# Kissing Magnet Design for the pp Collider

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Preliminary designs for the kissing magnets required for proton-proton colliding beams have been worked out at Argonne by the Accelarator Research Facilities Division. The magnets were sized for 150 GeV in the main ring and 1000 GeV in the energy saver/doubler, assuming nearby main ring dipoles to be "rolled" for prebending, but the energy saver/doubler to be planar, with no prebending. This geometry is shown in Fig. 1.

The magnets "A" (farthest from the intersection) and "B" are septum magnets which utilize correction windings to reduce the fringe field outside the gap to a very low value. They are similar to the ZGS extraction magnets[1], and to a low fringe-field septum magnet[2] built at Argonne for an ISR experiment. The attached specification sheets (Tables I, II, and III) and fabrication cost estimates (Table IV) indicate that the six kissing magnets can be built for a total cost of about $473 K, and will consume a total of about ~~2.3~~ 25 MW of electrical power when run DC at full current.

The field quality which can be achieved in magnets of this type is very high, as shown in Figure 2 (taken from Ref. 1) and Figure 3 (taken from Ref. 2). The ZGS extraction magnets have a leakage $\int B \cdot dl$ outside the gap which is less than $1.5 \times 10^{-4}$ of the $\int B \cdot dl$ inside the gap and a variation of $\int B \cdot dl$ across the gap of less than $1.3 \times 10^{-3}$ of the central $\int B \cdot dl$. The ISR septum magnet[2] achieved a maximum leakage field gradient of less than the 0.005 kG-m/cm limit set by the ISR circulating beams, only 5 cm from the 18 kG-m field of the magnet (see Fig. 3). It should be noted, however, that the correction winding currents will probably need to be programmed independently from the main coil currents in the A and B magnets, since the optimum correction coil current will depend on the main coil excitation.

The kissing magnet designs presented here demonstrate that the required magnets are straightforward to build, and provide an accurate estimate of costs and power consumption. The configurations shown in Tables I, II, and III are not tightly constrained, and leave ample freedom to achieve field qualities as good or better than the main-ring dipoles, although the final details of conductor placement have not yet been worked out. The conductor current densities are conservative enough (~~11~~ 14 kA/in$^2$ maximum) that thinner septa could be accommodated if necessary. For example, the coil plus retaining plate thickness is only 1.2" for the ZGS extraction magnets and 2" for the ISR septum magnet (see Fig. 3), compared with the 6" and ~~4.5"~~ 3.75" space allowed in the present design for magnets A and B, respectively.

The cost estimates are based on very recent experience with magnet fabrication for the IPNS-I accelerator, and do not depend strongly on the details of the design. These magnets can be fabricated easily and could be ready to operate 20 months after the final design optimization is started.

## References

1. Robert J. Lari, "Magnetic Measurements of Bending Magnets BM-101," Argonne National Laboratory, Particle Accelerator Division Internal Report, RJL-2, September 18, 1962.

2. L. G. Ratner, R. J. Lari, J. A. Bywater, E. C. Berrill, "Design of a Low Fringe Field Septum Magnet for use at the CERN ISR," Proceedings of the Fourth International Conference on Magnet Technology, Brookhaven, 1972, p. 167.

Table I. KISSING MAGNET "A" PARAMETERS

| | |
|---|---|
| Effective length | 4.4 m |
| Maximum field | 18.2 kG |
| Good field region (h X v) | 3.5" x 3.5" |
| Operating current | 3083 A |
| Operating voltage | 97 V |
| Conductor current density | 7.7 kA/in$^2$ |
| Layers | 6 |
| Rows | 8 |
| Power dissipation | 300 kW |
| Transverse force on coil | 190 psi |
| Lamination thickness | 0.025" |
| Iron weight | 34,130 lb |
| Coil weight | 2,220 lb |
| Fabrication cost (1 magnet) | $ 67K |

