Conference Paper

Measurements of the beam and target analyzing powers and spin correlation parameter A_{NN} in elastic pp scattering at 45 Gev/c

V V Abramov[1], A A Bogdanov[2], M A Chetvertkov[3], V A Chetvertkova[4], V V Mochalov[1,2], S B Nurushev[1,2], M B Nurusheva[2], V A Okorokov[2], V L Rykov[2], P A Semenov[1,2], M N Strikhanov[2], and A N Vasiliev[1,2]

[1]NRC «Kurchatov Institute» - IHEP, Protvino, Moscow region, 142281, Russia
[2]National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, 115409, Russia
[3]MD Anderson Cancer Center, Department of Radiation Physics, 1515 Holcombe Blvd, Unit 1420, Houston, TX 77030, USA[4]GSI, Plankstrasse 1, 64291, Darmstadt, Germany

Abstract

We propose to measure the beam and target analyzing powers and spin correlation parameter A_{NN} in elastic pp scattering by using the transversely polarized proton beam and target, at momentum p = 45 GeV/c. Such a study will allow us to test experimentally the equality of polarization to analyzing power. This equality has been theoretically proven and is widely used for extraction the polarization observables with unpolarized beam and polarized target. One needs to use both polarized beam and target to measure simultaneously A_B, A_T and A_{NN}.

Corresponding Author:
M B Nurusheva
mbnurusheva@mail.ru

Received: 25 December 2017
Accepted: 2 February 2018
Published: 9 April 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICPPA Conference Committee.

1. Introduction

Spin correlation parameter A_{NN} was measured earlier in diffractive region at the momentum less than 12 GeV/c [1–3]. We propose to measure the beam and target analyzing power and the initial state spin-spin correlation parameter in proton-proton elastic scattering at -t from 0.075 to 0.6 (GeV/c)^2 using a 45 GeV polarized proton beam at the new IHEP beam line 24A [4].

The results of this experiment can be described by a set of spin parameters, which are related to the pure-initial-spin state differential elastic cross sections by the formula:

$$\left[\frac{d\sigma}{d\Omega}\right]_{ij} = \left[\frac{d\sigma}{d\Omega}\right]_0 \left[1 + P_B(ij)\,A_B + P_T(ij)\,A_T + P_B(ij)P_T(ij)\,A_{nn}\right] \tag{1}$$

where P_B and P_T are the beam and target polarizations, A_B and A_T are the beam and target analyzing powers, A_{NN} is the initial state spin-spin correlation parameter. The $A_{NN,}$ A_B, and A_T can be expressed by equations (2-4), respectively:

$$A_{NN} = \frac{1}{P_B\ P_T} \frac{N(\uparrow\uparrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow) + N(\downarrow\downarrow)}{N(\uparrow\uparrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow) + N(\downarrow\downarrow)} \tag{2}$$

$$A_B = \frac{1}{P_B} \frac{N(\uparrow\uparrow) + N(\uparrow\downarrow) - N(\downarrow\uparrow) - N(\downarrow\downarrow)}{N(\uparrow\uparrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow) + N(\downarrow\downarrow)} \tag{3}$$

$$A_T = \frac{1}{P_T} \frac{N(\uparrow\uparrow) - N(\uparrow\downarrow) + N(\downarrow\uparrow) - N(\downarrow\downarrow)}{N(\uparrow\uparrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow) + N(\downarrow\downarrow)}, \tag{4}$$

where N(ij) is the number of events normalized to the incident proton flux with the beam's (i) and target's (j) spin direction up (↑) or down (↓). Our main goal is to determine the momentum dependence of the spin-correlation parameters in the range of 12-45 GeV/*c* in the diffractive kinematic region.

2. Existing experimental data of the A_N and A_{NN} in proton-proton elastic scattering

A_N is fairly well measured at various energies (see Figure 1 which was presented originally in Ref. [5]). The solid line is the fitting function with poles, suggested by the Regge model, namely, A_N=a1+a2/$\sqrt{p_{beam}}$ + a3/p_{beam} [6].

Measured value of A_N at 45 GeV/*c* is equals to (2.3±0.2) % [7], and this value is used here for estimating the required beam time. The experimental data on the spin correlation parameter A_{NN} in the diffractive region are very scarce. This parameter has been measured only at the momenta of 3.3; 6; 11.75 GeV/*c* [1–3] in laboratory system (see Figure 2). The solid line presents the fit to experimental data with the function A_{NN} = $a(p/p_0)^b{}_{beam}$, where a=0.57±0.23 and b=-0.86±0.33, and po=1 GeV/*c*. The expected value for A_{NN} at 45 GeV/*c* is (2.2±1.1)%.

