Particle production multiplicities at LHCb

Andrea Contu
University of Oxford
On behalf of the LHCb collaboration

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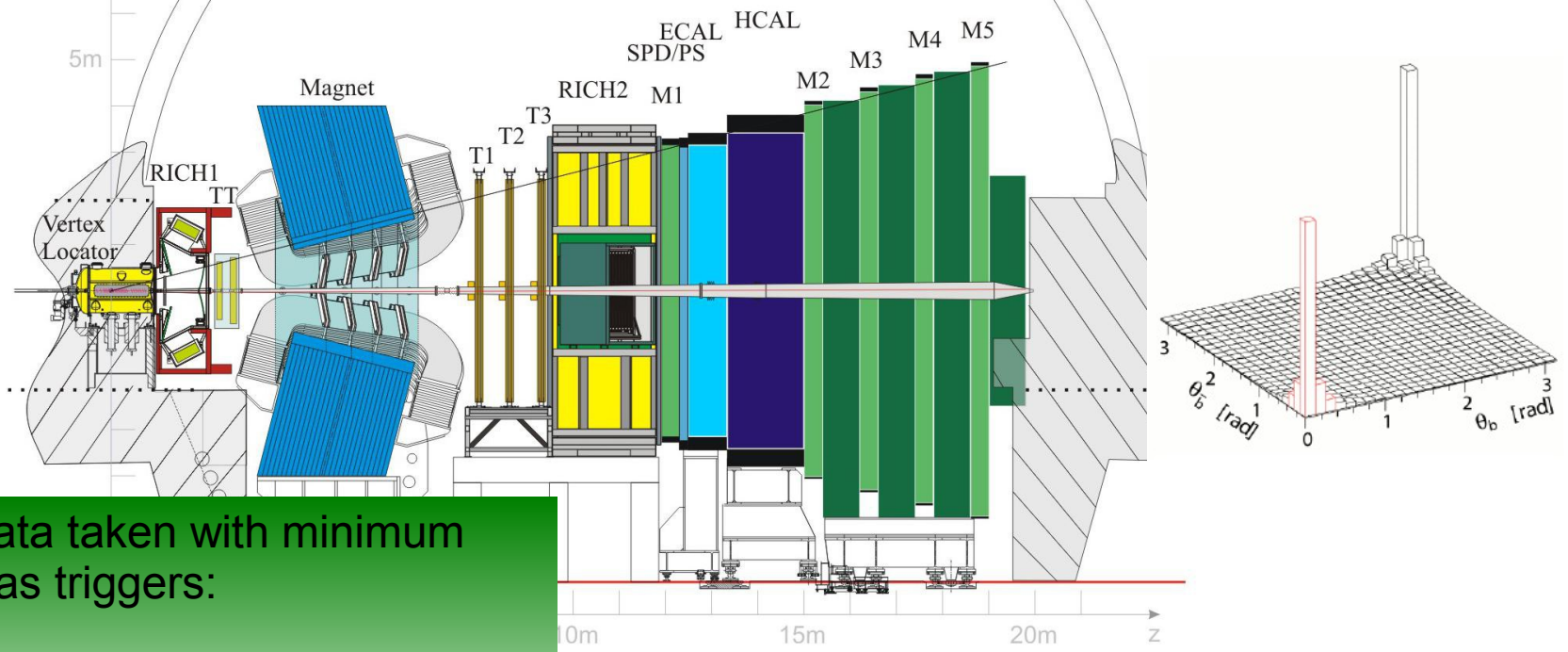
Kruger National Park – South Africa

Contents

- Introduction to LHCb
- K_S production cross section
- $\overline{\Lambda}/\Lambda$, $\overline{\Lambda}/K_S$ production ratios
- $\overline{p}/p$ production ratio
- Inclusive Φ cross section
- Summary

The LHCb Experiment

Single arm spectrometer (2<η<5) for precision measurements of CP violation and rare B decays

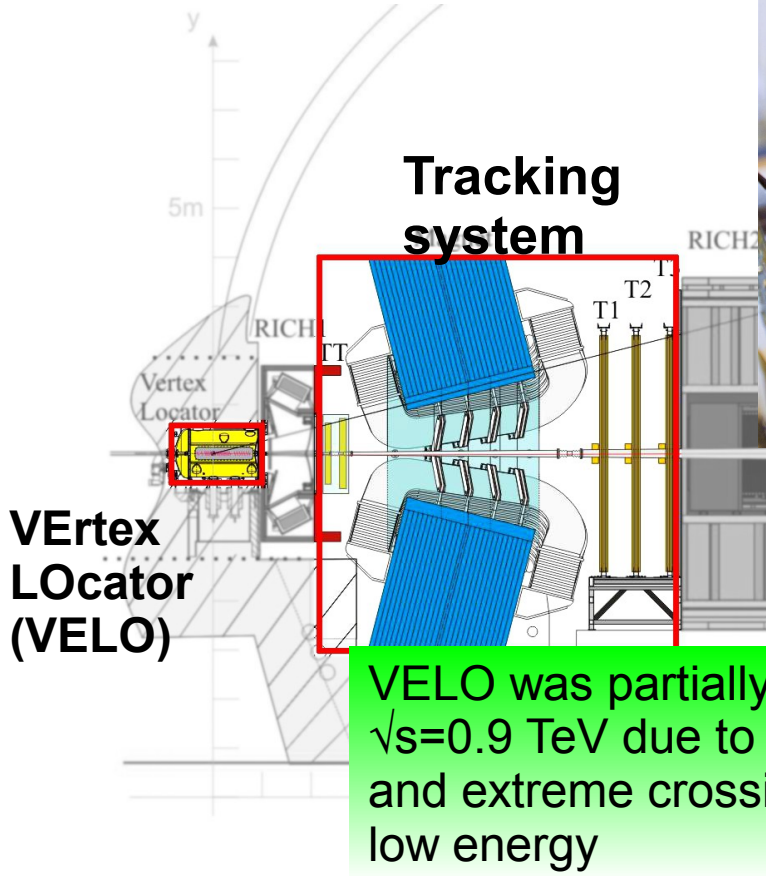


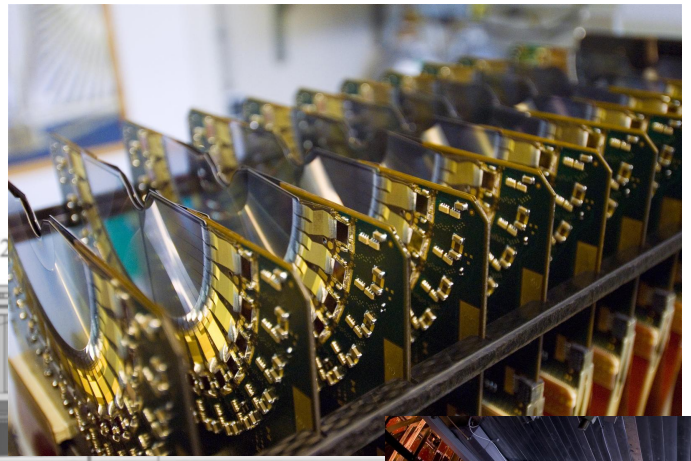
Data taken with minimum bias triggers:

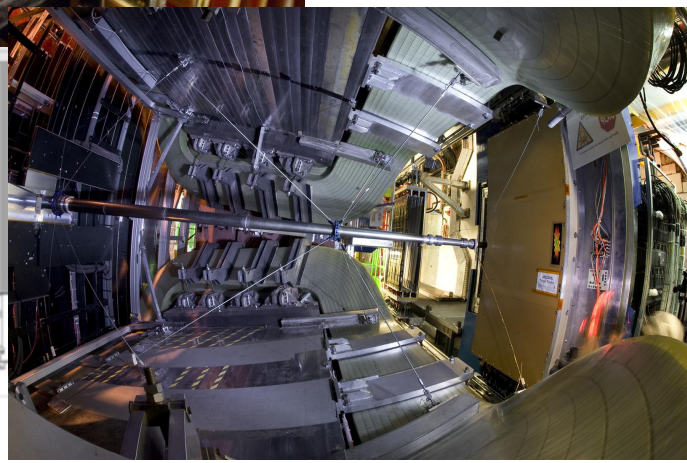
2009: Calo ($7\mu b^{-1}$)
2010: 1 or more reconstructed tracks ($14nb^{-1}$)

