Gluonic Penguin Decays of B mesons with Belle

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The Belle Collaboration

Outline

- **Analysis Overview**
- **$B \to \eta^{(\prime)} h^{(*)}$**
- **$B \to \omega h$**
- **$B \to \phi K^{(*)}$**

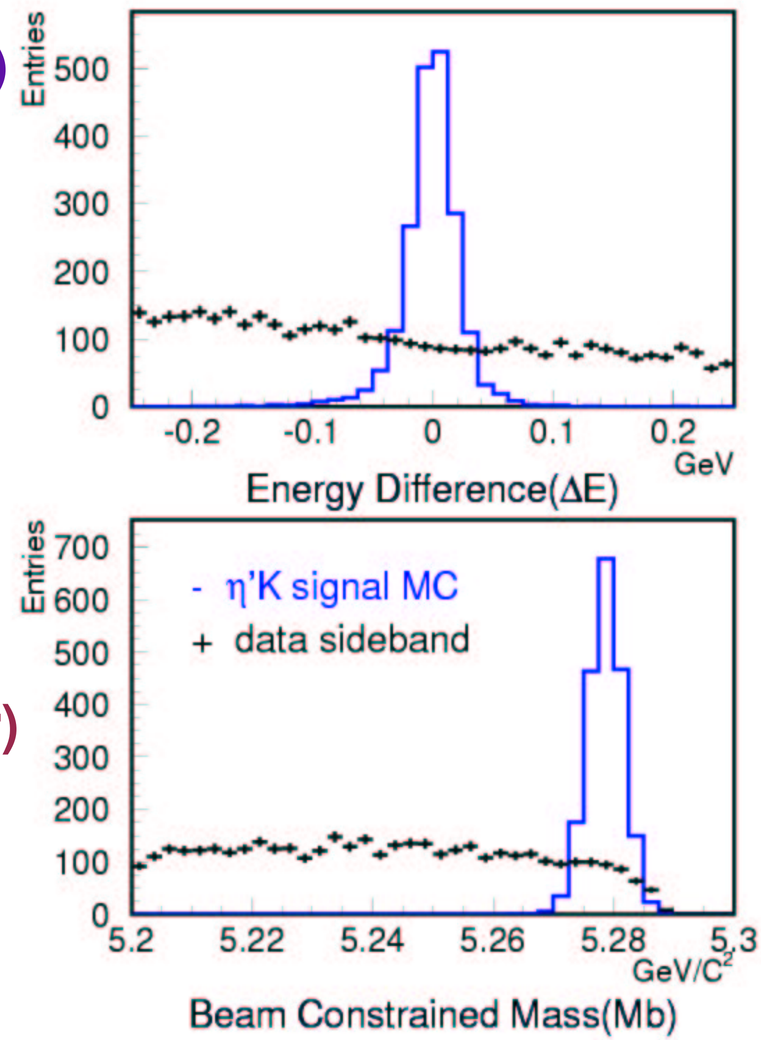
Analysis Overview

- B candidates are identified by the beam constrained mass(Mb) and the energy difference(ΔE):

$$M_b = \sqrt{E_{beam}^2 - P_B^2}$$
$$\Delta E = E_B - E_{beam}$$

where $E_{beam} \approx 5.29\,GeV$ is the beam energy at the rest frame.

- High momentum PID with ACC(Aerogel Čerenkov Counter) and dE/dx.
- Continuum suppression by shape variables.
- Other B background is studied by Monte Carlo Simulation.



$B \to \eta^{(')} h^{(*)}$ Introduction

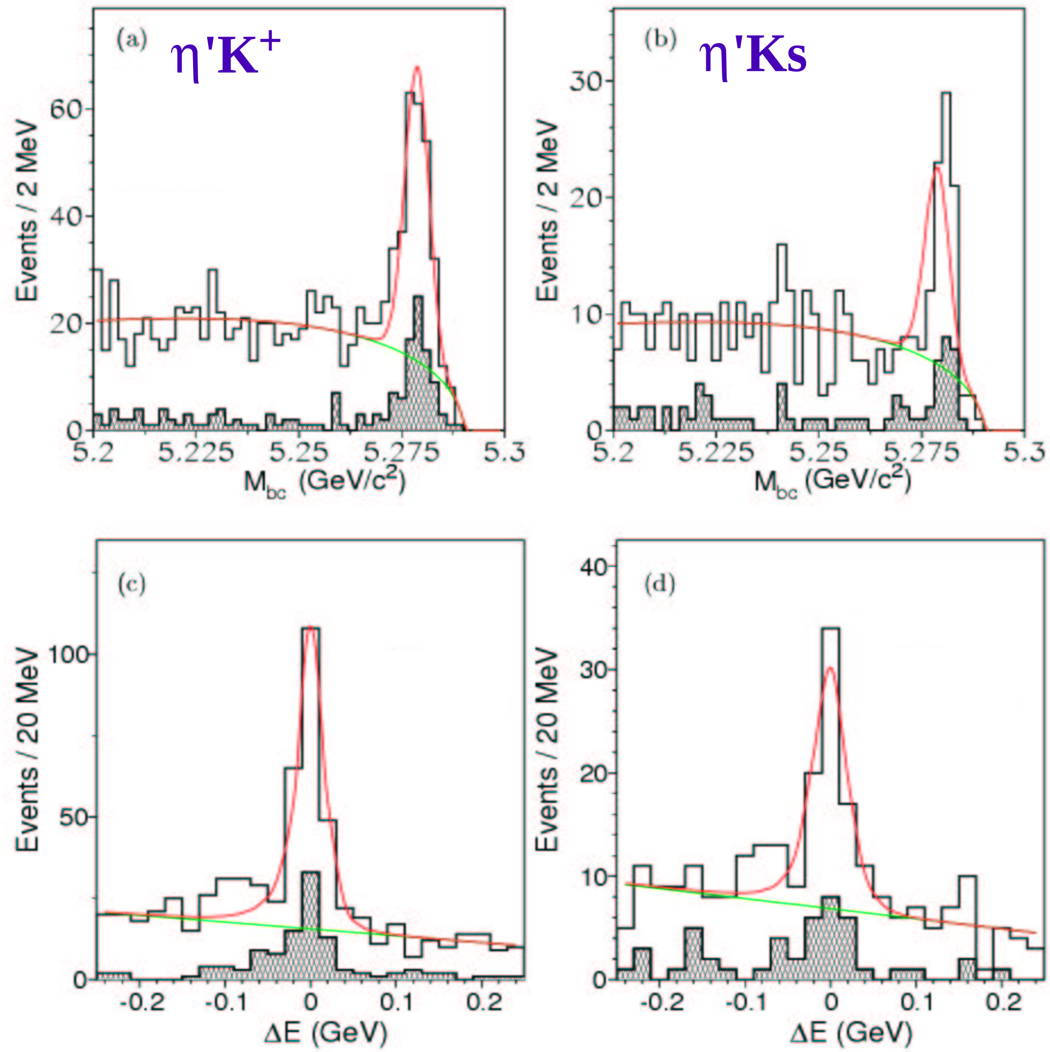
- **The branching fractions of $B \to \eta' K$ and $B \to \eta K^*$ were first found to be larger than expected by CLEO; confirmed by Belle and BaBar.**
- **Penguin interference picture: $\mathcal{B}(B \to \eta' K) >> \mathcal{B}(B \to \eta' K^*)$, $\mathcal{B}(B \to \eta K^*) >> \mathcal{B}(B \to \eta K)$, and $O(\mathcal{B}(B \to \eta' K)) \sim O(\mathcal{B}(B \to \eta K^*))$.**
- **The decay $B^\pm \to \eta \pi^\pm$ is predicted to have large direct CP violation.**
- **The relative strong phases of penguin and tree amplitudes and ϕ_2 can be determined by studying both rates and CP asymmetries. [Chiang & Rosner, hep-ph/0112285]**

