Fundamental mode damper heating

AIP Project – 56 MHz SRF RHIC CAVITY

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Outline

- ❑ Introduction
- ❑ Analysis setup
- ❑ Heating calculation
- ❑ Measurements
- ❑ Conclusions

Introduction

Fundamental mode damper requirements and challenges:

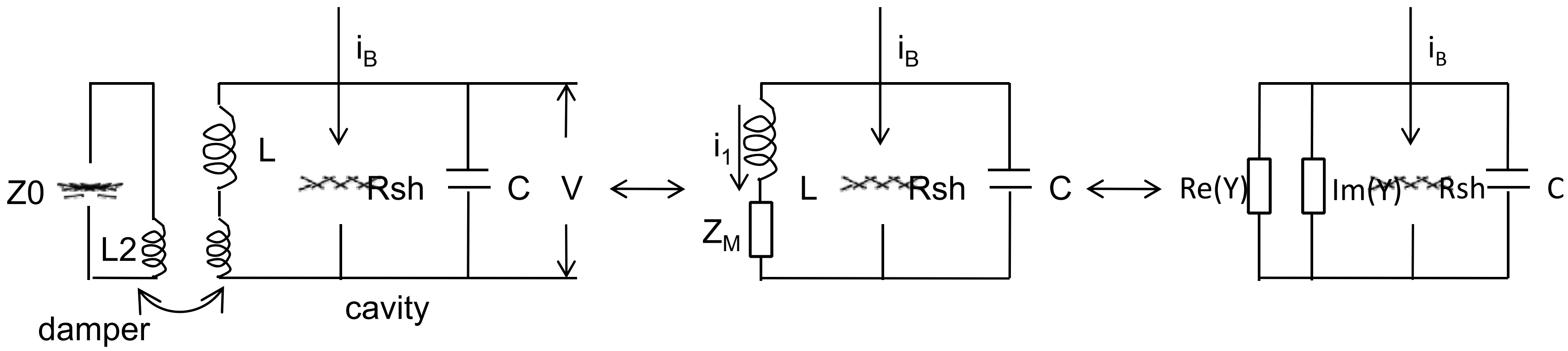
- From injection, a fundamental mode damper will be in because during ramp-up, the beam will go through the cavity's resonance.
- At storage, the damper will be withdrawn. And the cavity frequency will always remain below the beam frequency to fulfill Robinson stability condition.
- During the damper withdrawn, the cavity will experience the frequency shift.

The shifted frequency should not cross the beam revolution frequency!!

- The fundamental mode damping factor is going to be around 10^7.
  - $Q_0 \sim 10^9$
  - $Q_{load} \sim 10^2$

❖***MAC report:*** **The committee is concerned that this damper might have to withstand very large power loads depending on the ramp scenario, and detailed heating simulations are needed.**

Circuit Setup



$$Z_M = \frac{(\omega M)^2}{Z_0 + j\omega L_2}$$

$$\frac{1}{Z_{tot}} = \frac{1}{Z_M + j\omega L} + \frac{1}{R_{sh}} + j\omega C$$

$$Z_{tot} = \frac{R_{sh}\left(Z_M + j\omega L\right)}{R_{sh} + Z_M + j\omega L + R_{sh}\left(Z_M + j\omega L\right)j\omega C}$$

