B Decays Involving Light Mesons

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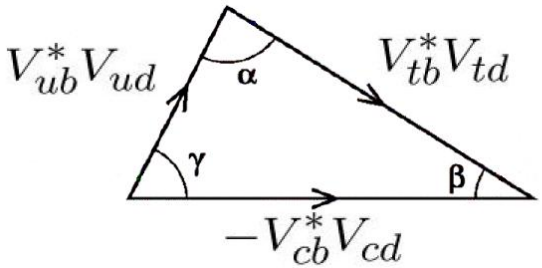
B Decays to Light Mesons

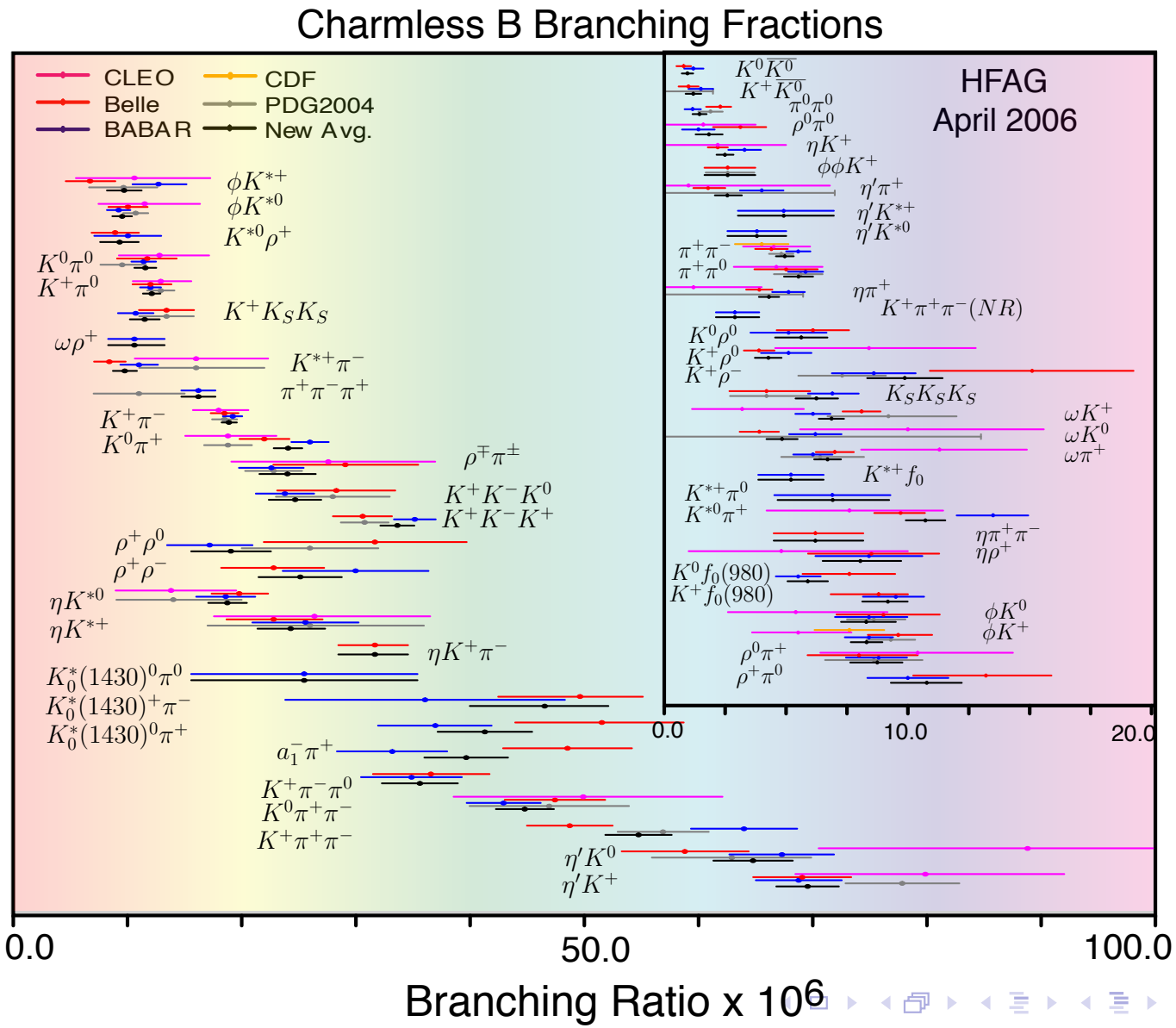
- This talk's focus: new *BABAR* results for charmless *B* decay branching fractions
  - *BABAR* charm news: see Mark Pelizaeus' talk today at 12:00
  - *BABAR CP* studies covered in Maurizio Biasini's talk on Friday
- Outline:
  1. Brief introduction to *BABAR* charmless analyses
  2. *B* decays to final states containing η'
  3. *B* decays to two vector mesons
  4. Other recent results (if time allows)
  5. Summary and outlook

Why measure charmless *B* decays?

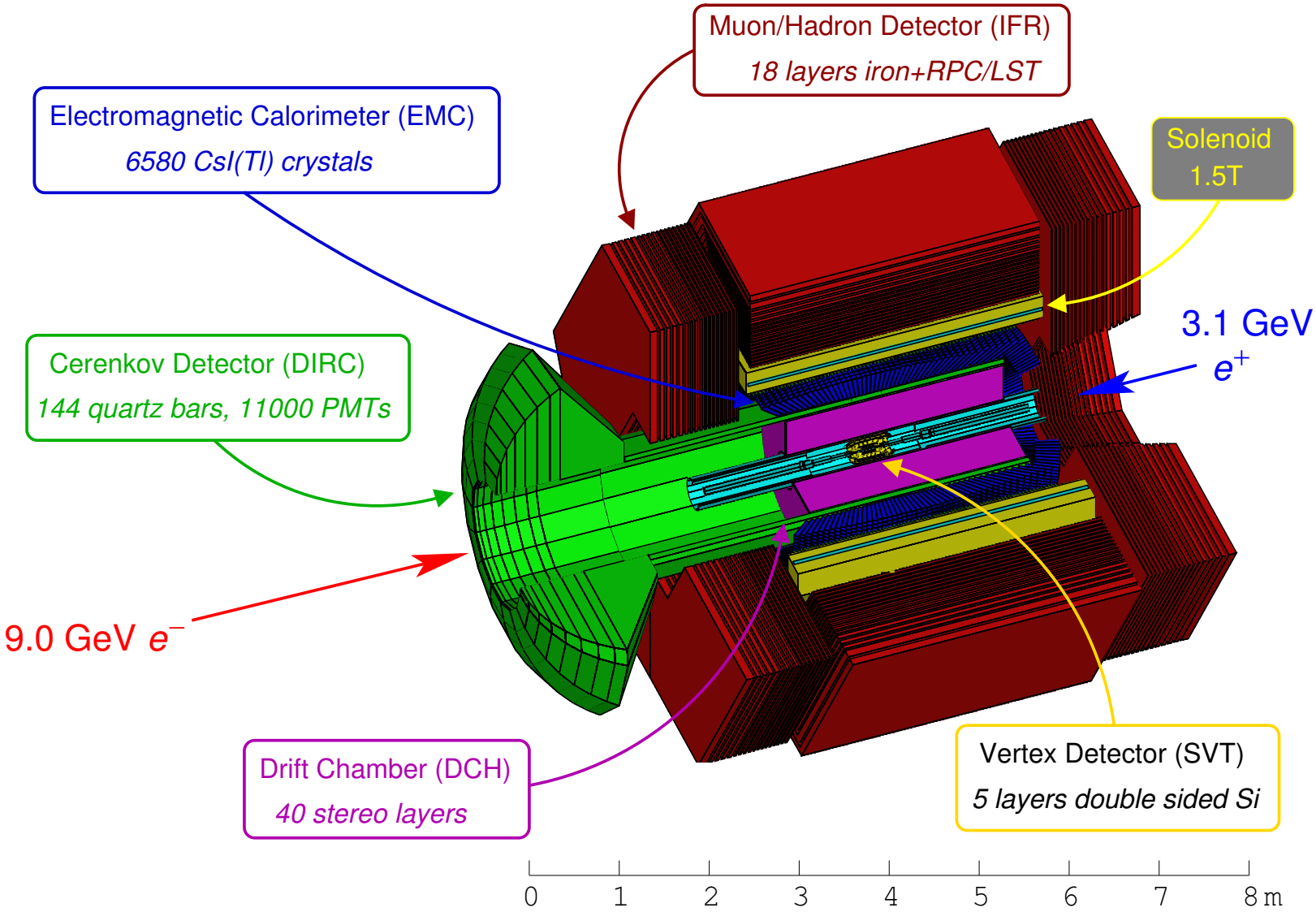
- Measure CKM angles $\alpha(=\phi_2)$ and $\gamma(=\phi_3)$
- Search for direct *CP* violation (charge asymmetry)
- Study penguin vs. tree dominance
- Final state interactions?
- Lots of ongoing activity among theorists
  - See parallel session, talks by L. Lesniak and M. Sowa



