Measurements of Charmless B Decays related to α @ BaBar

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On behalf of the BaBar Collaboration

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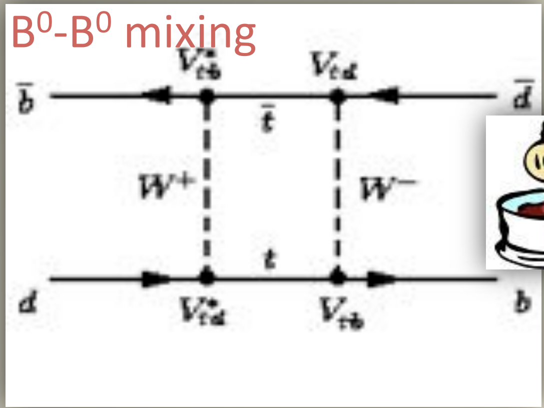
Outline

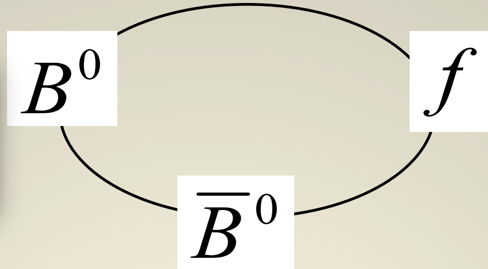
- **Improved Measurements of $B^+ \to \rho^+\rho^0$**
  Determination of the Quark-Mixing Phase α in $B \to \rho\rho$

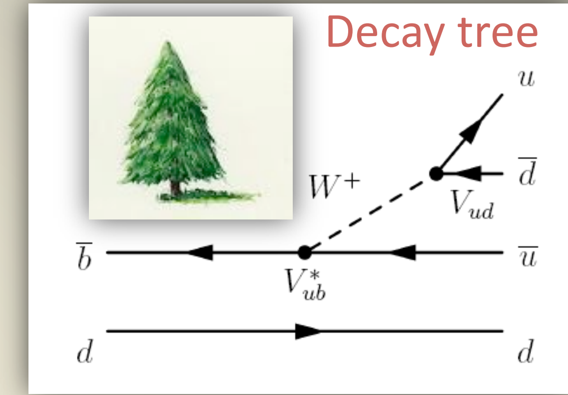
- **Measurement of B decays to $K_1(1270)\,\pi$ and $K_1(1400)\,\pi$**
  Observation of the neutral modes
  Extraction of CKM angle α from the measurement B^0 to $a_1(1260)\,\pi$

- **Measurement of Branching Fraction of B^0 to $a_1(1260)^+\,a_1(1260)^-$**
  First Observation of this decay mode
  First polarization measurement of $B \to AA$
  In principle this mode can be used to measure α

Measuring α_{eff}



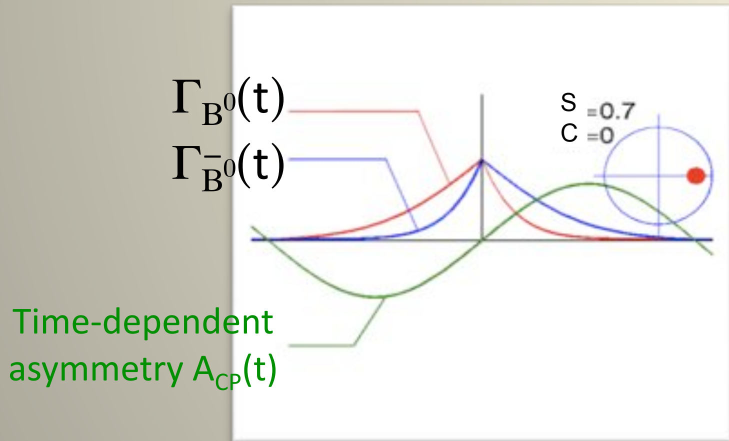




If f is a CP eigenstate ($\pi^+\pi^-$ for instance) and **if** only one CKM amplitude contributes to the decay:

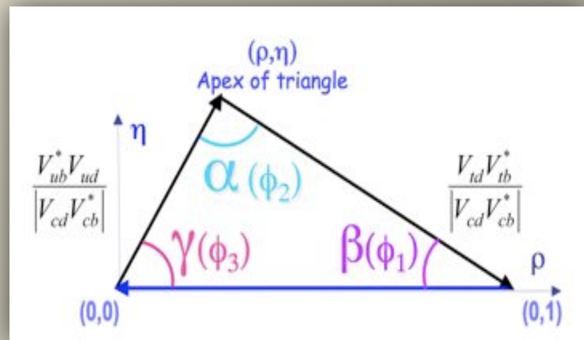
$$a_{CP}(t) \equiv \frac{\Gamma(\overline{B}^0(t) \to \pi^+\pi^-) - \Gamma(B^0(t) \to \pi^+\pi^-)}{\Gamma(\overline{B}^0(t) \to \pi^+\pi^-) + \Gamma(B^0(t) \to \pi^+\pi^-)}$$

$$= S \sin(\Delta m_d t) - C \cos(\Delta m_d t)$$

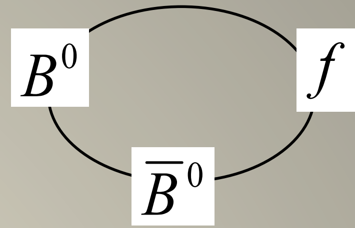


$S=\sin(2\alpha)$, $C=0$

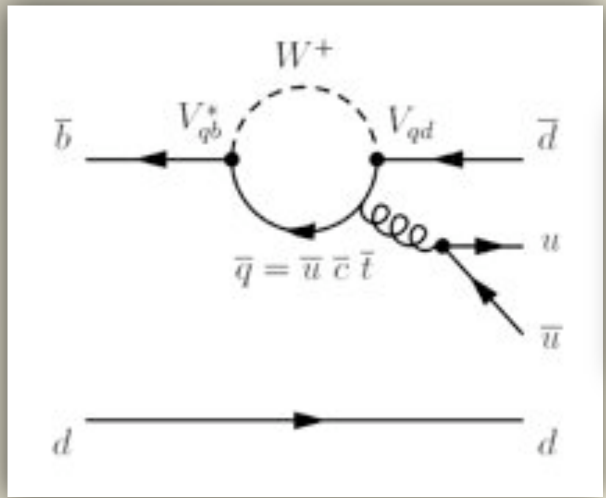
$$S = \frac{2\,\mathrm{Im}\,\lambda}{1+|\lambda|^2} \quad C = \frac{1-|\lambda|^2}{1+|\lambda|^2} \quad \lambda = \frac{q}{p}\frac{\overline{A}}{A} = e^{-i2\beta}e^{-i2\gamma} = e^{i2\alpha}$$

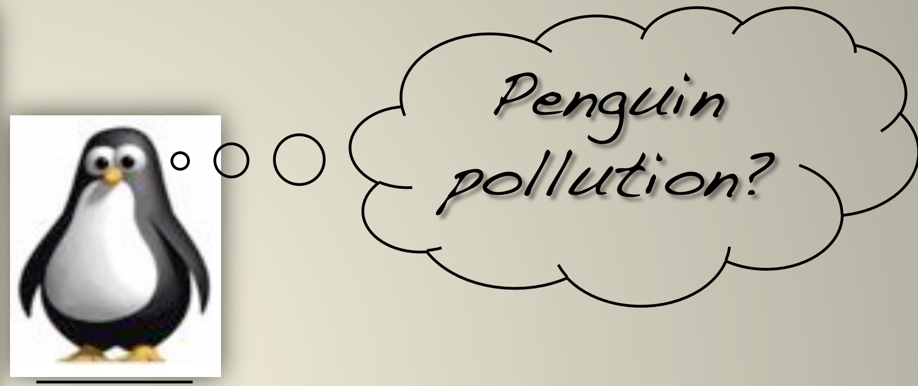


Measuring α_{eff}



In fact there are additional diagrams with a different CKM phase information...





$$\lambda = \frac{q}{p}\frac{\bar{A}}{A} = e^{i2\alpha} \rightarrow e^{i2\alpha}\frac{1+\frac{P}{T}e^{+i\gamma}e^{i\delta}}{1+\frac{P}{T}e^{-i\gamma}e^{i\delta}}$$

