

Report on Intensity Frontier Fellowship

Raj Gandhi, 2014

I spent about 18 weeks at Fermilab as IF Fellow in 2014 . I list below a summary of what was accomplished during this period.

1) *Specific activities that were facilitated by the Fellowship Funding:*

A: Work and many extensive discussions with Sanjib Mishra, Xinchun Tian and Roberto Petti on the physics of the ND, with its three major goals of i) Systematics reduction for FD oscillation measurements, ii) Precision measurements related to neutrino physics and iii) Searches for new physics in the FGT ND. This contributed to the preparation of detailed documents, many currently on docdb and some submitted to Indian funding agencies. A clear understanding of the rich physics capabilities of an FGT is of paramount importance to fully realize the short baseline physics potential of the LBNF program, and a major portion of my time as IF fellow was spent on discussions related to this. Work (including many iterations and revisions) on this is recorded the 177 page detailed project report (DPR) submitted to the Indian Funding agencies.(**Doc 6704** in the LBNE document database.)

B: Initiation and Completion of Level 1 Physics requirements of the ND. This work is documented in **LBNE-doc-8806**. I wrote the requirements for the ND aided by regular discussions with Milind Diwan, Jeff Dolph, Sanjib Mishra, Christopher Mauger and Roberto Petti.

C: Discussions and meetings with Christopher Mauger, Jim Strait, Milind Diwan, Bob Wilson and others related to the formation and development of the Indian group in LBNE/LBNF.

D: It was felt (both by students and members of the PPD) that Indian students lacked a certain advanced preparation which would allow them to be well-rounded in particle physics. For about 6 weeks in the evenings, twice every week, I gave lectures to them in the Black Hole in WH on “*Group Theory and Particle Physics*”. They were intended to be about an hour and 15 mins each, but there were so many questions that they often ran over two hours.

E: I attended Neutrino 2014, was part of the organizing committee for the Near Neutrino Detector Workshop held at Fermilab in July, where I also gave a talk. In addition, I participated in the program “Present and Future Neutrino Physics” at KITP, Santa Barbara (Oct 20- Nov 7 2014) . I also gave an Invited Talk at the conference “**Neutrinos: Recent Developments and Future Challenges**”, on

"LBNE :Physics and Status", on Nov 7, 2014, at KITP. I also participated in the "Physics of the NND" workshop at CETUP 2014 in Lead, SD.

2) Discussion of how being at Fermilab aided in these activities:

Both **A** and **C** above were greatly aided by my presence at Fermilab. While these activities were initiated while I was in India prior to coming, and are continuing now, the 10.5 (9.5) hour time difference between India and CT (ET), was a substantial impediment. In addition, the in-person discussions and the ease with which they could happen was a great asset to carrying the LBNE-ND effort forward.

In addition, **D** would have been impossible without actually being there. while **B** was again made much easier by the frequency with which discussions were held (mostly on Readytalk) with Milind Diwan, Christopher Mauger and Jeff Dolph.

3) Comparison of the things you got done with what you expected when proposing, including new things that happened.

When proposing, I had intended to make progress on **A**, **B** and **C** above. This happened to a large degree, although much work remains to be done under all 3 heads, especially in the context of the new internationalization process underway in LBNF.

A very unexpected and personally satisfying experience, (not planned prior to coming there) was the course I taught to 8 PPD students (**D** above) in the evenings in WH. I did not expect the kind of response it received -- after all these were experimentalists and I was talking about Group theory in Particle Physics, which I thought was perhaps not something they would be very excited about. However, the lectures turned into very interactive sessions with many questions and in-depth discussions, which were very rewarding for me as a teacher. They (the students) have made me promise to give a second course on my next long visit whenever it happens, and this time they want to hear about advanced topics in the Standard Model. It made me realize that there might be other students at Fermilab who could benefit from such a course, again something that I did not anticipate when I started to give these lectures.

During my tenure, I had discussions with Boris Kayser. We had felt that (from a theory/phenomenology perspective) we could do more to connect the SBL and LBL programs, both of which were so important to the lab. We (one of my graduate students, my postdoc, Boris and I) are studying the effect of the additional CP phases that enter into 3+N models (where the standard scenario is augmented by N sterile neutrinos) and the effect they would have on the CP sensitivity of LBNF.

4) *Your perspective on how Fermilab benefitted from your ability to be here, including interactions with collaborators and others.*

Almost all I would have liked to say on this topic has been included in 1-3 above, so I will not repeat it here.

5) *Any publications or other documents resulting from your stay:*

Papers worked on and written while at Fermilab (in which the IFF and Fermilab are acknowledged):

a) A Chatterjee et al, "*Testing non-standard neutrino matter interactions in atmospheric neutrino propagation*", **arXiv 1409.8472, submitted to Nucl. Phys. B.**

b) A. Bhattacharya et al, "*Astrophysical neutrinos, PeV events at IceCube, and the Direct Detection of Dark Matter*", **arXiv 1407.3280, submitted to JCAP.**

c) **Doc # 6704 and 8806 in the LBNE database.**

6) *Conferences or other presentations made possible by your funding.*

Invited Talk at the conference "**Neutrinos: Recent Developments and Future Challenges**", on "*LBNE :Physics and Status*", on Nov 7, 2014, KITP, Santa Barbara.

Invited Talk at the **Workshop on the Near Neutrino Detector** on "*Physics Issues related to the near Detector*", on July 29, 2014, Fermilab.

While at Fermilab I also gave a **High Energy/Cosmology Theory Seminar** on **2 October 2014 at UW Madison, on *Astrophysical neutrinos, PeV events at IceCube, and the Direct Detection of Dark Matter***

(the expenses were paid by the hosts).

