SC Quadrupole Discussion

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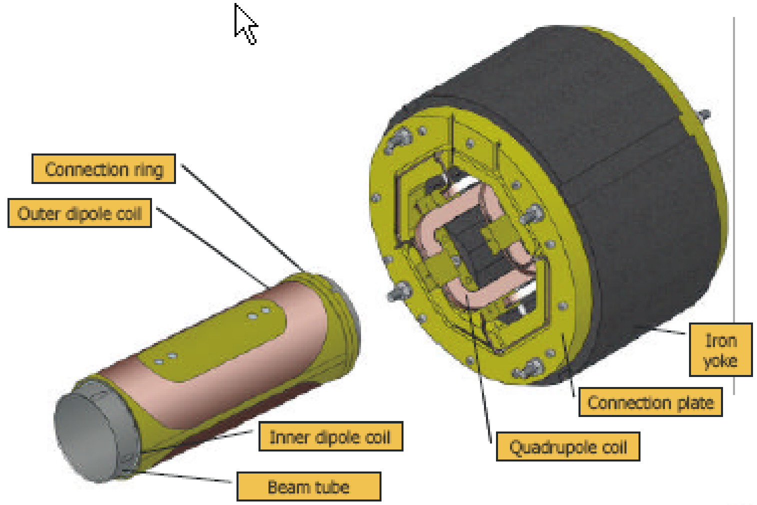
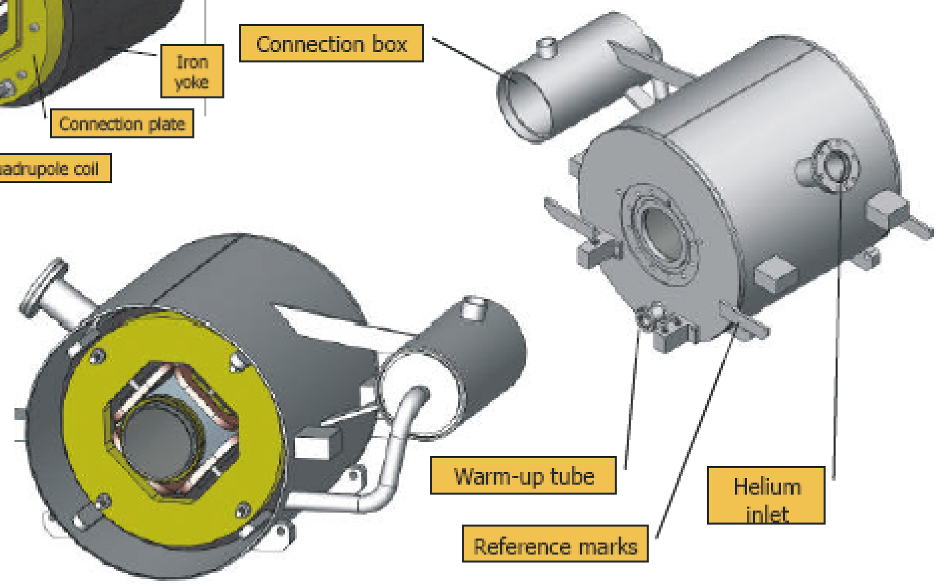
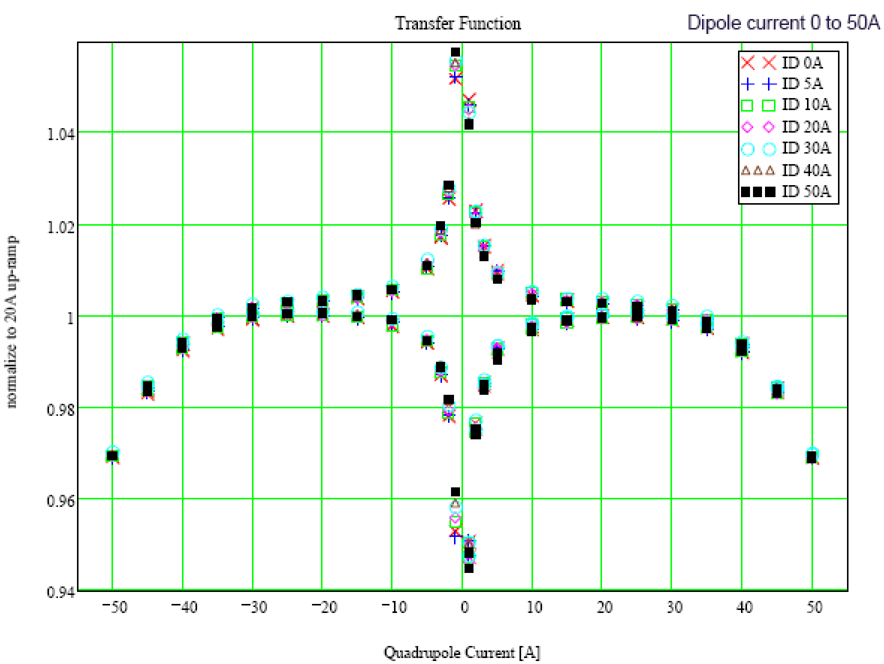
Comments from Fernando Toral on SC Development for XFEL and ILC

