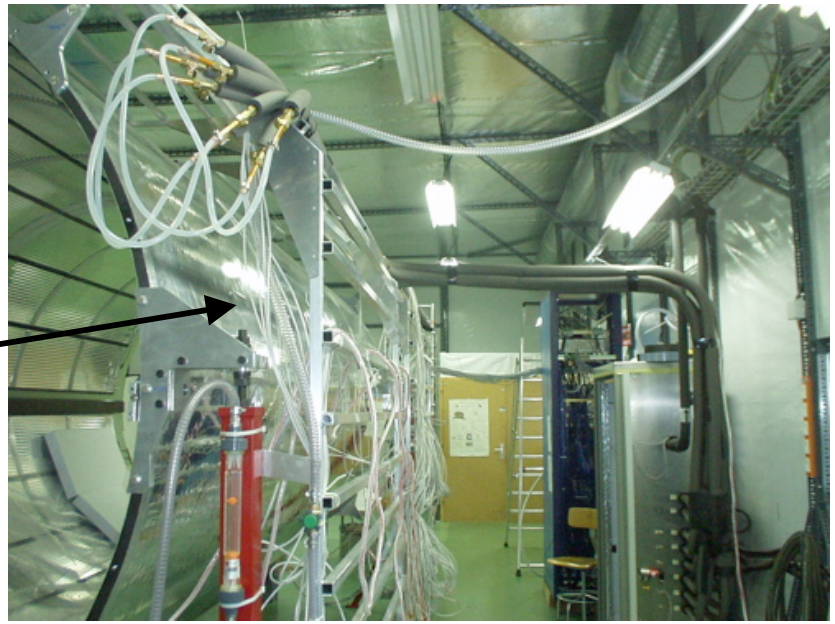
TK Thermal Screen Testing



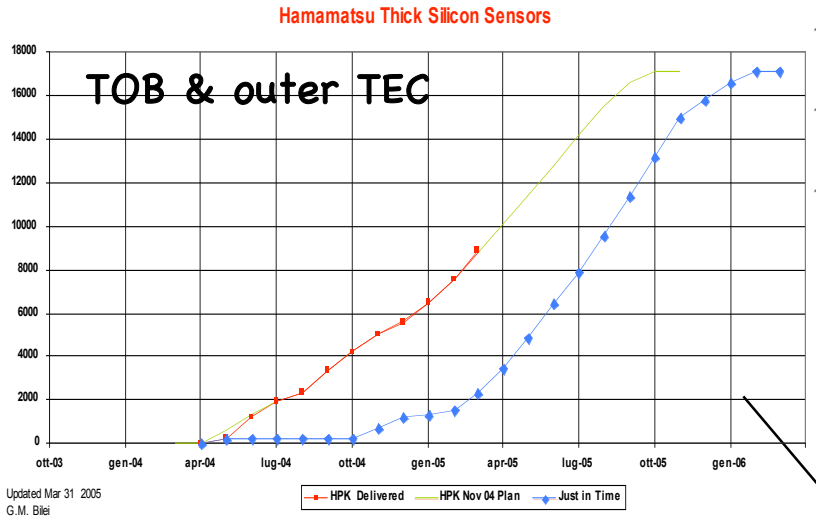


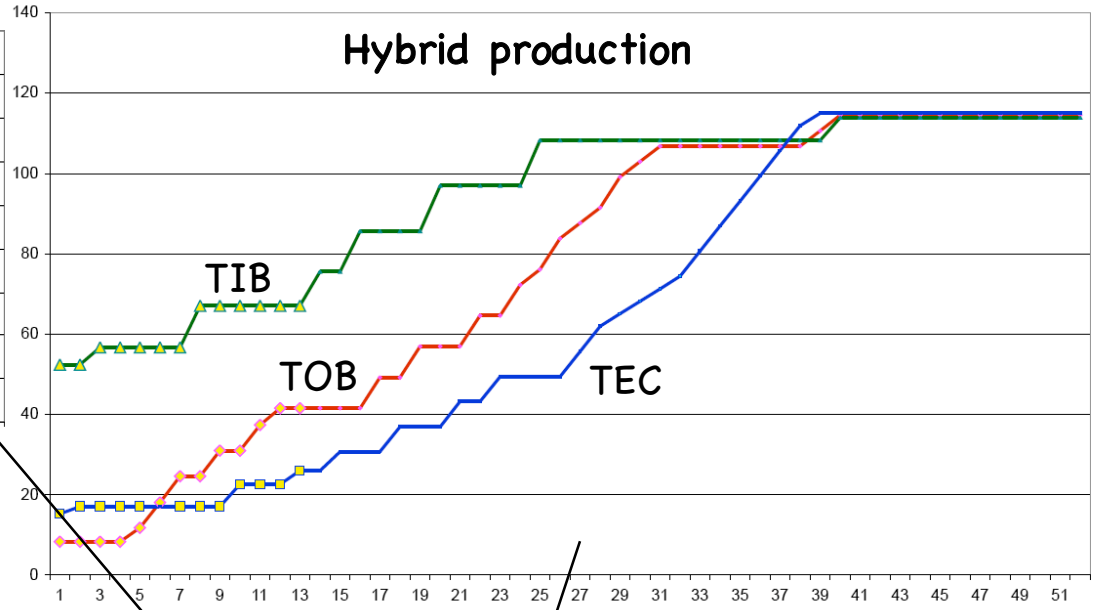
Cooling tests of TK thermal screen

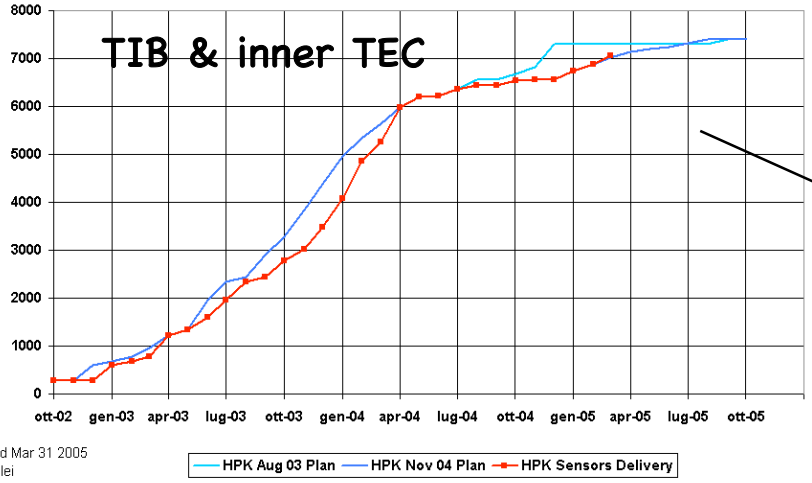


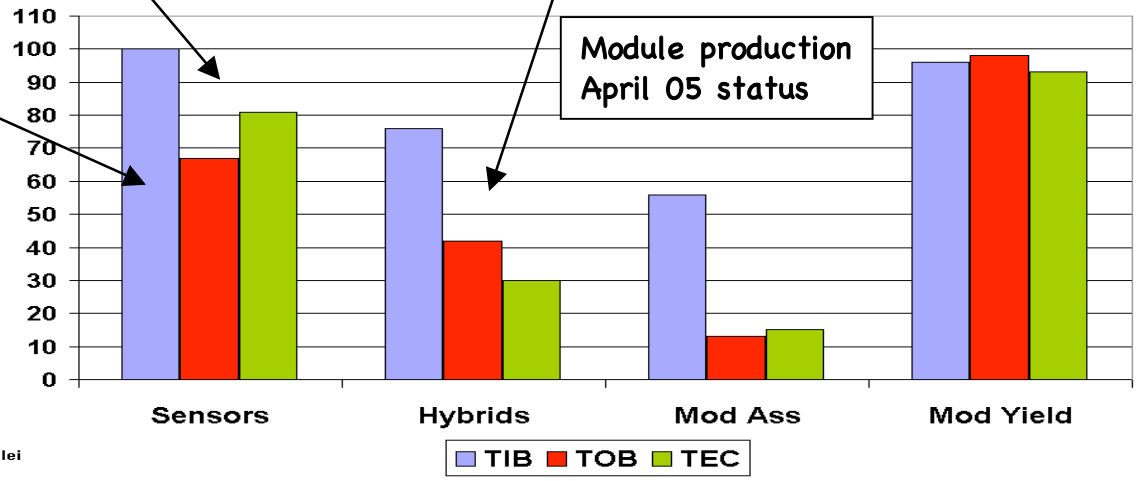


Tracker Production Status





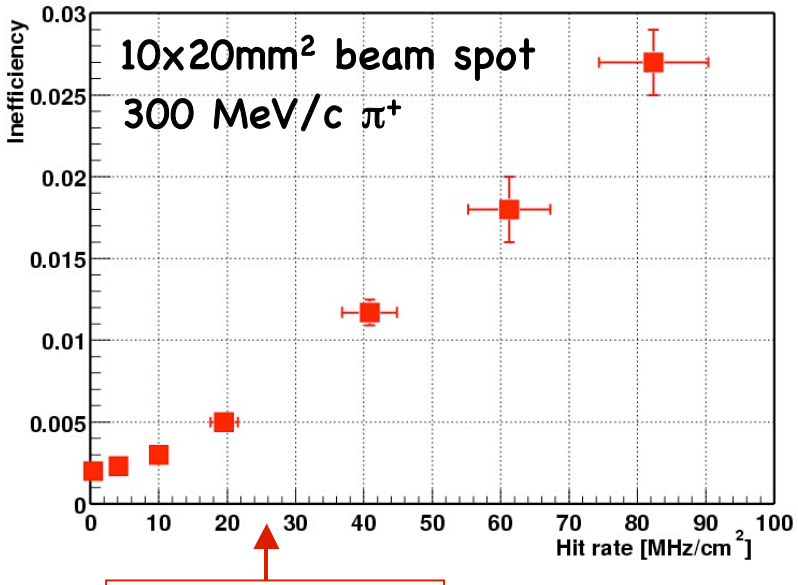




Pixel Status & Performance

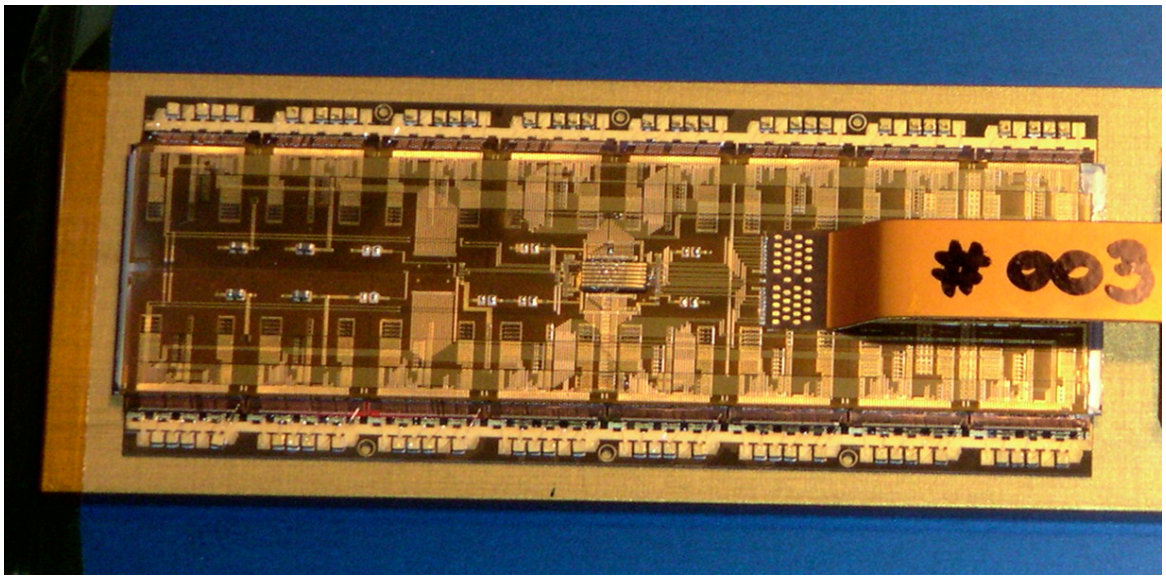
Order for 360 Barrel sensors placed

Expect to have 10% of final modules by end 2005



