LAL 88-51
November 1988

Laboratoire de l'Accélérateur Linéaire

NEW DM2 RESULTS ON D/f_1(1285) AND ι/η(1440)

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Presented to Workshop on Glueballs, Hybrids and Exotic Hadrons
Brookhaven, Upton (N.Y.), USA, Aug. 29–Sept. 1, 1988

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Abstract

Preliminary results from Partial Wave Analysis on the $D/f_1(1285)$ mass region in the $J/\psi \to \gamma 4\pi^{\pm}$ decay and on the $\iota/\eta(1440)$ region in the $J/\psi \to \gamma K\bar{K}\pi$ decays are presented. In the first channel the PWA excludes a $\eta(1275)$ contribution, so supporting the f_1 identification for the observed peak.

A clear pseudoscalar signal is evidenced in the $K\bar{K}\pi$ mass spectrum decaying via $\delta/a_0(980)$ as well as $K^*(892)$ dynamics. Its width is smaller than in the total spectrum, two other contributions, a narrow (less than 30 MeV/c^2) 1^{++} peak at 1395 MeV/c^2 which decays into $\delta\pi$ and a shoulder at 1515 MeV/c^2 observed in the direct 3-body decay $K\bar{K}\pi$, being present. This last state might have a spin-parity 1^{++} even if within large statistical limitations.

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Introduction

In the J/ψ radiative decays an abundant pseudoscalar production has been observed from the analysis in early '80 by Crystal Ball and Mark II up to the more recent results produced by Mark III and DM2. In particular a strong pseudoscalar signal, the ι (now $\eta(1440)$), was observed [1] in $K\bar{K}\pi$ at 1440 MeV/c^2. It was claimed for the discovery of a glueball state as due to the large measured branching ratio. Presently, this resonance is still subjected to controversial identifications either for the presence of an analogous peak observed in hadroproduction with possible 1^{++} assignment [2] or for its unlike shape which could be determined by more than a single resonance [3].

Moreover, clear pseudoscalar productions have been observed into the vector-vector channels mostly at the threshold [4]. This production is best shown by the $\rho^0\rho^0$ channel where three states are observed (Fig.1) at 1500, 1800 and 2100 MeV/c^2. Radial excitations of the standard η, η' mesons are foreseen by previous theoretical works [5] in the 1 $\div$ 2 GeV/c^2 mass region. However, an acceptable understanding cannot forget any of the pseudoscalar signals present in this region, which must be studied as a whole.

Another related point of interest is the existence of a narrow signal at 1285 MeV/c^2, an example of which is found in the $J/\psi \to \gamma 4\pi^\pm$ channel. Its identification with the D/f_1 axial vector meson seems more and more supported even if 1^{++} mesons are not expected in the radiative decays of the J/ψ where two gluons contribute at the first order (Yang theorem [6]). Nevertheless the spin-parity of this signal must be carefully studied for the contemporary presence of another pseudoscalar state at roughly the same mass position, the $\eta(1275)$.

Therefore the two $q\bar{q}$ nonets 0^{-+} and 1^{++} are far from settled and are suspected to let room for glueball or exotic states.

Partial Wave Analysis (PWA) have been developed for the signal at 1285 MeV/c^2 decaying in the $4\pi^\pm$ inclusive channel, as well as for the "ι" signal observed in the coupled channels $K^0_S K^\pm \pi^\mp$ and $K^+K^-\pi^0$. The results here presented come out from the 8.6 million of J/ψ events collected by the DM2 experiment at DCI, the Orsay e^+e^- colliding ring. The detector has been described elsewhere [7].

$D/f_1(1285)$ region

The selection of the events $J/\psi \to \gamma 4\pi^\pm$ is described in [8] and [9]. The signal has to be unfolded from various contributions: $\gamma 4\pi$ direct production, $\gamma\rho^0\pi^+\pi^-$ and $\gamma\rho^0\rho^0$ non resonant productions, and the resonant pseudoscalar production $\gamma 0^-(\rho^0\rho^0)$ already analyzed [9]. The result from PWA including these four waves is shown in Fig.2. All the signal goes into the isotropic $\rho\pi\pi$ wave, as expected for a D/f_1 origin.

