

$B \rightarrow \rho K^*$ and rare VV modes

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Outline

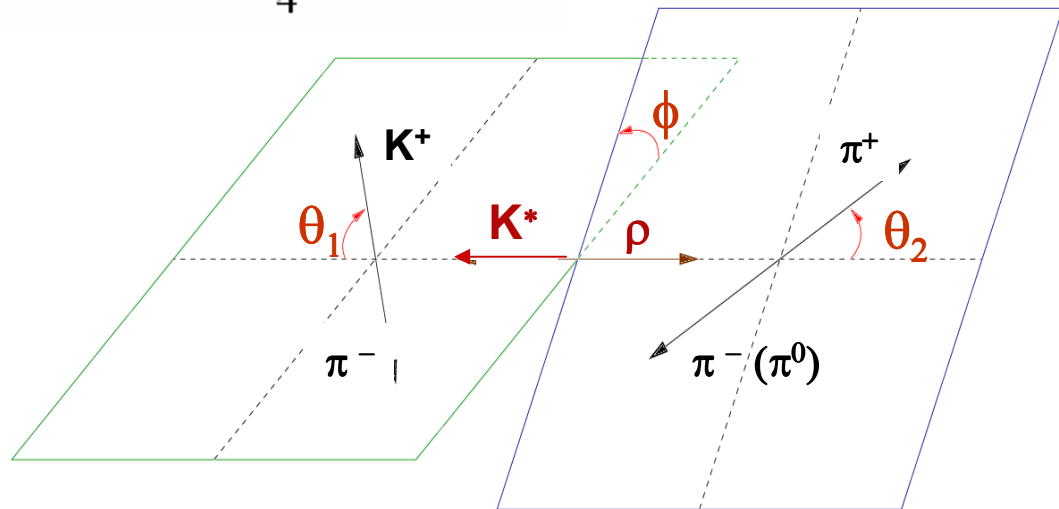
- Motivations
- ρK^* modes
- Modes with ω
- Conclusion

- Note:
 - φK^* modes: see Chen's talk
 - $\rho\rho$ modes: see Somov's talk

Motivations

- Find some **unobserved signal**.
- Compare **branching fractions** with model prediction.
- Measure **fraction of longitudinal polarization**.

$$\frac{dN}{d \cos \theta_1 d \cos \theta_2} \sim f_L \times (\cos \theta_1 \cos \theta_2)^2 + (1 - f_L) \times \frac{1}{4} (\sin \theta_1 \sin \theta_2)^2$$



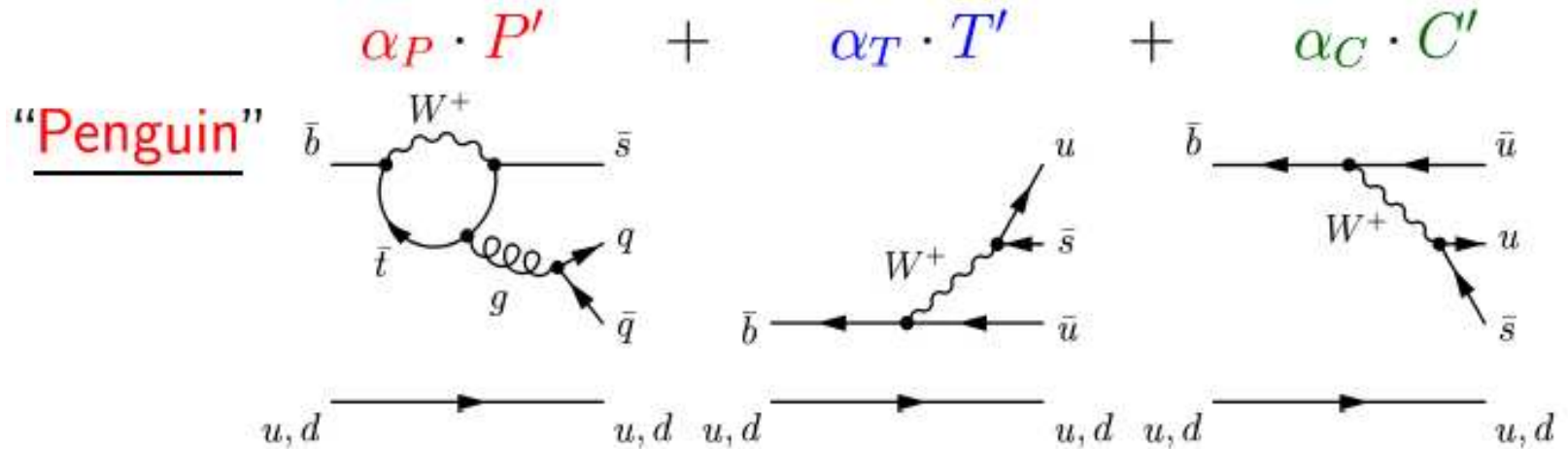
- Measure **direct CP violation**.
- Later can be used for CP studies.
 - $\rho^+ K^{*0}$ used to reduce penguin error on α

