HRS Quads - Replacement for TN17-032

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Abstract

The model of the HRS quad which originated with Bogdan Wojtsekhowski and was passed on to me via Juliette Mammei was extracted from the latter's model of CREX septa and two quads. It was meshed with 2 cm maximum size except for a 12 cm radius cylinder through the bore of the quad (1 cm mesh maximum). In the previous version this volume was also meshed at 2 cm maximum. The change in mesh size alters the effects previously cited and reveals yet another problem: field superposition among the two quads. The single quad was modeled in three variations: as installed, without field clamps and with 13" ID hole in both front and back field clamps. The latter two used exactly the same mesh; the BH properties of the field clamps were set to air when I wished to eliminate their effect. Opera's default BH curve was used for all steel. This TN should be read with summary_bookbook.ods.

Details

The as-installed model is shown at left below. The hole in the downstream field clamp is 21.4" ID vs 13" ID in the front clamp (not shown). The modified version is at right.

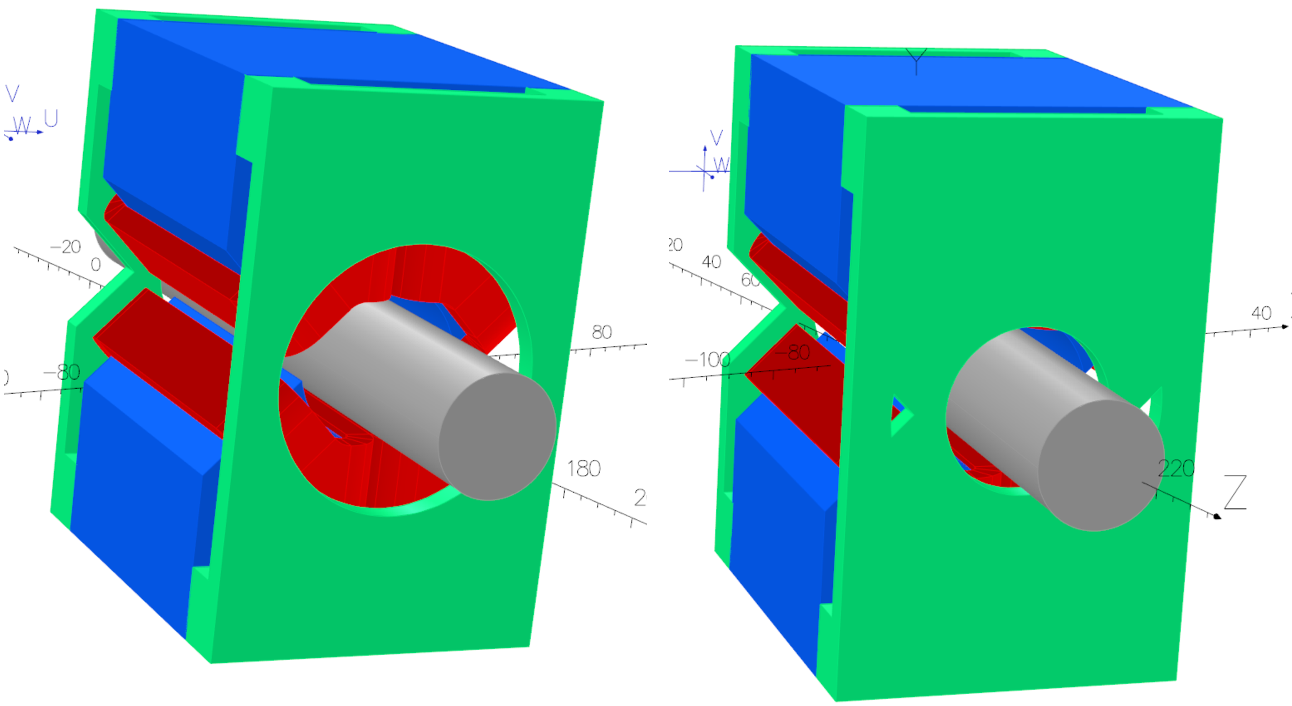

Figure 1. The two models. Left: as installed. Right modified.

