MI-RF Status and Plans

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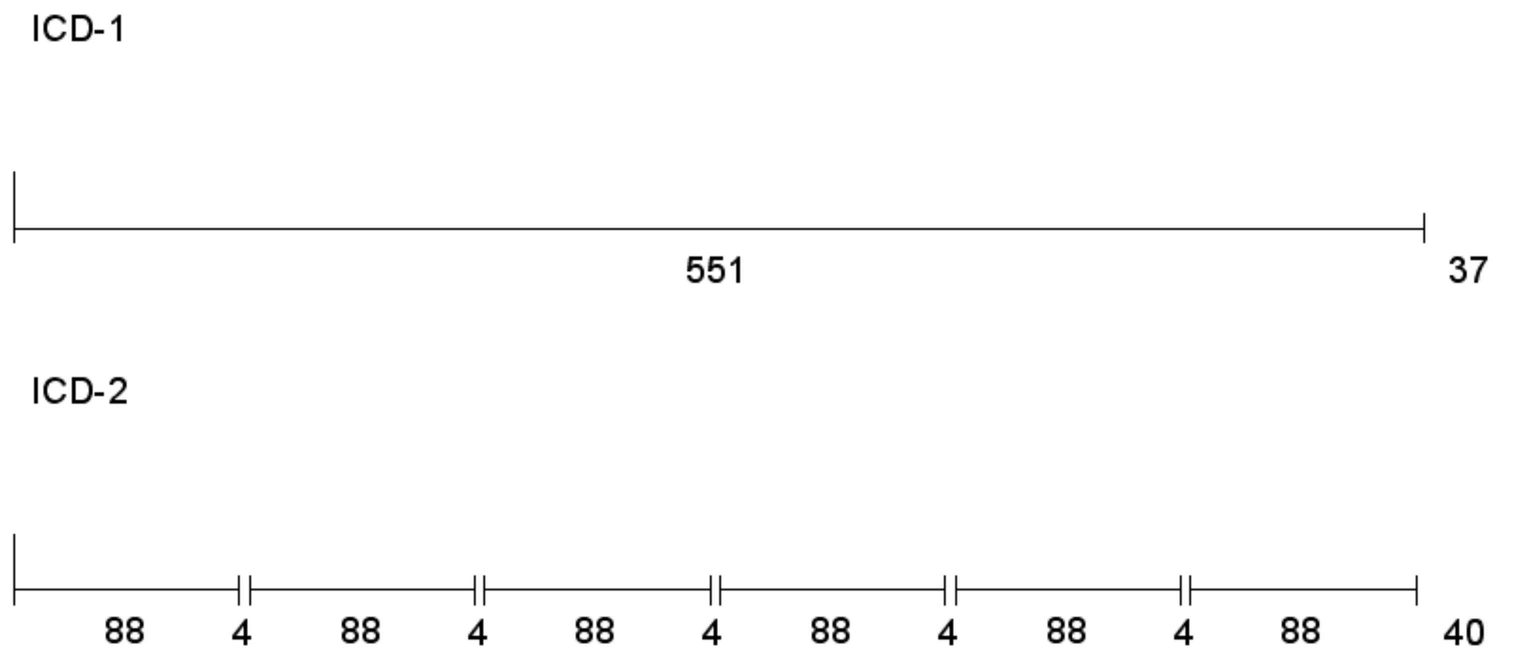
MI RF System Specifications

Parameter	Value	Units
Frequency	52.811-53.104	MHz
Max. Acceleration Rate	240	GeV/sec
Frequency slew rate	1.6	MHz/sec
Acceleration Voltage	2.7	MV
Beam Power	6.2	MW
Average Beam Power	3.0	MW
Peak Voltage	4.7	MV
Average Beam Current	2.3	A
Fundamental rf Current	3.7-4.1	A

Main Injector Beam Distribution



ICD-1: Painting in Recycler

h = 588

ICD-2: Recycler Accumulates Beam while MI Ramps

Cavity Parameters

Joe Dey
8/31/10

	Project X New Cavity Design
Harmonic Number	588
Frequency	52.617-53.104 MHz
Acceleration Ramp Slope	240 GeV/s
Peak Beam Current	4.51 A
Total Beam Accelerating Power	6.144 MW
Number of Accelerating Cavities	20
Cavity R/Q	50
Q	10000
Maximum Cavity Accelerating Voltage	240 kV/Cavity
Accelerating Voltage Required: $V\sin\phi_s$	2.66 MV
Total Accelerating Voltage Available	4.80 MV

