

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 perpendicular 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 $N_z 4\pi M_s$
 - 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? Eddy currents slow down ramp, will cuts help?
- Problems with AlN is that it hydrolyzes in the presence of water.
 - May or may not be a problem. Will do experiment with AlN after leaving in 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.

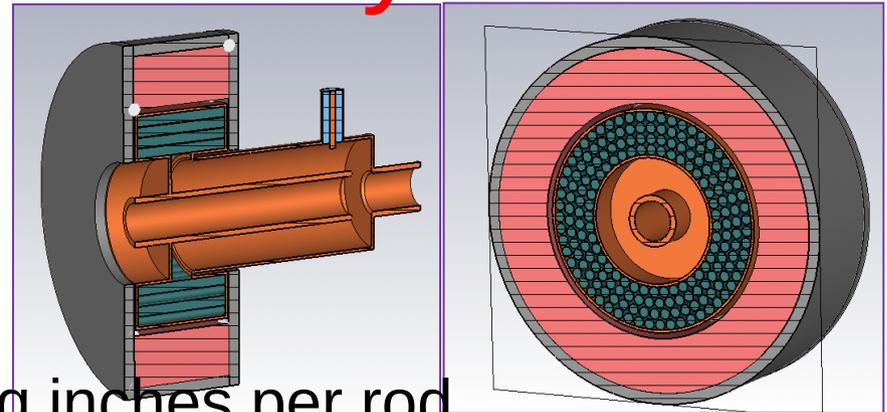
- Golden heat transfer fluid (Same chemical family as Fluorinert)

- Proposed as cooling liquid for SSCL LEB perpendicular biased cavity.
 - Looking at the datasheets, Golden seems to be better than Fluorinert.
 - Radiation damage? Data sheet claims good radiation resistance. Used in nuclear industry to produce UF6.

- Leaks!

- SSC LEB test cavity leaked.

Change ferrite geometry to rods



- More surface area

- For rods

- $(2 \times \pi \times 0.375) \times 10.5 = 24.7$ sq inches per rod
 - Total surface area = $160 \times 24.7 = 3958$ sq inches.

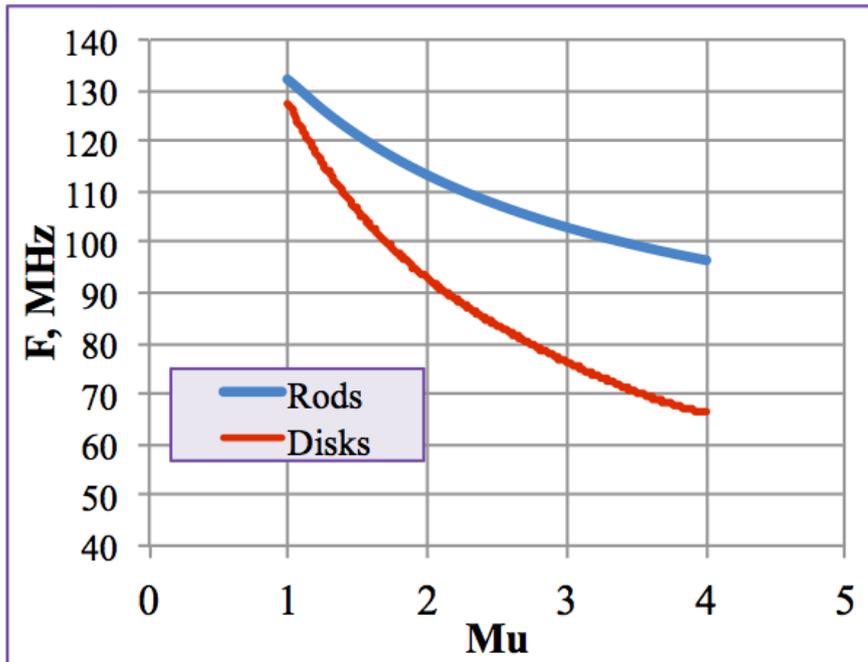
- For annuli

- Each annulus has surface area
 - $2 \times \left[\pi (r_2^2 - r_1^2) \right] = 2 \times 126 = 252.5$ sq inches
 - But there are 6 annuli, and so total surface area is 1515 sq inches < 3958 sq inches. Therefore, rods should be cooler

