Minimum Bias Physics at LHCb

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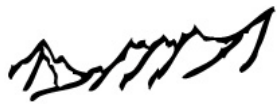
On behalf of the LHCb collaboration

ÉCOLE DE PHYSIQUE
des HOUCHES



Winter Workshop on Recent QCD Advances at the LHC
Les Houches, February 13th - 18th, 2011

Minimum Bias Physics

Strangeness Production

- K_s^0 cross-section

  only tracking information, low luminosity, early calibration

- ϕ cross-section

  particle identification (PID) for at least one track

Baryon Number Transport

- $\overline{\Lambda}/\Lambda$ ratios

  only tracking information, no need for absolute luminosity, systematics cancel

- $\bar{p}/p$ ratio

  PID required, no need for absolute luminosity

Baryon Suppression

- $\overline{\Lambda}/K_s^0$ ratio

  only tracking, no need for absolute luminosity

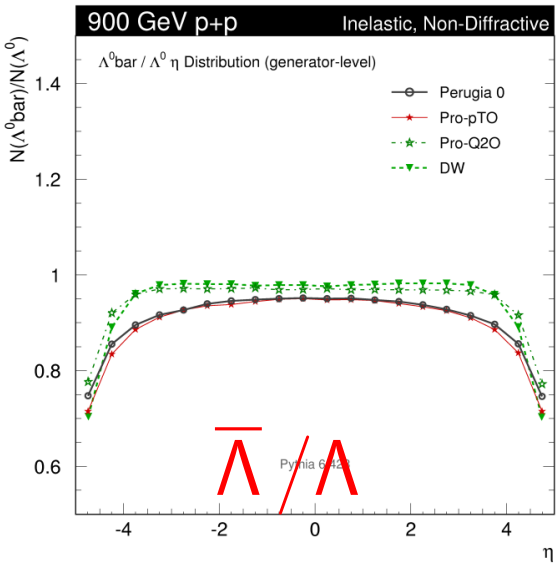
Motivation

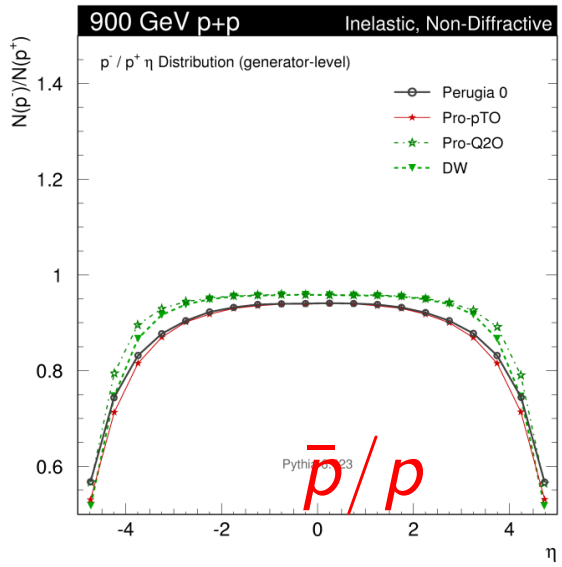
- test fragmentation models
- first pp measurements at the TeV scale
- tune generators

LHCb covers forward rapidity region and can measure down to $p_T \sim 0$

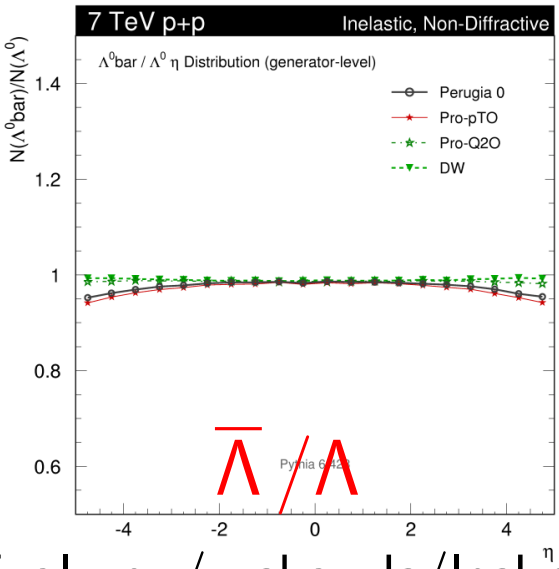
The forward region is more sensitive to Baryon Number Transport

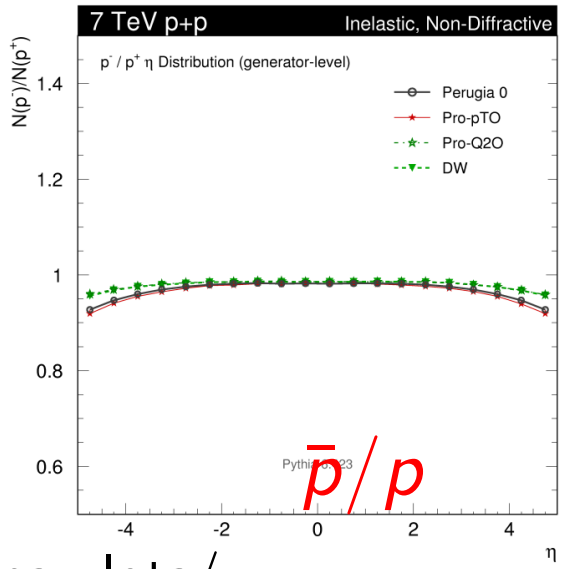
0.9 TeV





7 TeV





http://home.fnal.gov/∽skands/leshouches-plots/

Generators

Results will be compared to predictions from two generators

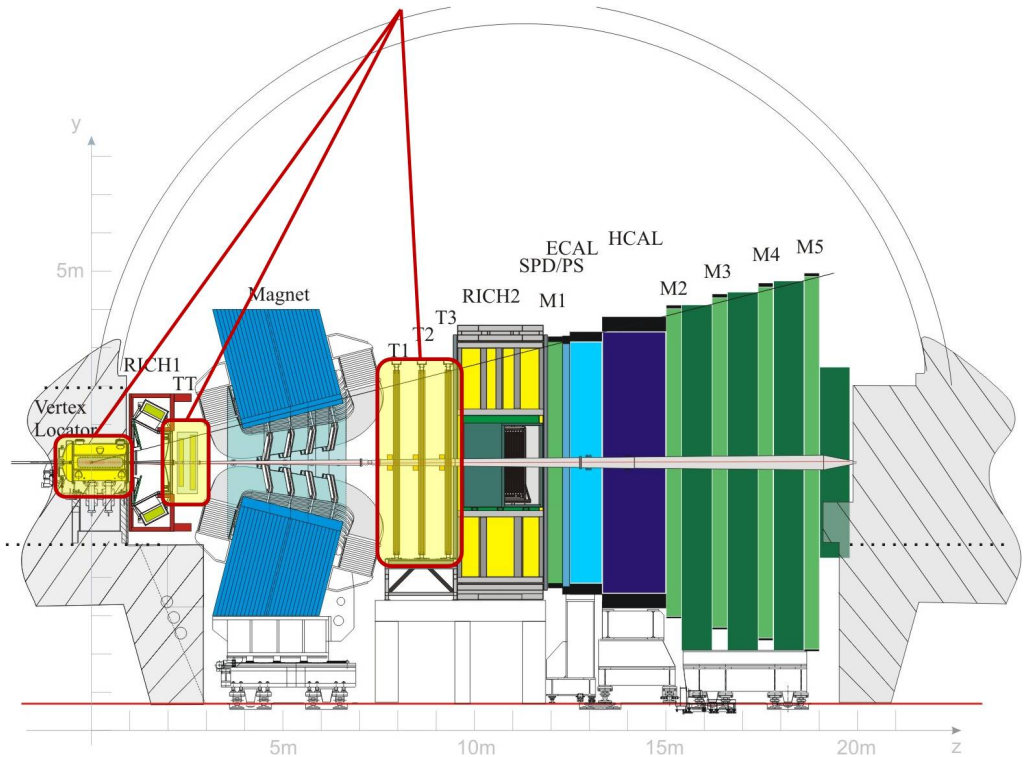
- Perugia0 tune Phys. Rev. D82:074018, 2010
- LHCb tune PYTHIA 6.421 LHAPDF-CTEQL61

Particles decayed through EVTGEN

The LHCb Detetctor

LHCb is a forward spectrometer ($2<\eta<5$)
intended for precision measurements of
CP violation and rare decays

