Radiative B Decay into Higher Kaonic Resonances

Penguin Mediated B Decays at Belle

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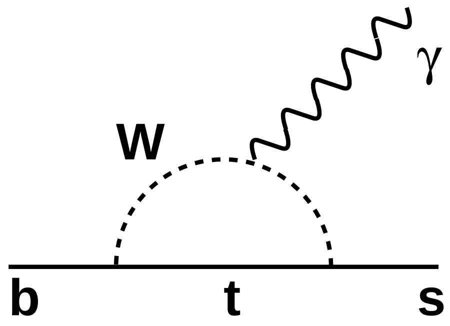
Introduction

$b \to s\gamma$ process

- Electroweak penguin.
- Good probe for New Physics.
- $\mathcal{B}(B \to X_s\gamma)$: already measured
- $\mathcal{B}(B \to K^*(892)\gamma)/\mathcal{B}(B \to X_s\gamma) \sim 15\%$



Radiative decay to higher kaonic resonances (K_X)

- $B \to K_X\gamma$: More than 20 % of the $b \to s\gamma$ decays
- Knowledge of the contribution of resonances is required for the detailed study of $b \to s\gamma$ process.
- Several predictions based on non-relativistic or relativistic form factor calculations.

Introduction

kaonic resonances

resonances	width [MeV/c^2]	sub-decay modes
$K^*(892)$	51	$K\pi$ [$\sim$100%]
$K_1(1270)$	90	$K\rho$ [42%], $K_0^*(1430)\pi$ [28%]
$K_1(1400)$	174	$K^*(892)\pi$ [94%], $K\rho$ [3%]
$K^*(1410)$	232	$K^*(892)\pi$ [>40%], $K\pi$ [7%]
$K_2^*(1430)$	100	$K\pi$ [50%], $K^*(892)\pi$ [25%]
$K^*(1680)$	322	$K\pi$ [39%], $K\rho$ [31%], $K^*(892)\pi$ [30%]
$K_3^*(1780)$	159	$K\rho$ [31%], $K^*(892)\pi$ [20%], $K\pi$ [19%]

We study $B \to K\pi\gamma$, $B \to K^*(892)\pi\gamma$ and $B \to K\rho\gamma$.

Introduction

An indication of a $B \to K_2^*(1430)\gamma$ signal (With the assumption of no contamination from $B \to K^*(1410)\gamma$ or non-resonant $B \to K\pi\gamma$).

- $\mathcal{B}(B \to \text{“}K_2^*(1430)\text{”}\gamma) = (1.66\,^{+0.59}_{-0.53} \pm 0.13) \times 10^{-5}$ (CLEO)
- $\mathcal{B}(B \to \text{“}K_2^*(1430)\text{”}\gamma) = (1.89 \pm 0.56 \pm 0.18) \times 10^{-5}$ (Belle BCP4)

c.f.) Prediction

- $\mathcal{B}(B \to K_2^*(1430)\gamma) = (6.9 \sim 14.8) \times 10^{-5}$ (Ali-Ohl-Mannel = non-relativistic)
- $\mathcal{B}(B \to K_2^*(1430)\gamma) = (1.73 \pm 0.80) \times 10^{-5}$ (Veseli-Olsson = relativistic)

Analysis

Analysis

Dataset: $21.3\ \mathrm{fb}^{-1}$ on-resonance data ($22.8 \times 10^6\ B\bar{B}$)

Reconstruction: $K^+\pi^-\gamma$ and $K^+\pi^-\pi^+\gamma$ final state

Background Suppression:

Main background source is continuum $q\bar{q}$ production.

π^0/η veto. ($\pi^0 \to \gamma\gamma$...)

