Spin Filtering Studies at COSY and AD

Alexander Nass for the PAX-Collaboration

Phys. Institut der Universität Erlangen Nürnberg, E.-Rommel-Str. 1, 91058 Erlangen, Germany

Abstract. The high physics potential of experiments with stored high-energy polarized antiprotons led to the proposal of PAX (Polarized Antiproton eXperiment) [1] for the High Energy Storage Ring (HESR) of the FAIR at GSI (Darmstadt/Germany). It is proposed to polarize a stored antiproton beam by means of spin filtering with a polarized H (D) gas target. The feasibility of spin filtering has been demonstrated in the FILTEX experiment. The current interpretation foresees a self-cancellation of the electron contribution to the filtering process and only the hadronic contribution is effective. Several experimental studies with protons (at COSY/Jülich) as well as antiprotons (at AD/CERN) will be carried out to test the principle and measure $\vec{\bar{p}}\vec{p}$ and $\vec{\bar{p}}\vec{d}$ cross sections. A polarized internal gas target (PIT) with surrounding Silicon detectors immersed into a low-β section has to be set up.

Keywords: Polarized Targets, Elastic Proton scattering, Antiproton-induced reactions
PACS: 29.25.Pj, 25.40.Cm, 25.43.+t

PRINCIPLE OF SPIN FILTERING

Several methods to polarize antiprotons were reviewed on workhops held in Bodega Bay, 1985 [4], Daresbury, UK, 2007 [5] and the Heräus Workshop in Bad Honnef, Germany, 2008 [6]. The only successfully tested method is spin filtering. It is based on the effect of selective removal of (anti)protons of a stored beam by a polarized target. The total cross section

$$\sigma_{tot} = \sigma_0 + \sigma_{\perp}\vec{P}\cdot\vec{Q} + \sigma_{\parallel}(\vec{P}\cdot\vec{k})(\vec{Q}\cdot\vec{k}) \tag{1}$$

consists of a transverse and longitudinal part, where $\vec{P}$ is the proton beam polarization, $\vec{Q}$ the target polarization and $\vec{k}$ the proton beam direction. For initially equally populated states $\uparrow$ $(m = +\frac{1}{2})$ and $\downarrow$ $(m = -\frac{1}{2})$ the total cross sections for the transverse and longitudinal cases are

$$\sigma^{\perp}_{tot\pm} = \sigma_0 \pm \sigma_{\perp}\vec{Q} \quad \text{and} \quad \sigma^{\parallel}_{tot\pm} = \sigma_0 \pm (\sigma_{\perp} + \sigma_{\parallel})\cdot\vec{Q}\,, \tag{2}$$

respectively. Therefore an initially unpolarized (anti)proton beam will become polarized.

Experiments at the Test Storage Ring (TSR) at Heidelberg in 1993 (Fig. 1) showed that the spin-filtering technique works in principle [2]. A polarization buildup was observed (Fig. 1, right panel) with a cross section is $\sigma_{\perp} = 72.5 \pm 5.8$ mb. The current interpretation [3, 7] shows that by considering only elastic pp-scattering, a total cross section of $\sigma_{\perp} = 85.6$ mb is obtained.

Further experimental tests are necessary to fully understand the polarization buildup process. Depolarization experiments were already carried out at COSY [8]. Spin-filtering experiments [9] will be carried out at COSY with protons, followed by spin-filtering experiments with antiprotons at the Antiproton Decelerator Ring (AD/CERN) [10].

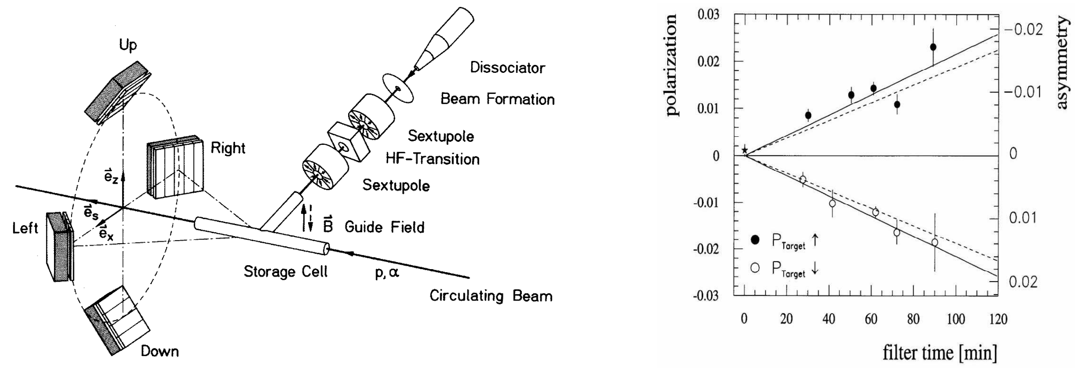

FIGURE 1. The setup of the test experiment at TSR and the results [2].

