A Quadrupole Design for Crab Cavity Optics

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Crab Cavity Optics

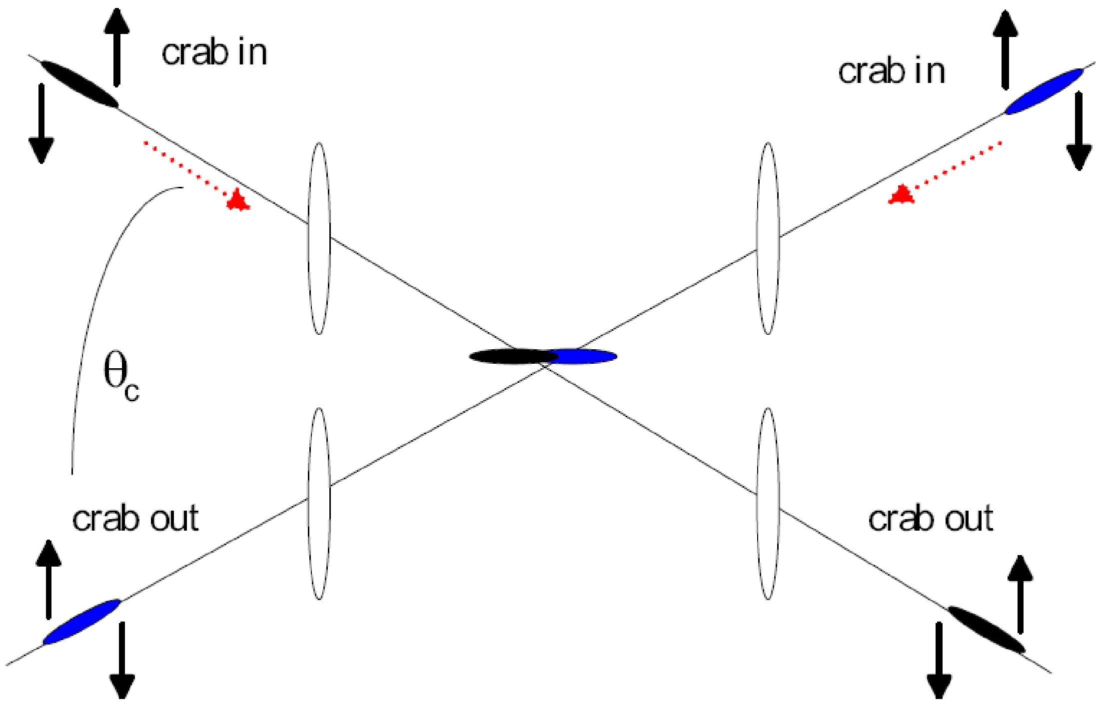


Figure 4: The crab crossing principle. Incoming bunches are tilted by transverse deflecting mode crab cavities on the extremities of the IR so that they collide head-on. The tilt is removed on exit by another set of RF cavities [2].

From:

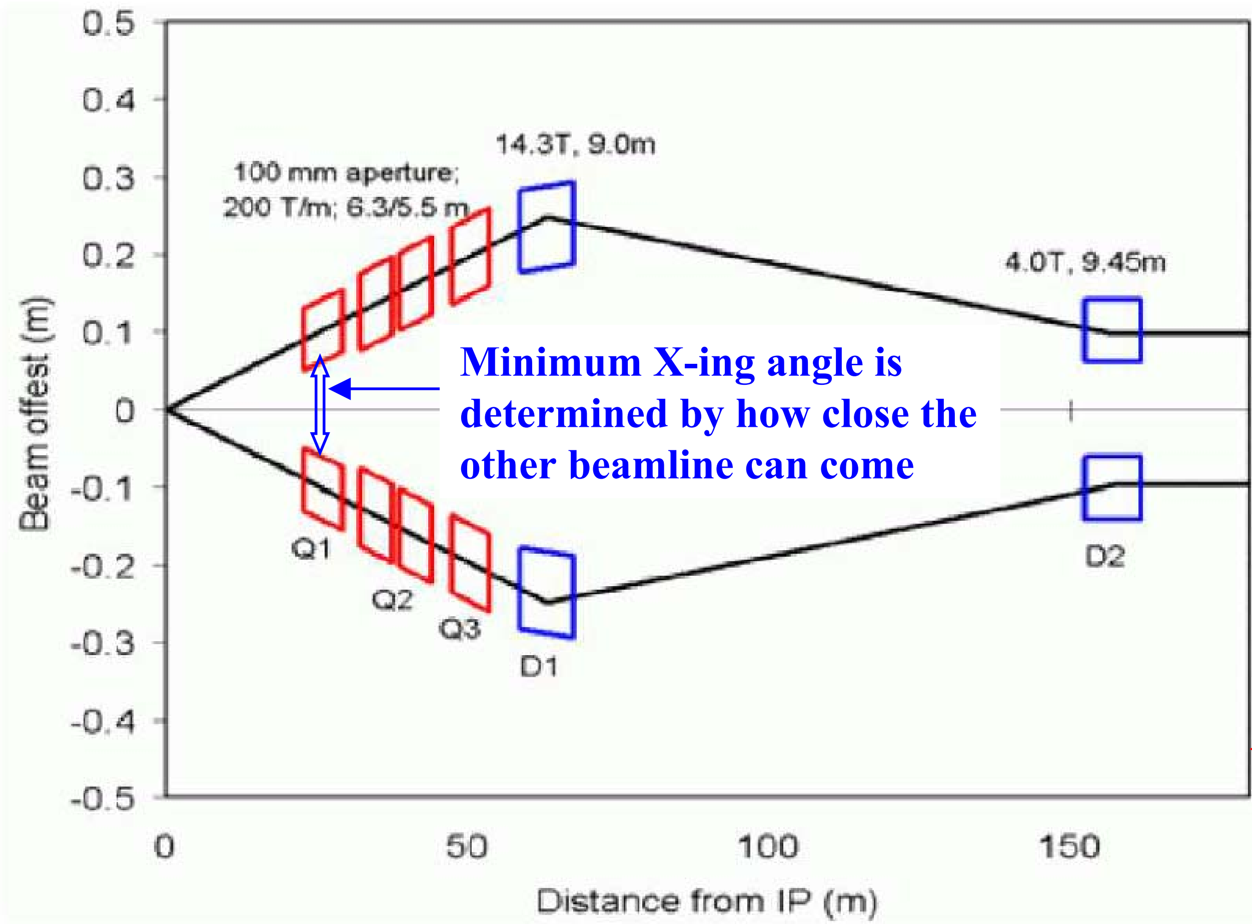
SUMMARY:
LHC IR Upgrade and Beam Choices

S. Peggs, O. Bruning

Quad Pairs for (not so) Large Crossing Angle

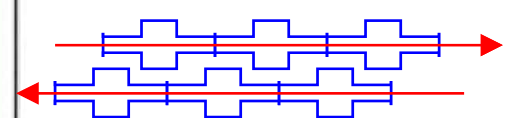
Consider the two counter-rotating beams with the first going through a quad.

How close the second beam can be?



