Status of the LHCb Experiment

LHCC Open Session at CERN
15 November 2006

on behalf of the LHCb Collaboration

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CERN
and
EPFL

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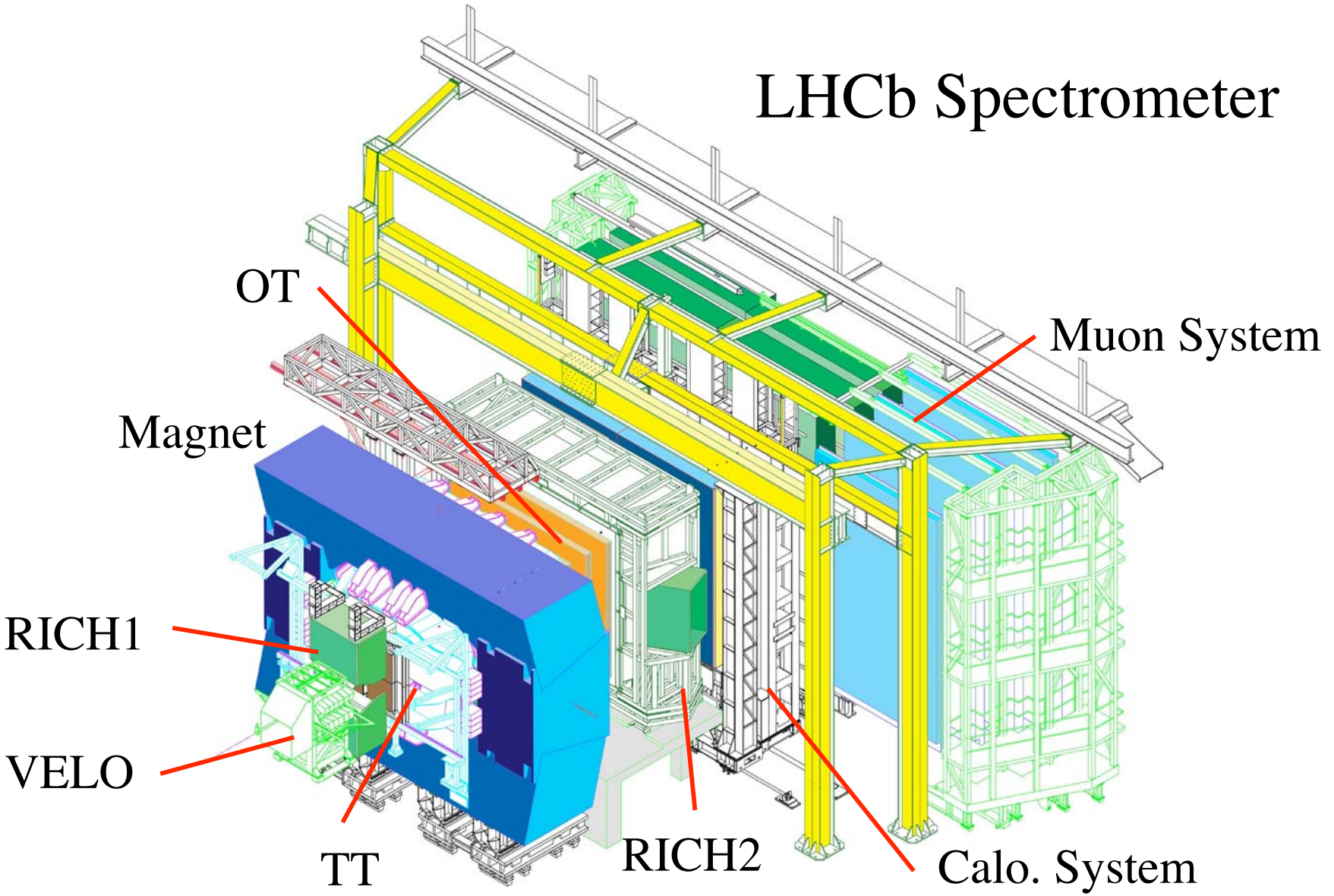
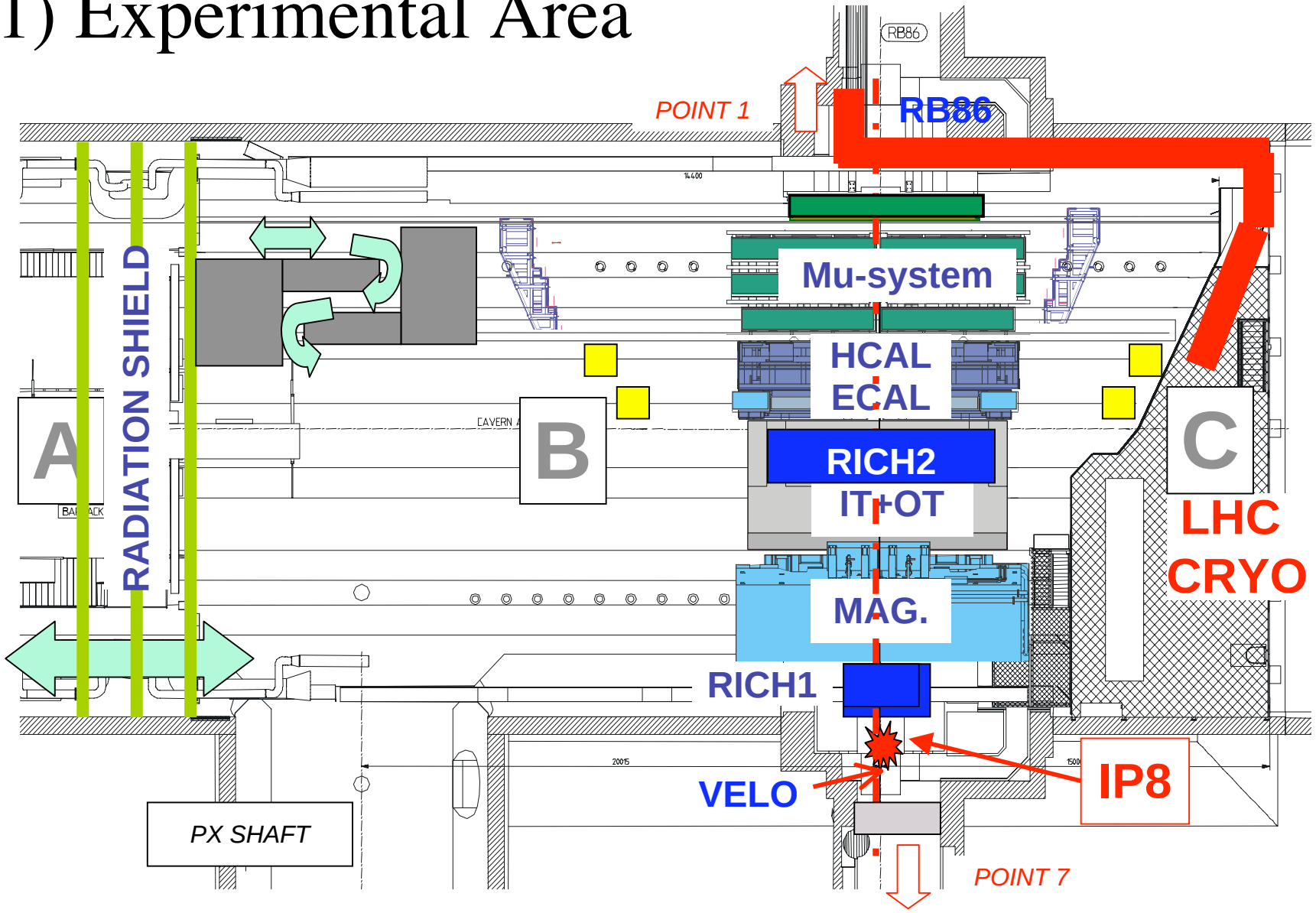
I) Construction Status



1) Experimental Area



Installation of the major metallic structures completed

Gas and cooling pipes installed in the detector area

Most of the cable trays installed

Installation of long HV, LV, ECS and signal cables and mounting of connectors in progress

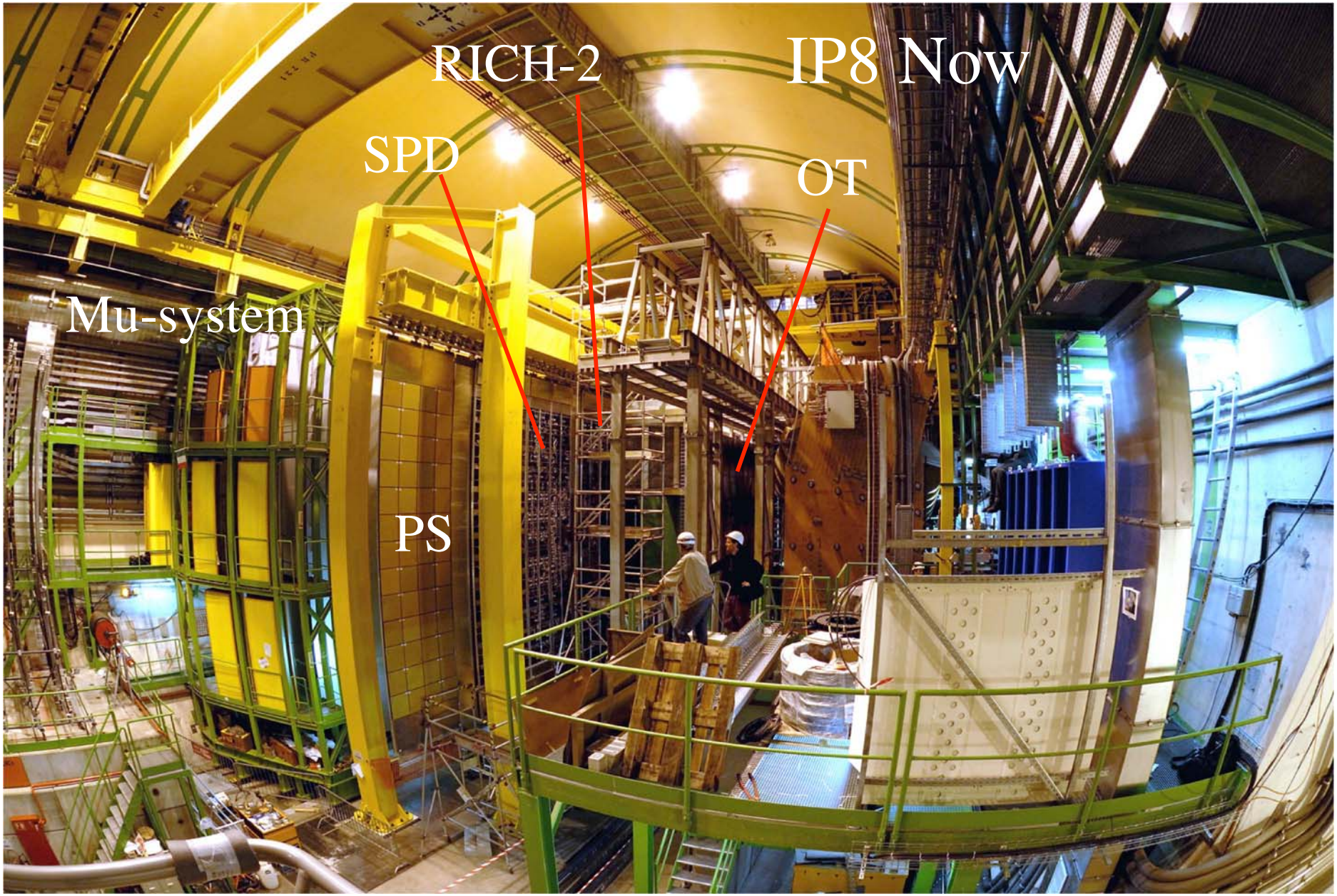
Installation of safety system in progress

