Status of the LHCb Experiment

Plenary talk at
Physics at LHC,
Krakow, Poland, 3-8 July 2006

on behalf of the LHCb Collaboration

Tatsuya NAKADA
CERN
and
Ecole Polytechnique Fédérale de Lausanne (EPFL)

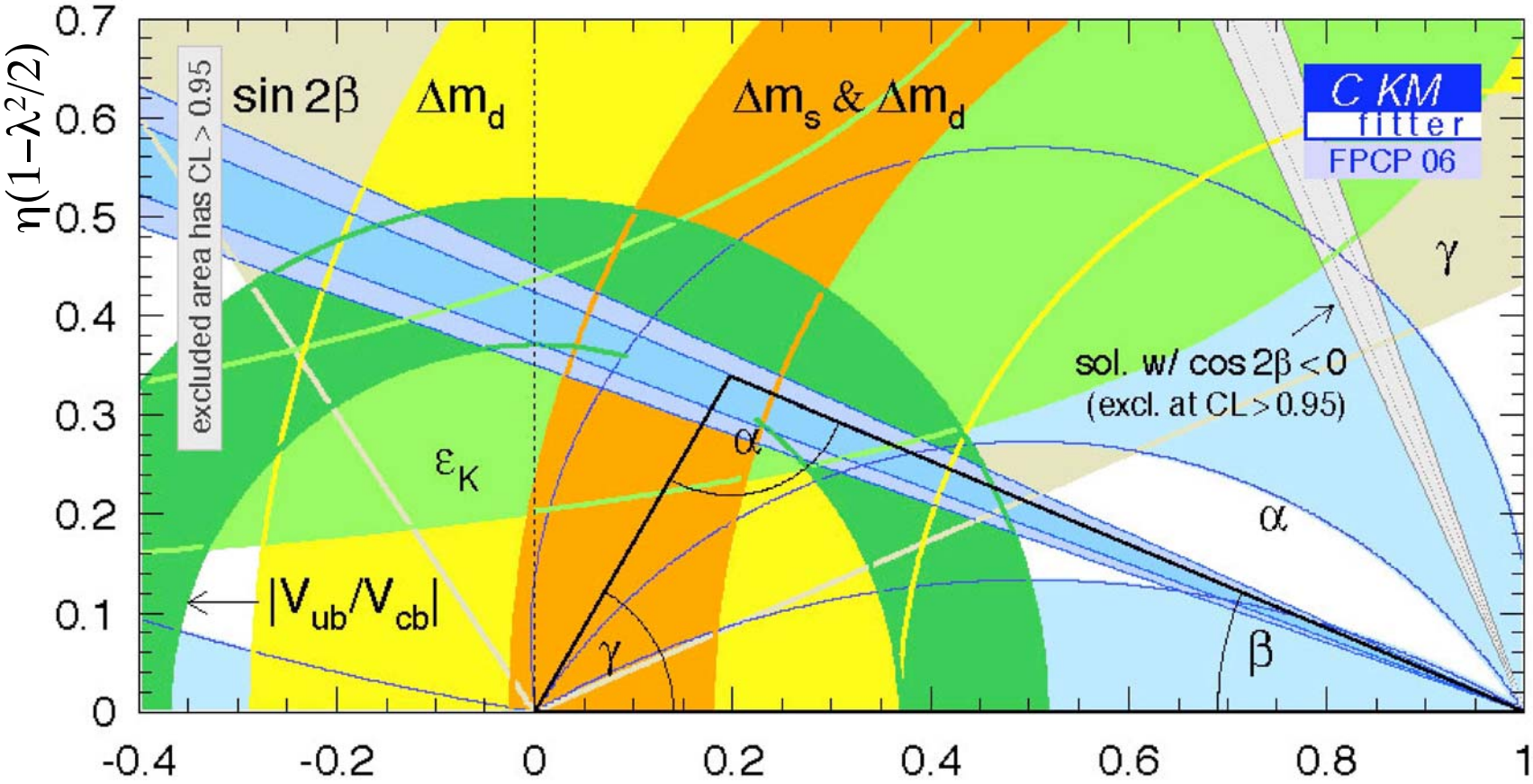
Contents of the talk

- Introduction
- Status of the Experiment
- Conclusions

NB: LHCb trigger and physics performance are covered by
- Trigger, in particular HLT by Jose Angel Hernando Morata
- Rare Decays, b→s processes by Ivan Belyaev
- CP study with B→ρπ and →ρρ by Olivier Deschamps
- γ measurements by Jonas Rademacker
- Measurements of B_s-$\overline{B}_s$ oscillation phase by Luis Fernandez

1) Introduction

Impressive progress made by the B-factory experiments and CDF+D0: compactly summarised in ρ-η plot

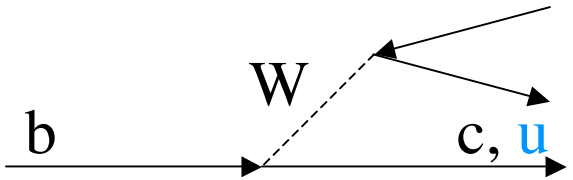


Quark flavour changing processes are successfully described by the Standard Model CKM prescription

Tree

$\Gamma(b\to c)$

$\Gamma(b\to u)$



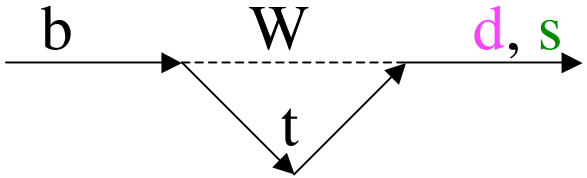
$|V_{cb}|$

$|V_{ub}|$

Penguin

$\Gamma(b\to s)$

$\Gamma(b\to d)$



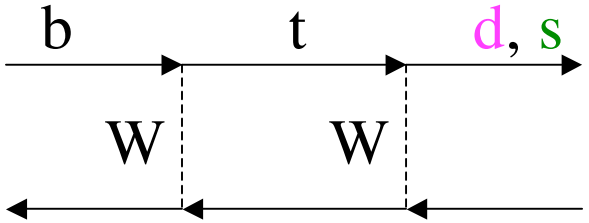
$|V_{td}|$

$|V_{ts}|$

Box

$\omega(B_d\text{-}\bar{B}_d)$

$\omega(B_s\text{-}\bar{B}_s)$



$|V_{td}|$

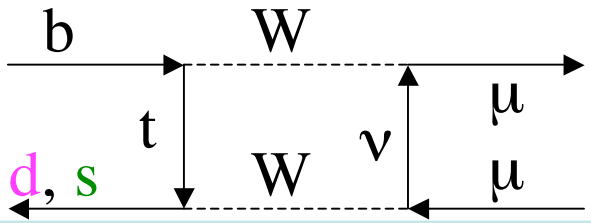
$|V_{ts}|$

~~CP~~(Box⊗Tree) $2\arg V_{td}(V_{ts}) + \arg V_{cb}(V_{ub})$

~~CP~~(Box⊗Peng) $2\arg V_{td}(V_{ts}) + \arg V_{td}$

$2\arg V_{td}(V_{ts}) + \arg V_{ts}$

$\Gamma(B\to\mu\mu)$



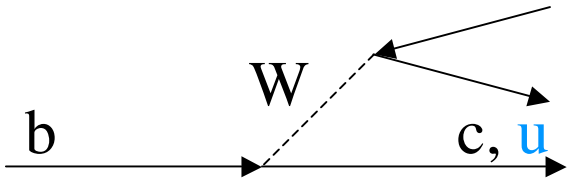
$|V_{td}|$

$|V_{ts}|$

Tree

$\Gamma(b\to c)$

$\Gamma(b\to u)$



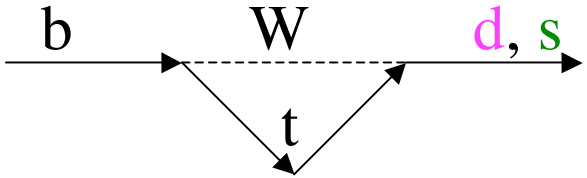
$|V_{cb}|$ ✓

$|V_{ub}|$ ✓

Penguin

$\Gamma(b\to s)$

$\Gamma(b\to d)$



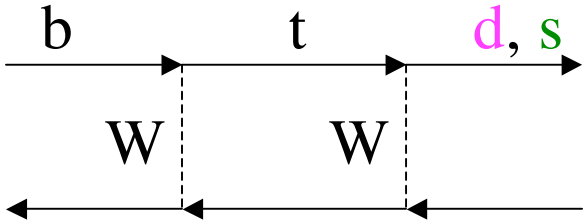
$|V_{td}|$ ✓

$|V_{ts}|$ ✓

Box

$\omega(B_d\text{-}\bar{B}_d)$

$\omega(B_s\text{-}\bar{B}_s)$



$|V_{td}|$ ✓

$|V_{ts}|$ ✓

~~CP~~(Box⊗Tree) $2\arg V_{td}(\quad) + \arg V_{cb}(V_{ub})$ ✓

~~CP~~(Box⊗Peng)

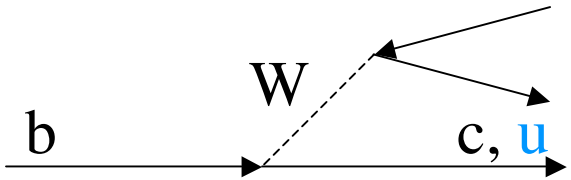
$2\arg V_{td}(\quad) + \arg V_{ts}$ ✓

Still some measurements are missing with B_s's and possible new physics....

Tree

$\Gamma(b\to c)$

$\Gamma(b\to u)$



$|V_{cb}|$

$|V_{ub}|$

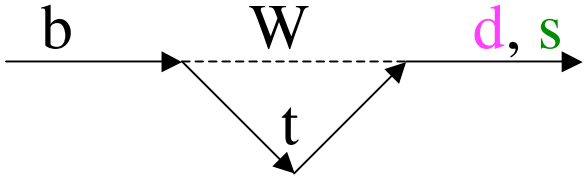
unaffected

New Physics

Penguin

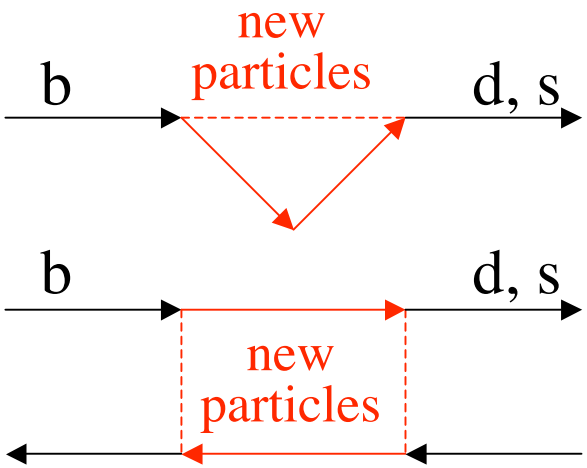
$\Gamma(b\to s)$

$\Gamma(b\to d)$



$|V_{td}| + \Delta_{peng(d)}$

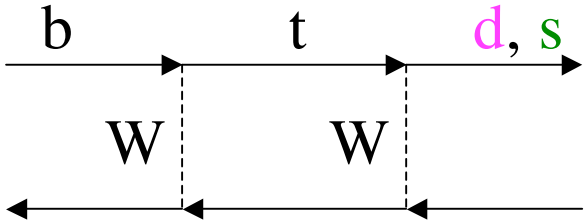
$|V_{ts}| + \Delta_{peng(s)}$



Box

$\omega(B_d\text{-}\bar{B}_d)$

$\omega(B_s\text{-}\bar{B}_s)$



$|V_{td}| + \Delta_{box(d)}$

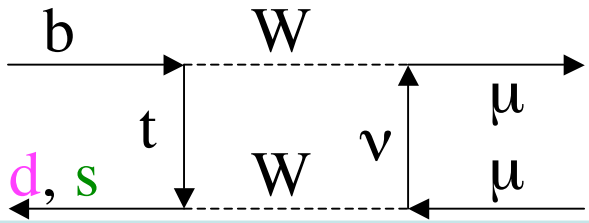
$|V_{ts}| + \Delta_{box(s)}$

~~CP~~(Box⊗Tree) $2\arg V_{td}\,(V_{ts}) + \arg V_{cb}\,(V_{ub}) + \Phi_{box(d)}\,(\Phi_{box(s)})$