It is 200 mm for the geometry on the right

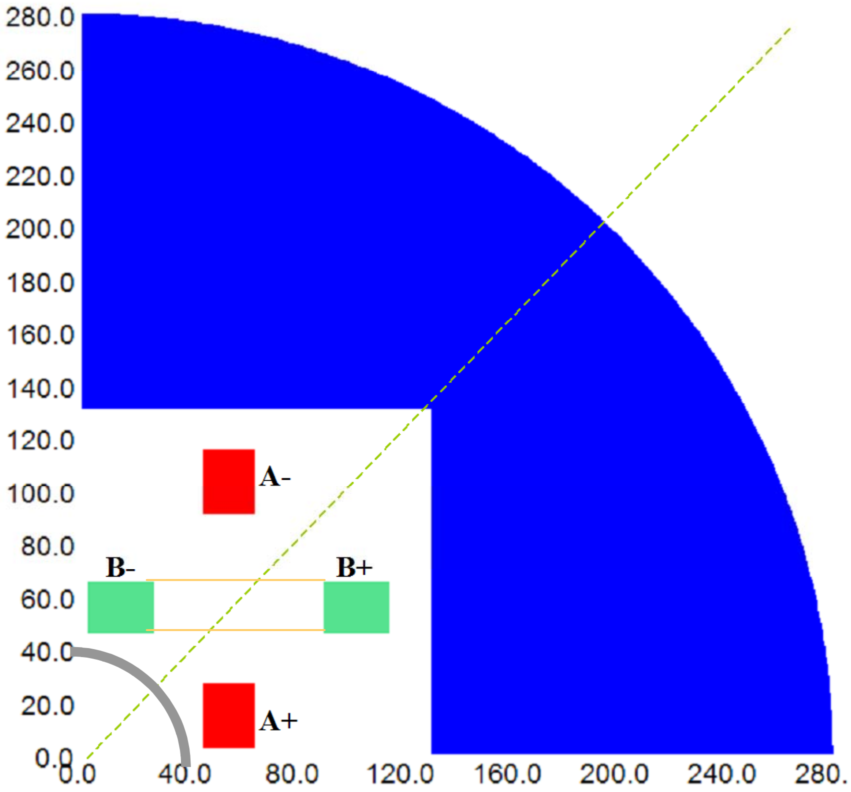
Displaced quads with the first beam in the quad and counter rotating beam just outside the coil in a field free region.



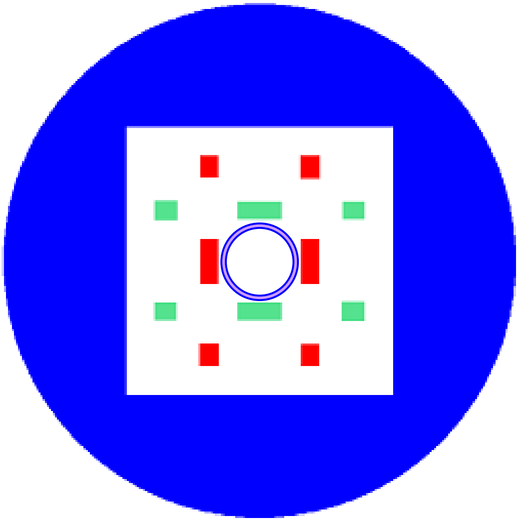
Modular Design for LARP Quadrupole

Cross-section of a Quadrant - made of 2 coils

(ideal eight fold quad symmetry - mirror symmetry at 45°)



Full Model

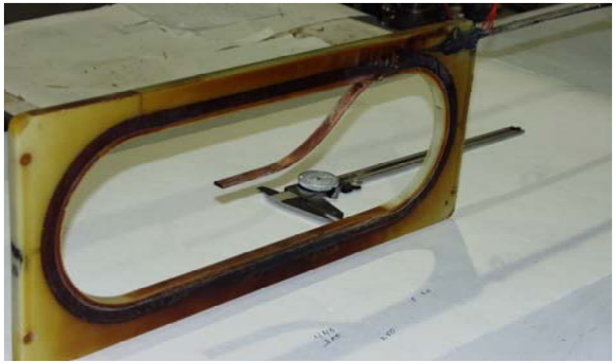


Quadrupole with all 8 coils

In this design, horizontal (or vertical) coils must interleave in to other.

Most field comes from A+ (return A-) and B-(return B+).
B+ and A- make positive but only a small contribution.

NOTE: The design needs about twice the conductor!