Data Set

- **The 31.7M $B\bar{B}$ pairs.**
- **Reconstruct $\eta' \to \eta \pi \pi$ and $\eta' \to \rho \gamma$.**
- **Reconstruct $\eta \to \pi \pi \pi^0$ and $\eta \to \gamma \gamma$.**
- **Branching fractions are obtained by a 2D ΔE-Mb Likelihood fit.**

$B \to \eta^{(\prime)} h^{(*)}$ Results

$B \to \eta' K$ Results



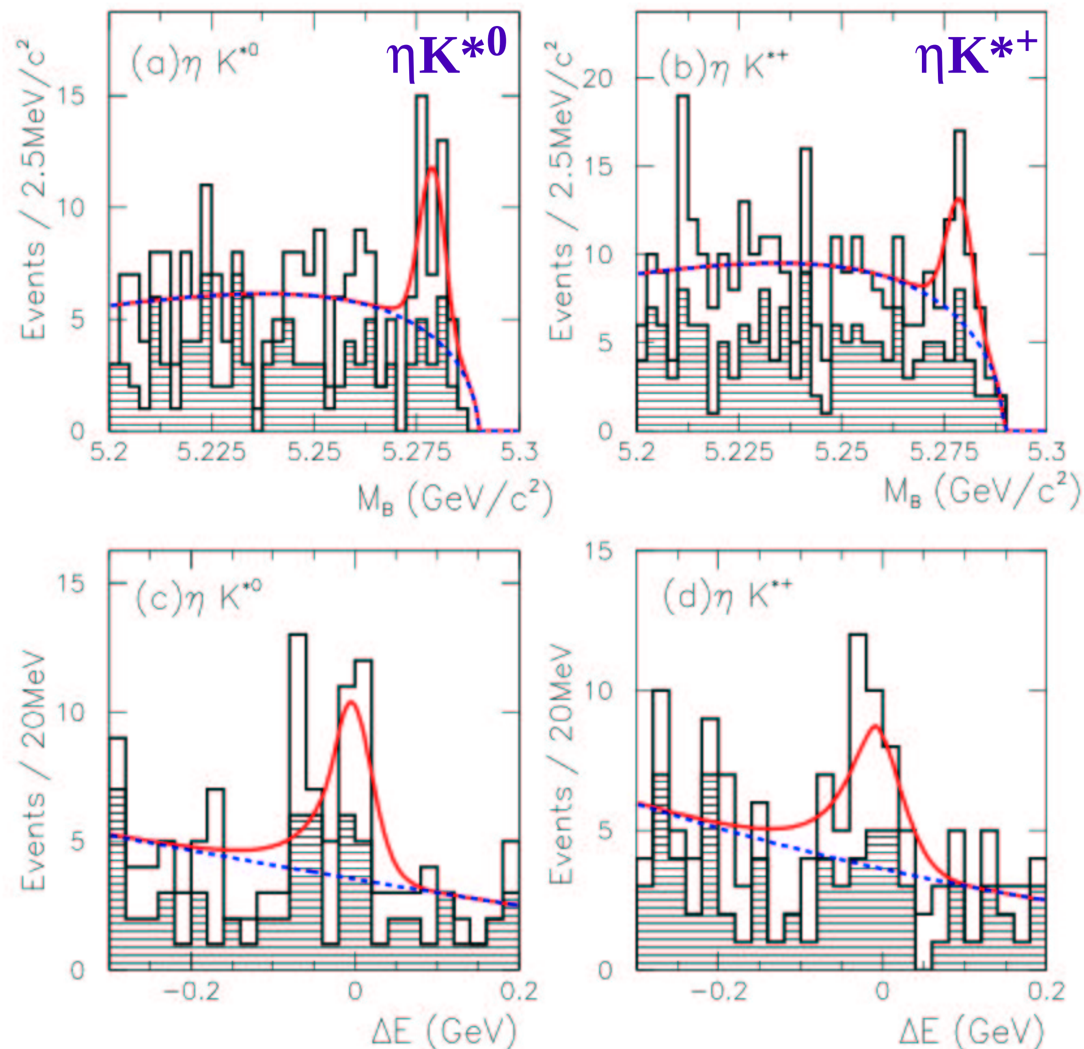
□ $\eta' \to \rho\gamma$

■ $\eta' \to \eta\pi\pi$

	Σ	$\mathcal{B}$(x10^{-6})	BaBar(x10^{-6})	CLEO(x10^{-6})
$B \to \eta' K^+$	21.2σ	$77.9^{+6.2}_{-5.9}{}^{+9.3}_{-8.7}$	$70 \pm 8 \pm 5$	$80^{+10}_{-9} \pm 7$
$B \to \eta' K^0$	10.9σ	$68.0^{+10.4}_{-9.6}{}^{+8.8}_{-8.2}$	$42^{+13}_{-11} \pm 4$	$89^{+18}_{-16} \pm 9$

