THE HERMES INTERNAL POLARIZED HYDROGEN AND DEUTERIUM TARGETS

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The HERMES Experiment at the electron ring of HERA at DESY studies the spin structure of proton and neutron by deep inelastic scattering of polarized electrons off the nucleons of a highly polarized internal gas target. The target makes use of a storage cell to increase the target density. A relaxation model based on the diffusion equation has been developed, which is used to calculate the corrections, which are needed to determine the target polarization using the measured values.

1 INTRODUCTION

The HERMES experiment in the HERA electron storage ring at DESY is studying the spin structure of the proton and neutron via deep inelastic scattering of polarized electrons off the nucleons in a highly polarized internal gas target. A schematic diagram of this target, which uses a storage cell to obtain a high target density, is shown in figure 1. A beam of hydrogen or deuterium atoms is generated in an RF dissociator which forms part of the atomic beam source (ABS). These atoms are electron polarized by means of Stern-Gerlach separation in the sextupole magnet system. This polarization is transferred to the nucleons by means of adiabatic high frequency transitions (HFT). The beam of nuclear polarized atoms is injected into the centre of the thin-walled storage cell via a side tube and the atoms then diffuse to the open ends of the cell where they are removed by a high speed pumping system. The cell is coated with Drifilm [3] in order to minimize wall interaction effects. A longitudinal magnetic field provides a quantisation axis for the spins and inhibits nuclear spin relaxation by decoupling nucleon and electron spins. A second side tube is provided to sample the gas within the target cell. The beam emerging from this tube is analysed with a Breit-Rabi polarimeter (BRP) to measure its atom polarization and a target gas analyser (TGA) to determine its atomic fraction [4]. During the atom diffusion process relaxation by wall and spin exchange collisions and wall recombination changes the polarization and the atomic fraction of the target gas. The atom polarization and atomic fraction values measured by the BRP and TGA must be corrected for these effects to obtain the target polarization. All numbers quoted below refer to the 1997 data taking period with a polarized H target.

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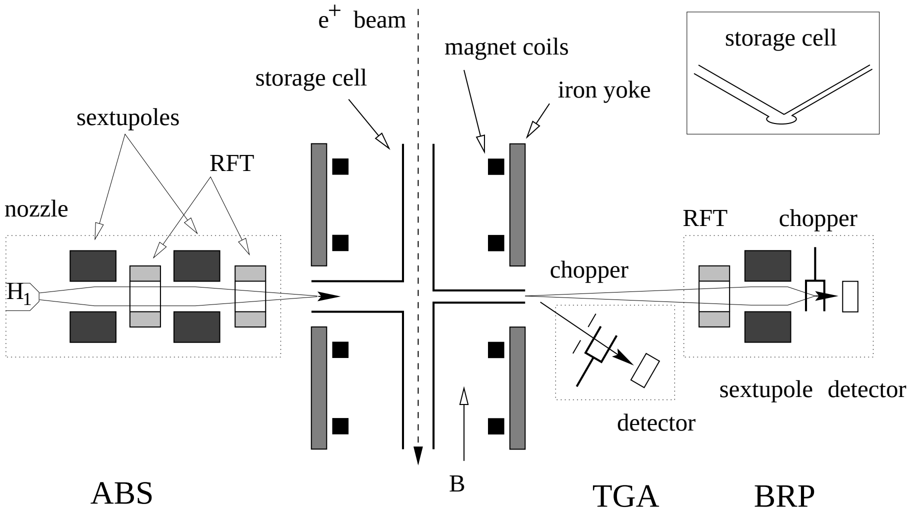

Figure 1: Schematic picture of the HERMES hydrogen target. The inset shows a cross section of the storage cell at its centre point.

2 THE RELAXATION MODEL

A new relaxation model, called the *rate equation model*, has been developed based on a combination of well established spin relaxation models and a one-dimensional diffusion equation, which describes the particle transport through storage cell and sampling tube. The new feature of this model is the spatial resolution implied by the diffusion term.

3 THE TARGET POLARIZATION

The target polarization P_T is calculated using the following expression:

$$P_T = \alpha_0 \, (\alpha_r + (1 - \alpha_r)\beta) \, P_T^{atom} \, , \tag{1}$$

where α_0 is the initial atomic fraction, which was in average $0.99 \pm 0.01 \, syst$, α_r is the fraction of atoms surviving recombination and β is the polarization of recombined molecules relative to the polarization of the atoms P_T^{atom}. In order to determine the target parameters by the corresponding measurement on the sample beam, so-called sampling corrections c_α and c_P have to be introduced, which are defined by

$$\alpha_r = c_\alpha \, \alpha_r^{TGA} \tag{2}$$

$$P_T^{atom} = c_P \, P_{BRP} \, . \tag{3}$$

A fit of the measured occupation numbers using the rate equation model allows the determination of the injected polarization for $\vec{H}$ atoms, which was typically 95.5%, and the relaxation parameters within small uncertainties. The average polarization loss was determined to be 2.5% by spin exchange collisions and about 1% by wall collisions. The model also allows the derivation of the sampling correction c_P and the limits of the possible influence of severe surface non-uniformity inside the cell on the average atomic polarization. The final result was $P_T^{atom} = 0.92 \pm 0.03 \, (syst.)$.

A comparison of the atomic beam intensities of the BRP and TGA, which have a different sensitivity to recombination occuring on the sample tube walls, showed that this effect is negligible. Using this information, the sampling correction c_α could be constrained within a fairly small range, when the values of α_r^{TGA} were high. The result for the average atomic fraction surviving recombination, α_r, was 0.93 ± 0.04. The range for β for data taking conditions could be limited to $0.2 \leq \beta \leq 1.0$ [5]. The result for the average target polarization was $P_T = 0.88 \pm 0.04$ and the average areal target density was $D_T = 7.62 \cdot 10^{13} nucleons \, cm^{-2}$.

4 CONCLUSIONS

The HERMES target target ran reliably with stable operation during the 1996 and 1997 running periods. The relaxation processes and particle transport inside the storage cell of the HERMES target were successfully modelled and understood on the basis of a diffusion equation with additional relaxation terms. The sampling corrections are known and understood within reasonable uncertainties. Since the winter shutdown 1997/1998 the target is running with deuterium.

References

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