ЕФИ-781(8)-85

ЦЕНТРАЛЬНЫЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ
ИНФОРМАЦИИ И ТЕХНИКО-ЭКОНОМИЧЕСКИХ ИССЛЕДОВАНИЙ
ПО АТОМНОЙ НАУКЕ И ТЕХНИКЕ

I.G.AZNAURYAN, I.A.TROSHENKOVA

ELECTRON SCATTERING FROM LIGHT NUCLEI IN THE REGIONS OF QUASI-ELASTIC PEAK AND Δ-ISOBAR EXCITATION

ЕРЕВАН-1985

ЕФИ-781(6)-85

I.G.AZHAURYAN, I.A.TROSHENKOVA

ELECTRON SCATTERING FROM LIGHT NUCLEI IN THE REGIONS OF QUASI-ELASTIC PEAK AND Δ-ISOBAR EXCITATION

The cross sections of the (e, e') reaction on nuclei are considered in the identical form for the quasi-elastic electron scattering and the quasi-free pion electroproduction. The cross sections on single nucleon in the Δ-isobar excitation region are obtained using the dispersion relations being in good agreement with the experiment. A consistent set of parameters for the shell model with the oscillator potentials is obtained for [illegible] Al and Si nuclei. The mean square radii of the nuclei charge distribution calculated with the use of these parameters agree with the rms obtained from the electron-nuclei elastic scattering experiments.

Yerevan Physics Institute

Yerevan 1985

ЕФИ-781(8)-85

И.Г.АЗНАУРЯН, И.А.ТРОШЕНКОВА

РАССЕЯНИЕ ЭЛЕКТРОНОВ НА ЛЕГКИХ ЯДРАХ В ОБЛАСТИ РОЖДЕНИЯ Δ - ИЗОБАРЫ И КВАЗИУПРУГОГО ПИКА

В предположении квазисвободных нуклонов строятся сечения процесса (e, e′) на ядрах в едином виде для областей квазиупругого пика и Δ - изобары. Сечения на отдельных нуклонах в области рождения Δ - изобары получены с помощью дисперсионных соотношений и хорошо согласуются с экспериментом. Для ядер Be , C , Mg , Al , Si получен согласованный набор параметров для оболочечной модели с осцилляторными потенциалами. Среднеквадратичные радиусы распределения заряда ядер, вычисленные с этими параметрами, согласуются с величинами радиусов, полученными из экспериментов по упругому рассеянию электронов на ядрах.

Ереванский физический институт

Ереван 1985

Introduction

At present, there are experiments [1,2] on electron-nuclei scattering, in which measurements were performed for a set of nuclei in the quasi-elastic peak as well as in inelastic region. Analyzing these data in the Δ -isobar region using the dispersion relations we have concluded that the cross sections on nuclei in this energy region are very sensitive to the nuclear models. This fact is connected with the pion production total cross section high sensitivity arising when taking into account Fermi motion and also with resonance nature of the processes on single nucleon. Therefore a joint analysis of the data in both regions (quasi-elastic scattering and pion electroproduction) enables one to obtain a more confident information on investigated models of a nucleus.

The shell models with different form of potentials are widely used in the analysis of experimental results on the light nuclei. Among them the model with oscillator potential is a most popular one. The $(e, e'p)$, $(p, 2p)$ experiments confirmed reliably the shell structure of nuclei and showed that the protons on different shells move at different potentials. At present, the information on binding energies ε for protons on different shells is available [3,4,5] for many nuclei with $A < 40$ with an accuracy from one up to several MeV. As to the parameters of the oscillator model p_c which are responsible for the momentum distribution of nucleons in nucleus, they are determined from the experiment indirectly, and there is no agreement in their values obtained in various investigations. For example, the oscillator parameters for carbon [3] are 1.5-2 times as high as those for ^{6}Li and ^{9}Be [5], being at the same time higher than for ^{28}Si [6]. For the other nuclei, there is practically no satisfactory information on the oscillator parameters for different shells. One of the aims of this paper is to test the possibility of consistent description of a set of light nuclei using the oscillator shell model assuming that nuclei having close atomic numbers would differ from each other due mainly to the outer unfilled shells.

This paper contains three sections.

In Sect. 1 we deal mainly with obtaining the cross section in the Δ-isobar region on a free nucleon using the dispersion relations over invariant mass of produced hadrons S. A good agreement with the experimental data on protons and deuterons is obtained.

