LHCb Detector Status

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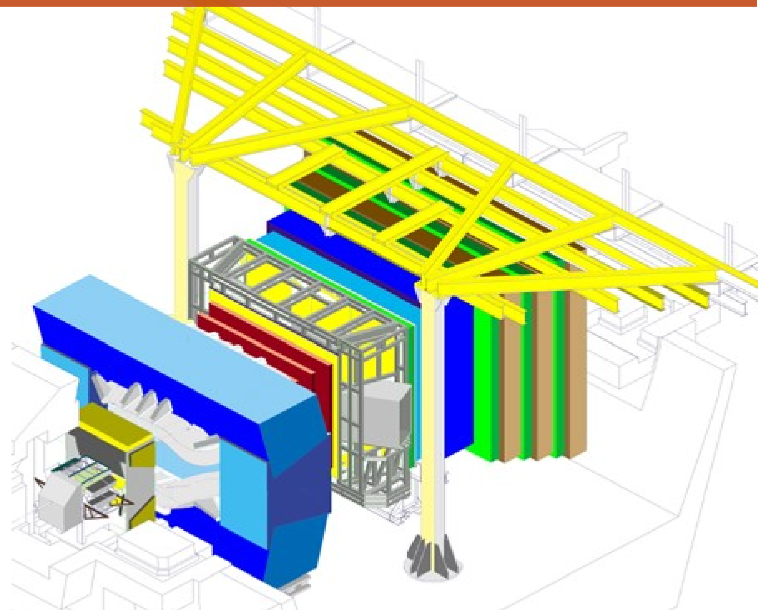


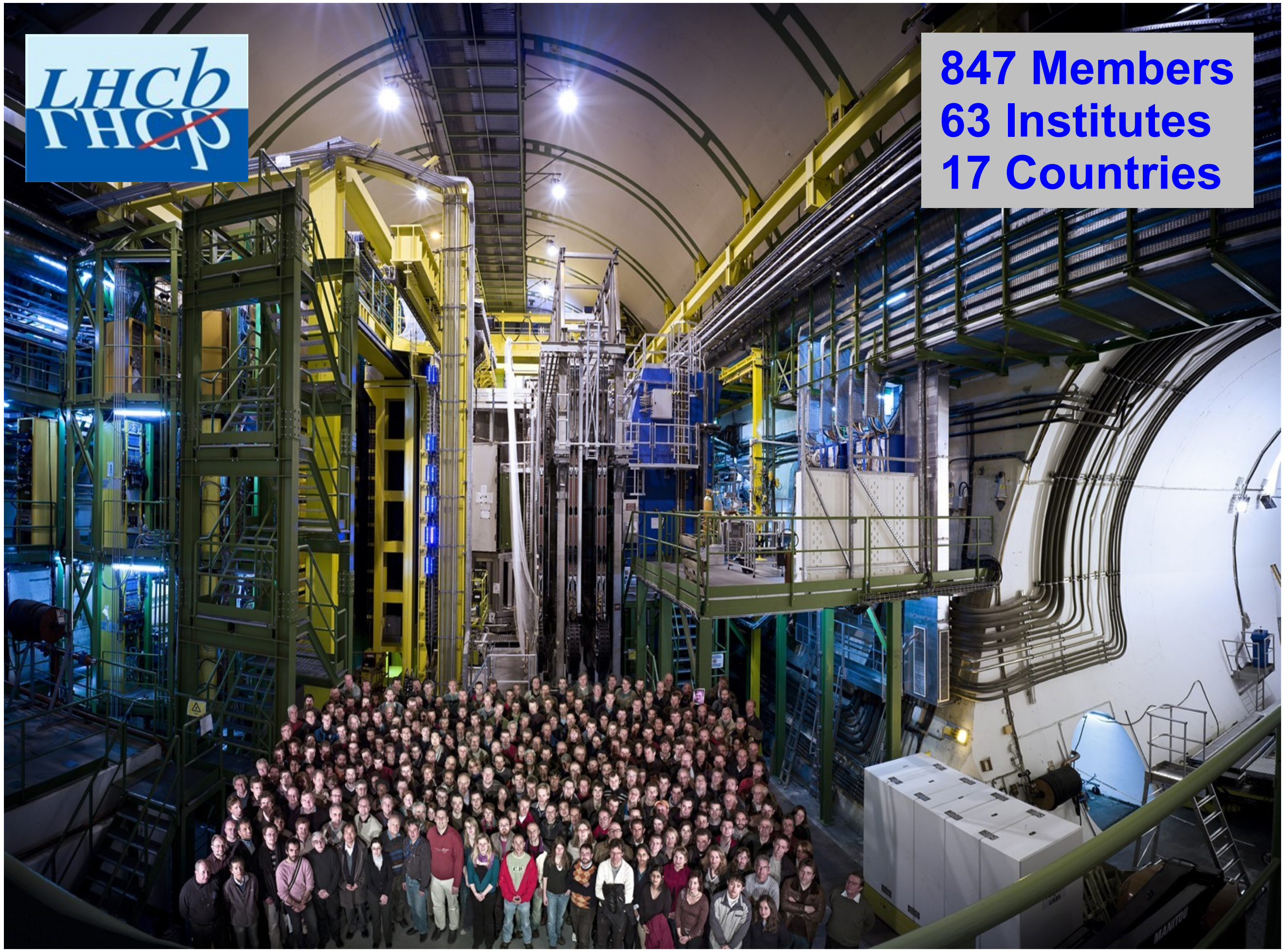
Outline

LHCb Detector:

- Vertexing
- Tracking
- PID
- Trigger

Performances

Operations



LHCb: Heavy Flavour Super Factory at LHC

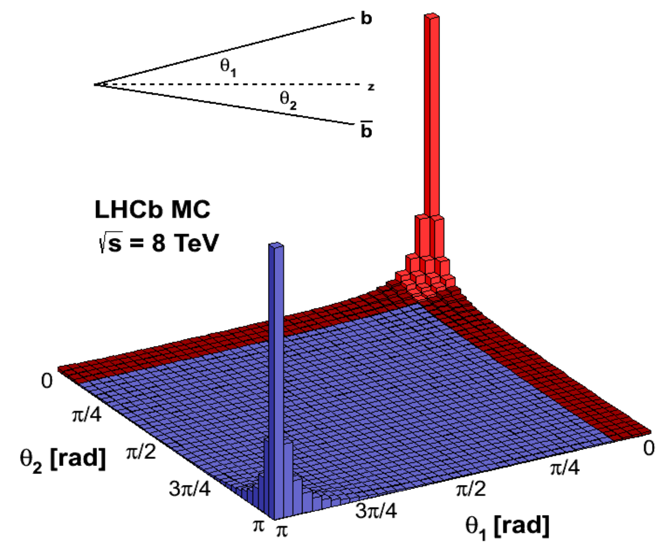
- LHCb is the dedicated **flavour physics experiment** at the LHC
  - Precision studies of *flavour changing* processes and *CP violation* with b and c-hadron decays
  - test SM/indirect evidence of NP + constraints on NP flavour structure

- Advantages to run at the LHC:
  - $b\bar{b}$ cross section: **~280 μb** (~75 ± 14 μb in LHCb acceptance) at $\sqrt{s}$=7 TeV [PLB 694 (2010) 209]
  - Charm production is 20 times larger: $\sigma(pp \to c\bar{c}X)$ = **~6 mb** [arXiv:1302.2864]
    - LHCb acceptance / 1 fb^{-1}:
      - **~10^{11} $b\bar{b}$ decays** [all species produced: B^0,B^+,B_s,B_c, Λ_b,..]
      - **~10^{12} $c\bar{c}$ decays**
  - Large boost: b-hadrons fly several millimeters before decaying
    - Signature for selecting events

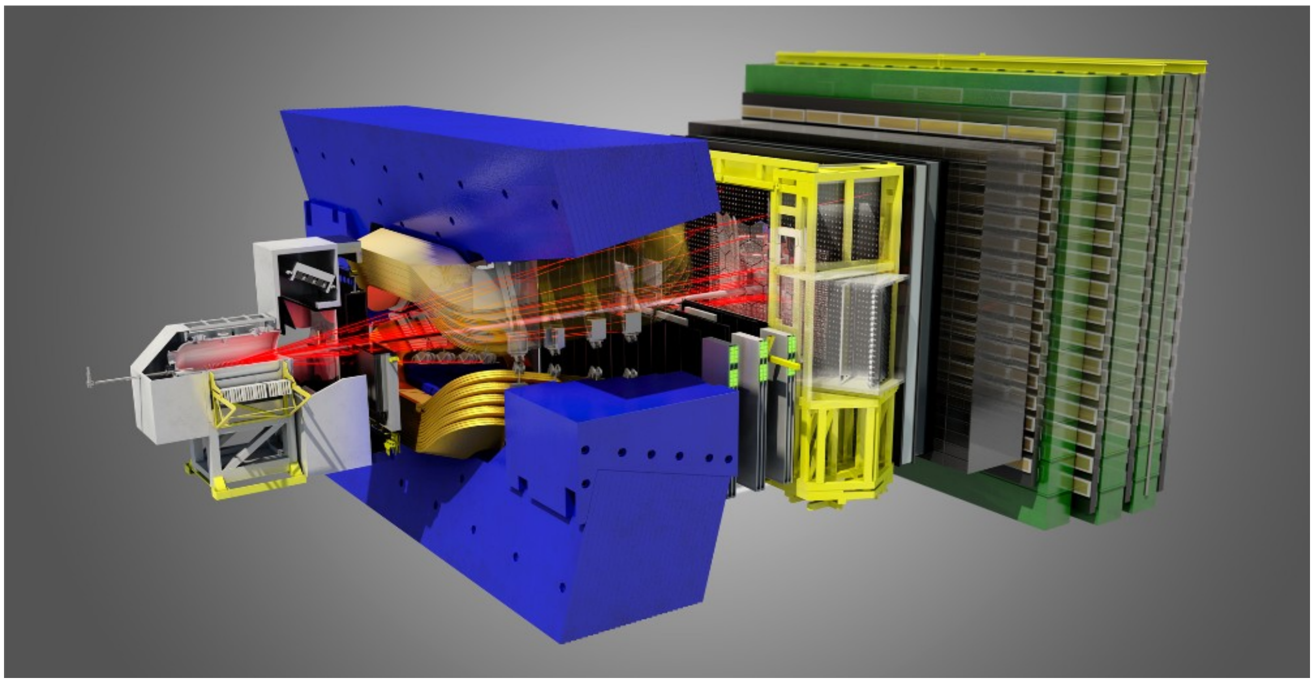
- Challenging background condition: efficient trigger essential
  - $\sigma(pp \to X)_{inel}$ = ~60 mb at $\sqrt{s}$=7 TeV [JINST (2012) P01010]

