Status of the LHCb Experiment

LHCC open session at CERN
16 November 2005

on behalf of the LHCb Collaboration

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CERN
and
EPFL

Contents

I) Status of the Collaboration

New Collaborator

Syracuse University (USA), funded by NSF and the university
It was one of the leading members of the BTeV experiment
6 PhD equivalent, many with long B physics experience

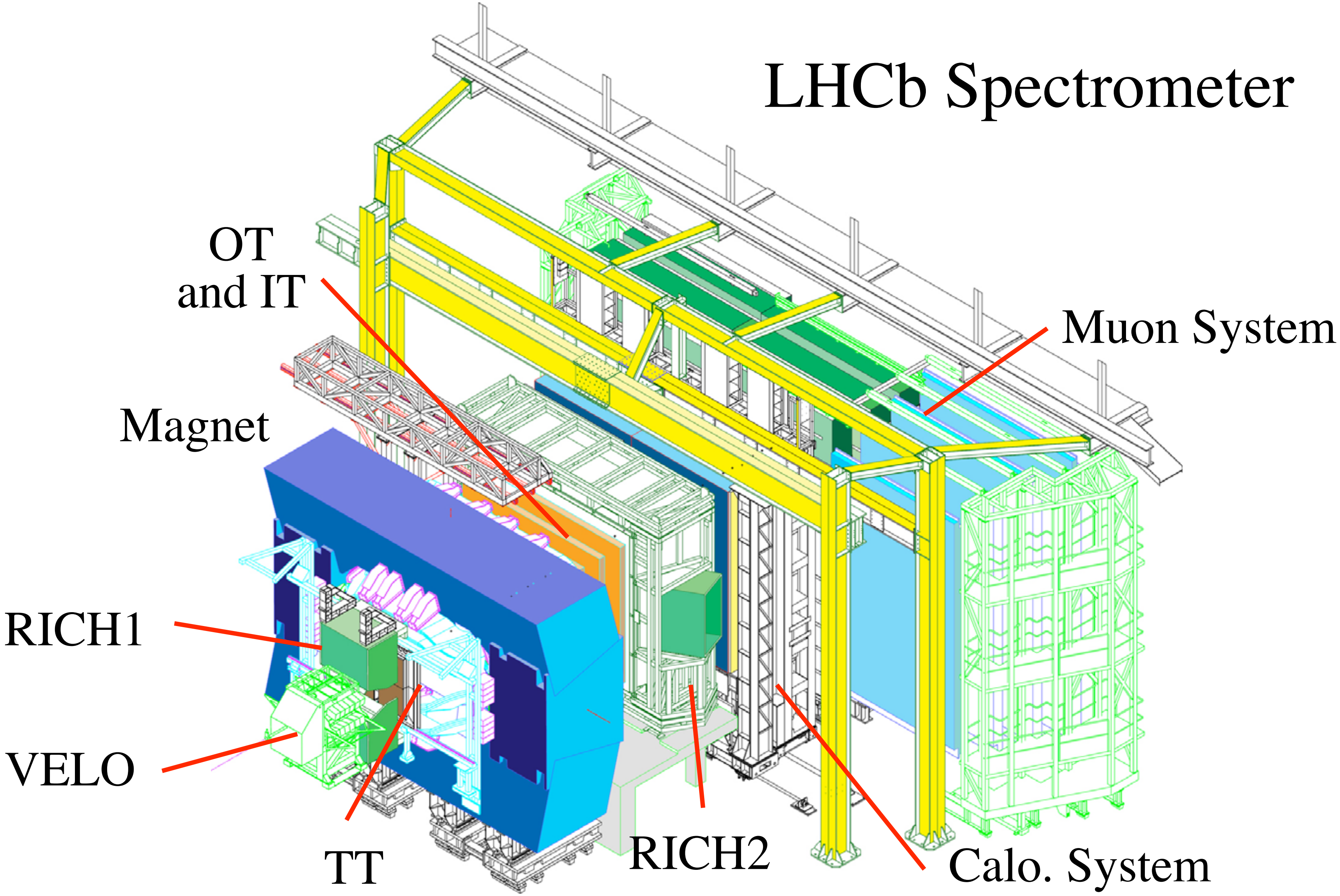
Due to the Congressional restriction, not able to fund the current detector construction:

Contributing to

→ Global alignment, trigger monitoring, analysis framework
VELO R&D and test beams and HPDs in the B field
CPUs for the event reconstruction farm in Pit-8

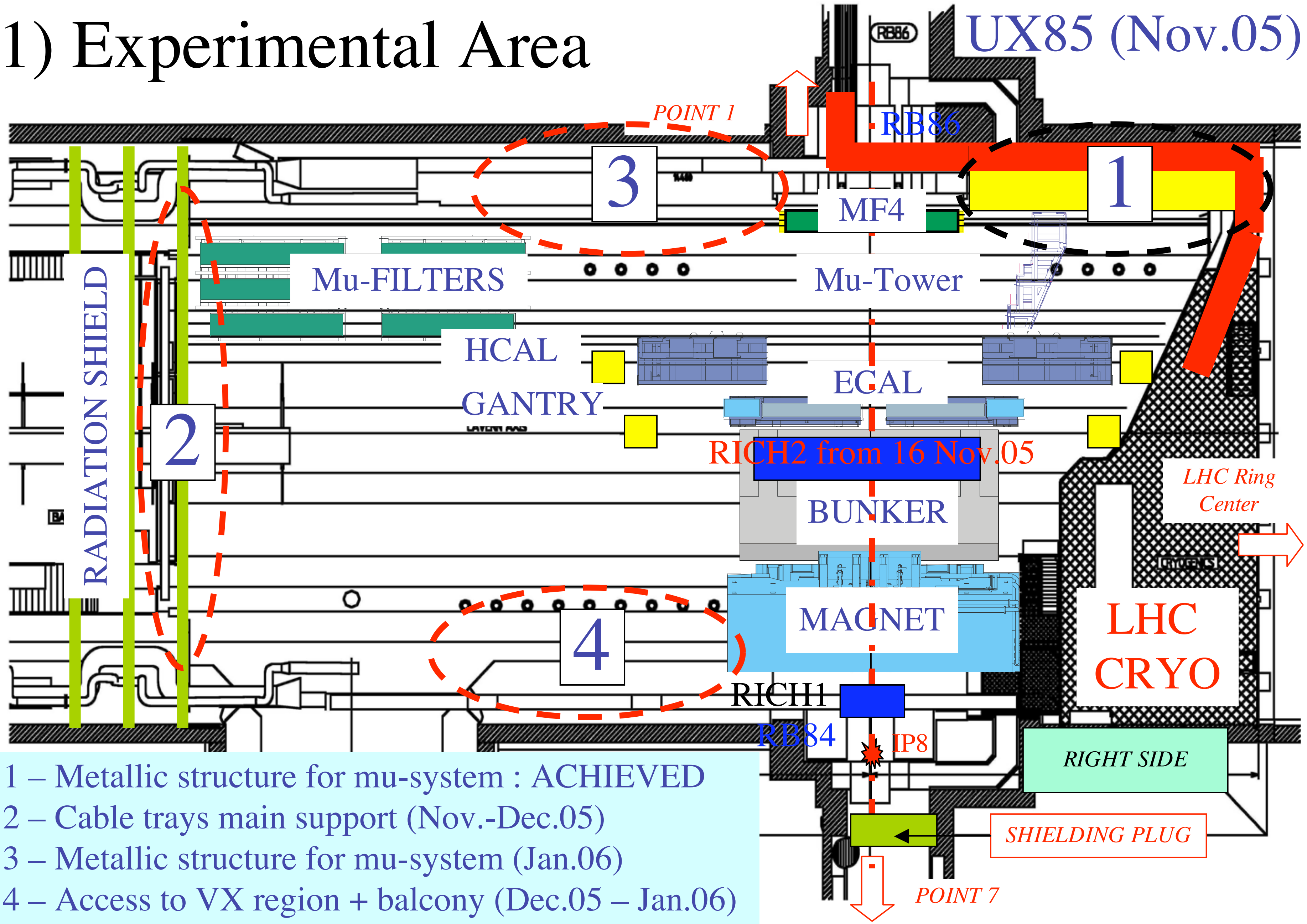
Now 14 countries with 47 institutes

II) Construction Status



1) Experimental Area

UX85 (Nov.05)



1 – Metallic structure for mu-system : ACHIEVED
2 – Cable trays main support (Nov.-Dec.05)
3 – Metallic structure for mu-system (Jan.06)
4 – Access to VX region + balcony (Dec.05 – Jan.06)

Machine work: Cryo-line installation above the M4 filter completed and scaffolding finally taken away

⇒introducing a delay of ~3 months to the LHCb installation

revised plan is in preparation

Metal structure for the muon system

Cryo line

Cohabitation with the machine

QRL Sector 8-7

- Cooling tests : Achieved until 19 October 05; now corrective actions are ongoing in various locations;
  + installation of the cryo-magnets;
  No longer major impact on the LHCb work

QRL 8-1 Junction

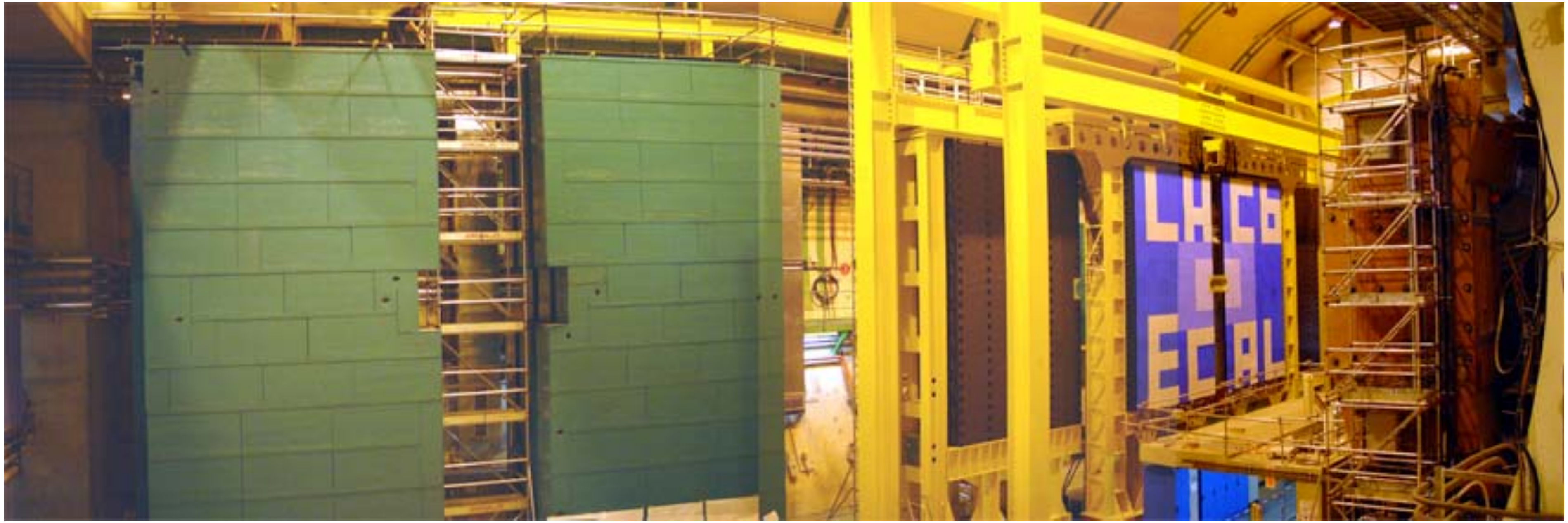
- Tightness tests : Achieved over September-October 2005.
- Dismantling of main scaffolding (RB86) : Achieved on 1st Oct.2005.
- Pressure tests : Achieved on 13th Nov.2005
- Cooling tests : Scheduled for week 47-48
  (affects the LHCb work only during the cool down time)

And Sector Test in November 2006

- Beam pipe to be installed and no LHCb detector installation work during the test (but to continue working behind the shielding wall)

Installation of RICH-2 delayed by 2 months: firstly due to the preparation and qualification of the lifting tool, then due to the availability of transportation from Hall-156
→Transport started last night to IP8, but...

⇒delay of B field measurement by ~1 month



2) Beam Pipe

needed for the sector test

-25 mrad Be section completed

-10 mrad Be
1st section being tested at IHEP, Protvino, small repair needed

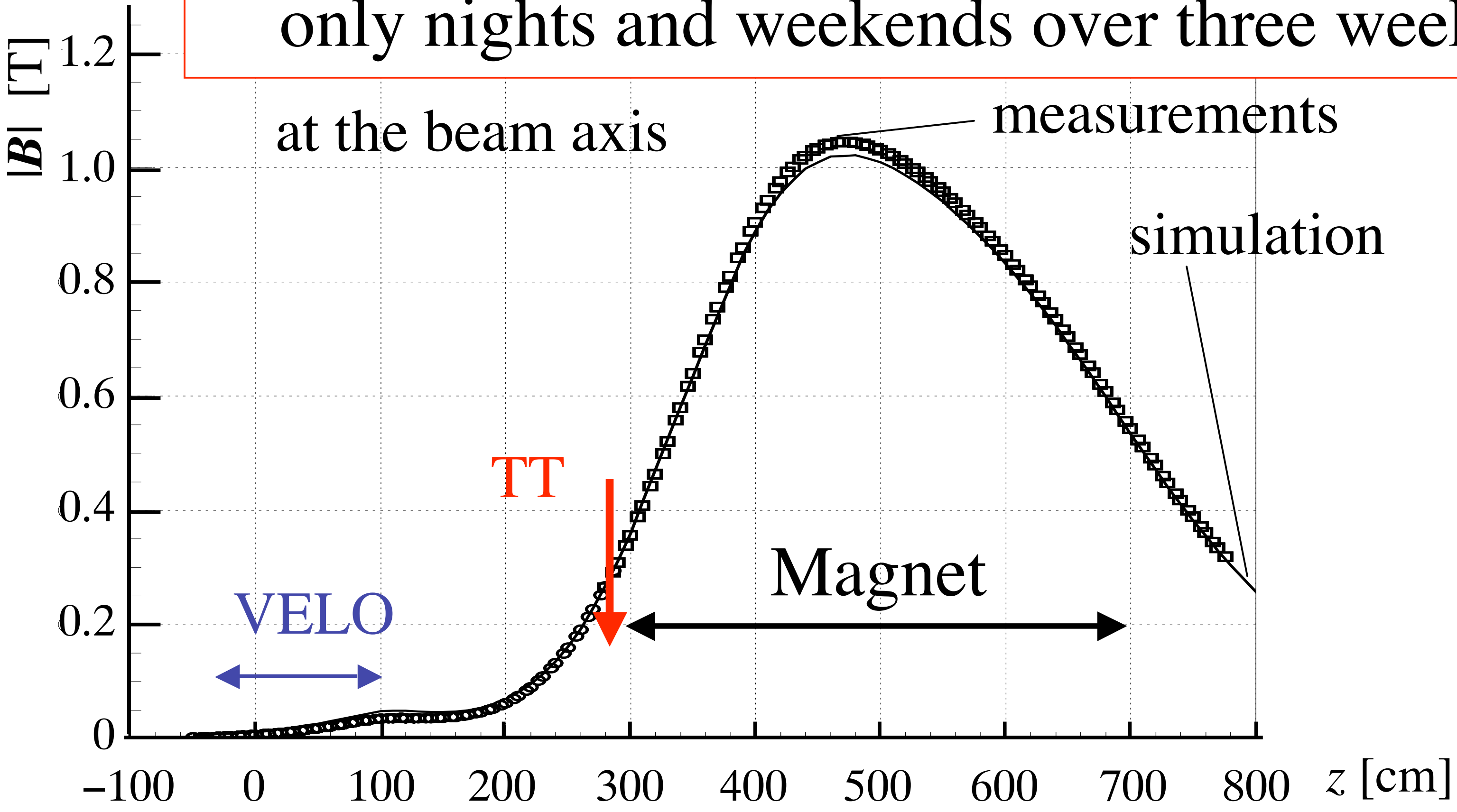
-10 mrad Be
2nd section under construction at Kompozit, Moscow

-One Al VELO exit window completed (two more to be made)

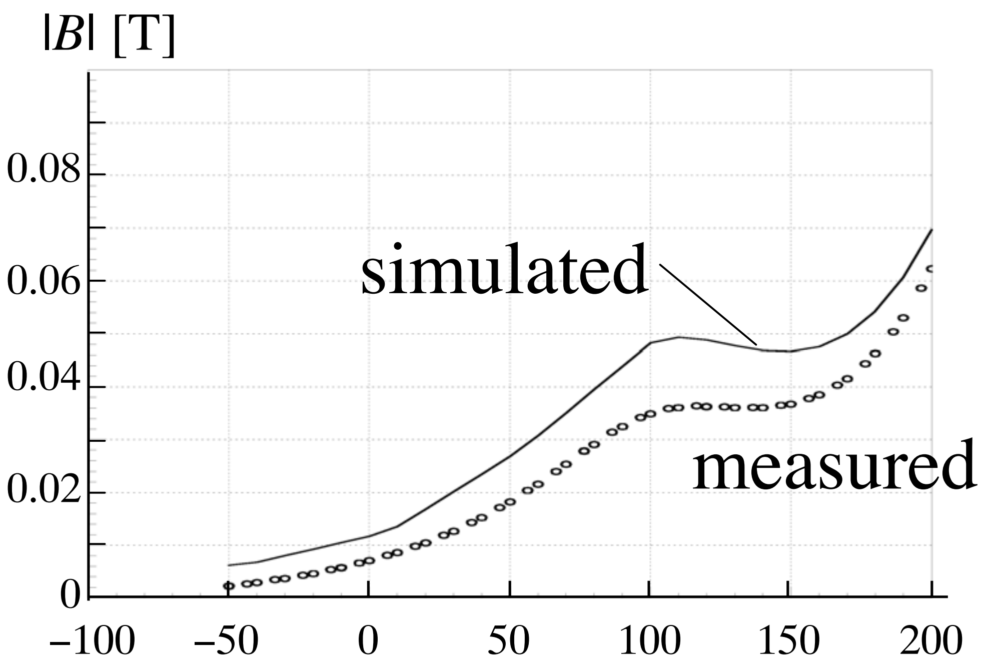
-Stainless steel section is close to completion

