THE REACTION $\pi^-p \to \eta n$ AND "UNIVERSALITY" OF COMPLEX TRAJECTORIES

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Submitted 7 June 1971
ZhETF Pis. Red. 14, No. 2, 120 - 123 (20 July 1971)

It is usually assumed that the behavior of the amplitude of the reaction $\pi^-p \to \eta n$ at high energies is determined by the Regge pole corresponding to the A_2 meson. Such a simple model, however, predicts a zero polarization of the recoil nucleons, which contradicts the experimental data [1]. To get around this difficulty one adds to the contribution of the A_2 pole the contributions of the effective trajectories of the type π_c [2, 3], or else cuts are taken into account [3, 4].

A number of authors have recently advanced the hypothesis that the Regge trajectories at $t < 0$ are complex [5] and the scattering amplitude at high energies can be effectively parametrized by pairs of complex-conjugate Regge poles [6].

In the present paper we use this parametrization to analyze the experimental data on the reaction $\pi^-p \to \eta n$. As will be shown below, the assumption that the A_2 trajectory is complex (at $t < 0$) makes it possible to obtain the correct value of the polarization and to satisfy the entire set of experimental data for the differential cross section. We note also that a complex A_2 trajectory does not give rise to the problem of the "ghost" at $t \simeq 0.5 - 0.6$ $(\mathrm{GeV/c})^2$ (where, by assumption, $\alpha_{A_2}(t) = 0$), for in this case the signature factor has no pole.

It seems to us that the attraction of the model of complex poles for a phenomenological description of scattering depends to a considerable degree on whether the complex trajectory $\alpha(t)$ is universal (i.e., independent of the external particles). Since $\mathrm{Im}\alpha(t)$ is determined by the dynamics of the interaction of the trajectory and its "accompanying" cut, the universality is not obvious beforehand.

Let us assume that the universality does take place and, in particular, the trajectories of the ρ and A_2 mesons in the processes $\pi^-p \to \pi^0 n(\rho)$ and $\pi^-p \to \eta n(A_2)$ coincide with the trajectories determining the reaction $K^+N \to K^0p(-\rho + A_2)$. If we now take into account the exotic nature of the latter reaction, we arrive at the condition

$$\mathrm{Re}\,\alpha_\rho(t) = \mathrm{Re}\,\alpha_{A_2}(t);\ \mathrm{Im}\,\alpha_\rho(t) = \mathrm{Im}\,\alpha_{A_2}(t) \qquad (1)$$

which is analogous to the condition of exchange degeneracy for real trajectories.

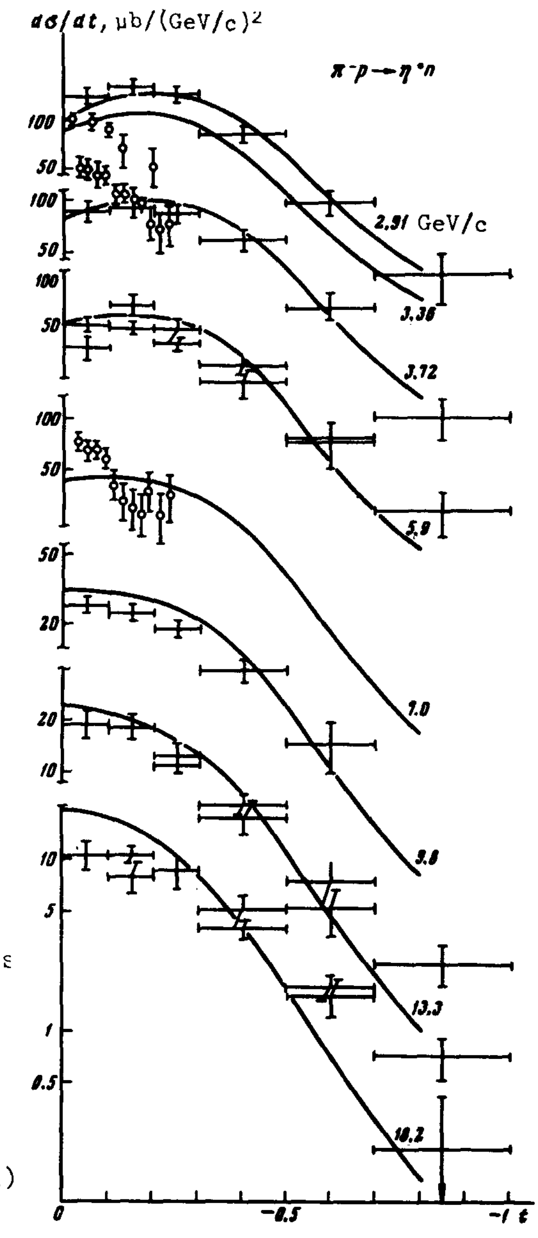

Fig. 1

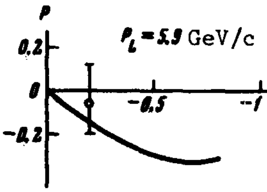

Fig. 2

Starting from this, we shall use for the trajectory of the A_2 meson the values obtained in [7] for the ρ trajectory

$$\mathrm{Re}\,\alpha(t) = 0.55 + t; \quad \mathrm{Im}\,\alpha(t) = \frac{1}{2}\sqrt{\frac{t}{t - 4\mu^2}}. \tag{2}$$

