Further Studies of the X(1910) Meson

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Abstract

New data on the $\eta'\eta$ system produced in π^-p charge-exchange reaction at 38 GeV/c momentum confirm the existence of the narrow $\eta'\eta$ resonance X(1910). The hypothesis of X(1910) quantum numbers being a $J^{PC} = 1^{-+}$, forbidden for $q\bar{q}$ meson, is proposed to explain the extremely low limits obtained for X(1910) decays through $\pi^0\pi^0$, $\eta\eta$ and $K_s^0K_s^0$ channels and the flat t -dependence of X(1910) production cross section.

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The narrow X(1910) meson was originally observed through its decay into $\eta'\eta$ in the charge-exchange reaction

at large momentum transfer [1]. It is well known that at small $|t|$ the one-pion exchange (OPE) mechanism dominates in this reaction [2,3]. For $|t| > 0.2 \text{ (GeV/c)}^2$ OPE contributions are small and leave room to the possible observation of exotic states (as for $\eta\eta$ [4]).

Statistics have been doubled in a run made at IHEP with GAMS-2000 [5]. The setup and the methods of measurement and calibration have been described earlier [1]. A total of $1.6 \cdot 10^3 \eta'\eta$ events have been selected for further analysis together with the original data [1]. Preliminary results have already been presented [3,6].

The invariant mass spectrum shows a narrow peak around 1.9 GeV, which becomes more evident with increasing $|t|$. The best peak to background ratio is obtained in the interval $0.35 \text{ (GeV/c)}^2 < |t| < 0.60 \text{ (GeV/c)}^2$ (fig. 1).

The background has been analyzed by dividing the four-gamma mass spectrum in a series of intervals. In each event, a gamma pair with an invariant mass in the range $470 \text{ MeV} < M_{\gamma\gamma_2} < 630 \text{ MeV}$ was first identified as η . The η peak is free of background in all mass intervals. The invariant mass spectrum of the second gamma pair $M_{\gamma\gamma_4}$ shows a characteristic η' peak in almost all intervals but the background clearly depends on the mass of the 4γ -system (fig. 2). This background is minimal around 1.9 GeV but is prominent near the threshold of reaction (1). After background subtraction there are very few $\eta'\eta$ events with mass less than 1.7 GeV at large $|t|$ (hatched histogram of fig. 1).

The mass of this meson is

$$M = 1911 \pm 10 \text{ MeV} \quad (2)$$

in good agreement with the first measurement [1]. Its width has been determined by taking into account the instrumental GAMS resolution of 70 MeV :

$$\Gamma = 90 \pm 35 \text{ MeV}. \quad (3)$$

The t -dependence of the differential cross-section of the reaction $\pi^- p \rightarrow X(1910)n$ for $|t| < 0.6 \text{ (GeV/c)}^2$ is reproduced by an exponential function e^{bt} with

$$b = 2.3 \pm 1.3 \text{ (GeV/c)}^{-2} \quad (4)$$

which is quite small compared to the OPE standards (fig. 3).

The angular distributions of the decay of X(1910) in the Gottfried-Jackson frame are isotropic up to the level of experimental precision (fig. 4).

The $\eta\eta$ decay channel of X(1910) has been simultaneously looked for in the same experiment amongst the $8 \cdot 10^4$ events of reaction

More severe selection criteria have been applied in order to decrease the contribution of isobars N^* that might decay into $n\pi^0$ or $n\pi^0\pi^0$. The detection

threshold of gammas in the lead-glass guard system surrounding the liquid hydrogen target has been lowered to less than 12 MeV [7]. This procedure has no consequence on the results for reaction (1) but essentially decreases the number of η -pairs observed at large $|t|$ as compared with the evaluation that was made in the first paper [1].

The $\eta\eta$ invariant mass spectrum in the range $0.35 \text{ (GeV/c)}^2 < |t| < 0.60 \text{ (GeV/c)}^2$ shows no significant structures (fig. 5a). An upper limit (90% confidence level) to the ratio of the branching ratios of the decay of $X(1910)$ into $\eta\eta$ and $\eta'\eta$ may be given by comparing the spectra of fig. 1 and fig. 5a :

$$\text{BR}(X \rightarrow \eta\eta) / \text{BR}(X \rightarrow \eta'\eta) < 1/20. \quad (6)$$

Strong limits may then be deduced for the ratio of the squares of the matrix elements

$$|T(X \rightarrow \eta\eta)|^2 / |T(X \rightarrow \eta'\eta)|^2 < \begin{matrix} 1/30 & \text{for } J = 0 \\ 1/100 & \text{for } J = 2 \end{matrix} \quad (7)$$

for two possible values of the spin of $X(1910)$.

