Heavy Flavour Production and Spectroscopy at LHCb

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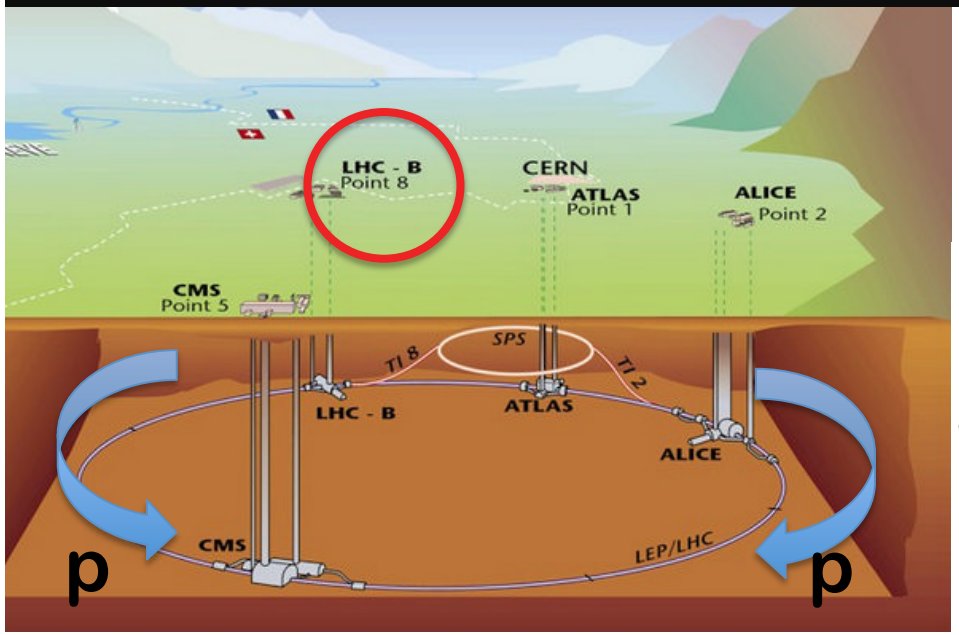
Rencontres de Blois, Blois (FR), 30th May 2012

Outline

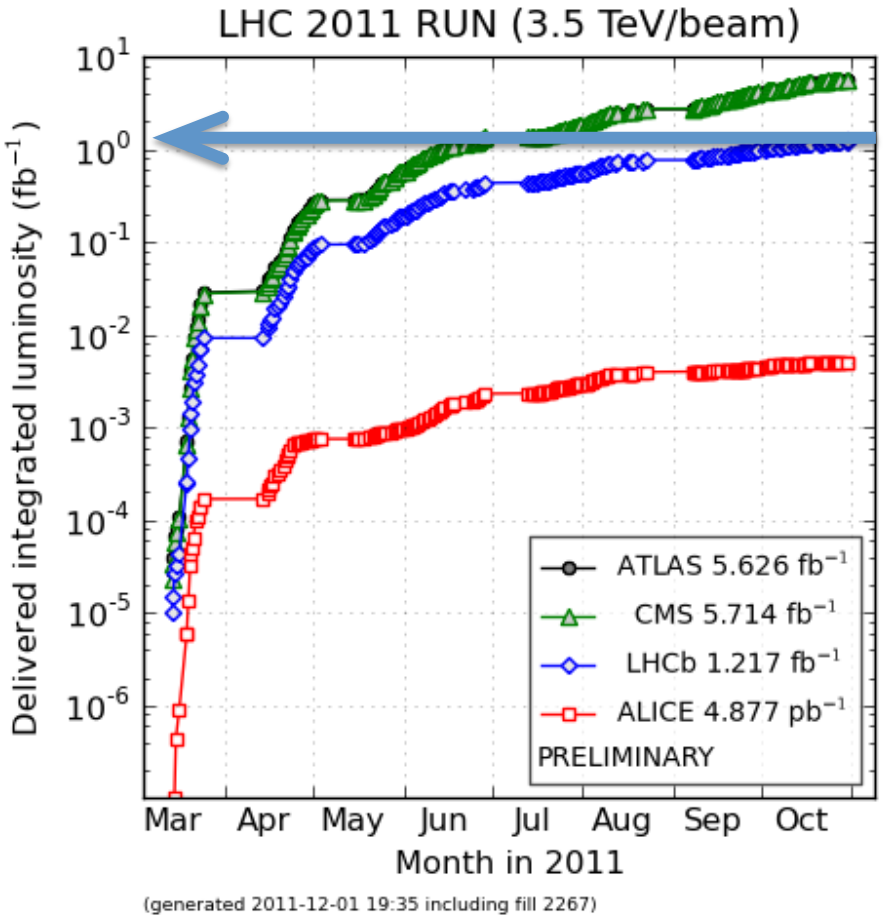
- The LHCb Detector
- Theory and motivation
- Selected results
  - B hadrons
  - Quarkonium
  - Exotic spectroscopy
- Conclusions and outlook

LHC and LHCb



pp collider : 2010-2011:

- @ √s = 7 TeV
- L = 40 pb^{-1} – 1.1 fb^{-1}



pp collider : NOW (2012) :

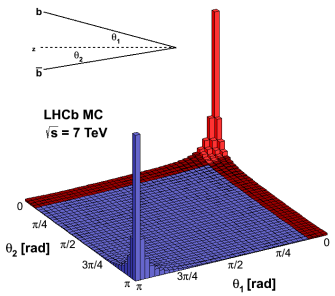
- @ √s = 8 TeV
- Goal: 1.5 fb^{-1}

Uncertainty on Luminosity in these analyses : 3.5%
(*J. Instrum.* 7 (2012) P01010)

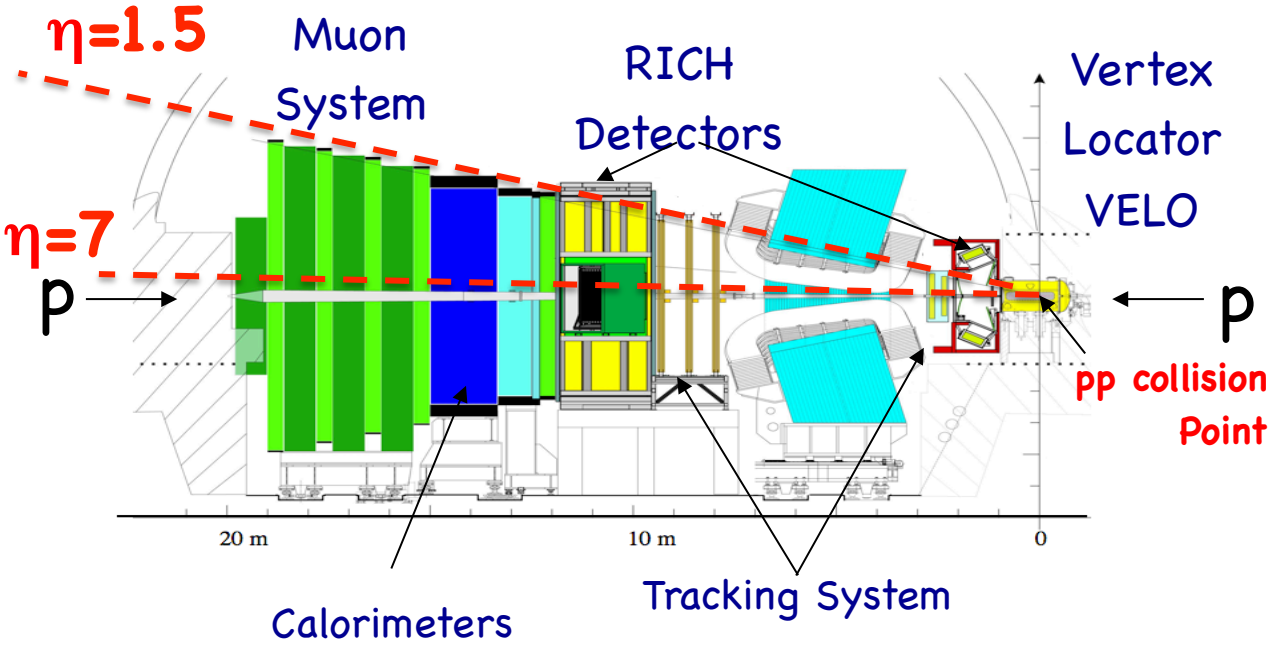
The LHCb detector

JINST 3 (2008) S08005

Angular acceptance : $10<\theta<300$ mrad



σ_{bb}=0.3 mb,
25% in acceptance



Trigger : three levels, first hardware, two software

- Performance numbers relevant to these analyses:
  - Charged tracks $\Delta p/p$ = 0.35 % - 0.55%, $\sigma(m)$=10-25 MeV/c^2
  - ECAL $\sigma(E)/E$= 10% $(E/GeV)^{-1/2} \oplus$ 1 %
  - Muon ID: $\varepsilon(\mu\to\mu)$ = 97%, mis-ID rate $(\pi\to\mu)$ = 1-3 %
  - Vertexing: proper time resolution 30-50 fs

