

Study of $B \rightarrow \phi\pi$ decays

J.H Kim¹

¹Sungkyunkwan University, Suwon

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Outline

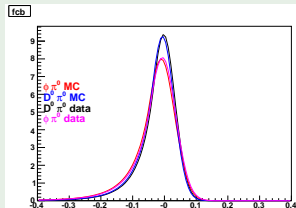
- 1 Open the box for $605fb^{-1}$

Calibration of $B^0 \rightarrow \phi\pi^0$ with $B^0 \rightarrow \overline{D^0}\pi^0$

	$B^0 \rightarrow \phi\pi^0$ MC	$B^0 \rightarrow \overline{D^0}\pi^0$ MC	$B^0 \rightarrow \overline{D^0}\pi^0$ data	$B^0 \rightarrow \phi\pi^0$ data
$\mu_{\Delta E}$	-0.00998 ± 0.000614	-0.00617 ± 0.00191	$-0.00241 \quad 0.00350$ -0.00375	$-0.00622 \quad 0.004039$ -0.004252
$\sigma_{\Delta E}$	0.04218 ± 0.000454	0.0364 ± 0.00136	$0.035976 \quad 0.00328$ -0.00292	$0.04172 \quad 0.004130$ -0.003742
$\mu_{M_{bc}}$	5.2793 ± 0.0000270	5.27944 ± 0.000127	$5.27966 \quad 0.000186$ -0.000191	$5.27952 \quad 0.000227$ -0.000231
$\sigma_{M_{bc}}$	0.003281 ± 0.0000191	0.003141 ± 0.0000901	$0.00261 \quad 0.000158$ -0.000147	$0.00273 \quad 0.000183$ -0.000173

- control sample : $B^0 \rightarrow \overline{D^0}\pi^0$
- $\mu_{\phi\pi^0}^{data} = \mu_{\phi\pi^0}^{MC} + (\mu_{D\pi^0}^{data} - \mu_{D\pi^0}^{MC})$
- $\sigma_{\phi\pi^0}^{data} = \sigma_{\phi\pi^0}^{MC} \times (\sigma_{D\pi^0}^{data} / \sigma_{D\pi^0}^{MC})$

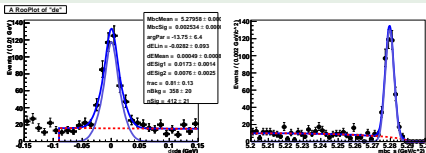
CB shape



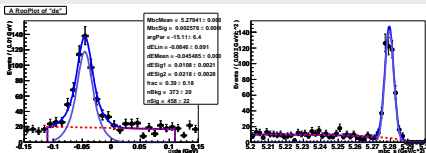
Calibration of $B^+ \rightarrow \phi\pi^+$, $B^+ \rightarrow \phi K^+$ Background with $B^+ \rightarrow \phi K^+$

$B^+ \rightarrow \phi K^+$ for data: $\text{prob}(K/\pi) > 0.6$

$B^+ \rightarrow \phi\pi^+$ calibration



$B^+ \rightarrow \phi K^+$ Background calibration



$B^+ \rightarrow \phi\pi^+$ calibration

	$B^+ \rightarrow \phi\pi^+$	$B^+ \rightarrow \phi K^+$
$\text{prob}(K/\pi)$	0.6	0.6
$M_{bc}\mu$	5.27958	5.27941
$M_{bc}\sigma$	0.002534	0.002578
$\Delta E\sigma_A$	0.00173	0.0108
$\Delta E\sigma_B$	0.0076	0.0218
$\Delta E\mu$	0.00049	-0.04549
ΔE fraction	0.81	0.39
expectation		33.79

Peaking Backgrounds of $B \rightarrow \phi\pi$ with the side band of $M_{K^+K^-}$

Decay Mode	Br(10^{-6})
$B^0 \rightarrow K^+K^-\pi^0$	
$B^0 \rightarrow a_0^0\pi^0$	
$B^0 \rightarrow f_0\pi^0$	
$B^\pm \rightarrow K^+K^-\pi^\pm$	
$B^\pm \rightarrow a_0^0\pi^\pm$	< 5.8
$B^\pm \rightarrow f_0\pi^\pm$	