Provides measurements in a region of phase space complementary to GP detectors

Tracking





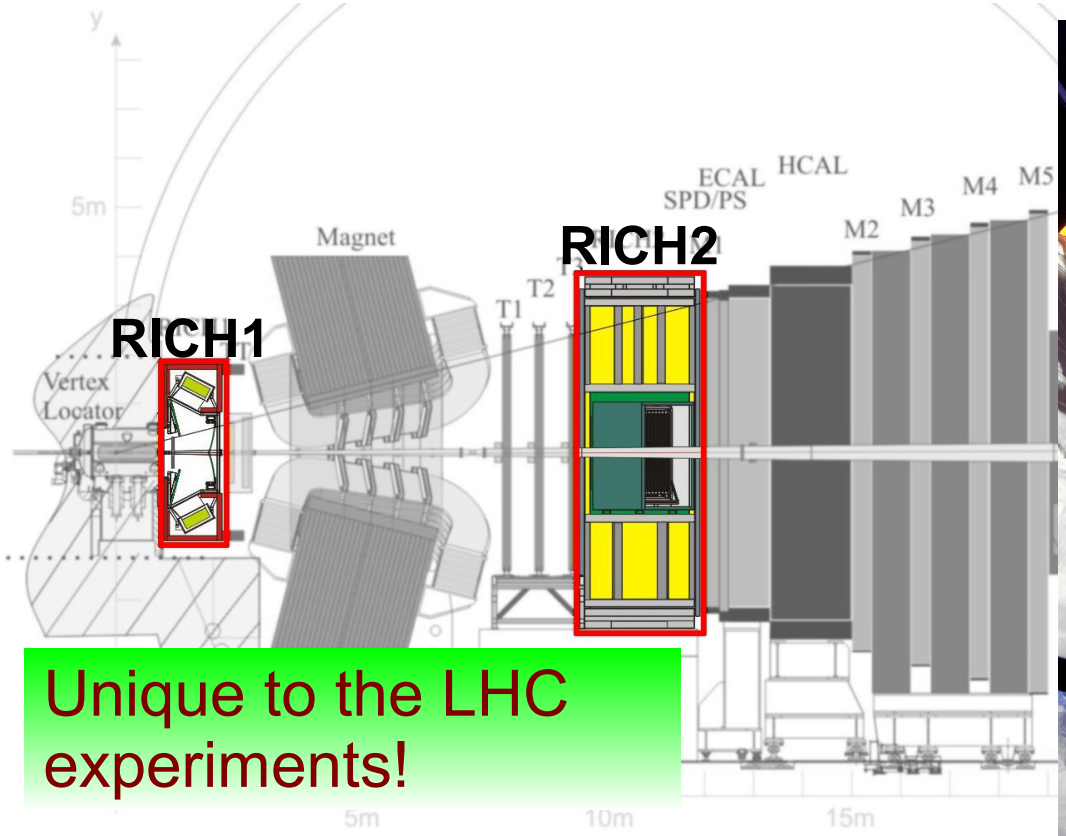


VELO was partially opened at $\sqrt{s}$=0.9 TeV due to beam size and extreme crossing angle at low energy

$\delta p/p$ ~ 0.5% - reconstruction efficiency ~95%

Resolution for primary(secondary) vertices is σ_z~50(150) μm

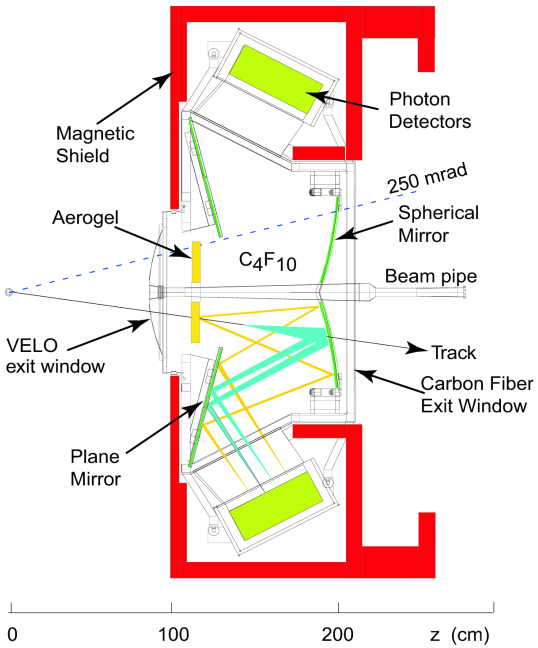
RICH Detectors



Unique to the LHC experiments!

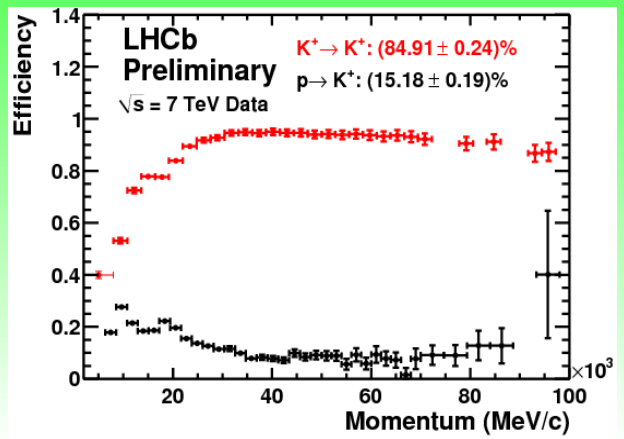
2 Ring Imaging CHerenkov (RICH) detectors provide charged particle identification in a momentum range of 2 - 100 GeV

RICH Detectors



RICH detectors provide excellent Particle Identification

Vital for K/π/p discrimination and good tagging efficiency



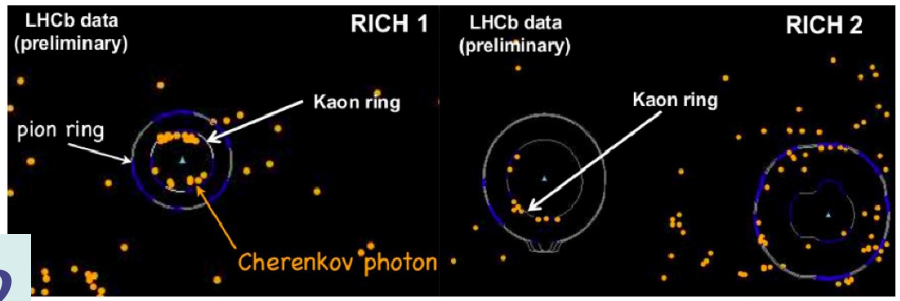
3 Radiators needed

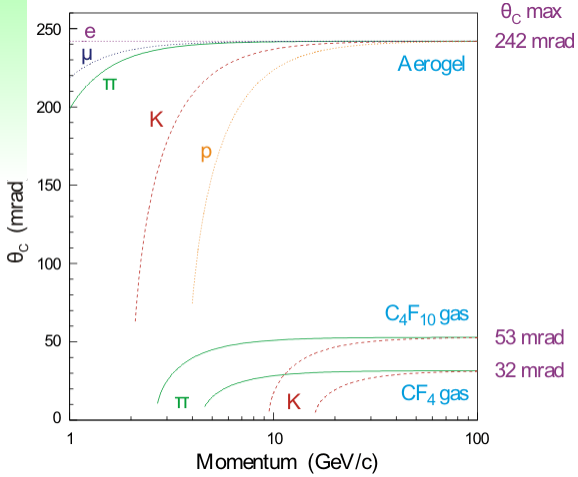
RICH1 (2<p<60 GeV):

- Aerogel, n~1.03
- C_4F_{10}, n~1.0014

RICH2 (p>20 GeV)

- CF_4, n~1.0005

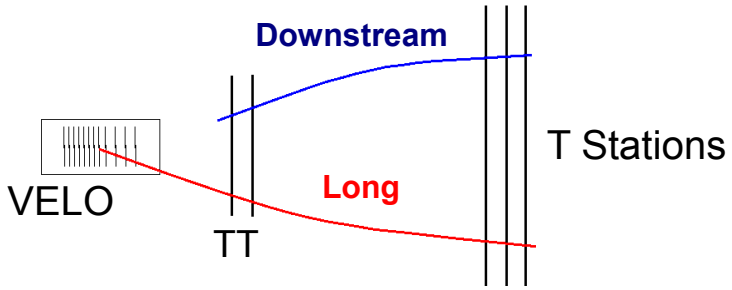




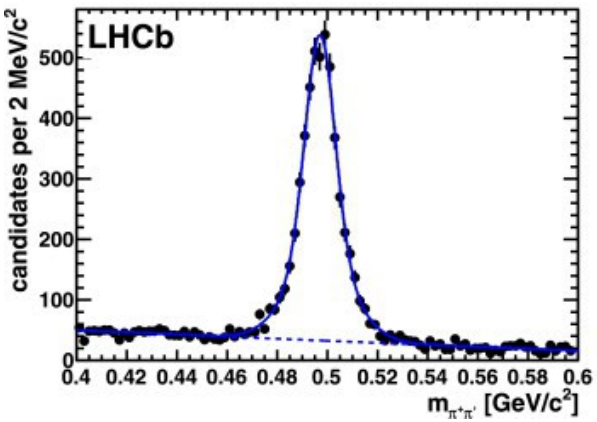
K_s Production Cross Section

- First measurement for LHCb with 2009 pilot run data
- $K_s \rightarrow \pi\pi$ selection based on tracking and impact parameters
- Two selections with long and downstream tracks
- First test for detector calibration

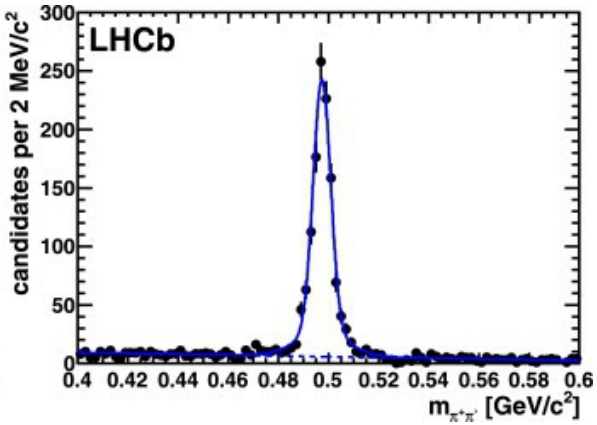
Published in: Phys. Lett. B 693 (2010) 69-80