3) Magnet

First systematic B field measurement in June
only nights and weekends over three weeks

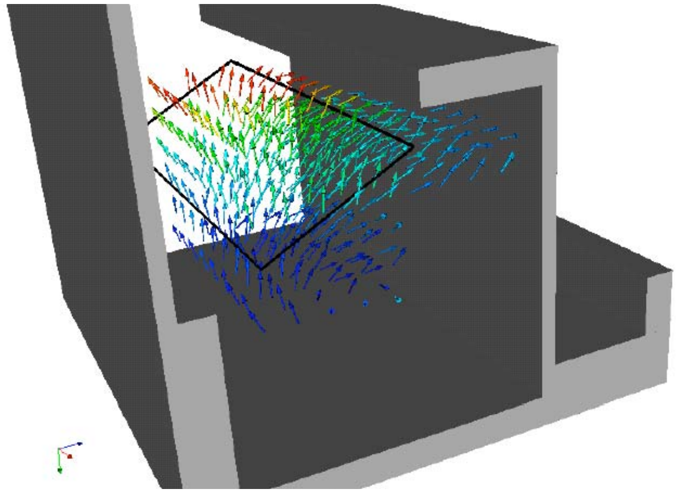


November: complete field map with all the iron structure around, day and night measurements
(with some improvement on the electric insulation of the coil)

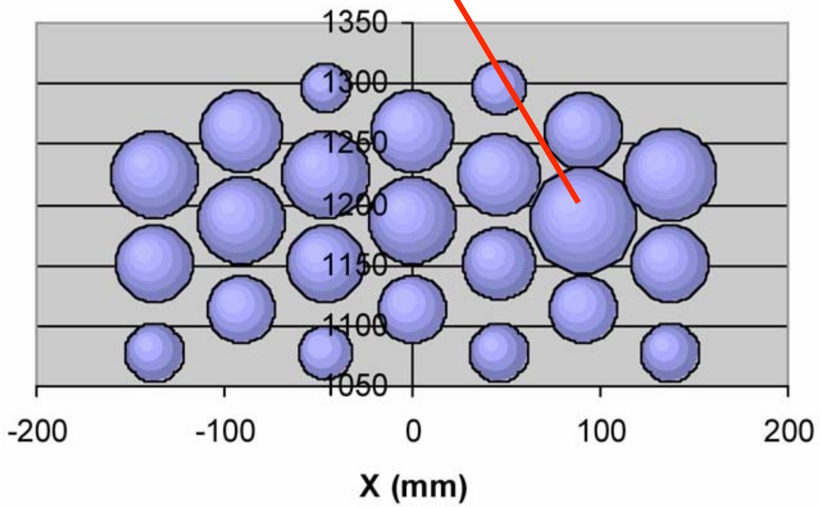


∫Bd*l* in VELO-TT lower by
20% compared to simulation
→ has to be taken into account
for the trigger studies

Inside RICH1 shielding box,
on the HPD plane with μ-metal

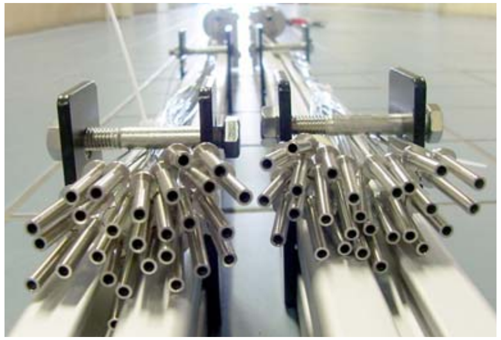


Largest circle 13.6 G
Smallest circles ~ 4G
Intermediate 7-10 G



Acceptable for
the HPD operation

4) VErtex LOcator



CO_2 cooling capillaries

vacuum feedthrough flanges

VELO tank installed in the support frame and connected to the vacuum system

rectangular vacuum bellows

detector rf box

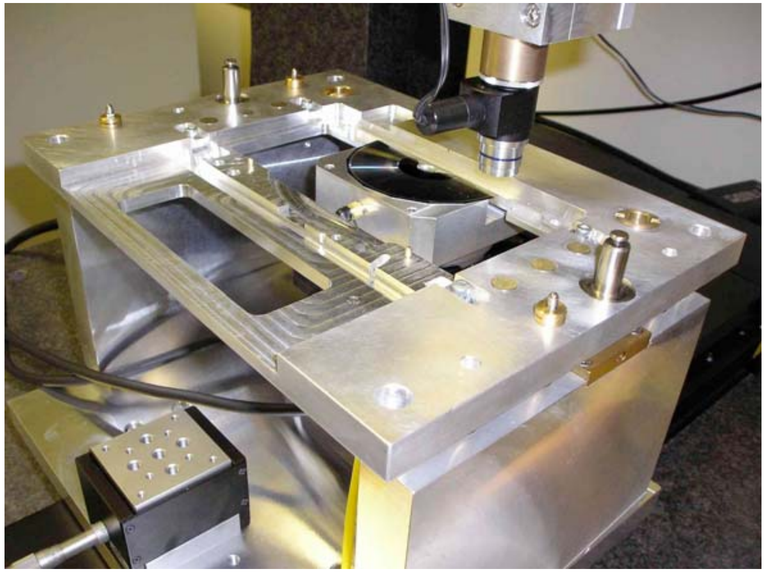
Start of the sensor module production delayed by 5 months due to

-problems with the pitch adapter and hybrid which were not present with their prototypes

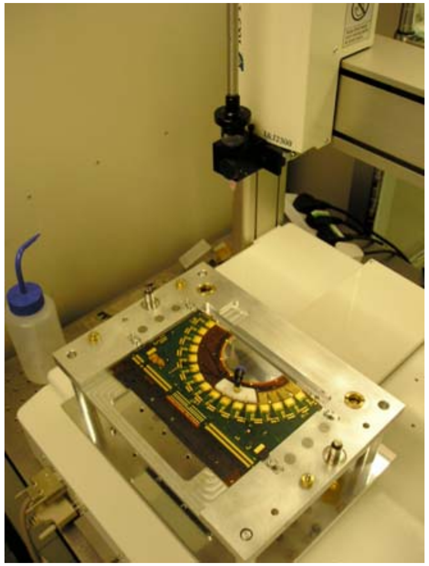
-longer time needed for design and preparation of tooling

Now ready to start ⇒ PRR in December

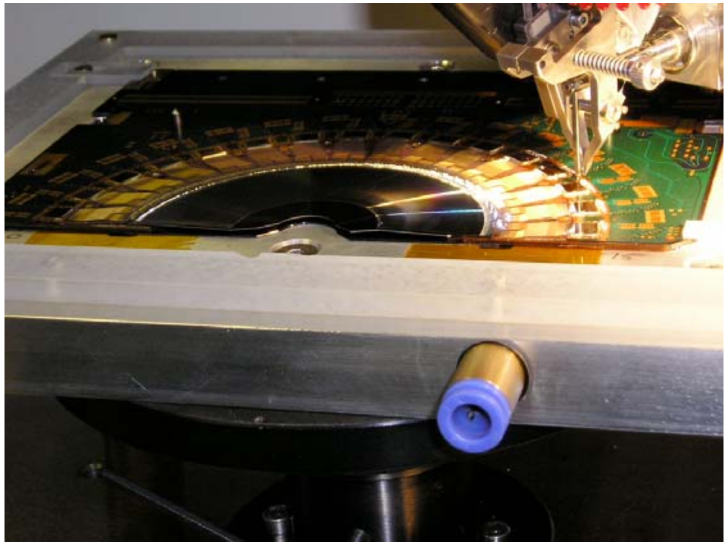
Production facility is well prepared



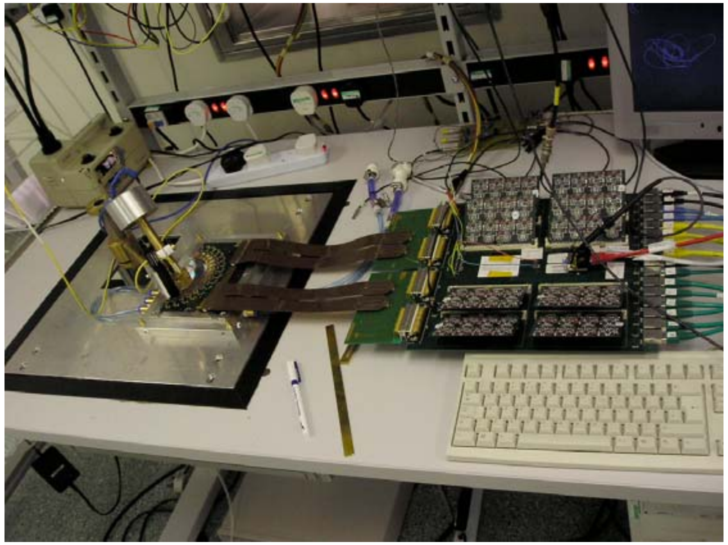
module assembly



glue dispenser



bonding machine



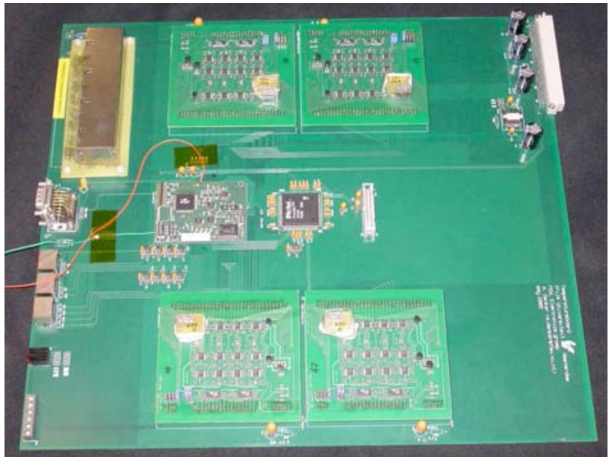
laser testing

Anticipated production rate, 2 modules/week still to be shown
Total of 42 modules are needed.
Modules will be mounted, surveyed and tested at CERN
before being installed in the vacuum tank.

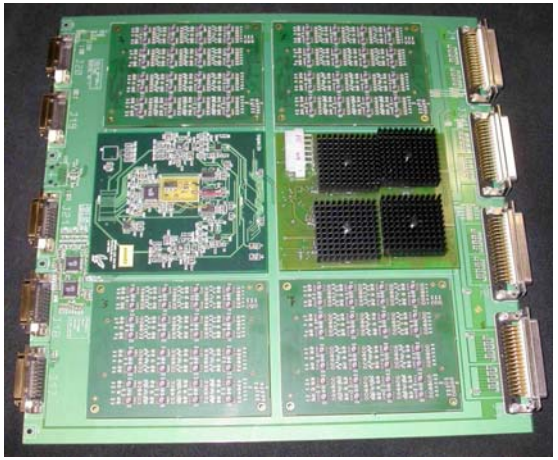
⇒ very tight schedule

Quality of the delivered sensors is good
Sensor delivery speed is still a concern
(20% of needed sensors in hand)

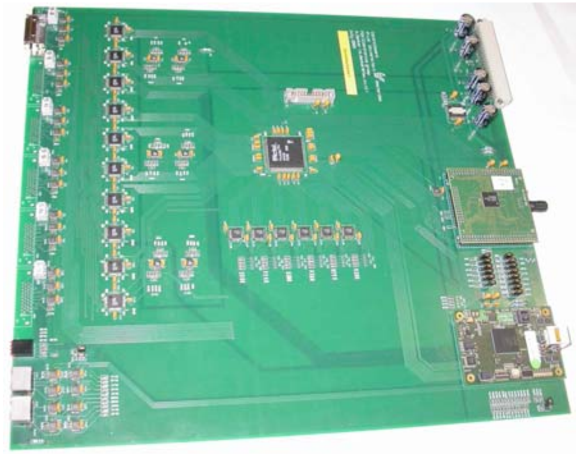
Preproduction of all the electronics cards has started



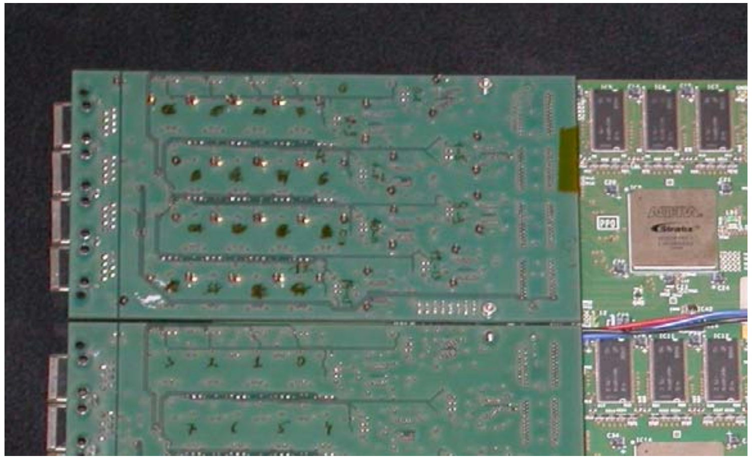
temperature card



repeater card



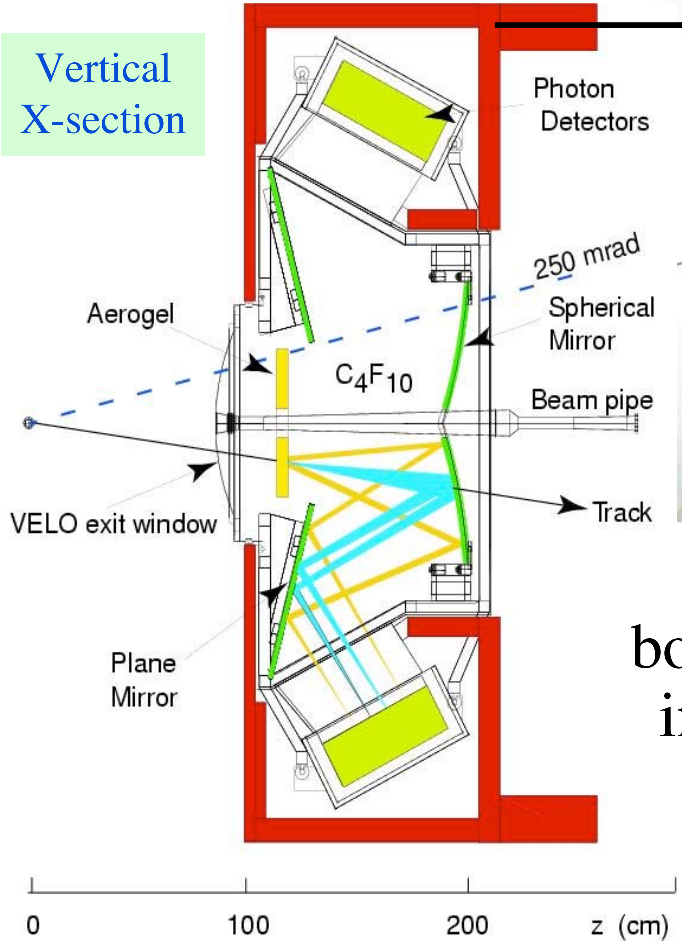
control cards

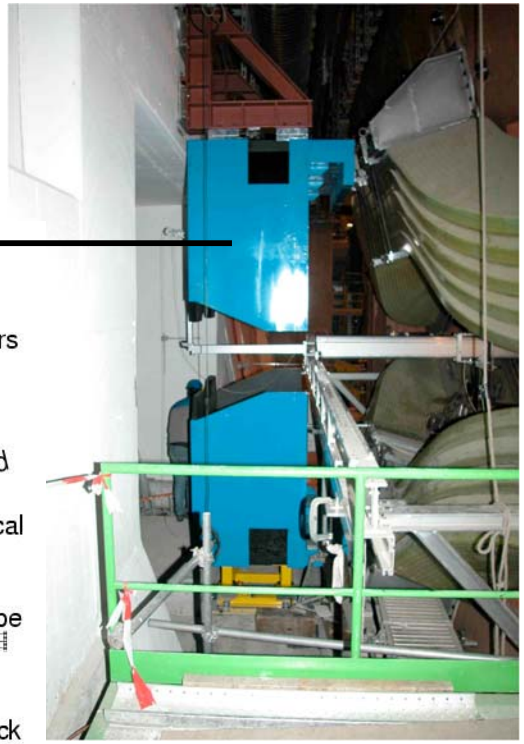


analogue ADC for TELL1

5) RICH

RICH1





HPD shielding
box aligned and fixed
in the final position

Gas enclosure box
produced and
will be delivered to CERN
early next year

Spherical Be mirrors (8)

