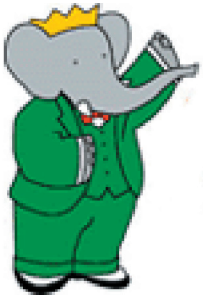

BABAR

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technische universität
dortmund

Charmless Quasi-Two-Body Hadronic B Decays at BaBar

Jesko Merkel, TU Dortmund

MESON2008
7. June 2008

Outline

General Motivation

Analysis Strategy

Recent Results

$B^0 \to \eta K^0$

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

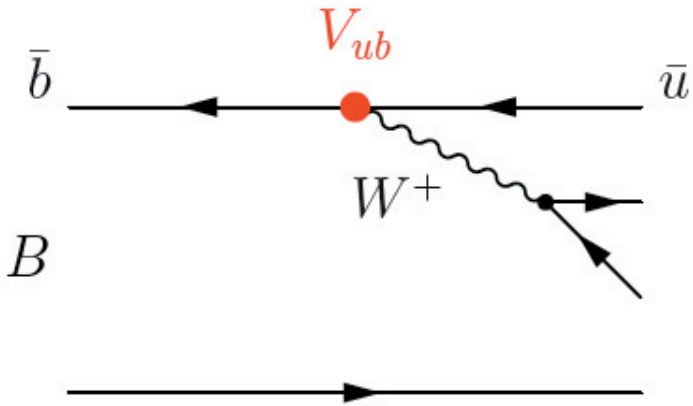
$B \to b_1(\pi, K)$

$B^0 \to b_1^- \rho^+$

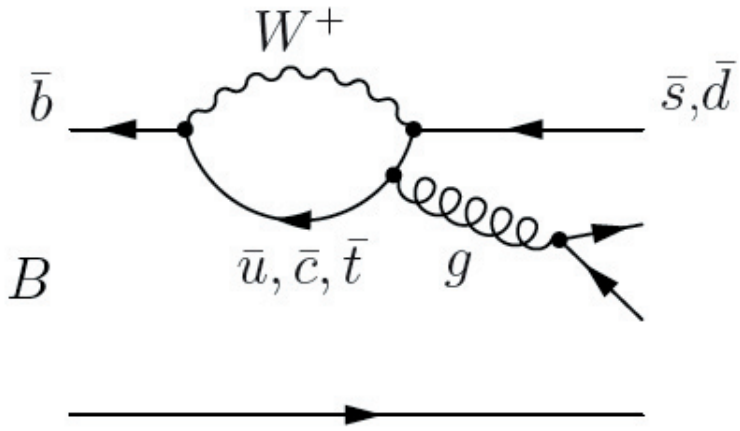
Motivation

General Motivation

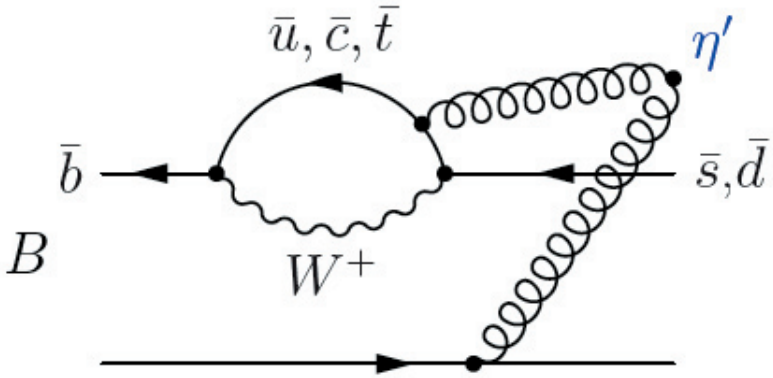
Contributing Amplitudes:
  CKM suppressed trees, penguins, ...



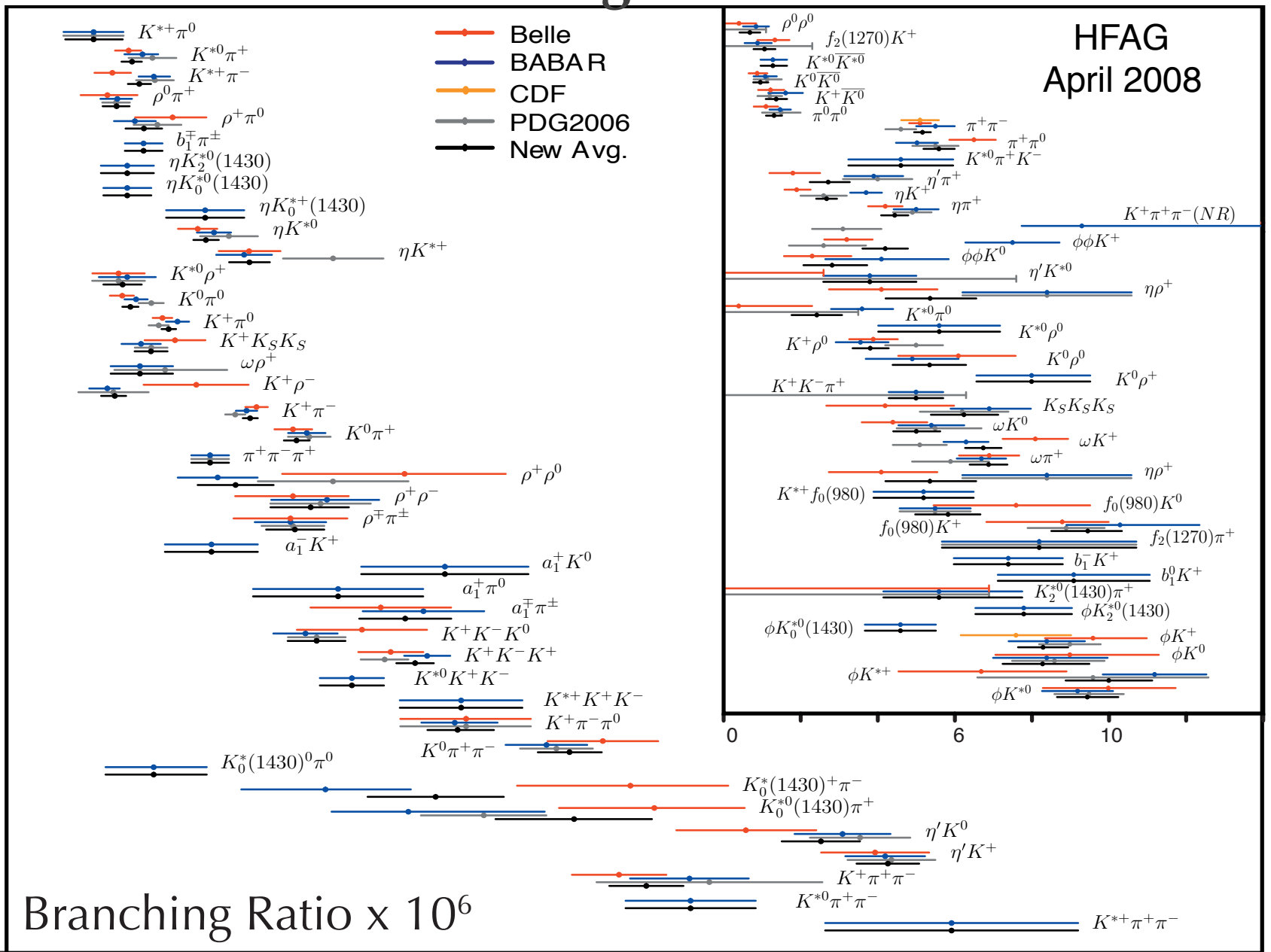
Can be used to study:
  Interfering SM amplitudes
  CP violation
  Effects of new particles in loop
  (window on higher energy scales)



Constrain models



Chamless Mesonic B Branching Fractions



Analysis Strategy

General Analysis Strategy

Find small number of signal events (Small branching fractions ~10^{-6}) in a sea of background events. Challenging Analysis.

