

Hadronic B decays into final states including vector mesons.

A.Bozek
for the Belle Collaboration
Inst. of Nuclear Physics,
Kraków

Search for charmless B decays:

- $B \rightarrow VP$

- $B \rightarrow \phi K$ includes update on ϕK^\pm ;

the first observation by Belle at ICHEP2000

- $B \rightarrow \rho h$

- $B \rightarrow \omega h$

- $B \rightarrow VV$

- $B \rightarrow \phi K^*$

Results based on the sample of 11.1×10^6 B mesons pair collected up to the end of 2000



Motivations

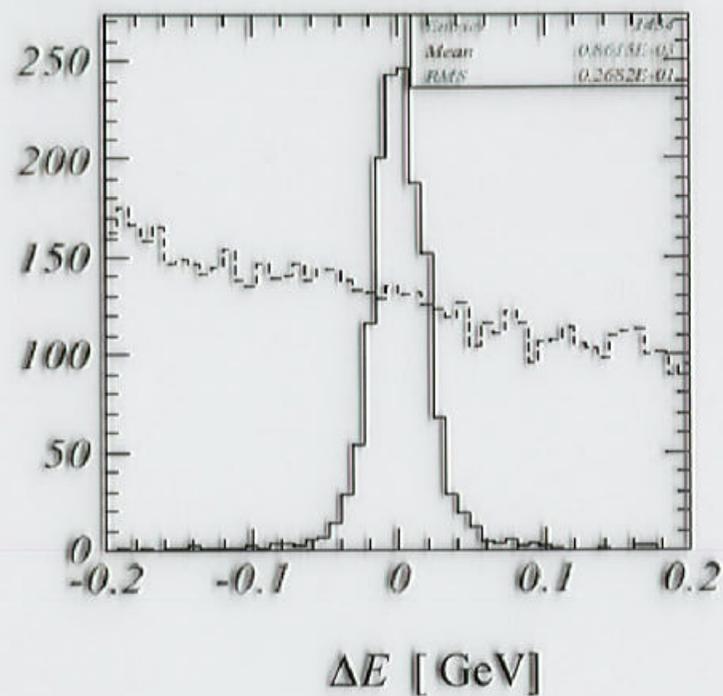
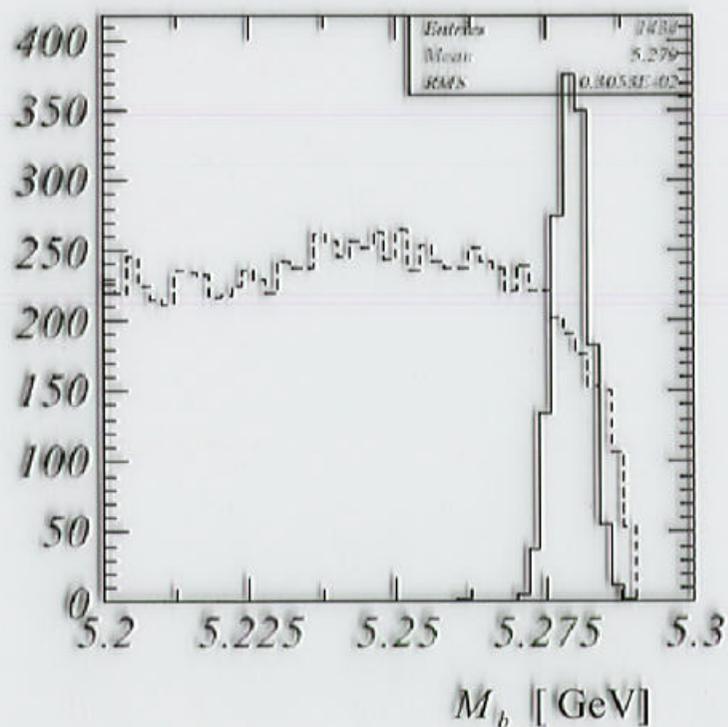
- Tests of unitarity of the KM matrix
 - $\rho h, \omega h$: measurement of $\beta + \gamma(\phi_1 + \phi_3)$
 - direct CP violation
 - ϕK_S^0 : check of $\sin(2\phi_1)(\sin(2\beta))$ measurement
- ϕK are mostly produced via the gluonic penguin.
 - Search for non SM physics



Signal from Background separation (kinematics)

$$M_b = \sqrt{(E_{beam}^*)^2 - (\sum P_j^*)^2}$$

$$E_{beam}^* \approx 5.29 \text{ GeV}$$



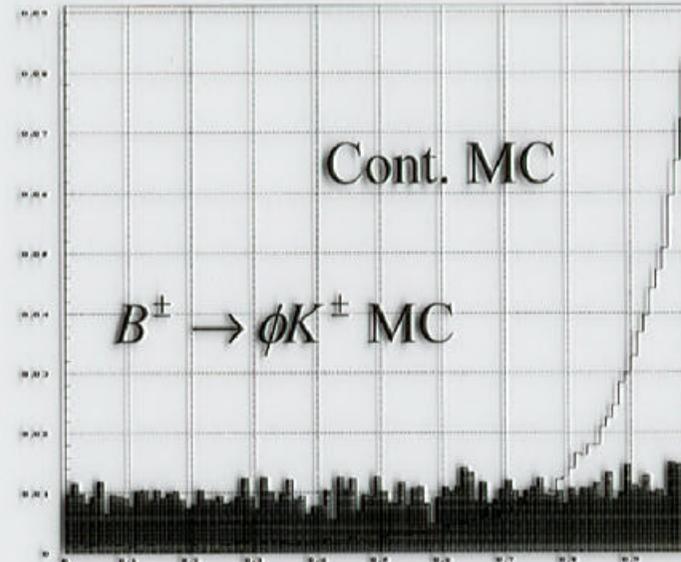
$$\Delta E = E_{reconstructed}^* - E_{beam}^*$$



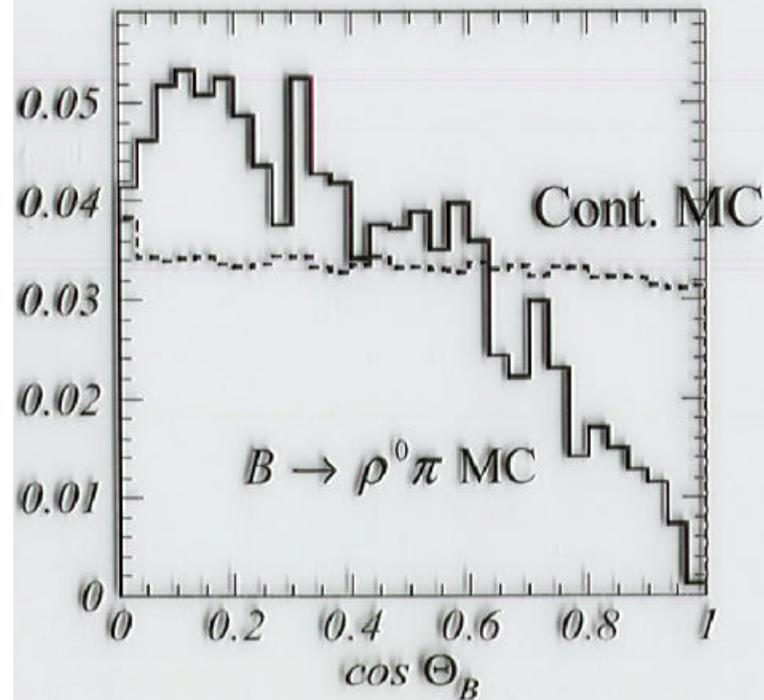
Signal from Background separation

$\cos(\theta_{\pi})$

θ_{π} : the angle between B candidate and the thrust vector of remaining tracks



$\cos(\theta_{\pi})$



$\cos(\theta_B^*)$

θ_B^* : B candidate production angle in the CM system.



