Main Injector Quadrupole Lengths

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David Harding

The Main Injector design calls for three lengths of quadrupole, all with the same gradient as a function of current. The nominal lengths of the magnets are 84.00", 100.13", and 116.26". We want to build magnets that have their effective lengths in that ratio.

To build magnets with the correct effective length we must determine the relationship between the length of the magnet steel and the effective length of the magnet. The quadrupoles are constructed from a stack of laminations with a 1.50" solid steel end pack at each end. We may assume that the effective length of the laminations is the same as the length of steel and define the difference between the total effective length and the length of the laminations to be the sum of the lengths of the two ends.

Stan Pruss has compared measurements on a collection of existing 84-inch Main Ring quadrupoles (81" of laminations plus two 1.5" end packs) and 52-inch quads (49" of laminations and two 1.5" end packs). These measurements were taken over a range of currents from 90 A to 1575 A. From 195 A (near the MI injection field) to 1575 A there is a steady rise in effective length of the ends from 1.82" to 2.56".

Stan has also examined the integrated gradient as a function of probe depth for three magnets as currents from 500 A to 3500 A. BQB347 is of sufficiently poor quality, as demonstrated by the octupole component of its body field that, we write remove it from consideration. The other two magnets, BQB348 and BQB349, show a general gentle fall in effective length of the end over the measurement range.

All measurements between 500 A and 3500 A (except BQB347) fall within a band 0.4" wide. Ignoring one point brings the band down to 0.3" full width. The band rises gently from about 2.2" at 400 A to about 2.4" at 1500 A. The band then falls gently to about 2.1" at 3500 A. Perhaps a length of 2.2" best typifies the whole curve.

If we take that length of 2.2" for the effective length of the two ends together, we maintain the effective length ratios desired by using 96.976" and 112.953" of laminations respectively for the 100.13" and 116.26" quadrupoles. Even if the effective length of the end is wrong by as much as 0.5", and there is that much variation during the ramp, the ratios of the effective strengths remain good to within 0.002.

It would be good to have more high current measurements. We have only measured three quads over the top half of the operating range and one of those has significant problems which bring into question its value as a "typical" magnet. Until such time as we can do more study, the lengths quoted above are the best we can do, and they should be sufficient in any case.

Return to the MI Notes Index

Fermilab Main Injector Page