B_c CHARMELESS THREE BODY DECAYS AT LHCb

LHCb COLLABORATION
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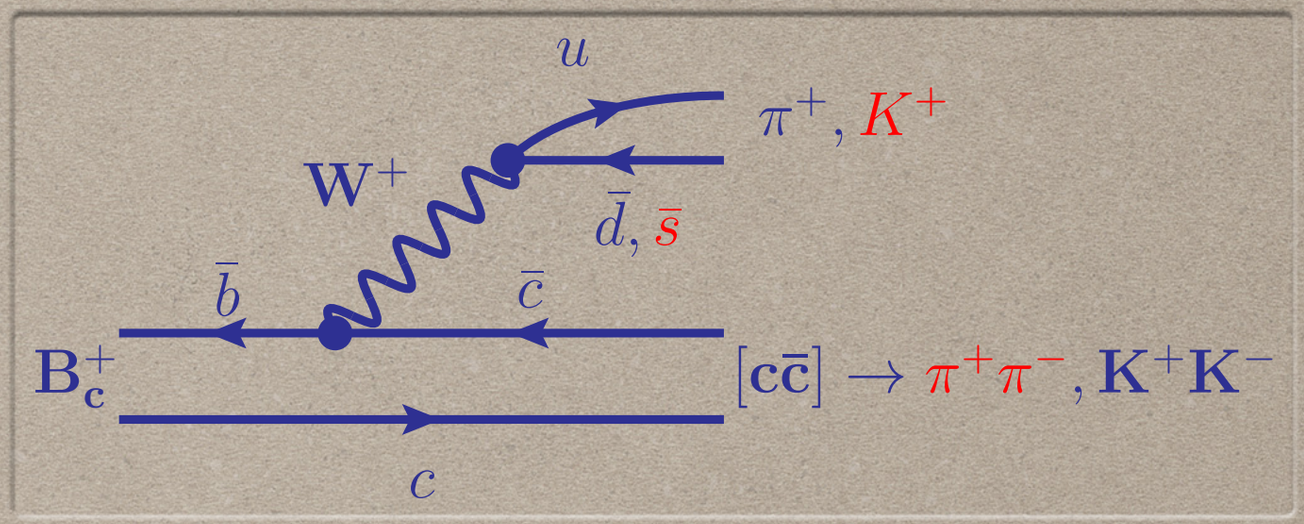
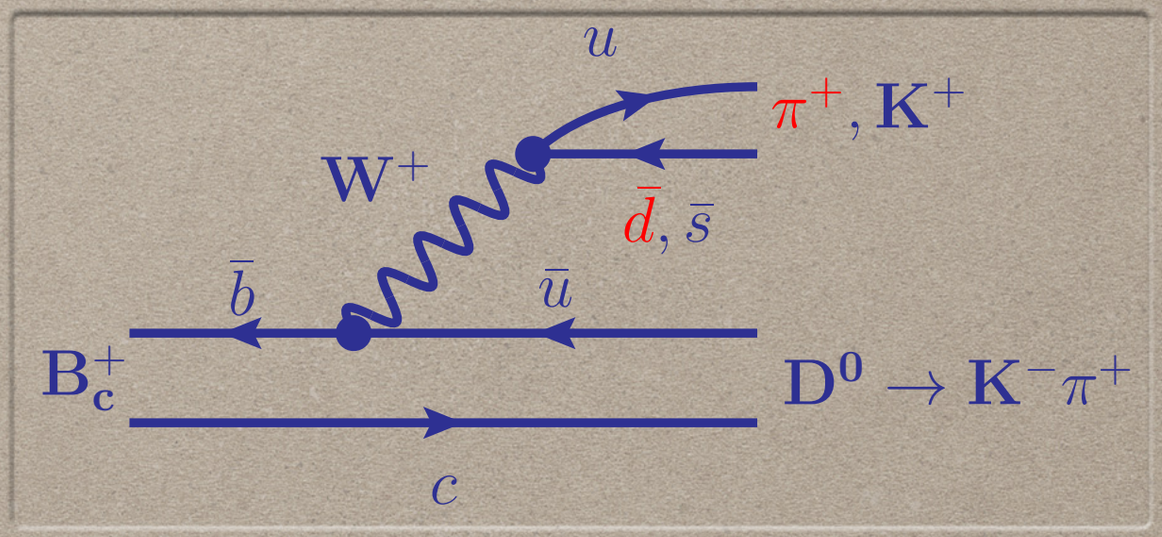
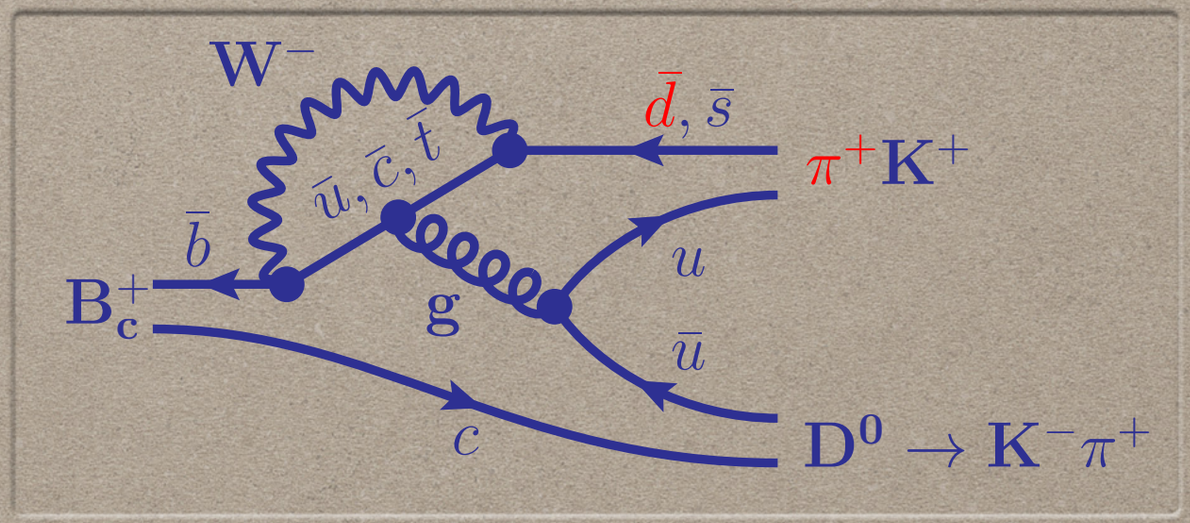
$\mathbf{B_c^+ \to h^+ h^- h^+}$