Module 0

4 mm thick Be

<0.5 mm glass

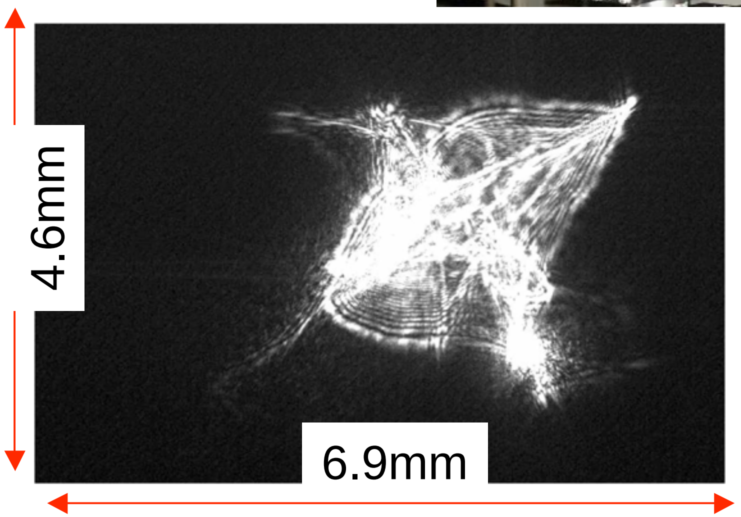
Optical quality is adequate

measured

$R \approx 2675$ mm, $D_0 = 3.33$ mm

specification

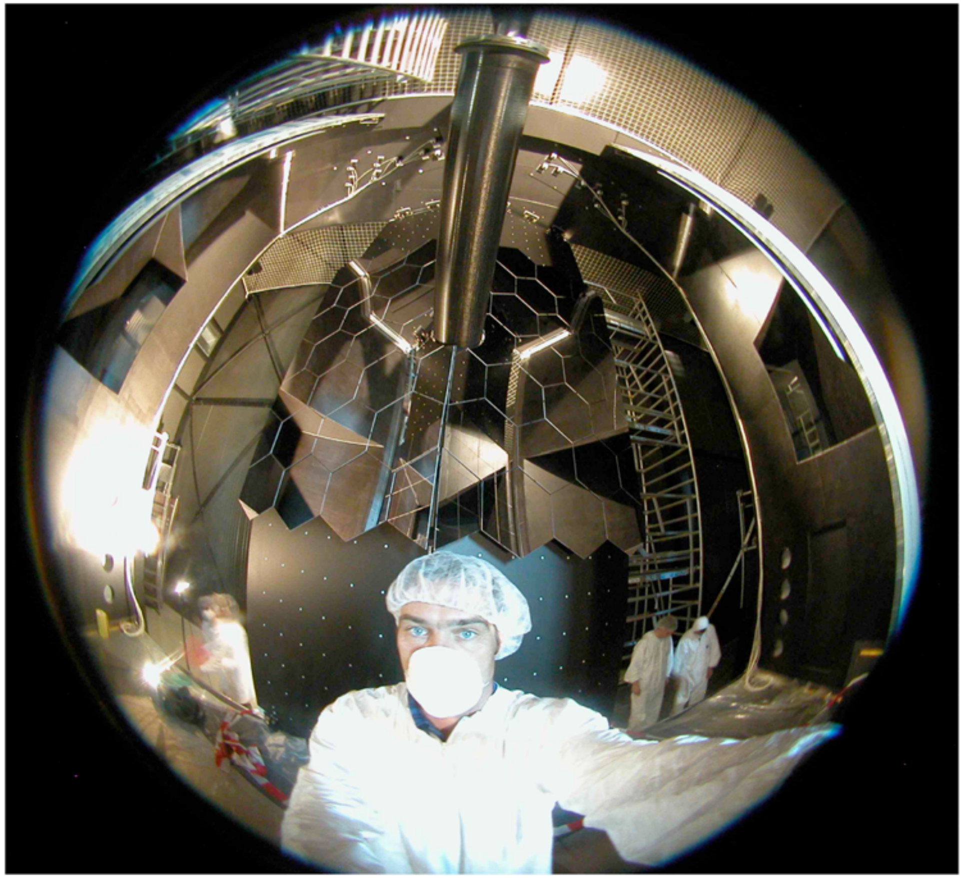
$R = 2700$ mm $\pm$ 1%, $D_0 = 2.5$ mm



spread of the focal point

ISTC contract with IHEP+
Kompozit (Be) and Vavilov
Technically feasible
but a logistic challenge
⇒very tight schedule

RICH-2



Spherical mirror alignment to 50μrad (spherical plus planar to 150μrad)

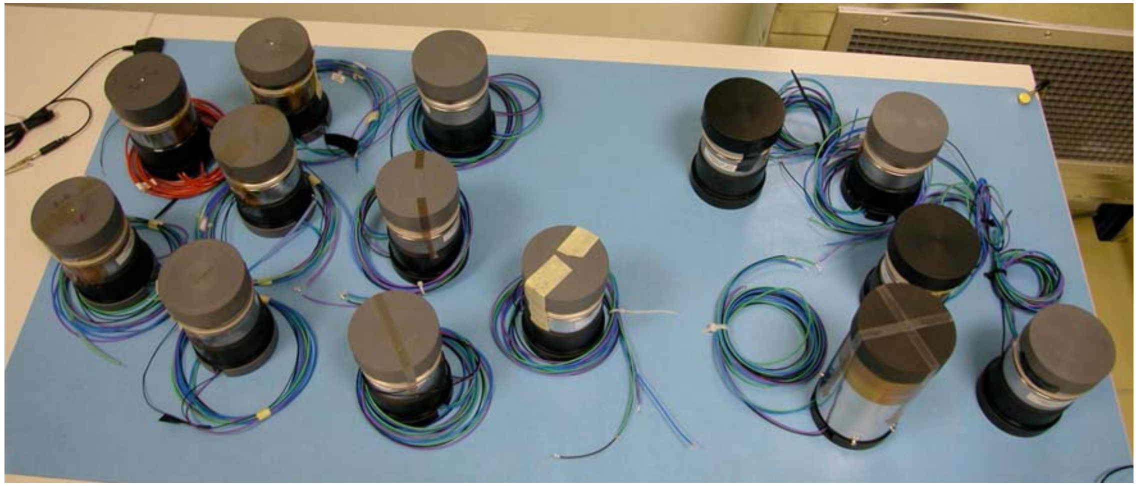
RICH2 lifting test (28*t*) ready for the transport

RICH-2 transport to IP8 last night

Unfortunately, the trailer broke down on its way..., however hope to complete still this week.

HPD: 550 tubes required

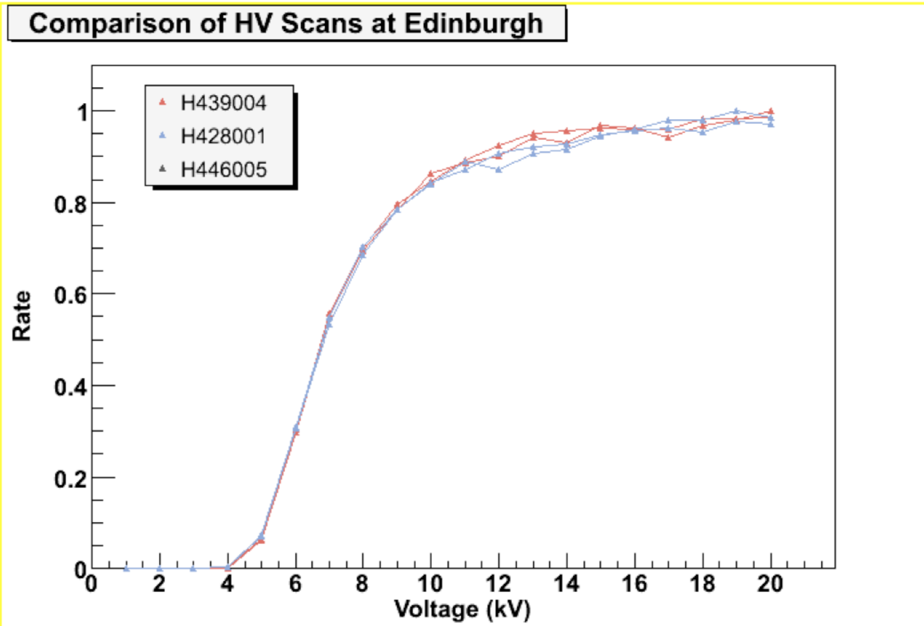
First batch of the series production (21) arrived in Sept.
Second batch (28) arrived in Nov.
From third batch, 14 are ready
→good progress approaching to the 30/month yield



~450 good bump bonded (sensor+chip)s in hand
→good progress

Rest of the anode production in progress
→Rate of gold plating of the carriers at CERN is a concern

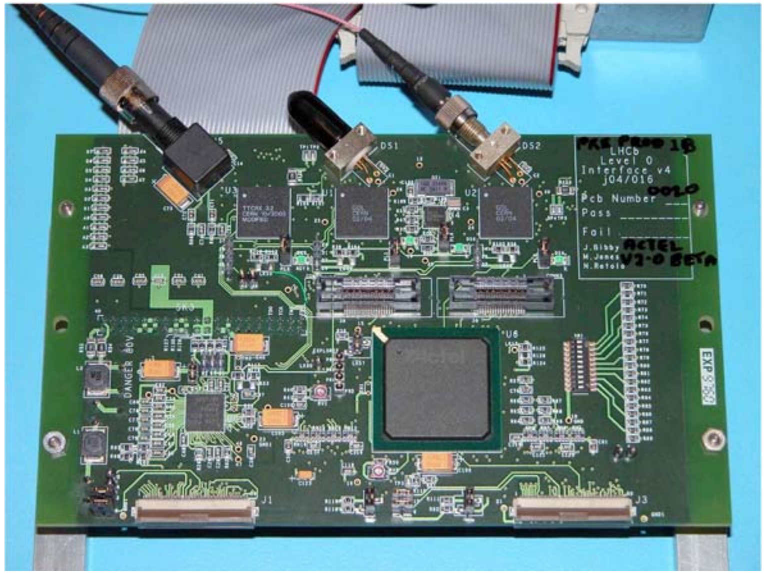
HPD test facilities at Edinburgh and Glasgow in operation



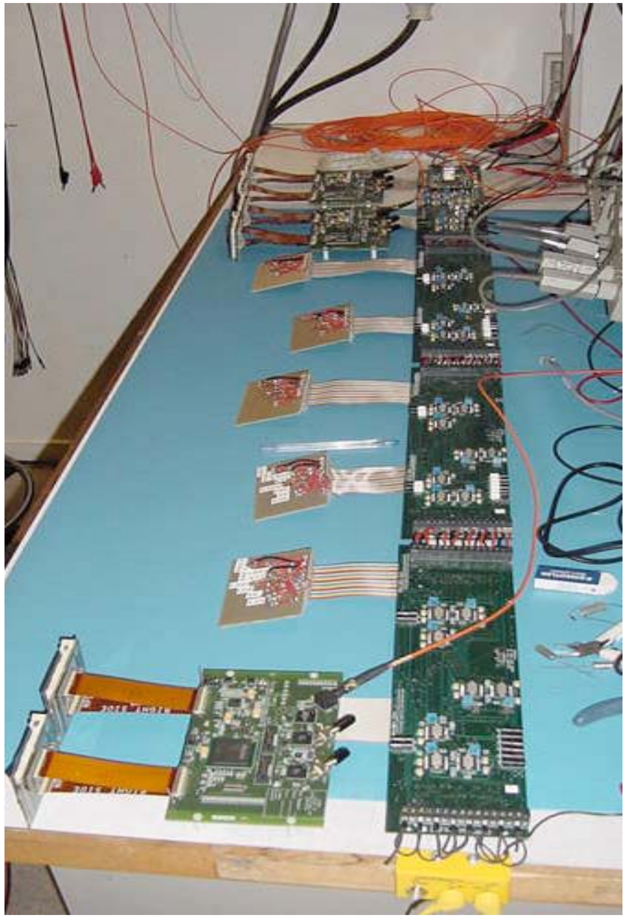
Counting rate vs HV

Has to match the HPD production rate of 30/month

Readout electronics



Level-0 board
production has started

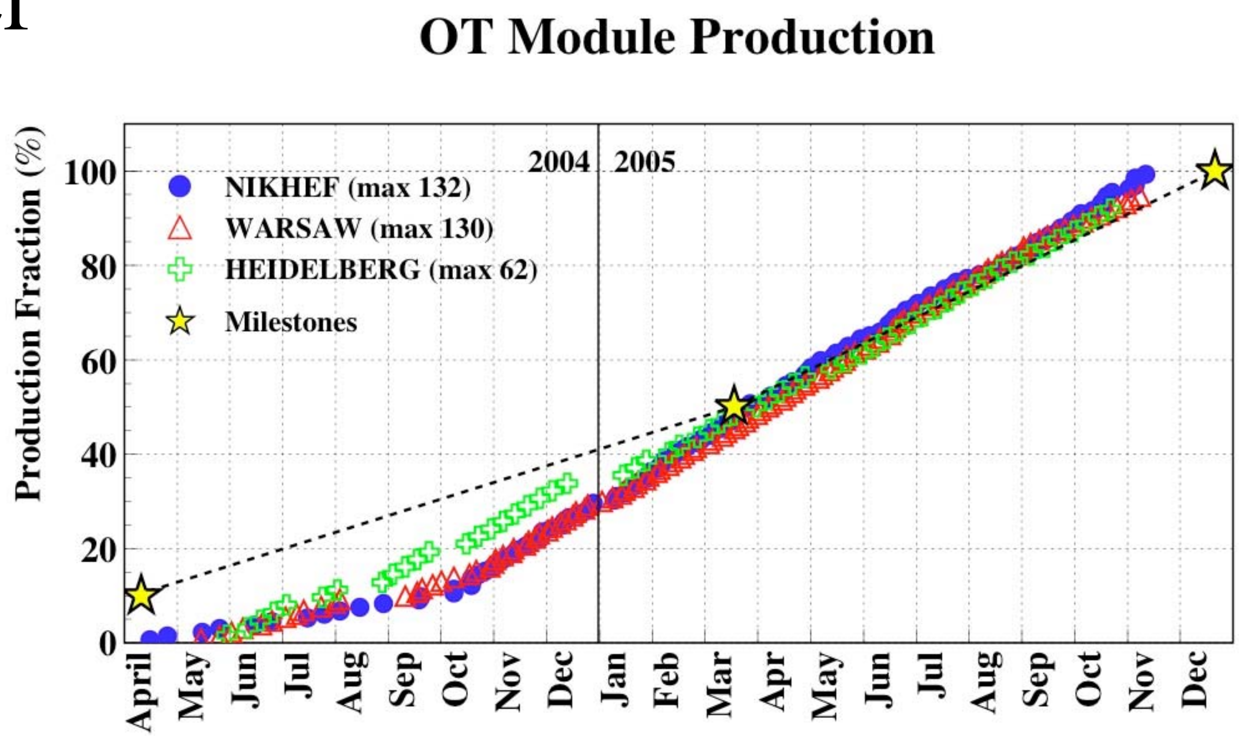


LV board
production starts now

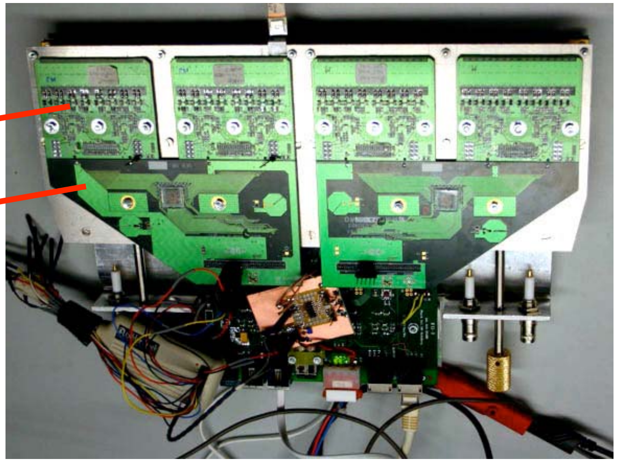
6) Outer Tracker

Straw chamber module production as planned.

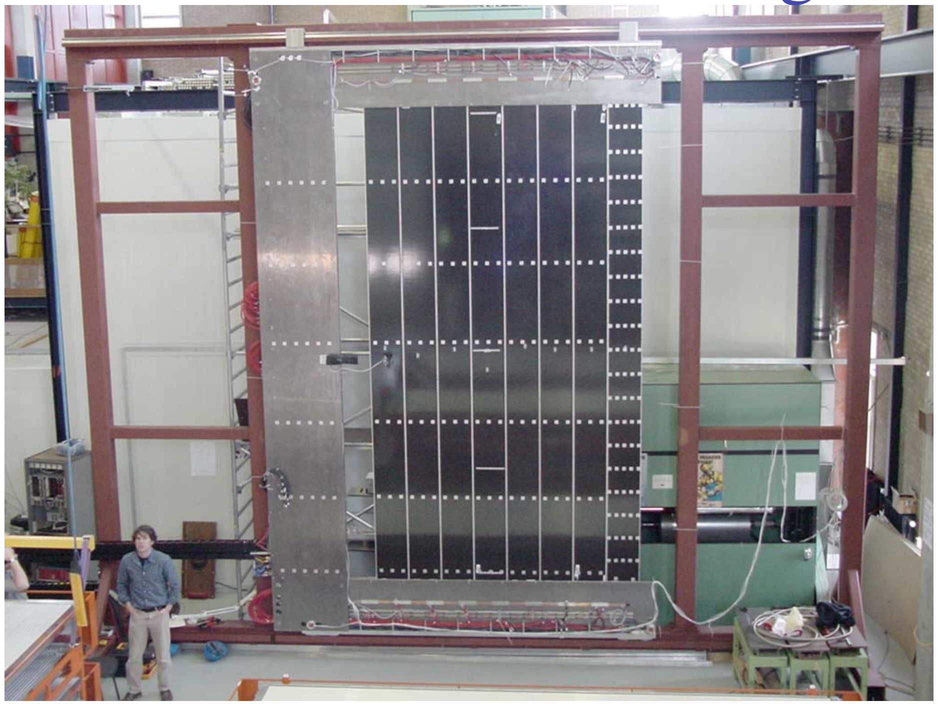
Completed by the end of 2005



Mass production of electronics started:
2,000 HV Boards
4,000 ASDBLR Boards
2,000 OTIS TDC Boards
500 GOL/AUX Board



