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VIRTUAL EXCITATION OF NUCLEON ISOBARS IN NUCLEI AND REACTIONS OF QUASIELASTIC "KNOCKOUT" OF ISOBARS OF HIGH ENERGIES

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The role of nucleon resonances (isobars) in the description of nuclear properties and interactions was discussed earlier in connection with the calculation of the nucleon-nucleon potential [1, 2], the binding energy of nuclei [3], electromagnetic [4] and weak [5] coupling constants, and also in connection with a description of certain nuclear reactions [6, 7].

The purpose of the present article is to propose a new method of experimentally verifying the existence of isobars in nuclei on the basis of a study of the formation of isobars in reactions where high-energy hadrons interact with nuclei.

Let us list first certain experimental facts pertaining to the isobar-production reactions [8, 9]

$$\text{hadron} + N \rightarrow \text{hadron} + N^* \ (\Delta), \tag{1}$$

and which will serve as a basis for subsequent analysis.

1. The cross sections for the production of N*-isobars with isospin I = 1/2, namely N*(1420), N*(1520), and N*(1690), vary slowly with increasing energy in πN and NN reactions of type (1), and the cross section for formation of Δ(1238) with isospin I = 3/2 decreases rapidly (approximately like E_{lab}^{-1}, where E is the energy of the incident particle).

2. The cross sections for the production of N*-isobars at zero angle are small compared with the cross section for elastic scattering

$$\frac{d\sigma(N(\pi) + N \rightarrow N(\pi) + N^*)}{d\sigma(N(\pi) + N \rightarrow N(\pi) + N)} \approx 10^{-2}. \tag{2}$$

3. The diffraction-cone slopes

$$B = \frac{d}{dt}\left(\ln \frac{d\sigma}{dt}\right)\bigg|_{t=0}$$

for πN and NN reactions of type (1) satisfy the relation

$$B(N^*(1420),\ \Delta(1238)) : B_{el} : B(N^*(1520),\ N^*(1690)) = 2 : 1 : 0.6. \tag{3}$$

Let us consider now the formation of isobars in interactions of hadrons with nuclei.

One can expect virtual excitation of the isobars to occur, with a certain probability, in the bound state of the nucleus, i.e., the nucleons and the nucleon resonances can be regarded as "partons," making up the nucleus. The interaction of the incident hadron with the nucleus is determined by the interaction with all the "partons" of the nucleus. Obviously, the mechanism of "knocking out" the isobars from the nuclei will contribute to the total cross section of isobar production.

Starting from the additive quark model, we assume that the amplitudes for elastic scattering of the hadron by a nucleus and by an isobar in the region of the diffraction peak are approximately equal to each other;

$$T\ (\text{hadron} + N \rightarrow \text{hadron} + N) \simeq T\ (\text{hadron} + N^*\ (\Delta) \rightarrow \text{hadron} + N^*\ (\Delta)) \qquad (4)$$

If the probability for the existence of nucleon isobars in the deuteron is approximately 1% (a value of this order is given by estimates [4, 7] for the $\Delta\Delta$ configuration), then we obtain the following experimental consequences:

1) The ratio of the cross section for the production of two Δ resonances on a deuteron

$$\text{hadron} + d \rightarrow \text{hadron} + \Delta^{++(0)} + \Delta^{-(+)} \qquad (5)$$

to the cross section for elastic scattering of the given hadron by the nucleon will be approximately equal at all energies and momentum transfers. At sufficiently high energies ($E_{lab} \gtrsim 15$ GeV), the cross section (5) will exceed the cross section for the production of one isobar:

$$\text{hadron} + d \rightarrow \text{hadron} + \Delta^{+(0)} + n(p). \qquad (6)$$

2) By virtue of relations (2) and (4), the cross section for the production of N*-isobars on a deuteron should exceed the expected cross section for the production on a quasi-free nucleon, as calculated with allowance for corrections for multiple scattering.

3) By virtue of (3), the difference between the total cross section for the production of $\Delta(1238)$ and N*(1420) and the value predicted by the usual mechanism of production on quasi-free nucleons (i.e., neglecting the contribution from the "knockout" reaction) should increase with increasing momentum transfer $|t|$, and should decrease, to the contrary, for N*(1520) and N*(1690).

4) The effects of averaging of the Fermi motion of the momenta (for example, the effective broadening and smoothing of the resonance curves), should be more pronounced for the mechanism of "knocking out" isobars from nuclei, since the characteristic momenta of the configuration $d \leftrightarrow N + N^*$, $\Delta + \Delta$ is much larger than the average momentum of the usual configuration $d \leftrightarrow N + N$.

