First results from LHCb experiment

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Review of results on behalf of LHCb Collaboration

Focus on QCD

Cracow School of Theoretical Physics, Zakopane Poland

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Outline

- LHCb and LHC
- Detector performance
- QCD measurements
  - Strangeness production, baryon number transport
  - Charm and beauty production
  - Exclusive dimuon production
- Examples of CP and New Physics results
- Summary

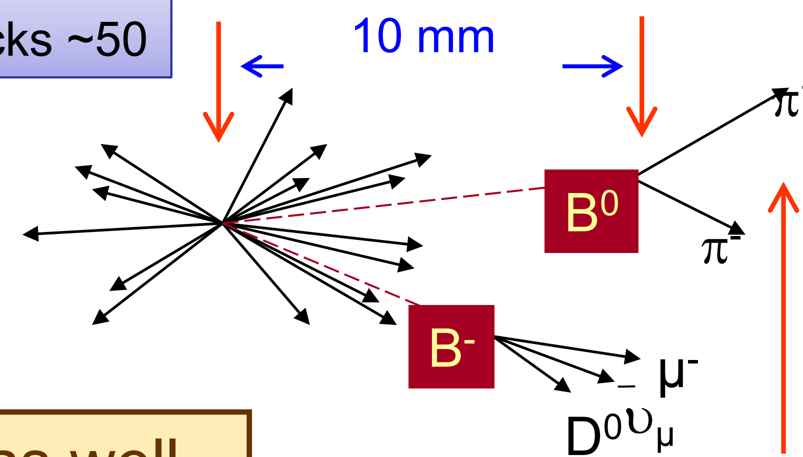
The LHCb goals

LHCb is a dedicated experiment to study flavour physics at the LHC

- Search for New Physics in quantum loop processes
- CP violation and rare decays allowing to probe beyond the LHC energy frontier

Primary vertex:
many tracks ~50

B decay vertices:
a few tracks



K/π separation

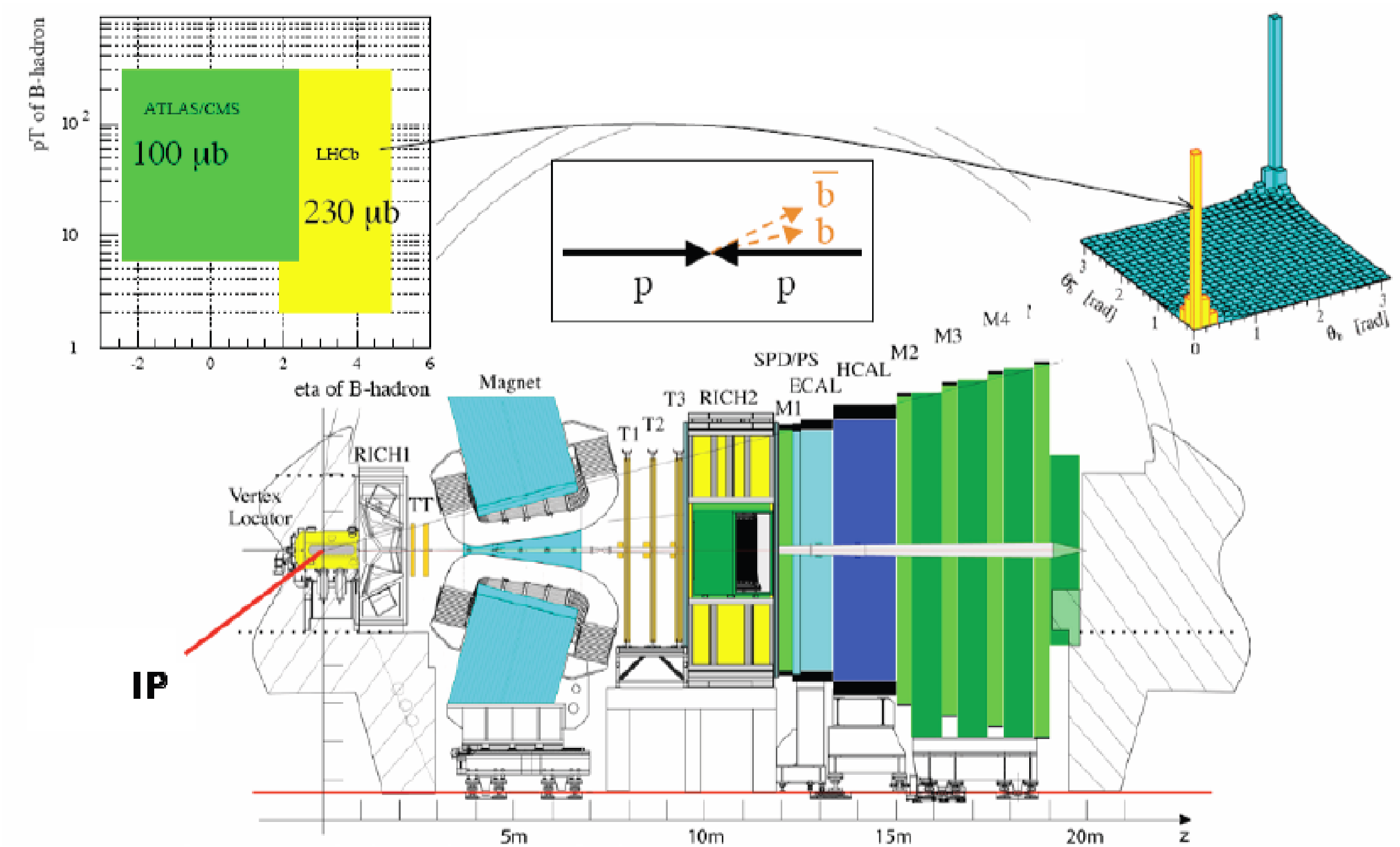
Detector requirements

- Efficient trigger for both leptonic and hadronic final states
- Excellent vertex finding and tracking efficiency
- Outstanding particle identification

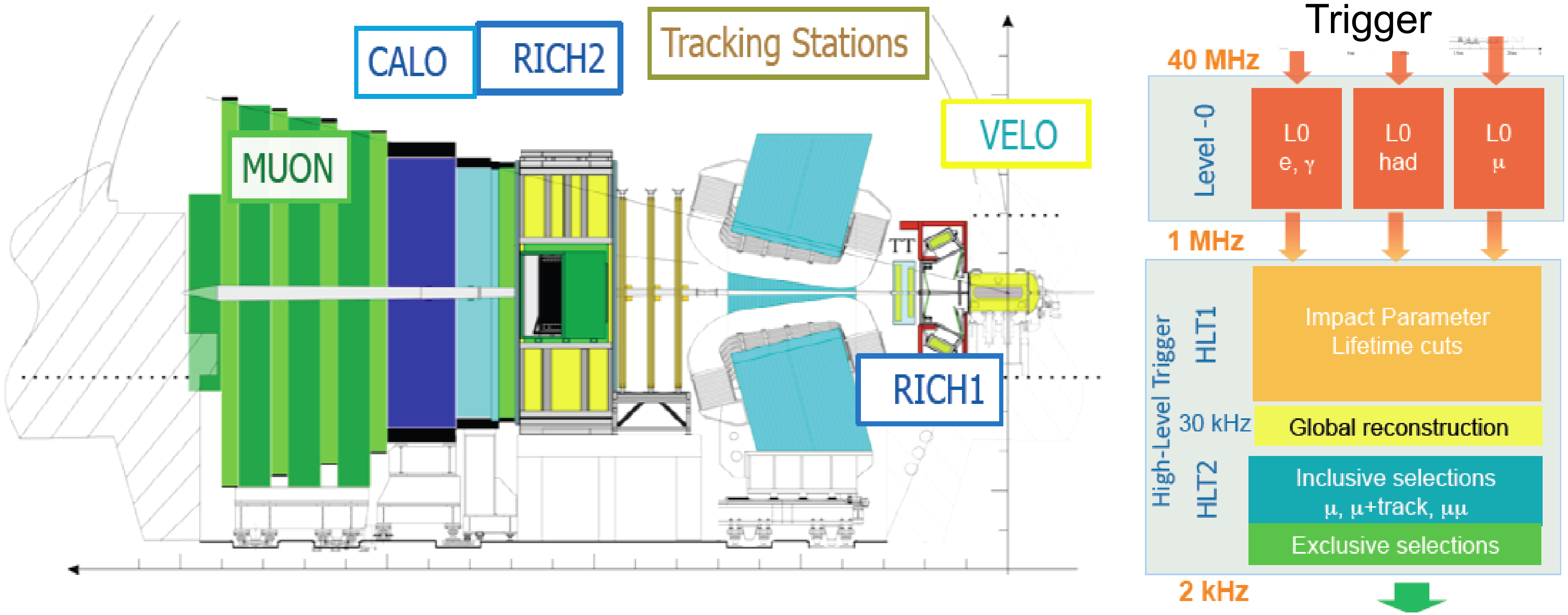
LHCb good to study the QCD as well
(focus on QCD results in this talk)

The spectrometer

Unique, fully equipped coverage in the rapidity region $1.9 < \eta < 4.9$
Only LHC experiment that can study in the high η low p_T region

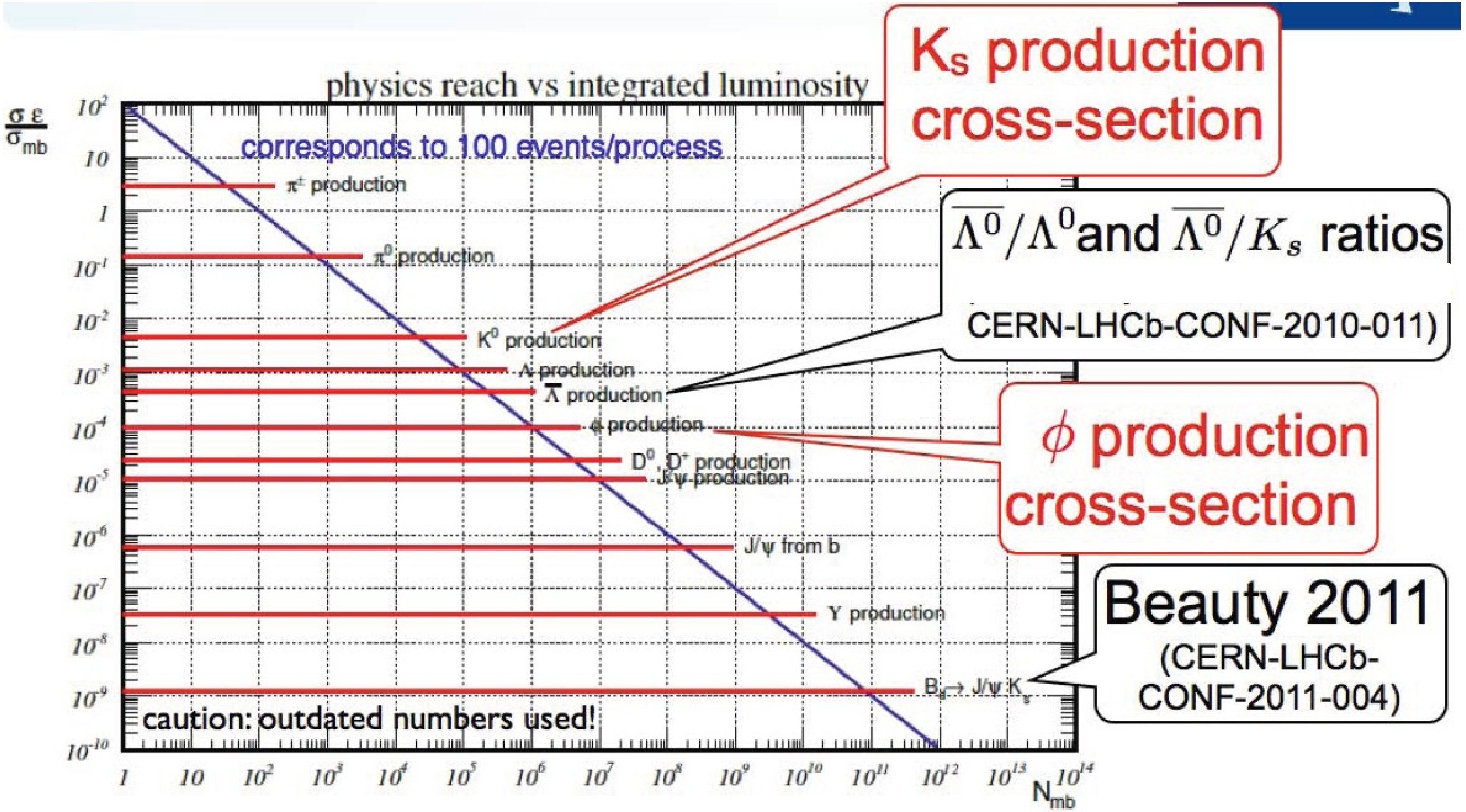


Subsystems

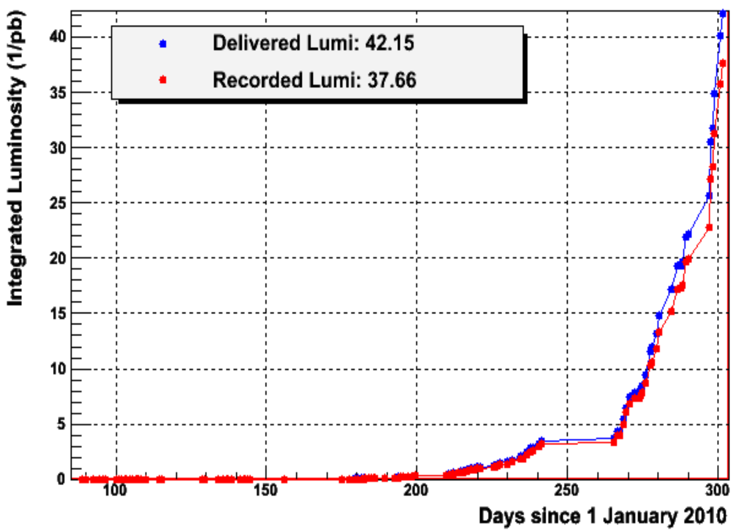


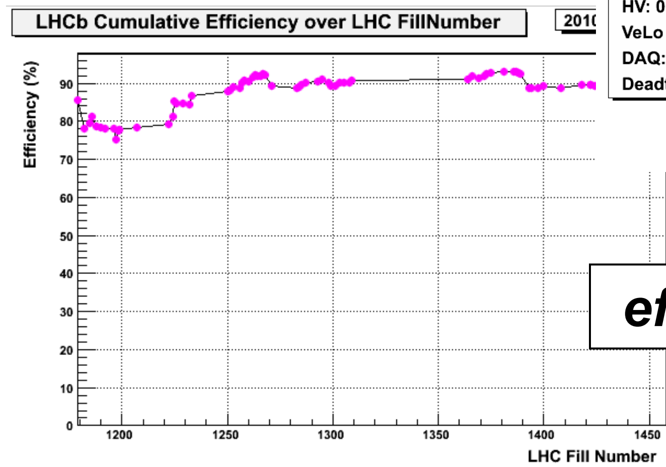
- Trigger dedicated to b physics however it is flexible and can be tuned according to particular physics studies
- LHC lumi changed 5 orders of magnitude in 200 days
  - First collisions at low lumi with minimal trigger (minimum bias or micro bias trigger) suitable for QCD measurements
  - At intermediate lumi gradually switching HLT1 and then HLT2 (charm physics, low L0 E_T cut)
  - At high lumi special trigger lines added to allow for non-b physics (like CEP μμ, Z→ μμ, etc.)

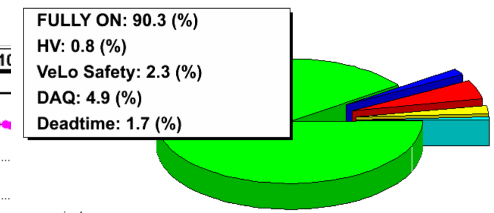
Physics reach vs luminosity



LHC and LHCb



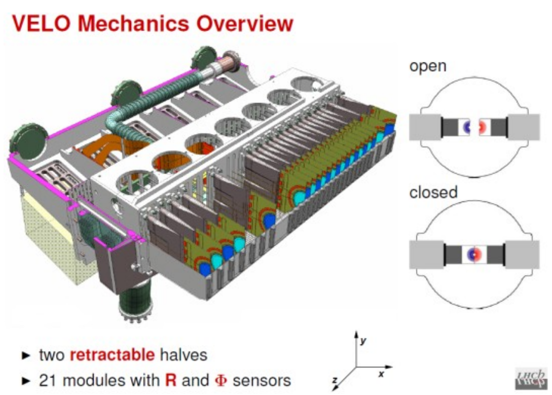




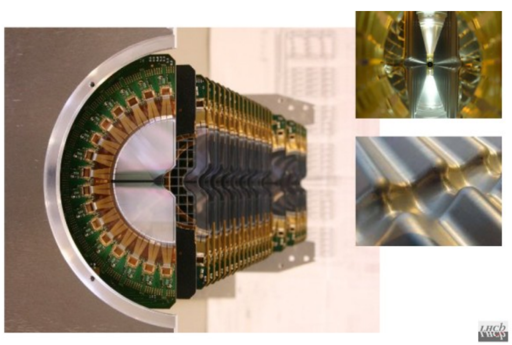
$eff_{LHCb} = 90.3\%$

- Excellent performance of LHC and LHCb
  - Recorded 38 pb^{-1} in 2010, 10^{10} bb-pairs produced
  - Flexible trigger, adjusted to LHC lumi and physics goals
- Data samples used in various studies
  - 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.
  - 14 nb^{-1} at 7 TeV in 2010 collected with Minimum Bias trigger: requires 1 track in the VELO
  - 37.7 pb^{-1} at 7 TeV collected in 2010.

