$b \longrightarrow s$ Hadronic Decays at Belle

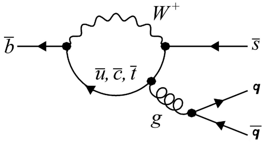
Sunghyon Kyeong
Yonsei University, Seoul, Korea
(on Behalf of the Belle Collaboration)

Europhysics Conference on High Energy Physics
Kraków, Poland, 16-22 July, 2009

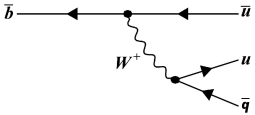
sunghyon.kyeong@gmail.com

INTRODUCTION

In the Standard Model (SM), Charmless hadronic *B* decays occur mainly via two processes.



(i) $b \to s$ penguin diagram



(ii) $b \to u$ tree diagram

Charmless hadronic *B*-decays give us plenty of information.

* Search for new physics effects by studying loop processes.
* $b \to s$ quark transitions are sensitive to physics beyond SM.
* Direct CP Violation : Interefering SM amplitudes.
* Measuring BF, angular correlations could help the phenomenological test/development of the theoretical models.

MOTIVATION

- Measurements of f_L in rare B decays to VV, such as $B \to \phi K^*$, have revealed an unexpectedly large fraction of transverse polarisation.
- This implies that non-factorizable contributions to the decay amplitude play a significant role.
- Further information about these effects can be obtained with $\mathcal{B}$ and f_L in $\boldsymbol{B^0 \to \rho^0 K^{*0}}$ (also $b \to s$ penguin-dominated).

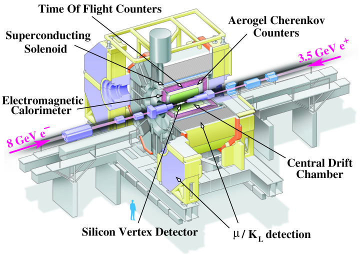
BaBar's Results, PRL 97, 201801, (2006) with 232 $\times$ 10^6 $B\bar{B}$

Mode	Y (events)	ε (%)	$\mathcal{S}$ (σ)	$\mathcal{B}$ (10^{-6})	f_L
$\rho^0 K^{*0}$	185±30	22.9	5.3	5.6±0.9±1.3	0.57±0.09±0.08
$f_0(980)K^{*0}$	83±19	21.7	3.5	2.6±0.6±0.9	

KEKB AND BELLE DETECTOR

- Ring circumference of KEKB is approximately 3.0 km.

- KEKB has two separate rings for e^+ and e^-.



* located at energy asymmetric e^+e^- collider KEKB.

* Belle detector has a large-solid-angle magnetic spectrometer, providing excellent tracking, vertexing and PID.

Approximately 0.8 billion $B\bar{B}$ pairs recorded at Belle!

ANALYSIS METHOD

* **Recontruction Variables:**
  - $\Delta E = E_B - E_{\rm beam}$: Energy difference
  - $M_{\rm bc} = \sqrt{E_{\rm beam}^2 - P_B^2}$: Beam-energy constrained mass
  - Invariant masses of $\pi\pi$ and $K\pi$ (*i.e.* $M_{\pi\pi}$ and $M_{K\pi}$)
* **Continuum ($e^+e^- \to q\bar{q}$) Suppression:**
  - Modified Fox-Wolfram moments, B flight direction ($\cos\theta_{B*}$), and the decay vertex differences between the signal B and that of the other B in z direction (Δz).
  - Perform Figure of Merit study to get a continuum suppression cut value.
* **Veto $B \to D^{*\pm}X,\ D^{\pm}X,\ D^0X$ modes**

YIELD EXTRACTION BY 4-D FIT

4-D Extended Unbinned ML Function:

$$\mathcal{L} = \frac{\exp\left(-\sum_j Y_j\right)}{N!} \prod_{i=1}^{N_{\rm cand}} \left(\sum_j Y_j \mathcal{P}^i{}_j\right) \qquad (1)$$

where, $\mathcal{P}^i{}_j = \mathcal{P}_j(M^i_{\rm bc})\mathcal{P}_j(\Delta E^i)\mathcal{P}_j(M^i_{\pi\pi})\mathcal{P}_j(M^i_{K\pi})$, for component j, and i runs over all events in the sample.