XFEL Prototype Superferric 6 T SC Quad

- Design according to TUEV pressure vessel rules
- Copperized beam tube
- Sliding supports on linear bearings
- BPM attached on endplate







Fernando Toral

XFEL (1)

- The persistent current effect of the dipole wires is very important at low currents. We are using now a 12 micron dipole wire, with 4.2 Cu to Sc ratio. As the dipole currents are very low (maximum 50 A), we should get a dipole wire with even higher Cu to Sc ratio (to decrease the superconductor volume) or thinner filament.

- Up to now, Oxford Superconductors has refused to make a quotation, and I am still waiting a reply from Luvata and Advanced Superconductors. By the way, could you suggest me an alternative supplier? Vladimir, where did you get the very thin filament wire that you use for your ILC-like quadrupole?

XFEL (2)

- Heiner has kindly made some preliminary measurements of the variation of the magnetic axis with quadrupole current. As you may see on next slide, axis movement (y-scale is mm) is significant at low currents.

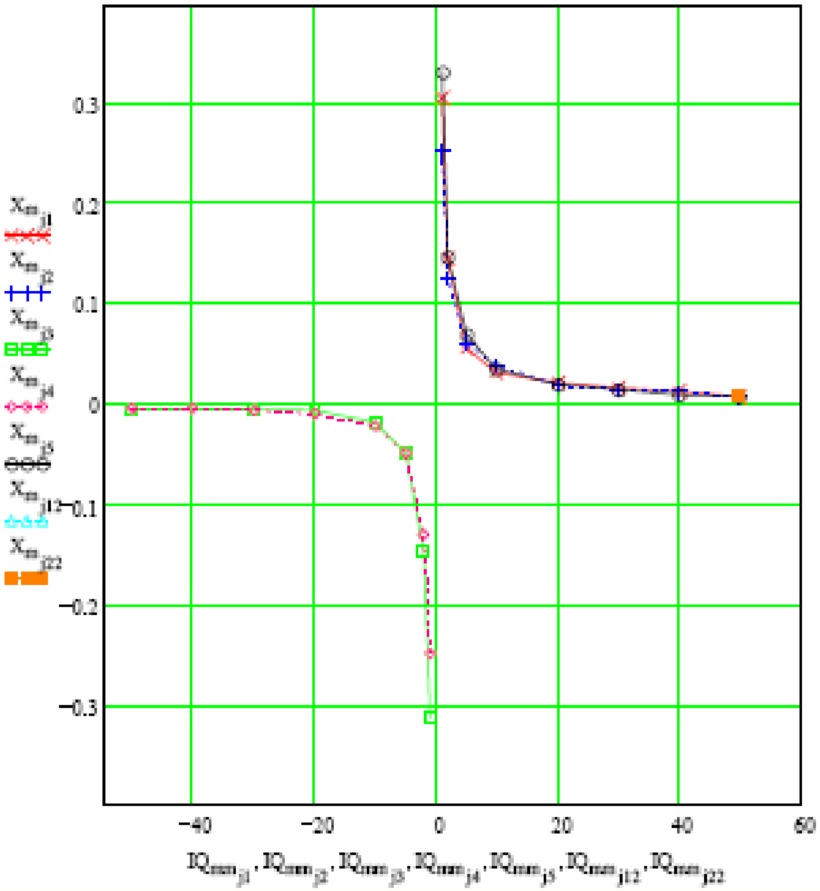
- As far as I know, the beam based alignment at ILC will be done with 20% quadrupole field variation. Obviously, at quad nominal current, it seems ok, but not if we look at a low quadrupole current.

