Recent Results on Charmless Hadronic *B* Decays at Belle

Pablo Goldenzweig
University of Cincinnati
Representing the Belle Collaboration

European Physical Society
Manchester, England, 19-25 July , 2007

BARYONIC

$B^+ \to p\bar{p}K^+$
$B^+ \to p\bar{p}\pi^+$

$B+ \to p\bar{\Lambda}\gamma$
$B^0 \to p\bar{\Lambda}\pi^-$

$B+ \to p\bar{\Lambda}\pi^0$

VECTOR-VECTOR

$B^0 \to \omega K^{*0}$

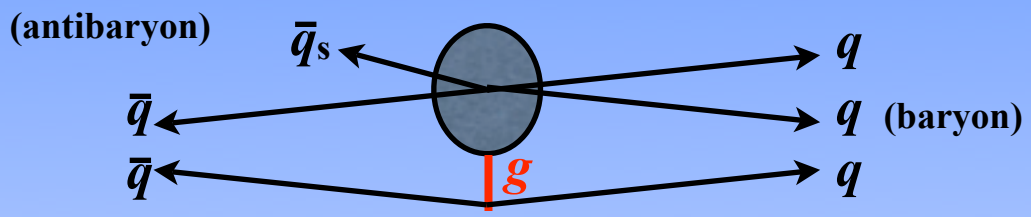
Baryonic *B* decays

- a unique and well-established feature of *B* meson decay
- ***Br****(3-body) >* ***Br****(2-body)*
- threshold enhancement of the baryon-antibaryon mass spectra
- angular distributions discriminate between decay mechanisms

Short-distance (SD) picture

-dominance of 3-body modes-
-threshold enhancement of dibaryon mass spectra-

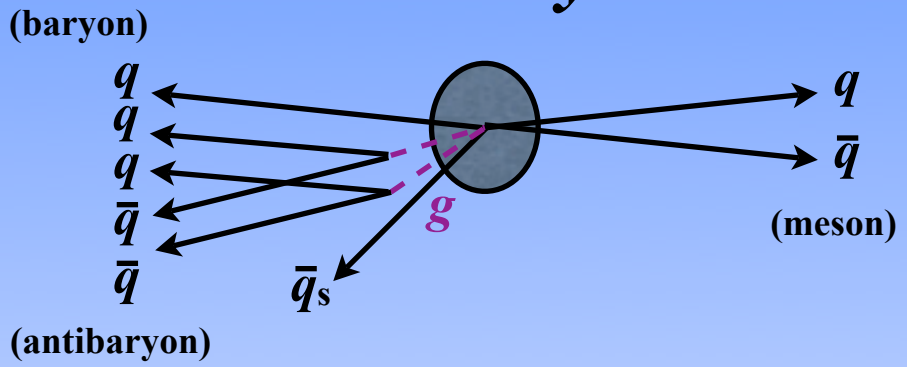
2-body



energetic qq pair must be emitted back to back ⇒ gluon is highly off mass shell and

mechanism is SD suppressed

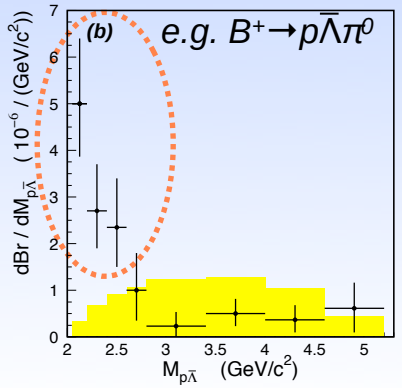
3-body



qq pairs emitted by gluons nearly in the same direction ⇒ gluon is close to mass shell and

the SD suppression does not occur.

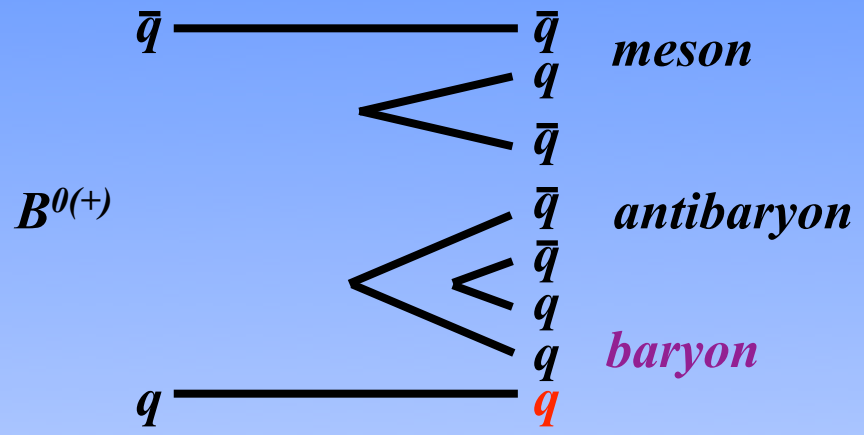
baryon-antibaryon pair have small relative momentum => threshold-enhancement.



as described in
M. Suzuki, J. Phys. G **34**, 283 (2007)

SD picture

penguin diagram



-the baryon picks up the slow moving spectator quark and therefore its momentum is smaller than that of the antibaryon in the $B^{0(+)}$ rest frame.

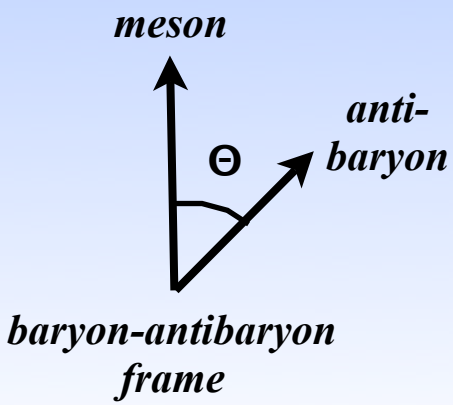
-the antibaryon should tend to move away from the meson in the baryon-antibaryon frame.