~~CP~~(Box⊗Peng) $2\arg V_{td}\,(V_{ts}) + \arg V_{td} + \Phi_{box(d)}\,(\Phi_{box(s)}) + \Phi_{peng(d)}$

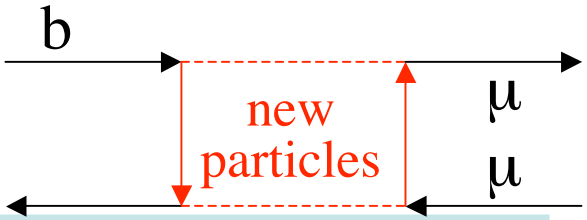
$2\arg V_{td}\,(V_{ts}) + \arg V_{ts} + \Phi_{box(d)}\,(\Phi_{box(s)}) + \Phi_{peng(s)}$

$\Gamma(B\to\mu\mu)$

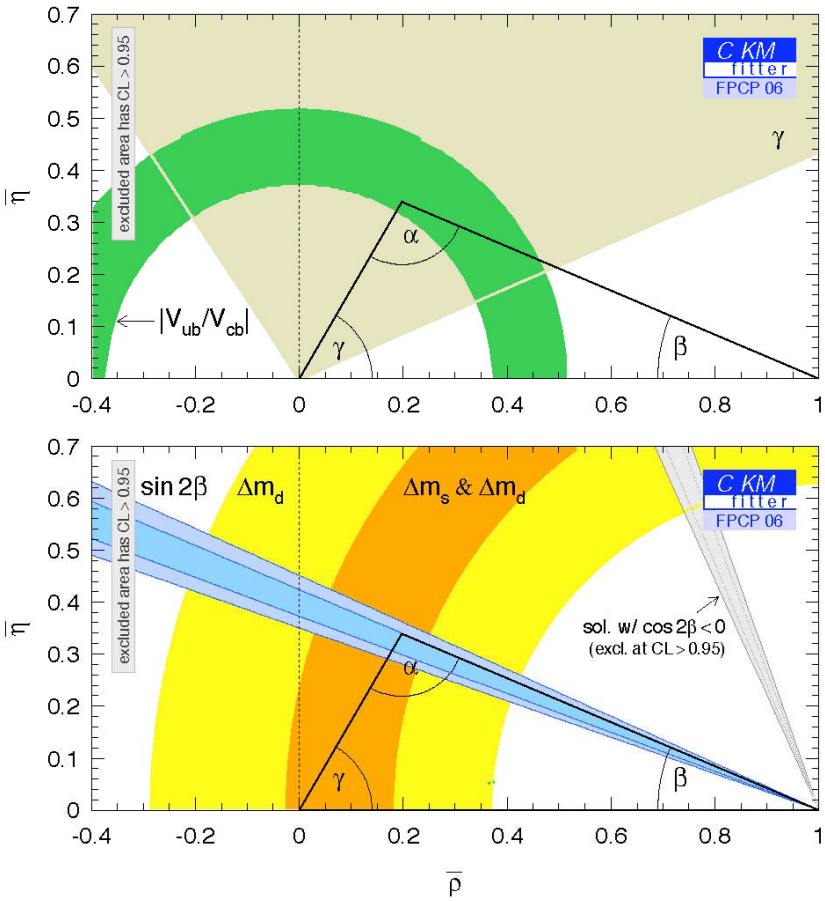


$|V_{td}| + \Delta_{\mu\mu(d)}$

$|V_{ts}| + \Delta_{\mu\mu(s)}$



An example of the next analysis steps...



a)
extracting (ρ, η) from the tree processes
⇒ true CKM (ρ, η)

b)
extracting (ρ, η) from the box processes
⇒ an effective (ρ, η)
with New Physics contaminations

a) + b) will disentangle the new physics contribution, but need

Much better measurements of γ, $\sigma_\gamma < 5°$

Improving hadronic theory, $B_B \times f_B^2$ and $|V_{ub}|$

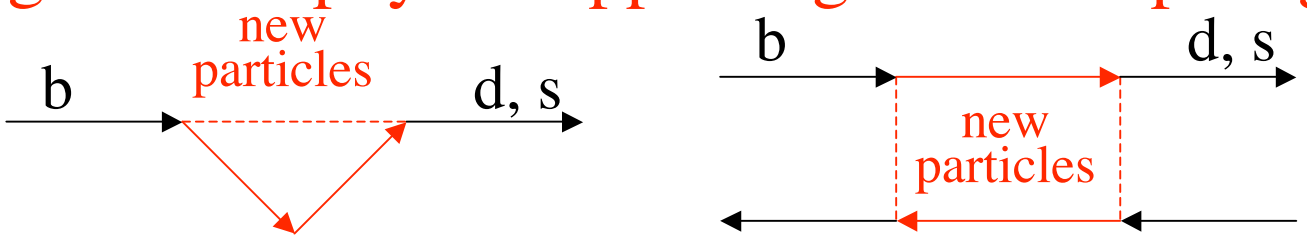
and a further improvement on ~~CP~~ in $b \to c\bar{c}s$

LHCb currently is the only approved experiment with a dedicated b physics programme beyond 2009

Aim to

- measure γ with $\sigma_\gamma < 5^\circ$ using different methods
- high statistics studies of $b \to s\gamma$, $b \to s\ell\ell$
- ~~CP~~ in B_s via $b \to c\bar{c}s$ to the level of the SM prediction (~0.04)
- search for $B_s \to \mu\mu$ to the level of the SM prediction
- improve $\alpha+\beta$ and β measurements
- and others, e.g. B_c, b-baryons, D^0 oscillations, D^0 CP violation, etc.

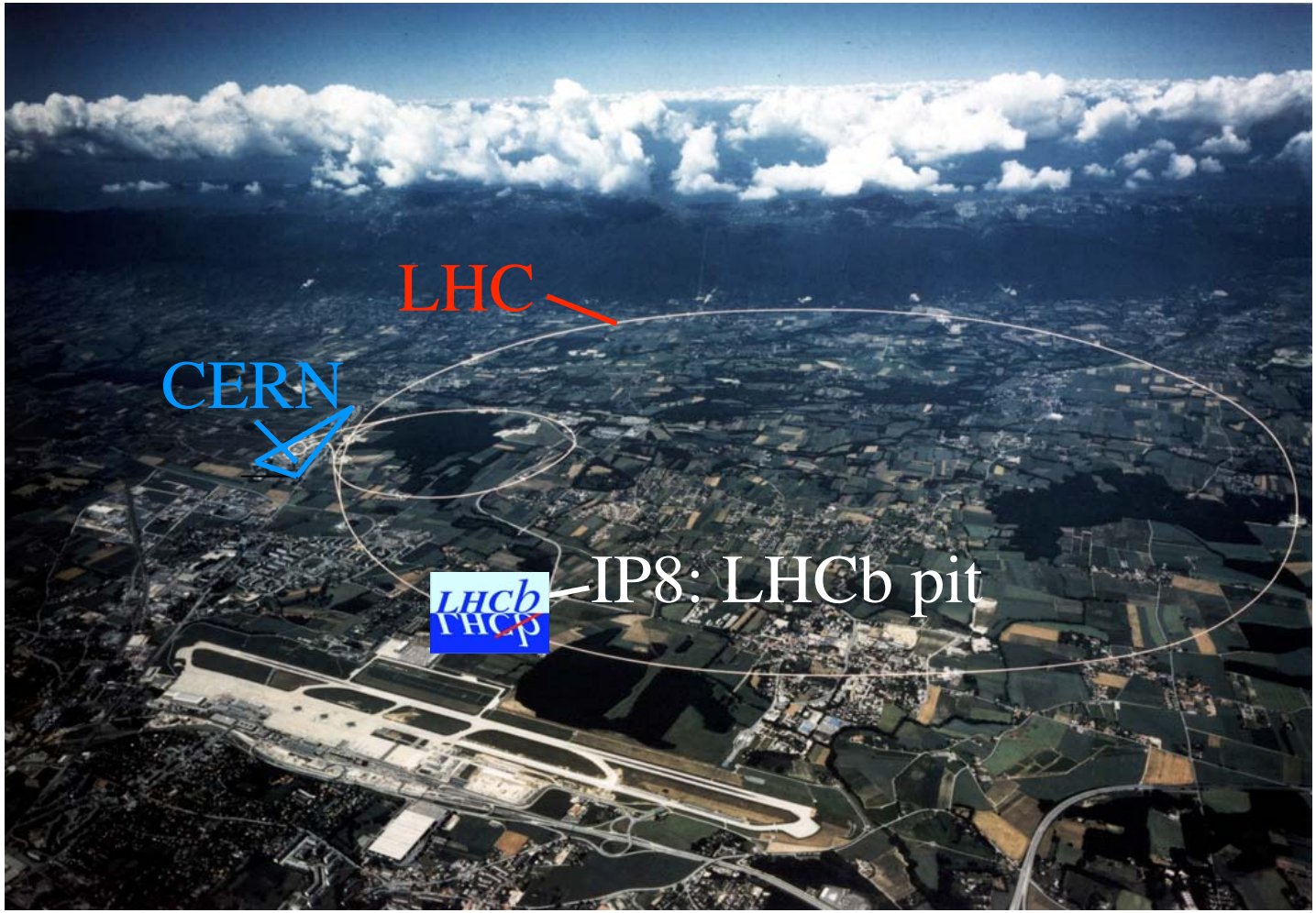
Searching for new physics appearing in the loop diagrams



Complementary approach to ATLAS and CMS
real versus virtual states

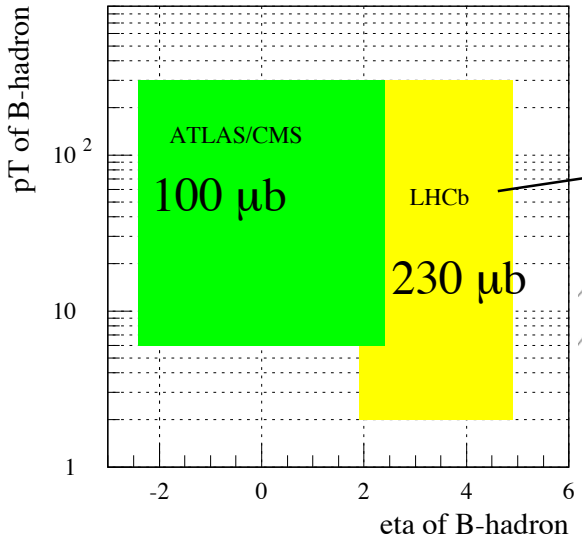
Sensitive to the masses and couplings
important for identifying the class of new physics if found

