CP violation difference in $B^o$ and $B^\pm$ decays explained
No tree-penguin interference in $B^+ \to K^+\pi^0$

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Abstract

A new experimental analysis of $B \to K\pi$ decays provides finite experimental values for the contributions from interference terms between the dominant penguin amplitude and the color-favored and color-suppressed tree amplitudes. These results can explain the puzzling failure to see CP violation in $B^\pm \to K\pi$ decays. Tree-penguin interference contributions are commonly believed to be the source of the observed direct CP violation in $B^o \to K^\mp\pi^\mp$ decays. The data show that the color-favored and color-suppressed tree contributions interfere destructively in $B^\pm \to K^\pm\pi^o$ decays and nearly cancel. This surprising cancellation is not predicted by present theory. There is also no prediction for any difference produced by changing the flavor of the spectator quark. Isospin and Pauli effects that change with spectator quark flavor are examined and show using group theory and the color-spun SU(6) algebra how they produce both the near cancellation and the dependence on spectator quark flavor. The standard $B \to K\pi$ analysis which treats tree-penguin interference only in first order has three parameters overdetermined by four experimental branching ratios. Previous analyses confirmed the model but with large errors leaving the values of tree-penguin interference contributions less that two standard deviations from zero. The new analysis finds interference contributions well above the errors.

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I. INTRODUCTION

A. Experiment indicates vanishing of the tree contribution in $B^+ \to K^+\pi^0$ decay

A general theorem from CPT invariance shows [1] that direct CP violation can occur only via the interference between two amplitudes which have different weak phases and different strong phases. This holds also for all contributions from new physics beyond the standard model which conserve CPT. Thus the experimental observation of direct CP violation [2] in $B_d \to K^+\pi^-$ and the knowledge that the penguin amplitude is dominant for this decay require that the decay amplitude must contain at least one additional amplitude with both weak and strong phases different from those of the penguin.

This raises the questions what is this “other amplitude” and what can we learn about it from experiment. The failure to observe CP violation in charged decays [2] is still considered a puzzle [3]-[10]. One asks the question: “Why should changing the flavor of a spectator quark which does not participate in the weak decay vertex make a difference?”

After wading through many theoretical papers on the subject I am reminded of my iconoclastic letter in Physics Today, July 2000, “Who Ordered Theorists?” The answers to these questions are already in the experimental data. This paper begins by showing how to separate the signal from the noise and find the answers. The new questions raised by these answers are then addressed using isospin and permutation symmetry, the Pauli principle and group theory.

The agreement with experiment [2] of the approximate isospin sum rule [11–13] suggests that the dominant “other amplitudes” are the color-favored and color-suppressed tree amplitudes and that they are sufficiently small to be treated in first order. Second order contributions are negligible.

There is no new theory at this point. The theoretical implications of the experiment data are discussed below. There are four experimental branching ratios available for $B \to K\pi$. Therefore three different independent differences between these branching ratios can be defined which eliminate the penguin contribution. These can overdetermine the two remaining free parameters in the theory, the interference contributions between the penguin amplitude and the color-favored and color-suppressed tree amplitudes. Unfortunately experimental errors in previous analyses were too large to show that these parameters differed from zero.

We choose three differences in a way that minimizes experimental errors and find that there now are two significant signals in the data that are well above the noise of experimental errors and that they still fit an overdetermination of the two parameters. These indicate the presence of finite tree-penguin interference contributions that can be the source of the observed direct CP violation in neutral B-decays. However the third difference is consistent with zero well below the noise and below the other two contributions. The absence of tree-penguin contributions in this difference is completely unpredicted, provides a new challenge to theorists and can explain the failure to observe direct CP violation in charged B decays.

A difference between the tree-penguin interference contributions to charged and neutral decays is already shown in the experimental analysis of the difference rule [13] eq. (1.13) of ref. [13].

$$2 \cdot (12.1 \pm 0.8) - (24.1 \pm 1.3) = 0.1 \pm 2.1 \approx (18.2 \pm 0.8) - 2 \cdot (11.5 \pm 1.0) = -4.8 \pm 2.2$$

(1.1)
The charged decay contribution on the left hand side is zero, with an unfortunately large experimental error. The neutral decay contributions on the right hand side are finite and a bit more than two standard deviations from zero. But this difference was still not convincing.

