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PRODUCTION MECHANISM OF THE X(1740) MESON

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Abstract

New data from π^+p charge-exchange at 38 GeV/c confirm the existence of the narrow X(1740) meson, observed in its $\eta\eta$ decay mode. The upper limit on its width is 80 MeV. It is not observed decaying into either $\eta'\eta$ or $\pi^0\pi^0$. This meson is produced in charge-exchange by a mechanism other than OPE with a nucleon isobar (probably $\Delta(1232)$), and not with a neutron.

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Further studies on the meson with a mass of about 1750 MeV, originally discovered at the 70 GeV IHEP accelerator through its decay into two η [1], have been made with the same spectrometer GAMS-2000 [2] in an improved version of the experiment.

The simple charge-exchange reaction

as well as those that produce an excited neutron decaying by the emission of one or more π^0

have been measured.

Data for the first reaction were initially obtained [1] with a guard system of lead-glass counters [3], surrounding the liquid hydrogen target, in anticoincidence in the primary trigger. This favoured the detection of the first reaction and reduced the contribution of the second one. The gamma detection threshold of this system was set to about 70 MeV eliminating a substantial fraction of isobars. The charged decay mode of isobars $N^* \rightarrow p\pi^-$ was excluded by the scintillation counters of the guard system.

A faster data acquisition system has permitted the recording of both reactions (1) and (2) in a new series of measurements that did not include the gamma counters of the guard system in the trigger. The signals of these counters have been written on tape and analyzed together with the signals of GAMS [4].

The method of data analysis is the same as that described in ref. [1]. The total number of recorded η -pairs has been doubled and it amounts to 10^5 for $5 \cdot 10^{12}$ incident π^- on the hydrogen target.

Most $\eta\eta$ events are concentrated in the region of small 4-momentum transfer, $|t| < 0.2 \text{ (GeV/c)}^2$, dominated by one-pion exchange (OPE) [1, 5]. Events from both reactions have been selected according to the level of signal amplitudes in the guard system. The events from reaction (1) are characterized by the absence of a gamma with energy greater than $E_{th} = 12 \text{ MeV}$, the noise level of any individual counter in the guard system. In the case of any contribution larger than this threshold the event is considered as coming from reaction (2). The proportion of events of this type is about a quarter of the total number. It increases with $|t|$.

As shown earlier, a narrow peak appears in the $\eta\eta$ mass spectrum with increasing $|t|$ (fig. 1), showing the production of an $\eta\eta$ resonance. Its mass is

$$M = 1732 \pm 20 \text{ MeV.} \quad (3)$$

Taking the mean with the former data [1], one gets :

$$M = 1744 \pm 15 \text{ MeV.} \quad (4)$$

The peak width is close to the instrumental width (70 MeV). One thus gets an upper 90% CL limit for the width of X(1740) :

$$\Gamma < 80 \text{ MeV.} \quad (5)$$

The narrow $\eta\eta$ resonance discovered by the GAMS collaboration is thus confirmed, but its production mechanism differs from what was assumed in ref. [1]. As it may be observed on fig. 1a, X(1740) appears only when gammas are detected in

the guard system. There is no such peak in the η -pair mass spectrum of reaction (1) (fig. 1c) up to less than a third of the peak in fig. 1a. This is confirmed by a new analysis of the part of the first batch of data for which the guard system had not been placed in the trigger and pulse heights of individual counters had been recorded. Here also X(1740) appears only when a significant gamma signal is measured in the guard system (fig.2).

The guard system was not been designed for a detailed study of reactions of type (2). The thickness of the lead-glass counters is only 5 radiation lengths, enough to detect photons that are emitted laterally from the target but not sufficient to measure their energy precisely. Nevertheless the analysis of the signals from these counters gives useful additional information on these processes which are accompanied by the excitation of the target nucleon.

Electromagnetic showers usually spread over several adjacent counters forming a cluster. Events from fig. 1a have been sorted according to the number of clusters in the guard system. Most of the time, there is only one cluster. Less than 10% events are accompanied by three or more clusters. X(1740) appears in neither case. It is only visible amongst the two-cluster events, in agreement with the topology expected from the reaction

The analysis of the energy deposited in the guard system may provide information on the excited nucleon. Relative calibration of individual counters have been made with muons. The absolute scale in this case is not defined to better than a factor 2. So calibration coefficients have been adjusted with the help of energy balance, the energy released in the guard system being the difference between the beam energy and the energy deposited in GAMS, after correction for the recoiling particle (details are given in [6]).