Polarization puzzle

- Helicity conservation argument:
 - f_L close to 1
 - Expected to be true for both **tree** and **penguins**
- Experimental situation more complex:
 - $f_L \sim 1$ in $\rho\rho$ (tree dominated)
 - $f_L \sim 0.5$ in ϕK^* (penguin dominated)
- Tentative explanations:
 - Rescattering, Annihilation or EW penguin, Transverse gluon, New physics
- Measure other VV modes:
 - Tree-dominated: $\omega \rho$, $\omega \omega$
 - Penguin-dominated: ρK^* , ωK^*

$$f_L \approx 1 - m_V^2/m_B^2$$

B \rightarrow ρ K^* modes

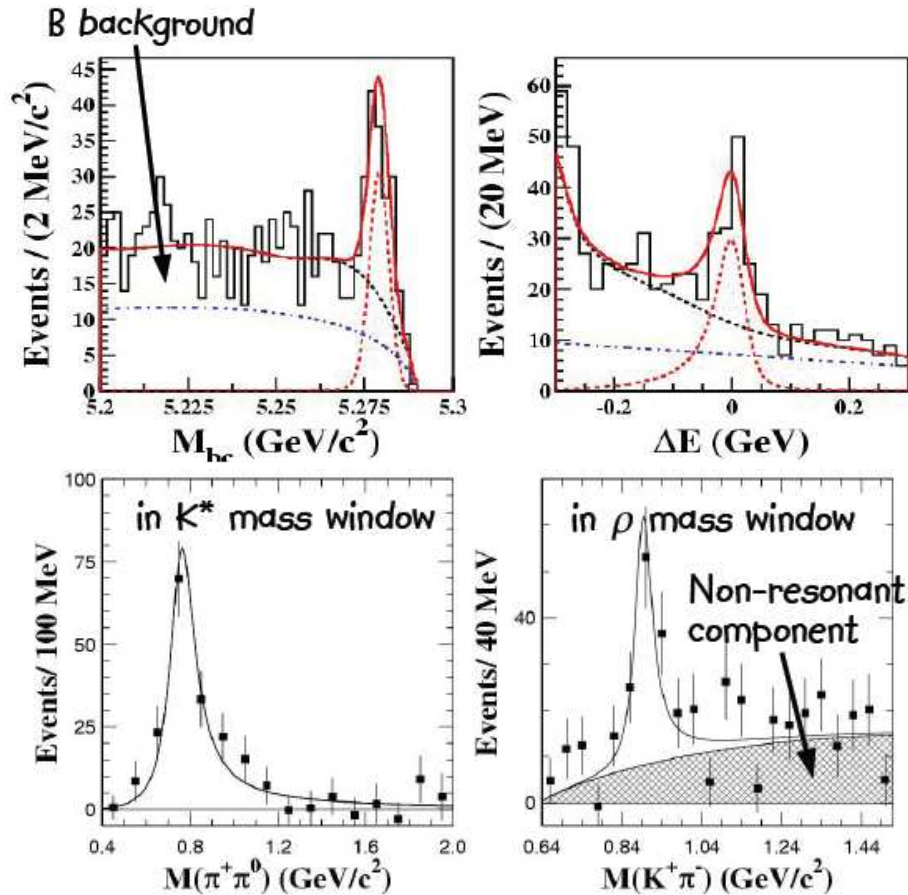


- $B \rightarrow \rho K^*$ are charmless hadronic decays, **dominated by a $b \rightarrow s g$ penguin diagram.**
 - Tree doubly Cabibbo-suppressed.
- $B^+ \rightarrow \rho^+ K^{*0}$ is a pure penguin.

