Studies of particle production with LHCb

Workshop on High Energy Frontier

1-2 September 2010

Physik-Institut der Universität Zürich

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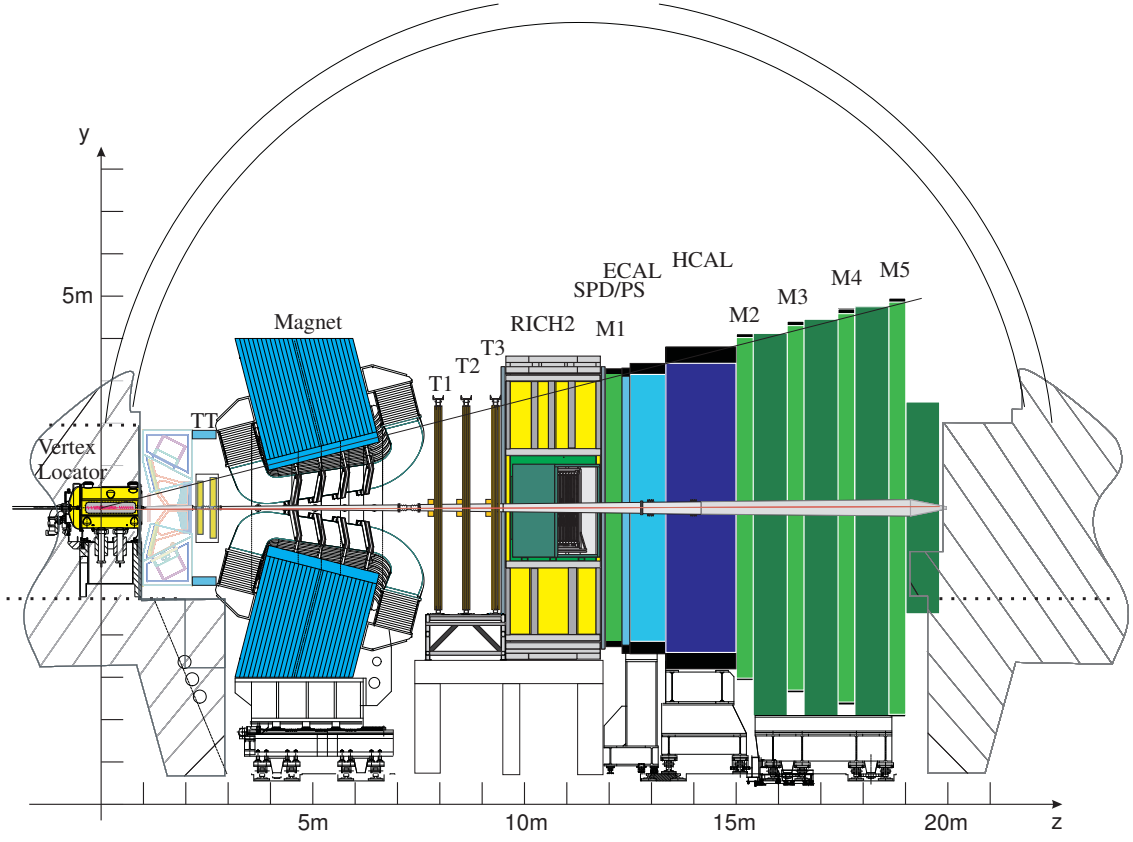
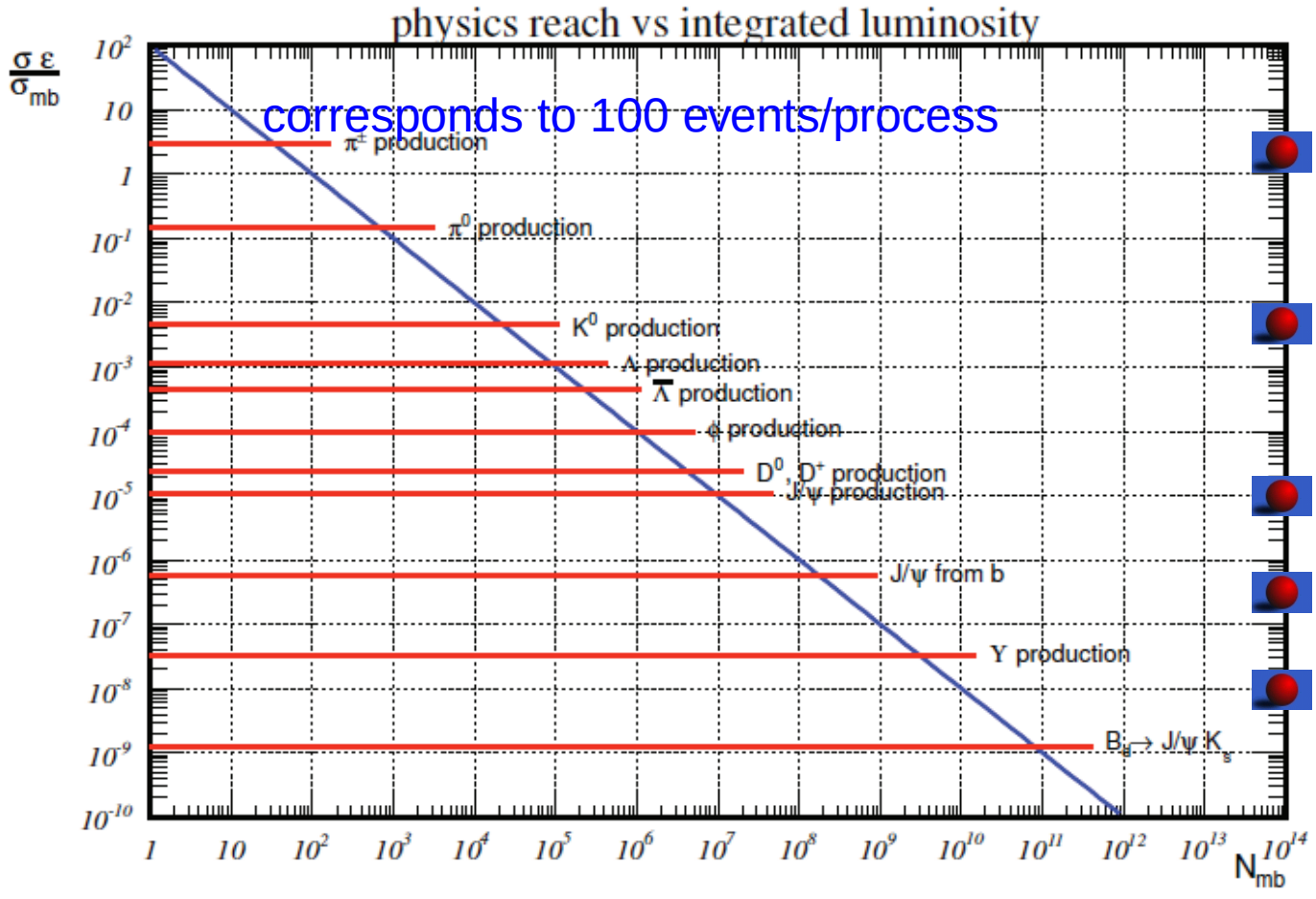
EPFL

LHCb detector



- Dedicated b-physics experiment: CP violation and rare decays
- Forward single arm spectrometer - large and correlated $b\bar{b}$ quark production in the forward region.
- Coverage: 15-300(250) mrad

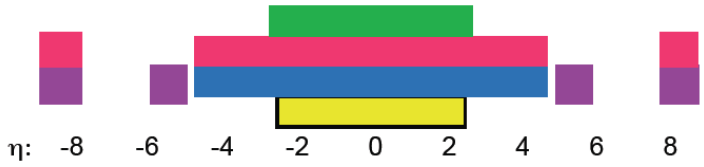
First data analysis



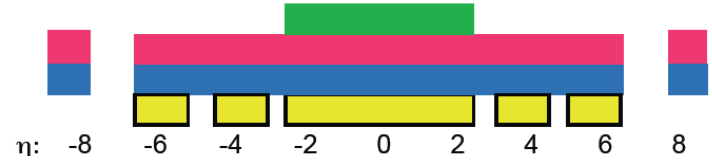
- Inclusive distributions
- Strangeness production
- Charm signals
- J/ψ production
- we are here
  first b results...

Pseudorapidity range

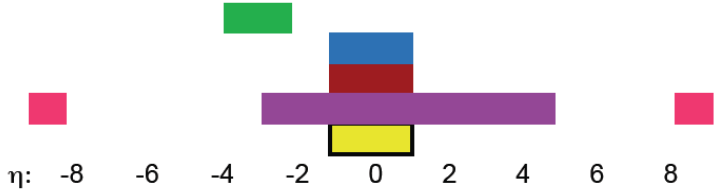
First LHCb public physics results - particle production - exploiting the interest for measurements in the forward region where production models were extrapolated not only in energy but also in rapidity.



