Analysis of $B^{\pm} \to \pi^{\pm}(\mu^{+}\mu^{-})_{\psi}$ decays at LHCb

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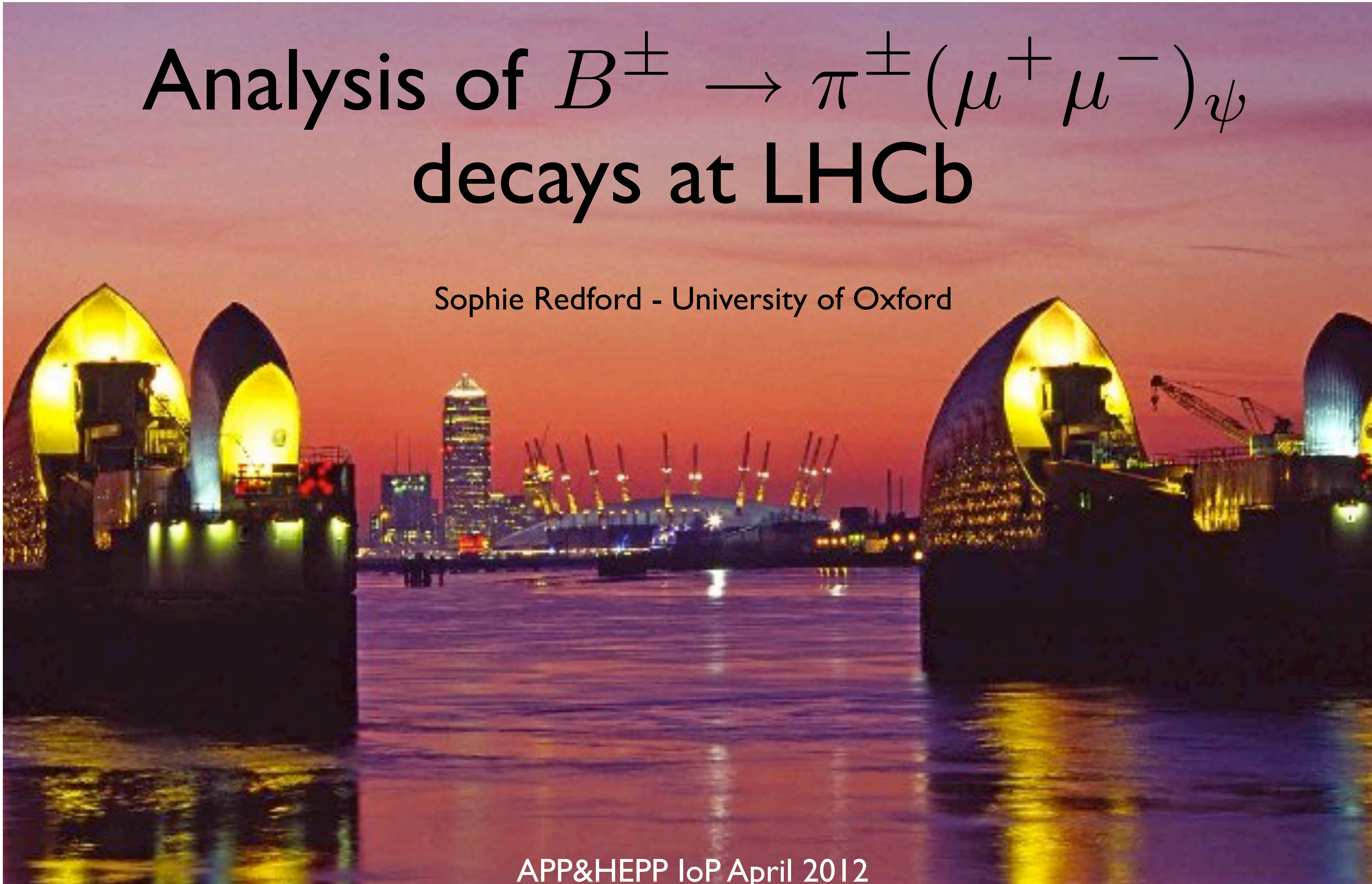


APP&HEPP IoP April 2012

Introduction to

$$B^{\pm} \rightarrow \pi^{\pm}(\mu^{+}\mu^{-})_{\psi}$$

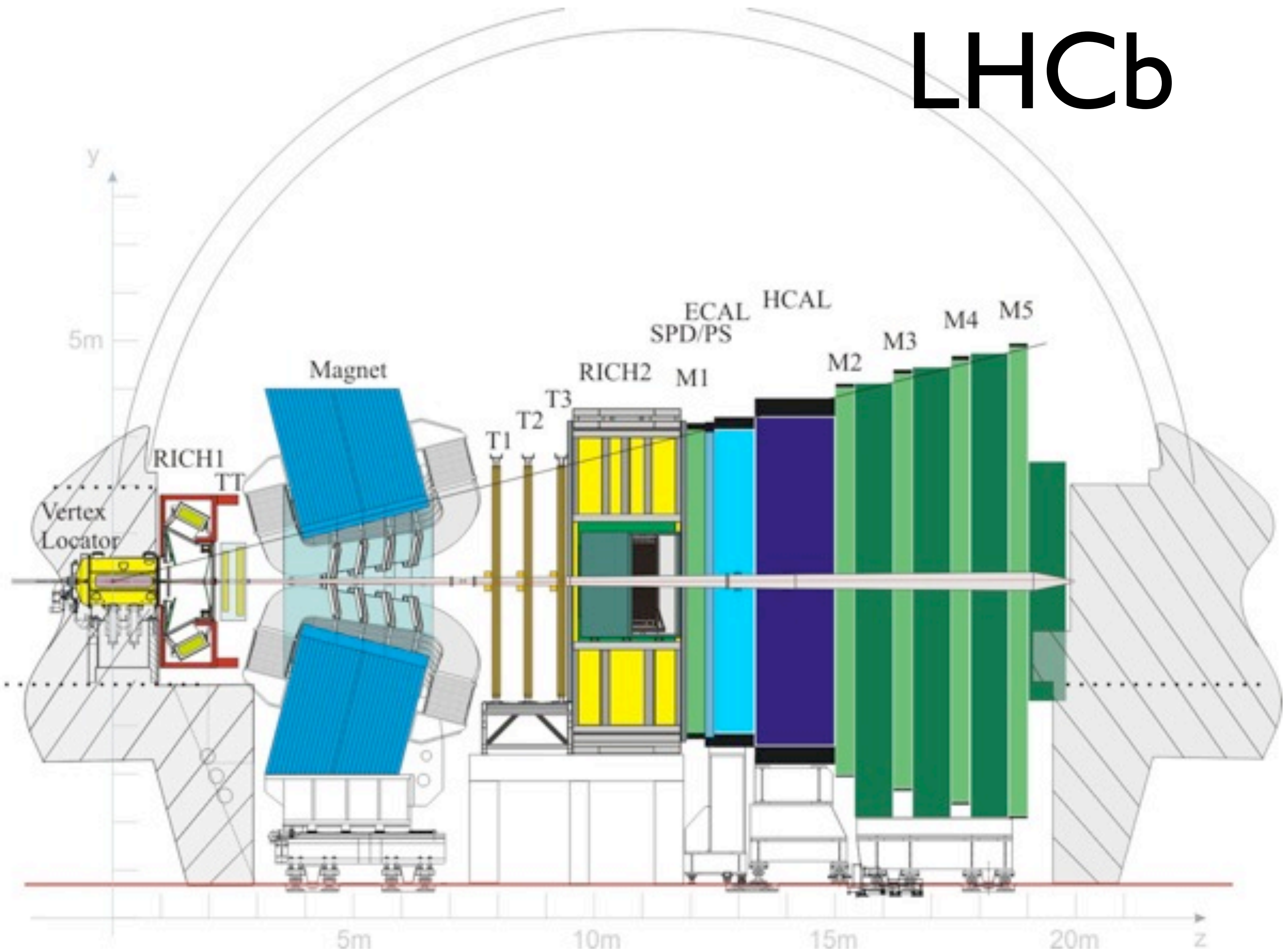
$$B^{\pm} \rightarrow \psi\pi^{\pm}$$

- Resonant decay to dimuon final state
- Plentiful statistics
- BF, charge asymmetry measurements

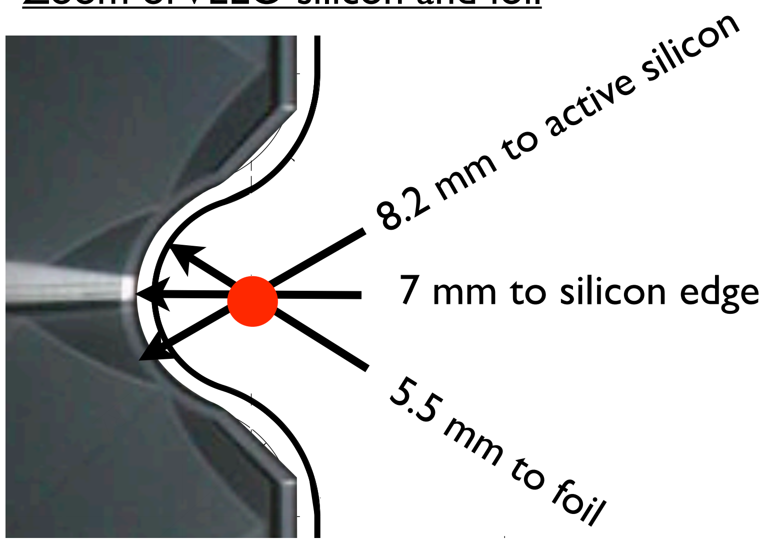
$$B^{\pm} \rightarrow \pi^{\pm}\mu^{+}\mu^{-}$$

- Non-resonant decay
- Challenging statistics
- Observation, BF measurement

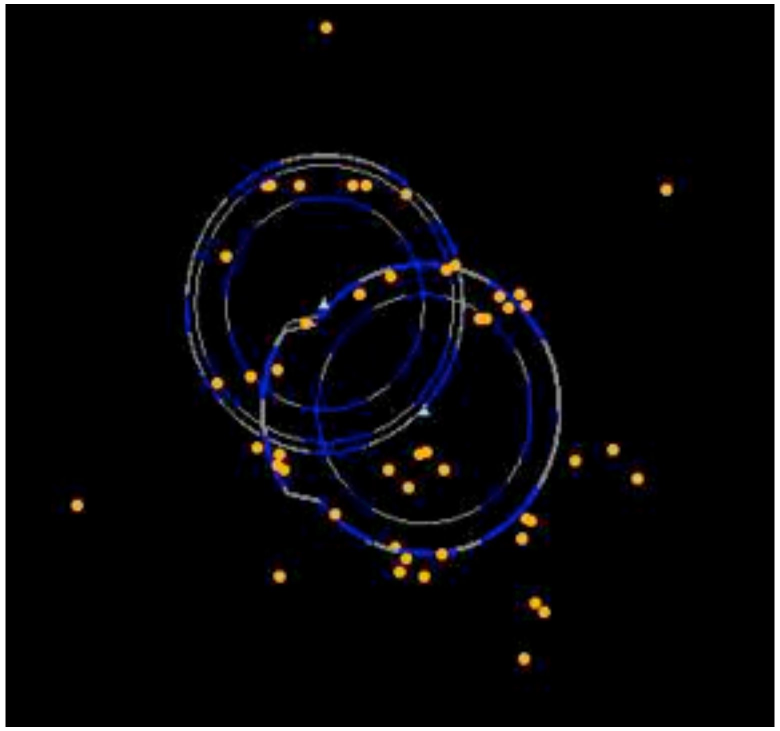
LHCb



Zoom of VELO silicon and foil



Zoom of RICH Cherenkov rings



- Precise vertexing (VELO)
- Charge separation (dipole magnet)
- Hadron separation (RICH)
- Muon identification (muon chambers)

