ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
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ДУБНА

E1 - 7024

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1973

ЛАБОРАТОРИЯ ВЫСОКИХ ЭНЕРГИЙ

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SMALL ANGLE $\pi^- \, {}^4He$ ELASTIC SCATTERING AT 3.48 AND 6.13 GEV/C

Submitted to *ЯФ*

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E1 - 7024

Упругое $\pi^- {}^4He$ -рассеяние на малые углы при 3,48 и 6,13 Гэв/с

Измерены дифференциальные сечения упругого $\pi^- {}^4He$ рассеяния в области малых переданных квадратов четырехмерных импульсов $0{,}0056 \le |t| \le 0{,}087$ и $0{,}0056 \le |t| \le 0{,}0462$ (Гэв/с)^2 при 3,48 и 6,13 Гэв/с соответственно. Данные анализировались при помощи теории Глаубера. Определено полное сечение упругого $\pi^- {}^4He$ -рассеяния и эквивалентный радиус ядра ${}^4He$, а также параметр наклона бесспиновой амплитуды упругого πN рассеяния.

Препринт Объединенного института ядерных исследований.
Дубна, 1973

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E1 - 7024

Small Angle $\pi^- {}^4He$ Elastic Scattering at 3.48 and 6.13 GeV/c

N-75

The $\pi^- {}^4He$ elastic scattering differential cross sections were measured in the range of the small squared four-momentum transfers of $0.0056 \le |t| \le 0.087$ and $0.0056 \le |t| \le 0.0462$ (GeV/c)^2 at 3.48 and 6.13 GeV, respectively. The data were analysed by the Glauber theory. The slope parameter of the spin-independent differential cross sections of the πN elastic scattering was obtained. The slope parameter of the diffraction cone, the total $\pi^- {}^4He$ elastic scattering cross section and the equivalent radius of the ${}^4He$ nucleus were also determined.

Preprint. Joint Institute for Nuclear Research.
Dubna, 1973

1. Inrtoduction

In this paper the small angle coherent $\pi^- {}^4He$ scattering has been investigated at 3.48 and 6.13 GeV/c. The $\pi^- + {}^4He \to \pi^- + {}^4He$ process is interesting because it permits to study elastic scattering of spinless particles and makes it possible to estimate a spin-independent part of the πN elastic scattering amplitude in the framework of the Glauber model /1/. In the range of small momentum transfers, where the single scattering of the particle in the nucleus predominates according to the Glauber theory, the influence of spin effects upon the measured differential cross sections is practically excluded /2/.

2. Experimental Description

To detect $\pi^- {}^4He$ elastic scattering events, we used recoil α-particles that were generated by pions in a 50 x 50 x 15 cm^3 cloud chamber filled with helium at 1.14 and 3.5 atm and located in a magnetic field. A pion flux of 4 x 10^4 particles per expansion passed through the chamber.

The chamber worked under conditions of lower sensitivity. Use was made of the fact that low-energy recoil α-particle ionization exceeded that of beam relativistic particles by a factor of ~100.

To determine the direction of the beam pions, an exposure in which 5 - 10 relativistic particles per cycle passed through the chamber has been made.

In absolute measurements of the pion flux were made with the help of the nuclear photoemulsion placed behind the chamber to overlap the entire beam and also by means of an integral electronic system to measure the flux in each cycle.

3. Data Treatment. Measurement Accuracies and Background Estimates

After twice scanning the photographs, 15 000 events were selected for 3.48 GeV/c and 2 500 - for 6.13 GeV/c. The twice scanning efficiency was 99%.

After the treatment and subtraction of the background 2 450 and 400 elastic events were selected for 3.48 and 6.13 GeV/c, respectively (statistics contains only the events with a -particles that come to rest in the chamber gas, with the aim to obtain a very good t -resolution).

Elastic events were identified by kinematic criteria using a computer /3/. The momentum of the recoil a-particles, measured by its path, and its flight with respect to the primary direction of the beam pion were used as parameters.

Measurements were made in the range squared four-momentum transfers of $0.0056 \le |t| \le 0.087\ (GeV/c)^2$ and $0.0056 \le |t| \le 0.0462\ (GeV/c)^2$ for 3.48 and 6.13GeV/c, respectively.

