Measurement of the nuclear polarization in H_2 and D_2 molecules after recombination of polarized hydrogen or deuterium atoms

R. Engels, K. Grigoryev[a,b], L. Kotchenda[b], P. Kravtsov[b], M. Mikirtychyants[a,b], F. Rathmann, H. Paetz gen. Schieck[c], H. Seyfarth, H. Ströher, V. Trofimov[b], N. Chernov [b], and A. Vasilyev[b]

When polarized hydrogen atoms recombine in a storage cell, the residual H_2 molecules may still show nuclear polarization[1]. In a collaboration between PNPI, University of Cologne and FZ Jülich a device was built (Fig. 1) in the framework of an ISTC project (No.1861) and a DFG project (436 RUS 113/977/0-1) to measure the polarization of hydrogen(deuterium) atoms and hydrogen(deuterium) molecules after recombination of polarized atoms as a function of on different materials, temperatures and magnetic fields.

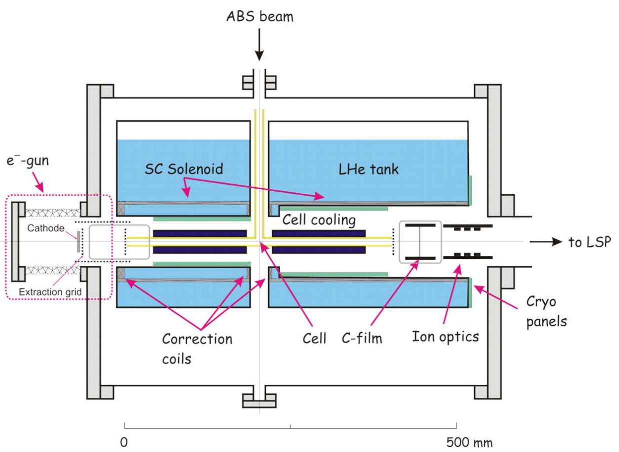

Fig. 1: Setup of the experiment to measure the polarization of hydrogen (deuterium) atoms and molecules after recombination of polarized atoms.

When the polarized atomic beam source (ABS) of the ANKE experiment is not in use investigations of the interaction of polarized atoms with the surface of a T-shaped storage cell inside a superconducting solenoid were carried out. The polarized atoms partly recombine in this storage cell, where the inner surface is covered with different materials. Both, atoms and molecules, are ionized afterwards by electron bombardment and the protons and H_2^+ ions produced are accelerated to an energy of a few keV. Inside the solenoid both ions have to pass a thin carbon foil, where the last electron of the H_2^+ ions is stripped off and, therefore, two protons are produced. These protons share the kinetic energy of the H_2^+ ion and can be separated by the Wien filter of the Lamb-shift polarimeter (LSP)[2] from the protons, originated from the initial atoms. In this way, the nuclear polarization of the atoms and the molecules can be measured under various conditions.
After intensive commissioning studies, in the summer of 2009 first experiments were performed on a gold-plated storage cell. These studies revealed a surprising result shown in Fig. 2. The polarization in the provided magnetic field was constant with temperature down to 47 K. Until now, no material has been found which could preserve the polarization of atoms at temperatures below 80 K [1]. In addition, a small polarization of the molecules could be observed without any optimization.

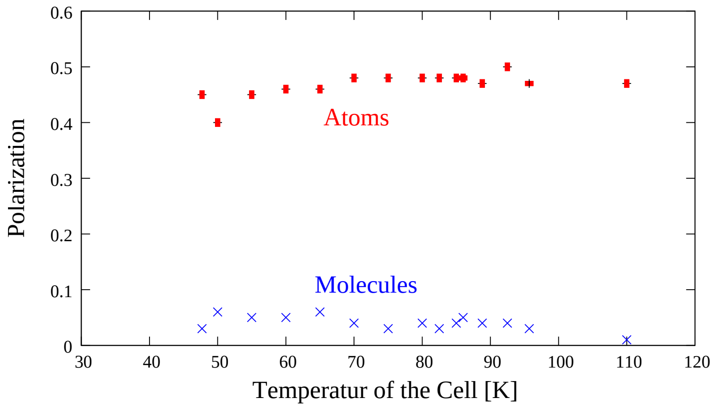

Fig. 2: One of the first results with polarized hydrogen atoms in a storage cell with a golden surface. The polarization for atoms in HFS 1 is stable and independent of the temperature. (Magnetic field: 0.28 T, ion beam energy: 4 keV). In addition, a small polarization of the corresponding molecules was measured.

One possible reason for the stable polarization might be that there was no water on the surface of the storage cell. When the solenoid is cooled down the storage cell is heated and, therefore, all water is frozen out at the cryo panels of the liquid helium tanks. All other measurements in this field were performed at different facilities where it was difficult to remove this water layer from a cold surface.
During this measurement the polarization of the atoms from the ABS was not larger than 0.5 and strongly depended on the magnetic field of the superconducting solenoid. This unexpected behaviour may be explained by zero-field transitions between the ABS and the solenoid, which could be partially overcome by higher stray fields of the solenoid. For the next measurements it is planned to produce a guiding magnetic field for this critical region.

References:

[1] T.Wise et al., Phys. Rev. Lett. **87**, 042701 (2001).
[2] R. Engels et al., Rev. Sci. Instr. **74** (2003) 4607.

[a] Institut für Kernphysik, Forschungszentrum Jülich, Germany
[b] Petersburg Nuclear Physics Institute, Gatchina, Russia
[c] Institut für Kernphysik, Universität zu Köln, Germany