The new data analysis sharpens this difference by isolating the color-favored and color-suppressed contributions. Both tree-penguin interference contributions are now shown to be appreciable and well above the background of experimental errors. The reason that changing the flavor of the spectator quark makes a difference is that color-flavored and color-suppressed contributions are incoherent when the flavor of the spectator quark is different from the flavor of the \( u \) quark created in the \( b \to u \) transition. This is the case in the neutral \( B \) decays where the spectator is a \( d \) quark. But in \( B^+ \to K^+\pi^o \), the spectator quark is also a \( u \) quark and the color-flavored and color-suppressed contributions are coherent and interfere. The data now tell us that these contributions are finite and well above the experimental errors but that they are equal and opposite and cancel in \( B^+ \to K^+\pi^o \). Thus tree-penguin interference can explain both the presence of CP violation in neutral decays and its absence charged decays.

New questions now arise because no present theory suggests this cancellation.

**B. Search for possible explanations for the cancellation**

We now look for reasons for this surprising cancellation and for the difference produced by the flavor of the spectator quark. In particular we wonder about some symmetry which produces a selection rule that cancels the tree contribution to \( B^+ \to K^+\pi^o \).

We first note that changing the flavor of the spectator quark produces a large isospin difference which may lead to some understanding and might lead to an isospin selection rule.

The tree diagram for \( B^+ \to K^+\pi^o \) has a four-body \( u\bar{s}u\bar{u} \) state containing a \( u \) spectator quark and the \( \bar{u}s\bar{u} \) produced by the \( \bar{b} \) antiquark weak decay. Combining the two \( u \) quarks in an \( I = 1 \) isospin state with the \( (I = 1/2) \bar{u} \) antiquark gives a unique four-body “tetraquark” state with unique isospin couplings. It is a definite mixture of two eigenstates of the total four-body isospin with \( I = 1/2 \) and \( I = 3/2 \) with unique relative magnitudes and phase. In the “fall-apart” model [14] this isospin constraint leads to a selection rule forbidding the tree contribution to the \( B^+ \to K^+\pi^o \) decay.

The isospin of the two quarks \( (u, d) \) in the corresponding tree diagram for the neutral \( B \) decays is not unique, it is a combination of \( I = 0 \) and \( I = 1 \). Thus there is no isospin constraint here and no selection rule forbidding the tree contribution. Changing the flavor of the spectator quark makes a crucial difference in the isospin analysis.

How can any selection rule arise purely from isospin apparently independent of the nature of the color-favored and color-suppressed transitions? The \( u\bar{s}u\bar{u} \) state contains two identical \( u \) quarks which must satisfy the Pauli principle. The definition of color-favored and color-suppressed tree diagrams treats the \( u \) quark produced in the weak vertex and the spectator \( u \) quark as distinguishable particles, ignoring the Pauli principle. The Pauli interchange in the state \( u\bar{s}u\bar{u} \) transforms between color-favored and color-suppressed tree diagrams, implying a symmetry.

The Pauli effect is investigated using the SU(6) color-spin algebra, denoted here by \( SU(6)_{cs} \). The \( u\bar{s}u\bar{u} \) “tetraquark” state which fragments into an s-state of two pseudoscalar...
mesons is shown to be in the singlet state of $SU(6)_{cs}$ and restricted by the Pauli principle to be in a unique state created by the product $15 \otimes 15$ and in a flavor $SU(3)$ state classified in the 27 dimensional representation with the eigenvalue $V = 2$ of the $V$ spin subgroup of $SU(3)$.

The same tree diagram for $B^o$ decays with a $d$ spectator quark creates a $u\bar{d}u\bar{d}$ tetraquark state with no Pauli restrictions. The states classified in the product $21 \otimes \bar{21}$ of $SU(6)_{cs}$ and in a flavor $SU(3)$ octet which are Pauli-forbidden for $B^{\pm}$ decays are favored here. This can produce a drastic difference between the $B^o$ and $B^{\pm}$ decays. We also note that it is only the two-pseudoscalar final state that is in the singlet state of $SU(6)_{cs}$. Other final states including vector mesons are classified in other representations of $SU(6)_{cs}$. Thus our treatment does not apply to these other final states.