$$Q_{ext} = \frac{\omega C}{\mathrm{Re}(Y) + 1/R_{sh}}$$

$$\frac{1}{Q_{load}} = \frac{1}{Q_0} + \frac{1}{Q_{ext}}$$

$$V = Z_{tot} \cdot i_B$$

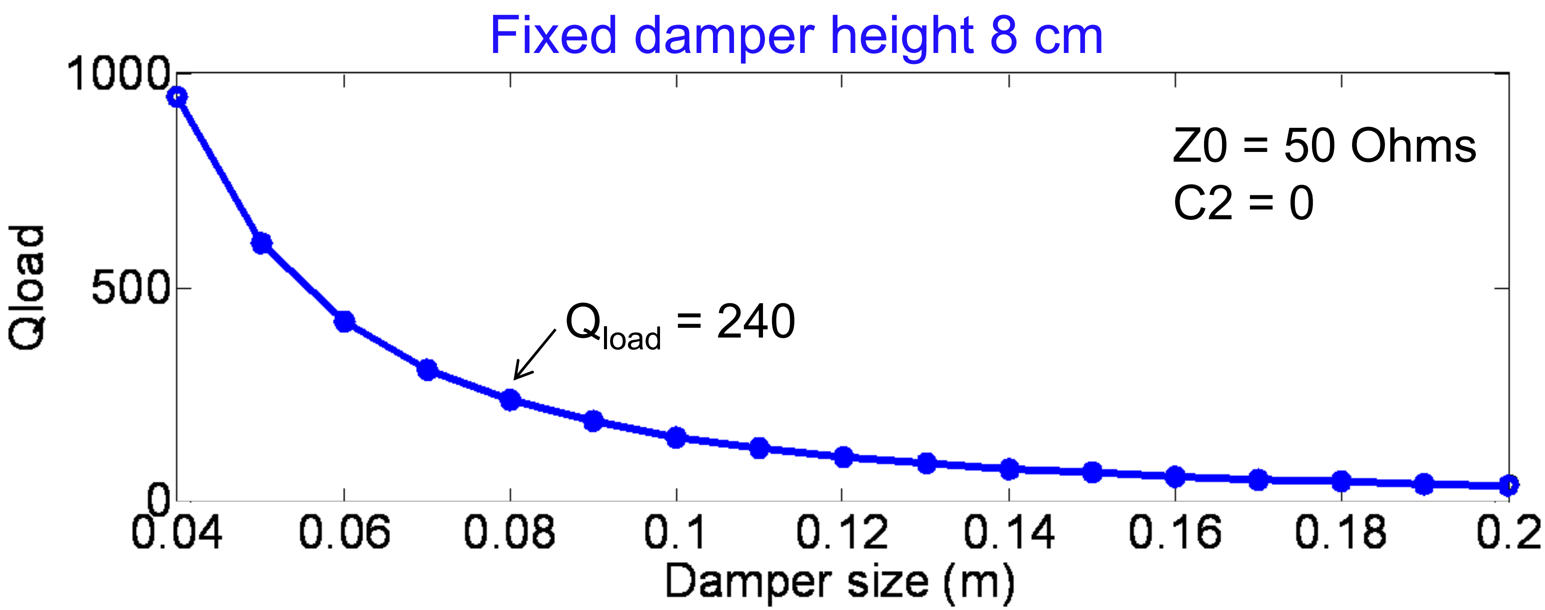
$$i_1 = \frac{V}{Z_M + j\omega L} = \frac{Z_{tot} \cdot i_B}{Z_M + j\omega L}$$

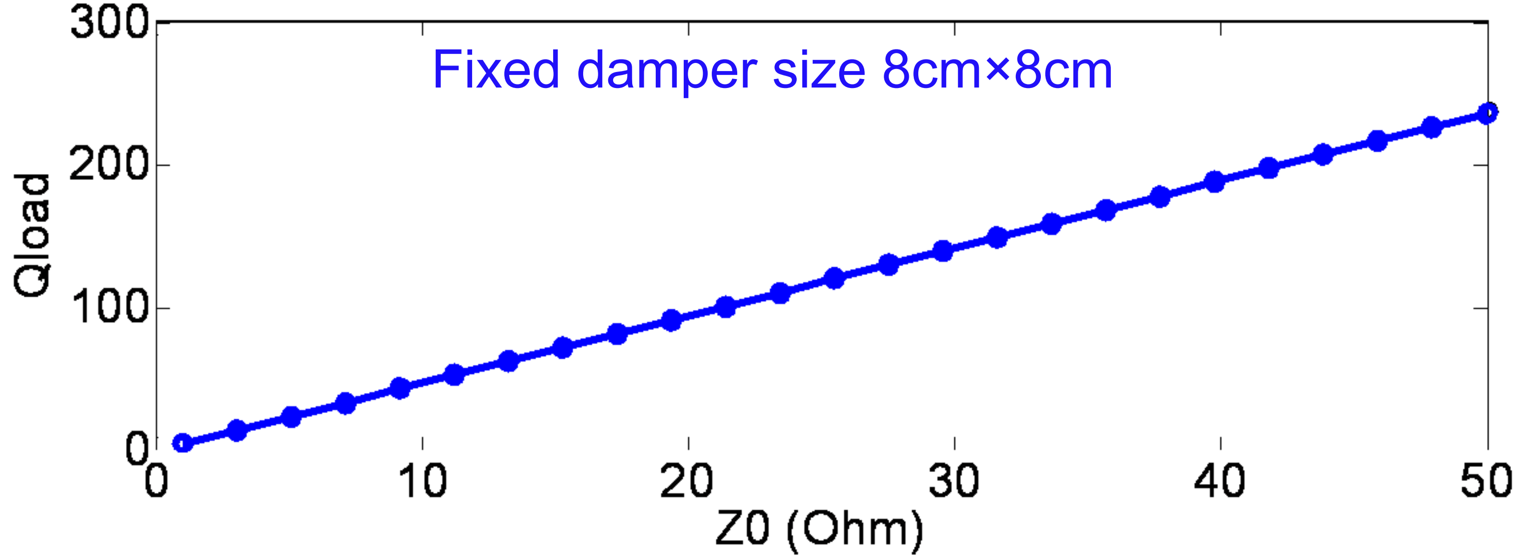
$$P_{diss,load} = \frac{1}{2}\mathrm{Re}(Z_M) i_1 \cdot i_1^*$$

