Exotic Meson Studies at LHCb

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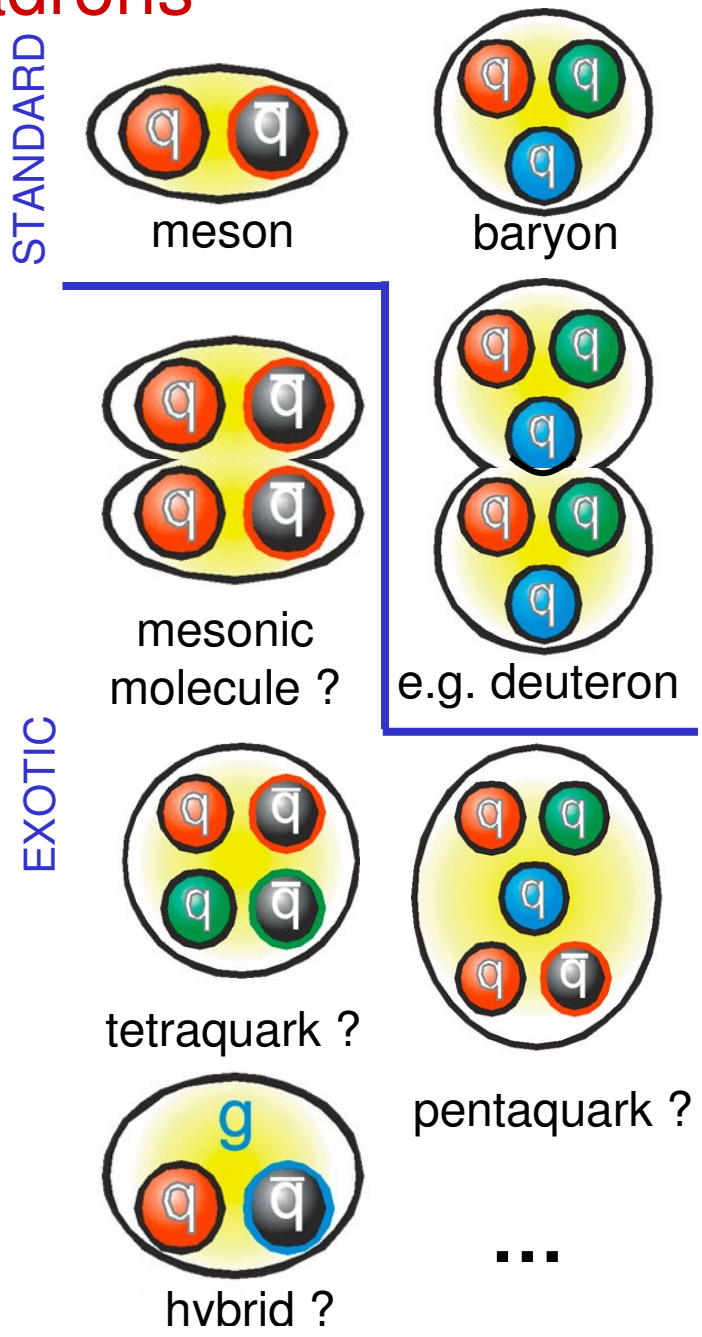
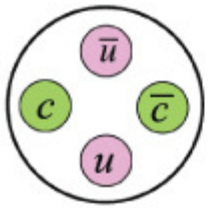
Representing LHCb collaboration

Standard and Exotic Hadrons

- Longstanding dispute in light meson spectroscopy if exotic states exist (too many scalar states?)
- No convincing experimental proofs for existence of elusive pentaquarks
- Recent discoveries in heavy quark states have revived hopes for conclusive proofs for existence of exotic mesons



X(3872)