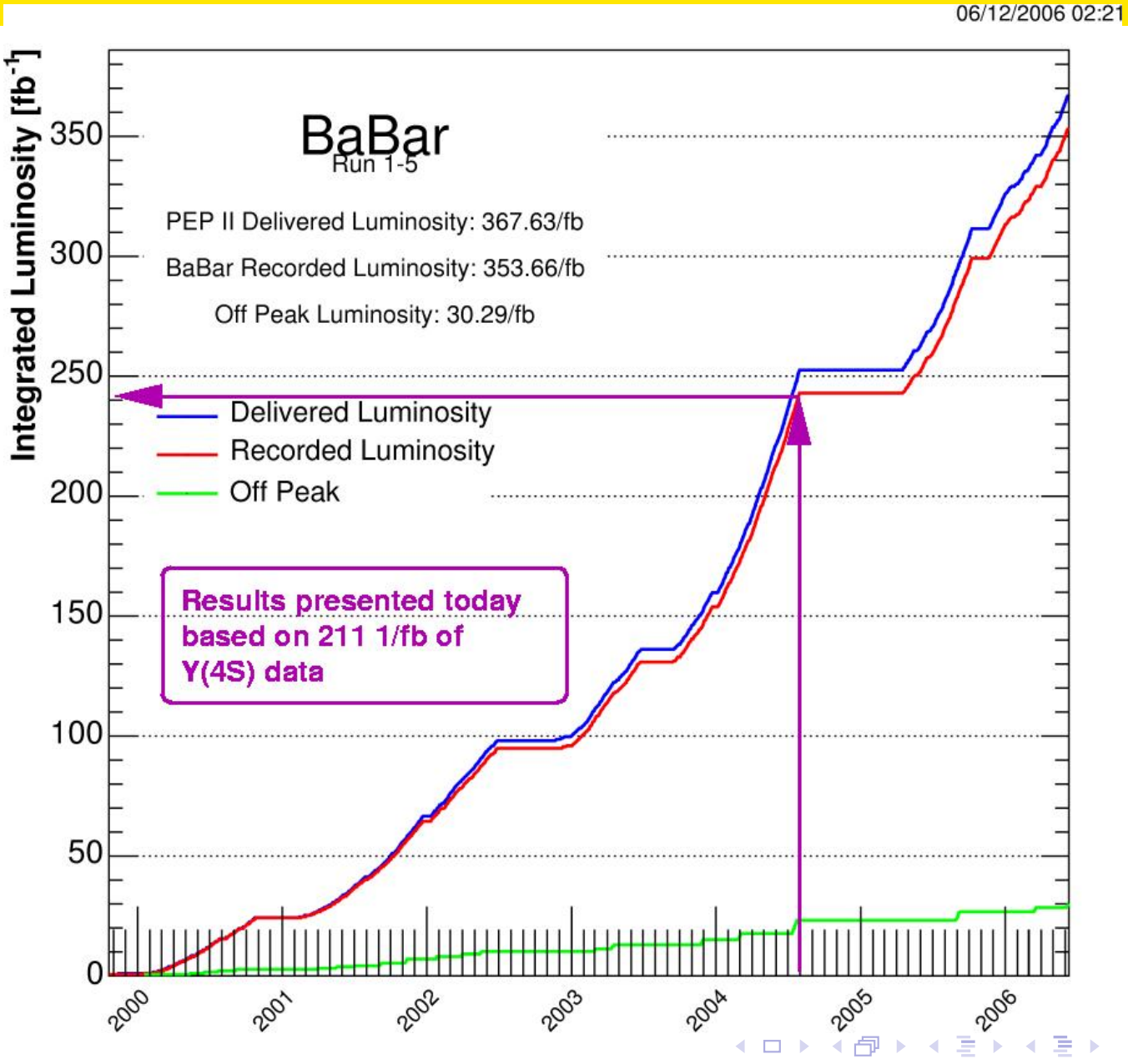
Charmless *B* Decays, 2006



The *BABAR* Detector



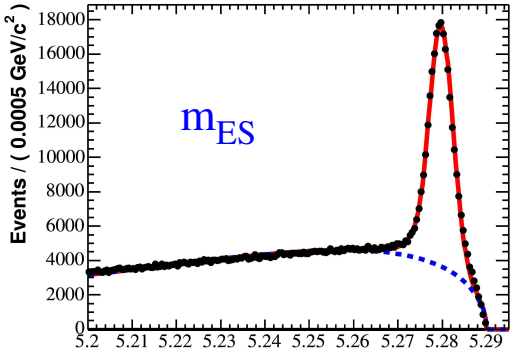
BABAR Performance

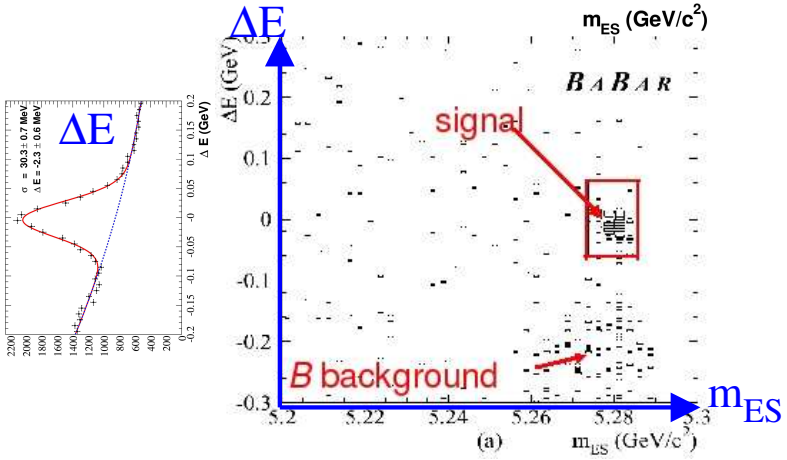


Charmless analysis at *BABAR*

Event selection:

- Quality cuts for tracks and showers
- Continuum rejection using event shape variables
- *B*-background estimated by modeling
- Kinematic signal identification
  - $m_{\mathrm{ES}} = \sqrt{E^{*2}_{\mathrm{beam}} - p^{*2}_{B}}$
  - $\Delta E = E^{*}_{B} - E^{*}_{\mathrm{beam}}$
- Yields, asymmetries determined by maximum likelihood fit over m_{ES}, ΔE, etc.