SFW : Fisher discriminant of Fox-Wolfram Moments

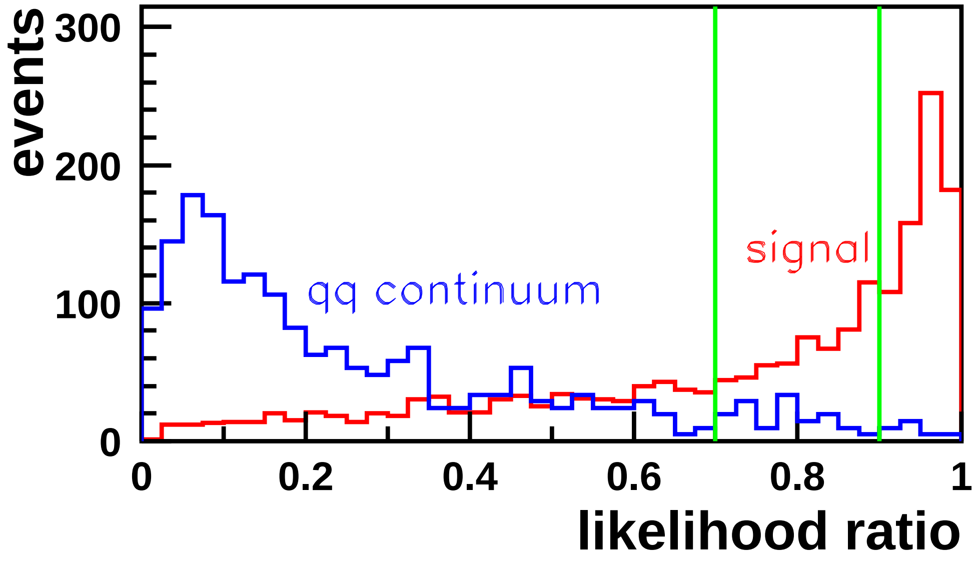
$$SFW = \alpha_2 R_2^{\mathrm{major}} + \alpha_4 R_4^{\mathrm{major}} + \sum_{l=1}^{4} \beta_l R_l^{\mathrm{minor}}$$

$$R_l^{\mathrm{major}} = \frac{\sum_i |p_i||p_\gamma| P_l(\cos\theta_{i\gamma})}{\sum_i |p_i||p_\gamma|}, \quad R_l^{\mathrm{minor}} = \frac{\sum_{i,j} |p_i||p_j| P_l(\cos\theta_{ij})}{\sum_{i,j} |p_i||p_j|}$$

Likelihood Ratio from *SFW* and $\cos\theta_B$

$$LR(SFW, \cos\theta_B) = \frac{p^{\mathrm{sig}}(SFW) p^{\mathrm{sig}}(\cos\theta_B)}{p^{\mathrm{sig}}(SFW) p^{\mathrm{sig}}(\cos\theta_B) + p^{\mathrm{bg}}(SFW) p^{\mathrm{bg}}(\cos\theta_B)}$$

Likelihood Ratio

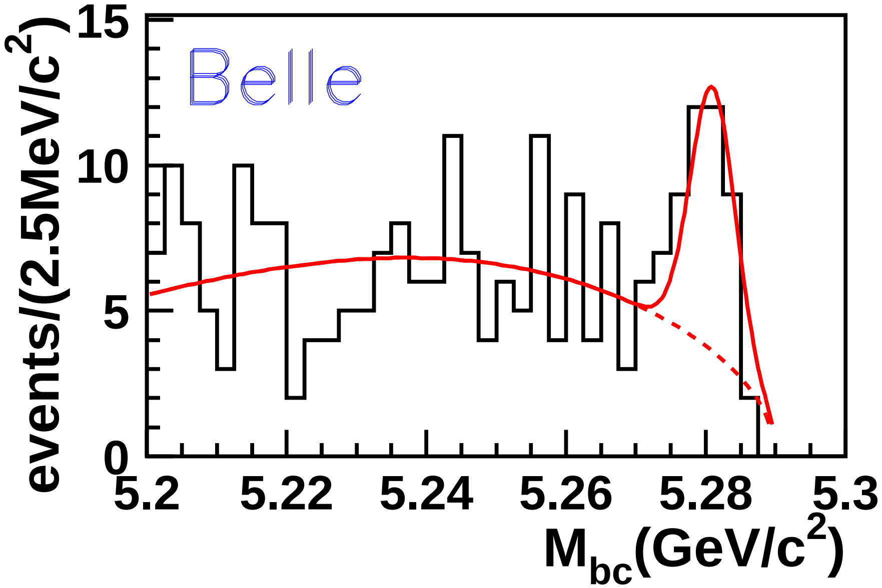


- $LR > 0.7$ for $K\pi\gamma$ final state
  (signal efficiency $\sim 70\%$, background reduction $\sim 90\%$)
- $LR > 0.9$ for $K\pi\pi\gamma$ final state
  (signal efficiency $\sim 40\%$, background reduction $\sim 97\%$)