ATLAS



CMS&TOTEM



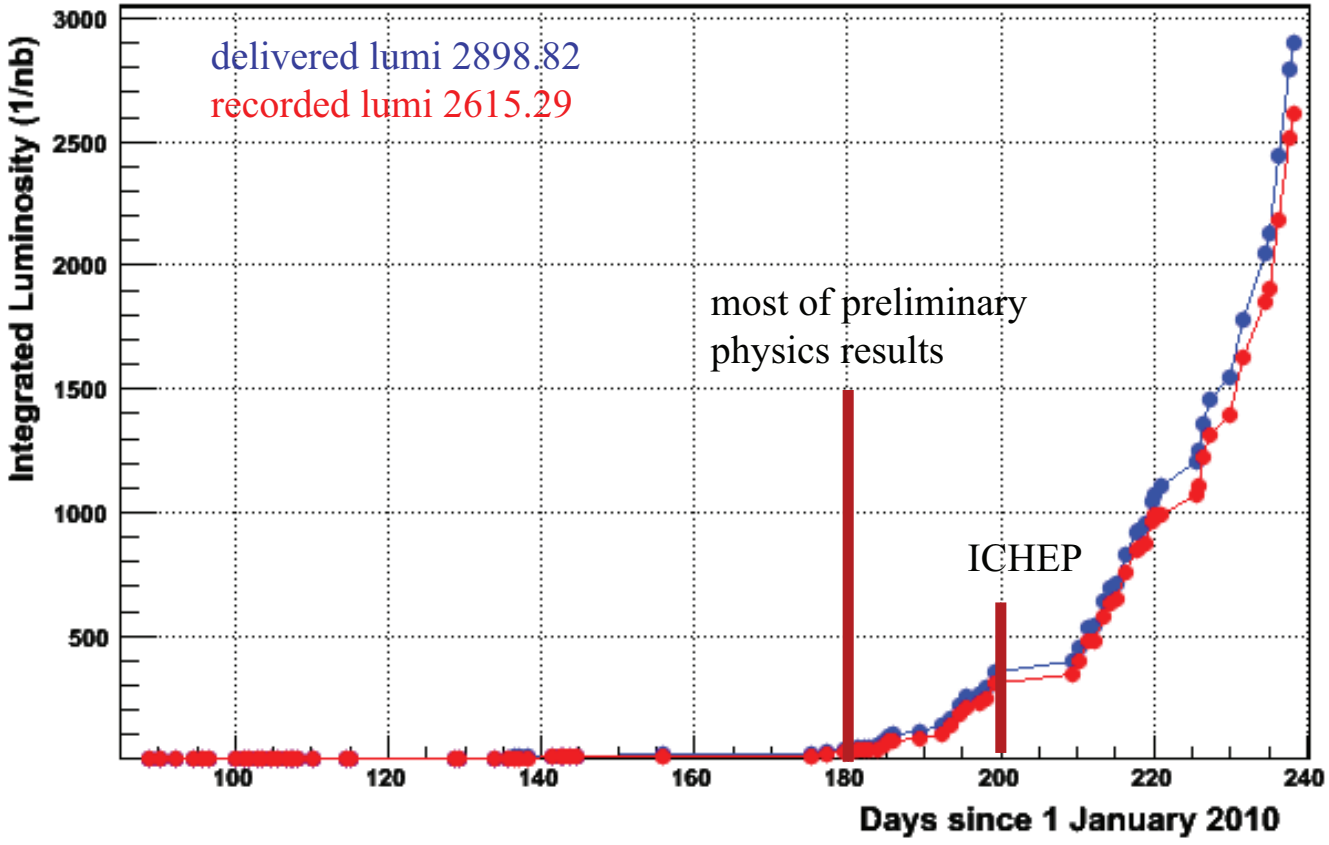
ALICE

LHCb

tracking, ECAL, HCAL, counters lumi, muon, hadron PID

LHCb data sample

7 TeV



0.9 TeV

6.8 μb^{-1} in the pilot run of 2009 and 0.31 nb^{-1} in 2010

Production measurements

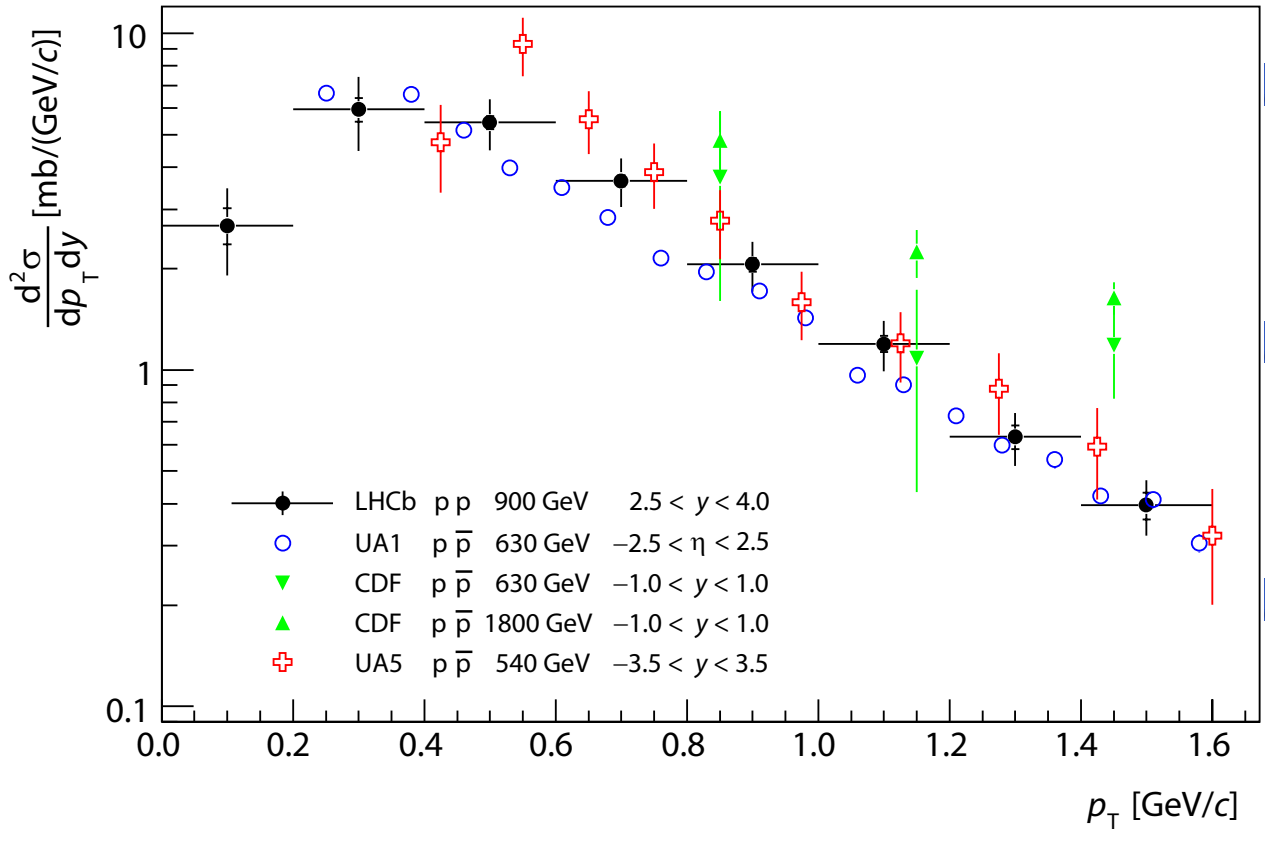
- Ks cross-section - using the 2009 pilot run data at 0.9TeV;
- Production ratios:
  - $\bar{\Lambda}/K^0_S$,
  - $\bar{\Lambda}/\Lambda$,
  - $\bar{p}/p$

  at 0.9 TeV and 7 TeV;
- Cross-sections:
  - J/ψ,
  - prompt charm,
  - $pp \to b\bar{b}X$.

  at 7 TeV

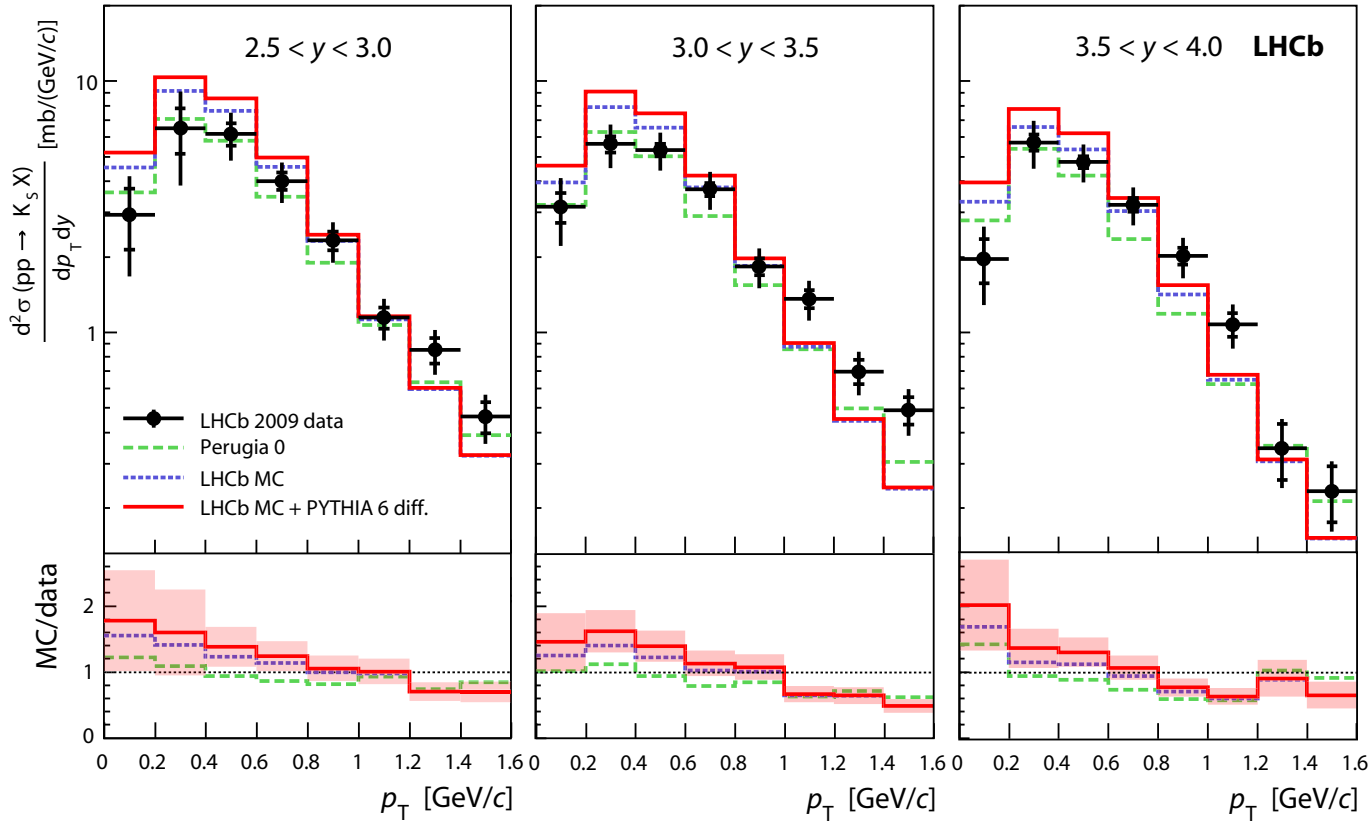
K^0_S production

Ideal first measurement for LHCb - high-purity selection without requiring particle identification



- Using the 6.8 μb^{-1} recorded in the pilot run;
- K^0_S cross-section not measured before at 0.9 TeV;
- y and p_T range were extended;

K^0_S production



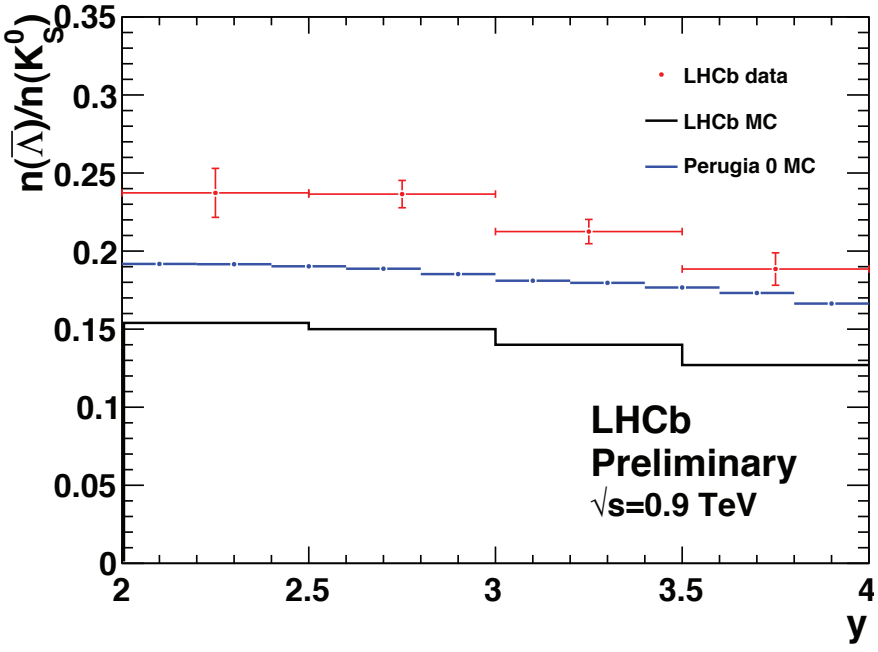
Important input for hadronization models, measured in bins of y and p_T and compared to LHCb MC and Perugia 0 (arXiv:1005.3457).