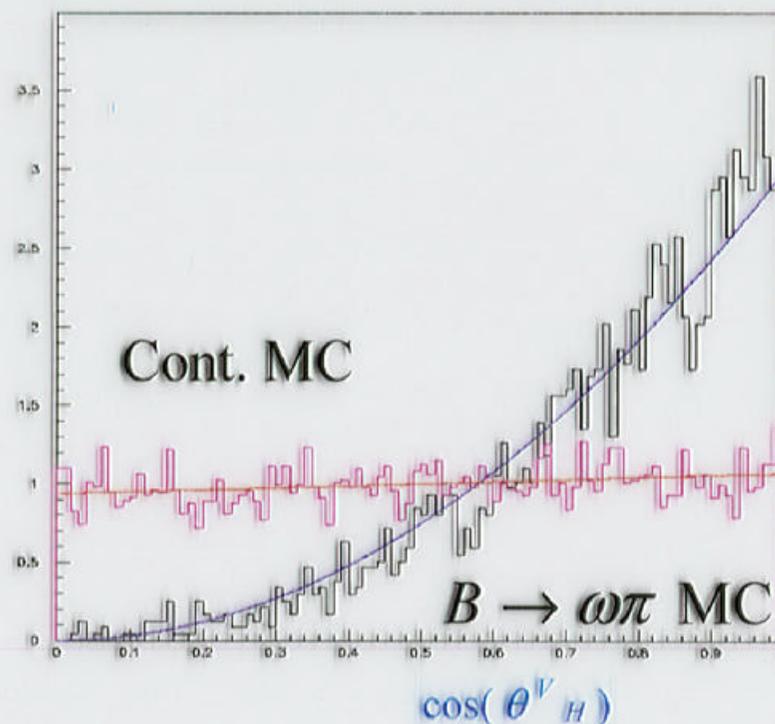
Signal from Background separation

For $B \rightarrow P + V$

$(0^- \rightarrow 0^- 1^-)$

$\cos(\theta_H^V)$

θ_H^V : helicity angle



Particle identification

$$L(h;p) = L^{ACC}(h;p) \times L^{dE/dx}(h;p) \times L^{TOF}(h;p)$$

$$D(K) = \frac{L(K)}{L(K) + L(\pi)}$$

$PID(K) > 0.6$ for most of the K selections

Use of vertexing + beam spot information



$B \rightarrow \phi K$ search

Distinct signature

$$P^* (K^+K^-) > 2 \text{ GeV}/c$$

loose K ID cut

$$M_\phi = 1.0193 \pm 0.0001 \text{ GeV}$$

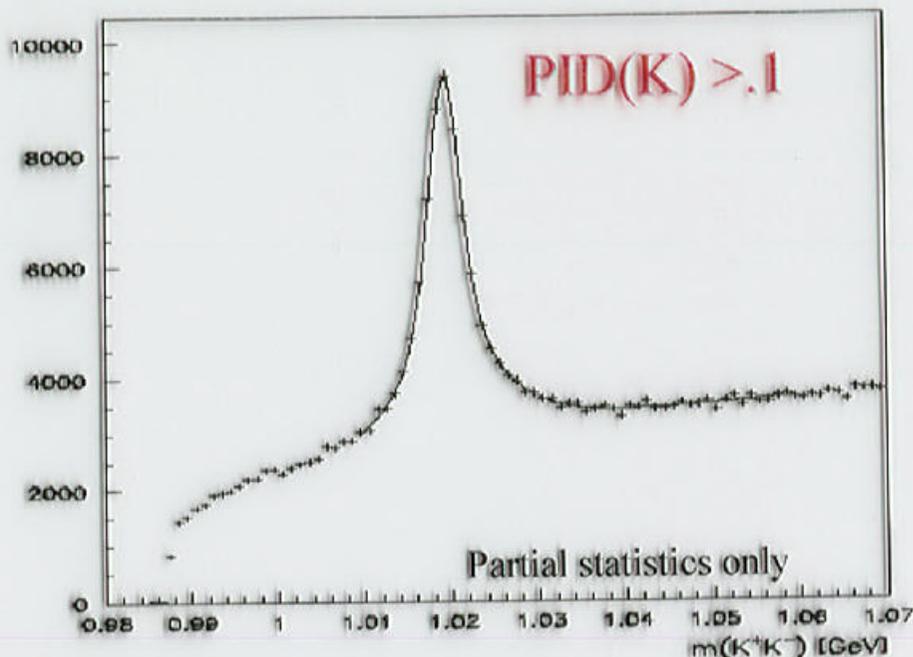
$$\sigma_{\text{resol}} = 1.00 \pm 0.01 \text{ MeV}$$

Additional cuts:

$$m(\phi) \pm 10 \text{ MeV}$$

$$m(K^*) \pm 50 \text{ MeV}$$

K_S^0 standard cuts



Continuum suppression

sequential cuts

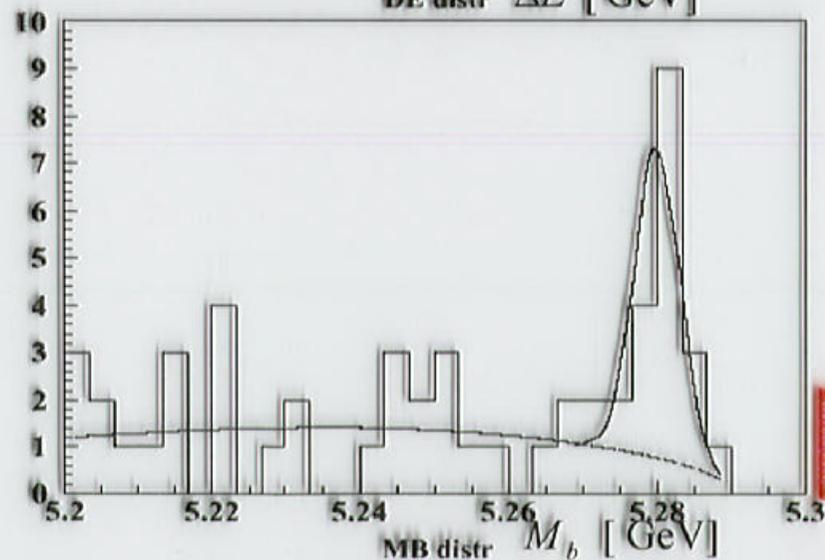
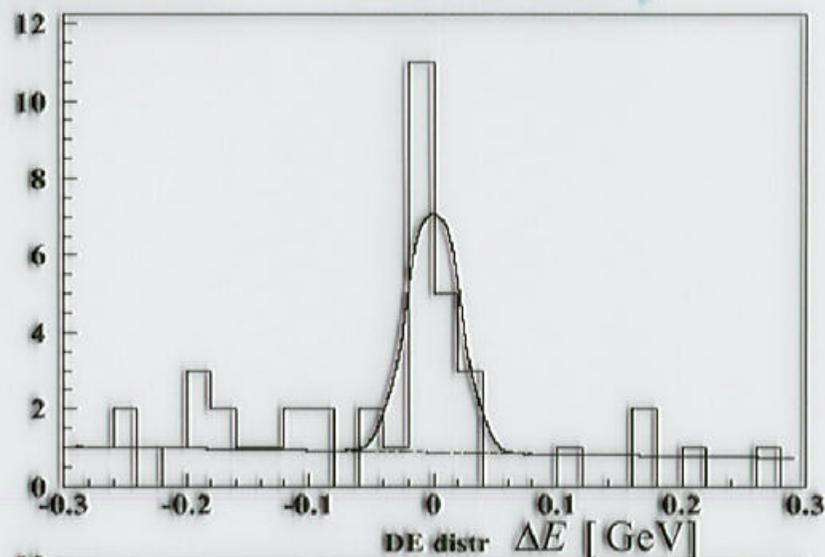
$$\cos(\theta_B^*) < 0.8$$

