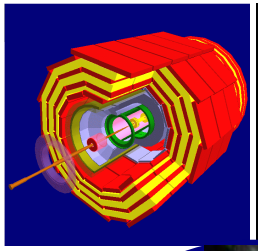
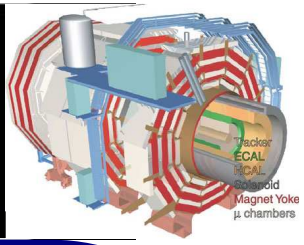




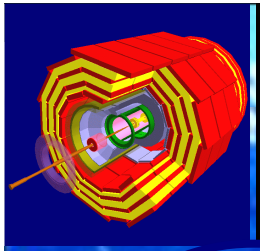
Presentation on the Status of the Compact Muon Solenoid Detector at the LHC

Presentation by
Prof. H. Neal (Yale University)
On behalf of the CMS Collaboration

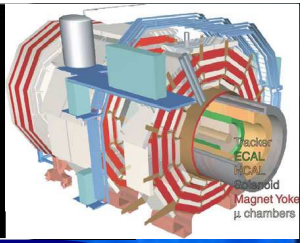
at

Beauty 2003

October 15th, 2003



The CERN Site



Lake Geneva

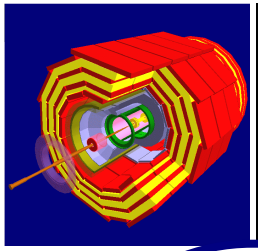
p-p collider

$\mathscr{L} = 10^{34} cm^{-2} s^{-1}$

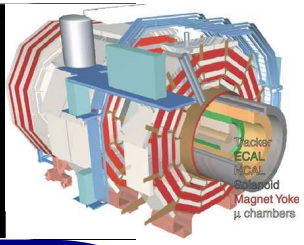
$\sqrt{s}$ up to 14 TeV

10^9 events/s

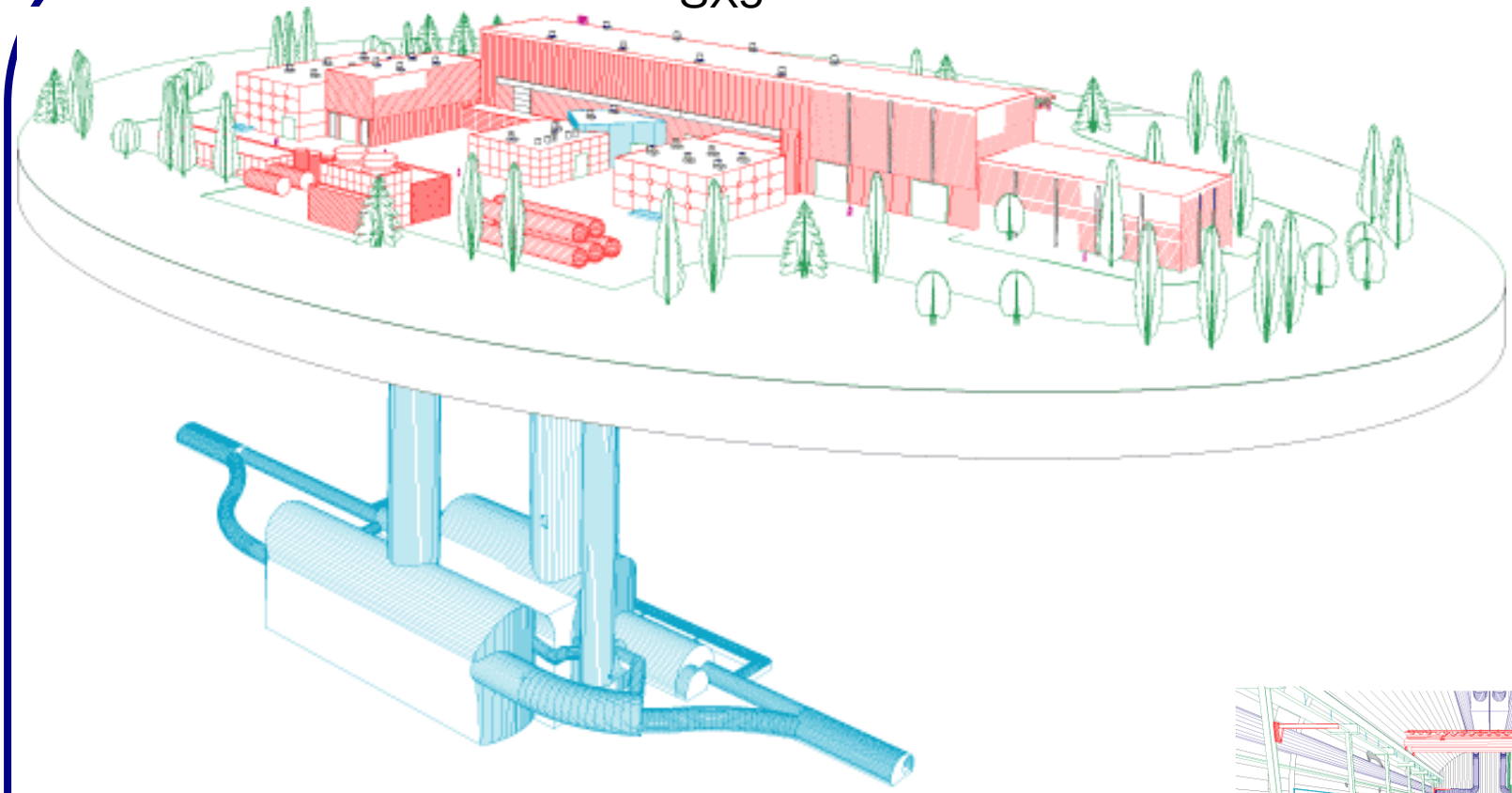
CMS



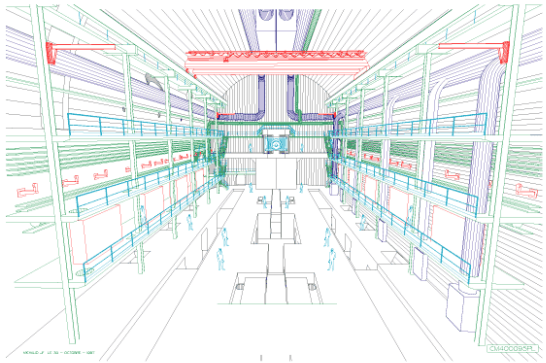
CMS Infrastructure



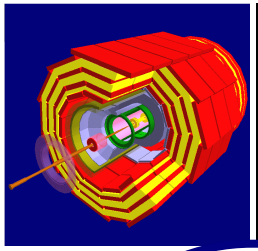
SX5

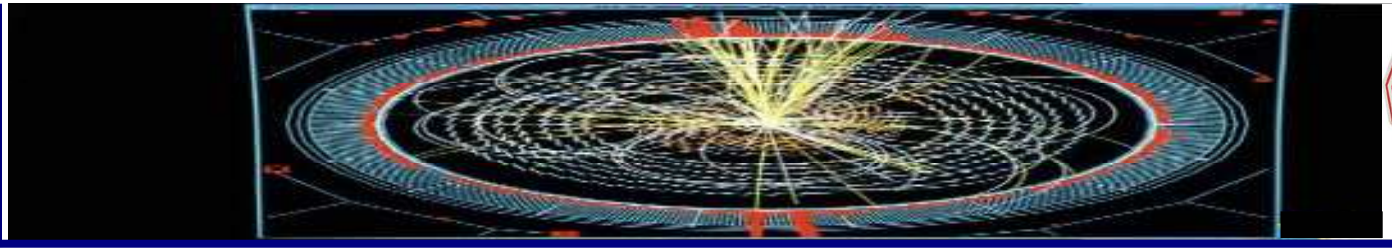


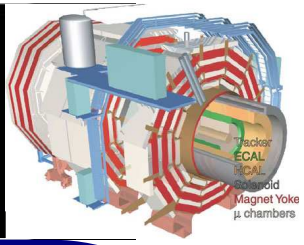
CMS experimental area overview



CMS experimental hall







CMS Collaboration

36 Nations, 159 Institutions, 1940 Scientists (February 2003)

TRIGGER & DATA ACQUISITION
Austria, Finland, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Switzerland, UK, USA

TRACKER
Austria, Belgium, Finland, France, Germany, Italy, Japan*, New Zealand, Switzerland, UK, USA

CRYSTAL ECAL
Belarus, China, Croatia, Cyprus, France, Italy, Japan*, Portugal, Russia, Serbia, Switzerland, UK, USA

PRESHOWER
Armenia, Belarus, Greece, India, Russia, Taipei, Uzbekistan

RETURN YOKE
Barrel: Czech Rep., Estonia, Germany, Greece, Russia
Endcap: Japan*, USA, Brazil

SUPERCONDUCTING MAGNET
All countries in CMS contribute to Magnet financing in particular: Finland, France, Italy, Japan*, Korea, Switzerland, USA

FEET
Pakistan
China

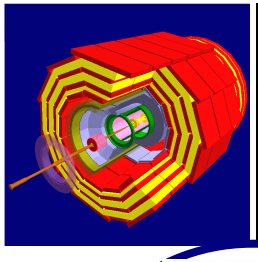
FORWARD CALORIMETER
Hungary, Iran, Russia,Turkey, USA

HCAL
Barrel: Bulgaria, India, Spain*, USA
Endcap: Belarus, Bulgaria, Russia, Ukraine
HO: India

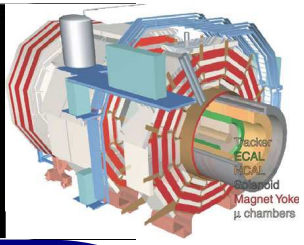
MUON CHAMBERS
Barrel: Austria, Bulgaria, China, Germany, Hungary, Italy, Spain,
Endcap: Belarus, Bulgaria, China, Korea, Pakistan, Russia, USA

* Only through industrial contracts

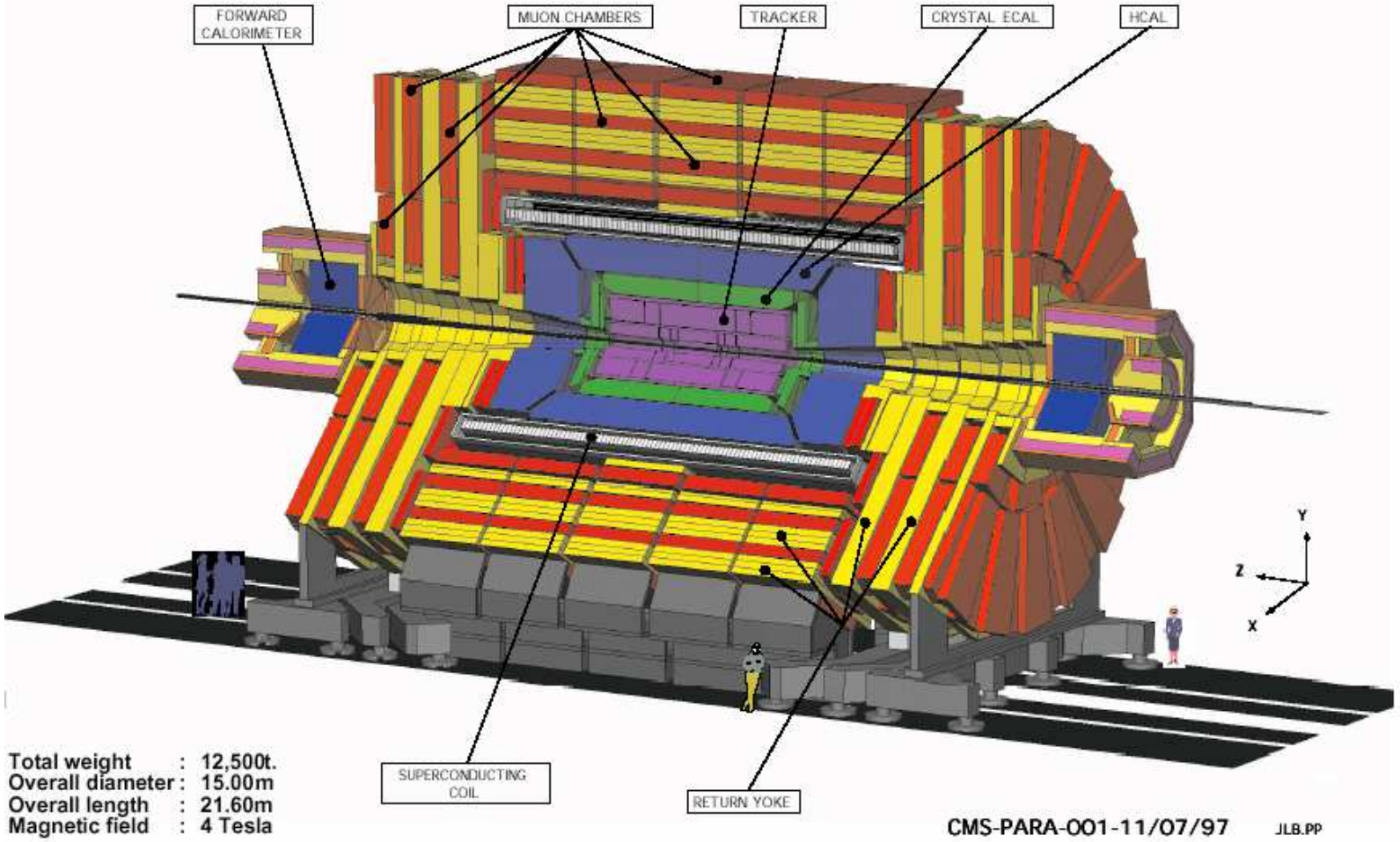
Total weight	: 12500 T
Overall diameter	: 15.0 m
Overall length	: 21.5 m
Magnetic field	: 4 Tesla

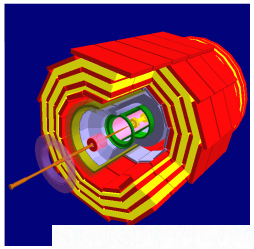


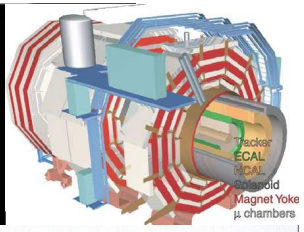
Detector Layout



CMS
A Compact Solenoidal Detector for LHC





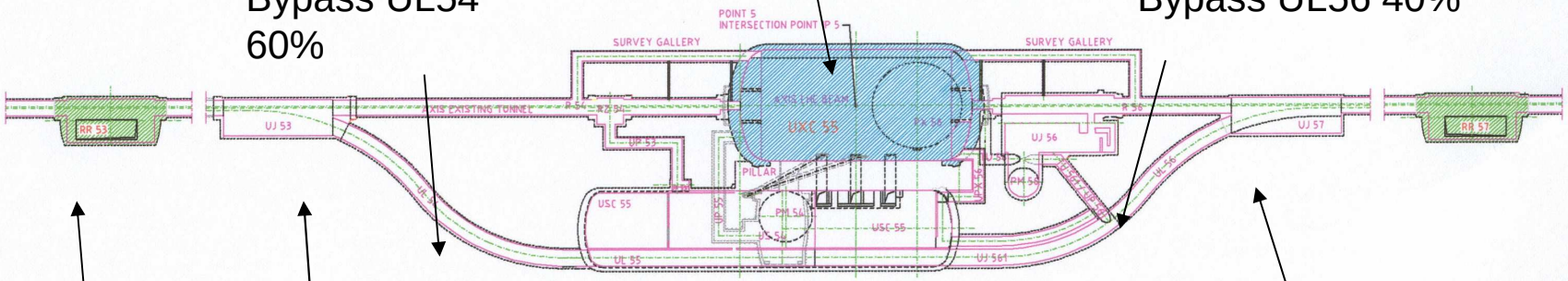
- **Cavern has a height of 26.5m and length of 53m**