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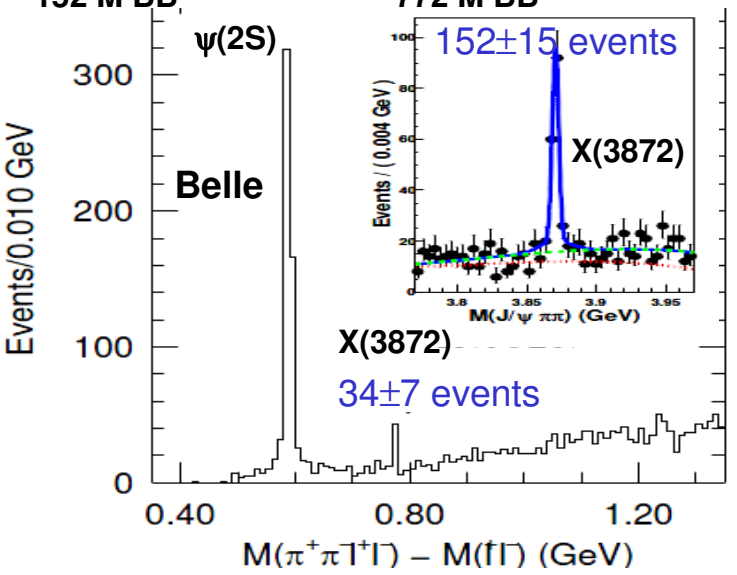
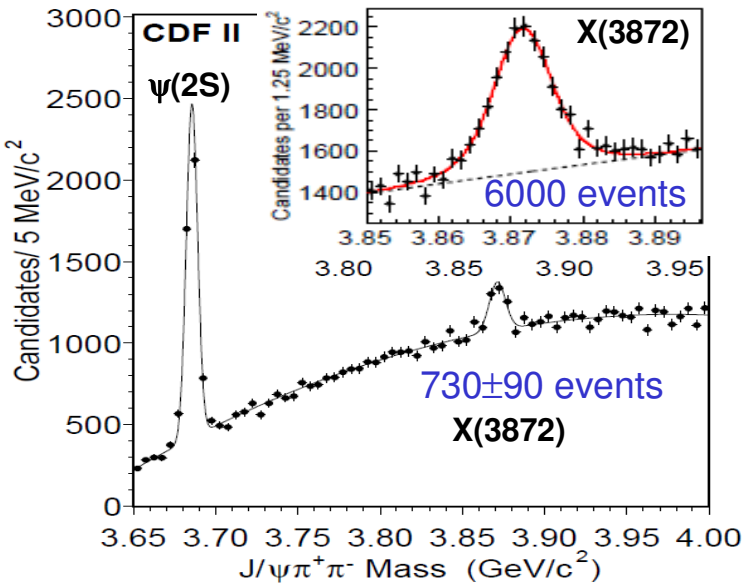
- Discovered by Belle in 2003 at e^+e^- B-factory in $B^+ \to X(3872)K^+$, $X(3872) \to J/\psi\,\pi^+\pi^-$
- Confirmed by CDF and D0 in 2004 at Tevatron, mostly prompt (~84%) production $pp \to X(3872)+\ldots$
- Also observed by BaBar in 2005
- Its mass and decay modes disfavor a standard $c\bar{c}$ state.
- $D\bar{D}^*$ molecule, tetraquark, hybrid…?
- Even 9 years after the discovery some basic experimental questions are not answered:
  - Is its mass below the $D\bar{D}^*$ threshold?
  - Is its $J^{PC}=1^{++}$ or 2^{-+} ?