	α_P	α_T	α_C
$\rho^+ K^{*0}$	$\sqrt{2}$	0	0
$\rho^- K^{*+}$	$-\sqrt{2}$	$-\sqrt{2}$	0
$\rho^0 K^{*0}$	1	0	-1
$\rho^0 K^{*+}$	-1	-1	-1

BELLE results on $\rho^+ K^{*0}$

- Signal yield extracted by a fit to ΔE and M_{bc} in bins of $M_{\pi\pi}$ and $M_{K\pi}$
 - Large non resonant component in $K\pi$ mass
 - Signal significance: 5.3σ



275 x 10⁶ BB



$$N(\rho^+ K^{*0}) = 85.4 \pm 16.1$$

$$BR(\rho^+ K^{*0}) = (8.9 \pm 1.7 \pm 1.2) 10^{-6}$$

$$f_L(\rho^+ K^{*0}) = 0.43 \pm 0.11^{+0.05}_{-0.02}$$

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BABAR ρK^* analyses

- Search for the four ρK^* channels
- Unbinned maximum likelihood fit based on 7 variables:
 - M_{ES} , ΔE ,
 - Event shape NN or Fisher,
 - $M_{K\pi}$, $M_{\pi\pi}$, $\cos \theta_{K\pi}$, $\cos \theta_{\pi\pi}$
- Main difficulty: **non resonant and other resonances** :
 - Studied in enlarged vector meson mass windows



Non-resonant in ρK^*

$$B \rightarrow (\pi\pi)_{S\text{-wave}} K^*$$

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

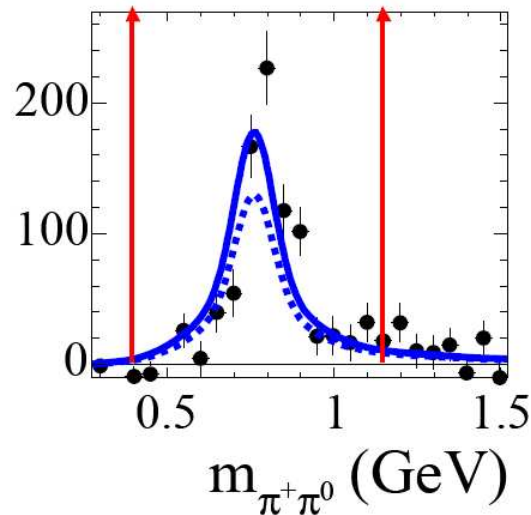
$$B \rightarrow f_0(1370) K^{*0}$$

$$B \rightarrow \rho(K\pi)_{S\text{-wave}}$$

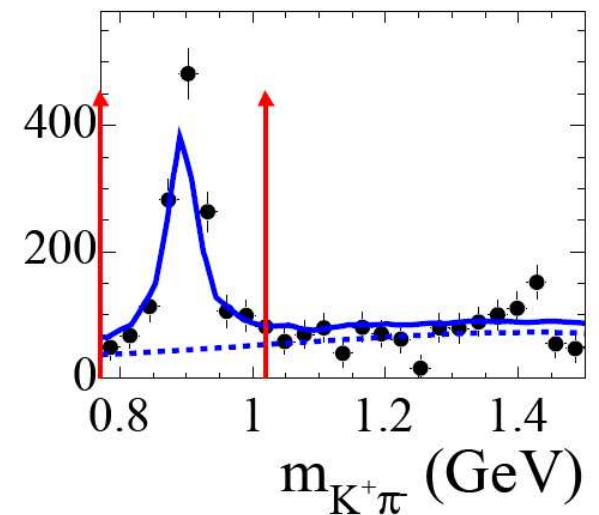
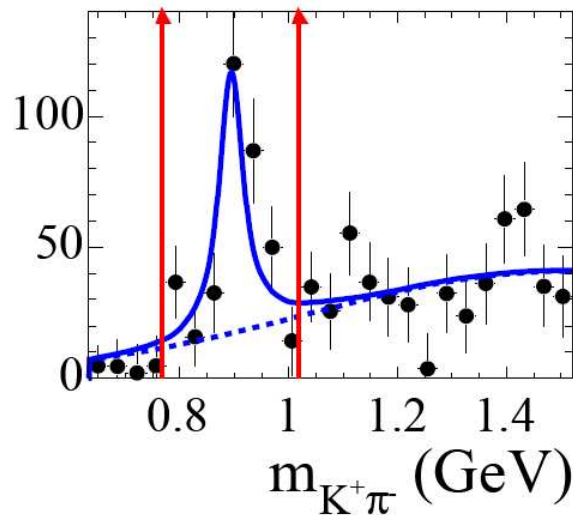
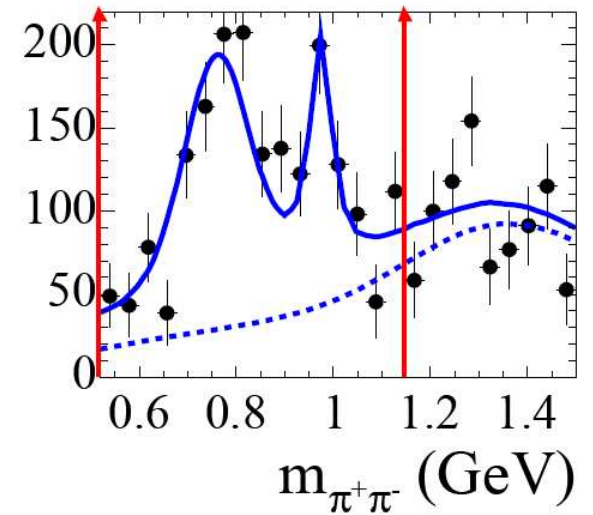
$$B \rightarrow \pi\pi K\pi$$