Calo access tower

cabling and connector mounting

gas system

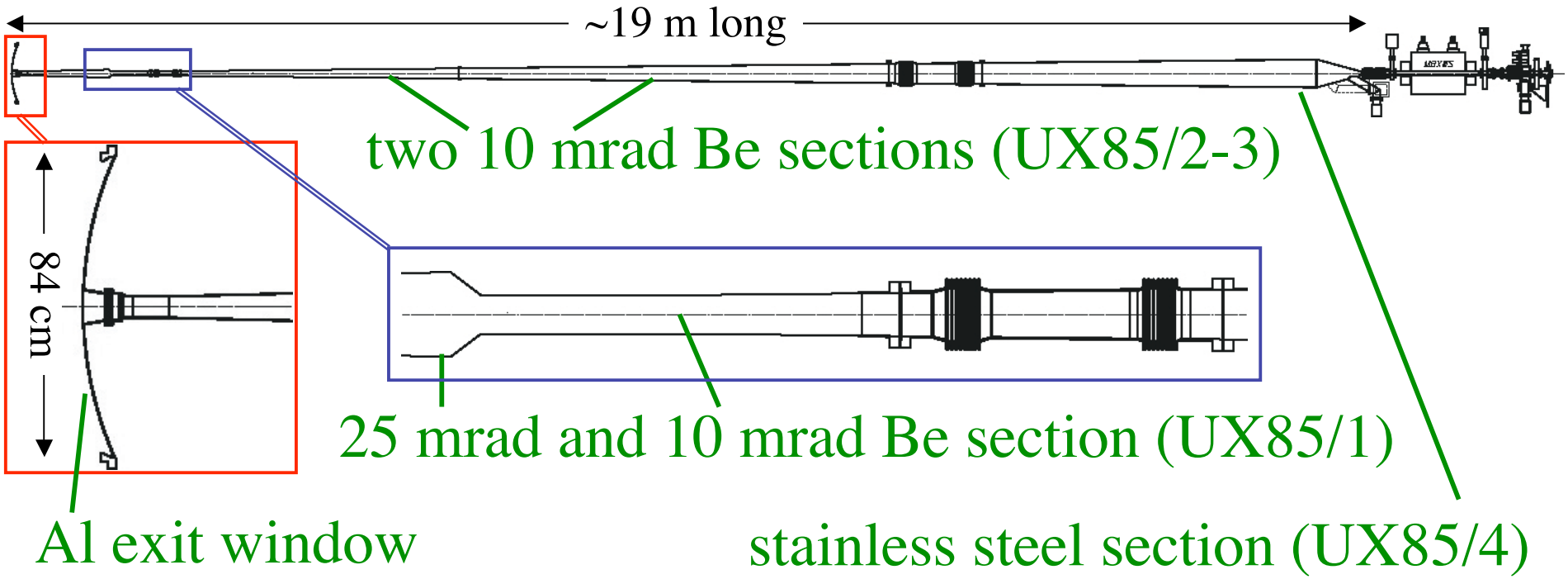
new access gate


RICH-2
IP8 Now
SPD
OT
Mu-system
PS

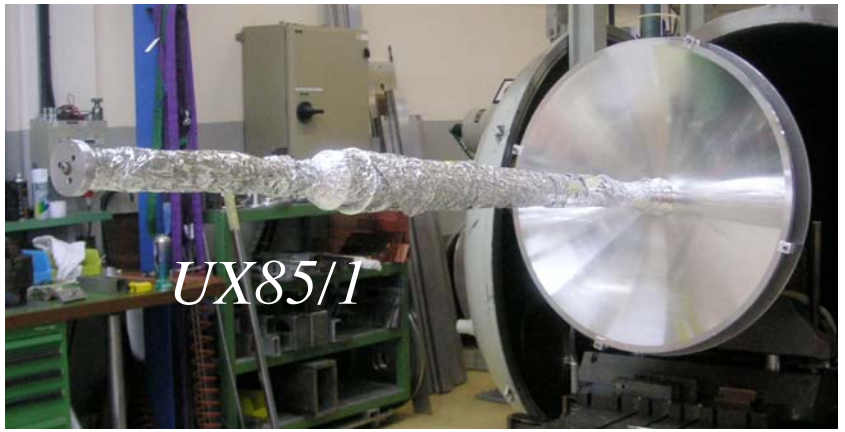
2) Beam Pipe

Under the responsibility of the LHC vacuum group with a close contact with the experiment

Built from four sections (3 Be and 1 stainless steel) joined by bellows and flanges (Al)
(+ Al backups for the Be sections)

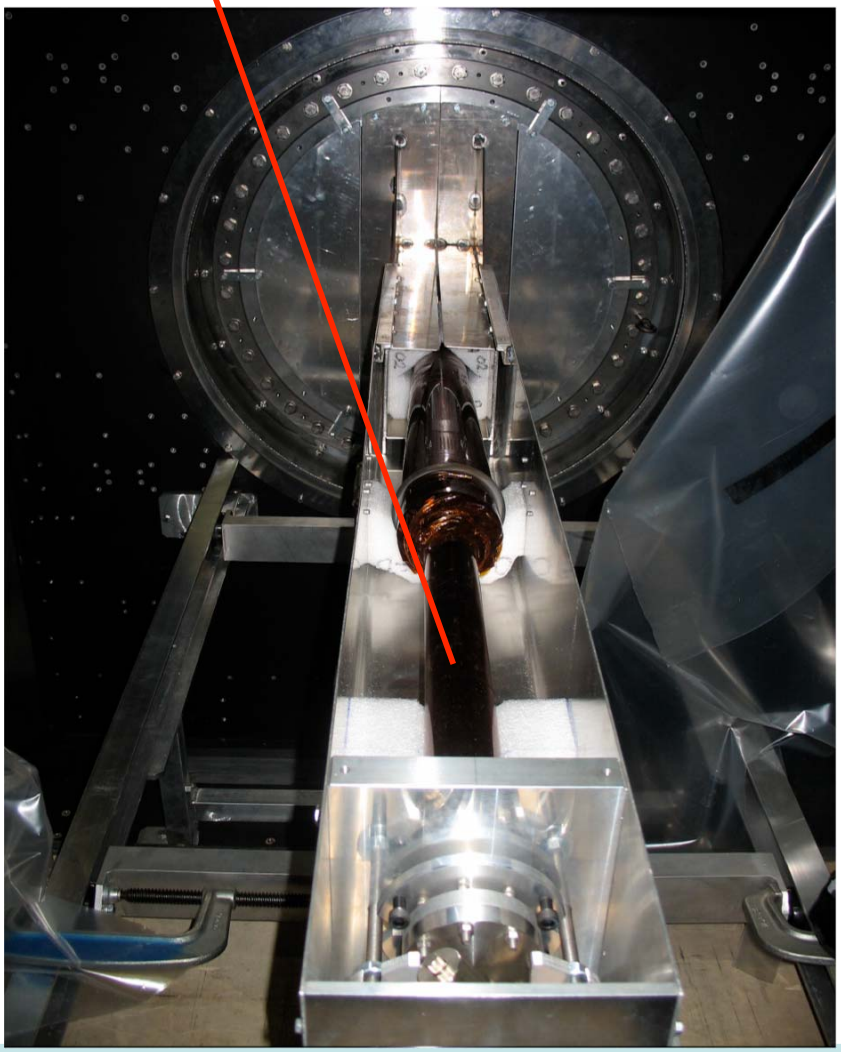


All the beam pipe sections delivered to CERN.
UX85/1, 2 and 4 ready for installation
UX85/3 just arrived with several months of delay,
undergoing
acceptance testing
(showing small leak,
to be investigated)



UX85/1 installed

Al exit window (protected)
+ UX85/1 Be beam pipe section

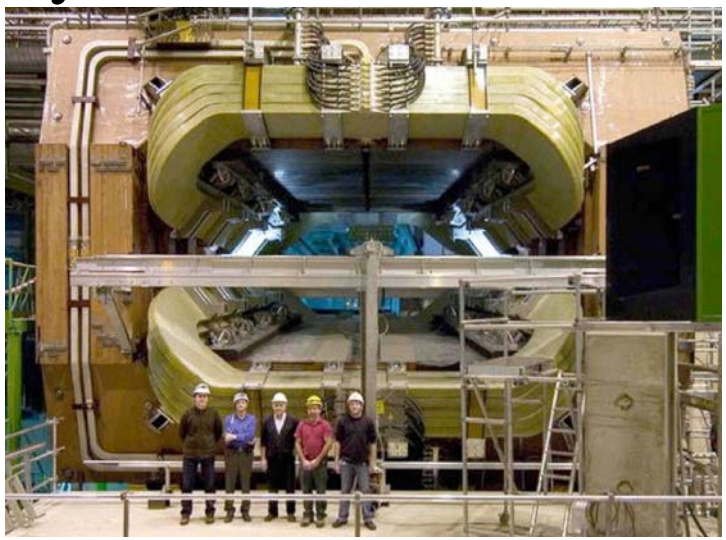


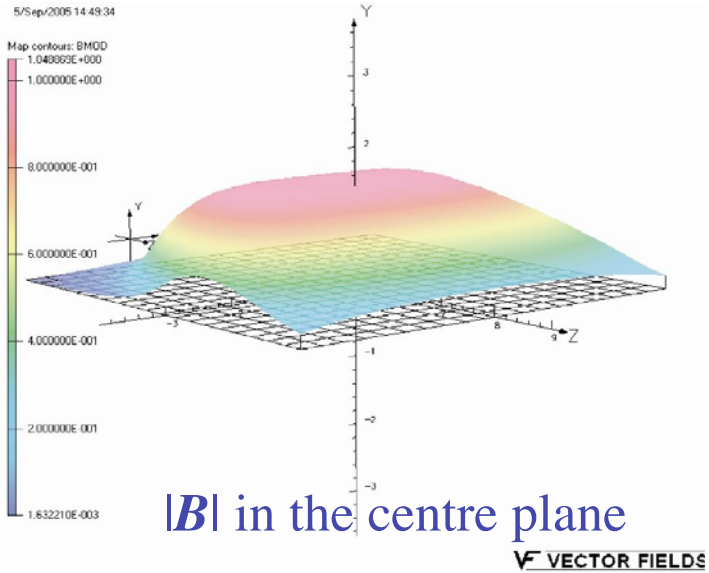
Production of the beam pipe supports in progress

Support-ring

3) Magnet

Fully commissioned and B field measured for both polarities



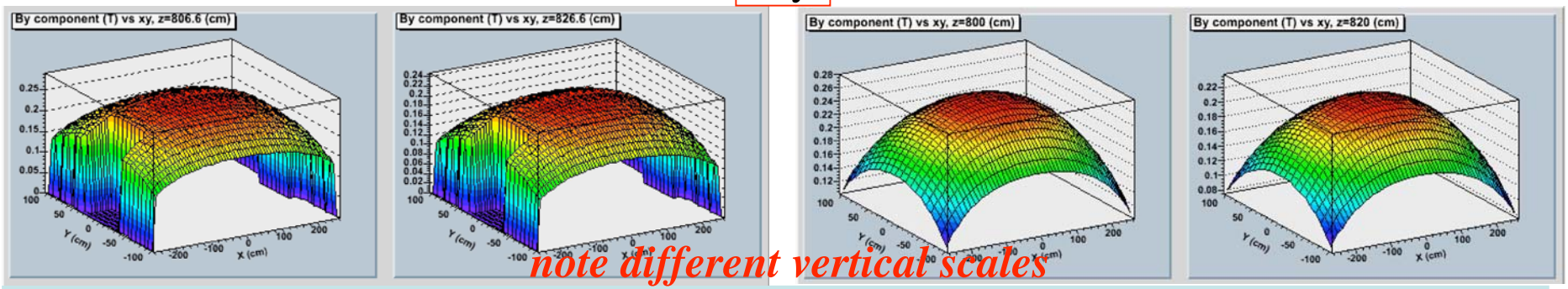


$|B|$ in the centre plane

VECTOR FIELDS

Analysis is in progress for incorporating the measurements into the software

measurements B_y calculation



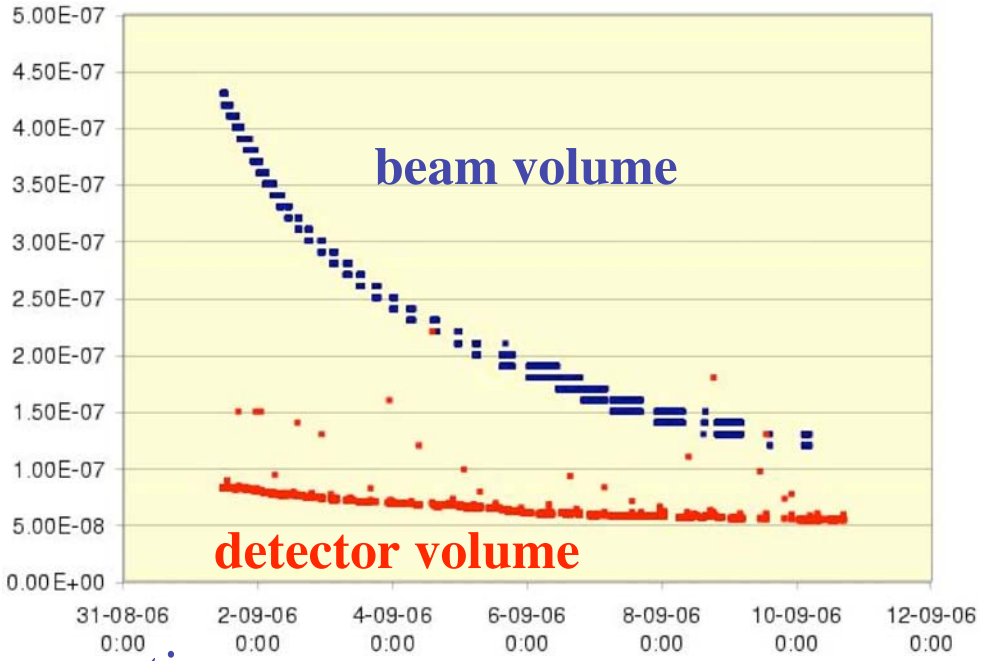
note different vertical scales

4) VErtex LOcator (CERN, CH, DE, GB, NL, US)

VELO tank and its vacuum system from NIKHEF installed at IP8; vacuum leak tested

Al exit window (downstream) together with the first section of the beam pipe connected