Detector Layout

Forward- and backward-peaked $b\bar{b}$ production:



LHCb is a single-arm forward spectrometer: $2 < \eta < 5$ (operating in collider mode)



General detector layout

- The vertex detector is a key component
- Dipole magnet, and tracking stations before/after, to measure accurately the momentum
- Particle identification by 2 RICH detectors, electromagnetic and hadronic calorimeters, and a muon system

The LHCb Detector (point 8)

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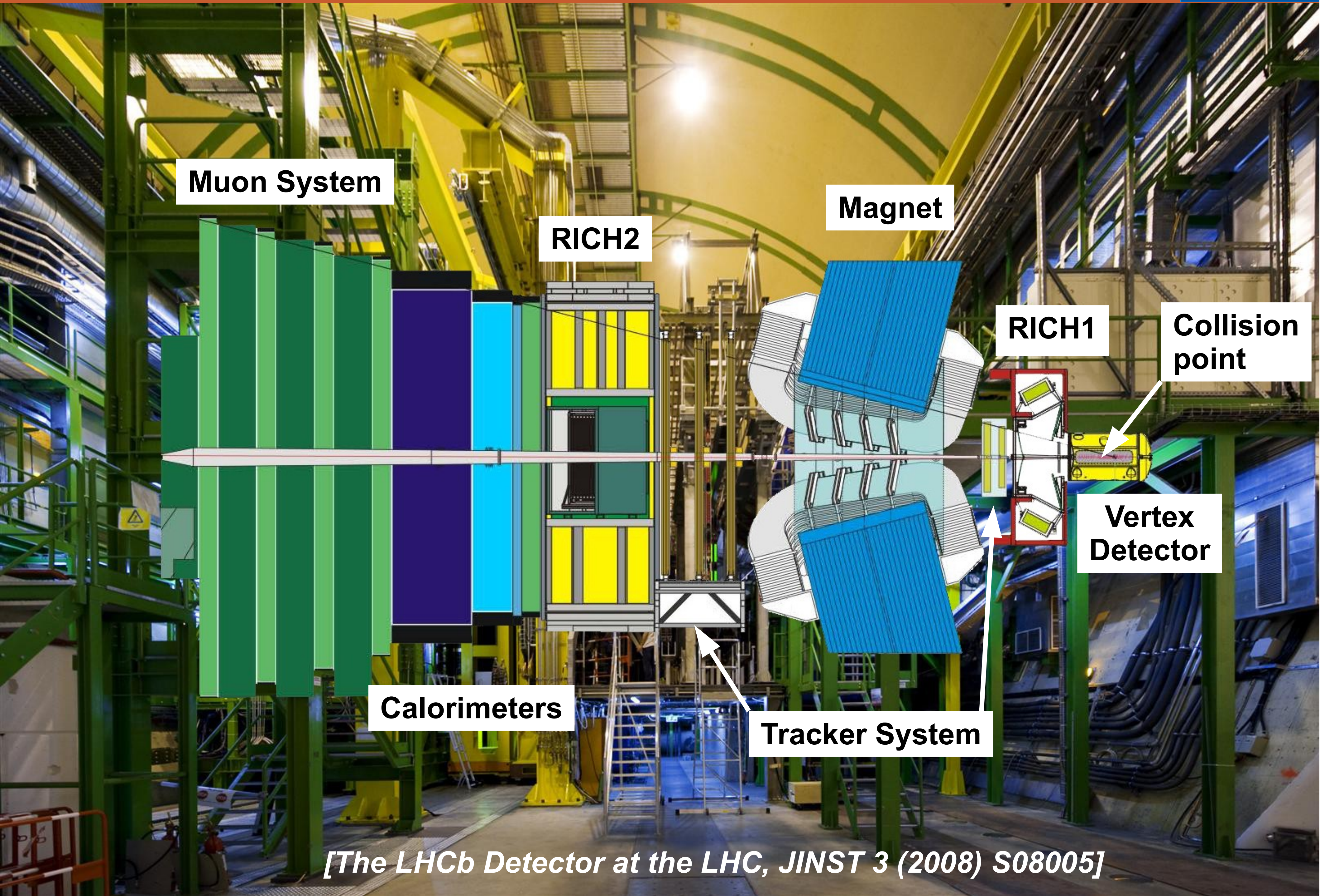
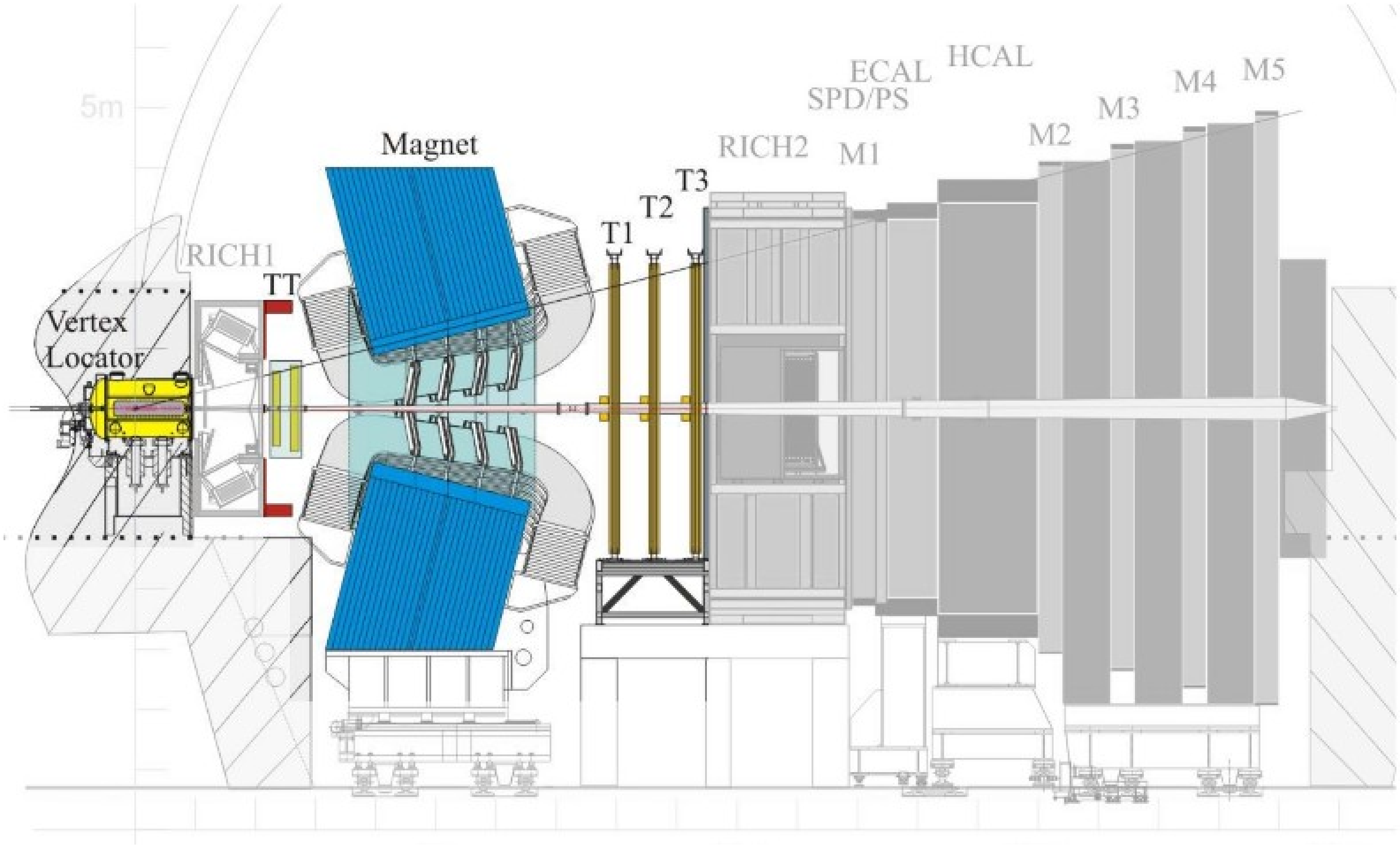


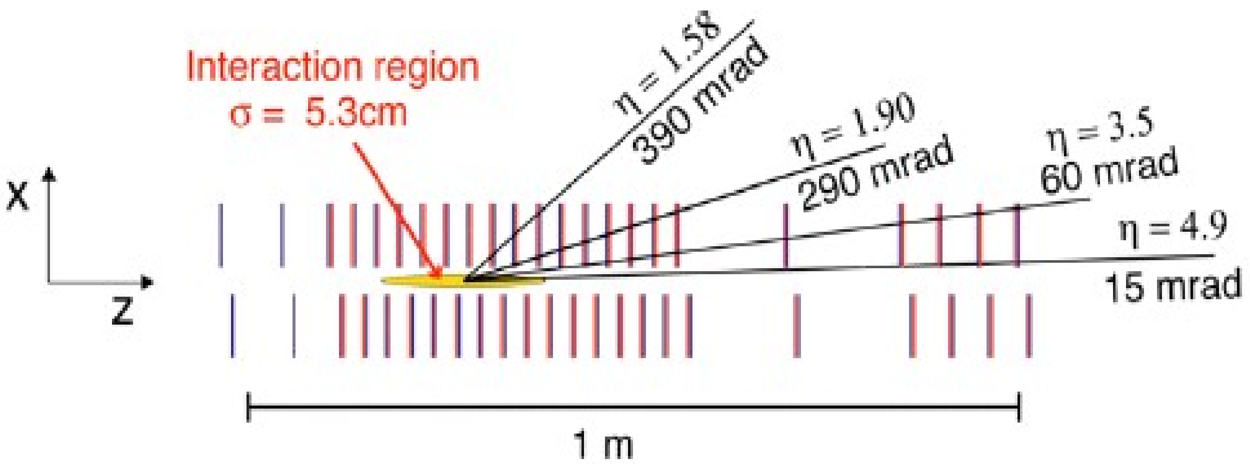
[The LHCb Detector at the LHC, JINST 3 (2008) S08005]