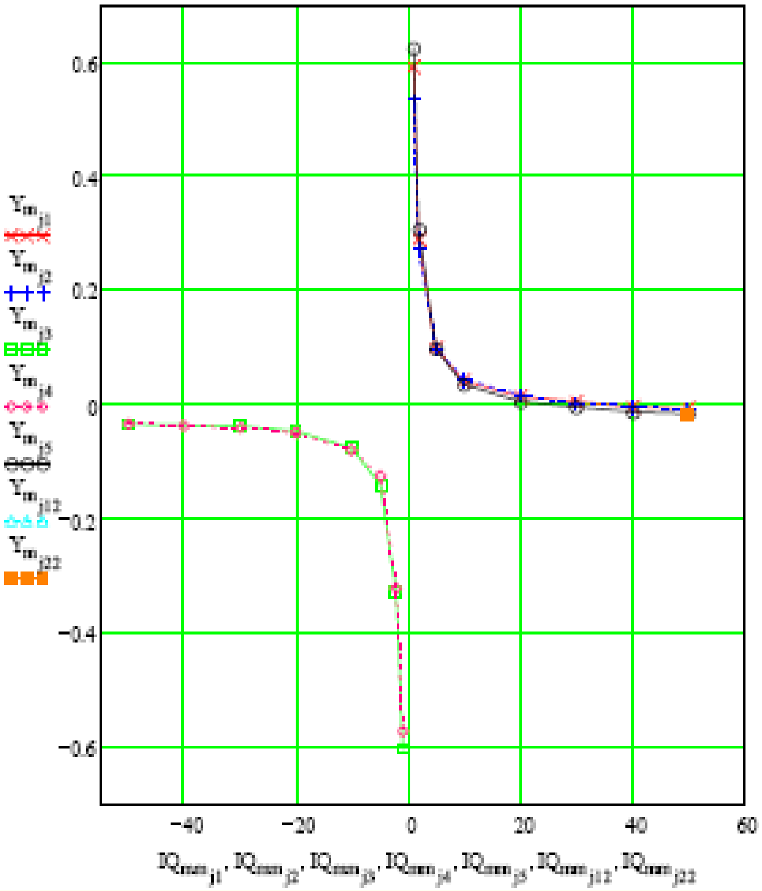
- The dipole wire magnetization decreases a lot with quadrupole cycling up to nominal current, which could help to solve the problem.

- The third prototype magnet is still cold at DESY test facility, and I think that Heiner could be so kind to perform some additional measurements of axis stability, if you define the interesting numbers to look for.