To get confidence on this identification a PWA based on explicit spin-parity waves for the $\rho\pi\pi$ system should be developed. The intrinsic difficulty to perform full 3-body PWA has been partially overcome following an original idea of L.Oliver and O.Pene [10]. Looking at the lowest angular momenta l between the two pions faced to the ρ, the $l = 0$ momentum is excluded by C-parity, while the $l = 1$ leads for the $(\pi^+\pi^-)$ system to the same quantum numbers of a ρ^0. Then, in the *approximation* of the lowest angular momentum for the

$(\pi^+\pi^-)$ system, the explicit amplitudes of the 3-body $\rho^0\pi\pi$ for states of specified J^P are equal to the corresponding amplitudes of the $\rho^0\rho^0$ system with only one imposed Breit-Wigner. Obviously full interference between the four possible ρ^0 combinations have to be considered. The result, shown in Fig.3 where 10 different spin-parity waves for the $\rho\pi\pi$ system ($l = 1$) have been included in the PWA, shows that the events belonging to the peak populate the $2^+(L = 0)$ wave, no events being present in the 0^- one. Limiting the possible waves to $J = 0, 1$ the peak signal is displaced into the 1^+ wave, the 0^- one remaining void. Within the lowest l approximation we conclude for the non observation of the $\eta(1275) \to 4\pi^\pm$ decay with an upper limit at 90% of C.L. :

$$BR(J/\psi \to \gamma\eta(1275)) \times BR(\eta(1275) \to 4\pi^\pm) < 5 \times 10^{-6}.$$

This result supports the identification of the observed peak with the $D/f_1(1285)$.

$\iota/\eta(1440)$ region

The selection of the events $J/\psi \to \gamma K^0_S K^\pm\pi^\mp, \gamma K^+K^-\pi^0$ is described in [11] with slight modifications, the final mass distributions being drawn in Fig.4. The decay chain $J/\psi \to \gamma X \to \gamma K\bar{K}\pi$ has been analyzed taking into account the isobars $K^*(892) \to K\pi$ and $\delta/a_0(980) \to K\bar{K}$ as well as the direct 3-body decay and considering all the possible waves with spin 0,1.

Since the state X is an eigenstate of $C = +1$, there are only two possible waves with δ/a_0 dynamics:

$$0^{-+} \to \delta\pi: \quad |A|^2 = 1 + \cos^2\theta_\gamma$$

$$1^{++} \to \delta\pi: \quad |A|^2 = (1 + \cos^2\theta_\gamma)\cos^2\theta_\delta + \frac{1}{2}x\sin 2\theta_\gamma \sin 2\theta_\delta \cos\varphi_\delta + x^2\sin^2\theta_\gamma\sin^2\theta_\delta$$

where $\theta_{\gamma,\delta}$ are the polar angles of the photon and the δ state in the lab frame and the X center of mass respectively; φ_δ is the azimuthal angle of δ in X-frame; x is the ratio of helicity amplitudes $\mathcal{A}_1/\mathcal{A}_0$. The δ state is described by a Flatté parametrization [12] with more recent values for the $g_{K\bar{K}}$ and $g_{\eta\pi}$ couplings [13]: $g_{K\bar{K}} = 0.225$, $g_{\eta\pi} = 0.15$.

The waves with K^* dynamics are four: $0^-, 1^+(L = 0), 1^+(L = 2), 1^-$. In this case, a complication is introduced by the two possible K^* combinations which can interfere each other. Within the helicity formalism the complex decay amplitude for $X \to K^*K$ is :

$$F_\mu = BW_1 \times |Q_{K^*}|^L \times \sum_h A_h \times D^1_{0,h} \times D^J_{\mu,-h} + (1 \leftrightarrow 2)$$

where μ, h are the helicities of the states X, K^* respectively, J is the spin of X, Q_{K^*} is the K^* momentum in the X-frame, BW_1 is the Breit-Wigner which describes [14] the first K^* combination, $(1 \leftrightarrow 2)$ represents symmetrization over the second K^* combination.

The direct 3-body decays permit all the three possibilities of spin-parity 0^-, 1^+, 1^-, but the analytical expressions for the total amplitudes are no more possible. After integration over 2 of the 5 angles which define the reaction $J/\psi \rightarrow \gamma K\bar{K}\pi$ the explicit amplitudes are however obtainable [15].