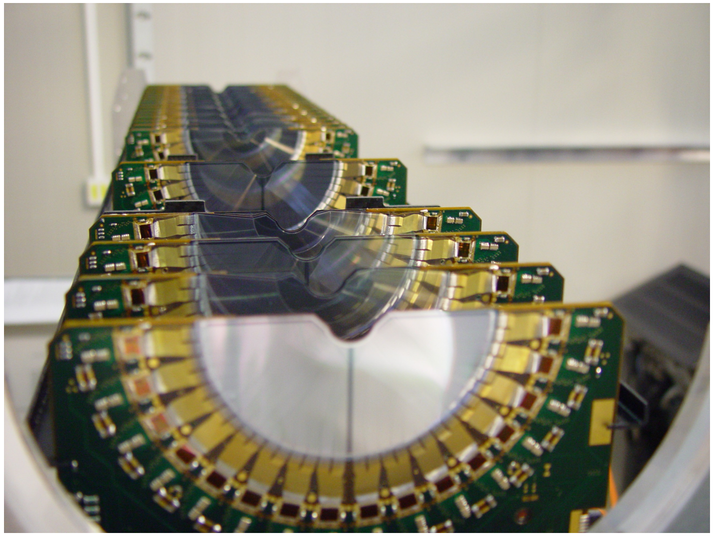
Vertexing and Tracking



Vertex Detection: VErtex LOcator (VELO)

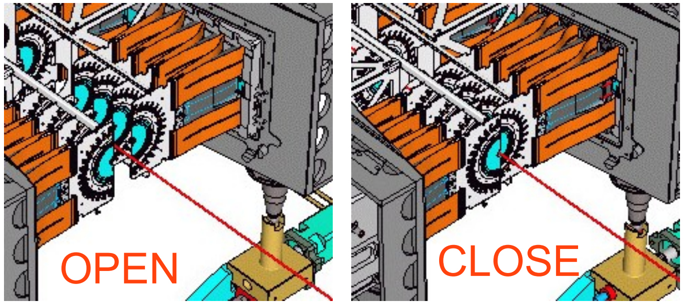
- Reconstruction of primary and decay vertices, track seeds + trigger input





- 21 modules of R-Φ silicon micro strip sensors
  - Pitch: ~40-100 μm
  - 44 mm radius

- Movable device (retracted for safety during beam injection):
  - 35 mm from beam in garage position
  - 8 mm from beam during "stable beams"



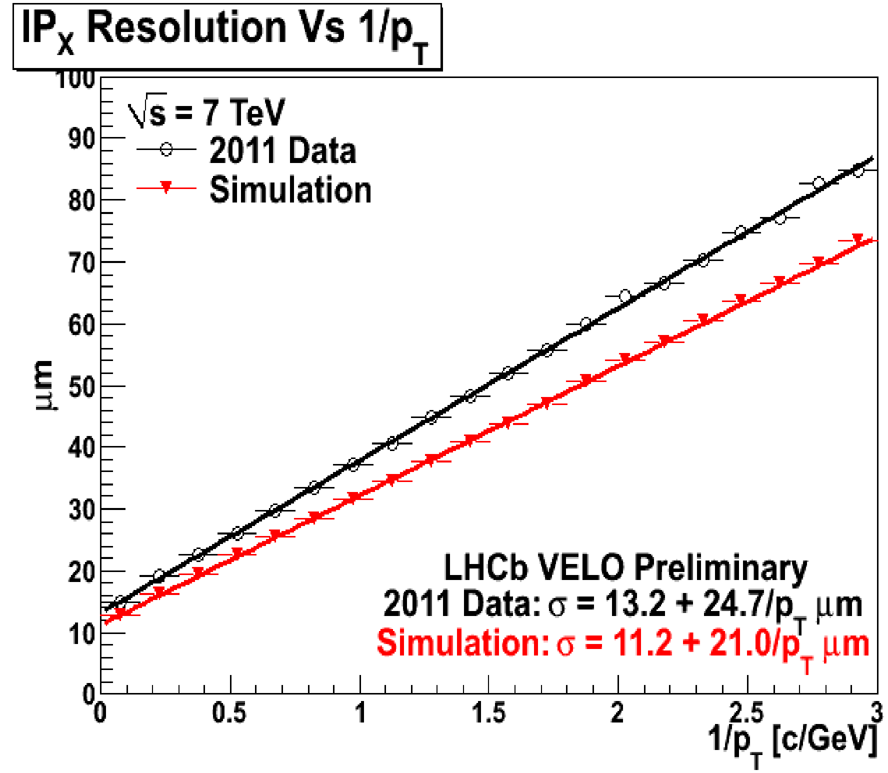
VELO Performances

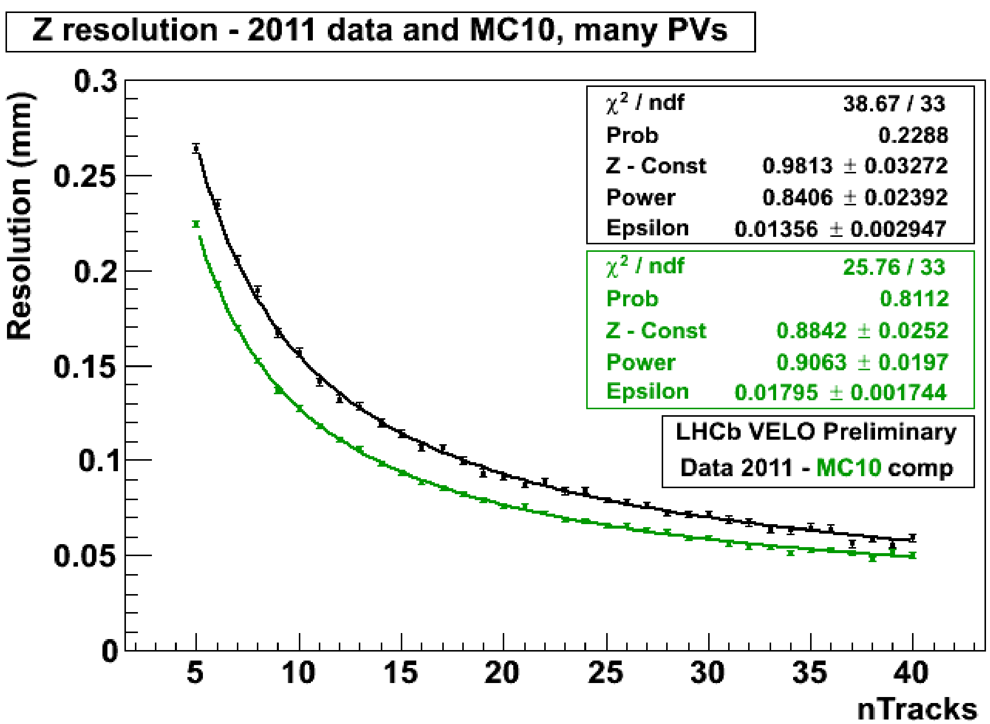
Impact parameter resolution:

- Essential to distinguish secondary from primary tracks

Very good resolution:

~ 20 μm for high p_T tracks (over 2 GeV/c)



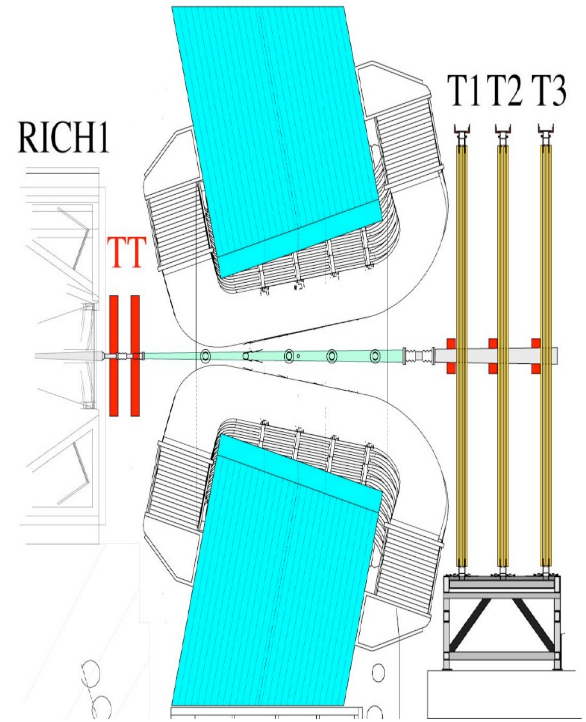


Primary vertex resolution: excellent

- 13 μm in x,y (25 tracks)
- 70 μm in z (25 tracks)