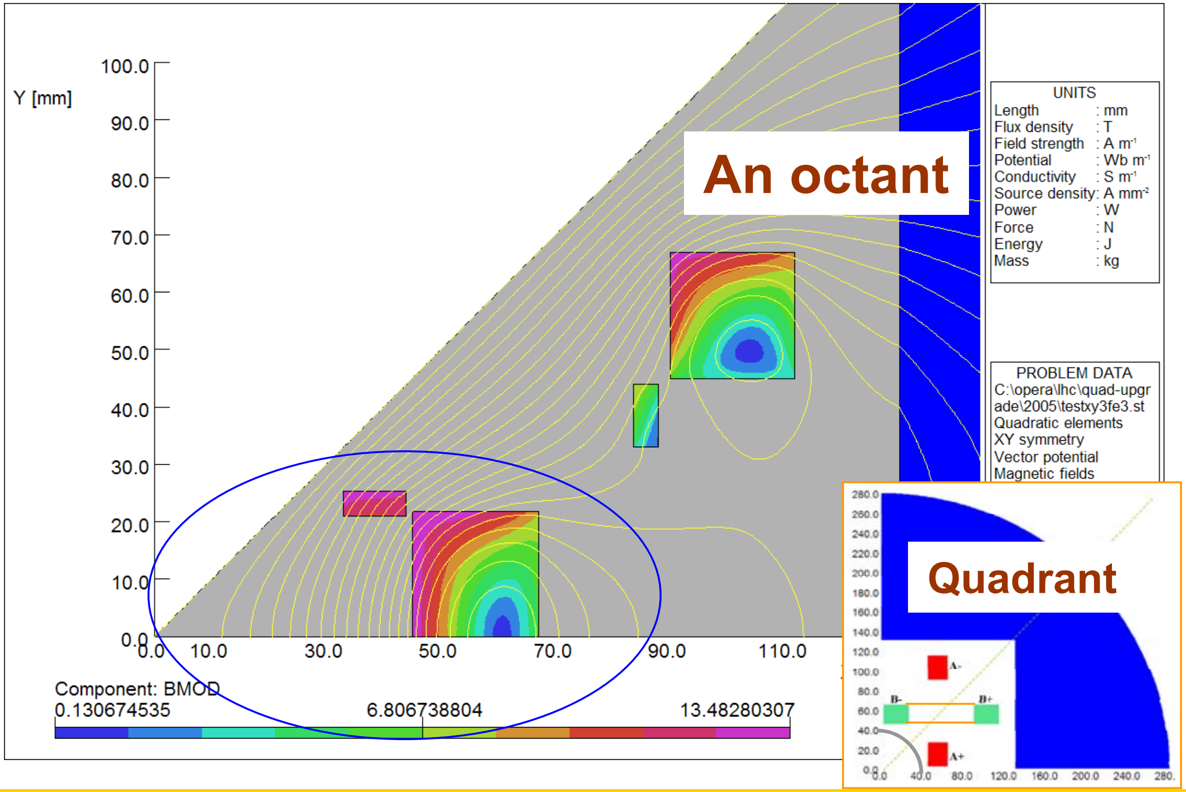


A bobbin-less coil

Efficient Design to Create Gradient
(not necessarily to minimize conductor usage)

- **The key is to have conductor at or near the midplane (@ quad radius).**

Quadrupole is different from dipole. Gradient implies increasing field on coil as one moves outward within the aperture. We loose substantially if conductor at midplane does not determine the field gradient.