3. Beam characteristics and beam polarization measurement

The polarized proton and antiproton beams are described in detail in Ref. [8]. We plan to do these measurements using the 45 Gev/*c* polarized proton beam with the narrow momentum width Δp/p=1,2% to fit into the polarized target of a diameter 18 mm [9].The beam properties are as follows: an average beam polarization P_B=40%, transverse dimensions σ(*x*)×σ(*y*) = 11×8.7 mm^2, angular divergences σ(x')×σ(y)=1.4×1.7 $mrad^2$, intensity I=5×10^6protons per cycle hitting the target.

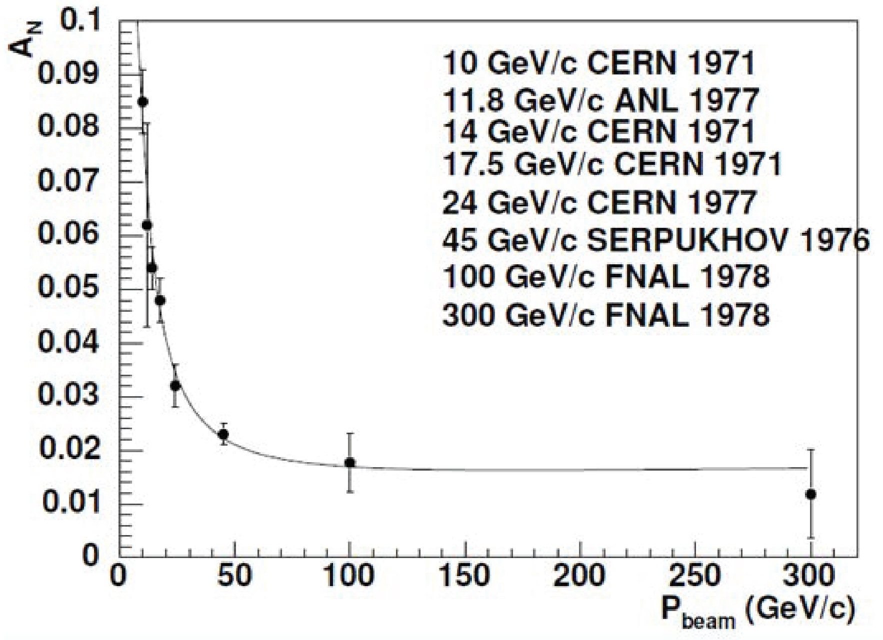

Figure 1: A_N for pp elastic scattering at –t=0.15 (GeV/c)^2 as a function of beam momentum.

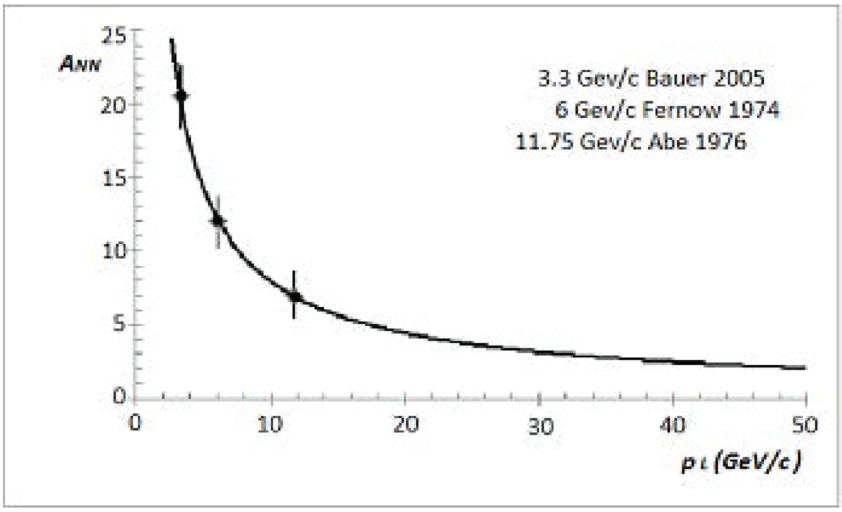

Figure 2: A_{NN} for pp elastic scattering at –t=0.6 (GeV/c)^2 as a function of beam momentum.

The transvers polarization dependence on the beam-ray position along the vertical axis in the intermediate focus is presented in Figure 3. It can be described by the function $\langle P_N \rangle$=ay+by^3, where a=(0.025 $\pm$ 0.027) mm^{-1}, b= -(0. 68 $\pm$0.19) $\times$ 10^{-5} mm^{-3}. The beam-tagging system will be used for measuring the polarization of each particle at the accuracy of about 1% [10]. The beam-tagging system will also be used for the polarized beam tune up at commissioning time.