Long-tracks

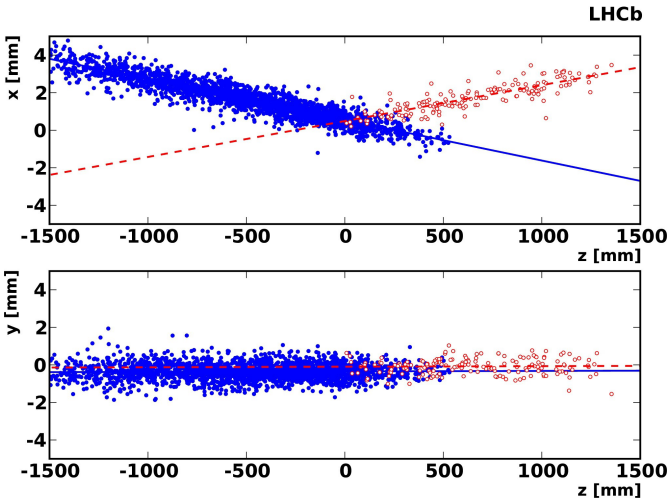


Downstream-tracks



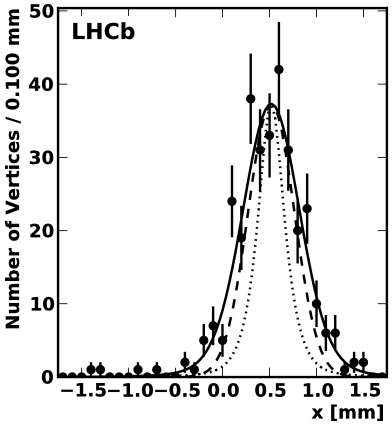
K_s Production Cross Section

New method to estimate luminosity using beam profiles estimated from vertices made by VELO tracks in beam-gas and beam-beam collisions

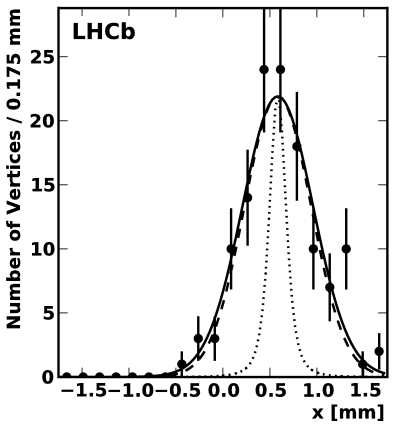


Most precise L determination for 2009 run
Limited only by uncertainty on beam intensity

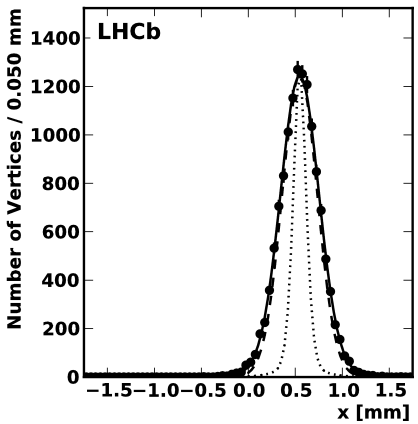
BEAM-1 PROFILE



BEAM-2 PROFILE



LUMINOUS REGION



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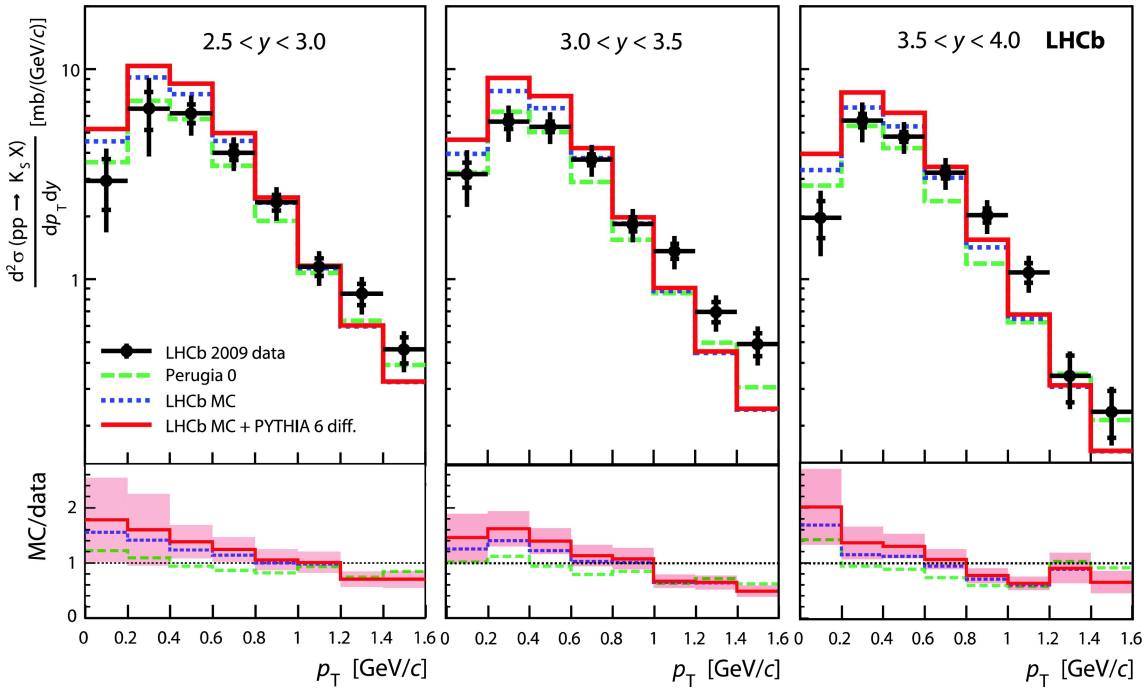
K_S Production Cross Section

Good consistency with PYTHIA expectations
P_T spectra slightly harder



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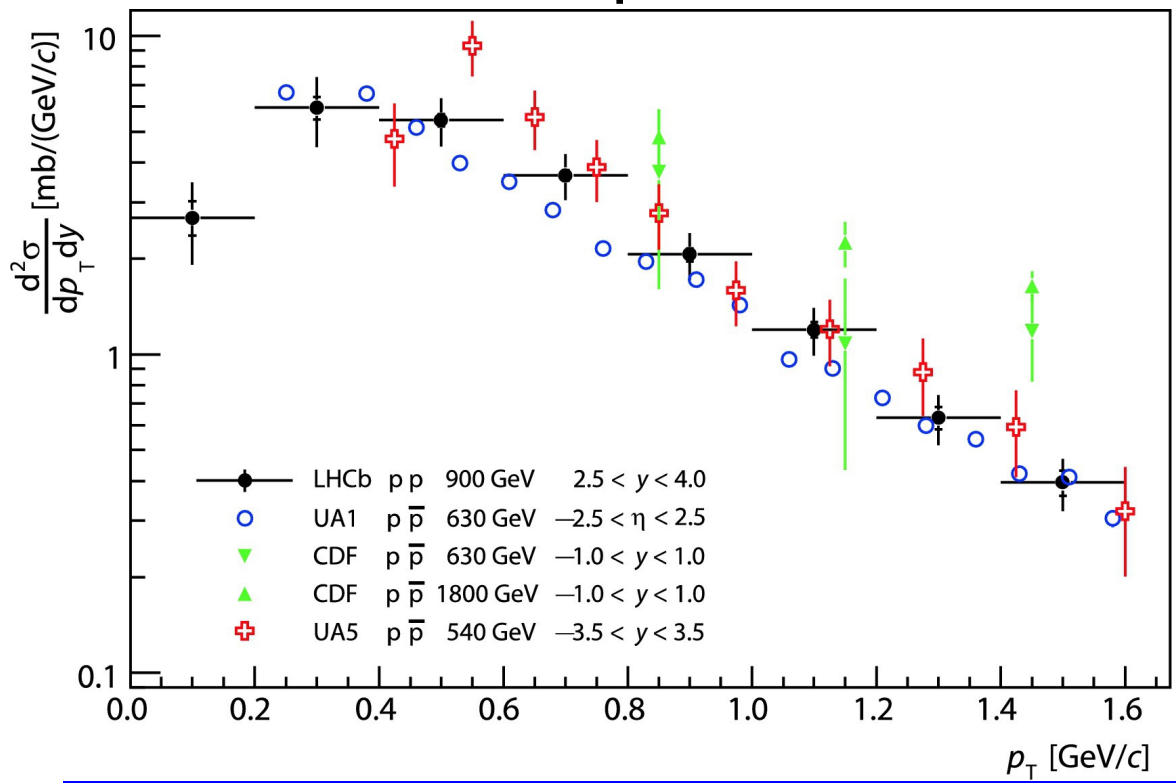
K_s Production Cross Section

Comparison with other experiments



Unique measurement at high rapidity and low P_T

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Hadron Production Ratios

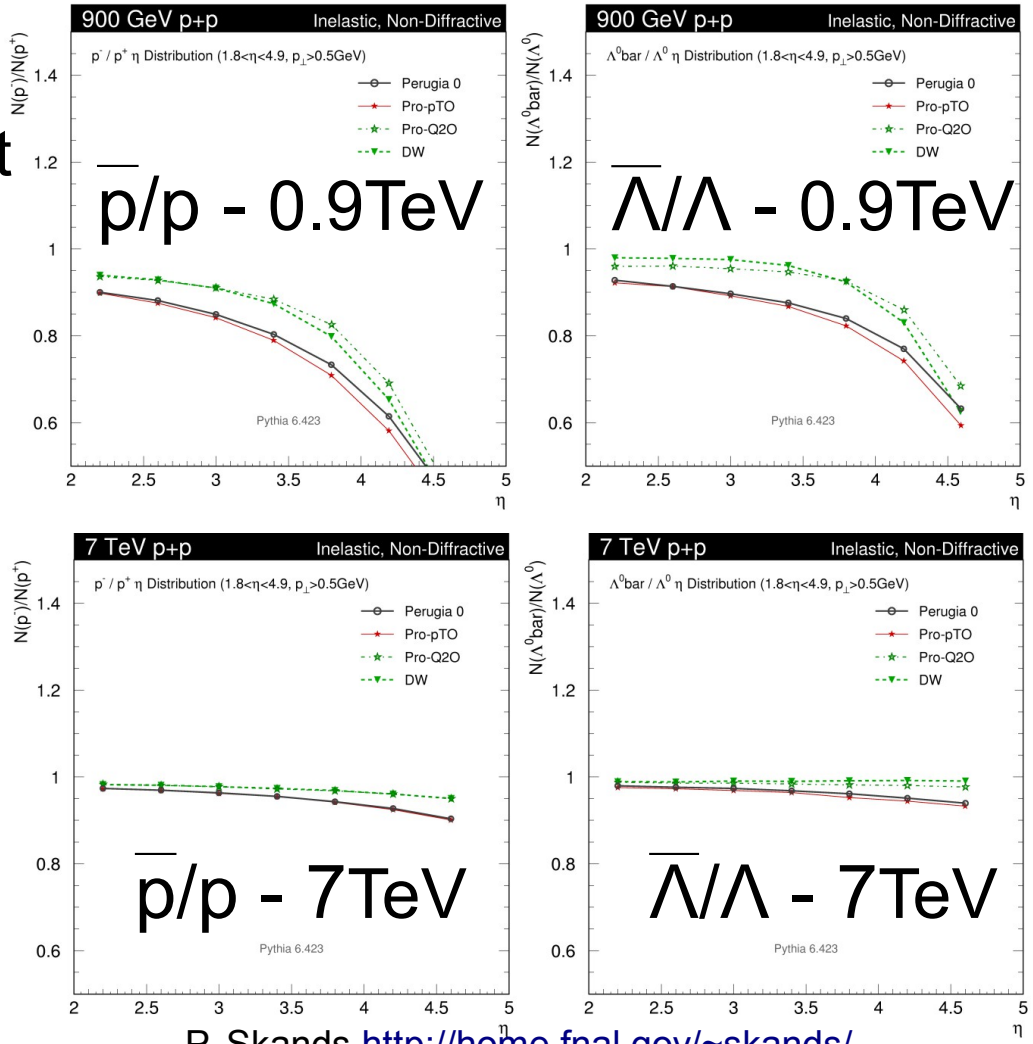
Motivation:

- Baryon number transport
- Hadronisation
- MC tuning

2 analyses:

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

Use minimum bias data
No need to know absolute L

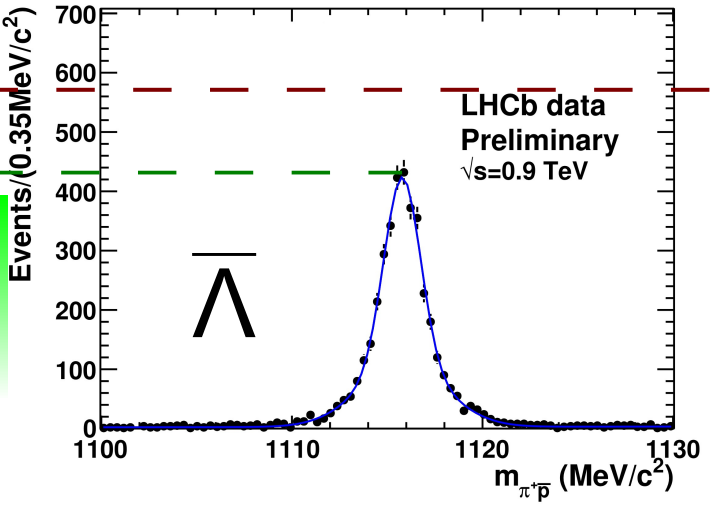


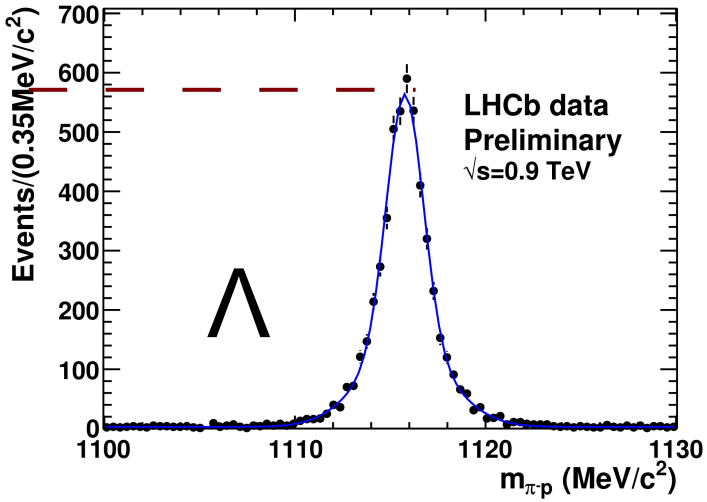
P. Skands http://home.fnal.gov/~skands/

$\overline{\Lambda}/\Lambda$ - $\overline{\Lambda}/K_s$ analysis

- Long tracks
- Purely kinematic PID (Armenteros-Podolanski)
- K_s and Λ selection based on impact parameters
- Systematics partially cancel

Clear yields asymmetry in raw mass plots





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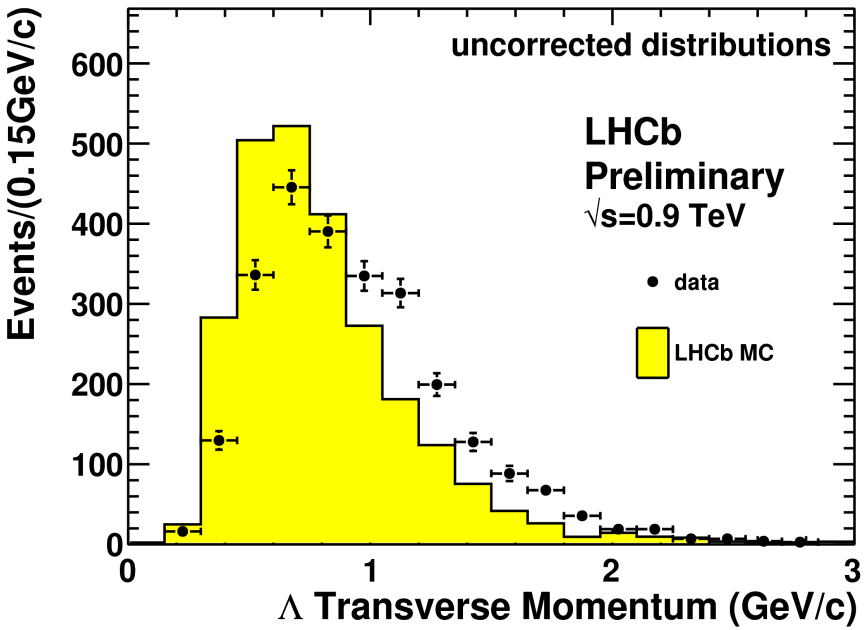
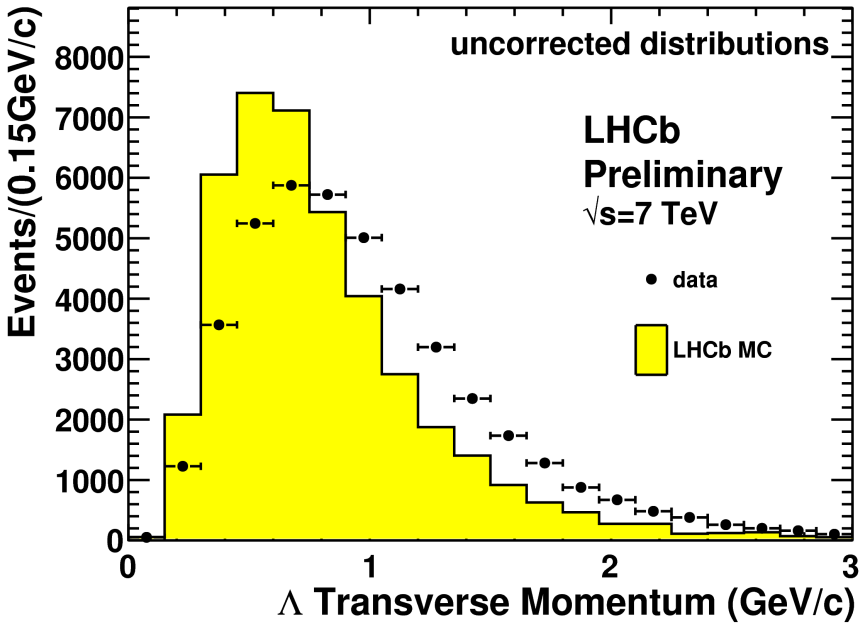
$\overline{\Lambda}/\Lambda$ analysis