possibility to reverse field polarity to check for detector

Heavy Flavour Physics at LHCb

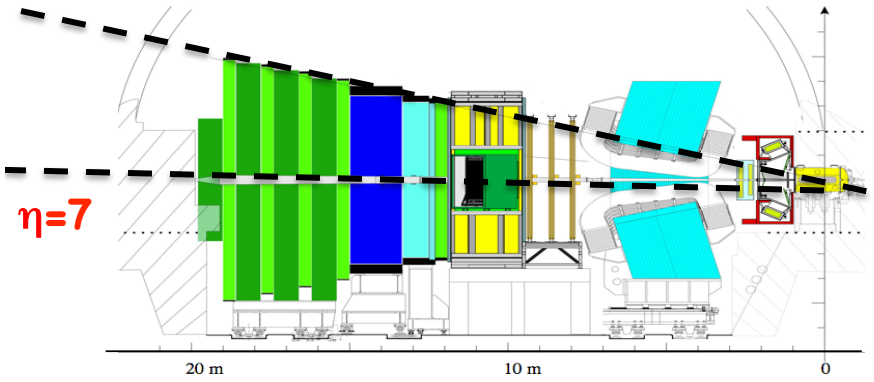
- Heavy flavour rates high at LHCb

$$\sigma(c\bar{c})_{2<y<6} = 1742 \pm 267 \quad \mu b \qquad \text{(LHCb-CONF-2010-013)}$$

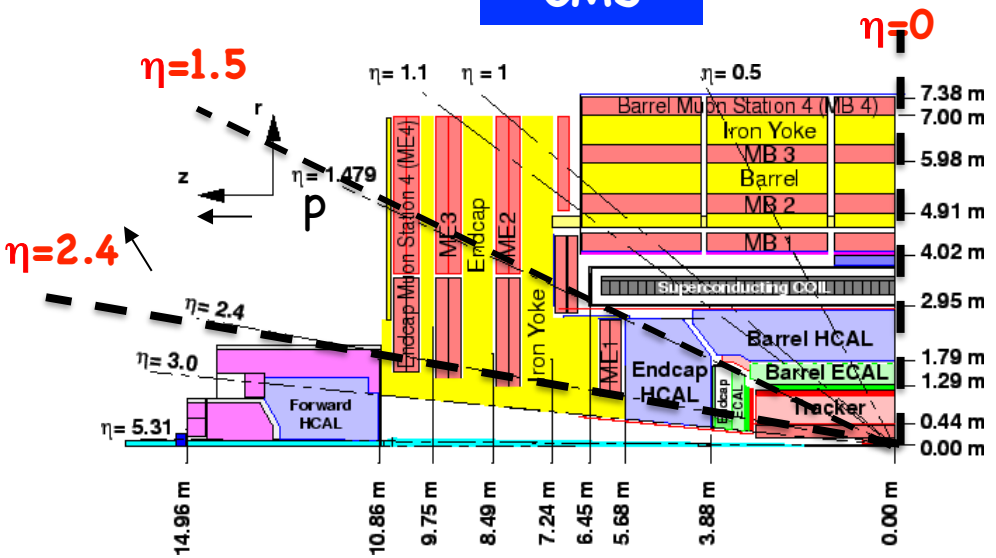
$$\sigma(b\bar{b})_{2<y<6} = 75.3 \pm 5.4 \pm 13.0 \quad \mu b \qquad \text{(Phys.Lett.B 694 (2010), 209)}$$

  - Quarkonium and B-hadrons production processes are powerful tests of perturbative and non-perturbative QCD models, exotic spectroscopy sheds light on underlying model
  - Due to the unique coverage of LHCb, results are complementary to Atlas and CMS and essential for a uniform picture

LHCb



CMS



B hadrons

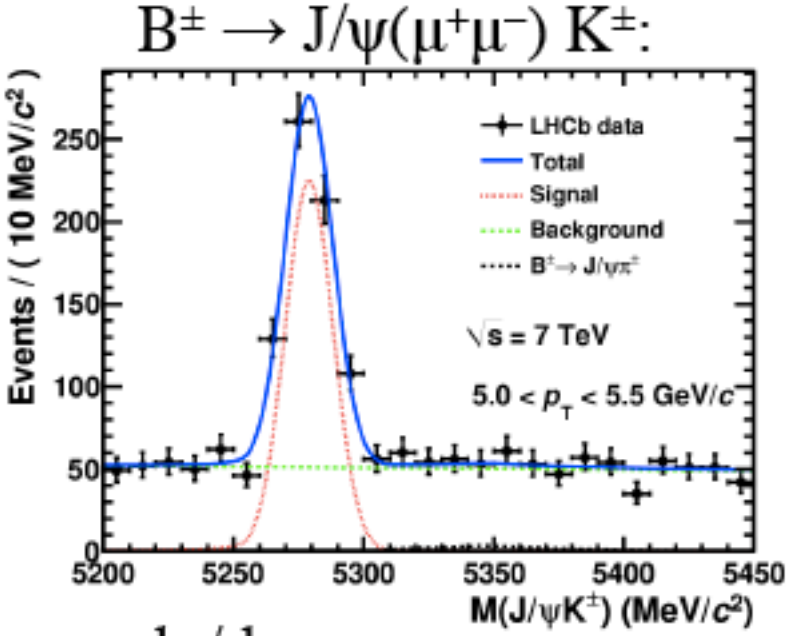
$B^{\pm}$ production

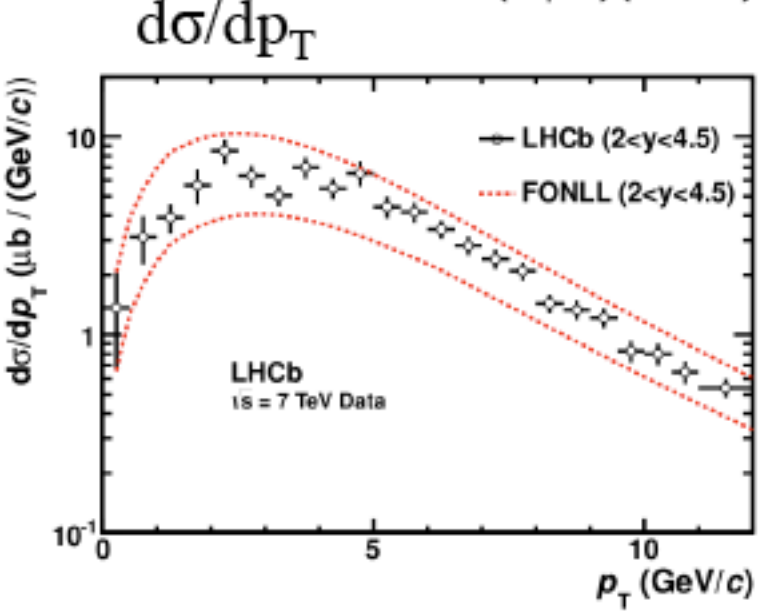
JHEP04(2012)093

- First $B^{\pm}$ production tests QCD@NLO
- Cross section measurement:
  - 35 pb^{-1} data-> ~9k $B^{\pm}$ signal events
  - $\sigma(pp \rightarrow B^{\pm}X)$ and $d\sigma/dp_T$ in range
    $2 < y < 4.5$ and $0 < p_T < 15$ GeV/c
  - Main systematics: tracking (4%) and muon ID (2.5%) efficiencies
- Compared to FONLL prediction