$$\cos(P_B, Thrust) < 0.8$$

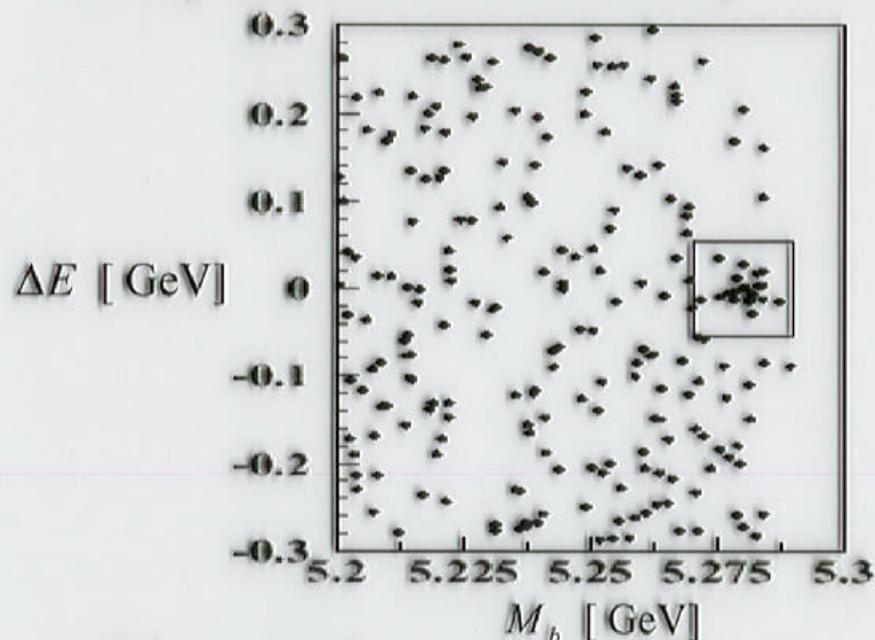
$$\cos(\theta_H^\phi) > 0.5$$



$B^\pm \rightarrow \phi K^\pm$
Preliminary



Unbinned ML fit
in M_b and ΔE simultaneously



$$B^\pm \rightarrow \phi K^\pm, n_s = 17.8^{+4.8}_{-4.2}$$

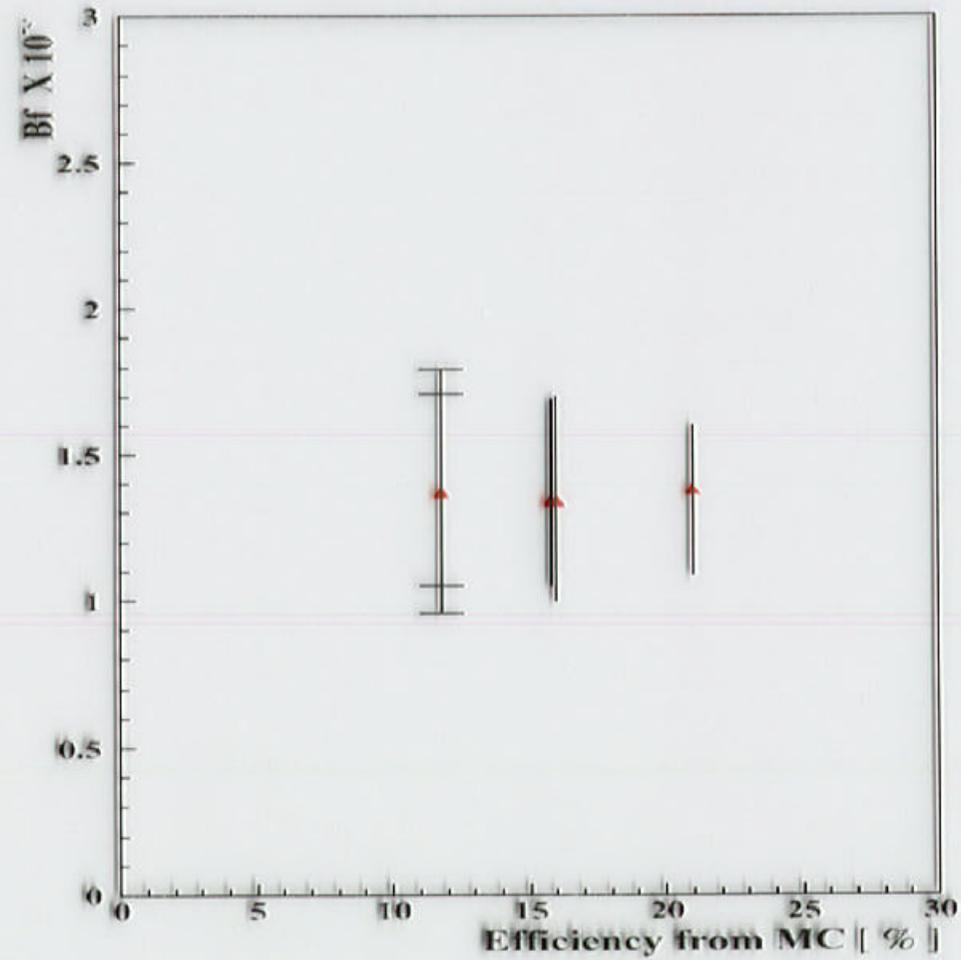
significance 7.5σ

eff. 11.8% (includes BF's)

$$BF(B^\pm \rightarrow \phi K^\pm) = (1.39^{+0.37}_{-0.33} \quad ^{+0.14}_{-0.24}) \times 10^{-5}$$

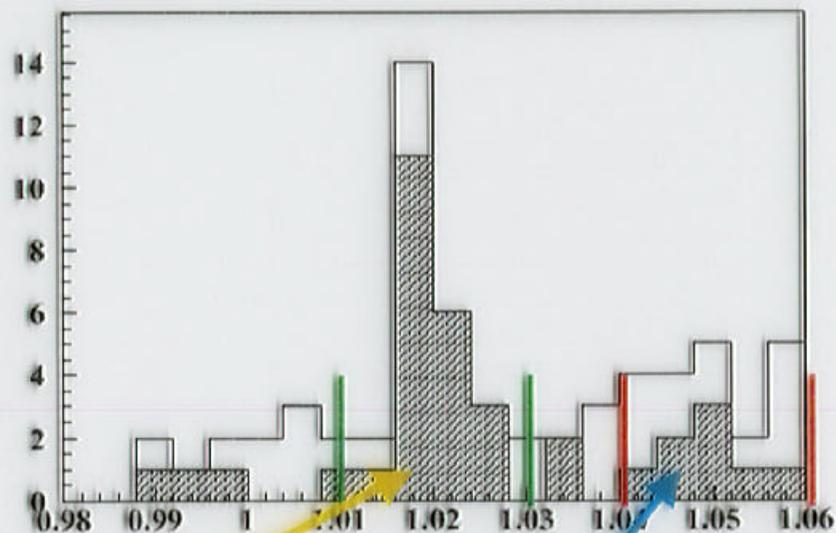


BF vs. Efficiency



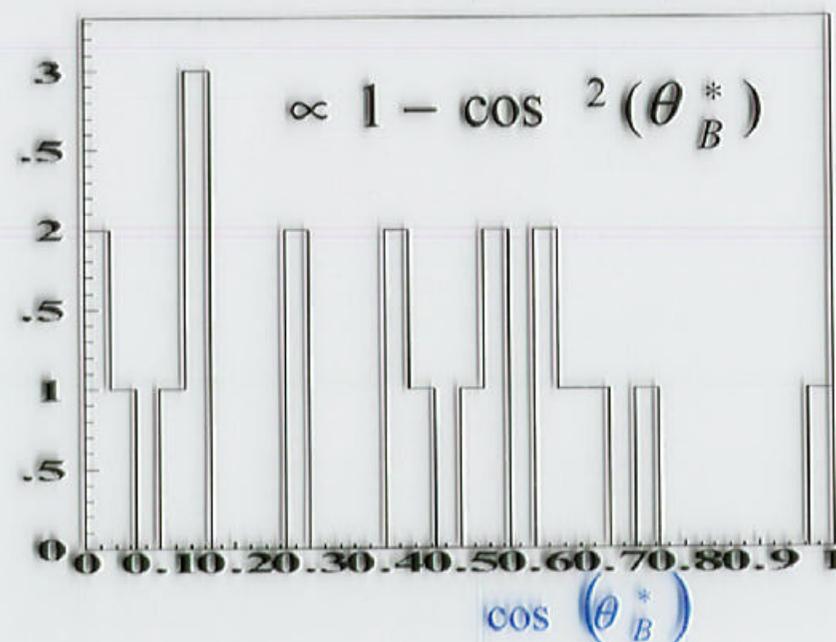
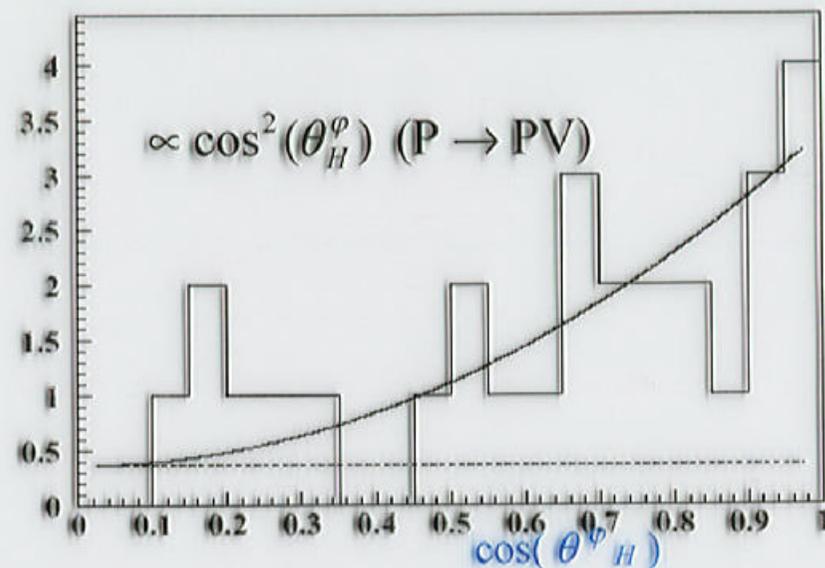