Table: Peaking BKGs for $B \rightarrow \phi\pi$ decays

- Signal yield = $n\text{Sig}(\phi\pi + a_0\pi + f_0\pi + K^+K^-\pi)$
- We can't get the expectation of peaking bkg from rareB MC.
- From the side band of $M_{(K^+K^-)}$, we can get the expectation of peaking background.
- The side band of $M_{(K^+K^-)}$:
 $1.000 \text{ GeV}/c^2 > M_{(K^+K^-)}$ or
 $1.039 \text{ GeV}/c^2 < M_{(K^+K^-)} < 1.100 \text{ GeV}/c^2$
- peaking bkg : $N_{peak} = a \times a_0^0\pi + b \times f_0\pi + c \times K^+K^-\pi$
 $N1_{peak} = a \times a_0^0\pi^0$
 $N2_{peak} = b \times f_0\pi$
 $N3_{peak} = c \times K^+K^-\pi$
- Fit sideband data with each component and estimate the expectation with each component
- Find the mode of the largest signal yield from signal box fitting.
- Take the mode as nominal(central mode)
- Assign the yield differences between central mode and the others into systematic error.

Peaking Backgrounds of $B \rightarrow \phi\pi$ with the side band of M_{K+K^-}

- To find the expectations by the each mode: $605fb^{-1}$.
→ We used the sideband of M_{K+K^-} .
- To take the PDFs of the each components
→ Select the signal box with signal MC.(histogram → PDF)

The expectation of $B^0 \rightarrow \phi\pi^0$

mode	fit result	expectation
$B^0 \rightarrow a_0\pi^0$	$3.84^{+3.94}_{-3.12}$	$1.21^{+1.26}_{-1.00}$
$B^0 \rightarrow f_0\pi^0$	$5.15^{+4.98}_{-4.02}$	$1.63^{+1.59}_{-1.28}$
$B^0 \rightarrow K^+K^-\pi^0$	$4.51^{+3.59}_{-2.88}$	$1.44^{+1.15}_{-0.92}$

The signal yield of $B^0 \rightarrow \phi\pi^0$

mode	fit result
$B^0 \rightarrow a_0\pi^0$	$-1.57^{+2.11}_{-1.31}$
$B^0 \rightarrow f_0\pi^0$	$-1.21^{+2.10}_{-1.29}$
$B^0 \rightarrow K^+K^-\pi^0$	$-0.55^{+2.05}_{-1.23}$

The expectation of $B^+ \rightarrow \phi\pi^+$

mode	fit result	expectation
$B^+ \rightarrow a_0\pi^+$	$19.90^{+6.20}_{-5.46}$	$6.36^{+1.98}_{-1.74}$
$B^+ \rightarrow f_0\pi^+$	$20.42^{+6.20}_{-5.44}$	$6.52^{+1.98}_{-1.74}$
$B^+ \rightarrow K^+K^-\pi^+$	$19.57^{+6.35}_{-5.61}$	$6.26^{+2.03}_{-1.79}$

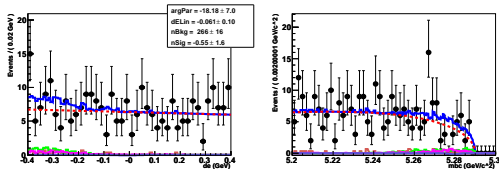
The signal yield of $B^+ \rightarrow \phi\pi^+$

mode	fit result
$B^+ \rightarrow a_0\pi^+$	$1.71^{+5.17}_{-4.36}$
$B^+ \rightarrow f_0\pi^+$	$1.62^{+5.15}_{-4.33}$
$B^+ \rightarrow K^+K^-\pi^+$	$2.40^{+5.02}_{-4.15}$

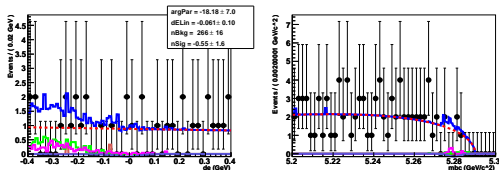
Data Fit of $B^0 \rightarrow \phi\pi^0$ decay: with $K^+K^-\pi^0$ central mode