Keeping in mind this limitation for the last 3 waves, the PWA has been developed with 12 different waves: $\delta\pi$ isotropic, $\delta\pi(0^-, 1^+)$, K^*K isotropic, $K^*K(0^-; 1^+L = 0, 1^+L = 2, 1^-)$, $K\bar{K}\pi$ isotropic, $K\bar{K}\pi(0^-, 1^+, 1^-)$, and preliminary conclusions have been obtained without the inclusion of interferences between waves with same J^P. Each mass bin of 30 MeV/c^2 has been independently fitted. The large number of free parameters (18) have constrained us to use the maximum available statistics, leading to a coupled channel analysis for the two modes $K^0_S K\pi$ and $K^+K^-\pi^0$.

An extensive Monte Carlo study has been performed to test the power of resolution of the PWA. Results are:

- the different dynamics are well established allowing to disentangle in the ι mass region δ, K^*, no isobar dynamics;
- $0^-(\delta\pi, K^*K)$ waves arise up fairly;
- spin $1(\delta\pi, K^*K)$ are well recognized and the helicity ratios $x = \mathcal{A}_1/\mathcal{A}_0$ are found out within 20% of error;
- the three $K\bar{K}\pi$ waves $(0^-, 1^\pm)$ are not disentangled proving that the use of only 3 of the 5 angles is not sufficient to separate the hypotheses [16].

The error on the single bin of the i-wave is taken as: $\delta N = \sqrt{\delta N^2_{TOT} + \delta N^2_i}$ where N_{TOT}, N_i are the numbers of events in the bin of the total spectrum and the i-wave distribution respectively.

We have first studied the relative contributions of the 3 isotropic waves ($\delta\pi$, K^*K, $K\bar{K}\pi$) to evidentiate the underlying dynamics. Having tested that the $K^+K^-\pi$ and $K^0_S K\pi$ channels give similar results, the coupled channel PWA leads to the contributions drawn in Fig.5. As a result the total peak is splitted into $\delta\pi$ and K^*K contributions at roughly 50% + 50%. Furthermore the highest mass zone of the structure receives a contribution from the shoulder observed at 1515 MeV/c^2 in the direct $K\bar{K}\pi$ wave, which contains also most of the background.

Then the coupled PWA (12 waves) have been developed. Different contributions are evident for the $0^-, 1^+$ waves, with both δ and K^* dynamics, in the ι region, while the shoulder at 1515 MeV/c^2 with no dynamics is compatible with 1^+. The $K^+K^-\pi^0$ and $K^0_S K^\pm\pi^\mp$ channels give similar results except for the $1^+(\delta\pi)$ wave (Fig.6), where a narrow peak is observed at 1395 MeV/c^2 in the $K^0_S K\pi$ mode and a smooth shape, easily interpreted as background, in the $K^+K^-\pi^0$ mode. In front of the ~ 50 events collected in the $K^0_S K\pi$, in the hypothesis of an isospin $I = 0$ for this structure and taking care of the lower efficiency, one should observe roughly 20 events in $K^+K^-\pi^0$. This no observation is not explained yet. However the peak turns out to be rather stable over different inputs for the PWA, and its preliminary definition is: $m = 1395 \pm 15$ MeV/c^2, $\Gamma < 15$ MeV/c^2, $BR(J/\psi \rightarrow \gamma X) \times BR(X \rightarrow K^0_S K\pi) \sim (5.6 \pm 1.4) \times 10^{-5}$.

A PWA of the $J/\psi \rightarrow \gamma\eta\pi\pi$ channel seems necessary to explore eventual correlations with the unknown structure observed at roughly the same mass region[11].