Event candidate composition.

Loose event selection (event shape, Particle ID, D-vetos, ...)
[reasonable high number of signal events vs background events].

Maximum Likelihood-Fit (see next slide).

[Fit Validation with toy MC experiments.]

Likelihood Fit

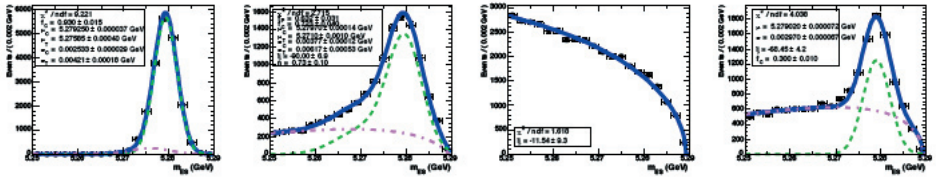
Maximum Likelihood-Fit with components

j = signal, continuum bkg, {charmless bkg, charm bkg, ...}

Discriminating variables $\vec{x}$

event shape variables

$P_j = P_j$ (m_{ES}, ΔE, { $\mathcal{F}$, NN}, resonance masses, helicity,



Modeling Probability Density Functions with MC and sideband data.

[Signal MC, $e^+e^- \to q\bar{q}$ B^+B^- B^0B^0 MC, ...]

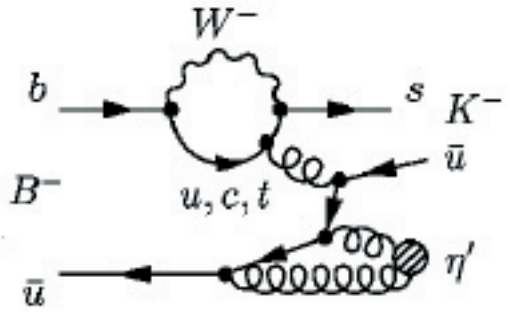
$$\mathcal{L} = \frac{e^{-\sum n_j}}{N!} \prod_{i=1}^{N} \mathcal{L}_i$$

$$\mathcal{L}_i = \sum_j n_j P_j(\vec{x}_i)$$

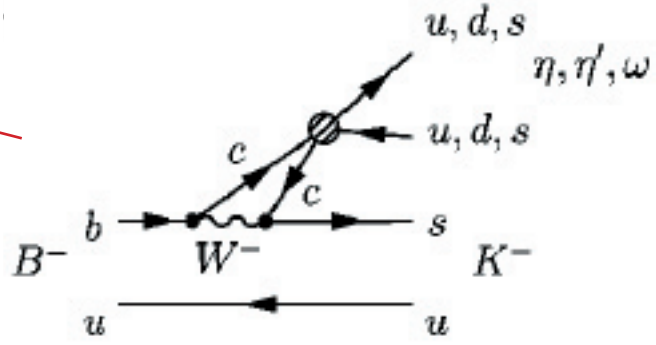
Fit on data to extract branching ratio and polarisation f_L.

Results

$B \to \eta K$ vs $B \to \eta' K$



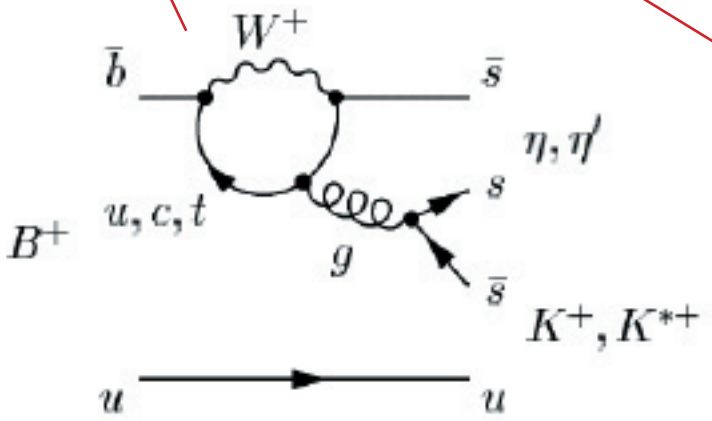
η' strong coupled to gluon and $c\bar{c}$

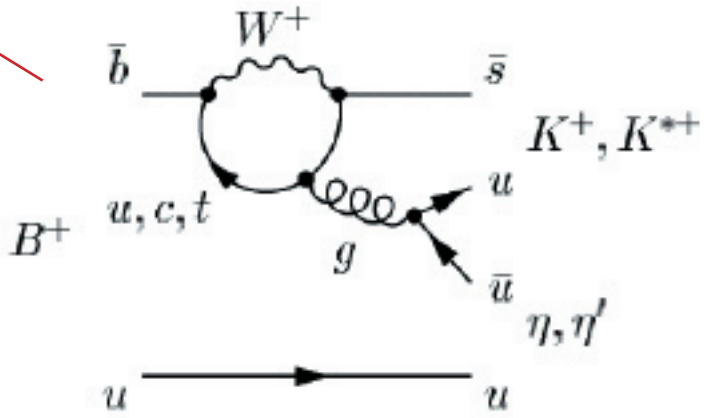


Constructive interference of $gs\bar{s}$ and $gq\bar{q}$

$$\eta' \cong \frac{1}{\sqrt{2}}(\eta_q + \eta_s)$$

$$\eta \cong \frac{1}{\sqrt{2}}(\eta_q - \eta_s)$$





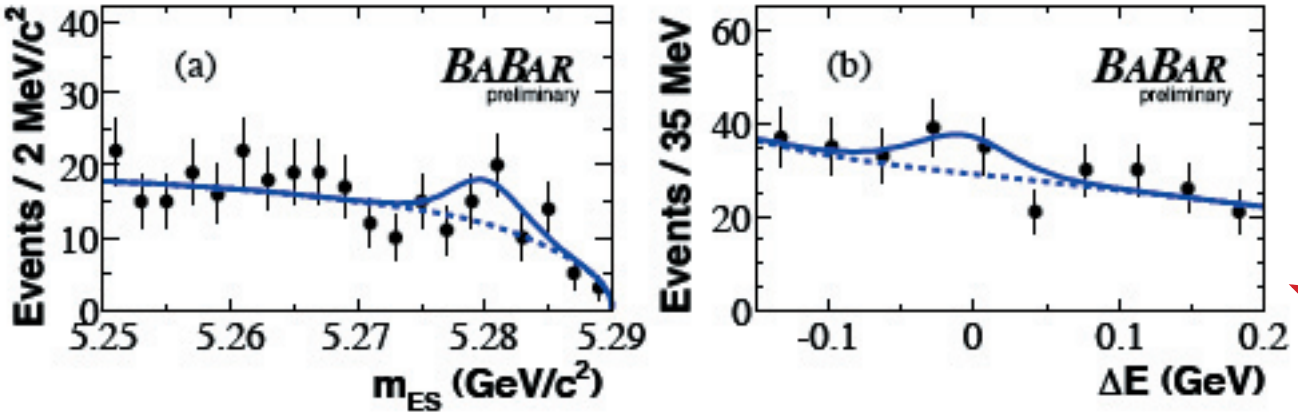
Search for $B^0 \to \eta K^0$

No clear signal found.