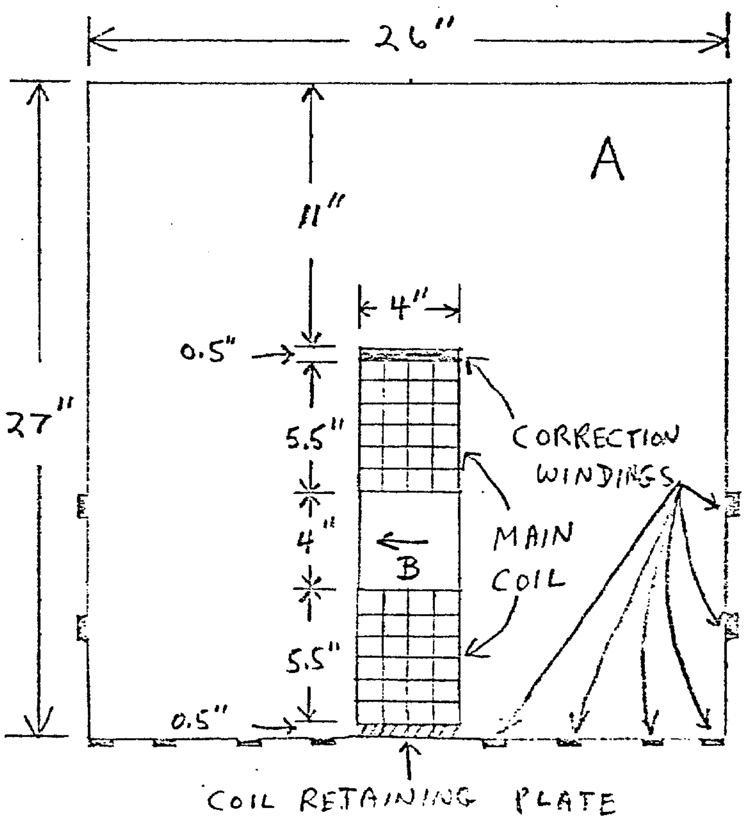

Table II. KISSING MAGNET "B" PARAMETERS

| | |
|---|---|
| Effective length | 6.3 m |
| Maximum field | 18.6 kG |
| Good field region (h × v) | 2.5" × 2.0" |
| Operating current | 1926 A |
| Operating voltage | 285 V |
| Conductor current density | 13.6 ~~11.2~~ kA/in$^2$ |
| Layers | 6 |
| Rows | 9 |
| Power dissipation | 550 ~~450~~ kW |
| Transverse force on coil | 199 psi |
| Lamination thickness | 0.025" |
| Iron weight | 18,000 ~~20,070~~ lb |
| Coil weight | 1324 ~~1,608~~ lb |
| Fabrication cost (1 magnet) | $ 64 K |

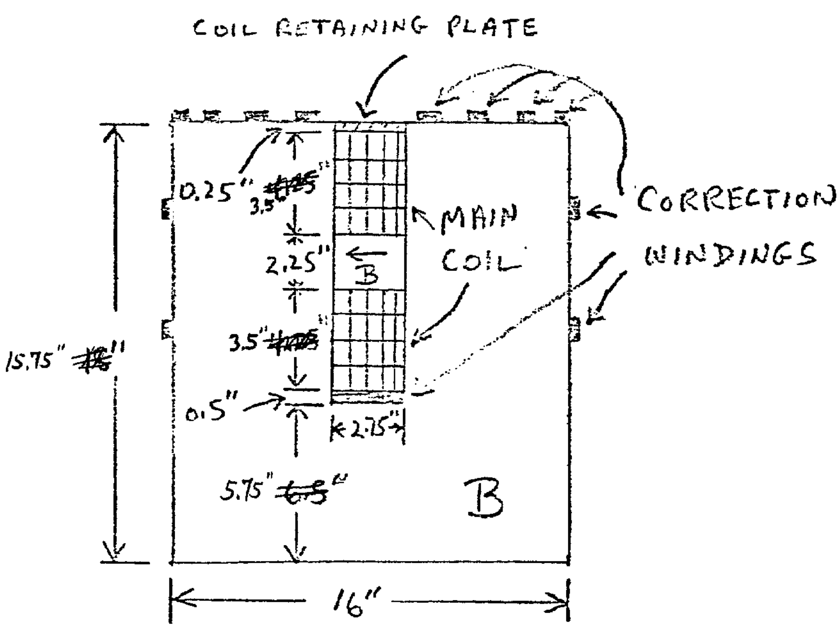

Table III. KISSING MAGNET "C" PARAMETERS

| | |
|---|---|
| Effective length | 6.2 m |
| Maximum field | 17.7 kG |
| Good field region (h X v) | 3.5" x 6.0" |
| Operating current | 2792 A |
| Operating voltage | 138 V |
| Conductor current density | 7.6 kA/in$^2$ |
| Layers | 6 |
| Rows | 8 |
| Power dissipation | 387 kW |
| Transverse force on coil | 177 psi |
| Lamination thickness | 0.025" |
| Iron weight | 60, 950 lb |
| Coil weight | 3, 000 lb |
| Fabrication cost (1 magnet) | $105 K |