Taking into account only the waves which really contribute, the results of the PWA with the five waves $0^-(\delta\pi, K^*K)$, $1^+(\delta\pi, K^*K)$, isotropic $K\bar{K}\pi$, are shown in Fig.7. The net result is a clear 0^{-+} production in $\delta\pi$ and K^*K, some activity 1^{++} in K^*K, the narrow peak in $1^{++}(\delta\pi)$ and the shoulder in $K\bar{K}\pi$ direct 3-body decay. The activity 1^{++} in K^*K owns a significance of $\sim 6\sigma$ with a branching ratio of the order: $BR(J/\psi \rightarrow \gamma X) \times BR(X \rightarrow K\bar{K}\pi) \sim (1.1 \pm 0.5) \times 10^{-3}$; its shape and mass position seems not to be related to the $E/f_1(1440)$ resonance. The shoulder at 1515 MeV/c^2 owns a statistical significance of $\sim 5\sigma$ and might be related to the recent observation of $D'/f_1(1530)$ [17]. The relative percentage of $\delta\pi$ and K^*K in the pseudoscalar waves cannot be easily computed as no interference has been inserted yet (a provisional conclusion is $\delta\pi + K^*K = 50\% + 50\%$). Adding the two 0^{-+} waves the "new" ι-signal (Fig.8) corresponds to 517 ± 40 events, with a mass $m = 1449 \pm 4$ MeV/c^2, width $\Gamma = 66 \pm 7$ MeV/c^2 and a product branching ratio: $BR(J/\psi \rightarrow \gamma\eta(1440)) \times BR(\eta(1440) \rightarrow K\bar{K}\pi) = (2.7 \pm 0.2 \pm 0.4) \times 10^{-3}$.

Conclusions

Partial Waves Analysis have been developed for the $J/\psi \rightarrow \gamma 4\pi^{\pm}$ channel in the $D/f_1(1285)$ zone and for the $J/\psi \rightarrow \gamma K\bar{K}\pi$ channel in the $\iota/\eta(1440)$ region.

An upper limit for the $\eta(1275) \rightarrow 4\pi^{\pm}$ decay is computed, which supports, within the limits of the performed analysis, the identification of the observed peak in the $4\pi^{\pm}$ mass with the $f_1(1285)$.

The presence of a unique pseudoscalar signal at 1450 MeV/c^2 decaying into $K\bar{K}\pi$ via both δ and K^* dynamics is preliminarily established. The somewhat narrower width of the resulting $\eta(1440)$ is due to the first observation of two different contributions at the two sides of the total signal. These ones are narrow in width (less than 30 MeV/c^2) and compatible with a 1^{++} assignment.

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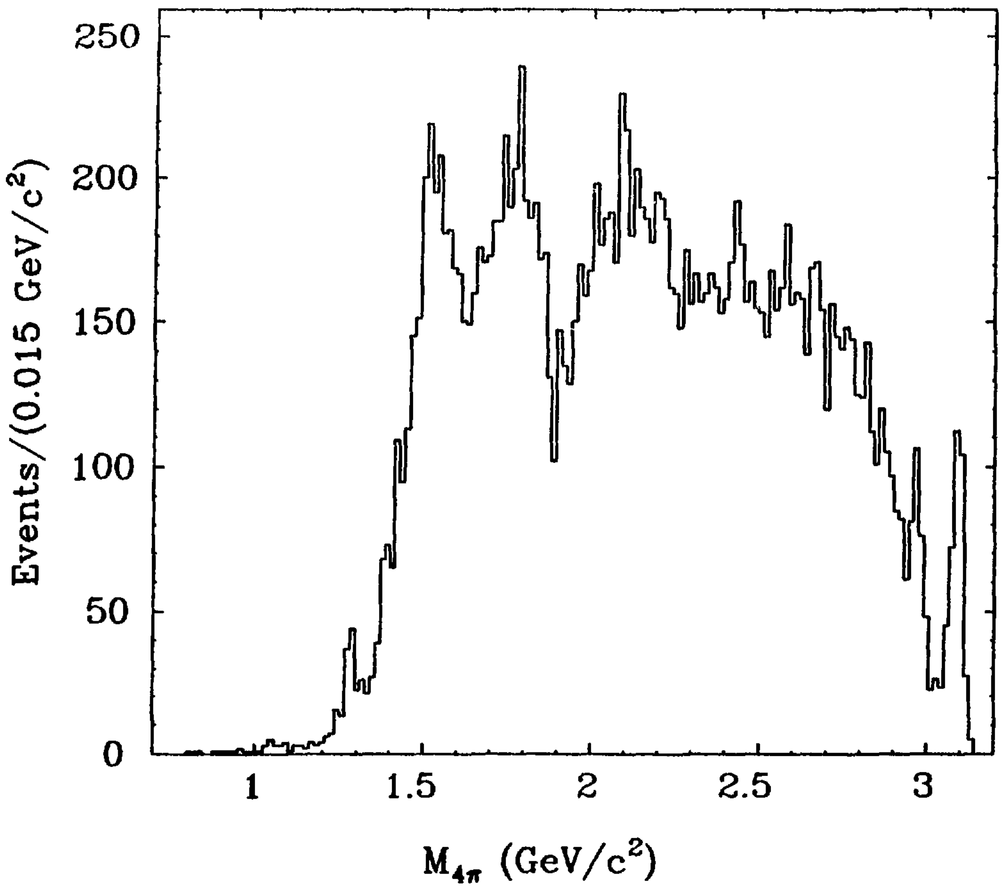

Fig.1 $4\pi^{\pm}$ invariant mass distribution.

