201.25 MHz NCRF R&D Program and Plans

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LBNL

201.25 MHz cavity design status

RF parameters for MICE

Components

Proposed manufacturing plan

- Fabrication tests

Foils and grids

Forces during a magnet quench

Conclusions

(Budget)

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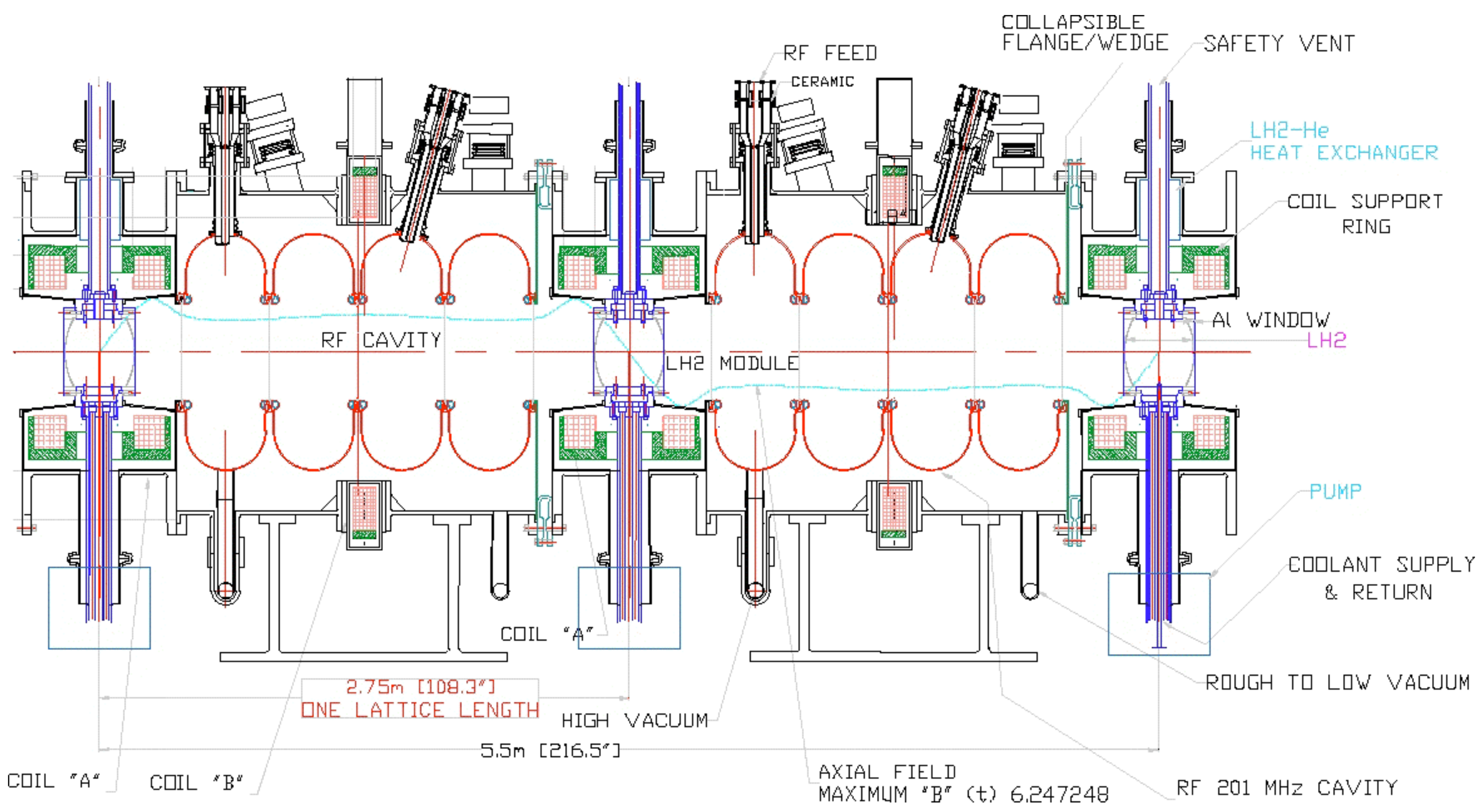
201.25 MHz cavity design status



Section of study-II cooling channel including 201.25 MHz cavities (proposed as a possible configuration for IMICE)

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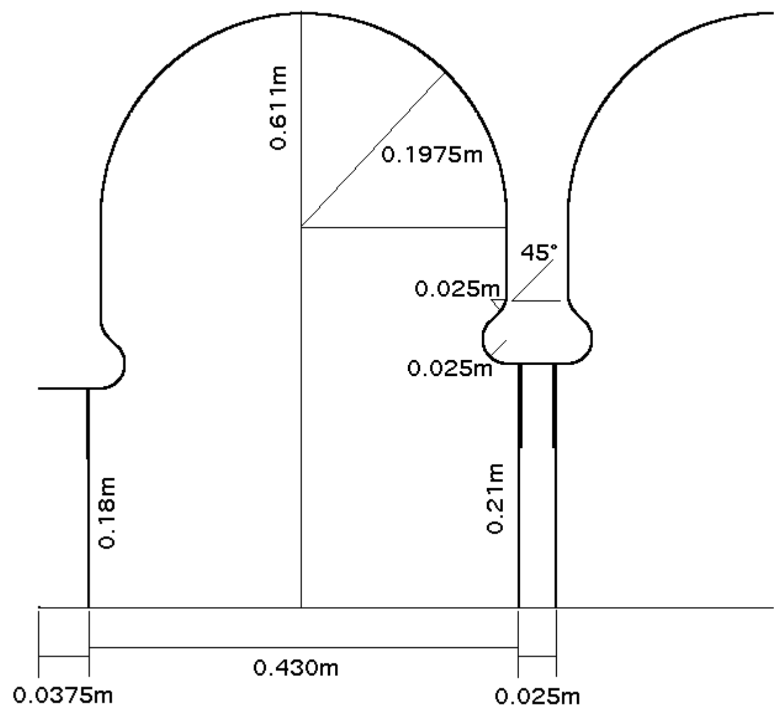
Conceptual design in study-II has been developed further. Dimensions modified slightly for mechanical clearance (tuner etc.).

Focus now on first **high-power test model.** 2-3 year fabrication plan before testing in **Linac Test Area** at FNAL.

First cavity can be tested with foils or grids.

First cavity may be suitable for use in **MICE** experiment.