F Toral

Quad Axis Position (mm) -vs- Current





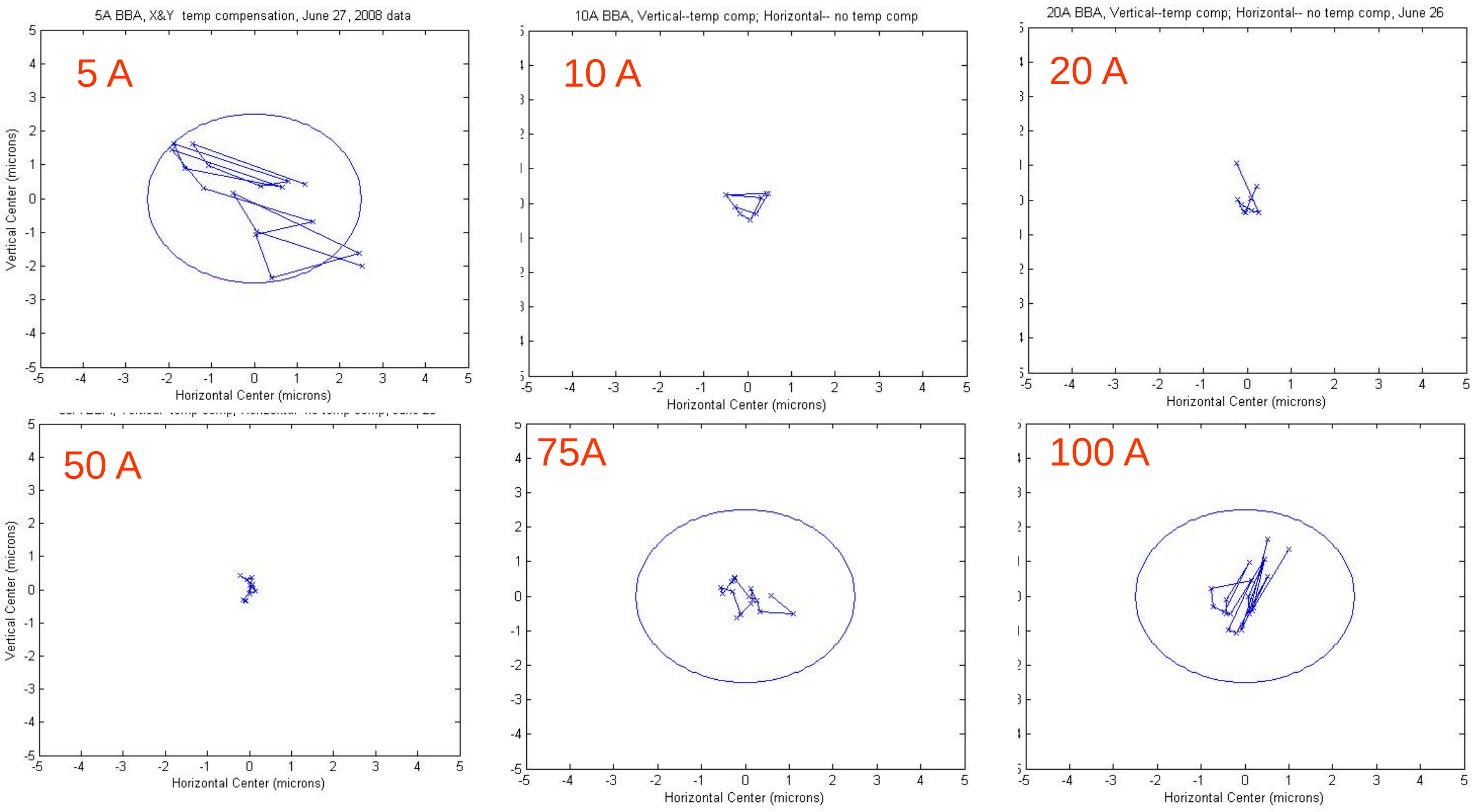
The large change of the quad axis is due to the persistent dipole after the massage cycle.
The magnetic axis in a quadrupole is defined as the axis where the dipole filed is zero.

XFEL (3)

- In any case, if you remember, the stability of CIEMAT cos-theta superferric combined magnet measured at SLAC was good, because the dipole coils were outside the quadrupole coils, so their contribution to the field was low. Here, they are very close to the aperture, and its relative contribution increases.

Center Motion with 20% Field Change

Motion Shown in Plots with +/- 5 μm Horizontal by +/- 5 μm Vertical Ranges



ILC (1)

- If you think of superferric quadrupole design for 36T, iron tip field is 36/0.660*0.039=2.13T, but the field around the coils would be notably higher, leading to a significant saturation, that is, nonlinear transfer function. Please notice that XFEL present design has a iron tip field of 1.65 T, and we already have a nonlinearity of 3.5%.

- Therefore, superferric quadrupole design for ILC at 36T is only possible if specifications allow for a strongly NONLINEAR transfer function.

