Analysis of the decay $\psi \rightarrow$ vector + pseudoscalar

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(Received 15 October 1984)

An analysis of eight two-body Okubo-Zweig-Iizuka-rule-violating decays of ψ to a vector and a pseudoscalar is carried out. The analysis uses the vector-dominance model and a standard parametrization of the Okubo-Zweig-Iizuka (OZI) process. It is pointed out that for two of the rates a second-order OZI process makes a substantial contribution. Seven of the eight rates are consistent with each other and the model; only $\psi \rightarrow \omega\eta$ is inconsistent. The average value of $G_{\omega\rho\pi}$ extracted from the data is 8.85 GeV^{-1}, consistent with the chiral result $G_{\omega\rho\pi} = m_\rho^2/\pi^2 F_\pi^3 = 9.3\ \text{GeV}^{-1}$.

INTRODUCTION

Recently, the Mark III collaboration measured eight decay rates of ψ to a vector meson and a pseudoscalar meson (Table I). These decays all violate the Okubo-Zweig-Iizuka (OZI) rule. In an analysis of their data, the Mark III group[1] assumed that the rates are dominated by the direct OZI (DOZI) process shown in Fig. 1(a) and the electromagnetic[2,3] (EM) process shown in Fig. 1(b). If this were the case, the quark content of the vector and pseudoscalar would be correlated. The vector mesons, being very nearly ideally mixed, could then be used to measure the quark and glue content of the pseudoscalars, a much less well understood multiplet. This analysis gives[1] an unconventional result for the quark content of the pseudoscalars.

Unfortunately, there is good reason to believe that the DOZI and EM processes do not dominate all the rates. From QCD we know that the strength of an OZI coupling $[Z(s)]$ must depend on both the J^{PC} and energy of the channel. OZI coupling strengths generally decrease with energy and the coupling in the 0^{-+} (P) channel which goes via two gluons is stronger than the OZI coupling in the 1^{-+} (V) channel which goes via three gluons. Therefore, the second-order OZI (SOZI) process shown in Fig. 1(c) must be considered since $Z_V(1)Z_P(1)$ can be comparable to $Z_V(10)$.

DESCRIPTION OF MODEL

To study this issue, we use a simple parametrization of the OZI couplings (Ref. 4). These OZI couplings are given in Table II. We see that the strength of the SOZI process is of order 10% of the DOZI process; therefore, the SOZI process can lead to a 20% correction in the rates (larger in this case because of the Clebsch-Gordan coefficients).

The EM process can be calculated using the vector-dominance model (VDM) for the intermediate vector meson $\bar{V}$ as indicated in Fig. 1(b):

$$\Gamma(\psi \rightarrow PV)_{\text{EM}} \sim \frac{G_{V\bar{V}P}{}^2}{12\pi} \zeta_\psi{}^2 A^2 \zeta_{\bar{V}}{}^2 P^3 \ ,$$

TABLE I. Branching ratios (in units of 10^{-3}) for $\psi \rightarrow V + P$ decays.

Mode	Previous experiments	Mark III
$\rho\pi$	12.2 ± 1.2	$14.9 \pm 0.15 \pm 2.2$
$K^{*+}K^- +$ c.c.	3.4 ± 0.5	$4.1 \pm 0.2 \pm 0.8$
$K^{*0}K^0 +$ c.c.	2.7 ± 0.6	$3.1 \pm 0.2 \pm 0.6$
$\omega\eta$	$\cdots$	$1.9 \pm 0.2 \pm 0.5$
$\omega\eta'$	$\cdots$	$0.31 \pm 0.08 \pm 0.06$
$\phi\eta$	1.0 ± 0.6	$0.68 \pm 0.06 \pm 0.09$
$\phi\eta'$	< 1.3	$0.37 \pm 0.06 \pm 0.06$
$\omega\pi^0$	$\cdots$	$0.67 \pm 0.06 \pm 0.16$

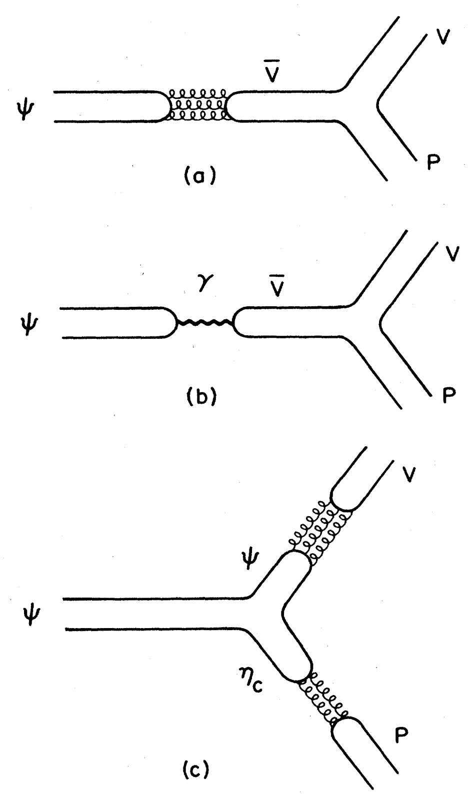

FIG. 1. (a) The direct OZI process. (b) The electromagnetic process. (c) The second-order OZI process.