CERN – LHC PROJECT
Point 5

UXC5 – Second Phase Invert 75%, Walls 50%

Bypass UL54 60%

Bypass UL56 40%



UJ57- 80%

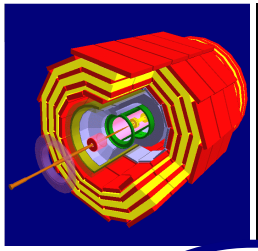
RR53 & RR57 Cavern Handed over May 2003

UJ53-95%

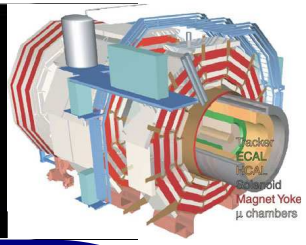
USC5 - Crown 40%

A. Hervé – August 25th,2003

GSG JV / BA / 05.05.03

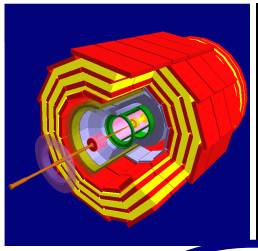


The CMS Pit

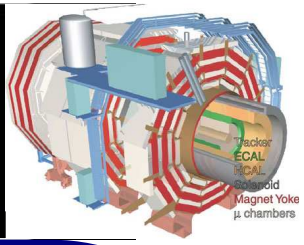


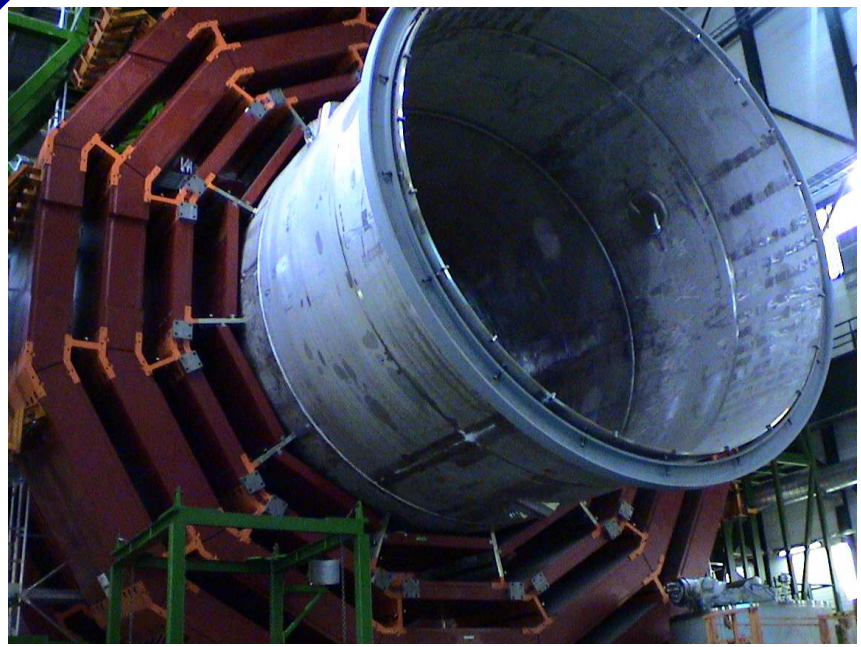
The main access shaft

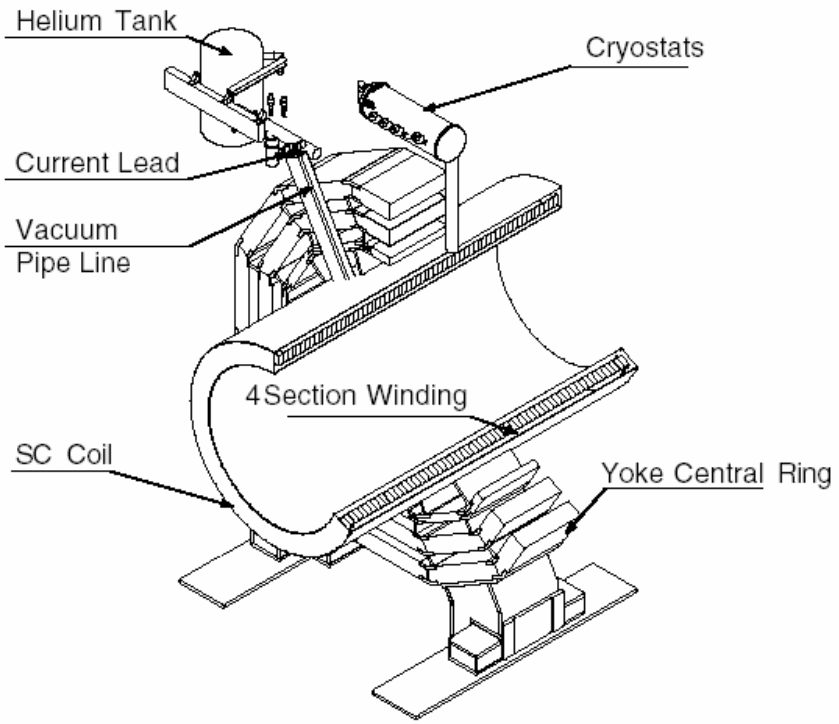
The detector pit



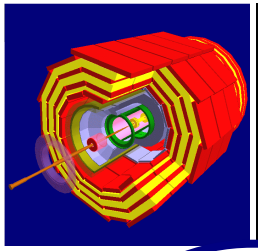
CMS Magnet



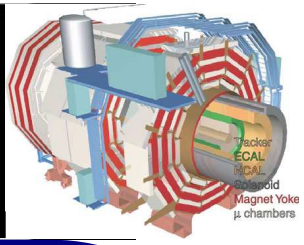


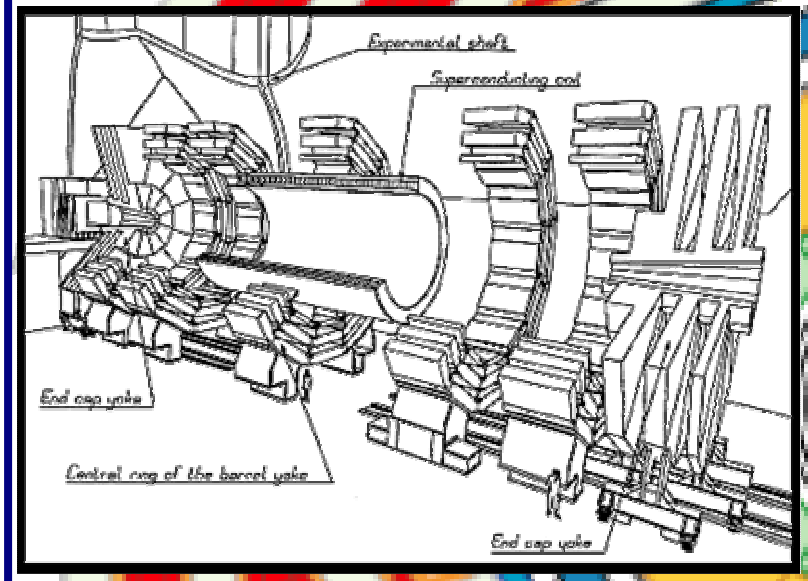


- 13 m long
- free inner diameter of 5.9 m
- measurement up to a pseudo rapidity of 2.4.
- The magnetic flux is returned via a 1.5 m thick saturated iron yoke
- Total iron mass = 7000 tons
- Total weight including coil is 12000 tons



The CMS Coil



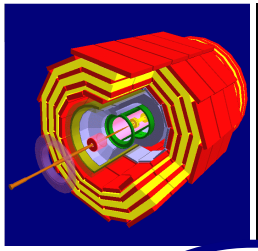


Inner radius = 3.18 meters

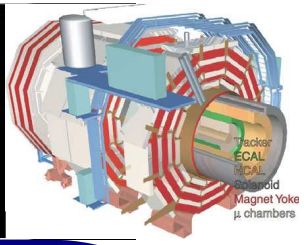
Length = 12.4 m

Stored energy = 2.7 Giga Joules

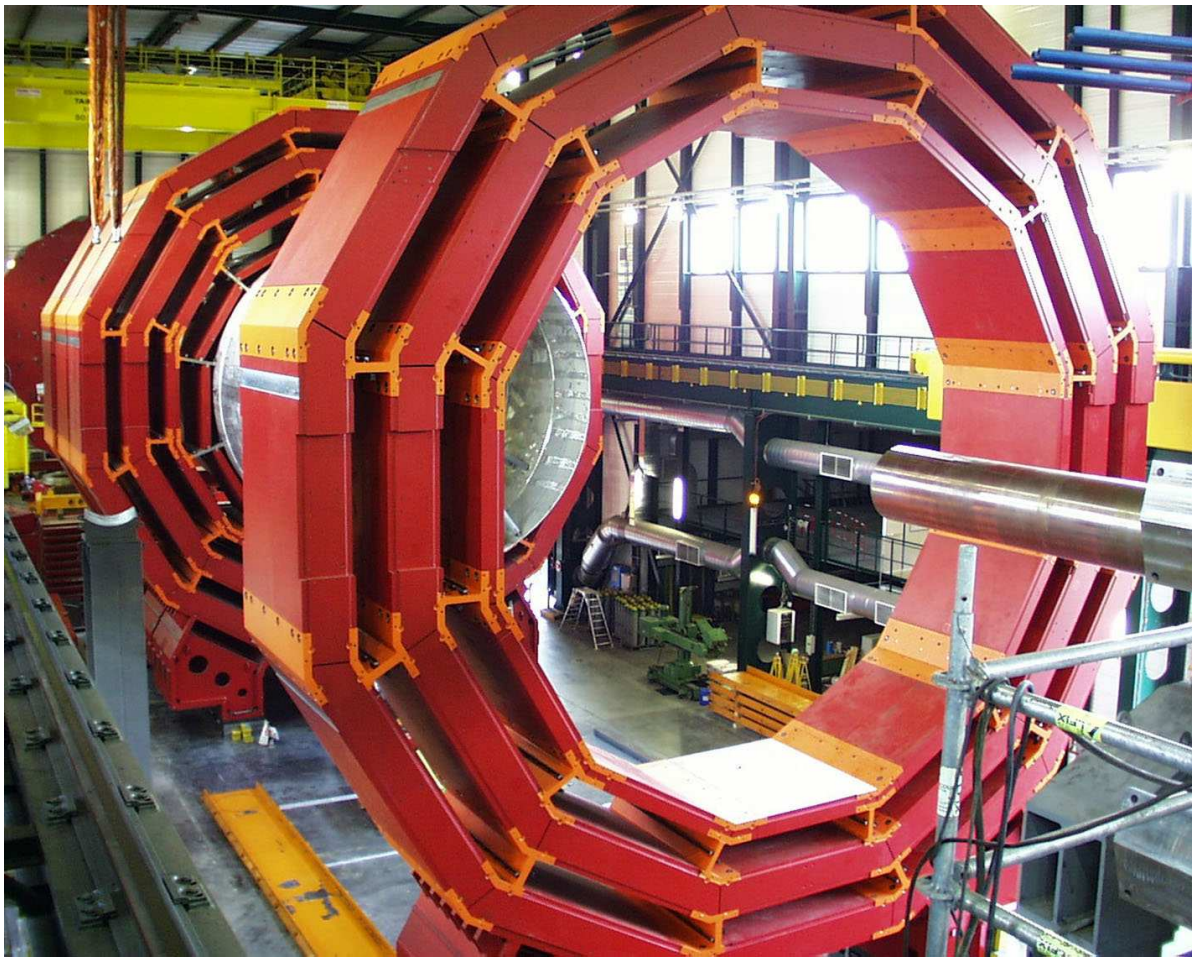
Compressive force at mid plane = 148 Mega Newtons



Status of Magnet Yoke

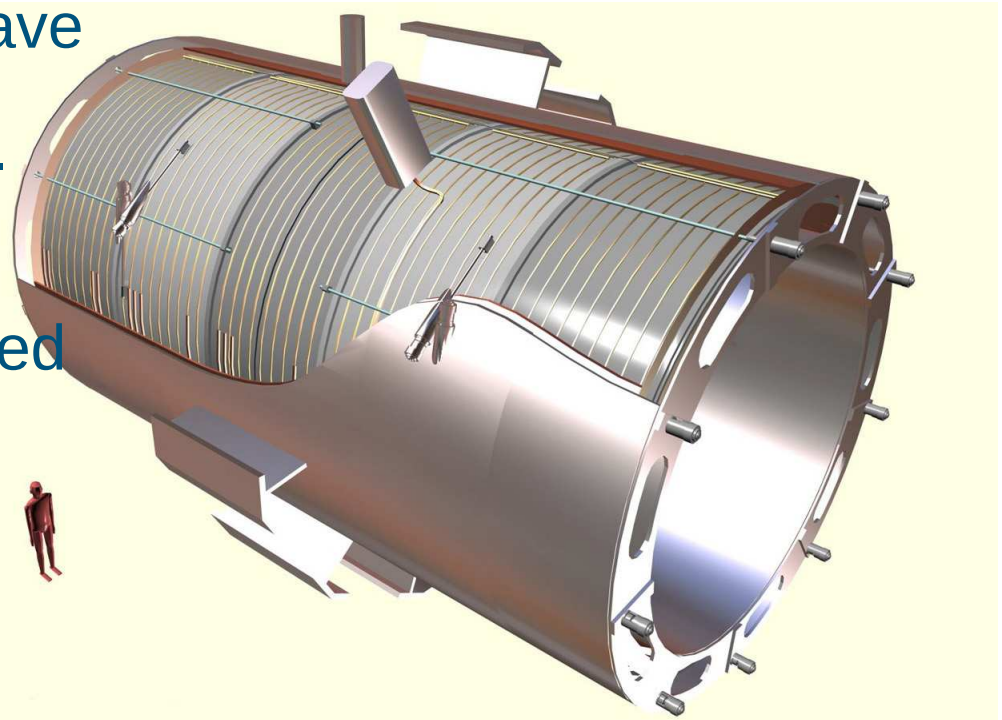


- Yoke and metallic structures completed one year ago

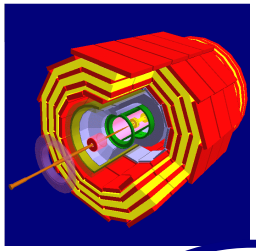


Coil Status

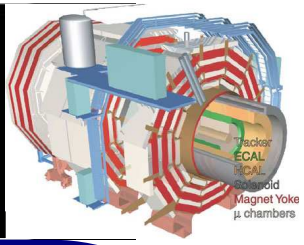
- 18.5 (out of 21) full lengths of conductor have been successfully produced at Techmeta.
- The 2.5 remaining lengths will be completed for mid October 2003.
- About 43% of the construction has been completed
- Test of the Magnet in Surface Hall first half of 2005