PRL 91, 262001 (2003) PRD 84, 052004 (2011)
152 M BB 772 M BB

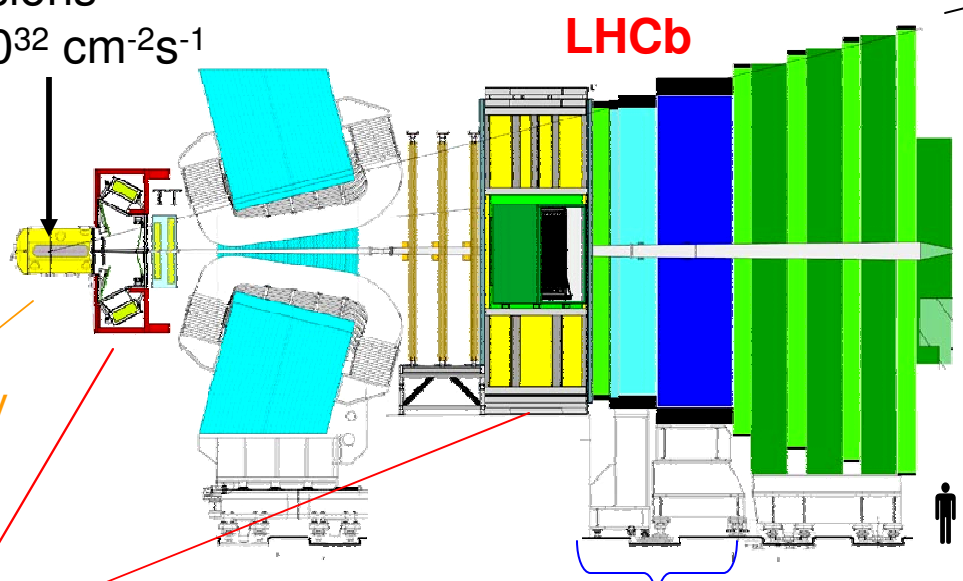


PRL 93, 072001 (2004) PRL 1003,152001 (2009)
0.22 fb^{-1} 2.4 fb^{-1}



LHCb experiment

pp collisions
L_{inst} up to 4×10^{32} cm^{-2}s^{-1}



Small solid angle with comparable cross-sections to the central region

⇓

small events size

⇓

large output trigger bandwidth ~3.5 kHz

Vertex detector to identify primary collisions points and B decay vertices

RICH detectors for good K/π separation

Tracking system with dipole magnet providing excellent momentum resolution

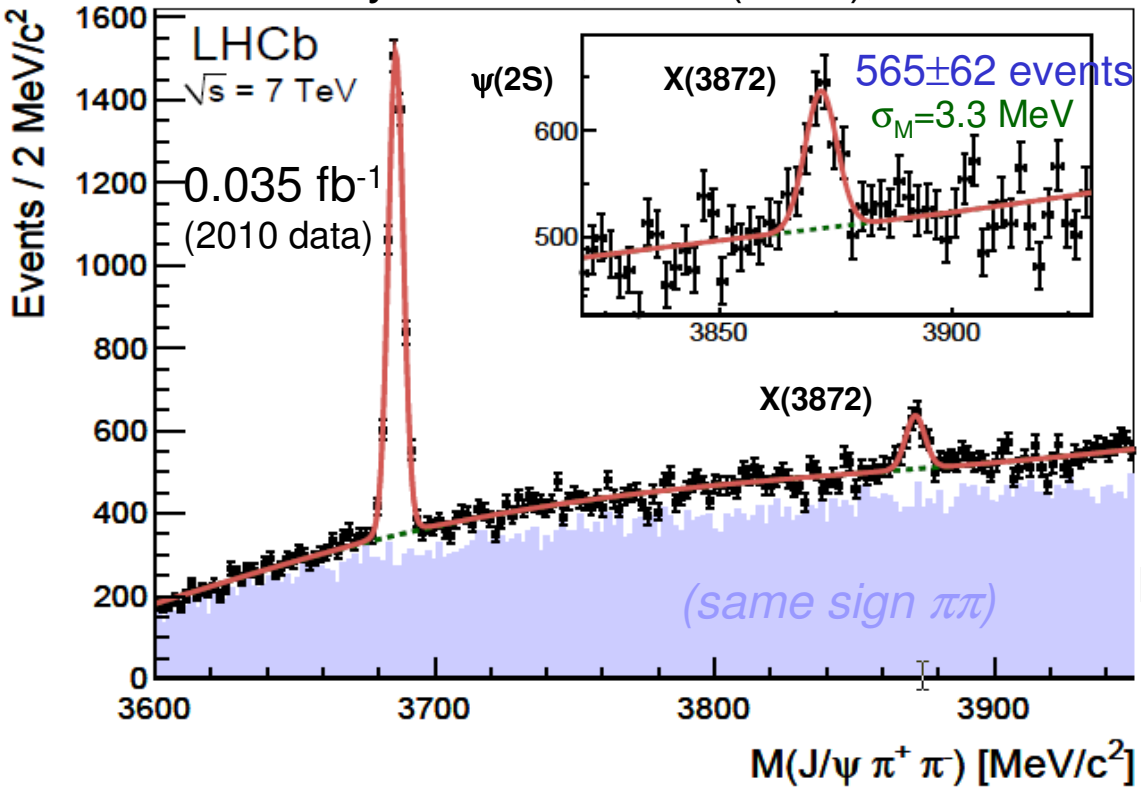
EM and HAD calorimeters for triggering on channels with no μ And for e,γ,π^0 detection

Muon system efficient μ and μμ triggers with low p_T thresholds

- Advantages vs e^+e^-:
  - Prompt production and orders of magnitude larger B production rates
- Advantages vs central detectors at LHC or Tevatron:
  - Large trigger bandwidth totally devoted to heavy flavor physics; higher trigger efficiencies
  - Can identify and trigger on lower p_T (di)muons
  - K/π separation
  - Larger production rates than at Tevatron

Inclusive X(3872) at LHCb (mostly prompt)

LHCb Eur. Phys. J. C72, 1972 (2012), arXiv:1112.5310



Mass resolution and S/B similar to CDF.
Signal yield/fb^{-1} 6.5 times higher than in CDF.

Also preliminary observation by CMS in 2010 data (CMS-PAS-BPH-10-018); similar yield/fb^{-1} but 2x resolution and 4.5 worse S/B *(see next slide)*

M[ψ(2s)] = 3686.12±0.06±0.10 MeV
vs PDG 3686.09±0.04 MeV

M[X(3872)] = 3871.95±0.48±0.12 MeV vs CDF 3871.61±0.16±0.19 MeV
Belle 3871.84±0.27±0.19 MeV

M(D^0)+M(D^{0*})= 3871.79±0.29 MeV

The statistical error on the mass measurement from 2010 data not competitive yet, but the systematic error is small.