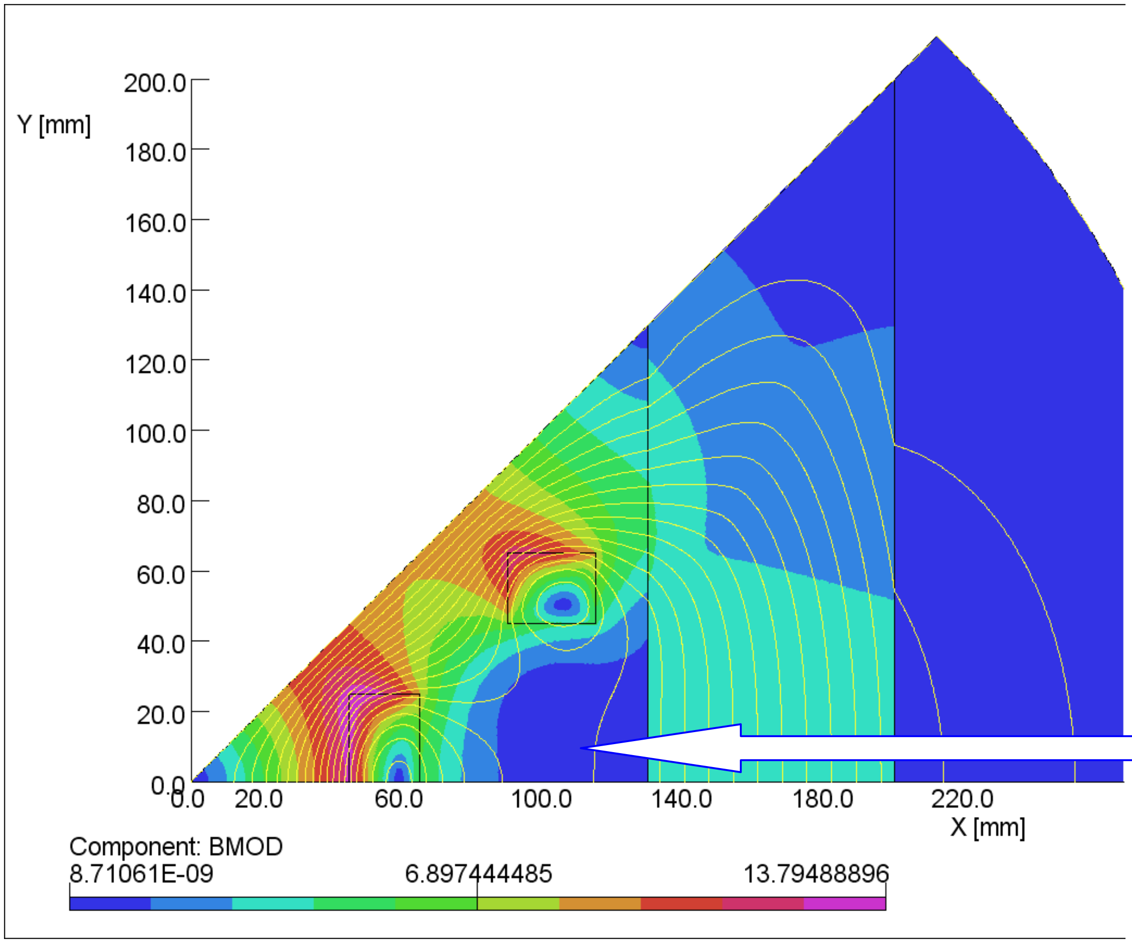
OPERA2d model of the octant of a 2 layer, 90 mm aperture LARP "Modular Quadrupole Design".

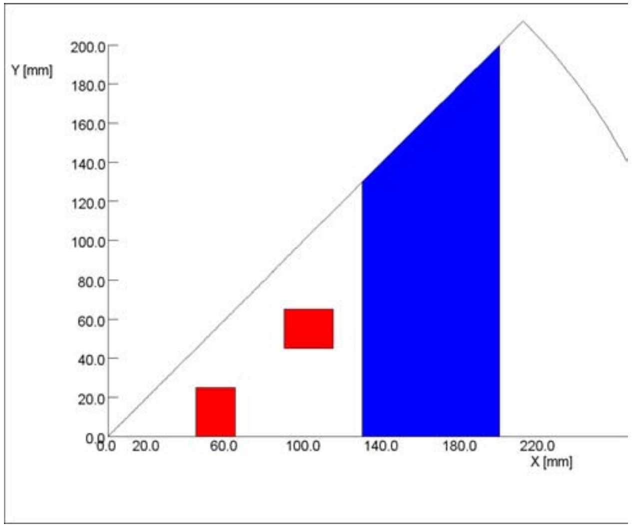
J_e = 1000 A/mm^2 generates a gradient of ~284 T/m.

Quench gradient ~258 T/m for J_c = 3000 A/mm^2 (4.2K, 12T).