The t-resolution is 0.001 and 0.0015 $(GeV/c)^2$ at 3.48 and 6.13 GeV/c. It is determined by the error in the path measurement, errors in the path-momentum ratio /4/, struggling and uncertainty in the chamber gas composition.

The error in measuring the recoil particle angle is determined by uncertainty in the field of beam pion directions, measurement error and Coulomb multiple and single scattering of the recoil a-particles.

The selection of elastic events is shown in fig. 1 that presents the distribution of the differences of the measured and kinematic angles for the given range of momentum transfers.

The peak widths of elastic events are in agreement with the above-mentioned error estimates in determining

the angle. On the left and on the right from the peak one can observe an isotropic background the source of which are neutrons and the processes of vaporizing character. The effect/background ratio is, on an average, 15/1.

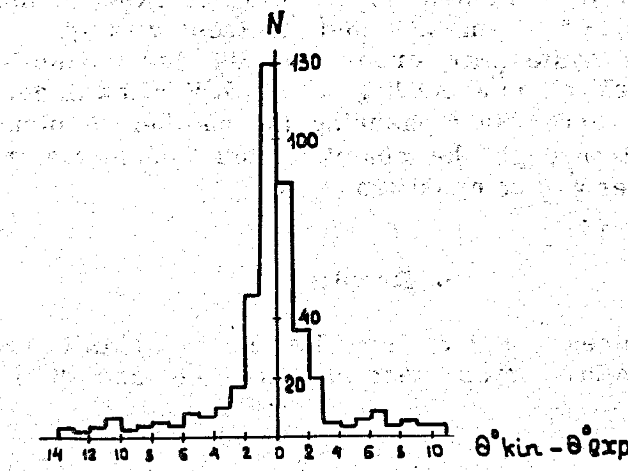

Fig. 1. Distribution of the differences of the measured and kinematic flight angles of recoil a -particles in one of the ranges of momentum transfers.

The processes of coherent production are easily discriminated by kinematic criteria. The quasi-elastic processes of the type $\pi^- + {}^4He \to \pi^- + n + {}^3He$ have a wide distribution spreaded by Fermi motion. Its maximum is shifted to the region of ~ 200 MeV/c a-particles momenta /5/ and we can consider this distribution as an isotropic one also in comparison with our elastic peak widths.

As in the chamber there are water vapours, $\pi^- + P \to \pi^- + P$ events, the kinematic parameters of which are similar to those of $\pi^-\ {}^4He$ elastic scattering, give an insignificant contamonation. The hydrogen in the chamber is 20 times less than that of helium, and the $\pi^- P$

elastic cross section is one order less than that of $\pi^- {}^4He$ elastic scattering. Therefore the contribution of this process does not exceed 0.5%.

The pion beam with a momentum of (3.48 ± 0.05)GeV/c contained (7 ± 1)% μ and (2.4 ± 0.3)% of electrons. In the beam with a momentum of (6.13 ± 0.14)GeV/c the contamination of μ -mesons and electrons was 6%.

The systematic error was 3% for measurement at 3.48 GeV/c and about 10% at 6.13 GeV/c. It was determined by the error in measuring the number of pions having passed through the chamber and by uncertainty in the chamber gas composition.

4. Results

Figures 2 and 3 show the $\pi^- {}^4He$ elastic scattering differential cross sections at 3.48 and 6.13 GeV/c.