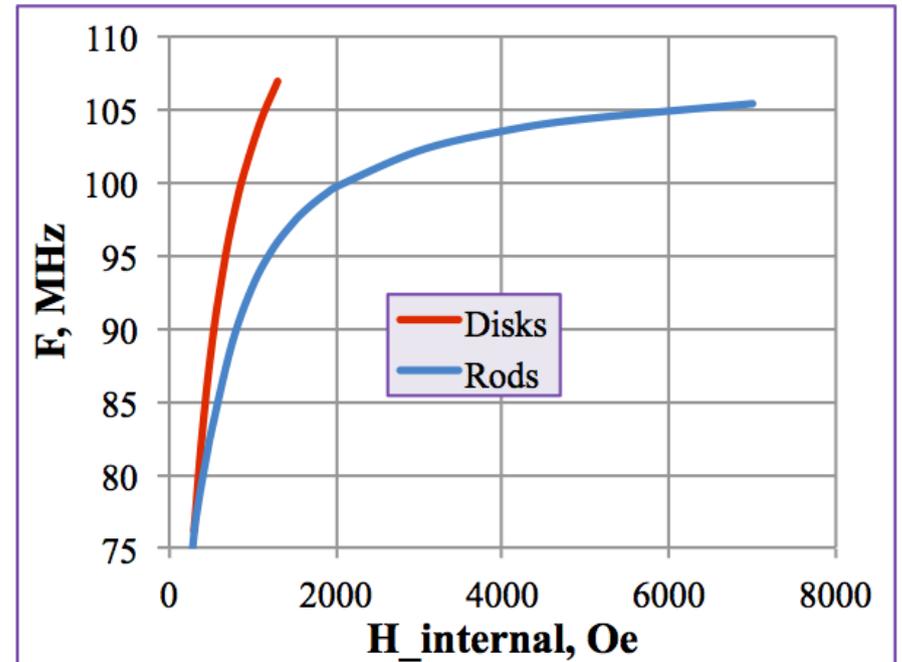
Advantages of rods (2)

- 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 ...



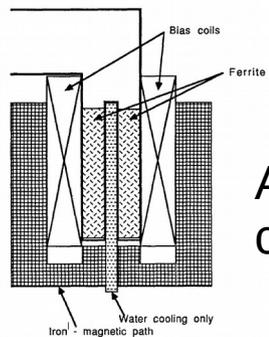
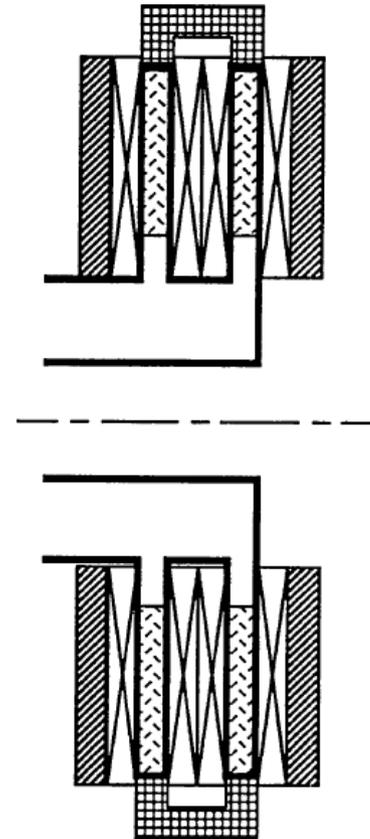
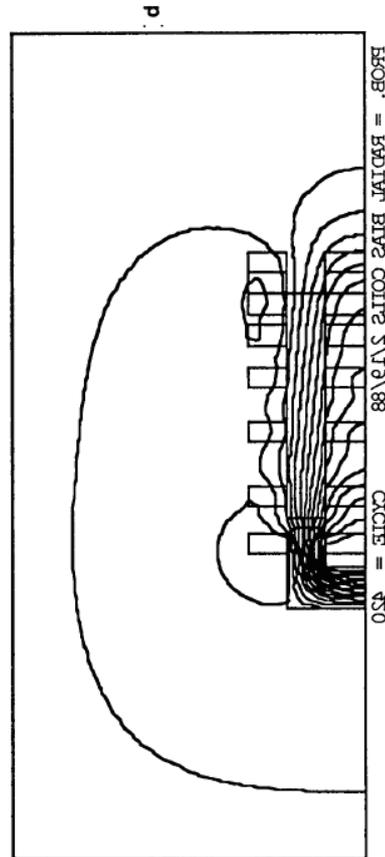
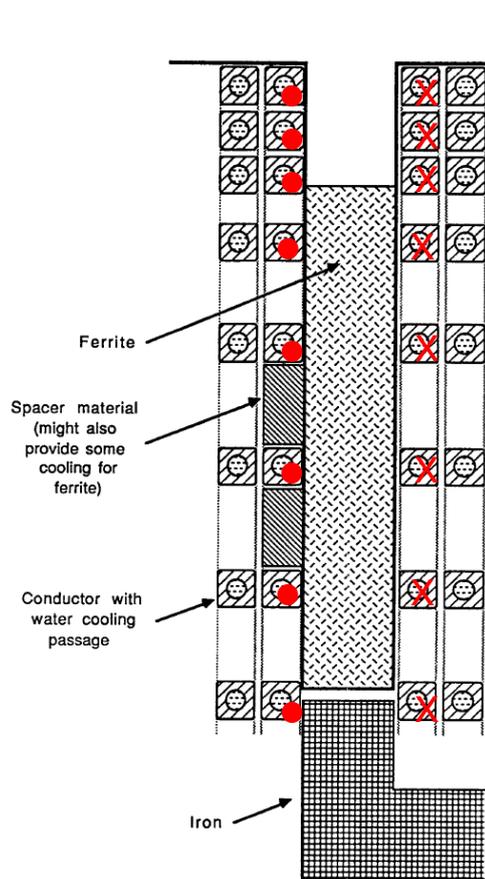
Tuning range for acceptable interval of μ .



