Results of Cooling MiniWorkshops

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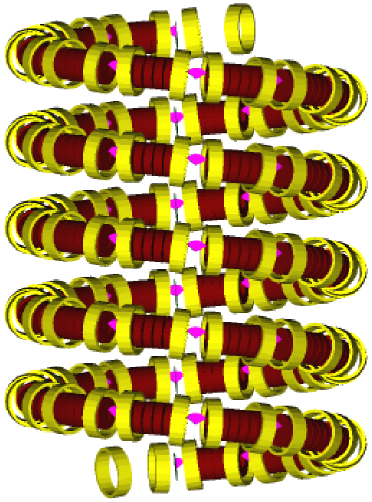
Overview

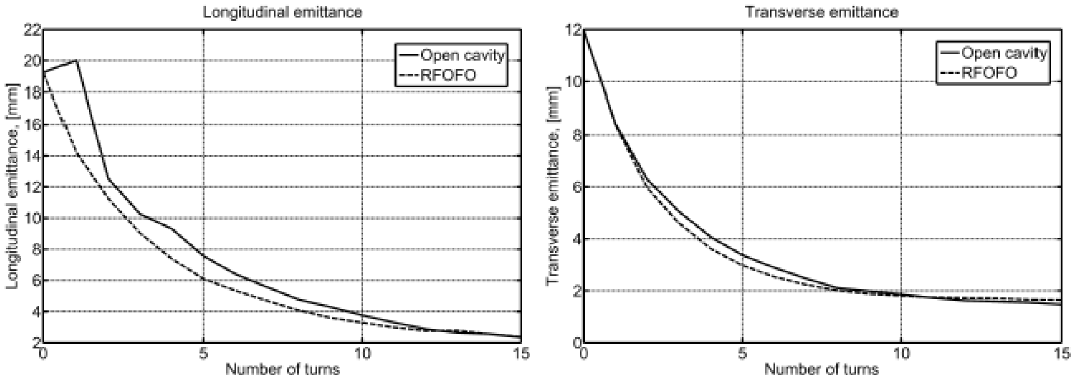
- Alvin suggested we have a series of mini-workshops to examine state of our cooling simulations
  - find out where the "shaky stuff" is in our simulations
  - prepare answers before we get caught out by an aggressive reviewer.
  - prepare for DOE review of MAP
  - try and flesh out a coherent process for the future.
- workshop at FNAL on Oct. 22
  - Guggenheim channel
- workshop at BNL on Dec. 2
  - Helical Cooling Channel (HCC)
  - Helical FOFO-snake (HFFS)
  - 50 T final 4D cooling
  - Li lens final 4D cooling

Guggenheim channel (BNL-Riverside)

- ICOOL simulations can now be done with realistic magnetic fields using a new field map-making program
- discussed using “open-cell” and magnetically insulated lattices
- G4BL simulations of open-cell lattice at 201 MHz give similar results as earlier simulations with coils outside RF
- present simulations with gaussian initial beams have Tr~50-60%
- points to need for designing tapered channels & careful matching

much consternation !





Questions at Guggenheim review (1)

RF engineering questions (RP: will look at high-level RF parameters)

1. Can we get 14 MV/m at 200 MHz?
2. What is the cavity Q?
3. What is the total required RF power?
4. How much real estate does the RF take?
5. Is the RF hardware servicable?
6. What is the RF pulse width?
7. What is the RF duty cycle?

Questions at Guggenheim review (2)

Other engineering questions

8. What is the expected beam loss?
9. Do we have a radiation problem?
10. What is expected heat load on the cryogenics?
11. Is there a problem with cryo plumbing on the Guggenheim helix?

Questions at Guggenheim review (3)

Beam optics questions: near-term “sanity checks”
(do programs agree?, are results as expected?)

12. Do ICOOL simulation of Pavel's open-cell 201 MHz channel.

RF: done using map method, e_{TN}=2.0 mm, Tr=60%, similar to PS

13. Try 201 MHz simulations using AlBeMet windows

RF: done, (e_{TN},e_{LN}) = (2.9, 3.8) for AlBeMet vs. (3.8, 5.0) for Be

14. Compare simulations of 805 MHz channel.

RF: done using map method, constant dipole, e_{TN}=0.41 mm, Tr=58%, similar to RP

PS: working on this now

15. Categorize the sources of errors in simulations

Riverside: will look into this

Questions at Guggenheim review (4)

