Краткие сообщения ОИЯИ № 1[52]-92 *JINR Rapid Communications No. 1[52]-92*
УДК 539.128

MEASUREMENTS OF THE $^{12}C(d, p)$ AND $p(d, p)$ FORWARD CROSS SECTIONS OVER A WIDE RANGE OF PROTON MOMENTA

V.G.Ableev, V.P.Ladygin, A.A.Nomofilov, L.Penchev, N.M.Piskunov, V.I.Sharov, I.M.Sitnik, E.A.Strokovsky, L.N.Strunov, S.A.Zaporozhets
Joint Institute for Nuclear Research, Dubna

I.Atanasov
Institute for Nuclear Research and Nuclear Energy, Sofia

S.Dshemuchadse
Zentralinstitut für·Kernforschung, Rossendorf

Measurements of the cross sections of deuteron stripping on carbon and protons were carried out at a deuteron momentum of $p_d = 9.1$ GeV/c in the region of momenta of forward emitted protons from $\cong p_d/2$ up to the kinematical limit. The cross sections of this reaction on proton were obtained using the CH_2-C subtraction method. The data tables are presented.

The investigation has been performed at the Laboratory of High Energies, JINR.

Измерение сечений реакций $^{12}C(d, p)$ и $p(d, p)$ в широком интервале импульсов вылетающих вперед протонов

В.Г.Аблеев и др.*

При импульсе дейтронов $p_d = 9{,}1$ ГэВ/с проведены измерения сечений реакции стриппинга дейтронов на углеродной и CH_2 мишенях в области импульсов протонов от $\cong p_d/2$ до кинематического предела. Сечение этой реакции на протоне получено с использованием вычитательной CH_2-C процедуры. Приводятся таблицы данных.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Introduction

Our previous measurements of the momentum spectra of forward emitted protons from the deuteron fragmentation on carbon performed over a wide range of proton momenta/1/ have revealed a promiment excess of the measured cross sections over the results of calculations based on the Relativistic Impulse Approximation (RIA)/1/ using popular deuteron wave functions (DWF) when the proton momenta taken in the deuteron rest frame (DRF) exceed 0.2 GeV/c. The importance of conclusions, which can be drawn from this observation, stimulated us to repeat measurements with an amended setup and enlarged statistics. To investigate a possible influence of the target-nucleus on the observed effect, new measurements were carried out using several nuclear targets (C, CH_2, Al, Cu). The new data were first presented at the Dubna conference/2/; first data on the proton-target are also shown in the figures of Ref./3/.

Some Experimental Details

Basically, the scheme of the experiment was not changed in comparison with the one described in Ref./1/, and so we point only to main features.

The experiment was performed at the JINR synchrophasotron. The spectrometer «ALPHA» was used in the deuteron beam with a momentum of 9.1 GeV/c (fig.1). The beam intensity varied between $5\cdot 10^7 \div 2\cdot 10^{10}$ particles/burst. The target support allowed one to use a pair of targets setting them on the beam in turn. The above targets were used in pairs (C, CH_2) and (Al, Cu). The intensity of the beam hitting the target was monitored with two sets of scintillation monitors looking at the target at an angle of about 90° relative to the beam direction.

The measured part of the entire momentum spectrum was chosen by setting a relevant current value in the magnet M0; the current in the coil of the M1 magnet was set in accordance with the M0 one. Two Čerenkov counters were used to separate protons from deuterons with the same momentum. Inelastically scattered deuteron background becomes appreciable at momenta close to 6 GeV/c and increases sharply with increasing momentum. The magnetic spectrometer with multiwire proportional chambers was used to measure the momenta and entering angles of particles directed into the spectrometer by the M0 magnet. The corresponding resolution of the spectrometer was $\sigma_p/p \cong 0.35\%$ and $\sigma_\theta \cong 0.5$ mrad.

The following amendments were made in comparison with the previous scheme.