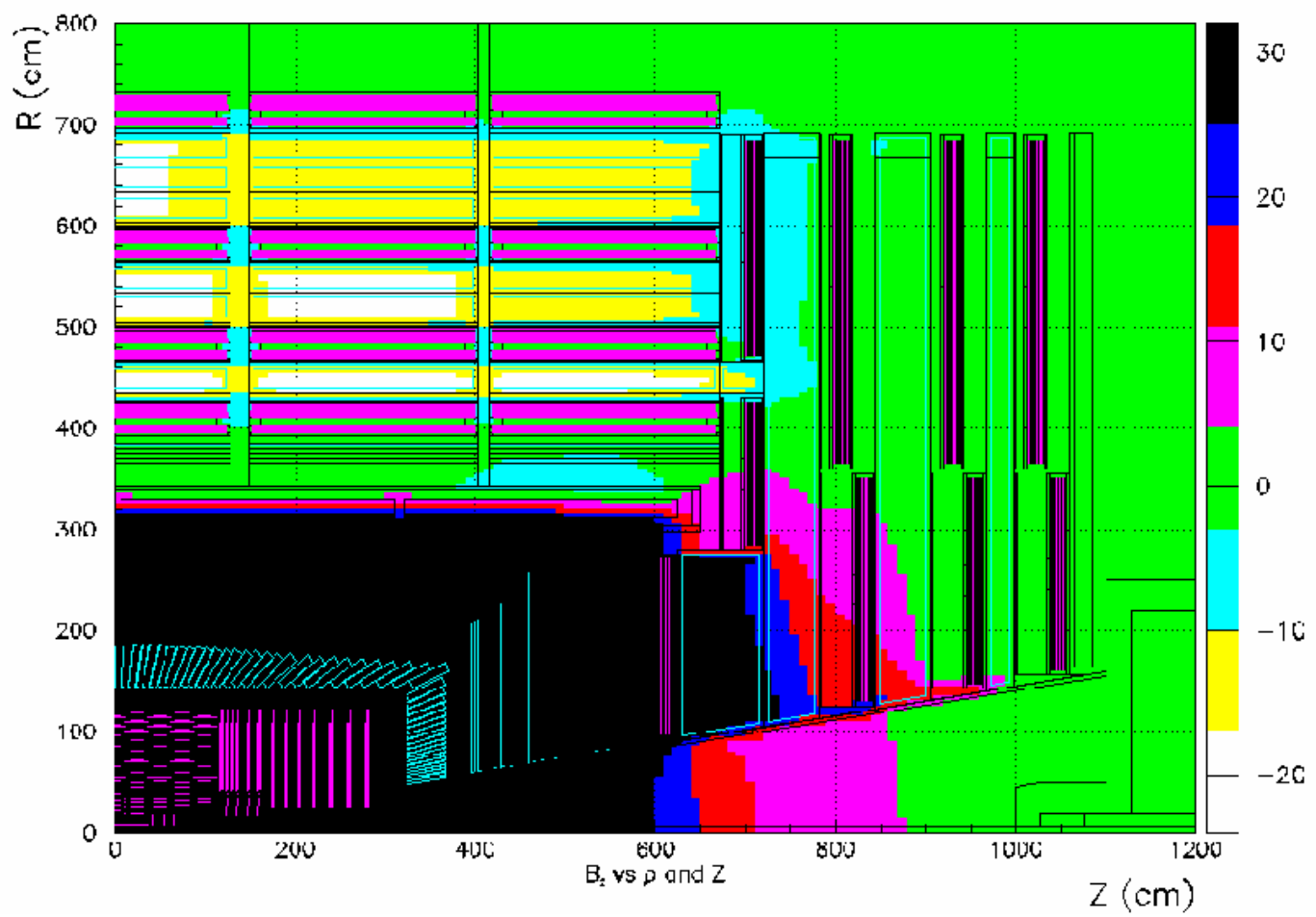
A. Hervé

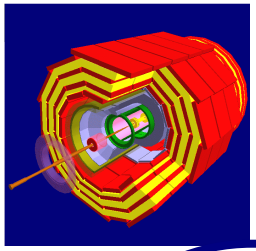


CMS Magnetic Field

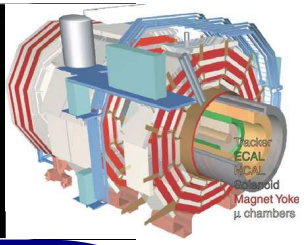


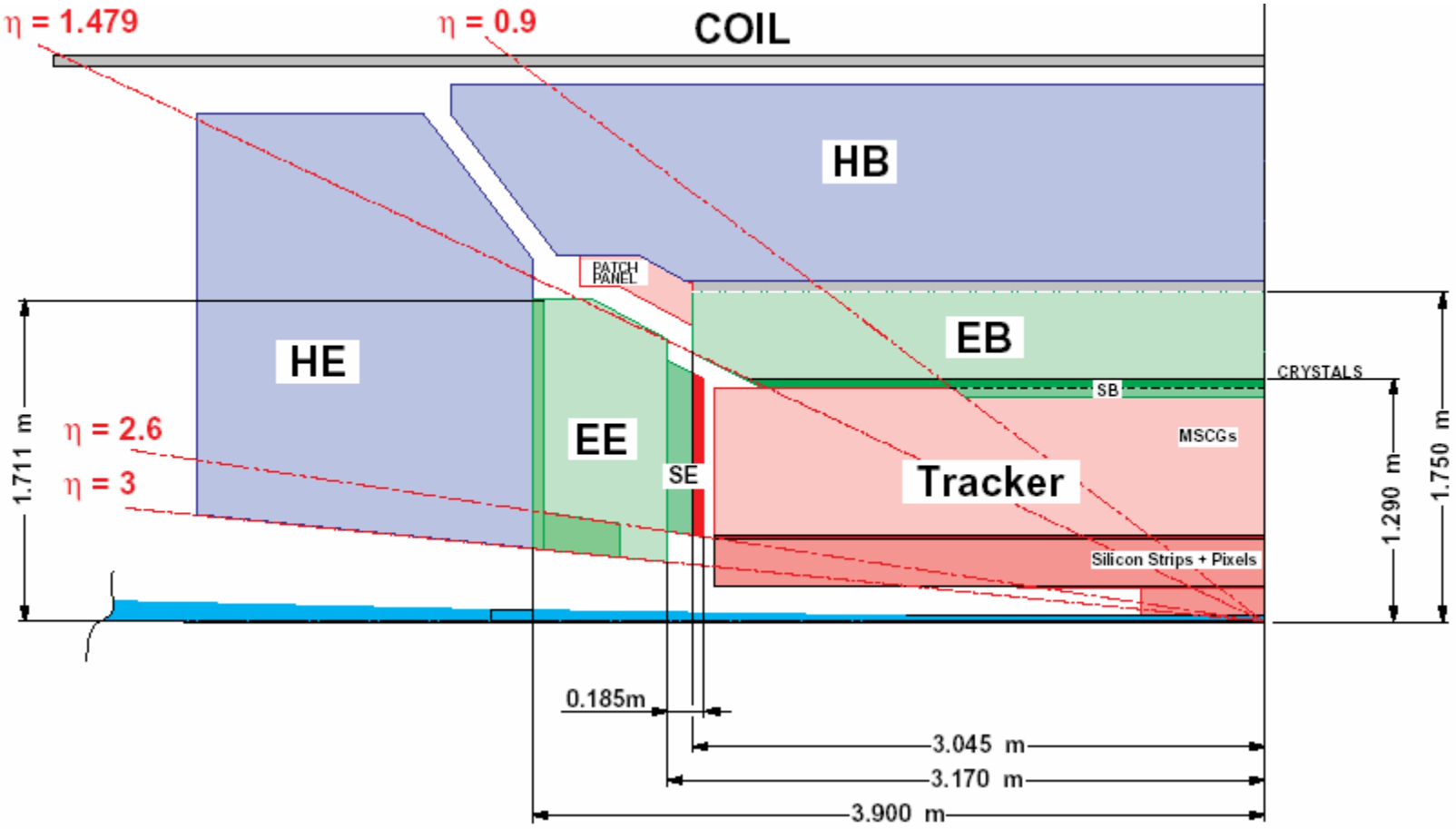
Z component of Magnetic field in kGauss



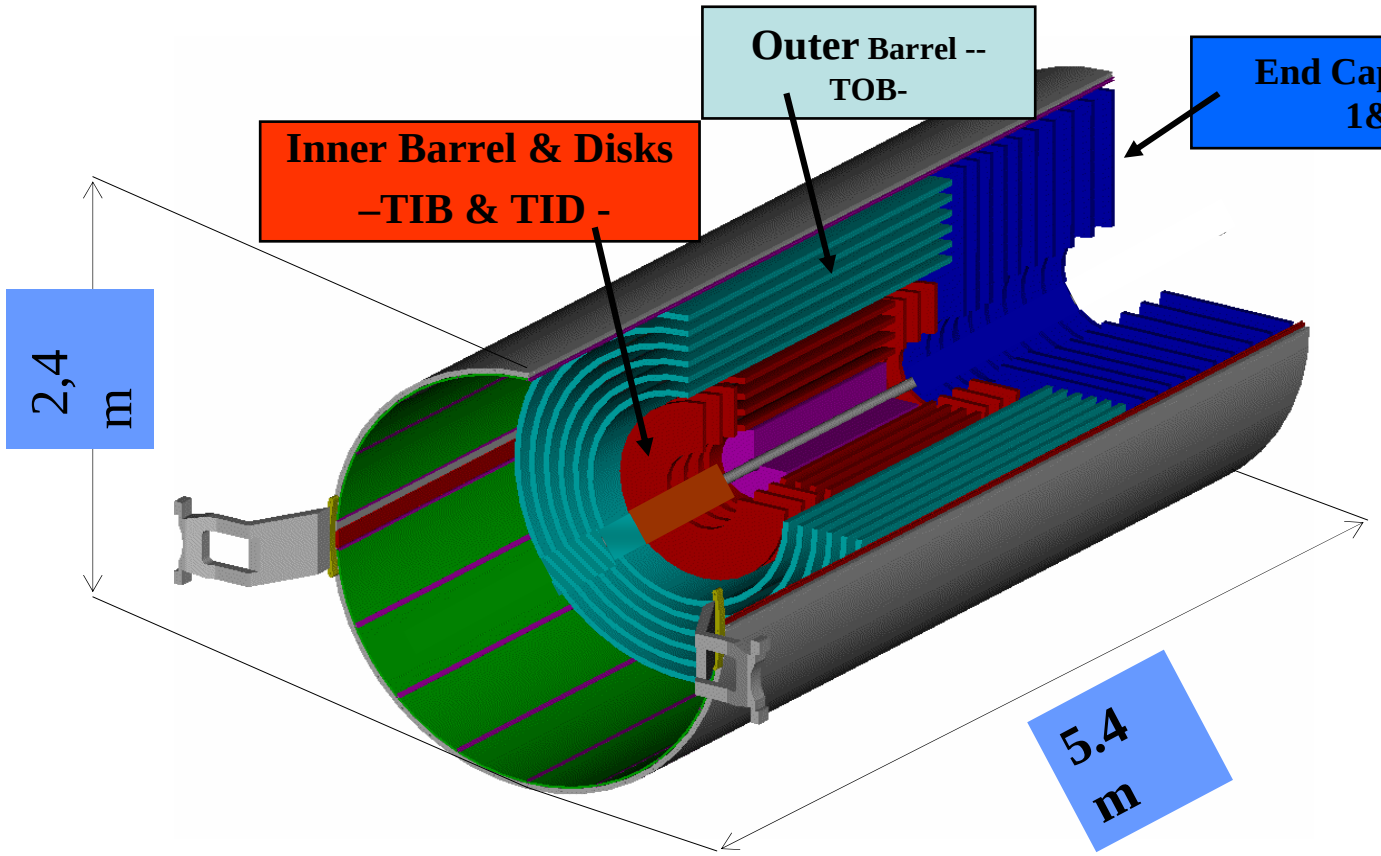


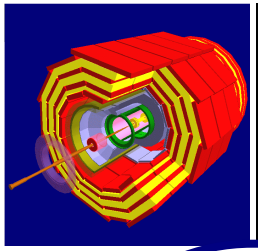
Tracker + Calorimetry + Coil



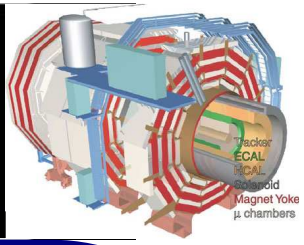


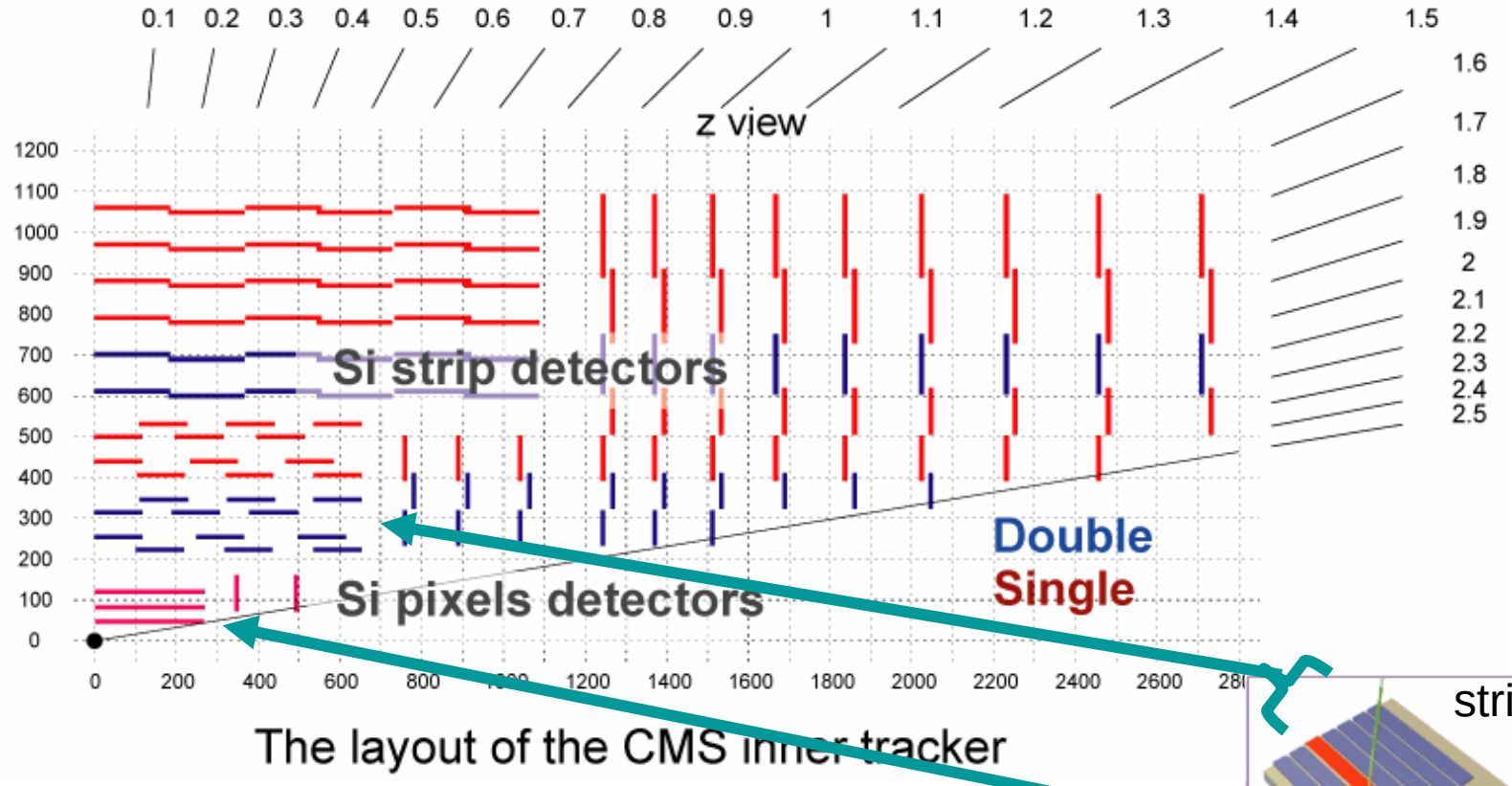
CMS Tracker: Silicon Strip Detectors

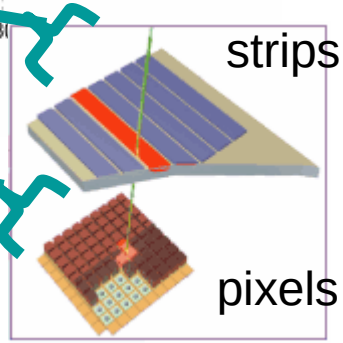




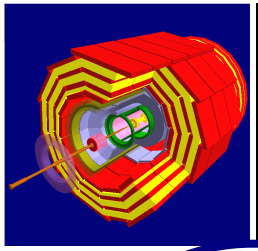
CMS Tracker w/ Pixels



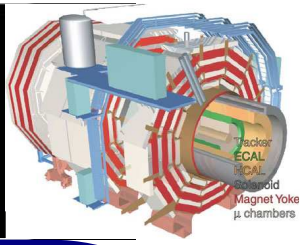




2→3 pixels +
10→14 strip hits



The CMS Tracker Effort



frames | sensors | hybrids | pitch adapter | hybrid carrier

CERN

Bonding Assembly Sensor QAC

Pisa | Perugia | Wien | Karlsruhe | Louvain Strasbourg

FNAL UCSB | Perugia Bari | Wien | Lyon | Brussels

FNAL UCSB | Padova Pisa Torino Bari Firenze | Wien Zurich Strasbourg Hamburg Karlsruhe Aachen

ROD INTEGRATION — FNAL UCSB

Shell/disks INTEGRATION — Pisa

PETALS INTEGRATION — Louvain Brussels Lyon Hamburg Strasbourg Karlsruhe Aachen

TOB assembly — CERN

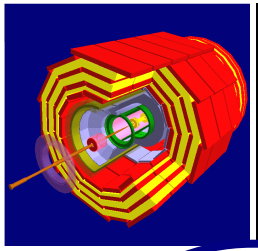
TIB TID assembly — Pisa

TEC assembly — Aachen

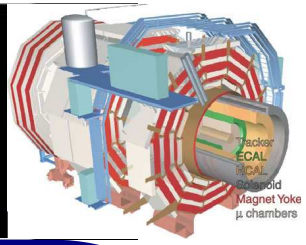
TEC assembly — Karlsruhe -> Lyon

CMS TK 2003

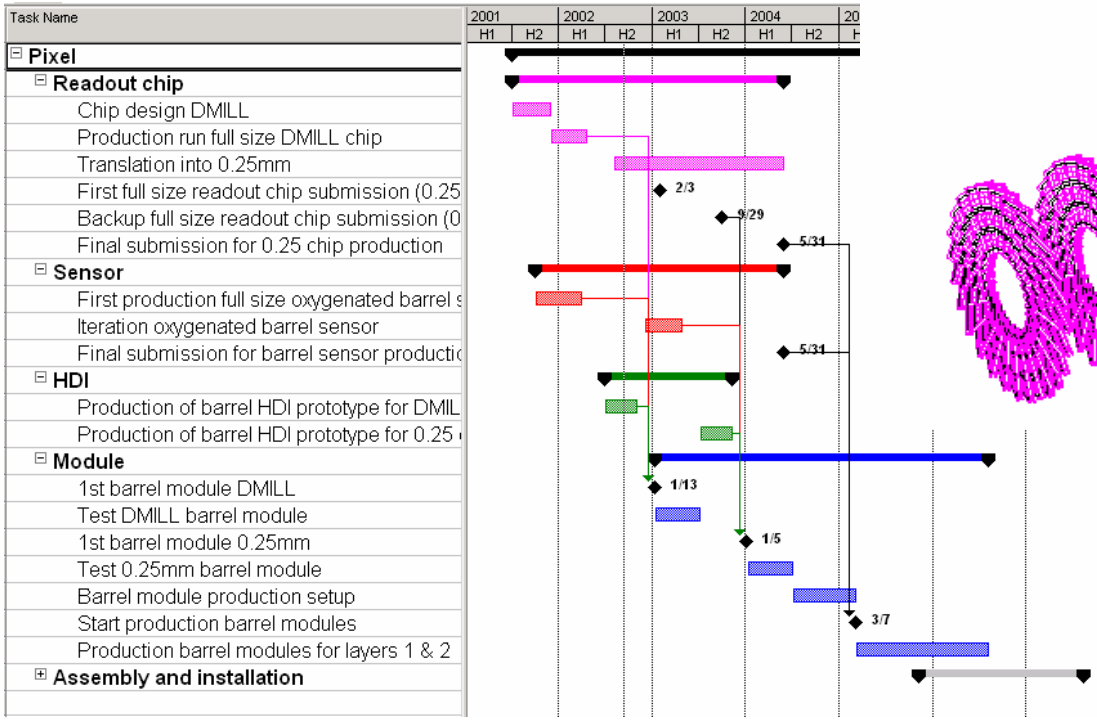
Tracker ASSEMBLY — CERN

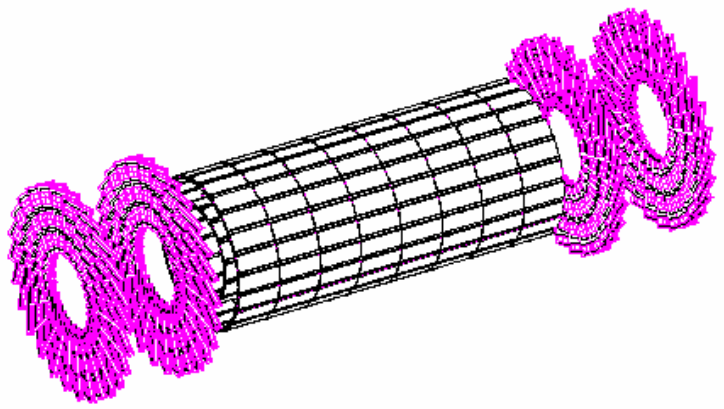


