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ON CONTRIBUTION OF THE QUASIDEUTERON MECHANISM IN THE CUMULATIVE PHOTOPRODUCTION OF PROTONS

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ԿՈՒՄՈՒԼՅԱՏԻՎ ՊՐՈՏՈՆՆԵՐԻ ՖՈՏՈԾՆՄԱՆ ԳՈՐԾԸՆԹԱՑՈՒՄ ՔՎԱԶԻԴԵՅՏՐՈՆԱՅԻՆ ՄԵԽԱՆԻԶՄԻ ՆԵՐԴՐՄԱՆ ՄԱՍԻՆ

Հաշվված են ինչպես առաջնային ֆոտոններով, այնպես էլ երկրորդային ցածր էներգիայի պիոններով միջուկում քվազիդեյտրոնների ծեղքմամբ պայմանավորված կումուլյատիվ պրոտոնների ֆոտոծնման ելքերը: Ցույց է տրված, որ դիտարկվող մեխանիզմների գումարային ներդրումը E_γ^{max} = 4,5 ԳէՎ դեպքում կարող է կազմել ^{12}C միջուկից կումուլյատիվ պրոտոնների չափված ելքերի մոտավորապես 25-ից /պրոտոնների էներգիան ≤ 100 ՄէՎ/ մինչև 5 տոկոսը / ≥ 200 ՄէՎ/ :

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Երևան 1987

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О ВКЛАДЕ КВАЗИДЕЙТРОННОГО МЕХАНИЗМА В ПРОЦЕССЕ ФОТООБРАЗОВАНИЯ КУМУЛЯТИВНЫХ ПРОТОНОВ

Вычислены выходы фотообразования кумулятивных протонов, обусловленные расщеплением квазидейтронов в ядре как первичными фотонами, так и вторичными малоэнергичными пионами. Показано, что суммарный вклад рассматриваемых механизмов может составить от 25 % (при энергии протонов $\leq$ 100 МэВ) до 5 % ($>$ 200 МэВ) экспериментально измеренных выходов кумулятивных протонов из ядра ^{12}C при E_{γ}^{max} = 4,5 ГэВ.

Ереванский физический институт

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M.J. AMARIAN, R.A. DEMIRCHIAN, M.S. OHANJANIAN,
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ON CONTRIBUTION OF THE QUASIDEUTERON MECHANISM IN THE CUMULATIVE PHOTOPRODUCTION OF PROTONS

The yields of the cumulative proton photoproduction due to disintegration of the quasideuteron in a nucleus by both incident photons and secondary low-energy pions are calculated. It is shown that the total contribution of the mechanisms considered can make from 25% (at the proton energy $\leqslant$ 100 MeV) to 5% ($\geqslant$ 200 MeV) of the experimentally measured yield of cumulative protons from a ^{12}C nucleus at E_{γ}^{max}= 4.5 GeV.

Yerevan Physics Institute
Yerevan 1987

Introduction

A number of theoretical models are proposed to explain the production mechanism of cumulative particles. According to their basic principles these models can be grouped into two categories: models based on secondary interactions [1-3] and ones based on direct interaction mechanisms [4-6]. For the complete understanding of the cumulative particle (CP) production one must determine the possible contributions from all the models.

One of the sources of the CP production is the interaction of the incident particle with the intranuclear nucleon formations. The range of the characteristics of such formations is a very wide one as in a nucleus there can be realized different states of different numbers of nucleons. The first and the simplest state considered still in 1951 by Levinger [7] for explanation of photoproduction from nuclei by up to 200 MeV γ-quanta, is the proton-neutron correlation with a deuteron's wave function - the so-called quasideuteron.

The quasideuteron disintegration, as a result of which a cumulative nucleon is produced, can be realized either directly by incident photons or by the secondary products of its interaction with the nucleus material. The first process, naturally, is an example of direct models, while the second one is a typical example of a model based on secondary interactions.

In the case of CP photoproduction two channels of the quasideuteron splitting are strongly distinguished by their character. Hence, they must be considered separately. In this work we are trying to estimate the mentioned two mechanisms of the CP photoproduction on ^{12}C nucleus at $E_{\gamma}^{max} = 4.5$ GeV [9-10]. The results of these calculations have been reported at the third all-union conference on limitting fragmentation of nuclei held in Nor-Amberd in 1984.