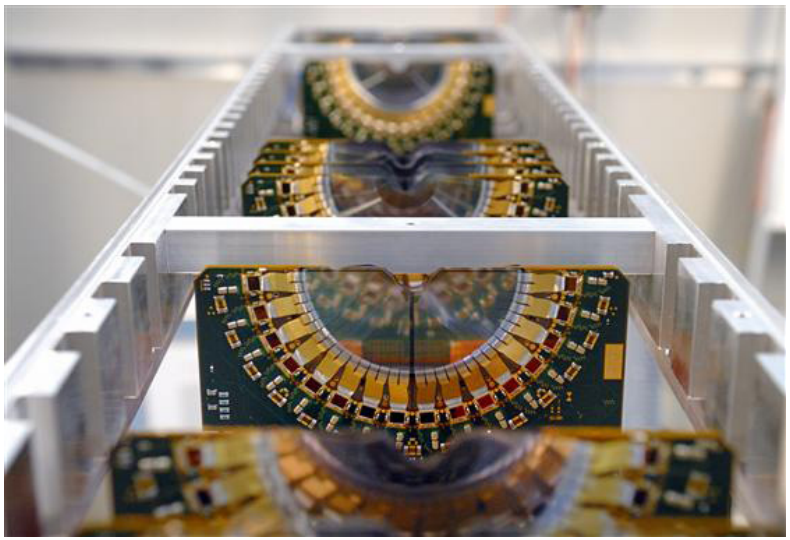
3 tracking subdetectors

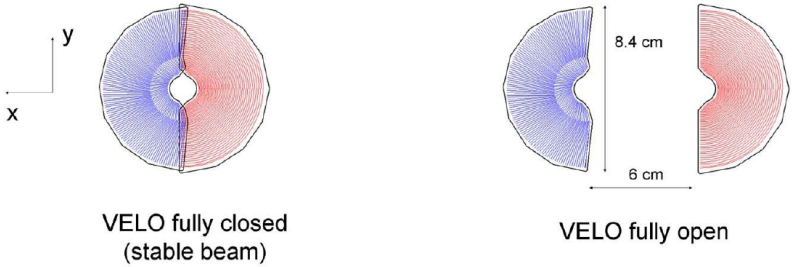


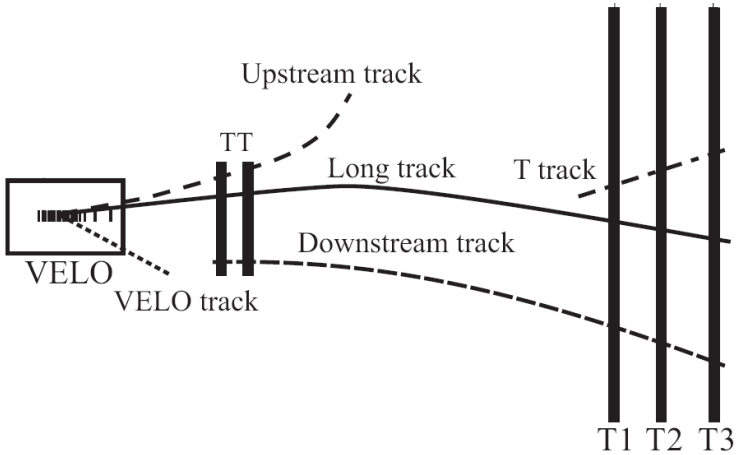
fully instrumented in its whole acceptance

- Tracking
  - **VELO**, **TT** and **T** stations
  - reconstruction efficiency 95%
- Magnet 4Tm($\pm$ polarity)
- ECAL γ,e
- HCAL p,K,π,n
- RICH
- MUON System

Tracking



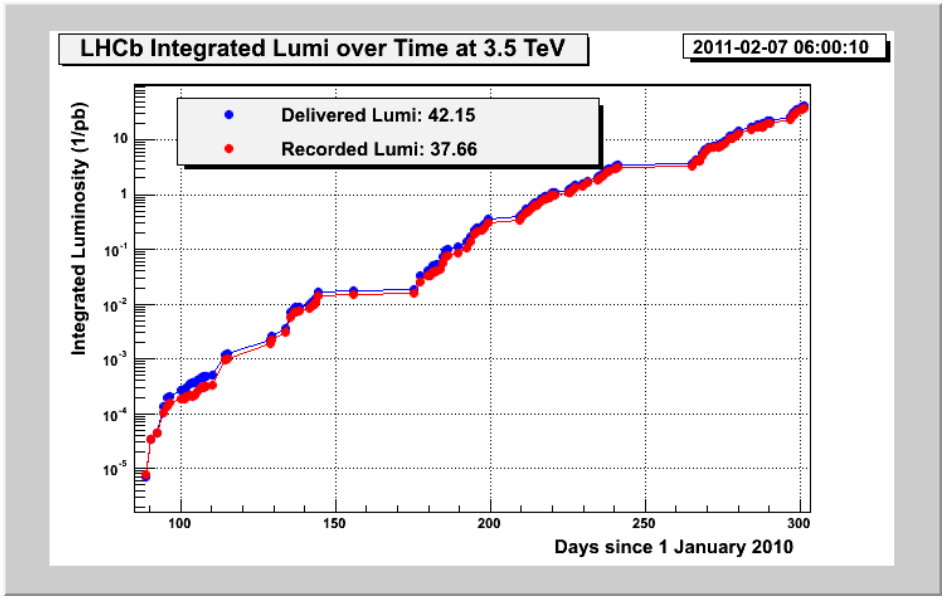




- VELO: r-ϕ geometry
- movable (very close to the beam)
- partially opened at 0.9 TeV
- resolution for primary(secondary) vertices $\sigma_z \approx 50(150)\ \mu$m
- long tracks provide best momentum information

Recorded luminosity

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



	0.9 TeV	7 TeV
K_s^0 cross-section	X	
ϕ cross-section		X
$\overline{\Lambda}/\Lambda$ & $\overline{\Lambda}/K_s^0$	X	X
$\bar{p}/p$	X	X

Strangeness Production

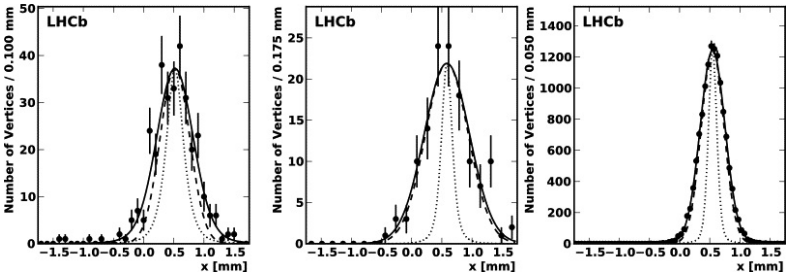
Prompt K_s^0 production in pp collisions at $\sqrt{s} = 0.9$ TeV

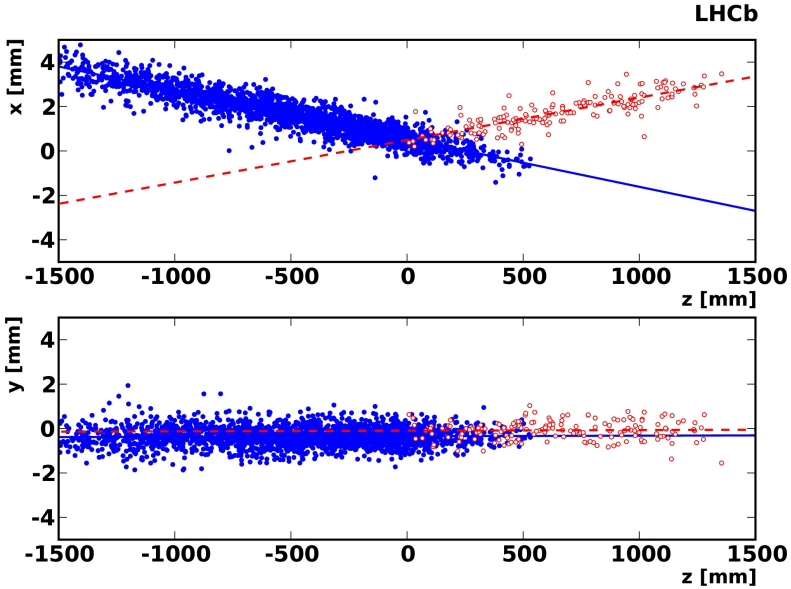
(Physics Letters B 693 (2010) pp. 69-80)

- prompt: directly produced in pp collision, or in a non-weakly decaying resonance
- cross sections in bins of transverse momentum p_T and rapidity y
- p_T below 0.2 GeV/c and $2.5 \leq$ y ≤ 4.0
- never explored before at this energy
- novel luminosity measurement technique

Luminosity Measurement

luminosity measurement combining accelerator and detector information





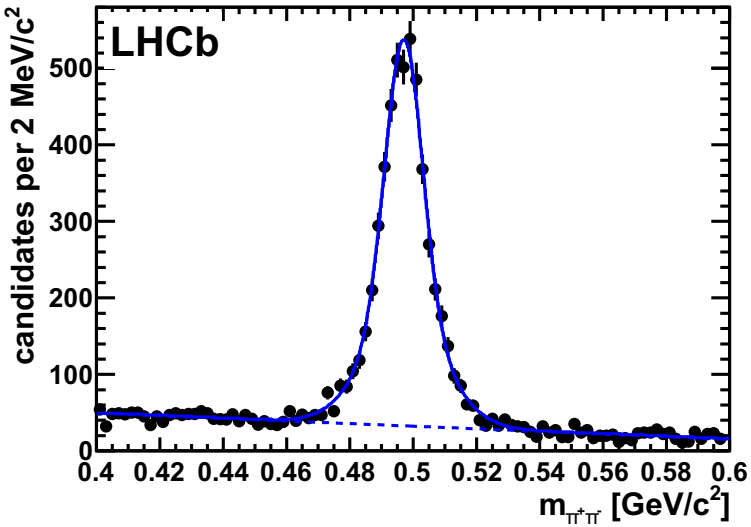
- bunch currents, taken from LHC machine measurements
- beam profiles and crossing angle measured with VELO (beam-gas events)
- profiles assumed to be gaussian

