Vacuum rf 6D Cooling Conclusion

R. B. Palmer
(BNL)

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Preliminary Conclusions

- Mark has requested a single option with 'end to end' simulation from phase rotation to final Cooling.
- Rob requests that the simulation should, as far as possible, use the standard codes icool or G4BL.
- At this point, our only option is for:

1. Diktys' ICOOL simulation of Valerys Rectilinear RFOFO lattices, from the end of phase rotation to the start of merge.
2. A 6D merge , using output from the above
3. A Diktys' ICOOL simulation of Valerys Rectilinear RFOFO lattices, using output this, to emittances of 0.32 mm transverse and 1.6 mm longitudinal (close to the specified 0.31 mm transverse & 1.5 mm longitudinal).

Reservations and comments:

1. This is based on a front-end without a chicane.
2. It is based on a simulation without the charge separation. Carys simulations have limited statistics, but show good transmission and only a small increase in longitudinal emittance. It is thus reasonable, as Mark had suggested, to use the high statistics output from the phase rotation.
3. The current "single option with 'end to end' simulation" uses parameters and detailed choices chosen by Diktys, that differ in several ways from those being studied by Valery.

   We cannot make direct comparisons of Diktys' and Valery's presented performances because of significant differences in the two simulation's assumptions: Gaussian vs. non Gaussian stochastic effects, and probable differences in energy loss assumptions. It will remain difficult to understand the differences until Valery uses one of the standard codes.

Some of these differences are:

- Valery uses fewer different 'stages', thus reducing the complexity of systems, while increasing the difficulties of matching between them.
- Valery uses only one rf frequency (325 MHz) throughout, while Diktys uses first 325, then 650 MHz.
- Diktys used liquid hydrogen absorbers throughout, while Valery uses liquid hydrogen first and LiH in later stages. The use of LiH makes the absorber design much easier, but requires lattices, at the end, with lower betas that probably greater demands on their coil design (see engineering comments below).

4. We are not now proposing initial cooling of both signs using a Helical FOFO snake, followed by later and easier charge separation. But if there are unexpected problems in the charge separation of the initial emittances, then performance could be better with this option.

5. We are not now proposing the use of Planar Snakes that might eliminate the duplication of cooling and merging channels. The idea, though attractive, and shown to work well in one particular case, is not yet well enough developed or understood.
6. We are, temporarily, using a non-standard simulation of the merge. This will be replaced with Baos G4BL simulations when available.
7. Although we are incorporating some engineering considerations in the lattice designs, there will need to be future iterations.

Engineering Questions

- rf Cavity design and waveguides. Diktys has already made modifications to the coil designs before the merge to allow straight radial waveguides. Similar modifications to stages after the merge do not appear difficult.

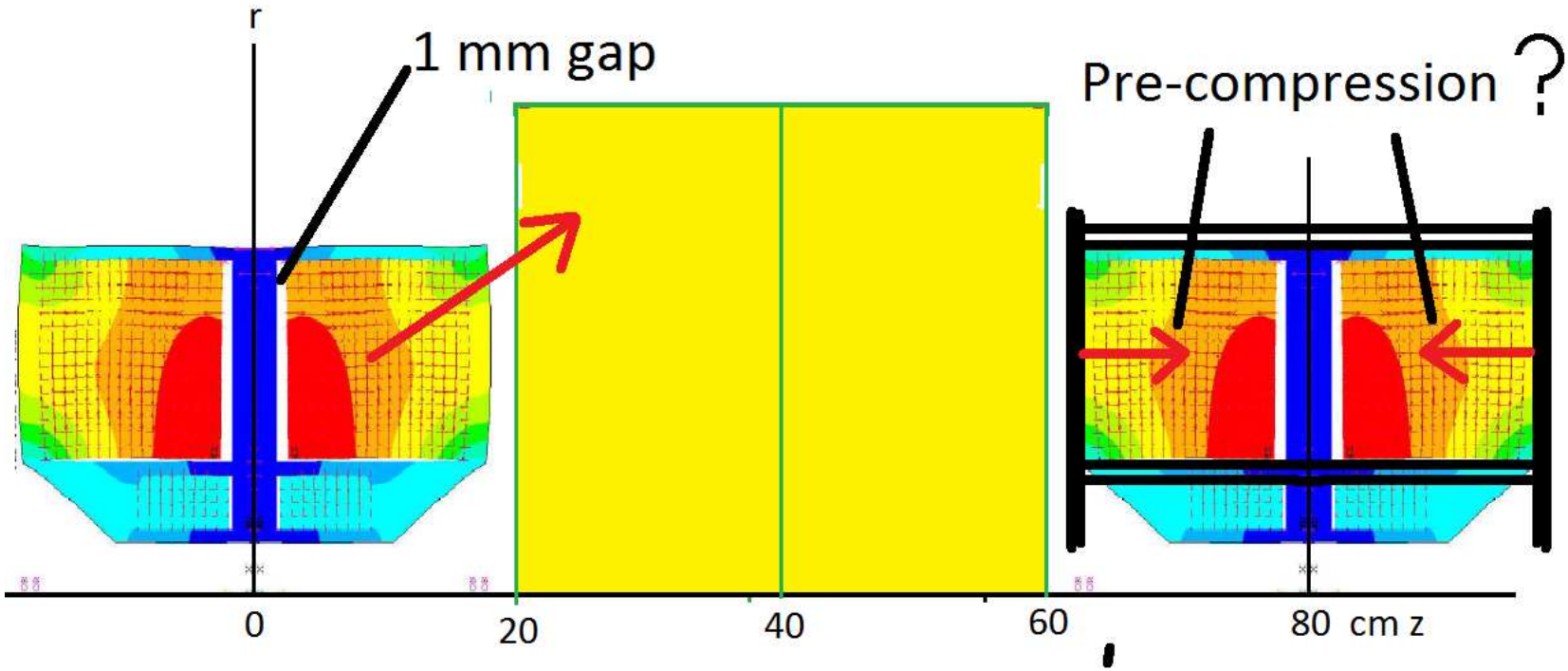
  Both designs, for their initial stages, have specified rf windows with 25-30 cm radial apertures. For a 325 MHz cavity these are very large and will generate a lot of heating at the larger radii. The required Be thicknesses to cool these cases have not been determined. It has been noted that the beams are not centered on the coils in these designs, and that the cavities, to reduce this required aperture requirement, should be appropriately displaced.

