Testing and Performance Goals for 56MHz Cavity

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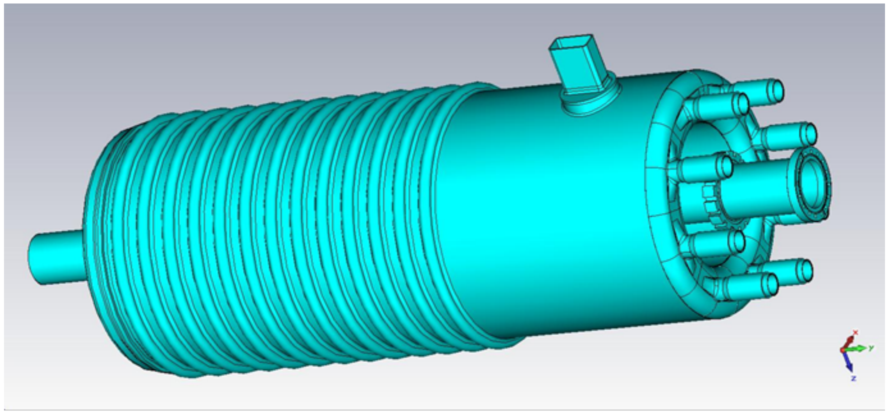
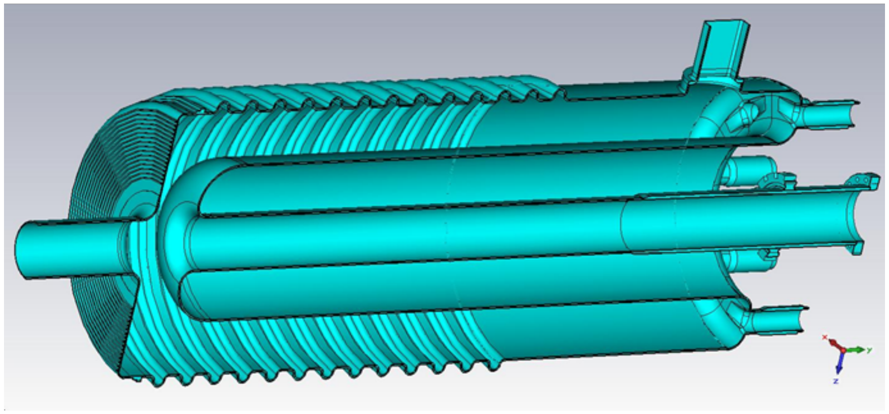
Outline

- The cavity
- HOM damper
- Fundamental damper (FD)
- Fundamental power coupler (FPC)
- Cavity testing
- Summary

56MHz Cavity Benefits





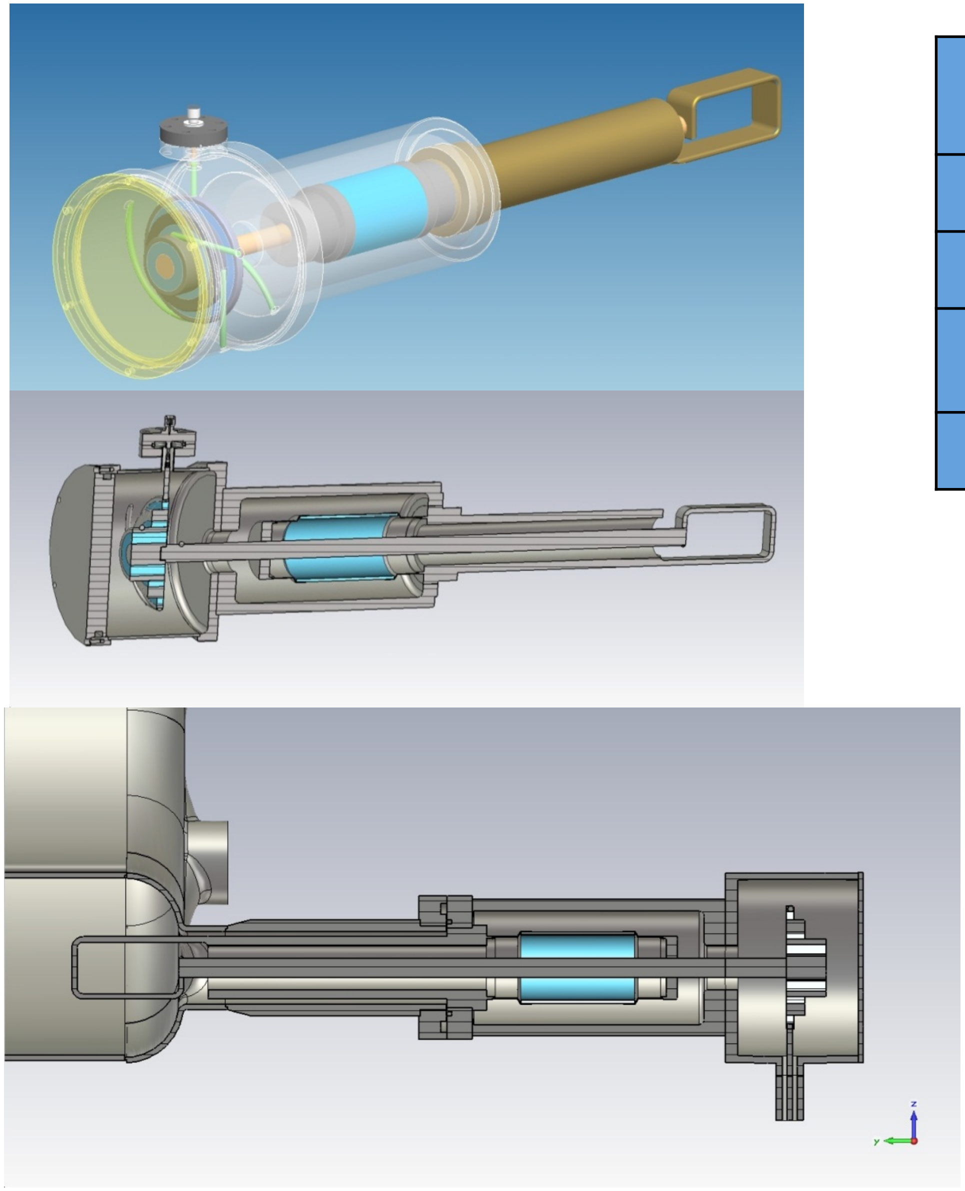
- Large bucket -5 times larger than 197 MHz cavities -no spill of ions
- Adiabatic re-capturing into 56 MHz does not increase longitudinal emittance in contrast with Rf-gymnastics with re-bucketing into the 197 MHz system
- Increased luminosity with and without stochastic cooling
- Improved luminosity in vertex for protons
- Perfect addition to the stochastic cooling

