Results in $B_c{}^+$ physics at LHCb

in particular the measurement of $\frac{BR(B_c{}^+ \to J/\psi \pi^+)}{BR(B_c{}^+ \to J/\psi \mu^+ \upsilon)}$

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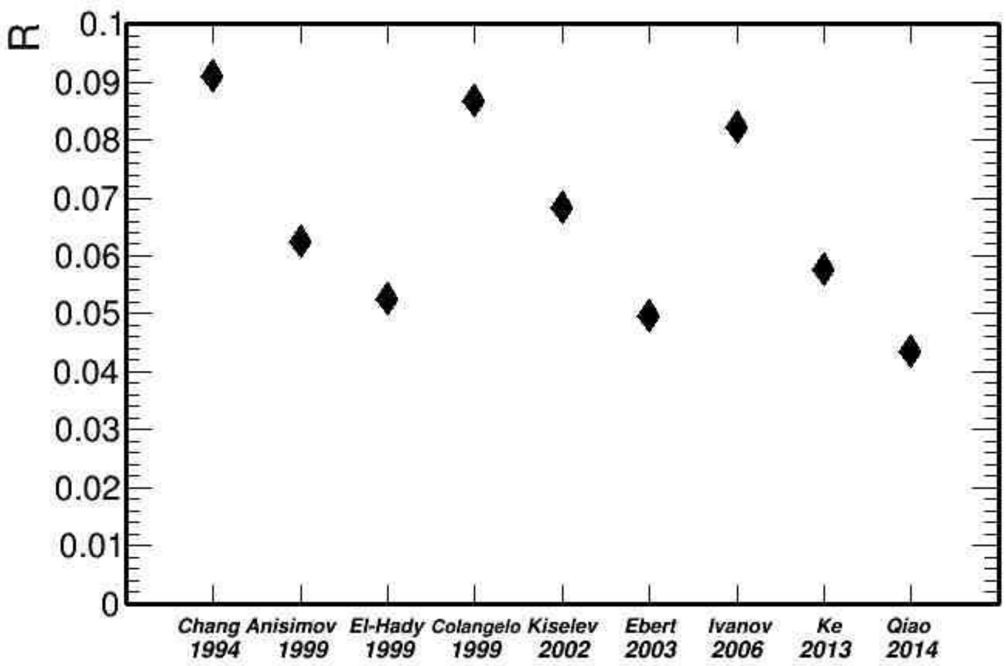
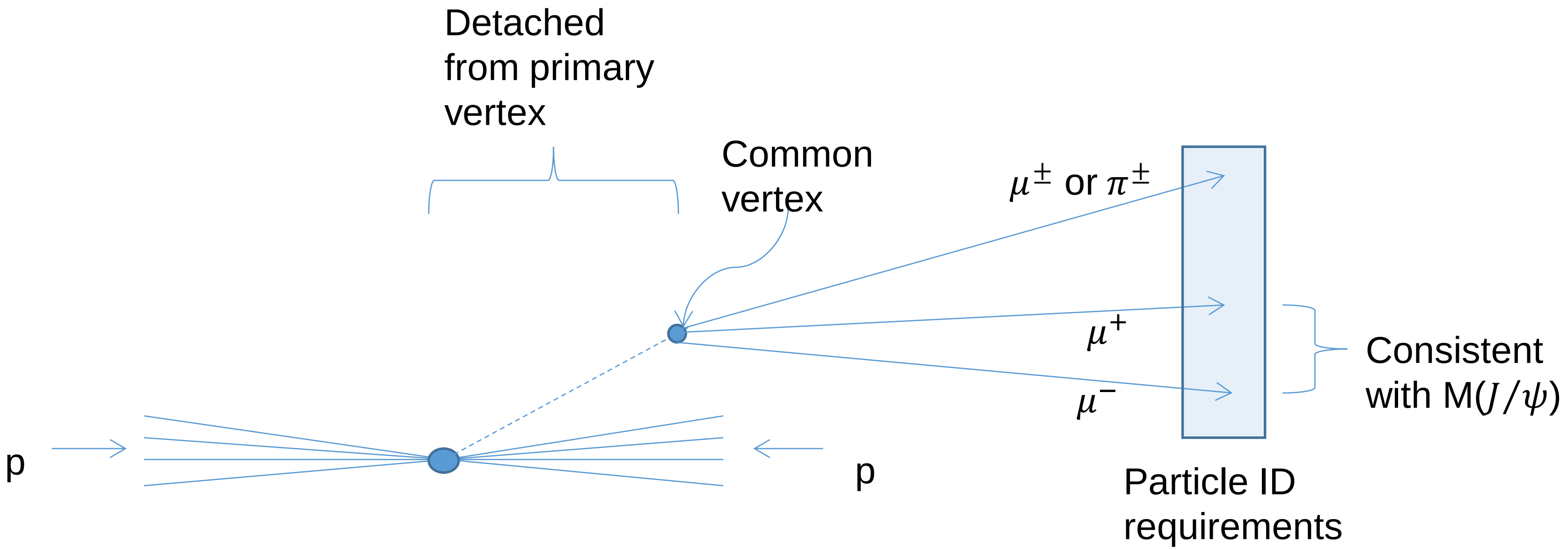
Physics Motivation