MICE cavity, modified from study-II

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RF Parameters for 201.25 MHz IMICE

Table 1. Ideal Pillbox cavities for IMICE

Pillbox E_o (=E_{pk} on surface)	**15.48 MV/m**
Length, L	**0.466 m**
Transit time factor, T	0.798
V_{eff} (on crest, on axis)	5.76 MV
Number of cavities per lattice cell, n	4
Approximate phase angle, □	33.6-35.9°
Peak power per cavity	3.646 MW
Forward power (3□ filling)	4.038 MW
Total per cooling cell	16.15 MW

Table 2. Omega shaped cavities for IMICE

V_{eff} (on crest)	**5.76 MV**
Length	0.430 m (T=0.827)
E_o equivalent	16.2 MV/m
E_{pk} on surface	26.5 MV/m
Peak power per cavity	4.18 MW
Forward power (3□ filling)	4.63 MW
Total per cooling cell	18.5 MW

Table 3. Stepped foil dimensions

End foil radius (inner/outer)	12/18 cm
End foil thickness (inner/outer)	200/400 μm
Middle foil radius (inner/outer)	14/21 cm
Middle foil thickness (inner/outer)	700/1400 μm

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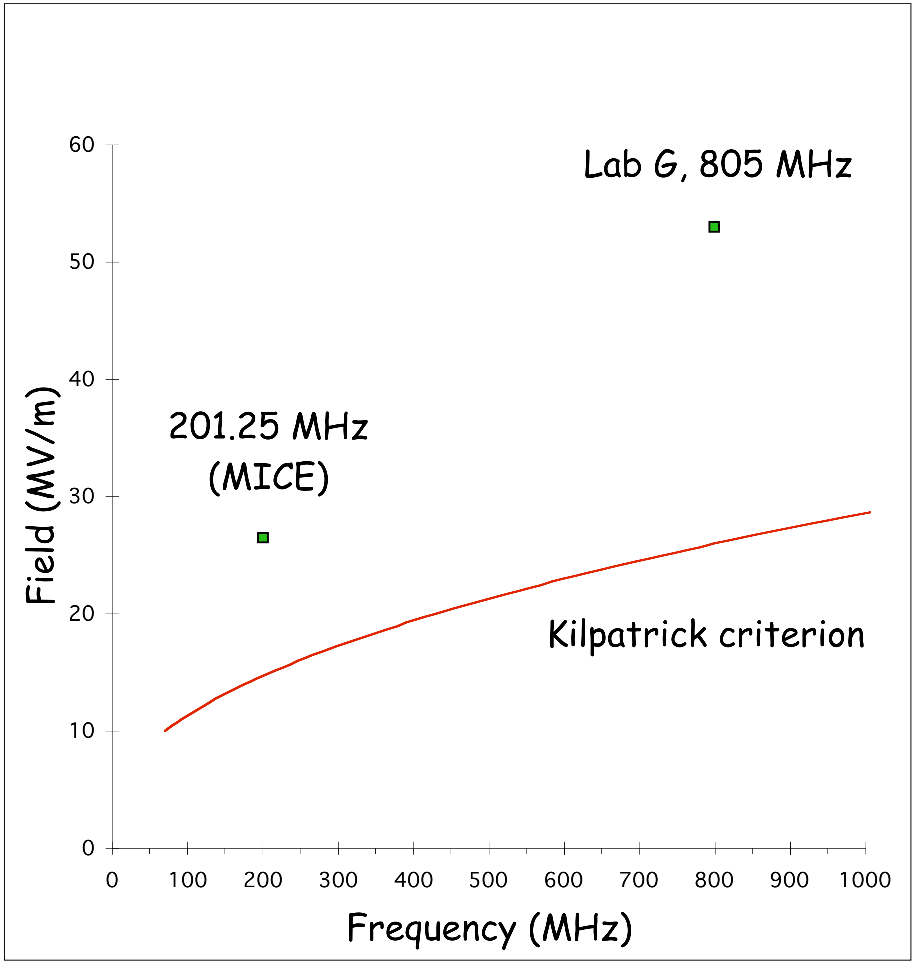

Surface fields compared to Kilpatrick for 805 and 201.25 MHz
(Q. Should we be working harder to lower field enhancement?)

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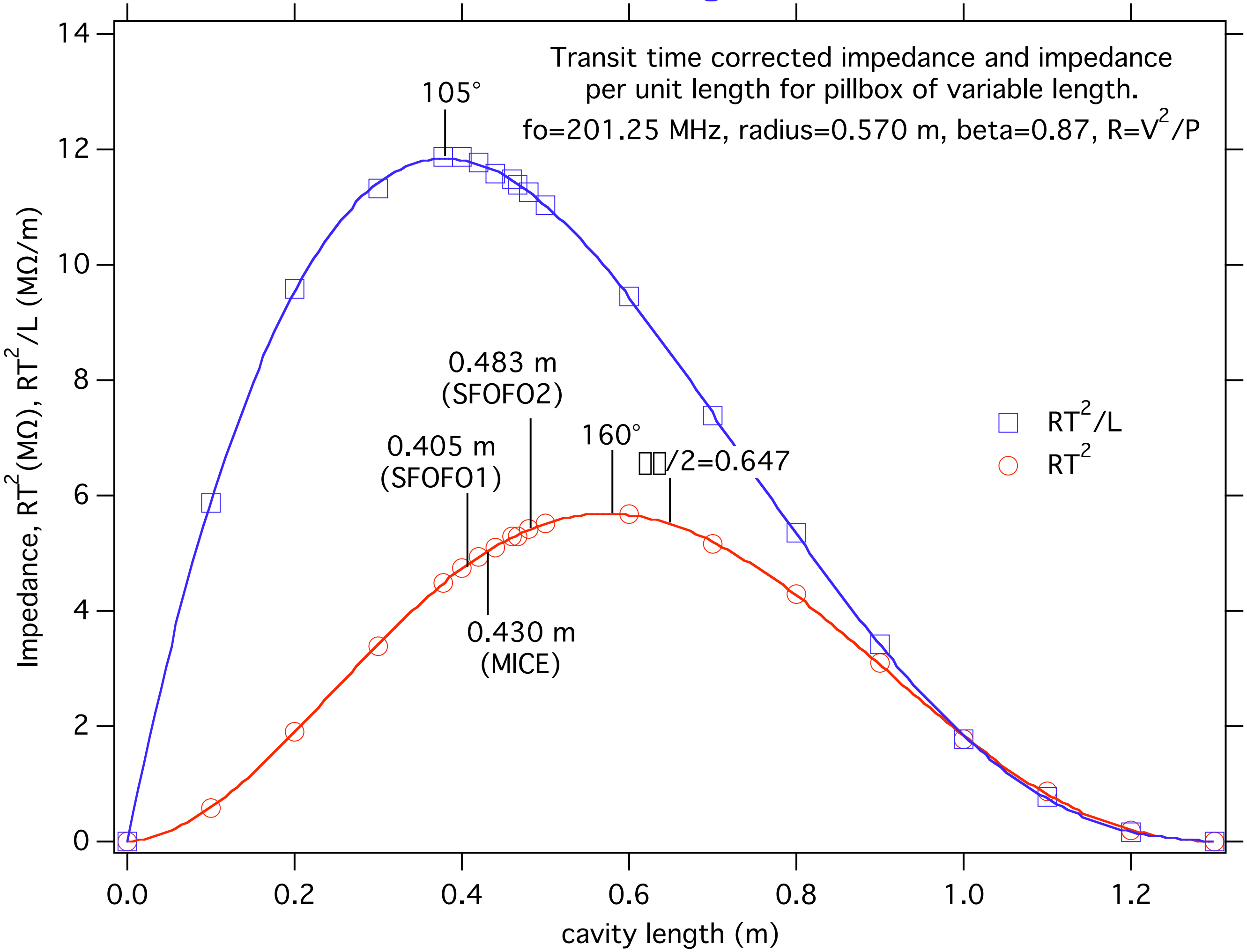

