FR 8801096

LAL 87-42
August 1987

Laboratoire de l'Accélérateur Linéaire

Pseudoscalar states in $J/\psi \rightarrow \gamma VV$ Decays. Results from DM2

Luca STANCO
Representing the DM2 Collaboration

Z. AJALTOUNI, A. DEKMOUCHE, A. FALVARD, P. HENRARD, H. JNAD, J. JOUSSET, B. MICHEL, J.C. MONTRET and M.H. TIXIER
Laboratoire de Physique Corpusculaire, Univ. Clermont II, Aubière, France

A. ANTONELLI, R. BALDINI, A. CALCATERRA and G. CAPON
Laboratori Nazionali di Frascati dell'INFN, Italy

J.E. AUGUSTIN, G. COSME, F. COUCHOT, B. DUDELZAK, F. FULDA, B. GRELAUD, G. GROSDIDIER, B. JEAN-MARIE, S. JULLIAN, D. LALANNE, V. LEPELTIER, F. MANE, C. PAULOT, R. RISKALLA, Ph. ROY, F. RUMPF and G. SZKLARZ
Laboratoire de l'Accélérateur Linéaire, Orsay, France

D. BISELLO, G. BUSETTO, A. CASTRO, S. LIMENTANI, M. NIGRO, M. PENZO, L. PESCARA, M. POSOCCO, P. SARTORI and L. STANCO
Dipartimento di Fisica dell'Università e INFN, Padova, Italy

Invited talk presented at the Topical Seminar on Heavy Flavours, San Miniato, Italy, May 25-29, 1987

U.E.R
de
l'Université Paris-Sud

Institut National
de Physique Nucléaire
et
de Physique des Particules

Bâtiment 200 - 91405 ORSAY Cedex

LAL-87-42
AUG. 1987

Pseudoscalar states in $J/\psi \to \gamma VV$ decays. Results from DM2.

Luca Stanco

I.N.F.N., Sezione di Padova, via Marzolo 8, 35131 Padova, Italy.

We present new results from the DM2 experiment on the η_c-state and the pseudoscalar production seen at the threshold of the *vector-vector* radiative decays at J/ψ.

The η_c shows a vector-vector dominance in its decays and has a decay pattern which follows the $SU(3)_F$ symmetry prediction, this being in contradiction with previous measurements. New pseudoscalar states are clearly present in the invariant mass spectrum of $\rho^0\rho^0$. There are at least three different resonances, here named L_1, L_2, L_3 to underline a supposed common origin. These states have no direct interpretation in the usual $q\bar{q}$ model and they are believed to have an isoscalar nature. An interesting new upper limit on the g_T's$(2000 \div 2500 MeV/c^2)$ production at J/ψ is given as a by-product of the $\rho^0\rho^0$ analysis.

1. INTRODUCTION

The J/ψ resonance is one of the most appealing environments where to look for standard physics in the non perturbative region and to study the behaviour of the lightest quark flavours. This is essentially due to its energy position, so that we face what I like to call u-,d-,s-quark democracy. In fact, the strong decays of the J/ψ occur only via gluon transmission (60% of the total decay rate) or together with a radiative photon (7%). This relatively high rate of radiative decays permits a reliable study of states originated by two gluon annihilation. From another point of view, the non abelian nature of QCD allows, without imposing, the physical presence of bound states of two or more gluons, called gluonium or glueballs. This automatically fixes the radiative decays of the J/ψ as the most important place where to look for these QCD-allowed states, to which the lightest flavour democracy is then extended.

Other contributions to the rate are given by the decay via η_c-transition (1%) and the electromagnetic decays (32%). The η_c is the lightest $c\bar{c}$ state ($^1S_0$ in spectroscopy notation) and it is useful to study gluon-gluon decays in comparison with the three-gluon decays of the J/ψ, testing in this way the $SU(3)_F$ symmetry breaking pattern[1].

Other important features of the J/ψ physics are the high sensitivity reached for the studied branching ratios (up to 10^{-5}) and by precise Partial Wave Analysis feasible as one starts from a definite J^{PC} state.

