QUASIELASTIC AND INELASTIC SCATTERING OF THE POLARIZED PROTONS ON NUCLEI (MSU-SPHERE EXPERIMENT)

A.A. Yershov[1†], V.P. Ladygin[2], V.V. Arkhipov[2], V.A. Bodiagin[1], V.K. Bondarev[2], K.A. Chikin[1], A.Yu. Isupov[2], V.I. Ivanov[2], A.N. Khrenov[2], N.A. Kruglov[1], A.G. Litvinenko[2], A.I. Malakhov[2], S.G. Reznikov[2], P.A. Rukojatkin[2], I. Rusanov[2], L.I. Sarycheva[1], G.D. Stoletov[2], V.N. Zhmyrov[2], L.S. Zolin[2]

(1) *Institute for Nuclear Physics of MSU, Moscow, Russia*
(2) *Joint Institute for Nuclear Research, Dubna*
† *E-mail: e@lav1.npi.msu.su*

Abstract

Basing on the analysis of the previous experimental data the hypothesis of the different reduction of the single spin asymmetry of $pp-$ and $pn-$ scattering on nuclei is suggested. In order to check this supposition an experiment for the investigation of the different channels of quasielastic proton-carbon scattering has been started at the LHE JINR synchrophasotron at SPHERE set up in June, 2000. The experiment is based on the polarized stripping proton using which was developed in the SMS MSU experiment. At the first run an analyzing power for $p \uparrow + C^{12} \to p_L + p(n)_R + X$, $d \uparrow + C^{12} \to p_L + p(n)_R + X$ and $p \uparrow + H(CH_2) \to p_L + p(n)_R + X$ reactions has been measured at 2.51 and 3.60 GeV of the initial proton energy. Scattered particle type was detected by the "time-of-flight" method, quasielastic peak region was determined by the separation on the leading proton momentum. Additionally an analyzing power dependence on the scattered proton momentum has been measured at 2.51 GeV for 7 values of the $u_L = p_L/p_0$ and an indication of the structure in the $A_{pC}(M_{miss})$ dependence has been confirmed.

Key-words: asymmetry, carbon, intranuclear, proton, neutron, polarimeter, spin

1 Status of the problem

Investigation of the process of the quasielastic scattering of the polarized protons on intranuclear nucleons looks interesting due to a number of physical and methodical reasons. On the one hand the direct measurement of spin observables is the important source of an information about both spin role in the strong interactions and spin stage of the nucleon. On the other hand the quasielastic channel of the proton-nucleus scattering is dominate at GeV energies and it's measurement seems principal for the development of the technique of polarimetry. In this work the problem of the behaviour of the single-spin asymmetry of the quasielastic proton-carbon scattering at the $T = 0.8 - 3.6$ GeV energy of the initial proton is considered.

The main discussed observable is analyzing power (a.p.), determined as normalized on the polarization (P) left-right asymmetry (A):

$$\sigma(\varphi, \theta) = \sigma_0(\theta)(1 + A(\theta)(\vec{P} \cdot \vec{n})).$$

By the comparison of this value for the scattering on the free and intranuclear nucleons the parameter R of the reduction of a.p. can be calculated as

$$R_{pN}(T) = \frac{2 \cdot A_{qe}(T)}{A_{pp}(T) + A_{pn}(T)}$$

for the scattering on any intranuclear nucleon, or

$$R_{pp}(T) = \frac{A^p_{qe}(T)}{A_{pp}(T)}$$

for the scattering on intranuclear proton only.

In the experiment the first case is corresponded to the measurement of the proton-carbon scattering a.p. at the detection of the quasielastic channel by the magnetic analysis of the scattered particle momentum, but without any separation of the proton-proton or proton-neutron interaction. This measurements were carried out on the beams of polarized protons at LAMPF [1] and in the previous experiment at LHE JINR synchrophasotron (SMS MSU) [2], and in the double scattering experiments at LINP and ITEP accelerators [3,4]. Moreover this data could be obtained from inclusive a.p. measurements (at the accelerator SATURNE II) [5] by the model dependent excluding of the other channel contributions, but systematic errors for the R are too large at this method. The compilation of the mentioned data is shown on the Fig.1 by open symbols and an estimation of the asymptotic behaviour ($R(T) \to 0.96$) is shown by the dashed line.