$$B^+ \rightarrow \rho^+ K^{*0}$$



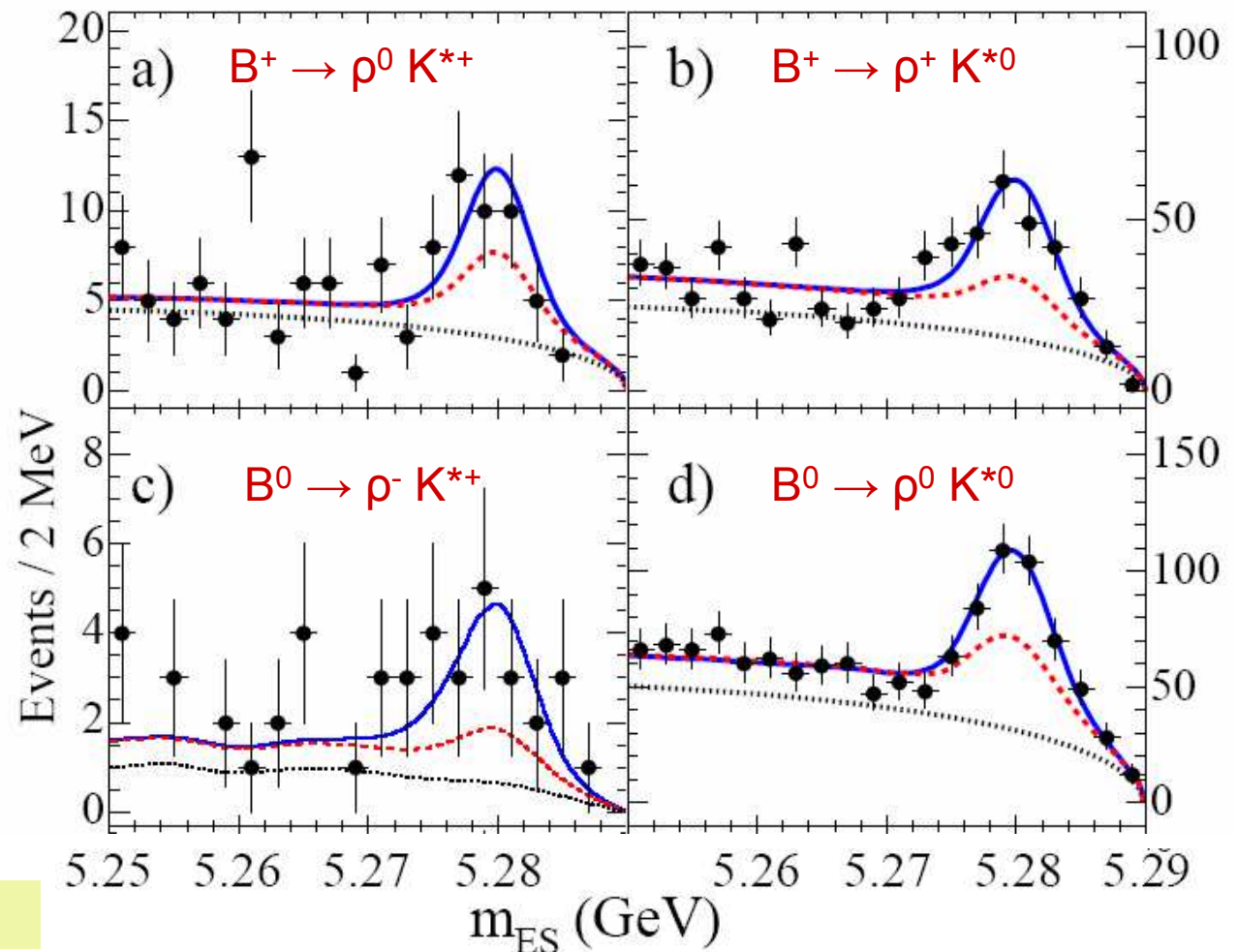
$$B^0 \rightarrow \rho^0 K^{*0}$$



ρK^* signals



- Significant signals seen in $\rho^+ K^{*0}$ (7.1σ) & $\rho^0 K^{*0}$ (5.3σ).
- Non significant signals seen in $\rho^0 K^{*+}$ (2.5σ) & $\rho^- K^{*+}$ (1.6σ).
 - However $f_0 K^{*+}$ observed



$$BR(f_0 K^{*+}) = (5.2 \pm 1.2 \pm 0.5) 10^{-6}$$

ρK^* results

Mode	BR ($\times 10^{-6}$)	f_L	A_{CP}