For Signal PDFs:

$$\mathcal{P}^i{}_j = (1 - f_{\rm SCF})\mathcal{P}^i_{\rm true} + f_{\rm SCF}\mathcal{P}^i_{\rm SCF} \qquad (2)$$

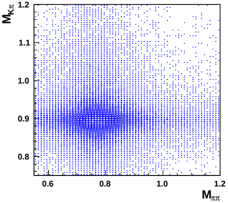
where, $f_{\rm SCF}$ is the SCF fraction.

Submitted to PRL
arXiv:0905.0763v1

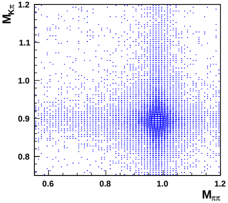
Measurements of $B^0 \to \rho^0 K^{*0}$ and $B^0 \to \pi^+\pi^- K^+\pi^-$

using a sample of 657 million $B\bar{B}$ pairs

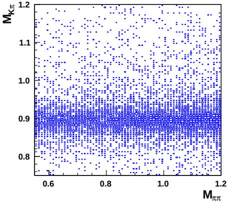
SIGNAL MC DISTRIBUTIONS



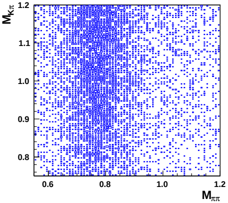
$\rho^0 K^{*0}$



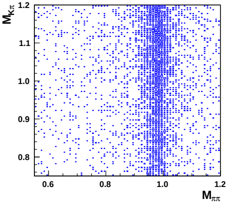
$f_0(980) K^{*0}$



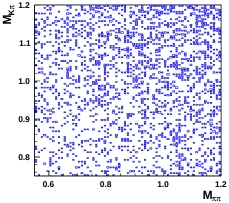
$\pi^+ \pi^- K^{*0}$



$\rho^0 K^+ \pi^-$



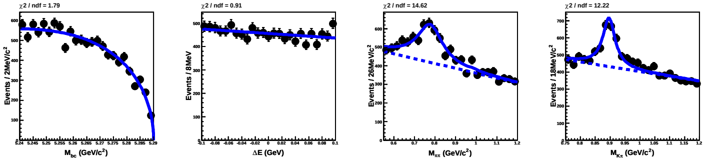
$f_0(980) K^+ \pi^-$



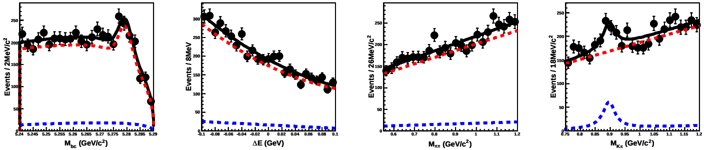
$\pi^+ \pi^- K^+ \pi^-$

BKG. MC DISTRIBUTIONS

- **Continuum ($e^+e^- \to q\bar{q}$).**

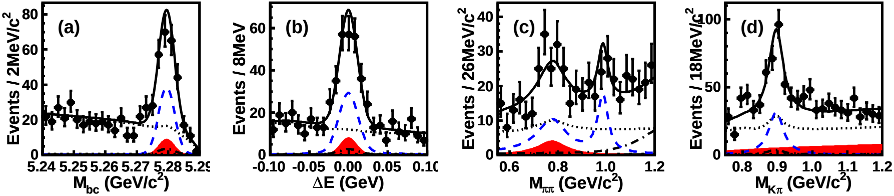


- **Charmed *B*-decays ($b \to c$).**



- **Charmless *B*-decays ($b \to s, u, d$), $B^0 \to f_2(1270)K^{*0}$, and feeddowns $B^0 \to a_1^-(1260)K^+$, $B^0 \to K_1^+(1270)\pi^-$ and $B^0 \to K_1^+(1400)\pi^-$ are also considered.**

4D FITTING PROJECTION



Projection of the 4D fit results on to (a) $M_{\rm bc}$, (b) ΔE, (c) $M_{\pi\pi}$ and (d) $M_{K\pi}$ with the other variables required to be the signal criteria (except for the variable plotted).