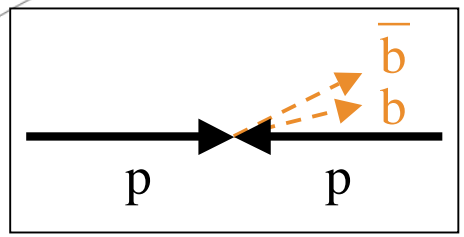
2) Status of the Experiment

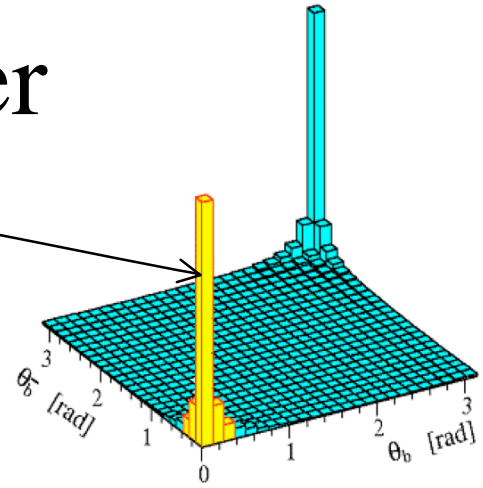


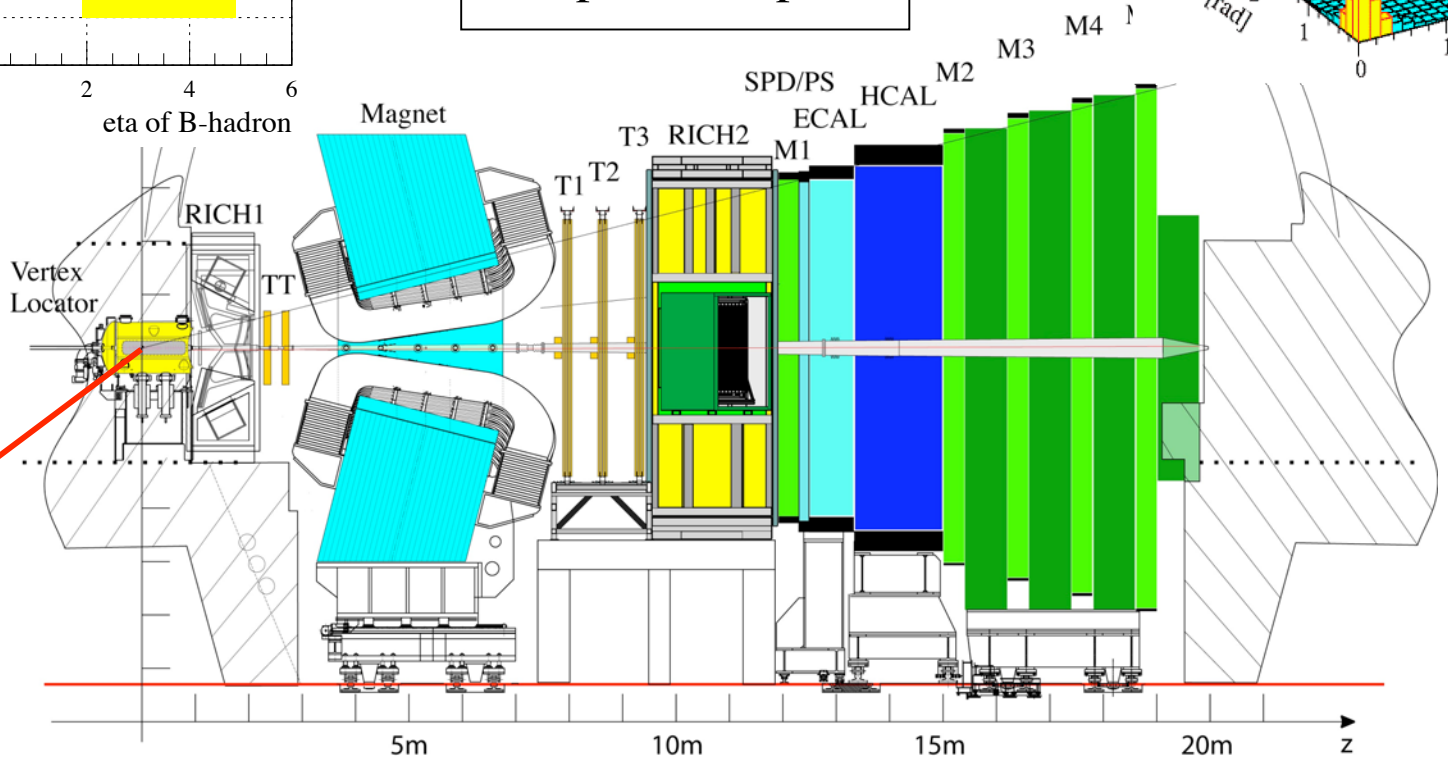
Brazil, China, France, Germany, Italy, Netherlands, Poland,
Romania, Russia, Spain, Switzerland, UK, Ukraine, USA
600 people, 75 MCHF

LHCb Spectrometer



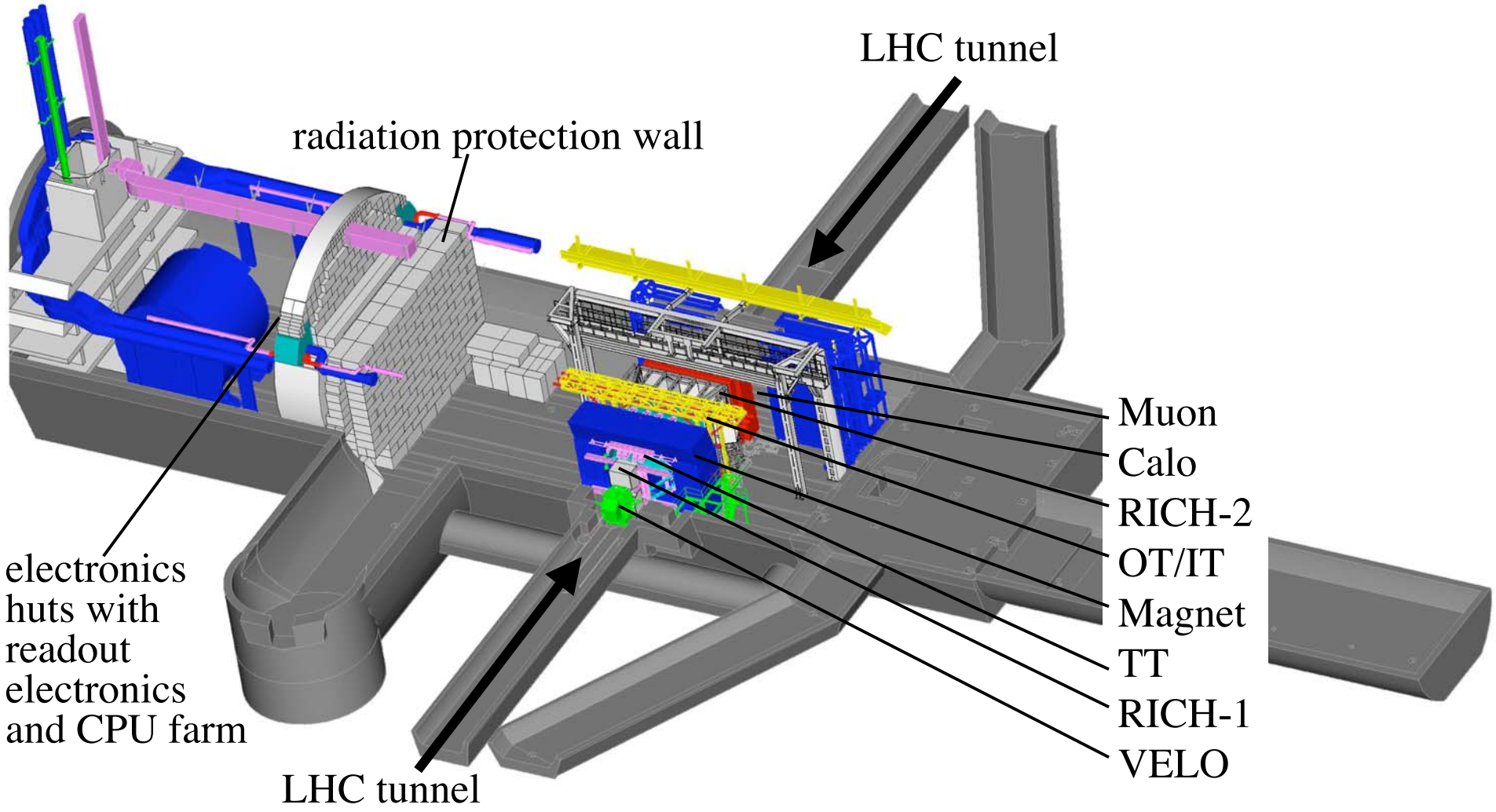






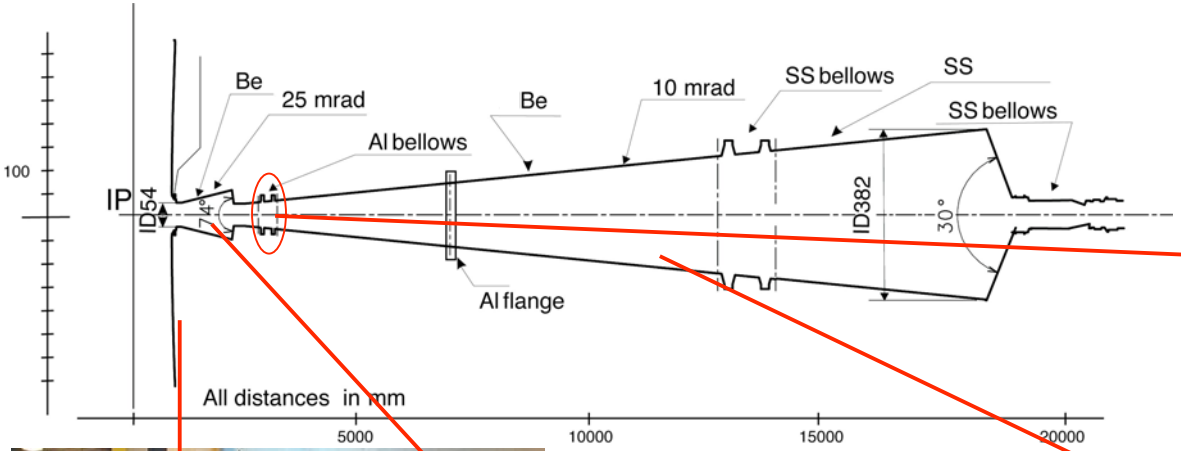
Shifted IP point

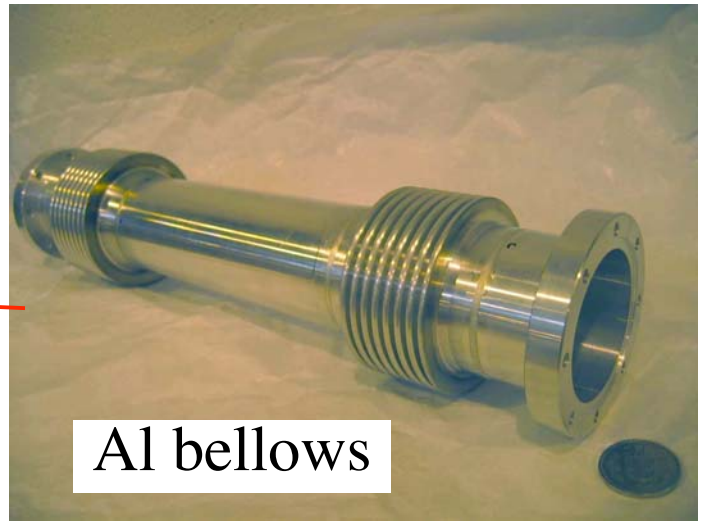
Good mass and eigentime resolution: VELO + tracking system
Hadron identification: RICH system
L0 Lepton and Hadron p_T trigger: Calorimeter and muon system



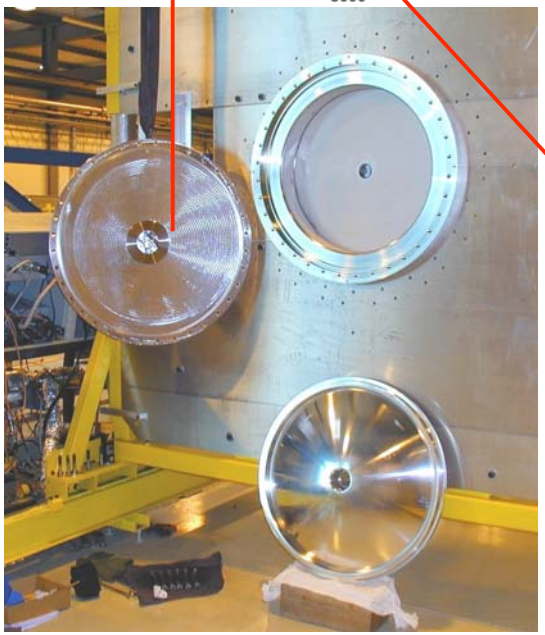
$\langle L \rangle \sim 2\times10^{32}$ ($L_{\text{nominal}} = 10^{34}$), $\sigma_b = 500$ μb ($\sigma_{\text{inelastic}} = 80$ mb),
10^{12} $b\bar{b}/10^{7}$ sec $B_{u,d,s,c}$, Λ_b, Σ_b, and other b-hadrons

