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LCLS II cavity HOM coupler tuning and measurements during cold test

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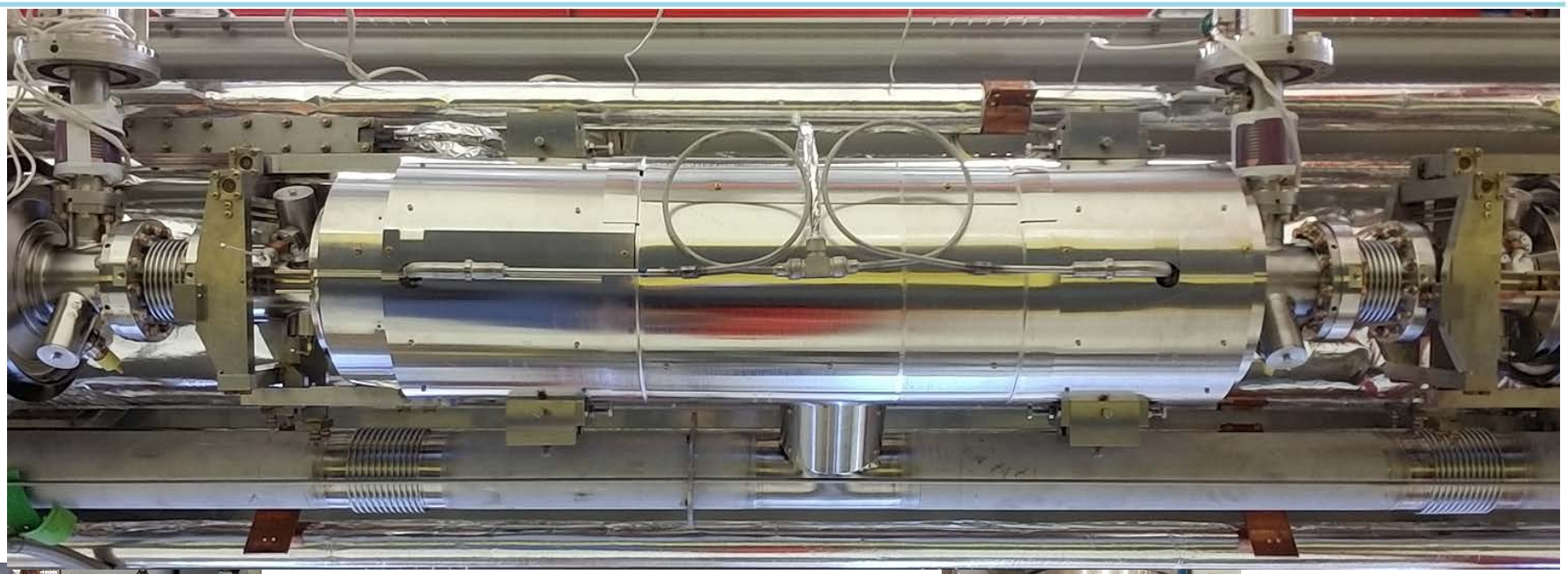
TTC meeting

8 February 2018

LCLS II cavity HOM coupler tuning and measurements

- HOM coupler optimized for extraction of power of high order modes from the cavity
- LCLS-II cavity HOM cables can transmit up to 10 W at 2 GHz average RF power
- Operating mode is decoupled due to notch filter properties at 1300 MHz
- Notch frequency need to be tuned for high field operation in order to avoid excessive power leak
  - Target is <0.5W at 1.3 GHz for 16 MV/m
- We are tuning HOM notch frequencies 1st time before VTS cold test and 2nd time during cold mass assembly at WS3
- HOM notch frequencies are monitored during CM assembly
- At CMTF HOM power measured during 2K operation

