Measurement of the baryon number transport with LHCb

Marco Adinolfi

University of Bristol
On behalf of the LHCb Collaboration

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Outline

1. Introduction
2. An overview of the LHCb experiment
3. $\bar{\Lambda}/\Lambda$ and $\bar{\Lambda}/K_S$ ratios
4. $\bar{p}/p$ ratio
5. Conclusions

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Introduction

- Full calculation of collision and hadronization process is not possible, only phenomenological models are available.
- Many different generators can be used to reproduce experimental data.
- Each generator can use one or more mechanisms to model the interaction.
- Studies of proton-proton collision at the LHC can help in selecting or tuning models.
- Good description of the underlying event fundamental for the whole LHCb physics programme.
- Useful quantities to study are the $\bar{\Lambda}/\Lambda$, $\bar{\Lambda}/K_S$ and $\bar{p}/p$ ratios.
- Already many different generators have, at LHC energies, different predictions, which diverge at the rapidities covered by LHCb.
- Many systematics cancel out.

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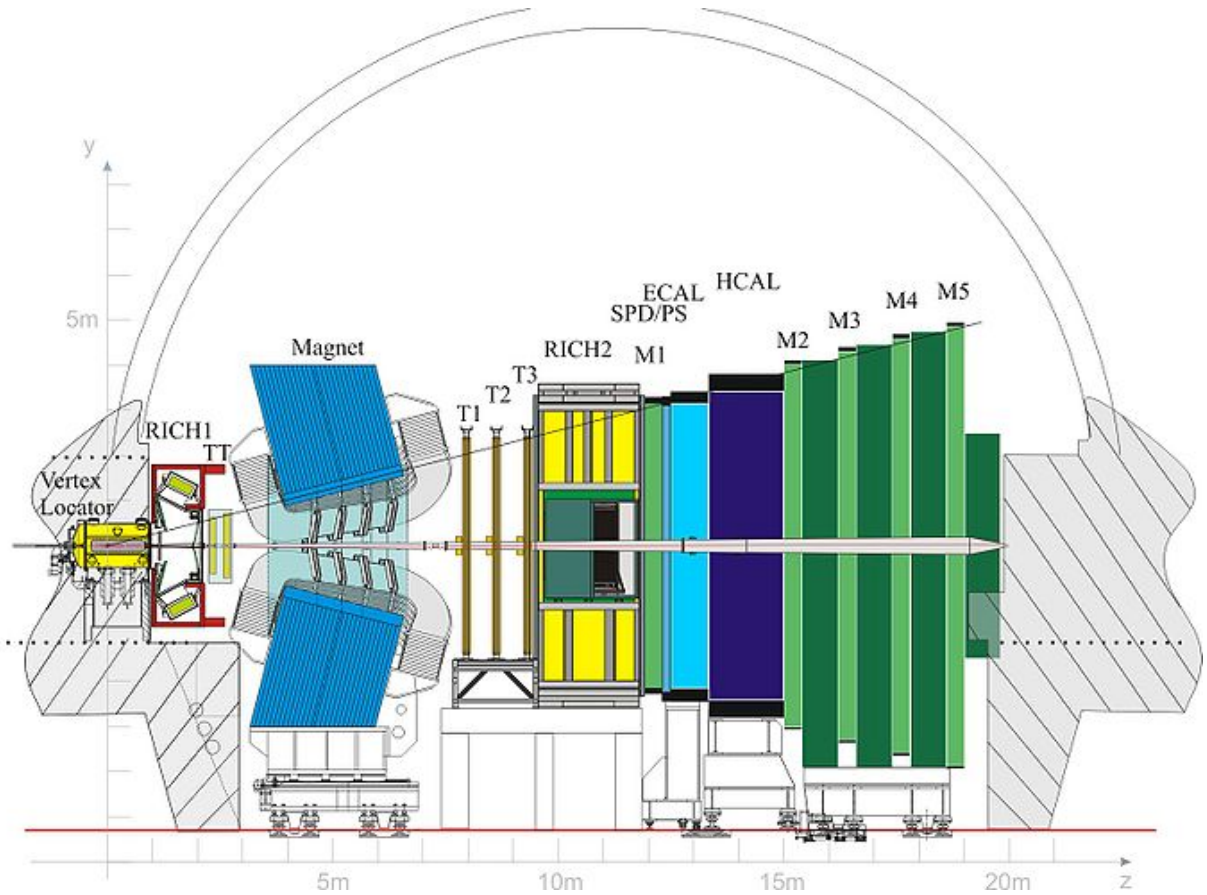
The LHCb detector



- Single arm forward spectrometer
- Low p_T
- Unique fully equipped coverage in the region $1.9 < \eta < 4.9$.
- Only LHC experiment that can study in the high η low p_T region.
- Designed for precision CP violation measurements and the search of rare B decays.
- 2×10^4 $b\bar{b}$ pairs per second: only 4% of the solid angle is covered but 40% of the pairs are captured.

Tracking

With current best reconstruction:

- IP resolution: 15 μm in the highest p_T bin.
- Resolution for primary and secondary vertices: 50 μm and 150 μm respectively.
- $\delta p/p \sim 0.5\%$
- Proper time resolution: 50 fs.

Tracking efficiency $\sim$ 95%.