This is similar to what is obtained in competing cosine theta designs.

Possible Use in Crab Cavity Optics (1)

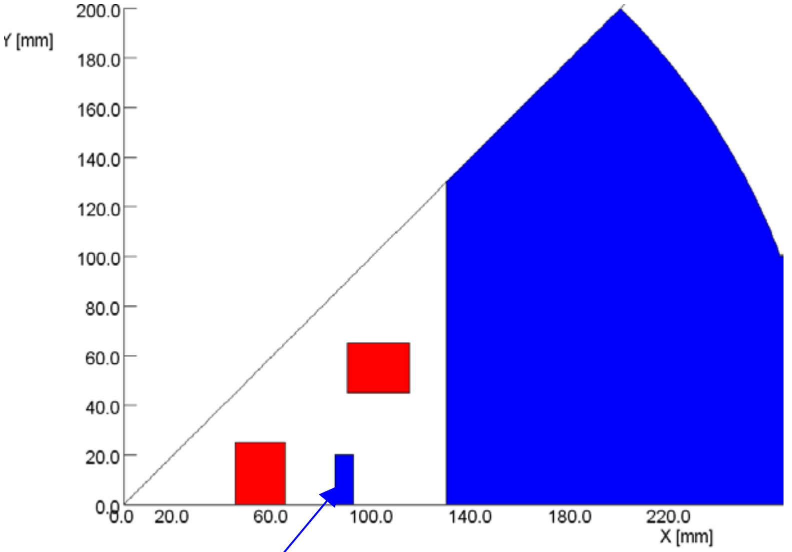




Steve Peggs noticed that the design naturally leaves a field free space that can be used by another beam in crab cavity optics.

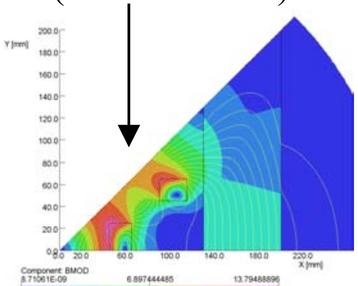
Possible Use in Crab Cavity Optics (2)

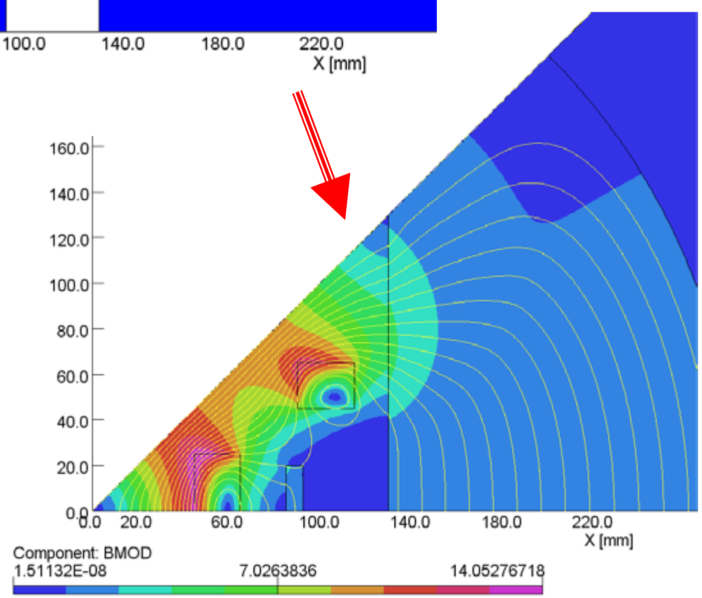
A shield can further reduce the field in the region of interest