In Sect. 2 the electron-nucleus cross sections are constructed, assuming impulse approximation in the identical form both for the elastic and resonance regions. A form of the cross sections is suggested which permits us to spread to the resonance region the ideas of the shell model usually [illegible] description of quasi-elastic peak. A similar approach was origin- [illegible] Atwood and West [7] for the deep-inelastic electron [illegible]

[illegible] Sect. [illegible] the results of calculations for [illegible], Al and S[illegible] [illegible] presented. [illegible] is shown that the initial assumptions [illegible] [illegible] and [illegible] applicatior to the region [illegible] [illegible] the experiment [illegible]

1. Electron Scattering on Free Nucleon in Elastic and Resonance Regions

Assuming one-photon exchange approximation the cross section of electron-nucleon elastic scattering as well as the total cross section of pion electroproduction in the resonance region are convenient to express in the identical form, in which the contributions of transversely and longitudinally polarized photons are separated explicitly:

$$\frac{d^2\sigma^{el}}{dE_2 d\Omega} = \frac{4\alpha^2 M}{\lambda^2}\frac{E_2}{E_1}\frac{1}{1-\varepsilon}\left(\tau G_M^2(\lambda^2) + \varepsilon G_E^2(\lambda^2)\right)\delta(s-M^2), \tag{1}$$

$$\frac{d^2\sigma^{\Delta}}{dE_2 d\Omega} = \Gamma\left(\sigma_T(s,\lambda^2) + \varepsilon\sigma_L(s,\lambda^2)\right)\theta\left(s-(M+\mu)^2\right), \tag{2}$$

$$\lambda^2 = -q^2 = 2E_1E_2(1-\cos\theta), \quad \tau = \lambda^2/4M^2, \tag{3}$$

$$\varepsilon = \left(1 + 2\frac{|\bar{q}|}{\lambda^2}tg^2\frac{\theta}{2}\right)^{-1}, \quad \Gamma = \frac{\alpha}{2\pi^2\lambda^2}\frac{s-M^2}{2M}\frac{1}{1-\varepsilon}\frac{E_2}{E_1}, \tag{4}$$

$$s = (q+p)^2 = M^2 + 2Mq_0 - \lambda^2. \tag{5}$$

Here M and μ are masses of nucleon and pion, $p(p_0, \bar{p})$ and $q(q_0, \bar{q})$ are four-momenta of nucleon and photon, respectively, E_1 and E_2 are the energies of the incident and outgoing electrons in the lab. system, θ is the angle between directions of these electrons.

In expression (1) for the electron-nucleon elastic scattering $G_M(\lambda^2)$ and $G_E(\lambda^2)$ are the Sachs nucleon formfactors which at $\lambda^2 \leqslant 1\left(\frac{GeV}{c}\right)^2$ are described well by the dipole formula

$$G \sim (1+\lambda^2/0{,}71)^{-2}.$$

To calculate the electroproduction cross section we use the dispersion relations for the invariant amplitudes $A_1(s,t) \ldots A_6(s,t)$ [8] at a fixed momentum transfer t. Note the main points of our calculations.

The real part of the amplitudes consists of the contributions of the Born diagrams (which include the formfactors of nucleons and pions) and the dispersion integrals from the imaginary parts of the corresponding amplitudes. The pion formfactor in the considered region is described well by VDM and has the form $\mathcal{F}_\pi(\lambda^2) = (1+\lambda^2/0{,}5)^{-1}$.

An essential difference of pion electroproduction from the real photoproduction in the resonance region consists in appearance of λ^2-dependence of the resonance couplings γNN^* as well as in appearance of longitudinal amplitudes. In Ref.[9] using the dispersion relations the analysis of available by that time experimental data on proton was carried out. [illegible] analysis a λ^2-parametrization of multipole amplitudes with relatively small number of fit parameters was suggested proceeding from analyticity and definite asymptotical behaviour of total cross sections at large λ^2. In calculations we used the results obtained in this analysis for multipoles M_{1+}, E_{1+} and S_{1+}, corresponding to resonance $P_{33}(1232)$.

The dispersion integrals are determined mainly by the $P_{33}(1232)$ resonance contribution. To estimate the high-energy contributions we included into the consideration also the contributions of resonances with larger masses [illegible], $P_{11}(1440)$, $D_{13}(1520)$, $F_{15}(1680)$ which, as shown in the analysis [9], pronounced distinctly in pion electroproduction. Their contribution turned out to be negligible in the first resonance region.