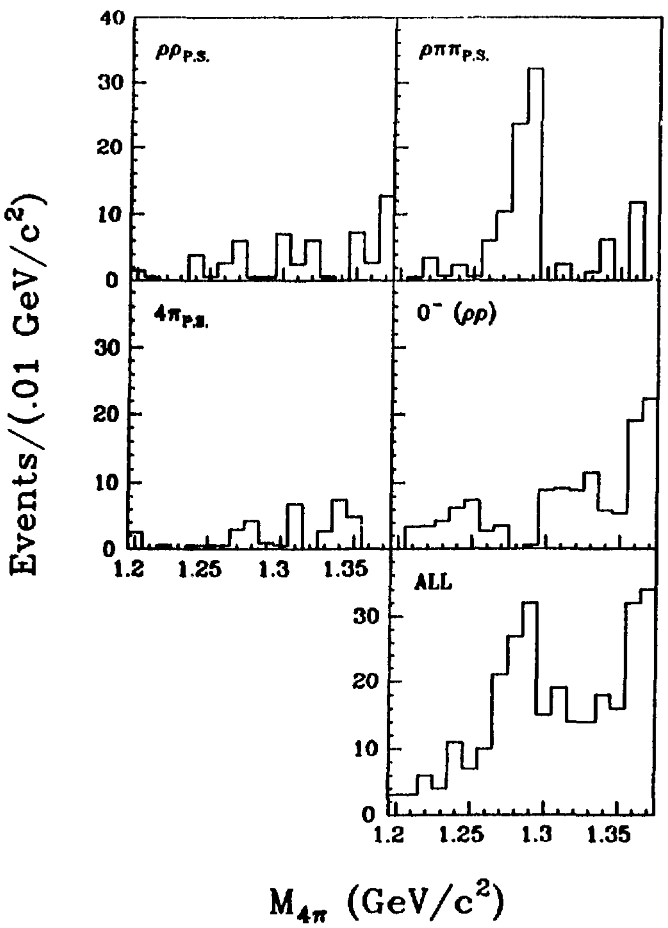

Fig.2 PWA in the "*D*" region: 4 waves considered.