465×10^6 $B\overline{B}$

Decay Mode	*BABAR*	Belle	HFAG average
ηK^0	< 1.6	< 1.9	< 1.9
ηK^+	$3.7 \pm 0.4 \pm 0.1$	$1.9 \pm 0.3^{+0.2}_{-0.1}$	2.7 ± 0.3
$\eta' K^0$	$66.6 \pm 2.6 \pm 2.8$	$58.9^{+3.6}_{-3.5} \pm 4.3$	64.9 ± 3.1
$\eta' K^+$	$70.0 \pm 1.5 \pm 2.8$	$69.2 \pm 2.2 \pm 3.7$	70.2 ± 2.5

x 10^{-6}



$B^0 \to \eta K^0$

$B \to (\eta,\ \eta')\ (K^{(*)},\ \pi,\ \rho)$ Picture

$\eta K << \eta' K$

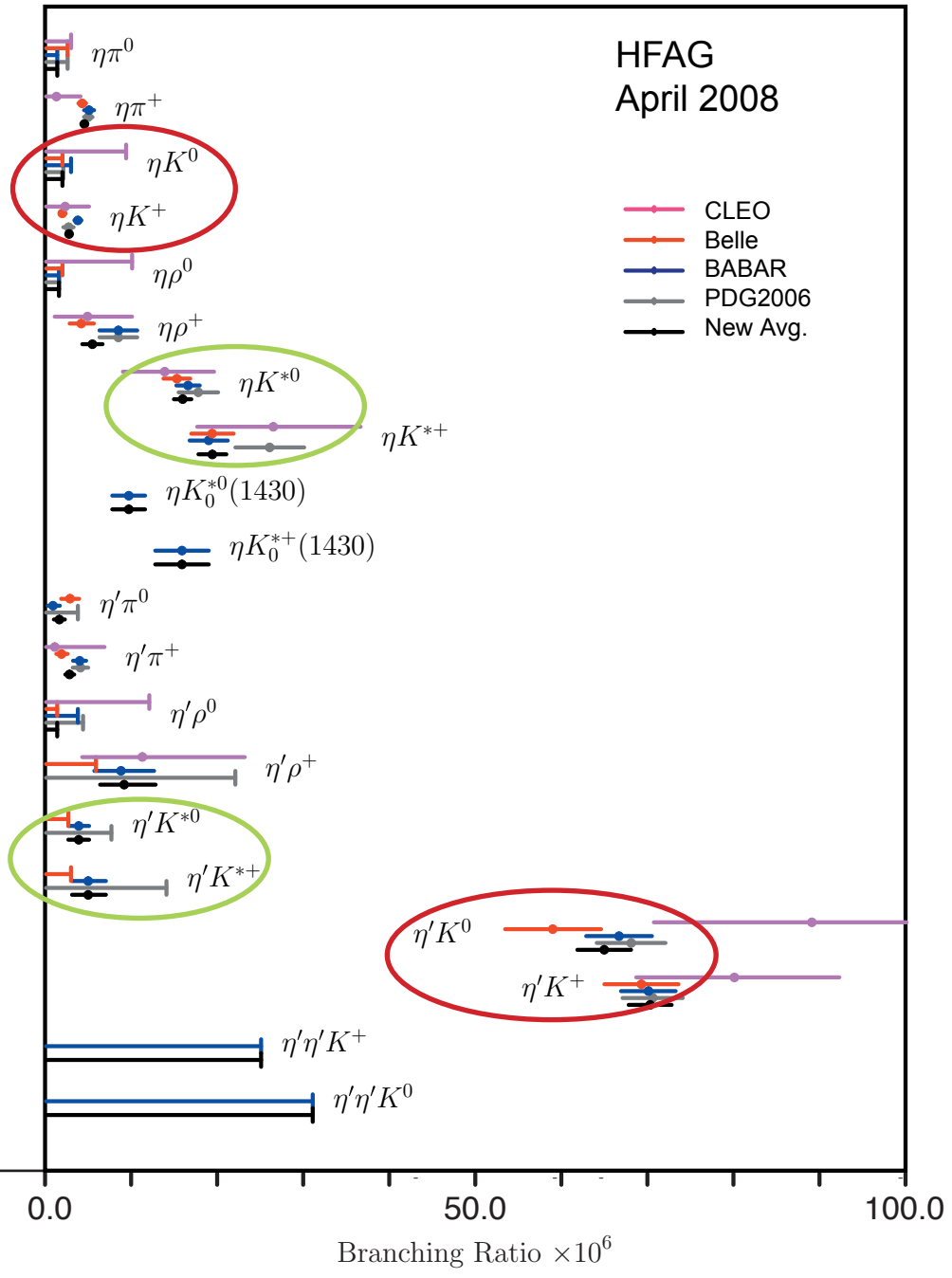
Consistent with interference of $gs\bar{s}$ and $gq\bar{q}$.

$\eta K^* >> \eta' K^*$

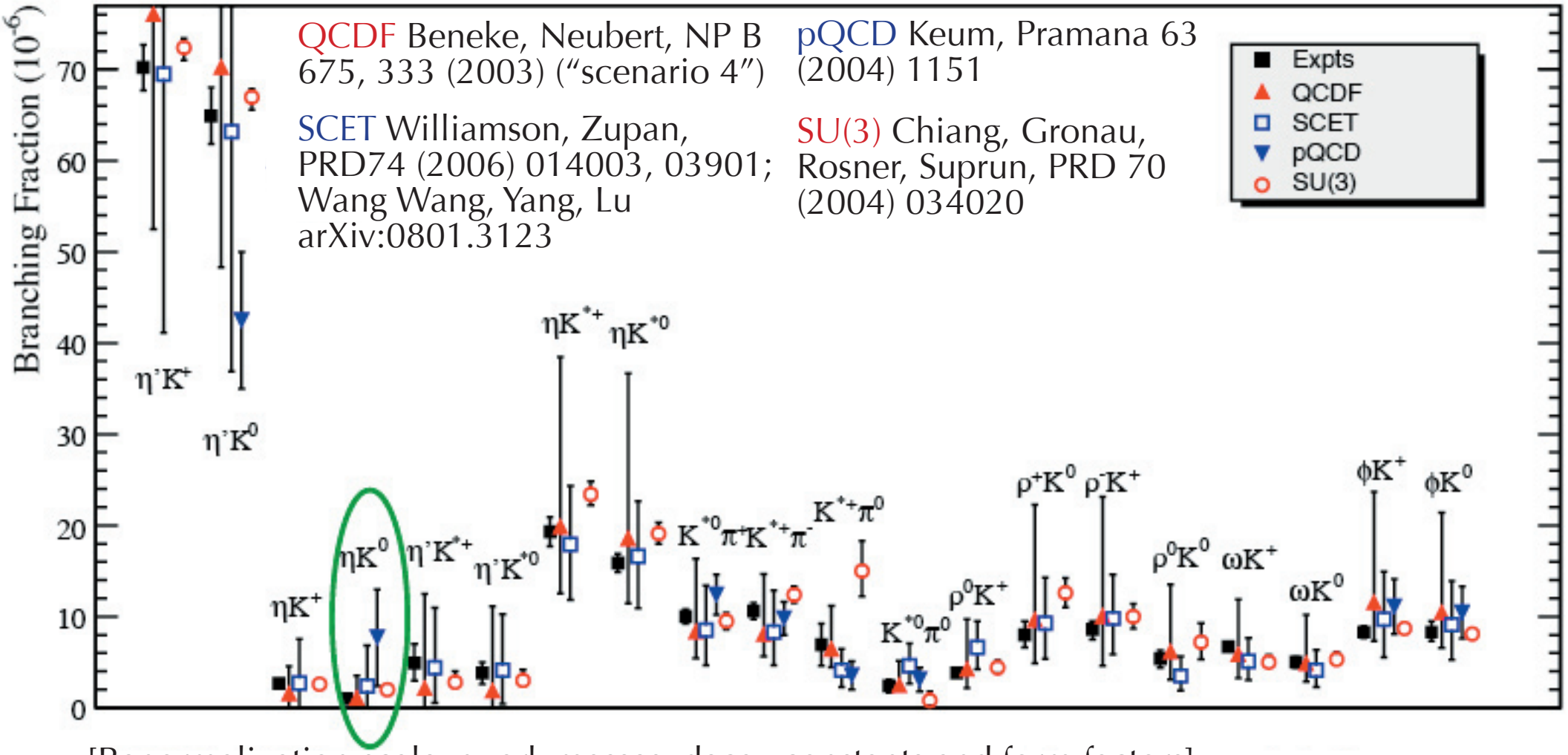
Consistent with interference of $gs\bar{s}$ and $gq\bar{q}$ if there is a sign flip for P-V decays.