Al window and wake field suppressor



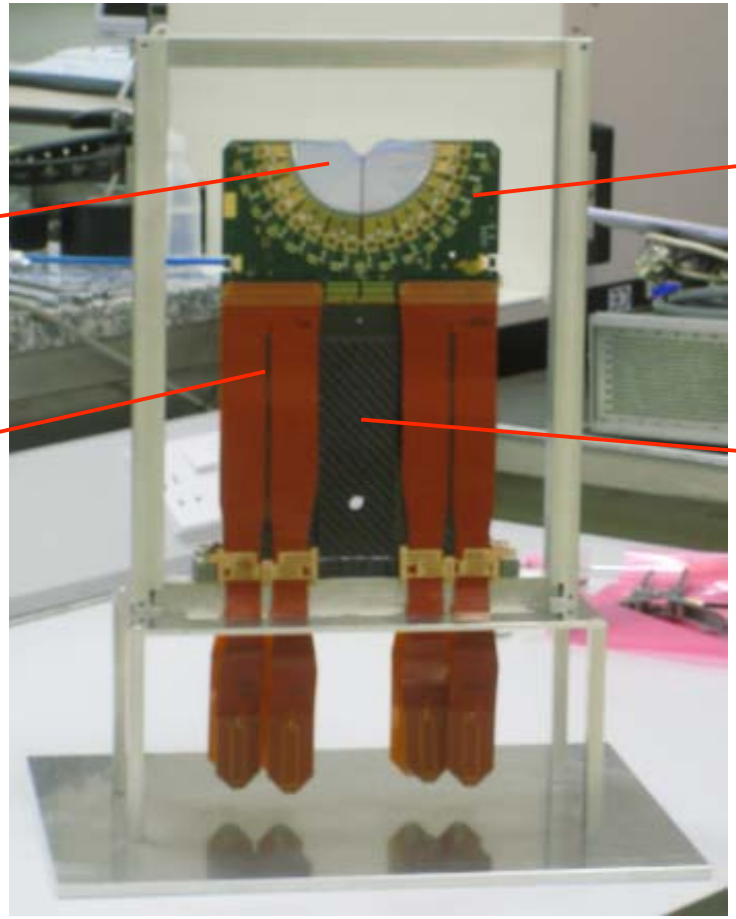
evacuation curve

Upstream side of the vacuum tank at IP8

Production of the sensor modules (42 + spares) started in Liverpool

r and ϕ sensors glued back-to back

Kapton cables for analogue signal and control

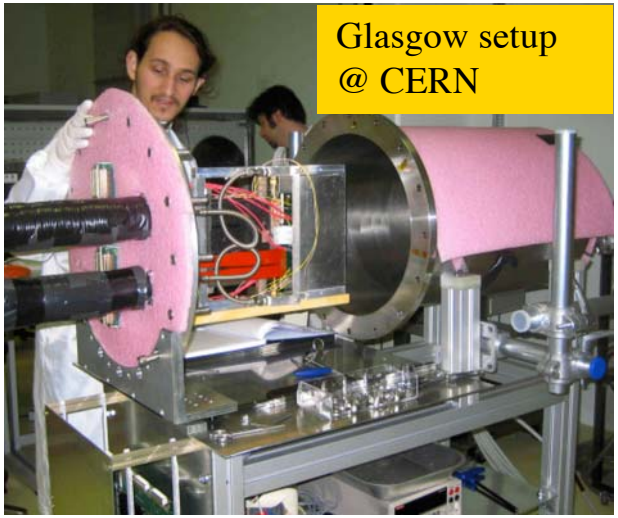


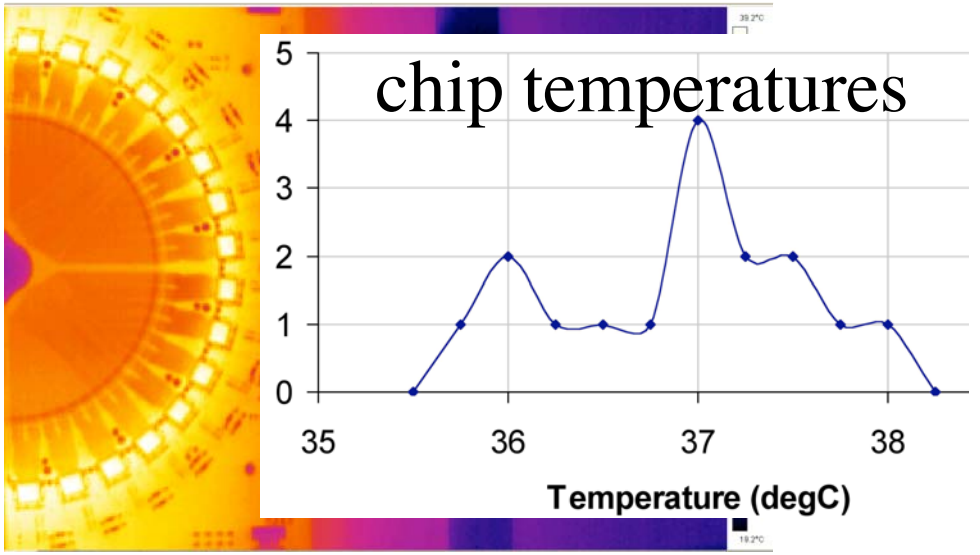
hybrid with Beetle readout chips

Carbon fibre support

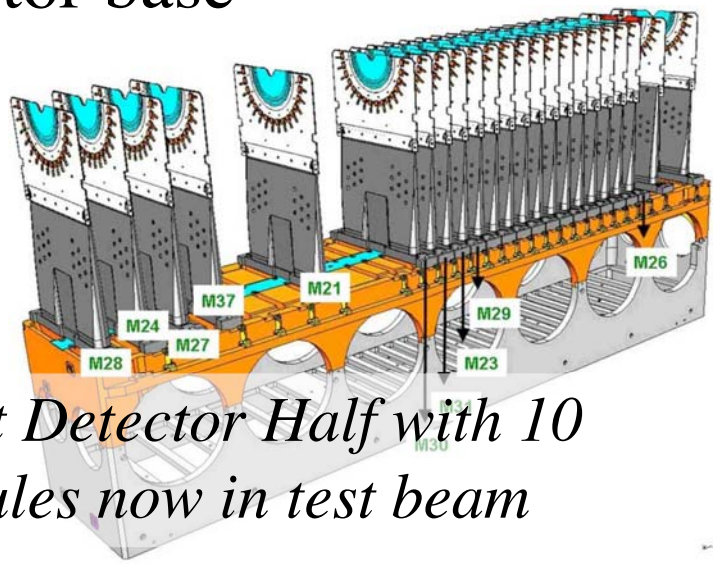
17 modules completed
Now reached the steady production stage, 2 modules/week
Expect to finish production by March 2007.

On arrival at CERN, visual inspection and burn-in test



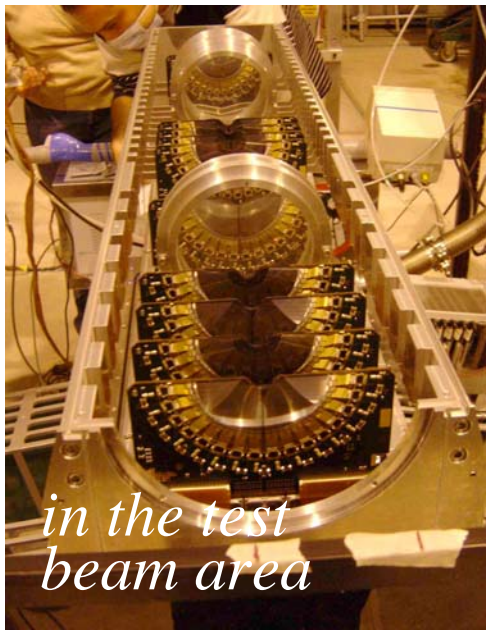


Followed by assembly onto the detector base

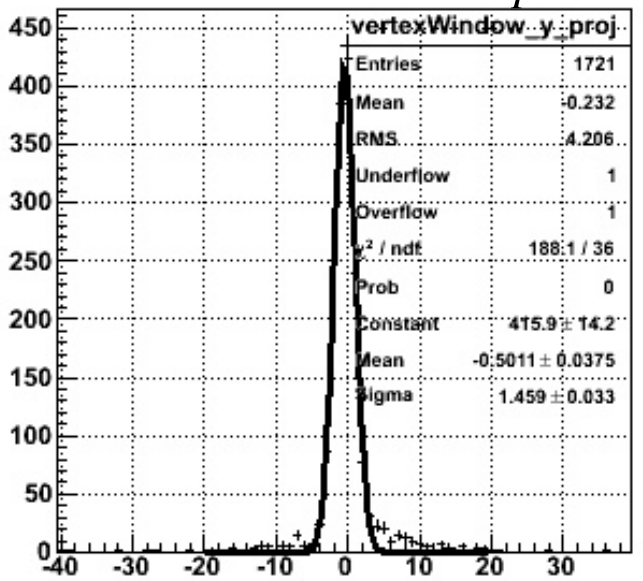


Right Detector Half with 10 modules now in test beam

2006 test beam: to test transportation, operation, alignment, event reconstruction, etc. with the full system (mechanics, readout, ECS, HV, LV)



y of reconstructed vertex in "open" position for beam-Al window interaction events,
$\sigma_y = 1.5\ \text{mm} \approx \sigma_{beam\text{-}spot}$

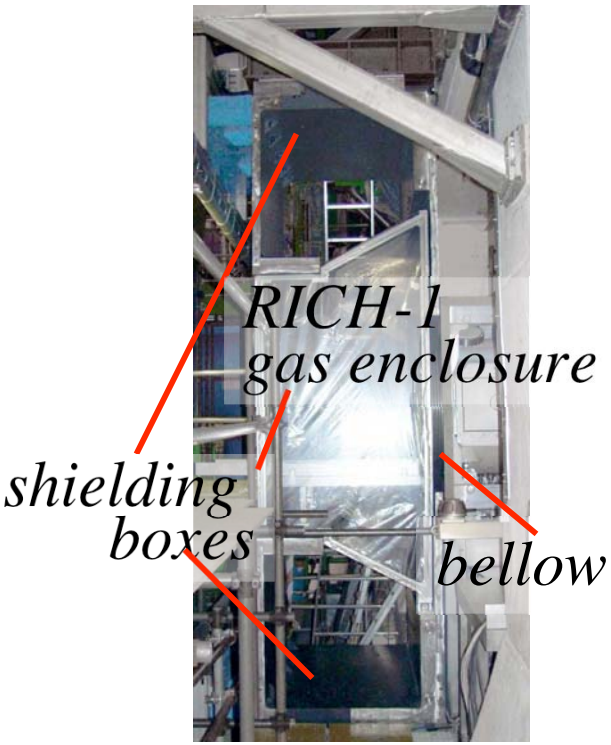


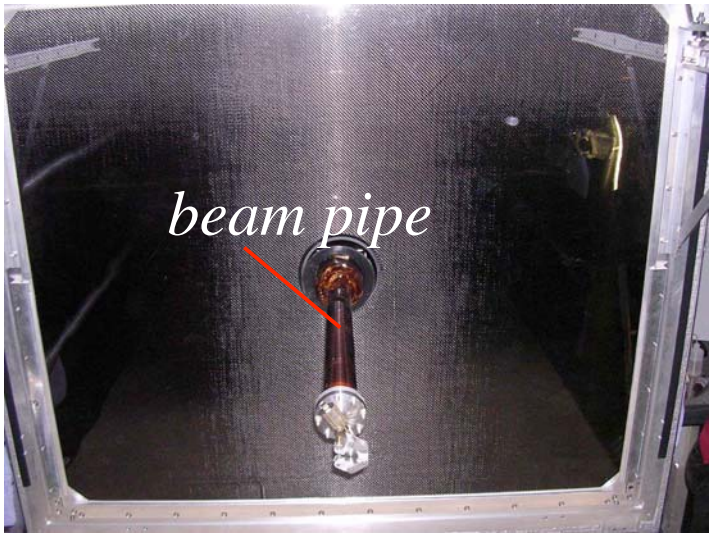
5) RICH (CERN, GB, IT)

RICH-2: In place and waiting for the Photon Detectors

RICH-1: Mag. shielding box, gas enclosure in place, gas shielding bellow connected to the VELO tank, exit window installed

RICH-2

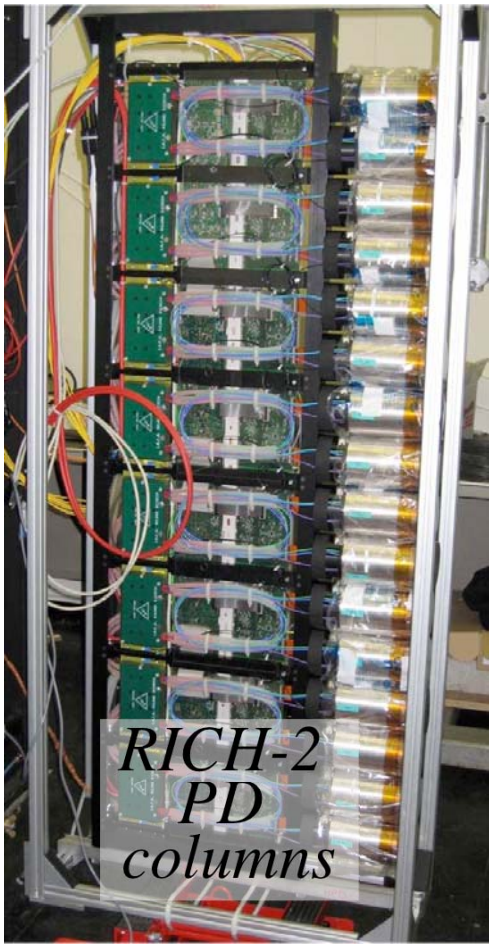


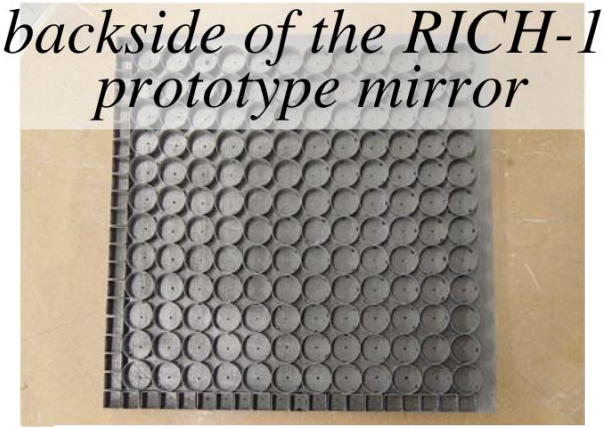


RICH-1 exit window

RICH-2: Photon Detector column assembly in progress
→installation for C-side starts in December

