Spin-exchange Polarized ^{3}He Target

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Polarized nucleon-polarized nuclei scattering is a unique probe to investigate the spin structure of nuclei since target-related observables are extremely sensitive to small spin-dependent components of the target wave function. It is this sensitivity that makes these spin observables such a severe test of theoretical models. In addition, one can obtain information about reaction mechanisms, spin dependent nucleon-nucleon interactions in the nuclear medium, and off-shell behaviors of the N-N amplitudes. The ^{3}He and ^{4}He nuclei are the most attractive in this aspect as well as for searches of 3N force effects because these nuclei are the most dense. We have proposed to measure the differential cross section and spin-spin correlation parameter C_{yy} of the p^3He elastic backward scattering at E_p = 200 - 400 MeV. For this purpose, we started to develop a thick and highly polarized ^{3}He target.

There are two methods to polarize ^{3}He nucleus. One uses the direct optical pumping of the metastable 2^3S_1 state of ^{3}He atom [1]. In the other method, ^{3}He is polarized by a two step process. At first, Rb vapor is polarized by optical pumping with a circularly polarized light. Next, the Rb electron polarization is transferred to the ^{3}He nucleus by the spin-exchange scattering [2]. We use the second method, which can be more easily applied for thick targets.

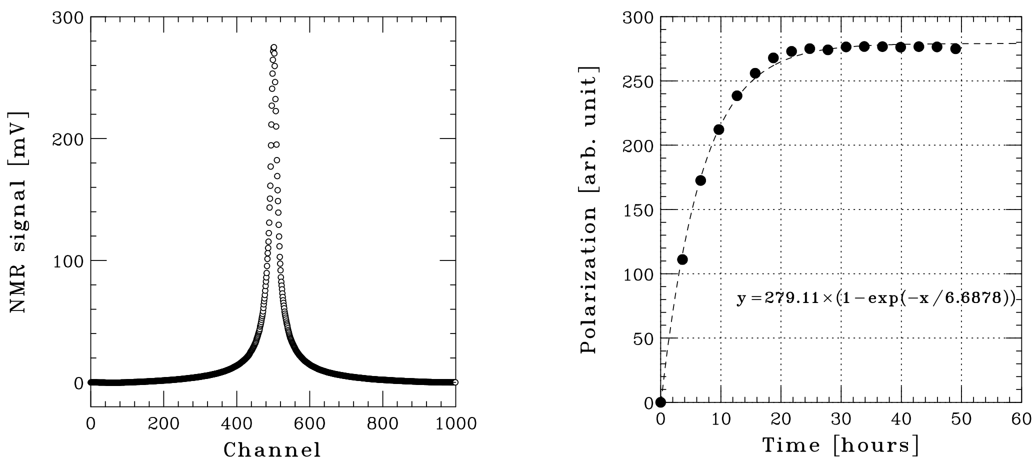
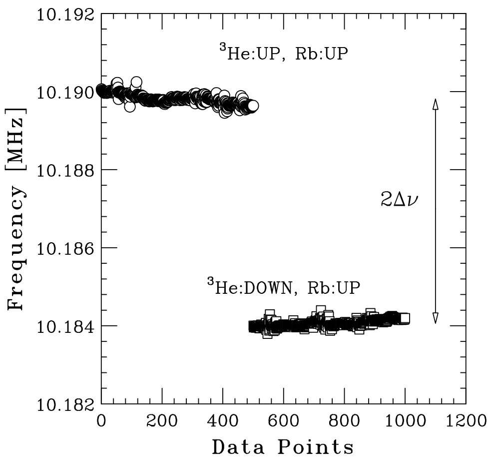


Figure 1: The left panel shows a typical AFP-NMR signal. The right panel shows the time development of ^{3}He polarization.

The polarization of ^{3}He was measured with an Adiabatic Fast Passage NMR(AFP-NMR) polarimeter. The strength of the NMR signal is proportional to the amount of polarization. The left panel in Fig. 1 shows a typical AFP-NMR signal. In this measurement, the signal-to-noise ratio is excellent. The time development of ^{3}He polarization is shown in the left panel in Fig. 1. In order to extract an absolute polarization of ^{3}He, the AFP-NMR system has to be calibrated.



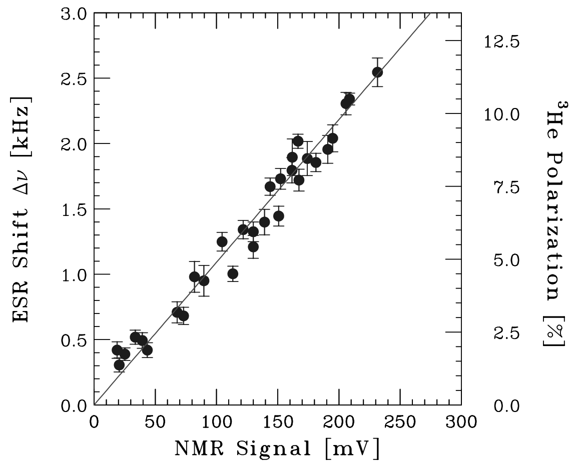


Figure 2: The left panel shows a typical set of ESR data. The right panel shows the relation between AFP-NMR signal and ^{3}He polarization.

The absolute polarization of ^{3}He was calibrated by ESR measurement which was based on the frequency shift of the Rb Zeeman resonance[3]. Rb-^{3}He spin exchange shifts the Rb Zeeman frequency. This frequency shift, $\Delta\nu$, is proportional to the ^{3}He polarization. For ^{3}He densities and polarizations usually necessary in nuclear physics experiments, this shift is very large, and can be easily measured in a typical magnetic field of 20 G. In order to obtain the shift contribution related to the ^{3}He polarization, a measurement was first done with the spins in one direction and then reversed. The left panel in Fig. 2 shows a set of ESR data. ESR measurements were performed at several AFP-NMR amplitudes. By fitting these data (the right panel in Fig. 2) with a linear function, the relation between ^{3}He polarization and AFP-NMR amplitude was given by

$$P_{^3\mathrm{He}} = (4.895 \pm 0.005) \times 10^{-2} \cdot V_{\mathrm{NMR}}.$$

In the present system, ^{3}He was about 13 % which might be determined mainly by the surface condition of the glass cell.

References

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