Status of the *LHCb* Experiment

LHCb RRB meeting

CERN, 23 October 2001

on behalf of the LHCb Collaboration

Tatsuya Nakada

The *LHCb* Collaboration (October 2001)

France:	**Annecy**, Clermont-Ferrand, CPPM Marseille, LAL Orsay
Germany:	Tech. Univ. Dresden, Phys. Inst. Univ. Heidelberg, KIP Univ. Heidelberg, MPI Heidelberg,
Italy:	Bologna, Cagliari , Ferrara, Firenze, Frascati, Genoa, Milan, Univ. Rome I (La Sapienza), Univ. Rome II (Tor Vergata)
Netherlands:	NIKHEF
Poland:	Cracow Inst. Nucl. Phys., Warsaw Univ.
Spain:	Univ. Barcelona, Univ. Santiago de Compostela
Switzerland:	Univ. Lausanne, Univ. Zürich
UK:	Univ. Bristol, Univ. Cambridge, Univ. Edinburgh, Univ. Glasgow, IC London, Univ. Liverpool, Univ. Oxford, RAL
CERN	
Brazil:	UFRJ, CPBF
China:	IHEP(Beijing), Tsinghua Univ.
Romania:	IFIN-HH (Bucharest)
Russia:	BINP, INR, ITEP, IHEP, PNPI
Ukraine:	Inst. Phys. Tech. (Kharkov), Inst. Nucl. Research (Kiev)
Technical Associate:	Espoo-Vantaa Inst. Tech. (Finland), Geneva Engineering School (Switzerland) CFET-RJ (Brazil)

45+3 institutes

MoU signatures are still missing from

- Brazil
- China
- BMBF (Germany)
- Poland
- Spain

LHCb Collaboration

Collaboration Board

Chair:	C. Matteuzzi

Management

Spokesperson:	T. Nakada
Deputy:	B. d'Almagne
Technical and Resource Coordinator:	H.J. Hilke

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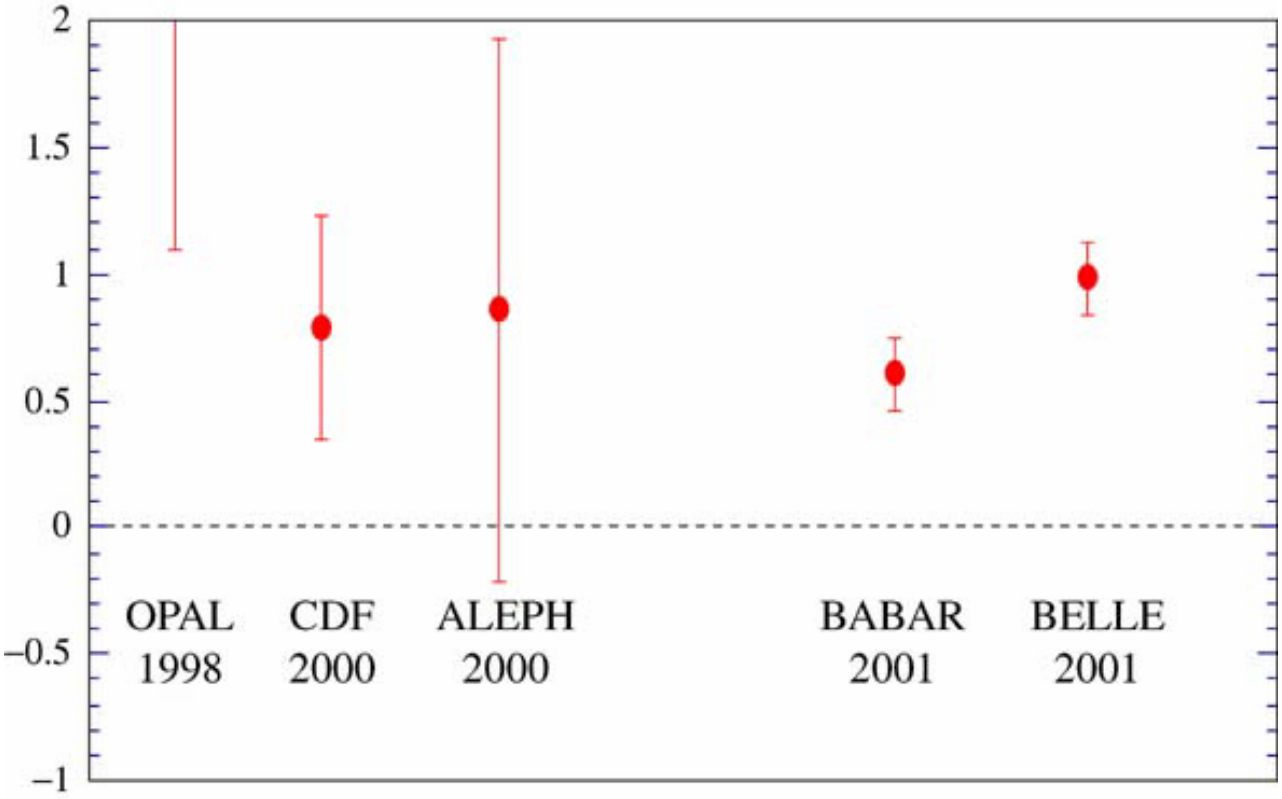
I) Physics

2001 Summer results from the B factories.

B-meson system: $\sin 2\beta$

BABAR (2001) $= 0.59 \pm 0.15$

BELLE (2001) $= 0.99 \pm 0.15$



~~*CP*~~ in B system is established.

Physics contribution of LHCb after one year of data taking

New aspect:

CP asymmetries in B_s system

Quantity improvement:

$$\sigma_{CP}\,(\text{LHCb one year}) < \sigma_{CP}\left(\int[\text{BABAR+BELLE+CDF+D0}]\,dt\right)$$

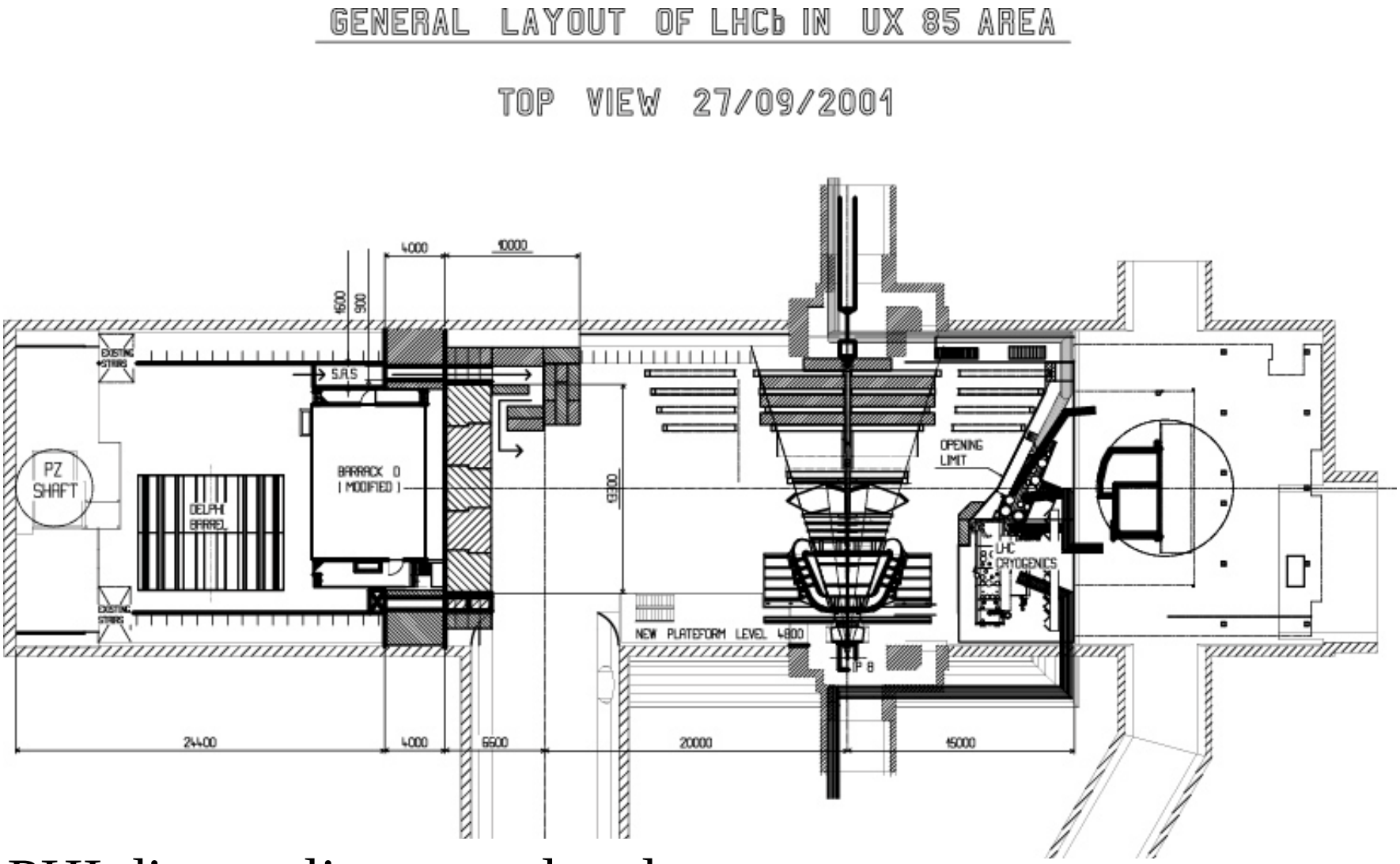
First time $(\rho,\eta)_{CP}$ with an accuracy comparable to $(\rho,\eta)_{side}$

$\rightarrow$ theoretically and statistically.

