The Polarized Target for Spin Filtering Studies at COSY and AD

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Abstract. The setup of the polarized target for the spin filtering studies at COSY and AD will be shown together with the planned measurements. The target fulfills all the requirements coming from the experiment.

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

INTRODUCTION

The high physics potential of experiments with stored high-energy polarized antiprotons led to the PAX-proposal (Polarized Antiproton eXperiment) for the High Energy Storage Ring (HESR) [1] of the FAIR facility at GSI (Darmstadt/Germany). It is proposed to polarize a stored antiproton beam by means of spin filtering with a polarized hydrogen (deuterium) gas target. The feasibility of spin filtering has been demonstrated in the FILTEX experiment [2]. The theoretical understanding of the collision of an (anti)proton with a polarized hydrogen (deuterium) target is crucial for the successful application of spin filtering. However, there exist two competing theoretical interpretations: one with substantial filtering of (anti)protons by polarized electrons [3], while the second one suggests a self-cancellation of the electron contribution to filtering [4]. In order to clarify this situation several experimental studies with protons (at COSY/Jülich) as well as antiprotons (at AD/CERN) have to be carried out. These include the setup of a polarized internal gas target (PIT) immersed into a low-β section, as well as a Siberian snake for longitudinal filtering at AD.

TARGET SETUP

The requirements to the target used for such an experiment are the following:

- high polarization at a density up to 10^{15} atoms/cm^2,
- variability of the quantization axis using different magnetic holding fields,
- ability to produce pure electron and pure nuclear polarization,
- measurement of the target polarization independent of the proton/antiproton beam

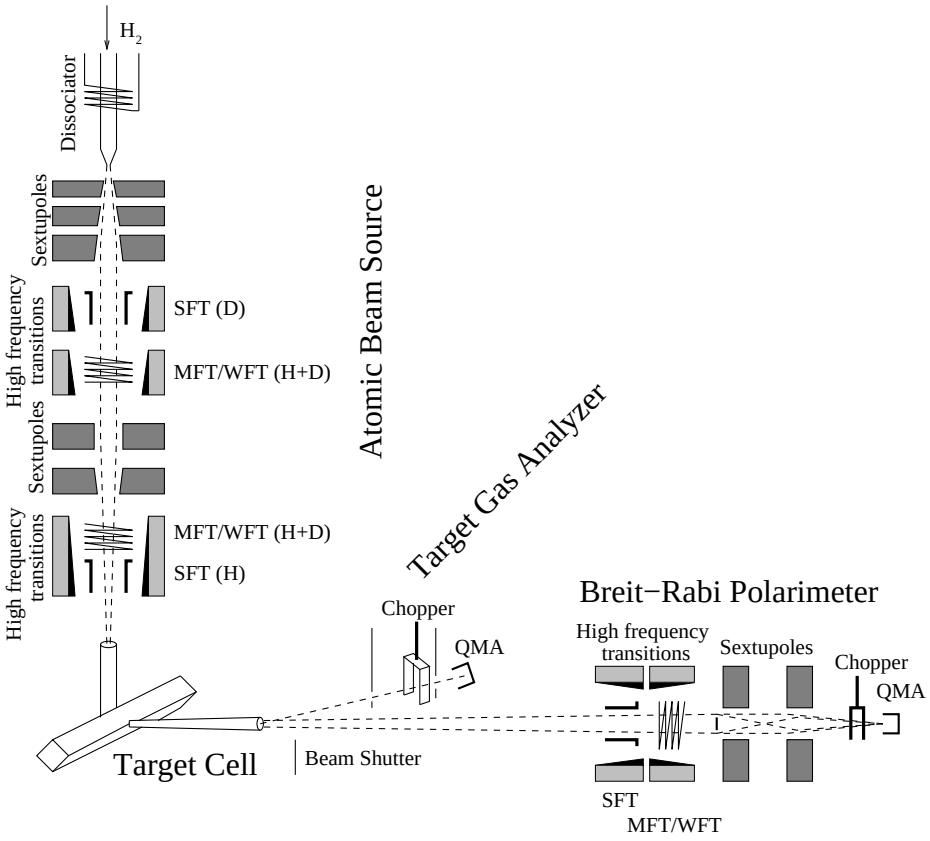

FIGURE 1. Schematic overview over the setup of the polarized target. SFT - Strong Field Transition, MFT - Medium Field Transition, WFT - Weak Field Transition.

- ability to produce polarized hydrogen and deuterium in a short sequence with the same set-up, e.g. for filtering with deuterium and measuring the proton/antiproton polarization with hydrogen.

The setup for the experimental studies will comprise a polarized internal gas target consisting of an Atomic Beam Source (ABS), a storage cell, and a so-called Breit-Rabi Polarimeter (BRP). A schematic drawing of the target is shown in Fig.1.