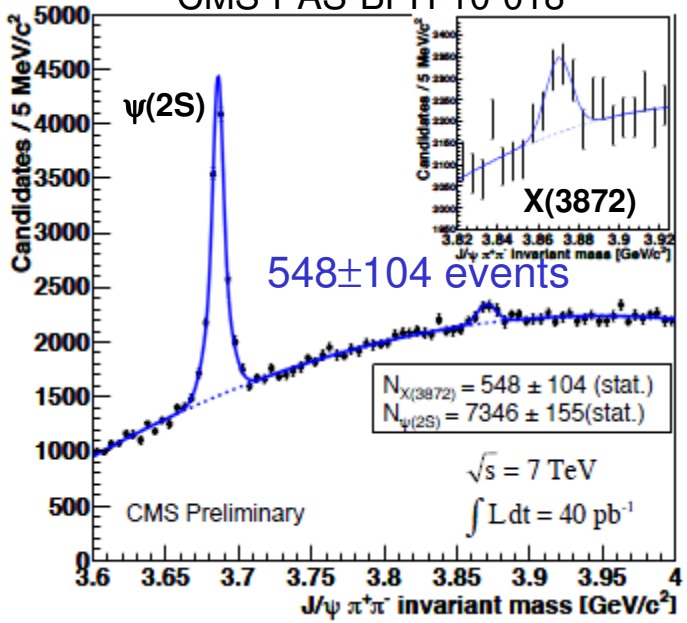
Already have 1 fb^{-1} collected in 2011. Expected statistical error ~0.1 MeV. Systematics ?
Better measurement of M(D^0)+M(D^{0*}) also needed.

X(3872) production

- X(3872) production cross-section measured at Tevatron:
  - Bignamini et al PRL103, 162001 (2009)
    - orders of magnitude too large to be a $D\bar{D}^*$ molecule
  - Artoisenet, Braaten PRD81, 114018 (2010); PRD83, 014019 (2011):
    - can be reconciled with the molecular model when $D\bar{D}^*$ rescattering is considered
    - they also predicted X(3872) pp $\sigma \times BR(X(3872) \to J/\psi\, \pi^+\pi^-)$ at LHC scaling from the measurement at Tevatron using NRQCD approach

- Preliminary CMS results based on 2010 data (0.04 fb^{-1}):
  - Measure $\sigma \times BR$ ratio between X(3872) and $\psi(2S)$ (p_T>8 GeV, |y|<2.2) : 0.087±0.017±0.009
    - Similar to CDF 2004 signal yield ratio: 0.10±0.02
  - no absolute $\sigma \times BR$ measurement

CMS-PAS-BPH-10-018



X(3872) production σ measured at LHCb

LHCb Eur. Phys. J. C72, 1972 (2012), arXiv:1112.5310

- Use smaller fiducial region:
  - $2.5 < y < 4.5$ and $5 < p_T < 20$ GeV
  - With well understood acceptance corrections
  - Reduces the signal yield by 30%

$$\sigma(pp \to X(3872)+\text{anything})\ BR(X(3872) \to J/\psi\pi^+\pi^-) = 4.7 \pm 1.1 \pm 0.7 \text{ nb}$$

Smaller than predicted for this fiducial region by Artoisenet-Braaten:

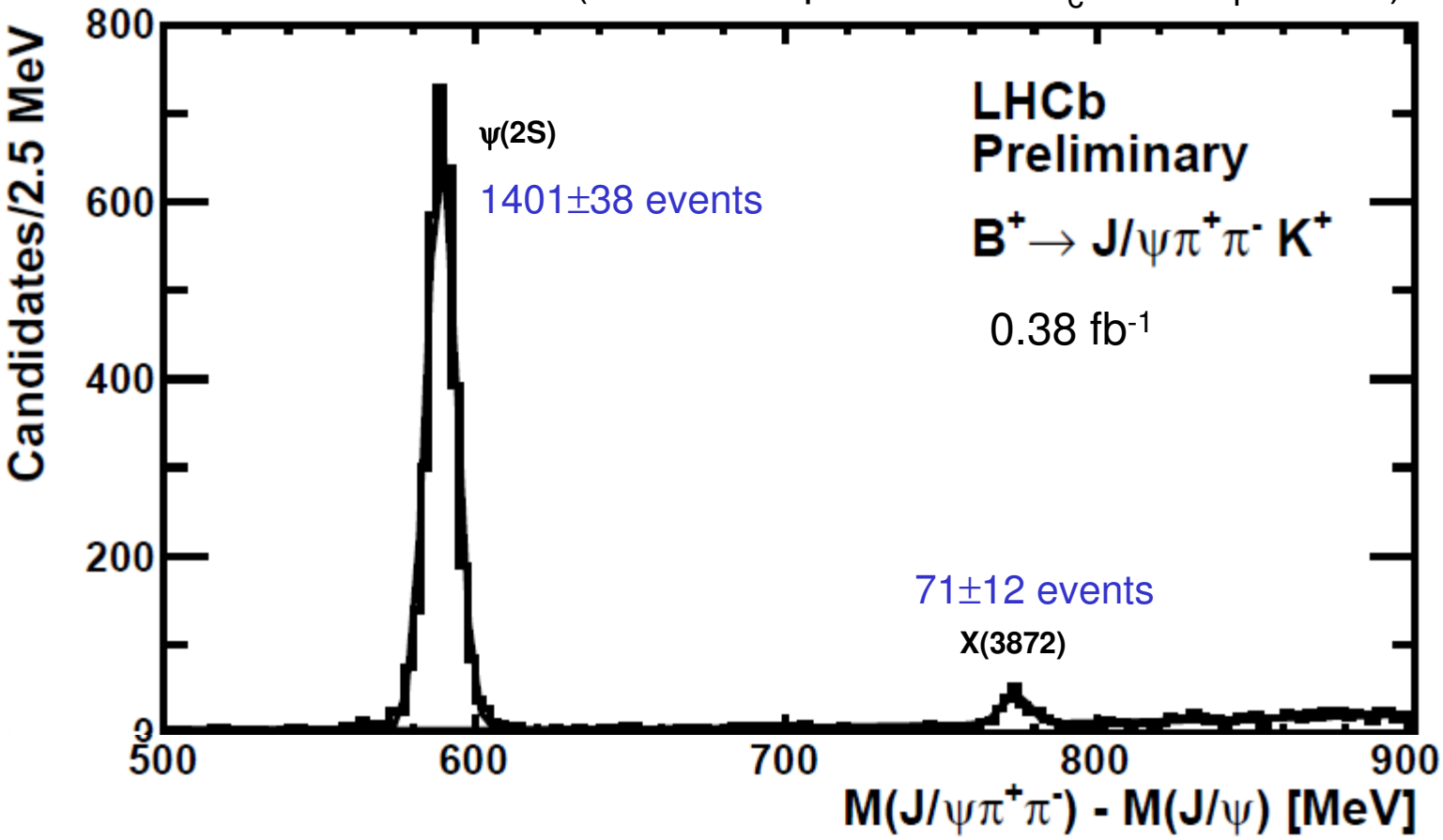
13.0 ± 2.7 nb

(error from experimental inputs only, theoretical uncertainty?)

With $1 fb^{-1}$ expect determination of prompt and B-production fractions vs p_T

X(3872) from B decays at LHCb

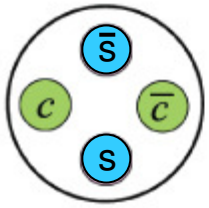
LHCb-CONF-2011-040 (selection optimized to $B_c^+ \to J/\psi\pi^+\pi^-\pi^+$)



- With selection optimized to X(3872) up to 300 events in 1 fb^{-1} (~2x Belle's signal statistics)
- Analysis of angular correlations to probe J^{PC} in progress

X(4140)

$B^+ \to J/\psi\phi\, K^+$
$(\phi \to K^+ K^-)$



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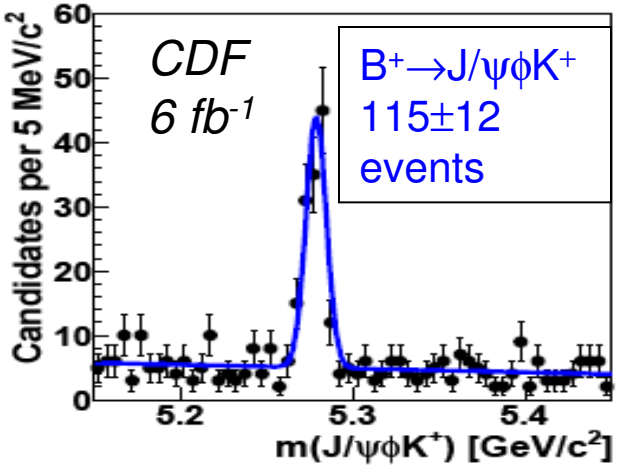
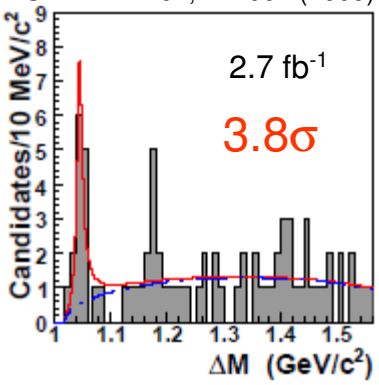
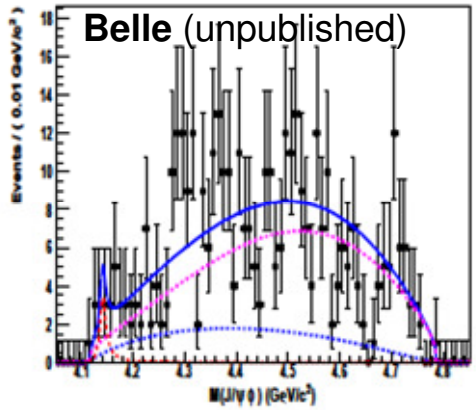


CDF PRL 102, 242002 (2009)



A narrow state at this mass decaying to J/ψφ necessarily exotic!