The curves are for the $\rho^0 K^+\pi^-$ (solid-shaded), the sum of $\rho^0 K^{*0}$ and $f_0(980)K^{*0}$ (dashed), the sum of backgrounds (dotted), and the total (solid).

FITTING RESULTS

Mode	Y (events)	ε (%)	$\mathcal{S}$ (σ)	$\mathcal{B}$ (10^{-6})	$\mathcal{B}_{\rm UL}$ (10^{-6})
$\rho^0 K^{*0}$	$77.6^{+28.6}_{-27.9}$	5.73	2.7	$2.1^{+0.8+0.9}_{-0.7-0.5}$	< 3.4
$f_0(980)K^{*0}$	$51.2^{+20.4}_{-19.3}$	5.56	2.5	$1.4^{+0.6+0.6}_{-0.5-0.4}$	< 2.2
$\rho^0 K^+\pi^-$	$207.8^{+39.8}_{-39.2}$	11.15	5.0	$2.8 \pm 0.5 \pm 0.5$	-
$f_0(980)K^+\pi^-$	$106.9^{+31.6}_{-29.9}$	11.43	3.5	$1.4 \pm 0.4^{+0.3}_{-0.4}$	< 2.1
$\pi^+\pi^- K^{*0}$	$200.7^{+46.7}_{-44.9}$	6.74	4.5	$4.5^{+1.1+0.9}_{-1.0-1.6}$	-
$\pi^+\pi^- K^+\pi^-$	$-5.4^{+54.9}_{-44.9}$	6.84	0.0	$-0.1^{+1.2+1.4}_{-1.1-0.8}$	< 2.1

※ $\mathcal{B}$ and $\mathcal{B}_{\rm UL}$ of the non-resonant decay are **partial one** for the ranges:

$$M_{\pi\pi} \in (0.55, 1.20)\ \mathrm{GeV}/c^2 \quad \text{and} \quad M_{K\pi} \in (0.75, 1.20)\ \mathrm{GeV}/c^2$$

ADDITIVE SYST. ERRROR

Source	ρK^*	$f_0 K^*$	$\rho K\pi$	$f_0 K\pi$	$\pi\pi K^*$	$\pi\pi K\pi$
Fitting PDFs	$+4.4$ -5.4	$+12.7$ -11.8	$+5.8$ -9.1	$+24.1$ -23.6	$+18.1$ -17.4	$+29.4$ -27.9
$f_{f_2(1270)K^{*0}}$	$+11.0$ -11.3	$+5.9$ -6.4	$+0.3$ -0.3	$+0.3$ -0.1	$+13.9$ -13.7	$+30.0$ -35.4
$f_{\mathrm{feed-down}}$	$+0.6$ -1.4	$+0.1$ -0.1	$+4.7$ -1.5	$+0.3$ -0.4	$+8.7$ -3.8	$+3.2$ -1.9
$f_{b\to s,u,d}$	$+1.9$ -2.1	$+0.1$ -0.0	$+7.0$ -9.8	$+0.3$ -0.4	$+0.0$ -1.2	$+3.7$ -0.8
f_{SCF}	$+2.1$ -2.1	$+1.2$ -1.2	$+19.9$ -20.6	$+7.4$ -7.3	$+8.2$ -8.3	$+11.8$ -11.4
$K_0^*(1430)^0$	$+29.0$ -0.0	$+14.7$ -0.0	$+16.9$ -12.4	$+0.0$ -19.3	$+0.0$ -54.8	$+69.1$ -0.0
Fitting bias	$+2.7$ -0.0	$+4.9$ -0.0	$+11.2$ -0.0	$+0.0$ -10.2	$+0.0$ -26.6	$+0.0$ -29.9
Interference	$+6.6$ -5.6	$+2.3$ -0.9	$+14.7$ -17.3	$+4.3$ -0.0	$+3.8$ -3.6	-
Sum (events)	$+31.5$ -12.2	$+20.5$ -12.3	$+34.8$ -31.3	$+25.6$ -32.9	$+35.5$ -69.8	$+76.2$ -42.6