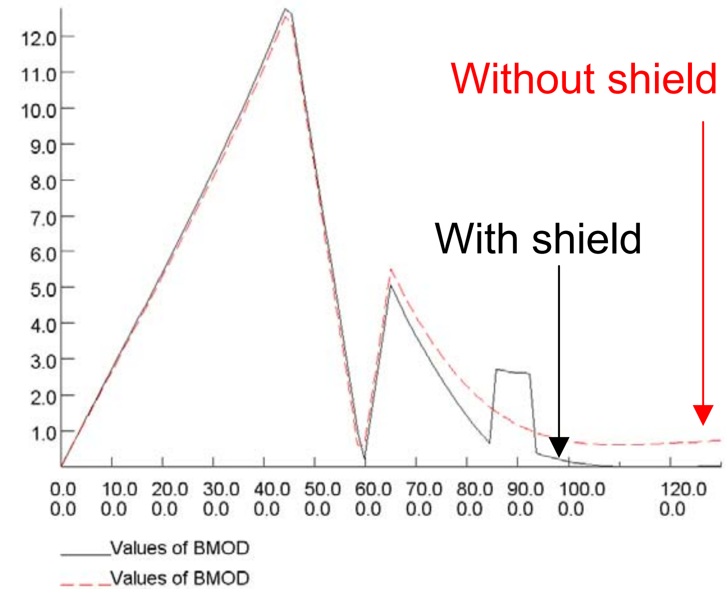


Iron shield

Original design (without shield)



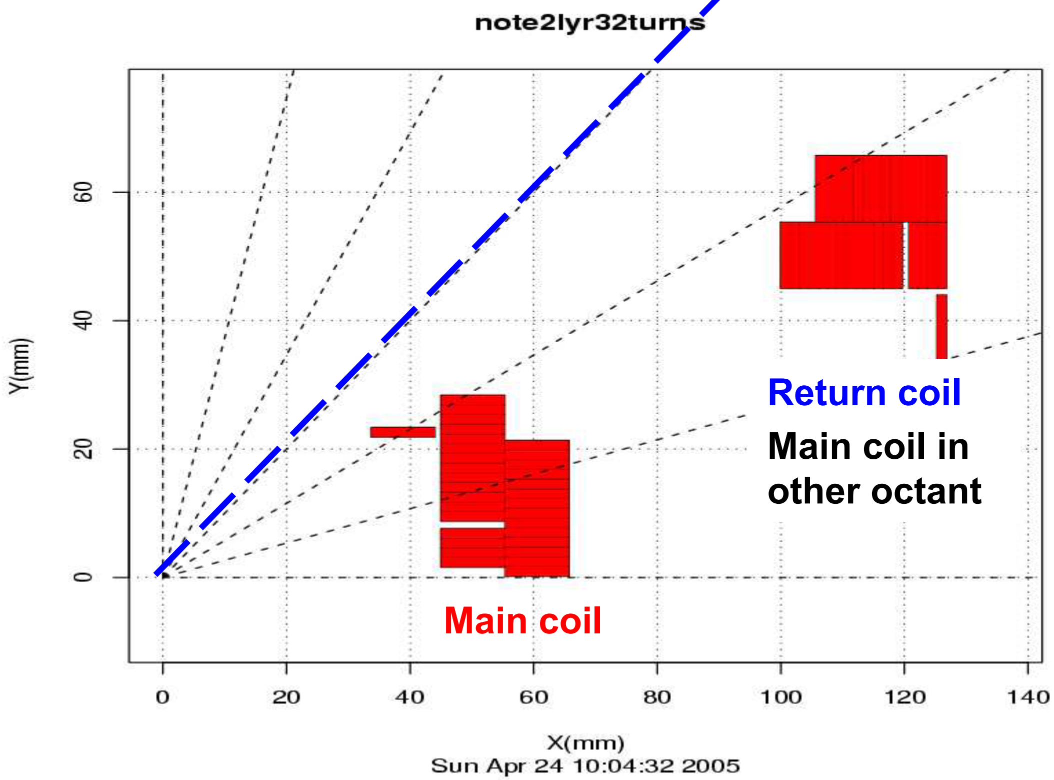


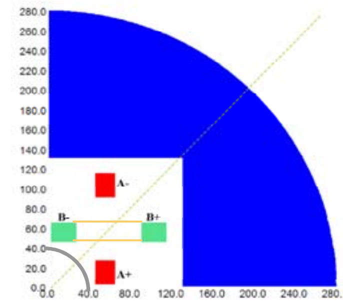


Note: In this geometry, the spacing between the center of the quad to the field free region is 100 mm, instead of 200 mm.

