

The LHCb Detector

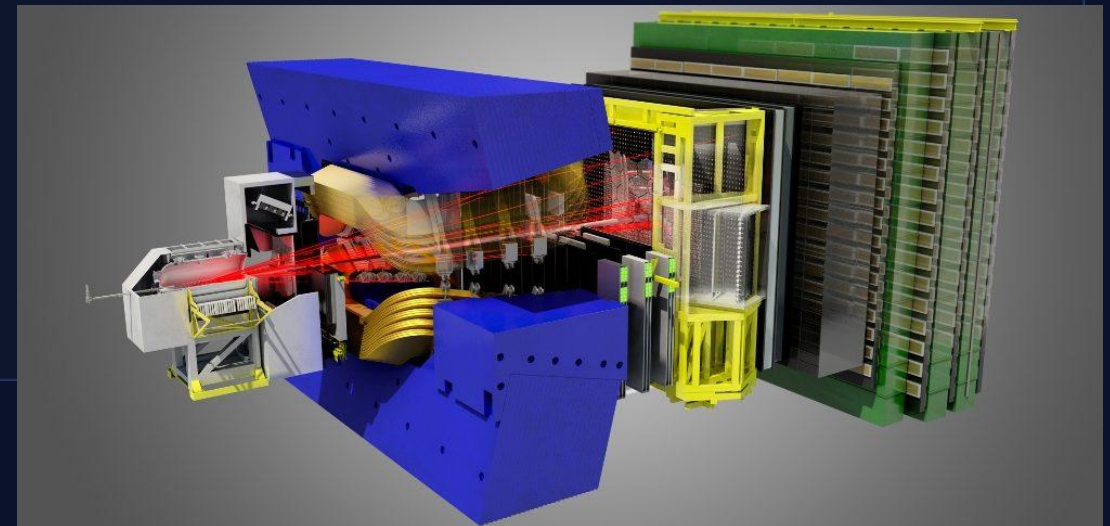
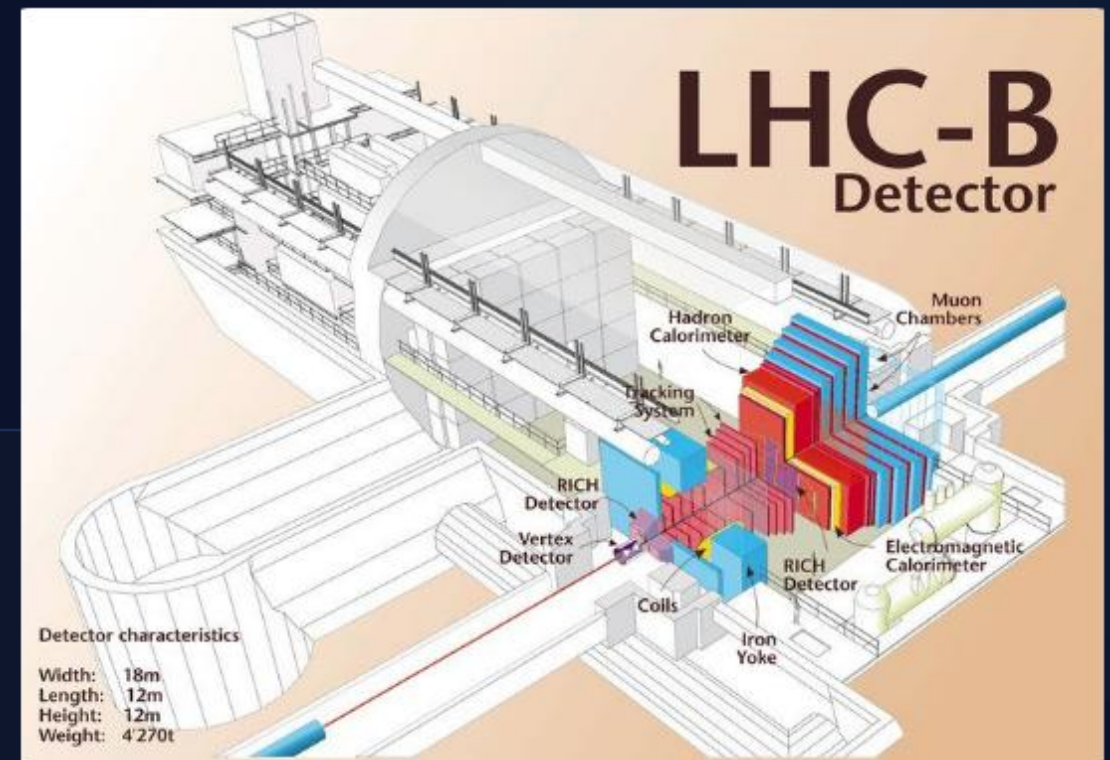
Precision Heavy Flavour Spectrometer at the LHC

