Imperial College London

Particle Production Studies at LHCb

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on behalf of the LHCb collaboration

6 September 2010

Minimum Bias and Underlying Event Working Group

LHCb

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- K_S production cross section
- Strange particle (V^0) ratios
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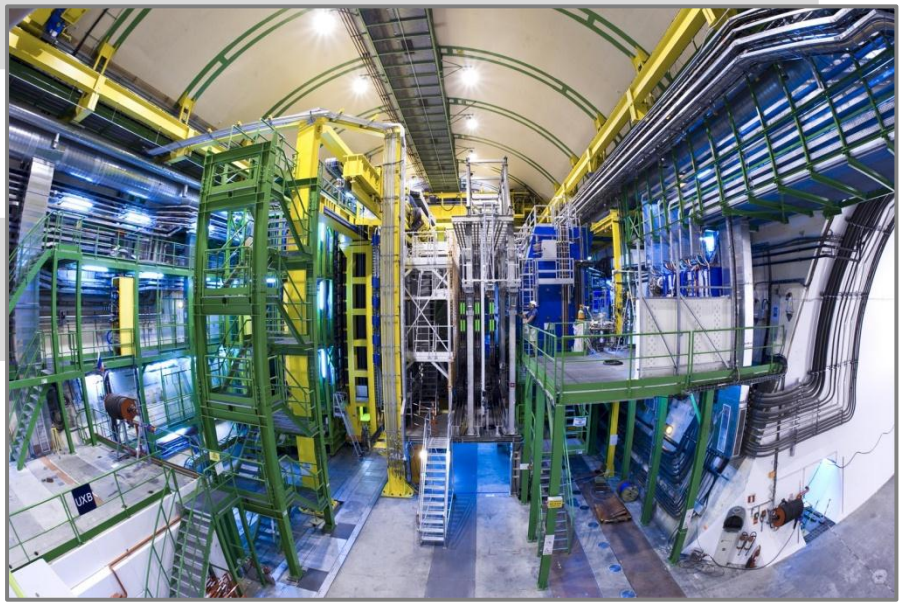
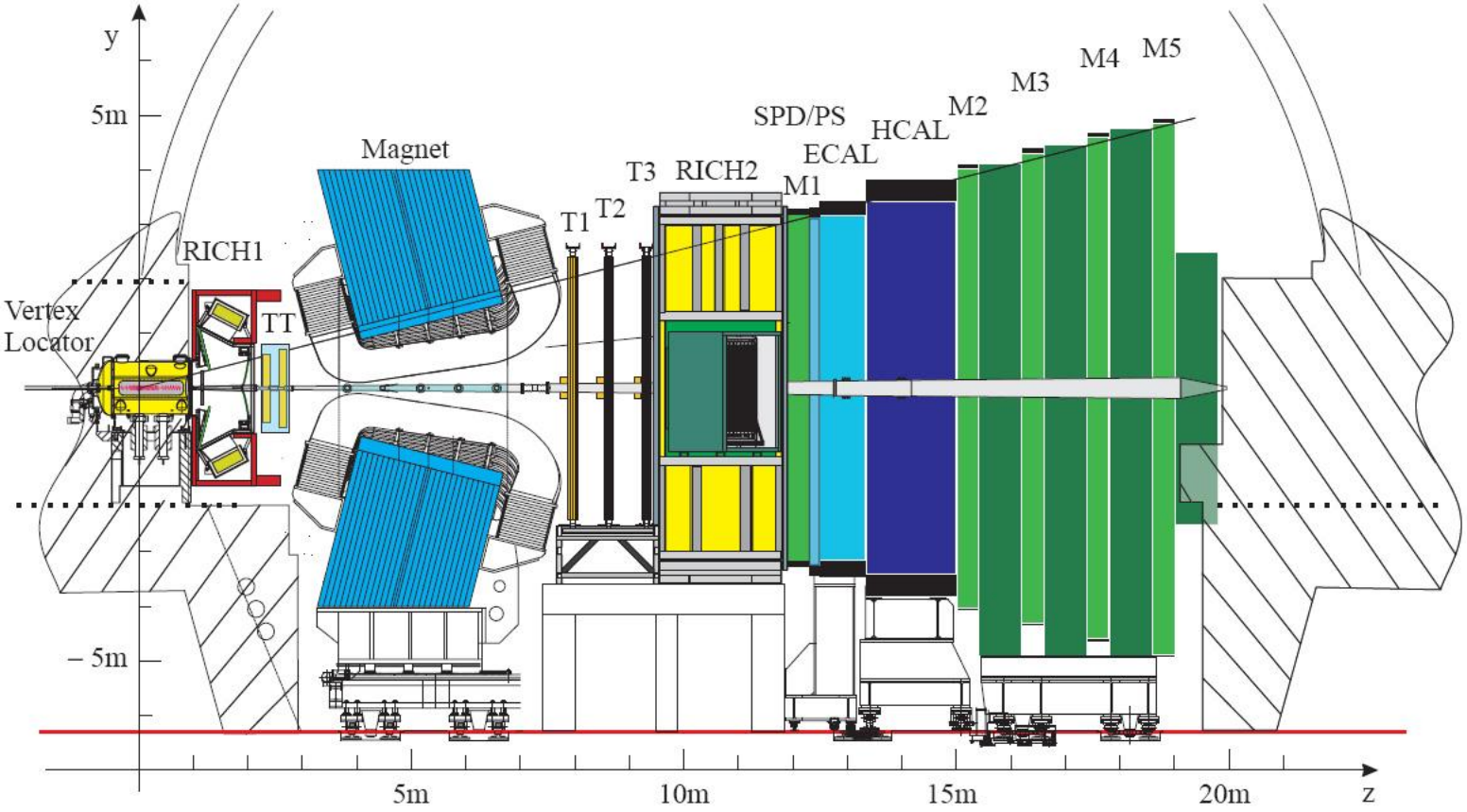
- Summary



The LHCb detector in the point 8 cavern at CERN

The LHCb Experiment

A forward detector ($2<\eta<5$) for precision measurement of CP violation and rare B-decays



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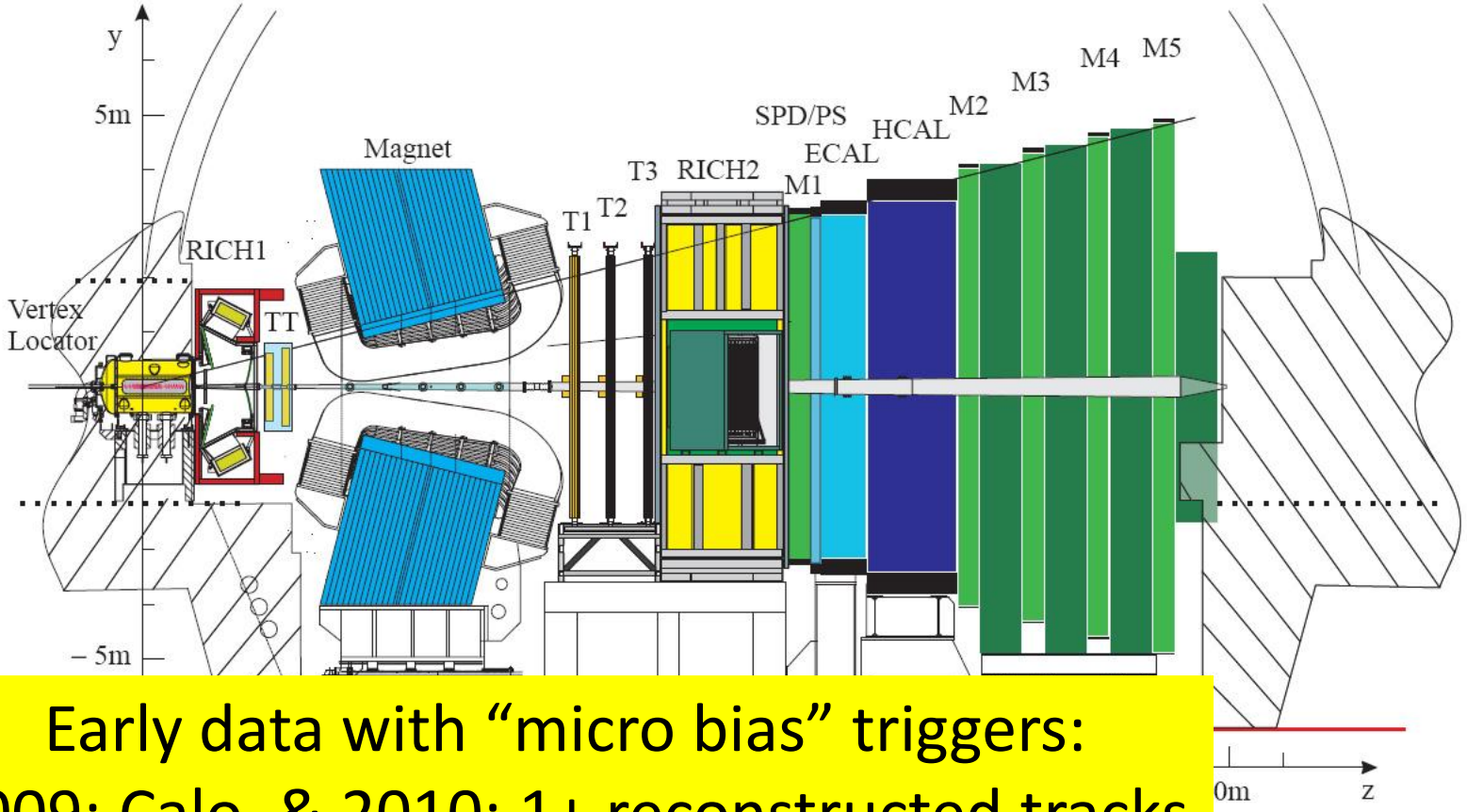


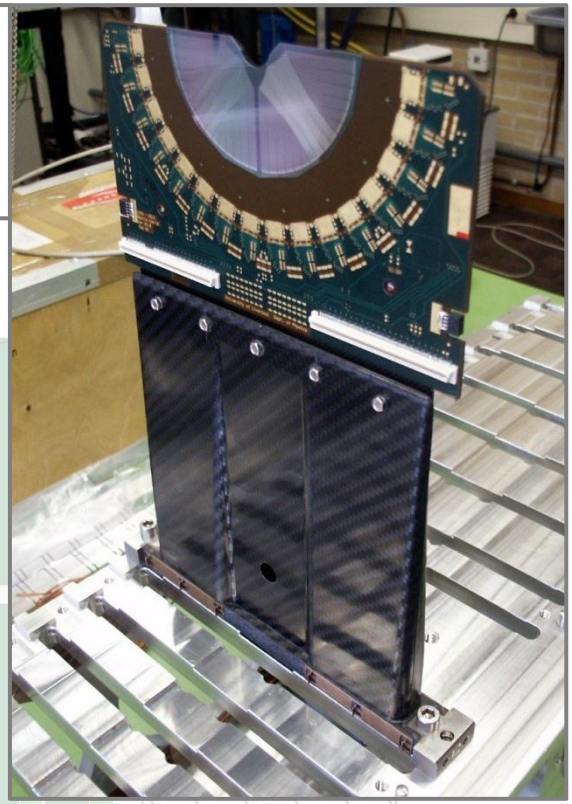
Early data with “micro bias” triggers:
2009: Calo. & 2010: 1+ reconstructed tracks

