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S.I.Bityukov, G.V.Borisov, Yu.B.Bushnin, V.S.Van'ev,
N.K.Vishnevsky, E.V.Vlasov, Yu.P.Guz, R.I.Dzhelyadin,
A.M.Zaitsev, Yu.M.Ivanyushenkov, A.N.Karyukhin,
I.A.Kachaev, G.A.Klyuchnikov, A.K.Konoplyannikov,
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A.P.Ostankov, D.I.Ryabchikov, V.K.Semenov,
E.A.Starchenko, Yu.A.Khokhlov
Institute for High Energy Physics, Protvino
G.M.Beladidze, T.A.Lomtadze, E.G.Tskhadadze
Physical Institute Academy of Science Georgia

OBSERVATION OF RESONANCE WITH MASS m=1814 MeV, DECAYING INTO $\pi^-\eta\eta$

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Abstract

Observation of Resonances with Mass m=1814 MeV, Decaying into $\pi^-\eta\eta$: IHEP Preprint 91-26. - Protvino, 1991. - p. 7, figs. 7, table 1, refs. 3.

The reaction $\pi^-N\to\eta\eta\pi^-N$ off carbon nucleus at P_π = 36 GeV/c has been studied with the help of a wide aperture magnetic spectrometer VES. In the $\pi^-\eta\eta$ system a resonance M=1814±10 MeV, Γ=205±18 MeV has been observed. Its most probable quantum numbers are $I^G=1^-$, $J^P=1^+$ or 2^-.

Аннотация

С.И.Битюков и др. Наблюдение резонанса с массой m=1814 МэВ, распадающегося на $\pi\eta\eta$: Препринт ИФВЭ 91-26. - Протвино, 1991. - 7 с., 7 рис., 1 табл., библиогр. 3.

Изучена реакция $\pi^-N\to\pi^-\eta\eta N$ на ядре углерода при P_π=36 ГэВ/с при помощи широкоапертурного магнитного спектрометра ВЕС. В системе $\pi^-\eta\eta$ наблюдается резонанс M=1814±10 МэВ, Γ=205±18 МэВ. Его наиболее вероятные квантовые числа $I^GJ^P=1^-1^+$ или 1^-2^-.

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We present here the results on studying the reaction

$$\pi^- N \to \pi^- \eta\eta N \qquad (1)$$

at incident momentum 36 GeV/c. It was studied on the Vertex Spectrometer (VES) at 70 GeV IHEP accelerator. This setup shown in fig.1 is a wide aperture spectrometer consisting of:

1. Beam detectors (scintillation and Cherenkov counters, proportional chambers).
2. An active target of eight 1-cm thick scintillation counters surrounded by veto system.
3. 29 planes of proportional and drift chambers, with the maximum sizes of the chambers 1.9 m × 2.5 m [1].
4. A magnet with the aperture of 1m × 2.5 m and transverse kick of 0.7 GeV.
5. 28-channel gas Cherenkov counter with the threshold for π-mesons of 4.4 GeV.
6. 200-channel scintillation hodoscope, used for multiplicity trigger.
7. 1600-channel γ-detector of lead glass 2 m × 2.5 m.

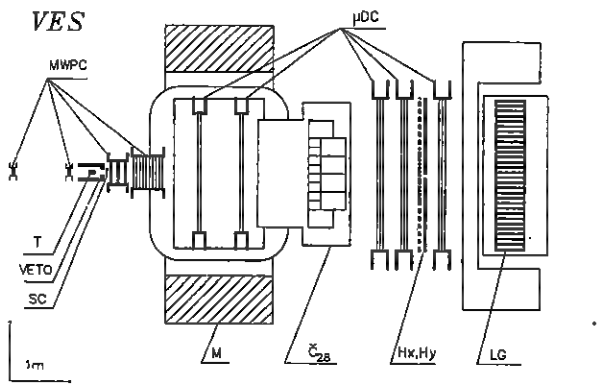

Fig. 1. VES facility.

The following conditions were required to trigger an event:

- presence of a beam particle;
- two or more charged particles, going forward from the target;
- no fast charged particles or quanta detected by the veto system.

The data acquisition system provided the detection of up to 10^3 events per cycle.

Under these trigger conditions $N=1.4\cdot10^8$ events were recorded on tapes. The first results, corresponding to the analysis of $2\cdot10^7$ reconstructed events, are presented in this paper.