1. The Contribution of the Quasideuteron Photodisintegration to the CP Production

The problem of the quasideuteron photodisintegration with detection of the reaction products (one or two nucleons in coincidence) was quite detailly investigated in the 60-ies. The most important result obtained is that with the increasing energy of γ-quanta the contribution of the quasideuteron photodisintegration strongly decreases and may be neglected at ~ 1 GeV. However, this statement must be considered as valid in the whole kinematic region. In the kinematically forbidden for the free nucleon region, where the yield of photonucleons is highly suppressed as compared to the kinematically permitted region, it may turn out that the contribution of the quasideuteron photodisintegration is not so small. This is especially important, as the process of the cumulative photoproton production is mainly investigated by the bremsstrahlung γ-quanta. So, consider the reaction

$$\gamma + "d" \rightarrow P_K + n \quad (1)$$

Where "d" is the quasideuteron, P_K is the cumulative proton. The expression for the yield of this reaction reads

$$f = L \frac{NZ}{A} \iint G \cdot |M|^2 \cdot W \cdot F \cdot d^3 P_d \, dE_\gamma , \quad (2)$$

where $/M/^2$ is the matrix element of the elementary process (2); $W(E_\gamma^{max}, E_\gamma)$ is the spectrum of bremsstrahlung γ-quanta; $F(P_d)$ is the momentum distribution of the quasideuterons in the nucleus-target; $G(E_\gamma, \vec{P}_d)$ is the kinematic factor. The matrix element $/M/^2$ is expressed through the measured cross sections of the photodisintegration of real deuterons [11-13], which we extrapolated up to 4.5 GeV. The momentum distribution $F(P_d)$ too is taken from the available experimental data [14]. Important is the problem of the value of the Levinger number L, the essence of which is [15] how much the pairing of two nucleons is intensified if they are in a nuclear medium as compared to the pairing in vacuum, i.e. in a real deuteron. The experimental value of L varies in a wide range (3÷10) which, apparently, is due to the use of photons of different energies. Apparently, the intensity of disintegration must increase with the energy, inasmuch as on one hand new channels of such disintegration (by secondaries) are involved, and on the other hand new stages of correlations are involved which differ from the classical quasideuteron. Hence, most correct must be considered the value of L found at E_γ = 100÷200 MeV, where the quasideuteron mechanism is the only source of photonucleons (at $E_\gamma >$ 100 MeV the giant resonance and the nuclear photoeffect have no contributions, and at $E_\gamma <$ 200 MeV the contribution of the new, powerfull channel of the pion photoproduction can be neglected). So, we took L = 2.5 found from the fit of the experimental dependence $f_p(E_\gamma^{max})$ [16] in the range of E_γ^{max} = 100÷250 MeV (see fig.1). The integral (3) was numerically calculated for ^{12}C at E_γ^{max} = 4.5 GeV. The results of calculations are presented in fig.2 . As it is seen, the absolute values of the calculated cross sections are much smaller than the experimental ones. It can be found that the contribution of the quasideuteron photodisintegration to the production of cumulative photoprotons does not exceed 5% for ^{12}C in the considered energy range of CP.

2. Contribution of the Pion Absorption by the Quasideuteron in the Cumulative Photoproton Production

At γ-quantum energies above the photoproduction threshold, a new mechanism reveals itself in the framework of the quasideuteron model

$$\begin{array}{l} \gamma + \text{"}N\text{"} \rightarrow \pi + \ldots \\ \quad\quad\quad\quad \hookrightarrow \pi + \text{"}d\text{"} \rightarrow p + N , \end{array} \quad (3)$$

when the pion produced in the photon-intranuclear nucleon "N" interaction may be absorbed by the quasideuteron and split it with a proton escaping from the nucleus. This proton may appear in the kinematically forbidden for the free nucleon region, i.e.

be a cumulative one.

For calculation of the reaction (3) the our obtained experimental spectra (energy and angular) of pions have been used at the same initial energies and nucleus-target [17-18]. However, it is necessary to correct these spectra for absorption in the nucleus in order to restore the "real" spectra of the pions from the first stage of the reaction (3). It can be done by using the investigated in ref. [19] A-dependences of the pion yields. When representing the yields versus A by $f_{\pi} \sim A^{n(\vartheta,T)}$, the spectra of pions produced on the intranuclear nucleons will read

$$f_{\pi} = A^{1-n} \cdot f_{\pi exp} , \qquad (4)$$

where $f_{\pi exp}$ are the measured spectra.

The dependences of n on the energy and angle of emergence of pions are given in ref. [19] . Assume that the absorption of pions takes place only due to the quasideuteron splitting, the cross section of which is mainly centred in the region of up to 280 MeV. According to [19] in this region $n < 1$ for all angles. The cross section of the pion absorption by the quasideuteron is taken from refs.[20,21] .

Calculations are carried out by the Monte-Carlo method. The quasideuteron momentum distribution from ref.[14] was used. Like in the case of the quasideuteron photodisintegration, the Pauli principle and the nuclear potential well for nucleus were taken into account. The experimental angular distributions of photoprotons from ^{12}C nucleus at $E_{\gamma}^{max} = 4.5$.GeV and the corresponding results of the present calculations are shown in fig.3 . As it is seen, in most of the cases the calculated data do not agree both in the form and absolute value. As to the absolute values, at the proton energies 80÷100 MeV the contribution of the mechanism presented can not exceed 25%. For higher energies (say, 200 MeV) the contribution decreases down to 5 ÷ 10%.