Shunt impedance and impedance per unit length vs. cavity length.
(Q. Should we consider a longer cavity for MICE?)

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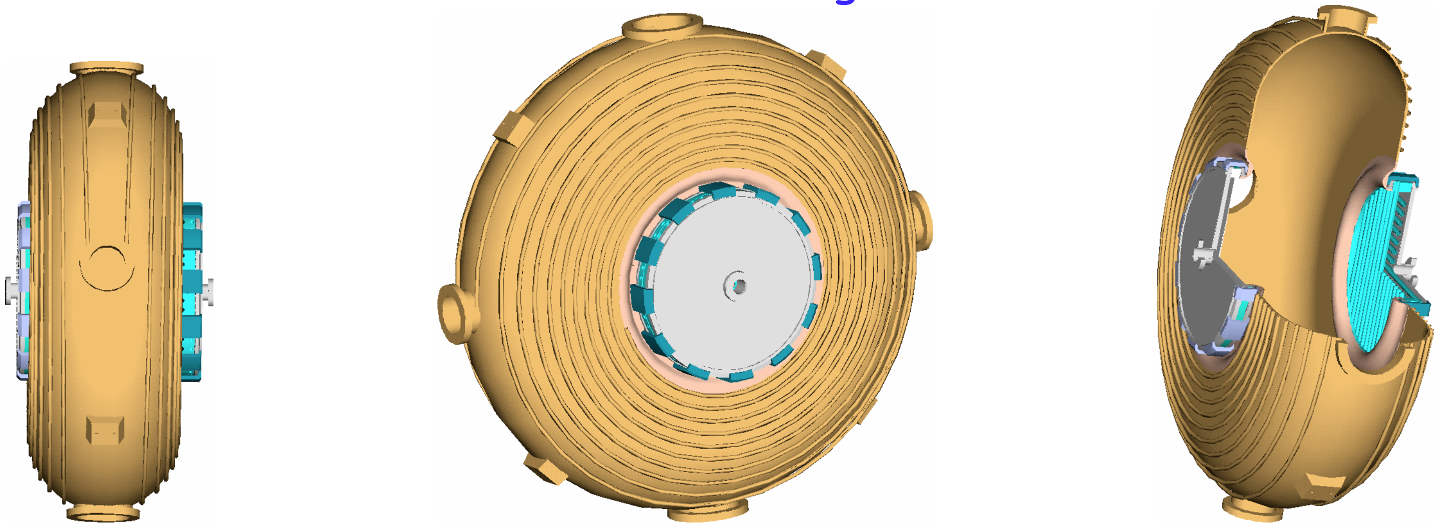
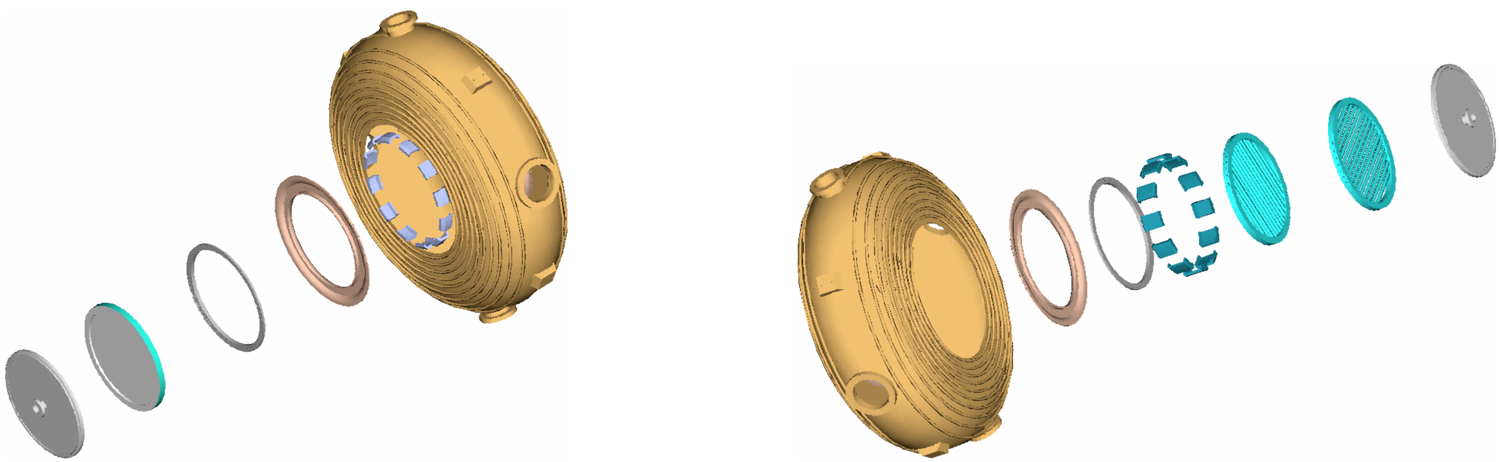
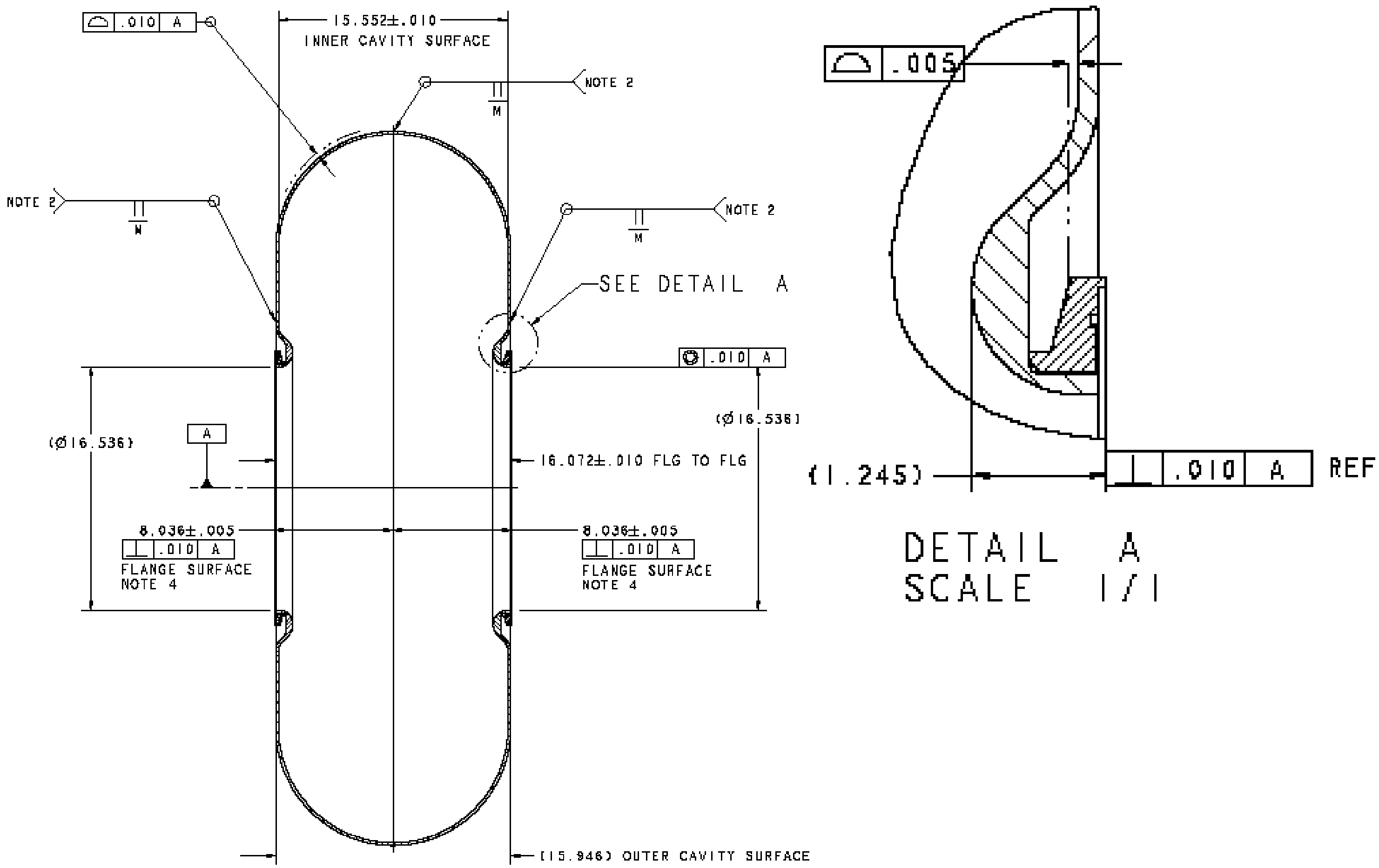