To eliminate the kinematic singularities in invariant amplitudes

$A_2(s,t)$ and $A_5(s,t)$ a subtraction procedure is usually used [8]. The calculations showed that the subtraction contribution in the cross section is negligible.

Thus the below-given results in the first resonance region practically were obtained with the help of the amplitudes whose imaginary parts are determined by the P_{33} (1232) resonance, while the real parts consist of the contributions of the Born diagrams and dispersion integrals where only the P_{33} (1232) resonance contribution is taken into account.

Fig. 2 presents the results of our calculations for electroproduction in the region of the P_{33} (1232) resonance on proton. One can see that there is a good agreement with the experiment [2,10].

To check up the results of calculations on neutron we calculated the cross sections on deuteron with the wave functions taken according to Ref.[11] . As is seen from Fig. 2, the agreement with the experiment is good.

2. Electron Scattering on Nuclei

Let us assume for a moment that a nucleus is a set of free moving nucleons and the probability of scattering on a nucleus is added from the probabilities of the processes on free nucleons; hence the electron-nucleus cross section can be written as

$$d\sigma^{A} = \frac{1}{I_A} \sum^{A} \int d\sigma^{N}(s,p,\lambda^2)\, I^{N} \rho(\vec{p})\, d\vec{p} \,, \qquad (7)$$

where I^{A} , I^{N} are invariant fluxes on nucleus and nucleon, respectively, $\rho(\vec{p})$ is the density of nucleon momentum distribution.

In order to obtain expressions for the cross section on moving nucleon we make in invariant cross sections (1, 2) the Lorentz transformation into the system moving with a velocity $\vec{p}/p_0$. Omitting the intermediate formulae present a final form of the cross section for electron scattering on moving nucleon:

$$\frac{d^2\sigma}{dE_2'd\Omega'} = \Gamma'\left(\sigma_T(s,p,\lambda^2) + \varepsilon\sigma_L(s,p,\lambda^2) + \sqrt{2\varepsilon(1-\varepsilon)}\,\sigma_{LT}(s,p,\lambda^2)\right), \quad (8)$$

$$\sigma_T(s,p,\lambda^2) = \sigma_T(s,\lambda^2) + \frac{\lambda^2 p^2 \sin^2\theta_p}{2M^2|q'|^2}\left(\sigma_T(s,\lambda^2) + \sigma_L(s,\lambda^2)\right), \quad (9)$$

$$\sigma_L(s,p,\lambda^2) = \sigma_L(s,\lambda^2) + \frac{\lambda^2 p^2 \sin^2\theta_p}{|q'|^2 M^2}\left(\sigma_T(s,\lambda^2) + \sigma_L(s,\lambda^2)\right)\left(\cos^2\varphi + \frac{1}{2}\right), \quad (10)$$

$$\sigma_{LT}(s,p,\lambda^2) = \left(\sigma_T(s,\lambda^2) + \sigma_L(s,\lambda^2)\right)\left(q_0|\bar{p}|\cos\theta_p - p_0|\bar{q}|\right)\frac{|p|\lambda^2(E_1+E_2)}{|\bar{q}|^2|\bar{q}'|^2}\sin\theta_p\cos\varphi, \quad (11)$$

$$s = (p+q)^2 = M^2 - \lambda^2 + 2p_0q_0 - 2|p||q|\cos\theta_p, \quad |q'|^2 = \frac{(s - M^2 + \lambda^2)^2}{4M^2} + \lambda^2. \quad (12)$$

Here θ_p and φ are polar and azimuthal angles of nucleon momentum if the Z axis coincides with a direction of q-momentum of virtual photon. The kinematic variables in the rest system of the target nucleon are characterized by a prime.

Substitute now the expression (8) into formula (7) taking into account that in the rest system of target nucleus $I^A = E_1 M_a$, $I^N = E_1' M = (E_1 p_0 - K_1 p)$ and from the invariance of the four-dimensional phase volume there follows $dE_2' d\Omega' = dE_2 d\Omega . E_2' / E_2$. Performing simultaneously the integration over azimuthal angle φ we arrive at the following expression for the cross section ... production on nucleus

$$\frac{d^2\sigma^A}{dE_2 d\Omega} = \frac{\alpha}{2\pi}\frac{E_2}{E_1}\frac{\lambda^2}{1-\varepsilon}\left(\sigma_T^A(\lambda^2) + \varepsilon\sigma_L^A(\lambda^2)\right), \qquad (13)$$

$$\tilde{\sigma}^A_{T,L}(\lambda^2) = 2\pi\int \rho(\bar{p})\frac{s-M^2}{2M}\sigma^N_{T,L}(s,p,\lambda^2)\theta(s-(M+\mu)^2)\,\bar{p}^{-2}d|\bar{p}|d\cos\theta_p . \qquad (14)$$

The cross sections on single nucleon $\sigma^N_{T,L}(s,p,\lambda^2)$ are given by formulae (9-10) with the obvious simplification $(\cos^2\varphi + \frac{1}{2}) \to 1$ for σ_L^N because of the integration over φ .