A Deep Dive into Magnetic Fields, VELO Vertexing, Tracking, & RICH Hadron Identification

LHCb Spectrometer Concept

Single-Arm Forward Spectrometer:

- Covers pseudorapidity range $1.9 < \eta < 4.9$ where $b\bar{b}$ pairs are predominantly produced.
- Optimized for studying CP violation and rare decays of heavy flavor (b and c quarks) hadrons
- Measures forward-boosted particles produced in high-energy proton-proton collisions.



Magnetic Field & Dipole Magnet

Dipole Magnet Specifications

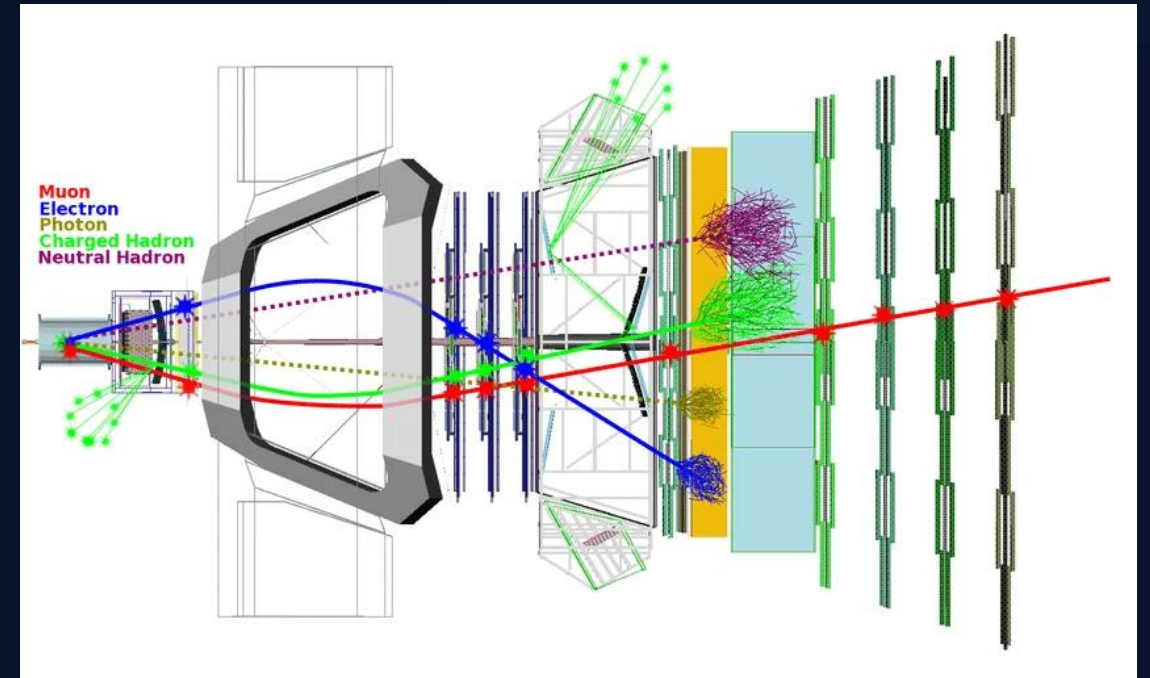
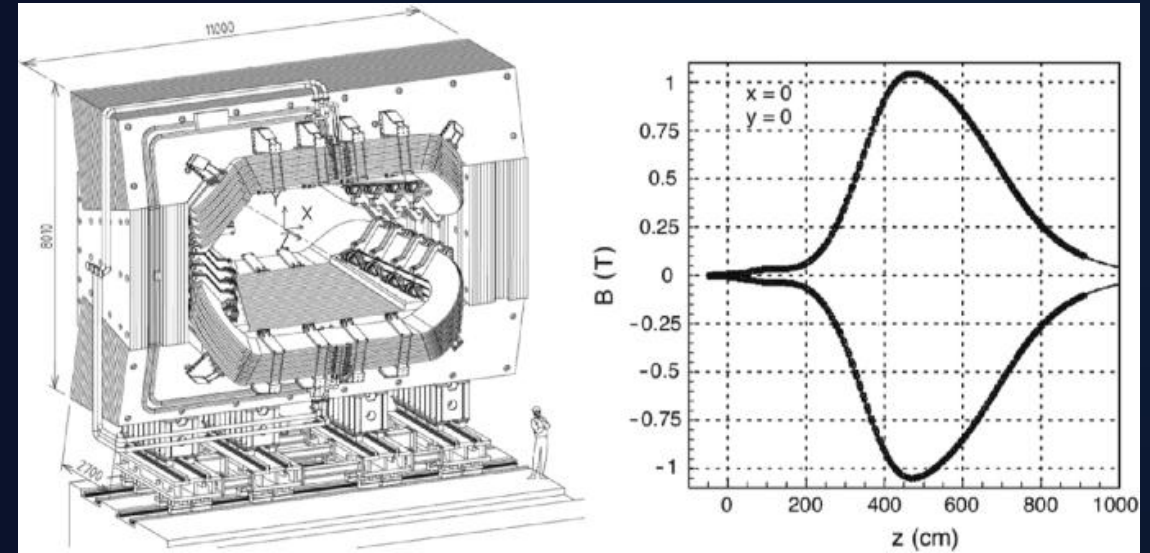
A warm dipole magnet provides an integrated magnetic field of over a length of 4.3 meters.

