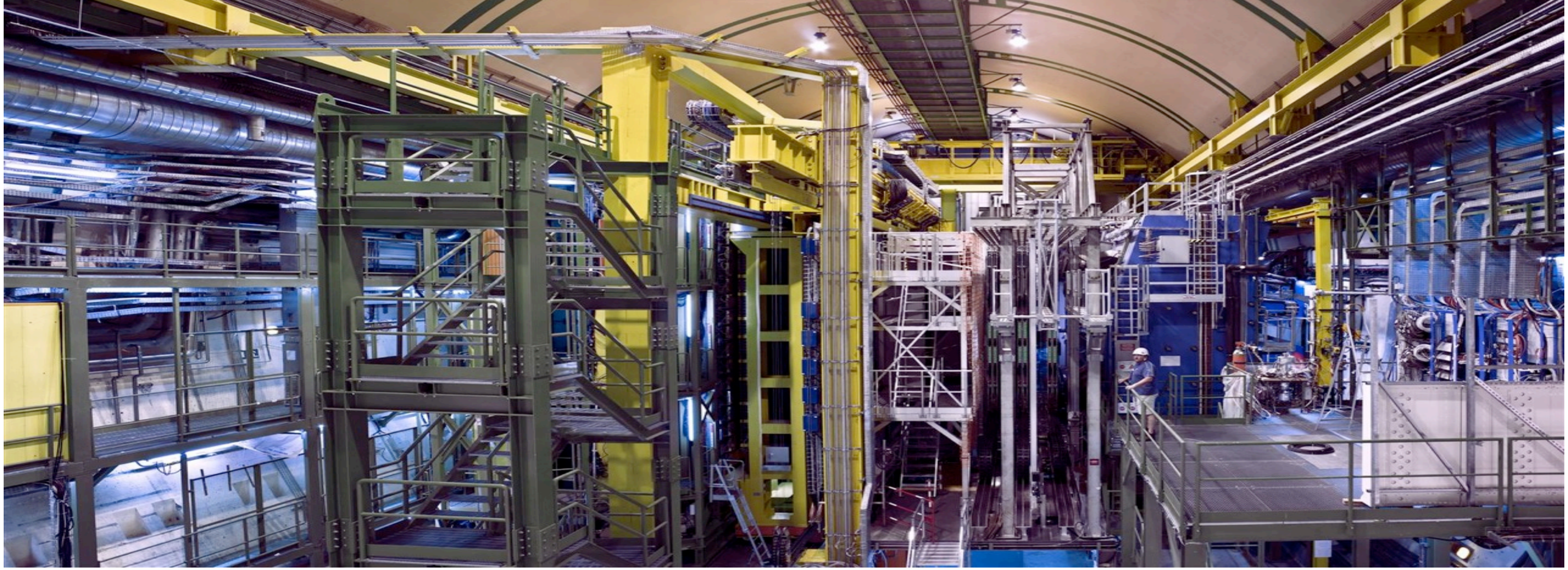


The Status of LHCb

Werner Witzeling

on behalf of the LHCb Collaboration

- Introduction
- The Detector and its Performance
- Summary

LHC Days in Split, 4 – 9 October 2010

The Goals of LHCb

LHCb is designed to search for indirect evidence of new physics beyond the standard model in the b and c sectors

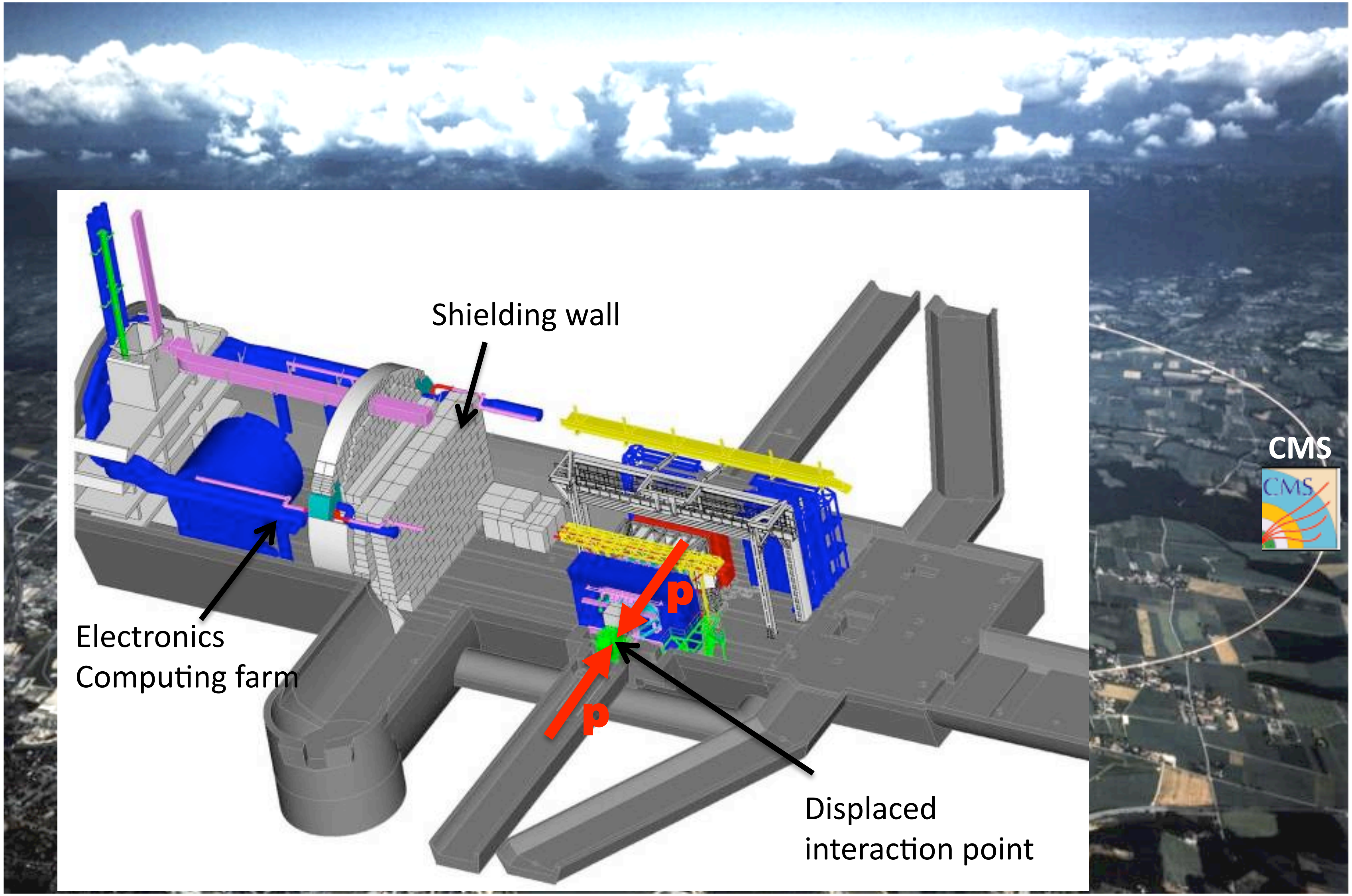
- Precision study of CP violation
- Study of rare b and c decays

This talk will concentrate on the LHCb detector and the performance of the different sub-systems

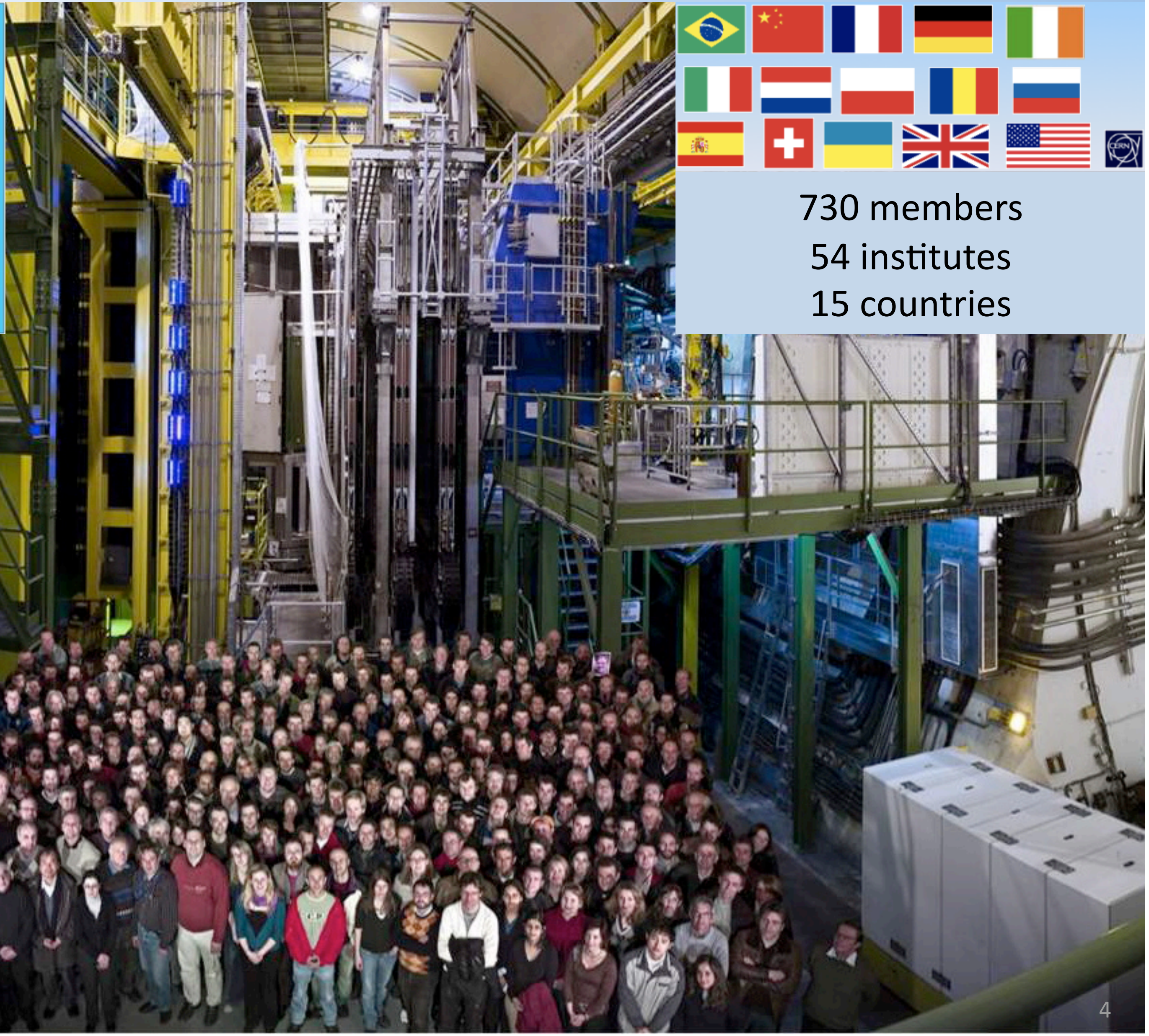
Physics will be covered in the two following talks:

- "First results from LHCb" by Tomasz Skwarnicki, University of Syracuse
- "LHCb Perspectives" by Jose Hernando Morata, University of Santiago de Compostela

LHCb at LHC


Shielding wall
Electronics
Computing farm
p
p
Displaced
interaction point
CMS

The LHCb Collaboration

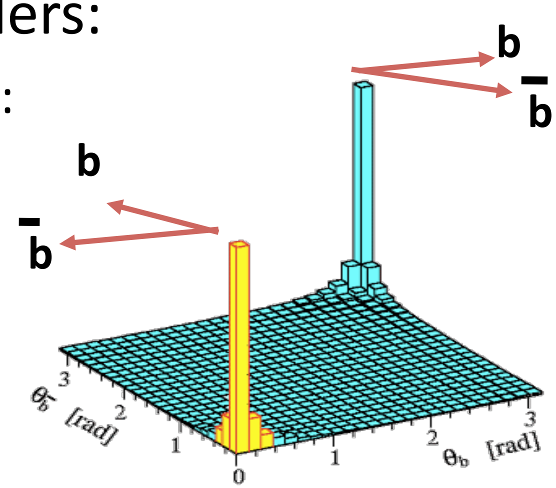


730 members
54 institutes
15 countries

B Physics at the LHC Machine

- Advantages of beauty physics at hadron colliders:
  - High cross section for bb-bar production expected:

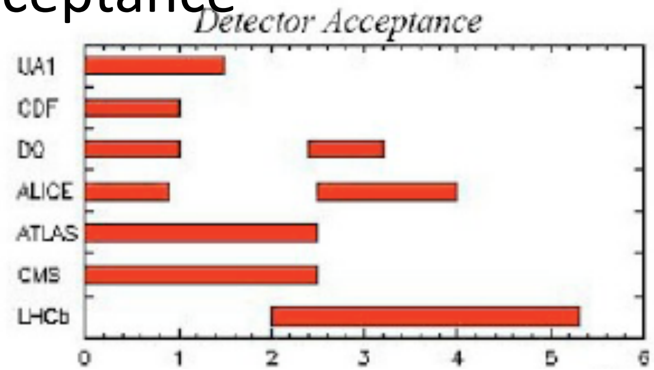
    σ_{bb} ~300 – 500 μb at √s =7 – 14 TeV
  - bb-bar pairs are mainly produced in the forward direction
  - Access to all quasi-stable b-flavored hadrons



- However, there are also challenges:
  - High multiplicity of tracks (~30 tracks per unit of rapidity)
  - High rate of background events (σ_{inel} ~ 60 mb at √s =7 TeV)
  - An efficient trigger is essential

The LHCb Experiment at the LHC Machine

- The LHCb detector is designed as a single arm forward spectrometer, maximizing the acceptance for b events
  - Coverage in η between 1.9 and 4.9
  - Low p_T trigger, efficient for hadronic decays