- via b decays

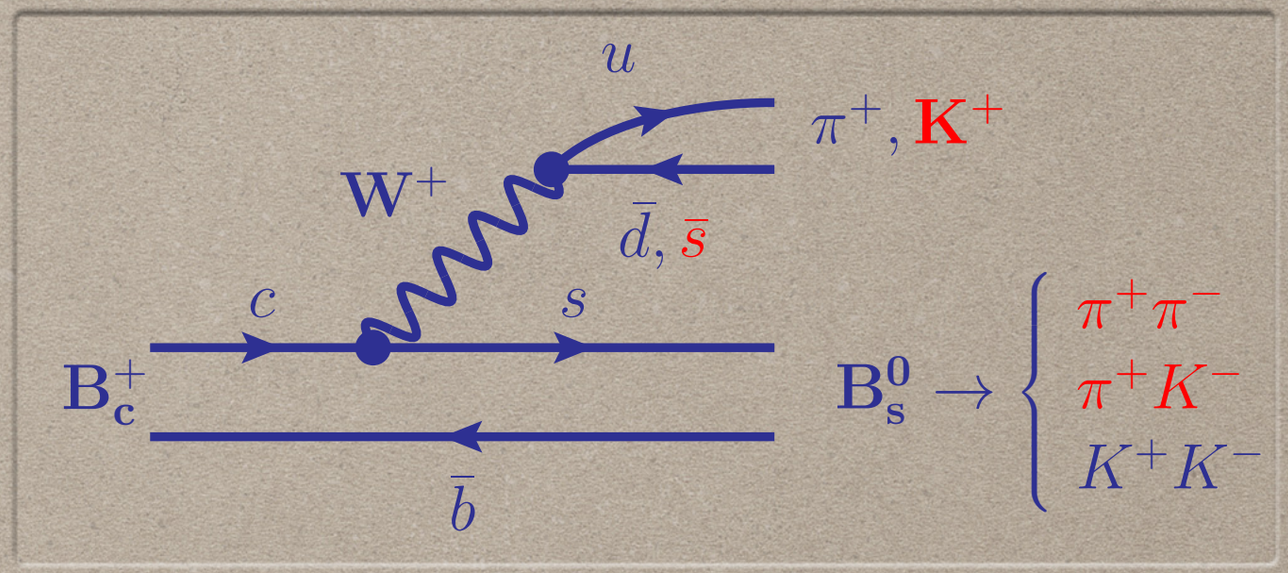


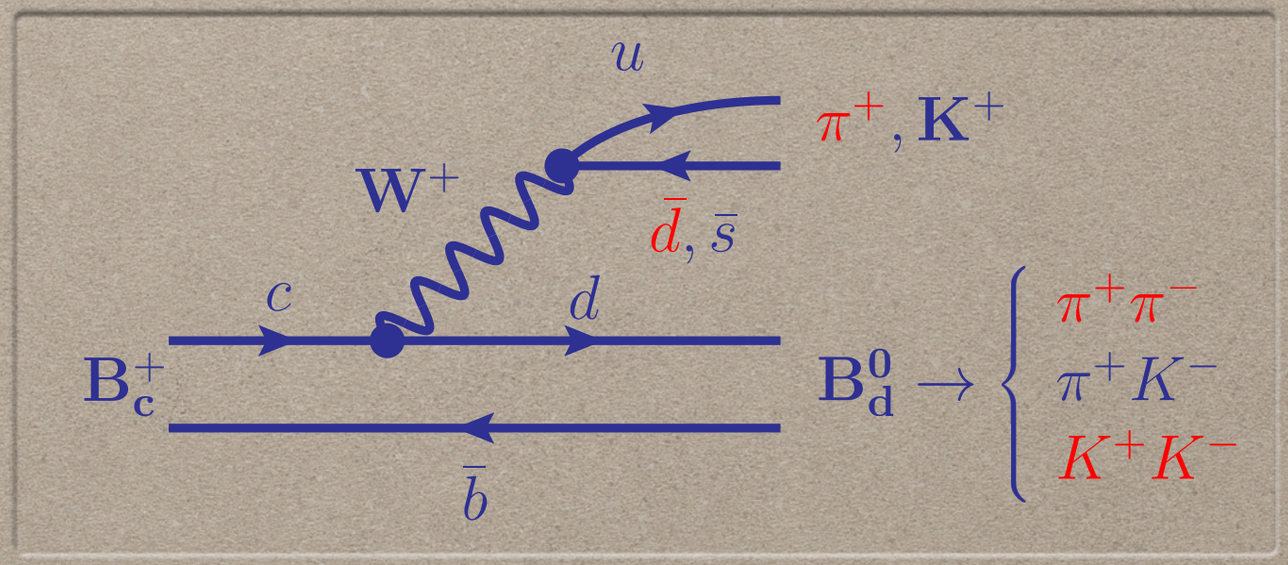




$\mathbf{B_c^+ \to h^+ h^- h^+}$

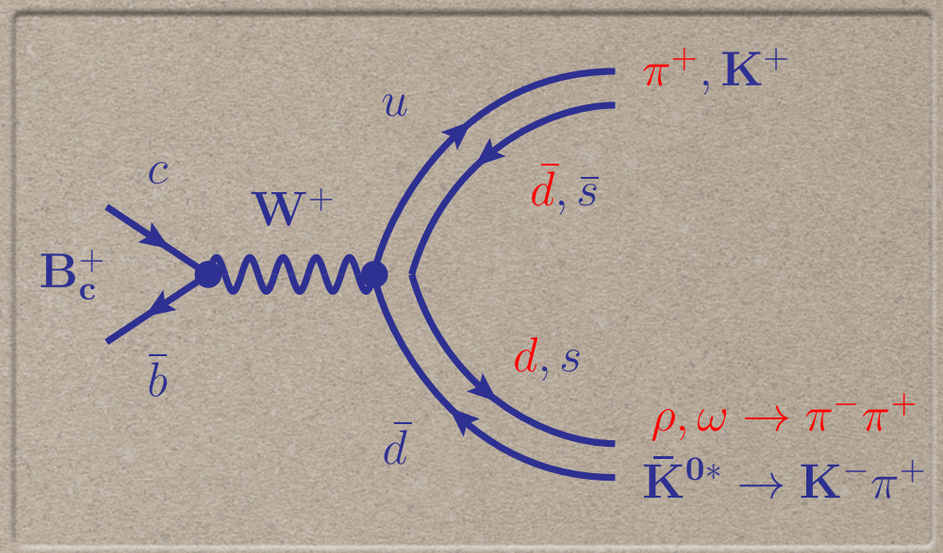
- via b decays
- via c decays

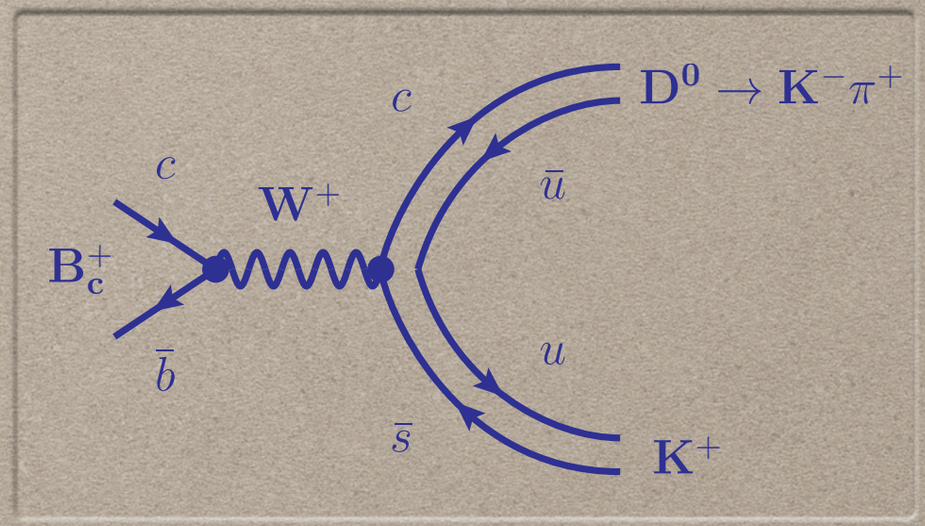


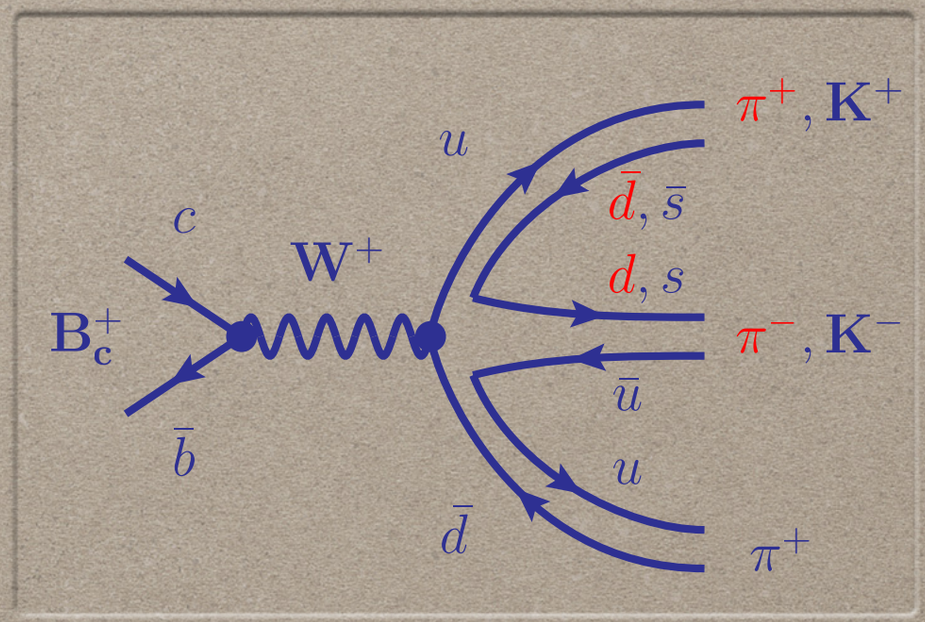


$B_c^+ \to h^+ h^- h^+$

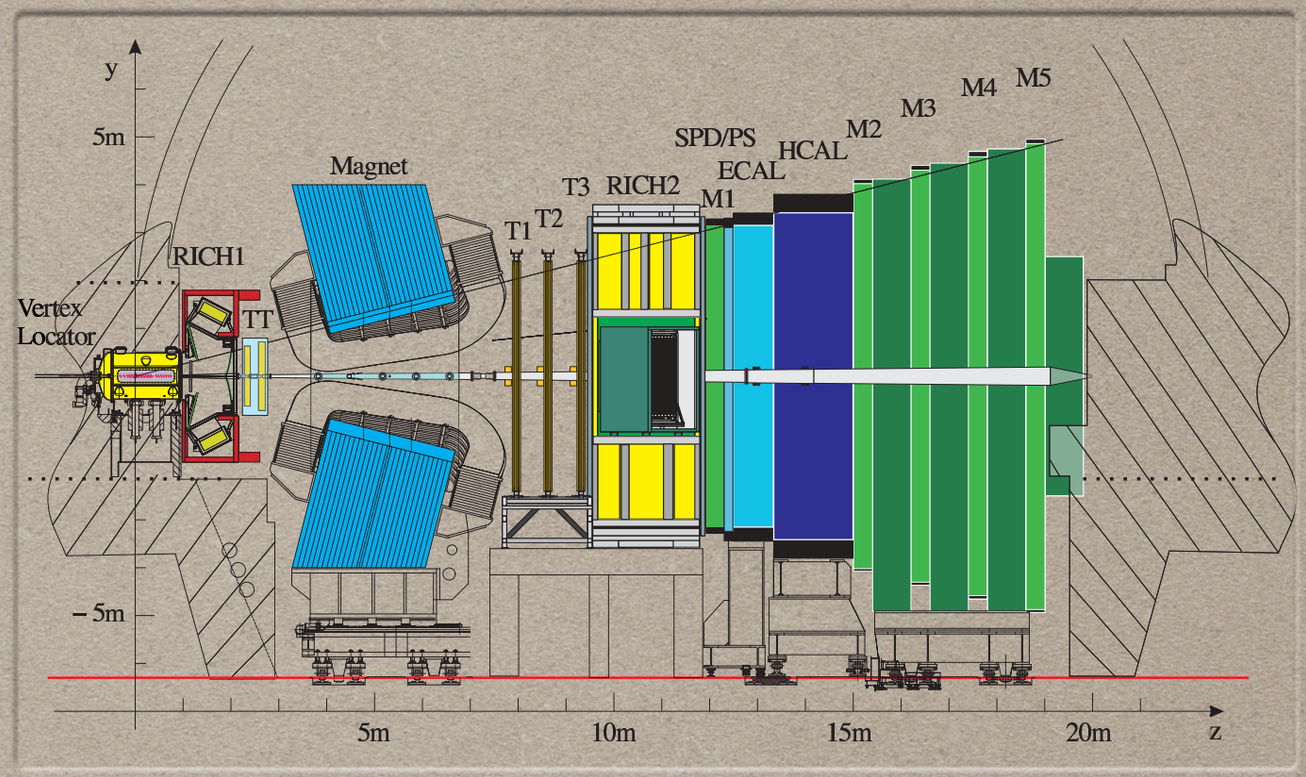
- via b decays
- via c decays
- **via annihilation**
  - ~ $V^*_{cb} V_{uq}$
  - BF in the range 10^{-8}-10^{-6}
  - can be useful to probe BSM process







$B_c^+ \to K^+K^-\pi^+$



- 2011 and 2012 LHCb data
- $p_T(B) < 20$ GeV/c
- $2.0 < y(B) < 4.5$
- 1.0 fb^{-1} @ 7 TeV + 2.0 fb^{-1} @ 8 TeV
- Control channel $B^+ \to D^0(\to K^+K^-)\pi^+$
