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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

ԳԻՏԱԿԱՆ ՀԱՂՈՐԴՈՒՄ НАУЧНОЕ СООБЩЕНИЕ

ЕФИ-98 (74)

Yu.K.AKIMOV, K.ANDERT, A.N.ARVANOV, G.V.BADALIAN, A.E.BANIFATOV, D.M.BEGLARIAN, C.BORCEA, A.BUTA, T.A.VARDANIAN, Yu.M.KAZARINOV, A.I.KALININ, V.S.KISELEV, L.I.LAPIDUS, G.E.MARKARIAN, G.I.MELIKOV, P.B.OSIPENKO, M.PETRASCU, J.V.PETROSSIAN, M.M.PETROV, V.S.POGOSOV, /A.M.CHATRCHIAN/ V.N.SHURAVIN

SMALL ANGLE ELASTIC ELECTRON-DEUTERON SCATTERING

АРУС

ԵՐԵՎԱՆ 1974 ЕРЕВАН

YEREVAN PHYSICS INSTITUTE

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УДК.539.171.016/2:539.171.13 Научное сообщение ЕФИ-98(74)

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УПРУГОЕ ЭЛЕКТРОН-ДЕЙТРОННОЕ РАССЕЯНИЕ НА МАЛЫЕ УГЛЫ

Представлены результаты предварительных измерений упругого электрон-дейтронного рассеяния в области передаваемых импульсов $(0{,}45 - 1{,}2)\,F^{-2}$, проведенных на внутреннем электронном пучке Ереванского синхротрона при энергии 4,5 Гэв. В эксперименте использовалась тонкая мишень $(CD_2)_n$. Спектр дейтронов и протонов отдачи измерялся кремниевыми полупроводниковыми детекторами. Даются значения дифференциальных сечений, зависящих от переданного дейтрону 4-х импульса, а также значения параметров электрического формфактора дейтрона и его среднеквадратичного радиуса.

Ереванский физический институт
Ереван 1974

Scientific Report ЕФИ-98(74)

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SMALL ANGLE ELASTIC ELECTRON-DEUTERON SCATTERING

The results of preliminary measurements of elastic electron-deuteron scattering in transverse momentum region of 0,45-1,2 F^{-2} on 4,5 GeV internal electron beam of Yerevan Synchrotron are presented. A thin $(CD_2)_n$ target has been used in experiment.

The spectra of recoil deuterons and protons were measured by silicon semiconductor detectors. The values of differential cross sections depending on the four-momentum transfer to deuteron as well as the parameters of electrical form factor and rms radii of deuteron are given.

Yerevan Physics Institute

Yerevan, 1974

1. Introduction

The high energy electron-deuteron elastic scattering experiments permit to obtain information on the electromagnetic structure of deuteron and neutron. In the one photon approximation the general expression for e-d elastic scattering cross section is described by the deuteron charge G_{cd} electric quadrupole G_{qd} and magnetic dipole G_{Md} form factors /1/. In the impulse approximation each of these form factors is proportional to the isoscalar combination of the nucleon form factors and the coefficient of proportionality $\mathcal{D}$ is expressed by the known integrals of the deuteron wave functions (structure factor). In the small momentum transfer region using the scaling low

$$G_{Md} = G_{cd}\,\mu_d \frac{M_d}{M_p} = \left(G_{Ep} + G_{En}\right)\mathcal{D}_c\,\mu_d \frac{M_d}{M_p}$$

where μ_d is the deuteron magnetic moment, one may write the following expression for the deuteron form factor /2/:

$$G_d^2 = \left(G_{Ep} + G_{En}\right)^2 \mathcal{D}_c^2 \left(1 + \frac{2}{3}\eta\,\mu_d^2\right). \tag{1}$$

Here, G_{Ep} and G_{En} are the proton and neutron electric form factors respectively, $\eta = q^2/4M_p^2$, q^2 is the square of the four-momentum transfered to deuteron, M_p is the proton mass. Then in the series expansion with respect to q^2 taking the terms up to the order of q^4 one obtains:

$$\begin{aligned}
\mathcal{D}_c &= 1 - \frac{\langle r_d^2\rangle}{6} q^2 + \lambda q^4 \\
G_{Ep} &= 1 - \frac{\langle r_p^2\rangle}{6} q^2 + \alpha q^4 \\
G_{En} &= \frac{\langle r_n^2\rangle}{6} q^2 + \beta q^4
\end{aligned} \tag{2}$$

where r_p, r_n are the proton, neutron electric radius, while r_d is the deuteron structure radius.