Rapidity η

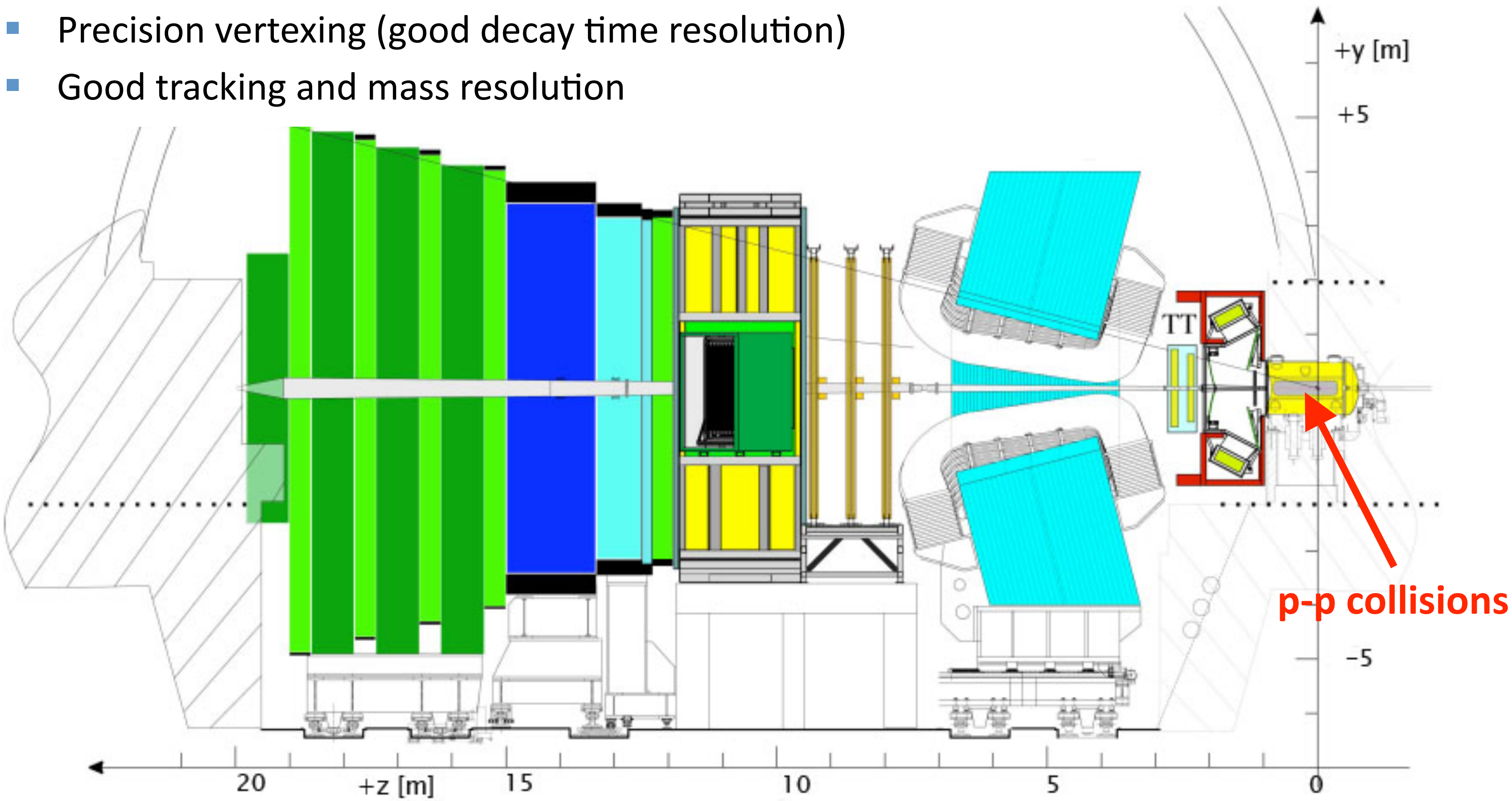
- LHCb nominal running conditions at √s=14 TeV:
  - Luminosity $2*10^{32}$ $cm^{-2}s^{-1}$ (by focusing less than at ATLAS and CMS)
  - With β* = 10 m ~ 0.4 visible pp interactions per bunch crossing

However, the present running conditions are different:

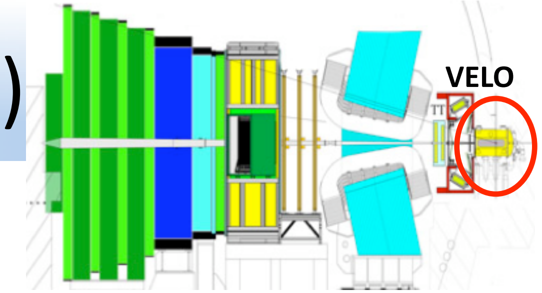
- Energy √s = 7 TeV, should reach close to nominal ***L*** ~10^{32} soon
- With β* = 3.5 m, we get ~ 2.0 visible pp interactions per crossing
- Use flexibility of trigger to adapt to actual conditions

The LHCb Detector

- The design criteria for the LHCb detector:
  - Efficient trigger for many B decay topologies
  - Efficient particle identification
  - Precision vertexing (good decay time resolution)
  - Good tracking and mass resolution



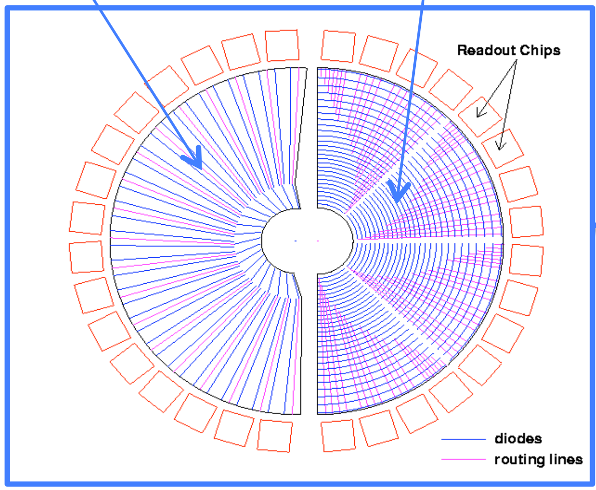
The Vertex Locator (VELO)

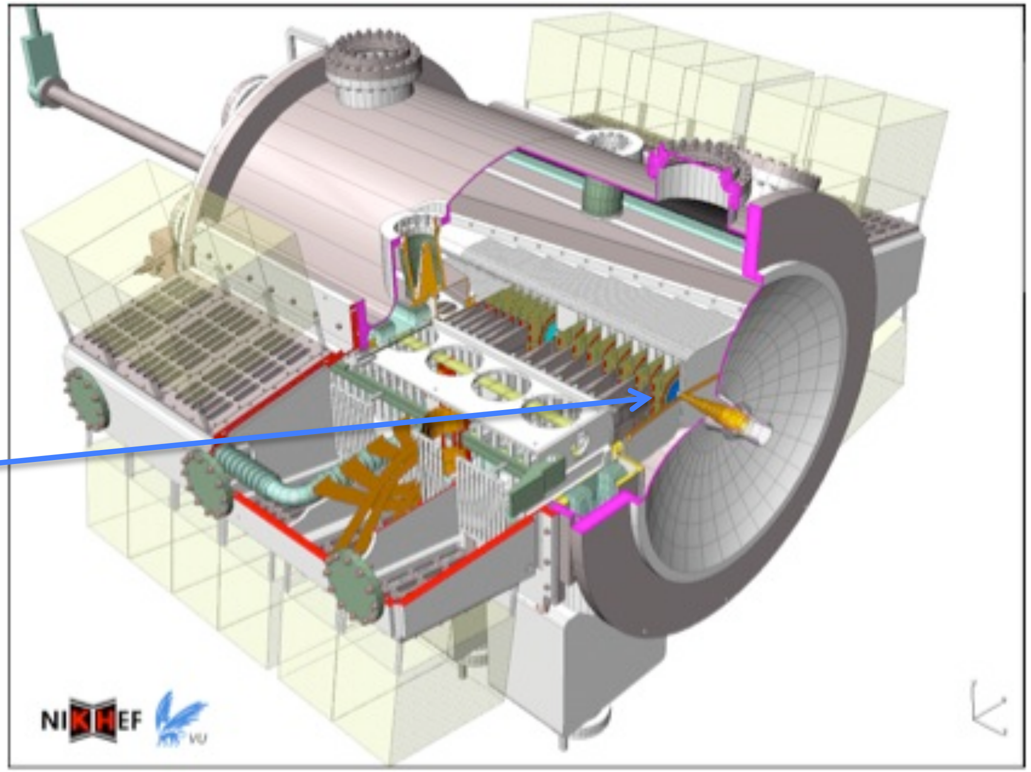


- Precision measurement at interaction point
  - Two halves with 21 stations each
  - Each station has 2 micro-strip silicon sensors providing R and ϕ measurement
  - The two halves are staggered in z to allow overlap
  - Separated from beam vacuum by 300 μm Al foil (serves also as RF shield)

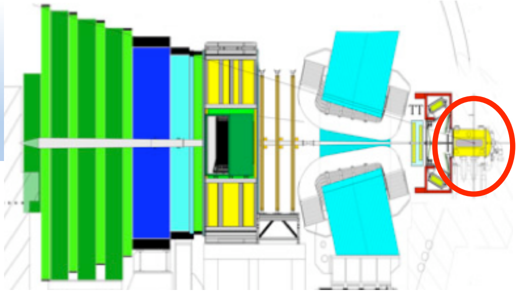
ϕ-sensor
10^0-20^0 stereo angle
Pitch 35 – 100 μm

r-sensor
4 x 45^0 sectors
Pitch 40 – 100 μm

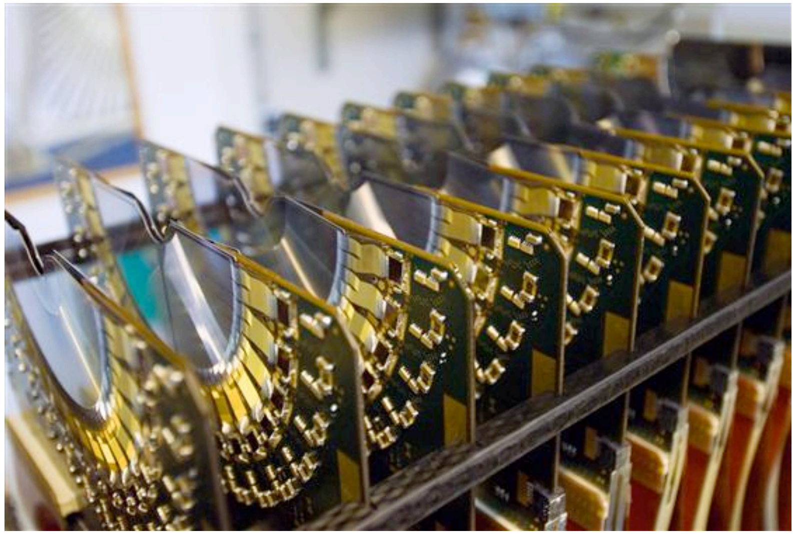


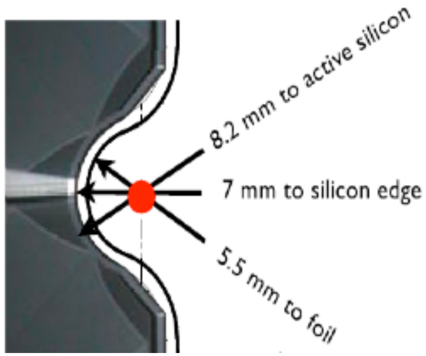


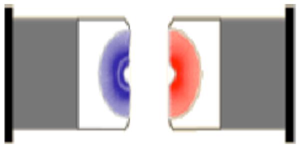
The Vertex Locator (VELO)



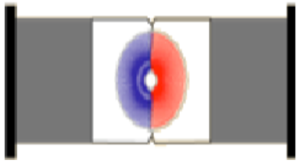
- All VELO sensors are operational
- VELO detector halves are retracted during "not-stable beam" periods by 3 cm
- Semi-automatic closing procedure



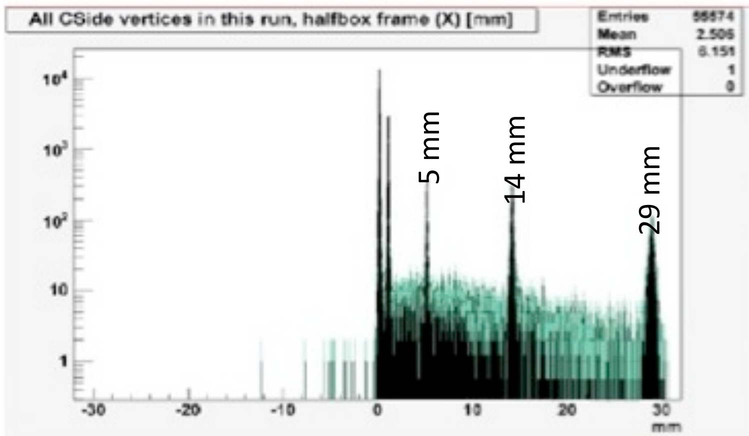




Open position



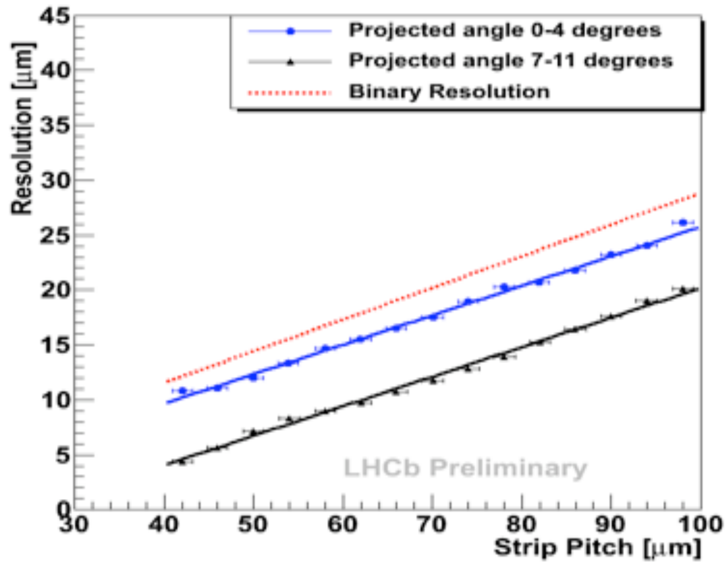
Closed: small overlap



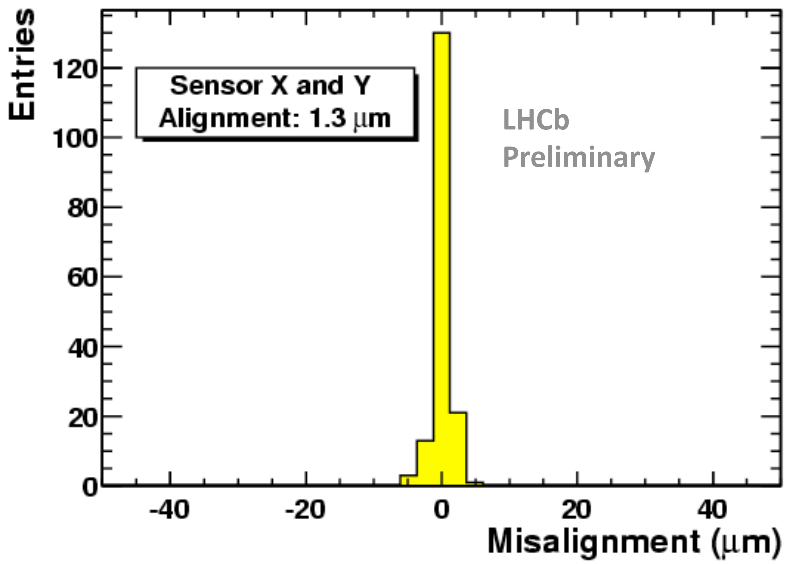
Distance from IP [mm]

