

ADDENDUM
to the
Memorandum of Understanding
between
US Universities & Accelerator Laboratories
and
Indian Universities & Accelerator Laboratories
concerning
Collaboration on R&D for Accelerator Physics and High Energy Physics
Projects

**Addendum IV: "US and Indian Institutions Collaboration on Neutrino
Physics, Related Experiments and Detector Development."**

Nov 10, 2009

1. Authority and Limitations

Pursuant to the Memorandum of Understanding ("MOU") between the U.S. Universities & Accelerator Laboratories and Indian Universities & Accelerator Laboratories dated January 9, 2006, Fermilab and Indian Accelerator Laboratories (the "Parties") intend to undertake the work described in this Addendum IV. The Parties acknowledge that their intended work shall be consistent with the terms and conditions of the MOU, the terms and conditions of their respective contracts and programs, and subject to the availability of appropriated funds as provided to them. The Parties further acknowledge and understand that their agreement with and signature to Addendum IV does not create a legal, contractual obligation for either Party nor may form the basis of a claim for reliance thereon. The Parties agree to comport their activities under Addendum IV in conformance with all applicable U.S. and Indian laws and regulations, including those related to export control.

2. Introduction

The work detailed in this document falls within the scope of the MOU cited above. It addresses two key areas of collaboration mentioned in the main MOU. These are: (i) Neutrino Physics; and (ii) Development of Novel and Large Particle Detectors. All terms and conditions under which the work will be carried out are found within the main MOU.

This Addendum to the MOU outlines the collaborative work that is being piloted on the US side by Fermilab, with active involvement of other US institutions collaborating on Fermilab Neutrino experiments, (referred to as the US Institutions in this document) and on the Indian side by a number of scientists from different universities and laboratories, including some from the institutions who are signatories of the January 2006 MOU. In particular it is being promoted by University of Delhi (DU) with active involvement of Banaras Hindu University (BHU), Cochin University of Science and Technology (CUSAT), Indian Institute of Technology Guwahati (IITG), Panjab University (PU), and University of Hyderabad (UH) with the guidance of Inter University Accelerator Center (IUAC). (Referred to as the Indian Institutions in this document) who plan to participate in various Fermilab based neutrino physics experiments (MINOS, NOvA and LB-DUSEL) and related experiment MIPP and the relevant atmospheric neutrino experiments.

3. Background

Fermilab and Indian Institutions have been collaborating on high energy physics experiments since 1985, first on the fixed target experiment E706 and then on the D0 collider experiment. The visiting scientists have made valuable contributions to the development and commissioning of the detectors, data taking, analysis, and publication of physics results. Several students have received Ph.D. degrees under the Indian Institutions-Fermilab collaboration. This collaboration has been flourishing with continued participation of many scientists on D0 and the collaboration of Indian Institutions on accelerator development under Addenda (I, II and III) to the MOU. (Addendum I: "Fermilab, RRCAT, BARC, IUAC and VECC Collaboration on ILC Main Linac SRF Accelerator Technology R&D", Addendum II: "SLAC, RRCAT, BARC, IUAC and VECC Collaboration on ILC RF Power Sources and Beam Dump Design R&D", and Addendum III: "Fermilab and Indian Accelerator Laboratories Collaboration on High Intensity Proton Accelerator and SRF Infrastructure Development"). Indian Institutions have made significant progress on the work that was outlined in Addenda I, II and III.

The Tevatron program at Fermilab is projected to last through FY2011. Its future running will depend on the progress made at CERN LHC. With the end of the Tevatron collider program, existing physics collaboration between Fermilab and Indian institutions on D0 experiment will come to an end. Furthermore, the energy frontier will shift from Fermilab to CERN.

The future of HEP at Fermilab as recommended by the P5 report on US particle Physics has three strong components – the energy frontier (LHC and future lepton colliders), the intensity frontier (neutrino and other fixed target experiments) and the cosmic frontier. Through this MOU we agree to participate in the current and future neutrino and related experiments at the intensity frontier that have been setup/envisioned at Fermilab, and in due course develop the much needed expert manpower for planned experiments in India. We wish to open a new chapter in this collaboration. The US Institutions are collaborators on Fermilab based experiments comprising the currently

running (MINOS and MIPP-I), under construction (NOvA), and the proposed (LB-DUSEL) experiments. The data from MIPP-I experiment is currently being analyzed. Based on the results of the MIPP-I data and a new proposal Fermilab management following the recommendations of the Fermilab Program Advisory Committee (PAC) and DOE-HEP may approve the construction and data taking of a follow-up experiment MIPP-II. All the MIPP-II discussion in this document should only be considered in the light of this pending approval.

