CMS results on B_c, B^+ production and decays

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(On behalf of CMS collaboration)

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Introduction

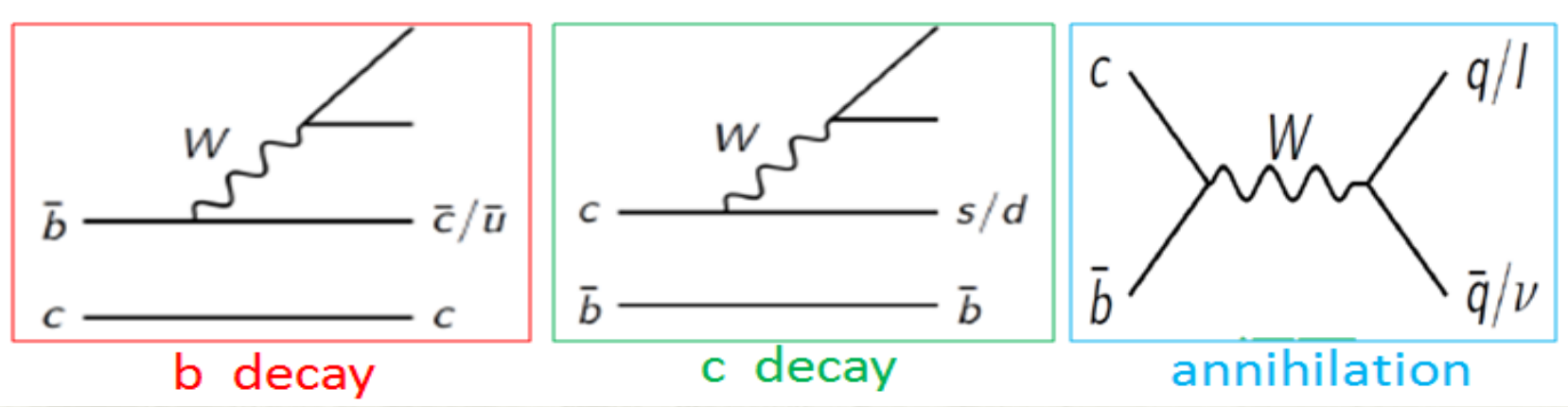
B_c is the lightest particle containing two different heavy flavor quarks (b, c), thus represents a unique laboratory in which to study heavy-quark dynamics.

B_c properties in PDG 2014

Mass	$m = 6.2756 \pm 0.0011$ GeV
Mean life	$\tau = (0.500 \pm 0.013) \times 10^{-12}$ s
$I(J^P)$	$0(0^-)$ need confirmation

B_c decay

The decay processes of the B_c can be divided into 3 classes: b quark decay, c quark decay, and the annihilation of the b and c quarks.
The b→c transition, accounting for about 20% of the decay rate, offers an easily accessible experimental signature, having a high probability of producing a J/ψ meson.



From the CDF exp. observed $B_c \to J/\psi\mu\nu$ in 1998, a broad list of B_c decays have been observed, especially in LHCb experiment. So far only at hadron colliders.

$B_c \to J/\psi\mu\nu$ (CDF), $B_c \to J/\psi\pi$ (CDF),
$B_c \to J/\psi\pi\pi\pi$ (LHCb/CMS), $B_c \to \psi(2S)\pi$ (LHCb) $B_c^+ \to J/\psi K^+$ (LHCb)
$B_c \to J/\psi D_s$ (LHCb), $B_c \to J/\psi D_s^*$ (LHCb), $B_c^+ \to J/\psi 3\pi^+ 2\pi^-$ (LHCb)
$B_c \to B_s\pi$ (LHCb), and $B_c \to J/\psi KK\pi$ (LHCb) $B_c^+ \to J/\psi p\bar{p}\pi^+$ (LHCb)

B_c analysis at CMS

- At CMS, $B_c^+ \to J/\psi\pi^+$ and $B_c^+ \to J/\psi\pi^+\pi^+\pi^-$ decays were observed in 2011with 5.1 fb^{-1} data.(Charge conjugate modes are included throughout this talk.)

