LHCb QCD results

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Outline

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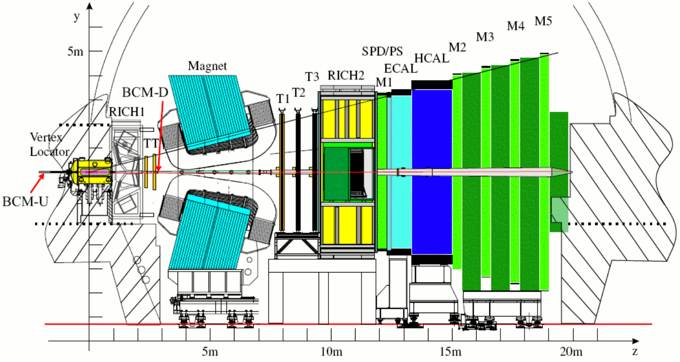
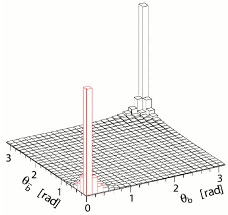
   - K_S^0 production
   - ϕ production
3. V0 ratios
   - $\bar{\Lambda}$ / Λ ratio
   - $\bar{\Lambda}$ / K_S^0 ratio
4. $\overline{p}$/ p ratio
5. vector boson production
   - Drell Yan p_T spectrum
   - W production p_T spectrum
   - charge asymmetry $W \rightarrow \mu\nu$

the LHCb experiment





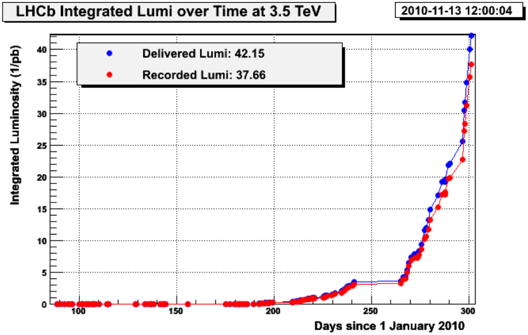
- single arm forward spectrometer $1.9 < \eta < 4.9$
- aims at precision measurements of CP violation in the b sector
- excellent lifetime resolution:
  VELO, 5 mm distance to beam, movable device
- $2 \cdot 10^4$ b-quarks per second

QCD at LHCb

- first data recorded at the LHC at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 7$ TeV
- two complementary efforts:
  - calibrate detector, understand tracking, PID ...
  - measure inclusive particle spectra, ratios, ...
- LHCb: studies in high-η region at unprecedented CM energy
- splendid input to QCD models:
  - strangeness production $\rightarrow$ fragmentation models
  - antiparticle/particle ratios $\rightarrow$ baryon number transport
  - baryon/meson ratios $\rightarrow$ fragmentation models

recorded Luminosity

year	luminosity	$\sqrt{s}$ /TeV
2009	$6.8\ \mu b^{-1}$	0.9
2010	$0.3\ nb^{-1}$	0.9
2010	$38\ pb^{-1}$	7.0



...90% data taking efficiency!

in this talk:

	$\sqrt{s} = 900$ GeV	$\sqrt{s} = 7$ TeV
K_S^0 cross section	X	
ϕ cross section		X
V0 ratios	X	X
$p/\ \overline{p}$ ratio	X	X
W production		X

trigger conditions

the LHCb trigger system

- Level 0: custom hardware (40 $\mathrm{MHz} \rightarrow$ 1 MHz)
- Higher Level Trigger: computing farm
  - Hlt1: (1 $\mathrm{MHz} \rightarrow$ 40 kHz)
  - Hlt2: (40 $\mathrm{kHz} \rightarrow$ 2 kHz)

first data:

- started with Minimum Bias trigger
- commissioned full system with growing event rate