Beam pipe





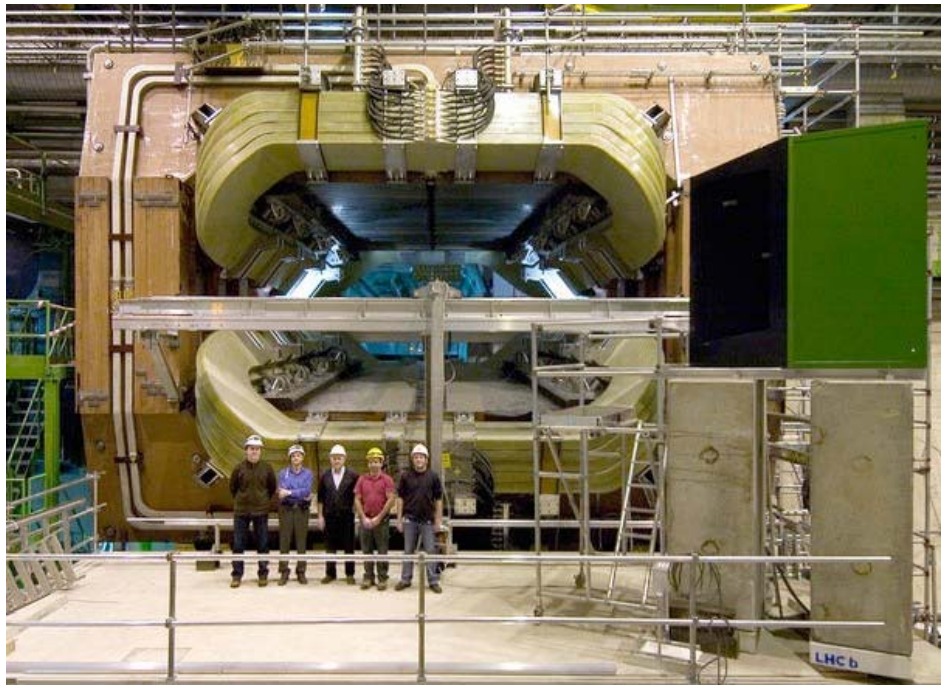
Almost ready

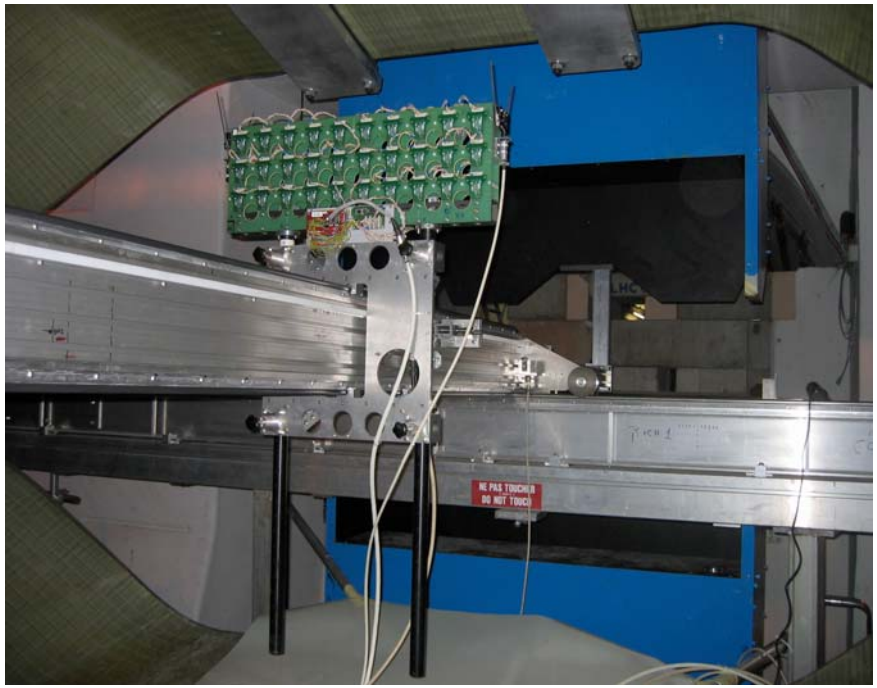


Al exit window of VELO tank

Magnet

BDL = 4 Tm, Power = 4.2 MW, Yoke = 1450 t



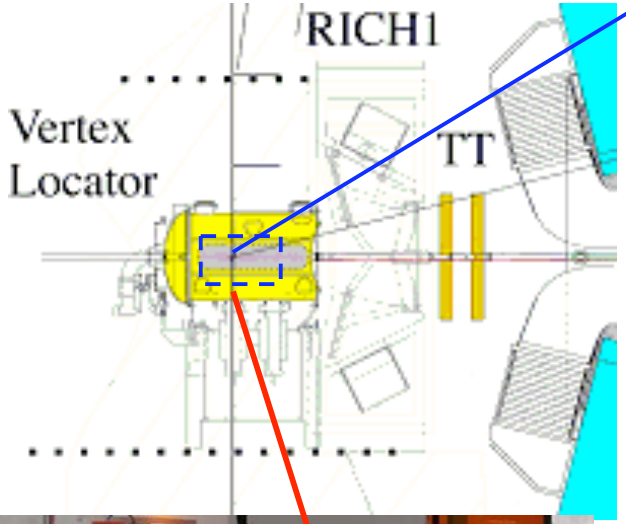


assembled, positioned, aligned, and field map measured

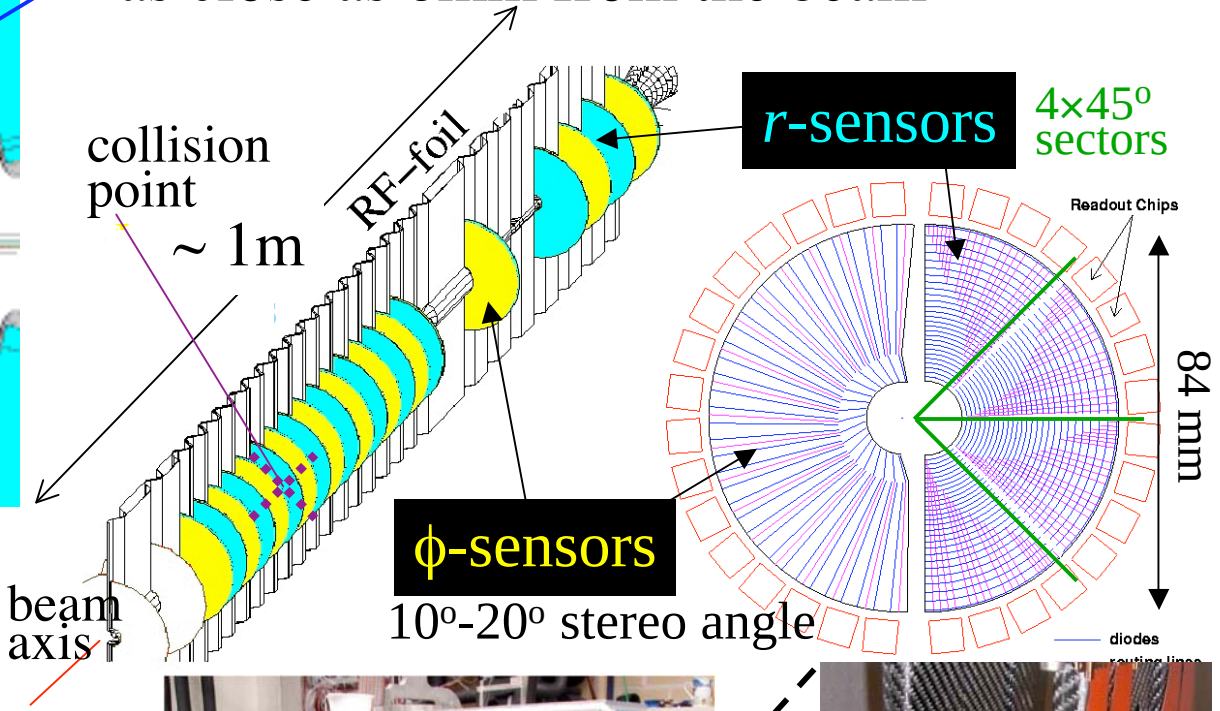
- the field was measured with a precision of 3×10^{-4} →fulfils the requirement
- good symmetry between the two polarities: $\Delta B/\langle B\rangle \sim 3\times10^{-4}$ →small "fake" P violation

