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Cheryl E. Patrick

Measurement of the  
Antineutrino  
Double-Differential  
Charged-Current  
Quasi-Elastic Scattering  
Cross Section at MINERvA

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*Dedicated to my Dad, Richard Patrick, who I  
wish was here to read this. I miss you.*

# Supervisor's Foreword

The MINERvA experiment is dedicated to the detailed study of neutrino cross sections in anticipation of a need for precision understanding of interaction rates at the 2–3% level for long baseline neutrino oscillation measurements. The clean quasi-elastic scattering channel (CCQE) is of particular interest as it allows a well-defined measurement of the otherwise unknown incoming neutrino energy.

Quasi-elastic scatters are relatively simple interactions that make up a large component of the total neutrino interaction cross section in the MINERvA energy range. The signature for neutrino quasi-elastic scattering is  $\nu + n \rightarrow \ell^- + p$ , while for antineutrinos, it is  $\bar{\nu} + p \rightarrow \ell^+ + n$ . In both cases, the full event kinematics can in principle be reconstructed from the angle and momentum of the outgoing charged lepton alone. Because of their simplicity and constrained kinematics, they are considered the “golden” signature for studies of the oscillation processes  $\nu_\mu \rightarrow \nu_e$  and  $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ . Precise knowledge of quasi-elastic scattering, in particular the effect of the nuclear environment on the kinematic reconstruction and rates, is therefore crucial to neutrino oscillation experiments such as NOvA, MINOS, T2K, and DUNE. An understanding of differences between neutrino and antineutrino cross sections for both electron and muon neutrinos will be essential for experiments hoping to measure CP violation. Cheryl E. Patrick's dissertation represents the most detailed of the rare antineutrino CCQE process in the few GeV range.

In this dissertation, Dr. Patrick reports the antineutrino scattering rate as a function of two kinematic variables which allows much more detailed study of the kinematics of the antineutrino nucleon interactions. This will be the definitive MINERvA measurement from the low energy running for CCQE in the antineutrino channel, and it will become an important contribution to the field of neutrino cross sections.

Corvallis, OR, USA  
August 20, 2017

Prof. Heidi Schellman

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