CMS Pixel Detector Status

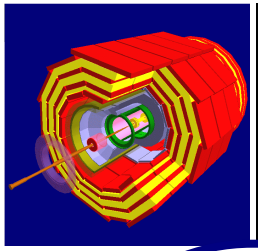


Pixel system currently in R&D phase

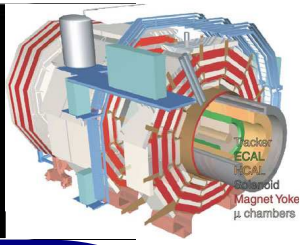




	Configuration	Radius [mm]	Faces (∗)	full/half Modules	Chips	Pixels	Area [m^2]
Layer 1	low luminos.	41–45	18	128/32	2304	6.35×10^6	0.15
Layer 2	low & high luminos.	70–74	30	224/32	3840	10.6×10^6	0.25
Layer 3	high lumi	107–112	46	352/32	5888	16.2×10^6	0.38



Status Schedule for Completion of Tracker



PIXEL System

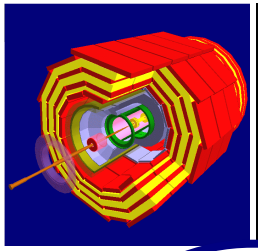
- conversion of the readout chips to 0.25 μm
- First prototype modules

Silicon Strip Tracker

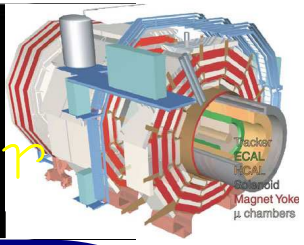
- All final contracts for module parts are active
- Start of module production and validation
- First Front End Driver prototype
- Large progress on procurement of mechanical structures

Status from Gigi Rolandi – 9/2003

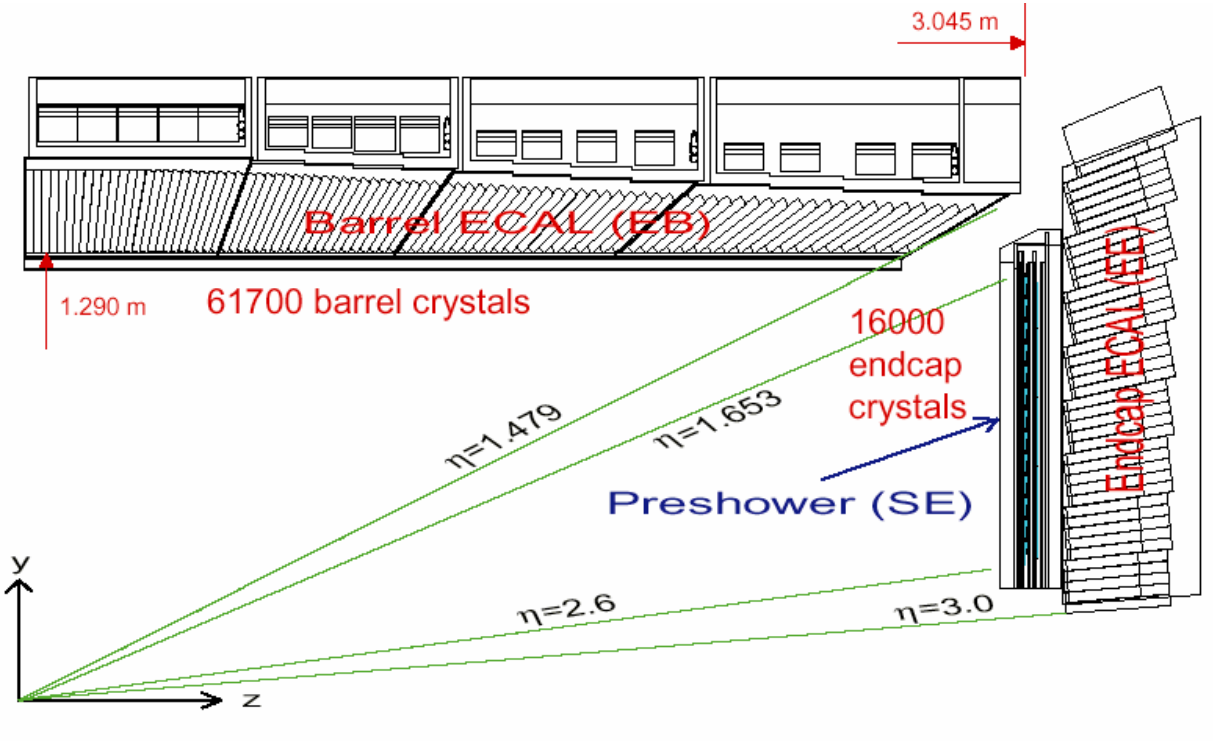
TIB reception at CERN & tests – Feb→Apr 2005
TOB completed - April 2005
Reception and tests of TEC – Oct 2005

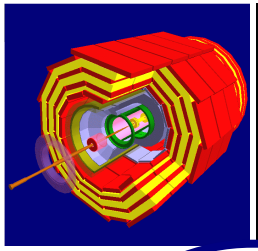


The Electromagnetic Calorimeter

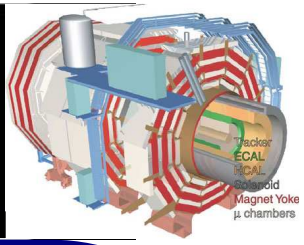


- **Composed of 80000 lead tungstate (PbWO4) crystals readout by avalanche photodiodes that collect the scintillating light**
- **Barrel uses 22x22x230mm crystals with thickness 25.8 X^o**
- **supported by 0.4mm thick alveolar structures made from carbon-fiber (in the endcaps) and glass fiber (in the barrel)**

