Status of the LHCb Experiment

LHCC open session

24 November 2004

on behalf of the LHCb Collaboration

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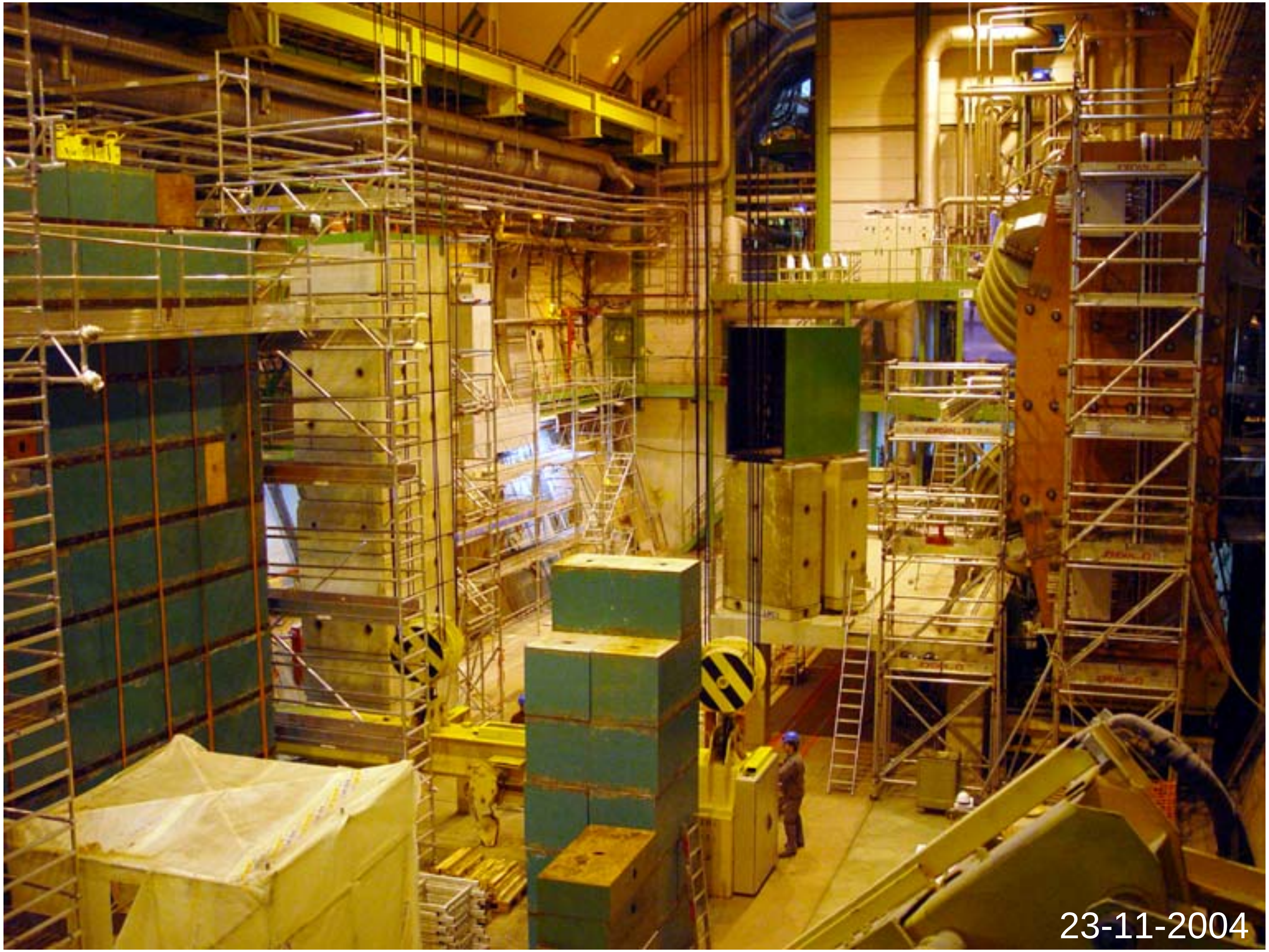
CERN

and

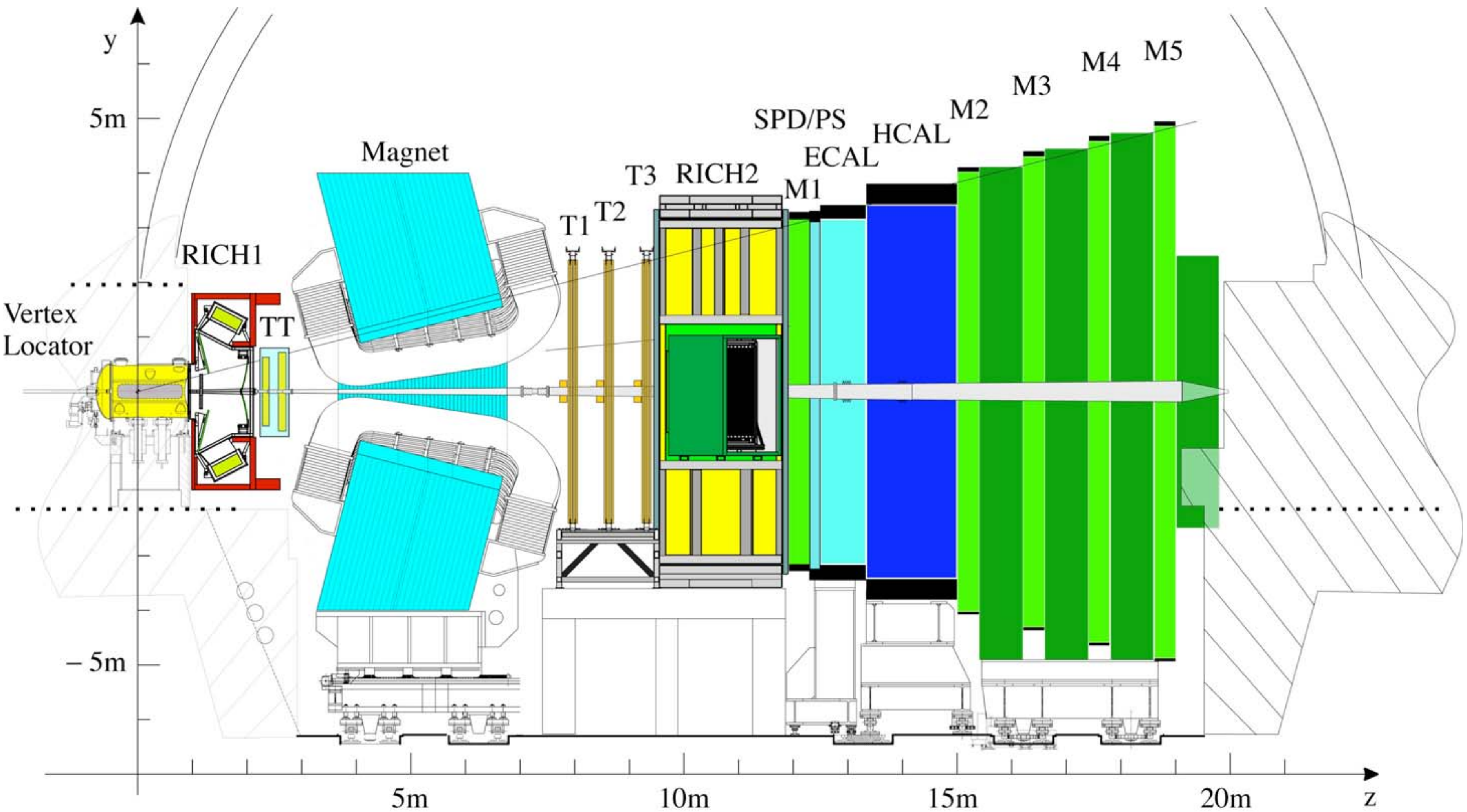
École Polytechnique Fédéral de Lausanne (EPFL)

Contents

I) Experimental Area

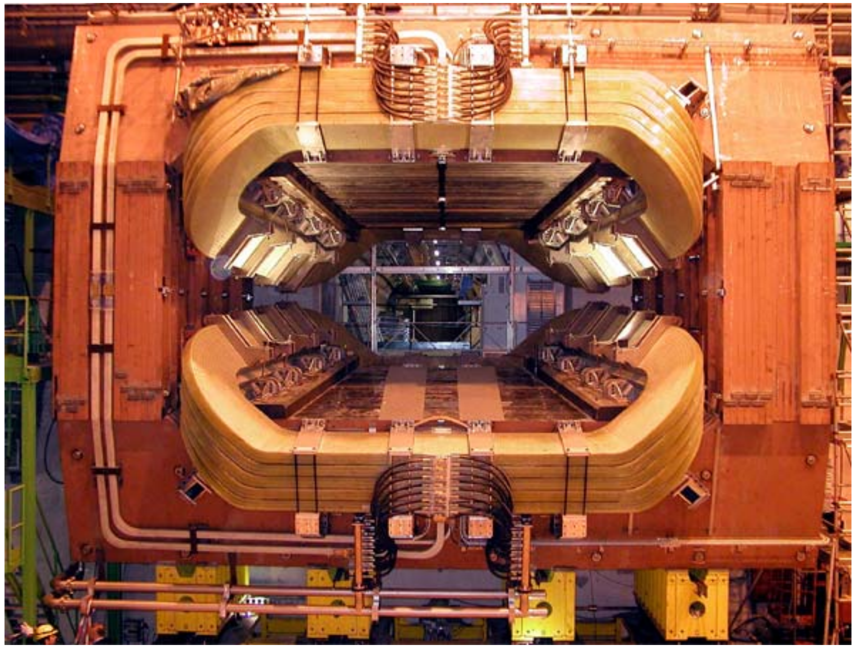


II) Status of Subsystems

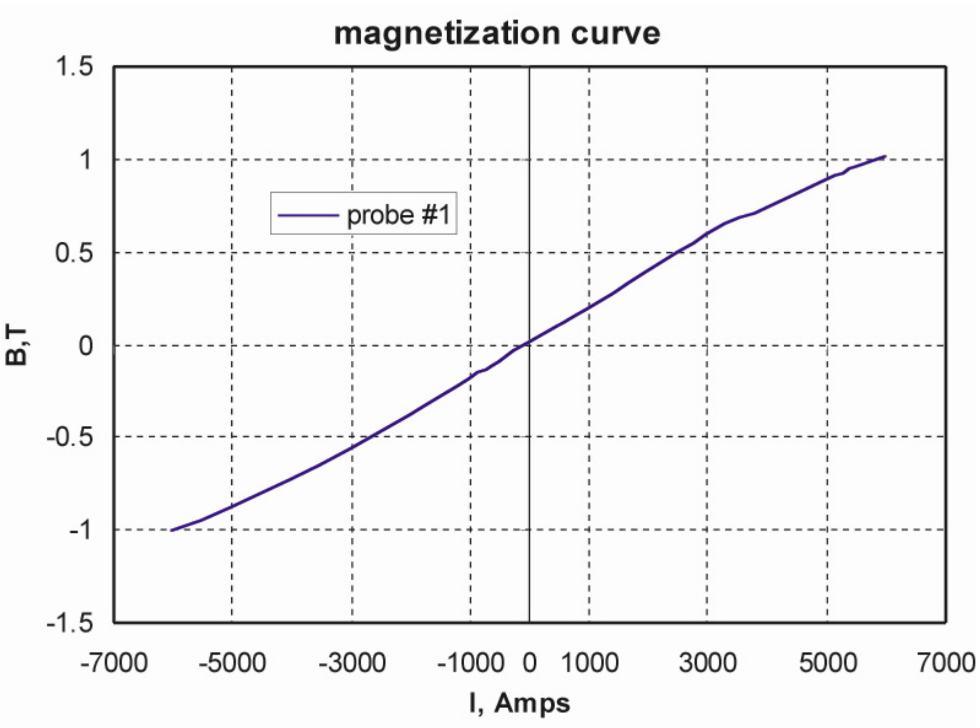


1) Magnet

Completed and successfully switched on!



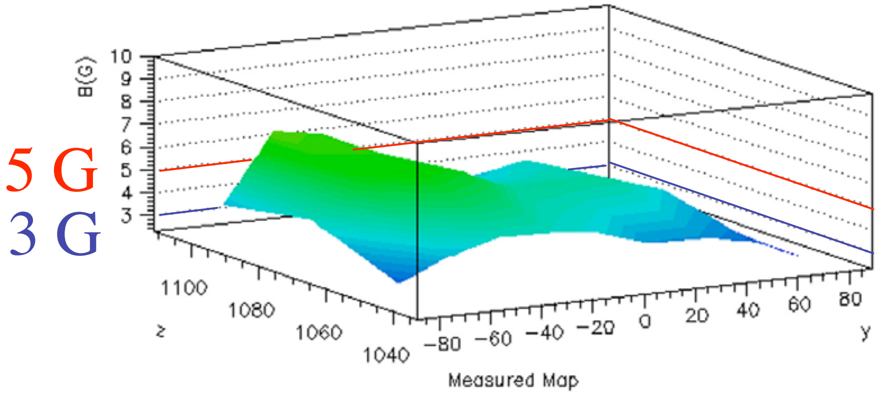
Fe Yoke 1.45 kt
Al normal conductive coil 2×25 t



Power 4.2MW at 1 T field

RICH-2 photon detector
shielding box placed
at right position

B field measurement in
the box along the HPD plane



No problem for the HPD operation

Agree within a few Gauss with
the simulation.