If there exists new physics

$\rightarrow$ unambiguous extraction of new physics contribution.

II) Experimental area

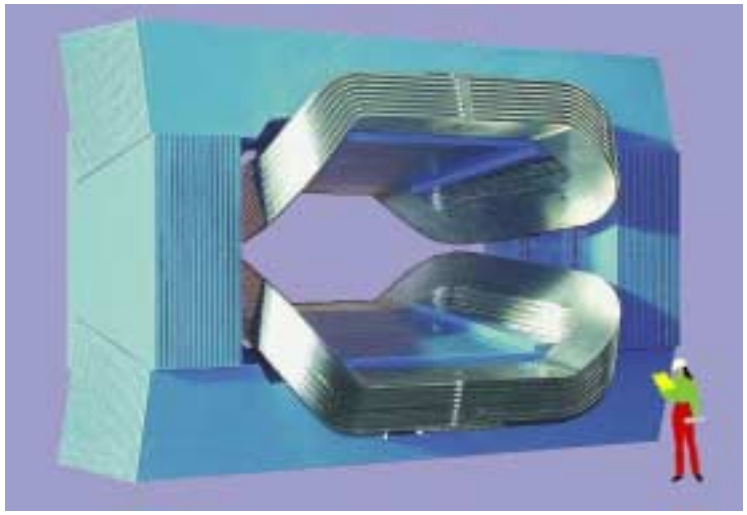


DELPHI dismantling completed.
Necessary modification work started.

Cost: 4MCHF (MoU)
Funding: Common Fund

III) Subsystems

Magnet



Cost: 6 MCHF (TDR)
Funding: Common Fund

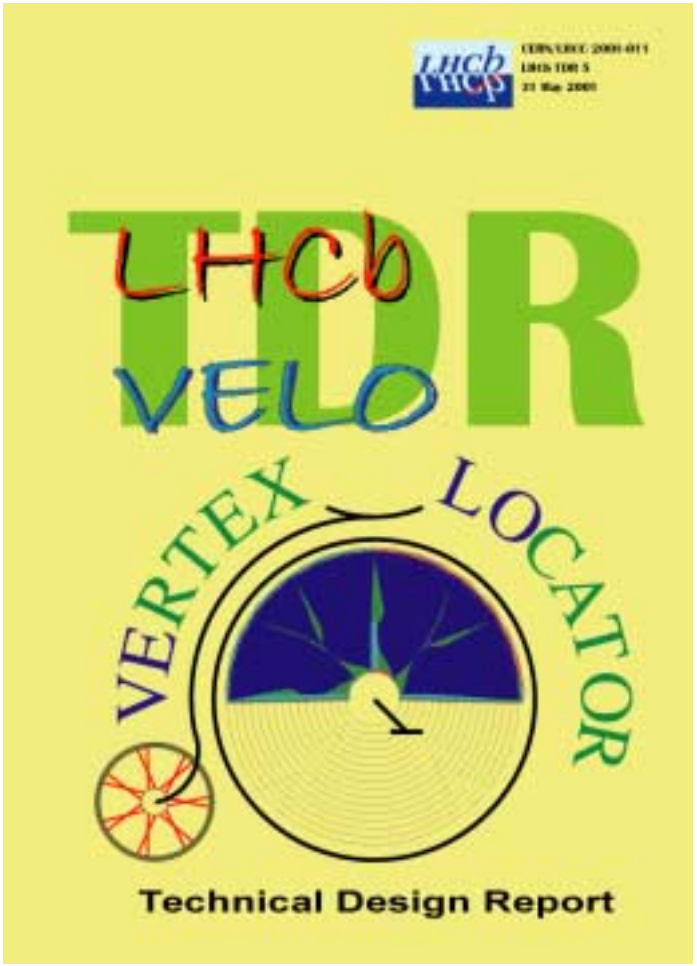
Al conductor (~50 t, ~9 km): committed
Steel plates for Yoke (~1.5 kt): committed
Construction of two coils: committed
} ~3.7 MCHF

Autumn 2002	Start yoke assembly
Dec. 2002	Coil delivery
May 2003	Complete magnet assembly

VELO

Cost: 4.822 MCHF (TDR)
Funding:CH, Germany, Netherlands, UK

May 2001 TDR submitted
October 2001 TDR recommended for approval



Baseline technology:

- Sensors:
  - 300μm n-on-n
  - short strips
  - double metal layer for readout
- Electronics:
  - SCTA-VELO (DMILL)
  - or
  - BEETLE (0.25μm CMOS)

Silicon

Jul 2002	Tests of prototypes completed design review and start of tendering
Dec 2002	Place final order
Jun 2003	Sensor production finished
Jun 2004	Module production finished

Front-end chip

Dec 2001	Characterization of chips completed
Dec 2002	Front-end chip decision
Dec 2002	Production/testing completed

L1 electronics

Sep 2001	Read-out board 3 prototype
Dec 2001	Analogue links tested on large scale
Mar 2002	Final prototype of digitisers board
Mar 2003	L1 electronics production starts
Aug 2003	10 % of boards completed
Apr 2004	50 % of boards completed
Mar 2005	Production/testing completed

being constructed

Mechanics/Vacuum

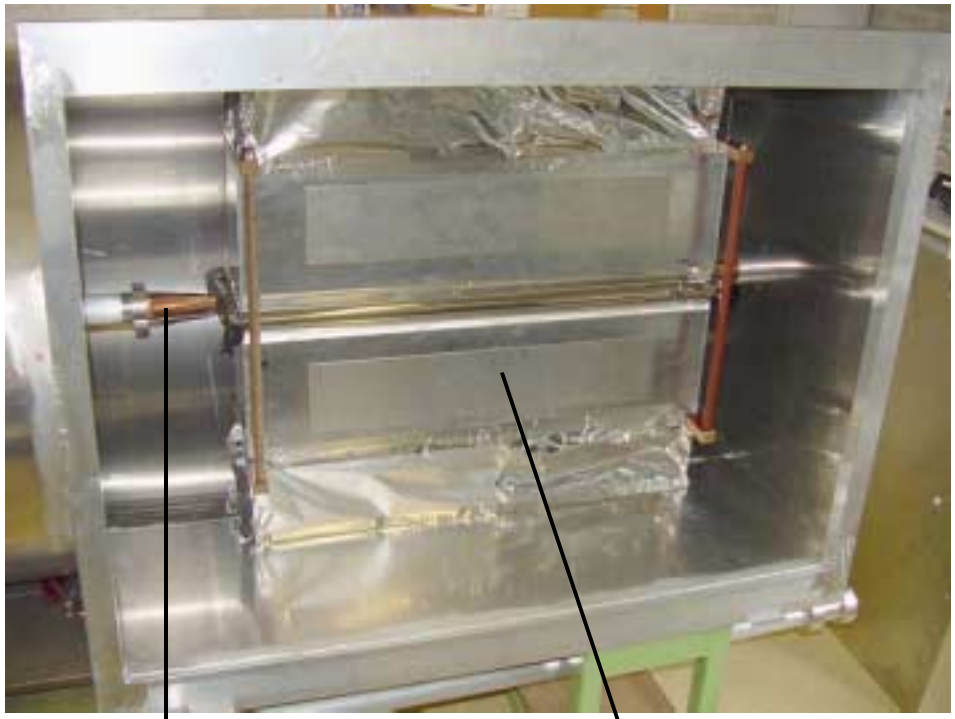
Feb 2002	Production readiness review with LHC groups
Mar 2003	All production drawings finished
Jun 2004	Production/testing completed

Installation

Dec 2004	Start installation in IP 8
Oct 2005	Commissioning of DAQ with other sub-detectors
Dec 2005	Installation completed