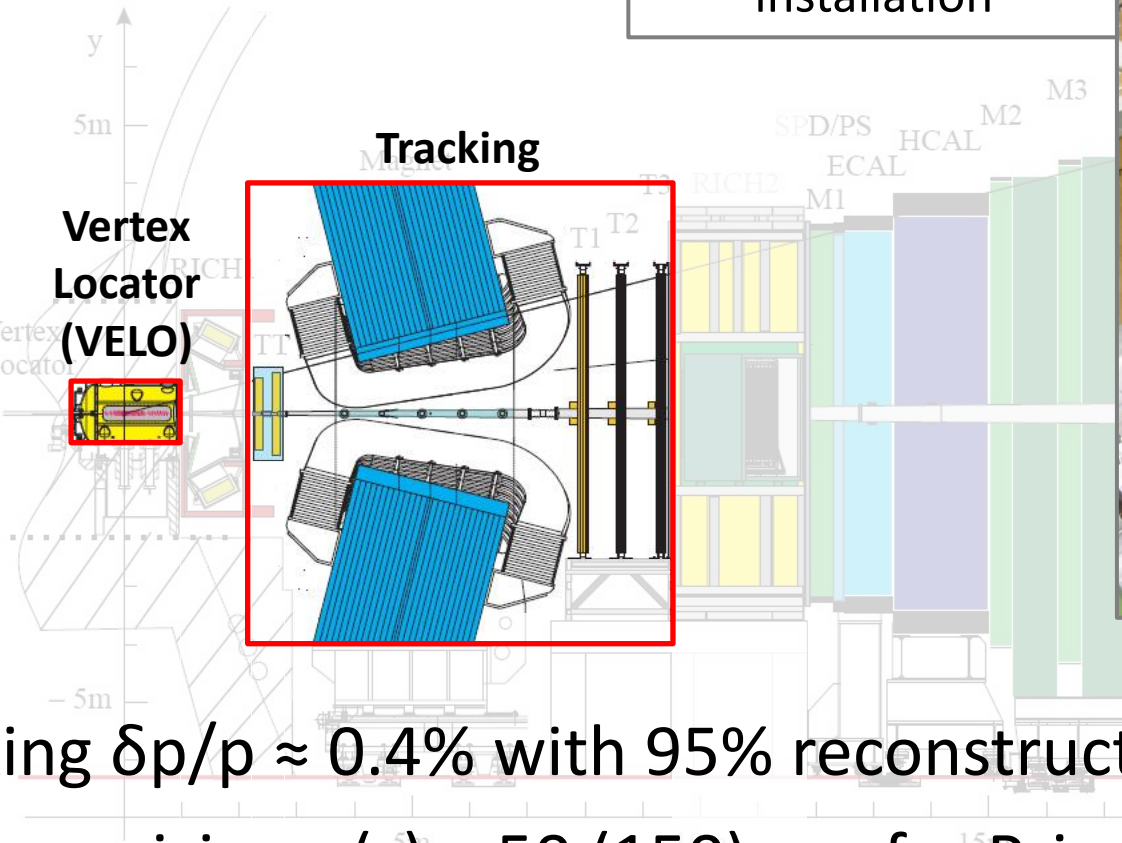
LHCb Tracking

A forward detector (2<η<5

CP violation and rare B-de

A completed VELO module before installation





Tracking $\delta p/p \approx 0.4\%$ with 95% reconstruction efficiency

VELO precision $\sigma(z) \approx 50$ (150) μm for Primary (Secondary) Vertex

LHCb Tracking

A forward detector (2<η<5
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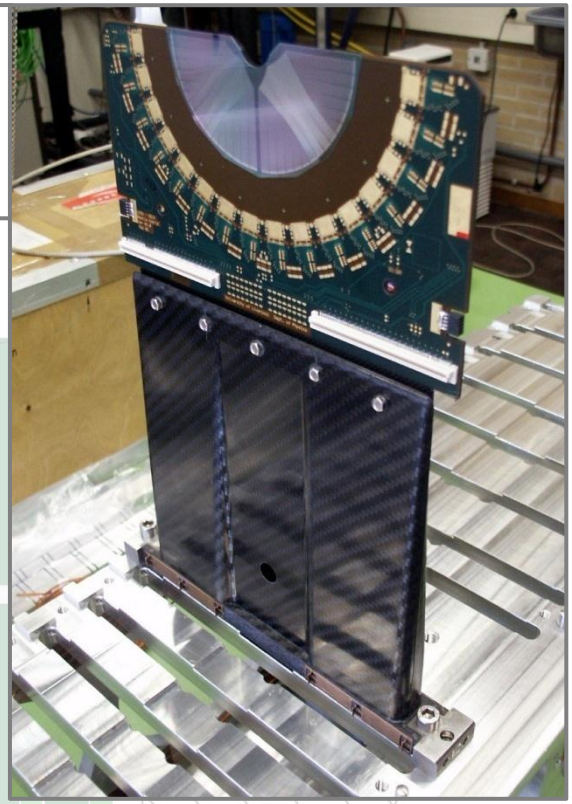
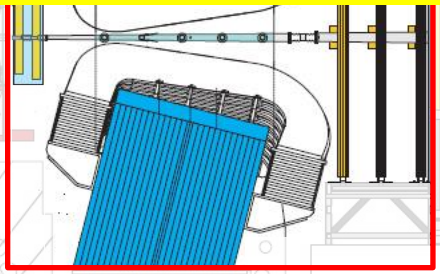


VELO opened at $\sqrt{s}$ = 0.9 TeV due to width of low energy beam (*by 15 mm in 2009 & 10 mm in 2010*)



Tracking δp/p ≈ 0.4% with 95% reconstruction efficiency

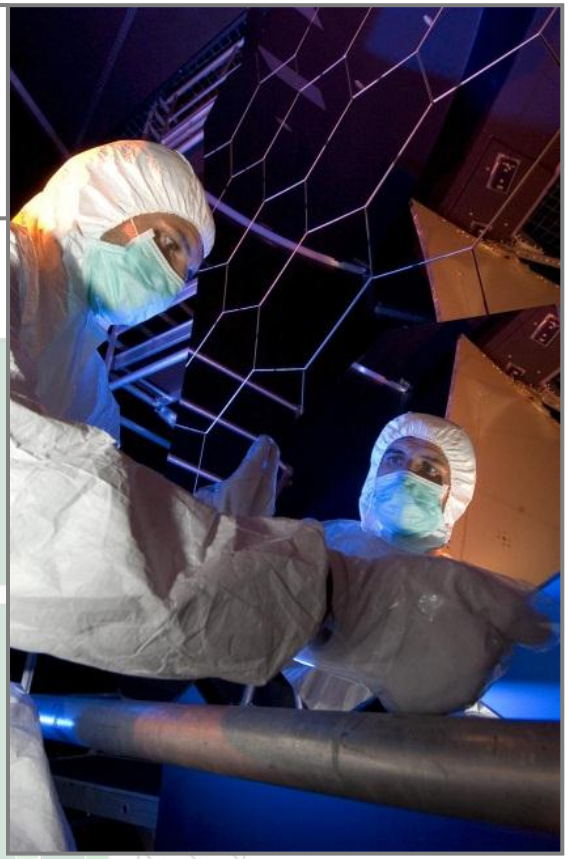
VELO precision σ(z) ≈ 50 (150) μm for Primary (Secondary) Vertex

