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2.22 GeV $\eta\eta'$ STRUCTURE
OBSERVED IN 38 GeV/c AND 100 GeV/c π^-p COLLISIONS

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(Joint CERN-IHEP experiment)

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ABSTRACT

A structure has been observed at 2220 MeV in the mass spectrum of $\eta\eta'$ systems produced by 38 GeV/c and 100 GeV/c negative pions on protons. The angular distribution of the decay products shows that this state has a spin $J \geq 2$.

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A rather narrow structure which decays into $\eta'\eta$ has been observed at 2.22 GeV in the course of a systematic study of exclusive reactions leading to the production of multiphoton final states :

$$\pi^- p \rightarrow M^0 n \quad (1) \\ \rightarrow k\gamma$$

The evidence is based on data gathered both at IHEP (6th Joint CERN-IHEP experiment) and at CERN (NA12 experiment), in 38 GeV/c and 100 GeV/c π^- beams, respectively. The experimental setups are rather similar. The main detector is an electromagnetic calorimeter of GAMS type, i.e. a cellular lead-glass Cerenkov calorimeter [1]. GAMS-2000, at IHEP, is a matrix of 32 x 48 parallelepipedic lead-glass counters, each 38 x 38 x 450 mm³. GAMS-4000, at CERN, is a matrix of 64 x 64 such counters.

The absence of a measurable signal in a guard system made of scintillation and lead-glass counters around the 60 cm long liquid-hydrogen target warrants selection of neutral final states produced in charge-exchange reaction (1).

The data analysis proceeds in two steps. First, individual showers are identified, gamma rays are sorted out and their energy as well as their impact coordinates in GAMS are determined. The procedures are described elsewhere [2]. Events produced in reaction (1) are then classified according to their respective number of gamma rays. More details on apparatus and data analysis are given in refs. [3-4].

Results of the analysis of 4 γ -events are presented here. They are heavily dominated by $\pi^0\pi^0$ and $\eta\pi^0$ pairs. To obtain a pure sample of $\eta'\eta$ events all 4 γ -events for which any pair of gammas has an invariant mass within a suitable range around the π^0 mass are rejected. Best cut intervals have been chosen for both sets of data. All γ -pairs with a mass ranging from 465 MeV to 645 MeV are identified with η . Events with two η are then rejected so that the remaining sample contains only 4 γ -events with one γ -pair identified with a η .

Fig. 1 shows the invariant mass spectrum of the other two gammas for both energies, 38 and 100 GeV. An η' peak is clearly seen on a relatively small background. Events where the mass of the second γ -pair lies in the range between 870 MeV and 1080 MeV are fitted with three constraints to the reaction :

$$\pi^- p \rightarrow \eta'\eta n \quad (2)$$

Events with a χ^2 larger than 9 are rejected.

The mass spectra of the selected $\eta'\eta$ events (fig. 2) show the presence of a peak centered at a mass of 2220 MeV with a 10 MeV uncertainty in both sets of data (higher statistics in the 38 GeV data allowed stronger cuts to be applied). This peak is insensitive to the choice of applied mass cuts. The fact that it is seen independently in two different sets of data taken at two different energies with two setups having different acceptances greatly strengthen the confidence in the existence of a state at 2220 MeV.

Although the statistics are rather poor, the width of this (2220)-peak seems to be mostly instrumental, the state itself contributing 80 MeV at most.

Fig.3 shows two-dimensional plots of the mass of $\eta'\eta$ systems versus $\cos \theta_{GJ}$, θ_{GJ} being the polar decay angle of the η measured in the Gottfried-Jackson frame. The plots on the left are for the measured events while those on the right have been obtained from Monte Carlo simulated events which have been submitted to the whole chain of analysis programs [2-4]. The simulated events have been generated starting from uniform distributions in $\cos \theta_{GJ}$ and mass so that the plots on the right represent the detection efficiency ϵ . One sees that, due to acceptance, ϵ decreases with increasing mass and when $|\cos \theta_{GJ}|$ is approaching 1. The latter effect is more pronounced at 38 GeV.

