

# Intensity Frontier Fellowship Final Report – Laura J Fields

I was a Fermilab Intensity Frontier Fellow from January 1st to December 31st 2014. During this time, I contributed roughly equal amounts of time and effort to two intensity frontier experiments: MINER $\nu$ A and LBNE (now known as ELBNF).

My primary contribution to the MINER $\nu$ A experiment was serving as the collaboration’s Analysis Coordinator – leader of the entire MINER $\nu$ A physics and data analysis program. I was responsible for developing long term plans for physics results and for overseeing approximately 20 active data analysis projects. During 2014, the MINER $\nu$ A analysis effort that I led published two papers in Physical Review Letters, submitted two more papers that are currently under journal review, gave three Fermilab Joint Experimental-Theoretical Seminars, and produced numerous other preliminary results that were shown at conferences such as Rencontres de Moriond and Neutrino 2014. We also began analyzing MINER $\nu$ A’s new “medium energy” data and laid a foundation for improvements to our software and algorithms that will allow MINER $\nu$ A’s data analysis effort to be successful for years to come.

On LBNE, I was both a leader of and a major contributor to the beam simulation effort. During 2014, our group reached a number of milestones, including a first complete estimate of LBNE alignment uncertainties, implementation of a new 1.2 MW beam design, and study of a variety of beam design options. I personally developed a new beam optimization algorithm that uses a genetic search heuristic to scan the phase space of beam parameters such as horn currents, horn positions, and target geometry. My algorithm includes a new method of calculating approximate CP sensitivity that gives similar results to LBNE’s Fast Monte Carlo simulation, but reduces the required CPU time from a week to a few seconds. This algorithm found several new beam configurations that improve ELBNF’s sensitivity to CP violation.

As part of the work described above, I also served as an informal advisor to several students working at Fermilab, including Cheryl Patrick, a Northwestern graduate student studying quasi-elastic interactions on MINER $\nu$ A, and Amit Bashal, an undergraduate student from the University of Texas at Arlington working on LBNE beam simulations.

## How Fermilab Aided These Activities

As the host institution for both MINER $\nu$ A and ELBNF, Fermilab is the backbone for all of the work I do. One particular way that the lab was helpful was by providing extremely capable personnel (including Debbie Harris, Minerba Betancourt, Paul LeBrun, Alberto Marchionni, Vaia Papadimitriou) who were very helpful in coordinating analysis plans on MINER $\nu$ A and in solving problems that arose during my various LBNE beam-related projects.

Another factor in the success of my work, particularly that which involved simulating the LBNE beam, was the computing infrastructure at Fermilab. To conduct the beam optimization study, I used hundreds of thousands of CPU-hours on the FermiGrid and got significant help

from Fermilab computing experts such as Mike Kirby and Tom Junk on how to best make use of computing resources.

## Comparison of Fellowship Activities to Proposal Activities

As I planned when writing my proposal, I split my fellowship time between contributions to MINER $\nu$ A and LBNE. The nature of those contributions was similar to but not identical to those I envisioned in the proposal. For example, I continued working on antineutrino quasi-elastic scattering as I had planned, but primarily through mentorship of Cheryl Patrick. Most of my work on MINER $\nu$ A was related to overseeing the collaboration's many different analysis projects. On LBNE, I devoted my attention to beam simulations work as I proposed, and finished the estimation of alignment uncertainty and tolerances that I mentioned in the proposal. Although I thought at the time of the proposal that our next major task would be related to estimation of hadron production systematics, requests of the LBNE beam group to study beam optimizations made that the primary focus of my LBNE work as an IF fellow.

## How Fermilab Benefited

Nearly all of my work during the fellowship period was aimed at aiding the Fermilab Neutrino program. Specific contributions included my leadership of the MINER $\nu$ A analysis program that produced several publications, executing many studies done at the request of LBNE and PIP II beam experts, and traveling around the country to speak about MINER $\nu$ A, LBNE, and the important work that is being done at Fermilab.

