MEASUREMENT OF THE BRANCHING RATIOS FOR THE DECAYS $J/\psi(3.1) \to f\omega$ AND $J/\psi(3.1) \to B\pi$

PLUTO Collaboration

J. BURMESTER, L. CRIEGEE, H.C. DEHNE, K. DERIKUM, R. DEVENISH, G. FLÜGGE, J.D. FOX, G. FRANKE, Ch. GERKE, P. HARMS, G. HORLITZ, Th. KAHL, G. KNIES, M. RÖSSLER, R. SCHMITZ, U. TIMM, H. WAHL*, P. WALOSCHEK, G.G. WINTER, S. WOLFF and W. ZIMMERMANN

Deutsches Elektronen-Synchrotron DESY, Hamburg, FRG

V. BLOBEL, B. KOPPITZ, E. LOHRMANN** and W. LÜHRSEN

II. Institut für Experimentalphysik der Universität Hamburg, Hamburg, FRG

A. BÄCKER, J. BÜRGER, C. GRUPEN and G. ZECH

Gesamthochschule Siegen, Siegen, FRG

and

H. MEYER and K. WACKER

Gesamthochschule Wuppertal, Wuppertal, FRG

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

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 $\bar{c}c$ 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 observed OZI-violating decays of the J/ψ may then be described by SU(4) breaking which, together with the mass splitting introduces a small mixing between $\bar{c}c$ and non-charmed $\bar{q}q$ states [2]. 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 [3].

Out of a total of 84 000 hadronic decays of the

* On leave from CERN.
** Now at CERN.

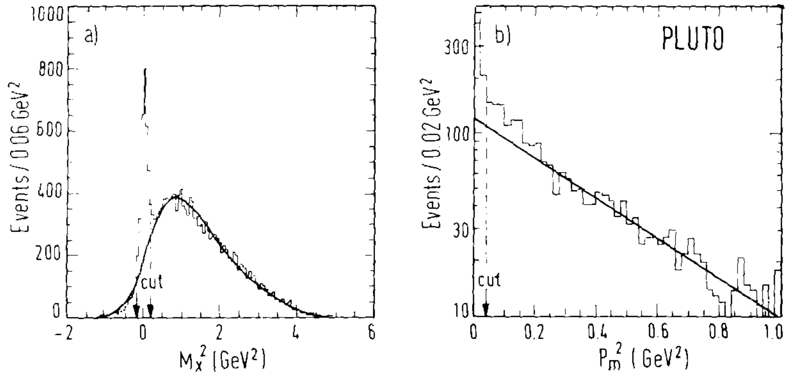

Fig. 1. Distribution of (a) squared missing mass M_X^2 for $J/\psi \to 2\pi^+2\pi^-X$, (b) squared missing momentum p_m^2 for $J/\psi \to 2\pi^+2\pi^-(\pi^0)$.

$J/\psi(3.1)$ 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 $M_X^2 = 0$ (fig. 1a). Events from the peak ($|M_X^2| < 0.2\ \mathrm{GeV}^2/c^4$) which fitted the hypothesis $e^+e^- \to 2\pi^+2\pi^-\pi^0$ were studied further. The distribution of the squared missing momentum p_m^2 is shown in fig. 1b. For large p_m^2 it follows an exponential function as indicated by the solid line. The excess at small p_m is attributed to channels without π^0 like $2\pi^+2\pi^-$, $K^+K^-\pi^+\pi^-$, and $K_S^0K^\pm\pi^\mp$. In order to reduce this background only events with $p_m > 0.2$ GeV/c were used for the subsequent analysis.

The invariant mass distribution of the $\pi^+\pi^-\pi^0$ system shown in fig. 2 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

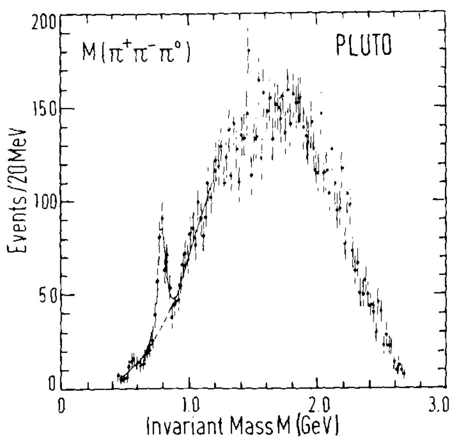

Fig. 2. Distribution of the invariant mass $M(\pi^+\pi^-\pi^0)$ for the decay $J/\psi \to 2(\pi^+\pi^-)\pi^0$.