Modes are estimated from theory with fits to data for poorly known parameters.

$\mathcal{B}(B \to (\eta,\ \eta')\ (K^{(*)},\ \pi,\ \rho))$



Theorie vs Experiment



[Renormalization scale, quark masses, decay constants and form factors]

[QCDFactorization; pertubativeQCD; SoftCollinearEffectiveTheory; flavour SU(3) relations]

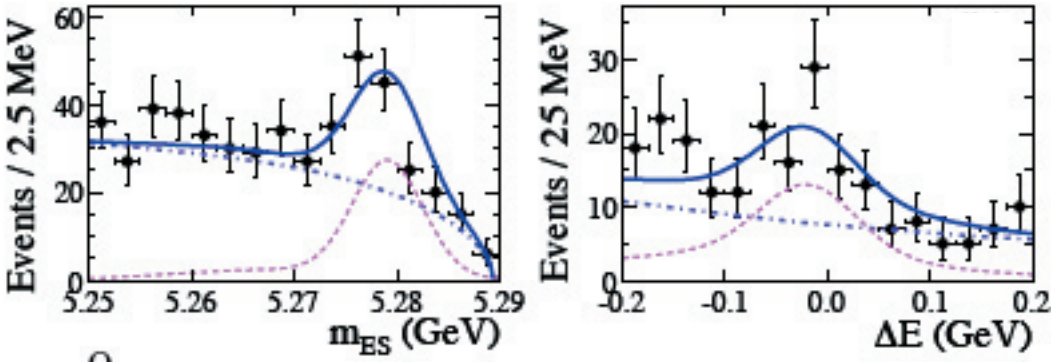
Observation of $B^+ \to \eta\rho^+$ (P-V decay)

$$\mathcal{B}(B^+ \to \eta\rho^+) = (9.9 \pm 1.2 \pm 0.8) \times 10^{-6}$$
$$\mathcal{A}_{ch} = 0.13 \pm 0.11 \pm 0.02$$

459×10^6 $B\overline{B}$

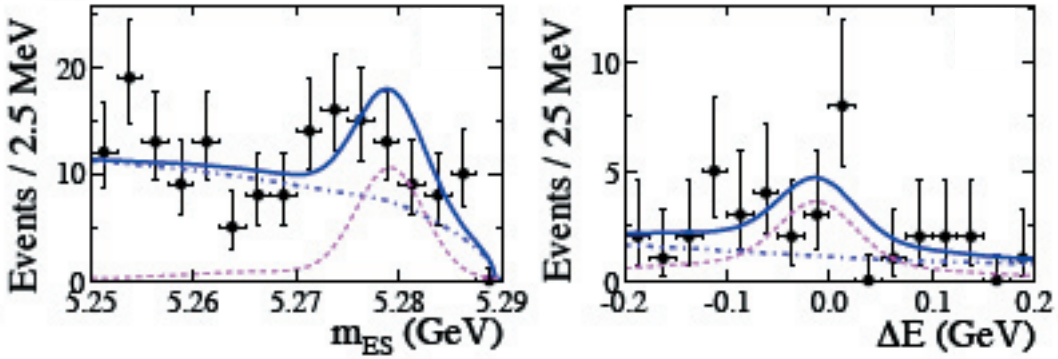
$$\mathcal{A}_{ch} \equiv (\Gamma^- - \Gamma^+)/(\Gamma^- + \Gamma^+)$$

$\eta \to \gamma\gamma$



326^{+44}_{-42} events

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



23^{+27}_{-26} events

Axial-Vector Mesons

$q\bar{q}$ - light quark model

$n\,^{2s+1}\ell_J$	J^{PC}	I = 1 $u\bar{d}$, $\bar{u}d$, $\frac{1}{\sqrt{2}}(d\bar{d}-u\bar{u})$	I = $\frac{1}{2}$ $u\bar{s}$, $d\bar{s}$; $\bar{d}s$, $-\bar{u}s$	I = 0 f'	I = 0 f
$1\,^1S_0$	0^{-+}	π	K	η	$\eta'(958)$
$1\,^3S_1$	1^{--}	$\rho(770)$	$K^*(892)$	$\phi(1020)$	$\omega(782)$
$1\,^1P_1$	1^{+-}	$b_1(1235)$	$K_{1B}{}^\dagger$	$h_1(1380)$	$h_1(1170)$
$1\,^3P_0$	0^{++}	$a_0(1450)$	$K_0^*(1430)$	$f_0(1710)$	$f_0(1370)$
$1\,^3P_1$	1^{++}	$a_1(1260)$	$K_{1A}{}^\dagger$	$f_1(1420)$	$f_1(1285)$

$b_1(1235)$ dominat decay through $\omega\pi$

$$\mathcal{B}(B^0 \to a_1^{\mp}\pi^{\pm}) = (33.2 \pm 3.8 \pm 3.0) \times 10^{-6}$$
$$= (29.8 \pm 3.2 \pm 4.6) \times 10^{-6}$$
$$\mathcal{B}(B^0 \to a_1^{-}K^{+}) = (8.2 \pm 1.5 \pm 1.2) \times 10^{-6}\ (5.1\sigma)$$
$$\mathcal{B}(B^{+} \to a_1^{+}K^{0}) = (17.4 \pm 2.5 \pm 2.2) \times 10^{-6}\ (6.2\sigma)$$

BaBar, PRL 97, 151802 (2006)
Belle, arXiv:0706.3276

BaBar, PRL 100, 051803 (2008)