P_T spectra harder than predicted





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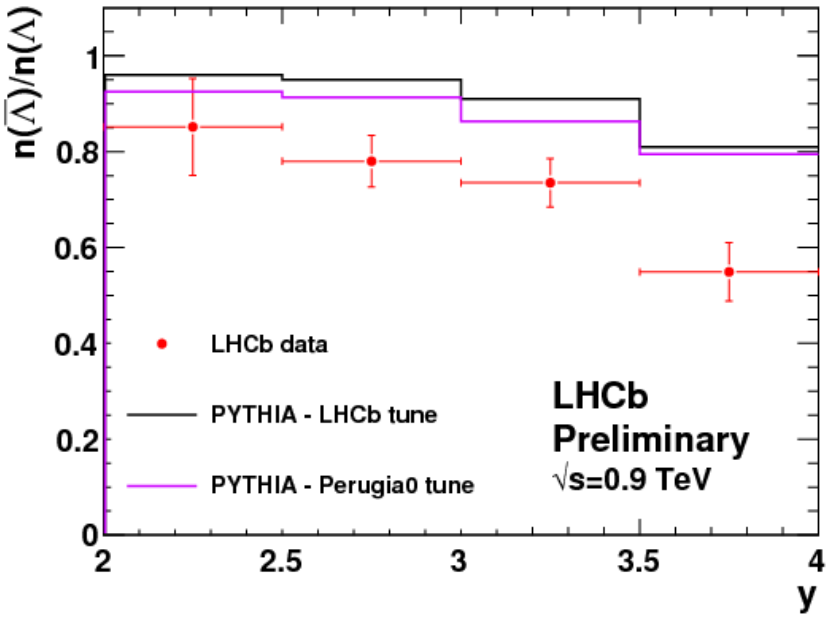
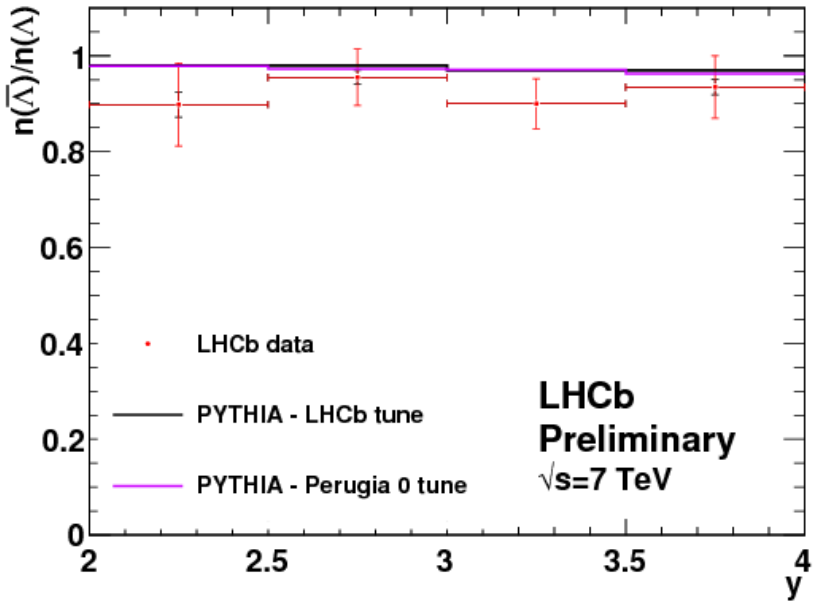
Preliminary Results - $\overline{\Lambda}/\Lambda$

Baryon transport higher than predicted at 0.9 TeV





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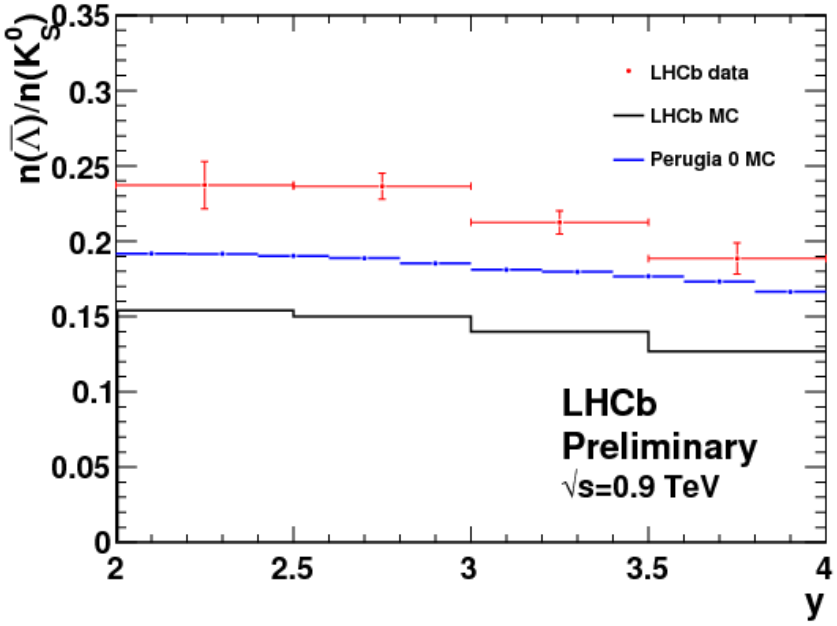
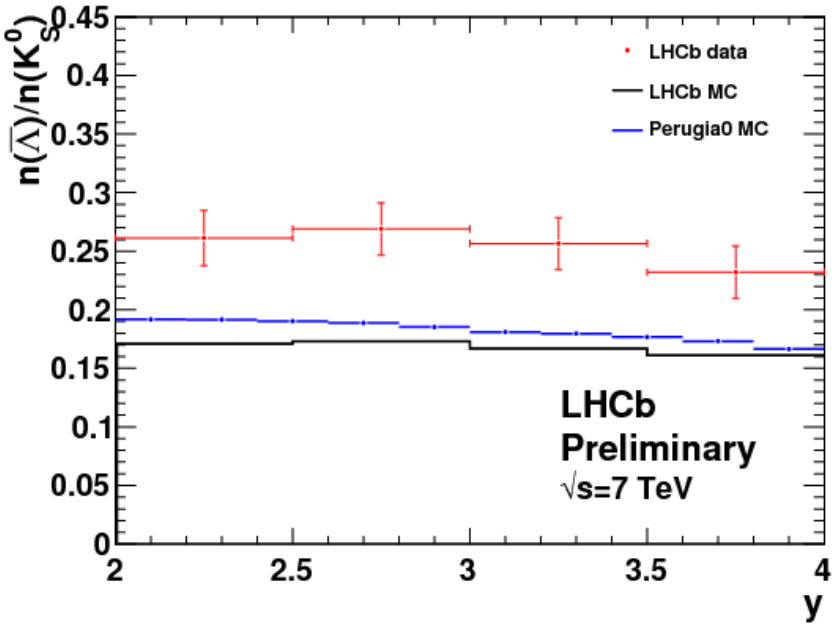
Preliminary Results - $\bar{\Lambda}/K_s$

Baryon/Meson suppression lower than predicted





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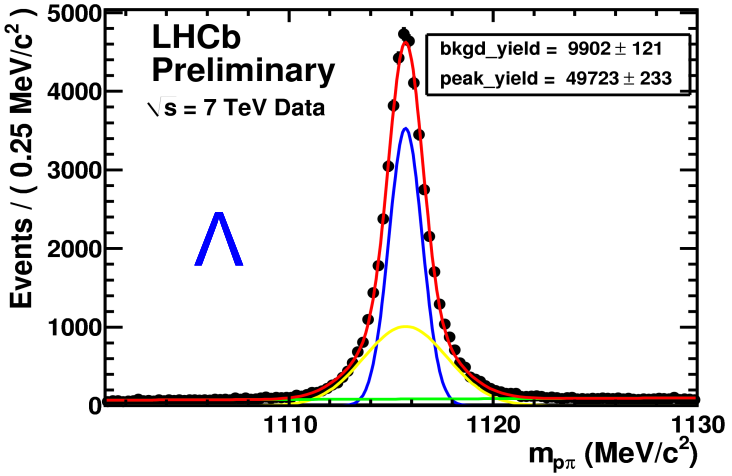
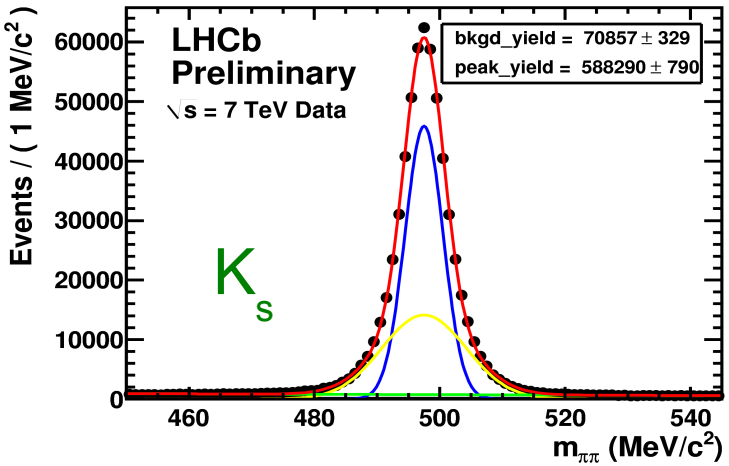
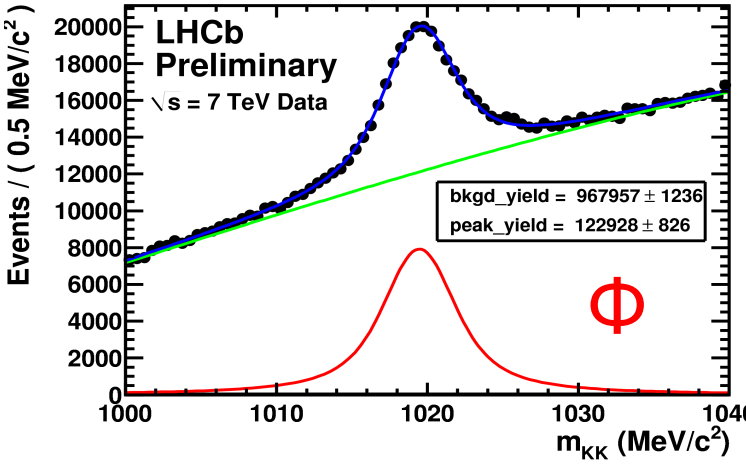
Prompt $\bar{p}/p$ Production Ratio

- 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 *mis*ID are extracted from data using calibration samples of $\Lambda \to p\pi$, $\Phi \to KK$, $K_s \to \pi\pi$



