LHCb Status Report

LHCC open session

CERN, 3 October 2001

on behalf of the LHCb Collaboration

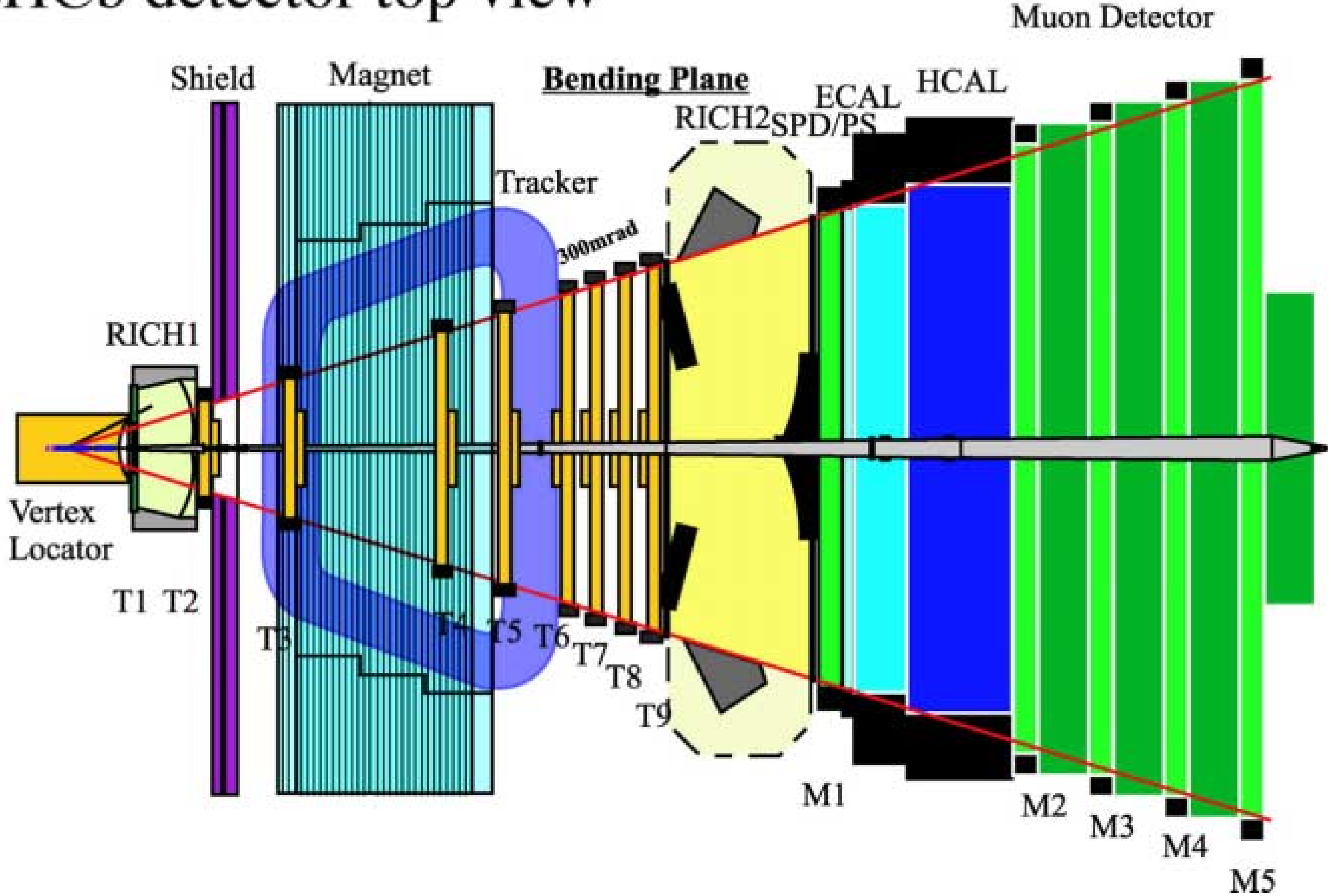
Tatsuya Nakada

The *LHCb* Collaboration (September 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.
Russia:	BINP, INR, ITEP, IHEP, PNPI
Romania:	IFIN-HH (Bucharest)
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

LHCb detector top view



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I) Introduction
II) Experimental Area
III) Subsystems
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   4) RICH
   5) Tracking: Outer Tracker, Inner Tracker
   6) Calorimeters
   7) Muon
   8) Trigger
   9) Computing, DAQ and ECS, Offline, Computing infrastructure
IV) Overall re-optimisation
V) Conclusions

I) Introduction

英和辞典
(dictionary)

$\alpha \Leftrightarrow \phi_2$

$\beta \Leftrightarrow \phi_1$

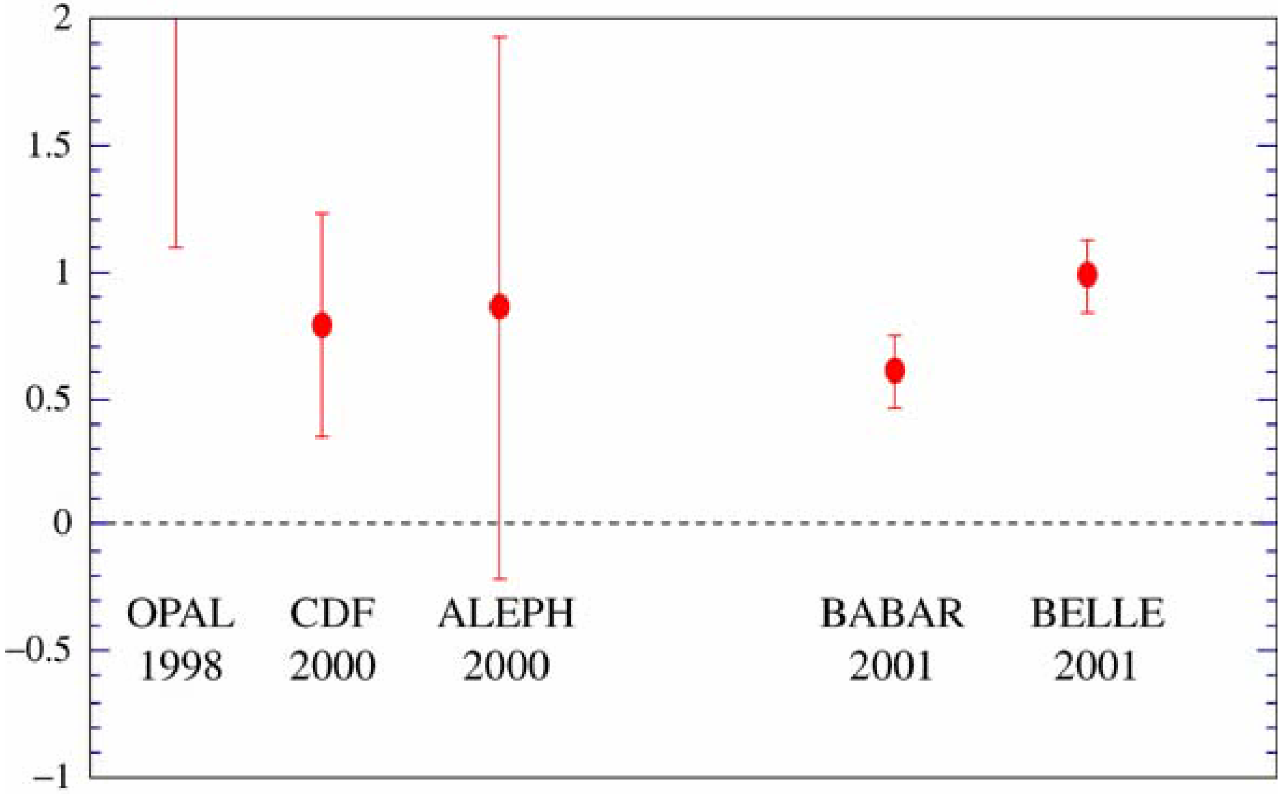
$\gamma \Leftrightarrow \phi_3$

Impressive results from the B factories!

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

BABAR (2001) $= 0.59 \pm 0.15$

BELLE (2001) $= 0.99 \pm 0.15$

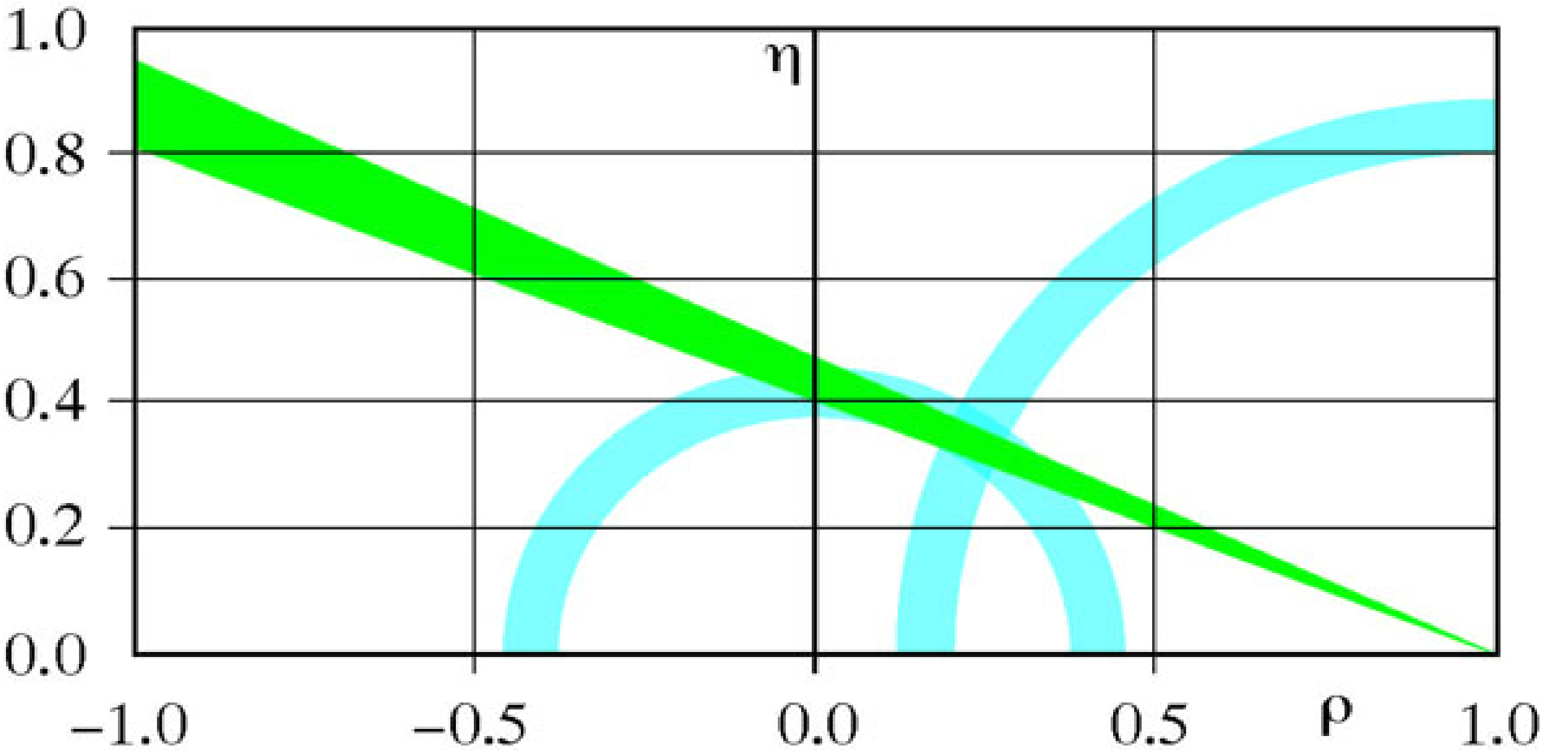


In 2005:

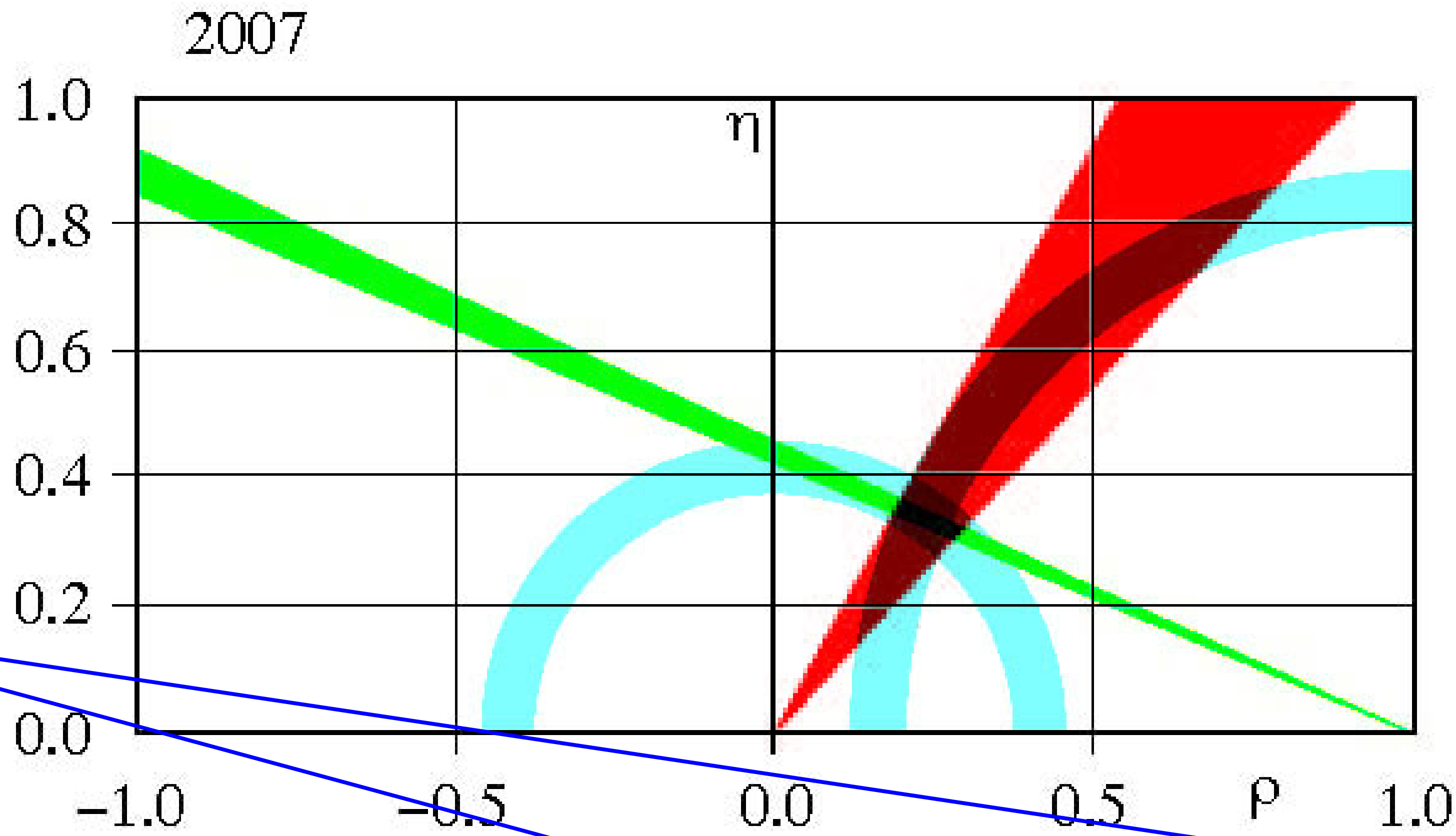
$\sigma_{\sin 2\beta} = \pm 0.03$: Σ (BABAR, BELLE, CDF, D0)

$|V_{td}/V_{ts}|$: Δm_s (CDF, D0) + unquenched lattice calculation

$|V_{ub}/V_{cb}|$: BABAR + BELLE + more QCD theory



Other CP asymmetries (ππ, Kπ etc.) have larger theoretical uncertainties: clean extraction of γ, or β+γ would be difficult.



Special to LHCb

γ by CP asymmetries in $B_d \to J/\psi K_S$+**D*π** and $B_s \to J/\psi\phi$+$\mathbf{D_s K}$ and β from $B_d \to J/\psi K_S$ ($\sigma_{\sin 2\beta} = \pm 0.02$) in 2006.

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

And a high statistics study with many other decay modes.