Photo of the cavity



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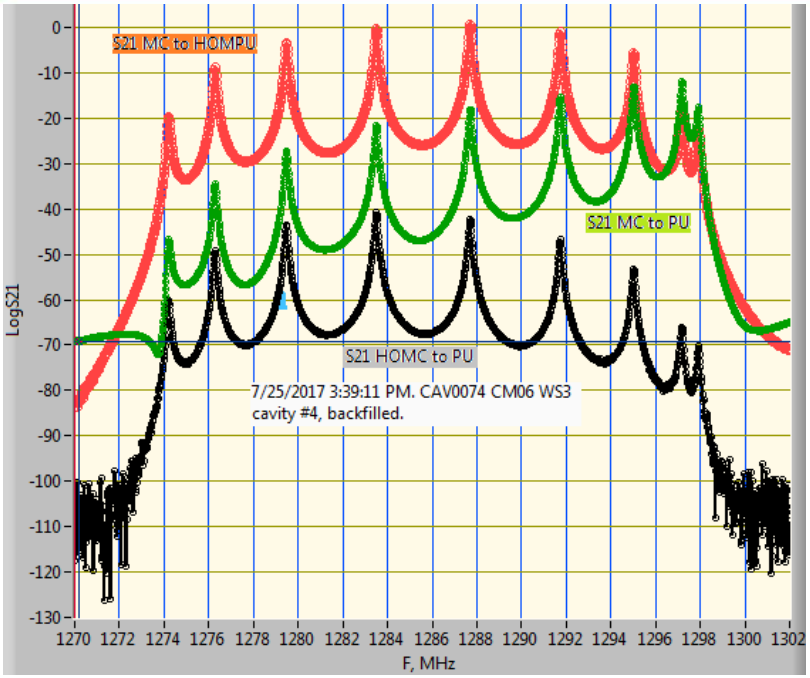
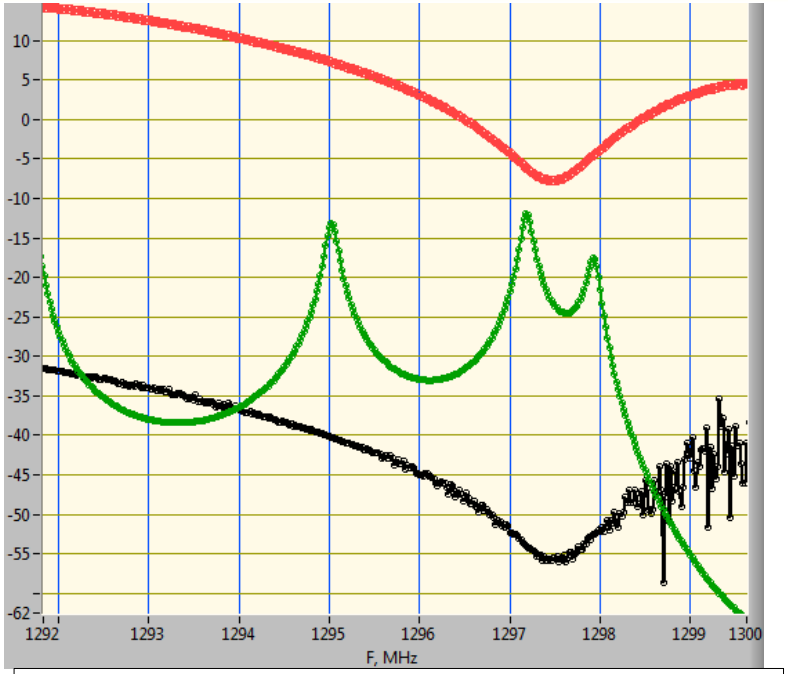
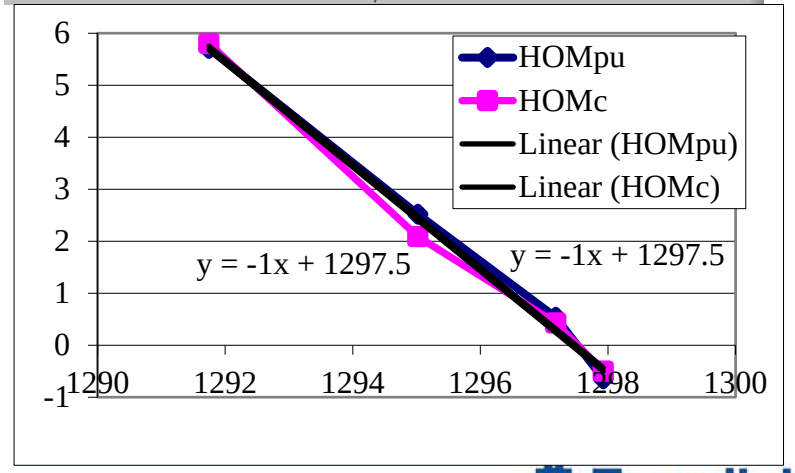
HOM notch frequency measurements at 300K