Integrated Luminosity:
$(6.8 \pm 1.0)\mu b^{-1}$

Two Selections

downstream tracks

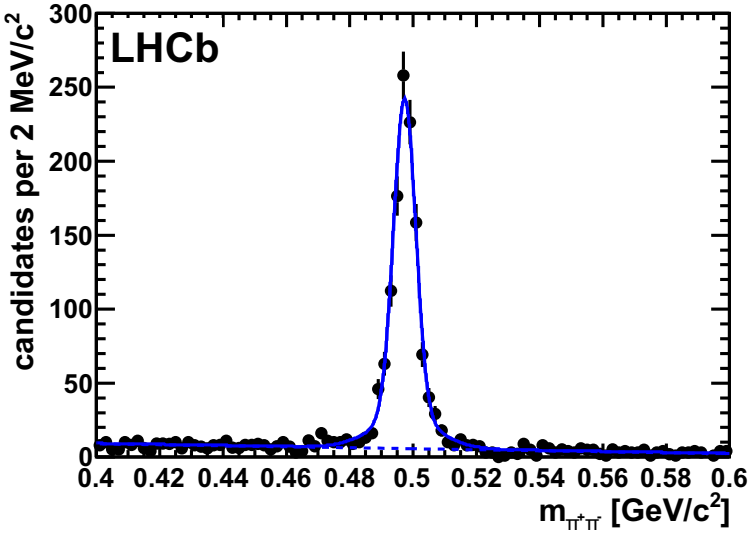
selection based on proper time and pointing angle



- higher statistics (due to VELO not being fully closed and K_s^0 long lifetime)
- most bins taken from this measurement

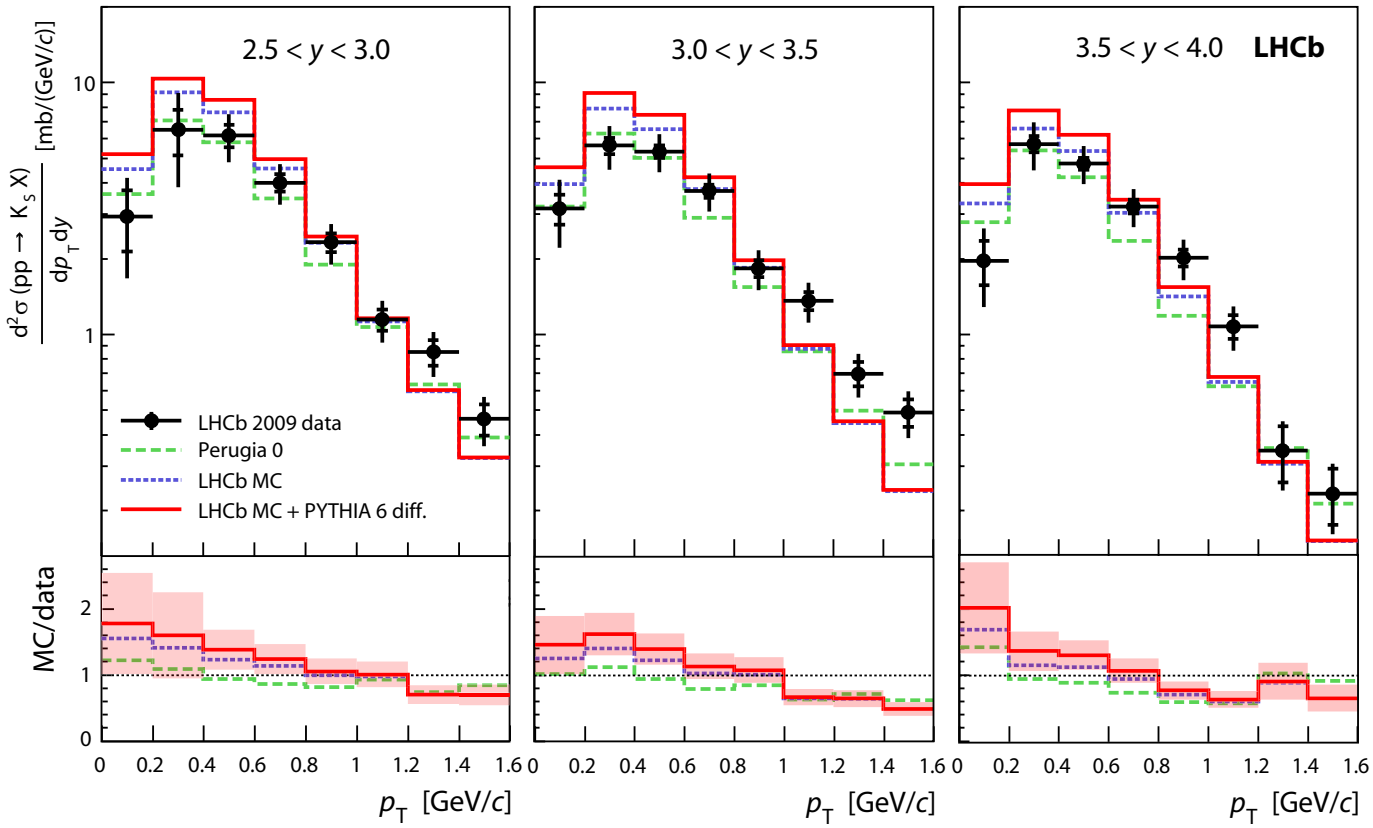
long tracks

selection based on impact parameters



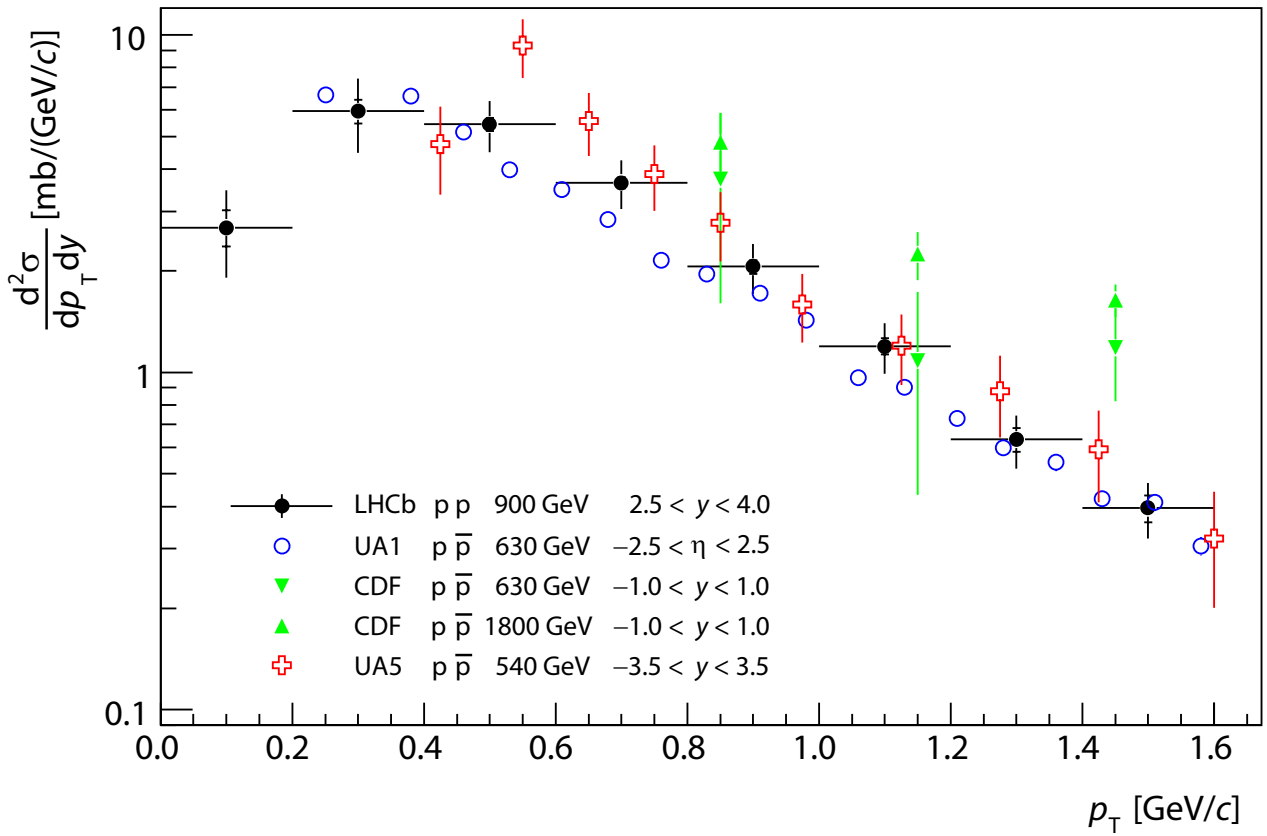
- better resolution
- lower background
- lowest p_T bins taken from this measurement

Prompt-K_s^0 cross section



- measured cross sections show harder p_T spectra than PYTHIA
- measurement contributes information for hadronization models