The lenses after the M0 magnet were removed: their matter became a brighter source of secondary particles than the main target creating too large particle flux when high momentum protons were directed to

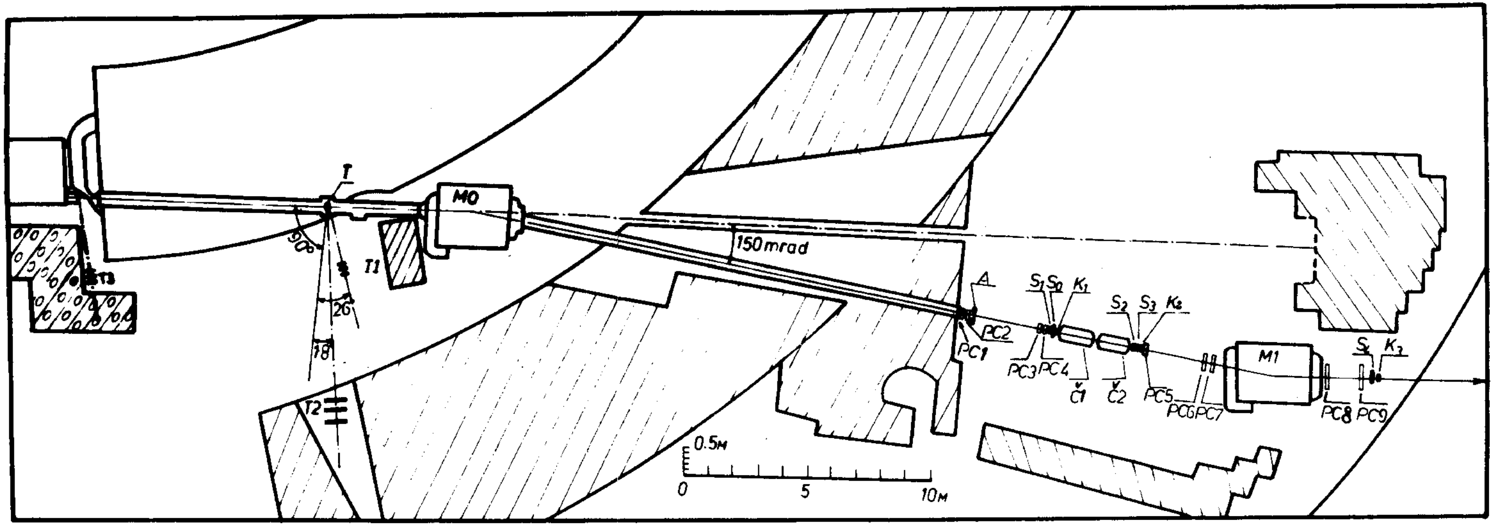

Fig.1. Schematic layout of the exprimental setup: S,K,A – scintillation counters; T1,T2 – monitoring telescopes, PC – multiwire proportional chambers; T – target; M0, M1 – bending and analysing magnets

the spectrometer because the trajectories of protons and primary deuterons were close to each other in this case.

The monitoring telescope system was updated which resulted in the improved ratio of counting rates with full and empty targets.

The data on magnetic fields from Hall probes in the magnets M0, M1 and the data on the beam distribution in the target area were transferred from the computer controlling the accelerator to our on-line computer.

The main trigger included a decision of the fast processor/4/, which selected events on the entering angles of detected particles. Strong correlations between the entering angles and momenta of particles allowed us to vary momentum acceptance of the spectrometer in such a way.

Data Analysis

Using information on beam characteristics, raw data were filtered: if the current beam location differed significantly from the mean one, the corresponding data stored during this cycle were excluded from further analysis. As a rule, the beam location was stable at a beam intensity of $\geq 10^9$. When the measurements were performed in the proton momentum region close to $p_d/2$ it was necessary to lower the beam intensity to $\cong 5 \cdot 10^7$ to keep counting rates in the spectrometer at an optimum level; in this case the beam location became unstable due to getting worse the operation of the beam control system at low intensity levels. This led to increasing the number of excluded cycles up to 30%.

Using the determined momentum and entering angle of the detected particle, the entering track was extrapolated to the target (taking into account the deflection in the M0 magnet and in the scattered magnetic field of the accelerator on the path between the M0 and the target), and the coordinates and angles of particle emission from the target were found. Taking into account the beam angular divergence, we estimate the emission angle resolution as $\cong 2$ mrad. Events were selected using a restriction on the coordinates of the particle emission point in the target.

