PIP: 2nd Harmonic Cavity Update

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Work that has been done so far ...

- Exploration of direct liquid cooling.
- Different garnet geometries.
- Better measurements of losses in AL400.
- Exploring another way to put in a perpendicula field called a “radial field”
- Rope in D. Sun to help us with this adventure.

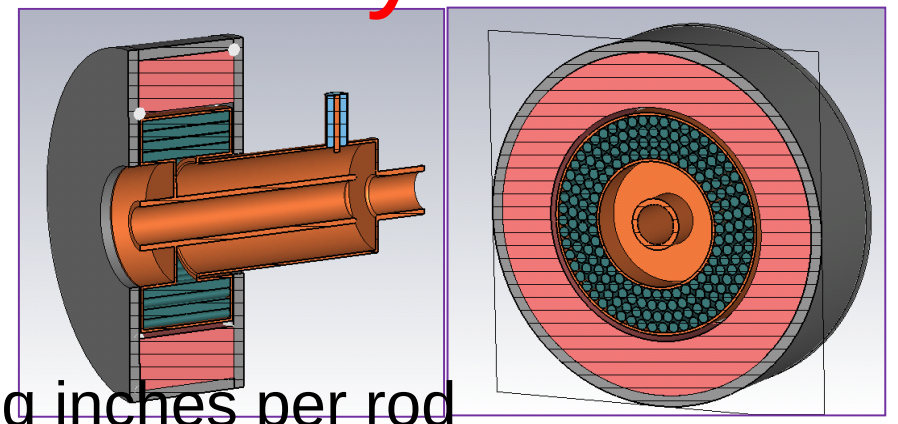
Why think of direct liquid cooling

- Initial motivation was because magnetization at the ends of the ferrite disks reduces H field inside (red herring …)
  - For example:
  - Demagnetization given by N_z 4π M_s
  - And N_z depends on geometry.
  - For annulus ID=8.661”, OD=15.354” and thickness=1”, N_z =0.74.
- Want to get away from BeO cooling disks.
  - BeO used because of Eddy currents at 50 Hz. We are going to run at 20 Hz max and heating scales as f^2. At least 4× lower in heating, consider copper instead. Is sparking between garnets still a concern with copper disks?
- Problems with AlN is that it hydrolyzes in the presence of water.
- KEK has considered using liquid cooling in their Finemet cavities.
  - And surprise, surprise, SSC low energy Booster cavities, are also perpendicularly biased and uses liquid cooling!

Problems with liquid cooling

- Possible liquids
  - Water
    - Too much permittivity losses at ~100 MHz.
    - Corrosion of ferrites.
  - Paraffin
    - Fire hazard!
      - 70 degC ignition!
    - Radiation damage
      - Mixed waste problem
    - Needs high flow rate for same amount of cooling as water, but get turbulent flow.
  - Fluorinert
    - Cost
    - Radiation damage.
    - Must operate < 120 deg C because of ion decomposition.
    - High flow rate to get same cooling as water. Again turbulent flow.
  - Galden heat transfer fluid (Same chemical family as Fluorinert)
    - Proposed as cooling liquid for SSCL LEB perpendicular biased cavity.
    - Looking at the datasheets, Galden seems to be better than Fluorinert.
    - Radiation damage? Data sheet claims good radiation resistance. Used in nuclear industry to produce UF6.