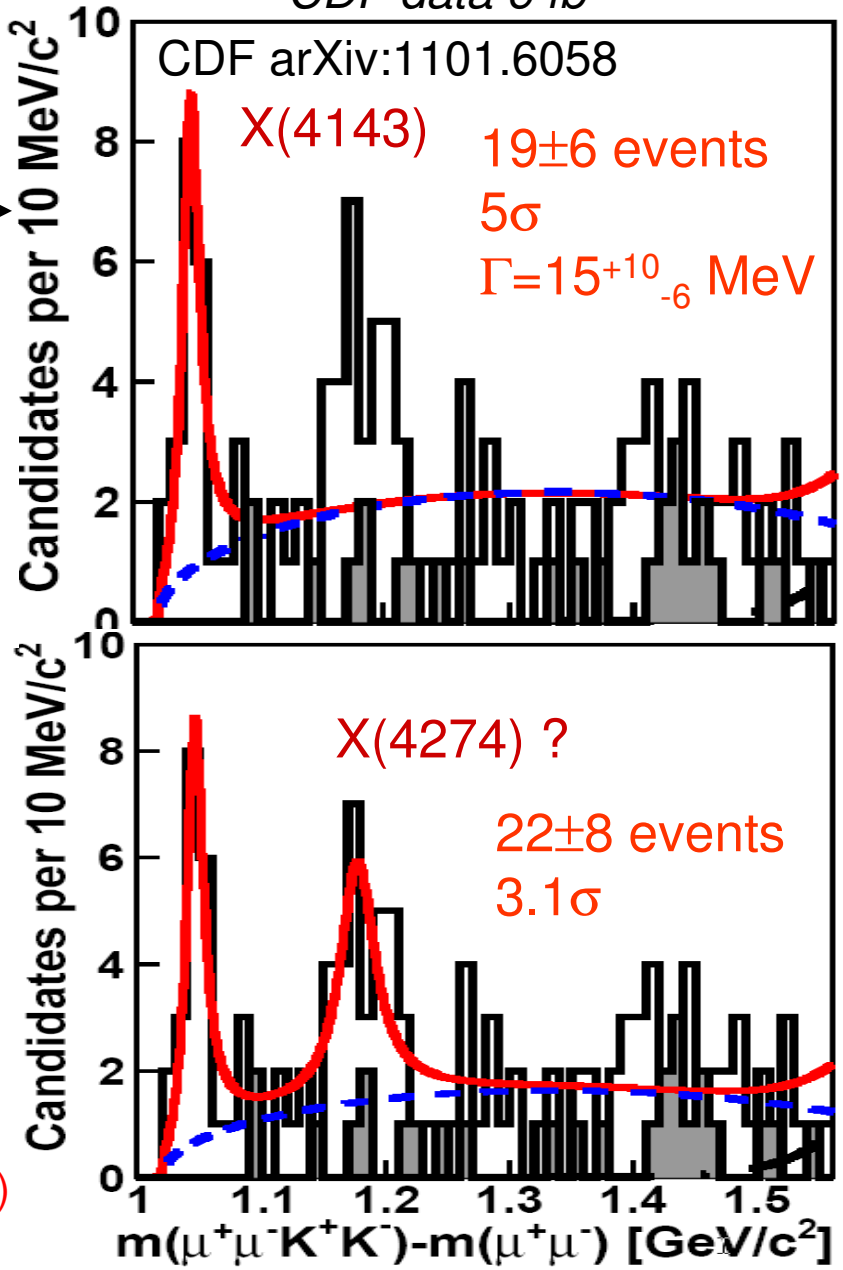
J. Brodzicka LP09 DOI:10.3204/DESY-PROC-2010-04/38



325±21 $B^+ \to J/\psi\phi K^+$ events but low efficiency near the $J/\psi\phi$ threshold

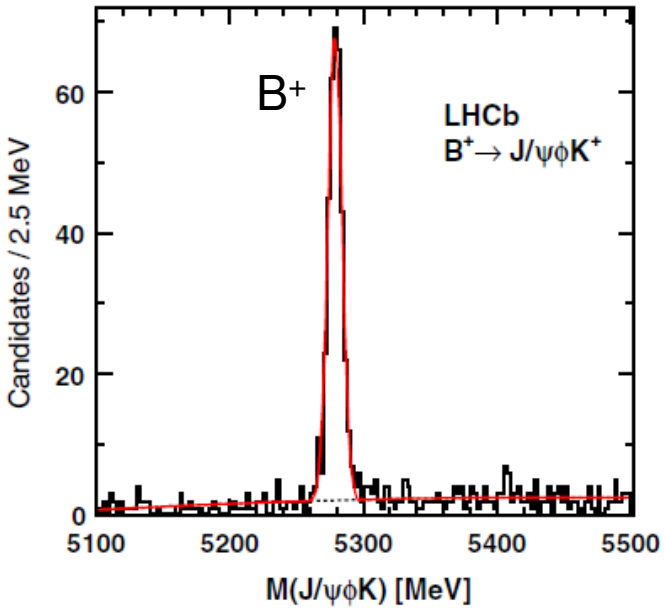
$BR(B^+ \to X(4140)K^+, X \to J/\psi\phi)$
$< 6 \times 10^{-6}$ (90%CL)
vs CDF x $BR_{PDG}(B^+ \to J/\psi\phi K^+)$
$= (8 \pm 2 \pm 3) \times 10^{-6}$

