CMS

Status Report

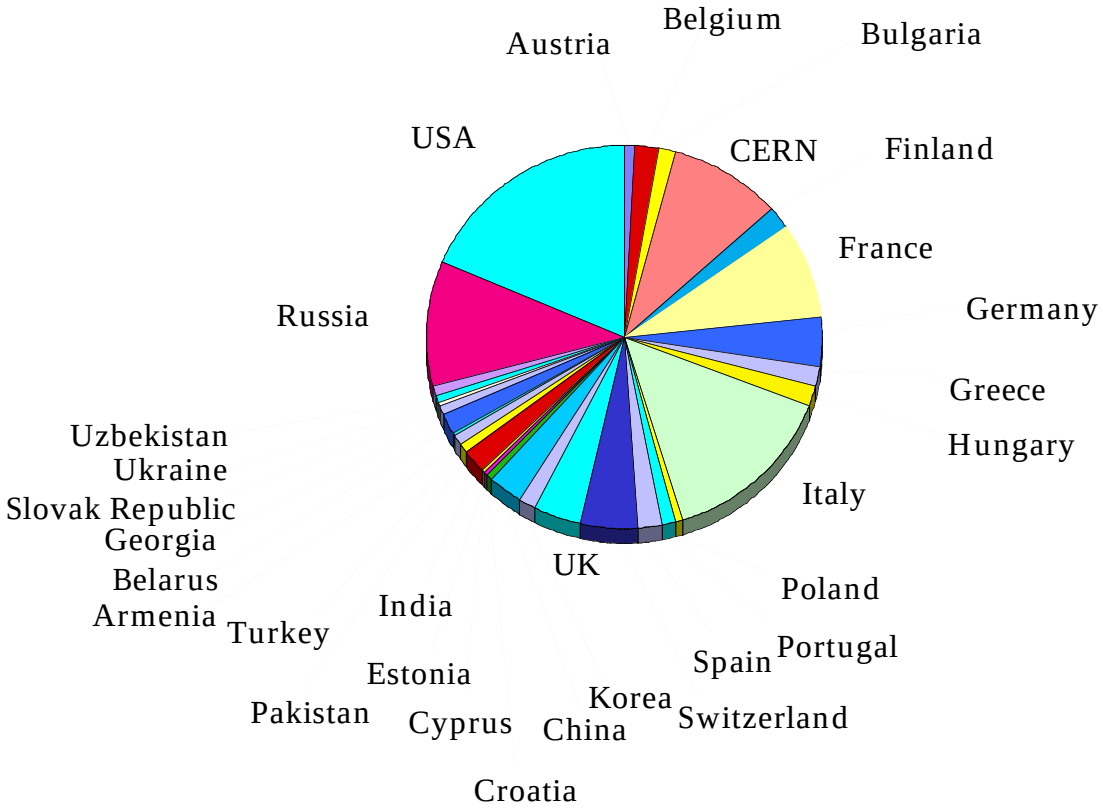
M. Della Negra

US CMS Review, Florida, 11 Oct 2000

Collaboration
Magnet and Infrastructure
Tracker
ECAL
HCAL
Muon
Trigger& DAQ
Physics Reconstruction and Selection
Software/Computing
Schedule

Compact Muon Solenoid

The CMS Collaboration



1809 Physicists & Engineers
31 Countries
144 Institutions

New Members
Taiwan (ECAL)

In discussions with
Brazil
Iran
Ireland

July 26, 2000
http://cmsdoc.cern.ch/pictures/cmsorg/overview.html

Schedule and Milestones

LHC Schedule: We should plan on 1 beam circulating in July 2005 followed by collisions in a **short (2 to 4 weeks?) pilot run in October (75 ns bunch spacing, 10^{32} luminosity).** The pilot run will be followed by a 5 month shutdown (Nov 05 to Mar 06). The LHC will then deliver collisions in April 2006 reaching 10^{33} luminosity very soon.

A new master planning v30 consistent with a complete detector in Apr 06 and a working detector for first collisions in 2005 (v30*) has been approved by the Collaboration last week. (v30 and v30* differ only in the installation phase). It will be presented in detail by A. Ball during the Management session Tuesday 3 October.

Milestones developed from v30 will be presented to LHCC in November. Formal re-baselining awaits the statement by the DG on LHC program at end 2000.

For this review, all sub-detector construction plans are (must be) consistent with v30 schedule.

Working Detector

The **Working CMS detector** for 1 October 2005 consists of:

Fully commissioned:
Magnet, HB, HE, HF, EB, one em Endcap (EE+, SE+)
RB+MB, ME (except ME4/2), RE1, Trigger, DCS,
DAQ (for installed detectors, with 25% of final target performance)

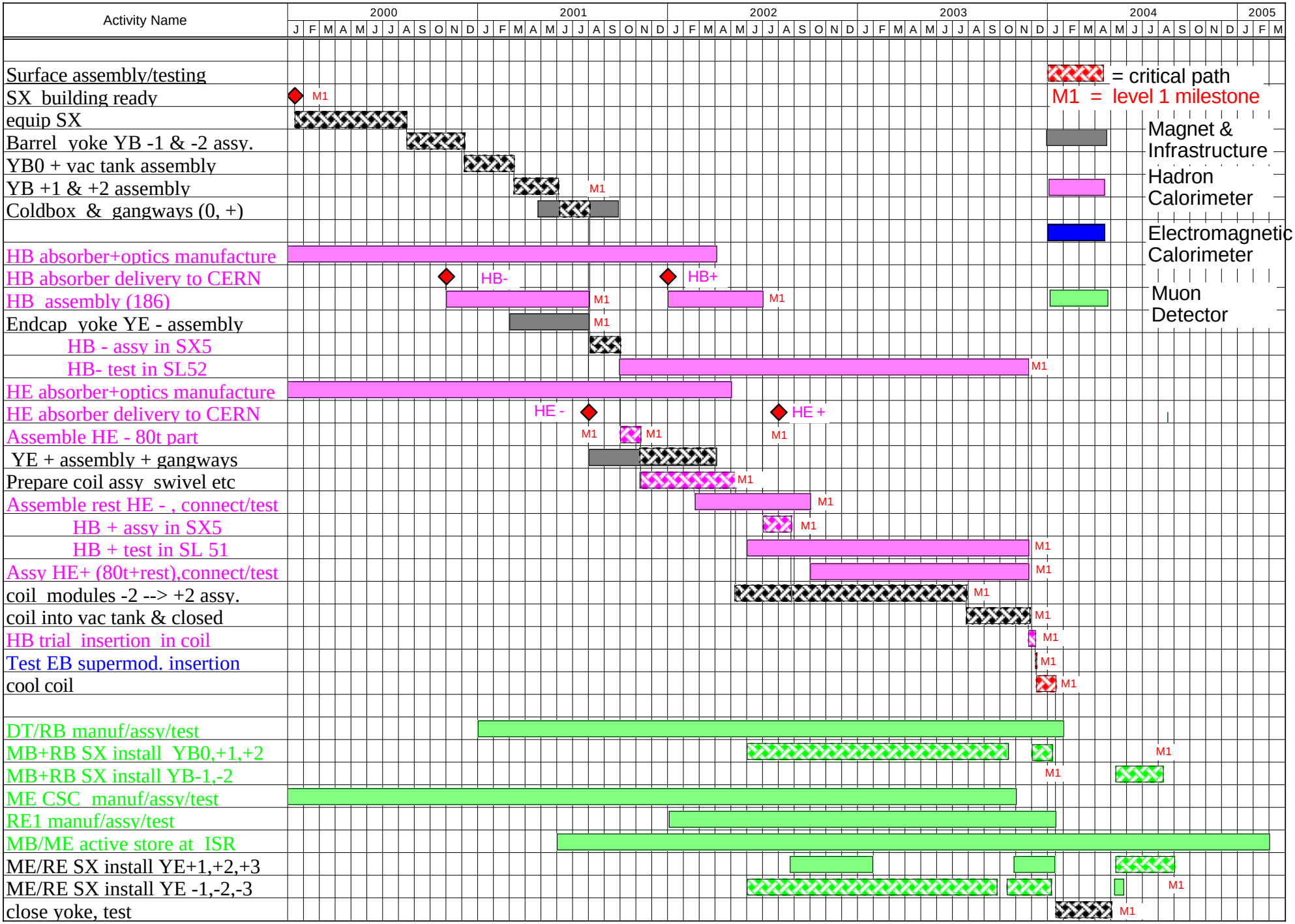
Installed but not fully commissioned:
TK, RE2,3,4

Not Installed:
Pixels, EE-, SE-

The detector will then be **completed during the winter shutdown 2005-2006 for physics in April 2006 (10^{33} luminosity).**

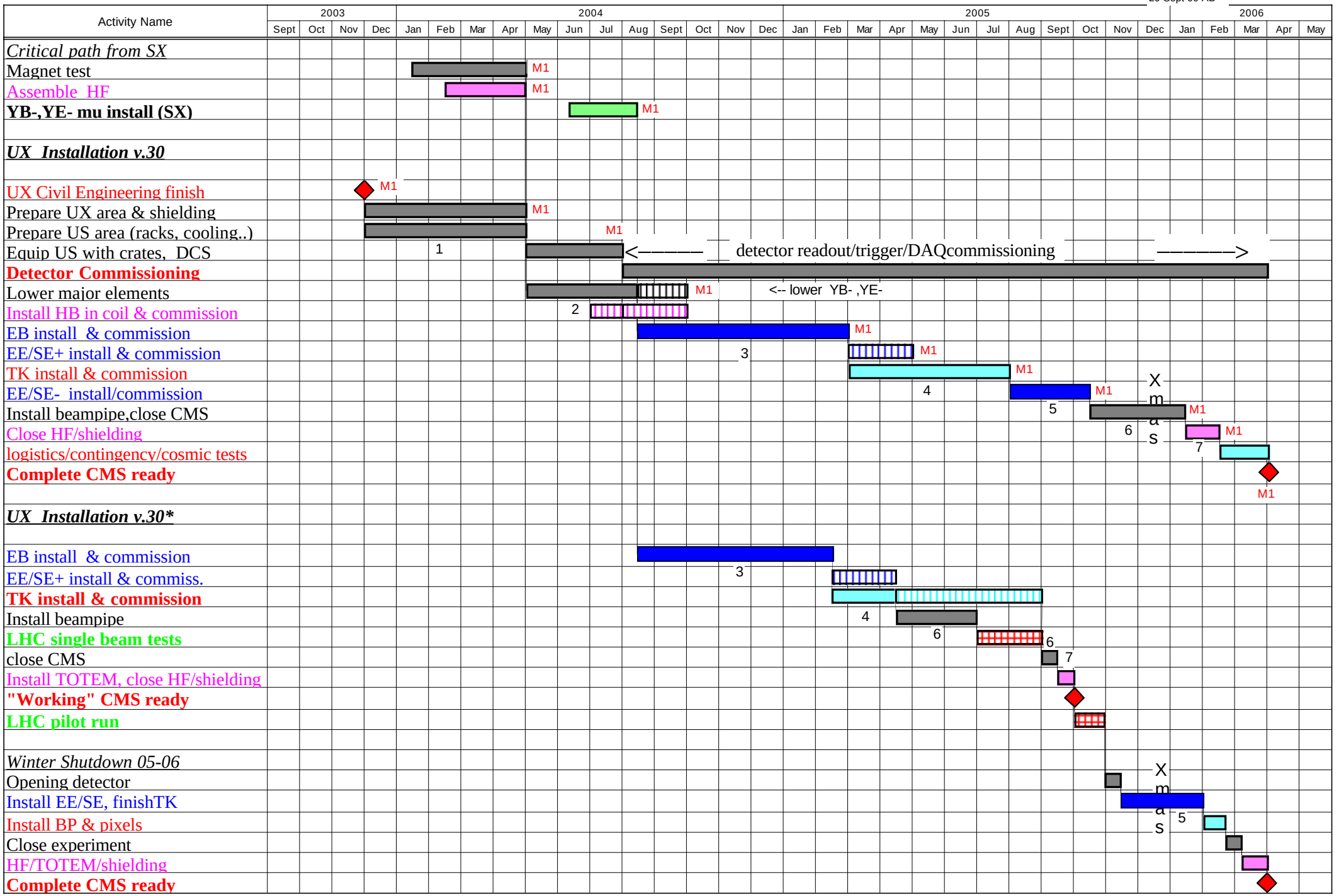
CMS sub-detector manufacture & SX assembly v30: critical phases