The modified version was constructed by copying the front field clamp onto the back clamp and unioning the two. This left the small air triangles seen in the right image and prevented the creation of small faces which previous attempts to create just the right size annulus had always provided, causing meshing to fail. As mentioned in the abstract, both green plates in the right image were set to steel in one set of simulations and to air in a second with exactly the same mesh. The left image was meshed separately. The grey cylinder is air meshed with 1 cm maximum voxel. In previous version of TN17-032 no such volume existed; all the air around the steel and the steel itself was 2 cm maximum voxels.

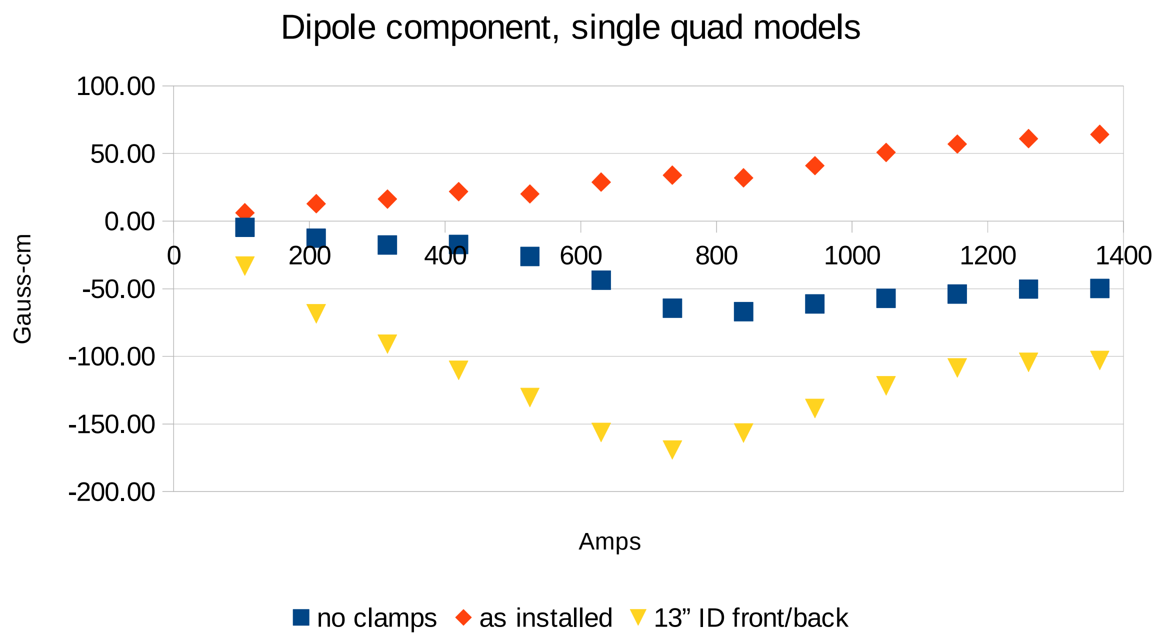

Figure 2. Dipole Fourier component along at 12.5 degree line originating at (-15.3677,0,0). The X starting point for the line was chosen to null this component at low current. Prior results suffered from feed-down from quadrupole term; 13” ID values still may. Two microns makes a difference.