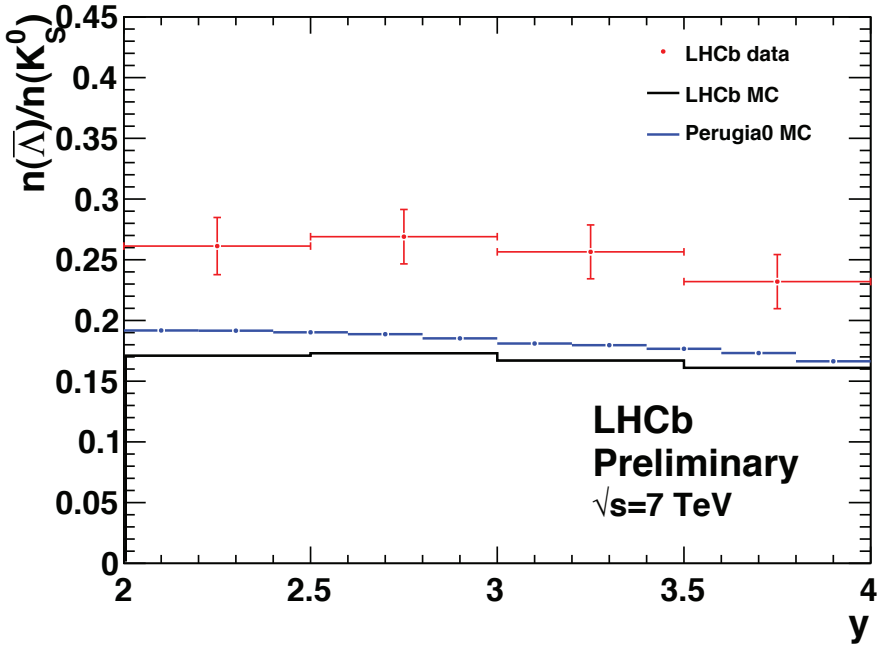
arXiv:1008.3105 - accepted for publication in PLB

Ratio measurements

- Theoretical interest in ratios:
  - Baryon vs. meson number suppression in hadronisation $\bar{\Lambda}/K^0_S$;
  - Baryon number transport $\bar{\Lambda}/\Lambda$, $\bar{p}/p$;
- Measurements performed both at 0.9 TeV and 7 TeV
  - V^0 ratios - only tracking & vertexing
  - $\bar{p}/p$ - RICH particle identification calibrated with tracking-selected samples: $\pi(K^0_S)$, $p(\Lambda)$, $K(\phi)$.

Baryon suppression with $\bar{\Lambda}/K^0_S$

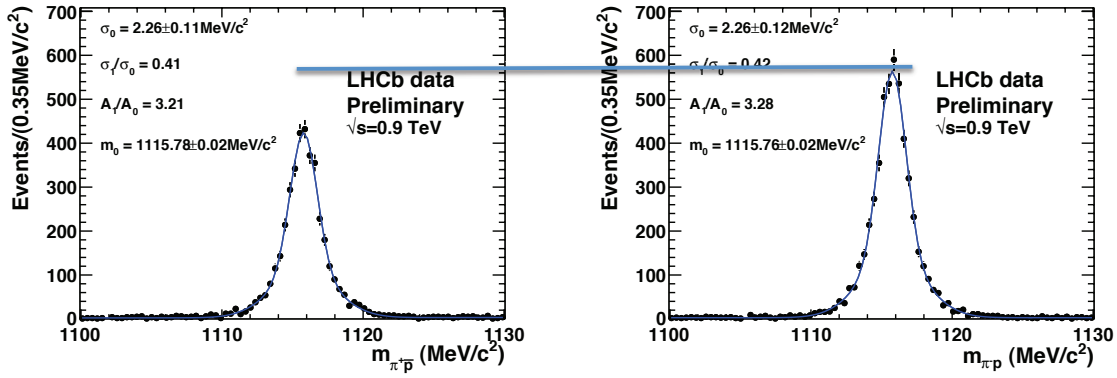




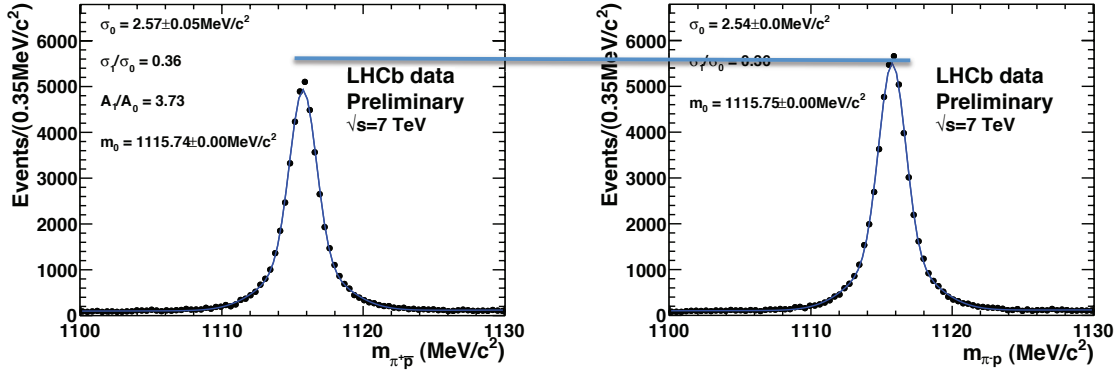
Ratio of $\bar{\Lambda}/K^0_S$ significantly higher than expectation at both energies.

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

Baryon number conservation requires the destroyed beam particles in inelastic non-diffractive collisions must be balanced by creation of baryons elsewhere.



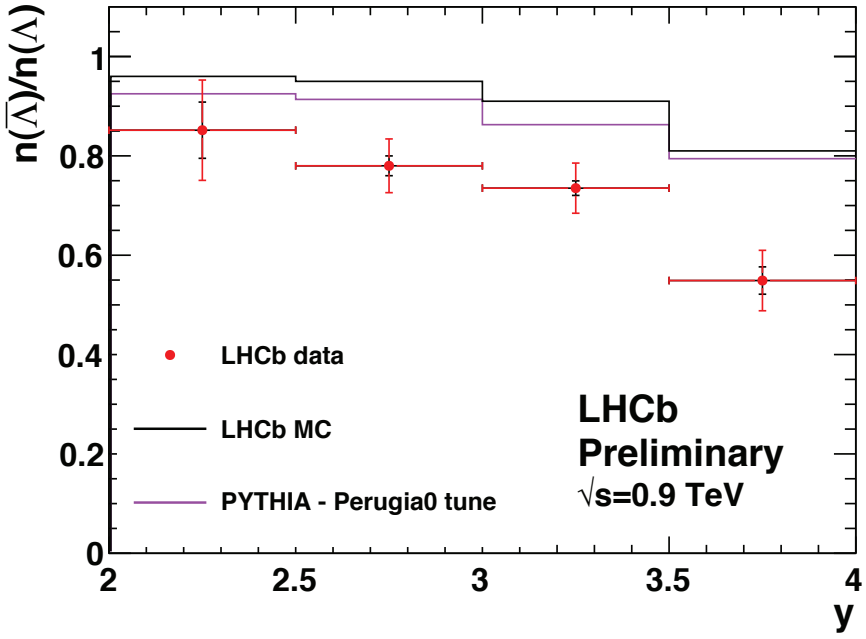
0.9 TeV

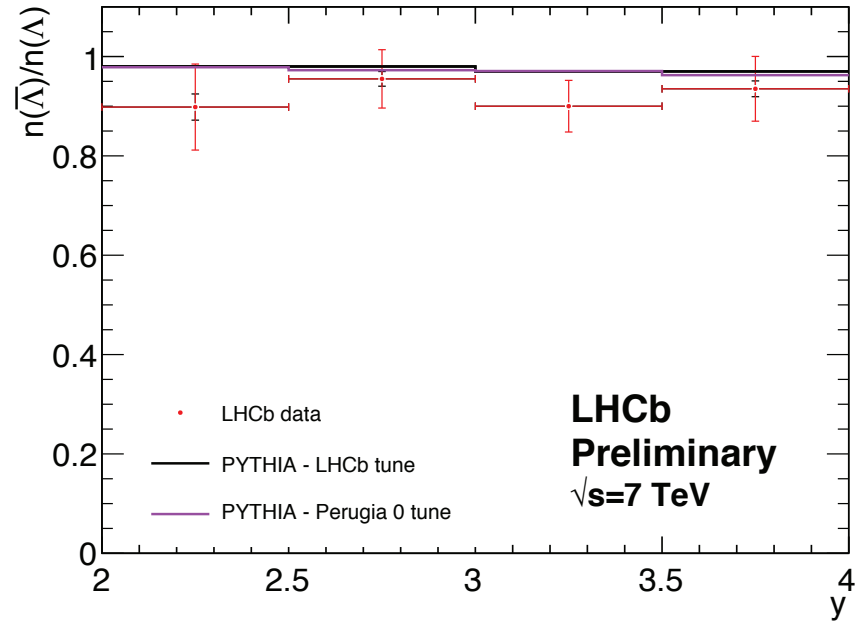


7 TeV

Raw yields LHCb preliminary

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



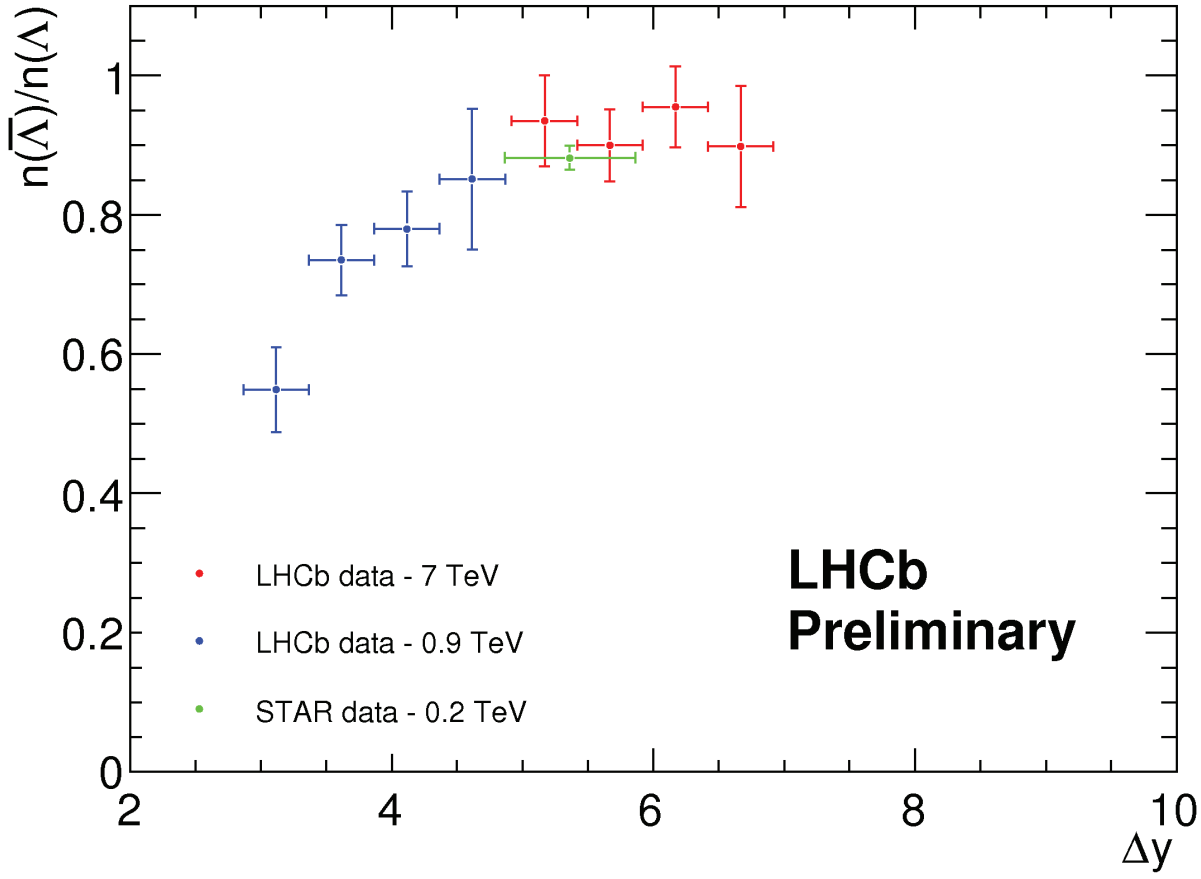


Measurements lie significantly under MC predictions at 0.9 TeV; reasonable agreement at 7 TeV.