$\sigma(m_{\mathrm{ES}}) = 2.7\,\mathrm{MeV}$

$\sigma(\Delta E) = 10..50\,\mathrm{MeV}$

$B \to \eta' X$

Common elements of all η' analyses presented:

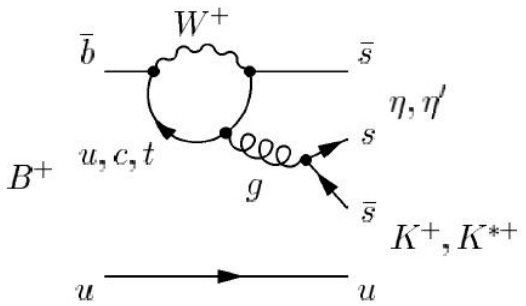
- η' (958) reconstructed as
  - $\eta' \to \eta \pi^+ \pi^- \ (\eta \to \gamma\gamma)$
  - $\eta' \to \rho^0 \gamma \ (\rho^0 \to \pi^+ \pi^-)$
- η' candidate mass constrained to PDG value
- Photon cuts:
  - γ from π^0: $E_\gamma > 30$ MeV
  - γ from η: $E_\gamma > 100$ MeV
  - γ from η': $E_\gamma > 200$ MeV

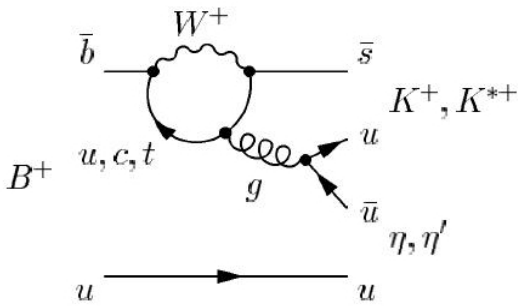
$B \to \eta^{(\prime)} K^{(*)}$

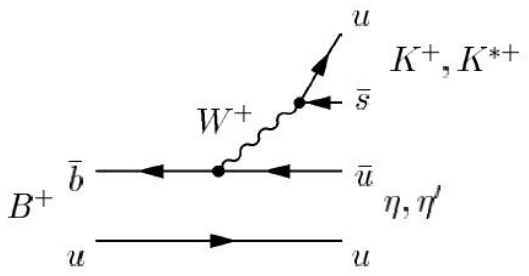
- Penguin diagrams dominant (tree cannot produce $s\bar{s}$)
- Interference between penguin diagrams combines with $\eta - \eta'$ mixing angle:

	η	η'
K	suppressed	enhanced
K^*	enhanced	suppressed

[Lipkin, PLB 254:247(1991)]

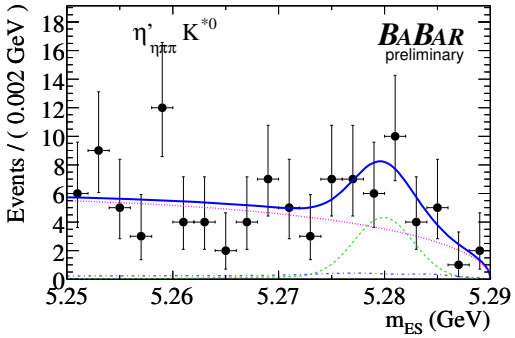


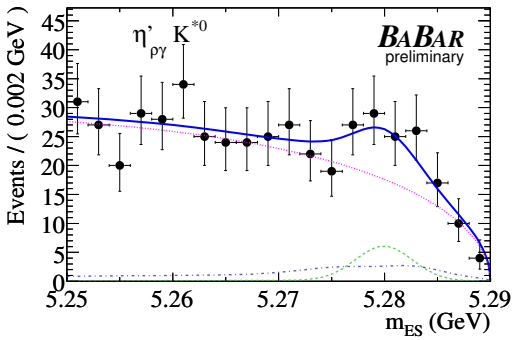




$B \to \eta' K^*$

$B^0 \to \eta' K^{*0}$





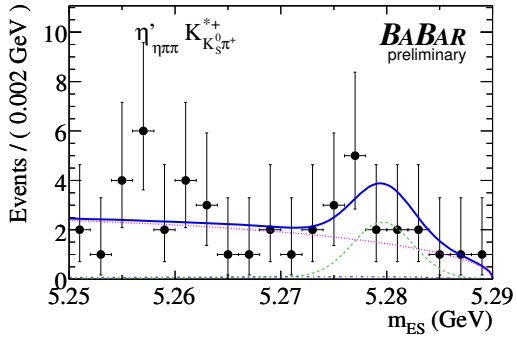
$\mathcal{B} \times 10^{-6} =$

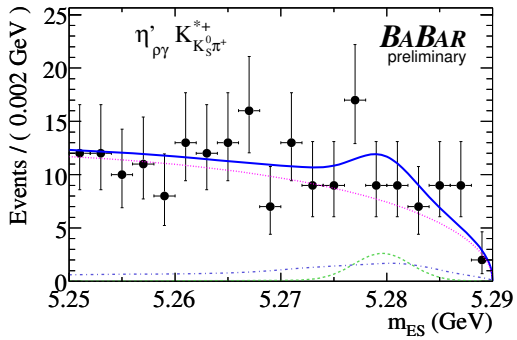
$3.8 \pm 1.1 \pm 0.5$

$(4.5\,\sigma)$

(232 million $B\bar{B}$ decays)

$B^\pm \to \eta' K^{*\pm}$ $(K^{*\pm} \to K^0 \pi^\pm)$



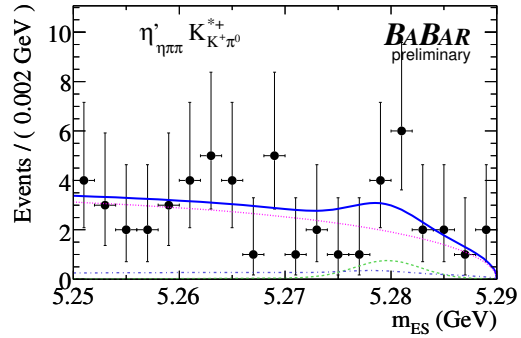


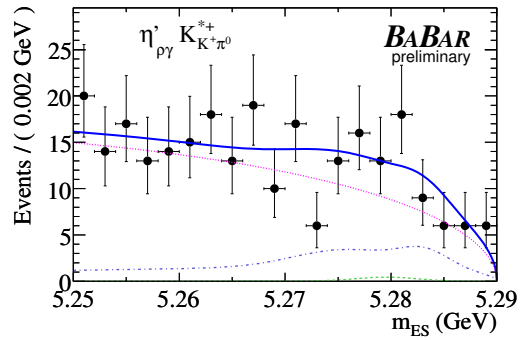
$\mathcal{B} \times 10^{-6} =$

$4.9^{+1.9}_{-1.7} \pm 0.8$

$(3.6\,\sigma)$

$B^\pm \to \eta' K^{*\pm}$ $(K^{*\pm} \to K^\pm \pi^0)$



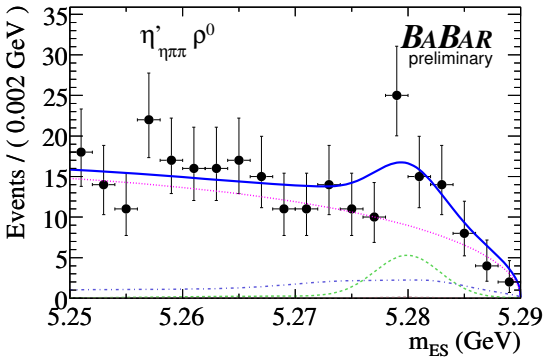


7.9×10^{-6}

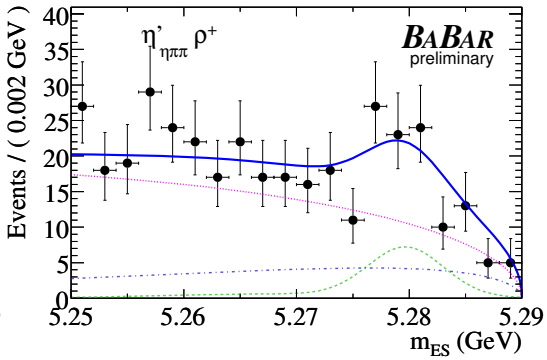
(90% UL)