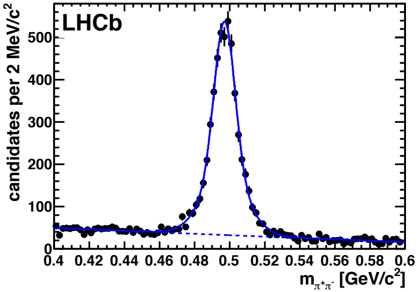
K_S^0 production

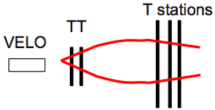
Physics Letters B 693 (2010) pp. 69-80 arXiv:1008.3105v2

- K_S^0 reconstructed in $K_S^0 \to \pi^+\pi^-$
- analyzed data from pilot run 2009
- low requirements on reconstruction, PID...
  - ideal 'first physics' channel
  - testing ground for detector understanding/calibration
- K_S^0 decay in distance from primary vertex
- two separate analyses done (with/without VELO information)

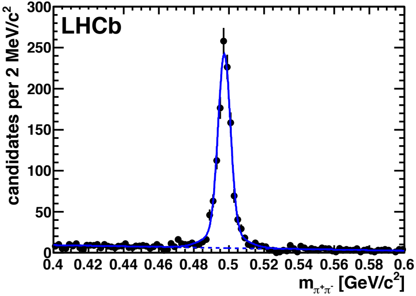
K_S^0 production

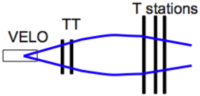
downstream tracks
resolution: 9.2 MeV/c^2