Machine related issues are crucial: wake field and vacuum

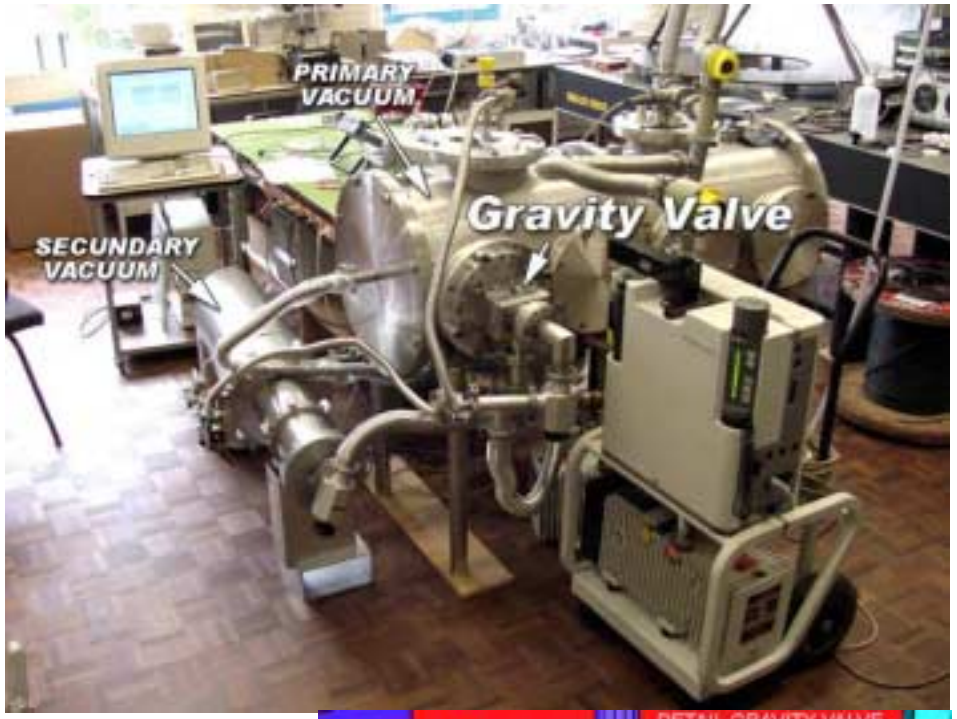
RF test tank

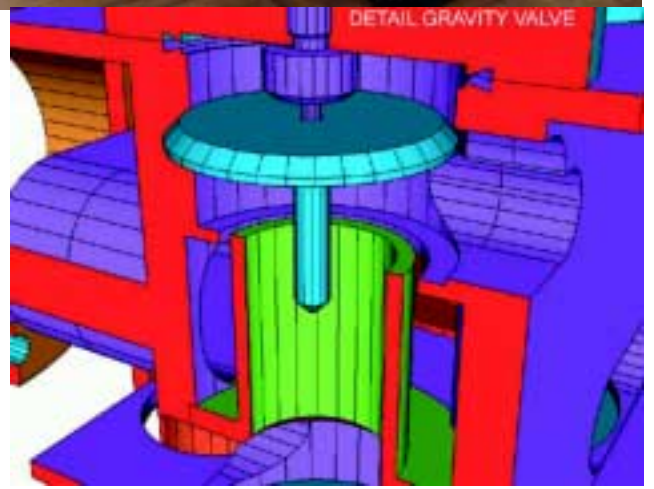


wake field suppressor

secondary vacuum box

Gravity valve test

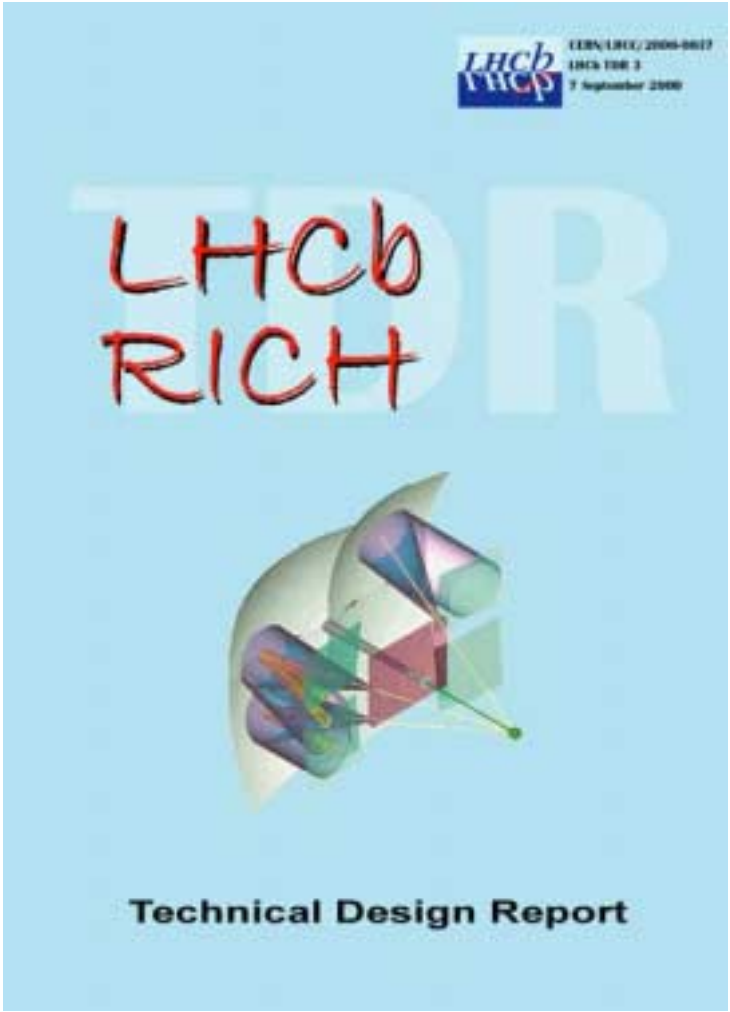




validating simulation results

RICH

Cost: 7.677 MCHF (TDR)
Funding: CERN, Italy, UK



TDR submitted in September 2000
approved February 2001

Baseline Technology

- Two RICH detectors with three radiators:
  - aerogel+C_4F_{10}
  - CF_4
- Photon detector:
  - Pixel HPD
  - MaPMT as backup

Mechanics and Optics

Mar 2002	finish optimising engineering design
Sep 2002	10% of mirrors produced
Jan 2003	50% of mirrors produced
Jun 2003	finish mirror production
Jan 2004	begin RICH-1 assembly in IP8
Jul 2004	begin RICH-2 installation in IP8

Photodetectors

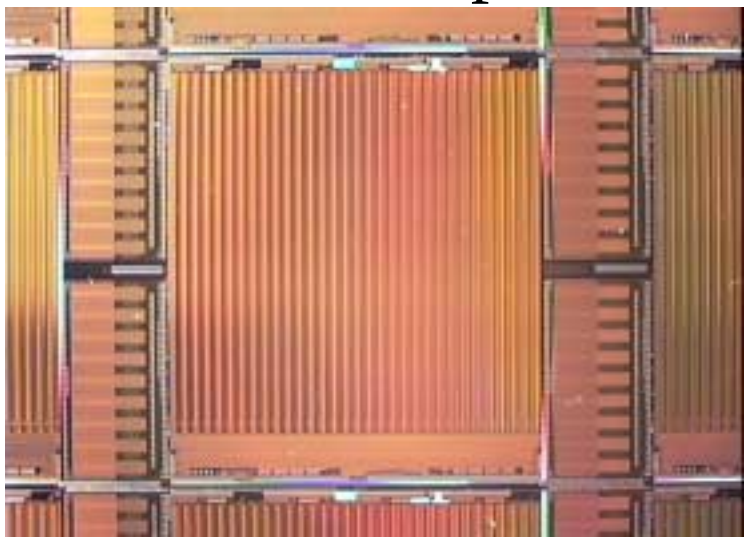
Jun 2001	finish prototype HPD
Sep 2001	technical choice
Nov 2001	production readiness review
Mar 2002	place photodetector order
Dec 2002	10% of detectors produced
Jun 2003	50% of detectors produced
Feb 2004	finish detector production
Mar 2004	finish detector testing

to be reviewed

L1 electronics

May 2002	finish prototype chain tests
Jul 2002	10 % of Level-0 units produced
Mar 2003	50 % of Level-0 units produced
Dec 2003	finish Level-0 unit production
Dec 2002	30 % of Level-1 units produced
Jun 2003	60 % of Level-1 units produced
Dec 2003	finish Level-1 unit production
Jan 2004	finish production and testing

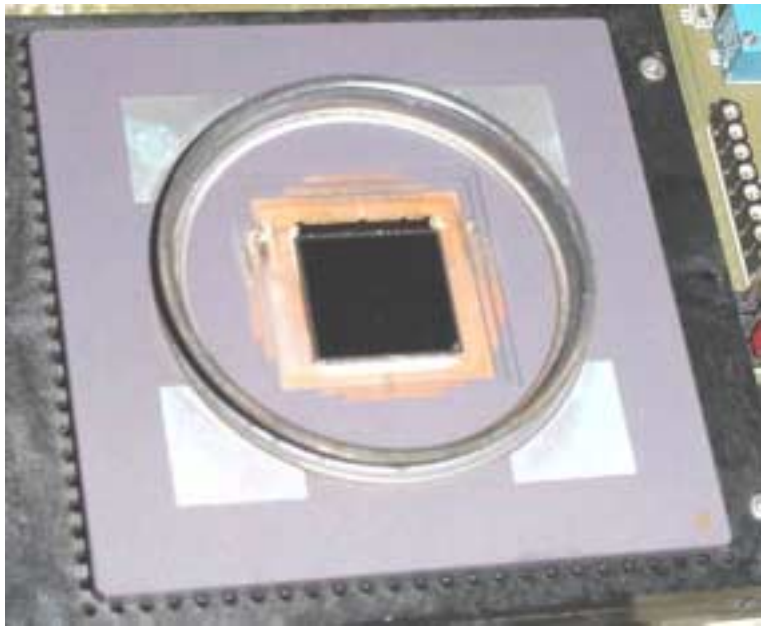
ALICE/LHCb pixel readout chip



readout speed < 20 MHz

Problems were found
and corrected.
New submission: November

HPD base plate with Bump-bonded pixel+readout chip



Two base plates sent to DEP
for encapsulation.