- In this talk, we report two ratio measurements at CMS (7 TeV, 5.1 fb^{-1})

  arXiv:1410.5729

  (submitted to JHEP)

Measurement of the ratio $\mathcal{B}(B_c^\pm \to J/\psi\pi^\pm\pi^\pm\pi^\mp)/\mathcal{B}(B_c^\pm \to J/\psi\pi^\pm)$ and the production cross sections times branching fractions of $B_c^\pm \to J/\psi\pi^\pm$ and $B^\pm \to J/\psi K^\pm$ in pp collisions at $\sqrt{s} = 7$ TeV

The CMS Collaboration*

Abstract

The $B_c^\pm \to J/\psi\pi^\pm$ and $B_c^\pm \to J/\psi\pi^\pm\pi^\pm\pi^\mp$ decay modes are studied in proton-proton collisions at a center-of-mass energy of 7 TeV with the CMS detector at the LHC. The kinematic region investigated requires $B_c^\pm$ mesons with transverse momentum $p_T > 15$ GeV and rapidity $|y| < 1.6$. The data sample corresponds to an integrated luminosity of 5.1 fb^{-1}. The ratio of the branching fractions $\mathcal{B}(B_c^\pm \to J/\psi\pi^\pm\pi^\pm\pi^\mp)/\mathcal{B}(B_c^\pm \to J/\psi\pi^\pm)$ is measured to be $2.55 \pm 0.80\,(\text{stat}) \pm$

$$\frac{\sigma(B_c)\times \mathrm{Br}(B_c \to J/\psi\pi^+)}{\sigma(B^+)\times \mathrm{Br}(B^+ \to J/\psi K^+)} \qquad \frac{\mathrm{Br}(B_c \to J/\psi\pi^+\pi^+\pi-)}{\mathrm{Br}(B_c \to J/\psi\pi^+)}$$

Submitted to the Journal of High Energy Physics

B_c analysis technology at CMS

In CMS measurement, the phase space covered: $p_T(B_c)>15$ GeV, $|y(B_c)|<1.6$, complementary to LHCb's kinematic coverage.

Relative measurement, many sys. errors ($\mathcal{L}$, trigger, Muon ID, tracking..) were canceled.

- Start with J/ψ trigger and selection:

Displaced–vertex di-μ triggers: (di-μ kinematic-vertex fit, cosα,Lxy/σ_{Lxy}, p_T, η…)

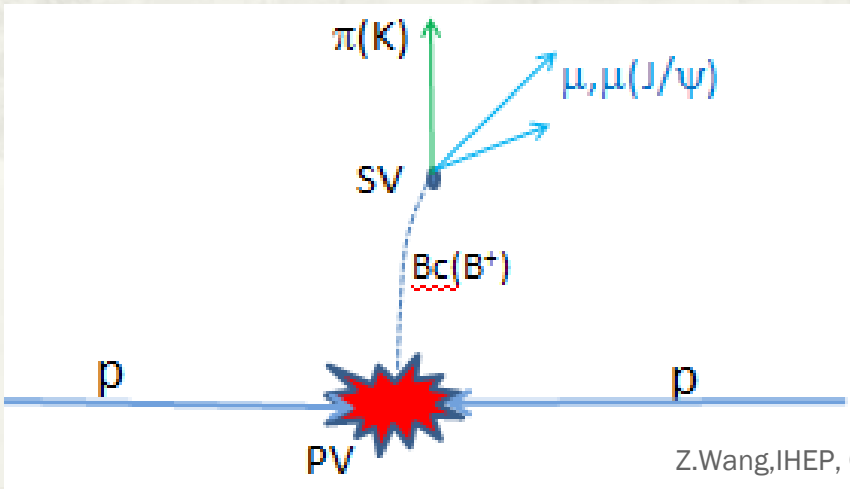
J/ψ mass	(2.9, 3.3)
J/ψ p_T	> 6.9 GeV/c
J/ψ Cosα	> 0.9
J/ψ LxyC	>3
di-mu DCA	< 0.5
J/ψ VtxCL	> 0.5%–0.15

- J/ψ and track(s) reconstruct $B_c(B^+)$:

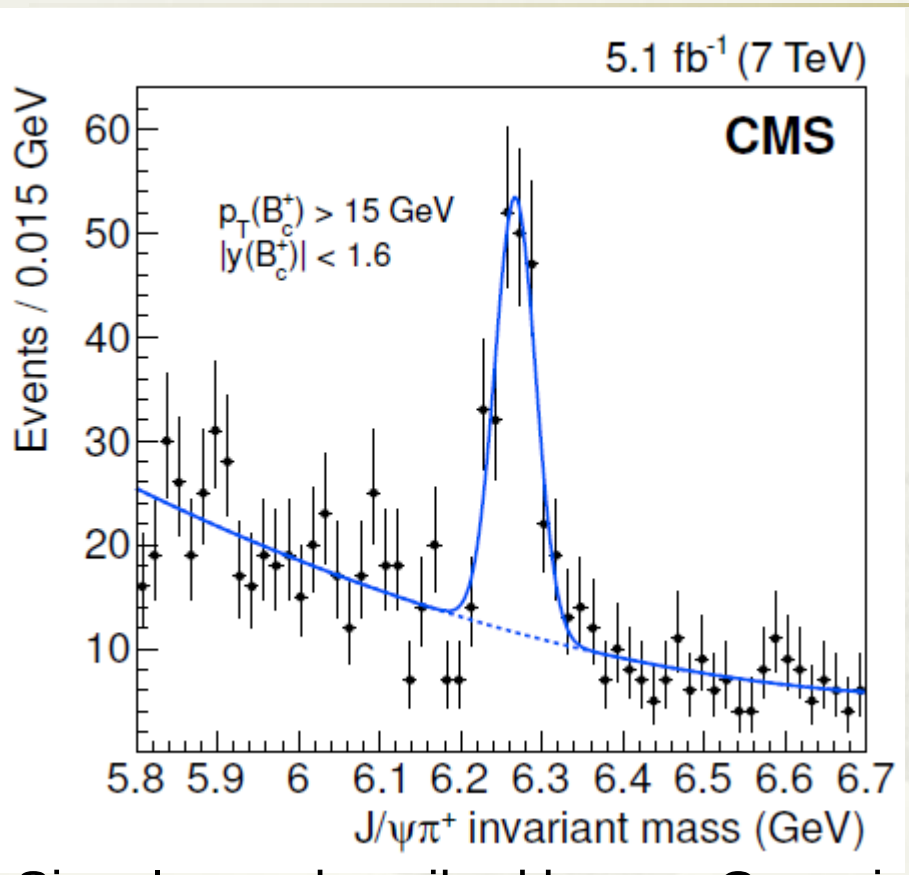
  kinematic fit with vertex constraint to reconstruct $B_c(B^+)$ SV.

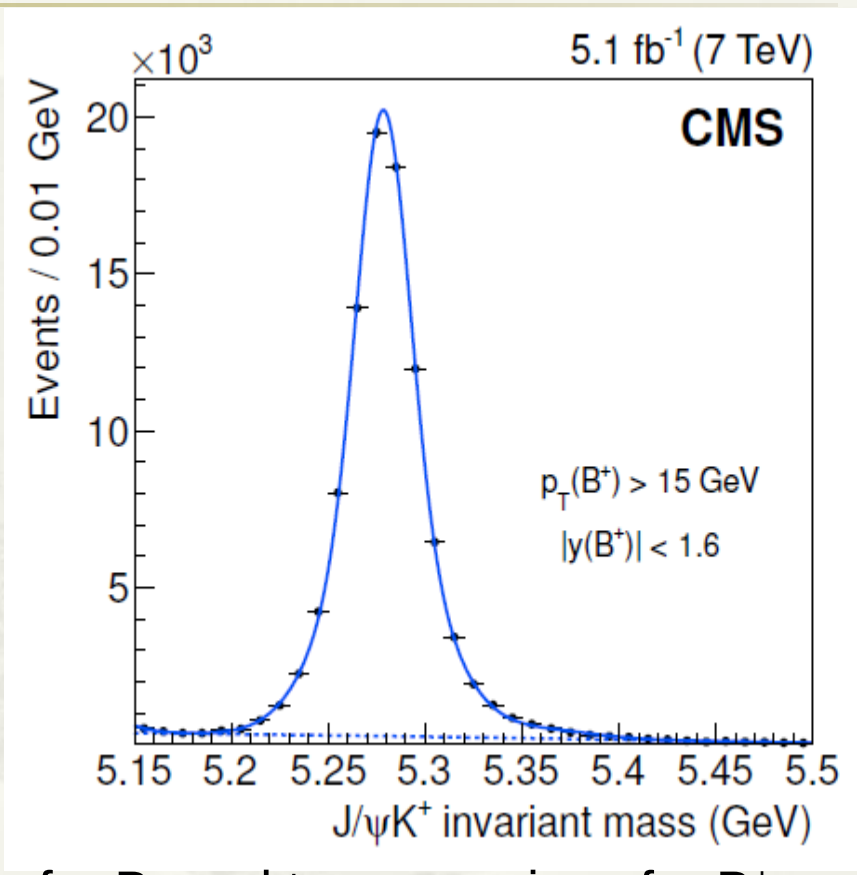
  Selection criteria optimized by $\frac{S}{\sqrt{S+B}}$