B_d: $\pi^+\pi^-$, $K^\pm\pi^\mp$, $\rho\pi$, ϕK_S, $K^{*0}\gamma$, $K^{*0}\mu^+\mu^-$

B_s: $K^\pm\pi^\mp$, K^+K^-, $K^*\pi$, $\phi\phi$, $\phi\gamma$, $\phi\mu^+\mu^-$

With presence of new physics

CKM+new physics

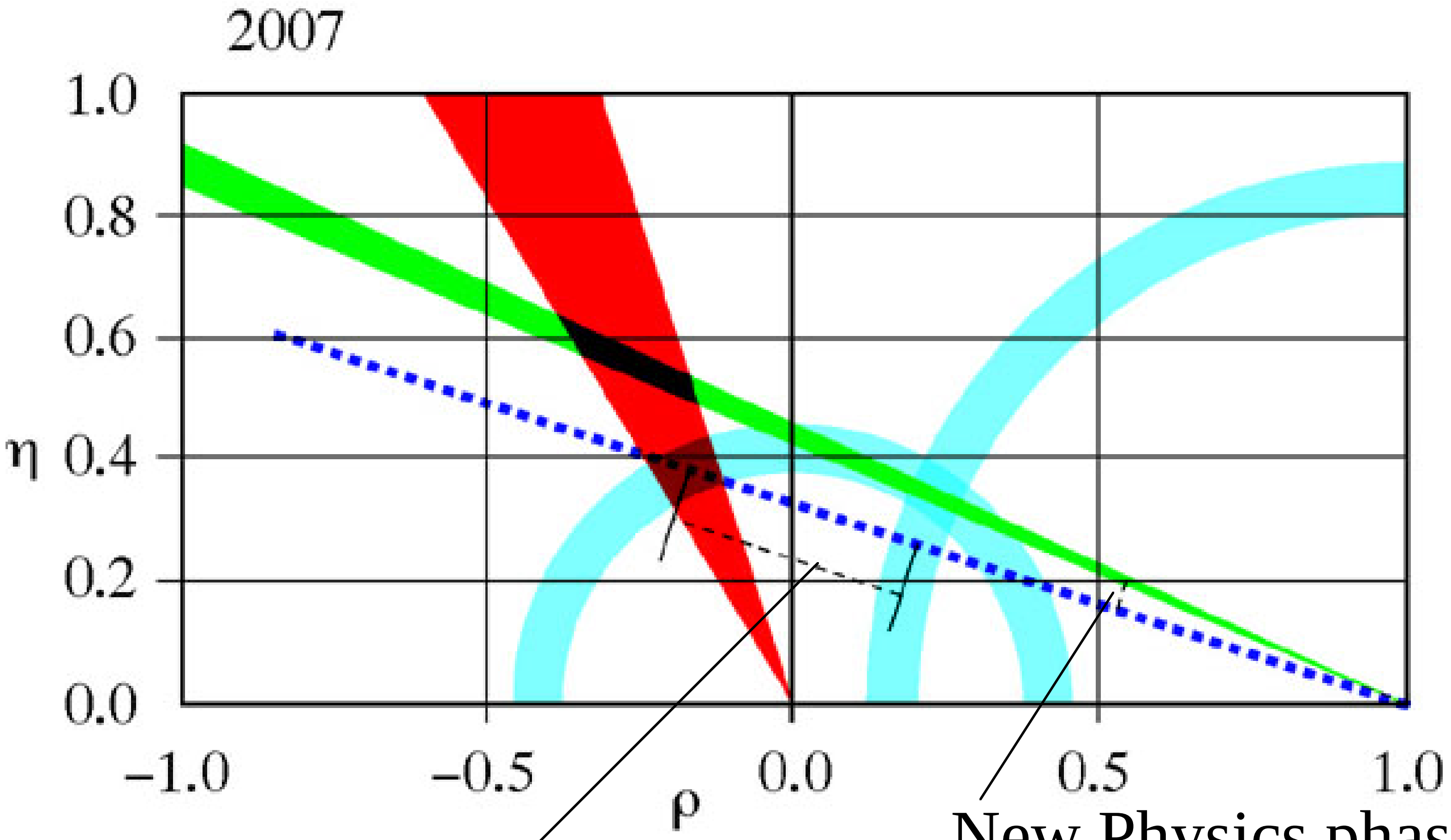
$\Delta m_d/\Delta m_s$

$\cancel{CP}$ in $B_d \rightarrow J/\psi K_S$

CKM only

$|V_{ub}/V_{cb}|$ from semileptonic decays

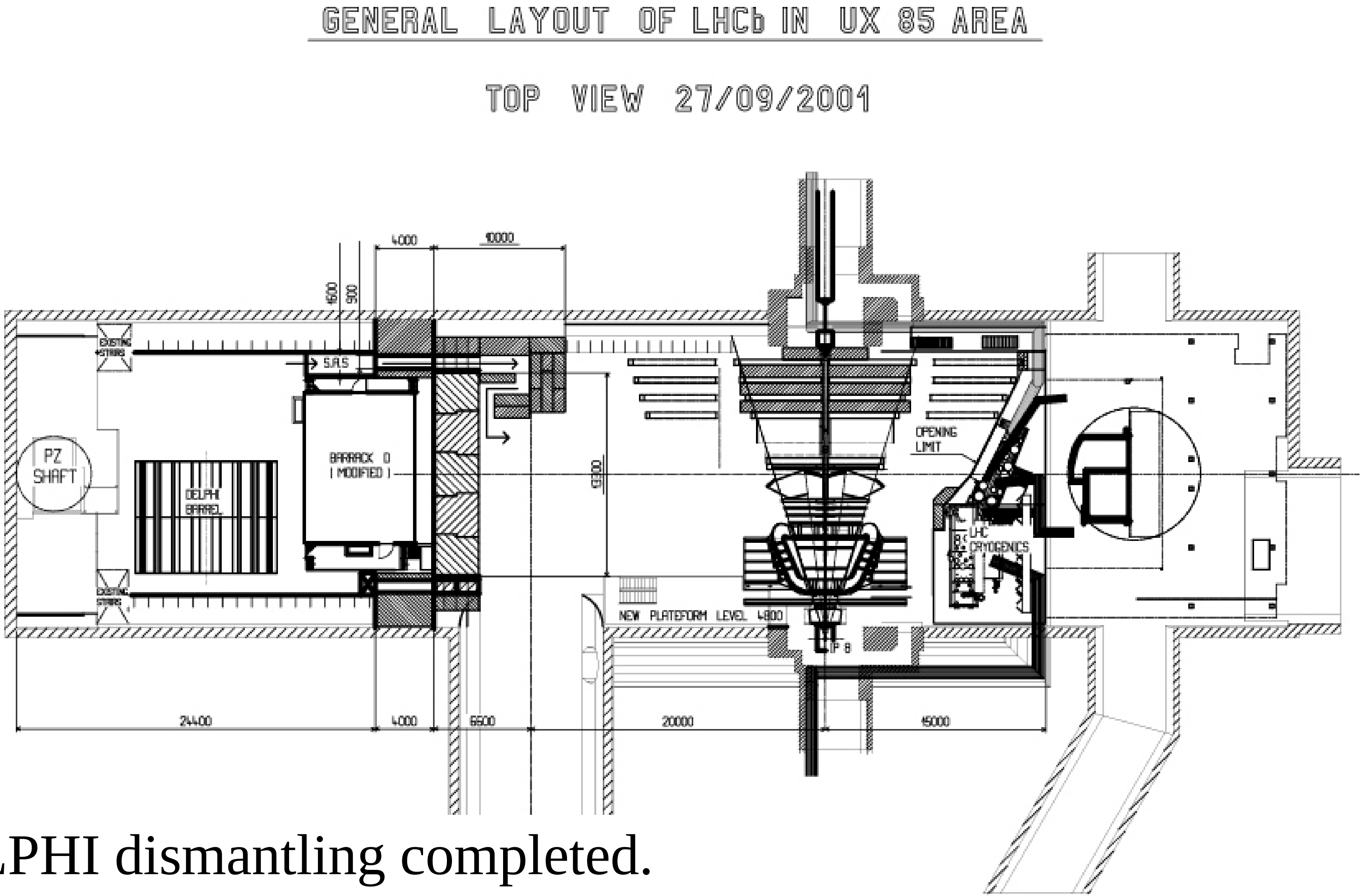
γ a la LHCb



New physics in $\Delta m_d/\Delta m_s$

New Physics phase in B_d-$\overline{B}_d$ oscillations.

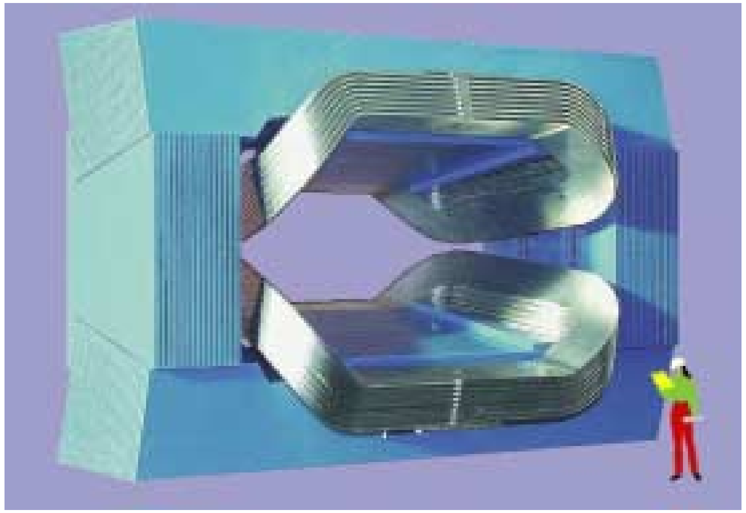
II) Experimental area



DELPHI dismantling completed.
Necessary modification work started.

III) Subsystems

Magnet



$\int B\, \mathrm{d}l = 4$ Tm
Normal conductor (Al)
Power = 4.2 MW

Al conductor (~50 t, ~9 km)
- 120m sample delivered for testing

Steel plates for Yoke (~1.5 kt)
- first sample arrives for test in October 2001

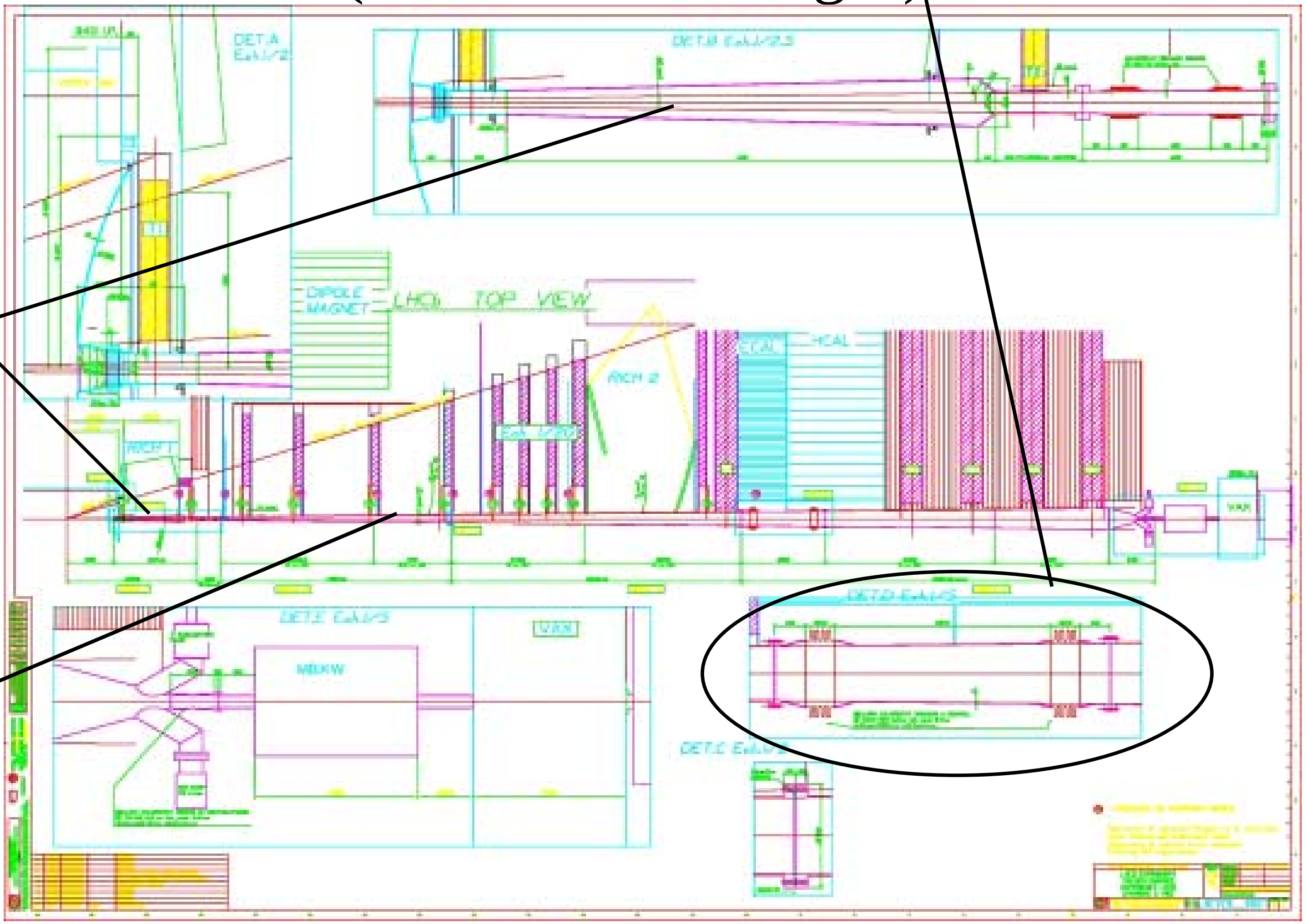
Construction of two coils
- winding line in preparation
- production of a dummy pancake (October 2001)

Beam pipe

First generation of a "realistic" beam pipe design:
Al pipe + Stainless steel transition pieces
(bellows and flanges)

25 mrad cone

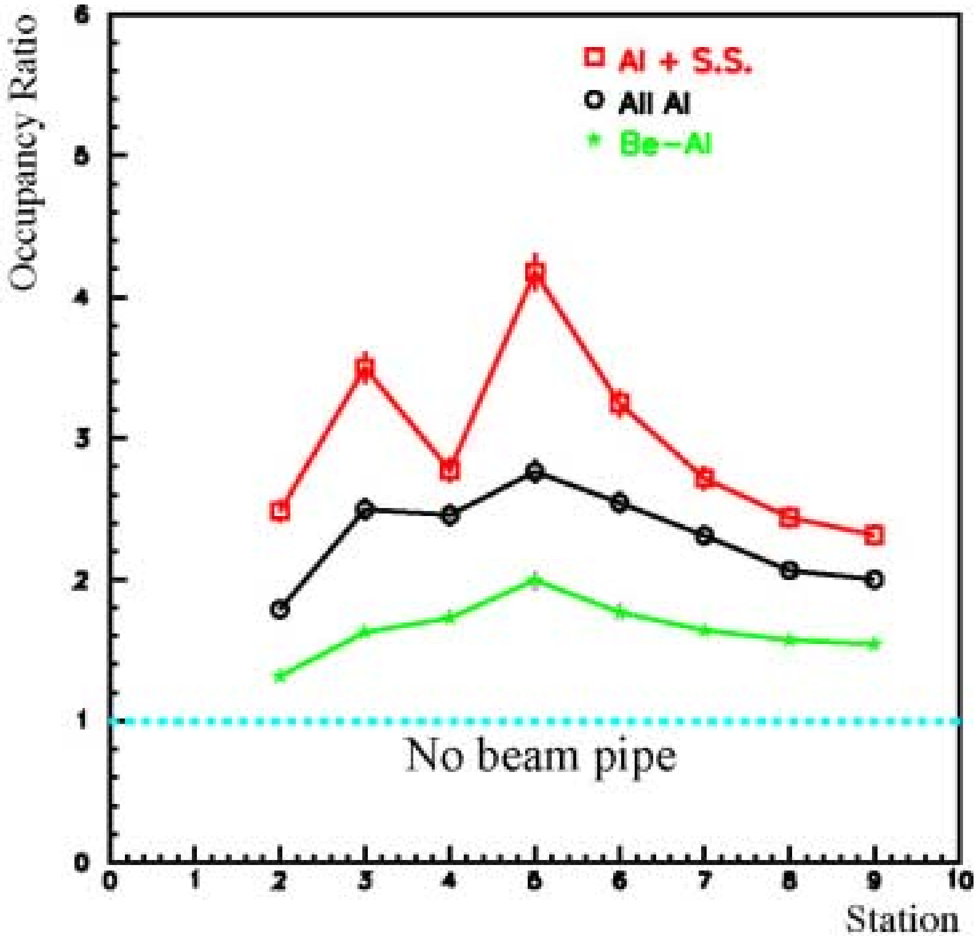
10 mrad cone



Too high background → Improvements needed

Al transition piece (R&D on the Al bellow)

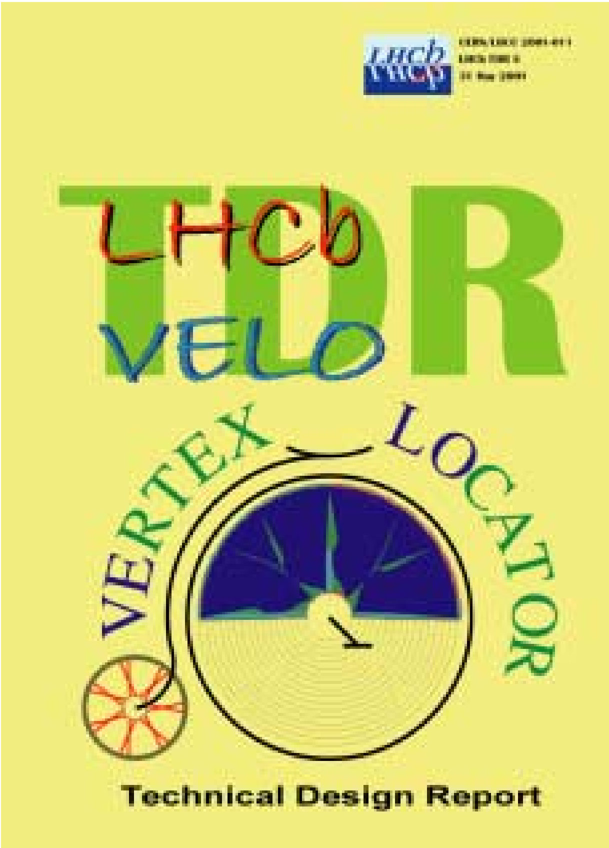
& Al-Be alloy beam pipe (test on the heating)



OT occupancies with respect to no beam pipe

Al-Be alloy pipe is an affordable solution that we are pursuing.