900 GeV data collected with the VELO partially open.

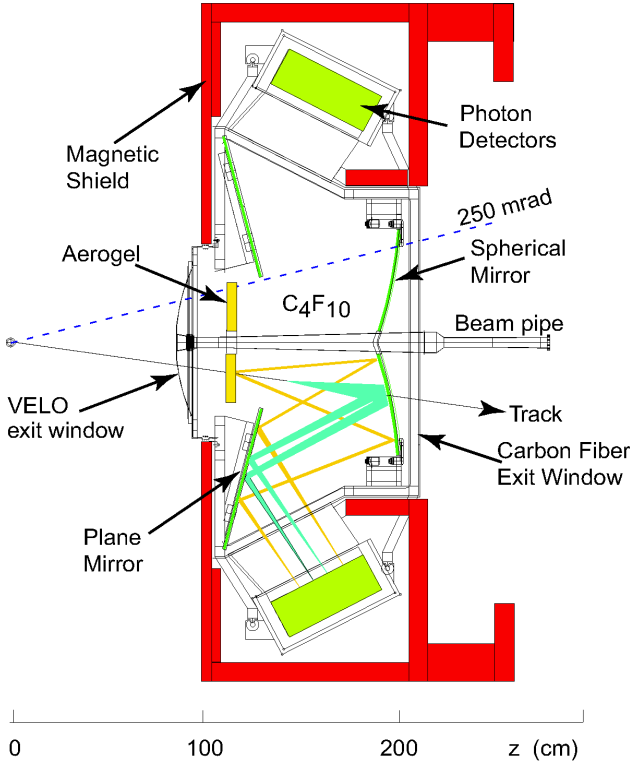
RICH detectors

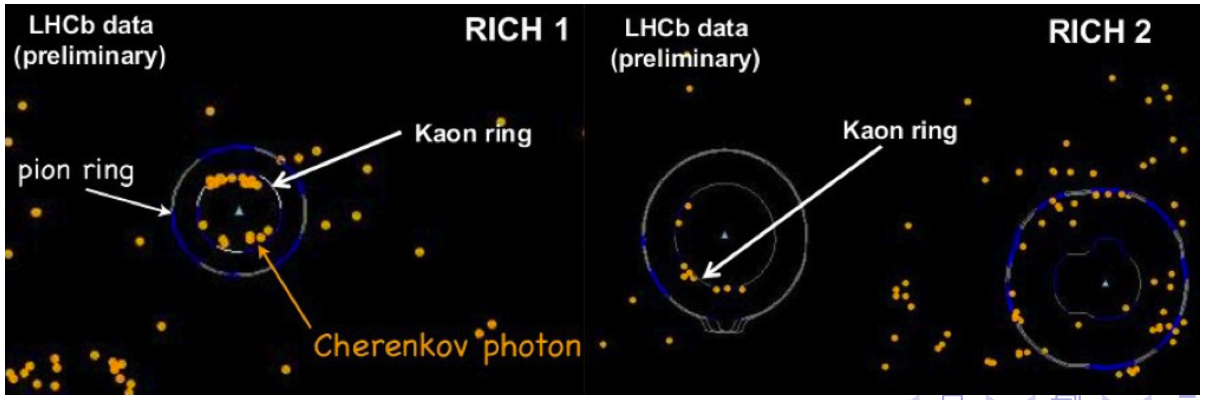
- Particle ID system based on 2 RICH detectors and 3 radiators.
- RICH 1:

Aerogel	$2\,GeV < p < 10\,GeV$
C_4F_{10}	$10\,GeV < p < 60\,GeV$

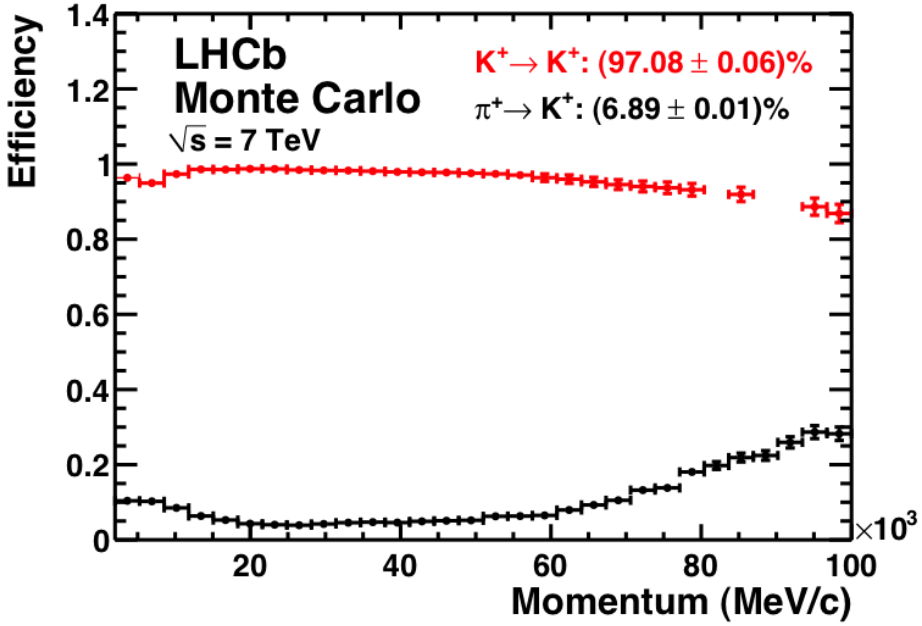
- RICH 2:

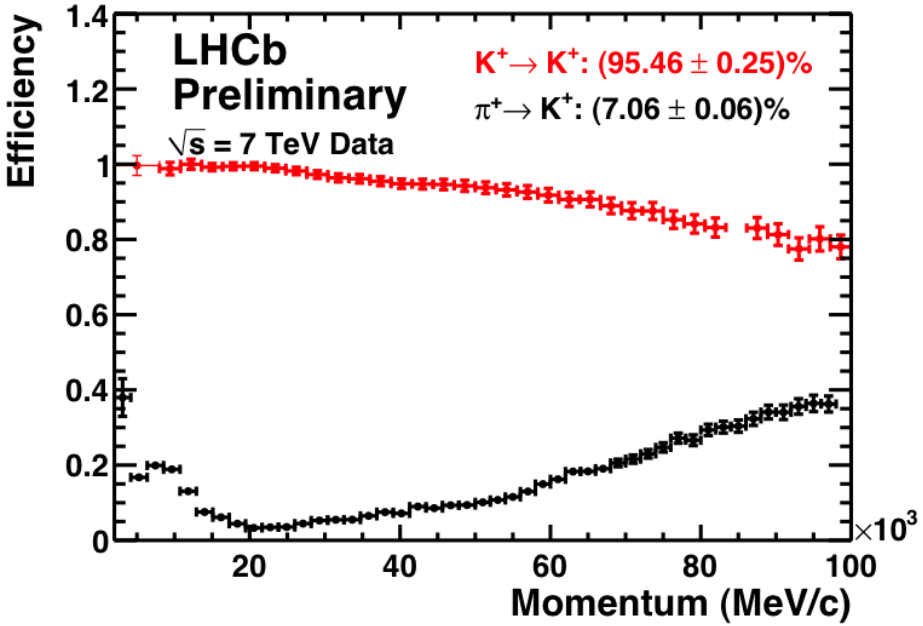
CF_4 $\quad 20\,GeV < p < 100\,GeV$





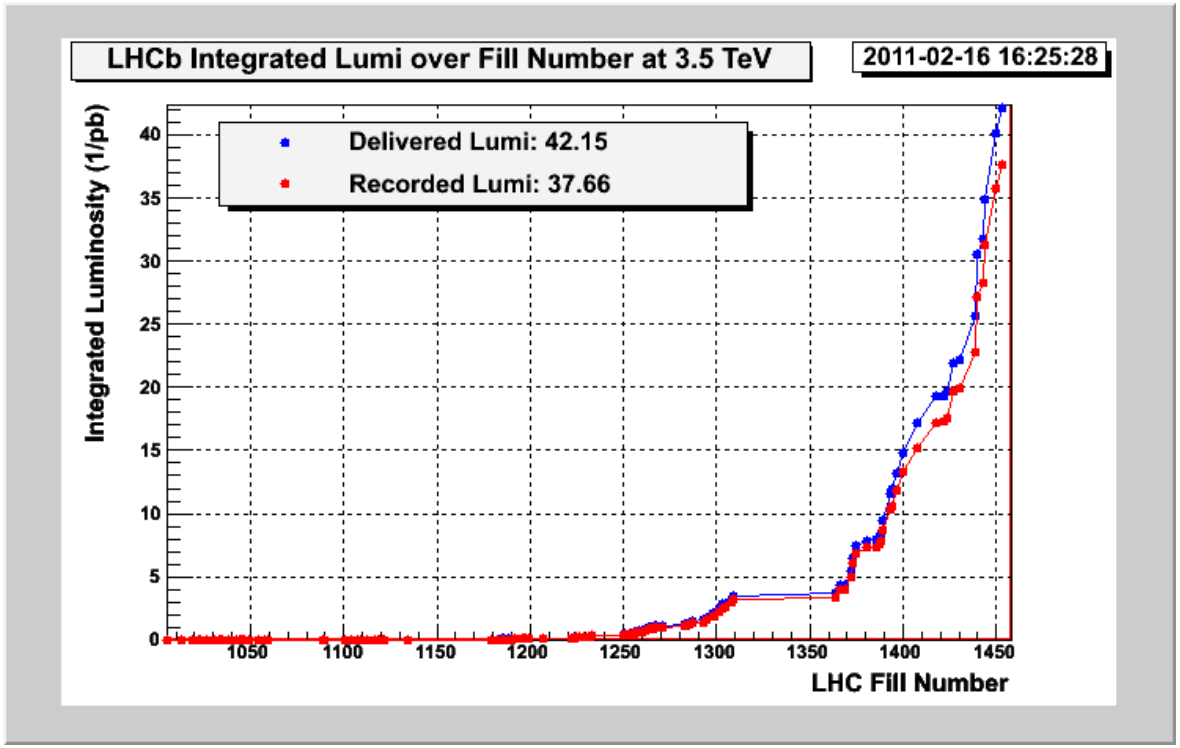
Particle ID





LHCb RICH detectors provide an excellent particle identification in good agreement with expectations over the entire design momentum spectrum.

Data sample



- 6.8 μb^{-1} at 900 GeV collected in 2009 with Minimum Bias trigger: requires activity in the calorimeter.
- 0.3 nb^{-1} at 900 GeV in 2010 collected with Minimum Bias trigger: requires 1 track in the VELO. Used in this analysis.
- 14 nb^{-1} at 7 TeV in 2010 collected with Minimum Bias trigger: requires 1 track in the VELO. Used in this analysis.
- Sub-sample of 37.7 pb^{-1} at 7 TeV collected in 2010.
- Data collected with 2 opposite magnet polarities (up and down).

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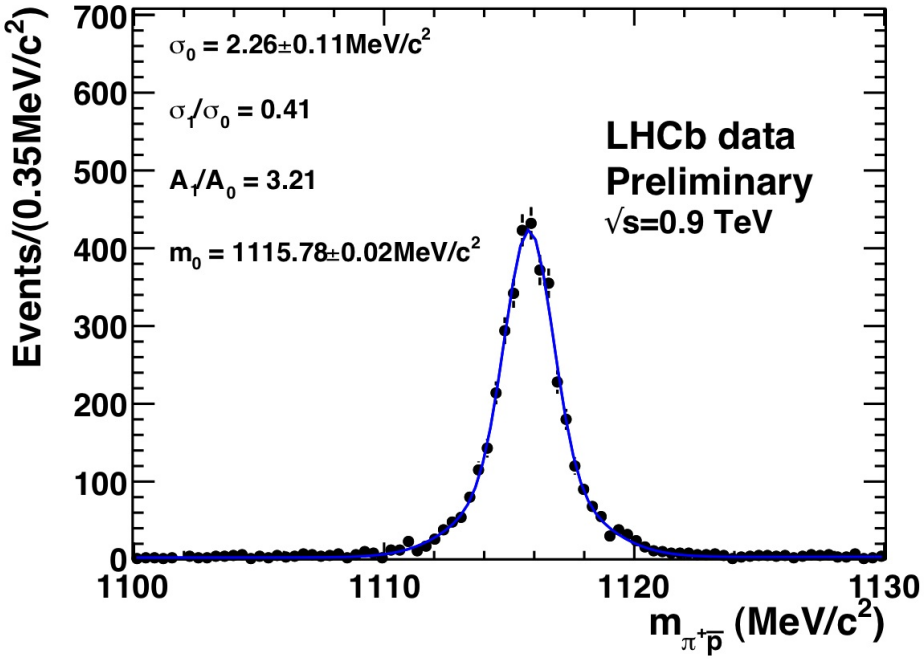
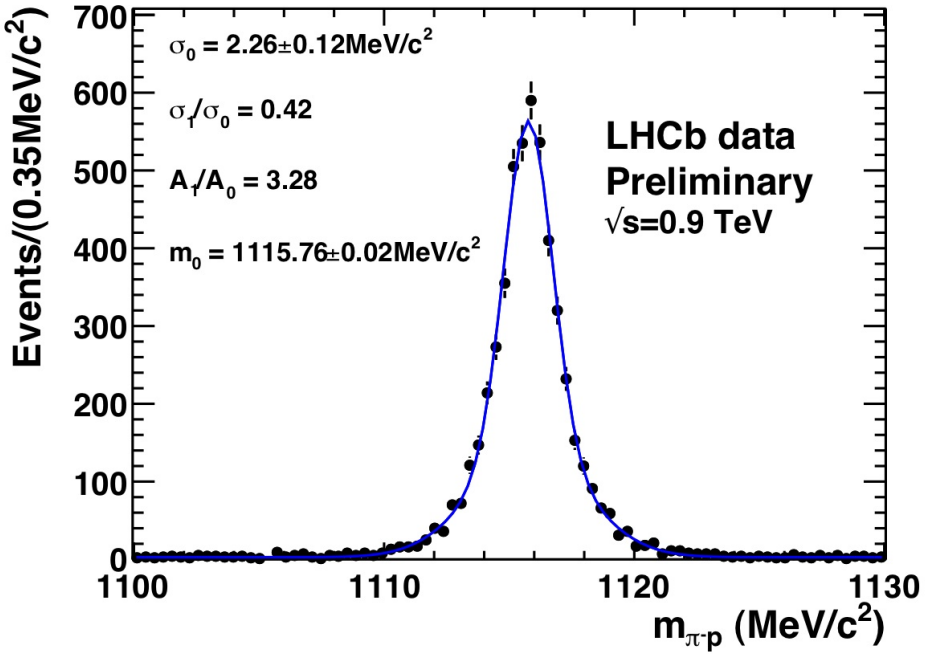
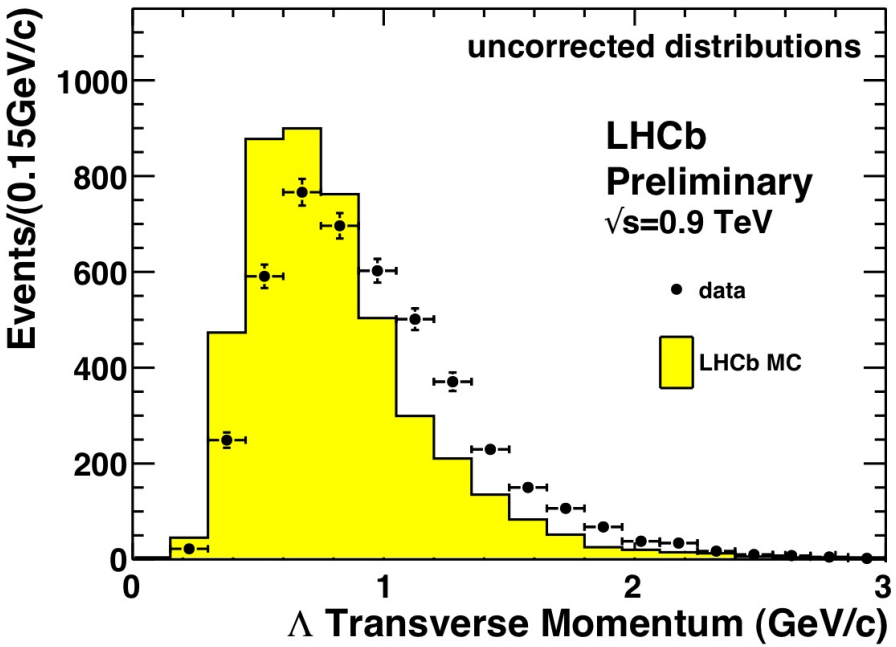
Particle selections