  (Fixed Order plus Next-to-Leading Logarithms, M.Cacciari et. al., JHEP 05 (1998) 007)
  - Assumed $f_{b\rightarrow B^{\pm}}$ = 40.1 ± 1.3% (PDG)
  - Uncertainties: *b* mass, CTEQ6.6, scales.
- $\sigma(B^{\pm}, 2.0 < y < 4.5, p_T<15$ GeV/c) =

  $41.4 \pm 1.5_{stat} \pm 3.1_{syst}$ μ b





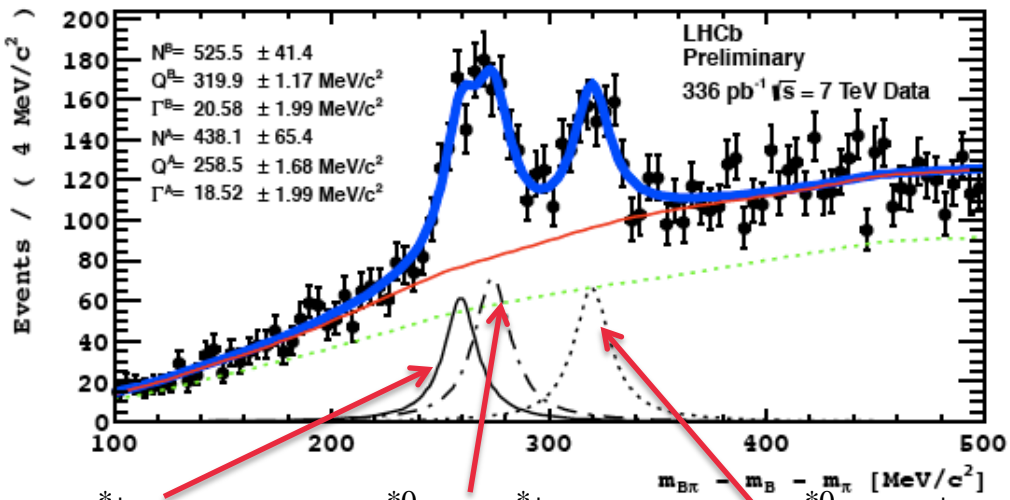
First measurement of B production in forward region!!
Being updated with more luminosity
& including B_s and B^0

B^{**} observation

LHCb-CONF-2011-053

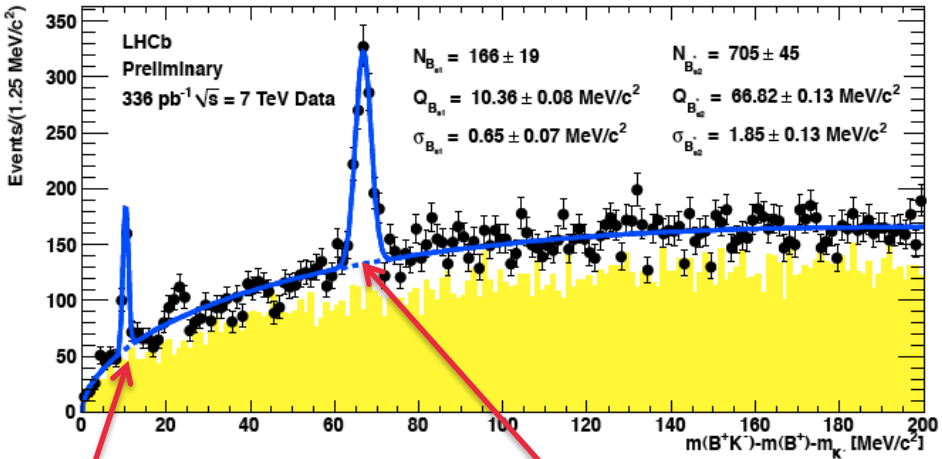
- B_s^{**}= excited B_s mesons (orbital momentum L = 1), predicted by Heavy Quark Effective Theory
- LHCb searches in B^+K^-, $B^+\pi^-$ and $B^0\pi^-$ in L=336 pb^{-1}
- Signals expected in Q=M(Bh)-M(B)-M(h) distribution

$B^+\pi^-$

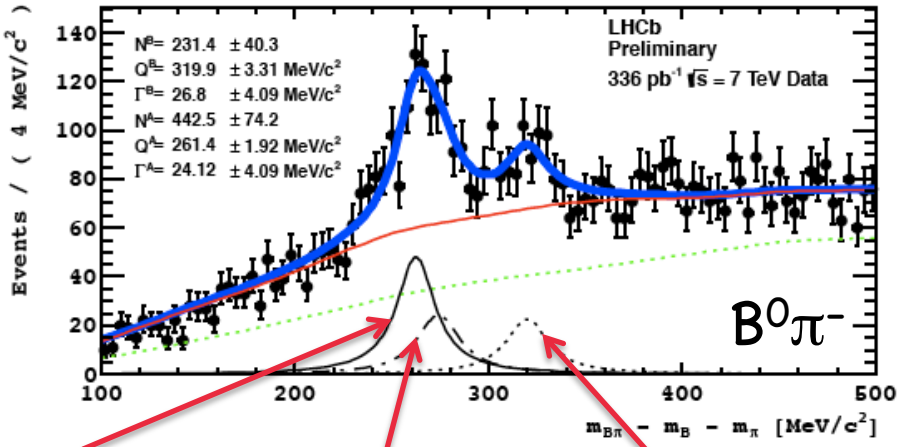


$B_1^0 \to B^{*+}\pi^-$ $B_2^{*0} \to B^{*+}\pi^-$ $B_2^{*0} \to B^+\pi^-$

B^+K^-



$B_{s1}^0 \to B^{*+}K^-$ $B_{s2}^{*0} \to B^+K^-$



$B_1^+ \to B^{*0}\pi^+$ $B_2^{*+} \to B^0\pi^+$ $B_2^{*+} \to B^{*0}\pi^+$

B^{**} observation

LHCb-CONF-2011-053

➡ The measured Q values are translated into masses:

$$
\begin{aligned}
M_{B_{s1}^0} &= (5828.99 \pm 0.08_{\rm stat} \pm 0.13_{\rm syst} \pm 0.45^{B\,\rm mass}_{\rm syst})\ \ {\rm MeV}/c^2\,, \\
M_{B_{s2}^{*0}} &= (5839.67 \pm 0.13_{\rm stat} \pm 0.17_{\rm syst} \pm 0.29^{B\,\rm mass}_{\rm syst})\ \ {\rm MeV}/c^2\,, \\
M_{B_1^0} &= (5724.1 \pm 1.7_{\rm stat} \pm 2.0_{\rm syst} \pm 0.5^{B\,\rm mass}_{\rm syst})\ \ {\rm MeV}/c^2\,, \\
M_{B_1^+} &= (5726.3 \pm 1.9_{\rm stat} \pm 3.0_{\rm syst} \pm 0.5^{B\,\rm mass}_{\rm syst})\ \ {\rm MeV}/c^2\,, \\
M_{B_2^{*0}} &= (5738.6 \pm 1.2_{\rm stat} \pm 1.2_{\rm syst} \pm 0.3^{B\,\rm mass}_{\rm syst})\ \ {\rm MeV}/c^2\,, \\
M_{B_2^{*+}} &= (5739.0 \pm 3.3_{\rm stat} \pm 1.6_{\rm syst} \pm 0.3^{B\,\rm mass}_{\rm syst})\ \ {\rm MeV}/c^2\,,
\end{aligned}
$$