4. Experimental setup

The design of the experimental setup is presented in Figure 4. The main detectors to be used are the trigger scintillator counters (S1-S8) and hodoscopes (H1-H8).

The parameters for all hodoscopes are presented in table 1. The hodoscopes are constructed in such a manner that each scintillator strip overlaps its two adjacent neighbors by one-third of the width. This kind of overlapping arrangement provides twice as many of the spatial segments for the same number of channels of encoding electronics as for the edge-butted array. It also eliminated the loss of tracking efficiency by eliminating the inter-segment gaps.

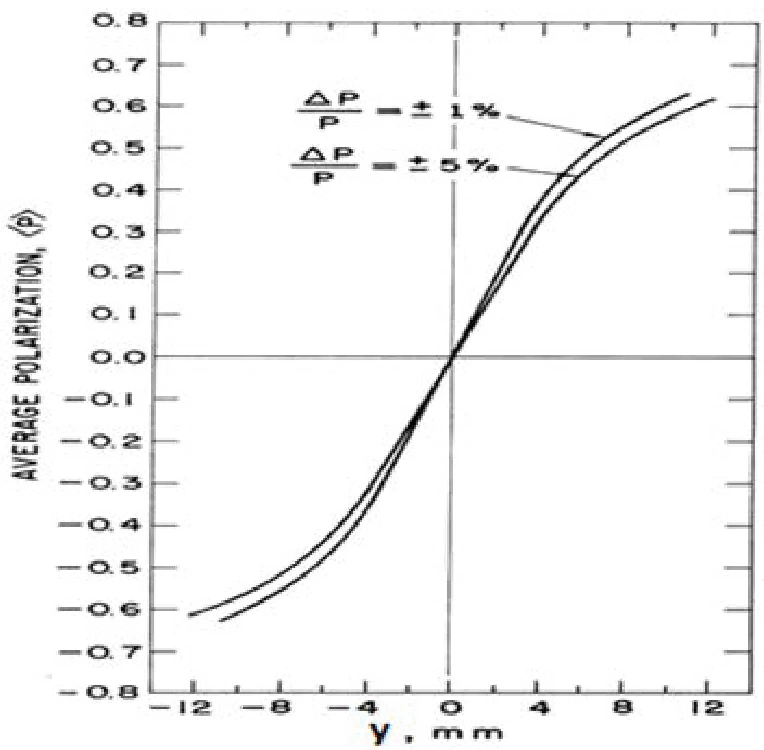

Figure 3: Correlation between the average vertical transverse polarization of protons and the vertical ray coordinate *y* in the plane of intermediate focus.

In order to suppress inelastic events, a special fast trigger will be organized on the base of coincidences between scattered and recoil protons in forward (H3-H4) and backward ((H5-H8) detectors. It worth mentioning, that elastic scattering measurements can be carried out simultaneously with the inclusive double-spin studies, using the main detectors of SPASCHARM experiment.

DOI 10.18502/ken.v3i1.1762

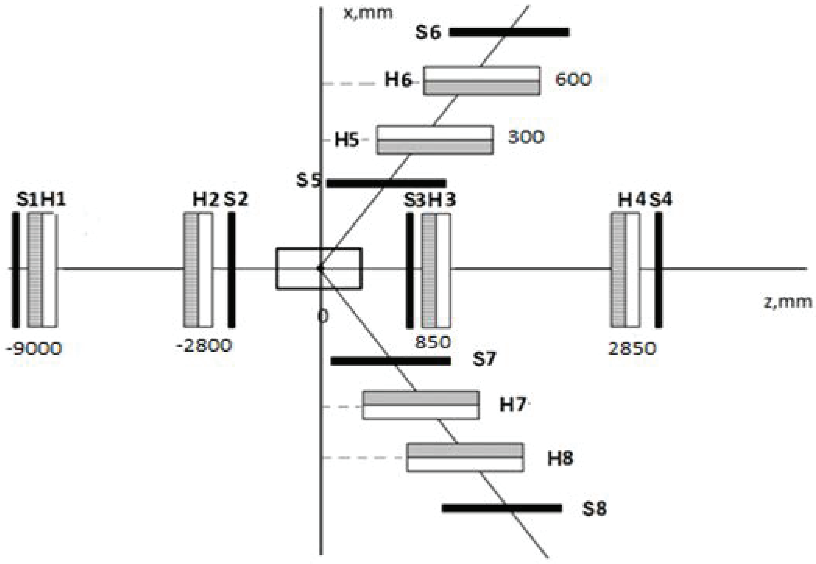

Figure 4: Design of the experimental setup.