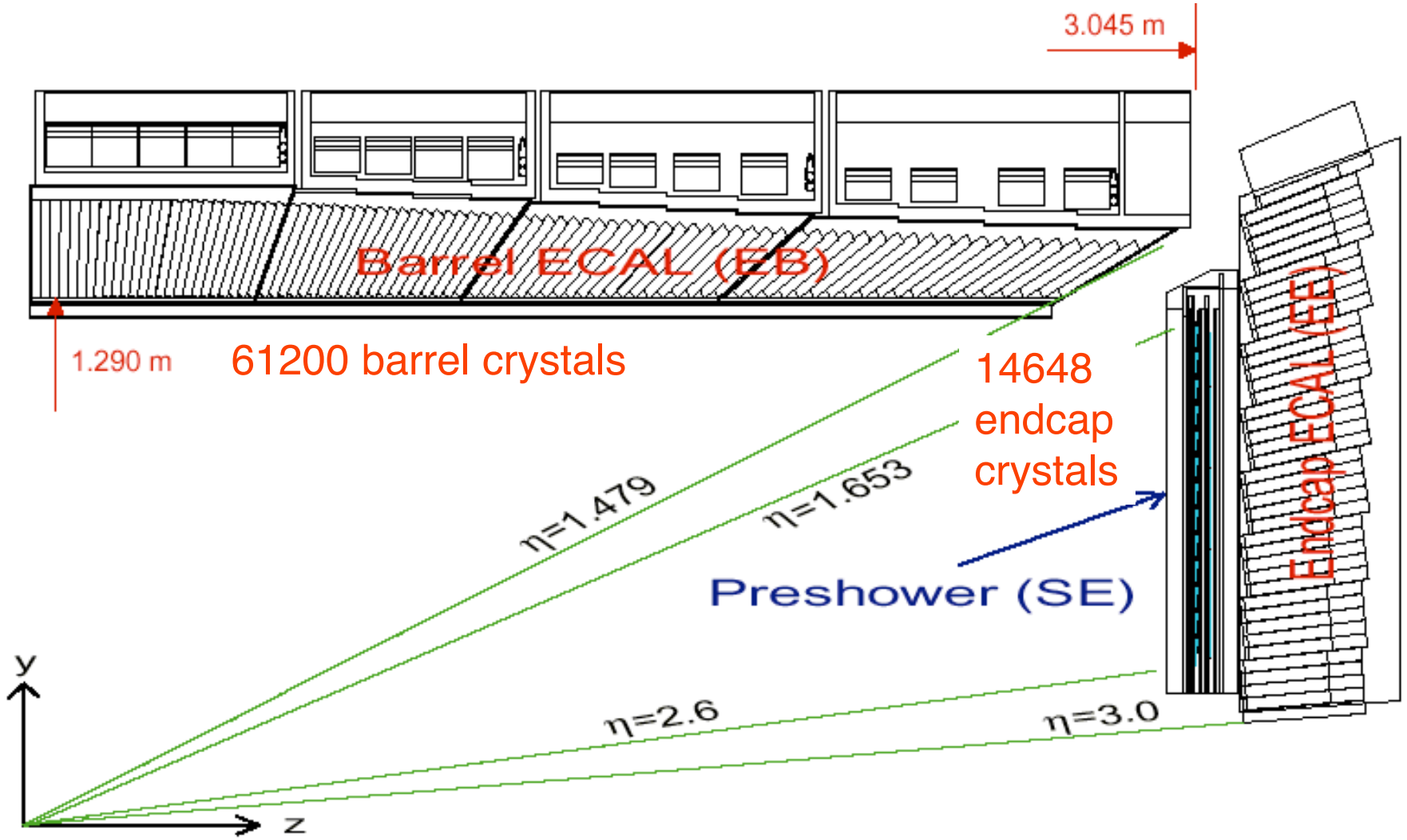
Rate at R=4cm

Only 0.8% inefficiency !

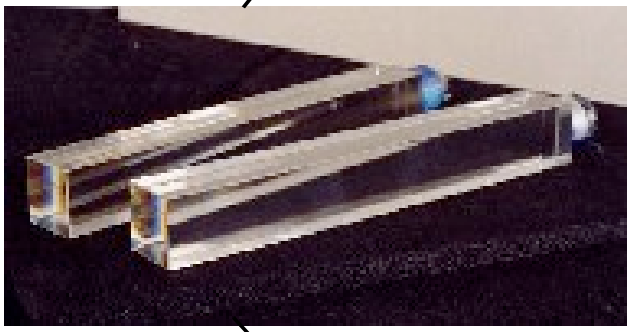


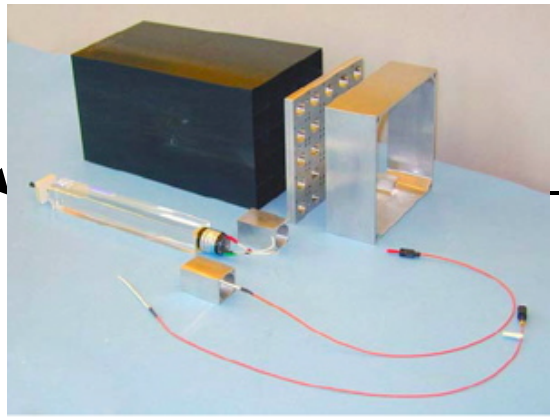
Pixel module with 0.25 μm ROC

Electromagnetic CALorimeter



ECAL Crystals and Supermodules





400-500 crystals

Module

4

Supermodule

36

ECAL

Supercrystal

25

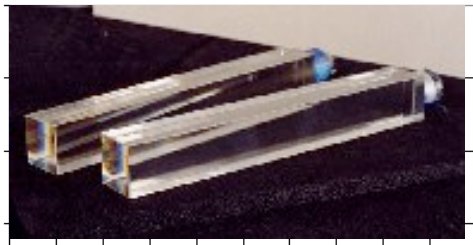
~156

DEE

4

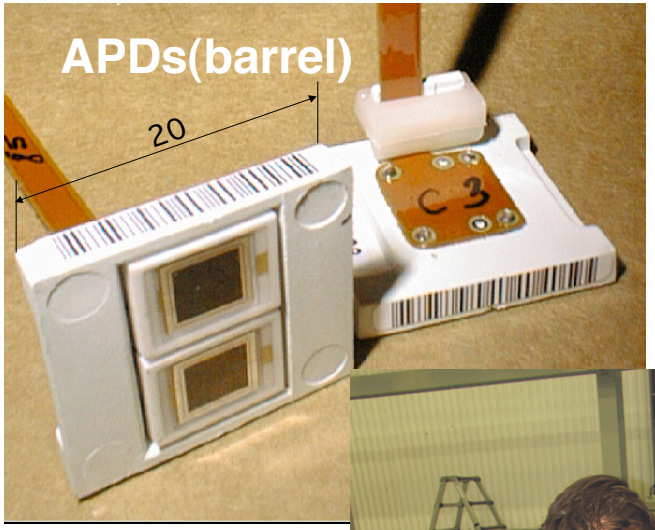
ECAL Crystal Delivery

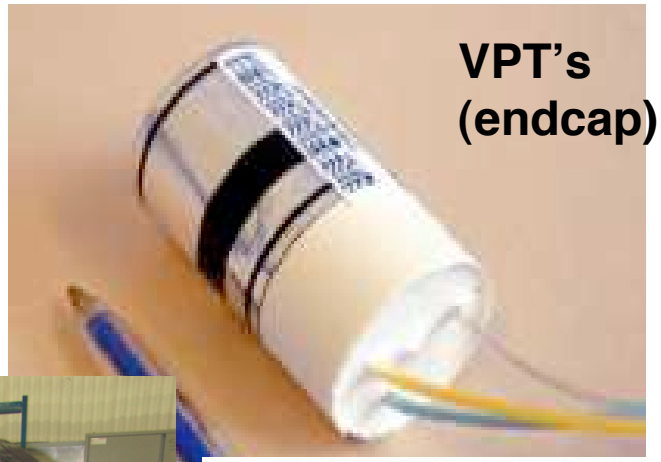
Barrel Crystal Production is on critical path



