Violazioni di CP e determinazione dell'angolo α

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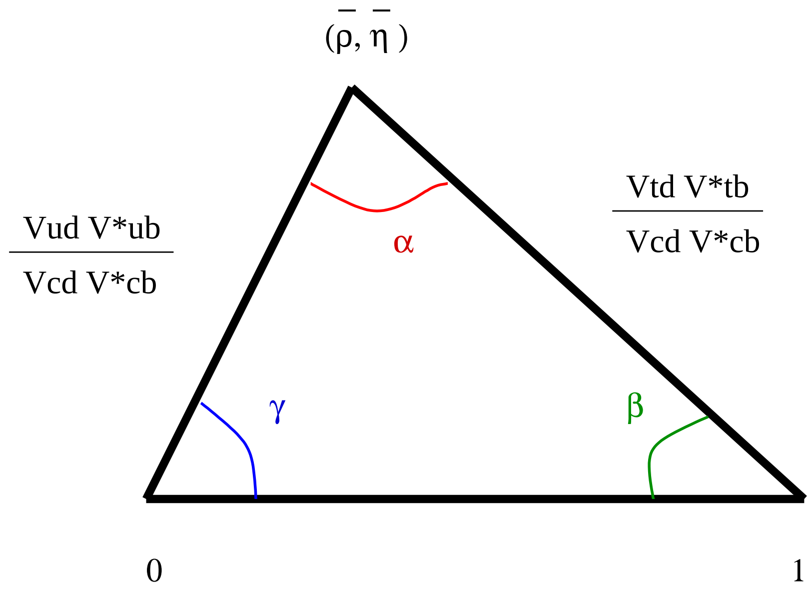
Unitarity triangle

$$\begin{matrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta(1-\lambda^2/2)) \\ -\lambda & 1-\lambda^2/2 - i\eta A^2\lambda^4 & A\lambda^2(1+i\eta\lambda^2) \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{matrix}$$



non–zero η allows for CP violation.

$$\bar{\rho} = \rho(1-\lambda^2/2) \ ; \ \bar{\eta} = \eta(1-\lambda^2/2)$$
$$A \approx 0.83$$

Parameters

Numbers from Caravaglios et al. (hep-ph/0002171) and from LEP Heavy Flavours Steering group, www.cern.ch/LEPHFS/

New experimental results are the first LEP averages for $|V_{cb}|$ and $|V_{ub}|$ and improved limit on Δm_s