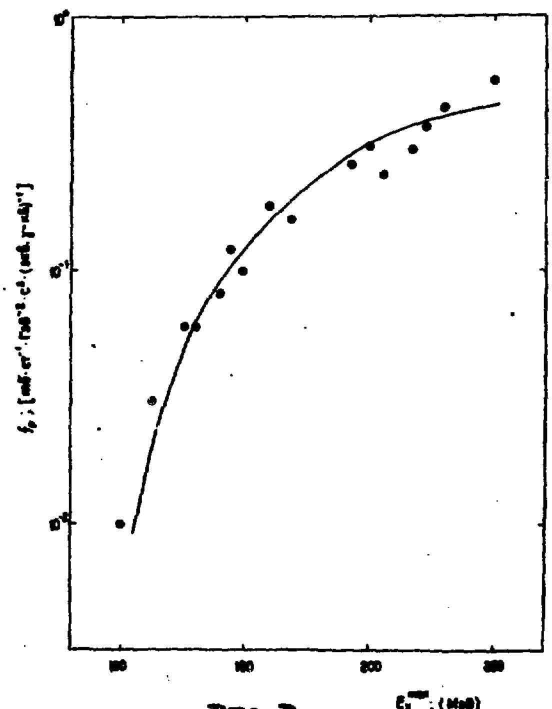

РИС.1

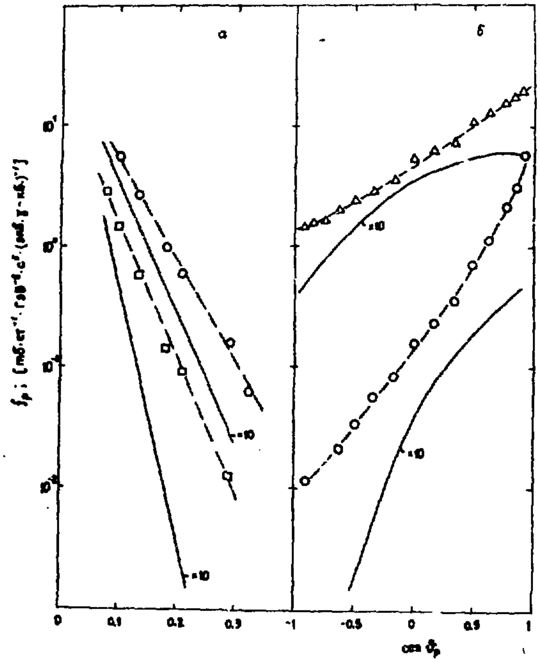

Рис.2

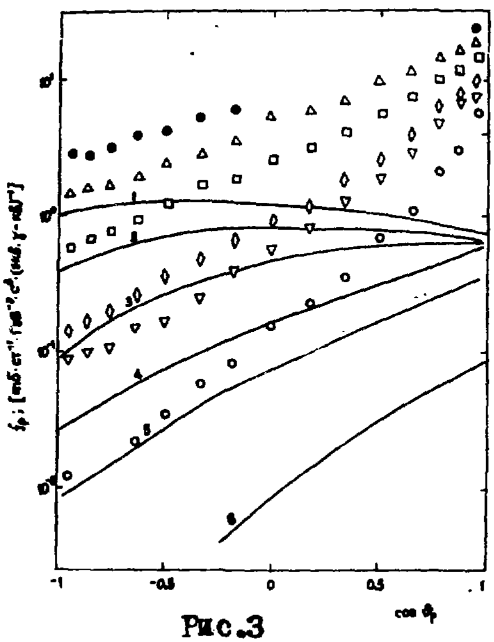

Рис.3

Figure Captions

Fig.1 The yield of $\gamma C \rightarrow pX$ versus E_γ^{max} at T_p = 83 MeV and = 60°. The experimental points ● are taken from ref.[16]. The solid line shows the calculation of the quasideuteron photodisintegration.

Fig.2 The proton spectra in $\gamma C \rightarrow pX$;

a) energy spectra at ϑp = 90° (o) and 160° (□),

b) angular spectra at T_p = 100 MeV (Δ) and 287 MeV(o)

Fig.3 Angular spectra of proton yields from ^{12}C nuclei at E_γ^{max} = 4.5 GeV. The experimental points are from refs. [9,10]. The solid curves (1 ÷ 6) show the results of the Monte-Carlo calculations in the model of absorption of pions by quasideuterons for the proton energies 80 MeV (●) (1); 100 MeV (Δ) (2); 136 MeV (□) (3); 180 MeV (◊) (4); 210 MeV (∇) (5) and 287 MeV (o) (6), respectively.

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О ВКЛАДЕ КВАЗИДЕЙТРОННОГО МЕХАНИЗМА В ПРОЦЕССЕ ФОТООБРАЗОВАНИЯ
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