(P) Penguin amplitude

(δ) strong phase

(T) Tree amplitude

$$S = \sqrt{1-C^2}\,\sin(2\alpha_{eff})$$

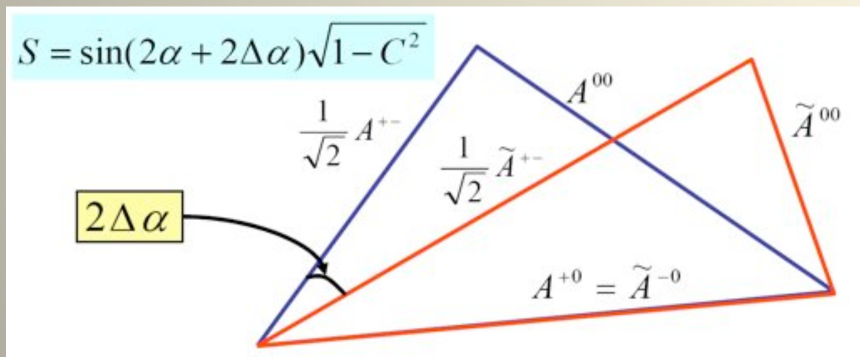
$$C \propto \sin\delta$$

α_{eff} is an effective value of α

Extraction of the angle α of the UT

- The difficulty in extracting α is the presence of subleading penguin amplitudes with a different weak phase than that of the dominat tree amplitudes.
- This difficulty can be overcome by using symmetries:
  - **isospin SU(2)** *Gronau, London PRL 65, 3381 (1990), Gronau, Zupan PRD 71, 074017 (2005)*
  - **approx. flavour SU(3)** *Dighe, Gronau, Rosner PRD 57, 1783 (1998), Beneke et al., PLB 638, 68 (2006)*

SU(2)



Neglecting EW penguins, ±0 is a pure tree mode, and so the two triangles share a common side:

$$A(B^+ \to h^+ h^0) = \tilde{A}(B^- \to h^- h^0)$$

$$A_{hh} = e^{+i\gamma} T + e^{-i\beta} P$$

$$\tilde{A}_{hh} = e^{-i\gamma} T + e^{+i\beta} P$$

$h = \pi, \rho, a_1$

SU(3)

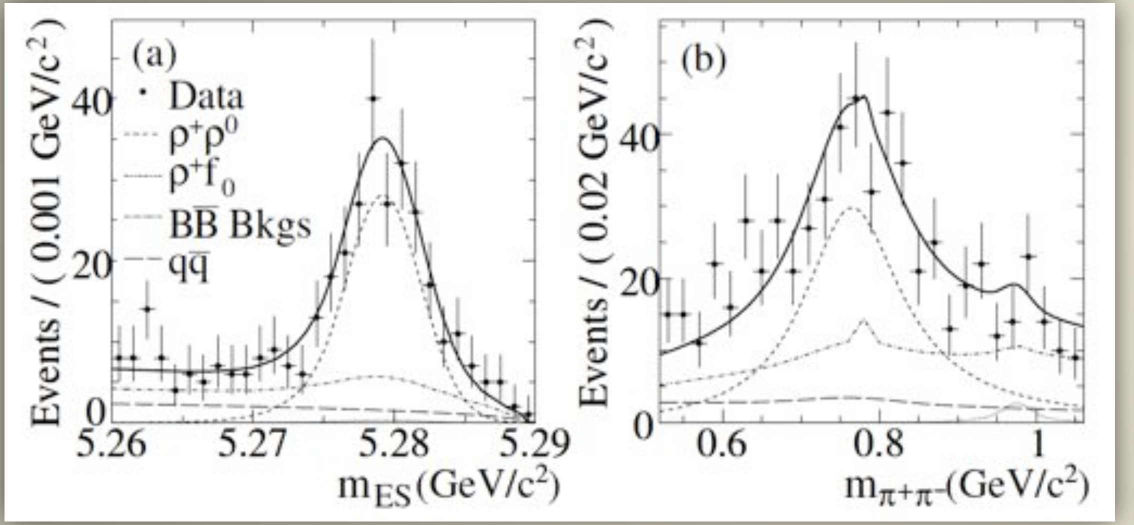
In $\Delta S = 0$ decays: $T \sim V_{ub} V_{ud}^*$ and $P \sim V_{cb} V_{cd}^*$
In $\Delta S = 1$ decays: $T' \sim V_{ub} V_{us}^*$ and $P' \sim V_{cb} V_{cs}^*$

thus P'/T' is $1/\lambda^2$ enhanced over P/T
$\Rightarrow$ can be used to bound P/T

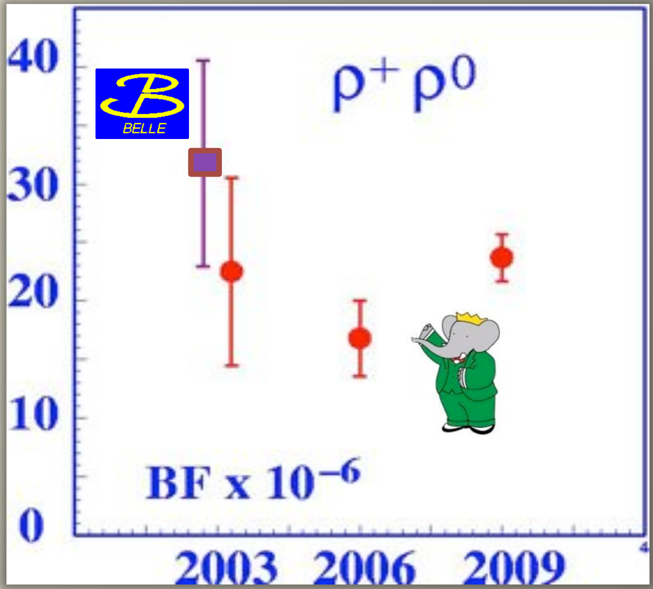
Improved Measurements of $B^+ \to \rho^+\rho^0$

465±5 M $B\bar{B}$ pairs

- Improved methods (3D PDFs) to account for correlations in the main (continuum & combinatoric BB) backgrounds



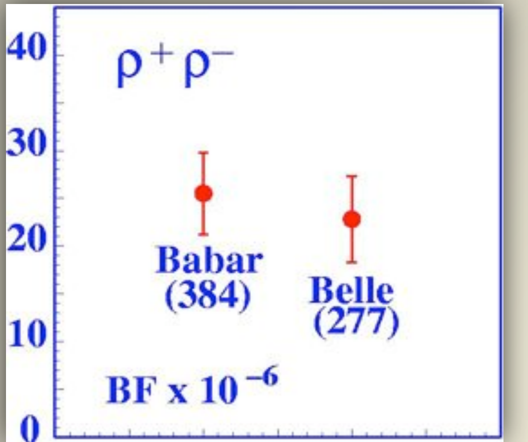
BaBar PRL102, 141802 (2009)



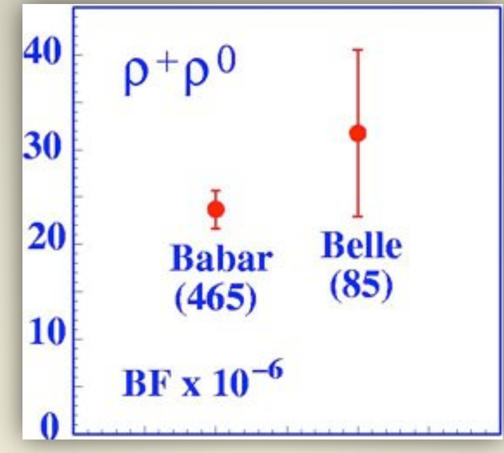
$\mathcal{B}(B^+ \to \rho^+\rho^0) = (23.7 \pm 1.4 \pm 1.4) \times 10^{-6}$

$f_L = 0.950 \pm 0.015 \pm 0.006$

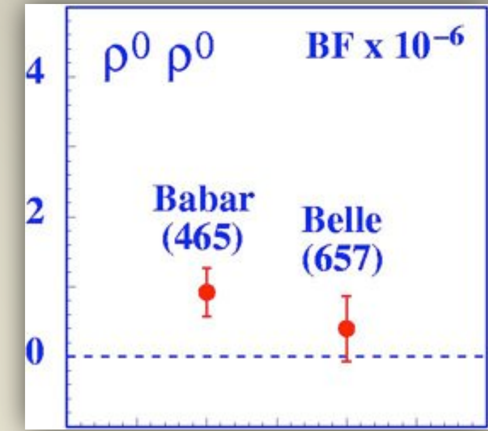
B → ρρ: Branching fractions and A_{CP}'s