VELO closing manager:
IP position (vertices) calculated on A-side in local frame
Procedure takes <6 min

VELO Performance



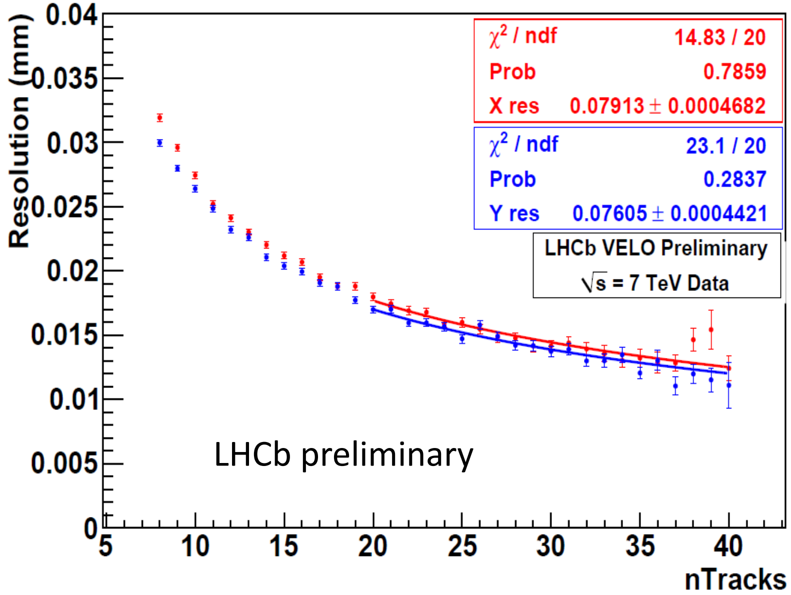
- Cluster finding efficiency is 99.7%
- Excellent single hit resolution (down to ~4 µm)

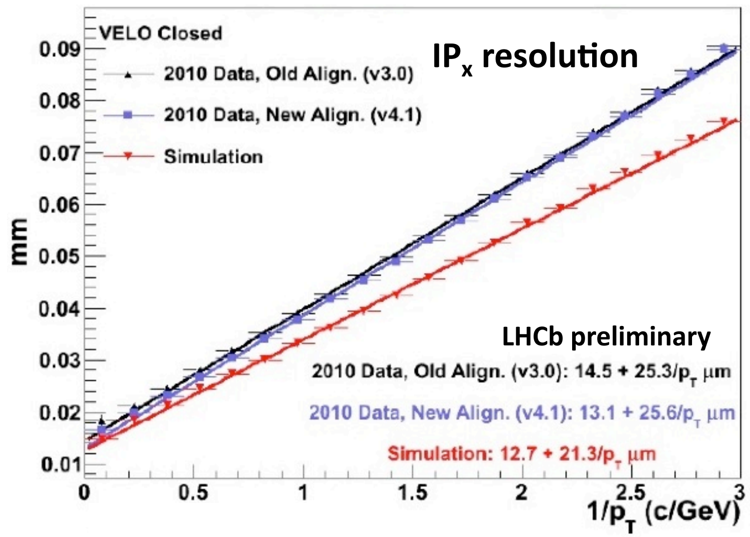


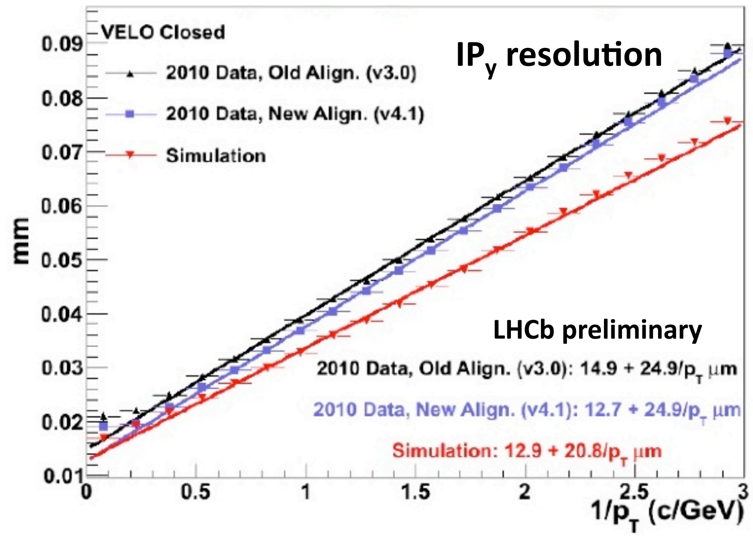
- Module and sensor alignment is better than 5 µm
- The variation from fill to fill is < 5 µm (opening and closing occurs for each fill)

VELO Performance

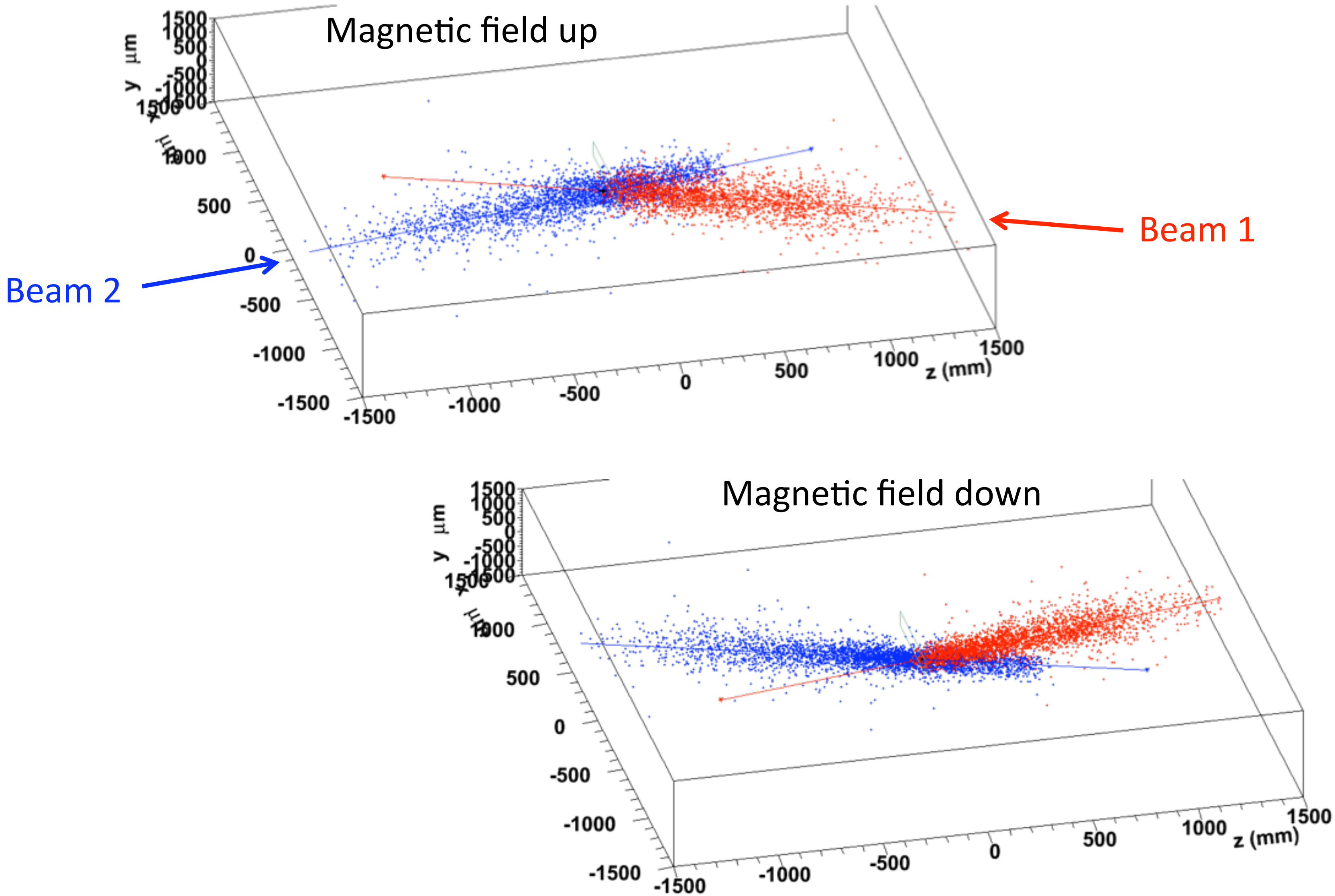
- Primary vertex resolution:
  - ~σ_x and σ_y = ~ 15 μm
  - σ_z = ~ 76 μm
- Rather good agreement with MC at high $p_{T,}$, but more details under study







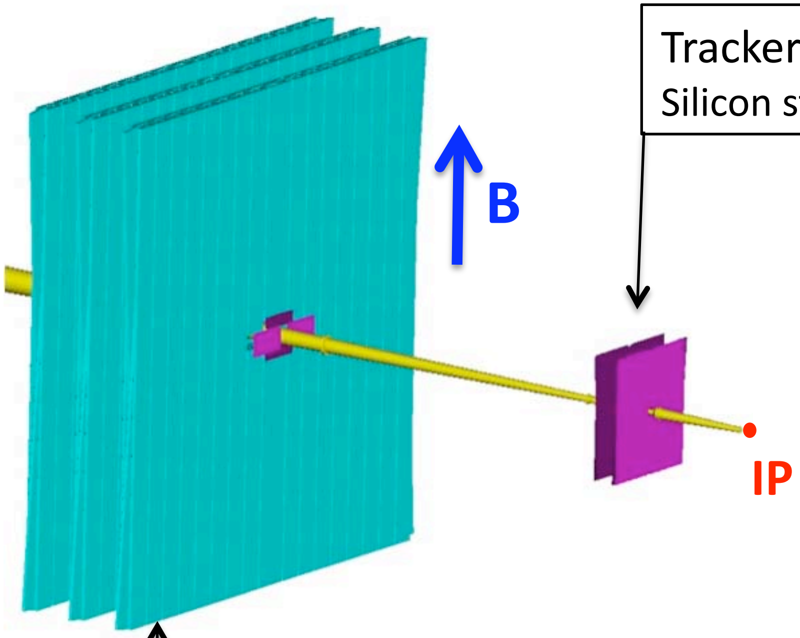
VELO: Beam – Gas Events



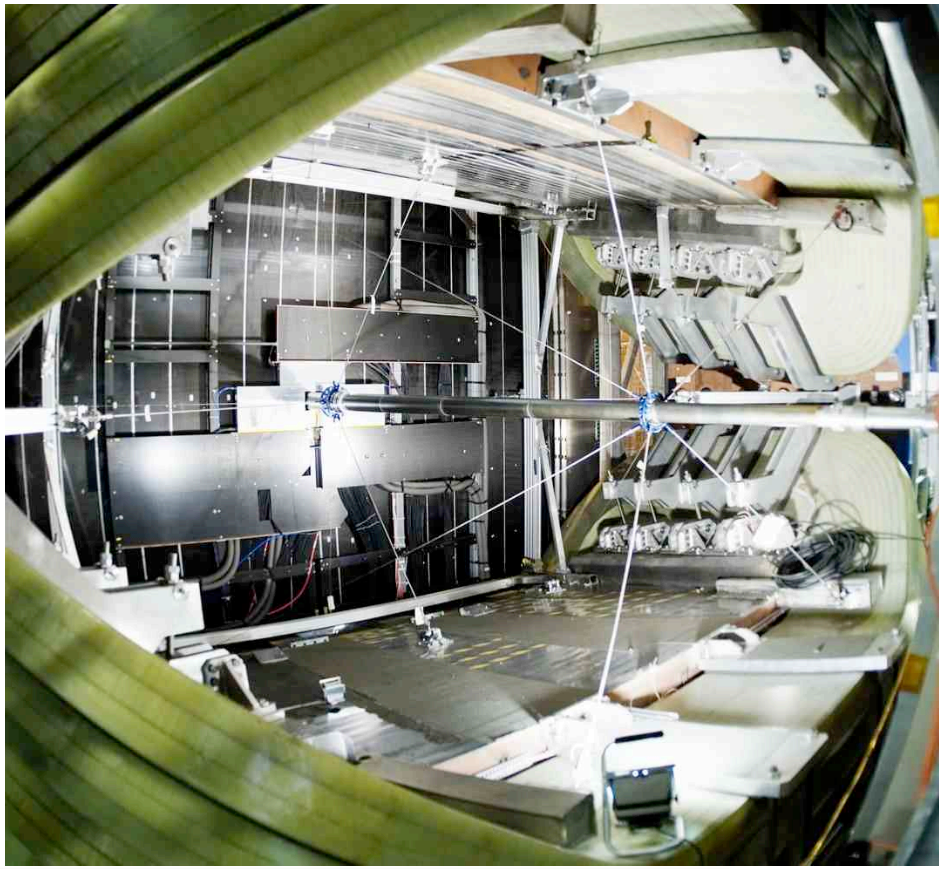
The Tracking System

- Hybrid system with Silicon detectors and straw tubes
- Dipole magnet

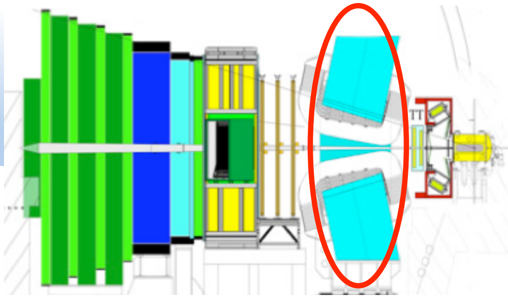
Tracker Turicensis (TT)
Silicon strip detector