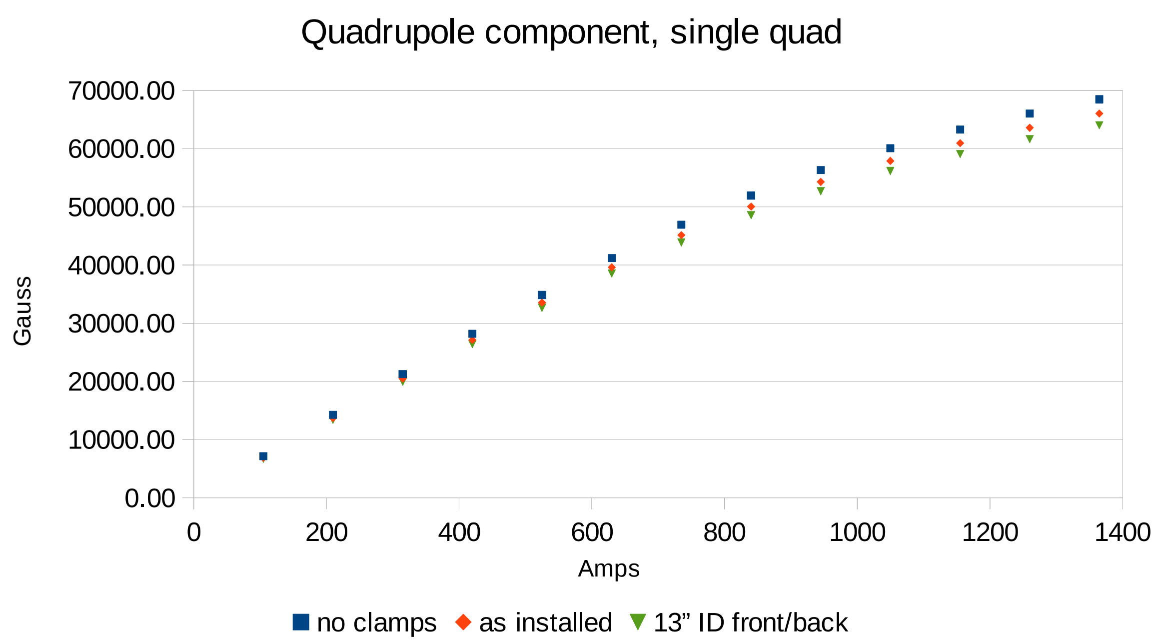

Figure 3. Quadrupole Fourier component as a function of current along the same line. With 13” holes front and back, quadrupole is reduced 1.6% at low current to 3% at high currents from as-installed values. Quadrupole term without field clamps is 3.8% higher than as-installed.

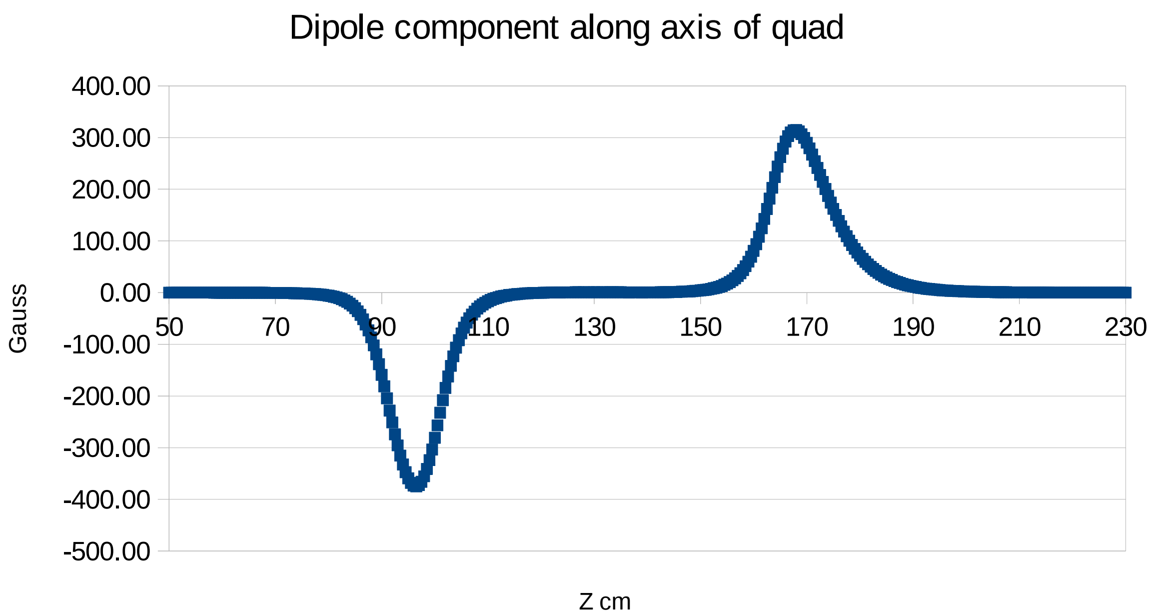

Figure 4. Dipole component through the quad as installed at 525A, about 2.5% saturation. Note that the shape is not front-back symmetric even though the integral in Figure 2 is only 20 G-cm. This is due to the difference in hole diameters front-back.