Robinson Stability at 30 GeV

$\phi s = 33.6327$ deg

Cavity Power Loss per Cavity = 57.6 kW

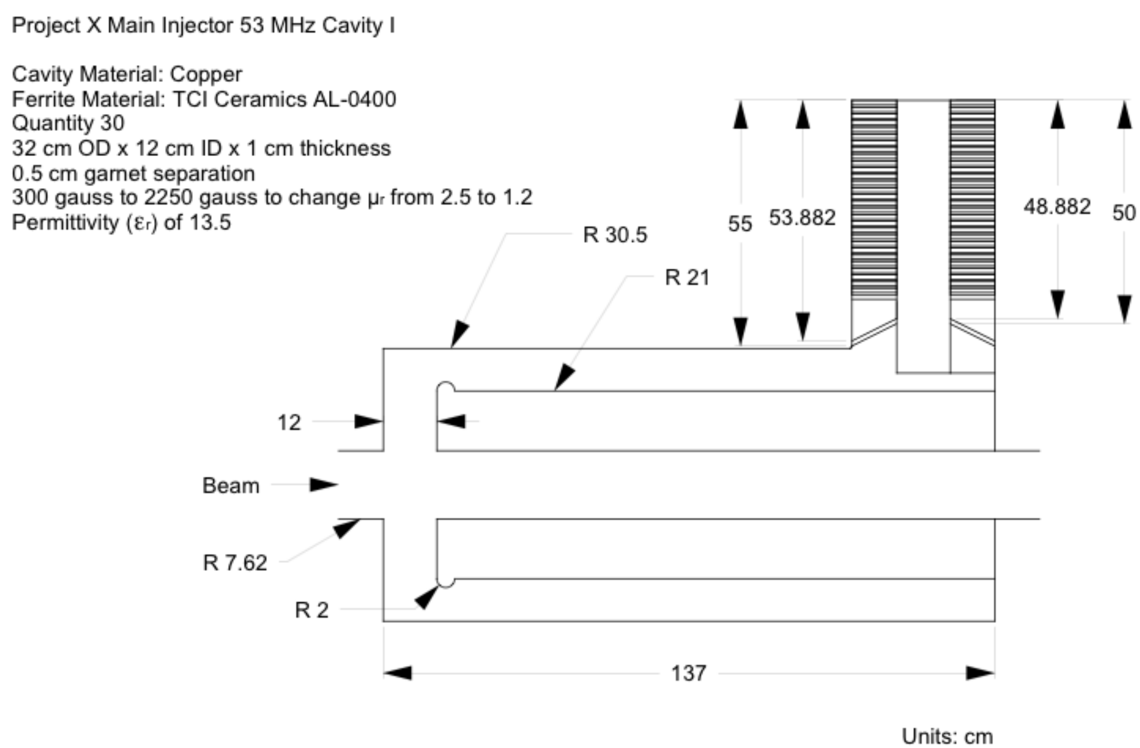
Total Apparent Power = 558.417×10^3 VA ∠ 50.209 degrees

Total Current = 4.65347 A ∠ 50.209 degrees

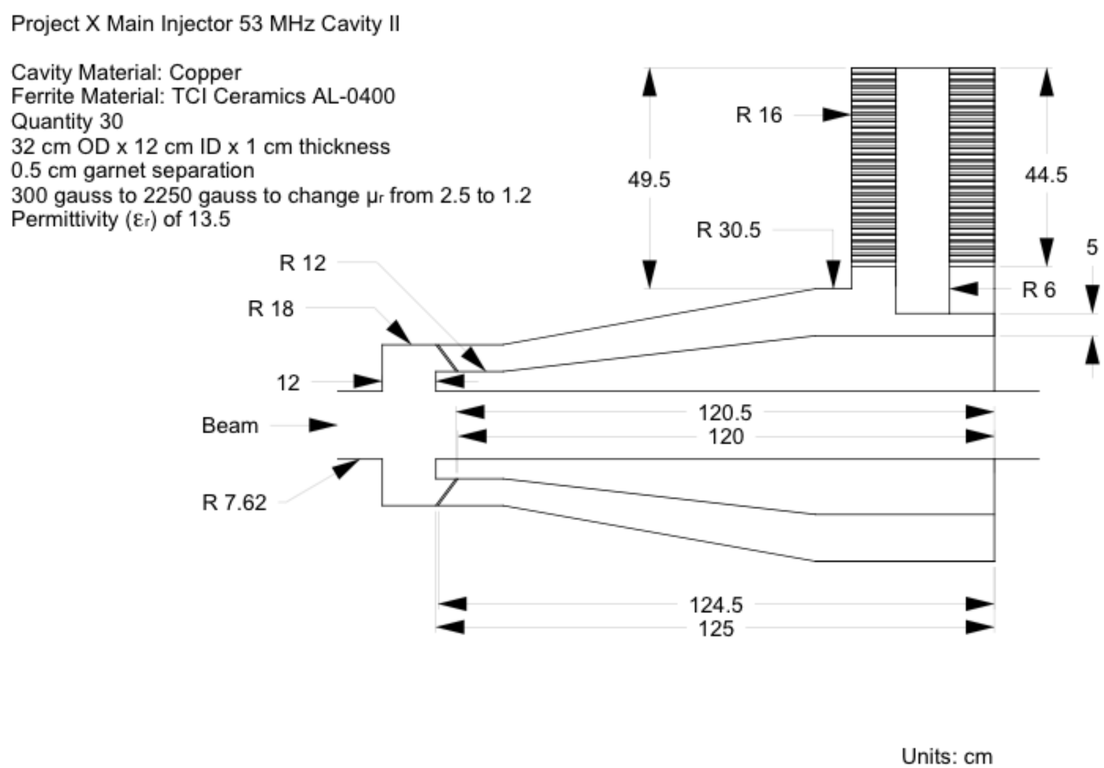
Percent of Induced Mode Compensated = 26.4 dB = 95.2137 %