measure angular asymmetry

$$A_\Theta = \frac{N_+ - N_-}{N_+ + N_-}$$

B yield

$$N_+ = \cos\Theta > 0$$
$$N_- = \cos\Theta < 0$$



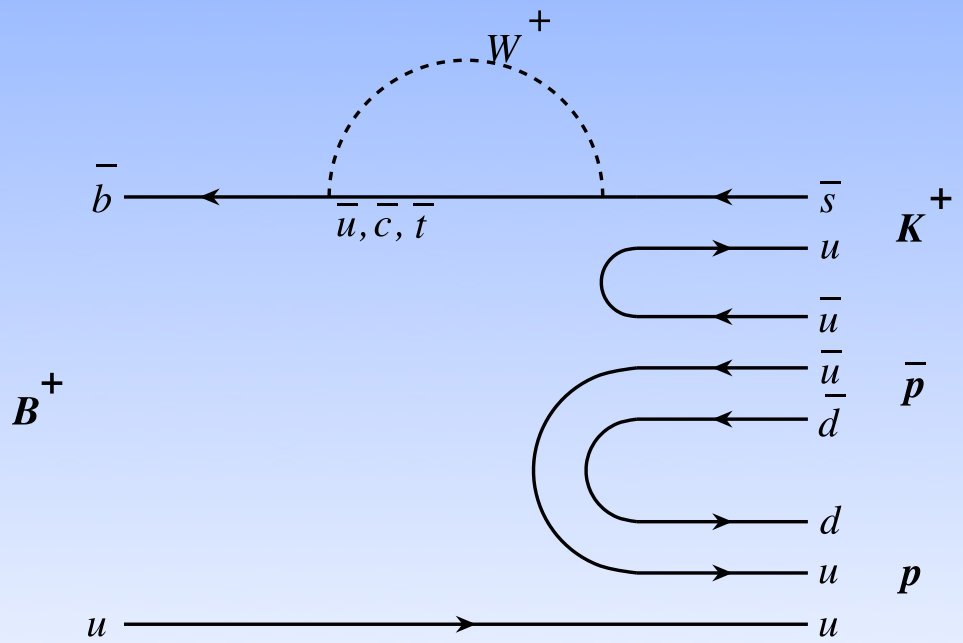
$A_\Theta <$ agrees with SD

$A_\Theta >$ disagrees with SD

-suggests importance of **long-distance** (LD) effects.
-fragmentation, pp rescattering through a hypothetical baryonium bound state (JPG **34**, 283) and the pole model contain LD effects in different ways.

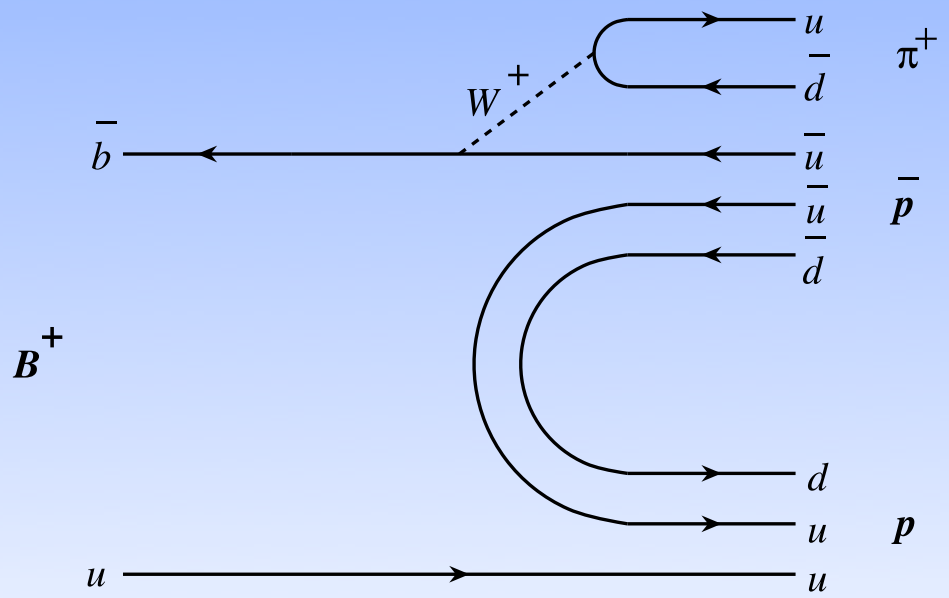
$B^+ \to p\bar{p}K^+$

$b \to s$ penguin



$B^+ \to p\bar{p}\pi^+$

$b \to u$ tree



Belle Collaboration, arXiv:0706.4167v1, submitted to Phys. Lett. B

Improved measurements

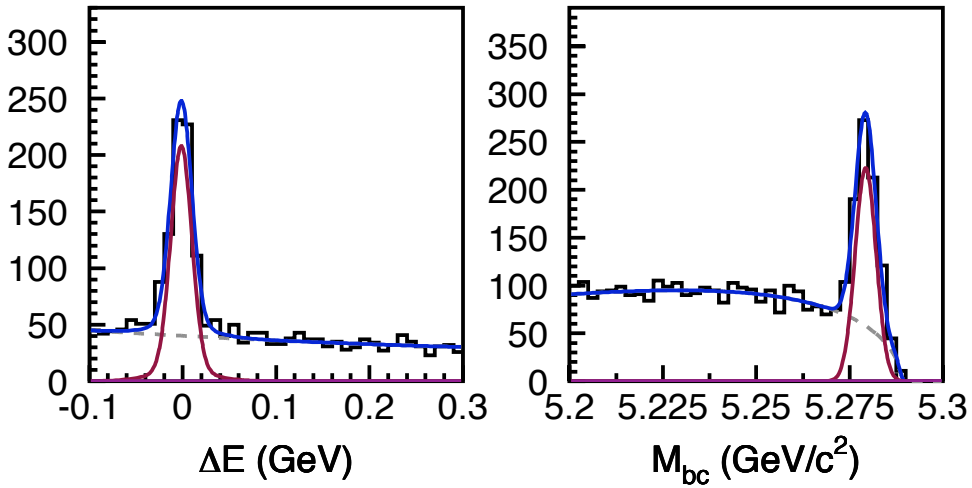
$N_{B\bar{B}}$ = 449M

Likelihood fit: $P_j^i = P_j(\Delta E^i, M_{bc}^i)$

$M_{p\bar{p}} < 2.85$ GeV/c^2

$p\bar{p}K^+$

$b \to s$



Yield = 632^{+29}_{-28}

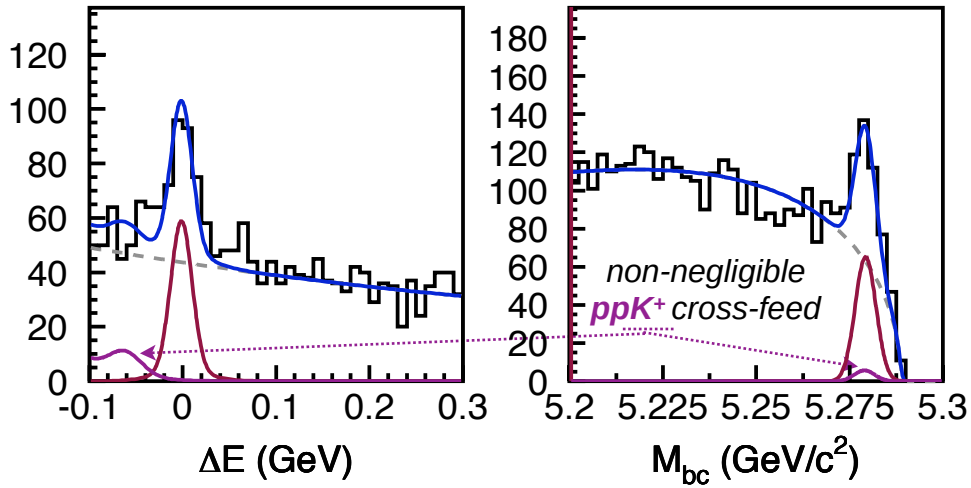
Br = $(5.39^{+0.26}_{-0.24} \pm 0.35) \times 10^{-6}$

