DOE/ER/40682--23

CMU-HEP92-01

Testing the Superweak Theory of CP Violation in Neutral B Decays

João M. Soares and Lincoln Wolfenstein

Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA

January 21, 1992

Abstract

In order to rule out the superweak theory for CP violation, future experiments will try to find a difference between the CP-violating asymmetries in the decays $B^0 \to \Psi K_S$ and $B^0 \to \pi^+\pi^-$. However, Winstein recently noted that, for some acceptable values of the CKM parameters, the standard model would give equal asymmetry parameters for these decays just as the superweak theory does. In this paper we show that, by considering both tree and penguin contributions to the decay amplitudes, the test can still be effective if a third asymmetry is measured with enough precision.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

The only evidence for CP violation comes from a study of K^0 decays [1]. It is still possible that the experimental results on K^0 decays can be explained entirely by CP violation in $K^0 - \bar{K}^0$ mixing. This type of violation could be explained by a superweak interaction much weaker than the electroweak interaction [2]. In contrast, the standard model predicts direct CP violation, that is, CP violation in the K^0 decay amplitudes. A CERN experiment [3] has indicated direct CP violation by measuring the parameter ϵ'/ϵ to be non-zero by three standard deviations, but this has not been confirmed by a Fermilab experiment [4].

The first goal of future experiments remains finding clearcut evidence for direct CP violation. Proposed experiments aim to measure ϵ'/ϵ with a precision close to 10^{-4}. Within the framework of the standard Kobayashi-Maskawa model, the theoretical prediction for ϵ'/ϵ varies from the order of 10^{-4} to 10^{-3} [5] so that it is probable, but by no means certain, that the proposed experiments will be sensitive enough.

Within the standard model much larger CP-violating effects are expected in B^0 decays. The experiments which are the focus of proposed B factories involve neutral B decays to CP eigenstates [6]. The CP violation is measured by

$$a(F) \equiv \frac{\Gamma(B^0 \to F) - \Gamma(\bar{B}^0 \to F)}{\Gamma(B^0 \to F) + \Gamma(\bar{B}^0 \to F)} \equiv \frac{x}{1+x^2}\, \eta_F\, \tilde{a}(F) \tag{1}$$

where $x = \frac{\Delta M}{\Gamma}$ and $\eta_F = 1\ (-1)$ for a CP-even (CP-odd) final state F. The states of most interest have been those reached by the quark transitions

$$b \;\to\; c + \bar{c} + s \tag{2}$$

$$b \;\to\; u + \bar{u} + d \tag{3}$$

The simplest decay of type (2) is $B^0 \to \Psi K_S$. The asymmetry is given by eq. 1 with

$$\tilde{a}(\Psi K_S) = \tilde{a}(2) = \sin 2\beta \tag{4}$$

where the CKM matrix element V_{td} is

$$V_{td} = |V_{td}| e^{-i\beta} = A\lambda^3(1 - \rho - i\eta) \tag{5}$$

The CP-violating asymmetry for transitions of this type could be explained in terms of a superweak CP-violating $B^0 - \bar{B}^0$ mixing and as by itself is not a sign of direct CP violation. While there is no reason to expect in superweak models a very large CP-violating effect in B^0 decays the possibility cannot be excluded [7]. Thus to see direct CP violation it is proposed to compare decays of type (3) with those of type (2). The superweak theory requires $\tilde{a}(3) = \tilde{a}(2)$ whereas differences in the direct CP violation in the two decays should make the asymmetries different. The simplest decay of this type is $B^0 \to \pi^+\pi^-$. Considering only tree amplitudes one finds

$$\tilde{a}(\pi^+\pi^-) = \tilde{a}(3) = \sin 2(\beta + \gamma) \tag{6}$$

where

$$V_{ub} = |V_{ub}|e^{-i\gamma} = A\lambda^3(\rho - i\eta) \tag{7}$$

It has recently been emphasized by Winstein [8] that even in the standard model $\tilde{a}(3)$ may equal $\tilde{a}(2)$ if the CKM matrix elements satisfy

$$\eta = (1 - \rho)\sqrt{\frac{\rho}{2 - \rho}} \tag{8}$$

For values of ρ between 0.1 and 0.5, eq. 8 (called by Winstein the curve of ambiguity) is consistent with all the present constraints on the CKM elements.