First measurement of the $B^*_2{}^+$ and B_1^+ masses

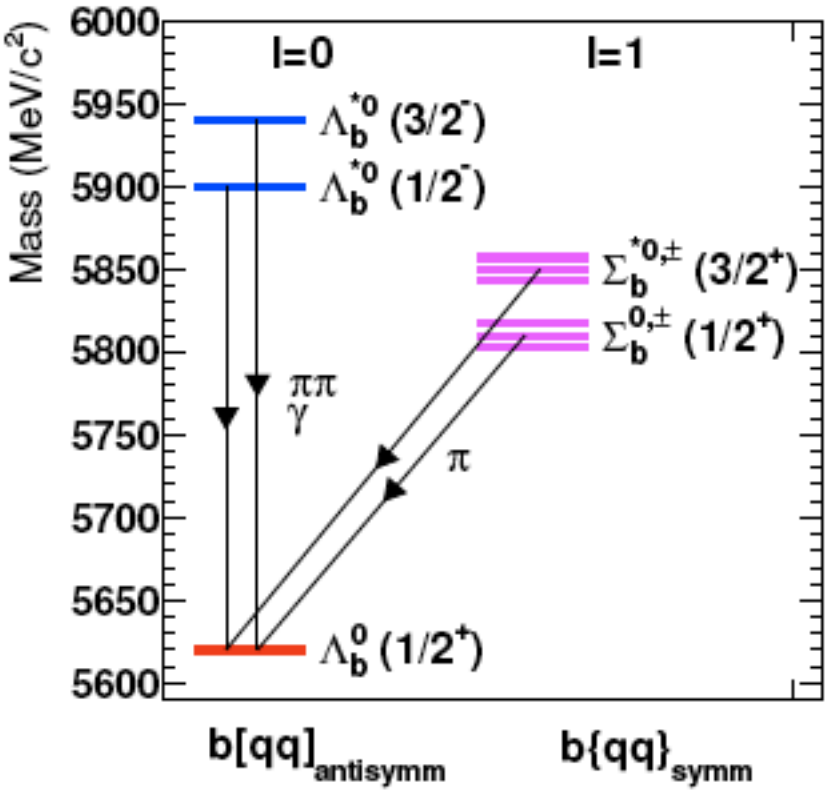
Being updated with more luminosity

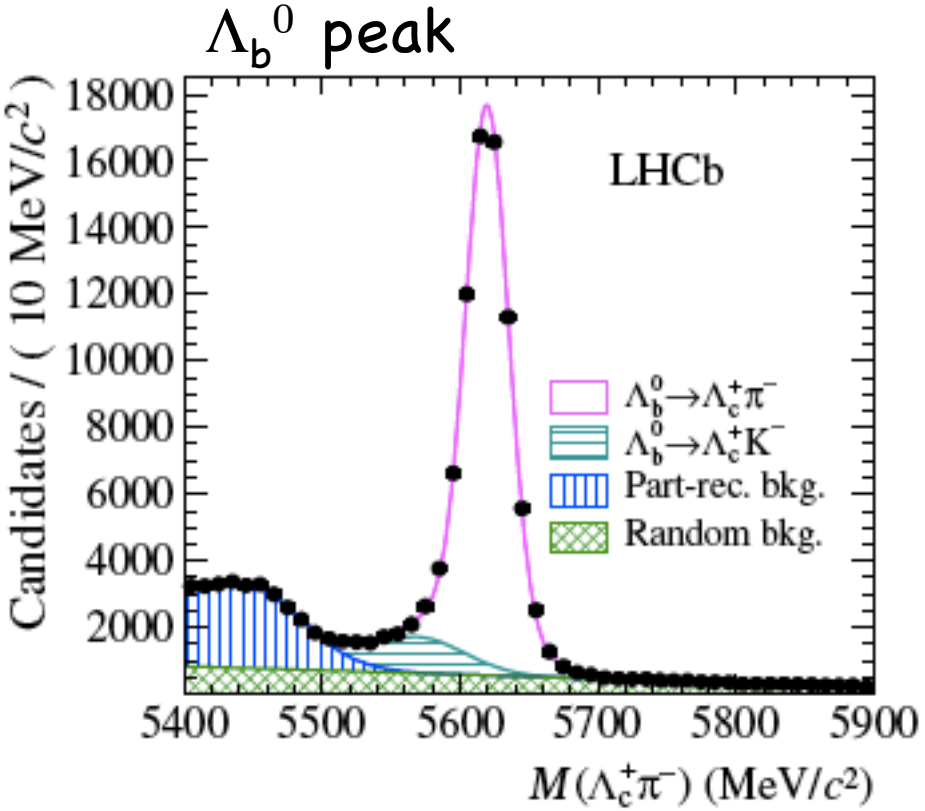
- Masses of ISOSPIN partners are compatible
- Good agreement with theory prediction
  - (M. Di Pierro and E. Eichten, Phys. Rev. D64 (2001) 114004)

NEW Λ_b^{0*} First Observation !!

arxiv:1205.3452

- Two narrow states are observed in $\Lambda_b^0\pi^+\pi^-$ spectrum in L=1.0 fb^{-1} data
- Expected at J^P = 1/2$^-$ and 3/2$^-$





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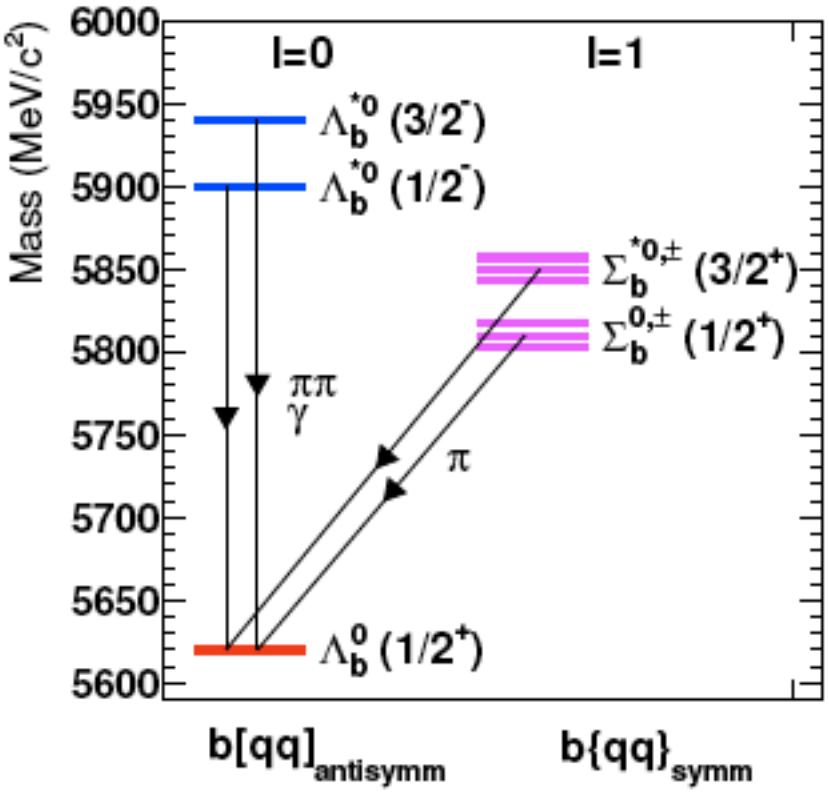