Perugia 0 and strange particle ratios: Performs poorly in describing $\bar{\Lambda}/\Lambda$ at low energy, and does not reproduce $\bar{\Lambda}/K^0_S$ data.

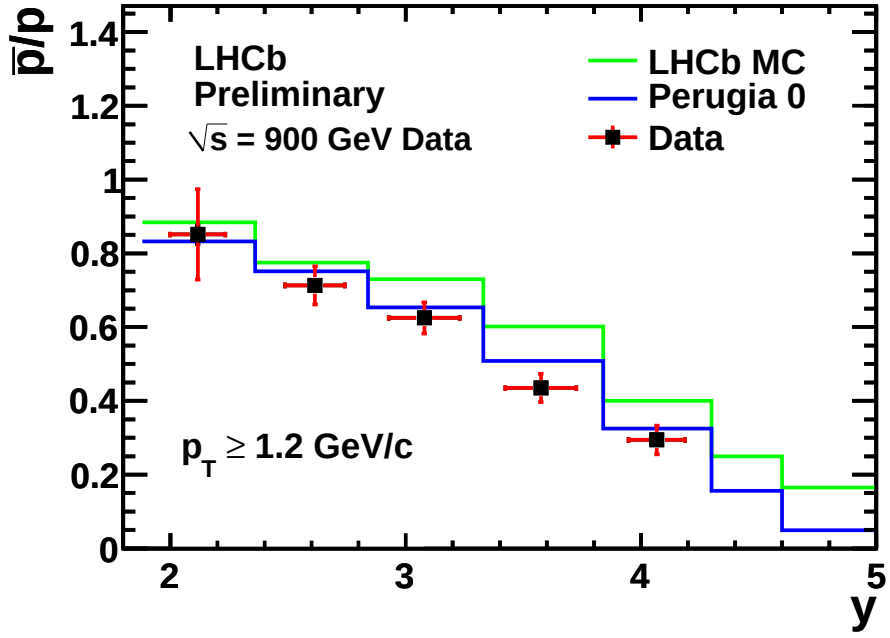
Baryon number transport $\bar{\Lambda}/\Lambda$

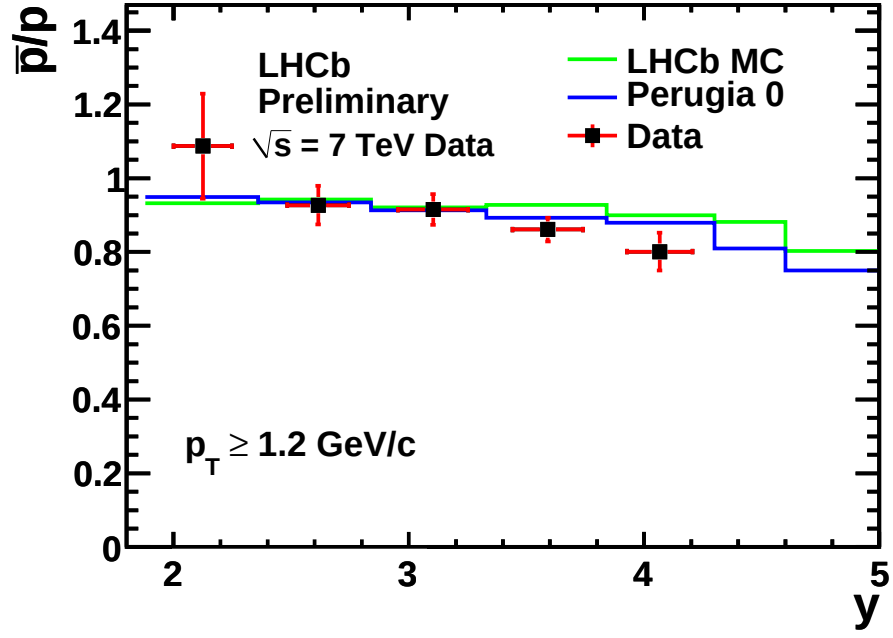
$$\Delta y = y_{beam} - y$$



Consistency between the two energy measurements and previous result.

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

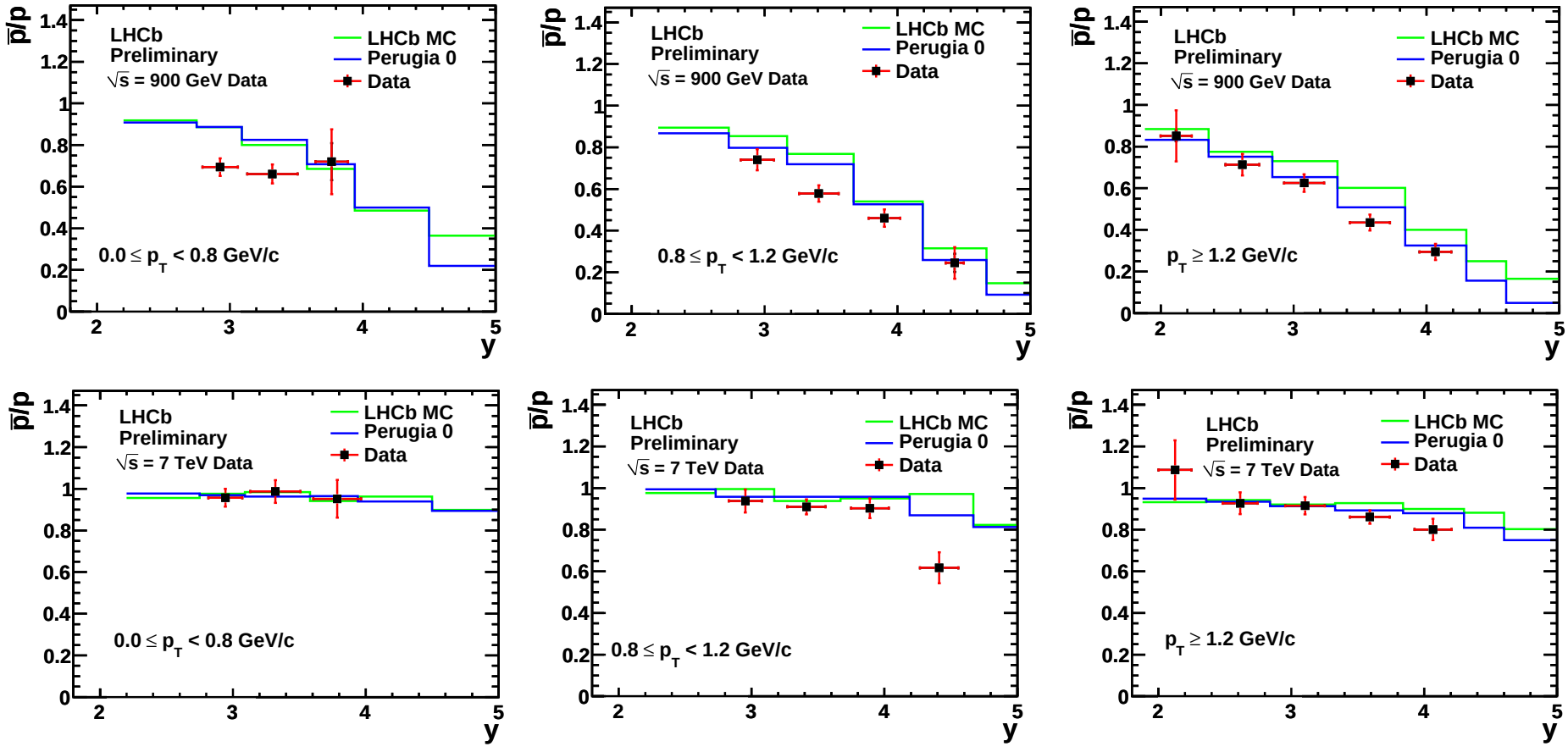




Measured in bins of y and p_T.

Example results for $p_T > 1.2$ GeV/c.

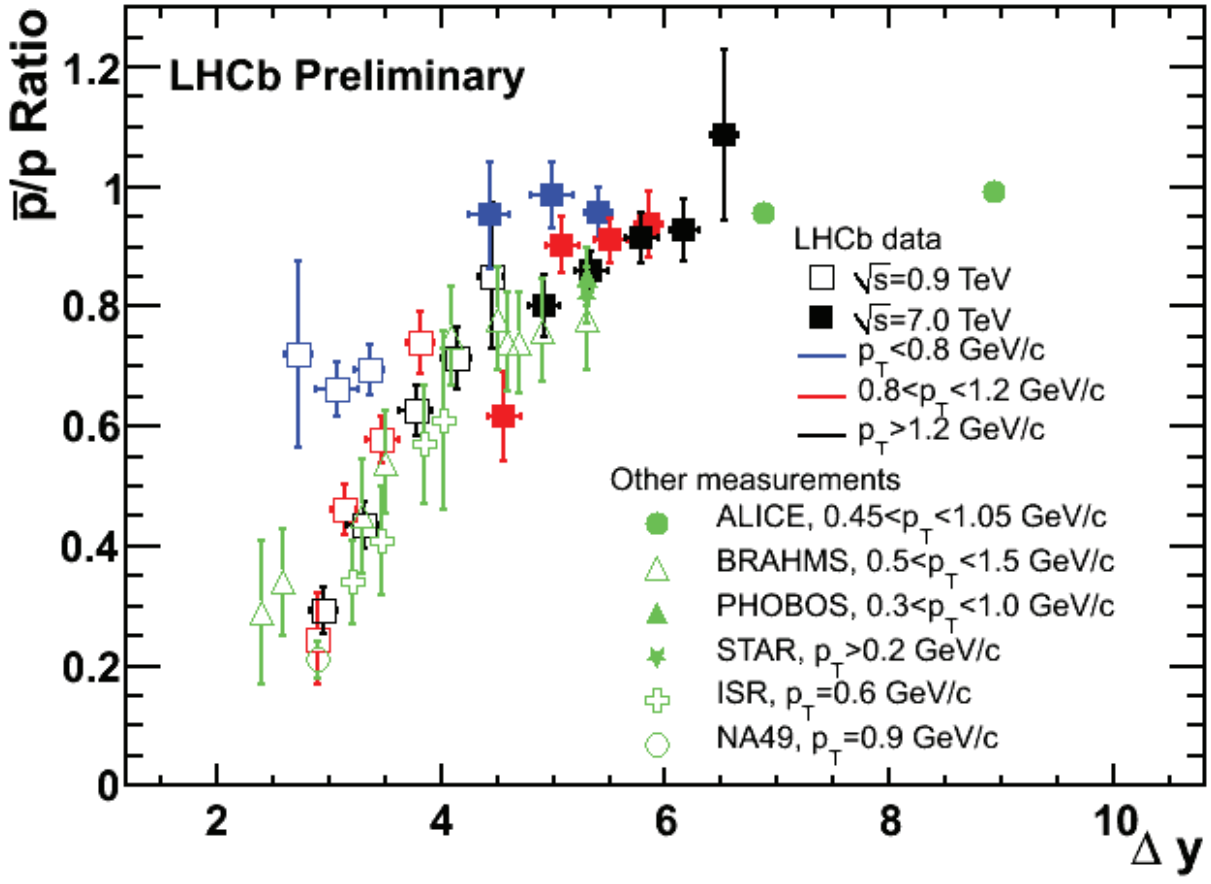
Baryon number transport $\bar{p}/p$



Big deviation in ratio from unity at low energy. Much less so at 7 TeV. Reasonable agreement observed with Perugia 0.