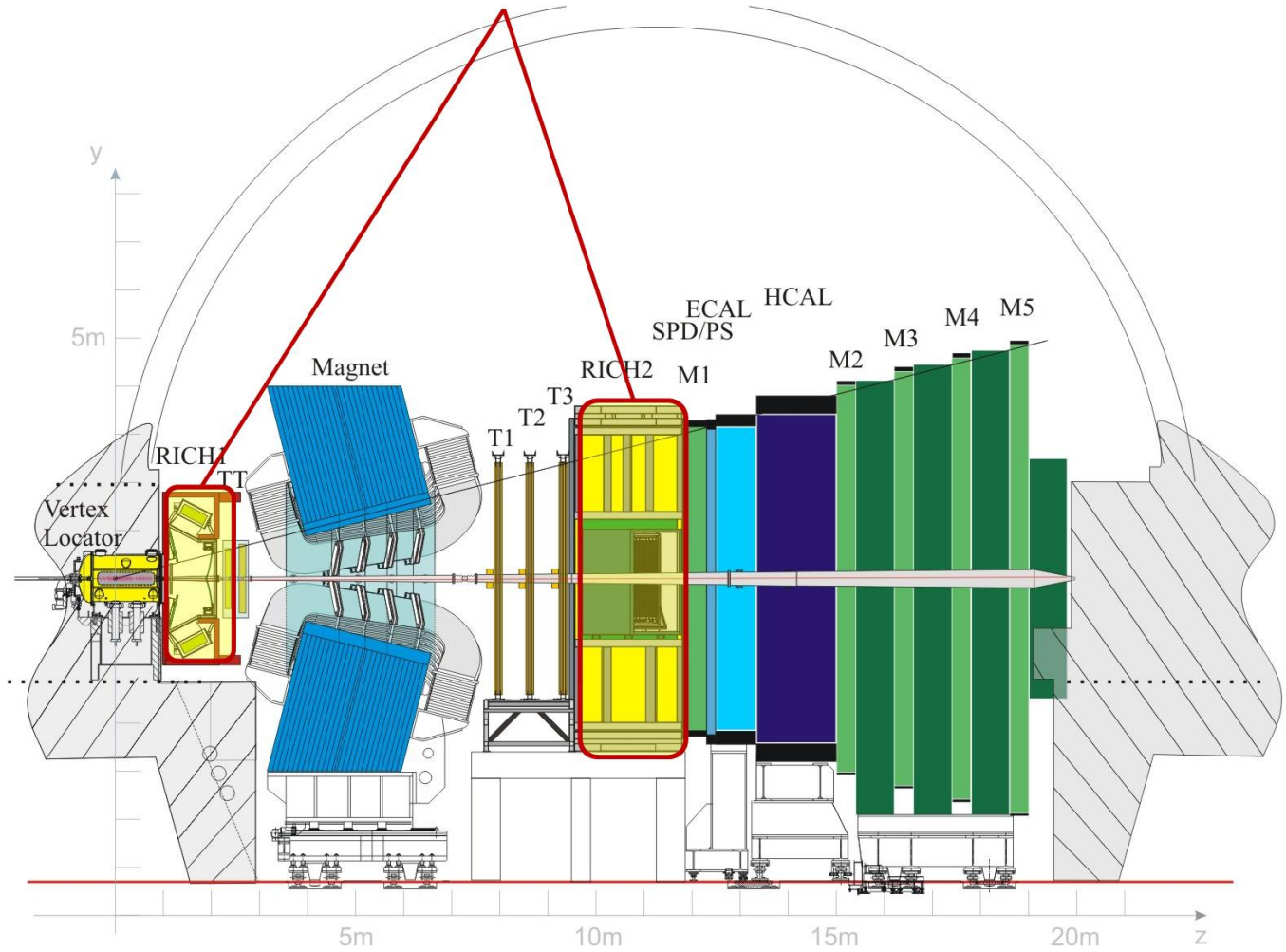
Prompt-K_s^0 cross section



- consistent with previous measurements
- K_s^0 cross-section measured for the first time at 0.9 TeV
- LHCb results extend to forward rapidity range and lower p_T

RICH PID

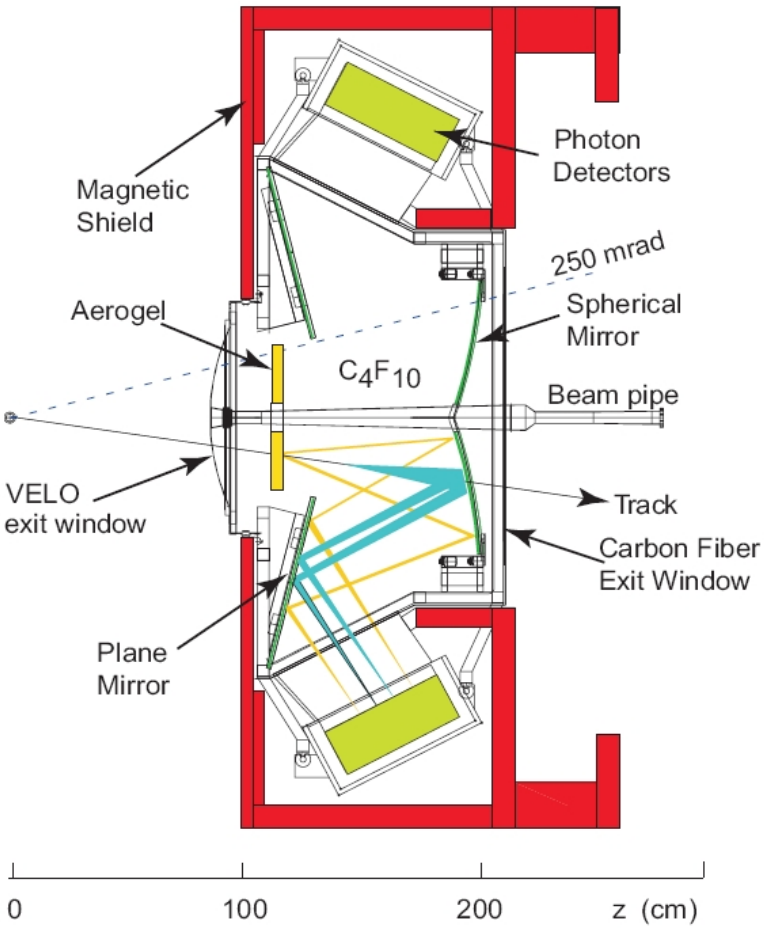
2 RICH detectors

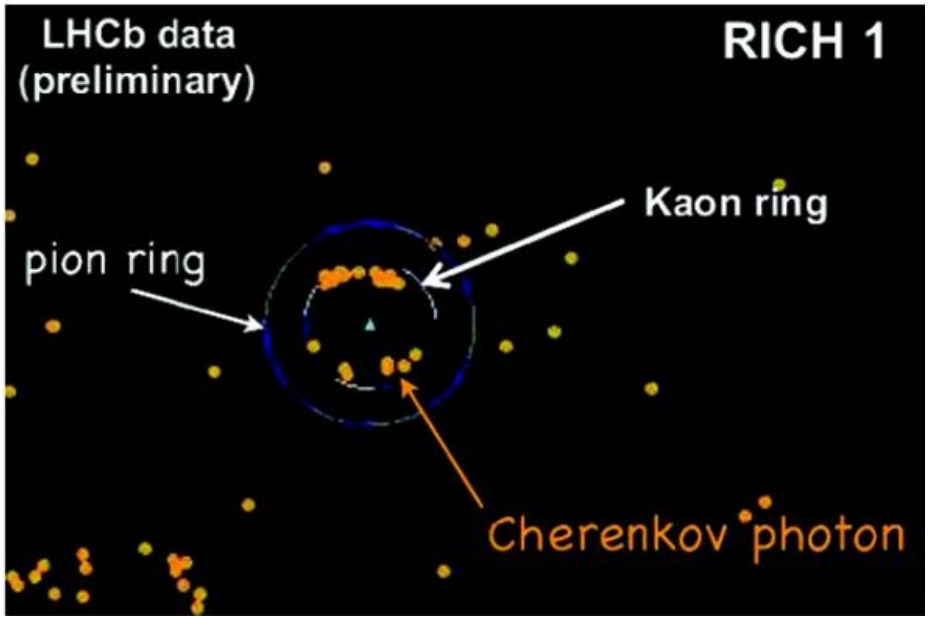


- charged particle identification in whole detector acceptance in a momentum range of 2 - 100 GeV/c
- unique in LHC experiments