Deflects charged particles horizontally, enabling high-precision momentum measurement before and after the tracking stations.

Polarity Flipping (MagUp / MagDown)

The magnetic field polarity is regularly reversed (**MagUp** and **MagDown**) throughout data taking.

Crucial for cancelling left-right detector asymmetries in precision CP violation measurements.



Tracking Performance & Resolution



Integrated tracking across VELO, Upstream Tracker (UT), and SciFi tracker yields an invariant mass resolution of $\sim 15\text{--}20 \text{ MeV}/c^2$ for B-meson decays.

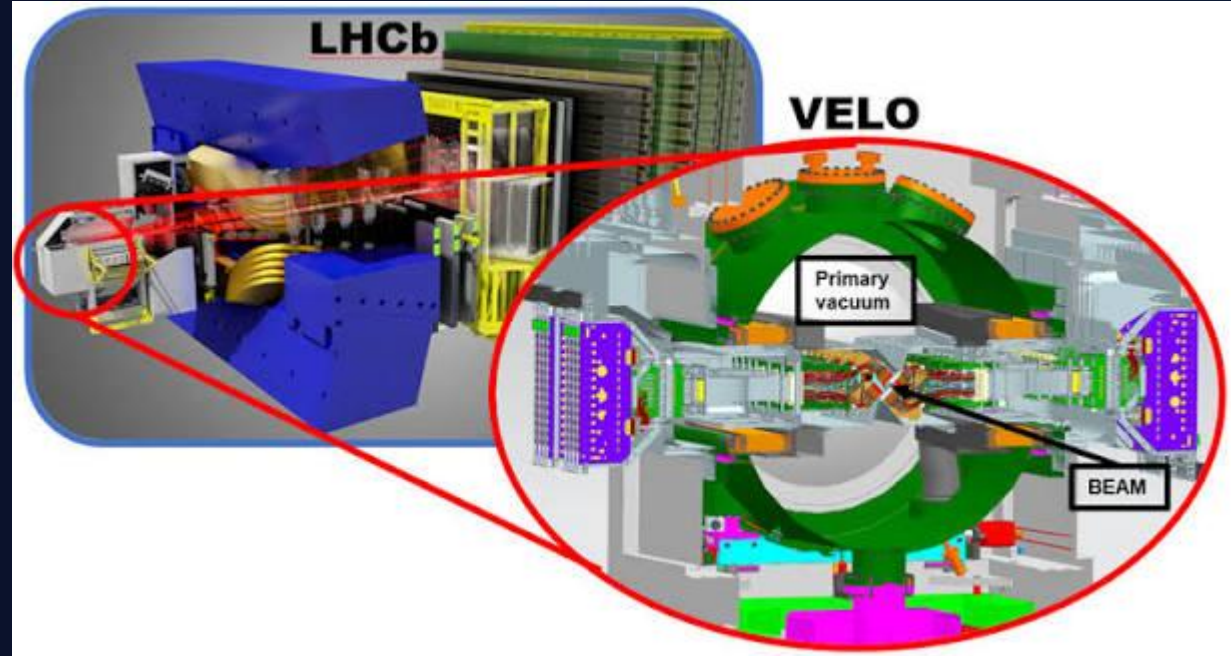
VELO & Vertexing

Vertex Locator (VELO)

Silicon strip sensors positioned just 8 mm from the LHC beam axis inside a dedicated vacuum vessel.

