THE PROSCAN BEAM LINE DOUBLE STEERING MAGNET

D. George, M. Negrazus

This paper describes a novel solution to the old problem of how to fit two magnets in the space of one and nevertheless achieve good field quality and save power at the same time.

INTRODUCTION

When a charged particle transfer beam line is being planned, the last components to be considered are the steering magnets. They have to fit in the remaining space. They should be cheap and, if possible, not require an expensive cooling water supply. As in the present case, it became necessary to use a number of double steering magnets. Classic double steering magnets are easy to make but provide poor field quality and run at power levels higher than single steering magnets. We will describe the basics of the problem and present a novel solution.

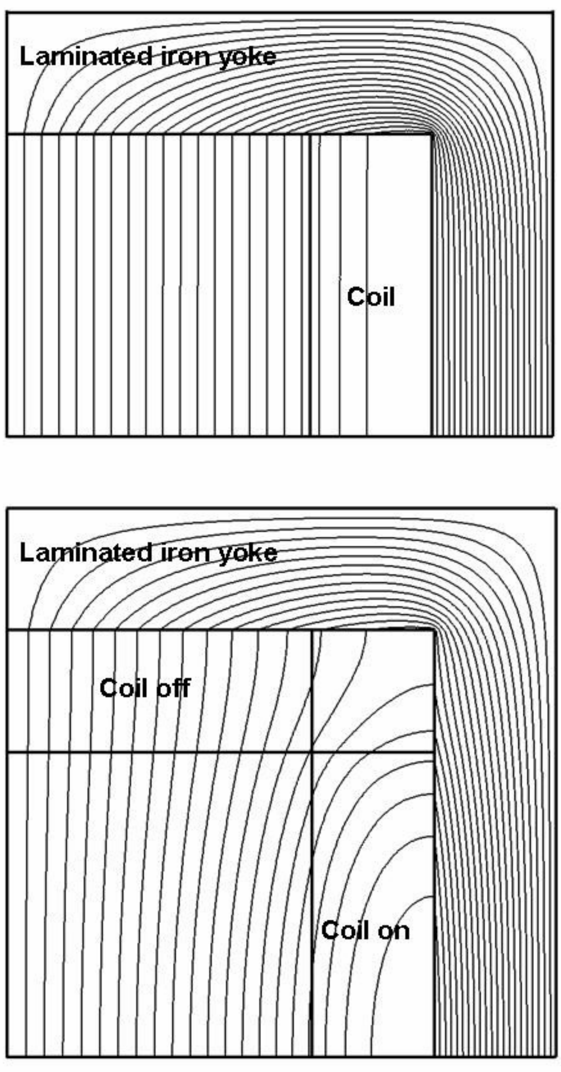

Fig. 1: 2D POISSON calculations for the classic single and double steering magnets. Only the first quadrant of the cross-section has to be calculated. The remaining three quadrants are symmetric.

FIELD CALCULATIONS

Fig. 1 shows the results of the 2D magnetic field calculations made using the programme POISSON.

The first flux plot on the left shows the classic single steering magnet. The coils fill up the space between the poles and the field quality is perfect. Below, we can see how the introduction of a second set of coils changes the geometry. The coils no longer extend to the poles and the air gap has been increased.

This has two consequences. The field is distorted and we need more current to achieve the required central field. If we increase the coil size to reduce the power loss, the gap increases even more and we worsen the field quality. The relative power consumption as a function of the coil thickness can be seen in Fig. 2, together with the respective deterioration of the field quality. In the present case, the air gap is 100 mm and we would normally choose a coil thickness of 20 mm.