LHCb RICH

RICH1

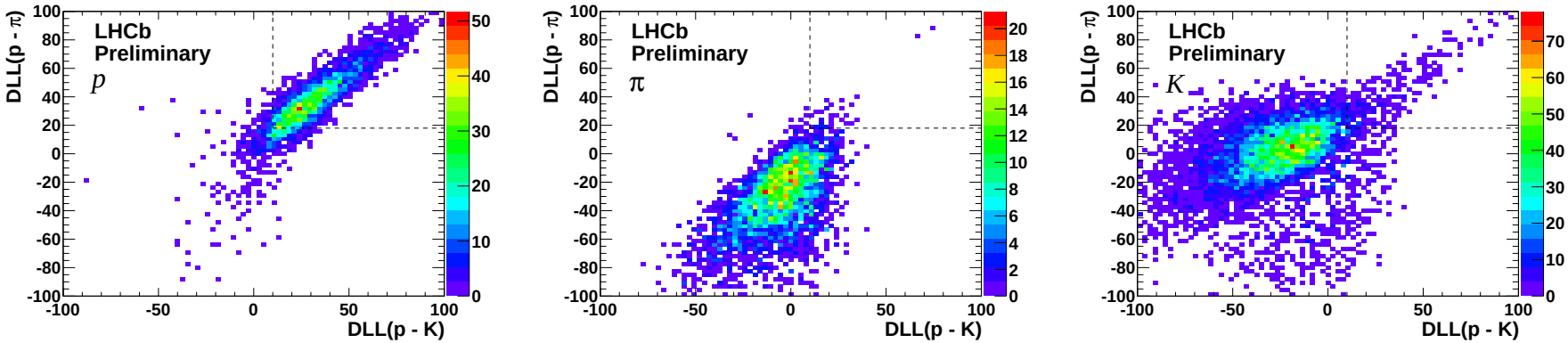




- measure projected Cherenkov radiation rings
- compare to hypothesis
- discriminate K,π,p

p,π,K discrimination

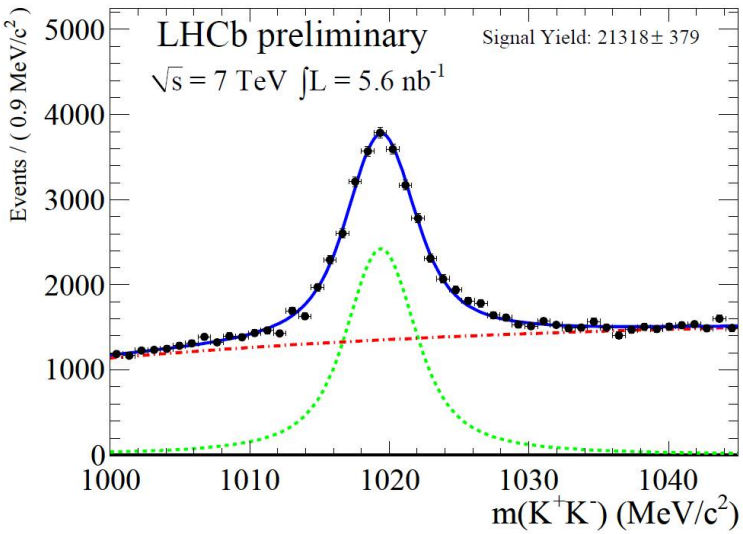
discrimination using
Delta Log Likelihood
DLL(a-b) = $\Delta ln_{ab} = ln(L_a/L_b)$



- π and p samples from V^0-decays: $K^0_s \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$
- K sample from $\Phi \to K^+K^-$, one track identified by RICH and the second left for PID measurement

Inclusive ϕ cross-section

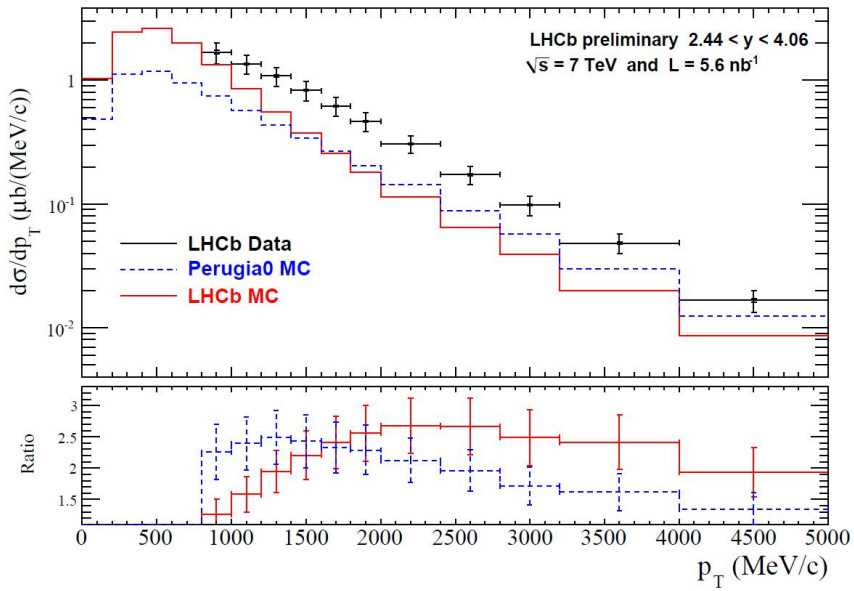
- study (hidden) strangeness production
- vector meson production
- test fragmentation models

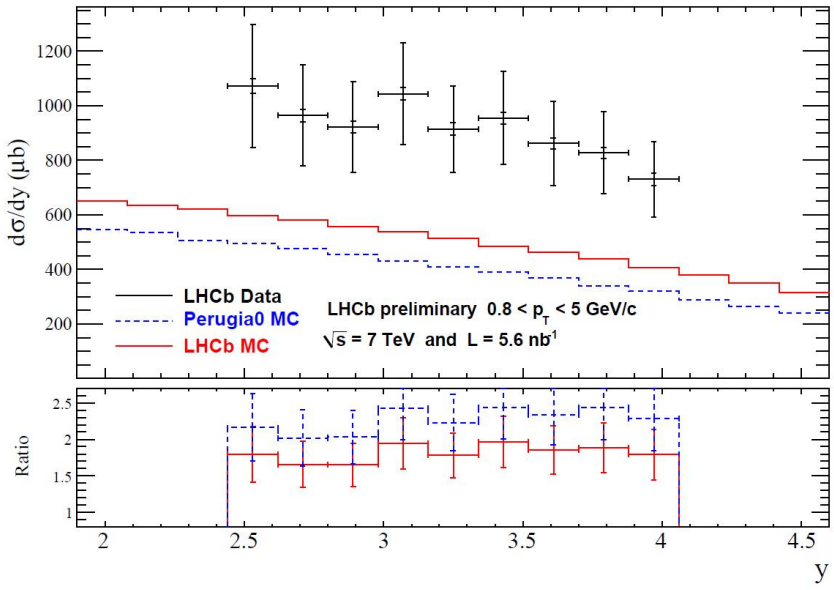


LHCb-CONF-2010-014

- $\phi \rightarrow K^+K^-$ candidate selection using RICH PID information
- 5.6 nb^{-1} at 7 TeV

Inclusive ϕ cross-section





- ϕ production larger than expectation
- p_T harder than models $\rightarrow$ similar to K^0_s results

Baryon Number Transport

Baryon Number Transport

- ratios for prompt particles
- 2010 data $\sqrt{s}$=0.9 TeV (0.3 nb^{-1}) and $\sqrt{s}$=7 TeV (0.2 nb^{-1})
- systematics cancel partially