We will concern ourselves only with radiative and η_c decays, for which an already rich harvest of measurements is available. From the inclusive measurement by the Crystal Ball[2] three prominent structures are drawn out: the $\eta'(958)$, the $\iota(1460)(0^{-+})$ and a broad structure at higher energy (1600 MeV). The latter has to be compared with exclusive results by DM2 and MARK III on $\eta\pi\pi$ and *vector-vector* production, which show related structures as we shall report in a moment.

The performances of the DM2 apparatus are described in detail elsewhere[3]. It is a classical spectrometer with cylindrical symmetry; charged track reconstruction and photon detection as well as time of flight measurements are performed. Our photon detection does not permit a full calorimetry, but indeed privileges pattern recognition. The overall accumulated statistics is of 8.6 ± 1.4 million of J/ψ events, corresponding to roughly three months of data taking.

2. η_c-ANALYSIS

The $\eta_c \rightarrow$*vector-vector* decay has been measured by DM2 for the $\phi\phi$[4], $K^{*0}\bar{K}^{*0}$, and $\rho^0\rho^0$ cases (fig.1) while an upper limit has been given for the $\omega\omega$ decay[5]. The result for the $\rho^0\rho^0$ channel being in contradiction with a previous result of the MARK III experiment[6], an exhaustive analysis has then been performed to well establish $\eta_c \rightarrow \rho^0\rho^0$ dynamics[7]. As a result we show in fig.2 the obtained $m_{4\pi}$ distribution for the 14 different channels inserted in a Partial Wave Analysis (PWA)[8]. In spite of 26 totally free parameters, the peak of η_c ($>$ 100 events) in the $\rho^0\rho^0(0^{-+})$ channel is wonderfully isolated. Else this is the best evidence of the pseudoscalar nature of the η_c. The measured branching ratios are:

$$
\begin{aligned}
BR(\eta_c \rightarrow \rho^0\rho^0) &= (8.7 \pm 2.6 \pm 1.3) \times 10^{-3} \\
BR(\eta_c \rightarrow \phi\phi) &= (3.1 \pm 0.7 \pm 0.4) \times 10^{-3} \\
BR(\eta_c \rightarrow K^{*0}\bar{K}^{*0}) &= (0.43 \pm 0.19) \times 10^{-3} \quad (preliminary) \\
BR(\eta_c \rightarrow \omega\omega) &< 0.7 \times 10^{-3} \qquad (90\% \; of \; C.L.).
\end{aligned}
$$

We conclude that the decay of η_c into 4 charged pseudoscalars seems to proceed mainly through *vector-vector* dynamics. If the reduced branching ratios, $\widetilde{BR}$, are used where the p^3 phase-space factor is skipped out, a simple criterion from $SU(3)_F$ symmetry predicts[1]:

$$
\begin{aligned}
&\widetilde{BR}(\eta_c \rightarrow \phi\phi) : \widetilde{BR}(\eta_c \rightarrow \omega\omega) : \widetilde{BR}(\eta_c \rightarrow \rho^0\rho^0) : \widetilde{BR}(\eta_c \rightarrow K^{*0}\bar{K}^{*0}) = \\
&= \quad 1 \quad : \quad 1 \quad : \quad 1 \quad : \quad 2
\end{aligned}
$$

In table I the experimental results are reported for both DM2 and MARK III experiments. While with the latter set of values s-quark component seemed to be favoured for the η_c-decays[6], the DM2 result supports the u-,d-,s-quark democracy.