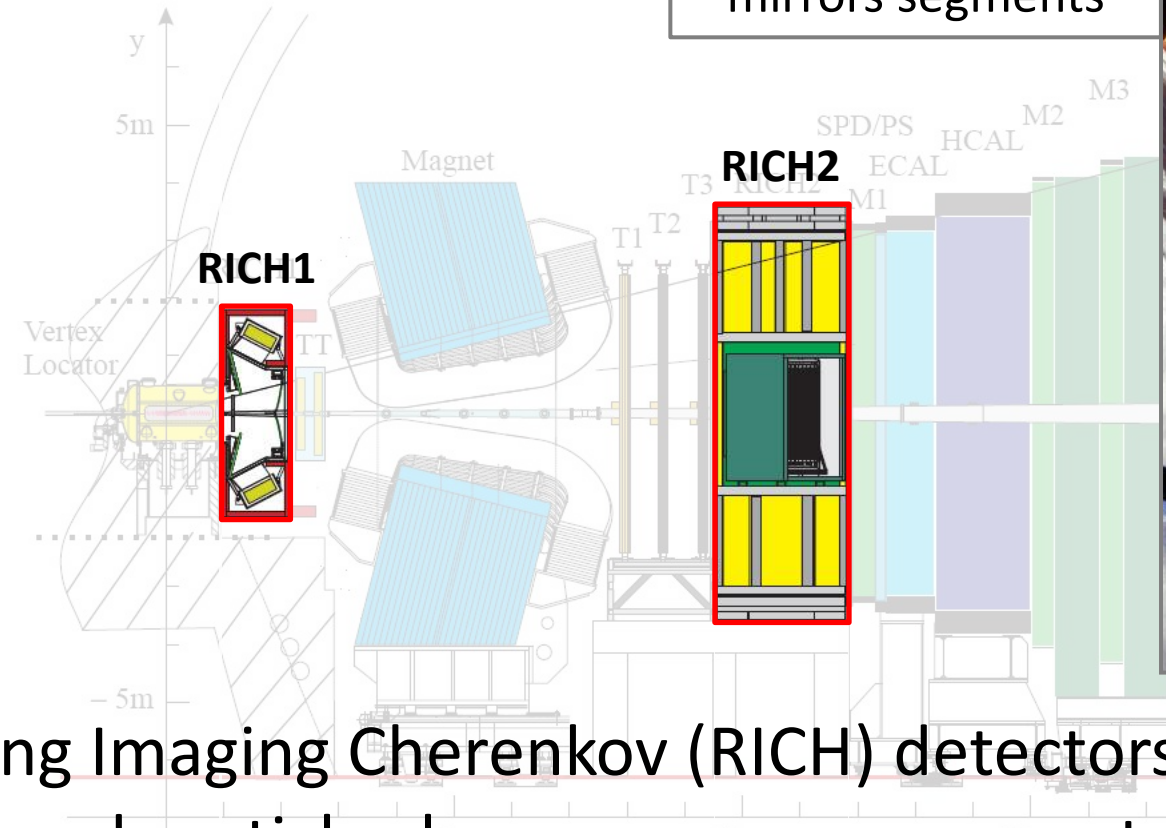
LHCb RICH Detectors

A forward detector (2<η<5

CP violation and rare B-de

Installation of the RICH2 spherical mirrors segments



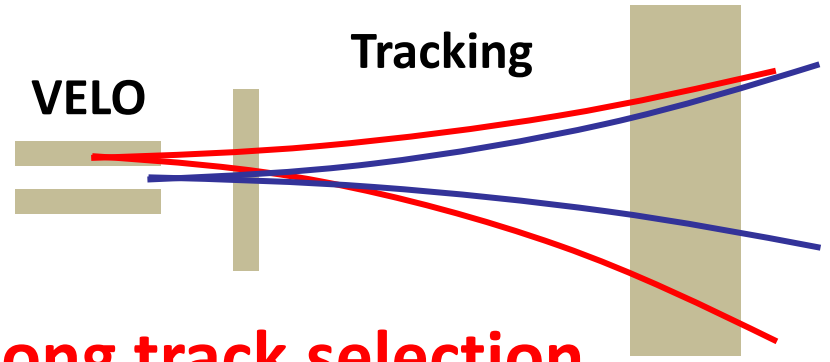


2 Ring Imaging Cherenkov (RICH) detectors distinguish charged particles by mass over a momentum range of 2 to ~100 GeV/c

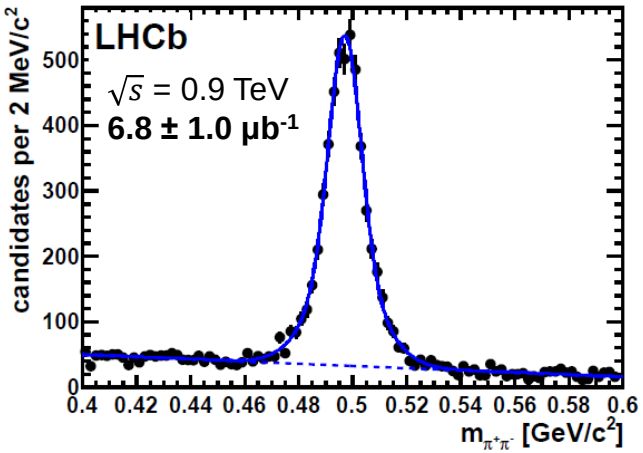
K_S Production Cross Section

An ideal first measurement for LHCb, with high purity selection of $K_S \to \pi\pi$ requiring no particle identification

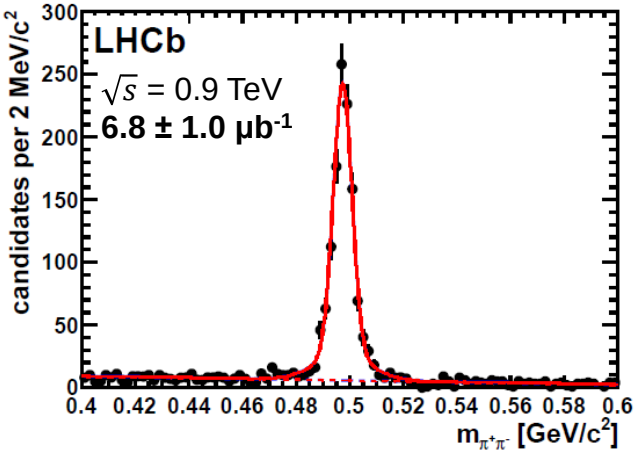
2 complimentary selections with average mass resolutions:
9.2 & **5.5** MeV/c^2



Downstream selection



Long track selection



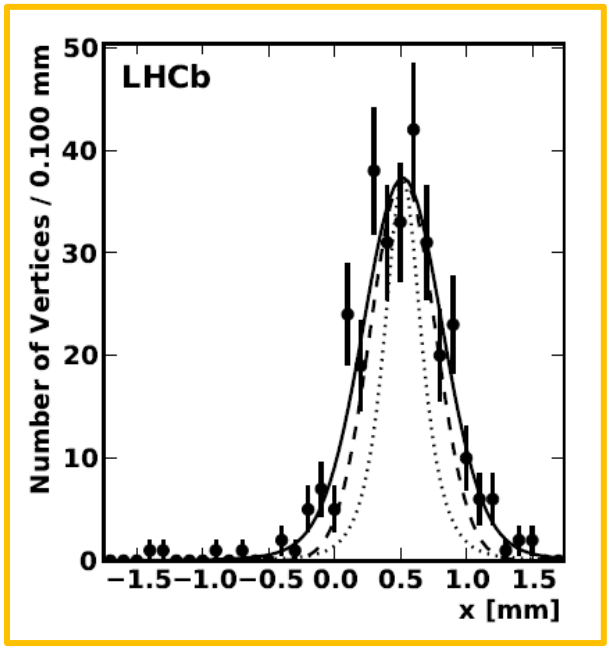
Luminosity Determination

The most precise LHC luminosity measurement is by LHCb

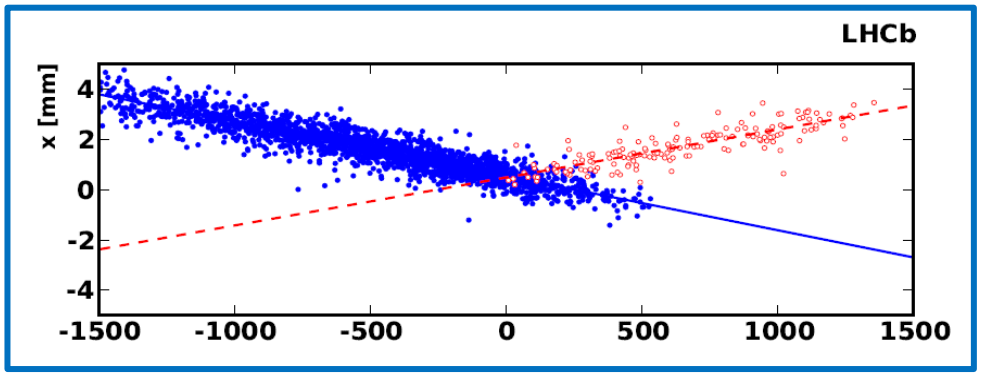
$$L = 2c n_1 n_2 f \cos^2\theta \int \rho_1(x,y,z,t)\rho_2(x,y,z,t)\,\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}t$$

Frequency and # protons per bunch measured by LHC instruments

Bunch size measured using vertex spread, subtracting VELO resolution



Beam crossing angle measured from collision vertices in the VELO



For the K_S data set:

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

K_S Cross Section Systematics

Result ***statistically limited*** in some kinematic regions

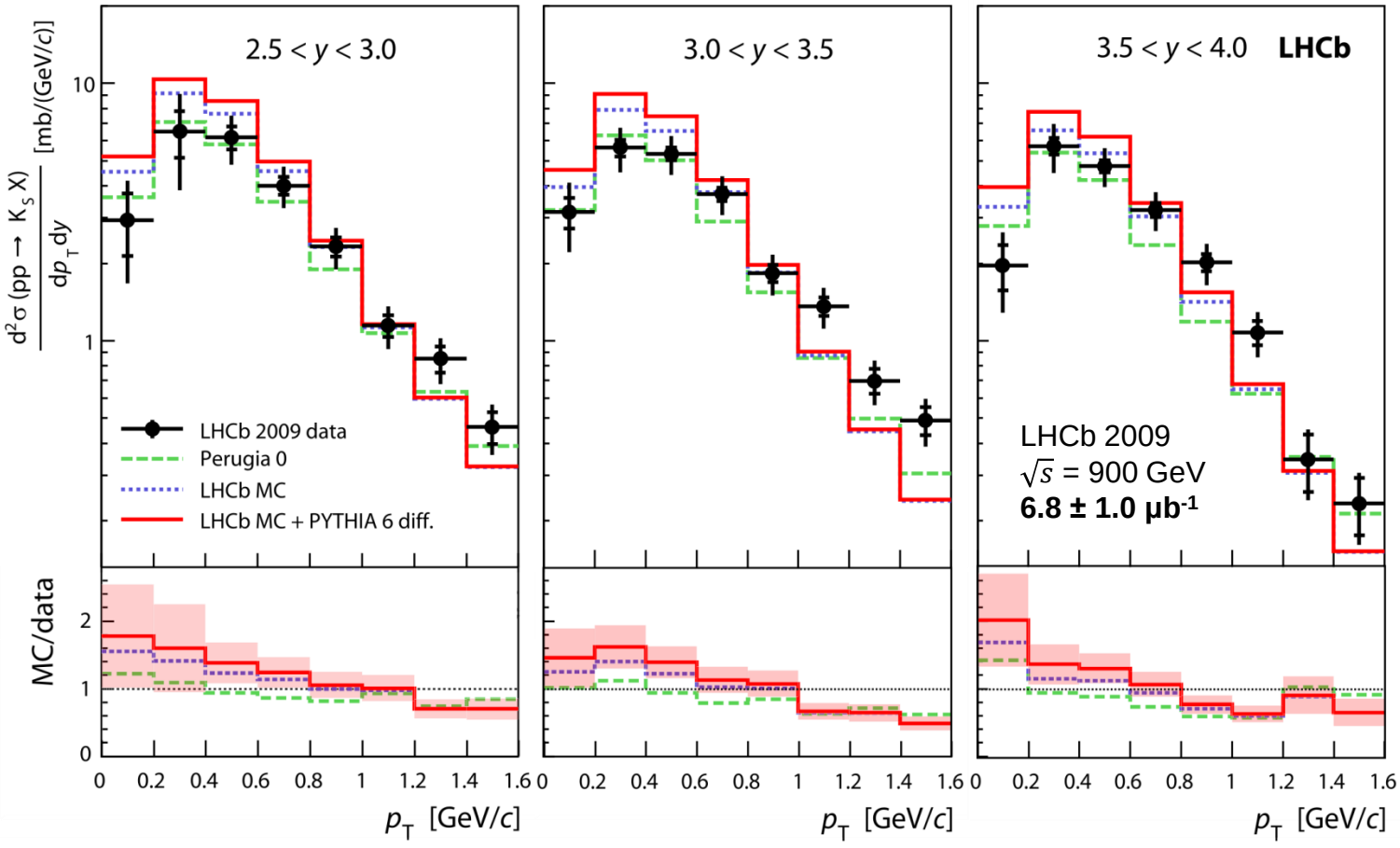
The largest single error comes from the measurement of ***bunch currents*** in the integrated $\mathcal{L}$ calculation

Source of uncertainty	uncorrelated	correlated
Yields N_i^{obs}		
– Data statistics	$5-25\,\%$	
– Signal extraction	$1-5\,\%$	
– Beam-gas subtraction		$<1\,\%$
Efficiency correction $(\epsilon_i^{\text{trig/sel}}\ \epsilon_i^{\text{sel}})^{-1}$		
– 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 $(L_{\text{int}})^{-1}$		
– Bunch currents		$12\,\%$
– Beam widths		$5\,\%$
– Beam positions		$3\,\%$
– Beam angles		$1\,\%$
Sum in quadrature	$6-28\,\%$	$16-23\,\%$