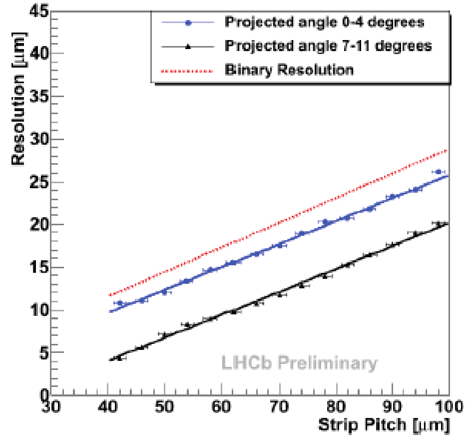
VELO performance



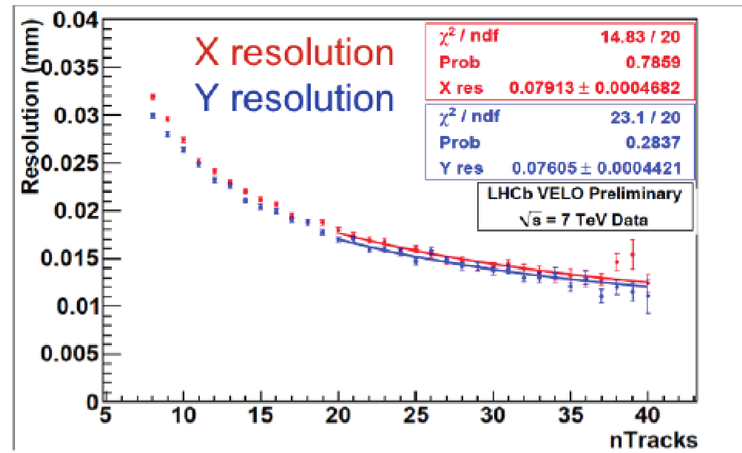
Macro movements ~cm
Micro precision ~μm



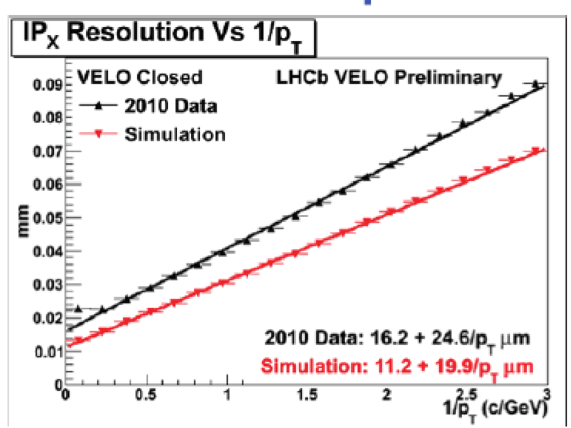
single hit resolution

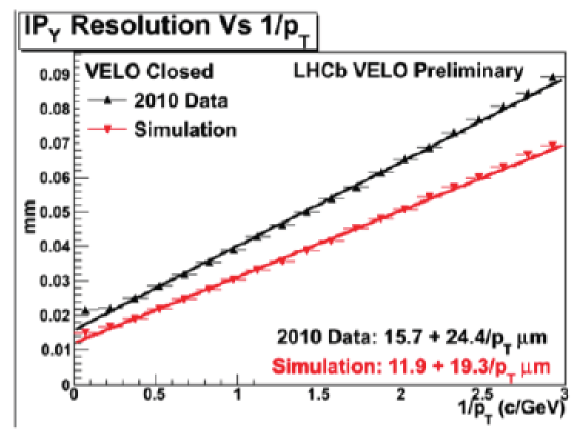


primary vertex resolution



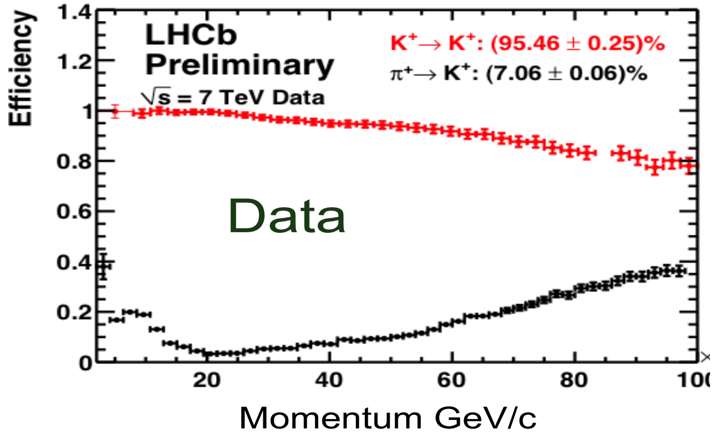
Impact Parameter Resolution

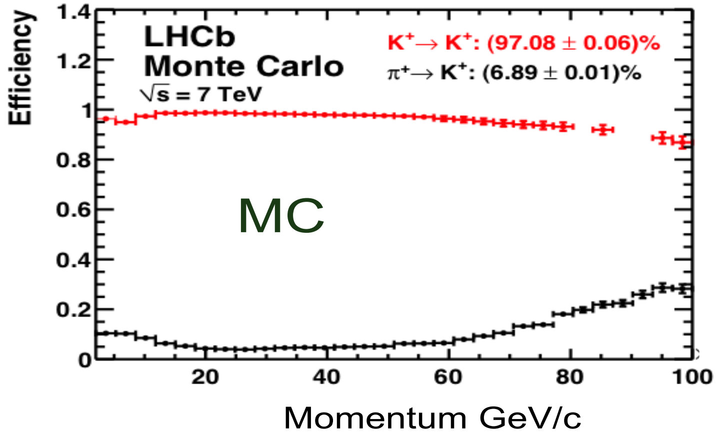




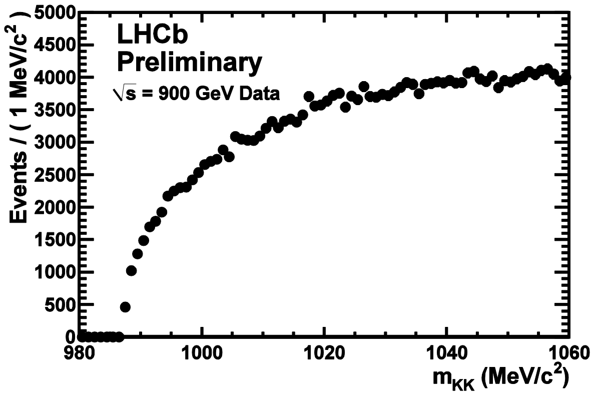
Particle Identification

RICH PID close to MC expectations across full momentum range

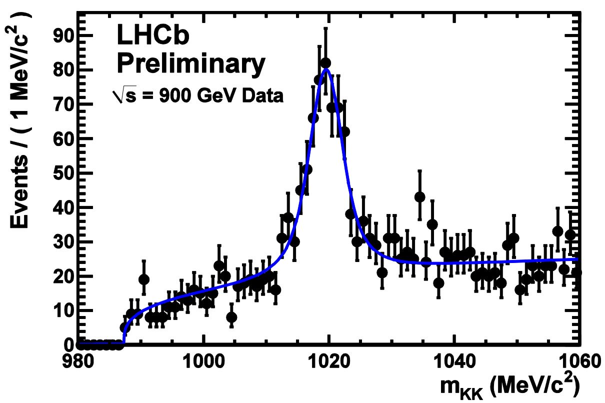




Clean reconstruction of hadronic decays
critical to many of following physics results



$\phi \to K^+ K^-$



B-hadron masses – detector quality test

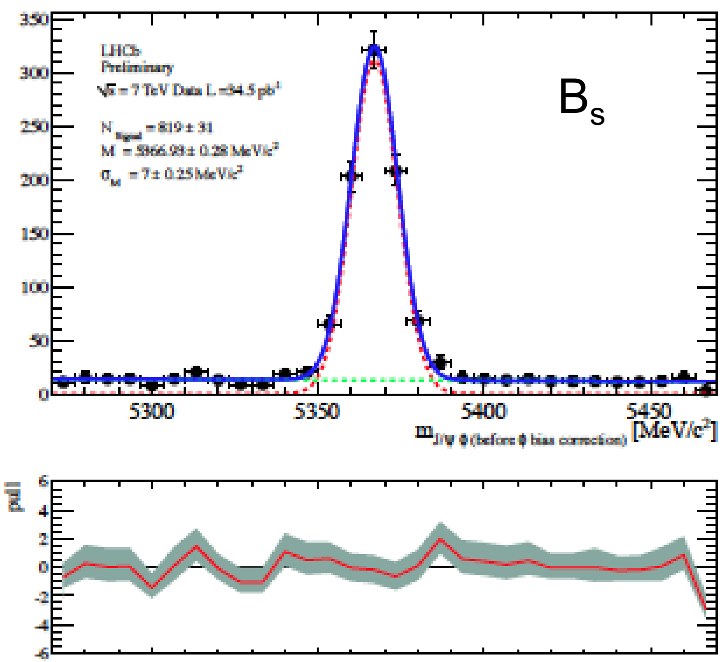
Key analysis element:
Momentum calibration
B field
Magnet up/down, alignment

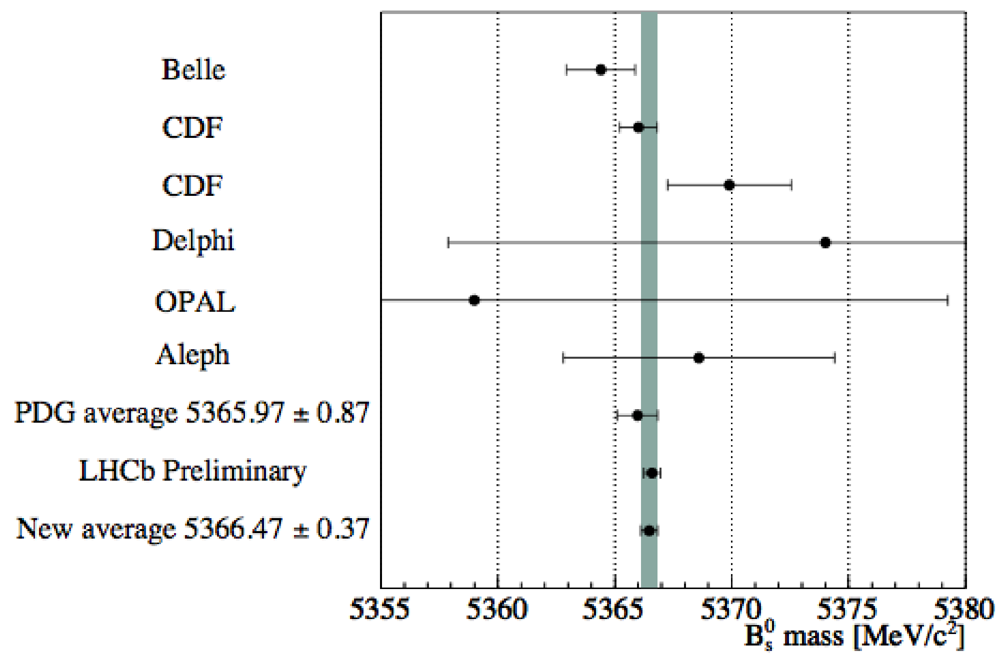
$B^+ \to J/\psi K$	$5279.27 \pm 0.11\,(\text{stat}) \pm 0.19\,(\text{syst})\ \text{MeV}/c^2$
$B^0 \to J/\psi K^{*0}$	$5279.54 \pm 0.15\,(\text{stat}) \pm 0.15\,(\text{syst})\ \text{MeV}/c^2$
$B^0 \to J/\psi K^0_S$	$5279.61 \pm 0.29\,(\text{stat}) \pm 0.20\,(\text{syst})\ \text{MeV}/c^2$
$B^0_s \to J/\psi \phi$	$5366.60 \pm 0.28\,(\text{stat}) \pm 0.21\,(\text{syst})\ \text{MeV}/c^2$
$\Lambda_b \to J/\psi \Lambda$	$5619.48 \pm 0.70\,(\text{stat}) \pm 0.19\,(\text{syst})\ \text{MeV}/c^2$
$B^+_c \to J/\psi \pi^+$	$6268.0 \pm 4.1\,(\text{stat}) \pm 0.5\,(\text{syst})\ \text{MeV}/c^2$

BEST

Masses and mass differences in J/ψX

e.g. B_s mass ~ factor 3 better than previous measurement





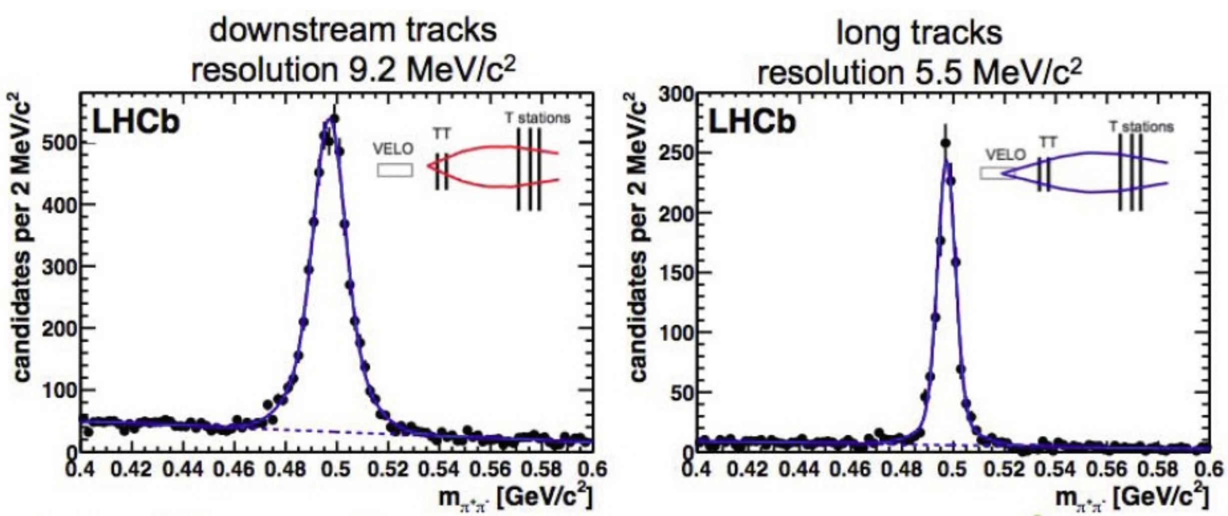
QCD measurements - motivation

- 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.
- Models tuned for central rapidity. Already many different generators give different predictions at LHC energies, which diverge at the rapidities covered by LHCb
- Interesting physics in new energy range

Strangeness production

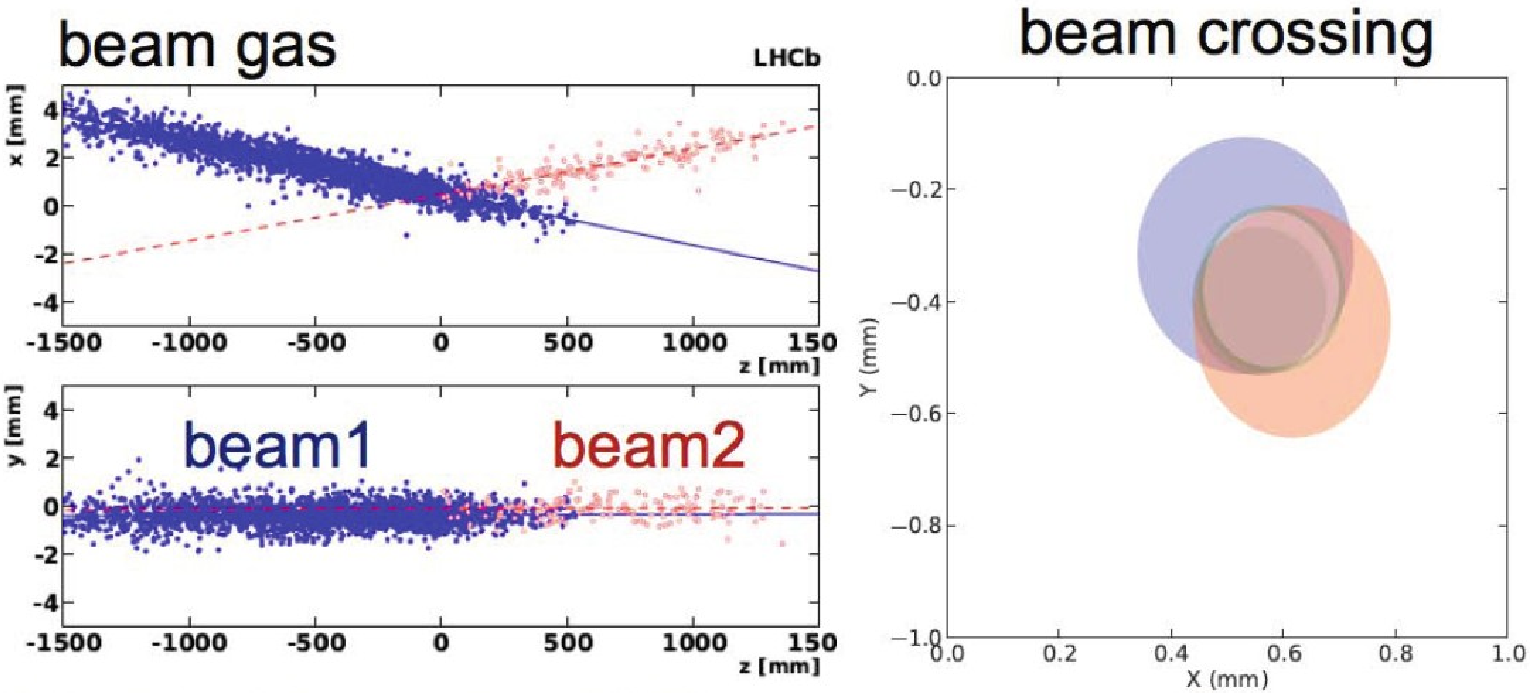
- Strangeness probes soft hadronic interactions ($\Lambda_{QCD} \sim m_s$)
  - Fragmentation
  - Soft non-perturbative production (suppressed but occurs)
  - Input to QCD models and MC tuning
- Analysis of Ks production
  - 7 ub^{-1} @ 0.9 TeV in 2009
  - Minimum bias trigger: activity in calorimeters
  - *R*econstruction of $K_s \rightarrow \pi^+\pi^-$, loose criteria

Phys. Lett. B 693 (2010) 69
arXiv:1008.3105v2



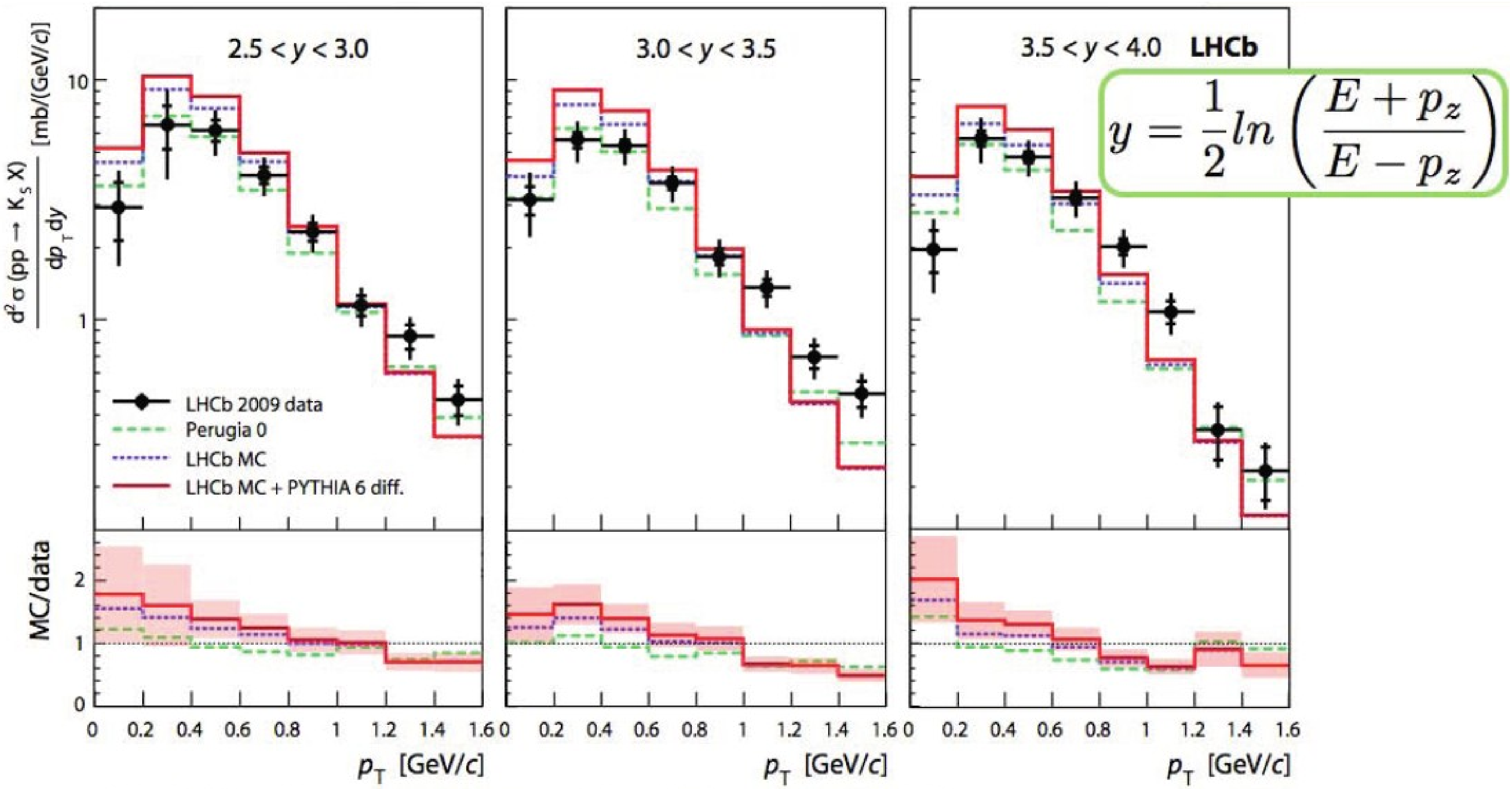
Luminosity determination

Novel absolute direct luminosity measurement from beam profiles, beam gas interaction and beam current



