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New Aspects of Storage Cell Developments for the Polarized Internal Target at LHCb

Hendrik Smitmanns[1,2], Ralf Engels[1], Kirill Grigoryev[1], Onur Bilen[1,3] and Andreas Lehrach[1,2], in collaboration with the LHCSpin project

[1]*Institut für Kernphysik (IKP), Forschungszentrum Jülich, Wilhelm-Johnen-Str. 1, 52425 Jülich, Germany*
[2]*III. Physikalisches Institut B, RWTH Aachen, Otto-Blumenthal-Straße, 52074 Aachen, Germany*
[3] *Institut für Laser– und Plasma–Physik (ILLP), Heinrich–Heine–Universität, Düsseldorf (HHUD), Universitätsstr. 1, 40225 Düsseldorf, Germany*

E-mail: hendrik.smitmanns@rwth-aachen.de

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The LHCSpin project aims to install a polarized internal target in front of the LHCb detector. An important part of the internal target is the storage cell. One possible material for the wall coating of this storage cell is carbon. Therefore, the properties of carbon coated storage cells have to be investigated with respect to polarization conservation. An experimental setup at Forschungszentrum Jülich is presented, which is ideally suited for the investigation of polarization conservation and recombination in carbon coated storage cells.

KEYWORDS: polarized gas target, storage cell, Lyman photons

1. Introduction

For the LHC Run 4, the LHCSpin project [1] aims to install an internal polarized gas target in front of the LHCb detector [2], bringing polarized physics to the LHC for the first time. An important part of the target will be an openable T-shaped storage cell, sharing the SMOG2 design [4]. The cell will be fed with polarized hydrogen or deuterium atoms produced by an atomic beam source (ABS). To avoid polarization losses of the injected atoms in the cell, a coating of the cell wall is foreseen. A possible material for the coating could be amorphous carbon [3], which should ensure a low Second Electron Yield to preserve the beam lifetime and a low recombination rate to prevent recombination of the injected polarized atoms, which would reduce the polarization. However, a carbon coated storage cell has never been experimentally investigated.

At the Institute for Nuclear Physics at the Research Center Jülich a setup exists dedicated to study polarization losses in storage cells as a function of surface materials, temperature, magnetic holding fields, and recombination. Using this setup, the recombination of hydrogen and deuterium on different metal coated storage cells has already been conducted [5], showing that recombined molecules only hold 50 % of the initial atomic polarization. Also, a Fomblin oil coated storage cell has been investigated [6], here the recombined molecules preserved nearly the full atomic polarization. For 2022 it is foreseen to investigate carbon coated storage cells with similar size as the storage cell that is planned to be used in the LHCb internal target.

Due to a modification of the ABS used in Jülich, it is also possible to investigate the influence of Lyman-α photons on the recombination process. Such measurements could give new insights to improve the construction of future polarized sources. Furthermore, the recombination of hydrogen atoms on carbon surfaces is thought to play an important role in the formation of molecular hydrogen clouds in the interstellar medium (ISM) [7].

2. Physics Case

For a hydrogen atom to get adsorbed on top of a carbon atom, it needs to overcome an energy barrier of about 200 meV [8]. Around the adsorbed hydrogen, the energy barrier for an additional hydrogen atom to get adsorbed is reduced. There are three energetic different adsorption sites around the adsorbed atom, where the para and ortho dimer adsorption sides are the most favorable [9]. An overview of the dimer states is shown in Fig. 1. This effect leads predominantly to the formation of adsorbed hydrogen pairs. Under certain conditions, these pairs can desorb as molecular hydrogen. Experiments have shown that exciting the carbon surface with a Ti-sapphire laser is one way of doing that [10]. Building on this, the hypothesis is made that such an excitation by Lyman-α photons could also be possible. The desorption of molecular hydrogen from the para dimer state should be favored because it has the lowest energy barrier of 1.4 eV. Any adsorbed hydrogen atom should lose its polarization due to the bounding to the carbon surface. Therefore, hydrogen molecules desorbed from the surface should be unpolarized.