The main point of the present paper is to show that even if $\tilde{a}(\Psi K_S) = \tilde{a}(\pi^+\pi^-)$ within experimental errors, it is probable that the asymmetry of a third B^0 decay could demonstrate direct CP violation and disprove the superweak alternative. The reason for this is the important role expected to be played by the penguin amplitudes [9]. Although, for decays of type (2) like $B^0 \to \Psi K_S$, the penguin amplitudes do not contribute to the asymmetry, there are two classes of decays for which they must be included:

- Decays reached by the transition (3). Penguin amplitudes are expected to play a larger role in decays to final states $\pi^0\pi^0$, $\rho^0\rho^0$, $\rho^0\pi^0$ than for $\pi^+\pi^-$. Thus there can be a large difference in the asymmetries for these different states contrary to the superweak prediction. This is completely analogous to the measurement of ϵ' in the K^0 system except that we expect a much larger effect in the B^0 case.

- Decays associated with the quark transitions

$$b \to u + \bar{u} + s \tag{9}$$

$$b \to d + \bar{d} + s \tag{10}$$

A typical transition would be $B^0 \to K_S \pi^0$. Because the tree diagram of (9) is doubly Cabibbo-suppressed one expects penguin diagrams to dominate. If tree amplitudes were neglected completely then

$$\tilde{a}(K_S \pi^0) = \tilde{a}(9) = \sin 2\beta \tag{11}$$

and so the ambiguity would not be resolved. In fact we find this is not expected to be a good approximation for most transitions of type (9).

If we consider tree and penguin diagrams for decays for which the transition (3) contributes, the amplitude has the form

$$\begin{aligned} A(\bar{B}^0 \to F) &= |A| e^{-i\phi_F} \\ &= v_u A_u (1 + R_F \frac{v_t}{v_u}) \end{aligned} \tag{12}$$

where

$$\begin{aligned} v_u &= V_{ub} V_{ud}^* = A\lambda^3(\rho - i\eta) \\ v_t &= V_{tb} V_{td}^* = A\lambda^3(1 - \rho + i\eta) \end{aligned} \tag{13}$$

and R_F is the ratio of the penguin amplitude to the tree amplitude. Neglecting final-state interactions (or the absorptive part of the penguin amplitude) R_F is real. Then

$$\tan \phi_F = \eta \frac{1 - R_F}{\rho + R_F(1 - \rho)} \tag{14}$$

and the CP-violating asymmetry is given by eq. 1 with

$$\tilde{a}(F) = \sin 2(\beta + \phi_F) \tag{15}$$

For decays of type (9) a similar analysis applies:

$$A(\bar{B}^0 \to F) = |A| e^{-i\psi_F} \tag{16}$$

and

$$\tilde{a}(F) = \sin 2(\beta + \psi_F) \tag{17}$$

with

$$\tan \psi_F = \frac{\eta \lambda^2}{\lambda^2 \rho - R_F} \tag{18}$$

In the limit where R_F goes to zero eq. 15 gives back eq. 6. In the limit λ^2 (really λ^2/R_F) goes to zero eq. 18 gives eq. 11. Note that the deviation from the approximate formula of eq. 6 increases with R_F whereas the deviation from eq. 11 increases with $1/R_F$.

We now give an estimate for the ratios R_F. The effective Hamiltonian for the quark level transitions of interest is

$$\mathcal{H}_{eff} = 2\sqrt{2}\, G_F \, [v_u(C_1\mathcal{O}_1 + C_2\mathcal{O}_2) + v_t \sum_{k=3}^{6} C_k\mathcal{O}_k + h.c.] \tag{19}$$

where $v_\beta = V_{\beta b}V^*_{\beta\alpha}$ and the operators $\mathcal{O}_k$ are

