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# Results of Measurements of the Analyzing Powers for Polarized Neutrons on $C$, $CH_2$ and $Cu$ Targets for Momenta Between 3 and 4.2 GeV/c.

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**Abstract.** The analyzing powers for neutron charge exchange $nA \to pX$ reactions on nuclei have been measured on C, CH2 and Cu targets at incident neutron momenta 3.0 - 4.2 GeV/c by detecting one charged particle in forward direction. The polarized neutron measurements are the first of their kind. The experiment was performed using the Nuclotron accelerator in JINR Dubna, where polarized neutrons and protons were obtained from breakup of a polarized deuteron beam which has a maximum momentum of 13 GeV/c. The polarimeter ALPOM2 was used to obtain the analyzing power dependence on the transverse momentum of the final-state nucleon. These data have been used to estimate the figure of merit of a proposed experiment at Jefferson Laboratory to measure the recoiling neutron polarization in the quasi-elastic $^2H(e, e'n)$ reaction, which yields information on the charge and magnetic elastic form factors of the neutron.

## 1. Introduction

The proposal E12-07-109 [1] to measure the $p/n$ polarization from the reaction $^2H(\vec{e}, e'p/n)$ up to momentum of $p/n$ equal 8 GeV/c needs to have analyzing power $A_y$ in dependence on solid scattering angle or its derivatives. This unique possibility takes place at the JINR NUCLOTRON. We are planning to measure $A_y$ at the beam momenta of protons/neutrons up to 6.5 GeV/c. A part of this program is completed and we present the data on analyzing power for the $nA$ interaction within the neutron momentum range 3.00 to 4.2 GeV/c.

## 2. Measurements

To obtain polarized proton/neutron beams we used the accelerated deuteron beam. After its interaction on the $T1$ target (see Fig.1), the secondary beams of protons/neutrons of half-momenta were directed to the $T2$ target. The $T1$ target was set at different locations to produce proton/neutron beams. The polarization transfer from deuteron to half-momentum nucleon is equal to 1. Spectra and $\varphi$-asymmetry of scattering on the $T2$ target were measured with the help of drift chambers. For the neutron beam the average value of the directions of the secondary particles was assumed as direction of the incident particles. These values were monitored every 10 min of beam time.

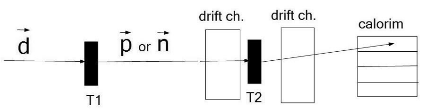

**Figure 1.** The scheme of the experiment.

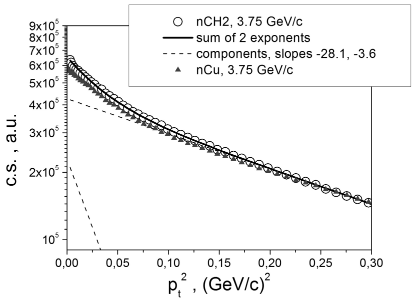

**Figure 2.** Spectra of the reaction $n + A \to p + X$.

To separate elastic and inelastic scattering on $T2$ information from the calorimeter was used.

More details on the experiment can be found in [2].

## 3. Results

The results are presented as a function of the variable $p_t = p_{lab} \sin\theta$. For elastic scattering of equal mass particles we have $p_t^2 \simeq -t$, where $t$ is a Mandelstam variable, which is good to the description of the elastic scattering spectra. Therefore, we present the obtained $n \to p$ spectra as a function of $p_t^2$.

Part of the obtained results is shown in Fig.2. Firstly, one can see that A-dependence is not observed. Secondly, we see two distinct exponential slopes in the spectra behavior. Alike behavior of $p \to n$ spectra was observed in, for example, [3]. There, a sharper slope has been attributed to $\rho$-exchange, the other one – to $\pi$-exchange.

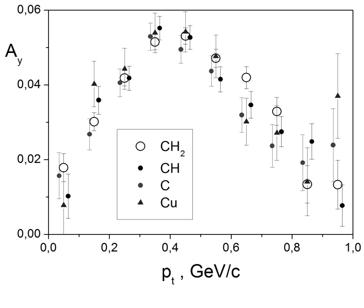

**Figure 3.** A-dependence of $A_y$ in the reaction $n + A \to p + X$.

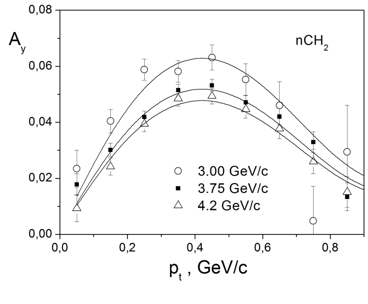

**Figure 4.** Momentum dependence of $A_y$ in the reaction $n+A \to p+X$.

Following Ref. [4], the $\varphi$-asymmetry of the reaction with the vector polarized beam is:

$$N(p_t, \varphi, P) = N_0(p_t)[1 + A_y(p_t) P \cos\varphi], \ -1 \leq P \leq 1 \tag{1}$$

where $N_0$ is yield on unpolarized beam, $P$ is vertical polarization. For 2 values of polarization we have 2 Eqs.1, and so, we can exclude $N_0$. The solution is given in [5].