27 Sept 2000 Austin Ball

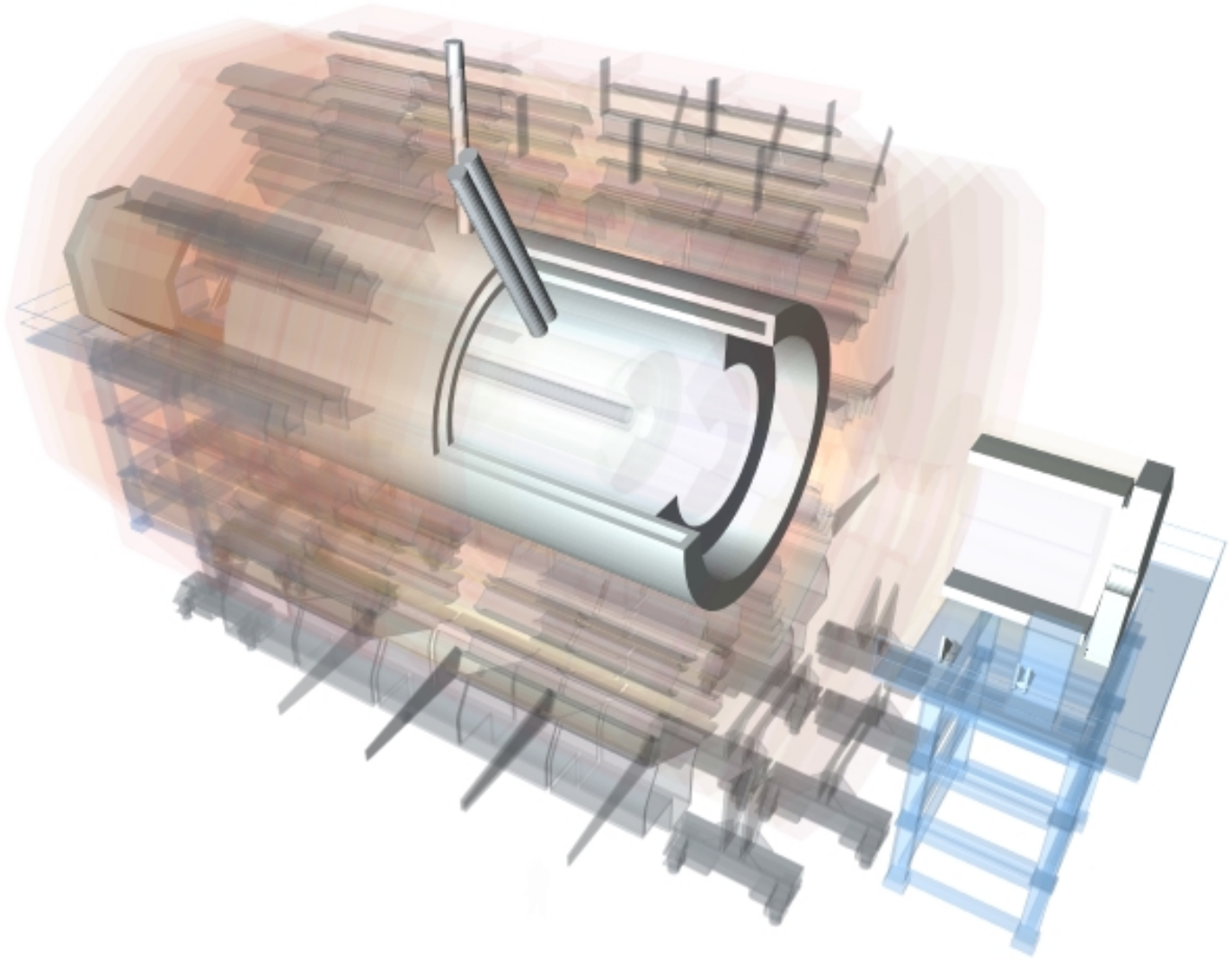


CMS UX installation v30: critical phases (v30* : option of "working detector" in 2005)

29 Sept 00 AB



1. Magnet and Infrastructure



Civil Engineering: Overview

The Status

- The surface hall, SX5, has been delivered on time
- The civil engineering of the underground cavern, UX5, is delayed by 5 months compared with the contractual planning
- Underground assembly schedule has been altered to ensure CMS is complete by 1st April 2006 whilst allowing a ‘working’ detector for first collisions in 2005

- Magnet yoke assembly has started in SX5

Underground Area has to be ready by end-03

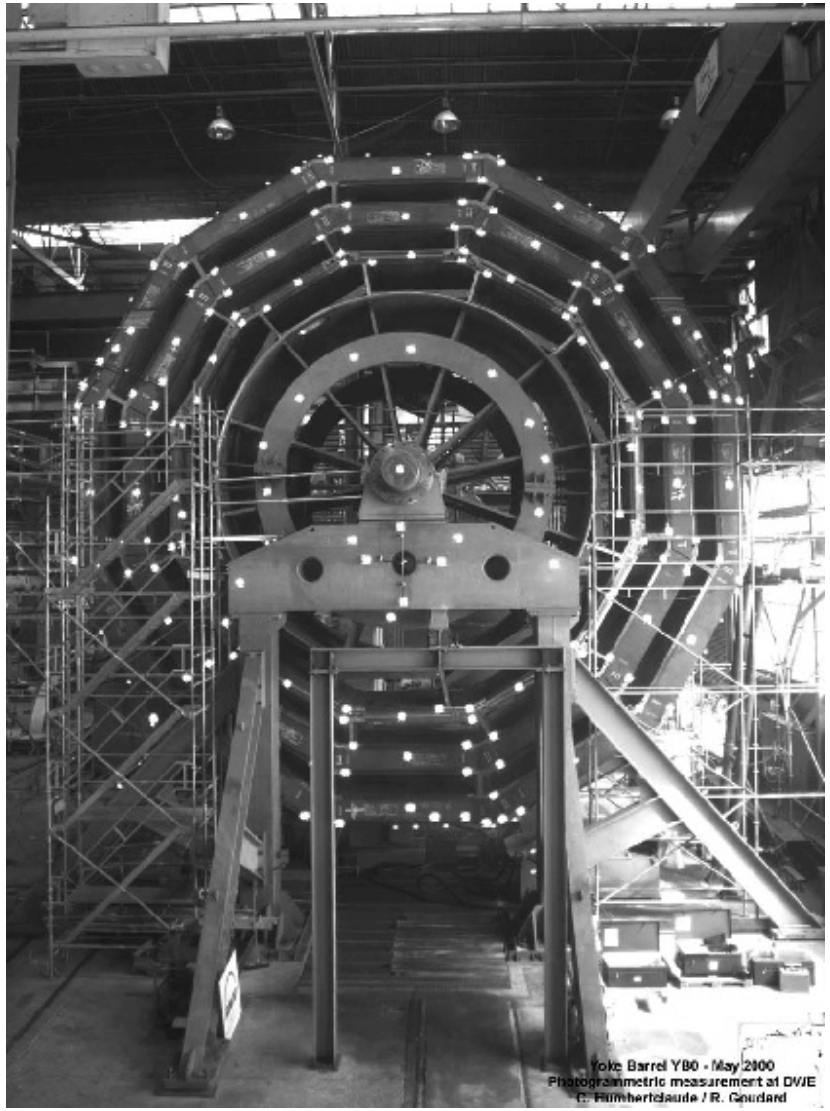
Magnet: Overview

The Status

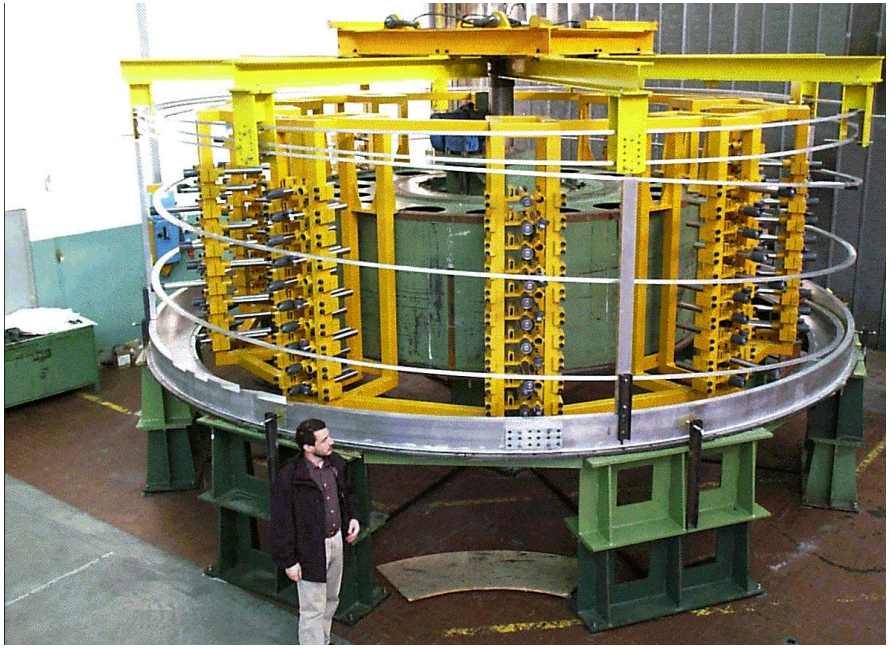
- All major contracts have been placed (90 MCHF (≈75%) worth are under contract)
- The cost estimate of the magnet (121.9 MCHF) is maintained
- Barrel yoke construction completed, endcap yoke 50% completed.
- The SC Coil schedule, based now on contractual dates, exhibits a 5 month delay (sits in the shadow of the delay in civil engineering).
- 2nd delivery of SC strands. First full length (2.65 km) Rutherford cable wound. Dummy insert (2.65 km) produced.

Finish Magnet Test on the surface by April 2004

Magnet Yoke


Yoke Barrel YB0 - May 2000
Photogrammetric measurement at DWE
C. Humbertclaude / R. Goudard