12 C-Frames, each holding two OT double layers



1/4 prototype C-frame with gas, HV and signal cables being built

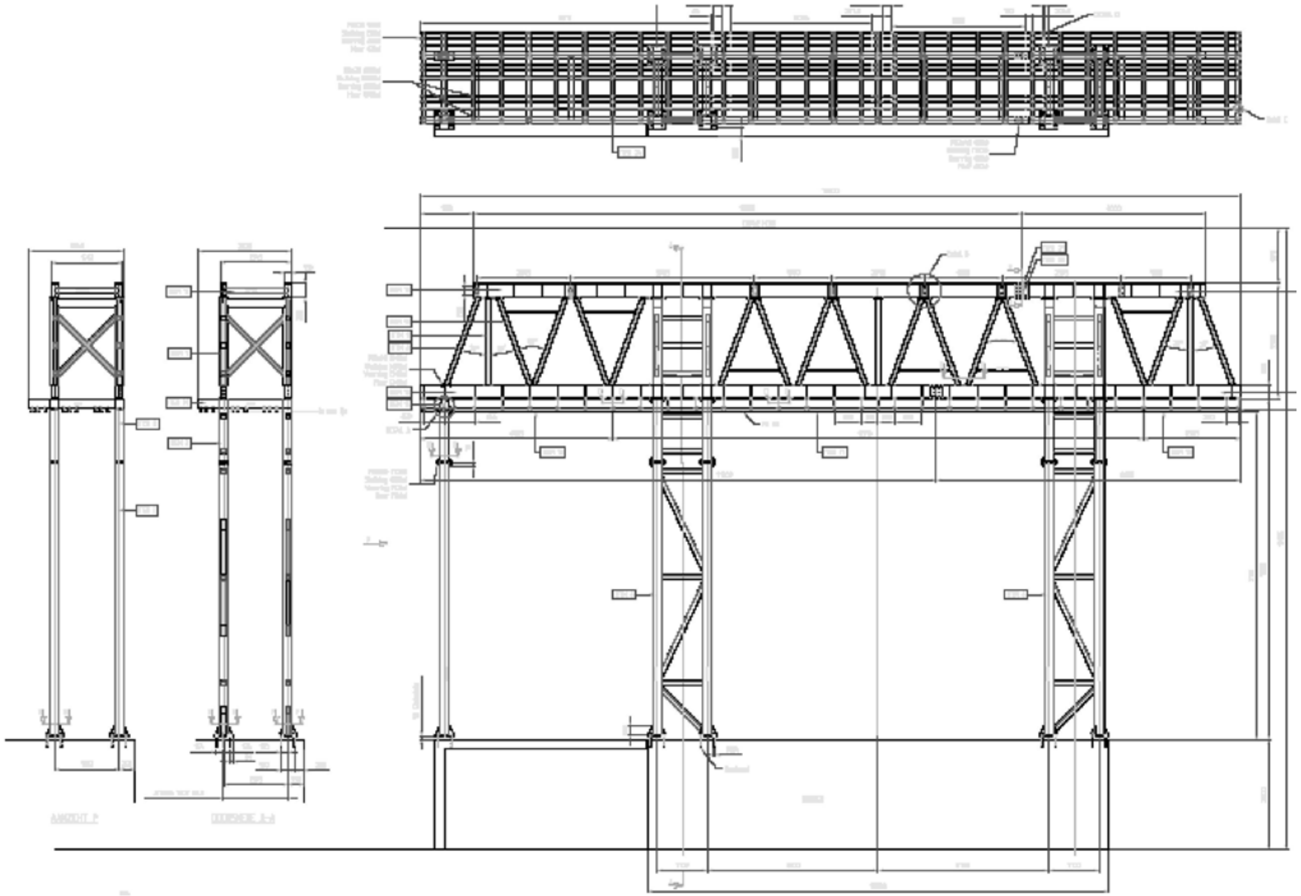
Order has been placed and
six frames delivered,
rest by the end of this year

Support bridge for OT and IT

Order for the top part placed

Order for the bottom part to be placed by early Dec.2005

delivery of both by Feb.2006



7) Silicon Tracker

Si sensors from HPK for

IT, 500 in hand (531 needed)

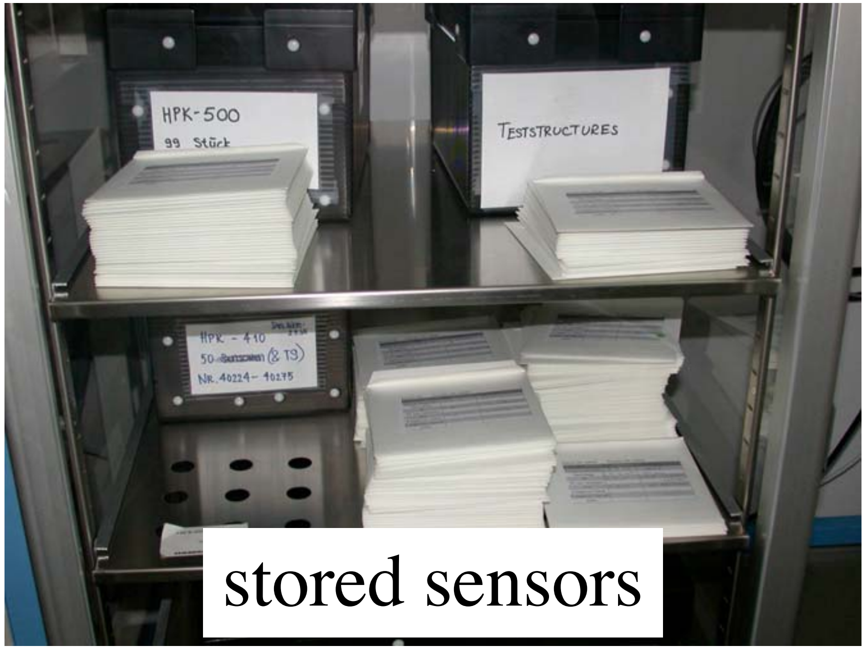
320 and 410 μm thick sensors

TT, 200 advanced loan from CMS

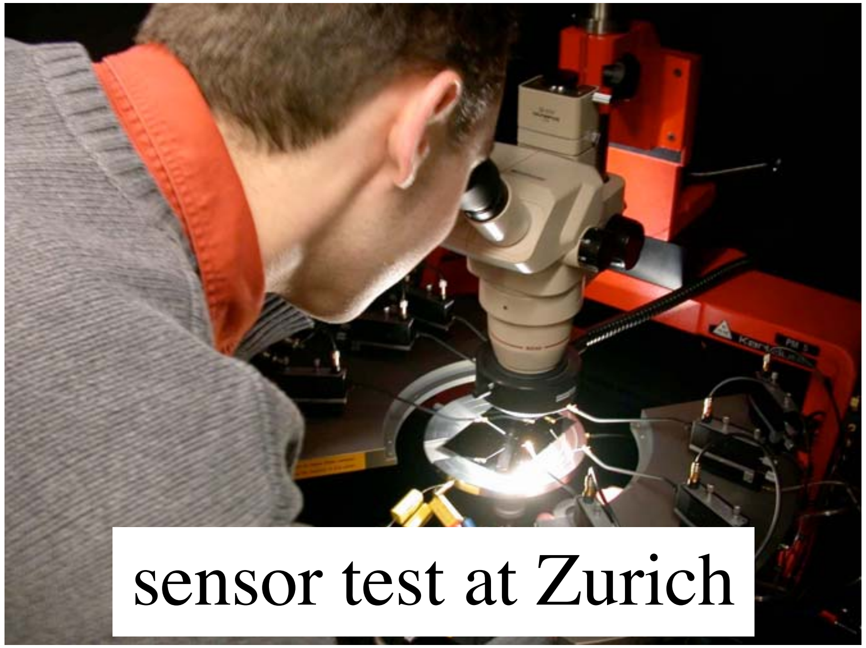
150 HPK first batch (1000 needed)

500 μm thick OB2 sensors

All with excellent quality, rest will arrive by end of year

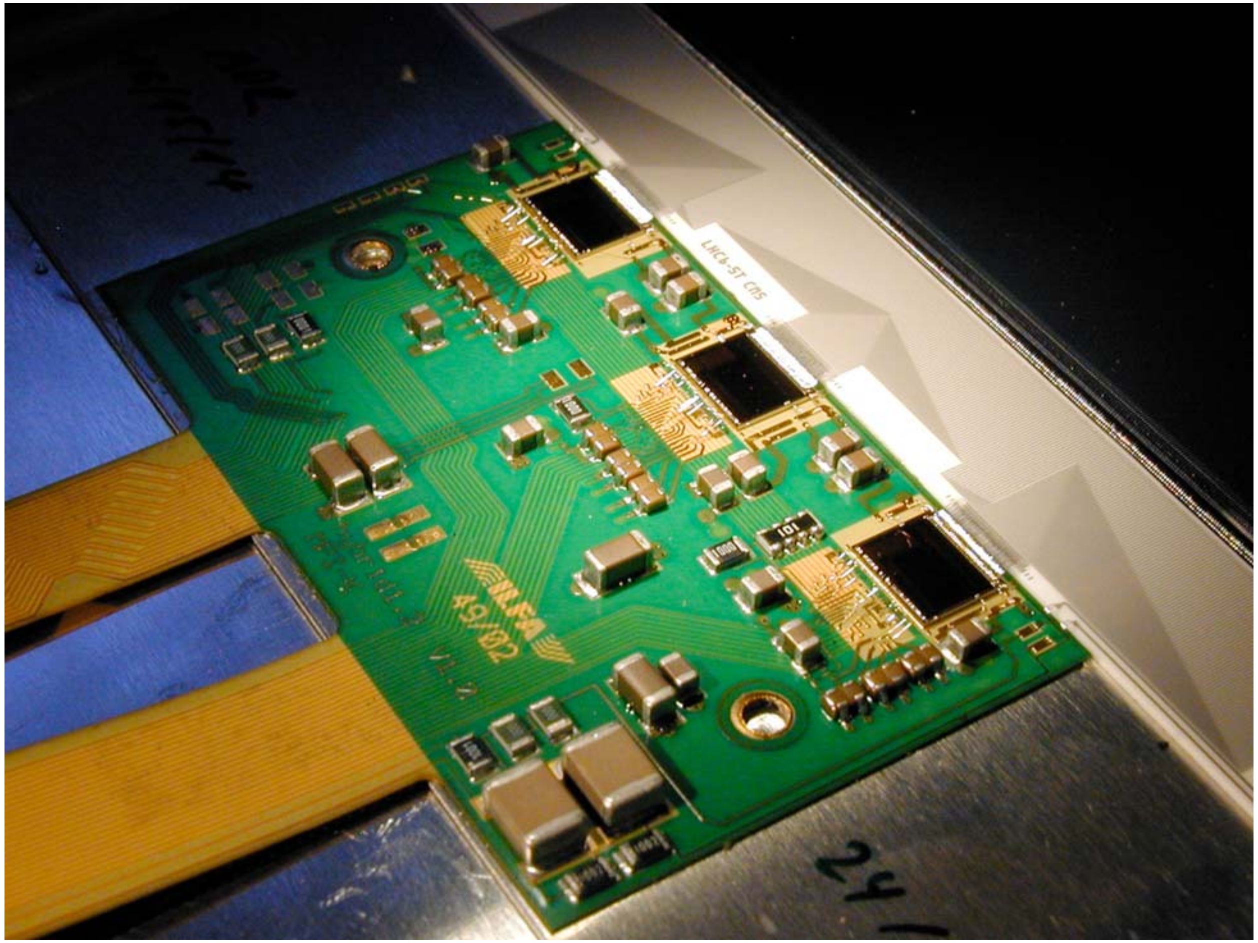


stored sensors



sensor test at Zurich

About 3600 qualified Beetle 1.3 chips in hand, 2200 needed



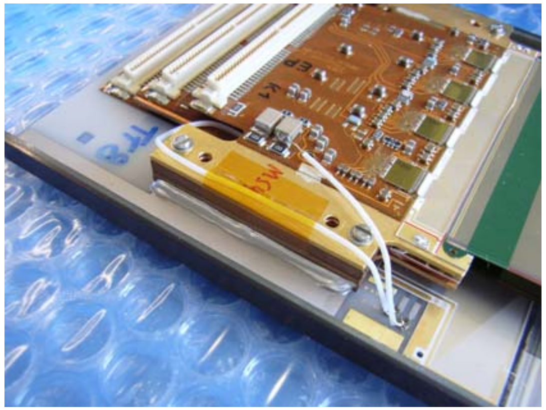
Hybrid pre-series production completed (IT and TT), passed PRR in Sep 05, series production launched

IT ladder preproduction completed

6 one-sensor modules
1 two-sensor modules
can be used in the experiment

Production rate 12 modules / week can be achieved
Series production had started and 35 modules glued,
but bonding problem with the pitch adapter and production is on hold

TT ladder series production in progress

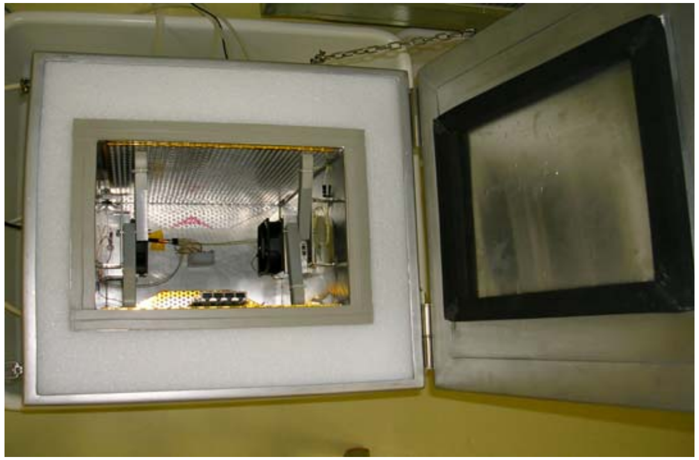


production rate 5 modules /week can be achieved

12 modules produced except the top long Kapton cable, which has just being delivered and being bonded

burn-in facilities for TT and IT

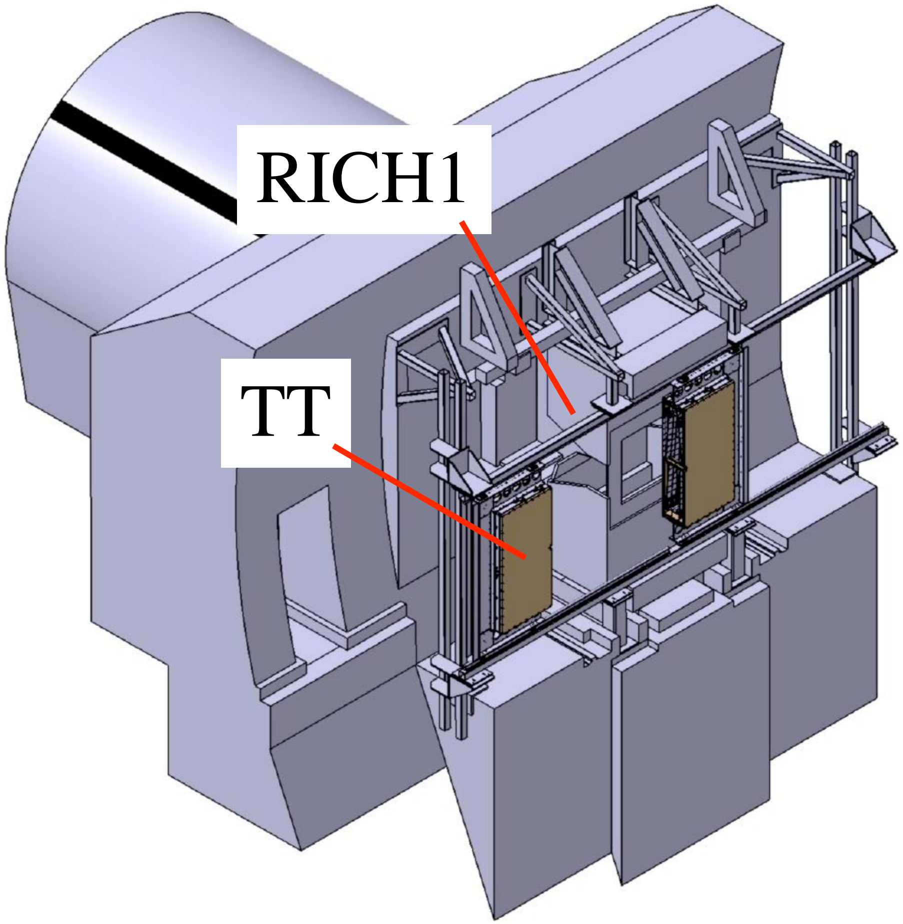
TT: ready to go



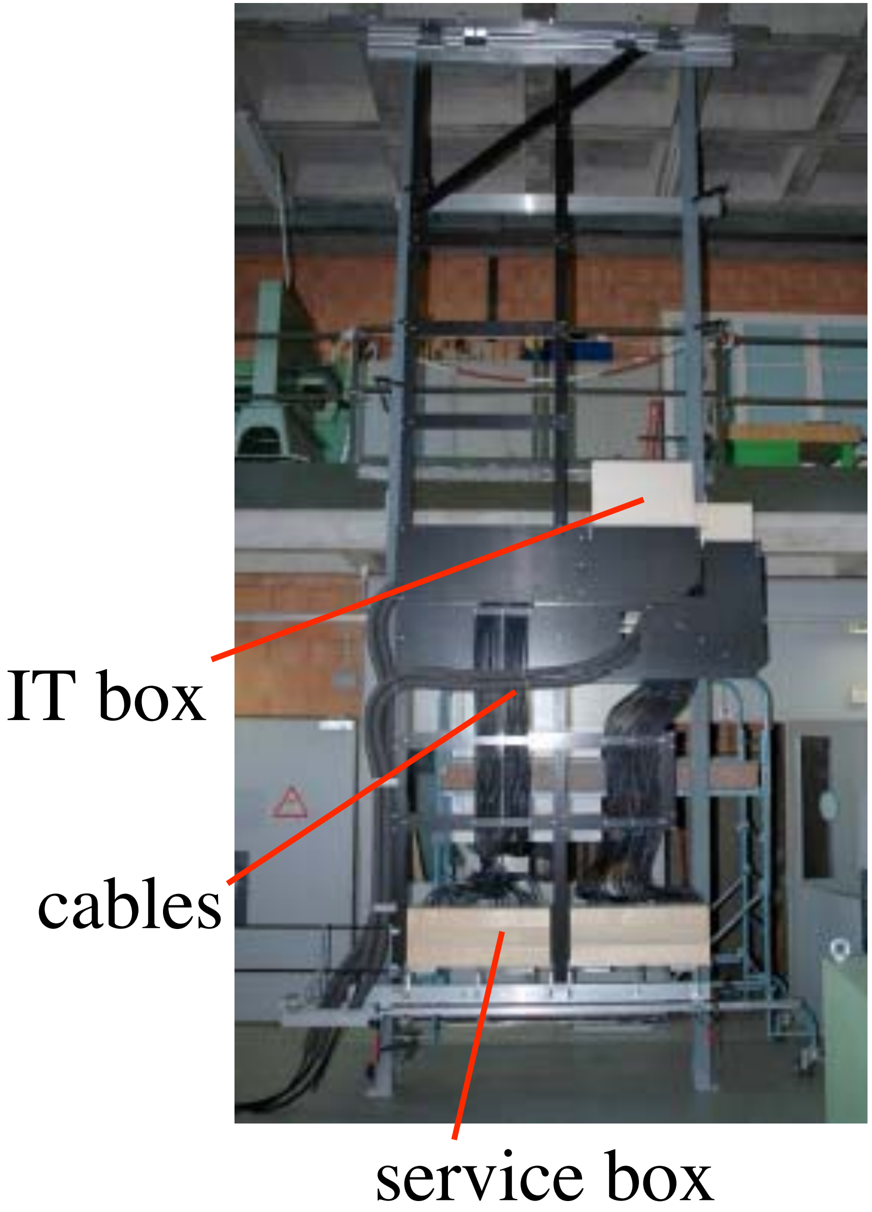
IT: almost ready

Module “burn-in” facility
temperature cycling (+50/–10ºC)
+ readout tests with the full final readout chain
(up to “TELL-1” readout board)