B at various points at the cryogenic plant given to machine group

Commissioning work will continue and improvement will be made for

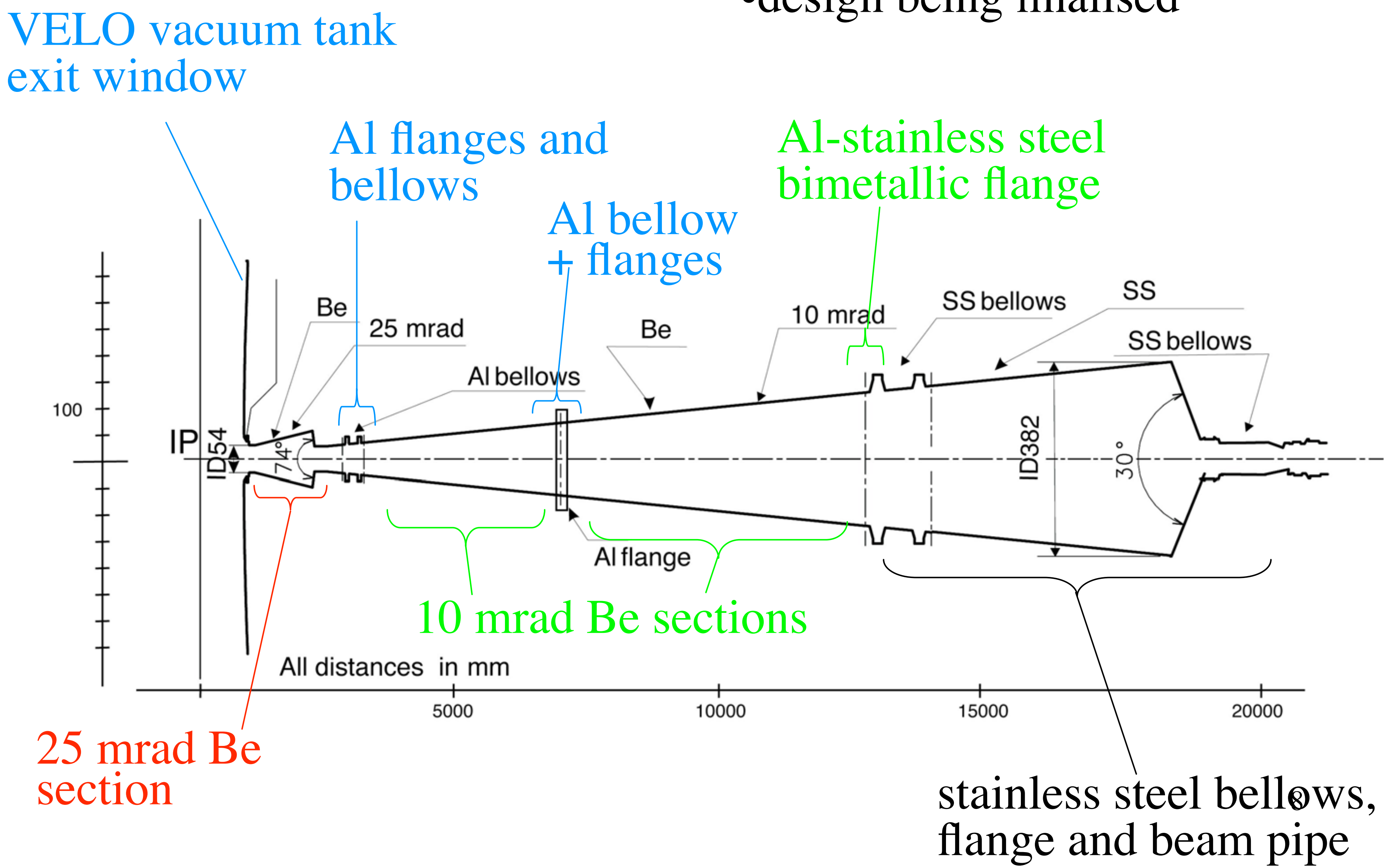
- better adjustment of the incoming water temperature control
- more cooling power for the summer operation

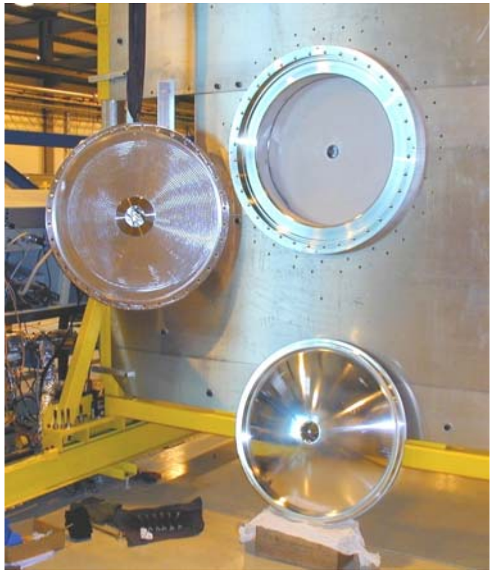
A field map measurement is planned for the coming period, but no firm schedule can be made due to the limited power availability at CERN over the winter.

The final field map must be measured after all the metallic structures around the magnet are installed → end of 2005.

2) Beam pipe

- completed by industry
- ready for fabrication at CERN
- being fabricated by industry
- design being finalised





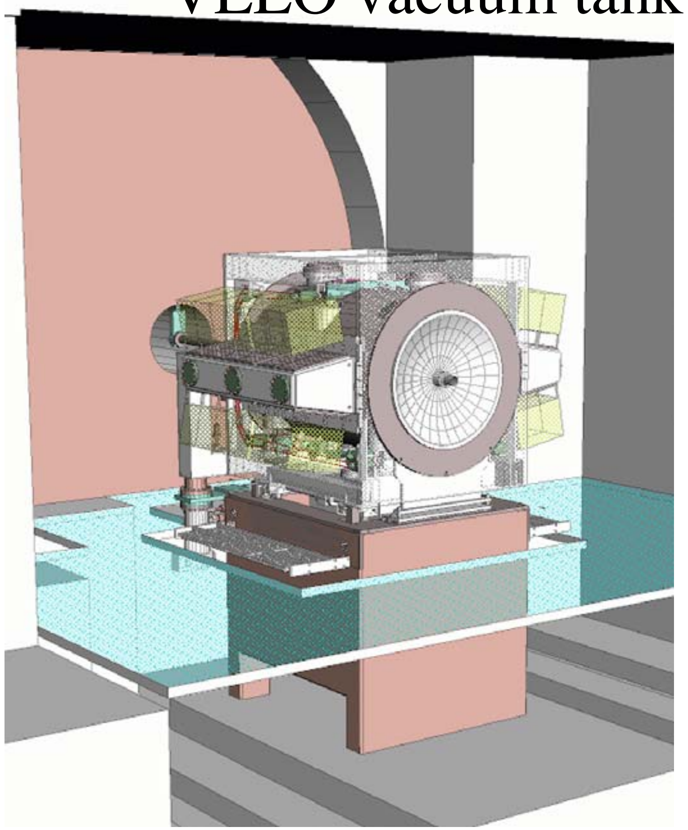
VELO window

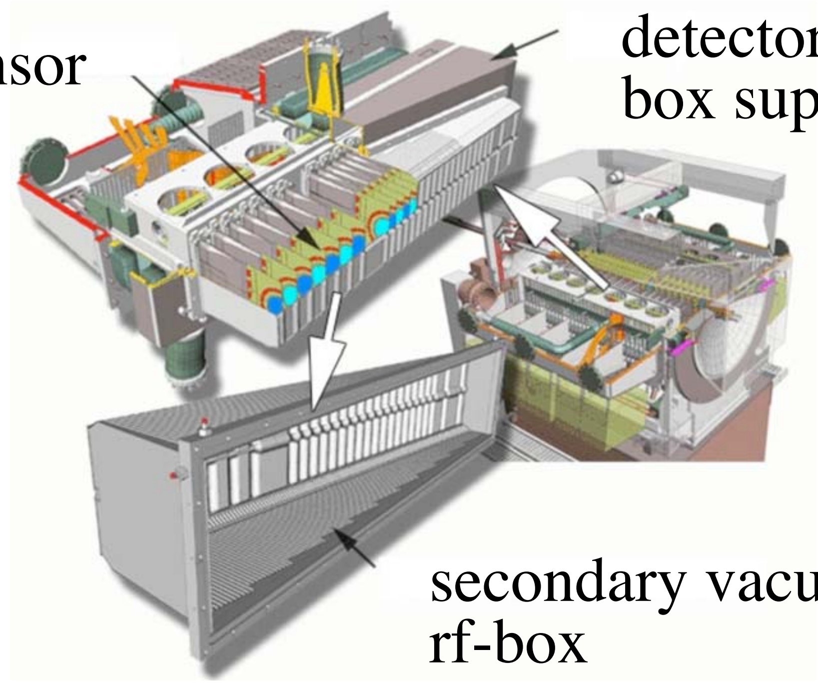
Al bellows and flanges

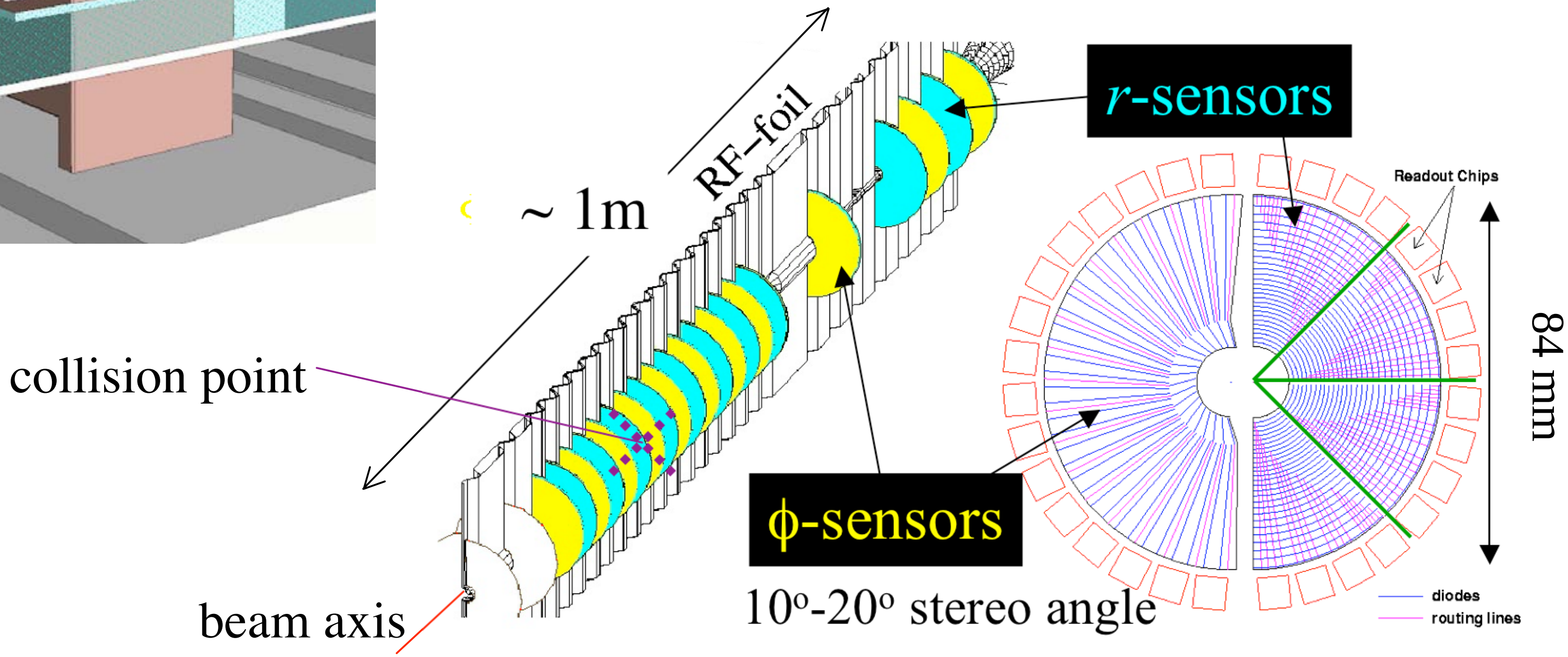
25 mrad Be pipe

Al bellow and flange

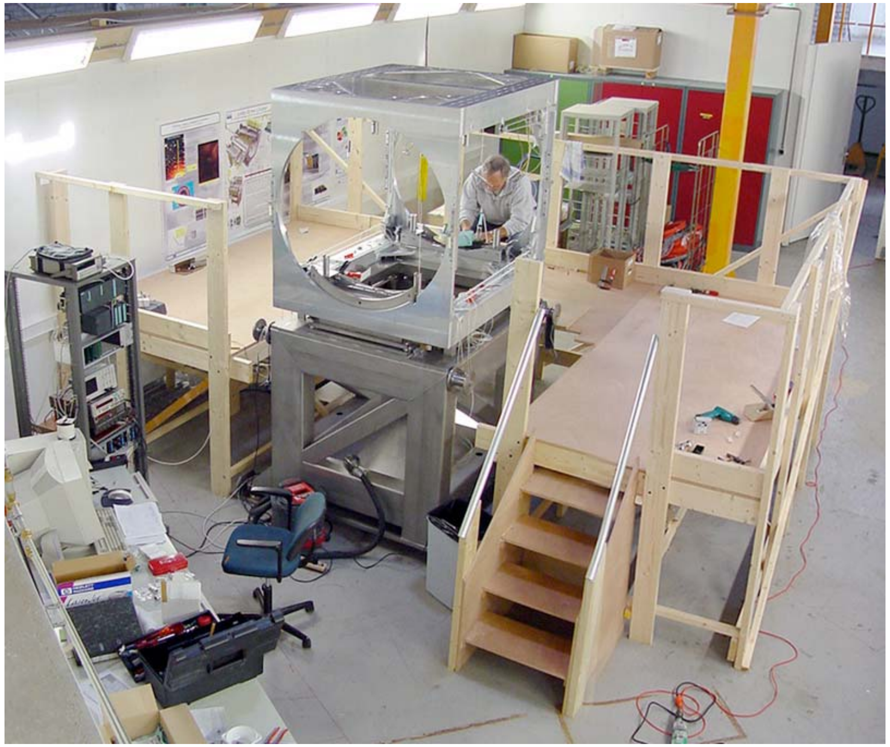
3) VELO


VELO vacuum tank


Si sensor
detector
box support
secondary vacuum
rf-box

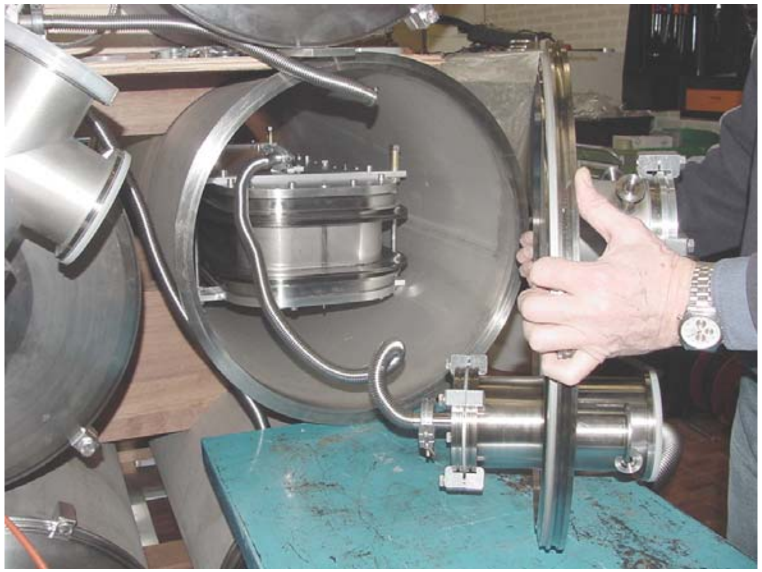

~ 1m
RF–foil
r-sensors
Readout Chips
84 mm
collision point
φ-sensors
10°-20° stereo angle
beam axis
diodes
routing lines