- Blind Analysis

- Simulated events
  - generation: PYTHIA 8.1, BCVEGPY with LHCb configuration
  - decays (hadronic): EVTGEN, PHOTOS
  - detector: GEANT4

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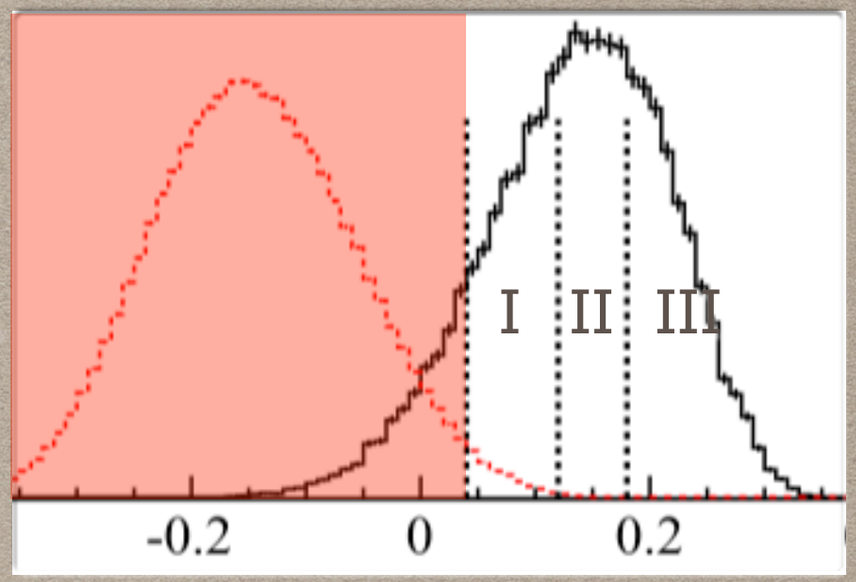
EVENT SELECTION



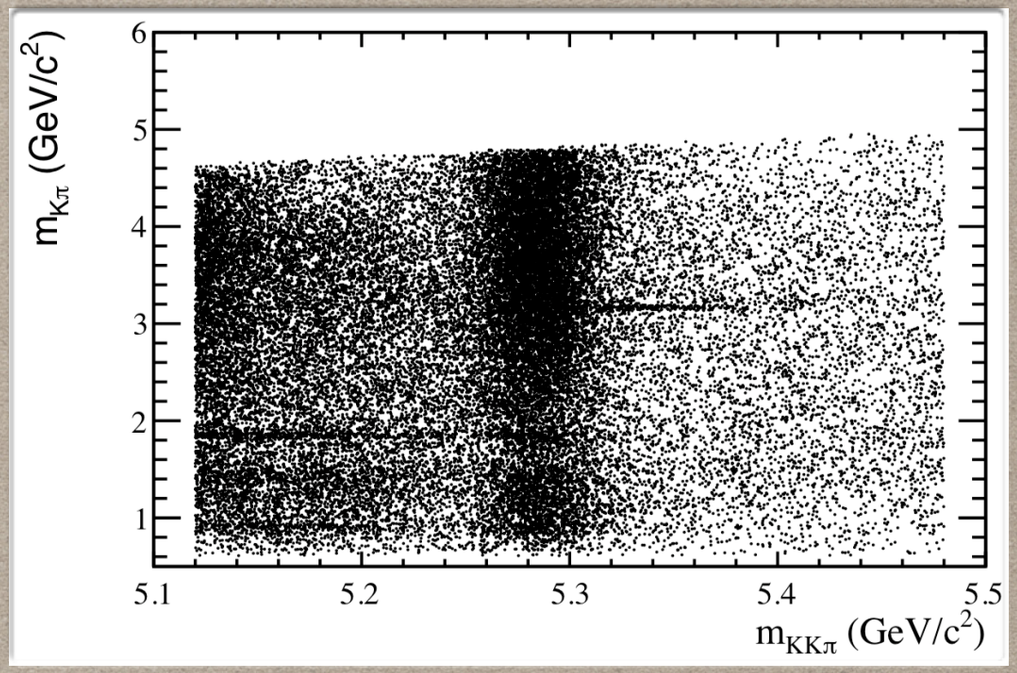
- A BDT classifier is used for $B_{(c)}$ selection
  - p, p_T, IP, of $B_{(c)}$ and daughters, $B_{(c)}$ flight distance
  - quality of tracks and vertices
- Training: simulation is used for signal and sidebands data for background
- PID information is combined with BDT to define three regions with similar expected yield but different background level (0.04, 0.12 and 0.18)