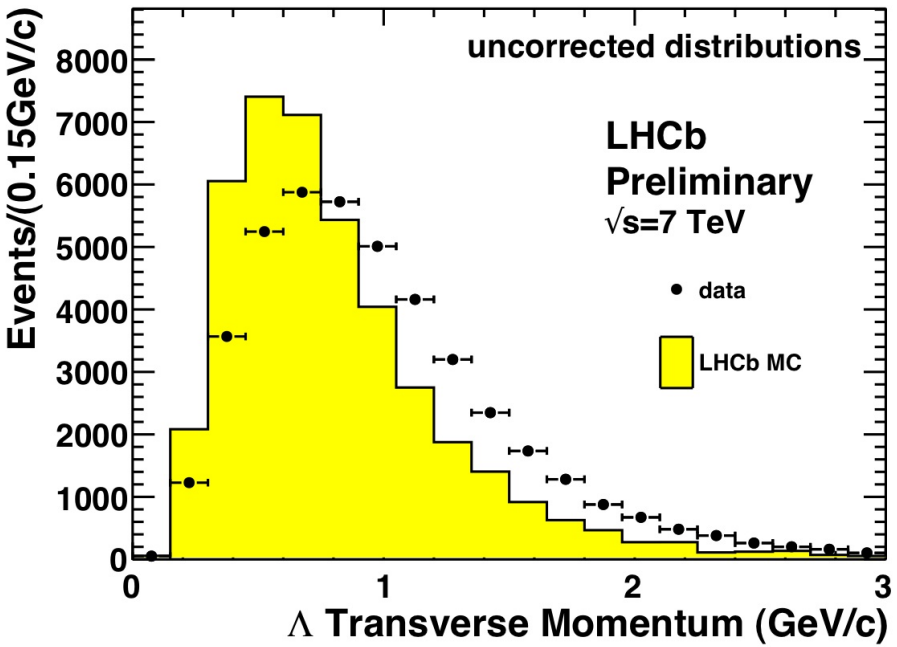




- Only tracks with in hits in VELO and downstream tracking (long tracks).
- Prompt Λ and K_S selected using a Fisher discriminant based on the mother and daughters impact parameter.
- Systematics partially cancel.

Λ p_T uncorrected spectra



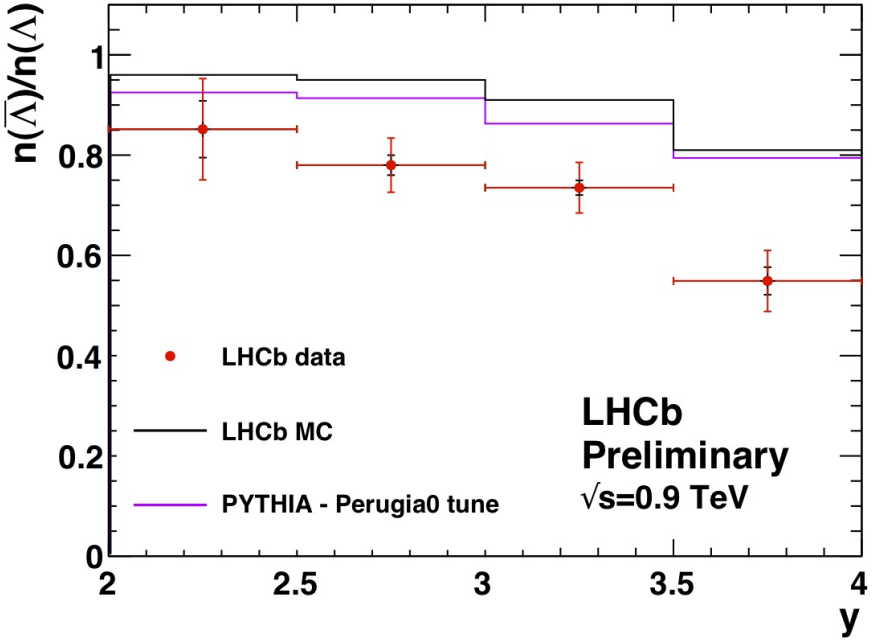


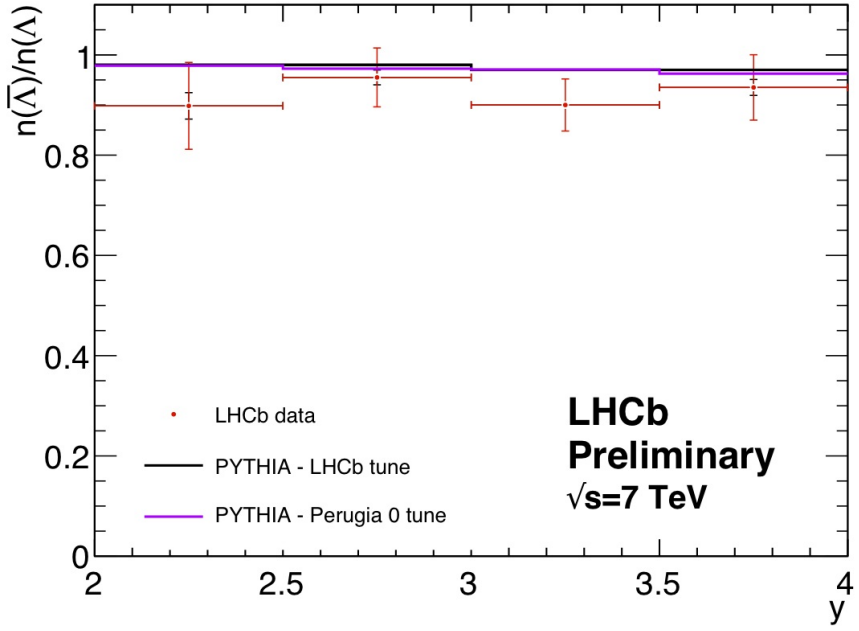
- The p_T uncorrected spectra for the Λ are harder than predicted by LHCb Monte Carlo.
- Efficiencies are estimated from Monte Carlo.
- Re-weighting procedure introduced to remove biases.