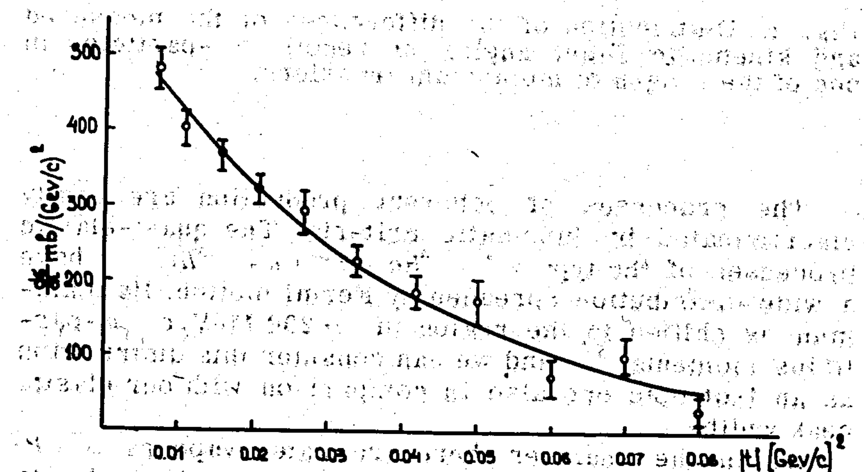

Fig. 2. $\pi^- {}^4He$ elastic scattering differential cross sections at 3.48 FeV/c. The curve is calculated by formula (1) at the following parameters: $\sigma_{\pi N}$ = 29.95 mb, α = 0.24, R = 1.37F, a = 6.41 (gEv/c)$^{-2}$, β = 1.035.

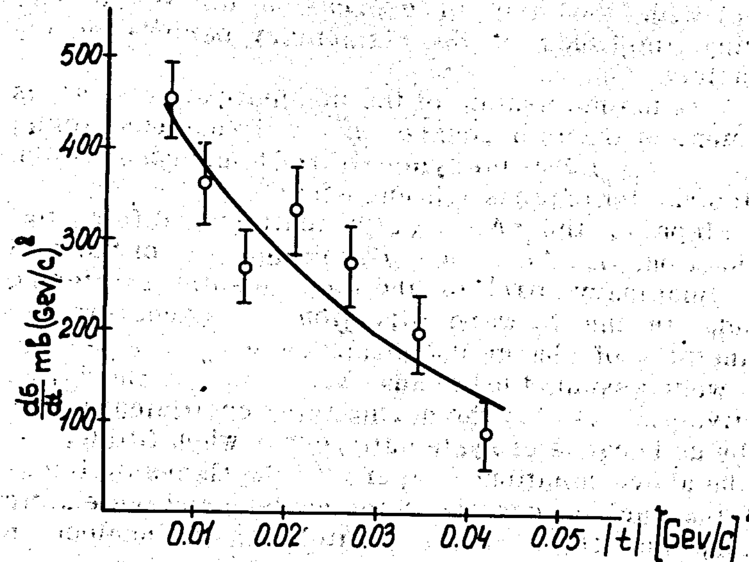

Fig. 3. $\pi^- {}^4He$ elastic scattering differential cross sections at 6.13 GeV/c. The curve is calculated at the following parameters: $\sigma_{\pi N}$ = 26.798 mb, α = 0.18, R = 1.37F, a = 12.89 (GeV/c)$^{-2}$, β = 1.153.

In the first range of $0.0056 \leq |t| \leq 0.0090$ (GeV/c)^2 the correction was made for the Coulomb scattering and for the Coulomb and nuclear scattering interference. In the other intervals $d\sigma/dt$ was not corrected because the corrections were essentially less than the statistical errors.

The analysis of the data was performed with the help of the Glauber model.

For the $\pi^- {}^4He$ elastic scattering differential cross section we use the ratio

$$\frac{d\sigma}{d\Omega_{c.m.}} = \beta \left(\frac{p_{c.m.}\sigma_{\pi N}}{\pi}\right)^2 \exp\left[-q^2\left(\frac{R^2+2a}{2} - \frac{R^2}{8}\right)\right] \left\{ \left(1 - \frac{3\sigma_{\pi N}}{8\pi(R^2+2a)} \times \exp[(R^2+2a)q^2/8]\right)^2 + \alpha^2 \left(1 - \frac{3\sigma_{\pi N}}{4\pi(R^2+2a)} \exp[(R^2+2a)q^2/8]\right)^2 \right\} \quad (1)$$

obtained with the help of expression for the elastic scattering amplitude of the elementary particle on the ^4He nucleus [6].