$$\begin{aligned}
\mathcal{O}_1 &= \bar{\alpha}\gamma^\mu\gamma_L b \; \bar{u}\gamma_\mu\gamma_L u \\
\mathcal{O}_2 &= \bar{u}\gamma^\mu\gamma_L b \; \bar{\alpha}\gamma_\mu\gamma_L u \\
\mathcal{O}_3 &= \sum_{q=u,d,s} \bar{\alpha}\gamma^\mu\gamma_L b \; \bar{q}\gamma_\mu\gamma_L q \\
\mathcal{O}_4 &= \sum_{q=u,d,s} \bar{q}\gamma^\mu\gamma_L b \; \bar{\alpha}\gamma_\mu\gamma_L q \\
\mathcal{O}_5 &= \sum_{q=u,d,s} \bar{\alpha}\gamma^\mu\gamma_L b \; \bar{q}\gamma_\mu\gamma_R q \\
\mathcal{O}_6 &= -2 \sum_{q=u,d,s} \bar{q}\gamma_L b \; \bar{\alpha}\gamma_R q
\end{aligned} \tag{20}$$

with $\gamma_{R,L} = (1 \pm \gamma_5)/2$. α represents the d-quark for the decays of the type (3), and the s-quark for those of the type (9) and (10). The coefficients C_k depend on the choice of the scale μ at which the hadronic matrix elements of H_{eff} are to be evaluated. We choose $\mu \simeq m_b$ and use the results in ref. [10] (with $\Lambda = 300 MeV$):

$$\begin{aligned}
C_1 &= -0.31 \\
C_2 &= 1.14 \\
C_3 &= -0.016 \\
C_4 &= 0.036 \\
C_5 &= -0.010 \\
C_6 &= 0.045
\end{aligned} \tag{21}$$

The next step is to evaluate the hadronic matrix elements of the operators $\mathcal{O}_k$. We follow the factorization procedure of Bauer, Stech and Wirbel (BSW)

[11], and neglect terms in $1/N_c$ (as suggested by the experimental data on the BR for $B^0 \to \Psi K^{*0}$). The results are given in the Appendix. The penguin to tree ratios, R_F, are

$$
\begin{aligned}
R_{\pi^+\pi^-} &= (C_4 + 0.67\, C_6)/C_2 = 0.06 \\
R_{\pi^0\pi^0} &= -(C_4 + 0.49\, C_6)/C_1 = 0.19 \\
R_{K_S\pi^0} &= -(C_4 + 0.69\, C_6)/(0.93\, C_1) = 0.23 \\
R_{K_S\rho^0} &= -(C_4 - 0.69\, C_6)/(1.9\, C_1) = 0.01 \\
R_{\pi^0\rho^0} &= -(C_4 - 0.17\, C_6)/C_1 = 0.09 \\
R_{\rho^0\rho^0} &= -C_4/C_1 = 0.12 \qquad (22)
\end{aligned}
$$

For the decay $B^0 \to \rho^0\rho^0$, the value given is for the final state of zero helicity. The other helicity states are not CP eigenstates, and according to our calculation have a rate suppressed by a factor of ten.

As discussed in the Appendix, the values of R_F do not depend strongly on the parameters that appear in the evaluation of the matrix elements of the quark operators (except for $R_{K_S\rho^0}$ which is very sensitive to the choice of quark masses). The main uncertainties are in the choice of the scale μ, that determines the values of the Wilson coefficients $C_k(\mu)$, and in the overall correctness of the factorization procedure.

The asymmetry in $B^0 \to \pi^+\pi^-$ is now given by eq. 15 due to the small penguin contribution. This means that the ambiguity curve is in fact

$$\eta = (1-\rho)\sqrt{\frac{\rho + R_{\pi^+\pi^-}(1-\rho)}{2-\rho-R_{\pi^+\pi^-}(1-\rho)}} \qquad (23)$$

and is plotted in fig. 1 We will be interested in the part of the curve having $0.1 \leq \rho \leq 0.5$ which is in the region allowed by the present constraints on the CKM matrix elements.

In table 1, we give the values for the BRs and the asymmetries, for two points on the ambiguity curve (the analytic expressions for the BRs can be found in the Appendix). The behavior of the asymmetries along that curve is plotted in fig. 2 for the more interesting cases (the curves corresponding to the CP-odd states must be inverted to obtain the asymmetry). In the region of interest the asymmetries can differ by a factor of two, for the lowest ρ, but only by a factor of 1.2, for the highest ρ. Therefore, provided such a precision can be achieved in the experiments, these asymmetries could provide evidence for direct CP violation in spite of the Winstein ambiguity.