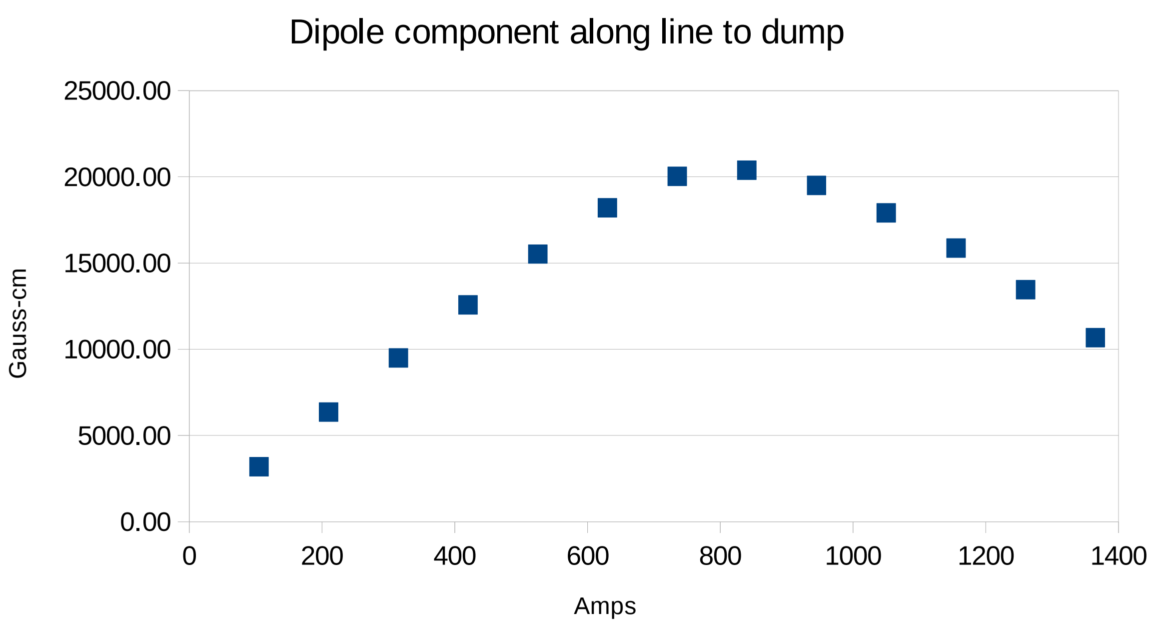

Figure 5. PREX/CREX principals asked that I check the field along the beam line to the dump with one of the quads off. This figure shows the integral as a function of current for the case with no clamps, the worst of the three. These models have coarse mesh along this line so the values are good only to a percent or so. As-installed values are about 70% of those shown - still an issue.

This work started, as alluded to in the abstract, with a result by PREX/CREX principals showing quadrupole components within the beam pipe to the dump between the septum coils and between the quads. Accordingly I have examined various carbon steel beam pipes as magnetic shields between the quads. These include 3” OD, 0.120” wall (factor of two overkill), 7” OD 0.250” wall (OK) and a cone with 3mm wall running from 8.2 cm OD at Z=60 to 19.6 cm OD at Z=220. I matched the starting and ending diameters of the stepped aluminum beam pipe which is now used between the quads. Z=0 is the center of the septum in these models. The 12.5 degree lines starting at (15.3677,0,0) that produce the near-null dipole terms in Figure 2 implies that the pivot is at (0,0,-69.3912) in the models.