$B \to \eta' \rho$ and $\eta' f_0$

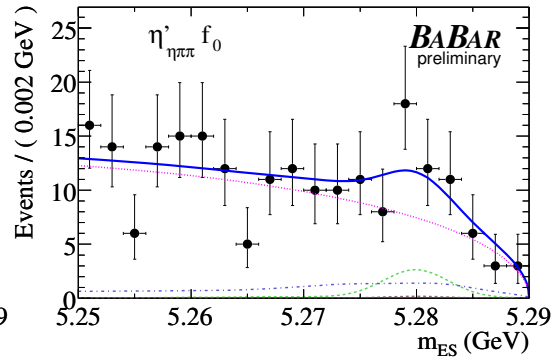
$B^0 \to \eta' \rho^0$



$B^+ \to \eta' \rho^+$



$B^0 \to \eta' f_0 (\to \pi^+\pi^-)$



$\mathcal{B}(B^0 \to \eta' \rho^0)$	$\mathcal{B}(B^+ \to \eta' \rho^+)$	$\mathcal{B}(B^0 \to \eta' f_0 (\to \pi^+\pi^-))$
(all $\times 10^{-6}$)		
$0.4^{+1.2+1.6}_{-0.9-0.6}\,(0.3\,\sigma)$	$6.8^{+3.2+3.9}_{-2.9-1.2}\,(2.3\,\sigma)$	$0.1^{+0.6+0.9}_{-0.4-0.4}\,(0.2\,\sigma)$
< 3.7	< 14	< 1.5
	(all 90% UL)	

(232 million $B\bar{B}$ decays)

$B \to \eta^{(\prime)} K^{(*)} / \rho / f_0$ Summary

Decay mode	Theoretical predictions SU(3) [1]	QCDF [2]	Experimental results HFAG	New *BABAR* results	
$B^0 \to \eta' K^{*0}$	$3.0^{+1.2}_{-0.3}$	$3.9^{+9.2}_{-5.1}$	< 7.6	$3.8 \pm 1.1 \pm 0.5$	
$B^+ \to \eta' K^{*+}$	$2.8^{+1.2}_{-0.3}$	$5.1^{+10.3}_{-5.9}$	< 14	$4.9^{+1.9}_{-1.7} \pm 0.8$	< 7.9
$B^0 \to \eta' \rho^0$	$0.07^{+0.10}_{-0.05}$	$0.01^{+0.12}_{-0.06}$	< 4.3	$(0.4^{+1.2\,+1.6}_{-0.9\,-0.6})$	< 3.7
$B^+ \to \eta' \rho^+$	$4.9^{+0.7}_{-0.7}$	$6.3^{+4.0}_{-3.3}$	< 22	$(6.8^{+3.2\,+3.9}_{-2.9\,-1.2})$	< 14
$B^0 \to \eta' f_0$	–		–	$(0.1^{+0.6\,+0.9}_{-0.4\,-0.4})$	< 1.5

[1] Chiang, Gronau, *et al.*, Phys. Rev. D 69: 034001 (2004)

[2] Beneke and Neubert, Nucl. Phys. B 675: 333 (2003)

$B \to \eta^{(\prime)} K^{(*)}$ branching fractions in comparison

(suppressed/enhanced)

	η	η'
$K^{\pm}$	2.5 ± 0.3	69.4 ± 2.7
$K^{*\pm}$	24.3 ± 3.0	< 7.9

	η	η'
K^0	< 1.9	63.2 ± 3.3
K^{*0}	18.7 ± 1.7	3.8 ± 1.2

Other recent $B \to \eta' X$ results

New upper limits for $B \to \eta^{(\prime)} \pi$ modes [hep-ex/0603013]

$$\mathcal{B}(B^0 \to \eta' \eta) < 1.7 \times 10^{-6}$$
$$\mathcal{B}(B^0 \to \eta \pi^0) < 1.3 \times 10^{-6}$$
$$\mathcal{B}(B^0 \to \eta' \pi^0) < 2.1 \times 10^{-6}$$

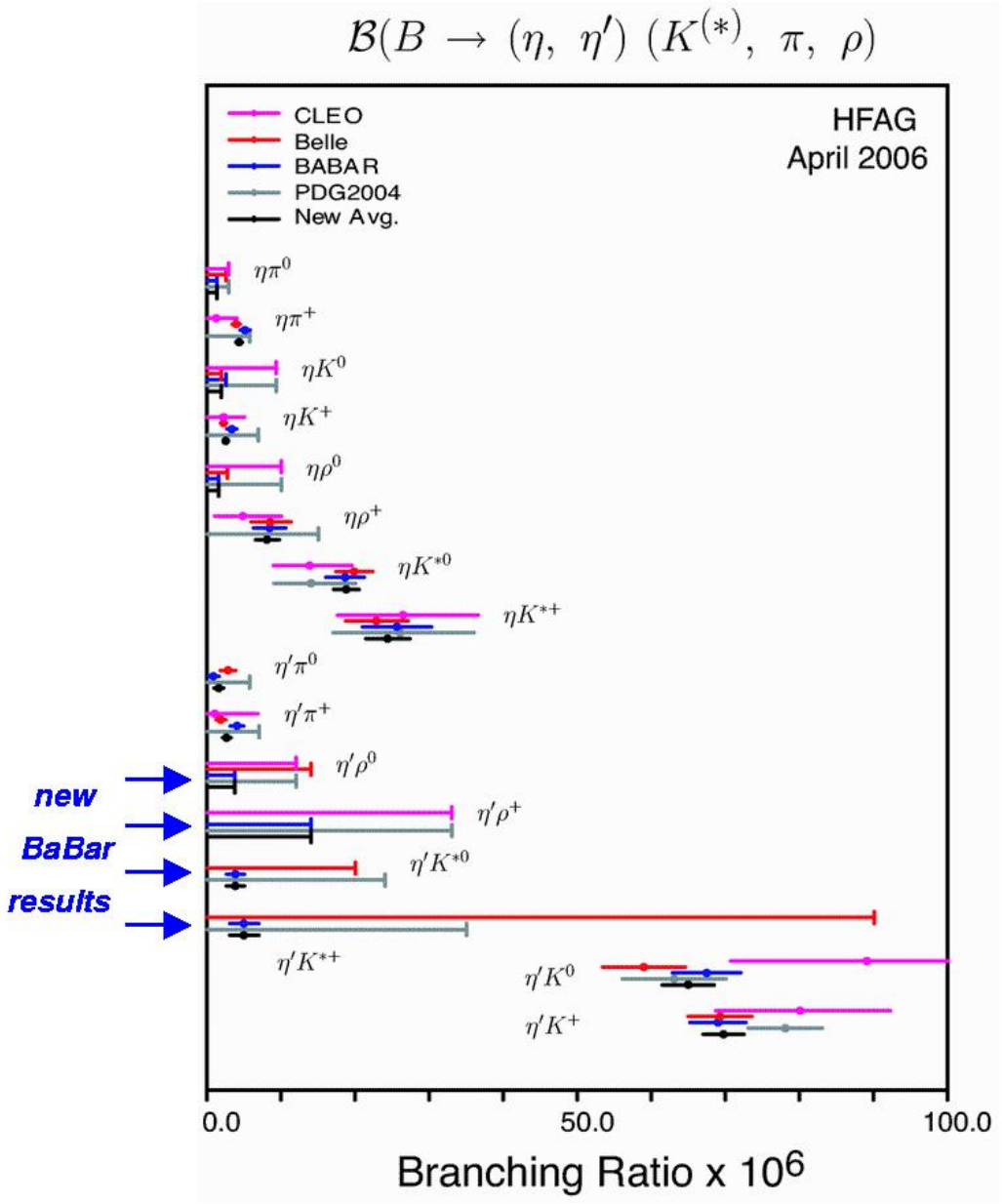
(232 million $B\bar{B}$ decays; 90% UL)

