Measurement of analyzing powers for polarized proton scattering on CH_2 target at proton momentum range from 1.75 to 5.3 GeV/c

L.S. Azghirey[*], V.A. Arefiev[*], I. Atanasov[†], S.N. Basilev[*],
Yu.P. Bushuev[*], V.V. Glagolev[*], M.K. Jones[**], D.A. Kirillov[*],
P.P. Korovin[*], G.F. Kumbartzky[‡], P.K. Manyakov[*], J. Mušinský[*],
L. Penchev[§], C.F. Perdrisat[§], N.M. Piskunov[*], V. Punjabi[¶], I.M. Sitink[*],
V.M. Slepnev[*], I.V. Slepnev[*] and E. Tomasi-Gustafsson[‖]

[*]*Joint Institute for Nuclear Research, Dubna, Moscow region, 141980 Russia*
[†]*Institute of Nuclear Research and Nuclear Energy BAS, Sofia, Bulgaria*
[**]*Thomas Jefferson National Accelerator Facility, Newport News, VA 23606 USA*
[‡]*Rutgers, The State University of New Jersey, Piscataway, NJ 08855 USA*
[§]*College of William and Mary, Williamsburg, VA 23187 USA*
[¶]*Norfolk State University, Norfolk, VA 23504 USA*
[‖]*DAPNIA/SPhN CEA/Saclay, 91191 Gif-sur-Yvette Cedex, France*

Abstract.
We report a new measurement of analyzing powers for the reaction $\vec{p} + CH_2 \to$ 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 an extended polarimeter based on this process. The experiment is performed at the accelerator complex of the JINR-LHE (Dubna).

As all fundamental interactions are spin-dependent, the knowledge of polarization observables is essential for the understanding of the structure of hadrons and for disentangling the reaction mechanism in nuclear reactions. The polarization of intermediate energy protons (i.e. in the range from a few hundreds MeV to a few GeV) is generally measured with full azimuthal acceptance focal plane polarimeters. They consist in large detectors which measure the angular distribution of a charged particle issued from an inclusive reaction, usually the scattering on a carbon target [1].

The availability of high luminosity polarized beams opens the possibility to develop the experimental study of spin degrees of freedom in hadron physics, at intermediate energy. In particular a recent experiment at the Jefferson Laboratory [2], through the measurement of the recoil proton polarization in the elastic scattering of longitudinally polarized electrons on a proton target, showed that the ratio of the two electromagnetic form factors of the proton, electric and magnetic, G_{Ep}/G_{Mp}, decreases monotonically with increasing four momentum squared, Q^2, starting at about 0.8 and up to 6 GeV^2, which corresponds to proton momenta up to 3.7 GeV/c. The extension of this measurement to larger momenta [3] requires the construction of a new polarimeter that will measure the polarization of recoil protons at momenta up to 5.7 GeV/c.

The experiment was carried out at a slowly extracted beam of vector polarized deuterons produced by the POLARIS ion source and accelerated by the Synchrophasotron at the Laboratory of High Energies, JINR, Dubna. The intensity of the primary beam was up to $2 \cdot 10^9$ particles per spill. The deuteron vector polarization was flipped at each beam spill, one spill over three been unpolarized. The deuteron vector polarization, P_d, was different for the two beam polarization states: $P^{(+)} = 0.568 \pm 0.037$ and $P^{(-)} = -0.612 \pm 0.037$.

The polarized protons were produced by fragmentation of the polarized deuteron beam on an 8 cm thick Be target, installed 60 m ahead of the polarimeter. Two dipoles of the beam transport line separated the break up protons at zero angles from the deuteron beam.

For the proton beam momentum of 5.3 GeV/c the deuteron beam momentum was 9 GeV/c. At this ratio of proton to deuteron momenta the polarization transfer from deuteron to proton is still equal to 1 [4, 7]. For the other proton momenta the corresponding deuteron beam momenta were twice as large as the proton momentum; hence, for the 4 proton momenta of this experiment the proton polarization was equal to the deuteron polarization.