vacuum tank stand and support frame



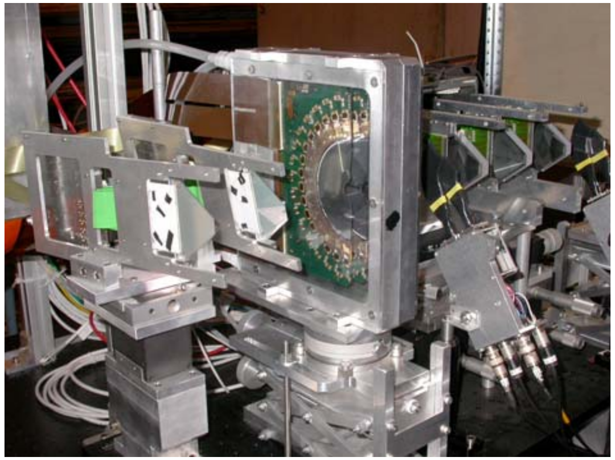
secondary vacuum rf-box

stress test of rectangular bellows

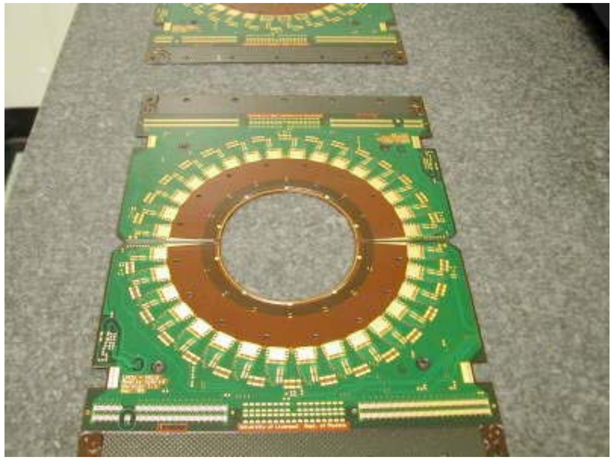


final sensor, hybrid and readout chip (Beetle) all tested

pre-production n-on-n 200 μm

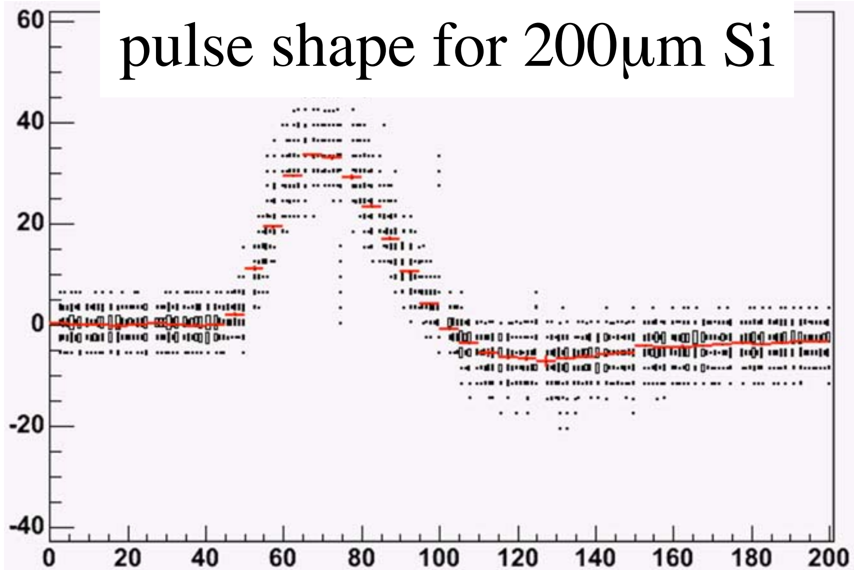


test beam set-up



final hybrid

pulse shape for 200μm Si

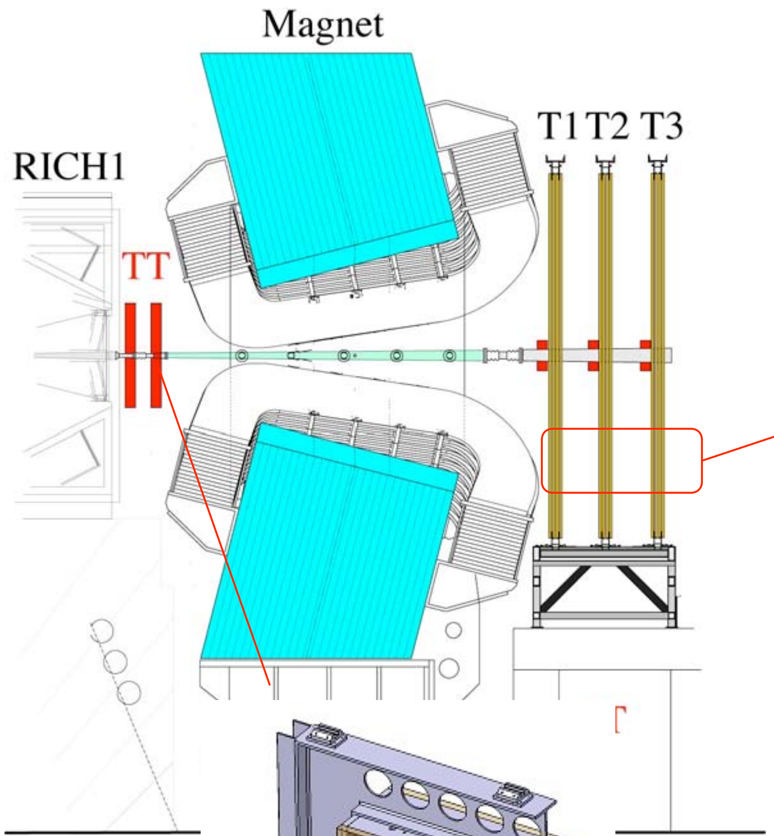


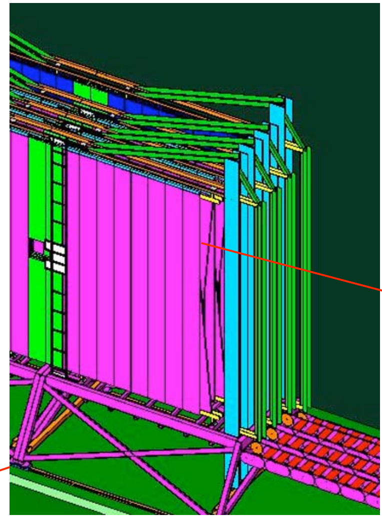
nsec

delivery of pre-production sensors delayed by 3 months

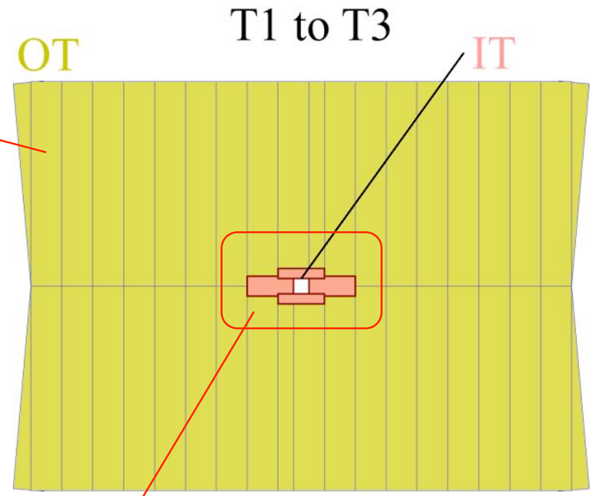
both 200 and 300 μm sensors measured→ decision in January 2005

4) Tracking System





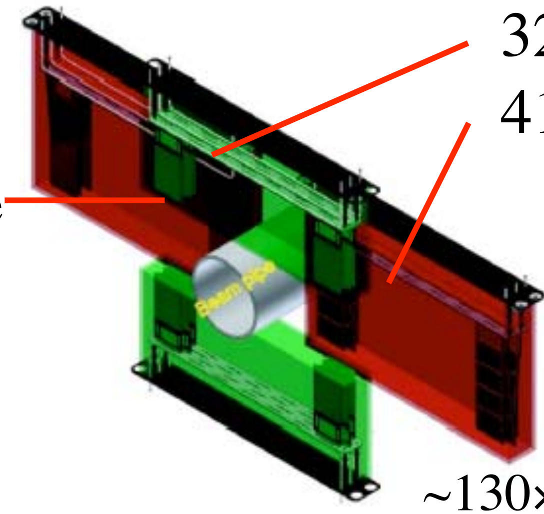
Outer Tracker
straw drift chambers



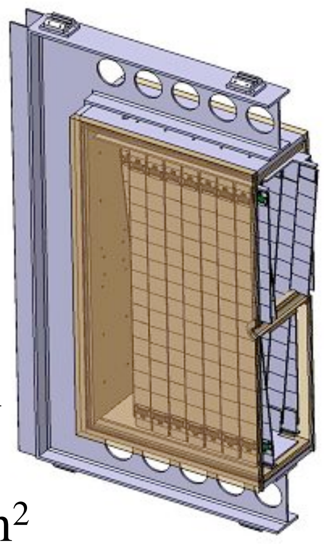
Inner Tracker

320 μm Si
410 μm Si

beam pipe



~130×45 cm²



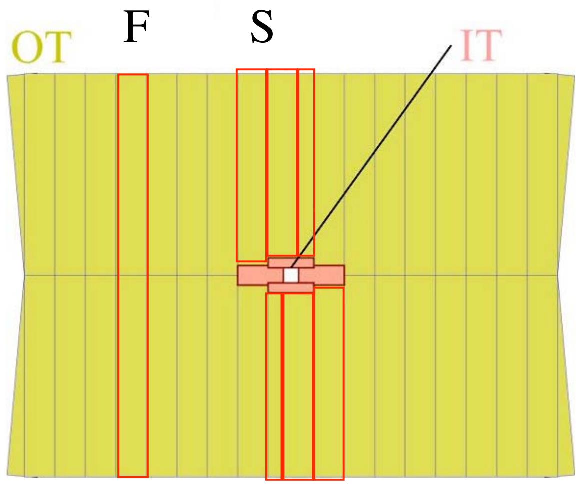
500 μm Si

~1.4×1.2 m²

Trigger Tracker

Outer Tracker

i.e. assembly of
- 56,000 straws
- 620 panels
- 185 F and 124 S Modules



Module production

-Krakow: all the panels produced

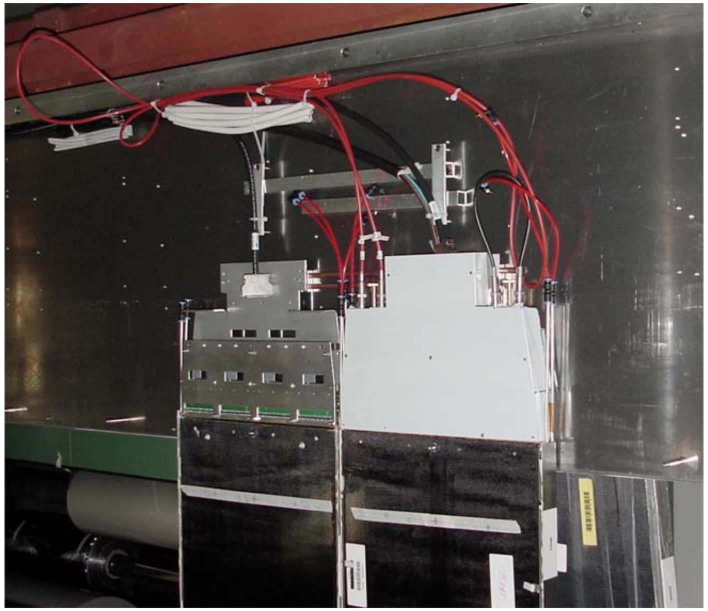
-Heidelberg: 60 F modules to be produced
17 produced 1 rejected (first one)
5 days/module