The $\eta\eta\pi$ system was selected from the final state $\pi^-\pi^+\pi^-\gamma\gamma\gamma\gamma$. One η meson decays into $\eta\to\pi^+\pi^-\pi^o$, the second one decays into $\gamma\gamma$. Out of the total bulk of exterimental events we chose the sample that satisfied the following criteria:

- 3 charged particles (2 negative and 1 positive) leave the target;
- 4 showers, not associated with the charged tracks, are to be detected in the γ detector;
- the energy, not associated with these four showers or showers from charged particles, is less than 0.5 GeV;
- total energy of charged particles is $\sum E^{ch}<33$ GeV;
- total energy of event (the sum of energies of charged and neutral particles) is: $34.5<\sum(E^{ch}+E^{\gamma})<37$ GeV;
- the mass of one pair of γ quanta lies within the interval $0.100<m_{\gamma\gamma}<0.170$ GeV, the mass of the other pair is within the interval $0.460<m_{\gamma\gamma}<0.630$ GeV.

The parameters of the relevant cuts are chosen over easily selected reactions, e.g., $\pi^-p\to n\pi^+\pi^-\pi^o$ and $\pi^-p\to n\eta$, $\pi^-p\to n\eta'$.

The quality of selecting reaction (1) is demonstrated in fig.2. The $\pi^+\pi^-\pi^o$ mass distribution in the selected events is shown in fig.2a. The $\gamma\gamma$ mass distribution, if $0.53<m_{\pi^+\pi^-\pi^o}<0.57$ GeV is presented in fig.2b by dashed line. Solid line on fig.2b was obtained after 10% background subtraction for η-meson, decaying along the $\pi^+\pi^-\pi^o$ channel. After all selection procedures 1800 events of reaction (1) are left.

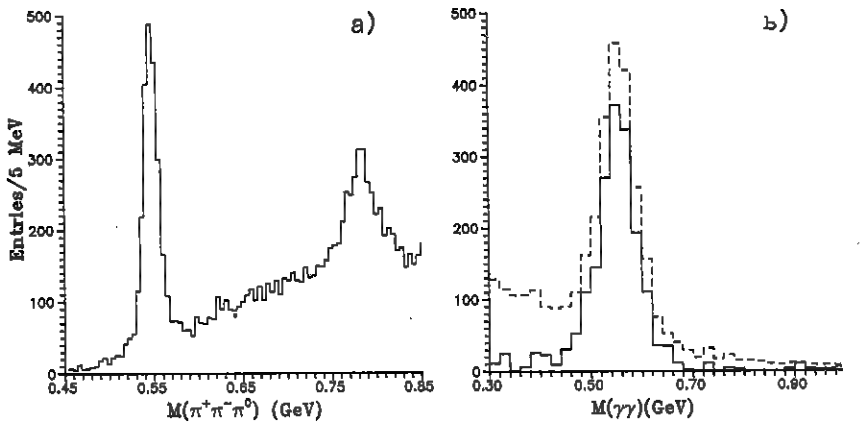

Fig. 2a,b. a) The effective $\pi^+\pi^-\pi^0$ mass spectrum for the selected events; b) Dashed line - the effective $(\gamma\gamma)$ mass spectrum for the events with $0.53<m(\pi^+\pi^-\pi^0)<0.57$ GeV; solid line - the same but after the background subtraction under $\eta(\pi^+\pi^-\pi^0)$ meson.

Fig.3 presents the distribution over the squared momentum transferred to the target. There is an evident peak at small $|t'|$. It is connected with the coherent production of the final state on carbon nuclei. For further analysis we selected the events from the peak: $-t'<0.08$ GeV$^2/c^2$.

Fig.4 gives the $m_{\eta\eta\pi}$-distribution. In this spectrum we observe a peak with the parameters:

$$M = 1.814\pm0.010 \text{ GeV/c},$$

$$\Gamma = 0.205\pm0.018 \text{ GeV/c},$$

$$N = 426\pm57 \text{ events}.$$

The $m_{\eta\pi}$ mass spectrum for the events from the region of the peak $1.71<m_{\eta\eta\pi}<1.95$ GeV is shown in fig.5a. No structures are observed.

The $m_{\eta\eta}$ mass spectrum for all $m_{\eta\eta\pi}$ masses is presented in fig.5b by dashed line. As for the events from the region of the peak $1.71<m_{\eta\eta\pi}<1.95$ GeV the $m_{\eta\eta}$ mass spectrum is shown in fig.5b by solid line. One can see a narrow structure with the mass $\approx$1.44 GeV.

