

# POLARIMETER ALPOM: RESULTS AND PERSPECTIVES

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## Abstract

We report the results recently obtained at the accelerator complex of the JINR-LHE (Dubna), concerning the analyzing powers for the reaction  $\vec{p} + CH_2 \rightarrow$  one charged particle  $+X$ , at proton momenta of 1.75, 3.8, 4.5 and 5.3 GeV/c. These results extend the existing data basis, necessary for proton polarimetry at intermediate energy, and confirm the feasibility of a large acceptance polarimeter based on this process. The polarimeter ALPOM is operational and can be installed on different beam lines. The plans of future measurements are also discussed.

Many studies in the intermediate energy physics require the measurement of the polarization of the secondary particles. These investigations provide rich information concerning the nuclear structure and the reaction mechanism. In particular the  $G_{Ep}$  collaboration at the Jefferson Laboratory [1] plans to extend the measurement of the ratio between the electric and the magnetic form factor,  $G_{Ep}/G_{Mp}$ , up to  $Q^2 = 9 \text{ GeV}^2$  by the recoil proton polarization method [2]. The 3rd phase of this experiment requires the construction of a new polarimeter that will measure the polarization of the recoil proton of momentum up to 5.5 GeV/c:

Polarization experiments are, in general time consuming. Therefore a thorough optimization of the characteristics of the polarimeter is desired. This requires a careful study of the analyzing reaction, which has to have large cross section and large analyzing powers. Usually polarimeters with  $2\pi$  azimuthal angular acceptances, based on inclusive scattering on a carbon target, are built for such purposes [3, 4]. The efficiency of such polarimeters can reach 40% for the inclusive reaction  $p + C(CH_2) \rightarrow p + X$  on thick  $C(CH_2)$  analyzers. An optimization of the nature and the thickness of the absorber as well as of the geometry of the detection system are required, and these depend strongly upon the kinematical conditions. The inclusive scattering on a C or  $CH_2$  target has been

used up to  $p_p = 4$  GeV/c at Jefferson Lab (JLab). The average analyzing power decreases smoothly with increasing momentum. A  $\text{CH}_2$  analyzer gives a better analyzing power than  $C$  [5].

To realize the experiment that we will describe here, the POMME polarimeter, which has been widely used at Saclay, was transported to Dubna and used as a part of the detection system of the ALPHA spectrometer. A schematic view of the detection is shown in Fig. 1.

The incident protons were detected by proportional chambers PC1, PC2 (ALPHA) with sensitive area  $12 \times 12$  cm<sup>2</sup>. The three wire chambers PC3-PC5 (POMME) with sensitive area  $48 \times 48$  cm<sup>2</sup> were used to detect the trajectory of the charged particle after the scattering on the  $\text{CH}_2$  analyzer. Each chamber has a  $x$ - and a  $y$ -plane and wire spacing of 2 mm. The plane angular resolution achieved with this polarimeter was 2.6 mrad. The trigger was defined by the coincidence of signals from scintillation counters S1 and S2 of a diameter of 48 mm. In order to improve the data acquisition system a new module was developed, which allows us to increase number of recorded events up to 4800 per beam spill.

During two beam runs at the Synchrophasotron we measured the analyzing power for the inclusive reaction  $p + \text{CH}_2 \rightarrow \text{one charged particle} + X$ , at proton momenta of 3.8, 4.5 and 5.3 GeV/c, for different thicknesses of the  $\text{CH}_2$  target, and at proton momentum 1.75 GeV/c, with a  $37.5$  g/cm<sup>2</sup> thick target.

The number of events, for the inclusive reaction  $\vec{p} + \text{CH}_2 \rightarrow \text{one charged particle} + X$ , is given by

$$N^\pm(\theta, \varphi) = N_0(\theta) (1 + P_y^{(\pm)} A_y(\theta) \cos \varphi), \quad (1)$$

where  $A_y$  is the analyzing power of the reaction and the sign  $\pm$  refers to the spin orientation of the incident protons. The  $z$ -axis is along the beam direction, the  $y$ -axis is along the beam polarization (upwards) and the  $x$ -axis such as to form a left handed system. The polar angle  $\theta$  is defined as the angle between the incident and the scattered trajectory. Due to the very narrow angular distribution of incident trajectories in the vertical plane ( $\pm 1$  mrad) the  $y$ -axis can be considered as perpendicular to all incident trajectories, and  $\varphi$  is then the angle between the  $y$ -axis and the normal to the scattering plane. The convention is that  $\varphi = 0^\circ$  for left scattering and  $\varphi = 90^\circ$  for down scattering.  $N_0(\theta)$  is the number of counts in some interval centered at  $\theta$  for unpolarized beam.

The coordinates in the  $xz$  and  $yz$  plane allow to find the parameters of the incident and scattered trajectories. The distance of closest approach is then calculated as the distance along a line perpendicular to both trajectories. The interaction vertex is the middle point of this segment. At least two planes in the rear chambers had to fire, in order to collect events into statistics.

The results (Fig. 2), show the following interesting features.

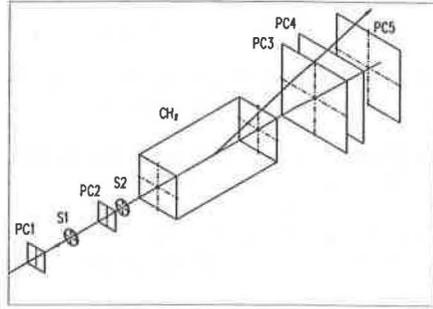


Figure 1: Schematic view of the setup.  $S_i$  – scintillation counters,  $PC_i$  – proportional chambers.