The helicity amplitudes $G_{+\pm}(s, t)$, which describe the process $\pi^- p \to \eta n$, will be parametrized as follows:

$$G_{+\pm}(s,t) = [a_\pm e^{-i\pi\alpha/2}\nu^{\alpha} + a_\pm^* e^{-i\pi\alpha^*/2}\nu^{\alpha^*}]\,\nu^{(\frac{-1\pm1}{2})}. \tag{3}$$

To find the moduli $|a_\pm|$ and the phases $\phi_\pm$ of the residues, we use the sum rules with continuous angular momentum [7]:

$$I_\pm(t,\delta) = \int_0^N \mathrm{Im}\{\nu G_{++},\ G_{+-}\}\,\nu^\delta e^{-i\pi\delta/2}\}\,d\nu = -\frac{2|a_\pm|N^{\alpha_R+\delta+1\pm1}}{\sqrt{(\alpha_R+\delta+1\pm1)^2+\alpha_I^2}}$$

$$\times[\sin^2\frac{\pi}{2}(\alpha_R+\delta) + \mathrm{sh}^2\frac{\pi\alpha_I}{2}]\cos\psi, \tag{4}$$

$$\psi = \phi_\pm + \alpha_I \ln N - \mathrm{arctg}\frac{\alpha_I}{\alpha_R+\delta+1\pm1} + \mathrm{arctg}\frac{\mathrm{th}\frac{\pi\alpha_I}{2}}{\mathrm{tg}\frac{\pi}{2}(\alpha_R+\delta)}. \tag{5}$$

Knowing the zeroes $\delta_\pm$ of the left side of (4) we can easily obtain the phases $\phi_\pm$ from (5). Then $|a_\pm|$ is determined in terms of $I_\pm(\delta)$ for any δ.

We used for $I_\pm(\delta)$ the values obtained in [3], where the left-hand sides of the sum rules were calculated using phase-shift analysis data ($N \simeq 2.4$ GeV). With the aid of the obtained quantities $|a_\pm(t)|$ and $\phi_\pm(t)$ we calculated the cross section of the polarization of the process $\pi^- p \to \eta n$, which are shown in Figs. 1 and 2.

The experimental data for the differential cross sections were taken from [8], and the data for small t from [9] (3.36 and 7 GeV) and from [10] (4 GeV). We note that in the region of small t there is a discrepancy between the experimental values obtained by different groups. We see that the theoretical curves describe well the data at $t < -0.2$. We emphasize that to determine the parameters we used (with the aid of the sum rules) only the low-energy data, and the differential cross sections on the polarization at high energies were predicted. Of course, the agreement can be improved by matching the model to these data.

Thus, the results show that the initial assumptions concerning the complexity (at $t < 0$) of the A_2 trajectory and the universality of the complex trajectories does not contradict the experimental data. For further verification of the model it is desirable to reconcile the experimental data on the cross section in the region of small $t(|t| \lesssim 0.2)$ and to measure the polarization of the recoil nucleons.

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ELECTROPRODUCTION OF PIONS ON NUCLEI IN BOUND STATES

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Submitted 10 June 1971
ZhETF Pis. Red. 14, No. 2, 124 - 127 (20 July 1971)

It is known that study of π-mesic atoms is one of the most sensitive methods of investigating the structure of the nucleus [1]. However, the usual method of formation of π-mesic atoms by capture of stopped (stopping) pions has one fundamental shortcoming. The point is that the probability of the capture of the pion by the nucleus increases with Z more rapidly than the probability of the radiative transition, and therefore, starting with a certain Z, transitions to states with lower orbital angular momentum cannot be seen. Thus, for example, the 2p - 1s transition is indiscernible already starting with Z = 12, and the transition 3d - 2p starting with Z = 27 [1]. Yet greatest interest attaches to just the levels with small ℓ and n, since their parameters are most sensitive to the interaction of the pion with the nucleus. It is therefore meaningful to consider an experiment on the production of a pion immediately in the bound state of the mesic atom. This experiment supplements all the available experiments and makes it possible to obtain data on the s-levels of mesic atoms with large Z.

The photoproduction of the π-mesic atom was considered in [2]. However, to register the production of the mesic atom it is more convenient to use the electroproduction process, because in this case the levels of the mesic atom correspond to the peaks in the energy distribution of the scattered electrons. The widths of these peaks amount to several dozen keV, and therefore for such an experiment it is necessary to have a beam of electrons with high monochromaticity. The most realistic, apparently, is the performance of the experiment with storage rings with internal gas target [3].

The cross section of this process is given by

$$\frac{d^2\sigma}{d\nu d\Omega} = \frac{2\alpha^2 f^2}{\mu^3 |q^2|}\frac{E'}{E}\left[|m_\perp|^2\left(\frac{E'E\cos^2\frac{\theta}{2}}{q^2} + \frac{1}{2}\right) + |m_\parallel|^2\frac{|q^2|}{\nu^2}\frac{2E'E\cos^2\frac{\theta}{2}}{q^2}\right]\frac{\Gamma_n}{\left(\nu + W_n - \mu - \frac{q^2}{2M^*}\right)^2 + \frac{\Gamma_n^2}{4}}, \quad (1)$$