V. Litvinenko @ AIP Project Launch Meeting

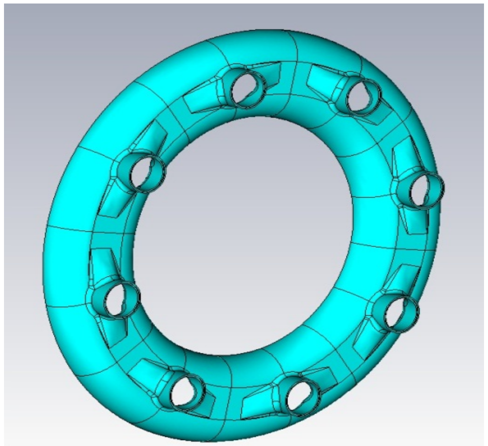
Cavity Design Parameters (@ 2.0MV gap voltage)

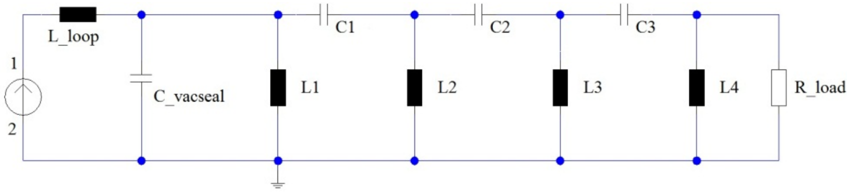
Stored Energy	140	Joules
Operating temperature	4.2	K
Power dissipation (10nΩ residual surface resistivity)	27	W
Q_0	3E9	
Q_L	4E7	
r/Q (accelerator notation)	80.5	Ω
Maximum surface electric field	35	MV/m
Maximum surface magnetic field	84	mT
Coarse tuning range	25.5	kHz
Coarse tuning speed	3666	Hz/sec
Tuning sensitivity	17	Hz/um
Fine tuning range by piezo drive	60	Hz
Fine tuning resolution	0.06	Hz/Volt
Lorentz Detuning	132	Hz

HOM Damper Testing

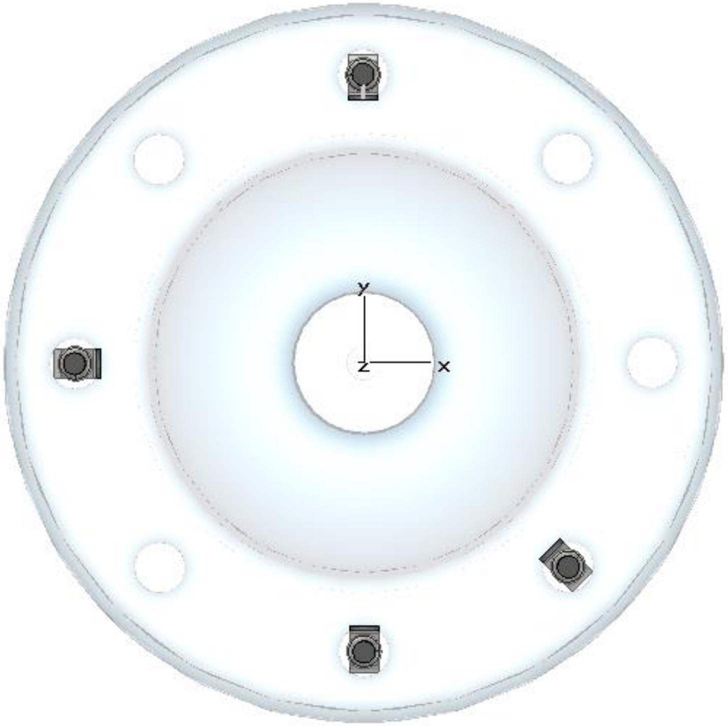


Dimension of damper inner loop	6cm x 2.88cm
Damper width	2cm
Damper thickness	0.3cm
Inner conductor radius	0.76cm
Port shape	r = 1.74cm



