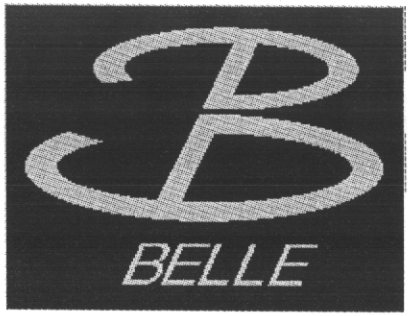
Charmless Rare B Decays at Belle



Toshifumi Tsukamoto (KEK,Japan)
representing the Belle collaboration
@ La Thuile 2001

Introduction

B decays

Detector

- K-id

Basics for rare B decay analysis

- B reconstruction
- continuum BG suppression

Charmless B decays in this talk

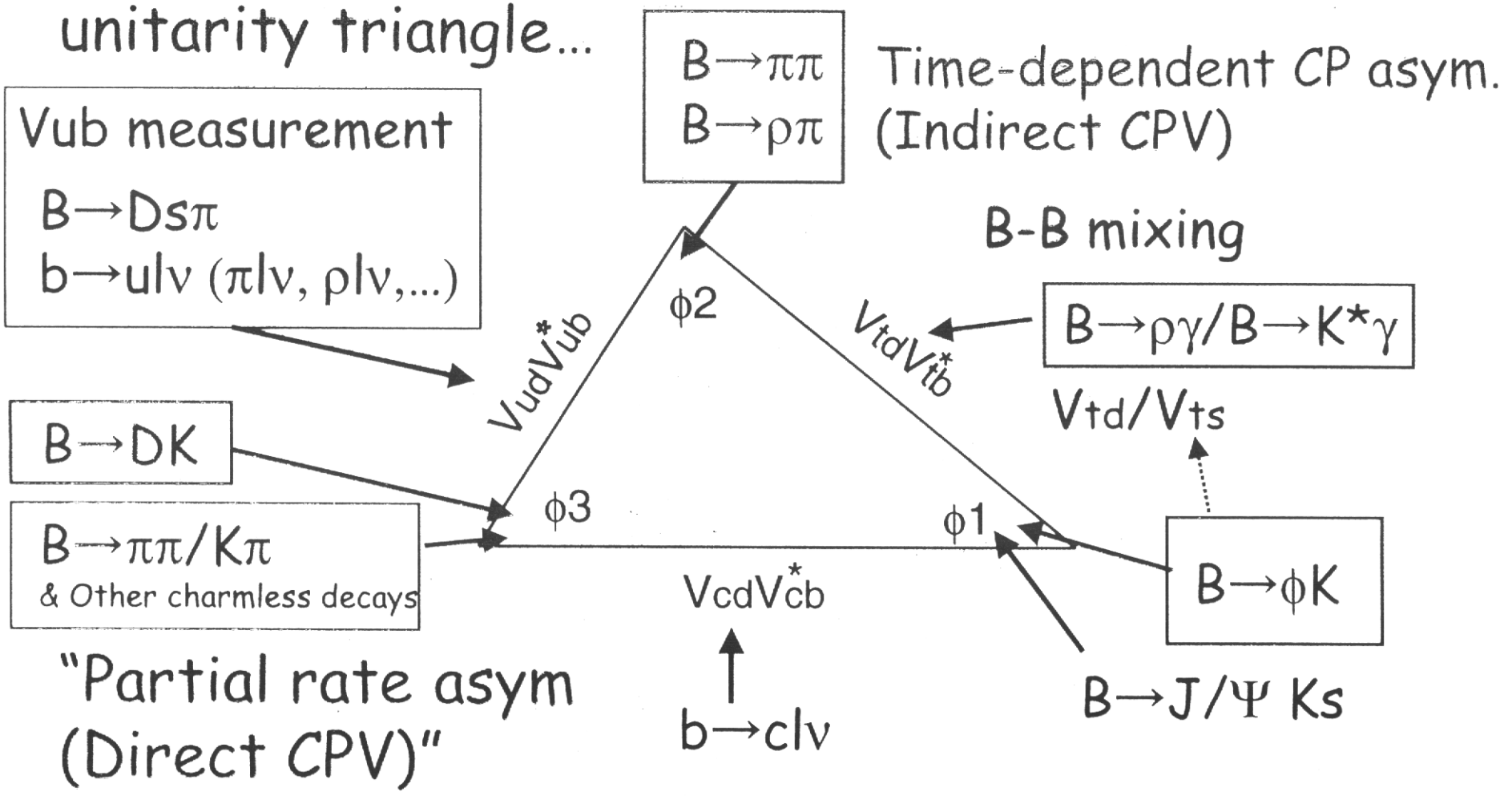
- B -> $\pi\,\pi$, K π, K K
- B -> ϕ $K^{(*)}$
- B -> K h h

Based on 10.5fb^{-1} data (11.1 M BB)

Results are preliminary

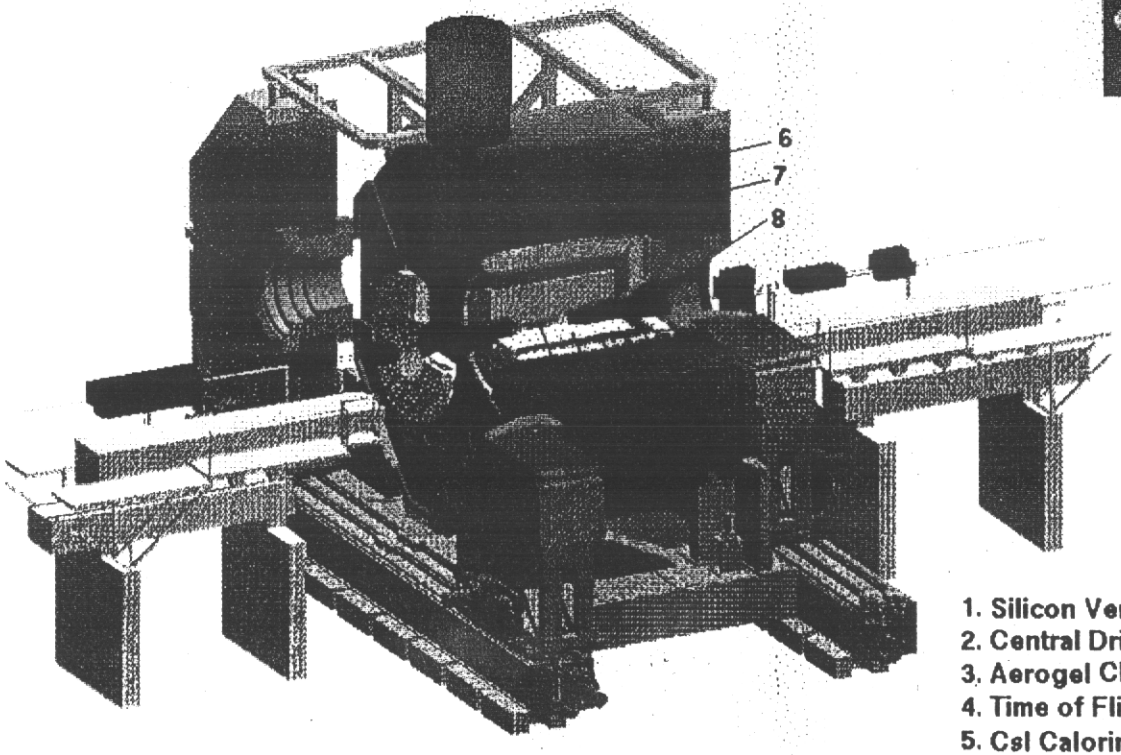
B Rare Decays and the Unitarity Triangle

- B Meson rare decays for determination of the unitarity triangle...



Belle Detector

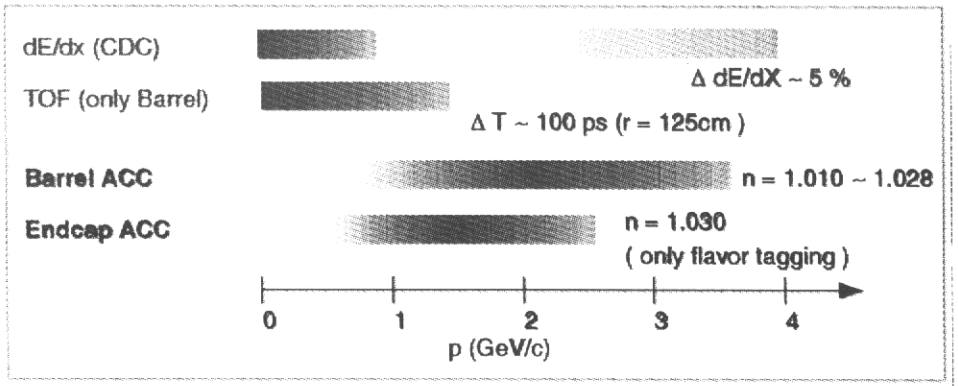
BELLE Detector



1. Silicon Vertex Detector
2. Central Drift Chamber
3. Aerogel Cherenkov Counter
4. Time of Flight Counter
5. CsI Calorimeter
6. KLM Detector
7. Superconducting Solenoid
8. Superconducting Final Focussing System