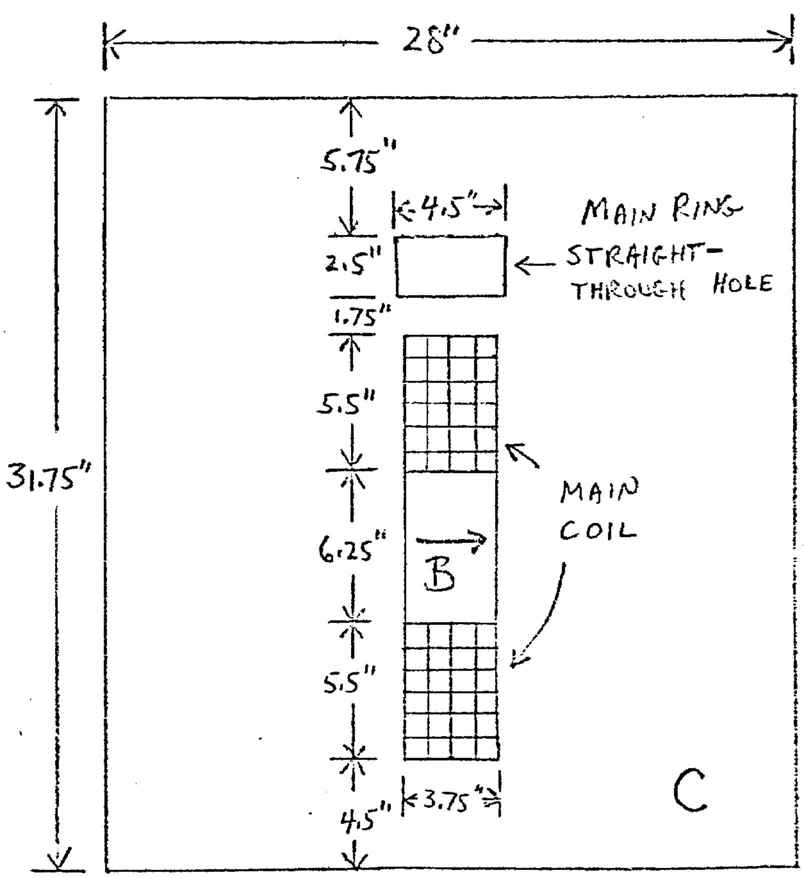

Table IV. Preliminary Cost Estimate for Kissing Magnets
J. Bywater

| Operation | Magnet A | Magnet B | Magnet C |
| --- | --- | --- | --- |
| | Cost per Magnet (in thousands of dollars) | | |
| I. Material | | | |
| 1. Steel | 17.1 | 10.0 | 30.5 |
| 2. Copper | 5.3 | 4.6 | 7.2 |
| 3. Misc. | 1.5 | 1.5 | 2.5 |
| II. Fabrication | | | |
| 1. Stamping | 3.5 | 5.0 | 9.8 |
| 2. Coil | 9.6 | 12.0 | 10.2 |
| 3. Iron Yoke* | 8.0 | 9.5 | 19.0 |
| III. Assembly and Testing (includes correction coil) | 3.2 | 2.8 | 2.4 |
| IV. Tooling** | | | |
| 1. Stamping die | 5.0 | 5.0 | 5.0 |
| 2. Coil fixtures | 2.5 | 2.5 | 3.5 |
| 3. Stacking fixture | 2.5 | 2.5 | 2.5 |
| V. Drafting, design** | 3.0 | 3.0 | 3.0 |
| VI. Contingency (10%) | 6.1 | 5.8 | 9.6 |
| Total (1 magnet): | 67.3 | 64.2 | 105.2 |
| | Total for 6 magnets: | $473.4K | |

*Assumes one piece yoke laminations for A and B, two pieces for C. Iron yoke fabrication costs for A and B will double if two piece construction is needed.

**Tooling, drafting and design costs per magnet assume that two magnets of each type are constructed.

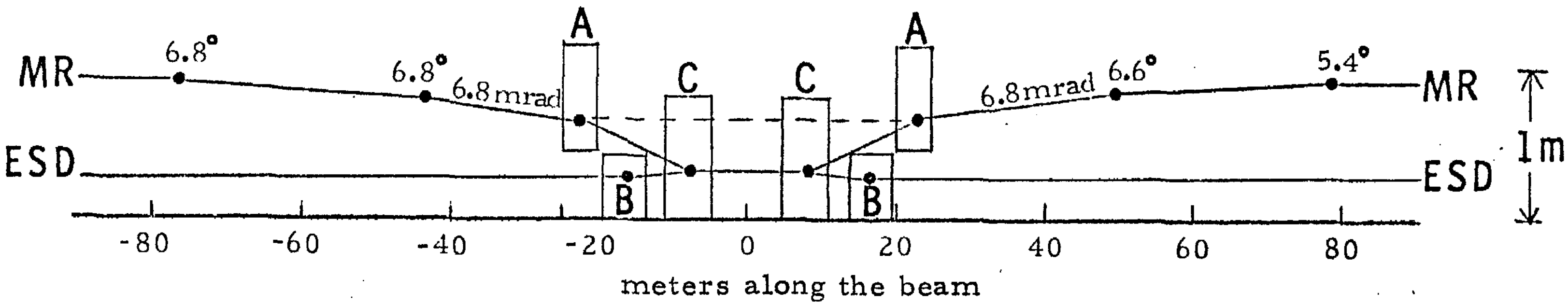


Fig. 1: Elevation view of the kissing scheme for 150 GeV × 1000 GeV pp collisions. Only the main ring has prebending, and the energy saver/doubler orbit lies in a plane if the kissing magnets are turned off.