Robinson Stable Limit = 4.01439

Project X
MI Cavity I



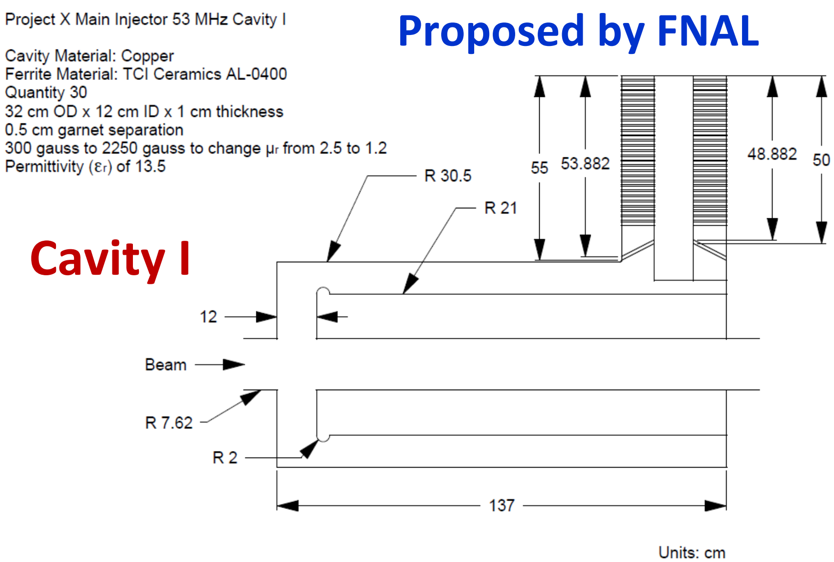
Project X
MI Cavity II

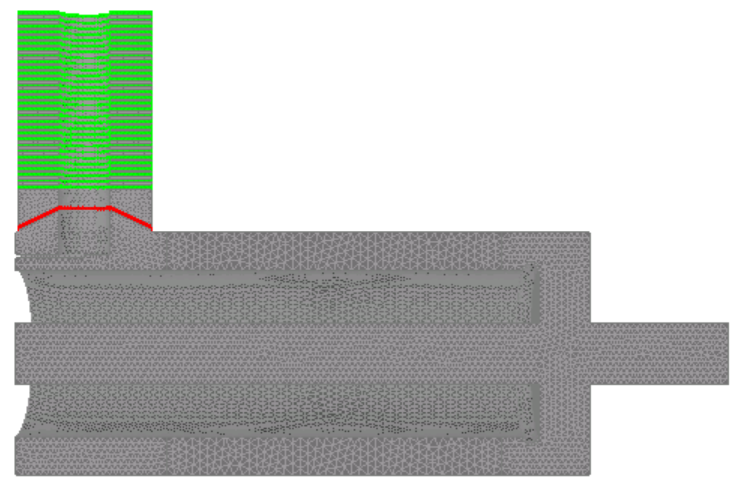


MI Cavity I and II for Project X

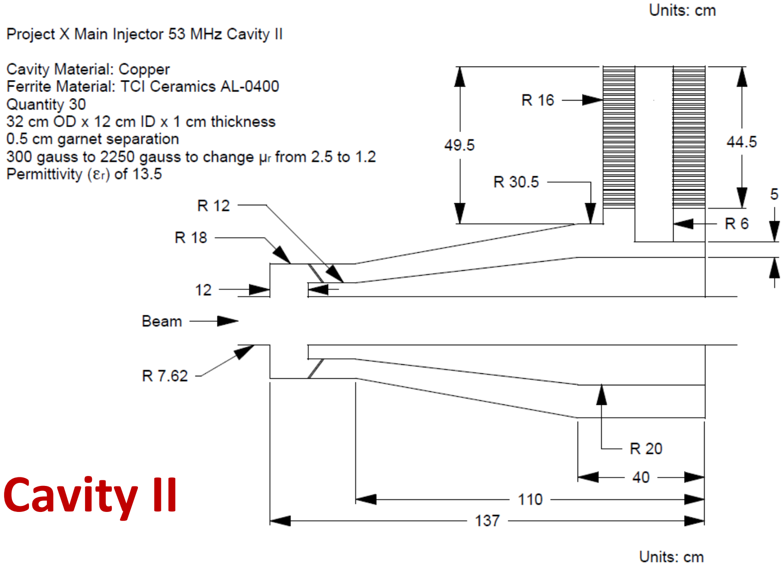
Proposed by FNAL | **Simulated and optimized by SLAC**

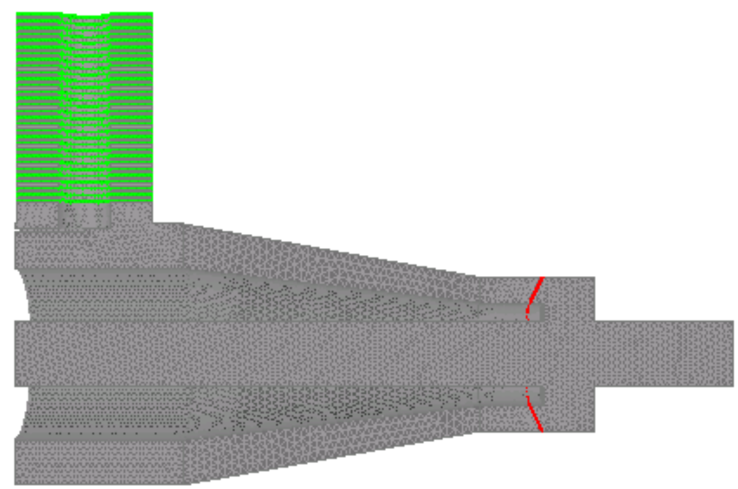
Cavity I





Cavity II





MI Cavity I & II Simulation Results

@μr=2.5, Vgap=240kV, tuner intrusion=55mm		MI-Cavity-I	MI-Cavity-II
Operating Mode	R/Q (Ω)	51.23	56.95
	F (MHz)	52.812	53.557
	Tuning range Δf (KHz)	584	539
	Max. Es (mV/m)	7.4	12.2
	Max. Bs (T)	39	32
Power Distributions	P(kW) (wall/ferrite/ceramic)	117/39/0.7	104/28/7
Monopole HOMs	Max. R/Q (Ω)	22	19
Horizontal Dipole HOMs	Max. R/Q_T (Ω)	17	1.5
Vertical Dipole HOMs	Max. R/Q_T (Ω)	17	1.6
	Max. center shift (mm)	43	29