Magnet: Coil



Model of Winding Machine

Major Contracts for Coil

Superconducting Strands
IGC-US, Outokumpu-Finland

Rutherford cable
Brugg Cabelmetal-CH

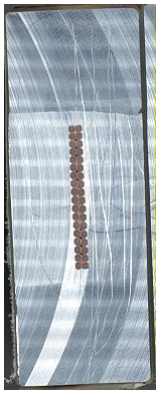
Pure Al Insert
Sumitomo HI, Japan

Insert Extrusion
Alcatel Suisse at Cortaillod, CH

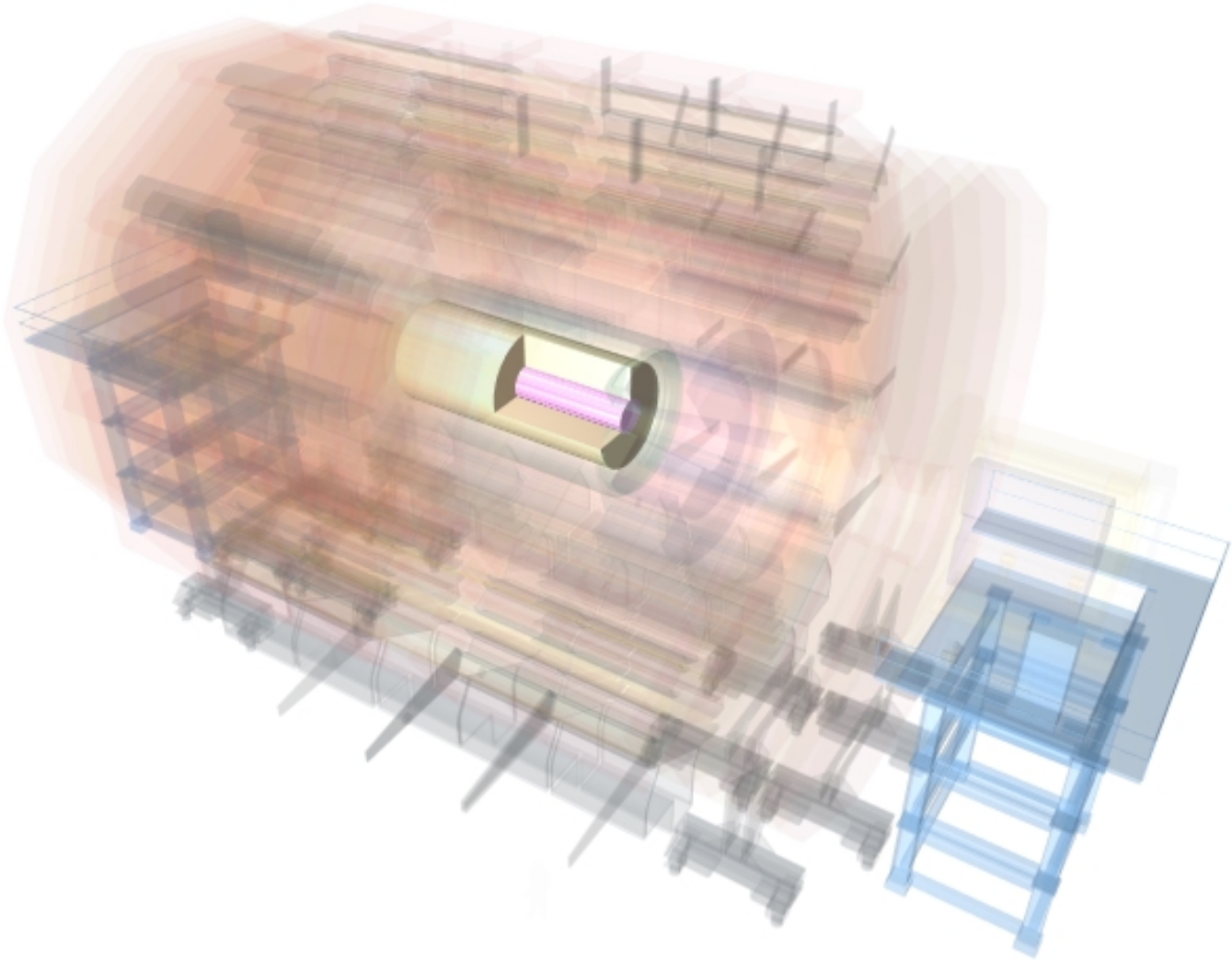
Electron Beam Welding
Techmeta, France

Winding
Ansaldo, Italy

External Cryogenics
Air Liquide, France



2. Tracker



Tracker: Overview

The Status

Since the submission of the TDR addendum

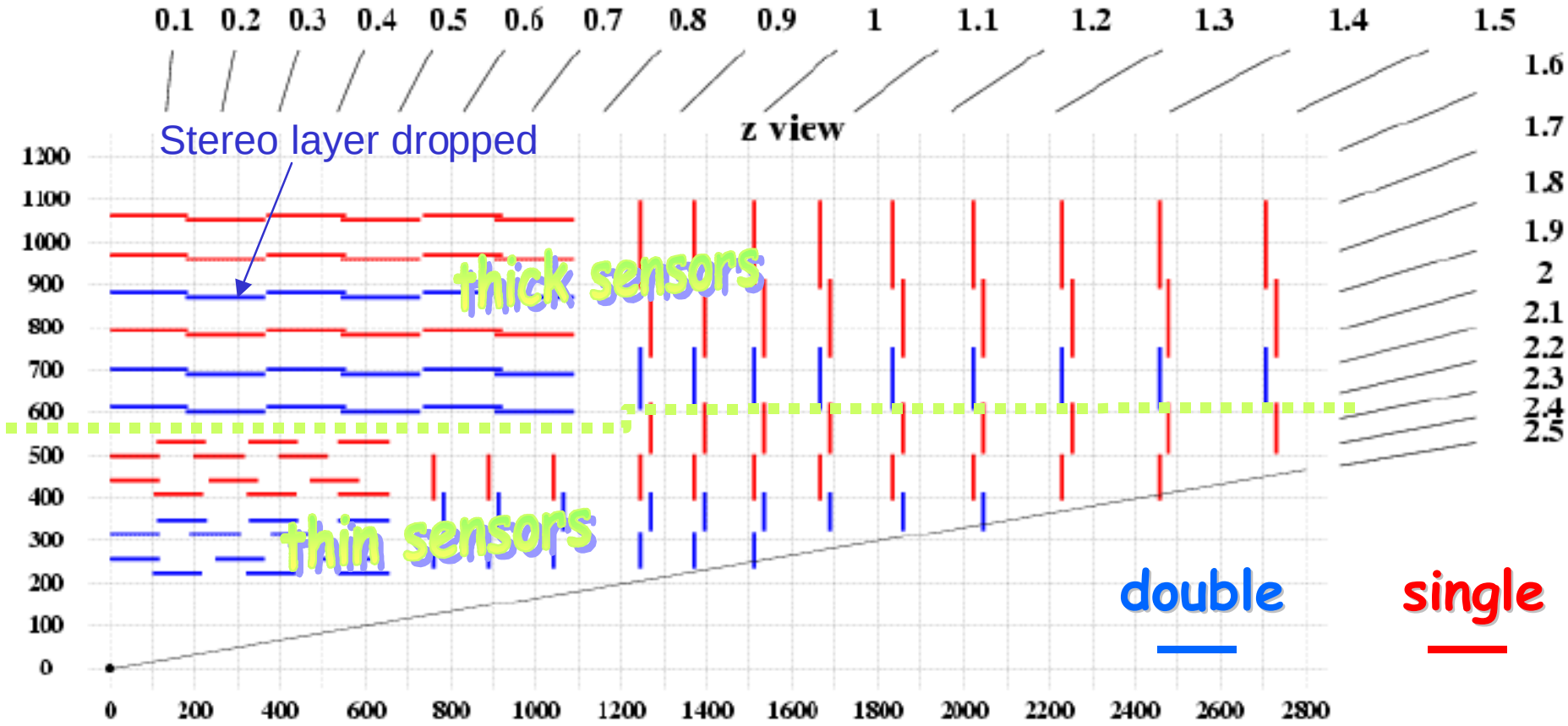
- Optimized layout -*remove central support tube*
- PRR passed in June - *pre-production of 200 detectors to exercise automated procedure*
- Systems tests in 25 ns beam - *tested functionality of full electronics chain*
- Beam tests of 0.25µm electronics - *confirm expected improved performance*
- Detailed construction schedule worked out
- Responsibilities have been shared out
- Costing has been re-evaluated - 77.5 MCHF ceiling -> drop 1 barrel stereo layer
- Prototypes of final size pixel sensors

- EDR in Nov 00

Concerns

- Timely launch of sensors tender

Optimized Tracker Layout



Central Support Tube removed

Pixels not shown can be installed independently

Tracker: Logistics

Some Numbers

6,136 Thin wafers
19,632 Thick wafers

6,136 Thin detectors (1 sensor)
9,816 Thick detectors (2 sensors)

3112 + 1512 Thin modules (ss +ds)
4776 + 2520 Thick modules (ss +ds)

10.0 M strips ≡ electronics channels

78,256 APV chips

26 M Bonds

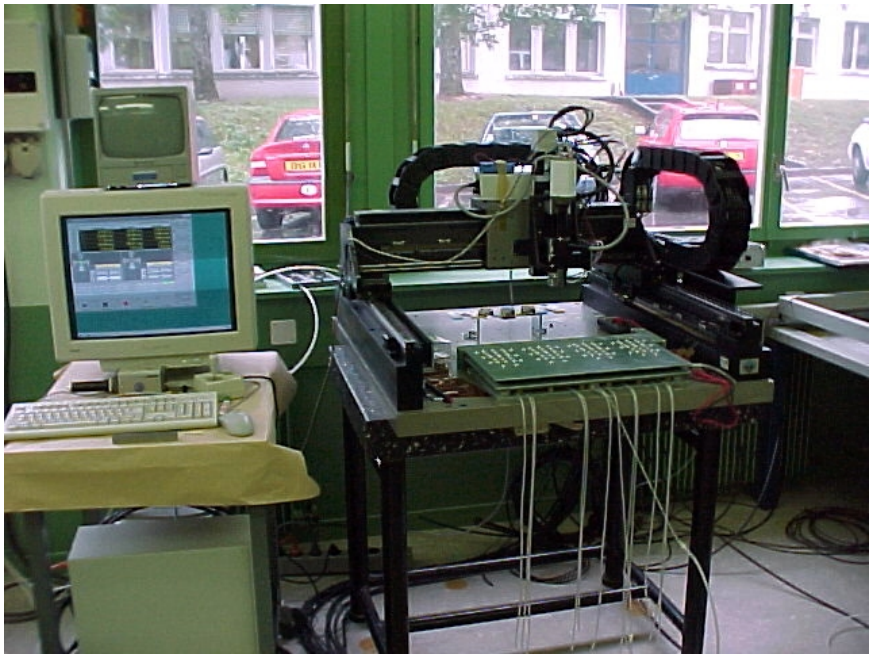
223 m^2 of silicon sensors

Automatic Module production

- All modules can be produced in 2.5 yrs
- 6 robots for module assembly
- 12 Delvotec 6400 bonding machines
- Significant over-capacity

Sensors: 2 producers can each deliver all in < 2.5 yr

Can produce electronics and mechanics in < 2.5yr



Tracker. Electronics status

- **Front end** *0.25 µm developments almost complete*

  Performance, power, size, cost well understood

  APV25 final chips produce - tender action complete

  Wafer testing systems and radiation qualification equipment in place

- **Optical link steady progress** - *tendering now under way*

  second most important cost driver for electronic system

- **DAQ interface** PMC FED used in beam tests -

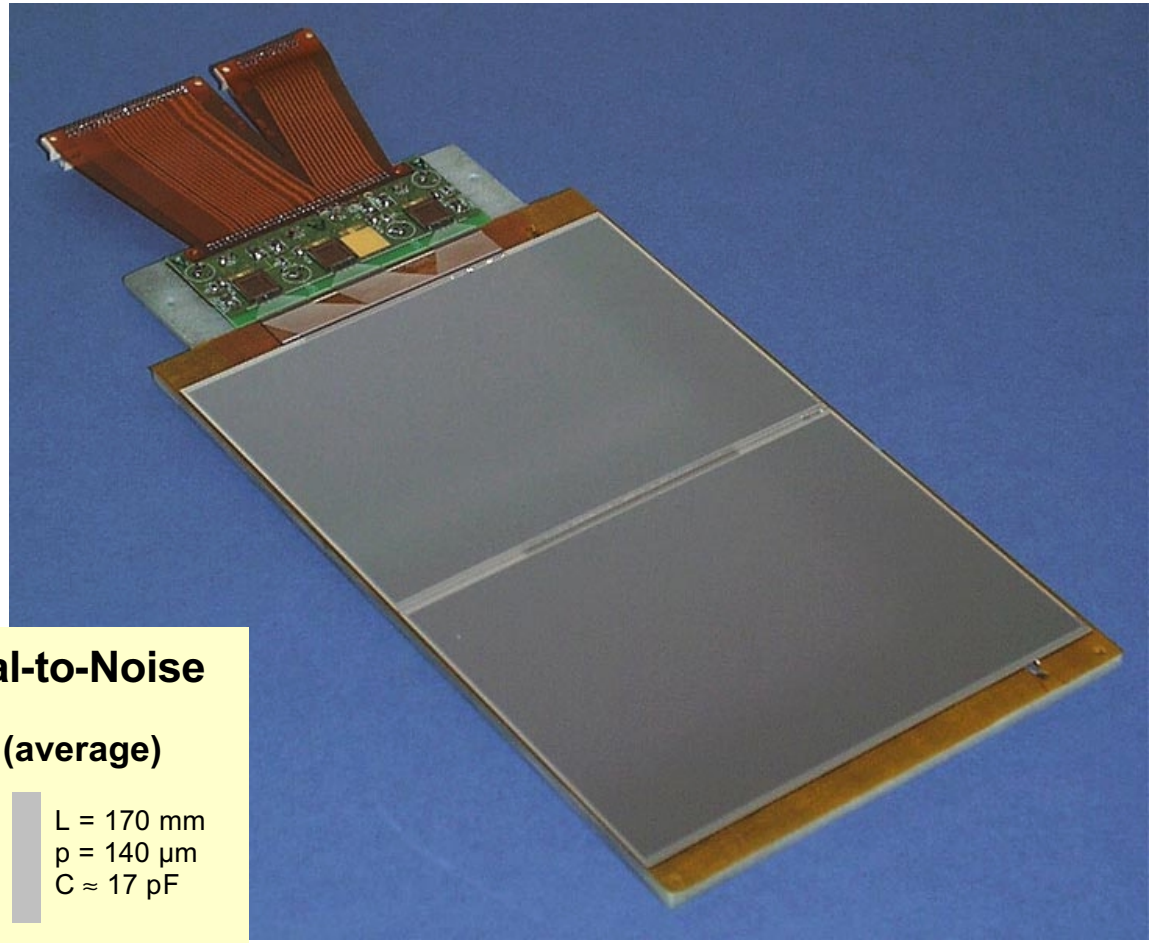
  final version being designed

- **Control system** 0.25µm chip set well advanced

- **System** small scale system evaluated in 25nsec beam

Tracker Front-end: APV25 Performance

Beam test in PSI
(Padova, Vienna)



APV25	**Deconvolution Signal-to-Noise**		
predict	**ENC [e] = 425 + 64 / [pF] (average)**		
Vienna	**SNR (meas.)**	**14**	L = 170 mm p = 140 µm C ≈ 17 pF
3 APV25	SNR (calc.)	14.8	
PD	**SNR (meas.)**	**21**	L = 64 mm p = 61 µm C ≈ 8 pF
1 APV25	SNR (calc.)	23.9	

Pixel. Status of detector

1) Pixel sensor

- Technique for bump bonding at 35µm established by PSI

2) Construction and tests of pixel minimodule (6 chips)

