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Observation of a 1750 MeV narrow meson decaying into $\eta\eta$

IHEP¹⁾ – IISN²⁾ – LANL³⁾ – LAPP⁴⁾ Collaboration

Joint CERN – IHEP experiment

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Abstract

A narrow meson which decays into $\eta\eta$ is observed in 38 GeV/c π^-p collisions at large momentum transfer. The experiment has been performed at the Serpukhov accelerator with the GAMS-2000 spectrometer. The mass of this new meson is (1755 ± 8) MeV, its width is less than 50 MeV. Its spin-parity is $J^{PC} = 0^{++}$ or less probably 2^{++} .

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The present paper describes further investigations of η pair systems produced in the reaction :

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

$$\quad \quad \quad \downarrow \eta\eta$$

$$\quad \quad \quad \quad \downarrow 4\gamma$$

in which the $G(1590)$ -meson, a scalar glueball candidate, had been discovered [1-6]. The measurements have been performed with the electromagnetic multiphoton spectrometer GAMS-2000 [7]. The experimental setup and the data analysis procedures have been described previously [1, 2, 7-9].

The data have been taken in the 38 GeV/c negative pion beam at the IHEP proton synchrotron. Part of them were taken in the same conditions of geometry prevailing in the first experiment [1]. The distance between the liquid hydrogen target and GAMS, which determines the acceptance of the spectrometer, was $L = 4.2$ m. The acceptance was increased during the second run by decreasing L to 3.4 m and by using a larger aperture guard system made of lead-scintillator sandwich counters around the target [10].

The total number of observed $\eta\eta$ pairs is five times larger than in the first experiment [1]. This increase of sensitivity made it possible to look for mesons decaying into $\eta\eta$ in the region of large momentum transfer, up to $|t| \approx 1$ (GeV/c)². Forty five thousand $\eta\eta$ events have been selected from all 4γ events from the data sample. No significant background is seen as in ref. [1,6].

Most events are concentrated at low $|t|$, a region which is dominated in reaction (1) by one-pion-exchange (OPE). In this region a large number of resonances are produced, like ϵ , f , $G(1590)$ and h . As a result, the mass spectrum and the angular distribution of $\eta\eta$ systems show complex structural variations [1,6]. The contributions of these resonances disappear quickly with increasing momentum transfer. Above $|t| \approx 0.3$ (GeV/c)² the angular distributions vary smoothly with the mass $M_{\eta\eta}$.

Starting in this range, a clear narrow peak appears at a mass of 1750 MeV above an otherwise continuous $M_{\eta\eta}$ spectrum (fig. 1). It is seen independently in the two runs as well as in different non-overlapping t -intervals. Its statistical significance is larger than seven standard deviations.

The mass of this new meson is :

$$M = (1755 \pm 8) \text{ MeV.}$$

The width of the peak is equal to the instrumental resolution of the spectrometer GAMS-2000, so that the intrinsic width of the resonance is :

$$\Gamma < 50 \text{ MeV.}$$

The integral t -distribution of the 1750 MeV peak events (fig. 2) is described by an exponential function $e^{\bar{b}t}$ with

$$\bar{b} = (3.8 \pm 1.5) (\text{GeV}/c)^{-2}.$$

This is significantly smaller than the value $\bar{b} \approx 10 (\text{GeV}/c)^{-2}$ at small $|t|$, typical for the other mesons that are produced by the OPE mechanism in reaction (1). The new state does not appear in the mass spectrum at $t \approx 0$ because it is masked by $G(1590)$ and other mesons that are more copiously produced in reaction (1) (fig. 2).

As already mentioned, the angular distribution of the $\eta\eta$ systems varies little for different mass bins at $|t| \gtrsim 0.3 (\text{GeV}/c)^2$. With increasing $|t|$ it appears mostly isotropic both below and above the 1750 MeV mass peak. The angular distribution (fig. 3) in the Gottfried-Jackson frame of the events in the 1750 MeV peak (shaded area on fig.1) is obtained by subtracting from the distribution in the peak mass interval a mean angular distribution for the continuum evaluated from the measurements in the neighbouring mass bins, taking into account the detection efficiency which varies weakly with the decay angle θ_{GJ} [1].

Even quantum numbers only are allowed for $\eta\eta$ pairs. The isotropic distribution of fig. 3 favors $J^{\text{PC}} = 0^{++}$, assuming spin alignment in the production process (1). A 2^{++} assignment, although having lower probability, is not excluded. Isospin and G-parity are $I^G = 0^+$.

The new meson, which will be further called $X(1750)$, not only is narrow but also it is produced with a very small cross-section in the reaction $\pi^- p \rightarrow X(1750)n$:

$$\sigma \cdot \text{BR}[X(1750) \rightarrow \eta\eta] = (3.5 \pm 1.5) \text{ nb}$$

evaluated by extrapolating from the range $0.2 < |t| < 1$ (GeV/c)² to $t = 0$ (fig. 2). This cross-section is significantly smaller than that for the other mesons observed at the same energy. The observation of the $\eta\eta$ decay channel may indicate the possible existence of a significant valence gluon component in X(1750) [3]. It may be valuable in evaluating the nature of this meson to also consider the existence of another narrow state with a mass of 2220 MeV [11].

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FIGURE CAPTIONS.

- Fig. 1 Mass spectrum of $\eta\eta$ events produced in reaction (1) at $|t| > 0.35 \text{ (GeV/c)}^2$.
 The bin width is 40 MeV. The dashed curve is a polynomial fit to the continuum under the peak at 1750 MeV.
- Fig. 2 Integral t-distribution of events in the 1750 MeV peak. $N(t) = \int_0^t (dN/dt) dt$.
 The measured points are fit with $e^{\bar{b}t}$ with $\bar{b} = 3.8 \text{ (GeV/c)}^{-2}$ (full line).
 The dashed curve represents the t-dependence for G(1590) (OPE, $\bar{b} = 10 \text{ (GeV/c)}^{-2}$ at $t \approx 0$ and $\bar{b} = 6.5 \text{ (GeV/c)}^{-2}$ at $|t| = 0.4 \text{ (GeV/c)}^2$) [1,6].
- Fig. 3 Efficiency corrected angular distribution of $X(1750) \rightarrow \eta\eta$ events (shaded area on fig.1) produced with $|t| > 0.35 \text{ (GeV/c)}^2$, as a function of the polar angle in the Gottfried-Jackson frame. The distribution is normalised to the number of measured events in the peak (150).

Fig. 1

Fig. 2

Fig. 3