$B^+ \rightarrow \rho^0 K^{*+}$	< 6.1 ($3.6 \pm 1.7 \pm 0.8$)	[0.9 ± 0.2]	
$B^0 \rightarrow \rho^- K^{*+}$	< 12.0 ($5.4 \pm 3.6 \pm 1.6$)		
$B^+ \rightarrow \rho^+ K^{*0}$	$9.6 \pm 1.7 \pm 1.5$	$0.52 \pm 0.10 \pm 0.04$	$-0.01 \pm 0.16 \pm 0.02$
$B^0 \rightarrow \rho^0 K^{*0}$	$5.6 \pm 0.9 \pm 1.3$	$0.57 \pm 0.09 \pm 0.08$	$0.09 \pm 0.19 \pm 0.02$

Upper limits are given at 90%CL

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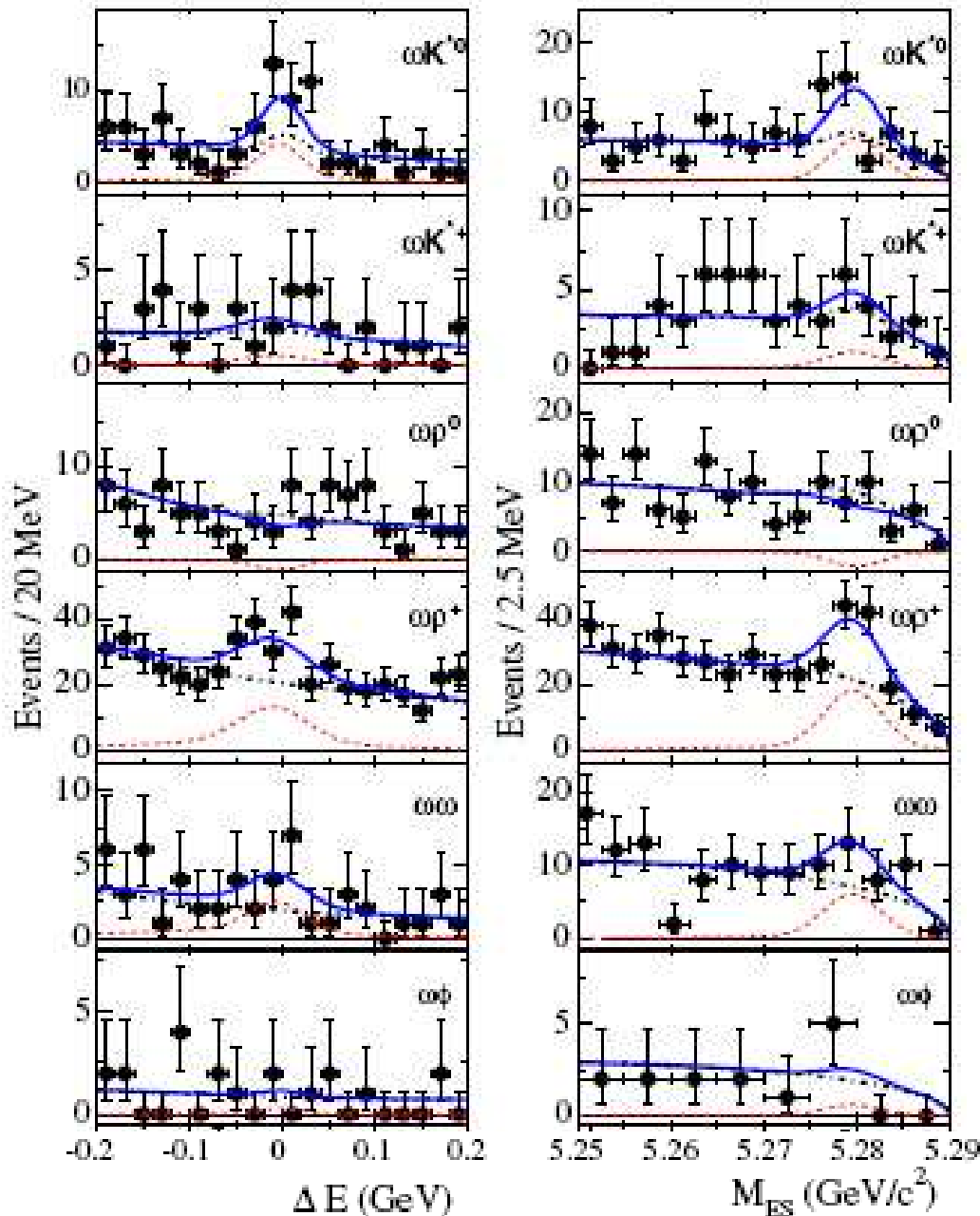
232 x 10⁶ BB