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

$$\Delta y = y_{beam} - y$$

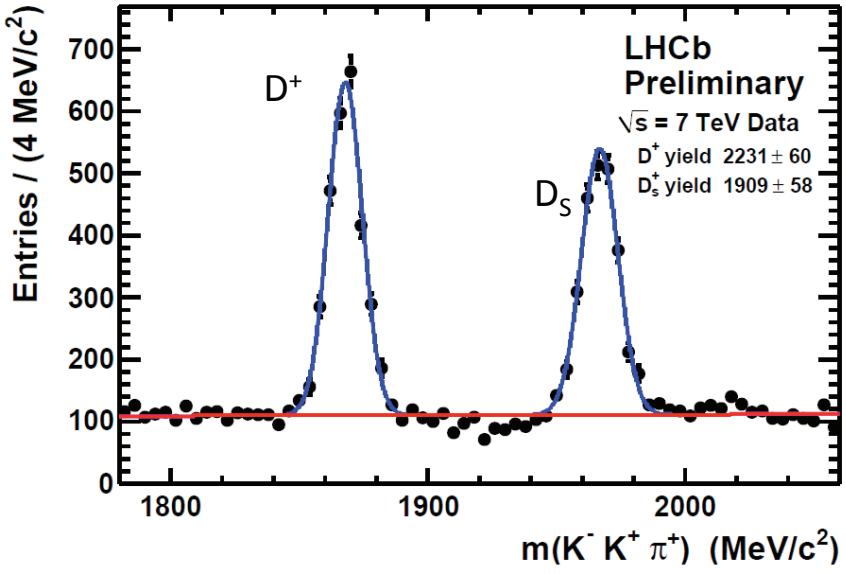


Uncertainty dominated by finite statistics of RICH calibration sample.

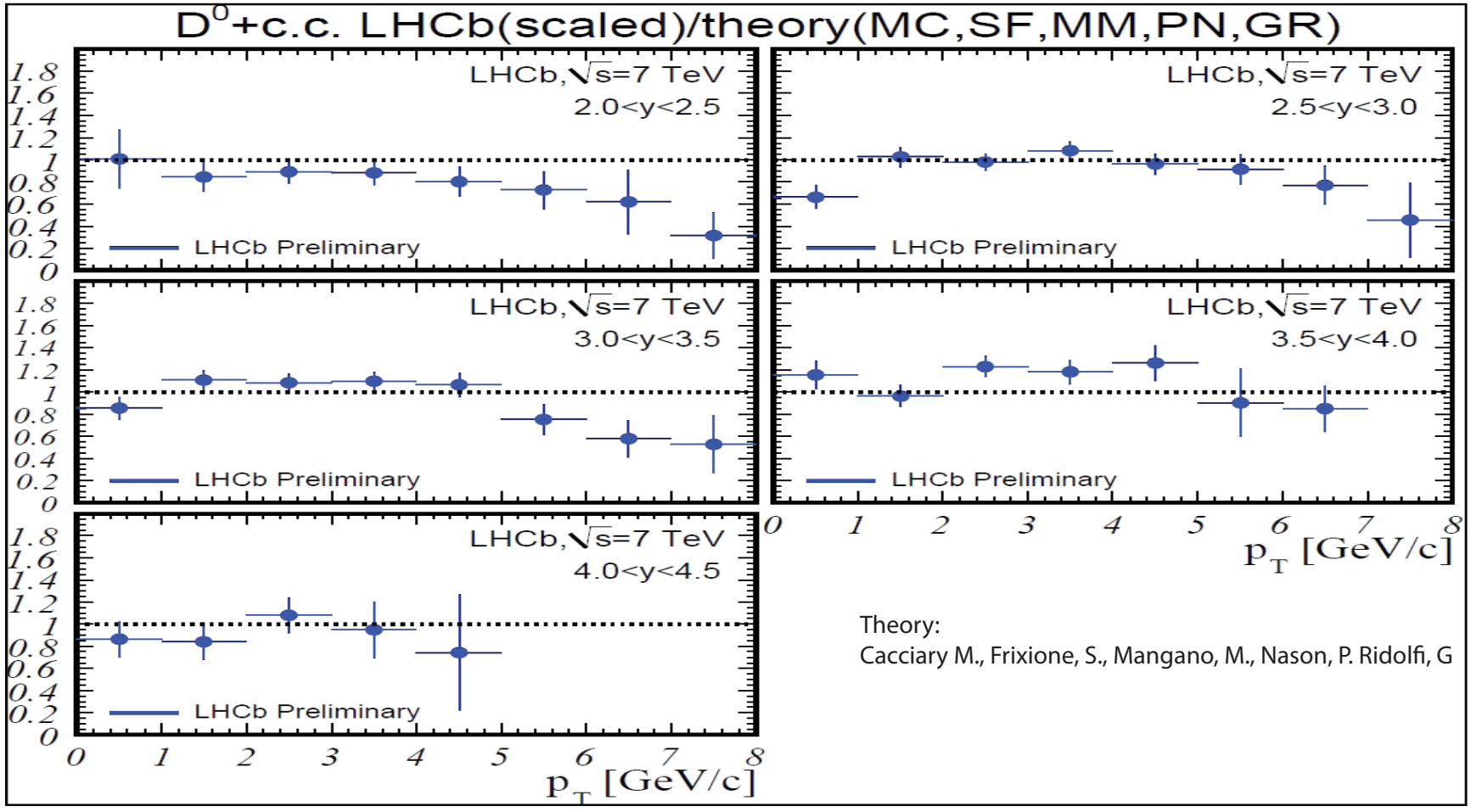
Reasonable consistency with previous measurements, better agreement at high p_t.

Open charm cross-section

- Prompt D^* ($D^{*+} \to \pi^+ D^0 (K^- pi^+)$), D^0 ($D^0 \to K^- \pi^+$), D^+, D_s cross-sections studied in the forward region 2<y<5:
  - test the QCD predictions in an unexplored rapidity region;
  - Estimate the sensitivity of LHCb for measurements of CP violation (e.g. $D^+ \to K^+ K^- \pi^+$ with $D_s^+ \to K^+ K^- \pi^+$ and $D^+ \to K^- \pi^+ \pi^+$ as control channels), mixing and rare decays (e.g. $D^0 \to \mu\mu$).

