A STRONG DOUBLE STEERING MAGNET FOR THE COMET EXTRACTION BEAM LINE

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When a beam is first extracted from a cyclotron, some uncertainty exists concerning the exact trajectory of the extracted beam. It is therefore necessary to be prepared to correct a relatively large beam angle in the horizontal plane. Due to the limited space available for the COMET extraction beam line, it was necessary to include the smaller required vertical correction in the same space by building a double steering magnet. The design of the magnet took advantage of the asymmetric requirements to provide the required magnetic fields with good homogeneity.

INTRODUCTION

The SMA1xy double steering magnet is placed at the takeover point between the new PSI COMET superconducting cyclotron and the PROSCAN extraction beam line. The specifications called for a horizontal (H) correction of up to 13 mRad and 5 mRad in the vertical (V) direction. Since the magnet is placed in front of the beam degrader, it will run at constant field and it was possible to use solid steel for the yoke structure.

THE UNCONVENTIONAL DESIGN

We decided to take advantage of the asymmetry between the horizontal and vertical directions. Referring to our report on the SMA2xy [1], which is symmetric, the same problems related to double steering magnets in a limited available space had to be solved. The H-coils had to be made using high current water cooled conductor. The Y-coils could possibly be made using air or indirectly cooled enamel wire with low current requirements. By placing the return section of the H-coils around the H-pole instead of the usual path around the return yoke, we exposed the latter, which also serves as the V-pole. This could then be extended to the maximum length of the magnet, thus increasing the effective length and consequently reducing the required field, ampere turns and power requirements. The power level is now low enough to enable the V-coils to be cooled using the H-coils as its cooling plate. Since they are wound around the same piece of iron, it was very simple to create a thermal bridge between the two coils.

CALCULATIONS AND DESIGN

The magnetic field calculations were performed using the commercially available 3D Tosca code. The solid iron yoke consists simply of four rectangular plates, bolted together to form a box, open on each end. The coils are wound around the shorter plates which serve both as the H-poles and the V-return-yokes. The longer plates form the V-poles and the H-return-yokes.

The H-coils are standard epoxy-glass insulated coils wound using water cooled hollow copper conductor. They were obtained commercially from one of our suppliers in America. The H-coils fill up most of the space between the pole plates, so there is not much space left for the V-coils. Following a series of 2D and 3D computer studies, we adopted the coil shape as shown in Fig. 1. The design packs in as much coil area as possible but the shape is also chosen for optimum homogeneity. Two coils of this complexity are not suitable for manufacture by external companies. We decided to make them in-house. Fig. 1 shows a cross section of the final magnet design.

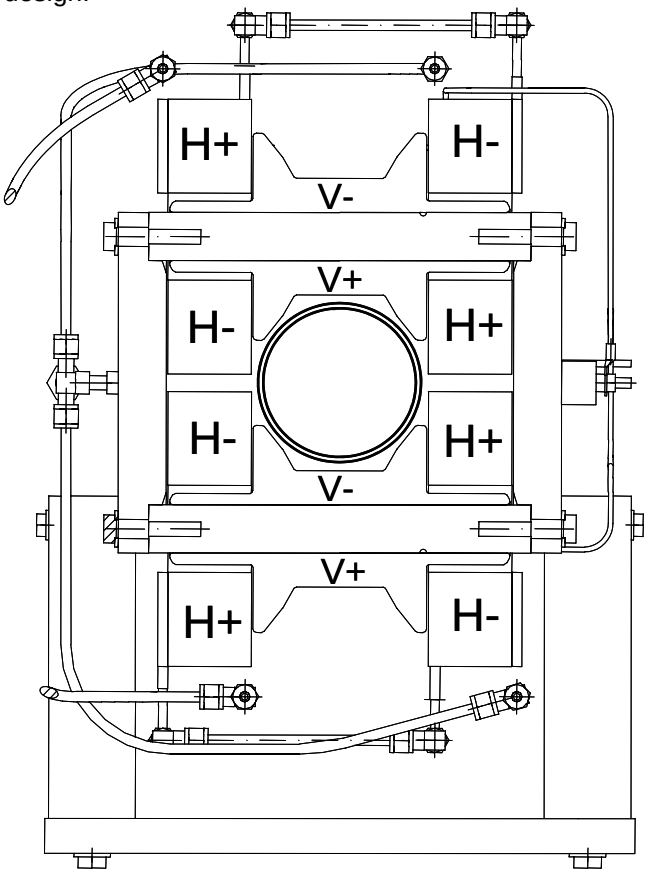

Fig. 1: A cross section view of the SMA1xy double steering magnet. The four ‘H’ coils provide a vertical magnetic field, which bends the beam sideways. The two ‘V’ coils create a horizontal magnetic field, which takes care of the vertical beam steering. The correct current direction in each coil is also indicated.