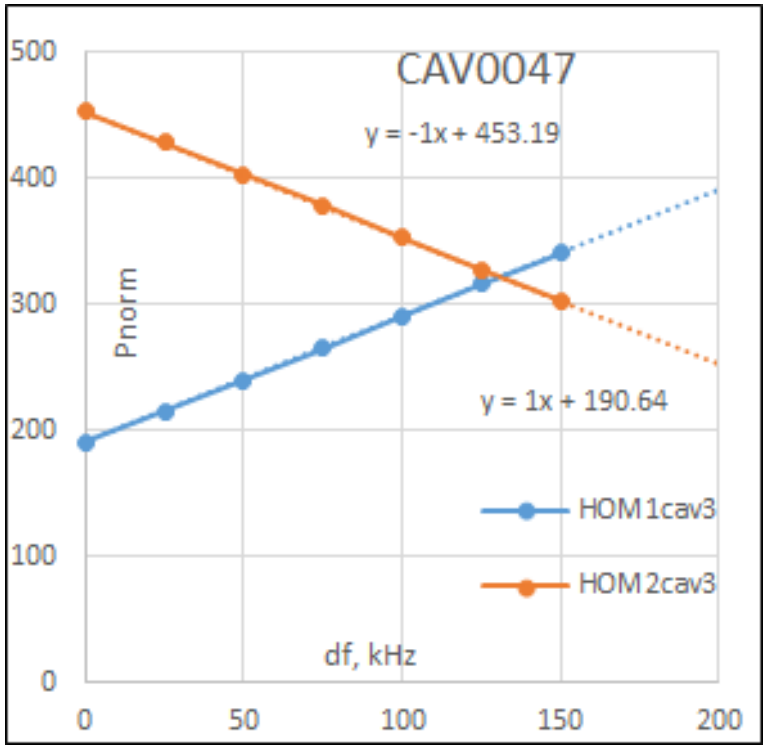
7/25/2017 3:39:11 PM. CAV0074 CM06 WS3 cavity #4. S21 MC to PU.					HOMpu	HOMc
7/25/2017 4:36:44 PM. CAV0074 CM06 WS3 cavity #4. S21 MC to HOMPU.					1297.5	1297.5
7/25/2017 4:33:41 PM. CAV0074 CM06 WS3 cavity #4. S21 HOMC to PU.					HOM2	HOM1
F, MHz	Q	PU	HOMpu	HOMc	1.0909	214.79
1274.21	9562	4.65E+00	1.03E+02	9.69E-01	24.073	44.762
1276.29	9767	1.92E+01	3.63E+02	3.51E+00	20.625	39.256
1279.48	9790	4.25E+01	6.72E+02	6.62E+00	17.236	33.401
1283.50	9778	8.17E+01	9.49E+02	8.98E+00	12.679	23.608
1287.70	9760	1.25E+02	1.06E+03	7.61E+00	9.291	13.087
1291.75	9721	1.73E+02	9.04E+02	4.67E+00	5.706	5.804
1295.02	9750	2.21E+02	5.11E+02	2.15E+00	2.519	2.089
1297.18	9602	2.50E+02	1.24E+02	4.99E-01	0.539	0.428
1297.93	9180	1.32E+02	7.84E+01	3.07E-01	-0.647	-0.498