- We are working at this moment on the Super-FRS superferric quads for FAIR, iron tip field is 2.5T, and superferric design is feasible, but nonlinearity is huge: transfer function at nominal current is only one half of transfer function at low current! Even so, the sensitivity of field quality to coil positioning is low, that is, magnet fabrication is easy and cheap.

F Toral

ILC (2)

- I agree with you that splittable quadrupole is feasible, and also indirect cooling, because there are void space inside the quadrupole, that would allow to place cooling pipes in direct contact with the inner side of the coils.

- Iron would cool down later than coils, but this is not important. Iron yoke could be made solid, instead of laminated, as the powering is not fastly ramped, and helps for mechanical assembly and heat transfer.

- A splittable cos-theta magnet yields important problems for the assembly: coil positioning accuracy and holding the Lorentz forces to avoid premature quenches.

ILC (3)

- The main problem for me is the situation of the dipole steerers.
- The straightforward solution would be to place independent magnets, but you need space for them! If they are nested inside the superferric quad, each dipole would be half a pipe, and both of them should be fixed to the beam pipe, but it is more tricky, and what is worse, you increase the aperture of the quad!
- The solution proposed by Vladimir in his magnet, that is, using the same quadrupole coils, also has some disadvantages.

ILC (4)

- BPM could be attached to the quadrupole end with pins, as I guess that the set BPM-magnet would be linked to the rest of the beam pipe by bellows to compensate misalignments.

Comments from Vladimir (1)

- Cooling down time depend on the magnet mass and efficiency of thermal path (cross-section and length). The main mass has iron core. We could imagine the situation when relatively quickly will be cooled SC coils having very low mass and later the iron core . So, the magnet should have the special design for an efficient conductive cooling.
- In our superferric model the iron lamination is solid but we could split it vertically or horizontally which way is more convenient should be discussed with cryomodule designers.
- It was supposed to have rigid connection BPM to Quadrupole end. With flexible BPM should be resolved the issue of BPM support before connection to the quadrupole.

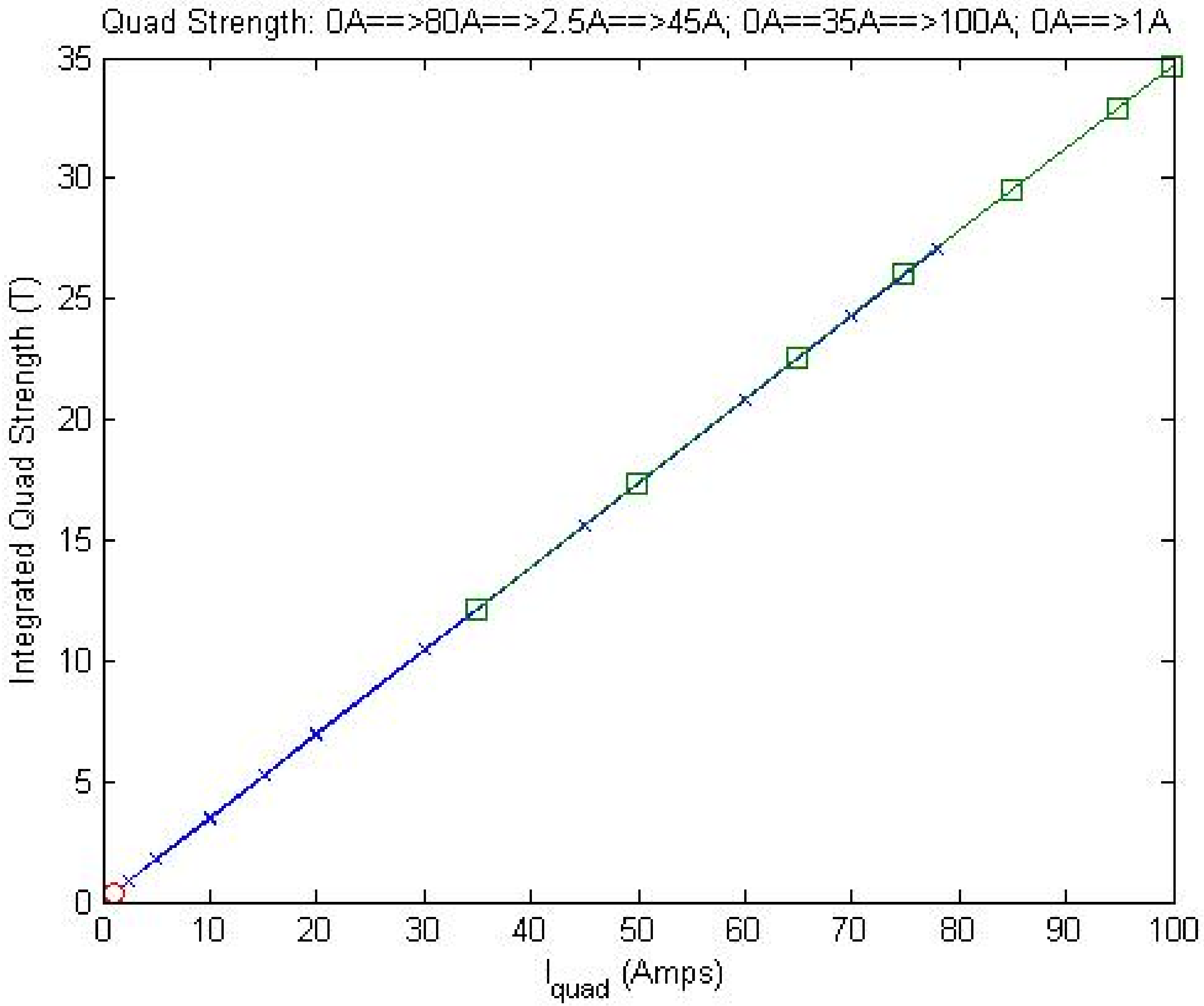
Comments from Vladimir (2)