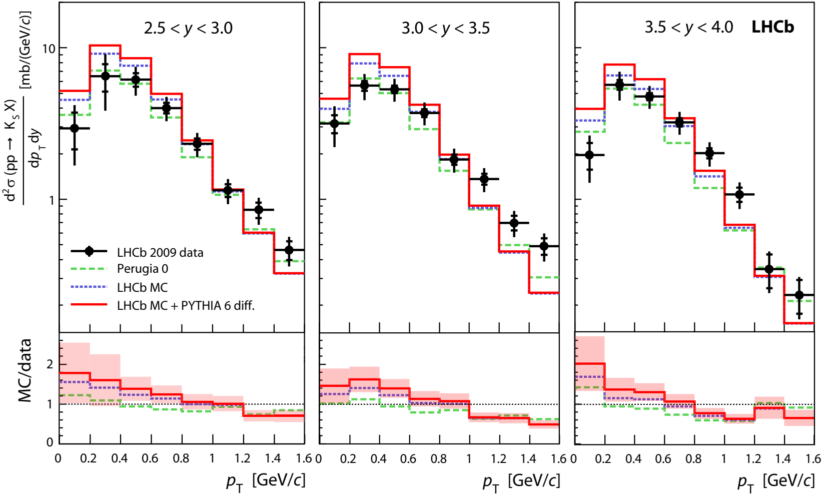


long tracks
5.5 MeV/c^2



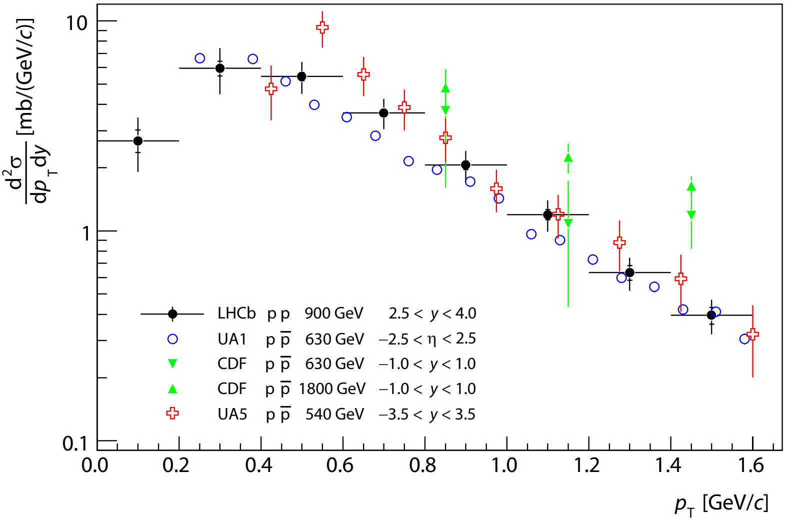


K_S^0 p_T spectra at $\sqrt{s} = 900$ GeV



- harder p_T spectrum in data than MC

Comparison with other experiments

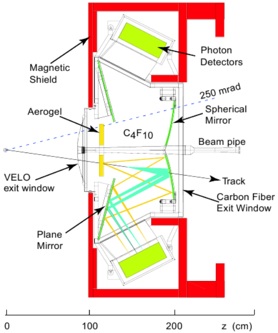


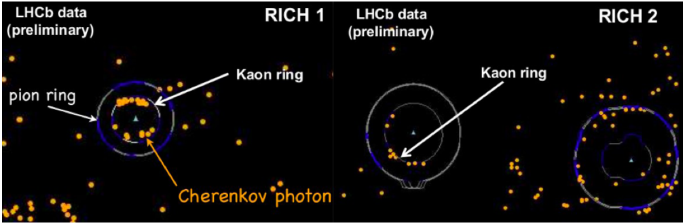
- measurement range extended by LHCb towards low p_T

ϕ production

two fold purpose:

- extremely good test for strangeness production (100% strange final state)
- study RICH PID system



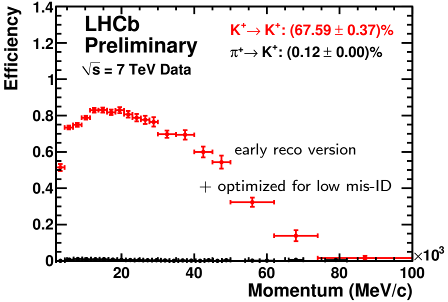


ϕ production

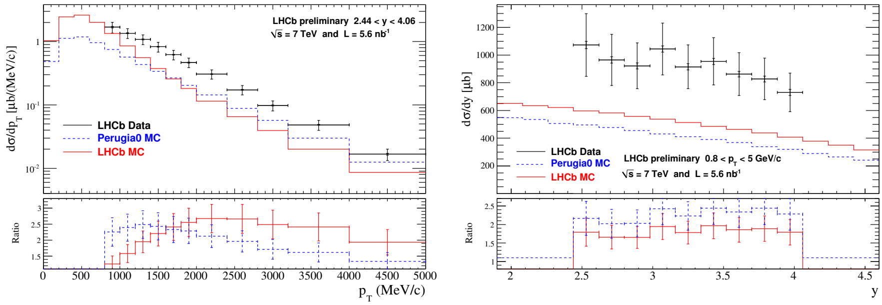
- ϕ production cross section measured in bins of transverse momentum p_T and rapidity y

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



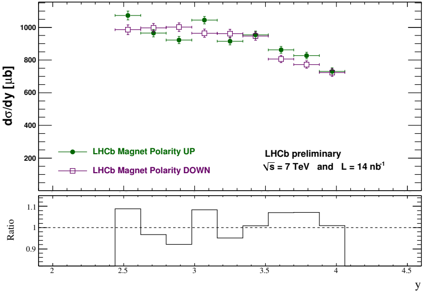
ϕ cross section projections

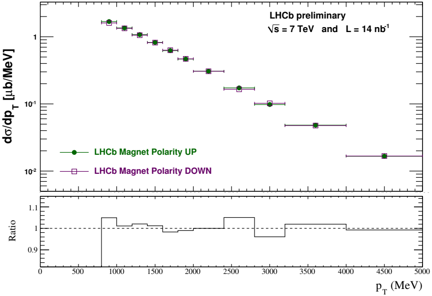


- error bars show total uncertainties, including correlated systematics
- ϕ production underestimated in the measured kinematic range by both PYTHIA tunings
- harder p_T spectrum as compared to MC

ϕ magnet-up and magnet-down

- the LHCb magnet polarity can be reversed to minimize systematics
- PID needs to be calibrated independently
- ϕ analysis done separately on both data sets
  OK!





