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Measurement of the Branching Ratios for the Decays J/Ψ (3.1) → fω and J/Ψ (3.1) → Bπ

PLUTO Collaboration

by

J. Burmester, L. Criegee, H.C. Dehne, K. Derikum, R. Devenish, G. Flügge, [illegible]
J.D. Fox, G. Franke, Ch. Gerke, P. Harms, G. Horlitz, Th. Kahl, G. Knies,
M. Rossler, R. Schmitz, U. Timm, H. Wahl, P. Waloschek, G.G. Winter,
S. Wolff and W. Zimmermann
Deutsches Elektronen-Synchrotron DESY, Hamburg

V. Blobel, B. Koppitz, E. Lohrmann and W. Lührsen
II. Institut für Experimentalphysik der Universität Hamburg

A. Bäcker, J. Bürger, C. Grupen and G. Zech
Gesamthochschule Siegen

H. Meyer and K. Wacker
Gesamthochschule Wuppertal

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Abstract

Decays of the $J/\psi(3.1)$ resonance into final states with four charged and one neutral pion have been investigated. We measured the branching ratios J/ψ (3.1) $\to f\omega$ = (0.40 ± 0.14)% and J/ψ (3.1) $\to B^{\pm}\pi^{\mp}$ = (0.28 ± 0.07)%.

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* on leave from CERN

** now at CERN

In this letter we describe the analysis of the decay $J/\psi \to \omega\pi^+\pi^-$ and in particular the observation of a $B\pi$ intermediate state. These decays result in a final state consisting of four charged and one neutral pion.

The popular assignment of the J/ψ particle is that of a $c\bar{c}$ state with "hidden" charm. The long lifetime is explained by the Okubo-Zweig-Iizuka (OZI) rule[1], which forbids transitions to hadronic final states via disconnected quark line diagrams. The rule does not render quantitative predictions. However, one can try to establish empirical systematics by comparing decays corresponding to different degrees of disconnected diagrams (zero, singly, doubly, etc.). An example for such a comparison are the decays $J/\psi \to \omega\pi\pi$ and $J/\psi \to \phi\pi\pi$ [2].

A more quantative approach to explain OZI violating decays tries to describe them by SU(4) breaking which, together with the mass splitting introduces a small mixing between $c\bar{c}$ and noncharmed $q\bar{q}$ states[3]. This leads in particular to a small admixture of ω to the J/ψ. The decay $J/\psi \to B\pi$ proceeds through this admixture via the ($\omega B\pi$) coupling strength (off mass shell). From the decay width and from the distribution of the production angle the coupling parameters can be determined independently thus giving a check of the validity of the model.

Data were taken with the magnetic detector PLUTO at the DESY e^+e^- storage rings DORIS. The detector consists of a superconducting solenoid producing a 2 Tesla magnetic field parallel to the beam. The usable magnetic volume of 1.4 m diameter and 1.0 m length is filled with 14 cylindrical proportional wire chambers which are used both for triggering and track recording. The trigger efficiency for the 2 $(\pi^+\pi^-)\pi^0$ final state discussed in this letter is 97 %. The probability for observing all four charged particles is 46 %. A more detailed description of the detector has been given before[4].

Out of a total of 84.000 hadronic decays of the J/ψ (3.1) we found 17.900 charge balanced four prong events. The distribution of the missing mass squared M_x^2 of this sample, assuming all particles to be pions, shows a clear peak at $M_x^2 = 0$. Events fitting the 1 C-Hypothesis $e^+e^- \to \pi^+\pi^+\pi^-\pi^-\pi^0$

and with $M_x^2 < 0.2\ (\mathrm{GeV}/c^2)^2$ have been studied further. The cut in M_x^2 reduces background of other channels, especially events with more than one neutral pion. A further cut is applied to the missing momentum, $p_m > 0.2$ GeV/c. This cut removes events from quasielastic channels like $2\pi^+2\pi^-$, $K_S^o K^\pm\pi^\mp$ and $K^+K^-\pi^+\pi^-$.