K_S Cross Section Results

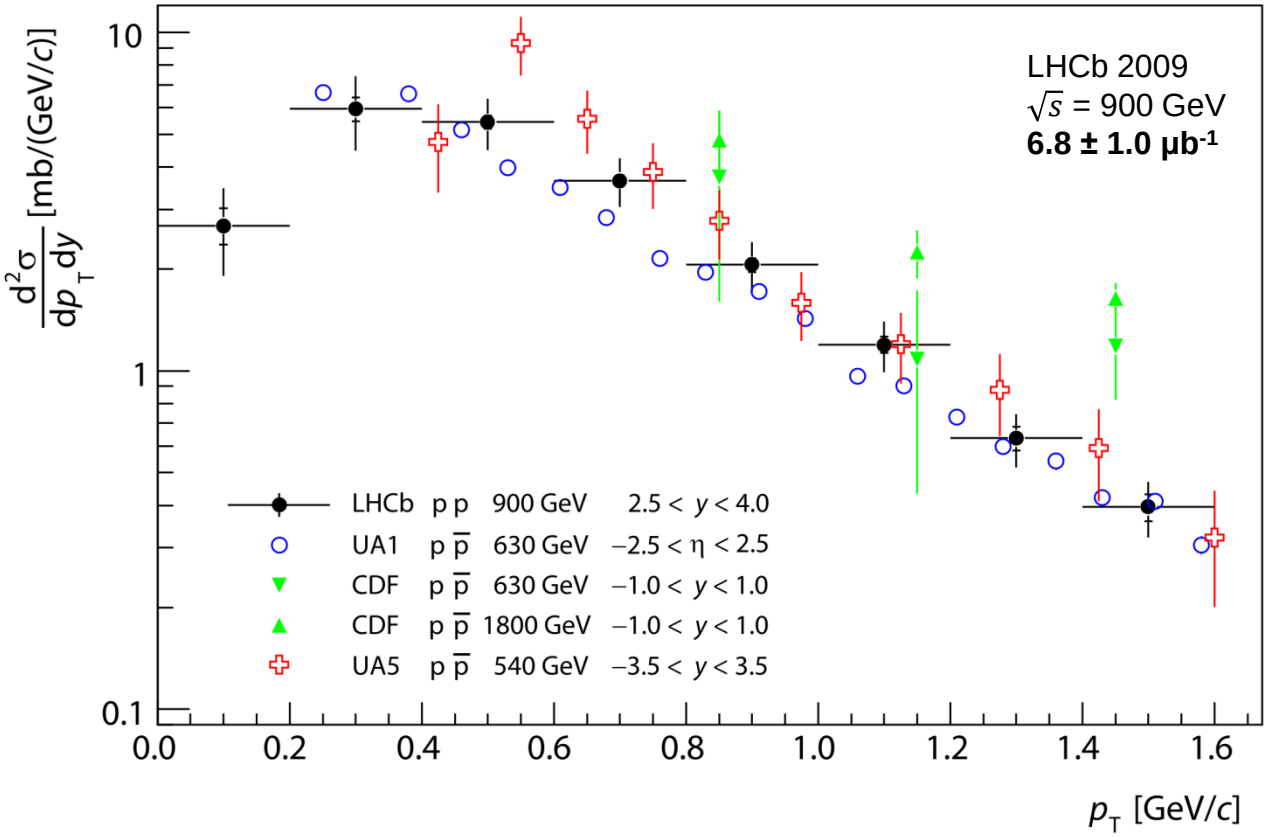
K_S production peaks between 0.2 & 0.4 GeV/c of p_T

The most consistent PYTHIA tuning tested was Perugia 0



K_S Cross Section Results

This first measurement at $\sqrt{s}$ = 900 GeV also extends to higher rapidity & lower p_T than previous experiments



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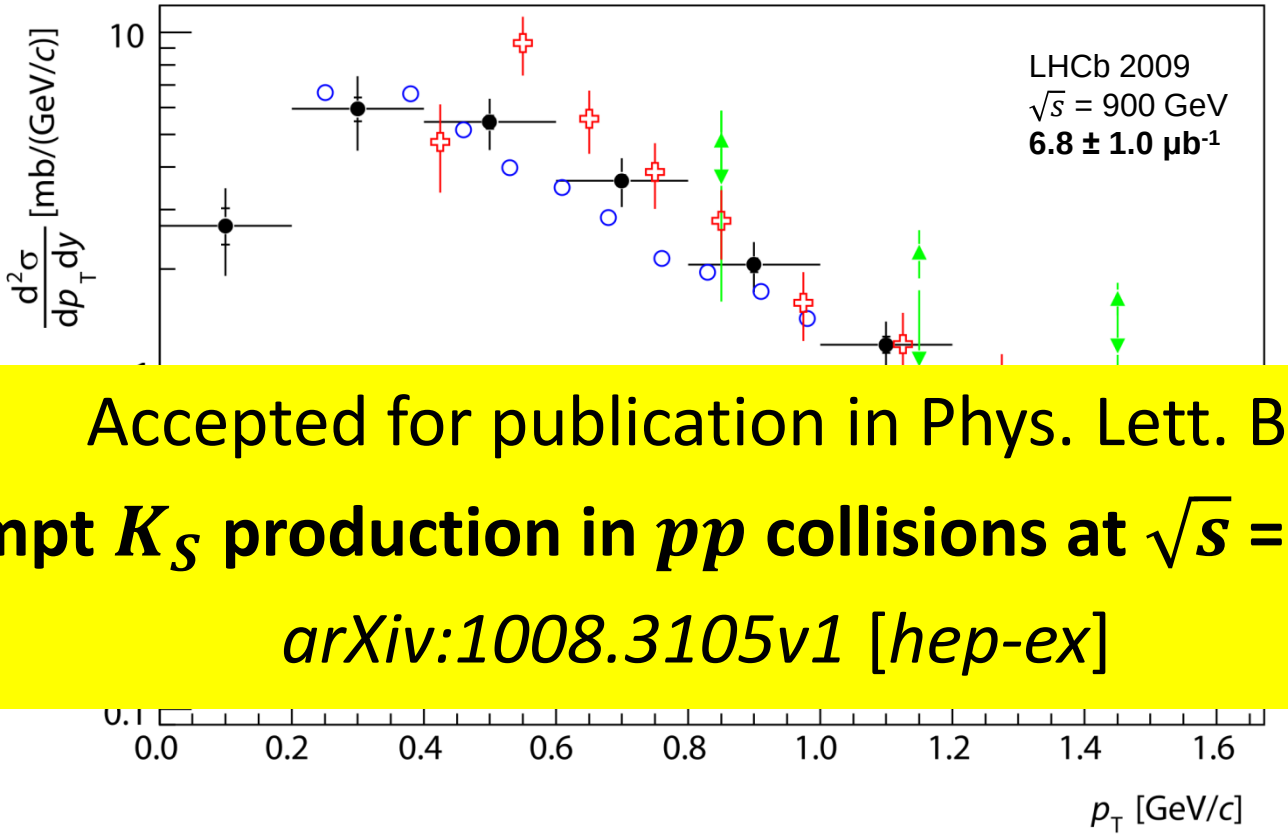


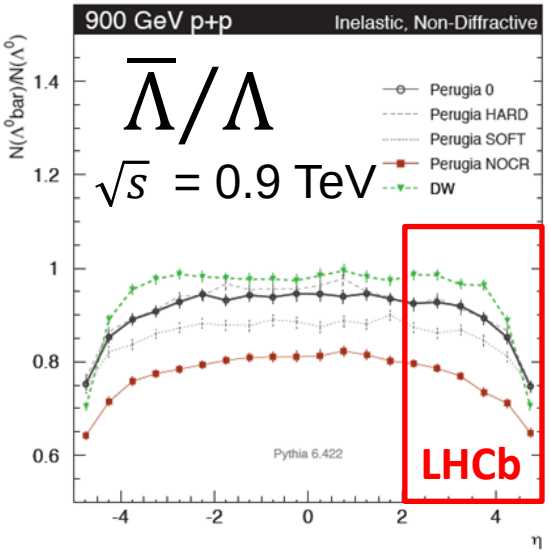
Accepted for publication in Phys. Lett. B:

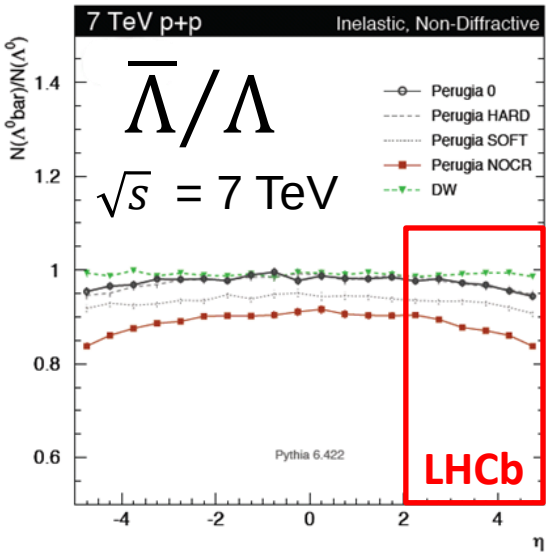
"Prompt K_S production in pp collisions at $\sqrt{s}$ = 0.9 TeV"

arXiv:1008.3105v1 [*hep-ex*]