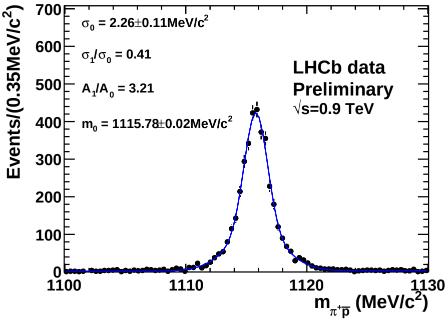
V0 ratios

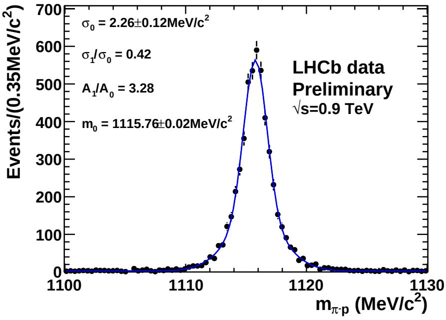
identification:

Λ	$\Lambda \rightarrow p\,\pi^-$
$\bar{\Lambda}$	$\bar{\Lambda} \rightarrow \bar{p}\,\pi^+$
K_S^0	$K_S^0 \rightarrow \pi^+\,\pi^-$

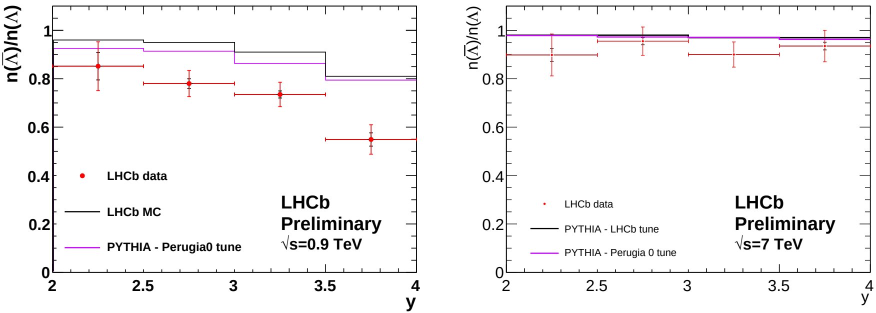
- PID purely kinematic (Armenteros-Podolanski)
- K_S^0 and Λ selection based on impact parameters
- independent from luminosity
- low systematical uncertainties (cancel partially)

$\bar{\Lambda}$ / Λ mass peaks at $\sqrt{s} = 900$ GeV





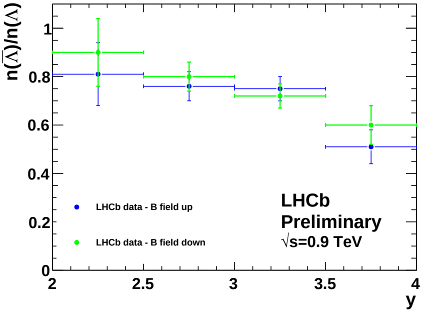
$\bar{\Lambda} / \Lambda$ ratio

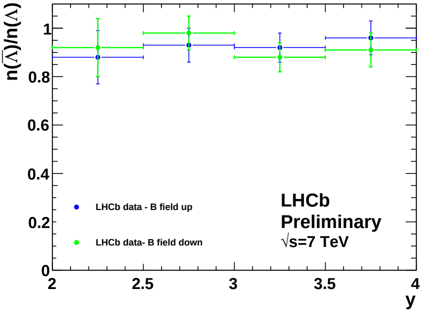


$\Rightarrow$ energy dependence:

- ratio overestimated by MC at $\sqrt{s} = 900$ GeV
- better agreement at $\sqrt{s} = 7$ TeV, but data still on the low side

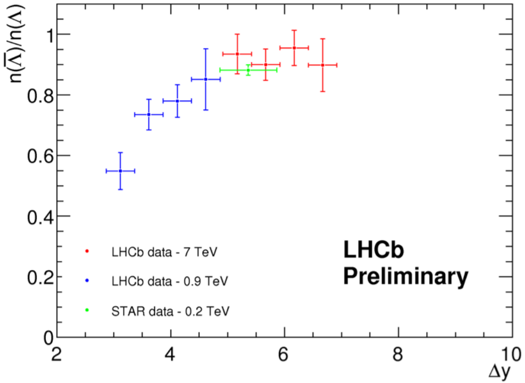
$\bar{\Lambda}$ / Λ ratio – LHCb magnet polarity comparison





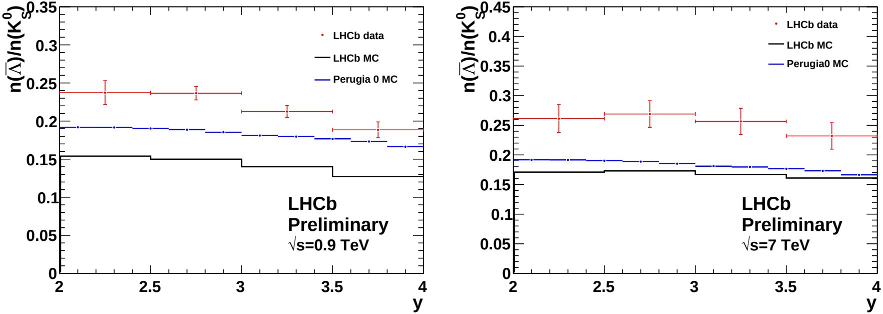
no polarity dependence. OK!

baryon transport $\bar{\Lambda}$ / Λ



$\Delta y = y_{\text{beam}} - y_{\text{baryon}}$ $\qquad$ $y_{\text{beam}} \approx \ln \frac{2E}{m}$