It should be emphasized that we do not believe our calculations are particularly reliable. There is at best qualitative evidence in favor of the BSW calculation method for B decays. The important point we make is that with reasonable estimates there are sizeable differences between the asymmetry parameter $\tilde{a}$ for different decays. Moreover, notice that the expressions for R_F in eq. 23 are approximately the same for the decays $K_S\pi^0$ and $\pi^0\pi^0$ (exactly the same in the SU(3)-flavor symmetric limit). As seen before, the difference to the superweak prediction for the asymmetry varies in opposite sense with R_F, for the two cases. Thus, at least one of the two asymmetries may be sufficiently different from that of ΨK_S and $\pi^+\pi^-$, and the exact value of R_F is not crucial. It is also worth noting that even though the final state $\rho_0\rho_0$ might not be a CP eigenstate, an observed value for the asymmetry parameter greater than that for ΨK_S and $\pi^+\pi^-$ would disprove the superweak alternative.

From the point of view of prospective experiments, there is the problem that those decays which deviate more strongly from the ambiguity value have suppressed rates. This follows since these are just the decays in which the leading amplitude (tree for transitions of type (3) and penguins for those of type (9)) is suppressed. Nevertheless, because we are dealing with very large asymmetries, experiments may still be practical.

A particularly curious example is the decay $B^0 \to K_S\rho^0$. In this case we find that due to a cancellation between $\mathcal{O}_4$ and $\mathcal{O}_6$, the tree amplitude becomes comparable with the penguin in spite of the double Cabibbo suppression. Given the uncertainty in the matrix element of $\mathcal{O}_6$, only very qualitative conclusions can be drawn. For a wide choice of parameters, the asymmetry is always far from the superweak prediction; however, the branching ratio is discouragingly small.

The importance of penguin amplitudes in B decays has been pointed out in many papers. Direct CP violation can be seen in the difference between partial decay rates of B^+ and B^- as a result of the interference between tree and penguin amplitudes [12]. This effect depends entirely on the existence of final state interactions. When these are estimated from the absorptive part of quark diagrams, the CP-violating effects become very small for decays generated by the quark diagrams (3), (9) and (10).

In contrast the effect we discuss here is large even in the absence of final state interactions. If we include a final state interaction phase difference δ between the tree and penguin terms, there are two effects. They are seen by looking at the time dependence of the decays, which has the form [6]

$$\Gamma(t) \propto 1 \pm X \cos(\Delta m\, t) \pm Y \sin(\Delta m\, t) \tag{24}$$

where the signs are for B^0 and $\bar{B}^0$. The term we have been calculating, which is Y, is multiplied by $\cos\delta$ and thus is not significantly changed if δ is small. The main effect of the final state interaction is to introduce the term X which is proportional to $\sin\delta$. This term gives a difference between B^0 and $\bar{B}^0$ decays even at time $t = 0$, and is the same term that determines the difference between B^+ and B^- decays. If this term were really large, then direct CP violation could be discovered from B^+ and B^- decays.

Penguin graphs have also been discussed in connection with the asymmetry in B^0, particularly for $B^0 \rightarrow \pi^+\pi^-$ and related decays. The main emphasis in previous papers has been the problem raised by penguins in the attempt to derive the CKM parameters from the observed asymmetry. It has been pointed out [13] that by combining several measurements it may be possible to determine the size of the penguin amplitude and so finally deduce CKM parameters. Here we have considered the much simpler problem of proving the existence of direct CP violation, in which case the penguin proves to be the solution rather than the problem.

This research was supported in part by the U.S. Department of Energy under Contract No. DE-AC02-76ER03066.