Angular distributions are quite different for $\eta'\eta$ events in the (2220)-peak and for those in neighbouring intervals. The events in the (2220)-peak have angular distributions which are notably anisotropic (fig. 4). This is most clearly seen in the 38 GeV data. Notwithstanding the two times smaller statistics and a higher background, the 100 GeV data are important because the efficiency ϵ is much higher for $\cos \theta_{GJ}$ near -1 at 100 GeV (fig. 3). They confirm the strong peaking of the data at $|\cos \theta_{GJ}| \sim 1$. They also display clearly the symmetry of the angular distribution.

The lack of statistics renders a partial wave analysis of the data impracticable. Nevertheless some indications on the quantum numbers of the (2220)-state are obtained. First of all its isospin and G-parity are $I^G = 0^+$ as it follows immediately from its decay mode in $\eta'\eta$. The very anisotropic angular distribution shows that its spin $J \geq 2$. If the state is a quark-antiquark meson, then $J^{PC} = 2^{++}$ or 4^{++} (production of higher spin states

in reaction (2) is strongly suppressed by barrier effects [3,5]).

The production cross-section has been estimated by comparing the production of $\eta'\eta$ systems with that of η -pairs measured simultaneously in the same setups and analysed in the same way [3,4] :

$$\sigma \cdot \text{BR} [(2220) \rightarrow \eta'\eta] = \begin{array}{ll} (50 \pm 17) \text{ nb at } 38 \text{ GeV/c} \\ (9 \pm 3) \text{ nb at } 100 \text{ GeV/c} \end{array} \quad (3)$$

The value at 38 GeV/c has been obtained by integration of the angular distribution (fig. 3) over the interval $0 \leq \cos \theta_{GJ} \leq 1$ supposing it to be symmetrical.

The mass and, possibly, the width of the observed structure at 2220 MeV are compatible with those of the narrow isoscalar meson ξ (2230) with even spin and parity observed in the radiative decay $J/\Psi \rightarrow \gamma KK$ by the MARK-III experiment [6]. Of course, it could well be that this is purely fortuitous and that the state observed at 2220 MeV in the $\eta'\eta$ decay channel is just another meson. At present, the status of the ξ is somewhat confused. [7]. The DM2 experiment does not observe a ξ signal in its high statistics data, though it has studied the same decay modes as MARK III [8]. The latter is confirming its results. The nature of ξ has given rise to much speculation : gluonium, Higgs boson, etc. [6]. The observation of its decay into η and η' mesons with a significant branching ratio would be a new guide line and possibly an indication that the ξ -meson might have an important gluon component [9], making it a tensor glueball candidate. It has also been proposed that ξ could be a 2^{++} ss meson with $L = 3$ [10] having large $\eta'\eta$ and $\eta\eta$ branching ratios and without measurable $\pi\pi$ decay.

More experimental information on $\eta'\eta$ as well as on other decay channels is needed to clarify the nature of the observed structure at 2220 MeV.

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FIGURE CAPTIONS

- Fig. 1 Invariant mass spectra of the other two gammas after identification of a γ -pair as an η -meson ($\eta \rightarrow \gamma_1 \gamma_2$) in the selected 4γ -events. The arrow points to the tabulated value of the η' mass.
- Fig. 2 Invariant mass spectra (not corrected for detection efficiency) of the selected $\eta'\eta$ events.
- Fig. 3 $\cos \theta_{GJ}$ versus invariant mass two-dimensional distributions for the selected $\eta'\eta$ events (left) and for simulated events (right). The arrow points to the maximum of the (2220)-peak.
- Fig. 4 Angular distribution of the $\eta'\eta$ selected events in the mass interval $2150 \text{ MeV} < M_{\eta'\eta} < 2310 \text{ MeV}$. The data are corrected for detection efficiency. The cross-shaded area near $\cos \theta_{GJ} = -1$ in the upper figure (38 GeV) is the limit below which the efficiency falls to zero. The average value of ϵ is ≈ 0.2 .

FIG. 1

FIG. 2

FIG. 3

FIG. 4.