Another small but important role that I was able to play involved facilitating communication across different parts of Fermilab's neutrino program. In particular, I was able to convey important beam simulation issues discovered by LBNE (such as the importance of simulating water on the focusing horns) to MINER $\nu$ A and, at the request of LBNE, extracted MINER $\nu$ A flux uncertainties and presented them for approval so that they can be used as placeholders for LBNE flux uncertainties.

## Conferences and Presentations

### Meetings, Talks, and Conferences Using Fellowship Travel Funding

- MINER $\nu$ A Collaboration Meeting, June 2014, Duluth, MN.
- LBNE Software and Computing Review, April 2014, Gaithersburg MD.

### Other Meetings, Talks, and Conferences During Fellowship Period

- *Recent Neutrino-Nucleus Scattering Results from MINER $\nu$ A*, Argonne National Laboratory HEP Lunch Seminar, 9 December 2014.

- *Neutrino-Nucleus Scattering Results from MINERνA*, Massachusetts Institute of Technology LNS Lunch Seminar, 30 September 2014.
- *MINERνA Constraints on the NuMI Beam Flux*, 9th International Workshop on Neutrino Beams and Instrumentation, 26 September 2014.
- *Cross Sections And What They Tell Us*, Fermilab IF Summer Lecture Series, 10 July 2014.
- *Recent Results from the MINERνA Experiment*, Fermilab User’s Meeting, 12 June 2014.
- *LBNE Neutrino Yields Versus Proton Energy*, PIP II Collaboration Meeting, 4 June 2014.
- *Neutrino Cross Sections*, APS April Meeting, 7 April 2014.
- *Bringing Neutrinos into Focus for LBNE*, Univ. Mississippi Colloquium, 17 May 2014.
- *Quasi-Elastic Scattering at MINERνA*, Michigan State HEP Seminar, 25 February 2014.
- *Quasi-Elastic Scattering at MINERνA*, Stony Brook HEP Seminar, 19 February 2014.
- *Quasi-Elastic Scattering at MINERνA*, SLAC Experimental Seminar, 14 January 2014.
- *Quasi-Elastic Scattering at MINERνA*, Pittsburgh PAC Seminar, 9 January 2014.

## Publications And Other Documents Resulting From Fellowship Activities

### Refereed Papers as MINERνA Analysis Coordinator

- [1] B. Eberly et al. “Charged Pion Production in  $\nu_\mu$  Interactions on Hydrocarbon at  $\langle E_\nu \rangle = 4.0$  GeV”. In: *Submitted to Phys.Lett.* (2014). arXiv: 1406.6415 [hep-ex].
- [2] A. Higuera et al. “Measurement of Coherent Production of  $\pi^\pm$  in Neutrino and Anti-Neutrino Beams on Carbon from  $E_\nu$  of 1.5 to 20 GeV”. In: *Phys.Rev.Lett.* 113 (2014), p. 261802. DOI: 10.1103/PhysRevLett.113.261802. arXiv: 1409.3835 [hep-ex].
- [3] B.G. Tice et al. “Measurement of Ratios of  $\nu_\mu$  Charged-Current Cross Sections on C, Fe, and Pb to CH at Neutrino Energies 2-20 GeV”. In: *Phys.Rev.Lett.* (2014). arXiv: 1403.2103 [hep-ex].
- [4] T. Walton et al. “Measurement of muon plus proton final states in  $\nu_\mu$  Interactions on Hydrocarbon at  $\langle E_\nu \rangle = 4.2$  GeV”. In: *Submitted to Phys.Rev. D RC* (2014). arXiv: 1409.4497 [hep-ex].

### Technical Notes

- [5] L. Fields. “LBNE Beam Alignment Tolerances and Systematic Uncertainties”. In: *LBNE DocDB 8410* (2014).