Some thoughts

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Abstract

A hope to consider some theoretical concerns and experimental practicality.

1 Beam Alignment

Question: Should the target field be aligned with the q-vector or with the incoming beam?

Answer : The canonical direction of the quantization axis for the initial deuteron state is the incoming virtual photon. It is possible to allow for arbitrary directions of the quantization axis with the use of general rotations, however one must remain consistent when extracting observables. This means that one can align the beam along the target field but must then rotate back to the quantization axis to look at observables. Jaffe commonly uses the same spin quantization axis for both the target and the virtual photon. Nevertheless, it is the virtual photon target cross section or asymmetry that we are interested in measuring. [1], [2].

2 Systematics of σ_{diff}

Question: Is the difference in cross section method better for extracting b1?

Answer : Considering the difference method, [3], we obtain the simplified relation between b_1 and the difference in counts,

$$KxP_{zz}b_1 = \frac{\Delta N}{QA_s}. \tag{1}$$

Recall from [3], that Eq. 5 comes from a simplification of,

$$\Delta N = Q_u A_u L_u \sigma_u - Q_p A_p L_p \sigma_p, \tag{2}$$

using $Q_p = Q_u(1 - dQ)$ for Q charge and similarly for acceptance A, and length l where dX is the residual measured difference in two. Recall that the configuration of this experimental setup depends on our ability to reduce these differences in the two cups. We end up with,

$$\delta\Delta N = Q_u A_u L_u(\sigma_u - \sigma_p(1 - dQ)(1 - dA)(1 - dl)), \tag{3}$$

$$\delta\Delta N = N_u - N_p(1-dQ)(1-dA)(1-dl), \tag{4}$$

in which case we want $\Delta N \gg \delta\Delta N$ so we need to minimize the uncertainty,

$$\delta\Delta N = \sqrt{\frac{\delta N_d^2 + \delta N_b^2}{(N_d - N_b)^2} N^2 + \delta N_u^2 + (\xi \delta N_p)^2 + (N_p \delta\xi)^2} \tag{5}$$

where N_d represent the number of counts observed from the D-state, and N_b number of counts from the S-state also including other nuclear effects and all contamination not included in the observable that we are measuring. This effectively give an uncertainty associated with the probability of events we expect to detect (more about this uncertainty in Section 3). N_u is the unpolarized counts and N_p is the polarized counts. The ξ represents the limit in ability to match luminosity in each cup. In the notation,

$$\xi = (1-dQ)(1-dA)(1-dp_f)(1-dl), \tag{6}$$

where, dp_f, the packing fraction is also included. The leading terms in the uncertainty in ξ are,

$$\frac{\delta\xi}{\xi} = \sqrt{\left(\frac{\delta dQ}{dQ}\right)^2 + \left(\frac{\delta dA}{dA}\right)^2}. \tag{7}$$

Notice that dQ and dA are systematic components almost purely driven by Monte Carlo. For this configuration dQ is the limitation in the Monte Carlo to resale the second cup to that the count are equivalent under $A_{zz} = 0$. Naturally we need dQ to be very small but our understanding of this renormalization has no systematic check to real data, this means δdQ can be on the same order as this very small quantity dQ. This would imply that $\delta\xi \sim \xi \sim 1$ leading to,

$$\delta\Delta N = \sqrt{(N_p \delta\xi)^2}, \tag{8}$$

which mean that the uncertainty can be on the same order a what is being measured for small ΔN. This rough run through neglects many contribution to the normalization uncertainty in the difference including the polarization uncertainty seen in δN_p.

3 Systematics of A_{zz}

To consider the asymmetry method we use,

$$\frac{d^2\sigma_p}{dx dQ^2} \approx \frac{d^2\sigma}{dx dQ^2}[1 + \frac{1}{2}P_{zz}A_{zz}]. \tag{9}$$