201.25 MHz cavity conceptual design



Exploded views showing foil and grid mounting hardware



- Preliminary component drawings sent to vendors
- Electro-polishing, diamond turning, surface coating or new materials may be incorporated into this cavity depending on results from 805 MHz.

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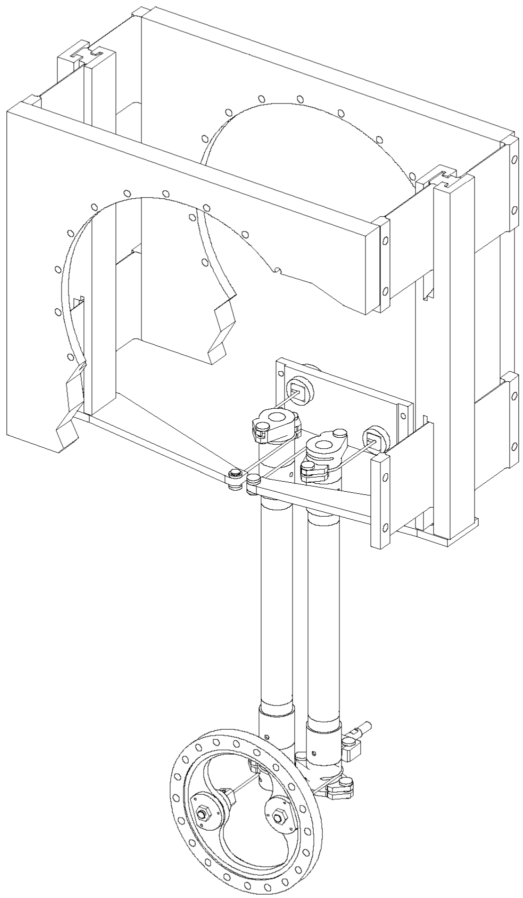
Spinning test at 500 MHz, picture courtesy of Enzo Palmieri, INFN

Tuner



- Plan to use adaptation of LHC-type tuner
- No sliding parts in vacuum (flexures used to provide compliance).
- Differential force input (minimizes forces on cavity mounts).
- Stroke needs to be increased for NCRF cavity.