Kaon Id

dE/dx(CDC) + TOF + ACC

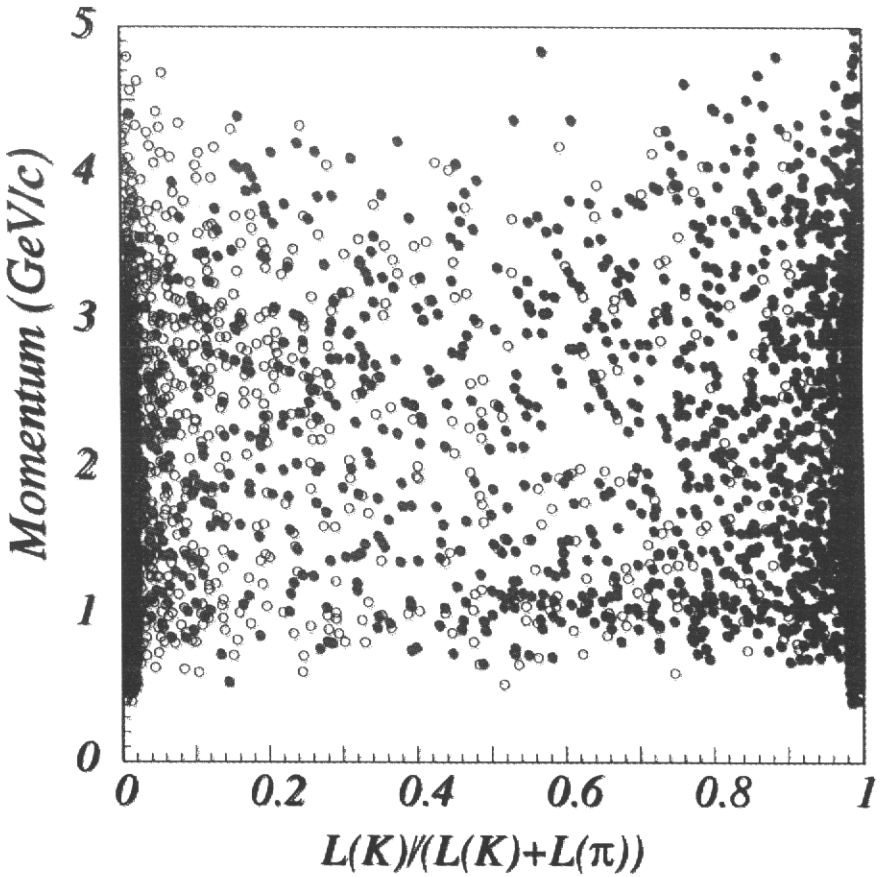


$D^{*+} \longrightarrow D^0 \pi^+_{slow}$ ← tag

$D^0 \longrightarrow K^- \pi^+$

Opposite charge K●

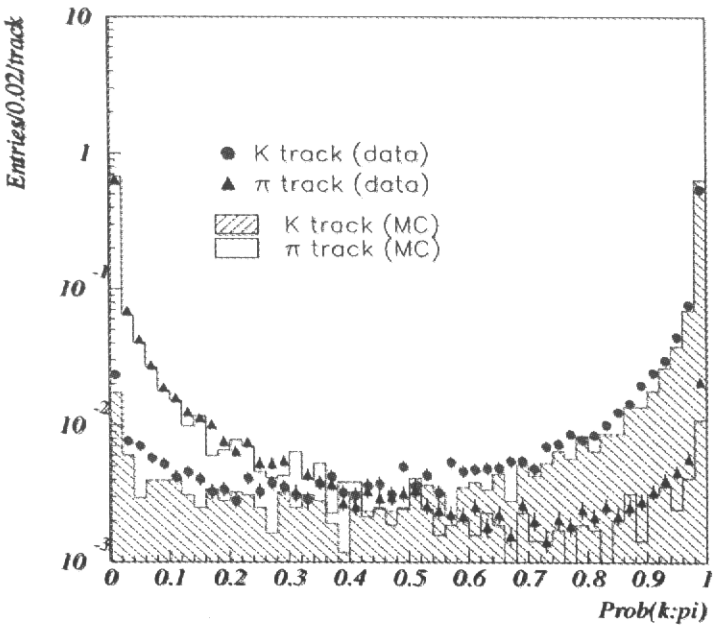
Same charge π●

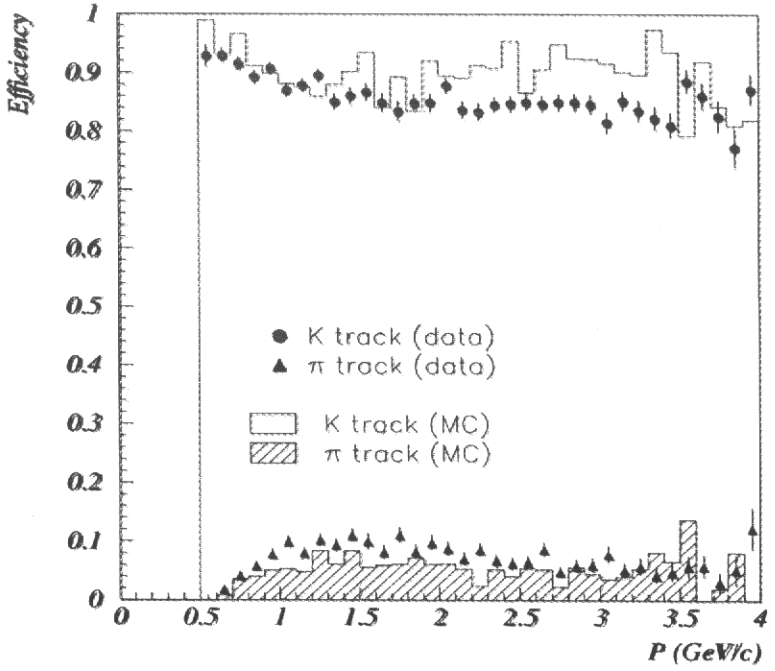


= PID(K)

Kaon ID

K-ID study with D*->D(Kπ) π_{slow}





B Reconstruction

- Exclusive B decays are kinematically reconstructed by using two (almost) independent variables, Mb and ΔE.
- Mb: beam energy constrained B mass.

$$Mb = \sqrt{(E^*_{beam})^2 - (\Sigma_i \vec{p}_i)^2}$$

$E^*_{beam} \sim 5.29GeV$: accuracy ~0.5%

$\Sigma_i \vec{p}_i$: small (-> small effect on error)

$\sigma \sim 3MeV$

- ΔE: energy imbalance

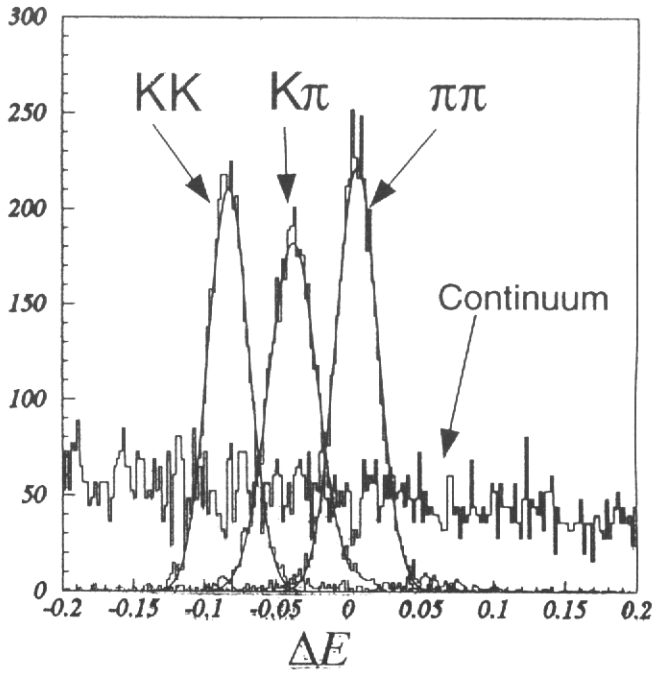
$$\Delta E = (\Sigma_i E_i^{mesured}) - E^*_{beam}$$

$E_i^{mesured}$: Calculated with assumed masses

+(-)44MeV shift / one π(K)

$\sigma \sim 16$–$40MeV$ depending on #tracks, $\#\pi^0$, $\#\gamma$ etc.