Beam optics questions: longer-term studies & suggestions

16. We should do linear & nonlinear beam optics analysis “like Yuri does”.

PS: will look into this using COSY & G4BL

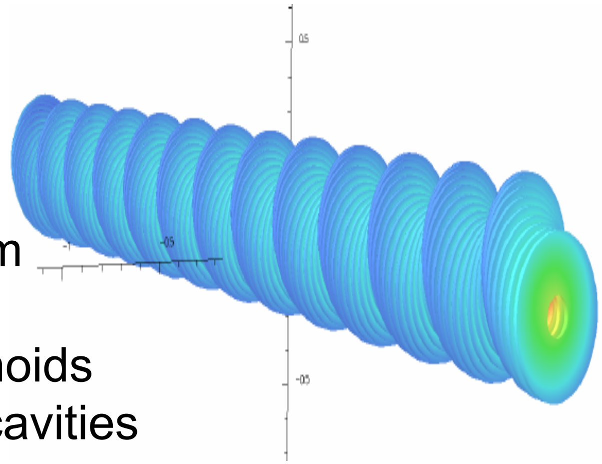
17. Do detailed linear and nonlinear optics before doing tapering.
18. Design a tapered channel ASAP.

most important task

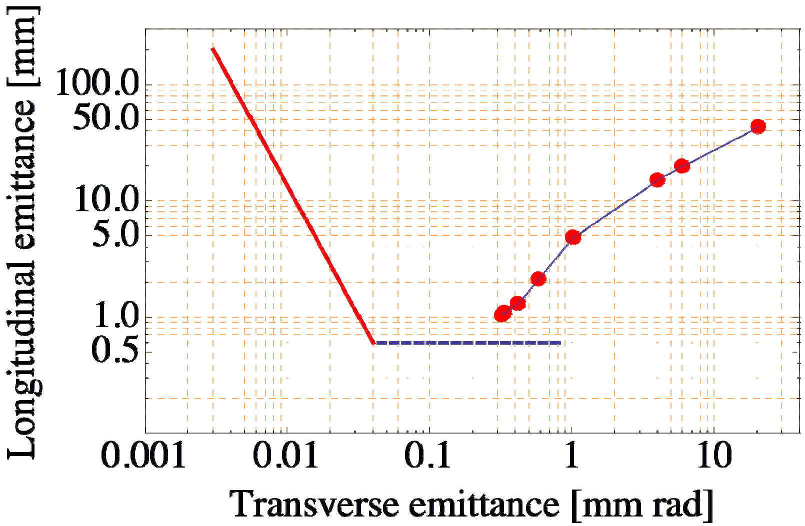
RP: started working on this, will report in a talk later

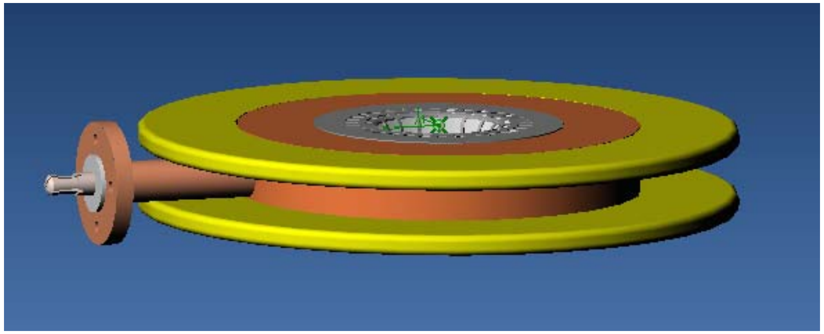
19. Design matching into Gug including dispersion.
20. Try chromaticity correction with bent solenoids
21. Try a planar snake configuration instead of a helical channel

Helical Cooling Channel (FNAL-Muons Inc)



- KY showed new 8-stage κ=1 design
- G4BL simulations achieves
  ε_{TN}=0.34 mm, ε_{LN}=1.1 mm, Tr=84% in 303 m
- RF frequencies range from 325 to 1300 MHz, E=27 MV/m
- last stage uses BD=4.3 T, G=5.6 T/m, BS~14 T
- Vl. K showed magnet optimization based on helical solenoids
- MN showed RF optimization based on dielectric loaded cavities





Questions at the HCC review (1)

- engineering requirements for HCC seem complicated
- highest priority is for a self-consistent strawman design incorporating all engineering constraints

    strawman = self-consistent, not fully engineered or optimized

  There is a lot of activity looking into this now
- need simulations that exactly correspond to this constrained design,

  i.e. with coils and cavities in their actual locations

Questions at the HCC review (2)

Magnet engineering questions & suggestions

1. Will all the fields in the channel be produced by Kashikhin helical solenoids, supplemented as necessary with additional quadrupole or solenoid windings?