Figure 2: Variation of $\int B \cdot dl$ across the gap of a ZGS extraction magnet, taken from Ref. 1 (Fig. 12).

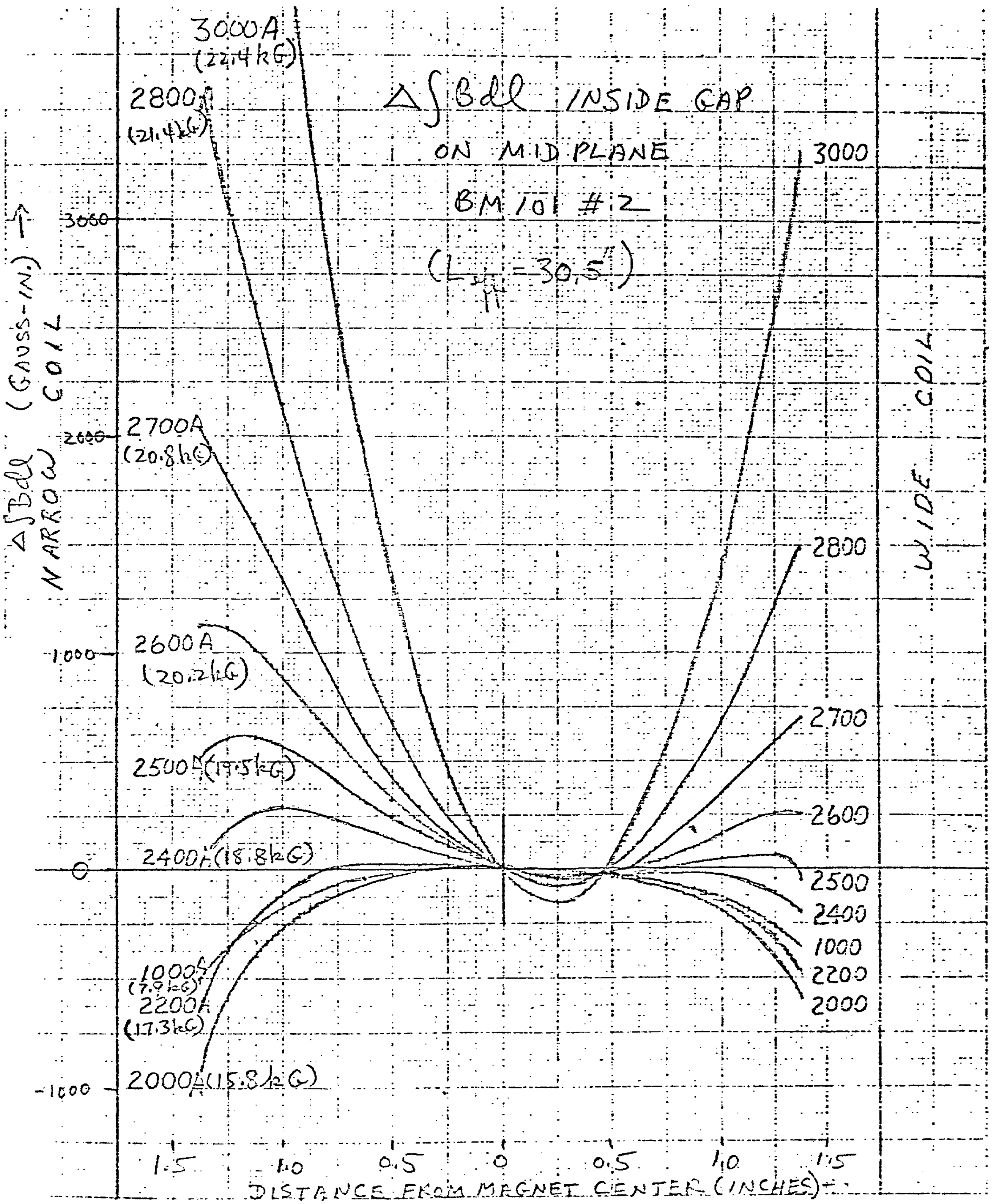

Figure 3: Performance characteristics of the ISR septum magnet, taken from Ref. 2 (Figs. 6-10).