The invariant mass distribution of the $\pi^+\pi^-\pi^o$ system shown in Fig. 1 exhibits a distinct peak at the ω mass. The curve through the data in this and the following figures is the result of a fit with a Gaussian distribution plus a polynomial background. The small structure at 550 MeV might result from the decay $\eta \to \pi^+\pi^-\pi^o$. Events in the ω band ($730 \leq M(\pi^+\pi^-\pi^o) \leq 840$ MeV/c^2) have been studied further. Fig. 2a shows the mass spectrum of the two pions recoiling against the 3π system of the ω band. A strong signal for the f meson is observed at $M(\pi^+\pi^-) = 1.30$ GeV/c^2. No indication of a ρ is seen since a decay $J/\psi(3.1) \to \omega\rho^o$ violates charge conjugation invariance. The 3π system of the ω band was combined with one of the remaining pions. In Fig. 2b the effective mass combination $M(\omega\pi^\pm)$ is plotted. A clear peak is visible at the mass of the B meson. The fitted mass is 1188 ± 32 MeV/c^2. The B meson thus originates from the decay $J/\psi \to B^\pm\pi^\mp$. The bump at 2.6 GeV is a kinematic reflection of the B resonance in a different 4π subsystem.

The observed number of events is calculated from the fits and given in Table 1. The efficiency is determined separately for each channel by a Monte-Carlo program. Isospin invariance and known decay parameters[6] are used to correct for unobserved decay modes. The total number of J/ψ (3.1) decays is obtained by correcting the observed number of hadronic events for acceptance and for 14 % leptonic decays.

The branching ratios have been checked by including events with $P_{miss} < 0.2$ GeV/c and by varying the width of the ω band and the cut in M_x^2 with the corresponding efficiencies calculated by Monte-Carlo procedures. Both methods give consistent results. The quoted errors include statistical errors as well as uncertainties in the analysis procedures.

Branching ratios for the decay channels listed in Table 1 - with the exception of $B\pi$ - have also been obtained in the SLAC-LBL experiment[2]. The agreement is good for the channels $4\pi\pi^o$ and $\omega\pi\pi$.

We have investigated the distribution of the production angle Θ_B of the B meson relative to the beam axis. To get a cleaner sample we have excluded all events from the f region and below by the cut $M(\pi^+\pi^-) < 1.5$ GeV/c^2. After corrections for background and acceptance we obtain an angular distribution consistent with the form $1 + A\cos^2\Theta_B$ with $A = 1.1 \pm 1.1$. If the B is produced in a helicity one state one expects $A = +1$[5], in contrast to $A = -1$ for a helicity zero state.

It is obvious from the branching ratios listed in Table 1 that a sizeable fraction of all $\omega\pi\pi$ events is contained in the ωf and $B\pi$ channels. We can give an upper limit of nonresonant $\omega\pi\pi$ production with dipion mass above 1.5 GeV/c^2. A fit to our data, corrected for the B-region, gives a branching ratio

$$J/\psi\ (3.1) \to \omega(\pi^+\pi^-)_{M_{\pi\pi} > 1.5\ \mathrm{GeV}} < 0.12\ \%\ (95\ \%\ \text{confidence level}).$$

One can compare the nonresonant $\omega\pi\pi$ rate to the $\phi\pi\pi$ rate in order to study the suppression due to doubly rather than singly OZI forbidden decays. A scale for this extra suppression has been set by the quasi twobody decay rates into ϕf and ωf', which were found to be more than a factor of ten lower than the corresponding rates into ϕf' and ωf.[2] In contrast, the overall suppression of $\phi\pi\pi$ to $\omega\pi\pi$ turned out to be only about a factor of five. The authors of Ref 2) find, however, a substantially larger suppression if they compare only events with dipion masses above 1 GeV. Our evidence is not in agreement with this statement. If we use our present data and subtract the contributions of ωf and $B\pi$, we find an even smaller overall suppression of $\phi\pi\pi$, namely just a factor of two. Moreover, due to the lack of corresponding $\omega\pi\pi$ events, no strong suppression can be postulated for the high dipion masses either. Therefore, in the case of the nonresonant decays into $\phi\pi\pi$ and $\omega\pi\pi$ we cannot find any evidence for an extra suppression due to doubly rather than singly disconnected quark diagrams.