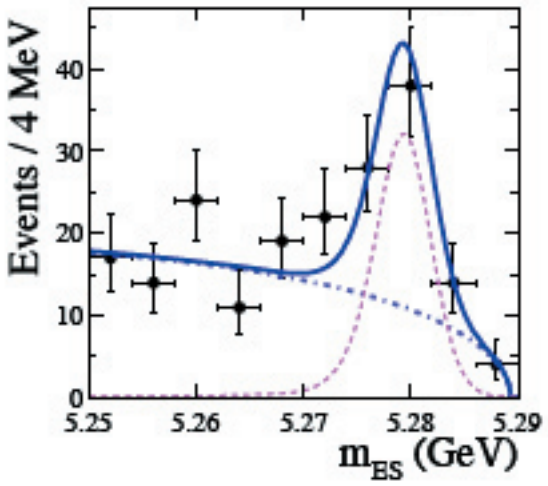
New measurment of $B \to b_1(\pi, K)$

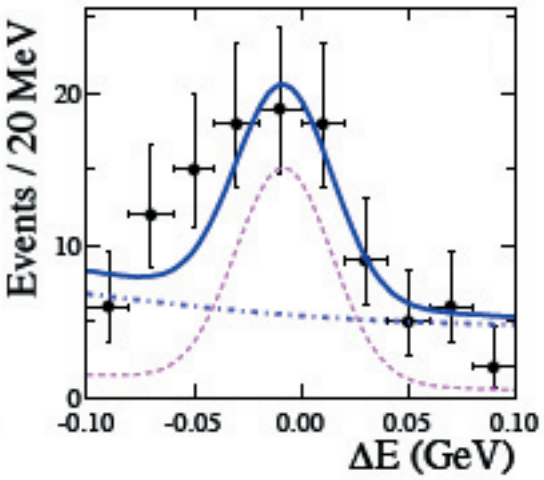
Clear observation

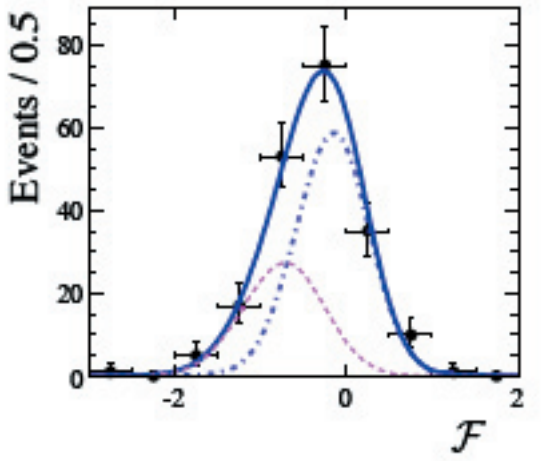
Mode	N (ev.)	Y_S (ev.)	Bias (ev.)	ϵ (%)	$\mathcal{S}$ (σ)	$\mathcal{B}$ (10^{-6})	$\mathcal{A}_{ch}$
$b_1^+ K^0$	9841	164^{+27}_{-25}	15±7	3.4	6.3	$9.6 \pm 1.7 \pm 0.9$	$-0.03 \pm 0.15 \pm 0.02$
$b_1^0 K^0$	5420	58^{+19}_{-17}	5±3	2.2	3.4	$5.1 \pm 1.8 \pm 0.5$ (< 7.8)	
$b_1^+ \pi^0$	28787	71^{+35}_{-32}	8±4	7.7	1.6	$1.8 \pm 0.9 \pm 0.2$ (< 3.3)	
$b_1^0 \pi^0$	10554	6^{+19}_{-16}	−2±2	4.8	0.5	$0.4 \pm 0.8 \pm 0.2$ (< 1.9)	

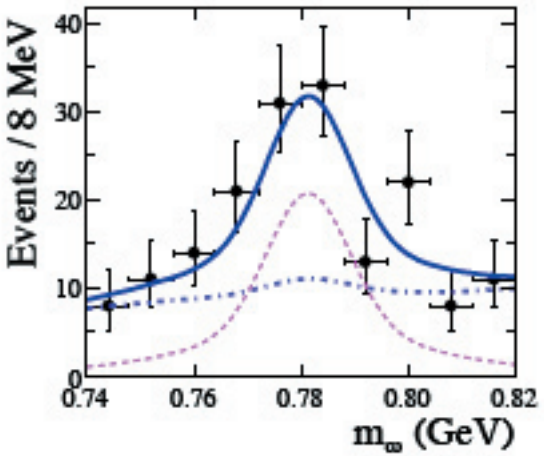
Evidence

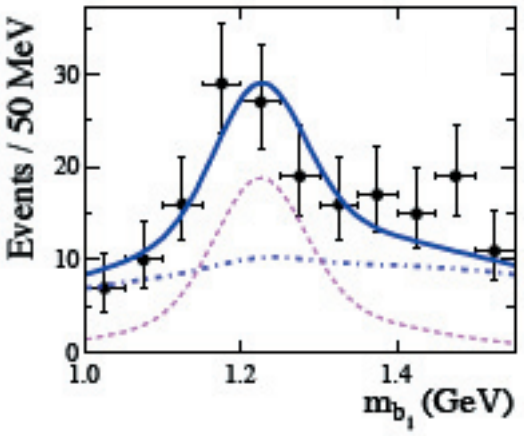
465×10^6 $B\overline{B}$











Compare with Theory

$\mathcal{B}$ $[10^{-6}]$ mode	Laporta *et al.* $\theta = 32°$	Laporta *et al.* $\theta = 58°$	Calderon *et al.*	Cheng&Yang	*BABAR*
$B^+ \to b_1^+ K^0$	30.0	3.0	41.5	14.0	$9.6 \pm 1.7 \pm 0.9$
$B^0 \to b_1^0 K^0$	41.0	4.0	19.3	7.3	< 7.8
$B^+ \to b_1^+ \pi^0$	4.8	0.5	0.3	0.4	< 3.3
$B^0 \to b_1^0 \pi^0$	0.5	0.01	0.15	1.1	< 1.9

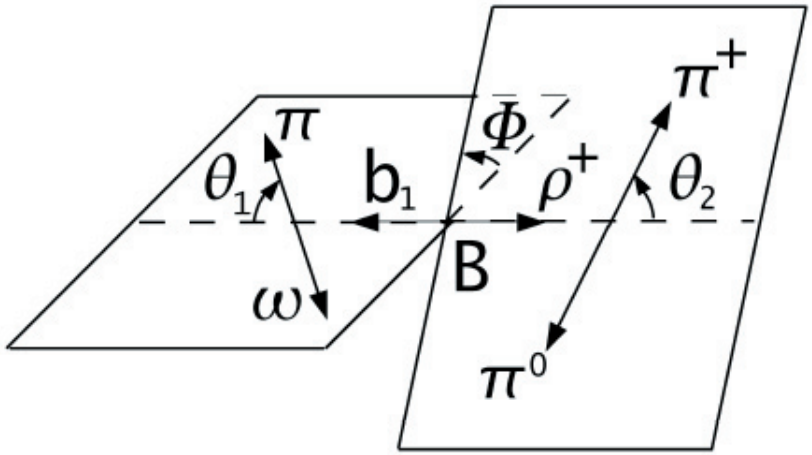
$$K_1(1270) = K_{1A}\sin\theta + K_{1B}\cos\theta$$
$$K_1(1400) = K_{1A}\cos\theta - K_{1B}\sin\theta$$

K_{1A} and K_{1B} are non-mass eigenstate strange partner of a_1 and b_1.