Expected to be back in November.

It was foreseen to have:

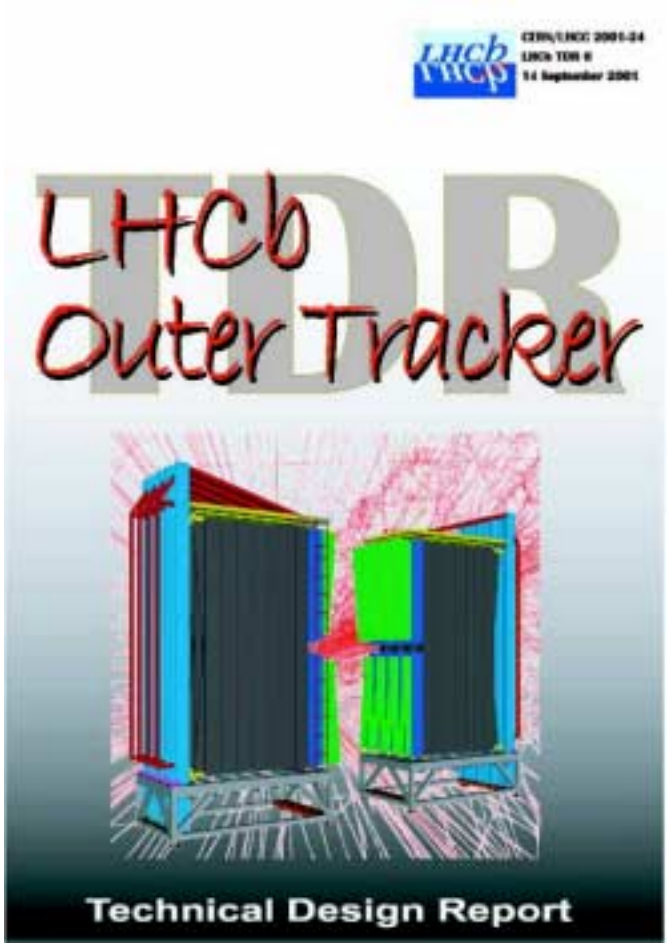
a working HPD with 20MHz chip

a working 40MHz chip

Both are missed by several months
Status will be reviewed this month.

Tracker: Outer and Inner

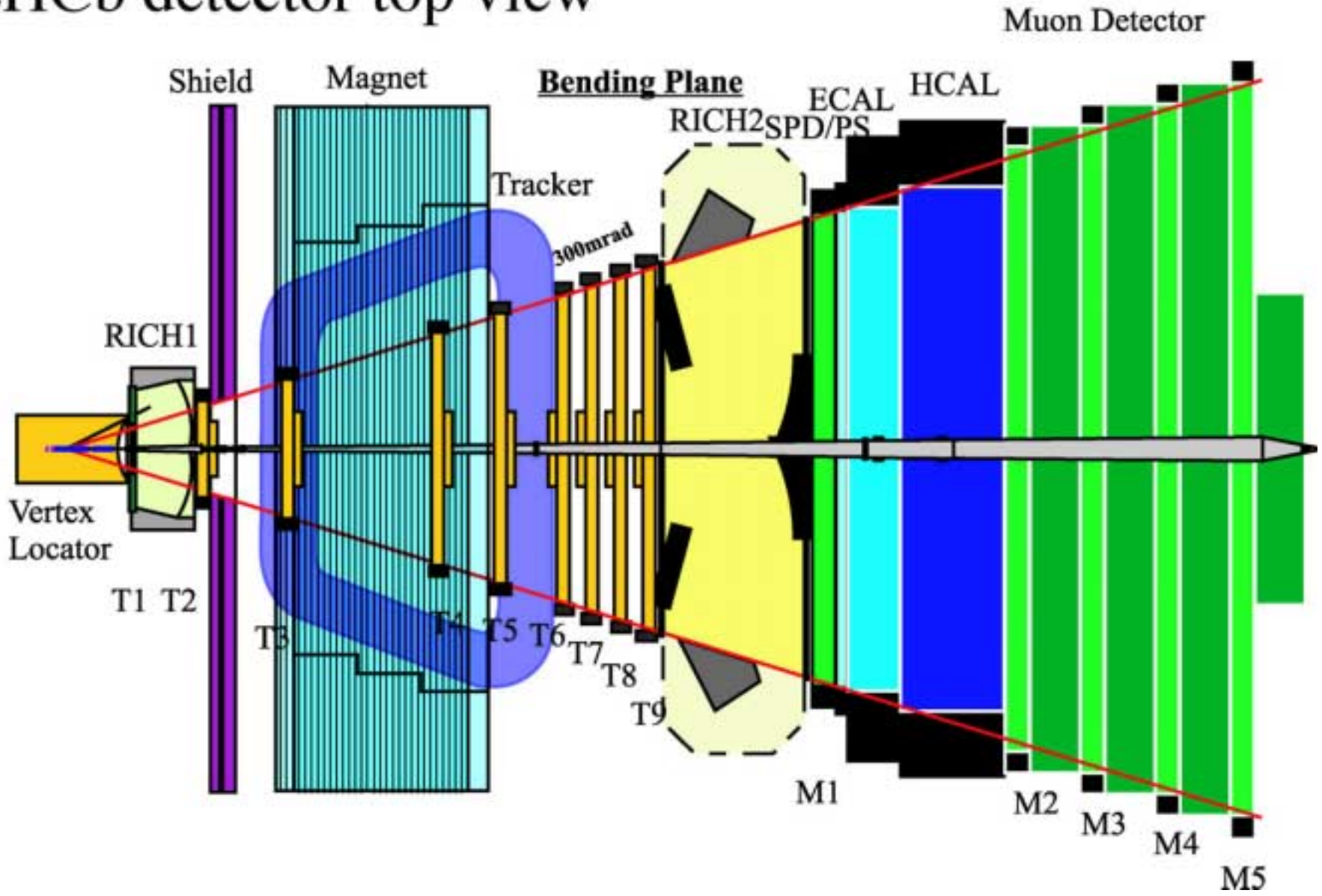
Cost: 9.300 MCHF (TDR) and ~5.150 MCHF (MoU)
Funding: CERN, CH, China, Germany, Netherlands, Poland,
Spain, Ukraine + Common Fund



Outer Tracker TDR
submitted on September 2001

- Technology well defined:
  straw tube
  custom made TDC
- Construction technique
  and plan well understood:

LHCb detector top view

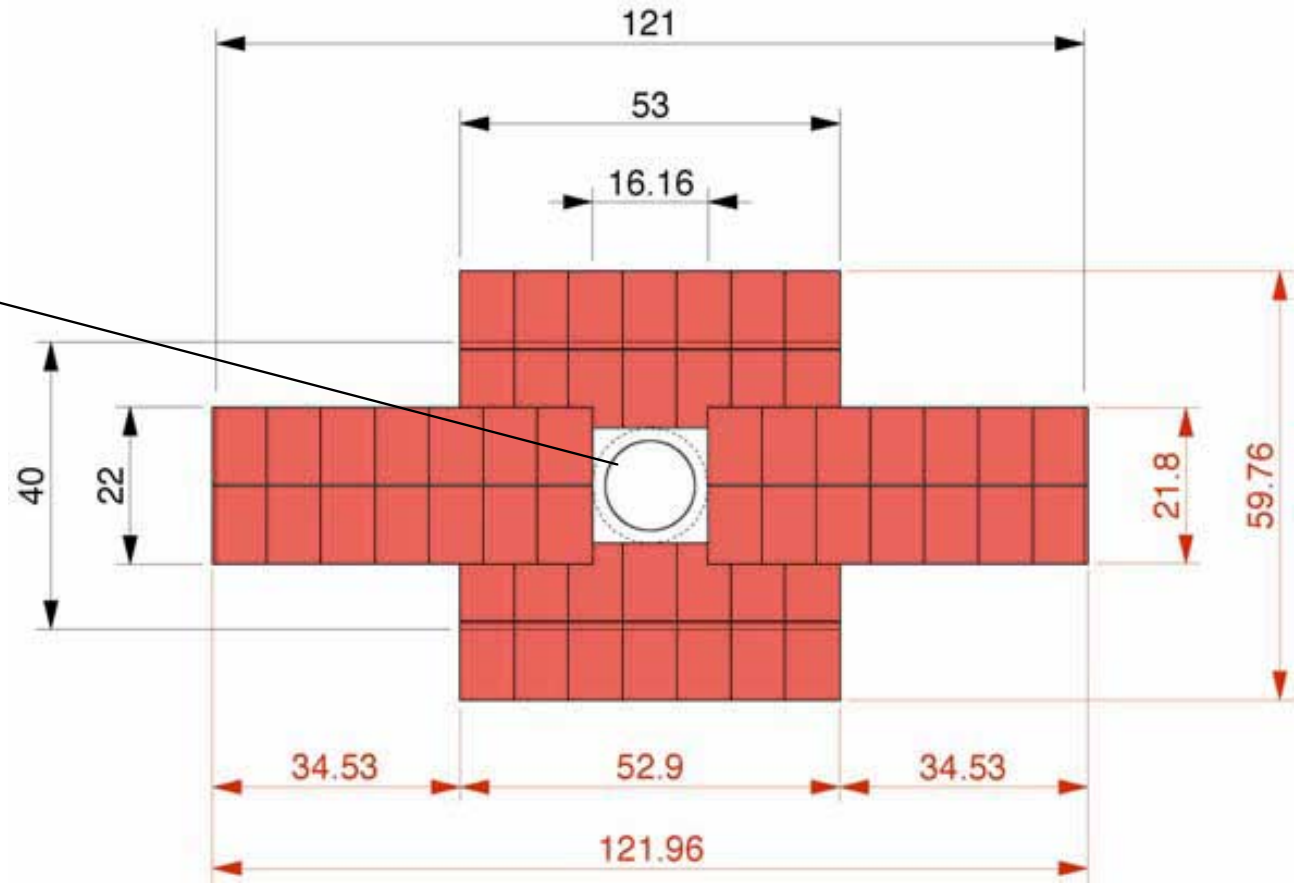


Inner Tracker All Si solution adopted.

Geometry of the Inner Tracker:

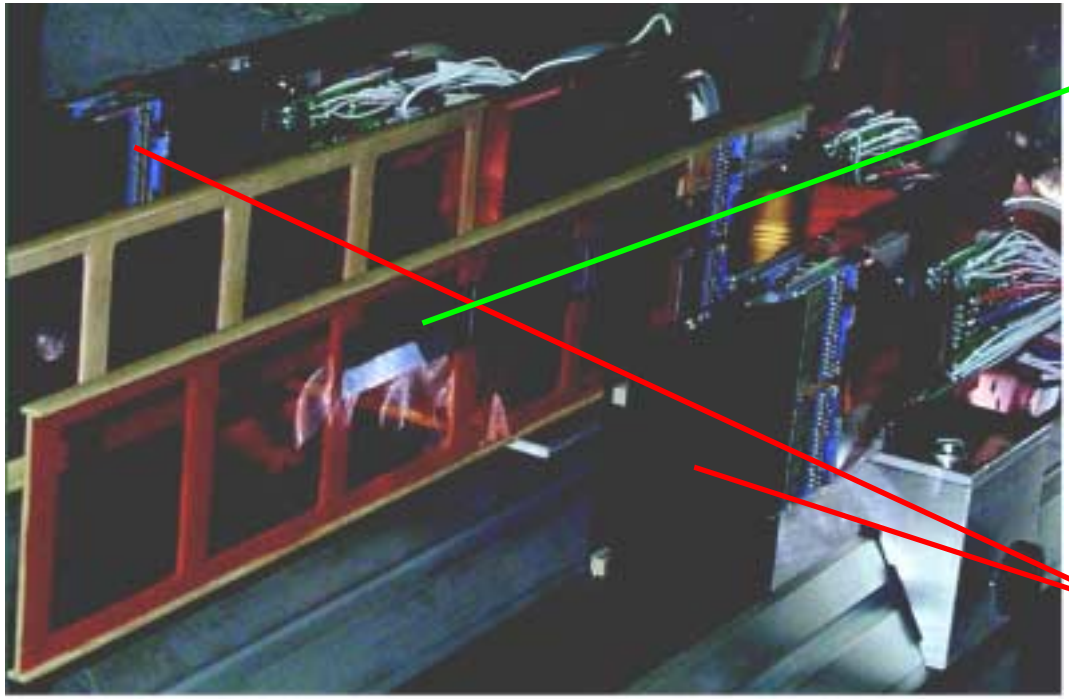
defined by the occupancy of the outer tracker.

beam pipe



Cross design: minimising the Si area

First beam test at CERN



test Si ladder
(300 μm p-on-n
oxygenated detectors)
read by
HELIX chip
(not LHC speed)

reference Si detectors

Spring 2002:read by SCTA-VELO and BEETLE (40 MHz)
S/N as a function of the strip length (10, 20, 30 cm?).

Increased size of the Si → more R&D needed
Better synchronization with the re-optimisation work.
TDR submission planned for the end of 2001
→ to be delayed to the end of 2001

Order all Si sensors by 1 July 2003,

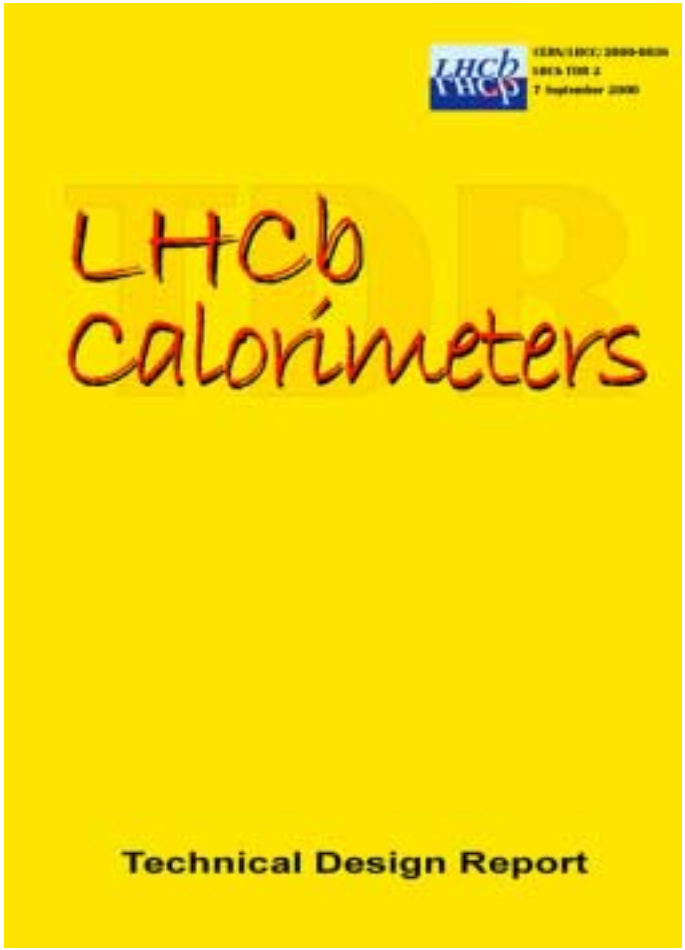
- 15 months for the construction of the detector,
- 6 months for the installation and commissioning.

Delay of TDR does not cause any problem for the overall plan.

Calorimeters

Cost: 15.360 MCHF (TDR)

Funding:CERN, France, Romania, Russia, Spain, Ukraine,
+ Common Fund



TDR submitted in September 2000
approved February 2001

Adopted Technology
- Scintillator-Pb-Scintillator (SPD and Preshower)
- Shashlik E-cal
- Fe-Scintillator tile H-cal

Photon detector
- PMT

ECAL

May 2001	finish optimising engineering design	see next
Jun 2001	start serial production	
Dec 2002	10% of modules produced	
Jul 2003	50% of modules produced	
Aug 2004	finish module production	
Nov 2004	finish module assembly	
Feb 2005	finish installation	

HCAL

Jun 2001	finish optimising engineering design	see next
Oct 2001	start serial production	
Jul 2002	10% of modules produced	
Jul 2003	50% of modules produced	
May 2004	finish module production	
Jun 2004	finish module assembly	
Dec 2004	finish installation	

E-cal and H-cal

Engineering Design Reviews completed
(with external reviewers)
Module-0 construction completed and tested @ CERN