- Events corrected by MC Efficiency: BcVegPy, pyThia



Selection: $B_c^{\pm} \to J/\psi\pi^{\pm}$, $B^{\pm} \to J/\psi K^{\pm}$

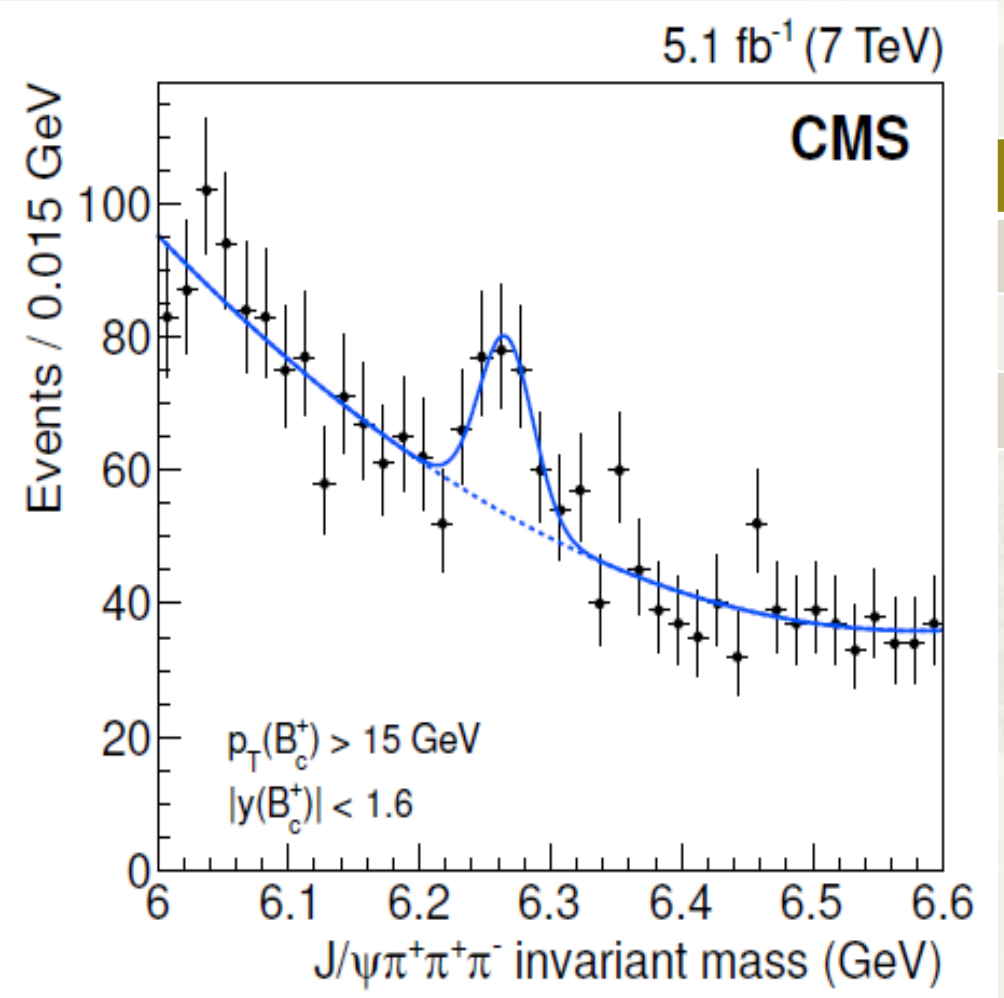




Signals are described by one Gaussian for B_c and two gaussians for B^+, we also take into account $B^+ \to J/\psi\pi^+$ and $B^0 \to J/\psi X$ contributions, using two additional Gaussian distributions.