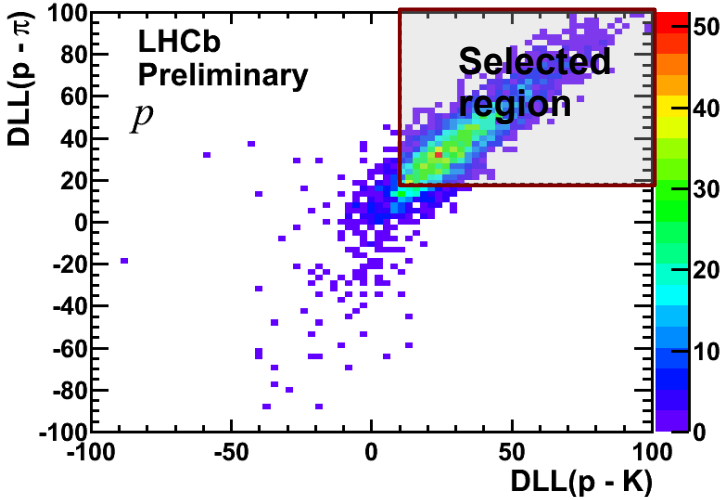


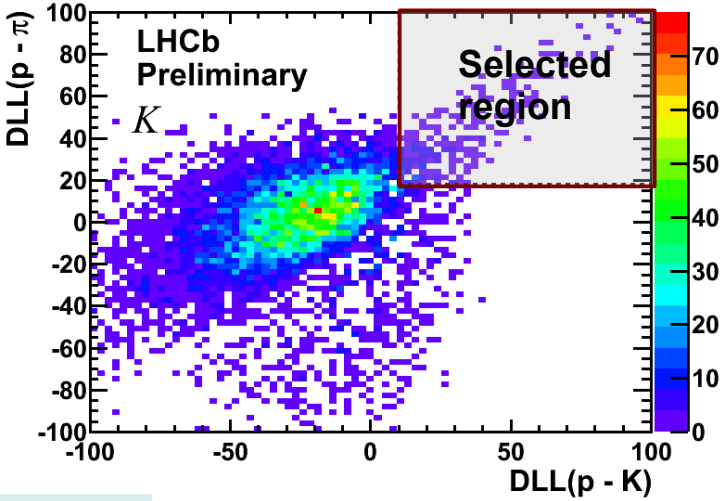


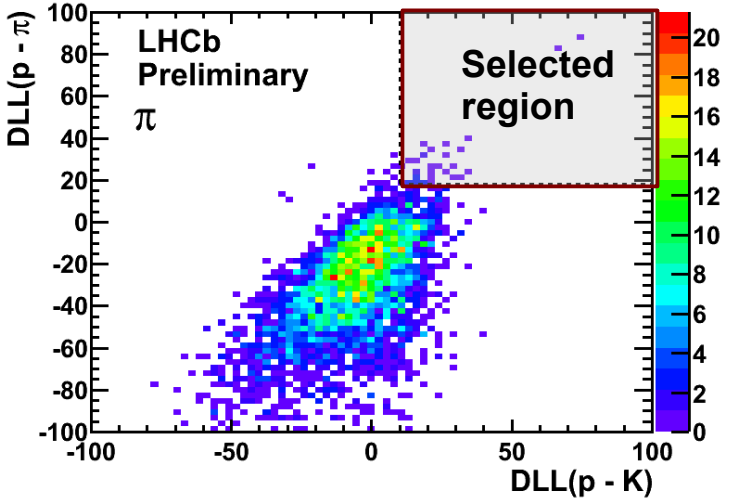
Prompt $\bar{p}/p$ Production Ratio

Tracks from calibration samples demonstrate that protons are effectively selected

Contamination from K and π is also quantified







DLL(x-y) = Delta Log Likelihood between x and y particle hypotheses

$\bar{p}/p$ ratio – Analysis strategy

Contamination correction

From data

$$\begin{pmatrix} p_{Sel} \\ K_{Sel} \\ \pi_{Sel} \end{pmatrix} = \begin{pmatrix} p \to p & K \to p & \pi \to p \\ p \to K & K \to K & p \to K \\ p \to \pi & K \to p & \pi \to \pi \end{pmatrix} \begin{pmatrix} p_{True} \\ K_{True} \\ \pi_{True} \end{pmatrix}$$

All corrections are applied independently for each (P_T,η) bin and particle charge

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

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

Preliminary Results – $\sqrt{s}$=0.9 TeV

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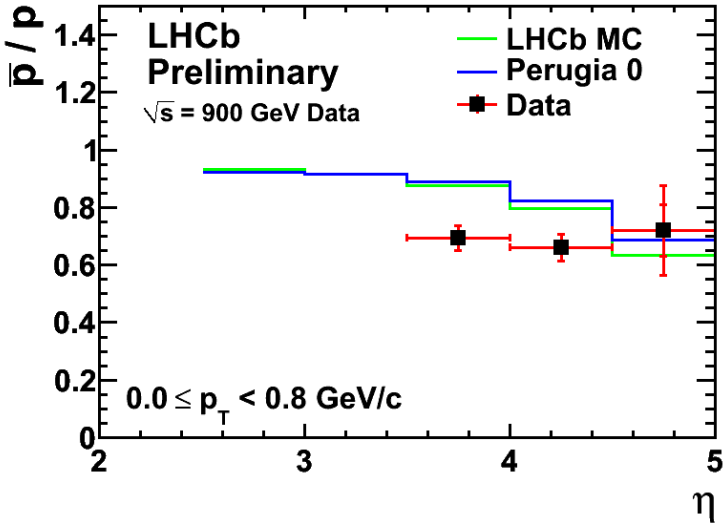
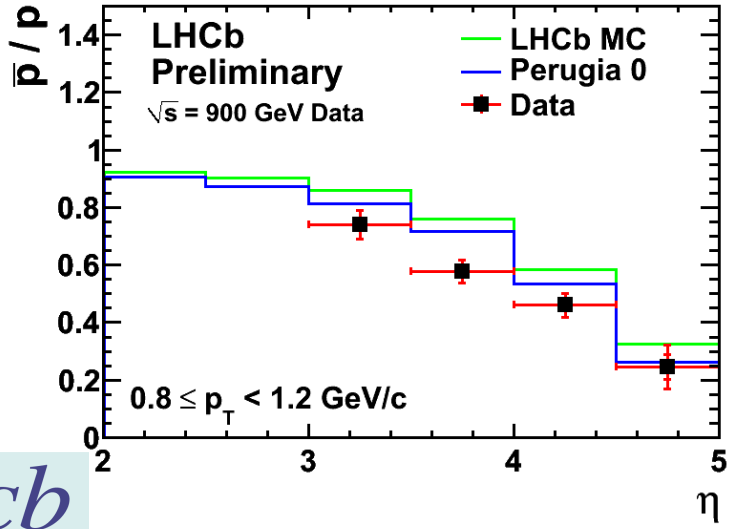
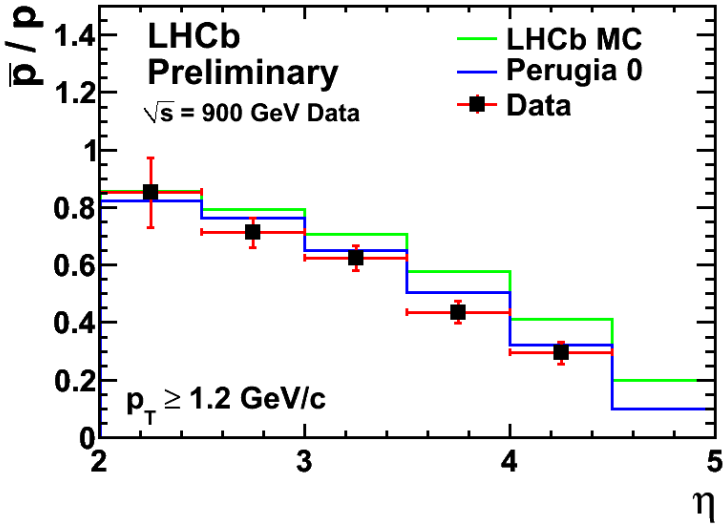
Baryon transport higher than predictions and consistent with $\overline{\Lambda}/\Lambda$







Preliminary Results – √s=7 TeV

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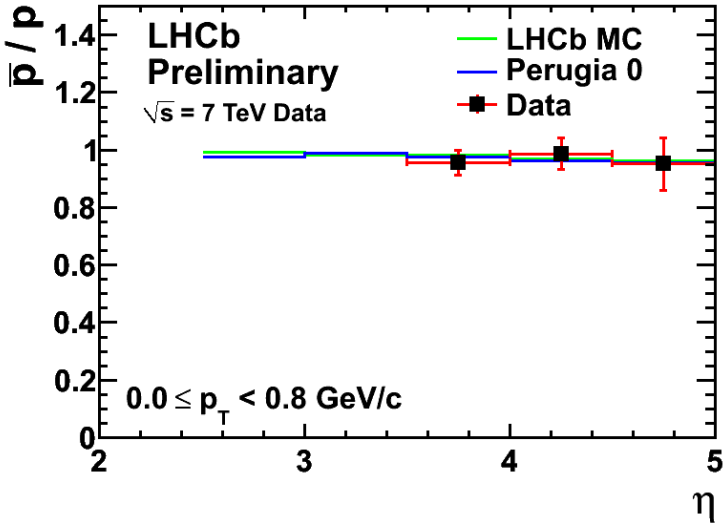
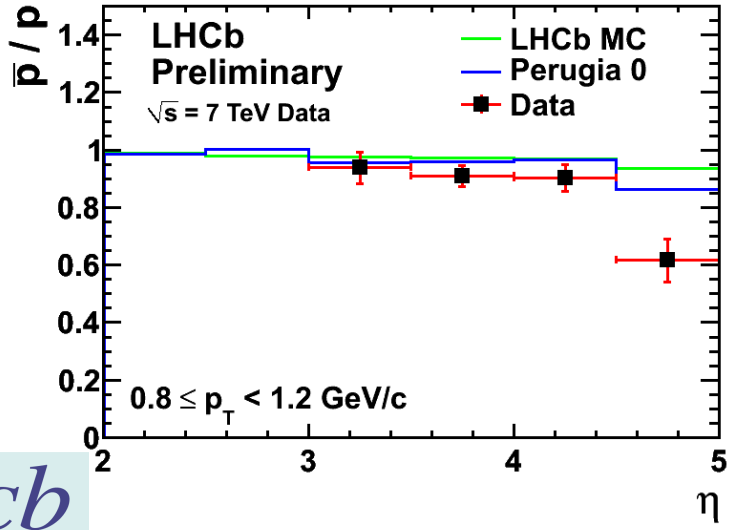
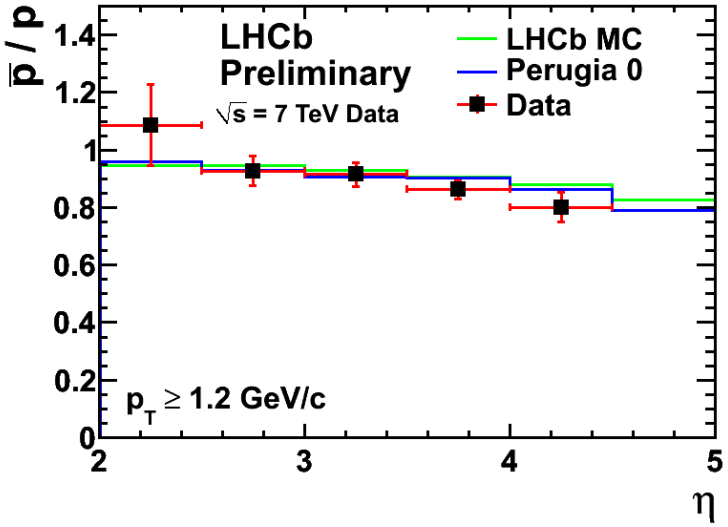
Ratios become flatter as predicted by models

