Soft QCD Measurements in the Forward Direction with the LHCb Experiment

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Outline

1. The LHCb experiment

PID system

LHCb data

2. K_S^0 production

3. V0 ratios

$\bar{\Lambda} / \Lambda$ ratio

$\bar{\Lambda} / K_S^0$ ratio

4. $\bar{p}/p$ ratio

5. ϕ production

6. Charged track multiplicities

The LHCb experiment

- ▶ aims at precision measurements of CP violation in the b sector
- ▶ single arm forward spectrometer $1.9 < \eta < 4.9$
(backwards: VELO “Pileup Unit”)
- ▶ excellent lifetime resolution: VELO, 5 mm distance to beam, movable

PID system

dedicated PID system based on RICH detectors:

- ▶ RICH1:
 - ▶ Aerogel $p < 10 \text{ GeV}/c$
 - ▶ C_4F_{10} $p < 60 \text{ GeV}/c$
- ▶ RICH2:
 - ▶ CF_4 $15 < p < 100 \text{ GeV}/c$

important ingredient e.g. to $\bar{p}/p$ and ϕ studies

Recorded luminosity

year	luminosity	$\sqrt{s}$ /TeV
2009	$6.8 \mu\text{b}^{-1}$	0.9
2010	0.3 nb^{-1}	0.9
2010 ⁺	$> 460 \text{ pb}^{-1}$	7.0

...90% data taking efficiency!

in this talk:

	$\sqrt{s} = 900 \text{ GeV}$	$\sqrt{s} = 7 \text{ TeV}$
K_s^0 cross-section	X	
ϕ cross-section		X
V0 ratios	X	X
$\bar{p}/p$ ratio	X	X
track multiplicities		X

K_S^0 production

Physics Letters B 693 (2010) pp. 69-80 arXiv:1008.3105v2

- ▶ K_S^0 reconstructed in $K_S^0 \rightarrow \pi^+ \pi^-$
- ▶ analyzed data from pilot run 2009
- ▶ low requirements on reconstruction, no PID...
 - ▶ ideal 'first physics' channel
 - ▶ testing ground for detector understanding/calibration
- ▶ K_S^0 decay far away from primary vertex
- ▶ two separate analyses done (with/without VELO information)

key systematics:

luminosity 12%

tracking efficiency 10%

K_S^0 p_T spectra at $\sqrt{s} = 900$ GeV

- harder p_T spectrum in data than MC

Comparison with other experiments

- ▶ first measurement at $\sqrt{s} = 900$ GeV
- ▶ y and p_T range extended

V0 ratios

arXiv:1107.0882v2 (submitted to JHEP)

identification:

$$\begin{array}{ll} \Lambda & \Lambda \rightarrow p \pi^- \\ \bar{\Lambda} & \bar{\Lambda} \rightarrow \bar{p} \pi^+ \\ K_S^0 & K_S^0 \rightarrow \pi^+ \pi^- \end{array}$$

- ▶ K_S^0 and Λ selection based on impact parameters
- ▶ independent from luminosity
- ▶ low systematic uncertainties (cancel partially)

$\bar{\Lambda} / \Lambda$ ratio

⇒ rapidity dependence:

- ▶ at low rapidity, ratio like Perugia 0
- ▶ at high rapidity, more like Perugia NOCR

$\bar{\Lambda} / \Lambda$ ratio – p_T dependence

⇒ energy dependence:

- ▶ at $\sqrt{s} = 900$ GeV, Perugia NOCR fits better
- ▶ at $\sqrt{s} = 7$ TeV, data closer to Perugia 0

Baryon transport $\bar{\Lambda} / \Lambda$

- consistency between $\sqrt{s} = 900$ GeV, 7 TeV and previous measurement

$\bar{\Lambda} / K_S^0$ ratio

- ratio underestimated by MC at both beam energies

- the higher p_T , the further off is the MC

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

- consistency between $\sqrt{s} = 900$ GeV, 7 TeV and previous measurement

$\bar{p}/p$ ratio – PID

- analysis strongly depends on PID system
- PID calibrated on data:
 - π and p from $K_S^0 \rightarrow \pi^+\pi^-$ and $\Lambda \rightarrow p\pi$
 - K from $\phi \rightarrow KK$

background rejection (top)
and signal retention (left)
 $\Rightarrow$ high purity $\bar{p}/p$ sample

$\bar{p}/p$ ratio

preliminary: CERN-LHCb-CONF-2010-009

- ▶ ratio overestimated at $\sqrt{s} = 900$ GeV
- ▶ good MC-data agreement at $\sqrt{s} = 7$ TeV

Baryon transport $\bar{p}/p$

$$\Delta y = y_{\text{beam}} - y_{\text{baryon}}$$

- consistency with other measurements, in particular at high p_T

ϕ production

arXiv:1107.3935 (submitted to PLB)

- ▶ ϕ production cross-section measured in bins of transverse momentum p_T and rapidity y

only reconstruction efficiency
relies on MC

RICH PID cut efficiency
determined on data (tag&probe)

- ▶ apply PID cut on
at least one kaon
- ▶ subsequently cut on
the *second* kaon
- ▶ deduce PID cut efficiency

ϕ production – tag-and-probe

tag sample

probe sample

$\Rightarrow$ PID efficiency

ϕ cross-section projections

- ▶ ϕ production underestimated in the measured kinematic range by both, LHCb-MC and Perugia 0
- ▶ p_T spectrum different from MC

Charged track multiplicities

- ▶ particles counted by reconstructing tracks in the VELO outside magnetic field, no momentum measurement
- ▶ only tracks from luminous region, non-prompt contamination (5-10%) corrected using MC
- ▶ no explicit momentum cut, efficiency drop versus low p_T corrected for
- ▶ pile-up is corrected for
- ▶ detector resolution is unfolded

Charged track multiplicities

normalized to events with at least one charged particle in the forward acceptance $2.0 < \eta < 4.5$

Charged track multiplicities

Hard interactions: normalized to events with at least one charged particle with $p_T > 1 \text{ GeV}/c$ in the forward acceptance $2.0 < \eta < 4.5$

best agreement of data with
Pythia 6 (NOCR)

Conclusions

LHCb delivers splendid input to Soft QCD physics in the high- η region

- ▶ K_s^0 production at $\sqrt{s} = 900$ GeV
harder p_T spectrum as compared to MC
- ▶ $\bar{\Lambda}/\Lambda$ ratio lower than Perugia 0, in particular at high y
- ▶ $\bar{\Lambda}/K_s^0$ ratio higher than Perugia 0
- ▶ $\bar{p}/p$ ratio slightly lower than Perugia 0 at $\sqrt{s} = 900$ GeV
- ▶ ϕ production at $\sqrt{s} = 7$ TeV
above Perugia 0 in the considered kinematical range
- ▶ track multiplicity generally higher on data than on MC
– better agreement for hard events only