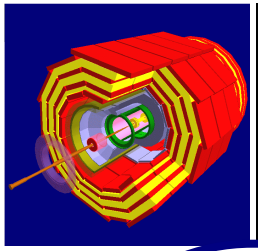




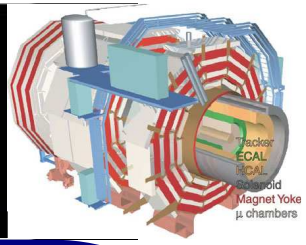
ECAL Design Parameters

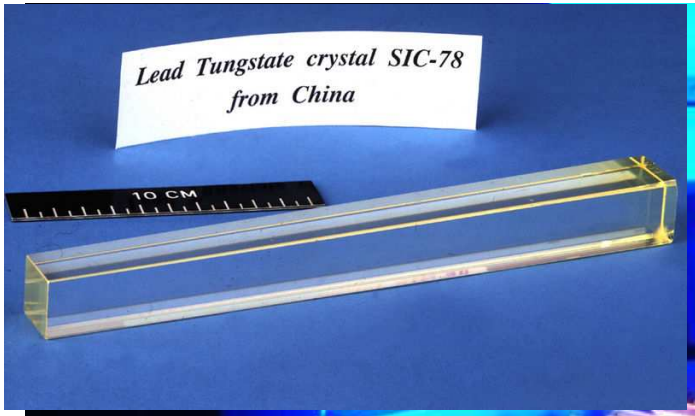


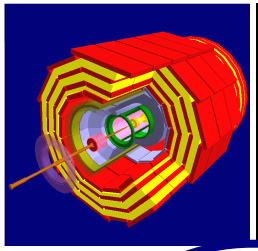
Parameter	Barrel	Endcaps
Pseudorapidity coverage	$\|\eta\| < 1.48$	$1.48 < \|\eta\| < 3.0$
ECAL envelope: r_{inner}, r_{outer} [mm]	1238, 1750	316, 1711
ECAL envelope: z_{inner} z_{outer} [mm]	0, ±3045	±3170, ±3900
Granularity: $\Delta\eta \times \Delta\phi$	0.0175×0.0175	0.0175×0.0175 to 0.05×0.05
Crystal dimension [mm^3]	typical: $21.8 \times 21.8 \times 230$	$24.7 \times 24.7 \times 220$
Depth in X_0	25.8	24.7
No. of crystals	61 200	21 528
Total crystal volume [m^3]	8.14	3.04
Total crystal weight [t]	67.4	25.2
Modularity	36 supermodules	4 Dees
1 supermodule/Dee	1700 crystals (20 in ϕ, 85 in η)	5382 crystals
1 supercrystal unit	–	36 crystals



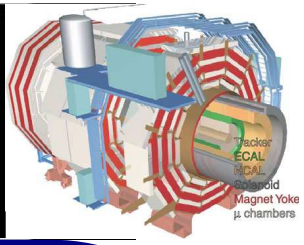
ECAL Crystal Preparation



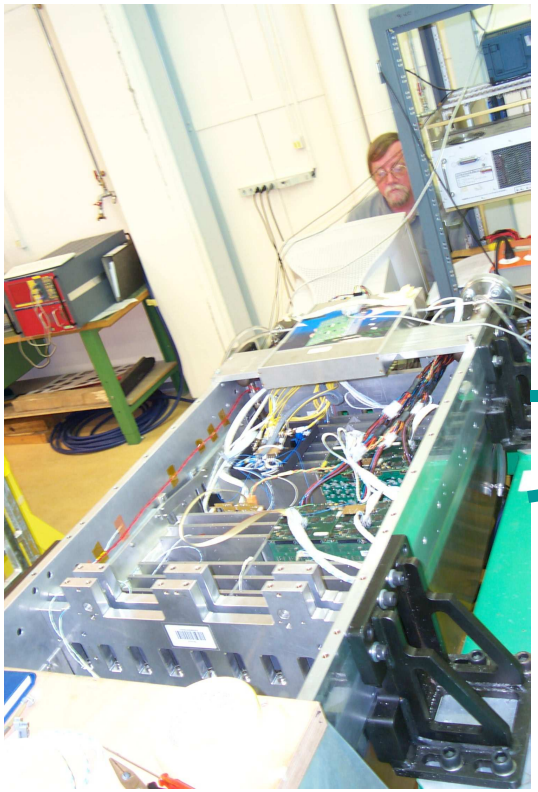


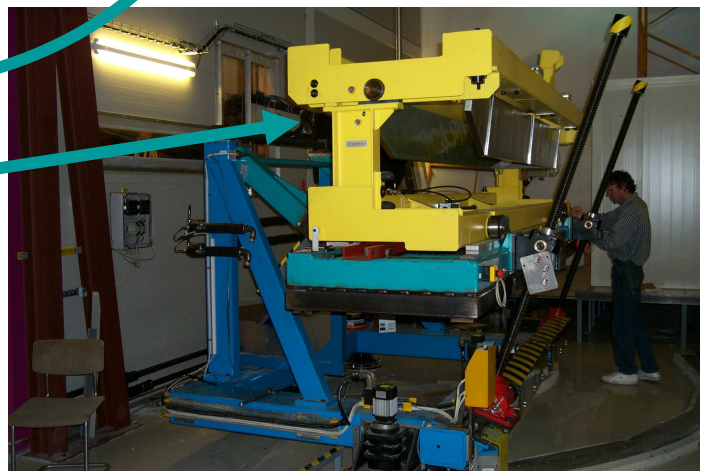


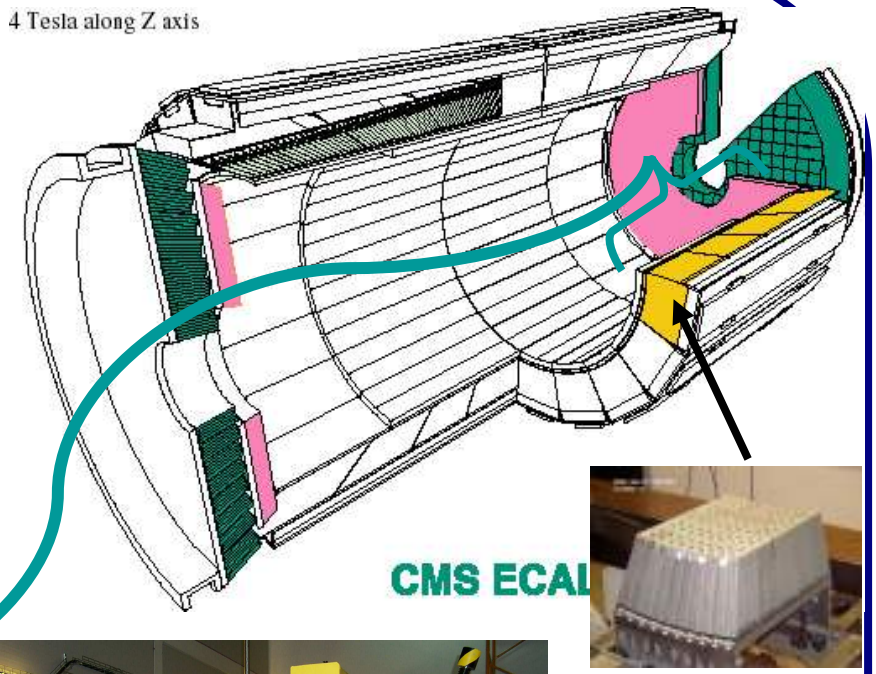
Test Beam 2003

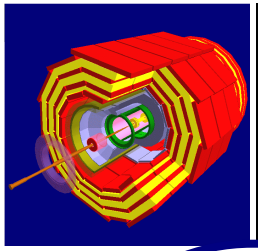


A full super-module has recently been assembled
and is currently being tested using beams from the
SPS

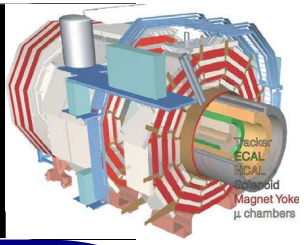




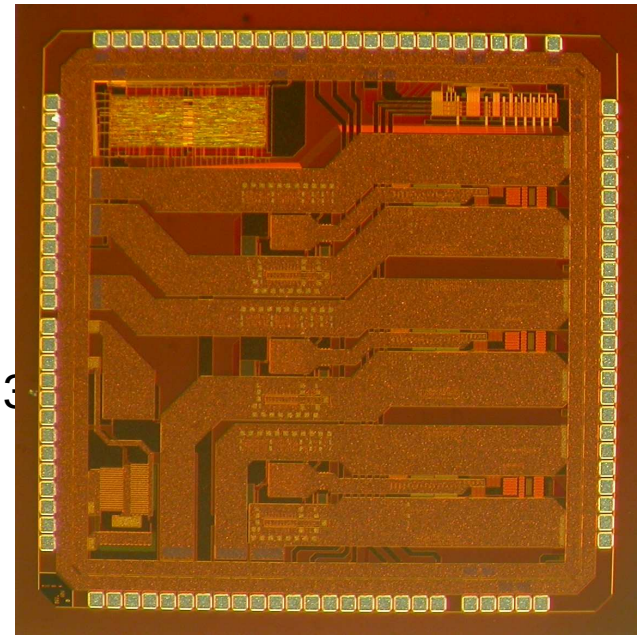


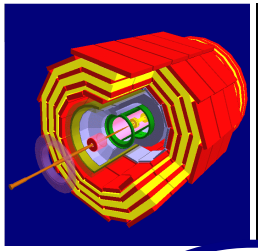
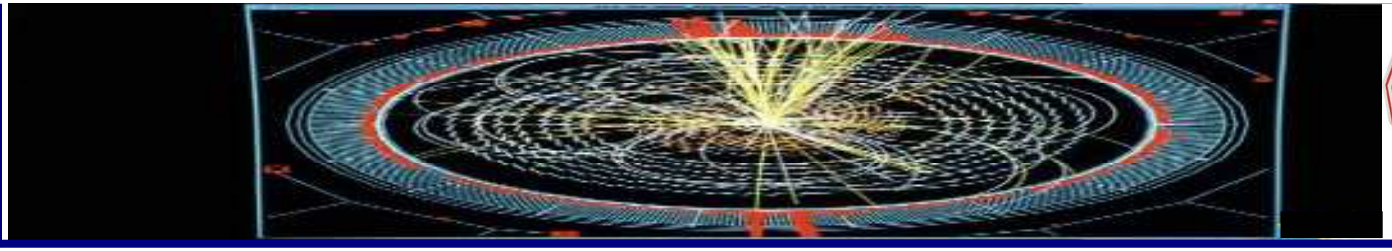
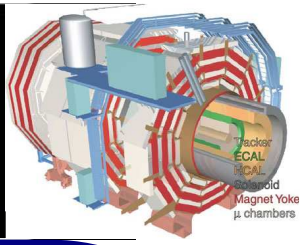


ECAL Status

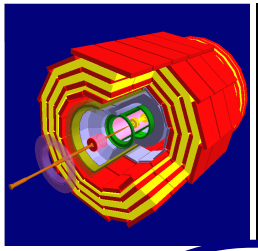


- New architecture front ends proto-typed and working
  - Currently being used in the test beam
    - Includes all new boards
    - Optical control and readout of data and trigger
- New technology chosen for ASICs. All hardware components prototyped VFE ASICS in 0.25µm developed
  - Chips tested and working
  - Small size system running
- Low voltage system and DCS system design progressing well
- 32 Barrel modules assembled
  Almost all Super-Module mechanics procured, 3
- Full system tests in progress

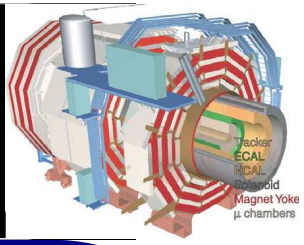


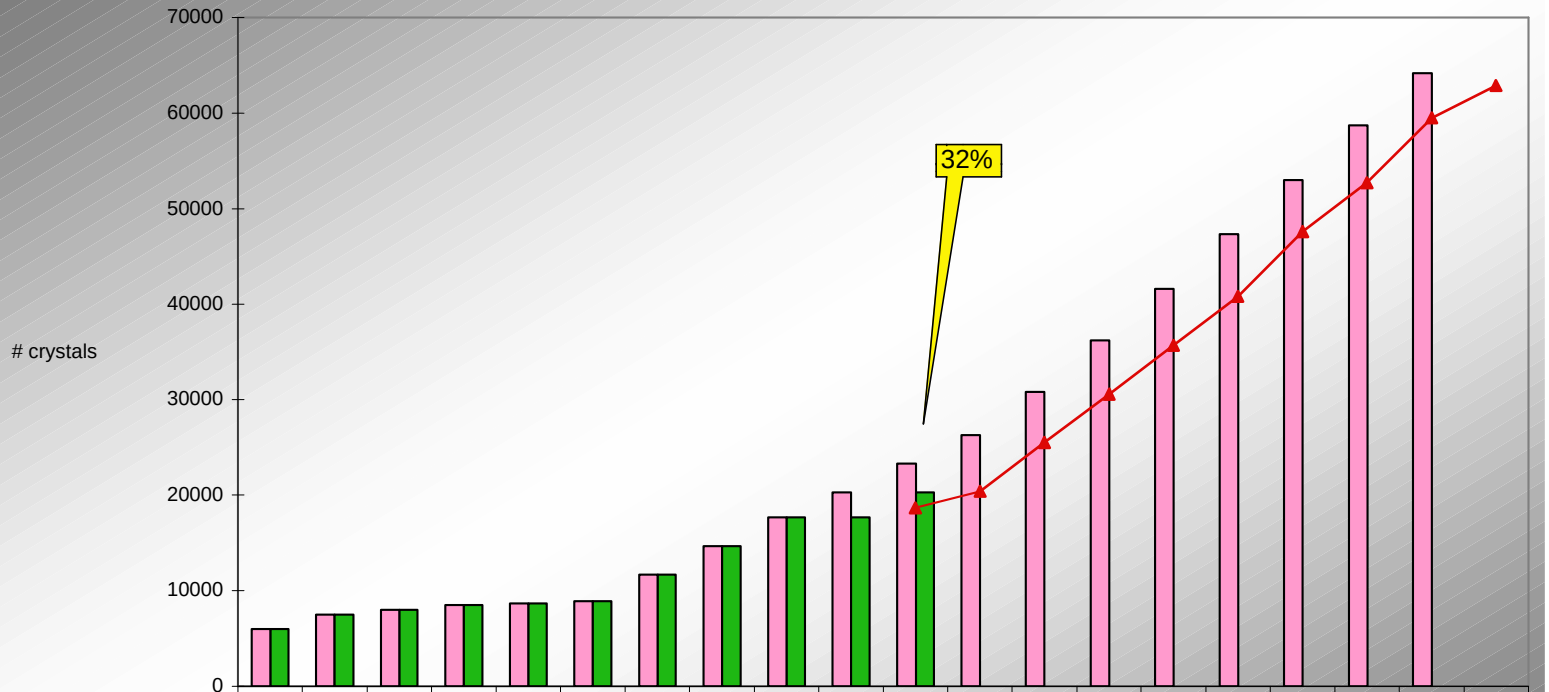
- Crystals: 32% delivered
- APD production/screening should be finished by April 04
- Capsules: 38% early Sept 03
- Alveolas : 50% delivered end Q2-03, completion by end 03
- Tablets: 73% end Q2-03
- Present daily rate: 50 x 2 (centres) = 100 crystals /day= 4 Modules /month