$$P_{diss,surface} = H^2 \cdot (area) \cdot R_{surf}$$

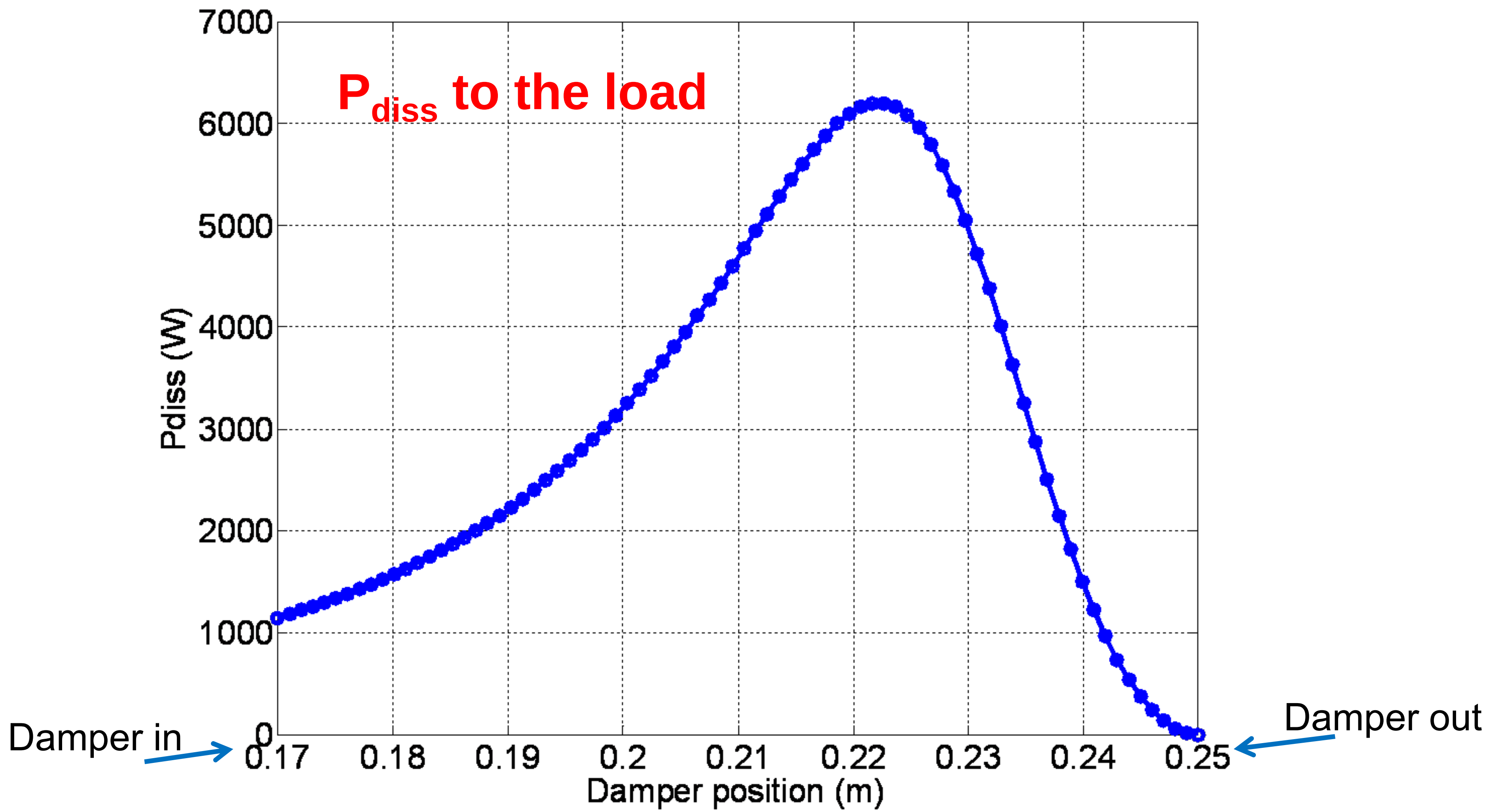
$$H = H_0 \cdot \left(\frac{V}{V_0}\right)$$