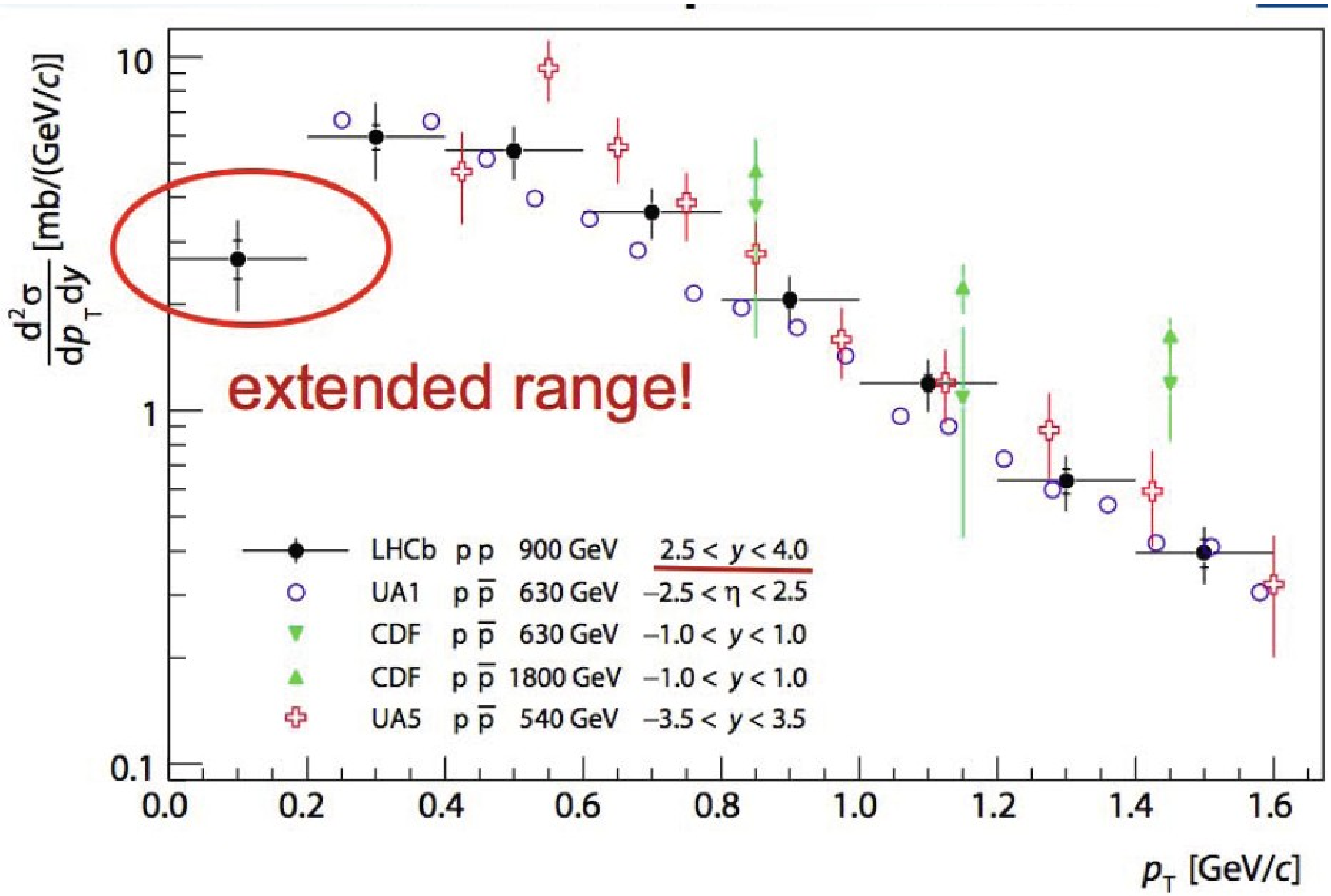
$$L = 2\,c\,n_1\,n_2\,f\,\cos^2\theta \int \rho_1(x,y,z,t)\rho_2(x,y,z,t)\;\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}t$$

K_s p_T spectra at 0.9 TeV



- harder p_T spectrum in data than MC

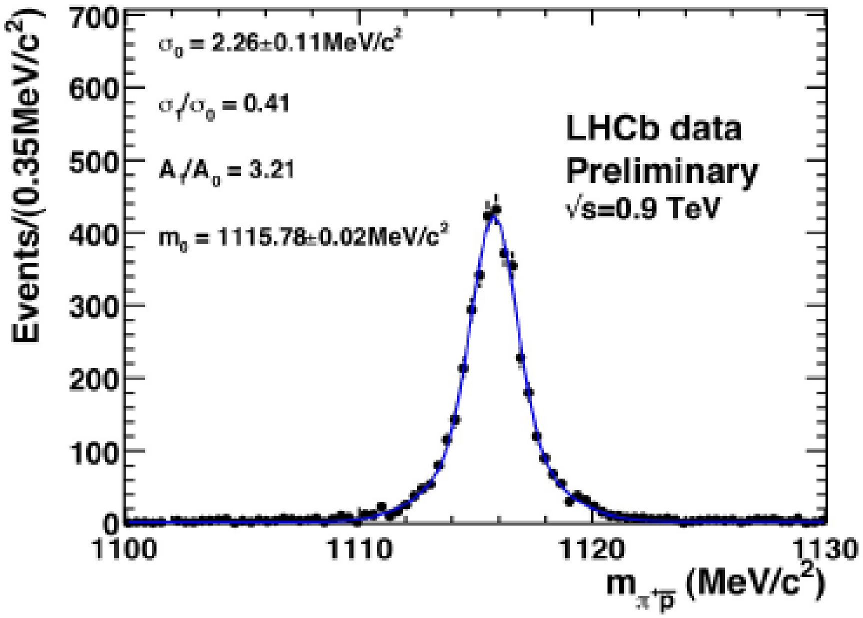
Comparison of K_s production measurements

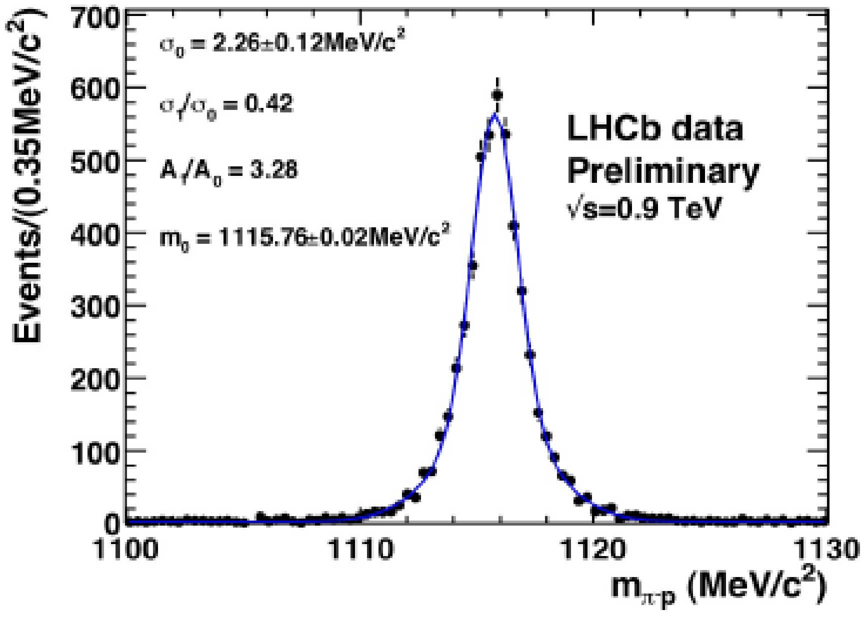


Particle production ratios
Barion number transport

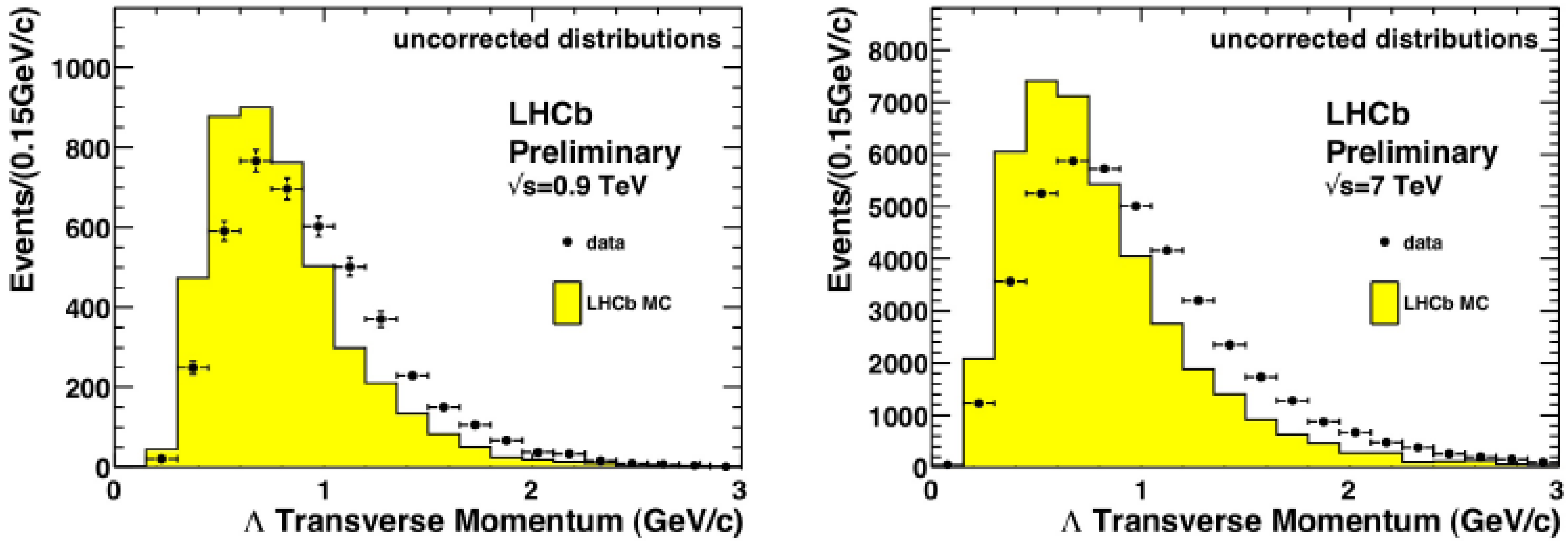
Λ selection

- Track selection: hits in VELO and in stations downstrem the magnet.
- Fisher discriminant based on impact parameter of p and π (large) and Λ (small).



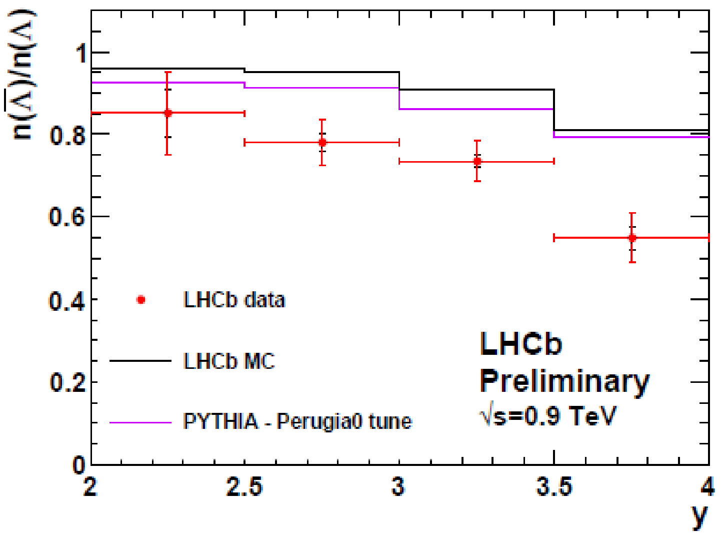


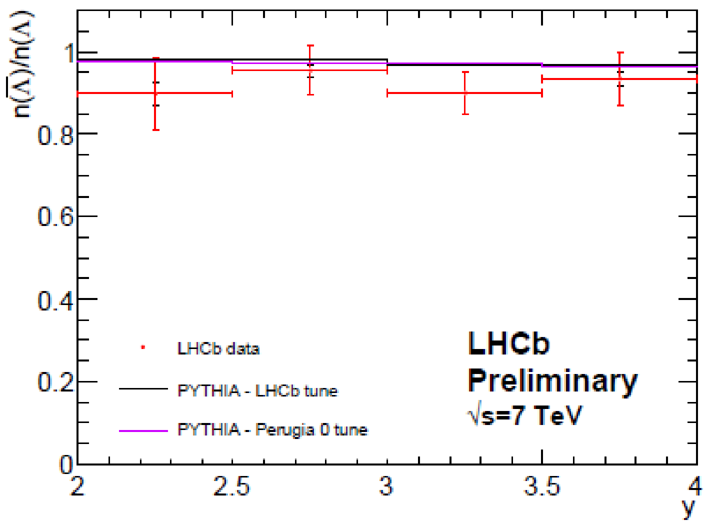
Uncorrected p_T distributions

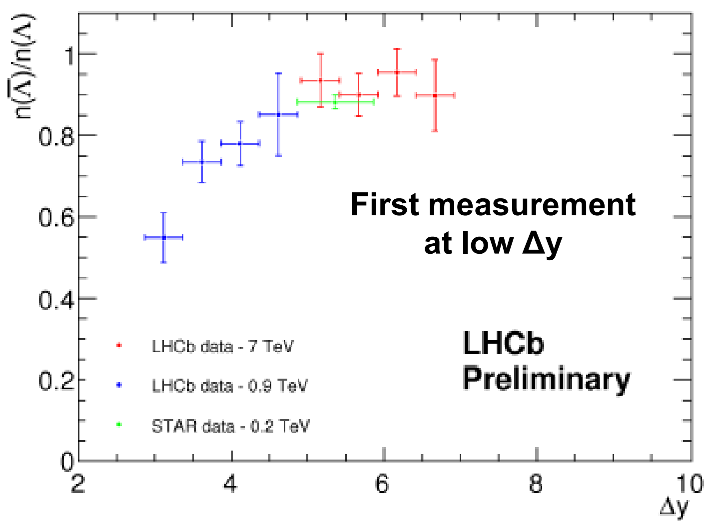


- Efficiencies are estimated from Monte Carlo
- Re-weighting procedure introduced to remove biases
- Uncorrected p_T spectra are harder than predicted by LHCb Monte Carlo

Baryon number transport - $\overline{\Lambda}/\Lambda$





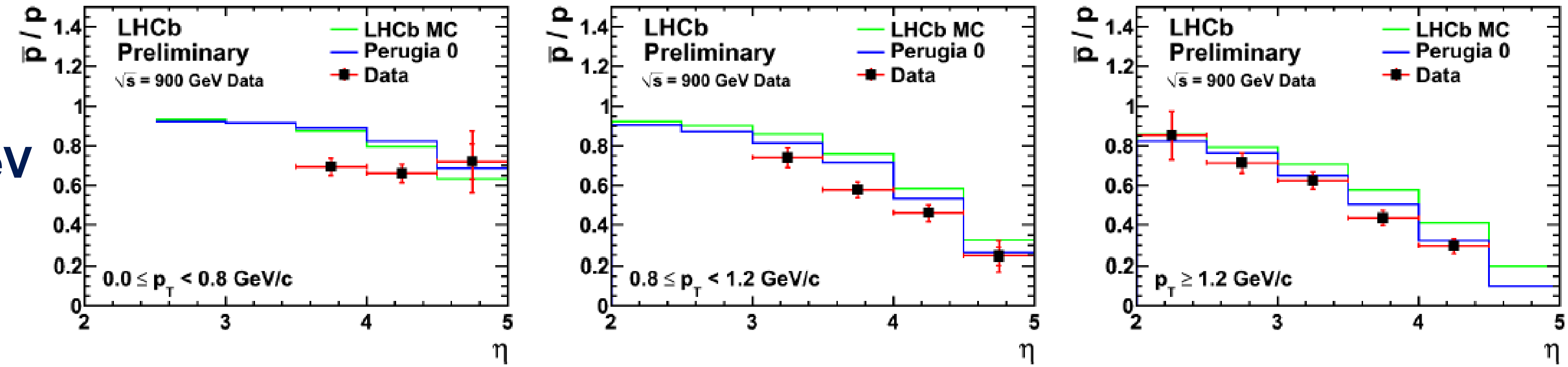


- clear energy dependence seen
- scaling in difference to beam rapidity
  - → $\sqrt{s} = 0.9\,\text{TeV}$: $y_{beam} = 6.6$
  - → $\sqrt{s} = 7.0\,\text{TeV}$: $y_{beam} = 8.3$
- consistent with STAR measurement

CERN-LHCb-CONF-2010-011
Perugia selection: Phys. Rev. D 82(7):074018(2010)

