

Cross section theoretical studies for neutrino experiments in the few-GeV region Intensity Frontier Fellow Closeout report

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Activities and presentations at Fermilab

- Organization of the NuSTEC Training in Neutrino Nucleus Scattering Physics

This Training program, aimed to provide the necessary theoretical background on the physics of electroweak interactions with nucleons and nuclei, was attended by more than a hundred participants. Fermilab, which hosted and partially sponsored the program, was key to its success. Being on site with the IF Fellowship in the days prior to the meeting was very helpful for the final organization efforts.

- Lectures on Electroweak interactions on the nucleon at the NuSTEC Training in Neutrino Nucleus Scattering Physics

These lectures, recorded in video and available at the Training web page (<http://nustec2014.phys.vt.edu/>) are part of the program's legacy to the community.

- Seminar entitled “Photon emission in NC interactions with nucleons and nuclei” at the *Neutrino Seminar Series*.
- Seminar entitled “Progress and open questions in the physics of neutrino interactions with nucleons and nuclei” at the *Theory Seminars*.
- Presentation on “Coherent pion production at MINERvA” at a MINERvA Collaboration meeting.

In this presentation, I showed and discussed results of the calculations performed at Fermilab to compare the predictions of our microscopic coherent pion production model with MINERvA measurements.

- Various working meetings with M. Betancourt, R. Gran, R. Hill, A. Meyer, G. Zeller regarding the extraction of the nucleon axial form factor from bubble chamber data and deuterium corrections.

One of my goals during my stays at Fermilab was to contribute to make a solid case for a new experiment to measure neutrino cross sections on hydrogen and deuterium targets, for example, in a NuSTORM type of facility. In the mean time it became clear that such an experiment is not strategically favored. Nevertheless, the need for more accurate information about neutrino interactions with nucleons remains crucial for the future of the neutrino oscillation program and is very interesting for hadronic physics. I was also unable to complete the planned update of the resonance excitation model within the GENIE generator because of the lack of time and man power. On the other hand, I benefited from useful information provided by Ornella Palamara about the MicroBooNE experiment and from discussions with Pilar Coloma about high energy neutrinos at IceCube. These inputs have influenced my current research activity and future plans.

Impact for Fermilab

Fermilab has embraced an ambitious program to make definitive determinations of neutrino properties. The success of this program requires a better understanding and modeling of neutrino interactions. During my stay at Fermilab, I have tried to contribute with the experience gathered in years of theoretical studies of electroweak interactions with nucleons and nuclei, working in close contact with the experimental colleagues.

Scientific publications and other documents

The following papers resulted from work partially carried out during my stays at Fermilab.

- Photon emission in neutral current interactions at the T2K experiment
E. Wang, L. Alvarez-Ruso, Y. Hayato, K. Mahn, J. Nieves, Phys. Rev. D92 (2015) 053005

Although the project does not involve anybody based at Fermilab, it benefited from the interaction with Kendall Mahn (MSU) during her visits to Fermilab.

- Antineutrino induced $\Lambda(1405)$ production off the proton
X. Ren, E. Oset, L. Alvarez-Ruso, M. J. Vicente Vacas, Phys. Rev. C91 (2015) 045201

This project included the calculation of $\Lambda(1405)$ production rates at the MINERvA experiment. For this purpose, discussions and input from Jorge Morfín were very useful.

- Nuclear Theory and the U.S. Experimental Neutrino Physics Program
L. Alvarez-Ruso, K. Mahn, C. Mariani, J. G. Morfín, O. Palamara and G. Zeller, FSNU TOWN Position Paper.