Change ferrite geometry to rods

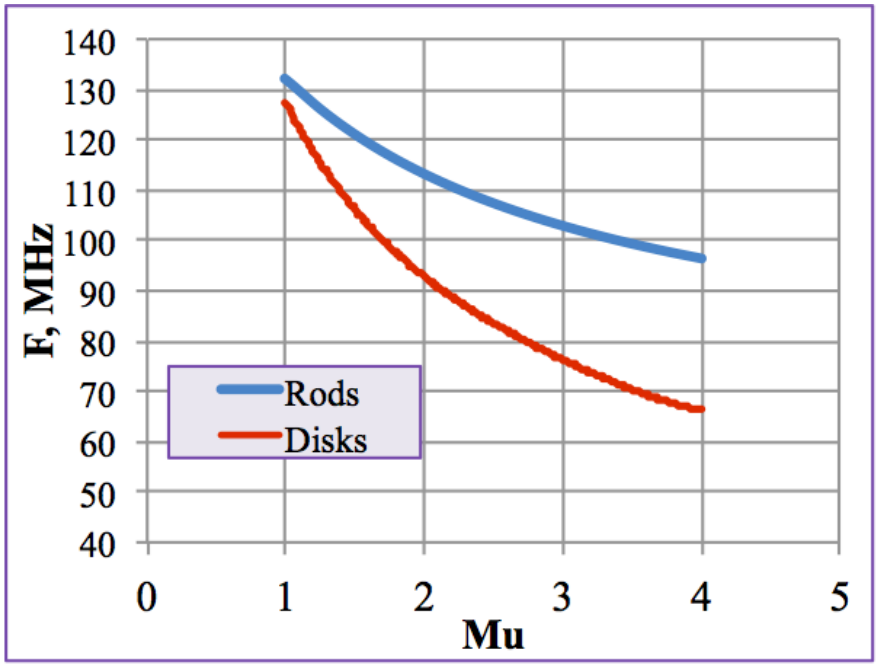


- More surface area
  - For rods
    - (2*π*0.375)*10.5 = 24.7 sq inches per rod
    - Total surface area = 160*24.7 = 3958 sq inches.
  - For annuli
    - Each annulus has surface area
    - $$2\times\left[\pi\left(r_2^2-r_1^2\right)\right]=2\times126=252.5 \text{ sq inches}$$
    - But there are 6 annuli, and so total surface area is 1515 sq inches < 3958 sq inches. Therefore, rods should be cooler

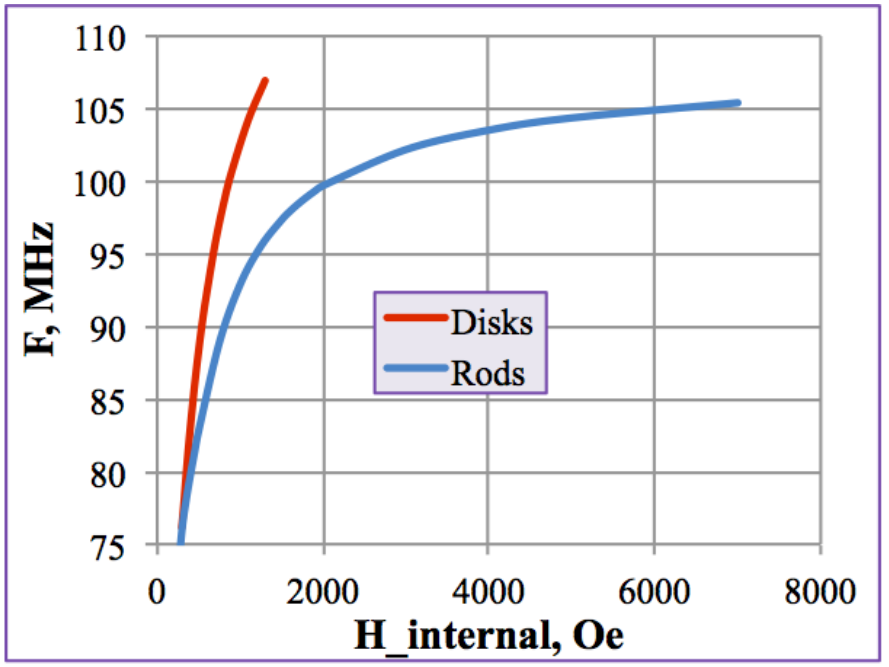
Advantages of rods (2)

- Possibly cheaper to buy.
- Easier to refurbish. Just pull rods out and put in new ones.
- Can use direct water cooling if we insulate the rods with inert material. (Does ferrite corrode in the first place? Recall formula $Y_3Fe_5O_{12}$, it's already has oxygen bonded to iron)
  - Must do this to prevent corrosion of rods.
  - Silica for insulate?
- Use sacrificial electrode like zinc????
- Expect maintenance/refurbishment schedule every 3 years?
  - Optimistic/Pessimistic?

Idea doesn't work ...