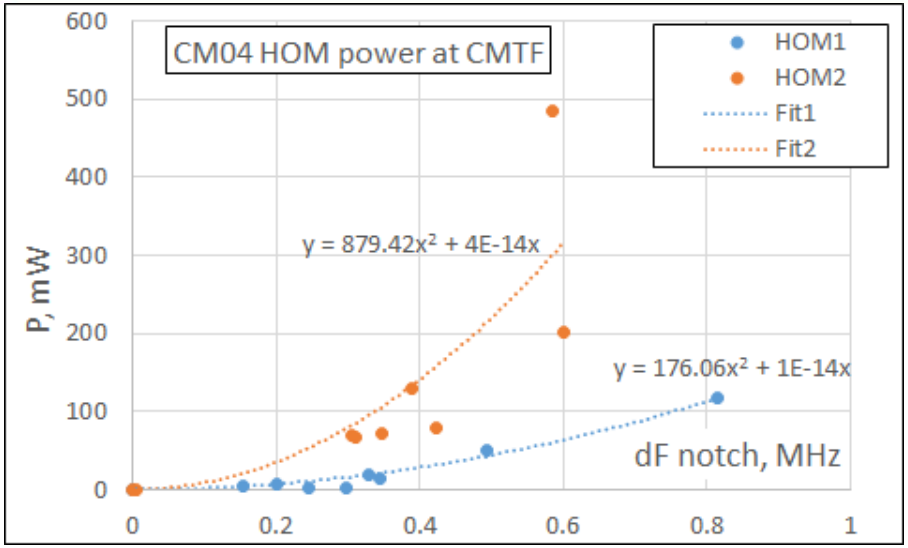
HOM notch frequency calculations at 2K

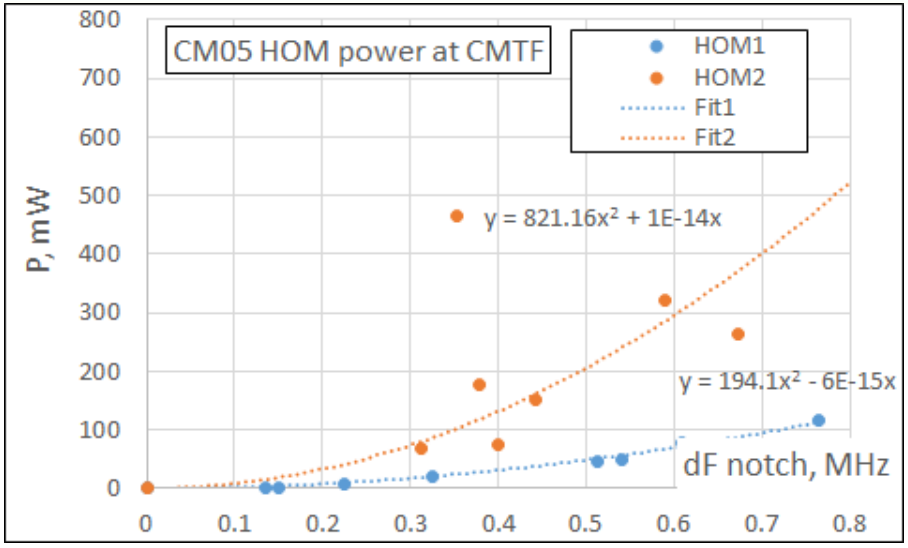
CM07	Pt, W							
df, kHz	Cav #1	Cav #2	Cav #3	Cav #4	Cav #5	Cav #6	Cav #7	Cav #8
0	0.07	0.09	0.12	0.06	0.03	0.03	0.06	0.03
25	0.07	0.09	0.12	0.06	0.03	0.03	0.06	0.03
50	0.07	0.09	0.11	0.06	0.03	0.03	0.06	0.03
75	0.07	0.09	0.12	0.06	0.03	0.03	0.06	0.03
100	0.07	0.09	0.12	0.06	0.03	0.03	0.06	0.03
125	0.07	0.09	0.12	0.06	0.03	0.03	0.06	0.03
150	0.06	0.07	0.11	0.06	0.03	0.03	0.06	0.03
	HOM1, mW							
0	0.02	0.02	0.26	0.02	0.03	0.06	0.82	0.87
25	0.03	0.02	0.34	0.02	0.02	0.04	0.69	0.80
50	0.04	0.02	0.41	0.02	0.02	0.03	0.57	0.73
75	0.05	0.02	0.51	0.02	0.02	0.02	0.45	0.65
100	0.08	0.04	0.61	0.02	0.03	0.02	0.35	0.58
125	0.10	0.06	0.72	0.02	0.04	0.02	0.27	0.53
150	0.12	0.08	0.79	0.02	0.06	0.02	0.20	0.47
	HOM2, mW							
0	1.99	4.41	6.22	2.72	0.36	2.47	9.53	1.47
25	1.67	3.80	5.56	2.41	0.24	2.17	8.59	1.28
50	1.36	3.23	4.89	2.12	0.14	1.89	7.71	1.10
75	1.10	2.71	4.34	1.85	0.07	1.64	6.84	0.92
100	0.85	2.25	3.77	1.58	0.04	1.39	5.98	0.76
125	0.66	1.81	3.26	1.38	0.02	1.19	5.37	0.65
150	0.41	1.23	2.62	1.15	0.03	1.00	4.73	0.53