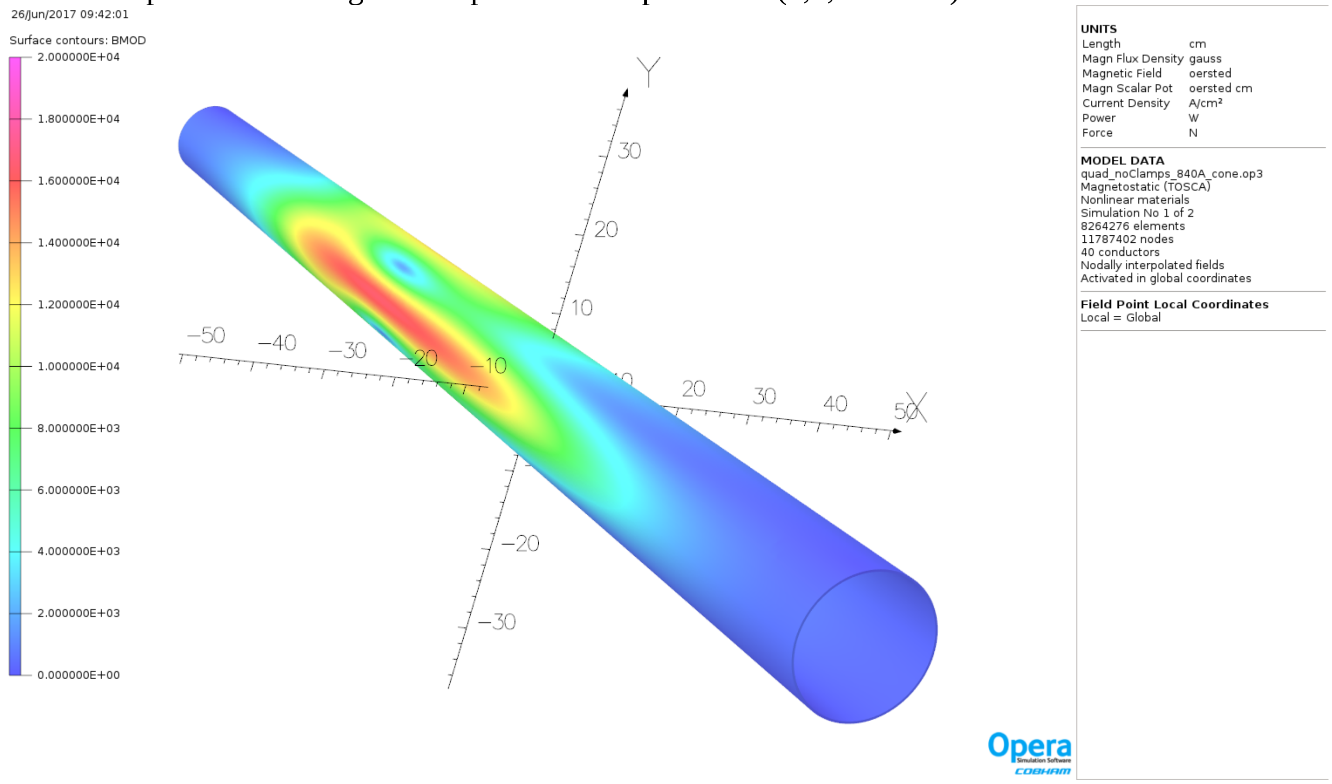

Figure 6. Field on the surface of the conical shield with 3 mm wall with 840A in no-clamp case, highest point in Figure 5. Peak field is 16.45 kG. It follows that #12 gauge, 0.1046" thick, would likely do as well magnetically as 3 mm. Modeling of the effect of this high-Z "target" after the physics target is required. Angle of cone is 2.04 degrees. As-installed peak field: 16.05 kG.

PREX/CREX

Modeling for PREX/CREX began and ended this six weeks of work. Through the septum the quadrupole is too high unless steel is added. Increasing the side wall of the shield from 4 mm to 7 mm is necessary because the fields are twice as high for CREX as PREX. The envelope of the region available through the septum is 8.4 cm wide by 9.6 cm high. A 7 cm diameter hole through steel in this region results in 2240 G quadrupole multipole for CREX, about 17% of the value without the additional 3mm of steel. For PREX, 250 G. Without the conical shield shown above, quadrupole between the quads is -1730G for CREX and -865G for PREX. These quadrupole "doublets" are tolerable per radiation modeling by collaboration members. However, if one of the quads fails, the dipole term becomes 5660 G-cm between the quads (CREX). The field maps along the beam line to the dump for PREX and CREX with one quad off were provided to collaboration members June 25; modeling results are not yet available.

Recommended fabrication for beam line through septum: Procure two 2" x 4" steel bars of needed length. Machine each to 4.2+ cm by 9.6 cm with 3.5 cm radius half-hole down the centerline of each. Machine weld prep top and bottom (in 1.3 cm material). "4.2+" was used above as weld shrinkage must be taken into account to get 8.4 cm final dimension. Weld prep should be relieved on inside to eliminate virtual vacuum leaks when outside weld is done. Brazing might be a better option. In either case circular recesses should be machined at each end equivalent to 3” OD so short tubes may be joined, vacuum tight, to the resulting rectangular part to function as weld cuffs to the needed stainless steel bellows. All four parts might be furnace brazed as a unit, in vacuum or inert gas.