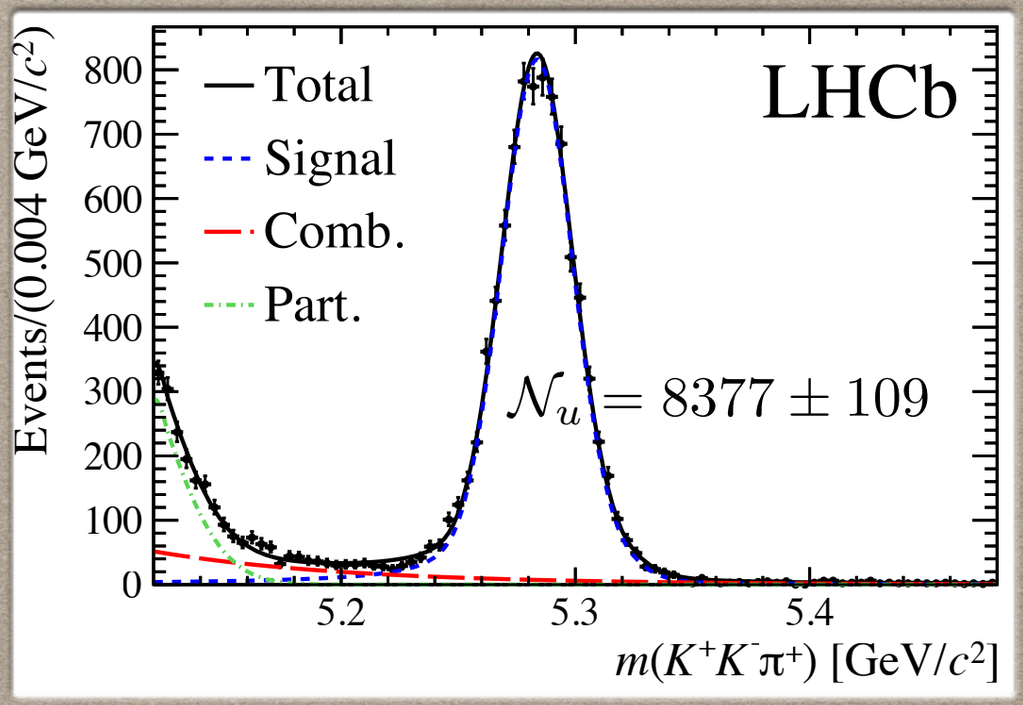
FITS TO THE DATA

- Unbinned maximum likelihood fit to the invariant mass distribution.
- Signal - two Crystal Ball functions with common mean
- Background
  - Fermi-Dirac function for possible partially reconstructed component
  - Exponential function for combinatorial bg