Required for the spin-filtering experiments is a highly polarized internal gas target with areal densities of up to 10^{14}atoms/cm^2 using a storage cell. A low-β section is necessary to pass the stored (anti)proton beam through the storage cell and to reduce the Coulomb losses in order to achieve long storage times of several hours. It is expected that nuclear polarized deuterium could be equally effective for spin filtering as hydrogen. Therefore the target should run with hydrogen and deuterium with nuclear polarization in variable target holding fields. Because no analyzing power measurement for $\vec{\bar{p}}\vec{d}$ scattering exists at this energy range, the target gas has to be exchanged with hydrogen in order to measure the antiproton beam polarization. For longitudinal spin filtering a Siberian snake has to be implemented in order to preserve the longitudinal polarization of the beam.

EXPERIMENTAL SETUP

The setup for the spin-filtering experiments (Fig. 2) consists of an Atomic Beam Source (ABS) to produce polarized target gas, a target chamber with storage cell and a detector system to detect forward and recoil (anti)protons. A so-called Breit-Rabi Polarimeter (BRP) is used to measure the polarization of the target gas. A low-β section consisting of 4(6) magnets is necessary for the measurements at COSY(AD). This is designed for the interaction point TP 1 at COSY, and for one of the straight sections at AD. For longitudinal spin filtering at COSY, the solenoids of WASA and the electron cooler, located in the opposite straight section, can be used as a Siberian snake, but at the AD, an additional snake is required.

The former HERMES-ABS was set up in Jülich with a modified vacuum system, mounted on a new support. The cryogenic pumps were replaced by turbo molecular pumps and an oil-free forevacuum system. It was completely recabled to allow a fast assembly and disassembly at COSY and AD. The control system was renewed to allow for a full remote control via computer. The vacuum system with the microwave dissociator is operating well. The achieved pressures show that the new vacuum system is functioning as anticipated. None of the large turbo pumps run into their compression limit. After construction of a new analysis chamber with QMS and a calibrated compression tube,

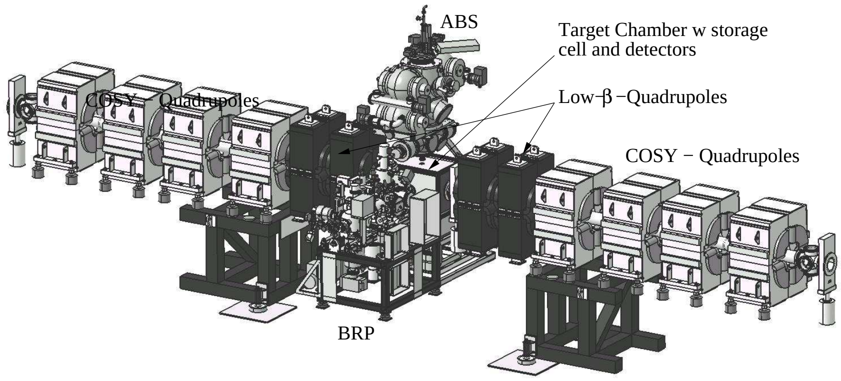

FIGURE 2. Overview over the setup for the spin filtering experiments.

the first intensity measurements were carried out. The measurements showed intensities of up to $6 \cdot 10^{16}$atoms/s for hydrogen in two hyperfine states. The new and unique feature of the present setup is that the ABS will be able to produce nuclear polarized hydrogen **or** deuterium beams in short sequence (5 min) without mechanical changes of components.

Since spin filtering requires areal densities of up to 10^{14}atoms/cm^2, the use of a storage cell is mandatory. The present cell design consists of 5 μm Teflon walls supported by an aluminum frame. Thin walls allow low energy recoil particles to pass through and be detected by the Silicon Tracking Telescopes (STT's). Teflon also suppresses depolarization and recombination of the target gas inside the cell. The cell has to be openable to provide enough space for the beam during injection at AD. The cell will be closed after the beam is decelerated and cooled. Subsequently the target gas is injected. Longitudinal and transverse weak holding field coils, added to the outside of the target chamber, provide the quantization axis for the polarized atoms.

