# The fourth IDS-NF plenary meeting, TIFR, Mumbai, 12—14 October 2009: discussion document

## *1. Introduction*

The fourth plenary meeting of the International Design Study for the Neutrino Factory (the IDS-NF) took place in Mumbai from the 12th to the 14th October 2009. The goals of the meeting were:

- To review progress in the development of the baseline for the Neutrino Factory accelerator complex and neutrino detector systems;
- To review the potential of the Low-energy Neutrino Factory, especially in the event that $\theta_{13}$ is determined to be large;
- To review the baseline specification for the accelerator complex and detector systems and to agree changes as appropriate; and
- To agree the process by which the content of the Interim Design Report, which is due to be completed at the end of 2010, is defined.

The meeting was a success, each of these issues being addressed within the working group sessions and through plenary discussion. The timing of the meeting and logistical issues meant that not all those wishing to participate in the discussions were able to attend the meeting. The purpose of this note, therefore, is to summarise the principal issues discussed by those present in Mumbai so that a more inclusive discussion can take place through the IDS-NF working groups in preparation for IDS-NF#5 which will take place at FNAL from the 8th to the 10th of April 2010.

This note is organised as follows: brief summaries of the progress presented in Mumbai are given in section 2; the changes to the baseline configuration (IDS-NF baseline 2007/1.0, see [1]), proposed in Mumbai are summarised in section 3; notes on the proposed convergence process for the Interim Design Report (IDR) are given in section 4. Working group discussions of the proposed changes to the baseline and the convergence process will be organised with a view to the production of a revised baseline-specification document for release in advance of the FNAL meeting.

## *2. Short notes on progress at IDS-NF#4*

### 2.1 Physics and Performance Evaluation Group

Apart from some discussion of fundamental physics and recent studies, most of the physics sessions were devoted to the review of the IDS-NF baseline, such as the case for a low energy version of the Neutrino Factory, the silver-channel detector at the intermediate baseline, and an upgrade of the detector mass to 100kt (see below for more detailed discussions and conclusions). In addition, the importance of a near detector was emphasized, both for standard oscillation physics (for example for the measurement of neutrino cross sections) and for the search for new physics (for example, the role of tau neutrino detection). It was pointed out that the requirements for the near detector, such as its location and size, are important for new physics searches, whereas for standard oscillation physics, the size of the event sample collected in the far detectors usually limits the performance. For example, for oscillations into sterile neutrinos, the anticipated sensitivity range for the mass-squared splitting determines the baseline (source-detector distance). For non-standard interactions, the statistics in the near detector(s) is a limiting factor, and therefore determines the necessary fiducial mass. In the near detector(s), a clear case for tau neutrino detection was identified. Finally, the roadmap towards the IDR was laid out.

## 2.2 Accelerator Group

Following an overview of the status of the accelerator effort, with a focus on critical issues and the integration of the IDS-NF and EUROν working groups, the status of the proton driver projects were discussed in the light of recent work on particle yield at lower proton energy (4 GeV). While yield calculations seem not to disfavour lower proton energies, the required bunch compression at such a low energy is a challenge. Recent results on shock in solid targets and the fluidised power-jet target have been acknowledged as encouraging and will be considered as fallback options. Front-end simulations have been performed using RF gradients lower than the baseline and simulations of bunch-rotation schemes using assuming lower accelerating gradient and lower frequency. The performance of the options studied is not as good as that of the baseline design, but are comparable to it. It was noted that the lowering the RF gradient in the front end would reduce the muon yield. Good progress was reported on the muon linac, the RLAs and the muon FFAG. While in each of the cases no major issue is expected, the FFAG design work will require a longer convergence period and a final decision on the design will not be expected at the Chicago plenary meeting. In a joint session of all working groups the status of the decay ring design and the efforts on the beam instrumentation was discussed in conjunction with the status of the near detector and the influence of the near detector on systematics. In a similar way, the interdependencies between the energy spread of the muon bunches due to beam loading effects and due to the time of flight effect for the proposed gutter acceleration was discussed. It was agreed that the RLA design should be revised and optimised in respect for a LENF option at 4 GeV.