Better agreement with MC







Preliminary Results Comparison

Results over the wide LHCb Δy spread show consistency with other experiments

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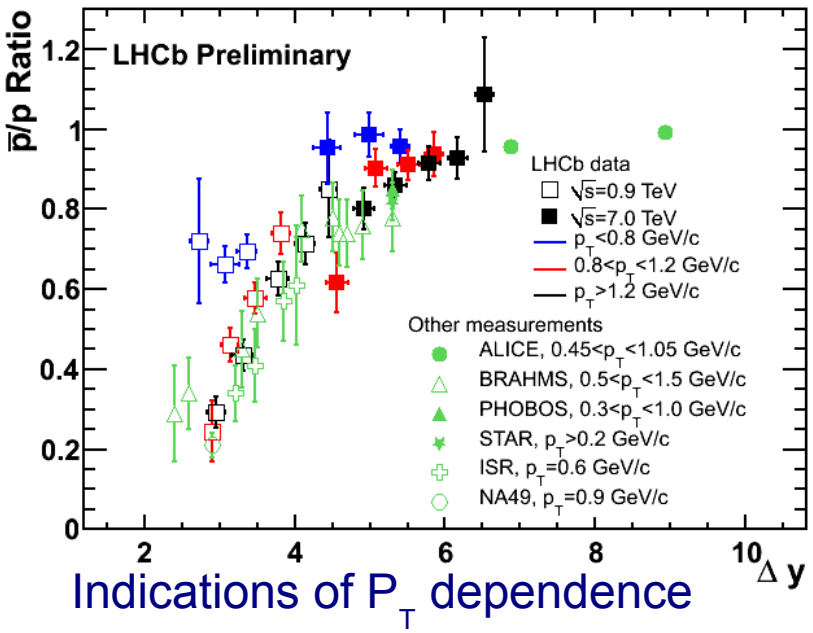

Indications of P_T dependence

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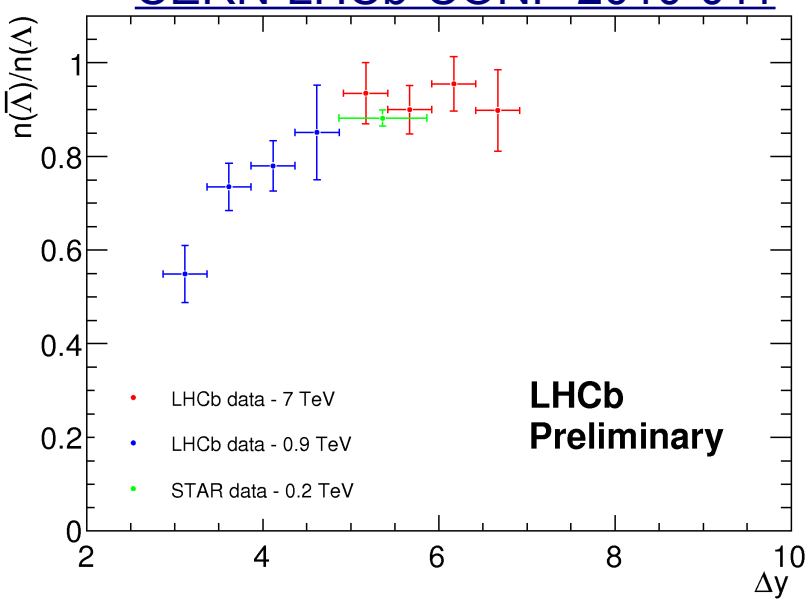


Δy=y(beam)-y(Λ,p)

Results are being finalised and higher precision is expected

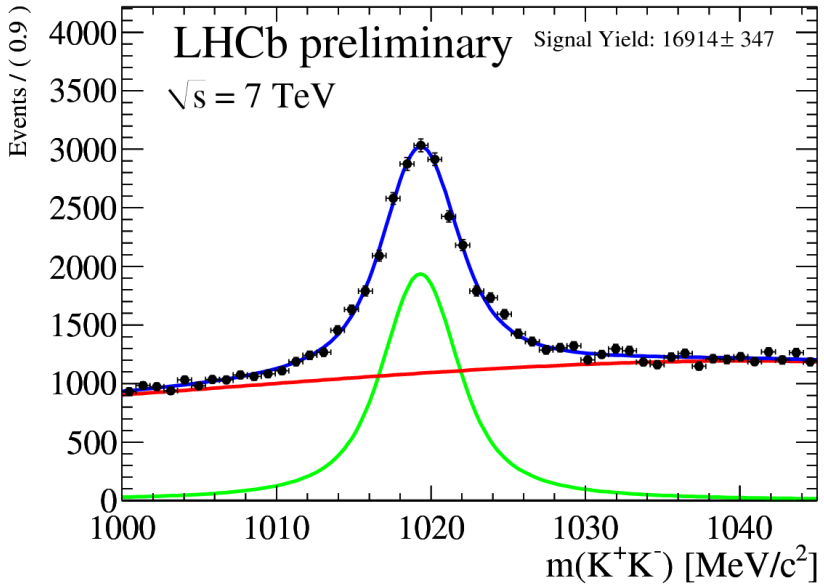
Inclusive Φ Cross Section

Unique way to study strangeness production

- 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

Same decay mode is used to test RICH system performance

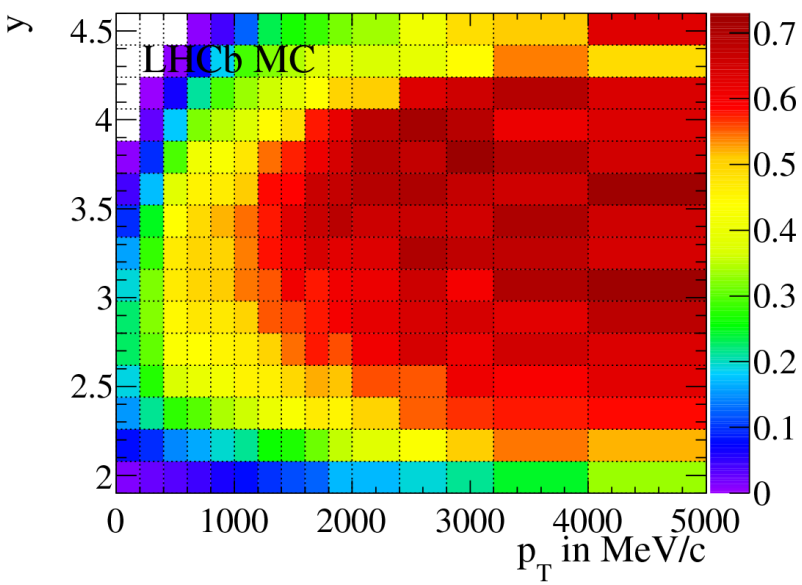


Inclusive Φ Cross Section

Cross section measurement is performed in bins of P_T and Y

$$\sigma = \frac{N}{L \cdot B(\Phi \to KK) \cdot \epsilon_{REC+PID}}$$

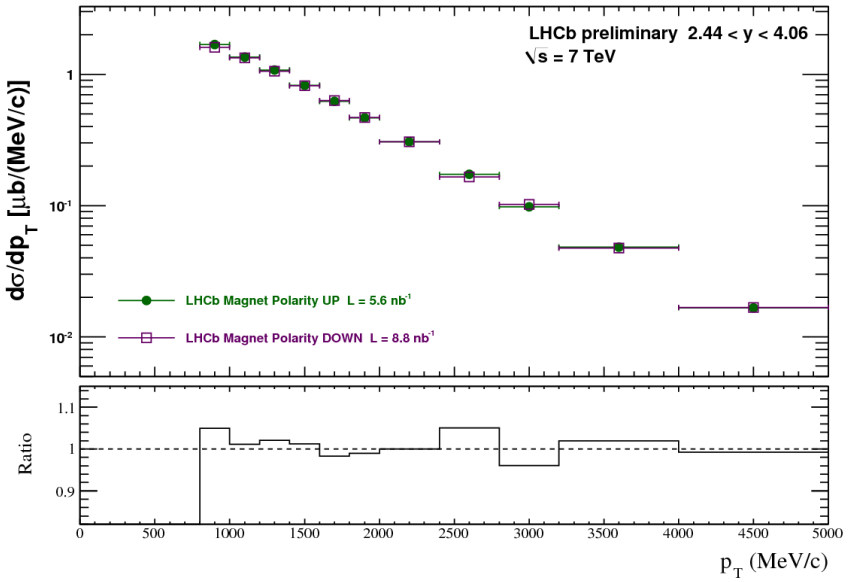
PID cuts efficiency estimated from data using tag&probe technique