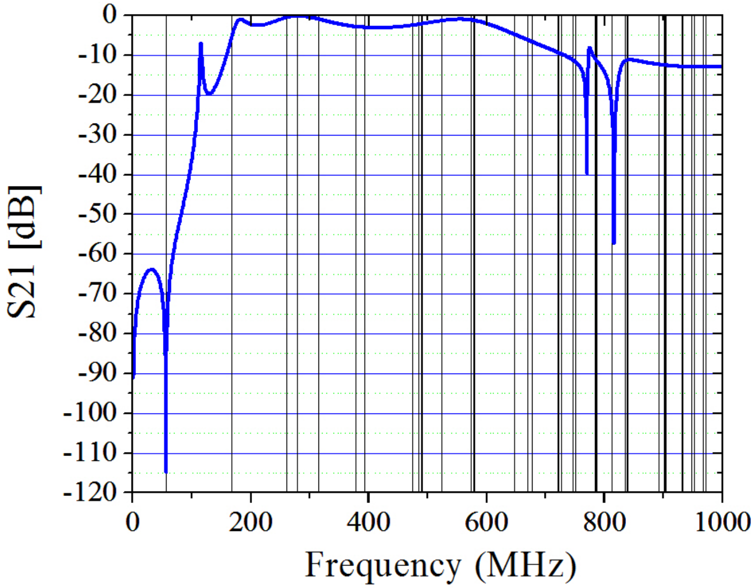


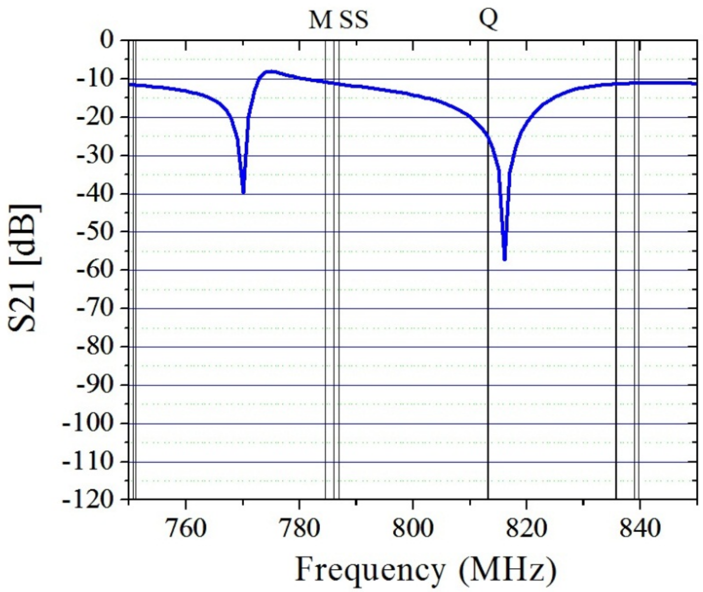
With optimization to all HOM modes up to 1GHz, the cavity will have 4 HOM dampers. The 4 dampers are inserted in an asymmetrical configuration as shown below, which ensures all modes can be extracted to a certain degree.



Frequency [MHz]	Mode Config.	R/Q [Ω]	Q_L
56.231	M	80.53	940
167.456	M	32.34	438
260.445	D	22.18	3817
278.583	M	25.4	428
314.605	D	16.58	760
378.767	M	27.77	514
393.22	D	19.17	543
475.135	M	22.63	621
484.371	D	19.73	1115
490.072	Q	0.000874	7334
524.115	Q	0.00056	2205
573.46	M	12.91	744
577.852	Q	0.081	1390
579.53	D	19.68	1102
646.969	Q	0.0016	990
647.105	Q	0.00211	3758
670.053	D	19.30	1683
677.37	M	6.63	838
721.767	S	4.91E-05	56720
726.747	Q	0.00106	953
746.283	S	0.000477	15679
747.159	S	0.00046	9811
750.743	D	21.44	2224
751.081	D	22.43	1099
784.496	M	3.74	1510
786.022	S	0.0555	4880
813.048	Q	0.00123	1287
835.634	D	6.86	2315
838.906	S	0.00236	0.64
892.829	M	2.63	7458
902.098	Q	0.000988	5122
903.064	S	0.000843	12132
932.277	D	2.68	4584