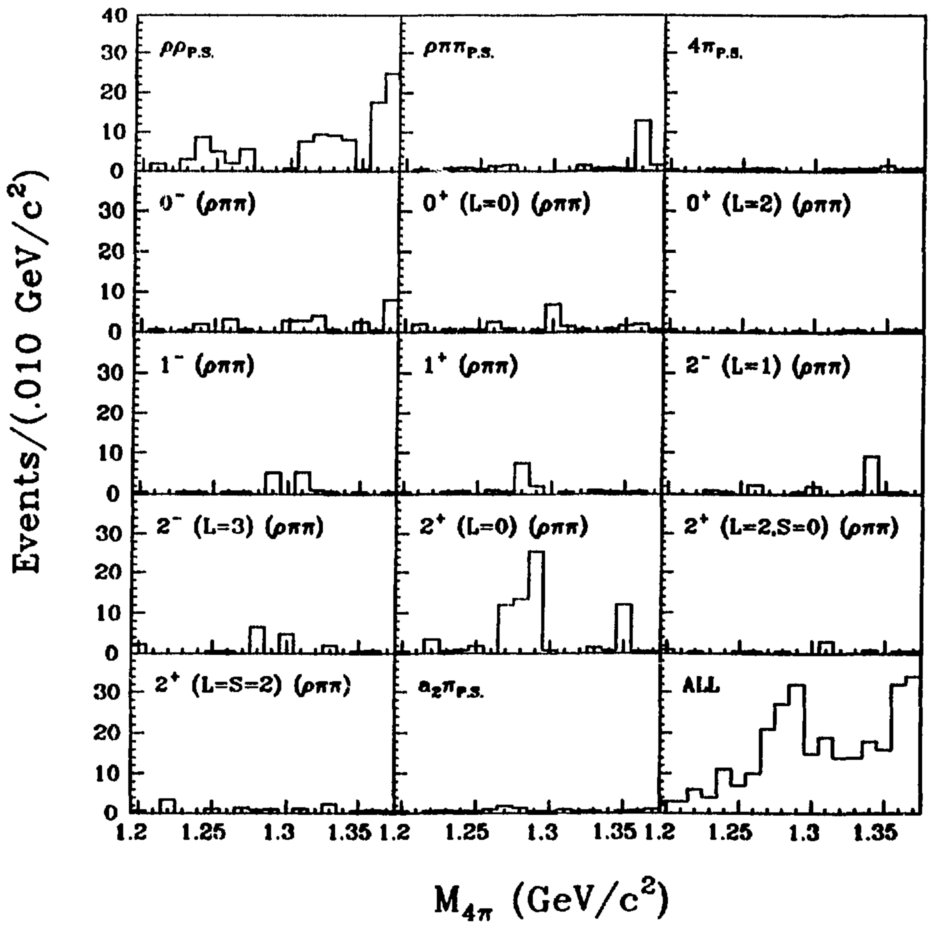

Fig.3 PWA in the "D" region: 10 $\rho\pi\pi$ pure waves plus 4 isotropic waves.

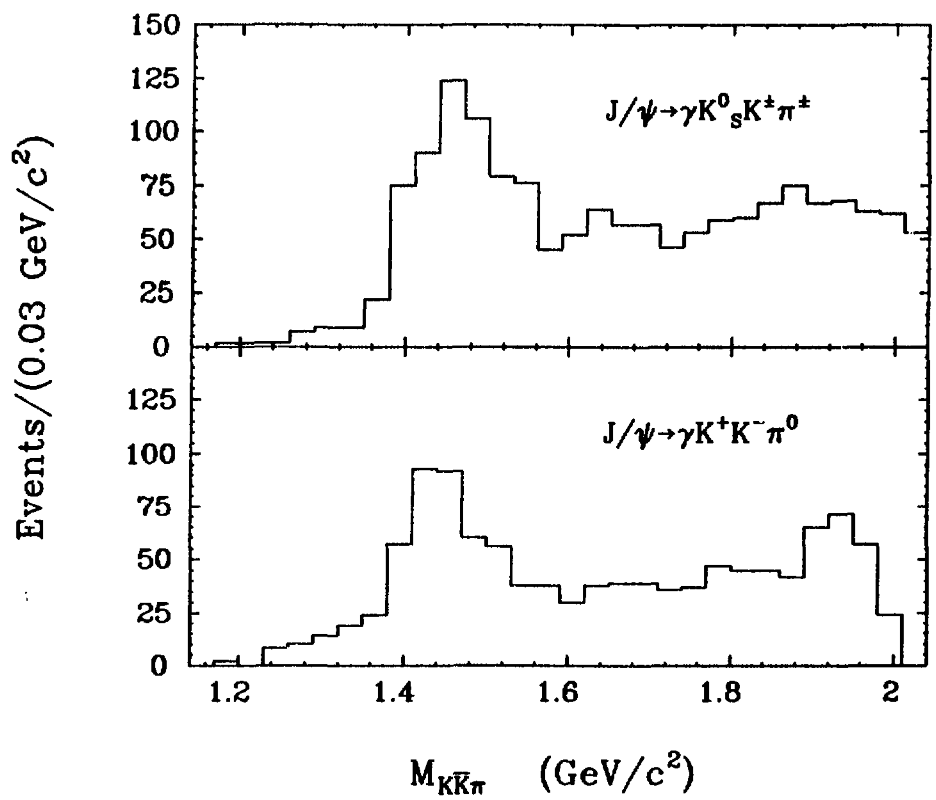

Fig.4 Experimental mass distributions for the two channels $J/\psi \to \gamma K\bar{K}\pi$.

