To the editors: We would like to thank the referees for their valuable comments. We have made modifications to the paper and highlighted the changes inline below. We have marked the referee comments in bold italics.

REFEREE 1:

Dear Dr. Fayyazuddin,

I have reviewed the manuscript named DZ12971 and titled "High-statistics measurement of antineutrino quasielastic-like scattering at E_nu ~ 6 GeV on a hydrocarbon target" by the MINERvA collaboration.

The paper reports a new measurement of muon anti-neutrinos CCQE-like cross section with the so-called Medium Energy (ME) beam, that complements an equivalent measurement using muon neutrinos as well as a muon antineutrino measurement that used the Low Energy beam.

After a brief description of the MINERvA detector, the event selection and the used Monte Carlo, uncertainties on the measurement are discussed. The cross section is reported as a double differential cross section in muon transverse and longitudinal momentum and also as a function of Q_QE^2. Several GENIE tune predictions are compared with the extracted cross section.

Results are valuable, however the paper could benefit from some additional details. Suggestions about reorganization of the plots distribution across the document are also made.

GENERAL COMMENTS
The description of the cross-section extraction technique is made very quickly and could benefit from additional details.

Also, it seems that two or three cross sections are extracted: a 2D cross section as a function of p_parallel and p_T, a 1D cross section as a function of Q_QE^2 and a 1D cross section as a function of E_nu.

However, when discussing the results, this is less clear, comments are given sometimes for the 2D cross section and sometimes for the 1D cross section where the reader can get confused.

We have expanded the section on the extraction technique and edited the text to be more specific about which result is being discussed. To help in this, we now include the systematic uncertainty in the Q2 and Enu results in the main text.

Concerning the cross section as a function of the true neutrino energy (Fig. 6), this is even less clear. Is this a third extracted cross section? Or just a projection of a previous extracted cross section as function of the neutrino energy? Please specify.

→ Added a separate cross section extraction section to explain the overall cross section technique. The main delivery of this analysis is the 2D cross section in the bins of muon momenta. As a secondary delivery, we provide cross sections as a function of anti-neutrino energy (E_{\nu}) and four momentum transfer squared (Q^{2}_{QE}). The 1D cross sections are the projection from 2-D ones.

We discuss the Enu cross section extraction more below.

Also, plot 7 and 9 of the supplemental material could definitely be part of the main text of the article. Being the less model dependent measurement of the article, I would leave more space to the discussion of those results, more than those in E_nu that have a dubious usefulness. Please consider to rearrange elements put in the main text and in the supplemental material.

We have moved those plots as suggested. We keep the E_{\nu} cross section to allow (qualitative) comparison of the results with other experiments and models with a warning that this cross section is more model dependent.

IMPORTANT DETAILED COMMENTS
PAGE 1 2nd COLUMN
“We also present cross section measurements as a function of the estimated four-momentum-transfer squared variable “
Please define Q^2_QE somewhere in the text, either here or when you show the corresponding cross section

Done.

“The correction from the observable Ev(QE) to Ev is sensitive to nuclear effects and introduces additional model uncertainties. “ What do you mean here? This aspect is not developed in the rest of the Text.

→ We have added the following text:
To extract the E_{ν} cross-section, the $(E_{\nu},Q^{2})_{QE}$ cross section is corrected to a true $({E_{\nu},Q^{2}})$ cross section and projected into the E_{ν} phase space. The neutrino flux is estimated both from simulation and from studies of multiple anti-neutrino processes and is parameterized as a function of true E_{ν}. The cross section as a function of ${E_{\nu}}$ is then the corrected number of events observed as a function of E_{ν}, corrected by the flux. $E_{\nu QE}$ is a more robust observable defined solely from muon kinematics but generally offset from the true E_{ν}. Determination of the transformation from the observable $E_{\nu QE}$ to the true E_{ν} requires simulation and hence introduces additional model dependencies as illustrated in Figure \ref{fig:fid error summaryEnu}. The E_{ν} cross section provides qualitative comparison of our data with other results but should not be used in global fits.

