Statement of Research

I developed a novel directional event reconstruction algorithm for high-energy $\gtrsim$GeV scale neutrinos while working with KamLAND (Kamioka Liquid Scintillation Antineutrino Detector), and demonstrated with data for the first time that this technique can be applied to indirect dark matter searches by looking for a directional flux of neutrinos from the core of the Sun and Earth. Studies done with Monte Carlo suggest that the accuracy of deducing the neutrino direction using this new method is better than that of water-Cherenkov detectors (the conventional method for directional neutrino detection) by $\sim$10° in this energy regime. This method was verified using never before observed neutrino events spilling into KamLAND from the T2K neutrino beam-line. The results were consistent with expectation. According to my knowledge, this is the first ever physics application of neutrino directionality in scintillator.

My work with KamLAND further involved demonstration of 3-dimensional topological event imaging techniques, originally developed in the LENA (Low Energy Neutrino Astronomy) collaboration, but applying this to data for the first time. The $\sim$3.5 ns timing resolution of the PMTs (photomultiplier tubes) employed in KamLAND are not good enough to do a detailed imaging of all the individual final state particle tracks in a neutrino event. Nevertheless $\gtrsim$GeV muon tracks and high enough energy tracks in a neutrino event were imaged as well as the overall average direction of the final state particles to resolve the incoming neutrino direction. In addition $\mathrm{d}E/\mathrm{d}x$ profiles were investigated to perform unprecedented particle ID studies in scintillator at these energies. A paper employing these techniques I developed to conduct an indirect dark matter search is currently under preparation.

In addition, I was the lead Geant4 simulation designer for the mini-TimeCube collaboration at University of Hawaii at Manoa. mini-TimeCube is an ambitious project to build the world's smallest portable neutrino detector. In this project, I conducted case studies for optimizing the detector design, tested candidate neutron capture doping elements in plastic scintillator, and simulated the response of the multi-channel-plate (MCP) PMTs deployed in the detector. The studies were used during construction of the detector, and to develop directional algorithms that are now being tested in analyses of neutrons from test sources as well as neutrinos from the nuclear reactor at NIST. Working with the mini-TimeCube project has further involved designing and fabricating PCB boards as well as contributing to the FPGA firmware for the readout electronics. A paper summarizing our accomplishments was published in 2016 (V. A. Li et al. Invited Article: miniTimeCube. Rev. Sci. Instrum., 87(2):021301, 2016, 1602.01405).

My work in scintillator R&D for HanoHano, a proposed 10 kt-scale deep-sea based neutrino detector, involved designing and building apparatuses using CAD for measuring light output of Linear alkylbenzene (LAB) based liquid scintillators when put in large electric potential gradients as well as testing their light transmissivities under extreme temperatures and pressures such as those found in deep-sea environments. This project included mentoring an undergraduate student on techniques for shielding electronic apparatuses and working with another graduate student on designing and operating the cold high pressure environment device.

I have been involved with the CUORE (Cryogenic Underground Observatory for Rare Events) experiment at the University of California, Los Angeles (UCLA) since early 2016. The main objective of the CUORE experiment is to search for Majorana neutrinos by observing neutrinoless double beta ($0\nu\beta\beta$) decay in ^{130}Te. CUORE employs an almost 20 fold increase in detector mass compared to its previously successful pilot experiment CUORE-0. My work in the collaboration currently involves development of a precision α background model to better understand the radioactive contaminations in the detector. The energy spectrum of the backgrounds in the so called α region ($\gtrsim$ 2.7 MeV) exhibit peculiar features that, if understood correctly, will better explain the types of contamination sources and their physical distributions in the materials comprising the experiment. This can help us to better understand our backgrounds and extrapolate this understanding to the energy region of interest (2465–2575 keV) for $0\nu\beta\beta$ decay in ^{130}Te. I have previously also mentored 2 undergraduate students and worked together with them to simulate and investigate new radioactivity shielding schemes for further background reduction in future $0\nu\beta\beta$ decay experiments that will cover the inverted hierarchy region of the effective Majorana neutrino mass. A paper for our first $0\nu\beta\beta$ analysis using CUORE data was published in March 2018 (https://arxiv.org/abs/1710.07988).

As a postdoctoral researcher in your team at Duke University, I would like to continue my research in the field of neutrino physics. I believe that my past accomplishments solving difficult problems with novel ideas and my solid experience working in a variety of neutrino detection experiments makes me a strong candidate for your position.