For computing the parameters of the decay $J/\psi \to B\pi$ we have used a SU(4) model assuming mass independence of the invariant coupling constants $F^{(1)}$ and $F^{(2)}$ [5]. The best fit to our data ($\Gamma = 100 \pm 30$ eV, A=1.1+1.1) gives a resulting D/S amplitude ration D/S=0.8 which is not compatible with measurements on the decay $B \to \omega\pi$ (D/S=0.25± 0.06)[6]. This seems to indicate that simple SU(4) models mixing and mass independent coupling parameters are not sufficient to describe the J/ψ decays.

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Figure Captions

1. Distribution of the invariant mass $M(\pi^+\pi^-\pi^o)$ for the decay $J/\psi \to 2(\pi^+\pi^-)\pi^o$

2. Invariant mass distributions for the decay $J/\psi \to (\pi^+\pi^-\pi^o)_\omega \pi^+\pi^-$
   a) Invariant mass of the $\pi^+\pi^-$ - system recoiling against the ω
   b) Invariant mass of the $\omega\pi^\pm$ - system

Decay mode	Observed number of events	Branching ratio (%)	Γ (eV)
$2(\pi^+\pi^-)\pi^o$	1500	3.64 ± 0.52	2548 ± 360
$\omega\pi^+\pi^-$	215 ± 30 *	0.78 ± 0.16	546 ± 110
ωf	70 ± 24 *	0.40 ± 0.14	280 ± 100
$B^\pm\ \pi^\mp$	87 ± 18 *	0.28 ± 0.07	196 ± 50

Table 1 Branching ratios for J/ψ (3.1) decay modes, corrected for efficiency and unobserved decay modes using the following branching ratios : BR $(\omega \to \pi^+\pi^-\pi^o) = 0.90$; BR $(f \to \pi^+\pi^-) = \frac{2}{3} \cdot 0.813$, BR $(B^\pm \to \omega\pi^\pm) = 1.0$

*) statistical error from the fit.

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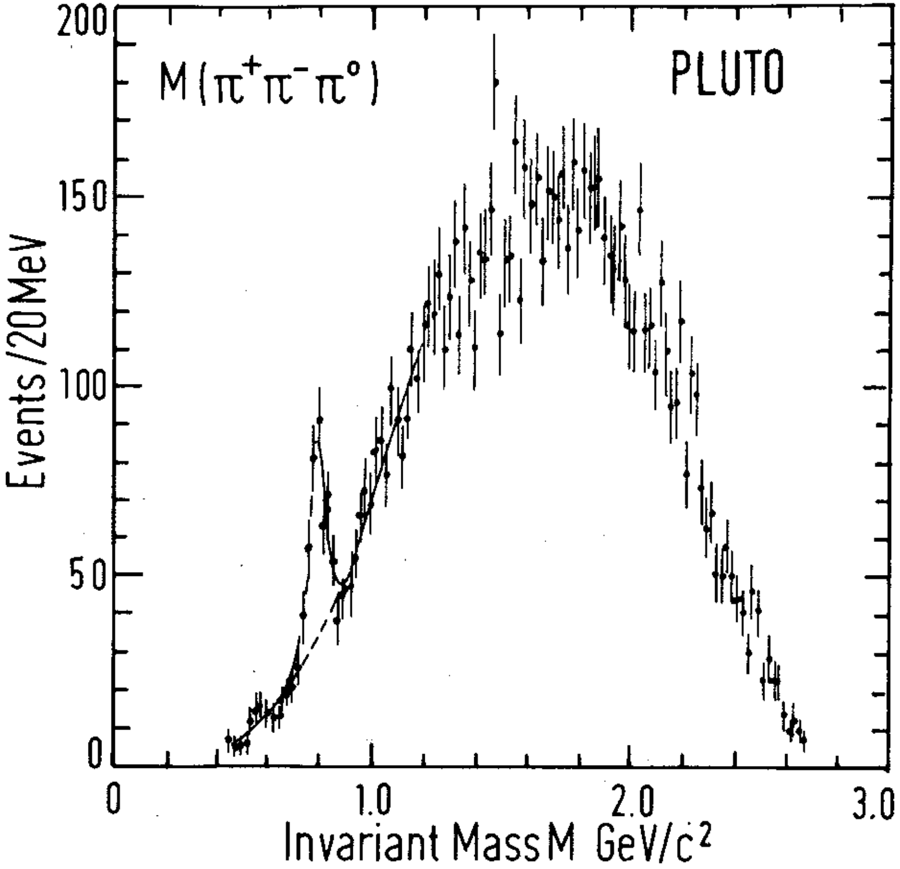