Systematics

	$\bar{\Lambda}/\Lambda$	$\bar{\Lambda}/K_S$
Diffractive event contamination	1-2%	1-2%
Non prompt contamination	$< 1\%$	$< 1\%$
Material interactions	$\sim 2\%$	$\sim 2\%$
Primary vertex finding	$< 2\%$	$< 1\%$
Track finding	negl.	$\sim 1\%$
MC kinematic corrections	$< 5\%$	$< 3\%$

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





Baryon number transport higher than expected at 900 GeV.

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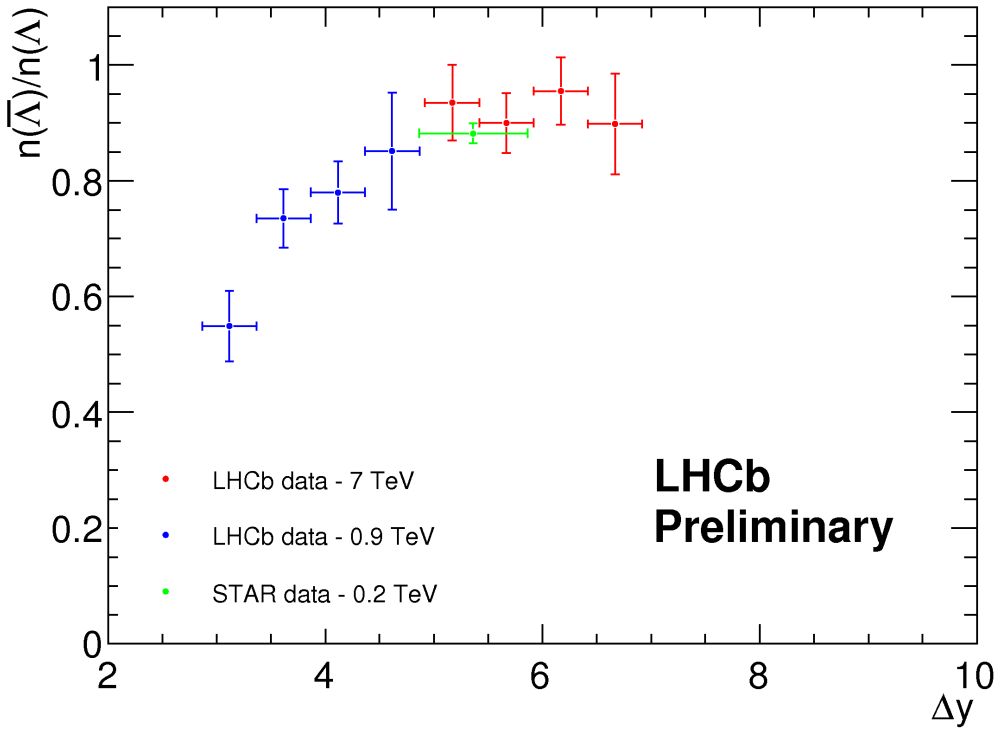
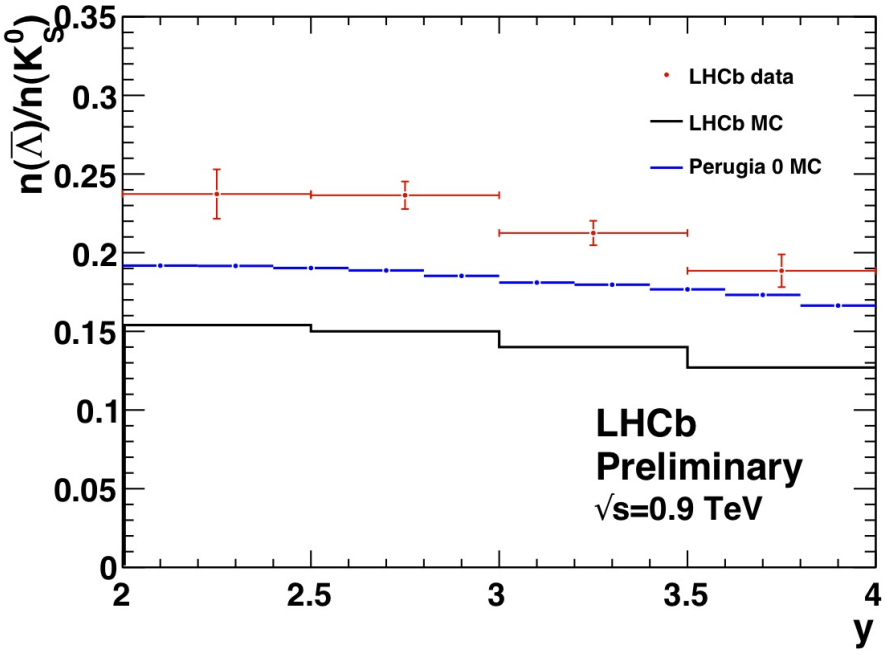
Perugia selection: Phys. Rev. D, 82(7):074018 (2010)