- $B^0 \rightarrow \rho^0 K^{*0}$ signal observed for the first time.
- $B^+ \rightarrow \rho^+ K^{*0}$ now in good agreement with Belle.
- BR ratio consistent with isospin expectation.
- f_L close to 0.5.



Modes with ω

- Many ωV modes searched for.
- Significant signal seen only in $\omega \rho^+$ (5.7σ).



ω V results

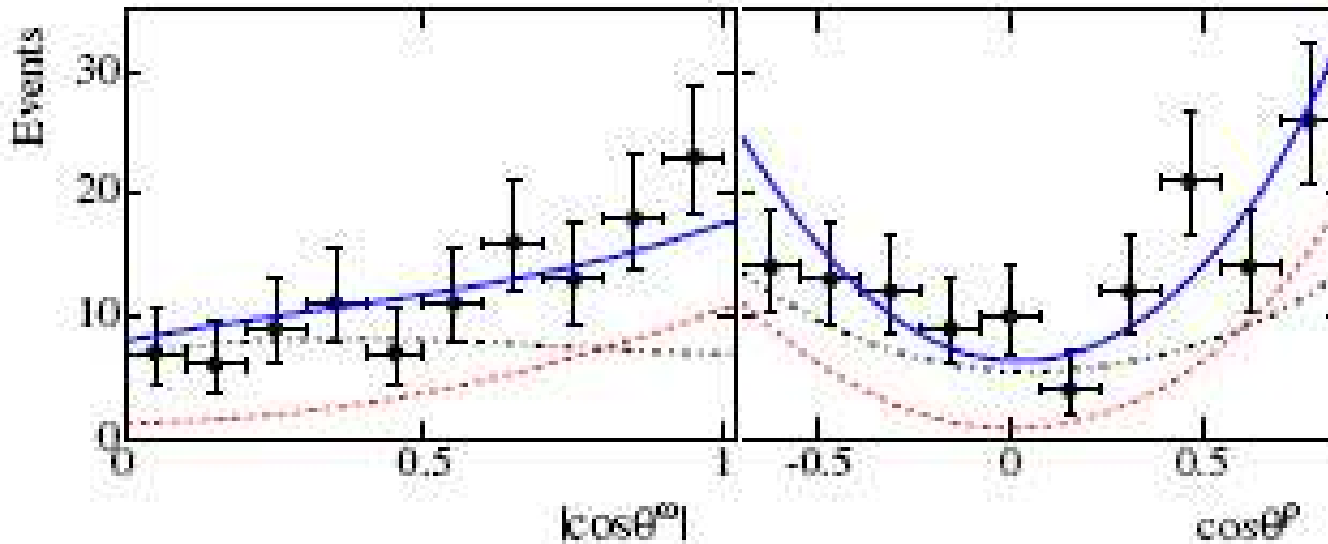
Mode	BR ($\times 10^{-6}$)	f_L
$B^0 \rightarrow \omega K^{*0}$	< 4.2 ($2.4 \pm 1.1 \pm 0.7$)	[$0.71^{+0.27}_{-0.24}$]
$B^+ \rightarrow \omega K^{*+}$	< 3.4 ($0.6 \pm 1.3 \pm 1.0$)	
$B^0 \rightarrow \omega \rho^0$	< 1.5 ($-0.6 \pm 0.7^{+0.8}_{-0.3}$)	
$B^+ \rightarrow \omega \rho^+$	$10.6 \pm 2.1^{+1.6}_{-1.0}$	$0.82 \pm 0.11 \pm 0.02$
$B^0 \rightarrow \omega \omega$	< 4.0 ($1.68^{+1.3}_{-0.9} \pm 0.4$)	[0.79 ± 0.34]
$B^0 \rightarrow \omega \varphi$	< 1.2 ($0.1 \pm 0.5 \pm 0.1$)	