VELO



TDR submitted on 31 May 2001

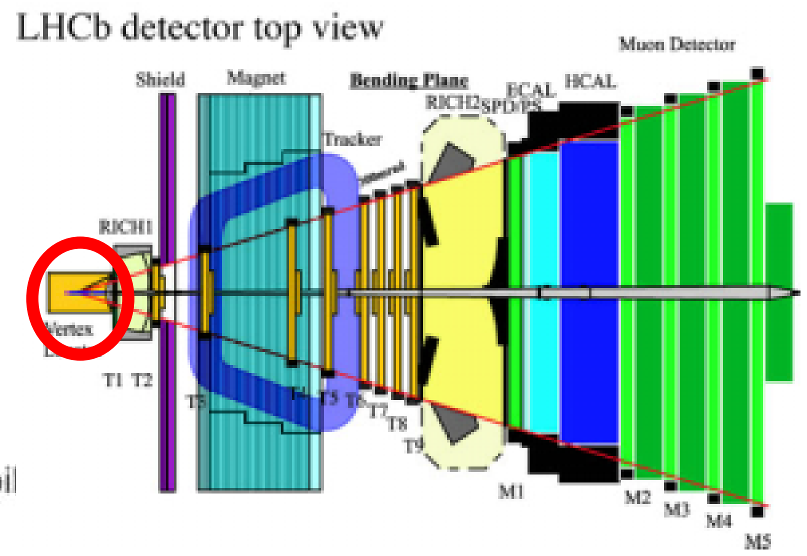
Baseline technology:

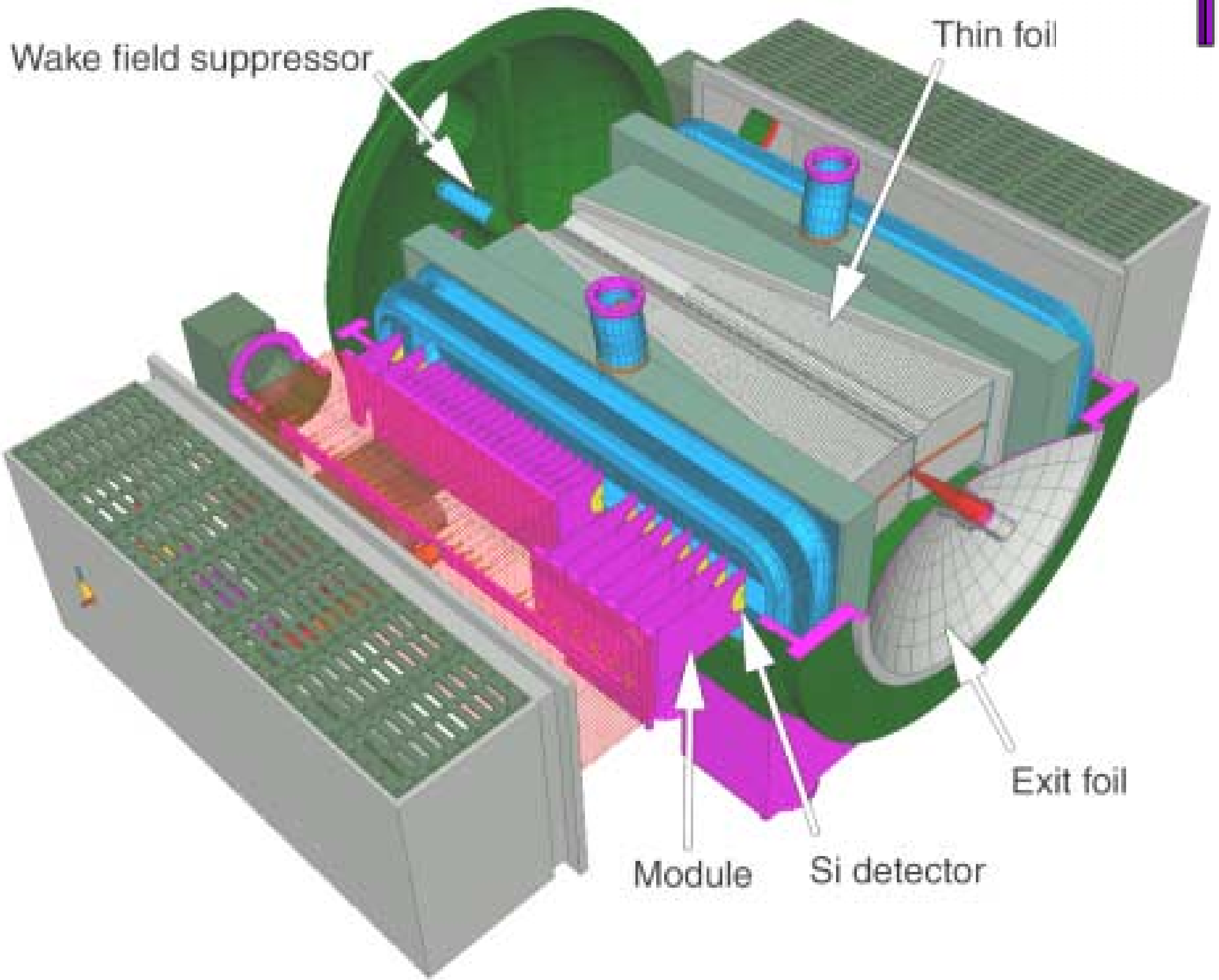
Sensors:

- 300μm n-on-n
- short strips
- double metal layer for readout

Electronics:

- SCTA-VELO: DMILL
- or
- BEETLE: 0.25μm CMOS


LHCb detector top view
Muon Detector
Shield
Magnet
Bending Plane
ECAL
HCAL
RICH2
SPD/PS
Tracker
RICH1
T1 T2
T3
T8
T9
M1
M2
M3
M4
M5