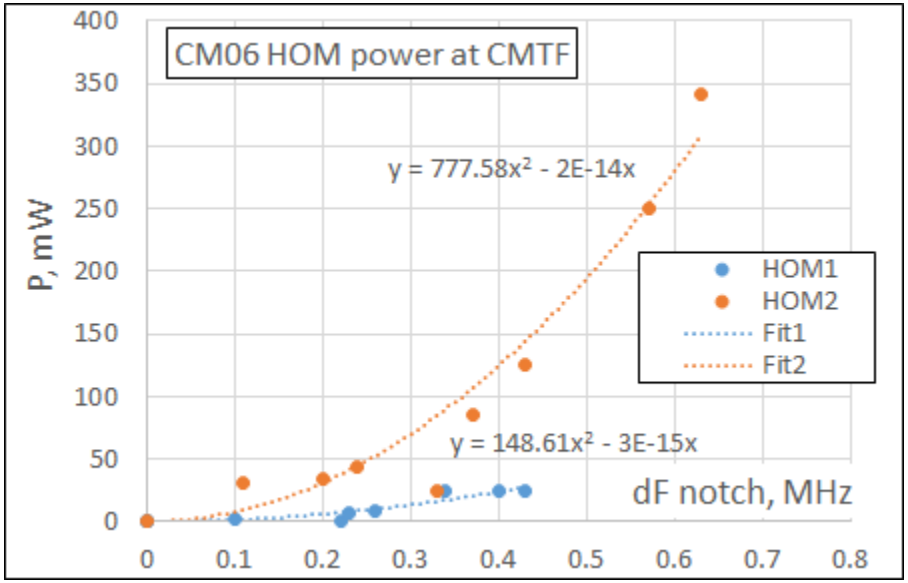
- RF power leak measured from HOM couplers during cavity frequency tuning
- Notch frequency calculated based on these data