232 x 10⁶ BB

f_L fixed in other modes



$\omega \rho^+$ results



232 x 10⁶ BB

$$N(\omega \rho^+) = 156 \pm 32$$

$$\text{BR}(\omega \rho^+) = (10.6 \pm 2.1^{+1.6}_{-1.0}) 10^{-6}$$

$$f_L(\omega \rho^+) = 0.82 \pm 0.11 \pm 0.02$$

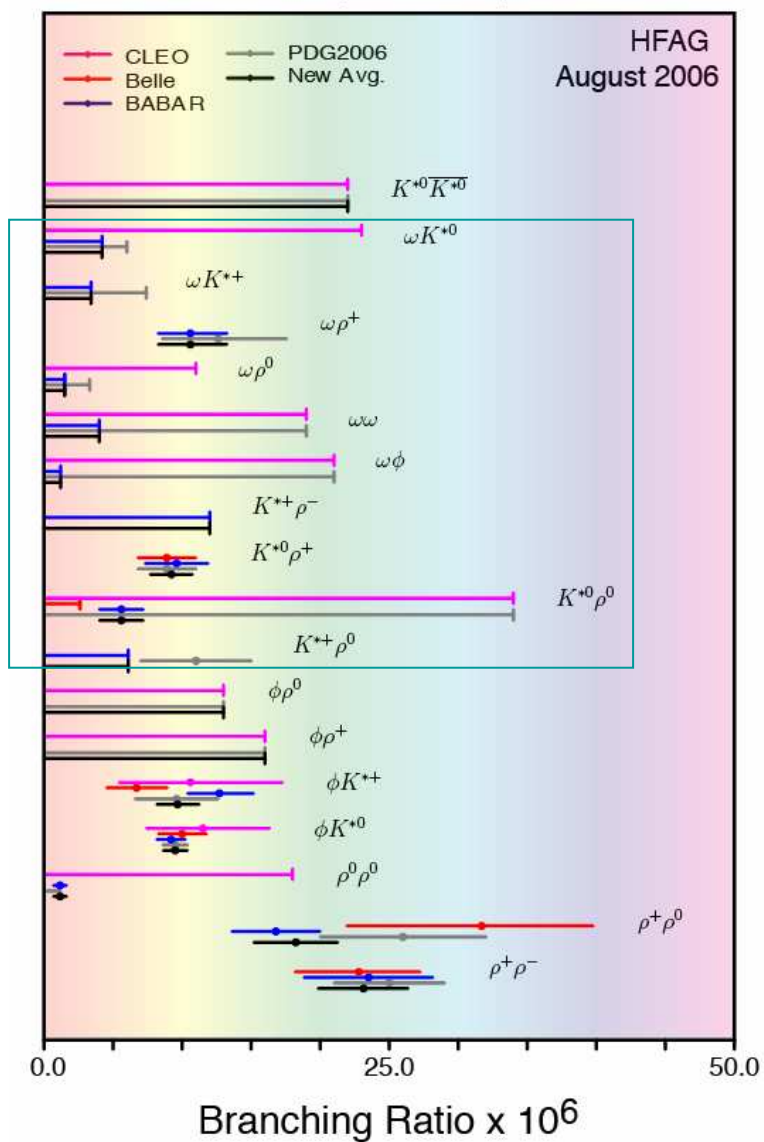
$$A_{\text{CP}}(\omega \rho^+) = 0.04 \pm 0.18 \pm 0.02$$