Fig. 1

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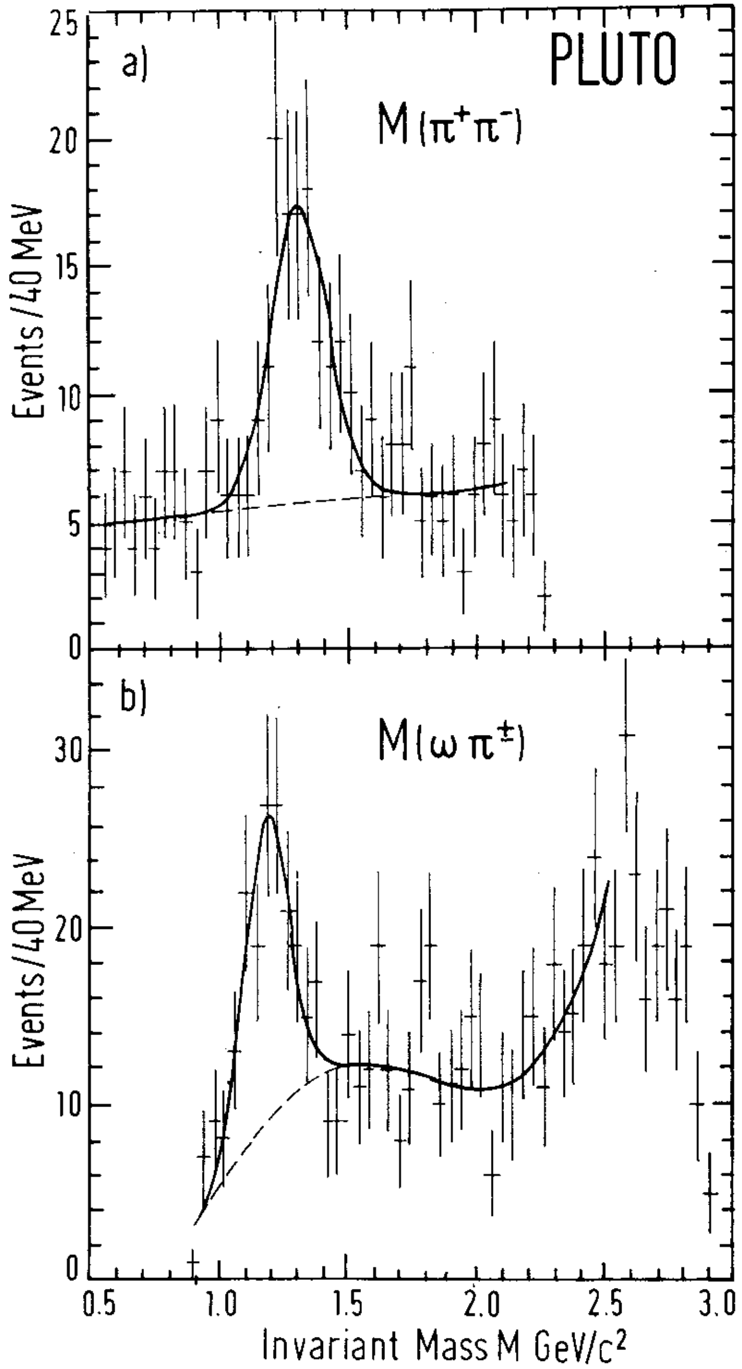

Fig. 2