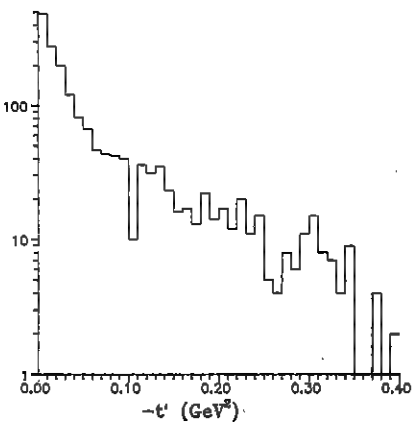

Fig. 3. The t' distribution for the $\eta\eta\pi$ system.

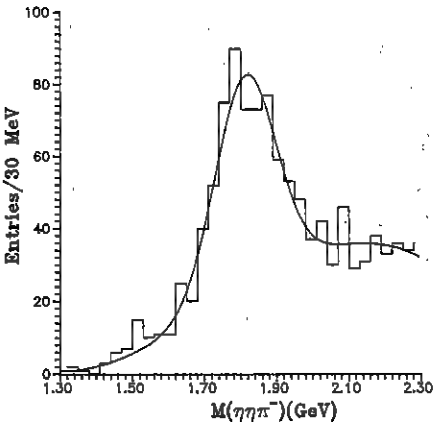

Fig. 4. The effective $\eta\eta\pi$-mass system at $t'<0.08$ GeV/c^2. Solid curve: the results of fitting the data with the sum of Gaussian distribution and polynomial background.

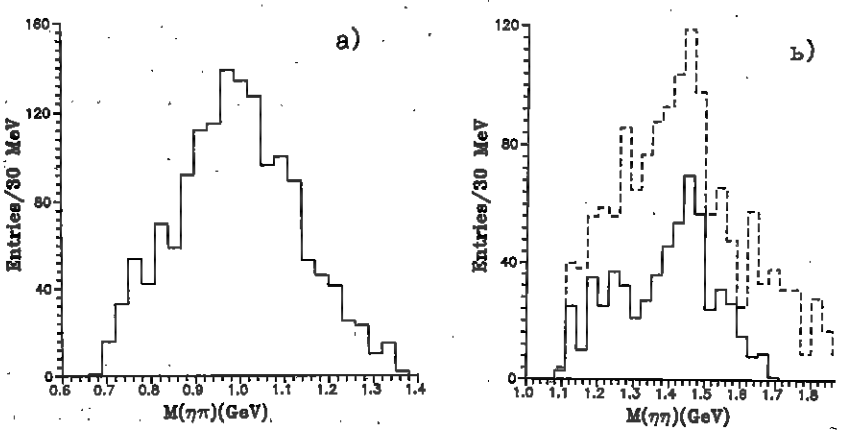

Fig. 5a,b. a) The effective $\eta\pi$ mass spectrum for the events in the region of the peak ($1.71<M(\eta\eta\pi^-)<1.95$ GeV); b) Dashed line: the effective $\eta\eta$ mass spectrum for all the $\eta\eta\pi$ events; solid line: the same, but for the events in the region of the peak ($1.71<M(\eta\eta\pi^-)<1.95$ GeV).

To determine the quantum numbers of the observed object we made the fit of anguar distributions. For the coherent process one can expect $J^P=0^-$, 1^+, 2^-... and a zero projection onto the Gottfried-Jackson axis. However, we have included into the fit all possible qunatum numbers up to J=2 and imposed no limitations onto the density matrix. The waves corresponding to different values of the orbital moment L of π^--meson and the moment S of $(\eta\eta)$-system were considered as noninterfering. The results of the fit are listed in table.

Table

J_P	0^-	1^+	1^-	2^-	2^+
Probability	$<10^{-4}$	0.04	0.06	0.6	$<10^{-4}$

The best description of the data is obtained for $J^P=1^+$, 1^- and 2^-. The fit for $J^P=2^-$ is illustrated in fig.6. In this case the $\eta\eta$ system is produced with S=0 and S=2 in the ratio 0.3/07. Fig.6a presents the angular distributions over the π-meson polar angle in the Gottfried-Jackson system. Fig.6b presents the distribution over the angle between the direction of the η meson emission in the $\eta\eta$ c.m.s. and Z-axis of Gottfried-Jackson frame.

The state $J^P=1^-$ also allows one to fit the angular distribitions with an acceptable χ^2. However in this case a large projection of the total moment onto the Gottfried-Jackson axis is required that does not correspond to a coherent production features. Note, that for 1^+ and 2^- this projection is small as was expected.