- ***Cavity II has better RF performance than cavity I in terms of HOM effects to the beam.***
- ***However, the stronger max. E-field in the ceramic limits its use for Project-X.***
- ***Therefore, cavity I is optimized for the MI cavity for Project-X.***

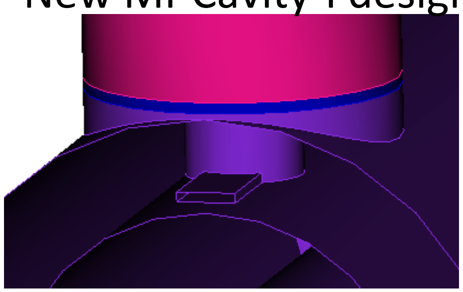
MI Cavity I Tuning Range

- *The tuning range of 487kHz is required for 6GeV to 120GeV operation.*
- *Optimal tuning range would be 1MHz to cover cavity imperfection, temperature variations etc.*
- *Using a narrow tuner loop, 1MHz tuning range can be obtained with a certain spacing between the tuner and the cavity inner conductors.*

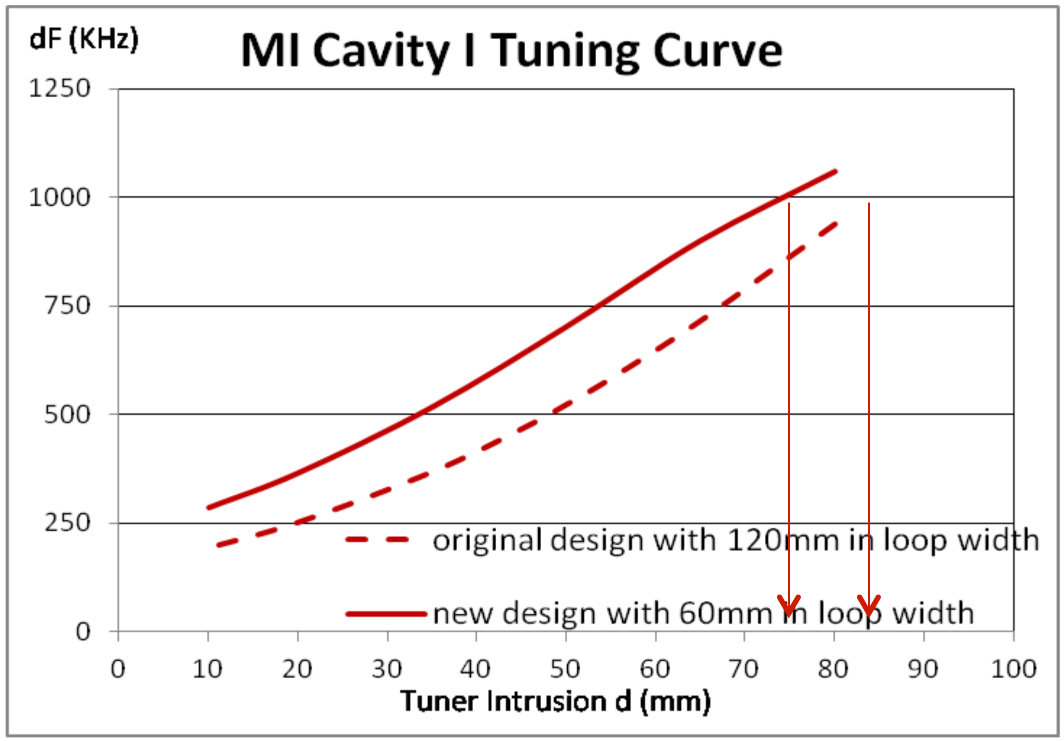
Original MI-Cavity-I design

Loop width=120mm, dF=1MHz @ d=85mm

New MI-Cavity-I design



Loop width=60mm, dF=1MHz @ d=75mm



MI Cavity I Dangerous HOM Modes

Monopole Modes

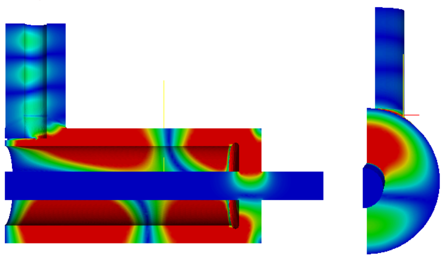
Cavity Type	Ferrite ur	F (MHz)	R/Q (Ω/cavity)	Q0	Rs (kΩ/cavity)
I	2.5	161.83	22.06	16580	366
		269.72	15.45	19973	309
	1.2	164.42	15.44	15310	236
		269.17	17.75	20026	355

Dipole Modes

Cavity-I (<300 MHz)		F (MHz)	R/Q_t (Ω/ cavity)	Q0	Rsh_t (kΩ/mm/ cavity)
Ur=2.5	H-dipole	205.39	16.79	20210	1.46
		261.08	15.60	23769	2.03
		261.63	4.03	29714	0.66
	V-dipole	206.39	17.05	20005	1.47
		264.20	11.55	22483	1.44
Ur=1.2	H-dipole	205.31	16.65	20161	1.44
		261.09	19.75	22103	2.39
	V-dipole	206.04	17.13	20000	1.48
		263.50	17.61	21500	2.09