$B \to \eta^{(\prime)} h^{(*)}$ Results

$B \to \eta K^*$ Results

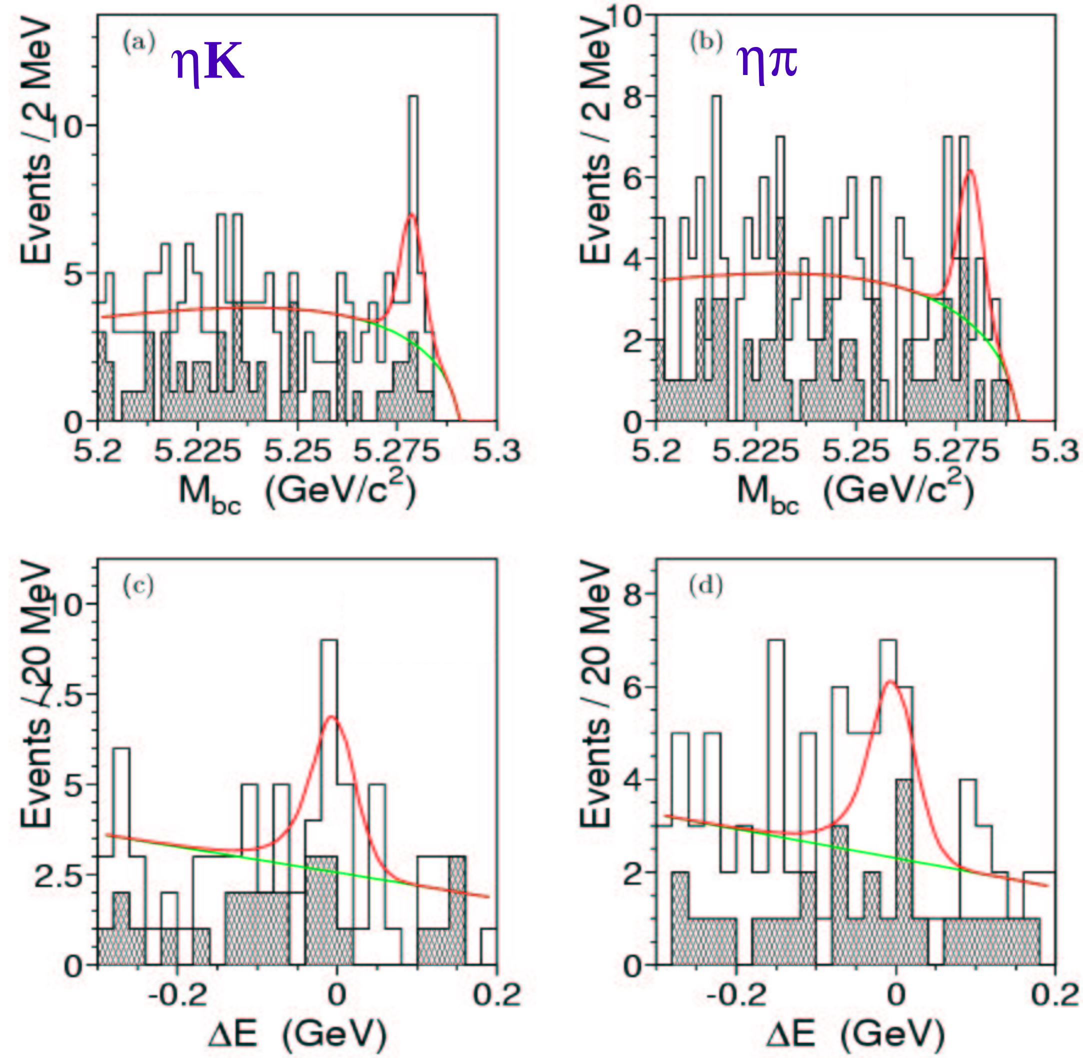


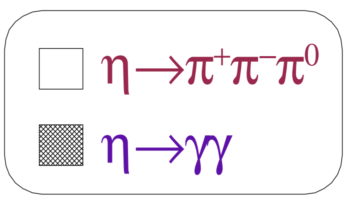
□ $\eta \to \pi^+\pi^-\pi^0$
▤ $\eta \to \gamma\gamma$

	Σ	$\mathcal{B}$(x10^{-6})	BaBar(x10^{-6})	CLEO(x10^{-6})
$B \to \eta K^{*0}$	5.0σ	$16.5^{+4.6}_{-4.2} \pm 1.2$	$19.8^{+6.5}_{-5.6} \pm 1.7$	$13.8^{+5.5}_{-4.6} \pm 1.6$
$B \to \eta K^{*+}$	4.7σ	$26.5^{+7.8}_{-7.0} \pm 3.0$	$22.1^{+11.1}_{-9.2} \pm 3.3$	$26.4^{+9.6}_{-8.2} \pm 3.3$

B→η(′)h(*) Results

B→ηK/π Results



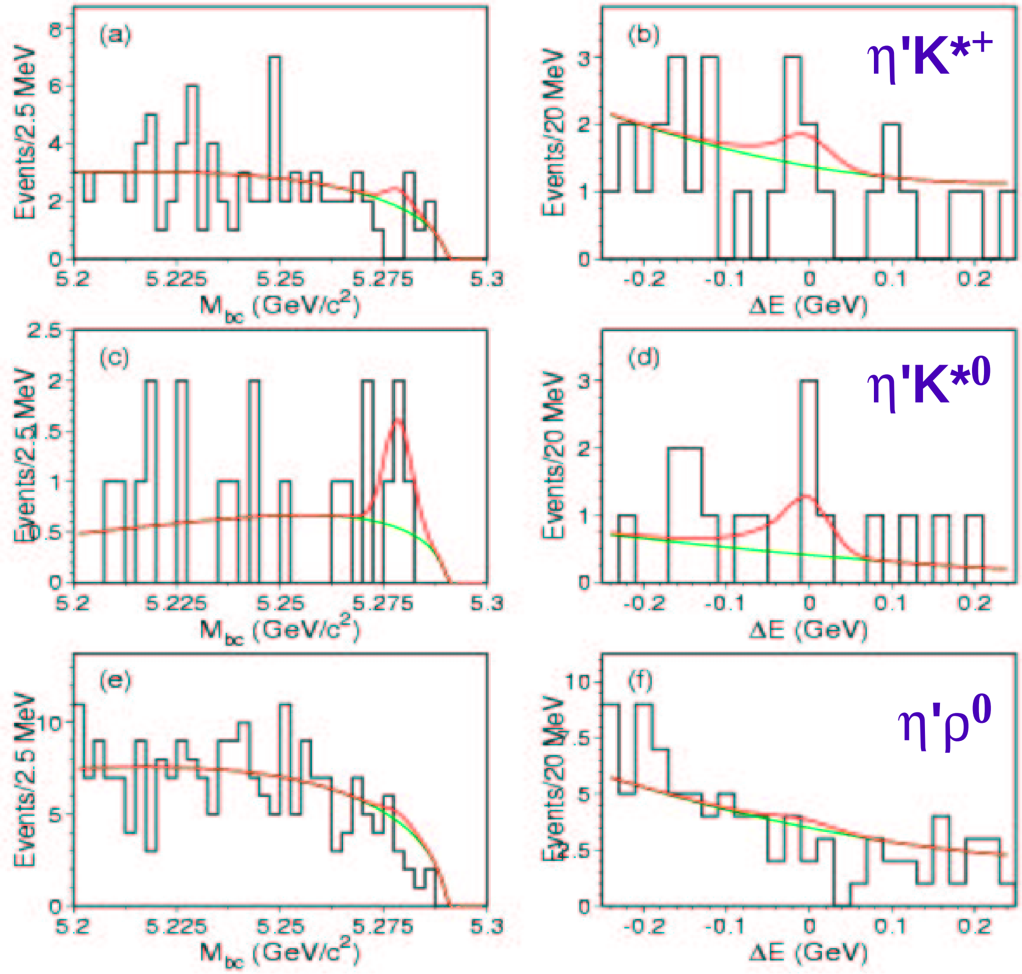


	$\mathcal{B}$(x10^{-6})	BaBar(x10^{-6})	CLEO(x10^{-6})
B→ηK	$<7.7\,(5.2^{+1.7}_{-1.5})$	< 6.4	< 6.9
B→ηπ	$<8.2\,(5.3^{+2.0}_{-1.7})$	<5.2	<5.7