V. Laporta, G. Nardulli, and T.N. Pham, Phys. Rev. D **74**, 054035 (2006) [hep-ph/0602243]; *op cit.* Phys. Rev. D **76**, 079903(E) (2007); G. Calderon, J.H. Munoz, C.E. Vera, Phys. Rev. D **76**, 094019 (2007).

H.-Y. Cheng and K.-C. Yang, Phys. Rev. D **76**, 114020 (2007).

Polarization in V-A decays



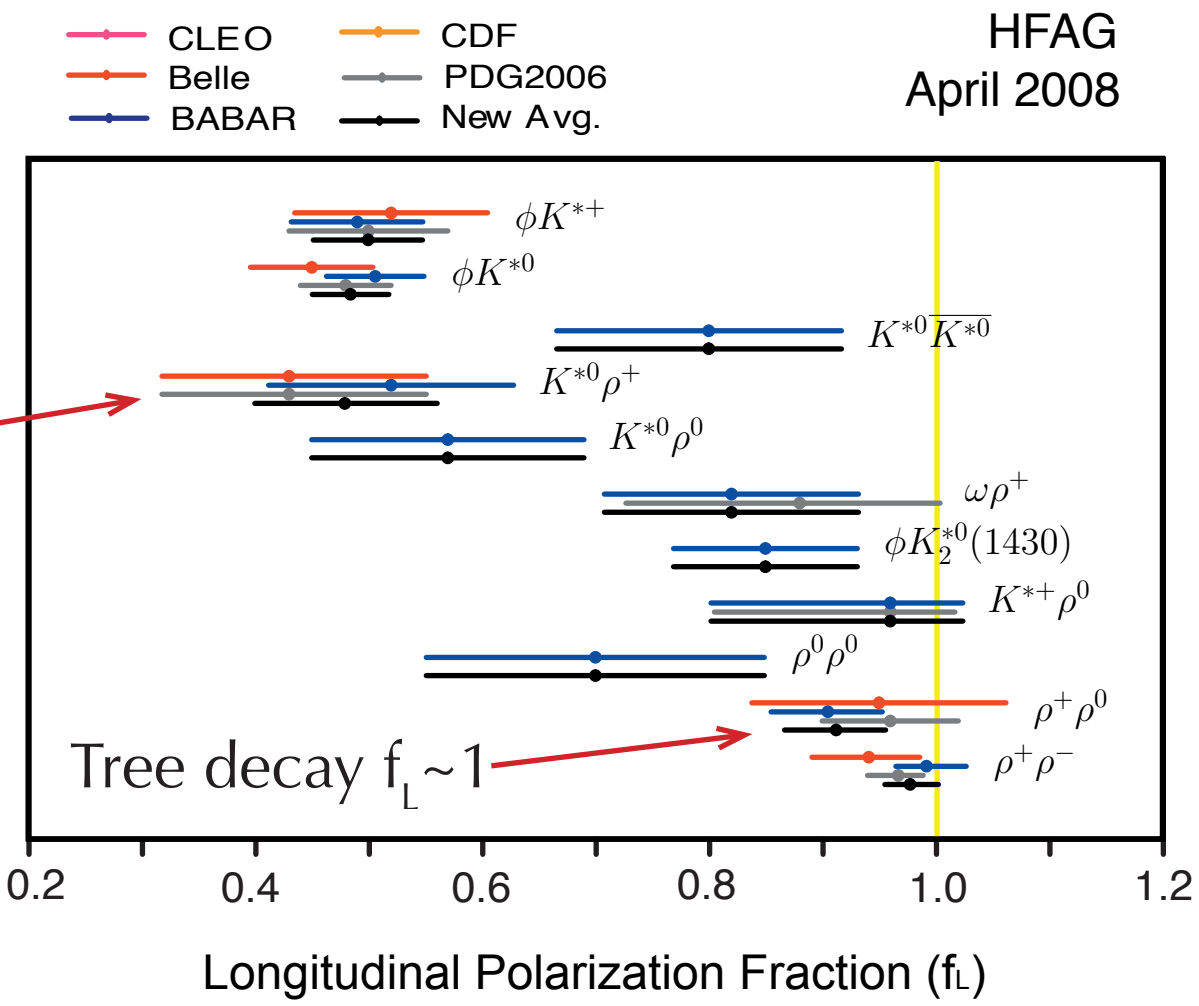
$$f_L \equiv A_0^2 / \sum_{i=-1}^{1} |A_i|^2$$

Helicity Amplitudes
longitudinal: A_0
transverse: A_{-1}, A_{+1}

Naive prediction: $1-f_L \sim O(1/m_b^2)$

Unexpected small f_L for penguin dominated modes.

Evidence for new physics?



Theory Predictions

Cheng & Yang 2008
[arXiv:0805.0329]

New experimental search at BaBar.

Prediction is about 3 x

$$\mathcal{B}(B^0 \to b_1^{\mp}\pi^{\pm}) = 10.9 \pm 1.2 \pm 0.9$$

PRL 99, 241803 (2007), 385M $B\bar{B}$ x 10^{-6}

Mode	$\mathcal{B}$ $[10^{-6}]$	f_L
$\overline{B}^0 \to b_1^+\rho^-$	$32.1^{+16.5+12.0}_{-14.7-\ 4.7}$	$(0.96^{+0.01}_{-0.02})$
$\overline{B}^0 \to b_1^-\rho^+$	$0.6^{+0.6+1.8}_{-0.3-0.2}$	$(0.98^{+0.00}_{-0.32})$
$\overline{B}^0 \to b_1^0\rho^0$	$0.4^{+0.4+21.3}_{-0.2-0}$	$(0.82^{+0.16}_{-0.51})$
$B^- \to b_1^0\rho^-$	$29.0^{+16.2+5.4}_{-10.6-5.8}$	$(0.96^{+0.01}_{-0.06})$
$B^- \to b_1^-\rho^0$	$0.9^{+1.7+2.6}_{-0.6-0.5}$	$(0.90^{+0.06}_{-0.33})$
$\overline{B}^0 \to b_1^0\omega$	$0.1^{+0.2+1.4}_{-0.0-0.0}$	$(0.10^{+1.04}_{-0.01})$
$B^- \to b_1^-\omega$	$0.9^{+1.4+2.7}_{-0.5-0.3}$	$(0.91^{+0.07}_{-0.33})$
$\overline{B}^0 \to b_1^0\phi$	$0.01^{+0.01+0.01}_{-0.00-0.00}$	$(0.98^{+0.01}_{-0.33})$
$B^- \to b_1^-\phi$	$0.02^{+0.02+0.03}_{-0.01-0.00}$	$(0.98^{+0.01}_{-0.33})$
$\overline{B}^0 \to b_1^+K^{*-}$	$7.6^{+3.3+40.7}_{-2.4-\ 7.1}$	$(0.71^{+0.17}_{-0.66})$
$\overline{B}^0 \to b_1^0\overline{K}^{*0}$	$3.0^{+1.1+4.6}_{-0.7-2.1}$	$(0.80^{+0.20}_{-0.70})$
$B^- \to b_1^-\overline{K}^{*0}$	$12.1^{+4.4+21.2}_{-3.2-\ 2.7}$	$(0.80^{+0.20}_{-0.70})$
$B^- \to b_1^0K^{*-}$	$6.8^{+2.4+12.5}_{-1.8-\ 4.4}$	$(0.84^{+0.15}_{-0.29})$