Each M0 current setting determined the nominal momentum p_0 with which a particle emitted from the center of the target at an emission angle of 0° goes along with the spectrometer Z-axis. Events with momenta in the interval $|(p - p_0)/p| \leq 0.05$ were taken for further analysis for every M0 current setting. The angular acceptance of the

Table. The invariant cross sections of the ^{12}C (d, p) and $p\ (d, p)$ reactions

q	C(d,p)	p(d,p)	q	C(d,p)	p(d,p)
MeV/c	b GeV/(GeV/c)^{3}sr		MeV/c	mb GeV/(GeV/c)^{3}sr	
- 85	12.6±0.43	2.41±0.37	205	140±5.9	37.8±4.6
- 75	19.3±0.49	3.63±0.43	215	114±4.6	28.8±3.7
- 65	28.7±0.48	5.63±0.45	225	90.5±3.7	18.8±3.0
- 55	45.0±0.85	8.40±0.64	235	75.3±2.3	17.1±2.0
- 45	70.6±1.1	14.9±0.87	245	59.1±2.1	17.1±1.8
- 35	109±1.3	20.9±1.0	255	47.9±1.6	12.9±1.4
- 25	167±3.1	30.2±2.7	265	43.7±1.3	11.0±1.16
- 15	239±3.3	43.2±2.9	275	34.8±1.0	11.3±0.97
- 5	281±5.1	52.7±4.6	285	31.8±0.87	8.53±0.80
5	290±4.5	52.2±3.9	295	26.7±0.77	7.82±0.74
15	244±2.7	45.6±2.4	305	22.7±0.61	6.22±0.56
25	179±1.9	30.4±1.7	315	19.8±0.56	5.31±0.51
35	113±1.5	20.7±1.4	325	18.5±0.46	4.30±0.41
45	70.6±1.1	13.2±1.0	335	15.5±0.37	4.30±0.35
55	40.6±0.83	8.17±0.73	345	13.4±0.29	3.97±0.28
65	25.6±0.59	4.41±0.54	355	11.4±0.26	3.32±0.24
75	15.4±0.52	3.12±0.43	365	9.37±0.19	2.63±0.16
85	9.98±0.33	2.07±0.27	375	7.62±0.17	2.30±0.16
95	6.31±0.21	1.25±0.19	385	6.46±0.14	1.88±0.14
105	4.35±0.15	0.83±0.14	395	4.88±0.12	1.66±0.11
115	2.84±0.099	0.66±0.089	405	3.99±0.11	1.22±0.099
125	1.81±0.080	0.42±0.071	415	3.20±0.095	0.859±0.082
135	1.22±0.046	0.25±0.041	425	2.40±0.074	0.732±0.068
145	0.811±0.031	0.197±0.029	435	1.89±0.065	0.566±0.059
155	0.570±0.023	0.153±0.022	445	1.53±0.061	0.483±0.057
165	0.416±0.019	0.102±0.017	455	1.20±0.051	0.345±0.048
175	0.299±0.012	0.091±0.012	465	0.886±0.045	0.240±0.041
185	0.229±0.008	0.062±0.008	475	0.668±0.039	0.194±0.035
195	0.182±0.007	0.037±0.007	485	0.491±0.032	0.140±0.029
			495	0.391±0.030	0.150±0.032
			505	0.333±0.033	0.129±0.031
			515	0.306±0.032	0.044±0.028

spectrometer was ≅1.5 mrad for fixed p inside this interval; the mean emission angle correlated with the value of $\delta p = (p - p_0)/p$ and varied from 0 up to 6 mrad when δp changed from 0 up to 0.05.

To obtain the cross sections, we analyzed the proton momentum distributions of events taken in DRF, namely:

$$q^2 = q_t^2 + q_l^2, \quad q_t = p\cdot\sin\theta, \quad q_l = F(p\cdot\cos\theta),$$

where p, θ are the momentum and emission angle of the proton in the laboratory; and F, the corresponding Lorentz transformation. The maximum value of q_t was about 30 MeV/c at $p = p_d/2$ (4.55 GeV/c) and about 50 MeV/c at p = 8 GeV/c. It is particularly important to take q_t into account in the vicinity of $p_d/2$, where $q_l \cong 0$, because in this case $q \cong q_t$. In this region the fragmentation cross section proportional to the DWF squared, i.e. $\Psi^2(q)$, has a very sharp dependence on q ($\Psi^2(0)/\Psi^2$ (30 MeV/c) = 1.9). The correctness of this procedure is confirmed by the fact, that the overlapped data sets, stored at close nominal p_0 in the region of $p_d/2$, agree very well when the q-distributions are compared and they disagree strongly when the q_l-distributions of the same data sets are used. The correctness of such a procedure is also supported by Refs./5,6/, where the angular distribution of proton-spectators with $q \leq 50$ MeV/c is shown to be isotropic; the difference between q and q_l is negligible at large q_l, where relativistic effects should be taken into account.