3-body decays with two η' [hep-ex/0605008]

$$\mathcal{B}(B^0 \to \eta' \eta' K^0) < 31 \times 10^{-6}$$
$$\mathcal{B}(B^+ \to \eta' \eta' K^0) < 25 \times 10^{-6}$$

(228 million $B\bar{B}$ decays; 90% UL)

$B \to \eta' X$ Summary



$B \to VV$ Decays

- Provide a wider set of observables than $B \to PP$ and $B \to PV$ modes
- CP asymmetries constructed from polarization components complement direct $\mathcal{A}_{CP}$
- Pure penguin decays particularly sensitive to new physics

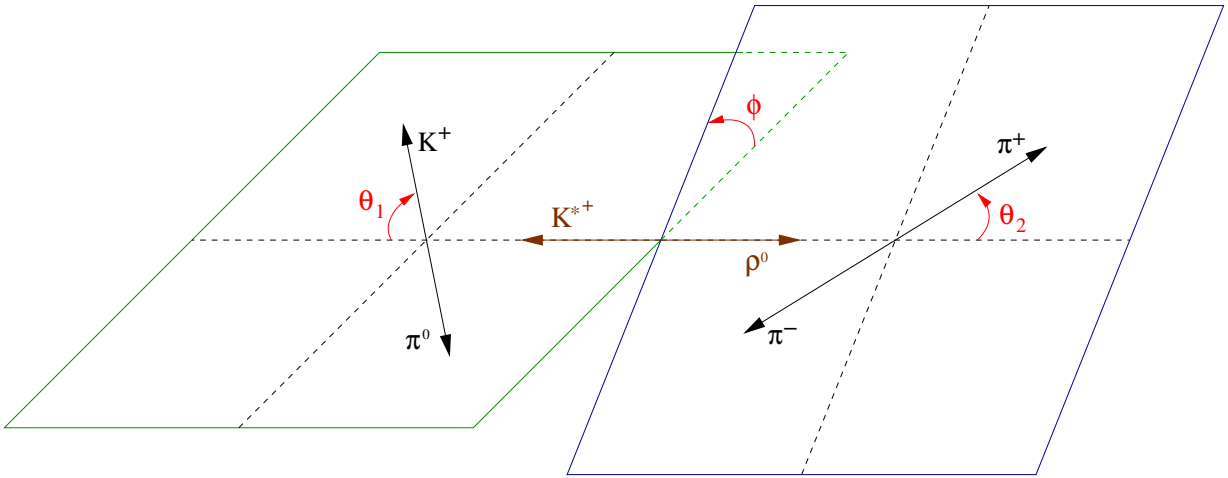
- SM prediction for longitudinal polarization fraction $f_L \sim 1$
- Both for tree- and penguin dominated decays
- However, $f_L \sim 0.5$ for $B^0 \to \Phi K^{*0}$ [*BABAR*, BELLE]

$B \to VV$ Decays

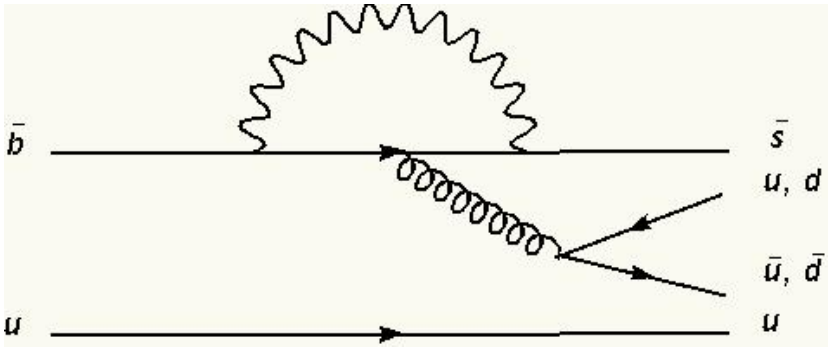
- Define helicity angles θ_1, θ_2
  - Direction between vector meson and its decay products in its rest frame
- Angle ϕ between decay planes

Longitudinal polarization fraction f_L

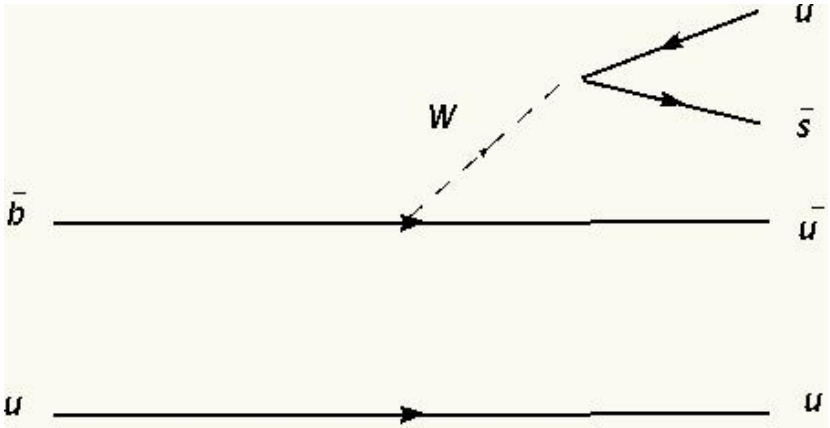
$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1 d\cos\theta_2} \sim \frac{1}{4}(1-f_L)\sin^2\theta_1\sin^2\theta_2 + f_L\cos^2\theta_1\cos^2\theta_2$$



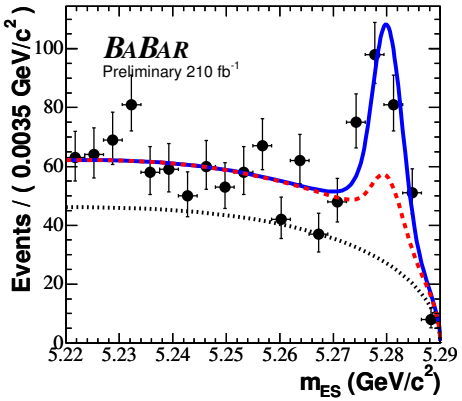
$B^+ \to \rho^0 K^{*+}$ and $B^+ \to K^{*0}\rho^+$