Reconstructs primary collision vertices and displaced secondary decay vertices of long-lived B and D hadrons.

Achieves exceptional primary vertex spatial resolution and an impact parameter resolution of $\sim 20\text{--}30\text{ }\mu\text{m}$.



Ring Imaging Cherenkov (RICH)

Dual Radiator System

RICH 1:

low momentum (10–65 GeV) using C_4F_{10} gas radiator

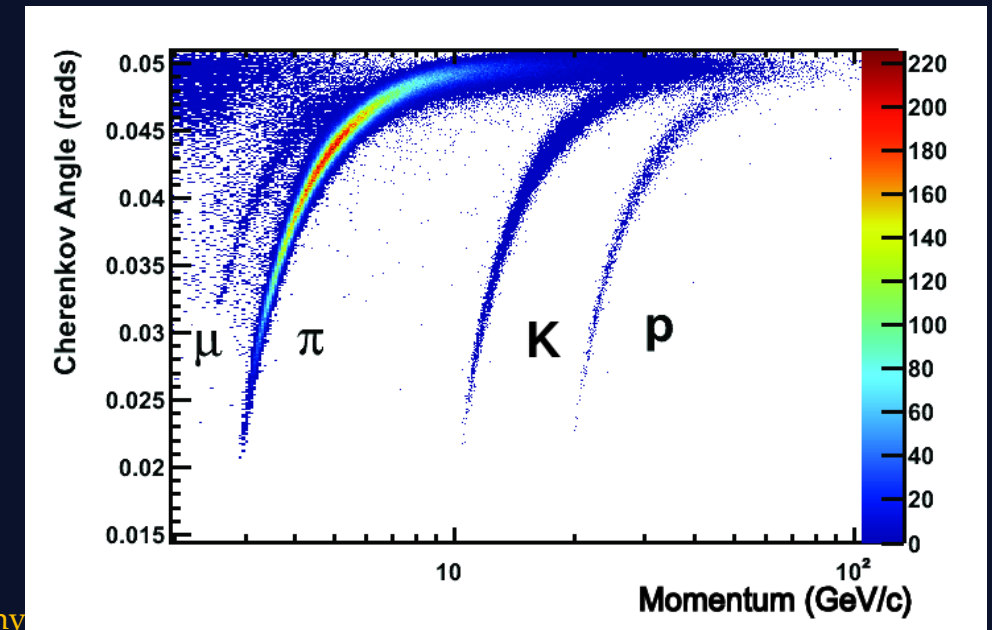
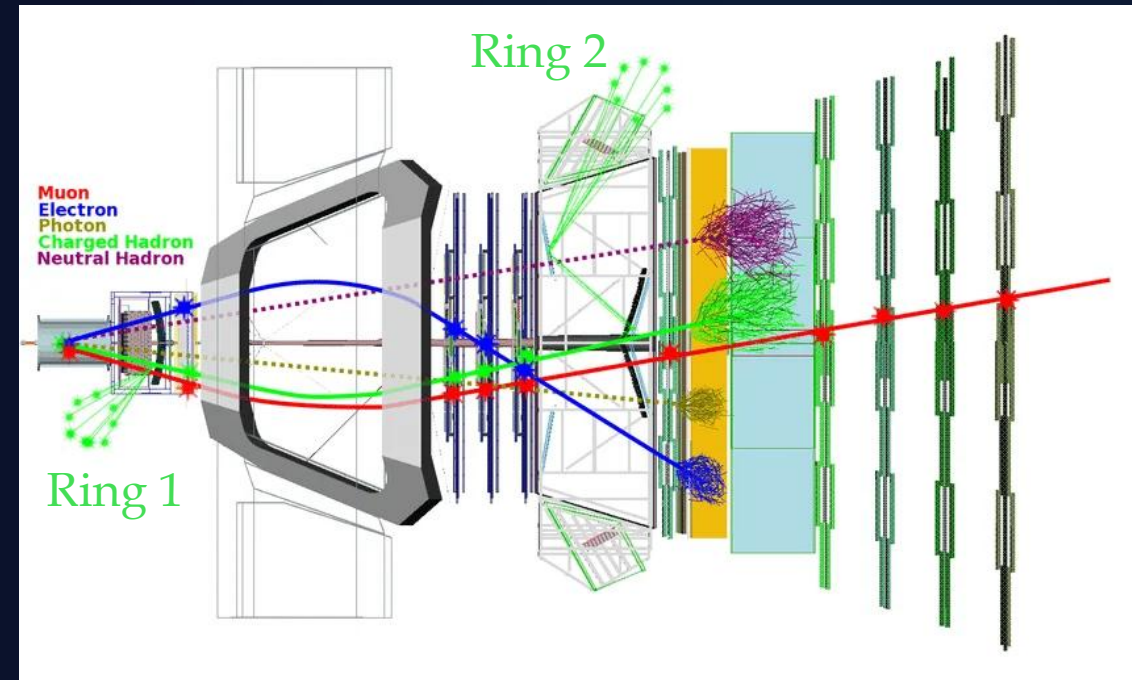
RICH 2:

high momentum (15–100+ GeV) using CF_4

Cherenkov Ring Reconstruction

Charged particles emit photons along Cherenkov light cones with angle θ_c connected to particle velocity as:

$$\beta = (n \cos\theta)^{-1}$$



Hadron Identification Performance

$\sim 95\%$

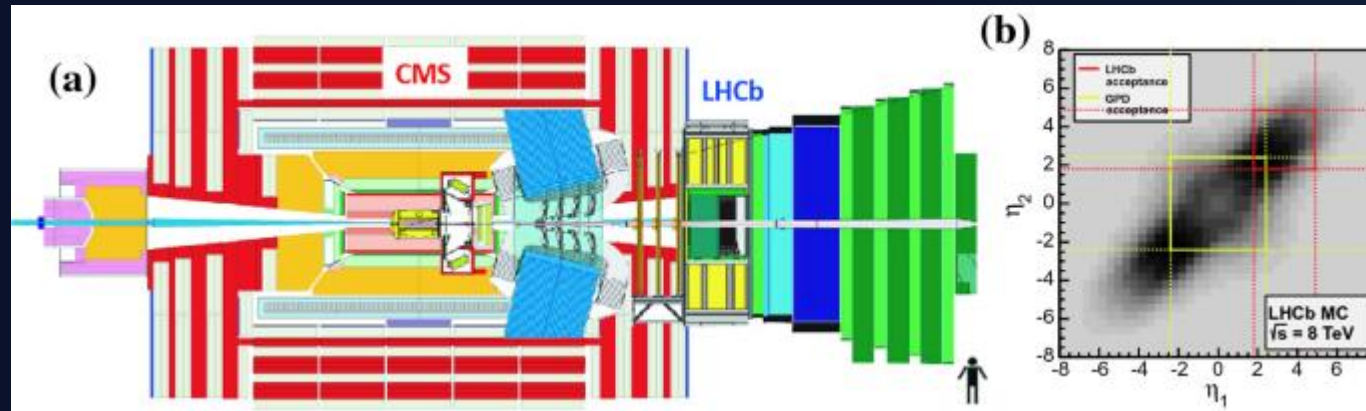
Kaon Identification Efficiency

Subsystem Discrimination

Combined RICH 1 & RICH 2 systems separate charged pions, kaons, and protons over a momentum range of **2 to 100 GeV/c**.

Maintains a low pion-to-kaon misidentification rate of **< 5%**, critical for isolating hadronic B-meson decays such as $B_s^0 \rightarrow K^+ K^-$ from $B_s^0 \rightarrow \pi^+ \pi^-$

CMS vs LHCb



CMS

Covers central pseudo-rapidity region:

$$0 < |\eta| < 2.4$$

Omni-purpose detector, focus on high p_T processes, (higgs, top, W, Z , Susy)

No hadron identification

Can be competitive in flavor physics (b and c hadrons) thanks to:

- Precision track and vertex reconstruction
- Refined μ identification, which allows triggering (i.e. selecting and recording) $pp \rightarrow b \bar{b} X$ events

LHCb

Covers forward pseudo-rapidity range

$$2 < \eta < 5$$

Devoted to flavor physics, thanks to:

- Precise tracking and vertex reconstruction
- Large forward boost of b, c hadrons, allowing more precise determination of the positions of b, c hadrons decay point
- Hadron identification