3. γVV FINAL STATES

The analysis of $J/\psi \rightarrow \gamma\phi\phi$ shows an accumulation of events at threshold (2.2 GeV/c^2) with a predominantly pseudoscalar character[9]. However the statistically small peak (12 events) over a presumed non resonant $\phi\phi$ production does not allow for an explicit resonance definition, the product branching ratio being of the order of:

$$BR(J/\psi \to \gamma X_{0^{-+}}) \times BR(X_{0^{-+}} \to \phi\phi) \simeq 5 \times 10^{-5}.$$

Another pseudoscalar production, much more statistically consistent ($\sim$ 100 events), is present at threshold (1.6 GeV/c^2) in the $\omega\omega$ mass spectrum of the $J/\psi \to \gamma\omega\omega$ decay channel[9]. The large bump of about 150 MeV/c^2 width corresponds to the product branching ratio:

$$BR(J/\psi \to \gamma X_{0^{+-}}) \times BR(X_{0^{+-}} \to \omega\omega) = (1.06 \pm 0.16 \pm 0.32) \times 10^{-3}.$$

With in mind these two results we have looked at $\rho^0\rho^0$ production in the $J/\psi \to \gamma 4\pi^{\pm}$ channel[10]. Here the high number of final events (18,053) allows for an important upgrading in the spectroscopic study of the corresponding mass region (fig.3a). In fact, together with signals associated to known states (η_c at 2980 and f_1 at 1280 MeV/c^2) or well isolated background source ($J/\psi \to 4\pi^{\pm}$ which is taken in by the presence of a fake photon), we find at least three new resonant structures at 1520, 1800 and 2100 MeV/c^2 which hereafter we will call L_1, L_2, L_3 respectively. If a simple $\rho^0\rho^0$ cut is implemented the inner distribution in fig.3a is obtained. What we conclude is that the L_i resonances seem to proceed mainly through $\rho^0\rho^0$ decay. In this case a first rough angular analysis can be developed taking into account the angle between the decay planes of the two vectors, χ[11]. Since the overall χ distribution of the 18,053 events has a strong 0^{-+} character, a fit to the pseudoscalar yield for the χ distribution in the single mass bin has been performed. The result is shown in fig.3b, and strongly suggests a pseudoscalar nature for our L_i resonances. Furthermore, L_3 seems to be splitted while L_2 is a little depressed in front of the total 4π spectrum.

More quantitative results are given by the PWA shown in fig.4. The result is indeed very impressive[12]. A wholly surprising result is the structured distribution obtained in the $\gamma a_2\pi$ channel, since this contribution was supposed to collect $J/\psi \to \rho a_2$ background. The structures are peaked at 1.8, 2.1 and 2.7 GeV/c^2 with a product branching ratio of the order of 2×10^{-4} and a 3σ statistical significance[13]. No idea on their origin is avaible yet. A signal of about 80 events is observed in the $\gamma\rho\pi\pi$ channel (not distinguished from $\gamma a_2\pi$) with mass and width coincident to $f_1(1285)$, above a negligeable background, with the following branching ratio:

$$BR(J/\psi \to \gamma f_1) \times BR(f_1 \to \rho^0\pi^+\pi^-) = (0.34 \pm 0.08 \pm 0.05) \times 10^{-4}.$$

From the few events found in the $\rho^0\rho^0(2^{++})$ waves, without any structure, a new upper limit can be set for the g_T's(2000 $\div$ 2500 MeV/c^2):

$$BR(J/\psi \to \gamma g_T) \times BR(g_T \to \rho^0\rho^0) < 0.8 \times 10^{-4} \qquad (90\%\ of\ C.L.).$$

This limit which is almost an order of magnitude smaller than previous results[14] seems to rule out completely a recent calculation[15] supposing a glueball nature for the g_T's resonances.

What about the pseudoscalar L_i states? A fit to the mass spectrum via Breit-Wigner functions has to take care of the opening of the $\rho^0\rho^0(0^{-+})$ channel. In fact the width of the ρ meson allows for $X \rightarrow \rho^0\rho^0$ decay even for X-masses below threshold but with strong distortion of the resonance shape. We have choosen to fit with 3 completely free non relativistic Breit-Wigner functions weighted by the non resonant shape of the $\rho^0\rho^0(0^{-+})$ channel and let L_1 and L_2 interfere; a polynomial background has been added too (fig.5). The important result is that L_1 has always a mass higher than the ι mass[16], while L_2 is almost completely "eaten" by the interference term. Explicit values are given in table II.