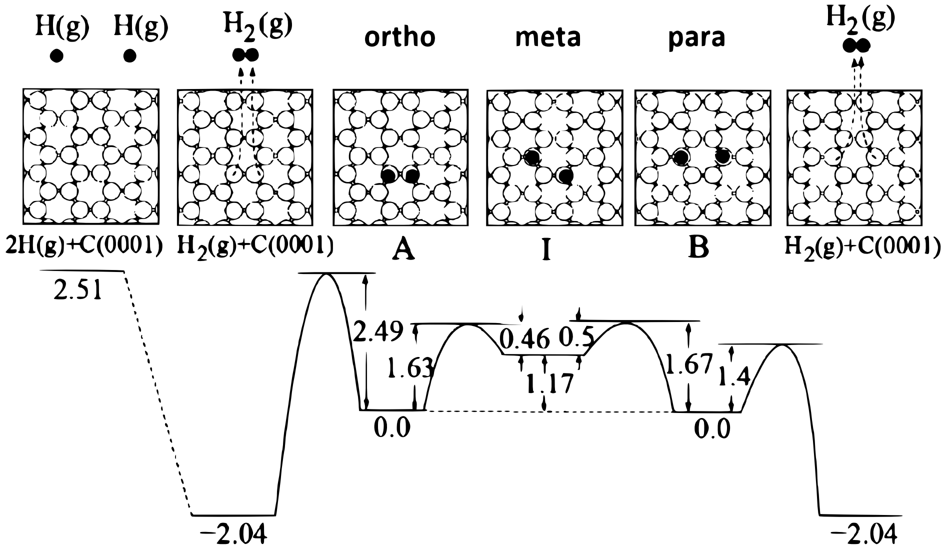

Fig. 1. Possible desorption pathways of adsorbed hydrogen on a carbon surface: The para state has the lowest energy barrier of 1.4 eV, while for the ortho state, a desorption pathway through the meta state should be favorable [9].

3. Experimental Setup

A beam of polarized hydrogen or deuterium atoms is produced by an ABS, formerly used as part of the ANKE experiment at COSY/Jülich [11]. The ABS is able to produce every possible combination of nuclear and electron spin orientations. The ABS is fueled with molecular gas that gets dissociated in an RF-induced plasma, a process which creates a high number of Lyman-α photons. The beam is fed into the storage cell located inside a liquid-helium-cooled superconducting magnet, which is located inside the interaction chamber. The solenoid allows inducing magnetic holding fields up to a field strength of 1 T. The wall temperature of the storage cell can be set between 45 K and 120 K using the cooling and a heater at the center of the cell. Inside the storage cell, some injected atoms and on the wall recombined molecules are ionized by electrons produced by an electron gun mounted on the left side of the interaction chamber. The ionized particles are accelerated to the other side of the storage cell using a static electric field and enter a Lamb-shift polarimeter (LSP). The LSP [12] is able to measure the polarization of all ionized particles leaving the storage cell. A Wien filter used as a velocity filter is installed between LSP and storage cell, separating ions of different masses. For a more detailed description of the setup and how the polarization is measured, look at [13, 14] and a detailed scheme of the whole setup is shown in Fig. 2.

