# Is the "h meson" a quasinuclear resonance?

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Arguments are advanced favoring a quasinuclear (nucleon-antinucleon) nature of the "h meson." The experimental consequences of this hypothesis are indicated.

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Experimental results indicating the discovery of a new meson resonance with approximate mass 2 GeV and approximate width 0.2 GeV were reported at the 1975 Palermo conference on high-energy physics.[1] The mass spectrum of the $2\pi^0$ system produced in the reaction

$$\pi^- p \to 2\pi^0 + X \tag{1}$$

was investigated experimentally in[2] at a $\pi^-$-meson momentum 40 GeV/$c$. The parameters of the resonances observed in this spectrum were

$$M = (2020 \pm 30)\,\text{MeV}; \quad \Gamma = (180 \pm 60)\,\text{MeV}.$$

Evidence of the existence of a boson resonance with close mass and width values, $M = 2050 \pm 25$ MeV and $\Gamma = 225^{+120}_{-70}$ MeV was obtained also in[3] in an analysis of the reaction

$$\pi^- p \to K^+ K^- n \tag{2}$$

($\pi^-$ momentum 18.4 GeV/$c$). Finally, a broad structure ($\Gamma \approx 200$ MeV) was observed also in the region of $M \approx 2000$ MeV in the energy dependence of the reaction[4]

$$\bar{p}p \to K^0 K^\pm \pi^\mp \tag{3}$$

It is quite probable that the new resonance, named "$h$ meson," is one of the quasinuclear mesons consisting of a nucleon and antinucleon ($N\bar{N}$) (see[5] and the references therein). A characteristic feature of resonances of the quasinuclear type ($N\bar{N}$) is their large partial width of decay via the $N\bar{N}$ channel: the ratio $\Gamma_{N\bar{N}}/\Gamma$ for these mesons is of the order of 0.1 to 1.

The results of[4] make it possible to estimate the order of the ratio $\Gamma_{p\bar{p}}/\Gamma = x$ of the new resonance. We have

$$x = \frac{\sigma}{(2J+1)}\,\frac{k^2}{\pi}\,\frac{\Gamma}{\Gamma_0}\,. \tag{4}$$

Here $J$ and $\Gamma$ are the spin and the total width of the resonance, $k$ is the momentum of $\bar{p}$ and $p$ in the c. m. s. at the resonance point, $\sigma$ is the cross section of the reaction (3) at resonance ($q = 150$ μb), and $\Gamma_0$ is the partial width of the decay via the $K^0K^\pm\pi^\mp$ channel. The ratio $\Gamma_0/\Gamma_a$ is equal to the ratio of the cross sections $\sigma_0(\bar{p}p \to K^0K^\pm\pi^\mp)$, and $\sigma_a$ (the total cross section for the annihilation form the states of $\bar{p}p$ with the quantum numbers of the given resonance. As an estimate we can assume that $\Gamma_0/\Gamma_a$ is equal to the ratio of the corresponding sections near resonance. These sections at the point $M = 2142$ MeV are equal to

  

$\sigma_0 = (0.252 \pm 0.014)$ mb [6], $\sigma_a = (68.3 \pm 1.8)$ mb [7].

For the quantity $x(1-x)(2J+1)$ we obtain from (4):

$$x(1-x)(2J+1) = 3.5\text{—}4.5. \tag{5}$$

According to the results[2] and[3], the spin and parity of the "$h$ meson" are $J^P = 4^+$. Putting $J=4$ in (5), we obtain $x \approx 0.5$. Since $\Gamma_{\bar{p}p} = (1/2)\Gamma_{N\bar{N}}$, it follows that $\Gamma_{N\bar{N}}/\Gamma = 2x \sim 1$, which corresponds to a meson of quasinuclear type. Values

$$x = 0.2\text{—}0.4, \tag{6}$$

which agree with the estimate (5), would lead to a resonance in the $\bar{p}p$ total cross section $\sigma_r = 15$ to 30 mb, which does not contradict the experimental data.[7]

Arguments confirming the correctness of the estimate (6) for the "$h$ meson" can be obtained also from an analysis of the experimental data on another resonance with mass 1932 MeV. This resonance was first obtained[8] in the total cross sections of $\bar{p}p$ and $\bar{p}d$, namely $M = 1932 \pm 2$, $\Gamma = (9^{+4}_{-3})$ MeV, and $\sigma = 18^{+3}_{+6}$ mb. Its existence was confirmed furthermore in the reaction $\bar{p}d \to p + m\pi$.[9] The cross section for elastic backward $\bar{p}p$ scattering yields an indication of the existence of two resonances near "1932", viz., $M_1 = 1923 \pm 3$, $\Gamma_1 = 29.6$ and $M_2 = 1953 \pm 2$, $\Gamma_2 = 29 \pm 9$,[10] and in the energy dependence of the charge-exchange $\bar{p}p \to \bar{n}n$, according to preliminary data,[11] there is no resonant behavior near the mass 1932. These two facts can be explained by taking interference effects into account.

The states $\bar{p}p$ and $n\bar{n}$ are superpositions of states with isospins 0 and 1 and with equal weights:

$$\bar{p}p = \frac{1}{\sqrt{2}}(|00\rangle - |10\rangle),$$

$$n\bar{n} = \frac{1}{\sqrt{2}}(|00\rangle + |10\rangle),$$

where $|00\rangle$ and $|10\rangle$ are the eigenvectors of the $|1.1_3\rangle$ isospin operator. The amplitude of the charge exchange $\bar{p}p \to n\bar{n}$ and of the elastic scattering $\bar{p}p \to \bar{p}p$ are, respectively

$$T_{ch} = \frac{1}{2}(T_0 - T_1),$$

$$T_{el} = \frac{1}{2}(T_0 + T_1),$$

where $T_0 = \langle 00|T|00\rangle$ and $T_1 = \langle 10|T|10\rangle$. Therefore in the cross sections of these reactions the amplitudes corresponding to different isospins interfere with one another. From the fact that the quantum numbers $J^P$ of the "$h$ meson" and of the resonance $N\bar{N}$ (1932) coincide (see[10]) and the isospins and $G$-parities are different ($I(1932) = 1$, since the resonance is observed also in the $\bar{p}n$ channel), we conclude that these two mesons will interfere in the elastic scattering and the charge exchange.