CMS ECAL Crystal Production

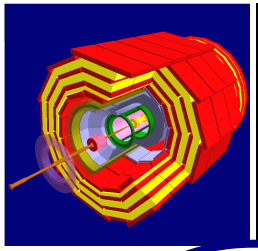


EB Crystal production

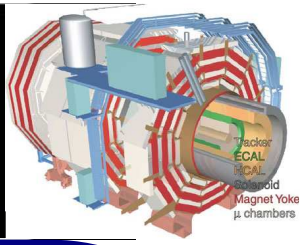


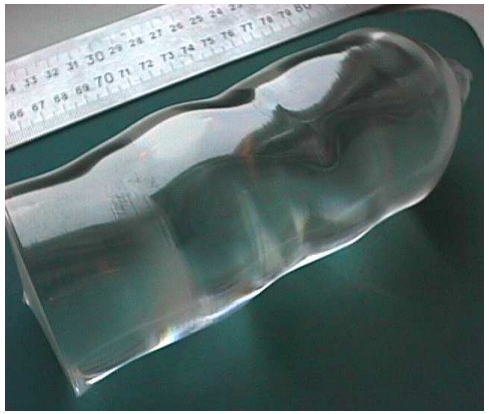
	Q1 2001	Q2 2001	Q3 2001	Q4 2001	Q1 2002	Q2 2002	Q3 2002	Q4 2002	Q1 2003	Q2 2003	Q3 2003	Q4 2003	Q1 2004	Q2 2004	Q3 2004	Q4 2004	Q1 2005	Q2 2005	Q3 2005	Q4 2005
Planning	6000	7500	8000	8500	8700	8900	11700	14700	17700	20300	23300	26300	30800	36200	41600	47300	53000	58700	64150	
Delivered jj-Sep-aa	6000	7500	8000	8500	8700	8900	11700	14700	17700	17700	20300									
Critical path											18700	20400	25500	30600	35700	40800	47600	52700	59500	62900

Date

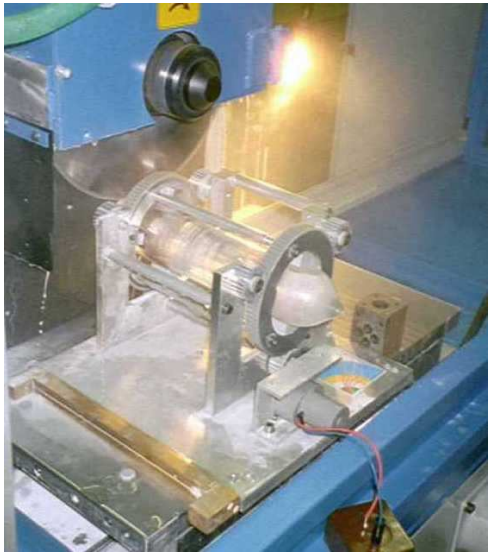


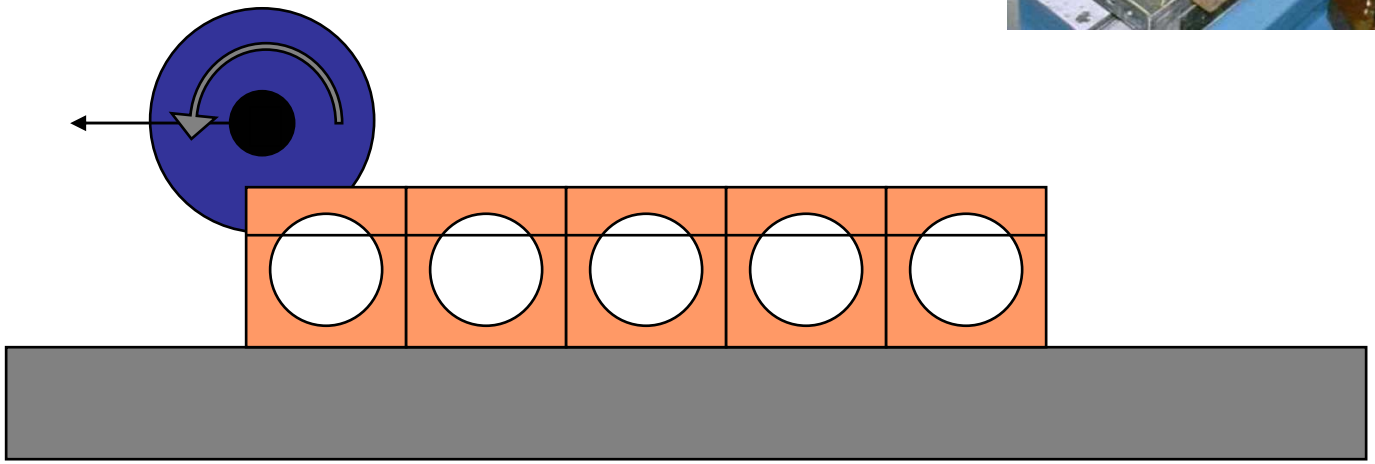
Lead Tungstate Crystals

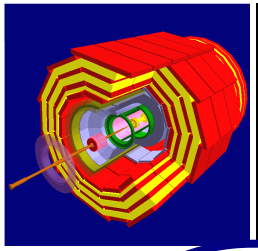




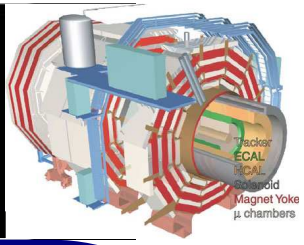
New methods of cutting ingots are speeding up crystal production



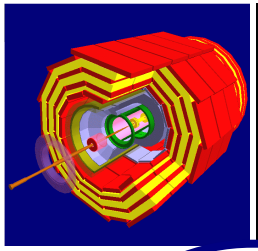




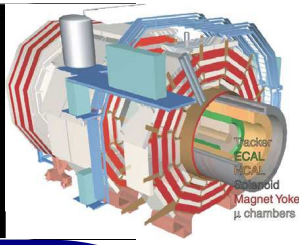
CMS ECAL Installation Dates



- EB Trial insertion of 1 SuperModule
  - Trial February 2005
- EB+
  - Installation in surface hall: 27/06/05 to 19/08/05
- EB-
  - Installation in pit: 1/12/05 to 6/01/06 & Cabling 15/02/06 to 31/03/06



Preshower Status

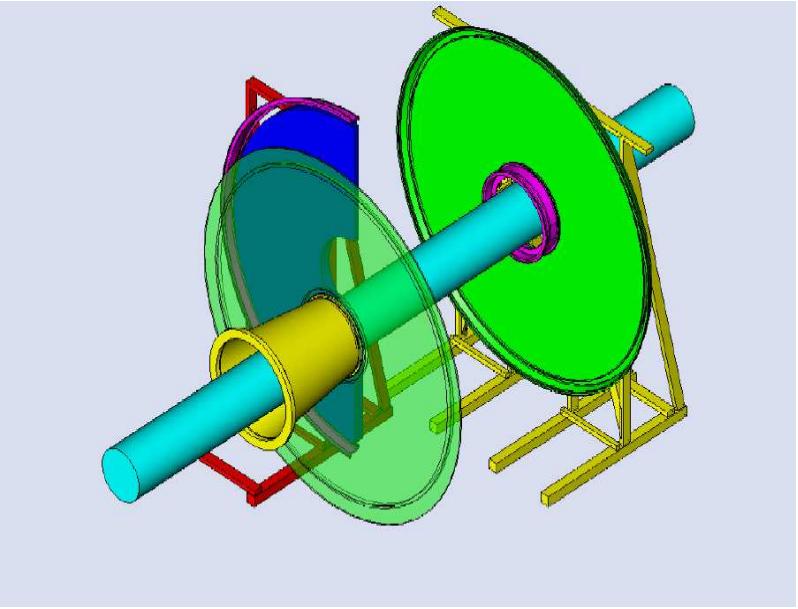


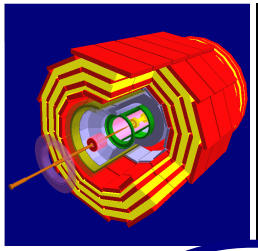
New Preshower mechanical design

- Windows (Al honeycomb + paraffin) + inner drum + support cone remain as complete discs – need to install BEFORE the beam pipe
- Lead planes stuffed with electronics divided into two “D”s – can be installed AFTER the beam pipe

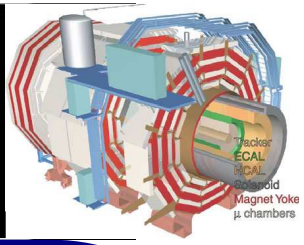
- Endorsed by CMS in march 2003

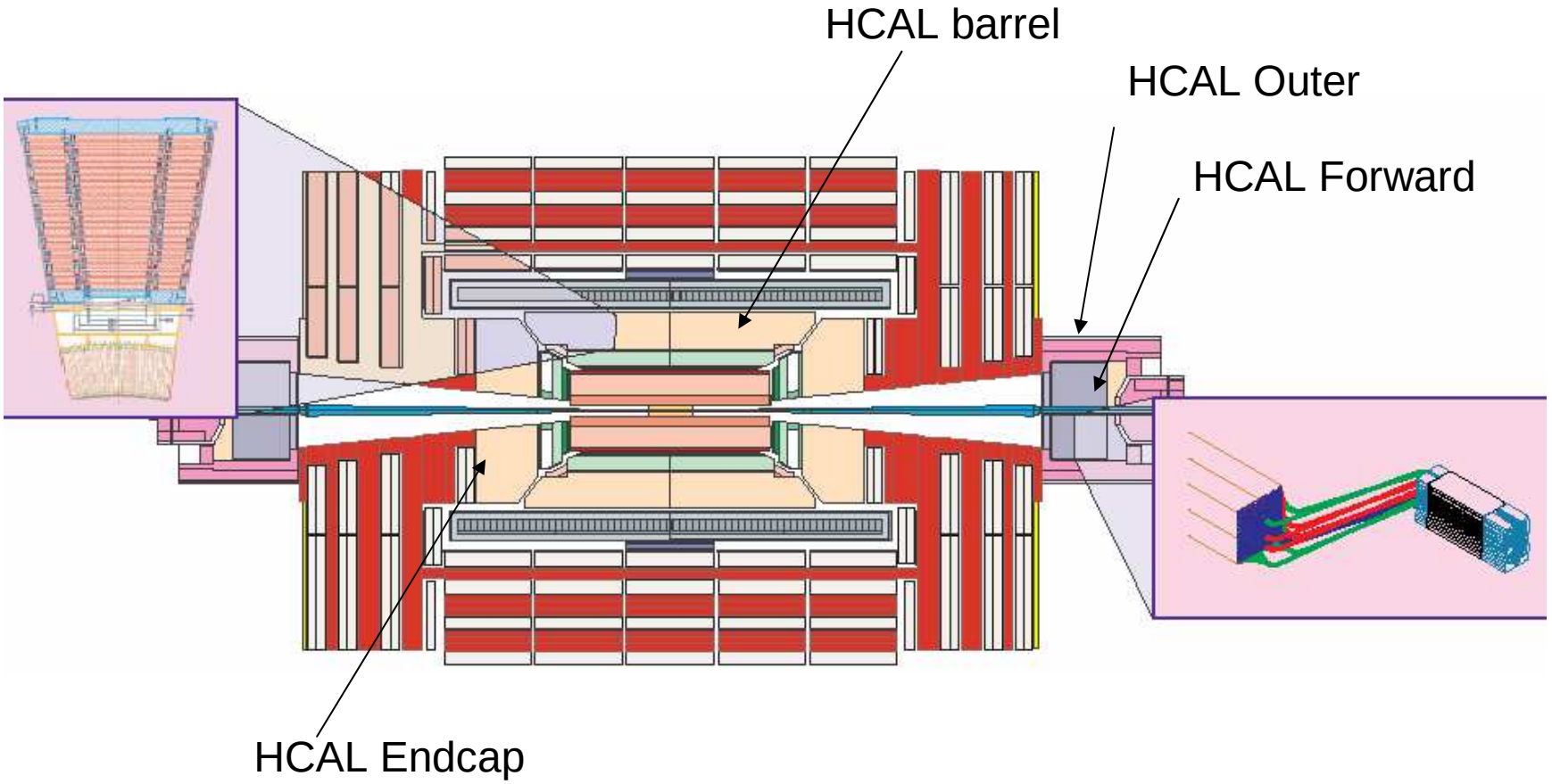
- Gives a degree of freedom to the Preshower installation schedule

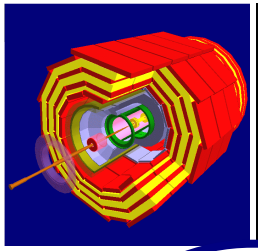




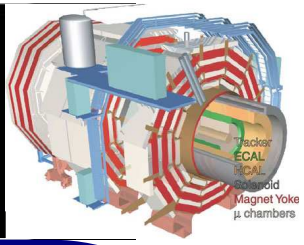
The CMS Hadron Calorimeter







The HCAL

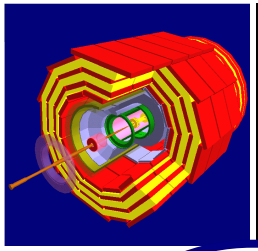


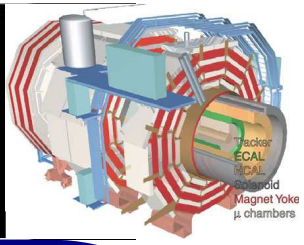
- Hadron Calorimeter (HCAL) Barrel (**HB**) covers 0 < |η |< 1.3 and r = 1.81→2.95 m
  79 cm deep, which at =0 is 5.15 λ in thickness
  2 half barrels of 18 calorimeter "wedges" Each is 4.3 meters long in z and weighs 25.7 metric tonnes.

- HCAL endcaps (**HE**) cover the pseudorapidity range 1.3 < |η| < 3.0
  - 10 absorption lengths (19 active layers)
  - brass absorber sampling thickness is 8 cm
  - front and back plates are made of stainless steel to increase strength
  - absorber plates are bolted together to form a single monolithic structure, with gaps for scintillator insertion.

- In the region |η|<3.0 the first muon absorber layer is instrumented with scintillator tiles to form an Outer Hadronic Calorimeter (**HO**).

- The region 3.0<|η|<5.0 is instrumented with a quartz fiber calorimeter (**HF**) for hermiticity





HCAL Project

Institution Board Chairperson
A. Skuja
Duputy Chairperson
N. Shumeiko

Technical Board

Project Manager
D. Green

Resource Manager
J. Hanlon

Barrel Project Coordinator
A. Skuja

Endcap Project Manager
I. Golutvin

Forward Project Coordinator
T. Camporesi

HB Technical Coord.
J. Freeman

HO Technical Coord.
K. Sudhakar

HE Technical Coord.
V. Kryshkin

Mechanical Prod.
V. Kalagin

HF Technical Coord.
N. Akchurin
Deputy: V. Gavrilov

CASTOR Technical Coord.

ZDC Technical Coord.