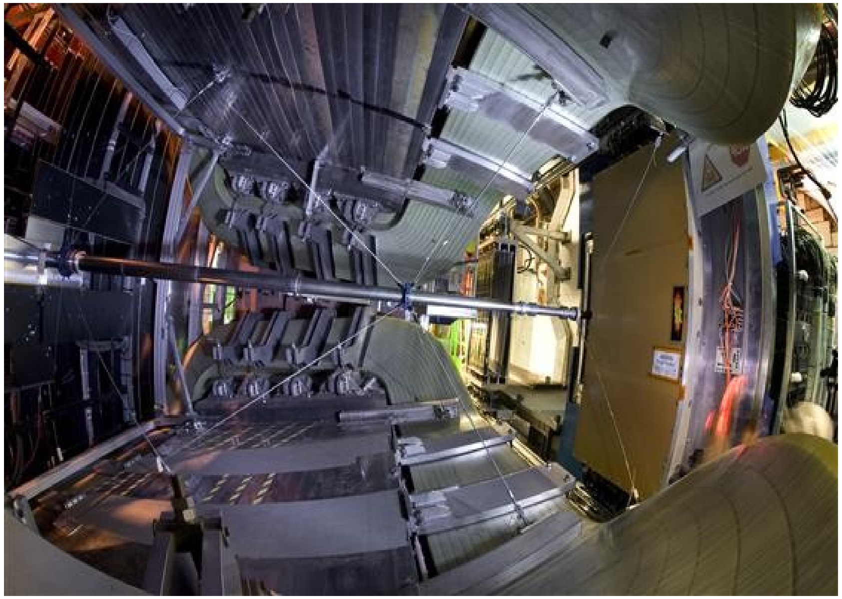
Tracking System

- One station (TT) before the magnet
  - Si strips, 4 layers
- Dipole magnet
  - ∫Bdl = ~ 4 Tm ; polarity switched regularly
- 3 stations after the magnet
  - Si strips in centre (IT), straw tubes outside (OT)
  - 4 layers per station x-u-v-x, (5 degree stereo angle)

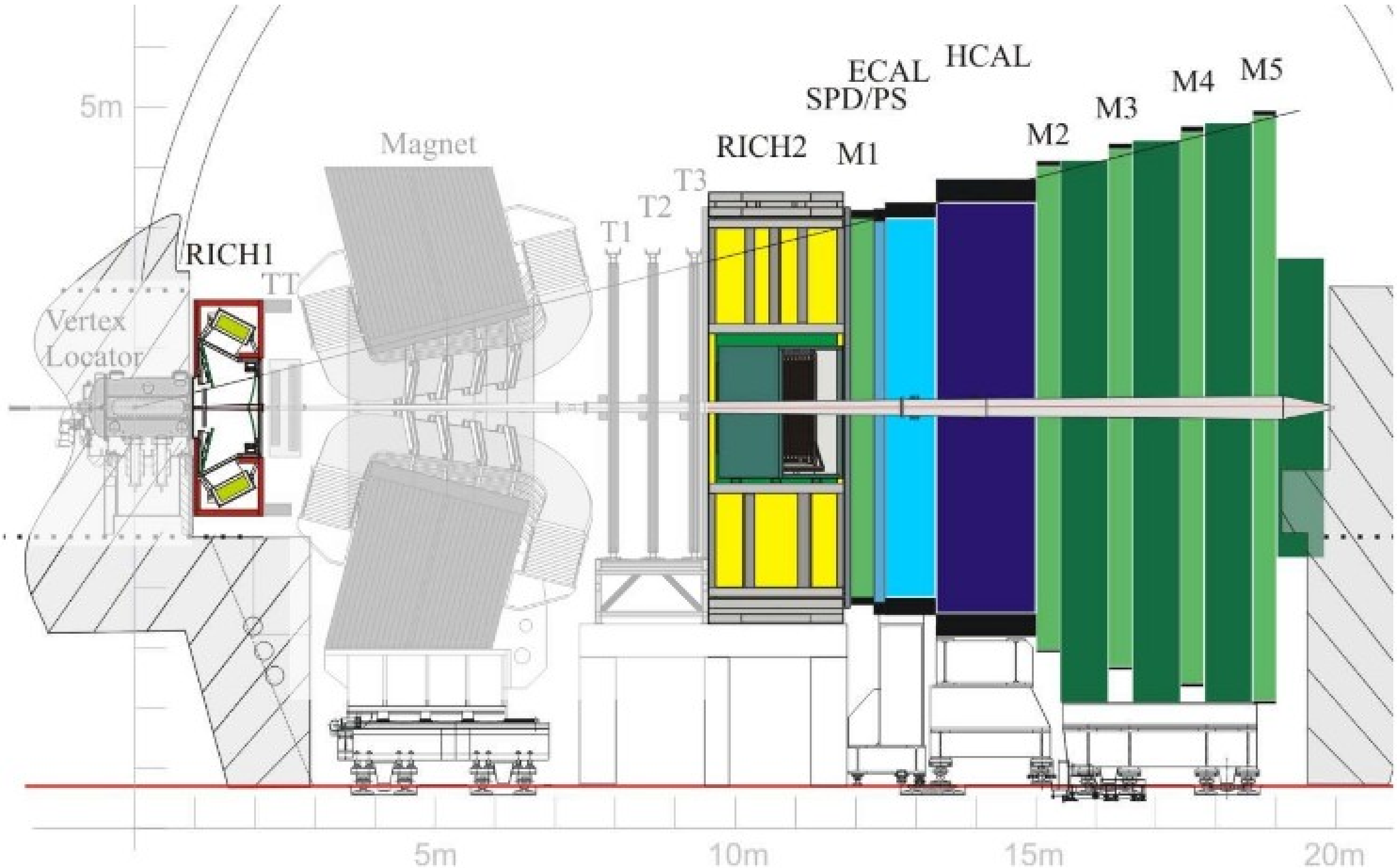


Tracking efficiency over 96%

For tracks traversing the whole detector, over 5 GeV/c momentum

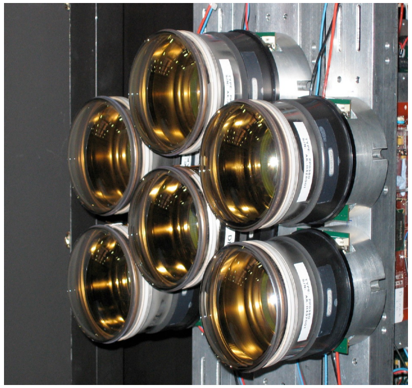


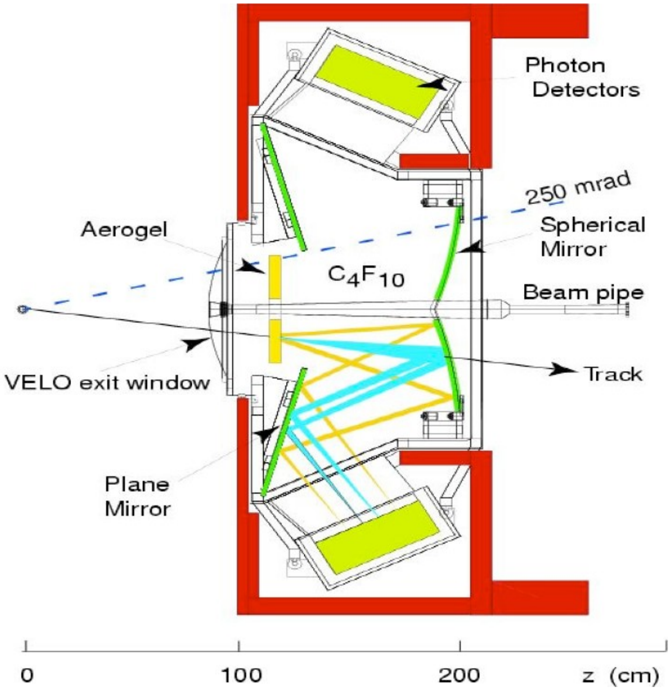
Particle Identification



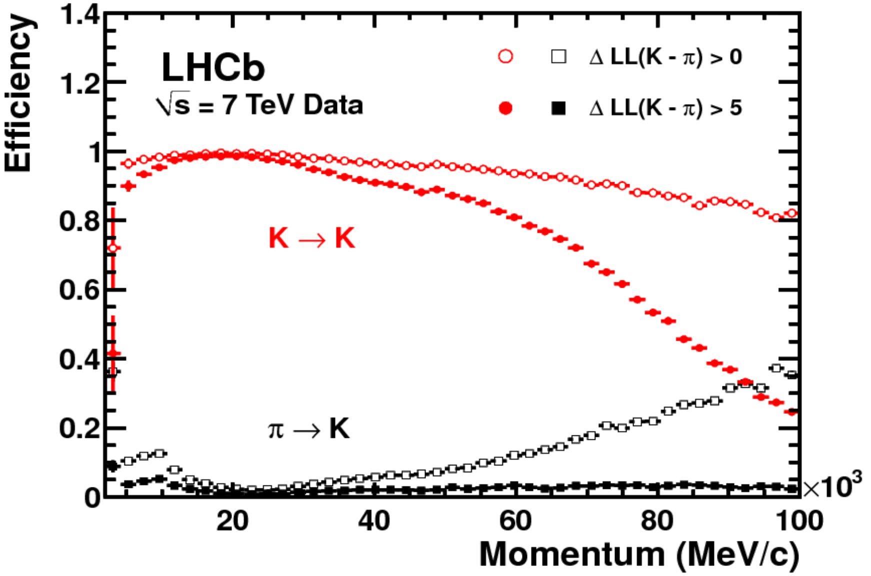
RICH

- Particle identification from 2 to ~100 GeV/c
  - 2 RICH detectors, 3 radiators:
    - RICH1: aerogel + C_4F_{10} (1-60 GeV/c)
    - RICH2: CF_4 (15-100 GeV/c)
  - Readout by HPD (Hybrid Photon Detectors)
    - ~500, 1024 pixels
    - High efficiency, low noise