- The Superferric Quadrupole designed to cover all range of integrated gradients up to 36 T. The only difference between both designs from the point of maximum gradient is that Cos coils placed closer to the aperture than Racetrack coils and magnet has smaller volume of superconductor per T-m/m. Because the racetracks far away there are enough space for extra superconductor. The cost of superconductor in these magnets are low.

- The iron saturated also in Cos magnet ~2.5 T at peak gradient [? - see next slide]. ARMCO type steel has Bs=2.1 T. The racetracks far away from aperture and field less sensitive to their displacement. These effects were simulated.

- Any of these designs could meet the spec. Splitting the Cos magnet is more problematic.

CIEMAT SC Quad Linearity



Akira Questions and Answers

- How long would it take the magnet to cool down
  - Order of one week, in my guess, based on the J-PARC corrector coil cool-down (with conduction only), and the cold mass weight is an order of 100 kg.
- Can the symmetry of the quad be maintained with the split design
  - I think (believe) that the symmetry is better and stable than cos2 theta winding. It is because the magnetic center is to be determined by the iron pole firmly assembled with purely mechanical tolerance.
  - In my understanding, iron pole of the quadrupole is usually assembled with originally split structure, and it would not be a problem.

Akira Questions and Answers

- The beampipe still needs to be opened for the BPM - i.e. one cannot make a split BPM since the beam has to go through the BPM cavity
  - My consideration is to assembly the BPM together with beam pipe (loosely or with keeping some flexibility, and it is to be well aligned with the quadrupole mechanically, after assembly of the quadrupole,
- A superferric quad is not strong enough at the end of the linac without either making the quad longer than in the baseline design or the beam pipe aperture smaller (half size, as I have proposed)
  - It is my concern as well, and I would like to get more professional advice from magnet experts. It is why, I am proposing to have a parallel session at the TILC-09.

Akira Questions and Answers

- The motion of the quad center with changing current is probably much larger in a superferric design compared to a cos(2phi) design because at high field the iron begins to saturate in the superferric design, and the field shape starts to depend on the coil location.
  - How the saturation effect is asymmetric is my question, too. Which is more stable with iron pole design and cos2-theta design. I would like to discuss it also.