$\overline{\Lambda}/\Lambda$ ratio

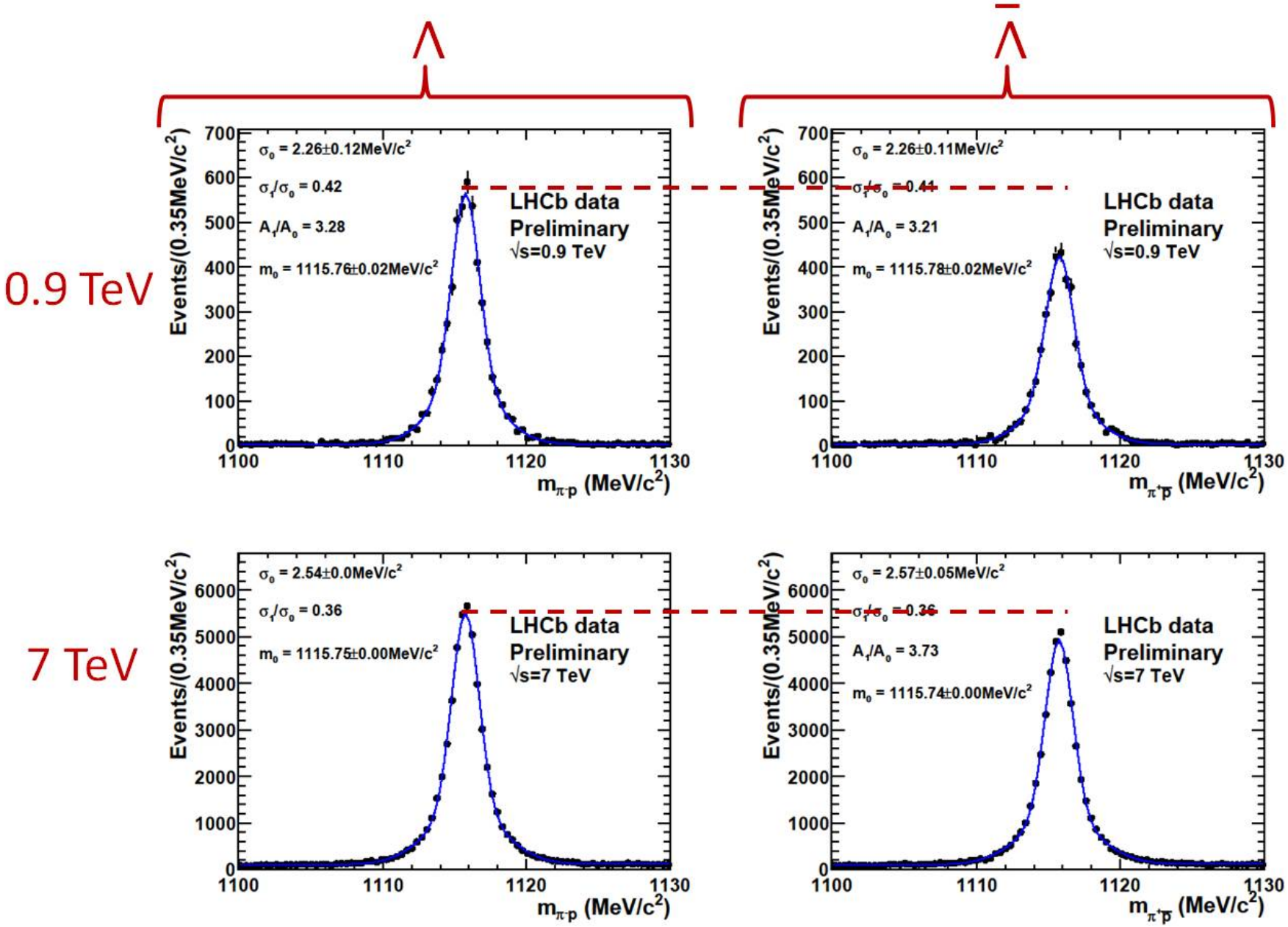
LHCb-CONF-2010-011

- kinematic selection based on impact parameters
- no PID used

$\bar{p}/p$ ratio

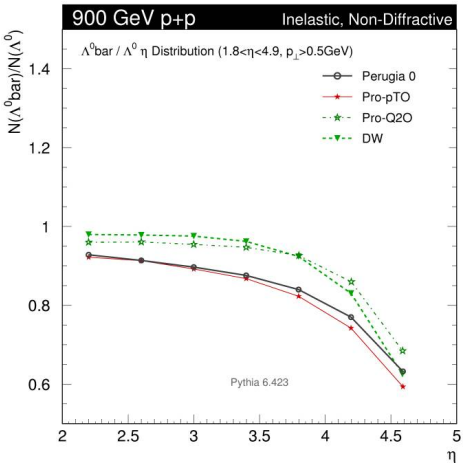
LHCb-CONF-2010-009

- RICH information
  $p(\bar{p})$ sample $\sim$ 95% purity
- independent systematics with respect to $\overline{\Lambda}/\Lambda$

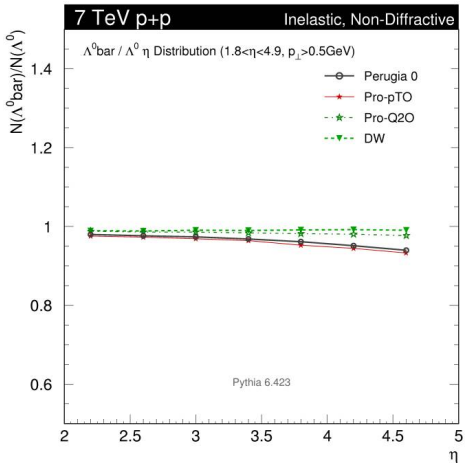


Evidence for energy dependence of $\bar{\Lambda}/\Lambda$

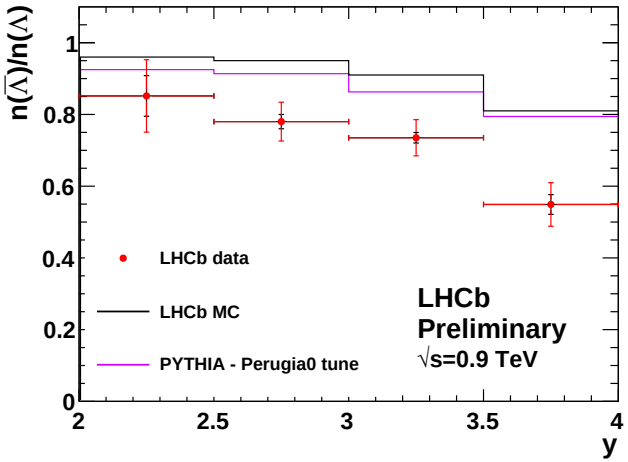
$\overline{\Lambda}/\Lambda$ ratio - clear energy dependence

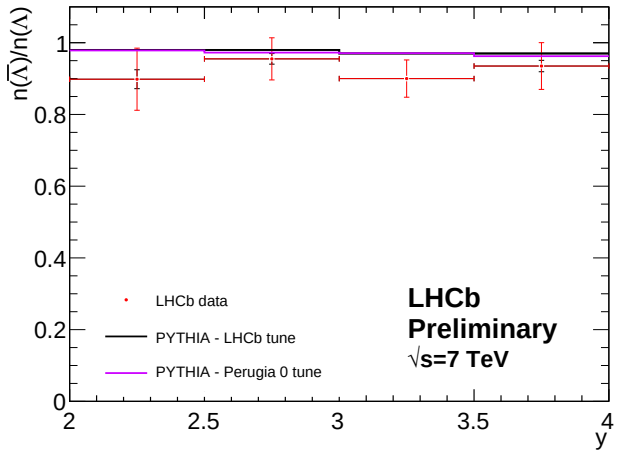


0.9 TeV



7 TeV





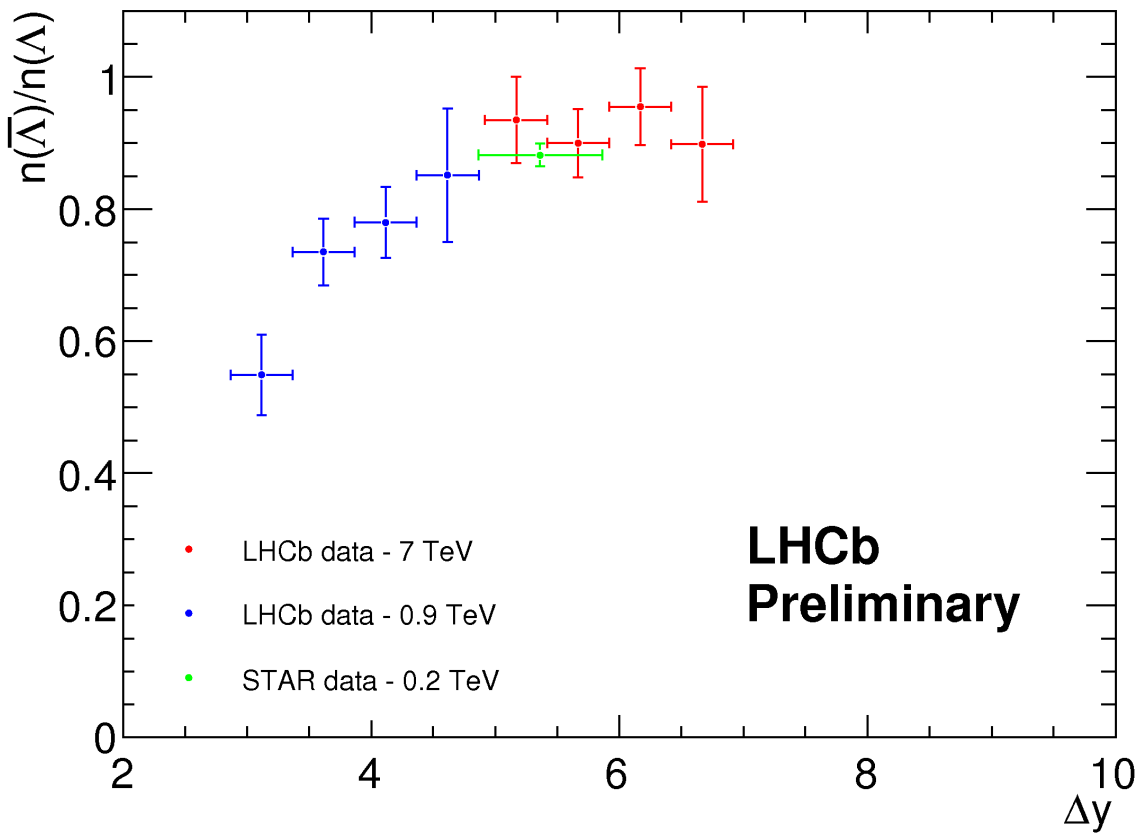
- baryon number transport higher that predicted
- ratio approaching unity

$\overline{\Lambda}/\Lambda$ Baryon Number Transport

observed dependence on difference to beam rapidity

$\Delta y = y_{beam} - y(\Lambda)$

(allows comparing measurements with different centre-of-mass energy)