There is a major program in India to establish an India-based Neutrino Observatory (INO) which proposes to measure the atmospheric muon neutrino and antineutrino interactions using a magnetized iron calorimeter (ICAL) and carry out neutrino oscillation studies over the largest range of neutrino energies and flight paths (L/E). INO would seek to measure neutrino mixing parameters and matter hierarchy. Building a strong manpower in Indian universities for this program is one of the major motivations of this proposal.

US and Indian Institutions have been in dialogue for collaborative effort since Nov. 2003. Projects in both countries have advanced to such a level that the benefits of mutual collaboration are manifest. The collaborators will work to advance the physics reach of these experiments, participate in detector design and technology development, and train the qualified technical human resources. During the Feb 10th 2009 meeting of the Fermilab and the Indian laboratories management the proposed work was discussed. We espouse a decade-long collaboration between US and Indian institutions scientists and technical staff on neutrino physics. The collaboration we envision is multifaceted.

Indian Institutions' interests: Indian Institutions participation in Fermilab based neutrino program will contribute to enhancing the physics capability of atmospheric neutrino experiments INO and LB-DUSEL.

- 1) To precisely interpret the data and enable future atmospheric neutrino experiments in reaching its full physics potential, it is crucial to have independent measurements from experiments at Fermilab.
- 2) First, the physics reach of any future atmospheric neutrino experiment including INO will be significantly enhanced by knowing the flux of neutrinos and anti-neutrinos from atmospheric cosmic ray showers. The atmospheric neutrino flux can be precisely measured by the upgraded MIPP experiment. Indian Institutions propose to collaborate on MIPP.
- 3) Second, any future atmospheric neutrino experiment (including INO) needs measurements of neutrino and antineutrino cross sections in the neutrino energy range from 0.5 to 20 GeV. But, most importantly, to reap the full benefit of an INO type program one needs to know the hadronic multiplicity (charged and neutral pions, kaons, protons) in neutrino induced charged and neutral current interactions as a function of neutrino energy (flux). The proposed HiResMu

experiment at Fermilab, which will also serve as an ideal near detector of the LB-DUSEL experiment, will provide these measurements with unparalleled precision.

- 4) Indian Institutions would like to train their scientific and engineering staff by participating in a running experiment that will enable valuable hands on experience in the design, fabrication, installation and operation of the INO type detector.
- 5) Indian Institutions would like to use Fermilab Test Beam facility for detector development.
- 6) The decade long vision for the Indo-US collaboration anticipates a continued participation of the Indian Institutions in the physics discovery that will be possible with the High Intensity Proton accelerators that are being developed under Addenda I, II and III of the MOU. The collaboration will begin with the MIPP experiment.

US Institutions' Interests:

- 1) US institutions wish to develop a long term intellectual partnership with Indian Institutions that can help break fresh ground through new collaborations in the ambitious neutrino projects at Fermilab: NOvA, DUSEL, and beyond. Such a sustained collaboration will provide much needed technical manpower, ideas, and instrumentation for these experiments of the future.
- 2) US institutions would also like to engage in and contribute to the growth of detector and related electronics development beneficial to Indian science program.

4. Work to be performed

The technical work to be carried out by this collaboration is outlined in the appendix. (Appendix: Indian Institutions Proposal) attached to this addendum to MOU. Here we present the Executive summary of the proposal.

The document "Indian Participation in the US Neutrino Program" is a proposal from Venktesh Singh (BHU), M.R. Anantharaman, V. C. Kuriakose, M. Sabir, Ramesh Babu Thayyullathil (Cochin University of Science and Technology), Brajesh Choudhary, Suresh Kumar, Samit Mandal (University of Delhi), Bindu Bambah, M. Sivakumar, A.K.Kapoor, R. Mohantha, Harikumar (University of Hyderabad), Bipul Bhuyan (IIT-Guwahati), Vipin Bhatnagar, Ashok Kumar, Jasbir Singh and Sandeep Sahijpal (Panjab University) to the Department of Science and Technology (DST) and Department of Atomic Energy (DAE) management in India. The consortium created by the proposed

project under the umbrella of DAE and DST would identify research tasks by the Indian groups in the Neutrino projects at Fermilab. The effort will enrich the Indian and the US Particle/Nuclear physics.