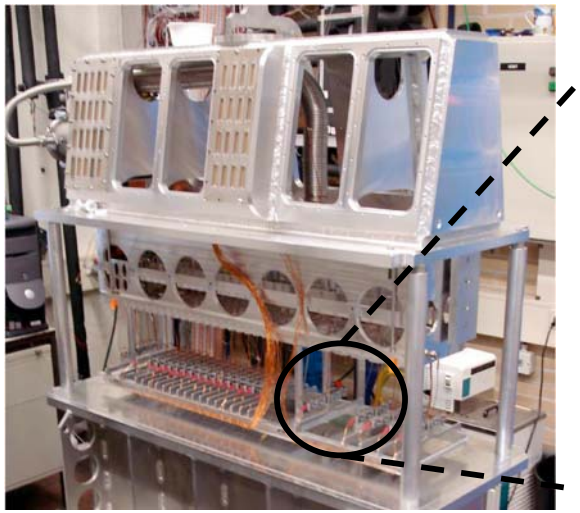
Magnet is now operational

VErtex LOcator

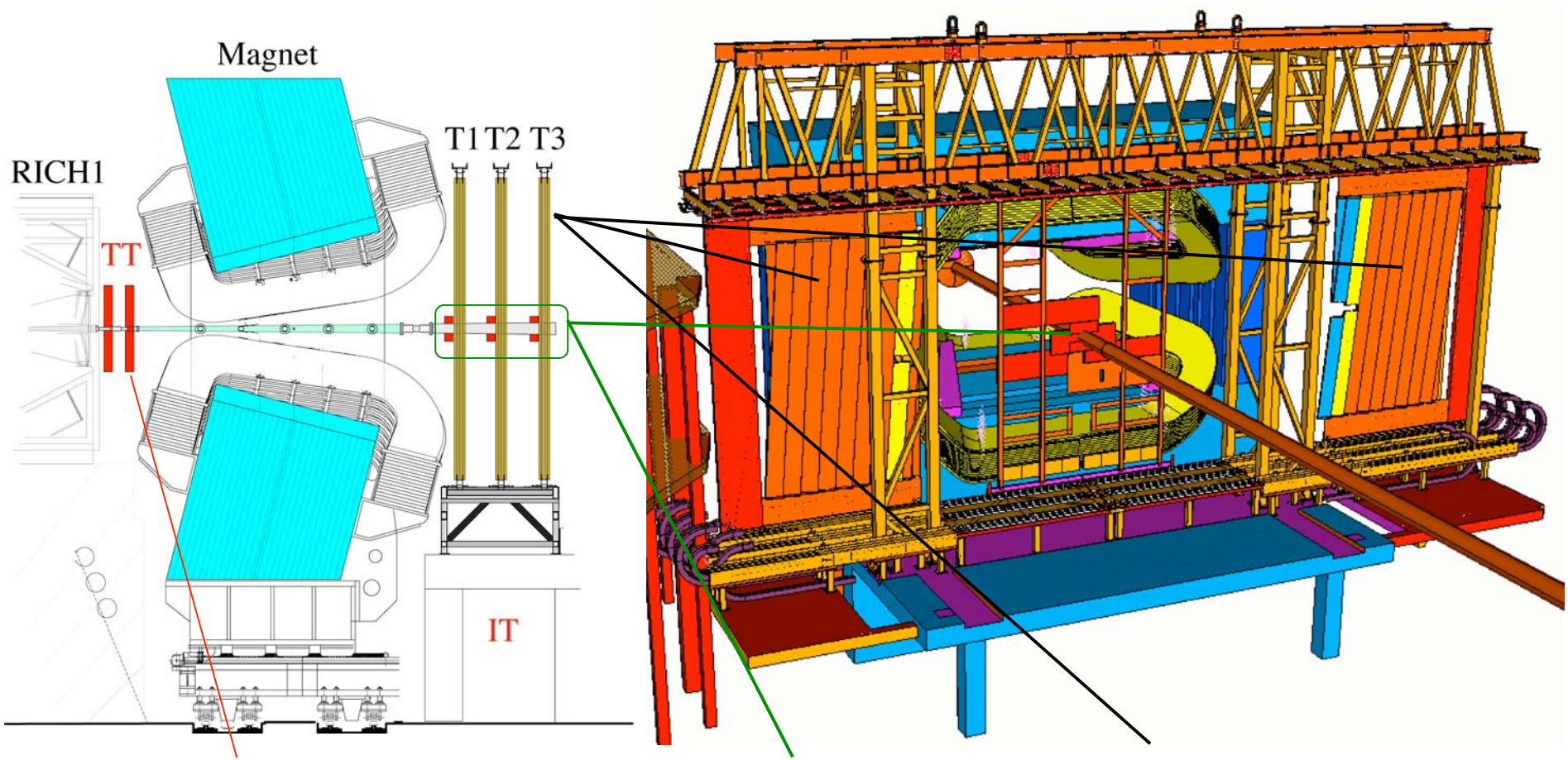


300 μm Si sensor
as close as 8mm from the beam





Outer Tracker and Silicon Tracker



Trigger Tracker Inner Tracker Outer Tracker

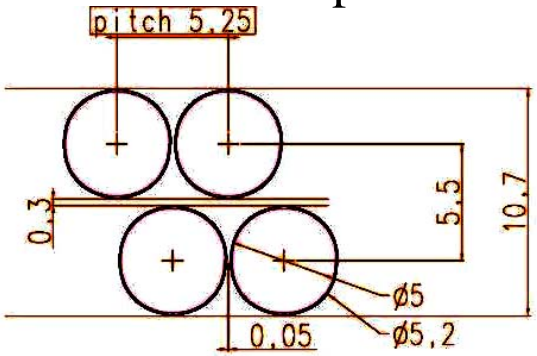
~1.4×1.2 m^2

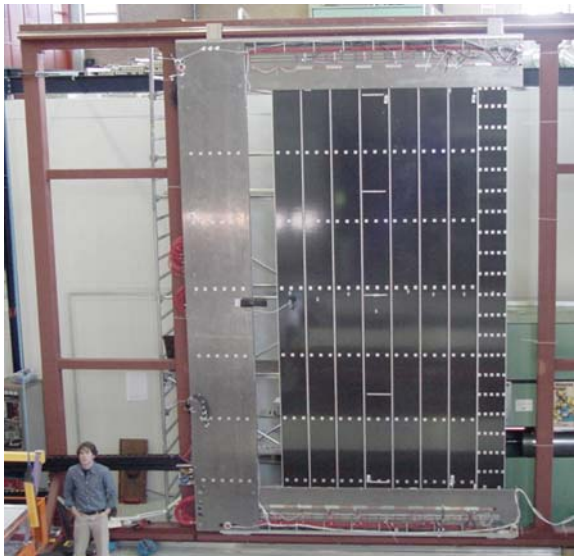
Silicon Tracker

Outer Tracker

Straw drift chambers

40μm Kapton XC-160
+ Laminated Kapton-Al





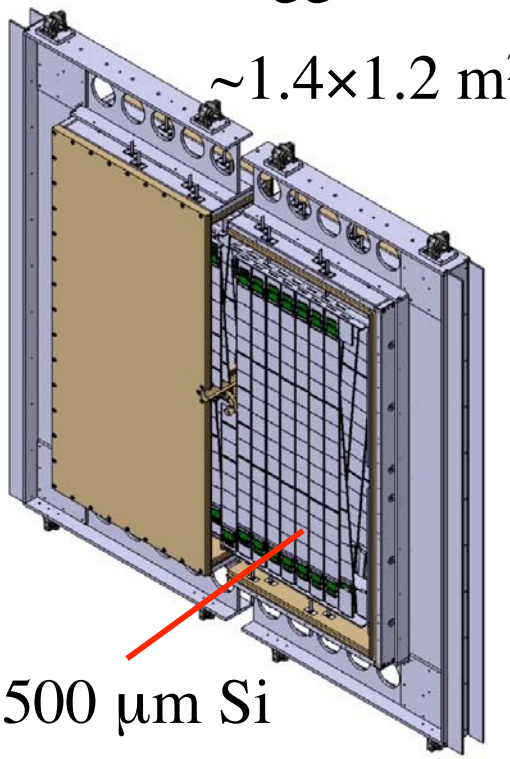
Module Support
-prototype tested
-ready for loading the modules