Background: 2nd order Chebyshev polynomials

Selection: $B_c^+ \to J/\psi\pi^+\pi^+\pi^-$



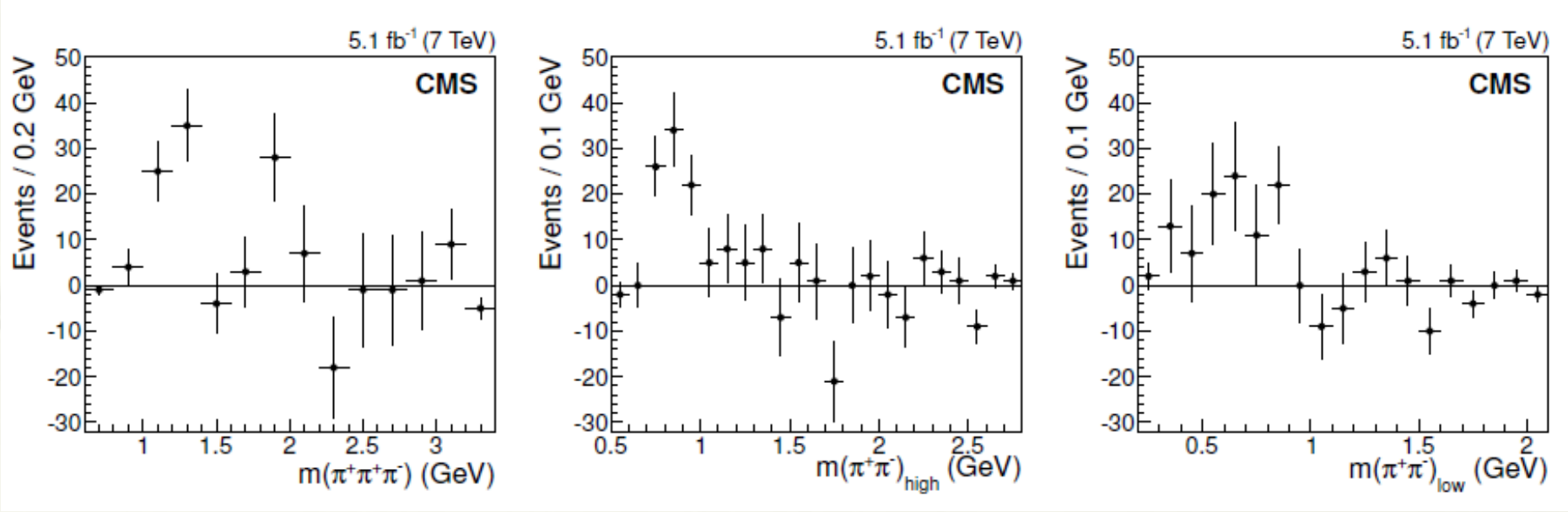
2011 data

Channel	Events
$B_c^+ \to J/\psi\pi^+\pi^+\pi^-$	92 ± 27
$B_c^+ \to J/\psi\pi^+$	176 ± 19
$B^+ \to J/\psi K^+$	90419 ± 352

Signal: Gaussian
Background: Chebyshev polynomials (2nd order)

Selection: $B_c^+ \to J/\psi\pi^+\pi^+\pi^-$

The $B_c \to J/\psi\pi\pi\pi$ decay can involve intermediate resonant states. Indeed, $\pi^+\pi^+\pi^-$, $\pi^+\pi^-$ invariant mass projections from data show evidence for the presence of $a_1(1260)$ and $\rho(770)$.



Efficiency

$$R_{B_c} = \frac{\mathcal{B}(B_c^+ \to J/\psi\pi^+\pi^+\pi^-)}{\mathcal{B}(B_c^+ \to J/\psi\pi^+)} = \frac{\Upsilon_{B_c^+ \to J/\psi\pi^+\pi^+\pi^-}}{\Upsilon_{B_c^+ \to J/\psi\pi^+}}$$

$$R_{c/u} = \frac{\sigma(B_c^+)\mathcal{B}(B_c^+ \to J/\psi\pi^+)}{\sigma(B^+)\mathcal{B}(B^+ \to J/\psi K^+)} = \frac{\Upsilon_{B_c^+ \to J/\psi\pi^+}}{\Upsilon_{B^+ \to J/\psi K^+}}$$

Efficiency-corrected signal number.

The selected events are corrected by the MC efficiencies. Eff. include geometrical acceptance, reconstruction, selection and trigger effects.

- 1π(K) channel: Efficiency determined in bins of p_T . Data are corrected event-by-event according to the candidate's p_T .
- 3π channel: 5-body final state phase space sampling (see following slide)

Efficiency

For the 3π channel, a non-resonant simulation sample has been used to study the efficiency as a function of a complete set of parameters for a 5-body final state.

- Efficiency function:

$$\varepsilon = |p_0 + p_1 x + p_2 y + p_3 z + p_4 w + p_5 r + p_6 t + p_7 s|$$

- Parameters p_i determined using an unbinned maximum likelihood fit

- Components mean: (Dalitz plot representation)

$x = m^2(\mu^+\pi^+)_{low}$ $y = m^2(\pi^+\pi^-)_{high}$ $z = m^2(\mu^+\pi^-)$

$w = m^2(\pi^+\pi^+)$ $r = m^2(\mu^-\pi^+)_{low}$ $t = m^2(\mu^-\pi^+)_{high}$ $s = m^2(\mu^-\pi^-)$

The resulting efficiency function is used to weight the data event-by-event.

Systematic uncertainties

$$R_{B_c} = \frac{\mathcal{B}(B_c^+ \to J/\psi \pi^+ \pi^+ \pi^-)}{\mathcal{B}(B_c^+ \to J/\psi \pi^+)}$$

$$R_{c/u} = \frac{\sigma(B_c^+)\mathcal{B}(B_c^+ \to J/\psi \pi^+)}{\sigma(B^+)\mathcal{B}(B^+ \to J/\psi K^+)}$$

Systematic source	%
Fit variant	9.4
MC sample size	4.1
Efficiency fit function	1.0
Efficiency binning	1.9
Tracking efficiency	7.8
Total uncertainty	13.1
Lifetime	$^{+1.6}_{-0.4}$

Systematic source	%
Fit variant	5.3
MC sample size	2.1
Efficiency binning	3.1
Total uncertainty	6.5
B_c lifetime	10.4

B_c lifetime uncertainty is quoted separately, it is estimated by varying the B_c lifetime in the simulation from the world average value minus its one standard deviation uncertainty, to the new LHCb measurement.