Fundamental damper



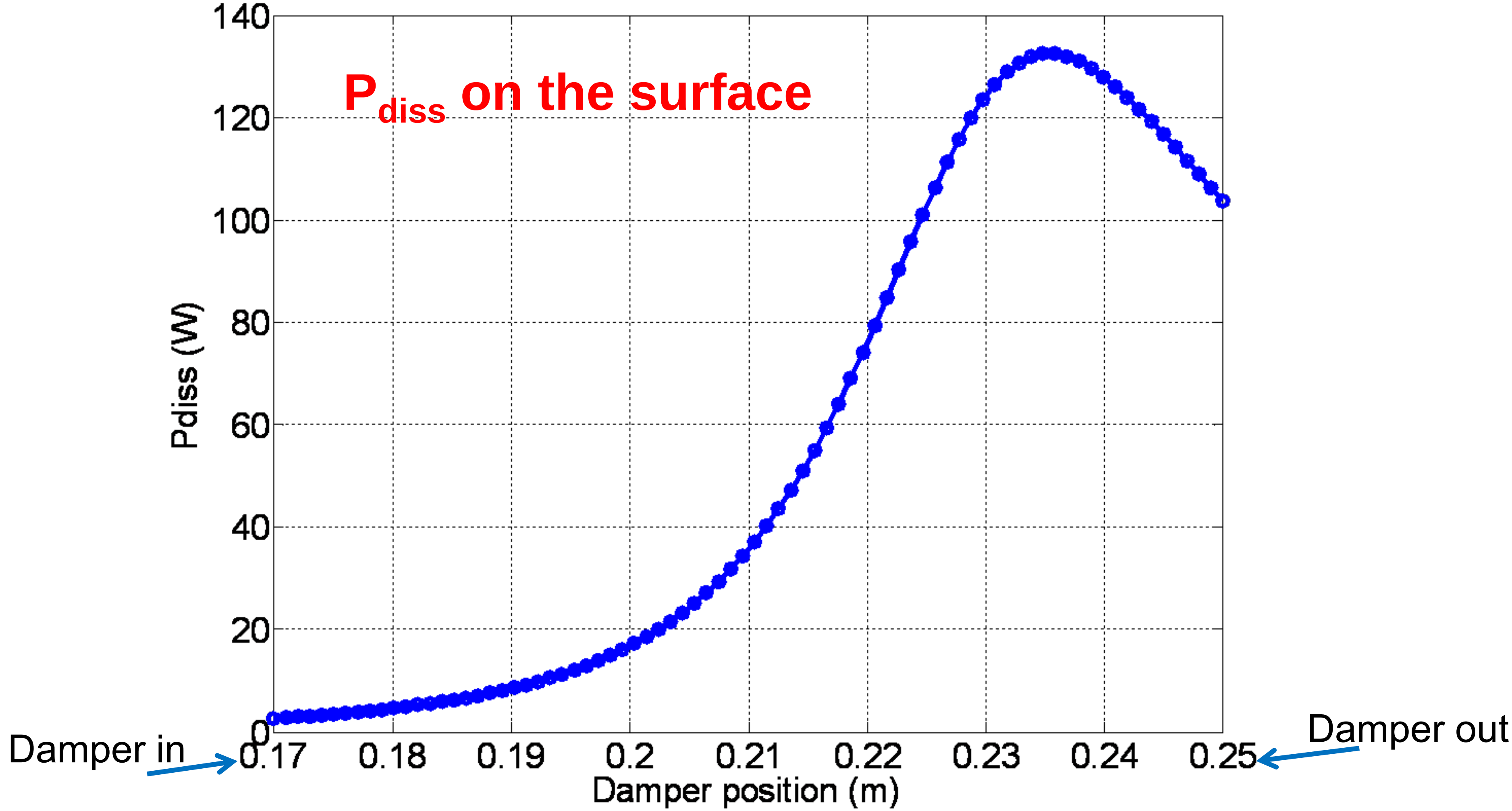


Dissipated power



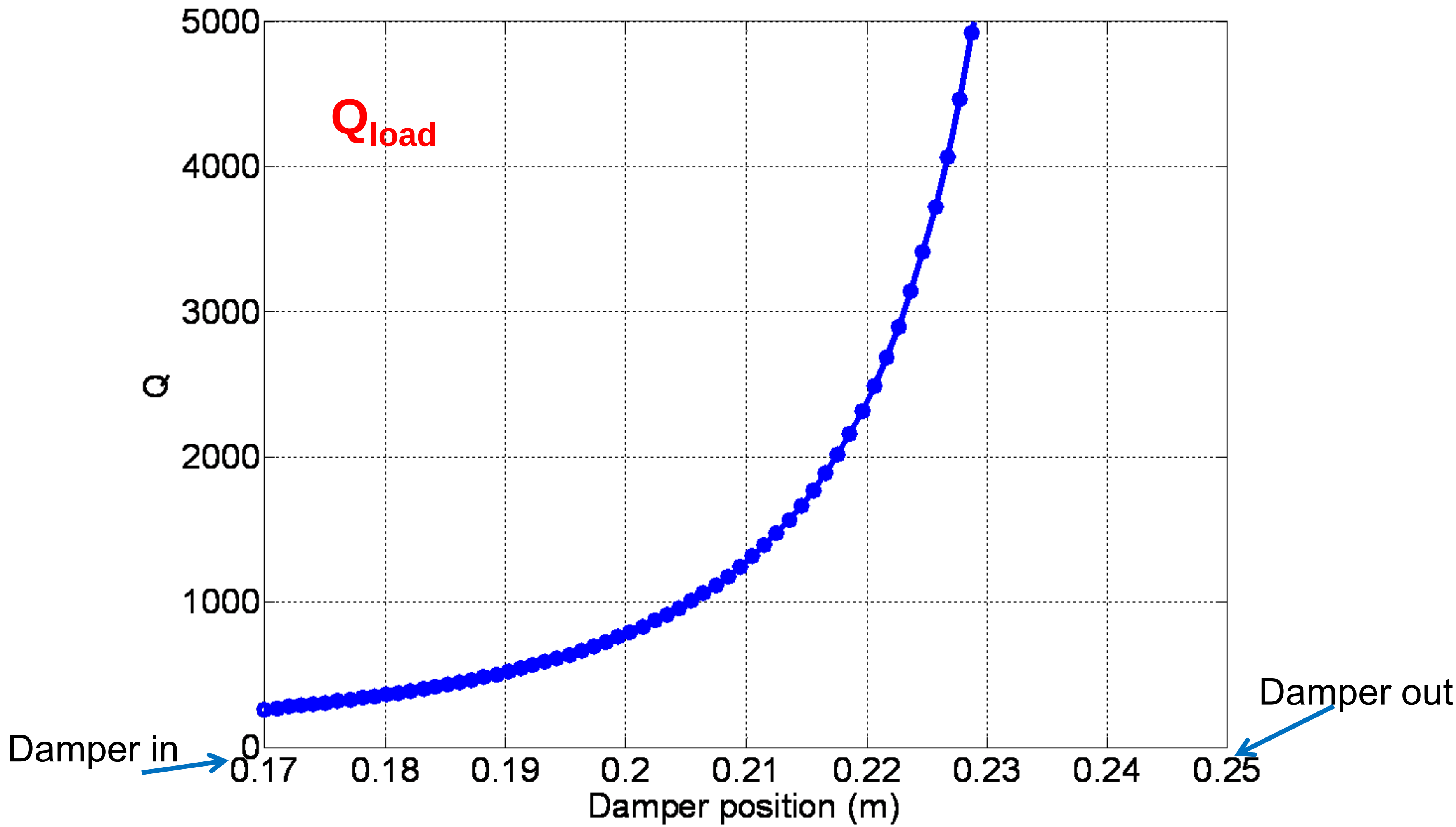
- ❑ Proton beam; beam current ~ 0.3 A
- ❑ The cavity is detuned to be -10 kHz with respect to the beam rev frequency.