4. DISCUSSION AND CONCLUSIONS

Among the glueball candidates the ι is the most attractive one as either it has the highest rate (0.5%) or the corresponding pseudoscalar $q\bar{q}$ nonet is already filled in the ground state and for $8/9^{ths}$ in its 1^{rst} radial excitation state. Here we report of even more 0^{-+} states (L_1, L_2, L_3) which decay into *vector-vector* channels[17], this implying a strong violation from the $q\bar{q}$ constituent hadron model. Before trying to relate the ι with these new states, we have to recall a strange behaviour of another mesonic state, the $E(1420)$. This resonance has been seen only in hadronic production and its presumed axial vector nature is not yet established, due to the 0^{-+} assignment in some of these experiments[18]. The 1^{++} assignment is supported by experiments which also observe the well established $f_1(1285)$ axial vector. Our observation of f_1 in the J/ψ decays lets us expect the presence of the E meson in these decays too, up till now never observed. Actually, the ι production dominates in this mass region, but we show here that the hypothesis of two resonances instead of one cannot be ruled out. We guess that the E is present at lower mass (1420) while a dominant pseudoscalar production is present at higher mass and this last one can be identified to our $L_1(1500)$. The high rate for L_1 permits to fix its candidature as the strongest glueball, while the relative low rate for $L_2(1800)$ supports the hypothesis that it is the missing 0^{-+} radially excited $q\bar{q}$ state. The presence of $L_3(2100)$ reveals new still unexplored features of the glueball states if its high branching ratio and possible connections with the (statistically poor) pseudoscalar production seen in the $\phi\phi$ channel are considered.

Concluding, J/ψ physics has still new and exciting things to show us as for glueballs the argument is far from being settled.

REFERENCES

1) H.E.Haber and J.Perrier, Phys. Rev. 32D (1985) 2961.
2) E.D.Bloom, 21^{rst} Int. Conf. on H.E.P., Paris, France, Jour. de Phys. 3C (1982) 407.
3) J.E.Augustin et al., Phys. Scripta 23 (1981) 623.
4) D.Bisello et al., Phys. Lett. 179B (1986) 289.
5) D.Bisello et al., Phys. Lett. 192B (1987) 239.

6) R.M.Baltrusaitis et al. Phys. Rev. 33D (1986) 629.

7) DM2 Collaboration, "First Observation of $\eta_c \to \rho^0\rho^0$ decay.", Subm. to Phys. Lett. B .

8) Four phase-space ($\gamma 4\pi$, $\gamma\rho\rho$, $\gamma\rho\pi\pi$, $\gamma a_2\pi$) and ten different pure waves of the ($\rho^0\rho^0$) system, with L, S values coresponding to a spin from $J = 0$ up to $J = 2$, have been considered.

9) D.Bisello et al., Phys. Lett. 179B (1986) 294.

10) L.Stanco, Tesi di Dottorato, Padova, Italy (1987), unpublished.

11) T.L.Trueman, Phys. Rev. 18D (1978) 3423.
C.N.Chang and C.T.Nelson, Phys. Rev. Lett. 40 (1978) 1617.

12) In each mass bin of 30 MeV/c^2 a likelihood maximization over the 14 percentages has been performed. No correlation is obviously present between different bins. What is impressive is that we can go down up to 30 MeV/c^2 in the binning without having consistent fluctuations but instead only soft changes from bin to bin.

13) From the fit the absolute error comes to be ~ 40 events in each mass bin. For more detail see [10].

14) R.M.Baltrusaitis et al. Phys. Rev. 33D (1986) 1222.

15) S.Okubo, R.Sinha, S.F.Tuan, Phys. Rev. 35D (1987) 952.

16) No fit convergence is obtained if the ι mass is imposed.

17) Preliminary results from $\gamma\rho^+\rho^-$ channel show similar structures in the $\pi^+\pi^0\pi^-\pi^0$ invariant mass distribution.

18) See for a report: S.Cooper, Rapp. talk at Int. Europhys. Conf. on H.E.P., Bari, Italy, SLAC-PUB-3819 (1985).