Ratio Measurements

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





Theoretical interest in ratios *e.g.*

- baryon number transport
- baryon *vs.* meson suppression in hadronisation

V^0 ratios $\overline{\Lambda}/\Lambda$ $\overline{\Lambda}/K_S$

Only tracking & vertexing

Proton ratio $\bar{p}/p$

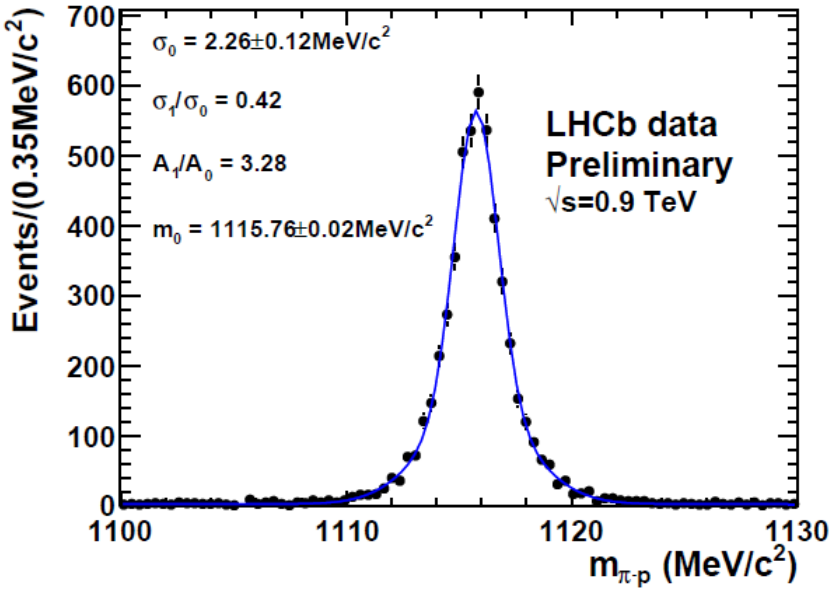
RICH particle identification

All abundant in minimum bias data

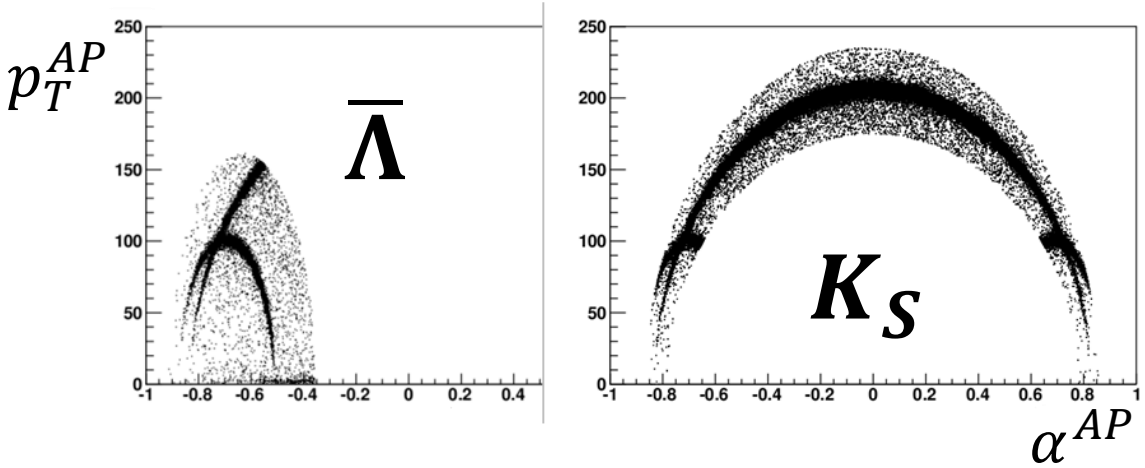
V^0 Selection

High-purity, prompt K_S & Λ samples selection based on a combination of impact parameters (IP)

$$\nu = lnIP^{+} + lnIP^{-} - lnIP^{V^0}$$

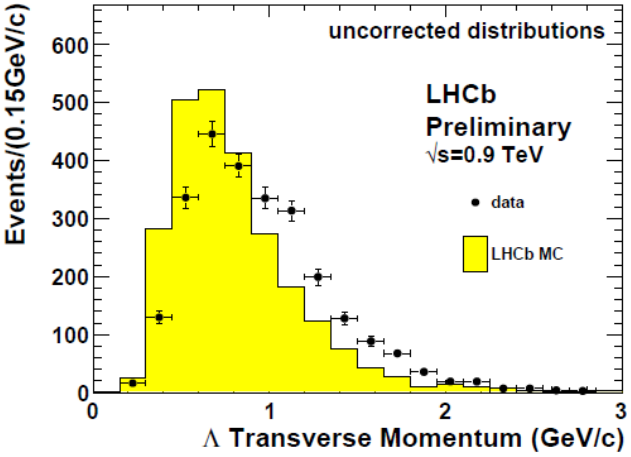


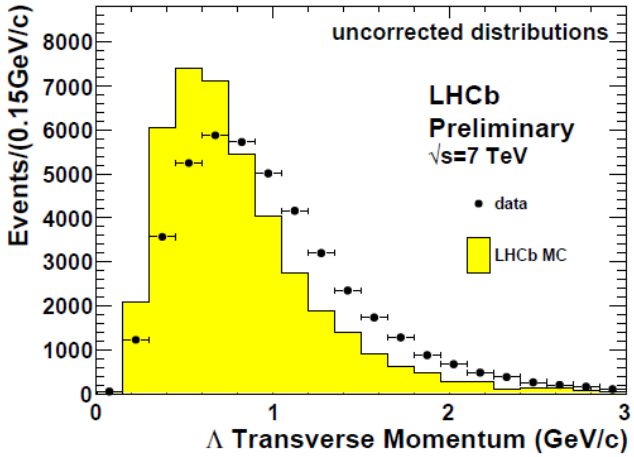
V^0 background seen in Armenteros-Podolanski variables & removed with an invariant mass cut on the "wrong" daughter hypothesis



V^0 Analysis

Analysis carried out in bins of V^0 p_T and rapidity, boost corrected for the beam crossing angle





Efficiency is estimated per bin with LHCb-tuned PYTHIA event generation and GEANT simulation for **prompt**, **non-diffractive** events

$\Sigma_{ancestors}\, c\tau_{PDG} < 10^{-6}$ mm

PYTHIA Process ID ≠ 91, 92 or 93

Efficiencies are calculated after reweighting of Monte Carlo p_T distributions

V^0 Ratio Systematics

Ratios benefit from reduced systematic uncertainties since ***absolute luminosity not required***

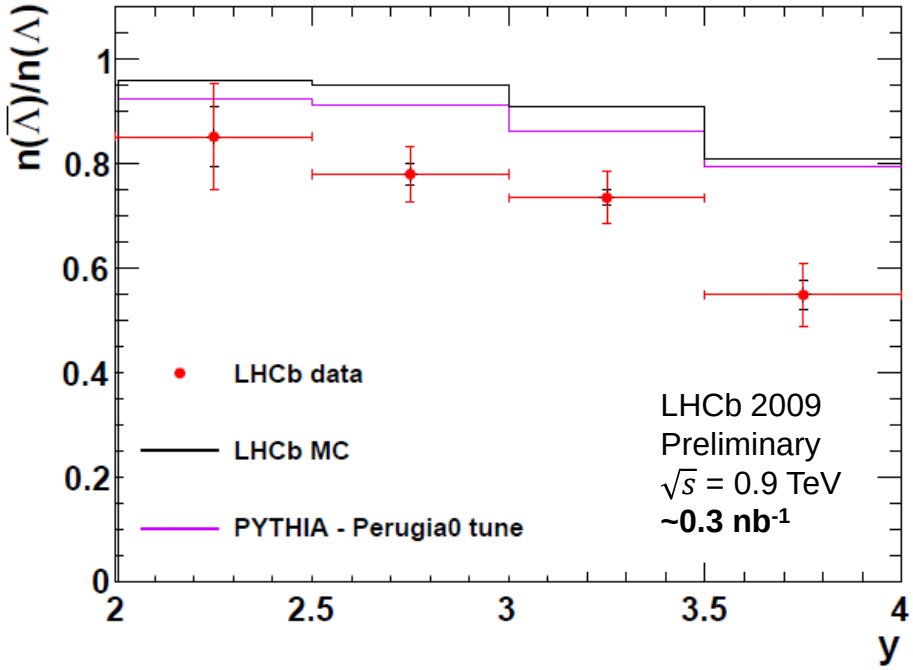
Remaining systematics relate to MC, data comparisons:

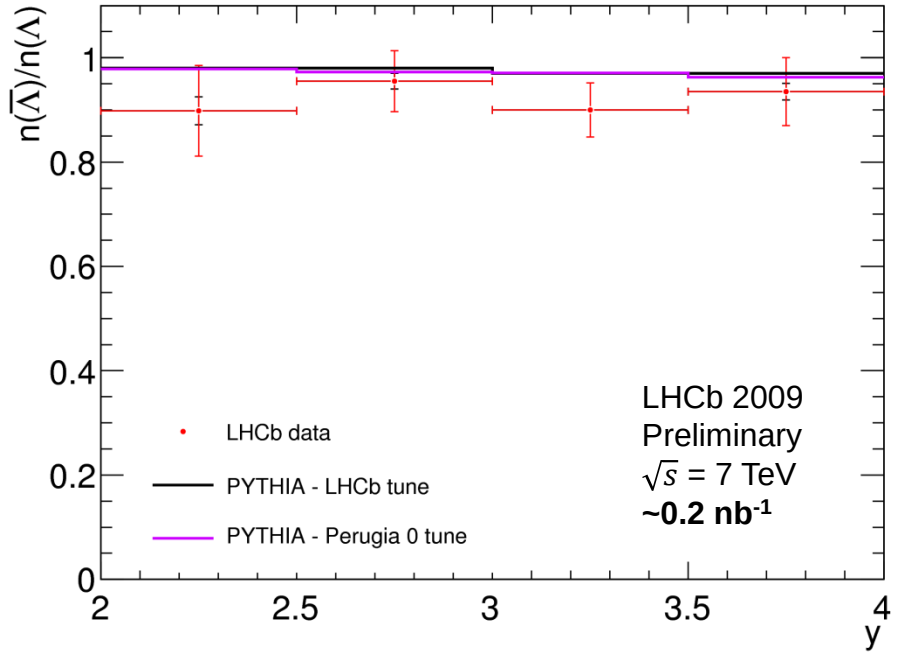
Uncertainties	Errors
p,π - nucleon interaction cross sections	~10%
V^0 production & interaction cross sections	~10%
LHCb material description	<10%
Λ transverse polarisation	<1%
Selection cuts	~1%
Ghost tracks	<2%
Acceptance asymmetries	~2%
Non-prompt contamination	<1%

Ratio	Total
$\overline{\Lambda}/\Lambda$	2%
$\overline{\Lambda}/K_S$	2-12%

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

Another unique measurement at high rapidity with pp collisions at $\sqrt{s}$ = 0.9 & 7 TeV