Dissipated power



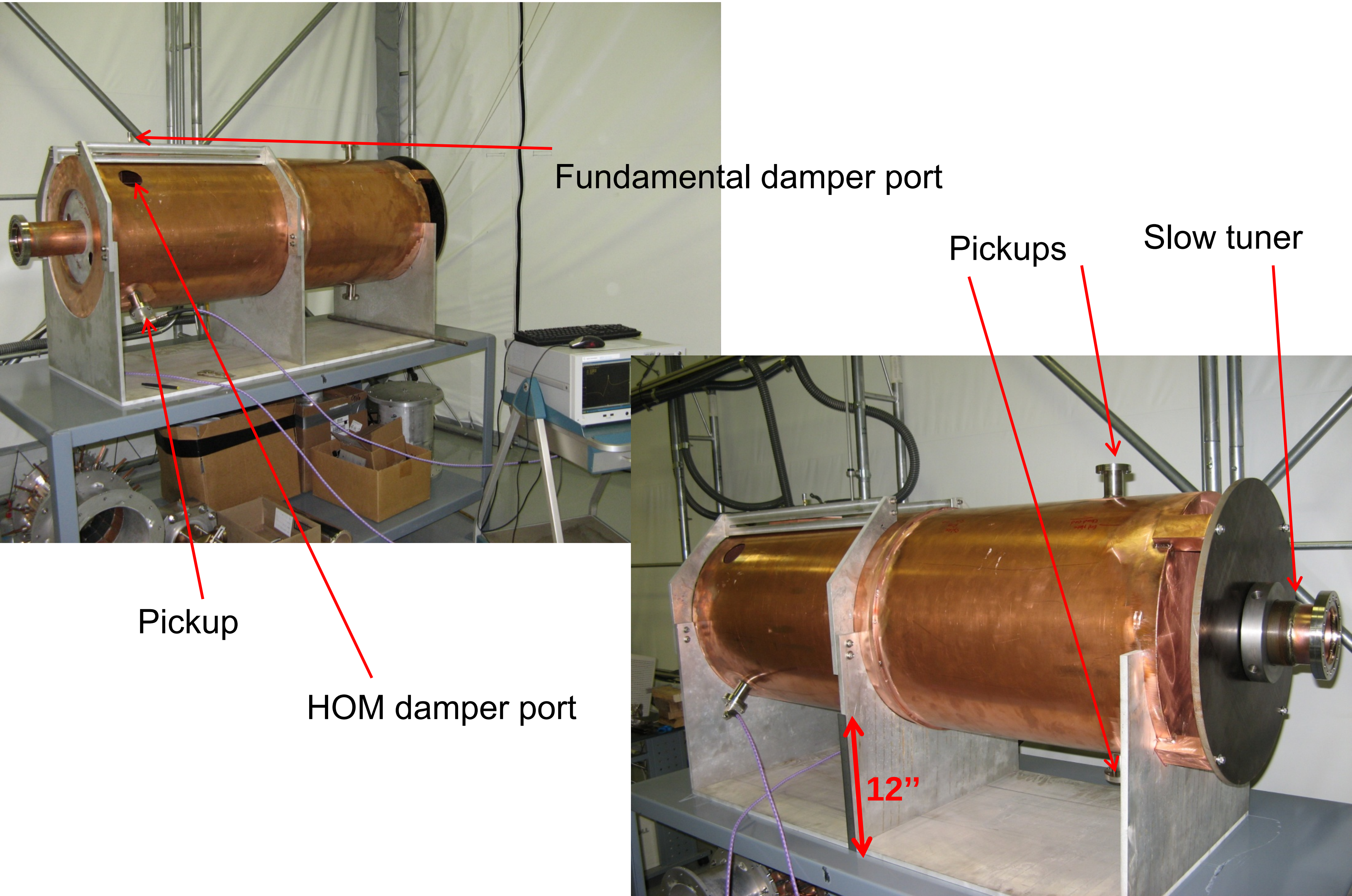
- ❑ Proton beam; beam current ~ 0.3 A
- ❑ The loop is copper; R_{Cu} ~ 10 mOhm
- ❑ The cavity is detuned to be -10 kHz with respect to the beam rev frequency.
- ❑ Loop size: 8 cm x 8 cm x 4 cm