- Consisting of two heavy quarks of different flavor, the $B_c{}^+$ meson can only decay weakly and is a useful laboratory for studying heavy quark dynamics among other things.
- A number of hadronic branching fraction measurements have recently been made, but this is the first measurement of a ratio of BRs for hadronic and semileptonic $B_c{}^+$ decays.
  - A large number of theoretical predictions exist for the ratio
    $$R = \frac{BR(B_c{}^+ \to J/\psi\pi^+)}{BR((B_c{}^+ \to J/\psi\mu^+ \upsilon)}$$
    which employ several different approaches to calculating the decay rates.
  - The numerical predictions cover a wide range, and are in need of experimental input!



Data Selection

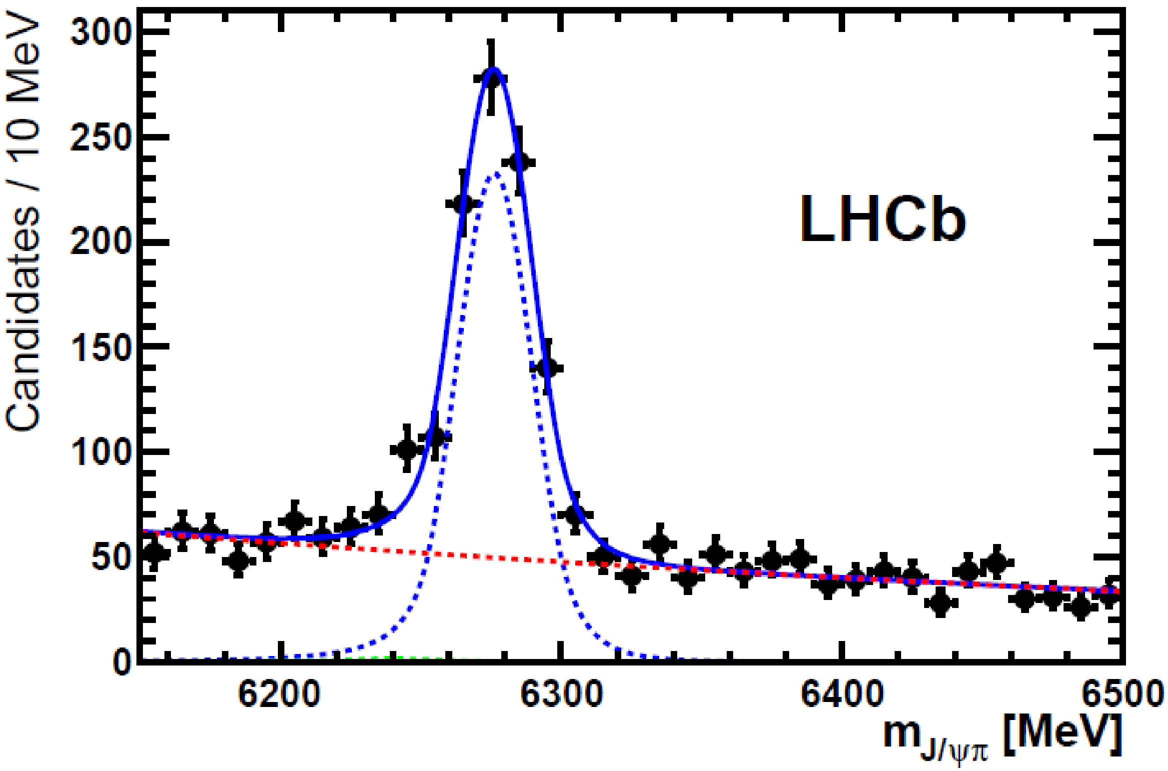
- This analysis was performed using 1 fb^{-1} of 2011 data.