Eur. Phys. J. C **74 (2014) 2839, doi:10.1140/epjc/s10052-014-2839-x,**arXiv:1401.6932.

Results

CMS measured two B_c ratios with 5.1 fb^{-1}, 7 TeV pp collision data.

$$R_{B_c} = \frac{Br(B_c^+ \to J/\psi\pi^+\pi^+\pi^-)}{Br(B_c^+ \to J/\psi\pi^+)} =$$

$$2.55 \pm 0.80(stat) \pm 0.33(syst)^{+0.04}_{-0.01}(\tau_{B_c})$$

CMS covers

$p_T(B_c) > 15$ GeV/c

$|y(B_c)| < 1{:}6$,

LHCb $(2.41 \pm 0.30 \pm 0.33)$

$$R_{c/u} = \frac{\sigma(B_c^+) \times Br(B_c^+ \to J/\psi\pi^+)}{\sigma(B^+) \times Br(B^+ \to J/\psi K^+)} =$$

$$\left[0.48 \pm 0.05(stat) \pm 0.03(syst) \pm 0.05(\tau_{B_c})\right]\%$$

LHCb

$p_T(B_c) > 4$ GeV/c

$2.5 < |\eta(B_c)| < 4.5$

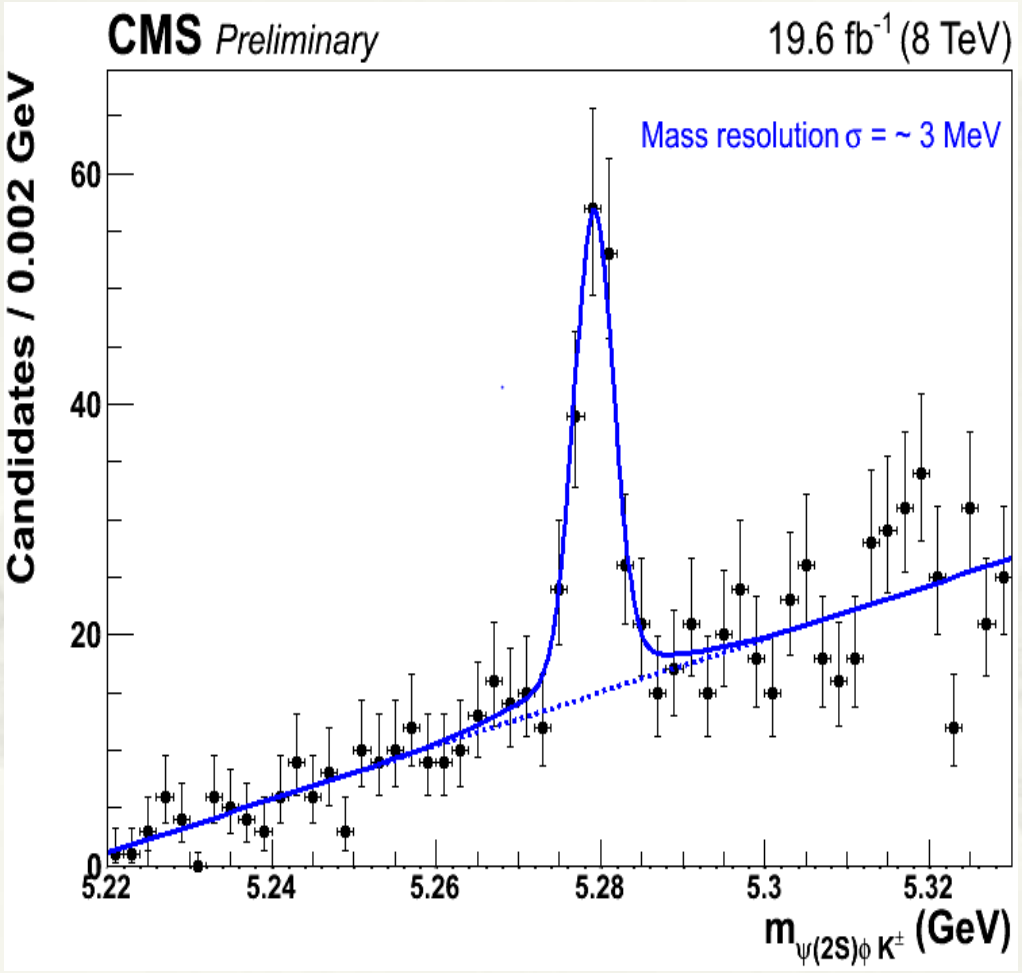
LHCb: $(0.68 \pm 0.10(\text{stat.}) \pm 0.03(\text{syst.}) \pm 0.05(\text{lifetime})) \times 10^{-2}$