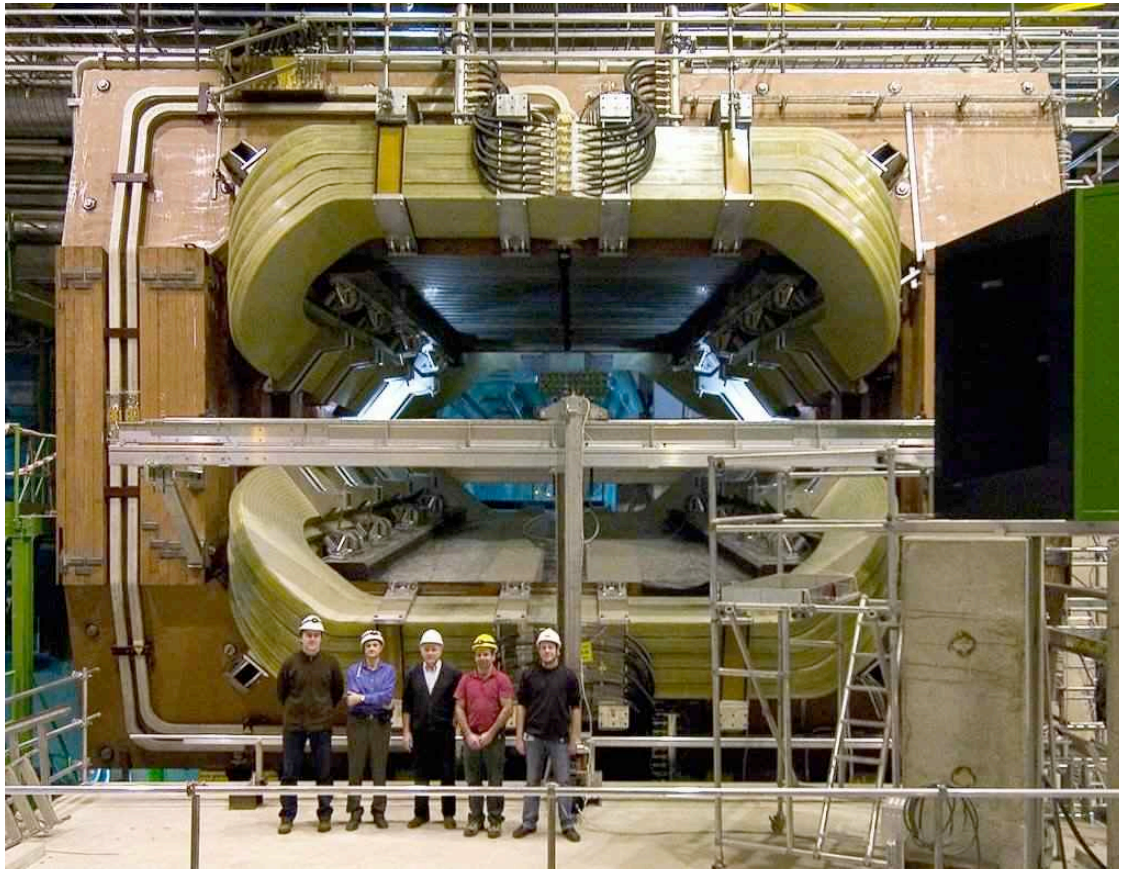


Three tracking stations downstream of magnet
- Inner part: Silicon strip detectors
- Outer part: Straw tubes



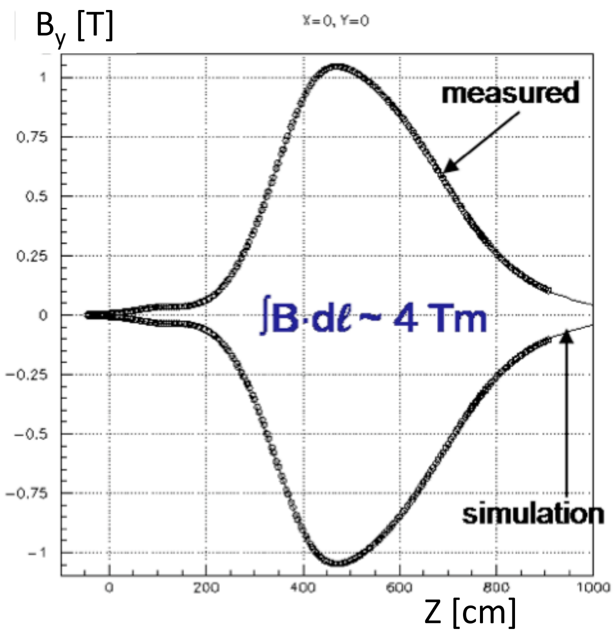
The Magnet



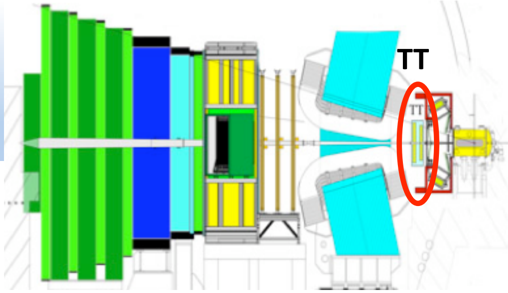


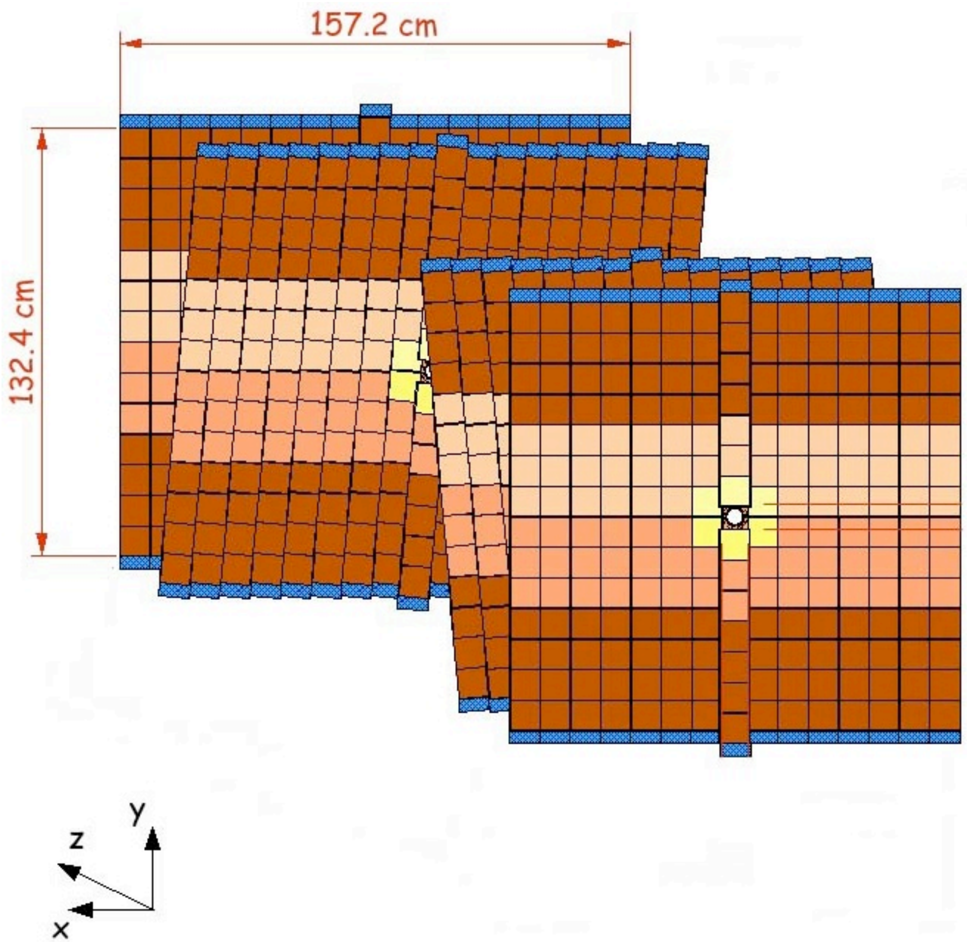
Magnet with field measurement device

- Water cooled Al conductor
- I_{oper} = 5850 A
- Power = 4.2 MW
- Peak field = 1.1 T
- Field integral (10m) = 4 Tm
- Polarity can be changed



Silicon Trackers - 1

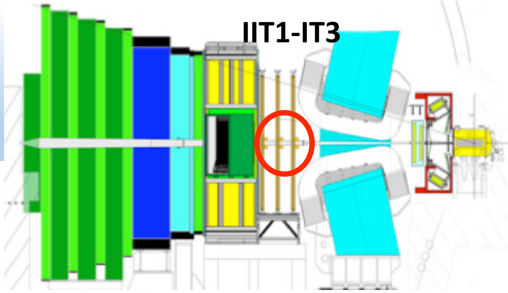


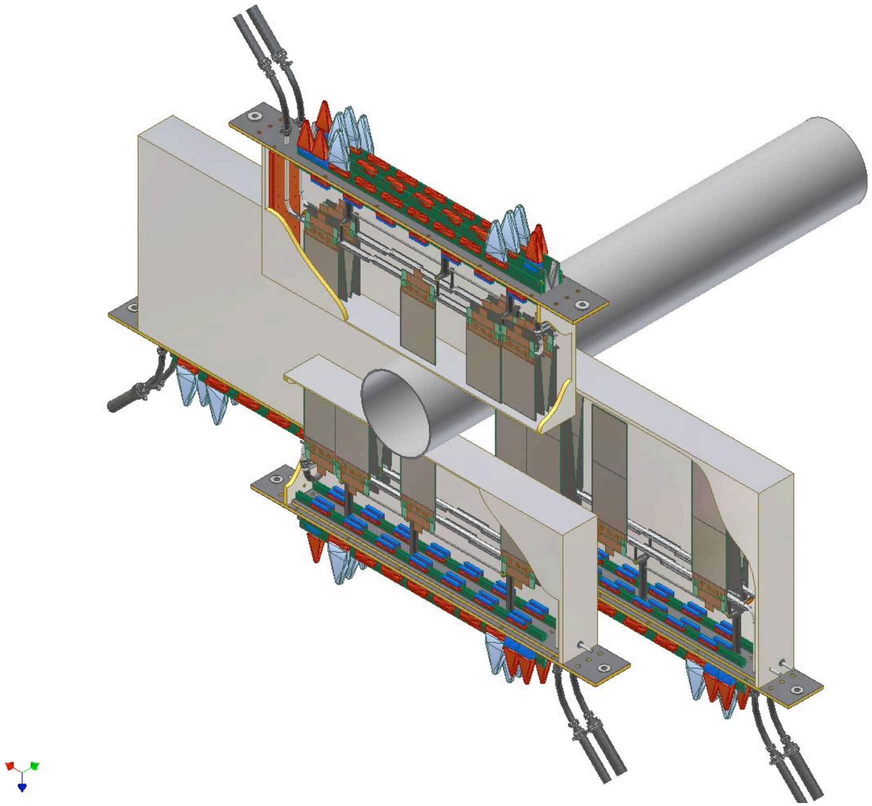


❑ Tracker Turicensis (TT)

- 4 layers of Si strip detectors with stereo angles (0°/±5°)
- 500 µm thick, 183 µm pitch
- 143 k channels

Silicon Trackers - 2





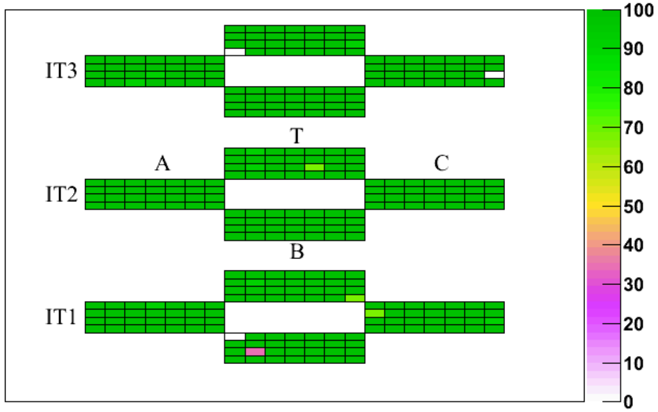
❑ Inner Tracker (IT)

- 3 stations with 4 layers of Si strip detectors, stereo angles (0°/±5°)
- 320/410 µm thick for 1/2 sensor ladders
- 198 µm pitch
- 130 k channels

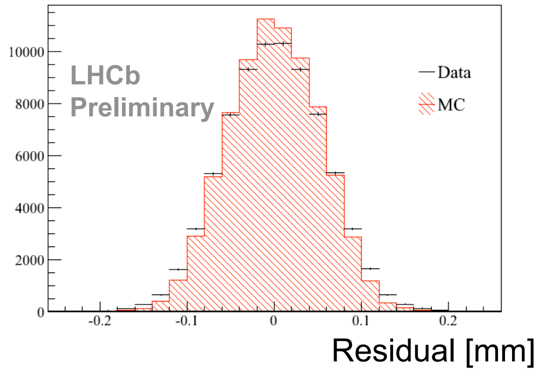
Silicon Tracker Performance

- Detectors are fully operational, the performance is still being improved (by refining the alignment)

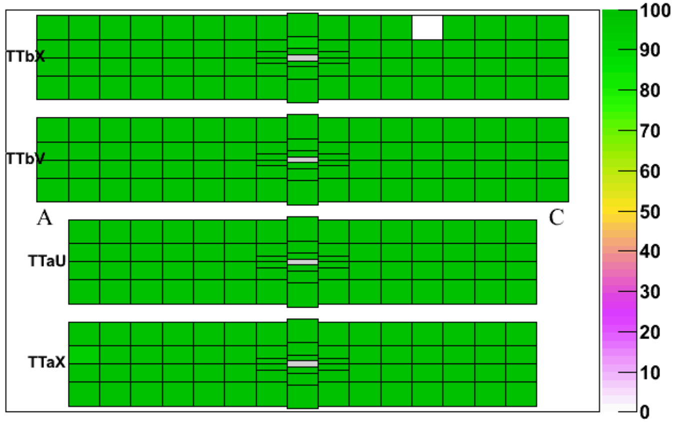
IT: 98.3% of channels working



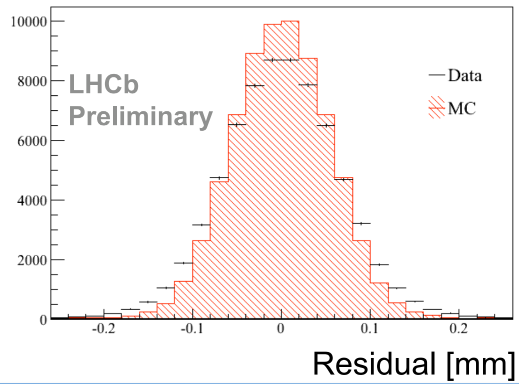
IT: Hit resolution 54 µm
misalignment 16 µm