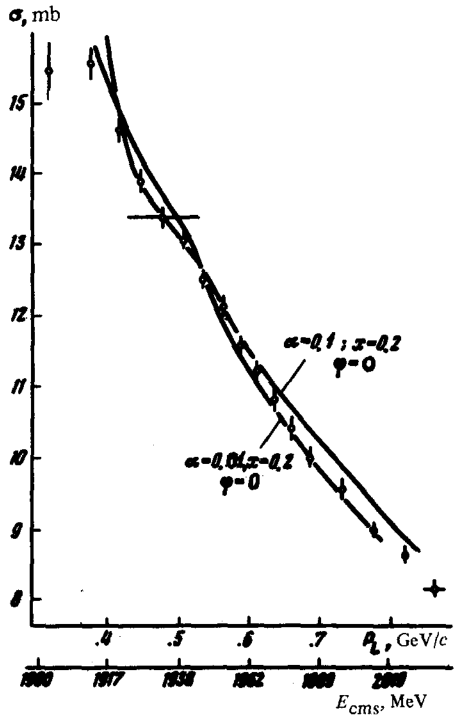


FIG. 1. Energy dependence of the $\bar{p}p \to \bar{n}n$ charge-exchange cross section. Experimental points—preliminary data from[11]. Solid curves—calculation with allowance for the interference between the resonances 1932 and 2020 and with the background. Parameters: $x = \Gamma_{\bar{p}p}/\Gamma$ of the resonance 2020, $\alpha$—fraction of the background amplitude with the quantum numbers $J^P = 4^+$, $\phi$—relative phase shift between the resonance amplitudes 1932 and 2020.

Figure 1 shows the theoretical plot of the charge-exchange cross section in the region of the 1932 resonance with allowance for the interference with the 2020 meson and with the background, under the assumption that the nonresonant amplitude is pure imaginary and that the cross section off resonance is $\sigma \sim 1/E$. The parameters used in the calculation were the elasticity of the $h(2020)$ resonance $(0.05 \leq x \leq 0.5)$. the fraction of the background amplitude interfering with the resonances $(0.01 \leq \alpha \leq 0.1)$ and the relative phase shift between the resonance amplitudes $(0 \leq \phi \leq \pi)$. It is impossible to draw unambiguous conclusions concerning the values of all these parameters from the available data: for example, when the interfering nonresonant amplitude is changed by a factor 10 the course of the curve changes little. However, a monotonic cross section can be obtained only when the elasticity of the $h(2020)$ resonance is of the order of or larger than the elasticity of $N\bar{N}(1932)$, which is equal to 0.179, and the phase between the resonance amplitudes is equal to zero.

Figure 2 shows curves calculated with the same values of the parameters as in Fig. 1, but the phase is reversed. As seen from the figure, reversal of the sign of the resonant part of the amplitude $T_1$ leads to a "splitting" of the resonances. This fact may explain (of course, only qualitatively) the energy dependence backward elastic $\bar{p}p$ scattering.[10] Both experiments can thus be explained without contradiction by the existence of an $N\bar{N}(2020)$ meson with values $x = 0.2$ to $0.4$.

It can be concluded that the existing data do not contradict the hypothesis that the $h$ meson is of the quasinuclear type. One more verification would be a

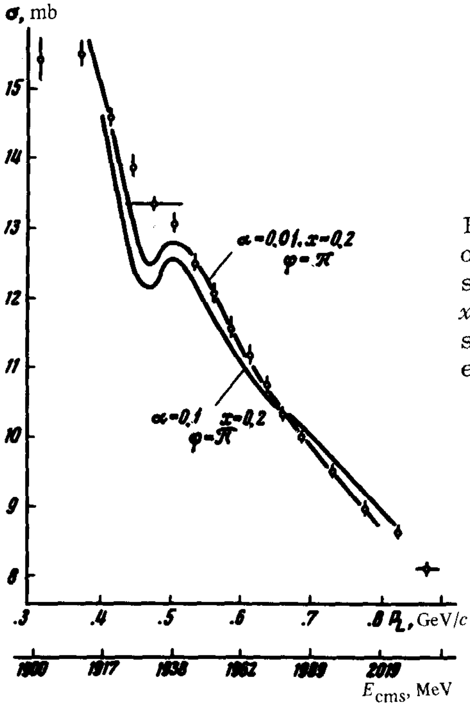


FIG. 2. Solid curves—calculation of the charge-exchange cross section with the same parameters $x$ and as in Fig. 1, but with opposite law governing the interference between the resonances.

measurement of the invariant mass of the $\bar{p}p$ system under the conditions of the experiments of[2] and[3]:

$$\pi^- p \rightarrow \bar{p}p + \dots . \tag{7}$$

In this case, if our hypothesis is correct, then a resonance will be observed in the mass spectrum of the $\bar{p}p$ produced in the reaction (7) and the cross section for its generation will be much larger than for the system $2\pi^0$ or $K^+K^-$, since two-meson decay modes are rare in annihilation, i.e., in quasinuclear resonances.


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