V-COIL MANUFACTURE

Fig. 2 shows one of the V-coils being wound at PSI. The 2.8 mm diameter copper conductor is commercially available heavy duty enamelled wire. We wound the complicated form in various stages using a wet-winding technique.

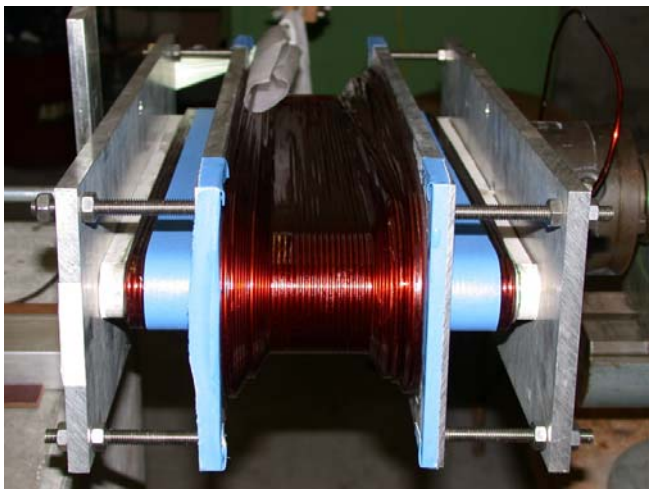

Fig. 2: The V-coils being wound at PSI.

MAGNET ASSEMBLY

Since the V-coils are wet-wound directly onto the insulated steel plate, they are automatically held in place. In order to fix the H-coils and at the same time, create a thermal bridge between the coils, the space between them was filled with a special epoxy potting compound as shown in Fig. 3. In Fig. 4, we can recognise the basic magnetic structure before the final assembly is completed, as shown in Fig. 5.

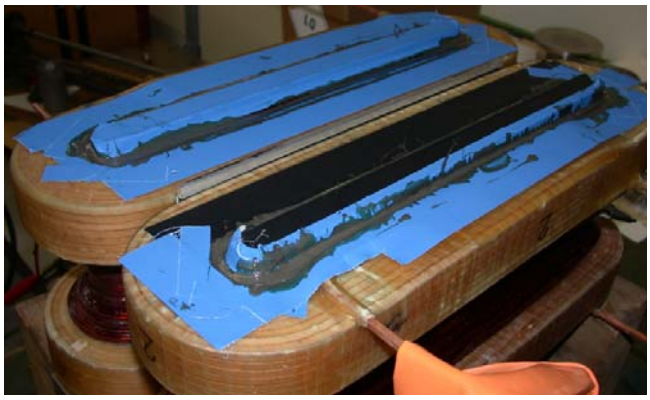

Fig. 3: The H-coils are mechanically and thermally attached to the V-coils using a special epoxy potting compound.

Fig. 4: The basic magnetic structure of the SMA1xy before mounting the water cooling and electrical connectors.

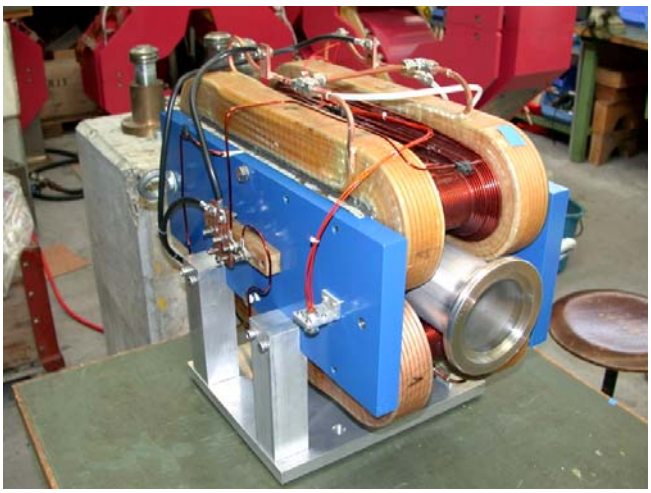

Fig. 5: SMA1xy ready for installation.

OPERATIONAL DATA

We performed an extensive series of magnetic measurements on the assembled magnet. The measurement results confirmed the calculations. We could also demonstrate that there is no measurable cross-talk between the horizontal and vertical fields.

The operational data for the SMA1xy double steering magnet for operation with 250 MeV protons is given in Table 1.

	SMA1x	SMA1y
Max. current - Amps	50	10
Max. voltage - Volts	17.1	21.6
Bending strength - mRad	13.44	7.47
Homogeneity - %	<0.3	ca.0.5
Magnetic field - Gauss	652	276
Leff - mm	500	658
Power - Watts	855	216
Water flow – litre/min	0.7	
Pressure drop - bar	8	
Temperature rise - °C	18	
Thermal switch - °C	78	78
Weight - kg	200	

Table 1: Operational data for the SMA1xy double steering magnet for 250 MeV protons.

REFERENCES

[1] D. George, M. Negrazus, *The PROSCAN Beam line double steering magnet,* PSI Scientific Report 2003, VI.