Table 1: Design of the hodoscopes.

Hodoscope	Distance from target (mm)	Total dimensions (mm)	Dimension of scintillator strips: Width×Thickness× Length (mm^3)		Numbers of channels	
	Z	X × Y	X	Y	X	Y
		Beam	Hodoscopes			
H1	-9000	40 × 40	6 × 3 × 40	6 × 3 × 40	9	9
H2	-2800	40 × 40	6 × 3 × 40	6 × 3 × 40	9	9
		Forward	Hodoscopes			
H3	850	62 × 45	6 × 3 × 62	6 × 3 × 45	15	11
H4	2850	182 × 86	6 × 3 × 182	6 × 3 × 86	45	21
		Recoil	Hodoscopes			
	X	Z × Y	Z	Y	Z	Y
H5 - H7	300	322 × 228	9 × 5 × 322	9 × 5 × 228	51	37
H6 - H8	600	432 × 430	9 × 5 × 432	9 × 5 × 420	71	69

5. Beam time estimation

Numerical calculations for the number of elastic scattering events has been done for the worst case scenario with the maximum value of |t|= 0.6 (GeV/c)^2 and Δt=±0,1 (GeV/c)^2, where the cross-section is the smallest. For measuring the t-dependence of A$_{NN}$, the following input parameters have been assumed in simulations: the main beam characteristics as they are described in Sec. 3, the beam duty factor ν=0.1, the polarized target proton density ρ = 0.12 g/sm^3,the intensity I=5×10^6protons per cycle, the vertical component of magnetic field in the frozen polarized target zone – 0.45 T, the target polarization P_T= (75±5)%. The corresponding luminosity is L=10^{28}sm^{-2}s^{-1} [8].

An event rate is defined as n=L Δt dσ/dt $\Delta\varphi/\varphi$, where dσ/dt =0.23 mb/(GeV/c)^2[11] and $\Delta\varphi/\varphi$=0.1. Finally, at the assumptions above, the counting rate n=0.04644 s^{-1}. In order to measure A_N with the statistical error ΔA_{NN}=A_{NN} = 2.2%, and taking into account both the beam and target polarizations the required beam time would be about 10 days. The parameters $A_B$and A_T will be measured at the same time with the precision of ~50% and 30%, respectively, for the same |t|= 0.6 (GeV/c)^2. The much better precisions for these observables are expected at the smaller |t|-values.

6. Summary

We proposed the experiment which allows to measure simultaneously three spin observables in elastic pp scattering at 45GeV/c in the |t/ interval of 0.07÷0.60 (GeV/c)^2.

10 days are required for measuring the t-dependence of A_{NN} in order to reach the precision ΔA_{NN}=A_{NN} at maximum -value. The time required for measuring the A_B and A_T with ~10% relative errors is significantly shorter at the smaller |t/.

The momentum dependence of these parameters can be studied in the wider momentum range from 15- to 45 GeV/c.

The work on estimations of the possibility to carry out the similar measurements with the polarized-antiproton beam is in progress.

This work has been supported in part by the RFBR Grant No. 16-02-00667 and by the Competitiveness Programme of National Research Nuclear University MEPhI.

References

[1] Auer P et al 1985 *Phys. Rev.* **D32** 1609

[2] Abe K et al 1976 *Phys. Lett.* **B63** 239

[3] Bauer F et al 2005 *Phys. Rev.* **C71** 054002

[4] Abramov V V et al 2011 *J.Phys.Conf.Ser. 295* 012018

[5] Okada H 2006 *Measurement of the Analyzing Power AN in pp Elastic scattering in the CNI Region with the Polarized Atomic Hydrogen Gas Target* PhD Thesis (Osaka)

[6] Trueman T L 1996 *Proc. 12th International Symposium in High Energy Spin Physics* (Amsterdam)

[7] Gaidot A et al 1976 *Phys.Lett*. **61B** 103

[8] Azhgirey I I et al 2017 *J.Phys.Conf.Ser. 798 (2017) no 1* 012177

[9] Apokin V D et al 1985 *Nucl. Phys.* **B255** 253

[10] Semenov P A et al 2016 *Int.J.Mod.Phys.Conf.Ser. 40 (2016) no.01* 1660086

[11] Bruneton C et al 1977 *Nucl. Phys* **B124** 391