The Atomic Beam Source

The ABS consists of 4 vacuum chambers with 7 turbo molecular pumps with a total pumping speed of about 10000 l/s. The atomic beam is produced when the dissociated hydrogen/deuterium gas expands through a cooled nozzle into the vacuum of the dissociator chamber. A skimmer and a collimator are used to form a high brilliance beam with a divergence that matches the acceptance angle of the first sextupole magnet. The sextupole magnets focus atoms with electron spin 1/2 (hyperfine states $|1\rangle$ and $|2\rangle$ for hydrogen) and defocus atoms with electron spin -1/2 (hyperfine states $|3\rangle$ and $|4\rangle$). Therefore electron polarization of the atomic beam is created. Nuclear polarization is

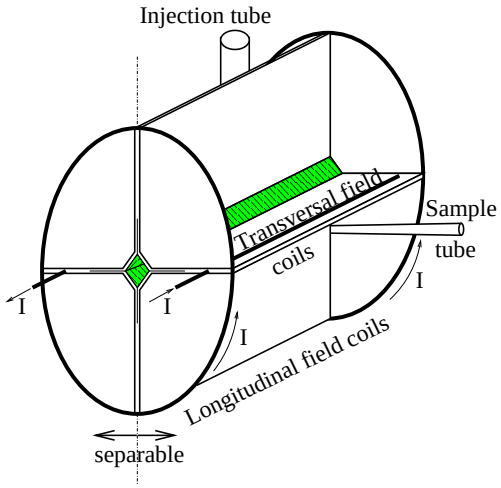

FIGURE 2. The storage cell with the coils for the longitudinal and transversal magnetic holding fields.

obtained using high frequency transitions (HFT) which exchange the population of hyperfine states. The setup of the ABS will contain two HFT's (lower transitions in Fig.1) to produce pure nuclear polarization for hydrogen in a high target holding field (300G) (injecting states $|1\rangle$ and $|4\rangle$ for positive or $|2\rangle$ and $|3\rangle$ for negative polarization). In addition one/two HFT's (upper transitions in Fig.1) are used so that hyperfine state $|1\rangle$ for hydrogen/deuterium is injected into the target cell in a low target holding field (10G).

The Storage Cell and Beam Vacuum

A storage cell is used to increase the target density to values up to 10^{15} atoms/cm^2. It will consist of a teflon foil supported by an aluminum frame (Fig.2) [5]. The frame also supports the coils for the weak longitudinal and tranverse holding field. Another pair of superconducting Helmholtz coils will be installed in the target region at COSY to perform the high field measurements with pure electron and nuclear polarization. The Teflon walls of the cell surface prevent recombination and depolarization of the target atoms. In addition it allows to detect the low-energy recoil protons. The cell has to be openable to allow the large injected antiproton beam at AD to pass through. After cooling and deceleration of the beam, the cell will be closed for filtering.

The vacuum of the beam line around the storage cell will be pumped by turbo molecular pumps with a total pumping speed of 5000 l/s. Flow limiters will prevent the target gas from diffusing into the adjacent sections. The large cold surfaces of the superconducting magnets will work like cryo pumps.

The Breit-Rabi Polarimeter

The analysis section of the target will consist of the Target Gas Analyzer (TGA) and the Breit-Rabi Polarimeter (BRP) (Fig.1). The TGA is used to measure the atomic

fraction of the target gas using a quadrupole mass analyzer. The BRP measures the polarization of the atoms using different settings of the built-in HFT's. Here, a special strong field transition (SFT) has to be constructed which works for both hydrogen and deuterium. Thus the polarimeter can be used to determine the polarization of hydrogen and deuterium without changes in the hardware. The BRP has to be calibrated for both gases in order to be able to switch from hydrogen to deuterium in short sequence. The measurement of the BRP will be cross checked using pp/$\bar{\text{p}}$p scattering, so that the sampling corrections needed for the measurements can be directly determined.

PLANNED MEASUREMENTS

There are several measurements planned at COSY and AD:

- Spin filtering with pure electron and nuclear polarization in a strong magnetic holding field using the proton beam at COSY to disentangle the electromagnetic and hadronic contributions.
- Spin filtering tests with nuclear polarized hydrogen and deuterium (hyperfine state $|1\rangle$) in a weak magnetic holding field using the COSY proton beam to extend the FILTEX measurements at different energies and to test the setup for the AD at CERN.
- Spin filtering measurements with nuclear polarized hydrogen and deuterium (hyperfine state $|1\rangle$) in a weak magnetic holding field using the antiproton beam of the AD at CERN to find the optimum energy of the spin filtering process.

SUMMARY

The internal polarized gas target, proposed here, meets the requirements for the planned spin filtering experiment. It is capable to produce highly polarized hydrogen and deuterium beams in a short sequence. The storage cell will increase the density of the target atoms to the required values and allow the detection of recoil protons. A change of spin direction can be achieved by switching the direction of the target holding field from transversal to longitudinal. The BRP is able to measure the polarization independent of the proton/antiproton beam. It can be calibrated using pp/$\bar{\text{p}}$p scattering. The target setup will be completed at the end of 2007. The measurements will start in 2009 at COSY and in 2010 at AD.

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. C.J. Horowitz and H.O. Meyer, *Phys. Rev. Lett.* **72**, 3981 (1994).
4. A.I. Milstein and V.M. Strakhovenko, *Phys. Rev. E* **72**, 066503 (2005).
5. W.A. Dezarn et al., *Nucl. Inst. Methods* **A 362**, 36 (1995).