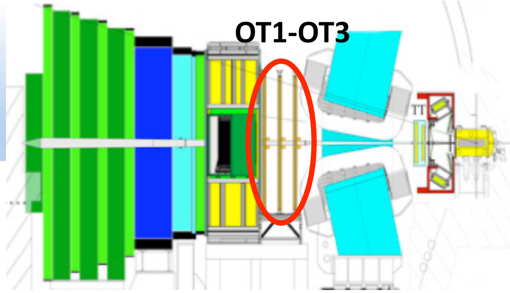
TT: 99.4% of channels working



TT: Hit resolution 55 µm
misalignment 35 µm

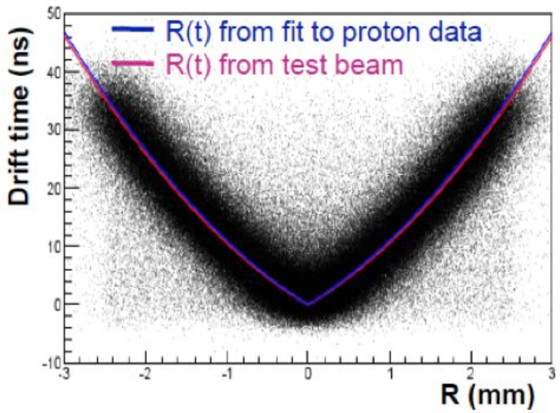


Outer Tracker

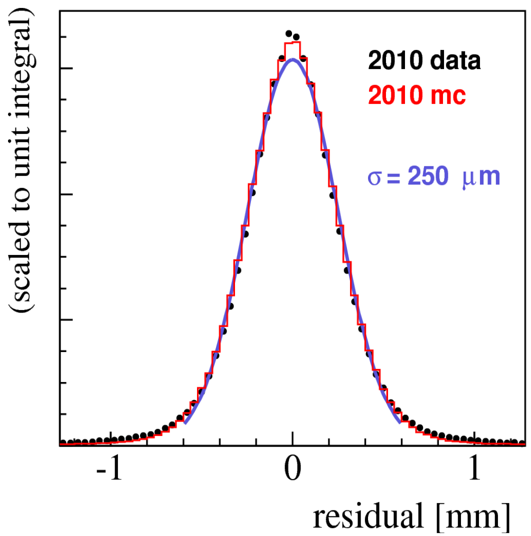


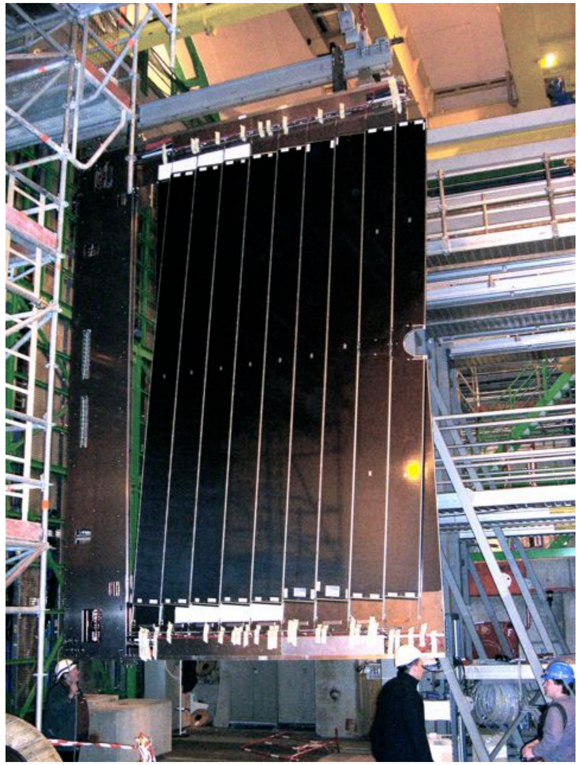
- Fully operational, 99.3% of channels working
  - 3 stations with 4 double layers of straw tubes, stereo angles (0°/±5°)
  - Straw tubes with 5 mm diameter
  - Gas: $Ar/CO_2/O_2$ = 70/28.5/1.5%
  - 56 k channels

Drift time – space relation (R(t)



OT resolution: σ = 250 µm close to nominal

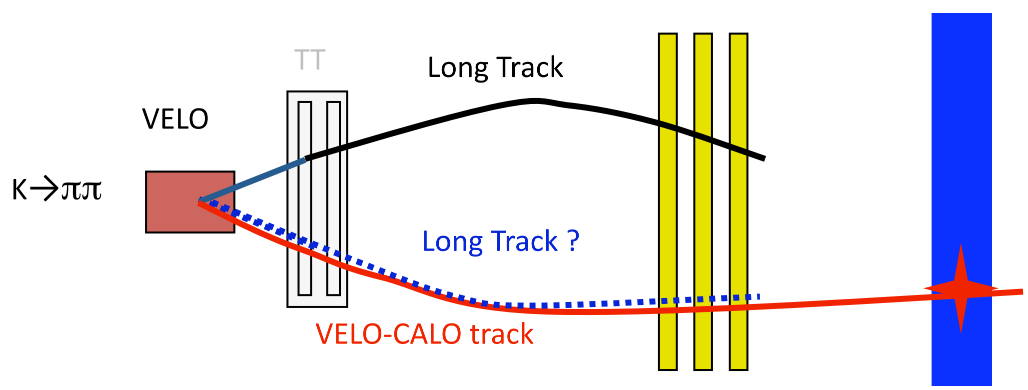


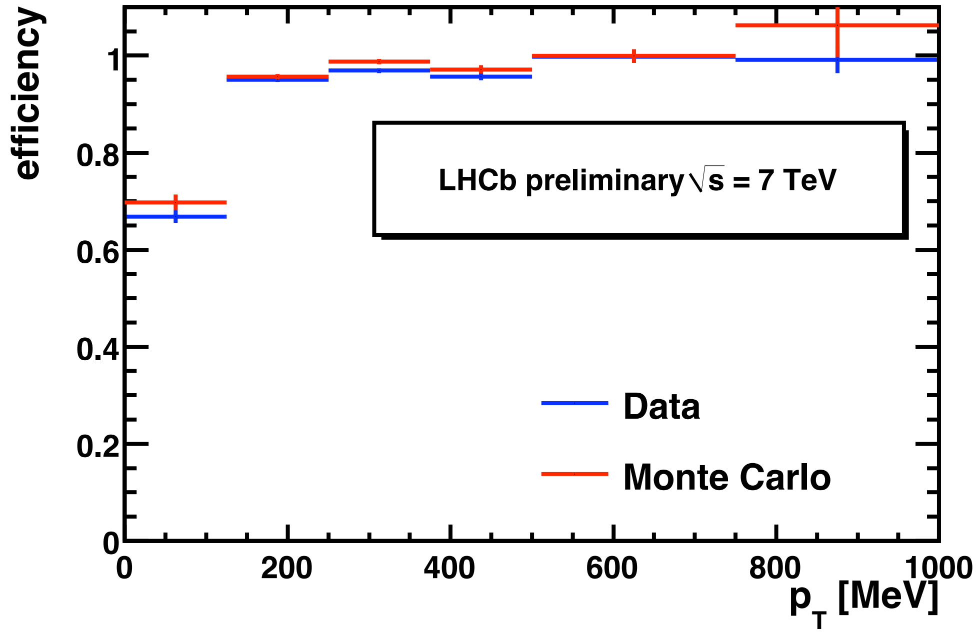


Tracking Efficiency

- Tracking performance (p_T) for T stations obtained using K_s candidates

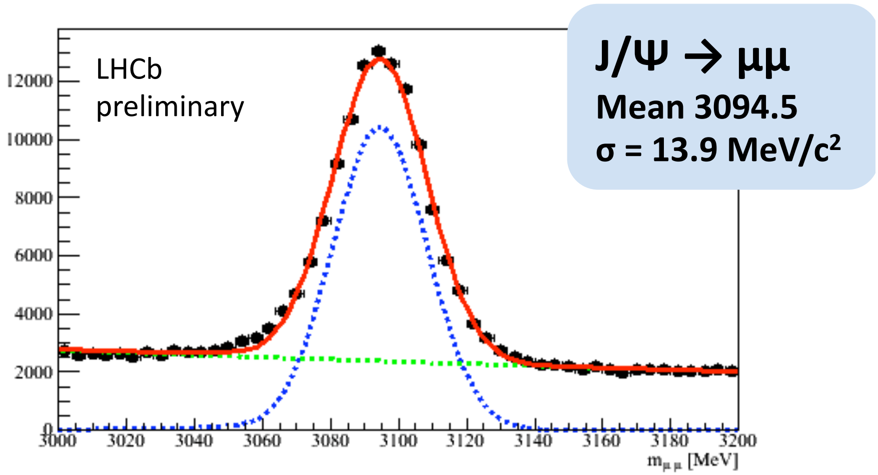
$$\varepsilon = \frac{\text{Tracks (VELO + IT/OT+CALO)}}{\text{Tracks (VELO + CALO)}}$$

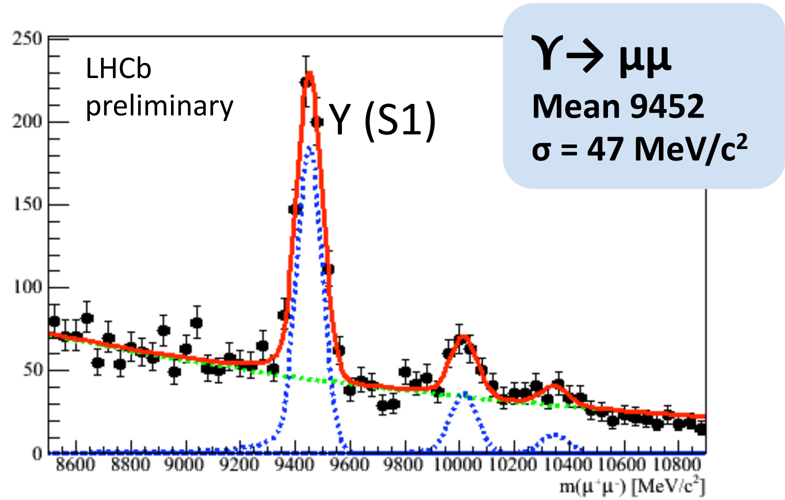




For more details see poster "Tracking Performance at LHCb" by Sebastian Wandernoth