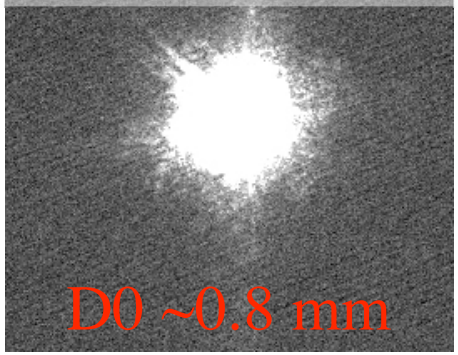
RICH-1: C-fibre spherical mirror prototype test successful, production in progress→ end of this year





Improvement needed for the Al + MgF_2 mirror coating to decrease the reflectivity loss in the UV region

Good optical quality

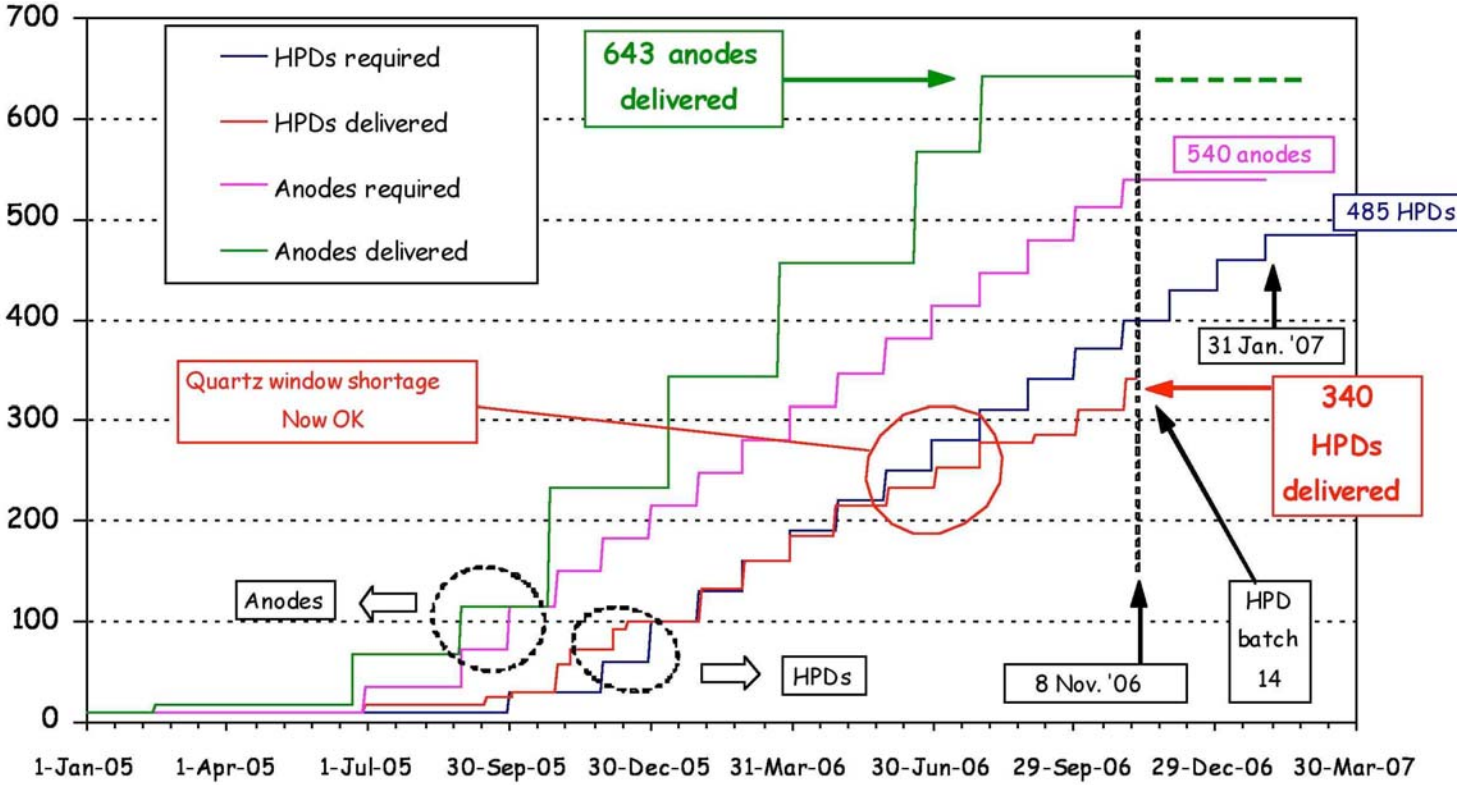


No deterioration in C_4F_{10} nor radiation

340 HPD's delivered out of 485 ordered (+ option for 65),
-2 months delay ⇒ recovery plan agreed with DEP
additional production line
-only 3% failed the acceptance test, very good quality

Test beam with the full readout chain successfully completed

HPD production plot



6) Outer Tracker (CN, DE, NL, PL)

Production of the detector modules completed in the three production centres: Heidelberg, NIKHEF, Warsaw

→ Delivered to CERN

Production of the module support C-frames completed and dressed with cables and tubes at NIKHEF

→ Delivered to CERN

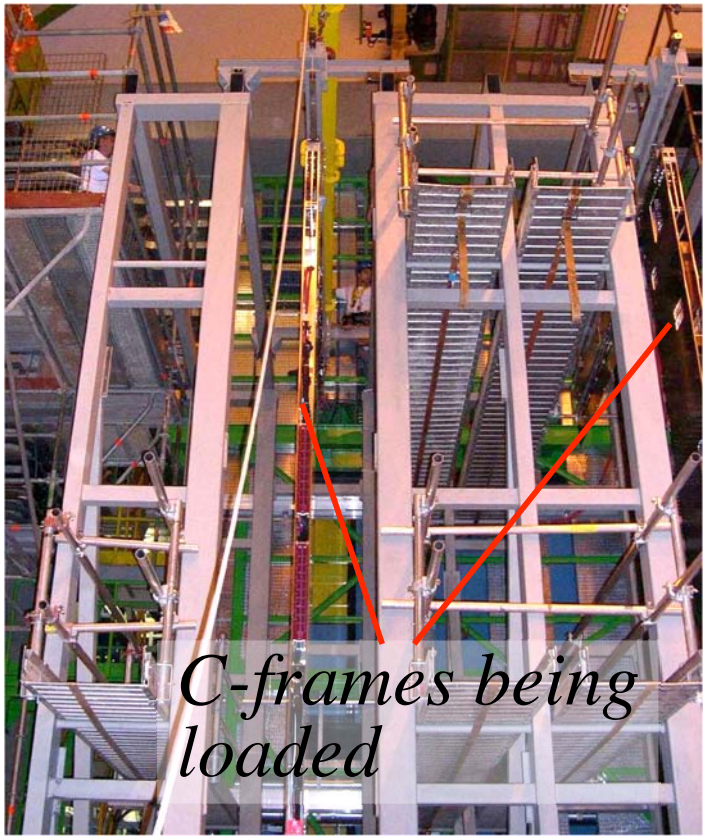
Production of the Outer Tracker/Inner Tracker support bridge structure completed

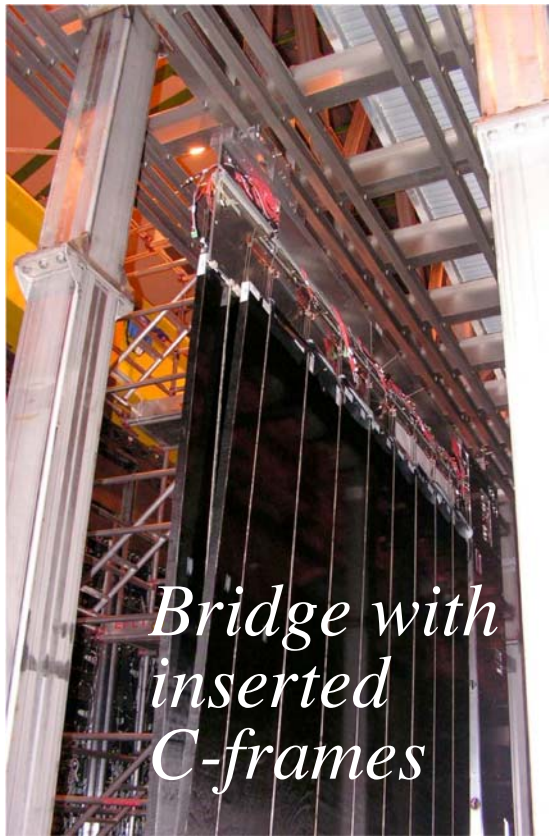
→ Delivered to CERN and assembled in IP8

Loading of the C-frame with modules in progress with specially built metal cage at IP8

OT/IT support bridge assembled

After testing, loaded C-frames are inserted to the bridge

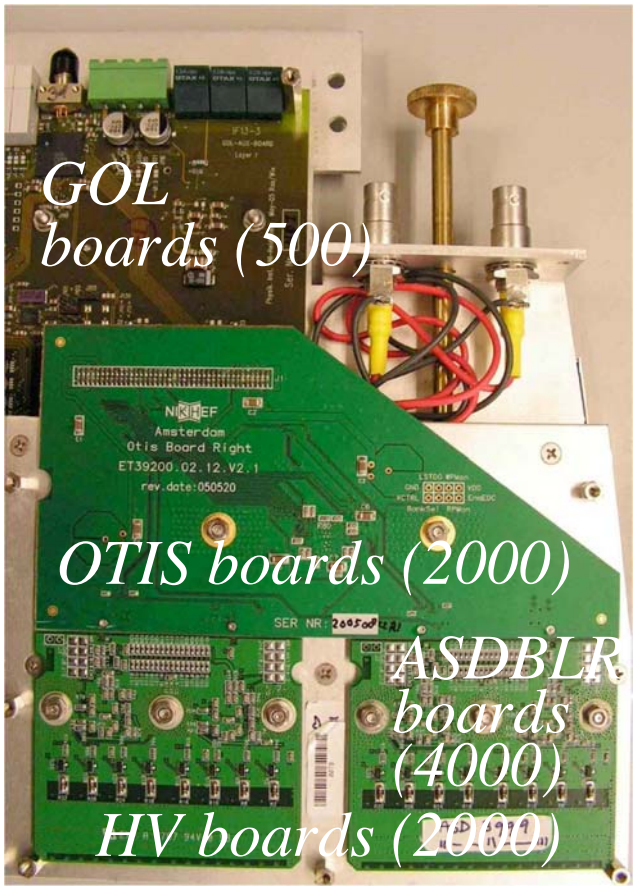




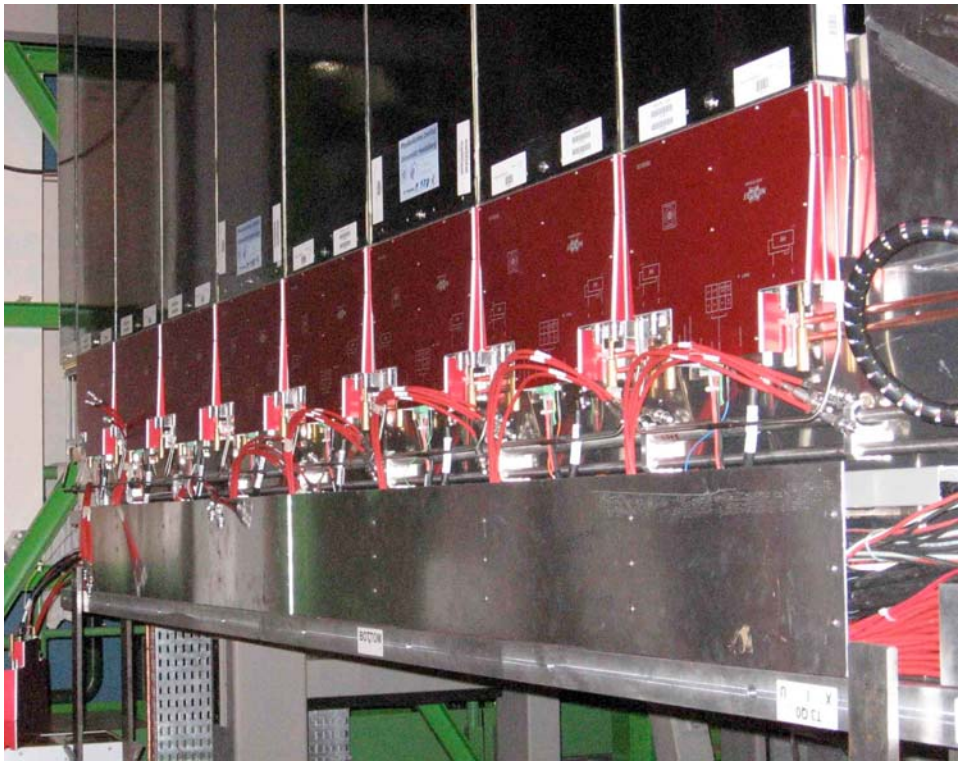
4/12 of C-frames inserted

Front-end electronics production in progress

All the ASIC chips produced and tested



Full scale test of the production front-end electronics with module loaded C-frame