Therefore, for G_d^2 one may introduce the following parametrization

$$G_d^2 = \left(1 - aq^2 + bq^4\right)^2 \left(1 + \frac{2}{3}\eta \mu^2 d\right) \qquad (3)$$

The scattered electrons were detected in the most of the experiments carried out up today including the experiments in the region of the small momentum transfers /3-7/. In this experiment the elastic e-d scattering has been studied by detecting the recoil deuteron. Taking into account the smallness of the recoil deuteron energy one may present the differential cross section of the process in the laboratory frame in the following form

$$\left(\frac{d\sigma}{d\omega}\right)_d = \left(\frac{e^2}{Md}\right)^2 \frac{\frac{2M_d}{T_d}}{\cos\gamma_d} \sin\gamma_d\, G_d \qquad (4)$$

where γ_d is the angle between the recoil deuteron and the incident electron momenta and T_d is the kinetic energy of the recoil deuteron.

Below, we give the description of the experiment as well as the results of the e-d elastic scattering preliminary measurements in the region $0.45 \leq q^2 \leq$ ... $^{-2}$.

2. The Experimental Arrangement

This experiment partly is similar to the one /8/ carried out earlier by us and devoted to the e-p elastic scattering. The experimental arrangement is shown schematically in Fig.1a. At an energy 4.5 GeV by means of a beam-bump system the internal electron beam of Yerevan synchrotron was thrown on to a rotating thin heavy polyethylene CD_2 target (~ 5μ) containing some percent of usual hydrogen. The recoil deuterons were detected by 4 semiconductor silicon surface-barier detectors placed at 1.5 m distance from the target under an angle about 90^0 with respect to the direction of the incident electrons. The working surfaces of each detectors were determined by collimators placed just before the detectors and were equal to 3 x 40mm^2 (Fig.1b). The size along the beam direction (3mm) were chosen in order to separate effec - tively the elastic proton and deuteron peaks in the spectrum of the charged particles recorded by the detectors.

The pulses from each detector were given to the input of a spectrometric circuit /9/ and then to a pulse height analyzer DIDAC-4000 through a mixer which divided the analyzer channels into four groups each of 1000 channels. In each group the spectrum of the charged particles recotded by corresponding detector was observed (Fig.2a).

The measurements were carried out at various positions of the detectors which allowed to study the momentum transfer region 0.45 $F^{-2} \leq q^2 \leq 1.2F^{-2}$, the corresponding kinetic energies of recoil deuterons being 4.8 -12.8 MeV. After each run of measurements with CD_2 target measurement were carried out with 6 μ thick teflon (C_2F_4) foil in order to determine the carbon background. A typical result of background measurements is shown in Fig.2b. The detectors were calibrated periodically by means of Am^{241} α -source and etalon pulse height generator. The energy resolution of the system was $\pm$ (50 - 60) KeV.

3. Data Treatment and Results of the Preliminary Measurements

Originally it was proposed to use the hydrogen peak (see Fig. 2a) as a monitor, considering, that the behaviour of the $e-p$ elastic scattering is known. However, we had to abandon this method since we have not succeeded to determine the precise percentage of the hydrogen admixture in the target. The spectrum of the particles recorded by the detectors arises due to the protons from hydrogen, deuterons from the deuterium of the target, protons from the deuteron desintegration and charged particles from the target carbon, i.e. the carbon background. Therefore, one may present the expected spectrum of a single detector in the following form:

$$Y(T) = n_p \left(\frac{d\sigma}{dT}\right)_p f_p(T) + n_d \left(\frac{d\sigma}{dT}\right)_d f_d(T) + n_b F_c(T) + F_d(T), \quad (5)$$

where n_p, n_d, n_b are normalization factors, T is the energy of the detected particle, $f_p(T)$ and $f_d(T)$ are the detection efficiencies respectively for protons and deuterons from elastic scattering (taking into account the radiation corrections), $F_c(T)$ is the carbon background, $F_d(T)$ is the background from deuteron desintegration, $\left(\frac{d\sigma}{dT}\right)_p$ is the known e-p elastic scattering cross section (here we have fixed the proton mean square radius $\langle r_p^2 \rangle = 0,64F^2$), $\left(\frac{d\sigma}{dT}\right)_d$ is obtained from (4) taking into account the parametrisation (3). The purpose of the data treatment consists in the determination of the deuteron form factor parameters a and b as well as the behaviour of the e-d elastic scattering differential cross section in the momentum transfer region under consideration. The data treatment has been carried out in two ways.