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

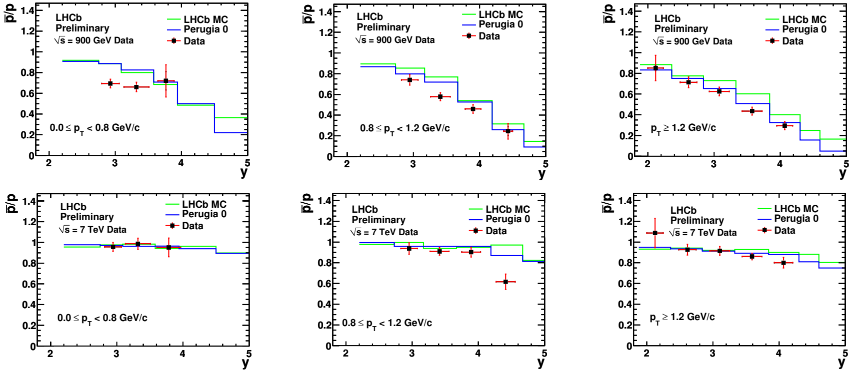


- ratio underestimated by MC at both beam energies

$\overline{p}/\ p$ ratio

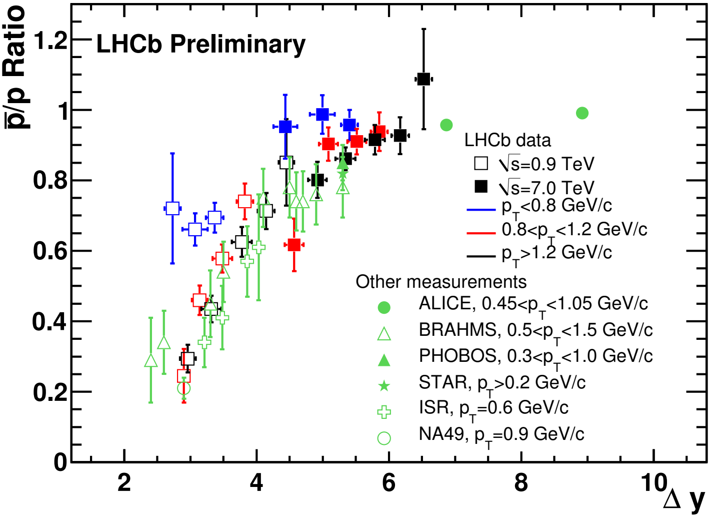
PID calibrated on data:

- π^+ and p from $K_S^0 \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$
- K from $\phi \to KK$ (evaluate contamination by mis-identified K)