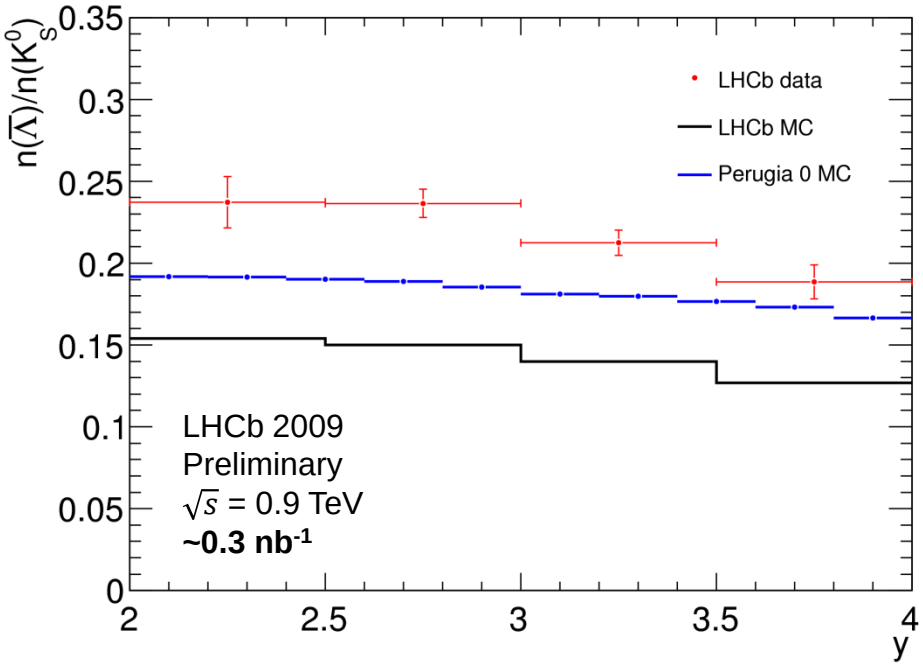


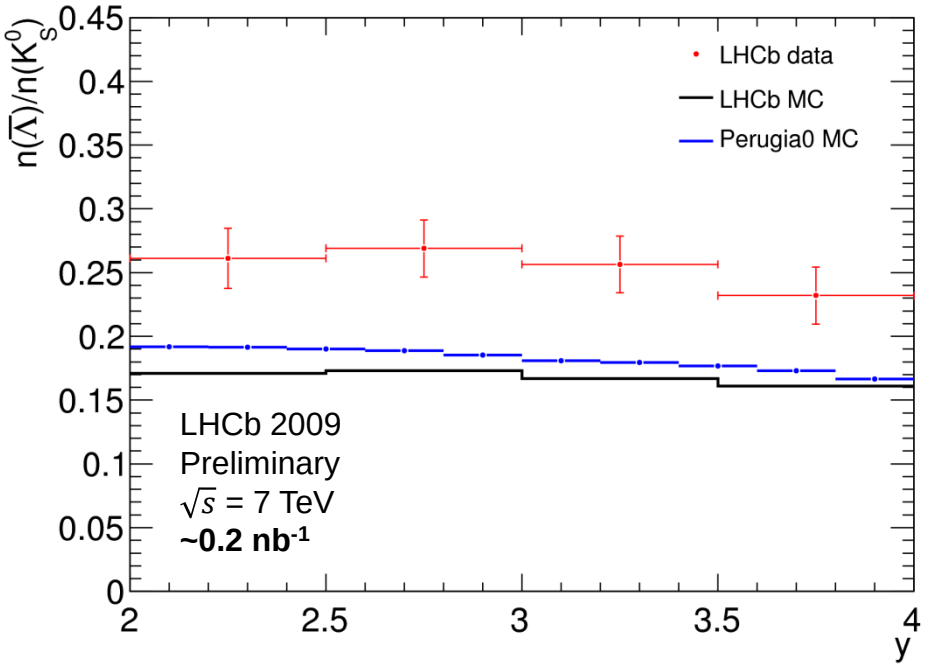


Measurements lie significantly lower than Perugia 0 expectation at $\sqrt{s}$ = 0.9 TeV

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

Baryon *vs.* meson production ratio measurement with pp collisions at $\sqrt{s}$ = 0.9 & 7 TeV

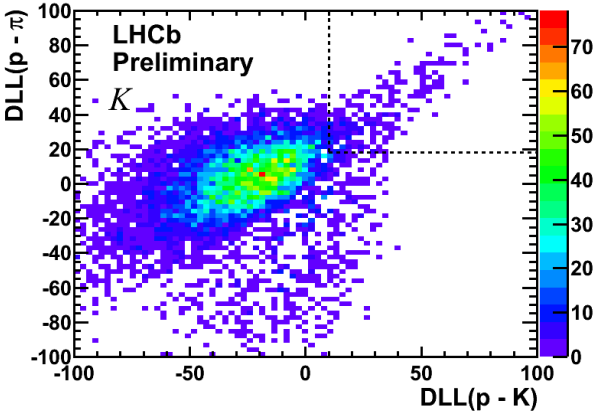


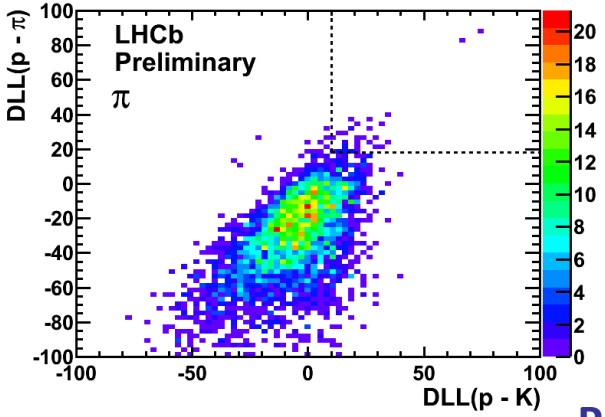


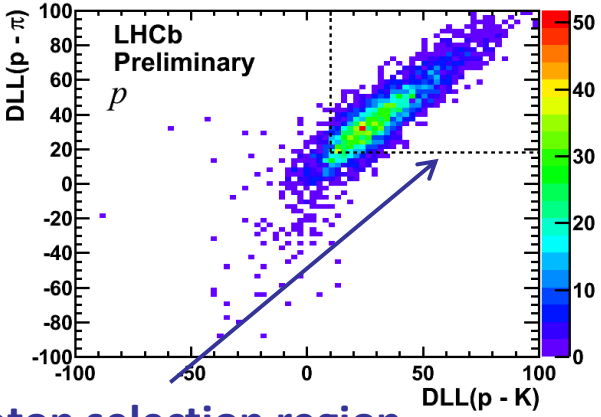
Baryon suppression in hadronisation significantly lower than predicted at both energies

Proton Ratio

Protons are selected with RICH particle identification, comparing the likelihoods (DLL) of π & K to p







Proton selection region

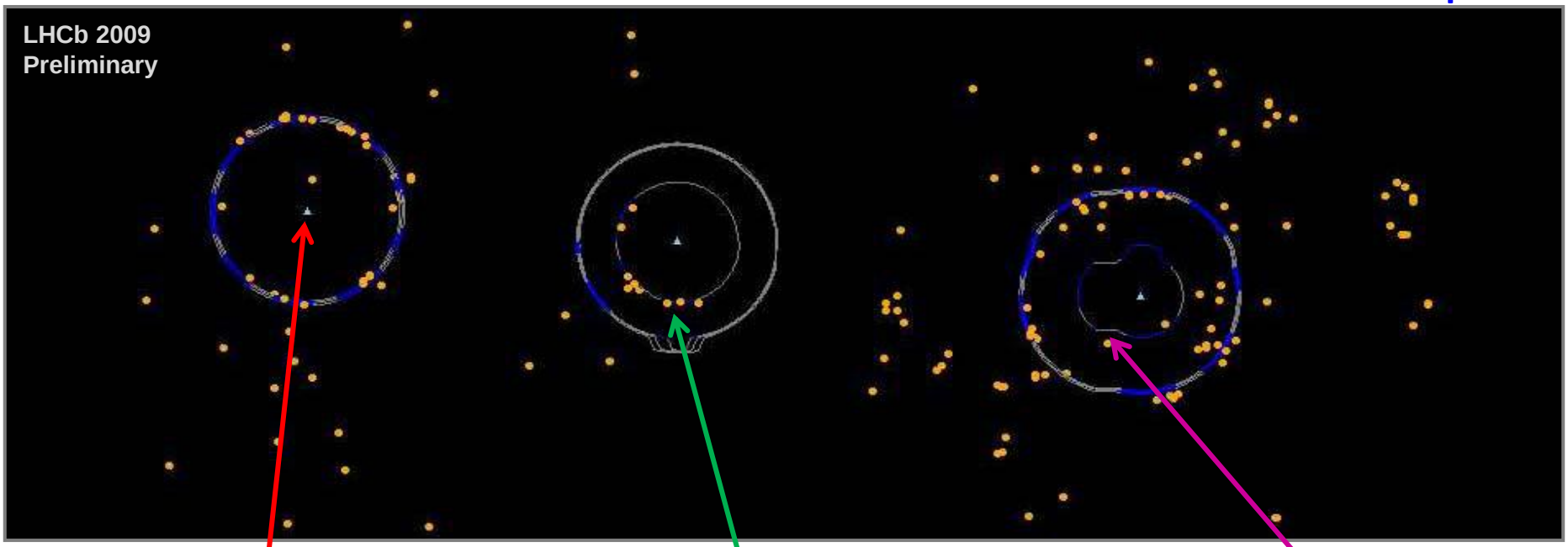
RICH particle identification calibrated with tracking-only selected samples of $K_S \to \pi^+\pi^-$, $\Lambda \to p\pi$ & tag-and-probe selected $\phi \to K^+K^-$

Cuts tuned for purity (*90-95%*) in MC in bins of p_T & η, with selection efficiency measured in data

RICH Particle Identification

An event display from real data show “rings” projected on to RICH2’s photon detector plane

Detector acceptance



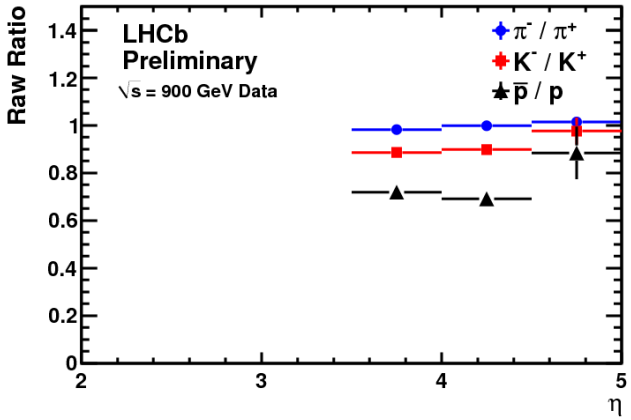
Saturated track: particle hypotheses indistinguishable

Photons clearly favour the Kaon ring hypothesis

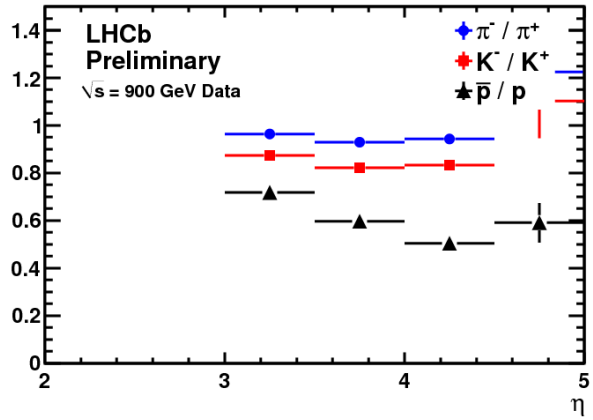
Ring distortions due to detector geometry

