"BAND Analysis" by Tyler Kutz et al. – First Round of Responses from the PWG Review Committee (S. Kuhn – chair, S. Stepanyan, A. Hobart)

General Comments:

The analysis note, dated July 14, is not yet complete. Some of the missing items are listed in Appendix A "Open Issues". These will have to be completed before the analysis note can be approved.

The main issue is the stark discrepancy between the absolute rates from data and from the MC for the tagged channel D(e,$e'n_S$)X. This discrepancy is even larger than indicated in A.1.2: While the INCLUSIVE analysis finds that the total data rate is only 0.6-0.7 times that predicted by the inclusive MC, the tagged data are a factor 7-10 higher than the MC simulation. In addition, from A.1.1 it appears as if the BAND efficiency is a factor of 2 less than in the simulation. It is not clear whether that factor has been accounted for in the tagged simulation – if so, the discrepancy is as much as (7 – 10) / [(0.6 – 0.7) * 0.5], as one would expect the tagged data rate to be further reduced by the BAND (= tagging) efficiency, not enhanced. This means the discrepancy is more than a factor of 20! While it is true that some acceptance, efficiency and luminosity effects cancel in the double ratio defined by the authors (Eq. 19), the observation that this ratio rises with x' (which would be surprising in the context of most interpretations of the EMC effect) could be due to a residual effect from this huge discrepancy. Hence, this discrepancy has to be understood before the results of this analysis can be presented. Therefore, a much more careful and detailed analysis and description of all of the ingredients going into the data analysis, MC, and computation of that double ratio is necessary before any interpretation of these data in terms of bound nucleon structure functions can be supported. We believe the following checks and additional information are needed:

1. Use the 4.2 GeV data for a cross check of the elastic proton cross section via n-spectator tagging. Also, show that using the kinematic correction afforded by the spectator kinematics results in the correct position of the elastic and resonance peaks for the 4.2 GeV data (this was successfully done in the original "Deeps" experiment, as well as BONuS).
2. Produce plots of purely experimental tagged data, e.g. $\Delta\sigma(\Delta Q^2, \Delta x', \Delta\alpha_S, \Delta p_T^2)$ vs. x' for suitable bins in $(\Delta Q^2, \Delta x', \Delta\alpha_S, \Delta p_T^2)$. Ideally, these should be luminosity-, acceptance-, efficiency- and radiation-corrected using the MC (not by dividing by the MC predictions, but rather by the ratio between MC events reconstructed and Born cross sections generated in those bins, as indicated in the equation at the bottom of p. 5). These can then be overlaid with the prediction from the MC. In addition, provide similar plots for the purely experimental ratio $\Delta\sigma(\Delta Q^2, \Delta x', \Delta\alpha_S, \Delta p_T^2)/\Delta\sigma(\Delta Q^2, \Delta x' = 0.3, \Delta\alpha_S, \Delta p_T^2)$.
   As a first step, please supply a table of the experimental tagged yield within the 2 alpha_S bins and all cuts, as a function of x', and the integrated luminosity within the target vertex cuts for all runs that you add your data for.
3. In the analysis note, the definition of x' is derived from W'. An alternative definition would use the 4-vector relationship $x' = \frac{Q^2}{(P_D - P_S)^{\mu} q_{\mu}}$ with P_D the initial four-momentum

of the deuteron and P_s the observed spectator momentum. The difference is not very big but could have some effect on the quantities you define (or the cross sections in the previous paragraph). You mentioned that you tried both definitions, but it would be helpful to see a direct, quantitative comparison of the important observables with *x*' calculated both ways.

4. This might be a very naïve comment and probably would not explain the factor >7 in data to MC, however, charge exchange is not very well estimated on theory side and is not included in event generators, so a recoiling spectator proton could undergo charge exchange inside the target and exits to band as a neutron, what is your opinion on that? I remember there was data taken in RGA configuration where band was installed, if this is true, could you try running your analysis in the same sense as you would do with RGB data? In the case of the RGA configuration, the target is hydrogen, so you do not expect neutrons. This would help estimate possible nonphysical background in band and at the same time have an estimation of this charge exchange if existing.