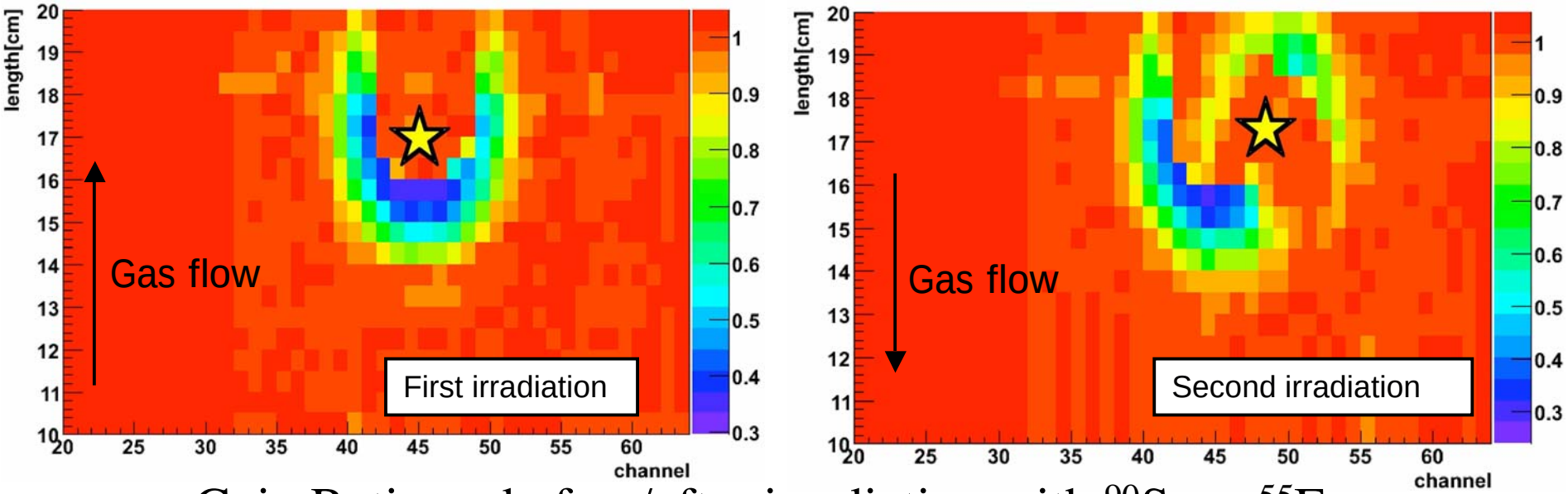
Comments on the aging issue:

Various prototype modules have been tested with X-rays and particle beams up to 3C/cm

⇓

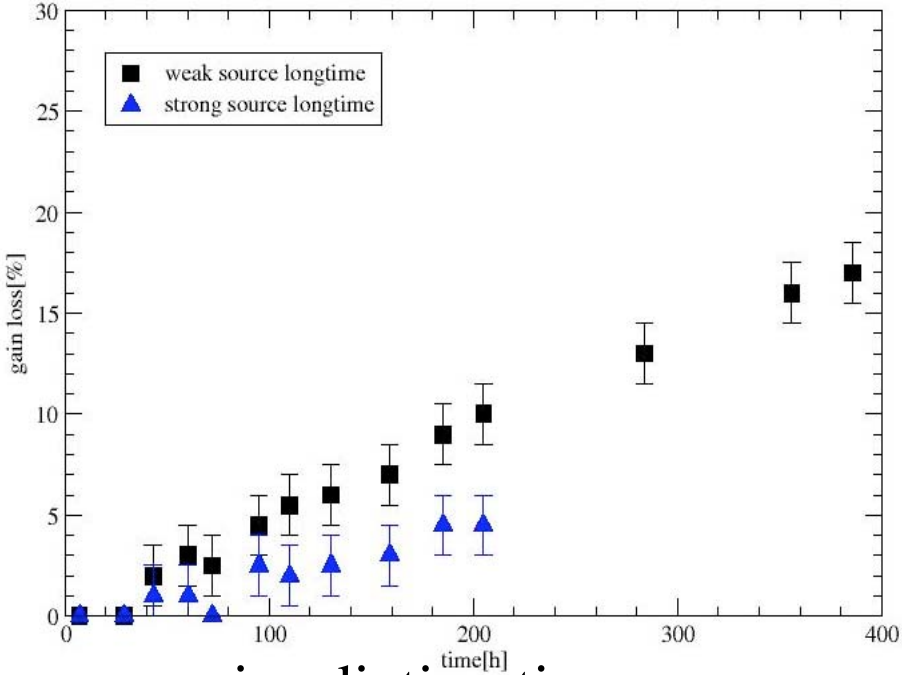
Showed no problem for 10 years of operation with Ar/CO_2

Accidentally, gain loss was observed for production modules at very small dose with weak sources (source centre ★)

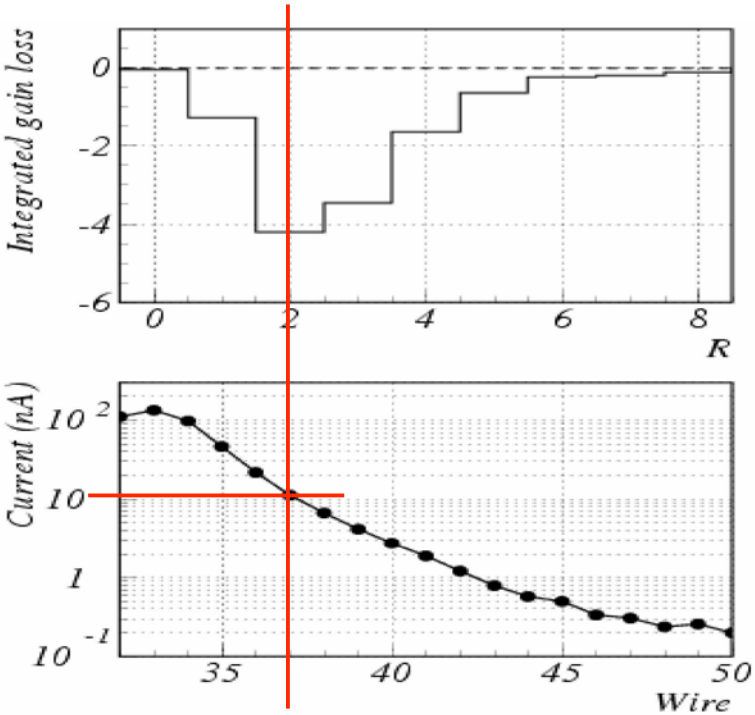


Gain Ratios = before/after irradiation with ^{90}Sr or ^{55}Fe

The gain drops as function of the irradiation time
Maximum gain loss is at ~10nA (LHCb hottest spot ~30nA)
At much higher irradiation no gain loss



irradiation time



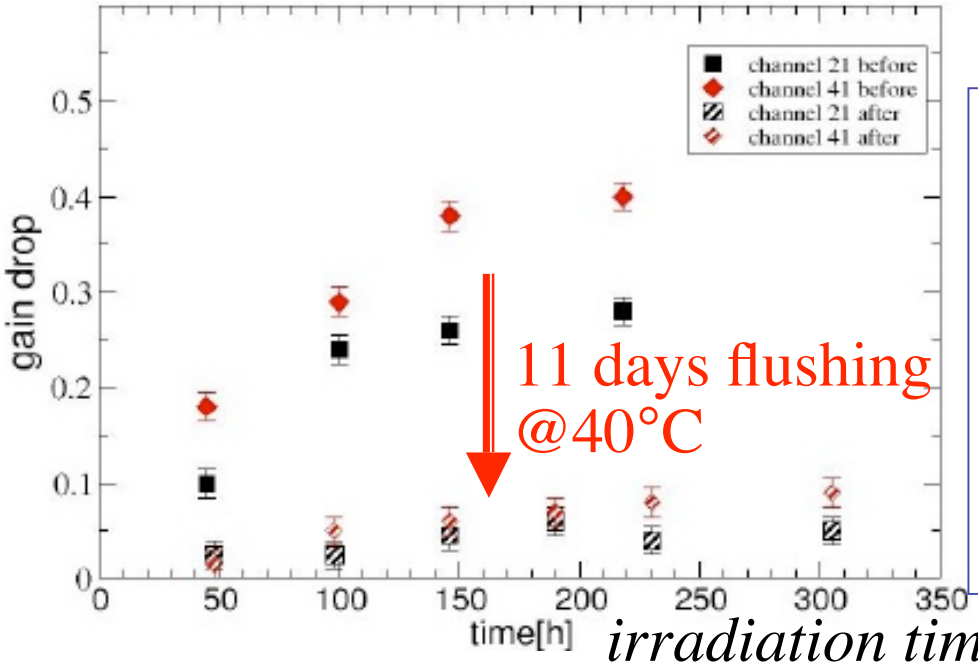
Large effort for investigation, including regular "workshops" with participation of external experts

No definite conclusion for the cause but strong indications for an out-gassing effect

Gain loss reduced after flushing the module for long time.

4 weeks flushing (Ar/CO_2): 20% gain drop @72 hr irradiation
6 months of flushing: 7% gain drop after @150 hr irradiation

Flushing at higher temperature, ~40°C, appears to accelerate the process



irradiation time

Module shrunk by ~1mm when heated (due to drying)

No other mechanical deformation.

Heating in situ somewhat complicated

Procedure for how to treat the modules being finalized:
in the mean time, modules being flushed continuously and infrastructure for heating being prepared.

7) Silicon Tracker (CH, DE, ES, UA)

Trigger Tracker

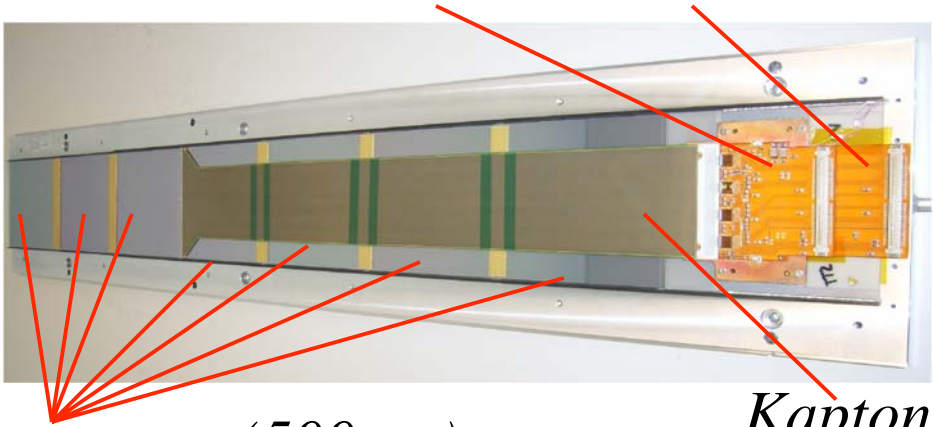
Ladder production completed

Inner Tracker

almost completed

tests are still on going

hybrid for the top and bottom

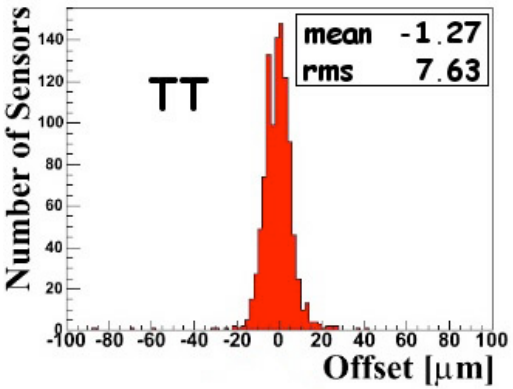


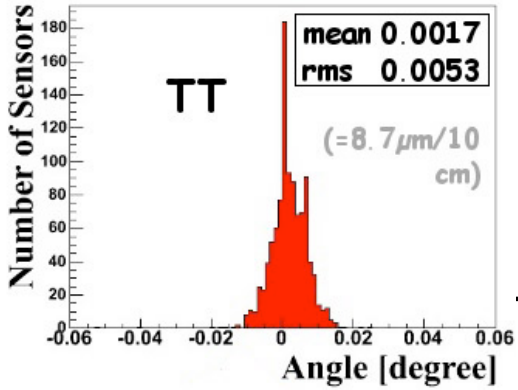
sensors (500μm)

