# Exciting Results In $B_c$ Physics

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# About the $B_c$ Meson

- $B_c$ mesons are heaviest known mesons composed of different flavored quarks.
- First observed at the Tevatron (15 years ago!) in the $B_c^+ \to J/\psi \mu^+ \nu X$ channel and subsequently in the $B_c^+ \to J/\psi\, \pi^+$ channel.
  - These channels were used to make measurements of the mass and lifetime, and make measurements on production properties.
- There has since been a large amount of theoretical studies of these particles
- On experimental side, still largely unexplored.
  - With the start up of the LHC, they are finally being produced copiously enough to study in detail and put the theory to the test.

# What makes this meson interesting?

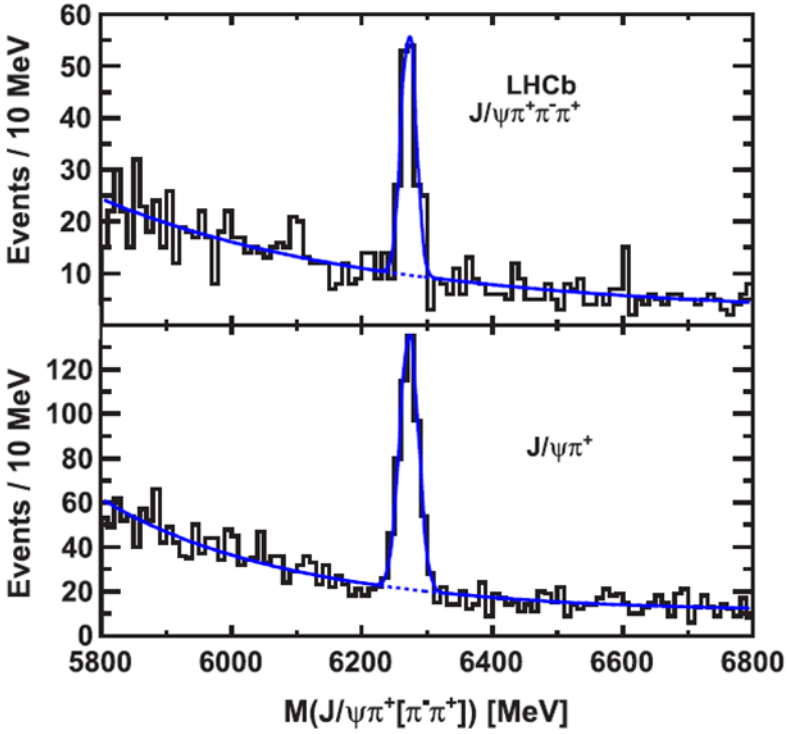
- The two quarks of different flavors mean it only can decay weakly.
- Despite b quark being heavier, decays through it are suppressed by small CKM matrix element - meaning the bottom and charm quark decays compete with each other.
  - Decay rates are appreciable for c quark (70%) and b quark decays (20%), as well as annihilation (10%), leading to rich landscape of possible decays
- Two heavy quarks means it is an ideal laboratory for the study of heavy quark dynamics.
- Their study can test a range of phenomenological models and can provide information about the parameters of weak Lagrangian and hadronic matrix elements.

# New Decay Channels At LHCb

- The third ever decay channel was observed in the decay $B_c^+ \to J/\psi\,\pi^+\pi^-\pi^+$ and its branching fraction relative to previously observed $B_c^+ \to J/\psi\,\pi^+$ was measured to be

$$\frac{BR(B_c^+ \to J/\psi\,\pi^+\pi^-\pi^+)}{BR(B_c^+ \to J/\psi\,\pi^+)} = 2.41 \pm 0.30(stat) \pm 0.33(syst)$$

- This was first ever test of theoretical prediction of $B_c^+$ branching fractions.
- Good agreement is seen, with theory predictions ranging from 1.5-2.3