The BRP is necessary to determine the nuclear polarization of deuterium at the AD because of the unknown analyzing power for $\bar{p}\vec{d}$ scattering. The former HERMES-BRP was rebuilt on a new support stucture with modifications due to the new configuration with the ABS. Tracking calculations led to a modified sextupole magnet configuration to adjust for the higher temperature of 300 K of the effusive hydrogen/deuterium beam out of the uncooled storage cell; at HERMES the cell was at 100 K. In addition a new strong field transition “Dual Cavity” was designed in order to induce transitions between hyperfine levels of hydrogen **or** deuterium.

The beam polarization will be measured by using pp ($p\bar{p}$)-elastic scattering. To this aim a detector system consisting of 12 STT's will be implemented around the target cell. The telescopes will detect both the low energy recoil particles (< 8 MeV) as well as the forward scattered particle with a large angular coverage and high resolution. In addition the proton polarization of the target can be measured with the initially unpolarized (anti)proton beam. This allows for the calibration of the BRP.

The vacuum system of the target section comprises three turbo molecular pumps, backed with smaller turbo molecular pumps and a dry forevacuum pump. This will ensure that most of the target gas exiting the storage cell is pumped away in the target

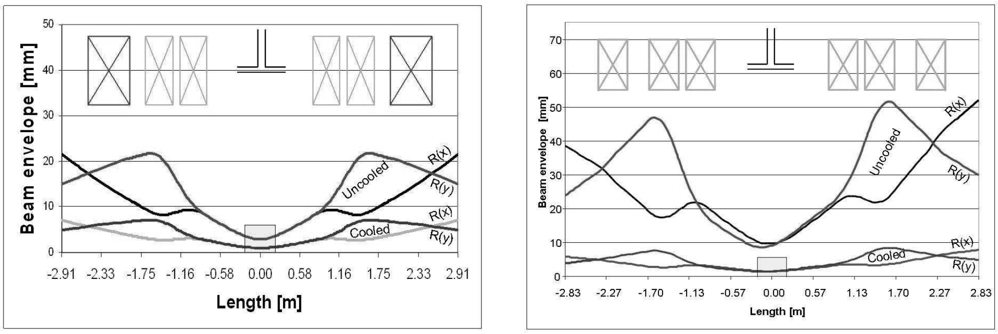

FIGURE 3. The beam size along the low-β-section at COSY (left) and AD (right).

chamber. Flow limiters will be installed between the target chamber and the magnet chambers in order to reduce the gas load.

The low-β-section will consist of 4(6) normal conducting quadrupole magnets. They will be implemented into the COSY (AD) lattice prior to the installation of the target. Calculations show the dependence of the beam envelope along the target section (Fig. 3).

PLANNED MEASUREMENTS

A first set of spin filtering measurements is planned to be carried out at COSY/Jülich with an initially unpolarized proton beam and a nuclear polarized target in a weak holding field. It will determine the polarization buildup effect [9] and comission the experiment for the AD. A second set of measurements is planned at AD/CERN. These measurements will provide data to estimate the achievable polarization in spin filtering with an antiproton beam [10].

REFERENCES

1. *Antiproton-Proton Scattering Experiments with Polarization*, Technical Proposal for the HESR at FAIR, Jülich (2005), e-Print Archive: hep-ex/0505054.
2. F. Rathmann et al., *Phys. Rev. Lett.* **71**, 1379 (1993).
3. A.I. Milstein and V.M. Strakhovenko, *Phys. Rev. E* **72**, 066503 (2005).
4. A. D. Krisch et al. (Eds.),*Polarized antiprotons*, AIP Conf. Proceedings **145** (1986).
5. D. P. Barber et al.(Eds.), *Polarized Antiproton Beams - How?*, AIP Conf. Proceedings **1008** (2008).
6. *Polarized Antiprotons*, WE-Heräus Seminar, Bad Honnef, Germany (2008), talks available under *http://www.fe.infn.it/heraeus/index.html*
7. N. N. Nikolaev and F. Pavlov *Spin Filtering of Stored (Anti)Protons: from FILTEX to COSY to AD to FAIR* (2007), e-Print Archive: hep-ph/0701175
8. F. Rathmann et al., *Do unpolarized electrons affect the polarization of a stored proton beam?*, published in these proceedings (2009).
9. *Spin-Filtering Studies at COSY*, Letter of Intent, Jülich (2006), available at http://www.fz-juelich.de/ikp/pax/.
10. *Measurement of the Spin-Dependence of the* $\bar{p}p$ *Interaction at the AD-Ring*, Letter of Intent, Jülich (2005), available at http://www.fz-juelich.de/ikp/pax/.