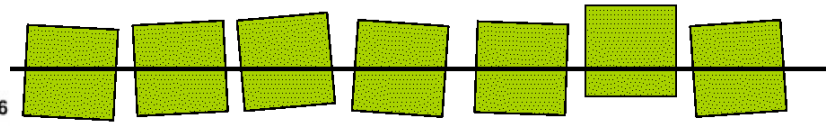
Kapton cable

two sensor (410 μm) ladder

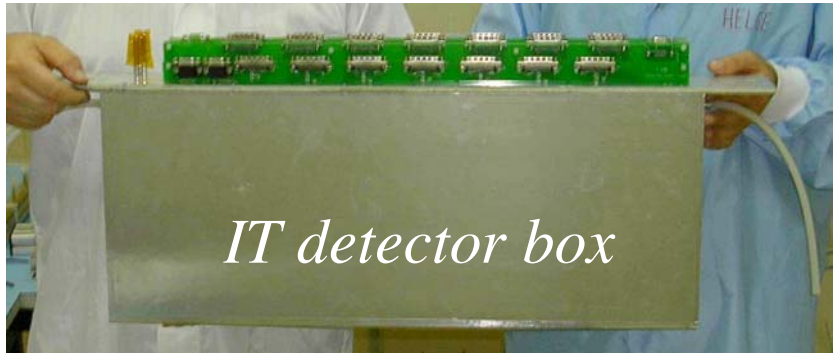
one sensor (320 μm) ladder





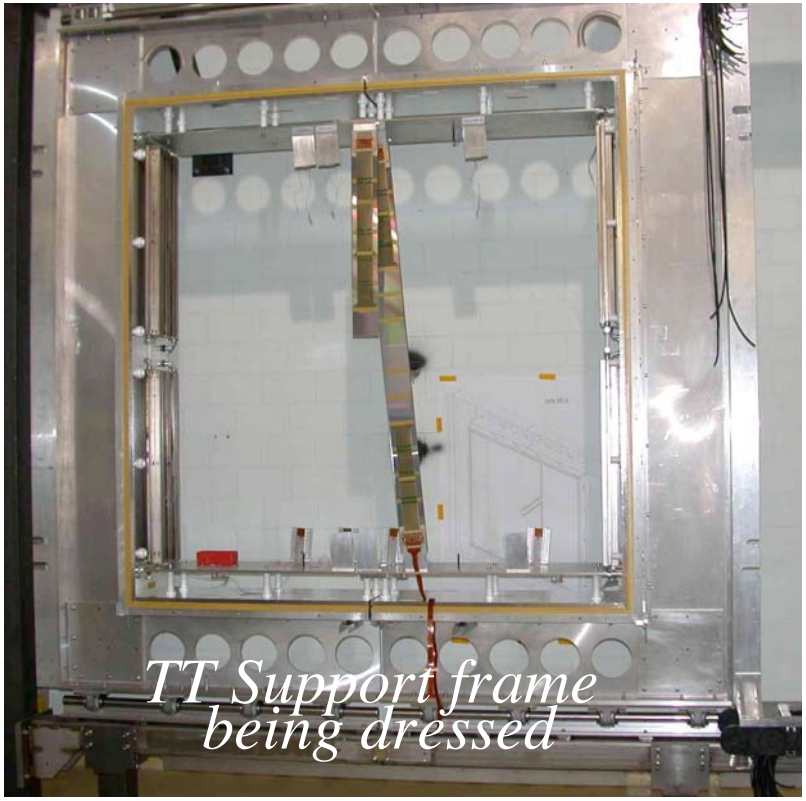


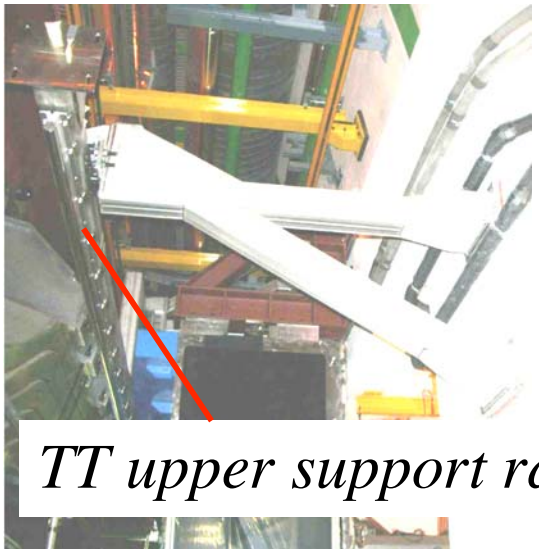
First IT box assembled



Some improvements for the tools and the next assembly starts soon

6 IT support frames constructed
3 cabled and inserted to the Bridge

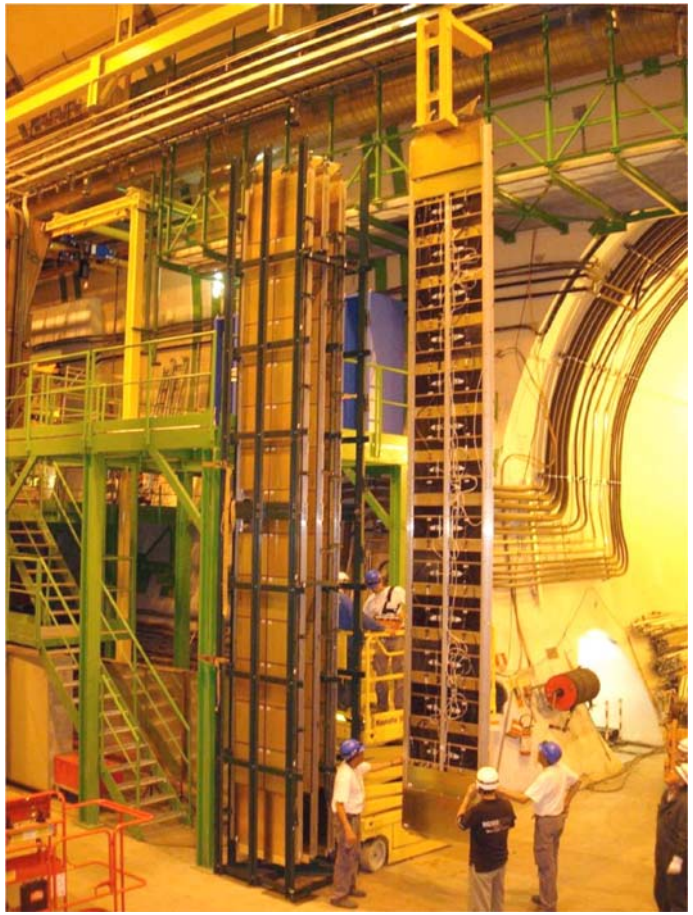




Service Box (in production) and Digitizer Boards (all produced)

8) Calorimeter System (CERN, ES, FR, RO, RU, UA)

Scintillator Pad Detector/Preshower (recently), E-cal and H-cal all installed



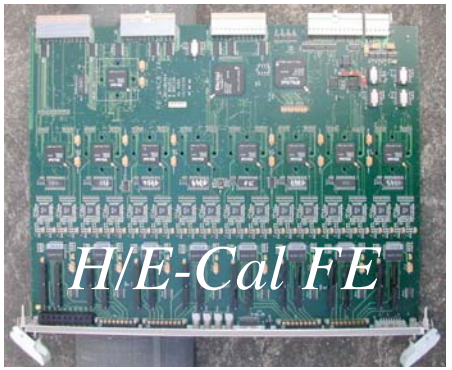
Insertion of the SPD super modules

Completed SPD/PS

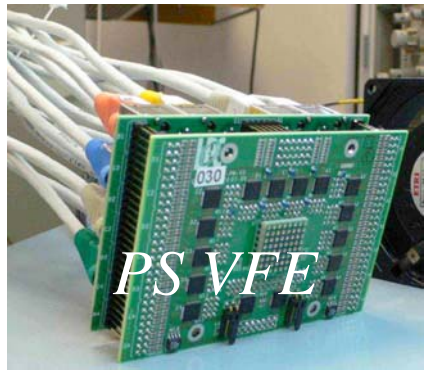
Electronics

E/H-Cal Front-End cards >90% produced
PS and SPD Very Front-End cards completed
PS FE cards production started (100 needed)
Calorimeter Read-Out Cards 2/26 produced
SPD Control boards PRR soon (16 needed)

Racks with E/H-Cal FE cards on the platform (top of the E-cal)

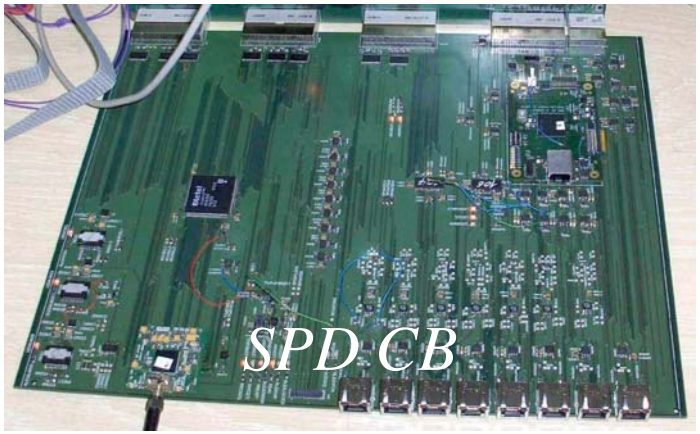


H/E-Cal FE



PS VFE

PS FE



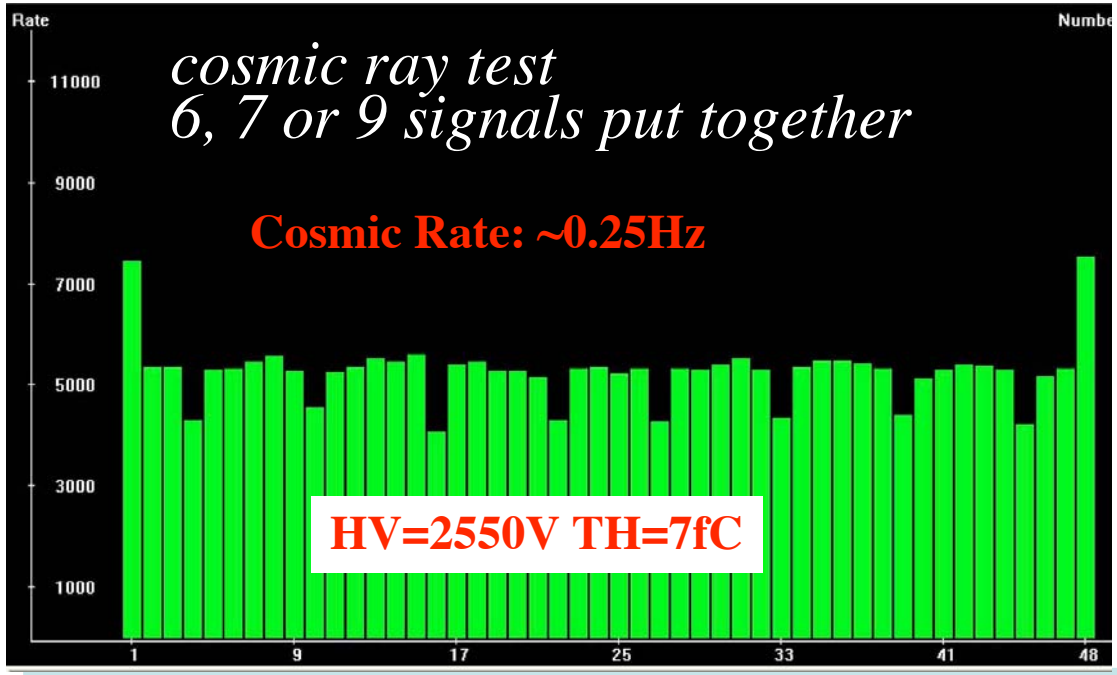
SPD CB

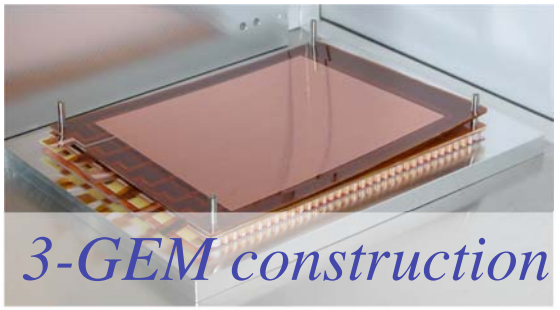
9) Muon System (CERN, IT, RU)

All the MWPCs except spares produced and tested
CERN, Ferrara, Firenze, Frascati, PNPI