Uncorrected Charged Particle Ratios

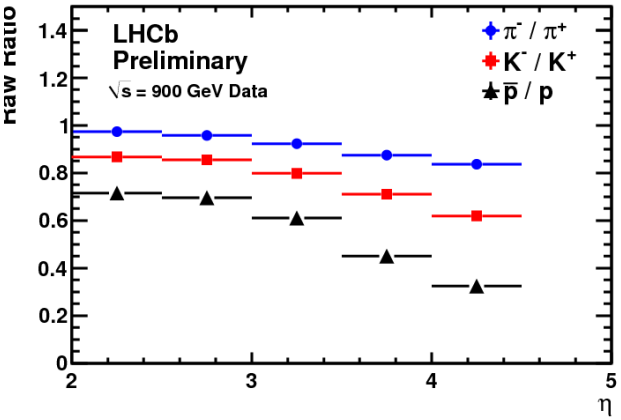
$\sqrt{s}$ = 0.9 TeV



p_T < 0.8 GeV/c

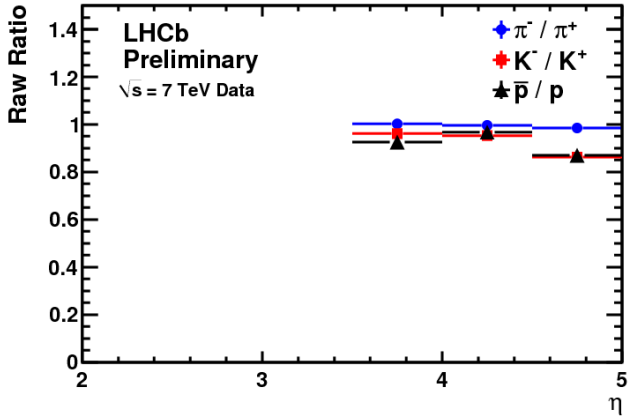


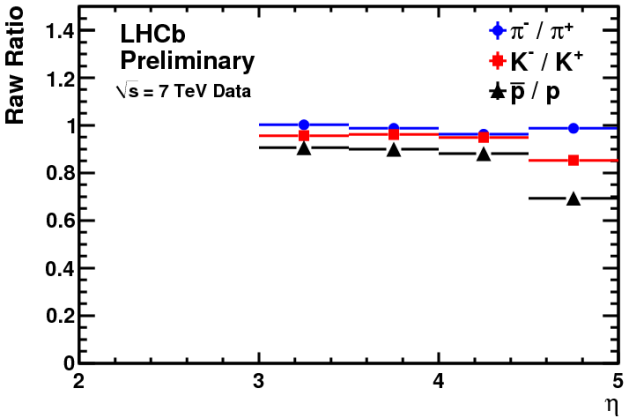
0.8 < p_T < 1.2 GeV/c

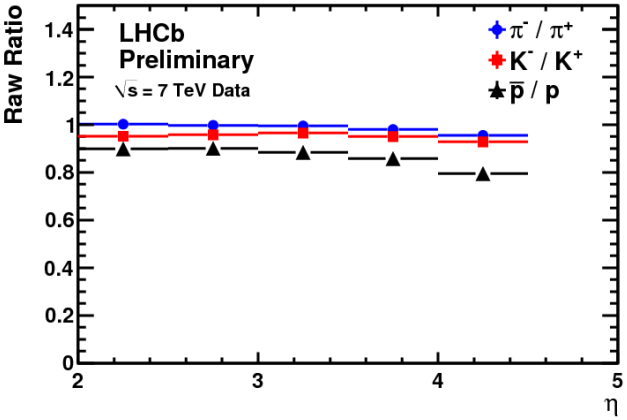


p_T >1.2 GeV/c

$\sqrt{s}$ = 7 TeV







Proton Ratio Systematics

RICH PID contributes the largest error, typically ***< 5%*** but increases due to statistically limited calibration samples in outer p_T, η bins

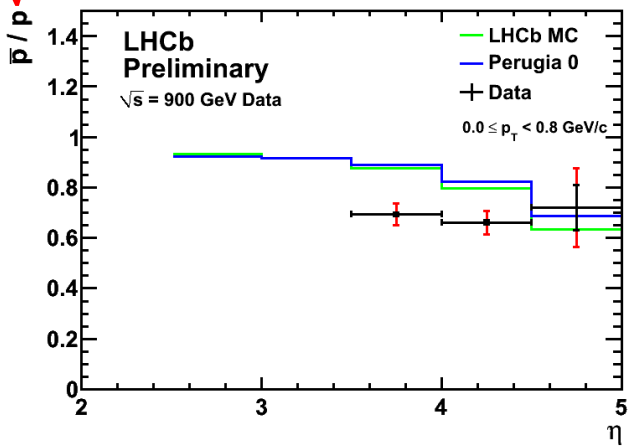
MC ***interactions between p, $\bar{p}$ & nucleons*** in agreement with COMPASS data ***±20%*** for momentum > 5 GeV/*c*

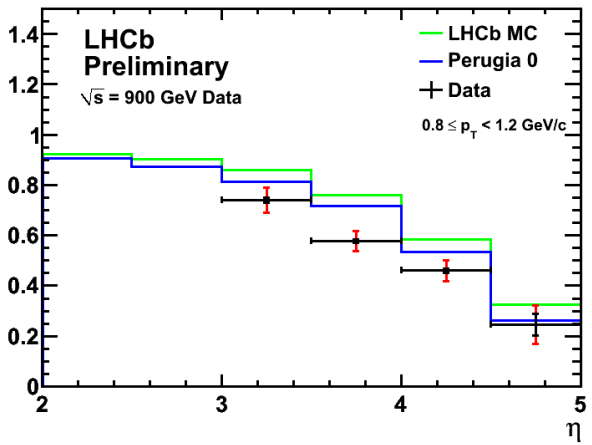
Contribution from ***fake tracks*** greatly reduced for protons associated to Cherenkov light but estimated contribution remains ***~1%***

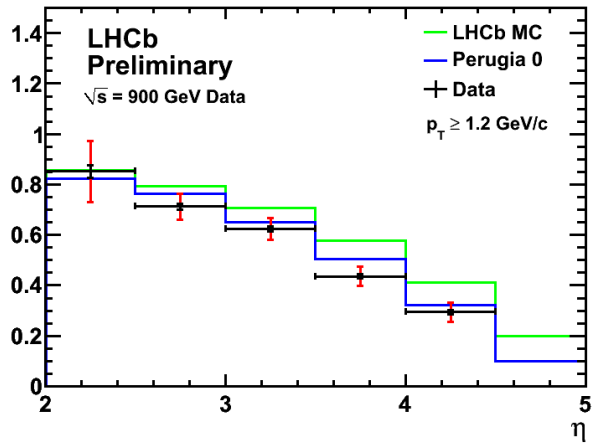
Consistent results found from cross-checks using tighter cuts on track quality & RICH PID and between magnetic field polarities

