Particle production studies at LHCb

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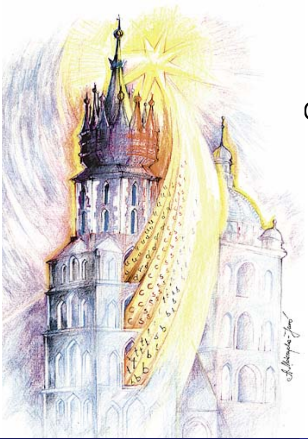
On behalf of LHCb Collaboration

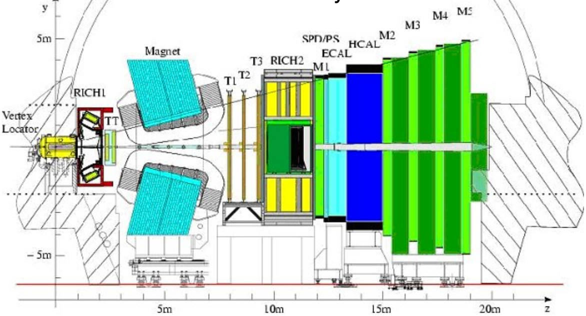


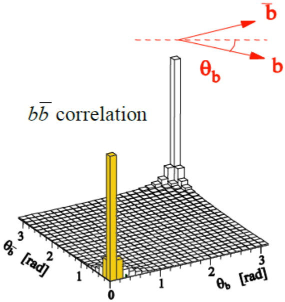
11.01.2011
Cracow Epiphany Conference
On the first year of the LHC

Outline

The LHCb Experiment

Single arm spectrometer for New Physics through precision measurements of CP violation and rare decays in b-sector.





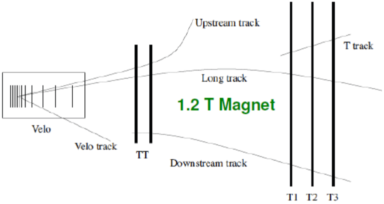
- It covers a unique range in pseudorapidity (1.9<η<4.9) complementary range to general purpose detectors.
- Fully instrumented[a] in the forward region

[a] For more information on detector and trigger see Patrizia de Simone's talk "Operation and Performance of the LHCb experiment"

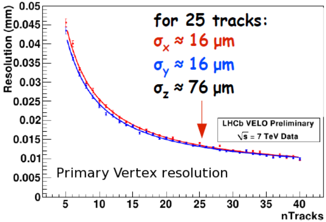
Data taken with minimum bias triggers:
2009: Calo ($7\mu b^{-1}$)
2010: 1 or more reconstructed tracks ($14nb^{-1}$)

LHCb Tracking

Excellent vertex resolution: VErtex LOcator, retractable device
and momentum resolution TT, 3 Tracking station after the magnet



velo open at 0.9 TeV - closed at 7 TeV

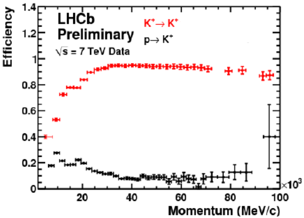


tracking: $\delta p/p \sim 0.45\%$ - reconstruction efficiency $\sim 95\%$ for $p > 5GeV$.
Data taken with two magnet polarizaties.

RICH Detectors

2 Cherenkov detectors, unique for the LHC experiments.

- Provide excellent Particle Identification (2-100GeV)
- Vital for $K/\pi/p$ discrimination and good tagging efficiency

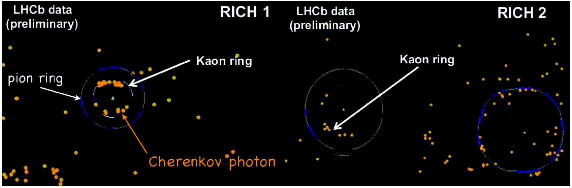


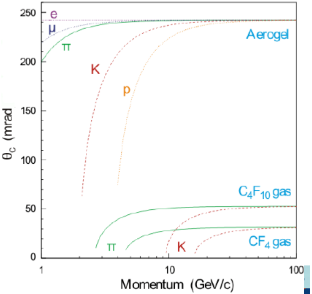
3 radiators needed RICH1 (2<p<60GeV):