Table I: $SU(3)_F$ measured values for η_c.

	MARK III	DM2
$\frac{\widetilde{BR}(\eta_c \to \rho^0 \rho^0)}{\widetilde{BR}(\eta_c \to \phi\phi)}$	< 0.64	1.73 ± 0.72
$\frac{\widetilde{BR}(\eta_c \to \omega\omega)}{\widetilde{BR}(\eta_c \to \phi\phi)}$	< 0.34	< 1.4
$\frac{\frac{1}{2}\widetilde{BR}(\eta_c \to K^* \overline{K}^*)}{\widetilde{BR}(\eta_c \to \phi\phi)}$	0.22 ± 0.13	0.6 ± 0.4 (preliminary)

Table II: Parameters for the L_i states.

state	L_1	L_2	L_3
mass (MeV/c^2)	1497 ± 3	1812 ± 4	2107 ± 9
width (MeV/c^2)	126 ± 2	110 ± 8	244 ± 23
number of events	2655	173	947
events of the interf. part	-69		
relative phase	2.73 ± 0.12		
background events	1016		

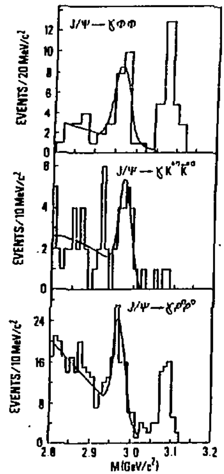

Fig.1 Mass distribution for the observed $\eta_c \to vector - vector$ decays.

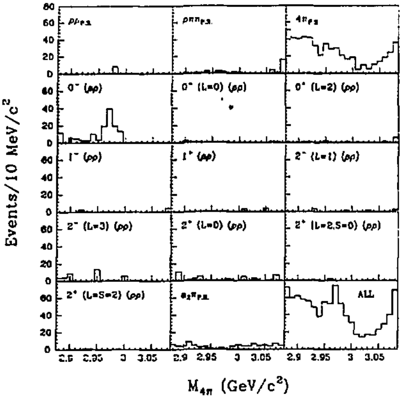

Fig.2 η_c-results of the PWA for the 14 channels considered in the $J/\psi \to \gamma 4\pi^{\pm}$ decay.

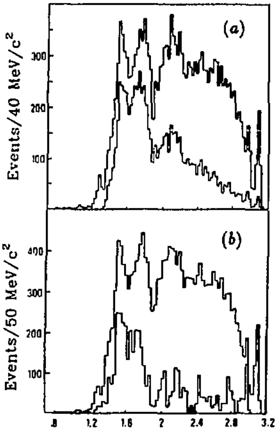

Fig.3 Mass distribution for the selected $\gamma 4\pi^{\pm}$ events. The inner distributions show results from (*a*) $\rho^0\rho^0$ cut; (*b*) pseudoscalar analysis.

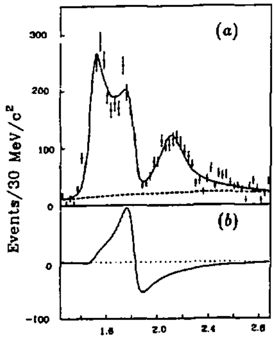

Fig.5 (*a*) Result from the fit of the $m_{4\pi}$ distribution.

(*b*) Contribution from the interference term between L_1 and L_2.

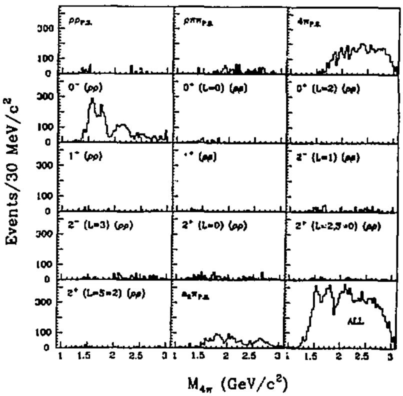

Fig.4 Results of the PWA for the total $4\pi^{\pm}$ spectrum.