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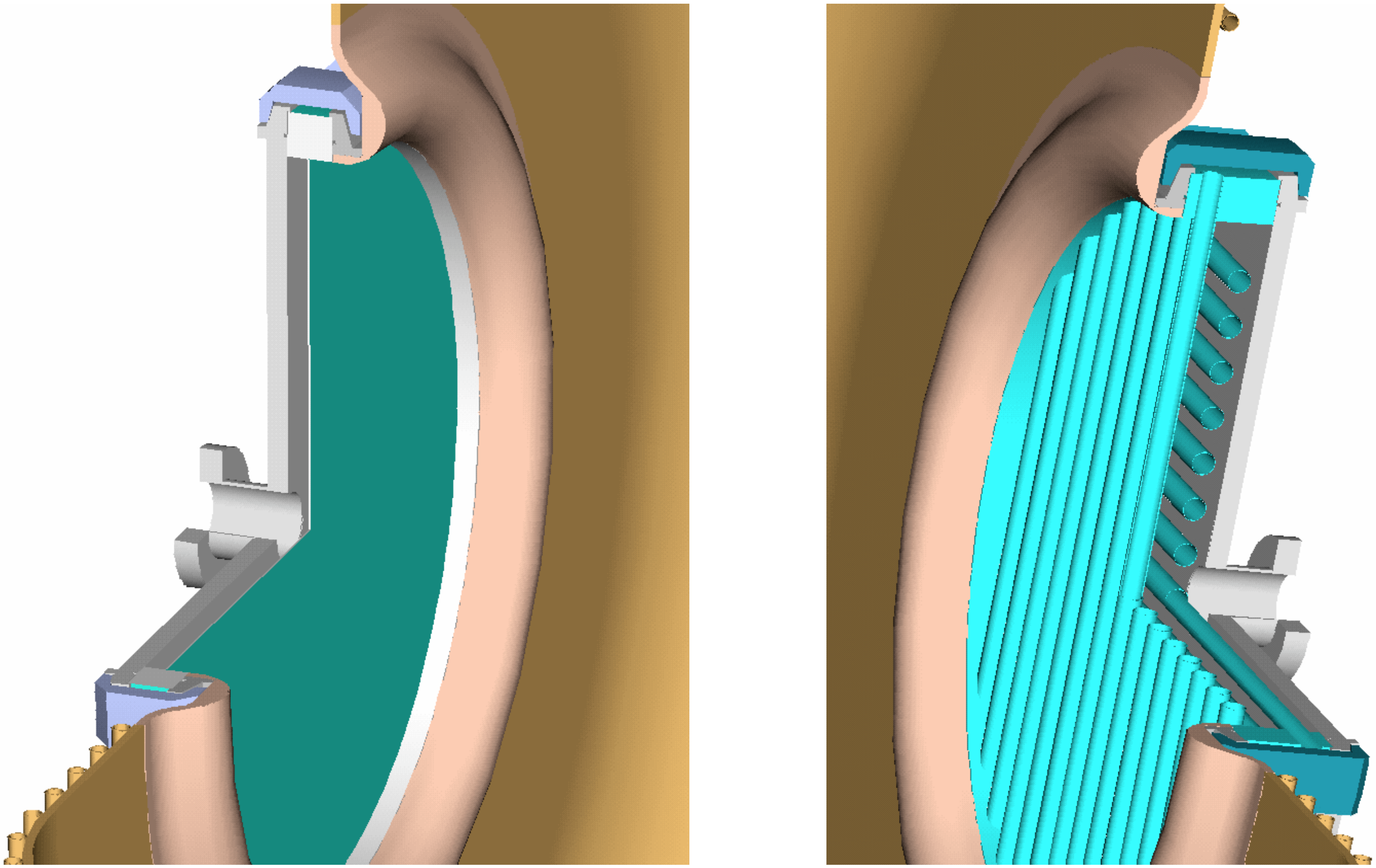
Foils and Grids



Detail views of foil and grid mounting assemblies

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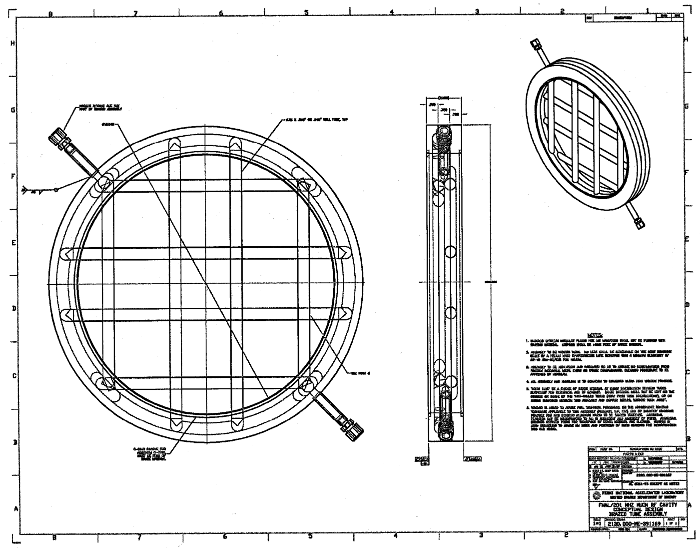