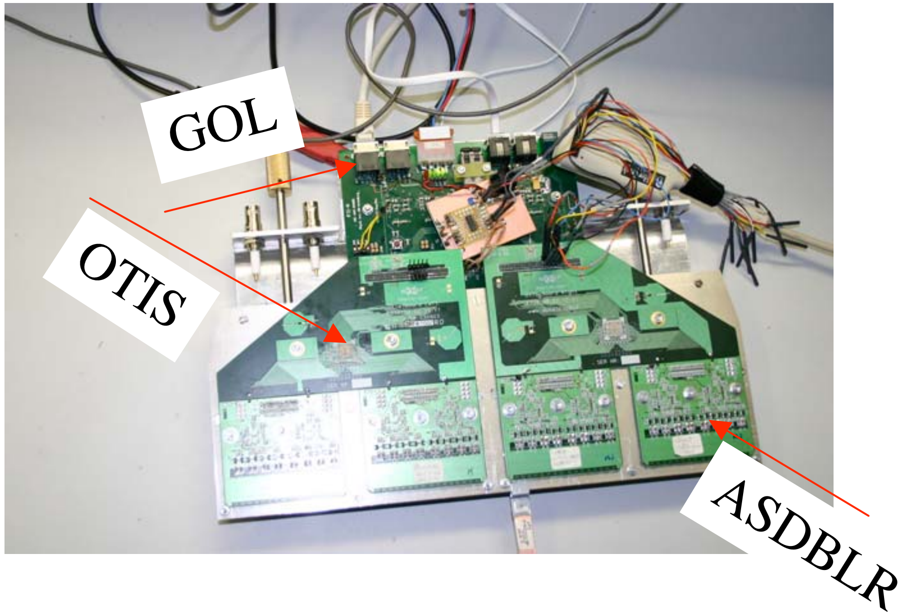
-NIKHEF: 125 F modules to be produced
30 produced 1 rejected (first one)
<3 days/module

-Warsaw: 124 S modules to be produced
28 produced 2 not gas tight and to be repaired
4.5 days/module

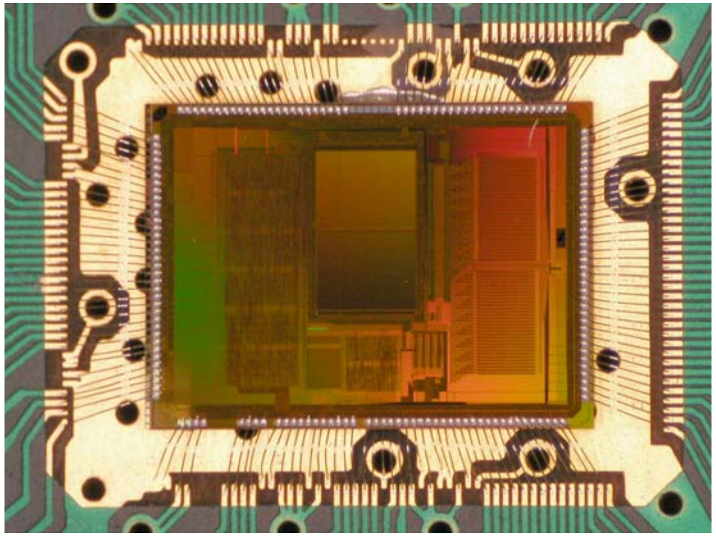
F module production OK S module production OK but tight.

OT front-end electronics



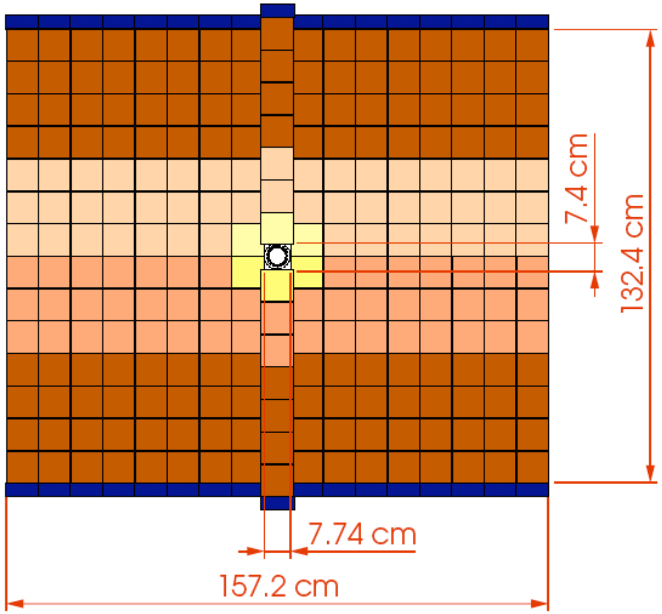


OTIS 1.2 (TDC chip) being tested and works well so far.
Engineering run summer next year.



Silicon Tracker

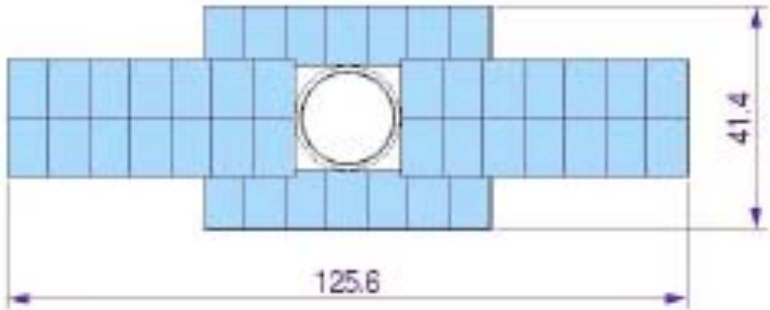
Trigger Tracker



2+2 Si layers
x-u↔30 cm↔v-x

thickness: 500 µm
strip pitch: 183 µm
so called CMS-OB2 from HPK
~1000 sensors being ordered
(problem with the production priority)

Inner Tracker



three stations
x-u-v-x/station

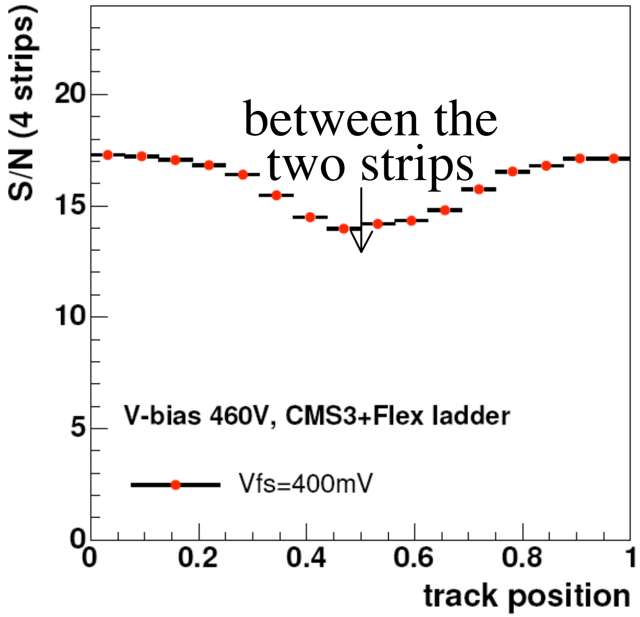
thickness: 300 µm for up and down
400 µm for left and right
strip pitch: 198 µm
~500 sensors ordered in June 2004
first delivery December 2004
last delivery Autumn 2005

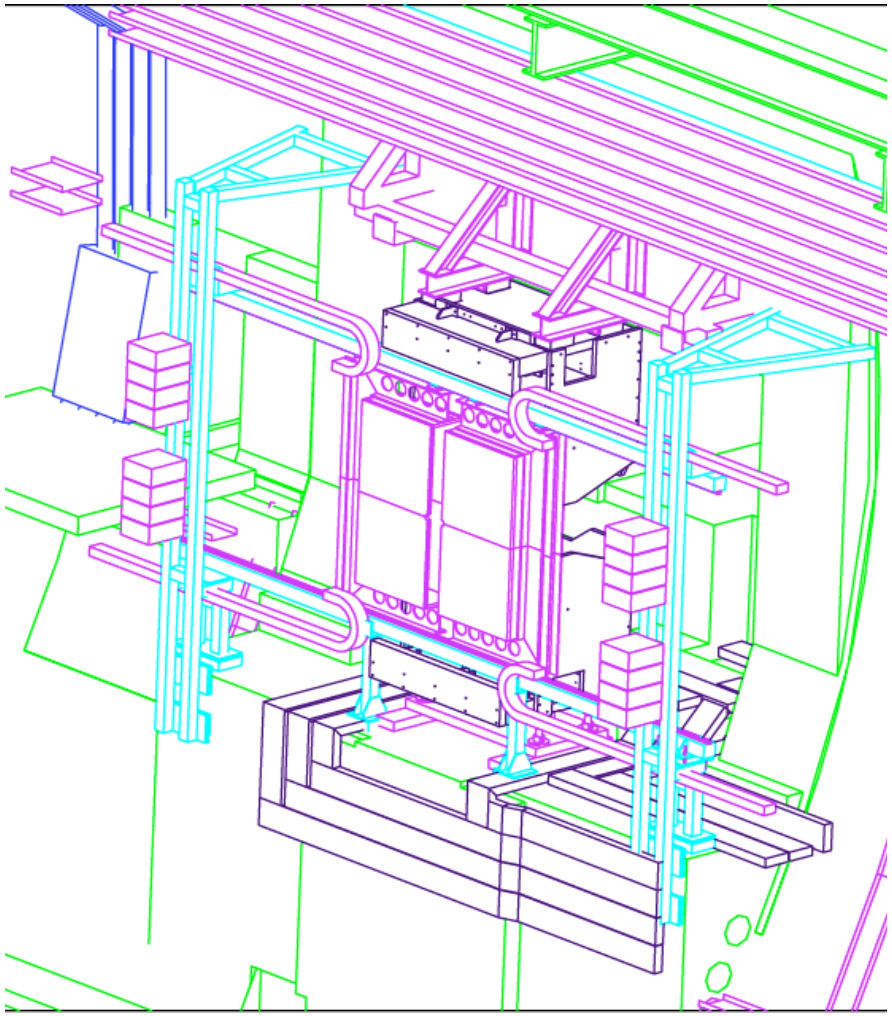
Both readout by the Beetle chip

Trigger Tracker

4 sensors
3 sensors + 39 cm Kapton cable
1 sensor + 59 cm Kapton cable

3 sensors + 39 cm Kapton cable

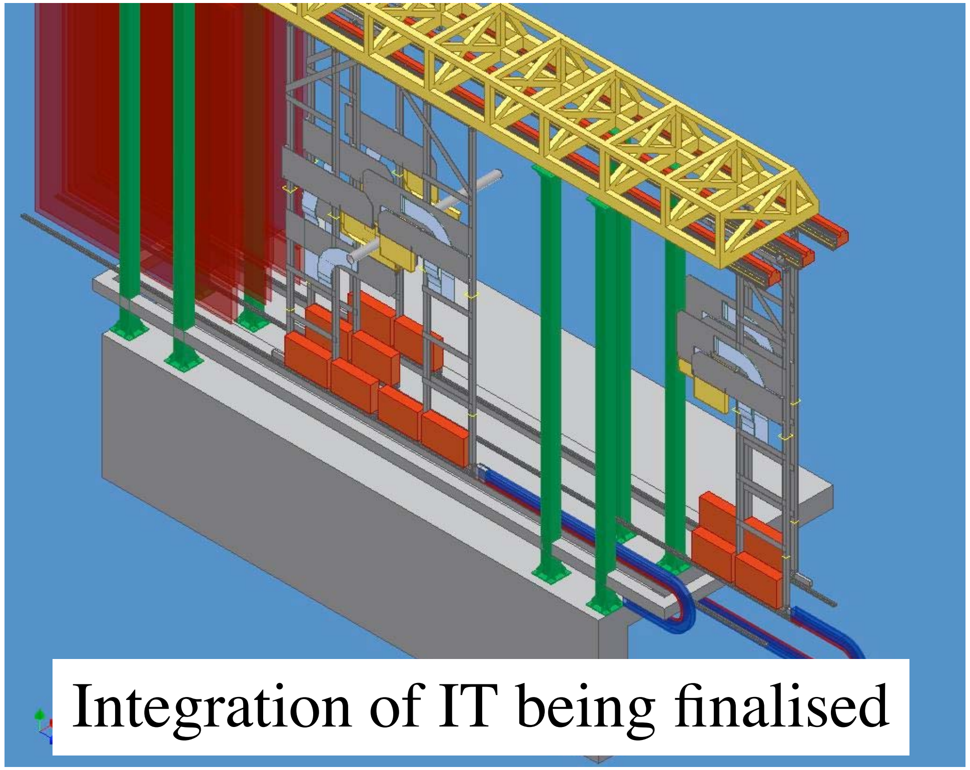




Integration of TT being finalised

Inner Tracker

IT detector box sits in the middle of the acceptance →
minimizing material is crucial



Integration of IT being finalised

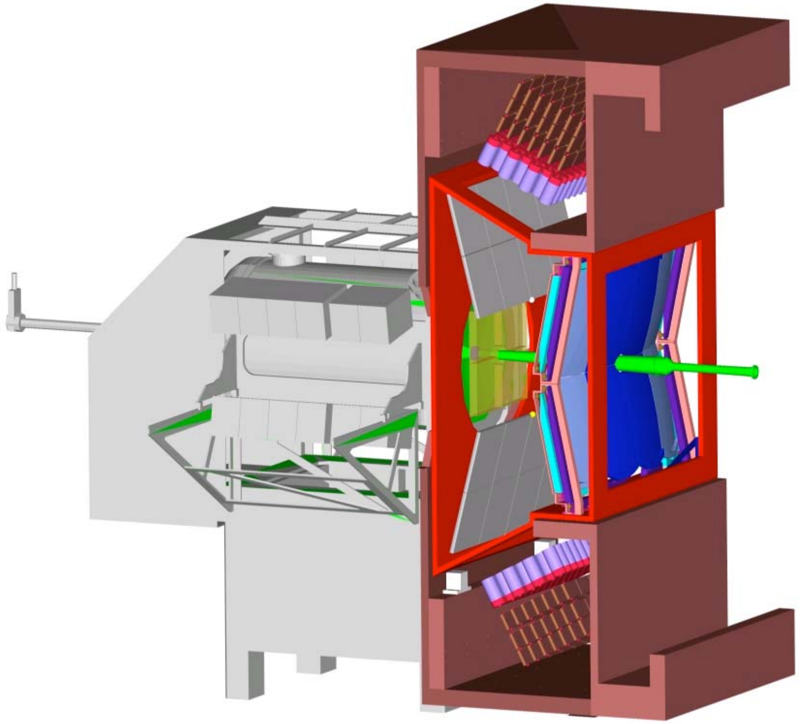
IT and OT can be moved independently of each other

EDR for IT and TT planned for December 2004.