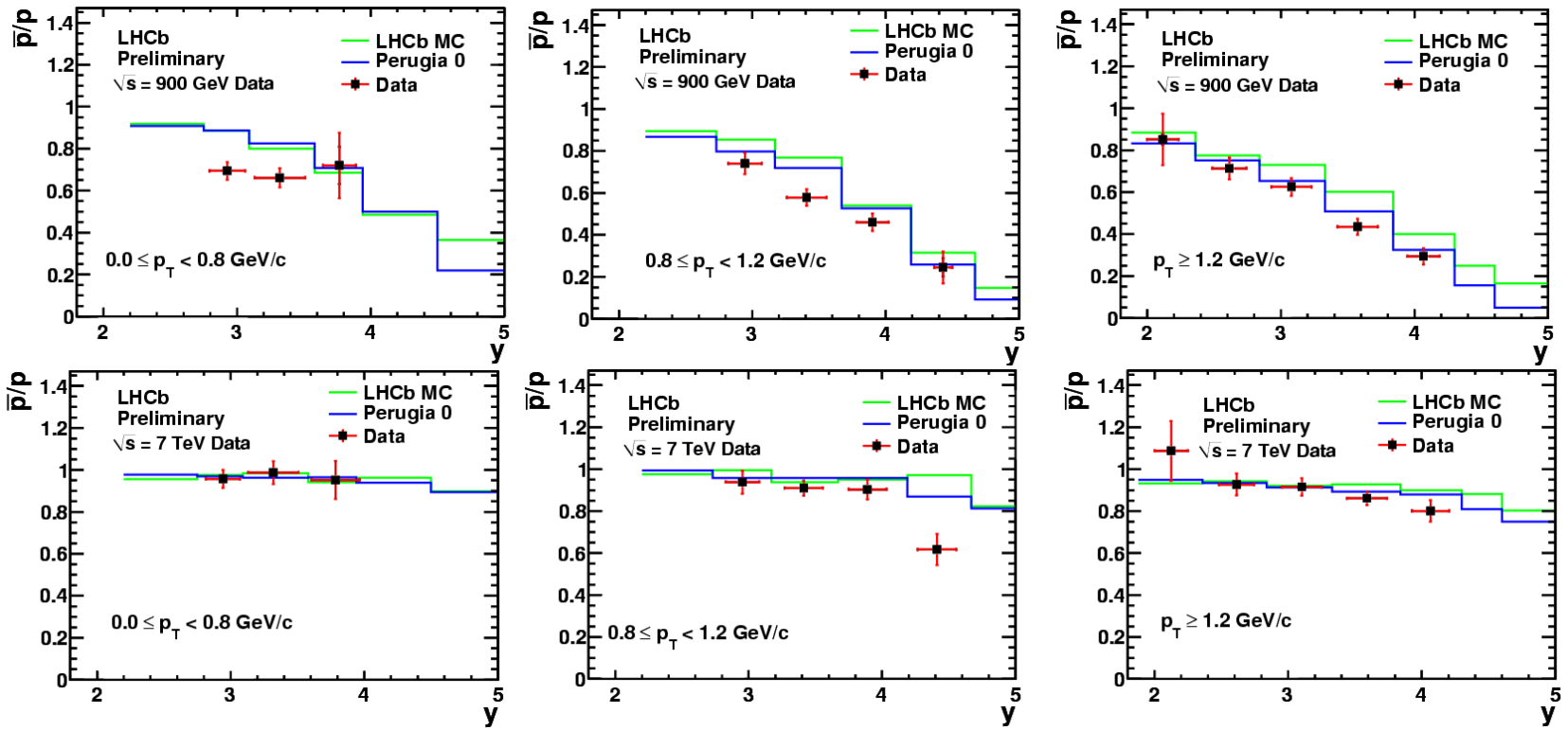


- scaling behaviour
- consistent with STAR

$\bar{p}/p$ Ratio

0.9 TeV

7 TeV

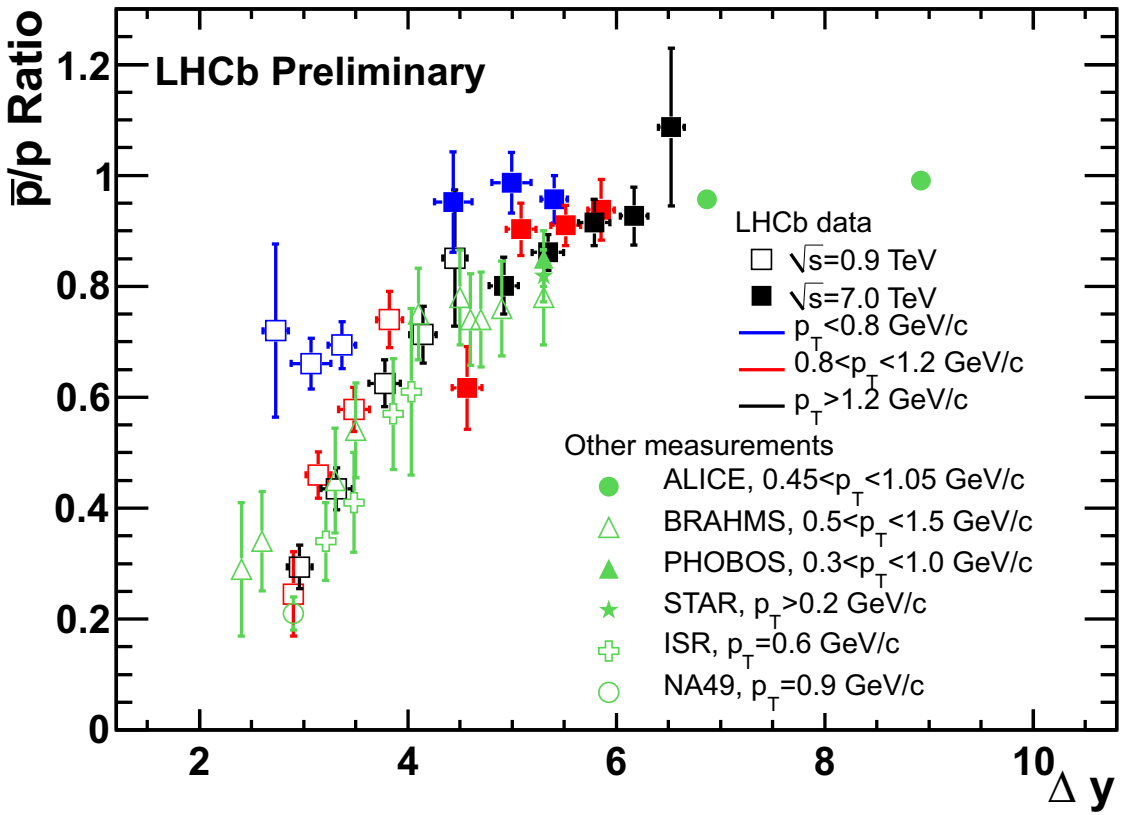


- energy dependence $\rightarrow$ similar to $\overline{\Lambda}/\Lambda$ results
- 0.9 TeV: baryon number transport higher than predictions dependence on p_T
- 7 TeV: data approaching expectations ratios approaching unity

$\bar{p}/p$ Baryon Number Transport

plot as a function of difference to beam rapidity

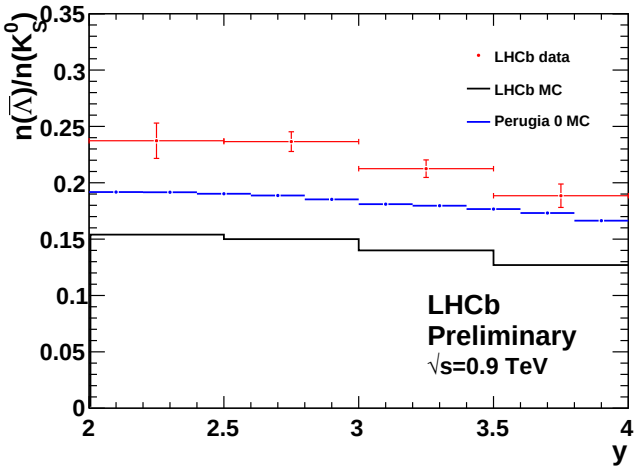
$\Delta y = y_{beam} - y(p)$

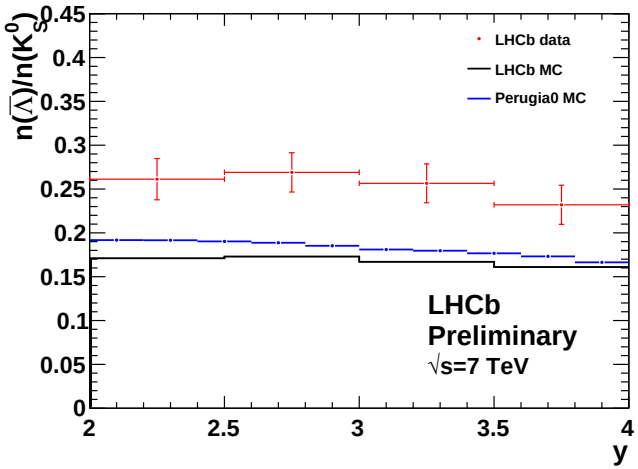


- similar behaviour as $\overline{\Lambda}/\Lambda$
- slight p_T dependence
- consistent with previous measurements

$\overline{\Lambda}/K^0_s$ Baryon Suppression

same analysis as $\overline{\Lambda}/\Lambda$ ratio
LHCb-CONF-2010-011





- baryon suppression lower than expected
- weak energy dependence
- sensitive observable for MC tunning

Summary

New kinematic region explored by LHCb

- K_s^0 production measurements extended to lower p_T and new y range
- will provide valuable input for hadronization models and MC tunning