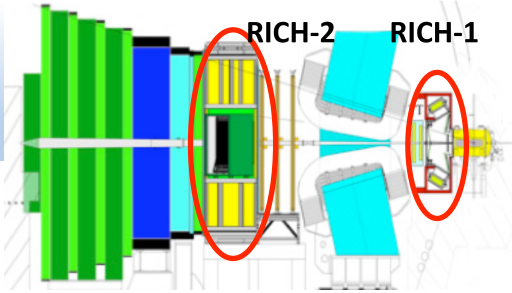
Mass Resolution



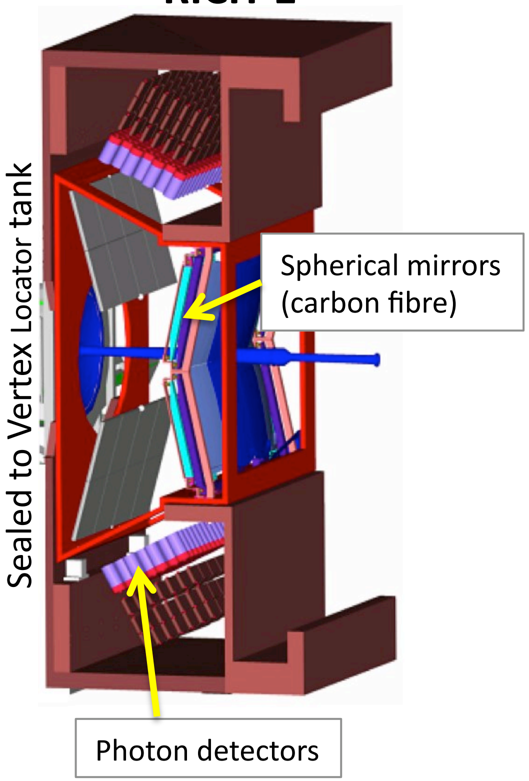


Mass resolution approaching MC expectation

RICH Detectors - Layout

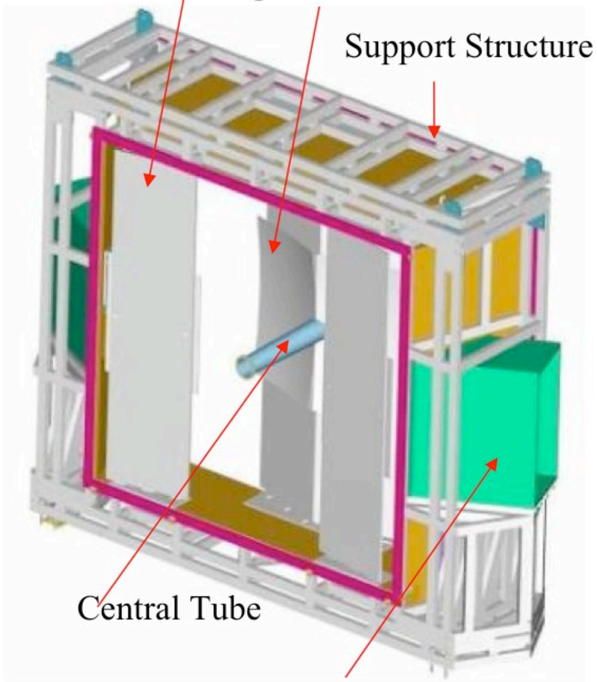


RICH-1



Acceptance: 300 mrad hor
25-250 mrad vert

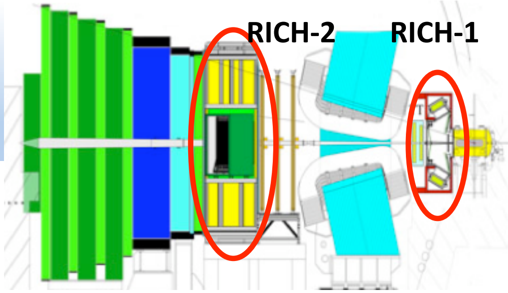
RICH-2

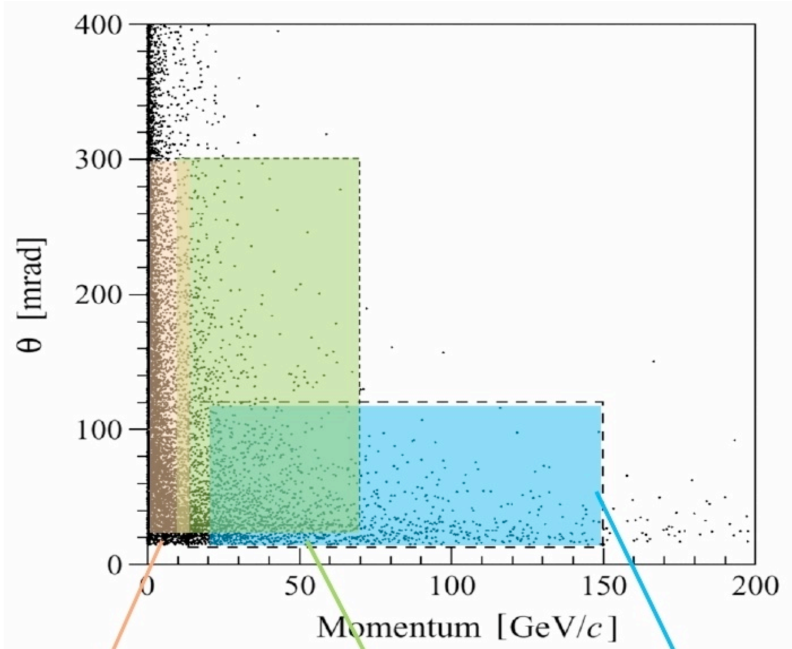


Acceptance: 15-120 mrad hor
15-100 mrad vert

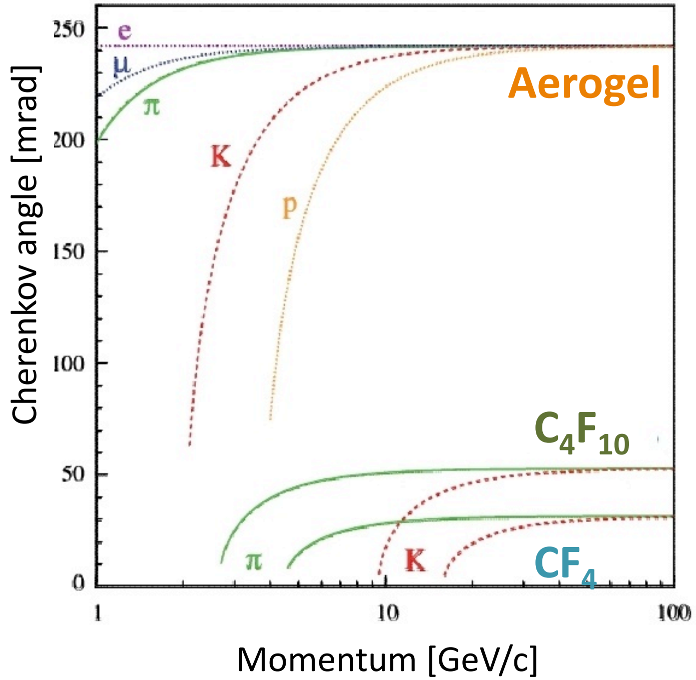
Photon detectors (484)
HPD diam. 83 mm, 1024 pixels

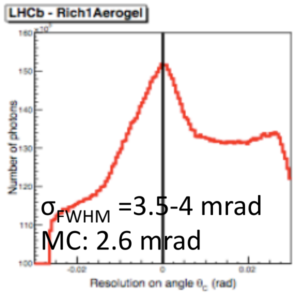
RICH Detectors

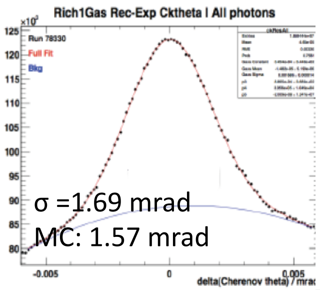


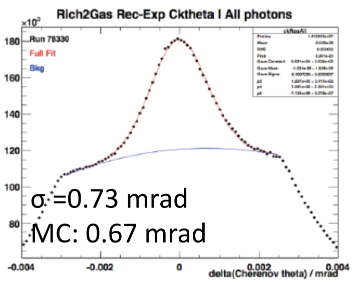


Aerogel	C_4F_{10} gas	CF_4 gas
n=1.03	n=1.0014	n=1.0005
1-10 GeV	Up to ~70 GeV	>100 GeV
RICH-1		**RICH-2**







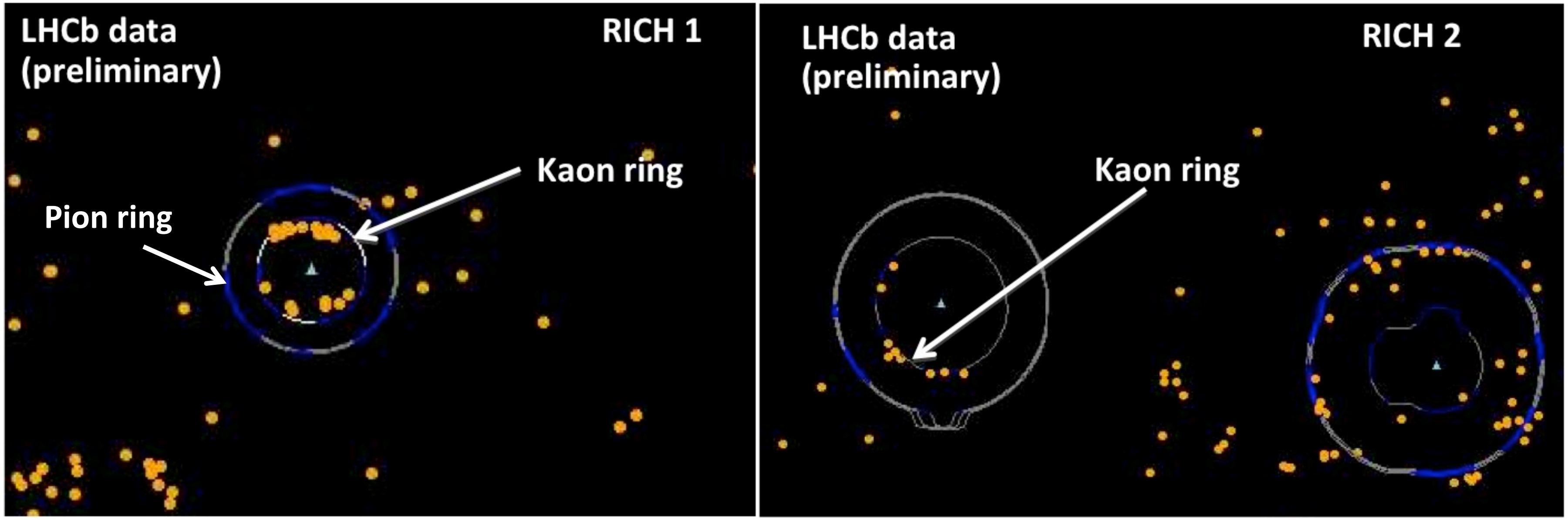


- Coverage: 1-100 GeV
- Resolution for gas radiators close to MC after alignment of mirrors and photon detectors
- Aerogel being improved

RICH performance

RICH-1 **RICH-2**

Dec 2009, √s=0.9 TeV

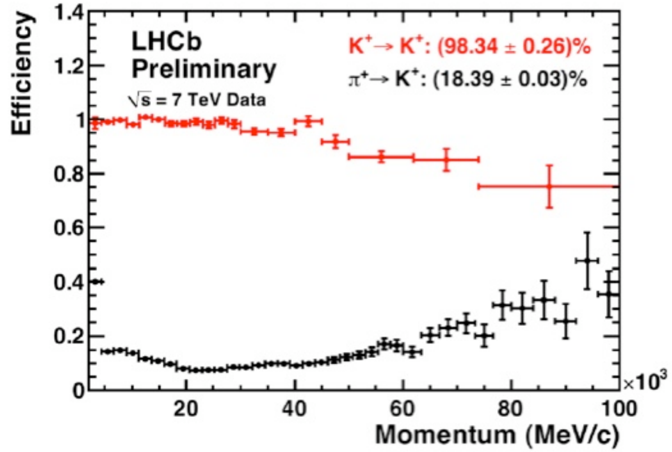


Points = photon hits, rings = hypotheses for particle types

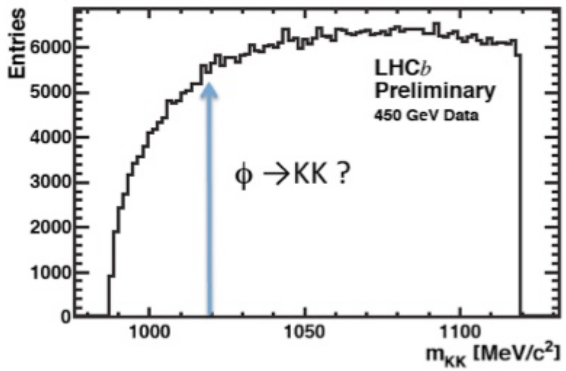
Particle Identification

- Calibration samples used:
  $\Lambda \rightarrow p\pi$, $Ks \rightarrow \pi\pi$, $\Phi \rightarrow KK$
- Performance still improving, getting close to MC

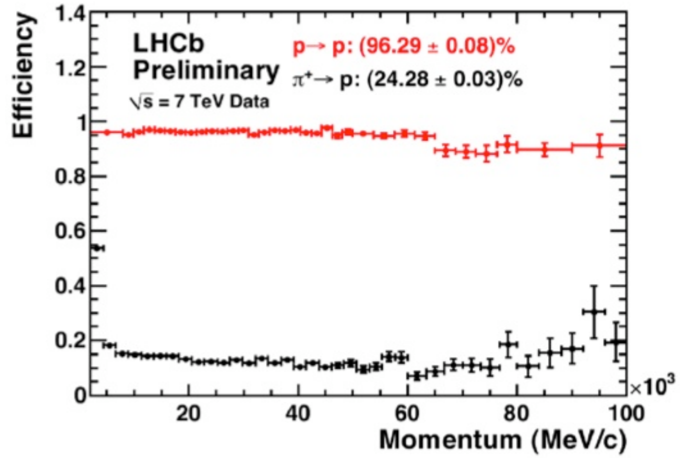
K-π separation



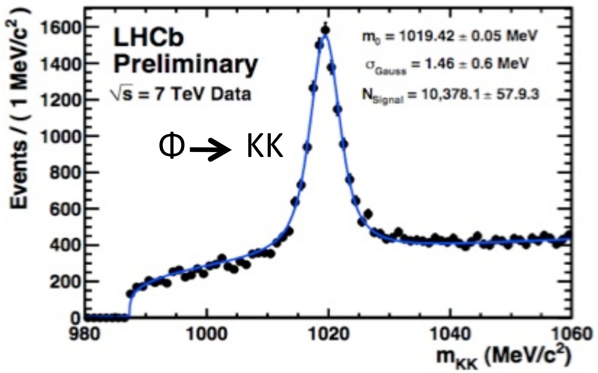
Without RICH PID



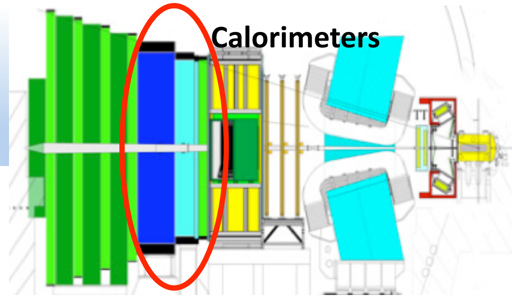
p-π separation

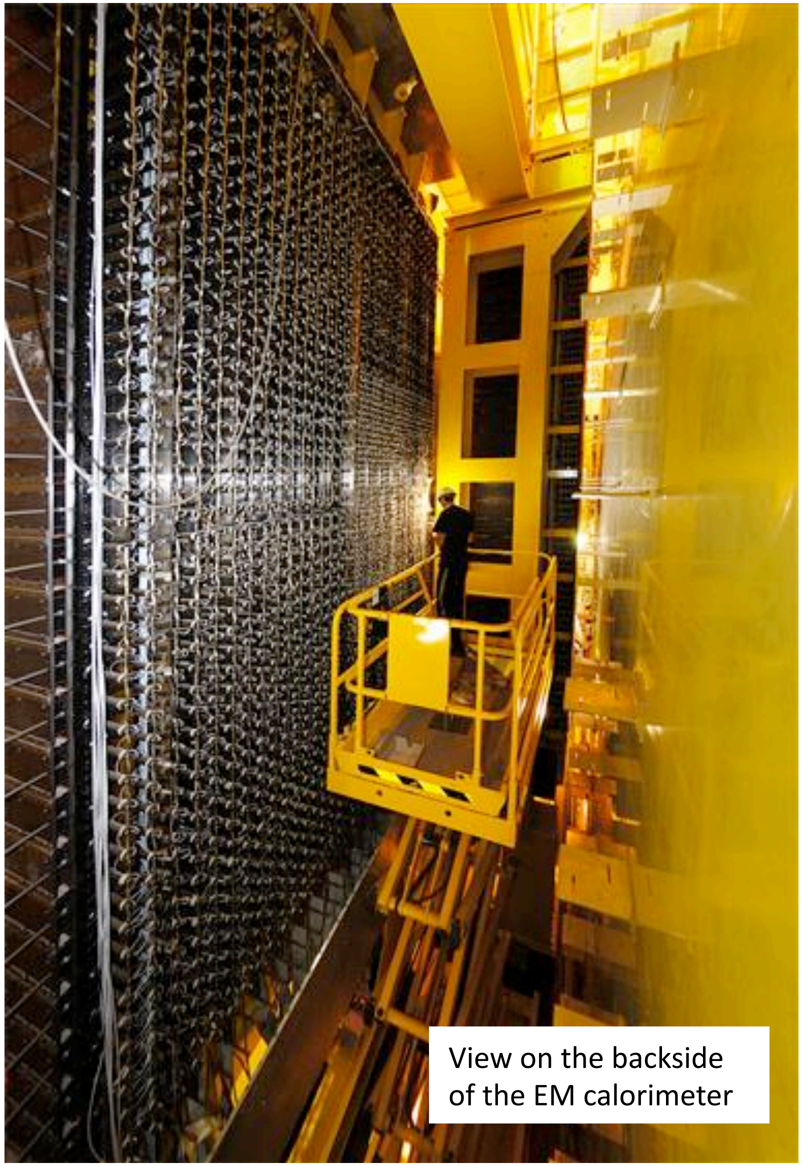


With RICH PID



Calorimeter System





View on the backside of the EM calorimeter

Scintillator Pad & Preshower Detector

- $2.5X_0$ lead converter sandwiched between two scintillator planes
- Three different cell sizes, 5952 cells