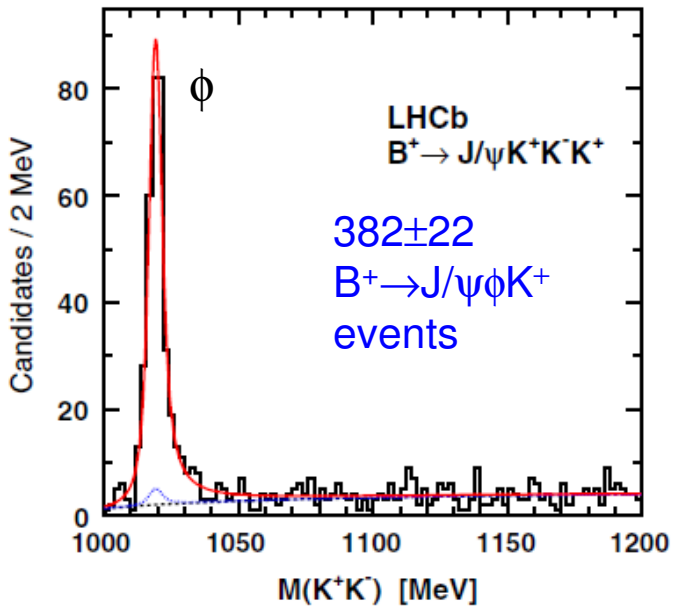
CDF data 6 fb-1



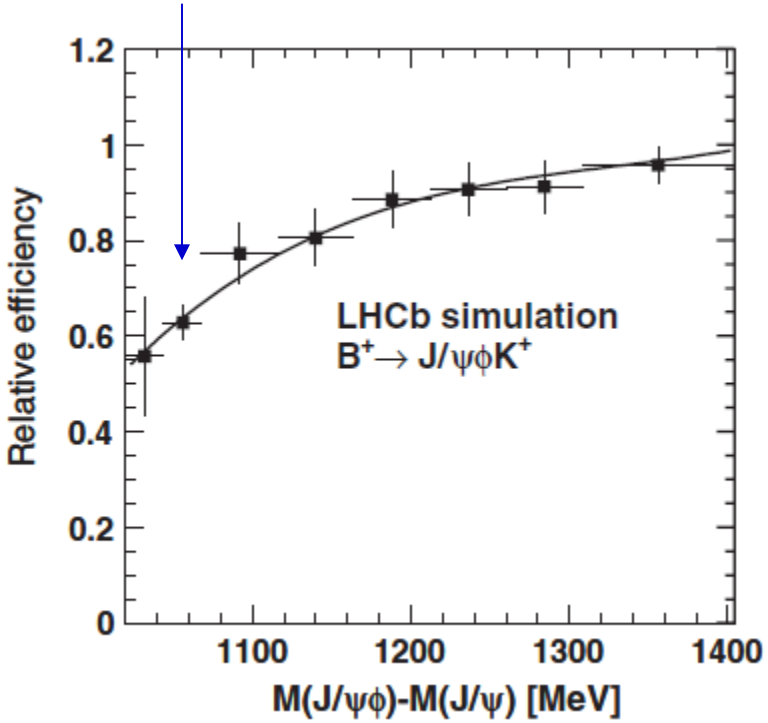
Search for X(4140) in LHCb

LHCb PRD 85, 091103(R) (2012)
0.37 fb^{-1} (partial 2011 data set)