MULTIPLICATIVE SYST. ERROR

Source	ρK^*	$f_0 K^*$	$\rho K\pi$	$f_0 K\pi$	$\pi\pi K^*$	$\pi\pi K\pi$
MC statistics	± 0.5	± 0.7	± 1.3	± 1.7	± 1.3	± 2.1
Tracking	± 4.2	± 4.2	± 4.2	± 4.2	± 4.2	± 4.2
PID	± 3.7	± 3.7	± 3.7	± 3.8	± 3.8	± 3.7
$\mathcal{R}_{q\bar{q}}$ cut	± 3.4	± 3.4	± 3.4	± 3.4	± 3.4	± 3.4
$N_{B\bar{B}}$	± 1.4	± 1.4	± 1.4	± 1.4	± 1.4	± 1.4
$f_{\rm L}$	${}^{+16.7}_{-18.9}$	-	-	-	-	-
Sum (%)	${}^{+18.0}_{-20.1}$	± 6.7	± 6.8	± 7.0	± 6.9	± 7.0

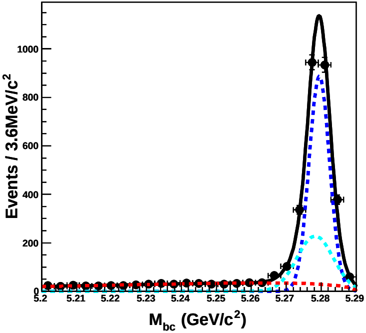
SUMMARY

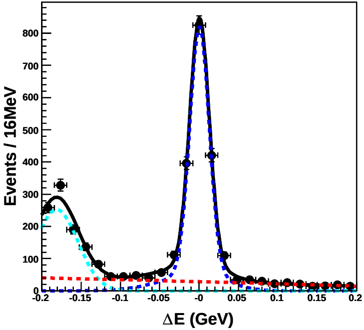
- * The **first observation** of the three-body decay $B^0 \to \rho^0 K^+ \pi^-$ decay with 5.0σ significance.
- * The **first evidences** for non-resonant $B^0 \to f_0(980) K^+ \pi^-$ and $B^0 \to \pi^+ \pi^- K^{*0}$ decays.
- * 90% C.L. upper limit for the fully non-resonant four-body decay $B^0 \to \pi^+ \pi^- K^+ \pi^-$ is calculated.
- * $\mathcal{B}$ and $\mathcal{B}_{\rm UL}$ of non-resonant decay are partial one for the ranges : $0.55 < M_{\pi\pi} < 1.20$ and $0.75 < M_{K\pi} < 1.20$.
- * Signal excesses for the two-body decays $B^0 \to f_0(980) K^{*0}$ and $B^0 \to \rho^0 K^{*0}$.
- * More data set could help our understanding of the polarization puzzle in the ρK^* and new physics effect on $B \to VV$ decays.

BACKUP SLIDES

CONTROL SAMPLE STUDY

We study the $B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$ as our control sample. We perform 2D ($M_{\rm bc}$ and ΔE) unbinned ML fit. We assume our control sample can be categorized into three components: $B^0 \to D^-(K\pi\pi)\pi^+$ signal, peaking background , and other non-resonant background.