$\pi\pi/K\pi/KK$ Monte Carlo



Continuum Suppression

- Event shape: "spherical B events" ⇔ "jetty qq events"
- Newly developed shape variable **"Super Fox Wolfram"** (R.Enomoto)

$$R_l^{so} = \sum_{i,s} |p_i| \cdot |p_s| \cdot P_l(\cos\theta_{is}) / \sum_{i,s} |p_i| \cdot |p_s| \quad \text{(signal-other)}$$

$$R_l^{oo} = \sum_{i,j} |p_i| \cdot |p_j| \cdot P_l(\cos\theta_{ij}) / \sum_{i,j} |p_i| \cdot |p_j| \quad \text{(other-other)}$$

$l : 1 \sim 4$

s : B cand. track, i, j : non−B

$\Rightarrow F_{SFW} = \Sigma_{l=1,4} [\, \alpha_l \cdot R_l^{so} + \beta_l \cdot R_l^{oo} \,]$

Fisher discriminants

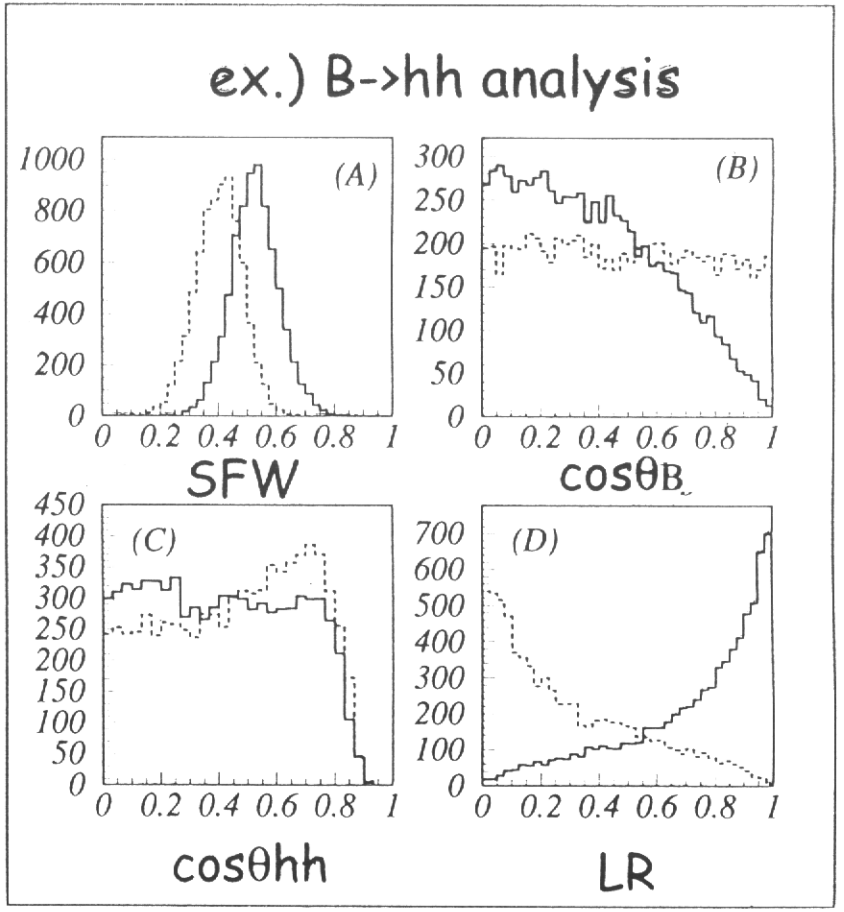
- + $\cos\theta_B$, $\cos\theta_{hh}$, $\cos\theta_H$, ...

⇒Likelihood ratio (LR)

$$L(B\bar{B}) = L_{B\bar{B}}^{SFW} \times L_{B\bar{B}}^{\cos\theta_B} \times L_{B\bar{B}}^{\cos\theta_{hh}} \times ,....$$

$$LR = \frac{L(B\bar{B})}{L(B\bar{B}) + L(q\bar{q})} \quad \Rightarrow \text{Slice cut}$$

- Systematic checked with
  - $B \rightarrow D\pi$ data for signals
  - Side-band data for background



Charmless Two-body Decays

- Extraction of ϕ_2 angle
  - $B^0 \Rightarrow \pi\pi$
  - $B^0 \Rightarrow \rho\pi$
- Search for direct CP violation
  - Tree and Penguin interference
    $\propto \sin\varphi_3 \cdot \sin(\delta_p - \delta_T)$
- Constraint on ϕ_3 angle using ratios of CP averaged Br($K\pi$) and Br($\pi\pi$).
  - Fleischer et al (hep-ph/0003323)
  - Neubert et al (hep-ph/0008072)
    "QCD factorization"

  and others...
- Probing New Physics
  - Any channel with an unexpected branching fraction

$$\frac{Br(\pi^+\pi^-)}{Br(K^\pm\pi^\mp)} \qquad \frac{Br(K^\pm\pi^\mp)}{2Br(K^0\pi^0)}$$

$$\frac{2Br(K^\pm\pi^0)}{Br(K^0\pi^\pm)} \qquad \frac{\tau_{B^+}}{\tau_{B^0}}\frac{Br(K^\pm\pi^\mp)}{Br(K^0\pi^\pm)}$$