II. EXPERIMENTAL ANALYSIS OF $B \to K\pi$

A. A new analysis of the data pinpointing tree-penguin interference

We first show explicitly that the present $B \to K\pi$ data do suggest a possible symmetry or selection rule.

We begin with a conventional analysis expressing the four $B \to K\pi$ amplitudes in terms of the three amplitudes $P$, $T$ and $S$ denoting respectively the penguin, color favored tree and color suppressed tree amplitudes while neglecting other contributions at this stage [11–13].

\begin{align}
A[K^o\pi^+] &= P; \quad A[K^+\pi^-] = T + P \\
A[K^o\pi^o] &= \frac{1}{\sqrt{2}}[S - P]; \quad A[K^+\pi^o] = \frac{1}{\sqrt{2}}[T + S + P]
\end{align}

(2.1)

We first note that a selection rule that eliminates the tree contribution to $B^+ \to K^+\pi^o$ predicts that both $B^+$ decays are pure penguin decays to the $I = 1/2$ $K\pi$ state. Experiment [15] shows agreement with this prediction to between one and two standard deviations.

\begin{align}
2B(B^+ \to K^+\pi^o) = 25.66 \pm 1.18 \approx B(B^+ \to K^o\pi^+) = 23.40 \pm 1.06
\end{align}

(2.2)

where $B$ denotes the branching ratio in units of $10^{-6}$

We now get a more sensitive tests by using all the $B \to K\pi$ data.

The agreement with experiment [2] of the approximate isospin sum rule [11–13] tells us that the two tree amplitudes $T$ and $S$ are sufficiently smaller than the dominant penguin amplitude $P$ and can be treated only to first order.

We now improve on the previous analysis [13] which converted the sum rule to a “difference rule” and obtained eq. (1.1). We use new data and define new differences which optimize the signal to noise ratio. Noting that the branching ratio $B(B^o \to K^+\pi^-)$ has the smallest experimental error, we define three independent differences which vanish for a pure penguin transition and are chosen to have the smallest experimental errors.
\[
\Delta(K^0\pi^+) \equiv |A[K^0\pi^+]|^2 - |A[K^+\pi^-]|^2 \approx -2\vec{P} \cdot \vec{T}
\]
\[
\Delta(K^+\pi^0) \equiv 2|A[K^+\pi^0]|^2 - |A[K^+\pi^-]|^2 \approx 2\vec{P} \cdot \vec{S}
\]
\[
\Delta(K^0\pi^0) \equiv 2|A[K^0\pi^0]|^2 - |A[K^+\pi^-]|^2 \approx -2\vec{P} \cdot (\vec{T} + \vec{S})
\]

where the approximate equalities hold to first order in the \( T \) and \( S \) amplitudes. The isospin sum rule \([11,12]\) is easily expressed in terms of these differences,

\[
\Delta(K^0\pi^0) + \Delta(K^+\pi^0) - \Delta(K^0\pi^+) \approx 0
\]

(2.4)

Since each of the three terms in eq. (2.4) vanish for a pure penguin transition, the sum rule is trivially satisfied in this case. We shall see that we can do better than the previous analysis \([13]\) that only showed that the sum rule was still only trivially satisfied with real data and that all terms proportional to tree-penguin interference were still statistically consistent with zero.