$B^\pm \rightarrow \phi K^\pm$
Preliminary



Signal region

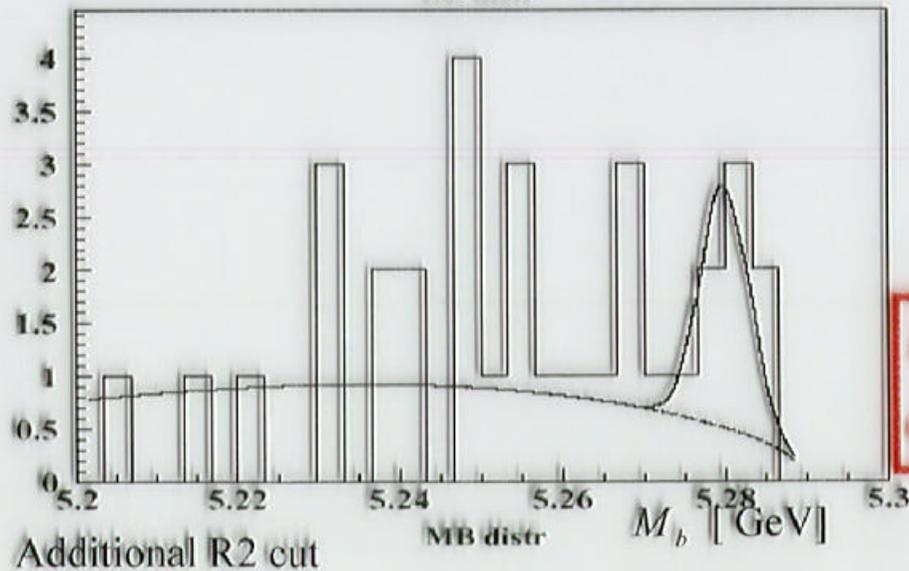
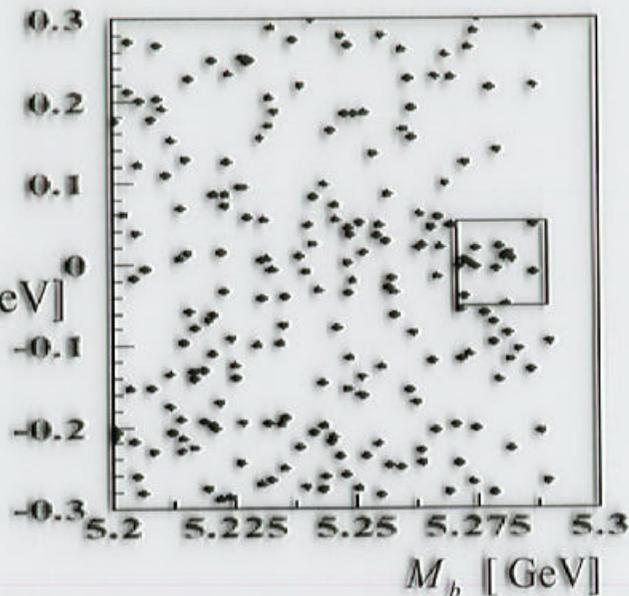
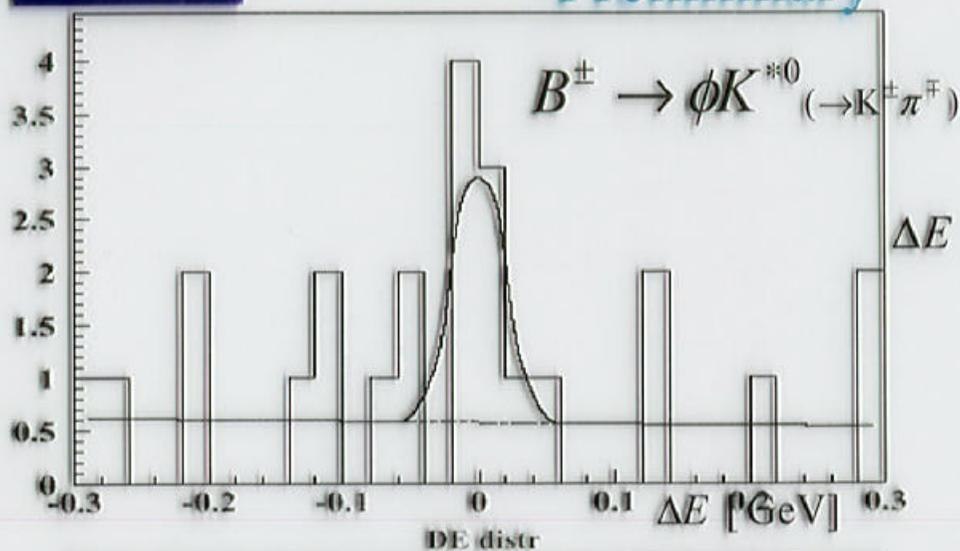
Sideband region used for non-resonant KK contribution estimation.





$B^0 \rightarrow \phi K^{*0}$ ($B \rightarrow VV$)