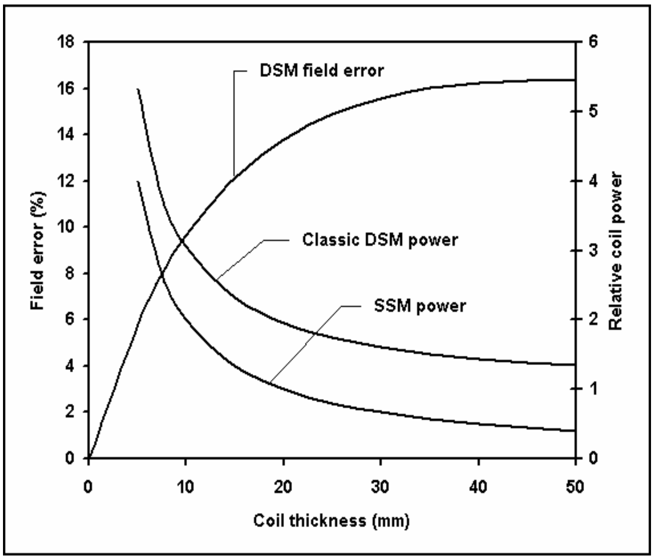

Fig. 2: Results of a 2D study of the variation of the coil thickness for classic double (DSM) and single (SSM) steering magnets.

THE 3-RIB DOUBLE STEERING MAGNET

In order to overcome the above mentioned aspects of this type of magnet, thin iron ribs are introduced into the coil. This is possible because of the low fields used in such magnets (Bo = 170 Gauss).

The geometric structure and the 2D POISSON field calculation can be seen in Fig. 3. The ribs effectively reduce the air gap size and recreate the single steering magnet structure.

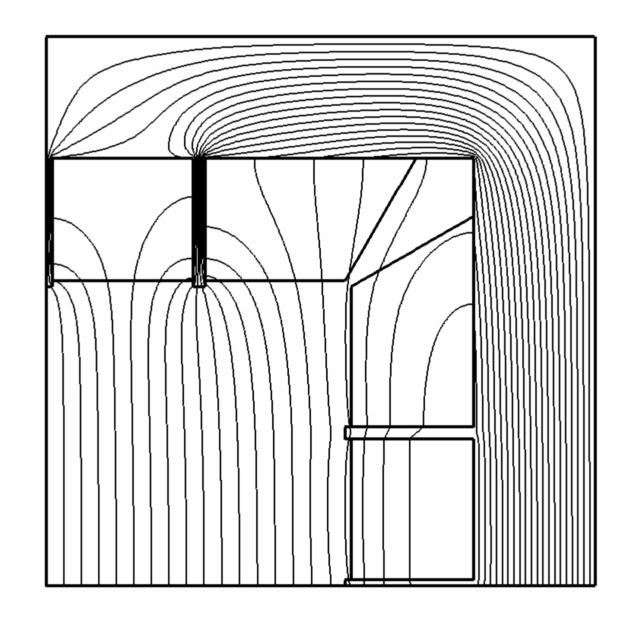

Fig. 3: 2D POISSON calculations for the 3-rib double steering magnet. The coil segments at the top of the air gap are not excited.

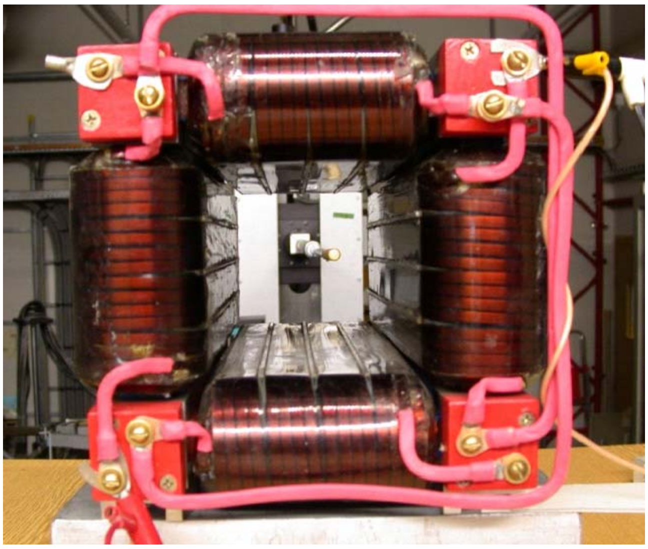

Fig. 4: The magnet as seen by the beam.