module production completed

Silicon Tracker

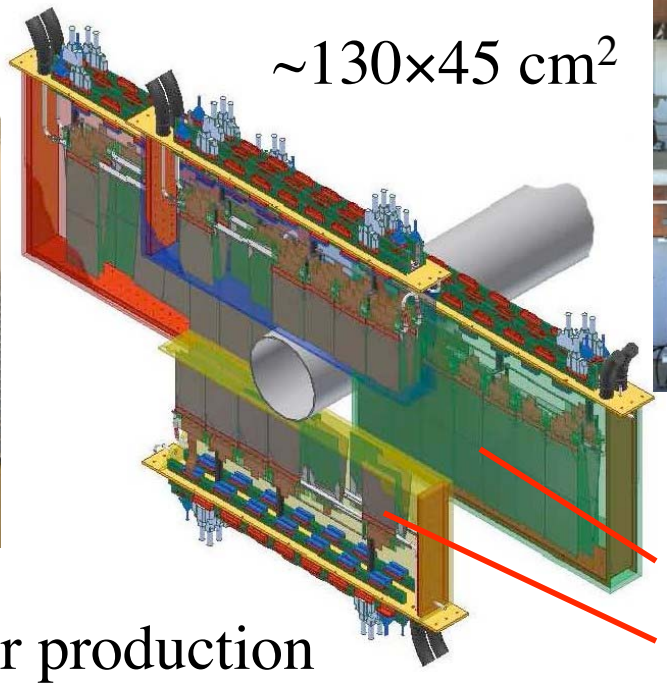
Trigger Tracker

~1.4×1.2 m^2

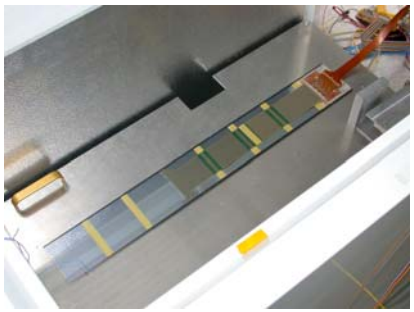


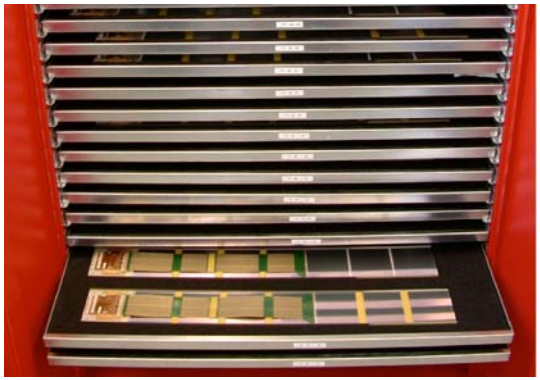
Inner Tracker

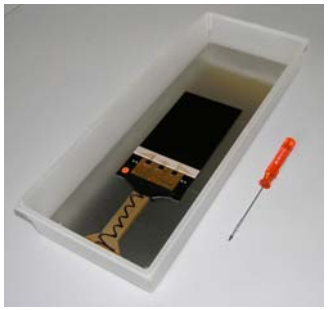
~130×45 cm^2



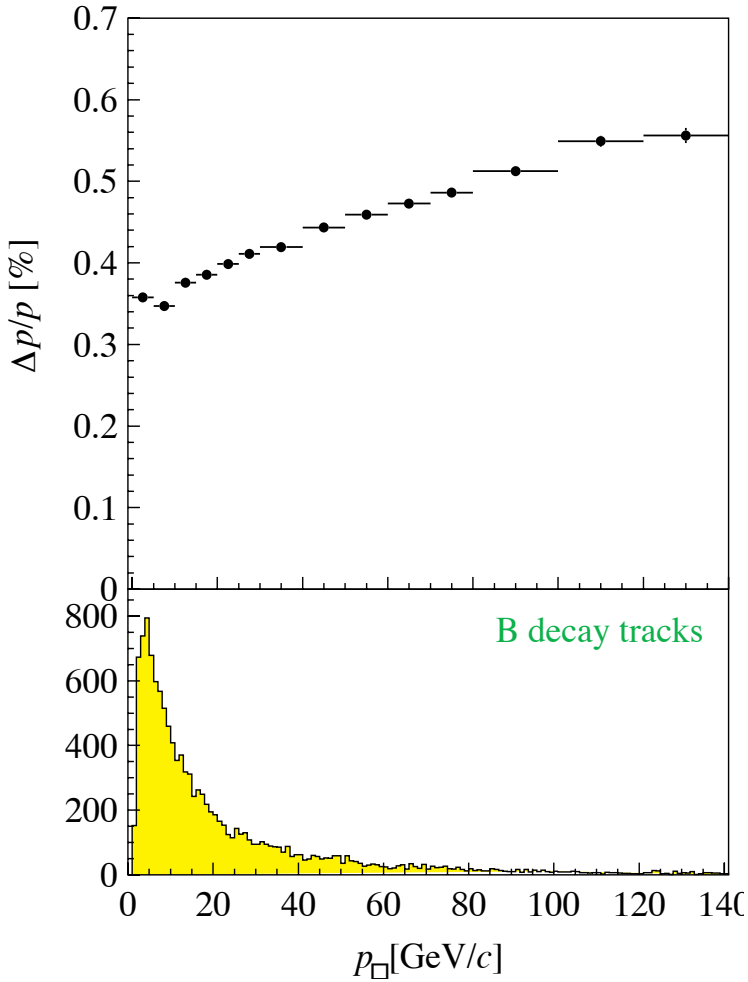
Si ladder production
in progress



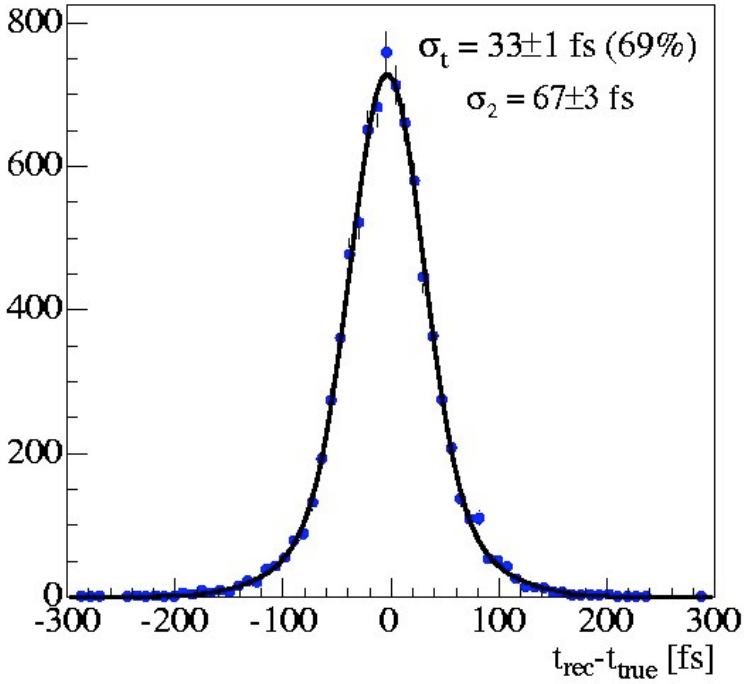




VELO + ST + OT + Magnet



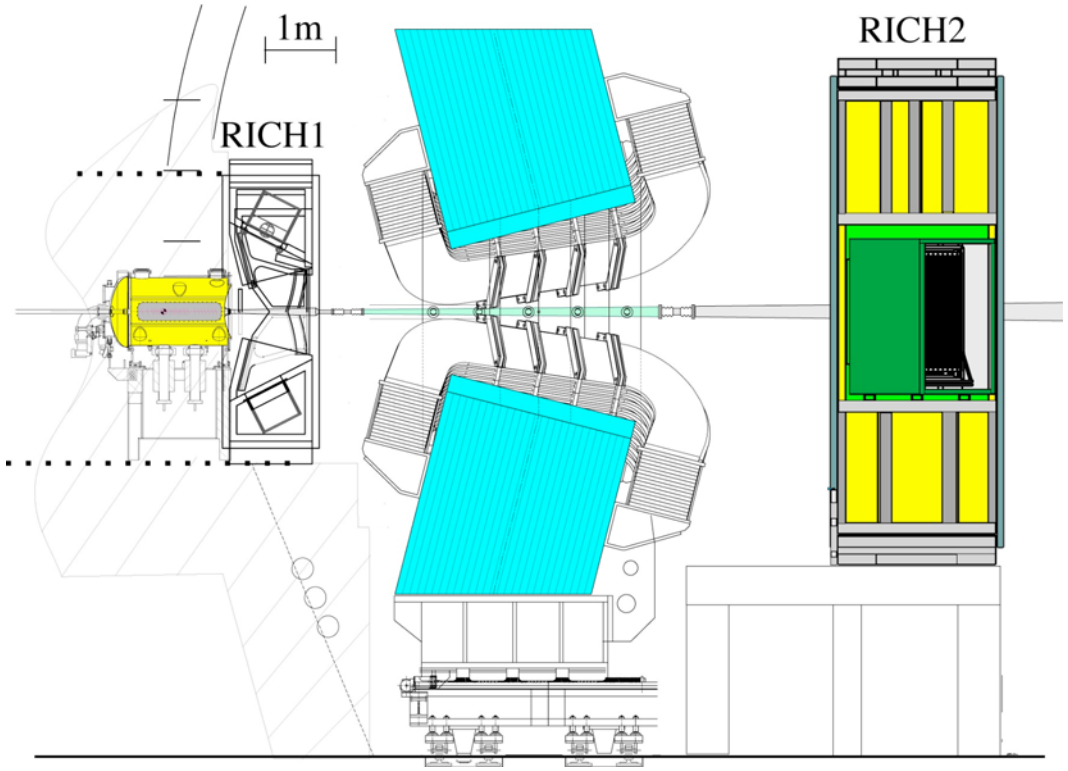
momentum resolution

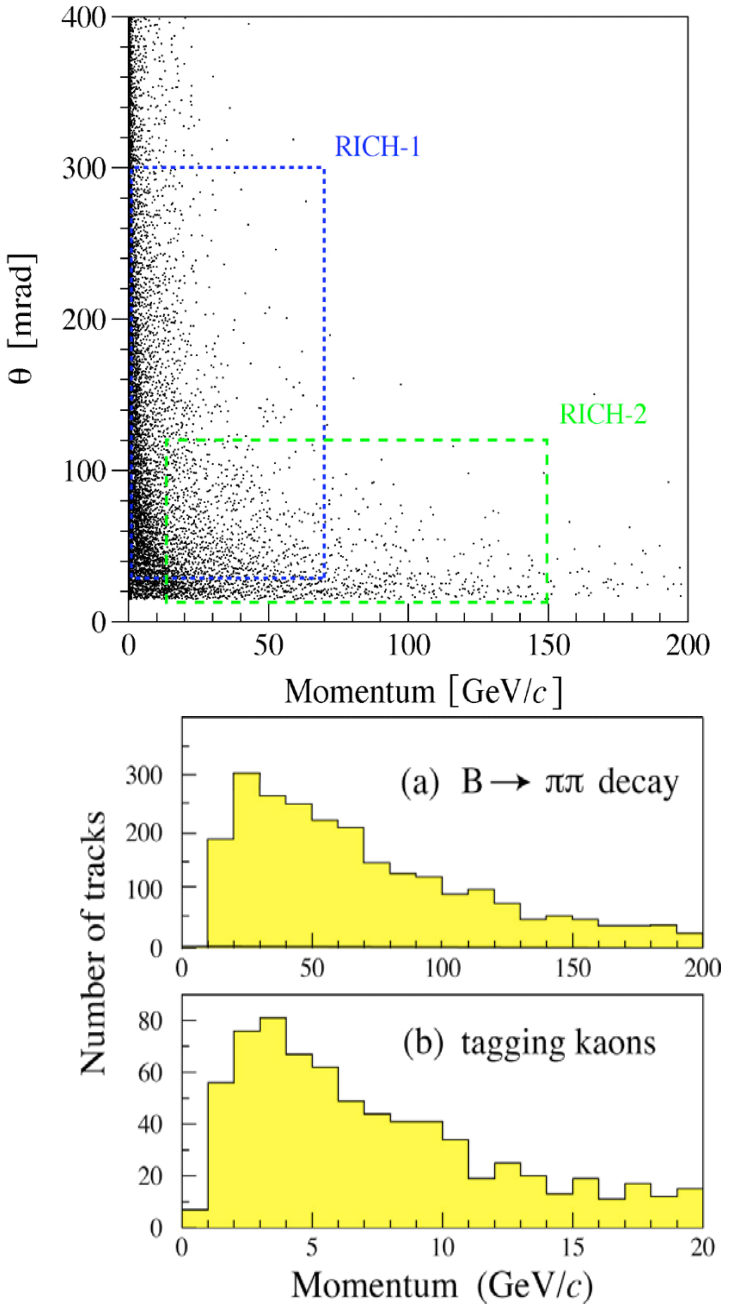


Proper time resolution ~ 40 fs

$B_s \rightarrow D_s^- \pi^+$

RICH





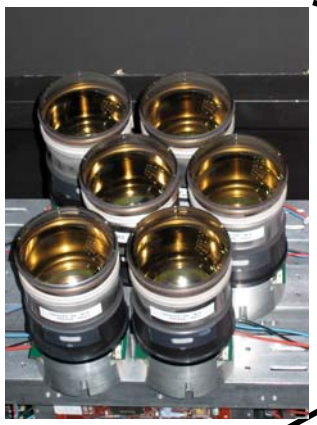
Two RICH with three radiators

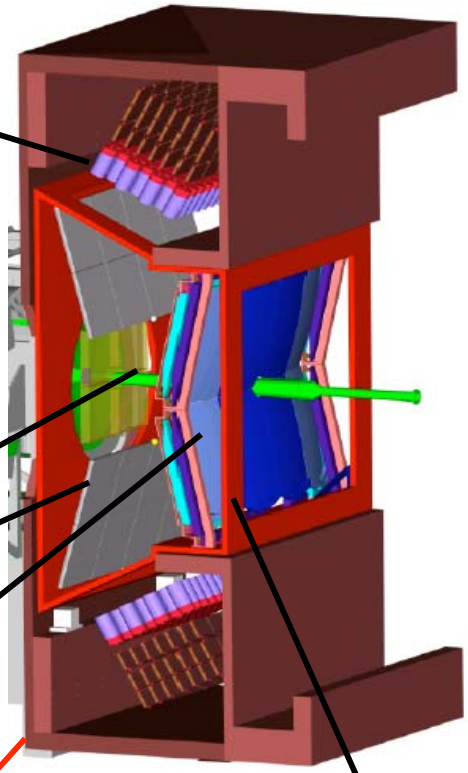
Aerogel, C_4F_{10} } RICH1 (25-300 mrad)

CF_4 RICH2 (15-120 mrad)

HPD
Photodetectors

RICH1





Beam Pipe

Flat Mirror

Spherical Mirror

Magnetic Shield

Gas Enclosure

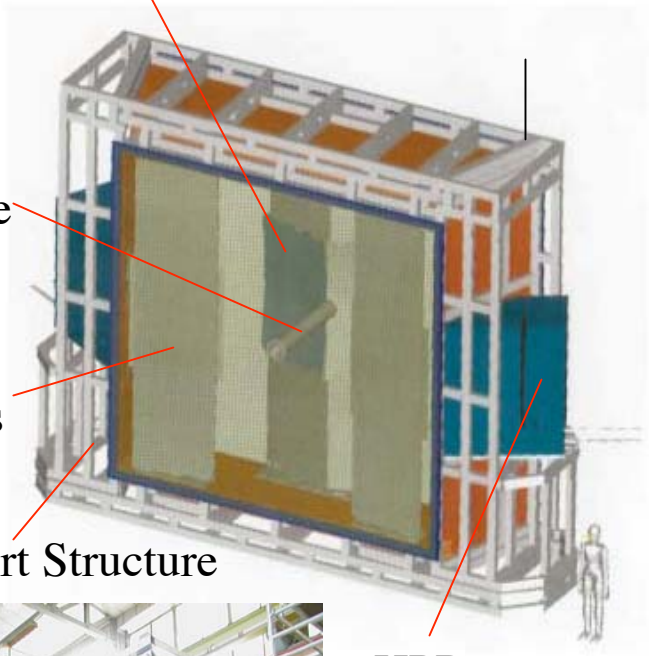
RICH2

Spherical Mirrors

Central Tube

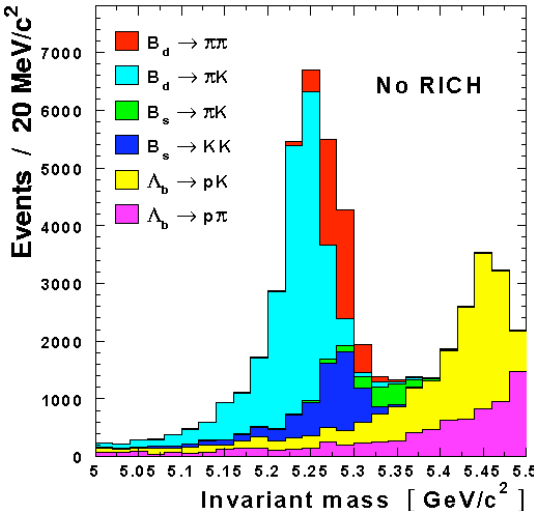
Flat mirrors

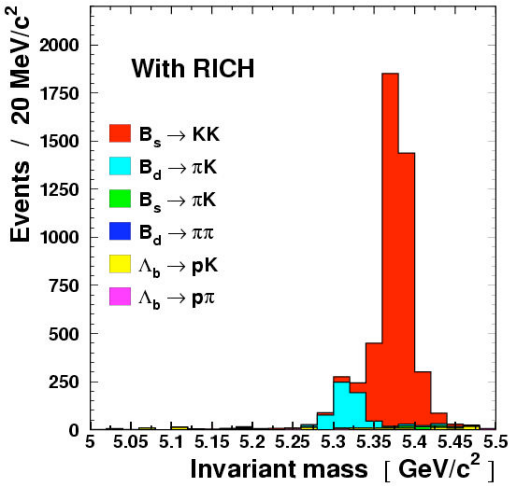
Support Structure

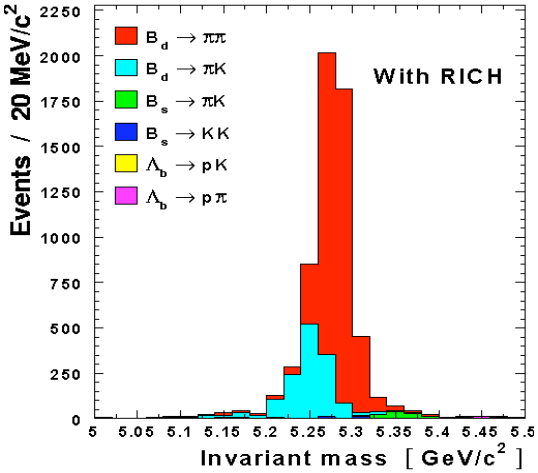


HPD
+ Shielding

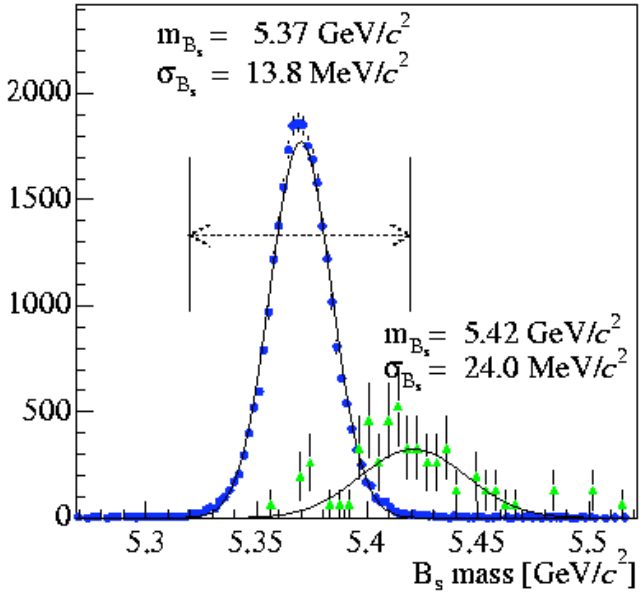
PID for $B \to \pi\pi$ and $B_s \to KK$ reconstruction