Appendix

The matrix elements of the quark current operators in the decay amplitudes are parameterized by form factors as follows:

$$
\begin{aligned}
< \pi^+ | \bar{u}\gamma^\mu \gamma_5 d | 0 > &= i f_\pi \, p_\pi^\mu \\
< \pi^+ | \bar{u}\gamma^\mu b | \bar{B}^0 > &= (p_B + p_\pi - \frac{m_B^2 - m_\pi^2}{q^2} q)^\mu \, F_\pi^1(q^2) \\
&+ \frac{m_B^2 - m_\pi^2}{q^2} q^\mu \, F_\pi^0(q^2) \qquad (25) \\
(q \equiv p_B - p_\pi)
\end{aligned}
$$

and similarly for the other mesons in the pseudoscalar octet. Whereas for the vector mesons

$$
\begin{aligned}
< \rho^+ | \bar{u}\gamma^\mu d | 0 > &= i f_\rho m_\rho \, \varepsilon^{\mu *} \\
< \rho^+ | \bar{u}\gamma^\mu \gamma_5 b | \bar{B}^0 > &= \varepsilon^{\mu *} (m_B + m_\rho) \, A_1(q^2) \\
&- \frac{\varepsilon^* . q}{m_B + m_\rho} (p_B + p_\rho)^\mu \, A_2(q^2) \qquad (26)
\end{aligned}
$$

The decay constants f_M are measured from the leptonic decay rate of the corresponding meson. The values of the other form factors are determined using an ansatz for the meson wave functions, and for the evolution with q^2. We use the values obtained in the model of Bauer, Stech and Wirbel [11]. Because the final state mesons in the B decays that we consider are nearly massless, we can take $q^2 = 0$. The ratio between the matrix elements of the penguin and the tree operators is then given by

$$
\pi^+\pi^- : \quad \frac{< Q_4 >}{< Q_2 >} = \frac{(m_u + m_d) m_b}{2 m_{\pi^+}^2} \frac{< Q_6 >}{< Q_2 >} = 1 \qquad (27)
$$

$$
\pi^0\pi^0 : \quad \frac{< Q_4 >}{< Q_1 >} = \frac{m_d m_b}{m_{\pi^0}^2} \frac{< Q_6 >}{< Q_1 >} = -1 \qquad (28)
$$

$$
K_S\pi^0 : \quad \frac{< Q_4 >}{< Q_1 >} = \frac{(m_s + m_d) m_b}{2 m_K^2} \frac{< Q_6 >}{< Q_1 >} = -\frac{f_K F_\pi^1(0)}{f_\pi F_K^1(0)} \qquad (29)
$$

$$
\pi^0\rho^0 : \quad \frac{< Q_4 >}{< Q_1 >} = -\frac{m_d m_b}{m_{\pi^0}^2} \frac{f_\pi F_\rho^1(0) + f_\rho F_\pi^1(0)}{f_\pi F_\rho^1(0)} \frac{< Q_6 >}{< Q_1 >} = -1 \qquad (30)
$$

$$K_S\rho^0: \qquad \frac{<Q_4>}{<Q_1>} = -\frac{(m_s+m_d)m_b}{2m_K^2}\frac{<Q_6>}{<Q_1>} = -\frac{f_K F_\rho^1(0)}{f_\rho F_K^1(0)} \qquad (31)$$

$$\rho^0\rho^0: \qquad \frac{<Q_4>}{<Q_1>} = -1 \qquad (32)$$

(The matrix elements of the operators that are not shown are zero). This shows that the ratios R_F that give the asymmetries do not depend strongly on the ansatz mentioned above (the dependence in the form factors actually disappears in the SU(6)-spin-flavor symmetric limit). If the factorization procedure is reliable, the expressions given in eq. 22 for R_F in terms of the Wilson coefficients should be a good approximation. The only exception is in the decays of the type $\bar{B}^0 \to PV$. Here the two penguin operators contribute with different signs, and the amount of cancellation depends on the values of the quark masses. We have taken $m_u = 4MeV$, $m_d = 7MeV$, and $m_s = 130MeV$.