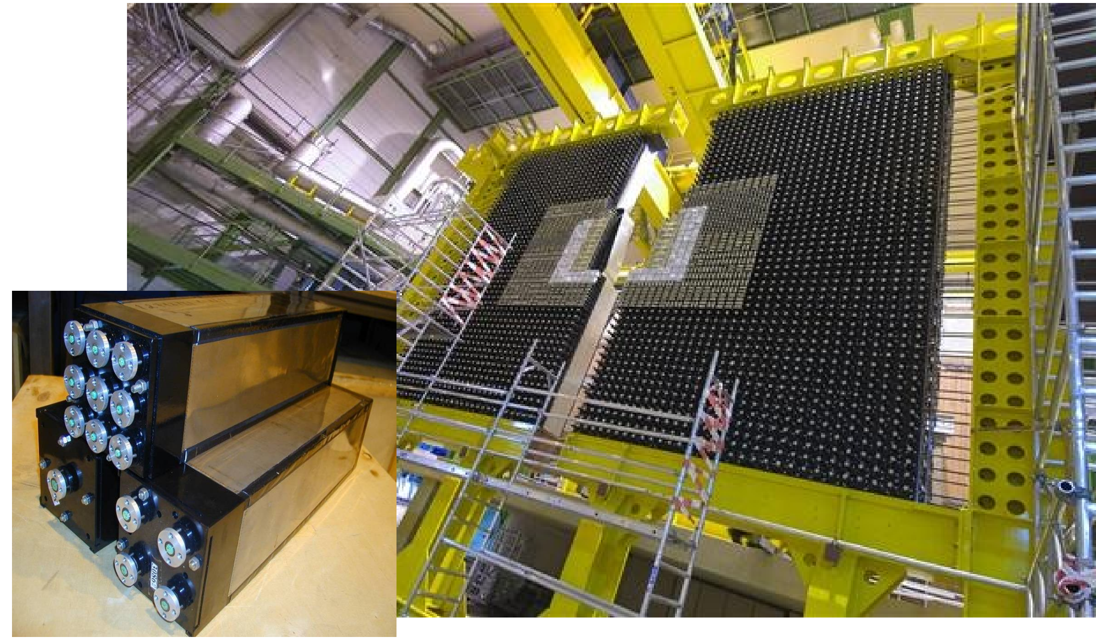


- Particle ID performance:
  - ~95% efficiency for 5% π-K contamination
    - Averaged over B daughter tracks

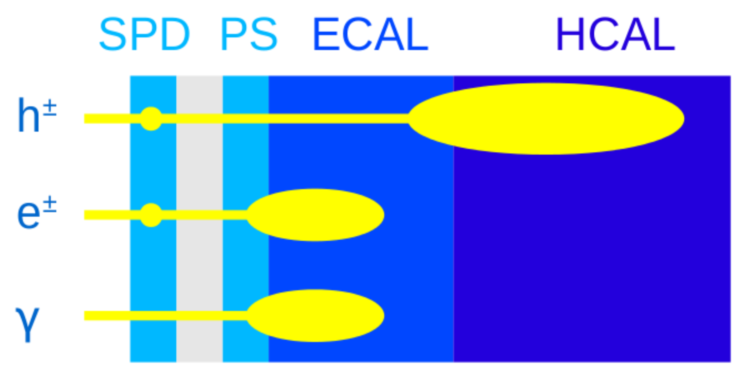


Calorimeters

- ECAL made of shashlik blocks
  - Lead - scintillator stack (25 X_0)
  - ~6000 channels, readout by PMT
  - $\sigma(E)/E \sim 10\% / \sqrt{E} + 1\%$



- HCAL: scintillating tiles in iron
  - ~1500 channels, same readout and electronics as ECAL
  - $\sigma(E)/E \sim 70\% / \sqrt{E} + 9\%$
  - Mainly used for trigger

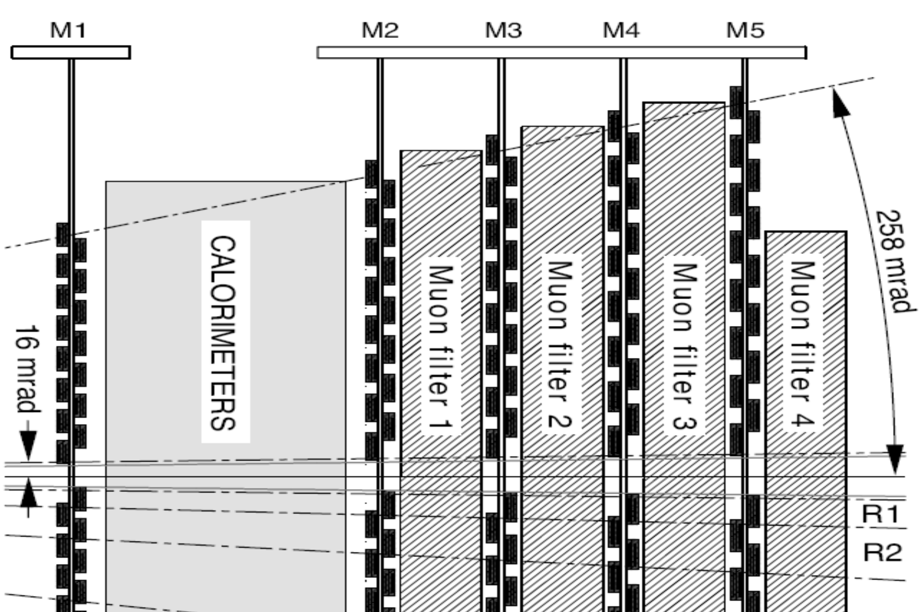


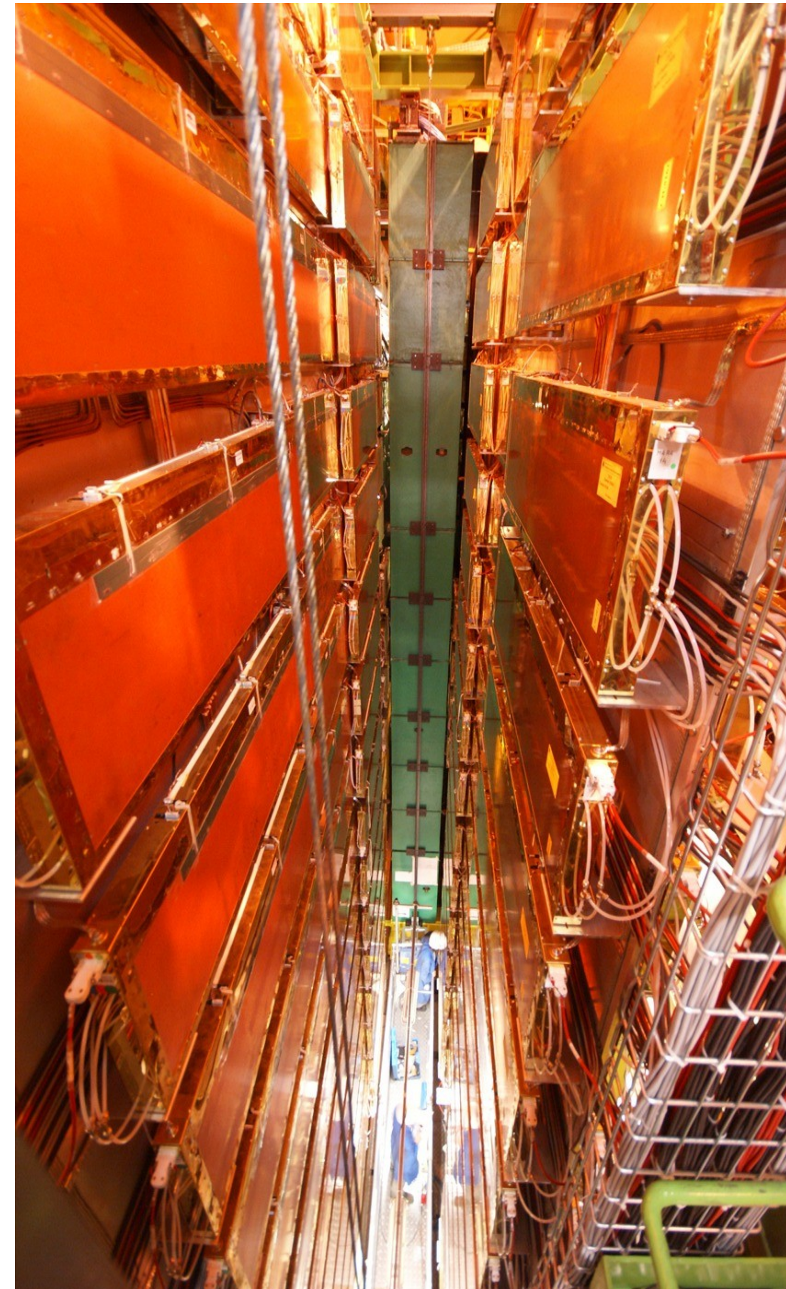
- SPD and PreShower
  - same geometry as ECAL
  - Scintillator tiles readout by MAPMT, separated by 2.5 X_0 lead sheet
  - Identify electron/photon, used in L0 trigger

Muons

- 5 stations (MWPCs) interleaved with iron walls
  - First station before the calorimeters
  - Projective geometry
    - Allows it to be used in the L0 trigger