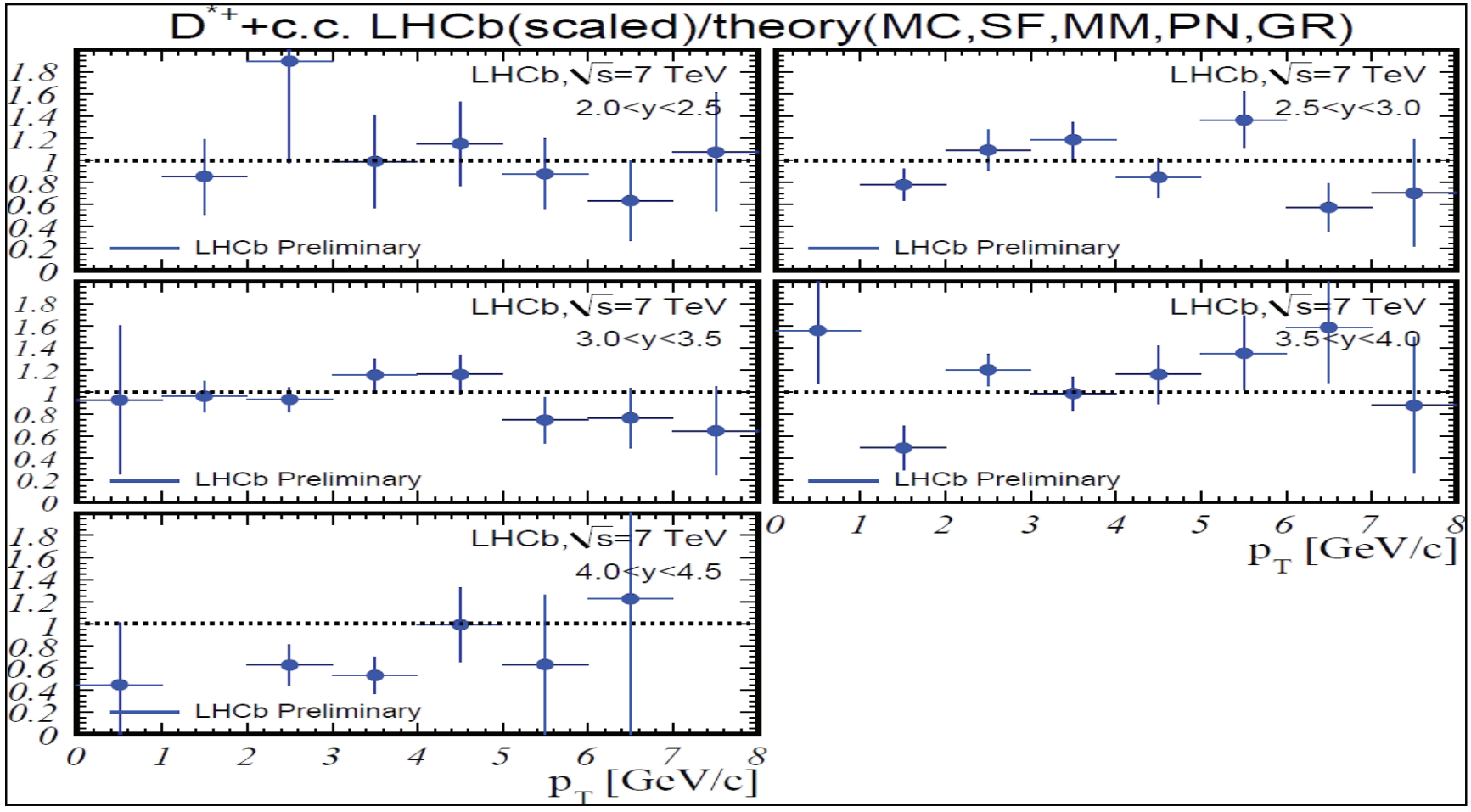


Open charm cross-section

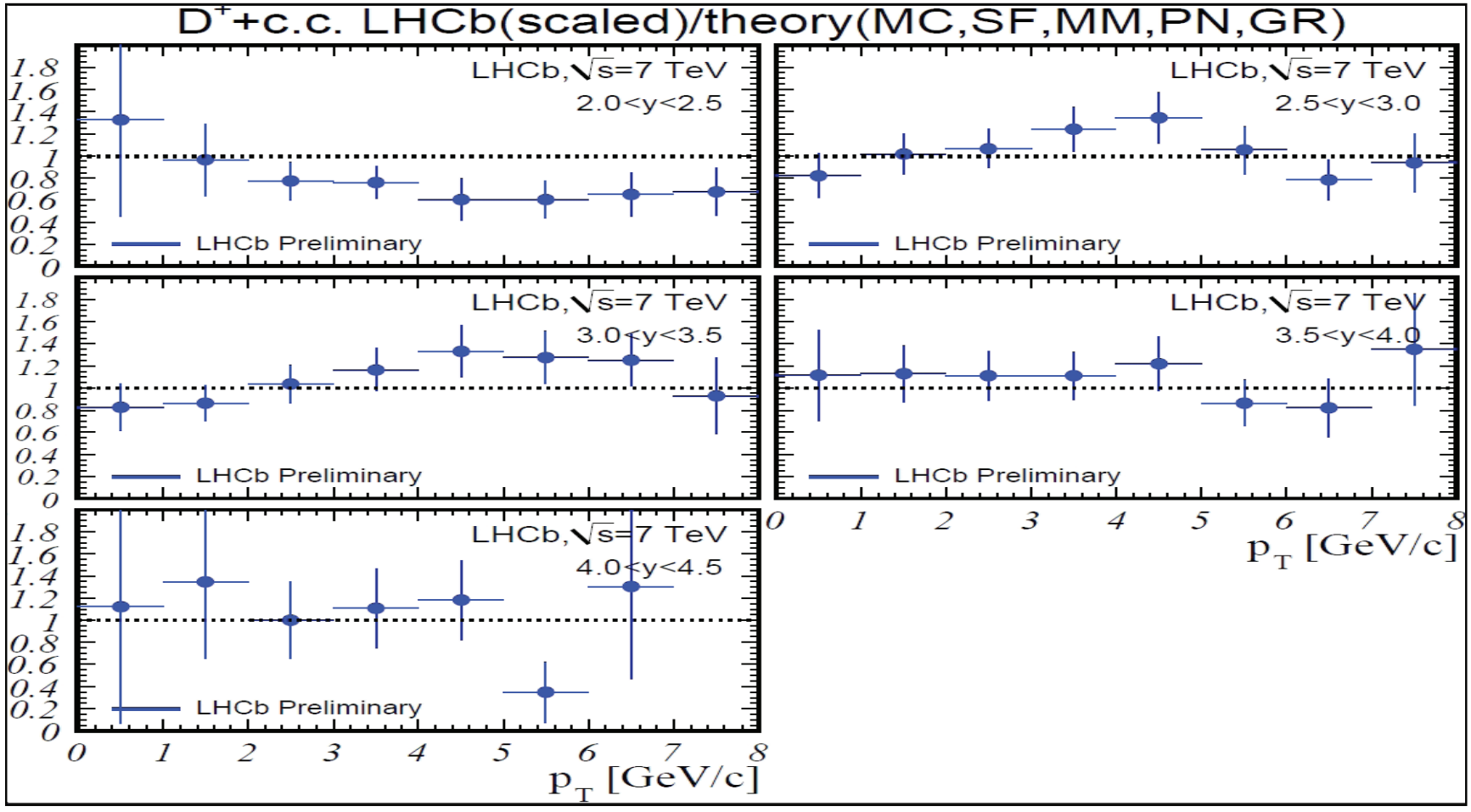


Theory:
Cacciary M., Frixione, S., Mangano, M., Nason, P. Ridolfi, G

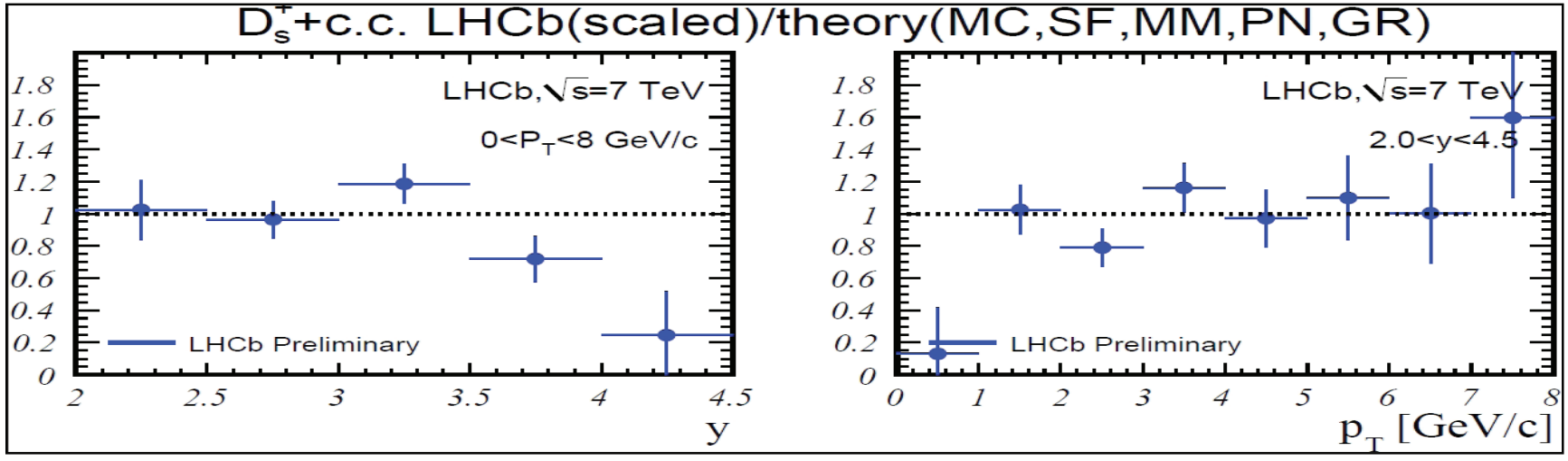
Open charm cross-section

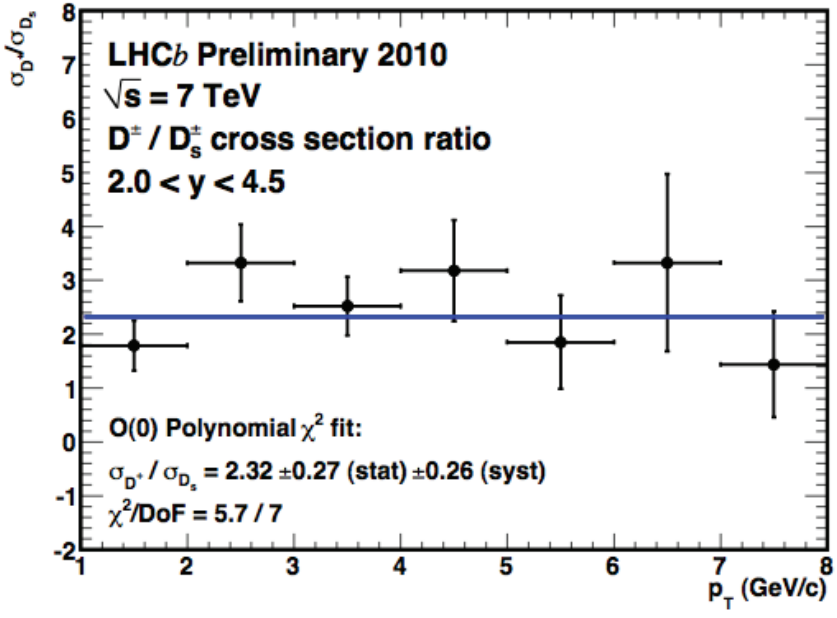


Open charm cross-section



Open charm cross-section





$$\sigma(D^+)/\sigma(D_s) = 2.32 \pm 0.27 \pm 0.26$$

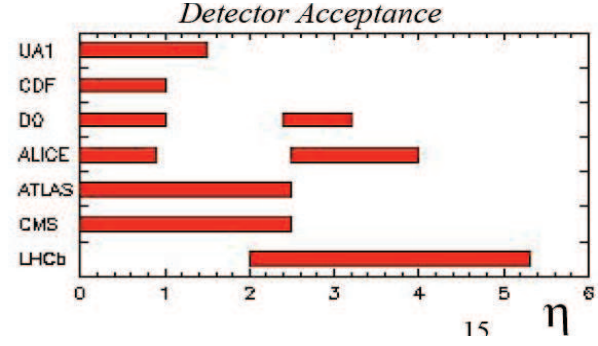
in agreement with PDG:

$$f(c \to D^+)/f(c \to D_s) = 3.08 \pm 0.70$$

J/ψ cross-section

- Prompt production mechanism not well understood
- Di-muons central to many of core LHCb flavour studies
- The Colour Octet Model reproduces the p_T spectrum measured at Tevatron, but not the production polarization ($\nearrow p_T$ not observed). Other models also predict the same p_T spectrum but no polarization.

Unique LHCb η coverage where theoretical predictions are less accurate.



J/ψ cross-section

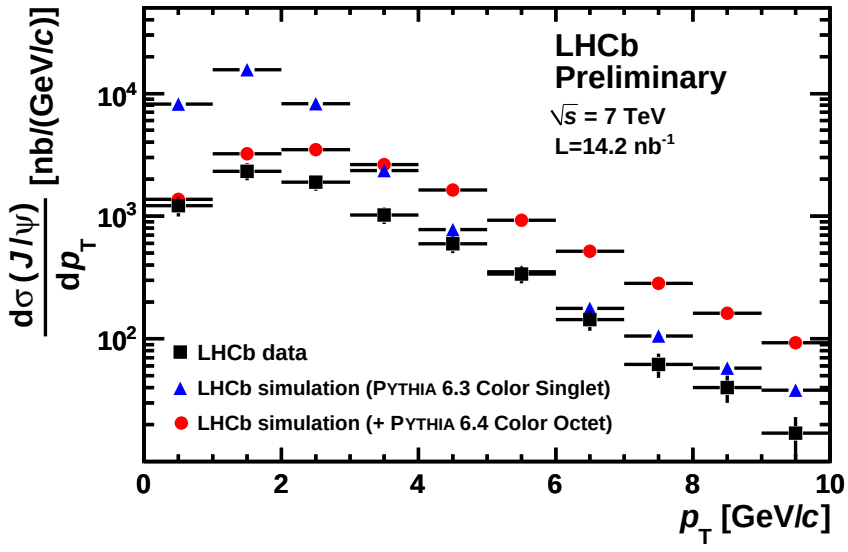
With 14 nb^{-1}:

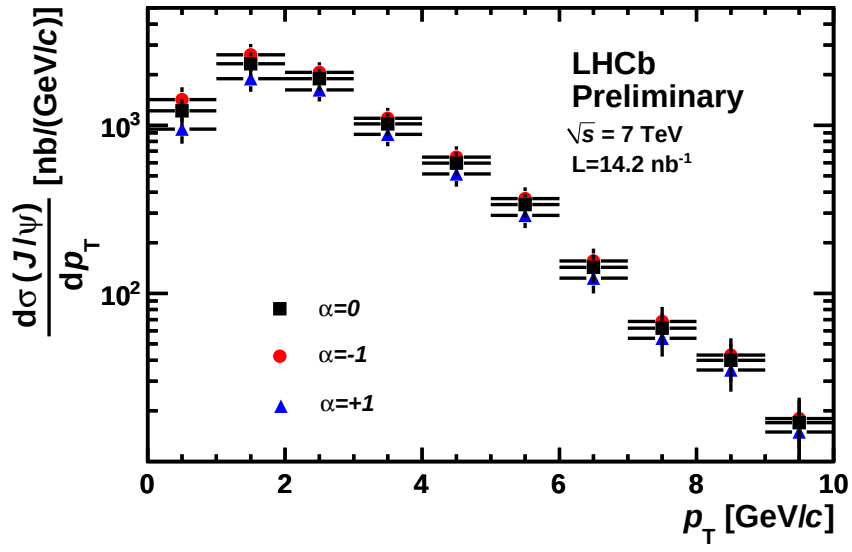
σ (incl. J/ψ, 2.5 <y<4, 0<p_t<10 GeV/c)=(7.65 $\pm$ 0.19 $\pm$ 1.10$^{+0.87}_{-1.27}$) μb,

the asymmetric error is the uncertainty from the polarization.

$\frac{dN}{dcos(\theta)} = \frac{1+\alpha\cos^2(\theta)}{2+2\alpha/3}$ with $\theta \angle(p^{CM}_{\mu^+}, p^{SL}_{J/\psi})$,

α=+1 transverse pol; α=-1 longitudinal pol; α=0 no polarization.