- Final background suppression was done with log-likelihood functions built from signal Monte Carlo and background sources.

Signal yield extraction for $B_c^+ \to J/\psi\pi^+$

- Straightforward – fit $M(J/\psi\pi^+)$



Signal:
Double-sided Crystal-Ball function with tail parameters fixed by fit to Monte Carlo simulation.

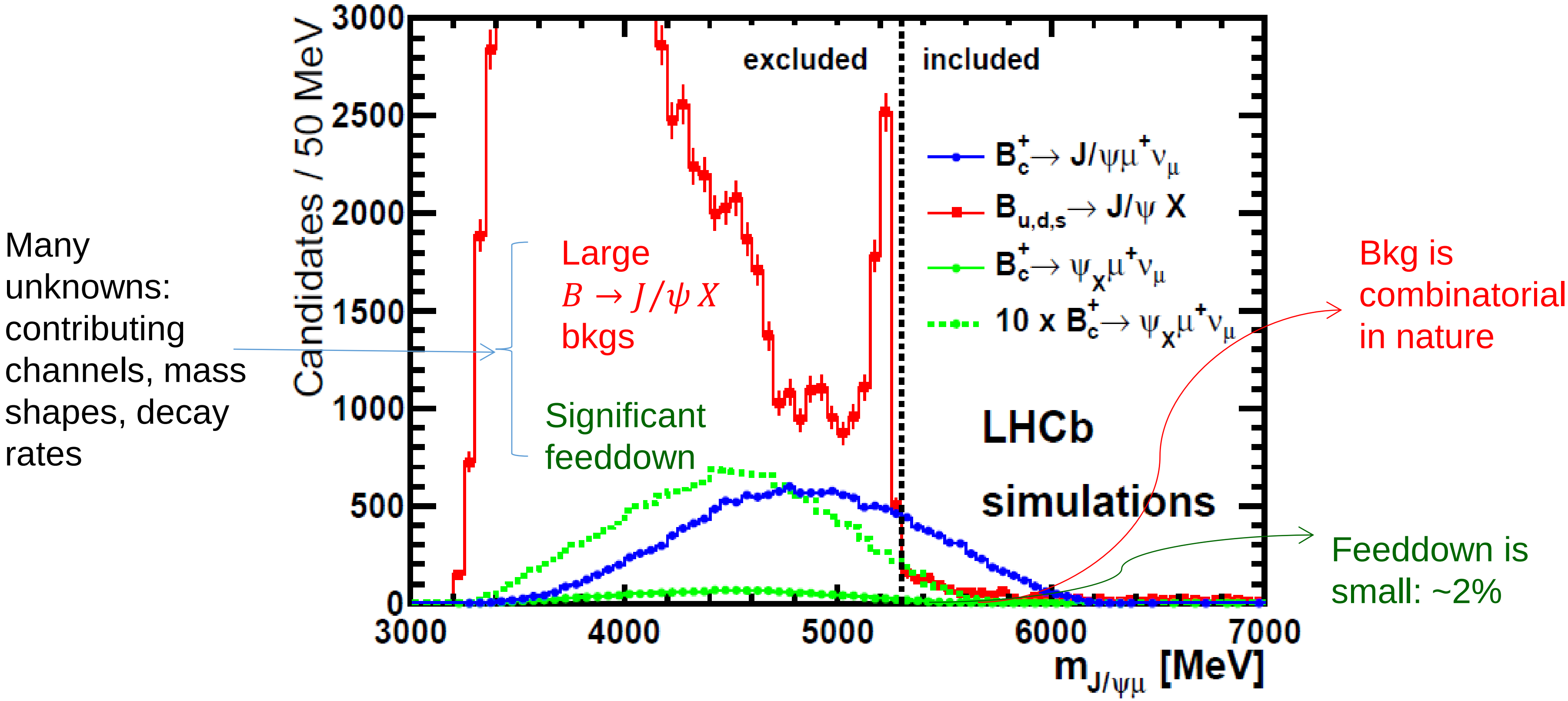
Background:
Exponential.

