Spin Relaxation at the HERMES Internal Deuterium Gas Target ◊

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The HERMES target [1,2,3] is operated with deuterium since spring 1998. The polarization of the target gas is monitored with a Breit-Rabi type polarimeter (BRP), which is able to resolve the population of all 6 hyperfine states (HFS) [4]. Measurements of the hyperfine populations (HFP) in dependence of the storage cell temperature between 38 and 250 K and the longitudinal magnetic holding field between 0 and 335 mT have been performed between HERA fills in order to study spin relaxation processes inside the storage cell, namely depolarization by wall collisions and spin exchange collisons between the atoms in the gas phase. The HFP N_a could be modelled with 6 master equations of the form

$$0 = \frac{N_a^{inj} - N_a}{\tau_d} + \frac{1}{\tau_f} \sum_b W_{ab}(N_b - N_a) + \frac{1}{\tau_{se}} \sum_{bc} M_{bc}^a N_b N_c \,,$$

where τ_d, τ_f and τ_{se} are the mean values of the residence time in the storage cell, the time of flight between wall collisions and time between spin exchange collisions. W_{ab} is the transition probability between HFS $|a\rangle$ and $|b\rangle$ for one wall collision and M_{bc}^a is a tensor, that describes the spin exchange process [5]. The injected HFP N_a^{inj} can be varied by the use of different adiabatic transitions in the atomic beam source (ABS), while the relaxation parameters τ_d, τ_f and τ_{se} stay constant, so that the number of master equations can be significantly increased. The master equations could then be used to determine the relaxation parameters and the efficiencies of the ABS transition units. The resulting injected nuclear polarization is 0.886 for P_{z+} and -0.899 for P_{z-}.

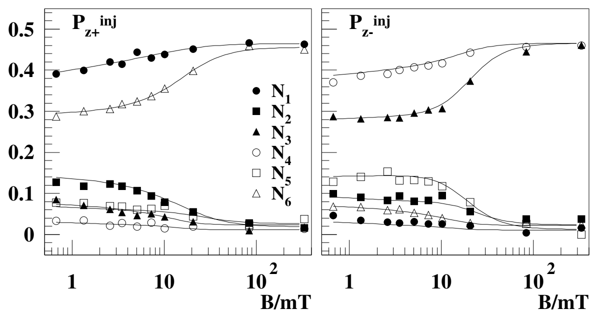

Fig. 1: Measured HFP (symbols) vs. target magnetic holding field for the injection modes $P_{z\pm}$ of the ABS. A fit of the data with the master equation is shown by the solid lines.

The absolut value of τ_d could be measured with a newly invented modulated beam technique (MBT) using pulsed hyperfine transitions (HFT). The measured value is in excellent agreement with the result of a molecular flow simulation of the storage cell. The corresponding signal in the BRP detector (QMS and channeltron) is shown in fig. 2. The measured average residence time τ_d was measured to be $\tau_d = \frac{L_d}{\langle v \rangle}$ with a length L_d of $425\,cm$ and the average thermal velocity $\langle v \rangle$ of the atoms.

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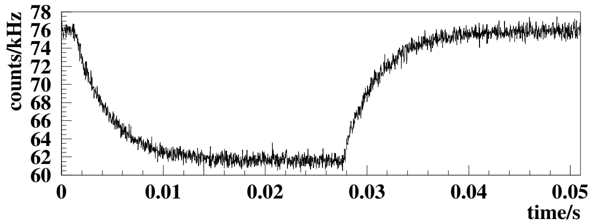

Fig. 2: Countrate in the BRP detector using a modulated injected beam. The modulation is realized with a pulsed HFT of the ABS.

The MBT was also used to measure the time of flight (TOF) of the atomic beam through the BRP sextupole system and found to be in agreement with sextupole tracking calculations.

The absolute value of τ_d and the fitted value of τ_{se} can be used to determine the absolute density of the atoms in the target storage cell. The resulting target thickness of up to $10^{14}\,nucleons\,cm^{-2}$ is in good agreement with the measurement of the HERMES luminosity monitor [6] and theoretical predictions of the spin exchange cross section σ_{se} [7].

The transition probabilities of wall depolarization W_{ab} were also investigated using the master equation. They are proportional to the spectral density, which was found to be constant within the frequency range in case of hydrogen. For deuterium, a significant deviation from a constant behavior was measured. The effect could be related to the properties of the surface diffusion process of the atoms during a wall collision [8].

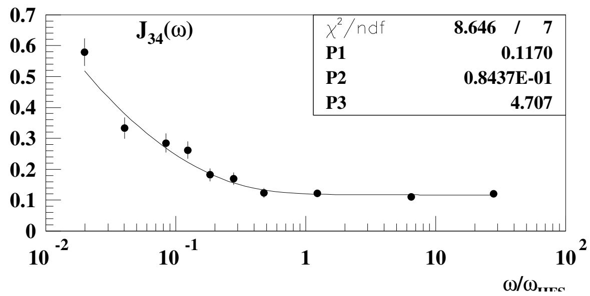

Fig. 3: Transition probability normalized to the matrix element of wall depolarization for 3-4 the transition vs. transition frequency.

References

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