The cross section of knocking out of the free nucleon from the nucleus is obtained from (13-14) and (9-10) by the replacements

$$\frac{\alpha\lambda^2}{2\pi} \to \frac{4M\alpha^2}{\lambda^2},\ \frac{s-M^2}{2M} \to 1,\ \theta(s-(M+\mu)^2) \to \delta(s-M^2),$$
$$\sigma_T^N(s\lambda^2) \to \tau G_M^2(\lambda^2),\ \sigma_L^N(s,\lambda^2) \to G_E^2(\lambda^2). \qquad (15)$$

When turning to electron scattering on real nuclei, there arises a question on validity of application of formulae (13,14) corresponding to quasi-free picture of nucleons. In the region under consideration, $\lambda^2 \geq 0,2\ (\frac{GeV}{c})^2$, the contributions of the coherent processes are small, and the effects connected with re-scattering of final particles as well as with the account of the Pauli principle may apparently be neglected.

To take into account the Fermi momentum of the target nucleons we have used the cross sections (7-10) for a free moving nucleon, where for nucleon on mass-shell the squared invariant mass of final hadrons was defined by formula (12). For the bound nucleon ($p_0^2 \neq \bar{p}^2 + M^2$) from the diagram corresponding to the impulse approximation (Fig.1) the invariant mass of final hadrons may be estimated not assuming relations between energy and momentum of intermediate nucleon. We proceed from the following definition:

$$s = p_x^2 = (p_A - p_{A-1} + q)^2 =$$

$$= s_o - 2(q_o + M)(\varepsilon + T_{A-1}) - \bar{p}^2 - 2|\bar{p}||\bar{q}|\cos\theta_p , \qquad (16)$$

$$s_o = M^2 + 2q_o M - \lambda^2 ,$$

applicable to any nucleus if under ε the binding energy of nucleon on the given shell for the given nucleus is implied. Here T_{A-1} is kinetic energy of the residual nucleus, $\bar{p}_{A-1} = -\bar{p}$, the other designations are defined according to Fig.1. For the calculations with use of the Fermi model $\bar{\varepsilon}$ would denote mean energy of separation of nucleon from nucleus.

Although we ignore partially the off-shell effects for the bound nucleon assuming in $\tilde{\sigma}^N_{T,L}(s, p, \lambda^2)$ the λ^2 dependence being the same as the one for the free nucleon, nevertheless, having defined [illegible] (16) we have accounted these effects through the main variable [illegible] for the strong energy structure (resonance or δ-functions [illegible]) cross sections in the considered region $\sqrt{s} \leqslant 1.6$ GeV.

For comparison we introduced into (1) the quantity s_o [illegible] invariant mass of final hadrons produced on a free nucleon at rest, which [illegible] used as a variable for energy spectra on nuclei. [illegible]

[illegible] least [illegible]

[illegible] scattering [illegible]

[illegible]

knocked-out nucleon is dominant, from (16) for the energy of the ejected nucleon $E_{\bar{p}+\bar{q}}$ follows the expression

$$E_{\bar{p}+\bar{q}} = M + q_0 - \varepsilon - T_{A-1} \quad ,$$

usually used in investigation of the ($e, e'p$) reaction. The use of variable s is preferable because it allows us to include promptly the inelastic processes. Thus the cross section on nucleus is determined by integrals (14) over phase volume of moving nucleon with the weighting functions

$$\tilde{\sigma}^{N}_{T,L}(s,p,\lambda^2) = \tilde{\sigma}^{\Delta}_{T,L}(s,p,\lambda^2)\,\theta\left(s-(M+\mu)^2\right) + \tilde{\sigma}^{el}_{T,L}(s,p,\lambda^2)\,\delta\left(s-M^2\right), \quad (17)$$

where $\tilde{\sigma}^{\Delta}_{T,L}$ and $\tilde{\sigma}^{el}_{T,L}$ are defined in (9, 10, 15).

