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THE (e,e′p) REACTION ON ^{12}C WITH BACKWARD PROTONS

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ԿՈՒՄՈՒԼՅԱՏԻՎ ՊՐՈՏՈՆՆԵՐՈՎ (e,e′p) ՌԵԱԿՑԻԱՆ ^{12}C ՄԻՋՈՒԿԻ ՎՐԱ

Ներկայացվում են միջուկների սահմանային էլեկտրաֆրագմենտացիայի հետազոտմանը նվիրված առաջին փորձարարական տվյալները՝ ստացված կումուլյատիվ պրոտոններով ուղեկցված $e + {}^{12}C \longrightarrow e' + p + X$ ռեակցիայի միջոցով: Այդպիսի պրոցեսները կարևոր ինֆորմացիա են կրում միջուկային նյութի տարբեր ազատության աստիճանների մասին: 2 ԳէՎ սկզբնական էներգիայի ժամանակ ուսումնասիրվել են վերը նշված ռեակցիայում 15°-ի տակ ցրված էլեկտրոնների էներգետիկ սպեկտրները՝ կախված $66-140^{\circ}$-ի տակ ծնված և 80-200 ՄէՎ էներգիայով օժտված պրոտոնների կումուլյատիվության աստիճանից: Ստացված փորձարարական տվյալները.ըստ երևույթին վկայում են ետ թռչող պրոտոնների առաջացման սպեկտատորային մեխանիզմի օգտին:

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The (e,e′ p) REACTION ON ^{12}C WITH BACKWARD PROTONS

The first experimental results on investigation of limiting nuclear fragmentation in the reaction $e + {}^{12}C \longrightarrow e' + p + X$ with backward (cumulative) protons are presented. Such processes carry a direct information about different degrees of freedom of nuclear matter.The energy spectra of the scattered electrons (at incident energy 2 GeV and scattering angle 15°) in dependence with the "cumulativity" of the coincidence proton (in angular region $66-140^{\circ}$ and with energy 80 - 200 MeV) was studied.The experimental data obtained gives a strong argument in favour of the Spectator Mechanism of the backward proton production.

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РЕАКЦИЯ (e,e'p) НА ЯДРЕ ^{12}C С КУМУЛЯТИВНЫМ ПРОТОНОМ

Приведены первые экспериментальные результаты по исследованию предельной фрагментации ядер в реакции $e + {}^{12}C \longrightarrow e'+p+X$ с летящими назад (кумулятивными) протонами. Такие процессы дают прямую информацию о различных степенях свободы ядерной материи. Изучались энергетические спектры рассеянных электронов (при начальной энергии 2 ГэВ и угле рассеяния 15^{0}) в зависимости от "кумулятивности" протонов совпадения (в угловом интервале $65-140^{0}$ и при энергии 30-200 МэВ). Полученные экспериментальные данные свидетельствуют в пользу спектаторного механизма образования протонов в заднюю полусферу.

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1. Introduction

In this paper the first experimental results on investigation of limiting nuclear fragmentation by intermediate energy electrons are presented. Such processes, the most pronounced of which is cumulative particle production, carry a direct information about different degrees (nucleon, meson, quark-parton) of freedom of nuclear matter.

Limiting nuclear fragmentation by electrons has different aspects. It is in fact a new, not yet investigated problem, the detailed study of which requires considerable efforts. The present work is the first step in this way. It is devoted to the investigation of the energy spectra of the electrons scattered on the nucleus in the reaction

$$e + {}^{12}C \longrightarrow e' + p + X \qquad (1)$$

in dependence with the "cumulativity" of the coincidence proton.

The interest in the study of the process (1) increased due to the fact that it allows to check some predictions of one of the popular theoretical models of cumulative proton production - the predictions of the so-called spectator mechanism (SM) of the few-body correlation model [1].

In this model the electron is elastically (Diagram 1a) or inelastically (1b) scattered on the correlated nucleon with forward momentum $\vec{p}_1$. The correlation is broken and the nucleon-spectator having a backward, compensated (before interaction) momentum $\vec{p}_s$ gets free and passes into the cumulative region.