B→η(')h(*) Results

B→η'K*/ρ Results

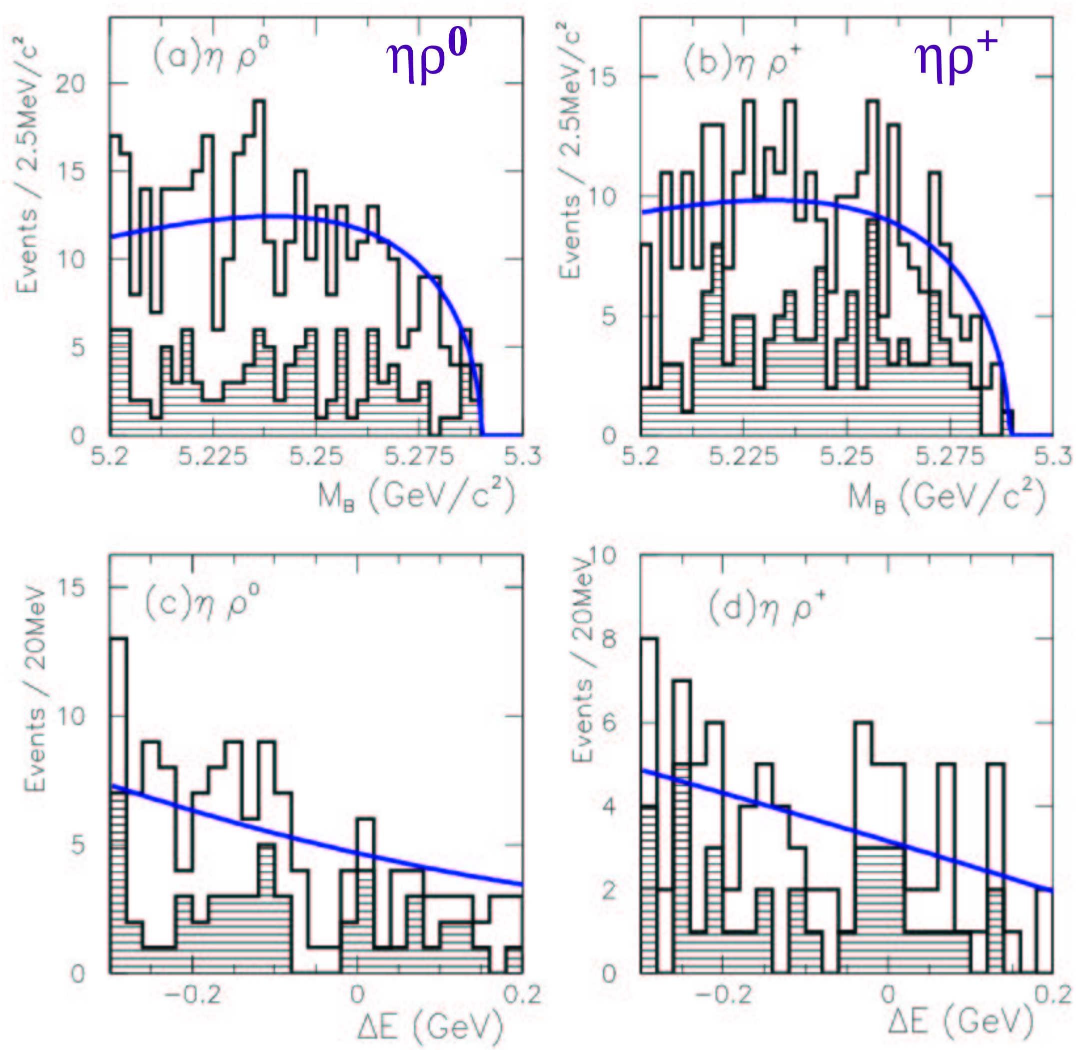
- η'→ηππ mode only.



	$\mathcal{B}$(x10^{-6})	CLEO(x10^{-6})	BaBar(x10^{-6})
B→η'K*+	< 90	< 35	-
B→η'K*0	< 20	< 24	< 13 ($4.0^{+3.5}_{-2.4}$)
B→η'ρ0	< 14	< 12	-

$B \to \eta^{(\prime)} h^{(*)}$ Results

$B \to \eta\rho$ Results



$\eta \to \pi^+\pi^-\pi^0$

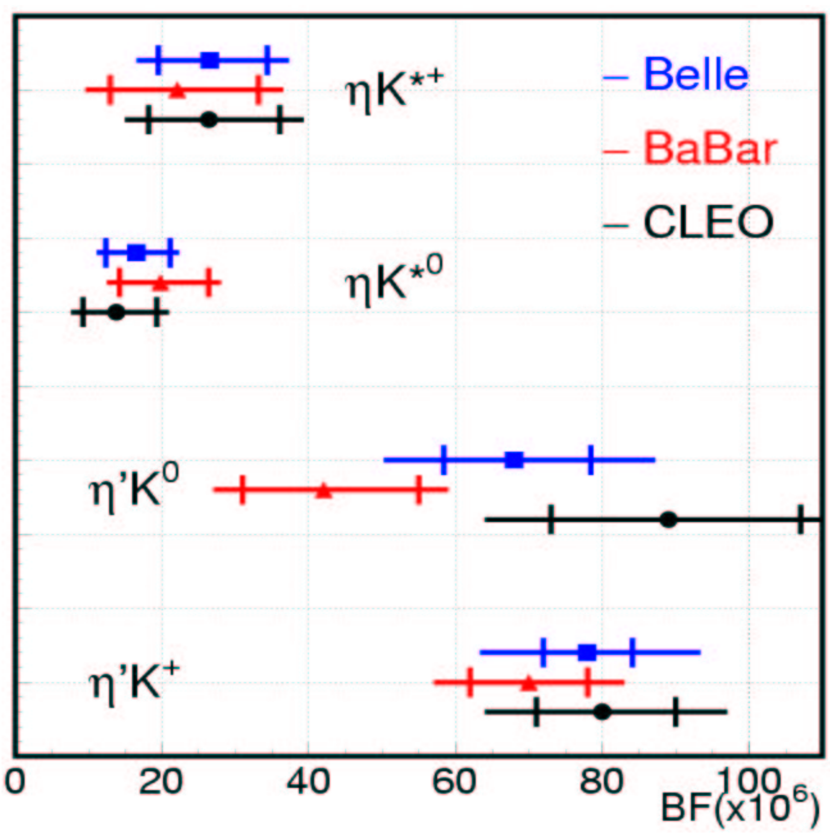
$\eta \to \gamma\gamma$

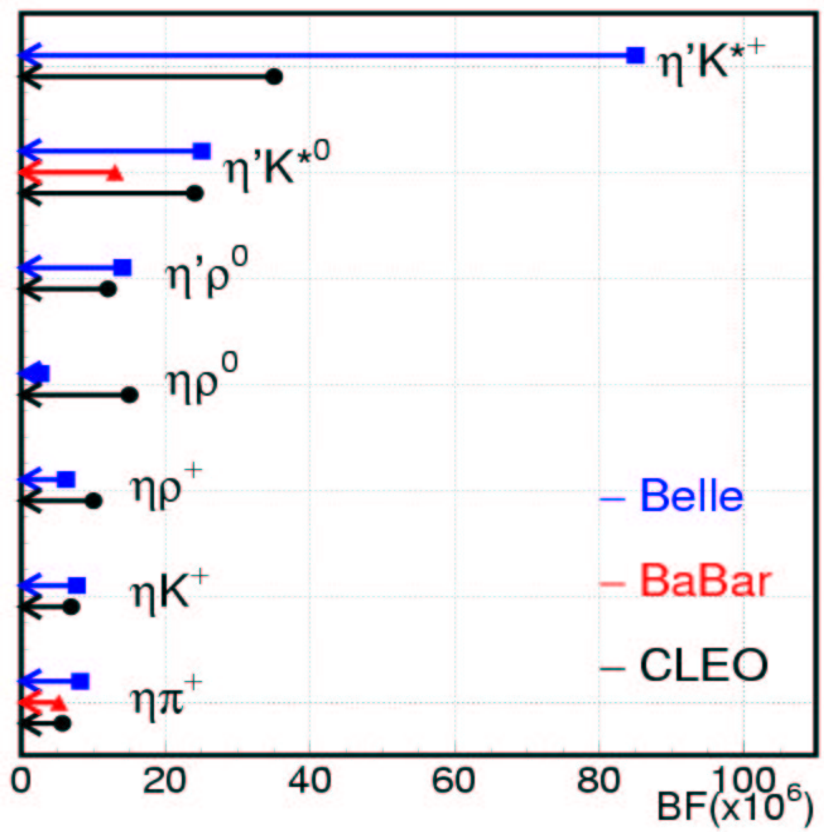
	$\mathcal{B}$(x10^{-6})	CLEO(x10^{-6})
$B \to \eta\rho^0$	**< 2.7**	**< 15**
$B \to \eta\rho^+$	**< 6.2**	**<10**