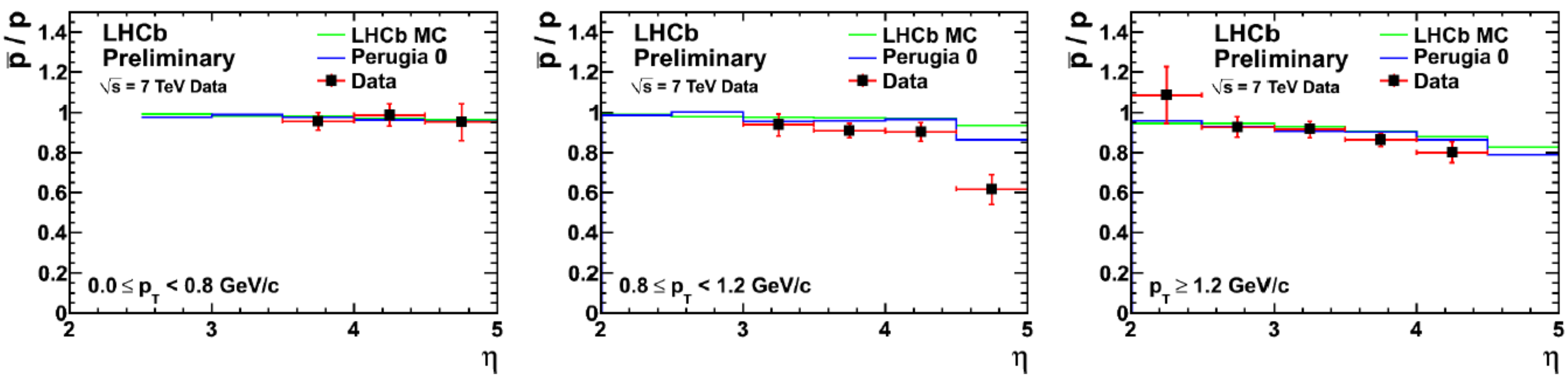
Baryon number transport $\bar{p}/p$

0.9 TeV



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

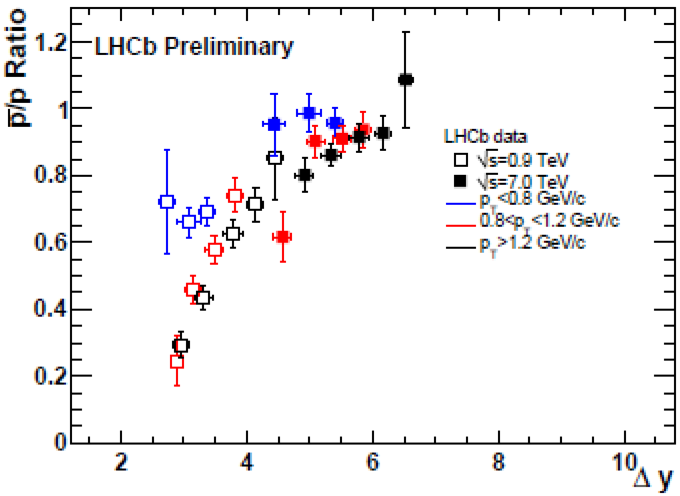
7 TeV

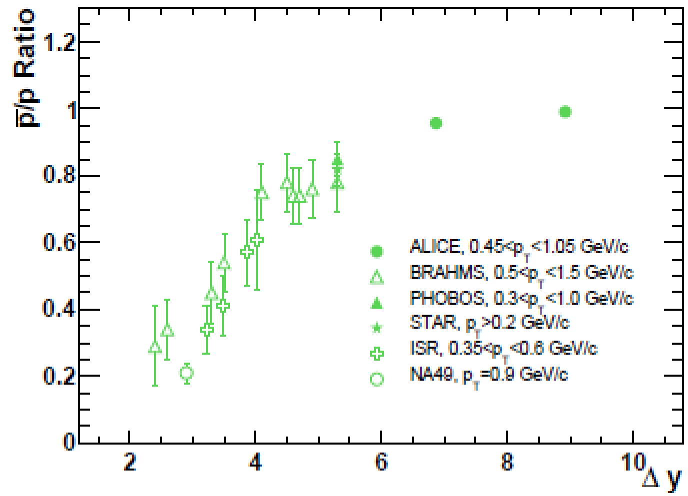


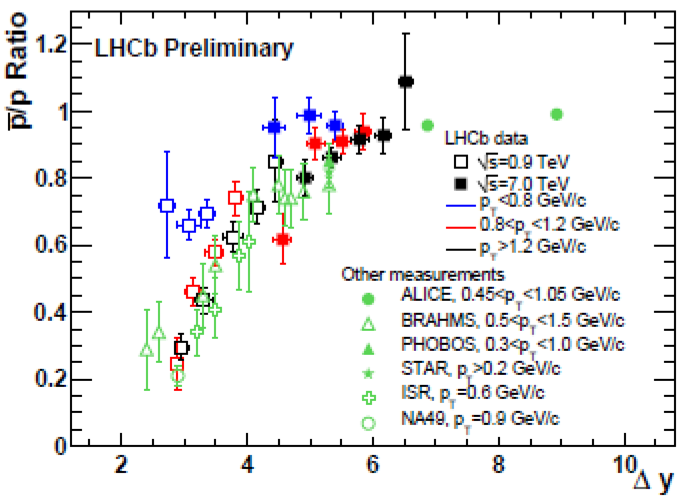
- Ratios become flatter as expected from models.
- Better agreement with Monte Carlo than at 900 GeV.
- Consistent with $\bar{\Lambda}/\Lambda$ ratio result.

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

➜ *ratio as a function of the rapidity difference to the beam*

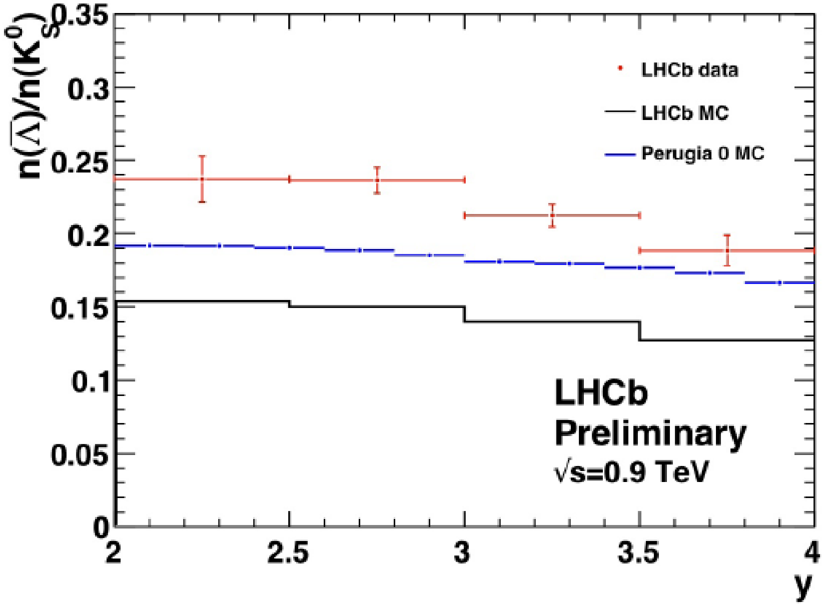


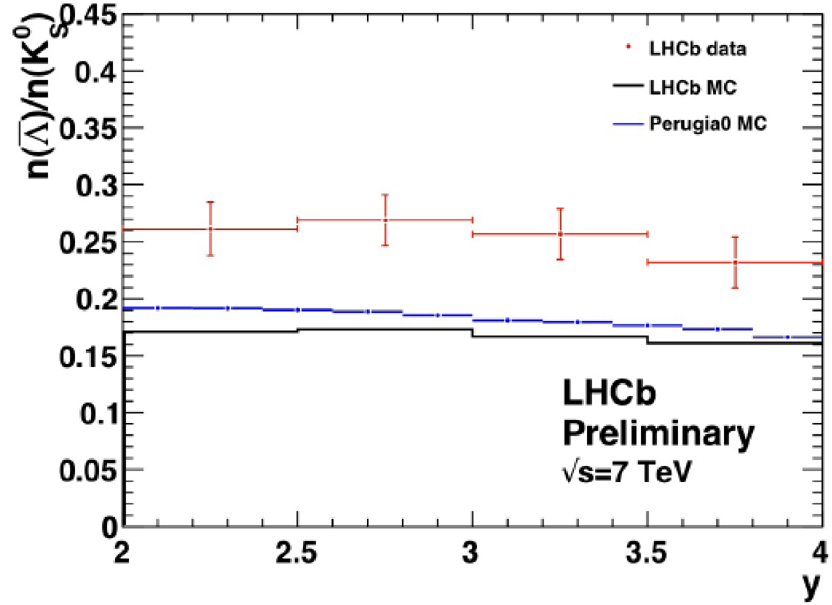




- scaling behaviour seen
- possibly slight dependence on p_T
- consistent with other measurements

$\overline{\Lambda}/K_s$ ratio





- Baryon/meson suppression significantly lower than predicted by models
  - Forward region not well described by models

CERN-LHCb-CONF-2010-011

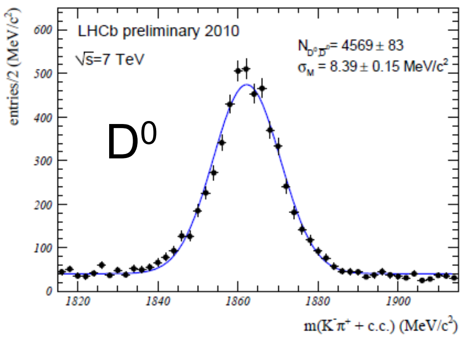
Open charm production

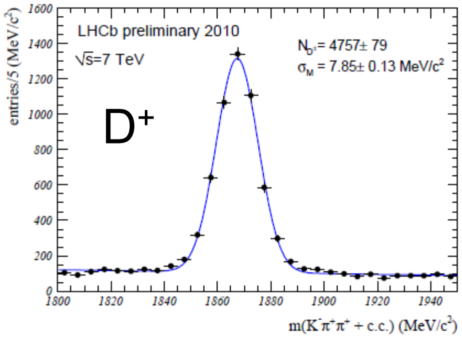
Open charm production

- 1.8 nb-1 taken in 2010 at 7 TeV with minimum bias trigger

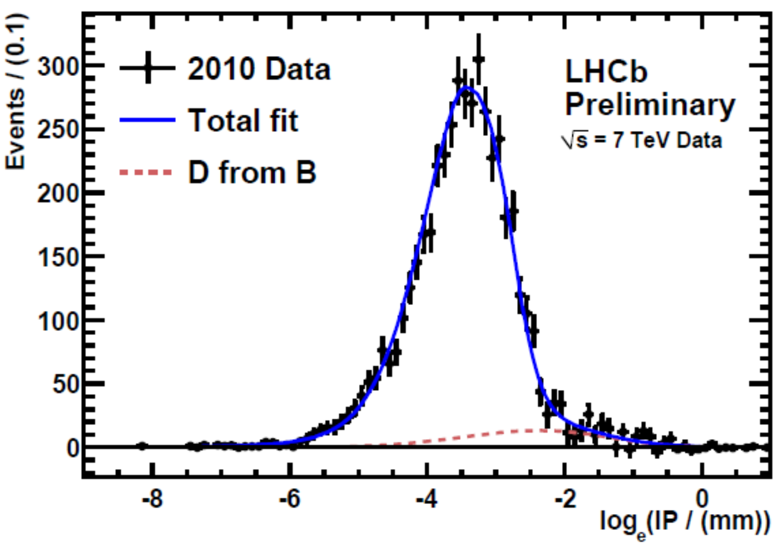
LHCb-CONF-2010-013

- Selection strategy (reduce b→c)
  - Short proper time
  - D momentum pointing to primary vertex
  - Good secondary vertex

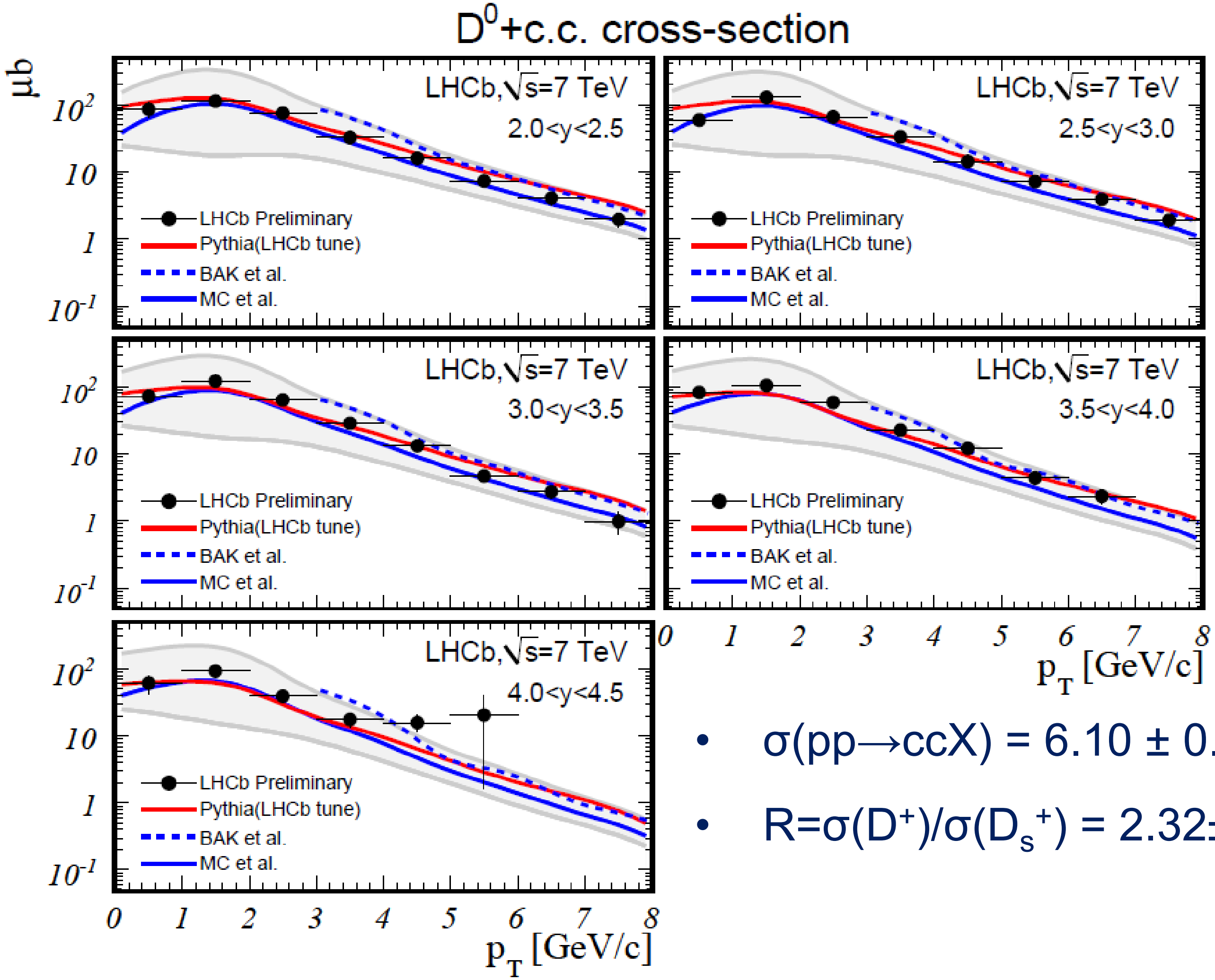




- D^0: $D^0 \to K^-\pi^+$,
- D^+: $D^+ \to K^-\pi^+\pi^+$,
- D^{*+}: $D^{*+} \to \pi^+ D^0(K^-\pi^+)$,
- $D^+_{(s)}$: $D^+ \to \phi(K^-K^+)\pi^+$ or $D^+_s \to \phi(K^-K$



Open charm production



- $\sigma(pp\rightarrow c\bar{c}X)$ = 6.10 ± 0.93 mb (4π extrapol.)
- $R=\sigma(D^+)/\sigma(D_s^+)$ = 2.32±0.27(stat)± 0.26(syst)

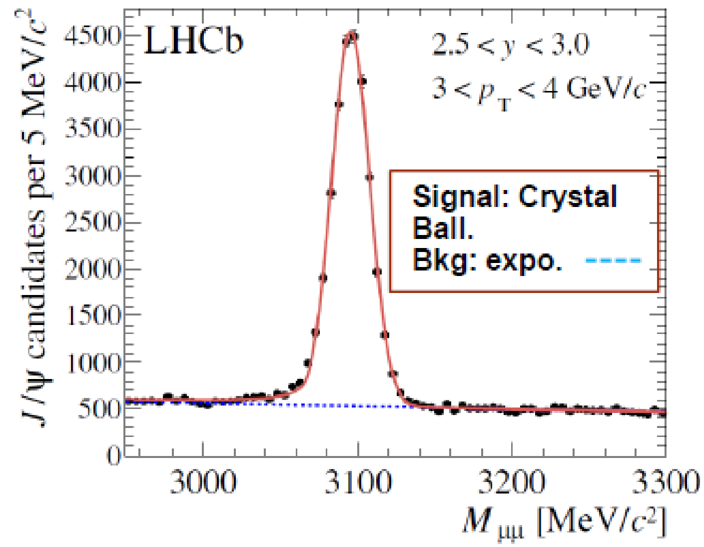
BAK et al. - B.A. Kniehl, G. Kramer, I. Schienbein, and H. Spiesberger, private comunication
MC et al. - M. Cacciari, S. Frixione, M. Mangano, P. Nason, and G. Ridolfi, private comunication

Quarkonia production - J/ψ and Υ

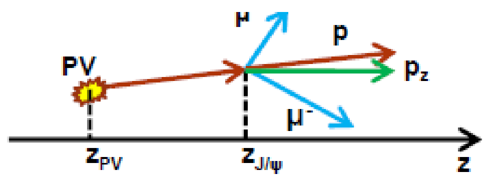
- The production mechanism in pp collisions still unclear
- Several models developed
  - Color singlet(CSM)
    - Undershoots the data, no polarisation prediction
  - CSM extendend to color octet (COM) mechanisms
    - Better agreement for cross-section,
    - predicts TRANSVERSE polarisation,
    - not confirmed by experiments
  - NLO CSM
    - describes cross-section
    - allows LONGITUDINAL polarisation!