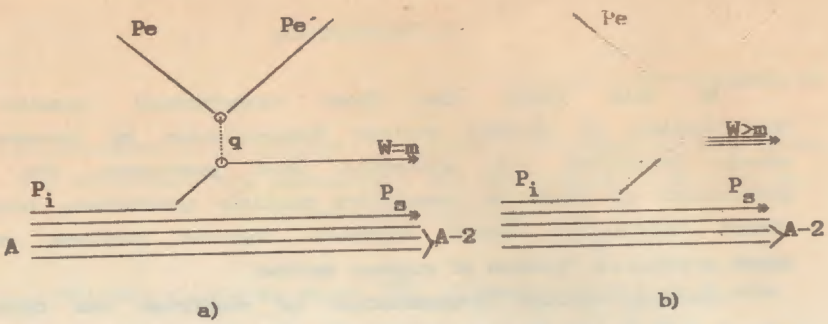

Diagram 1

In Impulse Approximation (IA) the factorized form of the cross section of the process (1) can be written as [2]

$$d^4\sigma/d\Omega_e\, dE_e\, d\Omega_p\, dE_p = P_s\, E_s\, \sigma_{eN}\, D(\vec{p}_i, E_i, \vec{p}_s, E_s, \vec{p}_{A-2}) \quad (2)$$

where σ_{eN} is the cross section of the interaction of electrons with bound nucleons, $D(\vec{p}_i, E_i, \vec{p}_s, E_s, \vec{p}_{A-2})$ is the so-called decay function – the probability to find in nucleus A a nucleon with momentum $\vec{p}_i$ and removal energy E_i times the probability that the residual A-1 system decays into the nucleon with momentum $\vec{p}_s$ and removal energy E_s and into the system A-2 with momentum $\vec{p}_{A-2}$.

Fig.1 shows the cross section of (1) calculated in the spectator mechanism of pair correlation model [1] (for the pair in rest, i.e. $p_{A-2} = 0$; $\vec{p}_i = -\vec{p}_s$; $E_i = E_s$) for the spectator proton detection angles 120° (b) and 140° (c). The results of the knock-out cross section calculations in the quasifree kinematics are also presented (curve a). The nonrelataviatic form of D – function and De Forest off-shell approximation for σ_{eN} [3] have been used for the curves b and c.

As is seen, the electron spectra shift to lower electron energies with increasing "cumulativity" of protons (the

increasing of detection angle). These shifts are one of the main features of the spectator mechanism in cumulative production, hence their experimental investigation gives an opportunity to check the validity of this model.

2. Experiment

The energy spectra of electrons scattered in the reaction (1) at E_e = 1.94 GeV, $\theta_{e'}$ = 15°±2°, T_p = (82.5÷200) MeV, θ_{ep} = 66°, 90°, 120°, 140° have been investigated.

The experiment has been carried out at the Yerevan synchrotron external electron beam on the set-up "Deuteron-2" [4]

The main characteristics of the electron beam are described in [5]. The average intensity of beam was 10^{10} el/s, the duty factor was 10%.

The scattered electrons were detected by a magnetic spectrometer [6] with a momentum acceptance of $(\Delta p/p)_e$ = ·45%, and a solid angle of $\Delta\Omega_{e'}$ = 2.75 msr. The momentum resolution $(\delta p/p)_e$ = ± 1.5%, the angular acceptance $\Delta\theta_{e'}$ = ±2°, $\Delta\varphi$ = ±1°, the angular resolutions $\delta\theta_{e'}$ = ±0.3°, $\delta\varphi$ = ±1°. The detection angle and the momentum of electrons can be varied from 10° to 90° and from 0.5 to 3 GeV/c, respectively. Electrons were identified by the π/e rejection system [7] consisting of a gaseous threshold Cherenkov counter [8] with freon filling and a lead-scintillator shower detector [9]. The rejection factor was 10^{-2}, which under the above-mentioned kinematics reduces the pion admixture down to less than 1%.