Measurements of the branching fractions and CP asymmetries of $B^{\pm} \to J/\psi\pi^{\pm}$ and $B^{\pm} \to \psi(2S)\pi^{\pm}$ decays

$0.37\ \mathrm{fb}^{-1}$

LHCb-PAPER-2011-024

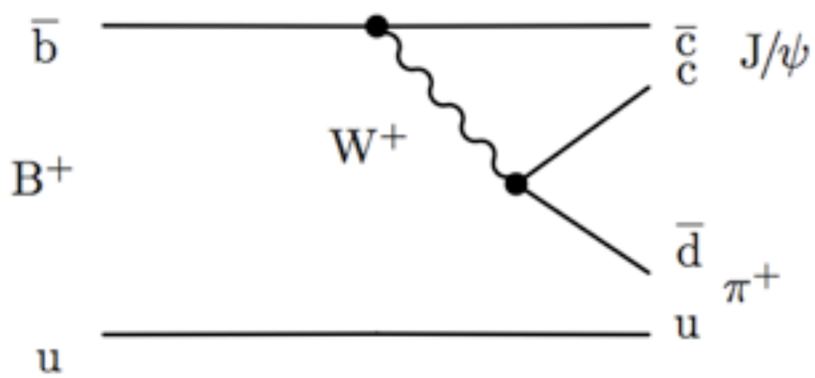
arXiv:1203.3592v1

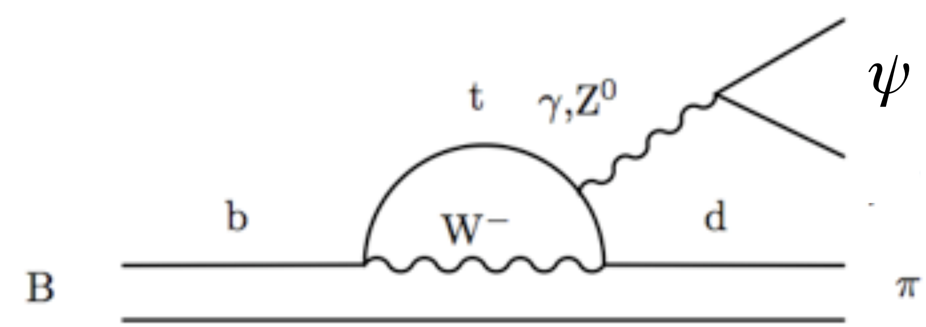
Observables and motivation

$$R = \frac{\mathcal{BF}(B^{\pm} \to \psi\pi^{\pm})}{\mathcal{BF}(B^{\pm} \to \psi K^{\pm})} \quad \text{for} \quad \psi = J/\psi, \psi(2S)$$

$$A_{CP} = \frac{\mathcal{BF}(B^{-} \to \psi h^{-}) - \mathcal{BF}(B^{+} \to \psi h^{+})}{\mathcal{BF}(B^{-} \to \psi h^{-}) + \mathcal{BF}(B^{+} \to \psi h^{+})} \quad \text{for} \quad \begin{array}{l} \psi = J/\psi, \psi(2S) \\ h = \pi, K \end{array}$$

- Sensitive to interference of electroweak penguin with tree-level process:



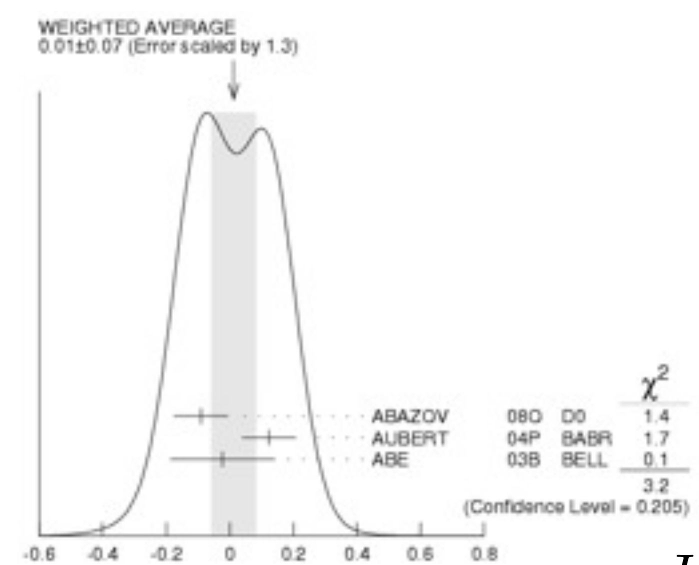


- Asymmetry of B → J/Ψ K well measured:

$$A_{CP}^{J/\psi K} = (1 \pm 7) \times 10^{-3}$$

- Asymmetry of B → J/Ψ π measured to good accuracy by DØ and BaBar, but results differ slightly