Overlay of the Filter Spectrum and HOMs of the Cavity





F[MHz]	Mode Type	Qext_tot	dB	R/Q	Qext_real	Qlimit
167.456	M	438	-5.35	32.34	1501	2000
378.767	M	514	-2.85	27.77	991	25000
475.135	M	621	-2.46	22.63	1093	7000
573.46	M	744	-1.17	12.91	975	5000
677.37	M	838	-6.63	6.63	3856	25000
784.496	M	1510	-10.87	3.74	18459	100000

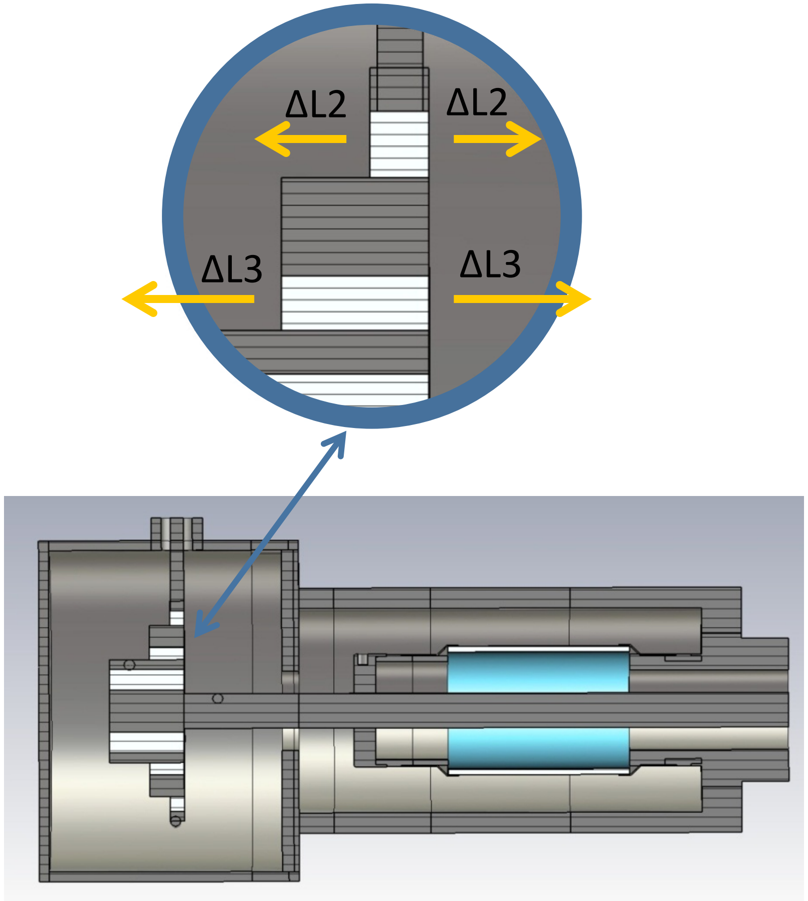
The power of the fundamental mode (FM) in the cavity is >80MW with 2.5MV voltage at the gap. The filter provides -110dB attenuation at -56.3MHz, which limited the output power of the fundamental mode to less than 1mW.

The total power of the HOM modes excited by the beam in the 56MHz SRF cavity is ~1.1W/damper during operation, both rings are included. With the filter installed, the HOM total power output is ~0.33W/damper.

The filter limited some of the HOM damping of the cavity. But more important, it significantly decreased the output power from the fundamental mode.

Tuning of the Filter

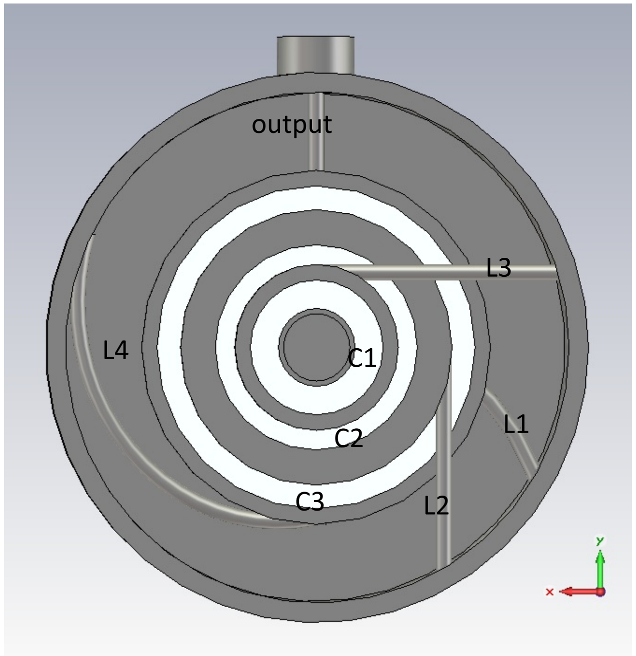
Instead of fixing all the sapphire pieces, we leave two outer most sapphire rings in the filter movable between the niobium cuffs. This will give us plenty of room to correct the error brought by fabrication.