The spectrum of the total energy deposited in the guard system for X(1740) events is shown in fig. 3. The background has been subtracted by evaluation from adjacent mass intervals around the X(1740) peak (fig. 1). Fitting of the spectrum of fig. 3 gives a value of 1180 ± 40 MeV for the mass of N^* produced together with X(1740) in reaction (6). It may be identified as $\Delta(1232)$, the lowest lying isobar decaying predominantly into $n\pi^0$. Heavier isobar contributions are excluded by the shape of the spectrum of fig. 3 as well as by the absence of $n\pi^0\pi^0$ decays shown by the cluster analysis.

The measured t -distribution (fig. 4) of the cross-section of reaction (6) agrees with the previous measurements [1]. If it is described by e^{bt} , the slope b of this cross-section is quite small in comparison with a OPE process

$$b = 2.4 \pm 1.5 (\text{GeV}/c)^{-2}. \quad (7)$$

The ratio of cross-sections summed over t in the small $|t|$ interval ($0 \div 0.2$ $(\text{GeV}/c)^2$) and in the large $|t|$ interval ($0.2 \div 0.6$ $(\text{GeV}/c)^2$) is less than 1. It is expected to be 4 under OPE dominance.

The cross-section for the production of X(1740) in reaction (6) in the interval $0.2 (\text{GeV}/c)^2 < |t| < 0.6 (\text{GeV}/c)^2$ is 1 nb when the γ -detection efficiency in the guard system is taken into account. Extrapolating to $t = 0$ yields a cross-section

$$\sigma \cdot \text{BR} [X(1740) \rightarrow \eta\eta] = 1.5 \pm 0.7 \text{ nb} \quad (8)$$

which is several orders of magnitude lower than that of "ordinary" mesons at this energy.

The distribution of the cosine of the polar angle of the X(1740) decay in its Gottfried-Jackson frame is isotropic within the experimental errors (fig. 5). The

accuracy is limited by the small statistics and by the subtraction of a substantial continuum under the X(1740) peak.

The mass spectra of $\eta'\eta$ and of $\pi^0\pi^0$ systems measured in the same experiment do not show any statistically significant structure in the region of X(1740). With a 90% CL, $BR(X \rightarrow \eta'\eta)$ and $BR(X \rightarrow \pi^0\pi^0)$ are smaller than $BR(X \rightarrow \eta\eta)$.

X(1740) cannot be identified with $f_0(1750)$ (the former S(1730)) as suggested in the Review of Particle Properties [7]. $f_0(1750)$ is a broad resonance that is observed through its $K_s^0\bar{K}_s^0$ decay. Contrary to X(1740), it is produced in πp charge-exchange through OPE predominantly, with a hundred times larger cross-section [8,9].

In summary, X(1740) shows exotic characteristics that differ from those of "ordinary" mesons :

- weak coupling to a pion pair as manifested by the suppression of the OPE mechanism,
- very small production cross-section,
- narrow width,
- production accompanied by isobars but not by neutrons.

Many of these unusual features are shared by X(1910), another seemingly exotic meson [10].

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Figure captions

Fig. 1 Invariant mass spectrum of η -pairs :

- a) $E_\gamma > E_{th}$;
- b) same as in a) but two clusters in the guard system are selected;
- c) $E_\gamma < E_{th}$, $0.2 \text{ (GeV/c)}^2 < |t| < 0.6 \text{ (GeV/c)}^2$.

Fig. 2 Invariant mass spectrum of η -pairs (data in ref. [1]) :

- a) $E_\gamma > E_{th}$;
- c) $E_\gamma < E_{th}$, $0.2 \text{ (GeV/c)}^2 < |t| < 0.6 \text{ (GeV/c)}^2$.

Fig. 3 Spectrum of the total energy deposited in the guard system by gammas accompanying η -pair production in the region of X(1740)-peak (fig. 1). The solid curve shows the fit corresponding to a $\pi\pi^0$ -system with a mass of 1180 MeV. The other curves correspond to the decays of Δ and N isobars.

Fig. 4 Integral t -distribution for the number of $\eta\eta$ events in the X(1740)-peak. The curve is the cross section in the case of dominating OPE normalized to the experimental data at $|t| = 0.3 \text{ (GeV/c)}^2$.

Fig. 5 Angular distribution for the $\eta\eta$ events in the X(1740)-peak in the Gottfried-Jackson frame; $0.2 \text{ (GeV/c)}^2 < |t| < 0.6 \text{ (GeV/c)}^2$.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5