Indian physicists plan to build a 50 kton magnetized iron and resistive plate chamber (RPC) detector at India-based Neutrino Observatory (INO). It will detect atmospheric neutrinos and anti-neutrinos. The magnetic field allows separation of neutrino induced negative muon from anti-neutrino induced positive muons. Its major goal would be to measure CP violation and the mass hierarchy in the neutrino sector. The ability to distinguish in situ neutrinos from anti-neutrinos and the largest range of neutrino flight path and energy makes INO unique among the current and future long baseline projects.

Fermilab neutrino project includes MINOS, 5 kton magnetized iron calorimeter to measure neutrinos, MIPP-I and the proposed upgraded MIPP-II which will measure the neutrino flux with different beam projectiles (protons, pions, and kaons) interacting with nuclear targets that span the periodic table. The flux measurements from MIPP-II would prove most valuable for INO to achieve its full physics potential. A hands on experience with operating MINOS will prove an invaluable laboratory to train students and post-docs. The future neutrino projects at Fermilab --- NOvA and, especially, DUSEL are complementary to INO. The DUSEL project will follow INO and once the latter is in data collection mode, DUSEL offers a natural collaboration between the Indian and the US neutrino community.

Authors on this proposal are experienced nuclear and particle physicists. They bring varied research experience conducted at FNAL, CERN, BNL, GSI, LNGS, SLAC, and Taiwan. They aim to conduct precision measurements (MIPP-II, HiResMnu in DUSEL) at Fermilab that would be most valuable for INO's physics success. They seek to train students at MINOS which will serve Indian program's needs in reconstruction, simulation, and analysis. The proposed research will comprise: i) analysis of MIPP-I data ii) acquiring data on targets comprising of atmospheric nuclei on MIPP-II and subsequent data analysis iii) gain a hands on experience with the MINOS detector which can later help INO.

The proposal requests a three year funding from the Indian agencies for the calendar years 2010, 2011 and 2012

5. Scope of Work in FY10 - 12

We plan to start the collaboration by building up to a team equivalent of 6 FTE composed of Indian students and faculty. The team will begin work on the MIPP project. The students will start with the ongoing analysis of MIPP-I data. Most importantly, they initiate participation in the MIPP-II experiment once it is approved (expected in the last quarter of 2009). MIPP-II requires electronics upgrade that would enable the experiment to collect data - 150 times faster. The participants will gain valuable expertise in testing the prototype electronics cards. Indian institutions intend to build some fraction of the electronics once they have passed the prototyping stage as part of their hardware contribution to MIPP-II. This work is expected to take most of FY10.

The institutes would participate in acquiring data on targets comprising of atmospheric nuclei on MIPP-II and subsequent data analysis, and analyzing the pion and kaon production cross-section from these data will be handled by the Indian groups. These data will accurately measure the atmospheric neutrino and anti-neutrino flux.

The scope of this decade long collaboration, however, is much broader than the MIPP-upgrade data. The operational MINOS experiment is a 5kT magnetized calorimeter operating in the Soudan mine. We aim to train a set of two post-docs and two students to actively participate in learning the simulation, reconstruction, and analysis of the data acquired by MINOS. The hands-on-experience so acquired will-facilitate transfer of knowledge (acquired over decades of man-years) from MINOS to Indian Institutions.

Finally, future projects like NOvA --- and most importantly --- the long baseline DUSEL experiments offer natural collaboration between trained Indian neutrino community and the US neutrino research. To attain the full physics potential of a atmospheric neutrino experiment, we need measurements on the neutrino cross section and detailed multiplicity of particles produced in the neutrino interactions. These can only be accomplished at HiResMnu project which will serve as the 'ideal' near detector for DUSEL. The point is that HiResMnu will also serve as the ideal 'near detector' for any future atmospheric neutrino experiment. We emphasize that these projects at FNAL are in consonance with the INO objectives and the participation in them of community of Indian physicists will bring benefit to the Indian and US neutrino community --- and the physics community at large.

6. Schedule and Review

The detailed schedule of work described in this Addendum to the MOU will be elaborated in the Technical Annexes and a Technical Project Management document.

The schedule will be approved by the respective Project Managers in consultation with the Collaboration Coordinators. The schedule and progress will be jointly reviewed every six months and tasks may be added, deleted, or modified by mutual agreement. Both groups agree to report and evaluate progress at individual laboratory reviews by their respective funding agencies.