$B \to K_2^*(1430)\gamma$

Analysis of $B \to K_2^*(1430)\gamma$

Reconstruct $K_2^*(1430)$ from $K^+\pi^-$.
$|M_{K\pi} - M_{K_2^*(1430)}| < 125$ MeV$/c^2$



$29.1 \pm 6.7\,^{+2.4}_{-1.9}$ events observed for neutral $B^0 \to K_2^*(1430)^0\gamma$

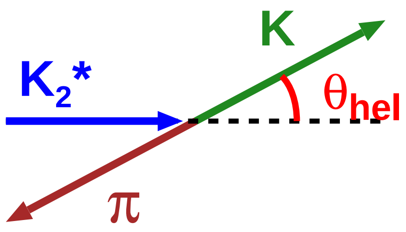
Are these really $K_2^*(1430)$???

- $B \to K^*(1410)\gamma$: $\mathcal{B}(K^*(1410) \to K\pi) \sim 7\%$
- Non-resonant $B \to K\pi\gamma$ decay

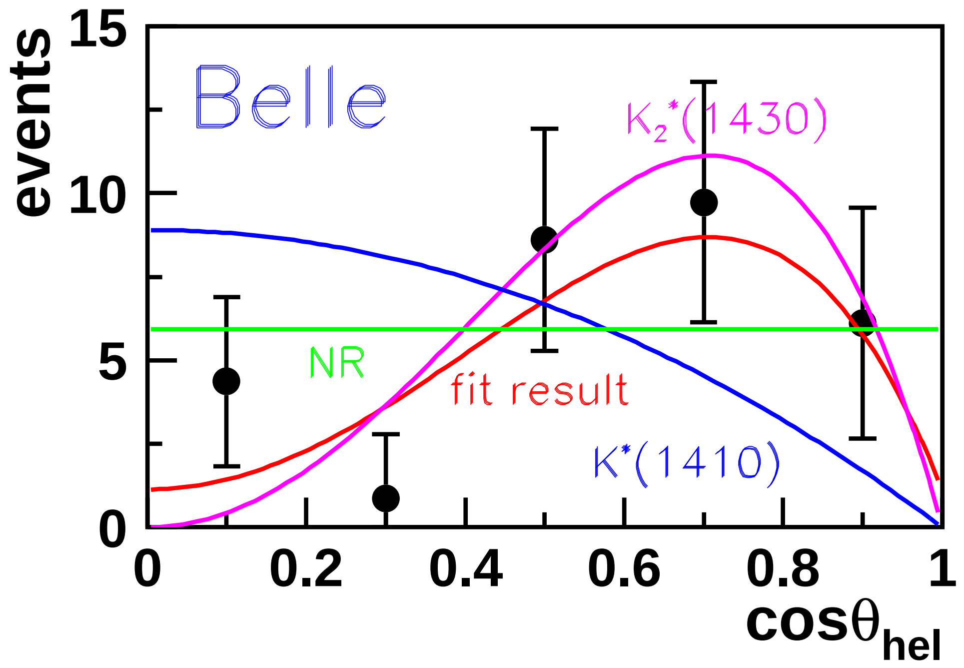
$B \to K_2^*(1430)\gamma$ *(cont'd)*

$K_2^*(1430)$ decay helicity angle ($\cos\theta_{\rm hel}$)

$\propto \cos^2\theta_{\rm hel} - \cos^4\theta_{\rm hel}$	for $K_2^*(1430)\gamma$
$\propto 1 - \cos^2\theta_{\rm hel}$	for $K^*(1410)\gamma$
$\propto 1$	for non-resonant