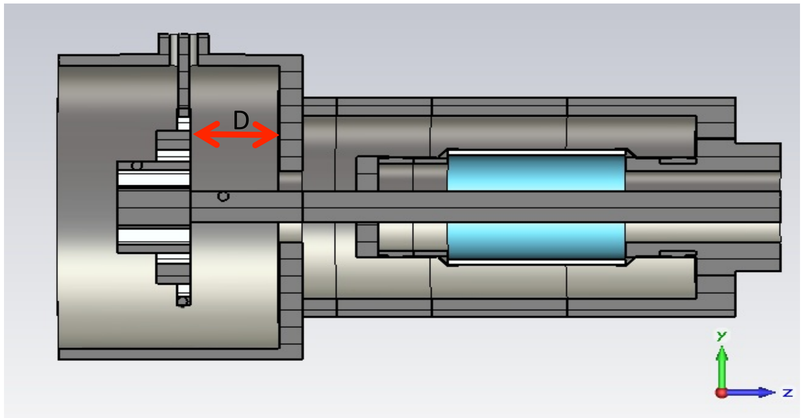


S21 @ 56MHz [dB]	S21min Frq [MHz]	ΔL2 [cm]	ΔL3 [cm]	S21 after adjust [dB]
-110	56	0	0	-110
-75	54	0	0.1	-92
-71	51	0.9	0.1	-95
-77	59	0	0.1	-100
-69	62	0.9	0	-93

ΔL2 and ΔL3 are the changes in effective capacitor length of the sapphire ring 2 and 3 respectively.

Mechanical Tolerance of the Filter





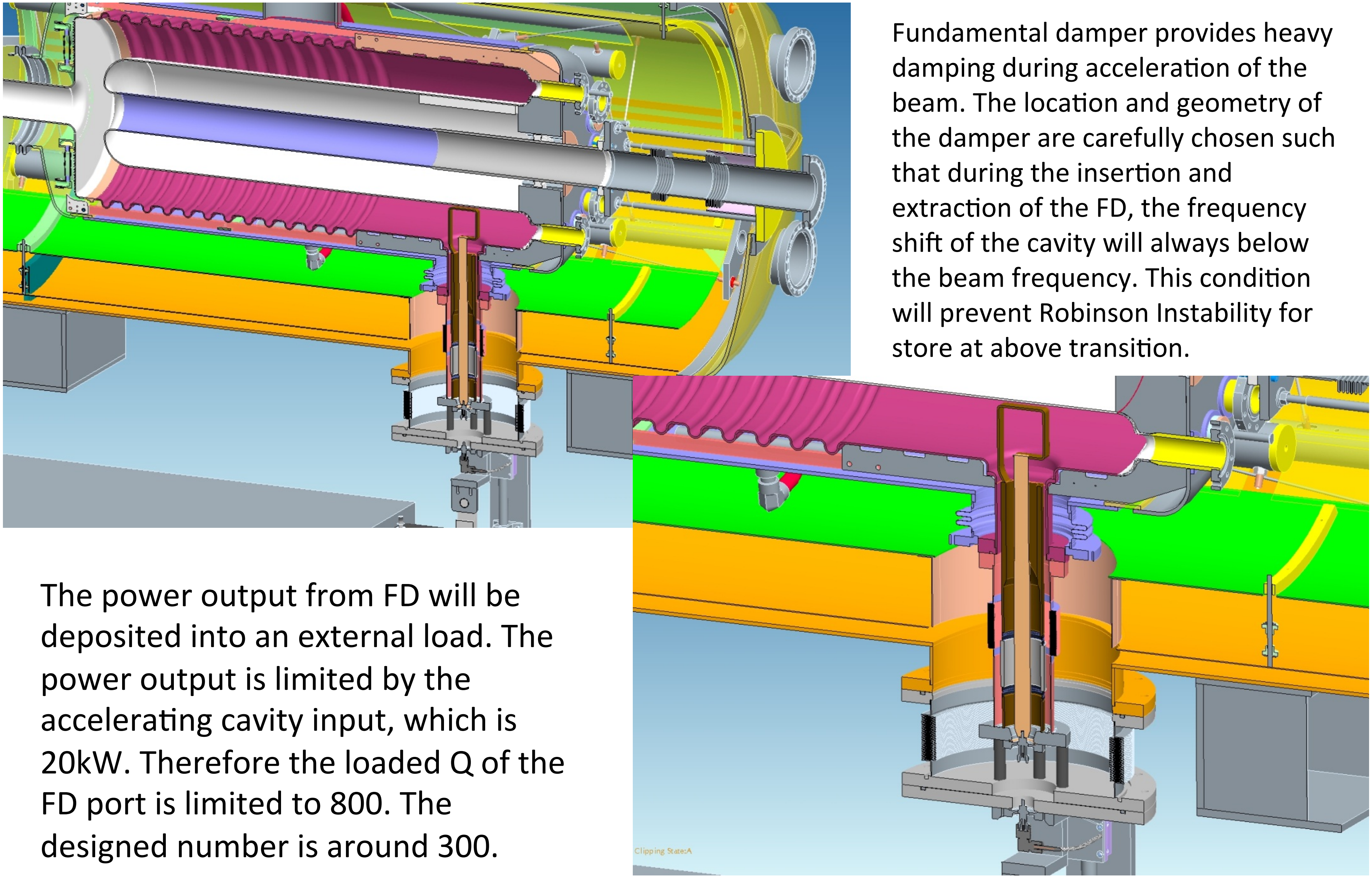
The criteria for the tolerance limit is S21<-70dB at the fundamental mode. The power output at -70dB for the fundamental mode is ~3W, which we used as the upper limit in the design of the connection cable between the filter and the external load.