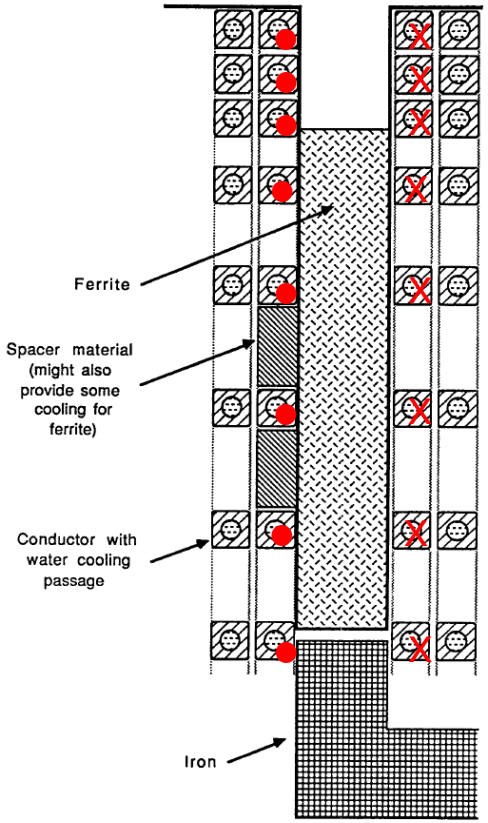
Tuning range for acceptable interval of μ.

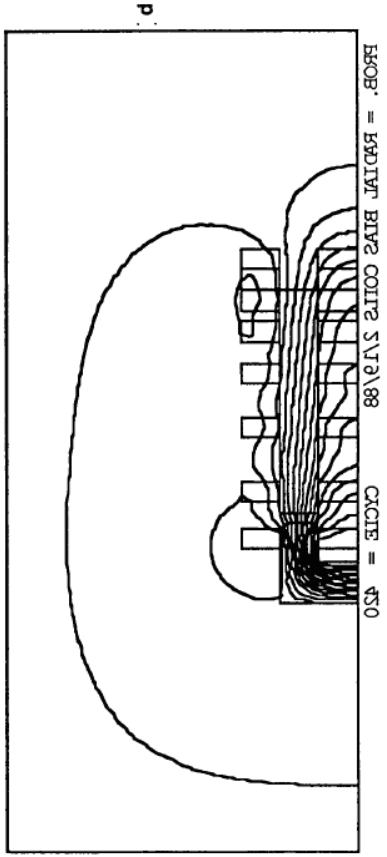


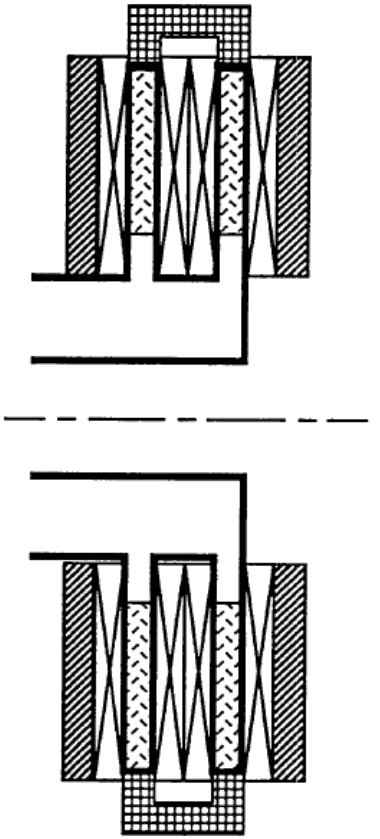
Interval of H_internal needed to cover required frequency span

