**DUNE Science**

**Opportunity:** The primary focus of the DUNE science program is to address the fundamental open questions in particle physics and astro-particle physics to determine if there is CP-violation in the lepton sector. The ANL science and research goal is to maximize the sensitivity to CP-violation with a combination of improved energy reconstruction and optimized event classification. Measurement of the CP-violation phase requires determination of the electron neutrino and antineutrino spectra, as measured with charged-current reactions with electrons or positrons in the final state. In addition, improvements in energy scale and event reconstruction would enhance physics sensitivities with other physics topics such as potential SN observation, proton-decay search, and BSM physics. The DUNE target is <1% on the energy scale bias across the entire FD volume.

**ANL Contribution:** The ANL research program is focused on improving physics sensitivities using energy scale calibration and energy reconstruction that combines collected TPC charge with measured PDS light (with information on event timing and number of observed photons). The proposed technical contributions include 1) HVS (to provide efficient charge collection), 2) Laser Calibration (to reduce energy scale systematics from electric field non-uniformities), and 3) PDS calibration system (to monitor PDS stability in terms of gain, time-resolution, light collection efficiency, and linearity). The overall research focus builds upon ANL prior roles in successful construction, operation, and data analysis in ProtoDUNE-SP. In LAr, individual particle tracks ionize and some of the ions recombine with ionized electrons, producing prompt photons, whereas the non-recombined ions and electrons are collected by the TPC. Use of the light from recombination combined with collected charge has been shown to improve overall energy resolution in experiments like EXO. Our research program proposes to utilize calibration techniques that are being developed by ANL with ProtoDUNE data, such as Michel electrons, through-going muons and test beam particles to improve physics sensitivities. ANL analysis, construction and operations roles will enable the group to utilize expertise and capabilities in High-Performance Computing, in areas of data-intensive computing (simulation, data processing, machine-learning based event classification). The computing will be used to optimize event classification to maximize the electron-neutrino electron efficiency. We propose to benchmark “baseline” data-intensive computing techniques against conventional data-flow/H-matrix algorithms.

**Deliverables:** (1) Energy calorimetry using event tracks (TPC) and recombination photons (PDS), with the goal to measure the lepton energy deposition with a bias less than 1%. (2) Particle identification based on calorimetric and track reconstruction.

**Impact:** The Argonne group will strengthen the DUNE physics program with improved physics sensitivities through energy calibration and energy scale reconstruction, using beam particle and cosmic muon data from ProtoDUNE-I and ProtoDUNE-II. Argonne will transfer the ProtoDUNE energy scale calibration and improvements to DUNE. ANL group will enable improvements in particle identification through data processing with advanced HPC algorithms.

**Estimated effort**: Activities 1) - 2) will be staged, with a constant 1 FTE scientist and 1 FTE postdoc, starting in 2020 and continuing through DUNE Science phase. The scientist and postdoc science efforts are split with technical roles in HVS, PDS, Laser Calibration, and Computing areas.