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Polarization analysis of $\bar{p}$ produced in pA collisions

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Abstract. A quite simple procedure for the generation of a polarized antiproton beam could be worked out if antiprotons are produced with some polarization. In order to investigate this possibility measurements of the polarization of produced antiprotons have been started at a CERN/PS test beam. The polarization will be determined from the asymmetry of the elastic antiproton scattering at a liquid hydrogen target in the CNI region for which the analyzing power is well known. The data are under analysis and an additional measurement is done in 2018. Details on the experiment and the ongoing data analysis will be given.

1 Introduction

The polarization analysis of antiprotons generated in the production process is motivated by the request for a polarized antiproton beam. A polarized antiproton beam would allow for the extraction of more detailed information in various fields like the structure of hadrons and their interaction but till now, although possible methods have been discussed since the first antiproton beams were produced [1], no simple procedure for the preparation of a well defined polarized antiproton beam is available. A number of different possibilities to generate a polarized antiproton beam have been proposed [2, 3] but mostly the expected intensity and polarization is quite low for a reasonable beam. Up to now only one experiment with a polarized antiproton beam has been performed by using antiprotons from $\bar{\Lambda}$ decay which have a helicity of -0.64. In this experiment a 200 GeV $\bar{p}$ beam with a polarization of 0.45

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was achieved with an intensity of 10^4 $\bar{p}$/s [4]. Similar experiments are planned with the SPACHARM project currently under development at the U-70 accelerator of IHEP [5].

The most practical solution for the preparation of a polarized antiproton beam proposed by the PAX collaboration [6] is currently the spin filter method which generates polarization of a stored antiproton beam by passing through a polarized atomic beam target due to the spin dependent interaction. The feasibility of this technique has been shown for protons [7, 8] and in general it will also work for antiprotons but needs some instrumental effort.

A rather simple polarized beam preparation could be performed if the production process itself generates some polarization [9, 10]. In that case the separation of a certain azimuthal angular range results directly in a polarized beam. But up to now a possible polarization of produced antiprotons has never been checked experimentally.

2 Polarization measurement

The determination of the antiproton polarization will be performed by measuring the right/left asymmetry of the elastic $\bar{p}p$-scattering given by: $d\sigma/(d\theta d\phi) = d\sigma/d\theta(1 + A_Y \cdot P \cdot \cos(\phi))$ for a transverse polarized beam with analyzing power A_Y and polarization P. In order to measure a polarization the analyzing power has to be known which is the case for the Coulomb-nuclear interference (CNI) region. At high energies and small squared four momentum transfer t the theoretical description of the analyzing power simplifies [11–13] and its calculations coincides very well with experimental data taken for elastic proton-proton scattering in the CNI region [14]. At 100 GeV/c momentum the maximum A_Y is at 4.5% at a t-value of t=-0.003 (GeV/c)^2. Due to G-parity conservation the antiproton-proton scattering will result in the same value of the analyzing power. And it is still valid for beam momenta of a few GeV/c as confirmed by preliminary calculations of the analyzing power in $\bar{p}p$ scattering down to about 5 GeV/c [15] resulting in the same amplitude of about 4.5 % at a bit lower t-value.

The measurement of the antiproton polarization was performed at the CERN PS test beam line T11 where secondary particles produced by the 24 GeV/c proton beam from PS in a production angular range of about 150 mrad are selected. The beam line was adjusted for negatively charged particles of 3.5 GeV/c which corresponds to the momentum used for the antiproton beam preparation at CERN/AD. The produced particles are mostly pions and only a small percentage of antiprotons, about 1%, is expected [16]. For the selection of elastic $\bar{p}p$ scattering events the antiproton has to be identified and its track before and after the scattering process has to be measured. In the considered t-range of the CNI region the target proton will be stopped within a rather short range. Therefore the event topology is a single track with a kink in the target volume.

3 Experimental setup

In Fig. 1 a sketch and a corresponding photo of the experimental setup is shown. The particle tracks were measured with drift chambers and for the particle ID Cherenkov detectors were used. A scintillating fiber hodoscope was installed as beam monitor in front of the first drift chamber and plastic scintillators were used for the trigger signal generation. As trigger signal a coincidence between start- and stop-scintillators with a veto from the aerogel Cherenkov counter was used. The aerogel has a refractive index of n=1.03 in which only pions with a threshold value of n=1.0008 at 3.5 GeV/c momentum will create Cherenkov light but not the antiprotons with a threshold value of n=1.035. The spill length of the beam was about 400 ms with up to $5 \cdot 10^5$ particles . With this Cherenkov veto signal an online pion reduction by a factor of 30 to 40 was done resulting in trigger rates of a few 10 kHz which could be handled

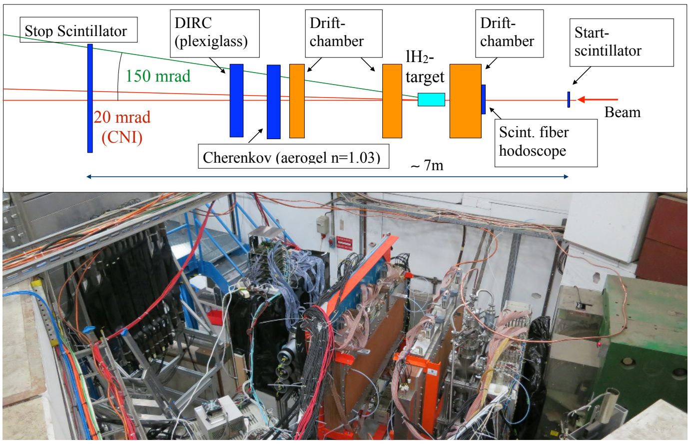

Figure 1. Detection setup for the antiproton polarization experiment with drift chambers for the track reconstruction and Cherenkov detectors for the particle identification. As target a 12 cm long liquid hydrogen volume is used.