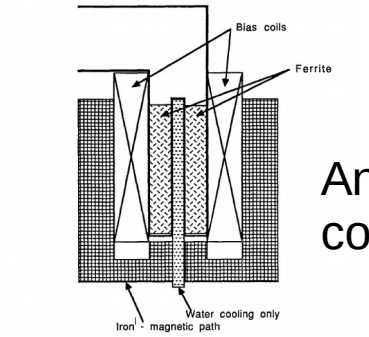
Calculations performed by G. Romanov

“Radial” B-field







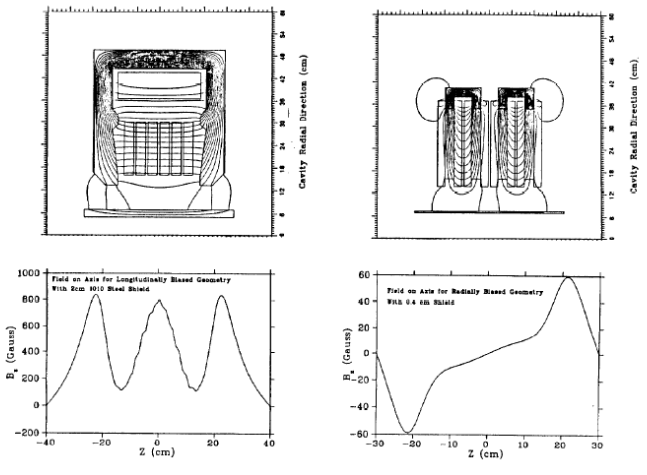


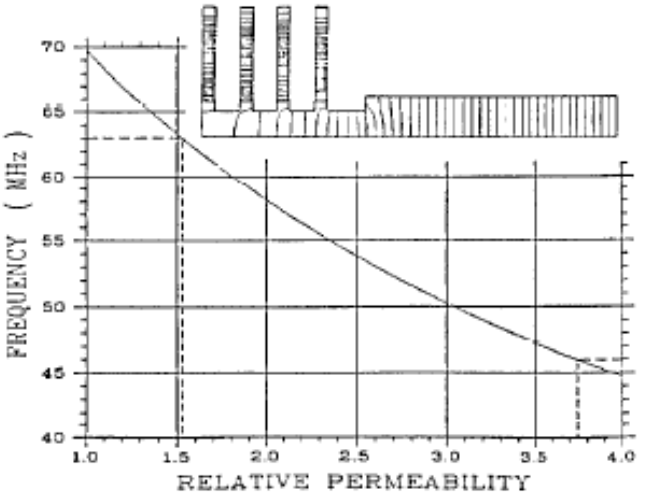
Another possible configuration

Suggested configuration from Poirier et al “Perpendicular Biased Ferrite Tuned RF cavity for the TRIUMF KAON Factory Booster Ring”, EPAC1998

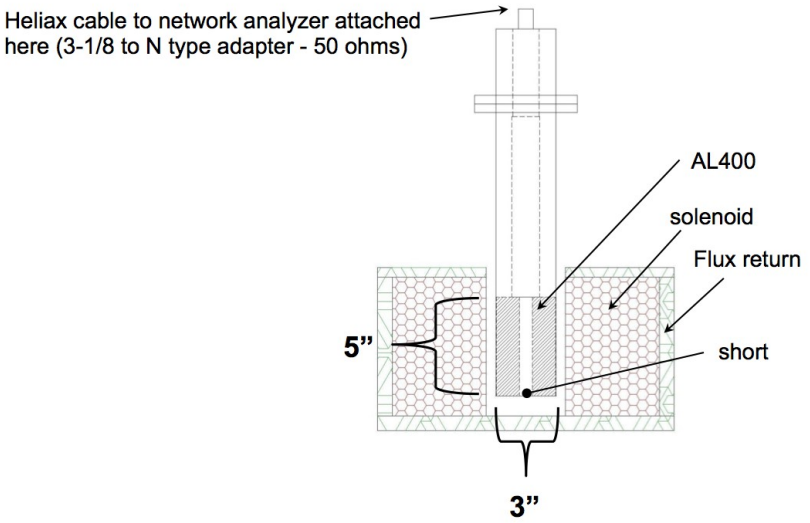
Advantages

- No eddy current problems at least inside
  - Still have to be careful outside on the shell
- Garnet can be cooled with water flowing in coils.
- Integral of on-axis field is zero