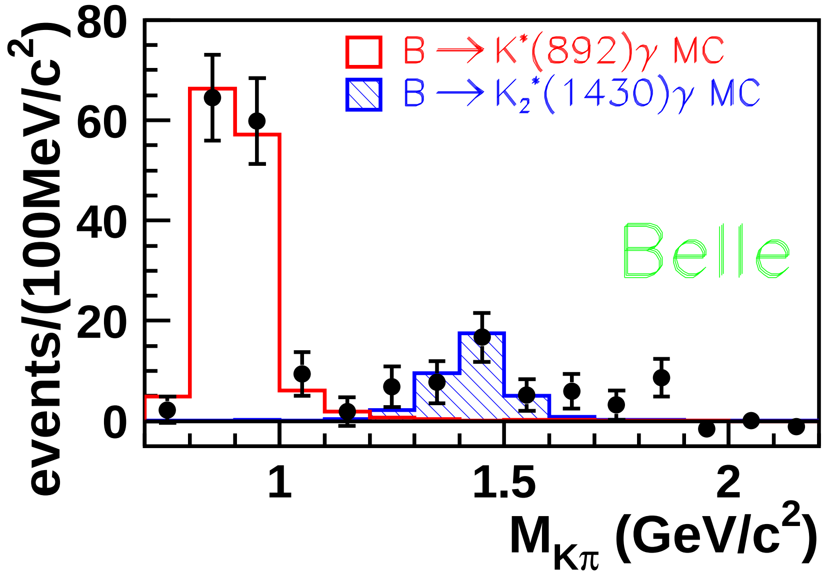


divide $\cos\theta_{\rm hel}$ into 5 bins, extract the yield in each bin $\to$ 20.1 ± 10.5 events out of $29.1 \pm 6.7\,^{+2.4}_{-1.9}$ events for $K_2^*(1430)\gamma$



$B \to K_2^*(1430)\gamma$ *(cont'd)*

Background subtracted $K\pi$ invariant mass distribution



- Clear peak for $B \to K^*(892)\gamma$
- Enhancement around 1.4 GeV$/c^2$ $\to$ supports the $K_2^*(1430)\gamma$ interpretation

Branching fractions:

$$\mathcal{B}(B^0 \to K_2^*(1430)^0\gamma) = (1.26 \pm 0.66 \pm 0.10) \times 10^{-5}$$

Preliminary

$$\mathcal{B}(B^0 \to K^*(1410)^0\gamma) < 8.0 \times 10^{-5} \text{ (90\% C.L.)}$$

Preliminary

$B \to K^+\pi^-\pi^+\gamma$

Analysis of $B \to K\pi\pi\gamma$

$B \to K^+\pi^-\pi^+\gamma$ analysis

1.0 GeV$/c^2 < M_{K\pi\pi} < 2.0$ GeV$/c^2$

Dalitz plot for $K\pi\pi$

- Backgrounds NOT subtracted.
- A clear $K^*(892)$ band.
- Events in the ρ mass region.