Off-center
Vertical Dipole Mode

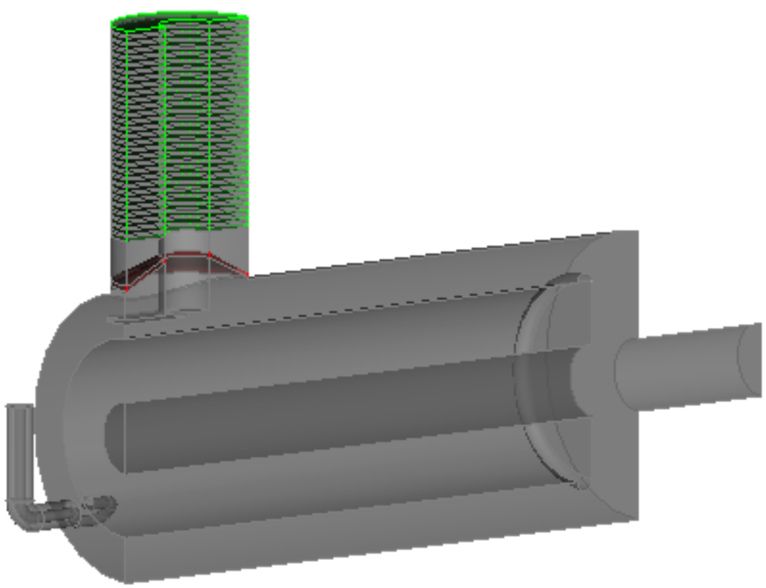
F=263.50MHz @ μr=1.2
off center=57mm



➢ ***Due to the ferrite vessel, the vertical dipole modes are all off-center from the ferrite vessel.***

HOM Damper w/o Filter

- *There are two dangerous monopole HOMs to be damped by HOM dampers.*
- *HOM dampers should be equipped with a fundamental mode rejection filter.*
- *HOM dampers can handle a certain amount of power.*

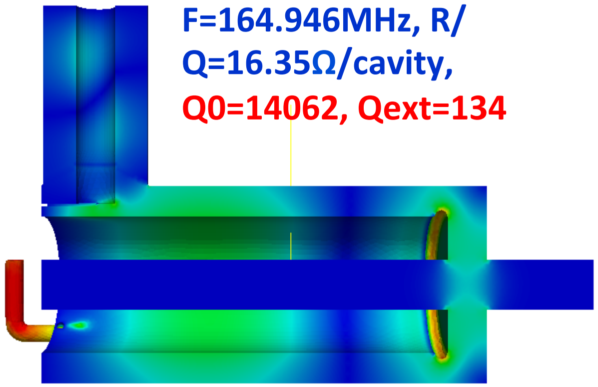


Cavity I with two mirrored HOM dampers w/o filter

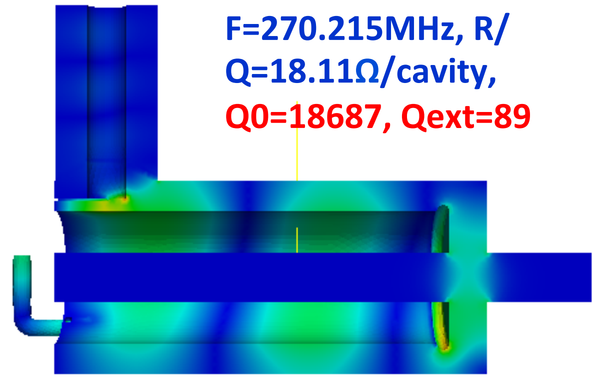
- *HOM damper using a coaxial line has a larger power capacity.* ***(D57.5mm/25mm)***
- *HOM coaxial damper with a large loop located at the rear end of the cavity can damp many HOMs.*
- *HOM damper with 45 degree orientation can damp both monopole and dipole modes.*
- *Rounded loop design can suppress multipacting activities at HOM damper.*
- *Bended HOM coaxial damper can take less space for installing two more RF cavities (18->20).*