$B_c^+ \to J/\psi K^+$:
Double-sided Crystal-Ball function with all parameters fixed by fit to MC.

We observe 839 ± 40 $B_c^+ \to J/\psi\,\pi^+$ events.

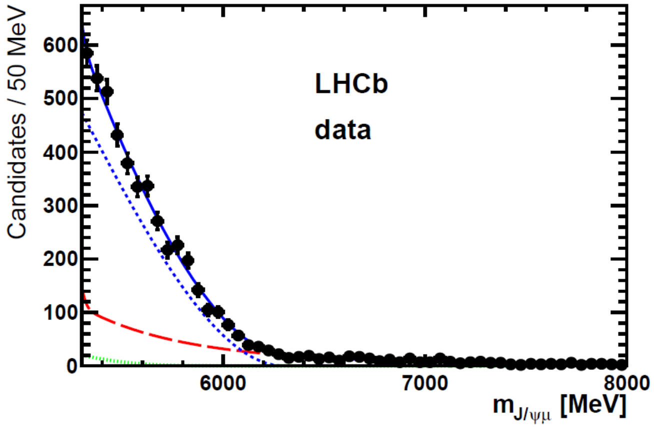
Signal yield extraction for $B_c^+ \to J/\psi\mu^+\nu$

- Fit is much more complicated due to the broad $M(J/\psi\,\mu)$ distribution:

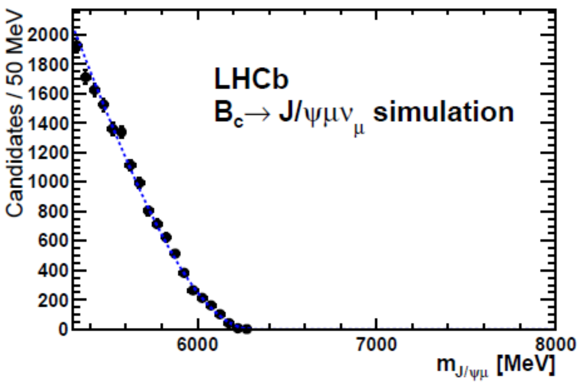


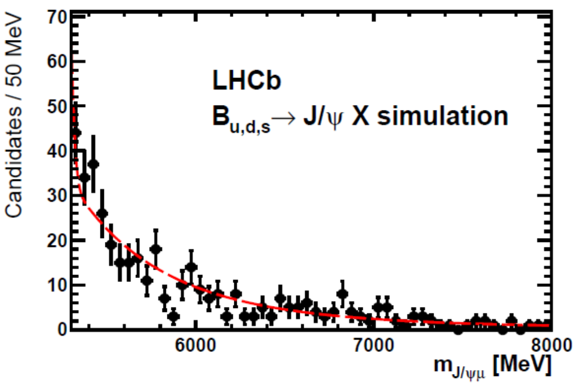
➢ We fit $M(J/\psi\,\mu)$ in endpoint region and extrapolate yield to the full phase space.

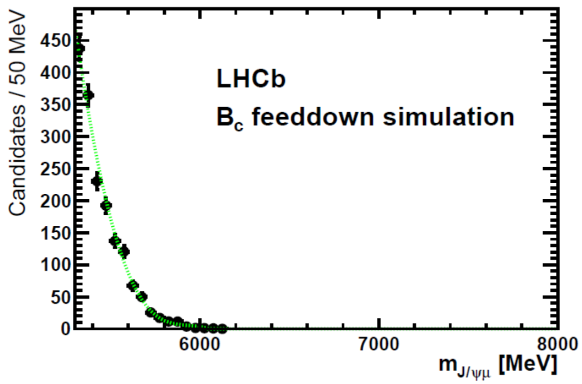
Signal yield extraction for $B_c^+ \to J/\psi\mu^+\nu$: **fit results**



Signal: shape determined from $B_c^+ \to J/\psi\mu^+\nu$ Monte Carlo
Background: shape determined from $B_{u,d,s} \to J/\psi\, X$ Monte Carlo
Feedown: shape determined from combined feeddown channel Monte Carlo