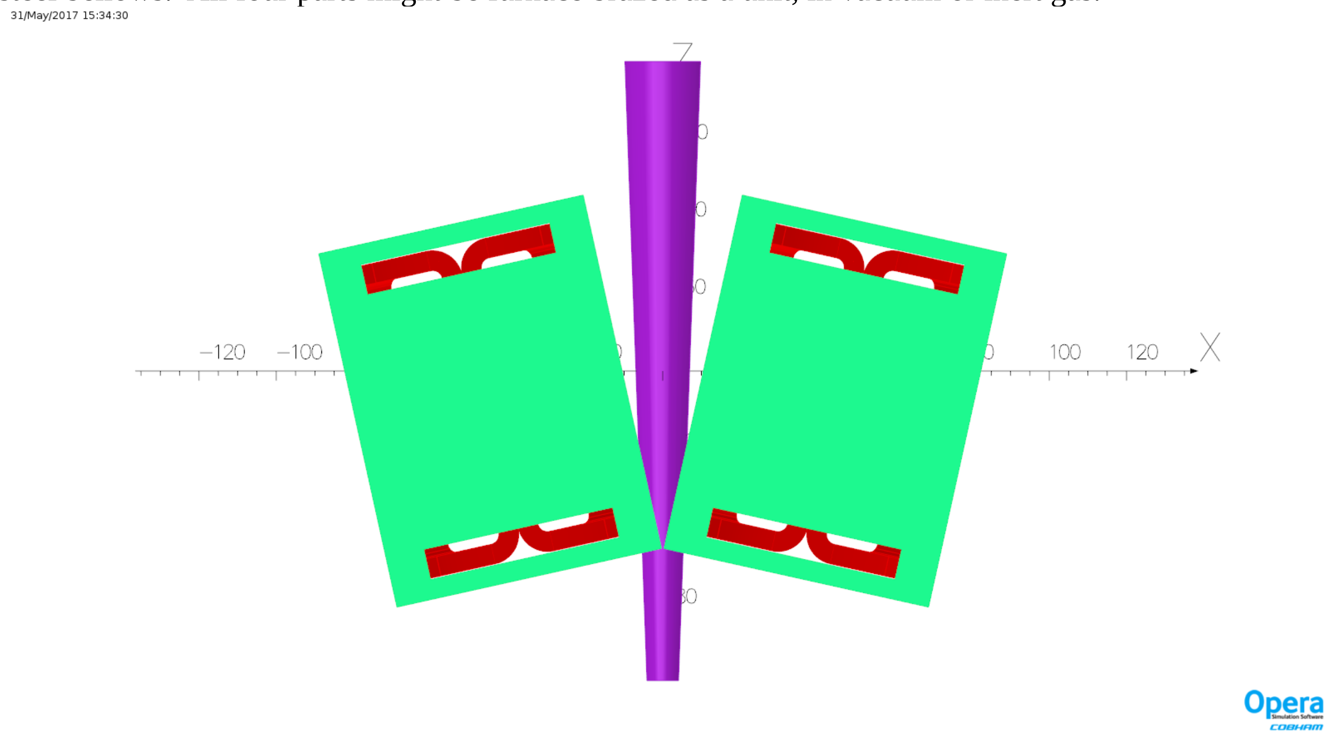

Figure 7. Two quads at minimum angle with modeled carbon steel beam pipe.

Conclusions

1. Above 420 A (~2 GeV/c) the steel of the quadrupoles is far enough into saturation that fringe fields extend beyond each and will affect the other spectrometer if it is close by. At 4.1 GeV the quad term is about 10% below linear.
2. It may be prudent to fill in the hole in the back plate (21.4” D) to match the front plate (13” D) to reduce the saturation of the back plate and make the dipole component more Z-symmetric. Machine four half-annuli from a 4' x 2' x 2” plate and secure a pair in each quad in TBD manner. This is not of great importance as Figure 2 shows.
3. Shielding the beam tube to the dump eliminates the quadrupole term seen by that beam when the spectrometers are at equal angles and eliminates the dipole+quadrupole which results when the two are arranged asymmetrically. Radiation effects modeling is required to determine if this is a good idea for people as well as spectrometers. The conical shield in Figures 6 and 7 has the same envelope as the existing stepped aluminum tube so cooling tubes are still accommodated. If it proves difficult to fabricate the cone with round section, one with square section may be used. The flat sides must be stiffened against air pressure by welding on steel angle.
4. If the beam pipe is shielded the field clamps may be removed without impact on beam to the dump. This will lower the amount of current needed for desired focusing, reducing optics non-linearity above 2 GeV/c modestly.