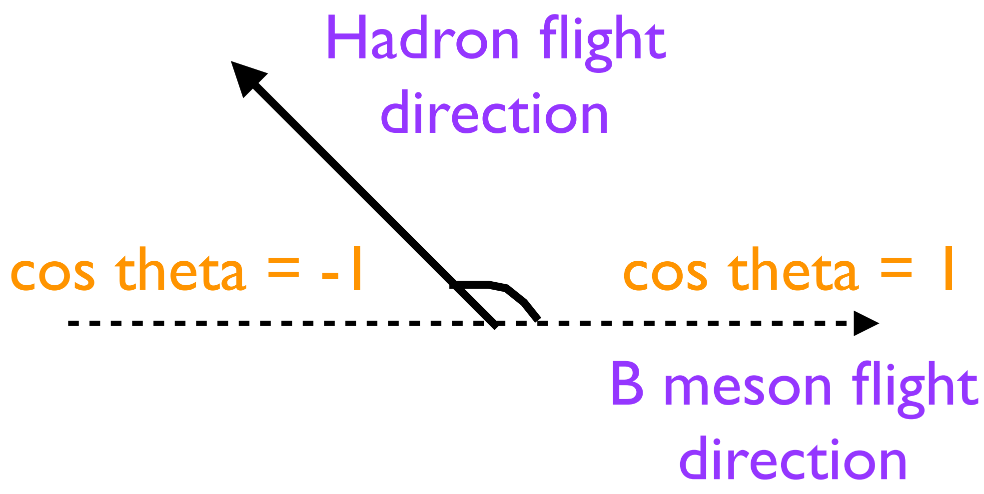
- B → Ψ(2S) h less well explored

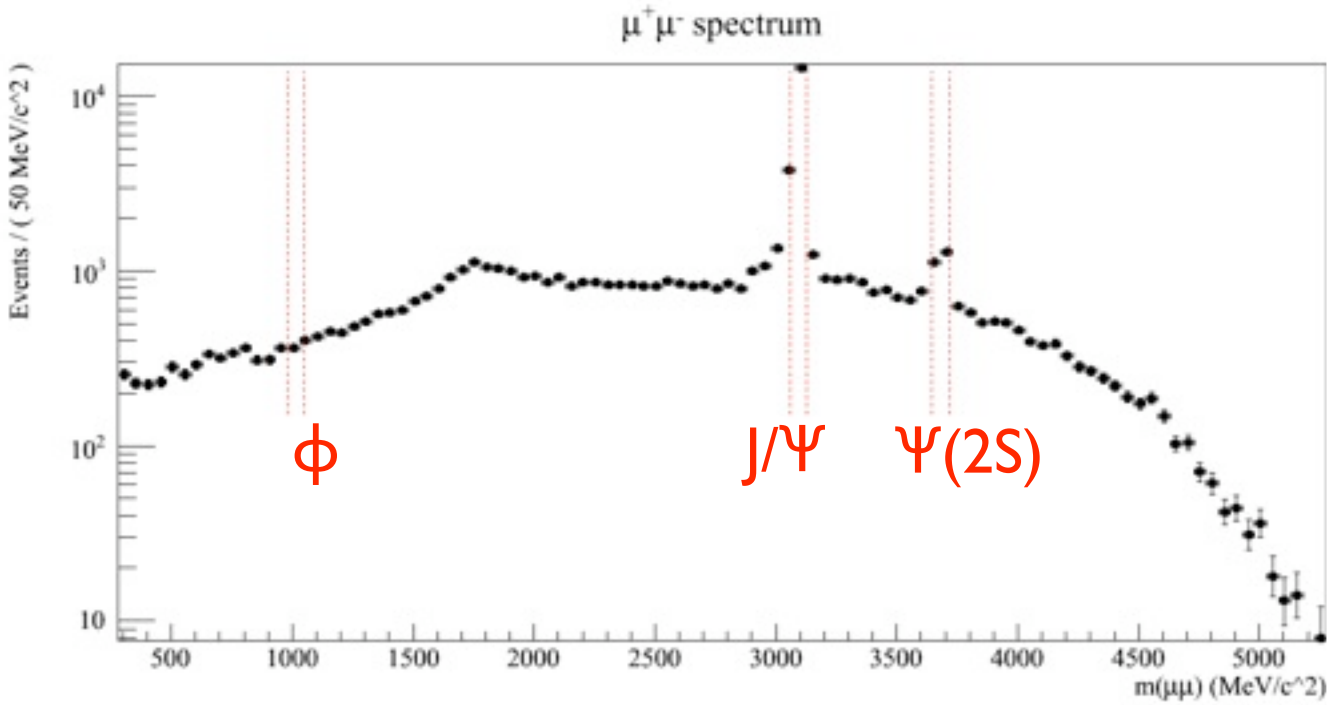


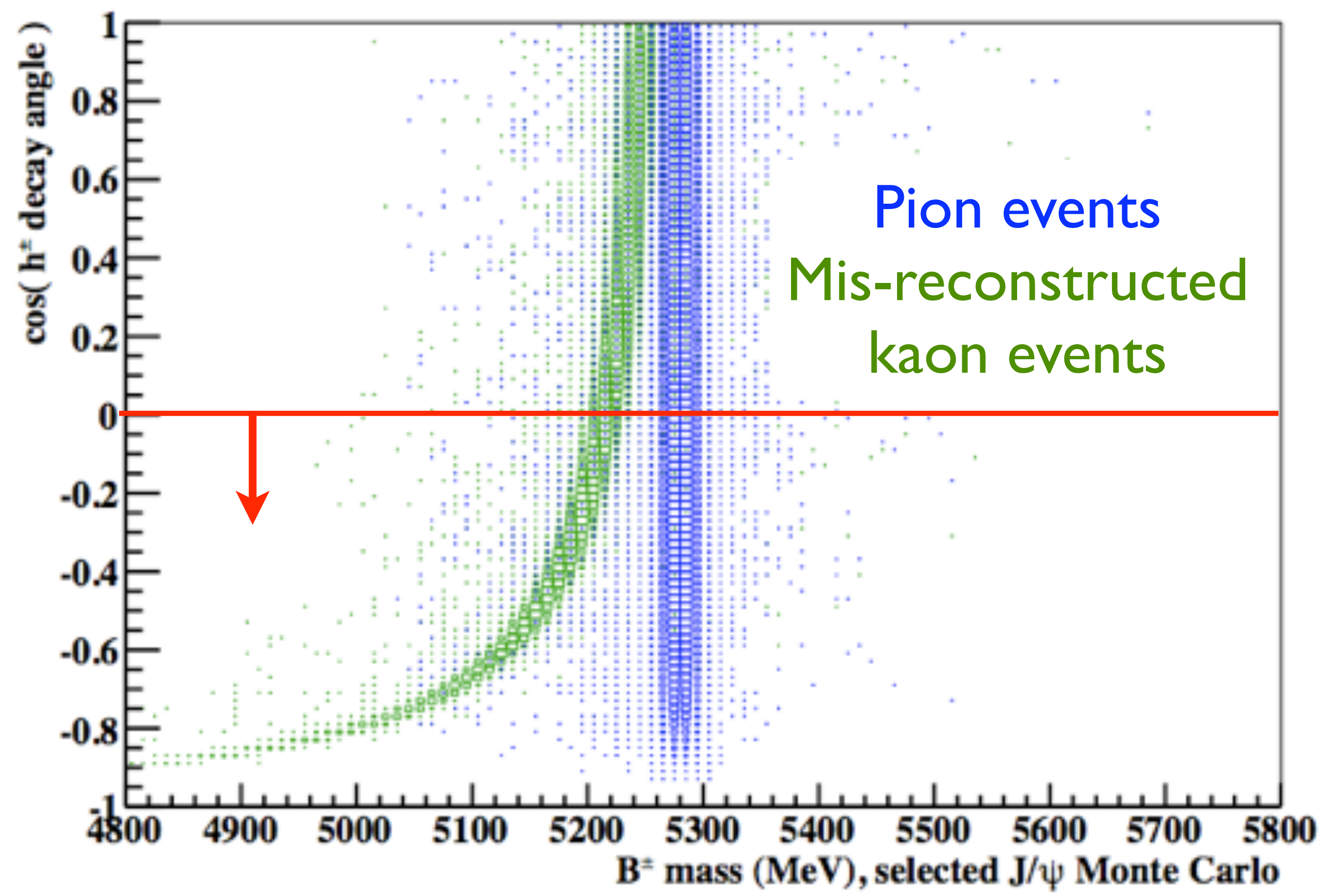
PDG average for $A_{CP}^{J/\psi\pi}$

Selection of $B^{\pm} \rightarrow \psi h^{\pm}$

- Isolate Ψ resonances with dimuon mass windows
- Rectangular cuts on kinematic variables
- Prefer slow hadrons:
  - J/Ψ analysis uses a decay angle selection
  - No similar selection for heavier Ψ(2S)



