

Two-body current contributions in neutrino-nucleus scattering

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I. SCIENTIFIC ISSUE

The proposed workshop will focus on the modeling of two-body currents for studies of neutrino interactions with nuclei in the hundreds-MeV to few-GeV energy region. There is a considerable interest in the study of these processes in connection with present and future accelerator-based neutrino oscillation experiments, where it is necessary to reduce systematic errors to the level of a few percent. Today one of the most important sources of systematic errors are neutrino-nucleus cross sections which in the mentioned energy region are known with a precision not exceeding 20%. A large contribution to such uncertainty is due to the very poor knowledge of two-body current contribution.

Since the charged-current quasielastic measurement performed by MiniBooNE [1] and the proposed explanation of its unexpected behavior based on the inclusion of multinucleon ejection channel [2], these two-body current contributions have attracted a lot of attention. In recent studies the effect of nucleon-nucleon correlations and meson exchange current contributions turned out to be significant. This point can be appreciated in the results obtained by different theoretical groups for the MiniBooNE flux-integrated neutrino- and antineutrino- charged-current quasielastic-like double-differential cross sections on carbon [3-9]. Recent ab-initio many-body calculations on neutral weak response functions and sum rules [10,11] also confirm that a large fraction of the nuclear response in the quasielastic region stems from two-body currents.

In spite of the general qualitative agreement between different theoretical models about the crucial role two-body current contributions play in the explanation of the MiniBooNE data, important quantitative differences remain between these calculations. These differences are related to the difficulty to treat two-body contributions without approximations. Even in the simple Fermi gas model an exact relativistic calculation is difficult for several reasons. First of all, it involves the computation of 7-dimensional integrals for a huge number of two particle-two hole (2p-2h) response Feynman diagrams. Second, divergences in the nucleon-nucleon correlations sector and in the angular distribution of the ejected nucleons [12,13] may appear and need to be regularized. Furthermore, the calculations should be performed for all the kinematics compatible with the experimental neutrino flux. For these reasons an exact relativistic calculation is computationally very demanding and therefore different approximations are employed by the different groups in order to reduce the dimension of the integrals and regularize the divergences. The choice of the subset of diagrams and terms that is calculated by the different theoretical groups also presents some differences. It is hence not surprising that these models produce different final results. The workshop will first of all be devoted to a comparison between the different approximations invoked in modeling the effects of correlations and meson-exchange contributions in two-nucleon knockout processes. Until recently two-body current contributions were totally ignored in Monte Carlo tools used in the neutrino cross section and oscillation experiments. Today there is an effort to include these contributions in several Monte Carlo simulations. A limitation of the present approaches is that they provide the differential cross sections only as a function of the lepton variables, the hadronic variables being already integrated out (inclusive cross sections). Discussions between theorists, and Monte Carlo developers and users, on the best strategy to implement the actual models and to develop theoretical tools able to provide results for exclusive cross sections (functions also of the ejected nucleons variables) will constitute an important part of the workshop. Recent work based on an analytical and factorized form for electron induced two-nucleon knockout cross sections [14] as well as the development of a framework in which the complexity of the nuclear short-range correlations is shifted from the wave functions to the operators (by calculating mean field wave functions, and by acting on them with correlation and meson exchange current operators) [15] seem very promising. Other promising approaches are related to the factorization ansatz [16].

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- [14] C. Colle, O. Hen, W. Cosyn, I. Korover, E. Piassetzky, J. Ryckebusch and L. B. Weinstein, Phys. Rev. C 92, 024604 (2015).
- [15] T. Van Cuyck, N. Jachowicz, R. González-Jiménez, M. Martini, V. Pandey, N. Van Dessel, and J. Ryckebusch, to be submitted.
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II. GOALS OF THE WORKSHOP

In summary, the goals of this workshop are:

1. Discuss the different approximations made to calculate the two-body current contributions to electron- and neutrino-nucleus cross sections: methods, limitations and perspectives.
2. Benchmark models against electron-scattering data.
3. Compare the results obtained in the different approaches for the electroweak nuclear response, the neutrino double differential cross sections at fixed neutrino energy as well as folded with different neutrino fluxes.
4. Discuss the best strategies to implement the actual models in the Monte Carlo and to develop theoretical tools able to provide results for the exclusive cross sections.

III. SHORT-TERM VISITORS

J. E. Amaro, J. A. Caballero T.W. Donnelly, A. De Pace, R. González Jiménez, R. Gran, G.D. Megias, O. Moreno, I. Ruiz-Simo, F. Sanchez, T. Van Cuyck