I. It has been minimised the functional

$$\chi^2 = \sum_{i,k} \left(\frac{N^k_{exp}(T_i) - Y^k(T_i)}{\Delta^k_i} \right)^2 , \quad (6)$$

where $N^k_{exp}(T_i)$ and Δ^k_i are the number of the events and the value of error respectively in the i-th channel of the pulse height analyser brought to unit energy interval for K-th detector, is the expected value presented in the form (5) where n_p, n_d, n_g, a, , and b are variable parameters, $F_c(T_i)$ is the background spectrum obtained experimentally and presented in table form (its error is included into Δ_i^k). The particle detection efficiercces $f_p(T)$ and $f_d(T)$ have been calculated taking into account the geometric sizes of the beam and detectors, the target thickness and the multiple Coulomb scattering in it. Besides, the radiation corrections calculated according to the work /10/, and not exceeding 1-2% have been included into the function of efficiency. The corrections for the contribution of particles from the deutron desintegration have also been taken into account. The minimization of the functional (6) has been carried out by the linearization method with the help of the program FUMILI /11/. All the calculations have been carried out on the computer БЭСМ-6. As a result we have obtained the following values for the form factors parameters.

$$a = 0{,}72 \pm 0{,}08\, F^2$$
$$b = 0{,}23 \pm 0{,}05\, F^4 ,$$

The estimate for the mean square structure radius for the deuteron carried out taking into account (1), (2) and (3) in the assumption $\langle r_p^2 \rangle = 0.64 F^2$ and $\langle r_n^2 \rangle = 0.116 F^2$ /12/ gives $\sqrt{\langle r_d^2 \rangle} =$ (1.95 ± 0.12) F in agreement with the work /7/.

Using the expression (3) one may estimate also the mean square charge radius of deuteron

$$\langle r_{ed}^2 \rangle^{1/2} = \left(-6 \frac{dG_d}{dq^2} \right)^{1/2}_{q \to 0} \simeq 2.08 \pm 0.12\, F$$

To obtain the differential cross sections the data treatment has been carried out in the following way:

II. The background parameters obtained in the above described manner for each run have been fixed. Then we have substracted the background from the experimental spectrum and determined the number of the protons and deuterons under the corresponding peaks.

The minimization of the functional

$$\chi^2=\sum_{i,k}\left(\frac{N_d^k(T_i)-n_d^k\left(\frac{d\sigma(T_i)}{d\Omega}\right)_d}{\Delta_i^k}\right)^2, \qquad (7)$$

where $N_d^k(T_i)$ is the number of the events under the deuteron peak of the i-th detector in k-th run, Δ_i^k is its error, n_d^k is a normalization factor general for all detectors in the given run, $\left(\frac{d\sigma(T_i)}{d\Omega}\right)_d$ is the e-d elastic scattering differential cross section taking into account the parametrization (3), has allowed to determine the values of the e-d scattering cross section from the expression

$$\frac{d\sigma(q^2)}{d\Omega}=\frac{N_d^k(q_i^2)}{n_d^k} \qquad (8)$$

which are presented in Table I and in Fig.3. Since there are no published direct experimental data for the electron energy and momentum transfer region under the investigation for comparison in Table I, and Fig.3 we present the corresponding cross section values obtained on the basis of the known data /4,7/on the deuteron form factor using the expression /4/. It is necessary to note, that our data are presented without taking into account the errors of the normalization factors (in the average about 10%). Taking into account these errors our data are in agreement with expected cross sections as it is seen from the Table.

The values of the parameters a and b obtained by the both methods (I,II) coincide within the limits of the errors. The values of deuteron form factor calculated on their basis are in agreement with the known data.

Thus, the preliminary measurements have shown, that the method used in this work allows to investigate in detail the behaviour of the $e-d$ elastic scattering in the region of small momentum transfers.

In conclusion the authors are greatly indebted to A.I.Alikhanian, A.Ts.Amatuni and V.P.Djelepov for their continuous interest to this work. They also thank C.L.Smirnova for preparing the polydeuterium foils, A.V.Tarasov who kindly gave the formulae for the calculations of corrections, P.Doychev and V.K.Tyupikov for the help during the measurements, G.A.Danielian for preparing the collimators, S.I.Bilenkaya, Ya.D.Nersesian, M.A.Garzoyan, O.I.Passoyan, I.P.Prokhorenko for the help during the preliminary tretment of the experimental data, and finally, Yerevan synchrotron staff for the stable work of the accelerator.

Table I.