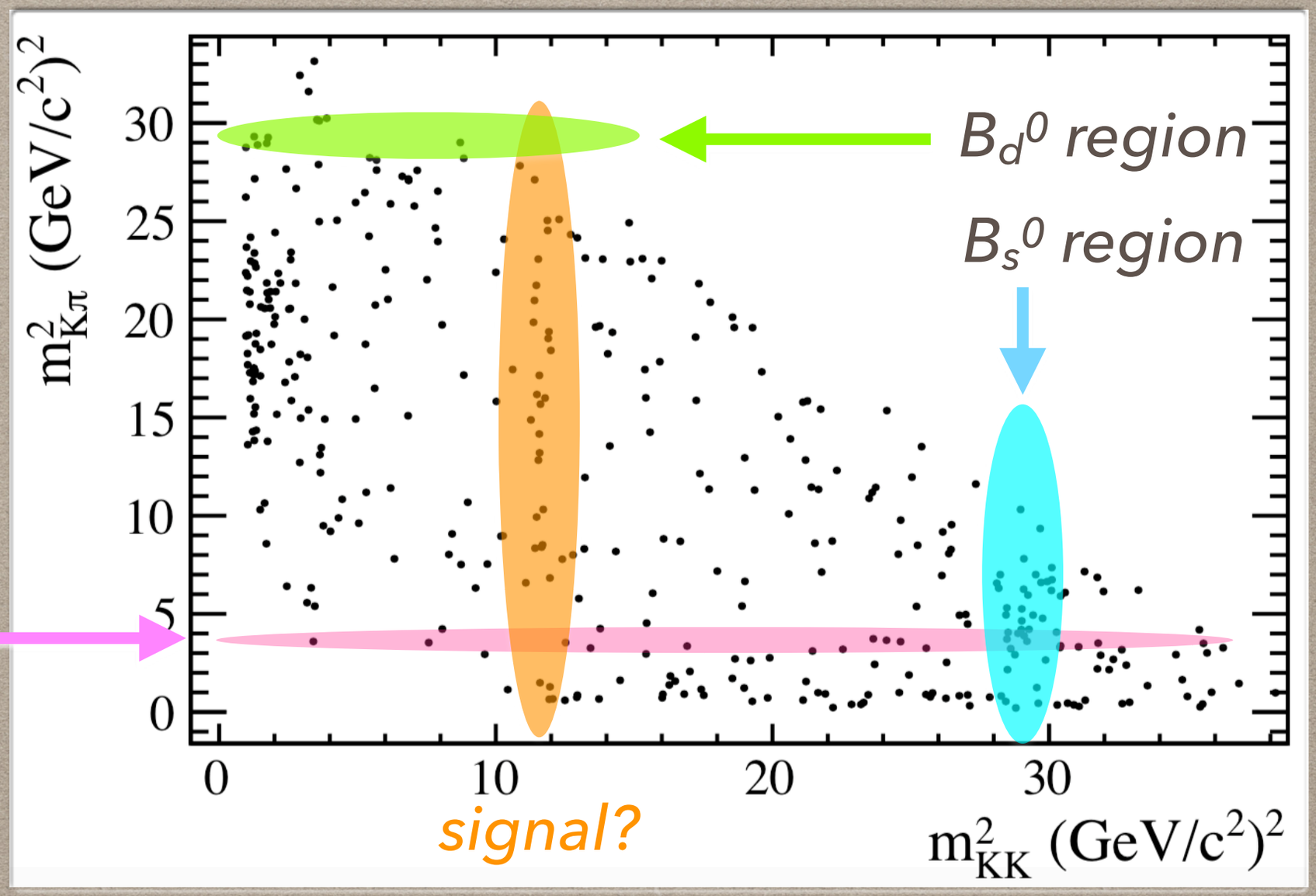
Control channel

$$\mathbf{B^+ \to D^0(K^+K^-)\pi^+}$$





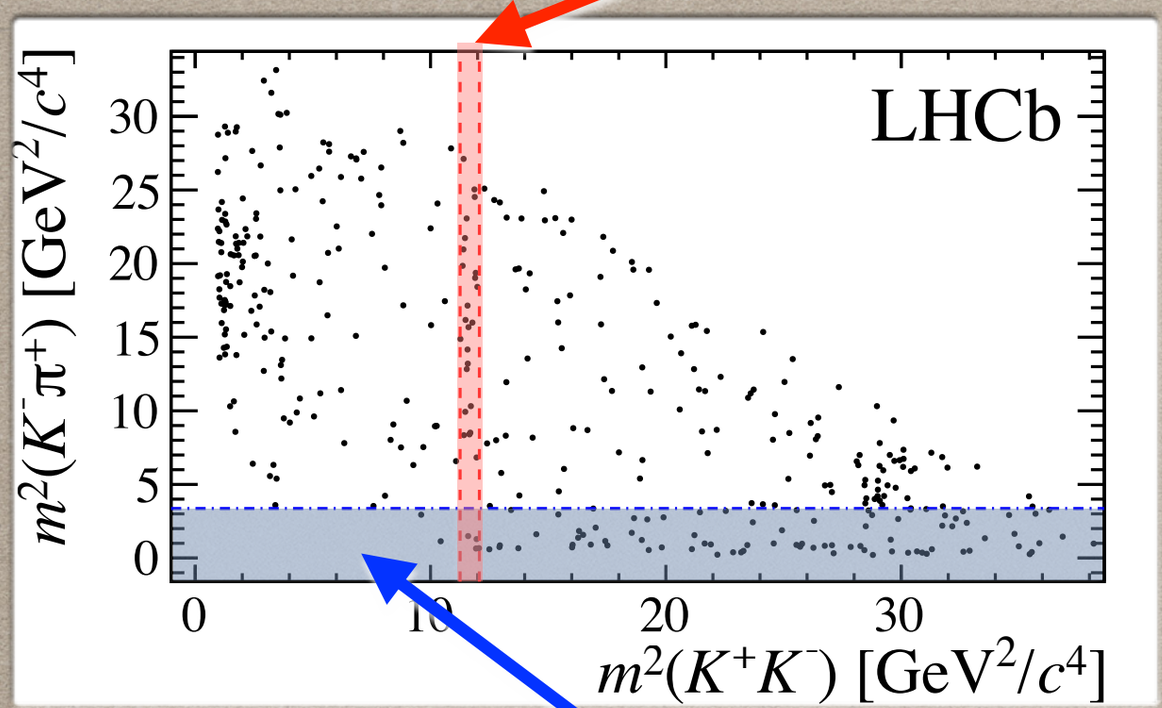
$\mathbf{B_c^+ \to K^+K^-\pi^+}$

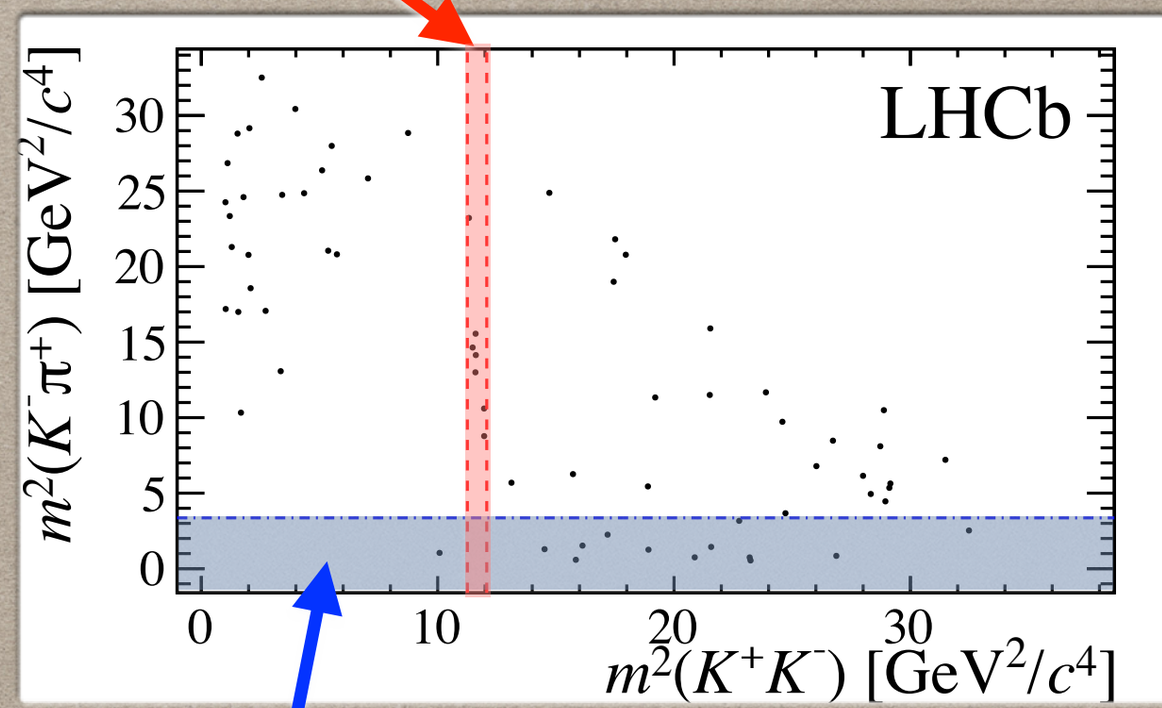


D^0 region

$B_s^0 \to K^+K^- + \pi^+$

$B_c^+ \to K^+K^-\pi^+$





χ_{c0} mass

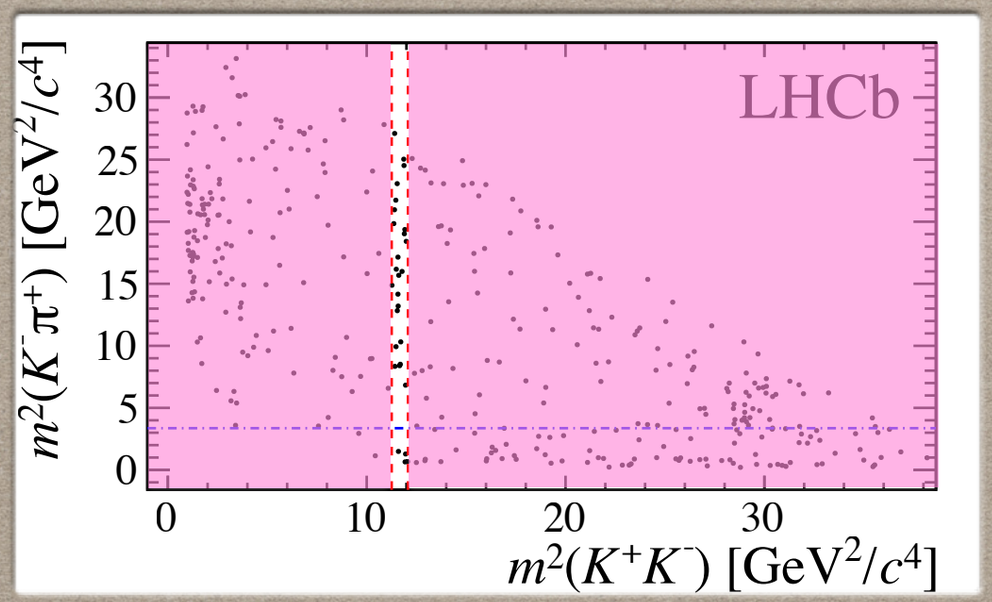
Classifier > 0.12