- Aerogel, $n \sim 1.03$
- C_4F_{10}, $n \sim 1.0014$

RICH2 (p>20GeV)

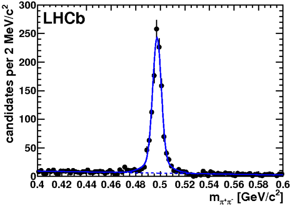
- CF_4, $n \sim 1.0005$

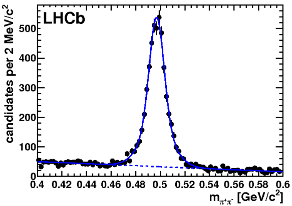




K_s^0 production at $\sqrt{s} = 0.9 TeV$

- First measurement for LHCb with 2009 pilot run data at 0.9 TeV
- $K_S^0 \to \pi\pi$ selection based on tracking and impact parameters
- Two selections with long and downstream tracks; prompt K_S^0





Long-tracks: $\sigma = 5.5 MeV/c^2$

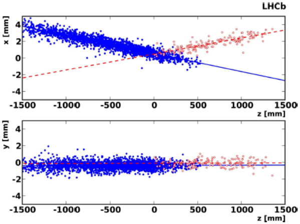
Downstream-tracks: $\sigma = 9.2 MeV/c^2$

$$\sigma = \frac{N^{obs}}{\epsilon^{trig/sel} \epsilon^{sel} L_{int}}$$

N^{obs}-events observed; $\epsilon^{trig/sel}$ reconstruction and selection efficiency; ϵ^{sel}-trigger eff on selected events; L_{int}-integrated luminosity

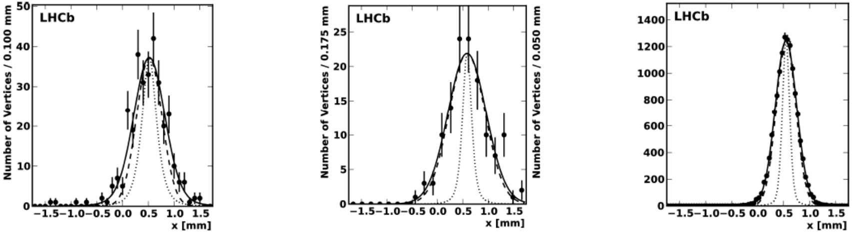
Luminosity measurement

Direct measurement of luminosity using beam profiles estimated from vertices made by VELO tracks in beam-gas and beam-beam collisions.

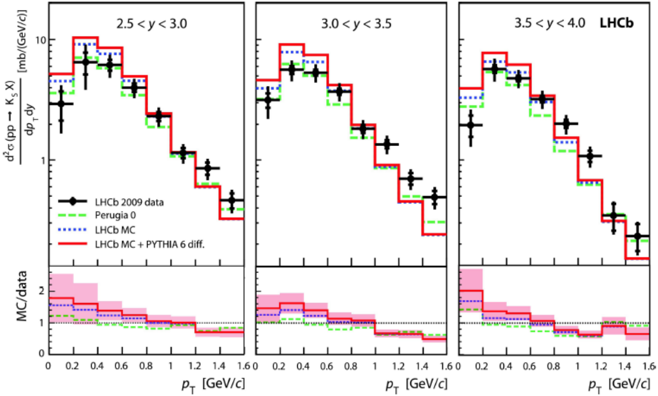


Most precise luminosity determination for 2009 run. Limited only by uncertainty on beam intensity.