The protons were detected by the range spectrometer [10] with a solid angle of $\delta\Omega$ = 8 msr and an angular spread of $\Delta\theta_p$ = $\Delta\varphi$ = ±8°. The protons were separated from π-mesons by measuring the dE/dx at a fixed range. The kinetic energy of protons varied within 80-200 MeV and was measured with uncertainties which are shown in Table 1. The detection angle can be varied in the range from 50 to 165°.

3. Experimental Results

Fig.2 shows the spectra of electrons scattered at 15±2° in coincidence with protons with kinetic energy from 82.5 to 200 MeV in the reaction (1). There are shown experimental points for quasielastic case (■), when the proton momentum is parallel to the virtual photon (θ_{ep} = 66±8°), and for backward protons (□), when θ_{ep} = 112-148°. The simultaneously measured inclusive electron spectrum is presented by a dotted line.

As is seen, the contribution of multiple scattering (see diagram 2) of nucleons in nuclei [11] to cumulative proton production is small. It is seen more unambiguously from Fig.3,

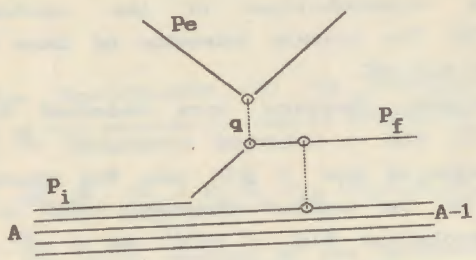

Diagram 2

where the ratio of backward to forward cross section is presented as a function of scattered electron energy. The fraction of the cross section in the quasielastic region is by an order less than that at lower energies of scattered electron.

Two more important conclusions can be drawn from the data in Fig.2. i) There is a big difference between the electron spectra when passing from forward over to backward angles of protons: at the latter case the spectrum shifts to the lower energy region of scattered electrons with respect to the former one. ii) For backward protons there are two peaks located in dip and Δ-regions. To understand the origin of these two peaks,

let us consider the spectra in two angular regions of backward protons: 120±8° and 140±8°. These two spectra are shown in Fig.4 (see Table 2). It is seen that the above-mentioned two peaks exist at 120±8° only, which means that in this case along with the one-step processes (OSP) (see diagram 1) the two step processes (TSP) with Δ-intermediate state (see diagram 3) could take an important part in backward proton production.

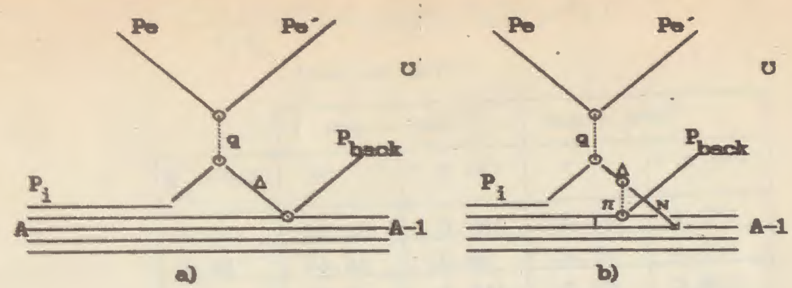

Diagram 3

The kinematical selection of the data from OSP can be used as a first step of suppressing the contribution of TSP. In case of pair correlation of OSP (with the pair in rest) the kinematical conditions are (see Diagram 1):

$$W^2 = (\nu + M_{pair} - E_s)^2 - (\vec{q} - \vec{p}_s)^2 . \qquad (3)$$

The data chosen according to eq.(3) under W = $m_{nucleon}$ (quasielastic scattering, see Diagram 1a) are presented in Fig.5 (see Table 3). As is seen, for θ_{ep} = 120° the peak in the Δ-region is suppressed by a factor of 2, while the peak in the dip region changes slightly. As to the case with θ_{ep} = 140°, after choosing the maximum remains the same. This is a strong argument in favour of the fact that the bump at high Ee′ for θ_{ep} = 120° and the single bump for θ_{ep} = 140° are contributions of the Spectator Mechanism in the quasielastic regime (see diagram 1a). However, a stronger evidence for this conclusion can be found by comparing these data with the theoretical calculations of the contributions of the processes presented by Diagrams 1 and 3, which will be done elsewhere.