Mechanics: ready, APD: ready
Cooling & Electronics integration: just starting

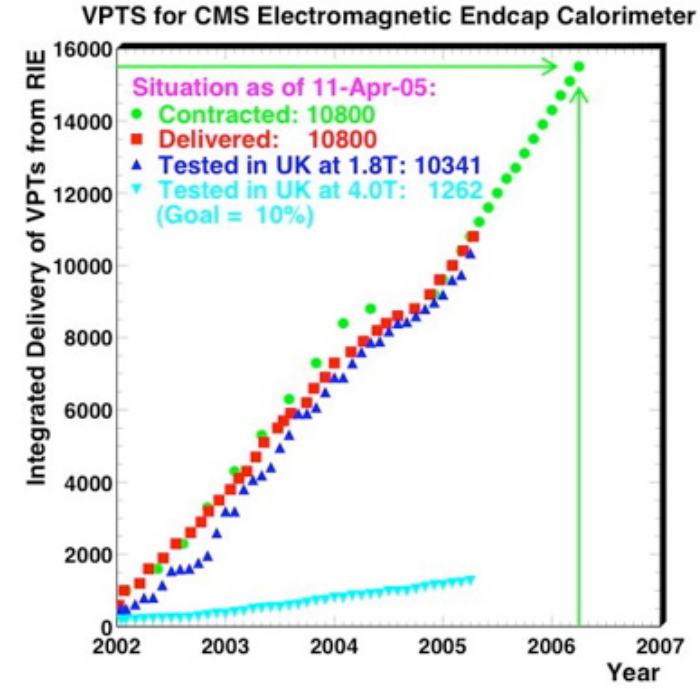
ECAL Electronics



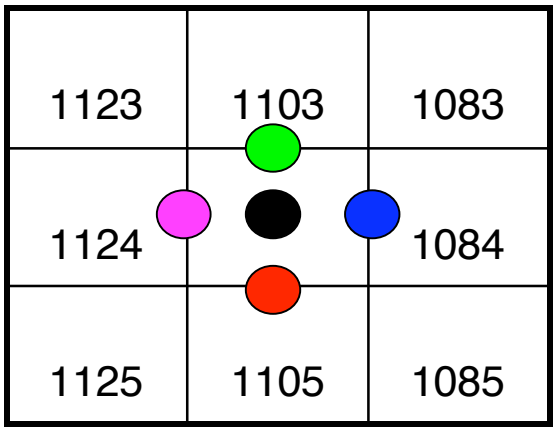


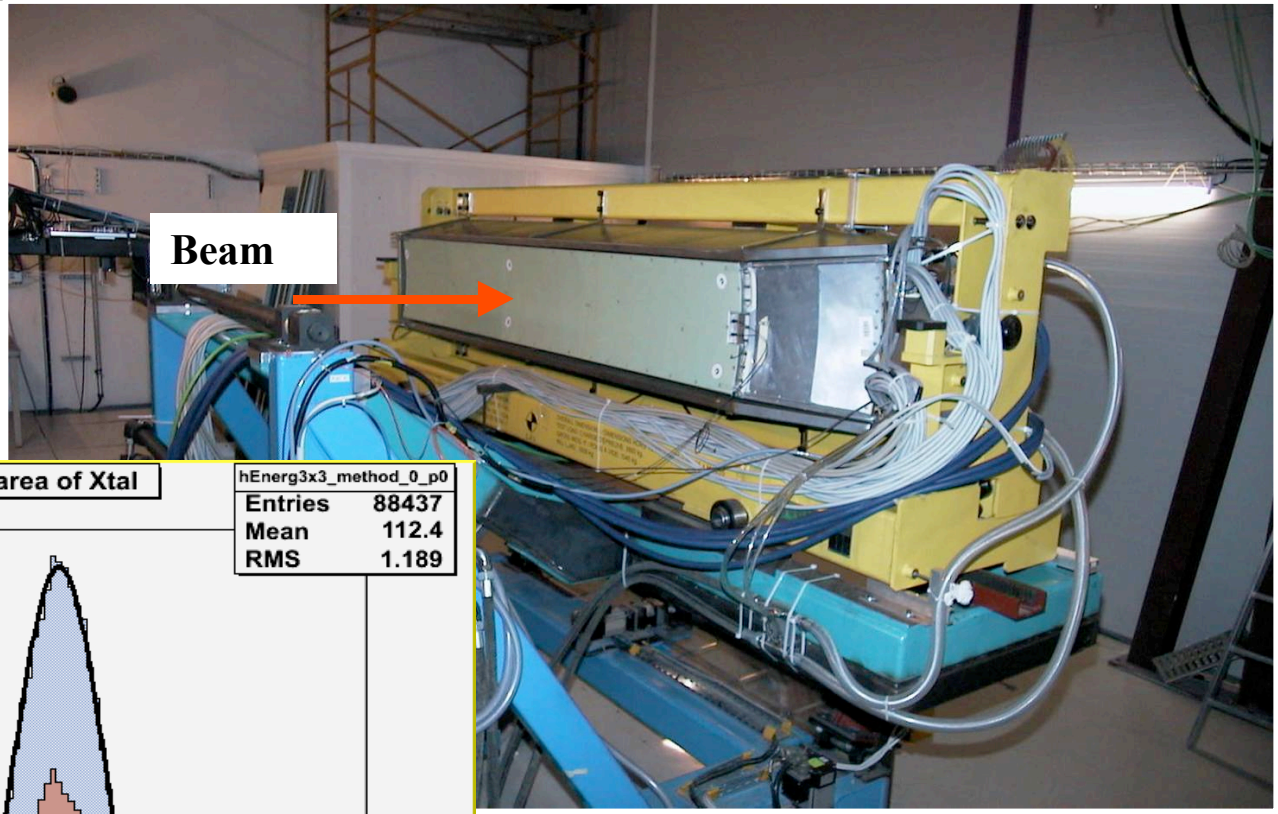
70% VPT produced & tested

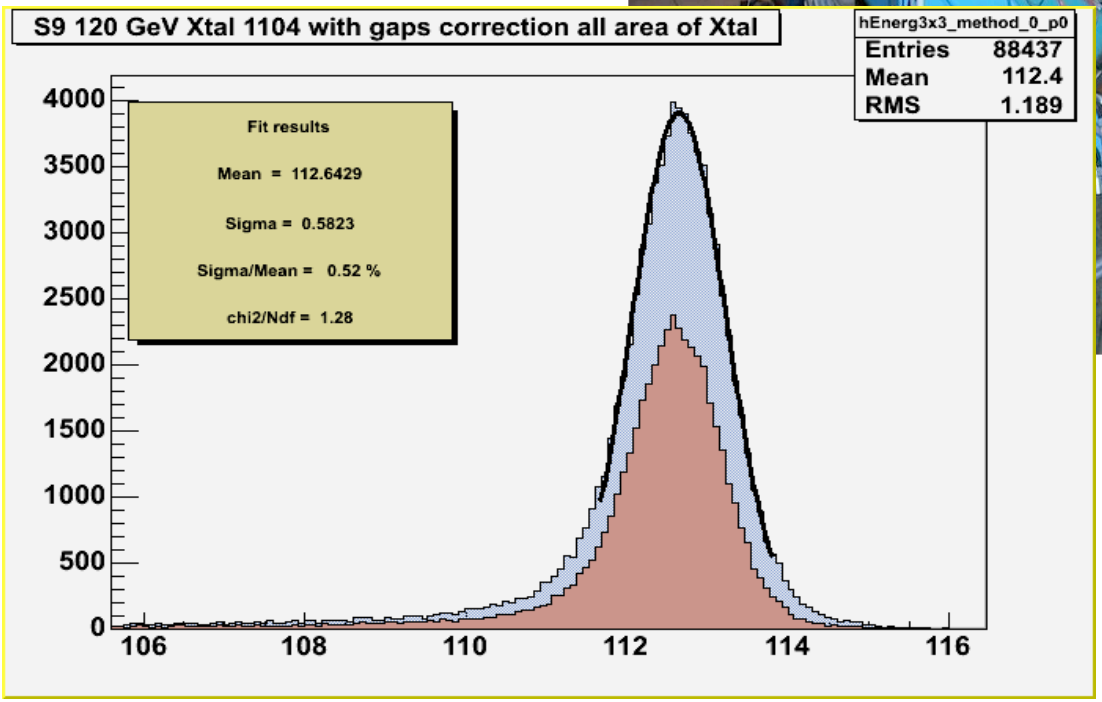
APD production completed, integration ongoing



ECAL SM in Test Beam







RESOLUTION:

0,52 %

At ~100 GeV

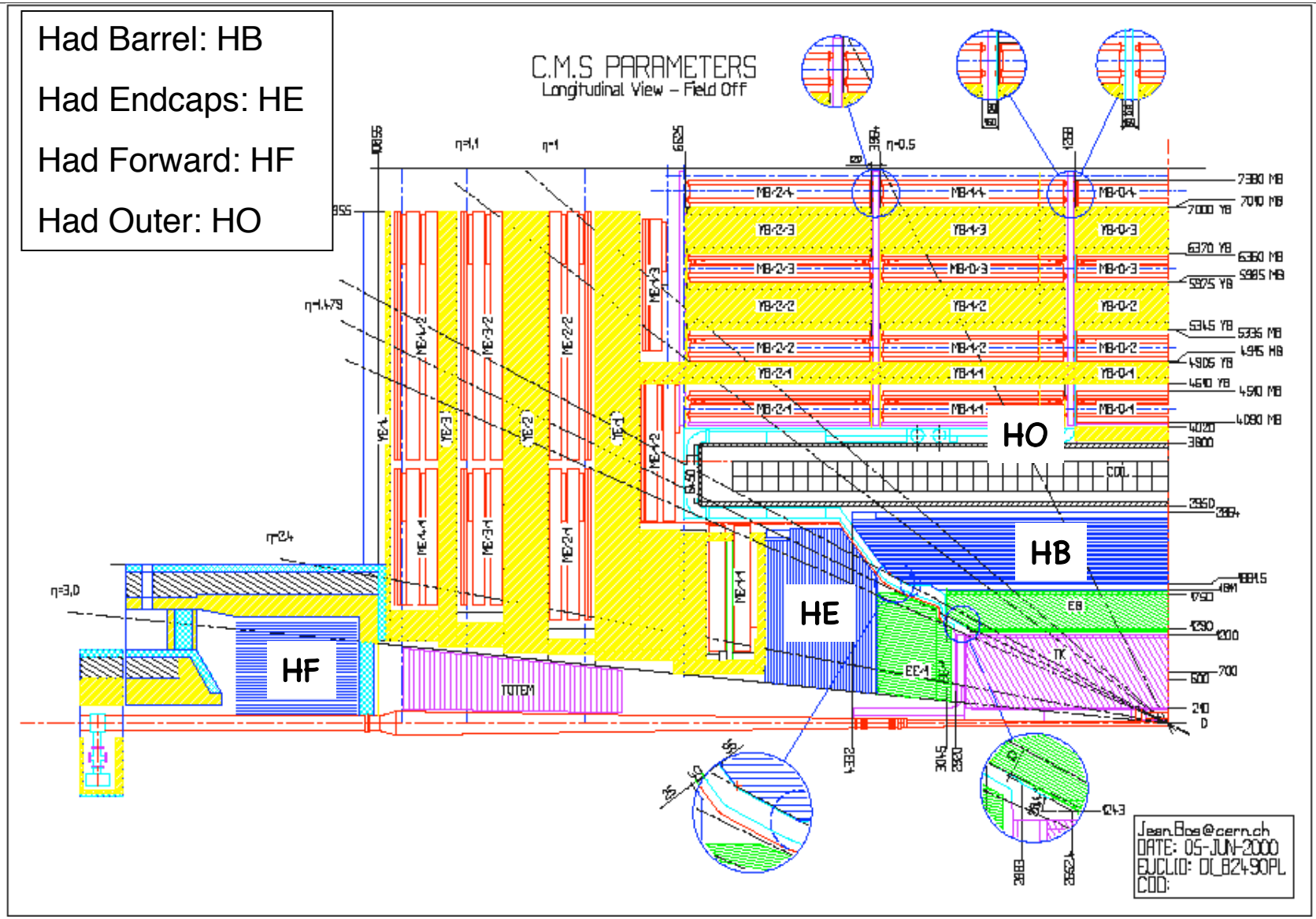
Hadron CALorimetry

Had Barrel: HB

Had Endcaps: HE

Had Forward: HF

Had Outer: HO



Forward Calorimeter (HF)