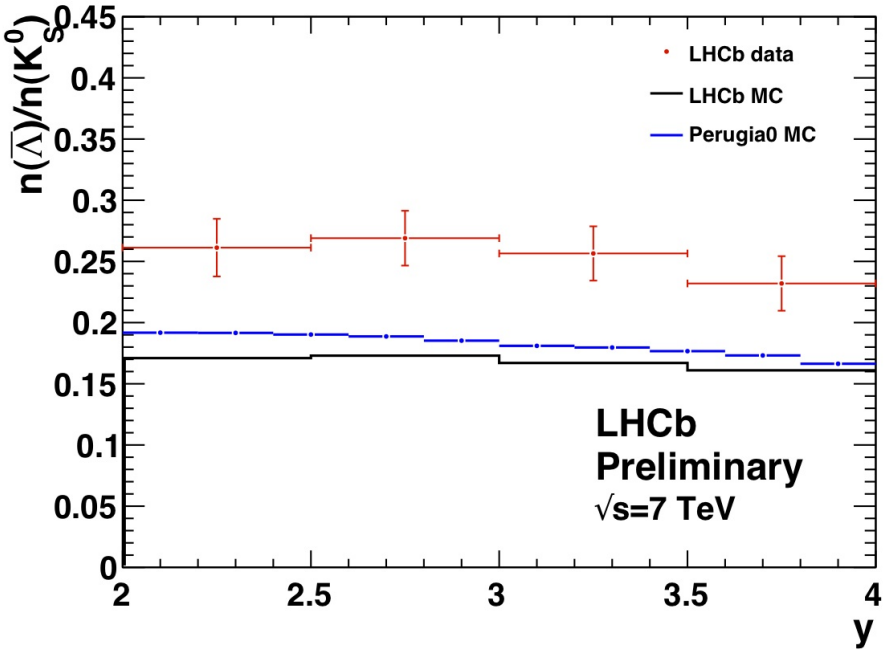
Baryon number transport $\bar{\Lambda}/\Lambda$



- $\Delta y = y_{beam} - y_{\Lambda}$ is a Lorentz invariant.
- Allows comparison between different CM energies.
- First measuments at low Δy.
- Consistent with other experiments.

$\bar{\Lambda}/K_S$ ratio





Baryon/Meson suppression lower than expected.

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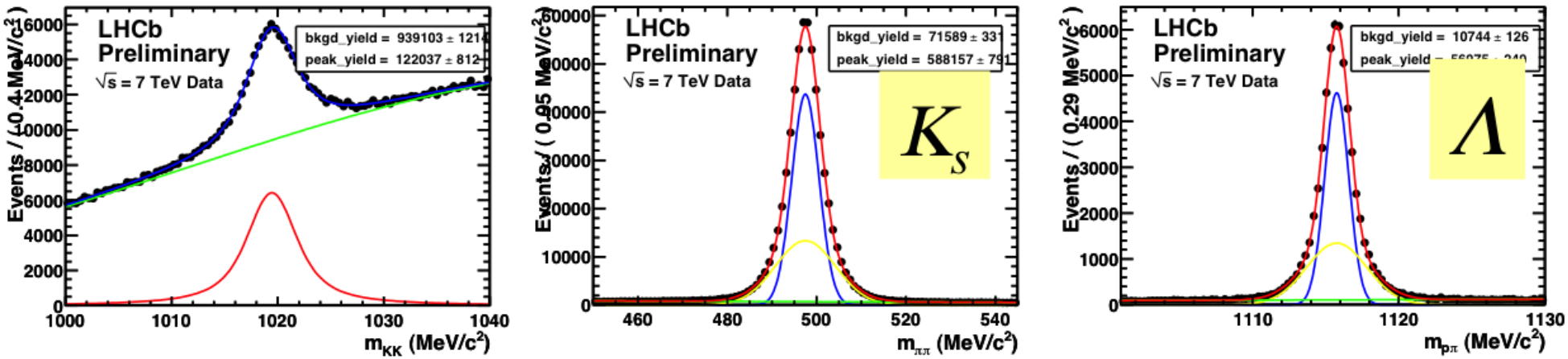
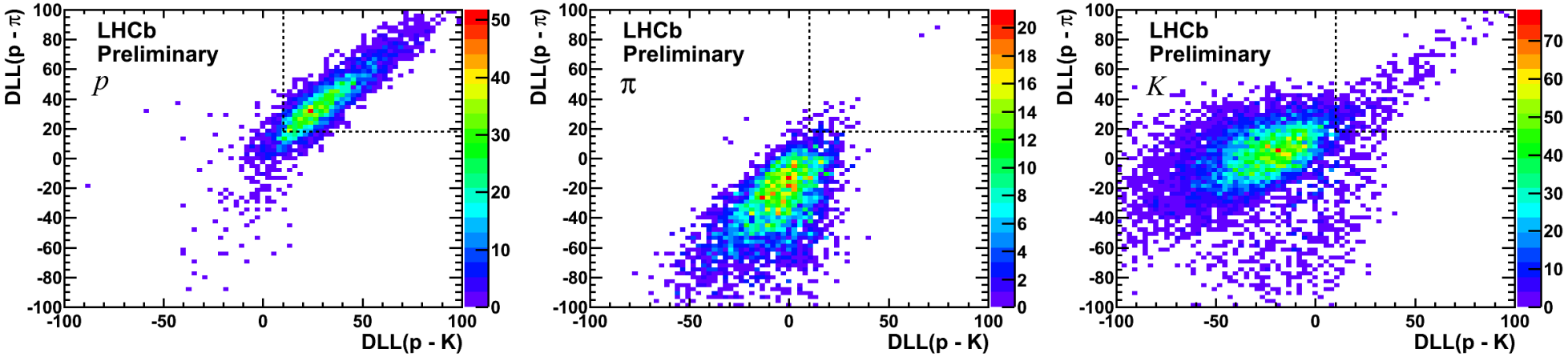
Particle ID calibration



- Only long tracks accepted.
- Cut on track χ^2 to remove fakes.
- Prompt tracks selected using the impact parameter.
- Cuts tuned on MC.
- Pure sample of protons then selected using RICH information.
- Efficiencies and mis-identification determined from data using calibrations samples.
- $\Phi \to K^+K^-$ $\quad K_S \to \pi^+\pi^-$ $\quad \Lambda \to \pi p$

Protons selection



DLL(x-y) = Delta log likelihood between x and y particle hypothesis.
Hashed lines show the selection region.

Calibration samples used to measure:

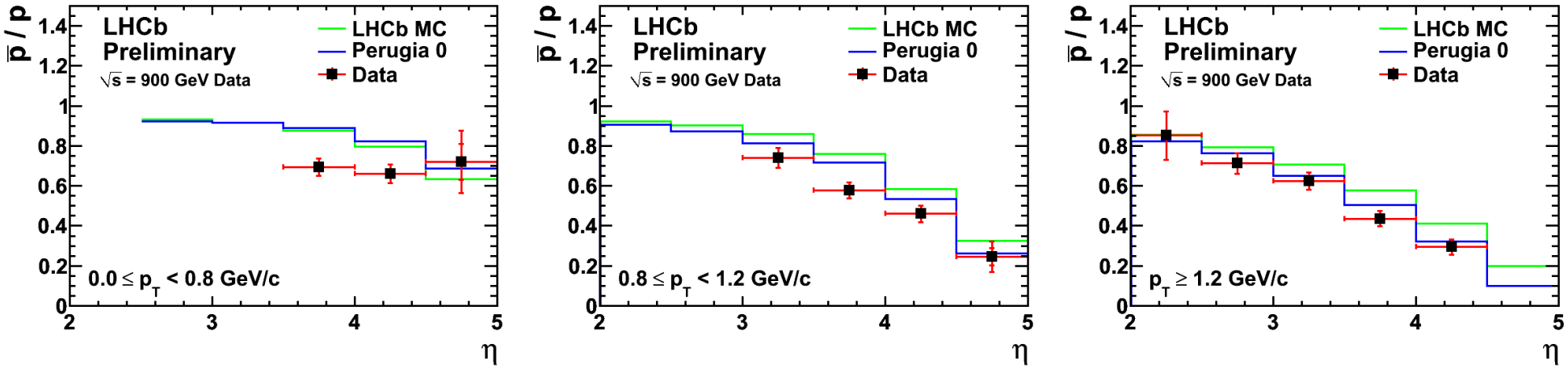
- proton selection efficiency;
- pion and kaon contamination.