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Table 1

Energy range of protons

Tp(MeV)	90	104	123	149	181
ΔTp(MeV)	15	13	20	29	35

Table 2

Experimental cross section of reaction (1).

$$\sigma = \int_{\theta_p}\int_{E_p} (d^4\sigma/d\Omega_e dE_e d\Omega_p dE_p)\, d\Omega_p dE_p$$

[nb/(sr GeV)]

	θep = 120°		θep = 140°	
E_e (GeV)	σ	± Δ (σ)	σ	± Δ (σ)
1.34	31.12	9.841	15.78	4.074
1.38	44.54	10.50	19.24	4.011
1.42	42.81	9.341	17.92	3.513
1.46	61.27	10.36	22.49	3.648
1.50	68.51	10.45	21.00	3.363
1.54	50.38	8.515	22.87	3.335
1.58	31.59	6.448	20.47	3.017
1.62	52.01	8.122	22.30	3.092
1.66	48.38	7.848	10.76	2.152
1.7	39.40	7.076	9.45	2.015
1.74	38.39	7.128	11.19	2.237
1.78	17.88	4.96	12.09	2.371
1.82	12.09	4.273	3.064	1.251
1.86	6.677	3.338	3.385	1.382
1.9	1.779	1.779	2.406	1.203

Table 3

Experimental cross section of reaction (1) chosed by eq (3).

$$\sigma = \int_{\theta_p}\int_{E_p} (d^4\sigma/d\Omega_e dE_e d\Omega_p dE_p)\, d\Omega_p dE_p$$

[nb/(sr GeV)]

	θ_{ep} = 120°		θ_{ep} = 140°	
Ee´(GeV)	σ	± Δ (σ)	σ	± Δ (σ)
1.38	21.78	8.24	7.36	2.79
1.42	17.32	6.55	10.87	3.02
1.46	36.69	8.65	22.49	3.96
1.50	40.26	8.40	21.00	3.69
1.54	28.68	6.76	22.87	3.335
1.58	24.47	5.93	17.03	2.88
1.62	51.33	8.22	16.46	2.71
1.66	45.67	7.61	7.718	1.819
1.7	33.10	6.49	5.164	1.491
1.74	35.58	6.74	3.007	1.136
1.78	10.59	3.76	0.447	0.448
1.82	9.63	3.64		
1.86	3.021	2.135		