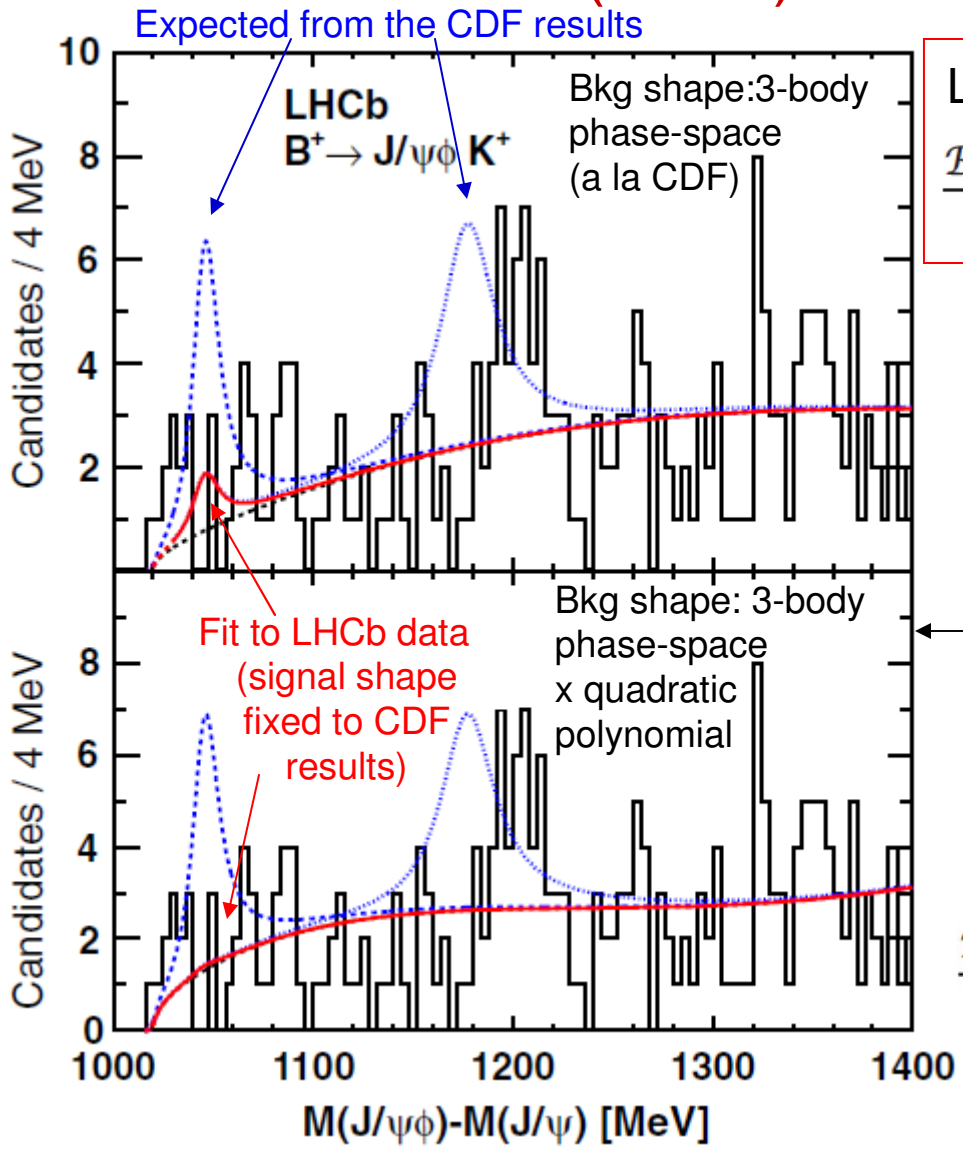


Sizeable efficiency at the threshold



- Factor of ~2 better sensitivity to X(4140) signal yield than in CDF

Search for X(4140) in LHCb



LHCb (90% CL):

$$\frac{\mathcal{B}(B^+ \to X(4140)K^+) \times \mathcal{B}(X(4140) \to J/\psi\phi)}{\mathcal{B}(B^+ \to J/\psi\phi K^+)} < 0.07$$

vs CDF: $0.149 \pm 0.039 \pm 0.024.$

2.4σ disagreement

(2.7σ disagreement)

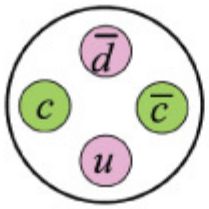
also set 90% C.L. on:

$$\frac{\mathcal{B}(B^+ \to X(4274)K^+) \times \mathcal{B}(X(4274) \to J/\psi\phi)}{\mathcal{B}(B^+ \to J/\psi\phi K^+)} < 0.08$$

- With more data plan multidimensional amplitude analysis in M(J/ψφ) vs M(φK⁺) vs angles

Summary

- LHCb results on inclusive X(3872) using 2010 data:
  - Measured mass consistent with, but not competitive yet, with the measurements by CDF and Belle.
  - Good efficiency, mass resolution and S/B. Potential to do the best mass measurement with the 2011 data.
  - The measured cross-section somewhat lower than predicted by Artoisenet-Braaten from the Tevatron data.
  - Will determine long-livetime / prompt ratio with the 2011 data
- Worlds best signal statistics for $B^+ \to X(3872)K^+$, $X(3872) \to J/\psi\pi^+\pi^-$ in the 2011 data:
  - J^{PC} determination and BR measurement in progress
- LHCb search for X(4140) in $B^+ \to X(4140)K^+$, $X(4140) \to J/\psi\phi$:
  - The most sensitive measurement to date
  - Don't find evidence for this state in 2.4σ disagreement with the CDF
- Other work in progress:
  - We have the worlds best statistics for $B^0 \to \psi(2S)\pi^+K^-$. Probe for $Z(4430)^+ \to \psi(2S)\pi^+$ (claimed by Belle, but not confirmed by BaBar).



$Z(4430)^+$
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