$B \to \eta^{(\prime)} h^{(*)}$ Summary

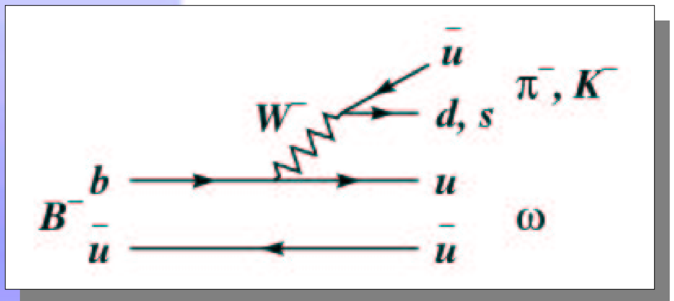
- **We have observed large signal for $B^{\pm} \to \eta' K^{\pm}$ and $\eta K^{*0/\pm}$, and evidence for $B^{\pm} \to \eta K^{\pm}/\pi^{\pm}$, upper limits for $B^{\pm} \to \eta' K^{*\pm}$ and $B^{0} \to \eta' K^{*0}$, and no indications for $B \to \eta \rho^{\pm}/\rho^{0}$ and $B^{\pm} \to \eta' \rho^{0}$.**

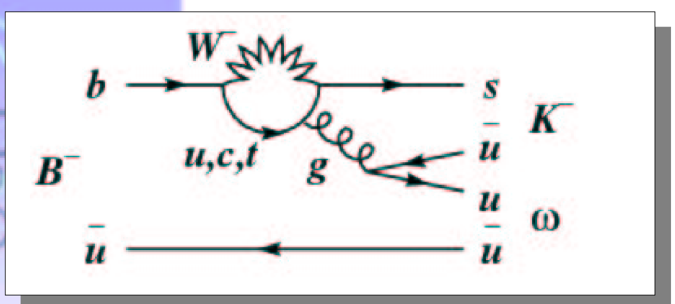
- **Compare results with other experiments:**





$B^{\pm}\to\omega h^{\pm}$ Introduction





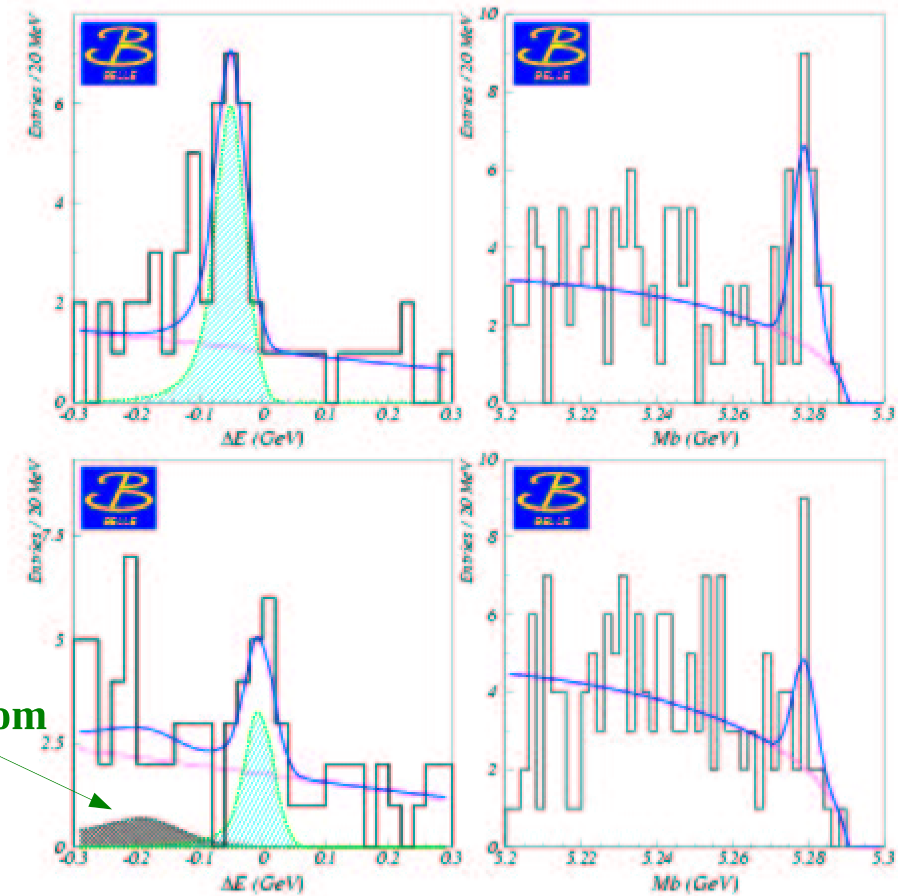
- **$B^{\pm}\to\omega h^{\pm}$ can test B decay models.**
- **Useful to search for direct CP violation.**
- **Brief History:**
  - **CLEO first reported the $B^{\pm}\to\omega K^{\pm}$ decay branching fractions in 1998.** [PRL **81**, 272(1998)]
  - **$B^{\pm}\to\omega\pi^{\pm}$ is found to be larger than $\omega K^{\pm}$ with new data set.** [PRL **85**, 2881(2000)]
  - **BaBar confirms $B^{\pm}\to\omega\pi^{\pm} > \omega K^{\pm}$.** [PRL **87**, 221802(2001)]

	$\mathcal{B}(B\to\omega\pi)\mathrm{x}10^{-6}$	$\mathcal{B}(B\to\omega K)\mathrm{x}10^{-6}$
CLEO(1998)	<2.3	$\mathbf{15^{+7}_{-6}\pm 2}$
CLEO(2000)	$\mathbf{11.3^{+3.3}_{-2.9}\pm 1.5}$	<8 $[\mathbf{3.2^{+2.4}_{-1.9}\pm 0.8}]$
BaBar(2001)	$\mathbf{6.6^{+2.1}_{-1.8}\pm 0.7}$	<4 $[\mathbf{1.4^{+1.3}_{-1.0}\pm 0.3}]$