Wake field suppressor
Thin foil
Exit foil
Module
Si detector

Machine related issues: wake field and vacuum

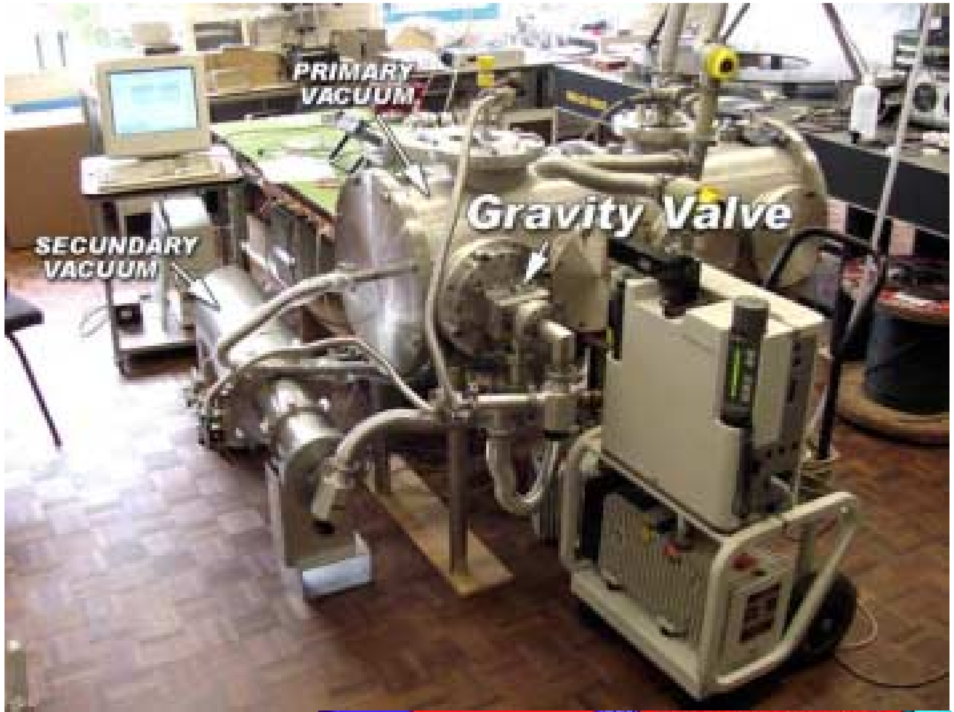
RF test tank

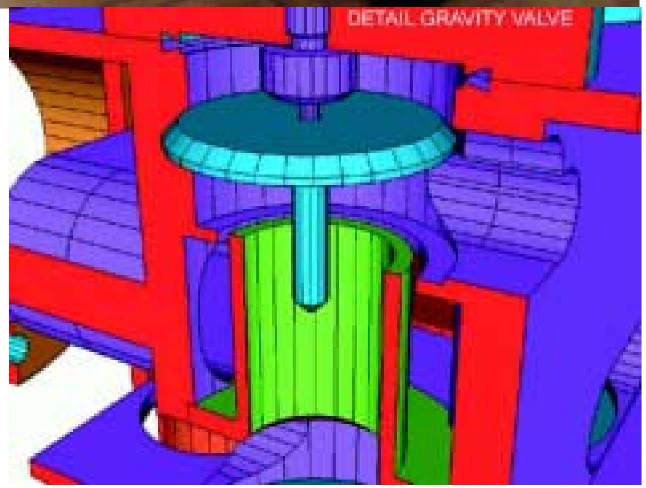
wake field suppressor

secondary vacuum box

validating simulation results

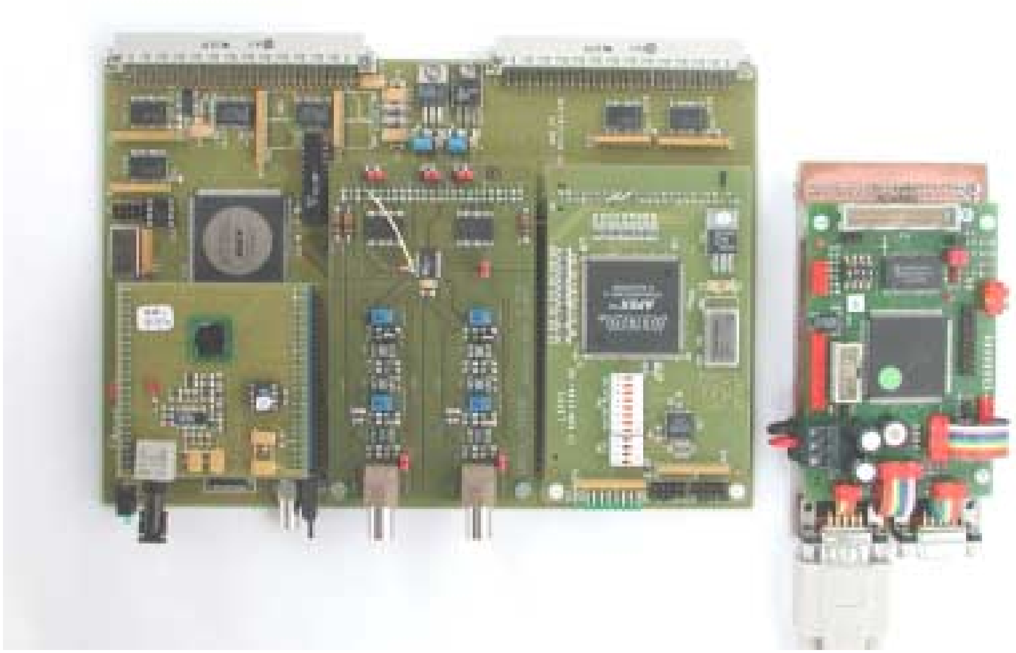
Gravity valve test

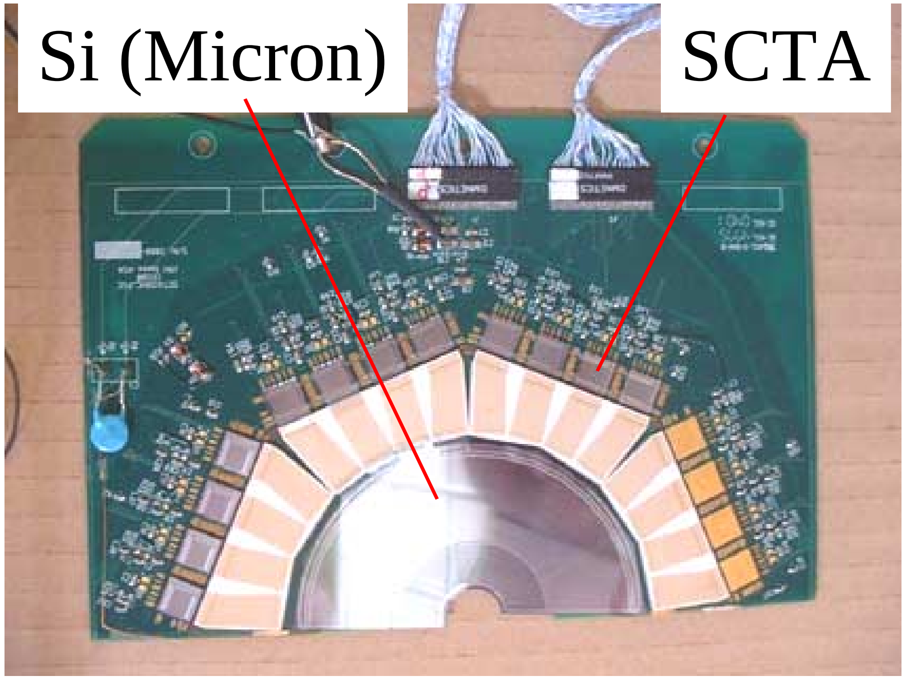


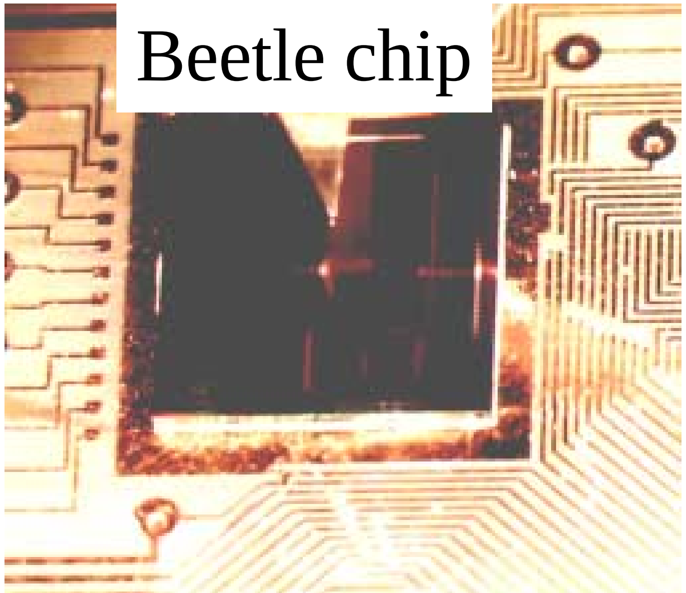


Electronics prototypes

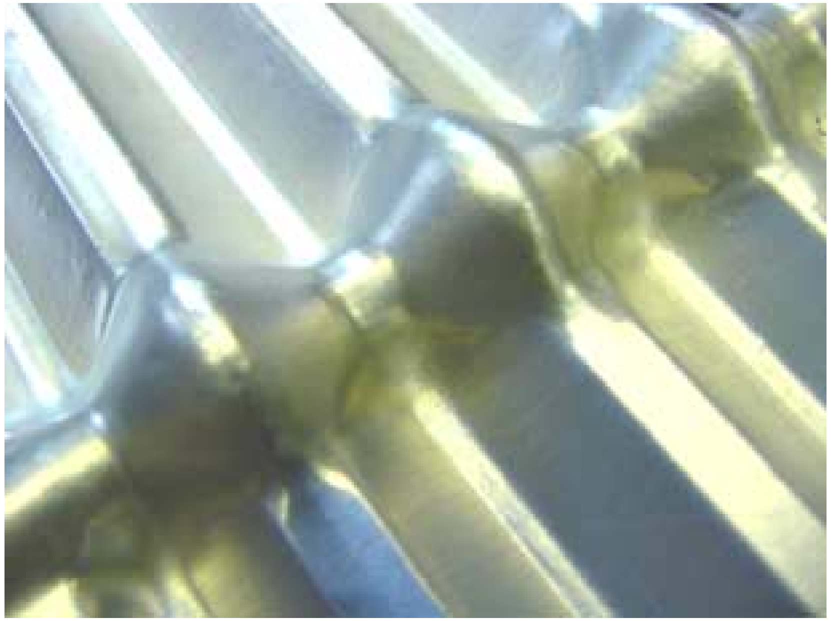
Level-
electronics





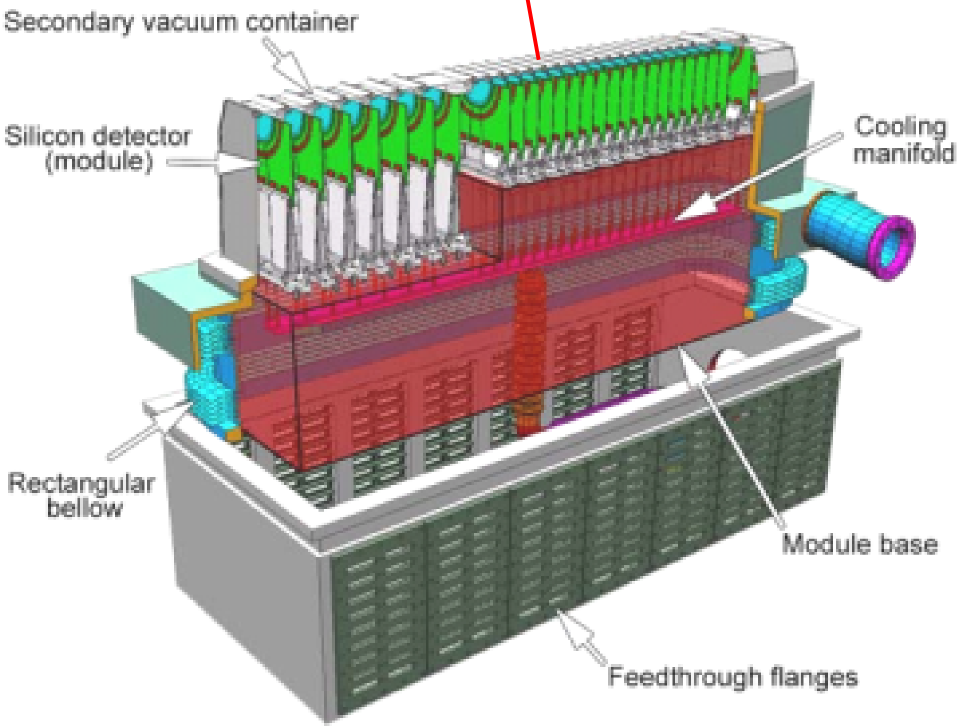


2000



now

RF foil



RICH

TDR submitted on 7 September 2000
approved February 2001

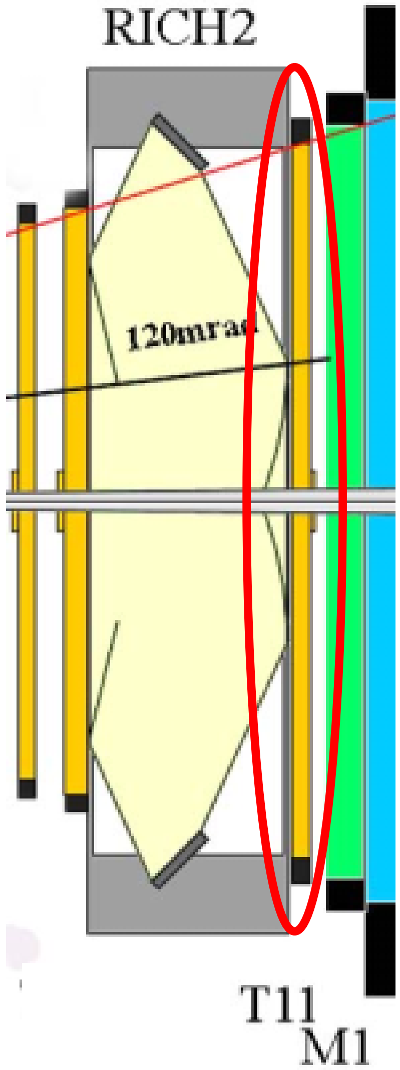
Baseline Technology

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

RICH-2 design modification and T11 station

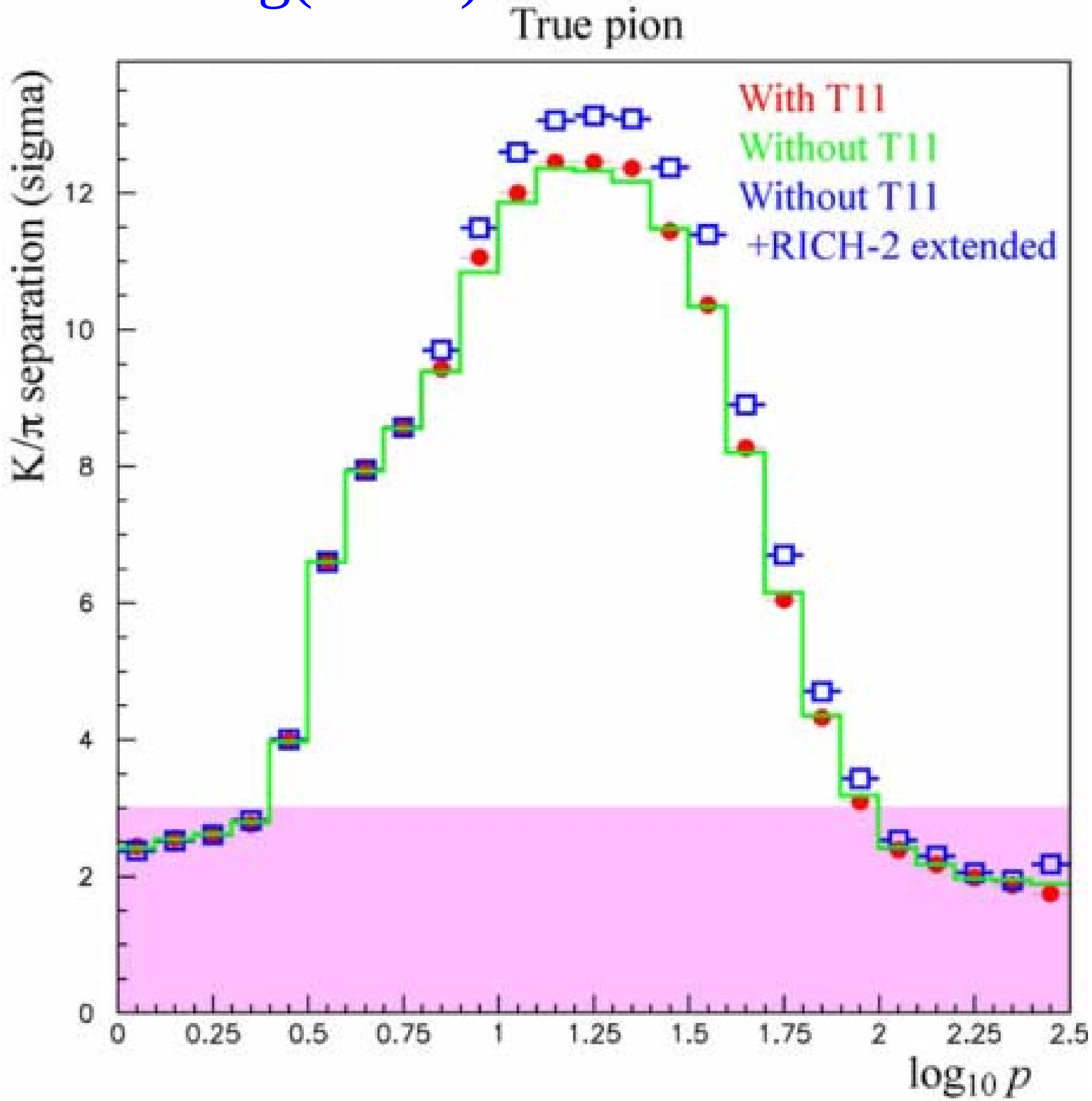
T11 Reduces the effect of multiple scattering due to RICH-2

$\rightarrow$ less important @ high *p* i.e. for RICH-2



Removing T11: little effect on the angular resolution

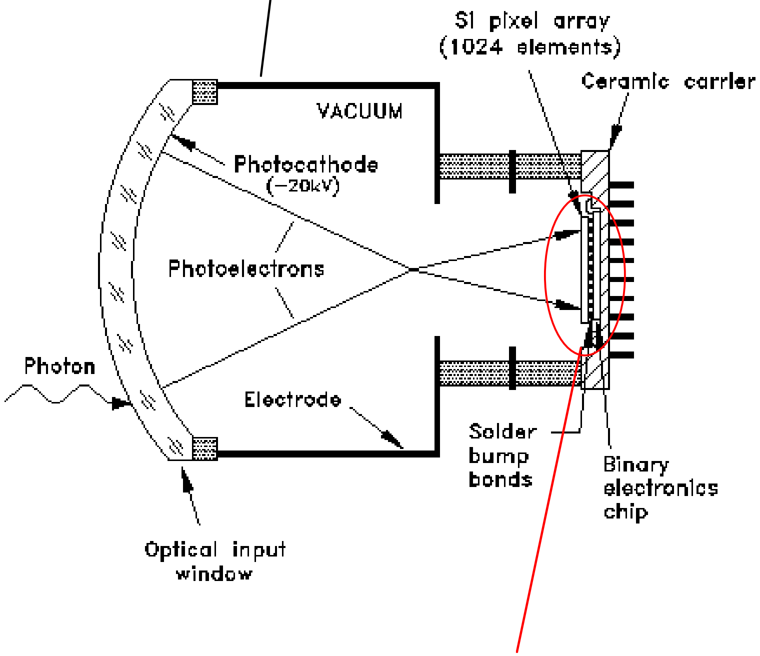
Extending(33cm) RICH-2: increases No. of photons by 18%



T11 is removed and RICH-2 extended.

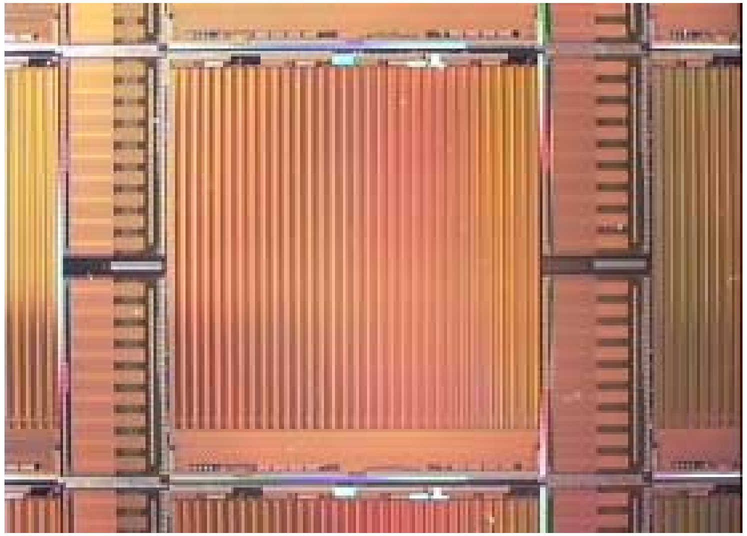
Pixel HPD development:

photocathode and tube encapsulation by DEP



1024 pixel (500μm×500μm) detector and bump-bonded pixel readout electronics.

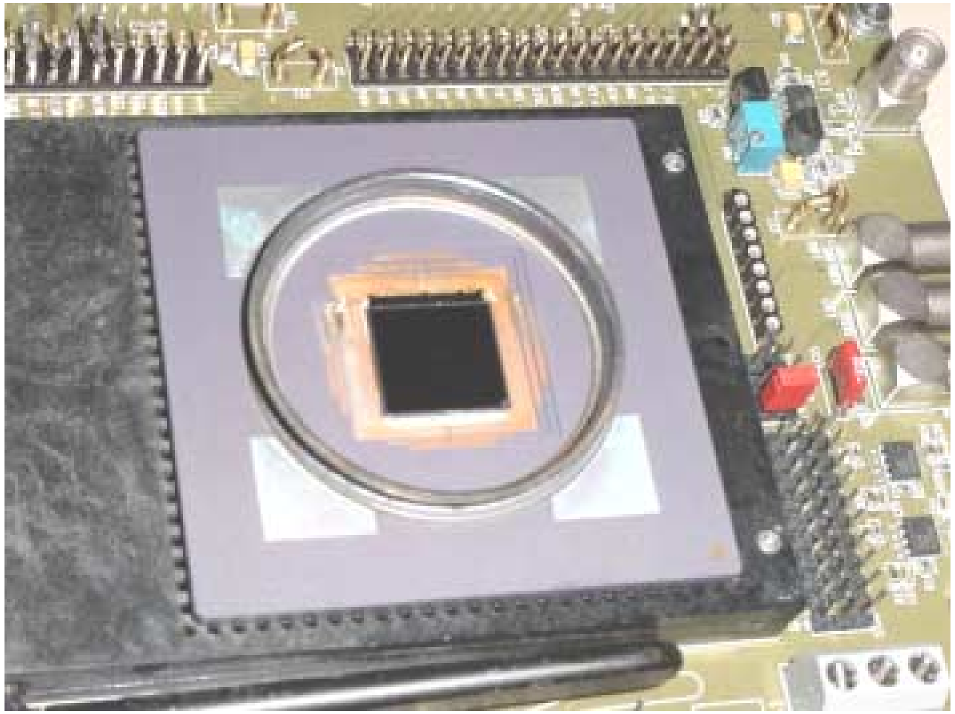
ALICE/LHCb pixel readout chip



☺ S/N = 50

☹ < 20 MHz

Problems were found and corrected.
New submission: mid-October



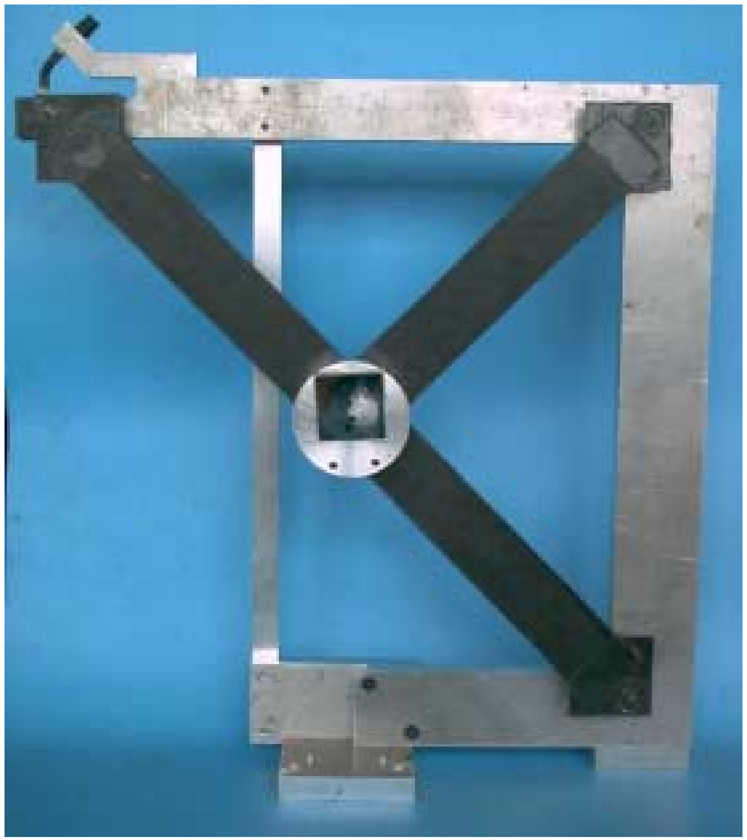
Bump-bonded pixel+readout chip
bonded on the HPD base plate
to be encapsulated.

Original milestones for October:

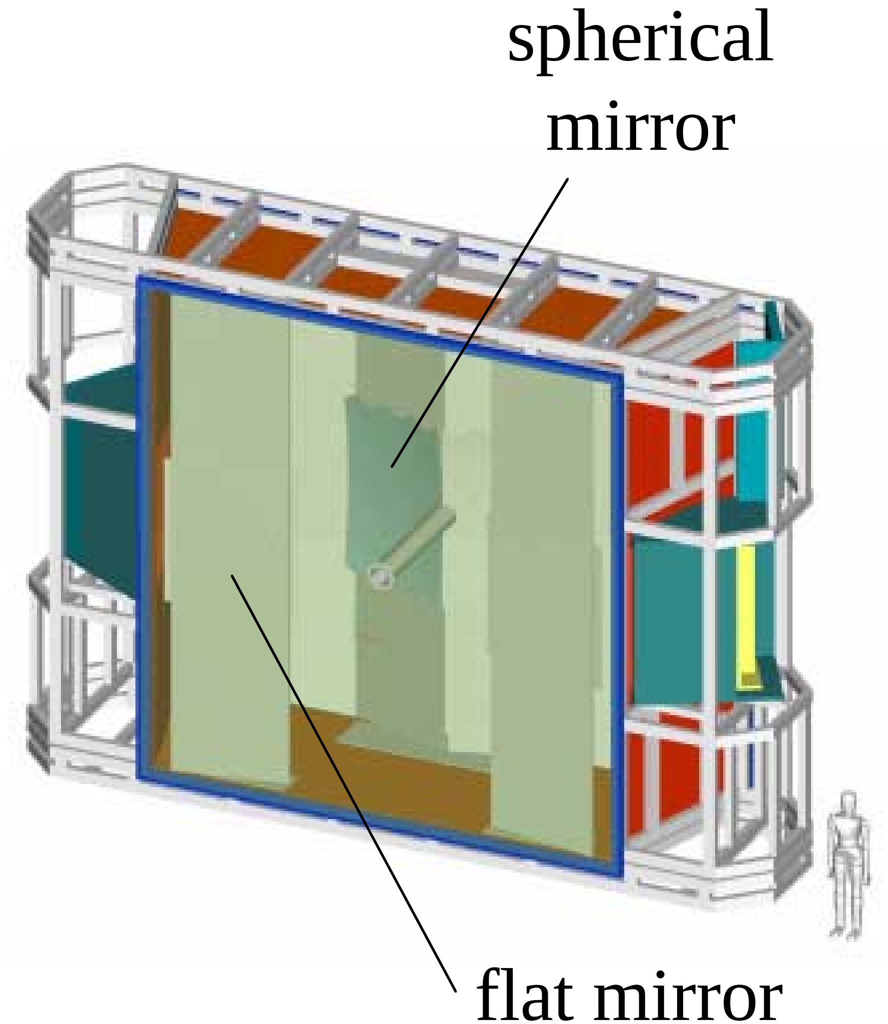
a working HPD with 20MHz chip
a working 40MHz chip

Missed by ~3 months
Status will be
reviewed this month.

RICH-1 mirror support prototype

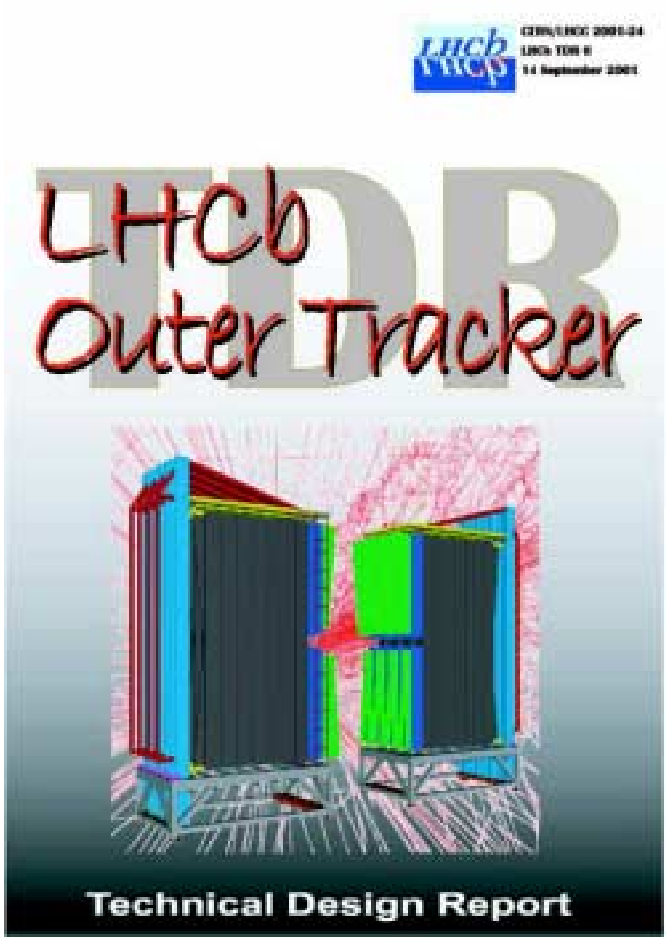


RICH-2 mechanics study



Tracker: Outer and Inner

Outer Tracker TDR submitted on 14 September 2001
Presentation to follow.



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

$\Rightarrow$ TDR presentation

Inner Tracker

TP with 3 options:	GEM/MSGC, Si, MCSC
Reduced to 2 options:	Triple GEM, Si
Recently converged to one option:	All Si

This requires more R&D
TDR submission planned for the end of 2001
$\rightarrow$ to be delayed

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.