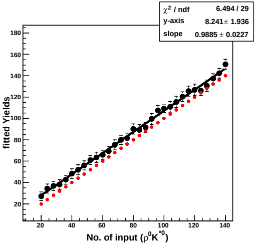


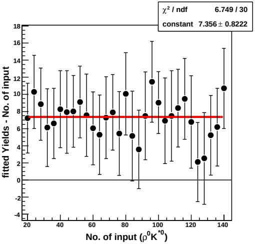


※ **$\mathcal{B}$ of our control sample is consistent with the PDG value.**

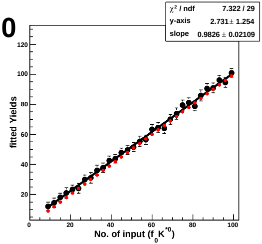
FITTING BIAS

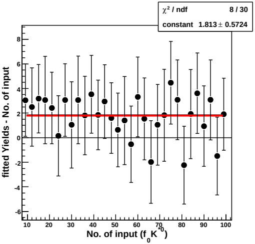
$B^0 \longrightarrow \rho^0 K^{*0}$





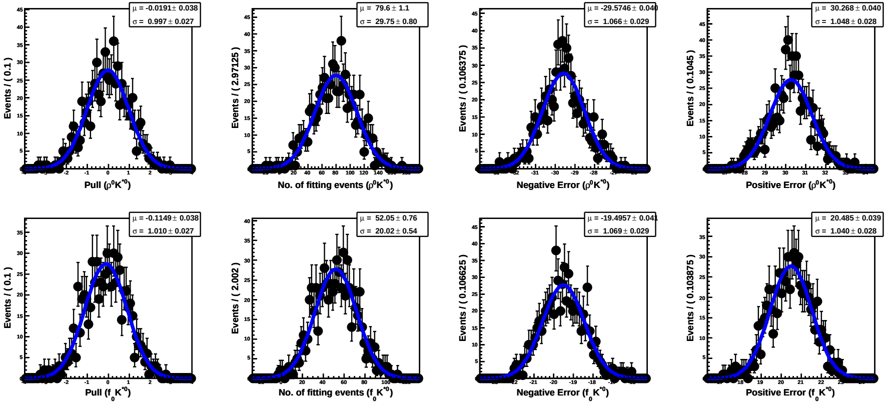
$B^0 \longrightarrow f_0(980) K^{*0}$





※ Fitting biases are considered as the systematics uncertainty.

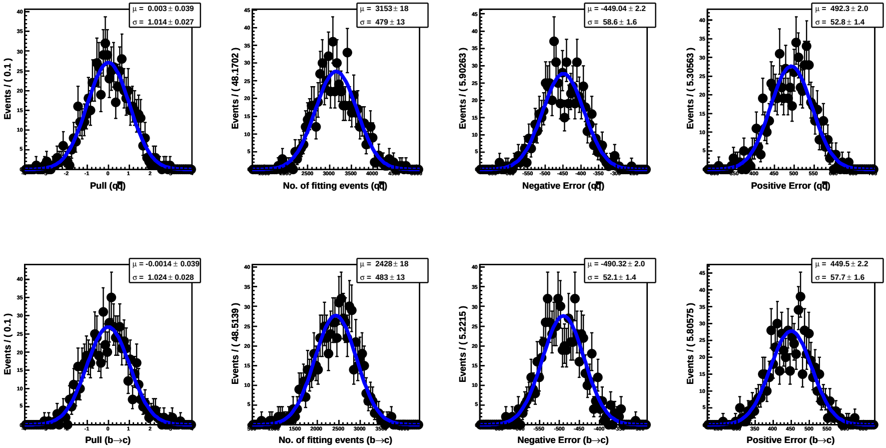
TOY MC STUDY (I)



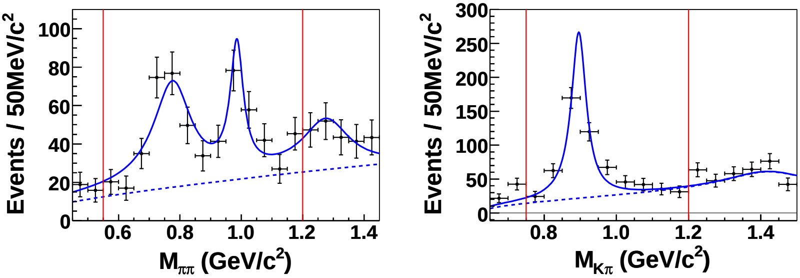
※ The definition of pull for contribution *j* is defined as

$$\mathrm{pull}(Y_j) = \frac{Y_j^{\mathrm{fit}} - Y_j^{\mathrm{true}}}{\sigma_j^{\mathrm{fit}}}$$

TOY MC STUDY (II)



BKG.-SUBTRACTED FIT



Figures show the yields obtained from the 2D M_{bc}–ΔE fitting results as function of $M_{\pi\pi}$ (left) and $M_{K\pi}$ (right).
Solid curves show the results of the fit and dashed lines indicates the non-resonant $\pi\pi$ (left) and the non-resonant $K\pi$ plus $K_0^*(1430)$ (right). The regions between the reddish straight lines show the nominal four-dimensional fit regions.