2-d Magnetic Design

An Octant





Field harmonics optimized with RACE2DOPT at 30 mm reference radius (2/3 of coil radius).

Harmonic	Value
b_6	0.005
b_{10}	-0.004
b_{14}	0.003
b_{18}	0.000

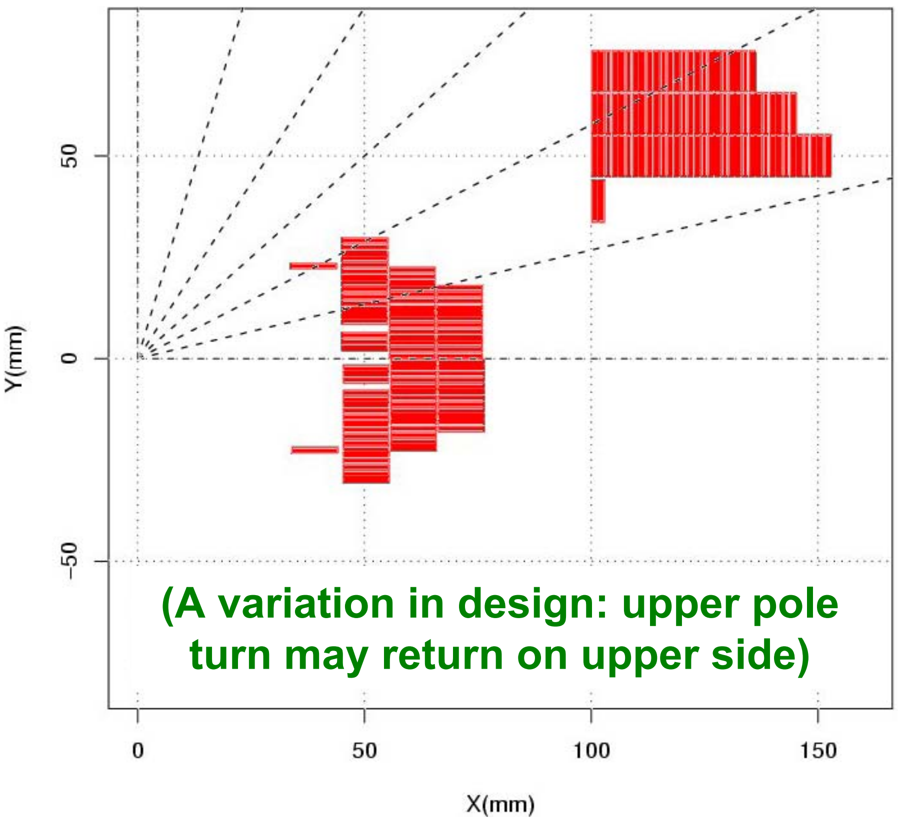
90 mm aperture LARP quadrupole design optimized for field quality with RACE2DOPT
(Thank you Pat Thompson for this program).

NOTE: The 2-d harmonics are essentially zero (within construction errors)

3-Layer Design for Higher Gradient

Relative increase in transfer function (in 3 layer design, as compared to in 2 layer) : ~28% (smaller gain in quench gradient).

(in two layer design, J_e = *1000 A/mm²* *generates a gradient of ~284 T/m.*



Field harmonics optimized with RACE2DOPT at 30 mm reference radius (2/3 of coil radius) in this 3-layer design.

n	a_n	b_n
6	-0.0049	-0.0015
10	0.0006	0.0075
14	0.0018	0.0231
18	0.0000	0.0000

Note: The 2-d harmonics are small.

SUMMARY

- Modular Quad design offers a field free region.
- This feature can be utilized in a crab cavity optics (Peggs).
- Field gradient in this quad design is similar to that in conventional cosine theta quadrupoles.