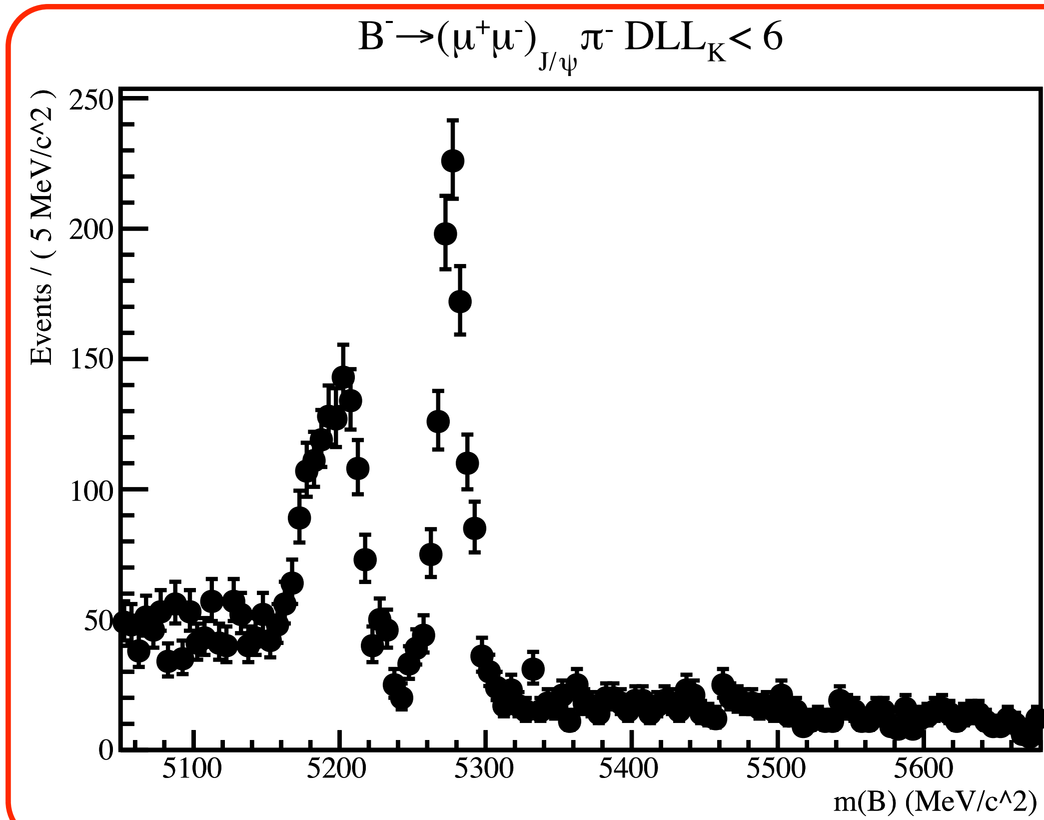


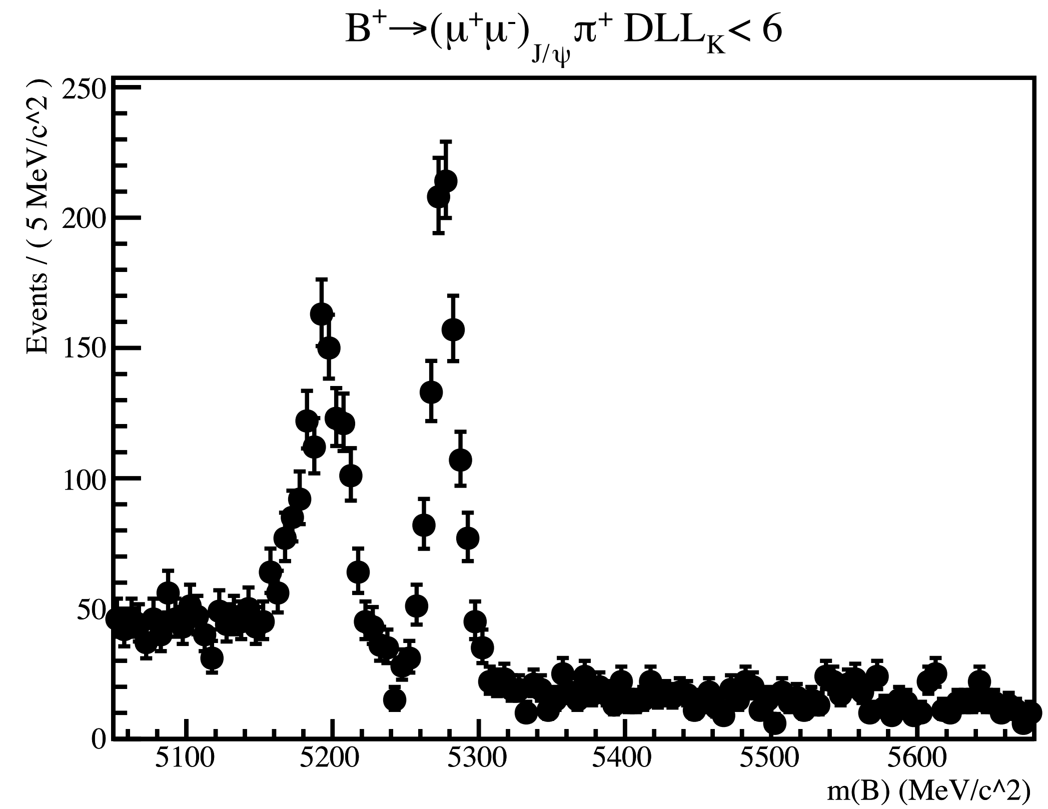


Analysis strategy

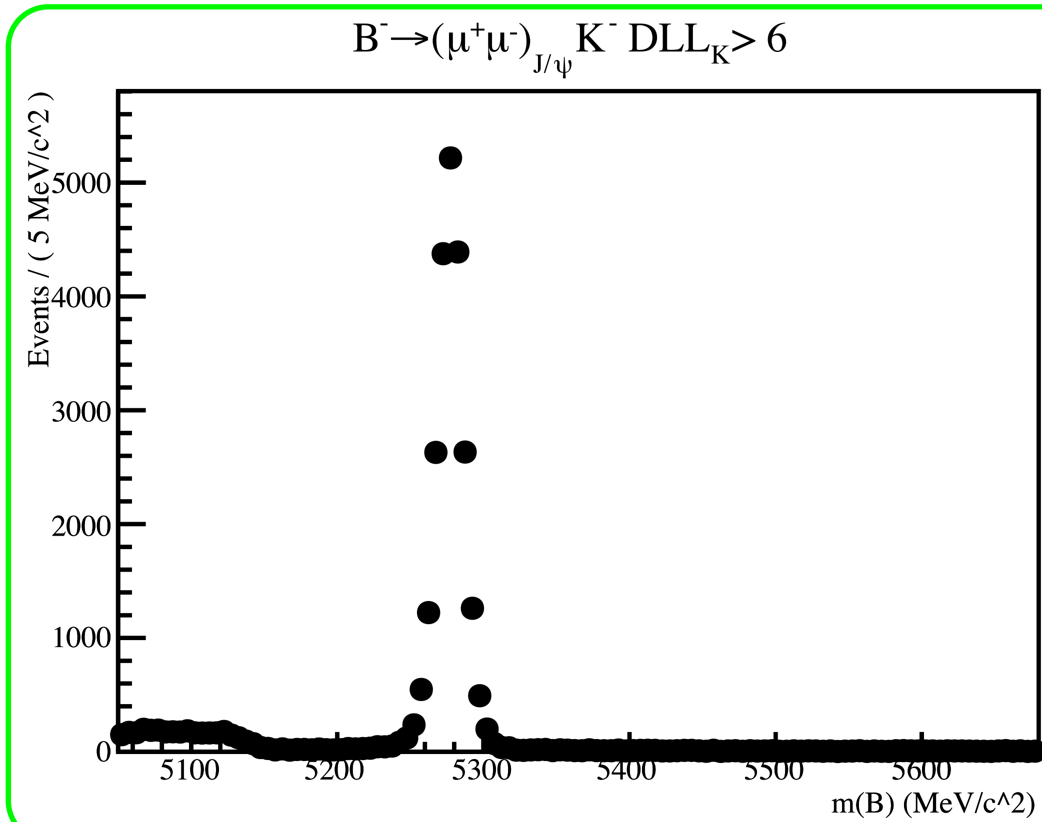
B- | B+

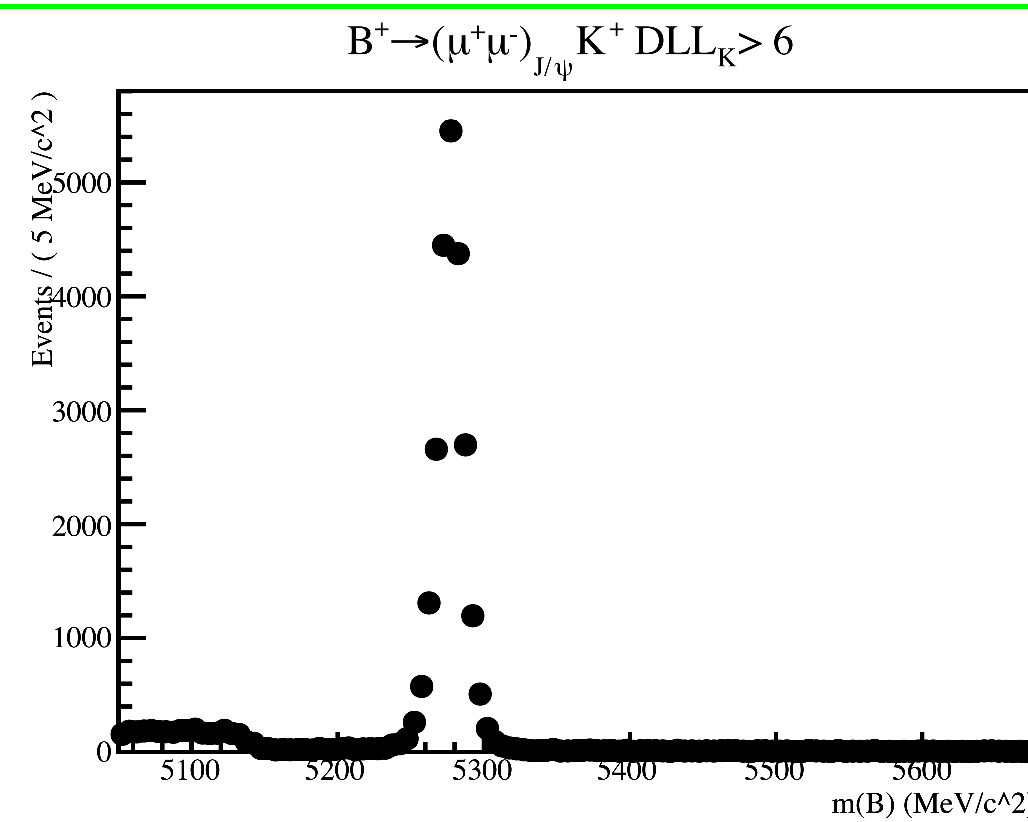
PASS DLL pion-like





FAIL DLL kaon-like





Analysis strategy

B- B+

PASS DLL pion-like

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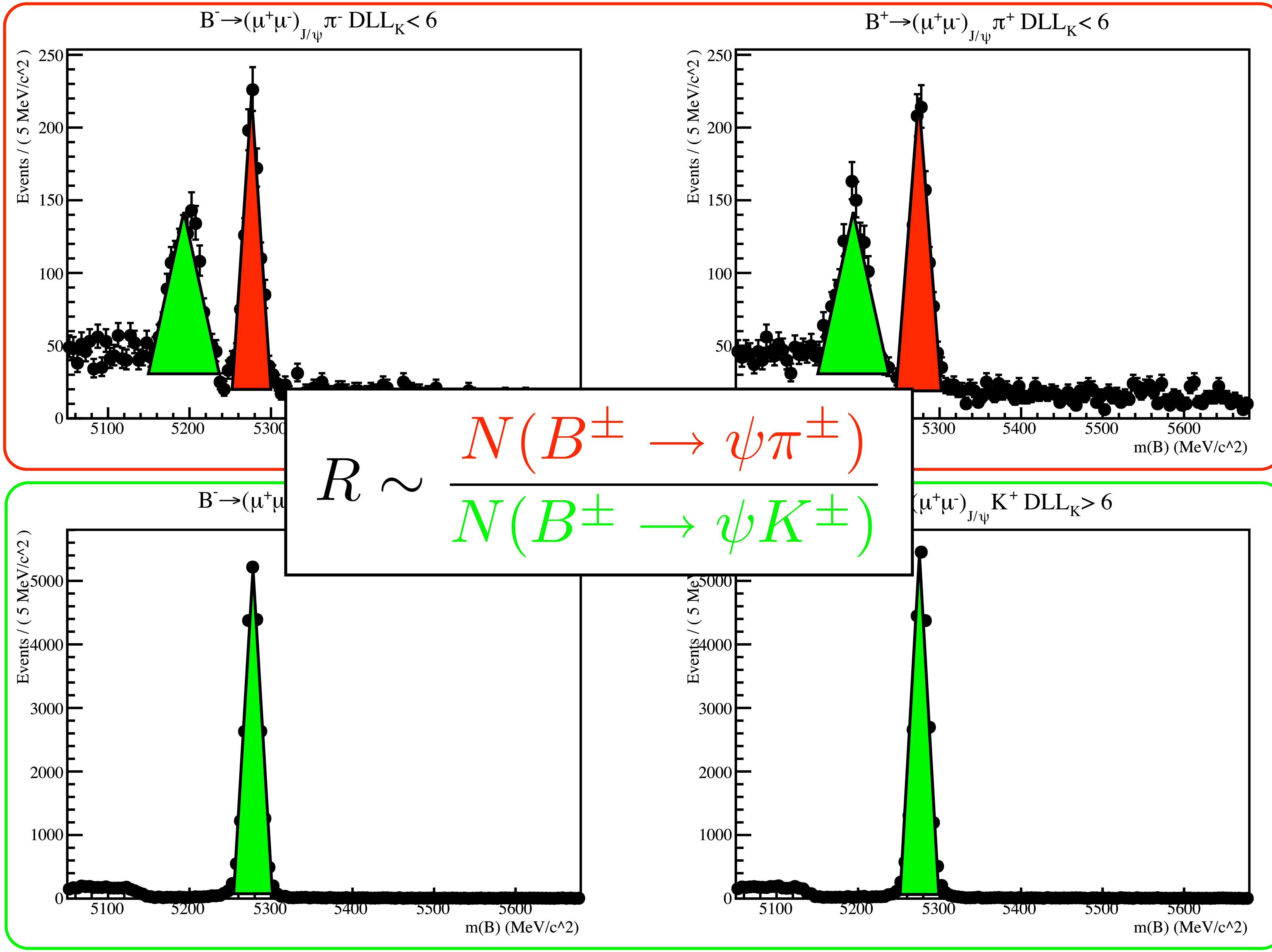
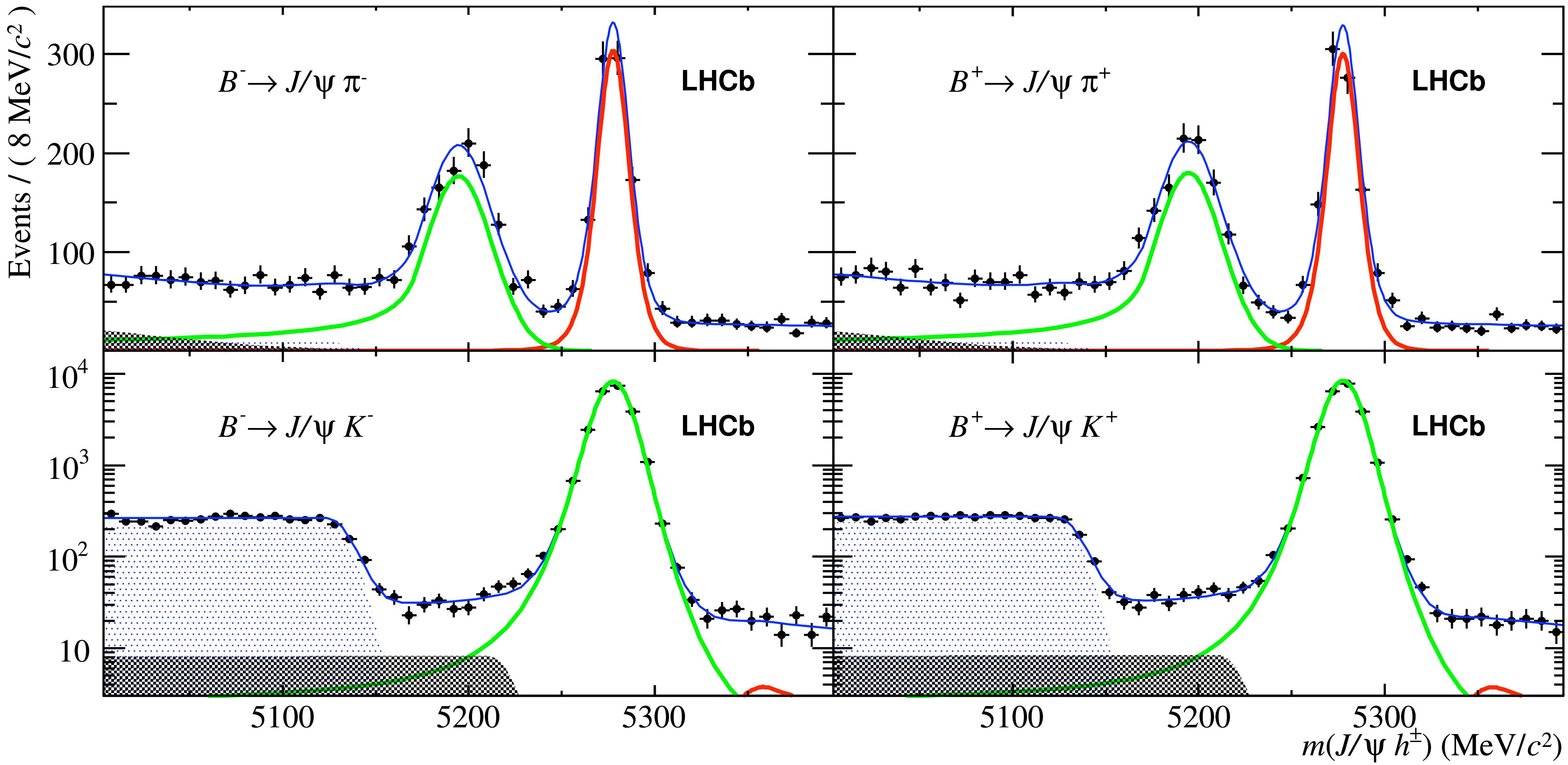