We now check whether these individual differences are sufficiently different from zero with available experimental branching ratio data corrected for the lifetime ratio \([15]\)

\[
\frac{\tau^0}{\tau^+} \cdot B(B^+ \rightarrow K^0\pi^+) - B(B^0 \rightarrow K^+\pi^-) = 2.04 \pm 1.17 \propto -\vec{P} \cdot \vec{T}
\]

\[
\frac{\tau^0}{\tau^+} \cdot 2B(B^+ \rightarrow K^+\pi^0) - B(B^0 \rightarrow K^+\pi^-) = 4.15 \pm 1.27 \propto \vec{P} \cdot \vec{S}
\]

(2.5)

\[
2B(B^0 \rightarrow K^0\pi^0) - B(B^0 \rightarrow K^+\pi^-) = -.05 \pm 1.41 \propto -\vec{P} \cdot (\vec{T} + \vec{S})
\]

The data are now sufficiently precise to show that the interference terms between the dominant penguin amplitude and the color-favored and color-suppressed amplitudes are both individually finite and one is well above the experimental errors. The sum rule is satisfied and is now nontrivial. But the term \( \Delta(K^0\pi^0) \) which is proportional to \( \vec{P} \cdot (\vec{T} + \vec{S}) \) is equal to zero and now well within the experimental errors. This suggests some symmetry or selection rule.

Thus tree-penguin interference can explain the observed CP violation in charged B-decays and its absence in neutral decays.

But there has been no theoretical prediction for this surprising cancellation.

**B. A recent restatement of the old sum rule which misses some physics**

The approximate isospin sum rule \([11–13]\) has recently been rearranged \([16,17]\) without noting the implications of the present paper.

\[
R_n \equiv \frac{\Gamma(K^+\pi^-)}{2\Gamma(K^0\pi^0)} = 0.99 \pm 0.07 = R_c \equiv \frac{2\Gamma(K^+\pi^0)}{\Gamma(K^0\pi^+)} = 1.11 \pm 0.07
\]

(2.6)

This restatement of the original agreement with the sum rule \([2]\) concludes that this agrees with the standard model and that the “\( K\pi \) puzzle” is no more. This particular rearrangement and its interpretation misses two crucial points.
1. The two sides of the equation not only agree; they are both equal to unity which is the value for the case of a pure penguin transition. The conclusion at this point is that any tree-interference is down in the noise of this experiment.

2. The difference between each side and unity is proportional to the interference between the penguin and the sum of the two tree contributions, \( \vec{P} \cdot (\vec{T} + \vec{S}) \) which we have seen is equal to zero well within the experimental errors.

\[
R_n \equiv \frac{\Gamma(K^+\pi^-)}{2\Gamma(K^0\pi^0)} = \frac{|\vec{P} + \vec{T}|^2}{|\vec{P} - \vec{S}|^2} \approx 1 + 2 \cdot \frac{\vec{P} \cdot (\vec{T} + \vec{S})}{P^2}
\]

\[
R_c \equiv \frac{2\Gamma(K^+\pi^0)}{\Gamma(K^0\pi^0)} = \frac{|\vec{P} + \vec{T} + \vec{S}|^2}{|\vec{P}|^2} \approx 1 + 2 \cdot \frac{\vec{P} \cdot (\vec{T} + \vec{S})}{P^2}
\]  

Our analysis shows that no deviations from unity appear on either side of the relation (2.6) because the two tree contributions cancel. That the two contributions are both indeed finite and interesting is missed in this way of presenting the sum rule.

III. SOME ISOSPIN ARGUMENTS SEARCHING FOR A SELECTION RULE

To try to understand a possible theoretical basis for this accidental cancellation of the color-favored and color-suppressed contributions to \( B^+ \rightarrow K^+\pi^0 \) we examine an isospin analysis of the initial and final states.

In the tree diagram the \( \bar{b} \rightarrow \bar{u}u\bar{s} \) decay together with a \( u \) spectator quark produce a \( u\bar{s}u\bar{u} \) state. This “tetraquark” state contains two \( u \) quarks with isospin \( I = 1, I_z = 1 \). The \( \bar{u} \) antiquark is in a well defined isospin state with \( I = 1/2, I_z = -(1/2) \) and the strange antiquark has isospin zero. The total four-body state is thus a state with well defined isospin. It is a definite linear combination of states with \( I = 1/2 \) and \( I = 3/2 \) with relative magnitudes and phases determined by isospin Clebsch-Gordan coefficients for coupling two states with \( I = 1 \) and \( I = 1/2 \) to \( I = 1/2 \) and \( I = 3/2 \).