$A_{CP} = -0.02 \pm 0.05 \pm 0.02$

First observation of a charmless baryonic B meson decay
*[Belle Collaboration PRL **88,** 181803 (2002)]*

$p\bar{p}\pi^+$

$b \to u$



Yield = 184 ± 19

Br = $(1.68^{+0.19}_{-0.17} \pm 0.12) \times 10^{-6}$

Significance = 13.6σ

$A_{CP} = -0.17 \pm 0.10 \pm 0.02$

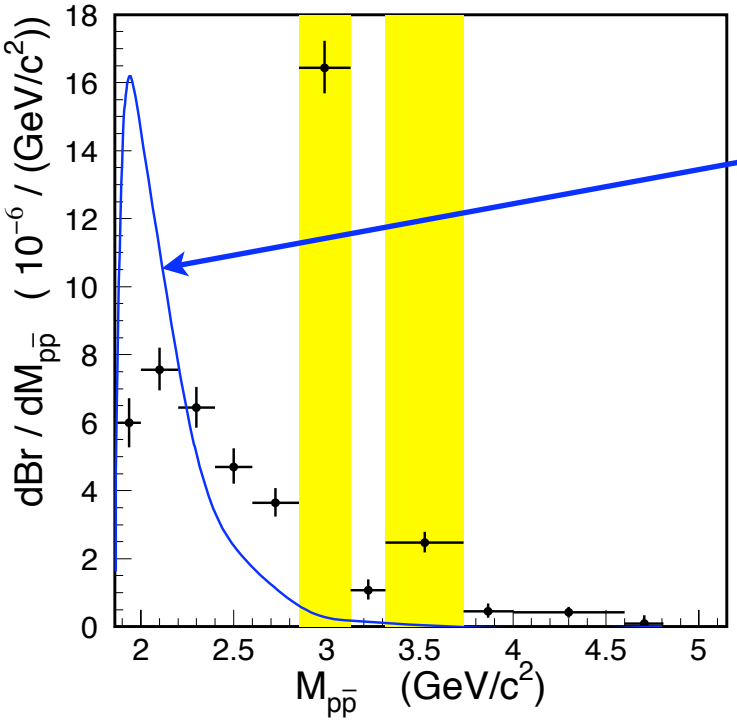
Threshold enhancement

$N_{B\bar{B}}$ = 449M

Likelihood fit: $P_j^i = P_j(\Delta E^i, M_{bc}^i)$

full region in $M_{p\bar{p}}$ bins

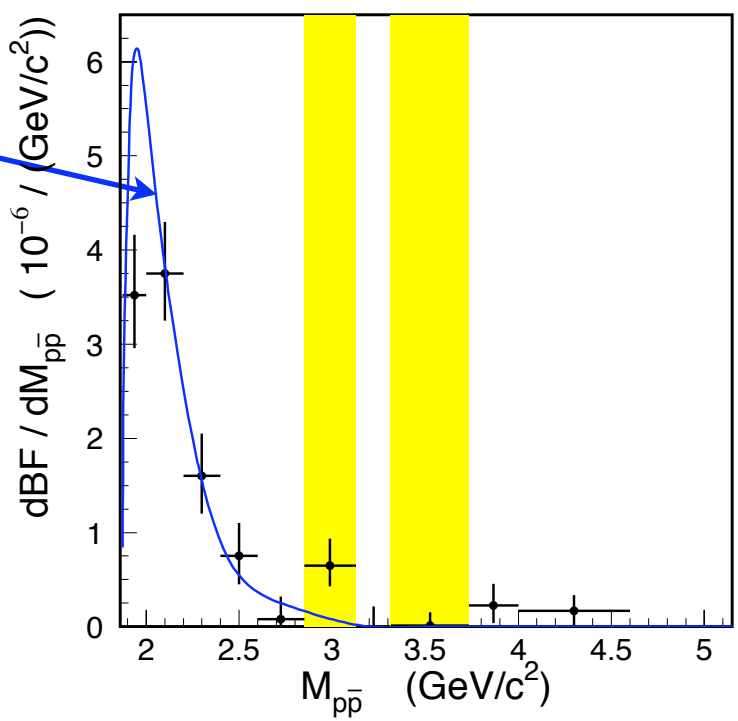
$p\bar{p}K^+$ $b \to s$



theoretical prediction based on factorization approach (PRD **66,** 054004)

exclude η_c, J/ψ, ψ′, χ_{c0}, χ_{c1}

$p\bar{p}\pi^+$ $b \to u$



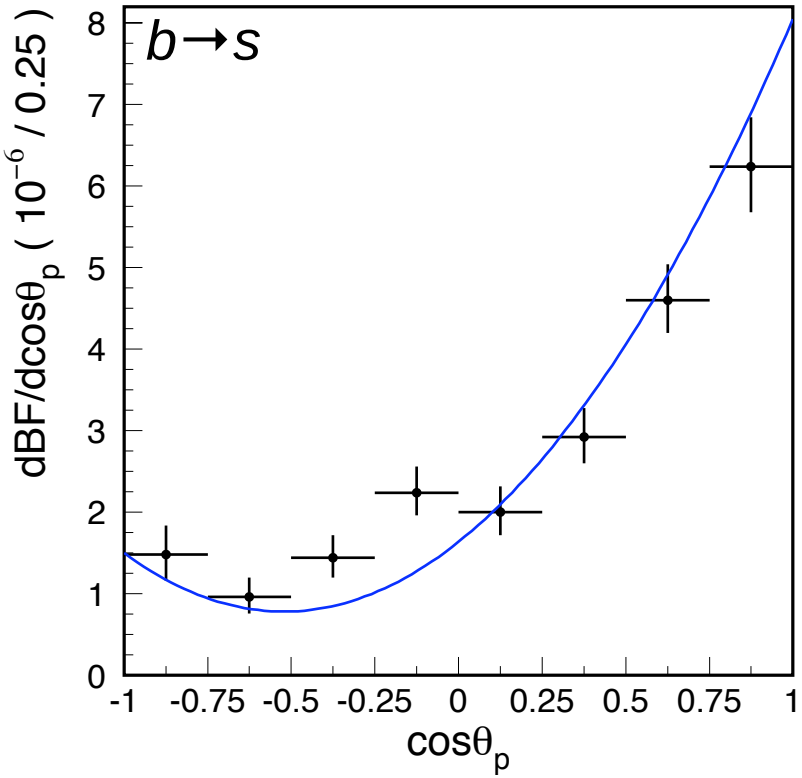
narrower width than $p\bar{p}K^+$
better agreement with theoretical curve