Observation of $B^+ \to \psi(2S)\phi K^+$

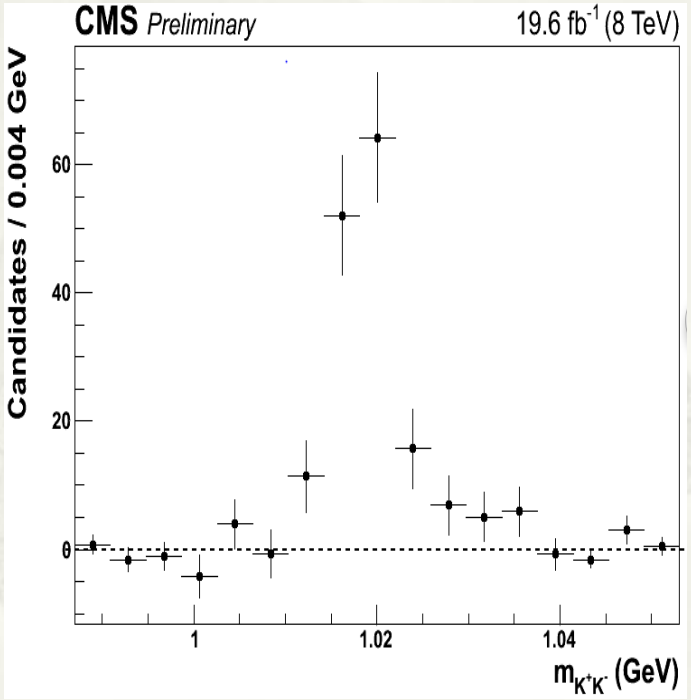
The high luminosity and large cross section for b quark production at the LHC makes possible the observation and study of many rare B meson decays.

Recently, CMS reported on the presence of substructures in the known decay $B^+ \to J/\psi\phi K^+$ (Phys.Lett. B 734 (2014) 261). As part of that investigation, the final state $B^+ \to \psi(2S)\phi K^+$, with $\psi(2S) \to \mu^+\mu^-$ and $\phi \to K^+K^-$ was also observed in 19.6 fb^{-1} 8 TeV data.

Observation of $B^+ \to \psi(2S)\phi K^+$



Clear B^+ peak was found in the inv. mass distribution of $\psi(2S)\phi K^+$



CMS PAS BPH-13-009

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsBPH13009

Summary

- CMS contributes the measurements of R_{Bc} and $R_{c/u}$ in the central rapidity region. The measurements are complementary to LHCb's forward rapidity region measurement.

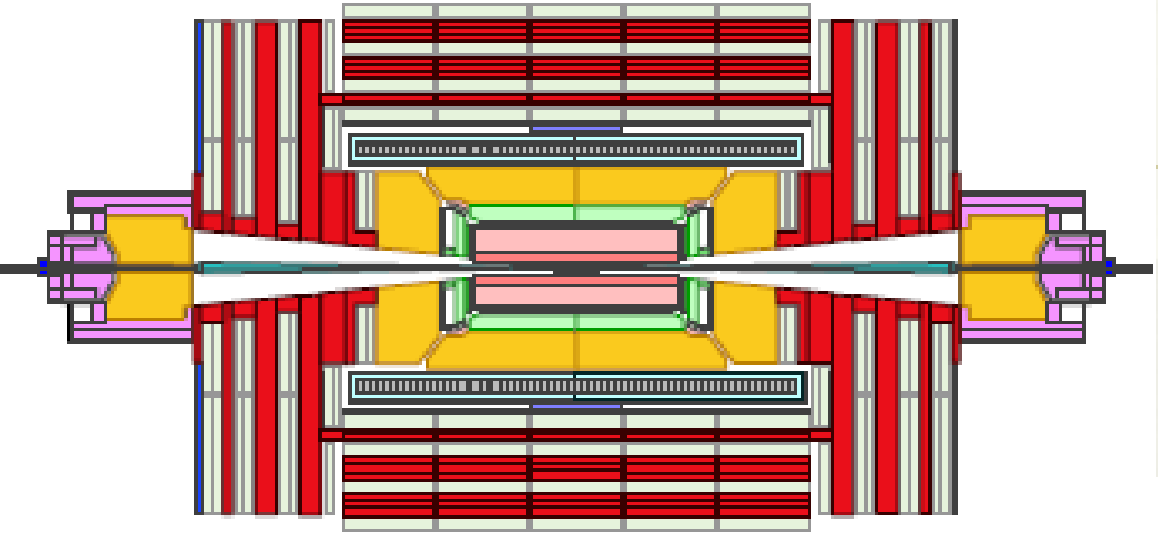
- CMS measurement of R_{Bc} is in good agreement with the result from LHCb experiment (in different kinematic range).