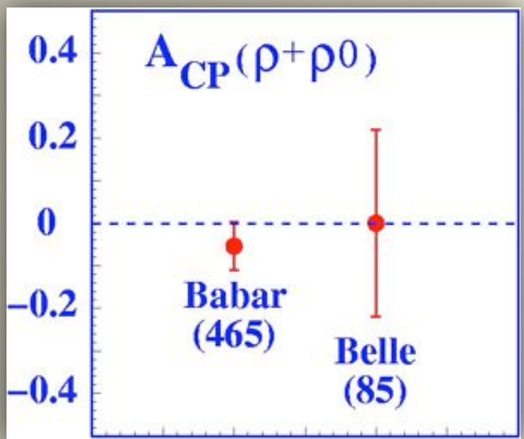
Babar PRD76 (2007) 052007
Belle PRL96 (2006) 171801

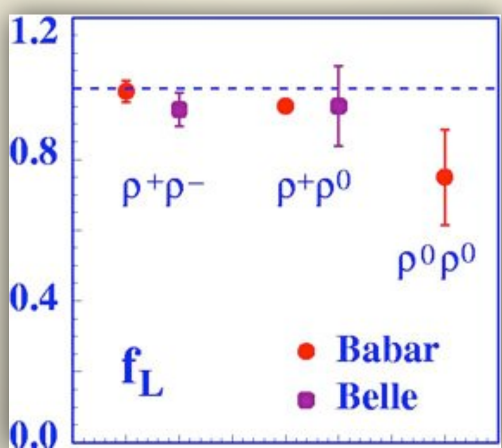


Babar PRL102 (2009) 141802
Belle PRL91 (2003) 221801



Babar PRD78 (2008) 071104
Belle PRD78 (2008) 111102



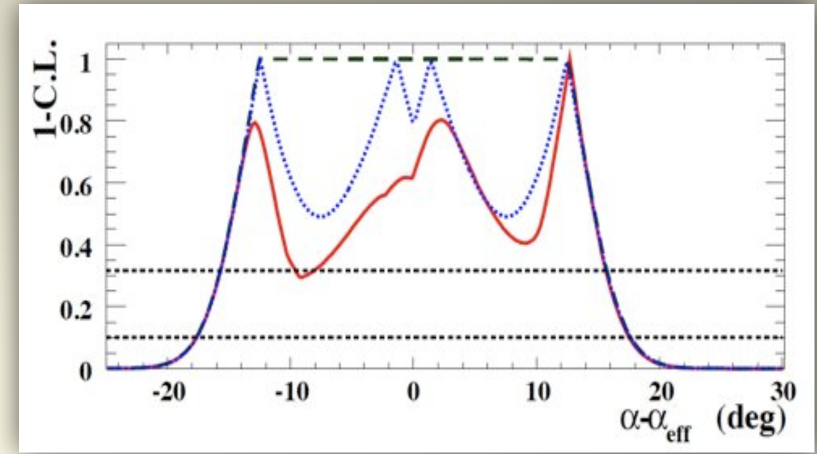


- $BF(\rho^0\rho^0)/BF(\rho^+\rho^-) \approx (3.6 \pm 1.5)\%$
  small penguin contribution
- $A_{CP}(\rho^+\rho^0) \approx 0$
  small EW penguin contribution

Babar PRL102 (2009) 141802
Belle PRL91 (2003) 221801

Isospin analysis $B \to (\rho\rho)_{Long}$

- 10 inputs: 3 BF's, 3 f_L's, 2 S's & 2 C's
- Perform α scan, minimize χ^2



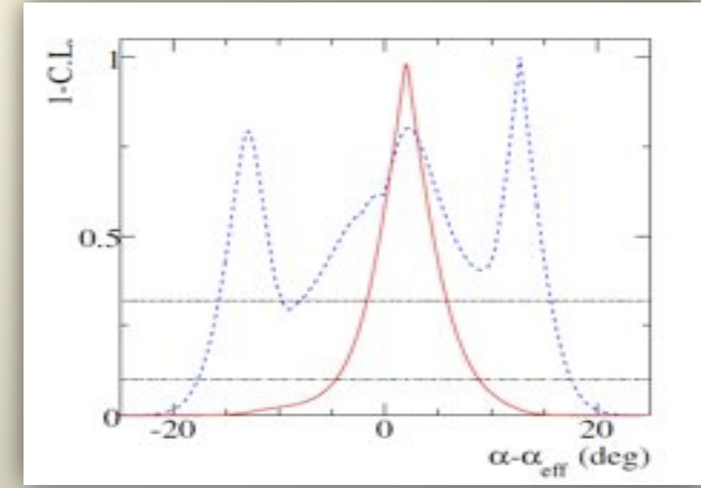
- **Impact of S^{00} and C^{00}:**

  BaBar PRD78, 071104 (2008)

  - - - **without S^{00} or C^{00}**

  ········ **with only C^{00}**

  —— **with S^{00} and C^{00}**



- **Impact of BF ($B^+ \to \rho^+\rho^0$):**

  BaBar PRL102, 141802 (2009)

  ········ **with 2006 result**

  —— **with 2009 result**

$\alpha_{\rho\rho} = (92.4_{-6.5}^{+6.0})°$ and $-1.8° < \Delta\alpha < 6.7°$ @ 68% CL

Measurement of B decays to $K_1(1270)\,\pi$ and $K_1(1400)\,\pi$

NEW

Theoretical predictions for BF's $O(10^{-6})$

- Laporta et al., PRD 74, 054035 (2006)

- Calderon et al., PRD 76, 094019 (2007)

- Cheng et al., PRD 76, 114020 (2007)

From ARGUS Coll., *PLB 254, 288 (1991):*

$\mathcal{B}(B^0 \to K_1(1400)^+\pi^-) < 1.1\times10^{-3}$ @ 90% C.L.

$\mathcal{B}(B^+ \to K_1(1400)^0\pi^+) < 2.6\times10^{-3}$ @ 90% C.L.

BaBar Preliminary result (ICHEP 2008)

$\mathcal{B}(B^0 \to K_1(1400)^+\pi^- + K_1(1270)^+\pi^-) \sim O(10^{-5})$

Measurement of B decays to $K_1(1270)\,\pi$ and $K_1(1400)\,\pi$

- $K_1(1270) + K_1(1400)$ treated as a whole
  - SU(3) octet states K_{1A} , K_{1B}:
    $|K_1(1400)\rangle = \ |K_{1A}\rangle \cos\theta \ + |K_{1B}\rangle \sin\theta$ $\theta=58^\circ$
    $|K_1(1270)\rangle = -\,|K_{1A}\rangle \sin\theta \ + |K_{1B}\rangle \cos\theta$ *Cheng, Yang PRD76, 114020 (2007)*
  - nearly equal masses
  - same quantum numbers and final state ($K\pi\pi$)

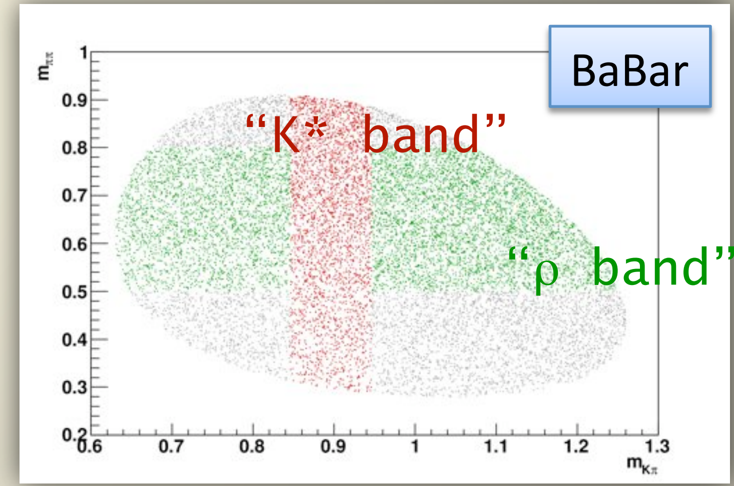
    interference effects
- Most high-statistics data from WA3 exp. ($K^-p \to K^-\pi^+\pi^-p$)
  - *ACCMOR Coll., NPB 187, 1 (1981)*
  - $K\pi\pi$ analyzed using a two-resonance, six channel K-matrix model