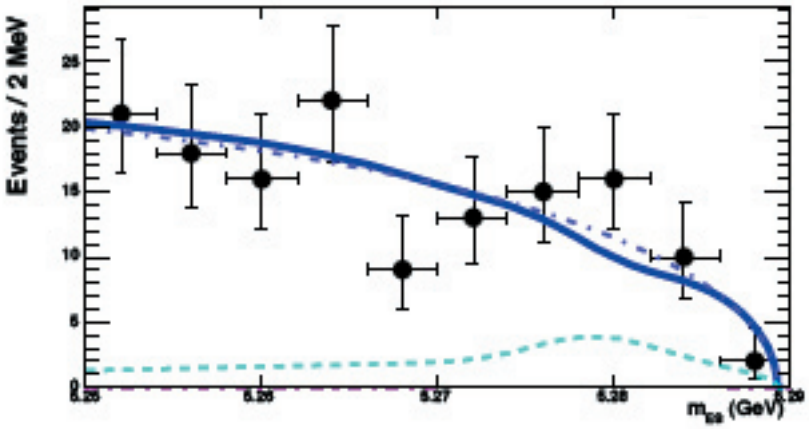
Search for $B^0 \to b_1^- \rho^+$

$465 \times 10^6 \; B\overline{B}$

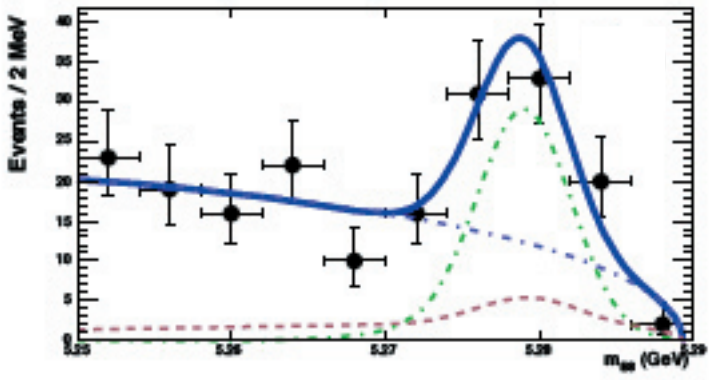
$$\mathcal{B}(B^0 \to b_1^{\mp} \rho^{\pm}) = (-0.1 \pm 0.9 \pm 0.7) \times 10^{-6}$$
$$(< 1.7 \times 10^{-6}, \; 90\% \text{ C.L.})$$

No Signal found.

Puzzling lack of agreement with the theoretical estimation.



Added 100 signal MC events



Conclusion

General analysis strategy for rare charmless B decays.

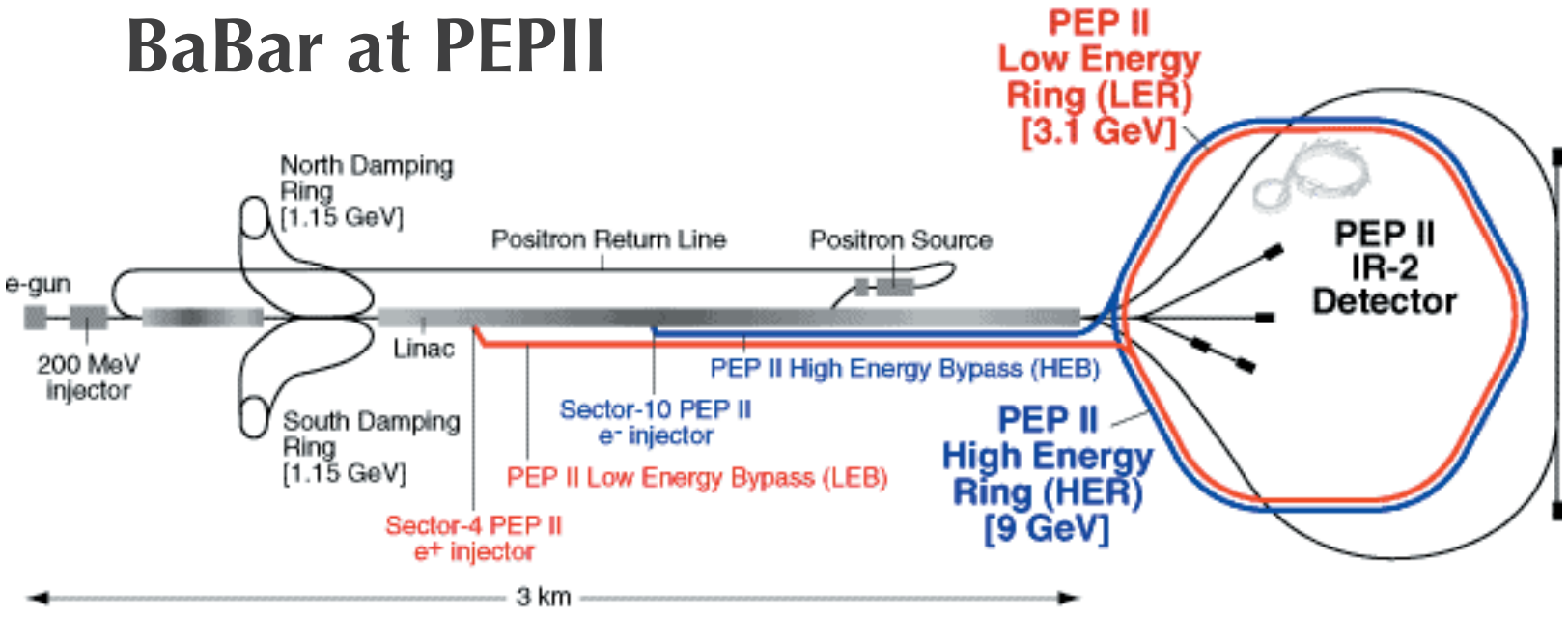
Search for $B^0 \to \eta K^0$

Observation of $B^+ \to \eta \rho^+$

New analysis with decays involving axial-vectors.
Prediction good for A-P modes. But where are the A-V modes?