TABLE II. OZI and vector-dominance coupling strengths (in units of 10^{-2}).

$Z_V(10)$	$Z_V(1)$	$Z_P(1)$	ζ_ρ	ζ_ψ	ζ_ω	ζ_ϕ	A
0.021	0.16	−1.3	6.15	2.48	1.87	2.3	6.6

where

$$\zeta_V{}^2 = \frac{3\Gamma(V \rightarrow e^+e^-)}{\alpha m_V}$$

and

$$A = (M_\psi{}^2/m_V{}^2 - 1)^{-1} \; .$$

These are tabulated in Table II. The decay rates for all eight processes can therefore be calculated from the following formula where C_1 is the number of charge states and C_2 through C_6 are Clebsch-Gordan coefficients (the C's given in Table III):

$$\Gamma(\psi \rightarrow VP) = \frac{G_{VVP}{}^2}{12\pi} C_1 [C_2 Z_V(10) + \zeta_\psi A (C_3\zeta_\rho + C_4\zeta_\omega + C_s\zeta_\phi) - C_6 Z_V(1) Z_P(1)]^2 P^3$$

and $G_{\omega\rho\pi} = \sqrt{2} G_{VV\rho}$.

For the purposes of this calculation, we have assumed that the vector nonet is ideally mixed, that the η is a pure octet, and that the η' is a pure singlet. Comparing the results of this calculation with the data, one can extract a value of

$$(G_{VV\rho}{}^2/12\pi)^{1/2}$$

necessary to fit each reaction. These are plotted in Fig. 2. The average value is 1.02 GeV^{-1}, which gives a value of $G_{\omega\rho\pi}$ of 8.85 GeV^{-1}, consistent with the value extracted from chiral theories,[5]

$$G_{\omega\rho\pi} = m_\rho{}^2/\pi^2 F_\pi{}^3 = 9.3 \text{ GeV}^{-1} \; .$$

The errors shown in Fig. 2 are just those from the $\psi \rightarrow P + V$ data, and do not include errors on the data used to calculate the OZI or VMD couplings, or the theoretical uncertainties of the model.

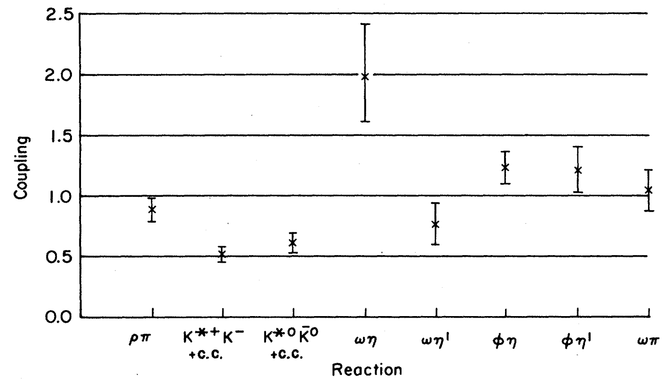

FIG. 2. $(G_{VVP}{}^2/12\pi)^{1/2}$ extracted from the fit to each of the eight reactions.

DISCUSSION

There are several points to be made from this analysis.

(1) All the rates, save $\psi \rightarrow \omega\eta$, are reasonably consistent with each other and with the model.

(2) No reasonable variation of the model, singlet-octet mixing, mixing with glue, etc., will make the rate $\psi \rightarrow \omega\eta$ consistent.

(3) Removing the SOZI leads to a 20% variation in the amplitudes for $\psi \rightarrow \omega\eta'$ and $\psi \rightarrow \phi\eta'$.

(4) The EM processes make important contributions and can be reasonably accurately calculated from the VDM, as seen from the $\psi \rightarrow \omega\pi^0$ rate which only goes via the EM process.

(5) The uncertainties in the model and the data are too large to carry out a quark decomposition in the manner of Rosner.[6]

(6) The processes that would give information about the glue content of the η' are the very ones that have the added uncertainties of the SOZI contribution.

(7) There appears to be no pattern of stronger couplings of glue to strange quarks. The $\phi\eta$ and $\phi\eta'$ appear larger than average, and K^*K rates appear smaller than average.

TABLE III. Charge multiplicities and Clebsch-Gordan coefficients.

Reaction	C_1	C_2	C_3	C_4	C_5	C_6
$\zeta\pi$	3	2	0	$\sqrt{2}$	0	0
$K^{*+}K^-$ + c.c.	2	2	$\sqrt{1/2}$	$\sqrt{1/2}$	1	0
$K^{*0}\bar{K}^0$ + c.c.	2	2	$-\sqrt{1/2}$	$\sqrt{1/2}$	1	0
$\omega\eta$	1	$\sqrt{1/3}$	0	$\sqrt{1/6}$	0	0
$\omega\eta'$	1	$\sqrt{2/3}$	0	$\sqrt{1/3}$	0	$\sqrt{2}$
$\phi\eta$	1	$\sqrt{2/3}$	0	0	$-\sqrt{2/3}$	0
$\phi\eta'$	1	$\sqrt{1/3}$	0	0	$\sqrt{1/3}$	1
$\omega\pi^0$	1	0	$\sqrt{2}$	0	0	0

The author would like to thank T. Burnett and S. Meshkov for many useful conversations, and to acknowledge the Aspen Center for Physics, where this work was begun.

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