LHCb Particle Identification and Performance

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Introduction

LHCb is a forward arm spectrometer at the LHC and focuses on precise measurements of CP violation and rare decays of B-mesons.
Particle identification systems

The Rich Detectors, the Calorimeter Systems and Muon System all contribute to particle identification.
Why do we need particle identification?

Typical measurement – invariant mass of $B \rightarrow \pi \pi$:

<table>
<thead>
<tr>
<th>Signal decay</th>
<th>$B^0 \rightarrow \pi^+ \pi^-$</th>
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<tbody>
<tr>
<td>Background</td>
<td>$B_s^0 \rightarrow \pi^+ K^- \quad B^0 \rightarrow K^+ \pi^-$</td>
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Signal and background topologically similar $\rightarrow$ require pion / kaon ID

Invariant mass distribution of $B \rightarrow \pi \pi$ decays including background
Other requirements for PID

• RICH
  – Identify events of interest in the HLT
  – Reduce combinatorics in many-body events

• CALO
  – Photon identification to reconstruct $\pi^0$

• MUON
  – Identify high $p_T$ muons for L0 trigger decision
Why two RICHes?

Cherenkov angle vs. particle momentum

Coverage of all particles from $B \rightarrow \pi\pi$ decays

Two RICHes and 3 radiators cover the particle phase space almost completely
• Spherical Mirrors
  – Focus Cherenkov radiation
  – Mirror tilt removes photon detectors from detector acceptance
• Secondary Flat Mirrors
  – Minimizes detector length
• Magnetic shielding
  – Maintain bending power upstream of first (Trigger) Tracking station
  – Shield HPDs from fringe B-field
• C₄F₁₀ and Aerogel Radiators
  – Covers 1 to 60 GeV/c
• Acceptance of 25 – 300 mrad
RICH 2

- CF$_4$ Radiator
- Acceptance of 15 to 120 mrad
- Covers high momentum tracks from 20 to 100 GeV/c
- Uses same photon detectors as RICH 1
- HPDs sensitive to a single photon in the range $\lambda = 200$ to 600 nm
Hadron Identification with RICH

1. Given a set of track ID hypotheses, the probability distribution for finding photons in each pixel of the detector is determined.
2. PID likelihood formed from comparison with observed hit distribution.
3. Particle ID hypotheses adjusted to maximize likelihood.

Kaon identification efficiency ~ 88%
Pion misidentification ~ 3%
Reconstruction of $\pi^0$

Efficiency of $\pi^0$ identification vs. $p_T$ (compared to MC truth)

• Photon candidates paired to reconstruct the resolved $\pi^0$

• Algorithm disentangles the photon pair from a merged cluster and reconstructs $\pi^0$

• Efficiency ~ 53%
Calorimeter - $\pi^0$ reconstruction

Decay channel: $B^0 \rightarrow \pi^+ \pi^- \pi^0$ produces $\pi^0$ with $<p_T> \approx 3$ GeV/c

**Resolved $\pi^0$ mass distribution**

Mass Resolution: $\sim 10$ MeV/c$^2$

**Merged $\pi^0$ mass distribution**

Mass Resolution: $\sim 15$ MeV/c$^2$

$\pi^0$ ID gives us a $B^0$ mass of $\sim 5.26$ GeV/c$^2$ with a resolution of $\sim 60$ MeV/c$^2$
Muon Identification

- Muons selected by searching for muon stations hits compatible with reconstructed track extrapolations
  - Compare track slopes and distance of muon station hits from track extrapolation to remove background
  - Global PID can be used to reduce the misidentification rate e.g. $\pi$ ID from the RICHes

For $p > 3\text{GeV/c}$

$\mu_{\text{eff}} = 96.7 \pm 0.2\%$, $\pi_{\text{misid}} = 2.50 \pm 0.04\%$

Mass dist for $B^0 \rightarrow J/\psi(\mu\mu)K^0_S$

Resolution $\sim 9\text{ MeV/c}^2$ (12 MeV/c$^2$ downstream)
Particle ID is vital for the LHCb Physics Program!

On target for 2007
The Hybrid Photon Detector

Requirements:
- 2.6 m² coverage with 75% active area
- 2.5 x 2.5 mm² granularity
- Single photon efficiency
- 40 MHz readout

Developed by CERN/ DEP(NL) cross-focused, 83mm Ø, encapsulated binary electronics 32 x 32 pixels (500 µm x 500 µm).

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