Parameter	Component	Designed Value	Tolerance
OD/ID	C1	2	±10%
	C2	1.2375	±10%
	C3	1.173	±1%
Length	C1	2.21cm	±10%
	C2	1.02cm	>±20%
	C3	0.41cm	+10%/-5%
Radius	L1	0.15875cm	±10%
	L2	0.15875cm	>±20%
	L3	0.15875cm	>±20%
	L4	0.15875cm	±8%
	Output	0.15875cm	>±20%
IR	Outer can	4.921cm	±2%
D	Outer can	2.67cm	±2.5%

HOM Damper Testing Goals

- RT
  - Spectrum
  - Adjustment of filter, tuning, predict parameters @cold temp
  - Tolerance
  - Multipacting
- Cold--Stand Alone
  - Spectrum
  - Heat generation, temp
  - Tuning, compare with prediction
  - Tolerance
  - Multipacting
- Cold--Assembled
  - Spectrum
  - Heat generation, temp
  - Multipacting

Fundamental Damper Testing



Fundamental damper provides heavy damping during acceleration of the beam. The location and geometry of the damper are carefully chosen such that during the insertion and extraction of the FD, the frequency shift of the cavity will always below the beam frequency. This condition will prevent Robinson Instability for store at above transition.

The power output from FD will be deposited into an external load. The power output is limited by the accelerating cavity input, which is 20kW. Therefore the loaded Q of the FD port is limited to 800. The designed number is around 300.

Operation Sequence

Injection:

- FD fully inserted
- Tuning Plate move to farthest location
- Inject beam
- Beam @ Store
- Fully extract FD
- Tuning plate move to center location
- RF amplifier tuning cavity to desired frequency

If quenching happens:

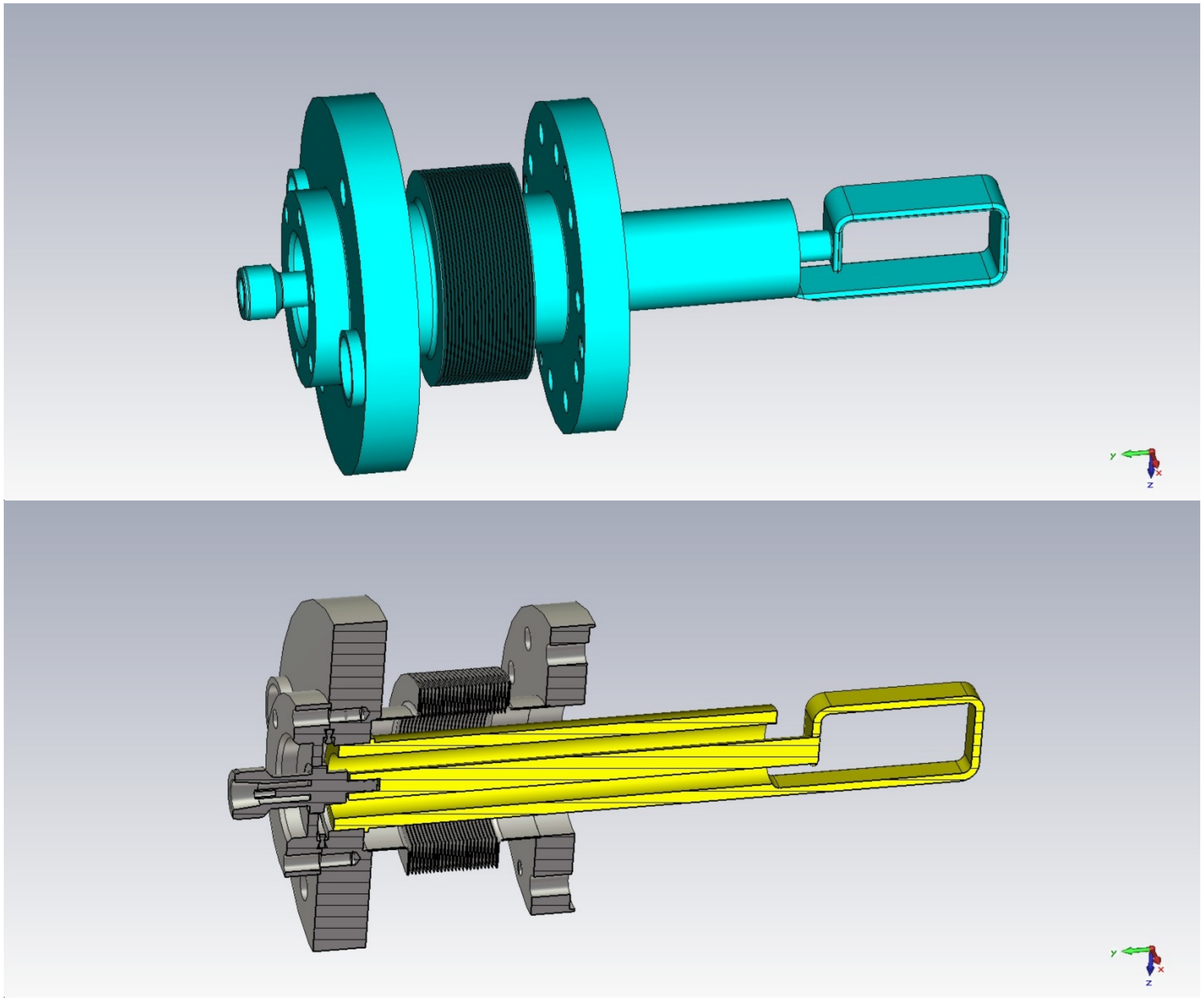
- Tuning Plate move to farthest location (Detuning of the Cavity)
- Fully insert FD

