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ANALYZING POWER IN $d\uparrow C \rightarrow pX$ AND $d\uparrow C \rightarrow pp(d)X$ REACTIONS FOR FAST PROTONS SCATTERED AT LARGE ANGLES

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Measurements of the vector analyzing power, A_y, for $d\uparrow C \rightarrow pX$ reaction at deuteron energies 1.2, 1.6, 2.0 and 4.2 GeV and for $d\uparrow C \rightarrow pp(d)X$ reaction at 1.6 GeV are reported. The protons weie detected at a large angle in kinematic region forbidden for scattering on free protons. Inclusive data are in good agreement with the previous $p\uparrow C \rightarrow pX$ measurements. Some simple scaling for A_y is demonstrated. The strong correlation between A_y value and the energy of forward protons (deuterons) was found for $d\uparrow C \rightarrow pp(d)X$ reaction. It seems possible to separate the contributions of two different mechanisms of fast proton production at large angles.

The investigation has been performed at the Particle Physics Laboratory, JINR.

Анализирующая способность $d\uparrow C \rightarrow pX$ и $d\uparrow C \rightarrow pp(d)X$ реакций для быстрых протонов, рассеянных на большие углы

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Докладываются результаты измерения анализирующей способности, A_y, для реакции $d\uparrow C \rightarrow pX$ при энергии дейтронного пучка 1,2; 1,6; 2,0 и 4,2 ГэВ и для реакции $d\uparrow C \rightarrow pp(d)X$ при энергии дейтронного пучка 1,6 ГэВ. Протоны детектировались под большими углами, в области, кинематически запрещенной для свободного протон-протонного рассеяния. Инклюзивные данные находятся в хорошем согласии с данными, полученными ранее для реакции $p\uparrow C \rightarrow pX$. Для анализирующей способности продемонстрирован простой скейлинг. Для реакции $d\uparrow C \rightarrow pp(d)X$ обнаружена сильная корреляция между анализирующей способностью и энергией протонов (дейтронов), испущенных в переднюю полусферу под малыми углами. Полученные данные демонстрируют возможность разделения вкладов двух различных механизмов образования протонов под большими углами в дейтрон-ядерных взаимодействиях.

Работа выполнена в Лаборатории сверхвысоких энергий ОИЯИ.

This paper describes the measurements of the vector analyzing power A_y in reactions $d\uparrow C \to pX$ and $d\uparrow C \to pp(d)X$ in kinematic region forbidden for scattering on free protons.

The problem of energetic proton production in backward directions in proton-nucleus collisions has been discussed for several years. There are many models based on different assumptions about the reaction mechanisms successfully used to explain the inclusive cross section data[1-6]. Two types of experiments are expected to clarify this situation: analyzing power measurements and two-particle correlation measurements.

The present inclusive measurements of A_y in reactions induced by vector polarized deuterons complete the previous results obtained for the reactions with polarized protons at energies in the range of 0.3 — 0.8 GeV[7-10].

The measurements of A_y for backward proton scattering from Be and C with 303 MeV polarized protons[7] have shown that A_y is small and negative. Only for the narrow region near the kinematic limit A_y value is large and negative, and approaches the predictions of Single Scattering Model (SSM)[11]. The measurements of A_y at higher energies (500 MeV and 800 MeV)[8-10] contradict the SSM predictions. For backward angles A_y is small, too. But at 60°-90° near the kinematical limit, A_y value is large and positive, whereas SSM predicts large negative values.

Our inclusive data can be useful for understanding the dependence of A_y on the projectile energy. We also present the measurements of A_y for $d\uparrow C \to pp(d)X$ reaction at 800 MeV/nucleon. The two-particle correlation measurement with a polarized beam can be helpful to determine the relative role of various mechanisms in fast proton production. We suppose that in the fast proton production at a large angle only one of deuteron's nucleon interacts violently. The other nucleon plays a spectator role and it goes forward as a stripping. Interactions of the spectator nucleon inside the nucleus can increase some "background" but cannot change general features of the scattering mechanism.