Angular distributions

$N_{B\bar{B}}$ = 449M

opposite trends

$p\bar{p}K^+$

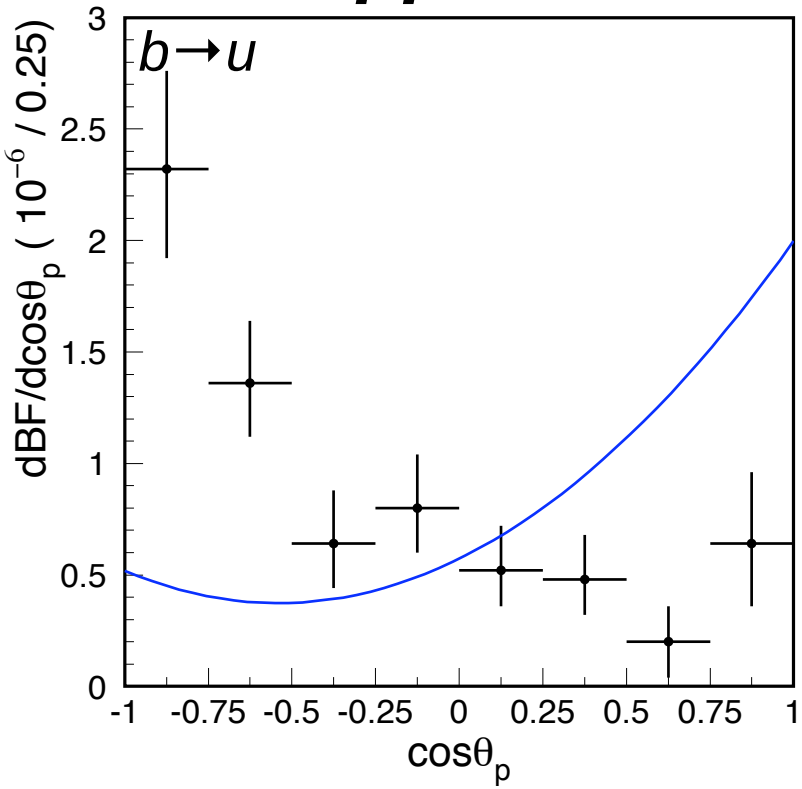


$A_\Theta = 0.44 \pm 0.05 \pm 0.03$

disagrees with the SD picture.

agrees with the theoretical prediction in the framework of perturbative QCD (PRD **74,** 094023).

$p\bar{p}\pi^+$



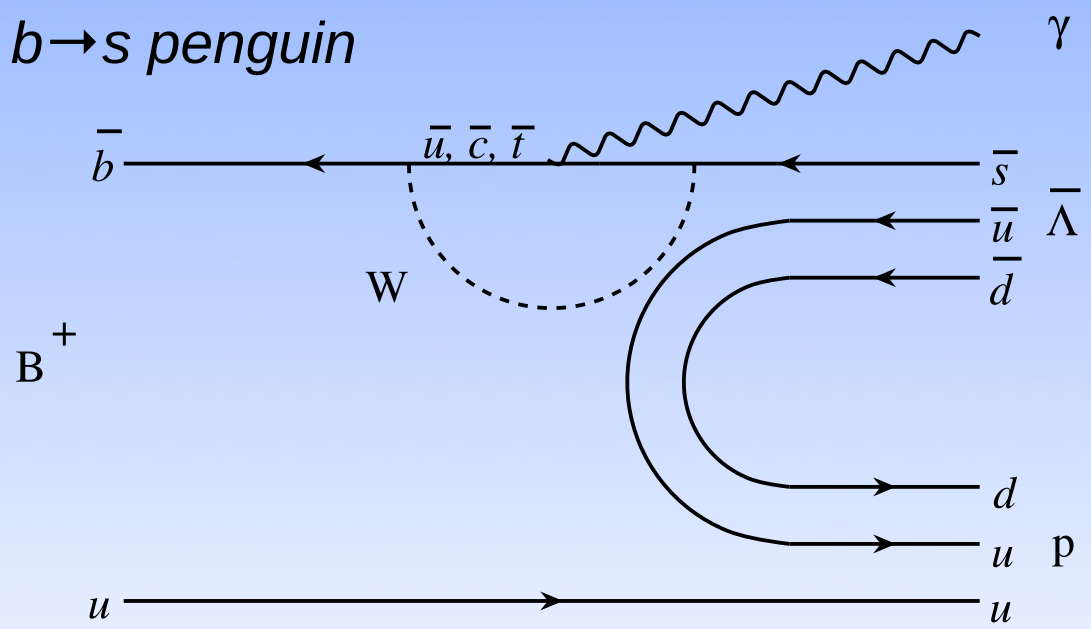
$A_\Theta = -0.48 \pm 0.12 \pm 0.03$

agrees with the SD picture.

disagrees with the theoretical prediction based on extrapolation of the ppK^+ data.

$B^0 \to p\bar{\Lambda}\pi^-$ $B^+ \to p\bar{\Lambda}\pi^0$

$B^+ \to p\bar{\Lambda}\gamma$

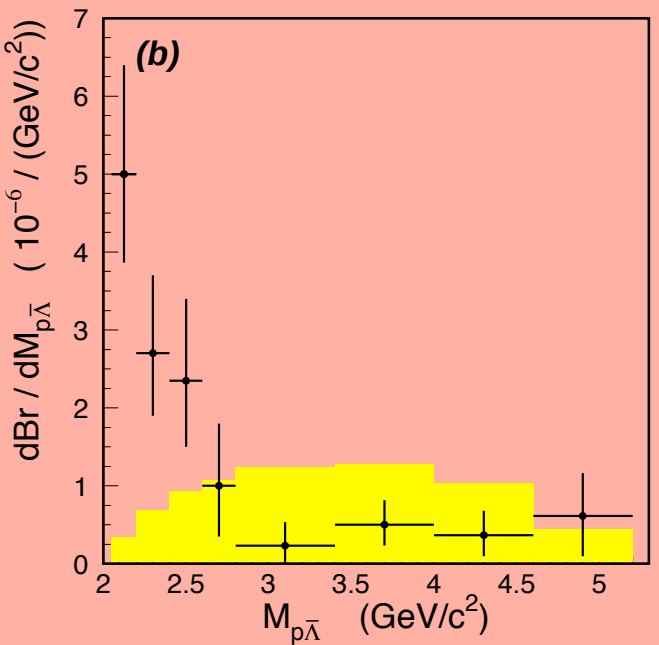


Belle Collaboration, arXiv:0704.2672v3, submitted to Phys. Rev. D

First observation of $B^+ \to p\bar{\Lambda}\pi^0$

$N_{B\bar{B}}$ = 449M

Likelihood fit to full region in bins of $M_{p\Lambda}$: $P_j^i = P_j(\Delta E^i, M_{bc}^i)$