BACKUP SLIDES

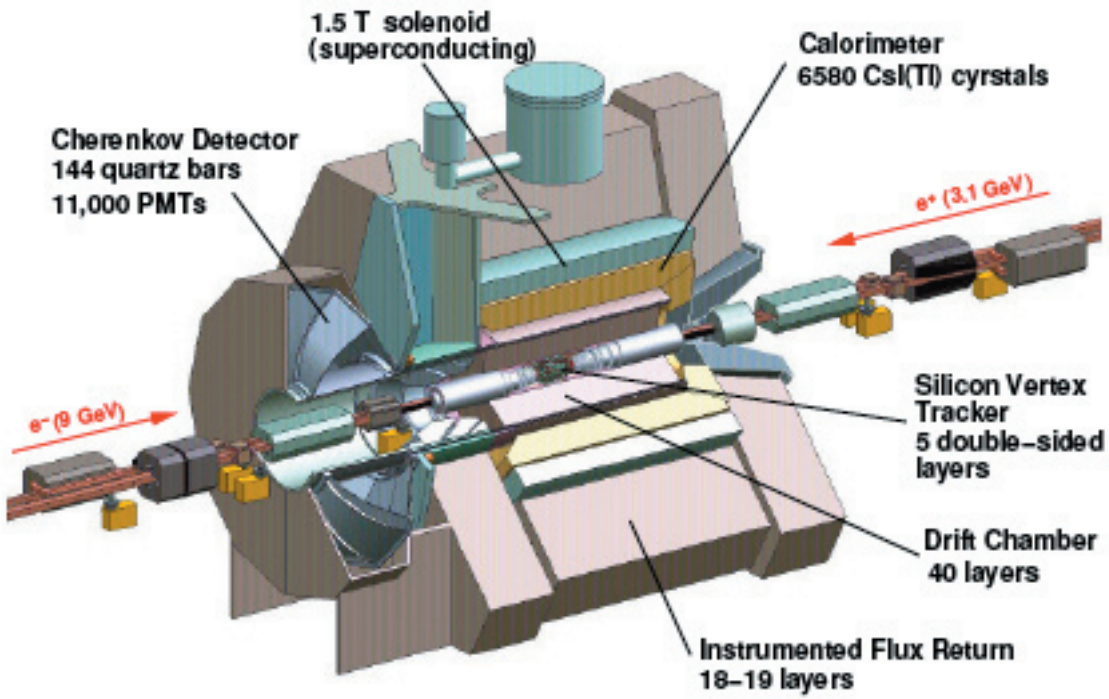
BaBar at PEPII



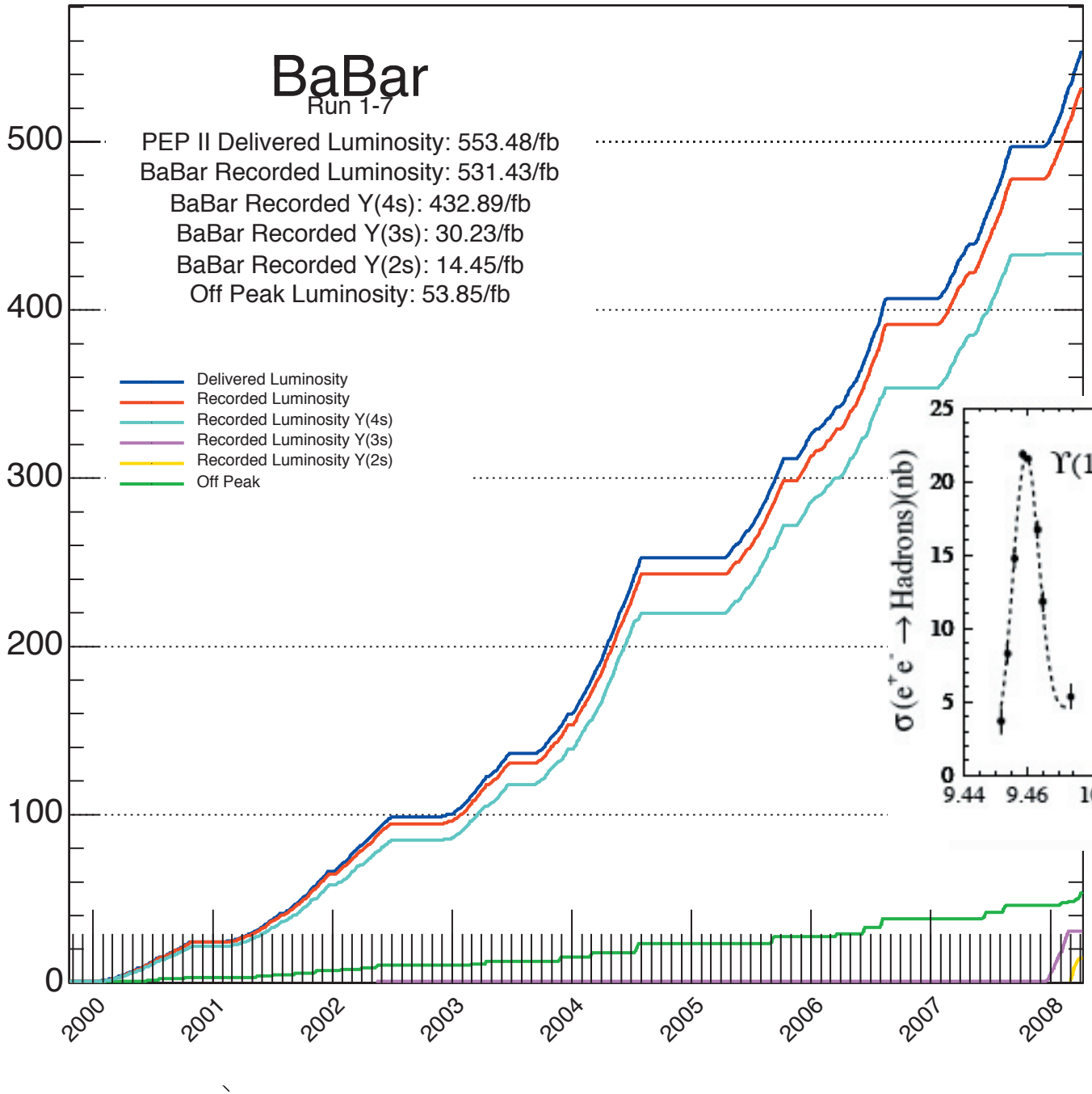
Asymmetric beam energies

$$9\,\mathrm{GeV}\ e^- \times 3.1\,\mathrm{GeV}\ e^+$$

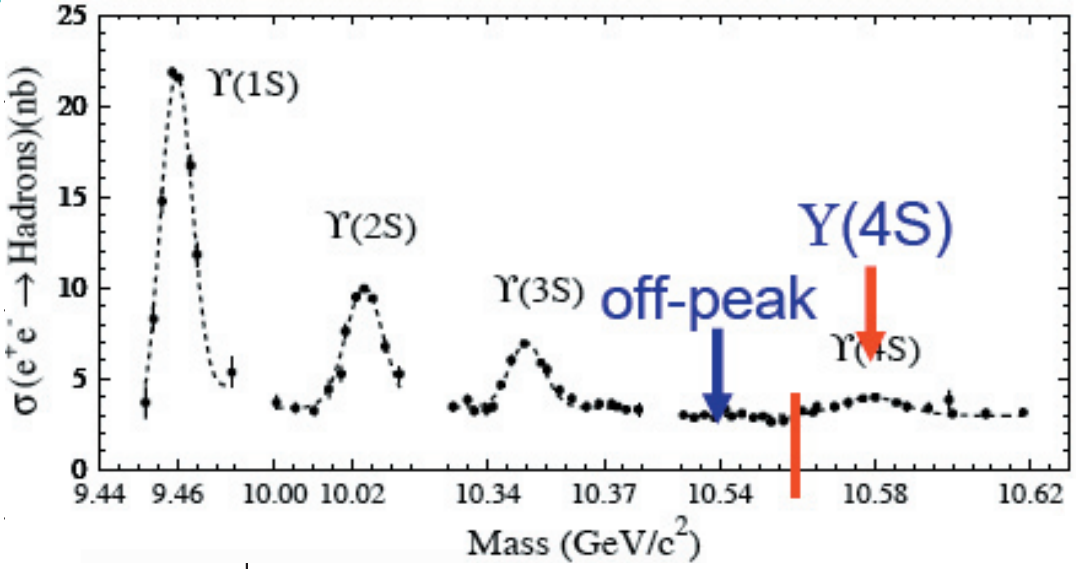
$$e^+e^- \to \Upsilon(4S) \to B\bar{B}$$



PEPII BaBar Luminosity



Integrated Luminosity [fb^{-1}]



Background/Signal

Larges background from $e^+e^- \rightarrow q\bar{q}$

Kinematic Variables m_{ES} and ΔE

Event shape for background suppression.