Electromagnetic Calorimeter

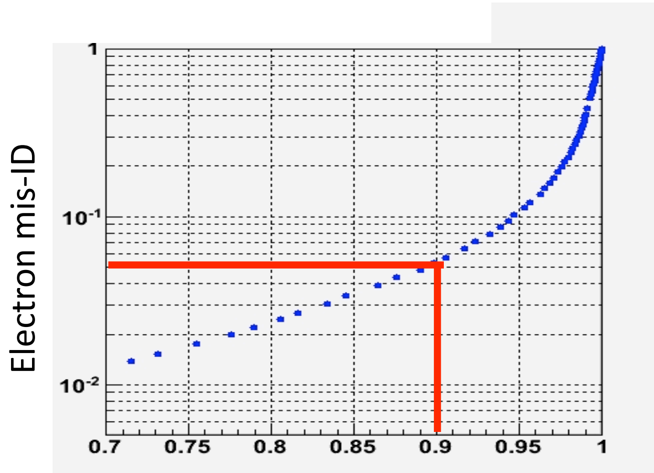
- 25 X_0 "Shashlik" type modules
- Three sections with different granularity
- 66 layers of 2 mm Pb and 4 mm scintillator
- 5952 channels

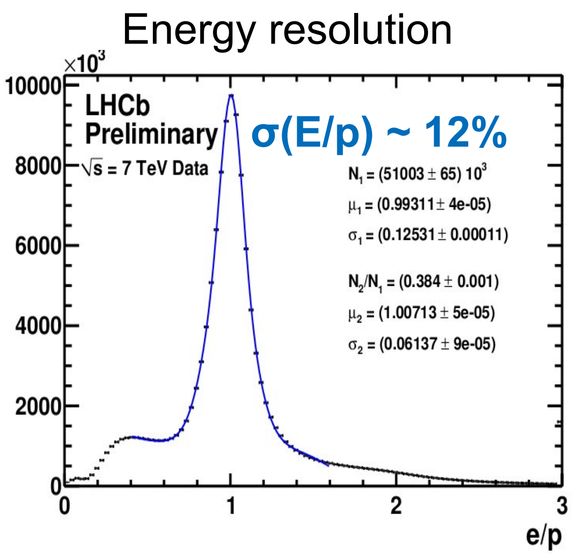
Hadronic Calorimeter

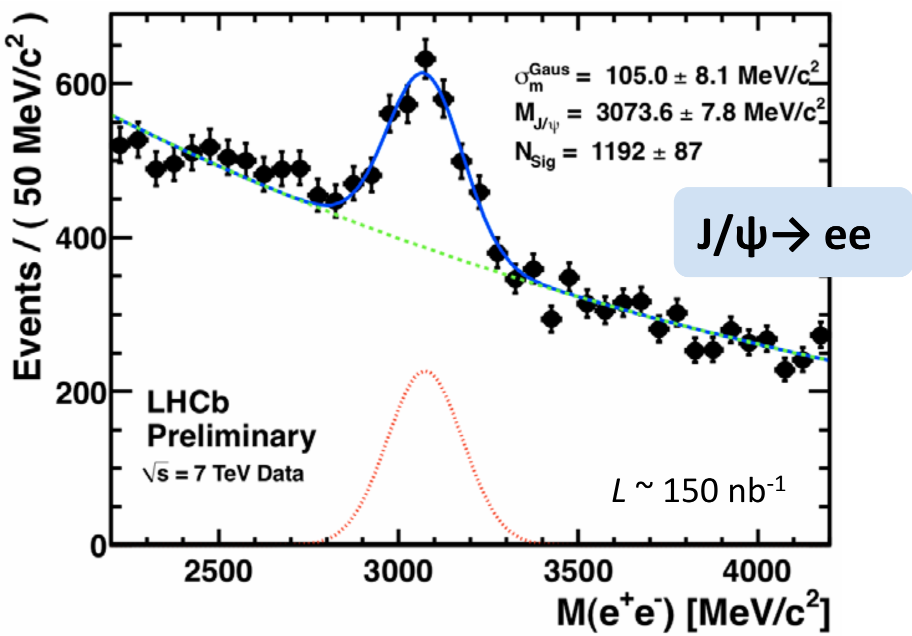
- Sampling calorimeter with Fe/scintillator tiles
- Depth 5.6 λ_0
- 52 modules, 1468 channels

Electron Identification

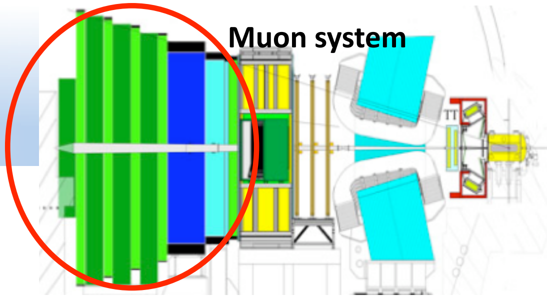
- Achieved 2-2.5% inter calibration with π^0
- Electron mis-identification rate is 5% for 90% efficiency
- MC: 4.5% at same efficiency, in good agreement



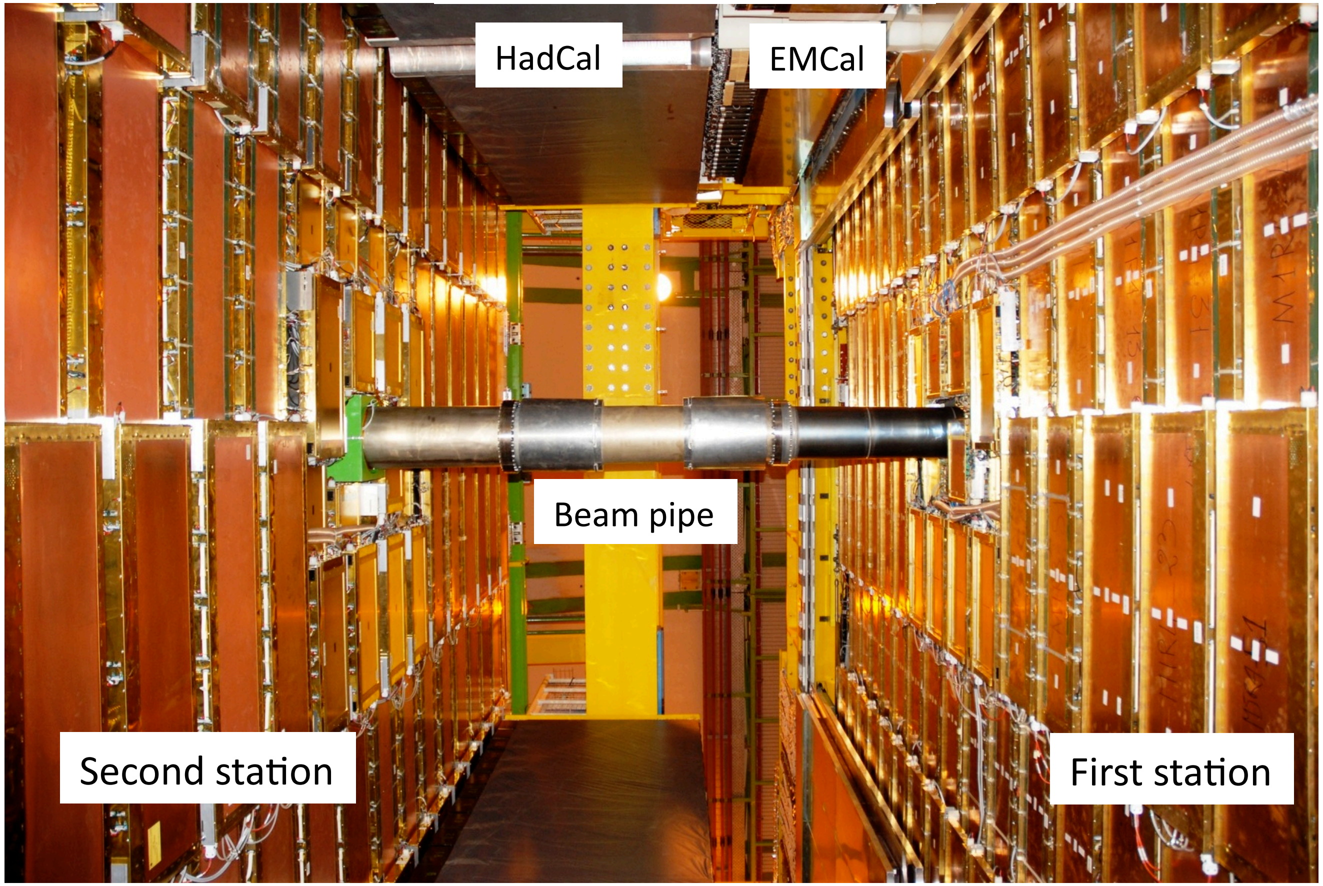




Muon System



Calorimeters in open position



View from bottom up

Five stations sandwiched with iron filter

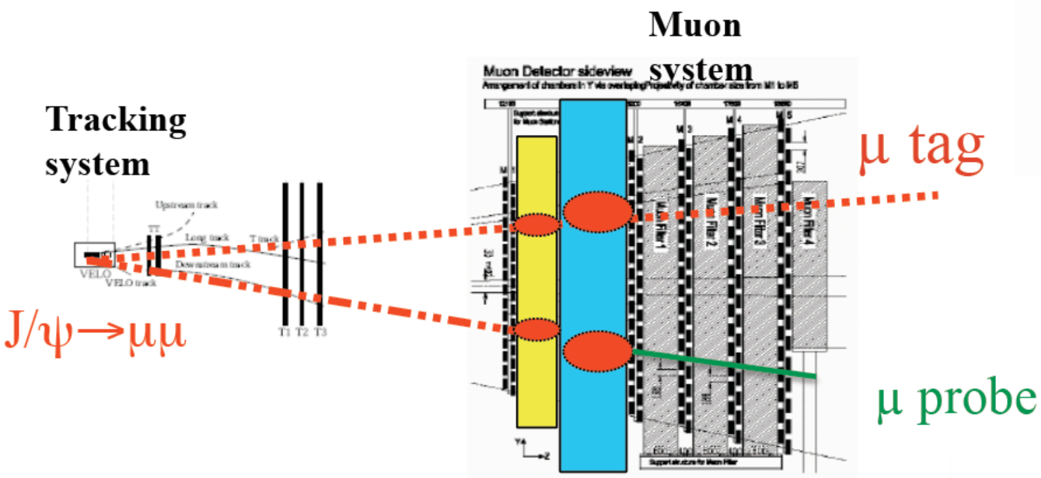
1368 Multi Wire Proportional Chambers ($438\ m^2$) with two double gaps

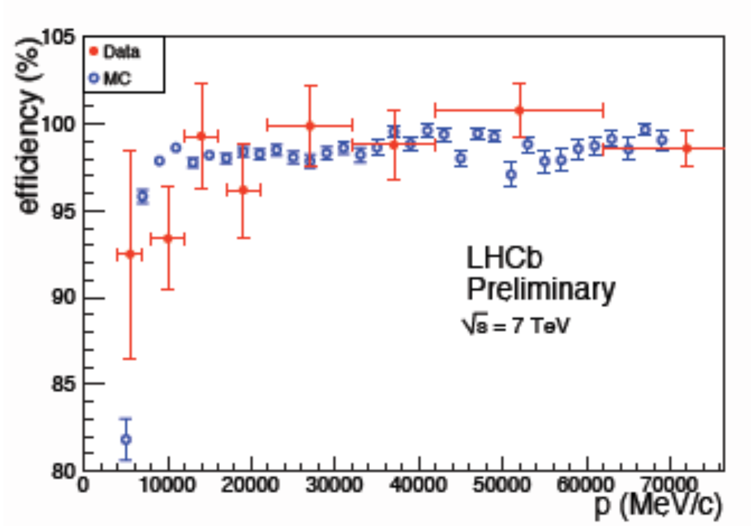
24 Triple GEM chambers in inner part of first station

The 'logical OR' of two double gaps allows to reach an efficiency of >99% per station

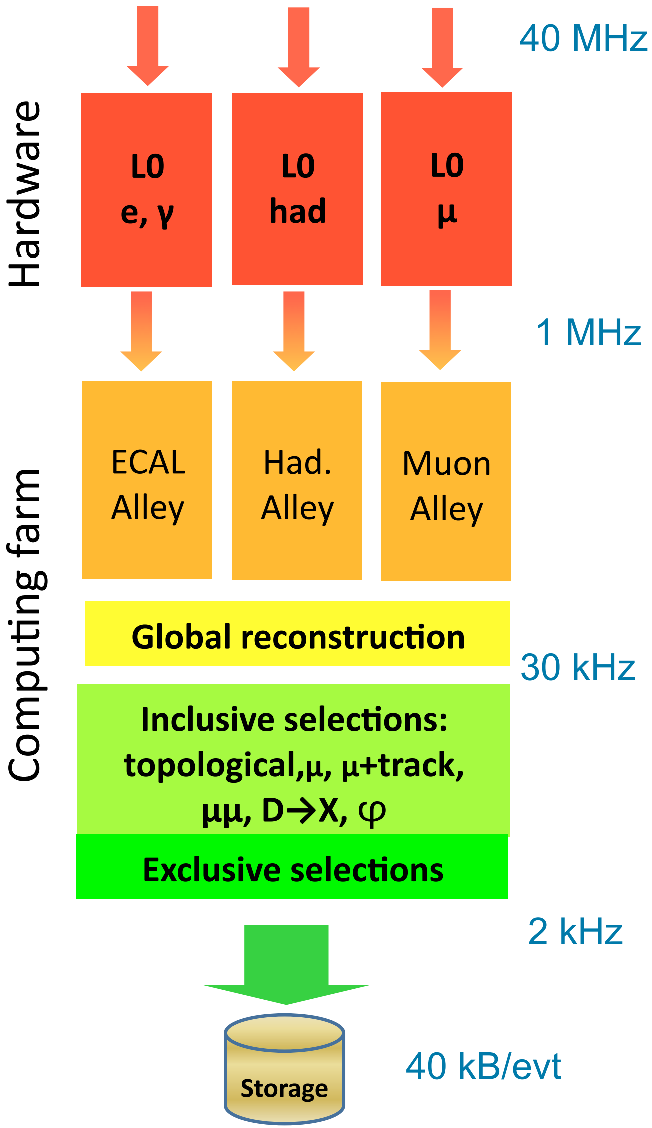
Muon ID Performance

- Muon ID efficiency estimated from J/ψ data with "tag/probe" method
- ε(μ) = 97.3 ± 1.2 (stat)% very good agreement!
- Also, mis-ID has been tested with different channels – good agreement found