Interval of H_{internal} needed to cover required frequency span

Calculations performed by G. Romanov

“Radial” B-field

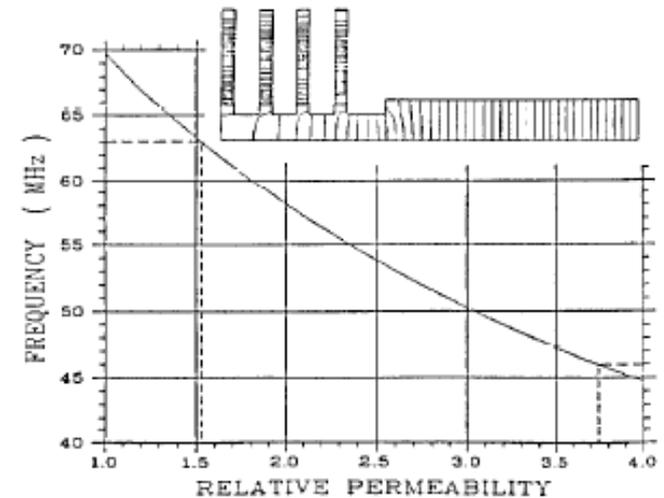
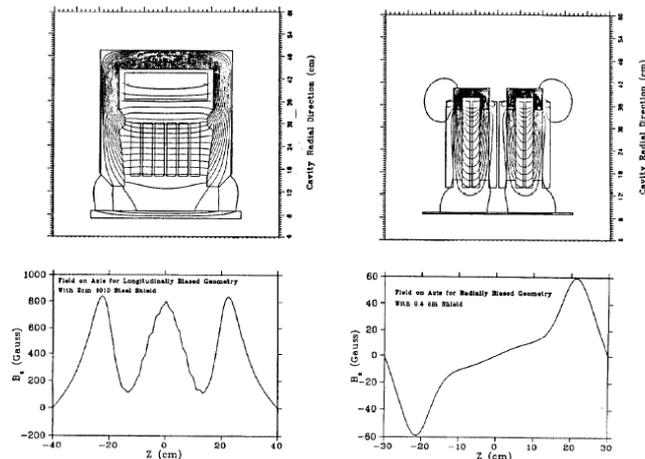


Another possible configuration

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

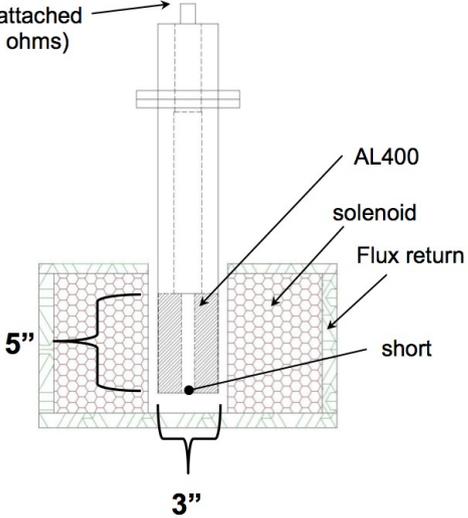
Advantages

- 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



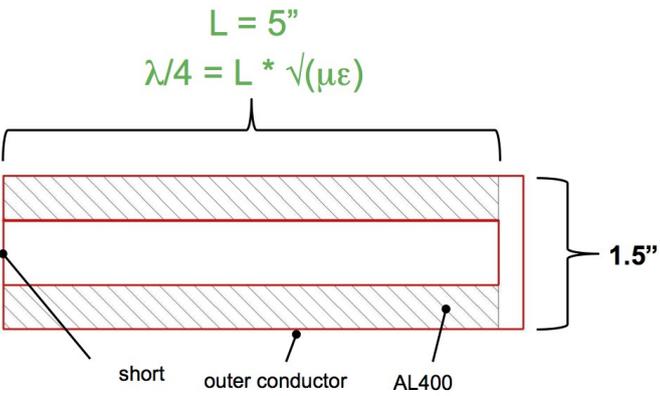
Progress on AL400 measurements

Heliax cable to network analyzer attached here (3-1/8 to N type adapter - 50 ohms)