   KY: TD people have design of HS magnet for final critical stage; large solenoid needed, but not a quad

2. How much space do these coils need for thermal insulation and mechanical support?

   KY: two conceptual designs still under consideration

3. The parameter lists should include the inner radius, outer radius, length, current density, and peak field for each of the different types of coils.

4. The parameter lists should indicate which stages, if any, need additional quadrupole or solenoid windings.

Questions at the HCC review (3)

RF engineering questions (MN: these are tractable engineering issues)

5. Will all the RF in the channel be provided by dielectric-loaded RF cavities similar to the design shown by Neubauer? What are the cavity dimensions including those of the ceramic and what is its shunt impedance?

6. How much space do these cavities need for feedthrus, thermal insulation and mechanical support?

7. What are the maximum Lorentz forces expected on the gridded cavity windows?

KY,MN: negligible detuning due to estimated window deformation

8. What is the peak electric field enhancement on the grids?

MN: can use a diaphragm instead to isolate E-field and equalize pressure

9. How many RF cavities and what total peak power will be required at each RF frequency?

Questions at the HCC review (4)

Mechanical engineering questions

10. What is the temperature and pressure of the hydrogen gas?

KY: two concepts under consideration

11. Where are the high pressure boundaries located in the layout?

12. It seems hard to believe that this design can just use two high pressure gas windows separated by ~300 m. What is a reasonable number of windows to include, taking into account safety, maintenance, and the possible desirability of tapering the gas pressure in the channel?

RJ: any safety windows do not have to be in muon beam path

KY: FNAL safety people think 300 m of gaseous hydrogen is OK

13. What material will the pressure windows be made of?

KY: Inconel 780

Questions at the HCC review (5)

Beam optics questions

14. Simulations of representative stages should be done taking into account the actual locations of all the coils, spaces for engineering purposes, RF cavities, windows and all physical apertures.

15. Is there a self-consistent solution for the layout of the last, low emittance stage of the channel?

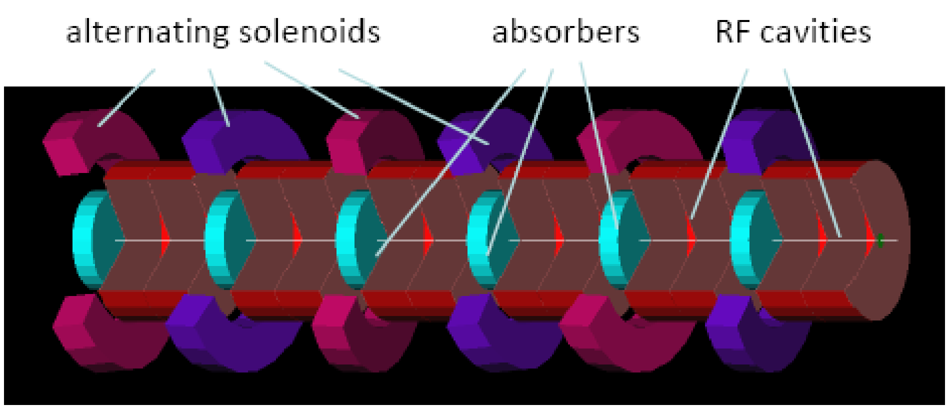
16. Does one or more field flips improve the channel performance?

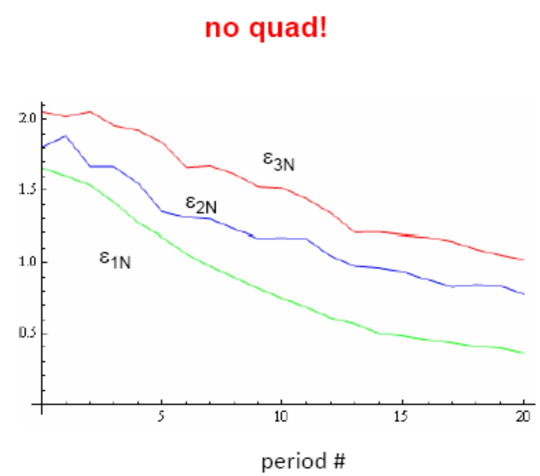
RJ: doesn’t think so

MCTF

HFOFO-snake channel (Y. Alexahin)