## 2.3 Detector Group

The magnetized iron detector (MIND) remains the baseline detector for high-energy neutrino factory and its basic design is well established. There are only a few significant R&D areas for this detector. These include studying whether a field of 1.7 T can readily be obtained in the iron, participating in the global effort on the silicon photomultiplier (SiPM) photodetector, and determining what test beam work is needed to vet the simulations and to integrate our efforts with the broader R&D effort in Europe (see below). The cross-sectional size of the detector still needs to be finalized as does the final plate thickness (4 cm versus 3 cm) and the type and shape of scintillator readout cells. A good deal of discussion was devoted to how MIND (or Neutrino Factory detectors in general) R&D is aligned with the detector R&D in EUROnu and the potential for participation in AIDA from the point of view of a neutrino detector test beam at CERN. The software framework for full neutrino event and detector simulation/reconstruction is now at an advanced stage (focusing on MIND) and should be applicable to study other detectors such as the Totally Active Scintillator Detector (TASD). There was an update on TASD with the low-energy neutrino factory option (LENF) but, so far, TASD has not been integrated into the software framework and work has only just begun on this effort. Detector R&D for TASD, which in addition to a common effort on photodetectors for wavelength-shifting fibre readout of scintillator, focuses on the proof-of-principle for very large air-core magnetic volumes. Although an R&D plan for these large magnets has been in place for some time, funding this effort remains a problem. We heard a report on the status of large Liquid Argon (LAr) detector R&D in Europe and in the US, but there still is not a strong push within the IDS-NF community to propose and/or study a LAr detector, which would have to be magnetized, as an option for the IDS-NF. The requirements for the Near Detector(s) (ND) at a Neutrino Factory were presented and discussed as were some of the unique physics possibilities. At this time, there is not a well-developed design for the near detector and, in this area, the IDS-NF is falling behind with respect to having a ND concept developed and costed at the level necessary for the Interim Design Report. Finally, a case for increasing the mass of the intermediate-baseline detector (CP detector) was made noting that the doubling in size is not unreasonable from a technology or cost standpoint and this doubling makes a significant improvement on the CP sensitivity. More work on systematic uncertainties needs to be done, however.

## *3. Changes to the IDS-NF baseline proposed at IDS-NF#4*

The present IDS-NF baseline (IDS-NF baseline 2007/1.0) is described in [1]. The changes to the baseline that were proposed at IDS-NF#4 are summarised below.

### 2.1 Low energy Neutrino Factory

The physics case for the Low Energy Neutrino Factory (LENF) was presented in [2] and the technical specification was reviewed in [3]. Further, the LENF was discussed in a number of working group sessions (see sessions listed in [4]). The IDS-NF approach to the LENF, and a specification of the proposed LENF configuration, was presented in [5].

Recognising that, for 'large $\theta_{13}$' ($\sin^2 2\theta_{13} > 10^{-3}$), the LENF has excellent performance for the determination of the standard neutrino oscillation parameters it was proposed that:

- The Low Energy Neutrino Factory will be presented as an option in the IDR.

The performance of the LENF is critically dependent on the low energy threshold and excellent energy resolution of the totally active scintillator detector (TASD) proposed as the baseline detector technology and on the delivery of the assumed neutrino flux. The Detector and Accelerator Working Group will review the proposed designs to provide assurance that the required performance can be achieved. The Physics and Performance Evaluation Group (PPEG) will review the optimisation of the LENF (stored-muon energy and source-detector distance).

### 2.2 Silver-channel detector at the intermediate baseline (3000—5000 km)

The issue of the justification of the inclusion of a detector dedicated to the detection of the silver, $\tau$-appearance, channel at the intermediate baseline was raised at IDS-NF#2 (FNAL, June 2008) [6]. In view of the importance of the issue, a dedicated discussion of the physics case for a dedicated silver channel detector at the intermediate channel was held at IDS-NF#3 (CERN, March 2008) [7]. The presentations for and against the inclusion of a silver-channel detector, and the subsequent discussion, provided sufficient justification for a review of the inclusion of the silver-channel detector to be initiated [8]. The PPEG group therefore prepared an IDS-NF note [9] in which the role of the silver channel was reviewed for discussion at IDS-NF#4. The discussions to date indicate that the following conclusions may be drawn:

- The statistical weight of the MECC presently included in the baseline intermediate-detector configuration does not give a significant impact on the determination of the standard oscillation parameters;
- The detection of the silver channel is important in the search for non-standard interactions and in the efforts to establish whether the neutrino-mixing matrix is unitary; and
- There is a strong case for the study of $\tau$-production at the near detector.

In order to maintain the capability of including a $\tau$-detector at the intermediate, and possibly the long, baseline, the IDR will carry the cost of sizing the cavern (or caverns) such that a $\tau$-detector can be implemented. A detector concept capable of delivering a statistically significant sample of $\tau$-neutrinos is required. For this to be achieved in time for an improved concept to be included in the IDR requires additional resources to be identified.

## 2.3 Mass of Magnetised Iron Neutrino Detector (MIND)

The issue of increasing the mass of the MIND detector at the intermediate baseline from 50 kT to 100 kT was initially raised at IDS-NF#3 [8,11]. Discussion at IDS-NF#3 concluded that the baseline mass should remain 50 kT. The case for increasing the mass of the MIND detector at the intermediate baseline to 100 kT was presented again at IDS-NF#4 [12]. In view of the increased sensitivity (see [12] and [13]) and the fact that the increased detector mass gives some margin for possible shortfalls in neutrino flux, it was proposed that:

- The mass of the MIND detector at the intermediate baseline (3000—5000 km) be increased from 50 kT to 100 kT; and
- The mass and granularity of the MIND detector at the magic baseline (7000—8000 km) be reviewed by the PPEG and Detector working groups with a view to revising the baseline specification for the MIND at the magic baseline.