E-cal

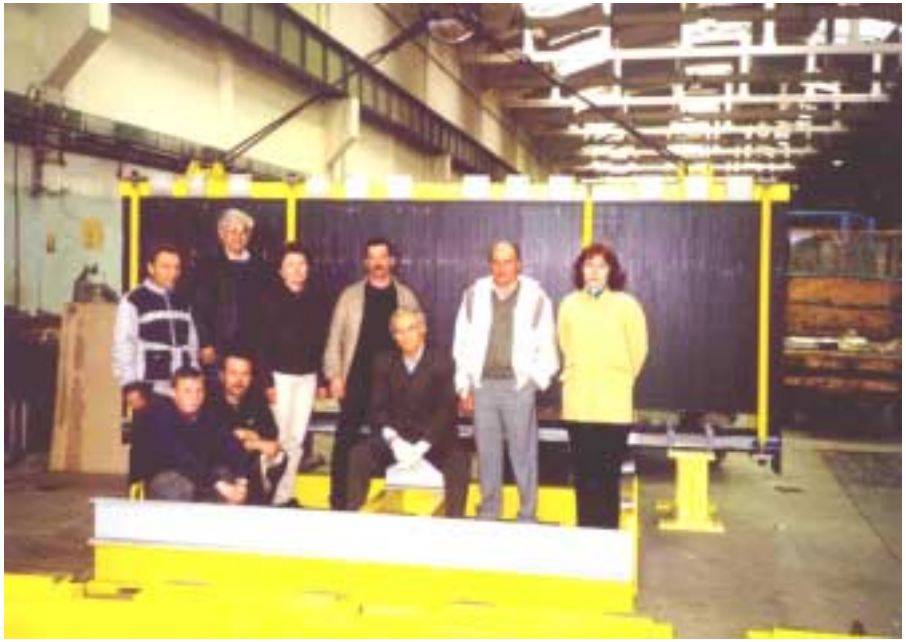
Shashlik front face

Shashlik back side

200 outer-most modules construction@ ITEP
(~3300 modules total)

H-Cal module-0

Mechanical assembly @ IHEP Optical assembly @ CERN



(52 modules total)

No major surprise in the Module-0 production.
Based on this experience…

Production Readiness Reviews for E-cal and H-cal are being conducted.

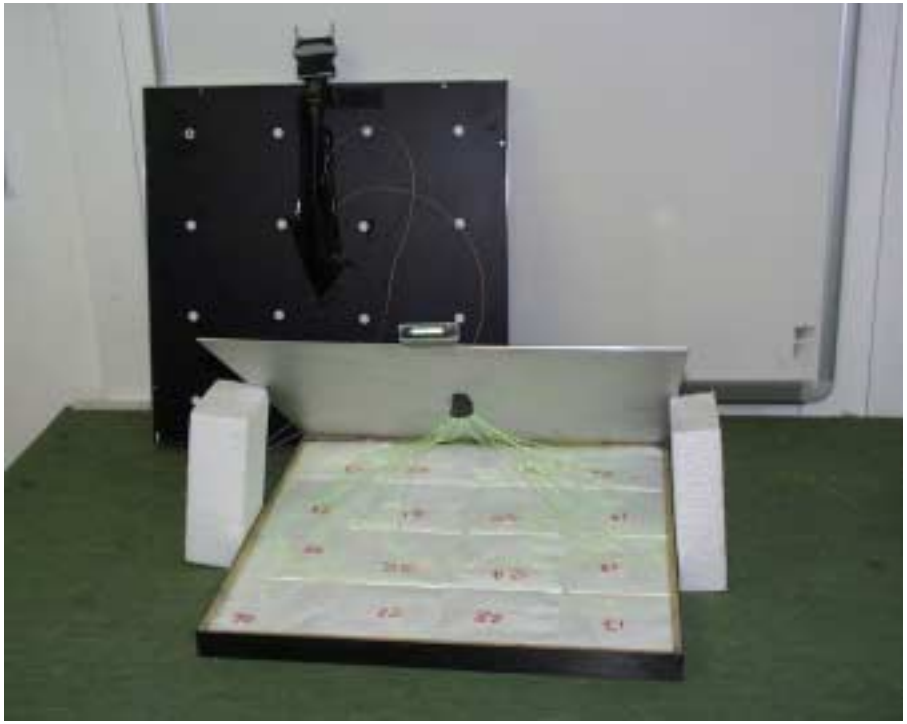
Raw material (Pb, steel, scintillators, fibres etc.) have been ordered.

-committed ~3MCHF TDR costing-

Series production of E-cal and H-cal will start very soon.
-a couple of months later than planned-

SPD/Preshower

Jul 2001	finish optimising engineering design → Jan 2002
Jul 2001	start serial production → Apr 2002
Jul 2002	10% of modules produced
Jul 2003	50% of modules produced
Jul 2004	finish module production
Dec 2004	finish module assembly
Mar 2005	finish installation



Delay is not critical:

Only 466 modules

2 boxes have been made.

Electronics

SPD

Dec 2002	finish optimising engineering design
Mar 2003	start serial production
May 2003	10% of ASIC produced
Sep 2003	50% of ASIC produced
Sep 2004	finish acceptance test
Apr 2005	finish installation

Preshower

Jun 2002	finish chip engineering design $\rightarrow$ completed
Jul 2002	start chip serial production
Dec 2002	finish optimising engineering design
Dec 2003	10% of cards produced
Jul 2004	50% of cards produced
Nov 2004	finish acceptance test
Apr 2005	finish installation

E/H Cal

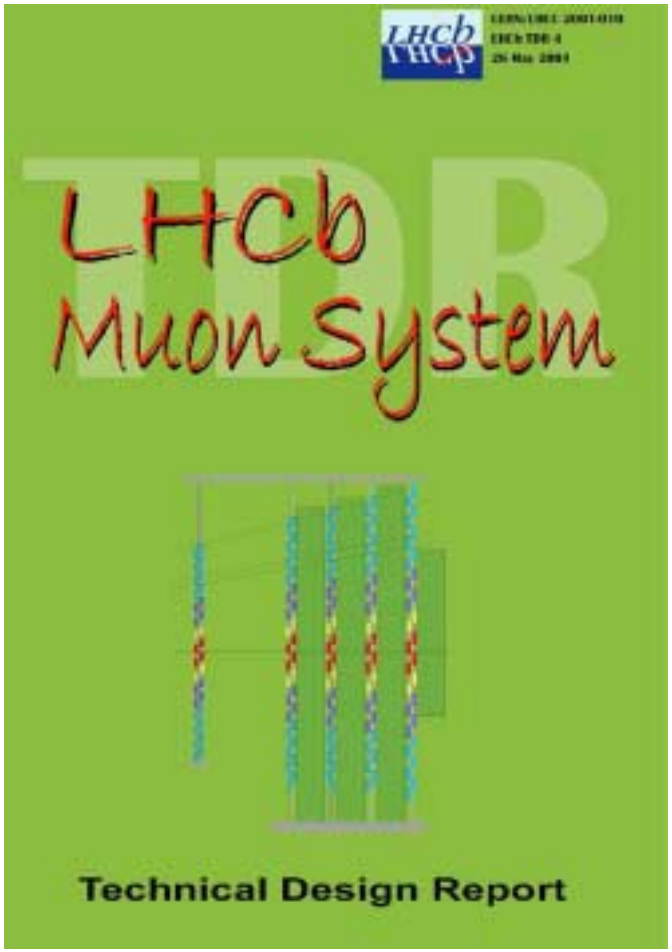
Sep 2002	finish optimising engineering design
Oct 2003	start serial card production
Nov 2003	10% of cards produced
Aug 2004	50% of cards produced
Jan 2005	finish acceptance test
Apr 2005	finish installation

Front-end ASIC's design completed.

Muon

Cost: 10.83 MCHF (TDR)
Funding: Brazil, CERN, Italy, Russia

May 2001 TDR submitted
October 2001 TDR recommended for approval



Single gap RPC (2 in OR)
for "low" rate region < 1 kHz/cm^2
(48% of area)

MWPC
with cathode and/or wire readout
for "high" rate region <100 kHz/cm^2

3GEM or MWPC
for a small region >100 kHz/cm^2
(<1%, 3 m^2)
R&D in progress

MWPC detectors

Jan 2002	Engineering design completed
Jan 2003	Begin chamber construction and tests
Jun 2003	10 % of chamber construction done
Mar 2004	50 % of chamber construction done
Dec 2004	Chamber construction completed

RPC detectors

Dec 2001	Decision on use of linseed oil
Jan 2002	RPC engineering design completed
May 2003	Begin RPC assembly and tests
Sep 2003	10 % of chamber construction done
Jun 2004	50 % of chamber construction done
Dec 2004	Chamber construction completed