Preliminary



$$B^0 \rightarrow \phi K^{*0} (\rightarrow K^\pm \pi^\mp) 6.5^{+3.5}_{-2.7}$$

significance 3.6σ

efficiency 4.0%

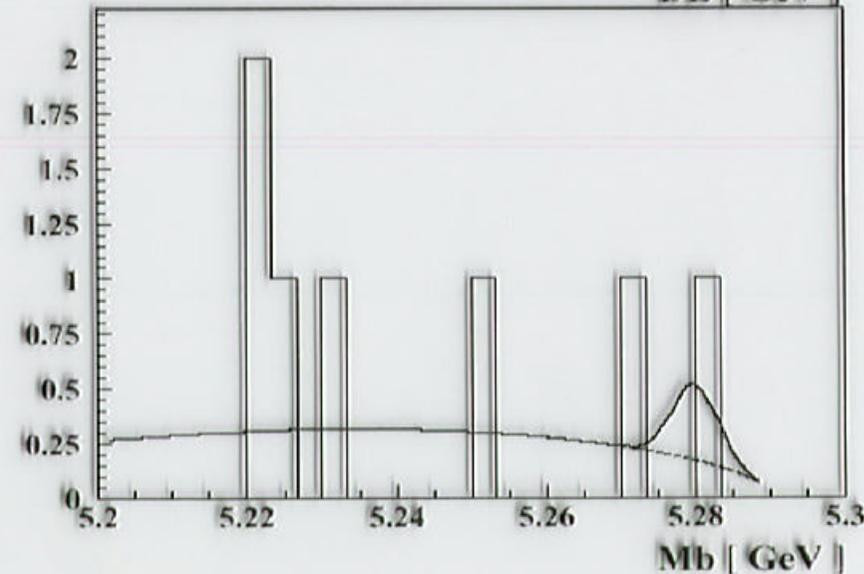
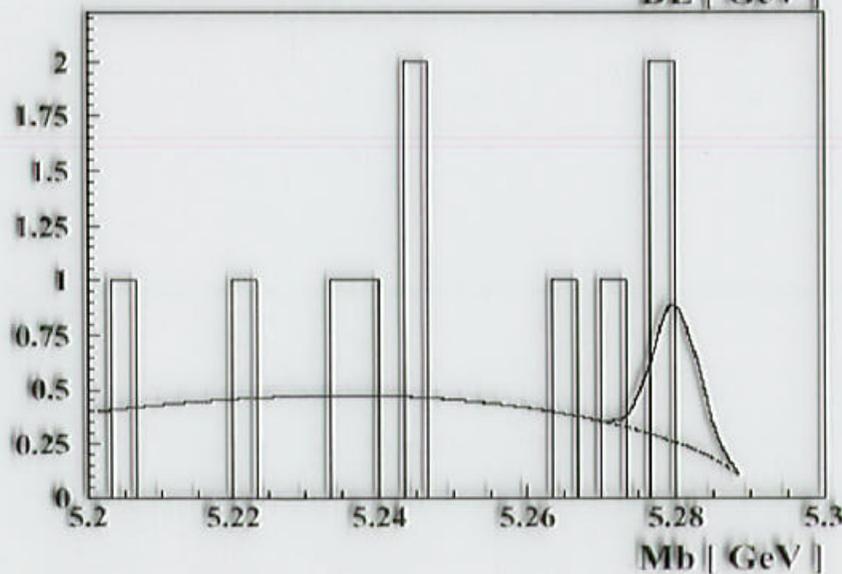
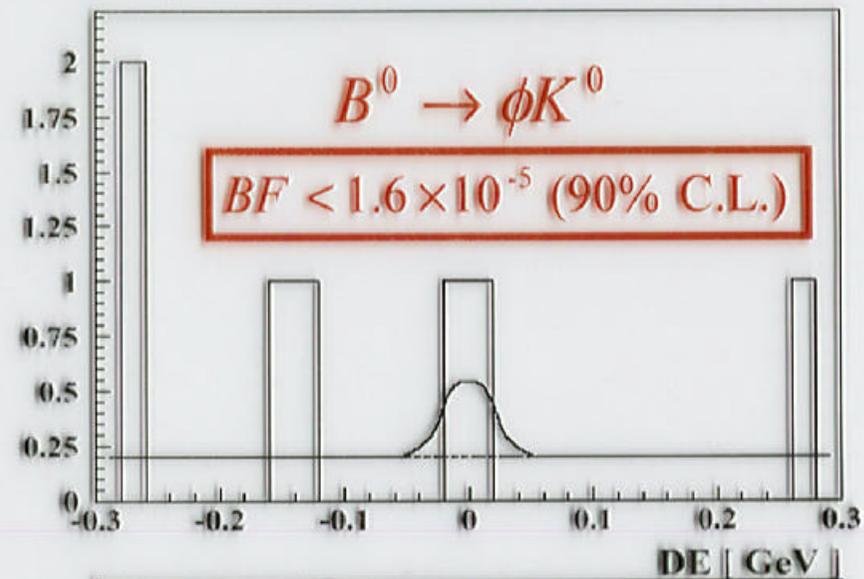
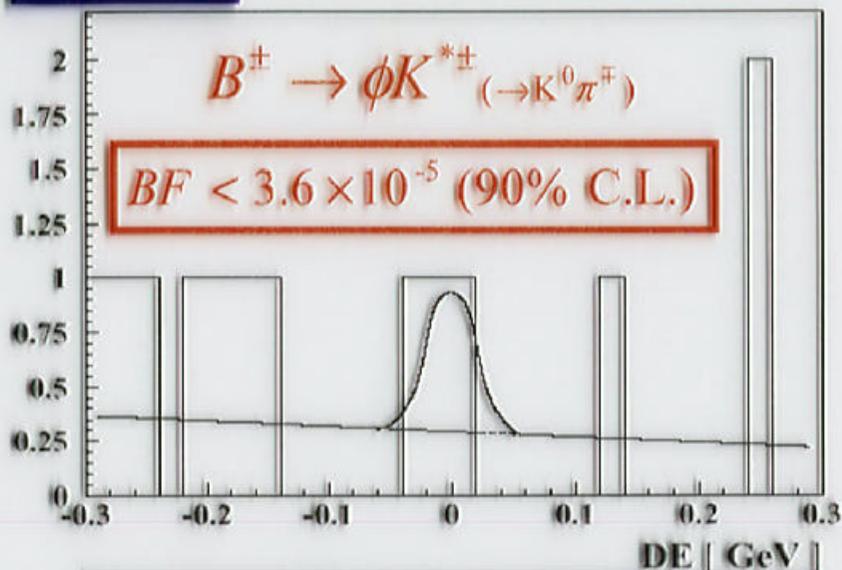
$$BF(B^0 \rightarrow \phi K^{*0}) < 3.0 \times 10^{-5} \text{ (90\% C.L.)}$$

$$\text{or } BF(B^0 \rightarrow \phi K^{*0}) = (1.5^{+0.8}_{-0.6} \pm 0.3) \times 10^{-5}$$