- 6 pixel chips (22x30 pixels) bumpbonded with pixel sensor - bad pixels 0.13%

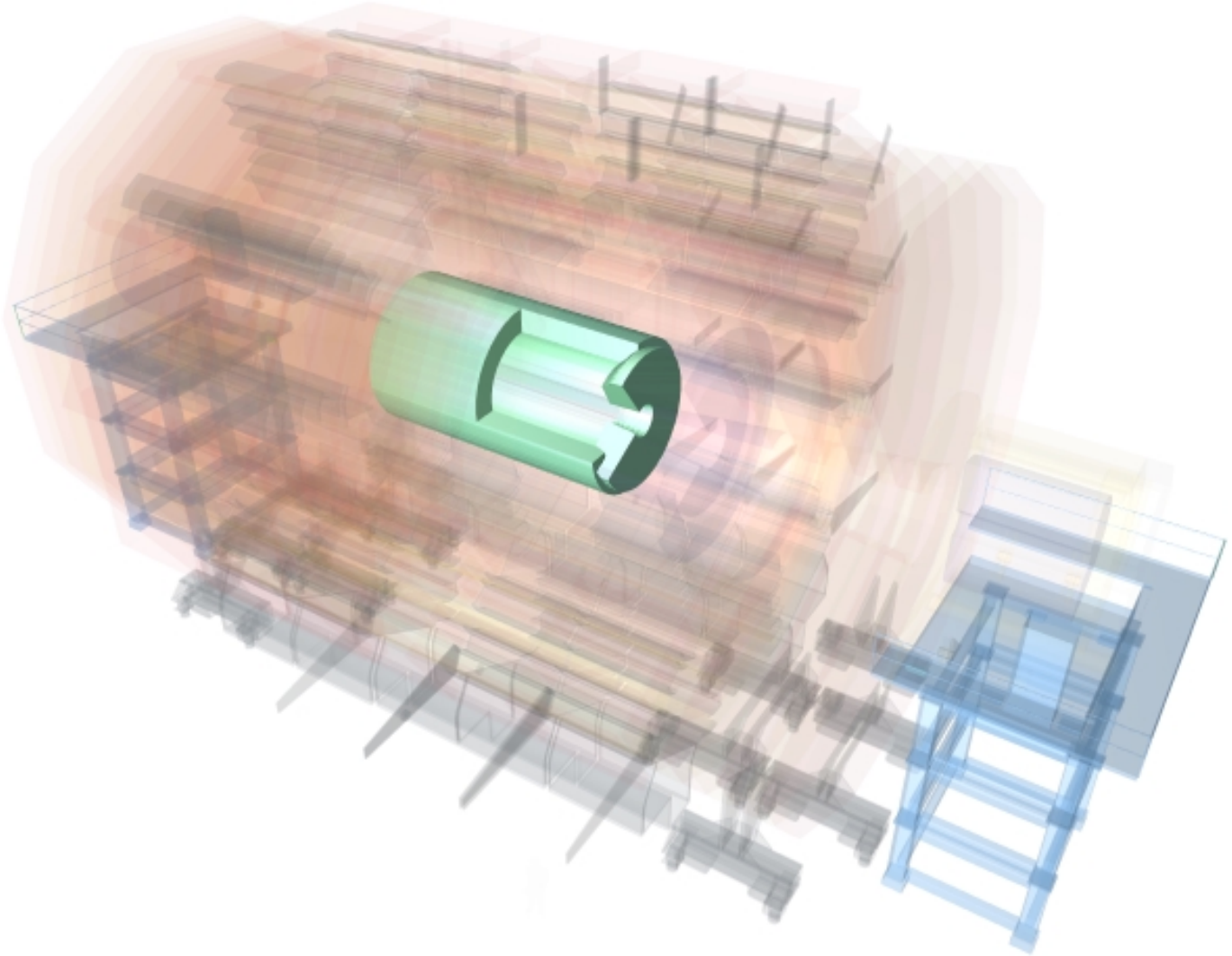
3) Development of final Pixel ROC, 52x53 pixels (ROC = Read Out Chip)

- Pixel chip (36x40) with final architecture submitted in DMILL technology Aug ‘00
- Backup: Translate design into 0.25µm technology in Spring ‘01 (Σt ~ 6months)

4) Services and Installation

- Cooling, cabling and installation studied using mockups
- Pixels can be inserted after the beam pipe has been installed and baked out and independently of the rest of the tracker.

3. ECAL



ECAL: Overview

The Status

- 5000 Russian crystals delivered on schedule. Reject ≤ 2% (within target)
- Contract signed for manufacture 30k Russian crystals (1.6 $/cc)
- Investment made in Russia for additional ovens

- 200 crystals received from China - define pre-production specifications
- Expect to receive pre-production crystals from China by end-00

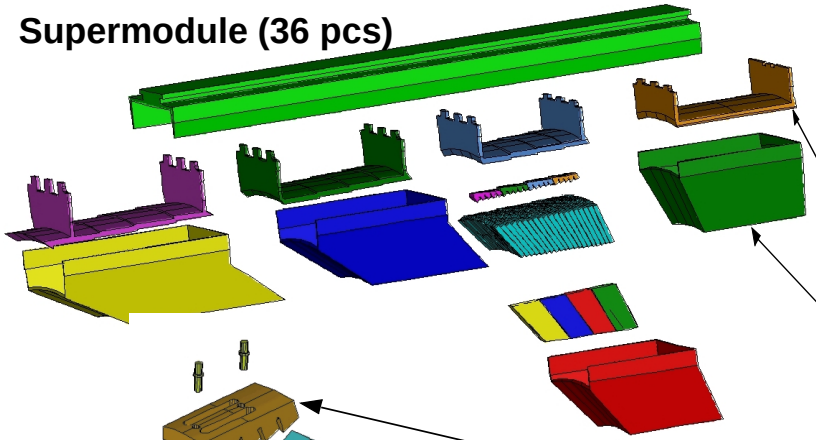
- Two milestones missed (delay of ≈ 9 months)
  - *Module-0* - manufacturing error - unacceptable mechanical distortion of 'grid'
  - Tender for grid resulted in unacceptably high cost - after consultation with industry grid/basket design being revised
  - *500 electronics channel* - very low yield (but ones received performed well)
  - Small fraction of APDs dying after during accelerated aging and irradiation - Hamamatsu working on the problem - expect new APDs Oct 00.

Concerns

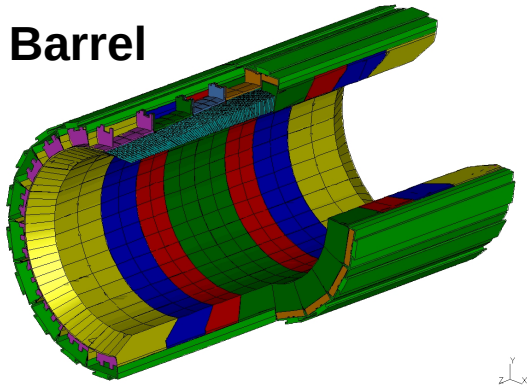
- Start of APD production
- The present low yield of some components in the electronics chain
- Crystals production in China
- Crystals are priced in $/cc. Prevailing $/SFr higher than in Cost Book V9 (MoU).

ECAL. EB Exploded View

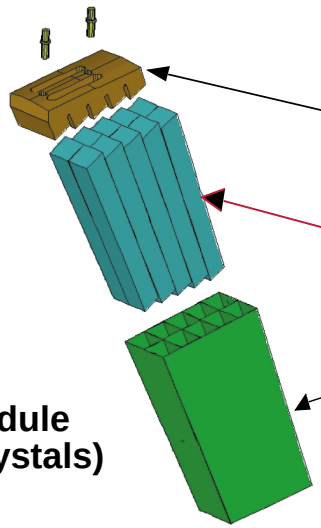
Supermodule (36 pcs)



Barrel

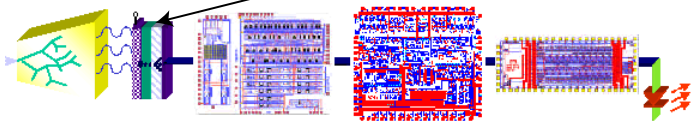


Mechanics
Modules (144 pcs)
Tendering in 2000
Submodules (2448 pcs)
Contracts signed in 1999
Total value of 3MCHF



Submodule (2x5 crystals)

PbWo4 Crystals
Preproduction in Russia, R&D in China
Production agreement signed in Russia
Letter of Intent signed in China
both at 1.6 $/cc
Total Volume11 m^3 (77400 crystals)

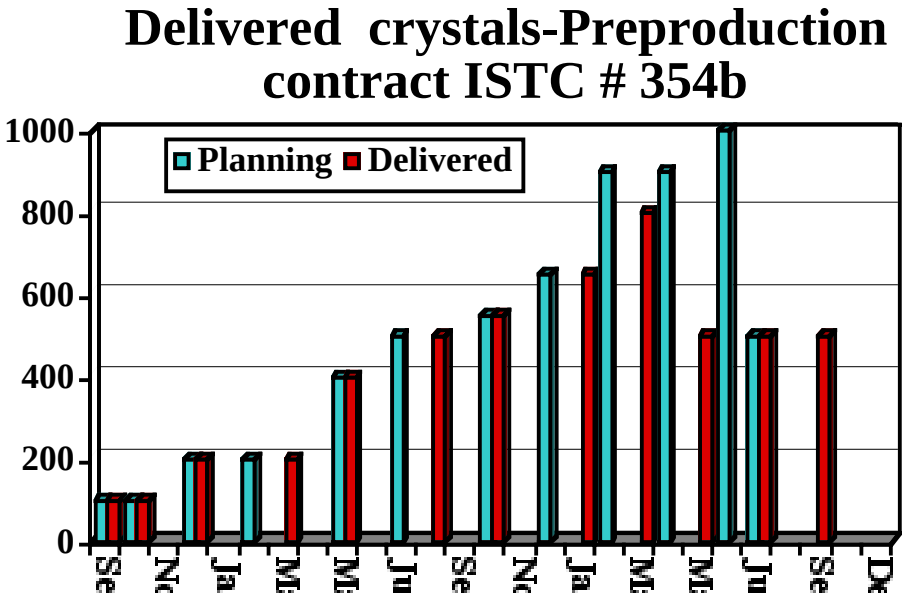


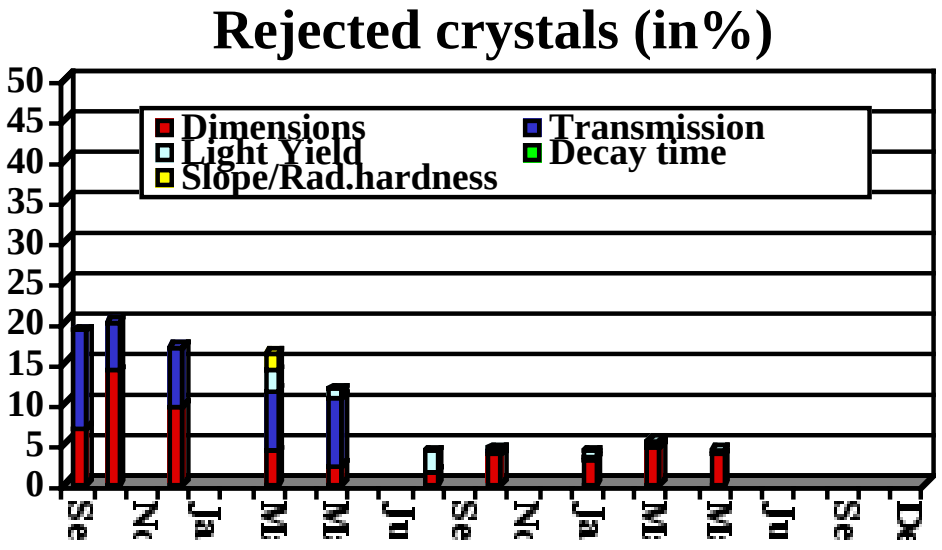
Avalanche PhotoDiode (120000 pcs)
Hamamatsu
Contract Oct 1999. 7 MCHF

Electronic Channel (80.000 pcs)

ECAL. Status of crystal delivery (Russia)

5000 crystals have been delivered (Jul 00)





Schedule more or less followed, target yield achieved.