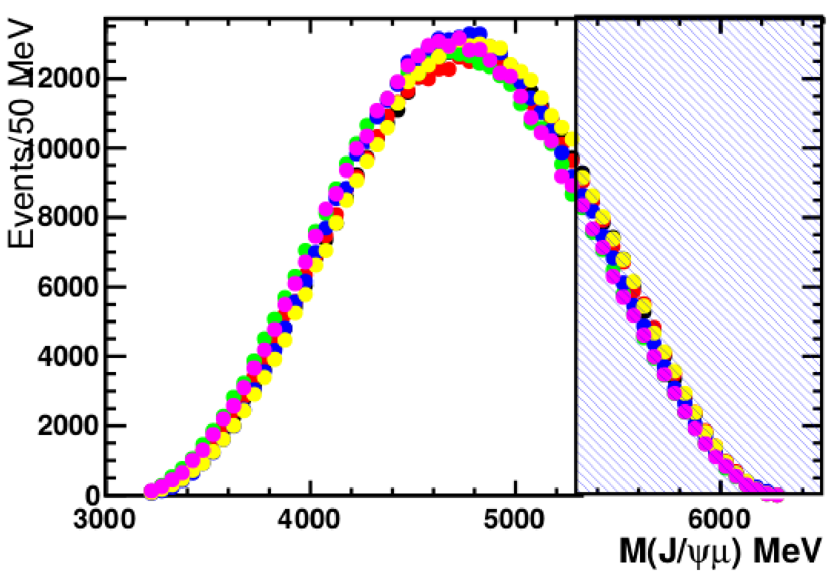


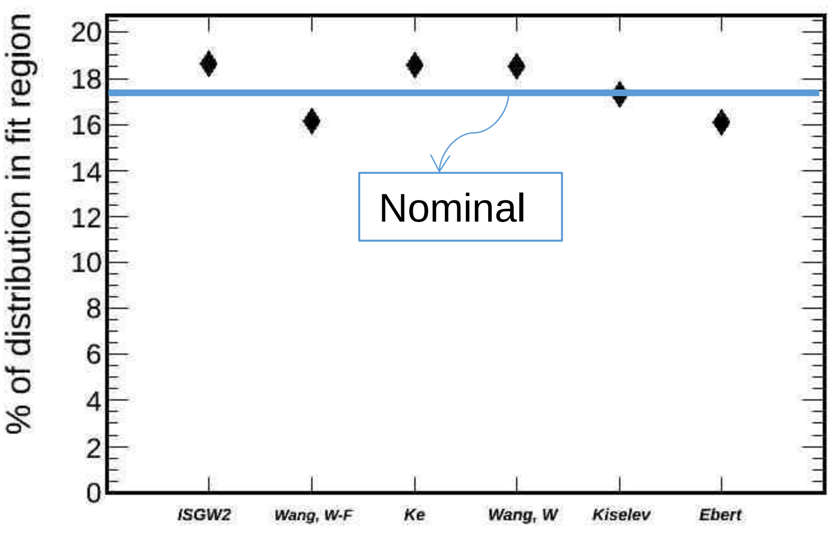


- The fit to signal and background MC is done simultaneously to the fit to the data.
- We observe 3537±125 $B_c^+ \to J/\psi\mu^+\nu$ signal events

Extrapolation of semileptonic signal yield

- Form factors from a survey of theoretical models were used in the production of different signal Monte Carlo sets in this analysis.
  - ➢ Their respective $M(J/\psi\,\mu)$ distributions were compared and, being a good middle ground, the model from Kiselev et al. was used for the extrapolation.
- This is the source of the largest systematic error, which was set from the largest deviation from the nominal (Kiselev) model to be 7.9%.





