

Beam polarimetry at the SPASCHARM experiment at IHEP U-70 accelerator

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Abstract. We describe the absolute polarimeters for the beam channel intended to transport polarized proton and antiproton beam at U70 accelerator. The circulating proton beam of 60 GeV/c and intensity 10^{13} p/cycle is slowly extracted from accelerator. It strikes the external an aluminum target of one interaction length. The emitted on forward direction Λ and $\bar{\Lambda}$ hyperons by parity violating process serve as the source of the polarized protons and antiprotons. In this case we expect to get the polarized antiproton beams in the momentum range 10-40 GeV/c with intensity, approximately $10^4 - 4 \times 10^5$ antiprotons/cycle, 10^6 protons/cycle.

1. Polarimeters for measuring proton polarization

1.1. Diffractive ppolarimeter

Pp-elastic scattering in region of diffraction cone will be used as a reaction for this absolute polarimeter (Diffraction polarimeter). Polarization has been measured at U70 (HERA collaboration) for pp elastic scattering at 45 GeV/c [1]. Polarization is about 2% and is measured with accuracy 10% in t range 0,04— t —0,5. Overall data in this range of measurements leads to analyzing power $A_n = (2.370 \pm 0.12)\%$. This analysing power gives 5% statistical error in beam polarization. Data from other t gives insignificant changing in error of beam polarization. Taking into account 5% systematical error in measurements of target polarization leads to 10% accuracy in measurements of beam polarization on this diffraction polarimeter.

Cross sections of pp elastic scattering was measured with accuracy 1-4% at momentum 44.5 GeV/c [2]. Factor of merit (FoM) $FoM = P^2 \frac{d\sigma}{dt}$ can be defined using this data. FoM increases with the decreasing of t . This immediately suggests to explore the possibilities of simultaneous use of

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diffraction polarimeter and polarimeter based on effect of the Coulomb-nuclear interference (CNI). These two polarimeters are planned to be joined in one paired polarimeter.

Each kinematic interval of elastic scattering corresponds to two intervals of protons angles: scattering angles and recoil angles. Diffraction polarimeter consists of a scintillation hodoscopes overlapping these two intervals of angles (figure 1). Time to measure polarization with 10% accuracy is about to 120 hours [3]. This calculation was made at $-t=0.22 \text{ (GeV/c)}^2$. At this t we have maximum of FoM.

1.2. Interference polarimeter

Polarization in elastic pp scattering was not measured at momentum 45 GeV/c in CNI region. However, such measurements were carried out at RHIC at energies in centre of mass system $\sqrt{s}=6,8, 7,7, 13,7, 21,7 \text{ GeV}$ [4,5]. Results of reference [6] were used to calculate analysing power. To calculate analysing power at $\sqrt{s}=9.3 \text{ GeV}$ Rer_5 and Imr_5 have to be defined at this energy. RHIC spin data were fitted using power law to find Rer_5 and Imr_5 .

The CNI polarimeter consists of the liquid hydrogen target (LHT), the GEM detectors G1-G6 the beam hodoscopes H1-H6 and magnet SP12 (figure 1). GEM detectors are grouped as pair 4m apart. G1-G2 have dimensions $100 \times 100 \text{ mm}^2$ each, G3-G4 $300 \times 200 \text{ mm}^2$ and G5-G6 $300 \times 300 \text{ mm}^2$. Such dimensions and selected distances between pairs allow to cover the $-t$ region $2 \times 10^{-3} - 5 \times 10^{-2} \text{ (GeV/c)}^2$. Such cover permits to check consistency of data obtained by two polarimeters. The GEM detector coordinate resolution is 70μ , while scintillator hodoscope has the resolution 600μ . This means that the angular and momentum resolutions of events selected by hodoscopes as fast trigger may be improved in angular and momentum resolutions in off-line analysis using the data from GEMs. As spectrometer magnet the SP12 will be used due to its suitable aperture ($H \times V = 500 \times 200 \text{ mm}^2$, without vacuum chamber and $390 \times 190 \text{ mm}^2$, with vacuum chamber). The magnetic field 1.8 T, the length along iron is 3 m, including coils 3.9 m. Assuming the field integral 5.4 Tm we get the bent angle for particle with momentum 45 GeV/c $\phi = 36 \text{ mrad}$. Therefore the momentum resolution for hodoscopes will be around 1% for GEM - 0.2%. This resolution will be adequate for measurement of analysing power in the CNI region.