$M_b, \Delta E$ unbinned ML fit

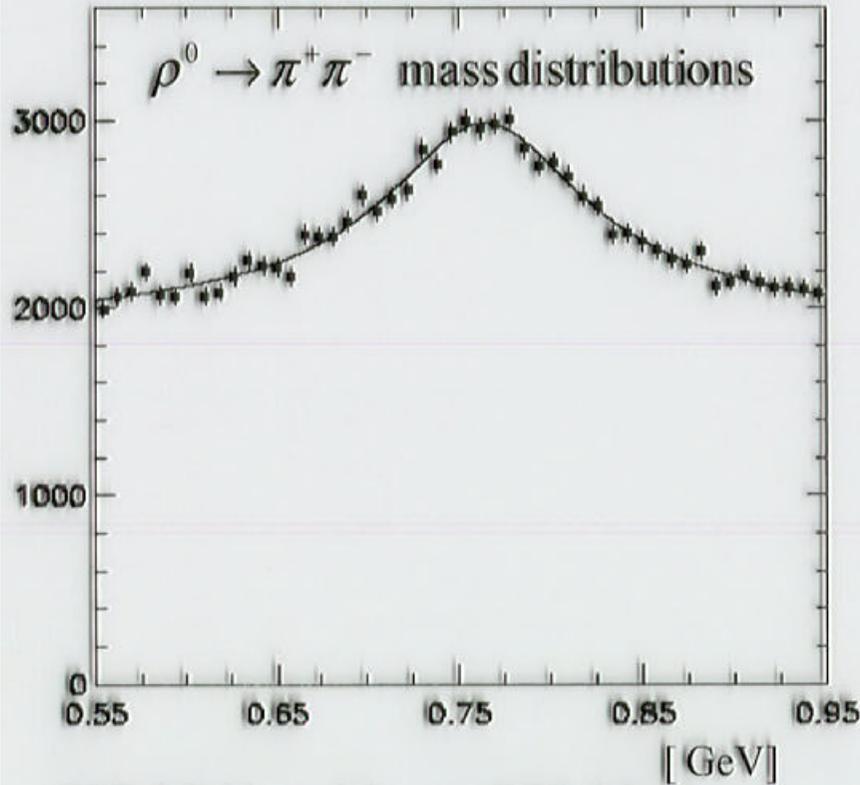


Preliminary



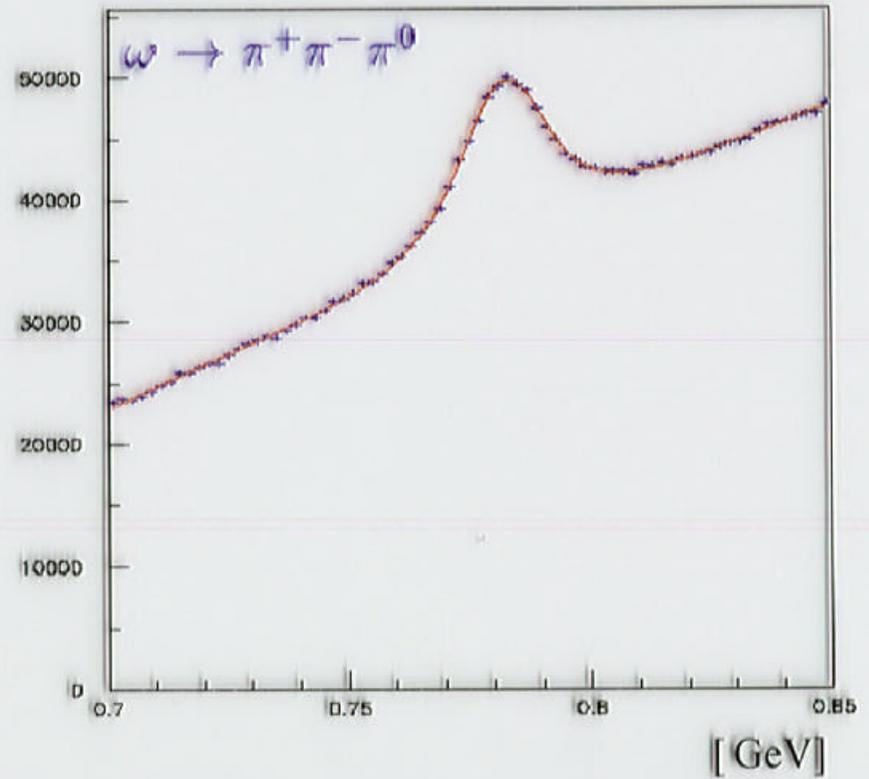


$B \rightarrow \rho h, \omega h$ search



$$610 \text{ MeV} < M_{\rho^0} < 950 \text{ MeV}$$

$$|m_{\pi^+ \pi^0} - m_{\rho^+}| < 200 \text{ MeV}$$



$$|m_{\pi^+ \pi^- \pi^0} - m_{\omega^0}| < 30 \text{ MeV}$$



$B \rightarrow \rho h, \omega h$ search

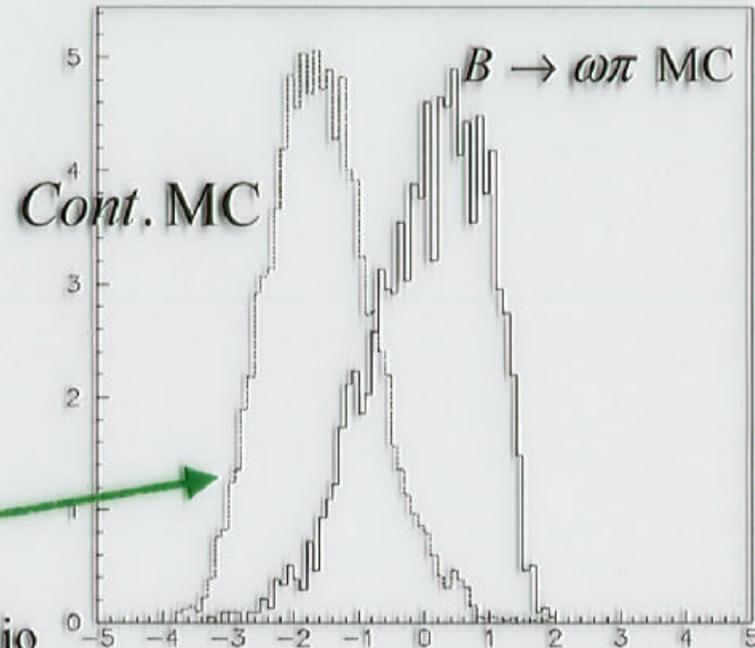
Fox-Wolfram moments used
(extended definition)

SFW $R_l = H_l/H_0$; $H_l = \sum ||p_i|| |p_j| P_l(\cos\theta_{ij})$
 $P_l(\cos\theta_{ij})$: l th Legendary polynomial

$R_l = R^{so} + R^{oo}$; l ranges from 1 to 4 (only uncorelated with Mb or ΔE R^{xx} are used)

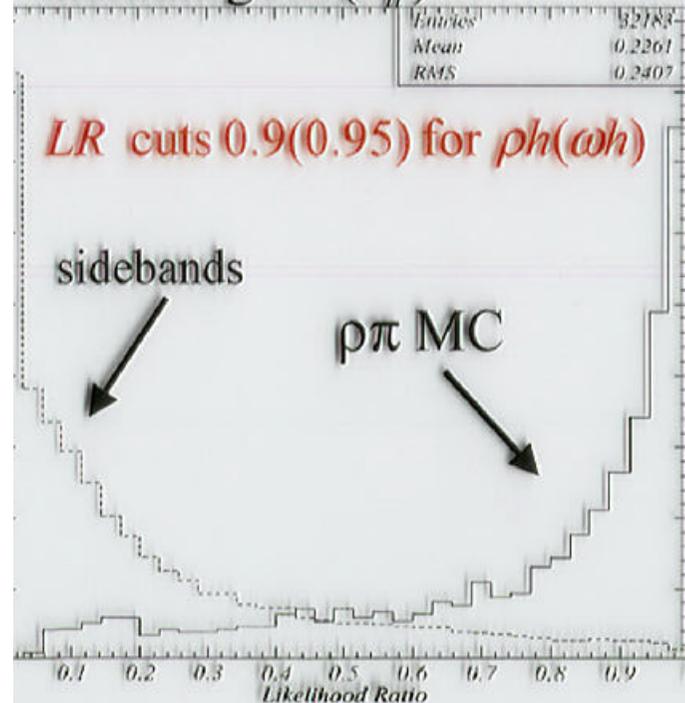
- Fisher discriminant variable is formed

including $\cos(\theta_H)$



Entries	52783
Mean	0.2261
RMS	0.2407

LR cuts 0.9(0.95) for $\rho h(\omega h)$



Likelihood ratio

- B meson production angle
- ρ, ω helicity angle
- Fisher discriminant (SFW variables and thrust angle)
- angle between $\rho\pi$ (for $\rho^0\pi^\pm$ mode)
- for ω decay a variable $\propto (\overline{p_\pi} \times \overline{p_\pi})$

$$LR = \frac{PDF_s}{PDF_s + PDF_b}$$



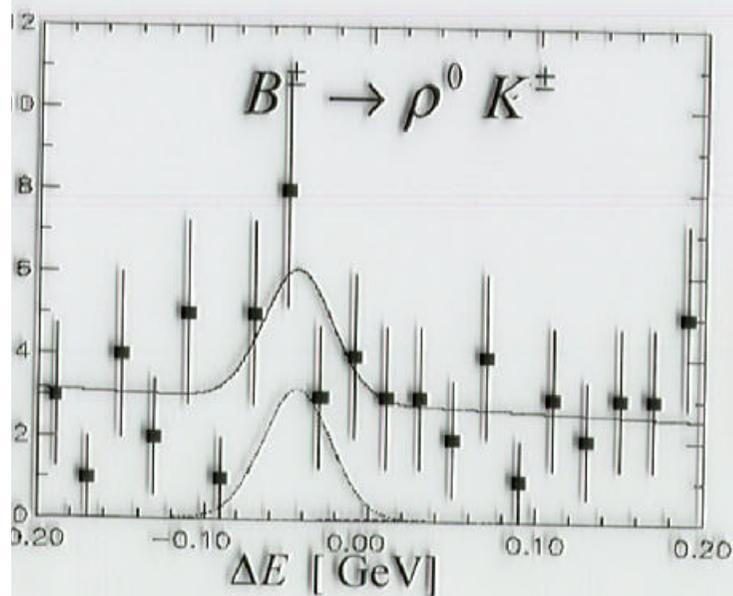
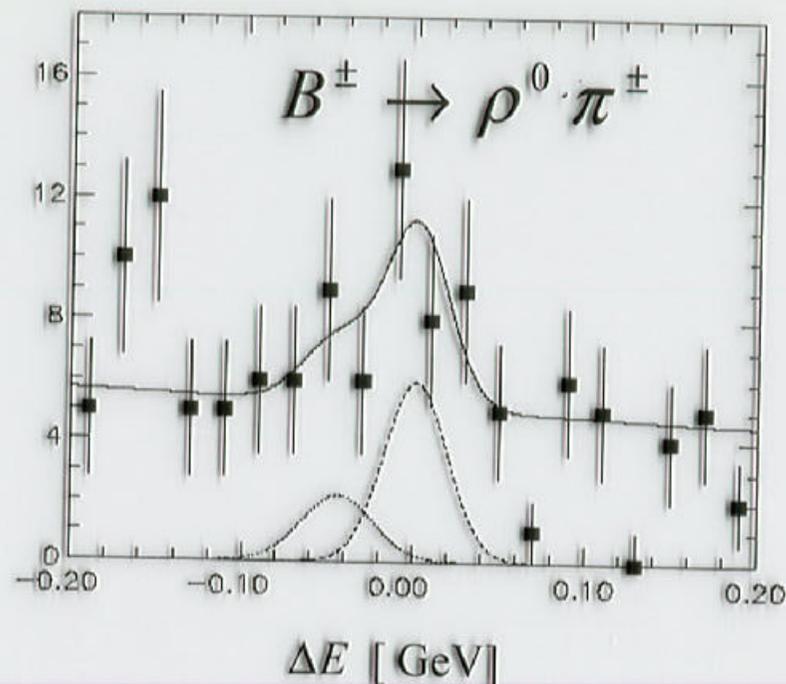
$$B^{\pm} \rightarrow \rho^0 h^{\pm}$$