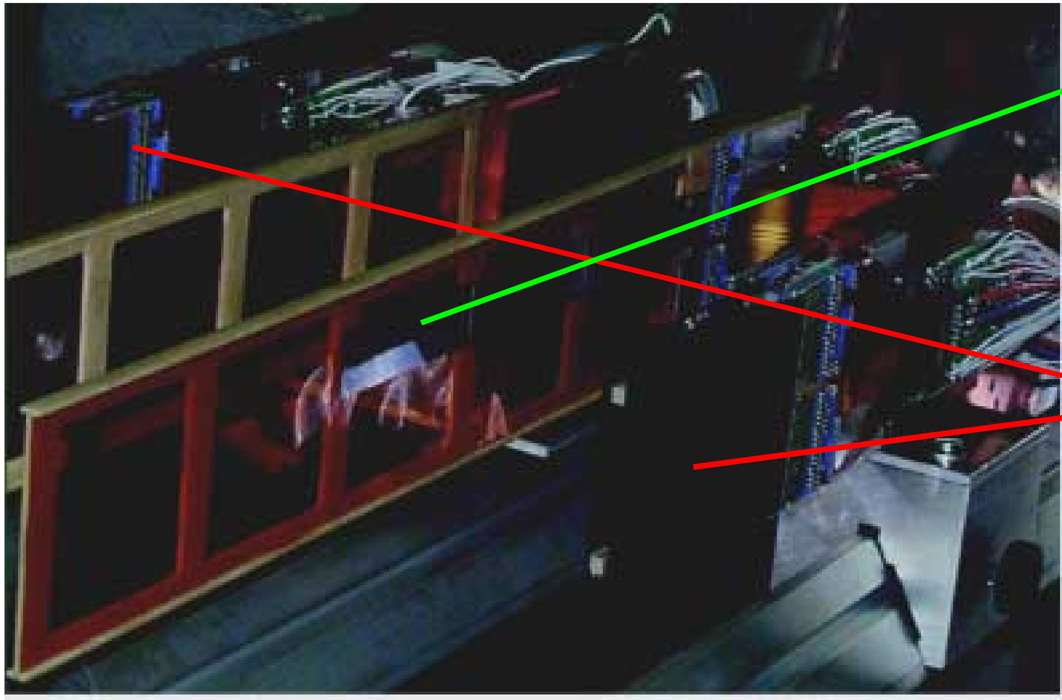
Prototype Si sensors:

300 μm p-on-n oxygenated detectors

4˝ wafers from Sintef and CNM Barcelona

manufactured by SPA DETECTOR in Kiev 240μm pitch

First beam test at CERN



test Si ladder read by HELIX chip (not LHC speed)

reference Si detectors

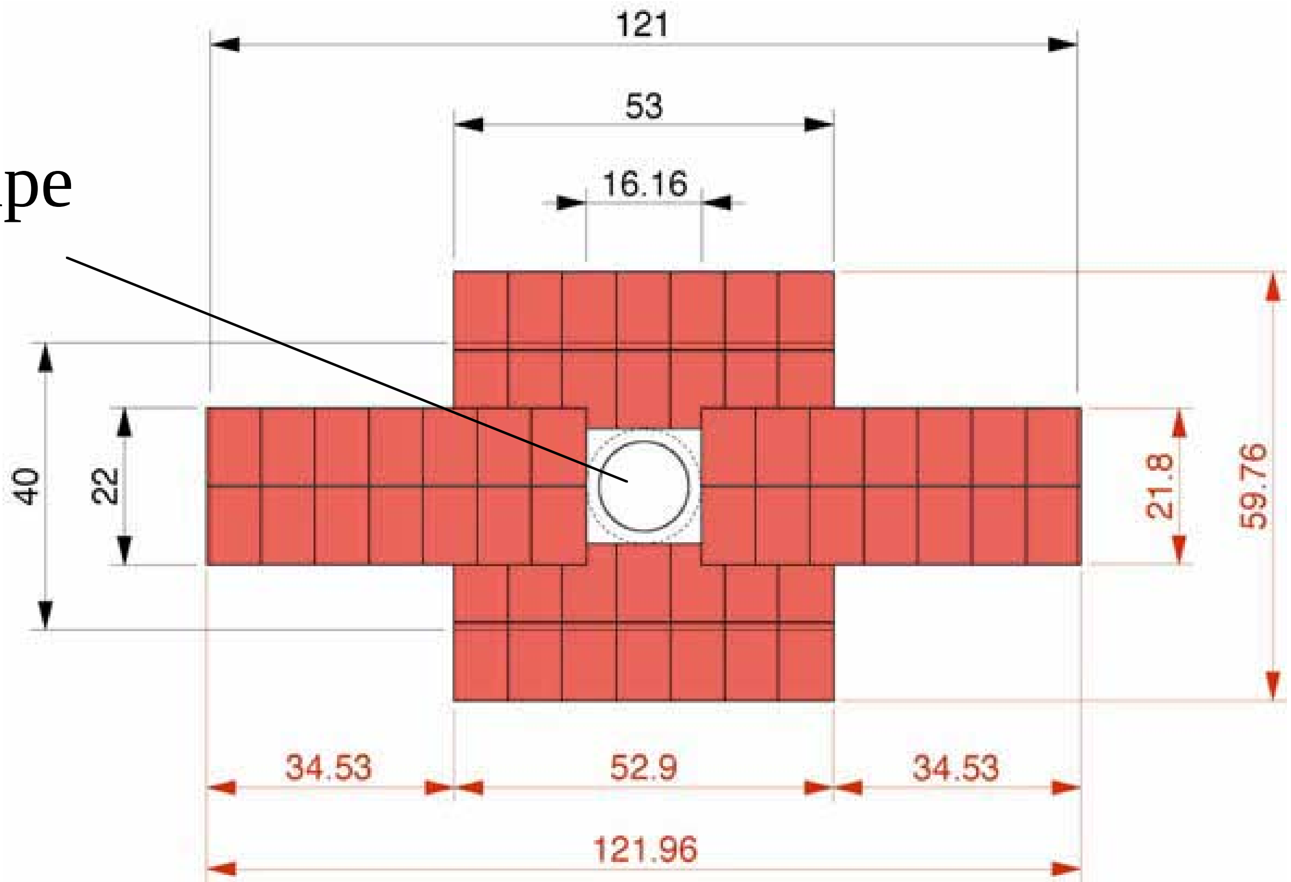
Spring 2002:

Hamamatsu detector read by SCTA-VELO and BEETLE

S/N as a function of the strip length (10, 20, 30 cm?).

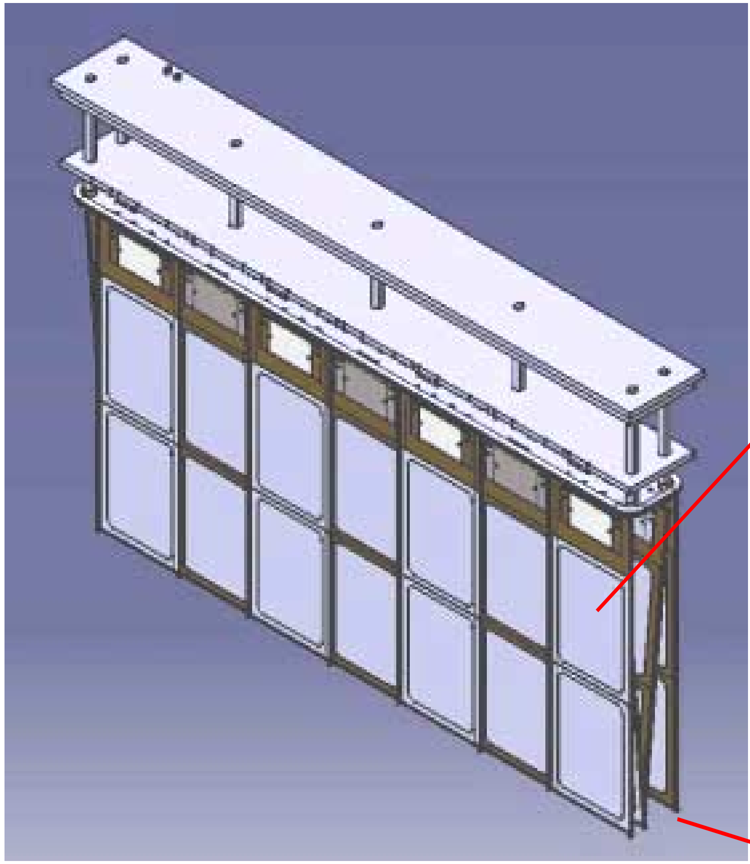
Si station design based on 22cm Si ladders

beam pipe

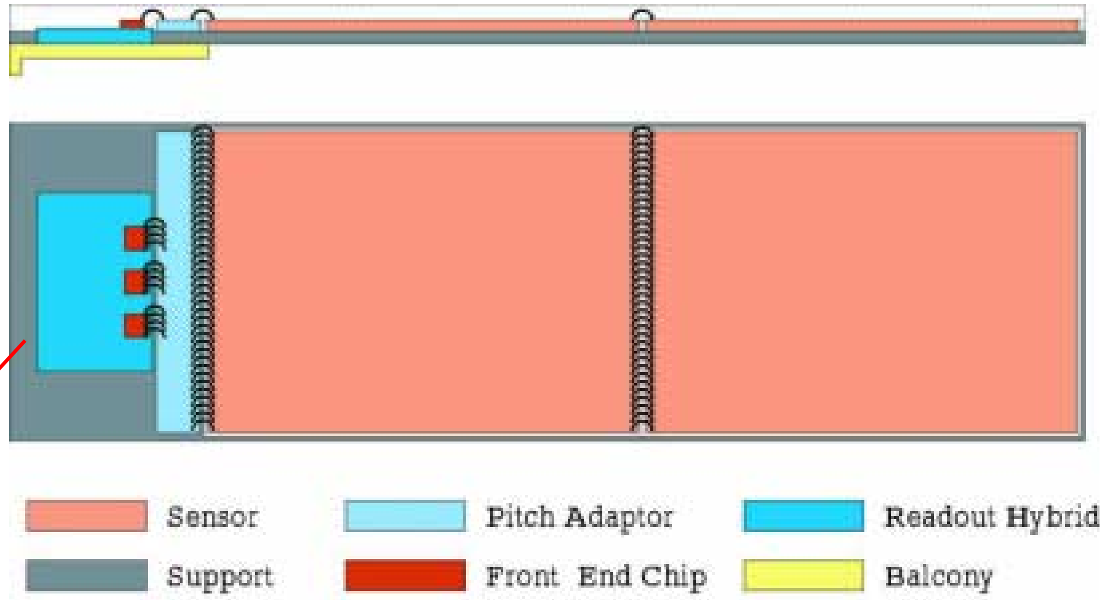


IT design with four boxes.
Each box with four Si layers.
The size is defined by the OT occupancy.

inside of the box



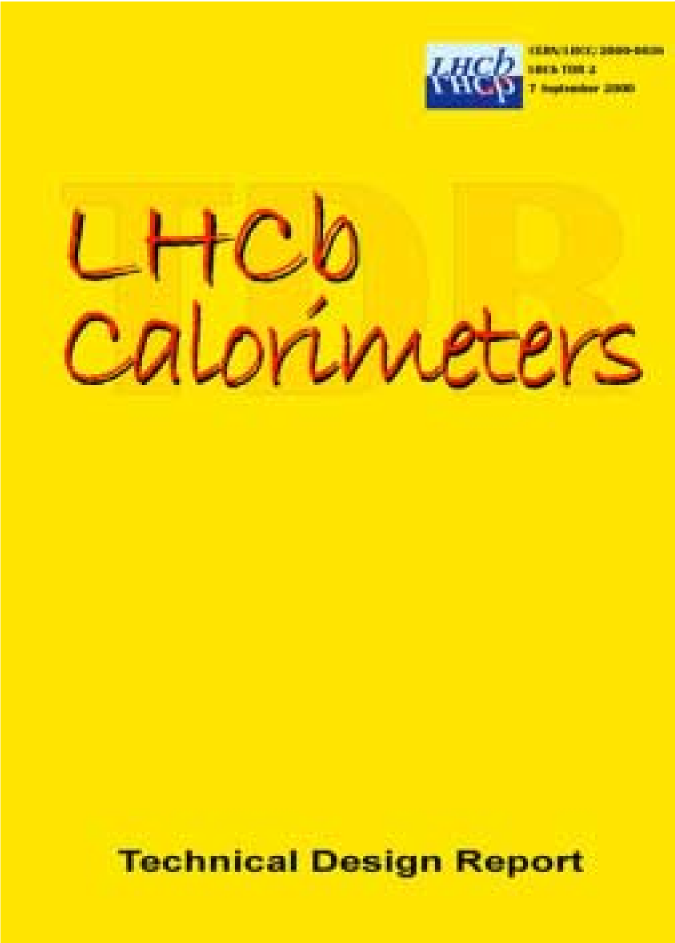
ladder



four layers

1.5 k sensors and 344 k channels with ~200 μm strip (287k channels if ~240 μm strip possible).

Calorimeters



TDR submitted on 7 September 2000
approved February 2001

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

Photon detector
- PMT

E-cal and H-cal

Engineering Design Reviews completed
(with external reviewers)
Module-0 construction completed

E-cal

Shashlik front face

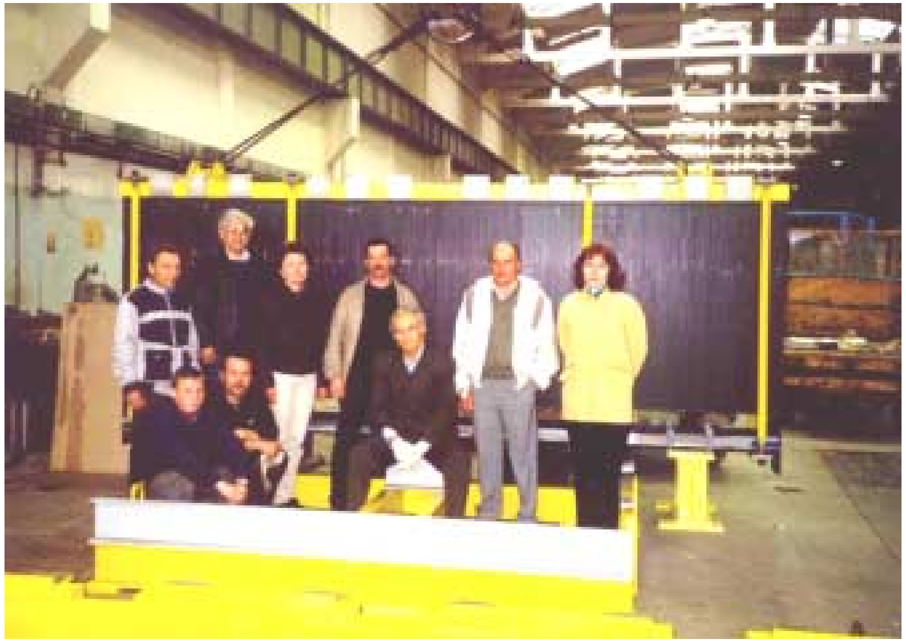
Shashlik back side

200 outer-most modules @ ITEP

Shashlik Module-0 in the test beam

H-Cal module-0

Mechanical assembly @ IHEP   Optical assembly @ CERN



H-cal Module-0 in the test beam

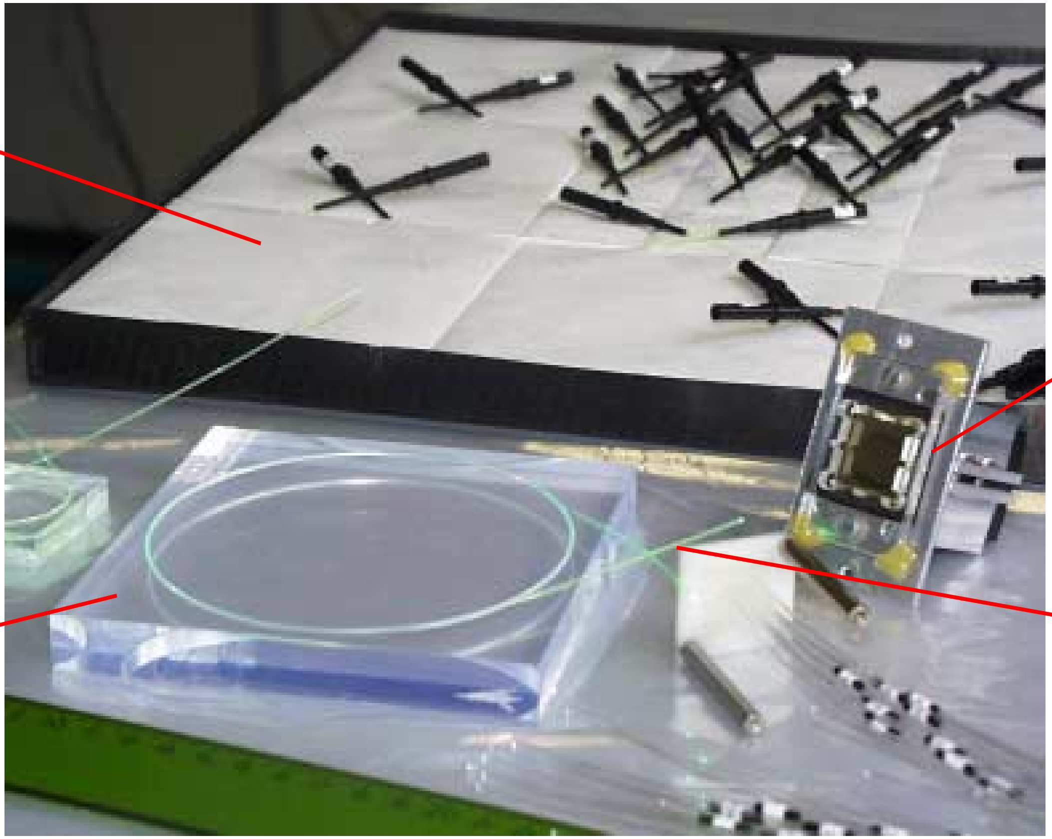
No major surprise in the Module-0 production.

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.

Series production of E-cal and H-cal will start soon.