Preliminary Results $\bar{p}/p$

$\sqrt{s}$ = 0.9 TeV

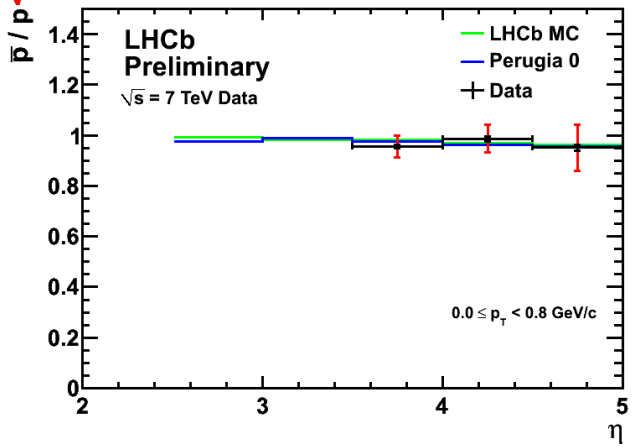


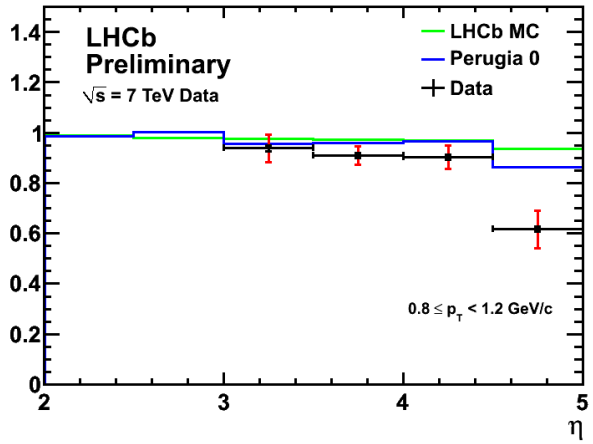


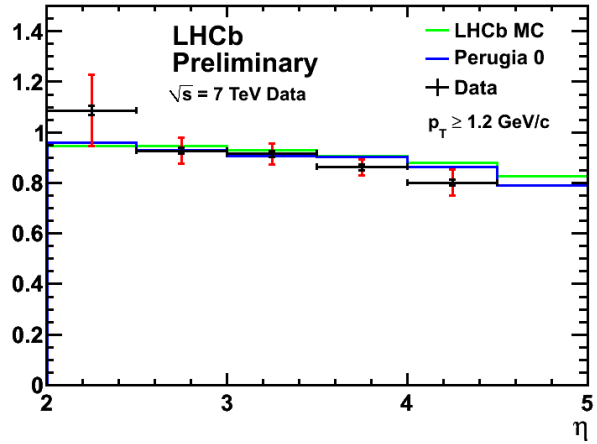


p_T < 0.8 GeV/c | 0.8 < p_T < 1.2 GeV/c | p_T >1.2 GeV/c

$\sqrt{s}$ = 7 TeV



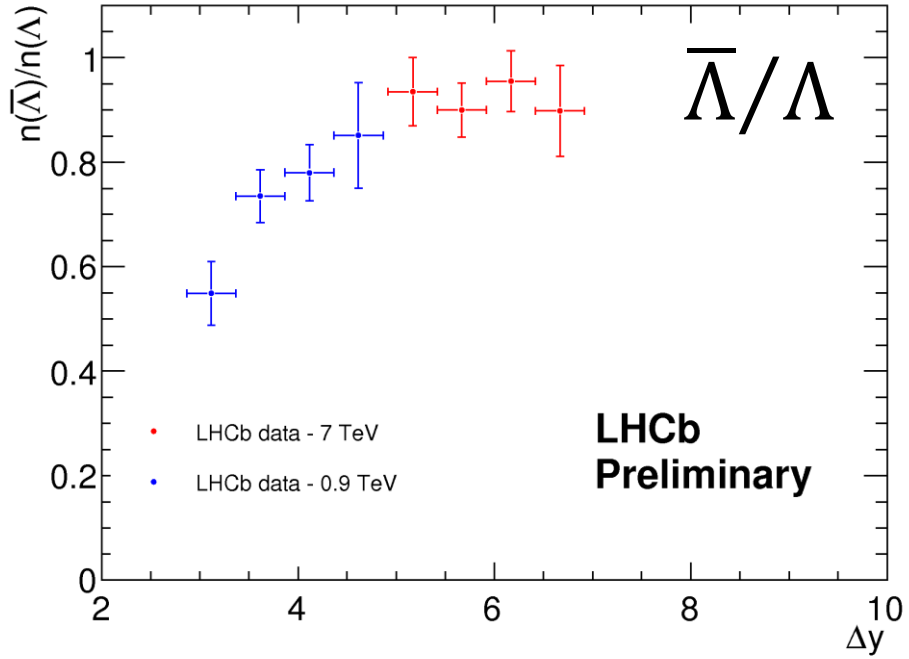


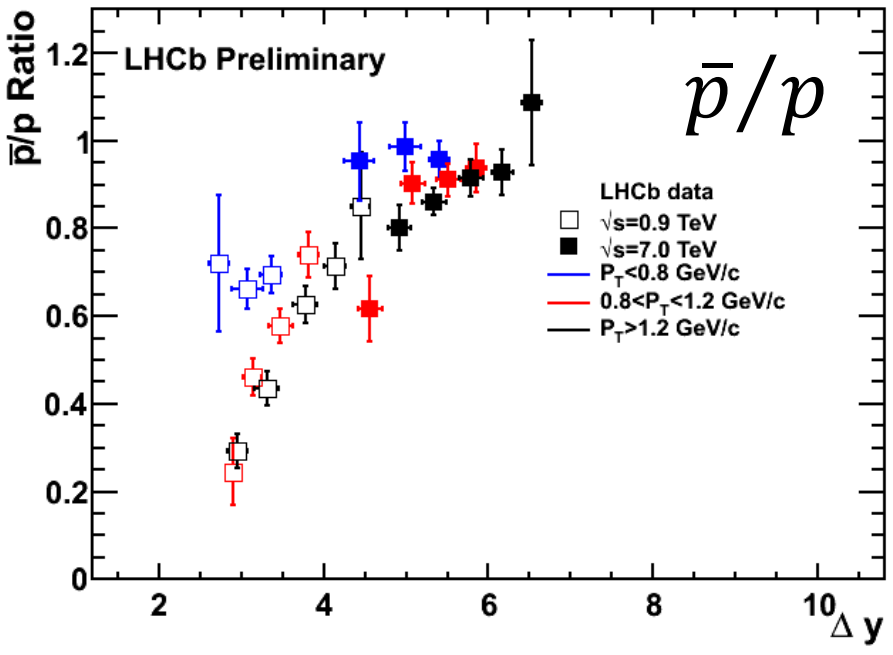


Baryon number transport closer to predictions

Preliminary Results Comparison

Results at both beam energies compared in ***Δy*** show consistency, also with other experiments





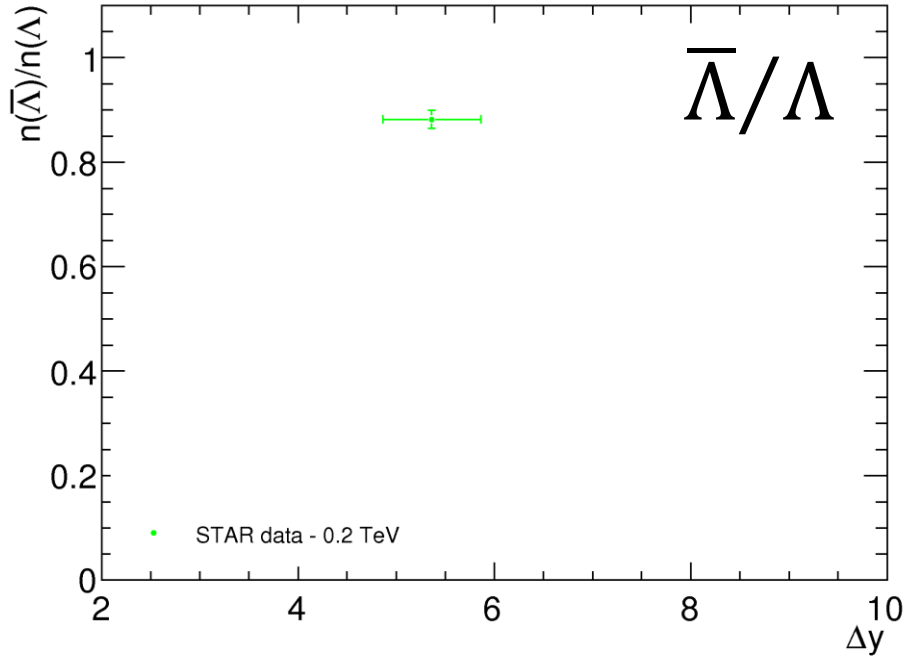
Δy = y(beam) – y(Λ,p)

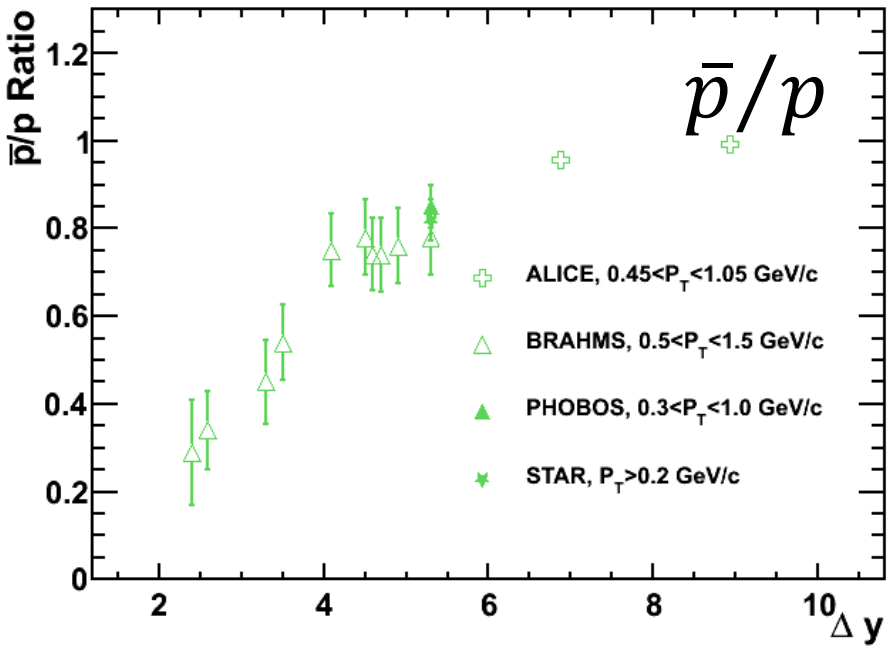
y(beam): 6.6 : $\sqrt{s}$ = 0.9 TeV

8.3 : $\sqrt{s}$ = 7 TeV

Preliminary Results Comparison

Results at both beam energies compared in ***Δy*** show consistency, also with other experiments





Δy = y(beam) – y(Λ,p)

y(beam): 6.6 : $\sqrt{s}$ = 0.9 TeV

8.3 : $\sqrt{s}$ = 7 TeV

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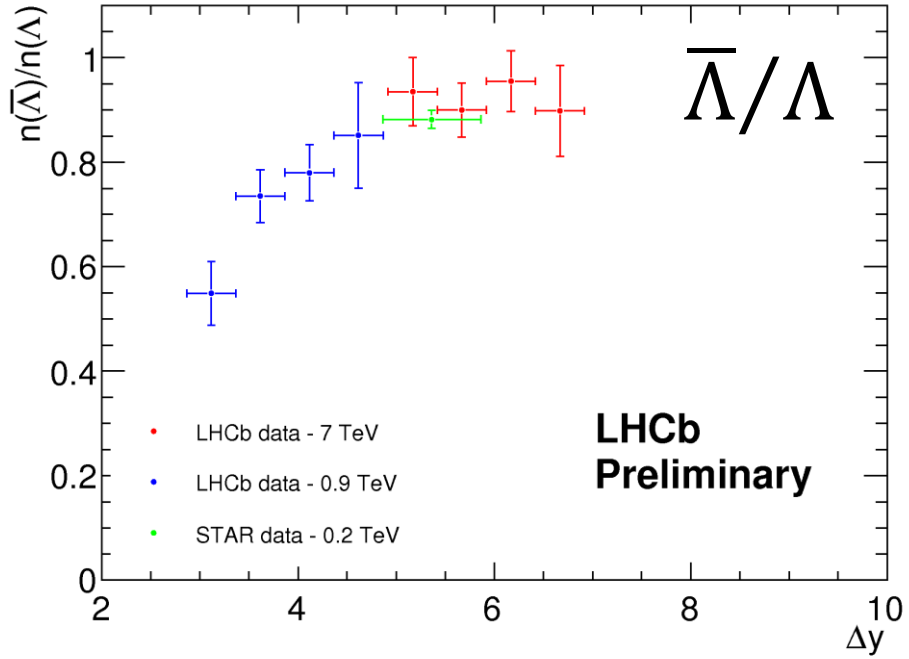

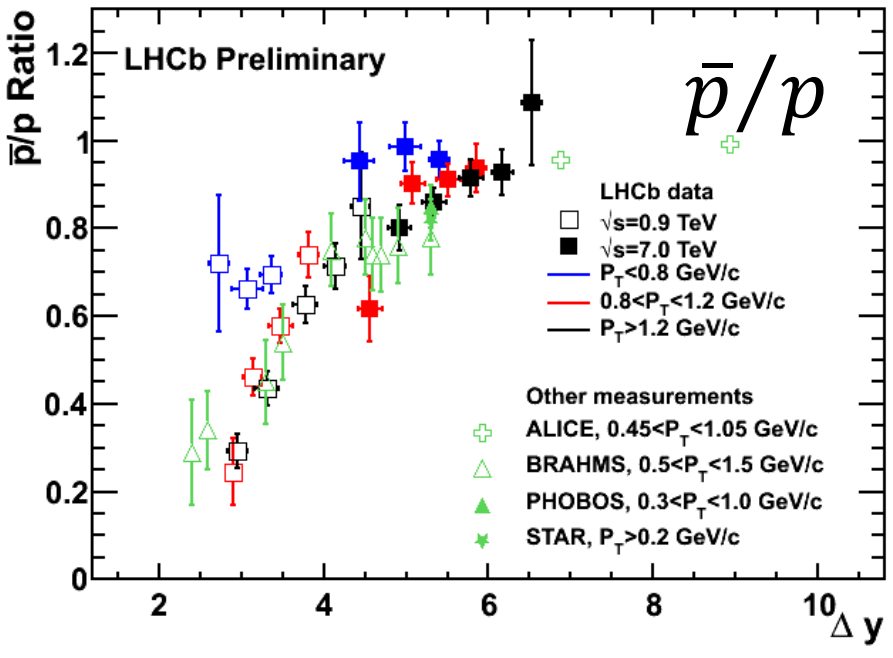

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Other on-going analyses:

- **Inclusive ϕ production**
- **Higher precision strangeness production**
- **Charged particle studies**

Look out for new LHCb publications soon!