HOM Mode Damping w/o Filter

Monopole Modes @μr=1.2

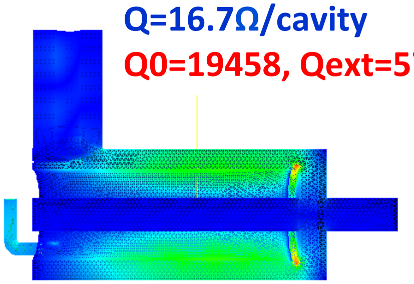


F=164.946MHz, R/Q=16.35Ω/cavity, Q0=14062, Qext=134

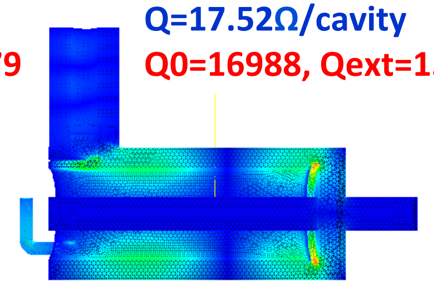


F=270.215MHz, R/Q=18.11Ω/cavity, Q0=18687, Qext=89

Vertical Dipole Modes @μr=1.2

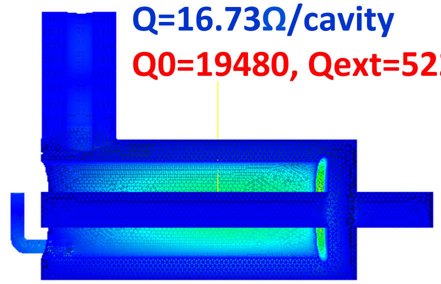


F=206.219MHz, R/Q=16.7Ω/cavity, Q0=19458, Qext=579

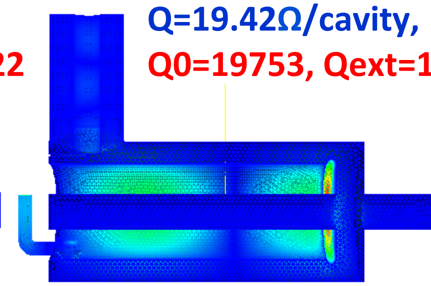


F=264.979MHz, R/Q=17.52Ω/cavity, Q0=16988, Qext=151

Horizontal Dipole Modes @μr=1.2



F=205.503MHz, R/Q=16.73Ω/cavity, Q0=19480, Qext=522

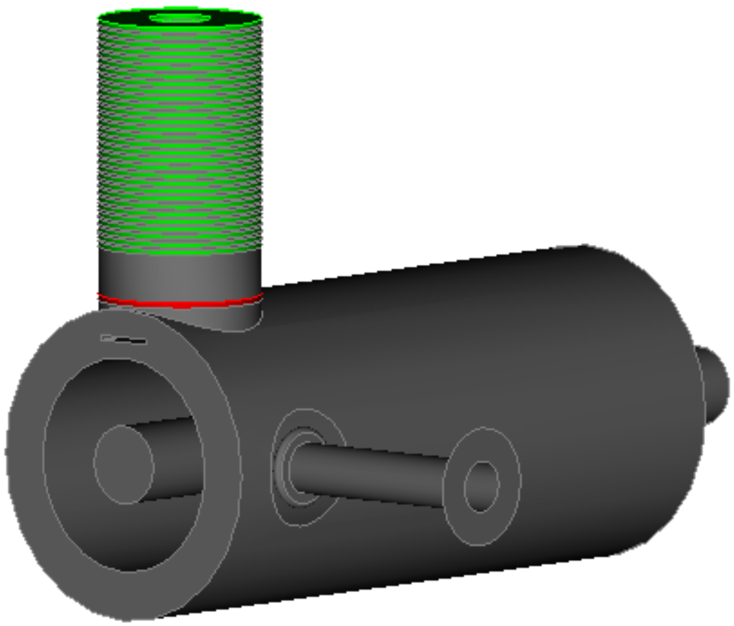


F=261.909MHz, R/Q=19.42Ω/cavity, Q0=19753, Qext=173

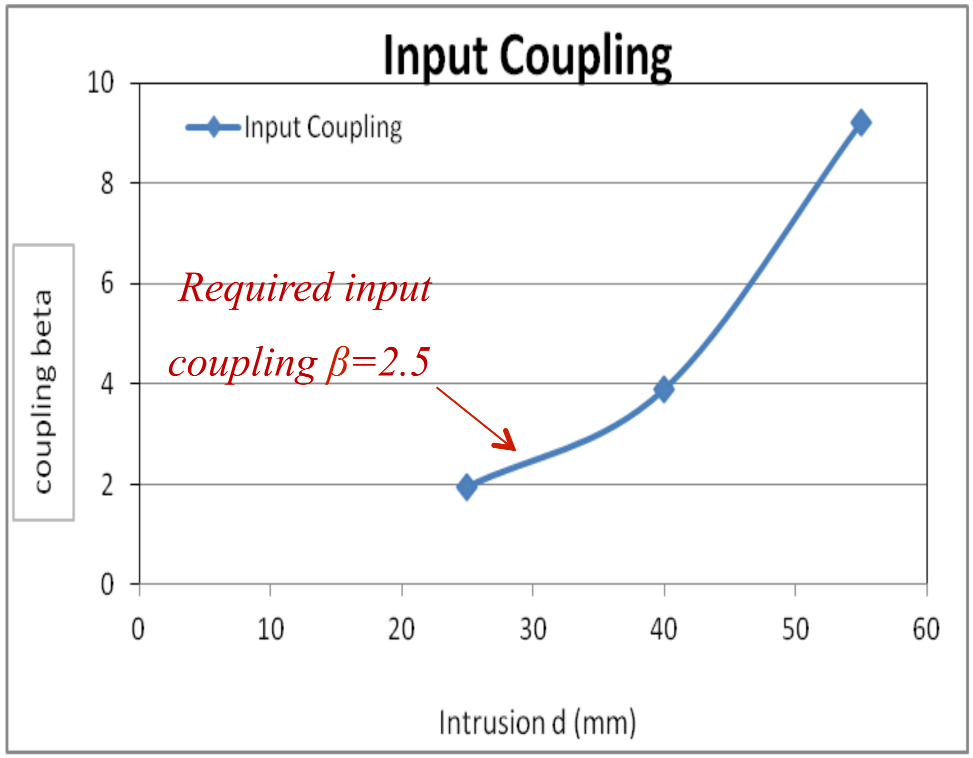
- ***The dangerous monopole and dipole modes can be heavily damped with the two mirrored HOM dampers.***

Power Input Coupler

- *Eimac 8973 power tetrode is chosen as the power source for the new MI cavity.*
- *It can operate at both 53MHz and 106 MHz with more than 1MW output power.*
- *E-probe coupling is adopted in MI cavity power input coupler design.*
- *The input coupling should be matched when the maximum beam current is accelerated.*