$q^2 (F^{-2})$	$\left(\frac{d\sigma}{d\Omega}\right)_d$ μb/Ω.	
	Our data	expected values
0.49	40.3 ± 2.5	43.4
0.575	32.5 ± 1.6	31.3
0.755	15.0 ± 0.16	17.1
0.855	11.1 ± 0.15	12.7
1.08	6.47 ± 0.07	7.17
1.19	4.84 ± 0.07	5.45

Figure Captions

Fig.1. a) The experimental arrangement.

b) The position of the semiconductor detectors.

Fig.2. a) A typical energy spectrum of the recoil particles observed by the pulse height analyzer in case of the deuterium polyethylene target.

b) A typical background spectrum observed in case of the carbon (teflon C_2F_4) target.

Fig.3. The dependence of the e-d elastic scattering differential cross section on the momentum transfer ($0.45 \leq q^2 \leq 1.2$ ...) at incident electron energy 4.5 GeV (without taking into account the errors of normalization factors.

. - our data

x - expected values

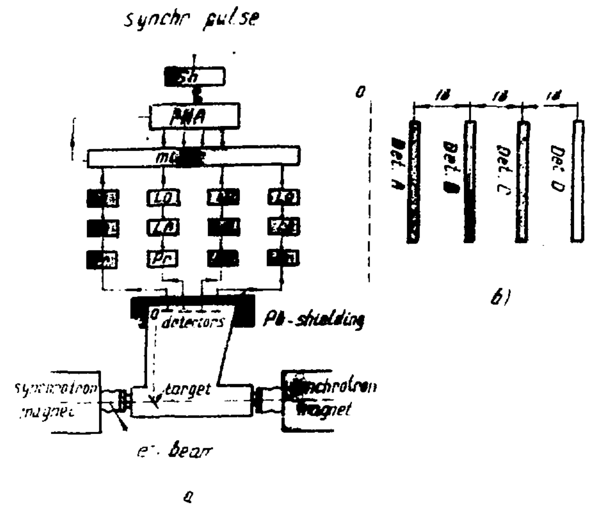
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Fig.1

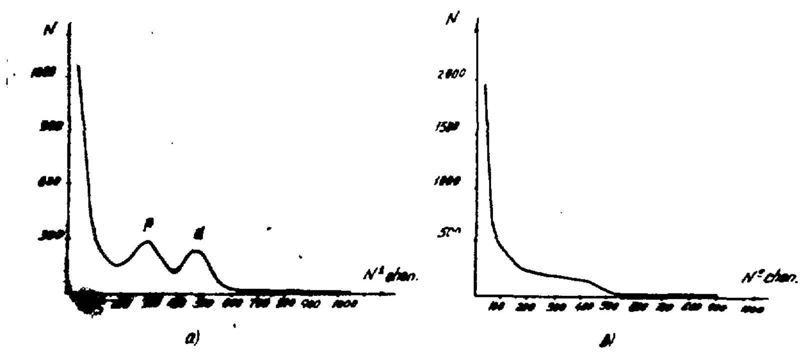
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Fig.2

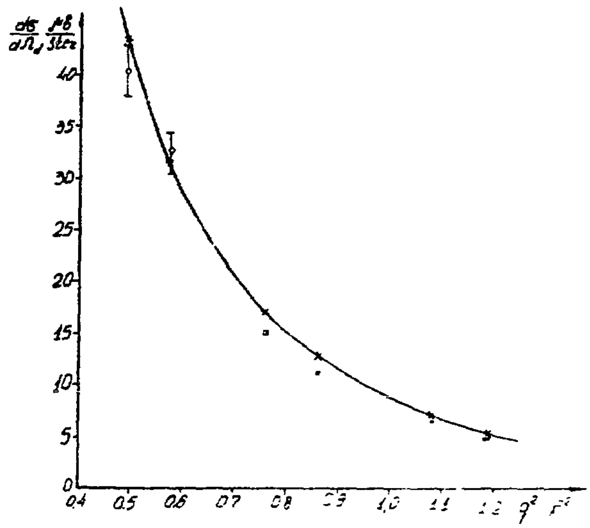

Fig.3

R E F E R E N C E S

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The manuscript was received on the 26th of July 1974

Тех.редактор А.С.Абрамян

Заказ 0988 ВФ-03468 Тираж 300

Подписано к печати 30/XII-74г. Формат издания 30 x 40

I,0 уч.изд.л. Ц.7 к.

Отпечатано на ротапринте
Ереванского физического институт,Ереван 36, ул. Маркаряна 2