  This requied Be thickness will depend on the choice of cavity operation temperature. If operated at 77 degrees, instead of room temperature, the effect of such heating will be much reduced, due to the order of magnitude reduction in thermal expansion at the lower temperature..

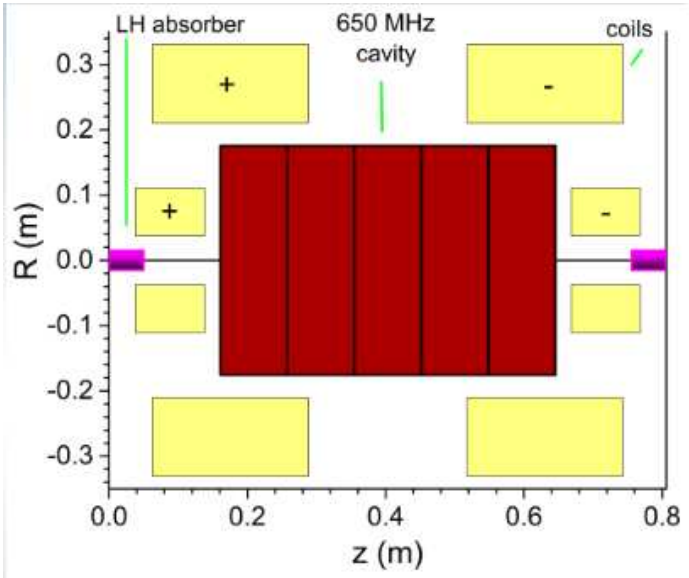
- Coil design.

  The current densities and calculated tension from coil radial forces appear to be within plausible limits for Nb_3Sn conductor. But, as shown by I. Novitski, the axial forces may be creating a problem. In the last stage of Valery's scheme, these forces, even after significant coil changes, are sufficient to move the conductors axially by as much as 1 mm. Novitski said, and I concur, that experience suggests that such motion would cause unacceptable training: a more normal limit for such motion would be 0.1 mm. Only actual coil construction and testing would confirm such a prediction, but this appears to present a problem.

  The use of cable in conduit would drastically lower the average current density. Adding pre-compression could be considered.

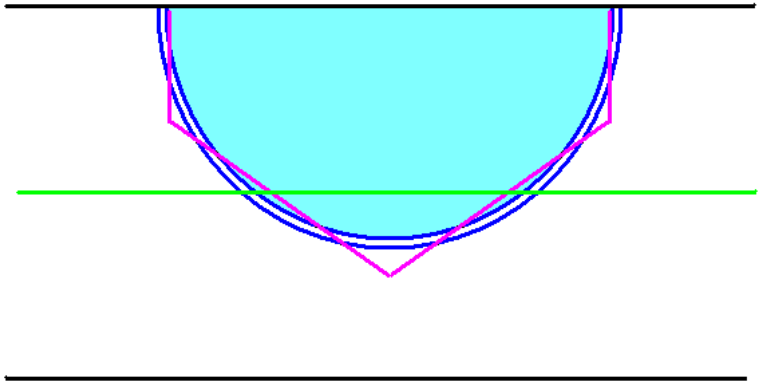


It is possible that Diktys' design will not be quite as bad because it does not need such a low beta function. But is still a worry.



- Design of thermal insulation between coils and rf systems
- A plausible design of 'wedge' absorbers

  a liquid hydrogen absorber with a true wedge shape is probaly unrealistic. A cylindrical shape would be far easier. It will be important to simulate such shapes to see if the required emittance exchange can still be achieved.



- Determination of coil and rf tolerances
- Determination of needed instrumentation

Conclusion

- Diktys reported the first 'end-to-end' simulation of the cooling, merge, and re-cooling, although the merge simulation was not fully 3D, and there are many other reservations.
- Valery continues to study several alternative ideas, but the approximations in his simulation tools do not allow a simple comparison of their performance with the Diktys version. We urge Valery to use G4BL. The fact that we must now move forward with Diktys' scheme does not mean that we cannot adopt more of Valery's ideas in the future.
- We are not now proposing to use an initial Helical FOFO snake that would allow the charge separation to be done later when the emittances are lower. We need more study of the charge separation before the use of this snake can be evaluated.
- We are not now proposing the use of a planar snake, despite its many advantages - it is not yet sufficiently studied or understood

- There are serious engineering questions that are now becoming apparent: rf windows, hydrogen absorber design, super-conducting coil motion, etc. Novitski's presentation was much appreciated.
- We are making real progress.