Particle Production Studies at LHCb

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on behalf of the LHCb collaboration

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• Introduction to LHCb: Tracking & Particle ID
• $K_S$ production cross-section
• Strange particle ($V^0$) ratios
• Proton ratios
• Summary

The LHCb detector in the point 8 cavern at CERN
The LHCb Experiment

A forward detector (2<\eta<5) for precision measurement of CP violation and rare B-decays:
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Early data with “micro-bias” triggers:
2009: Calo. & 2010: 1+ reconstructed tracks
A forward detector (2<\eta<5) for precision measurement of CP violation and rare B-decays:

**LHCb Tracking**

Tracking $\delta p/p \approx 0.4\%$ with 95% reconstruction efficiency

VELO precision $\sigma(z) \approx 50$ (150) $\mu$m for Primary (Secondary) Vertex

[see talk by Sylvia Borghi]
A forward detector ($2<\eta<5$) for precision measurement of CP violation and rare B-decays:

LHCb Tracking

A completed VELO module before installation

 VELO open 15 mm at $\sqrt{s} = 0.9$ TeV due to width of low-energy beam

Tracking $\delta p/p \approx 0.4\%$ with 95\% reconstruction efficiency

VELO precision $\sigma(z) \approx 50$ (150) $\mu$m for Primary (Secondary) Vertex

[see talk by Sylvia Borghi]
LHCb RICH Detectors

A forward detector ($2<\eta<5$) for precision measurement of CP violation and rare B-decays.

Ring Imaging Cherenkov (RICH) detectors distinguish charged particles by mass over a momentum range of 2 to ~100 GeV/c. [see talk by Andrew Powell]
**K_S Production Cross-Section**

An ideal first measurement for LHCb, with high-purity selections requiring no particle identification

![Graph showing K_S -> pi pi selection based on track and K_S impact parameters](image)

\[ M_{\pi\pi} \text{ [MeV/c}^2] \]

\[ \sigma = 4.1 \pm 0.1 \text{ MeV/c}^2 \]

**Key Systematic Contributions:**

- Luminosity (*beam current measurement*) ~12% 
  [see talk by Massi Ferro-Luzzi]
- Tracking efficiency ~10%

K_S -> pi pi selection based on track and K_S impact parameters

[see talk by Sylvia Borghi]

**LHCb 2009 Preliminary**

\[ \sqrt{s} = 0.9 \text{ TeV} \]

\[ 6.8 \pm 0.1 \mu\text{b}^{-1} \]

[Image of a graph showing the distribution of candidates per 2 MeV, with a peak at 420 MeV/c^2 and a sigma of 4.1 ± 0.1 MeV/c^2]
K_{S} Cross-Section Results

A unique measurement at high rapidity & at lower $p_T$ than previous experiments (see back up slide)
Theoretical interest in ratios e.g.
- baryon number transport,
- baryon vs. meson suppression in hadronisation

$V^0$ ratios $\bar{\Lambda}/\Lambda$ $\bar{\Lambda}/K_S$

Only tracking & vertexing

Proton ratio $\bar{p}/p$

RICH particle identification

All abundant in minimum bias data
$V^0$ Ratios

High-purity $K_S$ & $\Lambda$ selection based on a combination of impact parameters (IP): $\nu = \log \frac{IP^+ \times IP^-}{IP^{V_0}}$

$V^0$ background removed by changing daughter hypotheses

Binning $p_T, y$ after boost correction for beam crossing angle

Efficiency from LHCb-tuned PYTHIA generation and GEANT simulation for prompt, non-diffractive events
Another unique measurement at high rapidity with pp collisions at $\sqrt{s} = 0.9$ & 7 TeV

Baryon number transport appears higher than predicted at $\sqrt{s} = 0.9$ TeV
Baryon vs. meson production ratio measurement with pp collisions at $\sqrt{s} = 0.9$ & 7 TeV

Baryon suppression in hadronisation significantly lower than predicted
Proton Ratio