The $A$-dependence of the analyzing power is shown in Fig.3. One can see that no sizeable dependence is observed.

The dependence of the analyzing power on the beam momentum is shown in Fig.4.

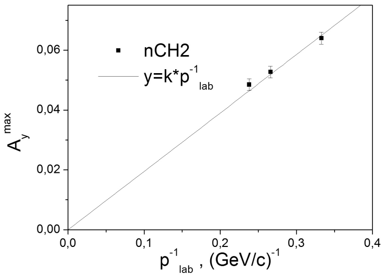

**Figure 5.** Dependence of $A_y^{max}$ on neutron beam momentum.

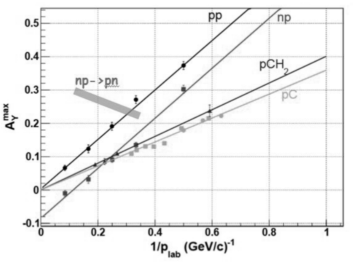

**Figure 6.** Dependence of $A_y^{max}$ on proton beam momentum.

We can remark here that the positions of maxima of $A_y$ coincide. The dependence of the values of maxima on the beam momentum is shown in Fig.5. We see that these value are proportional to $p_{lab}^{-1}$. A similar behavior in the $p \to p$ reaction was observed in [5] and other experiments (see Fig.6).

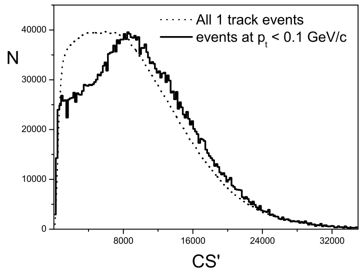

**Figure 7.** $CS'$ distributions.

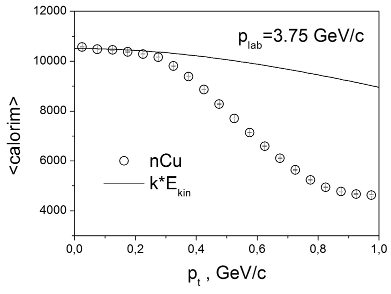

**Figure 8.** Average $CS$ vs $p_t$.

The polarization measurement error is described by the following formula:

$$\Delta P = \frac{1}{\mathcal{F}} \sqrt{\frac{2}{N_{inc}}}, \tag{2}$$

where $N_{inc}$ is the number of incident particles, $\mathcal{F}$ is the figure of merit. $\mathcal{F}$ is connected to analyzing power, differential cross section and target thickness by

$$\mathcal{F}^2 = N_{nucl} \int_{p_t} \frac{d\sigma}{dp_t} A_y^2(p_t) \, dp_t, \tag{3}$$

where $N_{nucl}$ is the number of nuclei in the target.

Let us consider now, how the calorimeter may improve $\mathcal{F}$. The distribution of given values, $CS' = CS * E_{kin}(0)/E_{kin}(p_t)$, where $CS$ is calorimeter signals, is shown in Fig.7. Also, it is shown the same distribution, but at $p_t < 0.1$ GeV/c (normalized), where events are certainly elastic. The average $CS$ vs $p_t$ is shown in Fig.8. We expect, for elastic scattered events these values are proportional to $E_{kin} = f(p_t, p_{lab})$. We see such a behavior at $p_t < 0.3$ GeV/c. At higher values of $p_t$ the average $CS$ are sizeable less due to contribution of inelastic scattering with small $A_y$. It is seen from Fig.9 that larger values of $A_y$ correspond to larger values of $CS$.

Subdividing all events on 3 slices along $CS'$, we can construct

$$\mathcal{F}_c^2 = \sum_{i=1}^{3} \mathcal{F}_i^2, \tag{4}$$

where $i$ is the slice number, $\mathcal{F}_i^2$ is Eq.3 for $i$-th slice. In Fig.10 it is seen that such an approach improves figure of merit.

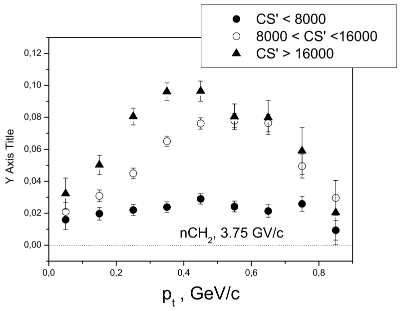

**Figure 9.** $A_y$ vs $p_t$ for 3 regions of $CS'$.

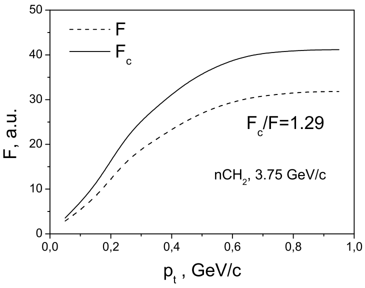

**Figure 10.** Figure of Merit vs acceptance of the setup.

For the track reconstruction via the drift chambers, the description of the spectra and obtaining of $A_y$, the soft [6, 7] was used.

## Acknowledgments

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