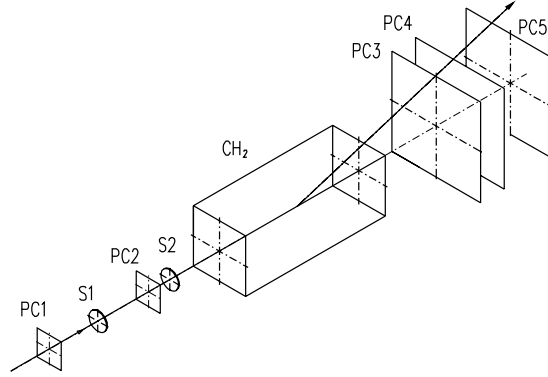A schematic view of the detection is shown in Fig.1. The incident protons were

FIGURE 1. A schematic view of the setup.

detected in the proportional chambers PC1, PC2. The polyethylene target thickness was varied between 37.5 and 79.8 g/cm^2. Outgoing particles were detected by PC3-PC5 (POMME [1]) with sensitive area 48×48 cm^2. The trigger was realized by coincidence of signals from scintillation counters S1 and S2 of a diameter of 5 cm. The data acquisition system was capable to record up to 4800 events per beam spill.

In the data analysis the scattered events were classified in bins of the transverse momentum transfer, $p_t = p \sin \theta$, and ϕ, the azimuthal scattering angle.

In Fig.2 a) the analyzing powers for all target thicknesses at p_p=3.8 GeV/c are presented. To evaluate dependence of analyzing power on target thickness, the data were fitted by a polynomial in p_t (see the curves). The fit shows that within error bars there is no dependence of analyzing power on target thickness. Analyzing powers averaged over the various target thickness at the 4 energies are in Fig.2 b).

The calculations of the figure of merit, $\mathcal{F}$, assuming 100% detection efficiency and using fitted values of the analyzer efficiency and of the analyzing power are presented in
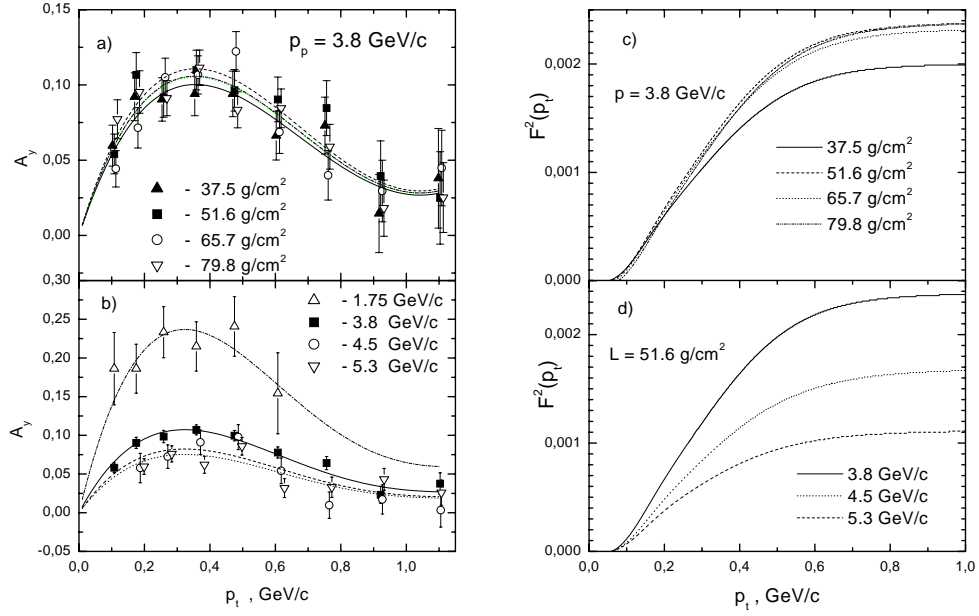
FIGURE 2. Dependence of: a) analyzing power on target thickness; b) analyzing power on energy; c) figure of merit on target thickness; c) figure of merit on energy.