$$\lambda : 0.2205 \pm 0.0018$$

$$|V_{cb}|\,(LEP) : (40.5 \pm 1.8) \times 10^{-3}$$

$$|V_{ub}|\,(LEP) : (4.05^{+0.62}_{-0.74}) \times 10^{-3}$$

$$\frac{|V_{ub}|}{|V_{cb}|}(CLEO) : 0.085 \pm 0.018$$

$$\frac{|V_{ub}|}{|V_{cb}|}(LEP) : 0.104 \pm 0.019$$

$$\bar{\rho} : 0.240^{+0.057}_{-0.047}$$

$$\bar{\eta} : 0.335 \pm 0.042$$

$$sin(2\alpha) : -0.38^{+0.24}_{-0.28}$$

$$sin(2\beta) : 0.91 \pm 0.35$$

$$\gamma : (55.5^{+6.0}_{-8.5})^o$$

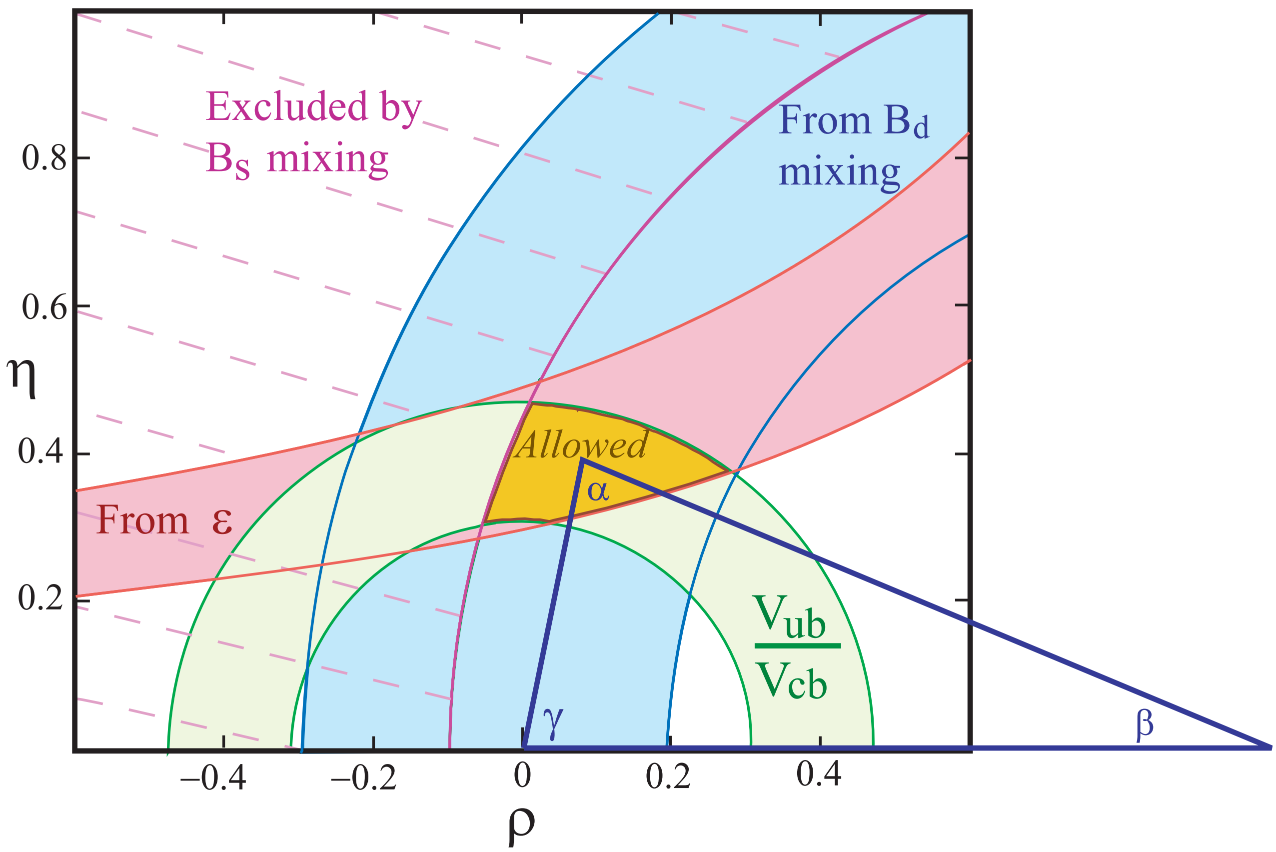


Figure 1: The CKM triangle shown in the $\rho - \eta$ plane. The shaded regions show $\pm 1\sigma$ contours given by $|V_{ub}/V_{cb}|$, neutral B mixing, and CP violation in K_L^o decay (ϵ). The dashed region is excluded by B_s mixing limits. The allowed region is defined by the overlap of the 3 permitted areas. From S. Stone, hep-ph/9910417