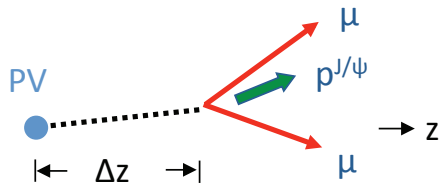


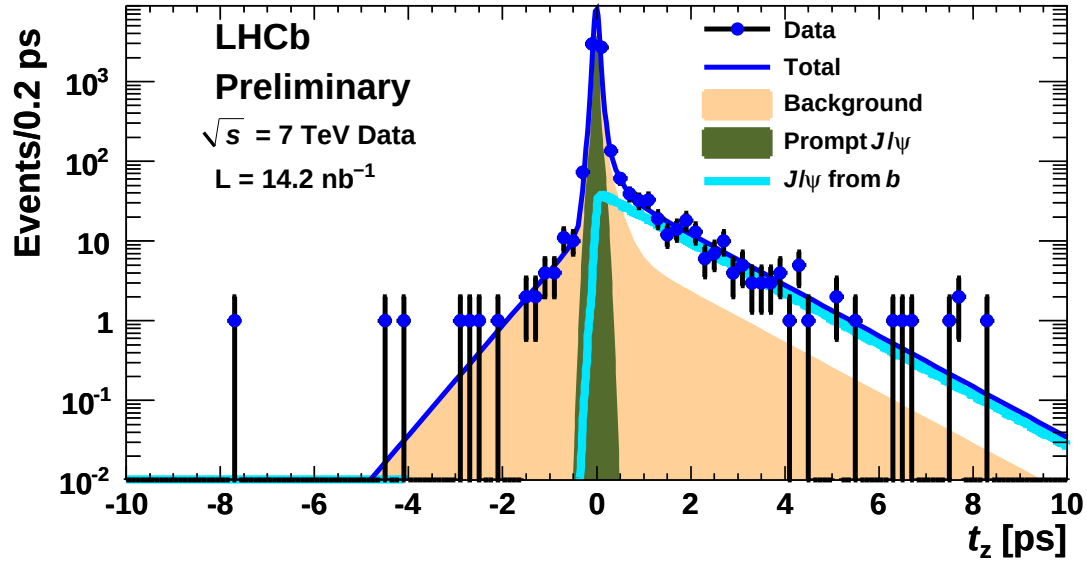
J/ψ cross-section

With 14 nb^{-1}:

σ (J/ψ from b, 2.5 <y<4, 0<p_t<10 GeV/c)=(0.81 $\pm$ 0.06 $\pm$ 0.13) μb,

The fraction of J/ψ from b is determined from a simultaneous fit to the pseudo-propertime $t_z = \frac{dz}{p_z^{J/\psi}} m^{J/\psi}$ and $\mu^+\mu^-$ invariant mass.





J/ψ cross-section - extrapolation

Using LHCb MC software J/ψ from b cross-section extrapolated to half of the cross-section for producing a single b (or $\bar{b}$) flavoured hadron H_b in the 2$< \eta <$6 region.

$$1/2\ \sigma(pp \to H_b X, 2 < \eta(H_b) < 6) = 84.5 \pm 6.3 \pm 15.6\ \mu b$$

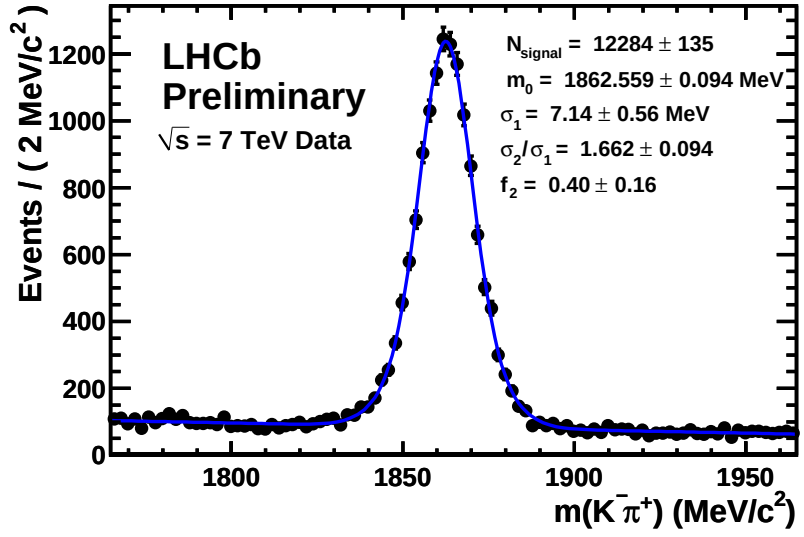
Same method was used to extrapolate to the full acceptance

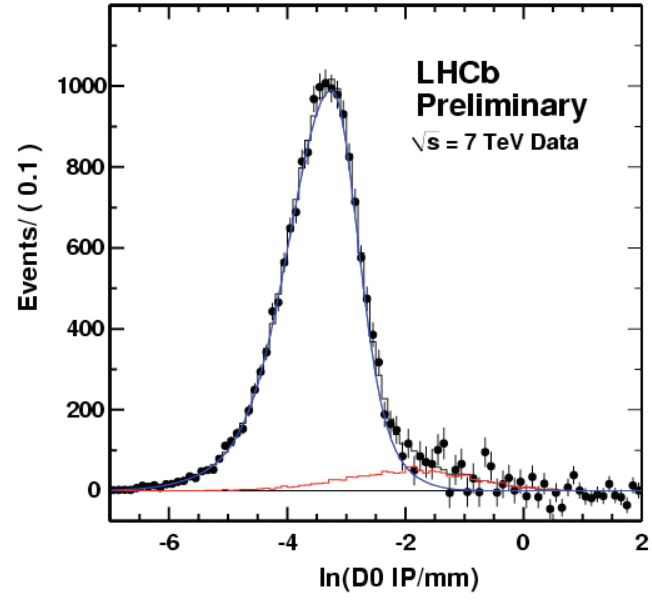
$$\sigma(pp \to b\bar{b}) = 319 \pm 24 \pm 59\ \mu b$$

No systematics was assigned to the extrapolation method

b-cross-section - $b \to D^0 X \mu^- \bar{\nu}$

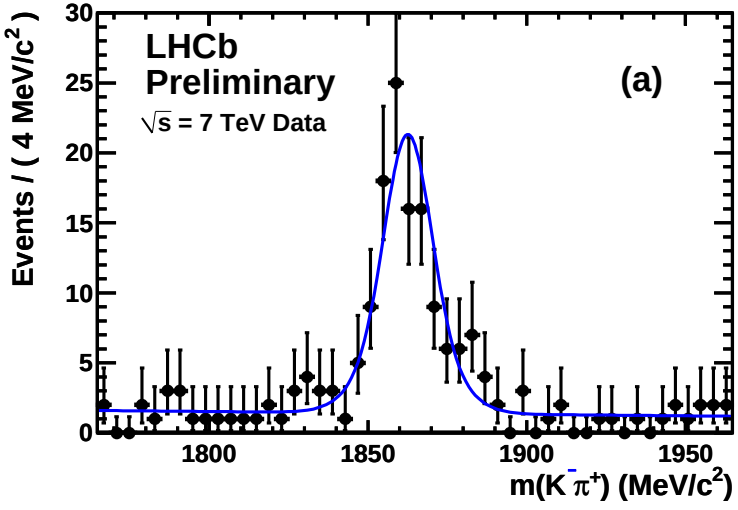
- Start from a clean $D^0 \to K\pi$ sample and use the impact parameter of D^0 direction w.r.t. PV to separate prompt and secondary component;
- Look for a μ with correctly correlated charge to isolate a decay with known BR$(b \to D^0 X \mu^- \bar{\nu}) = 6.82 \pm 0.35$ %
- Analysis performed both on a sample with a very loose interaction trigger ($\sim$ 3 nb^{-1}), and on a sample with p_t >1.3 GeV/c muon trigger ($\sim$ 12 nb^{-1})

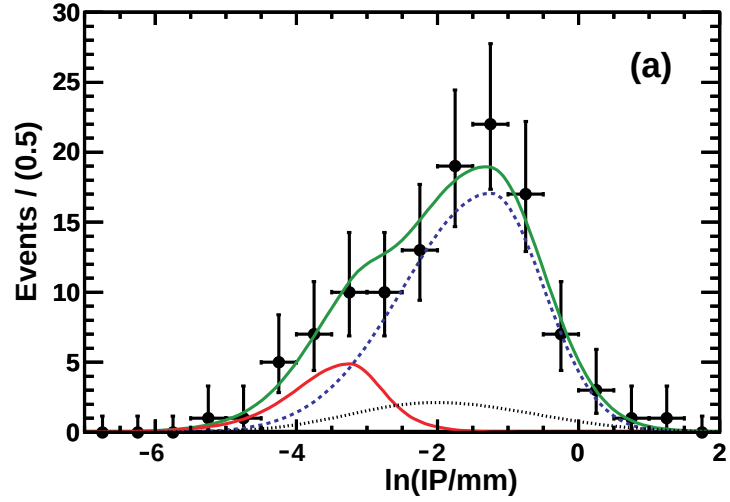




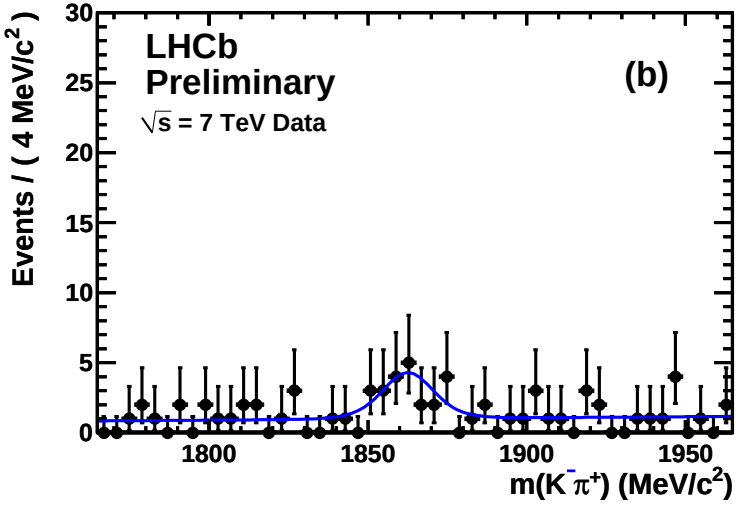
b-cross-section - $b \to D^0 X \mu^- \bar{\nu}$