The $K_s^0 K_s^0$ invariant mass spectrum measured in the same $\pi^- p$ charge-exchange reaction at 40 GeV/c with the ITEP magnetic spectrometer [8] also shows no $X(1910)$ signal for $|t| > 0.35 \text{ (GeV/c)}^2$ (fig. 5b, kindly communicated by V. Sokolovsky). The upper limit for the ratio of the branching ratios of the decay of $X(1910)$ into $K_s^0 K_s^0$ and $\eta'\eta$ is $< 1/15$, same as in the first paper [1].

A similar limit is given on the $X(1910) \rightarrow \pi^0 \pi^0$ channel by the analysis of $1.3 \cdot 10^6$ $\pi^0 \pi^0$ -events (1/3 of the total statistics collected by GAMS-2000).

The unusual production and decay characteristics of the $X(1910)$ are indications of its exotic nature as has been previously suggested [1,3]. The absence of the symmetric decay modes $\pi^0 \pi^0$, $\eta\eta$ and $K_s^0 K_s^0$ as well as the small slope in t (4), indicating a non-OPE production mechanism, could easily be explained if $X(1910)$ was not a pair of quark-antiquark and if it had the quantum numbers $J^{PC} = 1^{-+}$, which are forbidden for a $q\bar{q}$ -state. A 1^{-+} exotic $q\bar{q}g$ -state has been predicted in this mass region [9].

An abrupt decrease to a small value of $b \approx 2 \text{ (GeV/c)}^{-2}$ of the slope of the t -distributions is observed at a large $|t|$ in many two-body reactions. This can be attributed to a change in the reaction mechanism [10]. For small values of $|t|$, the cross-sections are dominated by reggeon exchanges. These decrease rapidly with increasing $|t|$. On the other hand, at larger $|t|$, processes of rescattering through reggeon exchanges in smaller interaction regions dominate [11, 12].

Both the small slope parameter (4) and the very low production cross-section of about 15 nb [1] for the $X(1910)$ might be explained if the latter mechanism dominates, even in the region of small $|t|$. As was recognized by S. Gershtein [13], this would happen if the $X(1910)$ contains a valence gluon, i.e. if it is a hybrid meson.

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Figure Captions

Fig.1 $\eta'\eta$ invariant mass spectrum for events in reaction (1) with $0.35 (\text{GeV}/c)^2 < |t| < 0.60 (\text{GeV}/c)^2$. Thin histogram : no background subtraction. Hatched histogram : after background subtraction. The arrow indicates the tabulated mass of X(1910).

Fig.2 Invariant mass spectrum (after 2 C-fit: the masses of n and η) of the second γ -pair in 4γ events when the first pair has been identified as $\eta \rightarrow \gamma\gamma$. The 4γ mass intervals are : a) 1507 MeV to 1690 MeV; b) 1690 MeV to 1850 MeV; c) 1850 MeV to 2000 MeV and d) 2000 MeV to 2150 MeV. The arrow indicates the tabulated mass of η' .

Fig.3 t -dependence of the differential cross-section of production of X(1910).

Fig.4 Polar and azimuthal angular distributions of the decay of X(1910) in the Gottfried-Jackson frame. $0.35 (\text{GeV}/c)^2 < |t| < 0.60 (\text{GeV}/c)^2$. Histograms are normalized so that the number of measured $\eta'\eta$ events is conserved.

Fig.5

- a) $\eta\eta$ invariant mass spectrum for events in reaction (5) with $0.35 (\text{GeV}/c)^2 < |t| < 0.60 (\text{GeV}/c)^2$.
- b) $K_s^0 K_s^0$ invariant mass spectrum for events in the reaction $\pi^- p \rightarrow K_s^0 K_s^0 n$ with $|t| > 0.35 (\text{GeV}/c)^2$ (ITEP measurements, [8]).

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