B -> K π , π π

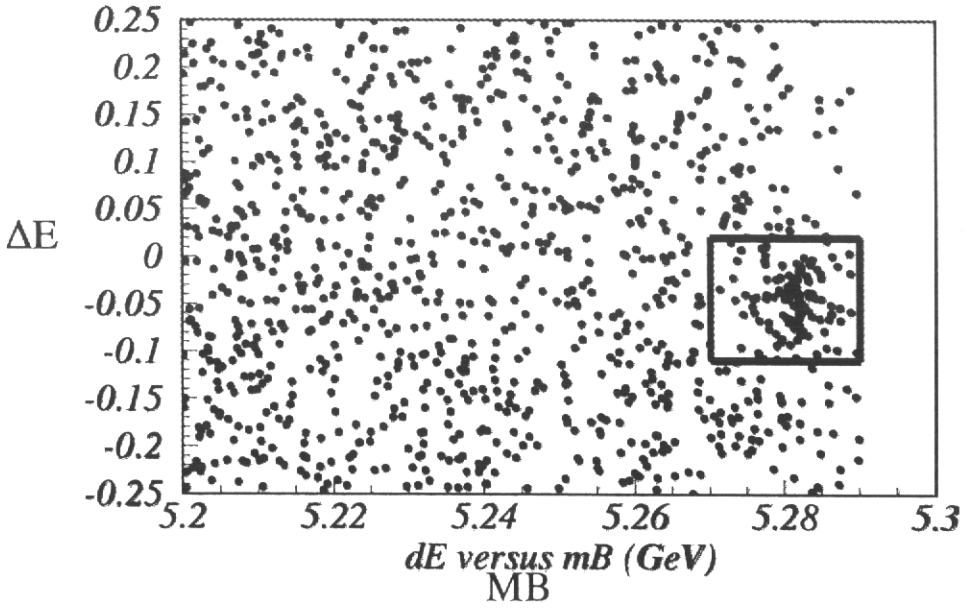
B^0 -> $K^+ \pi^-$

One of two tracks is required as K :PID(K)>0.6

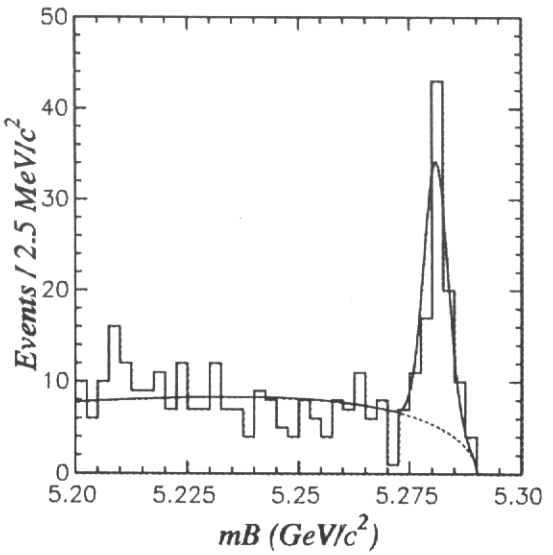
B^0 -> $\pi^+ \pi^-$

both tracks are π : PID(K)<0.4

B^0 -> $K^+ \pi^-$

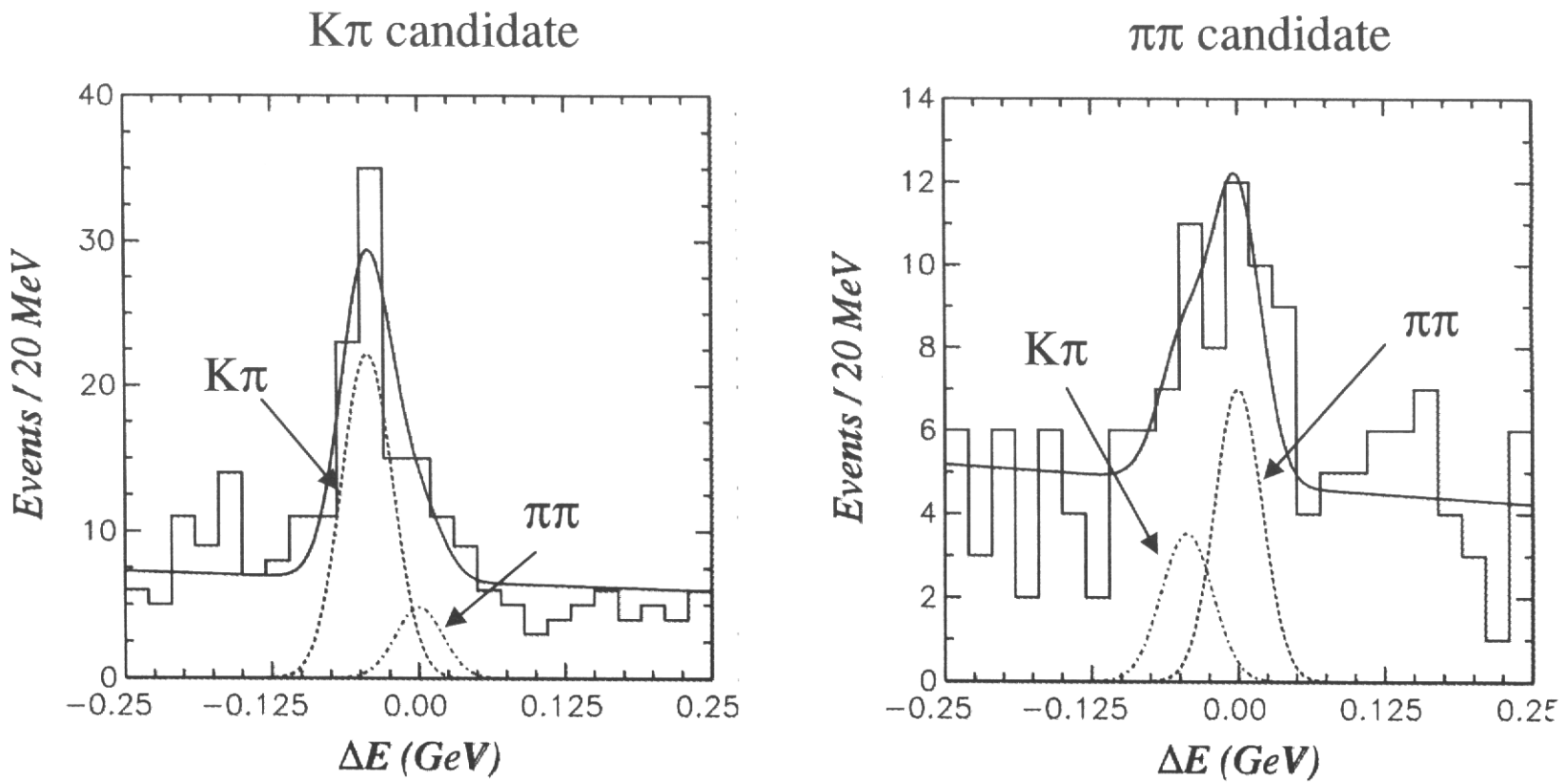


B^0 -> $K^+ \pi^-$



B -> K π , π π

K/π mis-id makes (Kπ as ππ) / (ππ as Kπ)
ΔE can distinguish such BG events from signal



B→Kπ : Acp Results

- B reconstruction and qq suppression are same as for Br. measurement.
- Require PID on both tracks to minimize double mis-identification for $K^+\pi^-/K^-\pi^+$. (double mis-ID probability = 0.46%)
- Acp($B \to K^{\pm}\pi^{\mp}$)

$N(\bar{B}^0 \to K^-\pi^+) = 27.7^{+6.8}_{-6.1}$

$N(B^0 \to K^+\pi^-) = 25.4^{+7.0}_{-6.3}$

$\Rightarrow Acp = 0.043 \pm 0.175 \pm 0.021$

- Acp($B \to K^{\pm}\pi^0$)

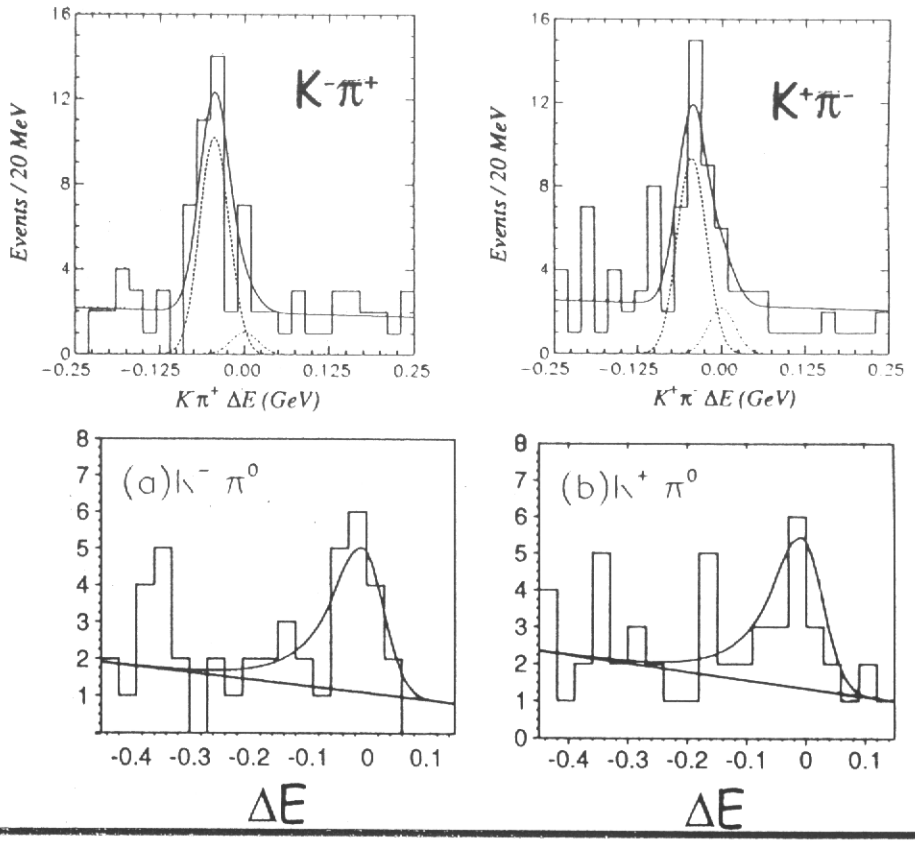
$N(\bar{B}^- \to K^-\pi^0) = 18.3^{+5.6}_{-4.9}$

$N(B^+ \to K^+\pi^0) = 17.6^{+5.5}_{-4.8}$

$\Rightarrow Acp = 0.019^{+0.219}_{-0.191}$

- Detector bias test w/ D→Kπ decays

$Acp = 0.001 \pm 0.006$



Ratio of Br($\pi\pi$),Br($K\pi$)

- Ratio of CP averaged $\pi\pi/K\pi$ branching fraction

  $\Rightarrow$Indirect information for ϕ_3 (SU(3), factorization...)

  - $\dfrac{Br(B^0 \to \pi^+\pi^-)}{Br(B^0 \to K^+\pi^-)} = 0.32^{+0.13}_{-0.14}$ $\quad \pi\pi < K\pi$
  - $\dfrac{Br(B^0 \to K^+\pi^-)}{2 \cdot Br(B^0 \to K^0\pi^0)} = 0.64^{+0.25}_{-0.29}$ $\quad K^0\pi^0$ larger than theory
  - $\dfrac{2 \cdot Br(B^+ \to K^+\pi^0)}{Br(B^+ \to K^0\pi^+)} = 2.60^{+1.07}_{-1.20}$ $\quad > 1$ (likely)
  - $\dfrac{\tau(B^+) \cdot Br(B^0 \to K^+\pi^-)}{\tau(B^0) \cdot Br(B^+ \to K^0\pi^+)} = 1.51^{+0.60}_{-0.68}$

  $\left(\dfrac{Br(B^0 \to K^+\pi^-)}{Br(B^+ \to K^0\pi^+)} = 1.43^{+0.56}_{-0.64} \right)$

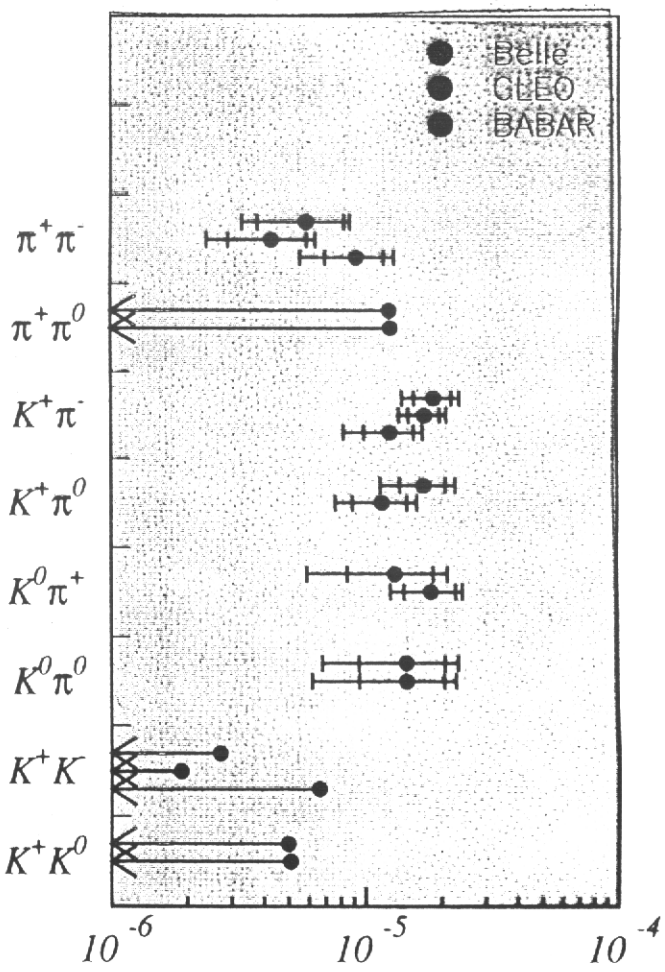
  ※ Systematic error under study

ππ/Kπ/KK Summary

- Results w/ 11.1M BB

Mode	Ns	Σ	Eff (%)	Br(10^{-5})	U.L. (10^{-5})
$B^0 \to \pi^+\pi^-$	$17.7^{+7.1}_{-6.4}$	3.1	28	$0.59^{+0.24}_{-0.21} \pm 0.05$	-
$B^+ \to \pi^+\pi^0$	$9.4^{+4.8}_{-4.0}$	2.9	12	$0.71^{+0.36}_{-0.30}{}^{+0.09}_{-0.12}$	1.26
$B^0 \to K^+\pi^-$	$60.3^{+10.6}_{-9.9}$	7.8	29	$1.87^{+0.33}_{-0.30} \pm 0.16$	-
$B^+ \to K^+\pi^0$	$35.8^{+7.7}_{-7.0}$	7.5	19	$1.70^{+0.37}_{-0.33}{}^{+0.20}_{-0.22}$	-
$B^+ \to K^0\pi^+$	$10.3^{+4.3}_{-3.6}$	3.5	13	$1.31^{+0.55}_{-0.46} \pm 0.26$	-
$B^0 \to K^0\pi^0$	$8.8^{+3.7}_{-3.1}$	4.2	11	$1.46^{+0.61}_{-0.51} \pm 0.27$	-
$B^0 \to K^+K^-$	$0.2^{+3.8}_{-0.2}$	-	24		0.27
$B^+ \to K^+K^0$	$0.0^{+0.9}_{-0.0}$	-	13		0.50

