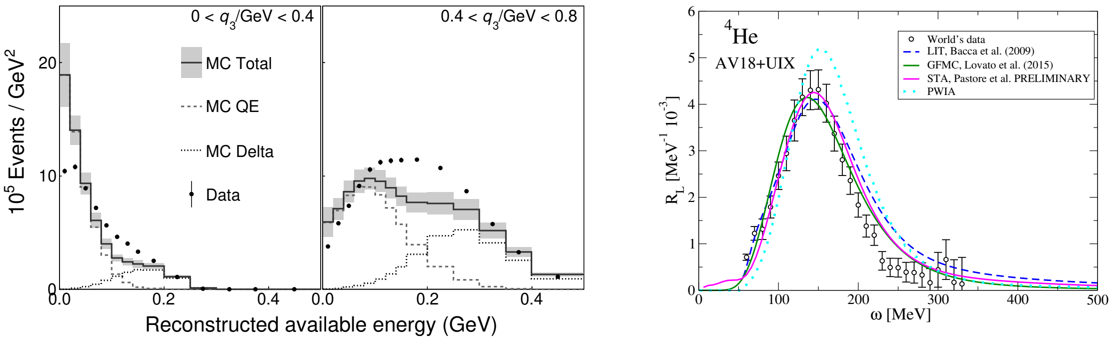

Figure 1: **Left**: Reconstructed available $E_{\rm avail}$ (dots) compared with GENIE simulations with QE process (dashed line), $\Delta(1232)$-resonance (dotted line), and the sum of the two plus unmodeled process (solid line). The lowest $E_{\rm avail}$ data is far below the simulation. Figure from PRL116(2016)071802. **Right**: ^{4}He Longitudinal Response at momentum transfer $q = 500$ MeV calculated in exact GFMC [1] (solid dark green), STA (solid magenta), LIT [2] (dashed blue), and Plane-Wave-Impulse Approximation (dotted cyan), to be compared with the experimental data (empty circles).

Interfacing Nuclear Theory with GENIE

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With this research plan I propose to utilize the Intensity Frontier Fellowship to efficiently and properly implement accurate neutrino-nucleus cross sections into neutrino generator codes. This will lead to improved neutrino energy reconstructions, which is crucial for the extraction of neutrino oscillation parameters. A close and active collaboration with GENIE developers and MINERνA experimentalists is essential. Therefore, I plan to utilize the fellowship to support short and extended stays at Fermi Lab during the period of October 15th 2017 - April 15th 2018. In order to emphasize the urgency and importance of this research plan, in the rigth panel of Fig. 1 it is shown a comparison between the reconstructed available energy and the one calculated from GENIE. The discrepancy between dotted and solid lines is a clear indication that a more sophisticated implementation of nuclear models into the GENIE code is required.

At Los Alamos National Laboratory, we are developing the Short-Time Approximation (STA) that allows to evaluated electroweak cross sections for $A > 12$ nuclei without losing the important dynamics that comes from two-body physics, which is crucial to explain available experimental data. In the left panel of Fig. 1, I compare the STA calculation of the ^{4}He Longitudinal Response function at $q = 500$ MeV with the exact calculation carried out in Refs. [2]. The agreement betweens STA and exact calculations is excellent. We plan to have inclusive electromagnetic and CC cross sections off ^{4}He, comprehensive of contributions from two-body electroweak currents, by August 2017. I propose to use the Intensity Frontier Fellowship to support and facilitate a close collaboration with the GENIE developers (Dr Gabriel Perdue *et al.*) and MINERνA experimentalists (Dr Minerba Betancourt *et al.*) with the goal of addressing the pressing issue of how to properly implement the calculated neutrino-nucleus cross sections into the neutrino generator codes.

1. S. Bacca and S. Pastore, 'Electromagnetic reactions on light nuclei', J. Phys. G: Nucl. Part. Phys. **41**, 123002 (2014) and references therein.

2. A. Lovato, S. Gandolfi, J. Carlson, Steven C. Pieper, R. Schiavilla 'Electromagnetic and neutral-weak response functions of ^{4}He and ^{12}C' Phys. Rev. C 91, 062501 (2015).

Close Out Report: Interfacing Nuclear Theory with GENIE

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I used the Intensity Frontier Fellowship to visit FNAL for less than the requested time due to a transition to a new job that did not allow me to travel for extended periods of time. However, the fellowship's deadline has been kindly extended until spring 2019. This gave me the opportunity to make significant progress in the proposed research.

During my visits I productively interacted especially with Joshua Barrow, Steven Gardiner, and Minerba Betancourt on how to effectively implement lepton-nucleus cross sections evaluated within the Short-Time-Approximation (STA) into GENIE.

My main contribution has been providing nuclear response functions and response densities, calculated using the STA supplemented by ab initio nuclear Quantum Monte Carlo computational methods [1], for different values of momentum and energy transfer to the nucleus.

Joshua Barrow and Steven Gardiner have implemented the STA nuclear response functions into GENIE and successfully validated them against available experimental data for electron scattering on the alpha particle. This is a very important prerequisite for all further implementations of calculated cross sections into GENIE. These include implementations of two-body (proton-proton, neutron-neutron, proton-neutron) nuclear electromagnetic response densities and validation against the experimental data; and implementations of electroweak response functions and response densities and extraction of neutrino energies.

The support provided by the IFF has been crucial to the advancement of the proposed research. During the visits at FNAL we were able to set up strong foundations for ongoing collaborations on properly implementing accurate neutrino-nucleus cross sections into the neutrino generator codes.