Chambers for the inner part of M1

Jan 2003	Technology choice
Dec 2004	Chamber construction completed

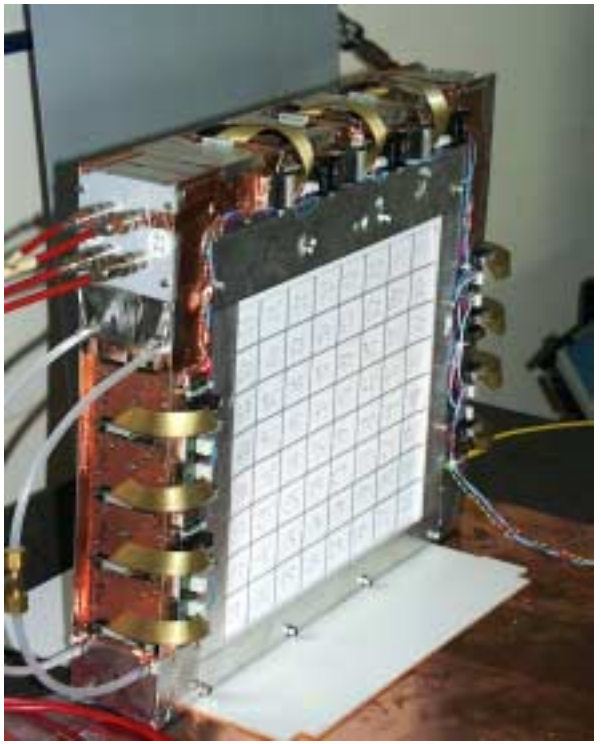
Electronics

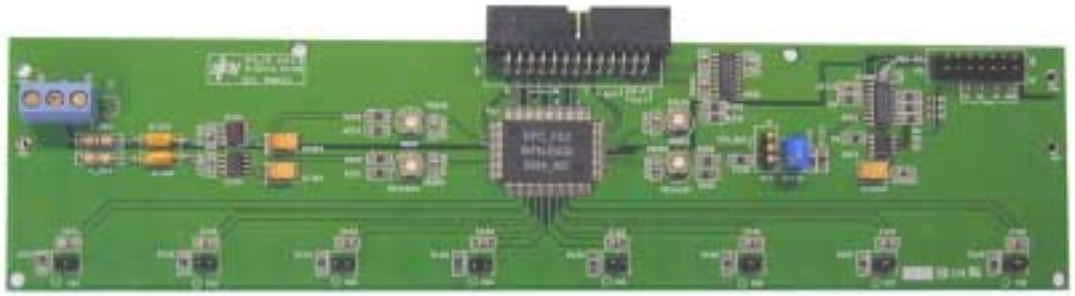
Mar 2002	CARIOCA design and test completed
Mar 2002	DIALOG design and test completed
Jun 2002	SYNC design and test completed
Oct 2002	Full chain electronics test completed
Jan 2003	Begin FE-board production
Jun 2003	10 % of FE-board production done
Feb 2004	50 % of FE-board production done
Jan 2004	10 % of IM- SB- and ODE-production done
Jul 2004	50 % of IM- SB- and ODE-production done
Dec 2004	Electronics assembly and test completed

Muon filter and support structures

Dec 2003	Iron filter installation completed
Jun 2004	Chamber support structures installed

Chamber prototypes and FE-chips





For RPC:
BiCMOS front-end chip
developed for CMS

For MWPC:
custom made 0.25 μm CMOS
(CARIOCA)

Trigger

Level-0 and Level-1
Cost: 3.400 MCHF (MoU)
Funding: France, CH, Germany, Italy
(Higher levels are under the online CPU farm)

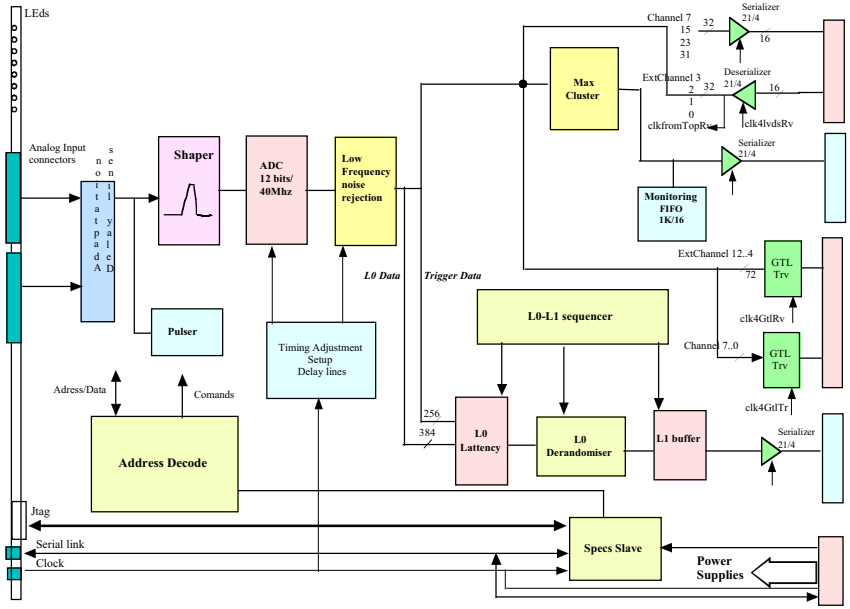
TDR completion: delayed
end of 2001 $\rightarrow$ end of 2002

-Better synchronization with the re-optimisation work
-No effect on the construction schedule:
Planned production starting in 2003.

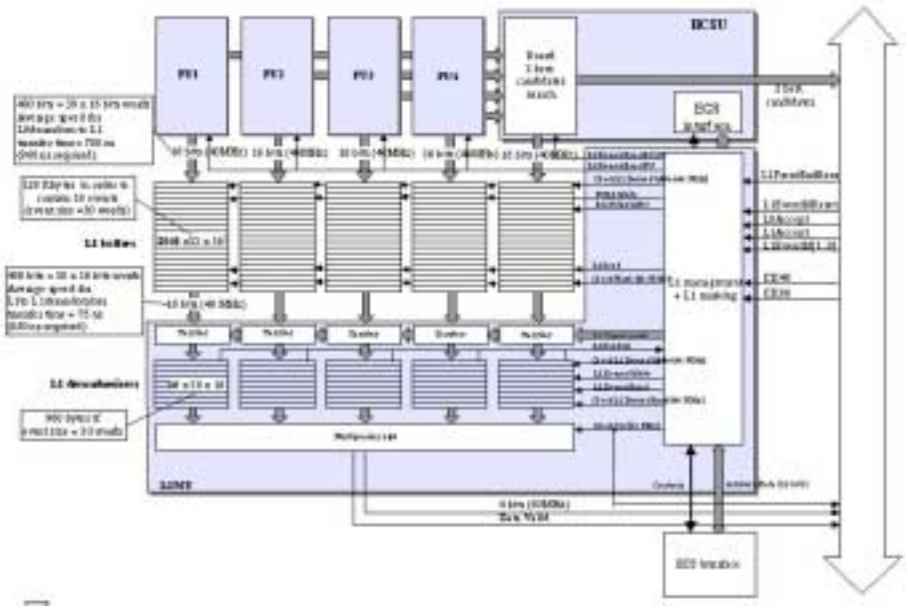
All the L-0 components have been designed and simulated.

Prototype production has started.

Calo front-end card

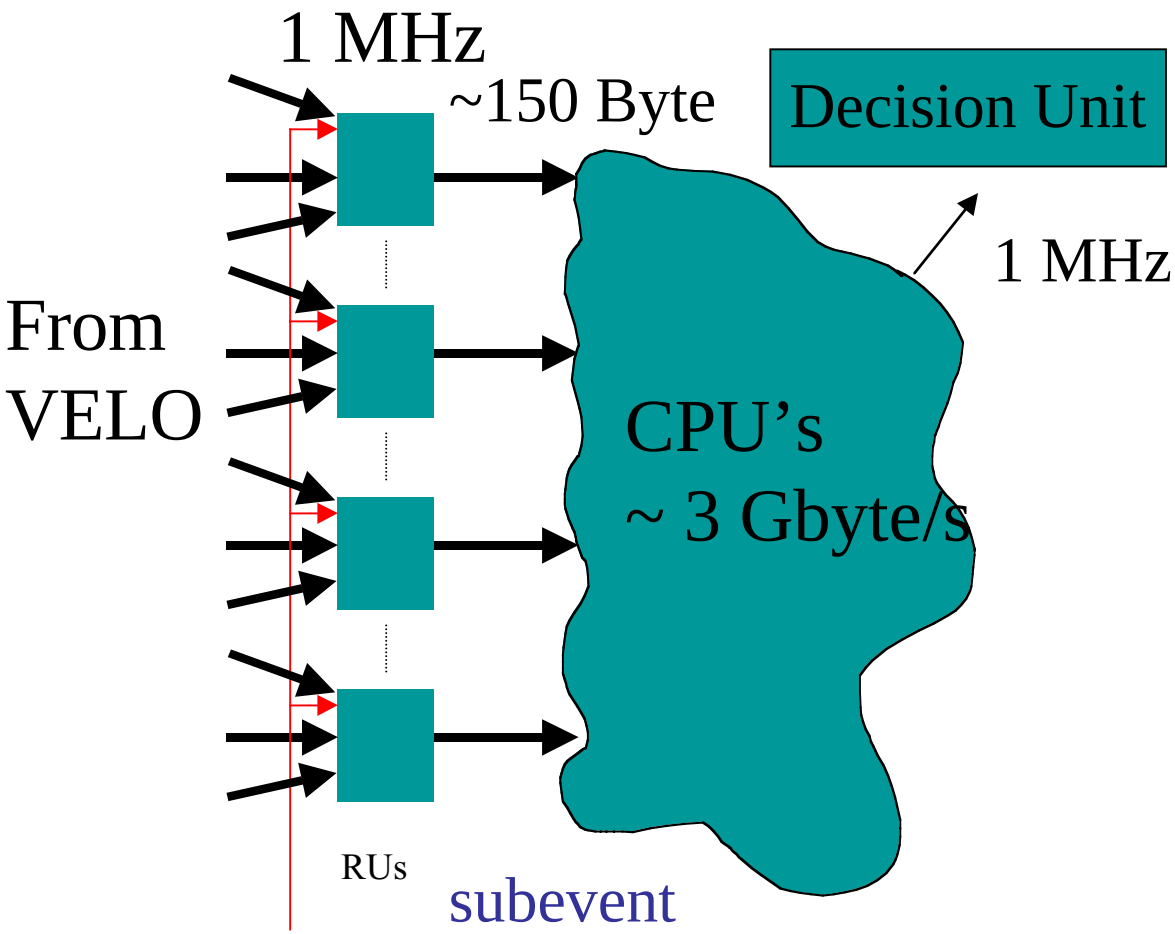


Muon trigger



L0 decision unit prototype also ~April 2002.