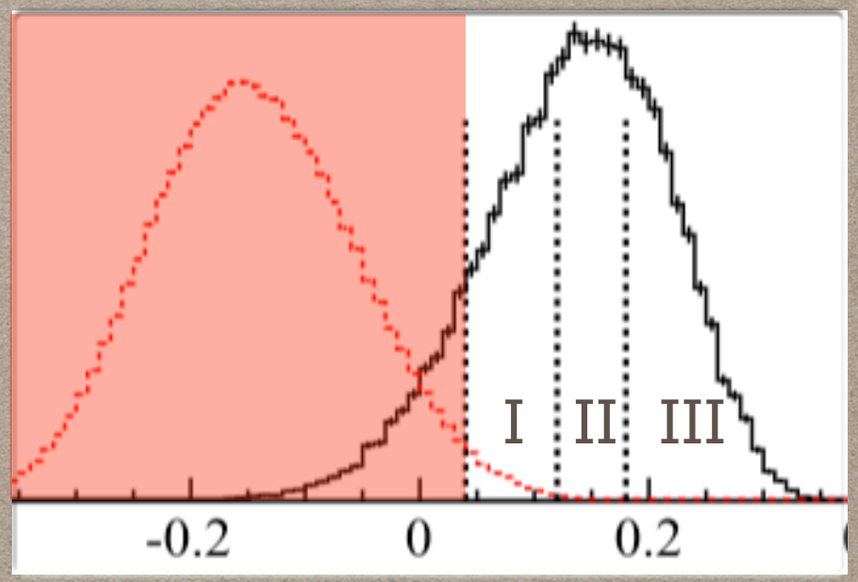
Classifier > 0.18

Annihilation region

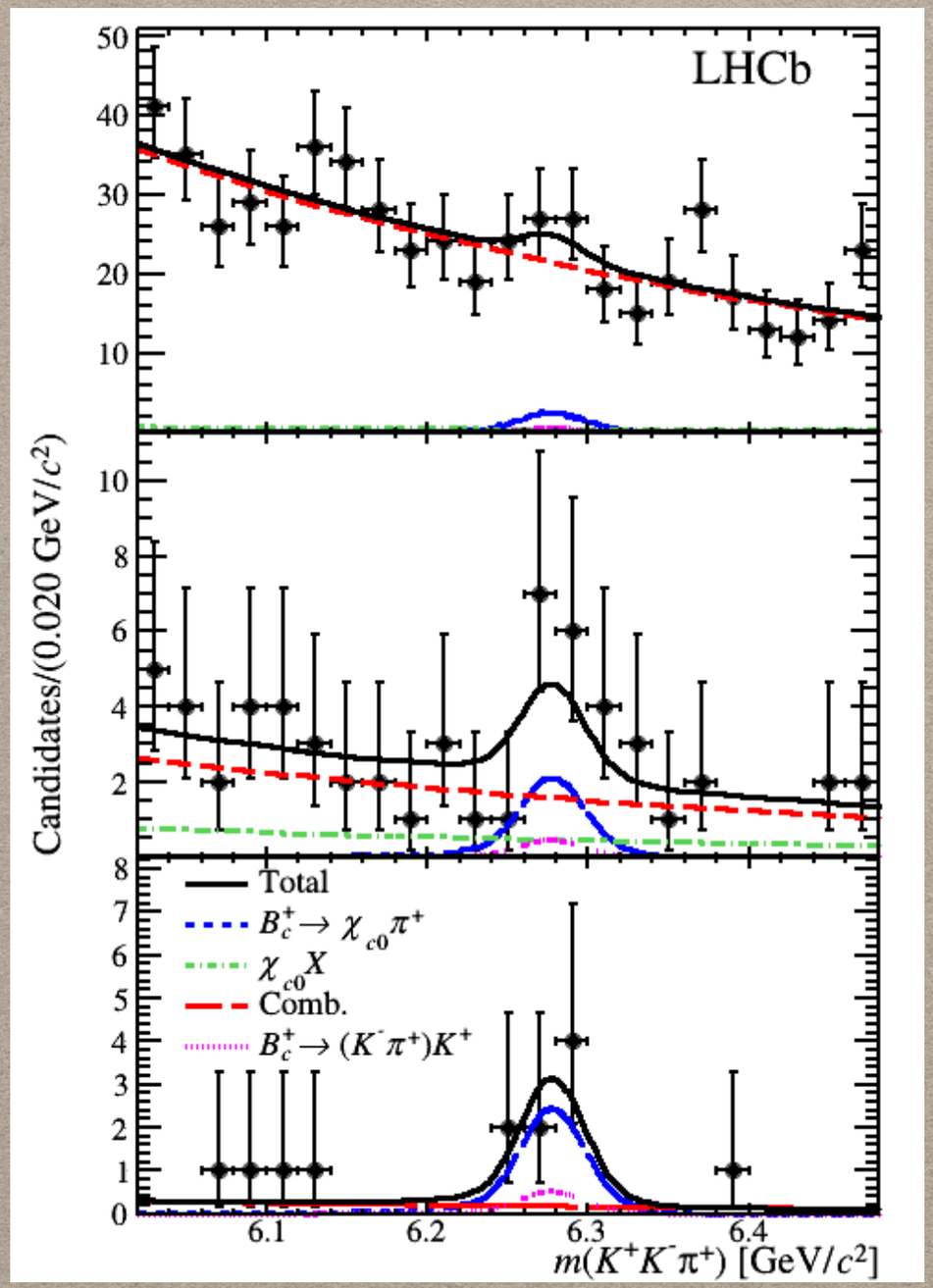
$\mathbf{B_c^+ \to \chi_{c0}(K^+K^-)\pi^+}$

- Two dimensional fit - m($K^+K^-\pi^+$)×m(K^+K^-) for each BDT bin
- m(K^+K^-)
  - Signal ⇒ Breit-Wigner convolved with a Gaussian
  - Background ⇒ first-order polynomial