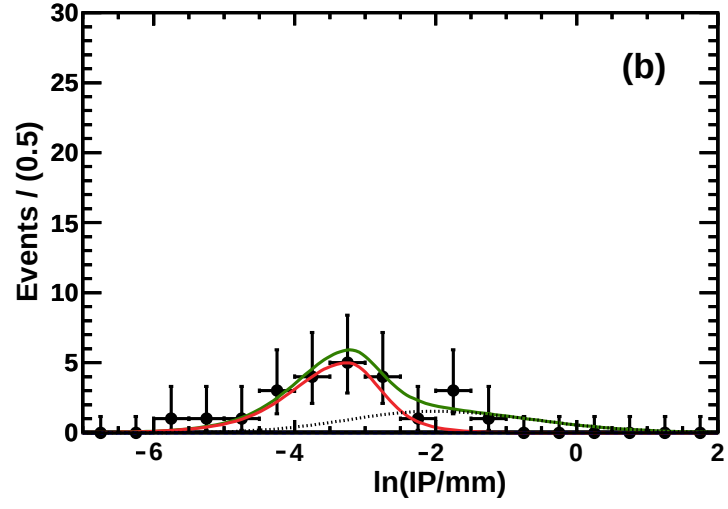
RS





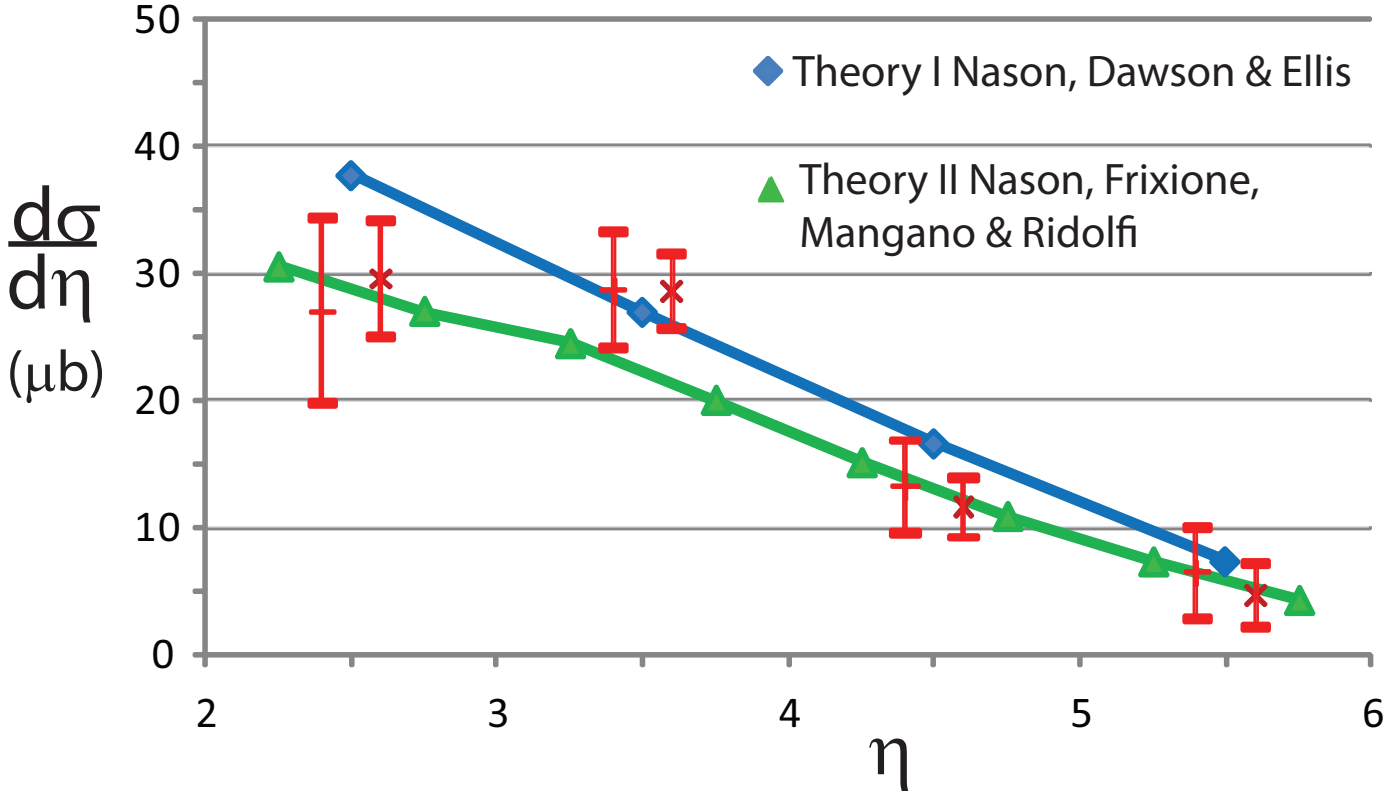
WS





D from B, prompt D, fake D

b-cross-section - $b \to D^0 X \mu^- \bar{\nu}$



+ loose int. trigger
x μ trigger

- in agreement with theory;
- cross-section averaged over the two sets:

  1/2 $\sigma(pp \to H_b X; 2 < \eta < 6) = 74.9 \pm 5.3 \pm 12.8 \mu$b

b-cross-section - combined

Weighted average of the J/ψ and $D^0\mu X$ results:

$$1/2\sigma(pp \to H_b X; 2 < \eta < 6) = 77.4 \pm 4.0 \pm 11.4 \mu\text{b}$$

also $D^{*-}\mu\nu X$ 1/2 $\sigma(pp \to H_b X; 2 < \eta < 6) = 73 \pm 12 \pm 17 \mu$b measurement was performed, less precise and strongly correlated with $D^0\mu X$

Using Pythia to extrapolate to full phase space

$$\sigma(pp \to bbX) = 292 \pm 15 \pm 43 \mu\text{b}$$

Consistent with teory expectations:

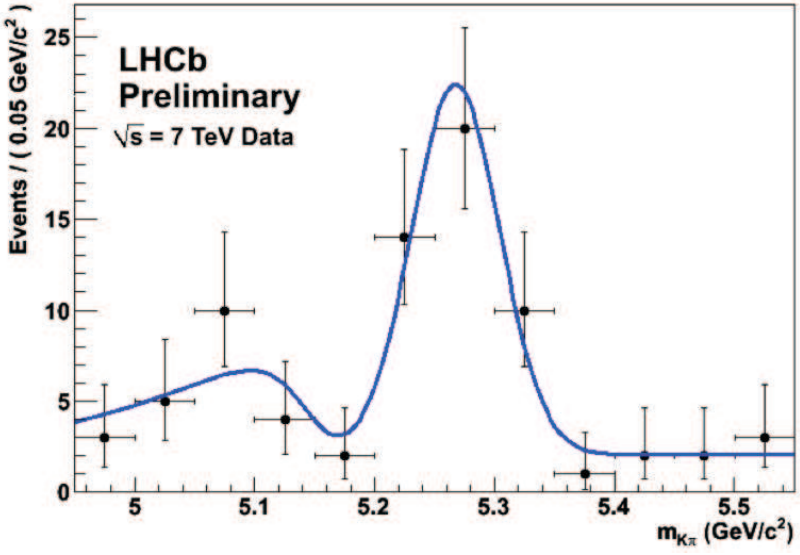
	Nason, Dawson, Ellis	Nason, Frixione, Mangano and Ridolfi
$1/2\sigma(pp \to H_b X; 2 < \eta < 6)$	89 μb	70 μb
$\sigma(pp \to bbX)$	332 μb	254 μb

Note that: all $\sqrt{s}$ = 7 TeV LHCb sensitivity studies until now assumed 250 μb and experimental numbers assume $B^+/B^0/B_S/\Lambda_b$ ratios measured at LEP.

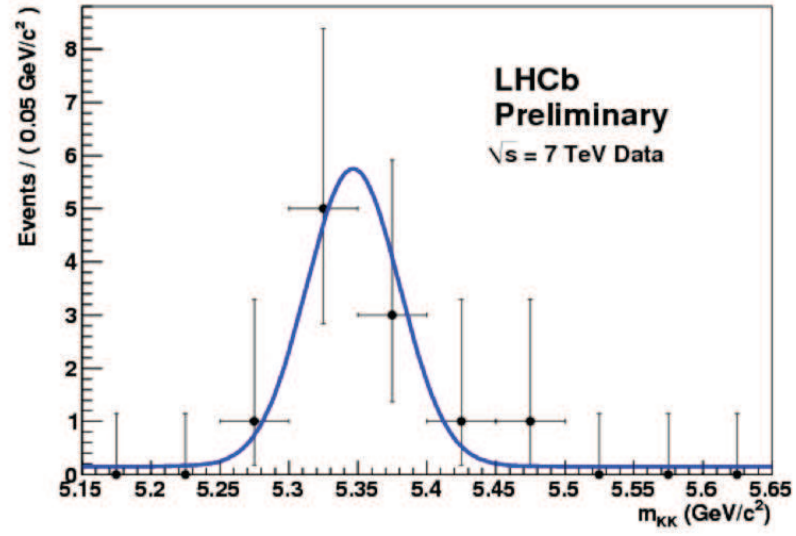
B signals - 230 nb^{-1}

Study of two body charmless B decays (BR $\sim 10^{-5}$) are core to LHCb programme: γ measurement, study of loop effects.

$B^0 \to K\pi$

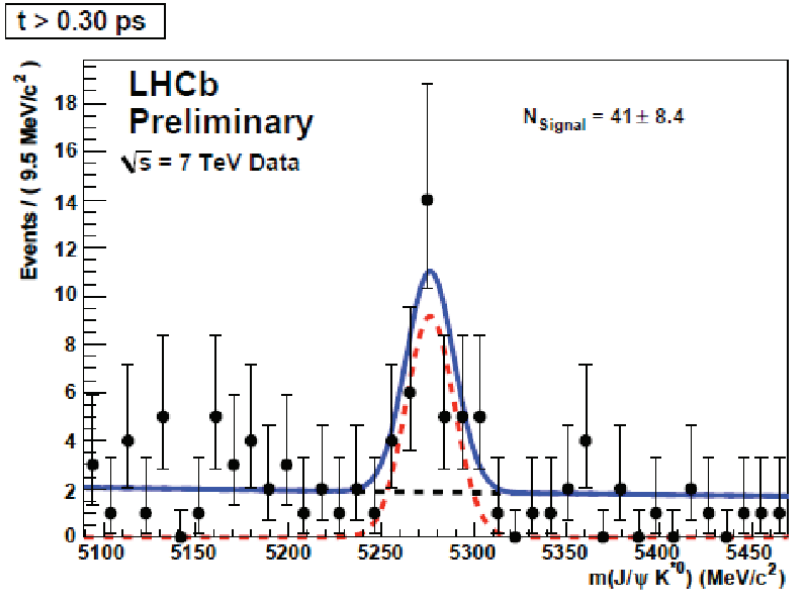


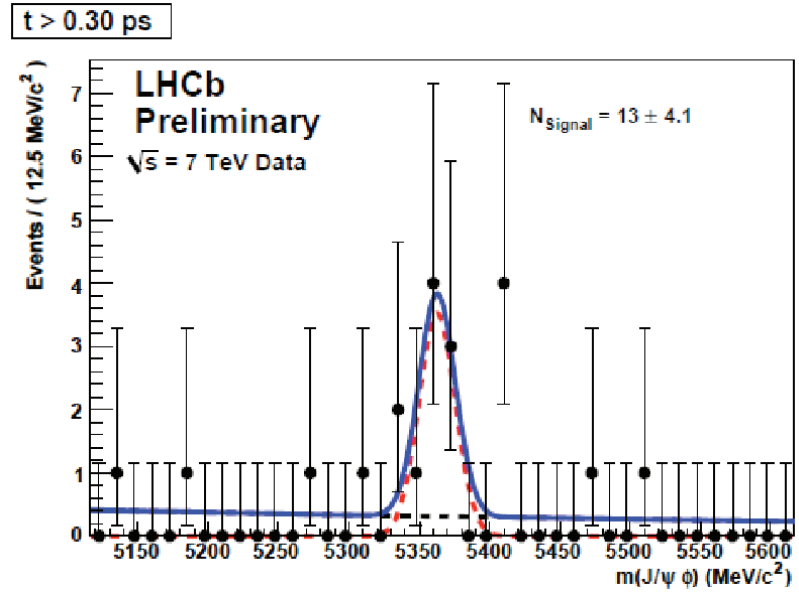
$B_s \to KK$



B signals - 230 nb^{-1}

Clear $B^0 \to J/\psi K^*$ signal





and $B_S^0 \to J/\psi\phi$ begins to show itself

Rates as expected from Monte Carlo.

Summary

- Although a flavour physics experiment LHCb is producing interesting results in minimum bias physics exploiting the unique rapidity and transverse momentum acceptance of the experiment;
- First measurements of J/ψ and open charm cross-sections were confronted with production models;
- $b\bar{b}$ cross-section measurements yield results consistent with expectations;
- Already many B peaks - rates as expected.

STAY TUNED FOR THE LHCb PUBLICATIONS