The number of evens are defined by,

$$N = \sigma^u \int_{\Delta t} dt \epsilon(t) L(t) \tag{10}$$

where Δt is the integrated time for that period of data at a give tensor polarization (most likely a run), $\epsilon(t)$ is the dead-time, and $L(t)$ luminosity as a function of time. leading to,

$$N^1 = \sigma^u L^1 A^1 (1 + \frac{1}{2}|P^1_{zz}|A_{zz}) \tag{11}$$

$$N^0 = \sigma^u L^0 A^0 (1 - \frac{1}{2}|P^0_{zz}|A_{zz}) \tag{12}$$

for $m = +1, -1 \rightarrow N^1$ and $m = 0 \rightarrow N^0$. The desired asymmetry is,

$$A_{zz} = \frac{2N^1 - 2N^0}{2N^1 + N^0}. \tag{13}$$

Using previous results and notation of [4] if differences in acceptances and luminosity are ignored,

$$A^{meas}_{zz} = \frac{\frac{A_{zz}}{2}(P^+_{zz} + P^-_{zz})}{2 + \frac{A_{zz}}{2}(P^+_{zz} - P^-_{zz})}. \tag{14}$$

But looking at uncertainty inherent in A_{zz} we need all terms such that,

$$\frac{\delta N^0}{N^0} = \sqrt{\left(\frac{\delta\epsilon^0}{\epsilon^0}\right)^2 + \left(\frac{\delta L^0}{L^0}\right)^2 + \left(\frac{\delta A^0}{A^0}\right)^2}, \tag{15}$$

simlarly for N^1 giving,

$$a = \frac{2}{(2N^1 + N^0)(2N^1 + N^0)} - \frac{2A_{zz}}{2N^1 + N^0}, \tag{16}$$

$$b = \frac{2}{(2N^1 + N^0)(2N^1 + N^0)} + \frac{A_{zz}}{2N^1 + N^0}, \tag{17}$$

leading to,

$$\delta A^N_{zz} = \sqrt{(a\delta N^1)^2 + (b\delta N^0)^2} \sim 2 \times 10^{-3}. \tag{18}$$

The estimate for δA_{zz} comes to 2×10^{-3} optimistically. This value uses similar systematic components from past Jlab experiments [5]. For the real measured contributions we want to minimize,

$$\delta A^{meas}_{zz} = \sqrt{(\delta A^N_{zz})^2 + (\delta A^{optics}_{zz})^2 + (\delta A^{NRM}_{zz})^2 + (A^{Det}_{zz})^2 + (\delta A^d_{zz})^2} \sim 2.3{\times}10^{-3}. \tag{19}$$

Table 1 lists all the additional components of systematic uncertainty. The error δA_{optics} is the uncertainty in the asymmetry based on limitations in optics. The δA^{NRM} is the uncertainty in the asymmetry from polarization measurement error combined with the uncertainty specific to NRM measurements of the deuteron. The δA^{e^-} is the uncertainty in the asymmetry from electron selection and identification. The δA^{rad} is the expected size of contribution in the asymmetry from radiative corrections. The δA^{Det} is the uncertainty in the asymmetry from detector efficiency and instrumental errors. The δA^d is the uncertainty in the asymmetry from miss-identification of d-state events. The value used in the calculation in Eq. 19 is under

(#)	source	error (%)
(1)	δA^{optics}	$5 \times 10^{-}4$
(2)	δA^{NRM}	$1 \times 10^{-}4$
(3)	δA^{e^-}	$1 \times 10^{-}5$
(5)	δA^{rad}	$1 \times 10^{-}5$
(7)	δA^{Det}	$1 \times 10^{-}3$
(8)	δA^{d}	$1 \times 10^{-}4$

Table 1: The systematic error estimates of the tensor asymmetry.

the assumption of low x. The back ground events N_b can not be properly expressed in the helicity amplitude relationship to A_{zz}. This value naturally has a x dependence and is likely much larger as the coherent length λ, [6], gets smaller and nuclear effects from n-p s-state become more dominant. To estimate the change in δA^d with respect to x a very crude approximation gives,

$$\delta A^d_{zz} \sim A_{zz}\sqrt{\frac{\delta N_d^2 + \delta N_b^2}{(N_d - N_b)}} \sim \frac{A^N_{zz}}{2}\frac{\delta N}{N}\frac{1.7}{\lambda}. \tag{20}$$

Here the 1.7 fm is the limit set for inter-nucleon separation in the nucleus. This implies a contribution to the uncertainty of $2.4 \times 10^{-}3$ at $x = 0.3$ which is likely a very conservative number considering the unknown nature of these effects. This would bring the total to 3.3×10^{-3}. Multiple scattering, double scattering, shadowing, and quadrapole admixture, can all be understood to some degree once the measurement is taken. All effects that lead to enhancement decrease at around the same 1.7 fm limit. This is not true for any event candidates that can not be represented in the asymmetry A_{zz} from the γ^*-deuteron amplitudes, this contributes a growing uncertainty as x increases.