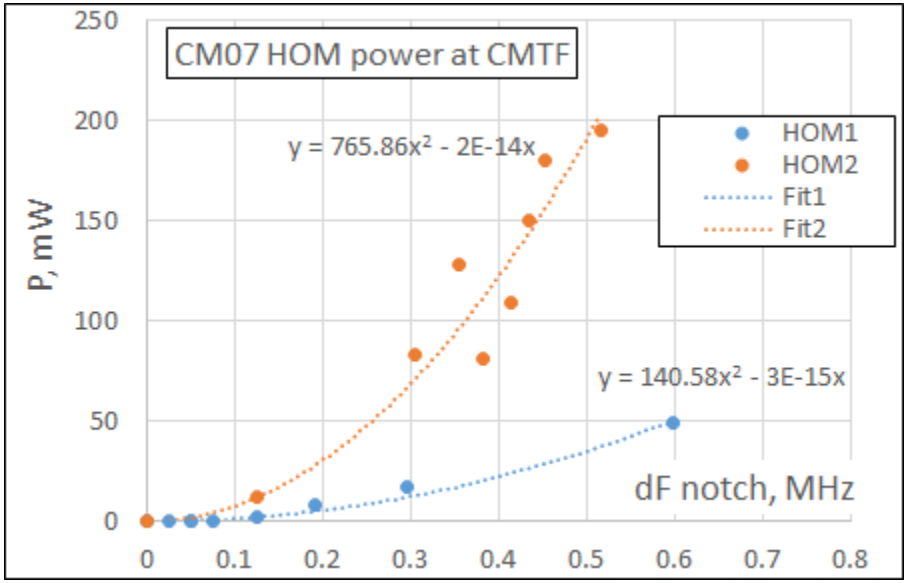


HOM notch frequency calculations at 2K









HOM notch frequency history

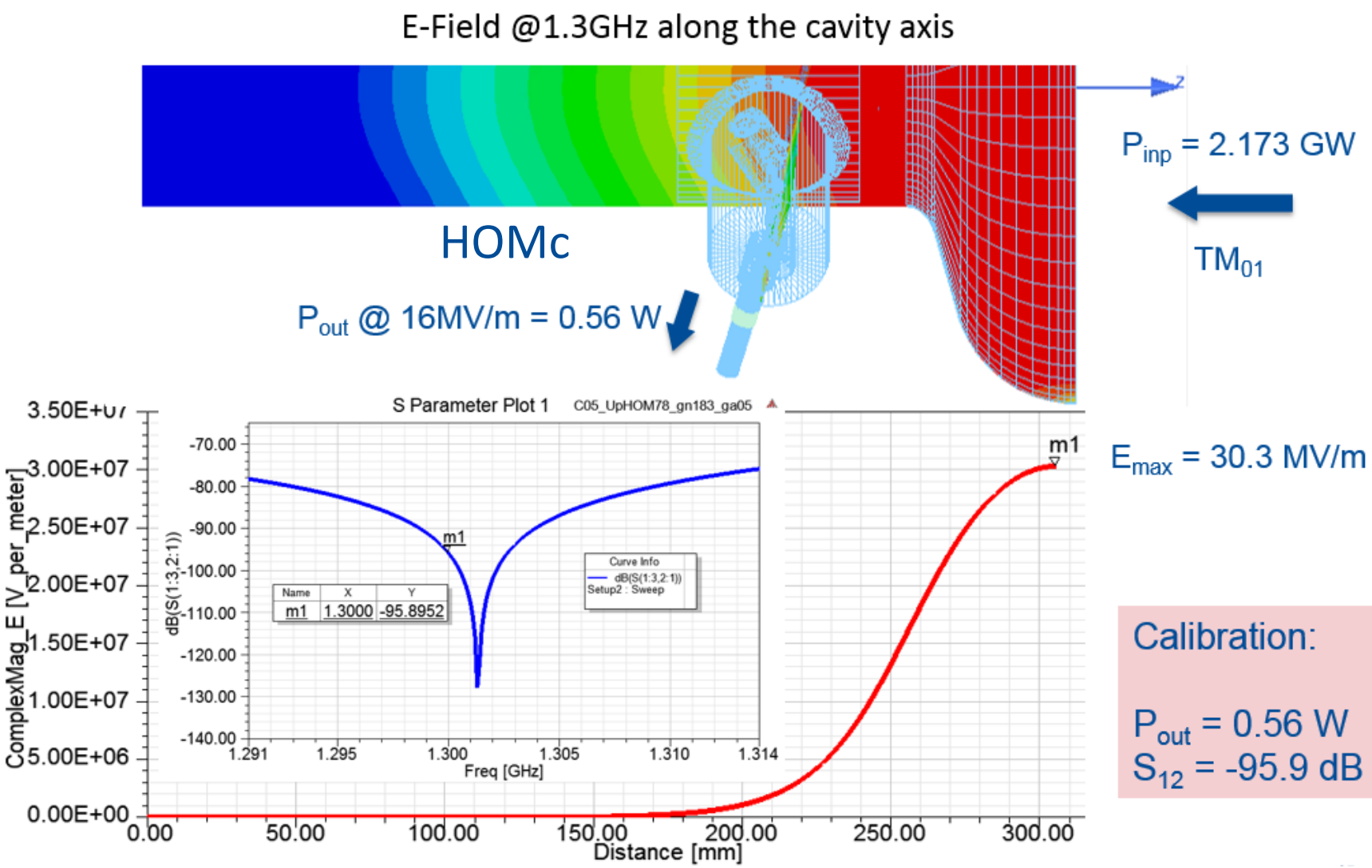
CM05	WS3-Tuned-111		WS3-Check-111		WS5-Check-111		WS5-Check-011		CMTF, mW		2K, notch fr.		WS6-011		WS5 vs WS5		WS6 vs WS5	
	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2
CAV0045	1297.4	1297.5	1297.4	1297.5	1297.5	1297.5	1297.0	1297.2	1.0	465	1300.1	1300.4			-0.5	-0.3	#####	#####
CAV0038	1297.4	1297.4	1297.4	1297.4	1297.5	1297.5	1297.1	1297.0	6.7	2100	1300.2	1298.4			-0.4	-0.5	#####	#####
CAV0047	1297.4	1297.4	1297.4	1297.5	1297.6	1297.4	1297.2	1297.0	20.0	178	1300.3	1300.4			-0.4	-0.4	#####	#####
CAV0050	1297.5	1297.5	1297.5	1297.5	1297.6	1297.5	1297.2	1297.1	0.3	75	1300.2	1300.4			-0.4	-0.4	#####	#####
CAV0070	1297.4	1297.5	1297.4	1297.5	1297.6	1297.5	1297.1	1297.2	48.0	152	1300.5	1300.4			-0.5	-0.3	#####	#####
CAV0223	1297.3	1297.3	1297.3	1297.4	1297.5	1297.4	1297.1	1297.0	77.0	69	1300.6	1300.3			-0.4	-0.4	#####	#####
CAV0069	1297.4	1297.5	1297.5	1297.5	1297.6	1297.5	1297.1	1297.1	117.0	320	1300.8	1300.6			-0.5	-0.4	#####	#####
CAV0037	1297.4	1297.5	1297.4	1297.5	1297.5	1297.5	1297.0	1297.1	46.0	262	1300.5	1300.7			-0.5	-0.4	#####	#####
	8/8/2017		8/8/2017		9/26/2017		11/20/2017								-0.45	-0.39	#####	#####