Trigger



Level-0

'High-p_T' signals in calorimeter & muon systems

HLT1

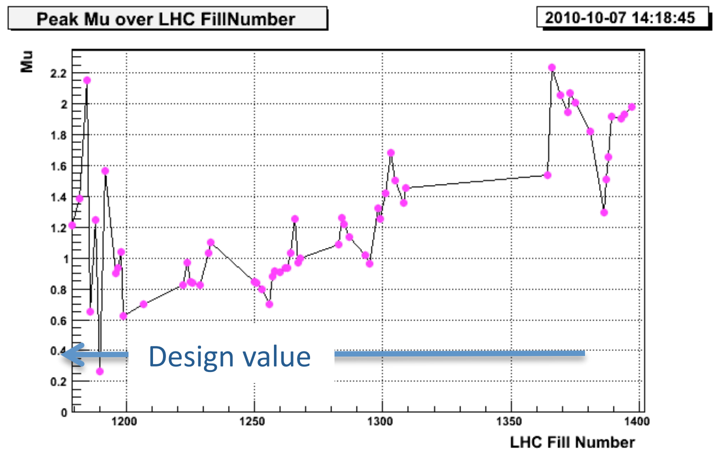
Associate Level-0 signals with tracks, especially those in VELO displaced from PV

HLT2

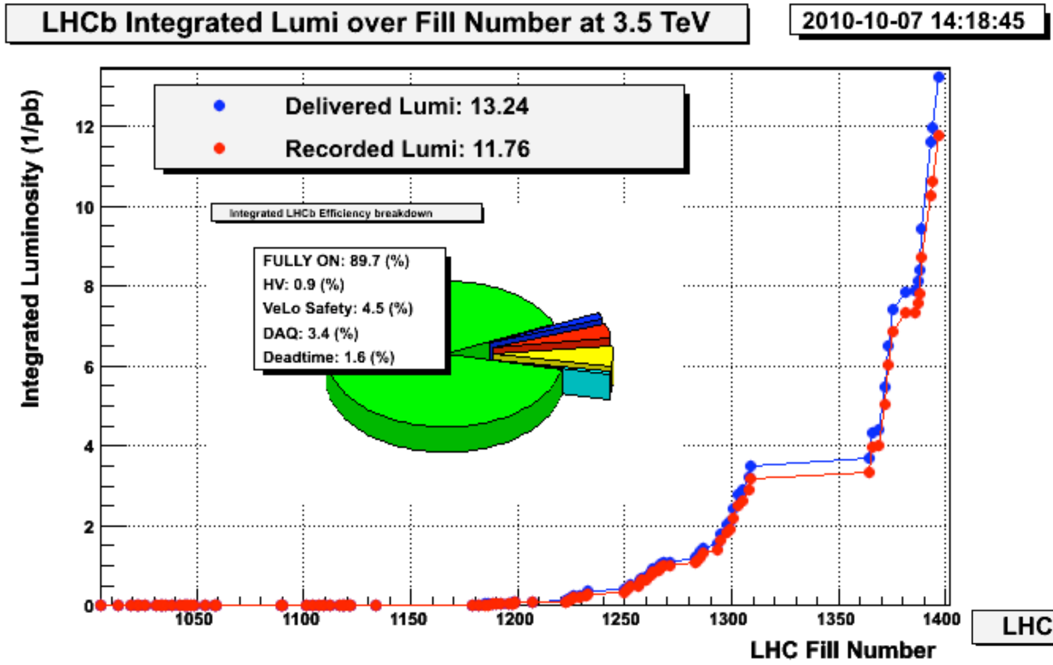
Full detector information available for inclusive and exclusive selections

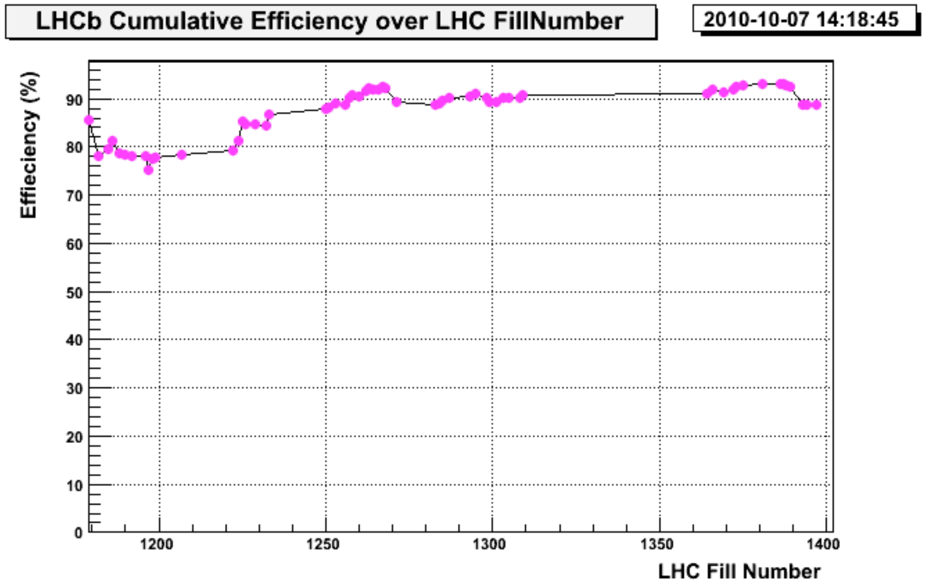
- In 2010 run HLT with loose requirements, but adapting to the increasing luminosity
- As from July running with higher pile-up than nominal LHCb conditions, which required adaptation of trigger settings

Average number of visible pp interactions per crossing (μ)



LHCb: accumulated data and efficiency

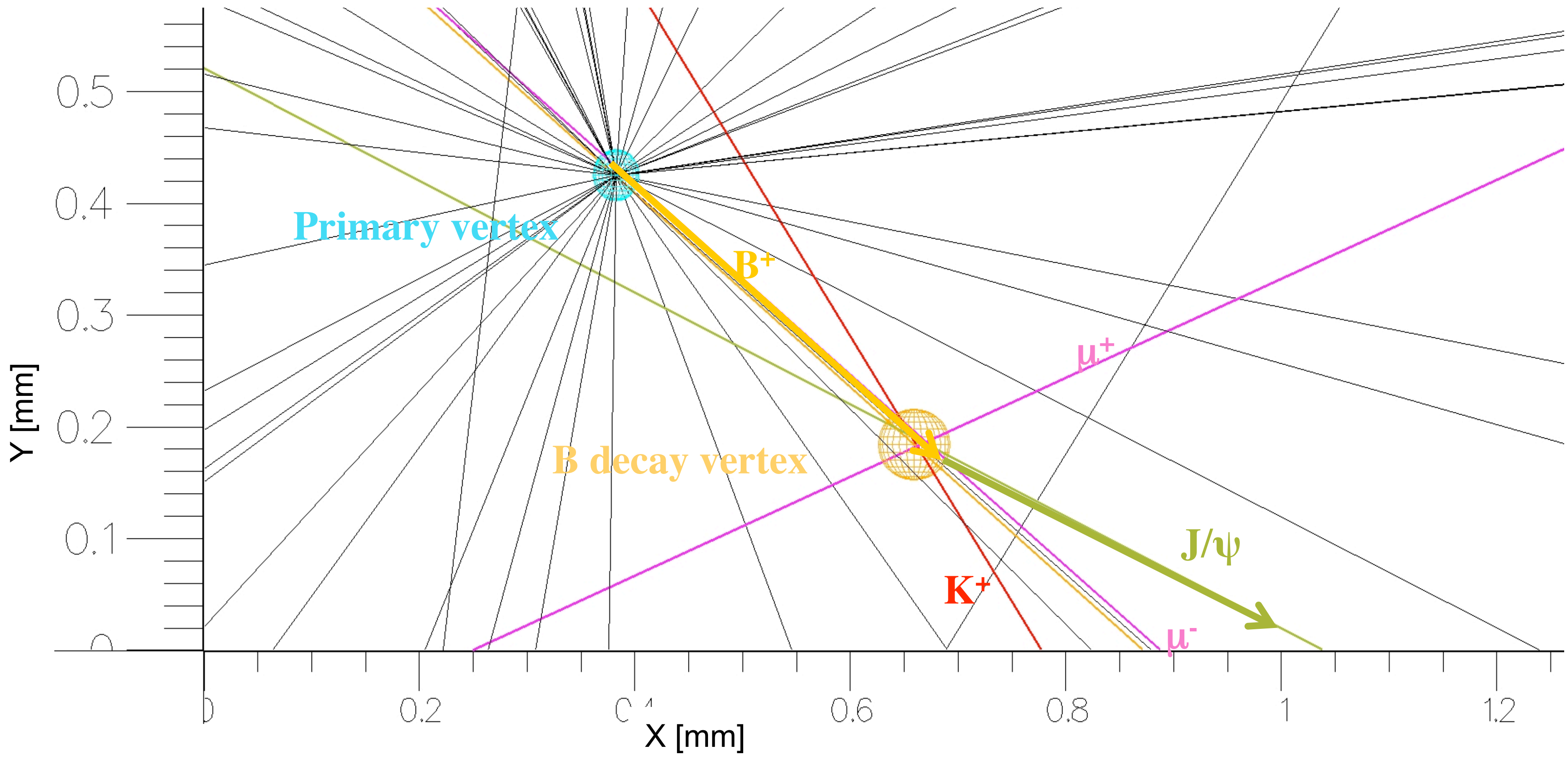




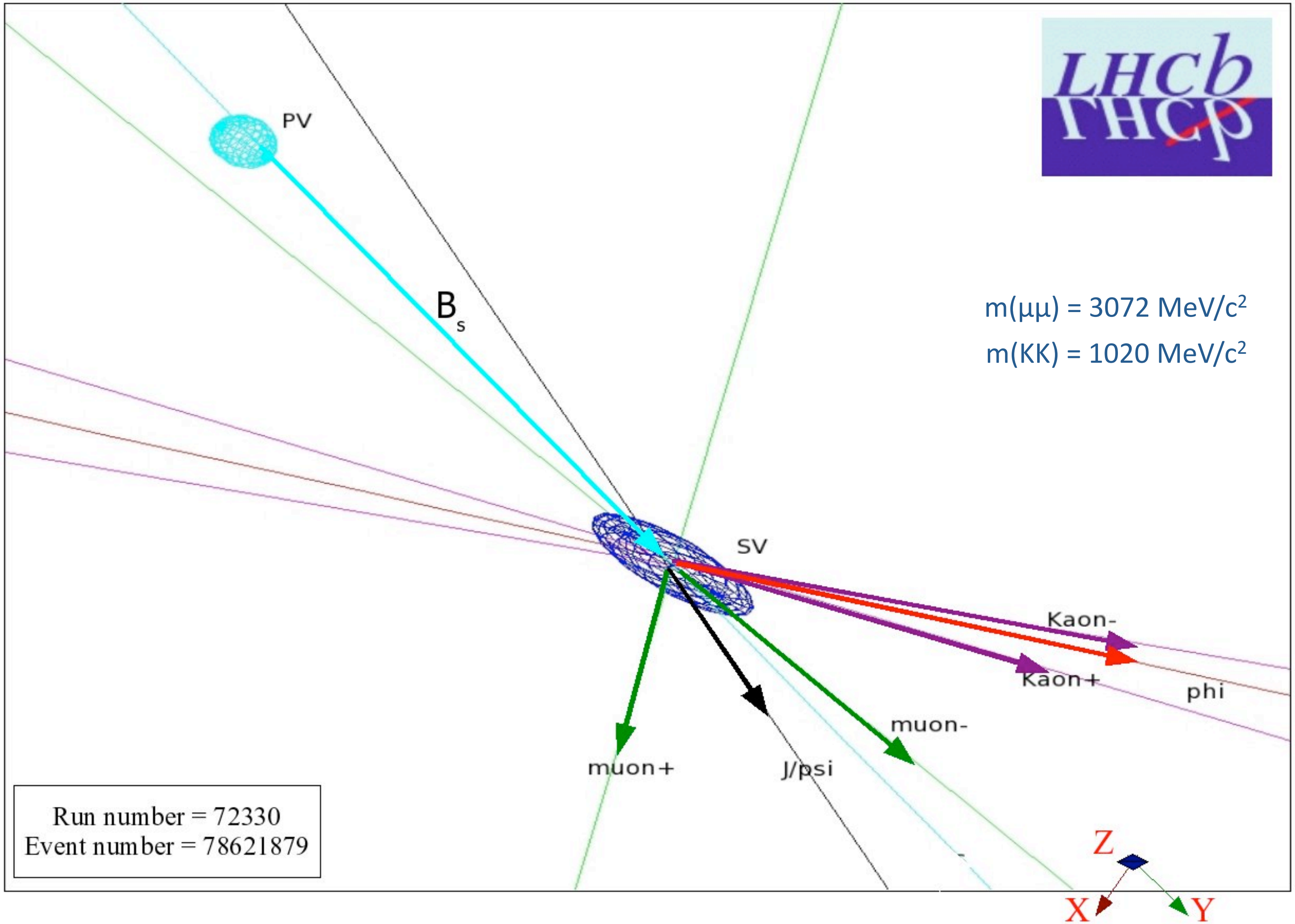
Cumulative data taking efficiency is reaching ~90 %

$B^+ \rightarrow J/\psi\ K^+$

21 April 2010 : first reconstructed beauty particle



$B_S \rightarrow J/\psi\ \phi$



Summary

- LHCb has successfully started taking data
- The detector shows excellent performance fulfilling the expectations
- First physics papers have been published
- With 1 fb^{-1} of data expected by the end of 2011 an exciting physics program lies ahead