- For protons of 3.8 GeV/c, the analyzing power is fairly independent from the amount of material in the analyzer, from 37 to 80 g/cm<sup>2</sup>.
- Taking a target thickness above nuclear collision length and values of the polarimeter acceptance above  $p_t > 0.7$  GeV/c do not improve figure of merit.
- In a wide region of momentum transfers, the analyzing power both for graphite and CH<sub>2</sub> targets has a maximum for  $p_t = p \cdot \sin \theta \simeq 0.3$  GeV/c.
- High angular resolution of the polarimeter is very important to increase the figure of merit.
- In the momentum range investigated so far, the analyzing power is inversely proportional to the incident momentum.
- The analyzing power decreases with increasing incident momentum, but it is still sizeable at a proton momentum of 5.3 GeV/c. This validates the proposal to build a new polarimeter based on this principle, in this kinematical range at the Thomas Jefferson National Accelerator Laboratory.

Preliminary results were previously presented [6] and more details can be found in a forthcoming paper [7].

These studies have led to assembling a new polarimeter at the JINR, which is mobile and can be set, in principle, at different beam lines.

To continue this project to higher proton momenta we are going to change the small proportional chambers to larger planes of drift tubes, of size 16×16 cm<sup>2</sup>. These tubes represent the contribution to the proposal from the American side of the collaboration. After this improvement the polarimeter can be installed at any place in the experimental area and used in other experiments, for example, the measurement of the transfer polarization coefficient in deuteron fragmentation. The drift tubes were successfully checked during the June 2003 run. The spatial resolution is shown in Fig. 3.

A polarized deuteron beam has been recently accelerated and extracted at the Nuclotron accelerator. The collaboration plans to continue the measurements of the analyzing powers for the reaction  $p + CH_2(C)$  at a proton momentum up to 6.5 GeV/c. No such measurements have ever been reported; such a database is generally of great interest; in

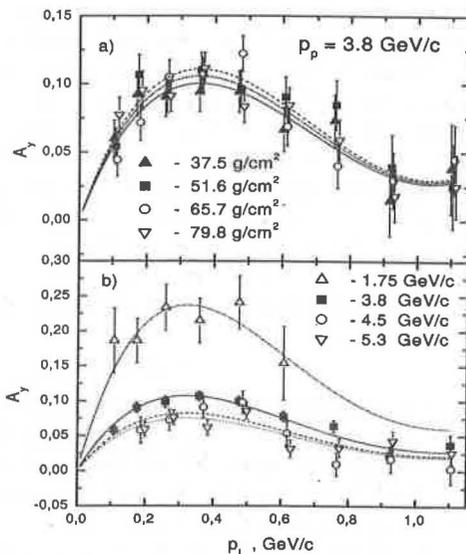


Figure 2: Analyzing powers as a function of  $p_t$ : (a) for different target thicknesses at 3.8 GeV/c; (b) for different momenta at  $L=51.6$  g/cm<sup>2</sup>.

particular it may support further investigations of the proton form factors to  $Q^2$  values larger than  $10 \text{ GeV}^2$  after the upgrade of JLab.

At the moment it is difficult to estimate precisely the beam time necessary for the future measurements, at deuteron beam momentum close to  $11 \text{ GeV}/c$ . In order to get a statistical error of 0.01 on analyzing power, one find that  $10^7$  counts are necessary for each of two polarization states, with polarization at the level of 0.55. For beam intensity of  $5 \cdot 10^8$  at deuteron beam momentum at  $11\text{-}11.5 \text{ GeV}/c$  we need 4 days of beam time. In addition for checking the equipment of the setup during its modernization 2 or 3 days are also needed.

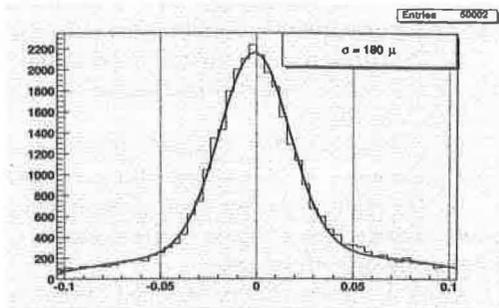


Figure 3: Spatial resolution of the drift tubes.

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## Discussion

**Q.** (D.Novinsky, PNPI, St. Petersburg): In which experiments are you going to obtain data on  $p + CH_2$  analyzing power? I mean that usually by means of such data (proton-carbon for example) the recoil proton polarization is defined.

**A:** Of course, we have several experimental ideas for this polarimeter usage. To obtain the reliable result on higher energies we urgently need to raise the Nuclotron intensity at least by a factor 10.

**Q.** (D.Svirida, ITEP, Moscow): Please, comment on advantages and disadvantages of  $CH_2$  polarimeter in comparison with pure carbon polarimeter.

**A:** The main advantage is the presence of hydrogen in the filter, making the analyzing power slightly higher. Even better could be  $CH_4$  or pure hydrogen, but these two are much more difficult to use.

**Q.** (V.Kanavets, ITEP, Moscow): What is the accuracy of the initial beam proton polarization?

**A:** Approximately 6-8%.