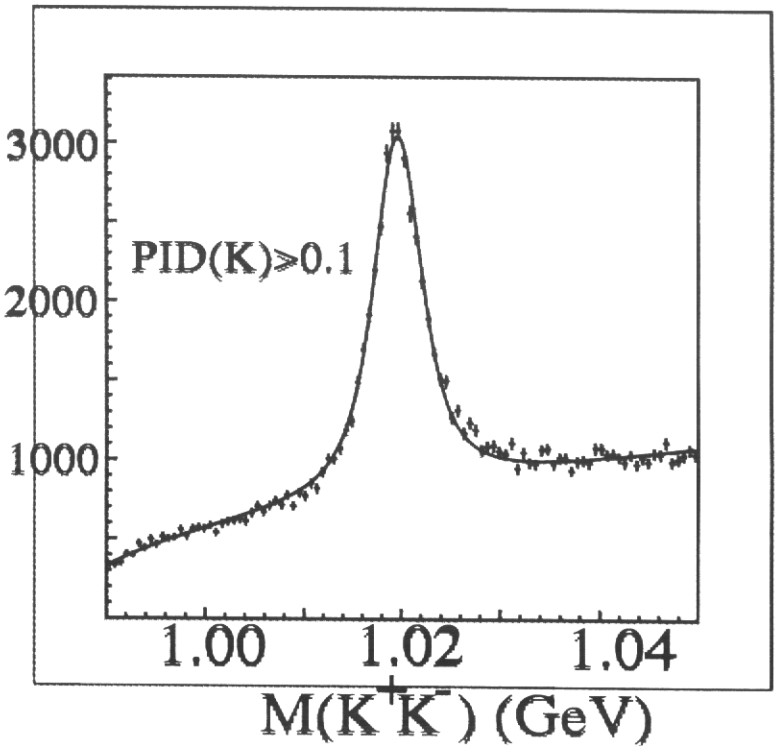
Belle(BCP4)
CLEO(PRL85,515(2000))
BABAR(ICHEP2000)



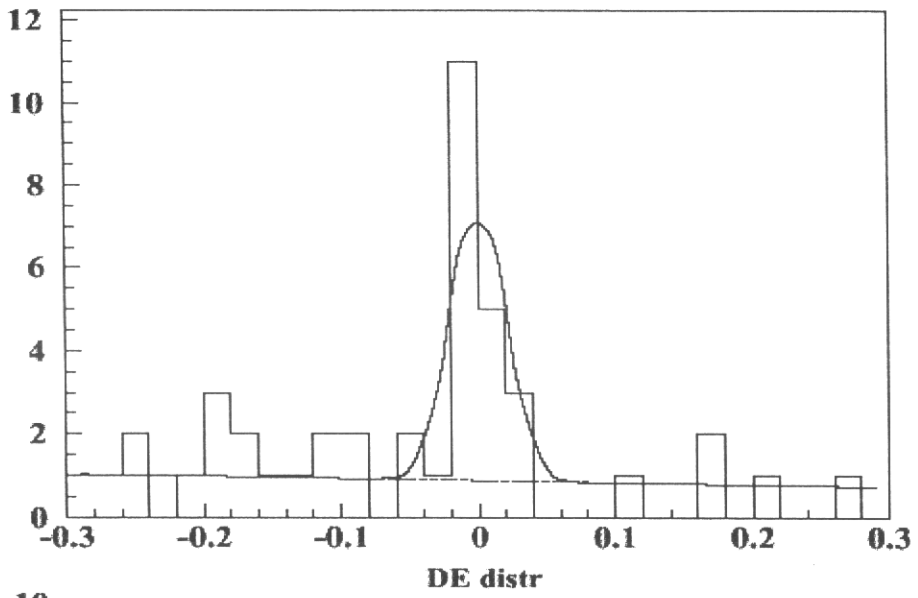
$B \to \phi K^{(*)}$

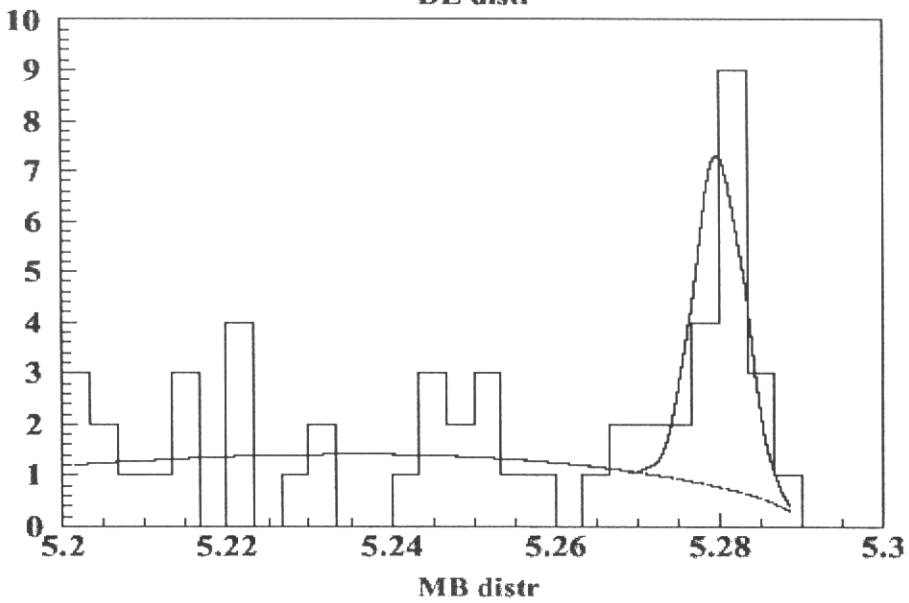
- modes
  - $B^+ \to \phi K^+, \phi K^{*+}$
  - $B^0 \to \phi K_s, \phi K^{*0}$
- Selection
  - $\phi \to K^+ K^-$
    - PID(K)>0.1
    - $P_{KK}^{cm} > 2GeV$
    - $M_{KK} - 1.1094 < 0.01GeV$
  - Kaon in $\phi K^{(*)}$
    - $K^\pm$: PID(K)>0.5
    - K^{*-} : $K_s \pi^0$, $K^- \pi^0$ $\pm 50MeV$
    - K^{*0} : $K_s \pi^0$, $K^- \pi^+$ mass window
  - Continuum suppression
    - θ_B^{cm}, θ(thrust-p_B), θhelicity

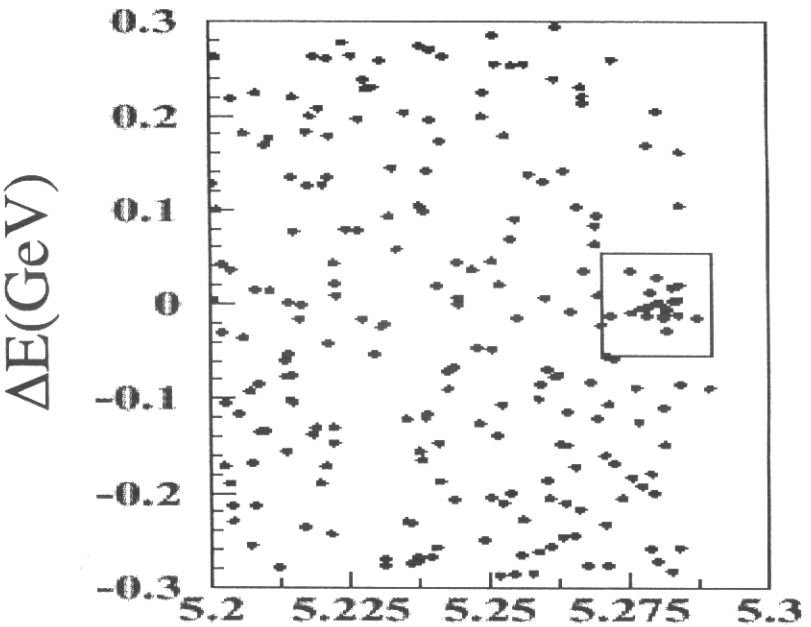
- b->sss which is not via tree level and penguin is expected to be dominate
- sensitive to Vts --> non-SM effect
- three kaons, ϕ —> clear signature for good K-ID