Yield = 89^{+19}_{-17}

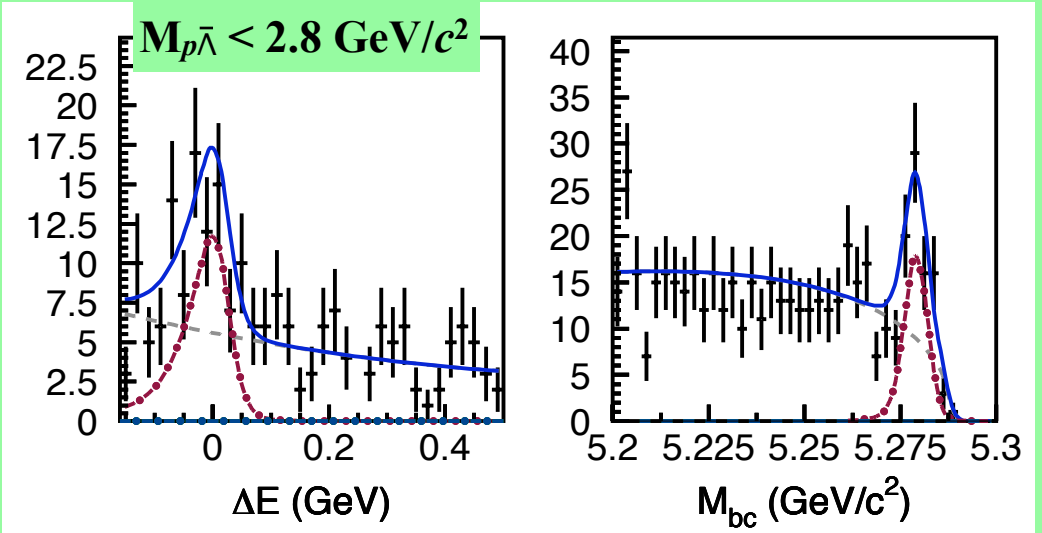
Br = $(3.00^{+0.61}_{-0.53} \pm 0.33) \times 10^{-6}$

Significance = 10.2σ

$A_{CP} = 0.01 \pm 0.17 \pm 0.04$

$A_\Theta = -0.16 \pm 0.18 \pm 0.03$

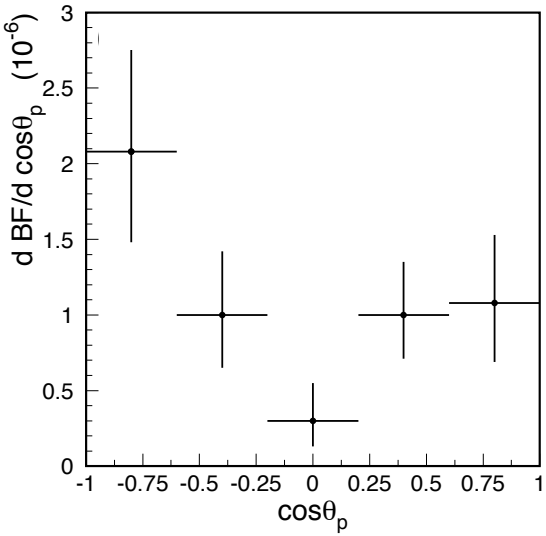
Projections in signal regions of ΔE and M_{bc} for threshold-mass-enhanced region



$$\frac{\mathrm{Br}(B^+ \to p\Lambda\pi^0)}{\mathrm{Br}(B^0 \to p\Lambda\pi^-)} = 0.93^{+0.21}_{-0.19} \pm 0.09$$

> 0.5 (theoretical prediction)

cannot rule out naive factorization picture with current statistics

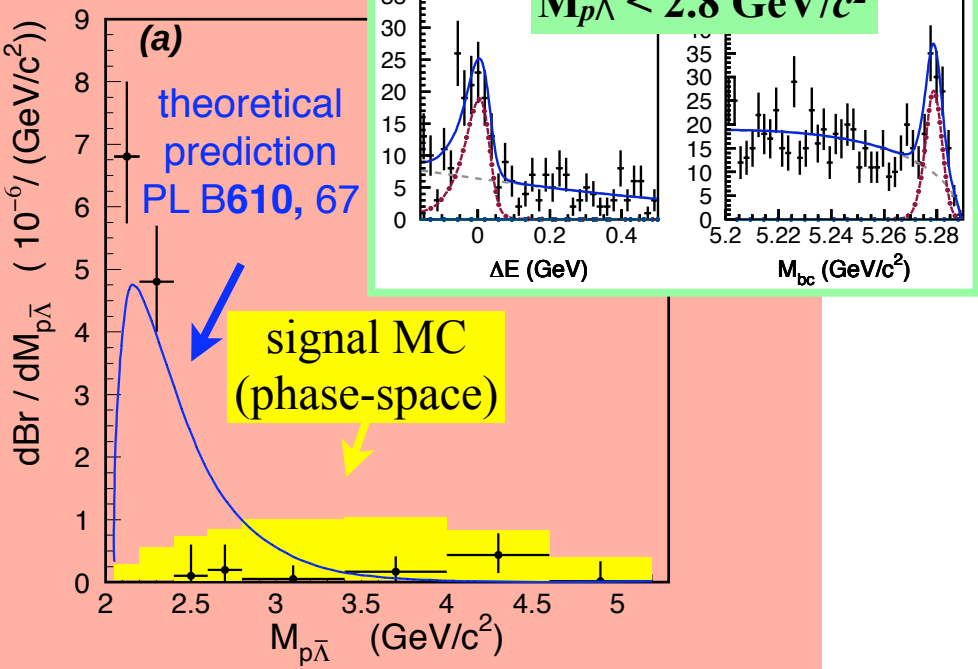


Improved measurements

$N_{B\bar{B}}$ = 449M

$p\bar{\Lambda}\gamma$

$b \to s\gamma$



Yield = 114^{+18}_{-16}

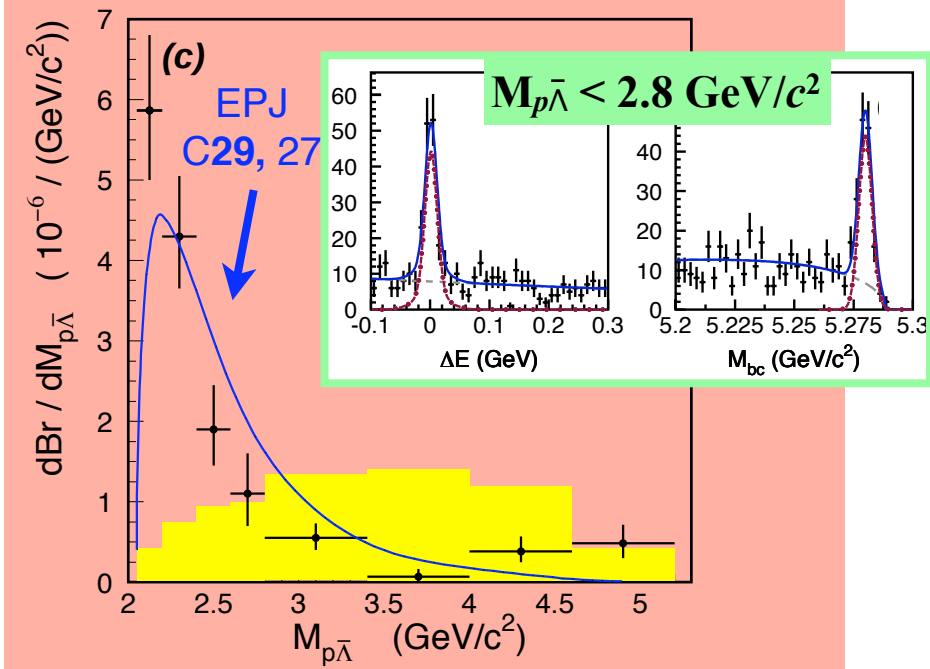
Br = $(2.45^{+0.44}_{-0.38} \pm 0.22) \times 10^{-6}$