605fb⁻¹ data

● Entire Region



● Slice Region



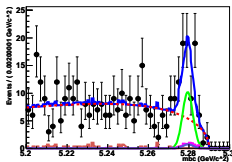
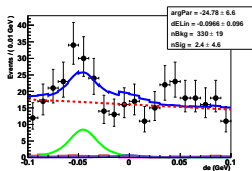
the fit result

	expected(input)	fit result
ArgPar		-18.18 ± 7.0
dElin		-0.061 ± 0.10
$q\bar{q}$	284.40	266 ± 16
$b \rightarrow c$	4.83	fixed
dominant B	8.10	fixed
peaking	1.44	fixed
the rest B	5.40	fixed
nSig	9.02	0.55 ± 1.6

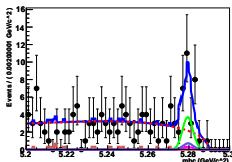
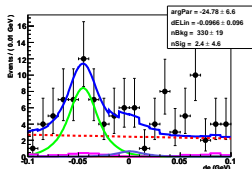
Data Fit of $B^+ \rightarrow \phi\pi^+$ decay : with $K^+K^-\pi^+$ central mode

605fb⁻¹ data

Entire Region



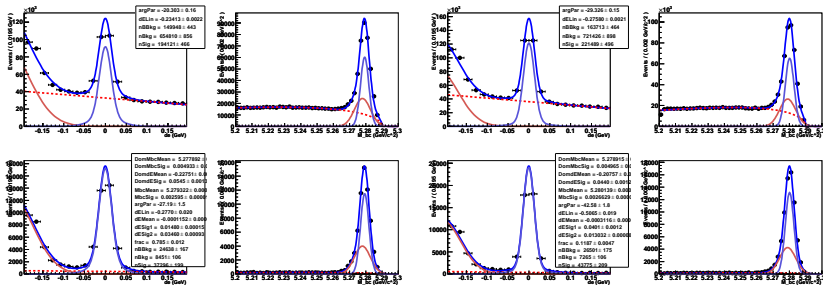
Slice Region



the fit result

parameters	expectation	fit result
ArgPar		-24.78 ± 6.6
dELin		-0.0966 ± 0.096
$q\bar{q}$	303.23	330 ± 19
$b \rightarrow c$	7.08	fixed
dominant B	33.79	fixed
the rest B	4.06	fixed
peaking	6.26	fixed
nSig	14.34	2.4 ± 4.6

LR systematic 2D fit result for neutral mode: $B^+ \rightarrow \bar{D}^0 \pi^+$



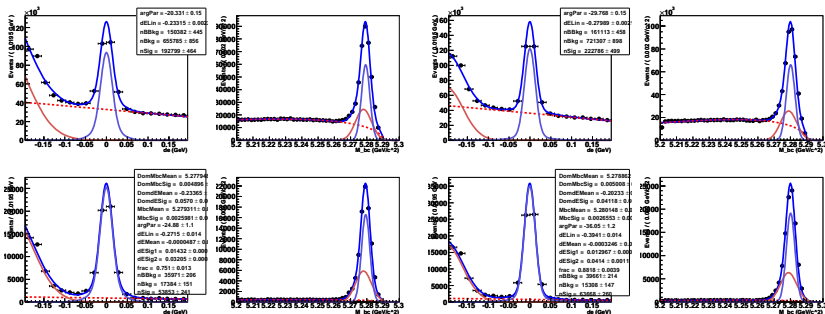
PDF: Gauss + double Gauss + 1^{st} Chebyshev polynomial

$B^0 \rightarrow \phi \pi^0$

type	before	after
data	194121 \pm 466	37396 \pm 199
MC	221489 \pm 496	43775 \pm 209

- $\epsilon_{MC} = 0.19764 \pm 0.00104$
- $\epsilon_{data} = 0.19212 \pm 0.00112$
- ratio = 0.9721 ± 0.0076
- systematic error = $\sqrt{(1 - \text{ratio})^2 + \text{error}^2} = 0.029$

