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

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) on 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 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.

To help set the stage for the reader, we have modified the text and replaced the fourth and fifth sentences of the second paragraph of section I on page 3 with the following:

"A mathematically complete experiment would require data, with negligible uncertainties, on a minimum of eight well-chosen observables at each center-of mass (c.m.) energy, W , and meson polar angle, cos $\theta_{c.m.}$). In practice, with realistically achievable uncertainties, measurements of many more are needed to select between competing partial wave solutions, and even knowledge of the sign of an asymmetry can provide valuable discrimination [22]. Furthermore, avoiding ambiguities in PWA solutions requires measurements of observables from each spin configuration of the three combinations of beam-target, target-recoil and beam-recoil polarization [22, 23]."

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: As discussed at the top of the right column of page 3, data on a single target species (proton or neutron, although the data base is much larger for proton targets) are sufficient to extract the I=3/2 multipoles. From these come the photo-couplings to Delta resonances. However, data from both proton and neutron targets are needed to extract the I=1/2 multipoles, and from these the associated neutron photo-couplings to N* resonances. The neutron and proton photo-couplings are in general different, reflect the structure of the N* resonances, and serve as tests for models of nucleon structure. In the energy range of the present experiment, resonances typically decay into several different channels. Thus, for a consistent treatment, simultaneous coupled-channel PWA are essential. There is no avoiding the fact that the latter simply requires a huge amount of data from a great many different experiments. Thus, perhaps unfortunately, it is not possible to say in advance precisely what the impact of each new datum will be. However, what is clear is that the modeling groups at Bonn University (BnGa), George Washington University (SAID), Osaka University and Argonne (AO), and others 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 used 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; although 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: We have rewritten the sentence in question to make this plainer. The definitions of P_T and P_0 are given. We realized that there was an unfortunate typo in the text that may have caused some confusion about the definition of the "E" asymmetry. In the sentence preceding Eqn (1), the words aligned and anti-aligned were interchanged. The text before Eqn (1) now reads:
"The beam-target helicity asymmetry E is formally defined as the normalized difference in photo-production yield between anti-parallel (σA) and parallel (σP) configurations, i.e., settings where the incident photon beam polarization is anti-aligned or aligned, respectively, with the longitudinal polarization of the target. Following [18 and 22], we write…"
We decided not to add another figure to the paper because Appendix B of Ref [22] tabulates the explicit combinations of measurements that are required to construct the "E" asymmetry (along with all of the others).

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.

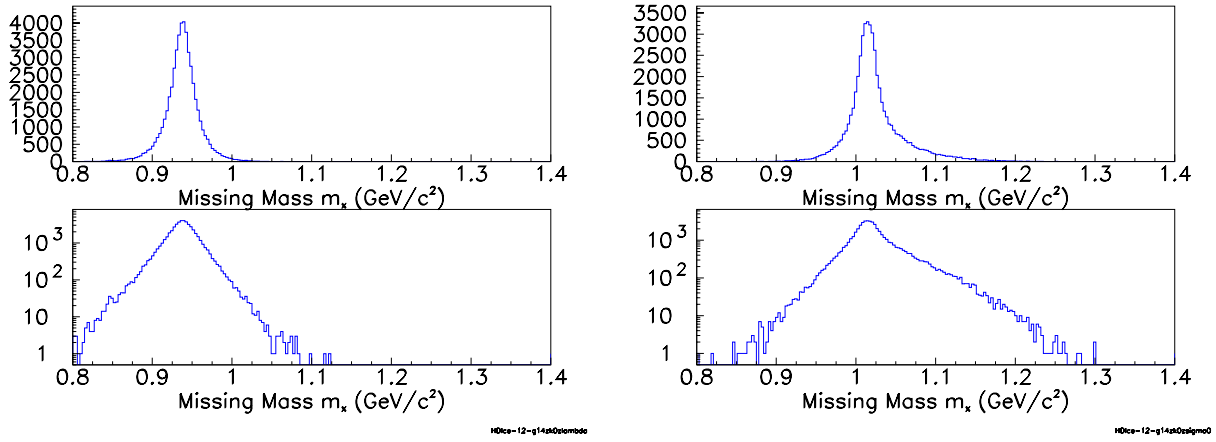
7) In page 5, Fig.1, if we have a drawing of the target material on top of the figure with the same z axis, we could better understand which peaks correspond to which materials.

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, or alternatively Fig. 7 of Ref. 50.

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 [50]. 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 Λ and Σ^0 distributions in Fig. 2. Below is a figure that shows the signal Monte Carlo events for the Λ case on the left and the Σ^0 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 extend 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 placed 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 lines 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 K^0 width was 27+-1 MeV. If the reviewer 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