For $B \to K^*\pi\gamma$

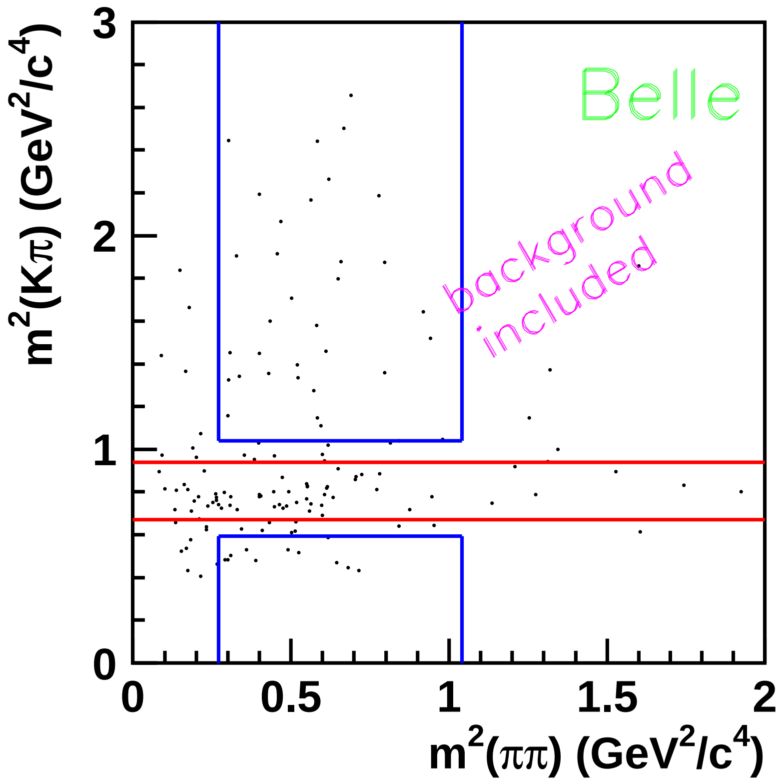
$|M_{K\pi} - M_{K^*}| < 75$ MeV$/c^2$

For $B \to K\rho\gamma$

$|M_{\pi\pi} - M_\rho| < 250$ MeV$/c^2$

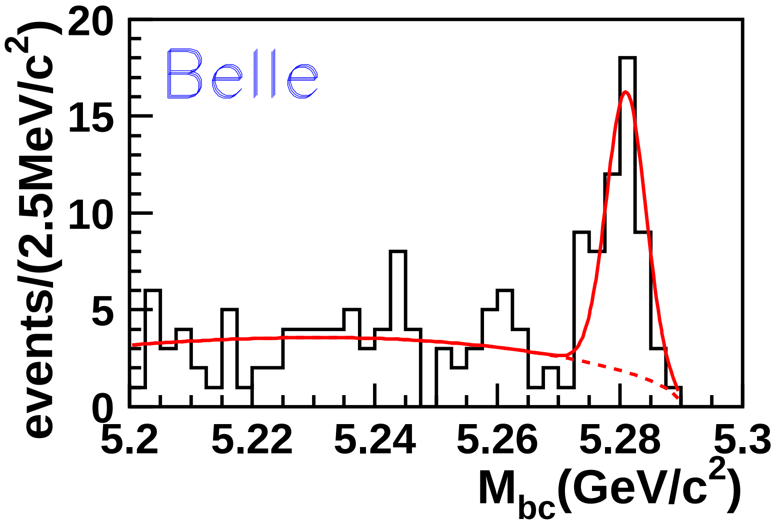
$|M_{K^+\pi^-} - M_{K^*}| > 125$ MeV$/c^2$

(K^* veto)



$B \to K^*\pi\gamma$

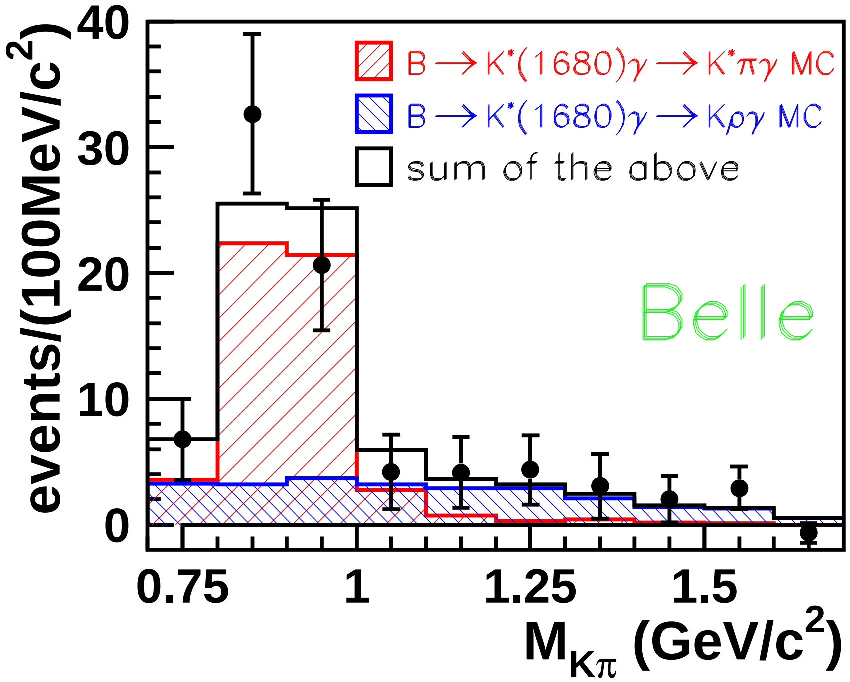
Analysis of $B \to K^*\pi\gamma$



- $46.4 \pm 7.3\,^{+1.6}_{-2.7}$ events
- Clear peak for $K^*(892)$.
- Subtracting the $B \to K\rho\gamma$ and $B \to K\pi\pi\gamma$ contributions