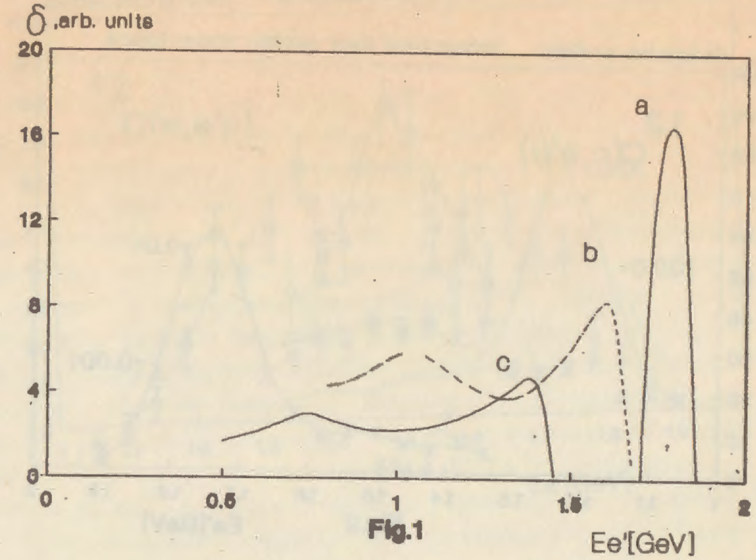

Fig.1

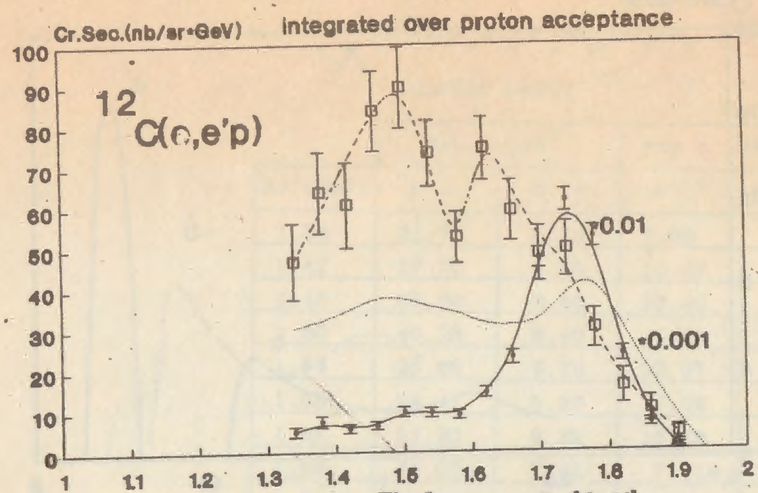

Fig.2

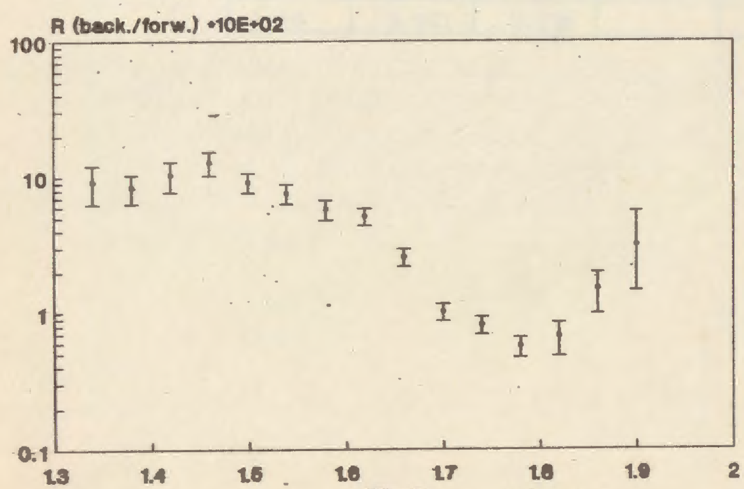

Fig.3

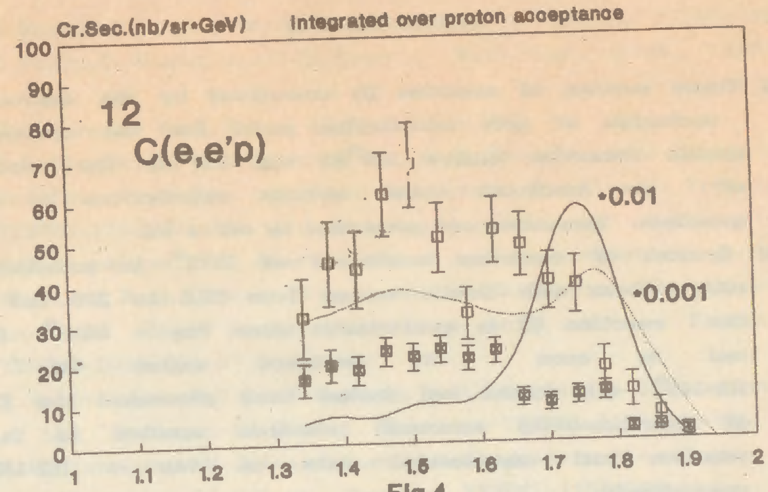

Fig.4

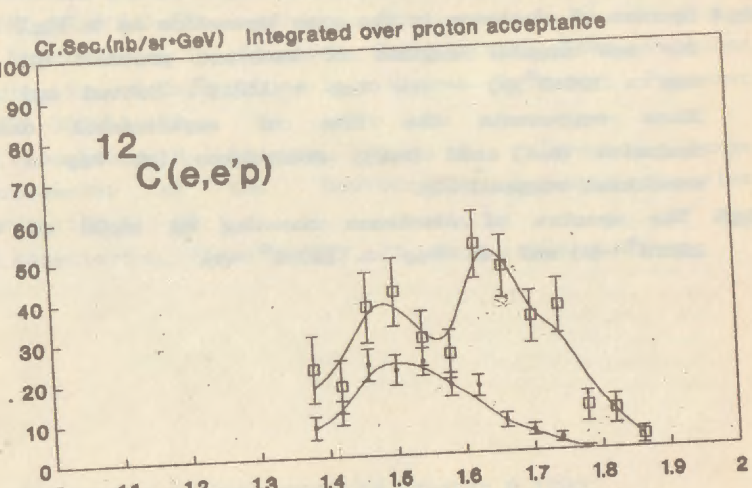

Fig.5

FIGURE CAPTIONS

Fig.1 Cross section of reaction (1) calculated by the spectator mechanism of pair correlation model for the spectator proton detection angles 120°(b) and 140°(c). The results of the knock-out cross section calculations in the quasifree kinematics are presented by curve (a).

Fig.2 Spectra of electrons scattered at 15±2° in coincidence with protons with kinetic energy from 82.5 to 200 MeV in the reaction (1) in quasielastic case θ_{ep} = 66±8° – (a) and in case of backward angles θ_{ep} = 112-148° –(b), dotted and dashed lines presented the fits of simultaneously measured electron spectra in (e,e') reaction and experimental data at θ_{ep} = 112-148°, respectively.

Fig.3 Ratio of cross section measured at backward (θ_{ep} = 112-148°) angles to forward (θ_{ep} = 66±8°) one.

Fig.4 Spectra of electrons in the same kinematics as in Fig.2 for two angular regions of backward protons: (b) – for θ_{ep} = 120±8°,(a) – for θ_{ep} = 140±8°. Dotted and dashed lines represents the fits of experimental data of inclusive (e,e') and (e,e'p) coincidence (at θ_{ep} = 66±8°) reactions, respectively.