In inclusive studies we have used the vector polarized deuteron beam of the Dubna synchrophasotron[12] at the energies of 0.6, 0.8, 1.0 and 2.1 GeV/nucleon and the intensity up to 0.5×10^9 deuterons per cycle. The vector polarization of the beam was reversed up and down every cycle. The typical values of the vector polarization were +0.35 and -0.35, respectively. The internal target of thin (2 micrometers) polyethylene foil was used. The beam polarization was controlled with measuring of $d\uparrow p$ elastic scattering asymmetry. For this purpose recoil protons were detected by two telescopes of semiconductor detectors at the angles of +82° and -82°.

The windows in the accelerator chamber at 75°, 102° and 120° were used to place three identical telescopes each covering the space angle of 2.5 msr. Every telescope consisted of two plastic scintillators (7 mm thick) and two NaI(TL) crystals (80 and 150 mm thick). To extend the upper limit of measurable proton energy up to 600 MeV, some absorbers were inserted between the plastic scintillators.

The measured A_y values are shown in Figs.1 and 2. At deuteron energy of 800 MeV/nucleon our data are in good agreement with the $p\uparrow C \to pX$ measurements at 800 MeV/9/. At the backward angles the values of A_y are small. At 75° common trend of data is obvious for all projectile energies. The low energy protons are mainly recoils of the quasi-free scattering of the beam particles on the nucleus protons. The value of A_y for them is negative. At higher proton energies A_y changes its sign and becomes positive and large.

If to present all data on A_y obtained at 75° as a function of cumulative number Q one can see that they follow the same Q-dependence at all projectile energies. (see Fig.3).

The Q equals the mass of the target where the proton should scatter elastically to be detected at the corresponding angle and can be calculated by the formula:

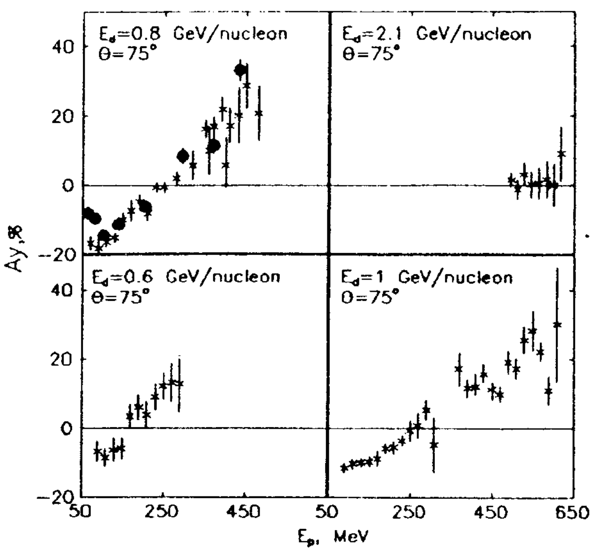

Fig.1. Dependence of analyzing power of $d\uparrow C \to p + X$ reaction on the energy of detected protons at angle 75°. x — data of the present experiment; ● — data from Refs.9.