The \( K\pi \) states are also linear combinations of states with isospin \( 1/2 \) and isospin \( 3/2 \) with relative amplitudes and phases determined completely by the requirement that the pion has isospin one and the kaon has isospin \( 1/2 \). The relevant Clebsch-Gordan coefficients for the \( K^+\pi^0 \) state are seen to be just those to make this linear combination exactly orthogonal to the combination in the \( u\bar{s}u\bar{u} \) state produced in the tree diagram by the \( \bar{b} \) decay. The overlap between the \( K^+\pi^0 \) state and the initial state thus vanishes. In the “fall-apart” [14] model commonly used in tetraquark decays this vanishing overlap indicates that the \( B^+ \rightarrow K^+\pi^0 \) transition is forbidden.

We now investigate this explicitly by expanding the initial and final states in isospin eigenstates,

\[
|i; u\bar{s}u\bar{u} \rangle \propto \left| \frac{1}{2}; \frac{1}{2} \right\rangle \left\langle \frac{1}{2}; \frac{1}{2} \right| (-\frac{1}{2}) \left| \frac{1}{2}; \frac{1}{2} \frac{1}{2}; \frac{1}{2} \frac{1}{2}; 2 \frac{1}{2} \right\rangle + \left| \frac{3}{2}; \frac{1}{2} \right\rangle \left\langle \frac{1}{2}; \frac{1}{2} \right| \frac{1}{2}; \frac{1}{2} \left| \frac{3}{2}; \frac{1}{2} \frac{1}{2}; \frac{1}{2} \frac{1}{2}; 2 \frac{1}{2} \right\rangle
\]

\[
|f; \pi^0K^+ \rangle \propto \left| \frac{1}{2}; \frac{1}{2} \right\rangle \left\langle \frac{1}{2}; \frac{1}{2} \right| 0 \left| \frac{1}{2}; \frac{1}{2} \frac{1}{2}; \frac{1}{2} \frac{1}{2}; 2 \frac{1}{2} \right\rangle + \left| \frac{3}{2}; \frac{1}{2} \right\rangle \left\langle \frac{1}{2}; \frac{1}{2} \right| \frac{1}{2}; \frac{1}{2} \left| \frac{3}{2}; \frac{1}{2} \frac{1}{2}; \frac{1}{2} \frac{1}{2}; 2 \frac{1}{2} \right\rangle
\]
where \( \langle j_1 j_2 m_1 m_2 | j_1 j_2 JM \rangle \) denotes a Clebsch-Gordan coefficient. From the orthogonality relation for Clebsch-Gordan coefficients

\[
\langle f; \pi^0 K^+ | i; u\bar{s}u \rangle = 0.
\] (3.3)

There is therefore no overlap between the initial “tetraquark” state \( | i; u\bar{s}u \rangle \) produced by the weak interaction and the \( K^+ \pi^0 \) final state.

The transition is therefore forbidden if the tetraquark state that fragments into a kaon and a pion is the same as the original tetraquark state created in the tree diagram by the \( \bar{b} \) antiquark decay; i.e. if the relative amplitude and phase between the \( I = 1/2 \) and \( I = 3/2 \) components are preserved between the creation and fragmentation of the tetraquark. This is true in the simple “fall-apart” [14] decay mode in common tetraquark models. The experimental data seem to indicate that the transition is indeed forbidden here.

The conventional analysis which does not include Pauli antisymmetrization has the amplitude for this transition given by the sum of independent color favored and color suppressed amplitudes. The experimentally observed vanishing of this transition suggests that these amplitudes must cancel for the decay \( B^+ \rightarrow K^+ \pi^0 \). It will be interesting to check whether this cancellation is required when Pauli antisymmetrization is introduced.

**IV. TETRAQUARK GROUP THEORY AND PAULI RESTRICTIONS**

We now use group theory to examine the effect of symmetry restrictions from the Pauli principle on the fragmentation of a \( uu\bar{u}\bar{s} \) tetraquark with no orbital angular momentum into a \( K^+ \pi^0 \) state.