For simplicity, despite of the existence of the beam, the cavity will be ALWAYS detuned first before inserting the Fundamental Damper.

FD Testing Goal

- RT
  - Mobility of FD: distance, speed, stability
  - Spectrum at various locations, if easy
  - Multipacting
- Cold—Stand alone
  - Mobility, same as above
  - Power
  - Vacuum
  - Heating and cooling
  - Radiation
  - Multipacting
- Cold—Assembled
  - Same as Stand alone test

FPC Testing



FPC for 56MHz cavity is planned to input ~1kW, and will act as a fast tuner (~1Hz). The location of the FPC and Pickup probe (PU) will be at the rear end of the cavity, and each occupy a cleaning port as the HOM dampers. The low power and rear-end location made the design of the FPC to refer to the HOM damper.

Some specs on FPC

- Relatively low power

  The 56MHz cavity is a passive resonator, and the FPC is used as a fast tuner for fine tuning of the fundamental mode frequency.

- Mobility

  Tuning with FPC is made feasible through the changing of the insertion depth of the end loop into the cavity.

- Feedback

  The FPC will need a feedback circuit from the PU probe designed for fast and accurate tuning

- Vacuum break window

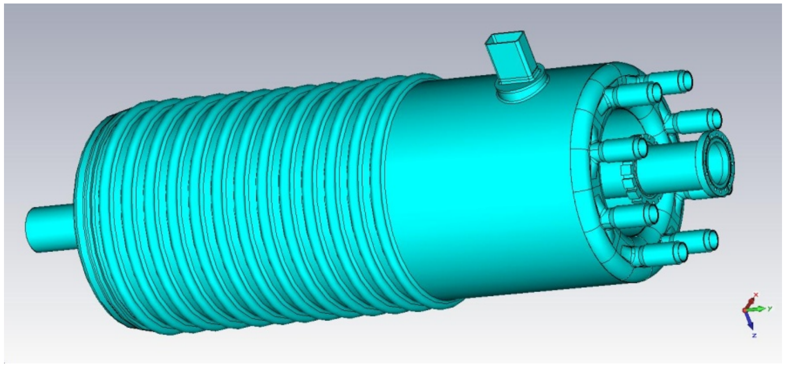
  The ceramic window will be a critical component as for vacuum break (cavity vac vs. isolation vac), voltage hold off (inner conductor vs. outer conductor), RF impedance matching (reflection unwanted), and temperature transition (LHe vs RT through entire FPC).

