Project Summary

This collaborative proposal from the University of Chicago, Columbia University, and Barnard College requests funds to construct the outer muon veto and tagging system for the Double Chooz neutrino oscillation experiment. The goal of the experiment is the measurement of θ_{13}, the last unmeasured angle of the neutrino mixing matrix, with almost an order-of-magnitude better sensitivity than the current best limit. The veto system is the main detector element used to suppress backgrounds and understand their systematic uncertainties, which will be essential to reaching the experiment's sensitivity goal. In addition, this proposal has a strong education and outreach component in which undergraduate students, including a significant group of female students from Barnard College, will take part in all aspects of the project.

Intellectual Merit: Recent years have seen enormous progress in the physics of neutrino mixing, but several critical questions remain: What is the value of θ_{13}, the last unmeasured mixing angle in the neutrino mixing matrix? What is the mass hierarchy? Do neutrino oscillations violate CP symmetry? Why are the quark and neutrino mixing matrices so different? The value of θ_{13} is central to each of these questions. Its value sets the scale for experiments needed to resolve the mass hierarchy and to search for CP violation. In addition, the size of θ_{13} with respect to the other mixing angles may give insights into the orgin of these angles and source of neutrino mass. Reactor experiments hold the promise of unambiguously determining the θ_{13} mixing angle.

The Double Chooz Experiment will use two Gd-loaded scintillator detectors near the Chooz Nuclear Power Station in France. Running will be performed in two phases, with a single far (L $\sim$ 1 km) detector run for 1.5 years, followed by a two detector (one near and one far) run beginning in 2009. The design sensitivity of $\sin^2 2\theta_{13} \sim 0.03$ will be reached after approximately three years of two-detector running, providing short-timescale information about the magnitude of θ_{13}.

As a result of the few MeV energy of the reactor antineutrinos, cosmogenic backgrounds are a serious issue for reactor experiments. The Double Chooz Experiment uses a two-part, inner-outer veto system to reduce and measure these backgrounds. We propose to construct the outer veto, a large-area system of scintillating counters placed above the detector. The combined inner-outer veto system reduces backgrounds from accidentals, fast neutrons, and muon capture by large factors. In addition to providing significant background suppression, the outer veto is expected to be a powerful tool in studying backgrounds, particularly the ^{9}Li background, which is not well understood and is the dominant background systematic uncertainty.

Broader Impact: As outlined in the APS Multidisciplinary Study on the Future of Neutrino Physics, the future program in neutrino oscillation physics depends on the magnitude of θ_{13}. If $\sin^2 2\theta_{13} < 0.01$, techniques beyond the currently planned long-baseline experiments will be needed to determine the mass hierarchy and observe CP violation. As mentioned above, the Double Chooz Experiment will provide the needed information about the scale of $\sin^2 2\theta_{13}$ on a short timescale.

If the Double Chooz experiment demonstrates that θ_{13} is nonzero, searches for CP violation will be particularly compelling. CP violation in the neutrino sector may ultimately help explain the baryon-antibaryon asymmetry in the universe through leptogenesis. Although most models of leptogenesis rely on direct CP violation in the decays of heavy Majorana neutrinos, observation of any CP violation in the neutrino sector would be an important clue to one of the most fundamental questions in particle physics.