Loaded Q

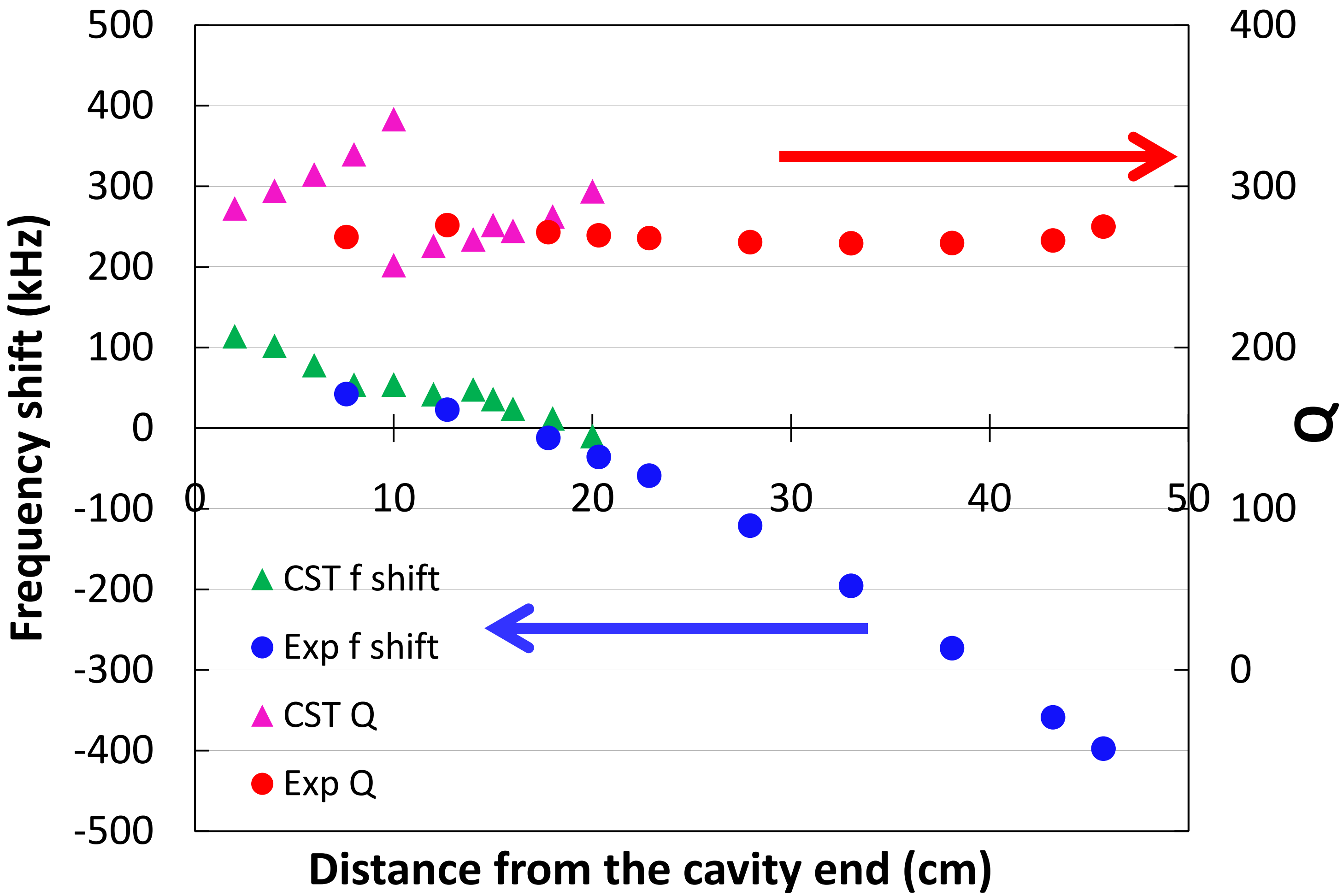


- Proton beam; beam current ~ 0.3 A
- The cavity is detuned to be -10 kHz with respect to the beam rev frequency.