Hence for the considered object the most probable are the quantum numbers $I^G = 1^-$, $J^P = 1^+$ or 2^-. We can call it $A_1/\pi_2(1814)$.

The production cross section for this object in reaction (1) off Carbon nucleus at P_π=36 GeV multiplied by the branching ratio for the decay in $\pi^-\eta\eta$ final state yields $\sigma \times BR=(3.1\pm1.0)$ μbarn.

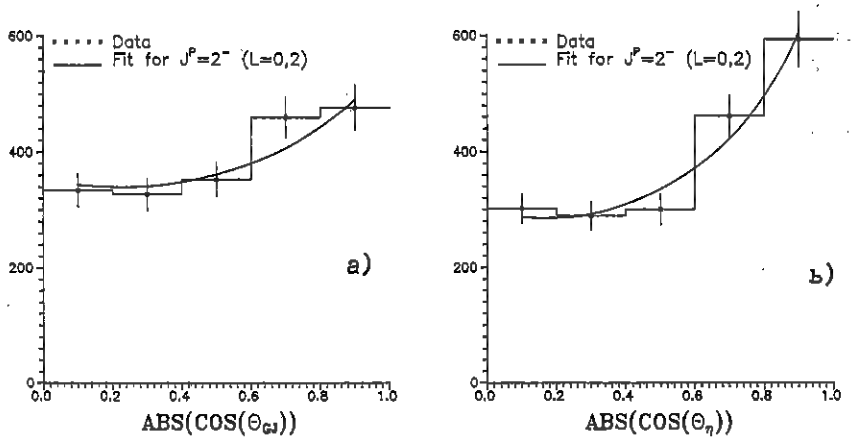

Fig. 6a, b. a) Distribution over the absolute value for the Gottfried-Jackson angle for π meson; b) Distribution over the absolute value for the angle between η meson and the z axis of the Gottfried-Jackson system in the c.m.s. of $(\eta\eta)$.

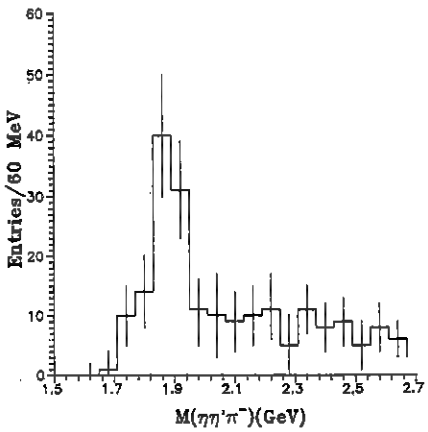

Fig. 7. The effective $\eta\eta'\pi^-$ mass spectrum.

The search for this resonance was undertaken also in the reaction $\pi^-N\to N\pi^-\eta(\gamma\gamma)\eta'(\pi^+\pi^-\eta_{\gamma\gamma})$. This reaction was selected in a similar way as reaction (1), the only difference was, that in the 4-gamma system two η-mesons were selected instead of π^0 and η. The mass spectrum for the $\pi^-\eta\eta'$ system is presented in fig.7. There is an enhancement at m≈1870 MeV. If the origin of this signal is the decay of the $A_1/\pi_2(1814)$ through the channel $\pi^-\eta'\eta$, then for the branching ratio of two channels we have $BR(\pi^-\eta'\eta)/BR(\pi^-\eta\eta)=0.3\pm0.1$.

The observed resonance cannot be unambiguously identified with the well established resonances [2]. There is a big difference in

masses between $\pi_2(1670)$ and the object observed which hinders this identification. This difference can not be described even if one introduces large orbital barrier factors, leading to the displacement of the π_2 peak.

However it is worth mentioning that in this mass region there was observed a complicated and ambiguously interpreted behaviour of wave 2^- in the reaction $\pi^-p\to\pi^-\pi^+\pi^-p$ [3].

In the $q\bar{q}$ scheme this object might have been a radial excitation of A_1 or π_2. However one should have expected a considerably larger width of the resonance in the first case, and a larger mass in the second. This fact and the indications to an unusually large $BR(\pi^-\eta'\eta)/BR(\pi^-\eta\eta)$ allow us to treat the observed object as a candidate for an exotic state.

This paper is the first publication of the results obtained at VES facility. Besides the authors of this paper, many other IHEP people made their contribution, and we are thankful to them.

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С.И.Битюков и др.

Наблюдение резонанса с массой m=1814 МэВ,
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Редактор А.А.Антипова. Технический редактор Л.П.Тимкина.

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Институт физики высоких энергий, 142284, Протвино
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