Measurement of B decays to $K_1(1270)\,\pi$ and $K_1(1400)\,\pi$

- Decay parameters fixed to the values extracted from a fit to WA3 data

- Extended ML fit for BF
- Fit variables: m_{ES}, ΔE, Fisher, $m_{K\pi\pi}$, $|H|$

- Neutral modes ($B^0 \to K_1^+\pi^-$)
  - simultaneous fit to "K*" and "ρ" band
  - signal, qq, $K^*(1410)\pi$, $K^*\pi\pi$ + $\rho K\pi$,



- Charged modes ($B^+ \to K_1^0\pi^+$)
  - fit to "K*" band only
  - signal, qq, $K^*(1410)\pi$, $K^*\pi\pi$ + $\rho K^0\pi$, $K^*\rho$

Fit results - $K_1\pi$

454±5 M $B\bar{B}$ pairs

BF($B^0 \to K_1(1400)^+\pi^-$ + $K_1(1270)^+\pi^-$)) = $(3.1^{+0.8}_{-0.7})\times10^{-5}$ S=7.5σ
BF($B^+ \to K_1(1400)^0\pi^+$ + $K_1(1270)^0\pi^+$)) = $(2.9^{+3.0}_{-1.7})\times10^{-5}$ S=3.2σ

Neutral modes

$\mathcal{B}(B^0 \to K_1(1400)^+\pi^-) = (1.6^{+0.8}_{-0.9})\times10^{-5}$
$\mathcal{B}(B^0 \to K_1(1270)^+\pi^-) = (1.6^{+0.9}_{-1.0})\times10^{-5}$
$\mathcal{B}(B^0 \to K_{1A}^+\pi^-) = (1.4^{+0.9}_{-1.0})\times10^{-5}$

Charged modes

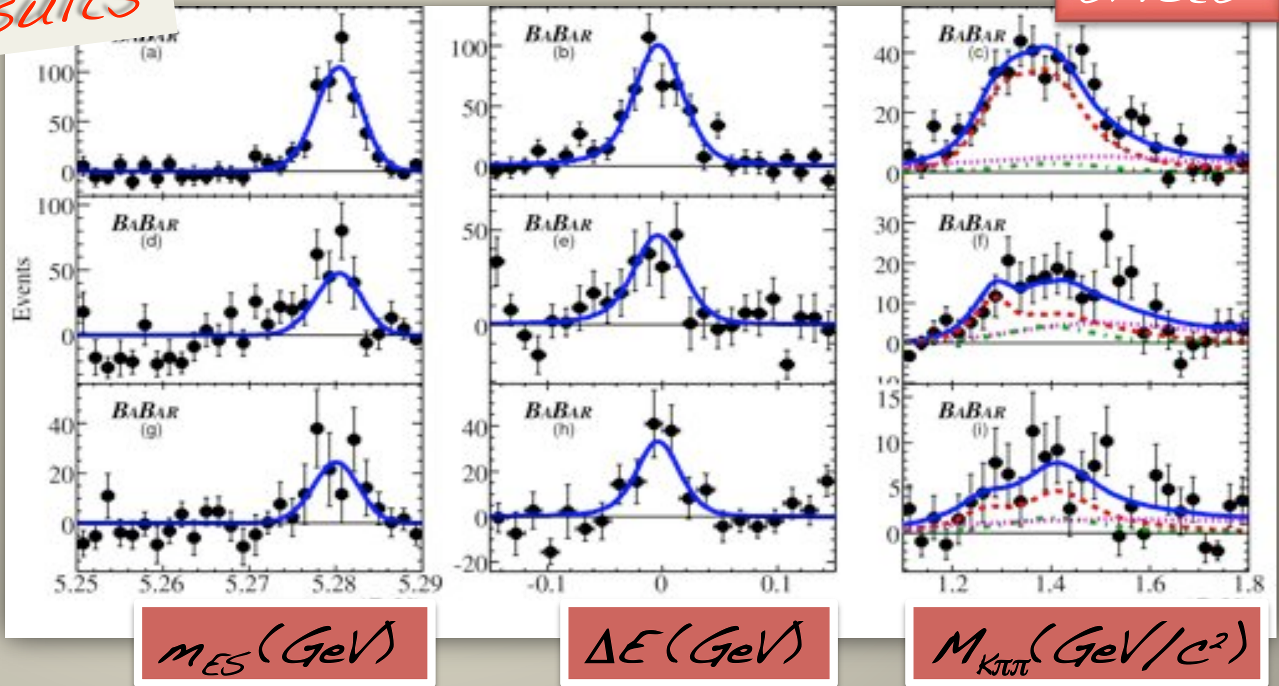
$\mathcal{B}(B^+ \to K_1(1400)^0\pi^+) < 3.9\times10^{-5}$
$\mathcal{B}(B^+ \to K_1(1270)^0\pi^+) < 4.0\times10^{-5}$
$\mathcal{B}(B^+ \to K_{1A}^0\pi^+) < 3.6\times10^{-5}$

Preliminary BaBar Results

Neutral modes: "K*" band, "ρ" band

Charged modes: "K*" band

sPlots



Bounds on α from CP-violation asymmetries in $B^0 \rightarrow a_1\pi$

The BF's and the CP asymmetries needed to extract α from $B^0 \rightarrow a_1\pi$ using flavor SU(3) are: ***Gronau and Zupan, PRD 73, 057502 (2006)***

- $B \rightarrow a_1\pi$ branching fraction ***PRL 97, 051802 (2006), BaBar Coll.***
- $B \rightarrow a_1\pi$ TD CPV asymmetries ($S=\sin 2\alpha_{eff}$) ***PRL 98, 181803 (2007), BaBar Coll.***
- $B \rightarrow a_1K$ branching fractions ***PRL 100, 051803 (2008), BaBar Coll.***
- $B \rightarrow K_1\pi$ branching fractions ***(to be submitted to PRD)***

We obtain $|\alpha_{eff}-\alpha|$ <11° (13°) at 68% (90%) probability

The determination of α presents an eightfold ambiguity in the range [0°,180°]. Assuming that the relative strong phase between the relevant tree amplitudes is negligible → ***two-fold ambiguity*** **(α_{eff} = 11°±7° and α_{eff} = 79°±7°)**.

We combine the solution near 90° with the bounds on $|\alpha_{eff}-\alpha|$ and estimate the weak phase:

$$\alpha_{a_1\pi} = 79°\pm7°\pm11°$$

NEW

Polarization Puzzle

- Considerable theoretical attention on charmless B decays to final states involving Vector mesons in the last few years

- Significant progress in experimental constraints on B→VV, VT, AV

We define the fraction of longitudinally polarised events as:

$$\frac{\Gamma_L}{\Gamma} = \frac{|H_0|^2}{|H_0|^2 + |H_{+1}|^2 + |H_{-1}|^2}, = f_L.$$

where the H_m are helicity amplitudes.

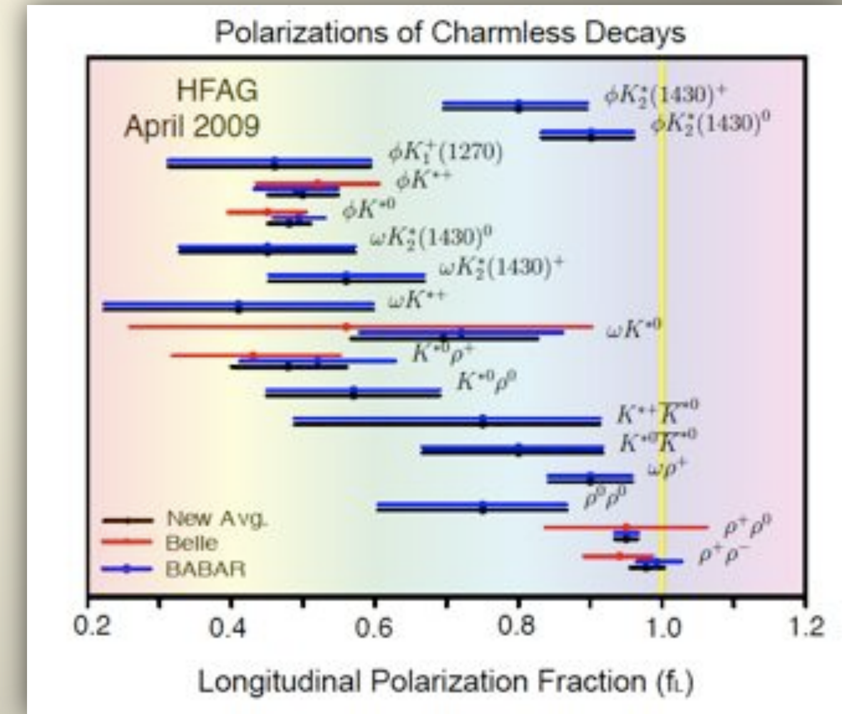
- B->ρρ decays fit the pattern $f_L = 1 - \frac{m_V^2}{m_B^2}$