The entire momentum spectra were normalized using the results of the specially performed measurements/7/.

The invariant forward cross sections of the reactions $^{12}C\,(d, p)$ and $p\,(d, p)$ are presented in the table as a function of proton momentum q in the DRF (we ascribed to q the sign coinciding with that of q_l to distinguish proton momenta in the laboratory $p \leq p_d/2$ and $p \geq p_d/2$).

Figure 2 presents the ratio of these cross sections. It changes as much as twice when q varies from 0 up to 0.2 GeV/c and remains almost constant when q increases above 0.2 GeV/c. Such a behavior is steeper than the one predicted by the Glauber-Sitenko calculations performed by us following Ref./8/ but it is not so sharp as predicted in Ref./9/. The full calculation for the carbon target and the one made in the framework of Impulse Approximation are presented in this paper. The comparison of the ratio of these calculations with the experimental one presented in fig.2 is correct if the Glauber-Sitenko corrections to the cross section of the reaction $p(d, p)$ are small. The data shown in fig.2, namely the

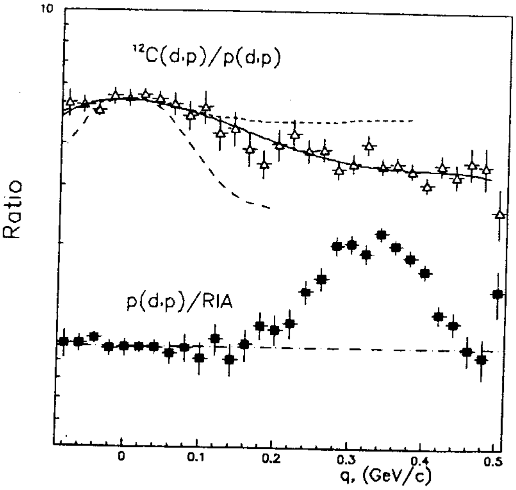

Fig. 2. The ratio of the cross sections of the $^{12}C\,(d, p)$ and $p\,(d, p)$ reactions (o). Solid line – the polinomial data fit; dashed lines – the calculations based on refs./8/ (long dashed) and/9/ (short dashed). (□) – the ratio of cross sections of the reaction to ones predicted by RIA using the Paris potential/10/

ratio of the measured cross sections of the reaction to the one calculated in the RIA framework with the Paris DWF[10], demonstrate a satisfactory agreement for $q \leq 0.2$ GeV/c (and hence the Glauber-Sitenko corrections are really small for $p(d, p)$ reaction).

The excess at $q \geq 0.2$ GeV/c of the measured cross sections over the ones calculated in the RIA, mentioned in the Introduction, is discussed in Refs.[1,2,11] (see also the references quoted therein).

References

1. Ableev V.G. et al. - Nucl. Phys., 1983, A393, p.491; A411, p.541(E).
2. Zaporozhets S.A. et al. - In: Proc. of the VIII Int.Seminar on High Energy Phys., JINR D1,2-86-668, Dubna, 1986, p.341.
3. Ableev V.G. et al. - Pis'ma Zh. Exp. Teor. Fiz., 1987, 45, p.467 (JETP Lett., 1987, 45, p.467).
4. Ableev V.G. et al. - PTE, 1978, 2, p.63.
5. Ableev V.G. et al. - Yad. Fiz., 1983, 37, p.132.
6. Aladashvili B.S. et al. - J.Phys. G: Nucl. Phys., 1983, 1, p.913.
7. Ableev V.G. et al. - this issue, p.5.
8. Bertocchi L., Treleani D. - Nuovo Cim., 1976, 36A, p.1.
9. Nissen-Meyer S. - Nucl. Phys., 1978, A306, p.499.
10. Lacombe M. et al. - Phys. Lett., 1981, 101B, p.139.
11. Brawn M.A., Vechernin V.V. - Yad. Fiz., 1984, 40, p.1588; Ignatenko M.A., Lykasov G.I. - Yad. Fiz., 1987, 46, p.1080 (Sov. J. Nucl. Phys., 1987, 46, p.661); Azhgirei L.S. et al. - Yad. Fiz., 1988, 48, p.87.

Received on December 29, 1991.