MEMO on Insensitivity-Problem

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1. Problem

The asymmetry

$$A = \frac{G_{en}^2 cos(\theta) + G_{en} G_{mn} sin(\theta)}{G_{en}^2 + G_{mn}^2} \quad (1)$$

(constant factors in front of all terms omitted) is linear in G_{en} for low G_{en}, and goes with $1/G_{en}$ for large G_{en}. So at some point there is a maximum, where A is totally insensitive to G_{en}. In this case, which we may be approaching at q^2=2, a measurement of A is useless, or inefficient.

2. Solution

a) at (say) q^2=1, use $^{14}ND_3$ target, B-field off and measure ratio

R= rate(e,e'n) / rate(e,e'p),

with cuts in missing momentum, energy loss etc that ensure that we deal with quasi-elastic scattering only. This ratio is given by

$$R = \frac{G_{en}^2 + G_{mn}^2}{G_{ep}^2 + G_{mp}^2} \epsilon \quad (2)$$

since we deal with a target (helium, nitrogen, deuterium) that has N=Z, and the same n and p momentum distribution. ϵ is the neutron detector efficiency.

Since all the G's are known (we will have measured G_{en} via A), we can measure $\epsilon(q^2 = 1)$. This is an easy measurement (cross sections only, no polarization needed, large beam currents possible).

b) Transfer this efficiency to the n-energy corresponding to q^2=2. According to MC calculations, ϵ changes only a few % between the energies corresponding to q^2=0.5 and q^2=2, so the *change* can be calculated to very good precision.

c) At q^2=2, use $^{15}ND_3$, polarized target, and measure instead of the usual asymmetry

$$\Delta N = (N_+ - N_-) = G_{en} G_{mn} \Omega t \epsilon(2) f_{cut} f_{dil} Q \quad (3)$$

We calculate the dilution factor f_{dil}, the loss from cutting off some of the tail of the neutron acceptance f_{cut}, measure the target thickness t (x-ray absorption) and charge Q, know solid angle of HMS Ω. Above equation then allows us to get G_{en} G_{mn} with a relative error of G_{en} that equals the relative error of ΔN.

As an potential improvement of the approach (to be discussed in more detail under 4)), we can also measure at q^2=2 the quantity ΔN for (e,e'p). This is given by

$$\Delta N = (N_+ - N_-)_{(e,e'p)} = G_{ep} G_{mp} \Omega t f_{cut} f_{dil} Q \qquad (4)$$

Since we know G_{ep} and G_{mp}, this quantity can be used to fix $\Omega t f_{cut} f_{dil} Q$. One would have to find out by comparing rates if this $\Delta N_{(e,e'p)}$ has good enough statistics to not contribute significantly as compared to the stat. error of $\Delta N_{(e,e'n)}$

This approach has some benefits, and some problems:

Benefits:

1. extra measurements involve cross section data only, are fast.

2. elimitates insensitivity-problem

Drawbacks:

1. need to measure t (but we have done that before)

2. need to calculate f_{cut}. This can be done to a few %, and we can verify it by applying the procedure to the q^2=1 data, where we know everything already.

3. Need to keep ϵ of detector *stable* between q^2=1 and q^2=2 point. The gains can be largely verified via the ADC-values of the peaks observed in (e,e'p). We can also, in the middle of the q^2=2 point, drop back to kinematics suitable for q^2=1 and do a check. This is easily possible by using a lesser electron energy (less recirculations) as we dont need *polarized* beam for the ϵ-measurement.

Open questions:

1. Is it better to use as reference q^2=1 or 0.5? At lower q G_{mn} is known much more accurately, but we have to transport ϵ over a larger energy-range.

2. Also, we need to see for which of the two points the kinematics is easier to reproduce during the q^2=2 measurement.

<u>3. Alternative</u>

We could use a similar approach, but determine the neutron detector efficiency in a different way.

At q^2=1, with $^{15}ND_3$ target, B-field oriented *parallel* to q instead of perpendicular, measure the ${G_{mn}}^2$ term. As G_{mn} is known, this fixes ϵ.

This approach has benefits and drawbacks:

Benefits:

1. $G_{mn}$is much larger than G_{en}, so the asymmetry is much faster to measure.