$\mathcal{L} = 6.8 \pm 1.0 \mu b^{-1}$



K_s^0 production cross section

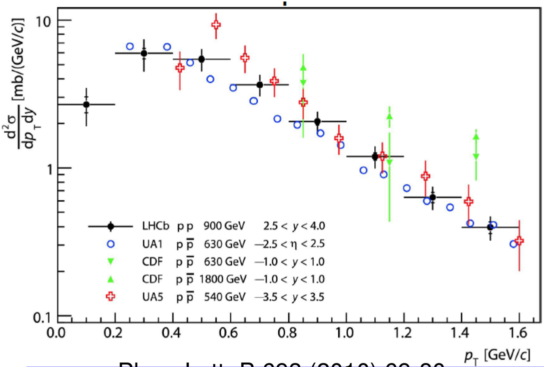


Phys. Lett. B 693 (2010) 69-80

Important input for hadronization models, measured in bins of y and p_T and compared to LHCb MC and Perugia 0 (Phys. Rev. D 82, 074018 (2010))
Good consistency with PYTHIA expectations p_T spectra slightly harder.

K_s^0 production cross section - 2009 Data

Comparison with other experiments



Phys. Lett. B 693 (2010) 69-80

- First measurement of the cross section @ 0.9 TeV;
- y and p_T range were extended;
- Main systematic contributions: luminosity $\sim$ 12%,
  tracking efficiency $\sim$ 10% (some bins)

Hadron production ratios

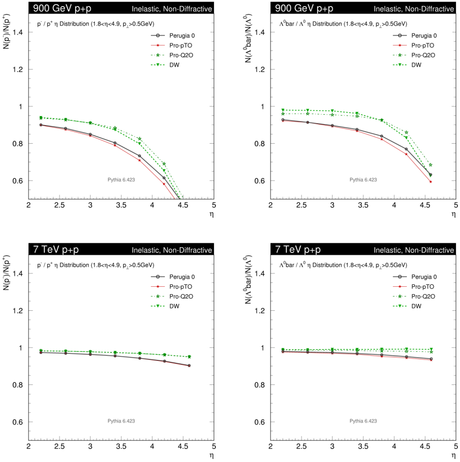
Motivation

- Baryon number transport - $\bar{\Lambda}/\Lambda$, $\bar{p}/p$
- Baryon vs. meson suppresion in hadronisation $\bar{\Lambda}/K^0_S$
- MC tuning input

2 analyses:

- V^0 ratios (tracking & vertexing only)
- $\bar{p}/p$ (+ RICH PID)

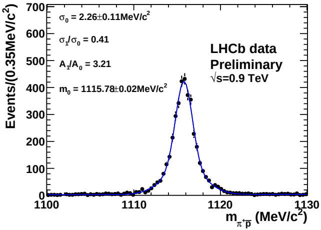
2010 data @ 0.9 TeV and 7 TeV
Use minimum bias data. No need to know absolute luminosity.

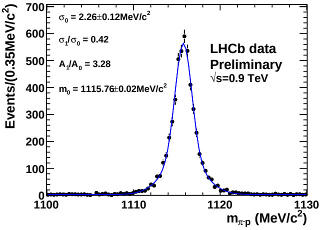


P. Skands
http://home.fnal.gov/~skands/

V^0 analysis

- Long tracks
- K_S^0 and Λ selection based on impact parameters
- PV requirement ensures that only the V^0 coming from non-diffractive events are kept
- Systematics uncertainties partially cancel
- $0.31nb^{-1}$ @ 0.9 TeV; $0.2nb^{-1}$ @ 7TeV

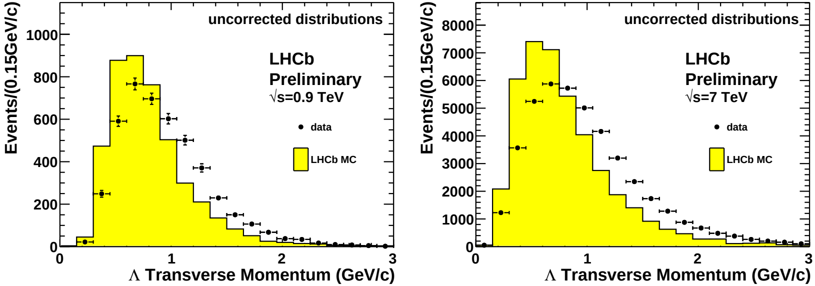




Visible asymmetry yields in raw data plots.