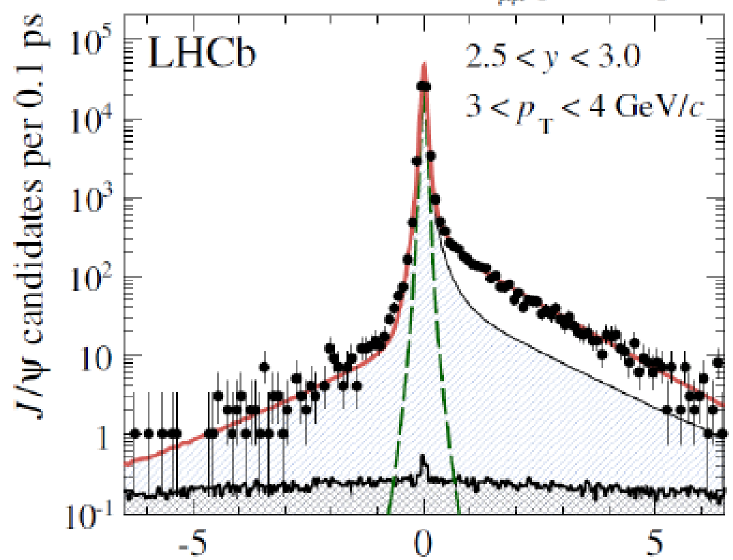
Production of *J/ψ*, fraction of *J/ψ* from *b*

- Dedicated muon and dimuon triggers+ offline selection.
- $J/\psi \to \mu^+\mu^-$ estimated from a fit to the J/ψ invariant mass.
- Fraction of J/ψ from b extracted from pseudo-proper time (t_z) fit



$$\boxed{t_z = \frac{(z_{J/\psi} - z_{PV}) \times M_{J/\psi}}{p_z}}$$





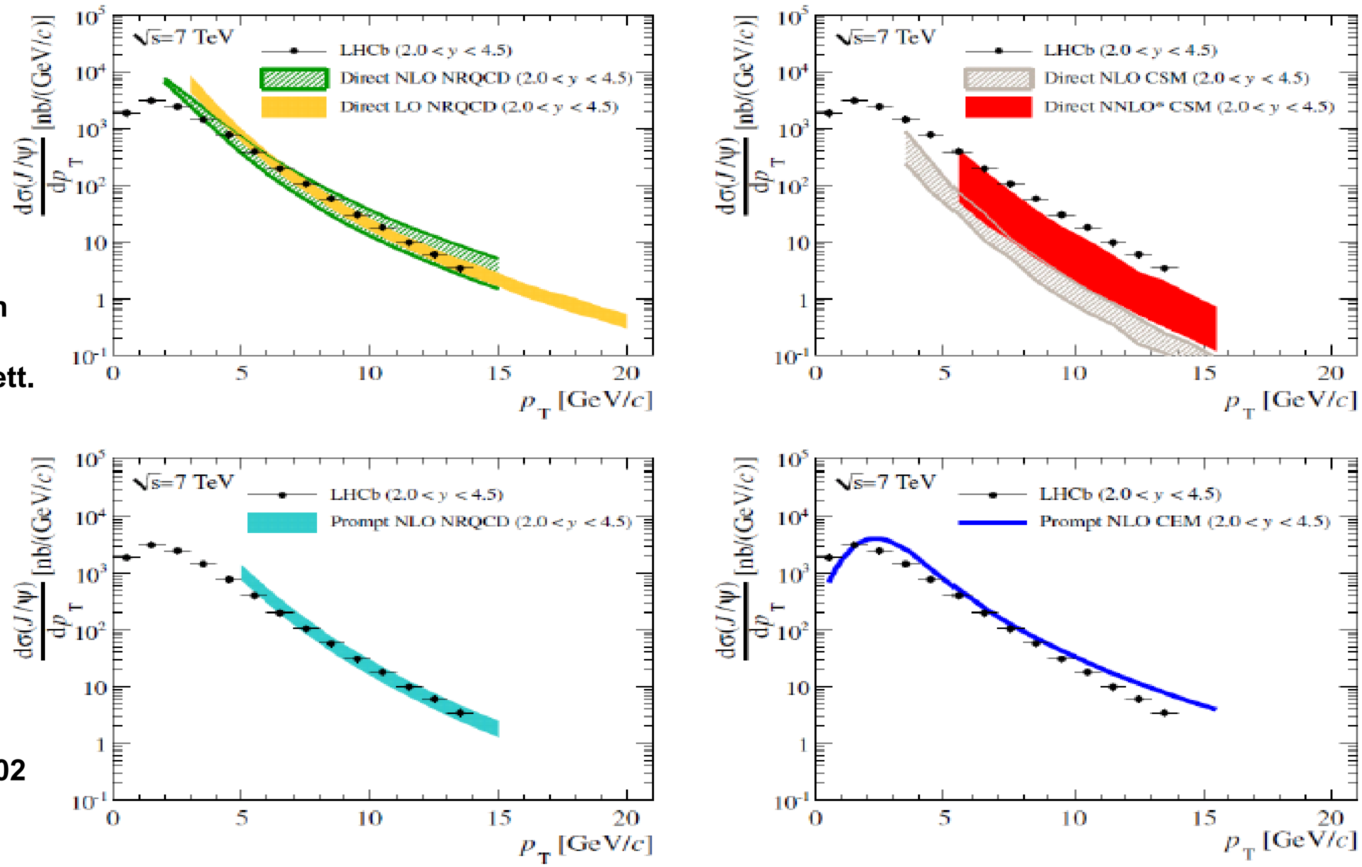
- Total fit function.
- Prompt J/ψ.
- Background.
- Tails from wrong PV association.

Prompt J/ψ production - comparison with theoretical models

P. Artoisenet
[PoS ICHEP 2010 (2010) 192]

M. Buteschon
B. Kniehl
Phys. Rev. Lett. 106 (2011)

J.-P. Lansberg
[Eur. Phys. J. C 61 (2009) 693



K.T Chao et al.
Phys. Rev. Lett. 106 (2011) 042002

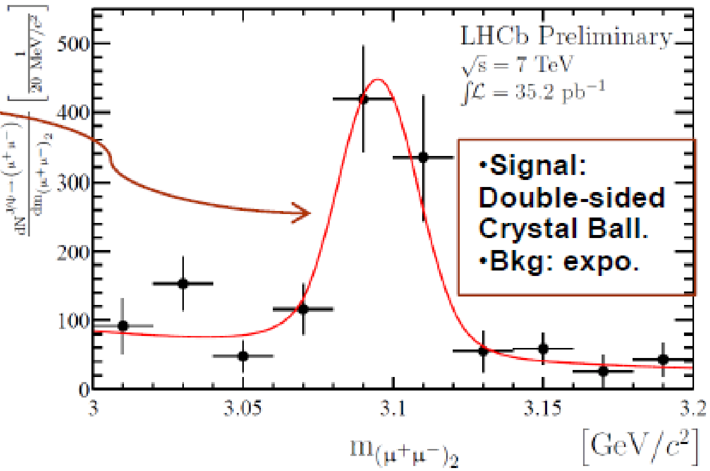
R. Vogt
Phys. Rep. 462 (2008) 125

- LHCb results for J/ψ not-polarized.
- Theoretical predictions
  - Direct production– upper plots. Prompt (direct+feed-down from χ_c etc.) bottom plots.
  - Direct = 0.7 * prompt

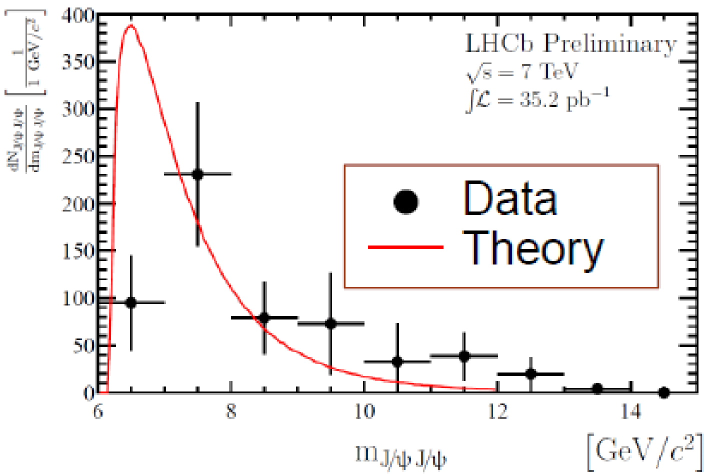
$$\sigma(\text{prompt } J/\psi,\, p_T < 14\ \text{GeV/c},\, 2.0 < y < 4.5) = 10.52 \pm 0.04 \pm 1.40^{+1.64}_{-2.20}\ \mu\text{b}$$

Double J/ψ production cross-section LHCb

Efficiency corrected fitted $(\mu^+\mu^-)_1$ yields in bins of $(\mu^+\mu^-)_2$ invariant mass (signal shape fixed from inclusive J/ψ sample).



- The measured cross-section in the fiducial region is model independent:
  - $5.6 \pm 1.1_{stat} \pm 1.2_{syst}$ nb
- LO QCD estimate (arXiv:1101.5581[hep-ph])
  - With initial state gluon radiation (ISR): 4.34 nb
  - Without ISR: 4.15 nb



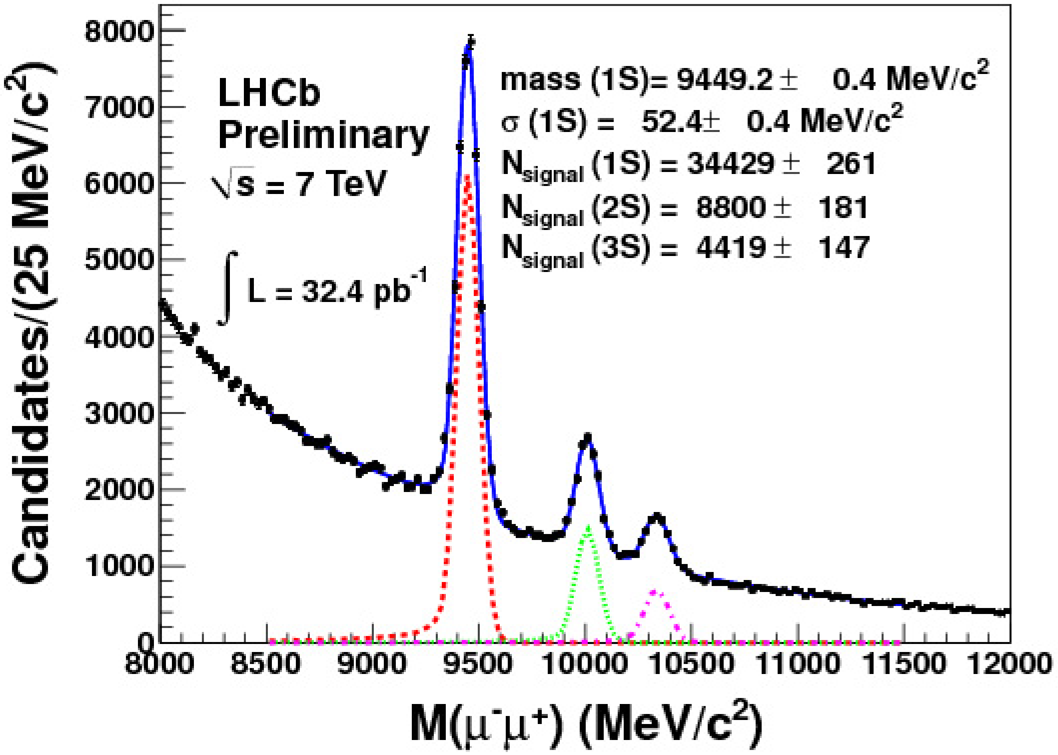
LHCb-CONF-2011-009

Production of Υ(1S)

- Observation of Υ(1S), Υ(2S) and Υ(3S) in $\Upsilon \rightarrow \mu^+\mu^-$
- Cross-section from number of observed events extracted from invariant mass fit

Signal – Crystal Ball

Background - exponential



Υ(1S) production – comparison with theory

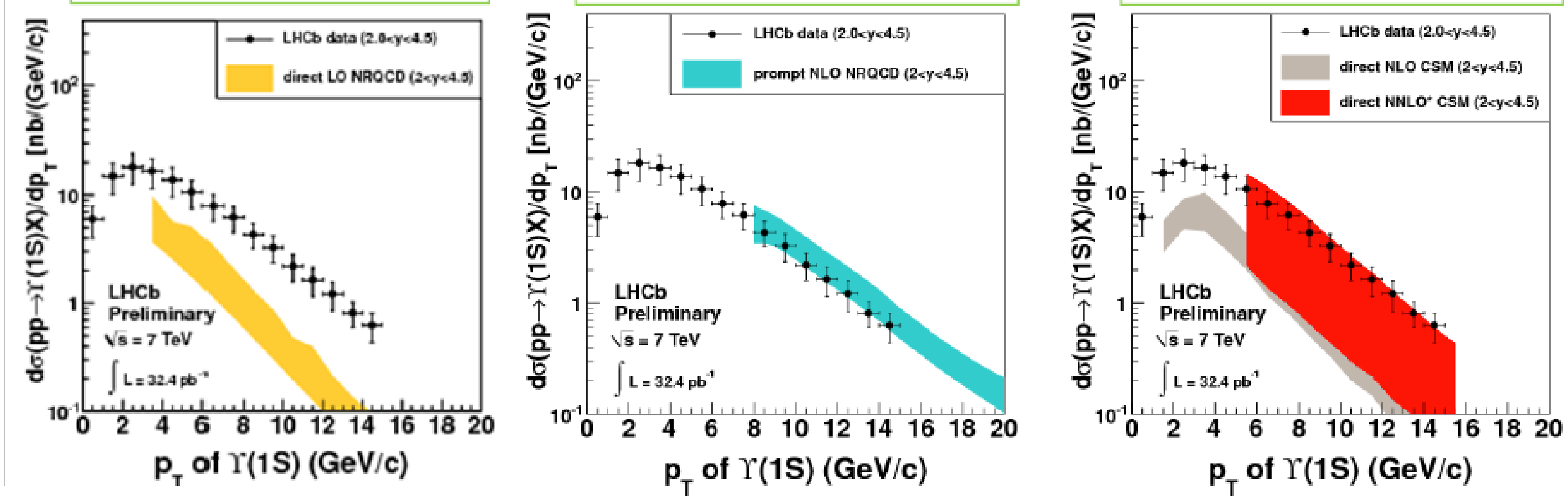
- Large systematic effect on efficiency due to unknown Υ(1S) polarization
- Comparison $d\sigma/dp_T$ in good agreement with Theory (LO model only direct Υ(1S)).

$$\sigma(0 < p_T < 15\,\mathrm{GeV/c}, 2 < y < 4.5) = 108.3 \pm 0.7\Big|_{\mathrm{stat}} {}^{+30.9}_{-25.8}\Big|_{\mathrm{sys}}\ \mathrm{nb}$$

PoS ICHEP 2010 (2010) 192

K. Wang, Y. Q. Ma, K. T. Chao

arXiv:0806.3282 [hep-ph]
arXiv:0811.4005 [hep-ph]

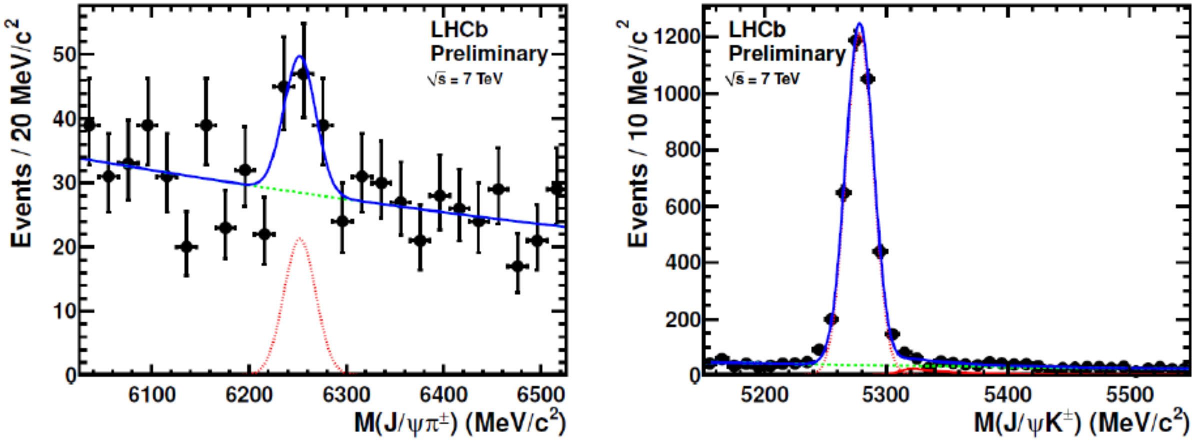


B_c^+ to B^+ production cross-section ratio

- B_c^+ is the lightest heavy quark meson. Its mass, lifetime and production can be used to constrain QCD calculation.
- Use $B_c^+ \to J/\psi\pi+$ and $B^+ \to J/\psi K+$
- BR of B_c^+ not known, measure σ*BR

$$R_{c+} = \frac{\sigma(B_c^+)\times BR(B_c^+ \to J/\psi\pi^+)}{\sigma(B^+)\times BR(B^+ \to J/\psi K^+)} = \frac{N(B_c^+ \to J/\psi\pi^+)}{\varepsilon_{tot}^c} \times \frac{\varepsilon_{tot}^+}{N(B^+ \to J/\psi K^+)}$$

Signal shape: Gaussian.
Combinatorial Background shape: exponential.
Cabibbo suppressed $B^+ \to J/\psi\ \pi^+$ shape: double Crystal Ball.



$$R_{c+} = \frac{\sigma(B_c^+)\times BR(B_c^+ \to J/\psi\pi^+)}{\sigma(B^+)\times BR(B^+ \to J/\psi K^+)} = (2.2 \pm 0.8|_{stat} \pm 0.2|_{sys})\%$$

LHCb measured in fudical region

$$R_{c^+}^{\text{model-dependant}} = (1.4 \pm 0.4|_{stat} \pm 0.1|_{sys})\%$$

BCVEGPY hep-ph/0604238

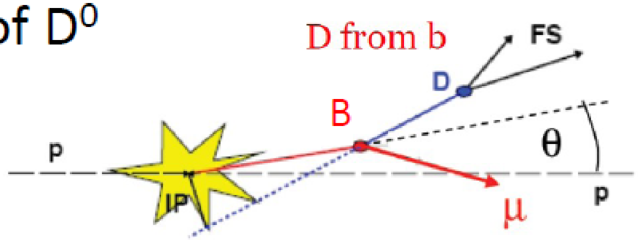
b production cross-section $\sigma(pp \rightarrow b\bar{b}X)$

- $b \longrightarrow D^0 X \mu \nu_\mu$
- $b \longrightarrow J/\psi X$

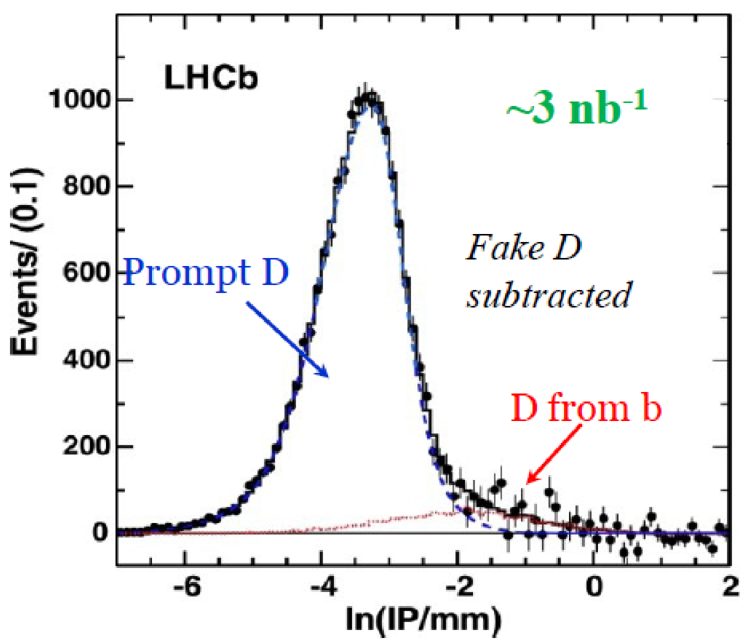
$b \to D^0 X \mu \nu_\mu$

Vertex $D^0(\to K\pi)$ with right-sign μ, cut on Impact Parameter (IP) of μ then distinguish prompt D^0 and D^0 from B using IP of D^0

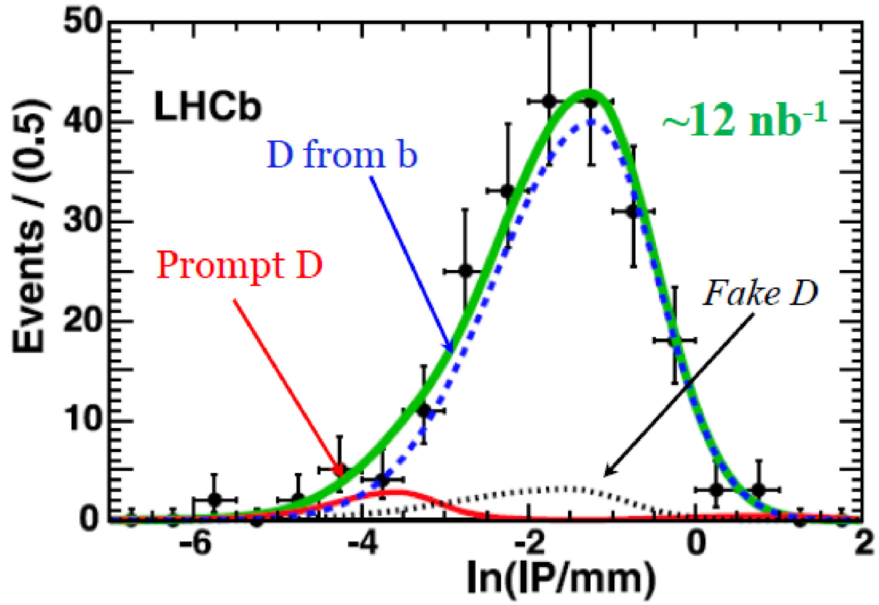
Two independent samples used: $3\,nb^{-1}$ taken with unbiased trigger, and $12\,nb^{-1}$ requiring single muon trigger