B -> φ K



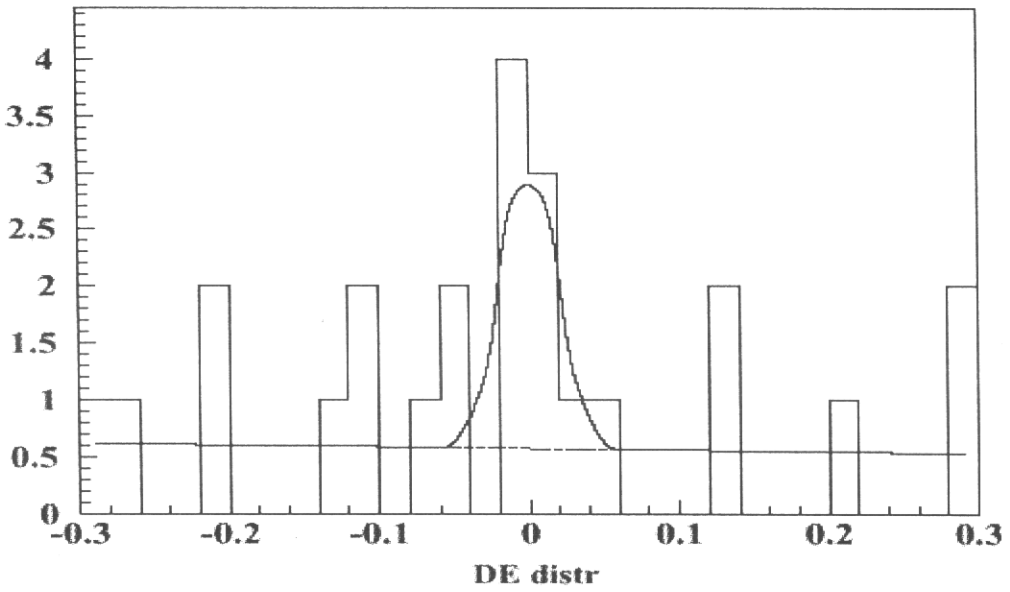


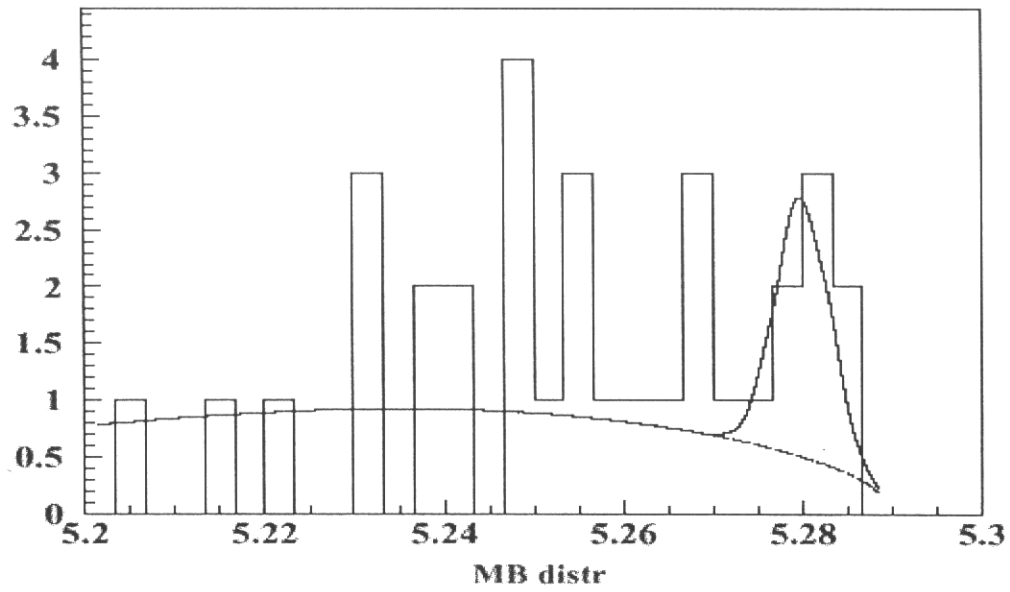


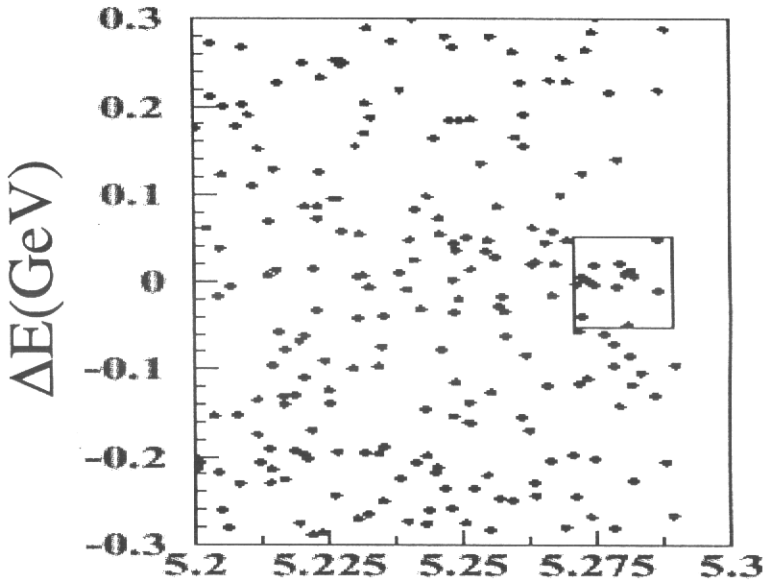
Yield 17.8 +4.8/-4.2
Significance 7.5σ

preliminary

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







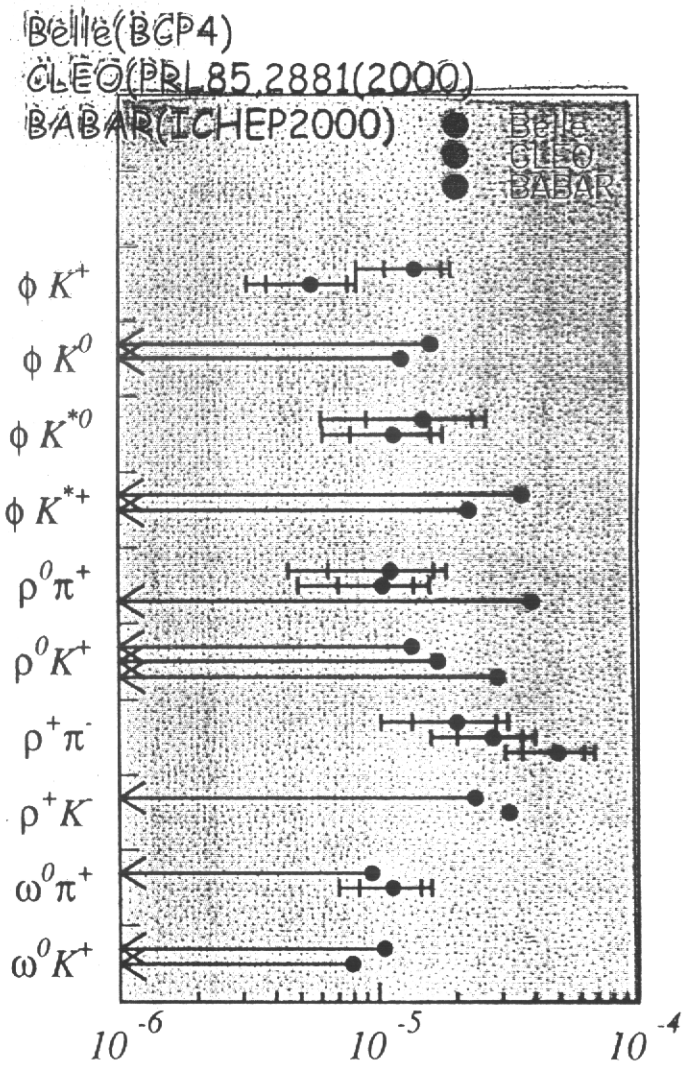
Yield 6.5 +3.5/-2.7

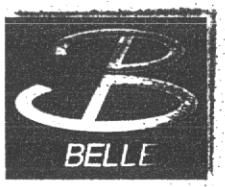
Significance 3.6σ

preliminary

$B \to \phi K^{(*)}$, ρh, ωh: Summary

Mode	Ns	Σ	Eff (%)	Br(10^{-5})	U.L. (10^{-5})
$B^+ \to \phi K^+$	$17.8^{+4.8}_{-4.2}$	7.5	12	$1.39^{+0.37}_{-0.33}{}^{+0.09}_{-0.22}$	-
$B^0 \to \phi K^0$	$0.9^{+1.5}_{-0.8}$	1.2	3.0	-	1.6
$B^0 \to \phi K^{*0}$	$6.5^{+3.5}_{-2.7}$	3.6	4.4	$1.5^{+0.8}_{-0.6} \pm 0.3$	3.0
$B^+ \to \phi K^{*+}$	$1.3^{+1.8}_{-1.1}$	1.4	1.0	-	1.6
$B^+ \to \rho^0 \pi^+$	$13.7^{+6.5}_{-5.9}$	2.9	12	$1.12^{+0.53}_{-0.48} \pm 0.19$	1.9
$B^+ \to \rho^0 K^+$	$8.3^{+5.1}_{-4.4}$	2.0	9.8	-	1.4
$B^0 \to \rho^+ \pi^-$	$21.0^{+7.8}_{-6.7}$	3.9	4.7	$2.02^{+0.83}_{-0.66} \pm 0.33$	3.57
$B^0 \to \rho^+ K^-$	$9.6^{+6.6}_{-4.7}$	2.5	4.7	-	2.36
$B^+ \to \omega^0 \pi^+$	$6.4^{+4.}_{-3.}$	1.8	12		1.41
$B^+ \to \omega^0 \pi^+$	$2.9^{+2.6}_{-2.8}$	1.1	11		0.94
$B^+ \to \omega^0 K^+$	$3.4^{+3.0}_{-2.2}$	1.8	9.3		1.05