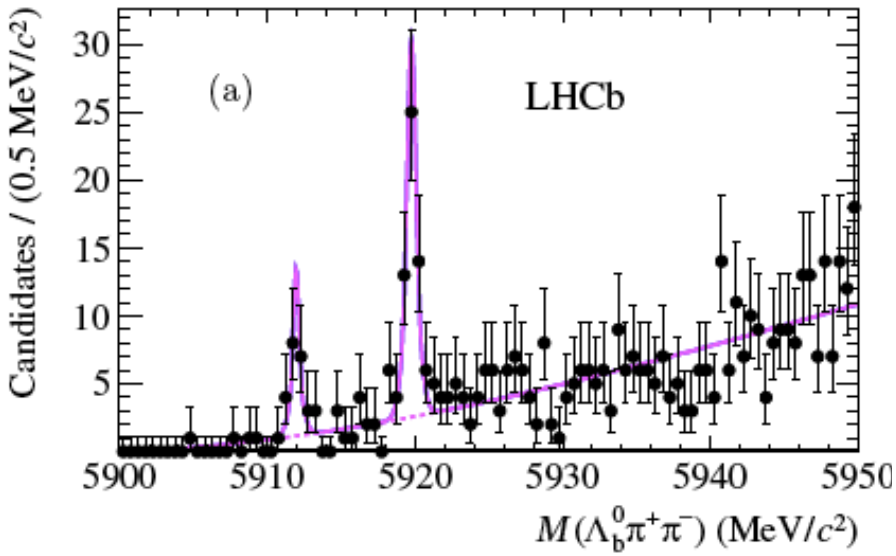

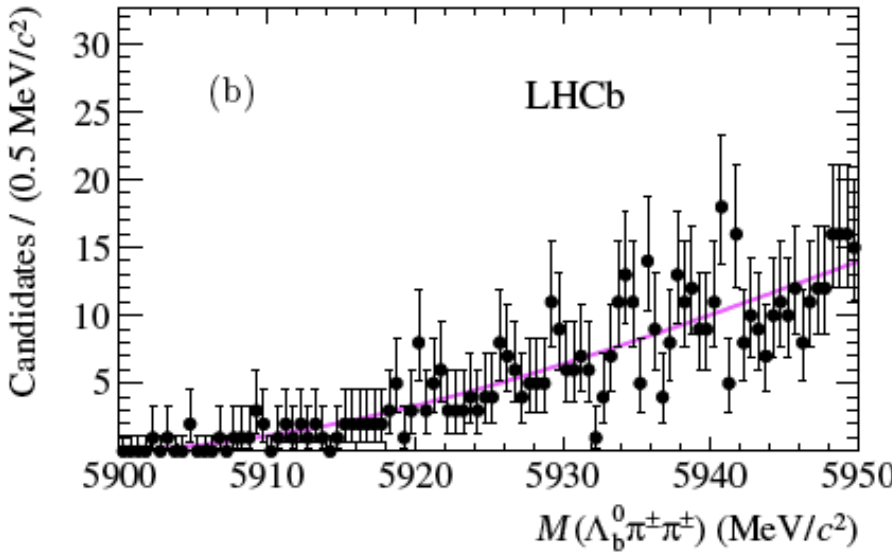

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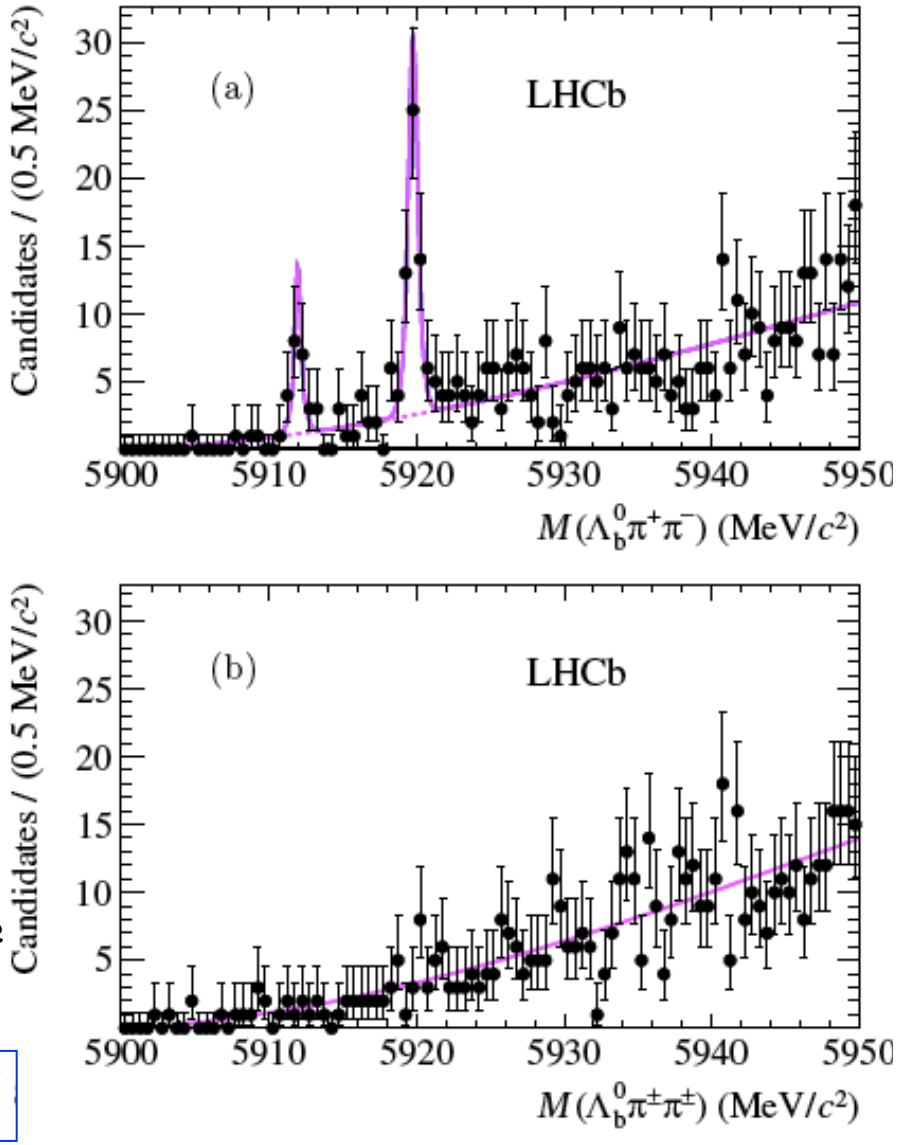
	Yield	width	Significance
$\Lambda_b^0(5912)$	16.4±4.7	0.19 MeV/c^2	4.6 σ
$\Lambda_b^0(5920)$	49.5±7.9	0.27MeV/c^2	10.1 σ

$$M_{\Lambda_b^{*0}(5912)} = 5911.95 \pm 0.12 \pm 0.03 \pm 0.66\ \mathrm{MeV}/c^2$$
$$M_{\Lambda_b^{*0}(5920)} = 5919.76 \pm 0.07 \pm 0.02 \pm 0.66\ \mathrm{MeV}/c^2$$