Expressions (13-17) together with the use of the shell model for description of nucleon momentum distribution are a generalization of the approach developed in Refs.[7] for deuteron for the case of nuclei with $A > 2$

Results

We have done numerical calculations for two groups of nuclei with close atomic numbers ^{6}Li, ^{9}Be, ^{12}C, and ^{24}Mg, ^{27}Al, ^{28}Si. The nucleon momentum distribution was assumed to correspond to the oscillator shell model with including only 1ℓ shells.

Binding energies ε for the light nuclei are known from the ($e, e'p$) and ($p, 2p$) experiments with an accuracy from one to several MeV (see, e.g. [3-5]). The values of these parameters used in our calculations and listed in the Table are obtained for reasons of a better description of the experiment and agree with the data of [3-5] .

The oscillator parameters ρ_o characterizing the nucleon momentum distribution in nucleus were chosen also for reasons of a better description of the experiment with certain restrictions. As a starting meaning for these parameters there served the values of ρ_o for carbon taken from experiment [3]. The parameters for the other nuclei were arranged in accordance with the conclusion [13] about almost linear growth of ρ_o with increasing the atomic number A for the inner shells, as well as proceeding from the requirement that the parameters of the closed shells of the nuclei with near-by A would not differ too much. After establishment of quantities ρ_o for the inner shells the values of parameters for outer shells were finally fitted. Various sensitivity of the cross sections in the regions of quasi-elastic and resonance peaks to parameters [illegible] strictly control these quantities. For comparison [illegible] experiments for carbon [3] are given in the Table [illegible].

Figs. 3 - 4 present the results of our calculations for the experiment [illegible] for Li, C, Mg and Be [illegible] Si nuclei at [illegible]. It is seen that the obtained curves describe well the experimental [illegible] reproduce the main features of scattered electron energy spectra [illegible] and the shapes of both quasi-elastic scattering and [illegible] peaks.

[illegible]

however to reach an agreement with the experiment they had to introduce the suppression coefficients connected with nucleon absorption [14] inside the nucleus. These coefficients (0.2 ÷ 0.5 for $(e,e'p)$ and 0.5 ÷ 0.8 for $(p,2p)$) are large and cannot be calculated precisely; therefore they may include both effects: real absorption and underestimation of parameters ρ_o. The magnitude of the so-called mean-square radius of nucleus charge distribution $\langle r^2 \rangle^{1/2}$ is determined by the same parameters ρ_o. The difficulties concerning the consistency of this quantity derived from different physical processes – the electron elastic scattering on nuclei and the quasi-elastic scattering on bound nucleons inside nucleus are mentioned in [illegible] works (see e.g. Ref. [illegible]). The [illegible] lists the values of $\langle r^2 \rangle^{1/2}$ [illegible] with our parameters [illegible] comparison with the quantities [illegible] from the elastic scattering [illegible] be observed for Mo and [illegible], nevertheless, [illegible] under [illegible] of the oscillator parameters for the whole nuclei group leads [illegible] of the nuclei mean square radii.

[illegible] seen [illegible] systematic excess of the expe[illegible] [illegible] between the [illegible] [illegible] investigations [illegible] [illegible] [illegible] We have [illegible] [illegible] parameters [illegible] it is impossible to remove the [illegible] wave functions [illegible] to oscillator potential [illegible] the experimental data [illegible] he nucleon inside nucleus are of the same order of magnitude thus enhancing the probability of the correlative processes.

Note in conclusion that we have carried out calculations assuming that the proton and neutron shell parameters are equal. As is mentioned in Ref. 19 , investigations of ($e, e'n$) processes are at the limit of the present-day experiment feasibilities. Therefore the processes (e, e') remain practically the only source to obtain information on neutron shells in the electron experiments. In the quasi-elastic peak region the neutron cross sections are suppressed as compared to the proton ones, especially at small λ^2 , therefore a relative weight of neutron shell contributions is small. In the resonance region total cross sections on neutrons and protons are approximately equal [20] , hence the resonance region is more sensitive to the neutron shell parameters. Unfortunately, there aren't at present many nuclei for which there exist experiments covering besides the quasi-elastic peak also the resonance region. Meanwhile, such data for the values of E_1 and λ^2 , at which both peaks are pronounced well, are of undoubted interest also from the viewpoint of studying neutron distribution in nucleus.

The authors are indebted to H.H.Vartapetyan and G.G.Mkrtchyan for the useful discussions.