$p_{c.m.}$ is the momentum of the incident particle; q^2 is the momentum transfer square; R is the nucleus radius; $\sigma_{\pi N} = (\sigma_{\pi^- p} + \sigma_{\pi^+ p})/2$ is the symmetrized total cross section of the interaction of pions with nucleons [7]; $a = (a_{\pi^- p} + a_{\pi^+ p})/2$ is the slope of the πN elastic scattering differential cross section; $a = (a_{\pi^- p} + a_{\pi^+ p})/2$ is the ratio of the real to the imaginary part of the πN elastic scattering amplitude in the forward direction [8]. (According to the principles of charge independence $\sigma_{\pi^- n}$, $a_{\pi^- n}$ and $a_{\pi^- n}$ were assumed to be equal $\sigma_{\pi^+ p}$, $a_{\pi^+ p}$ and $a_{\pi^+ p}$, respectively). β is the normalizing coefficient introduced by us because of systematic error when fitting.

In the above-mentioned paper [6] the Gauss distribution of the nucleon density in the nucleus and the elastic scattering amplitude of the particle on the nucleon in the form were used

$$f = \frac{(i + a)}{4\pi} p \sigma_{\pi N} \exp(-a q^2/2).$$

When fitting by the least-square method, β and a were free, the other parameters were fixed. As a result, the following values were obtained for the normalizing coefficient β and the slope parameter a of the spin-independent πN elastic scattering differential cross sections

$\beta = 1.035 \pm 0.029$ for 3.48 GeV/c,
$\beta = 1.153 \pm 0.086$ for 6.13 GeV/c,

(what is in agreement with the systematic errors determined by another method);

$a = (6.41 \pm 2.09)$ (GeV/c)$^{-2}$ at 3.48 GeV/c,
$a = (12.89 \pm 6.17)$ (GeV/c)$^{-2}$ at 6.13 GeV/c.
$\chi^2 = 7.43$, $n = 8$ at 3.48 GeV/c and
$\chi^2 = 6.97$, $n = 4$ at 6.13 GeV/c.

The slope a of the spin independent πN elastic scattering amplitude obtained by us within the error is not different from that of the amplitude obtained in πN scattering experiments.

If the ratio of the real to the imaginary part of the πN amplitude increases with t [9] the value a should somewhat be changed.

If the differential cross section are approximated by the expression $d\sigma/dt = Ae^{Bt}$ and then integrated one can obtain the total $\pi^- {}^4He$ elastic scattering cross section. At 3.48 GeV/c $\sigma^{el}_{tot} = A_0 \int^{\infty} e^{Bt} dt = (20.33 \pm 1.81)$ mb what agrees well with Barashenkov's and Toneev's calculations by the Glauber model, fig. 4 [11]. The slope

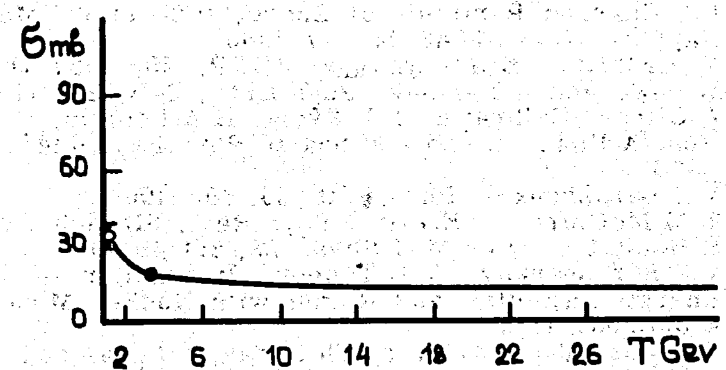

Fig. 4. Total $\pi^- {}^4He$ elastic scattering cross sections. The curve is calculated by the Glauber theory [11]. ⫯ - data of ref. [12], • - data of our paper.

parameters of the $\pi^- {}^4He$ scattering diffraction peak $B = (27.90 \pm 1.98)$ (GeV/c)$^{-2}$ at 3.48 GeV/c.

Using the model of black disk absorption we also obtain the equivalent radius of the ^4He nucleus

$$R_{eq} = 2\sqrt{B} = (2.086 \pm 0.074)\text{F}.$$

This is in agreement with the data on the electron scattering on nuclei [10]

$$R_{eq} = r_0 A^{1/3} = 1.31 A^{1/3} = 2.079 F.$$

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Received by Publishing Department
on March 26, 1973.