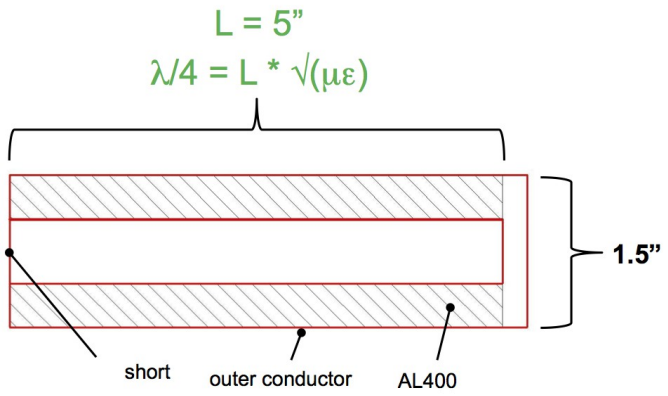


Progress on AL400 measurements



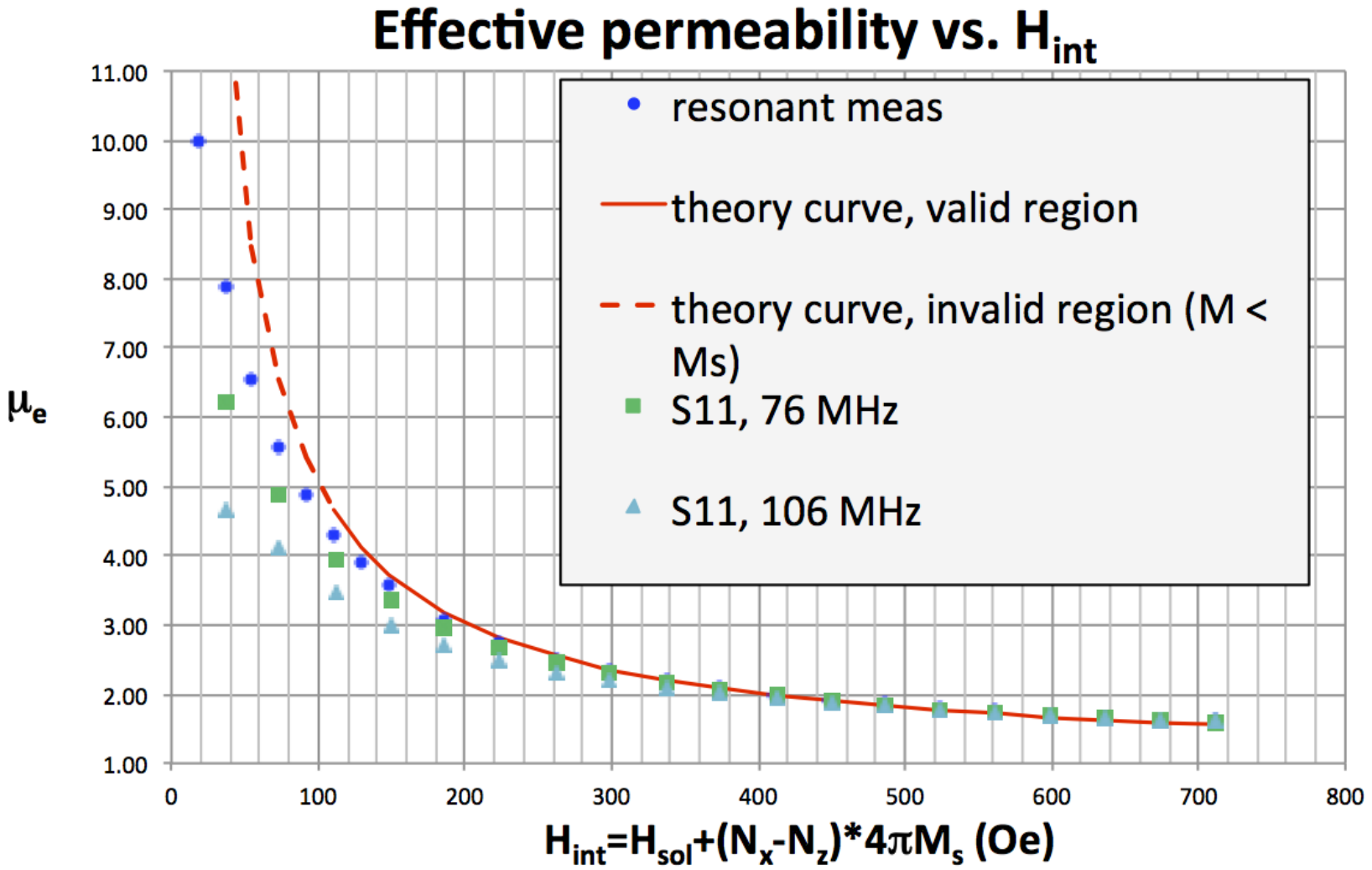
Moved from traveling wave to resonance measurement

Measured μ and Q (tan δ) resonantly with a 1.5” OD sample of AL400: measure f_{res}, then with $c = f \lambda$



Measurements performed by R. Madrak and D. Wildman

Results



A lot of technical details. See Robyn's write up at
https://beamdocs.fnal.gov/AD-private/DocDB/ShowDocument?docid=4601

Conclusion

- I think we should concentrate on using AlN as cooling disks first (copper being done in simulations)
  - Material coming in July time frame.
  - Perform epsilon measurements
  - Immerse in water (1 day? 1 week?) to see how AlN deteriorates.
- Al800 has come in. Perform measurements again.
- More simulations to understand where to put vacuum break.
  - Multipacting is a concern.
- Solenoid design and consider new “radial” B-field design.