The manuscript was received 4 January 1985

Table

			p		d		$\langle r^2 \rangle^{1/2}$ fm	
			E, MeV	P_0, MeV/c	E, MeV	P_0, MeV/c	This work	Elastic scattering [15]
[illegible]	[illegible]	[illegible]	4	[illegible]		-	2.2	
[illegible]	[illegible]	[illegible]	15	[illegible]		-	2.21	2.19
[illegible]	[illegible]	[illegible]	16 (16)	[illegible]		-	2.27 (2.85±25)	2.37
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	120	2.6	3.12
[illegible]	[illegible]	[illegible]	[illegible]		10	90	3.06	3.06
[illegible]	[illegible]	[illegible]	[illegible]		14	112	2.7	3.12

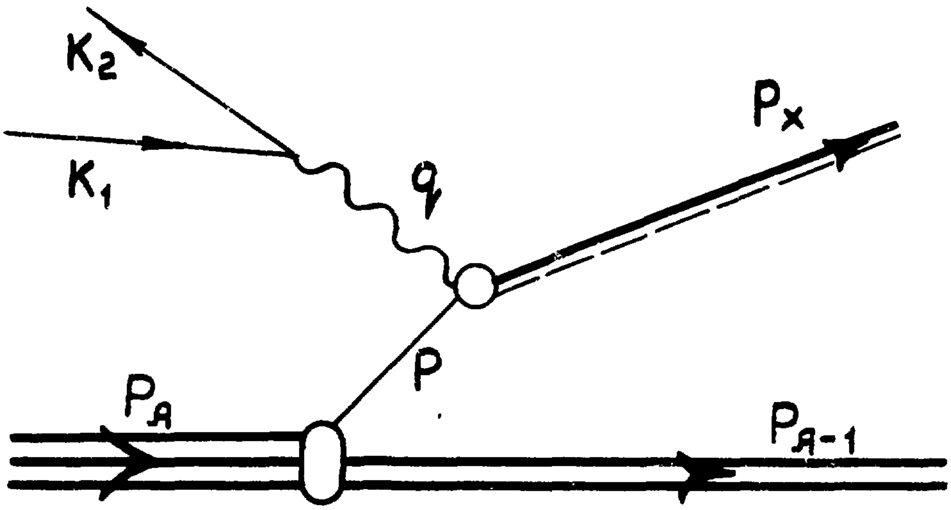
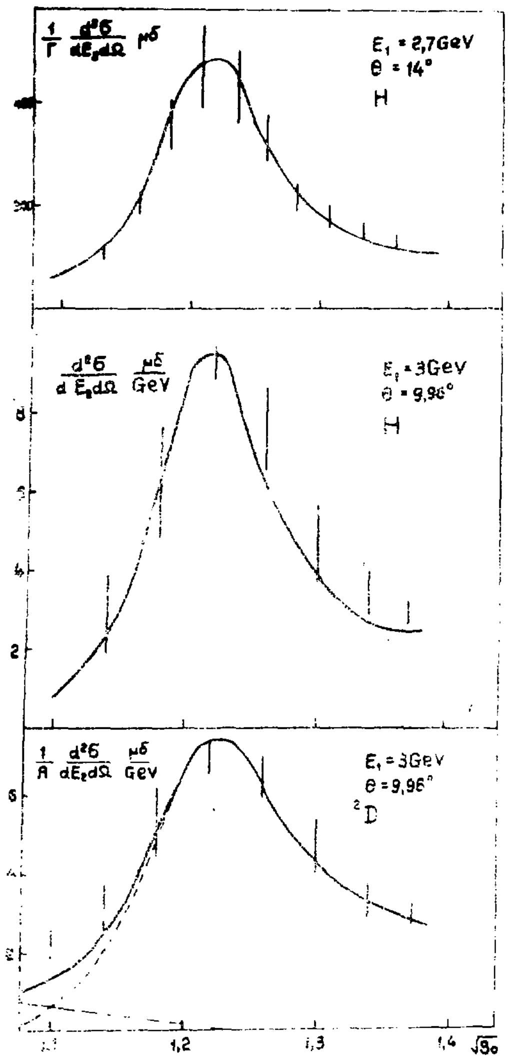


Fig.1



$\frac{1}{\Gamma}\frac{d^2\sigma}{dE_2 d\Omega}$ μб
E₁ = 2,7GeV
θ = 14°
H
$\frac{d^2\sigma}{dE_2 d\Omega}$ $\frac{\mu б}{GeV}$
E₁ = 3GeV
θ = 9,96°
H
$\frac{1}{A}\frac{d^2\sigma}{dE_2 d\Omega}$ $\frac{\mu б}{GeV}$
E₁ = 3GeV
θ = 9,96°
²D
1,2
1,3
1,4
√S₀