2. Problems related to f_{cut}, etc do not occur

3. Do not need exact orientation of B-field, direction can be 20 degrees off

Drawbacks:

1. It still will take a reasonably long time to get enough statistics, as the measurement is based on a pol. asymmetry. Since this measurement has to be done *before* we go to q^2=2, we dont know yet if G_{en} is indeed large enough to make the effort to get around the insensitivity-problem worthwile.

2. Turning the direction of B is also an effort, and may have significant impact on the e-beam which we might not be able to compensate with the chicane.

3. We still must be able to certify that the efficiency is stable, and we propbably cannot verify this by a repeated measurement as a) it takes too long, and b) it would require pol. beam at a lower energy, which may not be compatible with the other halls.

4. More detailed discussion of q^2=2 analysis

a) In our standard analysis of asymmetry-data, we measure

$$A = \frac{\sigma_- - \sigma_+}{\sigma_- + \sigma_+} \tag{5}$$

This is proportional to $G_{en} G_{mn} P_e P_D f_{dil}$. The dilution factor f_{dil} comes from the denominator, where the contributions of nitrogen, helium,.. do occur. This factor will require some effort, as it is of order 0.5, and depends on the structure of the N, He- nuclei. It can be determined experimentally when measuring (e,e'n) on NH_3 (which however requires precise control over the NH and ND target thicknesses and filling factors)

b) When using the idea to exploit $\sigma_- - \sigma_+ = \Delta\sigma$ rather than A we measure

$$\Delta N = G_{en} G_{mn} \Omega_{HMS} \epsilon_n t_D P_e P_D f_{\Omega_n} Q \tag{6}$$

where ϵ_n = netron detector efficiency, t_D=deuteron target thickness, f_{Ω_n}=fraction of (e,e'n) that falls into acceptance of n-detector. For a measurement of ΔN (rather than A) f_{Ω_n} can be quite close to one as we do not have to suppress the N, He-contributions. The analysis requires a determination of P_e, P_D (which are trivial), Q (the absolute value of which may or may not be easy), t_D (which we know how to do by gamma-absorption).

c) We can supplement b) by a measurement of ΔN for (e,e'p). This quantity is given by

$$\Delta N = G_{ep} G_{mp} \Omega_{HMS} t_D P_e P_D f_{\Omega_p} f_{dil,p} Q \tag{7}$$

The factor f_{Ω_p} is presumably very close to f_{Ω_n} as at large q the deflection of protons by the 5T field is small. The dilution factor $f_{dil,p}$ which accounts for the Nitrogen-contribution should be close to one as the polarization of protons in ^{15}N is low.

We then could take the ratio

$$\frac{\Delta N_{(e,e'n)}}{\Delta N_{(e,e'p)}} = \frac{G_{en} G_{mn}}{G_{ep} G_{mp}} \epsilon_n f_{dil,p} \tag{8}$$

Benefits:

1. All factors drop out, except ϵ_n which we measure at q^2=1, and $f_{dil,p}$ which is quite close to one.

Drawbacks:

1. While the rate of (e,e'p) is about 8 times bigger than (e,e'n) (efficiency detector, G_{ep} and G_{mp} are larger than G_{en},G_{mn}) taking a ratio still inreases the error of G_{en}. Effect about 8%.

2. We now have to deal also with the syst. errors of G_{ep},G_{mp}. They are smaller than the ones of G_{mn}, but still will contribute.

All together: option c) certainly should be pursued. For both b) and c) there is an additional important benefit: relative to our standard method to measure G_{en} via asymmetries, we get rid of the N, He-dilution factor problem (which for G_{en} is a bigger problem than for E143 since we are not dealing with a structureless background, as the q.e. peaks of deuterium and Nitrogen have different shapes).

5. Conclusions

It looks to me as if the solution with the (e,e'n)/(e,e'p) cross section ratio measurement involves a comparatively small additional effort, so that we can put in that effort *before* we go to q^2=2. The quick-and-dirty analysis described above seems to indicate that the syst. errors can be kept at a level that is much below the stat. error to be expected for the ΔN measurement. We therefore should seriously consider this, estimate some numbers (cross sections, rates, overhead) and try to integrate it in a run-plan.