$\bar{\Lambda}/\Lambda$ analysis

P_T spectra harder than predicted



CERN-LHCb-CONF-2010-011

Preliminary results - $\bar{\Lambda}/\Lambda$

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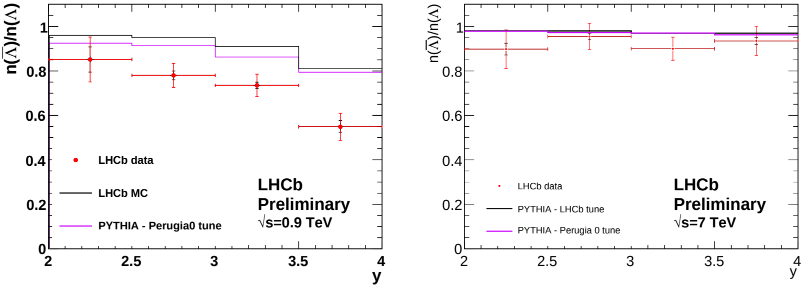

- Baryon transport higher than predicted at 0.9 TeV
- As expected, better agreement with the models closer to the beam in rapidity $((y_{beam} - y)@7\,TeV < (y_{beam} - y)@0.9\,TeV)$

Preliminary results - $\bar{\Lambda}/K^0_S$

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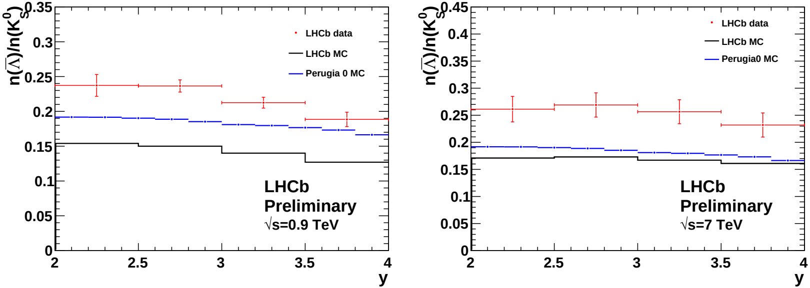
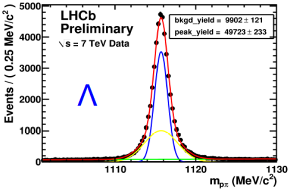
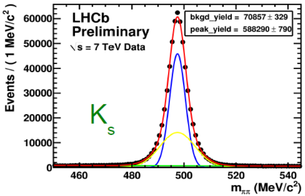


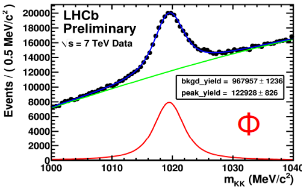
- Ratio of $\bar{\Lambda}/K^0_S$ higher than expectation at both energies
- Forward region not well described by hadronization models
- Sensitive observable for MC-tuning

Prompt $\bar{p}/p$ production ratio

- Pure samples of protons selected with RICH particle ID
- Need to select samples of K and π to keep contamination under control
- Cuts tuned on MC but real efficiencies and misID are extracted from data using calibration samples of $\Lambda \to p\pi$, $\phi \to KK$, $K_S \to \pi\pi$



