POLARIZATION MEASUREMENTS IN THIN FOILS OF DEUTERATED POLYETHYLENE

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We have dynamically polarized foils of deuterated polyethylene (DPE) doped with TEMPO and determined the polarizations by different independent methods. In a sample of 1.25 g material we achieved deuteron polarizations of $+15.4\pm0.7\%$ and $-14.4\pm0.7\%$, calibrated against the deuteron thermal equilibrium polarization (TEP) signal. The polarization of the residual 2% protons has also been measured and calibrated against the proton TEP signal. The values determined are consistent with the equal spin temperature (EST) hypothesis. In a second sample, consisting of only one foil with a thickness of about 50 μm weighing 20 mg, we achieved similar polarizations. Additionally, for both samples the deuteron polarization has been determined by the asymmetry method. To do so, the enhanced signals were fitted with a function including also a parameter taking into account the NMR-circuit characteristics.

As shown in experiments performed so far [1,2,3], polyethylene (PE) might be the polarized target material of choice for many scattering experiments, due to its convenient handling at room temperature, the easy doping with the paramagnetic centers and the possibility to shape it in any form.

Foils of 1.5×1.5 cm^2 with thicknesses of $50 \sim 70\mu$m were produced in a brass vessel with teflon-coated surfaces, from DPE powder pressed at a temperature of 160°C for 18 hours. Afterwards, TEMPO was introduced into the foils via diffusion at about 80°C during 20 hours in a glass vessel.

The dynamic nuclear polarization experiments were performed at 2.5 T and below 0.3 K in a standard PSI dilution refrigerator [4].

To achieve the high sensitivity necessary to measure deuteron thermal equilibrium signals and enhanced signals of small amounts of material, we

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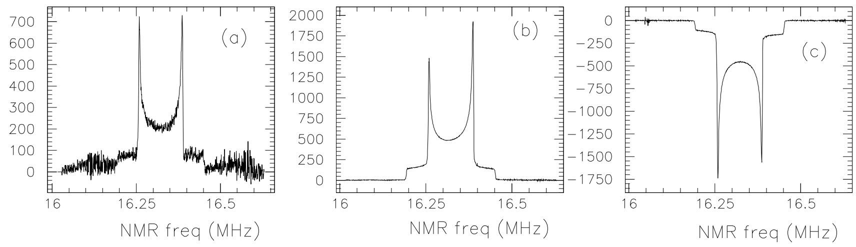

Figure 1: Deuteron NMR signals for sample I (1.25 g of material). TEP signal taken at T = 2.17 K (a), positively(b) and negatively(c) enhanced signals.

used a Liverpool Q-meter that had been modified for synchronous resonance tuning (SRT) and operated it in combination with the PSI NMR-system[5]. The proton signals were measured with a standard diode detection circuit operating on the same NMR-coil.

In the first sample, a stack of foils of 1.25 gram, doped with a nominal spin density of 2.5×10^{19} spins/cm^3, deuteron polarizations of $+15.7\pm0.8\%$ and $-14.4\pm0.7\%$ were obtained. The error quoted is mainly determined by the precision of the integral of the TE signals, which have been taken at 2.17 K and 1.06 K. Figure 1 illustrates the quality of the signals that can be achieved with the SRT, even in small amounts of material.

Furthermore we measured the signals of the residual 2 % protons in the sample and calibrated them taking TEP signals at 1.06 K. For the highest deuteron polarizations we measured the protons to be $+62.0\pm3.8\%$ and $-59.0\pm3.6\%$ polarized. In this case, the precision is limited by the error in the temperature measurement.

A plot of the deuteron versus proton polarizations (figure 2) shows that within errors, EST is valid for this deuterated polyethylen material.

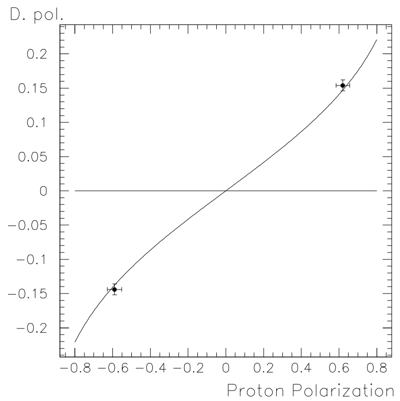

Figure 2: Deuteron vs. proton polarizations. The polarization values are consistent with the EST prediction (solid line).

To determine the polarization from the asymmetry in the deuteron NMR line we fitted the following function to it[6]

$$S(\omega) = C\,[1 + 1/2\xi(1+R)]\,f(\omega) + a_0 + a_1\omega + a_2\omega^2 + a_3\omega^3, \tag{1}$$

where $f(\omega) = C\left[I_+ F_+ (R,A) + I_- F_- (R,A)\right]$, $I_\pm$ are the transition intensities depending on the frequency and the polarization and $F_\pm$ are Lorentzian functions. The false asymmetry parameter ξ is introduced to account for the frequency dependent gain of the NMR circuit.

In figure 3 the polarizations values obtained from the asymmetry are plotted against the ones obtained by calibrating with a TEP signal. For $\xi = 0.08$, the two methods give consistent values, i.e. the data points are on the line representing the relation $P_{Asym.} = P_{TE}$. The error bars indicated originate from the TE calibration.

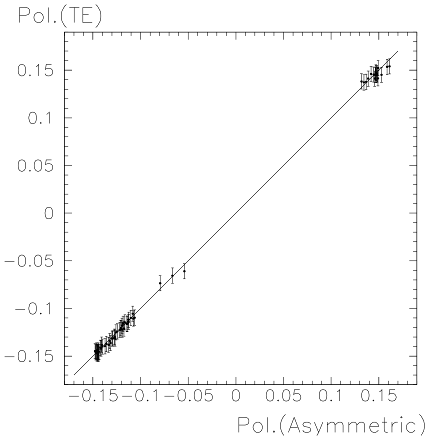

Figure 3: Results of fitting (see text)

For certain low energy scattering experiments, a thick target might not be suited as it gets heated up by the beam and also degrades the energy resolution significantly. We therefore investigated the limits of a reliable polarization determination in a small amount of material, taking a single foil of 50 μm thickness weighing about 20 mg with a nominal spin density of 4.7×10^{19} spins/cm^3. A TE calibration proved to be impossible, however, the asymmetry method could be applied with a sufficient accuracy due to the good quality of the polarized signals. The parameter ξ in the fit equation was set to be 0.09 by the requirement, that the polarization values deduced for a pair of positively and negatively enhanced signals having the same area should be equal. The polarization we achieved was determined to be $\sim \pm$ 15 % for positively and nagatively enhanced, respctively.

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