Final assembly of HF+ in surface hall 186

This is the first detector to go underground in Feb/2006 after testing

Start burn-in of both HF in mid-2005 continue to end of year

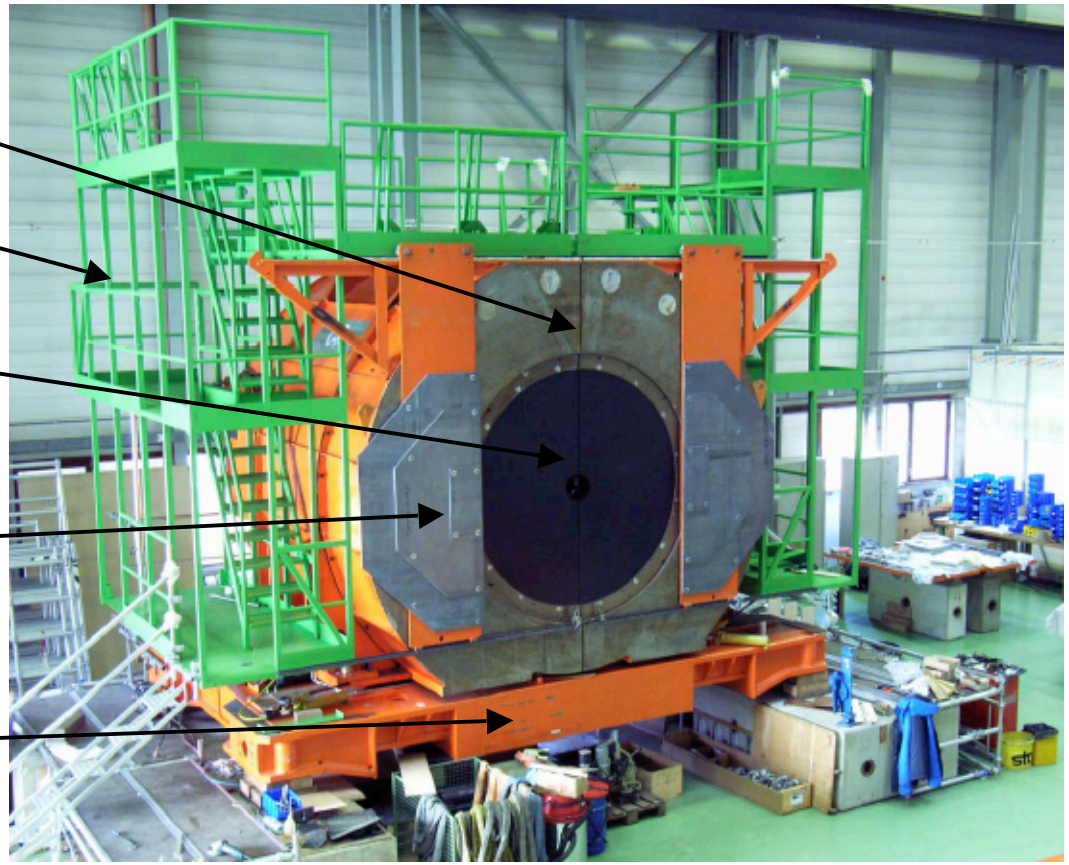
Lateral shielding

Space for electronics

Absorber & fibres

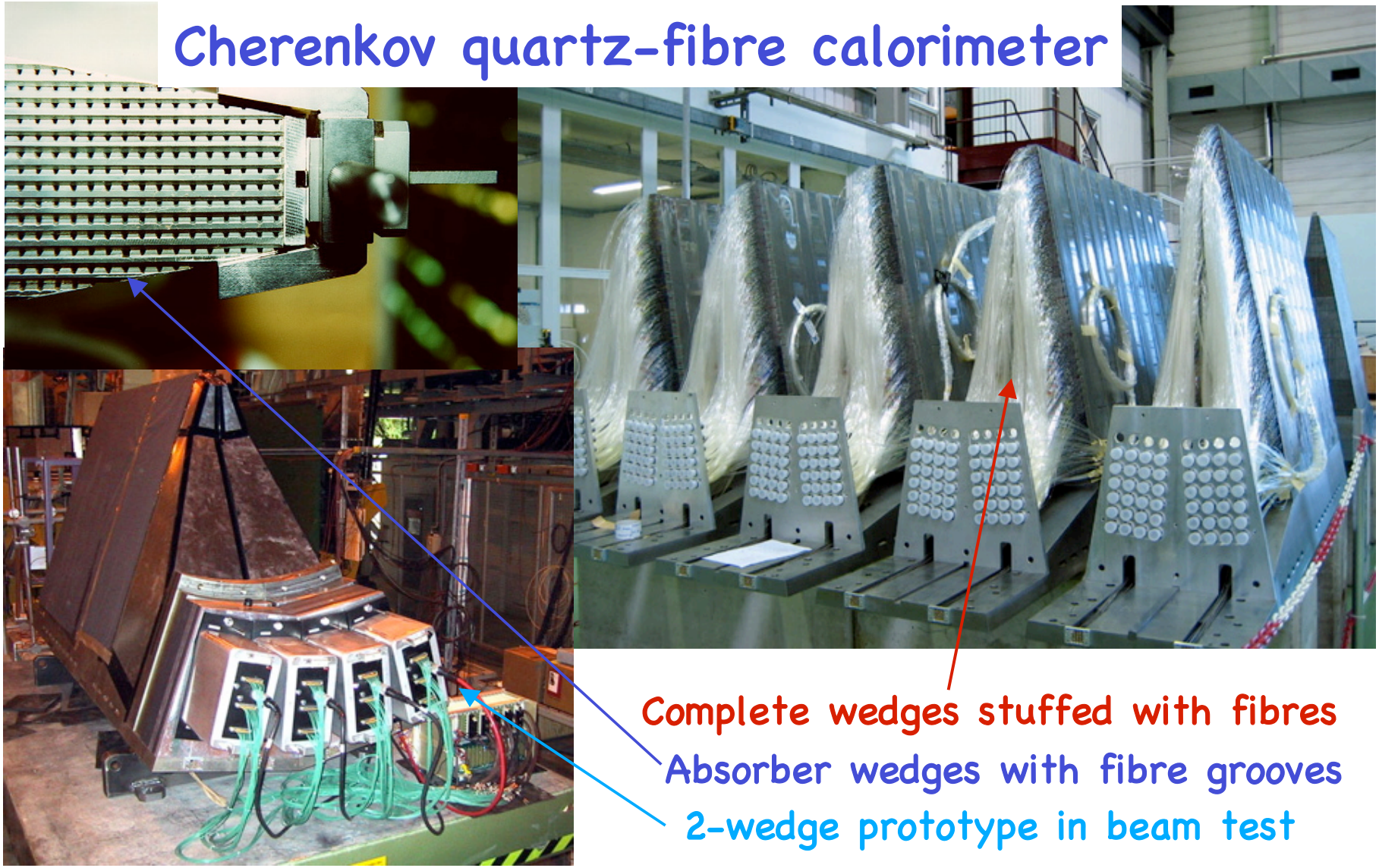
Lead 'curtains'
Operation: open
Maintenance: closed