$\mathbf{B_c^+ \to \chi_{c0}(K^+K^-)\pi^+}$



Region I

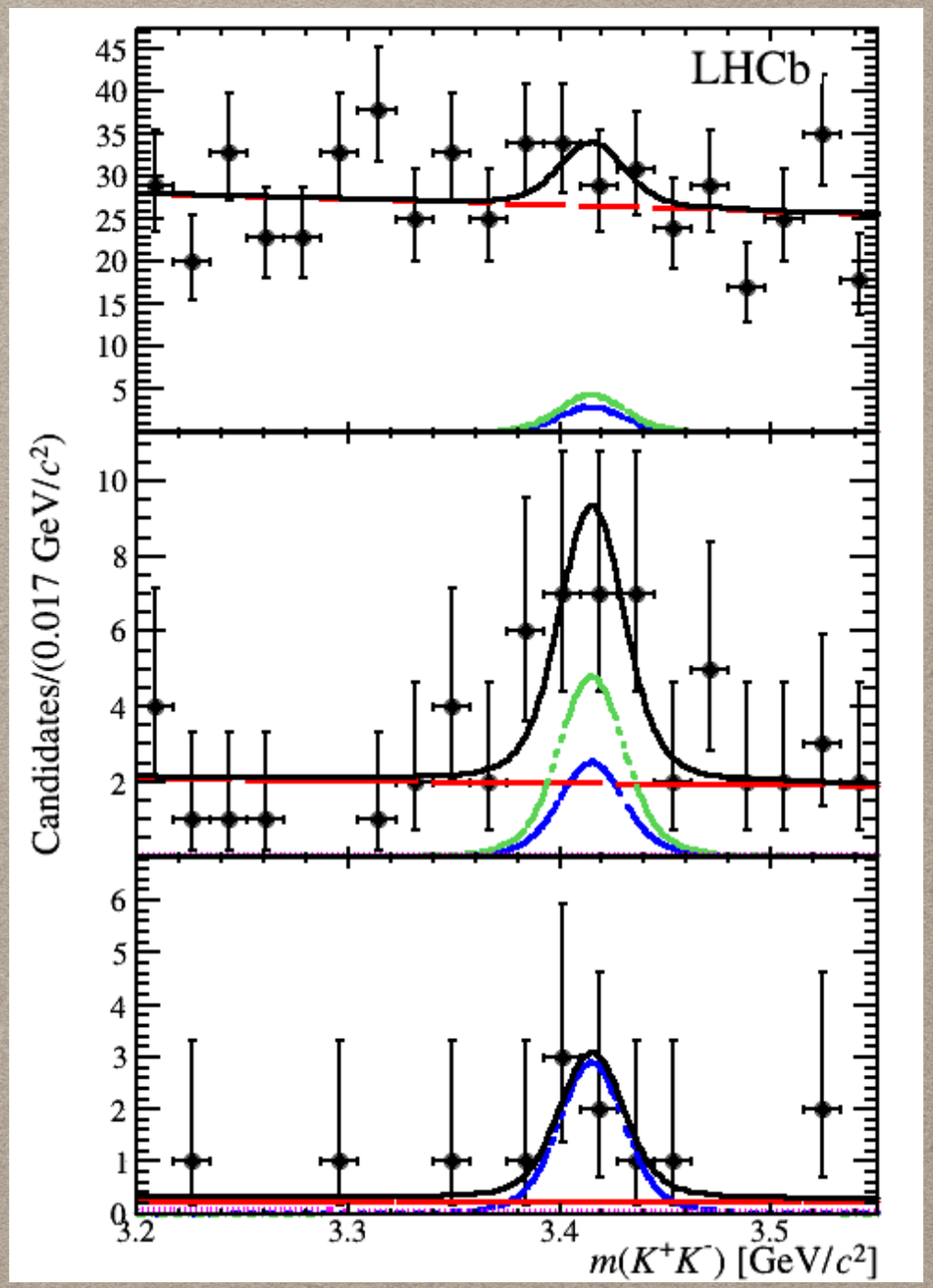
0.04<Classifier<0.12

Region II

0.12<Classifier<0.18

Region III

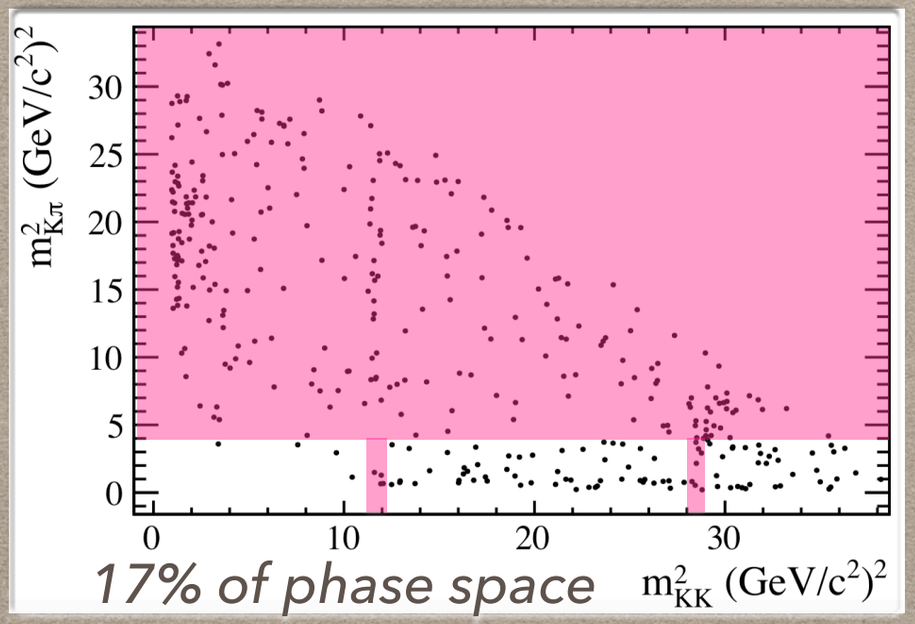
0.18 < Classifier

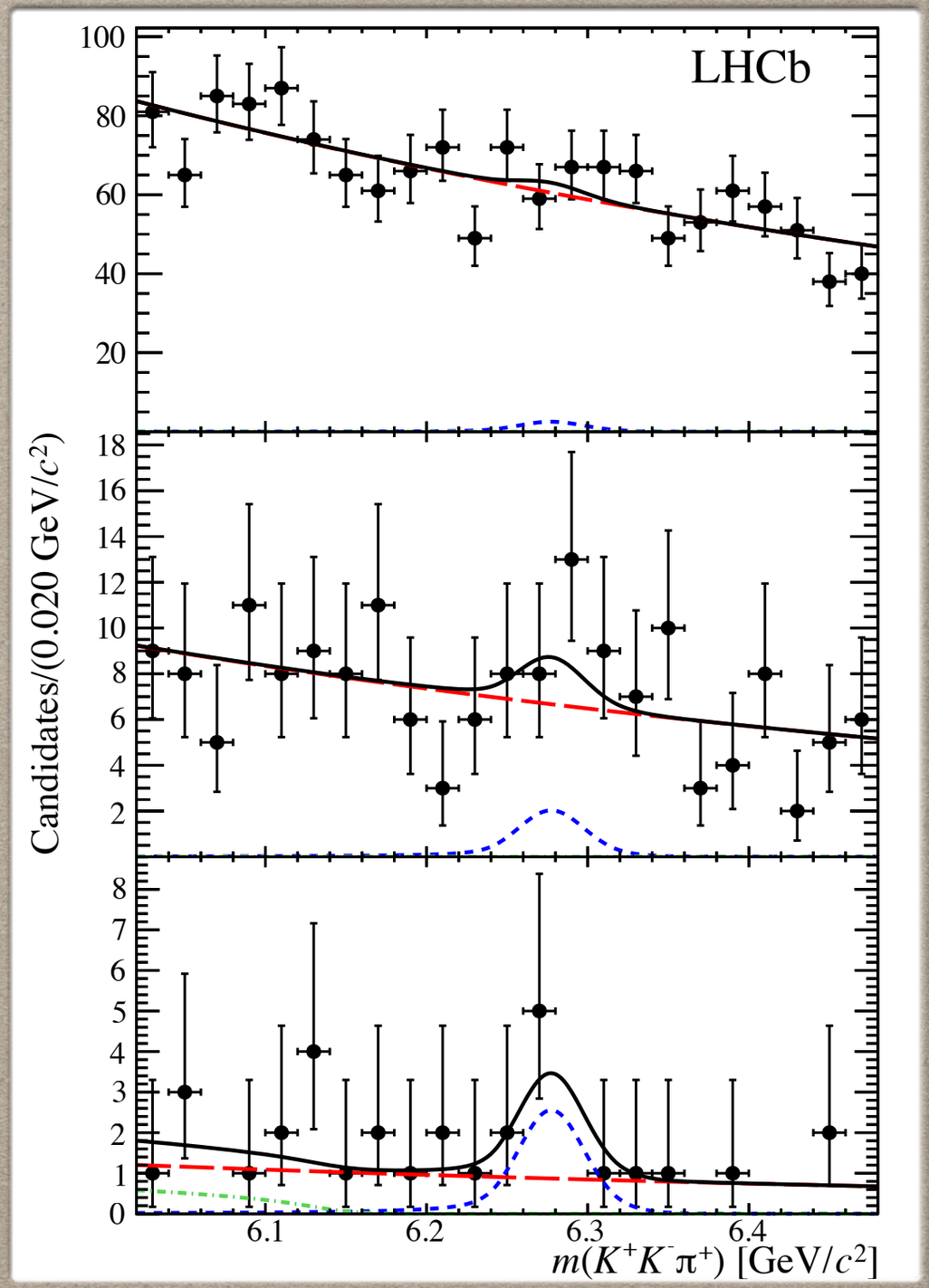


$\mathcal{N}_{\chi c0} = 20.8^{+7.2}_{-6.4}$ *4.1σ statistical significance*

ANNIHILATION REGION

- Vetoing
  - $D^0 \rightarrow K^-\pi^+$ - $1.834<m(K^-\pi^+)<1.894$ GeV/c^2
  - $\chi_{c0} \rightarrow K^-K^+$ - $3.38<m(K^-K^+)<3.46$ GeV/c^2
  - $B_s \rightarrow K^-K^+$ - $5.3<m(K^-K^+)<5.4$ GeV/c^2
- $\mathcal{N}_c = 20.8^{+11.4}_{-9.9}$
- Statistical significance 2.5σ