The quark and the antiquark are classified respectively in the sextet and antisextet representations of the color-spin \( SU(6) \) group, \( SU(6)_{cs} \). Pseudoscalar mesons are color singlets and spin singlets and are singlets in \( SU(6)_{cs} \). Vector mesons are color singlets and spin triplets and are classified in the 35 dimensional representation of \( SU(6)_{cs} \). Thus the pseudoscalar-pseudoscalar final states are color singlets and spin singlets and singlets in \( SU(6)_{cs} \) while the vector-pseudoscalar states are color singlets and spin triplets and are classified in the 35 dimensional representation of \( SU(6)_{cs} \). The particular simplicity of the pseudoscalar-pseudoscalar final state gives rise to the unique Pauli restrictions discussed below. These restrictions do not apply to other states which are not singlets in color spin and \( SU(6)_{cs} \).

States of two quarks are classified in \( SU(6)_{cs} \) in either the symmetric \( 6 \otimes 6 = 21 \) representation or the antisymmetric \( 6 \otimes 6 = 15 \) representation.

The \( uu\bar{u}\bar{s} \) tetraquark with no orbital angular momentum contains a \( uu \) pair which is required by the Pauli principle to be in the antisymmetric 15-dimensional representation of \( SU(6)_{cs} \). Because the final two-pseudoscalar meson state is in a spin-zero color-singlet state, the \( u\bar{s} \) pair must also be in the 15-dimensional representation. Although no Pauli principle forbids it from being in the symmetric 21-dimensional representation, the states in the product \( 15 \otimes 21 \) contain no spin-zero color singlet. Note that the product \( 15 \otimes 21 \) contain a spin-one color singlet and can be an allowed state for vector-pseudoscalar decays. Thus our treatment here applies exclusively only to the two-pseudoscalar decay modes.

The \( uu\bar{u}\bar{s} \) tetraquark contains only \( u \) and \( s \) flavors; its \( SU(3) \) flavor symmetry is conveniently described by using the \( SU(2) \) V-spin (\( us \)) subgroup. Both the \( uu \) diquark and the \( u\bar{s} \)
antidiquark are antisymmetric in color-spin. The generalized Pauli principle requires them both to be in the flavor-symmetric V-spin state with $V = 1$.

The $\langle V = 1, V_z = +1 \rangle$ diquark denoted by $\langle D(1, +1) \rangle$ and the $\langle V = 1, V_z = 0 \rangle$ antidiquark denoted by $\langle \bar{D}(1, 0) \rangle$ can be coupled either symmetrically to a tetraquark denoted by $\langle T(\bar{V} = 2, V_z = +1) \rangle$ with total V-spin $(\bar{V} = 2, V_z = +1)$ or antisymmetrically to a tetraquark denoted by $\langle T(\bar{V} = 1, V_z = +1) \rangle$ with total V-spin $(\bar{V} = 1, V_z = +1)$.

$$\langle T(\bar{V} = 2, V_z = +1) \rangle = \langle D(1, +1; \bar{D}(1, 0)) \rangle + \langle 
\bar{D}(1, +1; D(1, 0)) \rangle$$ (4.1)

$$\langle T(\bar{V} = 1, V_z = +1) \rangle = \langle D(1, +1; D(1, 0)) \rangle - \langle 
\bar{D}(1, +1; D(1, 0)) \rangle$$ (4.2)

The tetraquark state must be even under generalized charge conjugation to decay into two pseudoscalar mesons. That the state $\langle T(\bar{V} = 2, V_z = +1) \rangle$ satisfies this condition and the state $\langle T(\bar{V} = 1, V_z = +1) \rangle$ does not can be seen by examining the behavior of these states under the $G_{us}$ transformation, $u \rightarrow \bar{s}; s \rightarrow \bar{u}$; i.e. the analog of G-parity using V spin instead of $I$ spin.

$$G_{us} \langle D(1, +1; \bar{D}(1, 0)) \rangle = \langle \bar{D}(1, +1; D(1, 0)) \rangle$$ (4.3)

$$G_{us} \langle T(\bar{V} = 2, V_z = +1) \rangle = \langle T(\bar{V} = 2, V_z = +1) \rangle$$ (4.4)

$$G_{us} \langle T(\bar{V} = 1, V_z = +1) \rangle = -\langle T(\bar{V} = 1, V_z = +1) \rangle$$ (4.5)

The state $\langle T(\bar{V} = 2, V_z = +1) \rangle$ is in the 27-dimensional representation of flavor SU(3).