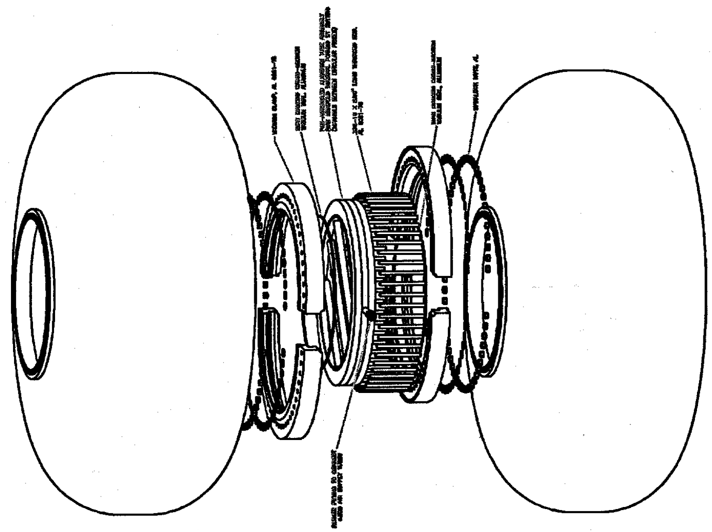

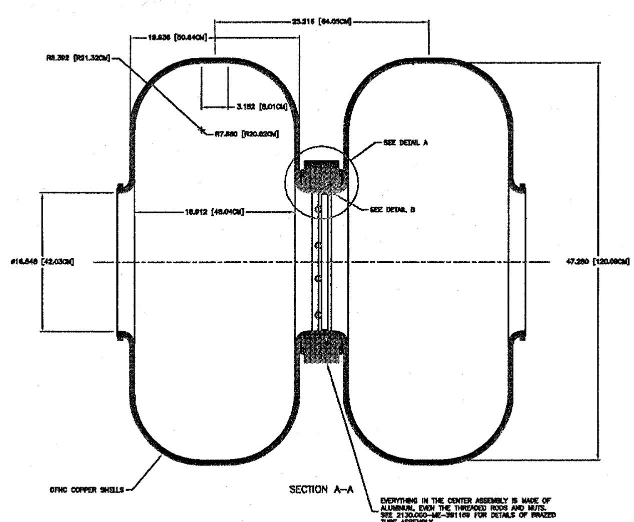

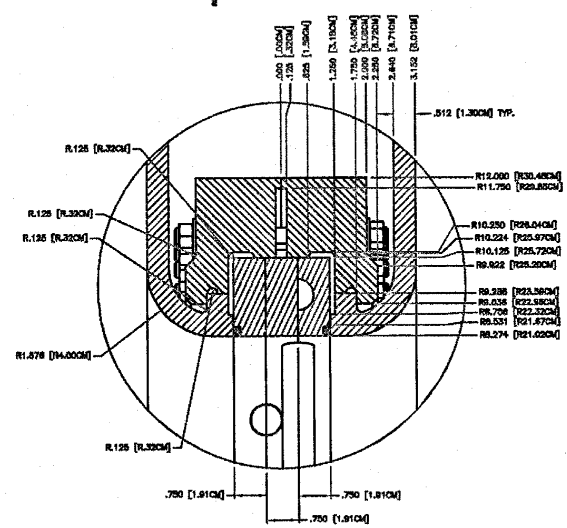

FNAL proposed sparse grid structure

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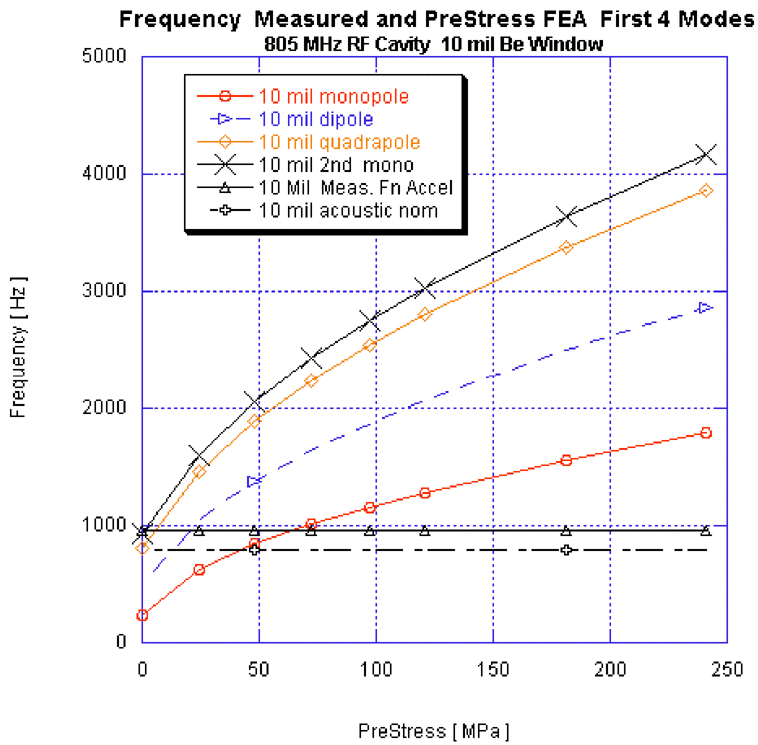

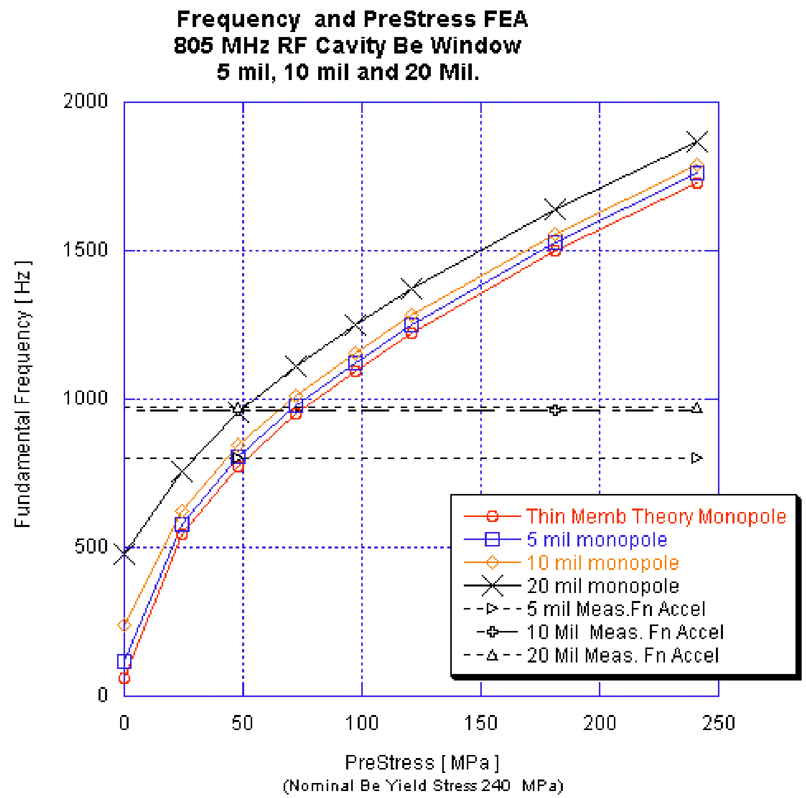

Acoustic data suggests pre-stress ~40-50 MPa (805 MHz foils)

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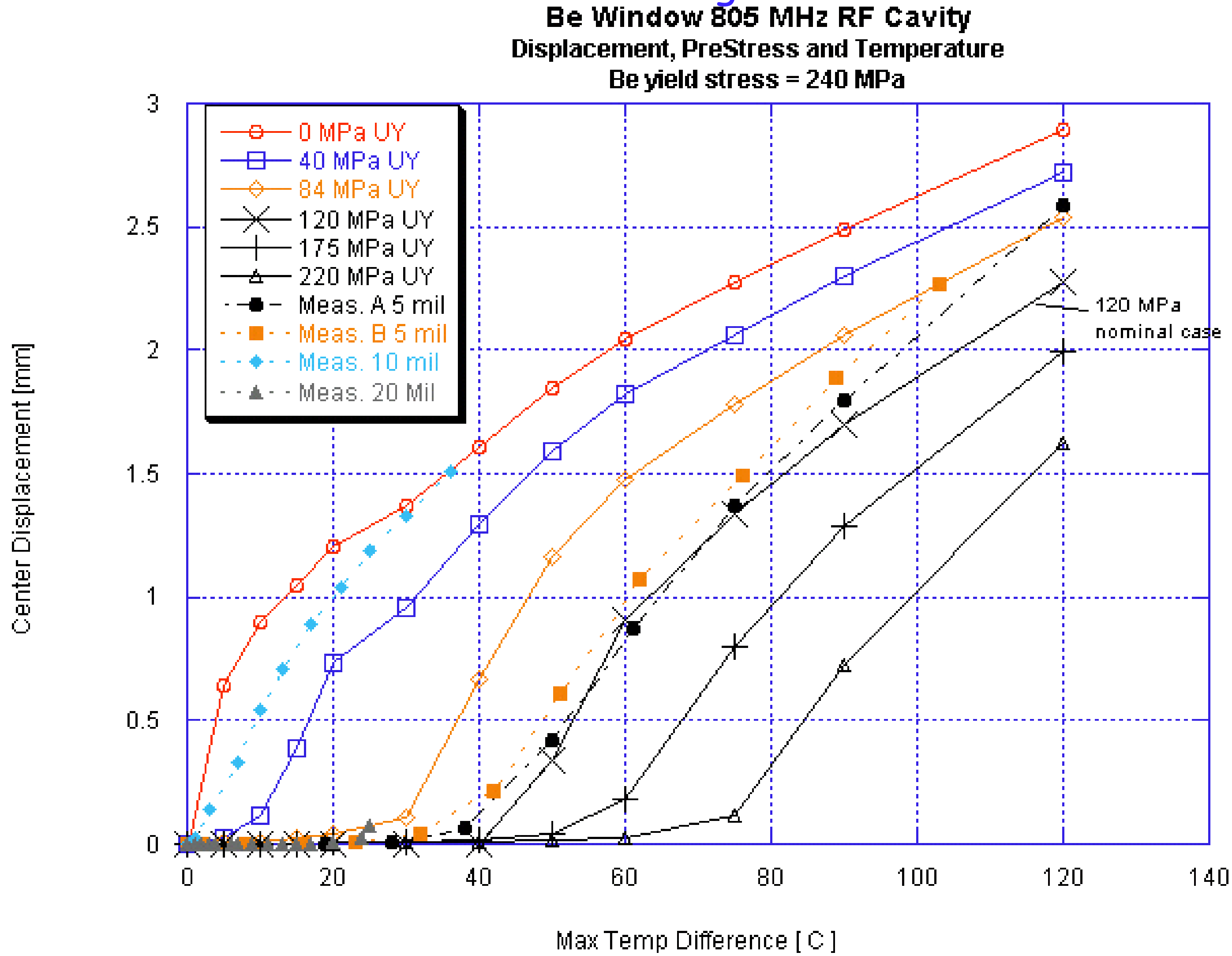