Moved from traveling wave to resonance measurement

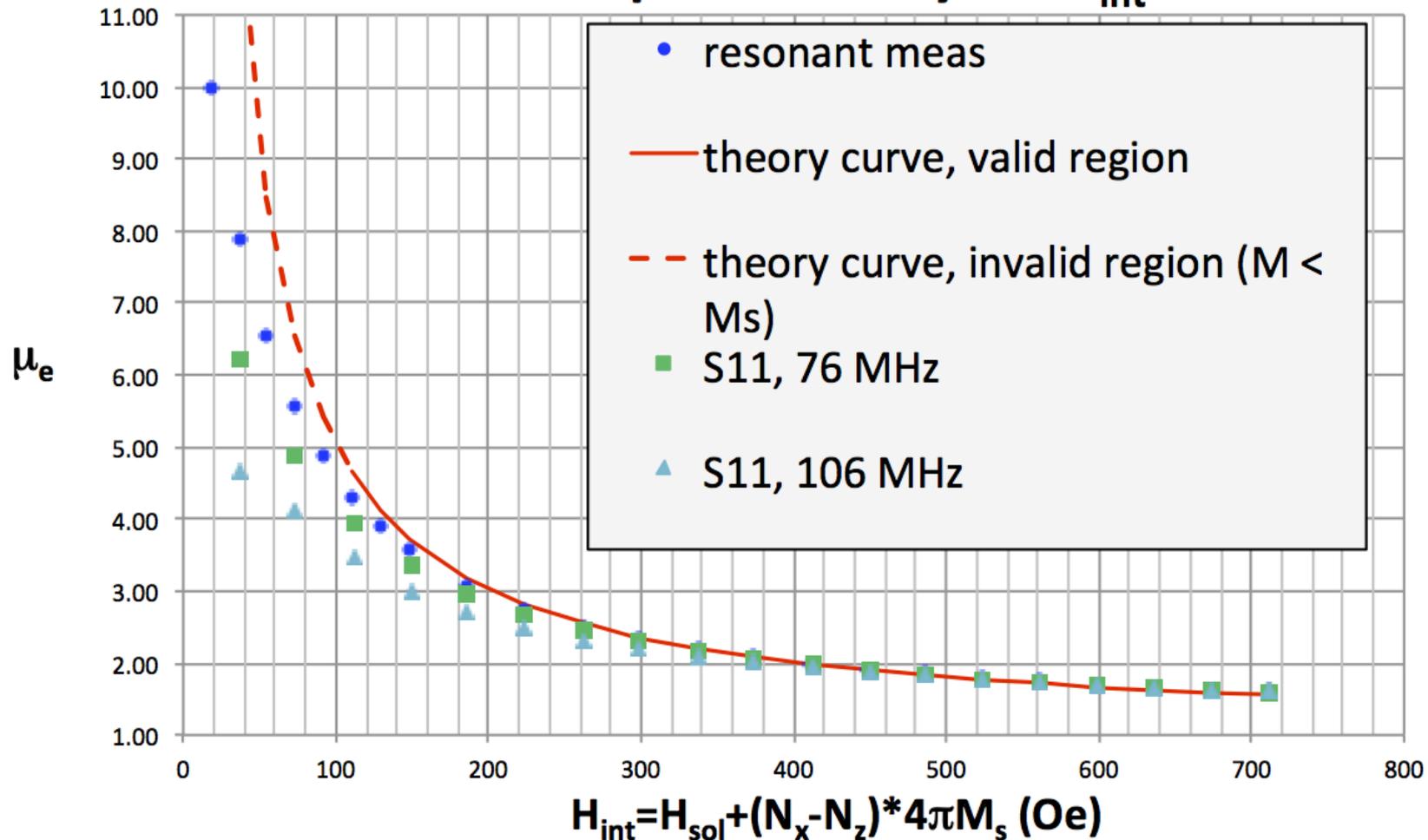
Measured μ and Q ($\tan \delta$) resonantly with a 1.5" OD sample of AL400:
measure f_{res} , then with $c = f \lambda$



Measurements performed by R. Madrak and D. Wildman

Results

Effective permeability vs. H_{int}



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.