SPD and Preshower



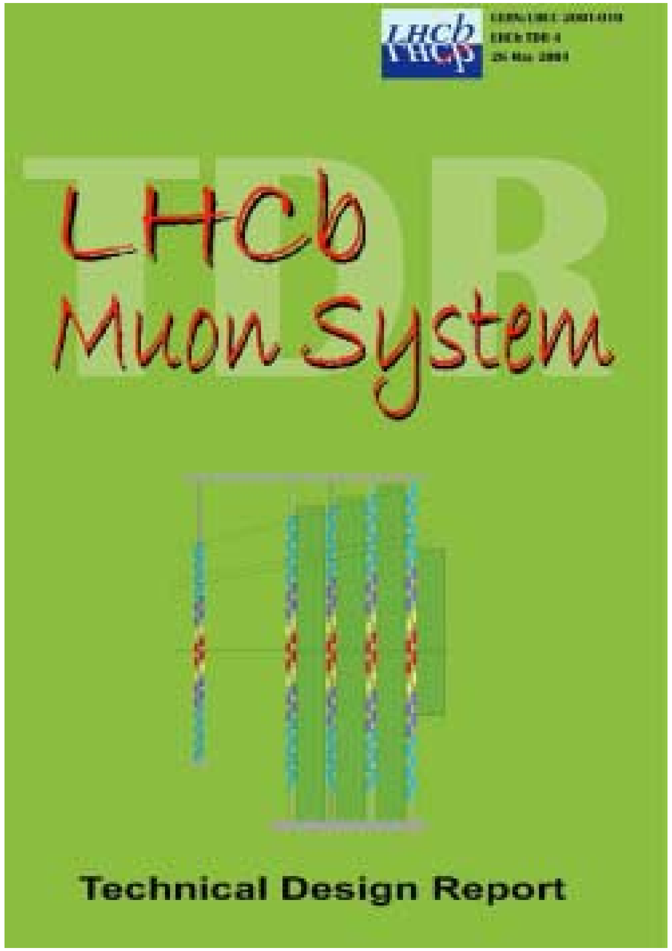
EDR planned for ~beginning of 2002

Front-end cards
(EH-cal, Preshower and SPD)

EDR's completed.
Digital part modified to be SEU immune
PRR's for the EH-cal and Preshower front-end ASIC's soon.

Muon

TDR submitted on 28 May 2001

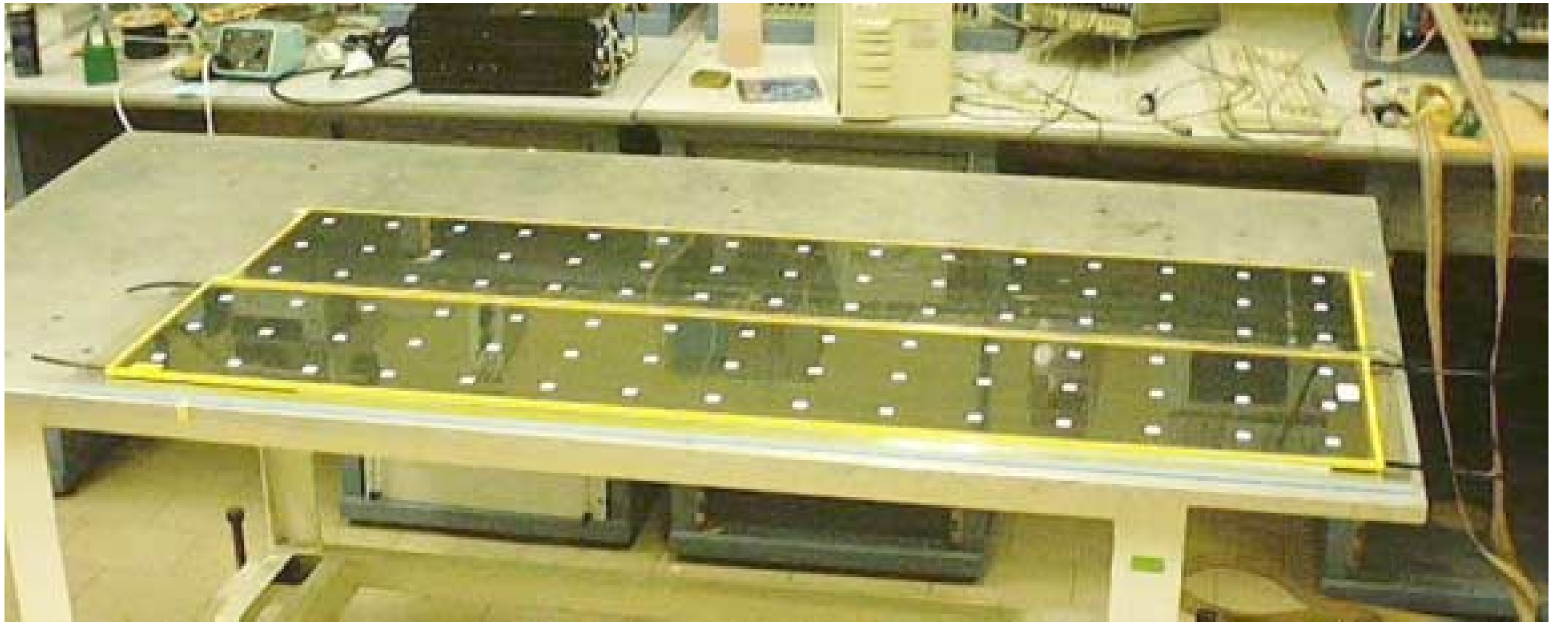


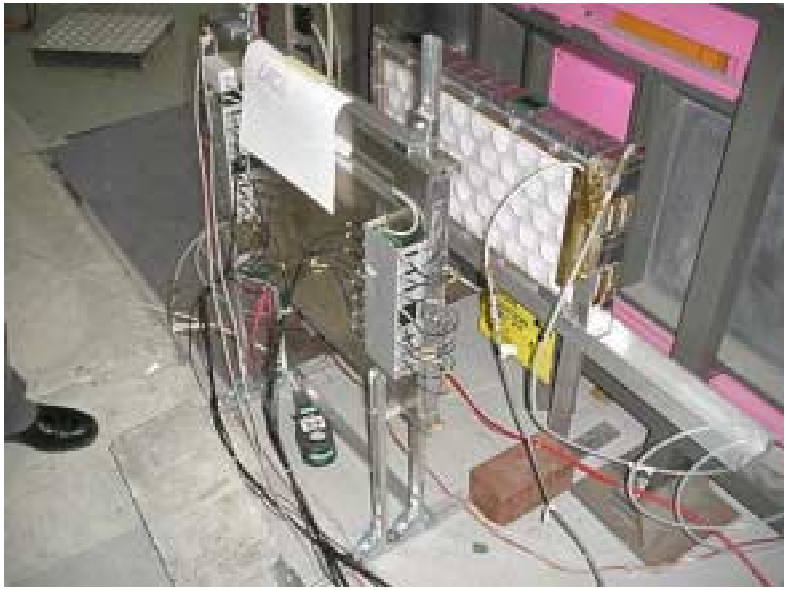
TP
- MRPC and CPC

Now
- **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

reduction of 45k $\rightarrow$ 26k logical channels

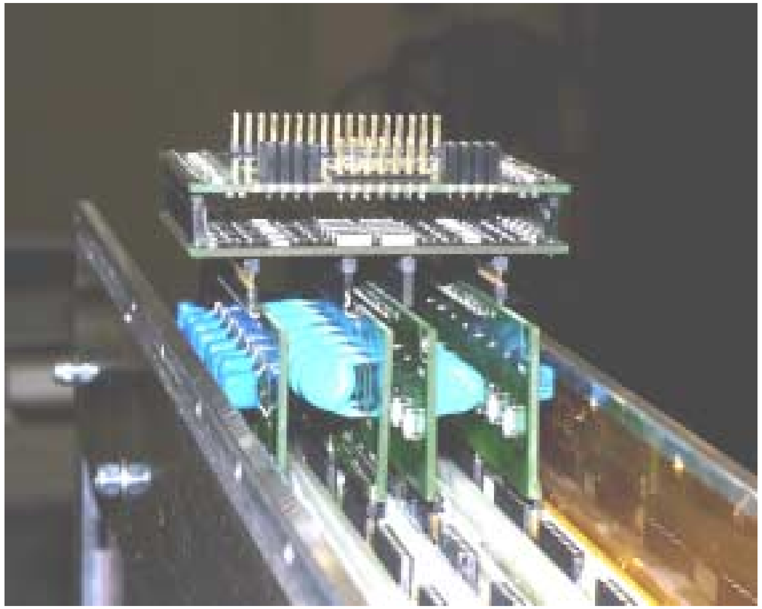
Chamber prototypes
full size RPC gap

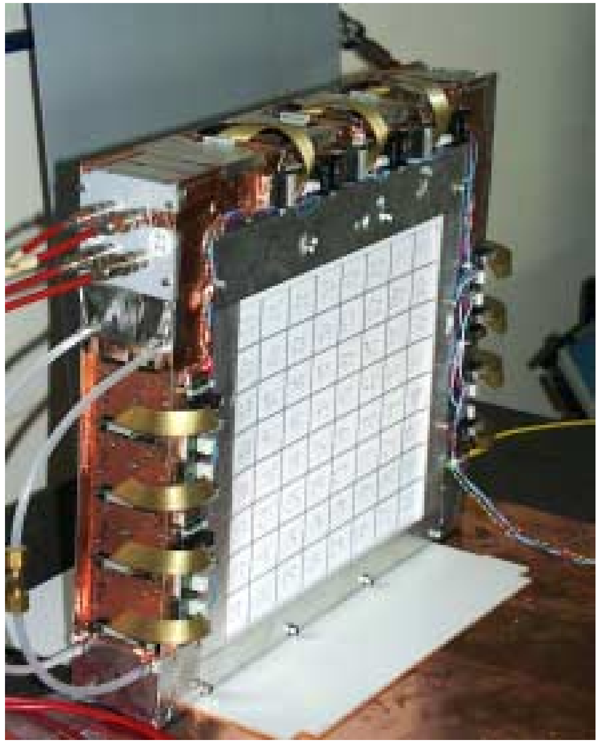


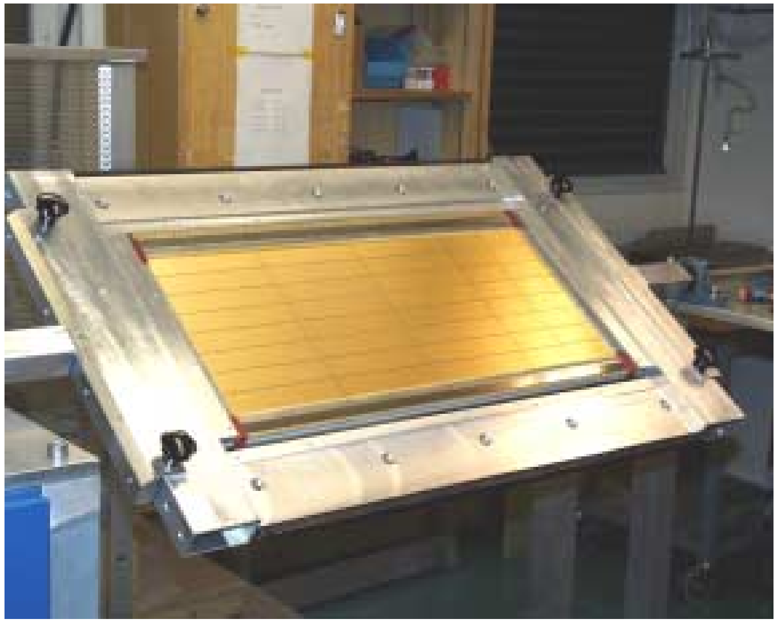


RPC GIF test

MWPC prototype construction
@CERN, Ferrara, PNPI, Frascati: all successful



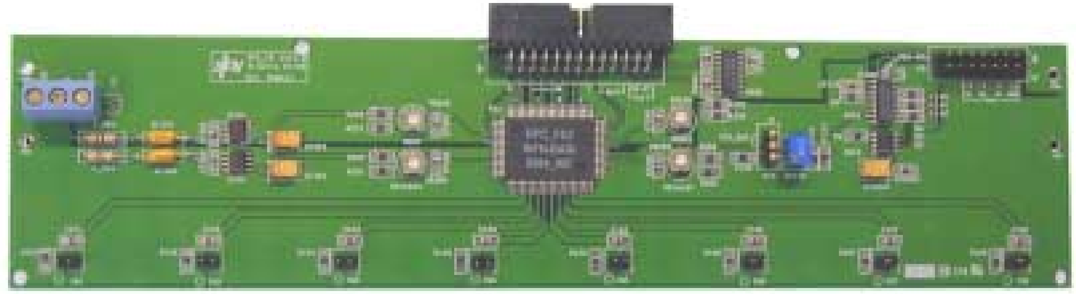




Front-end electronics also identified:

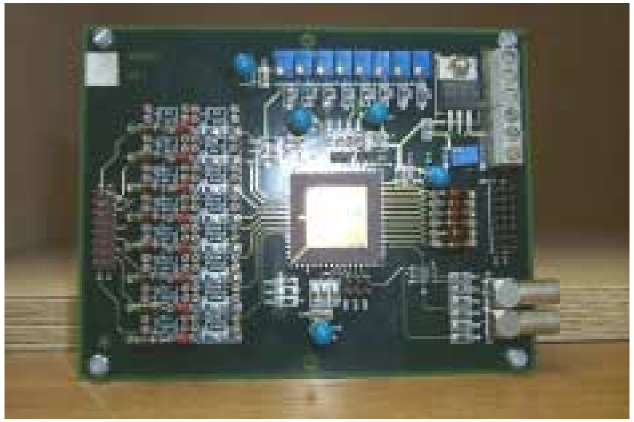
For RPC:

BiCMOS front-end chip developed for CMS

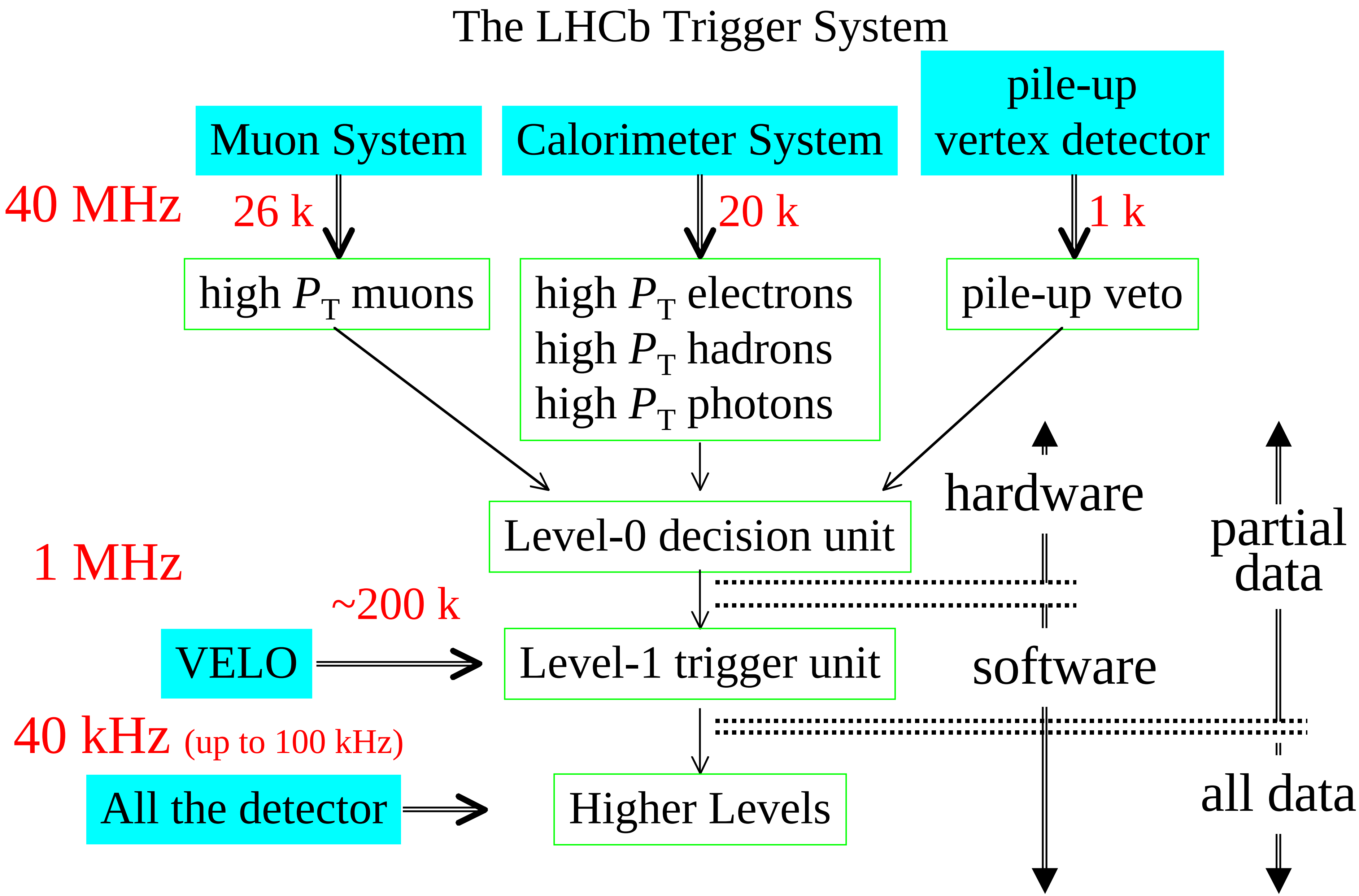


For MWPC:

custom made front-end chip in 0.25 μm CMOS technology
(CARIOCA)



Trigger

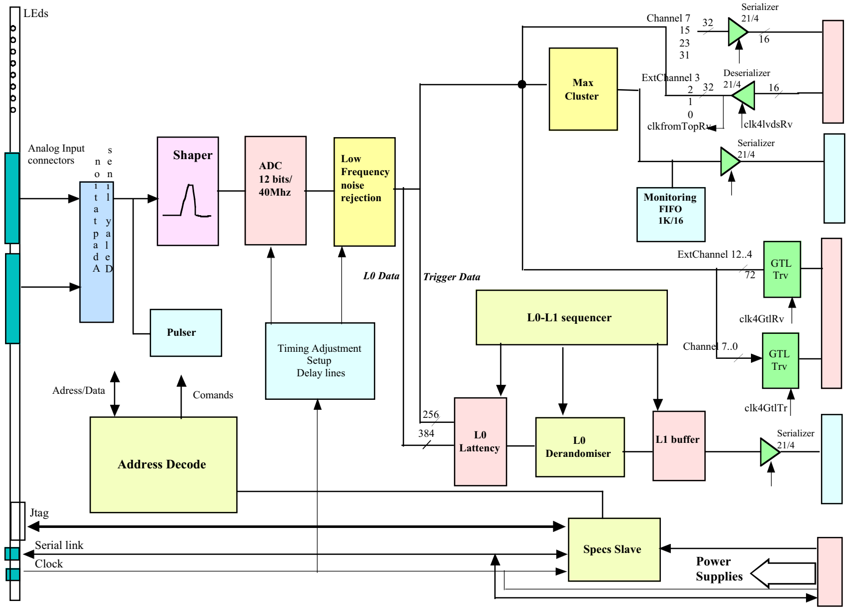


The LHCb Trigger System
Muon System
Calorimeter System
pile-up
vertex detector
40 MHz
26 k
20 k
1 k
high P_T muons
high P_T electrons
high P_T hadrons
high P_T photons
pile-up veto
hardware
partial
data
Level-0 decision unit
1 MHz
~200 k
VELO
Level-1 trigger unit
software
40 kHz (up to 100 kHz)
All the detector
Higher Levels
all data

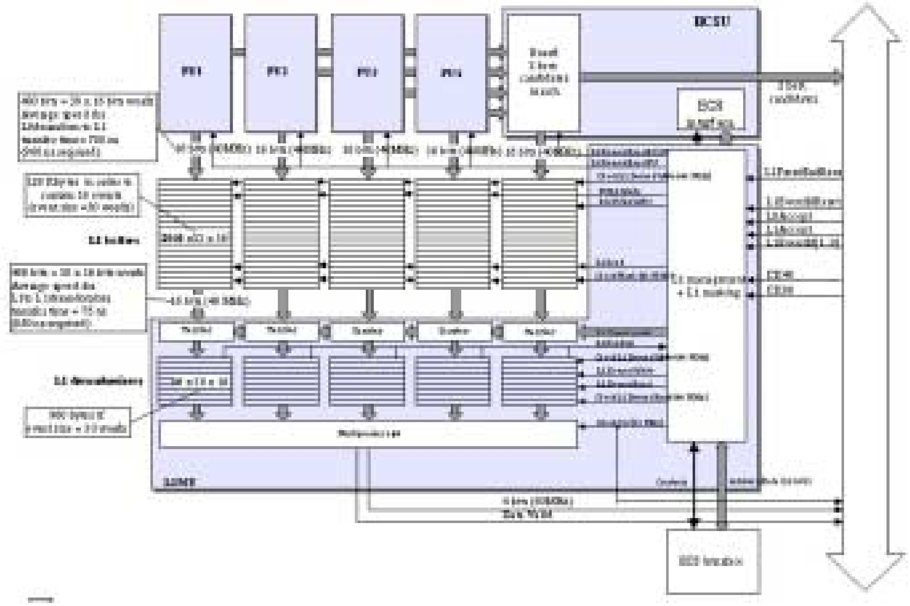
All the L-0 components have been designed and simulated.