Halogen lamp data suggests pre-stress ~ 100-120 MPa

805 MHz Be Window measurement data, 160 mm diameter

Window ID	Test ID	Description	I. Accel./ ANSYS Frequency Predicted Pre-Stress	II Acoustic / ANSYS Frequency Predicted Pre-Stress	III Halogen /ANSYS Thermal Predicted Pre-Stress
A	1	5 mil uncoated	40 MPa	45 MPa	~100 MPa
B	2	5 mil 125 Å TiN	-	48 MPa	~ 100 MPa
C	D	5 mil 125 Å TiN	-	50 MPa	-
D	B	10 mil uncoated	5 MPa	5 MPa	~ 0 MPa
E	4	10 mil 200 Å TiN	-	44 MPa	-
F	C	20 mil uncoated	45 MPa	42 MPa	*
G	3	20 mil 200 Å TiN	-	*	-

* Not enough data to make a prediction. Inconclusive

Outstanding Issues

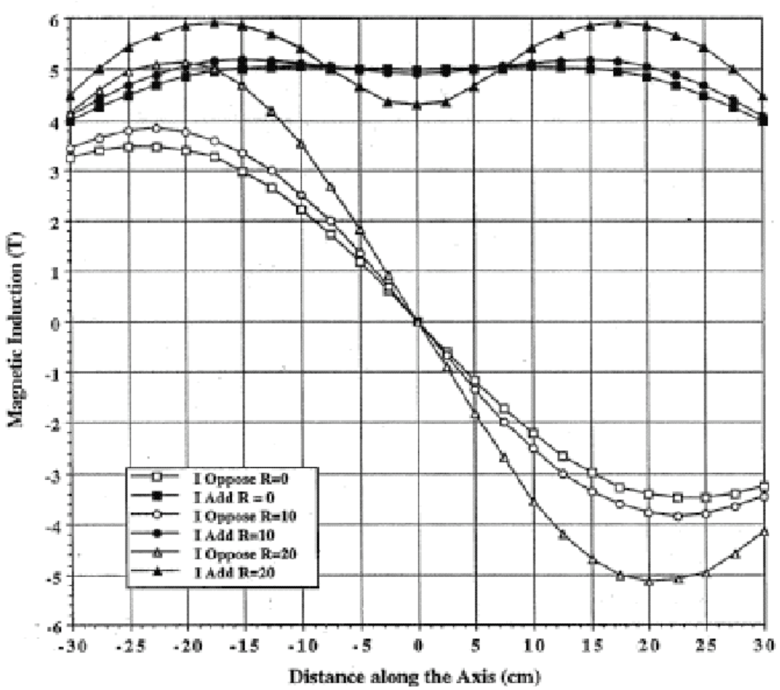
- Large, stepped Be foil will be very expensive.
- Consistency of the pre-stress is unknown for larger foil sizes.
  (Discrepancy in measurements needs to be understood)
- Microphonics and quench forces should be evaluated for large foils
  (both look OK at 805 MHz).
- EHS concerns with Be particles need to be addressed.

- Cooling of tubes with real RF heating should be calculated.
- Acceptable tube thickness should be determined.
- Manufacturing process for grids should be tested (at 805 MHz?).
- Transverse kicks from tubes should be included in simulations.
- Dark current and breakdown may damage cavity, foil or grids.

- LN_2 operation should be evaluated.

Forces during a magnet quench

- Lab G magnet capable of 5T peak field.
- Maximum dB/dt is about 1 T/s (Mike Green).



- Forces on 805 MHz foils seem OK?, on body can be very large!
- Similar fields/rates in 200 MHz channel(s) but $F_r \propto r^2$ and $F_z \propto r^3$.

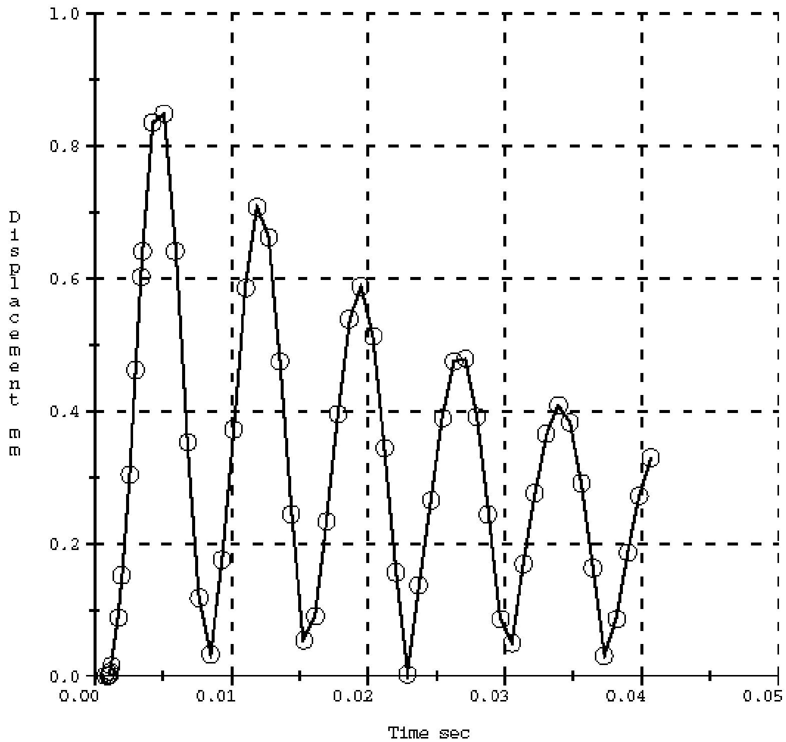
E.g.: Radial forces on 805 MHz Be foil in solenoid mode:
radius=8 cm, $\square=3\times10^{7}\square^{-1}m^{-1}$, B_z=5T, dB/dt=1T/s, radial stress ~0.5 MPa.
Thickness=0.005" (1.27×10^{-4}m) total force~31N (6.9lbs)