- f_L large also for $K^{*0}K^{*0}$, $\omega\rho^+$, ϕK_2^{*0}, ρK^{*+}

- $f_L \sim 0.5$ for some penguin dominated modes: notably ϕK^* and $K^{*0}\rho^+$

- Still puzzled by polarization: several non-trivial polarization have been measured

- Important to study polarization in new decays



Observation and Polarization measurement of B^0 to $a_1(1260)^+ a_1(1260)^-$ decay

NEW

Theoretical expectations for $B^0 \rightarrow a_1(1260)^+ a_1(1260)^-$

QCD Factorization framework

$$BF = 37.4^{+16.1+9.7}_{-13.7-1.4} \times 10^{-6}$$

$$f_{LN} = 0.64^{+0.07}_{-0.17}$$

Branching Ratios and Polarization in B-> VV, VA and AA decays
H.Y.Cheng and K.C.Yang Phys. Rev. D 78, 094001 (2008)

Assume naive factorization + improved nonrelativistic ISGW quark model for form factors $B \rightarrow A$ transitions

$BF = 6.4 \times 10^{-6}$

Nonleptonic two-body B-decays including axial-vector mesons in the final state
G. Calderon, J.H.Munoz and C.E.Vera Phys. Rev. D76, 094019 (2007)

BF upper limit of 2.8×10^{-3} @ 90% CL measured by CLEO (1989)

Observation and Polarization measurement of B^0 to $a_1(1260)^+ a_1(1260)^-$ decay

- First measurement of longitudinal polarization in this mode
- Don't separate the dominant P-wave $(\pi\pi)_\rho$ and S-wave $(\pi\pi)_\sigma$ in $a_1 \rightarrow 3\pi$ (accounted for in systematics)
- Limited number of signal to perform a full angular analysis
- Using helicity formalism (after integrating over azimutal angle between decay planes of the two a_1 mesons) we get:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta} \propto f_L(1-\cos^2\theta) + \frac{1}{2} f_T(1+\cos^2\theta)$$

$$f_T = 1 - f_L$$

f_L: longitudinal polarization fraction

where θ is the angle between the normal to the decay plane of the three pions of one a_1 and the flight direction of the other a_1, both calculated in the rest frame of the a_1

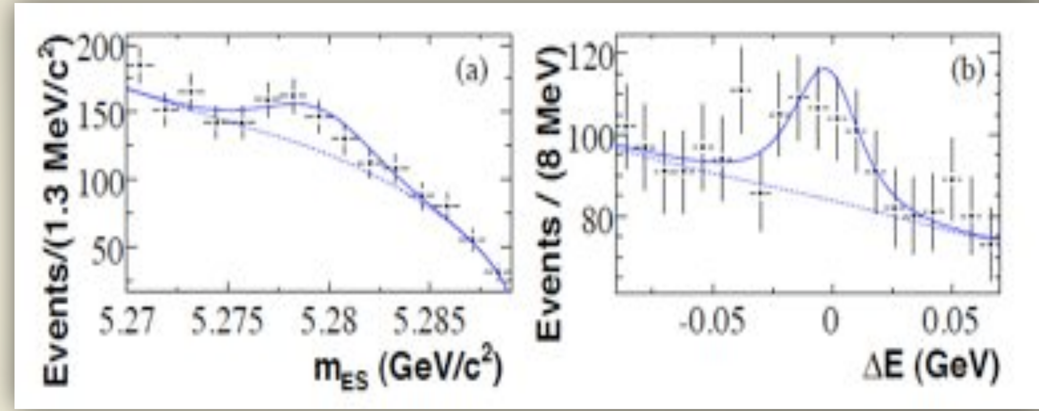
Observation and Polarization measurement of B^0 to $a_1(1260)^+ a_1(1260)^-$ decay

465±5 M $B\bar{B}$ pairs

ML fit results

Signal yield	545 ± 118
Signal yield bias	$+14$
f_L bias	-0.06
ϵ_L (%)	9.0
ϵ_T (%)	10.0
S (σ)	5.0
$\mathcal{B}$ ($\times 10^{-6}$)	$11.8 \pm 2.6 \pm 1.6$
f_L	$0.31 \pm 0.22 \pm 0.10$

Projections



- Specific component for charmless non-resonant backgrounds to 6 pions
- 5 sigma observation (f_L not defined in the zero signal hypotesis, taken into account)
- Assuming $BF(a_1^+ \to \pi^- \pi^+ \pi^+) = BF(a_1^- \to \pi^+ \pi^0 \pi^0)$ and $BF(a_1^+ \to (3\pi)^+) = 100\%$

$$\mathcal{B}(B^+ \to a_1^+ a_1^-) = (47.3 \pm 10.5 \pm 6.3) \cdot 10^{-6}$$

- BF and f_L in general agreement with QCD Factorization

arXiv: 0907.1776

NEW

Conclusions

- **Improved Measurements of $B^+ \to \rho^+\rho^0$**

  Determination of the Quark-Mixing Phase α in $B \to \rho\rho$

  $\alpha = (92.4_{-6.5}^{+6.0})°$ and $-1.8° < \Delta\alpha < 6.7°$ @ 68% CL (substantial improvement)

  CP asymmetries in $B \to \rho^+\rho^-$ using full dataset will improve further this measurement!

- **Measurement of B decays to $K_1(1270)\,\pi$ and $K_1(1400)\,\pi$**

  Observation of the neutral modes (7.5 σ)

  First time extraction of CKM angle α from the measurement B^0 to $a_1(1260)\,\pi$:

  $\alpha = 79° \pm 7° \pm 11°$

  A new and independent measurement of α is now available!

  $a_1\pi$ join the "$\pi\pi/\rho\rho/\rho\pi$" club for measuring α!

- **Measurement of Branching Fraction of B^0 to $a_1(1260)^+\,a_1(1260)^-$**

  First Observation of this decay mode (5.0 σ)