ECAL Crystals Procurement

	1999	2000	2001	2002	2003	2004	2005	
Barrel	2700	6400	11400	12600	12100	7000		
Extra(in R)*			1900	3400	3400	1000		
Endcap			200	500	2000	4500	4500	4000

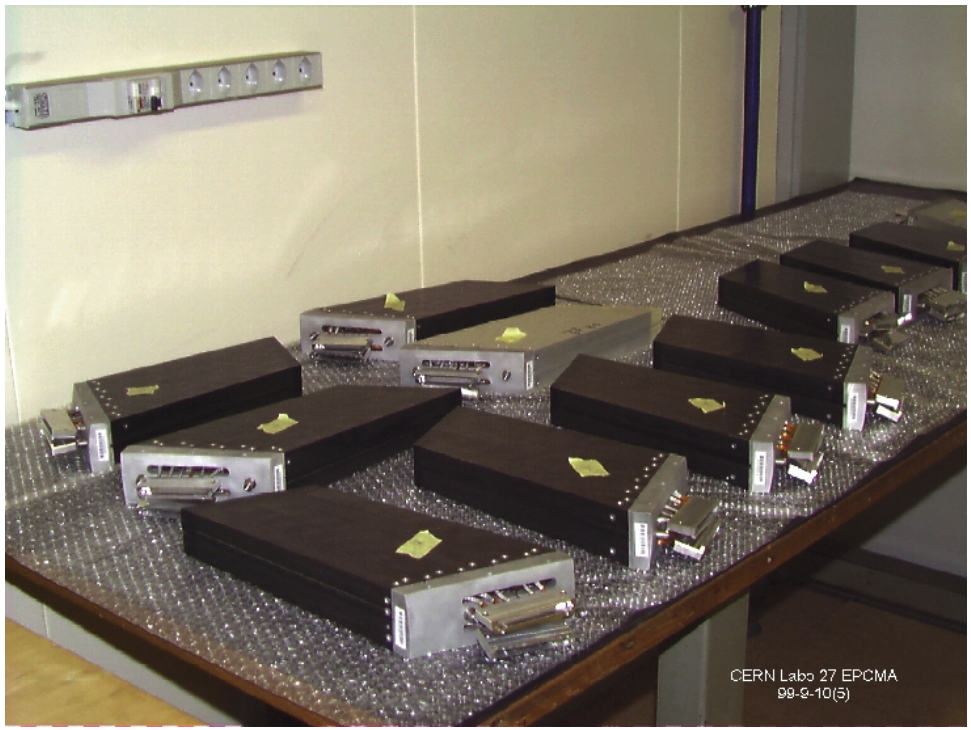
No. Of Barrel crystals 61900 Barrel Ready in mid-05

No. Of Endcap crystals 15700 Endcap Ready in end-05

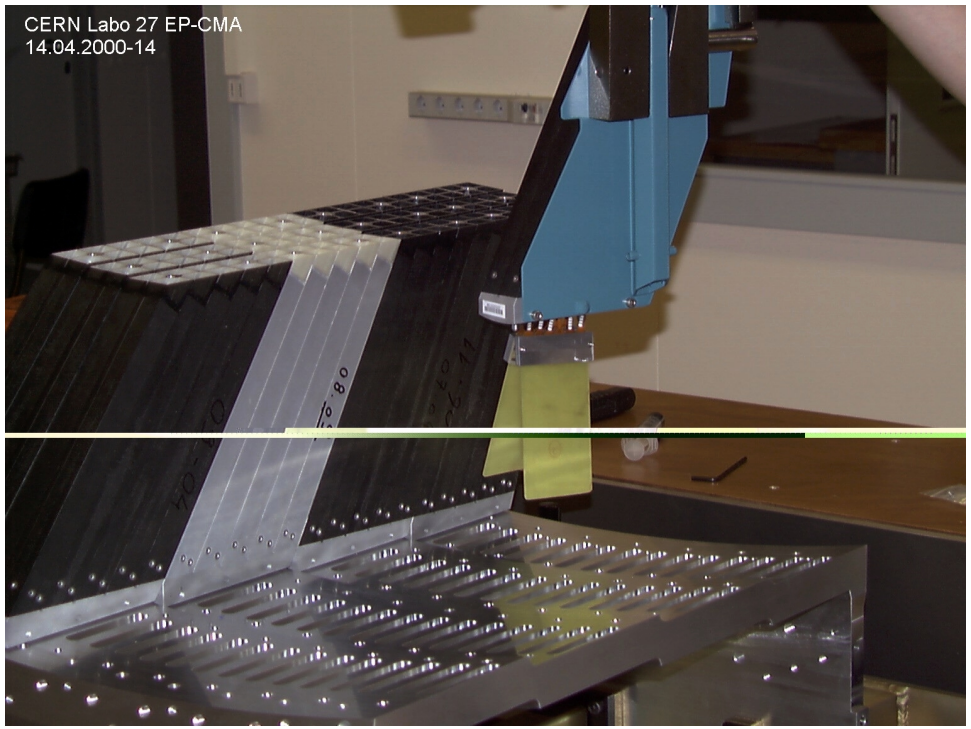
*Invest 1.5M$ now to increase capacity in Russia by 10k crystals

ECAL: Barrel Mechanics

Sub-modules



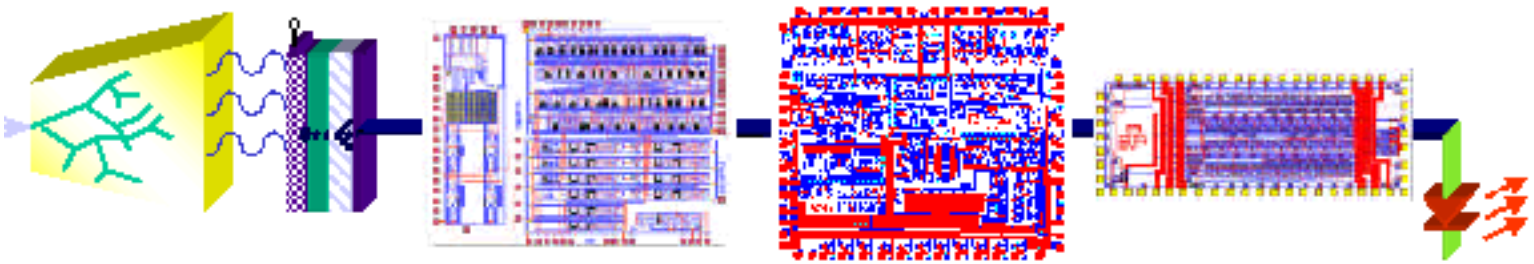
Trial mounting of sub-modules on Grid



Design is being revised

ECAL. Front-End chain

LIGHT to LIGHT



Hamamatsu
Contract placed
120k pieces
APDs dying !

APD

FPPA

Harris rad-hard process
low yield but perform well
Pre-production back Feb01

ADC

Analog Devices
OK

Serialiser

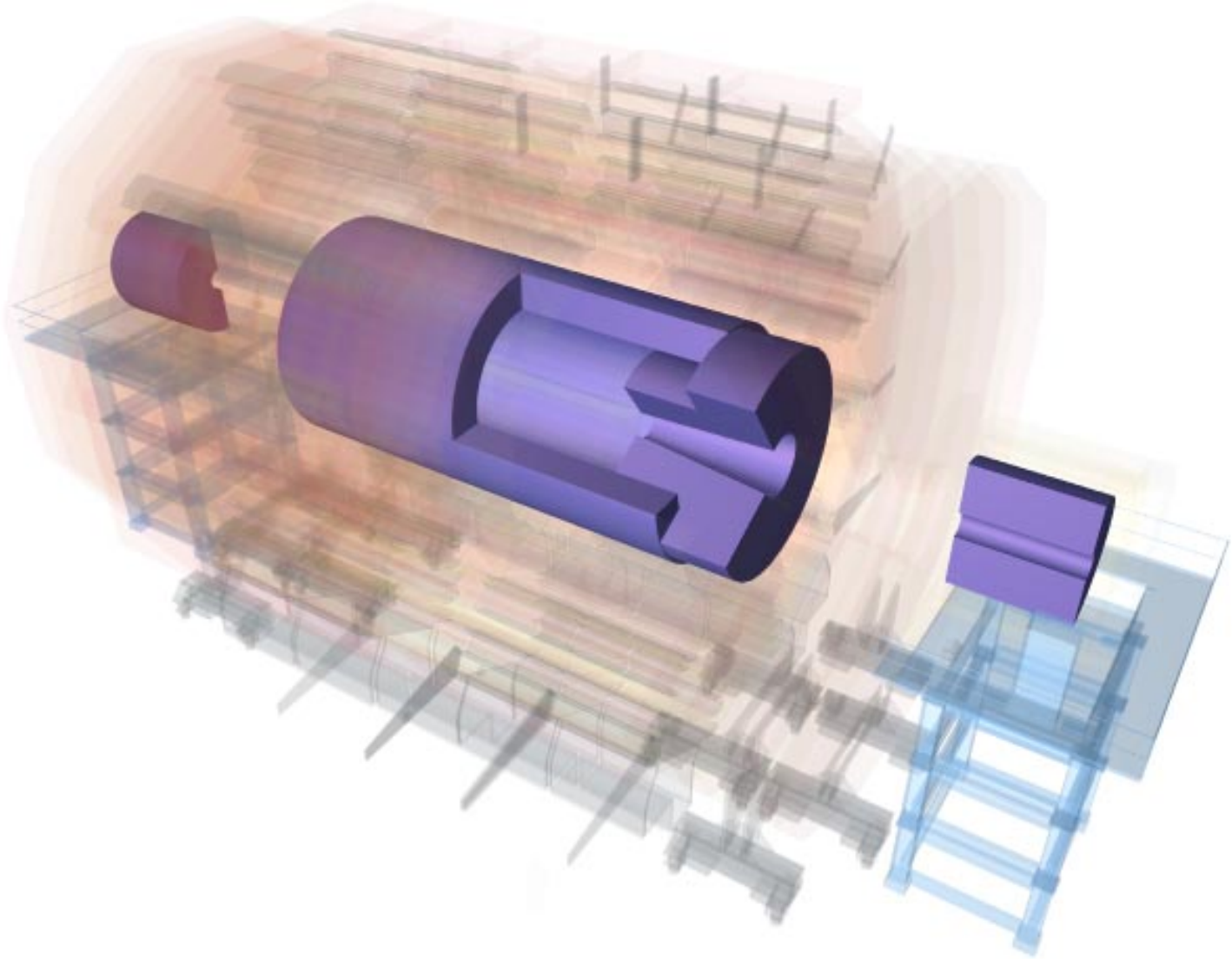
Honeywell - Low yield
in pilot production.
In-spec samples work
Delay in pre-production
Backup - deep submicron ?

VCSEL

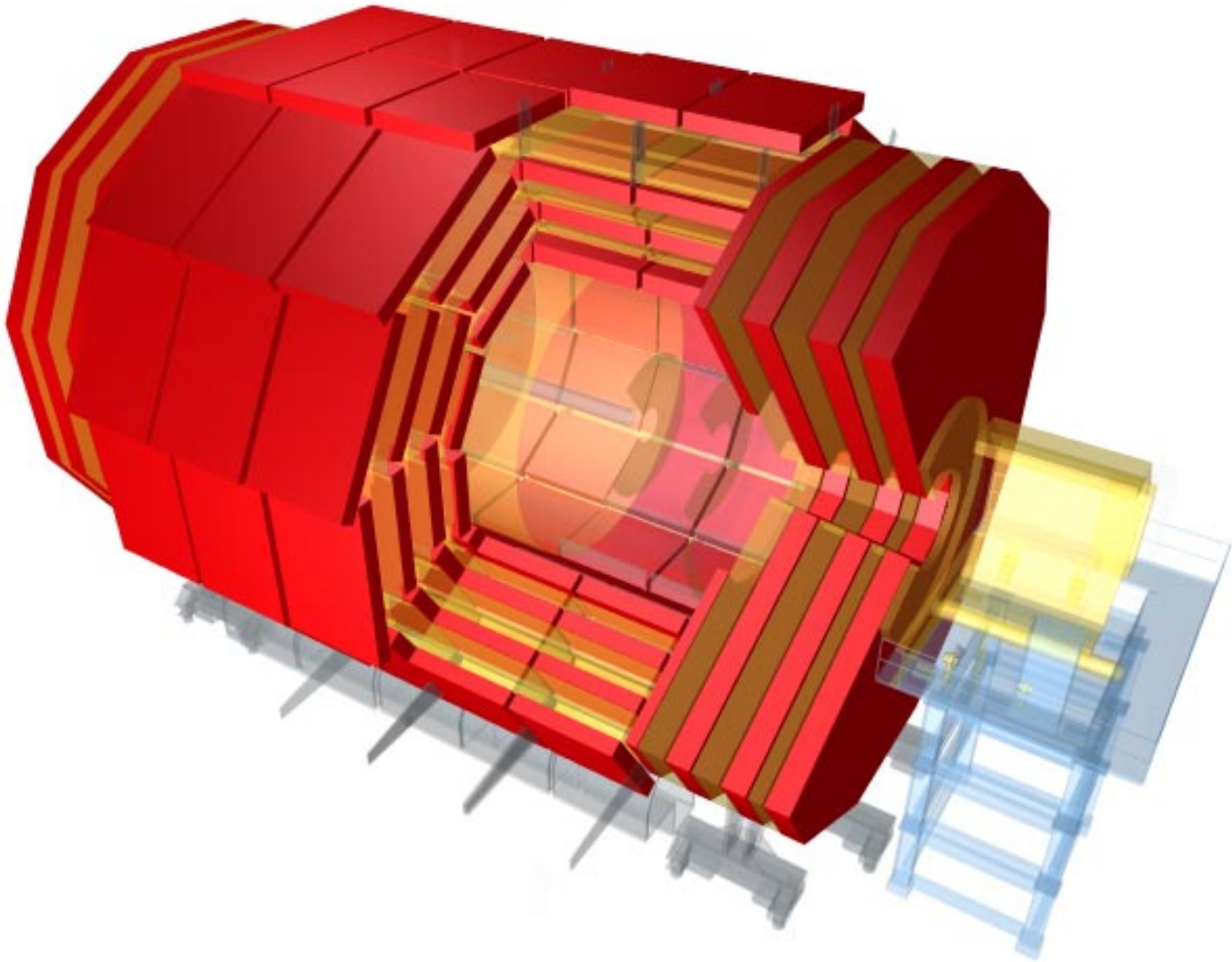
Discussing
packaging

Foresee few hundred channels test of whole chain in beam in ‘01

4. HCAL



5. Muon systems



Muon System: Overview

The Status

- Endcap CSCs: 12 chambers manufactured in FNAL. Personnel from IHEP, Beijing and St Petersburg have been trained at FNAL - know-how and tools transferred
- Manufacture 1/5th of CSCs by end-01
- ME1/1: Panel production started in Dubna - first chambers in mid-01