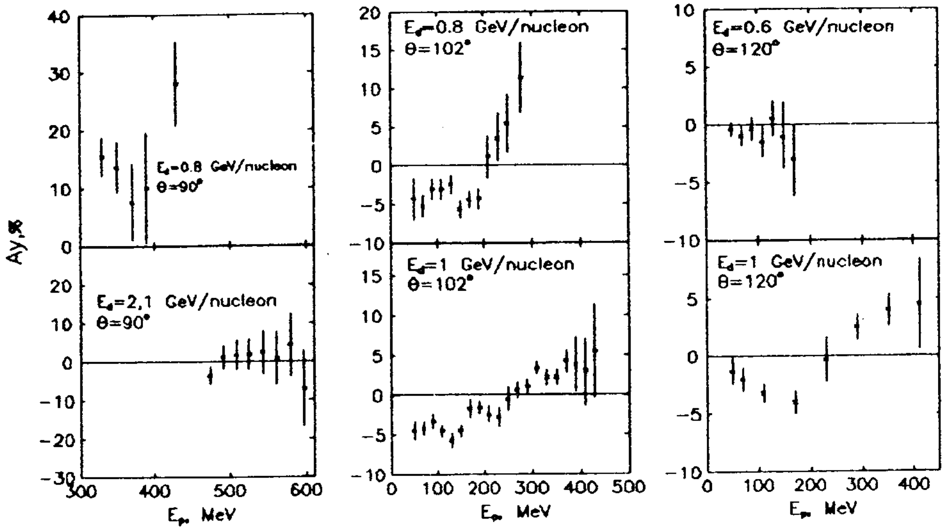

Fig.2. Dependence of analyzing power of d↑C → p + X reaction on the energy of detected protons at angles 90°, 102° and 120°.

$$Q = (E_0 \cdot E - P_0 \cdot P \cdot \cos\theta - M_p^2)/((E_0 - E) \cdot M_p),$$

where E_0 and P_0 are energy and momentum of the projectile, E, p, θ are energy, momentum and angle of the detected proton. This scaling may both: either reflect kinematics of internucleus scattering or just be the result of closeness to the kinematical limit.

The study of pA → pp(d)X reaction where the fast proton at a large angle is detected in coincidence with forward protons (deuterons), is more informative for investigation of cumulative proton production mechanism[6,13-15]. For example, at 800 MeV the coincidence experiment[15], distribution $d^4\sigma/dp_1(118°)dp_2(15°)d\Omega_1\, d\Omega_2$ as a function of p_1 and p_2 has shown two bumps: the first one is from quasielastic pp scattering and the second, more broad, — from p-(2N) breakup region.

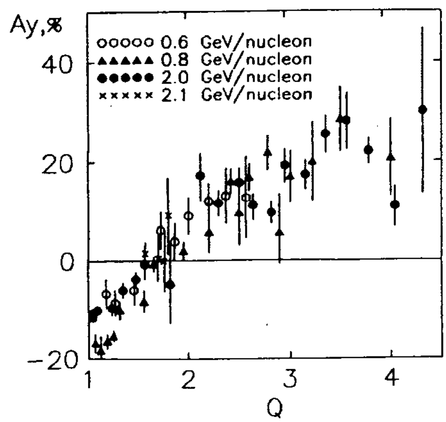

Fig.3. Analyzing power of d↑C → p + X reaction for angle 75° at different beam energies as a function of cumulative number.

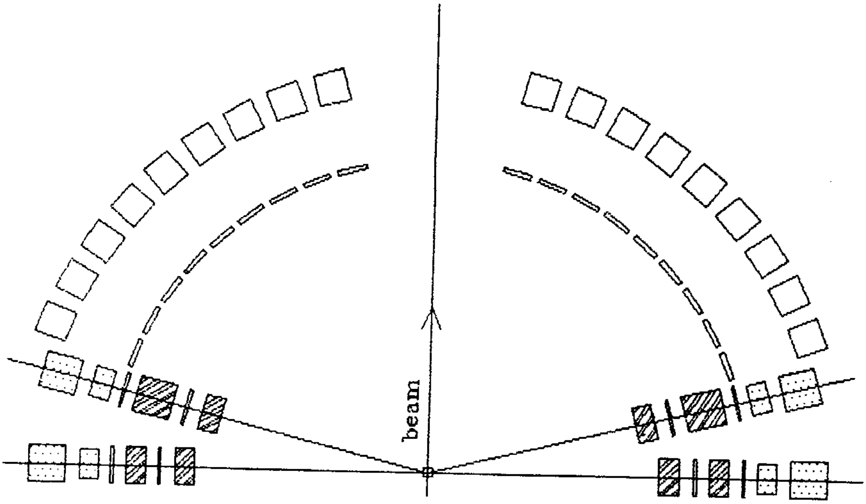

Fig.4. The setup of the correlation experiment. ⊞ — NaJ(TL) crystals; □ — plastic scintillators; ▨ — obsorbers.