Supporting table



HF details

Cherenkov quartz-fibre calorimeter

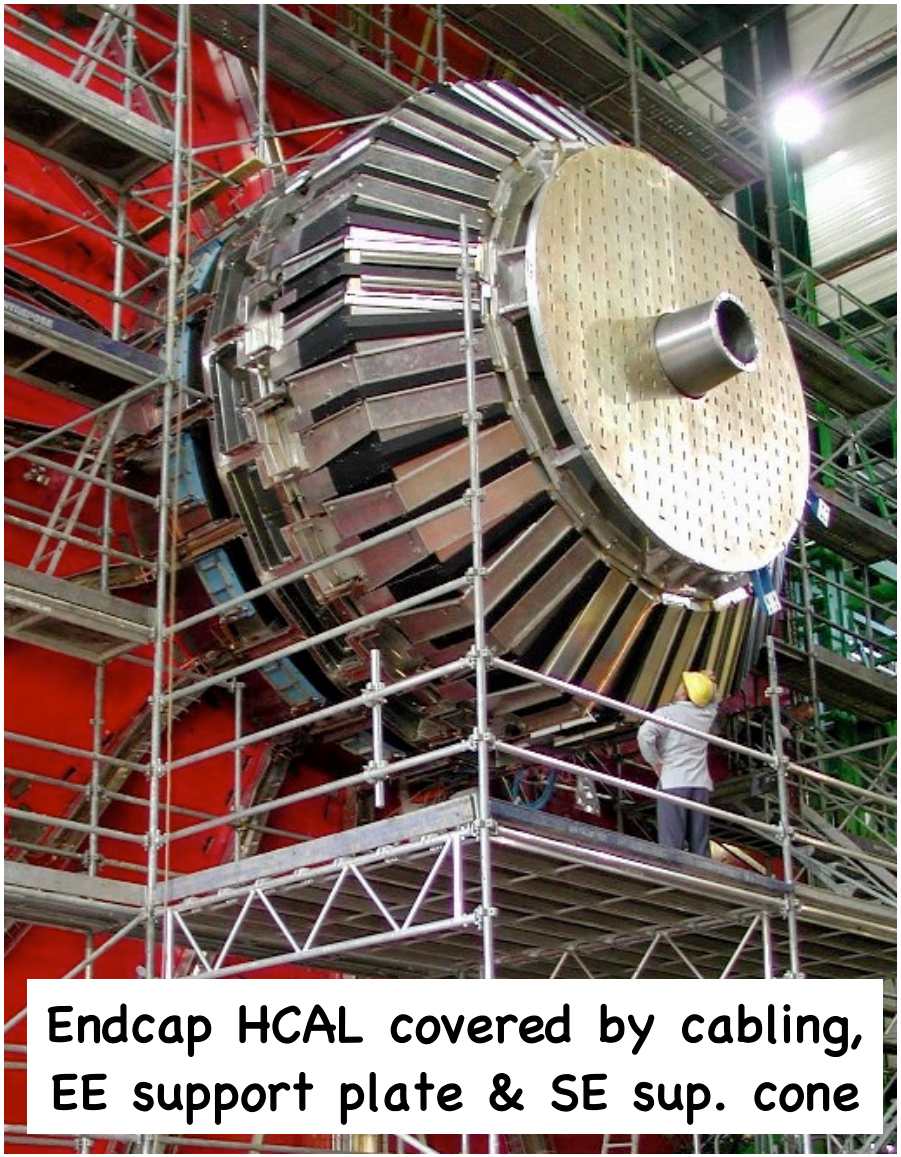


Complete wedges stuffed with fibres

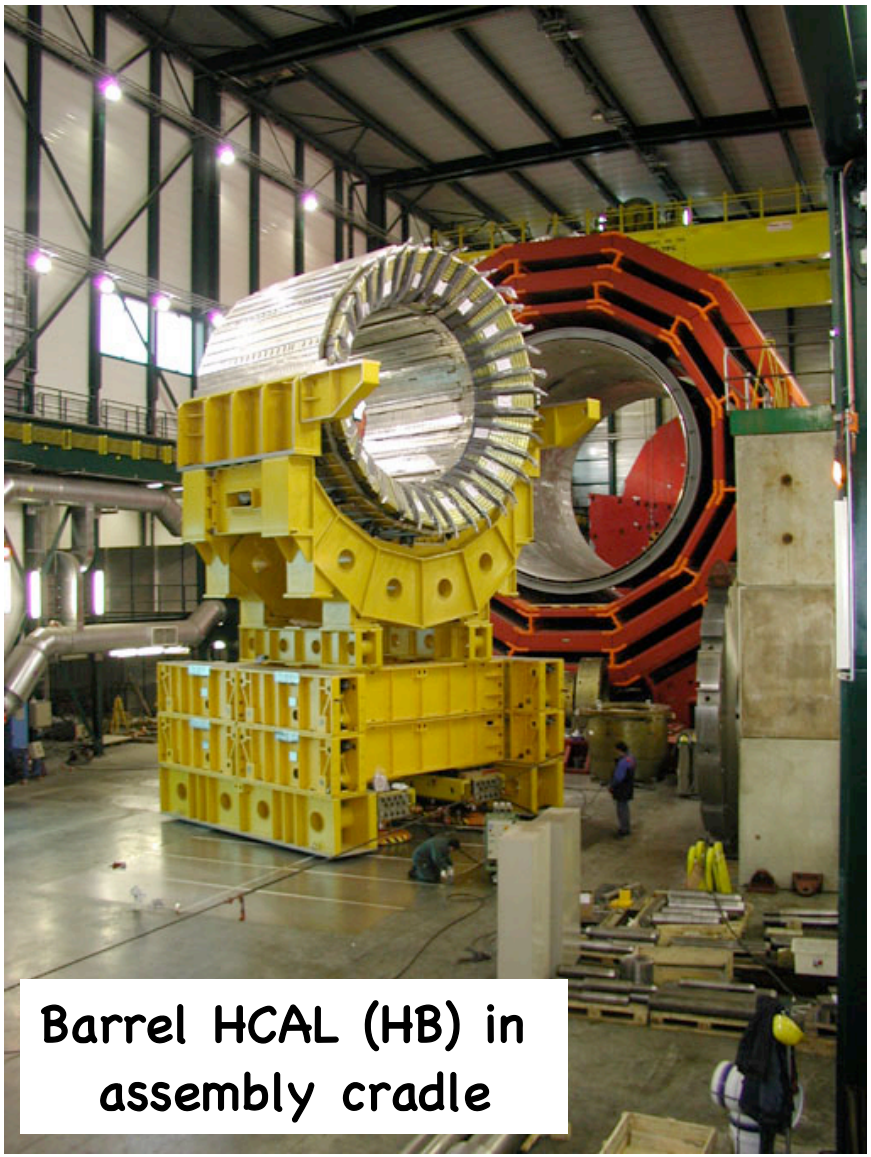
Absorber wedges with fibre grooves

2-wedge prototype in beam test

Hadronic Calorimeter (HB & HE)