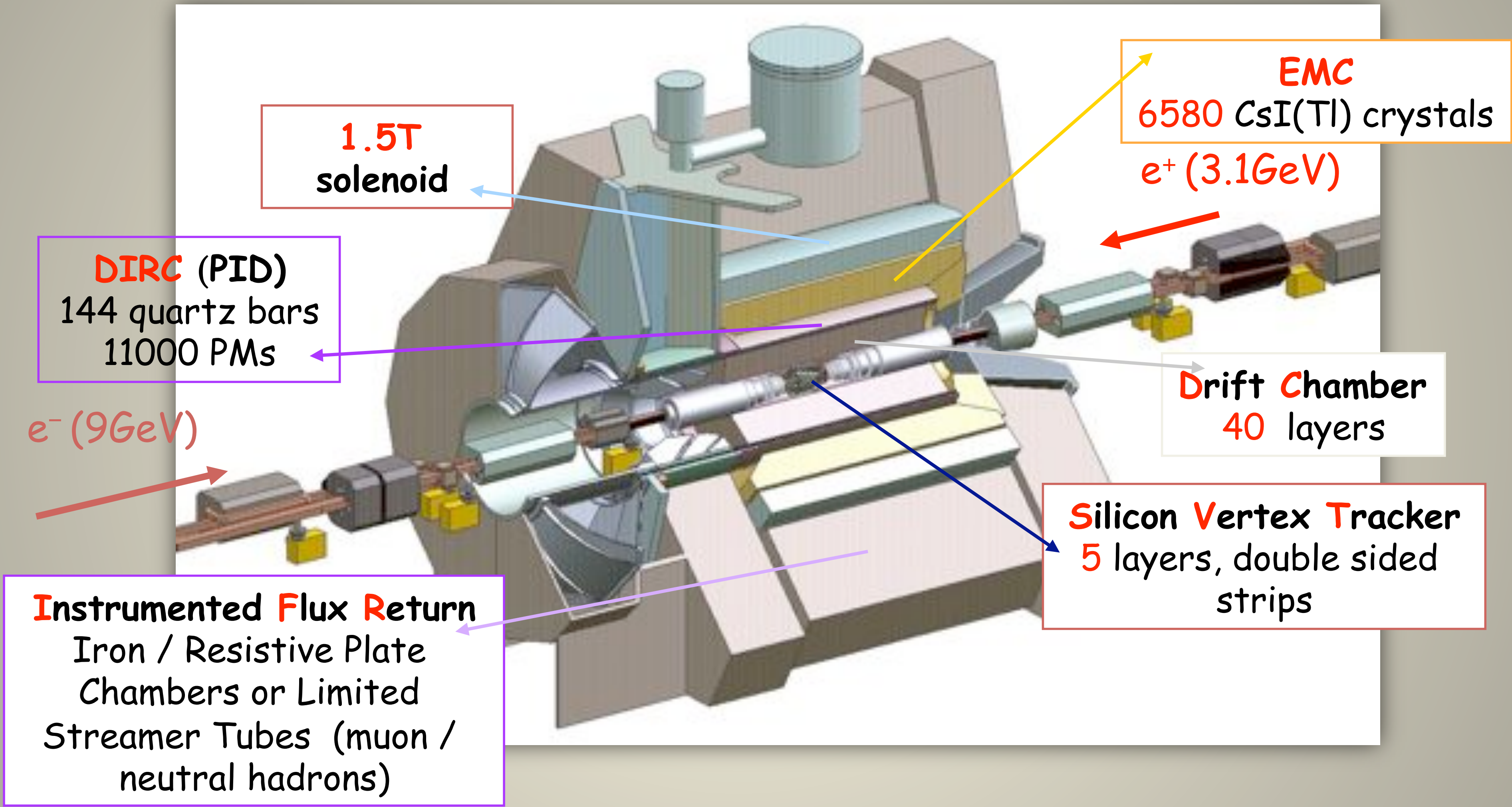
  First polarization measurement of $B \to AA$

  BF and longitudinal polarization in general agreement with QCD factorization

  Errors are too large to extract α with the available statistics

Backup Slides

Babar Detector



Physics Analysis with a Boosted $\Upsilon(4S)$

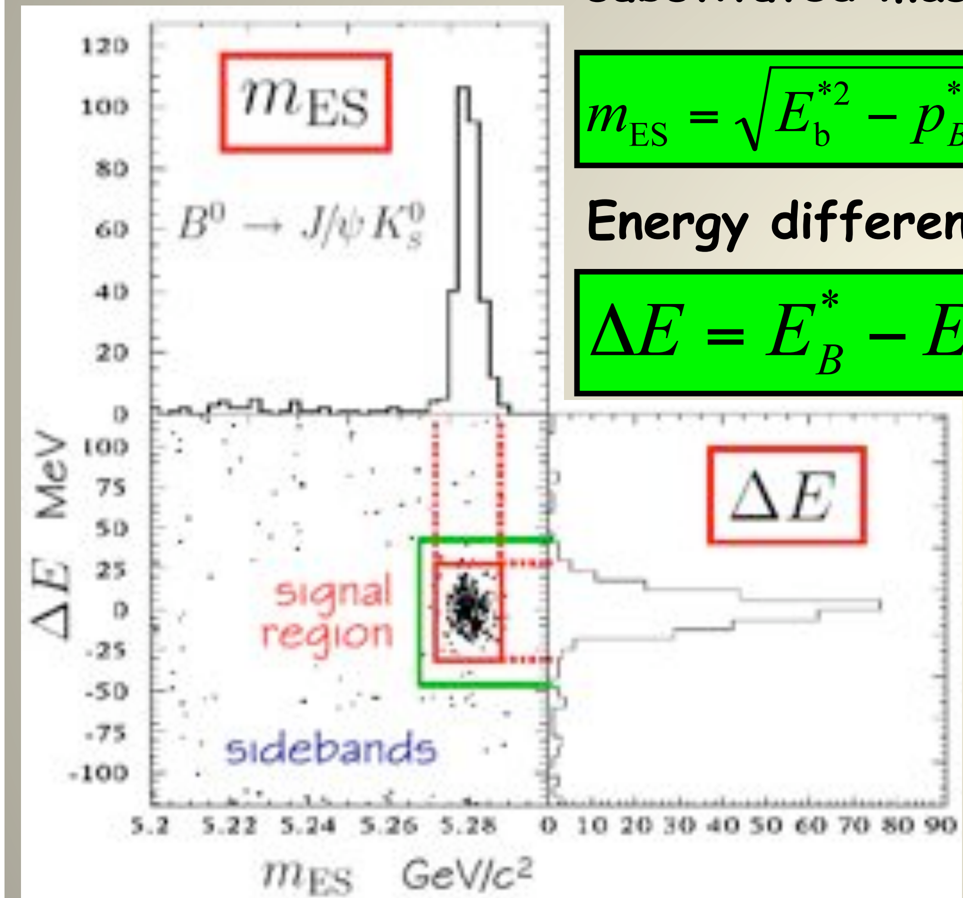
- Kinematics:

Beam energy substituted mass

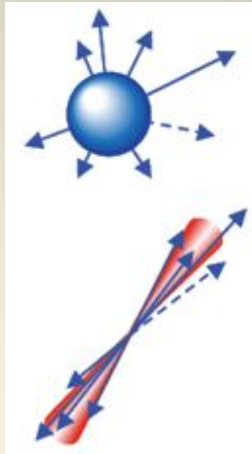
$$m_{ES} = \sqrt{E_b^{*2} - p_B^{*2}}$$

Energy difference

$$\Delta E = E_B^* - E_b^*$$



- Topology:

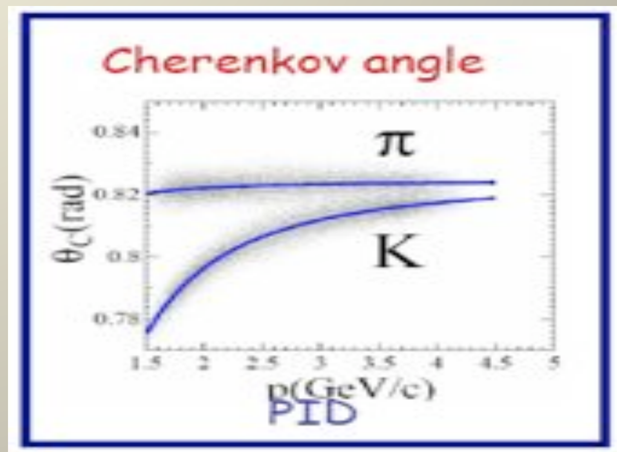


spherical BB events

"jetty" qq events

Event-shape variables combined in a neural network or Fisher discriminant to suppress jet-like continuum events.

