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Present Understanding of Spin Filtering Experiments

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Abstract

An overview on the present understanding of the spin filtering methods is given, and the planned measurements on spin filtering at the COSY ring with protons are described.

1 Introduction

Polarized antiprotons provide access to a wealth of single- and double-spin observables, from which outstanding physics questions like "What is the transversity distribution of the valence quarks in the proton?" may be answered. Interest in the polarization of antiprotons has recently been stimulated by a proposal to build a High Energy Storage Ring (HESR) for antiprotons at the new Facility for Antiproton and Ion Research (FAIR) at the Gesellschaft für Schwerionenforschung (GSI) [1]. A Letter-of-Intent for spin-physics experiments has been submitted by the PAX collaboration [2] to employ a polarized antiproton beam incident on a polarized internal storage cell target.

Although a number of different approaches were investigated in the past and new ideas have been put forward recently, the only viable way for producing polarized antiprotons for FAIR at present is via spin filtering [3]. This method exploits the spin-dependent scattering of an unpolarized beam of antiprotons on a polarized hydrogen target. Technically this will have to be done be repeatedly sending the stored beam in a cooler cyclotron through a storage cell of the polarized target. In fact, such an experiment (FILTEX) has been performed some time ago with protons at the TSR [4], proving the feasibility of the method. One of the (many) still open questions is, however, how spin filtering actually works, since two different interpretations of the FILTEX-result have been put forward, one with substantial spin-filtering of (anti)protons by polarized electrons [5, 6], while the second one suggests a self-cancellation of the electron contribution to spin-filtering [7] leaving only the hadronic contribution.

2 Polarization Buildup Mechanisms

All the possible methods to polarize (anti)protons are based on two mechanisms: selective loss or/and selective flip (see Fig. 1) [8]. In case of the selective loss one spin state is discarded more than the other one, while in the flip scenario one of the two states is reversed more intensively. The flip mechanism includes spin transfer by co-moving polarized electrons or positrons [6]. Another method is a dynamic nuclear polarization in flight with co-moving polarized electrons or positrons. The loss mechanism includes polarization of an antiproton beam via Stern-Gerlach separation. Theoretically this seems to be impossible due to averaging effects in a stored beam [9]. Another method is polarization by channeling trough bent crystals [10]. The only successfully tested method is spin filtering [4].

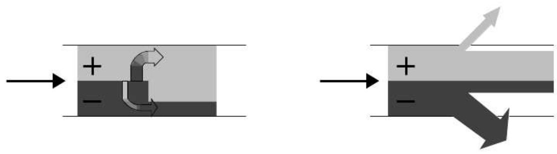

Figure 1: Two principles to polarize (anti)proton beam. The left figure depicts selective flip mechanism, while the right one illustrates selective loss.

3 Spin Filtering and Depolarization Experiments at COSY

Spin filtering at COSY has two main objectives, understanding of the spin filtering mechanism and disentangling of the electromagnetic and hadronic contributions to the polarizing cross section. The latter can be reached with help of experiments using pure electron and nuclear polarized targets. This in turn requires strong holding fields applied longitudinally followed by a necessity of having a Siberian snake in the ring. Such massive hardware modifications can be avoided in case simpler experiments are possible that could reveal the role of electrons.

It is natural to assume that if polarized electrons polarize an initially unpolarized beam, then unpolarized electrons should depolarize an initially polarized beam. Therefore, using deuterium as an effective electron target we would like to distinguish the electron effect from the depolarization in COSY without target. Prerequisites for these studies however are large beam and polarization lifetimes of the proton beam, and this is currently being tested at COSY. Provided, both lifetimes are large enough, a 4-5 σ target effect can result from a 4 week data taking period.

A different approach is to use co-moving electrons in the electron cooler of COSY instead of the target electron to observe depolarization. This idea is motivated by the recent Walcher-Arenhövel estimation of electron-to-proton spin transfer at low-relative energy [6]. It is predicted that the corresponding

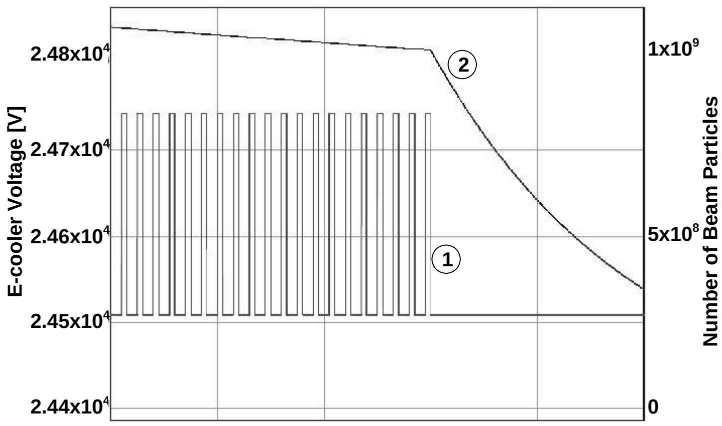

Figure 2: An example of COSY cycle structure for depolarization studies. E-cooler voltage (1) and the number of beam particles (2) are shown. The kink in the particle number is when the target is switched on.

cross section is very large at a proton kinetic energy of about 1 keV in the electron rest frame. The necessary experimental conditions are fulfilled by detuning the electron cooler in such a way that one can reach the required energy difference. The energy resolution of the detuned beam decreases rapidly, therefore only a limited time can be spent at these conditions. This leads to a periodically alternating structure of the cycle (see Fig. 2). After some time a target has to be switched on, and polarization of the beam must be measured. The polarization decrease is then directly related to the depolarizing cross section. This experiment is currently being prepared [11] and shall be performed in early 2008 provided the COSY Program Advisory Committee approves the investigation.

4 Spin Filtering: Status

Spin filtering is expected to be an effective way to polarize antiprotons. But a lack of experimental data leaves space for a controversy in explaining how spin filtering really works. The conclusion is that there are further experimental tests necessary to disentangle the effects of electrons and nucleons for the polarization buildup process. Depolarization as well as spin-filtering experiments will be carried out at COSY (Jülich) with protons, followed by spin-filtering experiments with antiprotons at the Antiproton Decelerator Ring (AD/CERN) [12].

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