The BRs for the decays shown in table 1, are given by

$$\begin{aligned}
BR(\pi^+\pi^-) &= 6.7\times10^{-5}\, C_2^2\, |\rho - i\eta + R_{\pi^+\pi^-}(1-\rho+i\eta)|^2 \\
BR(\pi^0\pi^0) &= 3.4\times10^{-5}\, C_1^2\, |\rho - i\eta + R_{\pi^0\pi^0}(1-\rho+i\eta)|^2 \\
BR(K_S\pi^0) &= 5.2\times10^{-4}\, (0.93\, C_1)^2\, |\lambda^2(\rho - i\eta) - R_{K_S\pi^0}|^2 \\
BR(\pi^0\rho^0) &= 1.1\times10^{-4}\, C_1^2\, |\rho - i\eta + R_{\pi^0\rho^0}(1-\rho+i\eta)|^2 \\
BR(K_S\rho^0) &= 3.5\times10^{-4}\, (1.9\, C_1)^2\, |\lambda^2(\rho - i\eta) - R_{K_S\rho^0}|^2 \\
BR(\rho^0\rho^0) &= 7.2\times10^{-5}\, C_1^2\, |\rho - i\eta + R_{\rho^0\rho^0}(1-\rho+i\eta)|^2 \qquad (33)
\end{aligned}$$

where $BR(\rho^0\rho^0)$ corresponds to the final state of zero helicity.

References

[1] J. H. Christenson *et al.*, Phys. Rev. Lett. **13** (1964) 138.

[2] L. Wolfenstein, Phys. Rev. Lett. **13** (1964) 562.

[3] H. Burkardt *et al.* (NA31 collaboration), Phys. Lett. **B 206** (1988) 169.

[4] J. R. Patterson *et al.* (E371 collaboration), Phys. Rev. Lett. **64** (1990) 1491.

[5] G. Buchalla, A. Buras and M. Harlander, Nucl. Phys. **B 337** (1990) 313.

[6] See for example I. I. Bigi *et al.*, in *CP violation*, edited by C. Jarlskog (World Scientific, Singapore, 1989).

[7] J.-M. Gérard and T. Nakada, Phys. Lett. **B 261** (1991) 474.

[8] B. Winstein, University of Chicago, EFI-91-54, 1991 (to be published).

[9] M. B. Gavela *et al.*, Phys. Lett. **B 154** (1985) 425; L.-L. Chau and H.-Y. Cheng, Phys. Rev. Lett. **59** (1987) 958; M. Gronau, Phys. Rev. Lett. **63** (1989) 1451; D. London and R. D. Peccei, Phys. Lett. **B 223** (1989) 257; B. Grinstein, Phys. Lett. **B 229** (1989) 280.

[10] A. Buras *et al.*, Max-Planck-Institut für Physik, MPI-PAE/PTh 56/91, TUM-T31-16/91, 1991 (to be published in Nucl. Phys. B).

[11] M. Bauer, B. Stech and M. Wirbel, Z. Phys. **C 29** (1985) 637; Z. Phys. **C 34** (1987) 103.

[12] J.-M. Gérard and W.-S. Hou, Phys. Rev. **D 43** (1991) 2909; H. Simma, G. Eilam and D. Wyler, Nucl. Phys. **B 352** (1991) 367.