- earlier HFOFO designs used 60° phase advance per cell (Φ)
- equalize transverse damping rates using quadrupole field ~0.06 T/m
  - insensitive to quad tilt & polarity and μ sign
- including absorber & RF windows increased ε_{eq} by ~30%
- simulated results give ε_{TN} ~ 6 mm & ε_{LN} ~ 10 mm
- is exploring further cooling using larger phase advances
- Φ=120°, 800 MHz, LiH, quad = 1.45 T/m, no windows → calculated ε_{eq}~0.8 mm
- found problems with momentum acceptance for Φ=270°
- thinks an acceptable solution with Φ=180° may be possible





Questions at HFOFO-snake review

Engineering questions

1. Is sufficient space allowed in this design for thermal insulation, mechanical support, and RF feedthrus?
   YA: will consult with engineers about space between coils & cavities thinks there is plenty of room for feedthrus
2. Will a quadrupole winding be included in the 0th order design?
   YA: required gradient is very small
   Where is it located?
   YA: Can be made from dedicated windings outside solenoid
3. How many RF cavities and what total peak power will be required at each RF frequency?
   YA: will work on this in 2010

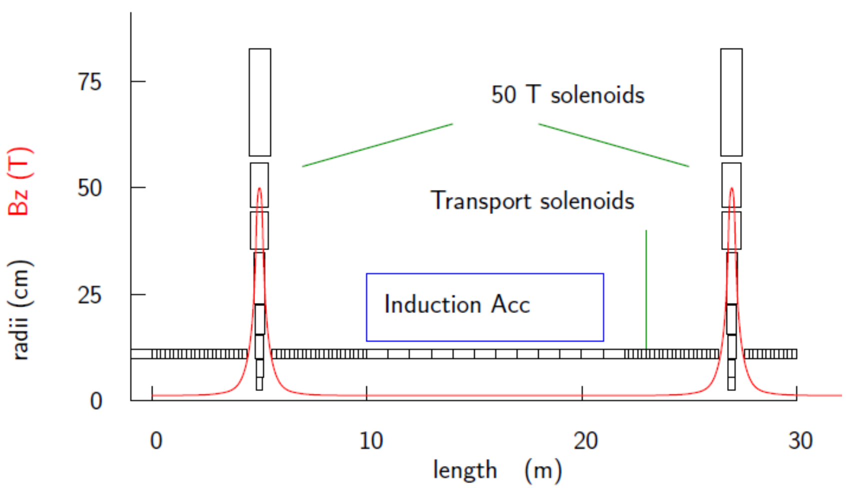
Questions at HFOFO-snake review (2)

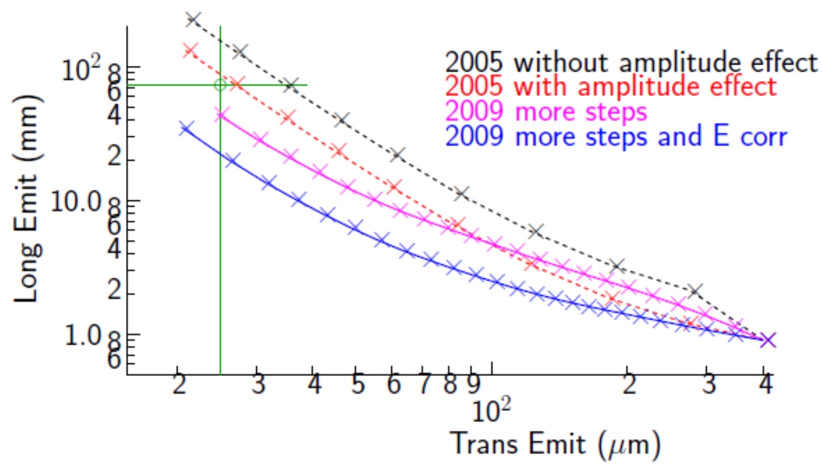
Beam optics questions

4. Simulate the present 200 MHz channel using the beam distribution from Dave Neuffer's front end design as input and including realistic radial apertures.
   YA: will do this in 2010
5. Does adding gas to raise the gradient help the performance, given the necessity of adding pressure windows and allowing space for the high pressure boundary?
   YA: no time to study this, could use some help
6. Can modified versions of this type of channel, including having low β at the absorber, reach ε_{TN} ~ 0.4 mm and ε_{LN} ~ 1 mm?
   YA: calculations shown at workshop suggests yes
   will work on this in 2010