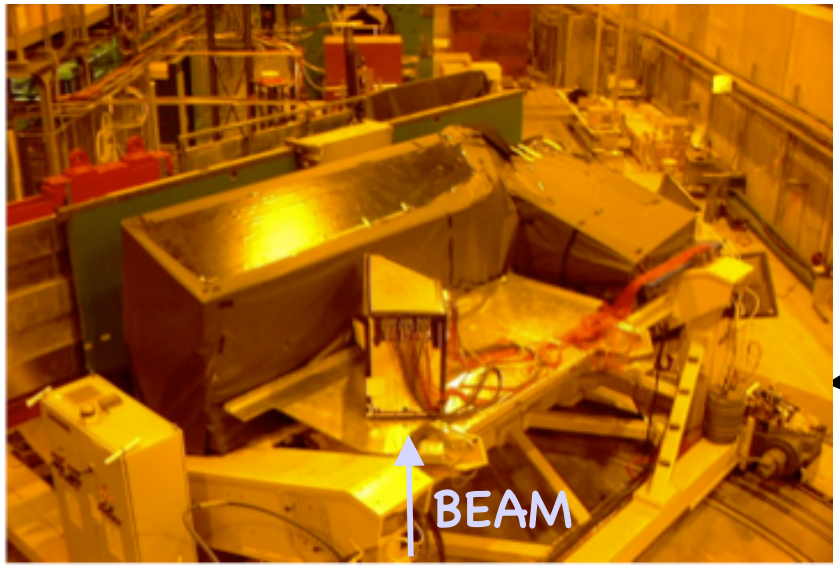


Endcap HCAL covered by cabling, EE support plate & SE sup. cone



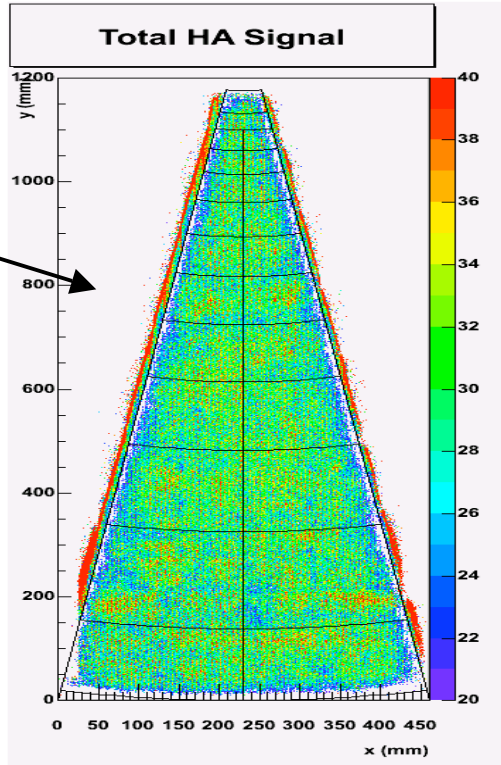
Barrel HCAL (HB) in assembly cradle

HCAL 2004 Test Beams

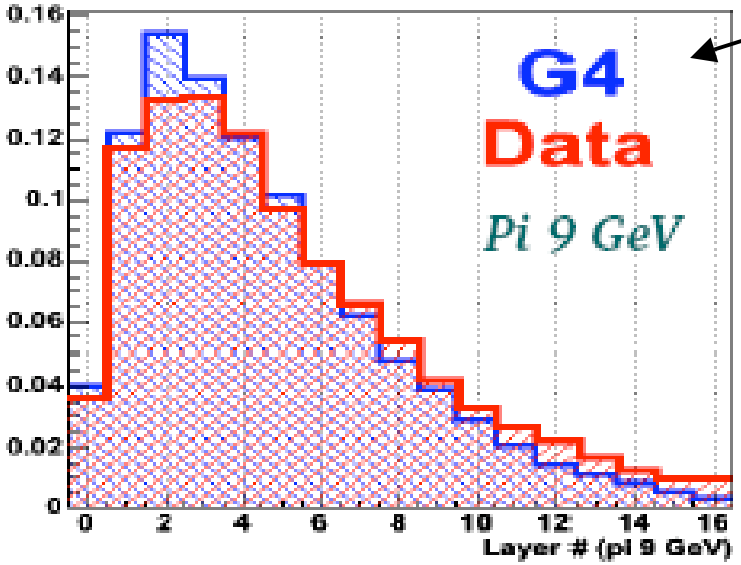


HB setup in H2

Uniformity scan in 2 HF wedges with 100 GeV π



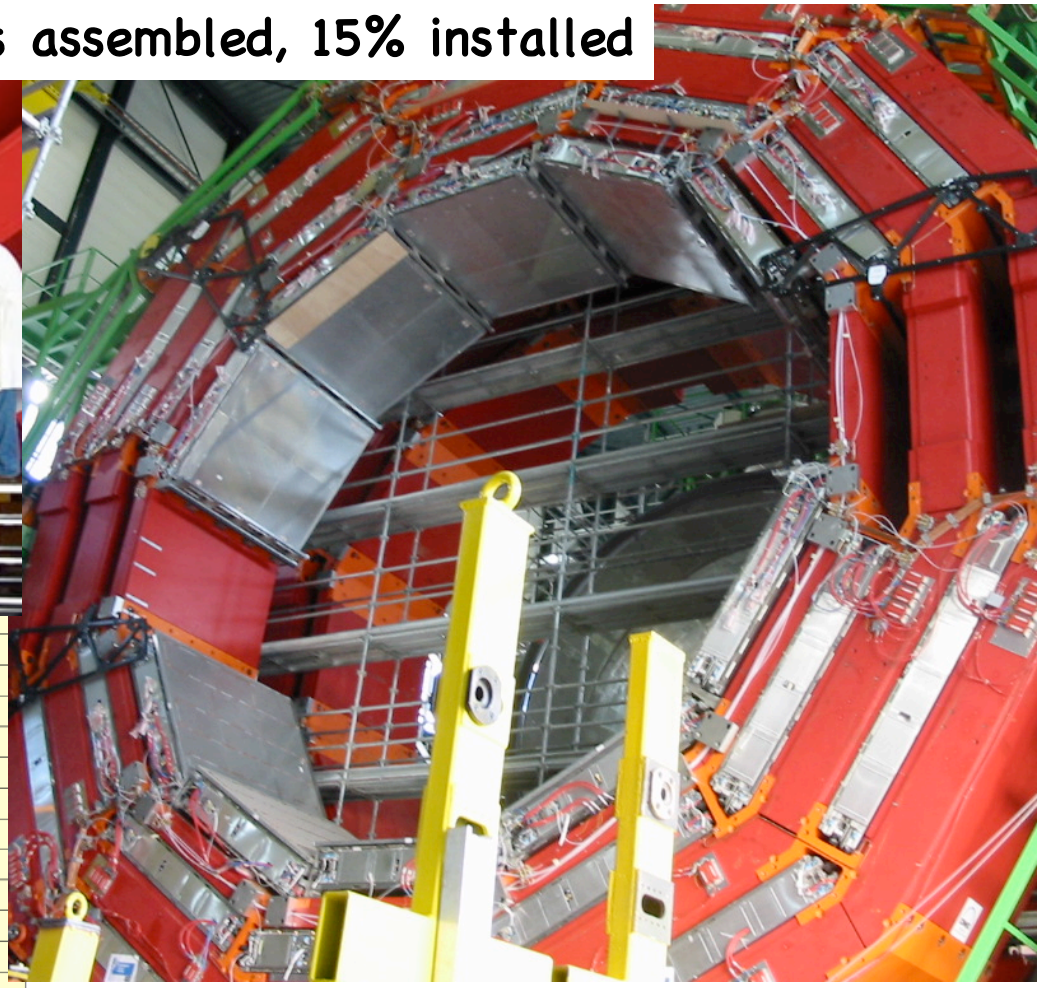
Comparison of Shower profiles

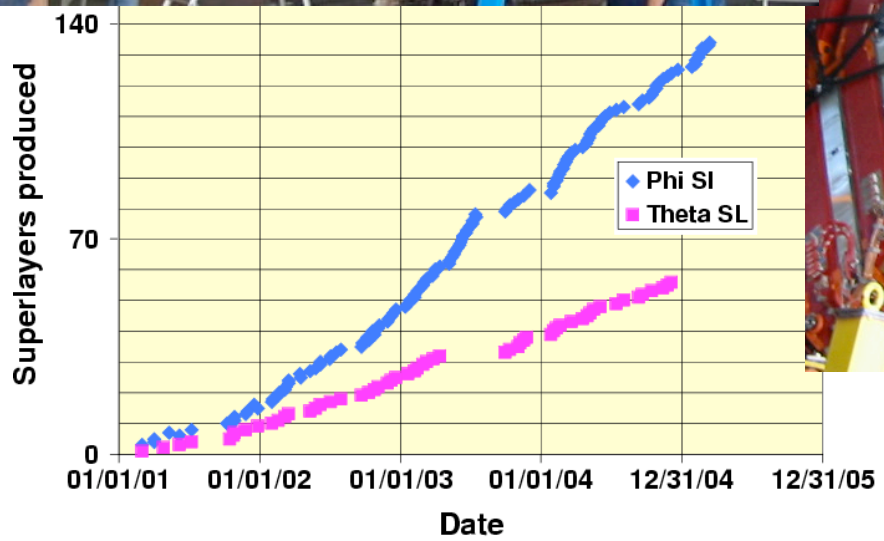


Combined beam test with full ECAL SM and HB wedge in H2 in 2006

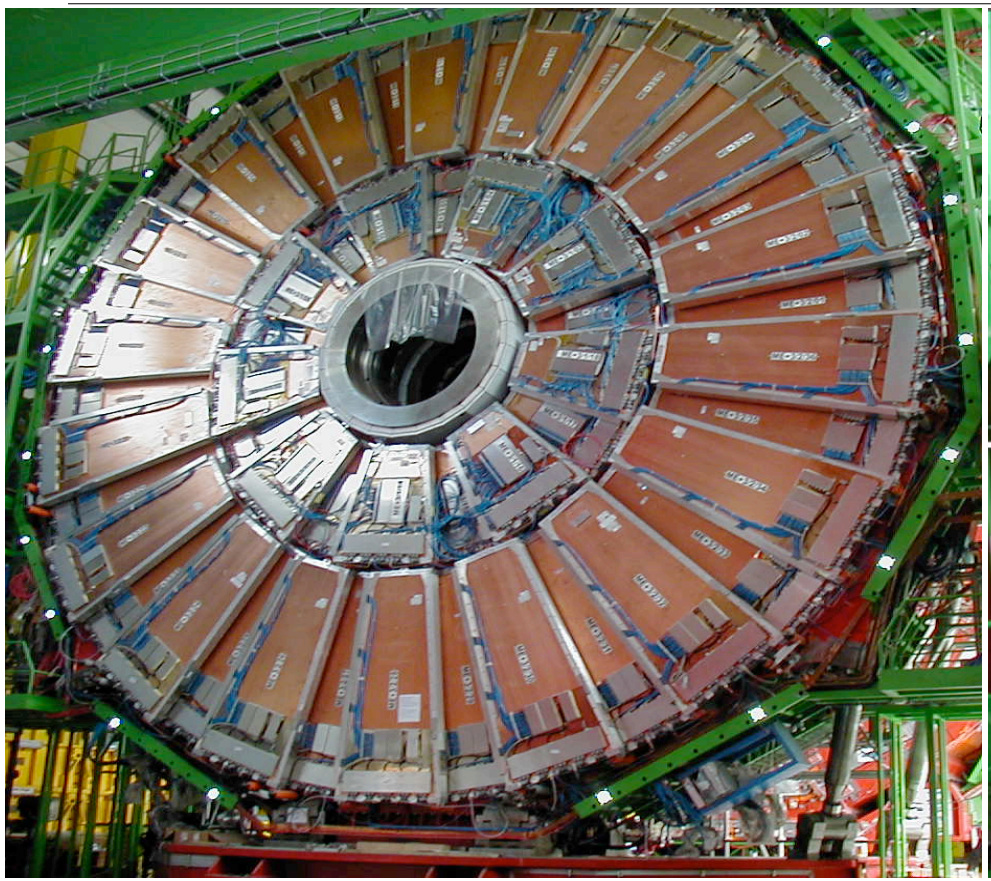
Barrel Muon Spectrometer

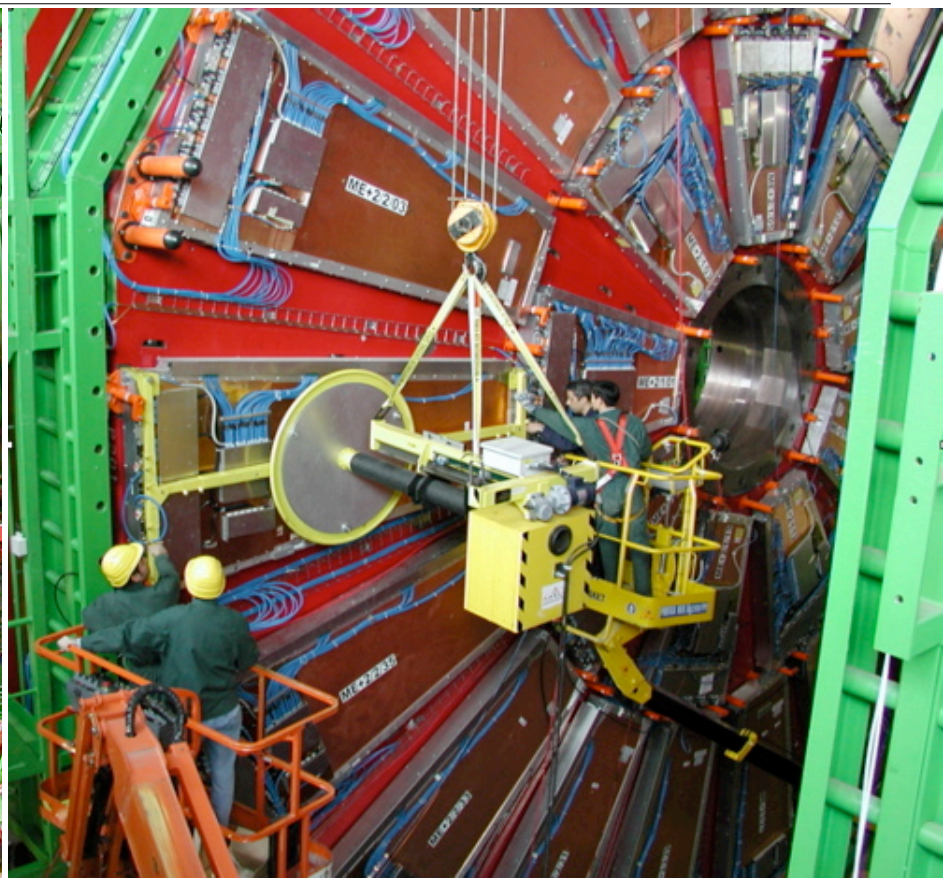
70% of DT chambers assembled, 15% installed





Endcap Muon Spectrometer





All 400 chambers produced !

60% CSCs installed, 40% commissioned

CSC installation

Major CMS Milestones

Feb/2005 : Underground cavern (UXC) delivered to CMS

→ Oct/05-Mar06 : Magnet test and cosmic challenge (on surface)

Feb/06 : Major UXC infrastructure ready

Feb-Jul/06 : Lower major part of CMS to UXC

Aug/04-May/06 : Equip underground control room (USC)

Apr/06-Sep/07 : Connect & commission Trigger/DAQ

Feb/07 : Magnet ready for physics

Apr/07 : Muon system ready for physics

May/07 : HCAL and Barrel ECAL ready for physics

May/07 : Tracker ready for physics

Mar-Jun/07 : Install and condition beam pipe

→ End Jun/07 : CMS (&TOTEM) closed for beam

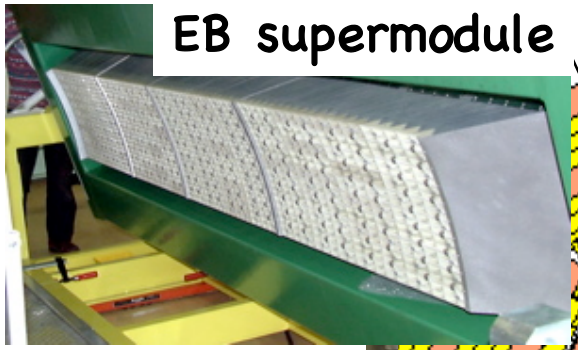
Jul-Sep/07 : LHC commissioning and CMS Trigger synch. with beam(s)

Q4/07 : Pilot physics run (no endcap ECAL, no pixel)

