Re: Manuscript CS10563, D. H. Ho et al. DRAFT

Dear Physical Review C Editors,

We received the comments by the referee for our paper, D. H. Ho et al. "Beam-Target Helicity Asymmetry E in $K^0\,\Lambda$ and $K^0\,\Sigma^0$ Photoproduction on the Neutron" on August 1, 2018, after a 10 week waiting period since submission to Phys. Rev. C on May 16, 2018. This letter is our reply to these comments, and it accompanies the resubmitted manuscript.

We thank the referee for his/her comments on our CLAS Collaboration paper "Beam-Target Helicity Asymmetry E in $K^0\,\Lambda$ and $K^0\,\Sigma^0$ Photoproduction on the Neutron". We are very pleased to see that the referee is of the opinion that "the manuscript of worth publishing in Phys. Rev. C". However, there were a number of thoughtful comments and suggestions to which we would like to respond. The accompanying revised manuscript includes all the changes itemized below.

The following text is from the referee report, with our replies embedded in blue italic font:

The manuscript entitled with "Beam-Target Helicity Asymmetry E in $K_0\Lambda_0$ and $K_0\Sigma_0$ Photoproduction on Neutron" by D.H. Ho et al. reports the first measurements of the beam-target asymmetry E for the $\gamma n \rightarrow K^0\Lambda$ and $K^0\,\Sigma$ channels in the energy region of $1.70<W<2.34$ GeV. These results are new information and useful to perform Partial Wave Analysis in a more complete way. In this regard, the manuscript is worth publishing in Phys. Rev. C. However, the present measurements are, unfortunately, statistics limited after all. As mentioned in the manuscript, they already have higher statistics data with many other polarization observables. In this situation, the significance and importance of the present measurements described in sec.1 should be reconsidered and modified in considering the following major points.

1) in page 3, left column, 2nd paragraph; it is discussed that 15 spin observables including an interaction cross section are needed to describe the complex amplitudes. However, in the present measurements only one new observable E is measured. The impacts of this limited measurement should be much clarified.

Reply: The introductory discussion on page 3 is intended to give the reader an outline overview of why photoproduction of pseudo-scalar mesons is interesting and valuable. The discussion in the second paragraph points to the ambitious agenda of the whole research field, including a significant part of the CLAS physics program. Indeed, the single double-spin observable, E, presented in this publication is quite a modest contribution to this program. Nevertheless, we think it is important to state in the Introduction what the broader picture is within which these results are valuable. Reference 17 to 35 may be consulted to see how many approaches and how many measurements have been explored to "triangulate" the unique answers for the four invariant amplitudes for the various reaction channels. Note that the final two paragraphs of the paper reiterates the situation, and frankly states that the present results provide only a modest, but unique, contribution to the field.

In the referee's first paragraph it is mistakenly stated "already have higher statistics data with many other polarization observables". While it is true that OTHER observables are still under analysis, some of them with more favorable statistics, the present measurement is UNIQUE. That is, no other measurement of this observable, E, in this reaction has been measured, and given how difficult the measurement was, it is very unlikely that it will ever get measured again, at least in the foreseeable future. That is part of our motivation for publishing these results.

We have not modified the text in response to this comment.

2) Later in the same paragraph, it is discussed that neutron target data are important to study I=1/2 transitions. It is, however, not clear what kind of new data are awaited quantitatively.

Reply: The answer is that these data will get included in partial wave analyses along with many other data for this and other observables. The nature of the field is that simultaneous fits to all observables at the same time are needed to reduce ambiguity and uncertainties are needed. Thus, perhaps unfortunately, it is not possible to say precisely what the impact of each new datum will be. However, what is clear is that the modeling phenomenological groups at Bonn University (BnGa), George Washington University (SAID), and possibly other will exploit these results when they are published.

3) In Sec. 3 "Data Analysis", the introduction of the Boosted Decision Tree (BDT) selection procedure is one of major successes in this work. It should be mentioned in the abstract or in sec. 1 "Introduction".

Reply: We agree that this is a good idea. The abstract of the paper has been modified to add the sentence: "The multivariate analysis method of Boosted Decision Trees was needed to isolate the reactions of interest."

Further, there are several minor comments to be considered in the revision process.

4) in page 3, right column, 2nd paragraph; a[though several variables are defined such as the beam-target observable E, sigma^A, sigma^P, P_T, P_o, etc., it is not easy to understand them for the general readers. It is better to use a figure with 3-dim. Arrows to define all those directions in relation to the incident beam direction. Further in this paragraph, just after the eq.(1), it is mentioned as "this observable is defined as eq.(2)". However "this observable" is not clear to me.

Reply: Well, the observable is "E". We have rewritten the sentence in question to make this plainer. The definitions of P_T and P_0 are given, and it is difficult to see how to make these even clearer. We decided not to add another figure to the paper because anyone who has ever learned the nomenclature for any of the spin observables of pseudo-scalar meson photoproduction will have the geometry in mind. A place where this is all clearly laid out is Ref. 18.

5) in page 4, left column, 1st paragraph in Sec. II, "which was measured routinely by the Hall-B Moller polarimeter [xxx]", here we need a reference.

Reply: As recommended, we have added a suitable reference, number 47, to the text.

6) in page 4, right column, end paragraph; "the Boosted Decision Tree (BDT)" is used for the first time in this manuscript without any references. Although a lot of references for the BDT are quoted later, it should be a reference at this position.