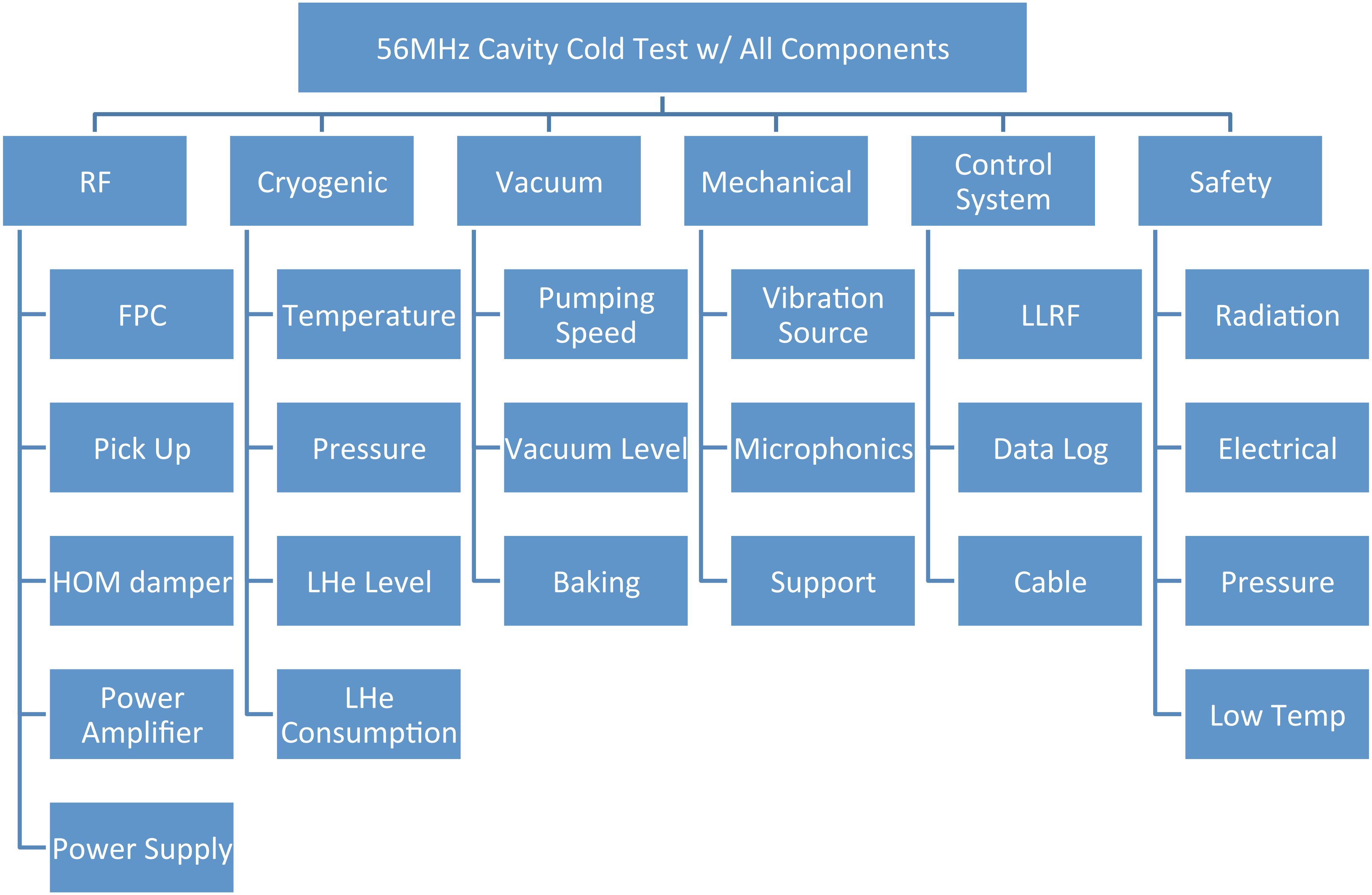
FPC Testing Goals

- RT
  - Tuning
  - Instrumentation and controls, feedback
  - Heat dissipation through windows
  - Vacuum
  - Multipacting
  - Qext (in copper cavity)
- Cold—Stand alone
  - Tuning
  - Heat dissipation and cooling
  - Multipacting
- Cold—Assembled
  - Qext
  - Tuning
  - Heat dissipation and cooling
  - Instrumentation and controls, feedback
  - Multipacting

Cavity Testing

1. Room temperature test
   - Mock up RF components at RT and measure the spectrum by NWA
2. Vertical test in the Dewar (4K)
   - Spectrum measurement
   - Q_0 vs Voltage
   - HOM damper
   - IR detector (intentional quenching)
   - Multipacting
   - Tuning
   - Power, heat
   - Noise measurement
3. Horizontal cryomodule test
   - Same as above
   - FD
   - Finalization before installing into tunnel
4. Assembly in tunnel
   - Horizontal cryomodule acceptance test
   - Beamline connection
   - Noise measurement
   - All parts assembly





- 56MHz Cavity Cold Test w/ All Components
  - RF
    - FPC
    - Pick Up
    - HOM damper
    - Power Amplifier
    - Power Supply
  - Cryogenic
    - Temperature
    - Pressure
    - LHe Level
    - LHe Consumption
  - Vacuum
    - Pumping Speed
    - Vacuum Level
    - Baking
  - Mechanical
    - Vibration Source
    - Microphonics
    - Support
  - Control System
    - LLRF
    - Data Log
    - Cable
  - Safety
    - Radiation
    - Electrical
    - Pressure
    - Low Temp

Some notes

- The RT test will be done with vacuum @ ~1E-8 Torr
- Vibration isolation stage should be tested before installing the cavity into the beamline.

Schedule

Test	Start	Duration	Notes
HOM RT	8/28/11	10 days	Test w/ first article
HOM cold stand alone	9/10/11	10 days	Test w/ first article
FD RT	1/31/12	5 days	
FD cold stand alone	2/7/12	10 days	
FPC RT	2/2/12	5 days	
FPC cold stand alone	2/13/12	10 days	
Assembly w/ cavity	3/1/12	30 days	Horizontal Cryomodule Test

Summary

- The test of the cavity components before installing into the beamline should be done separately and assembled for finalization test
- RT and cold tests will need supporting tools, parts, and facilities.
- Cooperation between each group is essential.