- Barrel DTs: Site a CIEMAT building first pre-production MB2 using final assembly tools and procedure
- Commissioning of MB drift tube assembly lines at Padua and Aachen well advanced

- Assembly of barrel RPCs gaps in industry has started.
- Results of a test of a minimal configuration of barrel alignment being analysed

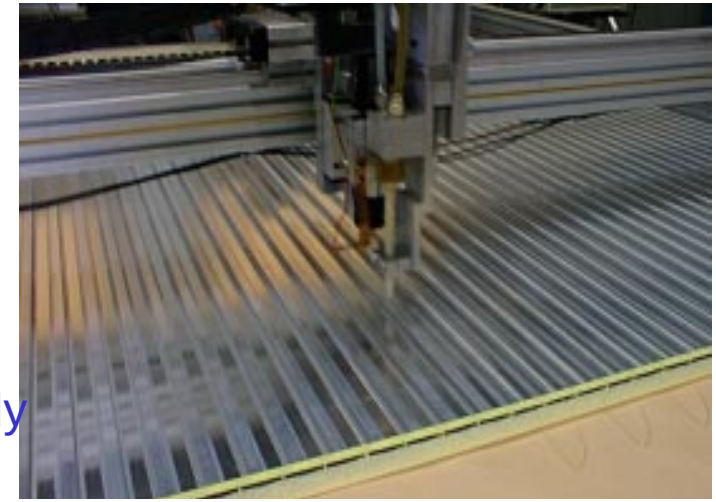
- 1st Electronic Systems Review - go-ahead for manufacture of CSC anode-front-end boards and some critical items of on-chamber electronics of muon chambers

Concerns

- Integration of endcap RPCs in the endcap system
- Rate of muon chambers manufacturing must be reviewed in 2001 to check consistency with installation schedule

MB.Assembly sites

CIEMAT
2ϕ, 1θ
1 assembly tables ready



Ciemat/MB2:Glue on top of 1st layer of I-beams

Ciemat/MB2:1st layer of I-beams

Ciemat/MB2 plate with glued strips

Legnaro/Theta SL assembly table

Legnaro
1ϕ, 1θ
1 asmbly tables ready

Muon. RPC overview

Barrel

- Single gaps from industry
- RB1 assembled in China
- RB2 assembled in Italy
- RB3 assembled in Bulgaria
- RB4 assembled in Italy

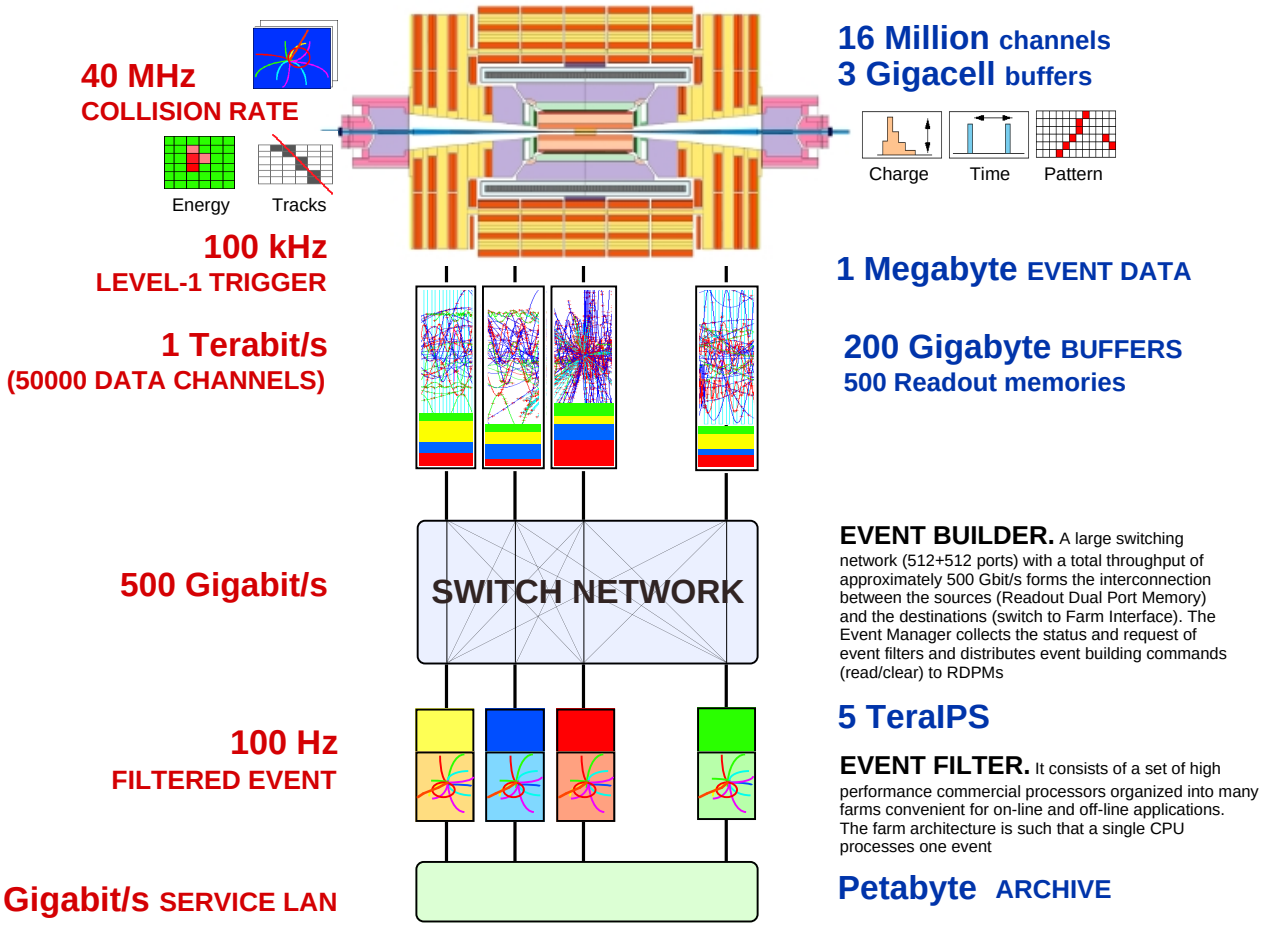
Forward

- Single gaps from Korea
- RE1 assembled in China
- RE n/1 assembled in Korea
- RB n/2 assembled in Pakistan
- RB n/3 assembled in Pakistan
-

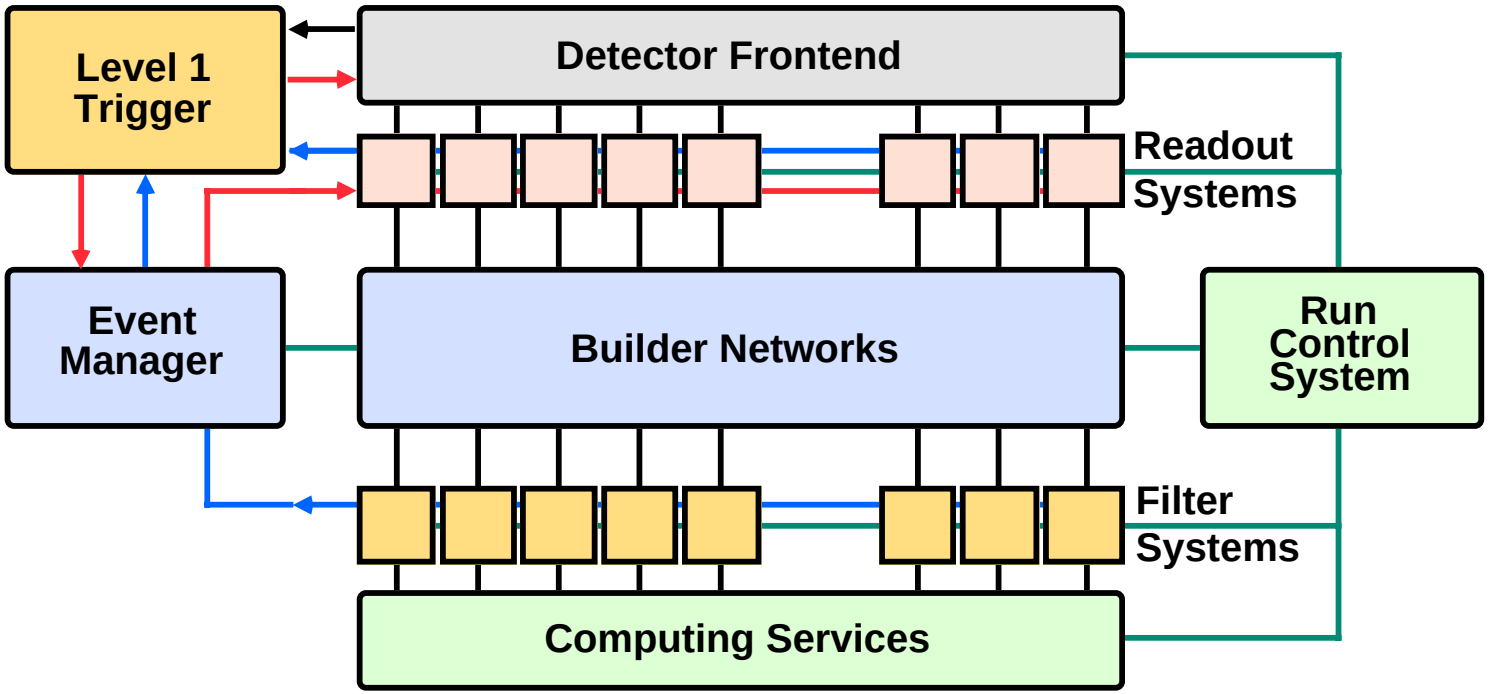
Concerns

Finalise design. EDR beg 2001

6. Trigger and data acquisition



DAQ main parameters



Collision rate		40 MHz
LV1 Maximum trigger rate		100 kHz
Average event size	≈	1 Mbyte
Data production	≈	Tbyte/day
Event Flow Control	≈	10^6 Mssg/s

I-O units bandwidth (512+512)		400 MByte/s
Builder network (512x512 port)	≥	500 Gbit/s
Event filter computing power	≈	5 10^6 MIPS
High Level Trigger acceptance		1 - 10 %
Overall dead time	≤	2%

Level 1 Trigger Update

Level 1 Trigger designed to lower rate to 100 kHz

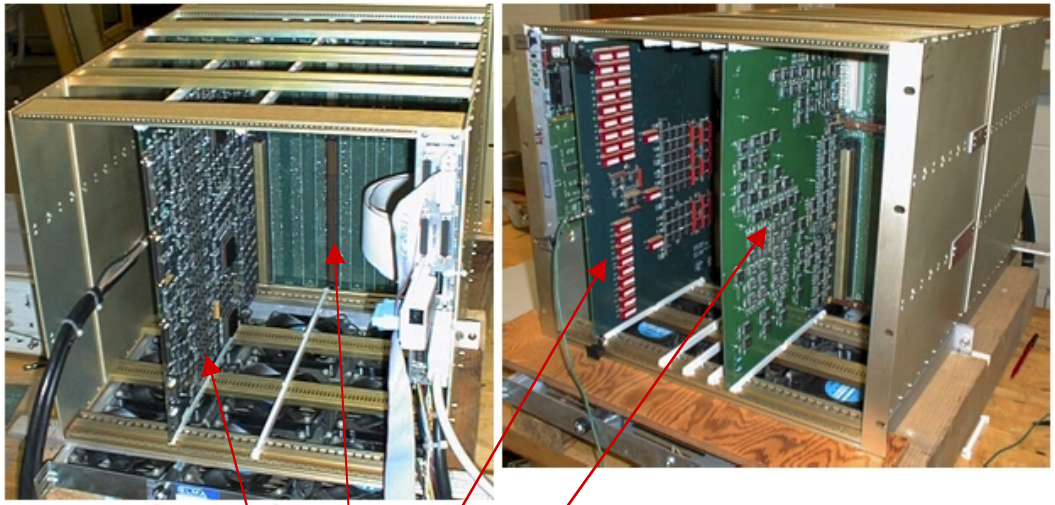
TDR for November 2000 - (Draft already in circulation)

Recent improvements in Calorimeter trigger:

Jet algorithm & Tau-Trigger

New design of jet algorithm with sharper efficiency turn-on and tau-jet bit for narrow jets based on 4x4 regions sums into 12x12 region jets with sliding windows logic.