The second case is corresponded to the proton-carbon a.p. measurement at the detection of the recoil proton. This measurement under the spectrometric selection of quasielastic kinematic region was carried out at KEK [6]. There was the analogous measurement at SATURNE II accelerator [7], but without any analysis of the momenta, so this data for the quasielastic scattering could be significantly distorted by the undetected contribution of the inelastic channels. To be included in the world data compilation this data were model dependently corrected under strong supposition, that a.p. of the inelastic channel of proton-carbon scattering is close to zero at this energies. The behaviour of the R for proton-proton quasielastic scattering is shown on the Fig.1 by closed symbols and interpolated by the solid line ($R(T) \to 0.67$).

Therefore the a.p. of the scattering on the intranuclear protons looks significantly reduced, and one can assume the different reduction of the a.p. for intranuclear protons and neutrons. One can show that this phenomena cannot be explained by the Fermi-motion effects. The other possible reasons are:

- relativistic effects for bounded state of target nucleon [8];
- nucleon clusterisation in nuclei [9];
- excitation of non-nucleon degrees of freedom [7].

It is necessary to stress that direct measurements in the region of GeV energies are KEK and LHE JINR (SMS MSU) data only, and obviously the existing information is not enough to make any definite conclusion. So the experiment to confirm or to reject the supposed phenomenon by the simultaneous measurement of both parameters at 1.46, 2.51 and 3.60 GeV is proposed to be carried out at the beam of polarized protons of Dubna synchrophasotron.

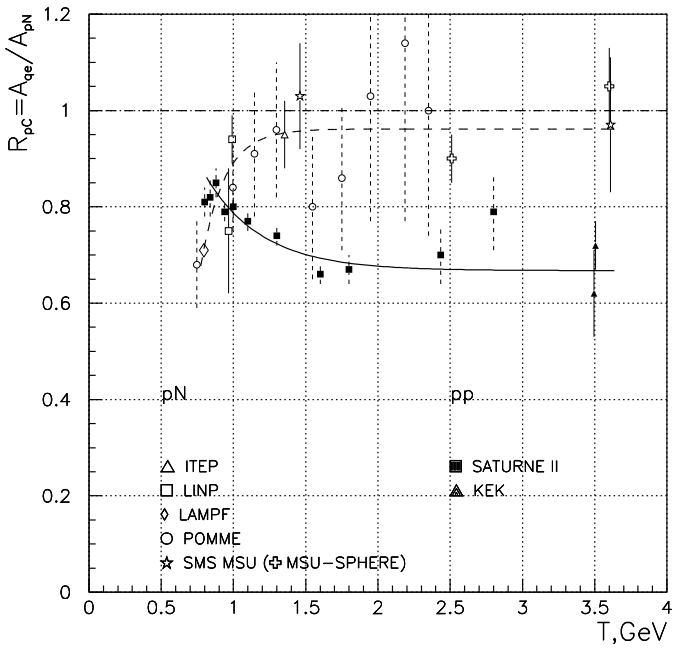

Figure 1: Compilation of the experimental data for $R_{pN} = A_{qe}/A_{pN}$ and $R_{pp} = A^p_{qe}/A_{pp}$ measurements. Data of the model dependent software analysis are marked by dashed error bars. Presented experiment data are shown by open crosses.

2 Experiment description and preliminary results

The region of energies of LHE synchrophasotron allows to measure in the frame of the same experiment the reduction parameter R for both proton-proton and arbitrary proton-nucleon scattering at shown above number of energies. Method of the measurement of a.p. by the single arm spectrometer is based on the measurement of the difference of cross sections of scattering for the different directions of the initial beam polarization. For the conditions of LHE synchrophasotron the principal methodic of experiment with the polarized proton beam was tested in the previous experiments at the SMS MSU set up [2]. The first run of the new experiment has been carried out in June, 2000 and devoted to the test of the methodic and preliminary measurements of the investigated reactions.

In the described experiment in order to produce the beam of polarized protons the reaction $d \uparrow + Be \rightarrow p \uparrow + X$ of the vector polarized deuterons stripping on the nuclear target at the half momentum proton selection is used. Using of the 16 g/cm^2 beryllium target in the LHE synchrophasotron deutron beam permits to form the beam of polarized protons with polarization $P \sim 0.5$ and intensity up to $I \simeq 5 \cdot 10^7$ protons/spill. Beam polarization is measured permanently by the double arm thin target beam polarimeter ("F4-polarimeter") [10]. The results of the measurements of the beam polarization are shown of the Fig.2. It is necessary to stress that polarization were measured by the different analyzing reactions at different energies, and there is very good agreement between data. So it is that allows us to state that polarization was stable during the all period of measurements.