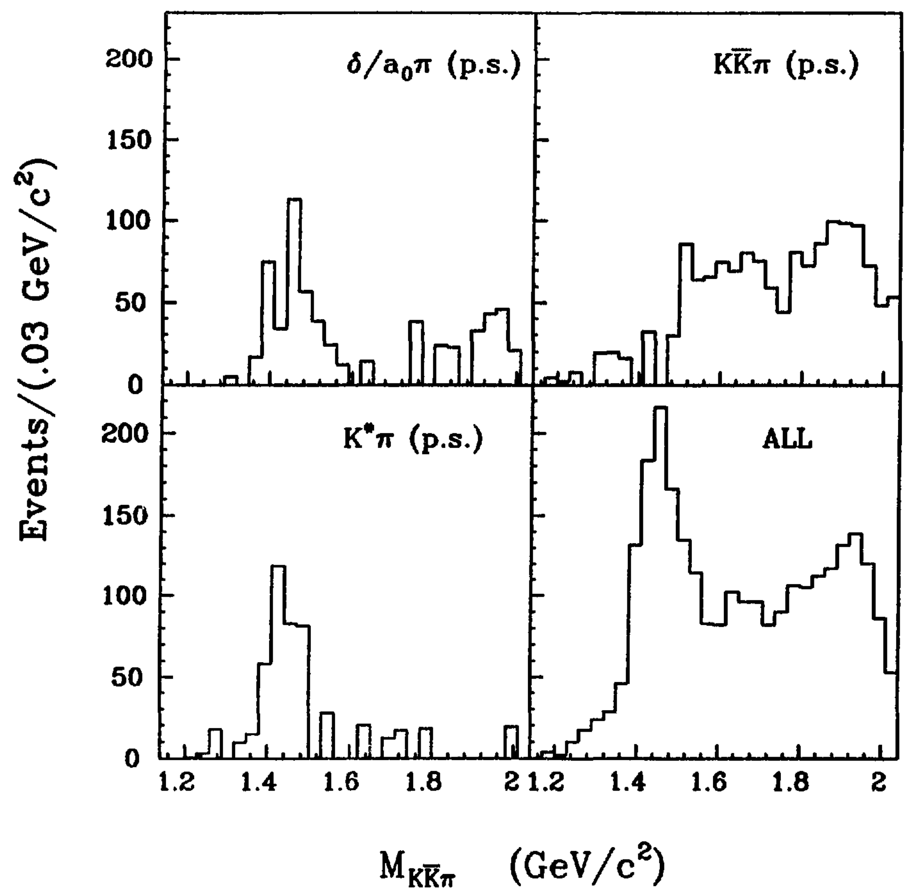

Fig.5 PWA for the "ι": 3 isotropic waves considered.

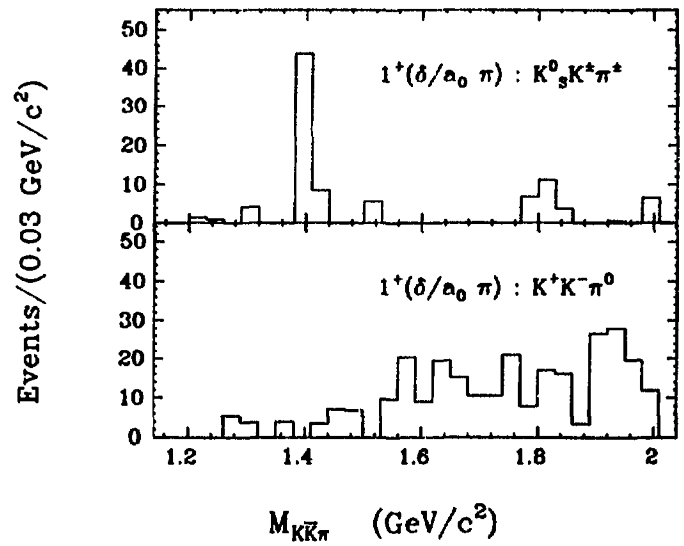

Fig.6 PWA results in the $1^+(\delta/a_0\pi)$ wave for the two modes.