Fig.2

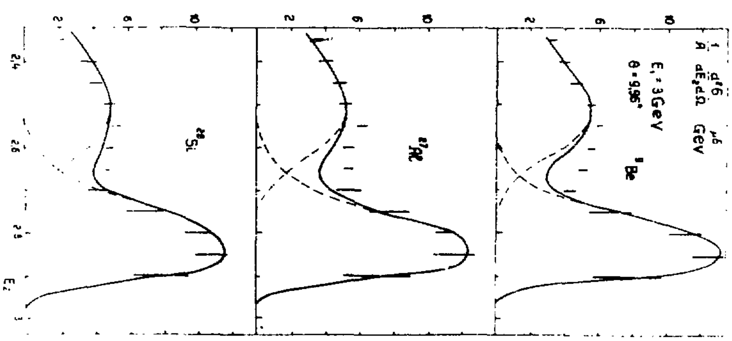


Fig.3

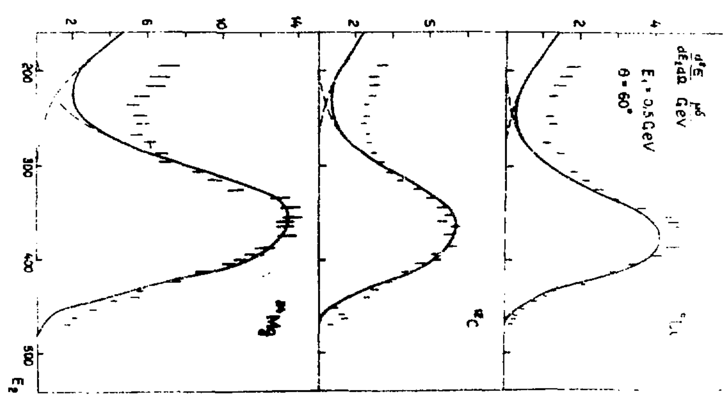


Fig.4

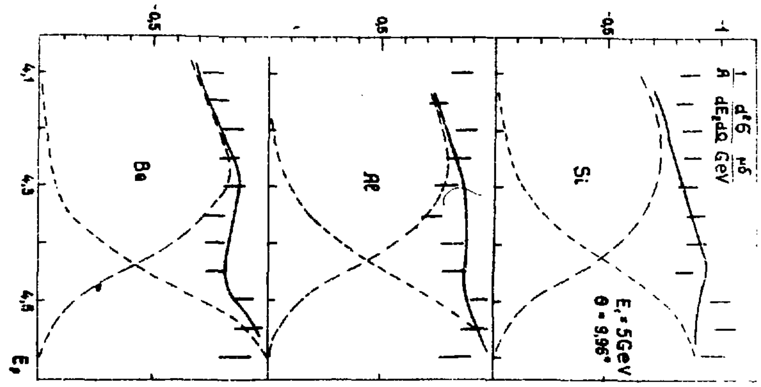


Fig.5

Figure Captions

Fig.1. The impulse approximation diagram.

Fig.2. The cross section of (e, e') process versus the invariant mass $W = \sqrt{s}$ for scattering on protons - experiment [10] at $\lambda^2 = 0.35\ (\mathrm{GeV}/c)^2$, $E_1 = 2.7$ GeV; on protons and deuterons - experiment [2] at $\lambda^2 \approx 0.23\ (\mathrm{GeV}/c)^2$, $E_1 = 3$ GeV.

Fig.3. Scattered electron energy spectra for Be, Al, Si target nuclei - experiment [2] at $\lambda^2 \sim 0.25\ (\mathrm{GeV}/c)^2$

Fig.4. Scattered electron energy spectra for Li, C, Mg target nuclei - experiment [1] at $\lambda^2 \sim 0.19\ (\mathrm{GeV}/c)^2$

Fig.5. Scattered electron energy spectra for Be, Al, Si target nuclei - experiment [2] at $\lambda^2 \sim 0.66\ (\mathrm{GeV}/c)^2$

REFERENCES

1. Whitney R.R., Sick I., Fienes J.R. et al. Quasielastic Electron Scattering. - Phys.Rev.C, 1974, v.9, p.2230.

2. Franz J., Guzielski G., Huber G. et al. Total Cross Section for Inclusive Electron Scattering in the Low q^2 Region. - Zeitschrift fur Phys., 1981, v.C10, p.105.