5) RICH System

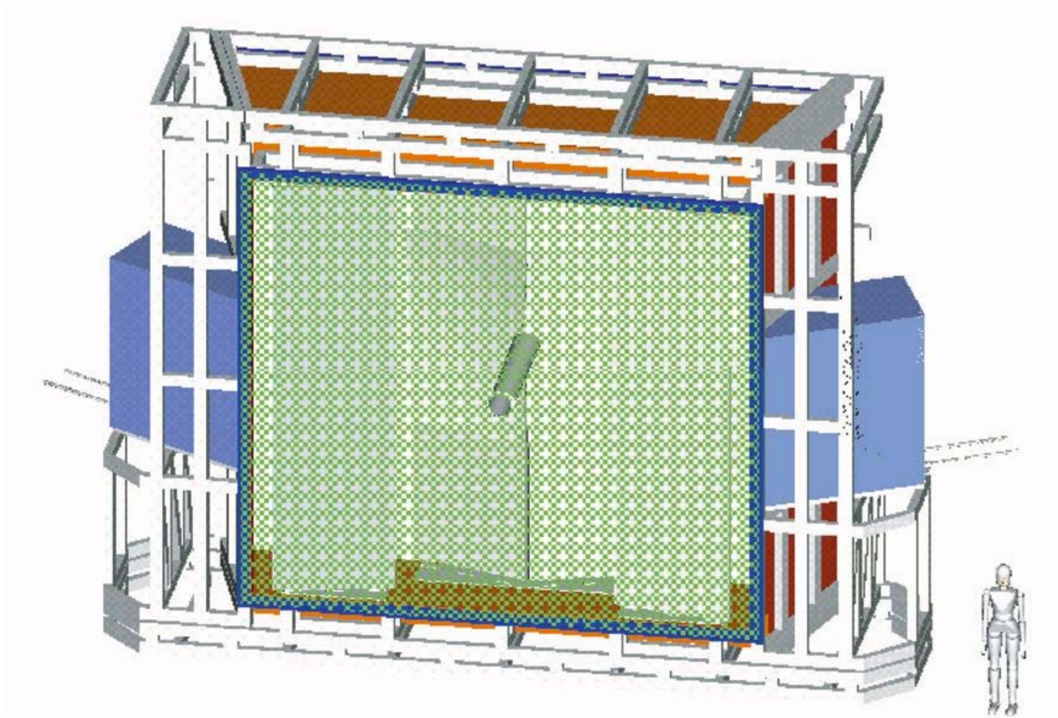
mechanics and radiator

RICH1



aerogel and C_4F_{10}

RICH2



CF_4

Photon detector: Hybrid Photo Diode

RICH2 mechanics

gas enclosure and
spherical mirror support

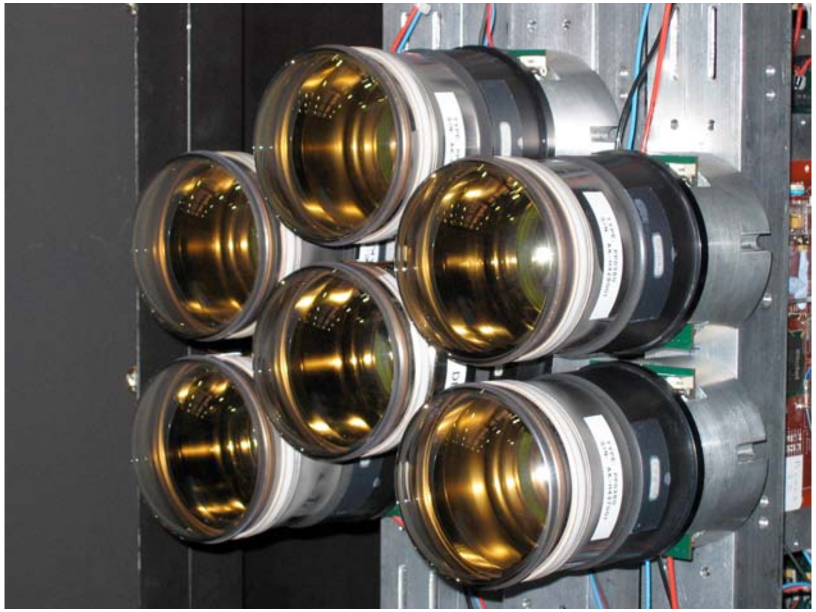
mounting of the front window

RICH1 mechanics

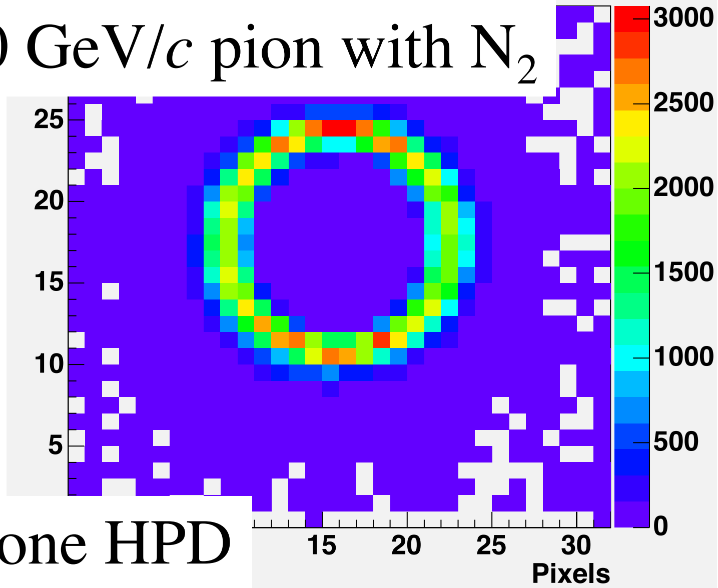
Engineering Design Report completed
HPD shielding box ordered
Schedule is tight → extra manpower has been injected

HPD

6 preproduction HPD's have just been tested in beam.

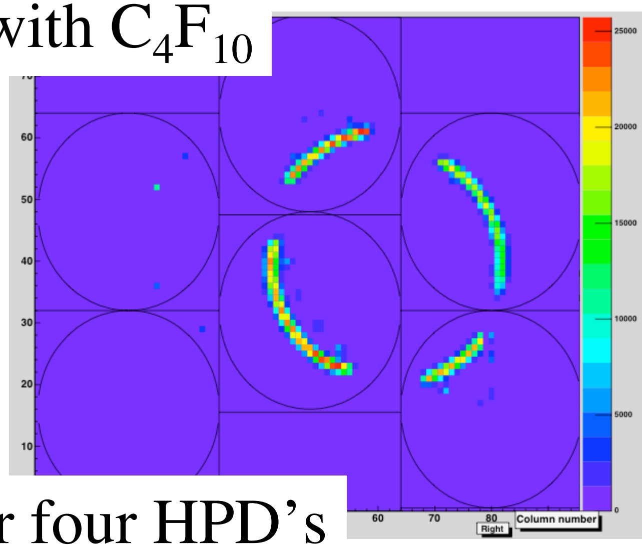


10 GeV/c pion with N_2



in one HPD

with C_4F_{10}



over four HPD's

Remaining issues before the HPD mass production

Technical problems with the sensor processing, never had before.

Compared with prototype Si sensors:

1) introducing SiO_2 passivation (front side)

photo-resist peels off (metallography)

no bump-solder deposit possible

→ Photo-resist sticks with an additional Ti/W coating

2) change of the Al sputtering machine at sub-contractor (back side)

back side Al peels off (quality control?)

no grounding possible

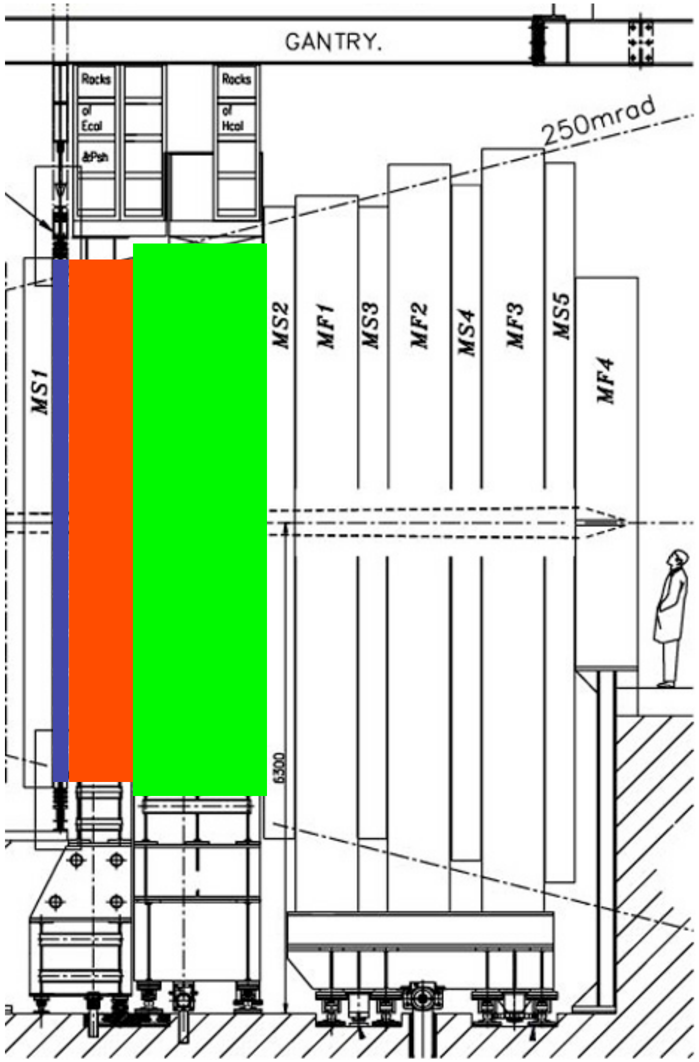
→ Sputtering redone at the bonding factory works fine

We believe that solutions are found

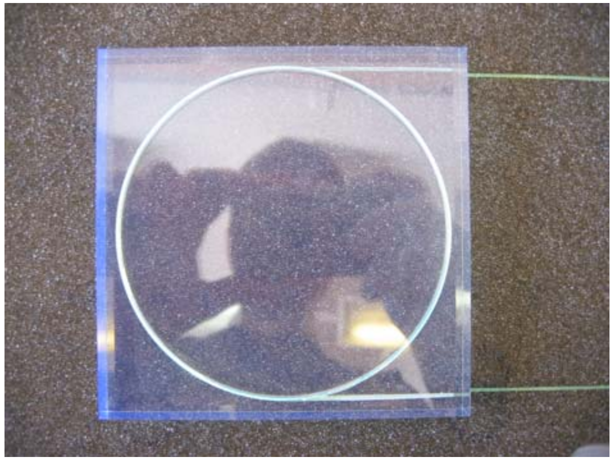
A couple of months delay has been introduced: as soon as the production starts, work out the overall plan→early next year.

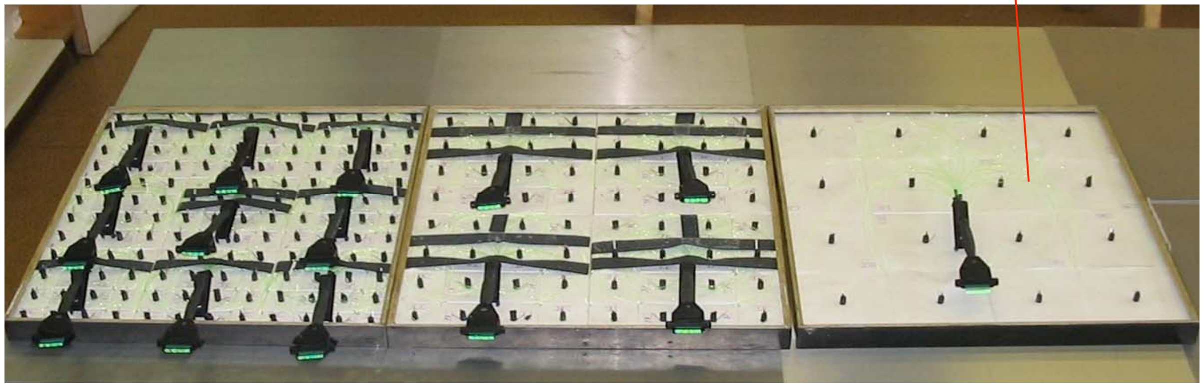
6) Calorimeter System

Scintillator-Pad-Detector, Preshower Detector,
EM-Calorimeter and H-Calorimeter



Preshower-SPD: more than 50% of modules completed (outer region)