Pure samples Protons selected with RICH particle ID

Particle identification ($DLL$) calibrated with tracking-selected samples: $\pi(K_S)$, $p(\Lambda)$ & $K(\phi)$ [see talk by Andrew Powell]

Cuts tuned for purity in MC, efficiency measured in data
Preliminary Results $\bar{p}/p$

$\sqrt{s} = 0.9$ TeV

- $0.8 < p_T < 1.2$ GeV/c
- $p_T > 1.2$ GeV/c

$\sqrt{s} = 7$ TeV

- $0.8 < p_T < 1.2$ GeV/c
- $p_T > 1.2$ GeV/c

Baryon number transport closer to predictions
Preliminary Ratio Systematics

Ratios a great target for early measurements since absolute luminosity measurement not required

Remaining systematics relate to MC, data comparisons

<table>
<thead>
<tr>
<th>Uncertainties</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p, \pi ) interaction cross-sections</td>
<td>(~10%)</td>
</tr>
<tr>
<td>( V^0 ) production &amp; interaction cross-sections</td>
<td>(~10%)</td>
</tr>
<tr>
<td>LHCb material description</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>( \Lambda ) transverse polarisation</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Selection cuts (\textit{dominated by PID})</td>
<td>1-14%</td>
</tr>
<tr>
<td>Ghost tracks</td>
<td>&lt;2%</td>
</tr>
<tr>
<td>Acceptance asymmetries</td>
<td>(~2%)</td>
</tr>
<tr>
<td>Non-prompt contamination</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{\Lambda}/\Lambda )</td>
<td>(~2%)</td>
</tr>
<tr>
<td>( \bar{\Lambda}/K_s )</td>
<td>2-12%</td>
</tr>
<tr>
<td>( \bar{p}/p )</td>
<td>3-14%</td>
</tr>
</tbody>
</table>
Preliminary Results Comparison

Results at both beam energies compared in $\Delta y$ show consistency, also with other experiments:

$\Delta y = y(\text{beam}) - y(\Lambda,p)$

$y(\text{beam})$: 6.6 : $\sqrt{s} = 0.9$ TeV
8.3 : $\sqrt{s} = 7$ TeV
Preliminary Results Comparison

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$y(\text{beam})$:
- $6.6 : \sqrt{s} = 0.9$ TeV
- $8.3 : \sqrt{s} = 7$ TeV

ALICE, $0.45 < p_T < 1.05$ GeV/c
BRAHMS, $0.5 < p_T < 1.5$ GeV/c
PHOBOS, $0.3 < p_T < 1.0$ GeV/c
STAR, $p_T > 0.2$ GeV/c

STAR data - 0.2 TeV
Results at both beam energies compared in $\Delta y$ show consistency, also with other experiments:

$\Delta y = y(beam) - y(\Lambda, p)$

$y(beam)$: 6.6 : $\sqrt{s} = 0.9$ TeV

8.3 : $\sqrt{s} = 7$ TeV
Summary

• $K_S$ cross-section measured with 2009 data

• Preliminary results in 2010 for ratios of $V^0$ & protons

• Results suggest lower Baryon suppression & higher Baryon transport in data than predicted

Look out for new LHCb publications soon!
Back up
K_\Sigma Cross-section Comparison

A measurement with lower p_T coverage than CDF, UA1, UA5

\[ \frac{d^2\sigma}{dp_T dy} (\text{mb}/(\text{GeV}/c)) \]

LHCb 2009
Preliminary
\( \sqrt{s} = 0.9 \text{ TeV} \)
\( 6.8 \pm 0.1 \mu\text{b}^{-1} \)
Raw Charged Particle Ratios

$\sqrt{s} = 0.9 \text{ TeV}$

- $p_T < 0.8 \text{ GeV/c}$
- $0.8 < p_T < 1.2 \text{ GeV/c}$
- $p_T > 1.2 \text{ GeV/c}$

$\sqrt{s} = 7 \text{ TeV}$

Corrected ratios for $K, \pi$ are a work in progress...