50 T cooling channel (R. Palmer)

- 2005 design had two main problems
  1) ε_L growth in early stages due to dependence of forward velocity on amplitude
  2) decay losses in final stages in long drifts and acceleration of long bunches
- new 2009 design
  reduced magnetic field in early stages (35 T)
  uses more (19) shorter stages
- 5 stages were simulated, effect of others derived from interpolation
- achieves ε_{TN}= 25 μm with lower ε_{LN}~40 mm than previously (70)
- avoids excessive decay losses



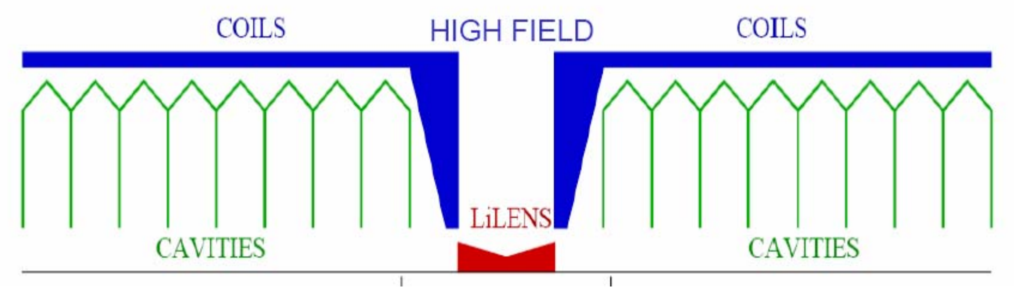


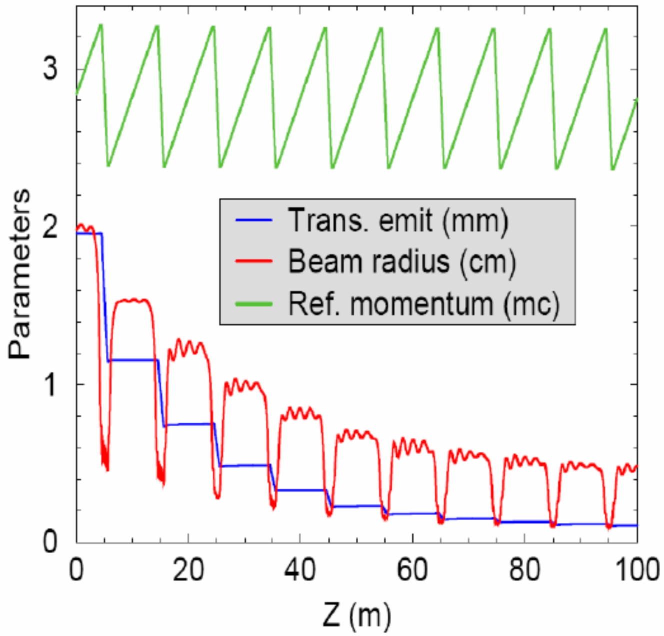
Questions at 50 T channel review

1. Prepare tables of parameters for the 19 stages in the new design.
2. Include windows in the simulations.
3. Does one or more field flips improve the channel performance?
4. Estimate the effect of space charge in new channel design.
5. How many RF cavities and induction linacs and what total peak power will be required?

Li lens cooling channel (V. Balbekov)

- main problem in Li lens channels is chromatic aberrations in matching sections
- explored using adiabatic solenoid matching into high gradient Li lenses
- used tapered solenoid & Li lens shapes
- best performance found in channel with
    - alternating B direction in the Li lenses
    - tapered Li lens gradients
- simulated reduction in ε_{TN} to 110 μm at 300 MeV/c
    - max Li lens gradient ~ 15 T/m, 10.5 T surface field
    - max solenoid B ~ 35 T
- angular momentum correlations suppressed in Li lens
- started exploring getting lower ε_{TN} by
    - reducing p, reducing f, shorter Li lenses





Questions at Li lens channel review

1. Can a realistic lithium lens channel produce ε_{TN} ~ 25 μm?

   VB: has simulated 35 μm without Be windows

   will continue working on optimization

2. If so, make a realistic tracking simulation including the induction linacs and physical apertures.

   VB: will incorporate induction linacs as part of optimization studies

SUMMARY

- these miniWorkshops turned out to be a useful exercise
- resulted in a lot of work
  - in progress now
  - or in people's near-term plans
- could serve as a model for focusing effort for other subsystems
- Tom Roberts is interim MAP manager for Cooling
  - will have primary responsibility for monitoring progress in this area