TT integration study in progress

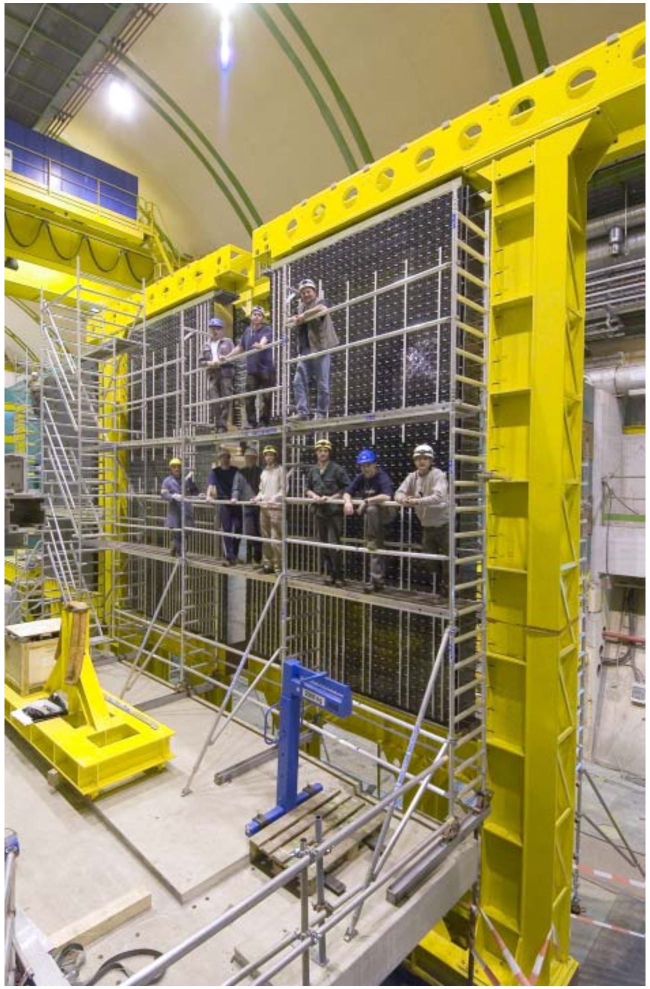


IT integration EDR, 14 Oct



8) Calorimeter System

ECAL and HCAL detectors have been installed in Pit-8

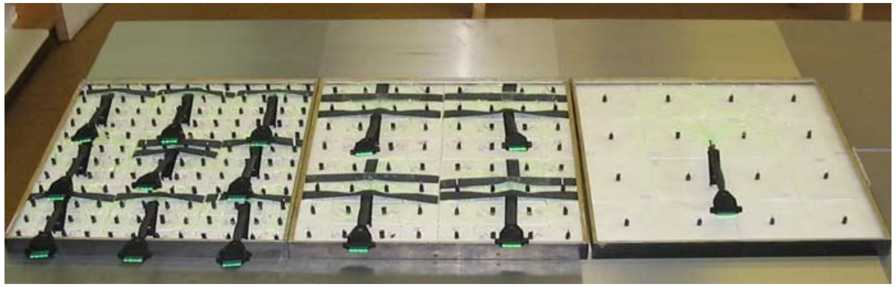


E-cal

H-cal

Preshower

Assembly of all modules finished



50% of supermodules produced

Suspension test with final Supermodules and final rail system in Bldg. 156

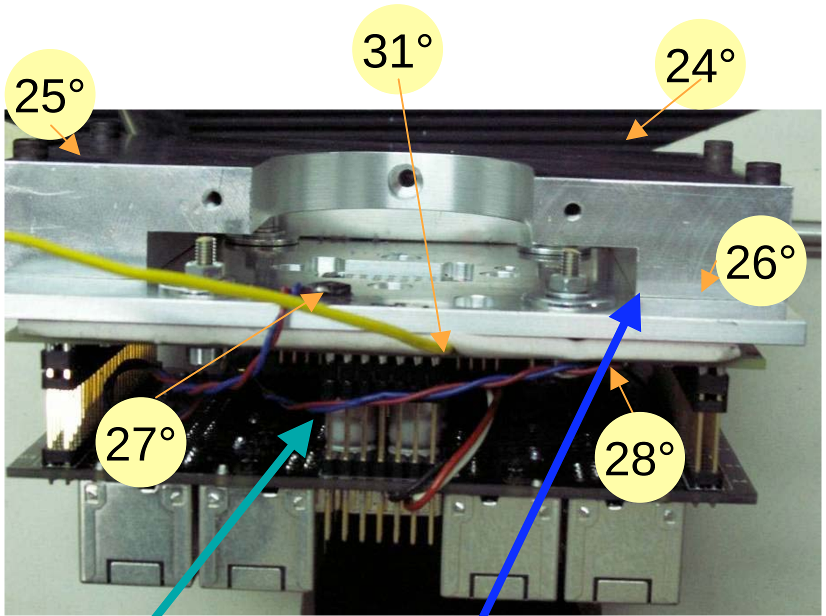
Electronics

Cooling system for Very-FE cards redesigned (change from air to water cooling) and cards production in progress

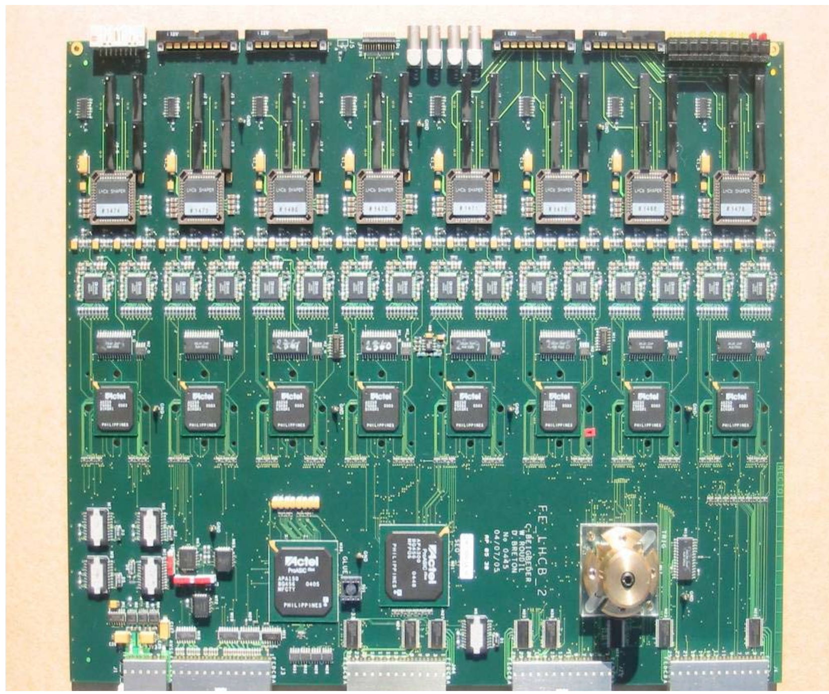
Frontend Boards for ECAL/HCAL and PS/SPD under test with final prototypes

CROC (Calorimeter ReadOut Card) development of final version in progress

Common Control System for HV and LED monitoring systems well advanced



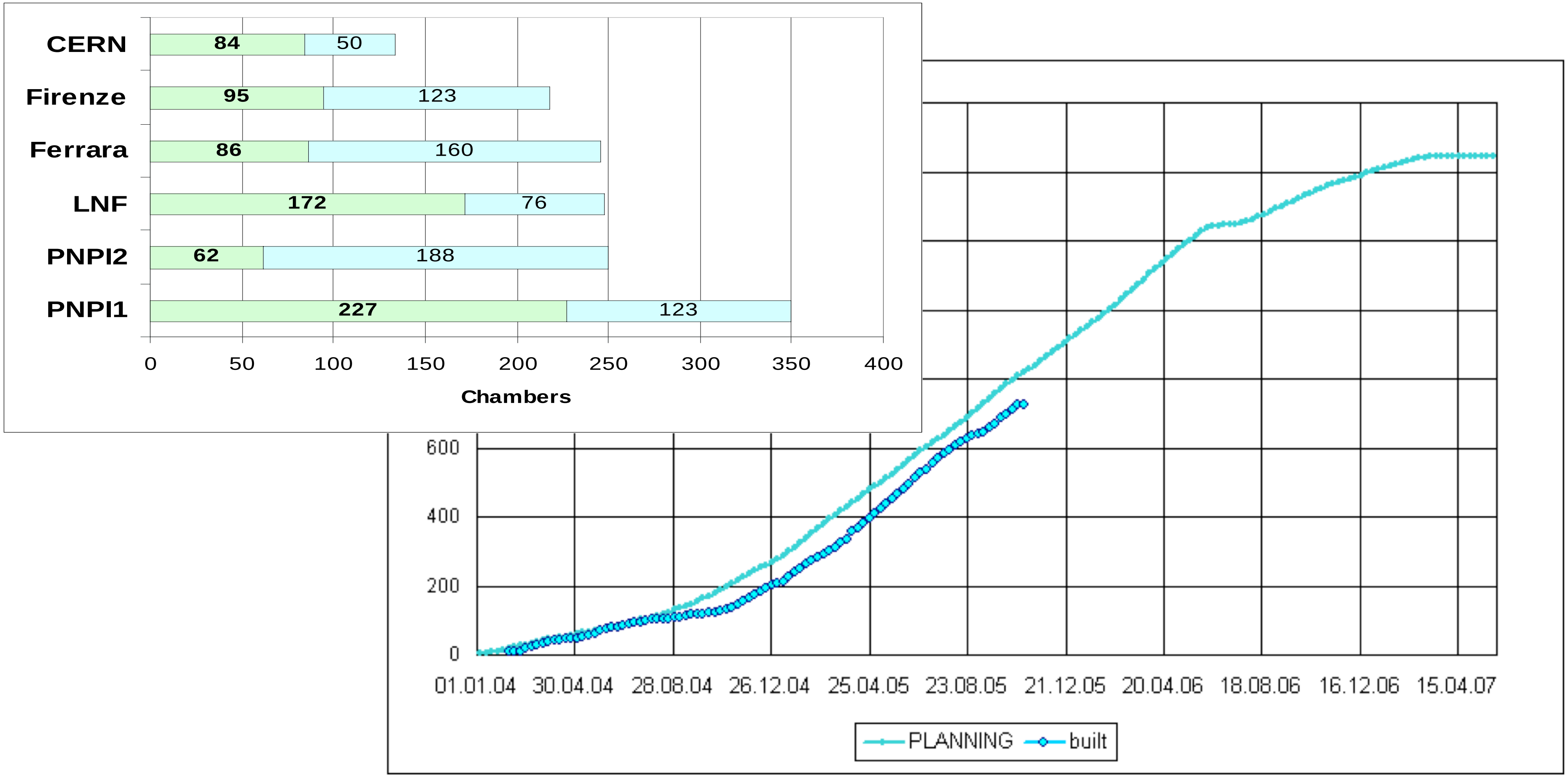
PS VFE board with new cooling system



Final prototype of ECAL/HCAL FE-card

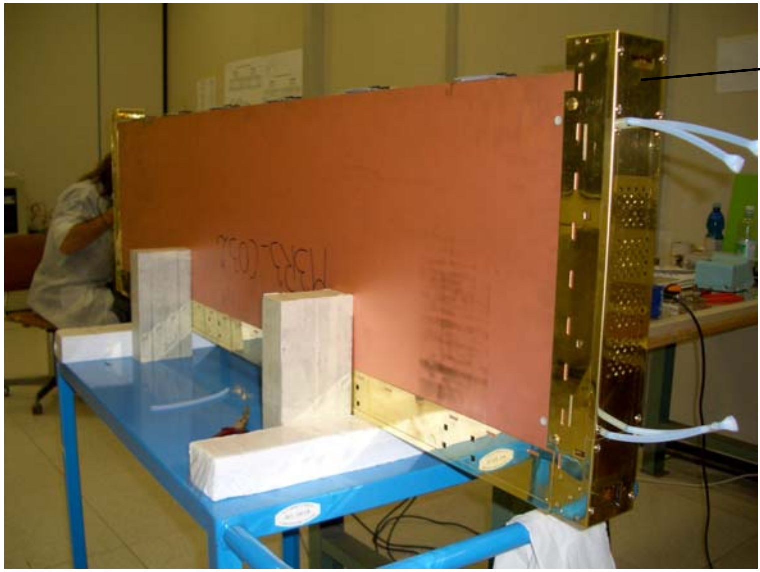
9) Muon System

50% of the chambers produced (end of Oct)



Delay has not been recovered but now progressing steadily in all the production centres.

The next step is "dressing" of the chambers



Faraday Cage assembly

-Mounting the two caps.

-Fixing the HV distribution bars.

-Welding the long cage on the SPB cards on one side.

-Turning the chamber and welding the second long cage on the other side.

-Putting the chamber horizontal and weld all the cage on top and bottom.

-Install the FE electronics and the Low Voltage regulator

and transport

Dressing and testing the chambers with final electronics are now critical.

Electronics

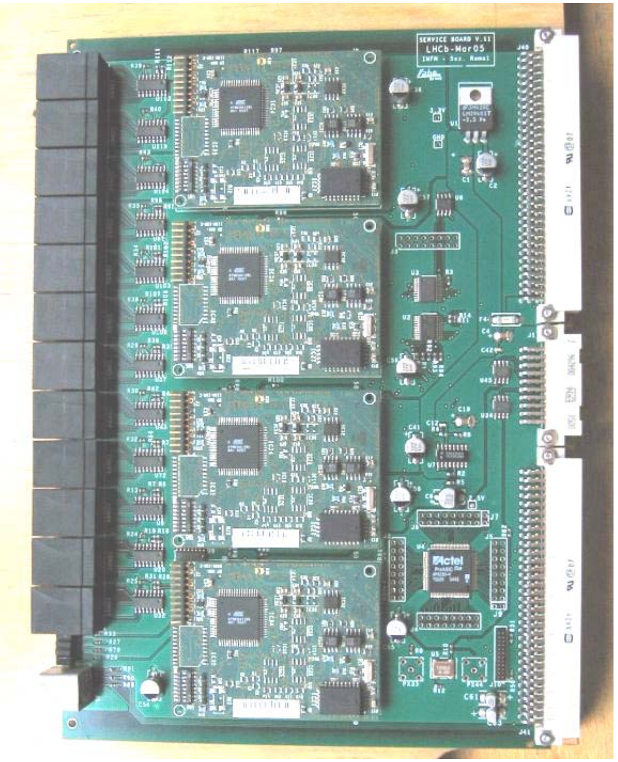
All the ASIC chips produced, packaged and being tested

Production of Spark Protection Boards completed.

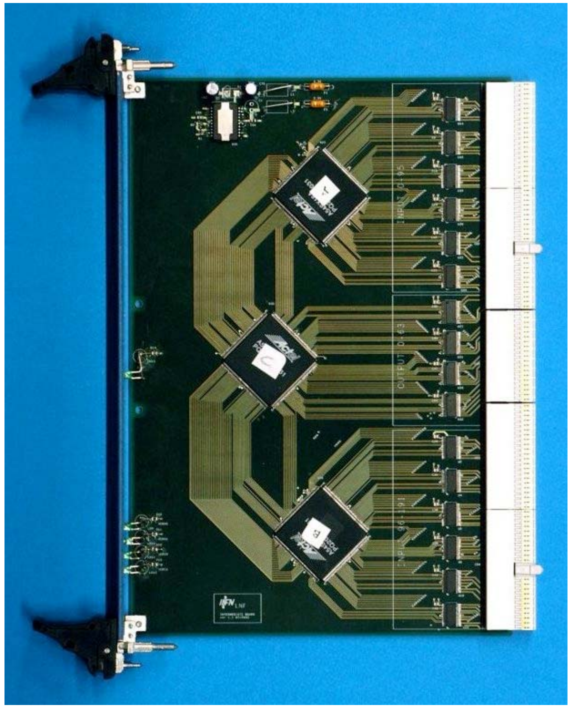
Intermediate Boards and Service Boards in production