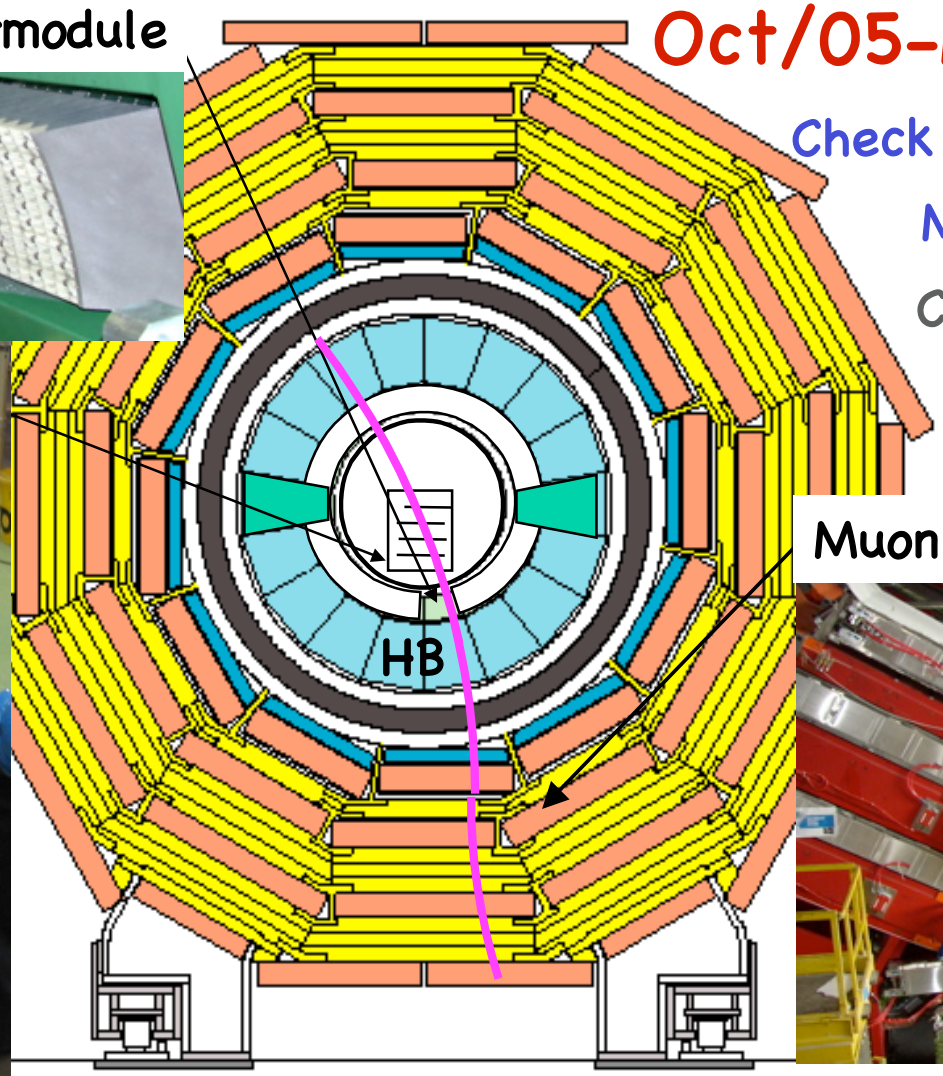
Nov/07-Apr/08 : Install endcap ECAL and pixel

Magnet test & Cosmic Challenge

EB supermodule



TK cosmic rack



Oct/05-Mar06 on surface

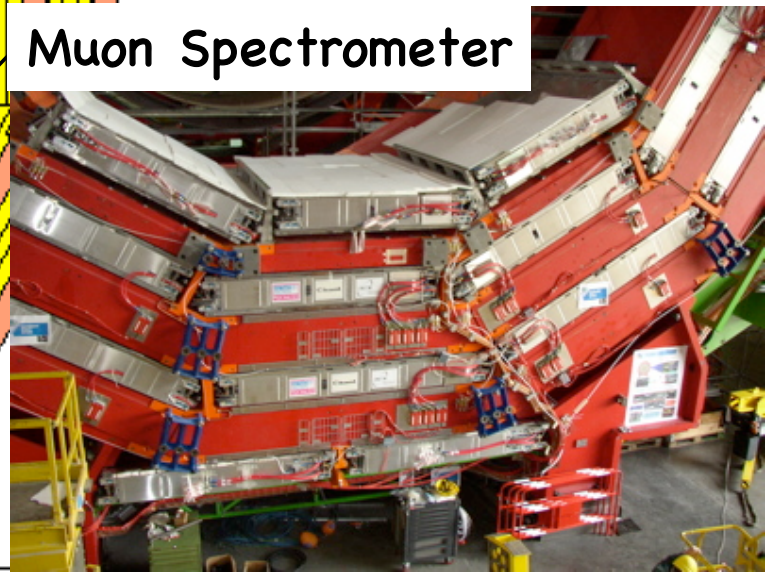
Check functionality of magnet

Map magnetic field

Commission sub-systems

Operate sub-systems together

Muon Spectrometer



Commissioning

How to turn CMS into an operational physics instrument

4 inter-dependent and partially overlapping phases

1) Pre-installation testing of individual elements (test beams, EIC)

2) Post-installation testing of basic functionality

3) Stand-alone commissioning using local DAQ
   Single system integration with Trigger/DAQ/DCS and synchronisation

4) Combined commissioning:
   Integration of complete system for cosmic challenge or LHC operation

Much of CMS will be assembled & commissioned on surface

Tracker Commissioning Plans

Special Tracker setup in Cosmic challenge

Pre-installation commissioning of sub-detectors at institutes

- Thermal screen & infrastructure: fully tested at -20 C (CERN)
- TIB/TID: fully tested at low T (Pisa)
- TOB: fully tested at room T (CERN)
- TEC: fully tested at low T (Aachen, Lyon, poss. CERN)
- Cross-talk & grounding checked
- Tracker arrives at P5 sealed but humid

Possibly complete system test in EIC (B904)

Post installation (in UXC)

- Connection and testing of slow control and power supply
- Commissioning with local DAQ and internal triggers
- Integration with global DAQ (ext. triggers, synchronisation)

Bottom Line

Be as ready as possible when coming to P5

ECAL Commissioning Plans

Much learnt from SM1 commissioning in 2004 -> implementing in local DAQ

Pre-installation (Labs and test-stands):

- All on-detector electronics thoroughly tested
- Electronics of each Trigger tower commissioned
- Full SM system checkout - using local DAQ
- Commissioning with cosmics (see next slide)
- Upper level readout & Trigger integration in B904 (EIC)

Bottom Line

Test as much as possible before coming to P5

Post-installation tests (at point 5)

- Test of each SM before/after installation in SX5/UXC
- Commission each SM separately (still using local DAQ)
- Operate 1-few SM simultaneously but stand-alone ← **Cosmic challenge**
- UXC: connect to final services & readout
- Integrate with central DAQ & Trigger

ECAL pre-calibration

For full physics performance, require calibration to 0.5%

Transmission & Light Yield measurements in LAB -> ~4%

- At least this, we will have for all SM and endcap DEE

Possible commissioning with cosmics -> ≤3%

- Promising results, but no direct comparison with test beam data yet
- Try to commission all SM with cosmics 1 week/SM (setup in B887)

Beam calibration -> 0.5% but transfer to final ECAL -> 2% (or better)

- Only possible in 2006 - can do only ~1 SM/month -> ~6 total
- Aim to calibrate ~20 EE supercrystals end 2006

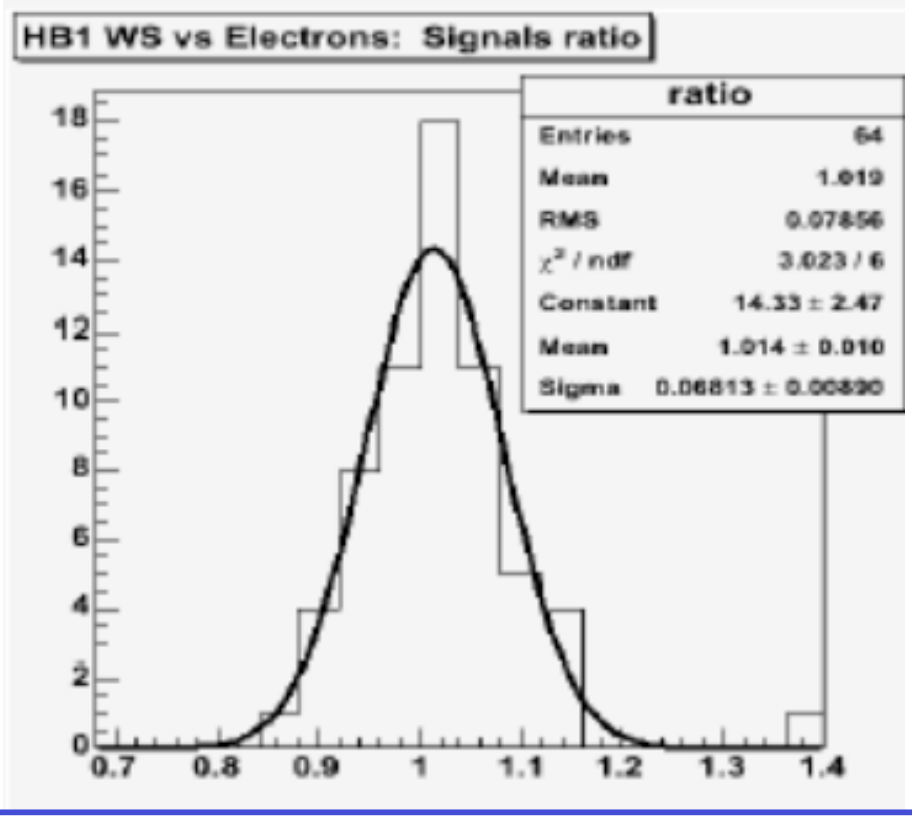
At installation the ECAL will have been calibrated to 2-3%

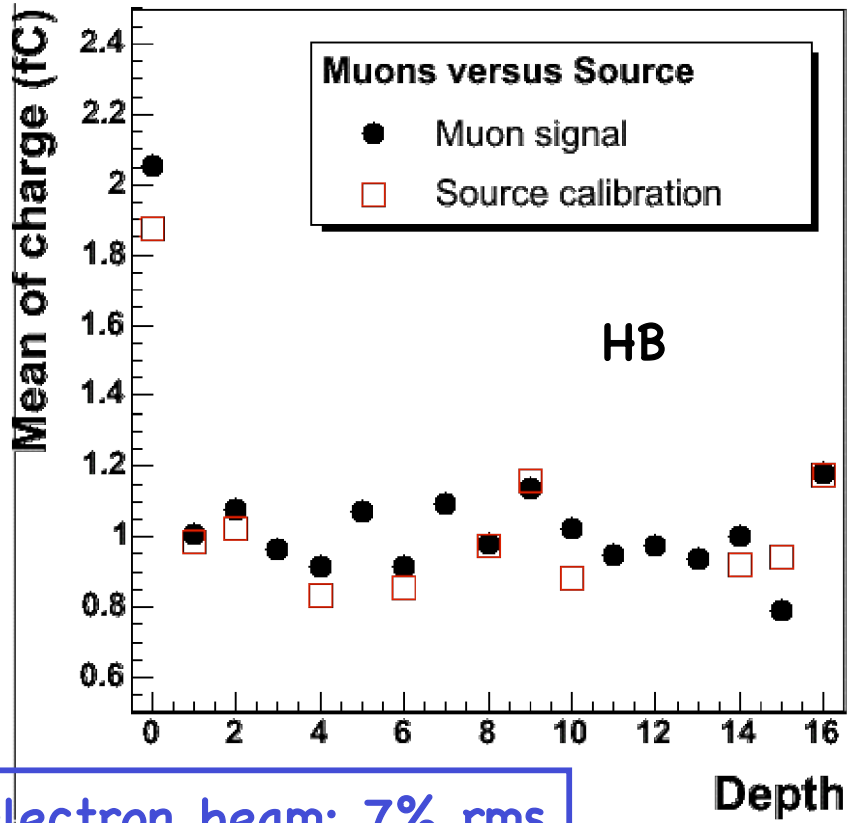
The 0.5% reached in-situ with physics events (see O.Buchmüller talk)