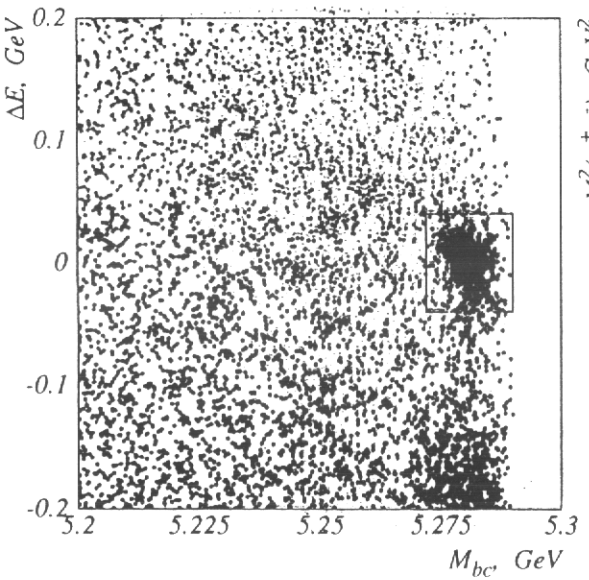


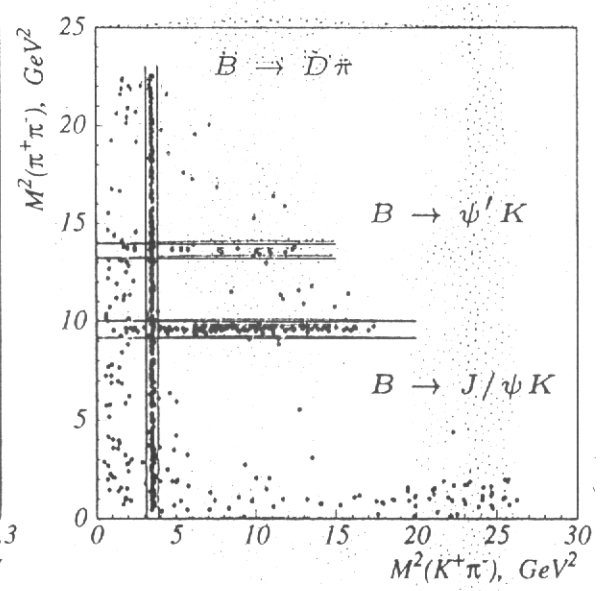


Motivations

- *A lot of new results on two–body charmless B decays came from CLEO Collaboration*
- *Study of penguin $b \to sq\bar{q}$ transitions (resulting in the odd number of kaons in final state)*
- *Good K/π separation capability of the Belle detector in a wide momentum region allows a study of three particle final state without any assumption on intermediate mechanism*
- *Search for New Physics (SUSY ...)*

$B^+ \Rightarrow K^+\pi^+\pi^-$

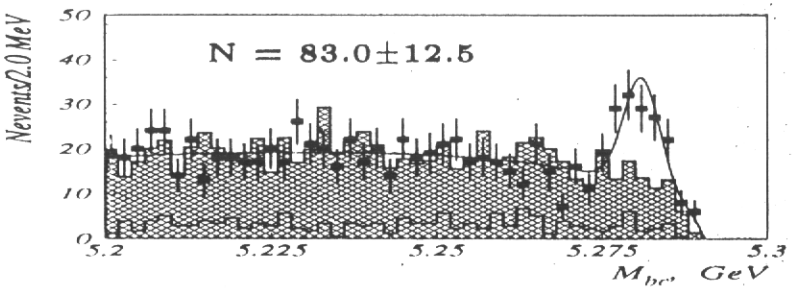


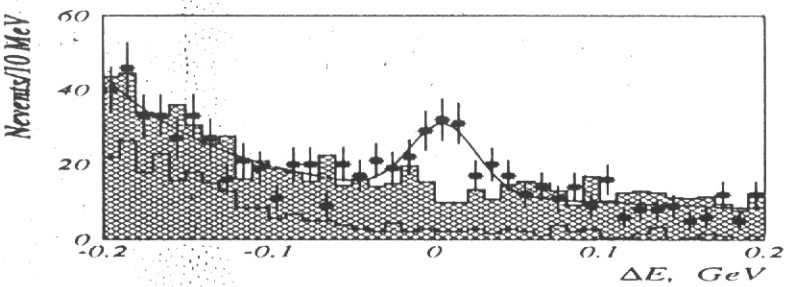


Vetoed candidates:

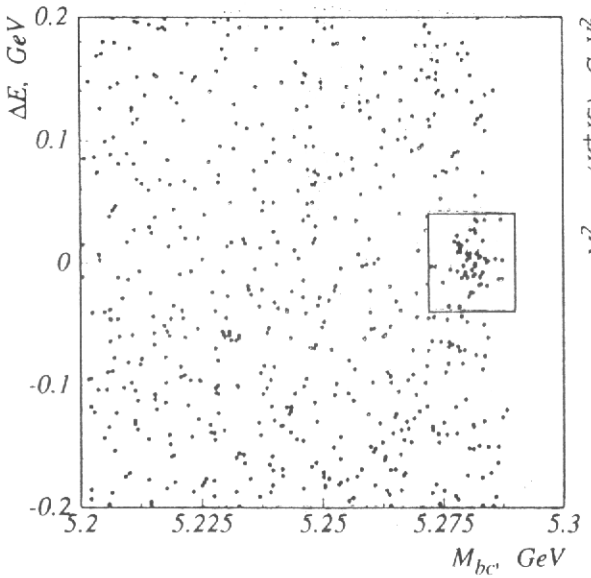
- $\bar{D}^0 \to K^+\pi^-$: ±100 MeV
- $J/\psi \to \mu^+\mu^-$: ±70 MeV
- $\psi' \to \mu^+\mu^-$: ±50 MeV

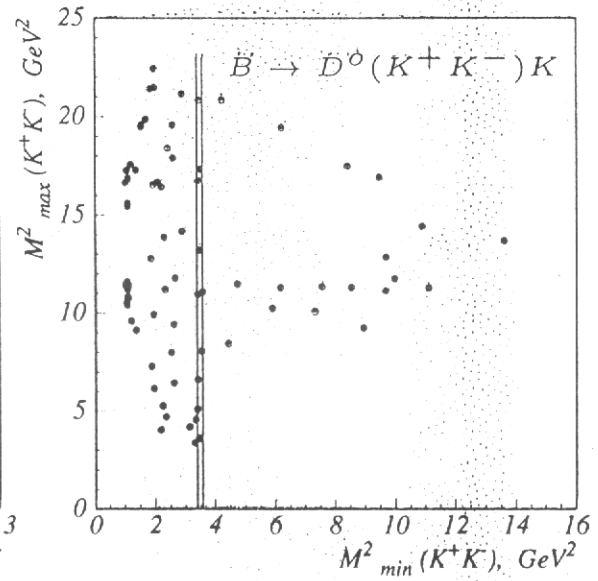
M_{bc} and ΔE distributions after D, J/ψ and ψ' veto





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

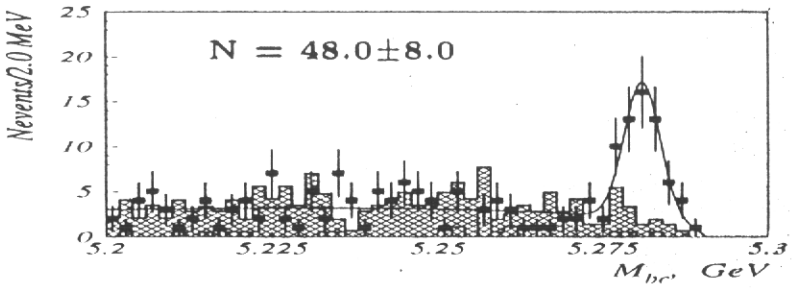


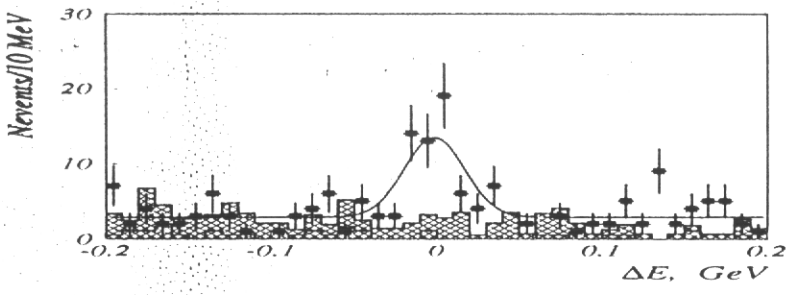


Vetoed candidates:

- $\bar{D}^0 \to K^+K^-$: **±25 MeV**

M_{bc} **and** ΔE **distributions after** D **veto**





Summary of the results

$$\mathcal{B}r(B^+ \to Xh^+) \times \mathcal{B}r(X \to h^+h^-) = \frac{N_X}{N_{D\pi}} \times \mathcal{B}r(B^+ \to \bar{D}^0\pi^+) \times \mathcal{B}r(\bar{D}^0 \to K^+\pi^-) \times \frac{1}{\varepsilon}$$

PRELIMINARY

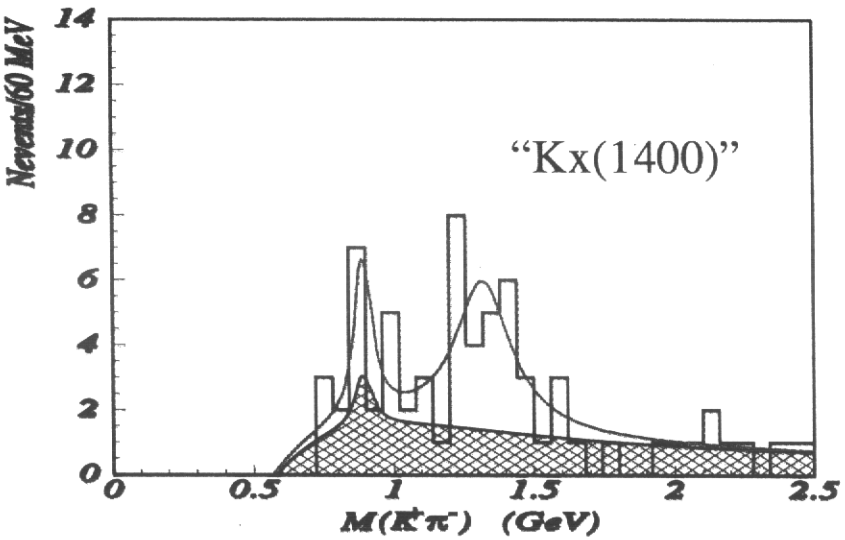
Mode	ε	Yield	Significance, σ	$\mathcal{B}r(10^{-6})$	$90\%UL(10^{-6})$	Note
$K^+\pi^-\pi^+$	0.94	83.0 ± 12.5	8.60	$64.8 \pm 10.0 \pm 7.0$	–	1
$K^+K^+K^-$	0.72	48.0 ± 8.0	9.30	$36.5 \pm 6.1 \pm 5.5$	–	2
$K^-\pi^+\pi^+$	0.94	$7.8^{+6.2}_{-5.5}$	–	–	< 12.8	3
$K^+K^+\pi^-$	0.83	$0.0^{+2.6}_{-0.0}$	–	–	< 5.20	4
$K^+K^-\pi^+$	0.83	$9.7^{+6.6}_{-5.9}$	–	–	< 17.0	5

1) CLEO2: $< 2.8 \times 10^{-5}$(NR); BaBar: $< 5.4 \times 10^{-5}$(NR); DELPHI: $< 3.3 \times 10^{-4}$(NR); ARGUS: $< 3.3 \times 10^{-4}$(NR)

2) CLEO2: $< 3.8 \times 10^{-5}$(NR); DELPHI: $< 2.0 \times 10^{-4}$; ARGUS: $< 3.5 \times 10^{-4}$

3) CLEO2: $< 5.6 \times 10^{-5}$(NR) 4) OPAL: $< 8.79 \times 10^{-5}$(NR)

5) CLEO2: $< 7.5 \times 10^{-5}$(NR) (NR – non-resonant)



$M(h^+h^-)$ fit

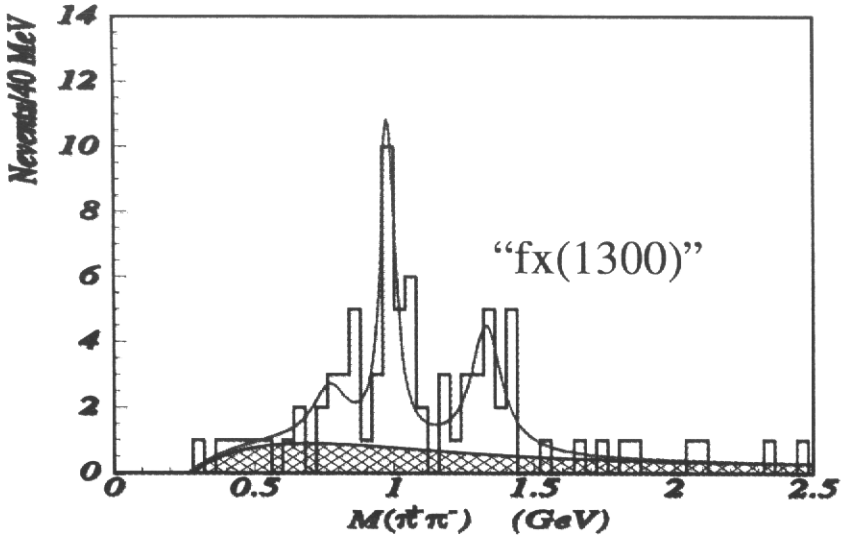
Fixed : peak and width for

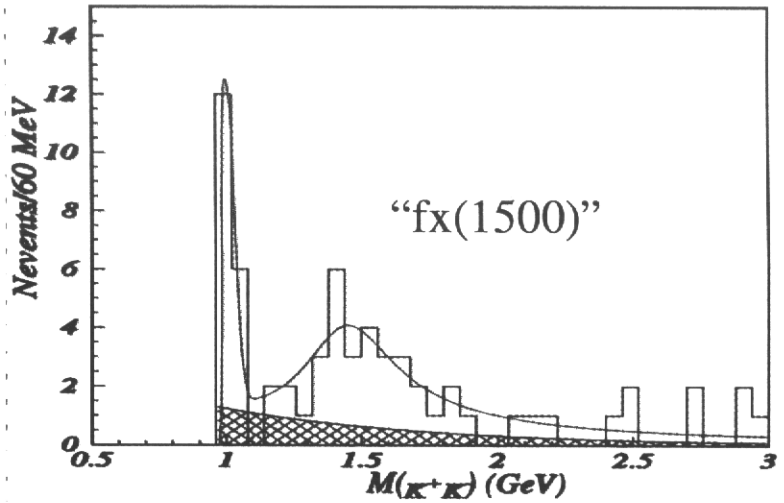
$K^*(892)$, $\rho(770)$, $f_0(980)$,$\phi(1020)$

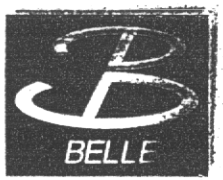
Float : peak and width for

"fx(1300)", "Kx(1400)", "fx(1500)"

all amplitudes







Summary of the results

PRELIMINARY

Mode	ε	Yield	Significance, σ	$\mathcal{B}r(B \to Xh) \times \mathcal{B}r(X \to hh)(10^{-6})$	Note
$K^{*o}(892)\pi^+$	0.92	$7.5^{+4.1}_{-3.4}$	2.8	< 11.6 90% CL	1
$"K^{*o}_X(1400)"\pi^+$	0.89	$29.1^{+6.9}_{-6.3}$	5.2	$23.8^{+5.6}_{-5.1} \pm 5.8$	2
$\rho^o(770)K^+$	0.67	$5.5^{+4.1}_{-3.4}$	1.6	< 13.5 90% CL	3
$f_o(980)K^+$	0.79	$17.9^{+5.3}_{-4.6}$	4.9	$16.4^{+4.9}_{-4.2} \pm 2.8$	4
$"f_X(1300)"K^+$	0.79	$20.4^{+5.7}_{-5.0}$	4.8	$18.8^{+5.3}_{-4.6} \pm 4.3$	–
$"f_X(1500)"K^+$	0.45	$17.6^{+5.7}_{-5.0}$	5.5	$25.1^{+6.6}_{-5.8} \pm 4.3$	–

1) $\mathrm{Br}(B^+ \to K^{*o}(892)\pi^+)$ **This Work:** $< 17.4 \times 10^{-6}$; **CLEO2:** $< 16 \times 10^{-6}$; BaBar : 28×10^{-6}

2) **ARGUS:** $\mathrm{Br}(B^+ \to K^*_2(1430)\pi^+) < 6.8 \times 10^{-4}$

3) $\mathrm{Br}(B^+ \to \rho^o(770)K^+)$ **This Work:** $< 13.5 \times 10^{-6}$; **CLEO2:** $< 17 \times 10^{-6}$; BaBar : 29×10^{-6}

4) $\mathrm{Br}(B^+ \to f_o(980)K^+)$ **This Work:** $(16.4^{+4.9}_{-4.2} \pm 2.8) \times 10^{-6}$; **CLEO:** $< 80 \times 10^{-6}$

Summary

- Belle has accumulated 10.5fb^{-1} (11.1M BB) and carried out various rare decay study
- New results on charmless rare B decay are presented
  - B-> $K^+ \pi^-, \pi^+ \pi^-, K^+ K^-$
    - BR, Acp
  - B-> $\phi K^{(*)}$
    - Confirmation of ϕ K. observation of ϕK^*
  - B^+ -> $K^+ h^+ h^-$
    - B^+ -> $f_0(980)$ K^+ is observed
    - Various $h^+ h^-$ invariant mass spectra 1300-1500MeV are observed
- More data will be taken, which are needed for study
  - Rate asymmetry
  - Angular analysis
  - etc.