PAGE 4 1st COLUMN
Last two paragraphs before the Section V are not related to SIMULATION (section IV), but are more related to the cross section extraction technique and to the data sample. Please add an additional section between the current sections IV and V, that you could call CROSS SECTION EXTRACTION. Also please, give more details about the unfolding techniques (the community is often at least interested to the chosen number of iteration and motivations about the choice).
Also, you could profit to this additional paragraph to better explain how the three presented cross sections (a 2D cross section as a function of muon kinematics, a 1D cross section as a function of Q^2_QE and 1D cross section as a function of E_nu) are calculated. I guess you extract three independent cross sections?

→A separate section on cross section extraction is added to explain cross section extraction for all variables.

PAGE 4 2nd COLUMN
"For the flux systematics which depend upon various beamline parameters, 500 "universes" are simulated "
How has this "500" number been tuned?

→ We did a study to see the statistical precision of the method by varying the number of universes. Studies done with 200,500 and 1000 universes showed that using 1000 universes did not increase the precision. Hence, we used 500 universes for our analysis.

FIG. 5 : please make those plots bigger, you can have for instance 4 rows and 3 columns
→ Done. Thanks for this suggestion, it is a great improvement.

DISCUSSION AND RESULTS
This section is a bit confusing. Please try to better separate the interpretation of the different extracted results. You could first discuss the 2D result only, then move to the 1D result.
I definitely suggest to put in this section plot 7 (or 9) from the supplemental material. Clearly those plots must be made bigger (3 columns x 4 raws for instance) and you should consider to split the model comparisons, for instance plot 7 from Sup. Mat. is presented once with only Genie 2 comparisons (and Mnv tunes) and once with Genie 3 comparisons. Plot 9 could remain in the sup. material, but please consider to make it bigger and to again split the model comparisons.
Also, in Table 1 you could report also the effect of each systematics on the 2D cross section, while in Table II we are missing the chi2 for the Q_qe^2 cross section (unless the Q_Qe^2 cross section is simply a projection of the 2D result?? But again, this would need clarification). Please add the information about the missing measurement in each table.

→ Chi squared comparisons were only shown for 2D because that is the main deliverable. All the 1D results are the projections of 2D (Enu,Q2)_{QE} results but not directly derived from the pz-pt results.
FIG 6: please consider putting this plot in Sup. Material. I'm a bit uncomfortable with those kind of plots appearing in the main text of a modern cross section paper.

→ This is provided as a qualitative picture of the data which is useful for non-experts. It is not the primary result of the paper and is not claimed to be one. This figure provides a qualitative picture of our data and, due to the increased theoretical uncertainties, should not be used in global fits. We have added the clarification in the main text as well.

MINOR COMMENTS
page 1 1st column
PNMS -> PMNS
by utilizing utilizing (repeated twice)
→ Done. Thanks for catching this.
Page 5 2nd column
“for the parallel neutrino data “ -> parallel is misleading here, try
to use
“corresponding” or similar
→ Done. Thanks for catching this.

--
Report of Referee B -- DZ12971/Bashyal
--

This manuscript is a follow up of a previous publication [C. Patrick et al. (MINERvA), Phys. Rev. D 97, 052002 (2018)] where now, apart from exploring a higher energy region, some improvements in the data analysis has been included. These new results at higher energies are also of interest for the validation of nuclear models for oscillation analyses. Likewise, the restrictions in the proton phase-space for antineutrinos with regard to the neutrino case introduce a novelty to test 2p2h models and check their capability to predict hadron kinematics properly.

In general, the paper is clearly written and of interest for the theoretical and experimental neutrino community so I recommend its publication after considering some questions and suggestions that can be found below these lines and that could make the article more readable and self-contained.

→Thanks for your detailed comments and suggestions. We have tried to address your questions and suggestions below.