Cavity I with a coax input coupler

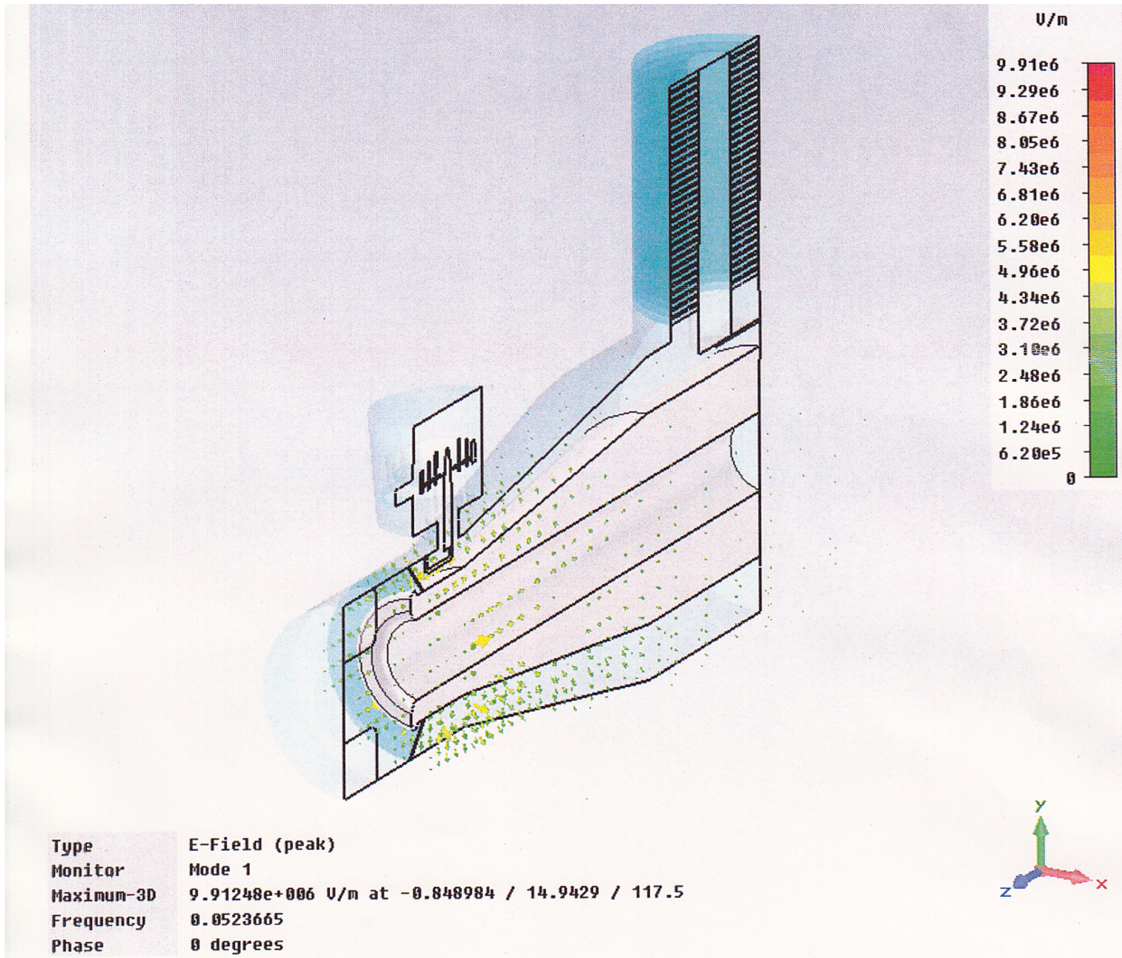


MI Cavity Simulation Plan

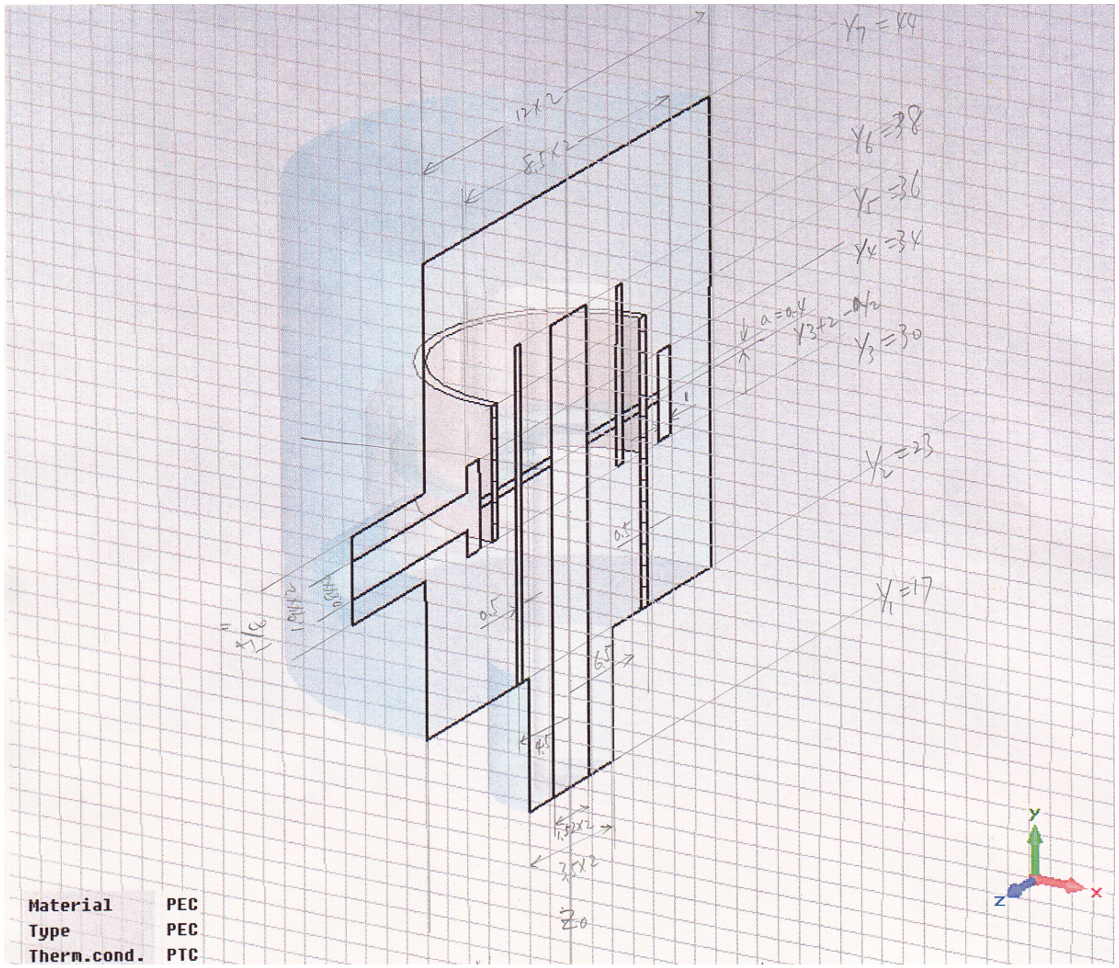
SLAC will continue to collaborate with FNAL