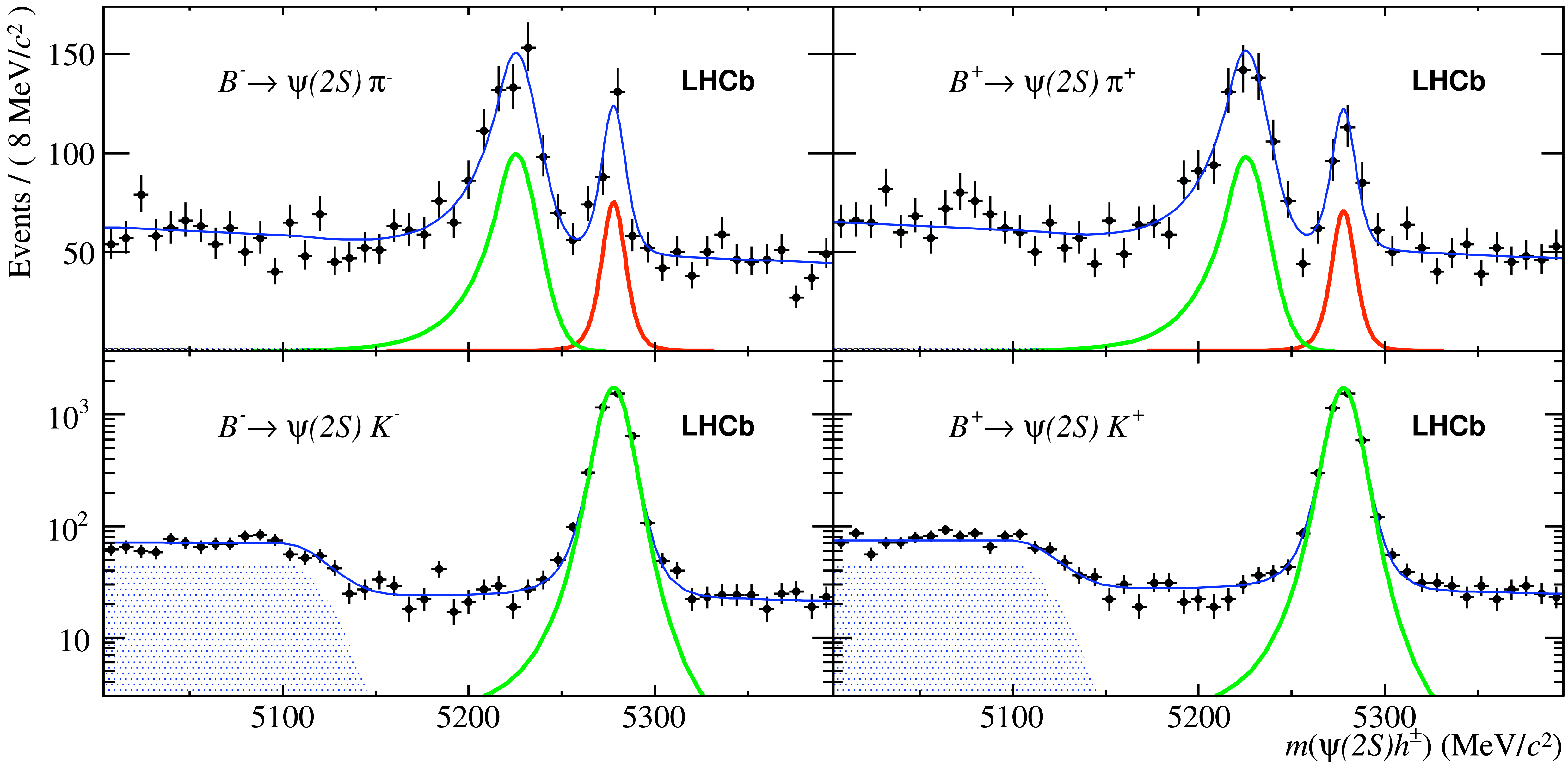
$$R \sim \frac{N(B^{\pm} \to \psi\pi^{\pm})}{N(B^{\pm} \to \psi K^{\pm})}$$

Fit results: J/ψ



$$\frac{B^\pm \to J\psi K^\pm \quad 50\text{k}}{B^\pm \to J\psi\pi^\pm \quad 2\text{k}}$$

Fit results: $\psi(2S)$



$$\frac{B^\pm \to \psi(2S)K^\pm \quad \text{10k}}{B^\pm \to \psi(2S)\pi^\pm \quad 400}$$

Corrections and results

$$R = \frac{N(B^\pm \to \psi\pi^\pm)}{N(B^\pm \to \psi K^\pm)} \times \frac{\varepsilon_{acc}(B^\pm \to \psi K^\pm)}{\varepsilon_{acc}(B^\pm \to \psi\pi^\pm)} \times \frac{\varepsilon_{sel}(B^\pm \to \psi K^\pm)}{\varepsilon_{sel}(B^\pm \to \psi\pi^\pm)} \times \frac{\varepsilon_{trig}(B^\pm \to \psi K^\pm)}{\varepsilon_{trig}(B^\pm \to \psi\pi^\pm)}$$

$$R^{J/\psi} = (3.83 \pm 0.11 \pm 0.07) \times 10^{-2}$$

$$R^{\psi(2S)} = (3.95 \pm 0.40 \pm 0.12) \times 10^{-2}$$

$$A_{Raw}^{B\to\psi K} = A_{Prod} + A_{Det}^{K} + A_{CP}^{B\to\psi K}$$

$$A_{Raw}^{B\to\psi\pi} = A_{Prod} + A_{Det}^{\pi} + A_{CP}^{B\to\psi\pi}$$

$$A_{CP}^{J/\psi\pi} = 0.005 \pm 0.027 \pm 0.011$$

$$A_{CP}^{\psi(2S)\pi} = 0.048 \pm 0.090 \pm 0.011$$

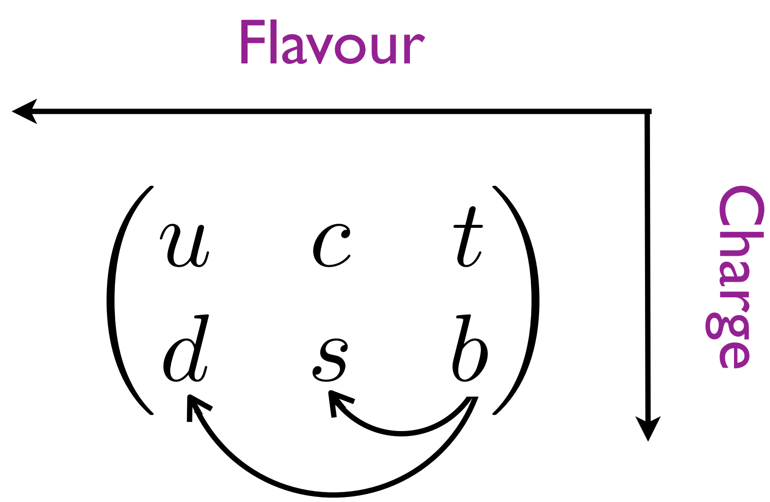
First measurement of $B^{\pm} \rightarrow \pi^{\pm}\mu^{+}\mu^{-}$

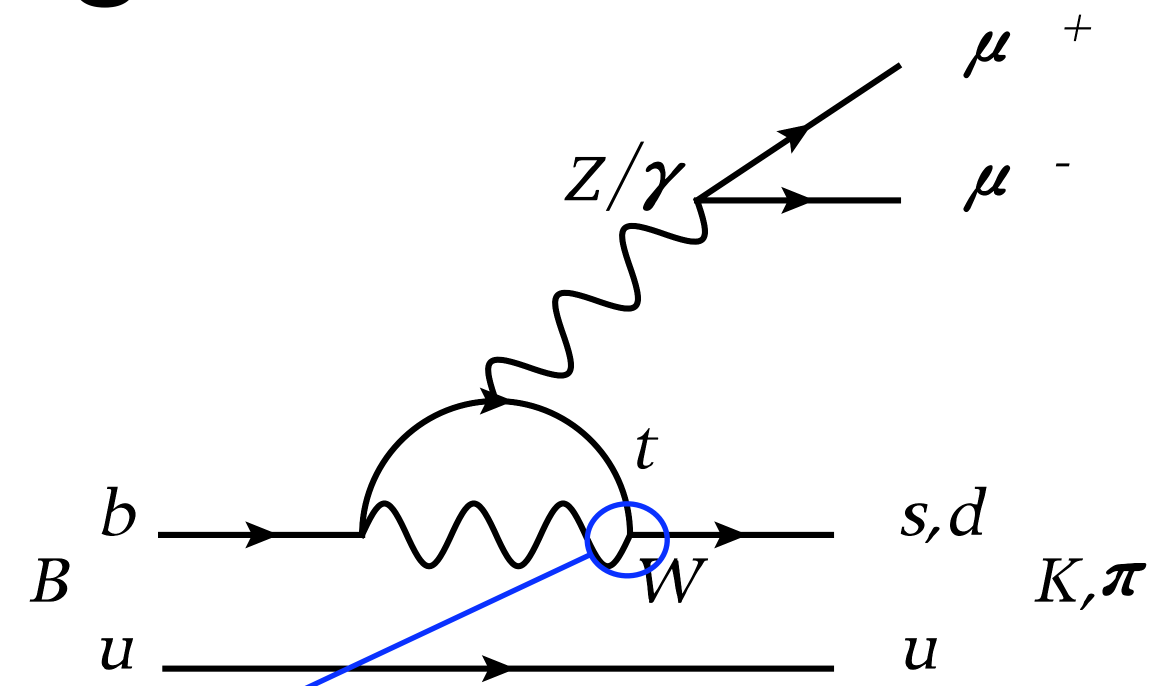
$1.0\ \mathrm{fb}^{-1}$

LHCb-CONF-2012-006

Greg Ciezarek, Malcolm John, Mitesh Patel, Sophie Redford

Flavour changing neutral currents





Interest in $\left|\frac{V_{td}}{V_{ts}}\right|^2$ (ratio of branching fractions)