Prototypes of many of the elements of the trigger system exist



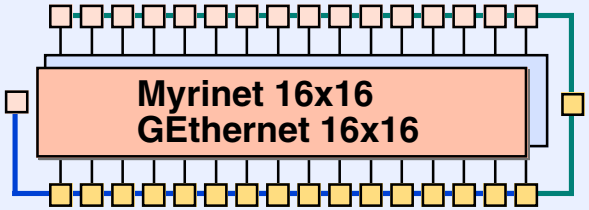
Eg.
Calo trig.

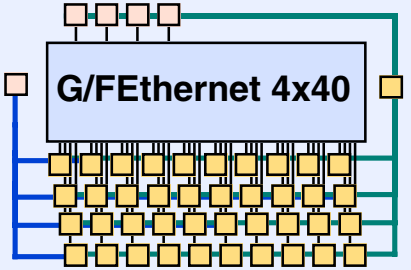
Prototype Crate with

- 160 MHz Backplane: timing & signals excellent
- Proto. Receiver Card (rear): VME, sharing, Adder ASICs checked
- Proto. Clock Card (front): Clocking checked
- Proto. Electron ID Card (front): VME, dataflow, timing checked

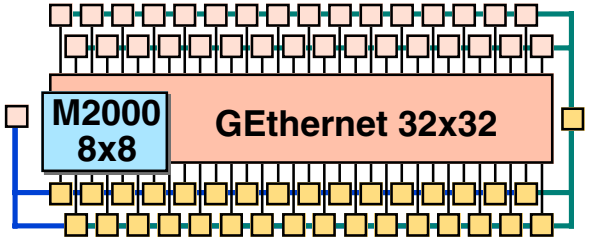
DAQ demonstrators 2000-01 plans

Oct 2000
- 33 PCs. **20 Gb/s EVB**
- Event Builder protocols
- Myrinet/GE evaluation

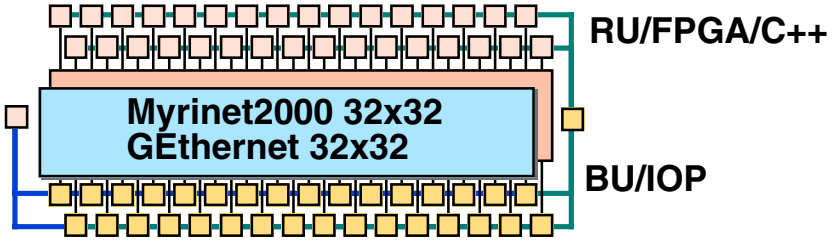




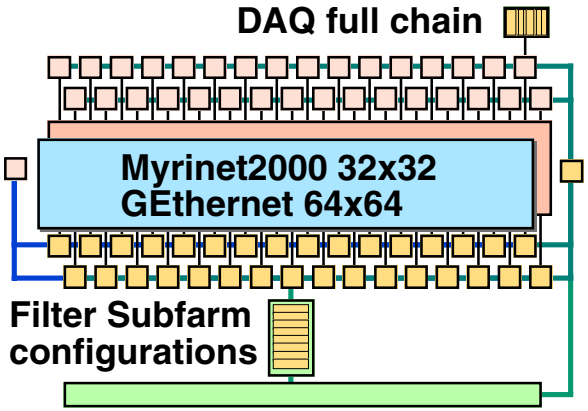
Nov 2000
- 65 PCs. **40 Gb/s EVB**
- Multistage/**Conic EVB**
- Myrinet/GE evaluation



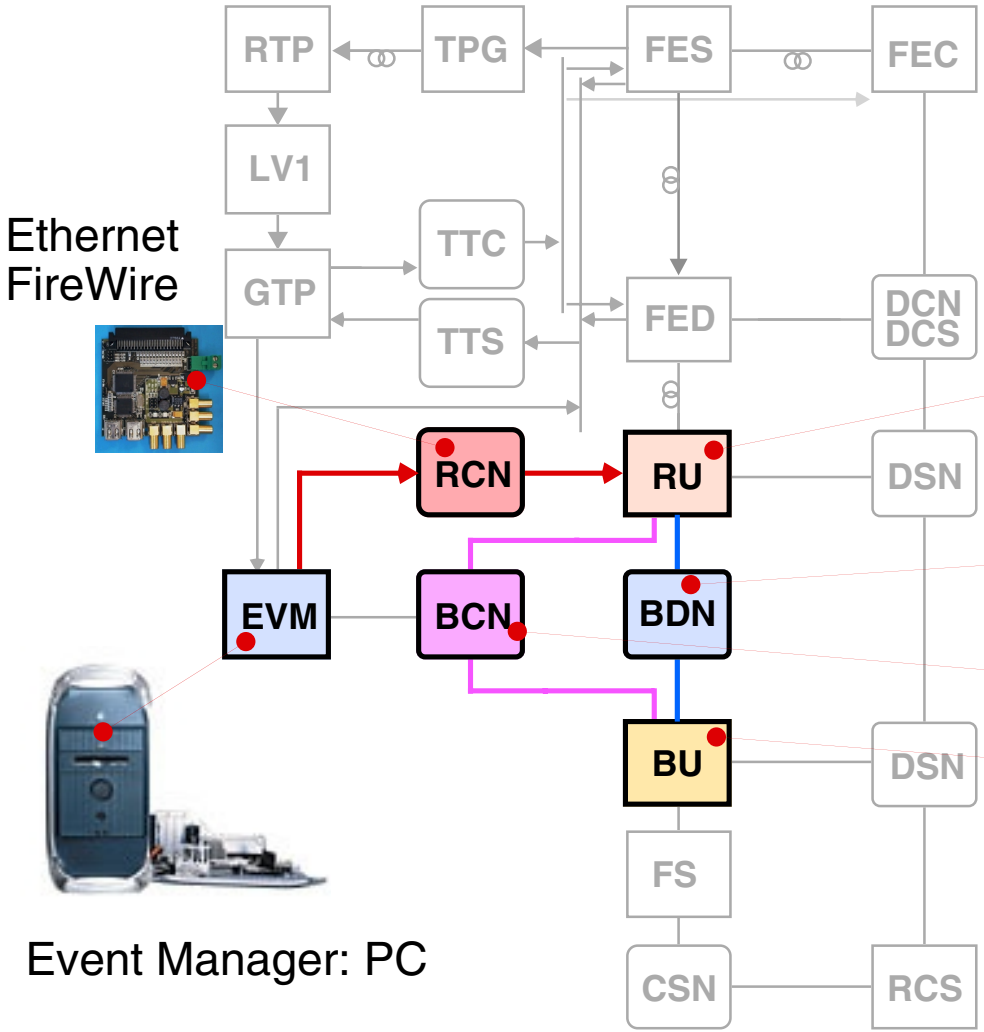
June 2001
- 65 PCs. **100 Gb/s EVB**
- Myrinet 2000 32x32
- GBethernet 32x32

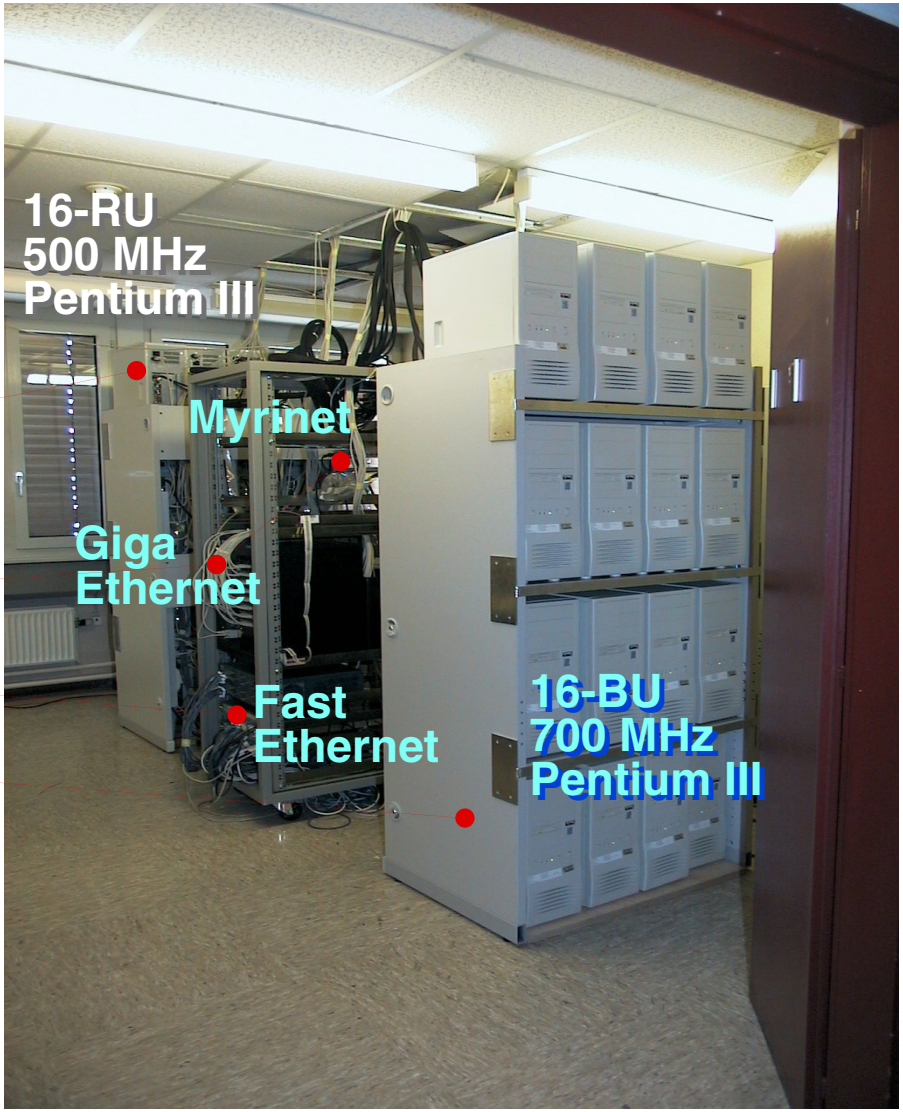


Nov 2001
- 65 PCs. **100-200 Gb/s EVB**
- Myrinet 2000 64x64
- GBethernet 32x32
- \+ **8-PC filter subfarm**
- DAQ full chain (**IO-HLT**)



Event Builder prototypes





- RU-BU Emulation software
- Test network performances and EVB protcols
- Evaluate technologies (switches and interfaces)

Sept 2000 Bat 32 Set up

DAQ raw schedule

4 Years

2000. Technology evaluation. Prototypes and demonstrators

2001. R&D. Technical Design Report (**TDR**)
Detector-DAQ interface final design

2002. Final technology choice (RU-BU design, Event Builder Data and Control networks)

2003. Preserie system (128x128) with full Integration (Data flow, Run Control, Event filter). FED-links RU-BU production

2004. Detector readout in place. Detector control in place
Installation of Event builder. Tests of full system

2005. Event Builder/Filter final design implemented to read 100% detector data at 25% of nominal rate

2006. Upgrade 1: (Event Builder/Filter to 50%)

2007. Upgrade 2: (Event Builder/Filter to 100%)

Higher Level Trigger

Basic Job: 100 kHz to 100 Hz (keeping physics)

After hardware Level-1 assume two steps:

- Level-2 only uses calorimeter & muon data
- Level-3 uses tracker data as well

New CMS Project: Physics Reconstruction & Selection (PRS):

- 4 PRS groups established in Apr 99
- b/τ (vertex), Electron/Photon, Jet/Missing E_T, Muons

Work in OO software (C++ reconstruction code)

- Start with high luminosity case

HLT milestone passed in July '00

- (Show reduction of rate of factor 10 using 25% of data)

HLT : Inclusive Electron Trigger

Single inclusive electron trigger

Lvl-1 thresh	E_T @ ε=95%	Lvl-1 kHz	Lvl-2 kHz
29.5	35	7.1	1.5

Efficiencies:

(a) H(170GeV)$\rightarrow$ZZ* $\rightarrow$4e

fid:99%; Lvl-1: 99%; Lvl-2: 97.5%

(b) H(120GeV) $\rightarrow 2\gamma$

fid/phys:52%; Lvl-1: 99%; Lvl-2: 96%

Introduce Tracking Information

Very preliminary

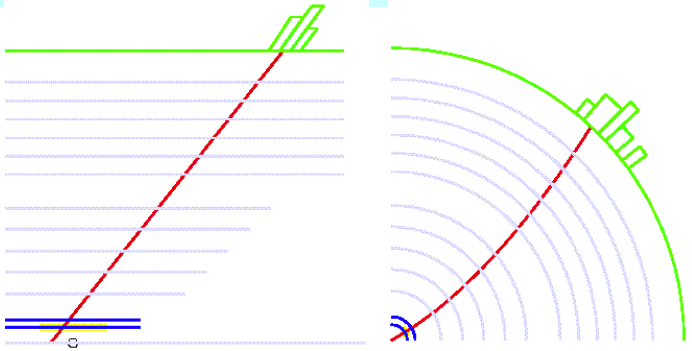
look for (barrel) pixel hits in electron road

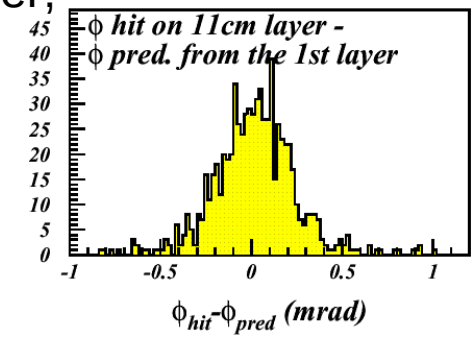
Vertex estimate: 1st pixel hit + ECAL cluster;

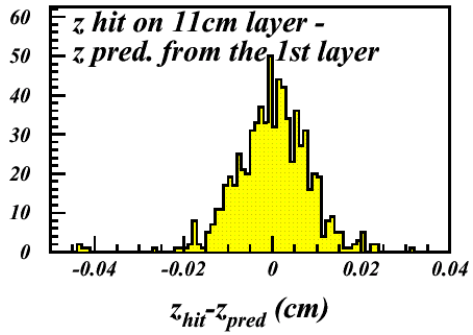
look at 2nd layer match:

Efficiency(single e): 93% E_T>15 GeV

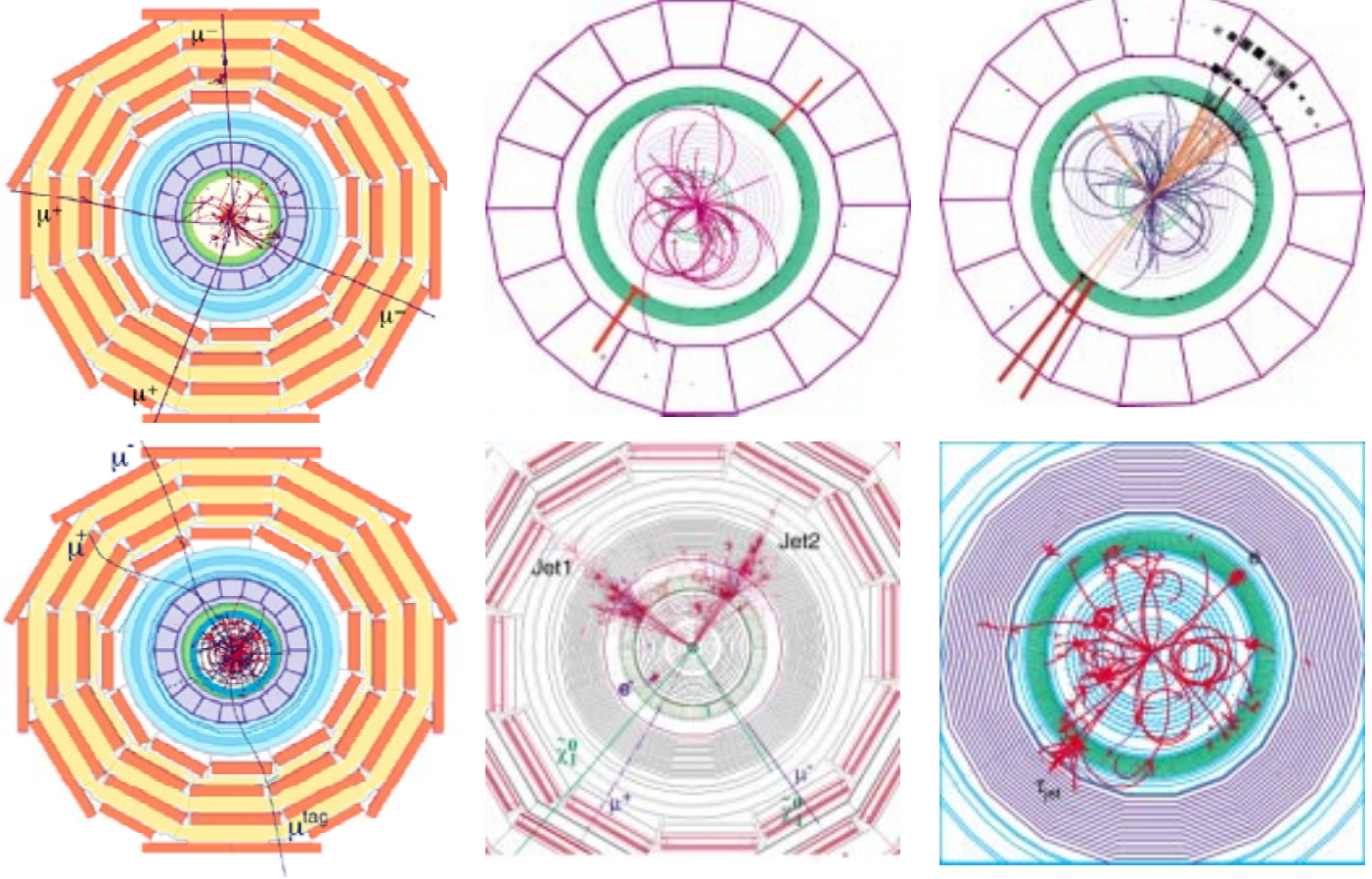
Background rejection: ~ 12 rejection







7. Software/Computing



Software/Computing: HLT Milestone

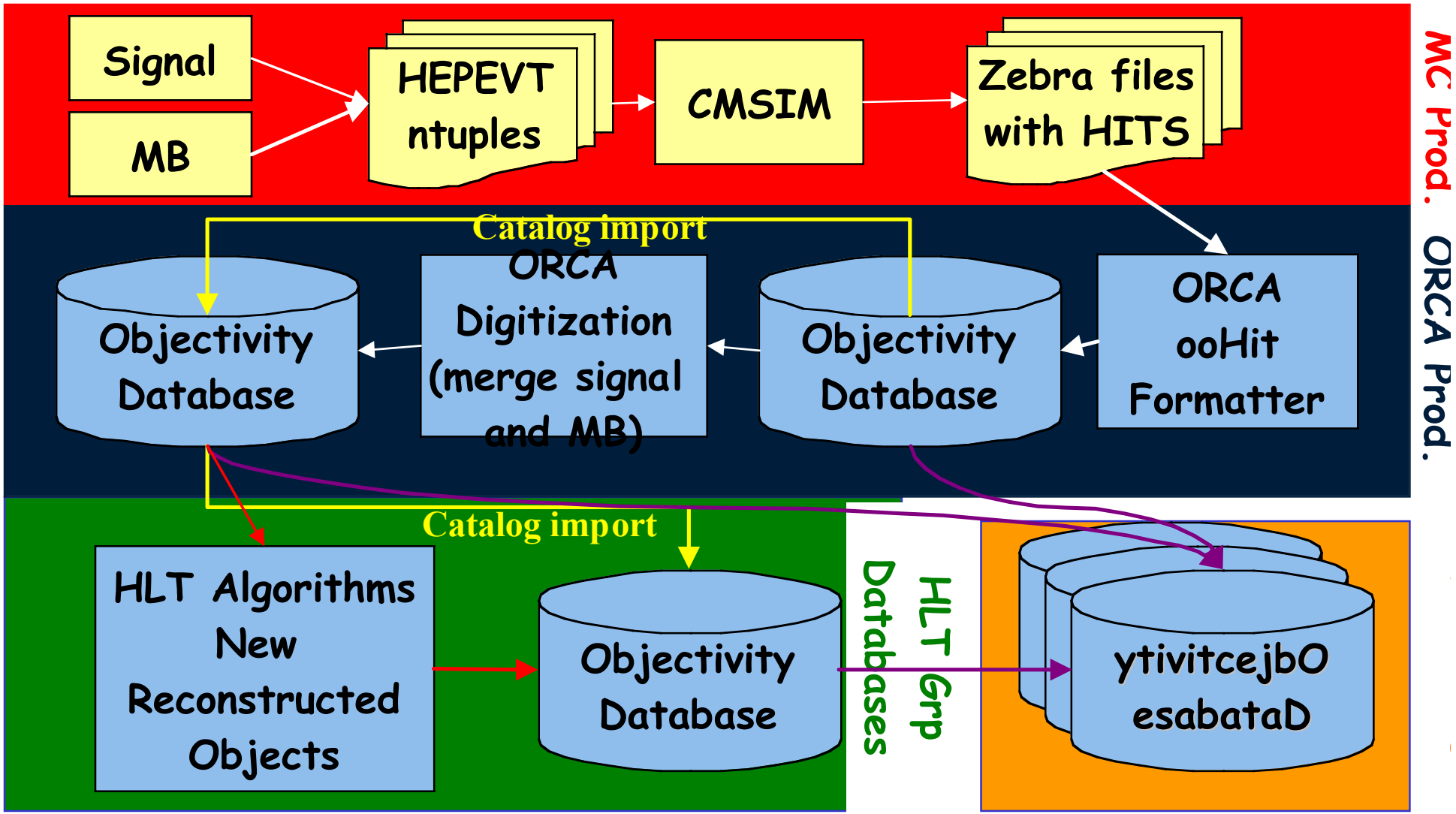
Recently the Software/Computing team and the Physics Reconstruction and Selection (PRS) group passed successfully the first High Level Trigger (HLT) milestone. After the release of a stable ORCA/CARF version in July, 100 PCs were run flat-out for two weeks to produce an initial sample of 2 million high luminosity fully digitized events to study. (ORCA: Object Oriented Reconstruction for CMS Analysis. CARF: CMS Analysis and Reconstruction Framework)

Two important steps have been made:

1) **We have made a realistic test of a large-scale use of an Object Database Management System** (ODBMS; in this case, Objectivity/DB) within the prototype framework/architecture CARF. This is a very good basis for future important decisions on the choice of the DB and the final architecture.

2) **We have put together a team (the PRS group) with expertise on the sub-detector physics performance and reconstruction**.

Simulation+reconstruction: Data flow



Software/Computing Organization

During last CMS week it was decided to evolve the Software/Computing organization:

1. **Establish the PRS activity as a CMS Project**, with the following scope:
Online reconstruction and Physics selection (HLT). Simulation of detector signals. Calibration of the detectors. Offline reconstruction.
Internally the PRS team is split into four groups:

- **ECAL-e/gamma**
- **HCAL-Jet/met**
- **Muon**
- **Tracker-b/tau**

2. **Redefine the scope of the present Software/Computing Project** to consist of the core software (Framework, Databases, Users Tools, Software support) and offline computing (Tier0 offline farm, Tier1, 2 regional centers, grid computing). **The project would be renamed as Core Software & Computing.**

3. **Redefine the scope of the present TriDAS Project:** Remove the actual filtering software.

4. **The 3 PMs will establish common (across the three projects) task forces**, such as: Framework and Architecture. Calibration constants and Calibration DB(s). Online and Offline farms. Software/Computing TDR. Physics TDR

Software/Computing Plans

CMS Computing and Software model is designed to meet LHC requirements; use **ORCA and HLT** to study this model in depth.

This HLT study is the first in a series of increasingly complex **"mock-data challenges"**

HLT L2 (calo+muon) reduction	July	2000
HLT L3 (tracker) reduction	Fall	2000
Trigger TDR	End	2000
DAQ TDR	End	2001
Software/Computing TDR		2002
(5% data challenge, Use Tier 0, 1, 2 centres)		
Physics TDR		2003
20% Mock-Data Challenge		2004

8. Conclusions

The Magnet schedule and cost are now well established.

Construction of HCAL is well underway, on schedule and within cost estimate (to watch - HPD and the electronics).

Pre-construction of Muon chambers in 2000 (to watch - rate of chamber production).

ECAL crystal production is under way in Russia. Cost of crystals (negotiated in $) and photo-sensors within cost estimate (to watch - crystals production, mechanics, APDs, serializer, consequences of exchange rate).

Tracker - change to all-Si sensors, new optimised layout, new schedule worked out, impressive results using 0.25 μm technology (to watch sensors contract and startup of automated production)

Trigger, DAQ and Software/Computing proceeding well. Trigger TDR end-00.

CMS has made plans for a complete detector for Apr 2006 and a 'working' CMS detector for first LHC beams in 2005, taking into account technical and financial constraints.

Cumulative Payment Profile