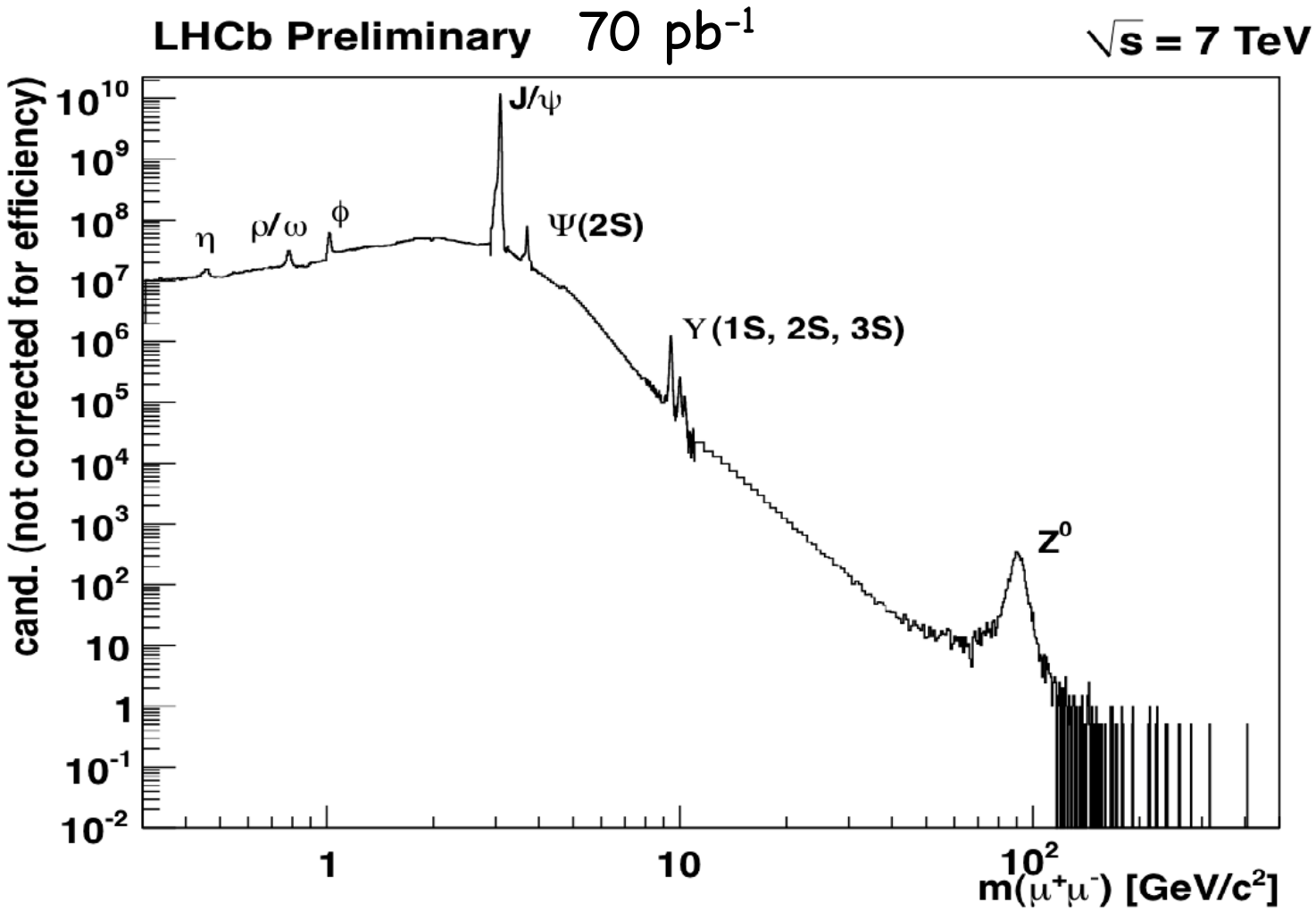
stat syst Λ_b^0mass

- Main systematics:
  - Signal/background modelling, momentum scale
- Limits on natural widths (95% C.L.) :

$$\Gamma_{\Lambda_b^{*0}(5912)} < 0.82\ \mathrm{MeV} \text{ and } \Gamma_{\Lambda_b^{*0}(5920)} < 0.71\ \mathrm{MeV}$$



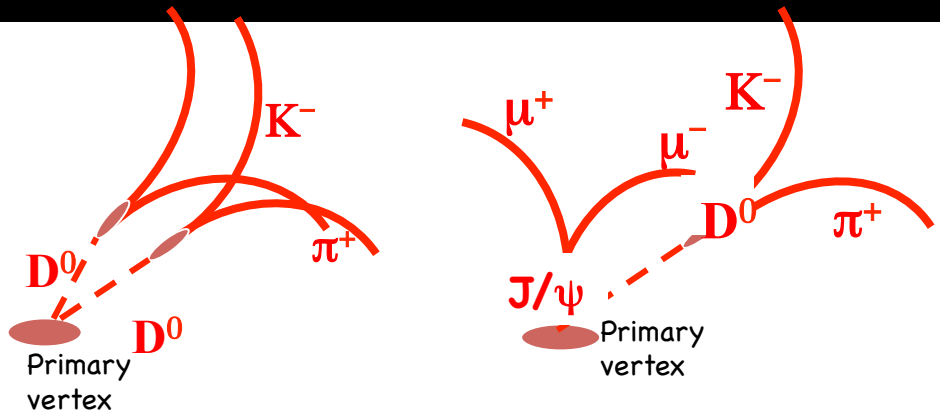
Quarkonium Results



Double Charm

arXiv:1205.0975

- J/ψC & CC/CCbar measured @ LHCb in 16 channels



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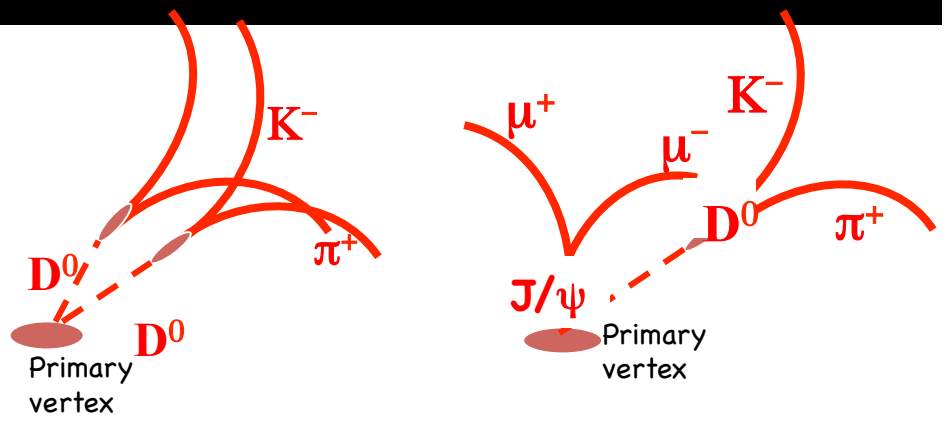