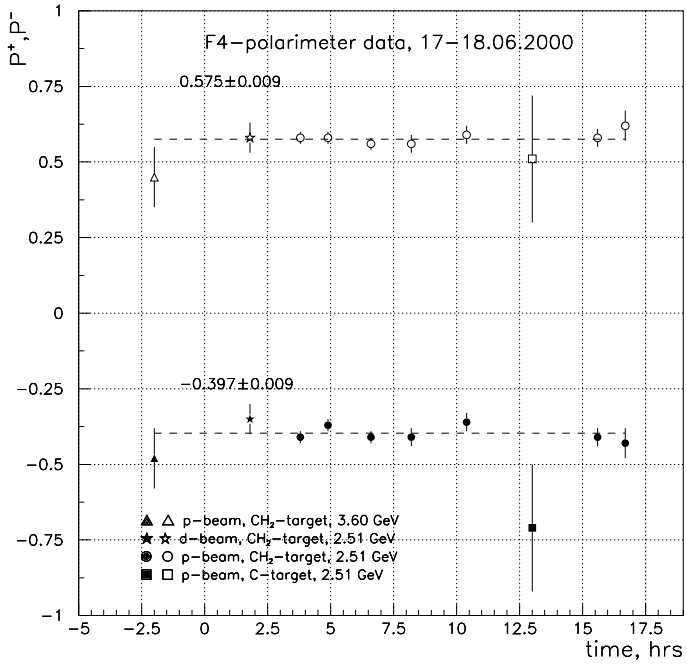

Figure 2: Measurements of the beam polarization by the "F4-polarimeter".

The selection of the necessary kinematics of scattering (angle and momentum) is provided by the adjustment of the magnetic elements of the channel. The choice of the scattering angle is defined correspondingly to the maximum of a.p. for the scattering on the free nucleon. The region of quasielastic scattering is selected by the channel tuning on the momentum of elastic nucleon-nucleon scattering. To separate proton-proton scattering the detection of the recoil proton is supposed. To exclude the possible background of mesons the "time-of-flight" system of the SPHERE experimental set up is used.

In the first run the a.p. of quasielastic scattering was measured at 2.51 and 3.60 GeV for proton-nucleon scattering in the reactions $p \uparrow + C^{12} \rightarrow p_L + p(n)_R + X$ and $d \uparrow + C^{12} \rightarrow p_L + p(n)_R + X$ (scattering angles are 9.0^o and 6.7^o, scattered proton momenta are 3.20 and 4.36 GeV/c correspondingly). Additionally the background measurements of the inelastic scattering a.p. were carried out in the reaction $p \uparrow + C^{12} \rightarrow p_L + X$ at 2.51 GeV. Moreover the a.p. of the elastic proton-proton scattering was measured as control one in the reaction $p \uparrow + H(CH_2) \rightarrow p_L + p_R + X$ on the polyethylene target. The results of the measurements are presented in the Table 1.

Preliminary data of quasielastic scattering are in the agreement with the assumed tendency in the behaviour of the R_{pN} for arbitrary scattering on the intranuclear proton or neutron (see Fig.1). Control measurement result for proton-proton scattering is in the agreement with the word data for the scattering on the free proton.

As a by-product of this experiment the dependence of the inelastic channel a.p. on the scattered particle momentum was measured. The data are presented on the Fig.3 in the terms of the a.p. dependence on the missing mass in the comparison with the data of the SMS MSU experiment [2], and an indication of the spin structure in the 1.35 GeV region is confirmed.

Table 1. Preliminary data of the Run 2000.