PS supermodules

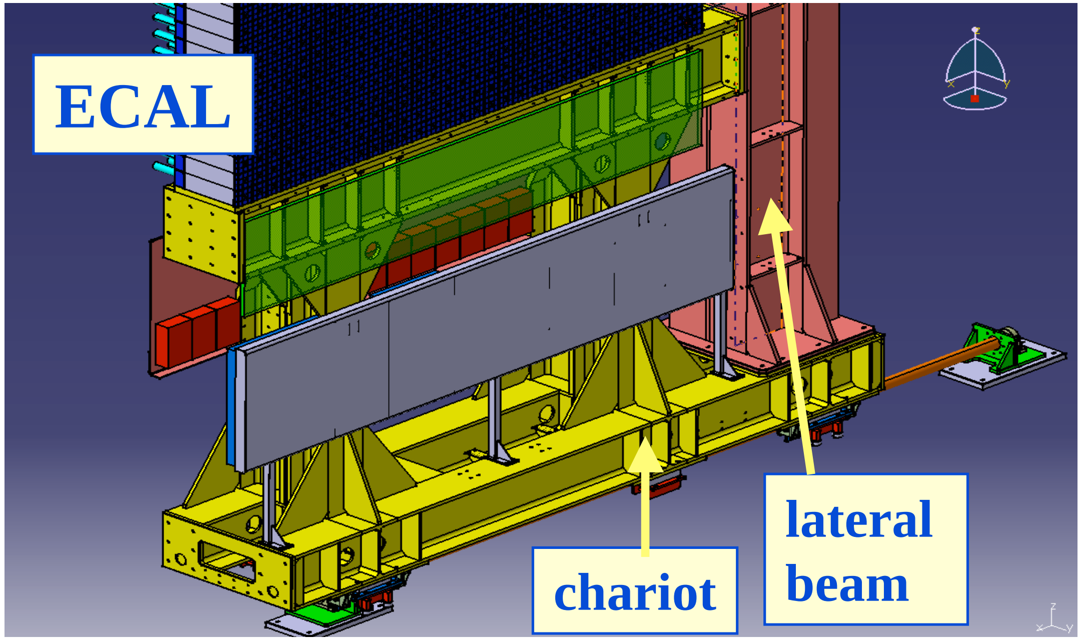
Ecal: 100% completed and being tested with the cosmic rays at CERN

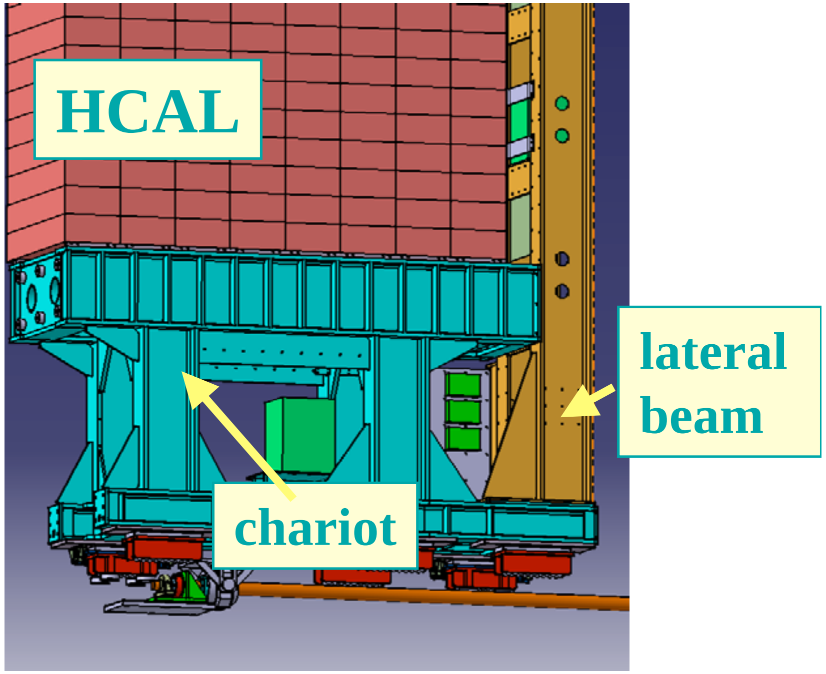
Light output variation between different modules is better than 8%.

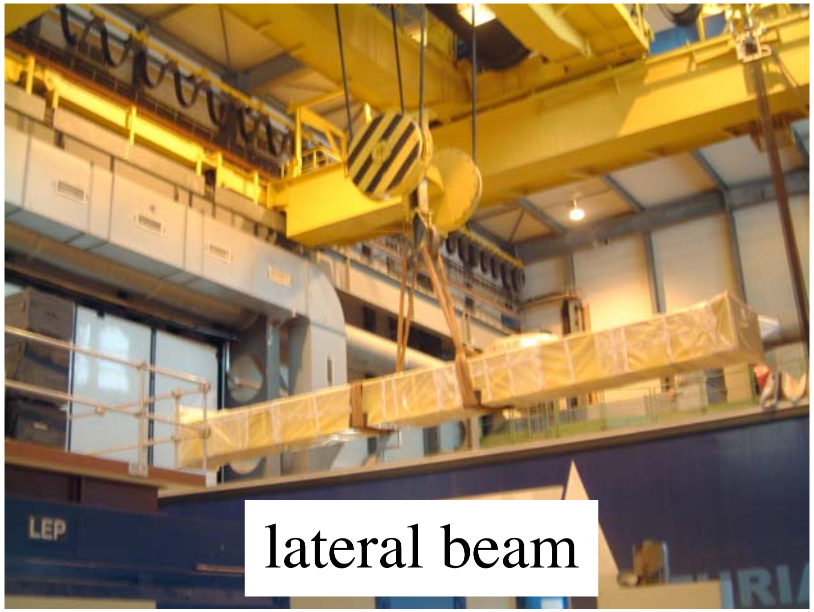
Hcal: 96% completed and being tested with ^{137}Cs at CERN

r.m.s. of light output from different scintillators in one module is only 4.7% in average.

support structures have been designed, constructed and arriving

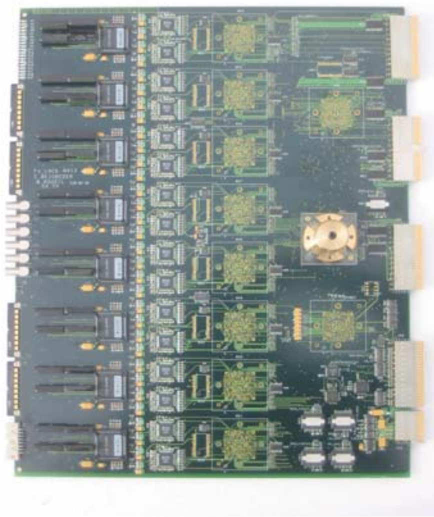






Calorimeter front-end electronics

Front-end cards for ECAL/HCAL and SPD/Preshower
using antifuse FPGA's have been fully prototyped and debugged.



However, recently reprogrammable FPGA's which can be used in radiation environment have become available

→ introduces 2 to 3 months delay

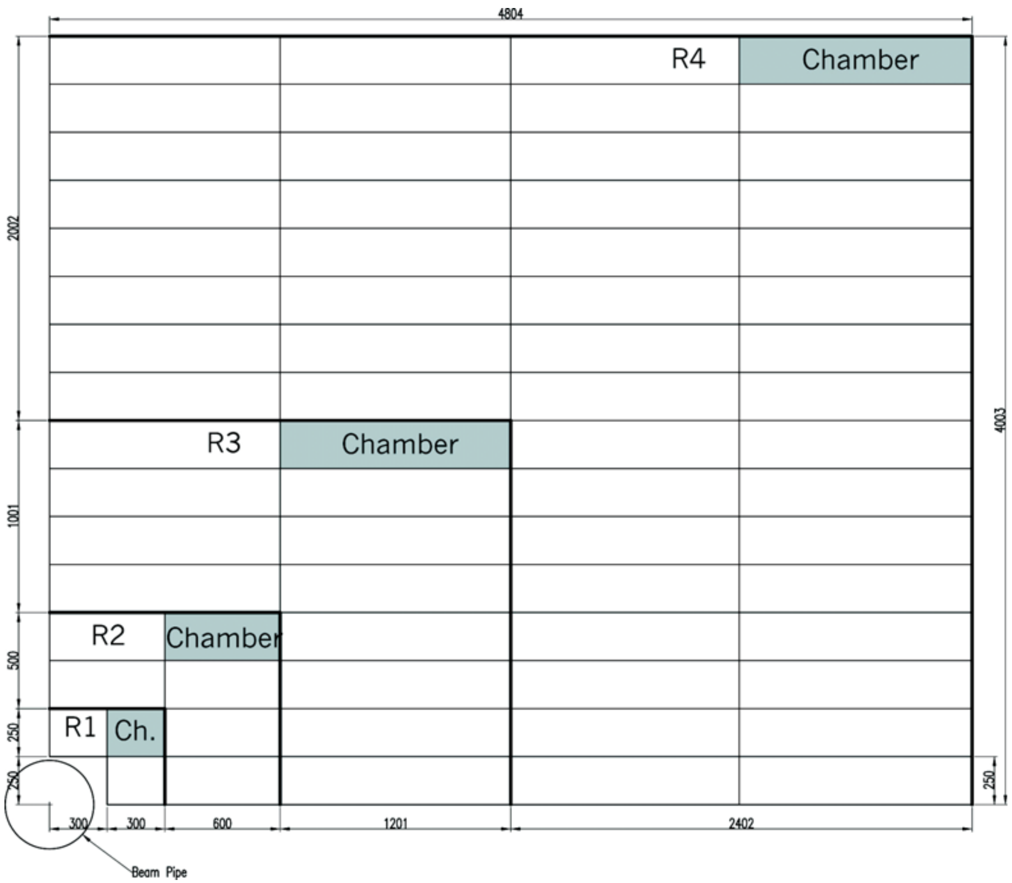
but large gain in flexibility

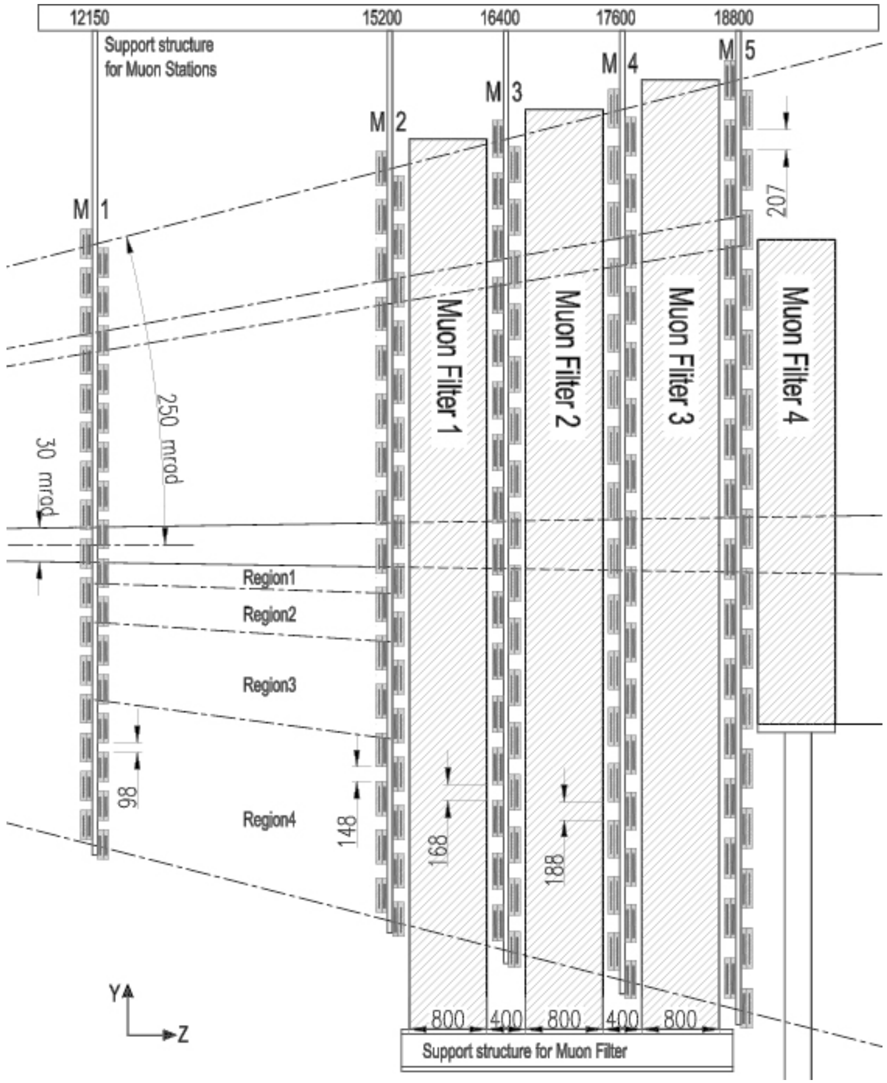
(details will be reported in January)