Level-1 trigger is like online farm,
but with small data size @ high frequency.



Prototype is being built
using SCI technology

Computing

Cost: 6.800 MCHF (MoU, Online part only)

Funding: CERN, CH, Germany, Italy, Spain, UK
+ Common Fund

Online TDR end of 2001

Complete DAQ architecture defined and simulated:

Experiment Control System (ECS)
Based on SCADA (outcome of JCOP)

Readout system technology choices

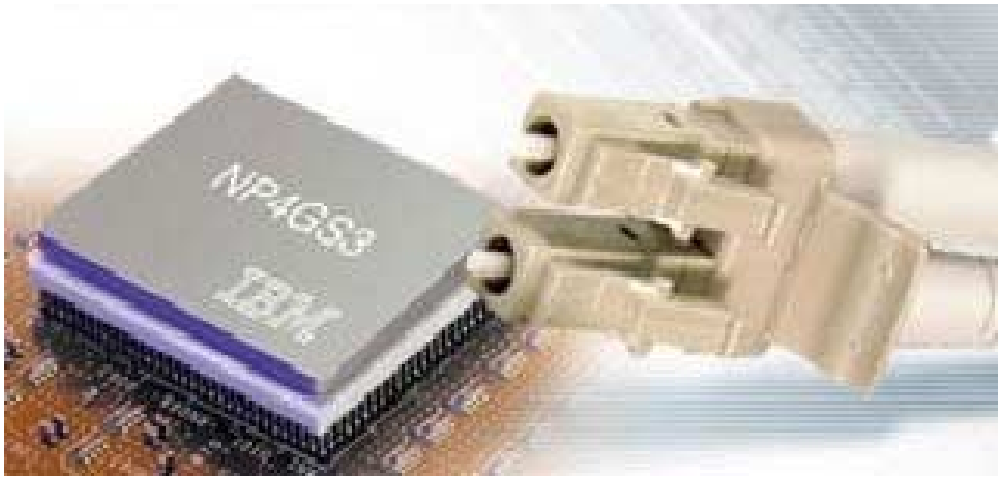
Readout Unit

baseline: Network processor

very flexible and bright future.

backup: FPGA based custom solution

prototypes have been built and are working.



Readout network

Baseline: Gb Ethernet

Offline Projects

OO software framework: GAUDI

- Consolidation phase (three new releases)
- Development of interactivity, visualisation etc.
- Joint development with ATLAS

OO applications

- Reconstruction (BRUNEL): used in production
  mixture of C++ and Fortran physics algorithm
- Simulation (GAUSS)
  integration of GAUDI with GEANT4
  RICH and Calorimeter work started
  GEANT3 based SICBMC still used in production
- Analysis (DAVINCI)
  physicists started to use it

Computing Infrastructure

Participation in EU DataGrid project (WP8)

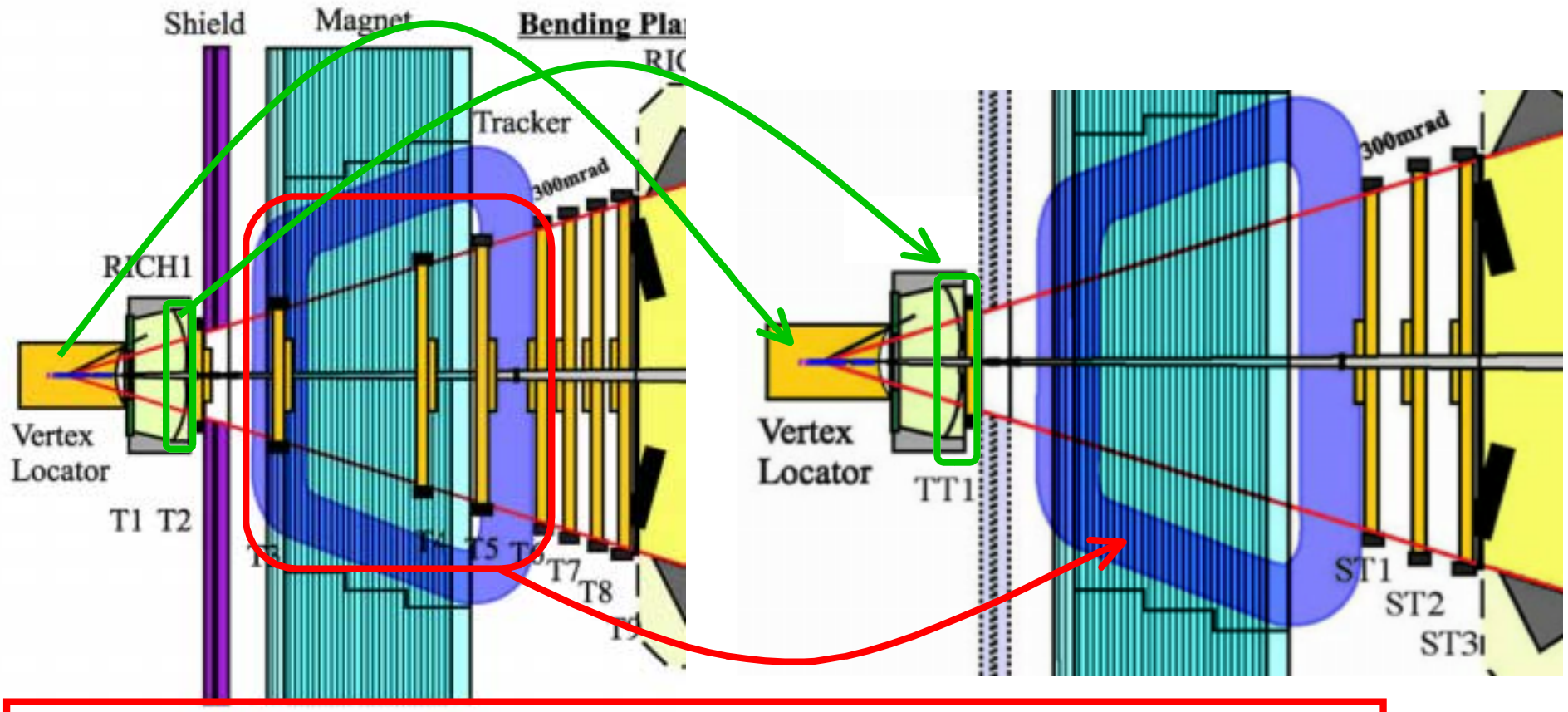
Preparation of Tier 1 centres
new comers are NIKHEF and Bologna

Preparation of Data Challenges

IV) Re-optimisation

Effort to reduce the material budget: ideas are…

Improving VELO (e.g. rf shield) & RICH-1 (e.g. mirror)



removing magnet stations ⇒ a la fixed target tracking

Our road map

By the end of 2001

1) Establish the validity of the new tracking strategy
2) Establish realistic new designs of RICH-1 and VELO

Late Spring 2002

Re-optimised LHCb detector

Autumn 2002

Addendum to LHCC on

fully re-optimised LHCb detector

No large scale design change is involved:

→ compatible with our construction plan.

(NB: RICH-2 and large OT stations not affected)

Cost neutral: design improvement & simplification.

V) Conclusions

With knowledge by BABAR, BELLE, CDF and D0, LHCb should unambiguously identify new physics in CP violation.

TDR approved: Magnet, Calo, RICH.
completed: VELO, Muon and OT.

Magnet, E-cal and H-cal construction started.

Remaining TDR's: Online end of 2001.
IT, Trigger and Computing end of 2002.

The LHCb detector is planed to be ready for the pilot run in April 2006 with full physics potential.

No indication for any additional cost beyond the MoU cost for the moment (and every efforts are made to stay so).