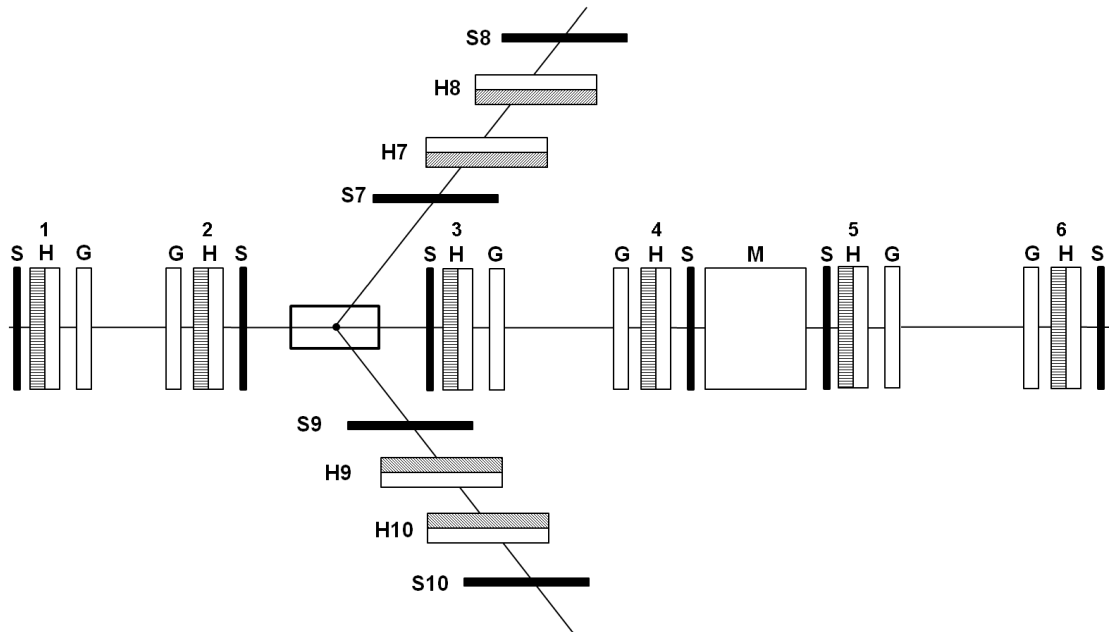


Figure 1. In this case simply justify the caption so that it is as the same width as the graphic.

2. Polarimeters for measuring antiproton polarization.

Since there are no experimental data on the process of elastic $\bar{p}p$ scattering in the region of interest (10 – 20 GeV/c), we have to measure this analyzing power directly using polarized proton target. However, we need to have a reference point in the area of t , where we expect a non-zero value of the analyzing power. We know two papers, in which analyzing power has been measured in elastic $\bar{p}p$ scattering: first work contain measurements in the interval of small initial momenta 0.1 – 2.0 GeV/c [7], in the second article data were obtained at 40 GeV/c [8]. Similar measurements of analyzing power were carried out for elastic pp scattering at 45 GeV/c [2]. A comparison between this two results shows that in both cases analyzing power has the same sign and approximately equal in magnitudes. Since we are interested in the region of momenta 10 – 20 GeV/c, we use the A_N data on elastic pp scattering from [9]. For elastic pp scattering we expect the same in magnitude A_N , as for elastic $\bar{p}p$ scattering at momentum 16 GeV/c. At the same time there is the region of t , where we can expect a non-zero analyzing power. We construct our polarimeter to scan this area with the required accuracy of A_N . This area was define as $0.10 - 0.55$ (GeV/c)².

2.1. Elastic $\bar{p}p$ polarimeter

Polarized beam of antiprotons obtained from decay of $\bar{\Lambda}$ consist of three parts: unpolarized central part and polarized peripheral parts of different sign. A special system of three steering magnets MCV1-MCV3 allows to select any of these parts of the beam and direct it on the polarimeter target. To measure the analyzing power of $\bar{p}p$ to $\bar{p}p$, scattered and recoil particles have to be detected. For registration scattered $\bar{p}$ and recoil p scintillation hodoscopes are used. Schema of the absolute polarimeter for polarized $\bar{p}$ beam is presented in figure 2.

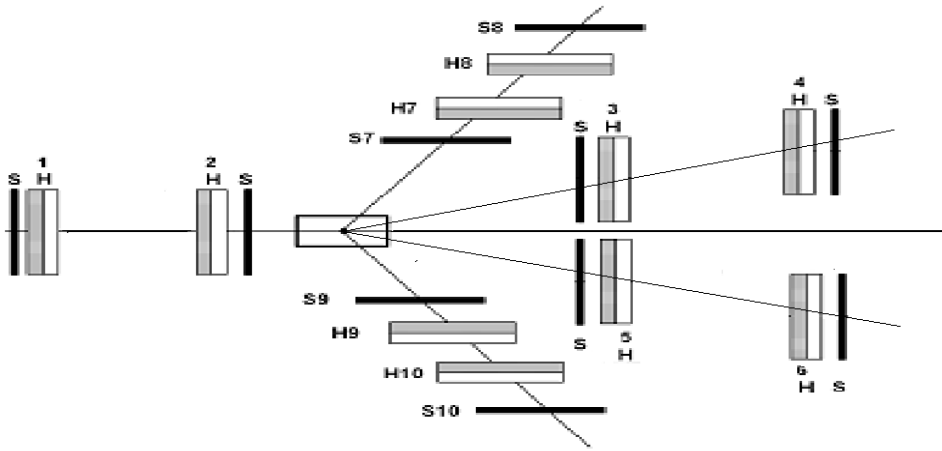


Figure 2. Layout of the absolute polarimeter for polarized $\bar{p}$ beam with momentum 16 GeV/c.