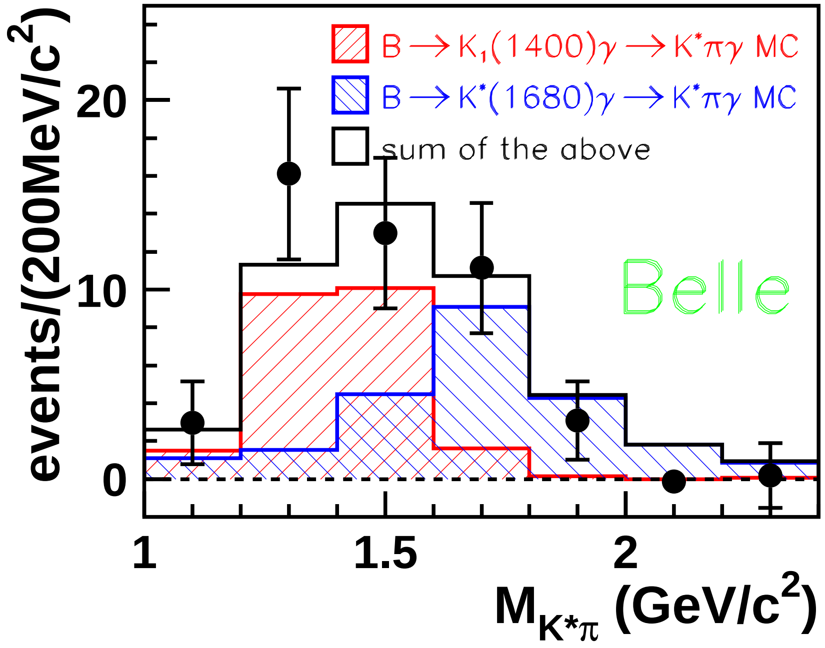
  $\to 40.7 \pm 7.6\,^{+1.8}_{-2.7}$ events

Background subtracted $K\pi$ invariant mass distribution



$B \to K^* \pi \gamma$ (cont'd)

Background subtracted $K_X(K\pi\pi)$ invariant mass distribution



M_{K_X} distribution cannot be explained by a single resonance

$$\mathcal{B}(B \to K^* \pi \gamma; \; M_{K^*\pi} < 2.0 \text{ GeV}/c^2) = (5.6 \pm 1.1 \pm 0.9) \times 10^{-5}$$

Preliminary

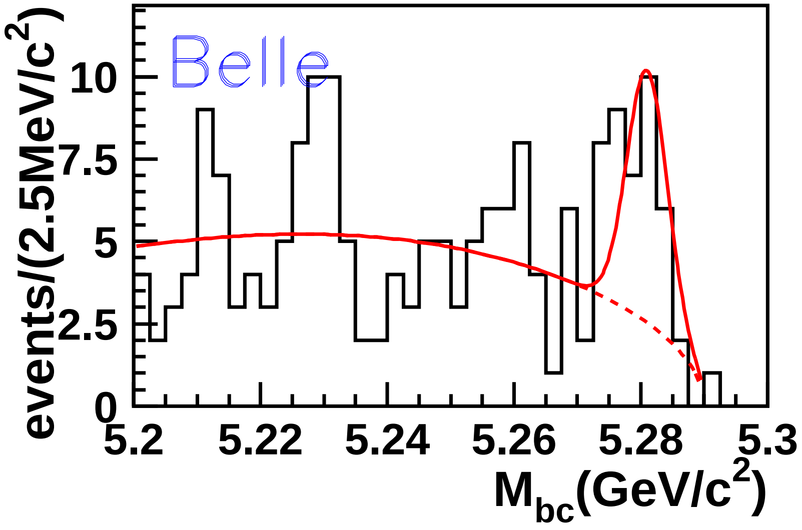
$1.2 \text{ GeV}/c^2 < M_{K_X} < 1.6 \text{ GeV}/c^2$

$$\frac{1}{2}\mathcal{B}(B \to K_1(1270)\gamma) + \mathcal{B}(B \to K_1(1400)\gamma) + \mathcal{B}(B \to K^*(1410)\gamma) < 5.1 \times 10^{-5} \quad (90\% \text{ C.L.})$$