IP D^0 (NO μ requirement)



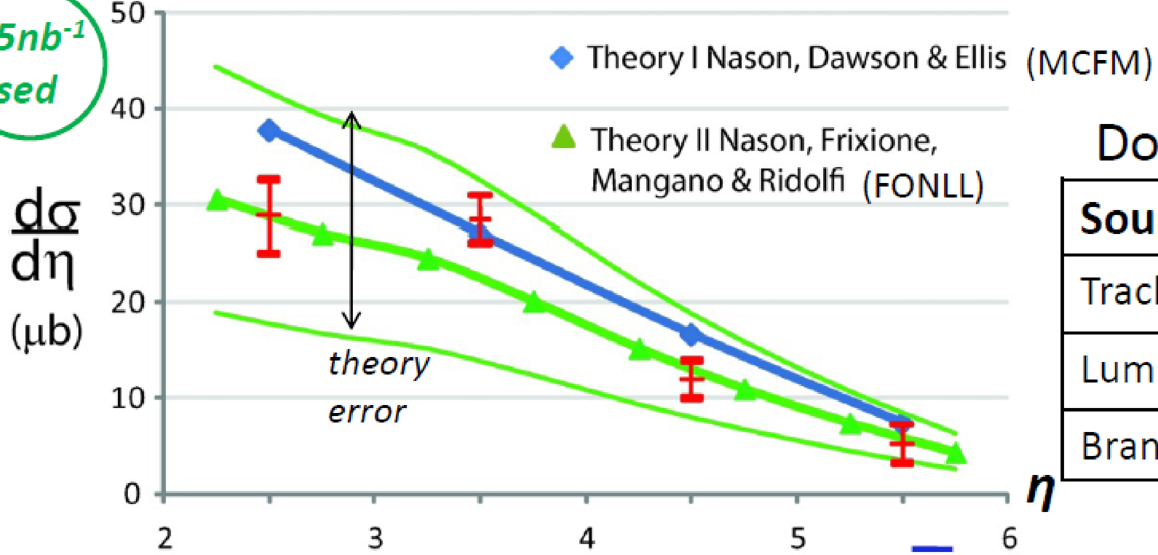
IP of D^0 (μ required)



$b \to D^0 X \mu \nu_\mu$

Use: $$\sigma(pp \to H_b X) = \frac{\#\text{ of detected } D^0\mu^- \text{ and } \overline{D}^0\mu^+ \text{ events}}{2\mathcal{L} \times \text{efficiency} \times \mathcal{B}(b \to D^0 X \mu^- \overline{\nu})\mathcal{B}(D^0 \to K^-\pi^+)}$$

15nb^{-1} used



Dominant systematics

Source	Size
Tracking efficiency	10%
Luminosity	10%
Branching/frag. fractions	8%

For $2 < \eta < 6$ (measured): $\sigma(pp \to b\overline{b}X) = (75.3 \pm 5.4_{(stat)} \pm 13.0_{(syst)})\ \mu b$

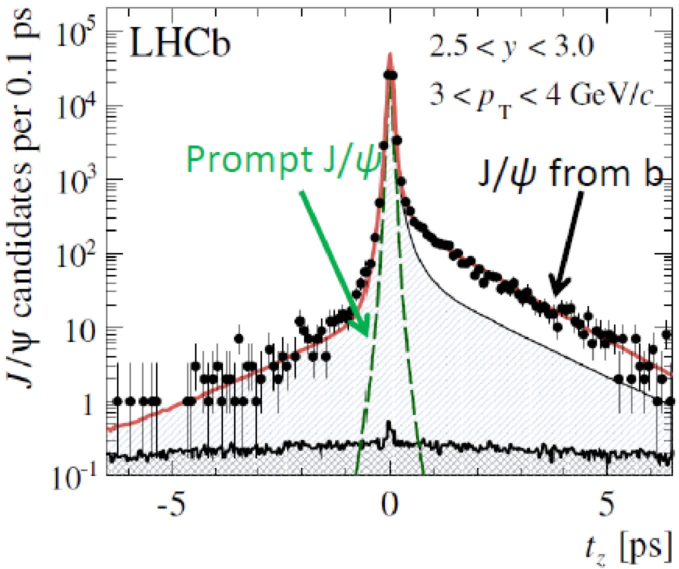
Extrapolate to 4π *(using Pythia)*: $\boxed{\sigma(pp \to b\overline{b}X) = (284 \pm 20 \pm 49)\ \mu b}$

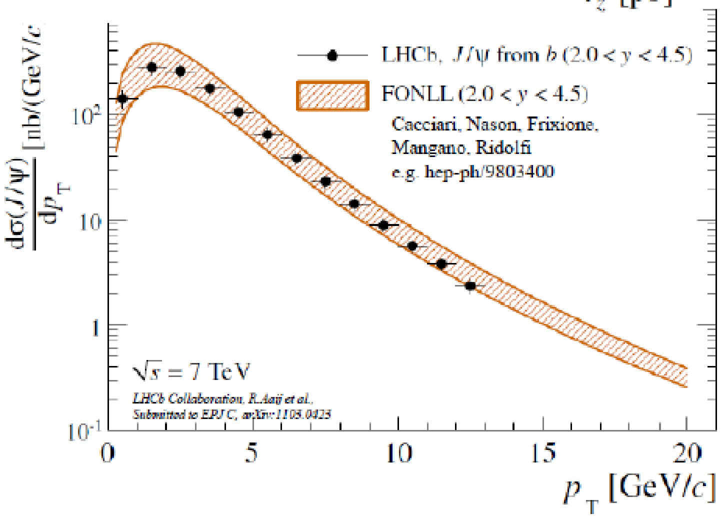
Using TeVatron (instead of LEP) fragmentation fractions gives: $\boxed{\sigma(pp \to b\overline{b}X) = (338 \pm 24 \pm 58)\ \mu b}$

(increase of 19%)

*Published in Phys. Lett. **B 694**, 209 (2010)*

b → J/ψX





Reconstruct $J/\psi \to \mu\mu$, using both single muon and dimuon triggers

Fit to pseudo-proper time,
$t_z \equiv (z_{J/\psi} - z_{PV}) \times M_{J/\psi} / p_z$ in bins of p_T and y

Dominant systematics:

Source	Size
Tracking efficiency	8%
Luminosity	10%
B.R.($b \to J/\psi X$)	9%

5.2pb^{-1} used

$\boxed{\sigma(pp \to b\bar{b}X) = (288 \pm 4 \pm 48)\ \mu b}$

(with LEP fragmentation fractions, 2% change when using TeVatron fractions is included in syst. error)

*Submitted to Eur. Phys. J **C***

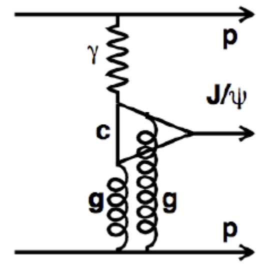
Preprint: hep-ex/1103.0423

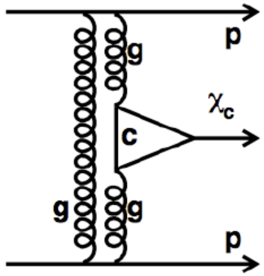
(also prompt J/ψ cross section)

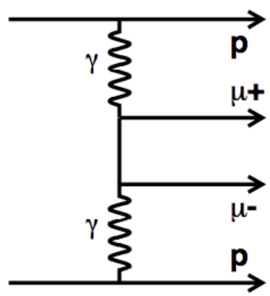
Central exclusive production of $\mu^+\mu^-$

Exclusive processes

- Exclusive $J/\psi \rightarrow \mu^+\mu^-$ and $\psi(2S) \rightarrow \mu^+\mu^-$
  - photon-pomeron fusion
  - **Starlight**: Models diphoton and photon pomeron fusion (S.R.Klein and J.Nystrand, Phys. Rev. Lett. 92 (2004) 142003).
- Exclusive $\chi_c \rightarrow \mu^+\mu^-\gamma$
  - double pomeron exchange
  - **SuperChiC**: MC for central exclusive production
  - (L.A. Harland-Lang, V.A. Khoze, M.G. Ryskin, W.J. Stirling, arXiv:0909.4748 [hep-ph].).
- Exclusive $\gamma\gamma \rightarrow \mu^+\mu^-$
  - Produced by $\gamma\gamma$ fusion
  - **LPAIR**: Models EM production of lepton pairs
  - (A.G.Shamov and V.I.Telnov, NIM A 494 (2002) 51).







Elastic Signal

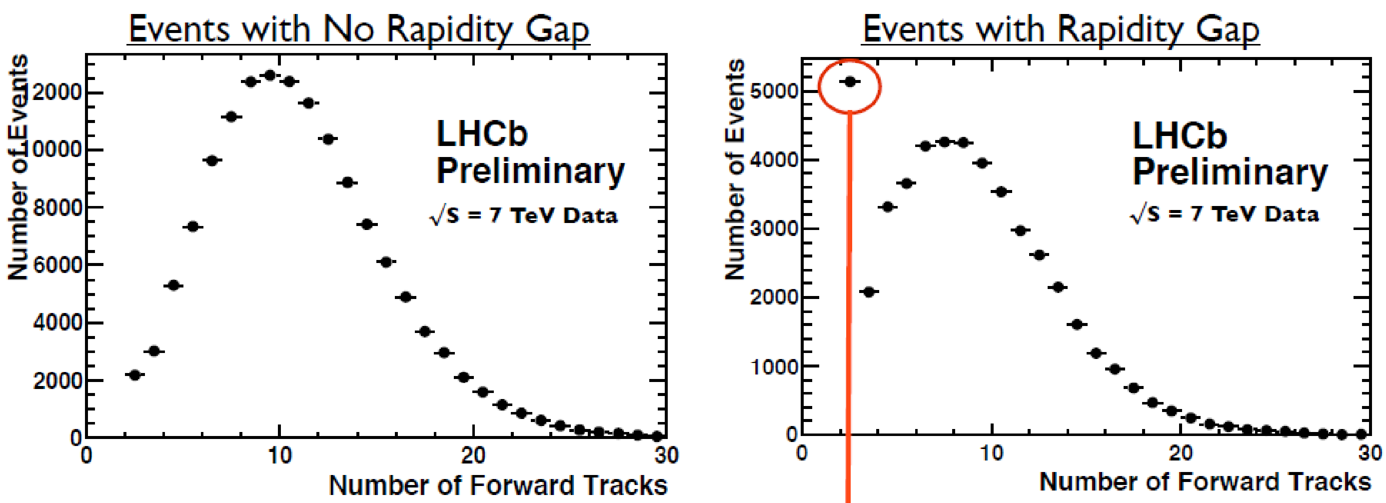
- Both protons remain intact
- Rapidity gaps
- p_T of central object small

Inelastic background

- Proton(s) dissociation
- Smaller rapidity gaps
- p_T of central object higher that fo signal

Exclusive trigger selection

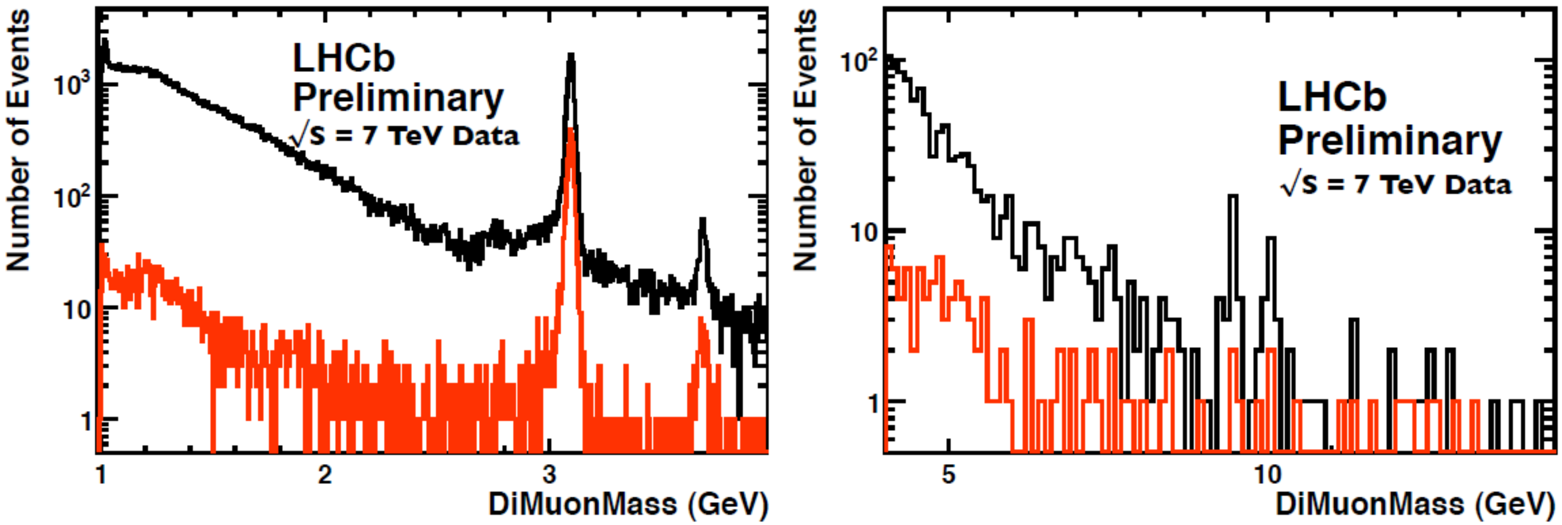
- Dedicated trigger lines
  - low track multiplicity (SPD hits < 20)
  - Presence of $\mu^+\mu^-$ with low dimuon p_T or high invariant mass
  - Effective int Lumi ~ 3 pb^{-1} out of 36 pb^{-1}
- Use VELO Backward Tracking to identify Rapidity gaps (2 units of rapidity)



Clear peak at 2 Forward Tracks when rapidity gap requested
Candidates for Exclusive production

Exclusive $\mu^+\mu^-$ invariant mass

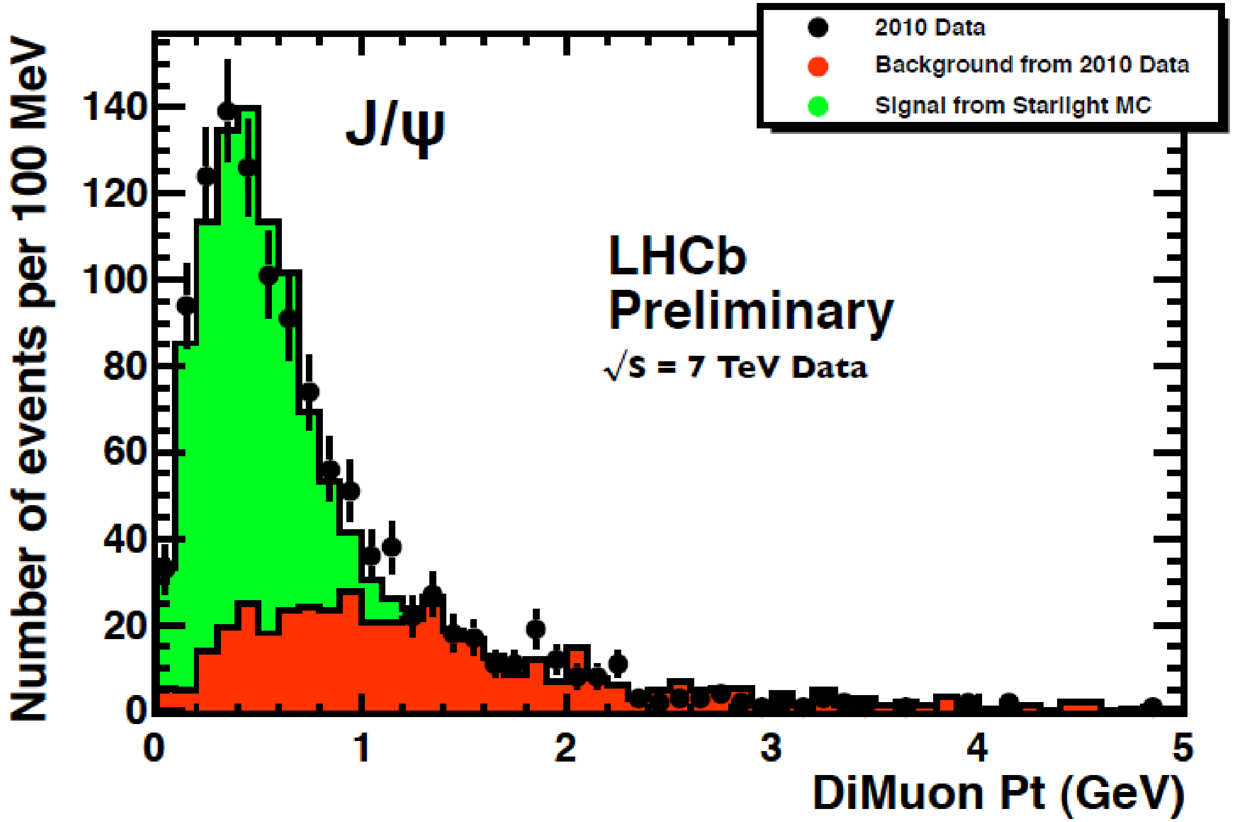
- $\mu^+\mu^-$ mass spectrum for events passing trigger
- + no backward tracks + 2 forward fracks



Exclusive J/ψ, $\psi(2S)$, $\gamma\gamma \to \mu^+\mu^-$ candidates clearly seen

Exclusive J/ψ, $\psi(2S)$

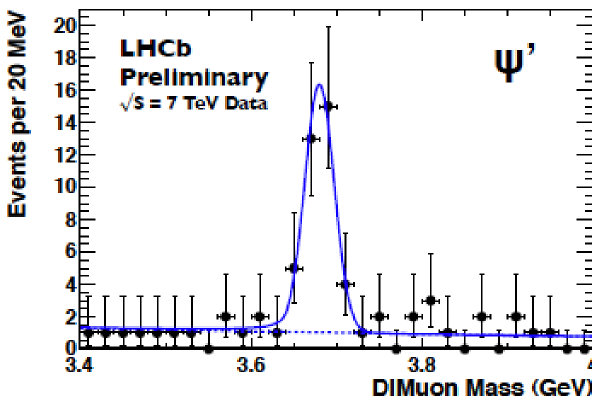
- Inelastic Background Pt Shape obtained from Data (no backward tracks, no photons and >2 Forward Tracks)
- Elastic Signal Pt Shape taken from Starlight MC and full LHCb simulation