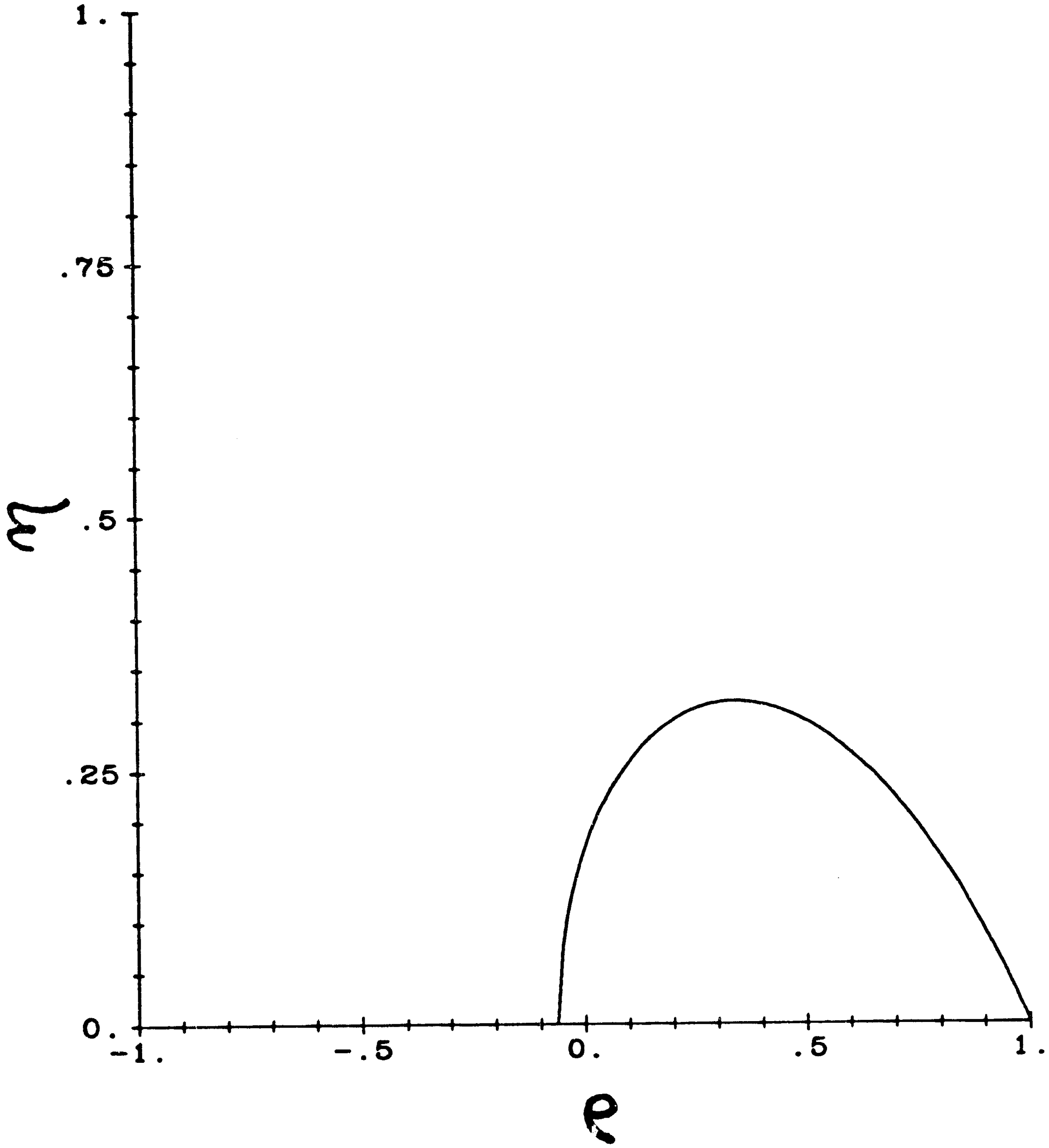
[13] M. Gronau and D. London, Phys. Rev. Lett. **65** (1990) 3381; Y. Nir and H. R. Quinn, Phys. Rev. Lett. **67** (1991) 541.

Table 1

	$\rho = 0.2$, $\eta = 0.3$		$\rho = 0.4$, $\eta = 0.3$	
	$\tilde{a}$	BR	$\tilde{a}$	BR
$\pi^+\pi^-$	0.66	1.2×10^{-5}	0.82	2.4×10^{-5}
$\pi^0\pi^0$	0.93	5.9×10^{-7}	0.95	1.1×10^{-6}
$K_S\pi^0$	0.55	2.2×10^{-6}	0.74	2.0×10^{-6}
$\pi^0\rho^0$	0.76	1.6×10^{-6}	0.86	3.1×10^{-6}
$K_S\rho^0$	-0.52	2.6×10^{-8}	0.27	4.3×10^{-8}
$\rho^0\rho^0$	0.82	1.1×10^{-6}	0.89	2.1×10^{-6}

Table 1: The asymmetries and BRs for two points of the ambiguity curve $\tilde{a}(\Psi K_S) = \tilde{a}(\pi^+\pi^-)$.

Figure 1: The ambiguity curve corresponding to $\tilde{a}(\Psi K_S) = \tilde{a}(\pi^+\pi^-)$.