CKM matrix

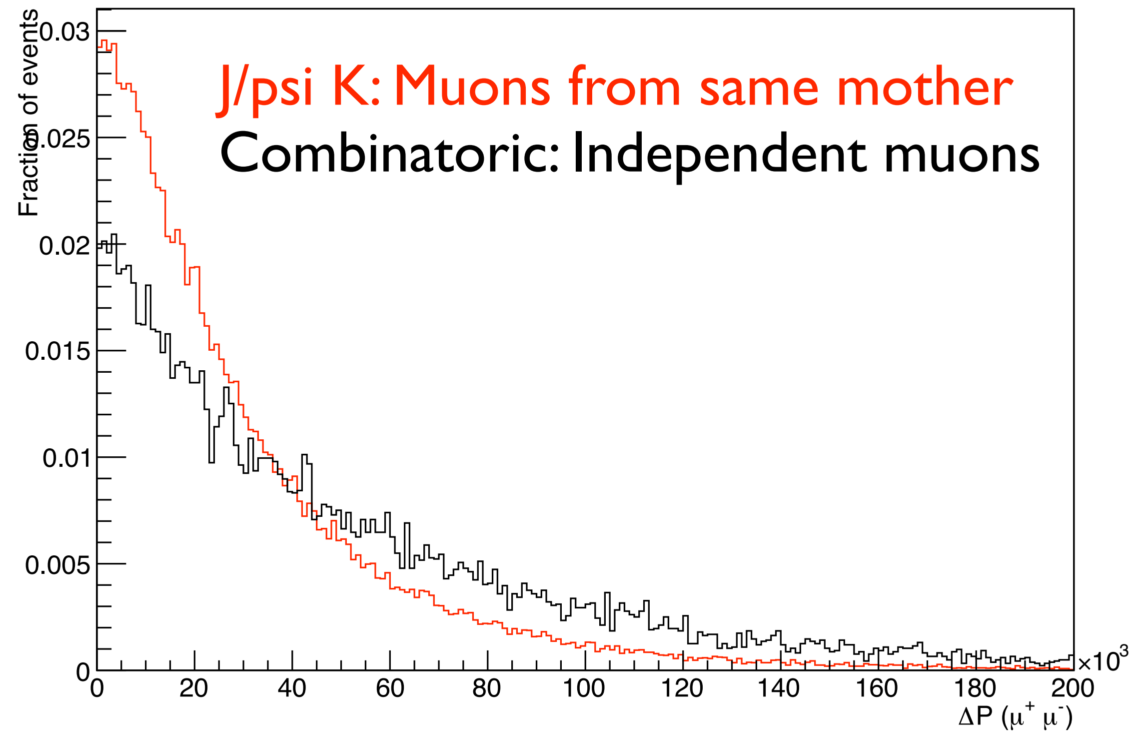
$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

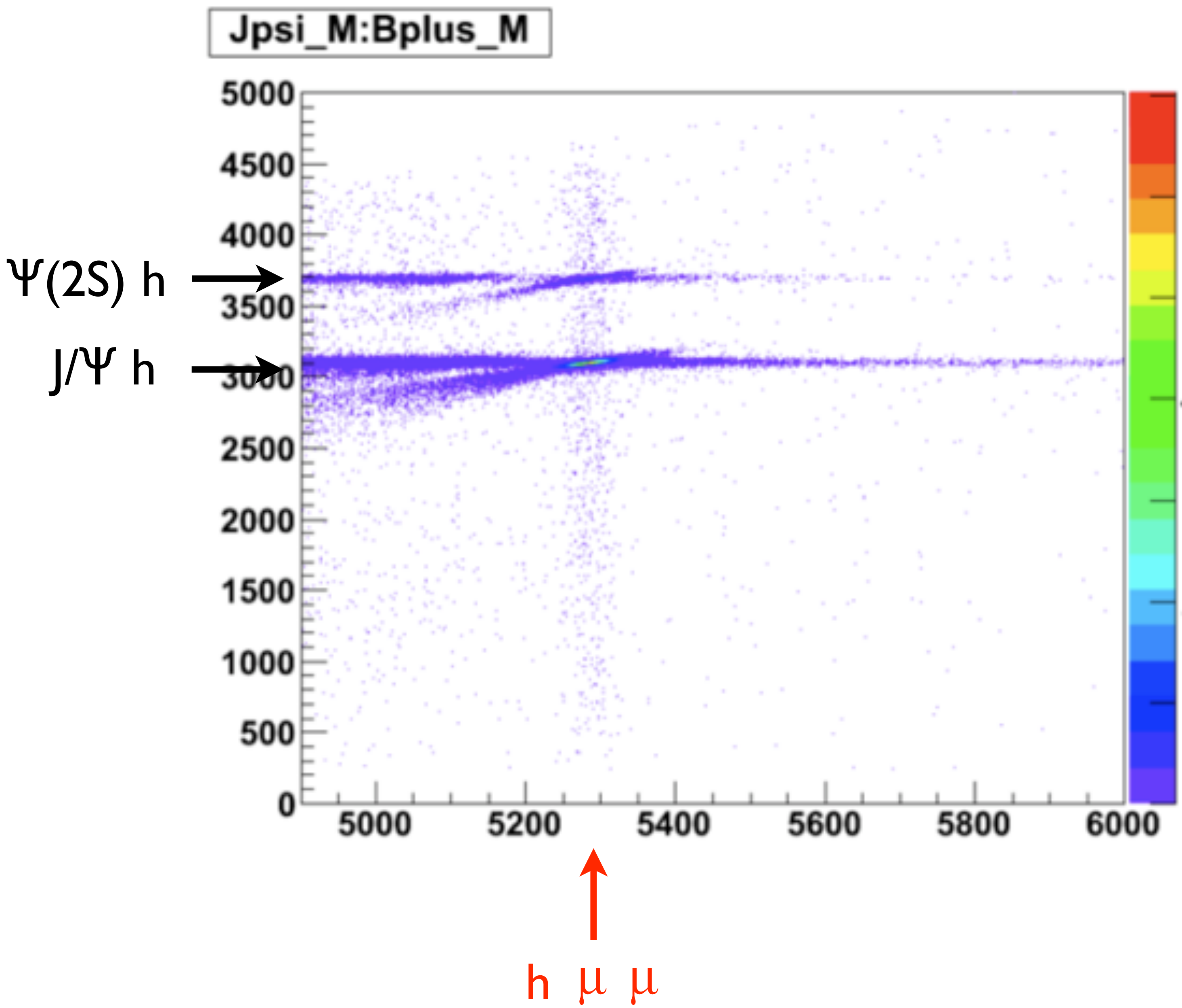
≈1

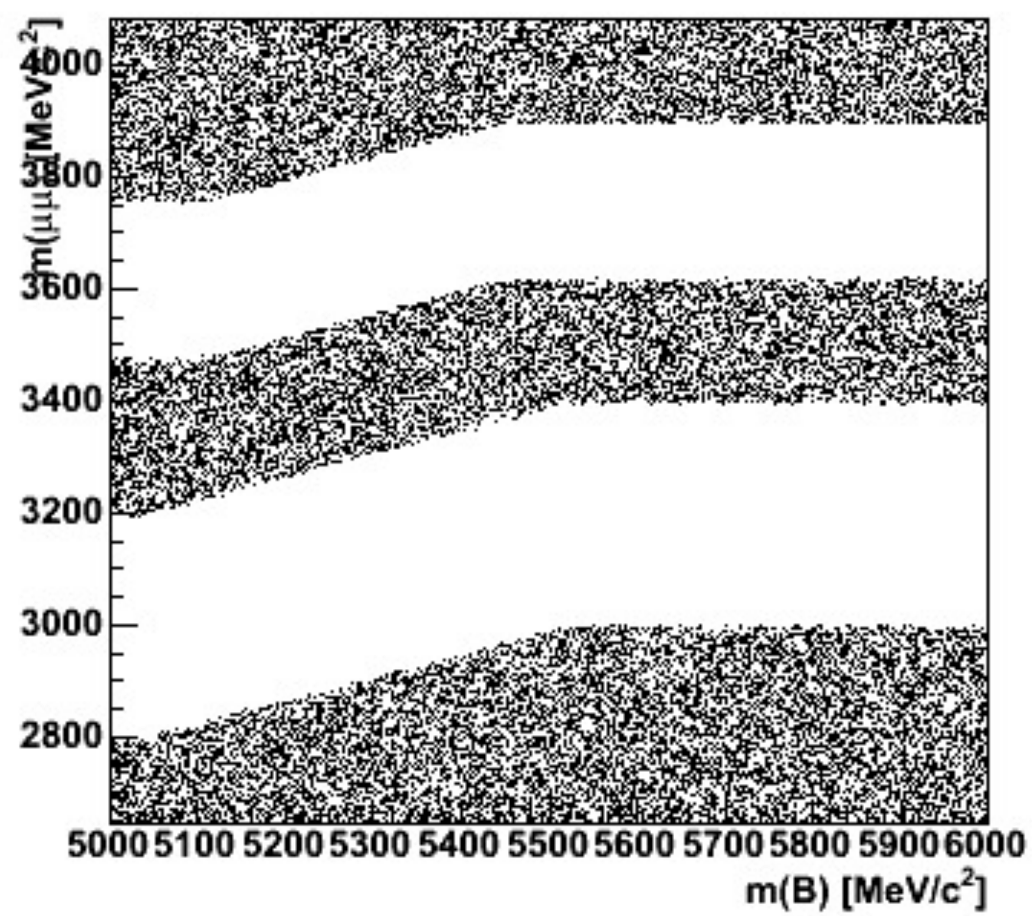
- Cabibbo suppression between $B^+ \rightarrow K^+\mu^+\mu^-$ and $B^+ \rightarrow \pi^+\mu^+\mu^-$
- With only the SM active, expect a factor 25 fewer $B^+ \rightarrow \pi^+\mu^+\mu^-$

Selection

- Loose preselection followed by a multivariate BDT
  - Kinematic variables, vertex quality, muon asymmetry
- Resonances excluded from search dataset - chicane

