Nuclear Polarization of Hydrogen Molecules from Recombination of Polarized Atoms

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The question to what extent the nuclear polarization of atoms is preserved after recombination is interesting. A recent measurement with deuterium [1] reported that molecules partially retain the tensor polarization of the atoms (fraction polarization retained = 0.81 $\pm$0.31). The present report is about a first measurement with H atoms, carried out by PINTEX at IUCF [2]. The idea of the experiment is to compare the nuclear polarization P_{at} of atoms from an atomic beam source to the nuclear polarization P_{mol} of molecules when the atoms are allowed to recombine on a copper surface. The nuclear polarization is measured by passing a 203 MeV polarized proton beam through a target cell (Fig. 1) containing the gas to be analyzed. The beam of polarized H atoms (state 1, m_I

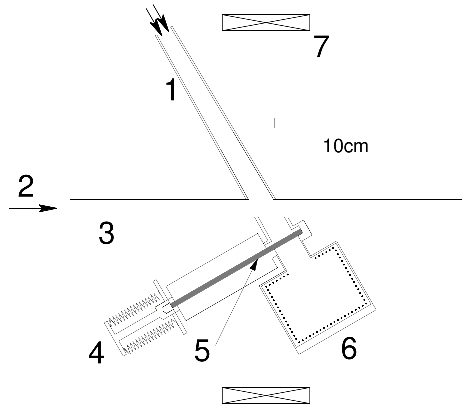

Fig. 1: Schematic scale drawing of recombiner volume and target cell. (1) tapered Teflon-coated entrance tube for polarized H atoms; (2) 203 MeV proton beam; (3) Teflon-coated Al target cell; (4) pneumatic valve actuator; (5) Teflon valve; (6) copper recombiner; (7) superconducting current loop. Figure from ref. [2].

= 1/2, m_j= 1/2) enters a recombination cell through a tapered entrance tube. In the recombiner, which is made of copper, atoms encounter enough wall collisions to lead to almost complete recombination. The H_2 molecules diffuse out of the recombiner into a thin-walled Al target cell through which the proton beam passes. The recombination cell is separated from the target cell by a remotely operated valve. To measure P_{at} the valve is closed, in which case the atoms from the polarized beam source diffuse into the target cell with negligible loss in polarization, because they encounter only the Teflon-coated surfaces of the recombiner valve and the target and entrance tubes, which are known to strongly inhibit depolarization and recombination. The present measurements determine the polarization P_{mol} of the H_2 molecules, relative to the polarization of the atoms before recombination, $R = P_{mol}/P_{at}$. The magnetic field is provided by a superconducting coil (Fig. 1) which produces fields up to 0.66 T at the recombiner. Thus the available field is large compared to the critical field of the hyperfine interaction in H of 50.7 mT. To avoid the large distortion of the proton closed orbit that a transverse B-field would have entailed, B was chosen longitudinal (z-direction). Forward wire chambers and scintillators detected protons from pp elastic scattering at lab angles in the range 30° - 60°. Event identification depended on detection of two protons in coincidence, with the requirement that they be coplanar. Parity conservation requires the longitudinal analyzing power to be zero. Consequently, to measure the longitudinal target polarization, one needs to resort to a spin correlation measurement (polarized beam *and* polarized target) . The number of observed pp coincidences for longitudinal beam polarization p and target polarization P can be written as $Y = kt(\alpha)[1 + pPA_{zz}(\theta)]$ where the dependence of Y on proton beam current was removed by dividing the observed number of counts by the integrated beam current obtained from a current transformer. In the above equation, target polarization P stands for either P_{open} or P_{closed}, depending on whether the recombiner valve is open or closed, and the constant k contains factors like the pp cross section and detector efficiencies. The spin correlation coefficient A_{zz} [3] is near 1 in the vicinity of θ_{lab} =45°. Exact values of p and A_{zz} are unimportant here because they cancel in the ratio P_{open} / P_{closed}. The target thickness t(α) is a function of the degree of dissociation of the target gas because the conductance depends on the mass of the target particles.

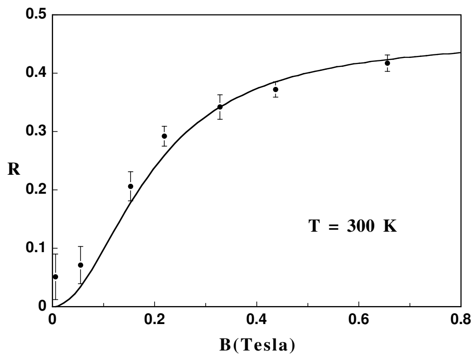

Fig. 2: Fraction R of proton polarization of the H atoms that is retained in the H_2 molecules after recombination on a room temperature copper surface in a magnetic field B. The error bars are probable errors that include the uncertainty from statistics as well as the systematic uncertainty from the incomplete knowledge of α_{open} and α_{closed} (see text).

The fraction R of polarization retained in the molecules shows a strong dependence on magnetic field B applied to the recombiner and target cell (Fig. 2). As the magnetic field is varied from 5 mT to 0.66 T, the nuclear polarization retained by the molecules rises from near zero to R = 0.42 $\pm$0.02.

References:

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