CM06	WS3-Tuned-111		WS3-Check-111		WS5-Check-111		WS5-Check-011		CMTF, mW		2K, notch fr.		WS6-011		WS5 vs WS5		WS6 vs WS5	
	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2
CAV0064	1297.6	1297.6	1297.5	1297.5	1297.6	1297.5	1297.1	1297.1	9.0	31	1300.3	1299.9	1297.3	1295.9	-0.5	-0.4	0.2	-1.2
CAV0081	1297.3	1297.4	1297.4	1297.5	1297.4	1297.4	1296.9	1296.7	0.0	34	1300.0	1300.2	1297.3	1296.3	-0.5	-0.7	0.4	-0.4
CAV0077	1297.4	1297.5	1297.3	1297.5	1297.4	1297.5	1297.0	1297.0	2.0	342	1300.1	1300.6	1296.9	1296.5	-0.4	-0.5	-0.1	-0.5
CAV0074	1297.5	1297.5	1297.4	1297.3	1297.5	1297.4	1297.1	1297.0	0.5	44	1300.2	1300.2	1297.1	1296.7	-0.4	-0.4	0.0	-0.3
CAV0078	1297.5	1297.6	1297.4	1297.5	1297.5	1297.5	1296.7	1297.0	25.0	250	1300.4	1300.6	1296.7	1296.6	-0.8	-0.5	0.0	-0.4
CAV0086	1297.5	1297.6	1297.4	1297.5	1297.5	1297.5	1297.0	1296.8	25.0	85	1300.3	1300.4	1296.8	1296.3	-0.5	-0.7	-0.2	-0.5
CAV0085	1297.4	1297.5	1297.3	1297.4	1297.4	1297.4	1296.9	1296.7	6.1	126	1300.2	1300.4	1296.8	1296.3	-0.5	-0.7	-0.1	-0.4
CAV0058	1297.5	1297.4	1297.4	1297.5	1297.6	1297.5	1297.1	1297.2	24.0	25	1300.4	1300.3	1296.7	1296.7	-0.5	-0.3	-0.4	-0.5
	7/25/2017		7/28/2017		8/17/2017		10/12/2017								-0.51	-0.53	-0.03	-0.53

