Study on improving the field uniformity in the INO magnet

Y.P. Viyogi* and P.R. Sarma
Variable Energy Cyclotron Centre, Block-AF, Bidhannagar, Kolkata-700064
** email:viyogi@vecc.gov.in*

Introduction

The iron calorimeter of the forthcoming Indian Neutrino Observatory (INO) [1] consists of a number of modules of huge magnets. Each module has been thought to be an independent magnet of 17000 ton in weight. The magnet will comprise of 140 layers of iron plates of a thickness of 5.6 cm and separated by a distance of 2.5 cm for inserting RPC charged particle detectors.

The design philosophy is that most of the iron volume in the magnet should be useful for the experiment. If a portion of the total volume remains unutilized, that is a loss to the effective use of the instrument built at an enormous cost. This means that one should make an endeavour to make the field as uniform as possible over the whole volume of an iron layer.

There are, of course, other considerations like ease of adding successive modules, possibility of placing RPC detectors in a staggered manner, etc.

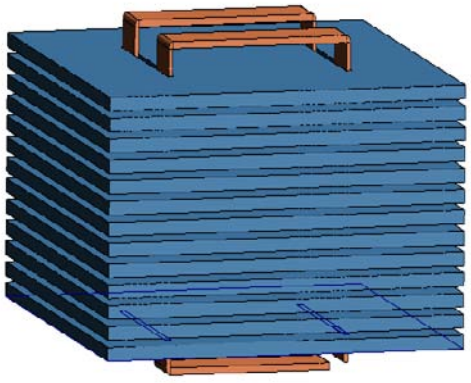

Fig.1. INO prototype magnet with a few layers

A prototype of the current design, which has not been frozen yet, is shown schematically in Fig.1 [2]. In the full magnet, each horizontal iron layer will be 16m long and 16m in width. There are two symmetrically placed slots of length 8m and about 20 cm in width, for inserting energizing coils.

As shown in in Fig.2, the magnetic lines of forces go around the coils as the magnetic circuit gets closed around it. As is evident, the lines of forces are predominantly parallel to the major length of the coil. The consequence is that the magnetic field also is uniform in that region. The field becomes non-uniform in the region where the lines of forces curve around. Therefore at the corners of the plates the field reduces drastically. This gives the idea that the coils (or rather, the coil slots) should be as long as practicable.

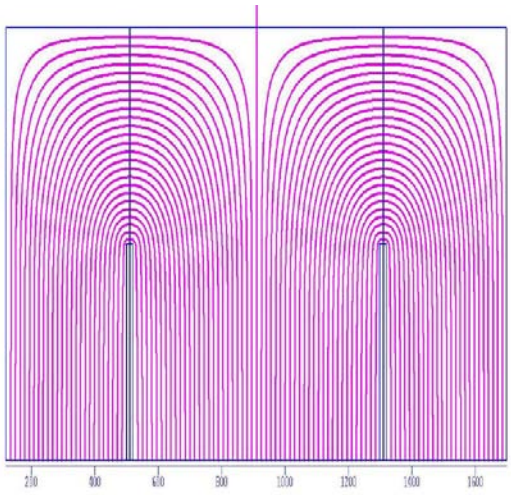

Fig.2. Field lines with coil slots 8 m separated.

Modified magnet assembly

Fig.3 shows a magnet geometry with longish coil slots. As a consequence of these long slots, the turnaround space for the lines of forces to pass through is smaller.

So the plate width also ought to be smaller, otherwise the magnitude of the field in the

uniform region decreases. As the plot of the field lines shows, the better uniformity in the major portion of the magnet is obvious.

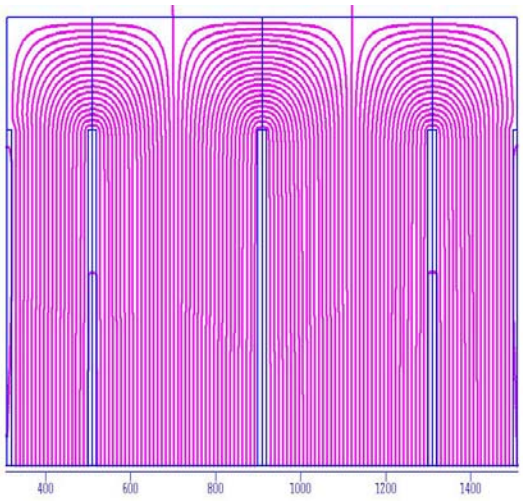

Fig.3. Field lines with coil slots 4m separated.

In order to have a quantitative idea of the improvement, we have plotted the percentage area in which the field is above a given value. Fig.4 shows the plot for various field levels. The field quality is evidently better for smaller slot widths.

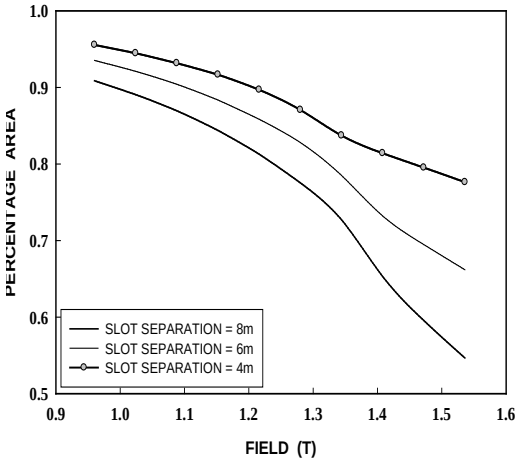

Fig.4. Improvement in field uniformity with slots separated by small distance.

Discussions

As can be seen from Fig.3 we have placed coils on the sides also. In a slot the coil is divided into two equal parts - one part goes to a slot on the right, and the other part goes to a slot on the left. This way, one does not have to build an entire module at one go. One can go on adding portions of the module progressively.

One should keep in mind the disadvantages also of having smaller separation between the slots. The number of coils and the associated cost increases in such an arrangement. The problem of staggering the detectors also is there. With this in mind one can think of a compromise by having a 6m separation between the coils.

In this calculation, no consideration has been taken that each iron plate will consist of smaller plates for ease of fabrication. The inevitable small gaps between the smaller plates will bring down the field. However, this will be so whatever the slot distances. The conclusions drawn in this calculation will still be valid.

References

[1] N.K. Mondal, Proc. Indian Natn. Sci. Acad. **70A**, 71 (2004).

[2] M.S.Bhatia, V.M. Datar, A.S.Dongare, P.R. Sarma, P.Verma and Y.P. Viyogi, DAE-BRNS Nucl. Phys. Symp. (Sambalpur) **52**, 609 (2007)