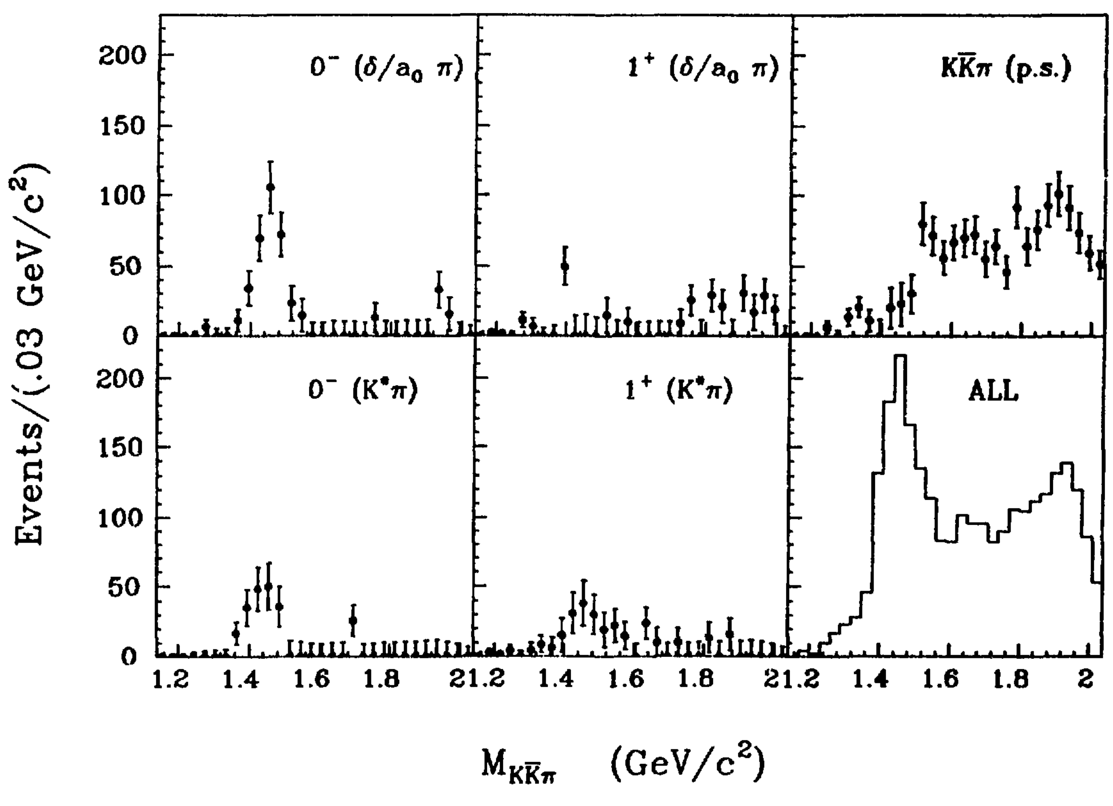

Fig.7 PWA for the "ι": the only 5 contributing waves are considered.

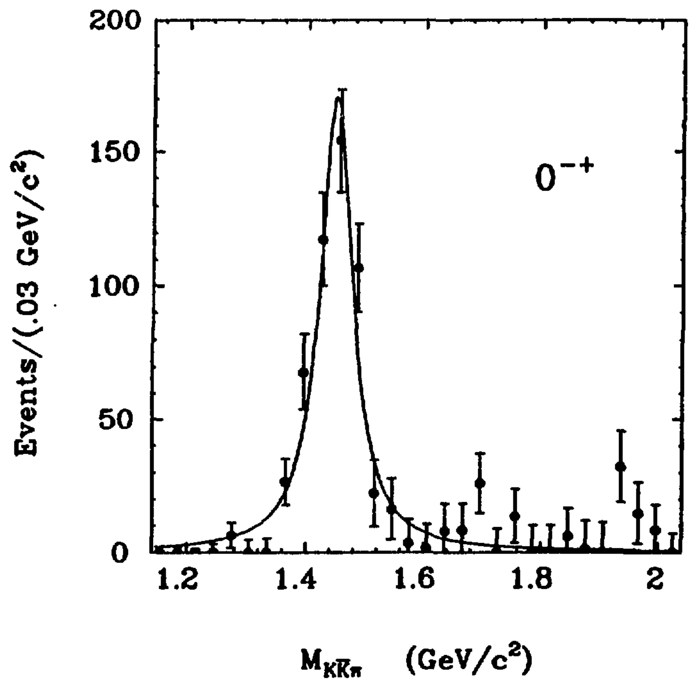

Fig.8 Fit result for the $0^{-}(\delta\pi + K^{*}K)$ mass distribution.