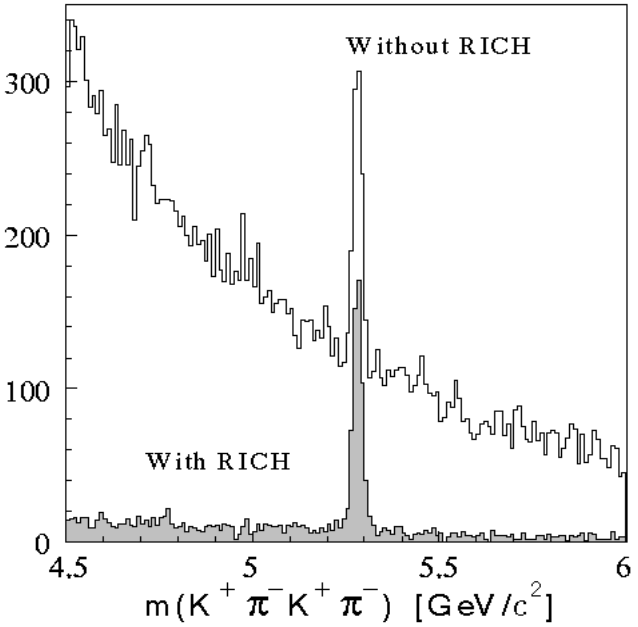




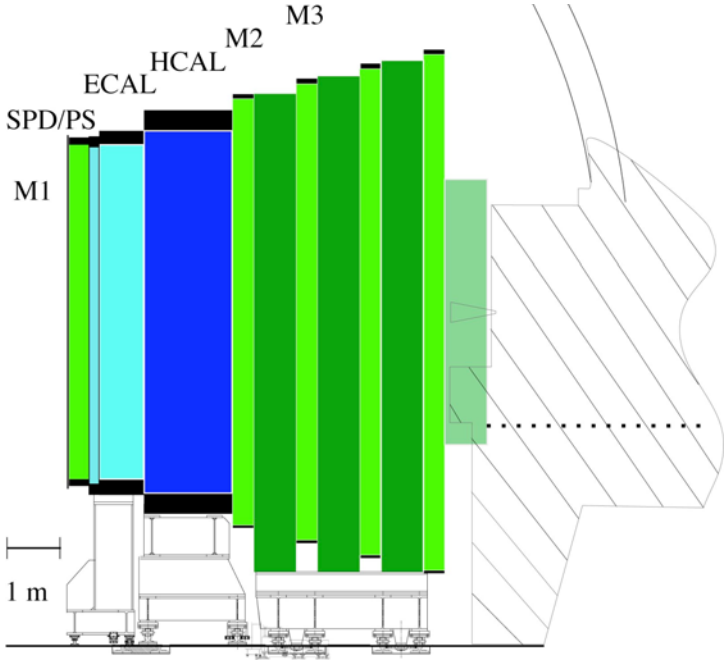
$B_s \to D_s\pi$ suppression with PID for $B_s \to D_sK$



Comb. suppression with PID for $B \to DK^{*0}$

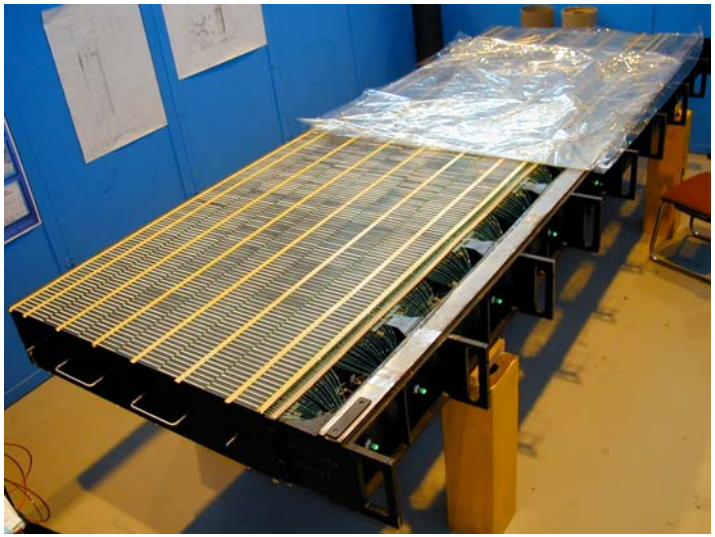


Calorimeter System



Ecal
Shashlik

Hcal
Fe-Scintillator tile



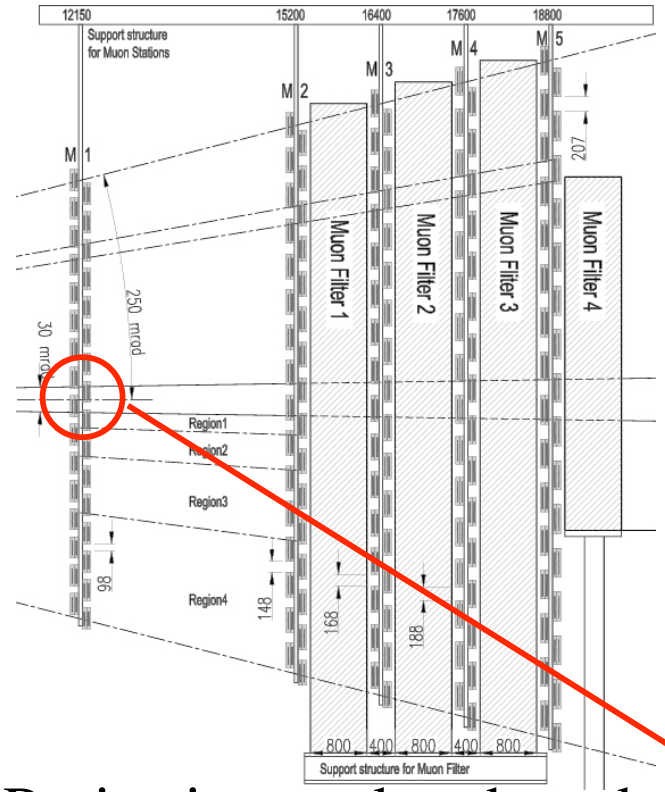
SPD/PS
Scintillator-Pb-Scintillator

Production completed

Ecal and Hcal installed and being commissioned

SPD and PS being installed

Muon System



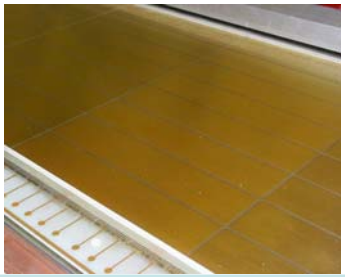
>80% of MWPC produced

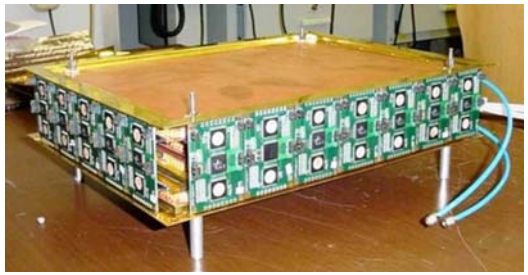
Fe shield

Electronics tower

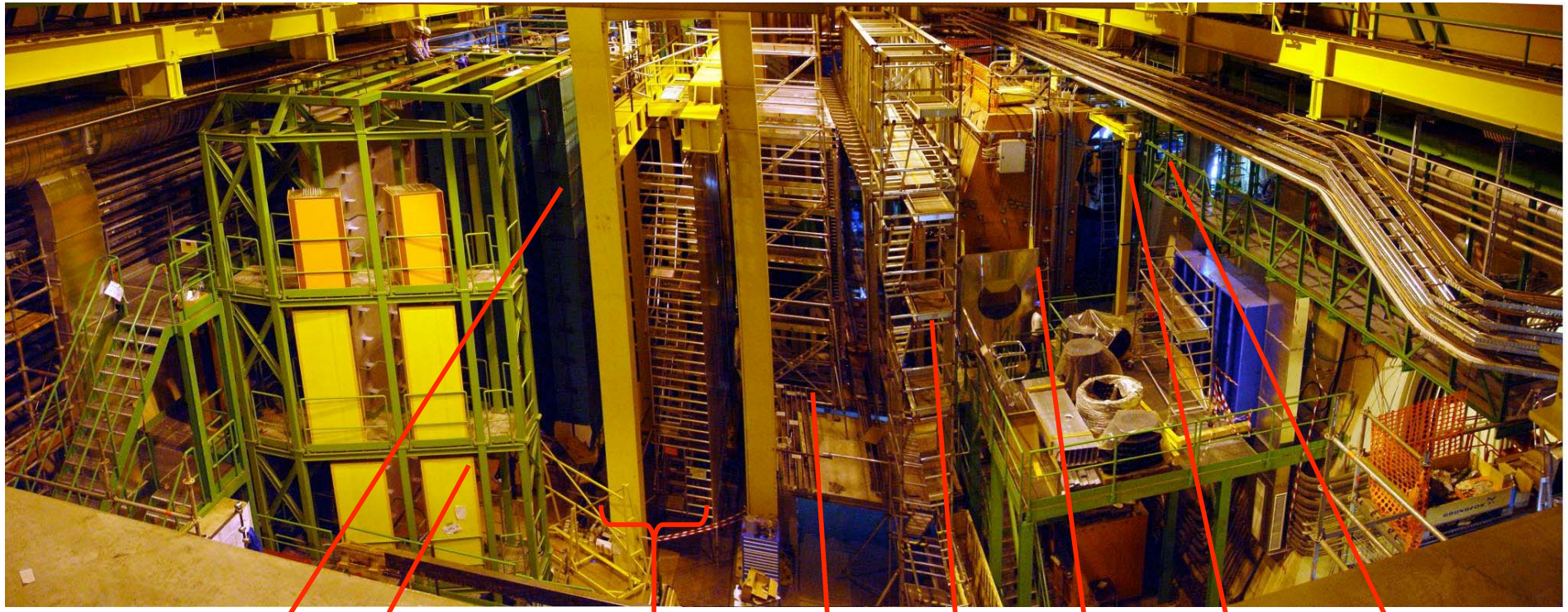
MWPC support wall

Projective readout based on MWPC's except 3-GEM at M1R1(high occupancy)