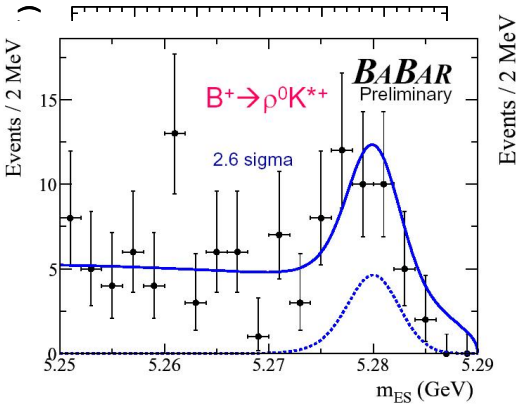


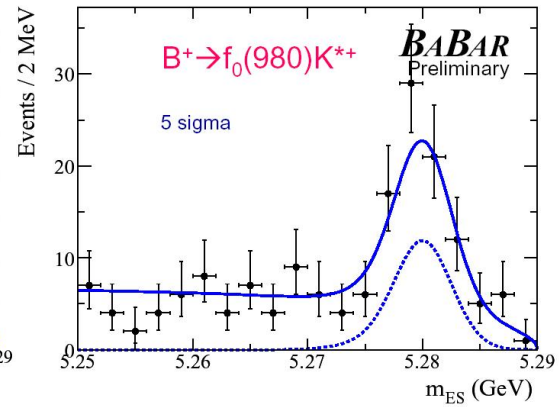
- $B^+ \to K^{*0}\rho^+$ pure penguin mode
- $B^+ \to \rho^0 K^{*+}$ also has a tree contribution



$B^+ \to \rho^0 K^{*+}$ and $B^+ \to K^{*0}\rho^+$







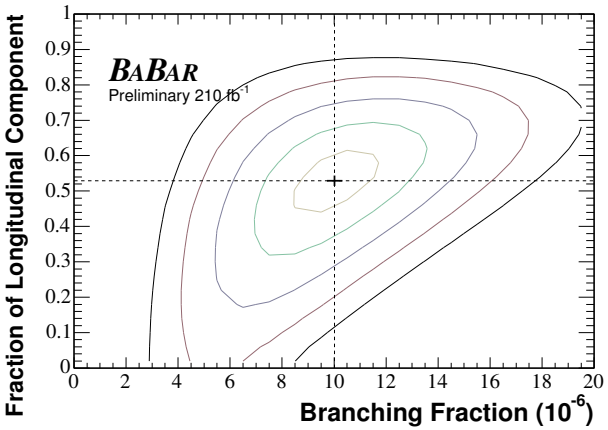
Branching fractions [$\times 10^{-6}$] (*BABAR* PRELIMINARY)

$B^+ \to K^{*0}\rho^+$	$10.0 \pm 1.7 \pm 2.4$	
$B^+ \to \rho^0 K^{*+}$	$3.6 \pm 1.7 \pm 0.8$	$(< 5.9$; 90% UL)
$B^+ \to f_0(980)K^{*+}$	$5.2 \pm 1.2 \pm 0.6$	

BELLE: $\mathcal{B}(B^+ \to K^{*0}\rho^+) = 8.9 \pm 1.7 \pm 1.2 \times 10^{-6}$

($275 \times 10^6 B\bar{B}$ decays [PRL 95, 141801 (2005)])

$B^+ \to \rho^0 K^{*+}$ and $B^+ \to K^{*0}\rho^+$



f_L and $\mathcal{A}_{CP}$ (*BABAR* PRELIMINARY)

	f_L	$\mathcal{A}_{CP}$
$B^+ \to K^{*0}\rho^+$	$0.53 \pm 0.10 \pm 0.06$	$-0.01 \pm 0.15 \pm 0.01$
$B^+ \to \rho^0 K^{*+}$	$0.91^{+0.22}_{-0.20} \pm 0.08$	
$B^+ \to f_0(980)K^{*+}$		$-0.34 \pm 0.21 \pm 0.02$

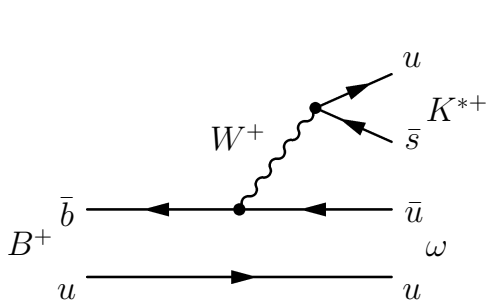
(232 million $B\bar{B}$ decays)

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

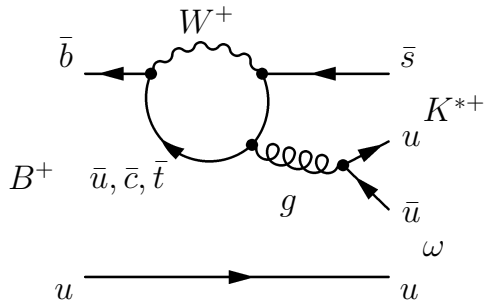
$B \to \omega K^*$ and $\omega\rho$

- Previous experimental evidence only from CLEO
- $B \to \omega K^*$ penguin dominated
- Tree contribution expected to be stronger in $B \to \omega\rho$

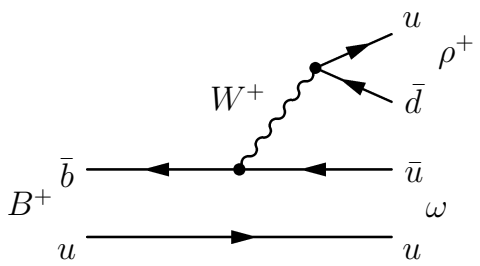
$B \to \omega K^*$ and $\omega \rho$



(a)



(b)



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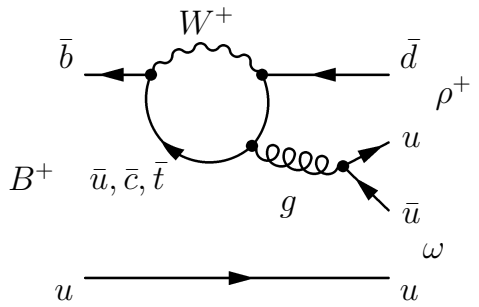