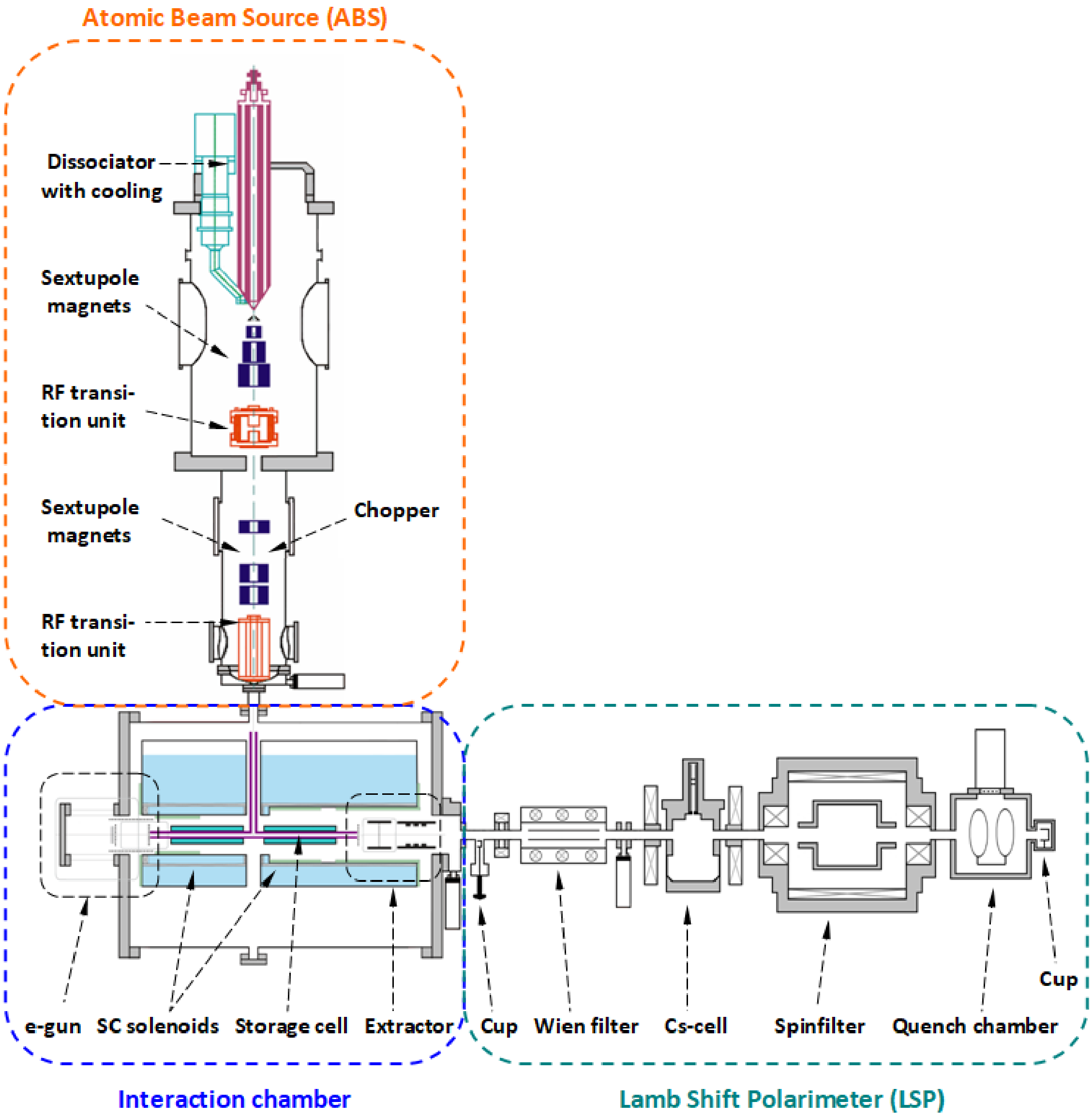

Fig. 2. Scheme of the experimental setup: The setup is separated in three main parts, the atomic beam source, the interaction chamber and the Lamb-shift polarimeter.

The photons generated inside the dissociator have the possibility to pass through the ABS into the storage cell with the atomic beam. To intentionally prevent these photons from entering the storage cell, a modified chopper was installed. The chopper is located inside the second group of six-pole magnets. The new chopper allows switching between two chopper positions. In the first position, a simple hole is rotated into the beamline, allowing the full ABS beam to pass through. In the second position, a modified hole is turned in the beamline, in the center of which a plate with three rods is fixed, blocking the center of the beam path. In Fig. 3, the new chopper is shown, and its position inside the ABS is marked in Fig. 2. Inside the six-pole magnets, the atoms are slightly bent off-axis due to their magnetic moment, while the photons coming from the dissociator remain on axis and are not affected by the magnetic fields. Therefore, most of the polarized atoms pass beside the plate in the middle of the modified chopper opening, while most of the photons should be blocked.

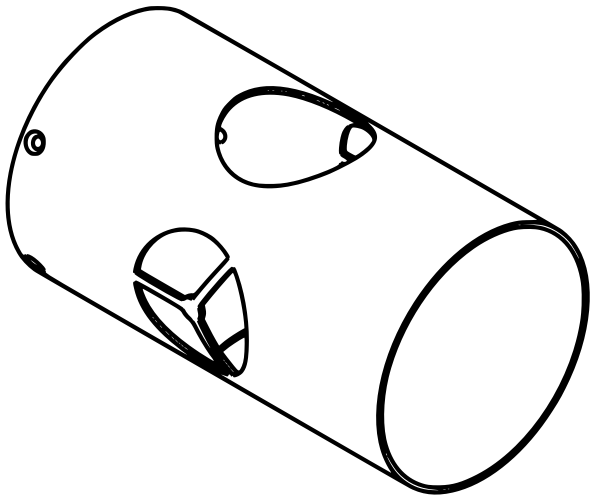

Fig. 3. The modified chopper: On the top is the old opening, on the side is the modified opening with the beam blocker on axis if rotated into the bam line.

4. Foreseen Measurements

Using the above described setup, it is foreseen to investigate the polarization preservation of polarized hydrogen and deuterium inside a carbon coated storage cell for the different chopper positions. For each position, the polarization of the atoms and molecules leaving the storage cell will be measured as a function of the magnetic holding fields inside the interaction chamber. From these measurements, one can calculate the fraction of atoms and molecules inside the storage cell, which also allows calculating the recombination rate [5, 6]. The polarization measurements combined with the recombination rate should then provide a detailed picture of polarization preservation inside a carbon coated storage cell. In addition, by comparing the results for the different chopper positions, it should also be revealed if Lyman-α photons have an influence on the recombination process.

5. Conclusion

The setup in Jülich is ideal for investigating the properties of carbon coated storage cells. Measurements foreseen for the near future will aim to determine the recombination rate inside carbon coated storage cells, as well as the accompanying change in the polarization of the hydrogen that possibly comes along with it. Also, due to a modification to the ABS, it is possible to investigate the influence of Lyman-α photons on the recombination process. If such an influence can be measured, it is on the one hand an important effect, that needs to be taken into account for the design of future atomic beam sources, and on the other hand gives possible new hints for the formation of hydrogen clouds inside the ISM.

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