7. Funding

Consistent with General Provision 2.3 of the MOU, each Party shall be responsible for funding its own participatory activities. All participatory activities and related procurements are subject to the availability of appropriated funds, personnel, and resources.

Fermilab neutrino projects fund have been allocated for supporting the local expenses of all Indian scientists and engineers visiting Fermilab for work and meetings under this Addendum. Indian Institutions will be submitting a funding proposal to Indian Department of Science and Technology (DST) and Department of Atomic Energy (DAE) for supporting its scientific and technical staff and technical work they propose to carry out in this MOU.

All labor, materials and components available in India will be supplied by the Indian Institutions. Any hardware needed for use and development of the Indian Institutions infrastructure for the work to be performed under this Addendum will be paid by the Indian Institutions. Fermilab and US universities will not charge for any technical assistance provided under this MOU. Indian Institutions will provide visiting US scientists and engineers with local accommodations when possible at the institutions' site. The cost of travel for US institutions staff to India will be covered by US-DOE funds. The Parties mutually agree that costs associated with shipping materials and components shall be borne by the shipping Party and that any customs or duties applied to the items so shipped shall be borne by the receiving party.

8. Proposed mechanism for IPR sharing

The Intellectual Property Rights (IPR) sharing has already been well defined and described in detail between the Institutes involved in the document: Memorandum of Understanding between U.S. Universities and Accelerator Laboratories and Indian Universities and Accelerator Laboratories concerning collaboration on R&D for various Accelerator Physics and High Energy Physics Projects. It is to be noted that for all collaborative work under this MOU the proposed mechanism for IPR sharing will be exactly as envisaged in that document.

9. Project Management, Responsibilities and Approval

The Fermilab Director, assisted by the Associate Director for Research and the Director/ Heads of the Indian Institutions group have the ultimate responsibility and approval authority for the scope of work contained in this Addendum. Collectively this group represents the Institutional Management for their respective partners.

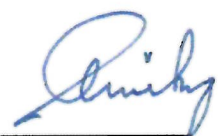
Fermilab and Indian Institutions in this collaboration will together provide oversight for the programs through a joint Collaboration Executive Committee (CEC). The CEC will be co-chaired by the Collaboration Coordinators. Collaboration Coordinators have the overall responsibility to provide oversight and coordinate the work done under this Addendum. They represent the institutions in their respective countries and serve as a single point of contact. Currently, Dr. Shekhar Mishra, Fermilab and Dr. Vinod C. Sahn, India serves as the Collaboration Coordinators. The technical work under this Addendum would be lead by Technical Project Managers (TPM). Prof. Sanjib Mishra, and Prof. Brajesh Choudhary are TPM representing US and Indian Institutions respectively.

This collaboration plans to submit a proposal to Indian funding agencies for work proposed under this MOU. The financial arrangement for this proposal will be worked out by Inter University Accelerator Center and the participating institutions, with the guidance from director of IUAC presently Dr. Amit Roy.

The membership of the CEC will be composed of Institutional representatives from each of the collaborating institutions in India and US, and a representative of IUAC in India. The collaboration coordinators will be able to appoint additional members and/or ex-officio members to the committee in order to represent a broader set of interests. The CEC, in consultation with the appropriate management structure of the various experiments in which this group will participate, will identify Liaison Officers, for each specific activity, who will facilitate collaboration.

The Collaboration Coordinators, in consultation with the CEC and the Liaison Officers, will call for periodic reviews of the project. They, in consultation with their respective Institutional Management will approve the plans developed by the Liaison Officers and decide on future direction of a project.

The following concur on the terms of this Memorandum of Understanding Addendum:

 10 Nov, 2009

Dr. Amit Roy
Director
IUAC

 11/16/09

Dr. Piermaria Oddone
Director,
Fermilab

 Nov 10, 2009

Dr. Vinod Sahni
Collaboration Coordinator
DAE, India

Date

 11/12/09

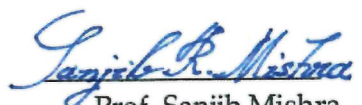
Dr. Shekhar Mishra,
Collaboration Coordinator,
Fermilab

Date

 10 Nov 2009

Prof. Brajesh Choudhary,
Technical Project Manager
University of Delhi, India

Date

 19 Nov. 09

Prof. Sanjib Mishra
Technical Project Manager
University of South Carolina, Columbia

Date