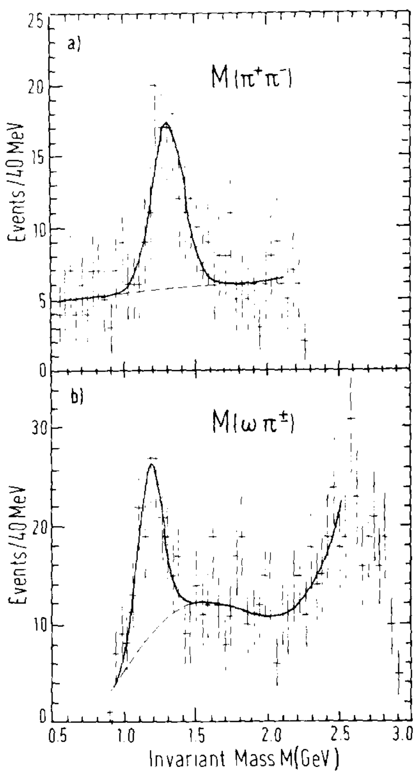

Fig. 3. Invariant mass distributions for the decay $J/\psi \to (\pi^+\pi^-\pi^0)_\omega\pi^+\pi^-$. (a) Invariant mass of the $\pi^+\pi^-$ system recoiling against the ω. (b) Invariant mass of the $\omega\pi^\pm$ system.

Table 1
Branching ratios for J/ψ (3.1) decay modes. The efficiency values include losses due to unobservabledecay modes.

Decay mode	Observed number of events	Effi-ciency	Branching ratio	
			(%)	(eV)
$2(\pi^+\pi^-)\pi^0$	1500	0.33	3.64 ± 0.52	2548 ± 360
$\omega\pi^+\pi^-$	215 ± 30 [a]	0.22	0.78 ± 0.16	546 ± 110
ωf	70 ± 24 [a]	0.14	0.40 ± 0.14	280 ± 100
$B^+\pi^- + B^-\pi^+$	87 ± 18 [a]	0.25	0.28 ± 0.07	196 ± 50

[a] Statistical error from the fit.

$\eta \to \pi^+\pi^-\pi^0$. Events in the ω band ($730 \leqslant M(\pi^+\pi^-\pi^0) \leqslant 840$ MeV/c^2) have been studied further. Fig. 3a 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 $J/\psi(3.1) \to \omega\rho^0$ violates charge conjugation invariance. The 3π system of the ω band was combined with one of the remaining pions. In fig. 3b 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 the other $\omega\pi^\mp$ 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 [4] are used to correct for unobserved decay modes. The total number of $J/\psi(3.1)$ 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 $P_m < 0.2$ 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. All methods give consistent results. A further check was made by excluding those events which satisfy both the criteria for the decay into fω and Bπ. The resulting losses in the two channels (20 and 26 events) are consistent with those expected from the Monte-Carlo simulation, assuming no interference. 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 Bπ – have also been obtained in the SLAC-LBL experiment [5]. The results agree within the quoted errors ($< 1\sigma$ for 5π and $\omega\pi\pi$, $\approx 2\sigma$ for ωf).

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 Bπ channels. We can give an upper limit of nonresonant $\omega\pi\pi$ production with dipion mass above 1.5 GeV/c^2. Extrapolating the event density from the nonresonant into the Bπ region we obtain the branching ratio: $J/\psi(3.1) \to \omega(\pi^+\pi^-)_{M_{\pi\pi} > 1.5\,\mathrm{GeV}} < 0.12\%$ (95% confidence level).

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 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 $A = +1$, in contrast to $A = -1$ for a helicity zero state.

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 $F^{(2)}$ [6]. If we adjust these coupling constants such as to give the observed widths $(J/\psi \to B^+\pi^-) = 98 \pm 25$ eV and $\Gamma(B \to \omega\pi) = 125$ MeV [4], we obtain $A = 0.1$, quite compatible with our measured angular distribution. However, the resulting D/S ratio is 0.80 (with an error of ± 0.03 resulting from that of Γ), in disagreement with the value 0.25 ± 0.06 observed in the decay $B \to \omega\pi$ [4]. This seems to indicate that simple SU(4) models with mixing and mass independent coupling constants are not sufficient to connect the decay properties of the J/ψ with those of the light mesons.

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