RESULTS

$$R_f \equiv \frac{\sigma(B_c^+)}{\sigma(B^+)} \times \mathcal{B}(B_c^+ \to f)$$

- $\mathbf{B_c^+ \to \chi_{c0}(K^+K^-)\pi^+}$

$$R_{\chi_{c0}\pi} = \frac{\mathcal{N}_{\chi_{\mathbf{c0}}\pi}}{\mathcal{N}_{\mathbf{u}}} \times \frac{\epsilon_u}{\epsilon_c(\chi_{c0})} \times \frac{\mathcal{B}(B^\pm \to D^0\pi^\pm) \times \mathcal{B}(D^0 \to K^+K^-)}{\mathcal{B}(\chi_{c0}\pi \to K^+K^-)}$$

$$R_{\chi_{c0}\pi} = (9.8^{+3.4}_{-3.0}(\text{stat}) \pm 0.8(\text{syst})) \times 10^{-6}$$

4.0 σ

systematic uncertainties

Branching fractions - 63%
BDT shape - 14%
Fit model - 9%
Bc lifetime - 7%
others - 7%

RESULTS

$$R_f \equiv \frac{\sigma(B_c^+)}{\sigma(B^+)} \times \mathcal{B}(B_c^+ \to f)$$

- Annihilation

$$R_{an,KK\pi} = \frac{\mathcal{N}_\mathbf{c}}{\mathcal{N}_\mathbf{u}} \times \frac{\epsilon_u}{\epsilon_c(an,\, KK\pi)} \times \mathcal{B}(B^\pm \to D^0\pi^\pm) \times \mathcal{B}(D^0 \to K^+K^-)$$

$$R_{an,KK\pi} = (8.0^{+4.4}_{-3.8}(\mathrm{stat}) \pm -0.6(\mathrm{syst})) \times 10^{-8}$$

only 2.4 σ

$$R_{an,KK\pi} < 15(17) \times 10^{-8} \text{ at } 90(95)\% \text{ C.L.}$$

systematic uncertainties

BDT shape - 44%
Branching fractions - 23%
Fit model - 10%
Bc lifetime - 7%
others - 16%

RESULTS

$$R_f \equiv \frac{\sigma(B_c^+)}{\sigma(B^+)} \times \mathcal{B}(B_c^+ \to f)$$

Unseen channels

- $B_c^+ \to B_s^0(K^+K^-)\pi^+$

  $R_{B_s^0\pi} < 4.5(5.4) \times 10^{-3}$ at $90(95)\%$ C.L.

- $B_c^+ \to D^0(K^+\pi^-)K^+$

  $R_{D^0K} < 1.3(1.6) \times 10^{-6}$ at $90(95)\%$ C.L.

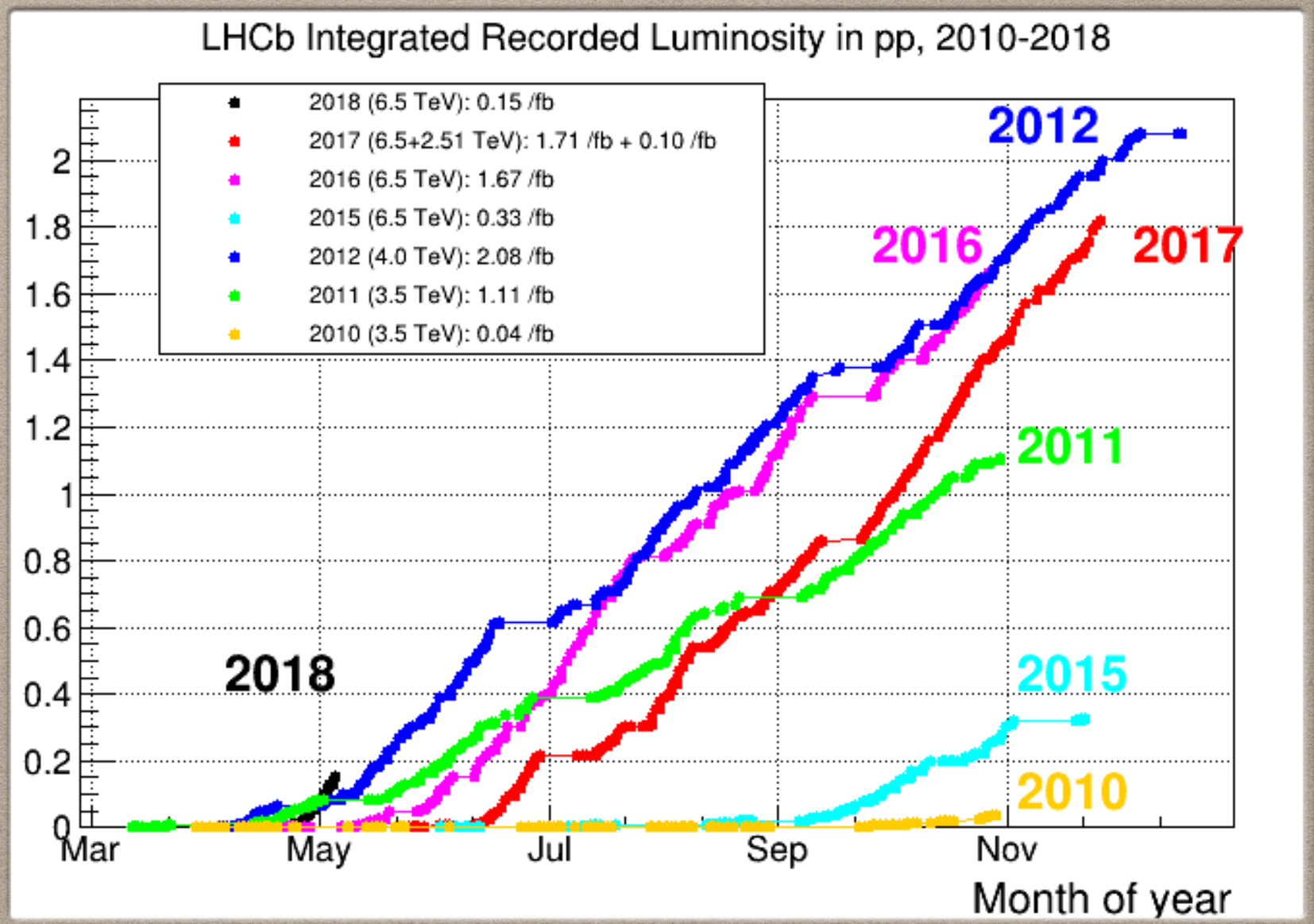
CONCLUSIONS

- First observation of $B_c^+ \to \chi_{c0}(K^+K^-)\pi^+$
  - $R_{\chi_{c0}\pi} = (9.8^{+3.4}_{-3.0}(\mathrm{stat}) \pm 0.8(\mathrm{syst})) \times 10^{-6}$
  - $R_{J/\Psi\pi} = (7.0 \pm 0.3) \times 10^{-6}$
- Indication (2.4σ) of $\bar{b}c$ annihilation at m(Kπ)<m(D^0)
  - $R_{an,KK\pi} = (8.0^{+4.4}_{-3.8}(\mathrm{stat}) \pm -0.6(\mathrm{syst})) \times 10^{-8}$
  - prediction of $R_{\overline{K}^* K^+} = [0.1, 1.7] \times 10^{-8}$

Z.-J. Xiao and X. Liu, Chin. Sci. Bull. ***59****, 3748 (2014)*
Z. Rui and Z.-T. Zhou, Phys. Dev. D ***90****, 114030 (2014)*
LHCb, Phys. Rev. Lett. ***114****, 132001 (2015)*

PROSPECTS

- $B_c^+ \to K^+K^-\pi^+$ include Run2 data (already 3.5 fb^{-1}@ 13 TeV)
- $B_c^+ \to \pi^+\pi^-\pi^+$ channel is under study
- $B_c^+ \to K^+\pi^-\pi^+$
- $B_c^+ \to K^+K^-K^+$
- Run 3

Run 1 - 3.0fb^{-1}
@ 7 / 8 TeV

Run 2 - 5.0fb^{-1}?
@ 13 TeV