Fig.5 The spectra of electrons choosing by eq.(3) at θ_{ep} = 120±8° –(b) and at θ_{ep} = 140±8° –(a).

References

1. L.Frankfurt and M.Strikman, Phys.Rep. 160,No.5,6 (1988) 237
2. S.Boffi,C.Giusti and F.D.Pacati, Nucl.Phys. A386, (1982) 599
3. T.deForest, Nucl.Phys. A392, (1984) 232
4. K.V.Alanakyan, M.J.Amaryan et. al., The "Deuteron-2" Set-up for Investigation of Electronuclear Reactions. Preprint YERPHI-1195(72)-89.
5. K.V.Alanakyan, M.J.Amaryan et. al., Characteristics of the Electron Beam Extracted onto the Installation "Deuteron-2" in the Low Background Room of YPI. Preprint YERPHI-1035(85)-87.
6. R.V.Ajvazyan, K.V.Alanakyan et. al., Magnetic Spectrometer of the "Deuteron-2" Set-up. Preprint YERPHI-1155(32)-89.
7. K.V.Alanakyan, M.J.Amaryan et. al., π/e Rejection System of the "Deuteron-2" Set-up. Preprint YERPHI-1153(30)-89.
8. K.V.Alanakyan, M.J.Amaryan et. al., Gaseous Threshold Cherenkov Counter of the Set-up "Deuteron-2". Preprint YERPHI-1034(84)-87.
9. E.M.Boyakhchyan, I.A.Keropyan, N.I.Nikitin, Some Data on Fluctuation of Energy Loss in a Shower Detector. Preprint YERPHI-333(58)-78.
10. K.V.Alanakyan, M.J.Amaryan et. al., Integral Range Spectrometer of the "Deuteron-2" Set-up. Preprint YERPHI-1154(31)-89.
11. V.B.Kopeliovich, Pisma v JETP, 23, No.6 (1976) 348

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