The channel $B \to \pi\pi$ for determining α

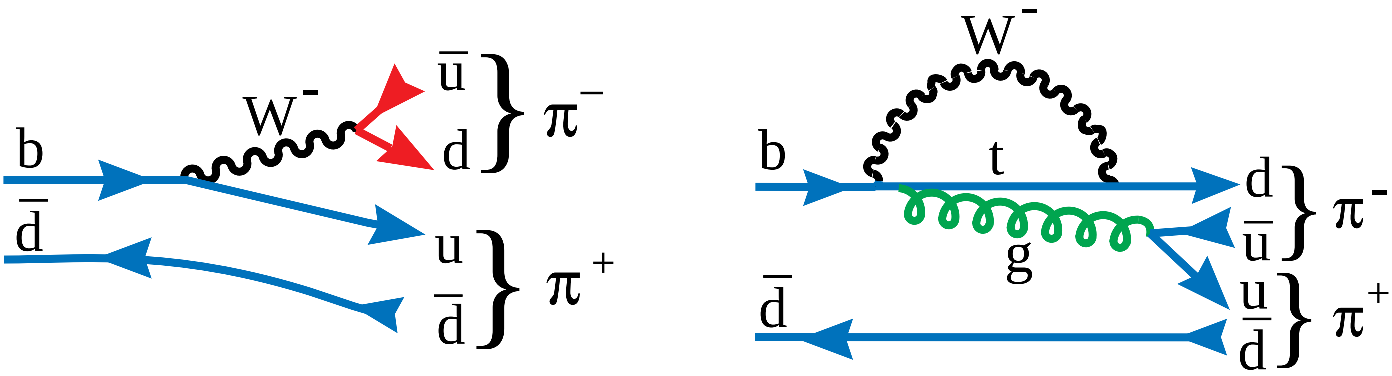


Figure 2: Processes for $B^o \to \pi^+\pi^-$: Tree (left) and Penguin (right). (hep-ph/9910417)

$$Br(B \to \pi^+\pi^-) = (4.3^{+1.6}_{-1.4} \pm 0.5) \times 10^{-6}$$

from CLEO (hep-ex/0001010).

Gronau–London method : measure $B(\bar{B}) \to \pi^+\pi^-, \pi^0\pi^0, \pi^\pm\pi^0$ and time dependent CP asymmetry in $\pi^+\pi^-$ under the assumption of isospin symmetry and neglecting electroweak penguins.

Tree are $I = 0$ or $I = 2$, Penguin (excluding EW penguins) are $I = 0$

Using isospin analysis one has two complex triangle relations:

$$(1/\sqrt{2})A^{+-} + A^{00} = A^{+0}$$

and a similar triangle relation for the charge conjugated processes.
Measuring the six widths

$$B(\bar{B}) \longrightarrow \pi^+\pi^- \qquad \pi^0\pi^0 \qquad \pi^\pm\pi^0$$

and the time dependent CP asymmetry for $\pi^+\pi^-$ determines α except for discrete ambiguities.

However

$B \longrightarrow \pi^0\pi^0$ probably small and difficult to detect

8-fold ambiguity in the solution for the angle 2α

penguin amplitudes $|P/T| \sim 0.2 - 0.5$ are large

The channel $B \to \rho\pi$ for determining α

Proposed by Quinn, Snyder, Lipkin, Nir to allow for an isospin analysis similar to $B \to \pi\pi$, without the $\pi^0\pi^0$ final state problems and without discrete ambiguities.

Penguin, Tree and α: total of 9 parameters assuming SU(2)-Isospin

BaBar studies: a full analysis of the time dependent Dalitz plot allows to extract the 9 parameters

Possible nonresonant effects in the $m_{\pi\pi}^2 \approx m_\rho^2$ region

hep-ph/0002038 Phys. Rev. D to appear.

Problems in determining α

One of the favourite proposals involves the study of the reaction

$$B \longrightarrow \rho\pi$$

It has an advantage over the isospin analysis for $B \longrightarrow \pi\pi$: no $\pi^0\pi^0$ in the final state. Channels arising from the neutral B decay:

$$\begin{aligned} \bar{B}^0 &\longrightarrow \rho^+\pi^- \\ \bar{B}^0 &\longrightarrow \rho^-\pi^+ \\ \bar{B}^0 &\longrightarrow \rho^0\pi^0 \end{aligned}$$

and the charged decay modes:

$$\begin{aligned} B^- &\longrightarrow \rho^-\pi^0 \\ B^- &\longrightarrow \rho^0\pi^- \end{aligned}$$

Together with the five charge–conjugate channels.

Signal of possible difficulties for this strategy: new results from the CLEO Collaborationreported at the DPF99, APS99 Conferences:

$$\mathcal{B}(B^\pm \rightarrow \rho^0\pi^\pm) = (1.5 \pm 0.5 \pm 0.4) \times 10^{-5}$$
$$\mathcal{B}(B \rightarrow \rho^\mp\pi^\pm) = (3.5^{+1.1}_{-1.0} \pm 0.5) \times 10^{-5}$$

with a ratio

$$R = \frac{\mathcal{B}(B \rightarrow \rho^\mp\pi^\pm)}{\mathcal{B}(B^\pm \rightarrow \rho^0\pi^\pm)} = 2.3 \pm 1.3$$

Updated CLEO result (PRL to appear) $R \simeq 2.6 \pm 1.5$.
Computed in simple approximation schemes (factorisation with no penguins), one gets, from the WBS (*Wirbel, Bauer, Stech*) model gives

$$R \simeq 6$$

Penguins? A calculation including penguins in the factorisation approximation (Deandrea et al.) gives

$$R \simeq 5.5$$

From hep-ph/9708222 (Ciuchini et al.) beyond factorisation:

$$QCDSR : R = 6.3$$

$$lattice : R = 5.5$$

$$QM : R = 6.4$$

$$ABLOPR : R = 8.1$$

Inclusion of new contributions?