Production still to be launched for ODE and CARDIAC

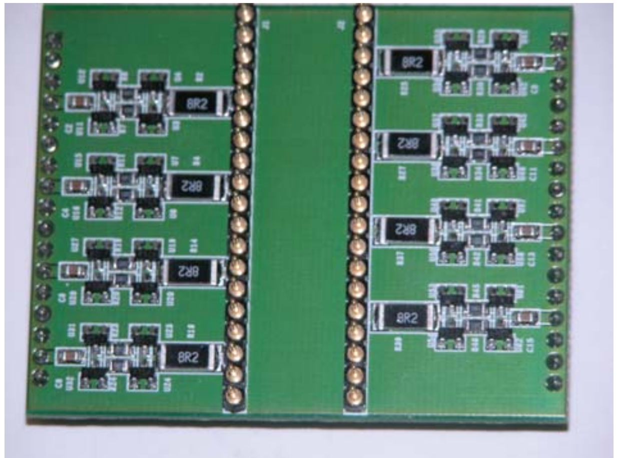
critical for the chamber installation



Service Board

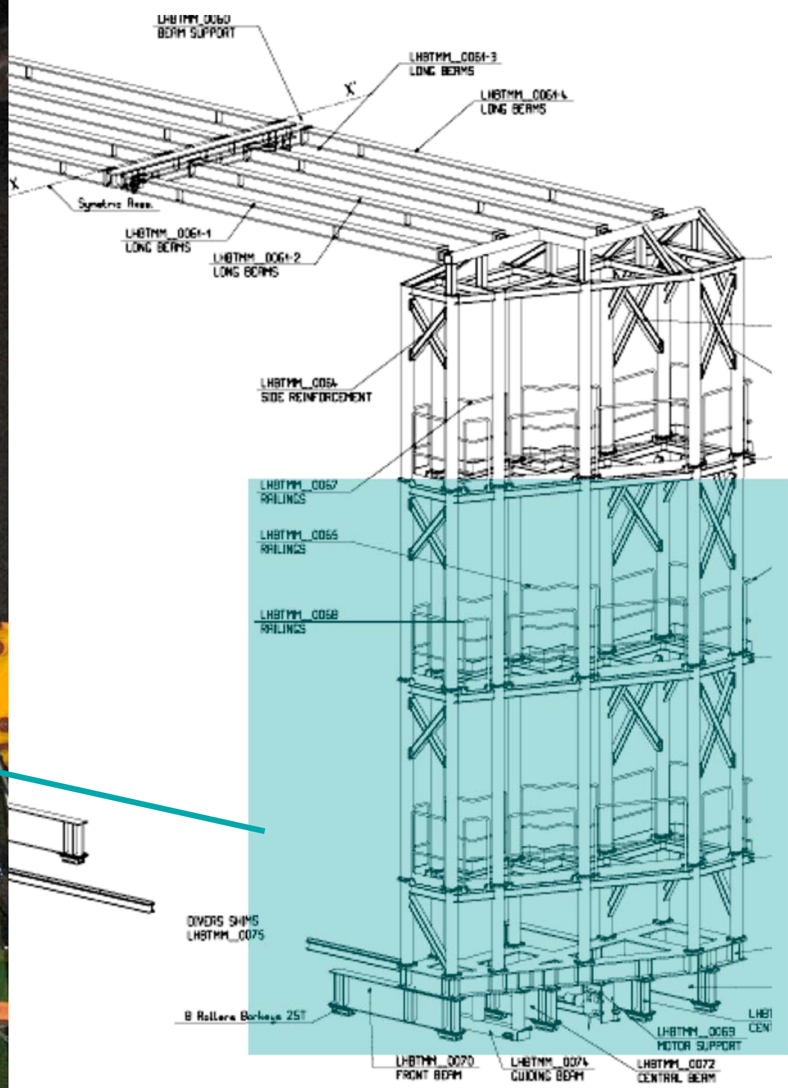


Intermediate Board



Protection Board

Muon tower assembly started



Testing the assembly of the chamber support wall (1:4 prototype)

gluing

riveting

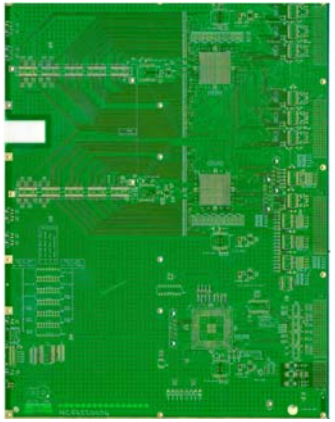
10) Level-0

Level-0 electronics
Calorimeter, Muon, Pile-up, Decision Unit

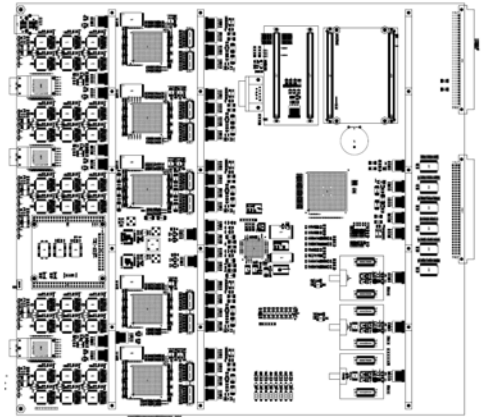
Production Readiness Reviews

			done
L0 Calorimeter	Optical Mezzanines Validation Card Selection Board	November 9, 2005 ~Jan 06 ~March 06	✔
L0 Muon	Processing Board Controller Board Backplane	Jan-Feb 06	
L0 Pile-Up	Hybrid Optical station Vertex finder board Output board	End of this year Q2 06	
L0DU	L0DU mezzanine	Q2 06	

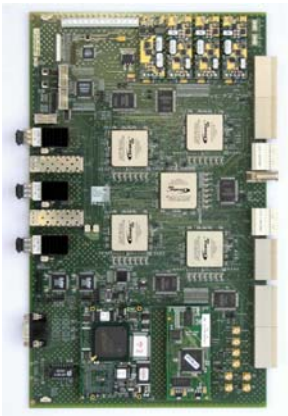
Calo
Optical Mezzanines Boards
PRR completed



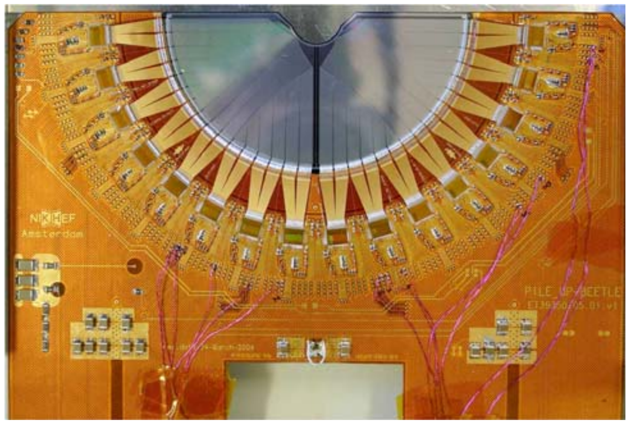
Calo
Validation card
prototype PCB made
test starts soon



Calo
Selection board
routing finished
prototype test early next year



Muon Processor Boards
two preseries completed



Pile-up sensor module
ready for PRR

L0 Decision Unit
prototype mezzanines card

11) Trigger and Online

Real Time Trigger Challenge in July:

Test all the features of the complete DAQ/CPU-farm system

-hardware for the data flow:

switches, sub-farm controller, CPU, ...

-hardware and software for the system control

Experiment Control System (ECS), monitoring, ...

Verify the necessary CPU budget to execute L1/HLT

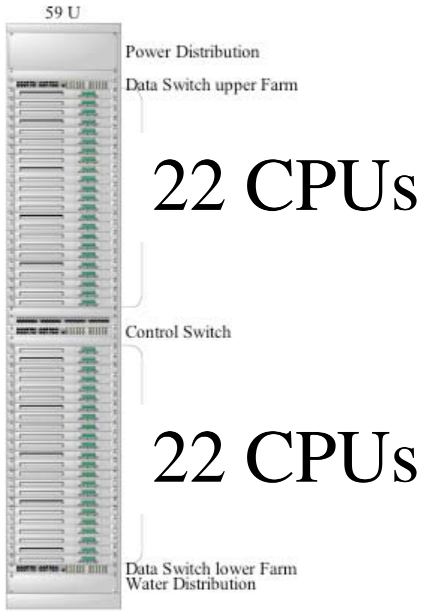
Also more "reliable" codes required, e.g. no memory leak

Hardware setup

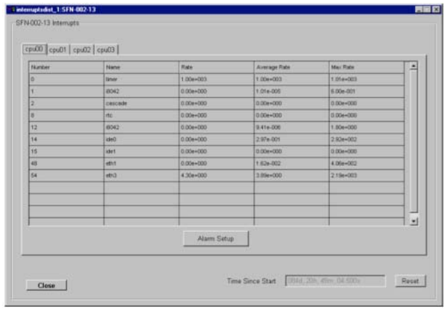
Network switch
One full rack with 2×2.8 GHz Xeon CPU 1U (44) servers
ECS

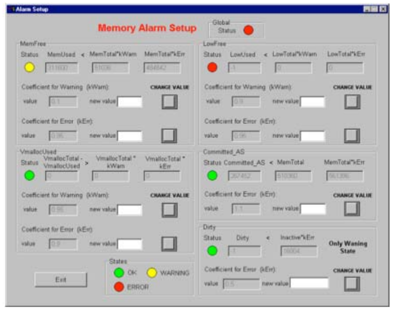
network switches and SFC

CPU farm



Farm monitor and control software





Successfully verified power, cooling, control and monitoring of farm nodes. Benchmarked trigger algorithms for L1 and HLT

Trigger timing measurements

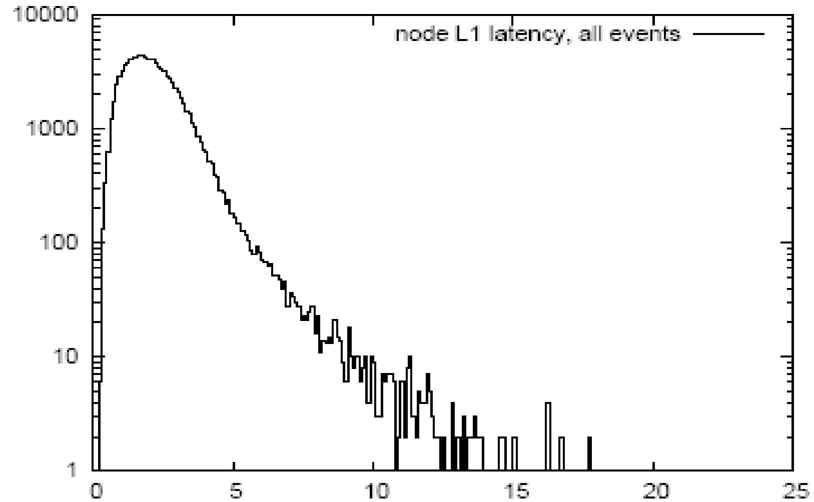
The Trigger TDR plan for 2007:

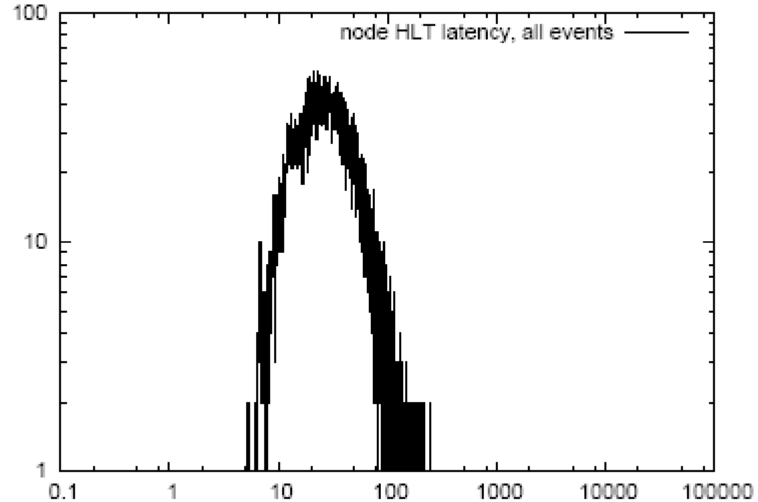
1 ms for L1 with 1000 CPUs
@ 1 MHz input

10 ms for HLT with 400 CPUs
@ 40 kHz input
(+200 CPUs for quasi offline)

Measured in RTTC (2005):
2.21 ms for L1
56 ms for HLT

If we build a system now, 4450 CPUs needed for the trigger
(2225 boxes)

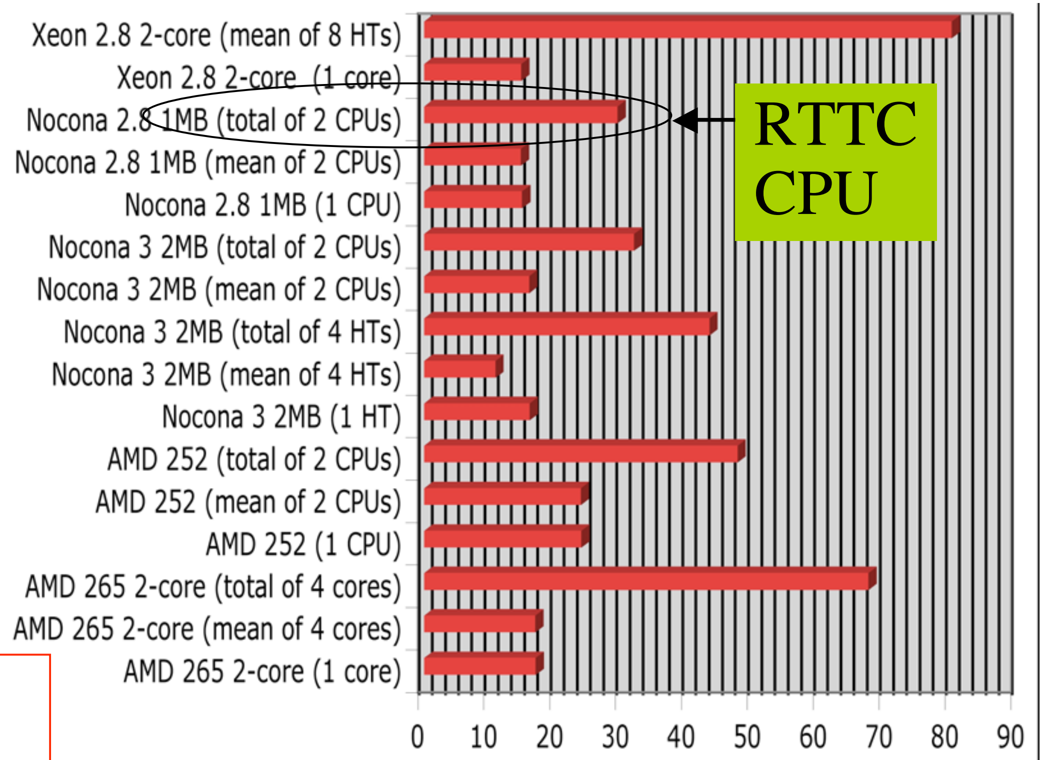




The infrastructure at Pit-8 can accommodate 2200 boxes.
The DAQ/CPU farm budget foresees 1800 boxes, assuming RTTC CPU price

CPU evaluation shows that there already exist CPU-boxes with required performance but are still expensive
Costs will drop by 2007

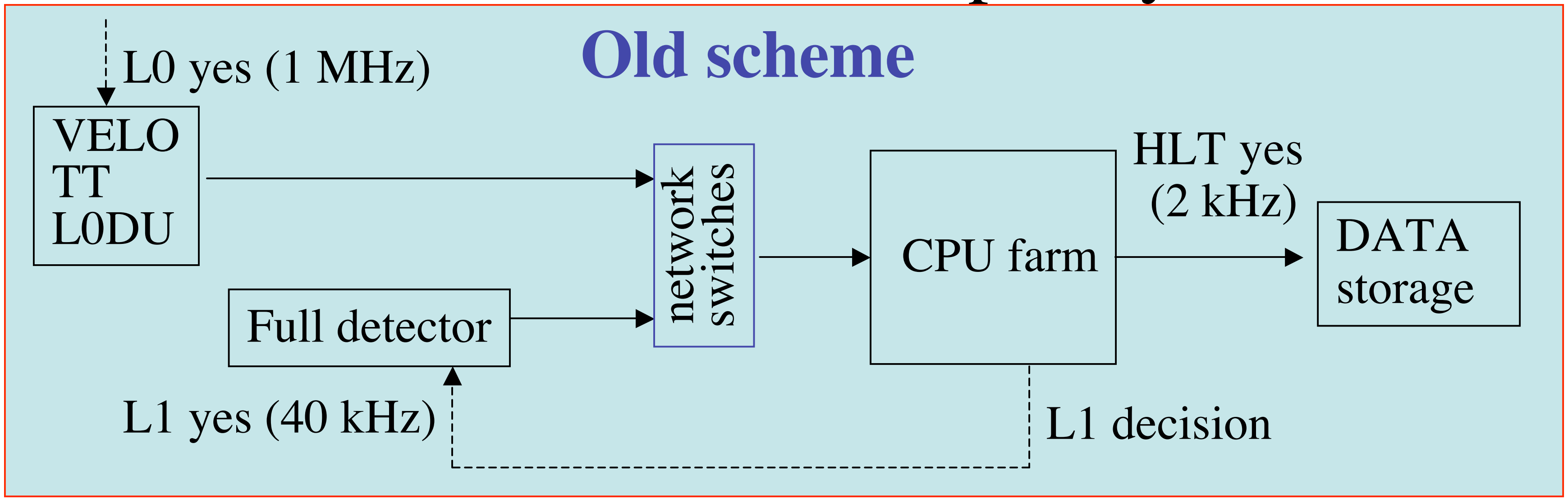
⇒ Should be possible to build the required CPU farm within the budget in 2007



CPU performance in arbitrary unit measured by running HLT.

RTTC will continue
→for 1MHz readout scheme

L-1 and HLT hardware now completely unified

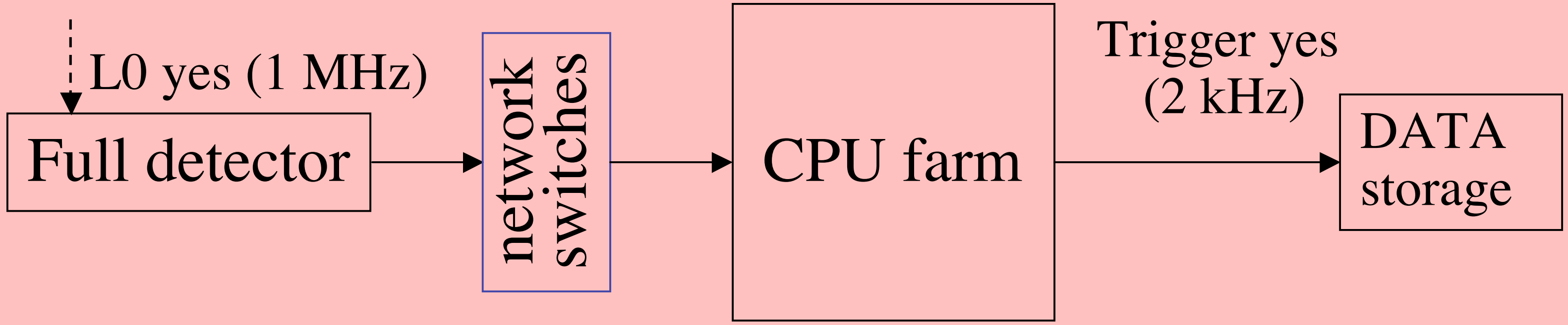


L0: custom made electronics, fixed latency of 4 μsec
High p_T objects (calorimeter, muon),
Pile-up information

L1: commercial CPU farm, maximum latency of 58 msec
tracks with high $p_T \oplus$ large impact parameter,
di-muon (VELO,TT, L0 objects)

HLT: commercial CPU farm,
event selection (full detector)

Newly adopted 1 MHz readout scheme



Logical flow of the event selection will not really change but,

☺ Simple DAQ system

single data stream, no L1 decision sorter, no subfarm controller

☹ more CPUs for event building shifted from subfarm controller

☹ slightly more software overhead for data unpacking

☺ No L1 latency limitation

latency limited by the available CPU power

☺ More flexible trigger decision

all the data available

This does not mean to run the HLT algorithm at 1 MHz
We can, for example

run L1 then HLT algorithms as it is

⇒the same performance

i.e. validity of the LHCb trigger unchanged!