Reply: This is a good observation. We have added three references at this point, including new ones that are numbered 52 and 53.

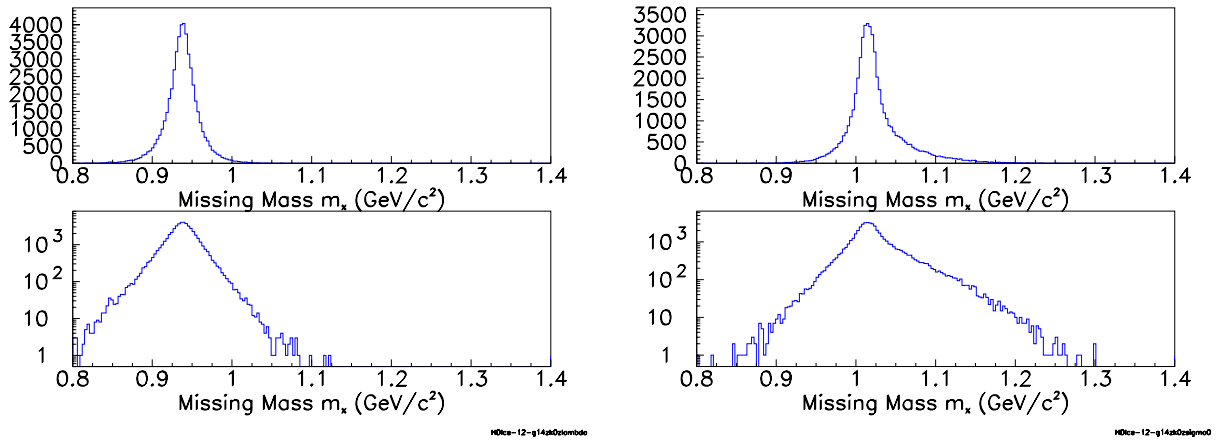
7) In page 5, Fig.1, if we have a drawing of the target material on top of the figure with the same z axis, we could better understand which peaks correspond to which materials.

Reply: Of course we have a detailed figure of the cryogenic target cell, but making a readable figure that combines both the engineering drawing and the vertex position data is very difficult. See Figure 2.18 in Ref. 57.

We have replaced Fig. 1 with an improved version that includes guideline for the reader to indicate the nominal target location. This necessitated changing the caption, which now reads:
"The vertex distribution of events along the beam line for a full target is the open histogram. The dashed red lines show the nominal target boundaries. The peaks at z>0 are from target-independent foils in the cryostat; the positions of two are highlighted with dotted blue lines. The filled histogram is the scaled target-empty background distribution."

8) in page 5, Fig.2, "the presence of Sigma0->pi-p(gamma) events" is not easy to identify in the present form. Could you please show the component in a different color or indicated with an arrow ?

Reply: Yes, it is hard to see the difference in the blended Lambda and Sigma0 distributions in Fig. 2. Below is a figure that shows the signal Monte Carlo events for the L case on the left and the S0 case on the right. The upper two plots are on a linear scale and the lower plots are the same two distributions on semi-log scales. Here the difference between the two cases is easily seen. The right-side distributions go up to about 1.3 GeV. The cut shown in Fig 2 in the paper, at a stage when the analysis of the real data is not yet complete, was places at 1.4 GeV, and thus should be very safe (i.e. not rejecting good events). We have not included the distributions shown below because they are not all that illuminating to the reader.



However, we have changed Fig. 2 in the following way. As per the referee's suggestion, we have added arrows to the figure to illustrate the location of the key points in the spectrum. The paragraph of description in the main text now reads, in part,
"A clear peak corresponding to the spectator proton is seen at Point 1 for events that produced a Λ particle. A loose cut was applied to reject events with missing mass larger than 1.4 GeV/c^2 at Point 4 because of the presence of $\Sigma^0 \rightarrow \pi^- \gamma$ events. These have a 73 MeV photon in the final state in addition to the proton, and the distribution peaks at Point 2 and has a kinematic tail to about Point 3."
The caption of Fig. 2 has also been changed in a similar way to reflect this improvement.

9) in page 7, Fig 4; here the invariant mass distributions are shown. Could you comment on the mass-resolution obtained from the fit and are they reasonable with your expectation ?

Reply: First let us point out that the fits shown in Figure 4 are not used in any of the subsequent analysis. They were not used to separate signal from background. Events in this experiment were classified event-by-event using the Boosted Decision Tree method, and the figure illustrates this with the two colors/shadings. The fits serve only as a guide to the eye and to lead into the discussion of residual background. In answer to the comment, the observed widths of the peaks were well reproduced by the

standard CLAS Monte Carlo model called GSIM. The Lambda width was 9.5 +- 0.5 MeV and the K0 width was 27+-1 MeV. If the reader is interested, see page 148 of the PhD thesis, which is Ref. 57 in the new draft of the manuscript.

To be absolutely clear, we have added the sentence to the caption of Fig. 4: "The fits aid the discussion in the text but were not relevant in the subsequent analysis."

10) in page 7, sec. C, in the first paragraph; some of the fractions should be expressed in display mode, not in text mode, they are hard to read.

Reply: Done.

In addition to the changes itemized above, we have added three names to the author list: Collins, Bass, and Whisnant. These people were identified after the submission of the paper to have been eligible for inclusion on the list, and so have been included now.

Sincerely, for the CLAS Collaboration,

Reinhard Schumacher
Professor of Physics