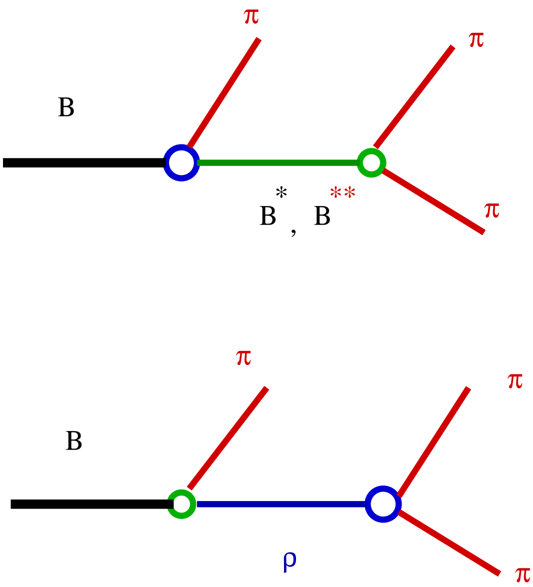


Figure 3: *The polar diagrams. For the B resonances the strong coupling is on the left and the weak coupling on the right; the situation is reversed for the ρ production (hep-ph/0002038, A. Deandrea et al.)*

It arises from virtual resonant production; the intermediate particle is B^*meson resonance or other excited states; they cannot be produced on-shell, but B^* contributions may be important (almost mass degenerate with B). The tail produces sizeable effects because it is known theoretically that the strong coupling constant $B\ B^*\ \pi$ is large.

Form factor necessary to take into account off-shell and hard pion effects.

Table 1: BRs for the charged Bdecay channels into three pions (strong coupling constants $g = 0.40$ and $h = -0.54$).

Channels	ρ	$\rho + B^*$	$\rho + B^* + B_0$
$B^- \to \pi^-\pi^0\pi^0$	1.0×10^{-5}	1.0×10^{-5}	1.0×10^{-5}
$B^- \to \pi^+\pi^-\pi^-$	0.41×10^{-5}	0.58×10^{-5}	0.63×10^{-5}

Table 2: BRs for the charged B decay channels into three pions (strong coupling constants $g = 0.60$ and $h = -0.70$).

Channels	ρ	$\rho + B^*$	$\rho + B^* + B_0$
$B^- \to \pi^-\pi^0\pi^0$	1.1×10^{-5}	1.0×10^{-5}	1.1×10^{-5}
$B^- \to \pi^+\pi^-\pi^-$	0.41×10^{-5}	0.74×10^{-5}	0.82×10^{-5}

In the $B^- \to \pi^+\pi^-\pi^-$ channel the $B^{*,**}$ resonance contribution may be as large as the ρ. Define

$\Gamma_{eff}(B^- \to \rho^0\pi^-) = \Gamma(B^- \to \pi^-\pi^+\pi^-)|_{\sqrt{s}\in(m_\rho \pm \delta)}$

($\delta = 200 - 300$ MeV); one has

$$BR_{eff}(B^- \to \rho^0\pi^-) = 0.82 \times 10^{-5}$$

$$BR(B^- \to \rho^0\pi^-) = 0.41 \times 10^{-5}$$

Table 3: BRs for the neutral Bdecay into $\pi^+\pi^-\pi^0$ ($g = 0.60$, $h = -0.70$).