IV. LIST OF SPEAKERS

- T.W. Donnelly, MIT, Cambridge Massachusetts, USA (donnelly@mit.edu), “2p-2h excitations in electron and neutrino scattering: past, present and future” (Lecture)
- T. Katori, QMU, London, UK (t.katori@qmul.ac.uk), “Neutrino-nucleus quasielastic cross section measurements” (Lecture)
- J.E. Amaro, UGR, Granada, Spain (amaro@ugr.es), “Fully relativistic treatment of pionic correlations and meson exchange currents”
- M. Barbaro, University of Turin and INFN, Italy (barbaro@to.infn.it), “Summary talk: theory”
- O. Benhar, INFN and Sapienza U, Roma, Italy (Omar.Benhar@roma1.infn.it), “Consistency between the description of the nuclear response in the 1p1h and 2p2h sectors”
- S. Bolognesi, IRFU/SPP, CEA-Saclay, France (sara.bolognesi@cea.fr) “2p-2h from an experimental point of view: future measurements, inputs and needs from theory”
- J. A. Caballero, Sevilla U, Sevilla, Spain (jac@us.es), “Relativistic Mean Field and Superscaling”
- C. Colle, UGent, Ghent, Belgium (Camille.Colle@ugent.be), “Final-state interactions in two-nucleon knockout reactions”
- A. De Pace, INFN, Torino, Italy (depace@to.infn.it), “The 2p -2h electromagnetic response in the quasielastic peak and beyond”

- C. Giusti, Pavia University, Pavia Italy (Carlotta.Giusti@pv.infn.it), “NN correlations and MEC in electron scattering”
- R. González Jiménez, UGent, Ghent, Belgium (raul.gonzalezjimenez@ugent.be), “From quasielastic to pion production”
- R. Gran, University of Minnesota Duluth (rgran@d.umn.edu), “Testing the IFIC Valencia model (via GENIE) against MINERvA measurement of the dip region”
- Y. Hayato, ICRR Tokyo U, Tokyo Japan (hayato@suketto.icrr.u-tokyo.ac.jp), “2p-2h excitations in NEUT”
- A. Lovato, ANL, Argonne USA (lovato@alcf.anl.gov), “Ab initio calculation of the electromagnetic and neutral-weak response functions”
- M. Martini, ESNT, IRFU/SPhN, CEA-Saclay, France (marco.martini@cea.fr), “Inclusion of 2p-2h excitations in a RPA-based approach”
- K. Mc. Farland Rochester U, Rochester USA (kevin@rochester.edu) “Identification of nuclear effects in neutrino-carbon scattering data from the MINERvA experiment”
- G.D. Megias, Sevilla U, Sevilla, Spain (megias@us.es), “Meson-exchange currents and quasielastic predictions in the superscaling approach”
- O. Moreno, Madrid U, Madrid Spain (osmoreno@fis.ucm.es) “Semi-inclusive neutrino-nucleus (deuteron) reactions”
- U. Mosel, Giessen U, Giessen, Germany (Ulrich.Mosel@theo.physik.uni-giessen.de), “2p-2h excitations in GiBUU”
- V. Pandey, UGent, Ghent, Belgium (vishvas.pandey@ugent.be), “Low-energy excitations and quasielastic”
- N. Rocco, INFN and Sapienza U, Roma, Italy (noemetta@hotmail.it) “2p2h final states in electron-carbon scattering within the spectral function formalism”
- I. Ruiz-Simo, UGR, Granada, Spain (ruizsig@ugr.es), “2p-2h excitations in neutrino scattering: angular distribution and frozen approximation”
- J. Ryckebusch, UGent, Ghent, Belgium (Jan.Ryckebusch@ugent.be), “Factorization of exclusive electron-induced two-nucleon knockout”
- F. Sanchez, IFAE, Barcelona, Spain (fsanchez@ifae.es), “Implementation of 1p1h and 2p2h in Nieves et al. model: an experimentalist approach”; “Summary talk: Monte Carlo and Experiments”
- J. Sobczyk, Wroclaw U, Wroclaw, Poland (jsobczyk@ift.uni.wroc.pl), “2p-2h excitations in NuWro”
- J. M. Udias, Madrid U, Madrid, Spain (jose@nuc2.fis.ucm.es) “FSI for the lepton-nucleus scattering at multi-GeV with Global Relativistic with a Folding Optical Potential: is there room for 2p-2h contribution in the data?”
- T. Van Cuyck, UGent, Ghent, Belgium (Tom.VanCuyck@ugent.be), “Impact of short range correlations on exclusive and inclusive neutrino-nucleus cross sections”

V. PROGRAM

18 th April	19 th April	20 th April	21 st and 22 nd April
Welcome	9h30 Ryckebusch	9h30 Lovato	Short term visitors
9h45 Donnelly	10h00 Colle	10h00 Ruiz-Simo	
10h30 Break	10h30 Break	10h30 Break	
11h00 Katori	11h00 Giusti	11h00 Van Cuyck	
11h45 Benhar	11h30 De Pace	11h30 Pandey	
12h15 Amaro	12h00 Rocco	12h00 Udias	
12h45 Lunch	12h30 Lunch	12h30 Lunch	12h30 Lunch
14h00 Megias	14h00 Moreno	14h00 Caballero	
14h30 Martini	14h30 Hayato	14h30 Gonzalez	
15h00 Sanchez	15h00 Gran	15h00 Sanchez	
15h30 Break	15h30 Break	15h30 Break	
16h00 Bolognesi	16h00 Sobczyk	16h00 Barbaro	
16h30 Mc Farland	16h30 Mosel	16h30 Discussions	
17h00 Discussions	17h00 Discussions	17h00 Discussions	
17h30 End	17h30 End	17h30 End Workshop	