Phys.Rev. D 74, 051102 (2006)

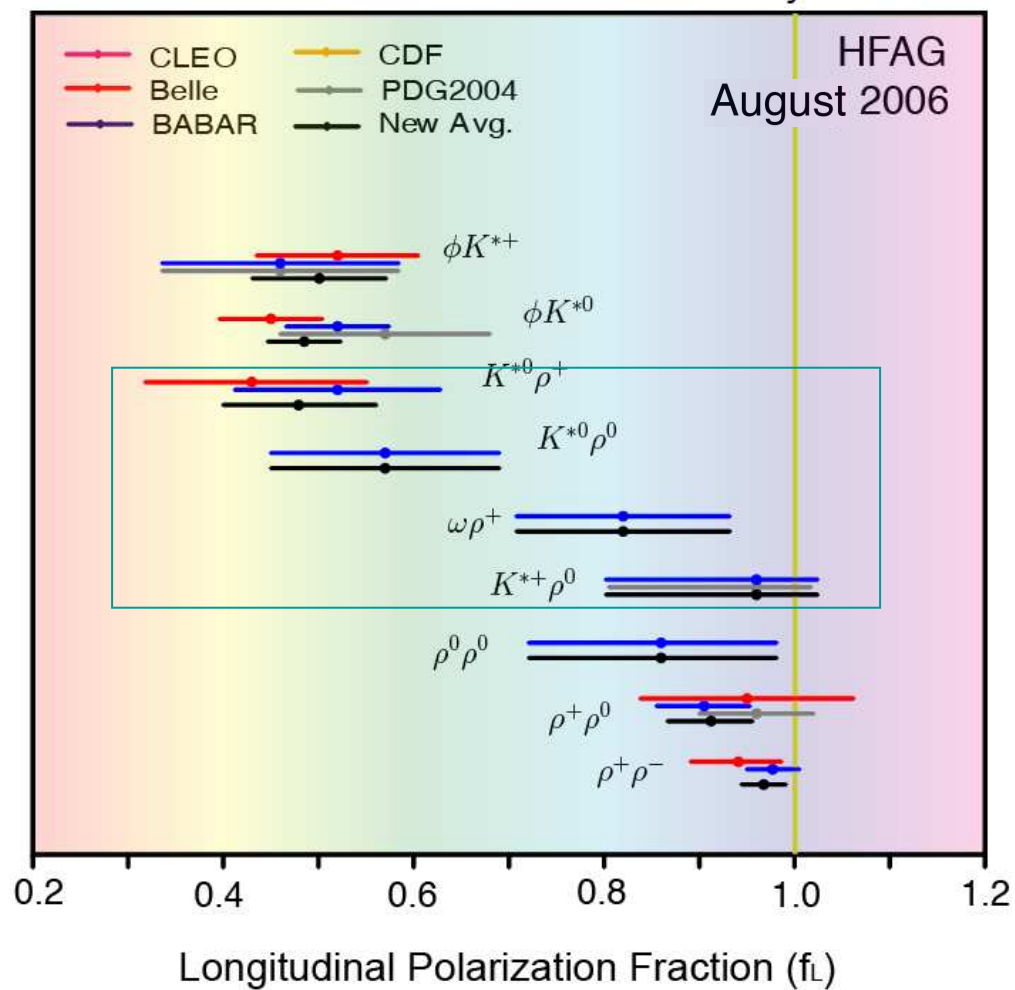
- Fraction of longitudinal polarization in tree-dominated $\omega \rho^+$ is high.

Summary

$\mathcal{B}(B \rightarrow VV)$



Polarizations of Charmless Decays



Conclusion

- More pieces to the polarization puzzle.
- Polarization in ρK^* agrees with ϕK^* .
- Polarization in $\omega \rho^+$ closer to the one in $\rho \rho$.
- More precise measurements needed.
 - Many VV modes still unobserved.
- More data are coming ...