5) The "knockout" mechanism can possess certain singularities of the spin dependences of the processes of elastic scattering in the high-energy region - for example, conservation of helicity in the direct channel of the reaction [10]. In this case, the angular distributions of the products of the nucleon resonances will not depend on the azimuthal angle in the c.m.s. of the direct channel.

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SPLITTING OF A_2 MESON

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Considerable interest attaches to the question of the nature of the experimentally observed [1] splitting of the maximum of the A_2 resonance [2]. Attempts to explain this phenomenon with the aid of two closely-lying resonances with identical quantum numbers [1, 3] or a dipole [1, 4] encounter certain difficulties in view of the recently reported experiments [5], in which no splitting of the A_2 meson was observed. We note in the present paper that the available experimental data can be explained if it is assumed that there exists a strong destructive interference between the A_2 resonance and the background.

When the A_2 meson is produced in the reactions $\pi^{\pm}p \to A_2^{\pm}p \to \rho^0\pi^{\pm}p$, (1), the mass spectra of the $\rho^0\pi^{\pm}$ systems indicate the existence of a considerable background under the A_2 peak (see Fig. 1). The A_2 meson has quantum numbers $I^P = 2^+$ [6], i.e., it corresponds to the d-wave of the $\rho\pi$ system, and the greater part of the background is apparently in other partial waves - for example, the s-wave. There are no grounds at all, however, for assuming that the background in the d-wave is not small. In this connection, we write down the amplitude for the production of the $\rho\pi$ system in the reaction (1) in the form (we can consider in similar fashion the production of A_2 in other processes and its transitions to the channels $K\bar{K}$ and $\eta\pi$)

$$T(M, s_i, t_i) = g(M, s_i, t_i)\left[\frac{\Gamma/2}{M_{A_2} - M - i\frac{\Gamma}{2}} + a(M, s_i, t_i) + i\beta(M, s_i, t_i)\right], \qquad (1)$$

where

$$M = s_{\rho\pi}^{1/2} = \sqrt{(E_\rho + E_\pi)^2 - (\mathbf{p}_\rho + \mathbf{p}_\pi)^2}$$

is the invariant mass of the $\rho\pi$ system, and s_i and t_i are the other invariant variables, on which the amplitude of the reaction may depend. The form of this relation is thus far immaterial to us.

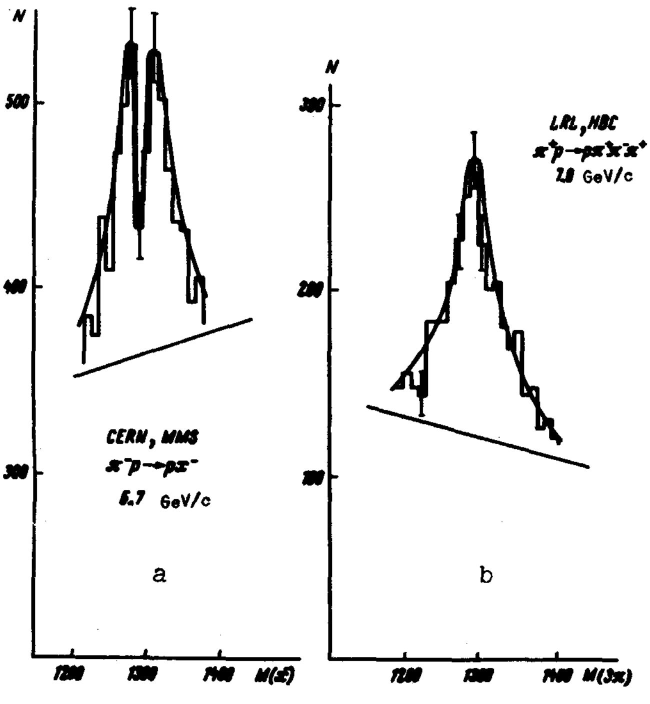

Fig. 1. Mass distributions in the region of the A_2 resonance: a - $\pi^-p \to px^-$ at $p_{\pi^-} = 6.7$ GeV/c [1], b - $\pi^+p \to p\pi^+\pi^-\pi^+$ at $p_{\pi^+} = 7.0$ GeV/c [5].

It is assumed that the functions $g(M, s_i, t_i)$, $\alpha(M, s_i, t_i)$,