7) Muon System

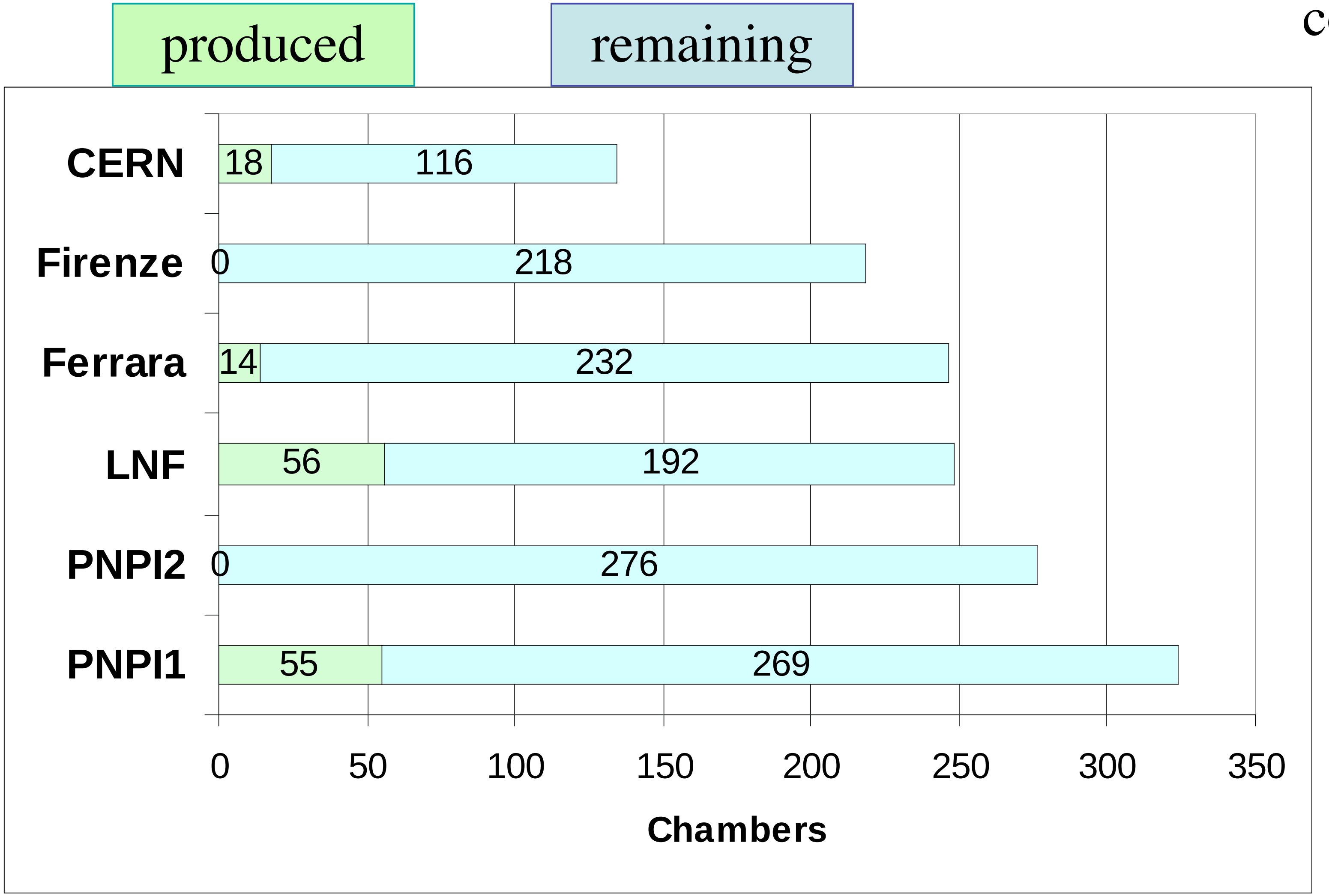
five stations with a pointing pad geometry in four regions

1368 MWPC's
12 GEM's for M1R1
+ spares





Chamber production in five sites:



expected completion date

Site	expected completion date
CERN	1.12.05
Firenze	23.02.07
Ferrara	22.05.07
LNF	29.11.06
PNPI2	11.06.06
PNPI1	14.04.06

10% milestone reached with 7.5 month delay

Enough chambers will be ready to start installation in 01.06

however not possible to complete by end 06 with current plan

main problem is manpower for production and testing

By March 2005, we should have enough experience in all sites to make a firm prediction:

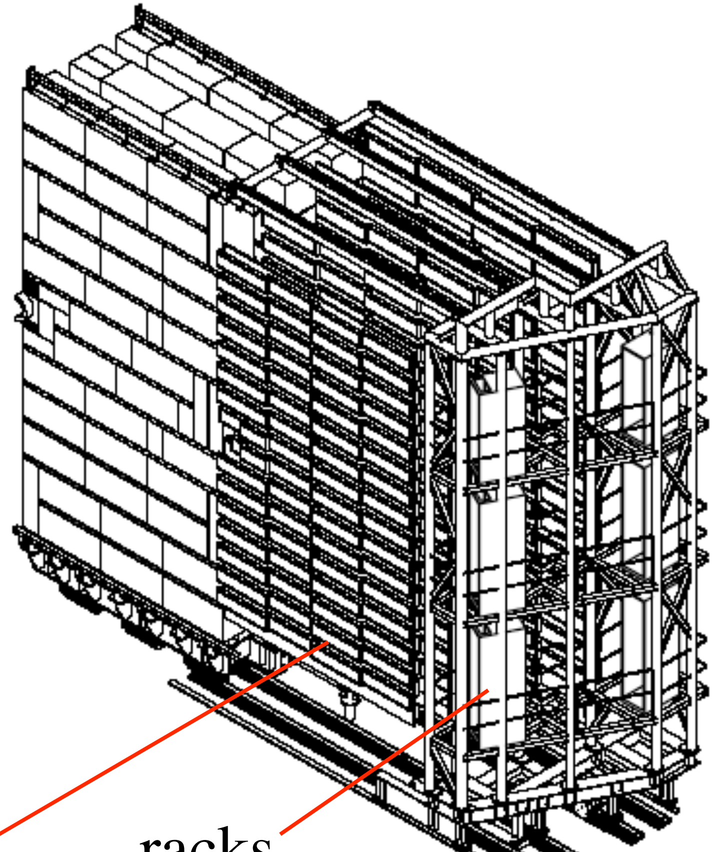
→ a scenario ensuring physics in 2007 will be worked out

Muon filter construction advancing well

one layer/week

completed by the end of 04

chamber and rack support structure

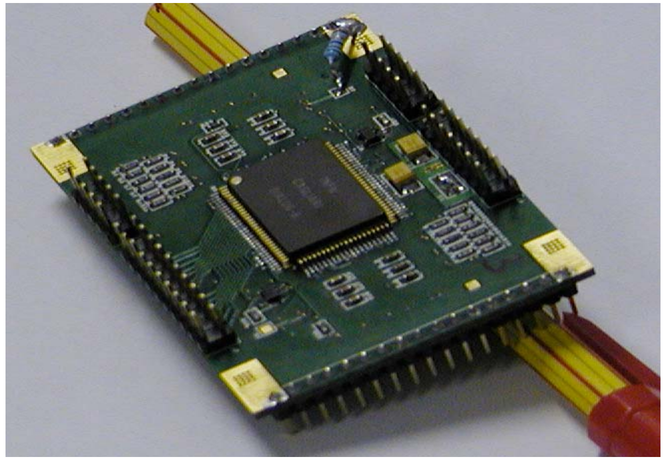


racks

chambers

EDR completed

Muon readout chain



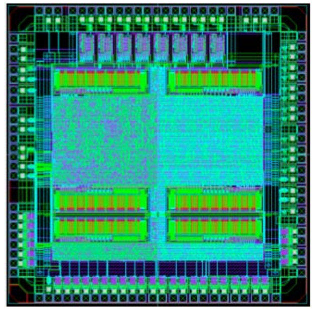
Chambers

FE-boards
Carioca chip: amplifier discriminator
DIALOG chip:
logical OR of the 2 double-gaps

LVDS links of ~12m length

Racks on the sides of the muon system

Intermediate boards
Required in some regions where the logical channels go across chambers.



ODE-boards
SYNC chip containing the L0-pipeline and time adjustment

Optical links of ~100m length
(with an intermediate patch panel on the balconies behind M5)

Electronics barracks

Tell1, originally developed for VELO now also adopted by TT, IT, OT,Calorimeters, L0 trigger and Muon

three types of chips from the engineering run are now being evaluated.

III) Trigger

Level-0

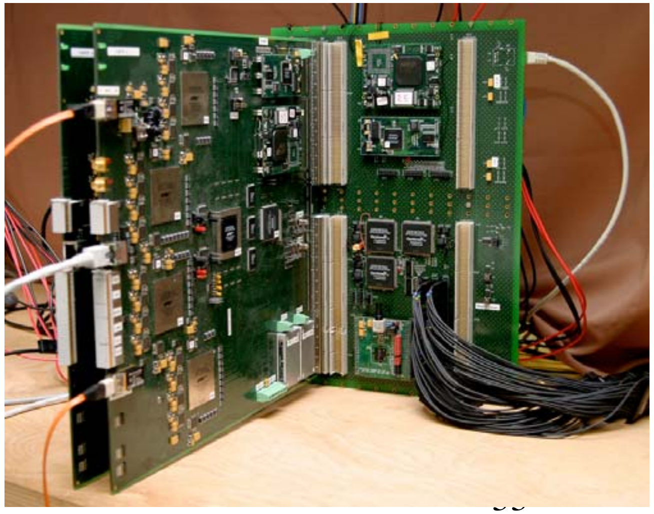
Input rate = 40 MHz bunch crossing → 1 MHz accept

High p_T h, e, γ, π^0, μ
pile-up information
→ L0 decision

custom made electronics (Calo, Muon, Pile-up, L0 Decision Unit)

Completing the prototype validation

Calorimeter Trigger; Production Readiness Review 2Q/2005
Muon Trigger; PRR 4Q/2005
Pile-up ; PRR 4Q/2005
L0 Decision Unit; PRR Q4/2005



Muon processor card

Level-1

Input rate = 1 MHz Level-0 accept → 40 kHz accept

p_T of 2 tracks with large impact parameters
single lepton with large IP and p_T
single γ with large p_T
dimuon

→ L1 decision

CPU farm common with High Level Trigger (VELO, TT, L0)

Improving the selection algorithms

efficiency on offline selected events

$B^0 \to \pi^+ \pi^-$	63%(TDR) → 81%
$B_s \to D_s K$	63%(TDR) → 81%
$B_s \to J/\psi\, \phi$	71%(TDR) → 87%

speed

with 1 GHz Pentium III	8.3 ms(TDR) → 5 ms*)

*) this is already within the allocated time budget with 2007 CPU

High Level Trigger

Input rate = 40 kHz Level-1 accept → event store rate
selections using all the detector information

CPU farm (all the detector)

Baseline selection

Exclusive B decay reconstruction modes e.g. given in TDR
work in progress, trigger rate is a few Hz for each decay mode,

i.e. 200Hz appears to be sufficient for them.

Recent development

We realised that J/ψ and D^0 are important for detector calibration,
a lesson from the Tevatron experiments

$J/\psi \to \mu^+\mu^-$ (well defined mass with two muons)

easy channel to trigger and reconstruct

→ dimuon trigger without impact parameter cuts

-Calibration of the absolute momentum (alignment, B field, dE/dx, etc.) then control it with $\psi(2S)$, $\Upsilon(1\text{-}3S)$ and Z^0

-Vertex resolution (prompt J/ψ)

-Control of the proper-time calibration ($B^+ \to J/\psi\, \pi^+$, $B^0 \to J/\psi\, K^{*0}$)

Signal rate

$L0 \times L1 \times$Offline reconstruction = 170 Hz of J/ψ signal

Trigger rate if

$L0 \times L1 \times$HLT ($m_{\mu^+\mu^-} \gtrsim J/\psi$ mass) = 600 Hz

$D^0 \to K^-\pi^+$ (well defined mass with two hadrons)

a good source for absolute momentum and PID calibration

and calibration of detector simulation for lifetime measurements.

Signal rate

$L0 \times L1 \times$Offline reconstruction ≈ 50 Hz of $D^{*+} \to \pi^+ D^0(K^-\pi^+)$

Trigger rate

$L0 \times L1 \times$HLT($D^{*+} \to \pi^+ D^0 \to h^+h^-$) = 300 Hz

and they also address interesting physics

b-hadron spectroscopy and lifetimes

$B_c \rightarrow J/\psi\pi$, $\Lambda_b \rightarrow J/\psi\Lambda$, $\Xi_b \rightarrow J/\psi\Lambda K_S$ etc.

if D^0 is tagged by π^+ from $D^{*+} \rightarrow \pi^+ D^0$

D-$\overline{D}$ oscillations

CP asymmetry in K^+K^- to a 10^{-4} level

NB: 50 M $D \rightarrow K^+K^-$ might be collected in 10^7s

(systematics is of course the issue)

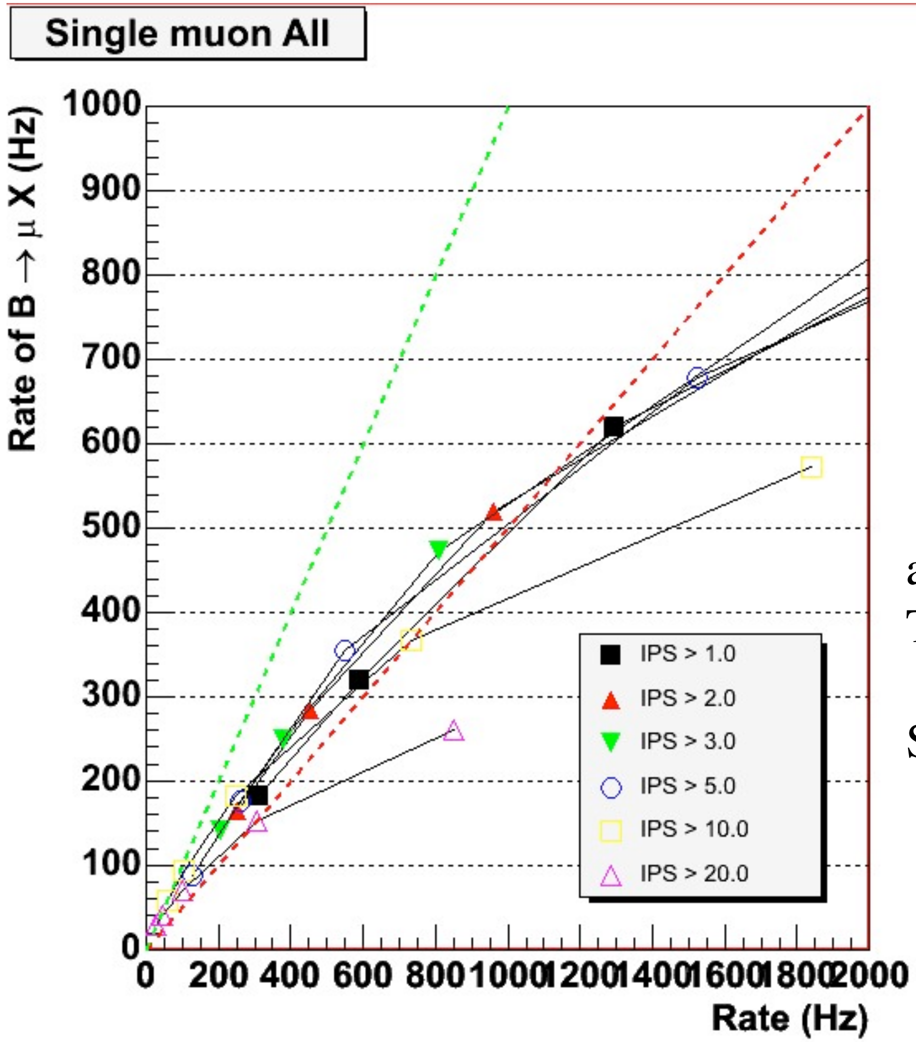
Another interesting possibility is

inclusive μ trigger with p_T and impact parameter cuts

triggering on $b \to \mu X$

simple trigger and other b-hadron unbiased

may be useful for the initial phase...



an example

Trigger rate

L0×L1×HLT(p_T>2GeV/c, IP>0.15mm) = 2 kHz

Signal rate

true $b \to \mu X$ events and m detected ≈ 800 Hz

Where do we stand?