$$B^{\pm} \rightarrow \rho^0 \pi^{\pm}$$

Preliminary

Yield $13.73^{+6.53}_{-5.85}$ significance 2.9σ

$BF(B^{\pm} \rightarrow \rho^0 \pi^{\pm}) < 1.88 \times 10^{-5}$ (90% C.L.)
or $BF(B^{\pm} \rightarrow \rho^0 \pi^{\pm}) = (1.12^{+.53}_{-.48} \pm 0.19) \times 10^{-5}$



$$B^{\pm} \rightarrow \rho^0 K^{\pm}$$

Preliminary

Yield $8.29^{+5.07}_{-4.43}$ significance 2.0σ

$BF(B^{\pm} \rightarrow \rho^0 K^{\pm}) < 1.35 \times 10^{-5}$ (90% C.L.)
or $BF(B^{\pm} \rightarrow \rho^0 K^{\pm}) = (0.72^{+.44}_{-.38} \pm 0.12) \times 10^{-5}$



$$B^0 \rightarrow \rho^{\mp} h^{\pm}$$

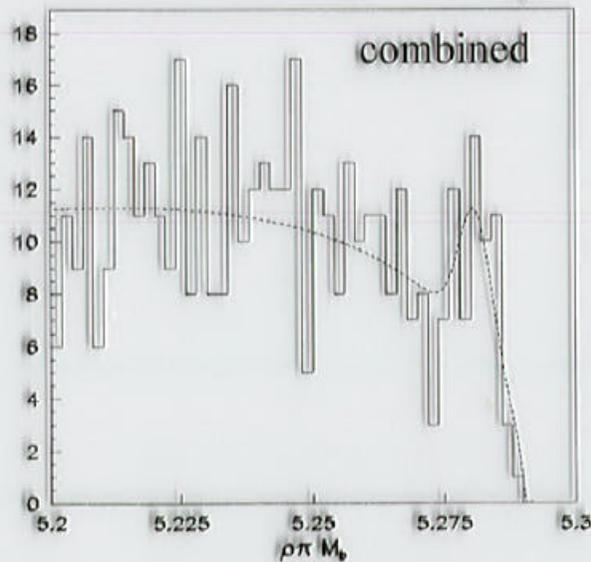
Preliminary

mode	Signal Yield	Efficiency (%)	Significance
$\rho\pi, \mathcal{H} > 0$	$10.9^{+5.5}_{-4.8}$	3.85	2.6
$\rho\pi, \mathcal{H} < 0$	$10.1^{+5.5}_{-4.7}$	5.59	2.4
$\rho K, \mathcal{H} > 0$	$5.0^{+3.8}_{-3.3}$	3.42	1.9
$\rho K, \mathcal{H} < 0$	$4.6^{+4.1}_{-3.3}$	4.92	1.5

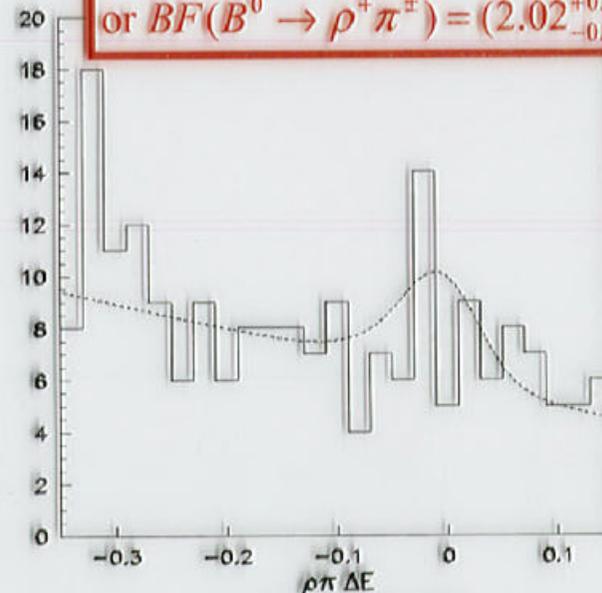
$\left. \begin{matrix} 2.6 \\ 2.4 \end{matrix} \right\} \Rightarrow 3.5 \text{ (combined)}$
 $\left. \begin{matrix} 1.9 \\ 1.5 \end{matrix} \right\} \Rightarrow 2.2 \text{ (combined)}$

$$B^0 \rightarrow \rho^{\mp} \pi^{\pm}$$

$BF(B^0 \rightarrow \rho^{\mp} \pi^{\pm}) < 3.57 \times 10^{-5} \text{ (90\% C.L.)}$
 or $BF(B^0 \rightarrow \rho^{\mp} \pi^{\pm}) = (2.02^{+0.83}_{-0.66} \pm 0.33) \times 10^{-5}$



M_b [GeV]



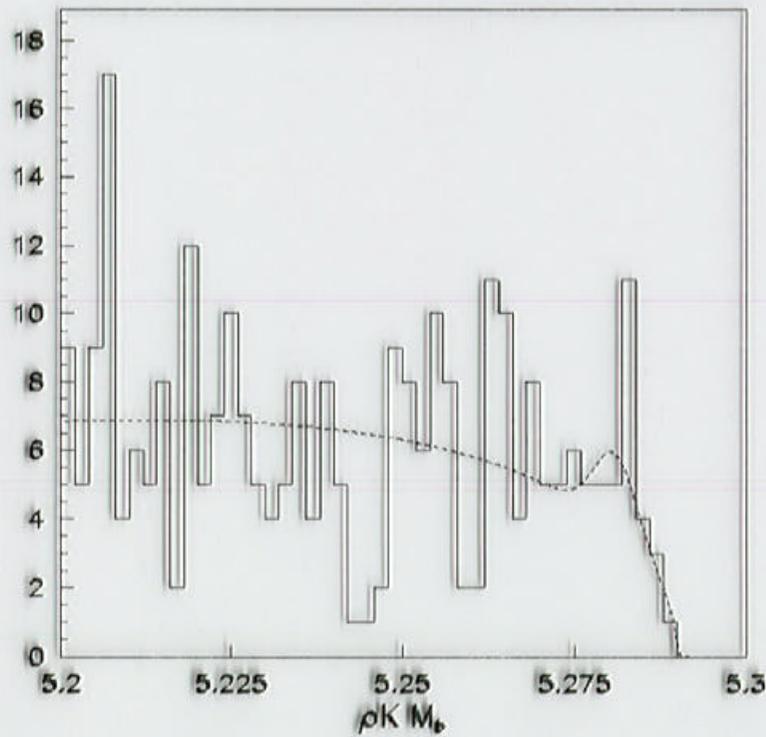
ΔE [GeV]



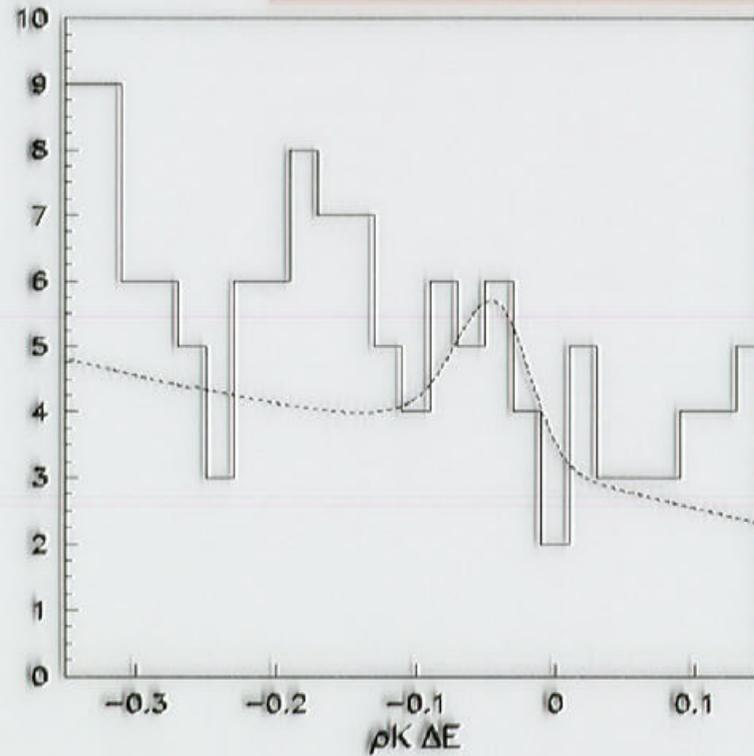
$$B^0 \rightarrow \rho^{\mp} h^{\pm}$$

Preliminary

$$B^0 \rightarrow \rho^{\mp} K^{\pm} \quad BF < 2.36 \times 10^{-5} \text{ (90\% C.L.)}$$