Interaction type	T, GeV	$\theta_L, l.f.$	$p_L, GeV/c$	$A_y(T, \theta_L, p_L)$
$d\uparrow + C \to p_L + X$	3.60	6.7^o	4.36	0.087 ± 0.019
$p\uparrow + C \to p_L + X$	3.60	6.7^o	4.36	0.137 ± 0.010
$d\uparrow + C \to p_L + X$	2.51	9.0^o	3.20	0.169 ± 0.020
$p\uparrow + C \to p_L + X$	2.51	9.0^o	3.20	0.178 ± 0.010
$p\uparrow + C \to p_L + X$	2.51	9.0^o	2.99	0.118 ± 0.021
$p\uparrow + C \to p_L + X$	2.51	9.0^o	2.78	0.078 ± 0.019
$p\uparrow + C \to p_L + X$	2.51	9.0^o	2.64	0.117 ± 0.021
$p\uparrow + C \to p_L + X$	2.51	9.0^o	2.50	0.057 ± 0.021
$p\uparrow + C \to p_L + X$	2.51	9.0^o	2.34	0.019 ± 0.019
$p\uparrow + C \to p_L + X$	2.51	9.0^o	2.00	0.012 ± 0.044
$p\uparrow + CH_2 \to p_L + X$	2.51	9.0^o	3.20	0.195 ± 0.010
$(p\uparrow + p \to p_L + X)$	2.51	9.0^o	3.20	0.226 ± 0.033

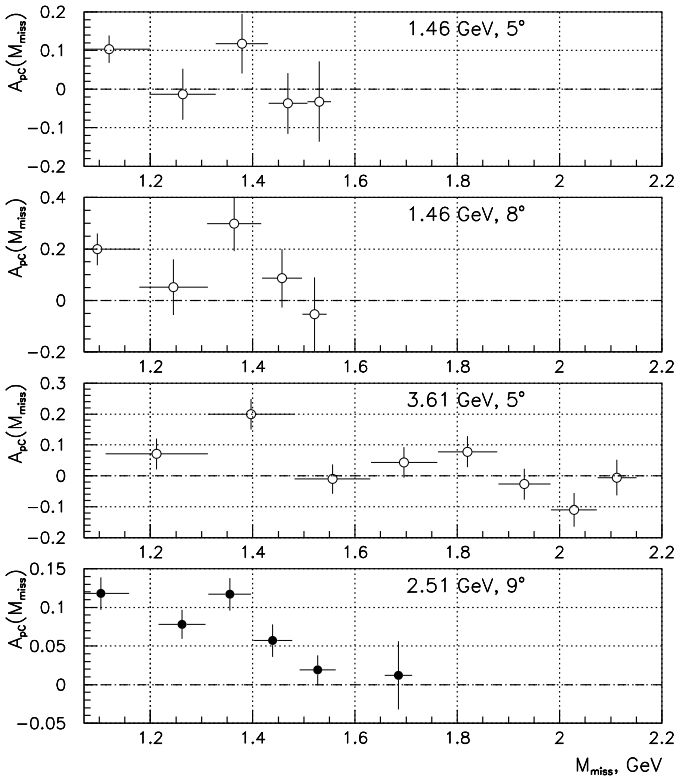

Figure 3: Comparison of the data of presented experiment for the inelastic proton-carbon scattering a.p. (closed symbols) with the data of the previous experiments (open symbols).

3 Conclusion

It is shown that proposed method of measurements permits to investigate experimentally the problem of the quasielastic scattering a.p. reduction at the scattering on nucleus. Preliminary data are in the good agreement with previous data and suppositions and it is necessary to take about 2 days of machine time to measure the R_{pp} at the same experimental equipment.

The work is supported by the state programmes "Universities of Russia" and "Russian Foundation of Basic Research".

References

[1] J.A. McGill et al., Phys. Lett. **B134**, 157 (1984).

[2] E.V. Anoshina et al., Phys. of Atom. Nucl. **60**, 224 (1997).

[3] V.G. Vovchenko et al., Preprint LINP **484**, (1979).

[4] V.V. Zhurkin et al., Yad. Fiz. **30**, 209 (1979).

[5] N.E. Chung et al., Nucl. Inst. and Meth. **A363**, 561 (1995).

[6] C. Ohmori et al., Phys. Lett. **B234**, 29 (1990).

[7] J. Bystricky et al., Lett. Nuovo Cim. **40**, 15 (1984).

[8] C.J. Horowitz, M.J. Iqbal., Phys. Rev. **C33**, 2059 (1986).

[9] M. Corcoran et al., Phys. Rev. **D22**, 2624 (1980).

[10] L.S. Azhgirej et al., Prib. i Teh. Eksp. **1**, 51 (1997).