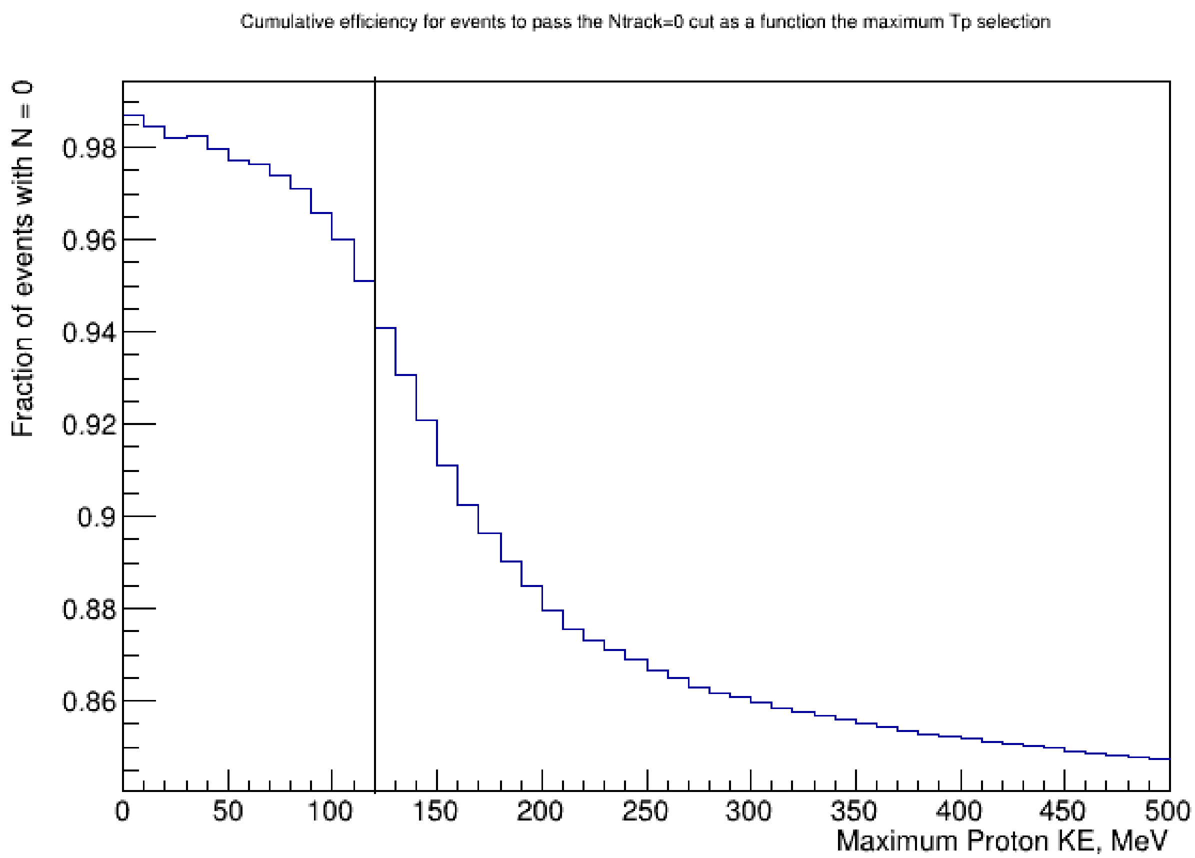
Comments and questions:

Page 3: The restrictions in the proton phase space (120 MeV) are interesting to analyze the neutron-proton contributions from the 2p2h channel. Is this 120 MeV threshold accounted for in the 2p2h model used? Is the 2p2h model considering a separation into the np and nn pairs in the final state?

→ The 120 MeV threshold is based on our detector's ability to detect the protons. We quote the cross section with a signal definition that excludes interactions which have a proton above that cutoff.
To show the overall effect of including protons above 120 MeV KE, we have added the 1D Enu cross section and error summary without excluding the protons above 120 MeV. However, events with additional tracks (other than muons) are still excluded.
The Low Recoil Systematics represents the total systematics due to both np and nn pairs.