Channels	ρ	$\rho + B^*$	$\rho + B^* + B_0$
$\bar{B}^0 \to \rho^-\pi^+$	0.50×10^{-5}	0.52×10^{-5}	0.49×10^{-5}
$\bar{B}^0 \to \rho^+\pi^-$	1.7×10^{-5}	1.7×10^{-5}	1.7×10^{-5}
$\bar{B}^0 \to \rho^0\pi^0$	0.10×10^{-5}	0.15×10^{-5}	0.12×10^{-5}
$B^0 \to \rho^+\pi^-$	0.49×10^{-5}	0.51×10^{-5}	0.48×10^{-5}
$B^0 \to \rho^-\pi^+$	1.7×10^{-5}	1.7×10^{-5}	1.7×10^{-5}
$B^0 \to \rho^0\pi^0$	0.11×10^{-5}	0.17×10^{-5}	0.15×10^{-5}

Neutral B decay modes

A moderate $\sim$ 20% (resp. 50%) for $\bar{B}^0$ (resp. B^0) effect for the $\rho^0\pi^0$ decay channel. (for $g = 0.60$, $h = -0.70$)

Remark

Other states: Their role decreases with mass, since there is no enhancement from the virtual particle propagator (the 0^+ state B_0 with $J^P = 0^+$ is special, as its coupling to a pion and the meson B is known theoretically to be uniformly (in momenta) large.

Discussion: Determination of α

The analysis shows that the effect of including B resonance polar diagrams is significant for the $B^- \to \pi^-\pi^-\pi^+$ and negligible for the other charged B decay mode. This result of some help in explaining recent results from the CLEO,

$$R = \frac{\mathcal{B}(B \to \rho^{\mp}\pi^{\pm})}{\mathcal{B}(B^{\pm} \to \rho^0\pi^{\pm})} = 3.5 \pm 0.8 \, ,$$

(exp. 2.3 ± 1.3).

ρ resonance alone produces a result up to a factor of 2 higher.

For neutral B decays, the only decay mode where $B^{*,**}$ may be significant is the neutral $\rho^0\pi^0$ decay channel.

As for the time–dependent asymmetry no significant effect is found.

The $B \to \pi\pi\pi$ decay channel allows an unambiguous measurement of α, with two provisos: 1) only the neutral B decay modes are considered; 2) the $\rho^0\pi^0$ channel can be disregarded.

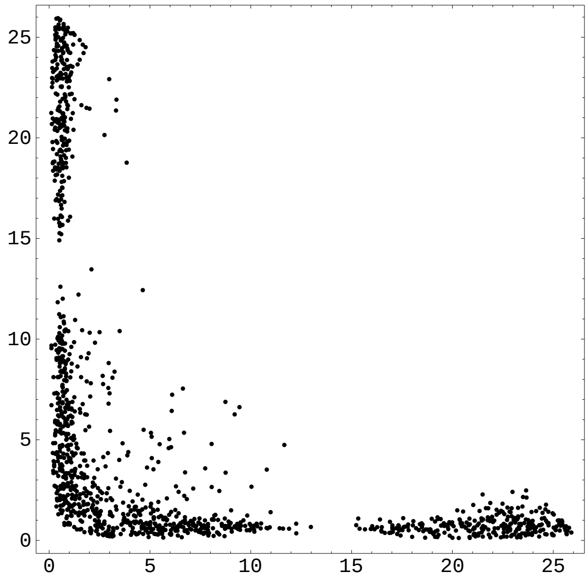


Figure 4: Dalitz plot for $B \to \rho\pi$

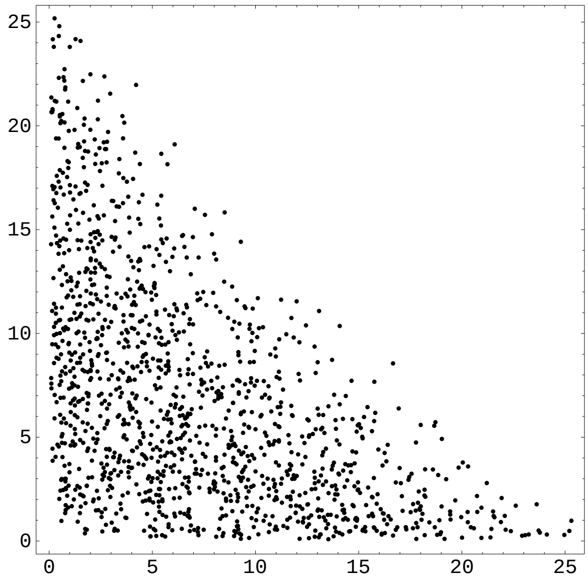


Figure 5: B resonances contribution