Prototype production has started.

Calo front-end card

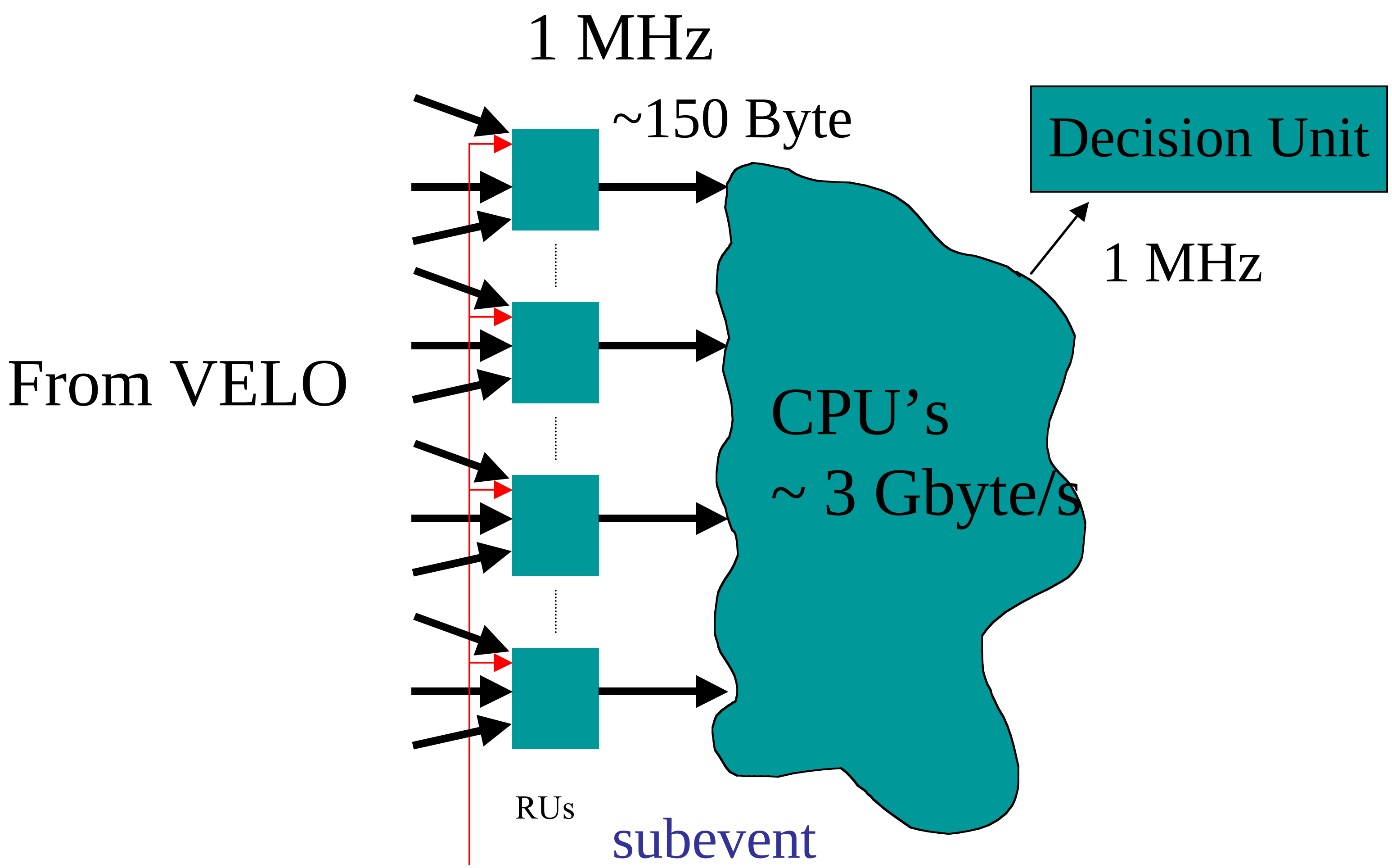


Muon trigger



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

Final network technology is
still open.

After TP,

- Pythia event generator tuned to UA5 and CDF data.
  - $\rightarrow \sigma_c$ and $\sigma_{b\text{-baryon}}$ increased.
- Multiple pp interactions/bunch crossing properly treated.

☹

TP Level-1 algorithm based on the VELO information alone:

$\rightarrow$ the performance dropped by a factor of ~1.5.

☺

This can be more than compensated by introducing P_T.

(b tracks have high $\langle P_T \rangle$.)

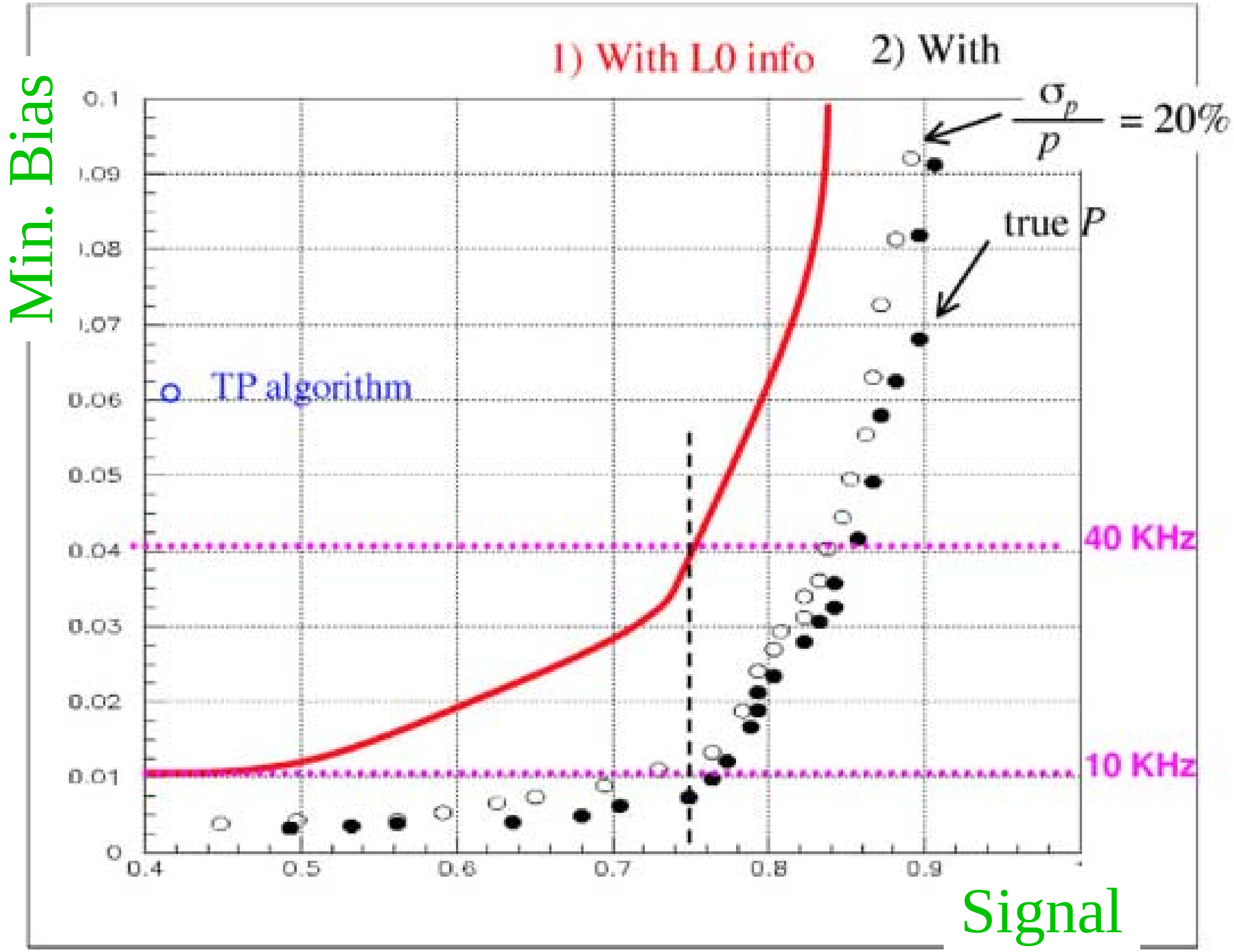
How do we introduce P_T?

VELO identifies tracks with large impact parameters:

Then…

1) connect them with the high P_T clusters found by Level-0.
   $\rightarrow$ feed Level-0 information into CPU.
2) measure their P using one or two tracking stations.
   $\rightarrow$ feed some tracker information into CPU

$B^0_d \to \pi^+\pi^-$



1) comes more or less free.

2) needs some work but gives **better performance**.

Possibilities under study. (NB L1 is a software trigger)

Trigger TDR delayed

No effect on the construction schedule:

Start production in 2003.

Better performing Level-1can be developed.

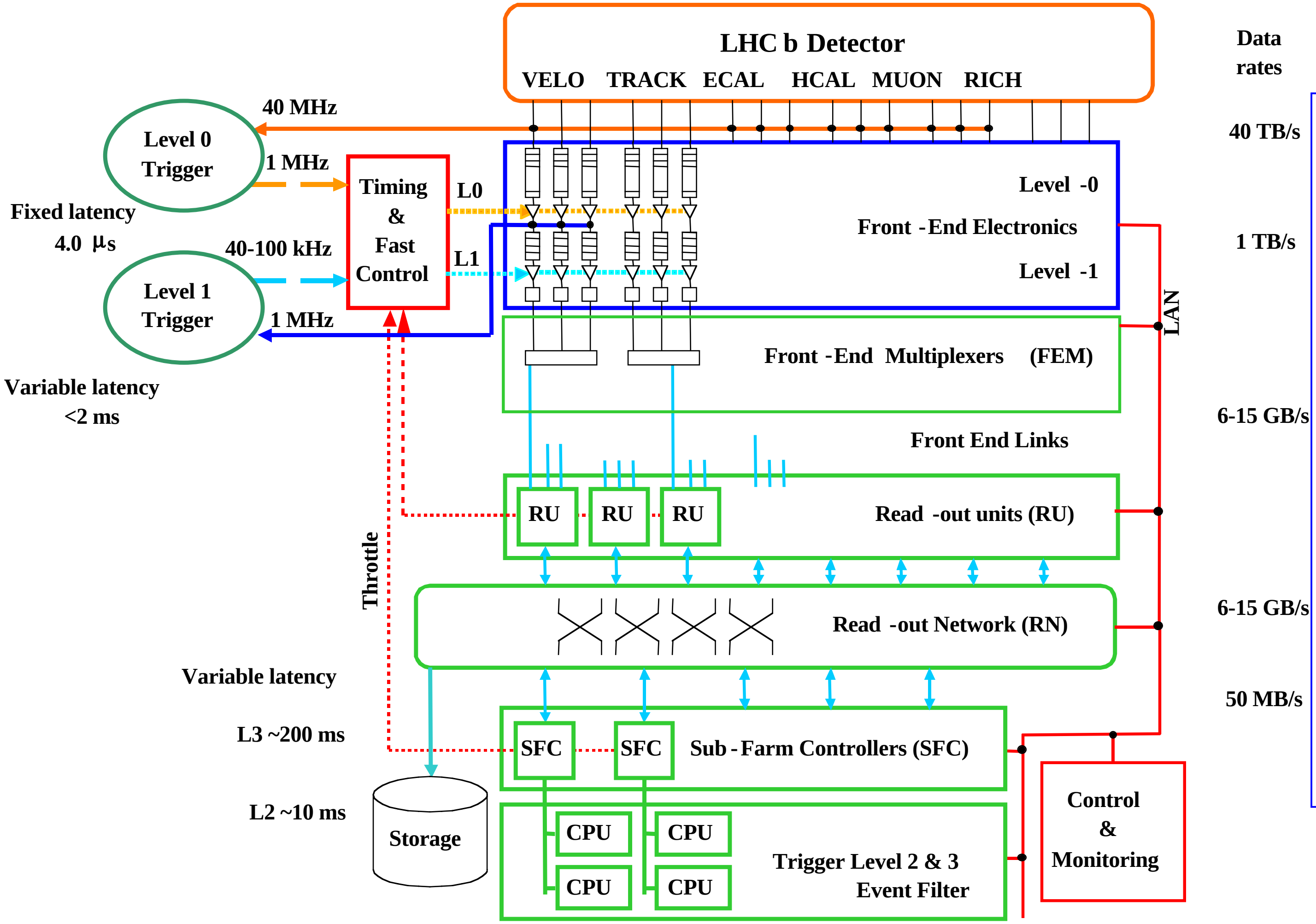
Results of many prototypes will be available.

Higher Level Triggers can be better understood.

Computing

TDR for the online system end of 2001

Complete DAQ architecture:



- -push protocol
- -traffic control with throttle
- -centrally controlled readout
- -point to point connection

Simple and scalable architecture.

Readout system technology choices

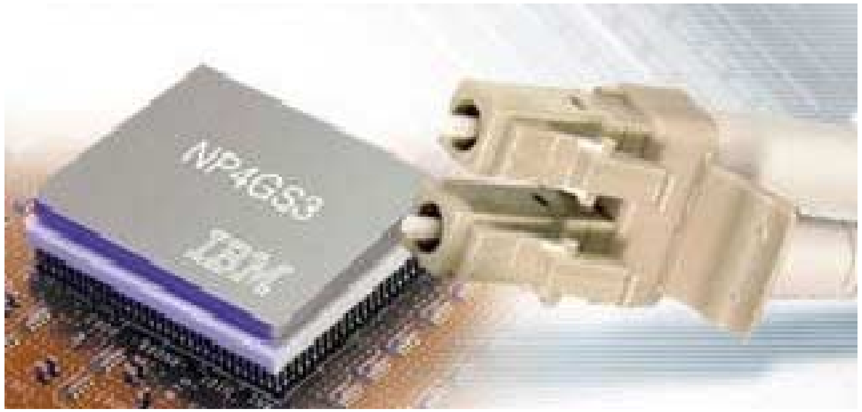
Readout Unit

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

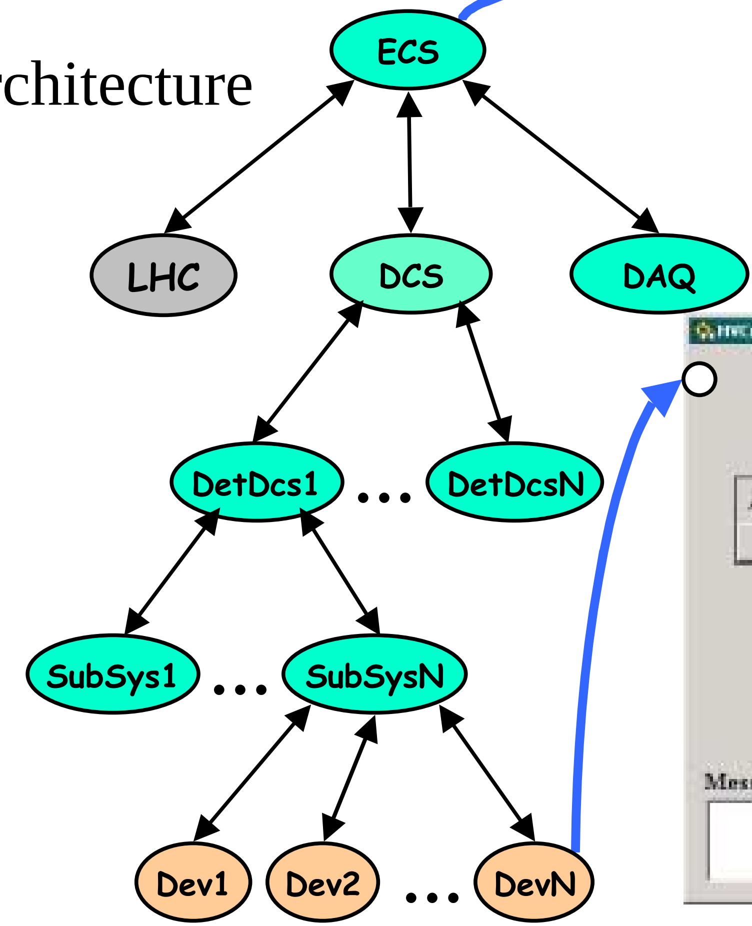
Timing and functionality of the complete DAQ system, including the front-end, has been simulated.