Preliminary

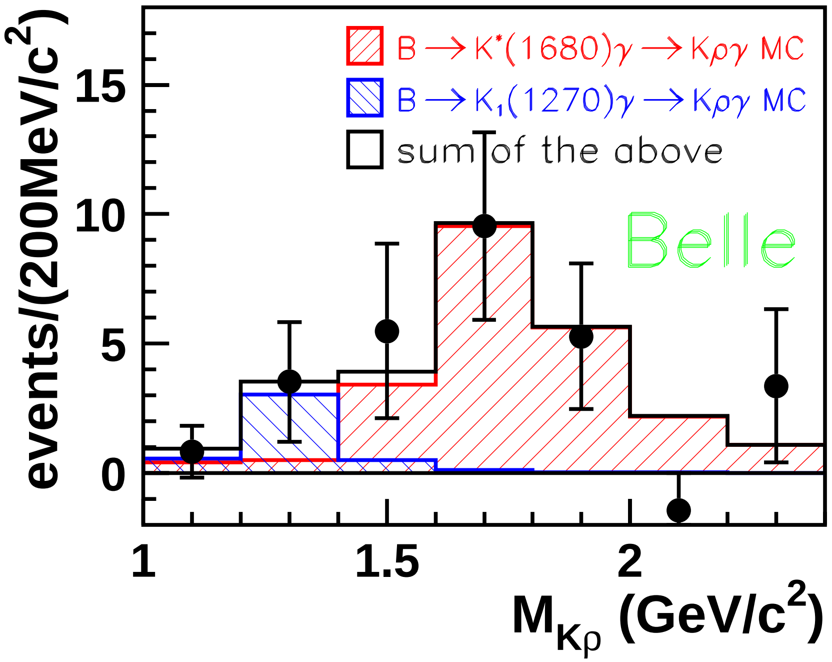
$B \to K\rho\gamma$

Analysis of $B \to K\rho\gamma$



$24.5 \pm 6.4\,^{+1.2}_{-2.3}$ events observed

Background subtracted $K_X(K\rho)$ invariant mass distribution



$B \to K\rho\gamma$ (cont'd)

- Cross-feed from other $b \to s\gamma$ decays is subtracted using MC.
- Neglect the non-resonant contribution.

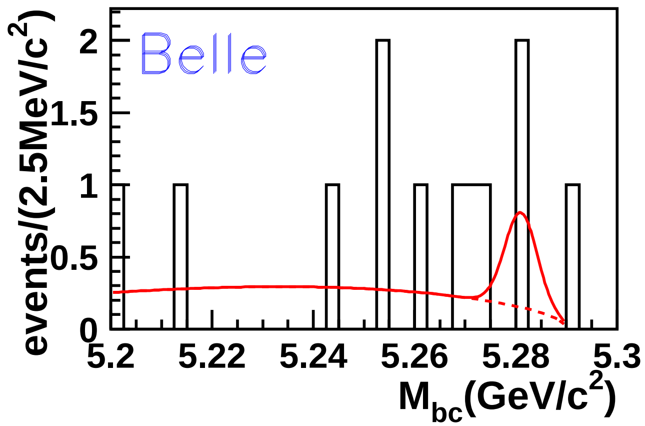
$$\mathcal{B}(B \to K\rho\gamma; M_{K\rho} < 2.0\ \text{GeV}/c^2) = (6.5 \pm 1.7\,^{+1.1}_{-1.2}) \times 10^{-5}$$

Preliminary

Search for $B \to K_1(1270)\gamma$

- $K_1(1270) \to K\rho$ (42%)
- $|M_{K_X} - M_{K_1(1270)}| < 0.1\ \text{GeV}/c^2$
- No significant signal.
- Upper limit of
  $\mathcal{B}(B \to K_1(1270)\gamma) < 9.6 \times 10^{-5}$
  (90% C.L.)

Preliminary



Summary

Summary

decay mode	BR($\times 10^{-5}$)	
$B^0 \to K^{*0}\gamma$	$4.96 \pm 0.67 \pm 0.45$	[Belle BCP4]
$B^+ \to K^{*+}\gamma$	$3.89 \pm 0.93 \pm 0.41$	[Belle BCP4]
$B^0 \to K_2^*(1430)^0\gamma$	$1.26 \pm 0.66 \pm 0.10$	updated
$B \to K^*\pi\gamma$	$5.6 \pm 1.1 \pm 0.9$	new
$B \to K\rho\gamma$	$6.5 \pm 1.7 {}^{+1.1}_{-1.2}$	new
$B \to X_s\gamma$	$33.6 \pm 5.3 \pm 4.2 {}^{+5.0}_{-5.4}$	[PLB **511** 151 (2001)]

- $B^0 \to K_2^*(1430)^0\gamma$ using the helicity angle distribution
- New observations of $B \to K^*\pi\gamma$, $B \to K\rho\gamma$
- Sum of exclusive modes $\sim$ Half of $b \to s\gamma$