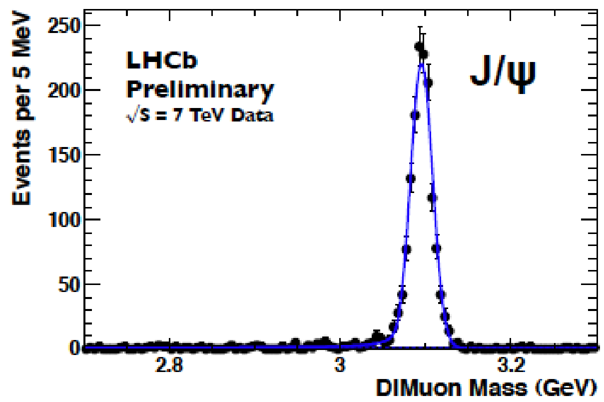


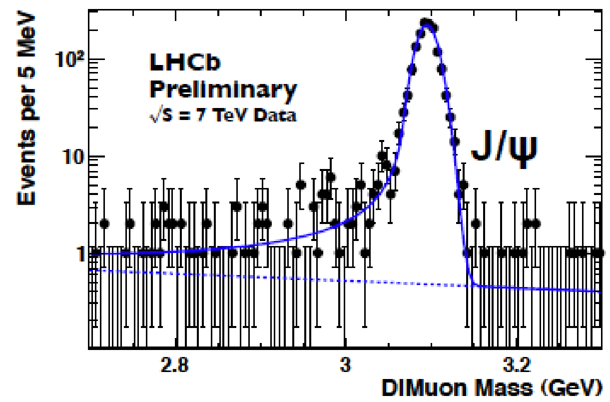
- For JPsi Pt < 900 MeV the Inelastic Background is estimated to be 20 +/- 3%

Mass distributions

- Non Resonant backgrounds from DiPhoton DiMuons or MisIdentified Pions and Kaons



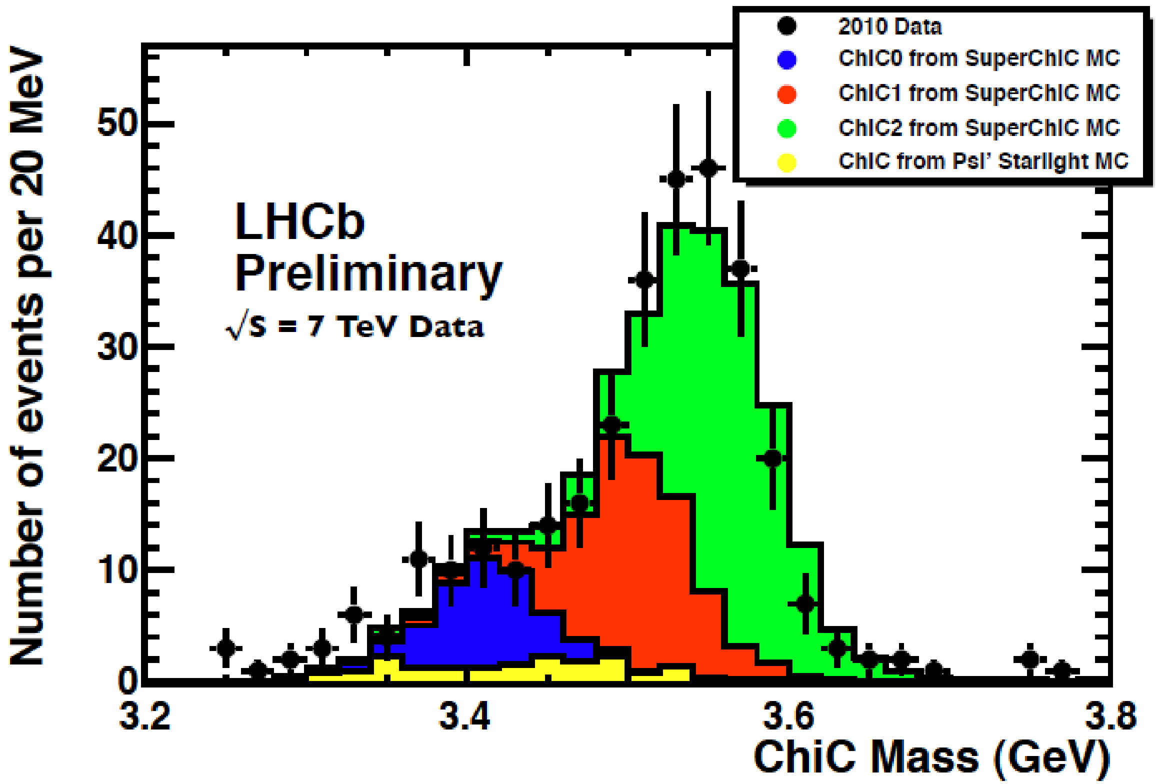




- 40 Events between 3.615 and 3.745 GeV (Non Resonant Background = 16%)
- 1468 Events between 3.035 and 3.165 GeV (Non Resonant Background = 0.8%)

Exclusive χ_c

- Shapes for ChiC0, ChiC1 and ChiC2 taken from SuperChiC MC + Full LHCb simulation
- Shape for Psi' taken from Starlight MC + full LHCb simulation



<u>Offline selection</u>

Mass within 65 MeV of PDG value
No backward tracks
2 forward tracks + 1 γ
$p_T(\mu\mu)$< 900 MeV

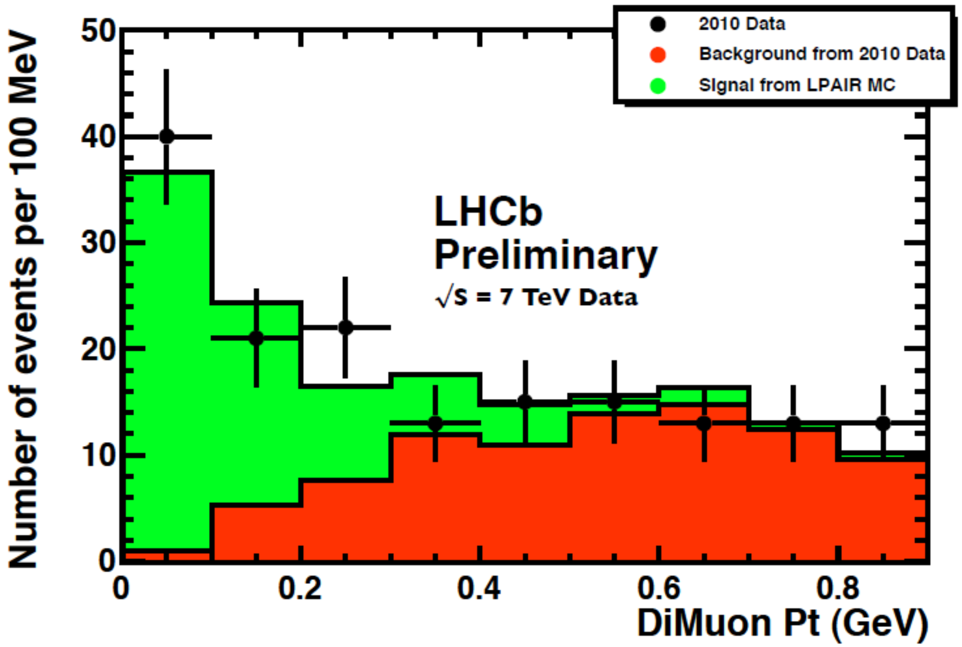
- Ratio of ChiC0 :ChiC1 : ChiC2 is 1 : 2.2 +/- 0.8 : 3.9 +/-1.1

$\gamma\gamma \to \mu^+\mu^-$

Offline selection

$M_{\mu\mu}$ > 2.5 GeV
Cut out *J/ψ, ψ(2S) area*
No backward tracks, no photons
$p_T(\mu\mu)$< 100 MeV

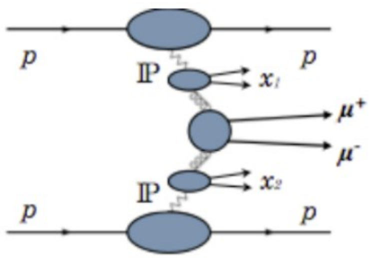
- Inelastic Background Pt Shape obtained from Data (no backward tracks, no photons and >2 Forward Tracks)
- Elastic Signal Pt Shape taken from LPAIR MC and full LHCb simulation



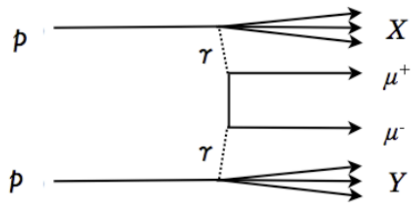
- For DiMuon Pt < 100 MeV there is a Signal Purity of 97 +/- 1%

Background considered

Double Pomeron Exchange
Generated with POMWIG



$\gamma\gamma$ process
Generated with LPAIR



Cross-sections

Experimental Results			Theory Predictions
$J/\psi \to \mu^+\mu^-$:	474 +/- 103 pb	$\longrightarrow$	292 pb (Starlight) 330 pb (SuperChic) 330 pb (Motyka&Watt) 710 pb (Schafer&Szczurek)
$\psi' \to \mu^+\mu^-$:	12.2 +/- 3.2 pb	$\longrightarrow$	6.1 pb (Starlight) 17 pb (Schafer&Szczurek)
$\chi_0 \to \mu^+\mu^-\gamma$:	9.3 +/- 4.5 pb	$\longrightarrow$	14 pb (SuperChic)
$\chi_1 \to \mu^+\mu^-\gamma$:	16.4 +/- 7.1 pb	$\longrightarrow$	10 pb (SuperChic)
$\chi_2 \to \mu^+\mu^-\gamma$:	28 +/- 12.3 pb	$\longrightarrow$	3 pb (SuperChic)
$\gamma\gamma \to \mu^+\mu^-$:	67 +/- 19 pb	$\longrightarrow$	42 pb (LPAIR)

- Large Theoretical uncertainties (Except DiPhoton DiMuon prediction, uncertainty ~ 1%)
- Predictions contain Rescattering Corrections (Extra strong Interaction between protons alters cross-section by ~20%)
- Results are consistent with predictions

Examples CP and New Physics results

Direct CP violation in $B_s \to K^- \pi^+$

- Production asymmetry
  - Controlled from $B^\pm \to J/\Psi K^\pm$ (A_P=-0.024±0.016).
- Detector asymmetry
  - Magnet up/down with D^* and $D^0 \to K\pi$ (A_D=-0.004±0.004)

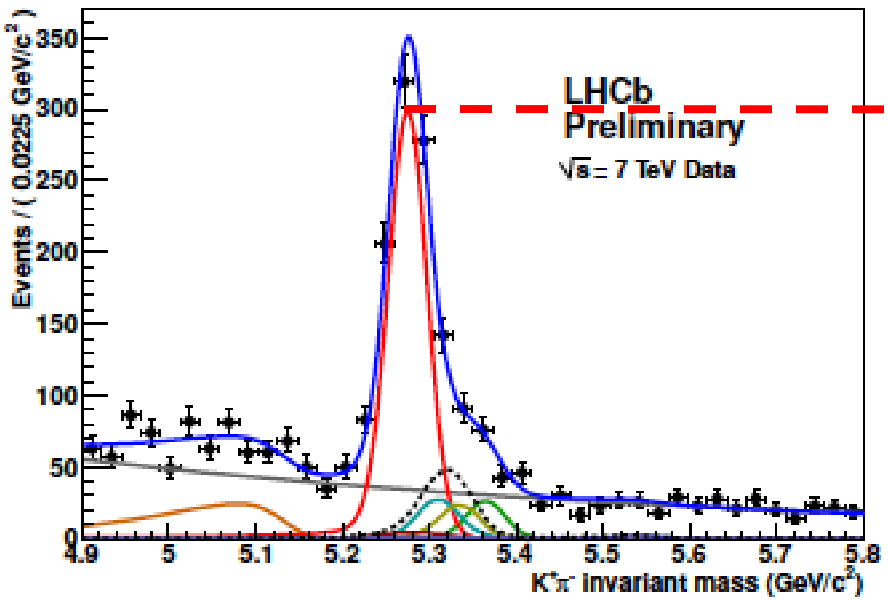
$$A_{CP}(B^0 \to K^+\pi^-) = -0.074 \pm 0.033 \pm 0.008$$

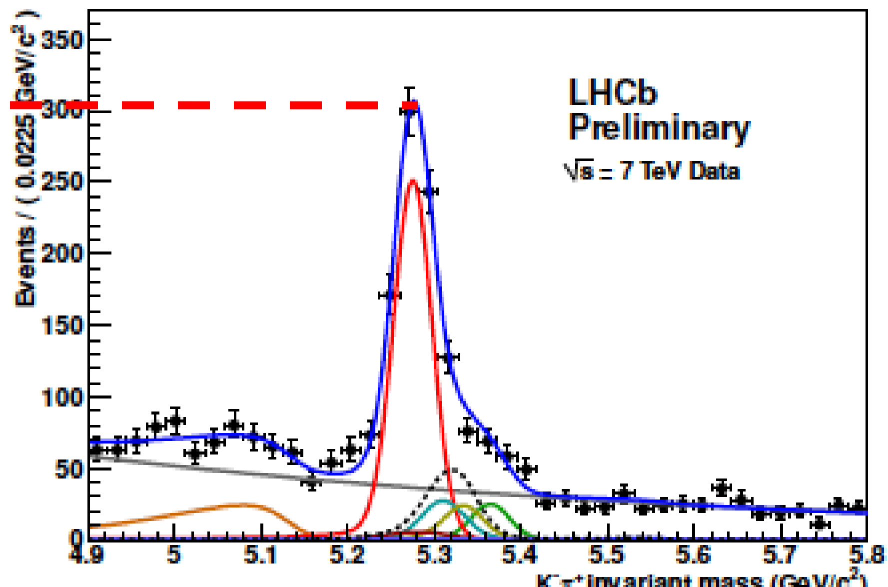
$$\boxed{A_{CP}(B_s^0 \to \pi^+K^-) = 0.15 \pm 0.19 \pm 0.02.}$$

HFAG average:

$$A_{CP}(B^0 \to K^+\pi^-) = -0.098^{+0.012}_{-0.011}$$

$$A_{CP}(B_s^0 \to \pi^+K^-) = 0.39 \pm 0.17$$

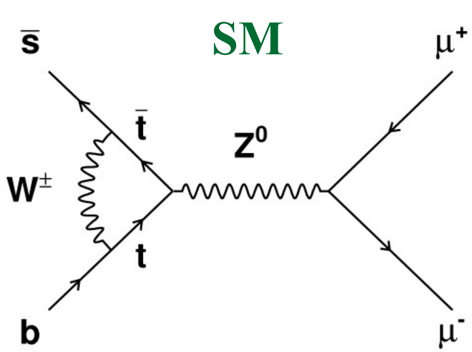


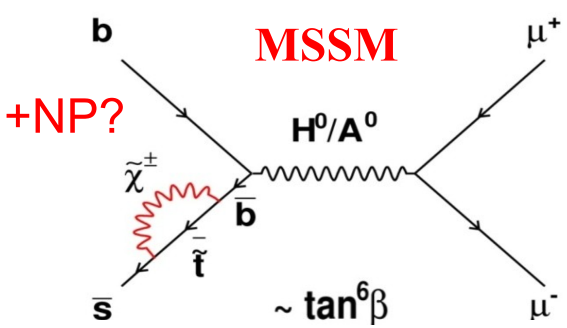


New Physics in $B_{s,d} \rightarrow \mu^+\mu^-$

$B_{s,d} \to \mu^+\mu^-$

- $B_{d,s} \to \mu\mu$ the super rare loop decay. In Standard Model:
  - $B(B_d \to \mu\,\mu) = (0.10 \pm 0.01)\times 10^{-9}$
  - $B(B_s \to \mu\,\mu) = (3.2 \pm 0.2)\times 10^{-9}$
- Sensitive to New Physics
  - can be strongly enhanced in SUSY with scalar Higgs exchange
    - however lower rate predicted with some models
  - sensitive probe for MSSM with large tanβ: $B(B_S \to \mu^+\mu^-) \sim \tan\beta^{\,6} / M_A^{\,4}$





$B_{s,d} \to \mu^+\mu^-$

Soft selection:

(pairs of opposite charged muons with high quality tracks, making a common vertex very displaced with respect to the PV and $M_{\mu\mu}$ in the range [4769-5969] MeV/c^2)

1) Keeps high efficiency for signals:

After selection **$B_s(B_d) \to \mu\mu$ events expected (if BR=BR(SM)): 0.3 (0.04)**

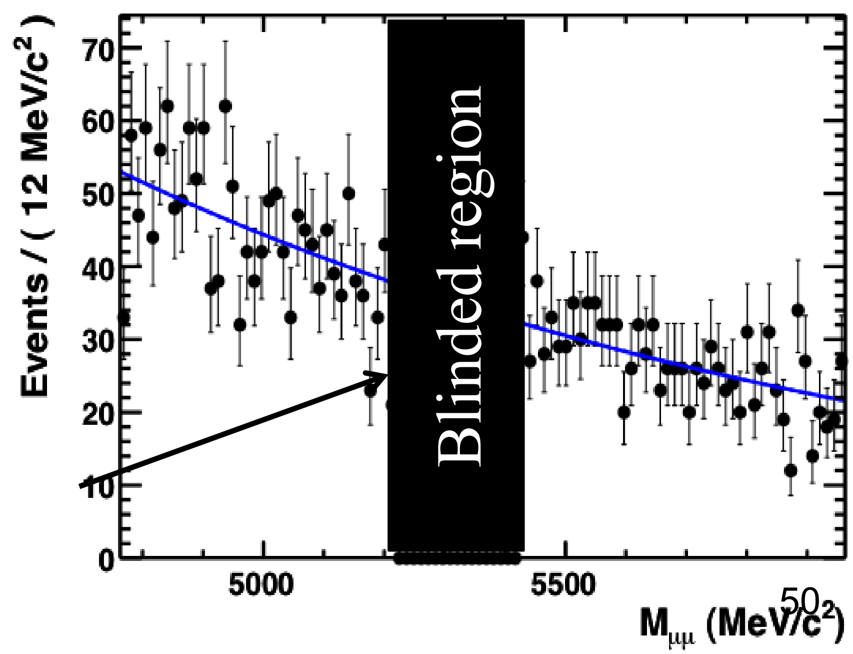
3) Rejects most of the background

→ ~ 3000 background events in the large mass range [4769-5969] MeV/c^2

~ 300 background events in the signal windows

$M(B_{s,d}) \pm 60$ MeV

Signal regions blinded up to the analysis end

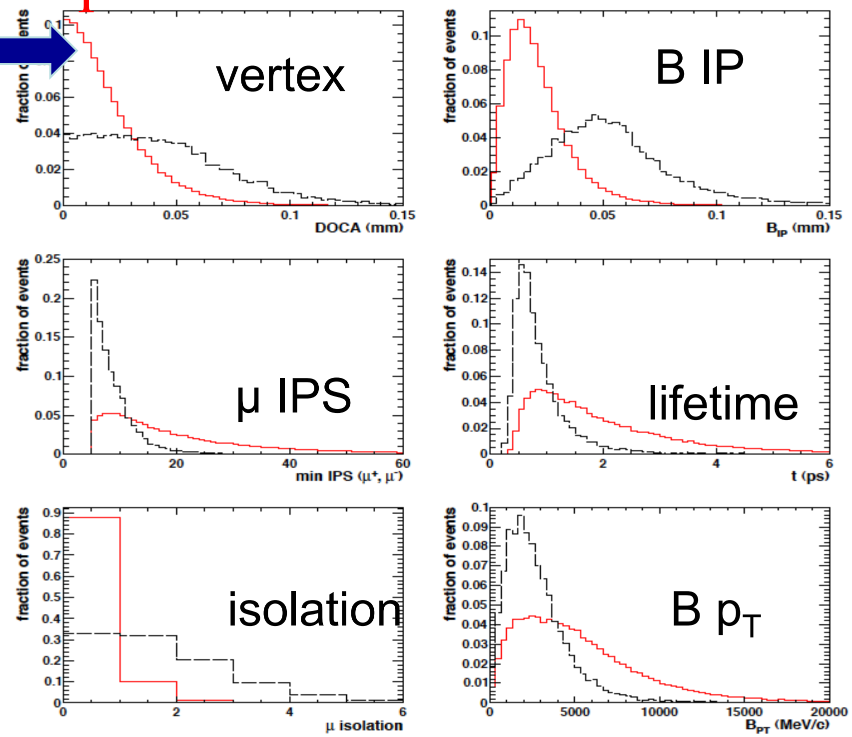


Geometrical Likelihood (GL)