HCAL Source Calibration

Source calibration in SX5: Apr-Nov/05 (ready by magnet test)

Verifies full chain: scintillator -> fibres -> HPD -> QIE -> Readout





Preliminary analysis: wire Source vs electron beam: 7% rms

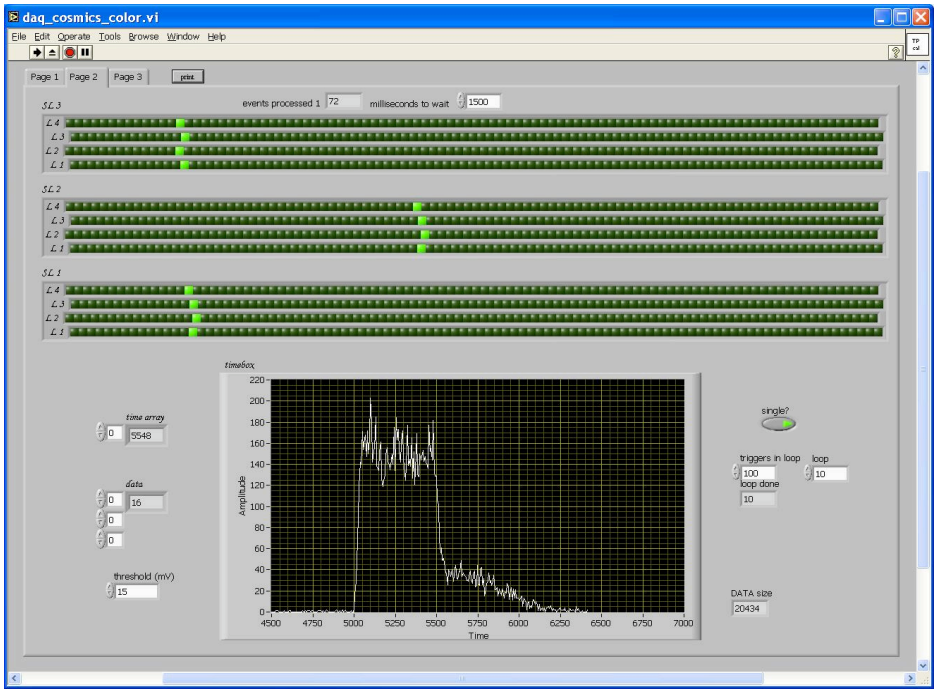
MUON Commissioning

Post-installation tests will be ~complete by early 2006 (lowering)

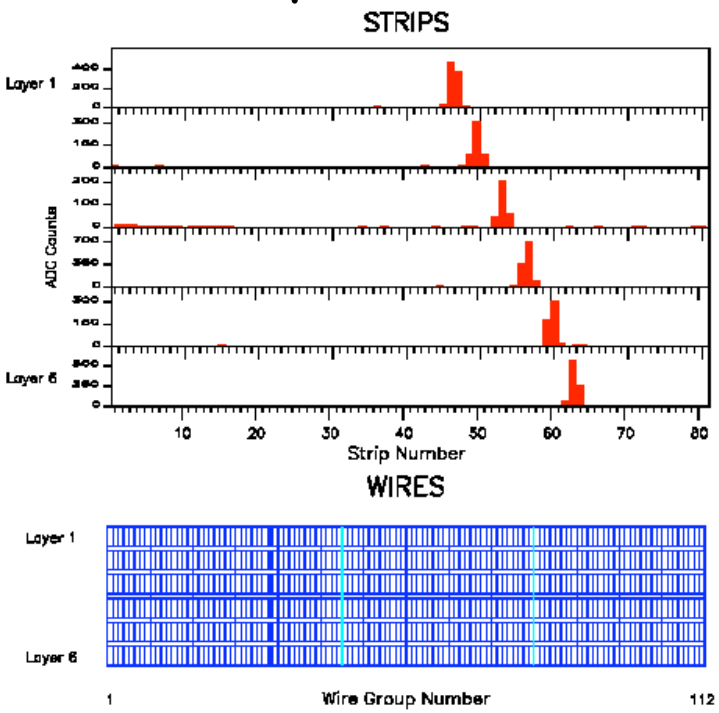
Repeat tests underground after connection to USC mounted electronics

First cosmic muons already seen by chambers in SX5

Barrel DT station



Endcap CSC station



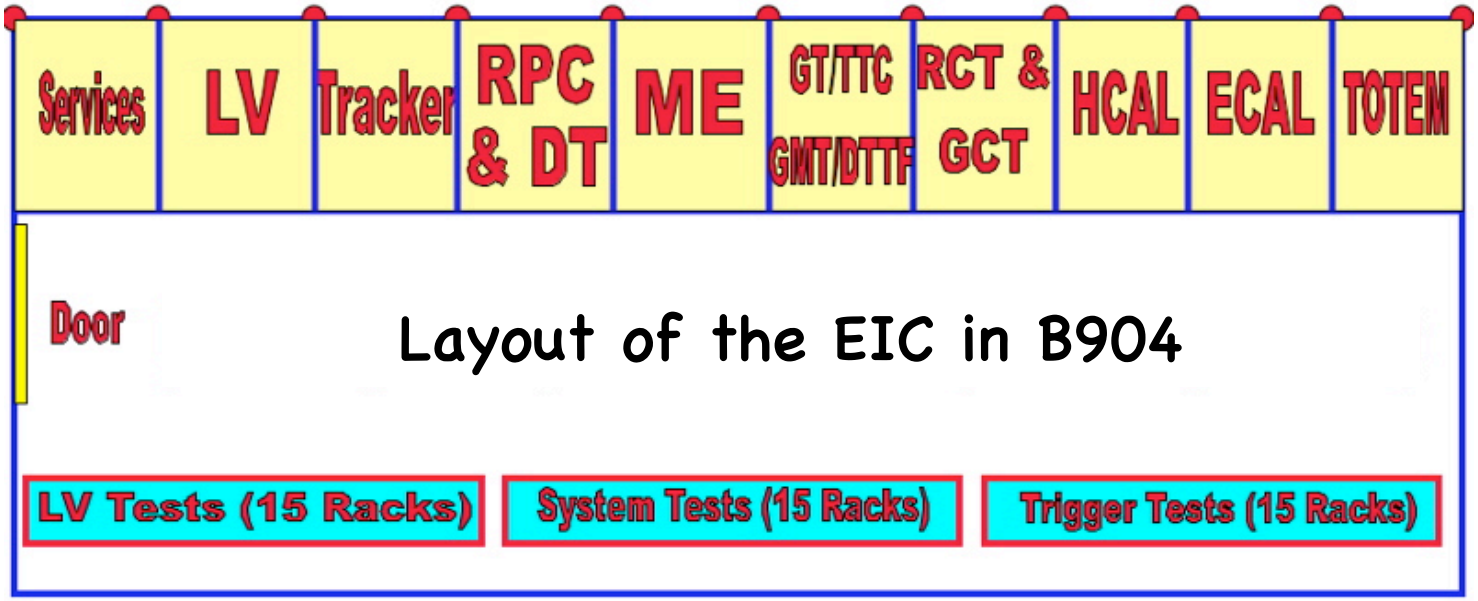
Electronics Commissioning Plans

Electronics integration center (EIC) in Bldg 904

No electronics will be installed in UXC/USC until
it has been commissioned and thoroughly tested in the EIC

Minimise underground commission time & problems
Common facilities and ease of access for institutes
Decouple commissioning from major installation

→ EIC set up to recuperate delay in USC delivery !



Preparing Trigger Installation

Much useful Trigger experience from 25 ns beams in 03/04

Delay of USC delivery had to be absorbed in Trigger schedule

Expect to start Trigger installation in USC in Nov/05

In preparation of this (to minimise UXC/USC commissioning time)

SURFACE TESTS IN SX5 & B904 (EIC)

Verify Trigger functions

Test electronics & integration in EIC & operate final systems

Test as much as possible before lowering CMS

Trigger installation schedule

Nov/05-May/06

Test(ed) trigger crates & pre-validate systems in EIC -> ship to P5
Stand-alone checks of crates & interfaces in USC

May/06-Oct/06

Connect CALO & MUON triggers to USC - install, test & synchronise
Connect Global Trigger to TTC distribution & test (local DAQ)

Oct/06-Mar/07

Verify trigger reception & start debugging with individual detectors
Detailed synchronisation & testing of all systems (central DAQ)

Mar/07-(Aug/07)

Test full Trigger operating all detectors simultaneously

Trigger Timing before Beam

Timing parameters estimated with timing model simulation
All cables and fibres are measured & stored in database

Use test patterns generated synchronously at R/O & trigger boards

- Adjust Trigger pipeline timing
- Adjust synch. between L1-accept and pipeline data

Problem shake-out

Run as long as possible with max volume/rate artificial data loaded es close to the front end as possible

Download simulated data on trigger and R/O and make sure these can yield physics signals on tape

Trigger/DAQ prototype

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

Will serve as test-bench

Scaleable HLT/DAQ

Buy/upgrade final system as late as possible to get best performance/CHF and highest capacity/CHF

Conclusions

We look back at 15 years hard work on

Design

R&D

Construction

We have a long "to do" list for the next 2 years

BUT

CMS will be ready for physics
when the LHC is ready to deliver collisions

Backup slides on CMS/LHC commissioning

Assumed LHC commissioning

	Commissioning	1st Year	Nominal	Ultimate
N_p^{Bunch} (x1E11)	1.15	0.4	1.15	1.67
N_{Bunch}	44	2808	2808	2808
β^* (m)	0.55	0.55	0.55	0.50
Luminosity (x1E34 $cm^{-2}s^{-1}$)	0.015	0.12	1.0	2.3
Events/BX	30	3	25	52
t_{BX} (ns)	2021	25	25	25
Θ_{cross} (μrad)	0	284	284	400
$\tau_{luminosity}$ (h)	15	28	14	8
Bunch length (cm)	7.55	7.55	7.55	7.55
I_{beam} (mA)	9	200	580	850
$E_{stored/beam}$ (MJ)	5.7	130	360	530

Trigger commissioning Plans

4 PHASES

1. Synchronisation & Trigger testing/evaluation

   Verify that data is properly set up and transported to farm nodes

2. Technical Validation of subdetector data

   Verify that detectors are read out properly and that all data is obtained and technically OK

3. Evalation/validation/calibration of subdetector data

   Study subdetector data calibration and performance to validate it for physics analysis

4. Evaluation of data by physics groups

   Make basic physics plots to validate performance, Compare with simulations