## 2.4 Near detector

While the ISS detector report [14] included a conceptual design for a near detector, the IDS-NF baseline 2007/1.0 does not. Those present at IDS-NF#4 recognised that this was a serious omission and therefore proposed that the Detector Group develop an appropriate near detector, or suite of near detectors. The case for the near detector and the measurements it would be required to make were presented [15]. In the absence of a concrete proposal for the near detector configuration, it was agreed to propose that the IDS-NF baseline be revised to include a near detector (or near detectors) that is capable of making the following measurements:

- Measurements required to address systematic uncertainties in the measurement of neutrino oscillation:
  - Measurement of neutrino flux;
  - Extrapolation of the neutrino flux to the far detector;
  - Measurement of background from charm production; and
  - Measurement of the cross sections for deep inelastic and quasi-elastic scattering and the resonance-production cross sections.
- Unique opportunities for neutrino physics at the near detector:
  - Electroweak, QCD, polarised and unpolarised structure function measurements; and
  - The search for non-standard interactions through the detection of $\nu_\tau$.

In the event that manpower limitations imply that a conceptual design that meets all these requirements can not be developed for the IDR, it was agreed to propose that the class of measurements that are essential for the neutrino-oscillation programme be given the higher priority.

## 2.5 Proton driver bunch spacing and beam energy

The IDS-NF baseline 2007/1.0 specification for the proton driver bunch train is that 3 bunches, each of length between 1 ns and 3 ns,is delivered at a repetition rate of 50 Hz. The time over which the three bunches must be delivered was specified to be greater than 17 μs and less than 40 μs. The upper limit on the bunch separation was determined before the MERIT experiment was carried out on the basis of estimates of the likely degradation of the pion-production rate following the disruption of the mercury jet caused by the passage of the first bunch in the bunch train.

The results of the MERIT experiment are consistent with no loss in particle rate for inter-bunch separations of up to 350 μs [14]. It was therefore agreed to propose that:

- The specification for the bunch timing in the proton driver bunch train be revised such that the inter-bunch spacing be greater than 17 μs and less than 140 μs.

In the 2007/1.0 baseline specification, the lower limit on the acceptable proton driver energy was 5 GeV. This was motivated by a sharp fall off in pion-production rate for lower energies observed in simulations of pion production and capture. Results from the HARP experiment [15] presented at NuFact09 [16] demonstrate that the sharp fall off is a feature of the simulation rather than the physics of pion production. It was therefore proposed that:

- The bunch compression in the proton driver at a beam energy of 4 GeV be reviewed. If it proves to be possible to deliver the required bunch structure, the Accelerator Working group will consider revising the specification such that the proton beam kinetic energy is required to be in the range 4—15 GeV.

## *4. Convergence towards the IDR*

The overall structure of the IDR and the timescale on which it should be produced was discussed. It was agreed to propose that:

- The IDR be produced as a single document, approximately 150 pages in length, with a self-contained executive summary; and
- Each working group will provide a chapter of the document, each chapter being approximately 50 pages in length.

The IDR timescale, presented graphically in figure 1, has the following principal milestones:

- IDS-NF#5, FNAL, 08—10 April 2010:
  - Review of proposed contents of IDR by working group;
- IDS-NF#6, Autumn 2010:
  - Deadline for contributions to IDR; and
  - Start of editing process by Working Group conveners and Steering Group.

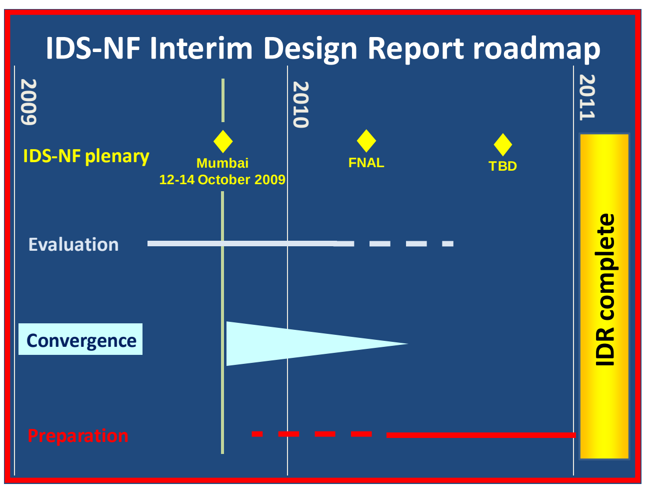


*Figure 1: Timeline for the preparation of the Interim Design Report.*

To meet this schedule not only requires significant amounts of preparation within the working groups, but improved cross-working-group communication. It will be important in the coming months to establish a pattern of working group, and inter-working group, tele-meetings that are well publicised to the IDS-NF community.

The planning of the route to the IDR that has been made within each of the working groups was presented in [17], [18], and [19]. These plans will now be developed further within the working groups.

The Steering Group will then work with the working group conveners to prepare a more detailed set of milestones for the preparation of IDS-NF plenary meetings 5 and 6 and for the preparation of the IDR itself.

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