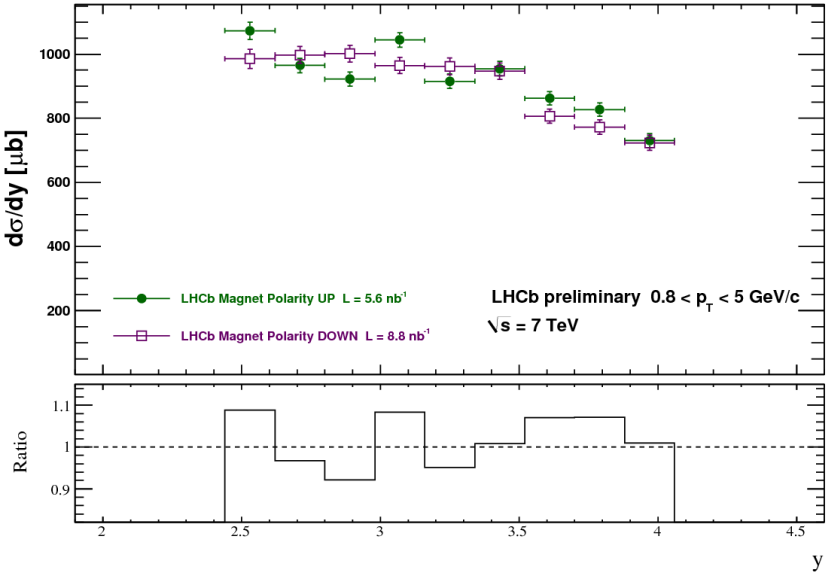


Major systematics uncertainties	(%)
Tracking	8
Track Multiplicity	5
Reconstruction (binned)	~2
PID efficiency (binned)	~3
Luminosity	10
Combined	14.4

Magnet polarities

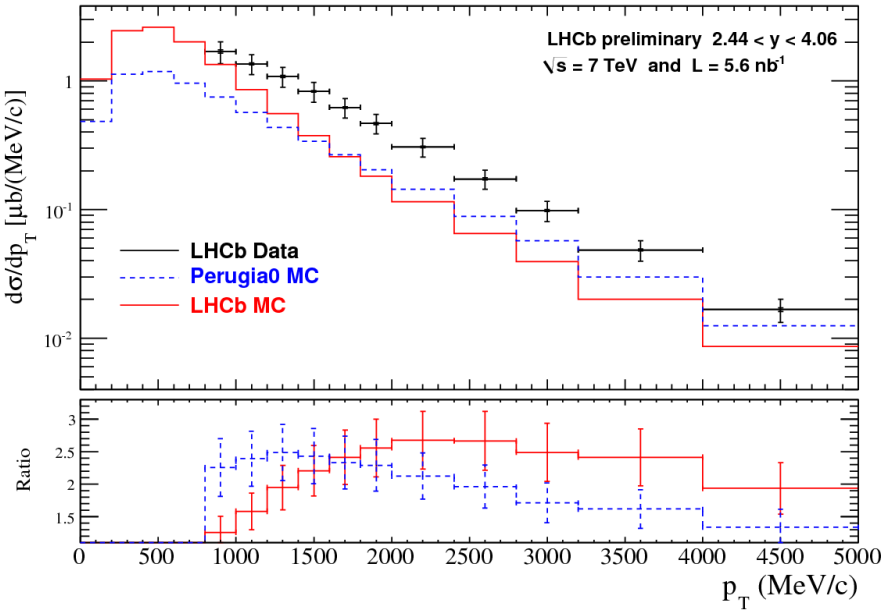
Data from both magnet polarities agree well

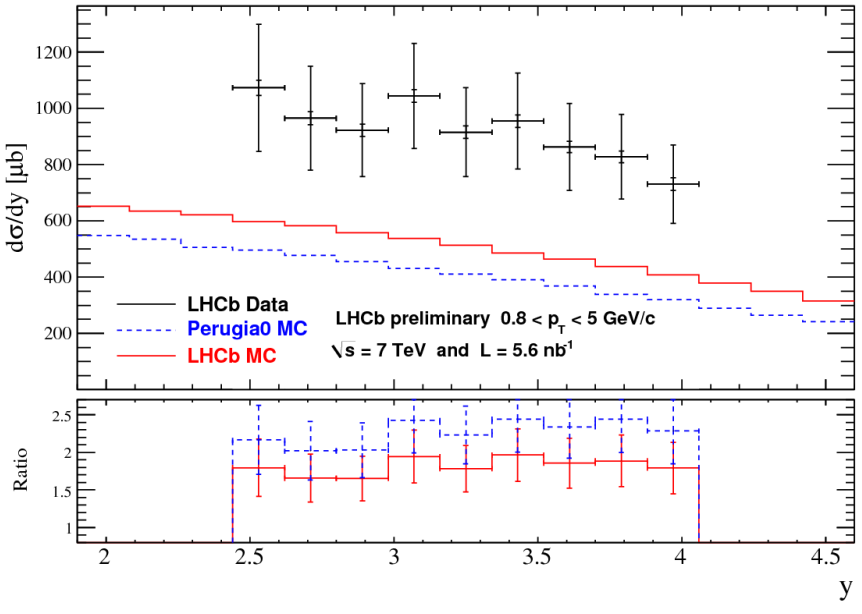




Statistical errors only

Preliminary Results - Φ





Both tunings underestimate Φ production in the measured kinematic range

Summary

LHCb has explored a unique kinematic region with first data

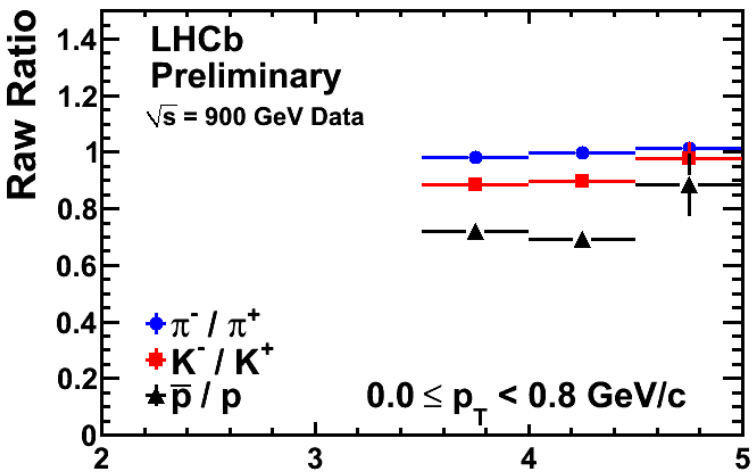
- All analyses limited by systematics
- Several analyses are investigating hadron production and will providing valuable input for QCD models and the LHCb MC retuning
- Proton analysis can be extended to provide further ratios

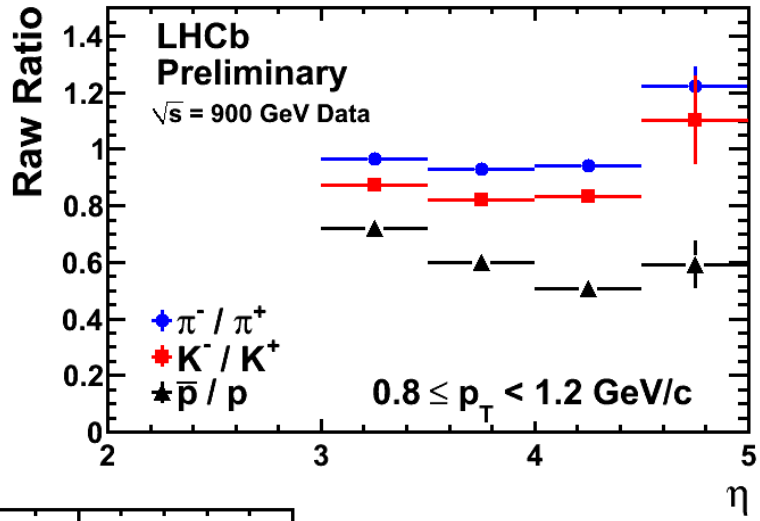
Preliminary results compared to models indicate:

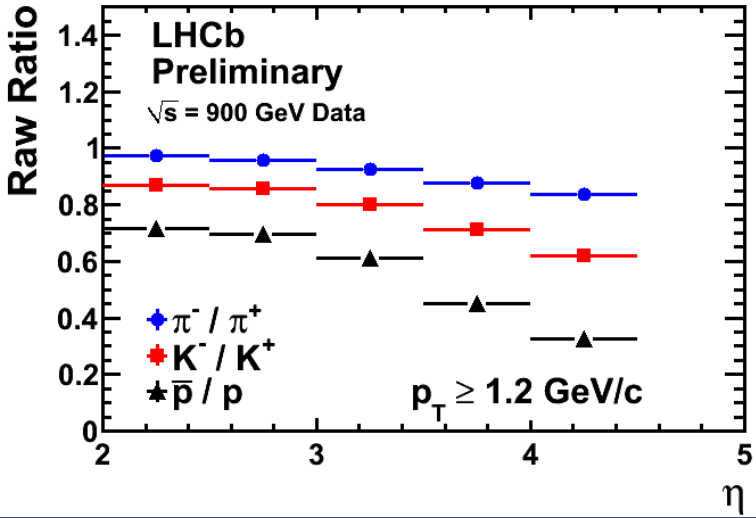
- Higher baryon transport
- Harder P_T spectra
- Underestimated strangeness production

Backup slides

$\bar{p}/p$ Analysis - raw ratios







$\bar{p}/p$ Analysis - raw ratios