Target Analysis Update for G_E^n Collaboration

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1 Gordon Conference Report

Brandon and I presented our poster to the Gordon Conference in Tilton, NH. The poster was sent to the collaboration, but is available upon request.

We received many comments from attendees, especially from theorists who are looking forward to our results. In particular, there should be a prediction from AdS/CFT. A theorist, Shitikova, was particularly pushing for us to send her results when then are available.

Overall a very exciting conference with a lot of good conversations sparked by some interesting results.

2 Plan for Diffusion Parameter

Right now, our largest uncertainty in the polarization comes from the diffusion of the polarization. We have calibrated our NMR signal to the polarization in the pumping chamber of the cell. The NMR signal is measured in the lower chamber. As 3He gas flows from one chamber to the other, it is no longer in contact with the polarized alkali metal, and starts to depolarize. We can think of a polarization current that flows from one chamber to the other.

$$J(z) = \frac{1}{2} n(z) D(z) \frac{dP}{dz} \tag{1}$$

Where $n(z)$ is the density of helium and $D(z)$ is the diffusion coefficient. Both are functions of position along the transfer tube due to the thermal gradient. After conserving the current and integrating along the transfer tube, we get

$$J = \frac{1}{2} D_t \frac{n_t}{L} K \left(P_p - P_t\right) \tag{2}$$

K is a constant that depends on the ratio of temperatures in the target and pumping chambers.

The rate of change in polarization due solely to diffusion (for each chamber) is therefore

$$\frac{dP_p}{dt} = -\frac{2JA_{tr}}{n_pV_p} \tag{3}$$

$$\frac{dP_t}{dt} = \frac{2JA_{tr}}{n_tV_t} \tag{4}$$

Finally, we are left with the following for the change in polarization due to diffusion.

$$\frac{dP_p}{dt} = -\frac{A_tr}{V_pL}\frac{n_t}{n_p}D_tK\left(P_p - P_t\right) \tag{5}$$

$$\frac{dP_t}{dt} = \frac{A_tr}{V_tL}D_tK\left(P_p - P_t\right) \tag{6}$$

This almost completely describes the polarization in the target chamber, since the polarized gas can only come from the upper chamber. The gas in the upper chamber, however, is continually polarized. The change in polarization in the upper chamber is

$$\frac{dP_p}{dt} = -\frac{A_tr}{V_pL}\frac{n_t}{n_p}D_tK\left(P_p - P_t\right) + \gamma_{SE}^{Rb}P_{Rb} + \gamma_{SE}^{K}P_K - \left(\gamma_{SE}^{Rb} + \gamma_{SE}^{K} + \Gamma_pP_p\right) \tag{7}$$

The target chamber polarization only needs a correction due to the depolarization effects in the target chamber.

$$\frac{dP_t}{dt} = \frac{A_tr}{V_tL}D_tK\left(P_p - P_t\right) - \Gamma_tP_t \tag{8}$$

If we consider P_t^{∞} and P_p^{∞}, the equilibrium cases, then we can set equations 7 and 8 equal to zero and conserving the number of particles in the cell, we can finally write the equalibrium polarization of the target chamber in terms of the pumping chamber.

$$P_t^{\infty} = \frac{P_p^{\infty}}{1 + \frac{\Gamma_t}{D_t}} \tag{9}$$

In priciple this equation has everything that we need to determine the relationship between the two chambers. In reality, we need to take this a step or two further. When the beam is on (or has recently been on, as is the case for most of our EPR calibrations), we need to determine the effect of the beam on the polarization.

$$\Gamma_t^{beamON} = \Gamma_t^{beamOFF} + \Gamma_{beam} \tag{10}$$

We do not have a direct measurement of $\Gamma_t^{beamOFF}$ for our in-hall setup. However, it can be approximated at a very high level from the data taken at UVa.

We have NMR signals at times where the beam was on and the beam was off. This will allow us to extract the polarization. Another way to write the polarization in the chambers makes this clear:

$$P_{p,t}^{BeamON} = \frac{P_{K,Rb} < \gamma_{SE} >}{< \gamma_{SE} > + < \Gamma > + f_t \Gamma_{beam}} \quad (11)$$

$$P_{p,t}^{BeamOFF} = \frac{P_{K,Rb} < \gamma_{SE} >}{< \gamma_{SE} > + < \Gamma >} \quad (12)$$

$$= \frac{P_{K,Rb} < \gamma_{SE} >}{\gamma_{spinup}} \quad (13)$$

Where f_t is the fraction of particles in the target chamber, Γ_{beam} and γ_{spinup} is the inverse of the time constant measured for the cell.

Since we are measuring in the same chamber without moving the cell at all, we can take a ratio of the signals, and let the factors of flux and calibration constant cancel

$$\frac{S^{beamON}}{S^{beamOFF}} = \frac{P_t^{beamON}}{P_t^{beamOFF}} = \frac{\gamma_{spinup} + f_t \Gamma_{beam}}{\gamma_{spinup}} \quad (14)$$

$$= 1 + \frac{f_t \Gamma_{beam}}{\gamma_{spinup}} \quad (15)$$

I have already determined γ_{spinup}.

$$1/\gamma_{spinup} = 6.174 \pm 0.058h$$

. I am working on establishing a good ratio for $P_t^{beamON}/P_t^{beamOFF}$. Once this is accomplished, I will be able to use equation 9 to determine the polarization in the lower chamber.

3 What's Next – Polarization

After this has been determined I will be able to go back to the EPR calibrations. I already have the knowledge to adjust the temperature of the cell. I will separate out the EPR calibrations into the two spin states, and separate out each spin state into "equilibrium states". Then I will be able to assign a calibration number (with somewhat reasonable error) to be applied to all NMR measurements.

There will still be room for improvement in terms of improving the fit and making sense of the data for the other cells, but within the next four weeks I believe I will have acceptable polarization numbers for the last kinematic point.

4 What's Next – Target Geometry

I have the survey reports and the target measurements that we made. From this I will be able to determine the location of the target. I should be able to produce a report in parallel to the polarization work above, but my main emphasis will be on the polarimetry.