- Hadron ID ⇒ separation π/K



SU(3) : ρρ

- Can relate the penguin contribution in $K^{*0}\rho^+$ to that in $\rho^+\rho^-$

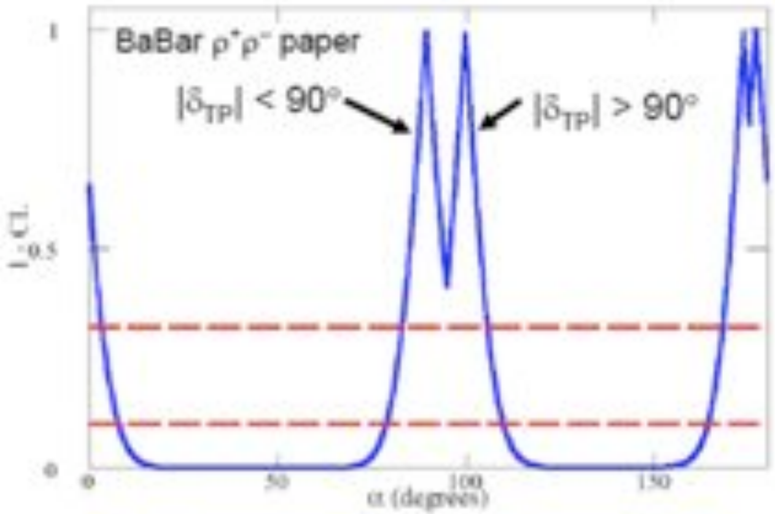
$$C_{\rm long} = \frac{2r\sin\delta_{\rm TP}\sin(\beta+\alpha)}{1-2r\cos\delta_{\rm TP}\cos(\beta+\alpha)+r^2},$$

$$S_{\rm long} = \frac{\sin 2\alpha + 2r\cos\delta_{\rm TP}\sin(\beta-\alpha) - r^2\sin 2\beta}{1-2r\cos\delta_{\rm TP}\cos(\beta+\alpha)+r^2}$$

$$\left(\frac{|V_{\rm cd}|f_\rho}{|V_{\rm cs}|f_{K^*}}\right)^2 \frac{\Gamma_{\rm L}(B^\pm\to K^{*0}\rho^+)}{\Gamma_{\rm L}(B^0\to\rho^+\rho^-)} = \frac{Fr^2}{1-2r\cos\delta_{\rm TP}\cos(\beta+\alpha)+r^2}$$

The dominant $SU(3)$ breaking correction accounted for by F is the neglect of annihilation diagrams in the $B^+\to K^{*0}\rho^+$ decay.

$$F = 0.9 \pm 0.6$$



- If we assume that $|\delta_{\rm TP}| < 90°$:

$$\alpha = (89.8^{+7.0}_{-6.4})°$$

- Relaxing this assumption:

$$\alpha = [83.3, 105.8]°$$

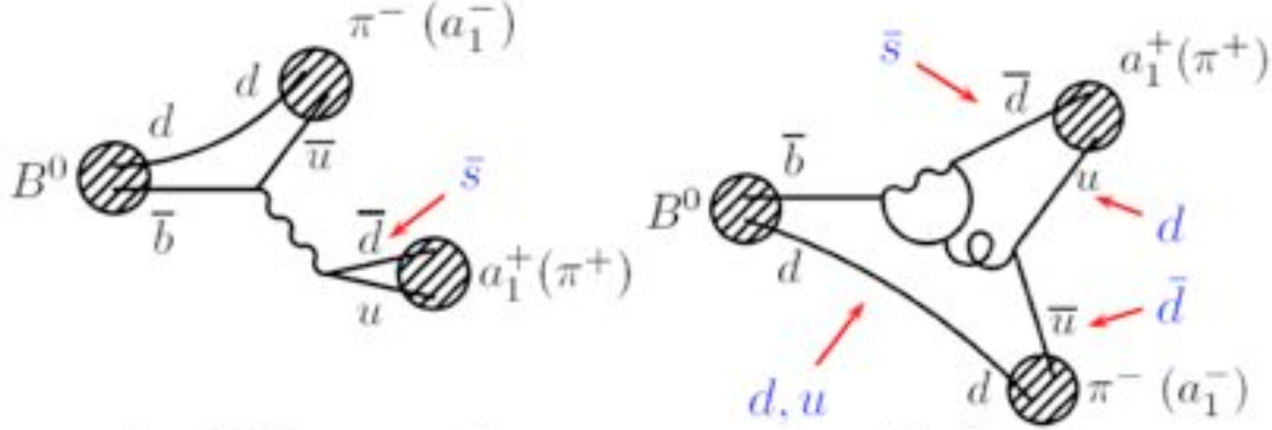
- Common inputs with SU(2) result, do not average the two!

M. Beneke, M. Gronau, J. Rohrer, and M. Spranger Phys. Lett. B 638, 68 (2006).

Systematics: B^0 to $K_1\pi$

	$B^0 \to K_1^+\pi^-$			$B^+ \to K_1^0\pi^+$	
Quantity	$\mathcal{B}$	ϑ	ϕ	$\mathcal{B}$	ϑ
PDF parameters (A)	0.8	0.01	0.15	1.4	0.07
MC/data correction (A)	0.8	0.00	0.01	1.0	0.02
ML fit bias (A)	0.6	0.03	0.02	2.0	0.08
Fixed phase (A)	–	–	–	0.6	0.06
Scan (A)	0.9	0.04	0.16	0.0	0.04
K_1 K–matrix parameters (A)	2.2	0.01	0.36	0.5	0.05
K_1 offset phases (A)	0.2	0.01	0.02	0.0	0.00
K_1 intermediate resonances (A)	0.5	0.00	0.06	0.2	0.02
K^*/ρ bands (A)	0.2	0.05	0.00	1.2	0.05
Peaking $B\overline{B}$ bkg (A)	0.8	0.01	0.13	1.0	0.01
Fixed background yields (A)	0.0	0.00	0.00	0.4	0.02
Interference (A)	6.0	0.25	0.52	10.6	0.43
MC statistics (M)	1.0	–	–	1.0	–
Particle identification (M)	2.9	–	–	3.1	–
Track finding (M)	1.0	–	–	0.8	–
K_S reconstruction (M)	–	–	–	1.6	–
$\cos\theta_{\mathrm{T}}$(M)	1.0	–	–	1.0	–
Track multiplicity (M)	1.0	–	–	1.0	–
Number $B\overline{B}$ (M)	1.1	–	–	1.1	–

Approx SU(3) flavour symmetry: $a_1\pi$



$$t'_+ = \frac{f_{K_1}}{f_{a_1}} \frac{V_{ub}^* V_{us}}{V_{ub}^* V_{ud}} t_+ = \frac{f_{K_1}}{f_{a_1}} \bar{\lambda} t_+ \qquad p'_+ = \frac{f_{K_1}}{f_{a_1}} \frac{V_{cb}^* V_{cs}}{V_{cb}^* V_{cd}} p_+ = -\frac{f_{K_1}}{f_{a_1}} \bar{\lambda}^{-1} p_+$$

$$t'_- = \frac{f_K}{f_\pi} \frac{V_{ub}^* V_{us}}{V_{ub}^* V_{ud}} t_- = \frac{f_K}{f_\pi} \bar{\lambda} t_- \qquad p'_+ = \frac{f_K}{f_\pi} \frac{V_{cb}^* V_{cs}}{V_{cb}^* V_{cd}} p_+ = -\frac{f_K}{f_\pi} \bar{\lambda}^{-1} p_+$$

penguins enhanced, tree suppressed, $\bar{\lambda} = 0.23$

factorized SU(3) breaking accounted for

annihilation like topologies neglected

Bounds on α from CP-violation asymmetries in $B^0 \to a_1\pi$

$$A_+ \equiv A(B^0 \to a_1^+\pi^-)\,, \quad A_- \equiv A(B^0 \to a_1^-\pi^+)\,,$$
$$\overline{A}_+ \equiv A(\overline{B} \to a_1^-\pi^+)\,, \quad \overline{A}_- \equiv A(\overline{B} \to a_1^+\pi^-)\,.$$

$$C \pm \Delta C \equiv \frac{|A_\pm|^2 - |\overline{A}_\mp|^2}{|A_\pm|^2 + |\overline{A}_\mp|^2}$$

$$\mathcal{A}^+_{CP} = -\frac{\mathcal{A}^{a_1\pi}_{CP}(1+\Delta C) + C}{1 + \mathcal{A}^{a_1\pi}_{CP}C + \Delta C},$$
$$\mathcal{A}^-_{CP} = \frac{\mathcal{A}^{a_1\pi}_{CP}(1-\Delta C) - C}{1 - \mathcal{A}^{a_1\pi}_{CP}C - \Delta C},$$

$\mathcal{A}_{CP}$ are time- and flavor- integrated charge asymmetry in $B^0 \to a_1\pi$