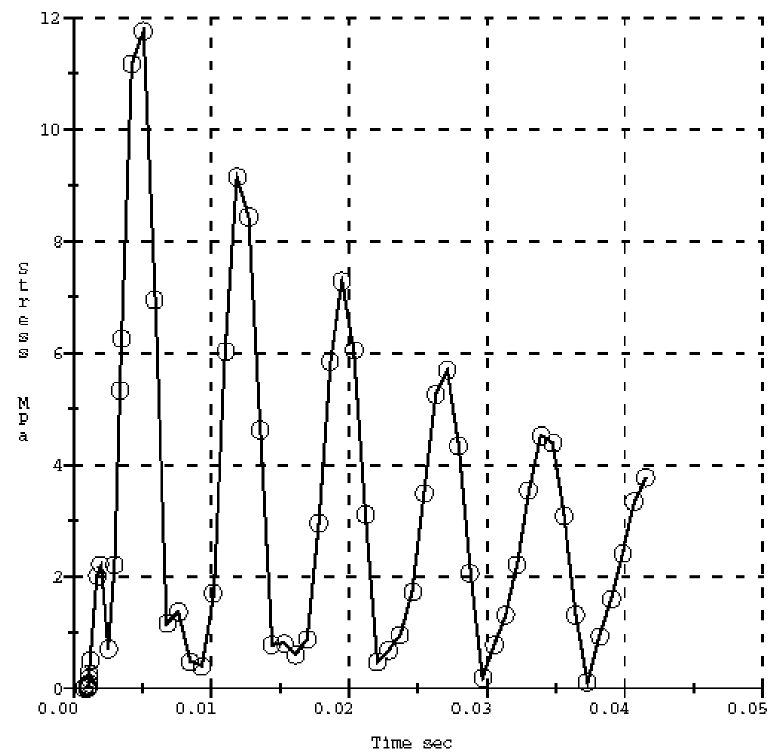
Radial forces on copper cavity:
Cu end plate (washer)
radial stress~1.7 MPa, total force ~48 kN (10,000 lbs!)
Cu body (hollow tube)
Max stress~0.5 MPa, total force ~86kN (20,000 lbs!)
total radial force ~182kN (40,000 lbs!) outwards?, net force=0

Axial force on 0.005" foil in gradient mode:
B_z=1T, dB/dt=0.2T/s, dB/dz~20T/s, axial force~1.3N (0.3 lbs), out?

Axial forces on half copper cavity: ~30 kN (6700 lbs), stress~1 MPa

Lorentz force impulse on large foils





Displacement and stress in 201.25 MHz foil after single 41N, 125 s impulse (no pre-stress)

Conclusions

- 201.25 MHz cavity conceptual design is complete. Detailed design work continues. Lab G operations have been very valuable in the study of surface field, dark currents, X-ray flux, breakdown and effects of magnetic fields on all of the above. Single-cell 805 MHz cavity will continue this work, including the effects of Be foils, surface coatings, polishing, materials, etc. Lessons learned at 805 MHz will be incorporated into 201.25 MHz cavity.

- FY02 plans:

  Finish detailed design, begin mechanical tests for fabrication, spinning, e-beam welding, etc. Procure one large foil (or grid?)

- FY03 plans: (assuming flat funding)

  Prototype tuner fab., cavity body assembly, procure second foil.

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• FY04 plans:

Complete cavity assembly. Purchase RF feedthrough and misc. equipment. Assemble for test.

• Schedule depends on funding. (Grid work currently funded by FNAL/ ICAR).

Current funding scenario extrapolated to FY04:

	FY02	FY03	FY04	total
LBNL effort	220	285	100	605
M&S	255	225	75	555
total	475	510	175	1160

(no FNAL/IIT grid work included)

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Additional information for Tech Board

Budget breakdown by type

Proposed budget -$50k	FY02				FY03 (est.)				FY04 (est.)				total Labor	total M&S
	LBNL effort	M&S	U-Miss	FNAL/IIT	LBNL effort	M&S	U-Miss	FNAL/IIT	LBNL effort	M&S	U-Miss	FNAL/IIT		
201 MHz cavity engineering	200			0	185			0	60					
designer & coordination	0				75				40					
cavity parts		40	50				0							
spinning/forming tests		50												
e-beam welding + assembly		35			0	75				25				
tuner fabrication						50								
RF Window purchase										50				
Foils / grids	20	80		0	25	100	0	75						
total	220	205	50	0	285	225	0	75	100	75	0	0	680	555
	475				585				175					

Note: FNAL/IT grid work pushed into FY03

Plan:

FY02: Continue 805 MHz testing in lab G, investigate breakdown, dark current etc. with magnetic field. Evaluate surface coatings, material inserts, Be foils if EHS concerns can be overcome. Conceptual design review (Q2), spinning, e-beam welding tests for 200 MHz cavity. IIT/FNAL continue to investigate grids, attempt to construct grid for 805 MHz (funds permitting). 200 MHz foil design work continues, procure one large foil if 805 MHz tests look encouraging. Misc. cavity parts made at U. Miss. Finish tuner design.

FY03: Test grid in 805 MHz cavity. Continue testing dark current remedies including new test structures if necessary (funds permitting). 200 MHz cavity body assembly begins, assuming successful spinning tests, otherwise tests continue. Procure second large foil if mechanical tests of first one are successful (pre-stress, flatness, etc.). Begin construction of 200 MHz grid if 805 MHz grid test is successful. Construct prototype tuner.

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FY04: Complete 200 MHz cavity assembly. Procure RF feedthrough and ancillary equipment. Integrate with tuner, mechanical tests. Vacuum tests. Ship to Fermilab for testing in Linac Test Area.

Questions for technical board:

Does this plan address the RF technical issues for MUCOOL/MICE?

Do we have sufficient flexibility to respond to results from the ongoing 805 MHz testing?

Is the funding level appropriate for the planned schedule?

Is the planned schedule consistent with programmatic goals (e.g. Linac Test Area, MICE)?

May we proceed with hardware tests/procurements for the first cavity?