Intensity Frontier Fellowship Final Report

Gil Paz
Wayne State University

Professor Gil Paz from Wayne State University spent the Fall 2018 semester at Fermilab supported by a Simons fellowship and an Intensity Frontier fellowship.

Paz participated in seminars of the neutrino division, seminars of the theoretical physics department, joint experimental-theoretical neutrino meetings, a tutorial for theorists by GENIE people, and a neutrino town hall meeting concerning the neutrino theory network.

Paz had many discussions with members of the neutrino devision, in particular with GENIE people. These discussions will influence Paz's future research directions:

- A recent development in neutrino experiment is the partial reconstruction of the nuclear final state. In particular, experiments are starting to measure kinematical information on a nucleon in the final state. Experimental processes like charge current quasi elastic scattering had traditionally only measured the final state charged lepton. In this sense the measurement is inclusive. The additional kinematical information implies that the measurement is becoming semi-inclusive and can be more differential. This calls for the calculation of semi-inclusive theoretical predictions to assist the experimental effort. An analog development has happened in B physics in the transition to the B factories. Paz has worked on this topic in B physics and he would like to address the theoretical need for neutrino physics in the near future.

- For new theoretical calculations there are typically two stages. The first is an analytic and/or numerical calculation and the second is its validation against experimental data from some experiment. After talking to the GENIE people Paz has realized the benefit of separating the second stage from the first and having it done in GENIE. This allows for a broader comparison to several experiments and expedites the completion and publication of the first stage.

During his fellowship Paz has also completed a paper on muon-proton scattering using an effective field theory called QED-NRQED. In such a scattering a muon with momentum of the order of the muon mass, described by QED, scatters off a proton, described by Non-Relativistic QED. A goal of such a scattering is to probe two-photon exchange effects that can be relevant for the proton radius puzzle. At the lowest power in the inverse of the proton mass these effects give rise to two contact interactions: a spin-independent one and a spin-dependent one. An explicit matching done in this paper gave the surprising result of a zero Wilson coefficient for the spin-independent interaction. This implies that such a muon-proton scattering will be sensitive mainly to the proton charge radius and not to spin-independent two-photon exchange effects. The paper is available on arxiv.org as arXiv:1812.05056.