- **BaBar shown the $B\to\omega K^0$ results. (Today!)**

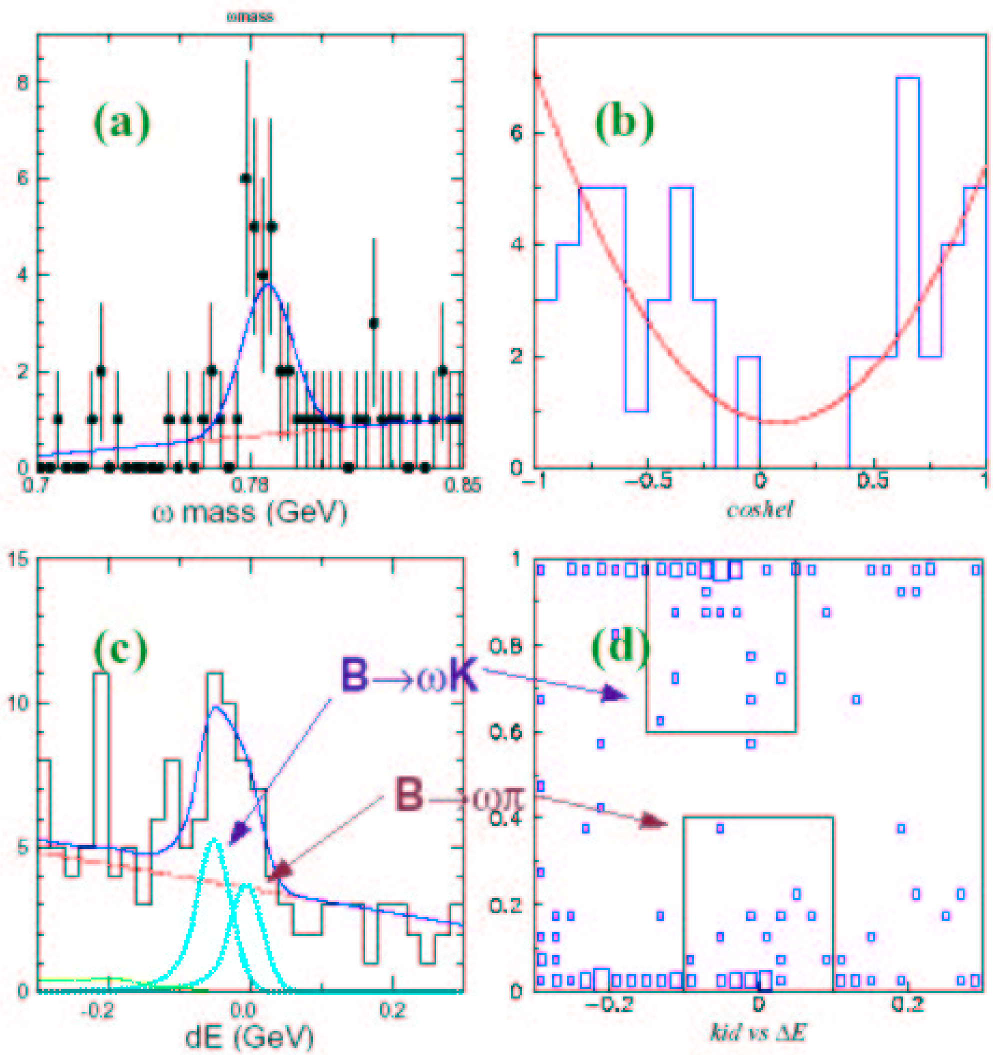
$B^{\pm} \to \omega h^{\pm}$ Results

- **Results from $\mathbf{31.7M}$ $B\bar{B}$ pairs.**
- **Yields are extracted by a 2-dimensional unbinned likelihood method.**



	Yield	Σ	ε	$\mathcal{B}(\times 10^{-6})$	U.L
$B \to \omega\pi$	$\mathbf{10.6^{+4.8+0.4}_{-4.5-0.6}}$	3.3σ	7.7%	$\mathbf{4.3^{+2.0}_{-1.8} \pm 0.5}$	<8.2
$B \to \omega K$	$\mathbf{19.7^{+5.4+0.7}_{-4.8-0.5}}$	6.4σ	6.3%	$\mathbf{9.9^{+2.7}_{-2.4} \pm 1.0}$	-

Consistency Checks



(a) A clear ω peak shown in $\pi^+\pi^-\pi^0$ spectrum with B candidate.

(b) The ω helicity angle distribution matches P→VP decay.

(c),(d) By removing the KID requirement, the ΔE distribution is consistent with ωK and ωπ yields.

Summary of $B^{\pm}\to\omega h^{\pm}$

$B\to\omega h$ Results

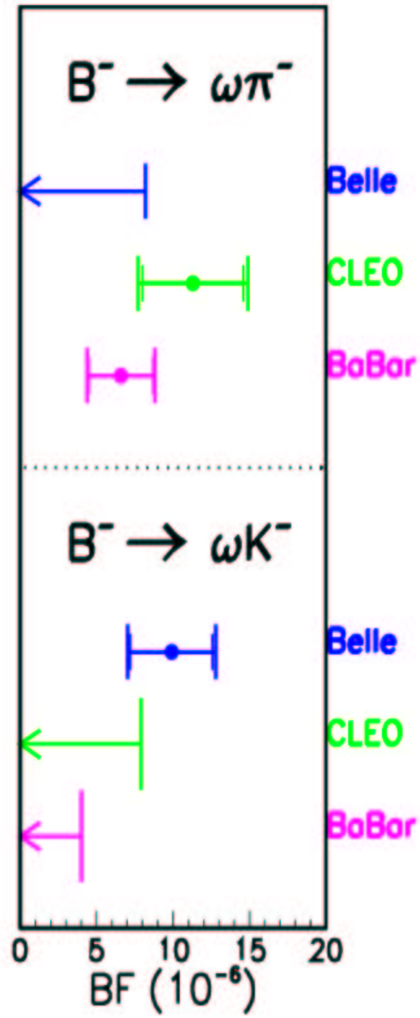
- **We have observed $B^{\pm}\to\omega K^{\pm}$, and evidence for $B^{\pm}\to\omega\pi^{\pm}$.**

$$\mathcal{B}(\omega K^{\pm}) = (9.9^{+2.7}_{-2.4} \pm 1.0) \times 10^{-6}\ (6.4\sigma)$$

$$\mathcal{B}(\omega\pi^{\pm}) = (4.3^{+2.0}_{-1.8} \pm 0.5) \times 10^{-6}\ (3.3\sigma) < 8.2 \times 10^{-6}$$

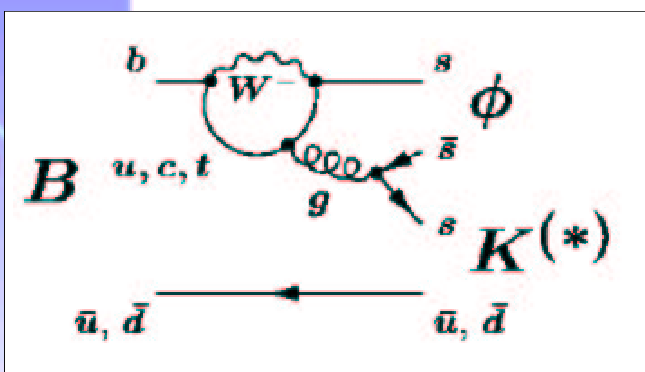
- **Compare results with other experiments:**

	$\mathcal{B}(B\to\omega\pi)\times10^{-6}$	$\mathcal{B}(B\to\omega K)\times10^{-6}$
Belle(2002)	$<8.2\ [\mathbf{4.3^{+2.0}_{-1.8}\pm0.5}]$	$\mathbf{9.9^{+2.7}_{-2.4}\pm1.0}$
BaBar(2001)	$\mathbf{6.6^{+2.1}_{-1.8}\pm0.7}$	$<4\ [\mathbf{1.4^{+1.3}_{-1.0}\pm0.3}]$
CLEO(2000)	$\mathbf{11.3^{+3.3}_{-2.9}\pm1.5}$	$<8\ [\mathbf{3.2^{+2.4}_{-1.9}\pm0.8}]$