Significance = 14.5σ

$A_{CP} = 0.17 \pm 0.16 \pm 0.05$

$p\bar{\Lambda}\pi^-$

$b \to s$



Yield = 178^{+18}_{-16}

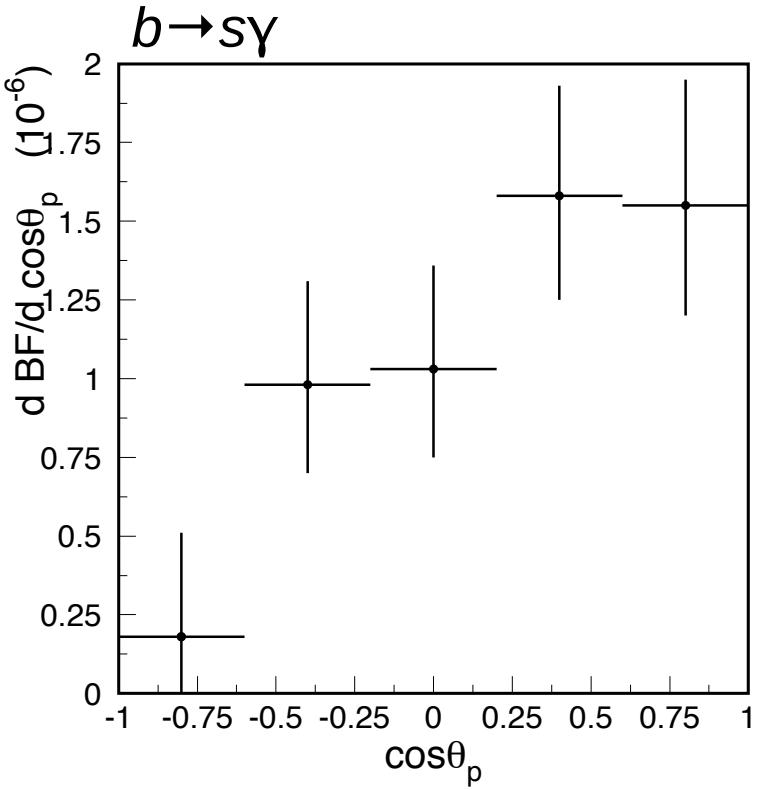
Br = $(3.23^{+0.33}_{-0.29} \pm 0.29) \times 10^{-6}$

$A_{CP} = -0.02 \pm 0.10 \pm 0.03$

Angular distributions

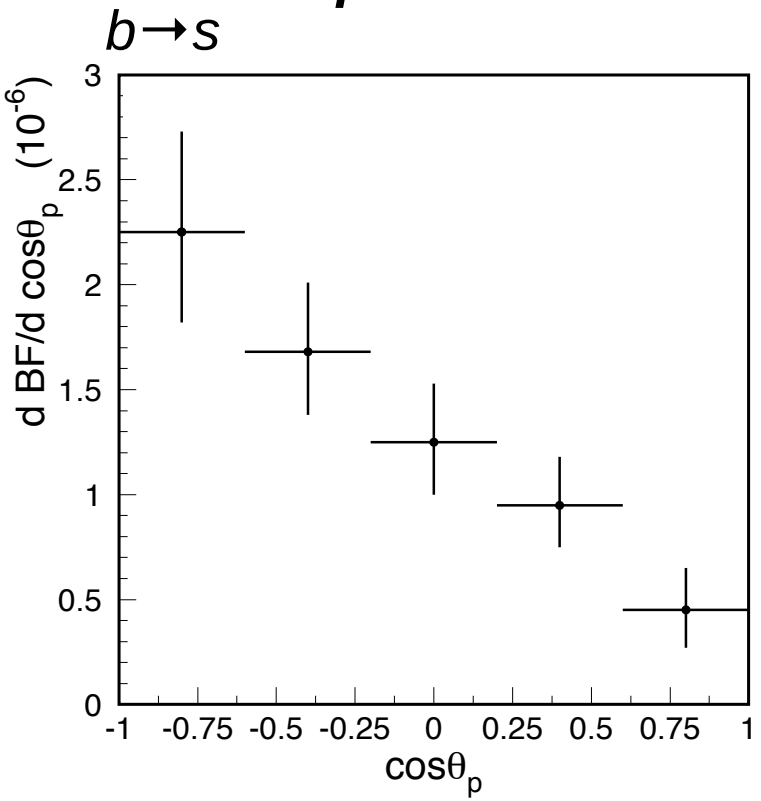
$N_{B\bar{B}}$ = 449M

$p\bar{\Lambda}\gamma$



$A_\Theta = 0.29 \pm 0.14 \pm 0.03$

$p\bar{\Lambda}\pi^-$



$A_\Theta = -0.41 \pm 0.11 \pm 0.03$

opposite slopes indicate that the $p\bar{\Lambda}\gamma$ decay ***agrees*** well with the short-distance $b \to s\gamma$ picture, while the $p\bar{\Lambda}\pi-$ decay ***disagrees*** with the short-distance $b \to sg$ (g = *hard gluon)* description.