Contamination correction

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

- Matrix determined from MonteCarlo in (p_T, η) bins.
- Matrix determined separately for p and $\bar{p}$.
- Different interaction cross section between p and $\bar{p}$ in particular at low momentum.
- Restrict to p $>$ 5 GeV and correct from MC.

Baryon number transport $\bar{p}/p$ at 900 GeV

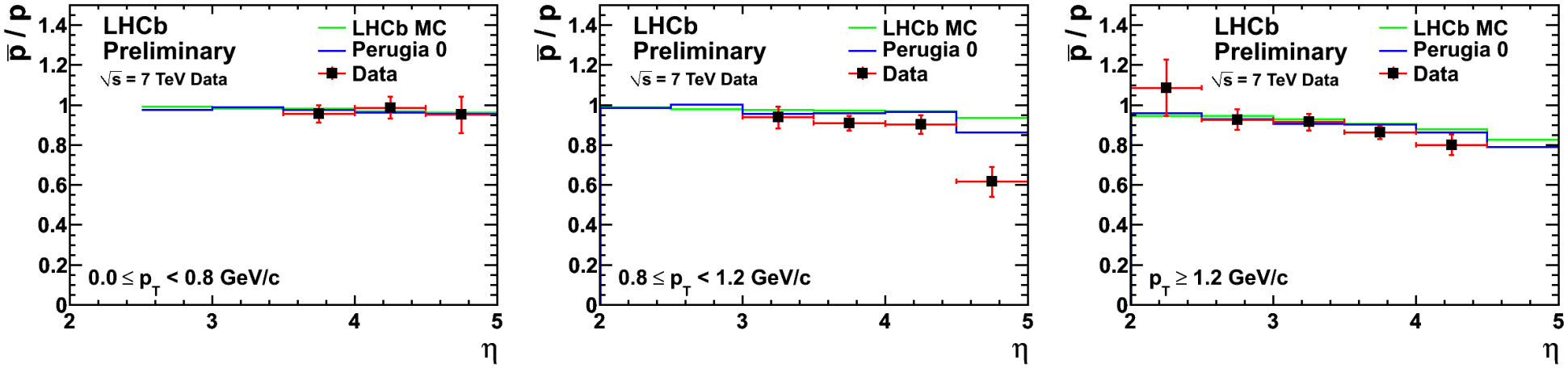


Major sources of systematic errors include:

	900 GeV	7 TeV
PID Contamination	2-14%	2-8%
Magnet polarity	0.1-3%	1-3%
Beam crossing angle	0.5 %	3%

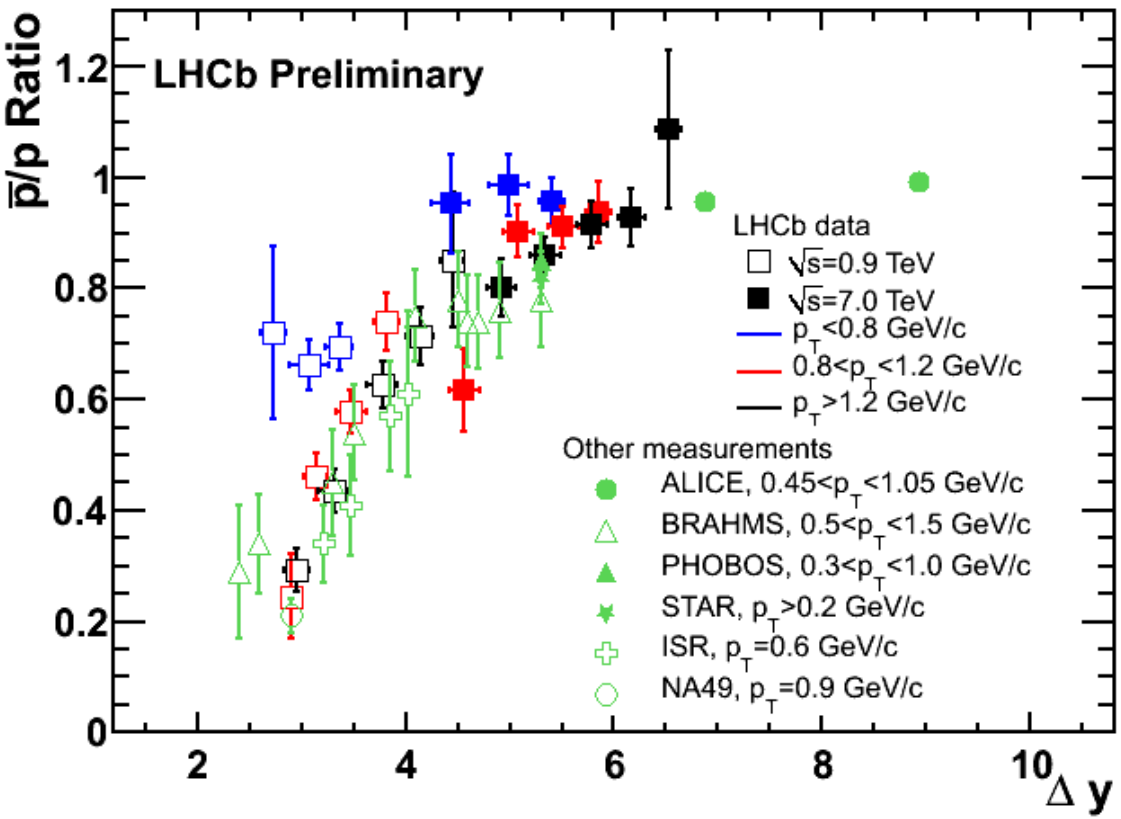
Baryon number transport higher than expected at 900 GeV and consistent with the $\bar{\Lambda}/\Lambda$ ratio result.

Baryon number transport $\bar{p}/p$ at 7 TeV



- Ratios become flatter as expectected from models.
- Better agreement with Monte Carlo than at 900 GeV.
- Consistent with the $\bar{\Lambda}/\Lambda$ ratio result.

Baryon number transport $\bar{p}/p$



- $\Delta y = y_{beam} - y_p$
- Results are consistent with previous experiments.