Hodoscopes are located in front of the target at distance of -220 cm and after the target at distance of 60 cm. S_1 - S_{10} are scintillation counters for flux measurement, H_1 , H_2 are beam hodoscopes for measurement of the polarized $\bar{p}$ beam parameters, H_3 – H_6 are hodoscopes for measurement forward scattered $\bar{p}$, H_7 – H_{10} are hodoscopes for measurement recoil protons. The trigger signal for reading information from hodoscopes is a coincidence of signals from the front hodoscopes and recoil hodoscopes.

To estimate the necessary data taking time we need define error of the raw asymmetry. We considered separately three cases. In first case unpolarized $\bar{p}$ with momentum 16 GeV/c scatter on polarized target. According to work [10] cross section of elastic $\bar{p}p$ and pp are close to each other at the same momentum of the beam and $d\sigma/dt = (3.77 \pm 0.16) \cdot 10^{-27} \frac{\text{mb}}{(\text{GeV}/c)^2}$ at $t=0.3$ (GeV/c)² and

luminosity $L=0.86 \cdot 10^{28} (\text{s}^{-1} \text{ cm}^{-2})$. Assuming relative error of raw asymmetry $\Delta\epsilon/\epsilon=0.05$. Data taking time is near 208 hours [11]. In the second case, polarized beam with unknown polarization scatter on an unpolarized target. Assuming relative error of raw asymmetry $\Delta\epsilon/\epsilon=0.12$, calculated data taking time near 490 hours. In the third case polarized beam scatter on polarized target this give possibility to measure spin correlation coefficient A_{NN} . With assumptions that spin correlation coefficient in elastic $\bar{p}p$ scattering is the same as in pp elastic scattering $A_{NN}=0.06$ [12], and relative error of raw asymmetry $\Delta\epsilon/\epsilon=0.15$, calculated data taking time is near 600 hours.

2.2. Survey of reactions for measuring antiproton polarization

2.2.1. Interference polarimeter. Analyzing power for reaction of $\bar{p}p$ scattering in CNI region was done in same way as for pp scattering in CNI region. Interference polarimeter consist of a liquid hydrogen target, six S_1 - S_6 scintillation flux counters, six GEM detectors $G_1 - G_6$, six hodoscopes $H_1 - H_6$ and magnetic spectrometer M. GEM provides a number of advantages: a small amount of the substance in the path of the beam, a low sensitivity to the magnetic field, the high spatial resolution close to $70 \mu\text{m}$. Schema of interference polarimeter is presented in figure 3.

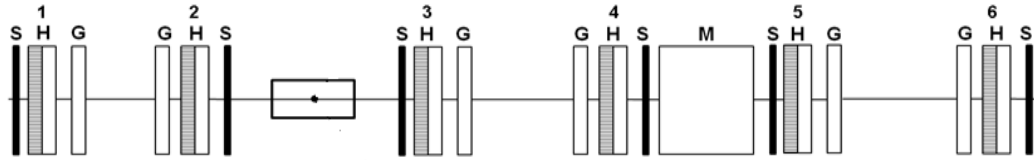


Figure 3. Schema of interference $\bar{p}$ polarimeter.

2.2.2. Inclusive π^0 , $\pi^\pm$ polarimeter Analyzing power of inclusive π^0 production at reaction $p(\uparrow) + p \rightarrow \pi^{0,\pm} + X$ was measured at $\sqrt{s}=200 \text{ GeV}$ [13] and at $\sqrt{s}=19.4 \text{ GeV}$ [14] has significant value at $p_T=1 \text{ GeV/c}$ and it is slightly depends from energy. It is possible to use SPASCHARM experimental apparatus and target as base apparatus for this polarimeter. Data taking time was estimated needed for 5% accuracy in measuring raw asymmetry in same way as in section 3. Time is near 20 hours for reaction of pp interaction and it near 500 hours for $\bar{p}p$ interaction for all reactions.

2.2.3. Inclusive online π^0 polarimeter This polarimeter is also based on reaction of inclusive π^0 production [15] but it placed behind SPASCHARM experimental setup and use proton or nuclear target. Main detector of this polarimeter is electromagnetic calorimeter [15]. Now it is under discussion one photon polarimeter same as suggested in [16]

3. Conclusion

We propose combined absolute polarimeter for measuring proton beam polarization at momentum of 40 GeV/c . We propose to create absolute polarimeter for polarized anti-proton beam on the basis of the process of elastic $\bar{p}p$ scattering. Specific estimates of the sizes of the detectors and analyzing power were carried out for momentum 16 GeV/c , since at this value of the momentum is expected maximum yield of $\bar{p}$. Polarized $\bar{p}$ beam can be used to study asymmetries in inclusive pions production, polarization in elastic $\bar{p}p$ scattering, also, spin-dependent total cross section $\Delta\sigma_T$. The advantage of elastic polarimeter is that: a) at any energy we can measure the unknown polarization of the beam, b) we can achieve the required accuracy in measurement of the polarization of the beam, d) simple adjust for different energy.

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