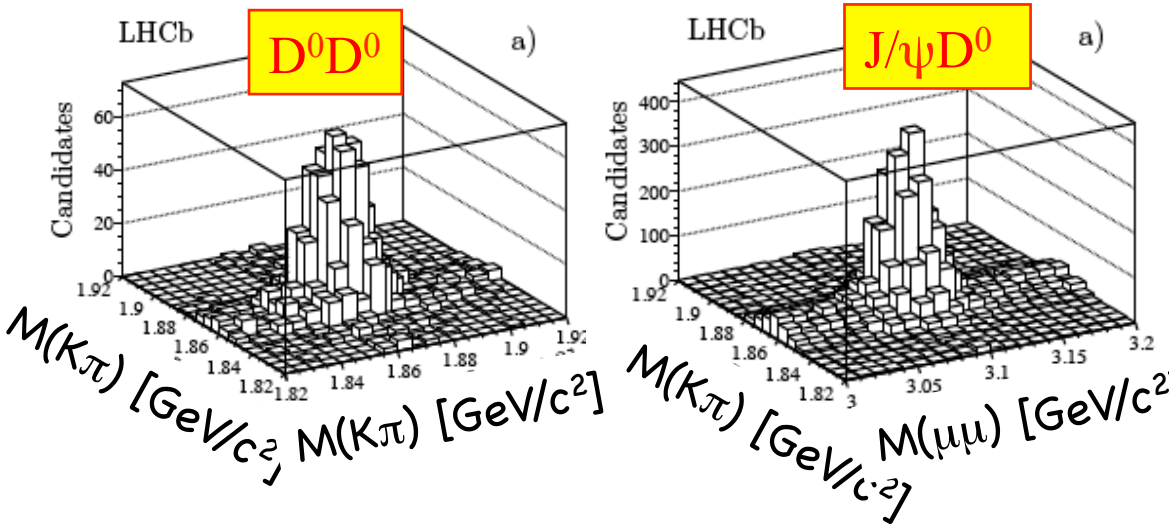

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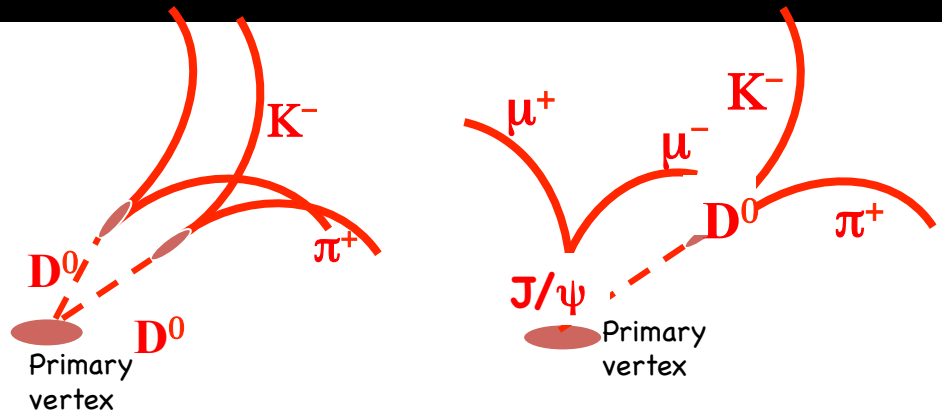
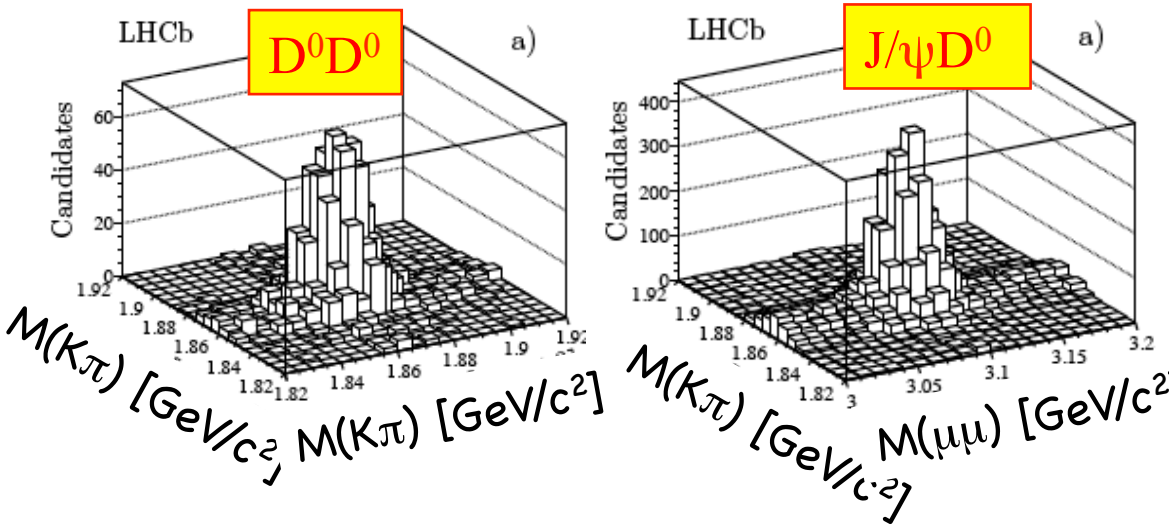
- J/ψC & CC/CCbar measured @ LHCb in 16 channels

Mode	yield
$J/\psi D^0$	4875 ± 86
$J/\psi D^+$	3323 ± 71
$J/\psi D_s^+$	328 ± 22
$J/\psi \Lambda_c^+$	116 ± 14
$D^0 D^0$	1087 ± 37
$D^0 \bar{D}^0$	10080 ± 105
$D^0 D^+$	1177 ± 39
$D^0 D^-$	11224 ± 112
$D^0 D_s^+$	111 ± 12
$D^0 D_s^-$	859 ± 31
$D^0 \Lambda_c^+$	41 ± 8
$D^0 \bar{\Lambda}_c^-$	308 ± 19
$D^+ D^+$	249 ± 19
$D^+ D^-$	3236 ± 61
$D^+ D_s^+$	52 ± 9
$D^+ D_s^-$	419 ± 22
$D^+ \Lambda_c^+$	21 ± 5
$D^+ \bar{\Lambda}_c^-$	137 ± 14





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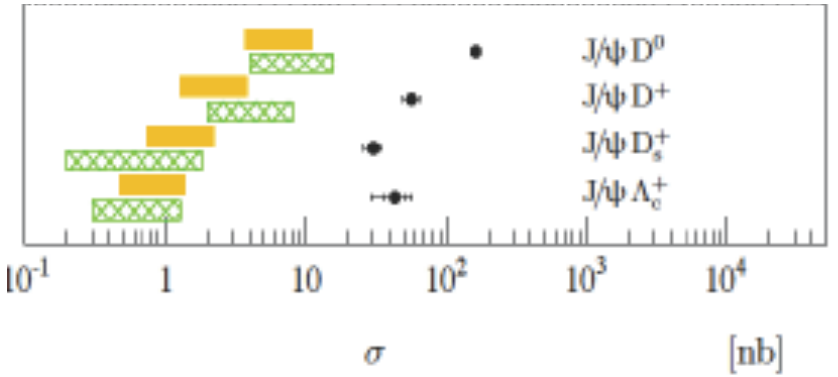
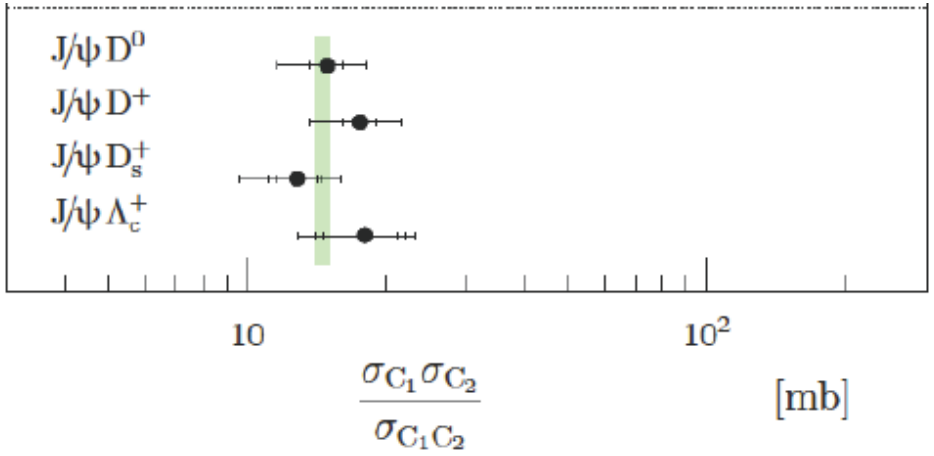
Compared with $gg \to J/\psi\, c\,\bar{c}$ computations:

A. V. Berezhnoy et al., Phys. Rev. D57 (1998) 4385

J.-P. Lansberg, Eur. Phys. J C61 (2009) 693



Compared with DPS



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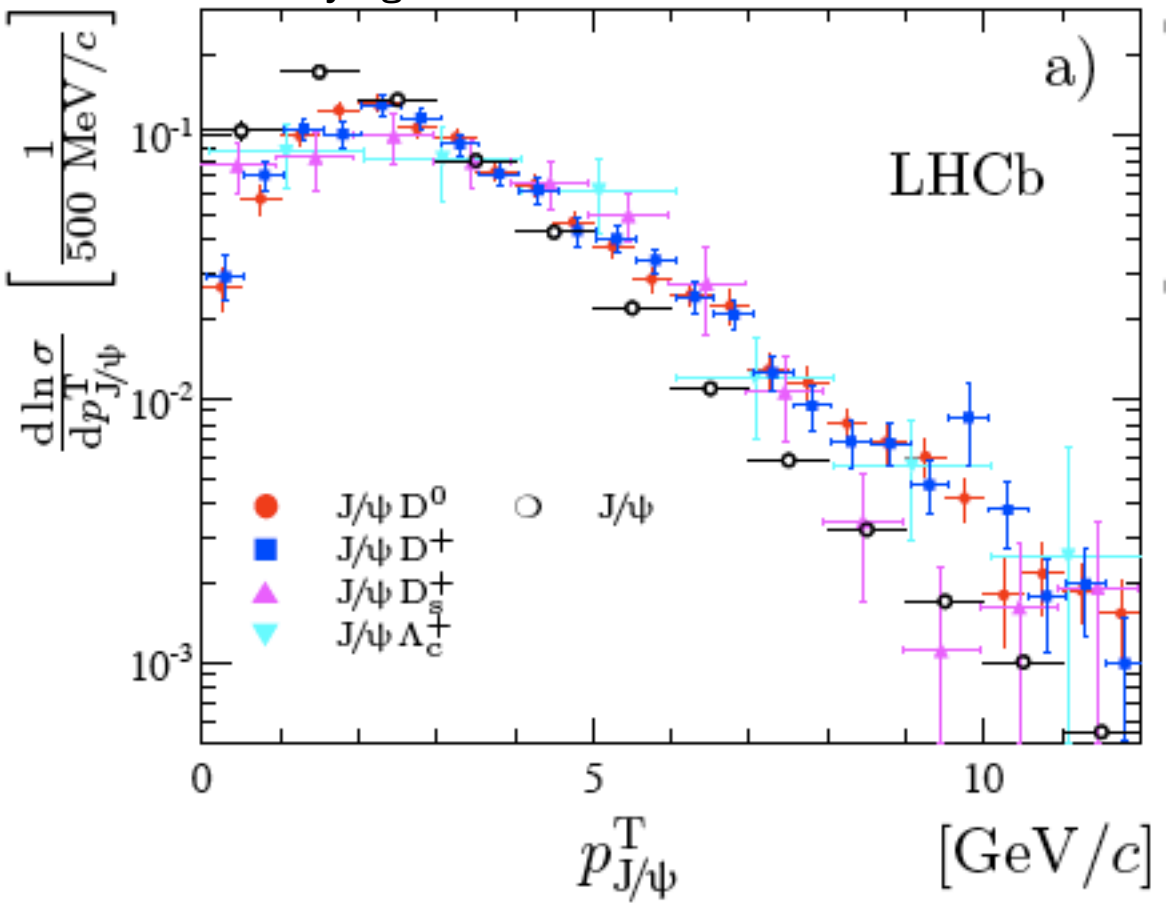
Studying the kinematics:

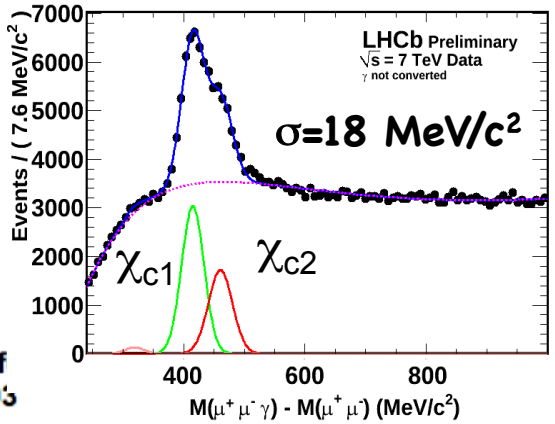


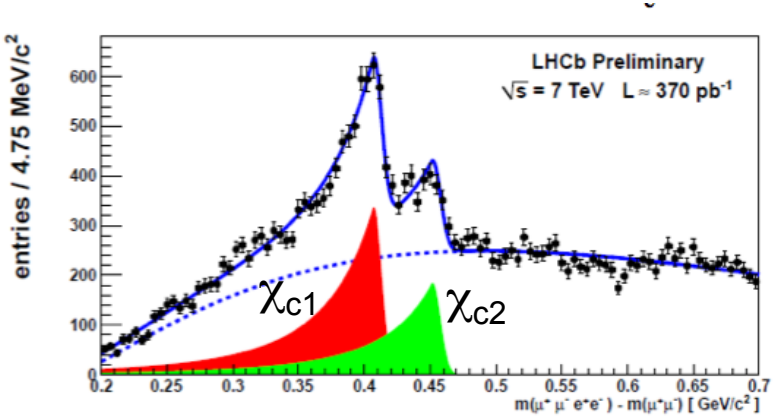
Many more channels to explore with increased statistics and new √s !

Production of χ_c

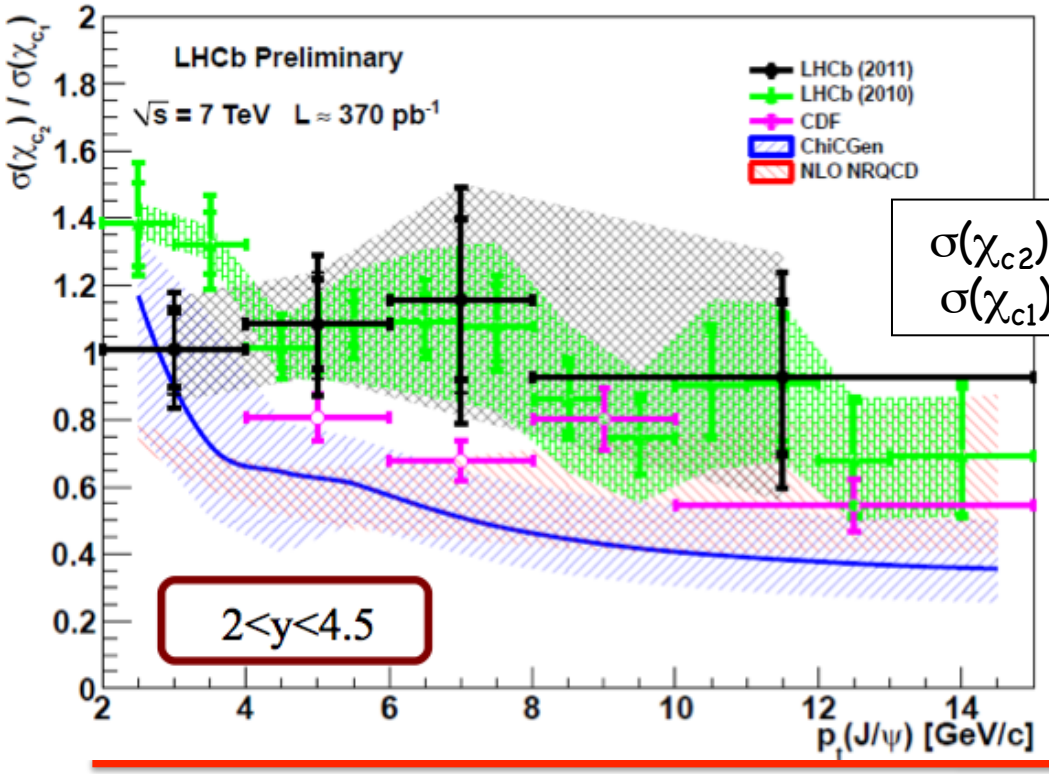
arXiv:1202.1080
arXiv:1204.1462

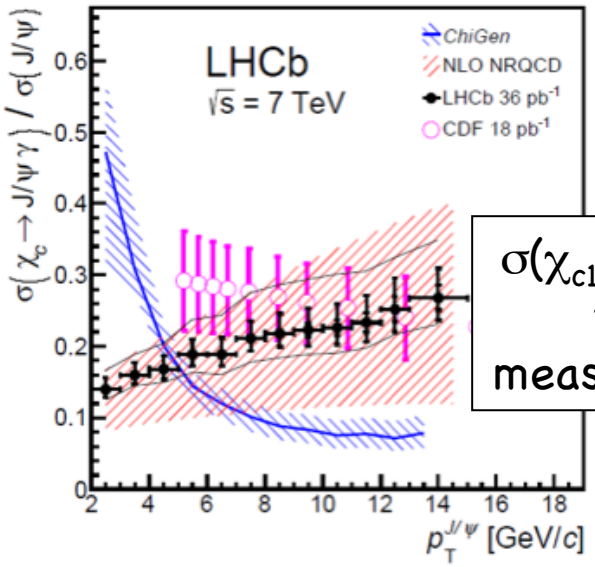
- Decays in J/ψ+γ->low p_T: challenge!!
- Analyses use photons reconstructed in the calo or converted (tracker)





CDF: PRL 98 (2007) 232001
ChiCGen: http://projects.hepf
NRQCD: PR D83 (2011) 111503





σ(χc1)/σ(J/ψ) first measurement

Conclusions and Outlook

- LHCb produced very many interesting results with datasets 0.04-1 fb^{-1}
- **Many** results are being updated with more luminosity
- Several production measurements will be repeated at 8 TeV
- Very rich program to explore in next future
  - Exotic spectroscopy
  - Double quarkonium
  - Precision measurements, B_c physics

- So...