3. Amaldi U., Campos Venuti G., Gortellessa G. et al. Inner-Shell Proton Binding Energies in C^{12} and Al^{27} from the (e, e'p) Reaction Using 550 MeV Electrons. - Phys.Rev.Lett., 1964, v.13, p.341.
Proton Angular Distribution in the High Energy $^{12}C(e, e'p)^{11}B$ Reaction.- Pnys.Lett.B, 1967, v.25, p.24.

4. Антуфьев Ю.П., Агранович В.Л., Кузьменко В.С., Сорокин П.В Исследование ядерных реакций (e,e'p).Материалы IX Зимней школы ЛИЯФ по физике ядра и элементарных частиц,1974,ч.Ш, с.574

5. Riou M. Information on Nuclear-Structure from (p, 2p) and Other Knock-out Reactions. - Rev. of Mod. Phys., 1965, v.37, p.375.

6. Дементий С.В., Афанасьев Н.Г., Аркатов И.М. и др. Квазиупругое рассеяние высокоэнергетических электронов на нуклонах ядер C^{12} и Si^{28}, ЯФ, 1970, т.II, с.I9.

7. Atwood W.B., West G.B. Extraction of Asymptotic Nucleon Cross Section from Deuterium Data. - Phys.Rev.D, 1973, v.7, p.773.

8. Berends F.A., Donnachie A., Weaver D.L. Photoproduction and Electroproduction of Pions. - Nucl.Phys.B, 1968, v.4, p.1.

9. Devenish R.C.E., Lyth D.H. Electromagnetic Form Factors of N^* Resonances and Their Determination from Pion Electroproduction. - Nucl.Phys.B. 1975, v.93, p.109.

10. Galster S., Hartwig G., Klein H. et al. Coincidence Experiment on Inelastic Electron-Proton Scattering in the Region of the Δ (1236) at q^2 = -0.35 and -1 GeV/c. - Phys.Rev.D, 1972, v.5, p.519.

11. Lacombe M., Loiseau B., Richard J.M., WinhMau R. Parametrization of the Paris N-N Potential. - Phys.Rev.C, 1980, v.21, p.861.

12. Омелаенко А.С. Электророждение пионов на ядрах. ЯФ, 1979 т.30, с.1504.

13. Amaldi U. Proc. Intern. Conf. on Low and Intermed. Energy Electromagnet. Interaction, Dubna, 1967, v.3, p.110.

14. Jacob G., Maris Th.A. Quasi-Free Electron-Proton Scattering. - Nucl. Phys., 1962, v.31, p.139.

15. Elton L. Nuclear Sizes. - Oxford Univ. Press, London, 1961. Lombard R.M., Bishop G.R. Scattering of High-Energy Electrons on ^{27}Al, ^{31}P, ^{32}S and the Core-Excitation model. - Nucl. Phys.A, 1967, v.101, p.601.
Хвастунов В.М., Афанасьев Н.Г., Афанасьев В.Д. и др. [illegible] ние электронов высокой энергии на изотопах Mg и [illegible] 1970, т.12, с.9.

[illegible] Heimlich F.H., Kobberling M., Moritz J. et al. High-energy [illegible] Scattering from [illegible] and ^{12}C [illegible] Nucl.Phys.A, 1974, v.221, [illegible]

[illegible] Nucl.Phys.A [illegible]

[illegible] Excitation of Nuclear Δ -Resonances in Deep Inelastic Electron Sca[illegible] Nucl.Phys.A, 1981, v.358, p.[illegible]

[illegible] Present Status and Future Trends. - [illegible] 1981, [illegible]

[illegible] Excitation of the Δ (1236) [illegible] Nucl. Phys. [illegible] 197[illegible] v.39, p.471

А.Г.АЗНАУРЯН, И.А.ТРОШЕНКОВА

РАССЕЯНИЕ ЭЛЕКТРОНОВ НА ЛЕГКИХ ЯДРАХ В ОБЛАСТИ РОЖДЕНИЯ

Δ - ИЗОБАРЫ И КВАЗИУПРУГОГО ПИКА

(на английском языке, перевод З.Н.Абрамян)

Редактор Л.П.Мукаян

Технический редактор А.С.Абрамян

Подписано в печать 26/IУ-85г. ВФ-00908 Формат 60x84/16
Офсетная печать.Уч.изд.л. 2,0 Тираж 299 экз. Ц. 30 к.
Зак.тип.№ 180 Индекс 3624

Отпечатано в Ереванском физическом институте
Ереван 36, Маркаряна 2