Well motivated exclusive final state trigger	
B exclusive decays for TDR physics	200 Hz
dimuon ($m_{\mu^+\mu^-} \gtrsim$ J/ψ mass)	600 Hz
$D^* \rightarrow D^0\pi$	300 Hz
An additional trigger for unbiased b sample	
high p_T, high IP μ trigger	up to ~2 kHz

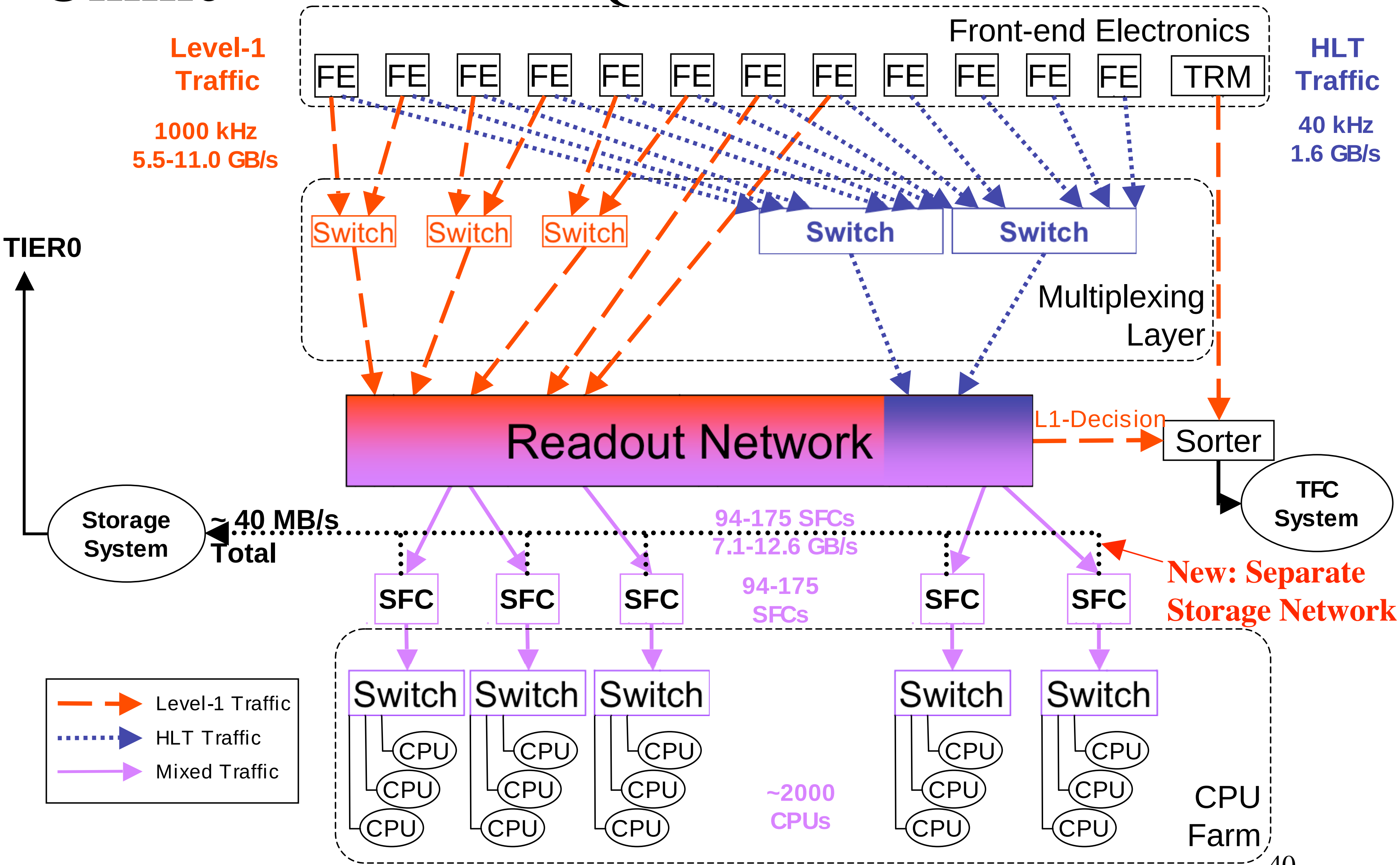
A sensible combination must be made to maximise physics within the available computing resources.

Desirable to have a flexible computing model which is scalable and able to accommodate different scenarios.

IV) Computing

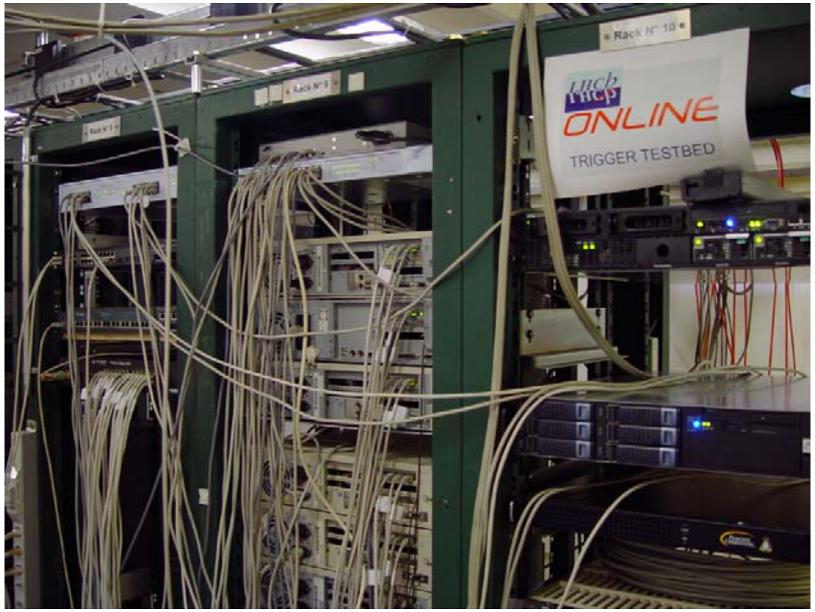
Online

DAQ architecture



DAQ has no limitation for a data storage rate of ~2 kHz

Testbed setup with two complete subfarms (2×23 Processors)



Ethernet Cabling in the barracks starts end 11.04

~3000 connections, ~300 patch panels

Optical Fibers from computer room to barracks will be done in 01.05

Experiment Control System software status

Configuration Database

-TFC system implemented including connectivity and paths

-navigation and visualization tools developed

PC farm monitoring & control

-monitoring of PC information within PVSS implemented

-control of running processes

-first prototype will be available at CERN soon.

Offline Computing

Software framework, GAUDI, based applications are in place for
detector simulation
event reconstruction
event analysis
however, consolidation with the ongoing development needed.

Event store is done by the LCG product, POOL

Strategy development for detector alignment and calibration started

Data Challenge 04
Phase-1 (MC production and reconstruction) completed
close collaboration with the LCG deployment team finally resulted in reaching to a stage where 3500 jobs concurrently running in LCG sites with an average of 61% efficiency

-due to a problem with the random number seed, only 16’777’216 unique events (24 bits). Now this is fixed and start some new generation-

Phase-2 (Fast event selection) just started
delayed due to adaptation of LHCb software to LCG and SRM (LCG software for mass storage access) not being ready

Evolution of the LHCb computing model

At the time of "Hoffmann review", we thought

- $b\bar{b}$ inclusive MC events were important to understand background
- for the real data, only events with exclusive B decay final states should be recorded

→ MC sample dominating the computing need

However now, we think

- no way to generate enough statistics to understand background in a generic way
- MC events are important to understand signal acceptance and specific background, as before
- real data must be used as much as possible to understand all the systematic effects and to tune the simulation

→ much less $b\bar{b}$ inclusive MC events needed
→ much more data such as J/ψ and D^0 needed

CPU and storage requirements would change
→ consequence is being studied

essential for the Computing TDR in 2005

IV) Coming Installation

•**Electromagnetic Calorimeter**	
•Support	January ‘05
•modules installation	February ‘05
•**Hadron Calorimeter**	
•Support	February ‘05
•modules installation	March ‘05
•**RICH 2**	August ’05
•**Preshower & SPD, lead & super-modules**	December ’06
•**Outer Tracker, structure and detector**	November ’05
•**Vertex Locator**	
•Vacuum vessel	November ‘05
•Sensors	October ‘06
•**RICH 1**	
•Shielding box	April ‘05
•Gas enclosure	November ‘05
•**Inner Tracker**	
•First box	February ‘06
•Remaining sensors	June ‘06
•**Trigger Tracker**	June ’06
•**Muon chamber installation**	January ’06
•**Beam pipe installation**	
•UX1&2	April ‘06
•UX3&4	May ‘06
•Bake out & commissioning	August ‘06

V) Conclusions

Good achievement made for the construction of many subsystems:

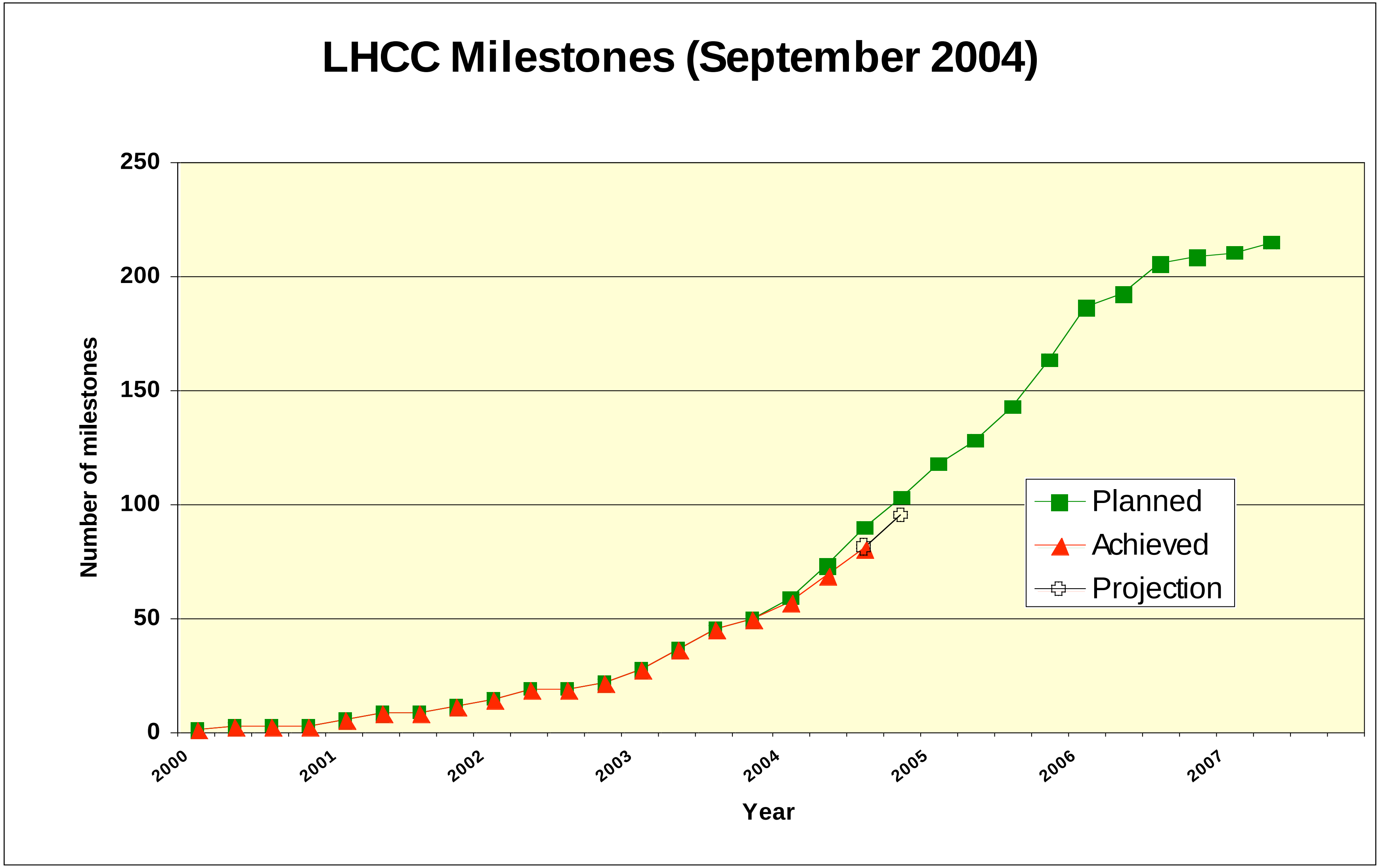
-Beam pipe, Magnet, RICH2 mechanics, Calorimeter system, and Online system are progressing well.

-Outer Tracker, RICH1 mechanics, HPD and VELO are also making good progress, however with tight planning.

-We are looking forward to seeing the production of the Trigger Tracker and Inner Tracker start as planned. A major concern is how to solve the conflict with CMS on the delivery schedule for the TT sensors.

-Production of the Muon chambers is facing a substantial delay. Necessary action will be decided in March 2005 when we expect to have all the information needed.

-Need on computing resource is evolving and its effect on computing model is being investigated.


LHCC Milestones (September 2004)
250
200
150
100
50
0
Number of milestones
2000
2001
2002
2003
2004
2005
2006
2007
Year
Planned
Achieved
Projection