by the data acquisition system. For the final antiproton identification the offline analysis of the DIRC signals are used. The elastic scattering events are selected by the track reconstruction in the drift chambers. The calibration of the drift chamber results in position resolutions of 150 - 300 μm from which track resolutions of below 1 mrad result. The expected precision for the measurement of the scattering angle is a few mrad by including the straggling in the material on the path of the antiprotons. From the data an actual resolution of about 5 mrad (FWHM) is estimated which will be improved by a fine tuning of the calibration. For details on the analysis see [17, 18]. The resolution is sufficient to separate the scattering events in the relevant angular range of 10 - 20 mrad.

In order to increase the statistics an additional measurement with an improved detection setup is performed in 2018. Fig. 2 shows a sketch of the new setup with essentially similar components, scintillators, tracking and Cherenkov detectors. A trigger signal will be generated by a small 2 cm x 2 cm plastic scintillator with a veto from aerogel Cherenkov counters directly behind the trigger scintillator. The Cherenkov counter include a 10 cm long aerogel tube with a diameter of 3 cm and the Cherenkov photons are reflected at a mirror foil into photomultipliers on both sides. For the primary track a scintillating fiber hodoscope will be used with 0.25 mm scintillating fibers readout with SiPM arrays. It includes two modules with double layers of scintillating fibers in x and y-direction separated by 40 cm. The tracks of the scattered particles will be measured with straw tubes, two modules with 3 double layers in vertical direction and rotated by ± 60 deg. Both tracking detector systems will give track resolutions of below 1 mrad. The target and the DIRC will be the same as used in the previous measurement. All detector components are mounted on one common frame which simplifies the geometrical adjustment.

4 Summary

In order to measure the polarization of antiprotons produced in pA interactions in view of a polarized antiproton beam data have been taken at the CERN PS test beam which will be increased in statistics by a follow-up experiment with an improved detection system. Both systems include tracking and Cherenkov detectors which allow to identify the particle ID and

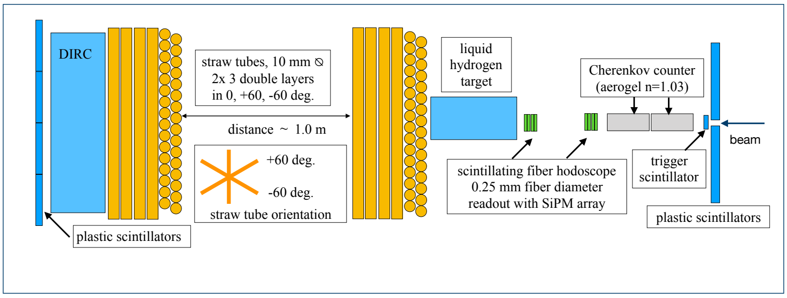

Figure 2. Sketch of the detection system for the follow-up experiment.

to reconstruct the scattering angle to determine the polarization. The data are presently under analysis. The track reconstructions with the existing data achieve the expected resolutions and with the photon distributions in the DIRC the antiprotons can be well separated from the pion background. Currently a fine tuning of the drift chamber calibration and positioning for an improved resolution and the particle identification from the photon distributions in the DIRC supported by simulation studies are performed. Furthermore the detector components for the follow-up experiment are prepared.

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References

[1] A. D. Krisch, AIP Conf. Proc. **145**, (1986)
[2] E. Steffens, AIP Conf.Proc. **1149**, 80-89 (2009)
[3] H. O. Meyer, AIP Conf.Proc. **1008**, 124-131 (2008)
[4] A. Bravar *et al.*, Phys. Rev. Lett. **77**, 2626-2629 (1996)
[5] V.V. Abramov *et al.*, Nucl.Instrum.Meth. A **901**, 62-68 (2018)
[6] P. Lenisa and F. Rathmann for the PAX collaboration, *arXiv:hep-ex/0505054v1* (2005)
[7] F. Rathmann *et al.*, Phys. Rev. Lett. **71**, 1379-1382 (1993)
[8] W. Augustyniak *et al.*, Phys.Lett. B **718**, 64-69 (2012)
[9] K. Kilian *et al.*, Int. J. Mod. Phys. A **26**, 757 (2011)
[10] D. Grzonka *et al.*, Acta Phys. Polon. B **46**, 191 (2015)
[11] B.Z. Kopeliovich and L.I. Lapidus, Sov. J. Nucl. Phys. **19**, 114 (1974)
[12] N. Akchurin *et al.*, Phys. Rev. D **48**, 3026 (1993)
[13] N. H. Buttimore *et al.*, Phys. Rev. D **59**, 114010-114057 (1999)
[14] H. Okada *et al.*, Phys. Lett. B **638**, 450-454 (2006)
[15] J. Haidenbauer, private communication
[16] T. Eichten *et al.*, Nucl. Phys. B **44**, 333-343 (1972)
[17] D. Alfs *et al.*, Acta Phys. Polon. B **48**, 1983 (2017)
[18] D. Alfs *et al.*, contribution to these proceedings