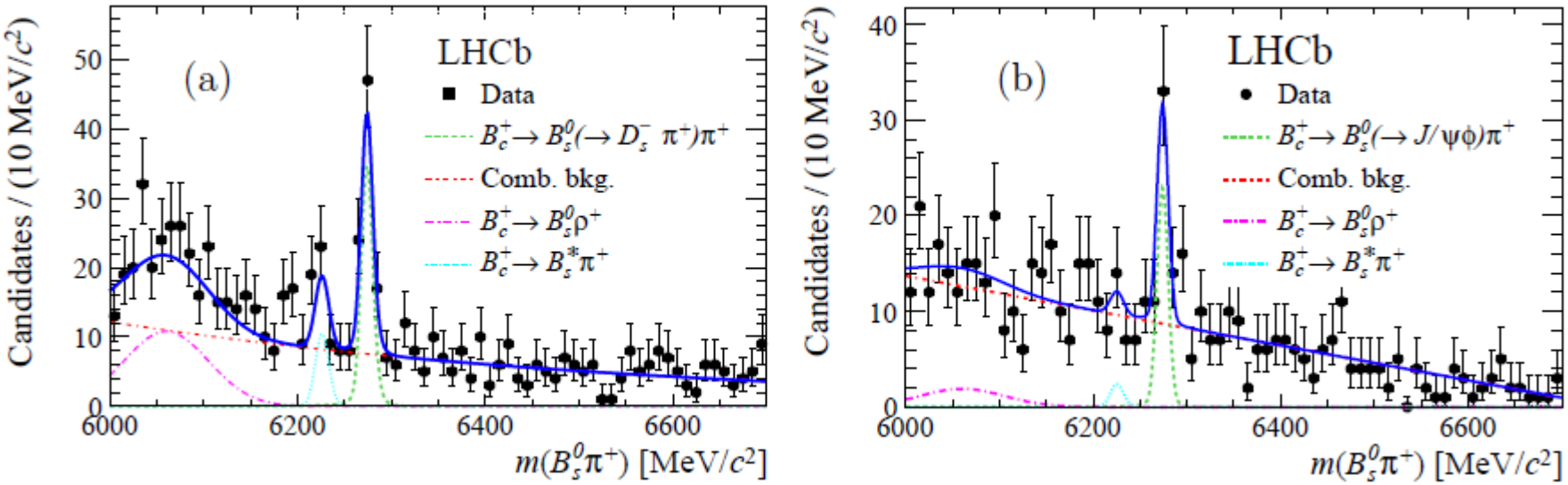


# Observation of $B_c^+ \to B_s^0 \pi^+$

- The first observation of $B_c^+$ decaying via c quark, and first case of B meson decaying to another B meson via weak interaction.

- And the measurement was made for:

$$\frac{\sigma(B_c^+)}{\sigma(B_s^0)} \times BR(B_c^+ \to B_s^0 \pi^+) = (2.37 \pm 0.31(stat) \pm 0.11(syst)^{+0.17}_{-0.13}(\tau_{B_c^+})) \times 10^{-3}$$



# Further Measurements

- Other new decay channels observed at LHCb consist of $B_c^+ \to J/\psi K^+$, $B_c^+ \to J/\psi K^+ K^- \pi^+$, $B_c^+ \to J/\psi D_s^+$, and $B_c^+ \to J/\psi\, D_s^{*+}$
  - Using $B_c^+ \to J/\psi D_s^+$ the most precise measurement of mass to date was also obtained: $6276.28 \pm 1.44 \pm 0.36$ MeV/$c^2$
- The production properties relative to $B^+$ was also measured

$$\frac{\sigma(B_c^+)}{\sigma(B^+)} \frac{BR(B_c^+ \to J/\psi\pi^+)}{BR(B^+ \to J/\psi K^+)} = \left(0.68 \pm 0.10(stat) \pm 0.03 \pm 0.05\left(\tau_{B_c^+}\right)\right)\%$$

For $\sqrt{s} = 7$TeV, $p_T > 4$GeV, $2.5 < \eta < 4.5$

- A similar measurement was made my CDF

$$\frac{\sigma(B_c^+)}{\sigma(B^+)} \frac{BR(B_c^+ \to J/\psi\mu^+\upsilon)}{BR(B^+ \to J/\psi K^+)} = \left(29.5 \pm 4.0(stat)^{+10.7}_{-7.6} \pm 3.6(p_T\ spec)\right)\%$$

For $\sqrt{s} = 1.96$TeV, $p_T > 4$GeV, $|\eta| < 1.0$

- This measurement leads to order of magnitude discrepancy when compared with theory predictions for $\frac{\sigma(B_c^+)}{\sigma(B^+)}$ and $BR(B_c^+ \to J/\psi\mu^+\upsilon)$.
  - Further production/branching ratio measurements needed to diagnose what is at fault!

# What else are we excited about?

- More decay channels waiting to be observed, and to be compared to theory.
- Lifetime measurements! PDG lifetime value currently only 7.3% precision. Better statistics will allow for more precise lifetime measurements. This will have important implications for both experiment and theory.
  - Lifetime uncertainty is sizeable systematic error in many analyses.
  - Will provide information on charm and beauty quark mass and normalization point of non-leptonic weak Lagrangian in $B_c^+$ decays.
- Search for excited states? Spectrum can be calculated reliably via QCD motivated potentials as well as sum rules.
- More interesting physics certain to be extracted from $B_c^+$ mesons in the future as well!