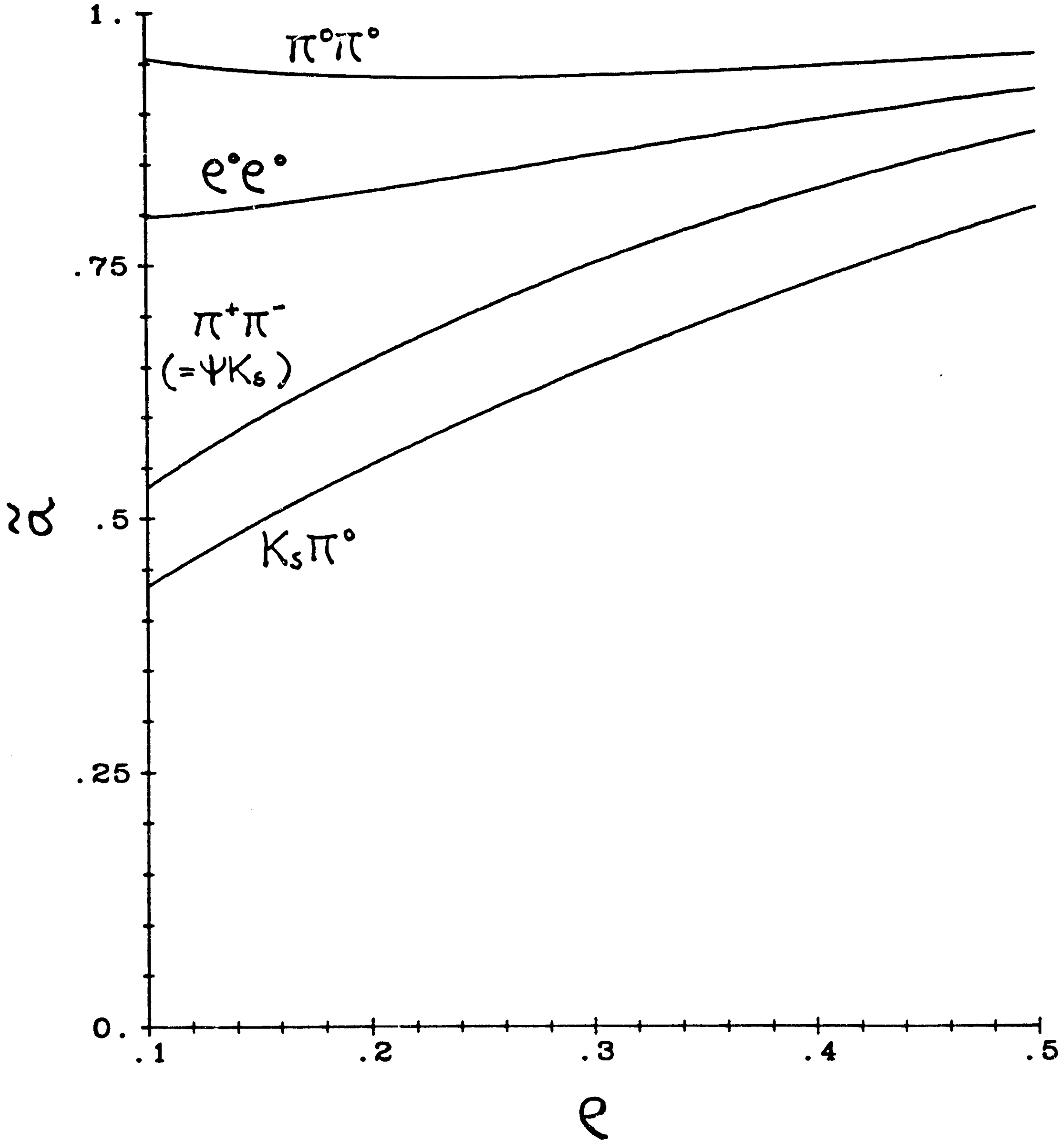


Figure 2: The asymmetries along the ambiguity curve $\tilde{a}(\Psi K_S) = \tilde{a}(\pi^+\pi^-)$.

END

DATE
FILMED
10/01/93