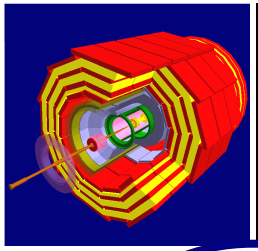
Readout and Electronics
J. Elias
HPDs: P. Cushman
PMTs: Y. Onel
Front End Electronics: J. Whitmore
Trigger/DAQ System: D. Baden

Installation and Commissioning
P. de Barbaro
SX5: D. Lazic
Assembly and Test: V. Smirnov
A. Zaitchenko
Front End Integration: A. Heering

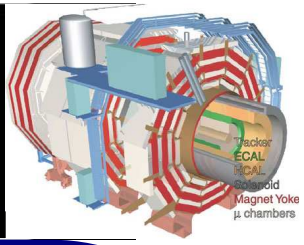
Detector Control System
J. Rohlf
LV: T. Shaw
HV (HPDs): I. Vankov/S. Sergueev
HV (PMTs): C. Rivetta/J. Hauptman
Sources: V. Barnes/I. Schmidt
Laser/LEDs: V. Hagopian/(D. Lazic)

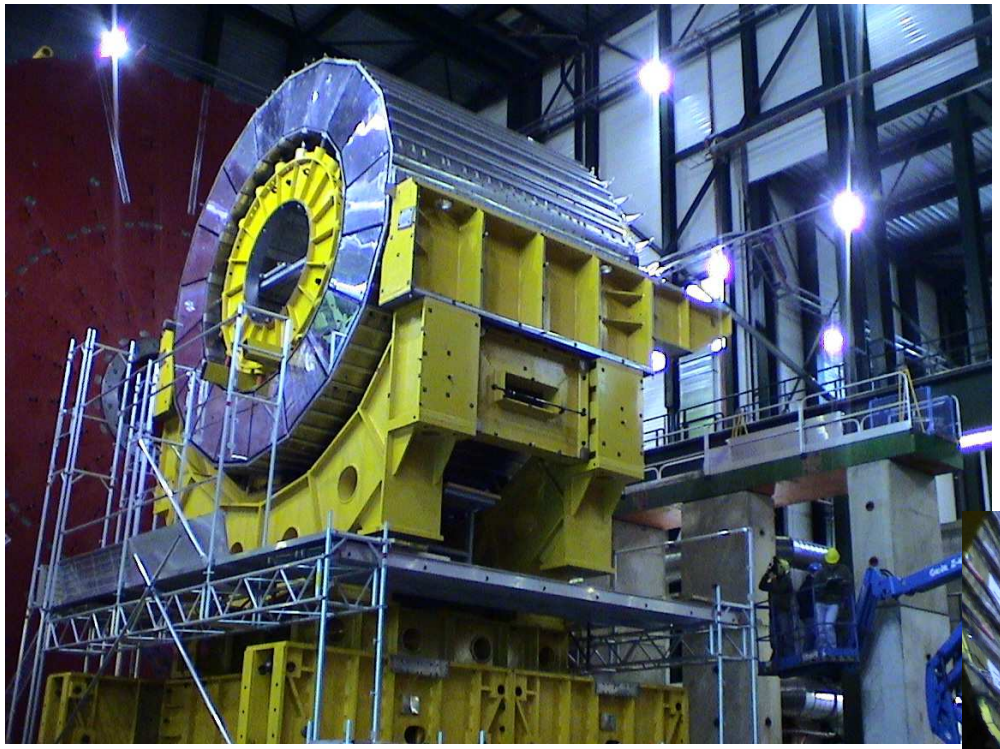
Physics Reconstruction and Selection (Jets/Missing E_T)
(J. Rohlf)
C. Tully
Detector simulation: S. Banerjee
Calibration and monitoring: O. Kodolova
Detector reconstruction: S. Abdullin
Physics object reconstruction: S. Nikitenko
Test beam analysis: S. Kunori

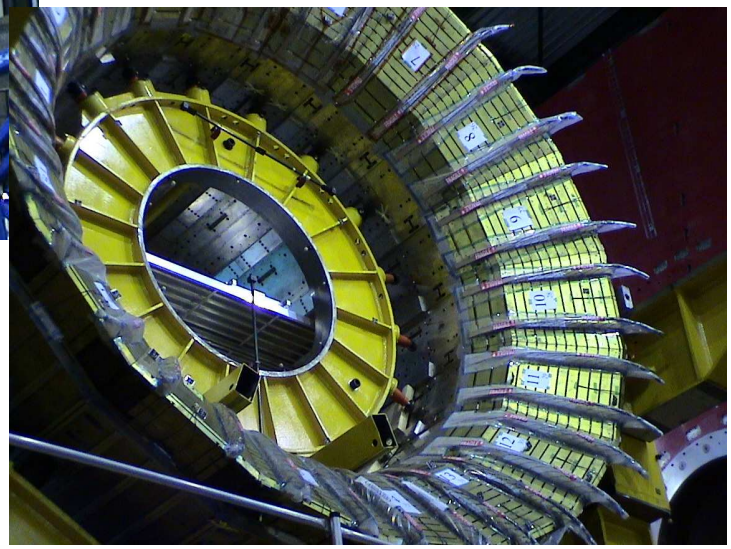
10 Dec 2002

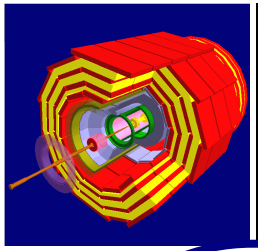


HCAL Barrel

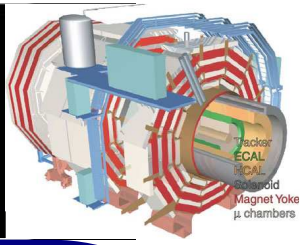


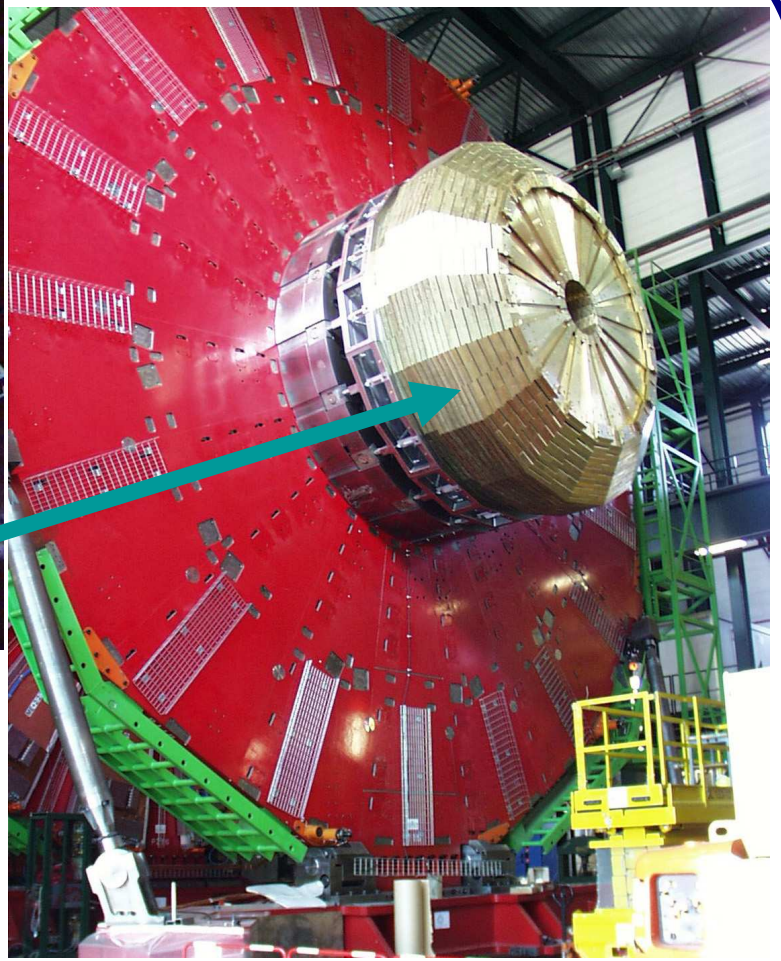






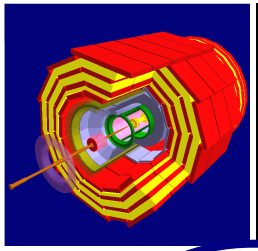
HCAL Endcap



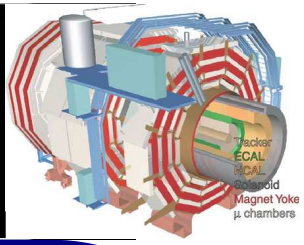


brass

Both HCAL endcaps have now been installed on the endcap yokes



The Muon System



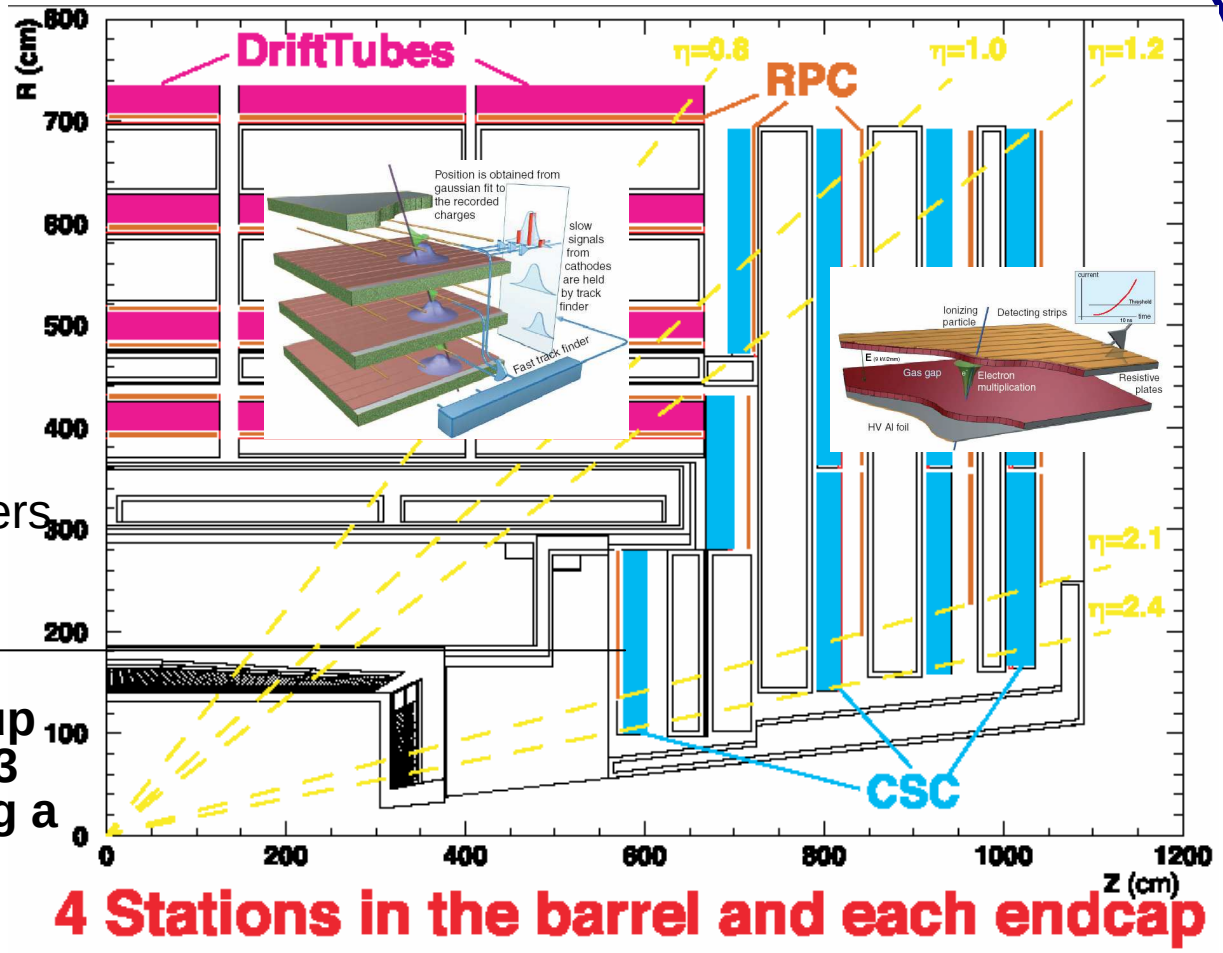
Muon Barrel

- Resistive Plate Chambers (RPC) for timing
- Drift Tubes (DT) for position

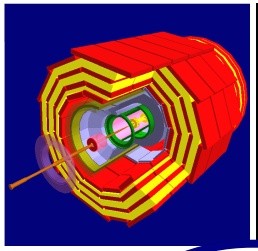
Muon EndCaps:

- RPCs
- Cathode Strip Chambers (CSC)

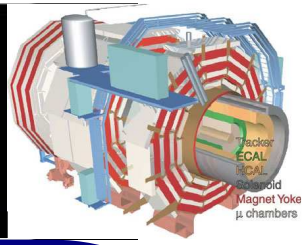
- **4 layers of Muon chambers covering up to |η|=2.4, providing 3 track segments along a muon track**



4 Stations in the barrel and each endcap

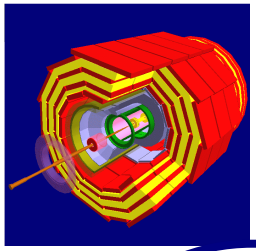


The CMS Muon System

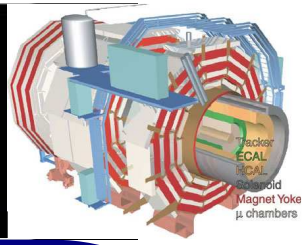


- Muon ID with at least 16 λ down to $|\eta|=2.4$
- Standalone transverse momentum res. 8-1
  $\delta pt/pt$ (at 10 GeV), 20-40% $\delta pt/pt$ (at 1 TeV)
- Global momentum resolution 1.0→1.5 % $\delta pt/pt$
- Unambiguous BX identification
- Single and di-muon first level trigger with variable pt thresholds down to $|\eta|=2.1$
- Correct charge assignment up to p=7 TeV
- Ability to withstand the highest radiation and interaction background foreseen at the LHC