The conclusion of that experiment/15/ is the following: the main contribution to backward energetic proton production appears to be given by the proton scattering on correlated nucleon clusters.

We have performed measurements of A_y for $d\uparrow C \to pp(d)X$ reaction at deuteron energy 800 MeV/nucleon. The setup used for this experiment is shown in Fig.4.

The protons at 75° and 90° with the energy region of 340-500 MeV were detected in coincidence with the forward protons (deuterons) at $\pm 18^\circ \leqslant \theta \leqslant \pm 72^\circ$ and $-5^\circ \leqslant \phi \leqslant +5^\circ$. The scintillator telescopes at 75° and 90° were the same as for the inclusive measurements. Eighteen scintillator telescopes were placed at the forward angles. Each of them consisted of the ΔE plastic scintillator of 20 mm thick and the E-plastic scintillator of 130 mm thick. The event trigger signal was generated by any particle passing through both the plastic scintillators and the absorber placed between them in any of the telescopes fixed at 75° or 90°. This trigger signal opened the gates for all ADC and gave start for all TDC. Thus, the amplitude and the time of flight were measured for every of the 44 scintillators. The typical beam intensity was 5×10^7 particles per beam and the beam repetition was 8 s. The duration of each beam was about 350 ms. The thickness of the target was 5 g/cm². The polarization of the deuteron beam was the same as for the inclusive measurements.

Table. The A_y values for $d\uparrow C \rightarrow pp(d)X$ reaction

75°	27° - 39°	A_y %
Protons 360-500 MeV	Protons 40-220 MeV	+31.5±7.8
	Deuterons 50-250 MeV	+37.3±15.9
	Protons, E > 220 MeV	-6.3±10.9
90°	**27° - 39°**	
Protons 340-480 MeV	Protons 40-220 MeV	+26.7±12.7
	Deuterons 50-250 MeV	+33.3±23.1
	Protons, E > 220 MeV	-24.4±15.9

The protons in thick NaJ(Tl) trigger telescopes were separated perfectly well from the pions and background. Due to the poor statistics we divided all the data in six groups, presented in the Table and shown in Fig.5. All the particles passing through the forward telescopes too fast to be identified in ΔExE or in txE plots, were considered the protons with energy higher than 220 MeV. The admixture of pions can be neglected for these rough measurements. Due to momentum conservation the 90% of all the particles in forward scintillators were registered in four counters which were close to the beam on the side opposite to the trigger particle. We have not included the data from the two forward counters nearest to the beam (one from both the sides) because of the big background and the big admixture of accidental coincidences.

It is seen from Fig.5 that there are two different mechanisms of fast proton production at large angles which give different values of A_y. The fast protons at 75° and 90° in coincidence with the fast forward

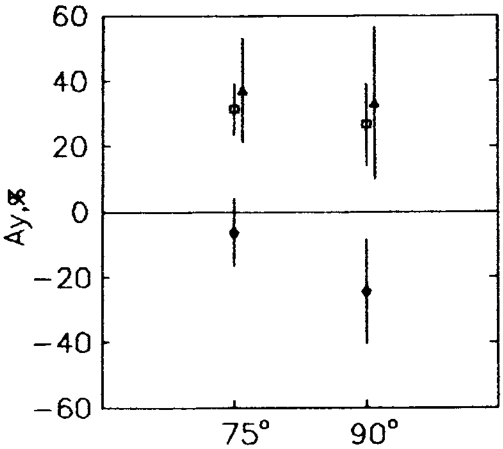

Fig.5. Analyzing power of $d\uparrow C \rightarrow p(p,d) + X$ reaction for protons coming out at angles 75° and 90° in coincidence with forward: □ — slow protons, ▲ — slow deuterons, ♦ — fast protons.

protons give the negative value of A_y, that agrees with the SSM predictions. The coincidence with the slow forward protons or deuterons gives large and positive value of A_y. It seems that in this kinematical region it is easy to separate the contributions of SSM mechanism and another one, cluster or quasi coherent mechanism, not only kinematically as it was done in reference 15 but taking into account the A_y.

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