The resulting local perturbations are limited to the outside diameter of the beam pipe.

The optimisation process was actually performed on a 3D model. Some fine tuning was introduced by adjusting the coil layout in the free corners.

MANUFACTURE

The PROSCAN beam lines are dynamic and therefore all the magnetic elements are manufactured using thin iron laminations for the magnetic circuits to reduce the eddy current effects. The ribs could be stamped as part of the manufacturing process although this proved not to be that easy in practice.

For conventional steering magnets, iron sheet material can be welded to the poles. This was done for the SXA steering magnets in the PSI 72 MeV proton injection beam line.

PROTOTYPE MEASUREMENTS

A prototype 3-rib double steering magnet has been manufactured for PSI at the Institute of Modern Physics in Lanzhou, China. It can be seen in Fig. 4 and Fig. 5 during the magnetic measurements at PSI. The measurement results are compared to the calculation for the central region and the 3D integral in Fig. 6.

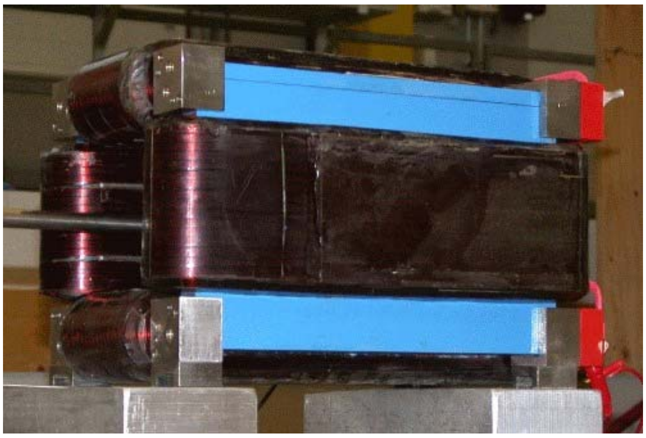

Fig. 5: The prototype double steering magnet.

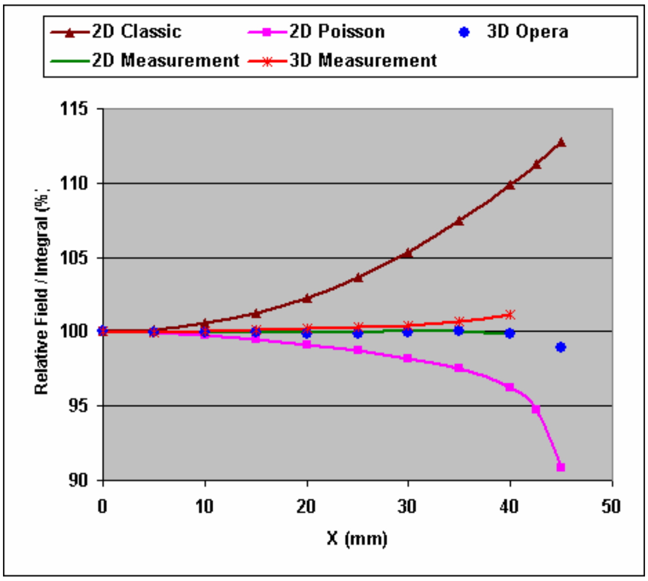

Fig. 6: Calculated and measured field profiles.

CONCLUSIONS

As can be seen in Fig. 6, we have achieved very good field quality especially in the central part of the magnet. However, the integral, which is what the beam will see, does show a sextupole component of about 1.3 %. This is still much better than the classic double steering magnet (15.5 %).

The effective air gap at full current calculated from the central field and the ampere turns in the coil is 109.4 mm compared to the physical gap of 100 mm for the single and 140 mm for the classic double steering magnet.