Then improvement can be achieved by

adding more information

e.g. start with L1 like algorithm:

large impact parameter and high p_T track,

but σ_{p_T} can be improved by adding T information

Work in progress

With GbEthernet technology

Event size: 52 kBytes / event with safety factor

(nominal size 35kBytes)

Data rate: 56 GBytes / second using Multi Event Package

Input link: 727 links, Load $_{max}$<85%

Output link: 530 links, Load $_{average}$~62%

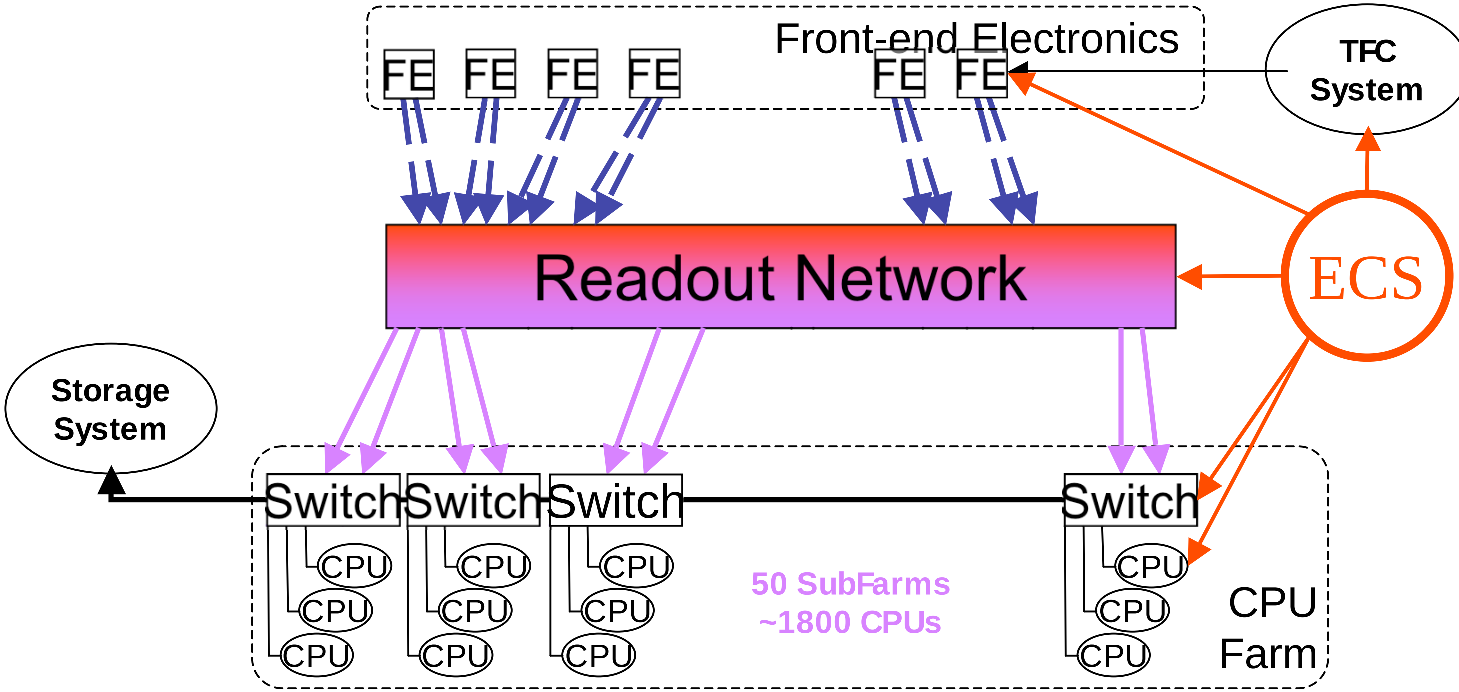
→an example of solutions, Force 10

1260 GbEthernet ports (needed 1257)

150GBytes/sec switching capacity

This has been already foreseen as an upgrade from the beginning,
⇒the cost of the network switches has dropped faster than anticipated.

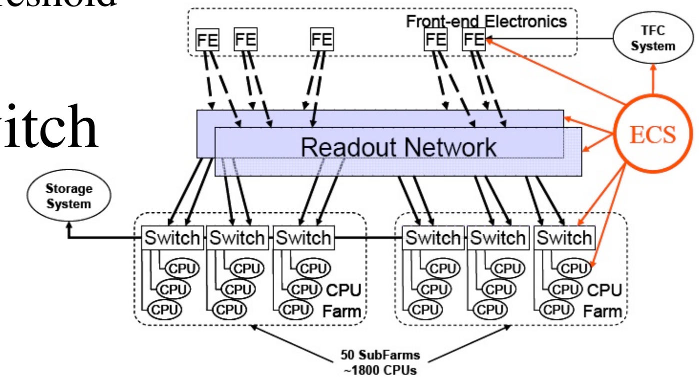
estimated cost ~300kCHF more than the old system
(but still within the cost given in DAQ TDR)



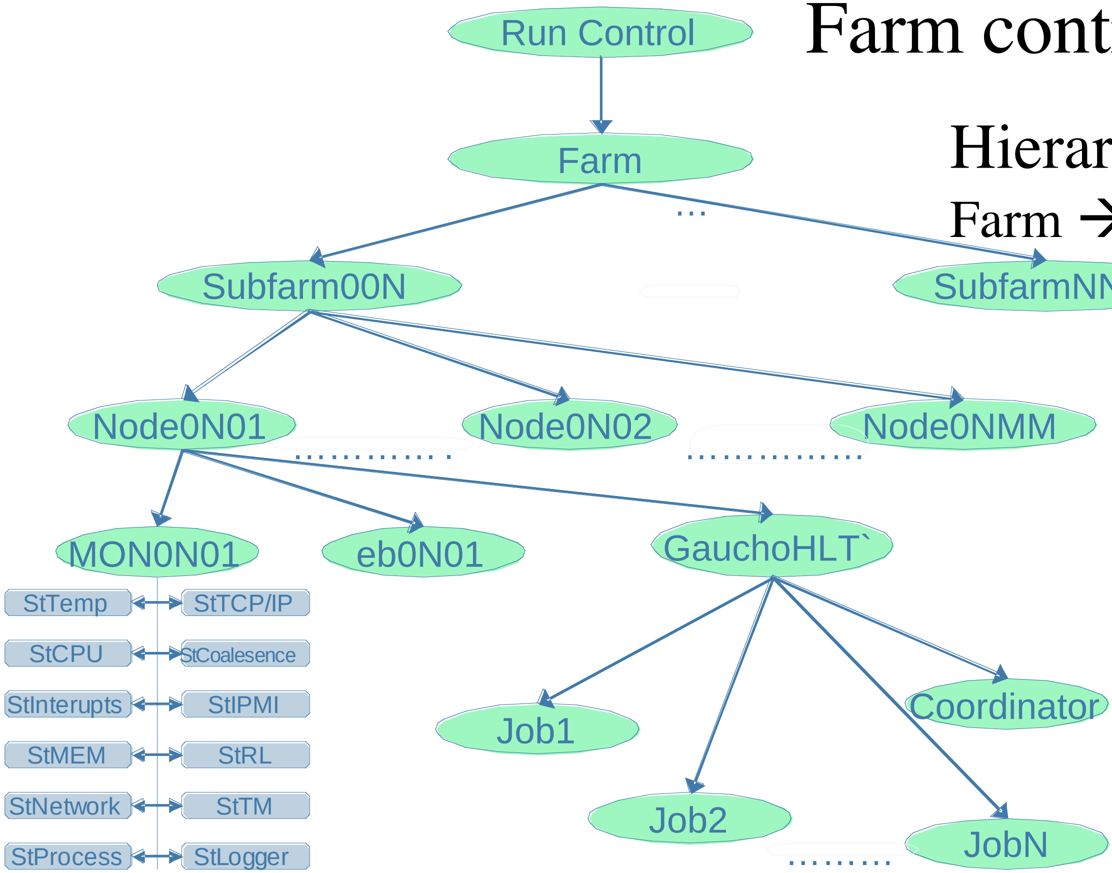
Force 10

System is sensitive to the detector occupancies:

-occupancy estimates are conservative
-temporarily reduce L0 rate by increasing $p_T^{threshold}$
-input-link distribution could be reoptimized
-system is scalable; introducing the second switch
cost increase of 200 to 400 kCHF
(TELL1 has already 4 output links)
similar to the CMS scheme



RTTC was a good test ground for the ECS



Farm control and monitoring

Hierarchical Controls Architecture

Farm → SubFarm → Node →Components (Event Builder, Monitoring...)

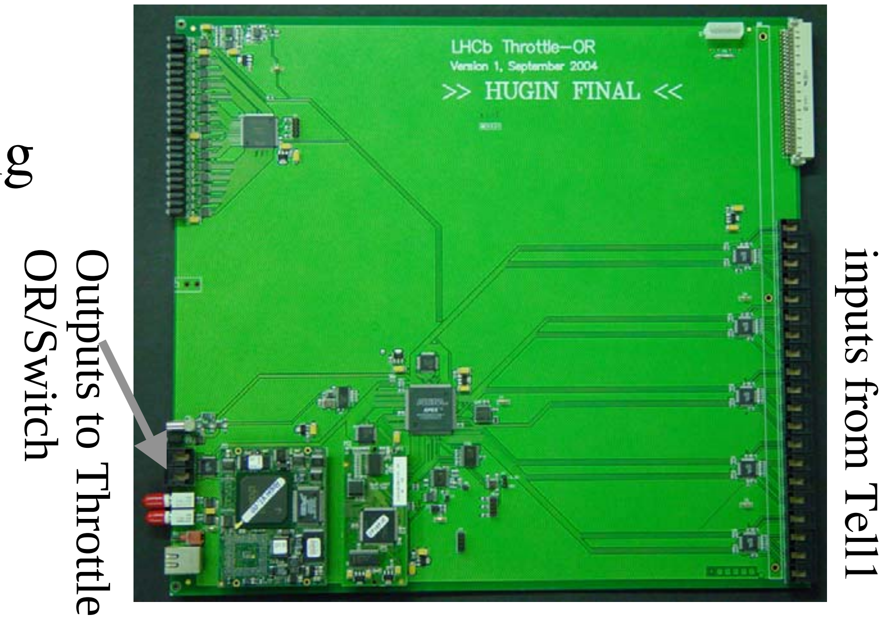
ECS interface for electronics control advancing

SPECS and CAN

Timing and Fast Control

Module Production

- Readout Supervisors
  - -10 produced (4 in use in sub-detector tests).
  - -Mounting of second batch 18 boards in progress.
- Throttle Switches
  - -2 final modules ready, 4 additional by Christmas
- Throttle Ors
  - -3 pre-production modules ready
  - -Series production of PCB starting



All TTC equipment received

TTC fibers for counting houses ordered

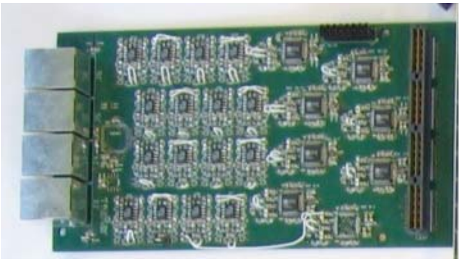
Common Readout Electronics (TELL1)

Input from the front-end electronics after Level-0 yes (1MHz)
Signal processing such as
noise suppression, zero suppression etc.
Multi Event Package building
Output MEP to the network switch
FE simulation for throttling

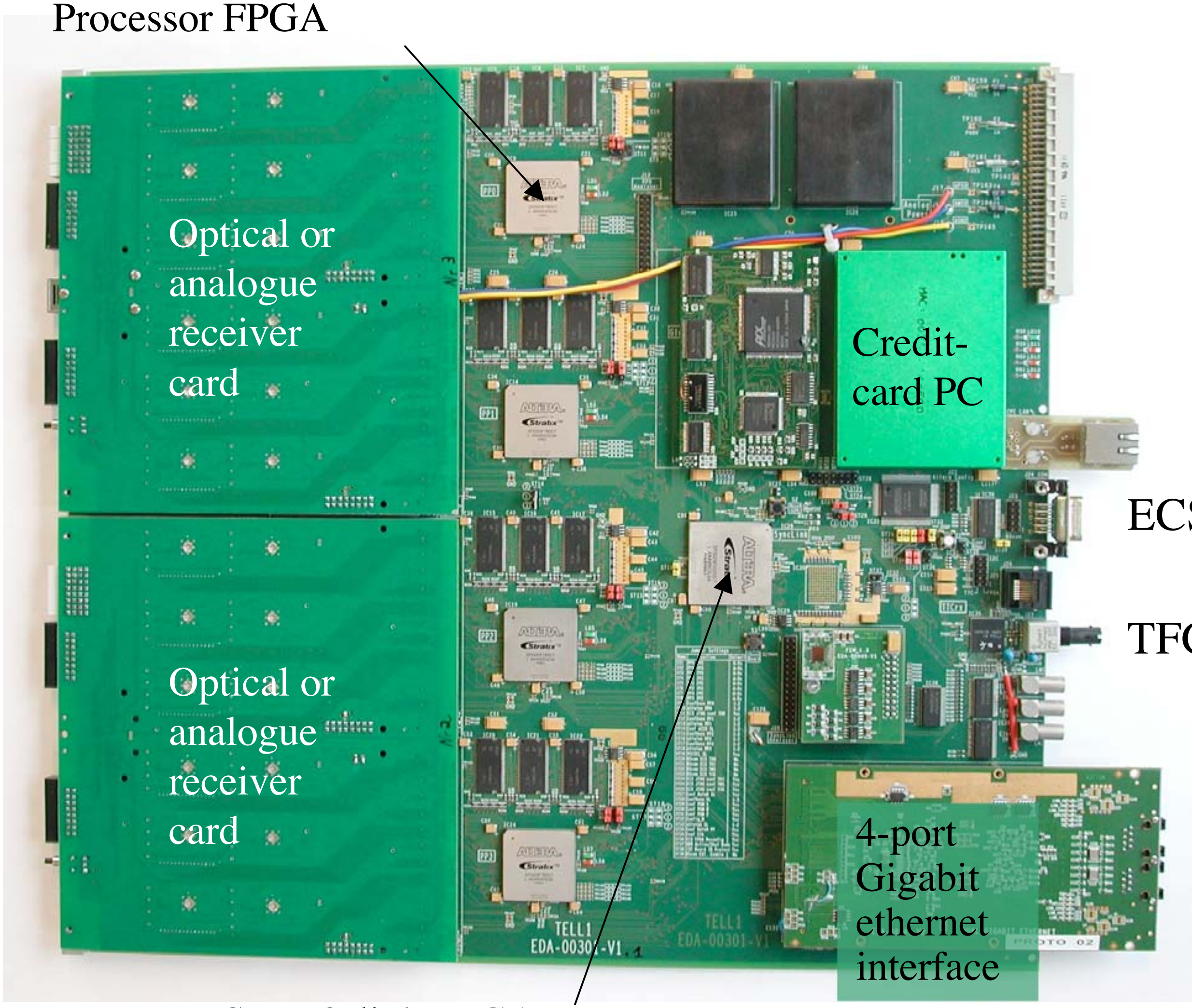
Pre-production 17 TELL1 have been built and fully tested.
Pre-series production of 30 more boards:
one damaged in assembly, one failed in boundary scan at the company
28 delivered TELL1 are now being tested
Series production of 320 more boards to be built in 2006.