- From P. Giacomelli



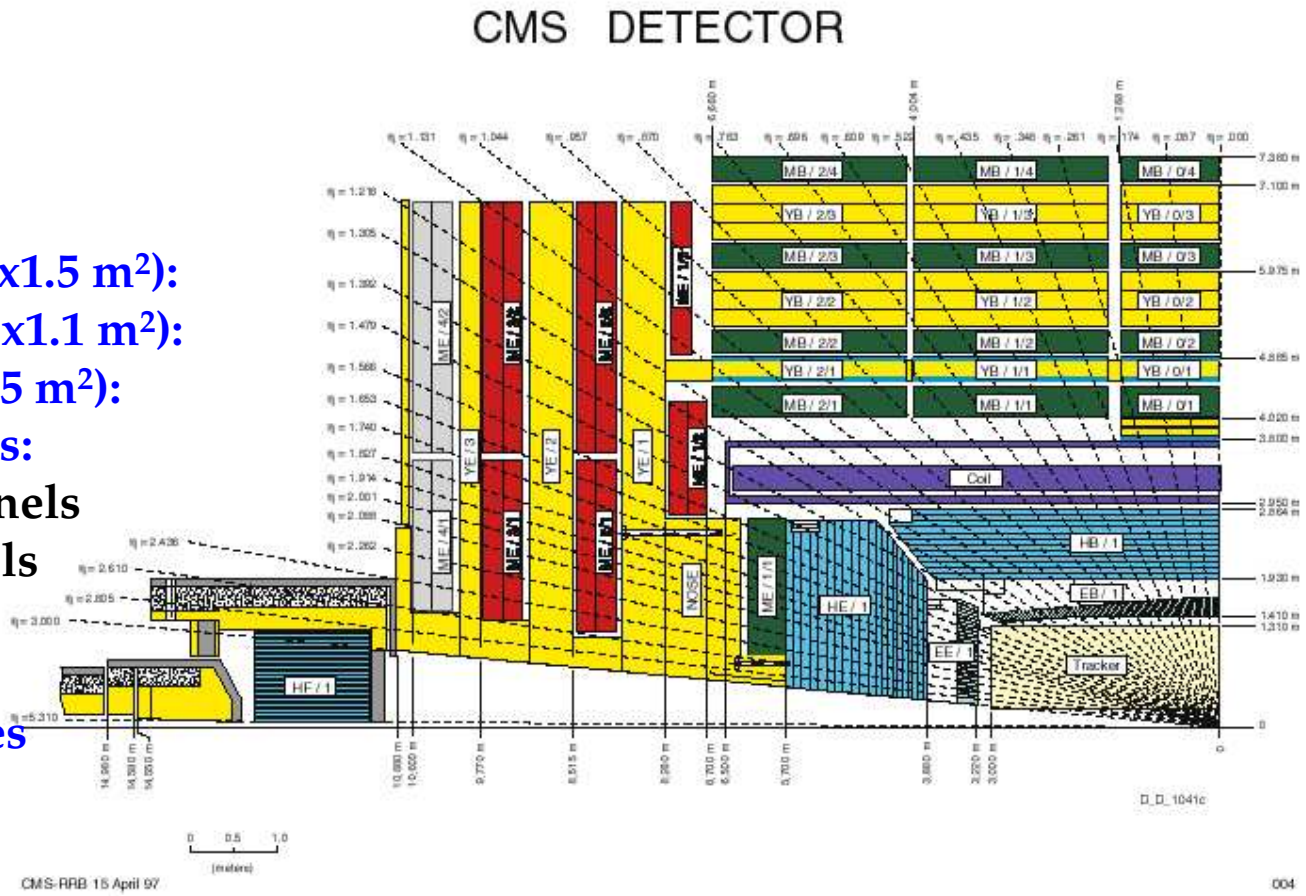
The Muon System

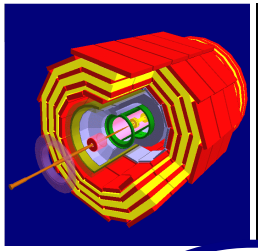


Endcap Cathode Strip Chambers (CSCs)

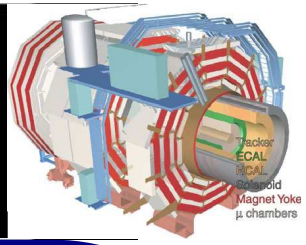
468 CSCs

- **144 Large CSCs (3.4x1.5 m²):**
- **216 Small CSCs (1.8x1.1 m²):**
- **108 20º CSCs (1.9x1.5 m²):**
- **Frontend Electronics:**
- **170K Cathode channels**
  140K Anode channels
- **Trigger&DAQ**
  (on-chamber part)
- **Alignment&Services**



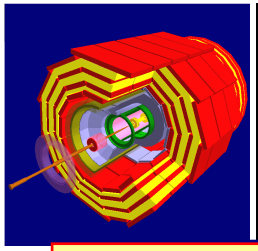


CSC Status

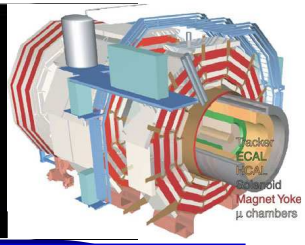


- Highlights:
  - 91% (439 of 482) chambers assembled
    - Fermilab assembly site finished in April 2003
    - IHEP assembly site will be finished in a month
  - 46% (223 of 482) chambers assembled with electronics and tested
    - PNPI and IHEP FAST sites are operational since March-April 2003
  - 26% (125 of 482) chambers are at CERN, 105 ready for installation
  - 20% (90 of 468) chambers are installed

*From **Guenakh Mitselmakher***

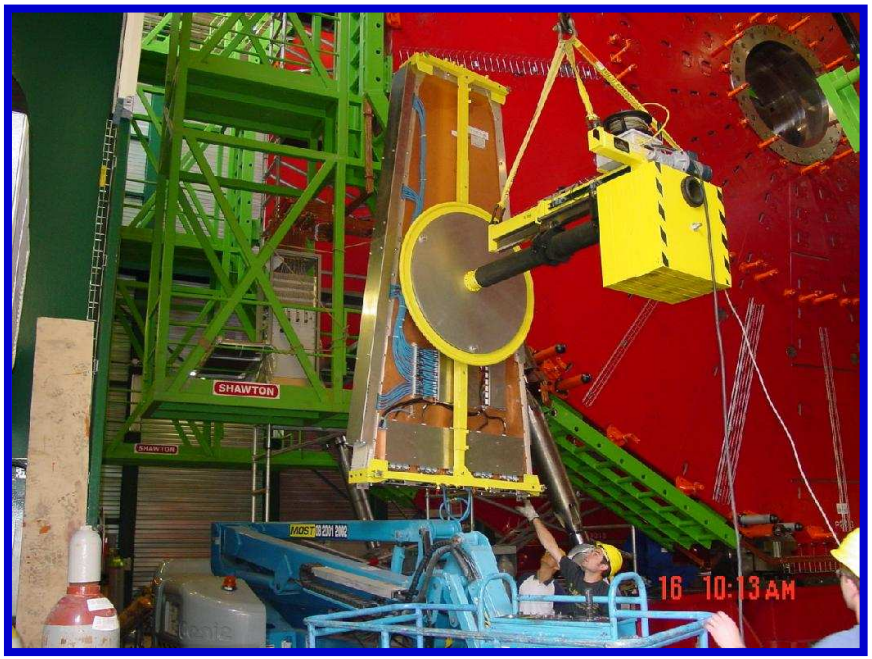


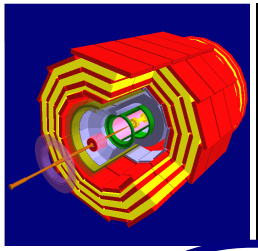
CSC Status



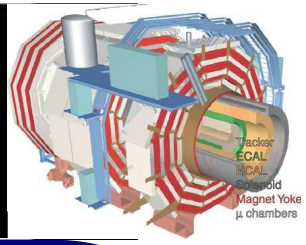
- June 16: installation at SX5 begins with 7 months of delay (SX5 was not ready)
- Installation rate 6 CSC/day (planned 4CSC/day)

90 chambers installed





CMS RPC Status



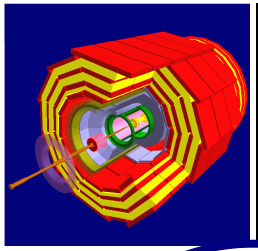
Assembled chambers

chamber type	number of assembled chambers	assembling site
RB1	11	HT
RB1	13	Bari
RB2	40	GT
RB3	50	Bari
	total=114	

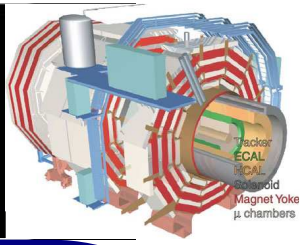
Tested chambers

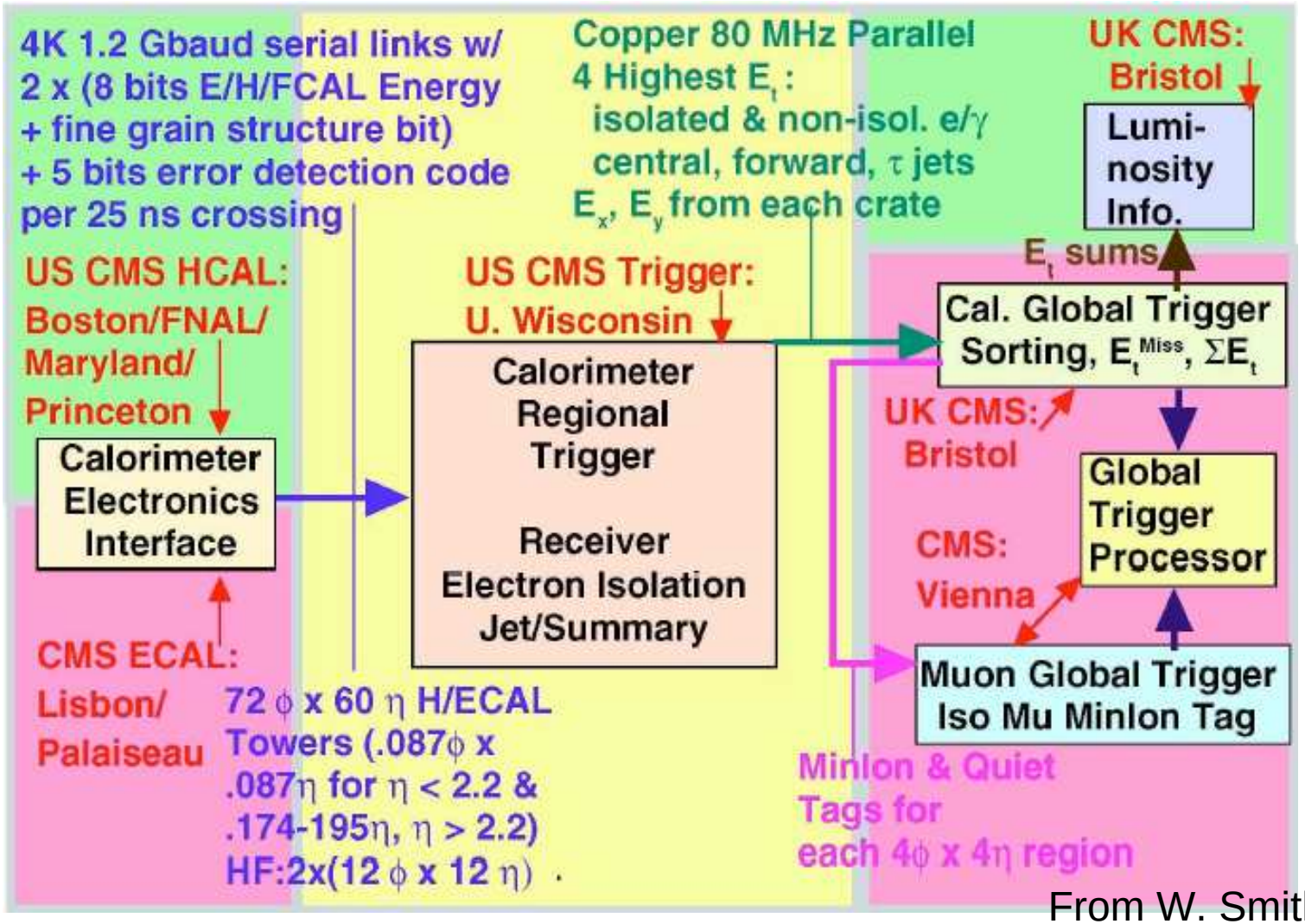
Tested chambers	number of chambers	test site
RB1	3	Bari
RB2	26	Bari
RB3	45	Bari
	total = 74	

From G. Iaselli

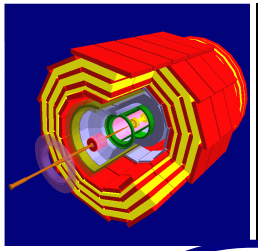


CMS Level-1 Trigger

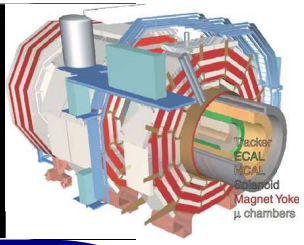




From W. Smith



CMS Level-1 Trigger Status



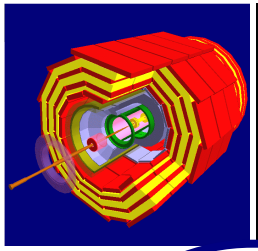
Status 2003: Good progress on all fronts

- **Prototypes manufactured & final validation tests completing**
- **Integration tests underway: Detector - Trigger - DAQ**
- **Tests with structured "LHC-like" beam (very valuable!)**
- **Software being developed for testing & operation**

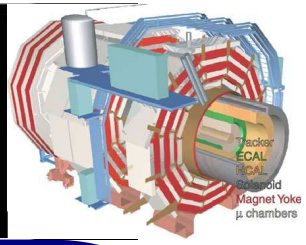
Plans for 2004:

- **Further tests: integration, surface (SX5), structured beam**
- **Production on all systems (some started in 2003)**

From W. Smith



Schedule



Pilot Run

First Beam in April 2007

Collisions in June 2007

Shutdown

Physics Run start in August/September 2007

@ 1→2 x 10^{33}

Run until 5-10 fb^{-1}

CMS Initial Detector for Physics Run

Staged items:

- Muons: ME4, RE4, REs at small radius (RE1/1, RE2/1, RE3/1)
- New: restore ME4/1.
- Tracker: 3rd forward pixel disks
- 50% DAQ

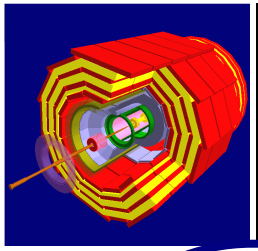
Descoped items:

- HCAL (reduced no. of longitudinal samplings), ME1/1a (3 channels in one, no muon trigger beyond $|\eta| = 2.1$)

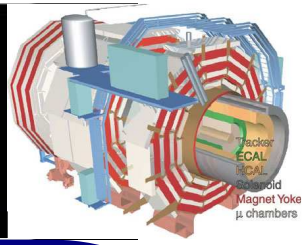
From M. Della Negra

- Muon barrel, 30-Jun-04
- Shielding 30-Sep-04
- Tracker 31-Dec-2005
- Beampipe 30-Apr-2006
- ECAL - barr 15-Mar-06
- ECAL +ecap 15-Oct-06
- ECAL -ecap 28-Feb-07
- Preshower 15-Aug-2006

from A.Ball – 22 Sept 2003



Summary



- Much progress has been made and CMS will be ready for the April 1st, 2007 LHC test run
- The schedule is very tight in many cases but recent developments should keep us on schedule

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- See presentations on the

CMS Online Event Selection by Marcin Konecki

and on

B-physics at CMS by Nanci Marinelli