While a full appraisal of the analysis has to await the results of these additional investigations / information, below we summarize some of the more specific items that will likely have to be addressed for the final analysis note.

Detailed Comments, referring to specific parts of the analysis note:

Title: I would suggest that the name of the analysis note be more specific for the physics analyses rather than just mention the subdetector with which the experimental data have been taken.

p.4, L77ff: you are referring to a plot that is not yet shown, maybe explain in a bit more detail.

p.5, 2nd paragraph: You show the relationship between initial proton three-momentum and spectator three-momentum. You should add the 4th component (energy) to that equation. (BTW, why are there no line numbers between 89 and 90?)

Equation 2: Y_exp and Y_sim both include radiative corrections however you equate them to the born theoretical cross section, am I missing something? (Justify the assumption that radiative effects are just multiplicative factors that cancel – in reality, there are radiative tails that ADD to the yields).

p.6 L120, x'=0.3, EMC x=0.3?, is this x_B=0.3? The x' will change with neutron kinematics, while x_b does not. How does this affect the double ratio vs. EMC comparison? Although not necessary, could you test choosing a different reference x' than 0.3?

p.7 L131: Define PWIA (Plane-Wave Impulse Approximation)

p.7 L133 + Eq. 5: The assumption that the F_2 ratio is equal to the cross section ratio is clearly not correct – there are kinematic factors that can be different for the 2 different kinematic points, including the infamous “flux factor”, and you ignore the contribution from F_L or R. This should be discussed in more detail.

p.8 L151ff: You claim that the formalism uses PWIA, but Ref. 14 even has the words “with … final state interaction” in the title. Provide more detail how the model in that reference was implemented.

p.9 Eq.9: Give more details on Eq. 9 (what P distribution did you use?).

p.9 L183ff: Again, more details on how the external, pre-scattering radiative corrections for an INCLUSIVE, TAGGED reaction were implemented from Ref. 12 are needed. (Does the “e,e’p” in the title of Ref. 12 indicated quasi-elastic proton knockout?). Similarly, re p.10 L189, it is not a priori clear that internal radiative effects on a proton at rest can be used for radiative effects on a moving proton inside a deuteron target. At least some justification/details of the implementation would be necessary.

Fig.1, show the ratio of WRS to the weighted distribution

p. 10 L218: Do you consider this as a systematic? What was the conclusion on the large-x_B discrepancy?

p.12-13: Some of the plots are hard to read (in particular the ratio plots should be blown up to clearly show the magnitude of the deviation, which appears to be up to 20% between the two generators). Does one of the generators contain FSI or not? (See above). Do you consider the 20% discrepancy in your systematic uncertainty later on?
The bottom left panels on the lhs of Fig. 3 should be plotted separately for your two different alpha_S bins, with all other cuts applied. What cuts WERE applied for Figs. 2-3?

p.15 L240: Are all of the comparison plots between data and MC AFTER applying smearing? If not, whhich ones are/aren’t?

p.19 L269, two scintillators (of PCal) will not make 14 cm

p.20 L276-278 typo? “outward” -> “Inward”?

p.22 L316 typo? “latter” -> “former”?

Fig.16, the occupancy vs. PCAL W, is this number of electrons? If this is the distribution for ANY hit in the EC bank, can we see electron rate vs. PCAL W?

p.20ff: Define “SF” in L284 (i.e., what is the numerator and the denominator?) Why do you not apply a minimum cut on E_{PCAL}? Why are the limits on SF cuts so generous (+/- 5σ = discovery!) For Fig. 13, it would be better to show just one plot for p < 4.5 and one for p > 4.5. The cut is already indicated by the red line, so that the bottom plot contains little information.