On schedule

Analogue receiver card with ADC



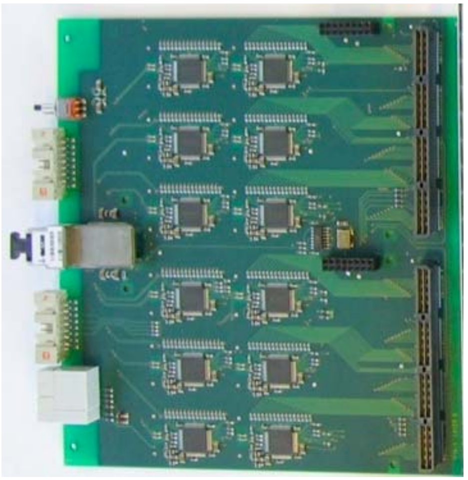
Processor FPGA



1 MHz input from FE electronics

ECS

TFC



Optical receiver card

Sync & link FPGA

1 MHz output to the Network Switches

12) Computing

Computing TDR submitted in June 05

Computing model for
simulation, reconstruction and analysis

Resource requirement at Tier-1s and Tier-2s

Software environment

Service Challenge III has started

Phase 1 (October)
Demonstrate Data Management tools to meet the requirements of the Computing Model

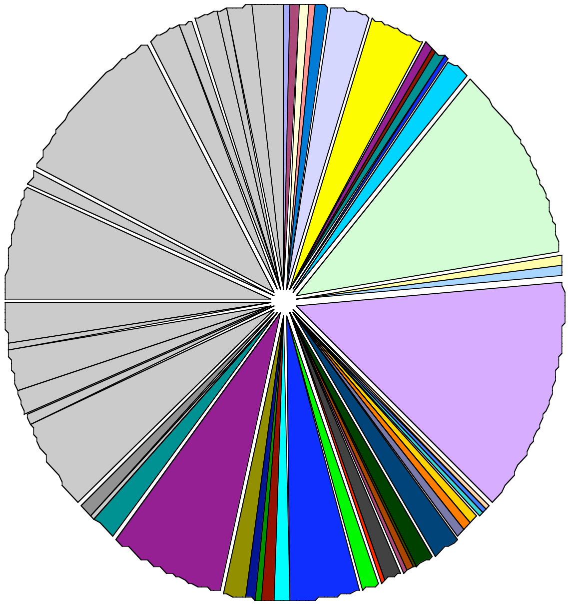
Still in progress

LHCb Usage of the Grid in 2005

Production over 74 sites - 60 WLCG sites, 14 DIRAC sites

CPU used: 6,389,638 h

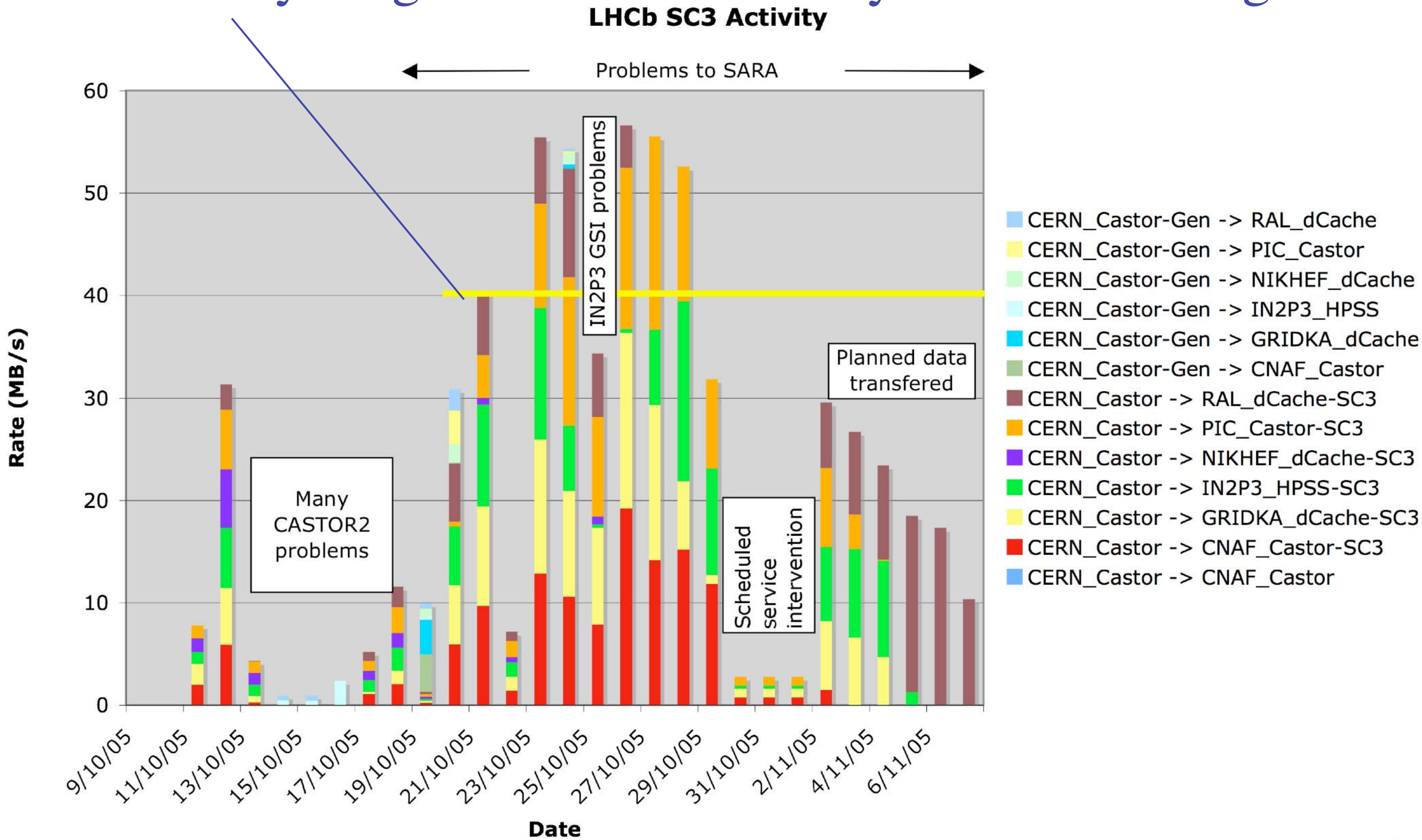
Data Output: 77 TB



"Tier-3" (not covered by WLCG) CPU can be included as DIRAC sites

Data transfer rate during the SC3

When everything works we can easily achieve the target.



Analysis on the Grid has started

CERN, CNAF, PIC, FZK, RAL & Cambridge

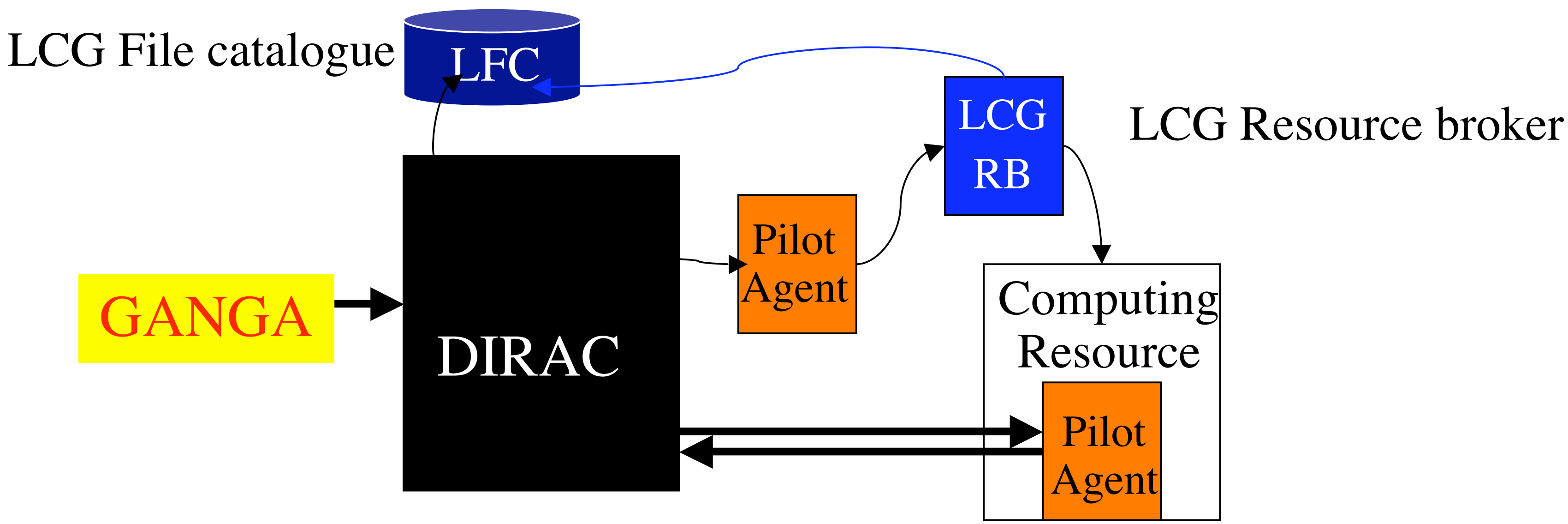
Recent performance:

17% jobs failed submission

- due to GANDA/DIRAC interface

Remaining 83% in “completed” state.

- No jobs reported as “completed” gave unexpected results.



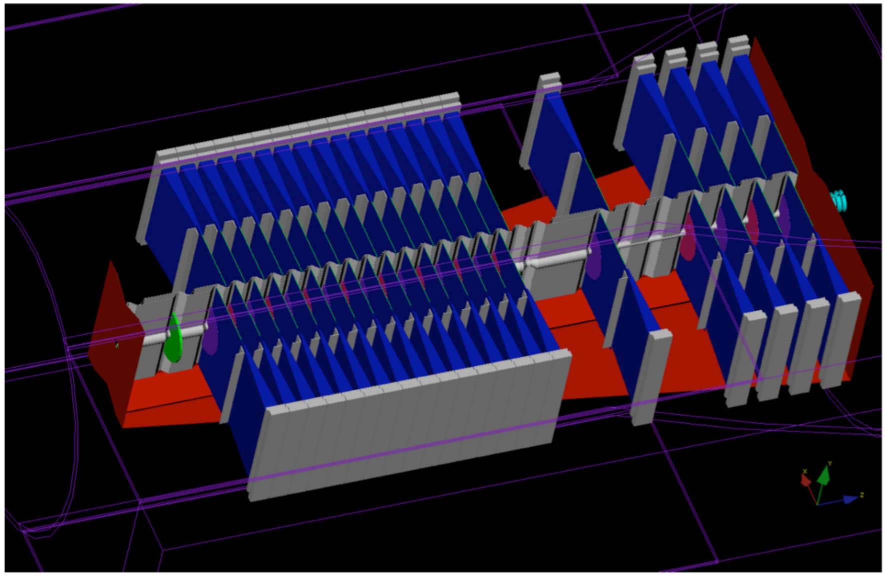
Application software

Baseline simulation, reconstruction and analysis software is in place. Now being improved, consolidated...

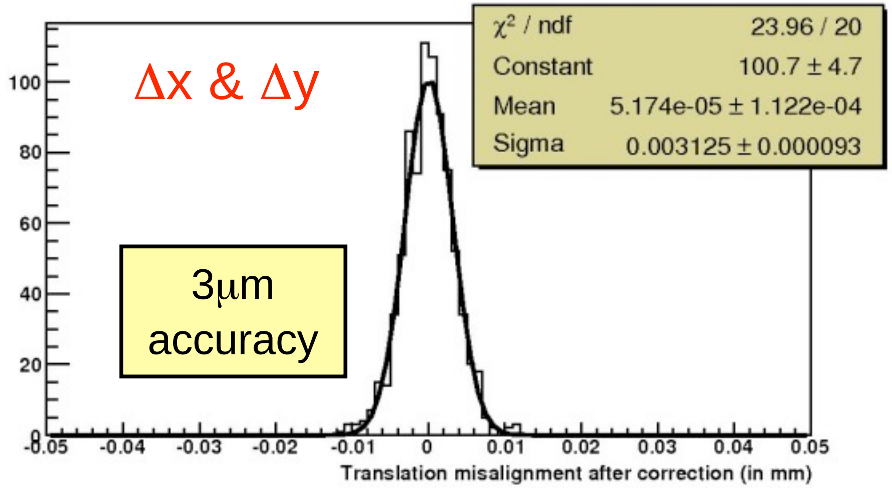
Event model reviewed and revised

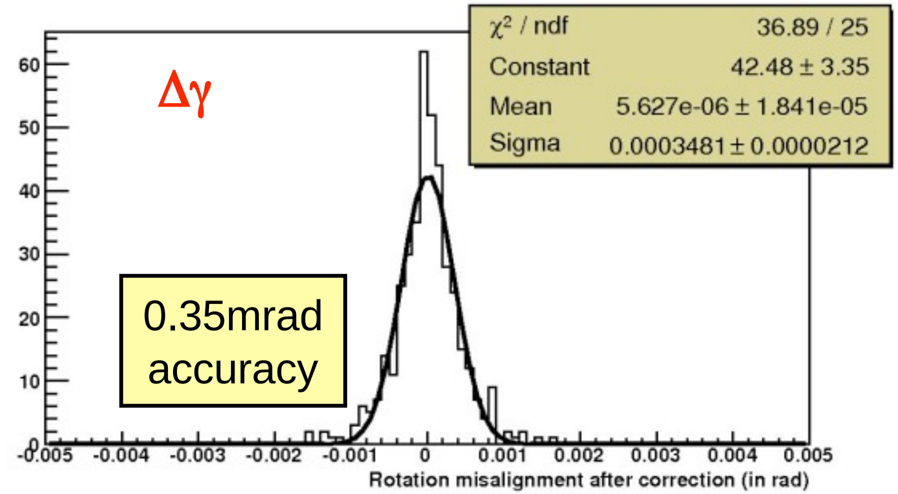
Major effort in the subdetector alignment

Example; VELO alignment



sensor residuals after the alignment





III) Preparation for the Data Taking

Commissioning Task Force installed

Chaired by Commissioning Coordinator; O. Callot (LAL)
with representatives from all the subsystems

Mandate;

- -Defining the mode of operation for data taking, and identifying, producing, implementing and testing all the tools necessary for this operation;
- -Commissioning the sub-systems;
- -Preparing the detector for steady data taking, through global commissioning, including the pilot run.

New physics organisation installed

A Physics Planning Group

Chaired by O. Schneider (EPFL), physics coordinator

6 physics working groups have been setup

- **Production and decay models WG**
  - Prepare and maintain physics generators
  - Address issues related to cross section and BR measurements, production asymmetries
- **Flavour tagging WG**
  - Develop tagging algorithms and ways to determine tagging performance and systematics
- **Proper time and mixing WG**
  - Develop understanding of the proper time reconstruction, resolution and systematics
- **CP measurements WG**
  - Develop tools and strategies for CP measurements
- **Rare decays WG**
  - Develop tools and strategies for measurements of rare decays
- **Jets WG**
  - Explore jets physics, in particular sensitivity to light SM Higgs

Activities

Develop and refine strategy for physics program

Identify missing tools/procedures/ideas,

Address “real” issues; trigger, reconstruction, calibration, systematics

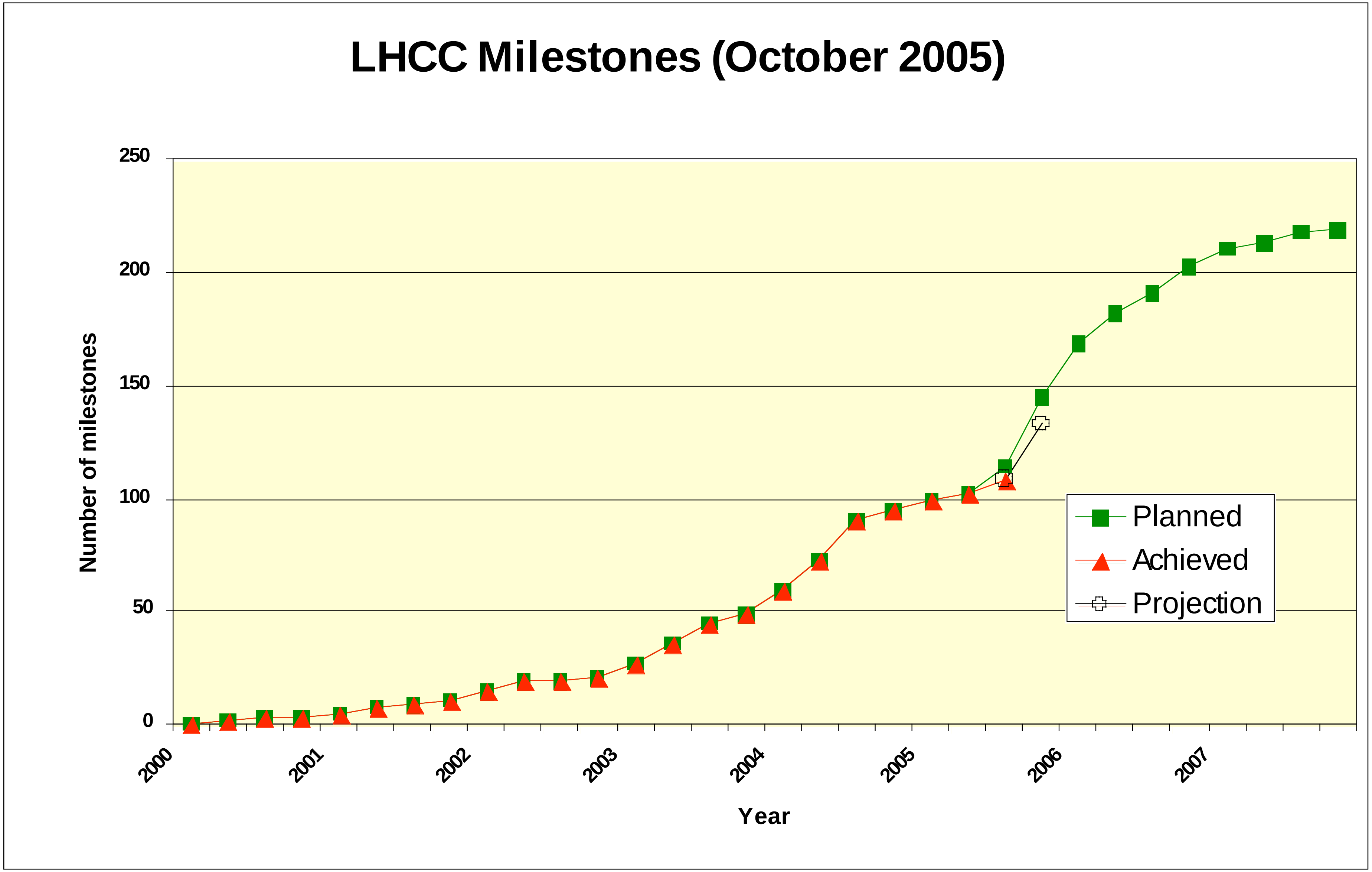
Plan

Focus on a few 1st-year measurements to be studied in depth:

- bb production cross section
- lifetime measurements from exclusive $b \to J/\psi\ X$ modes
- sin(2β), as a demonstration of tagging performance and capability of CP physics
- B_s oscillation frequency
- CP asymmetry in $B^0 \to \pi^+\pi^-$ and other exclusive $b \to h^+h^-$ modes
- $B^0 \to K^{*0}\ \mu^+\mu^-$ forward-backward asymmetry
- $B_s \to \mu^+\mu^-$ branching ratio

Report above studies in a written document together with:

- Survey of broader physics program and exploratory studies
- Realistic and quantified scenario for complete trigger


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

IV) Conclusions

1) Magnet, Calorimeter System, RICH-2, Outer Tracker, Trigger, Online and Computing advancing well.
2) Production of the muon chambers now advancing with the planned rate. The next critical issue is dressing.
3) No sensor procurement problem for Silicon Tracker any more. Module production has started, but bonding problem with IT pitch adapter. Urgent solution needed.
4) VELO mechanics advancing well. Delay in starting of the sensor module production, resulting in a tight schedule. Still a concern on the sensor delivery.
5) RICH1 mechanics now advancing. Be spherical mirror on the very critical path.
6) Installation plan to be revised to accommodate the delay caused by the machine cryo line installation.
7) Preparation for data taking started. Exciting time for LHCb as the detector construction reaches full speed.