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

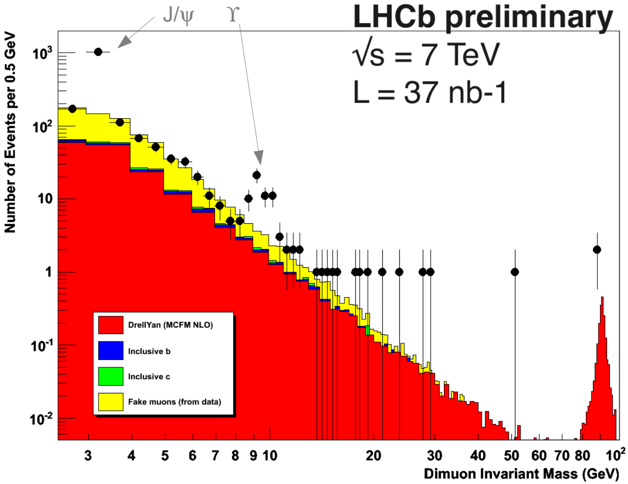
baryon transport $\overline{p}/\ p$



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

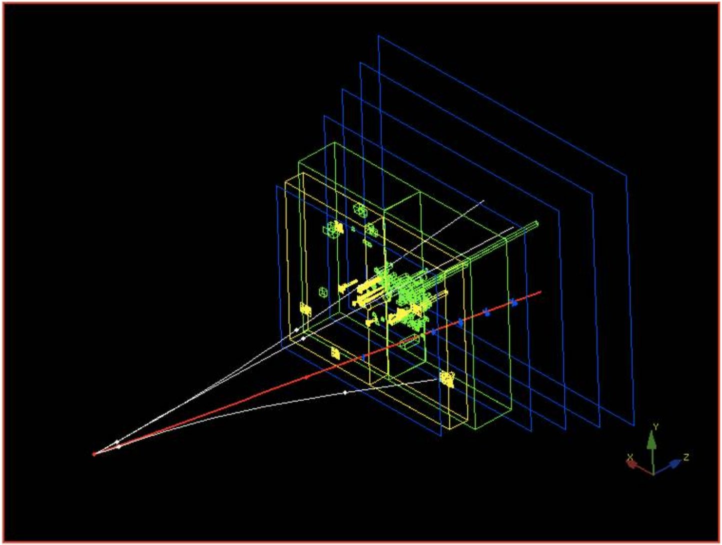
Drell Yan p_T spectrum

- require 2 isolated muons with $p_T > 1$ GeV/c



W production

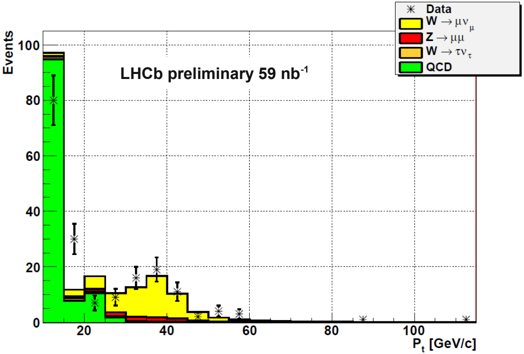
$W \to \mu\nu$ event in LHCb

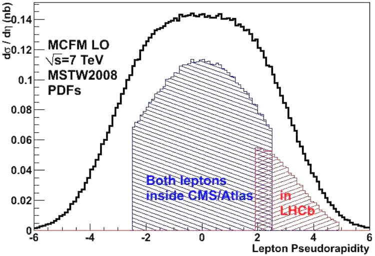


W production p_T spectrum

selection criteria (main selection requirements):

- require isolated muon
- proximity to primary vertex

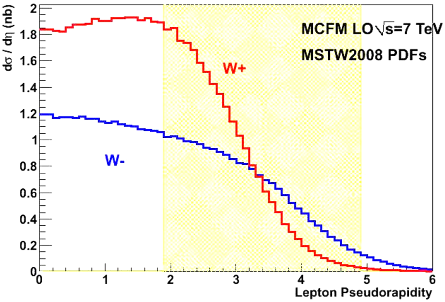


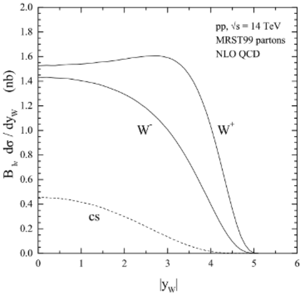


analysis on higher luminosity expected soon

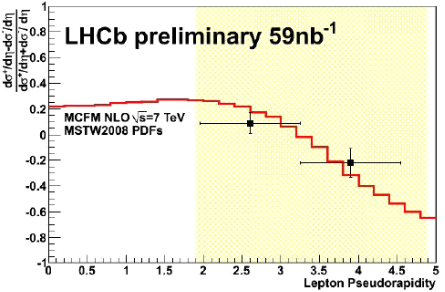
charge asymmetry $W \to \mu\nu$

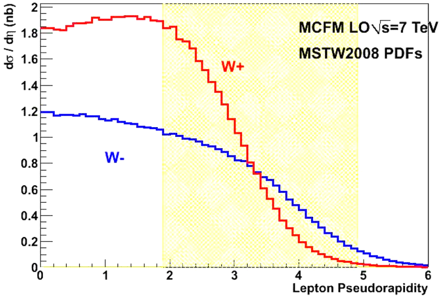
- W only produced from q-q
- high x: valence quark dominance
- proton (uud), $W^+/W^- \approx 2$ (forward direction)
- lepton asymmetry shifted in y wrt boson asymmmetry due to polarization of W

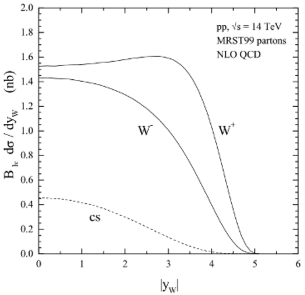




charge asymmetry $W \to \mu\nu$







conclusions

already on first data, LHCb delivers input to QCD models:

- soft QCD
  - K_S^0 production at $\sqrt{s} = 900$ GeV
    harder p_T spectrum as compared to PYTHIA
  - ϕ production at $\sqrt{s} = 7$ TeV production
    above MC in the considered kinematical range
  - $\bar{\Lambda}/\Lambda$ ratios at $\sqrt{s} = 900$ GeV lower than MC, y dependence differs
  - $\bar{\Lambda}/\Lambda$ ratios at $\sqrt{s} = 7$ TeV slightly on the low side
  - $\bar{\Lambda}/K_S^0$ ratio at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 7$ TeV:
    predicted baryon suppression is too high
  - $\overline{p}/p$ ratio overestimated by MC at $\sqrt{s} = 900$ GeV
- hard QCD
  - Drell-Yan production reasonably described by MC
  - W production fits to MC *within statistics*