(I realize that these choices have become "standard" following the first RGA analysis notes, but that doesn't mean I have to like them.) Finally, it would be nice to also show a histogram for nphe in HTCC before and after applying all other electron ID cuts.

p.27 L339, time-of-flight window depends on physics analysis window - what does this mean? Also, "good neutron candidate" is used twice within this paragraph – be more clear and detailed in your nomenclature. Finally, there is a blue "link" that is empty.

p. 28: are the blocked hits combined with the hit that blocked them to form a cluster? More general:

1. Why do you not apply a hit clustering algorithm which would help you eliminate double counting rather than making this blocking algorithm?
2. How are you sure that the blocked hit is not first in time, for example back scattering in bars?
3. Line 379: 3ns , 15 ns is this not too huge time window? Would this not mix events from two beam bunches?

Fig. 18: Can you also plot the ToF spectrum in ns?

Fig. 19: what are the units for dS/S, %?

Section IV: The discussion is rather confusing for non-experts. Please define clearly what "event mixing is" (what is mixed with what?), and how you actually apply the accidental background subtraction (with error propagation). Couldn't you just plot a TOF spectrum with the accidental background subtracted to show that only true coincidences remain?
Here are some more detailed questions/comments:

- l413, why hits from early time (-56 ns to -4ns) are labeled as neutrons? (Couldn't they be gammas instead?)
- l415, not clear how 4 ns increments are used. With 4 ns, any hit in the region -56 to -4 will end up in the window of 12 ns to 16 ns. How hits are then populated between 12 ns and 100 ns? The procedure "until it was in the signal region (TOF between 12
- 416 ns and 100 ns)" will not allow it.
- Plot a distribution similar to in Fig.18, but with mixed events. Select a hit that went into Fig.18, pair it with the electron from a different event, and recalculate ToF/m.
- can we see the distribution obtained from the procedure described in the 2nd paragraph of Section 4?
- Fig.20, does this background have anything to do with the event mixing? If so, should the mixed background be between 12 and 100 ns?
- Fig.21, no flat background. How are these backgrounds generated?

Fig.24, can we see red distributions separately? Or maybe multiplied by a factor of 10 to make them more visible? Explain more clearly the difference between Fig. 24 and Fig. 25 (why are the TOF spectra so different?).

Fig. 25: Did you subtract accidental backgrounds from both empty and full target data?
Fig. 26: aside from the open issue of a peak at 34 ns,

- do we understand why the beam bunch structure is seen in the full target data and not on the empty target?
- Can we see the red distribution without normalization, just the count rates?
- Where exactly is the photon peak, at 12 ns?
- Do you understand why higher E_{dep} thresholds result in relatively larger ratios empty/full?

Finally, a general comment: While the empty target data seem small relative to the full target ones, one cannot exclude secondary reactions in the target walls after scattering inside a full target which would be missed by the empty target results.

p.39 L527: the claim is the three types of events were analyzed for DQM run selection, but in Appendix C, only one type, signal+bg (not the one listed), is shown. Can we see charge normalized neutron events vs. the run number, also background and photon events vs. run number?

p.40: In the end, what fraction of data was discarded based on BAND selection compared to the RGB run list?

p.45 L611: You should state here by which scale factor you had to scale the MC data for each of the kinematic distributions shown (Figs. 30-33). Also please fix the reference to the Figs in line 613. Did you make a systematic check to see if the MC smearing applied has any effect on the comparison that you show in figures 30-32?

Section 8.1: kinematic variables α_S, *x*', *W*' are defined using the spectator momentum as p_n, by assuming the scattering of the proton in the pair. Plot the missing mass distributions of e'p_n, which should peak at the proton mass. Compare MM distributions of data and MC. (if possible, do this also for 10 GeV data in addition to for the 4.2 GeV data as specified under “General Comments”.)

Fig. 33: make the comparison of tagged MC and data, specifically *x*' dependence in Fig.33 for the same kinematic bins as presented in Figs.36 and 37

p.57: are the symbols R_{tag} (line 701) and R_{En} (Fig. 41 right) the same as R in Eq. 21 or R in Eq. 19? Be consistent with your use of symbols.

Concerning A.1.3 and A.1.4, did you check for any correlation between observed anomalies and run numbers/run period?