- Finalize the cavity I design to meet Project-X requirements.
- Simulate the cavity I temperature map that can be used for its cooling system design.
- Scale down the current cavity I as the baseline design of a second-harmonic cavity.
- Simulate the second harmonic cavity RF parameters.
- If needed, will realize a HOM damper design for the second-harmonic cavity.

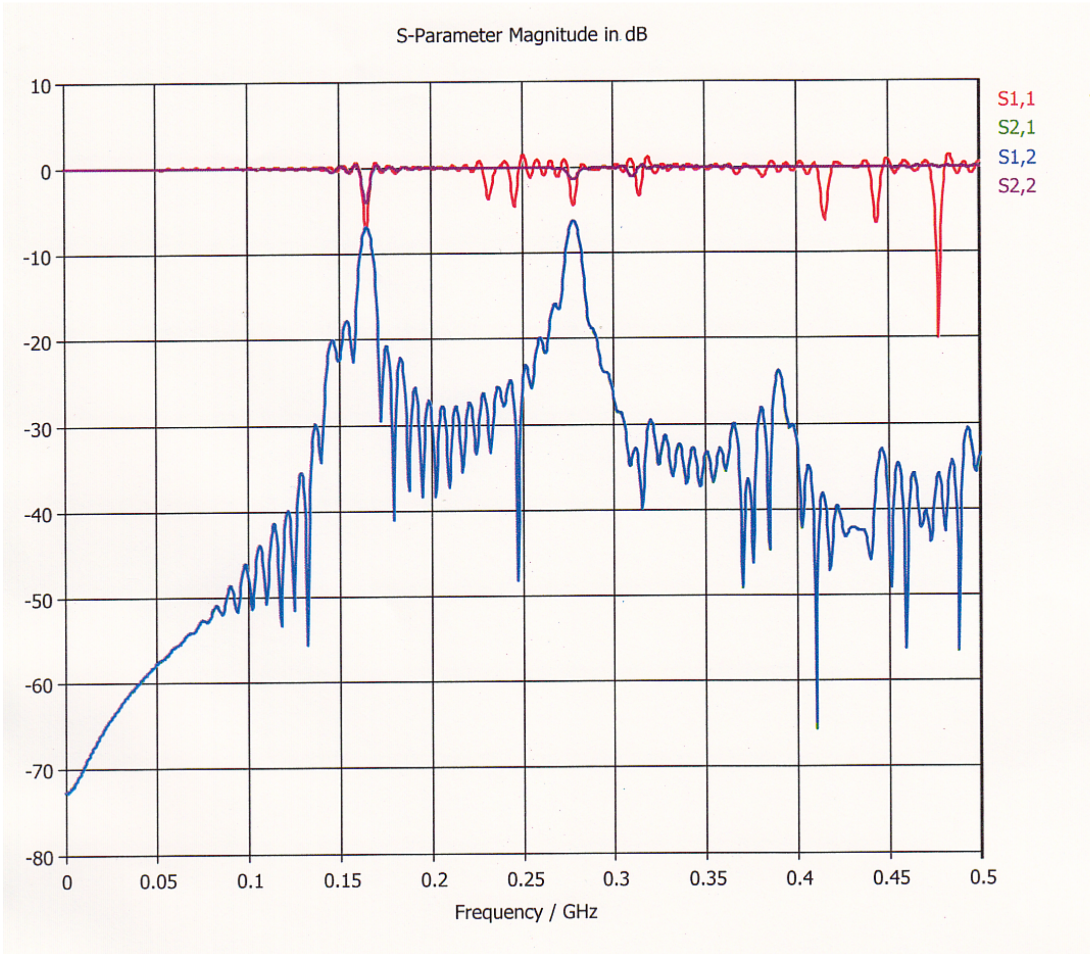
CST Microwave Studio Simulations



HOM Damper Design



HOM Damper Response



FY 2012 Plan

- Cavity
  - Build Copper Mockup of 53 MHz cavity
    - Look at Higher Order Modes, R/Q, and Coupling Issues
- Higher Order Mode Damper
  - Build Copper Mockup of 53 MHz cavity
    - Look at Cavity Mode Response with Dampers
- Second Harmonic Cavity, 106 MHz
  - Start Initial Paper Design
  - Cavity Simulations
  - Review Design