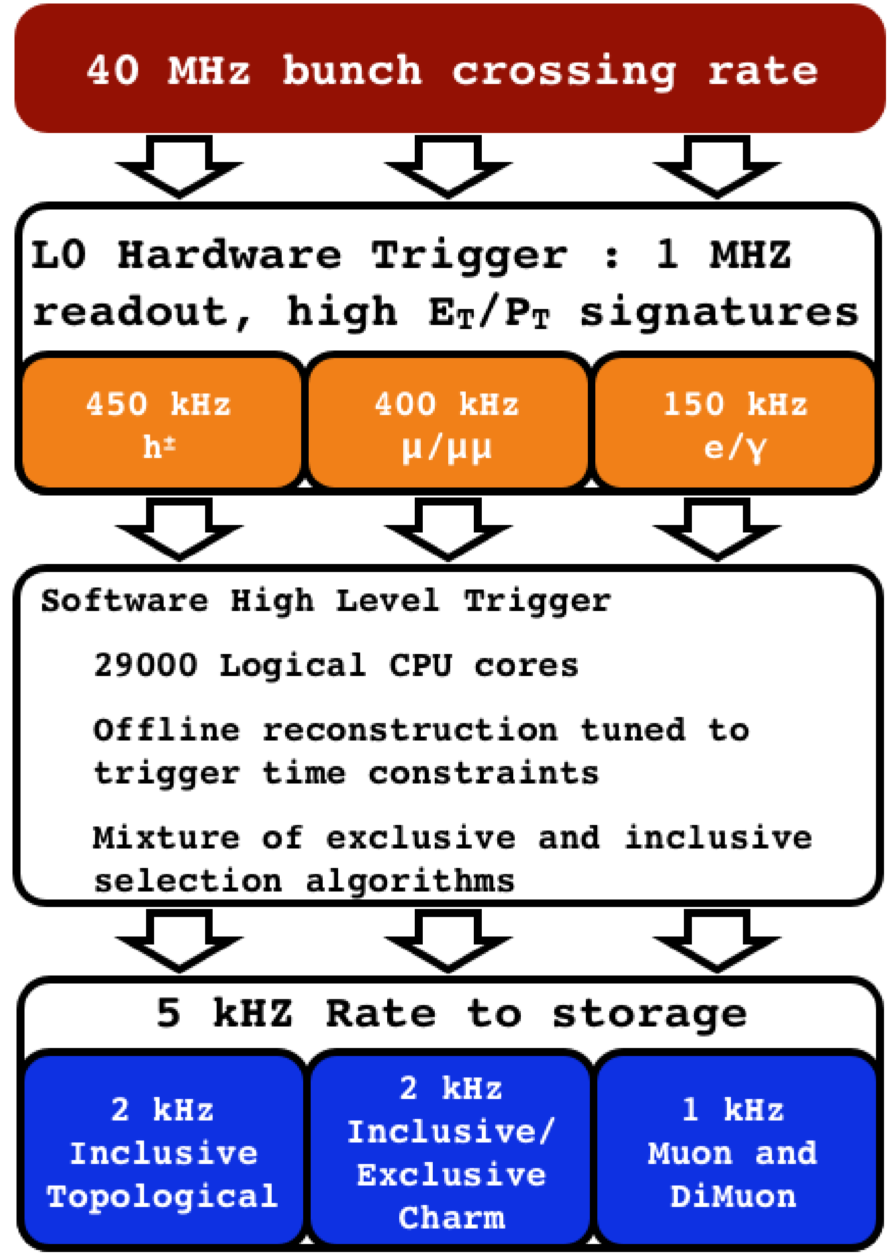
- Muon identification performance
  - ~97% efficiency for 3% π-μ miss-ID.





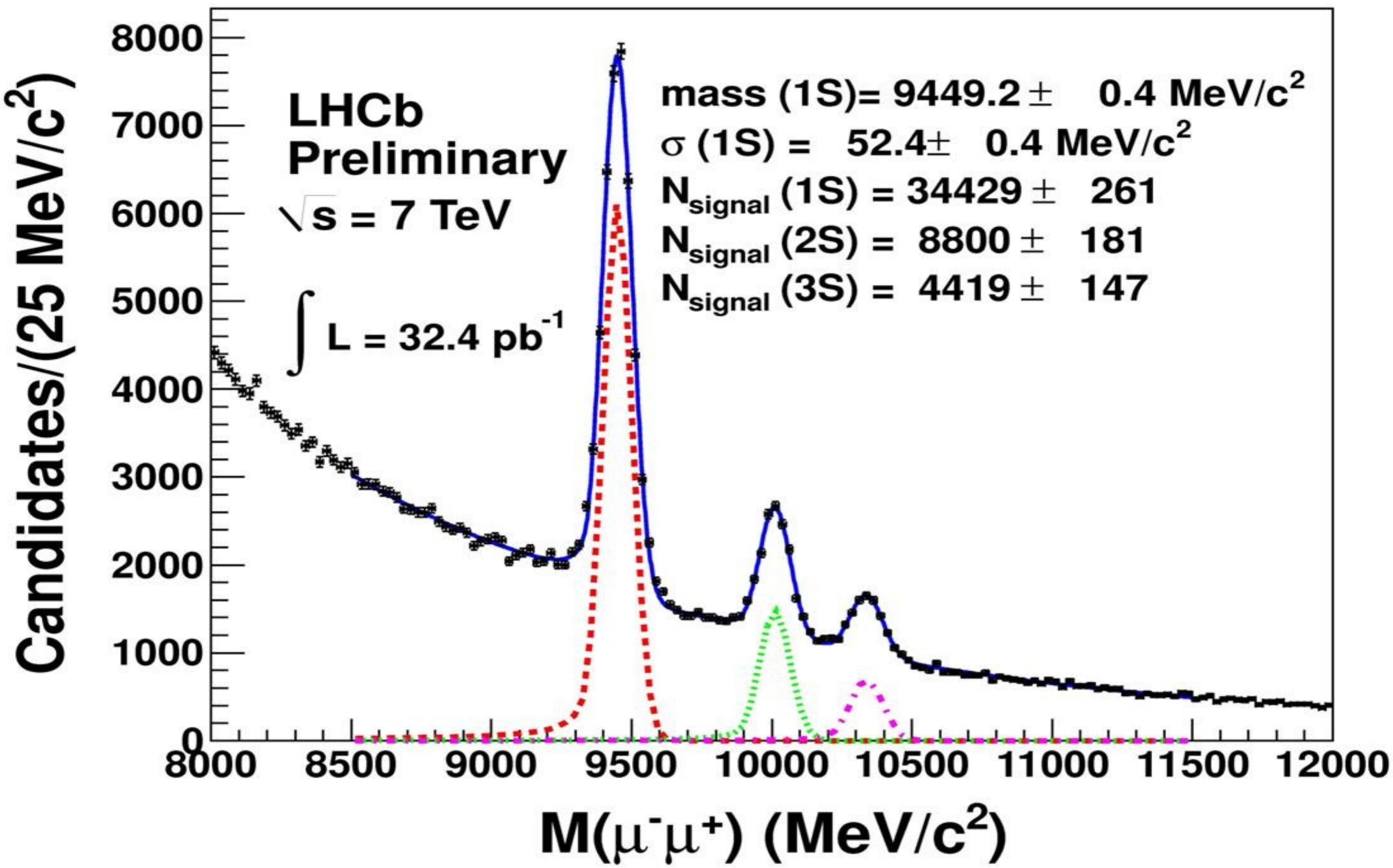
Trigger

- Level-0 trigger: hardware (1 MHz max)
  - 4 μs latency @ 40MHz
  - “Moderate” E_T/p_T threshold:
    - *$E_T(e/\gamma)>2.7$ GeV; $E_T(h)>3.6$ GeV*
    - *$p_T(\mu)>1.4$ GeV/c*
- HLT trigger: software
  - ~30000 tasks in parallel on ~1500 nodes
  - Processing time available O(35-40 ms)
- Storage rate: 5 kHz
- Combined efficiency (L0+HLT):
  - ~90 % for di-muon channels
  - ~30 % for multi-body hadronic final states
  - ~10-20% for charm decays



Design specs: HLT output rate 200 Hz

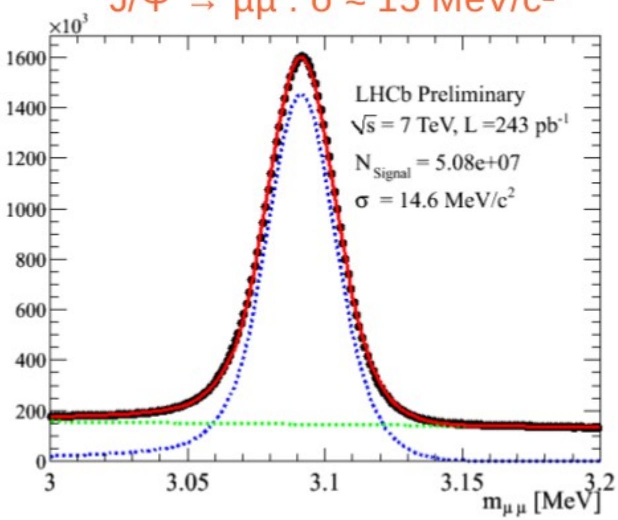
Performances: illustrations



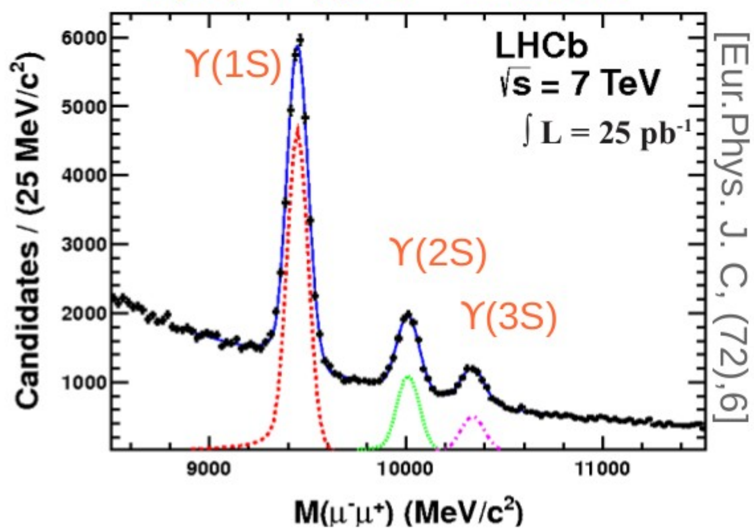
Tracking Performances

- Excellent momentum resolution
  - From 0.4% at 5 GeV/c to 0.6% at 100 GeV/c
    - Important ingredient to study narrow states
- Momentum scale and detector alignment well controlled:
  - World best measurements of b-hadron masses (2010 data, 37 pb^{-1})

