Background note regarding ICAL magnet R&D effort

The following summarizes the current status of the R&D effort on the ICAL magnet:

1. Initial first order simulations for the full ICAL magnet have been done for the 2 and 8-slot (symmetrically placed) configuration for the 16 kton magnet module (consisting of 16m x 16m planes of low carbon steel plates) using MagNet 6.26. The plates used were 2m x 4m areal dimension and 6cm thickness and of the default low-carbon content steel. As expected the 8-slot configuration shows inhomogeneity near the slot while the 2-slot configuration shows much better piece-wise uniformity. The fields have been calculated, making use of the reflection symmetry across 3 (orthogonal) central planes, in within 1/8 of the volume using the boundary conditions such as normal and tangential field continuity on appropriate surfaces. The effect of inserting different gaps between the plates has been investigated. The effect of placement of the coils in the 2-slot configuration is being done. These will be continued to explore design options that tend to give homogeneous fields by design.

2. Measurement equipment of B-H hysteresis loop for large samples (upto $0.5\text{m} \times 0.5\text{m} \times 6\text{cm}$) of low-carbon steel has been ordered and is in the final stages of completion with the vendor. We intend to evaluate the existing samples and others made available by various vendors.

3. We propose to make and evaluate non-standard material compositions to suit the requirements of INO such as easy magnetisation upto 1.5 T and (flat) saturation beyond. The material additives are being explored at first including those available in literature.

4. Measurements on the magnetic field will be done by the 4th week of Dec08 at VECC, Kolkata on the prototype magnet for individual layers using a fluxmeter and the sense coils on each layer.

5. The comparison of simulations of prototype with the measured results, to be obtained shortly, will yield information on practical inefficiencies owing to several factors (cutting methods, gaps, mis-alignment between plates, plate non-planarity etc etc). The information we generate shall be used in design of the final module.

6. Practical models to quantitatively validate these points raised above have to be fabricated and put to real test to raise realistic design data.

7. We expect to get some feedback from SAIL, a local steel company, on possible tolerances on the 2m x 4m x (nominal) 6cm thick low carbon steel suitable for ICAL magnet. A visit to the Rourkela plant of SAIL is planned for the first half of Jan 09.

8. An MoU for making a 1/10 scale ICAL magnet at NFTDC, Hyderabad is being discussed.

9. Vendor development process shall begin after some clarity is obtained on the material requirement and design.

SOME INPUTS THAT ARE WELCOME:

1. Would it be possible to bring data on magnetic characteristics of soft iron plates in the thickness range 5 to 6 cm and size 2m by 8m from steel manufacturers? The applicable tolerance on physical dimensions and planarity may also be brought, if possible. We also want to explore

possibility of orientation during rolling of these plates and also some information on cutting methods used to size these plates.

2. Please bring any available information on role of additives to cast iron and their influence on the B-H characteristics of steel plate samples. In any case the B-H characteristics of existing samples may be brought.

3. A list of magnet and coil manufacturers located in Japan who would be interested in executing this work.

4. Experiences in the differences/gaps between simulations and measurements and how to incorporate them in design stage.

5. Experience on scaling up from proto-types say $1/500^{th}$ size to actual and the possibility of deviations.

6. Experience in design with finite element based software in regard to meshing at poor aspect ratio and possible inaccuracies resulting due to above cause.