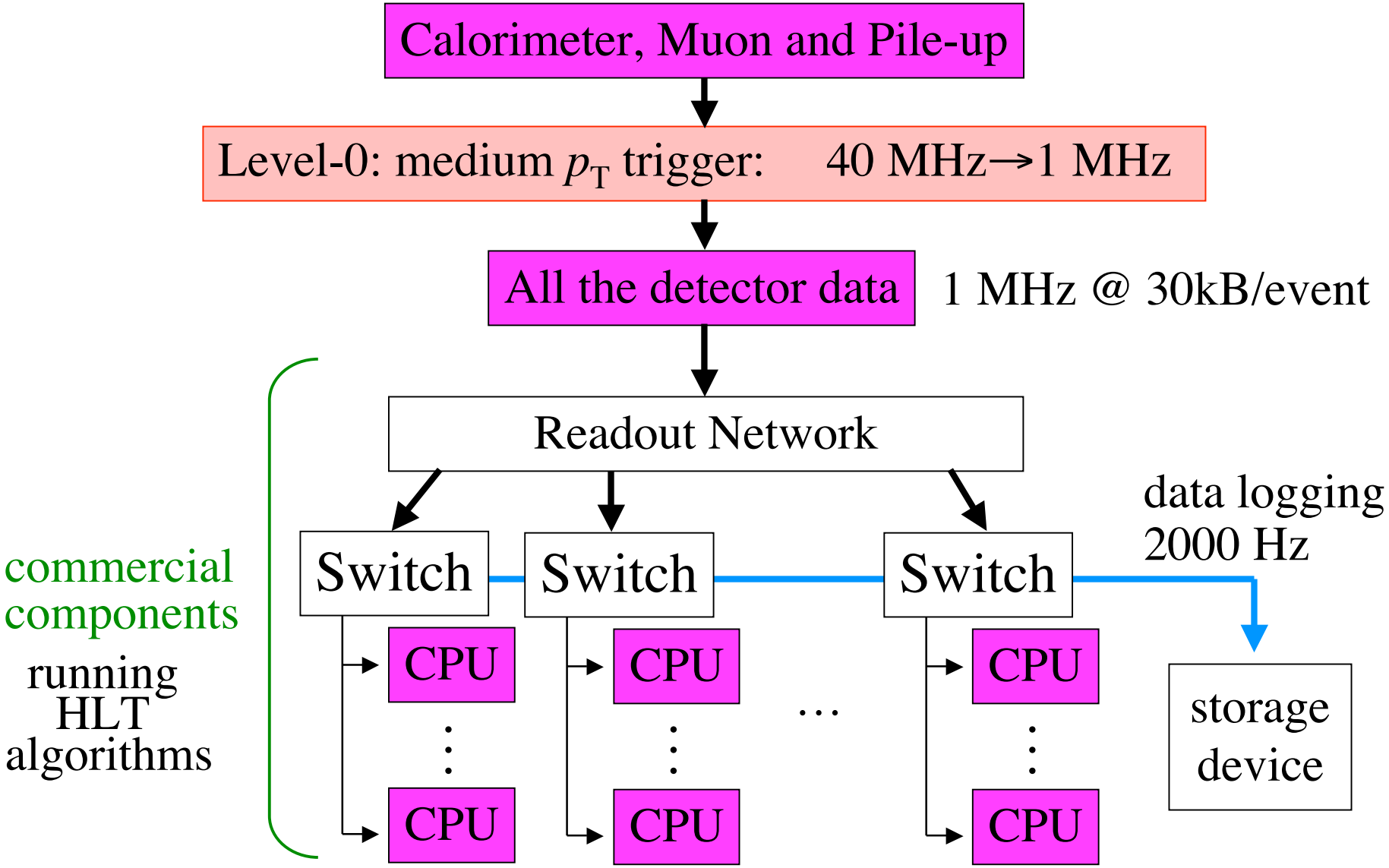




Current view of the pit (IP8)

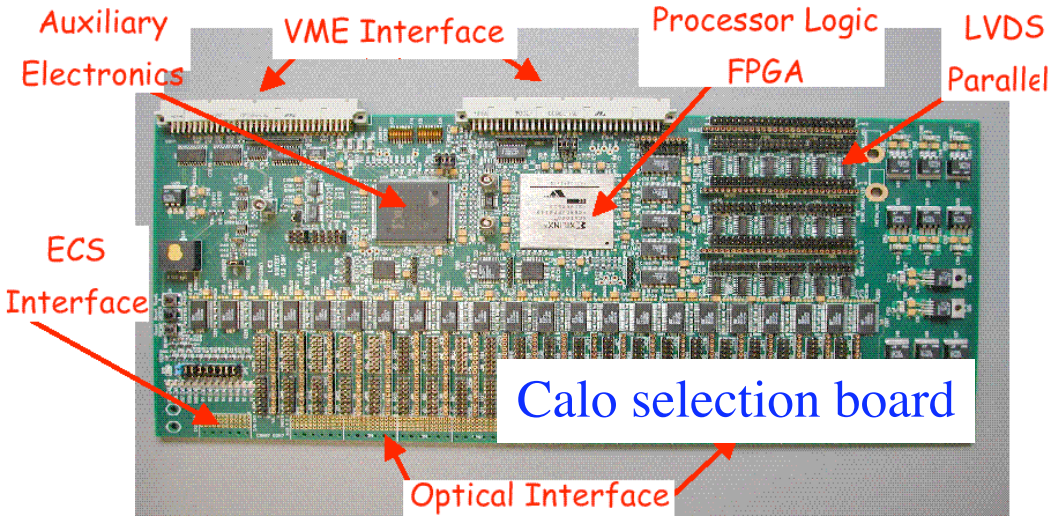


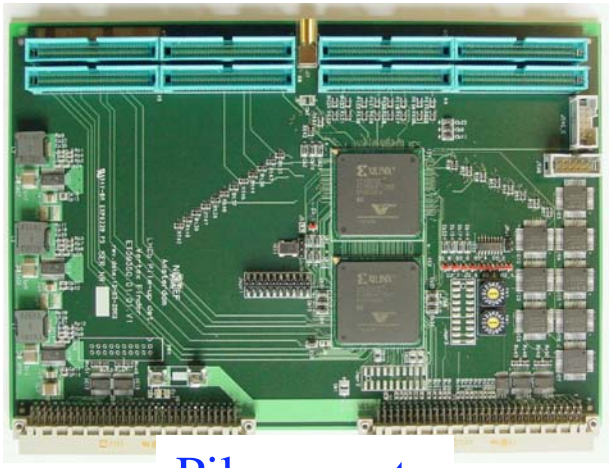
Trigger and Online



Level-0: Muon, Calorimeter (e, h, γ, π^0), Pile-up veto, Decision Unit prototypes.

Muon processor board

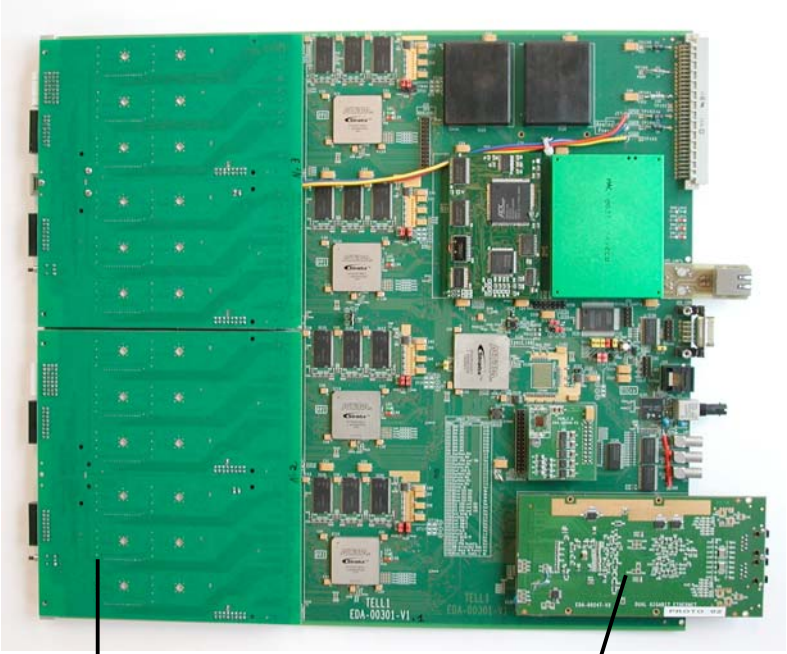




Pile-up veto

Decision Unit

Tell1:
LHCb **common**
readout board



Optical receiver card

Giga-bit Ethernet transmitter card

350 boards

Force10 E1200
network switch

CPU farm
prototype

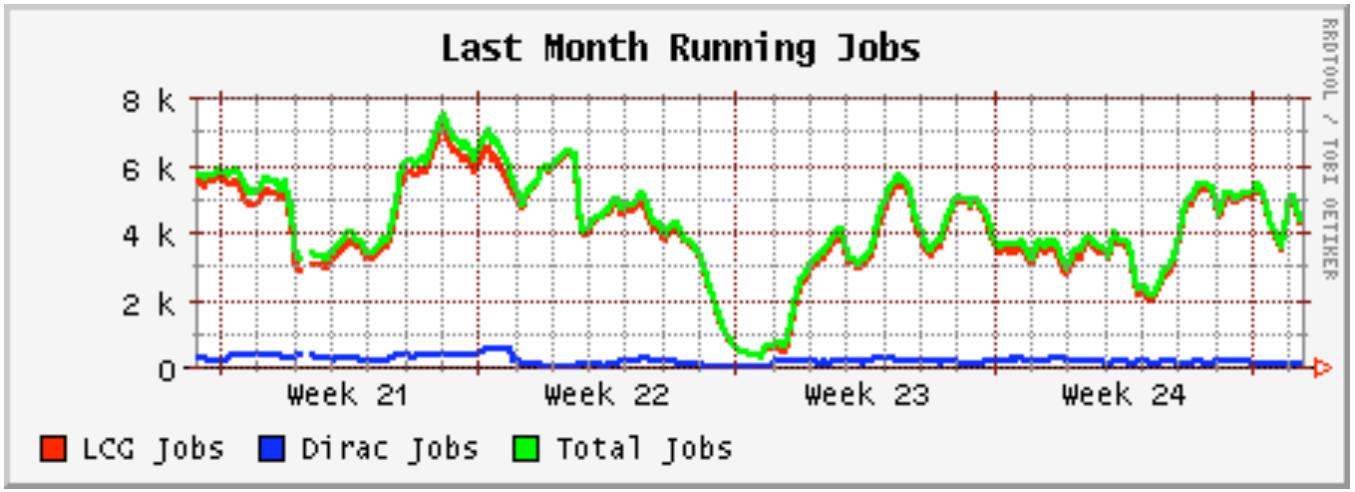
~1800 “boxes”
≈ 3600 CPU’s

Computing

C++ based LHCb complete software suite for simulation, reconstruction, analysis, alignment and calibration, and high level trigger are running under the uniform framework "GAUDI"

LHCb computing model based on
- reconstruction, pre-selection and analysis at Tier-1
- simulation at Tier-2

All the computing aspects are periodically tested through "Data Challenges"



simulation and reconstruction jobs running at WLCG sites in DC2006

On going!

Preparation for the first data

In order to be ready for

1) pilot run @900 GeV in November 2007

2) first physics run @14 TeV in Spring 2008

we have

Commissioning Task Force

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

Physics Planning Group

- Optimizing physics output for a given running scenario and preparing necessary tools

3) Conclusions

- LHCb expects to take B physics a significant step further than the B factories:
  - access to other b hadron species + high statistics
  - excellent vertexing and particle ID
  - flexible and efficient trigger, dedicated to B physics

  Many channels with different sensitivities to new physics
- Construction of the LHCb detector is advancing well
- Low luminosity (~10^{32}) required for the LHCb experiment will allow to exploit full physics potential from the beginning of the LHC operation, and we will be ready for the pilot run in 2007 and the start of physics exploitation in Spring 2008