Dressing at CERN (CERN and PNPI chambers) and Frascati (IT chambers) in progress

3-GEM 100% (Frascati) and 8/12 (Cagliari) for M1/R1 dressing to follow

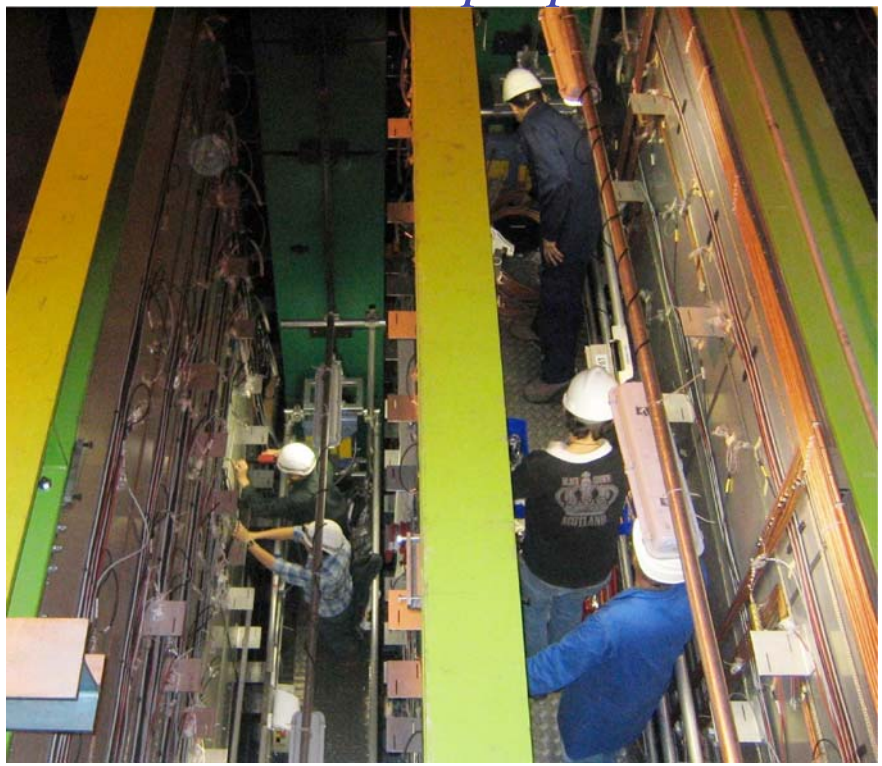




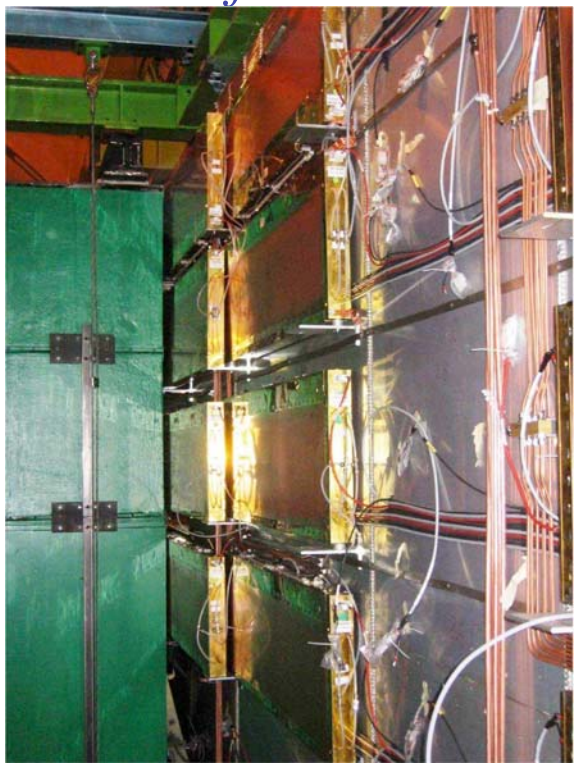
Chamber support wall for M2-M5 assembled and necessary infrastructure (gas, cable, etc.) being installed

Chamber installation for M5 started with delays
gas and cable connection and noise level tested
currently ~6 (2 to 4) chambers/day for installation (testing)
need to go up to 10 → Parallel installation required.

Muon wall preparation



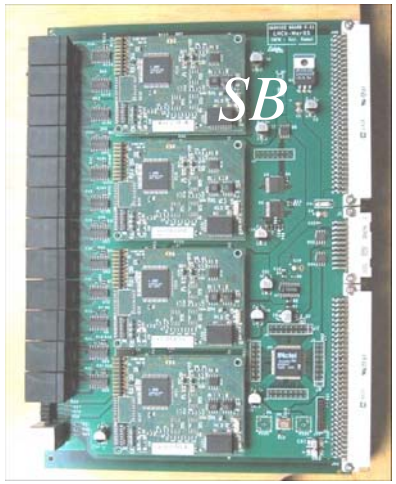
MWPC installation for M5

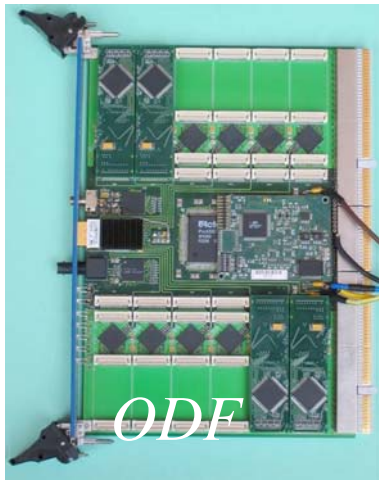


Electronics

All the ASIC's have been produced
Spark Protection Boards: 8000 needed, 80% completed
Cardiac Boards: 8000 needed, 70% completed
Intermediate Boards: 100% completed
Service Boards: 100%
Off-Detector Electronics boards: in production, 160 needed
3-GEM Cardiac Boards: in production, 300 needed

Full readout chain used in the test beam with MWPC and 3-GEM

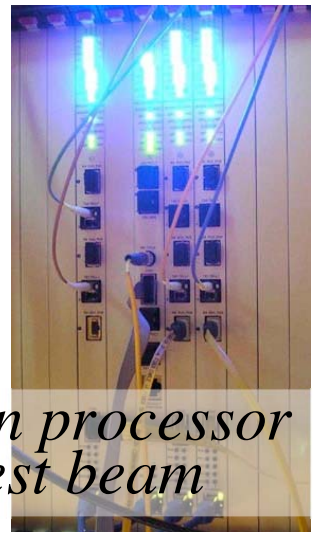




10) Trigger and Online (CERN, CH, CN, GB, DE, FR, ES, IT, NL)

L0 trigger hardware production:

- Muon trigger: four processor units needed
  - first processor unit almost completed
  - →most of commissioning work can be done
  - (data link tested in the test beam with the muon detector)
- Calo trigger:
  - Validation Cards, 4/28 in production
  - Selection board 2/8 in production
- Pile-up trigger:
  - Prototype test completed, PRR in 12/2006
  - 13 boards (three different types)
- L0 Decision Unit:
  - Working version is ready
  - Upgraded version prepared for 2008

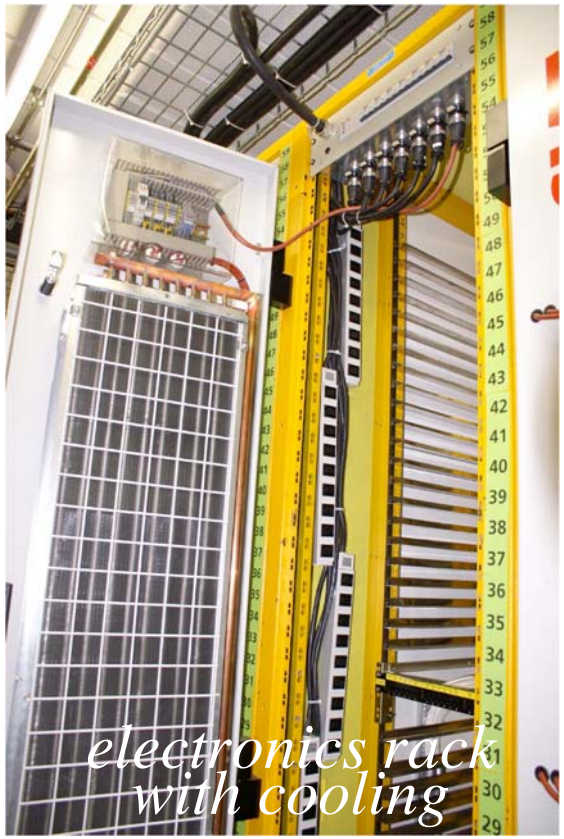


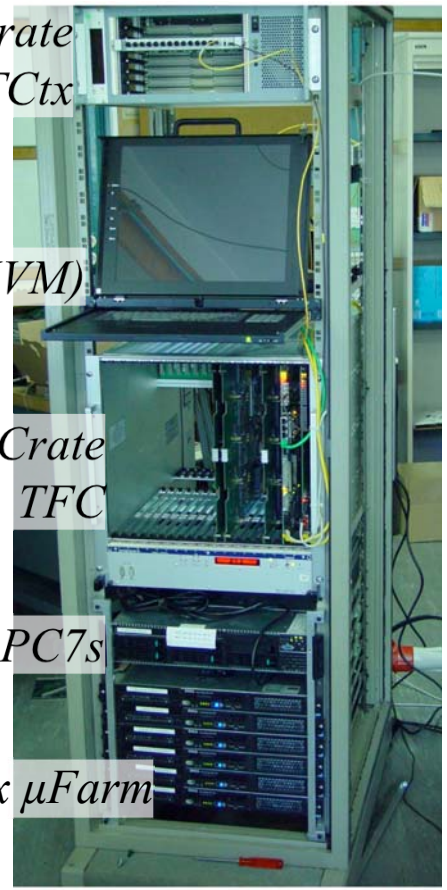
L0 Muon processor at test beam

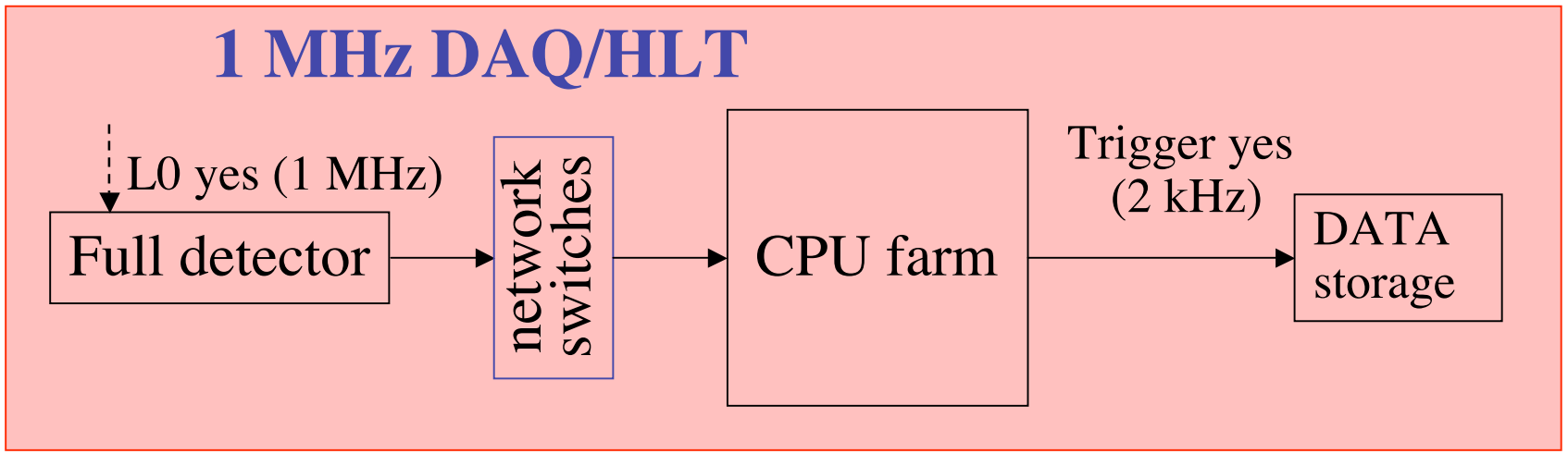
Infrastructure of the electronics huts at IP8 ready and cabling is being done

CPU's and servers necessary for the commissioning arrived

In order to ease the commissioning of the subsystems, Commissioning Racks with TFC and scaled down DAQ are prepared







Hardware implementation defined using Force10 network switch

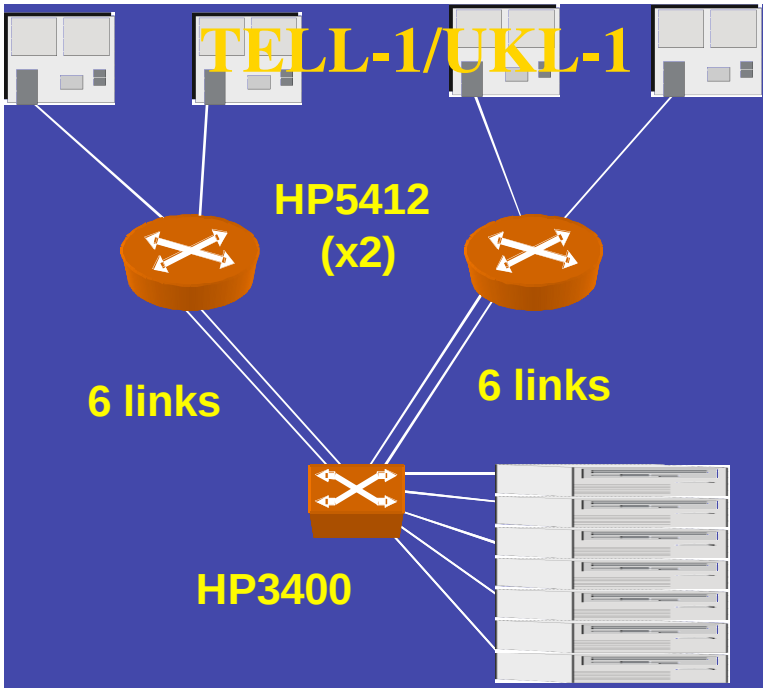
Software development: event building farm control etc. in progress.

Part of software being used in the test beam DAQ

ECS is now being implemented by the subsystems and partly used in the test beam.