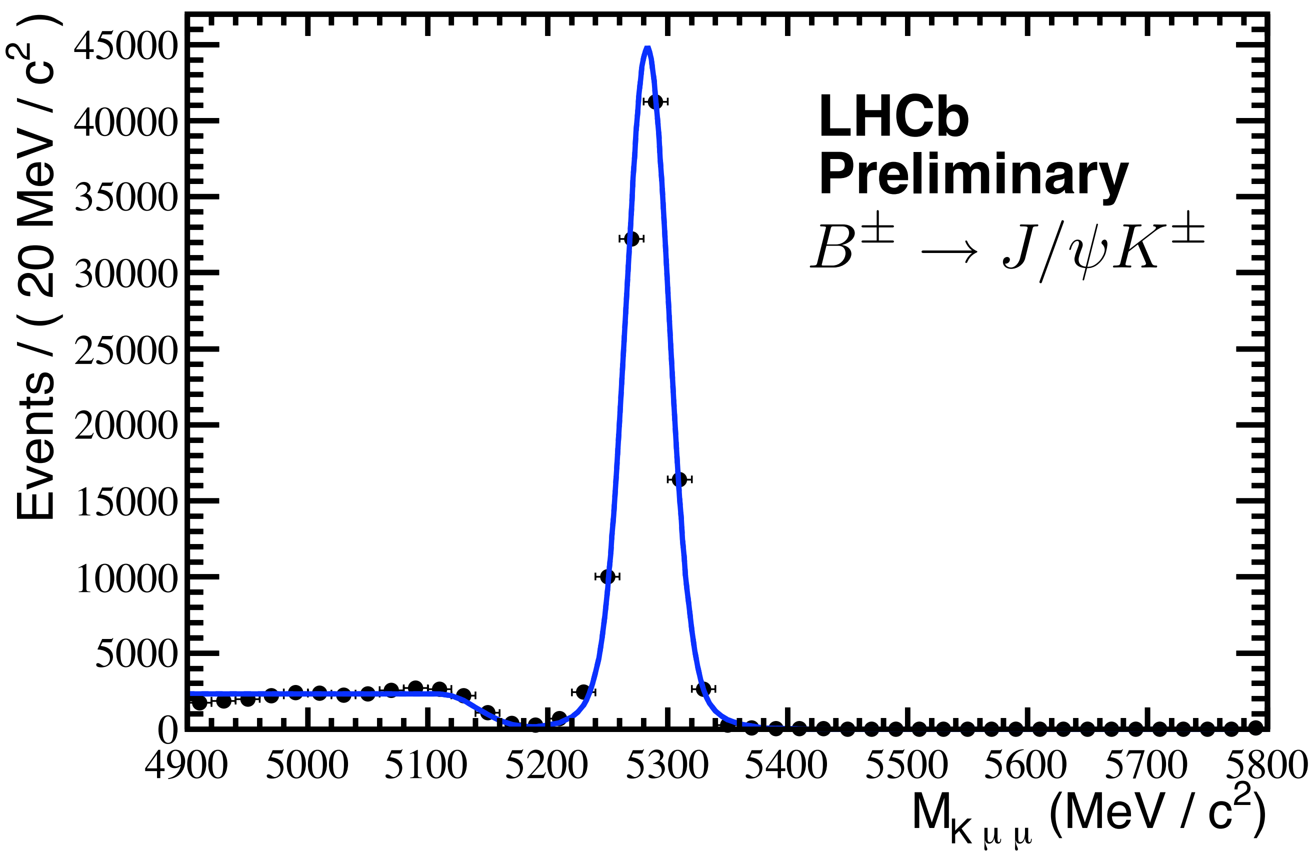




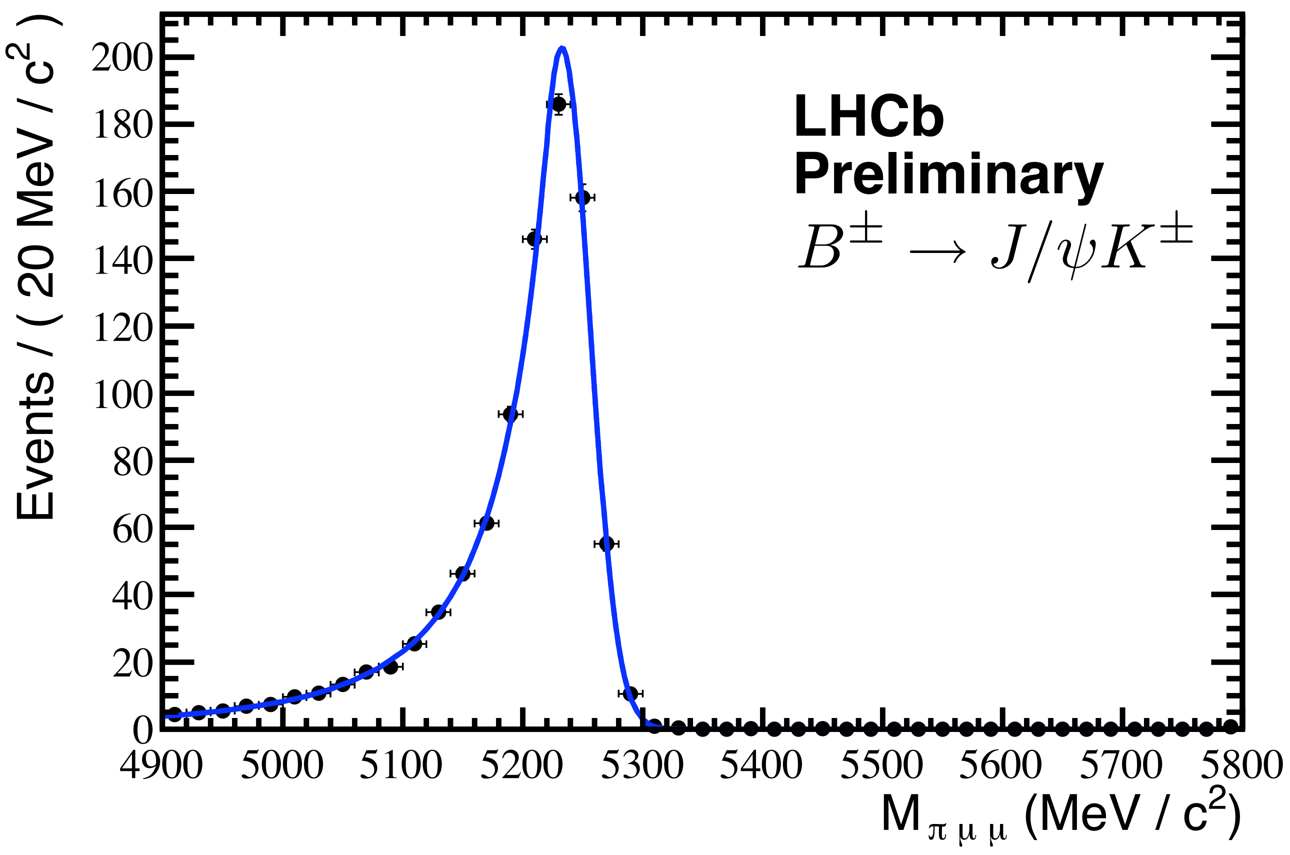


Fit strategy - $B^{\pm} \to J/\psi K^{\pm}$ proxy

Signal model:



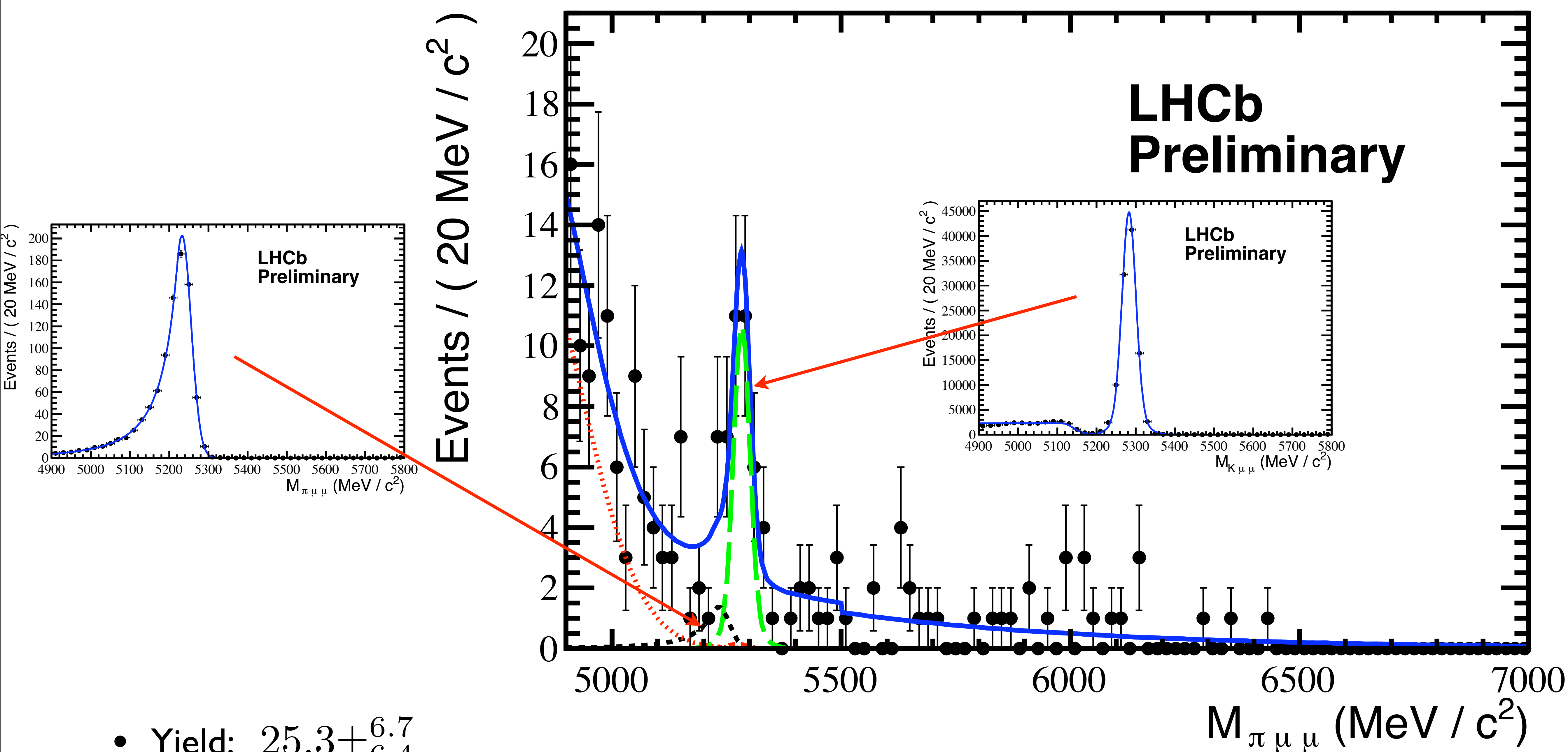
Peaking background model:



- Correctly reconstructed $B^{\pm} \to J/\psi K^{\pm}$
- Fitted with double Gaussian
- Mean and widths fixed
- Correction to take into account K-π resolution differences

- Misidentified $B^{\pm} \to J/\psi K^{\pm}$
- Fitted with Crystal Ball
- Shape and yield fixed
- Correction to take into account
  - PID effect on momentum spectrum
  - Altered dimuon mass spectrum