Searches for intermediate 2-body decays in

$B^+ \to p\bar{p}\pi^+$

$B^0 \to p\bar{\Lambda}\pi^-$

$B^+ \to p\bar{\Lambda}\pi^0$

No significant signals

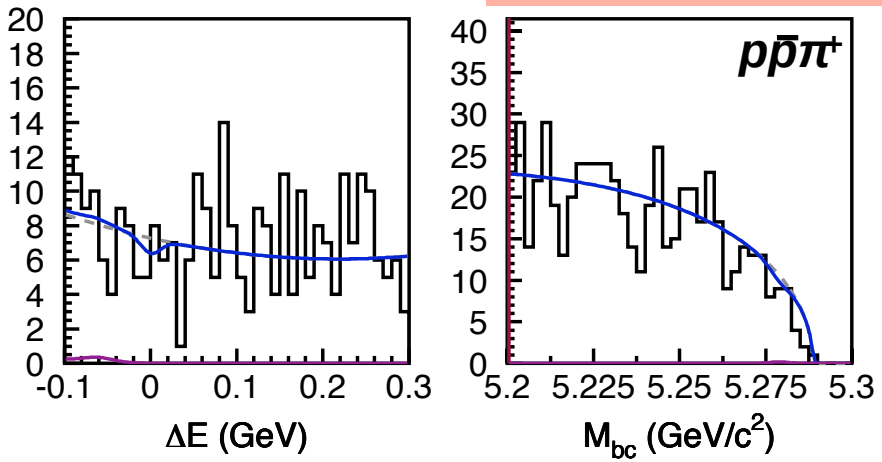
$N_{B\bar{B}}$ = 449M

$B^+ \to \bar{p}\Delta^{++}$

$M_{p\pi^+} < 1.4$ GeV/c^2

Yield < 7.5 (90% C.L.)

Br < 0.14×10^{-6}

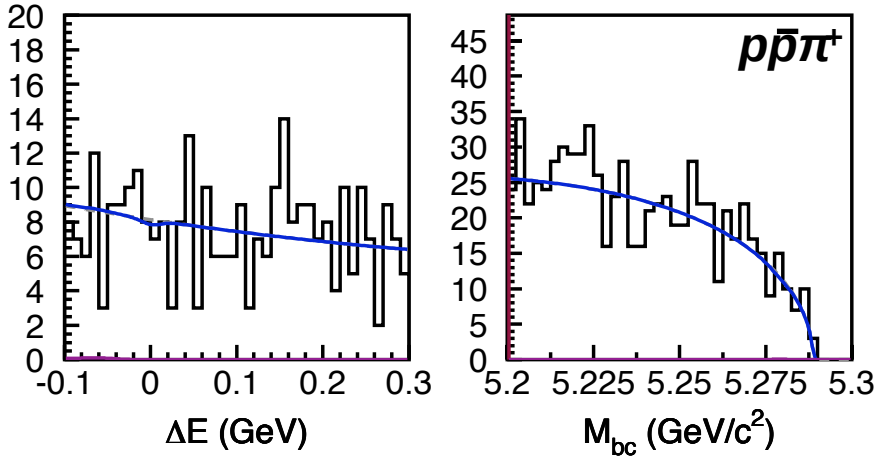


$B^+ \to p\bar{\Delta}^0$

$M_{\bar{p}\pi^+} < 1.4$ GeV/c^2

Yield < 25.9 (90% C.L.)

Br < 1.42×10^{-6}



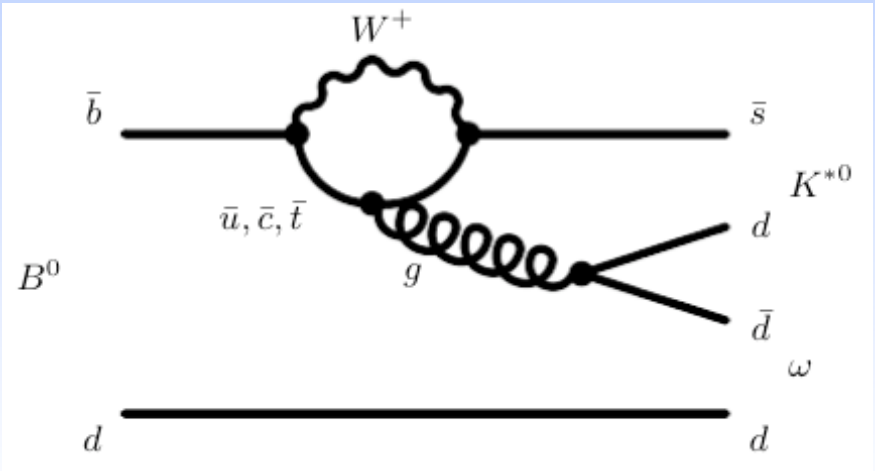
Channel	Yield	Br (10^{-6})
$B^0 \to p\bar{\Sigma}^{*-}$	< 10.9	< 0.26
$B^0 \to \Delta^0\bar{\Lambda}$	< 15.9	< 0.93
$B^+ \to p\bar{\Sigma}^{*0}$	< 11.3	< 0.47
$B^+ \to \Delta^+\bar{\Lambda}$	< 15.9	< 0.82

(90% C.L.)

where $\bar{\Sigma}^{*-,*0} \to \bar{\Lambda}\pi^{-,0}$ *and* $\Delta^{0,+} \to p\pi^{0,+}$

Search for $B^0 \to \omega K^{*0}$

- the SM with factorization predicts that the longitudinal polarization fraction (f_L) in B meson decays to light vector-vector (VV) final states is close to unity. A.L. Kagan, PLB **601**, 151 (2004)
- however, both Belle and BaBar measured an unexpectedly small longitudinal polarization ($f_L \approx 50\%$) in $b \to s$ penguin-dominated $B \to \Phi K^*$. Belle Collaboration, PRL **94**, 221804 (2005) BaBar Collaboration, arXiv:0705.1798 *[recent results]*
- this implies that non-factorizable contributions to the decay amplitude play a significant role.
- further information about these effects can be obtained with Br and polarization meausrements in $B^0 \to \omega K^{*0}$ (also $b \to s$ penguin-dominated).
- $B^0 \to \omega K^{*0}$ can also be useful for determining CKM angle $\Phi_3(=\gamma)$. Atwood & Soni, PRD **59**, 013007 (1999) Atwood & Soni, PRD **65**, 073018 (2002) Huang e*t al.*, PRD **73**, 014011 (2006)



Belle Collaboration, arXiv:0707.2462v1

Br result for $B^0 \to \omega K^{*0}$

Preliminary

$N_{B\bar{B}}$ = 520M

Likelihood fit:

$$P_j^i = P_j(\Delta E^i) \cdot P_j(M_{bc}^i) \cdot P_j(M_{\pi\pi\pi}^i) \cdot P_j(M_{K\pi}^i)$$