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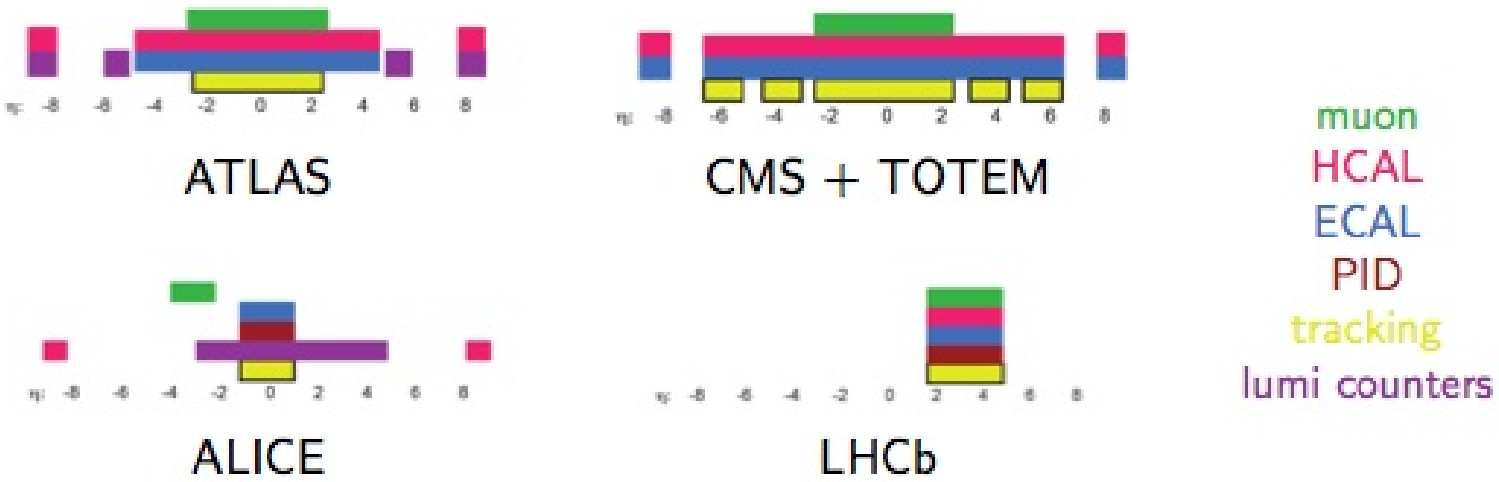
Conclusions

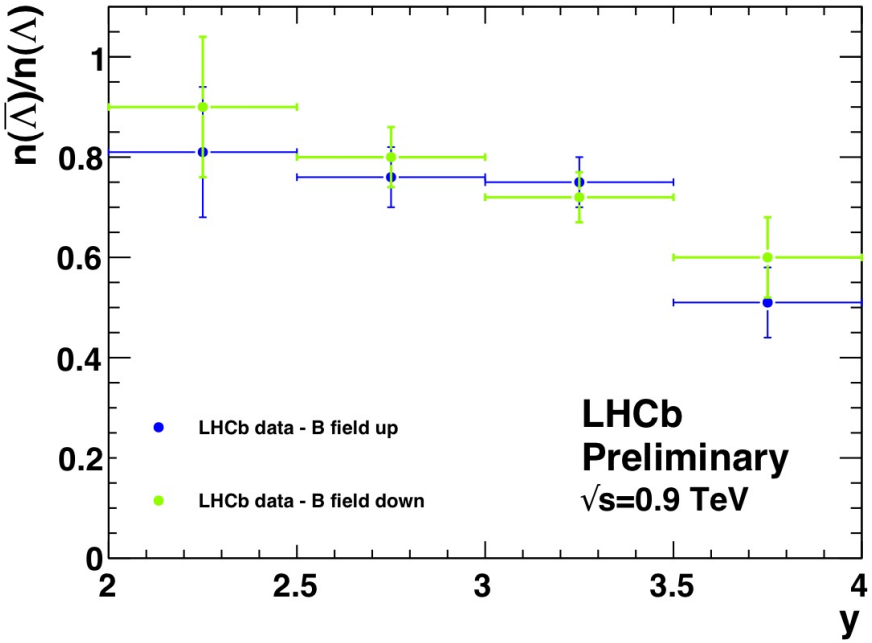
- LHCb delivers excellent results in Minimum Bias physics in the forward region and at low p_T.
- Preliminary results compared to current models indicate:
  - Harder p_T distributions.
  - Higher baryon number transport.
  - Lower baryon/meson suppression.
- Improved analysis with better estimate of calibrations and systematics in the queue for internal approval.
- Publication will immediately follow.
- Results will provide invaluable help in the development of QCD models and in the retuning of the LHCb Monte Carlo.
- More in the pipeline.
- Don't miss Jesko Merkel talk on LHCb strangeness results later in the morning.

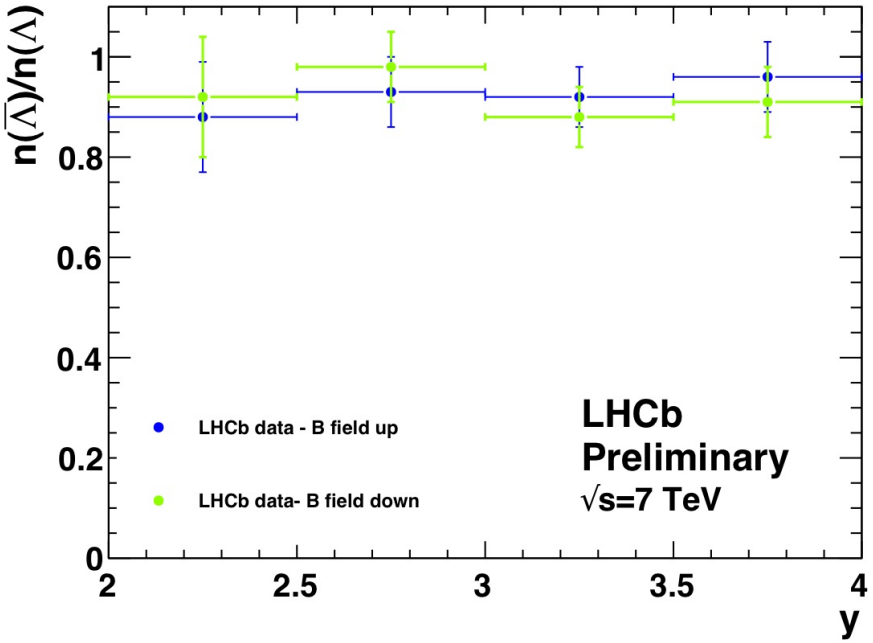
Backups

η coverage at LHC



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





As expected no dependance on LHCb magnetic field.