Although the SU(6) color-spin algebra is used in this analysis, there is no assumption here that the dynamics are invariant under SU(6). The algebra here is just a short cut for writing down the explicit wave functions and imposing the restriction of the Pauli principle. The requirement that this $uu\bar{u}\bar{s}$ tetraquark must be classified in the 27-dimensional representation of flavor SU(3) follows from the SU(3) flavor symmetry and the fact that it has no orbital angular momentum and spin zero and the generalized charge conjugation with SU(3) that allows the decay into two octet pseudoscalar mesons.

In contrast the $ud\bar{u}\bar{s}$ which is created in the tree diagram for $B_d$ decay has no such restrictions. In particular it can be in a flavor SU(3) octet as well as a 27. Its “diquark-antidiquark” configuration includes the flavor-SU(3) octet constructed from the spin-zero color-antitriplet flavor-antitriplet “good” diquark found in the $\Lambda$ baryon and its conjugate “good” antidiquark. These “good diquarks” do not exist in the corresponding $uu\bar{u}\bar{s}$ tetraquark configuration.

The final $K^{+}\pi^{o}$ state is a tetraquark state which is a linear combination of the $uu\bar{u}\bar{s}$ and $ud\bar{d}\bar{s}$ states. This state is seen to have only a small $V = 2$ component. The $\pi^{o}$ is $(3/4)$ $V = 0$ and only $(1/4)$ $V = 1$. Only the $V = 1$ component can couple with the $V = 1 K^{+}$ to make $V = 2$. The coupling of a $\langle V = 1, V_z = +1 \rangle$ state to a $\langle V = 1, V_z = 0 \rangle$ state has an equal probability of making states with $V = 2$ and $V = 1$. Thus the probability that the final $K^{+}\pi^{o}$ state has $V = 2$ is $(1/8)$. Only this small $V = 2$ component can contribute to the fragmentation process which creates the final $K^{+}\pi^{o}$ state from the $V = 2$ tetraquark in
the approximation where SU(3) is conserved and therefore also its V spin subgroup. This
suppression factor of \((1/8)\) does not arise in the \(B_d\) decays whose final states are expected
to be further enhanced by their creation from “good” diquarks in a flavor octet state.

We again see that the Pauli effects produce a drastic symmetry difference produced by
spectator quark flavor on the tree diagrams for \(B \rightarrow K\pi\) decays.

V. CONCLUSION

Experiment has shown that the penguin-tree interference contribution in \(B^+ \rightarrow K^+\pi^0\)
decay is very small and may even vanish. The corresponding interference contributions to
neutral \(B \rightarrow K\pi\) decays have been shown experimentally to be finite. This can explain why
CP violation has been observed in neutral \(B \rightarrow K\pi\) decays and not in charged decays. A new
isospin analysis suggests a possible selection rule justifying the apparent experimental fact
that the color-favored and color-suppressed contributions to the amplitude for the \(B^+ \rightarrow K^+\pi^0\) decay seem to be equal and opposite and cancel. The requirement that identical
quarks appearing in different final state hadrons must satisfy the Pauli principle has provided
serious constraints in a group-theoretical treatment selecting a unique allowed SU(3) flavor
final state with V-spin \(V = 2\). This could provide an additional constraint for analyses of
systematics and CP violation in \(B \rightarrow K\pi\) decays.

ACKNOWLEDGEMENTS

This research was supported in part by the U.S. Department of Energy, Division of High
Energy Physics, Contract W-31-109-ENG-38. It is a pleasure to thank Michael Gronau,
Yuval Grossman, Marek Karliner, Zoltan Ligeti, Yosef Nir, Jonathan Rosner, J.G. Smith,
and Frank Wuerthwein for discussions and comments.

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