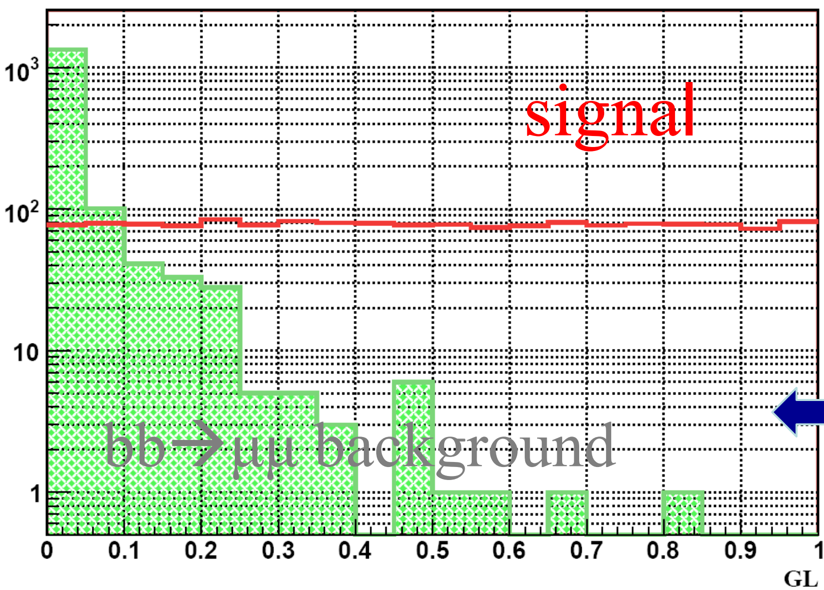
Our main background is combinatorial background from two real muons:

→ reduce it by using variables related to the "geometry" of the event: (vertex, pointing, μ IPS, lifetime, mu-isolation) + p_T of the B

Input Variables to the GL



Geometrical Likelihood (MC)

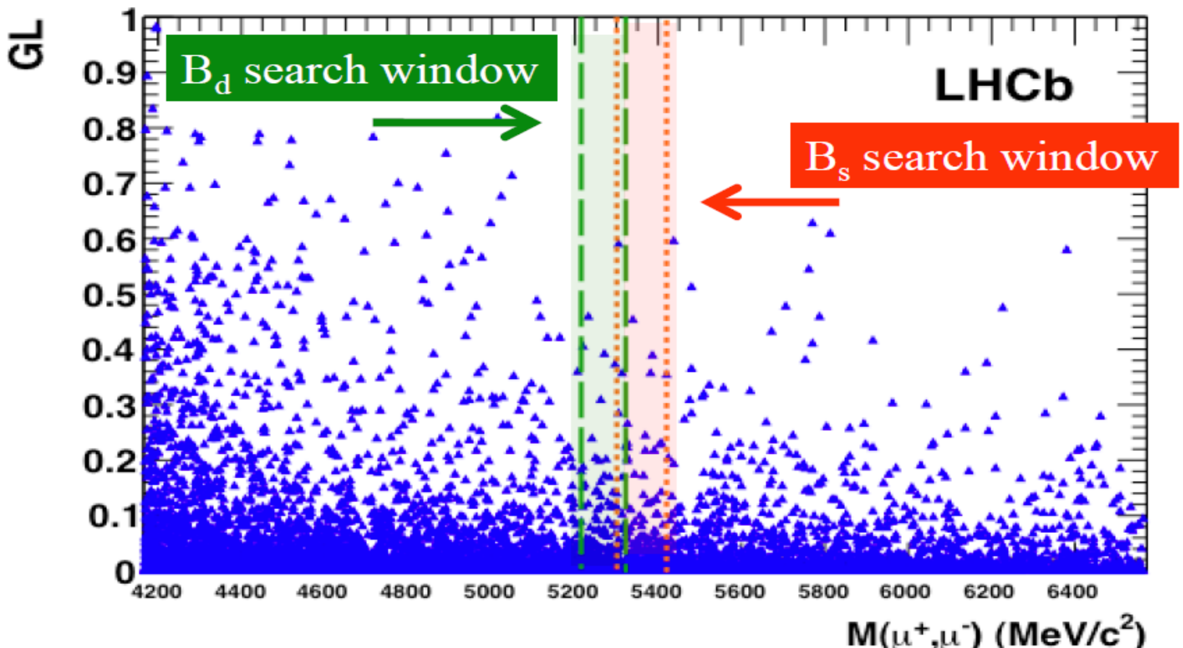


Variables are decorrelated and a Multi Variate Variable is built:

→ flat for signal

→ peaked at zero for background

Look inside the box….



1) count the events in the 4 GL bins and 6 mass bins,
2) compare observed events with the expected number of signal and background events

LHCb 38 pb^{-1}

$BR(B_s \to \mu^+\mu^-) < 4.3\ (5.6)\ 10^{-8}$ @ 90 (95% CL)

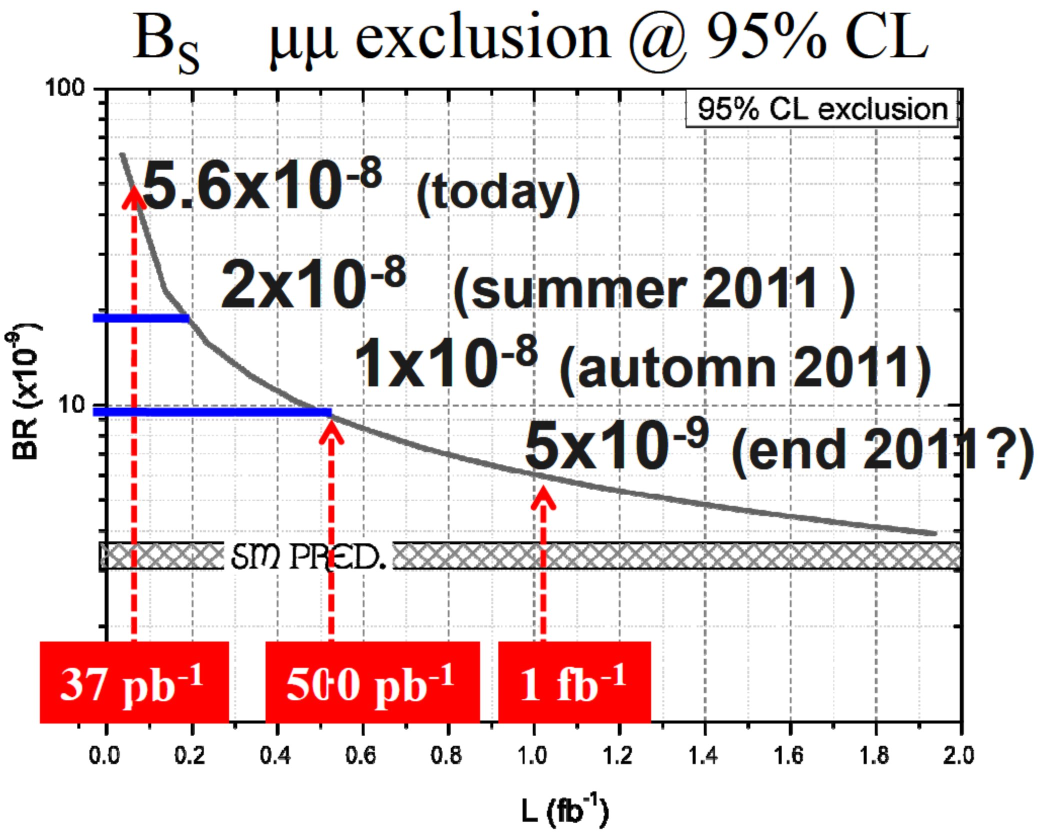
$BR(B^0 \to \mu^+\mu^-) < 1.2\ (1.5)\ 10^{-8}$ @ 90 (95% CL)

Already now competitive to worlds best limit (not published, CDF 3.7 fb^{-1}):

$BR(B_s \to \mu^+\mu^-) < 3.6\ (4.3)\ 10^{-8}$ @ 90 (95% CL)
$BR(B^0 \to \mu^+\mu^-) < 0.76\ (0.91)\ 10^{-8}$ @ 90 (95% CL)

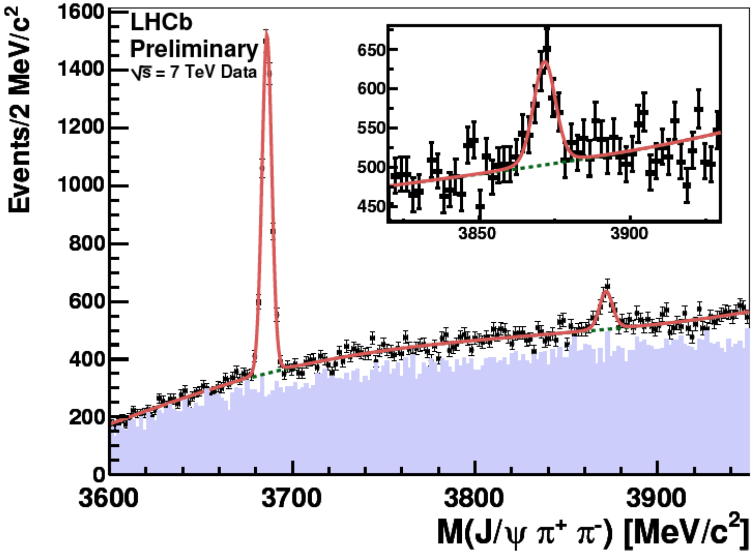
Physics Letters B 699 (2011) 330-340.

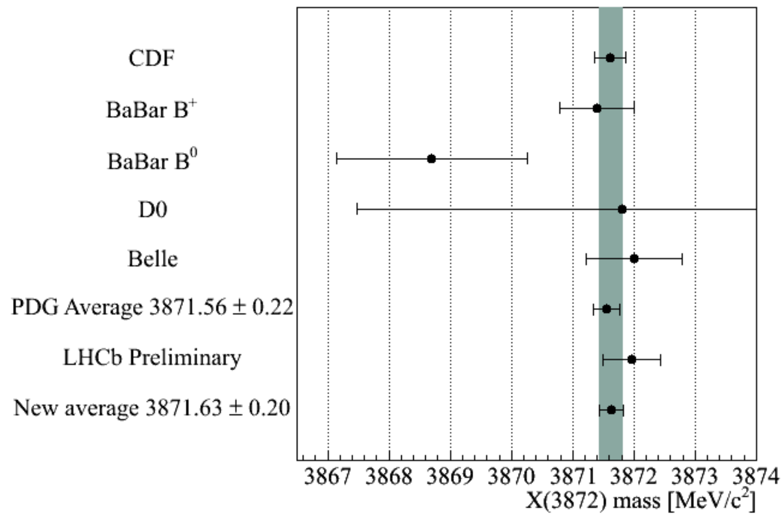
$B_s \to \mu\mu$: LHCb reach in 2011



With the data collected in 2011 we will be able to explore the very interesting region of BR~ 10^{-8} and below

Exotic meson spectrocopy: Mass X(3872)





$$M_{X(3872)} = 3871.96 \pm 0.46 \pm 0.10 \text{ MeV}/c^2$$

- Exotic charmonium state, discovered by Belle
  - $\eta_{c2}(1D)$ but X mass too high ?
  - $D^{*0}\bar{D}^0$ molecule ?
  - tetra-quark ?

Key analysis element:
Momentum calibration using J/Ψ
Cross-check ϒ,D^0,K_s

LHCb-CONF-2011-021

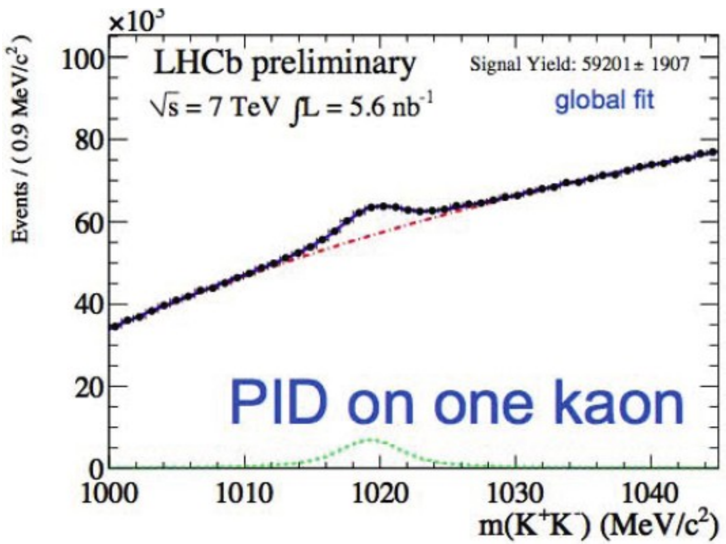
Summary

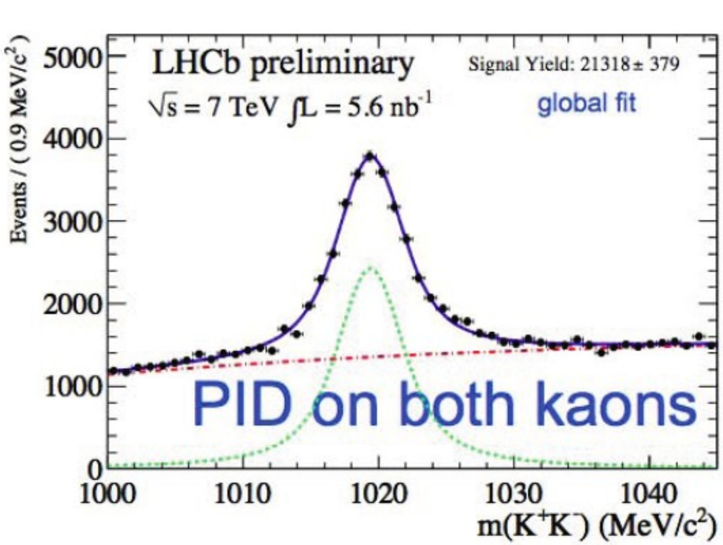
- The LHCb experiment provides lots of high quality measurements.
- The main LHCb goals is to search for new physics (rare decays and quantum loop processes) and standard CPV measurements.
- High quality of the detector enabled to perform many valuable QCD measurements (main part of this presentation)
- Most results from 2010 with 38 pb^{-1}. Many new and updated results to be released this summer for data collected in 2011 (300 pb^{-1} already on tape, 1fb^{-1} expected for the entire 2011)

Backup slides

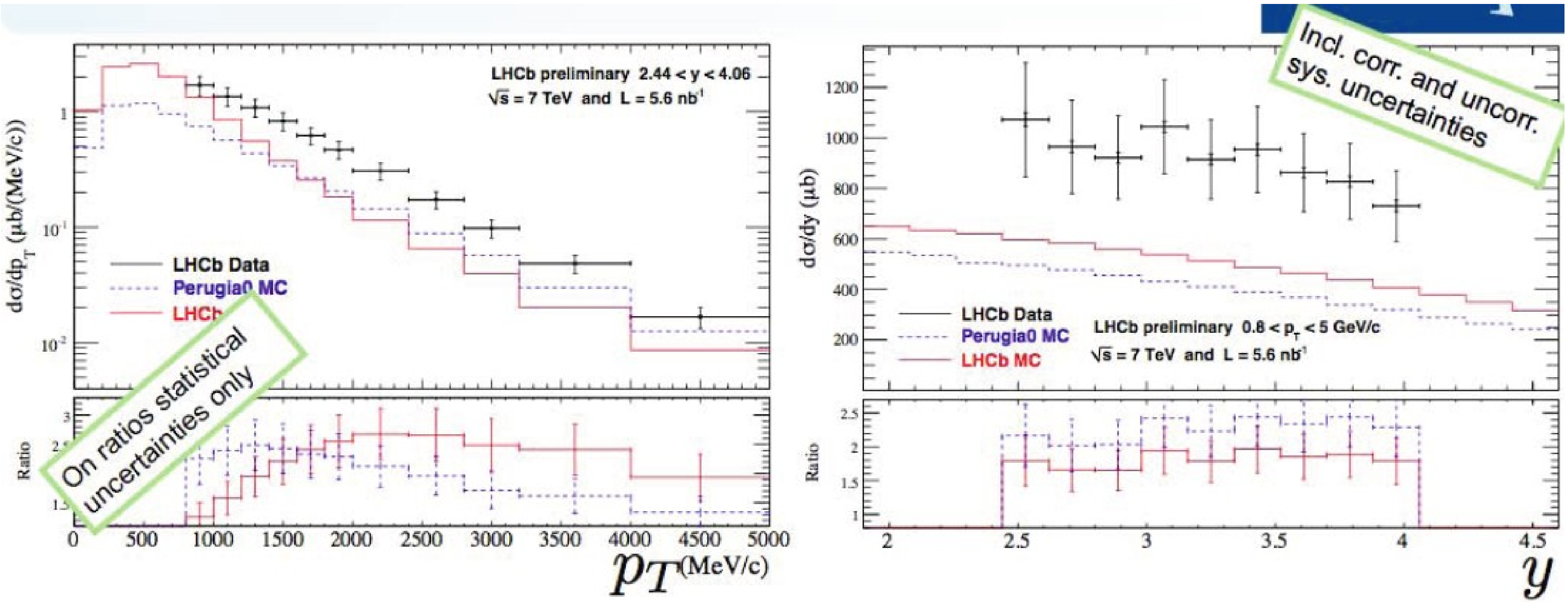
Inclusive ϕ production

- 5.6 nb^{-1} at 7 TeV
- Minimum bias trigger.
- PID important:
  - eff determined from tag and probe method.
  - Independent PID calibration of two magnet polarities and independent analysis
- Signal: Breit-Wigner shape * Gaussian resolution
- Background: polynomial





Inclusive ϕ production - preliminary results



- summed cross section:

$$\sigma(pp \to \phi X) = (1493 \pm 12(\text{stat}) \pm \underbrace{12(\text{uncorr.syst})}_{\text{bin-dependent}} \pm \underbrace{209(\text{corr.syst})}_{\text{global}})\ \mu\text{b}$$

- MC generator underestimates ϕ production

$y \in [2.44, 4.06]$

$p_T \in [0.8, 5.0]$ GeV/c