Yield = $15.1^{+11.1}_{-10.0}$

Br = $(1.2^{+0.9}_{-0.8} \pm 0.2) \times 10^{-6}$

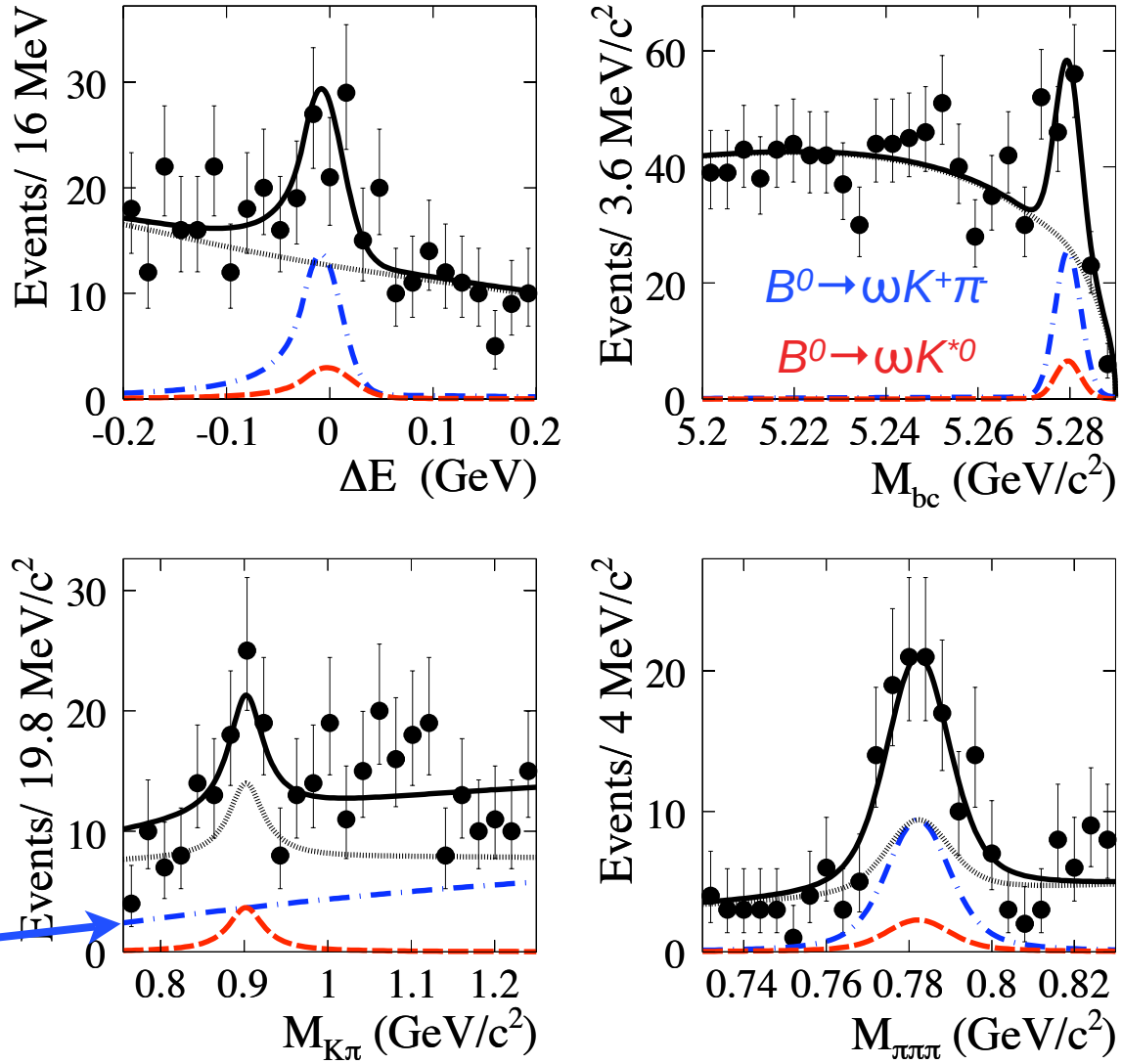
$< 2.7 \times 10^{-6}$

Significance = 1.6σ

$$\frac{Y_{\omega K^{*0}}}{Y_{\omega K^{*0}} + Y_{\omega K^+\pi^-}} = (10.3^{+7.7}_{-7.0})\ \%$$

large non-resonant $K\pi$

signal region projections



BaBar:

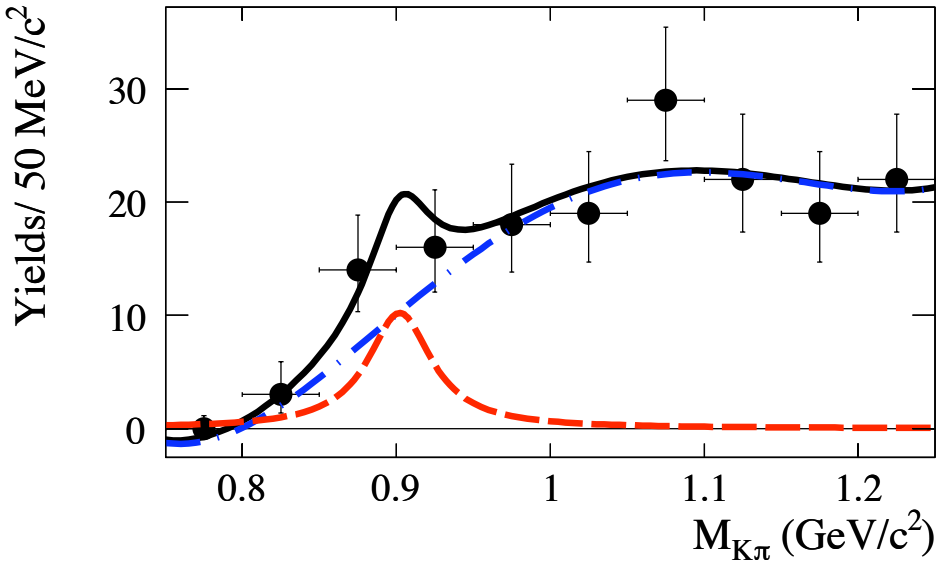
Br = [2.4±1.1±0.7 (<4.2)] × 10^{-6}, 2.4σ, f_L=$0.71^{+0.27}_{-0.24}$, $N_{B\bar{B}}$=232M. PRD **74** (2006) 051102

Verify high non-resonant yield

Preliminary

$N_{B\bar{B}}$ = 520M

- Likelihood fits in 50 MeV/c^2 bins of $M_{K\pi}$:
  $P_j^i = P_j(\Delta E^i) \cdot P_j(M_{bc}^i)$
- χ^2 fit to ΔE-M_{bc} yields:



$$\frac{Y_{\omega K^{*0}}}{Y_{\omega K^{*0}} + Y_{\omega K^+\pi^-}} = (9.3 \pm 10.6)\ \%$$

fractional signal yield is in good agreement with 4D fit

Summary

Charmless baryonic *B* decays with 449M *BB* pairs

- improved measurements of 3-body decays $B^+ \to p\bar{p}K^+$, $p\bar{p}\pi^+$, $p\bar{\Lambda}\gamma$ and $B^0 \to p\bar{\Lambda}\pi^-$.

- ★ *first observation of* $B^+ \to p\bar{\Lambda}\pi^0$, $Br = (3.00\ ^{+0.61}_{-0.53} \pm 0.33) \times 10^{-6}$.

- further theoretical investigations needed to explain the decay mechanisms involved.

- still no 2-body charmless decay found ➟ *upper limits (90% C.L.)*.

$B^0 \to \omega K^{*0}$ decays with 520M *BB* pairs

- no significant signal ➟ $Br < 2.7 \times 10^{-6}$ *(90% C.L.)*.

Preliminary

- large non-resonant Kπ contribution.