LR systematic 2D fit result for charged mode: $B^+ \rightarrow \overline{D^0}\pi^+$



PDF: Gauss + double Gauss + 1st Chebyshev polynomial

● $B^+ \rightarrow \phi\pi^+$

type	before	after
data	192799 ± 464	53853 ± 241
MC	222786 ± 499	63668 ± 260

● $\epsilon_{MC} = 0.2858 \pm 0.0013$

● $\epsilon_{data} = 0.2793 \pm 0.0014$

● ratio = 0.9774 ± 0.0067

● systematic error = $\sqrt{(1 - \text{ratio})^2 + \text{error}^2} = 0.024$

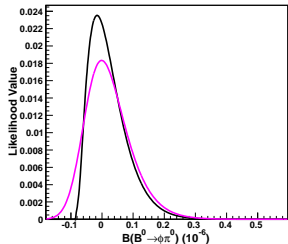
systematics of $B \rightarrow \phi\pi$ decays for 605fb^{-1}

Type		$B^0 \rightarrow \phi\pi^0$		$B^+ \rightarrow \phi\pi^+$	
		$+\sigma$	$-\sigma$	$+\sigma$	$-\sigma$
M_{bc}	σ_A	0.08	-0.12	0.07	-0.10
ΔE	σ_A	0.15	-0.21	0.41	-0.61
ΔE range	σ_A	0.47	-0.0	-	-
$b \rightarrow c, b \rightarrow u, d, s$ background	σ_A	0.04	-0.07	1.83	-1.54
The non resonance	σ_A	+0.01	-1.22	3.01	-2.46
The fitting bias	σ_A	0.88	-	0.33	-
MC acceptance	σ_M	+0.8%	-0.8%	+0.6%	-0.6%
PID	σ_M	+1.3%	-1.3%	+2.0%	-2.0%
Tracking	σ_M	+2.0%	-2.0%	+3.1%	-3.1%
π^0 detection efficiency	σ_M	+3.0%	-3.0%	-	-
MDLR efficiency	σ_M	+2.9%	-2.9%	+2.4%	-2.4%
$N_{B\bar{B}}$	σ_M	+1.4%	-1.4%	+1.4%	-1.4%
Sum: σ_A		+1.01	-1.25	+3.57	-2.97
Sum: σ_M		+5.07%	-5.07%	+4.66	-4.66

Upper Limit: $605fb^{-1}$ data

$B^0 \rightarrow \phi\pi^0$

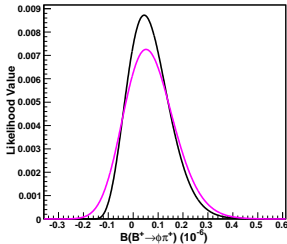
- Central mode : $B^0 \rightarrow K^+K^-\pi^0$



- Upper Limit without systematic : 0.13×10^{-6}
- Upper Limit with systematic : 0.15×10^{-6}
- $Br(B^0 \rightarrow \phi\pi^0)$:
 $(-0.02^{+0.06}_{-0.04}(stat)^{+0.03}_{-0.04}(syst)) \times 10^{-6}$
- PDG : 0.28×10^{-6} C.L 90%

$B^+ \rightarrow \phi\pi^+$

- Central mode : $B^+ \rightarrow K^+K^-\pi^+$



- Upper Limit without systematic : 0.19×10^{-6}
- Upper Limit with systematic : 0.20×10^{-6}
- $Br(B^+ \rightarrow \phi\pi^+)$:
 $(0.04^{+0.09}_{-0.07}(stat)^{+0.06}_{-0.05}(syst)) \times 10^{-6}$
- PDG : 0.24×10^{-6} C.L 90%

Summary and Next Step

- 1 The upper limits are measured $< 0.15 \times 10^{-6}$ for $B^0 \rightarrow \phi\pi^0$ and $< 0.20 \times 10^{-6}$ for $B^+ \rightarrow \phi\pi^+$:C.L. 90%
- 2 We will update the Belle note.
- 3 We should prepare to publish.
- 4 Acknowledgment : A part of this result is run on the resources from KISTI(NSDC).