Figs.2 c) and d): the coefficient of merit is defined as:

$$\mathcal{F}^2(p_t) = \int_{a(L)}^{p_t} A_y^2(p_t') \frac{d\varepsilon}{dp_t'} dp_t',$$

where $a(L)$ is the lowest p_t for each target thickness L, $d\varepsilon/dp_t = N(p_t)/(N_{inc}\Delta p_t)$, N_{inc} and $N(p_t)$ are the numbers of particles incident on the target and emitted into interval Δp_t, respectively.

Values of the maximum analyzing powers at the different energies are good observables to estimate the energy dependence. To compare the analyzing powers of CH_2 and C, a fit to existing data for carbon was made using the same approach as for CH_2. We observe that both CH_2- and C analyzing power are linearized when plotted versus the inverse of the proton momentum, as seen in Fig.3. Comparing values of A_y^{max} one can see that the ratio of the analyzing powers on C and CH_2 is approximately 0.89.

Summarizing the results presented here we emphasize the following main features:

- 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^2.

- A target thickness larger than the nuclear collision length in the material of the analyzer, and a polarimeter acceptance larger than $p_t \simeq 0.7$ GeV/c, do not improve the figure of merit.
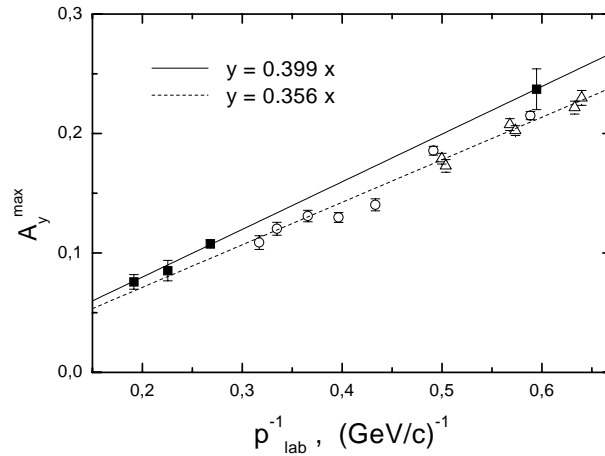
FIGURE 3. Momentum dependence of CH_2 and C data. Solid squares – current data, open circles – [5], open triangles – [6].

- The analyzing power decreases with increasing incident momentum, but it is still sizeable at a proton momentum of 5.3 GeV/c.
- The CH_2 shows a larger analyzing power than the carbon.
- In a wide region of momentum transfer, the analyzing power of both carbon and CH_2 targets has a maximum around $p_t = p\sin\theta \simeq 0.3$ GeV/c.
- High angular resolution of the polarimeter is important to maximize the figure of merit.

REFERENCES

1. B. Bonin *et al.*, Nucl. Instr. and Meth. A288, 379 (1991);
   E. Tomasi-Gustafsson, POMME Manual, LNS/Ph/92-07.
2. M. K. Jones *et al.*, Phys. Rev. Lett. **84**, 1398 (2000);
   O.Gayou *et al.*, Phys. Rev. Lett. **88**, 092301 (2002).
3. Proposal to JLab PAC18: 'Measurement of G_{Ep}/G_{Mp} to Q^2=9 GeV^2 via Recoil Polarization', (Spokepersons: C.F. Perdrisat, V. Punjabi, M.K. Jones and E. Brash), JLab, July 2001.
4. V. Punjabi *et al.*, Phys. Lett. B **350**, 178 (1995).
5. N.E. Cheung *et al.*, Nucl. Instr. & Meth., A **363**, 561 (1995).
6. I.G. Alekseev *et al.*, Nucl. Instr. & Meth., A **434**, 254 (1999).
7. B. Kuehn *et al.*, Phys. Lett. B **334**, 298 (1994);
   L.S. Azhgirey *et al.*, JINR Rapid Com. No. 3[77]-96, 23 (1996).