Online cont.

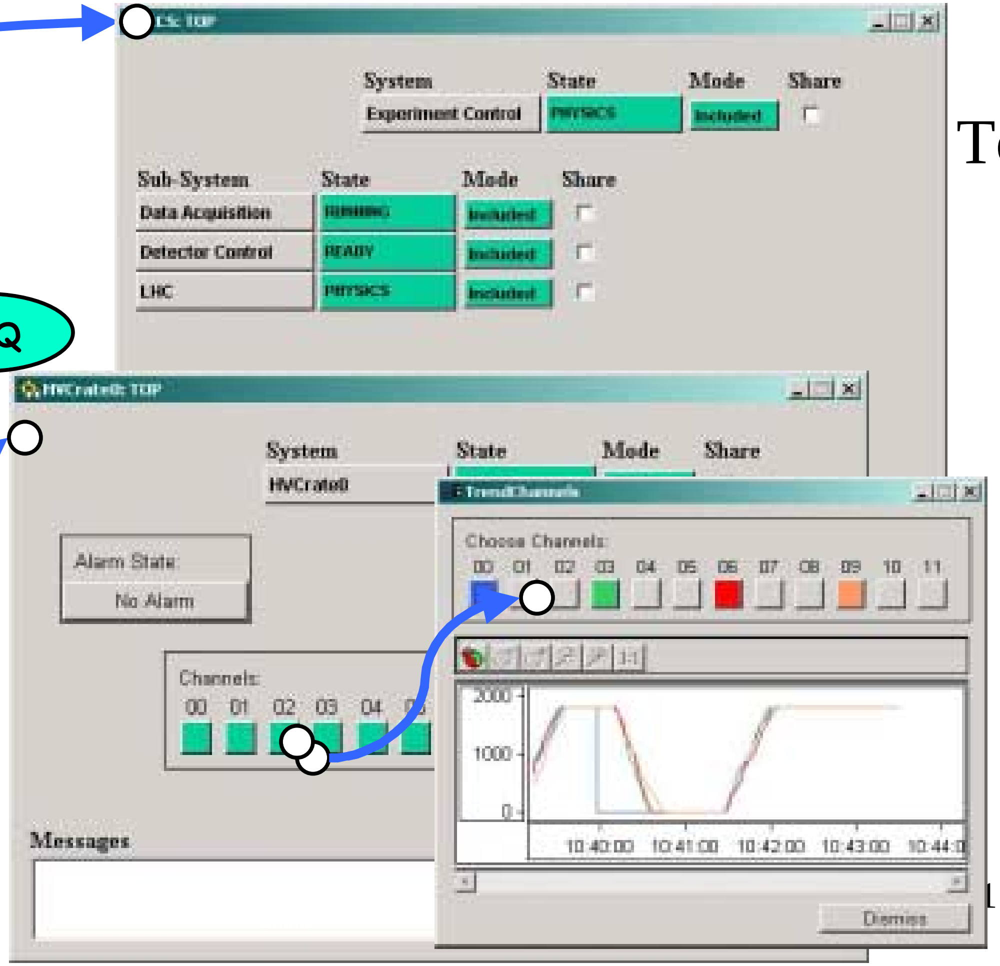
Experiment Control System (ECS)

- Control, configure and monitor the whole experiment
- Based on SCADA (outcome of JCOP)
- Detector interface to SPECS, Can-bus and Credit card PC.

Architecture



Tools



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

Material effects

- Loss of

  π^{0}´s

  $e^{\pm}$ $\longrightarrow$ X_0

  $\pi^{\pm}$ and $K^{\pm}$ $\longrightarrow$ λ_I

- Multiple scattering $\longrightarrow$ X_0
- Generating background $\longrightarrow$ X_0 and λ_I

Most of the detector TDR's have been completed:

$\rightarrow$ good knowledge on the material budget available.

Highest effort is put to reduce the material budget.

First effort already made: beam pipe: Al $\Rightarrow$ Be-Al alloy
(possibly the first 25 mrad cone with Be)

Second effort: detector material

VELO	0.19 X_0, 0.04 λ_I
RICH-1	0.14 X_0, 0.05 λ_I
Tracking 0.03 $X_0 \times 9$ stations	0.27 X_0, 0.11 λ_I

Material up to RICH-2 = 0.6 X_0, 0.2 λ_I

How to decrease it?

Improving the detector designs

RICH-1

TDR glass mirror: 30 kg, 0.046 X_0

3.5 mm of Be + 0.3 mm of glass, 16 kg, 0.01 X_0

2 mm Perspex C, 9 kg, 0.01 X_0

TDR mirror support: 0.03 X_0

With a lighter mirror, the support can be reduced or placed outside of the acceptance, $\rightarrow$ 0.01 X_0

This brings $0.14 \rightarrow 0.08\ X_0$
$0.045 \rightarrow 0.034\ \lambda_I$

VELO

Possibilities are being investigated for
Be RF shield, thinner Si, etc.

We may gain as much as $0.19 \rightarrow 0.11\ X_0$
$0.04 \rightarrow 0.035\ \lambda_I$

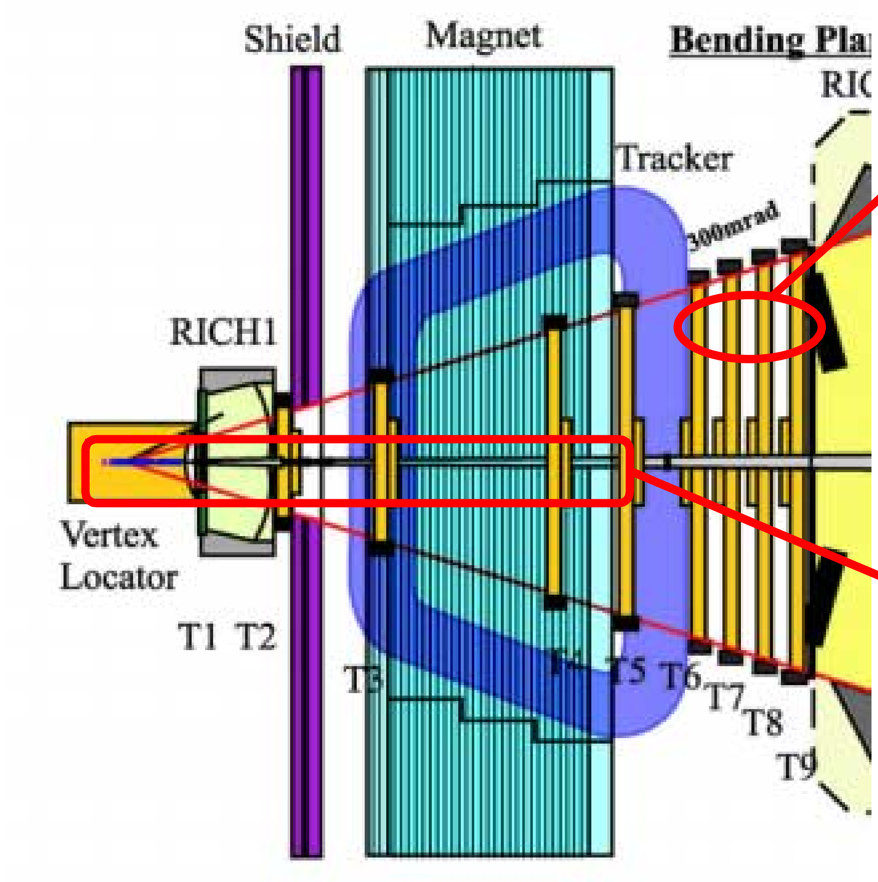
Improving the detector layout

No big gain for the Trackers from the design improvement.

→ changing the tracking strategy.

Track finding with Kalman filter

→continuous tracking stations.(as 4π detectors)

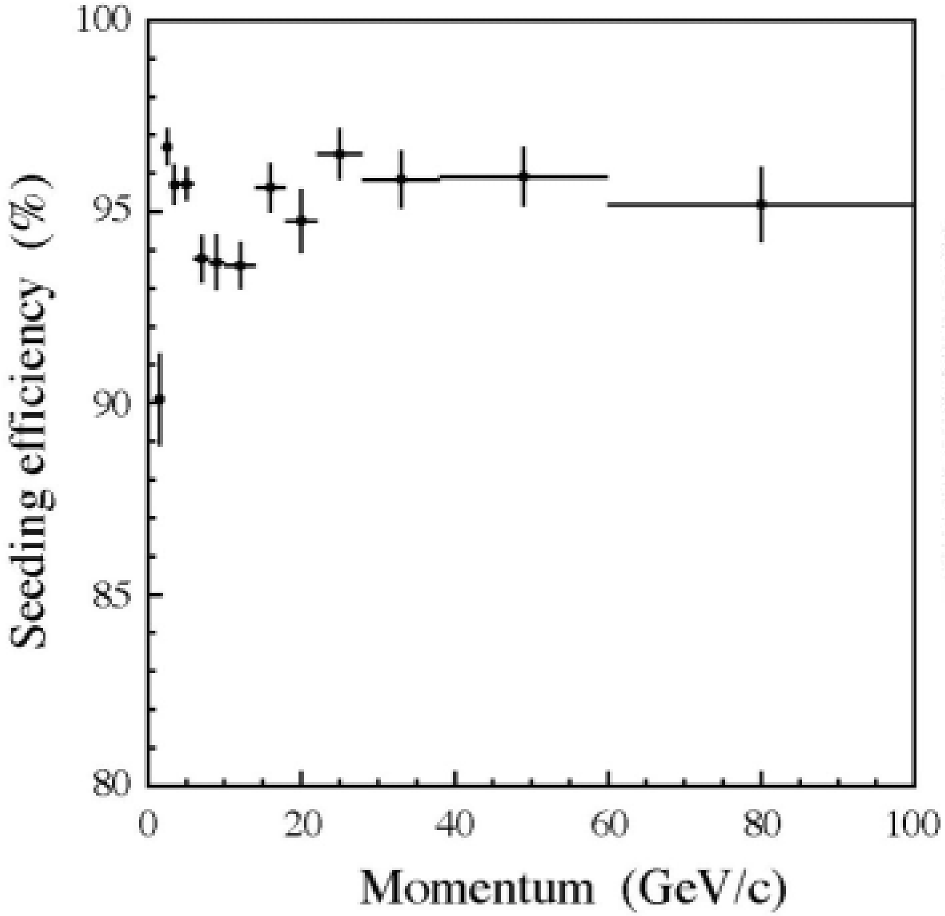


Track seeding

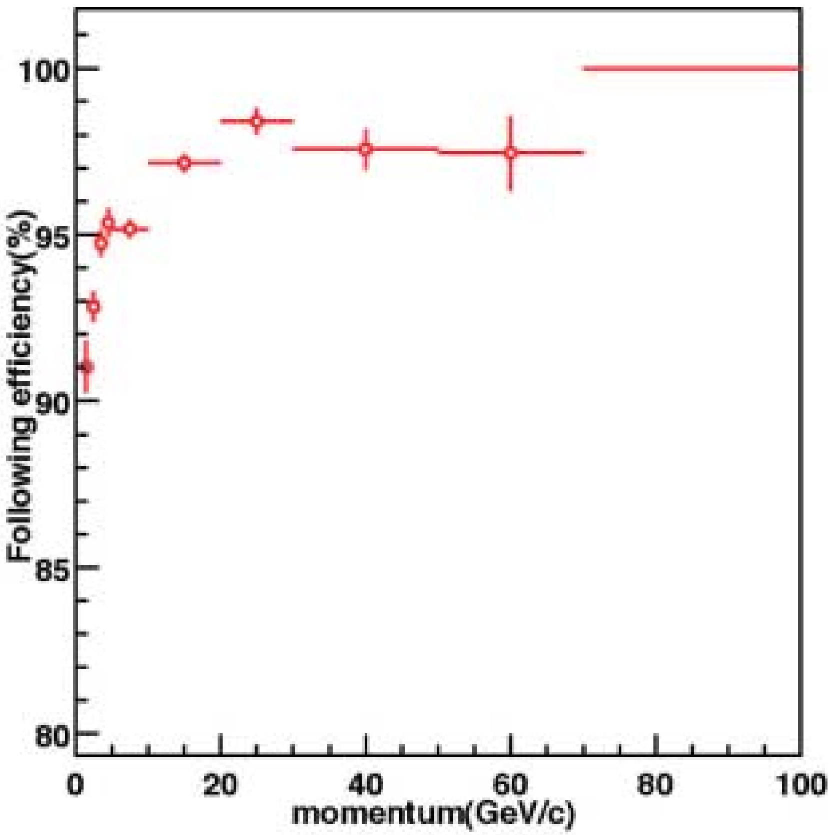
Track following

For physics tracks (hits in VELO and reach RICH-2)

Seeding

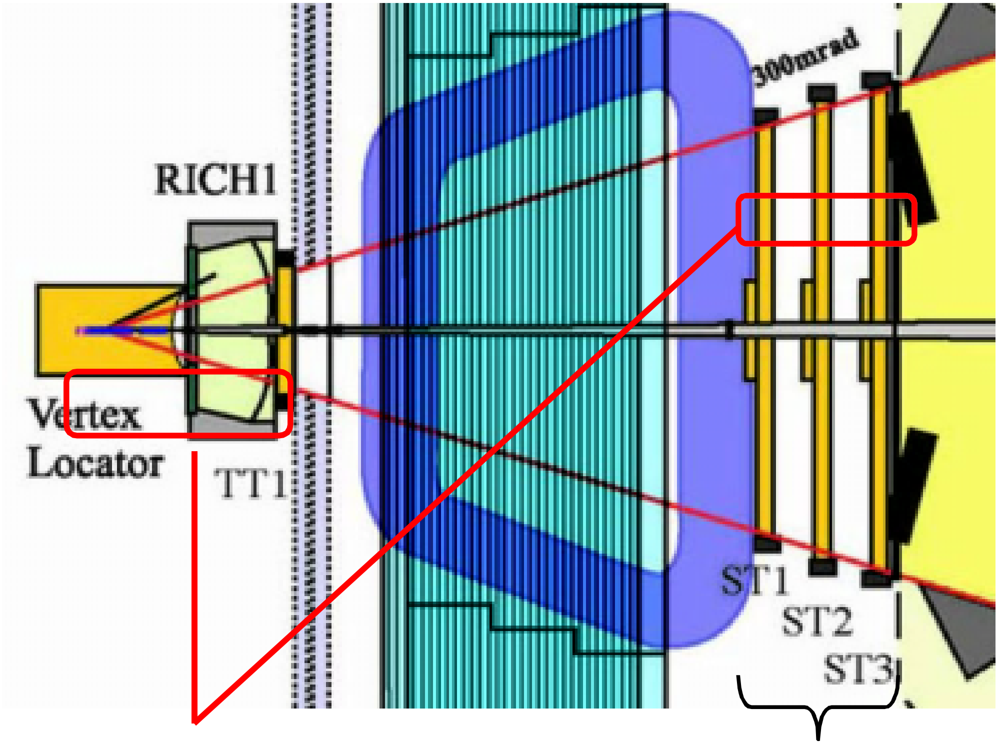


Following



From Outer Tracker TDR

Track finding by matching two track segments (like fixed-target experiments e.g. FOCUS)



Track segment

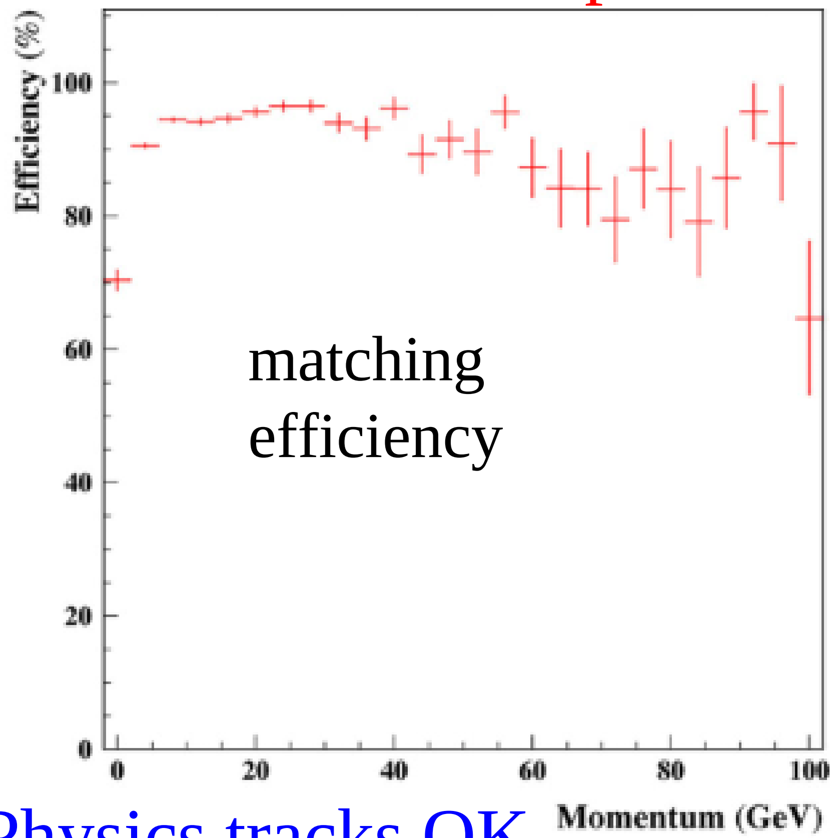
No design change.

Only
4 stations

$0.27 \rightarrow 0.12\ X_0$,

$0.11 \rightarrow 0.049\ \lambda_I$

First attempt



Physics tracks OK.

Being studied:

ghost tracks, K_S,

background tracks for RICH

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.

V) Conclusions

Knowledge accumulated by BABAR, BELLE, CDF and D0 will give LHCb a unique chance to unambiguously identify new physics in CP violation.

LHCb experiment is progressing well to be ready for day one (keep an eye on the HPD development).

Online TDR end of 2001, Computing TDR's end of 2002 as planned.

A promising prospect to improve the physics performance by cost neutral modifications is being studied. Plan to submit an addendum in autumn 2002. Inner Tracker and Trigger TDR's are delayed till the end of 2002 to synchronize, but this does not affect the overall schedule.