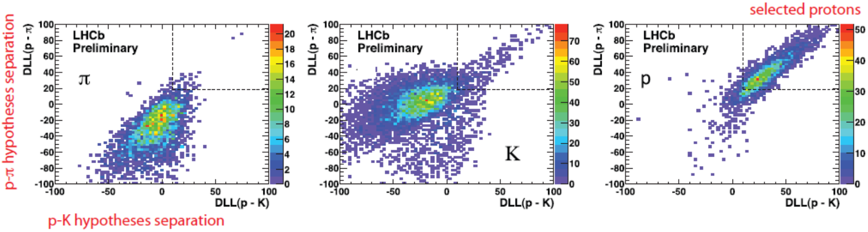




$0.31 nb^{-1}$ @ 0.9 TeV; $0.2 nb^{-1}$ @ 7TeV

Prompt $\bar{p}/p$ production ratio

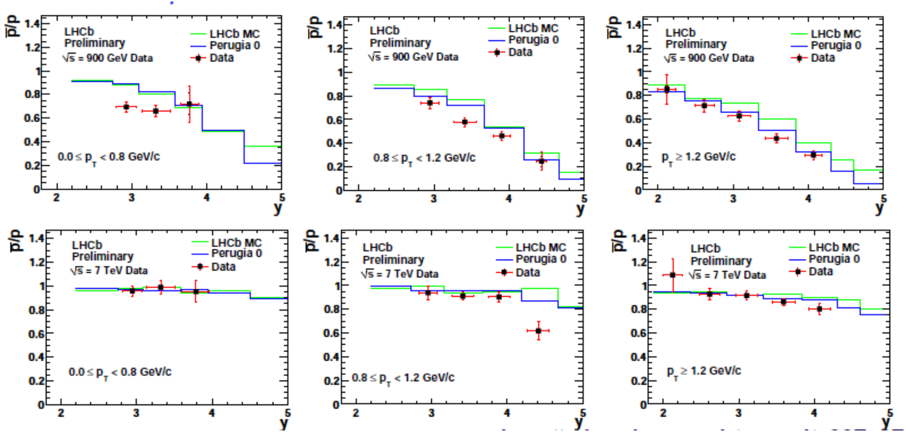
Tracks from calibration samples demonstrate that protons are effectively selected
Contamination from K and π is also quantified



Contamination correction $\begin{pmatrix} p_{True} \\ K_{True} \\ \pi_{True} \end{pmatrix} = \begin{pmatrix} p \to p & K \to p & \pi \to p \\ p \to K & K \to K & \pi \to K \\ p \to \pi & K \to \pi & \pi \to \pi \end{pmatrix}^{-1} \begin{pmatrix} p_{Sel} \\ K_{Sel} \\ \pi_{Sel} \end{pmatrix}$

Different interaction cross-sections in the material between p and $\bar{p}$, particulary at low momentum
Therefore limit analysis to tracks with $P > 5$GeV and correct using MC

Preliminary results - $\bar{p}/p$ ratio



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- @ 0.9 TeV baryon transport higher than predictions and similar to $\bar{\Lambda}/\Lambda$
- @ 7 TeV Ratios become flatter as predicted by models; better agreement with MC

Baryon number transport comparison

Wide coverage of Δy =y(beam)-y(Λ,p) .

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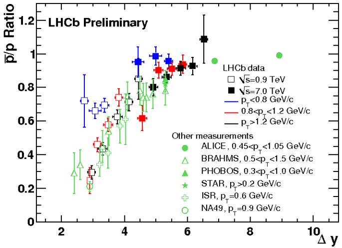

- Data in agreement with previous measurements for the same p_t region
- Indications of p_T dependence
- Limitation from the small sample used for calibration expected to drop

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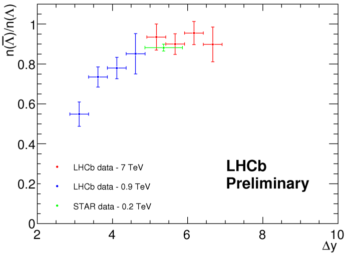


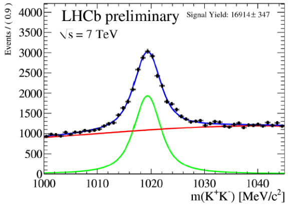
- Consistent with STAR measurement
- @ 0.9 TeV - first time investigated this y region; @ 7 TeV - probes scaling violation
- Systematic uncertainties: from the difference between MC and data

Inclusive Φ cross section

Unique way to study strangeness production (the strange quarks pair)

- Discrepancies from MC seen by all major LHC experiments
- Test QCD fragmentation models in *pp* interactions in LHCb's kinematic region

- $\Phi \rightarrow K^+K^-$ candidates selection requires RICH PID information
- PID cuts efficiency estimated from data using tag&probe technique
- Same decay mode is used to test RICH system performance