Start-up configuration for the DAQ system revised reflecting the new LHC plan:

In 12/2007, very low luminosity collisions with 900 GeV
low event rate and low event multiplicities
→ bandwidth and CPU needs are very limited:



Core network switch is two mid-range HP switches ("borrowed") and 80 CPU nodes for the farm

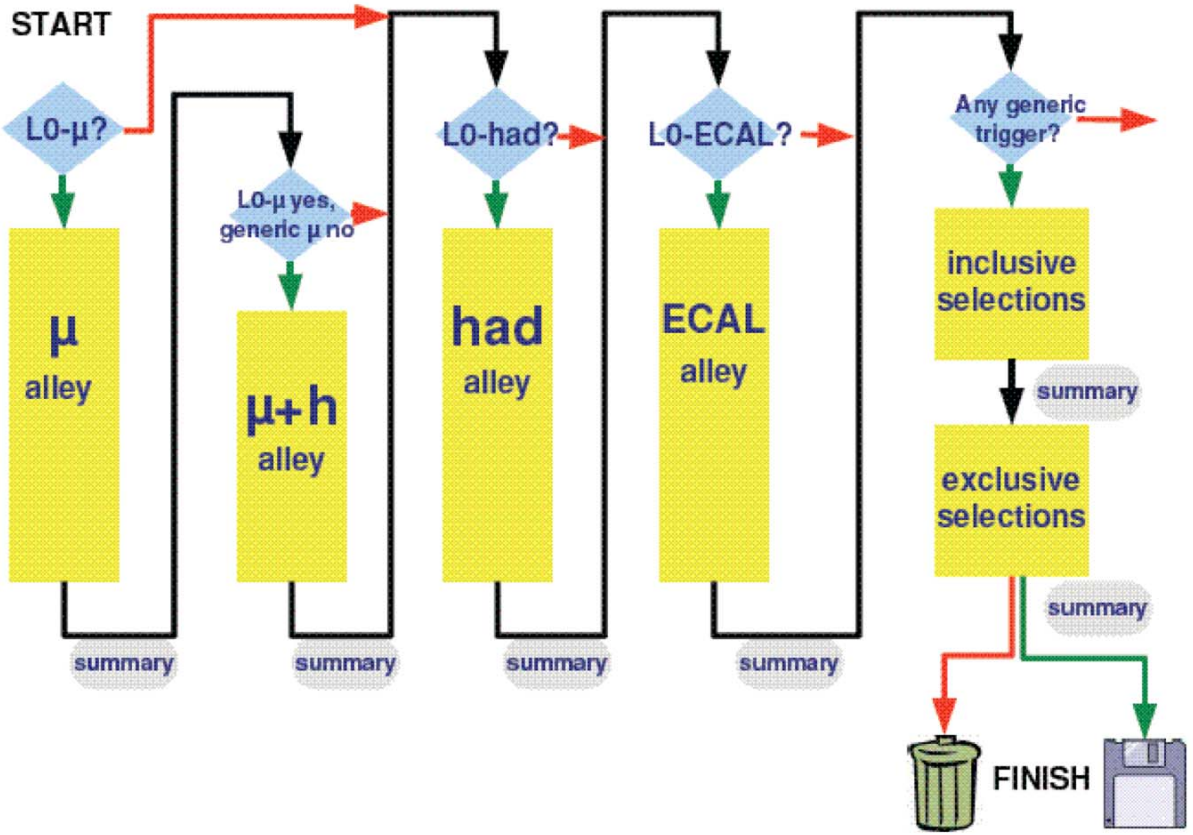
Delay the purchase of expensive Force-10 Linecards and CPU's

Final Switch can be easily introduced during the Jan-Mar/08 shutdown

New HLT selection framework (optimized for the 1MHz RO) is being developed: so called “HLT alleys”

Starting with the validation of the L0 objects

ends with exclusive final state reconstruction



11) Computing

Continuous improvement of software

Track reconstruction now adapted to the new event model
and detector geometry description
-material budget update
-subdetectors after the magnet tilted (3.6 mrad)
with respect to the beam direction

Tuning of the tracking and particle identification
performance in progress

Alignment strategy established and implementation started
global alignment challenge in early 2007

Event generator to accommodate new physics channels

Data Challenge 06 ongoing

Validation of the Computing model: i.e.
Event reconstruction, stripping and analysis by
CERN and Tier-1 centres
Monte Carlo production by Tier-2 centres

Phase I: events generated and stored at Tier-0 (CERN)
Phase II: events distributed to Tier-1's and reconstructed
Phase II′: events stripped at Tier-1's

Phase I worked well. (Well established procedure by now)
Phase II is now working in most of the Tier-1's
→Problems in data access had to be solved
Due to the incompatibility between the different systems at Tier-1's and LCG software
Phase II′ is now to be established

Triggering automatically reconstruction and stripping job after the completion of the previous task is functional

II) Cost and Funding

Cost: 75.341 MCHF (0.4% increase from MoU)
Funding: 74.039 MCHF
Missing: 1.302 MCHF

Funding priority is to complete the sub-detectors first
and delay the purchase of CPU's for HLT
→ agreed by RRB

This allows us to have a full detector system
for the 2007 pilot run

With the current funding, we can have only 2/3 of CPU power for HLT
more than enough for 2007, but a solution to be found for the 2008 run for full physics programme.

III) Physics Update

Quark flavour physics is evolving field: a recent result

B_s- $\overline{B}_s$ oscillations at Tevatron

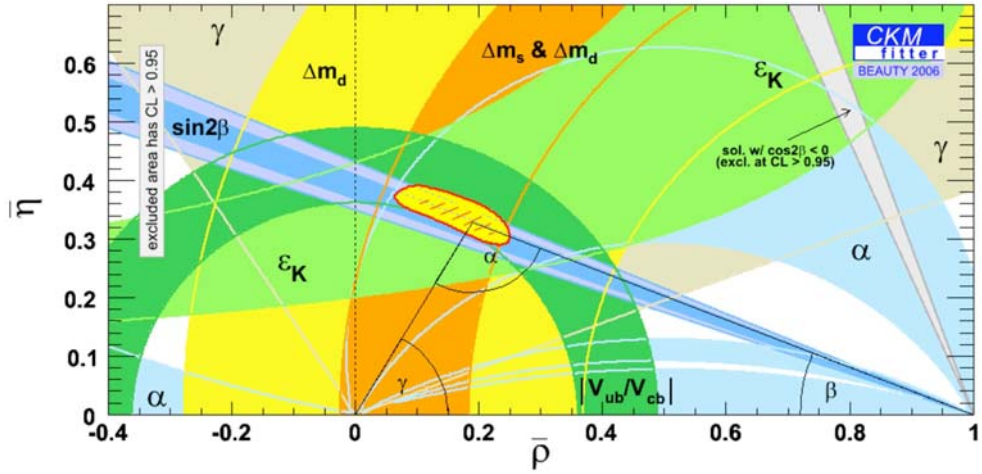
CDF observation with >5σ significance

$\Delta m_s = 17.77 \pm 0.10$ (stat) ± 0.07 (syst) ps^{-1}

→ this was anticipated already at the time of TP

The error on $(1-\rho)^2 + \eta^2$ in the η-ρ plane is reduced to the level close to that of the $\rho^2 + \eta^2$ from $|V_{ub}|$.

Both errors are dominated by the theoretical uncertainties



Very large New Physics in the B_s-$\overline{B}_s$ oscillation excluded

Due to large theoretical uncertainties, to identify a small NP contribution in Δm_s is very difficult

The phase of B_s-$\overline{B}_s$ transition amplitude needs to be measured with CP violation in $B_s \rightarrow J/\psi\phi$, $J/\psi\eta$, ...

Sensitive to new physics (SM contribution is small) and very small theoretical uncertainties, like $B_d \rightarrow J/\psi K_S$

$B_s \rightarrow \mu^+\mu^-$ now considered to be a place where New Physics could contribute a lot, e.g. large tanβ SUSY

LHCb physics consideration

2007 pilot run data

calibration and alignment, testing some HLT algorithms

2008 after trigger commissioning, with 0.5 fb^{-1} physics data

In addition to usual B&B (bread and butter) physics and initial B physics,

e.g. b-hadron lifetimes, Δm_s, sin 2β, etc.,

σ_{ϕ_s} = 0.04 rad, SM prediction $\phi_s \approx -0.04$ rad

cf. current D0 result: $\sigma_{\phi_s} = -0.43$ rad @1 fb^{-1}

$Br(B_s \rightarrow \mu^+\mu^-) <$ SM-Br (90% CL) SM-Br~3×10^{-9}

cf current CDF result $<0.8\times10^{-7}$ (90% CL) @780 pb^{-1}

cf current D0 results $<1.9\times10^{-7}$ (90% CL) @700 pb^{-1}

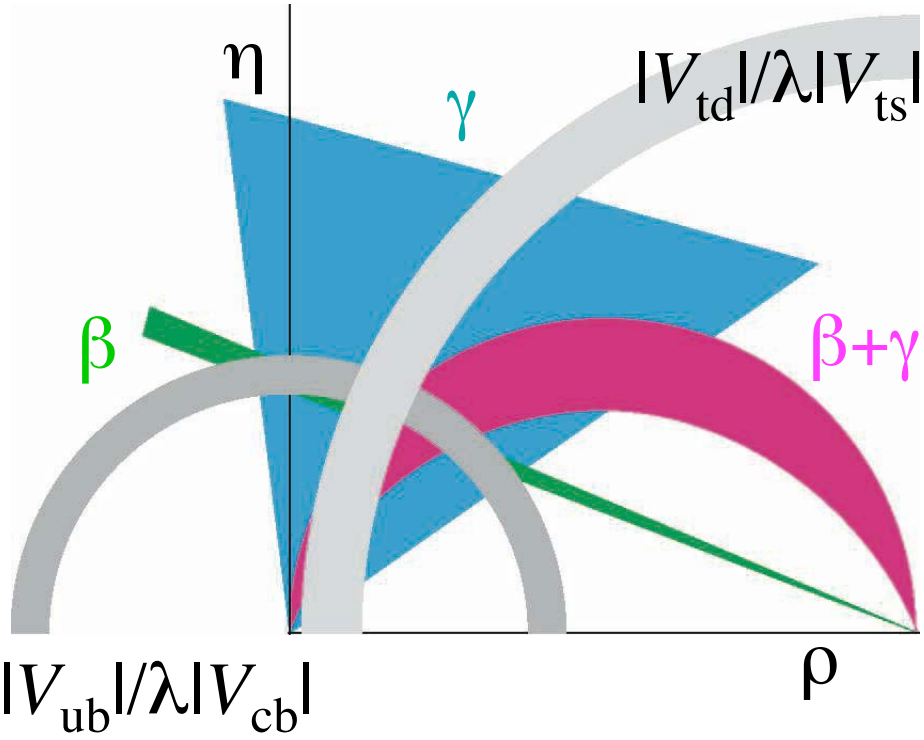
(~5 fb^{-1}/Exp Tevatron data by the end of 2009)

i.e. with 2008 LHCb data, we should be able to reach sensitivities to the level of the Standard Model predicted values, thus exclude large (or discover) NP contribution.

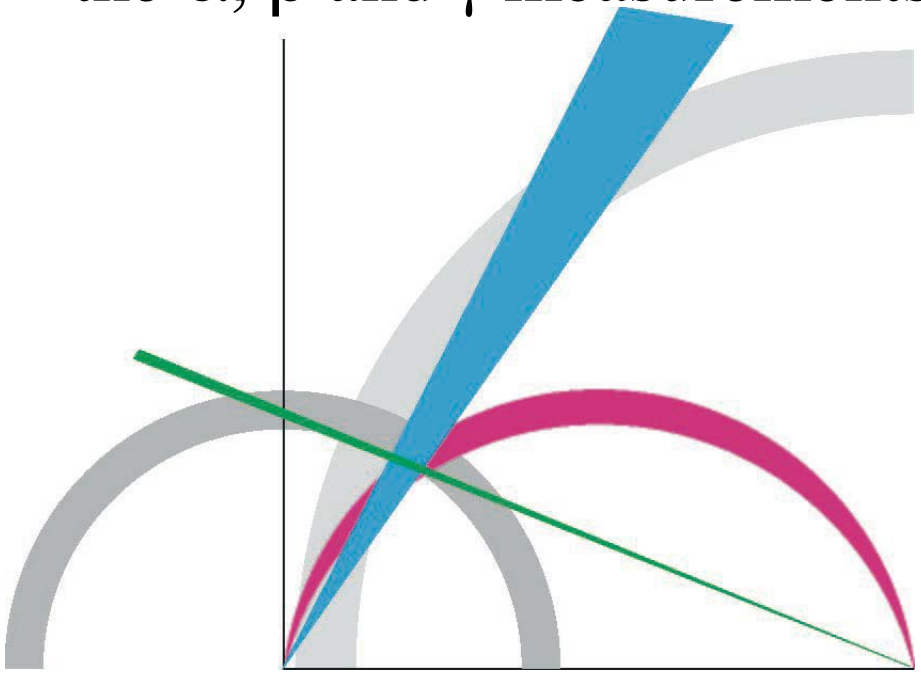
>2009 massive physics data production

For example...

current situation (1σ)



LHCb 6 fb^{-1} data for the α, β and γ measurements



5σ observation of $B_s \rightarrow \mu^+\mu^-$ if SM branching fraction

>3σ measurement of ϕ_s if SM value

and many others!

IV) Concluding Remarks

1) Generally good progress in the construction
   -VELO module production started and progresses well
   -IT/TT ladder production basically completed
   -OT module, Muon MWPC construction completed
   -Despite a small delay HPD production advancing well
   -RICH-1 good progress
2) Installation started for
   Beam-pipe, RICH-1 mechanics, OT, Muon
3) Installation completed for
   -VELO vacuum tank, RICH-2 mechanics, Calo detector
4) Magnet fully commissioned
5) Regular commissioning meetings started

6) Some subdetectors started commissioning
E-cal and H-cal with fully installed detector
And others during the installation
→Commissioning Racks

7) Global commissioning with (partial) subdetectors will start early Spring 2007

8) Accumulated delay makes installation plan very tight
many parallel activities needed→ locally crowded area
VELO+RICH-1+TT, IT+OT(+RICH-2), M1+SPD/PS
CALO+M2-M5
→Careful planning and discipline are mandatory and extra manpower likely to be needed

We expect to be ready for the 2007 run with full detector to exploit the data

LHCC milestone plot