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

- $B \to \phi K$ is forbidden in 1st order of SM.
  - Generated 2nd order loops ($b \to s s \bar{s}$ penguin)
- Measure sin2ϕ1 with ϕK^0(penguin)
  - $\leftrightarrow$ $J/\psi\ K^0$(tree)
- $B \to \phi K$ can test theoretical decay models.
- Previous measurements:



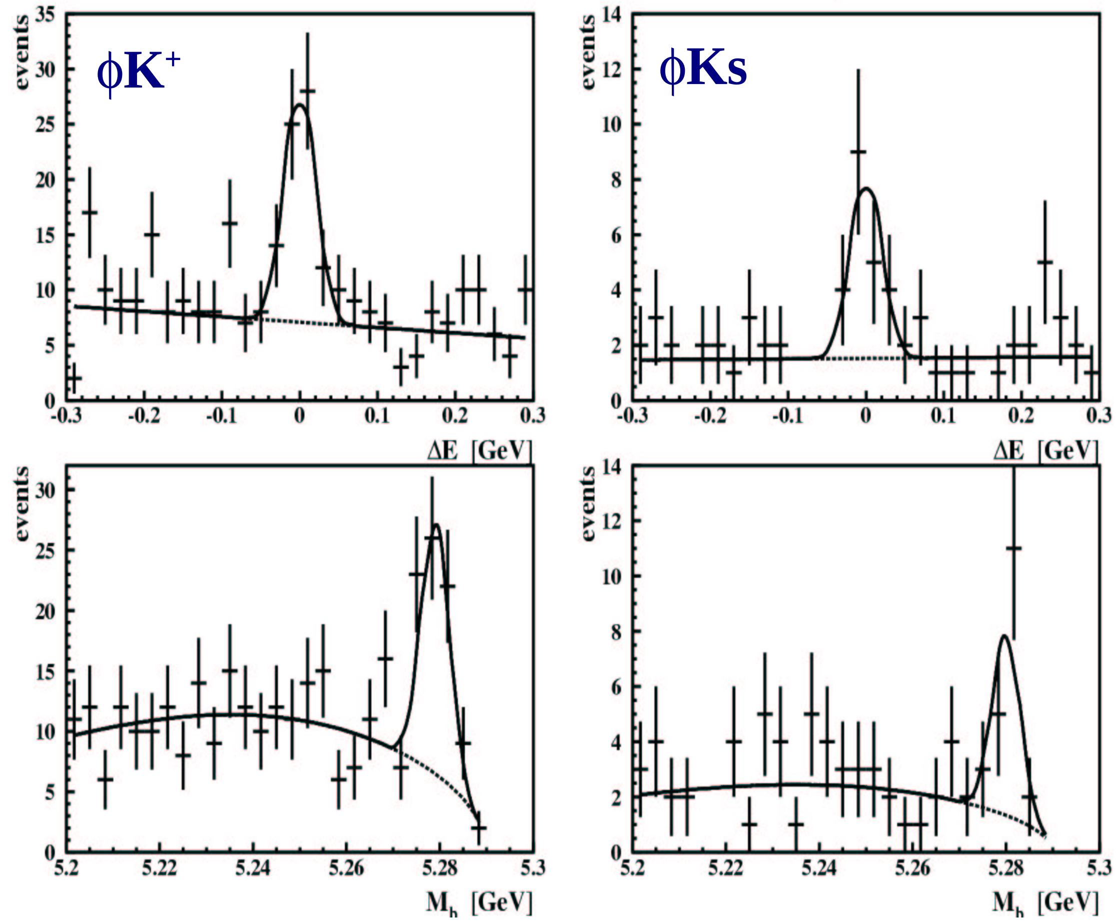
Mode	CLEO	BaBar	Belle
ϕK^+	$5.5^{+2.1}_{-1.8} \pm 0.6$	$7.7^{+1.6}_{-1.4} \pm 0.8$	$14.6^{+3.0}_{-2.8} \pm 2.0$
ϕK^0	< 12.3	$8.1^{+3.1}_{-2.5} \pm 0.8$	$13.0^{+6.1}_{-5.2} \pm 2.6$
ϕK^{*+}	< 22.5	$9.7^{+4.2}_{-3.4} \pm 1.7$	—
ϕK^{*0}	$11.5^{+4.5+1.8}_{-3.7-1.7}$	$8.7^{+2.5}_{-2.1} \pm 1.1$	—

[CLEO: PRL 86, 3718(2001)
BaBar: PRL 87, 151801(2001)
Belle: H.C.Huang, de Moriond, March 2002.]

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

$B\to\phi K$ Results

- Results from **86M** $B\bar{B}$ pairs.