M_b [GeV]

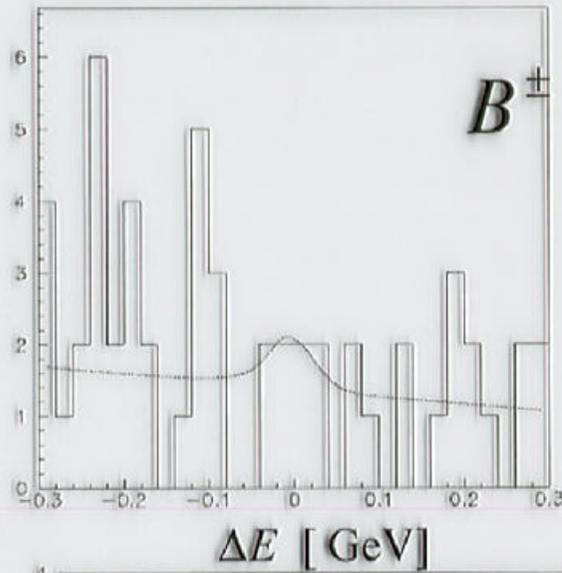


ΔE [GeV]



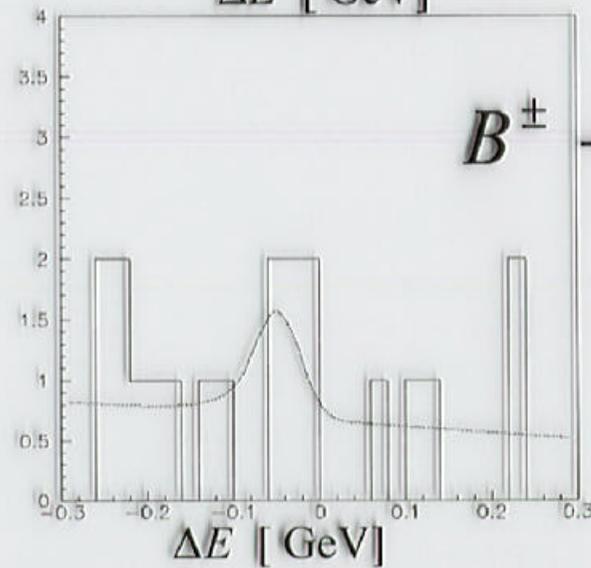
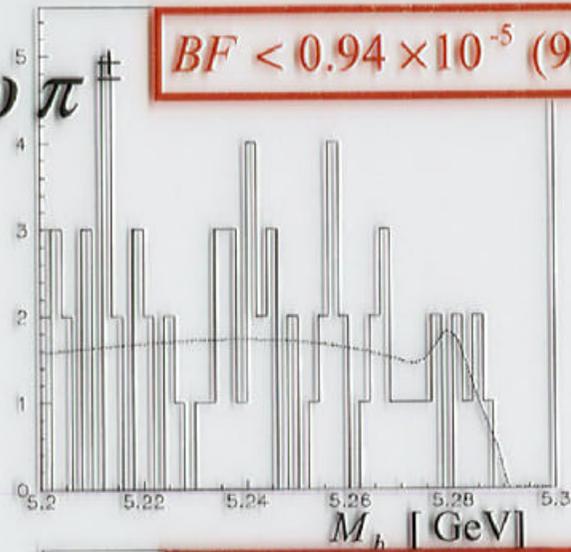
$B^\pm \rightarrow \omega h^\pm$

Preliminary



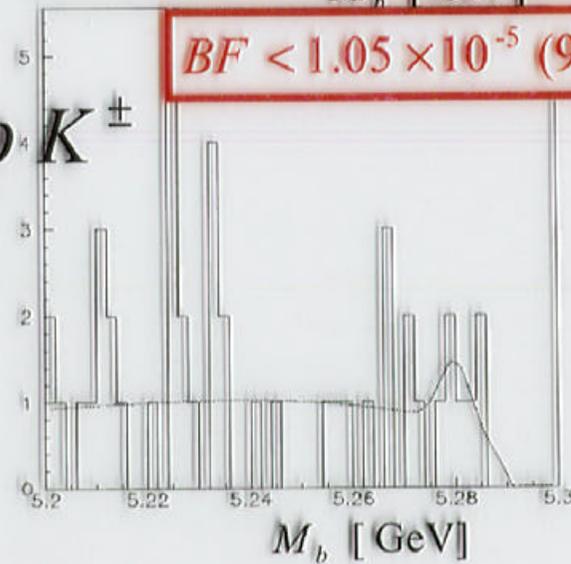
$B^\pm \rightarrow \omega \pi^\pm$

$BF < 0.94 \times 10^{-5}$ (90% C.L.)



$B^\pm \rightarrow \omega K^\pm$

$BF < 1.05 \times 10^{-5}$ (90% C.L.)





Summary

Preliminary

mode	Signal Yield	Eff.(%)	Signif.	BR ($\times 10^{-5}$)	UL 90% C.L. ($\times 10^{-5}$)	old BR ($\times 10^{-5}$)
$B^+ \rightarrow \phi(1020)K^+$	$17.8^{+1.8}_{-1.2}$	1.8	7.5	$1.39^{+0.37+0.14}_{-0.33-0.24}$		$1.72^{+0.67}_{-0.54} \pm 0.18$ Belle $0.55^{+0.21}_{-0.18} \pm 0.18$ Cleo
$B^0 \rightarrow \phi(1020)K^0$	$0.9^{+1.5}_{-0.8}$	3.0	1.2		1.6	< 1.23 Cleo
$B^+ \rightarrow \phi(1020)K^{*0}$	$6.5^{+3.5}_{-2.7}$	4.4	3.6	$1.5^{+0.8}_{-0.6} \pm 0.3$	3.0	$1.15^{+0.45+0.18}_{-0.37-0.17}$ Cleo
$B^+ \rightarrow \phi(1020)K^{*+}$	$1.3^{+1.8}_{-1.1}$	2.0	1.1		3.6	< 2.25 Cleo
$B^+ \rightarrow \rho^0\pi^+$	$13.73^{+6.33}_{-5.85}$	11.5	2.9	$1.12^{+0.53}_{-0.48} \pm 0.19$	1.88	$1.04 \pm 0.33 \pm 0.21$ Cleo $2.4 \pm 0.8 \pm 0.3$ Babar
$B^+ \rightarrow \rho^0K^+$	$8.29^{+5.07}_{-4.13}$	9.8	2.0		1.35	$0.84 \pm 0.38 \pm 0.18$ Cleo $1.0 \pm 0.6 \pm 0.2$ Babar
$B^0 \rightarrow \rho^+\pi^-$	$21.0^{+7.8}_{-6.7}$	4.7	3.9	$2.02^{+0.83}_{-0.66} \pm 0.33$	3.57	$2.76^{+0.81}_{-0.74} \pm 0.42$ Cleo $4.9 \pm 1.3^{+0.6}_{-0.5}$ Babar
$B^0 \rightarrow \rho^+K^-$	$9.6^{+5.6}_{-4.7}$	4.7	2.5		2.36	< 0.79 Cleo
$B^+ \rightarrow \omega h^+$	6.43 ± 8.94	11.5	1.8		1.41	< 2.2 Babar
$B^+ \rightarrow \omega\pi^+$	$2.86^{+2.59}_{-2.75}$	10.8	1.3		0.94	1.13 ± 0.14 Cleo
$B^+ \rightarrow \omega K^+$	$3.44^{+3.00}_{-2.21}$	9.3	1.8		1.05	< 0.79 Cleo



Summary

- First observation of $B^\pm \rightarrow \phi K^\pm$ reported at ICHEP200 is confirmed with larger statistical significance $\approx 8\sigma$
- Evidence for $B^{*\pm} \rightarrow \phi K^{*\pm}$, which could be the 1st observation of charmless $B \rightarrow VV$.
- Evidence of $B \rightarrow \rho^0 \pi$ and $B \rightarrow \rho^\pm \pi$ in our data.
- No observation of $B \rightarrow \omega h$