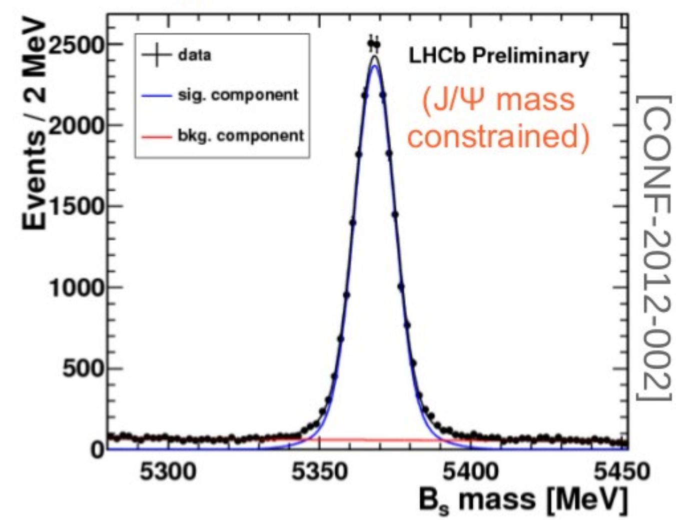
$J/\Psi \rightarrow \mu\mu$: $\sigma \approx 15$ MeV/c²



$\Upsilon(1S) \rightarrow \mu\mu$: $\sigma \approx 54$ MeV/c²



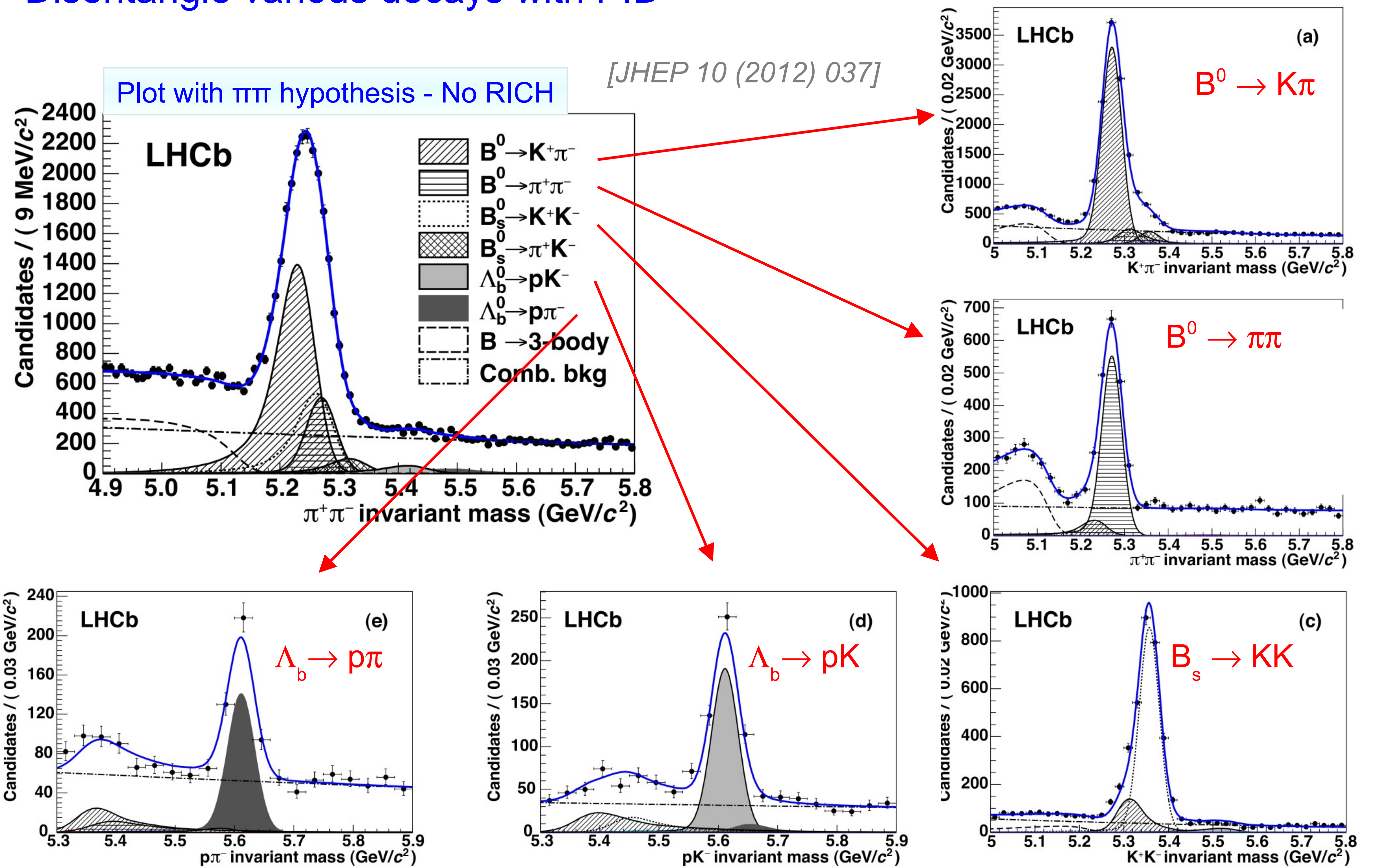
$B_s \rightarrow J/\Psi\Phi$: $\sigma \approx 8$ MeV/c²



[CMS DPS-2010-040] ~ 16 MeV/c²
[ATLAS CONF-2011-050] ~ 22 MeV/c²

Particle Identification Performances

Disentangle various decays with PID

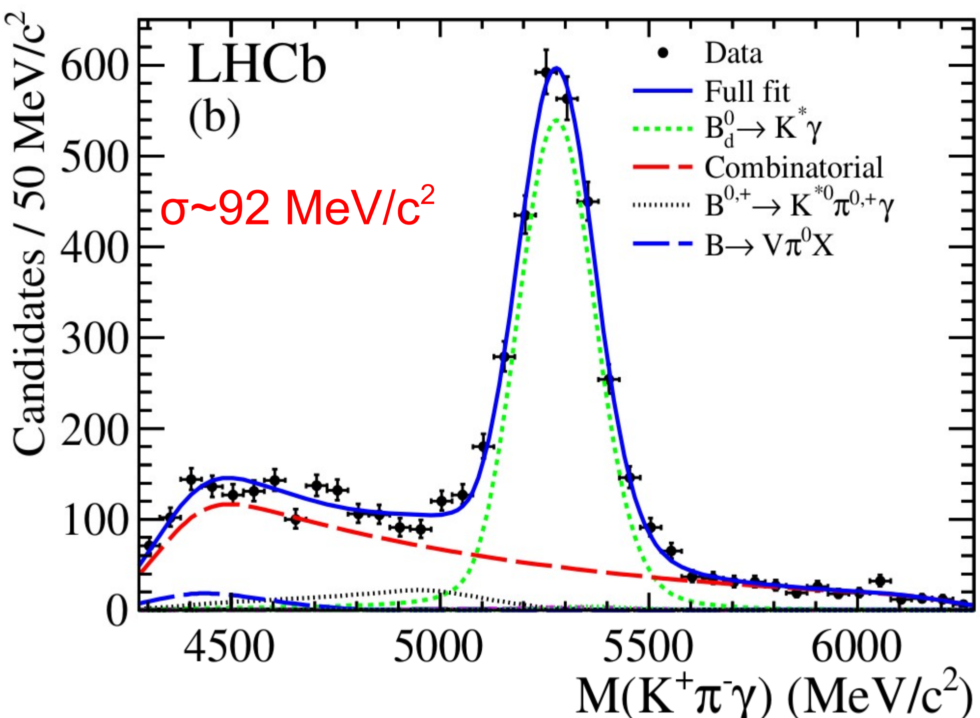


Calorimeter Performances

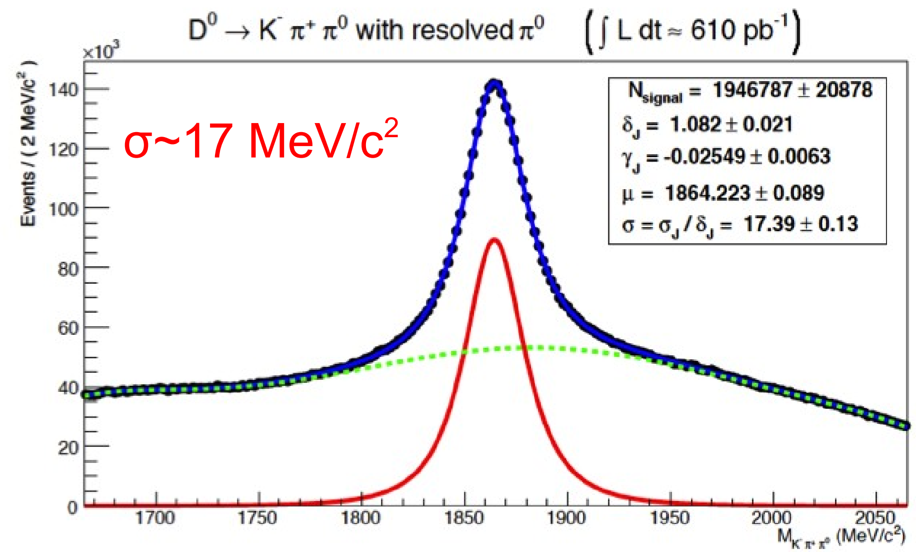
Invariant mass resolution:

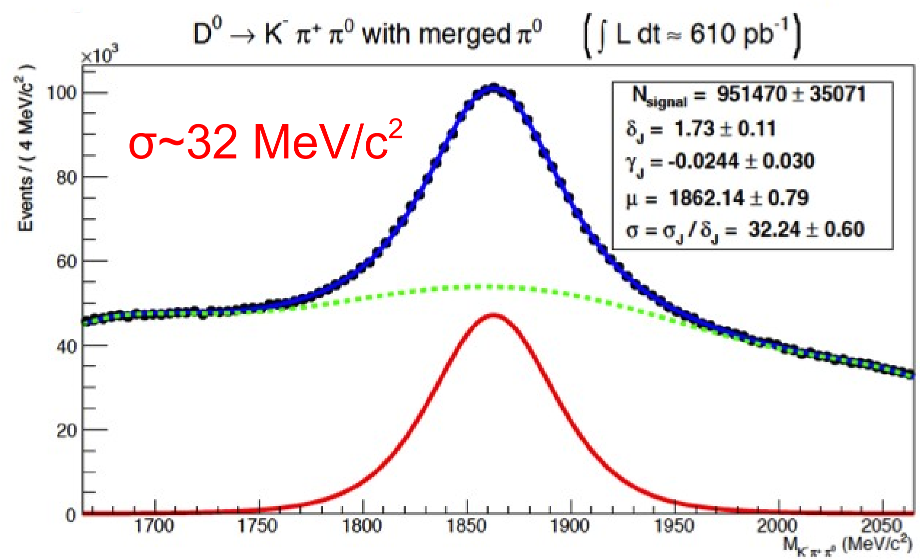
Neutral pion: $D^0 \rightarrow K\,\pi\,\pi^0$

High energy photon: $B^0 \rightarrow K^{*0}\,\gamma$



[NP B 867 (2012) 1]





LHCb Operation

Operation: Luminosity

LHCb designed luminosity:

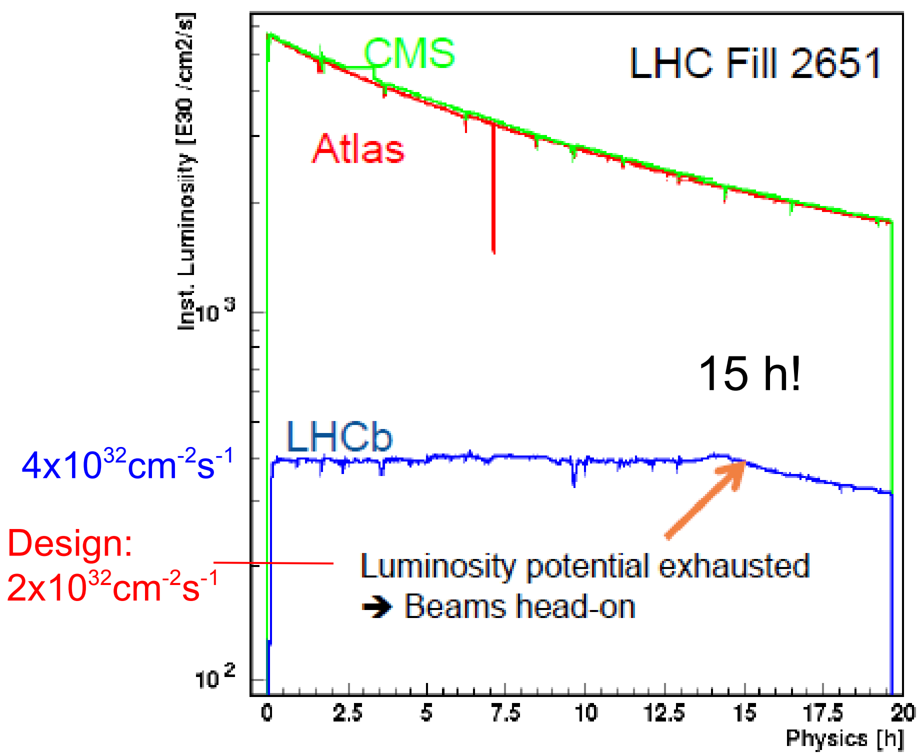
- L_{inst} = 2×10^{32} $cm^{-2}s^{-1}$ with μ=0.4 (# of visible pp int./crossing)

  [2622 bunches, 25ns, 14 TeV].
- We ran in 2012 at 4×10^{32} $cm^{-2}s^{-1}$ with μ=1.8 [1262 bunches, 50ns, 8TeV]
- This means 4 times more collisions per crossing than in the design
  - Higher occupancy in the detector, bigger event size
  - More challenging for the trigger → LHCb upgrade

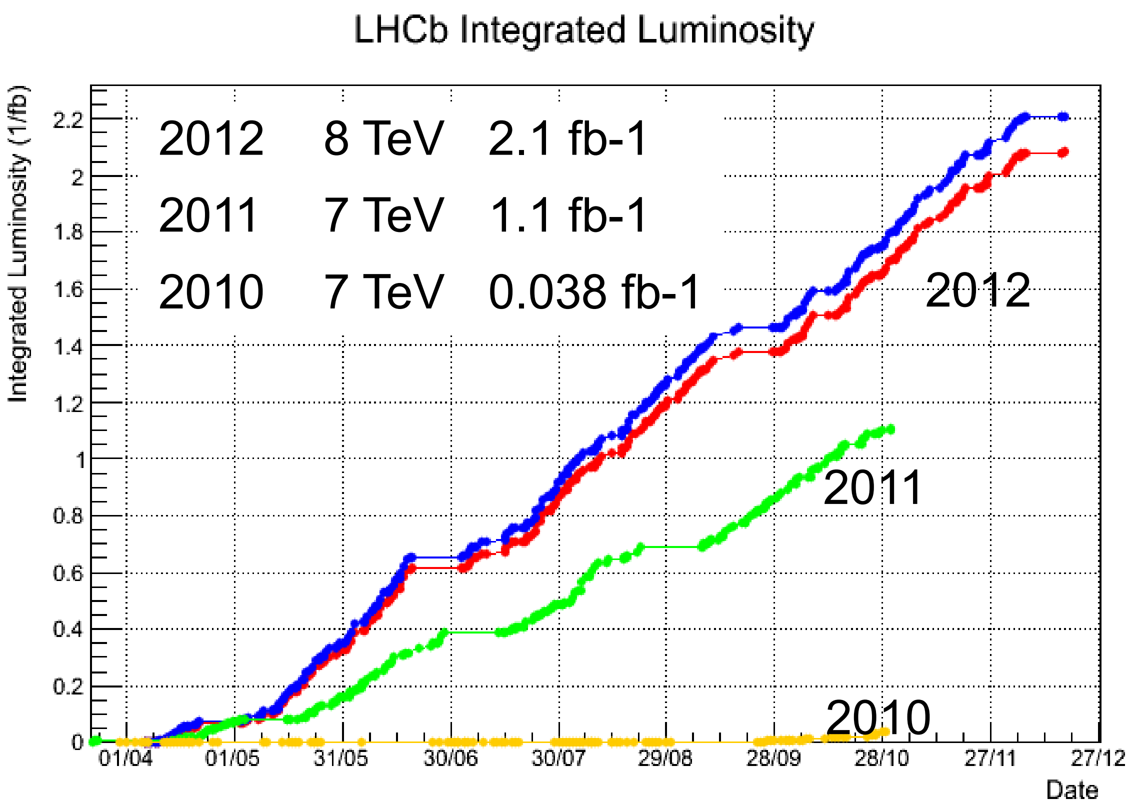
Luminosity Levelling:

Semi-continuous (automatic) adjustment of offset of colliding beams to keep the luminosity constant

Routine operation since 2011

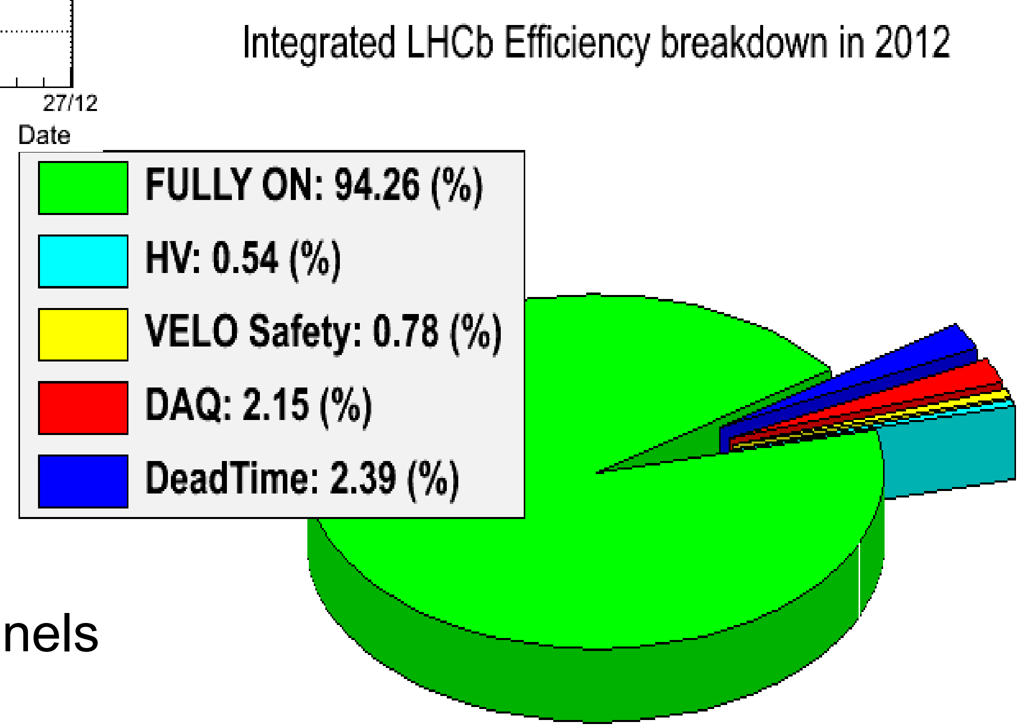


Operation: Data Taking



In 2012: Deferred HLT

25% of the L0-output events are stored to disk and processed on HLT farm during inter-fills



ε(operation)>94%

~98% are good data

Detectors all with >~99% active channels

Summary

- LHCb is performing very well in difficult conditions
  - Four times more interactions per crossing than in the design
  - All detectors over 99% operational
  - Resolutions in position and momentum conform to expectations
- High statistics available, a lot of results expected. Many already published.
- Higher luminosity bottleneck is 1 MHz L0-hardware trigger
  - LHCb upgrade

Two Heavy flavour sessions:

- Wednesday: 14:30 – 16:30 Heavy Flavours 1
- Friday: 11:00 – 13:00 Heavy Flavours 2

and LHCb Upgrade on Staturday


STOP