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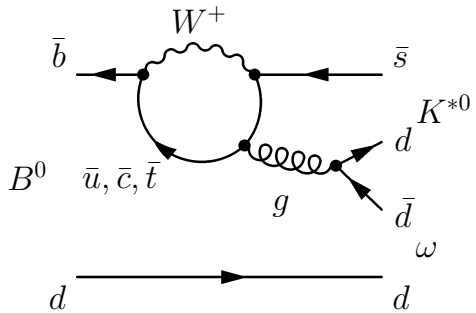
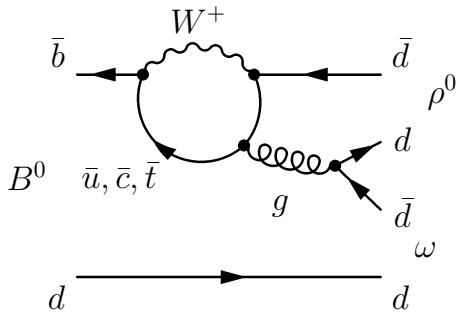
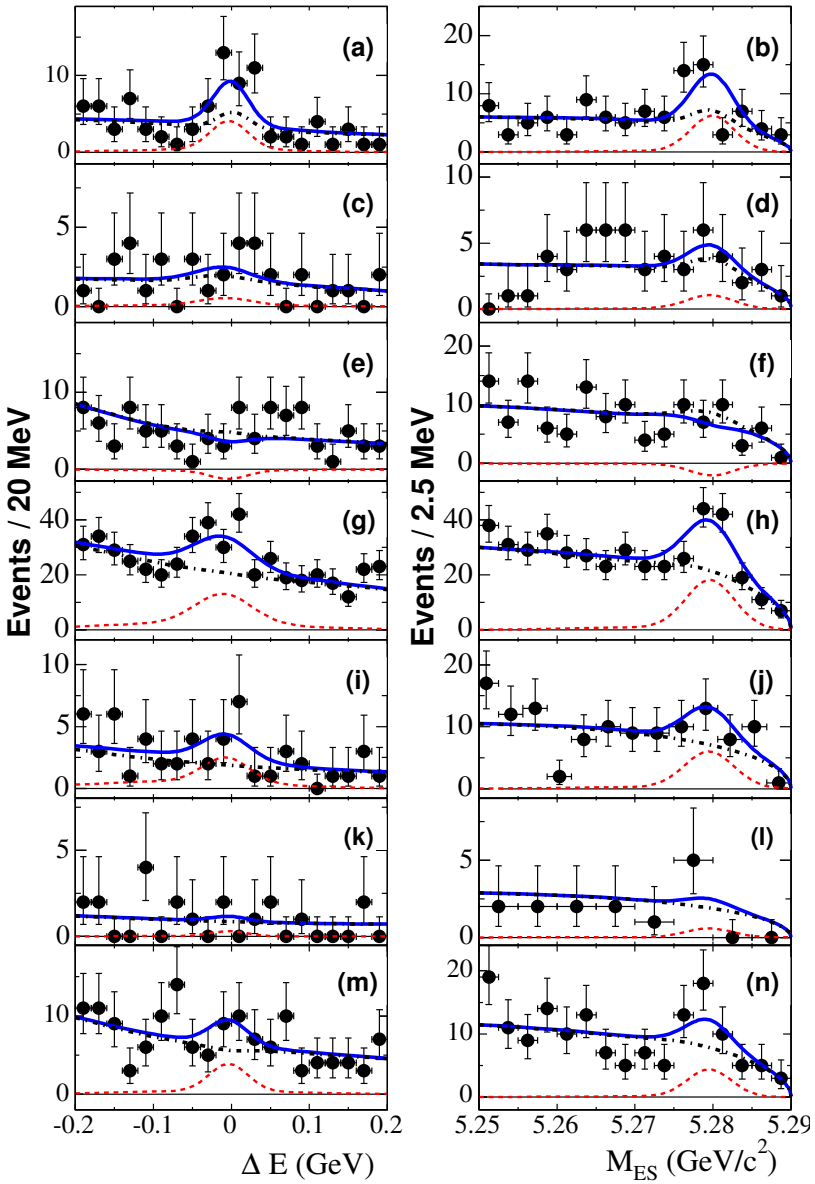


(e)



(f)

$B \to \omega K^*$ and $\omega\rho$

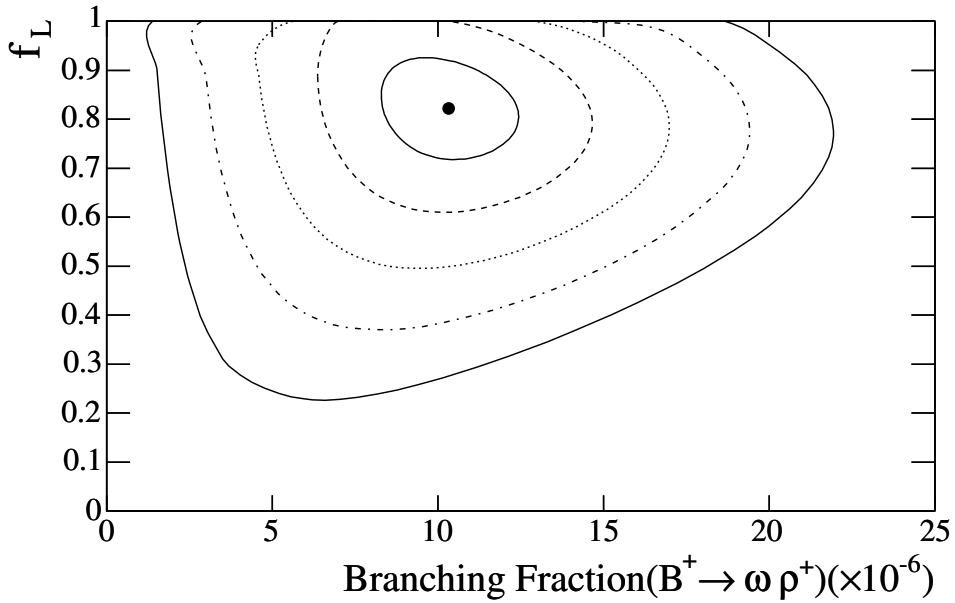


Branching fractions [$\times 10^{-6}$]

[hep-ex/0605017]

$B^0 \to \omega K^{*0}$	< 4.2
$B^+ \to \omega K^{*+}$	< 3.4
$B^0 \to \omega\rho^0$	< 1.5
$B^+ \to \omega\rho^+$	$10.6 \pm 2.1^{+1.6}_{-1.0}$
$B^0 \to \omega\omega$	< 4.0
$B^0 \to \omega\phi$	< 1.2
$B^0 \to \omega f_0$	< 1.5