4 Theoretical Model of A_{zz}

Question : Do we have a prediction for b_1 and A_{zz} without parameterization?

Answer: The answer discussed at the top in Section 1 implies that the last Hermes point at $< x >= 0.452$ is unreliable, this means that there are only two points that over lab with our desired kinematics both of which are consistent with zero within the Hermes error bars. If there is good theoretical basis to expect a measurable A_{zz} the experimental motivation is evident. If we are limited by experimental resolution and uncertainty at high x then it is critical to overlap with Hermes at lower x and corresponding Q^2 in order to motivate experiment. It is possible to use the predictions in [6] and [7] to get an idea of what A_{zz} might look like without the bias of parameterization from the Hermes data. In [7] diffractive nuclear shadowing of the nuclear excess of pions on the deuteron spin alignment leads to a substantial tensor polarization of sea partons in the deuteron which has the relation $A(x, Q2) = b_2(x, Q^2)/F_2^d(x, Q^2)$. Using [7] description for the double scattering contribution to b_2 and relation $b_1 = b_2 x$

it is possible to express the prediction for $Q^2 = 4$ GeV^2. The result is shown if Fig. 1, here it is clear that the value of the asymmetry that we are measuring is on the same order at our combined systematic and statistical uncertainty. This is a critical point because there are no other unparameterized prediction for A_{zz} that we can reach give our kinematic accessibility and experimental uncertainty, this is by far the largest prediction for A_{zz}.

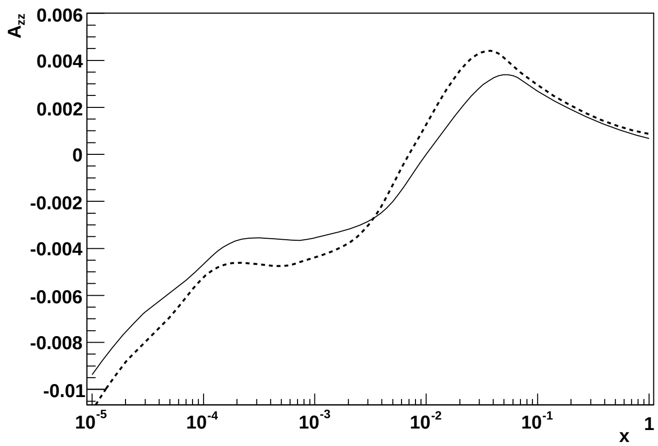

Figure 1: Prediction for A_{zz} using numerical values from [6] and [7]. The dashed line represents A_{zz} at $Q^2 = 4$ GeV^2 and the solid line at $Q^2 = 10$ GeV^2.

References

[1] H. Arenhovel, Few-Body Systems 28, 147-188 (2000).

[2] R. Jaffe, Nuclear Physics 321, 343-373 (1989).

[3] O. A. Rondon, Outline of a method for extracting b1 from longitudinal single spin deuteron cross sections.

[4] O. Rondon (INPP-UVA) and P. Solvignon (Jefferson Lab) Rates and Error calculations for measurement of A_{zz}.

[5] Silviu Doru Covrig,Phd Thesis, A measurement of parity-violating asymmetries (Hall C), Xiaochao Zheng, Phd Thesis, Percision Measurement of Neutron Spin Asymmetry (Hall A), Zhang, Chi, Ph. D. Measurement of tensor analyzing powers in elastic electron deuteron scattering (Hall A),Matthew Posik, d2n Analysis Workshop Asymmetry Update (Hall C).

[6] K. Bora, R. L. Jaffe The Double Scattering Contribution to b1 (x, Q2) in the Deuteron

[7] N. Nikolaeva, W. Schgfer Physics Letters B 398 245-251 (1997)