- SU(3) relations result in: *Gronau and Zupan, PRD 73, 057502 (2006)*

$$\cos 2(\alpha^\pm_{\rm eff} - \alpha) \geq \frac{1 - R^0_\pm}{\sqrt{1 - \mathcal{A}^{\pm\,2}_{CP}}}$$
$$\cos 2(\alpha^\pm_{\rm eff} - \alpha) \geq \frac{1 - R^+_\pm}{\sqrt{1 - \mathcal{A}^{\pm\,2}_{CP}}}$$

where

$$R^0_+ \equiv \frac{\bar\lambda^2 f^2_{a_1}\bar{\mathcal{B}}(K^+_{1A}\pi^-)}{f^2_{K_{1A}}\bar{\mathcal{B}}(a_1^+\pi^-)}$$
$$R^0_- \equiv \frac{\bar\lambda^2 f^2_{\pi}\bar{\mathcal{B}}(a_1^- K^+)}{f^2_{K}\bar{\mathcal{B}}(a_1^-\pi^+)}$$
$$R^+_+ \equiv \frac{\bar\lambda^2 f^2_{a_1}\bar{\mathcal{B}}(K^0_{1A}\pi^+)}{f^2_{K_{1A}}\bar{\mathcal{B}}(a_1^+\pi^-)}$$
$$R^+_- \equiv \frac{\bar\lambda^2 f^2_{\pi}\bar{\mathcal{B}}(a_1^+ K^0)}{f^2_{K}\bar{\mathcal{B}}(a_1^-\pi^+)}.$$

- $|\Delta\alpha| = (|\alpha_{eff}^{+}-\alpha|+|\alpha_{eff}^{-}-\alpha|)/2$
- get $|\alpha_{eff}^{+,-}-\alpha|$ by solving the system
- Metod works much better if smaller penguin/tree

BF and Polarization measurement of B^0 to $a_1(1260)^+ a_1(1260)^-$ decay

Selection - ML fit

- Reconstruct $a_1^+ \rightarrow \pi^+\pi^-\pi^+$ with 2π to form a ρ^0 candidate
- $0.87 < a_1$ mass < 1.75 GeV/c^2
- PID for pions
- Vetos to suppress charm bkg
- Best candidate from highest B vertex χ^2 probability

- 5 hypoteses in the likelihood model:
  signal, continuum bkg, charmless, generic charm and peaking charm bkg
- charmless non-resonant decays (6 pions in the final state) taken into account

Projections: B^0 to $a_1(1260)^+ a_1(1260)^-$ decay

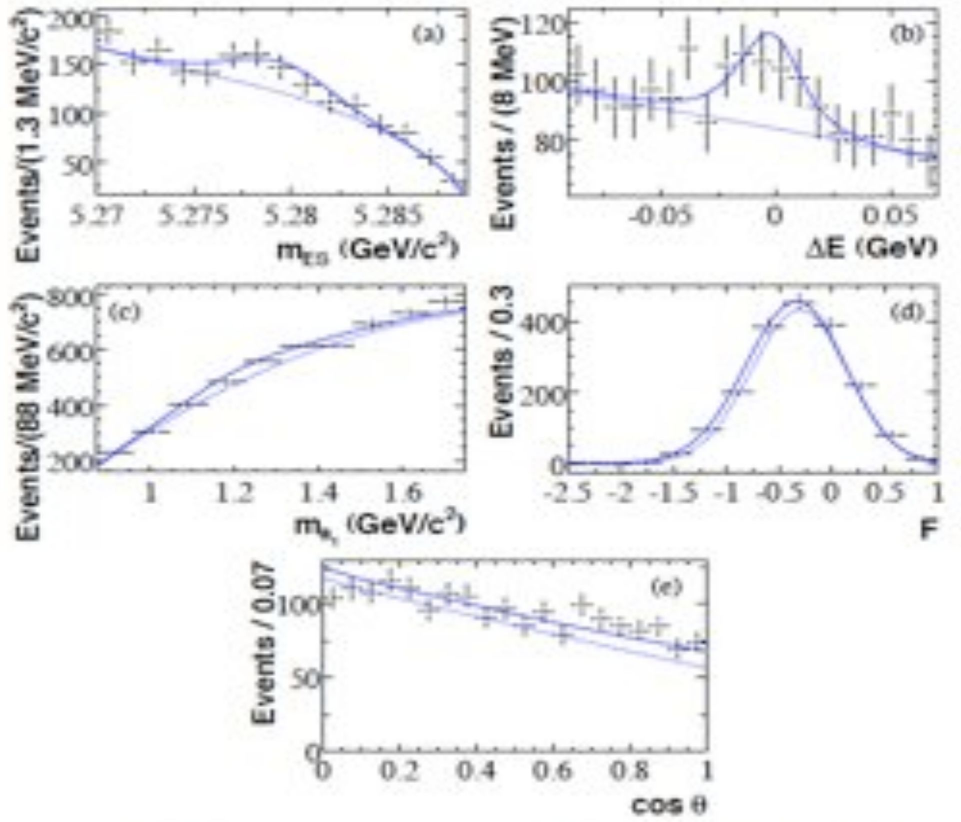
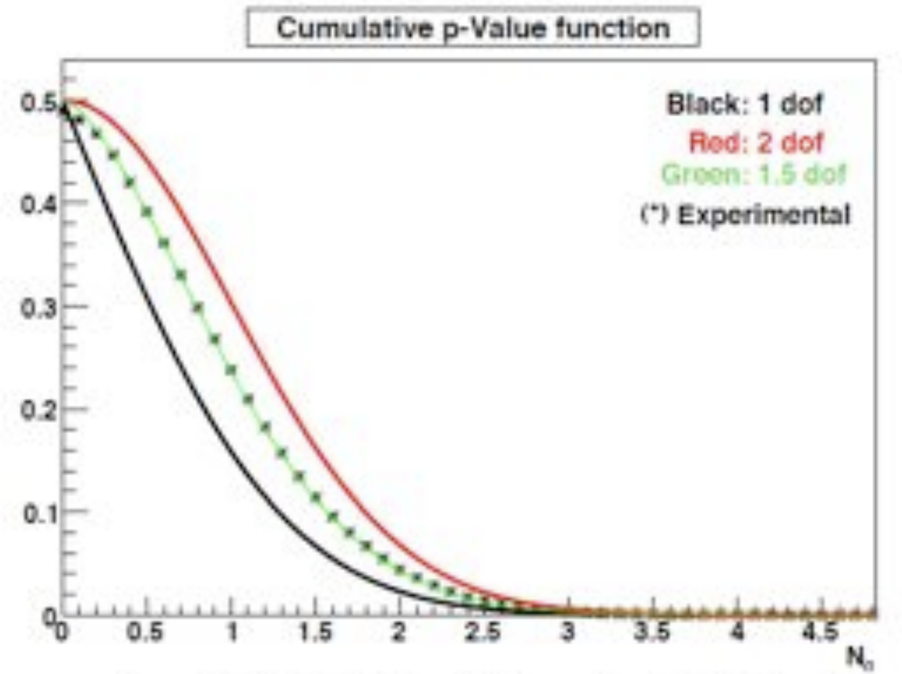


FIG. 1: Projections of (a) $m_{\rm ES}$, (b) ΔE, (c) a_1 invariant mass (average of $m_{a_1^+}$ and $m_{a_1^-}$ is shown), (d) $\mathcal{F}$ and (e) $\mathcal{H} = |\cos\theta|$ (average of $|\cos\theta_{a_1^+}|$ and $|\cos\theta_{a_1^-}|$ is shown). Points with error bars (statistical only) represent the data, the solid line the full fit function, and the dashed line the background component. These plots are made with a requirement on the signal likelihood that selects 25%-40% of the signal and 2%-5% of the background.

Significance: B^0 to $a_1(1260)^+$ $a_1(1260)^-$ decay



n	1 d.o.f.	2 d.o.f.	Experimental value
0	50%	50%	49.2%
1	15.9%	30.3%	23.8%
2	2.27%	6.76%	4.4%
3	0.13%	0.56%	0.32%
3.4	0.034%	0.15%	0.084 %
3.6	0.016%	0.077%	0.029 %
4.0	0.003%	0.017%	0.009 %

Systematics: B^0 to $a_1(1260)^+$ $a_1(1260)^-$ decay

Quantity	Sig. yield	f_{LN}
Additive errors (events)		
Fit yield	37.7	0.084
Fit bias	7.0	0.030
a_1 paramet.	30.8	0.043
SXF	12.1	0.009
NON-Res	10	0.015
$B^0 \to a_1^+ a_2^-$	19	0.01
Total additive (events)	55.0	0.101
Multiplicative errors (%)		
MC statistics	0.1	-
Track multiplicity	1.0	-
Tracking find eff.	1.4	-
PID	3.6	-
Number $B\overline{B}$	1.1	-
Evt shape	2.5	-
σ corr.	6.8	1.5
Total multiplicative (%)	8.3	1.5
Total (events)	70.7	0.101