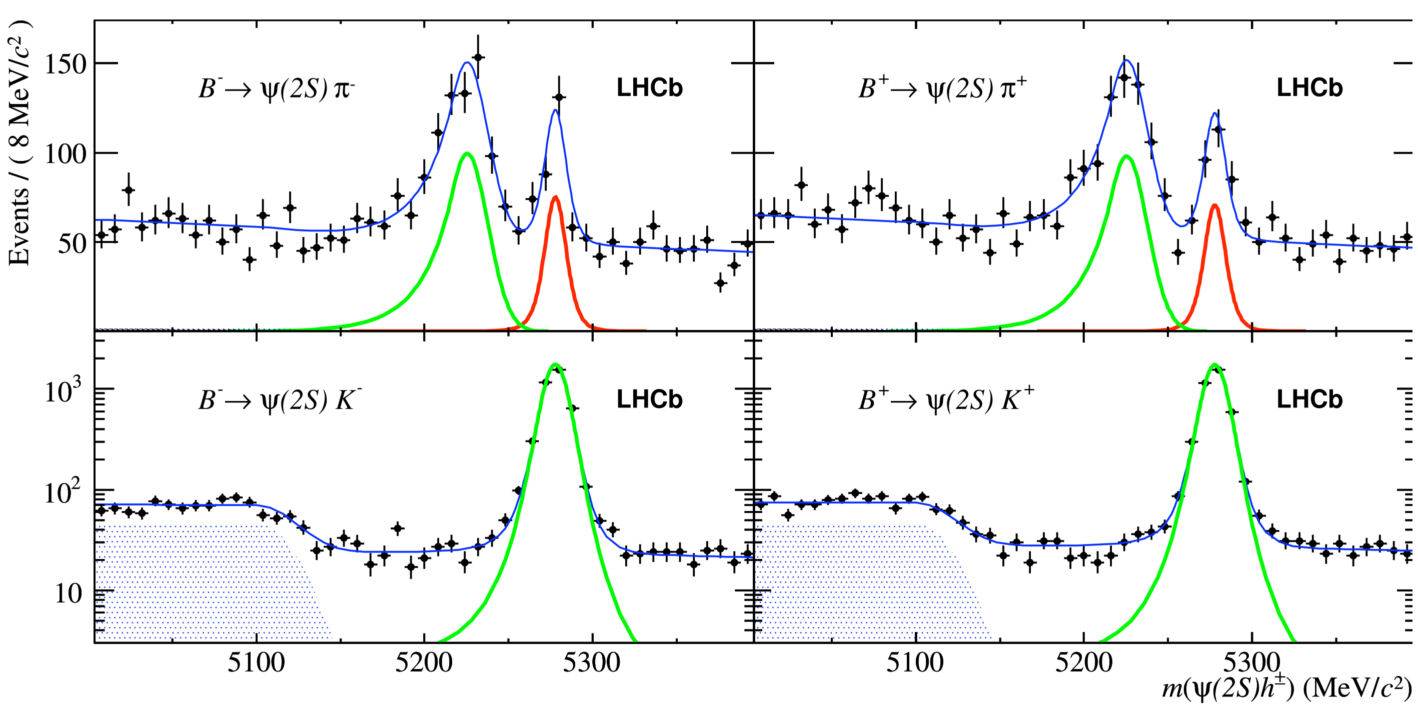
Signal observation

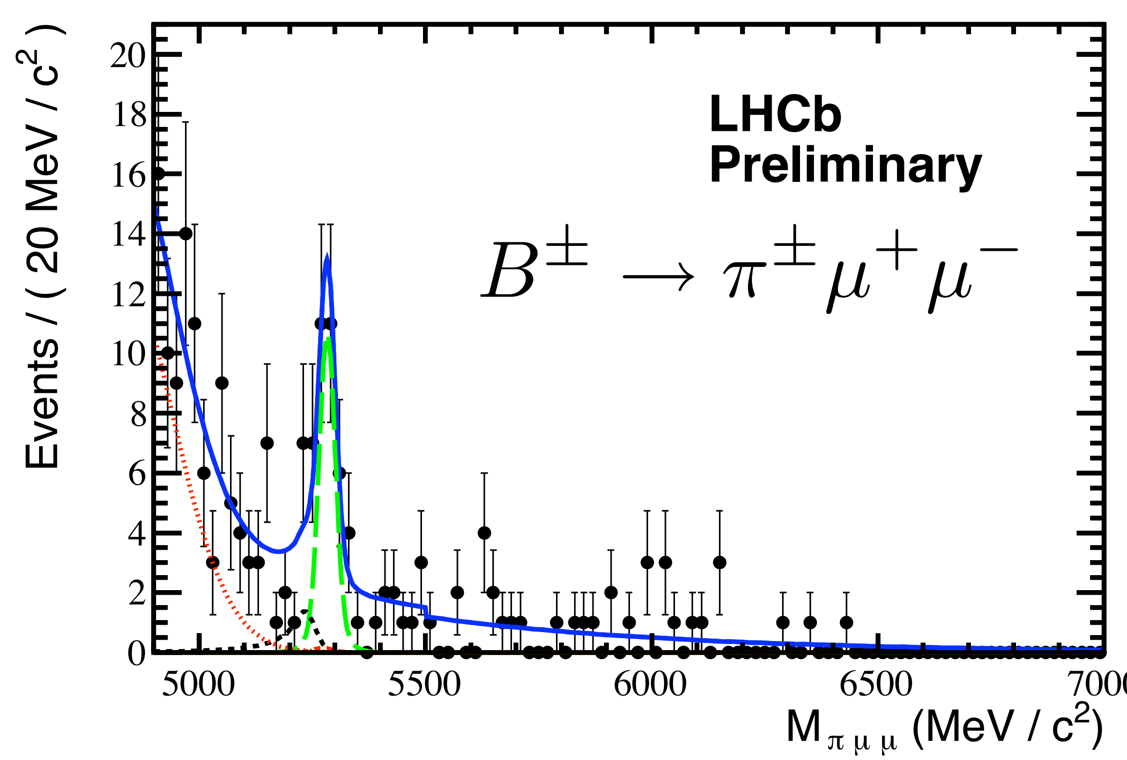


- Yield: $25.3\pm^{6.7}_{6.4}$
- Significance (Wilk's theorem): 5.2 σ
- Normalisation to $B^{\pm} \to J/\psi K^{\pm}$
  - $BR(B \to \pi\mu\mu) = (2.4 \pm 0.6\ (\mathrm{stat}) \pm 0.2\ (\mathrm{syst})) \times 10^{-8}$

Conclusions

- LHCb detector doing a great job finding π μ μ final states
- Published world-best branching fraction and CP asymmetry results for $B^{\pm} \rightarrow J/\psi\pi^{\pm}$ and $B^{\pm} \rightarrow \psi(2S)\pi^{\pm}$
- First observation of rare decay $B^{\pm} \rightarrow \pi^{\pm}\mu^{+}\mu^{-}$
- This is the rarest B decay yet seen



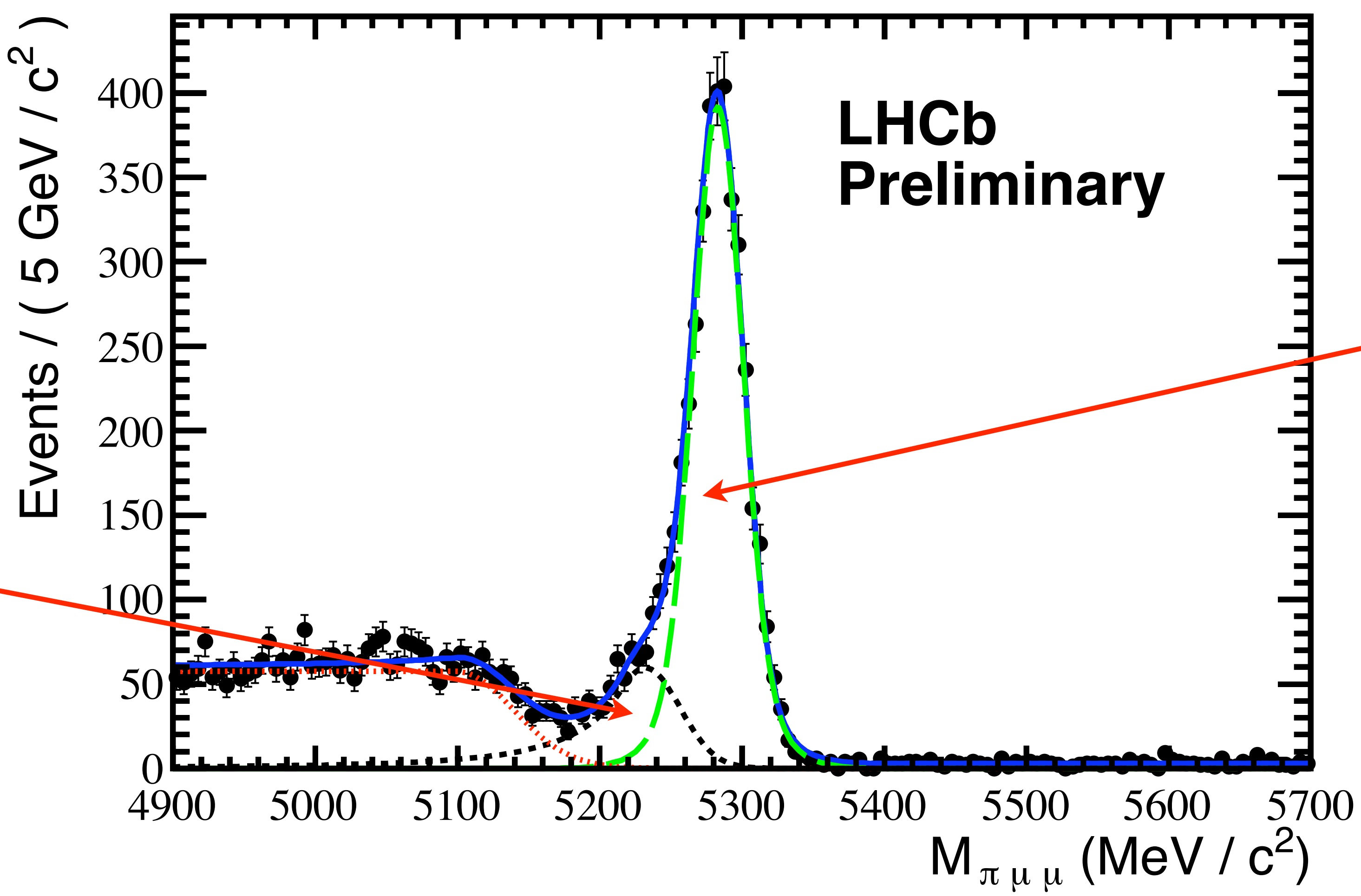


Backup Slides

Fit validation

- Test the fit strategy on $B^{\pm} \rightarrow J/\psi\pi^{\pm}$
- Checks fit mechanics
- Checks validity of K-pi proxy
- Doesn't check validity of J/psi - mumu proxy

$B^{\pm} \rightarrow J/\psi K^{\pm}$ modelled as mis-identified $B^{\pm} \rightarrow J/\psi K^{\pm}$



$B^{\pm} \rightarrow J/\psi\pi^{\pm}$ modelled as correctly identified $B^{\pm} \rightarrow J/\psi K^{\pm}$

Title

- text

Source

```
(2.4 \pm 0.6 \; (\mathrm{stat}) \pm 0.2 \; (\mathrm{syst})) \times 10^{-8}
```

```
\mathcal{B}(B^{\pm} \rightarrow J/\psi \pi^{\pm})= (3.88\pm 0.11 \pm 0.15) \times 10^{-5}\\
\mathcal{B}(B^{\pm} \rightarrow \psi(2S) \pi^{\pm})= (2.52 \pm 0.26 \pm 0.15) \times 10^{-5}
```

```
A_{CP}^{J/\psi \pi} &=& 0.005 \pm 0.027 \pm 0.011 \\
A_{CP}^{\psi(2S) \pi} &=& 0.048 \pm 0.090 \pm 0.011
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R^{J/\psi}=(3.83 \pm 0.11 \pm 0.07) \times 10^{-2} \\
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BR(B \rightarrow \pi \mu \mu) = (2.4 \pm 0.6 \; (\mathrm{stat}) \pm 0.2 \; (\mathrm{syst})) \times 10^{-8}
```