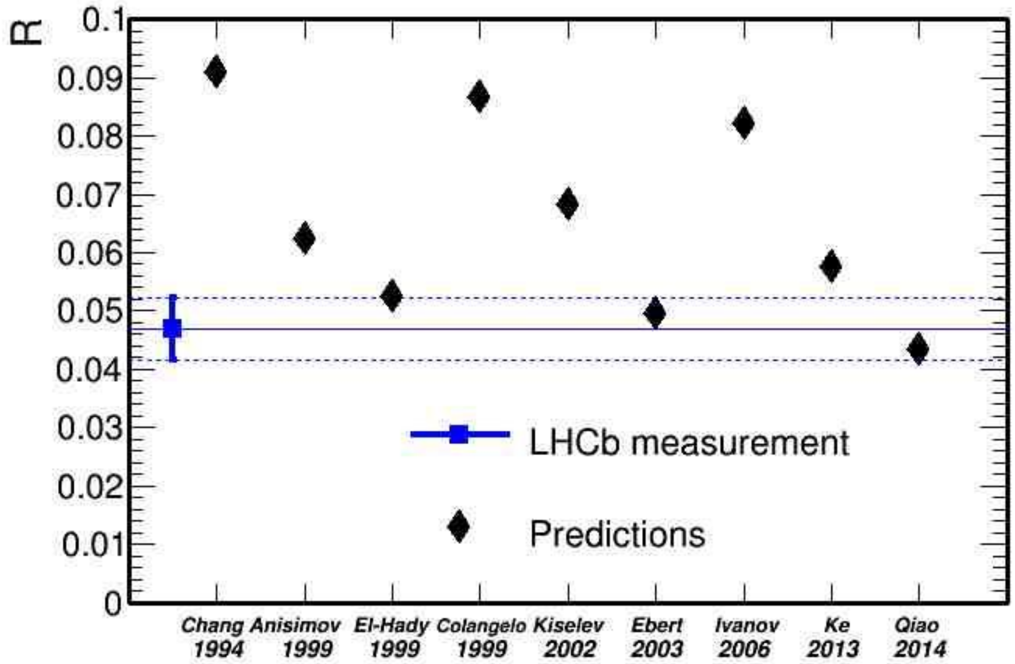
The result and comparison to the theory

- Within selected range:

$R(m_{J/\psi\mu} > 5300) = 0.271 \pm 0.016 \pm 0.016$

- In full mass range:

$R = 0.0469 \pm 0.0028 \pm 0.0046$



- The result is significantly lower than many of the theoretical predictions
- It agrees with the calculations of Ebert, Faustov, Galkin (2003); El-Hady, Munoz, Vary (1999); Ke, Li, Liu (2013); Qiao, Zhu, Sun, Yang (2014)

Summary

- We have measured the ratio of hadronic and semileptonic decay modes of B_c for the first time:

$$R = \left(\frac{BR(B_c{}^+ \to J/\psi\pi^+)}{BR(B_c{}^+ \to J/\psi\mu^+\upsilon)}\right) = 0.0469 \pm 0.0028(stat.) \pm 0.0046(syst.)$$

- There are a wide range of theoretical predictions available.
  - ➢The measured value is significantly lower than many predictions. However, it is in agreement with the lowest of the four.
- This measurement will provide some much needed experimental input and be useful in helping to discriminate between different models and their input parameters.

Backup Slides

Systematic error summary

Contribution	relative error
$m_{J/\psi\,\pi}$ signal shape	2.3%
$m_{J/\psi\,\pi}$ background shape	0.2%
$B_c \to J/\psi\,K$ component	0.1%
$m_{J/\psi\,\mu}$ signal shape	0.7%
$m_{J/\psi\,\mu}$ background shape	1.8%
B_c feeddown	0.6%
Lower $m_{J/\psi\,\mu}$ Fit Range Limit	1.6%
Upper $m_{J/\psi\,\mu}$ Fit Range Limit	1.5%
Fit $\Delta_{\mathrm{sig/bkg}}(-2\ln\mathrm{L})$ instead of $m_{J/\psi\,\mu}$	0.5%
$B_c^+ \to J/\psi\,\mu^+\nu_\mu$ model dependence of efficiency	1.3%
Pi PID	0.8%
Muon PID	1.9%
Lifetime	0.2%
Multiple Candidates	0.4%
$\Delta_{\mathrm{sig/bkg}}(-2\ln\mathrm{L})$ cut for $B_c^+ \to J/\psi\,\pi^+$	2.0%
Trigger simulation	3.4%
Total within selected $m_{J/\psi\,\mu}$ range	6.0%
$m_{J/\psi\,\mu}$ extrapolation	7.9%
Total	9.9%