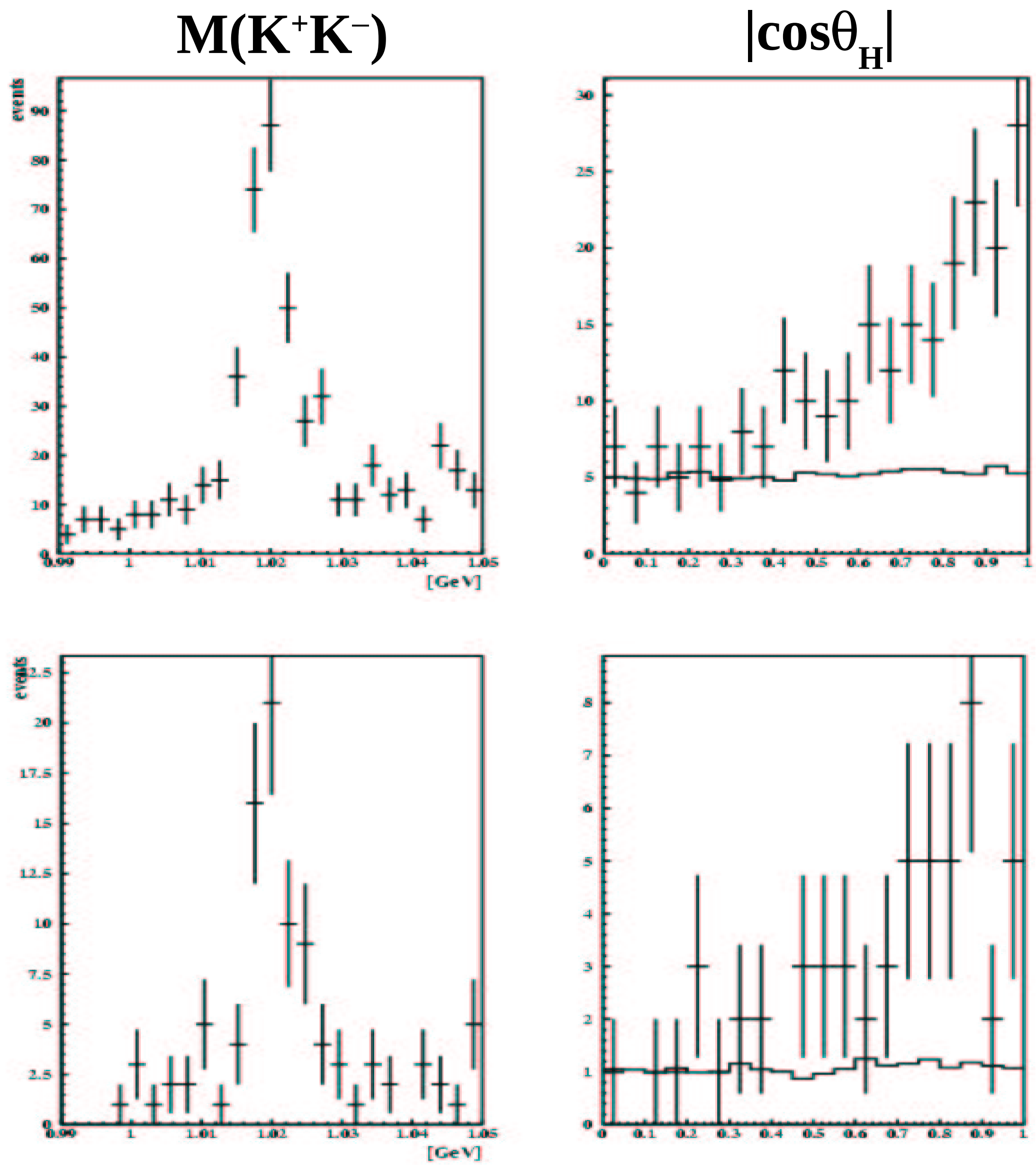


	Yield	Σ	ε	$\mathcal{B}(\times10^{-6})$
$B\to\phi K^+$	**159±15**	16.7σ	17.3%	$\mathbf{10.7\pm1.0^{+0.9}_{-1.6}}$
$B\to\phi K^0$	$\mathbf{39.4^{+7.5}_{-6.8}}$	8.7σ	4.6%	$\mathbf{10.0^{+1.9}_{-1.7}{}^{+0.9}_{-1.3}}$

Consistency Checks

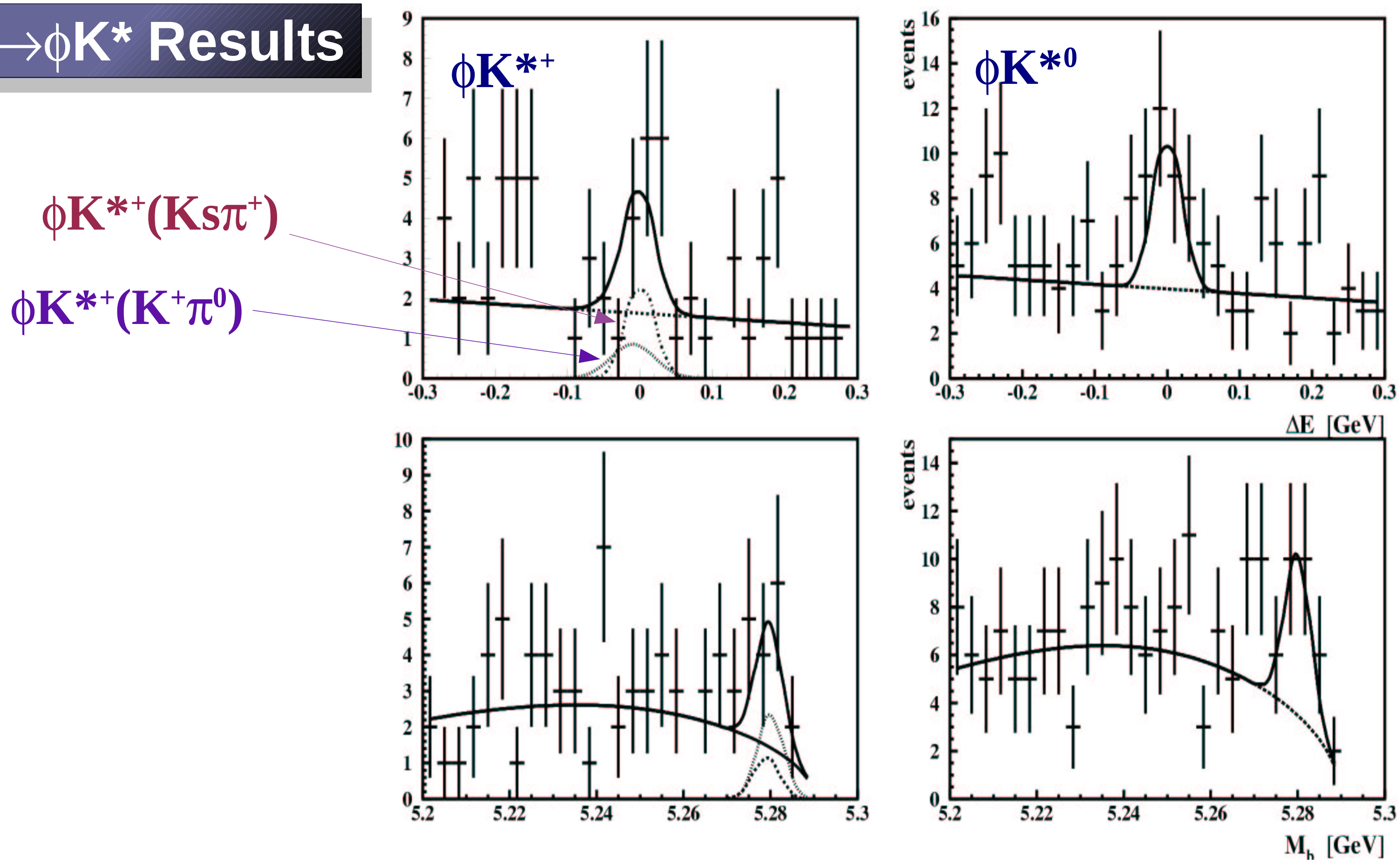
$B \to \phi K^{\pm}$

$B \to \phi K_S$



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

$B \to \phi K^*$ Results



	Yield	Σ	ε	$\mathcal{B}$(x10^{-6})
$B \to \phi K^{*0}$	$\mathbf{31.6^{+7.9}_{-7.1}}$	5.7σ	4.6%	$\mathbf{8.0^{+2.0}_{-1.8}{}^{+0.8}_{-1.1}}$
$B \to \phi K^{*+}$	$\mathbf{28.0^{+7.4}_{-6.4}}$	-	-	$\mathbf{11.2^{+3.3}_{-2.9}{}^{+1.3}_{-1.7}}$

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

- **We have measured $B^{\pm}\to\phi K^{\pm}$, $\phi K^{*\pm}$, ϕK_S, and ϕK^{*0} channels:**

$$\mathcal{B}(B^{\pm}\to\phi K^{\pm}) = (\ 10.7 \pm 1.0 ^{+0.9}_{-1.6}\ ) \times 10^{-6}\ (17\sigma)$$

$$\mathcal{B}(B^{0}\to\phi K^{0}) = (\ 10.0 ^{+1.9}_{-1.7}{}^{+0.9}_{-1.3}\ ) \times 10^{-6}\ (8.7\sigma)$$

$$\mathcal{B}(B^{\pm}\to\phi K^{*\pm}) = (\ 8.0 ^{+2.0}_{-1.8}{}^{+0.8}_{-1.1}\ ) \times 10^{-6}\ (5.7\sigma)$$

$$\mathcal{B}(B^{0}\to\phi K^{*0}) = (\ 11.2 ^{+3.3}_{-2.9}{}^{+1.3}_{-1.7}\ ) \times 10^{-6}$$

- **Compare results with other experiments:**