$B \to \omega\rho$ Polarization

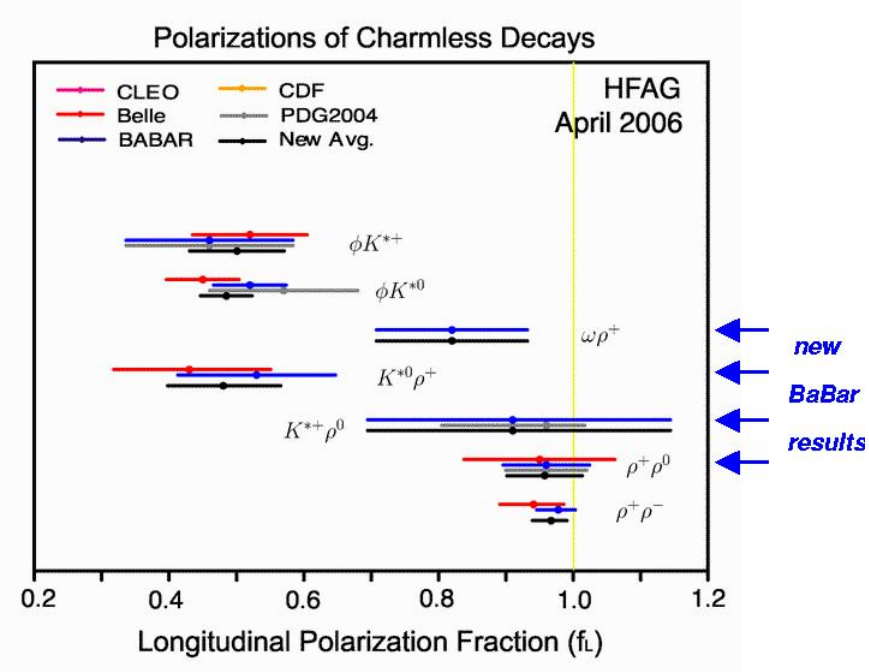


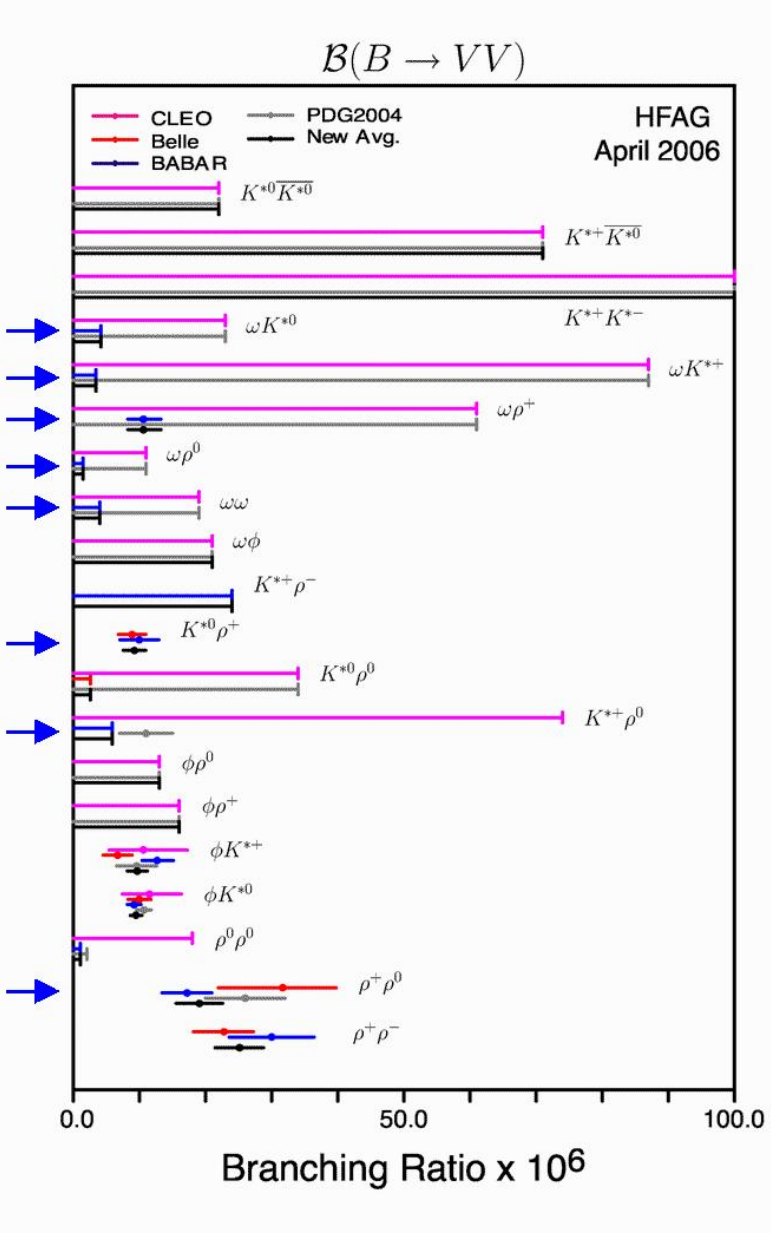
f_L and $\mathcal{A}_{CP}$ [hep-ex/0605017]

	f_L	$\mathcal{A}_{CP}$
$B^+ \to \omega\rho^+$	$0.82 \pm 0.11 \pm 0.02$	$0.04 \pm 0.18 \pm 0.02$

(232 million $B\bar{B}$ decays)

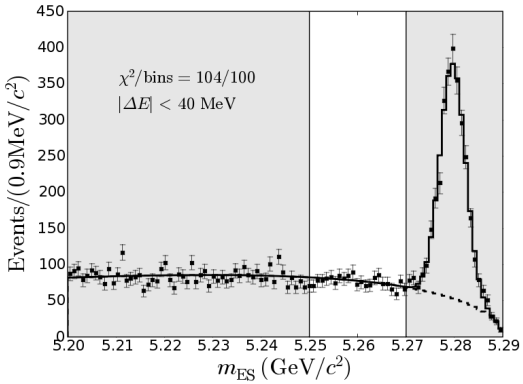
$B \to VV$ Summary

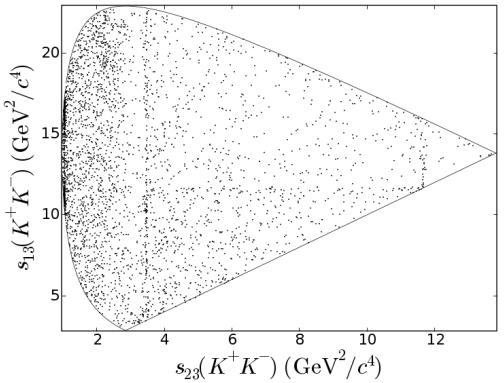


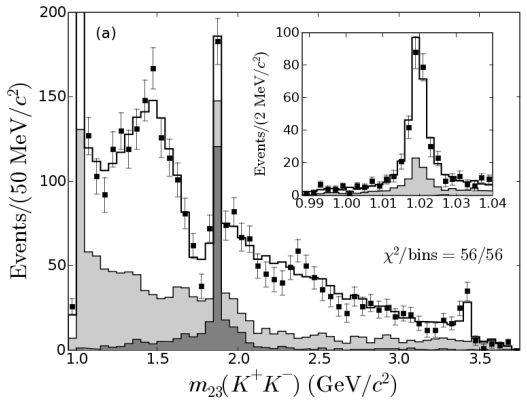


$B \to KKK$ Dalitz Plot Analysis

- K^+K^- S-wave isobar model fit / partial wave analysis:
  - broad scalar resonance at ~ 1.55 GeV
  - nonresonant component
  - $f_0(980)$







Results [hep-ex/0605003]

$$\mathcal{B}(B^\pm \to K^\pm K^\mp K^\pm) = (35.2 \pm 0.9 \pm 1.6) \times 10^{-6}$$
$$\mathcal{A}_{CP} = (-1.7 \pm 2.6 \pm 1.5)\%$$

(226 million $B\bar{B}$ events)

BELLE: $(30.6 \pm 1.2 \pm 1.6) \times 10^{-6}$ $(152 \times 10^6 B\bar{B})$ [PRD 71:092003(2005)]

Other recent results

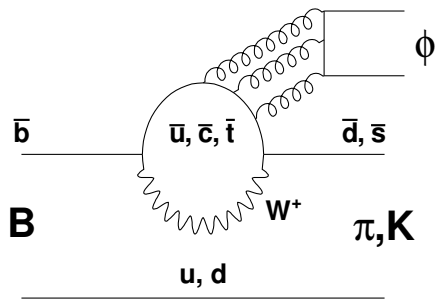
Search for $B^0 \to a_1^{\pm} \rho^{\mp}$ [hep-ex/0605024]

$\mathcal{B}(B^0 \to a_1^{\pm} \rho^{\mp}) < 30 \times 10^{-6}$ (90% UL)
$(a_1^{\pm} \to \pi^+ \pi^- \pi^{\pm})$

(110 million $B\bar{B}$ events)

ARGUS: $< 3.4 \times 10^{-3}$ (90% UL) [PLB 241:278(1990)]

Search for $B \to \phi \pi$ [hep-ex/0605037]



$\mathcal{B}(B^+ \to \phi \pi^+) < 0.24 \times 10^{-6}$
$\mathcal{B}(B^0 \to \phi \pi^0) < 0.28 \times 10^{-6}$

(232 million $B\bar{B}$ events); 90% UL

Conclusions

Many new charmless results since MESON2004 (too many to cover). Selection of most recent results:

- Significant progress on $B \to \eta' K^*/\rho/f_0$ branching fractions
- Many improved measurements in the $B \to VV$ sector
- $B \to KKK$ Dalitz analysis

- *BABAR* now becoming sensitive to branching fractions at the 10^{-7} level
- Expect better muon/K_L efficiency after 2006
- Data sample anticipated to quadruple by 2008