Cu Prototype cavity



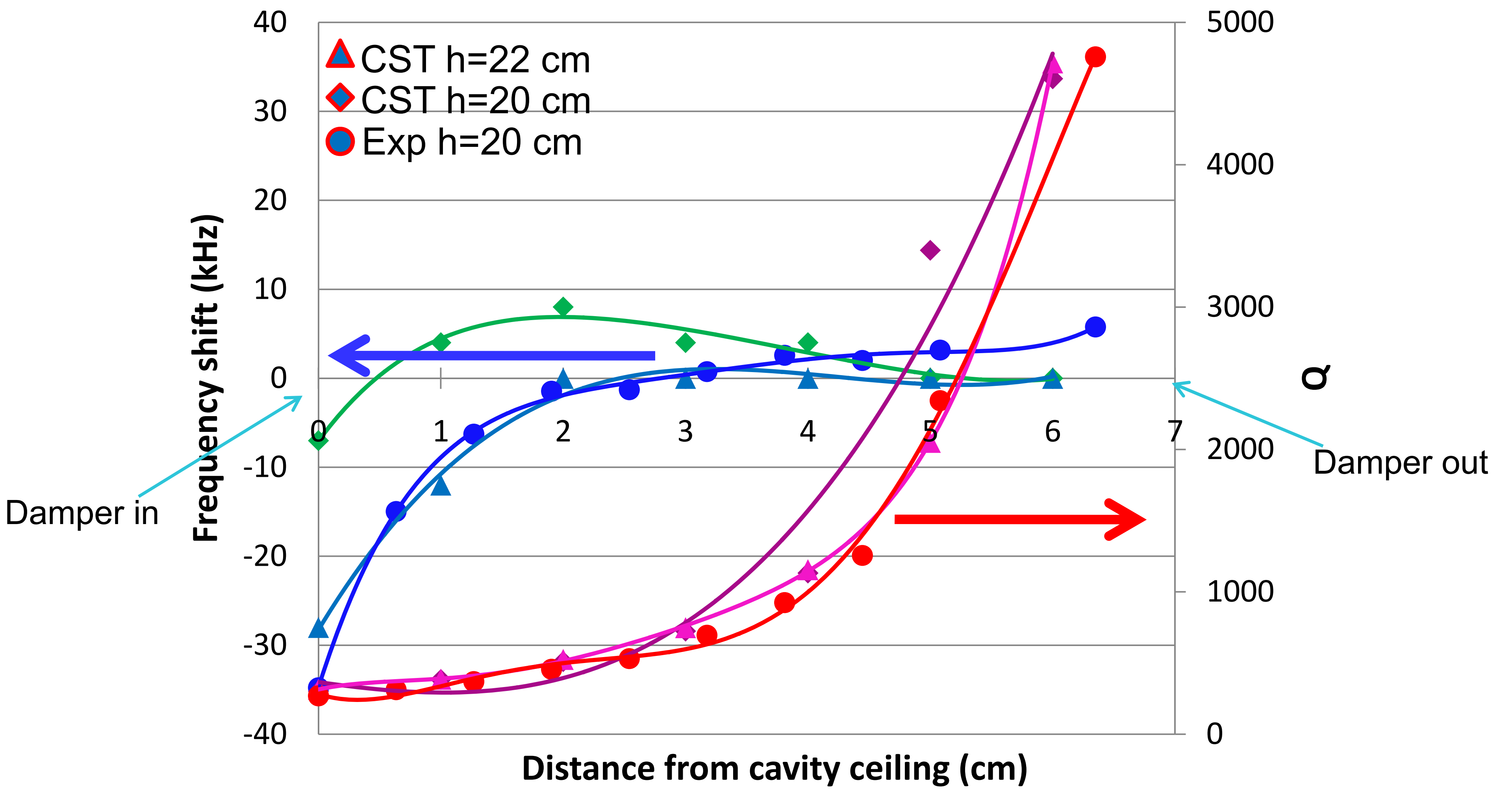
Measurement



❑ Good agreement between simulation and experiment

❑ As predicted in CST simulation, there is 0 frequency crossing point as the damper moves towards the cavity gap, while Q maintains almost constant.

Measurement



- ❑ Good agreement between simulation and experiment
- ❑ There is an optimum position where the damper experiences no frequency shift as it is withdrawn.

HOM damper

- *Results from Microwave studio: Empty cavity case.*

Monopoles		Dipoles	
F0 [MHz]	R/Q [Ω]	F0 [MHz]	R/Q [Ω]
56.264	81.1975	258.461	11.37
167.848	33.4439	310.261	17.05
276.156	30.4197	387.042	14.59
377.309	36.7545	476.751	12.99
468.380	36.5653	571.597	14.17
559.683	20.4173	663.436	21.65
657.928	8.4522	741.278	15.58
760.190	3.7061	813.868	12.1
862.256	1.8042	899.823	2.2
962.647	0.8958		
1105.129	28.8733		
1169.768	1.1905		

Beta = 0.995472

HOM Q values

HOM Q values at transition (F damper inserted)

Monopoles						Dipoles			
CST Results				Experiment		CST Results		Experiment	
f0 [MHz]	R/Q	f0 [MHz]	Q	f0 [MHz]	Q	f0 [MHz]	R/Q	f0 [MHz]	Q
56.209	80.1	56	~300	56.14186	270	260.360	10.1	253.82	26
167.979	30.5	167	~2000	165.936	100	314.633	17.5	299.994	39
277.620	23.6	276	~120	267.389	65	392.412	16.3	386.9632	777
383.444	22.8	377	~70			482.838	14.7		
483.158	13.5	468	~7000	484.787	6776	672.971	8.9		
484.517	21.4	560	~2700	510.5887	83	760.829	8.2		
584.040	22.4	657	~4800	579.3564	964	849.264	8.5		
686.890	9.8					946.759	1.7		
793.668	6.2					1047.23	1.6		
902.600	4.8								
1011.560	6.4			1014.2868	1240				

Conclusions

Fundamental mode damper:

- Calculation shows the maximum dissipated power to the load is 6.2 kW with 10 kHz detuning. If the detuning is 20 kHz, the maximum power can be reduced to 3 kW.
- Calculation shows the maximum dissipated power on the surface of the loop is 130 W; air cooling will be fine.
- Preliminary experimental results agree well with CST simulation results;
  - Q_L at 56 MHz: 270 (experiment) vs. 300 (CST)

HOMs:

- At injection, the CB stability condition of HOMs is satisfied only with the fundamental mode damper
- The measured Q of 1014 MHz mode is 1240 (This mode does exist).