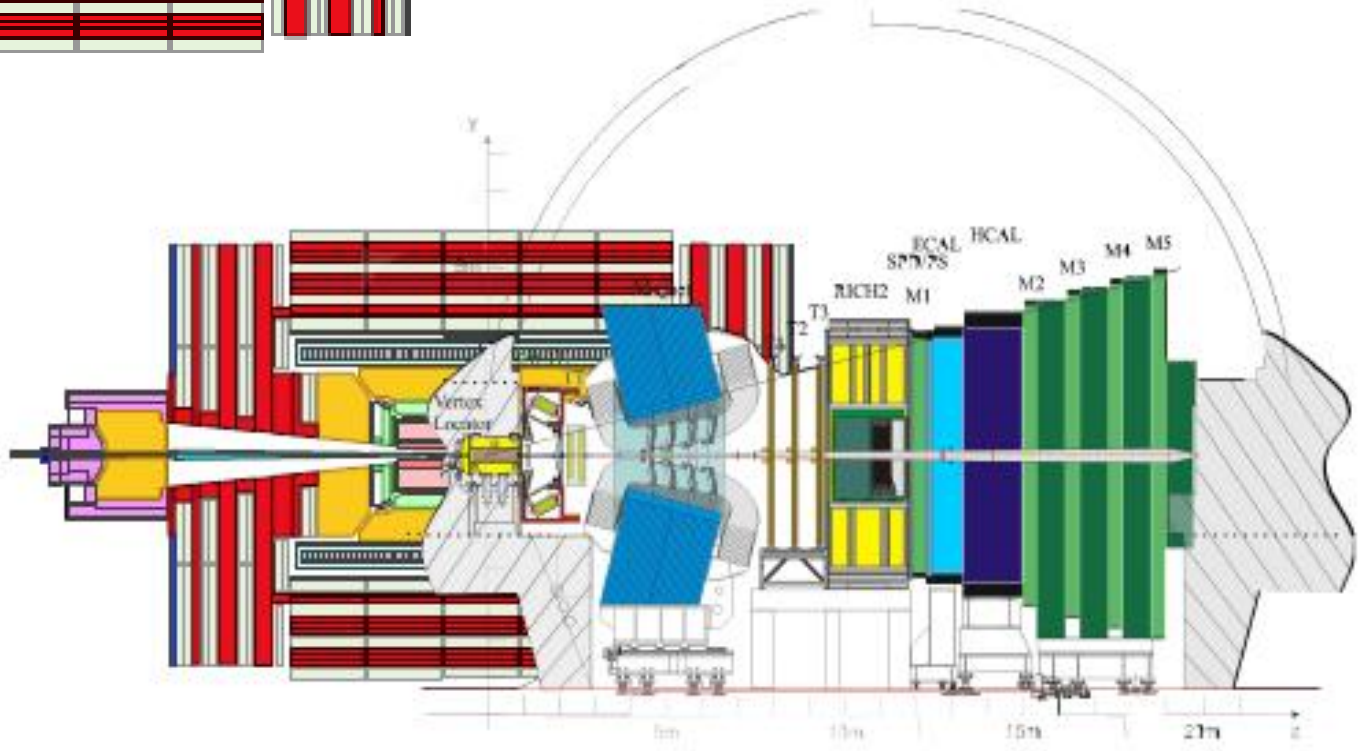
- The CMS production ratio of $R_{c/u}$ (high p_T) is smaller than LHCb's result (low p_T). It is because of the softer p_T distribution of B_c^+ with respect to that of B^+ in the central rapidity region, which implies a lower $R_{c/u}$ value at CMS.

- $B^+ \to \psi(2S)\phi K^+$ is observed in pp collisions $\sqrt{s}$ = 8 TeV by the CMS Collaboration. The $\mathcal{B}$ of $B^+ \to \psi(2S)\phi K^+$ will be measured based on this dataset.

- CMS results can give guidance to improve the theoretical calculations of various $B_c(B^+)$ decay/production models.

Thanks!





The two experiments coverage in pseudorapidity adds up.