Measurements indicate

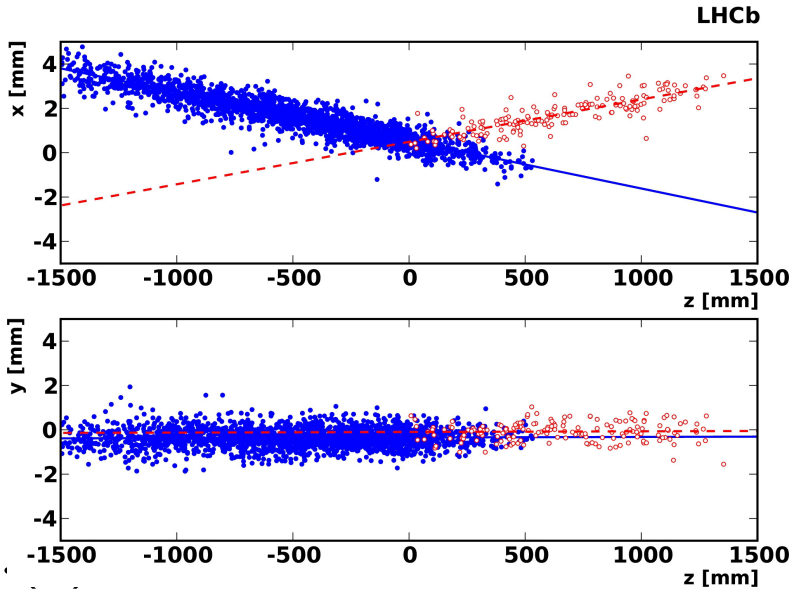
- harder p_T spectra than predicted
- higher baryon transport
- lower baryon suppression
- underestimated strangeness production

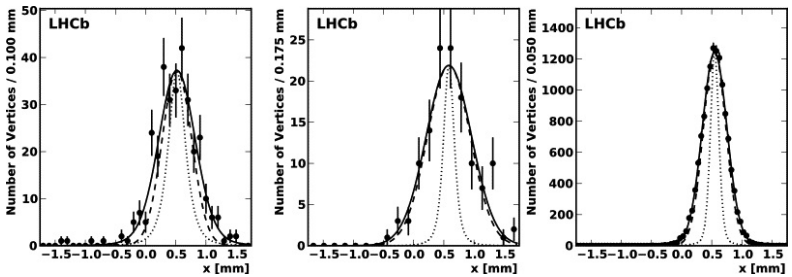
Backup

Luminosity Measurement

$$L = \frac{n_1 n_2 f}{2\pi\sqrt{1 + 2(\theta\sigma_z)^2/(\sigma_{1x}^2 + \sigma_{2x}^2)}}$$

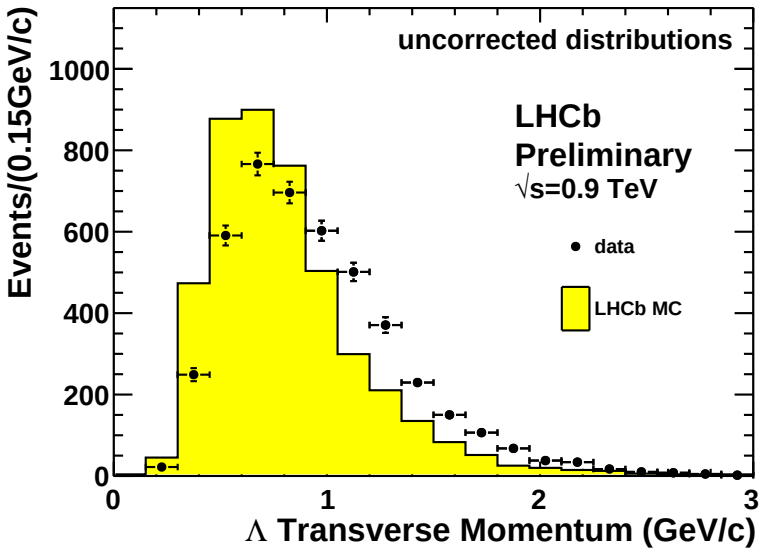
$$\prod_{j=x,y} \frac{1}{\sqrt{\sigma_{1j}^2+\sigma_{2j}^2}} \exp\left(-\frac{1}{2}\frac{(\mu_{1j}-\mu_{2j})^2}{\sigma_{1j}^2+\sigma_{2j}^2}\right)$$

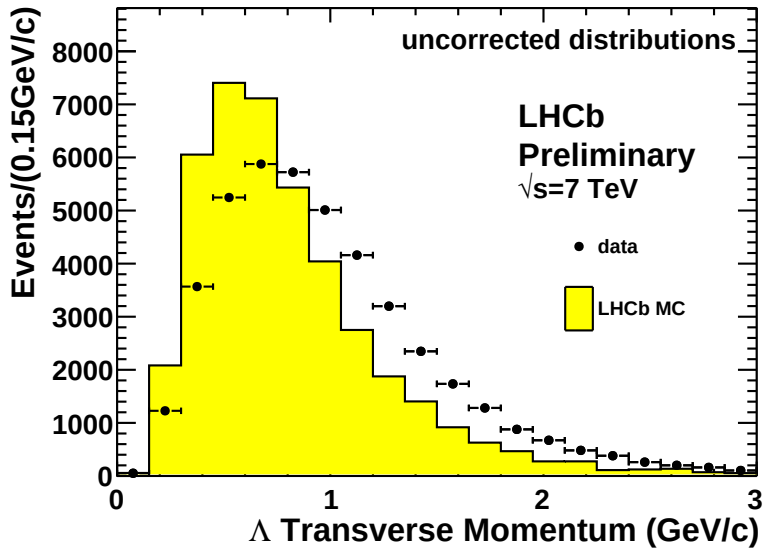




- n_i : bunch currents, taken from LHC machine measurements
- position μ_{ij} and Gaussian width σ_{ij} of the underlying distributions, measured beam profiles on VELO (beam-empty events)

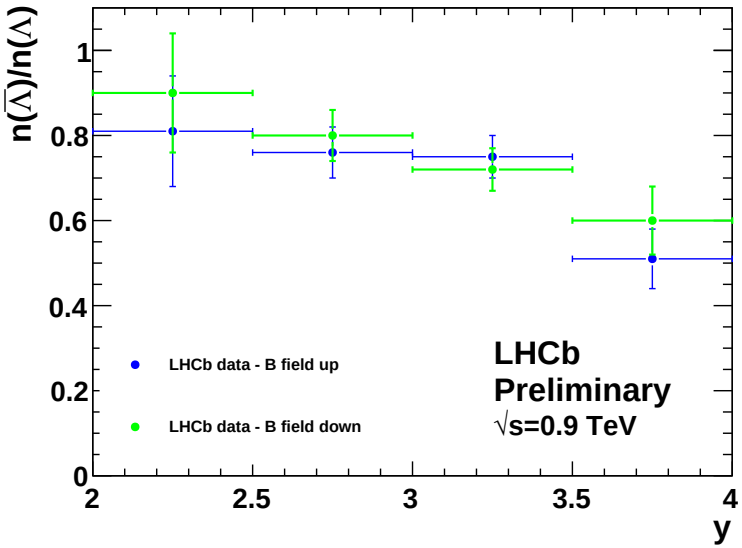
$\overline{\Lambda}/\Lambda$ p_T

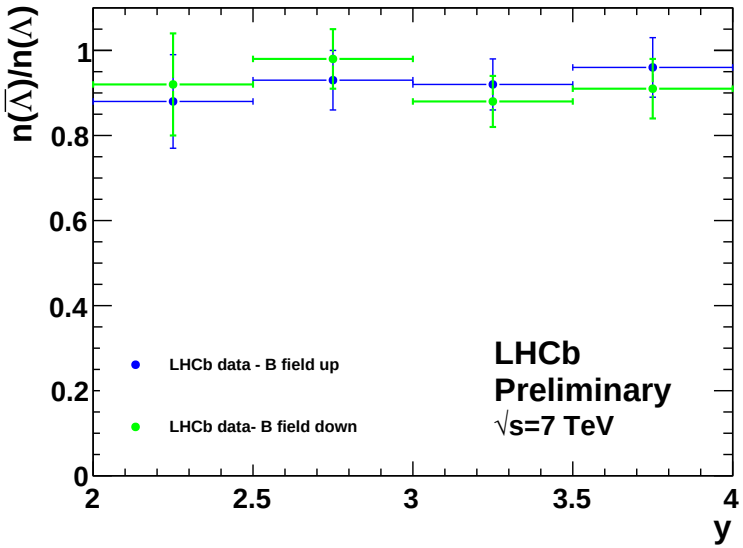




p_T harder than expectation $\rightarrow$ similar to K^0_s results

$\overline{\Lambda}/\Lambda$ magnet up and down





consistency between two magnet polarities

K_s^0 selections

Variable	Requirement
Downstream-track selection	
Each π-track momentum	> 2 GeV/c
Each π-track transverse momentum	> 0.05 GeV/c
Each track fit χ^2/ndf	< 25
Distance of closest approach of each π-track to the z axis	> 3 mm
K_S^0 decay vertex fit χ^2/ndf	< 25
z of K_S^0 decay vertex	< 2200 mm
$\|z\|$ of pseudo-PV	< 150 mm
$\cos\theta_{\text{pointing}}$	> 0.99995
K_S^0 proper time ($c\tau$)	> 5 mm
Long-track selection	
$\|z\|$ of associated PV	< 200 mm
Each track fit χ^2/ndf	< 25
K_S^0 decay vertex χ^2/ndf	< 100
$z(K_S^0) - z(\text{PV})$	> 0 mm
Variable ν related to impact parameters	> 2

RICH discrimination with DLL