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VIRTUAL EXCITATION OF NUCLEON ISOBARS IN NUCLEI AND QUASI-ELASTIC "KNOCKING-OUT" OF ISOBARS AT HIGH ENERGIES

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Виртуальное возбуждение нуклонных изобар в ядрах и реакции квазиупругого "выбивания" изобар при высоких энергиях

В качестве средства экспериментального обнаружения виртуального возбуждения нуклонных резонансов в ядрах предлагается изучение реакций образования нуклонных резонансов при столкновениях высокоэнергетических адронов с ядрами. Обсуждаются качественные особенности сечений квазиупругого "выбивания" изобар из ядер.

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Virtual Excitation of Nucleon Isobars in Nuclei and Quasielastic "Knocking-out" of Isobars at High Energies

The isobar production in the hadron-nucleus collisions at high energies is proposed as a possible experimental test of the virtual excitation of isobars in nuclei. The qualitative features of the quasielastic "knocking-out" of isobars from nuclei are discussed.

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The role of the nucleon resonances (isobars) in the description of the nuclear properties and interactions has been discussed in many papers, dealing with the calculation of the nucleon-nucleon potential [1,2], the nuclear binding energy [3], the nuclear electromagnetic [4] and weak [5] formfactors and the nuclear reactions [6,7].

The aim of this note is to propose a new experimental test of the "existence" of isobars in nuclei, making use of the isobar production in the hadron-nucleus reactions at high energies.

We begin with listing some empirical facts concerning the isobar production reactions

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

which will serve as the basis for the subsequent consideration. It is known experimentally [8,9], that:

1) The production cross sections of the $N^*(1420)$, $N^*(1520)$ and $N^*(1690)$ (i.e. the isospin -1/2 isobars belonging to the natural parity series) vary slowly with energy in the πN, NN -reactions, schematically represented by Eq. (1) while the $\Delta(1240)$ production (which is well-known isospin - 3/2 isobar) decreases rapidly (like E_{lab}^{-1}) with increasing projectile energy E_{lab}.

2) The N^*'s production in the forward direction is by about two orders of magnitude weaker as compared to the corresponding elastic cross sections:

$$\frac{d\sigma\,(N(\pi)+N \rightarrow N(\pi)+N^*)}{d\sigma(N(\pi)+N \rightarrow N(\pi)+N)} \cong 10^{-2} \qquad (2)$$

3) The logarithmic slopes of the differential cross sections

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

in the πN and NN-reactions given by Eq. (1), satisfy approximately the following relation:

$$B(N^*(1420),\ \Delta(1240)) : B_{el} : B(N^*(1520),\ N^*(1690)) \cong 2 : 1 : 0{,}5, \qquad (3)$$

where B_{el} is the slope of the elastic πN or NN -scattering. Let us turn now to the isobar production in the nuclear reactions at high energies.

It appears reasonable to expect, that the virtual excitation of the nucleon resonances will take place inside a nucleus with some small (but non-zero) probability due to the *N-N* interaction in the bound state. Hence, both nucleons and nucleon isobars may be considered, in a sence, as "partons" composing given nucleus. The incident high-energy hadron will scatter on all nuclear "partons". We conclude therefore that the quasi-elastic "knocking-out" of isobars from nuclei should contribute to the total cross section of the isobar production on the nuclear targets.

What kind of the observable effects will the presence of the "knocking-out" mechanism produce? How one can notice it in the "background" of the dominant isobar production on the quasi-free nucleons?

At this point we make additional dynamical assumption which can be justified within the quark model of the high-energy hadron scattering

$$T(\text{hadron} + N \to \text{hadron} + N) \cong T(\text{hadron} + \Delta(N^*) \to \text{hadron} + \Delta(N^*)), \qquad (4)$$

namely, we assume, that scattering amplitudes of a nucleon and isobar from given hadron are approximately equal to each other in the diffraction region.

For the sake of definiteness and simplicity we shall speak further about the particular case of the hadron-deuteron reactions.

If all assumptions we made are valid and if the probability to meet the isobars in the bound state of deuteron is of the order of 1% (this estimate was obtained recently for the $\Delta\Delta$ -configuration /4,7/), then we are able to make the following qualitative and testable predictions:

1. At sufficiently high energies ($E_{lab} \gtrsim 15$ GeV) the production cross section of two Δ's from deuteron

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

will exceed the single Δ -production

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

and furthermore the ratio of the cross section given by Eq. (5) to that of the elastic scattering of given hadron from nucleon should be approximately of the same value in the diffraction region.

2. By virtue of Eqs (2) and (4) the N^* -production in the forward direction should exceed the expected value, corresponding to the production on the quasi-free nucleons (i.e. neglecting the "knocking-out" mechanism).

3. In view of Eq. (3) the deviation of the experimental data from theoretical models, which do not include the "knocking-out" contribution, should increase (decrease) for the Δ (1240) and N^* (1420) (N^* (1520), N^* (1690)) - production with increasing momentum transfer $|t|$.

4. The Fermi-motion effects (resulting in effective broadening and smoothing of the resonance curves) should display itself stronger in the quasi-elastic "knocking-out" of the isobars from nuclei, inasmuch as the average momentum in the "isobar" configuration ($d \leftrightarrows NN^*$, $\Delta\Delta$)

should be much larger than that of the dominant configuration ($d \rightleftarrows pn$).

5. As a particular example of the elastic scattering, the "knocking-out" process is expected to exhibit the s-channel helicity conservation /10/. Should it be the case, the angular distribution of the isobar decay products would not depend on the azimuthal angle in the s-channel c.m. system /11/.

To conclude, the confirmation of the existence of isobars in nuclei would be of a great importance as an impetus for the development of new field of the relativistic nuclear physics.

The experimental study of the reaction (5) is particularly interesting and important for the verification of our basic assumption concerning the very existence and nuclear interactions of isobars in the bound state of nuclei.

The reactions using the beams of the deuterons and other lightest nuclei accelerated up to high energies may be of relevance to this end.

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