We previously studied the influence of the np/pp ratio for 2p2h in Patrick et al and found it affected our cross section extraction by < 1% (Table 5 of Patrick).

This figure shows the efficiency for events to pass the charged multiplicity N<1 cut (no charged tracks except for the muon) as a function of the maximum proton T in MeV allowed in the event, with all other cuts kept the same. Our detector is not supposed to be sensitive to protons below around 120 MeV and this plot shows that for events with protons with very low Tp (or no protons at all) the N=0 cut is almost always satisfied, as we expect. The asymptotic behavior at very high T_p is consistent with the expectation that events with protons in the final state are reasonably rare in anti-neutrino CCQE-like processes where n or nn are the most expected final states. The steep falloff between 80 and 160 MeV reflects our detectors increasing ability to see a final state proton as a second track and veto that event.



Page 3: The GENIE versions employed in this article are GENIE 2.12.6 and GENIE 3.0.6. In a recent preprint of the MicroBooNE Collaboration (arXiv:2301.03700 [hep-ex]), more recent GENIE versions are also employed to compare with data, using different nuclear models as well. Why are these options not included in this manuscript? Are the authors considering including these updates in further analyses?

→ We will be including these updated models in our future studies but did not have them integrated into our software in time for this paper.

Pages 3 and 4: RES and DIS are not defined. They should be defined in the first paragraph of page 3 where resonances and deep-inelastic scatters are mentioned for the first time. the models employed to describe the RES and DIS contributions should be also mentioned in the manuscript.

→ Defined now. Thanks.

Page 5: Figure 2. The ticks in the plots are difficult to see. They should be enlarged a little bit.

→Done.

Page 5: It is stated that "Recently available GENIE 3.0.6 models appear to better reproduce the high Q2 behavior and are shown on the right hand side of Fig. 4". These new GENIE models, although improve the agreement at low Q^2, also overestimate the last bin in that plot. Could the authors provide any explanation about this increase at large Q^2? If so, it should be included in the manuscript.

We are not completely certain which modification to GENIE between version 2 and 3 led to the increased cross section at high Q2, which is an improvement in the trend but still does not completely agree with our data.   https://arxiv.org/pdf/2104.09179.pdf states that they have substituted a Local Fermi Gas for the Relativistic Fermi Gas with Bodek-Ritchie correction and use the Valencia model for RPA/2p2h etc. They have also improved the FSI simulation. Overall, we find the new models to be a substantial improvement. We hope that the new pz/pt data will provide useful input.

Page 6: As stated in the text, "The \nu_\mu cross section includes

CCQE-like events with any number of protons, whereas the \bar\nu_\mu requires no protons above T_p = 120 MeV". Thus the antineutrino cross-section measurements introduce a restriction in the proton phase space that is absent in the neutrino case. The effect of this restriction can be of paramount relevance when analyzing data in terms of hadron kinematics or transverse kinematic imbalances, but it also affects cross-section measurements in terms of lepton kinematics. As shown in Phys. Rev. C 105, 054603 (2022), at Tp < 100 MeV, there are important differences (larger than 50 % in magnitude) between the intranuclear cascade models employed in generators and the relativistic optical potentials used in some neutrino interaction models. The treatment of FSI effects introduces relevant differences in cross sections at low T_p and could explain some of the discrepancies observed between GENIE and MINERvA data in this manuscript. The issues of cascade models when applied for small nucleon energies should be commented on in the text.

→ We do include uncertainties in the FSI modeling in our systematic uncertainty estimation for the cross section extraction itself and find them to not have a significant (< 5%) effect. We make the T<120 MeV selection exactly because we do not want to be dependent on FSI modeling's effects of our reconstruction efficiency in the region where we are not able to detect additional final state particles   However, our use of the Tp < 120 MeV selection does require that future model comparisons to our data include that selection. We prefer to make the data available for experts to compare to modern models.

Tables of the 2D cross sections in the bins of muon momenta and the related error summaries (both plots and tables) have been added in the supplementary materials.