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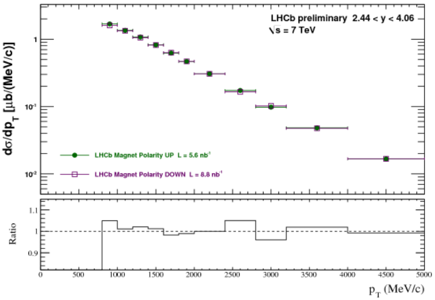
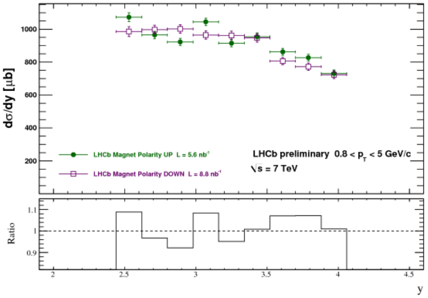
- The main systematics uncertainties come from luminosity and tracking estimations
- Does not separate between diffractive and non-diffractive processes
- $14.3nb^{-1}$ @ 7 TeV

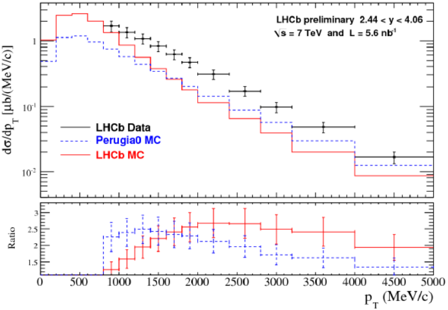
Magnet polarities





- The LHCb magnet polarity can be reversed to minimize systematics
- PID needs to be calibrated independently
- Φ analysis done separately on both data sets

Preliminary Results - Φ



- 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

Summary

LHCb has explored a unique kinematic region with first data

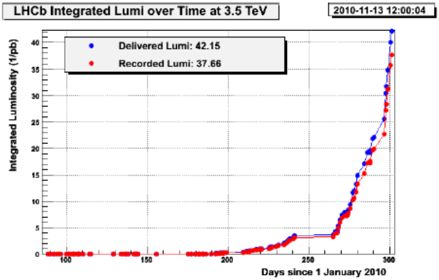
- All analyses limited by systematics
- Several analyses are investigating hadron production and will provide valuable input for QCD models and the LHCb MC retuning
- Proton analysis can be extended to provide further ratios π^-/π^+, K^-/K^+, etc.

Preliminary results compared to models indicate:

- Forward region not well described by models; harder P_T spectra
- Higher baryon transport
- The observed high value of baryon suppresion suggests underestimated strangeness production or total particle multiplicity in simulation

Back-up slides

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



... 90% taking efficiency!

	$\sqrt{s} = 0.9 TeV$	$\sqrt{s} = 7 TeV$
K_S^0 cross section	X	
V^0 ratios	X	X
$p/\bar{p}$	X	X
Φ cross section		X

Uncertainties of K_S^0 cross section measurement

Source of uncertainty	uncorrelated	correlated
Yields N_i^{obs}		
– Data statistics	$5-25\,\%$	
– Signal extraction	$1-5\,\%$	
– Beam-gas subtraction		$< 1\,\%$
Efficiency correction $(\epsilon_i^{trig/sel}\ \epsilon_i^{sel})^{-1}$		
– MC statistics	$1-5\,\%$	
– Track finding		$6-17\,\%$
– Selection		$4\,\%$
– Trigger		$2\,\%$
– p_T and y shape within bin	$0-20\,\%$	
– Diffraction modelling		$0-1\,\%$
– Non-prompt contamination		$< 1\,\%$
– Material interactions		$< 1\,\%$
Normalization $(L_{int})^{-1}$		
– Bunch currents		$12\,\%$
– Beam widths		$5\,\%$
– Beam positions		$3\,\%$
– Beam angles		$1\,\%$
Sum in quadrature	$6-28\,\%$	$16-23\,\%$

- measurement statistics limited in some regions of phase space
- largest systematics from luminosity (knowledge of bunch currents)