b_1 technical note 2013-05
May 2013

Diluting Asymmetries in Extracting b_1^d from a measurement of A_{zz}

E. Long (UNH), O. Rondon (INPP-UVA)

Abstract

The PR12-13-011 proposal to seeks to extract the deuteron structure function b_1^d from a measurement of A_{zz}. To leading order with an unpolarized electron beam, A_{zz} can be measured by taking a ratio of electrons scattered from a tensor-polarized deuterium target and electrons scattered from an unpolarized target. However, higher order asymmetry terms come into effect when the beam is polarized. This document includes these higher order terms into the equations used in the b_1^d proposal.

1 Asymmetries

The measurement that the PR12-13-001 proposal is promoting is a ratio of the number of electrons scattered off of tensor-polarized deuterium. Assuming an unpolarized beam, to leading order this ratio takes the form of

$$\frac{N_{Pol}}{N_u} - 1 = f\frac{1}{2}A_{zz}P_{zz}, \tag{1}$$

where N_{Pol} is the number of events scattered from a tensor-polarized target, N_u is the number of events scattered from an unpolarized target, f is a dilution factor, A_{zz} is the quantity being extracted, and P_{zz} is the tensor polarization.

A number of other quantities come into play when the beam is polarized, such that its helicity is parallel to the deuteron spin direction, and when higher order effects are considered. This includes A_V^d, $A_{\|} = D(A_1 + \eta A_2)$, and A_T^{ed} from equations 25-28 in [1] as well as the parity-violating asymmetry A_{EW}, where $\eta = \frac{\epsilon\sqrt{Q^2}}{E-E'\epsilon}$, ϵ is the longitudinal virtual photon polarization, $D = (1-\epsilon\frac{E'}{E})/(1+\epsilon R)$, and $R = \frac{\sigma_L}{\sigma_T}$. This gives the form of the counted events when the target is tensor-polarized as

$$N_{Pol} = \mathcal{A}\left[\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}\left(1 + A_{\|}P_bP_z + A_T^{ed}P_{zz}P_b + A_V^dP_z + \frac{1}{2}A_{zz}P_{zz}\right)\right]t_{Pol}, \tag{2}$$

and when the target is unpolarized as

$$N_u = \mathcal{A}\left(\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}\right)(1 + A_{EW}P_b)\,t_u. \tag{3}$$

Taking the ratio of these types of events, which will be measured during the experiment, leads to a derivation of

$$\frac{N_{Pol}}{N_u} = \frac{\mathcal{A}\left[\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}\left(1 + A_{\|}P_bP_z + A_T^{ed}P_{zz}P_b + A_V^dP_z + \frac{1}{2}A_{zz}P_{zz}\right)\right]t_{Pol}}{\mathcal{A}\left(\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}\right)(1 + A_{EW}P_b)\,t_u} \tag{4}$$

$$\begin{aligned}\frac{N_{Pol}}{N_u} = \left(\frac{t_{Pol}}{t_u}\right)\Bigg[&\frac{\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}\left(1 + A_{\|}P_bP_z + A_T^{ed}P_{zz}P_b + A_V^dP_z\right)}{\left(\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}\right)(1 + A_{EW}P_b)} \\ &+ \frac{\mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}}{\left(\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}\right)(1 + A_{EW}P_b)}\frac{1}{2}A_{zz}P_{zz}\Bigg].\end{aligned} \tag{5}$$

We can condense this by introducing a dilution factor,

$$f = \frac{\mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}}{\mathcal{L}_{\mathrm{He}}\sigma^u_{\mathrm{He}} + \mathcal{L}_{\mathrm{N}}\sigma^u_{\mathrm{N}} + \mathcal{L}_{\mathrm{D}}\sigma^u_{\mathrm{D}}}, \tag{6}$$

and assuming that $t_{Pol} \approx t_u$, such that

$$\frac{N_{Pol}}{N_u} = \frac{1}{(1 + A_{EW} P_b)} \left[1 + f \left(A_{\parallel} P_b P_z + A_T^{ed} P_{zz} P_b + A_V^d P_z \right) + f \frac{1}{2} A_{zz} P_{zz} \right]. \tag{7}$$

We can use this to determine A_{zz} by

$$A_{zz} = \frac{2}{f P_{zz}} \left[(1 + A_{EW} P_b) \left(\frac{N_{Pol}}{N_u} \right) - 1 - f \left(A_{\parallel} P_b P_z + A_T^{ed} P_{zz} P_b + A_V^d P_z \right) \right]. \tag{8}$$

If an unpolarized electron beam is available, $P_b = 0$ and A_{zz} is greatly simplified to

$$A_{zz} = \frac{2}{f P_{zz}} \left[\frac{N_{Pol}}{N_u} - 1 - f A_V^d P_z \right]. \tag{9}$$

References

[1] W. Leidemann, E.L. Tomusiak, and H. Arenhovel. Inclusive deuteron electrodisintegration with polarized electrons and a polarized target. *Phys.Rev.*, C43:1022–1037, 1991.