CM07	WS3-Tuned-111		WS3-Check-111		WS5-Check-111		WS5-Check-011		CMTF, mW		2K, notch fr.		WS6-011		WS5 vs WS5		WS6 vs WS5	
	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1, MHz	HOM2, MHz	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2	HOM1	HOM2
CAV0058	1297.4	1297.4	1297.4	1297.4	1297.3	1297.4	1297.1	1296.8	0.2	83	1299.9	1300.3			-0.2	-0.6	#####	#####
CAV0084	1297.4	1297.4	1297.4	1297.4	1297.3	1297.4	1296.9	1296.9	0.2	128	1300.0	1300.4			-0.4	-0.5	#####	#####
CAV0098	1297.3	1297.4	1297.3	1297.3	1297.2	1297.4	1296.8	1296.8	7.9	180	1299.8	1300.5			-0.4	-0.6	#####	#####
CAV0091	1297.4	1297.4	1297.4	1297.4	1297.3	1297.4	1297.0	1296.9	0.0	150	1300.1	1300.4			-0.3	-0.5	#####	#####
CAV0111	1297.4	1297.3	1297.4	1297.3	1297.3	1297.4	1297.0	1296.8	0.5	12.6	1300.1	1300.1			-0.3	-0.6	#####	#####
CAV0262	1297.4	1297.4	1297.4	1297.4	1297.3	1297.4	1296.7	1296.6	2.2	109	1300.1	1300.4			-0.6	-0.8	#####	#####
CAV0105	1297.4	1297.4	1297.3	1297.4	1297.3	1297.4	1296.9	1296.9	17.1	195	1300.3	1300.5			-0.4	-0.5	#####	#####
CAV0076	1297.4	1297.4	1297.4	1297.4	1297.4	1297.4	1297.0	1297.0	49.0	81	1300.6	1300.4			-0.4	-0.4	#####	#####
	10/26/2017		11/2/2017		12/6/2017		12/15/2017								-0.37	-0.56	#####	#####

Simulations

By A. Lunin



Simulations

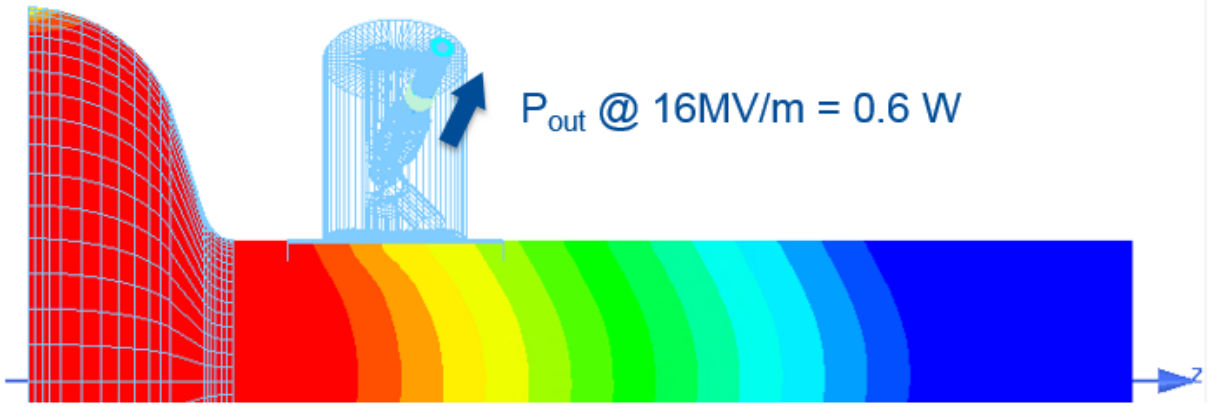
By A. Lunin

E-Field @1.3GHz along the cavity axis

P_{inp} = 2.139 GW

TM_{01}

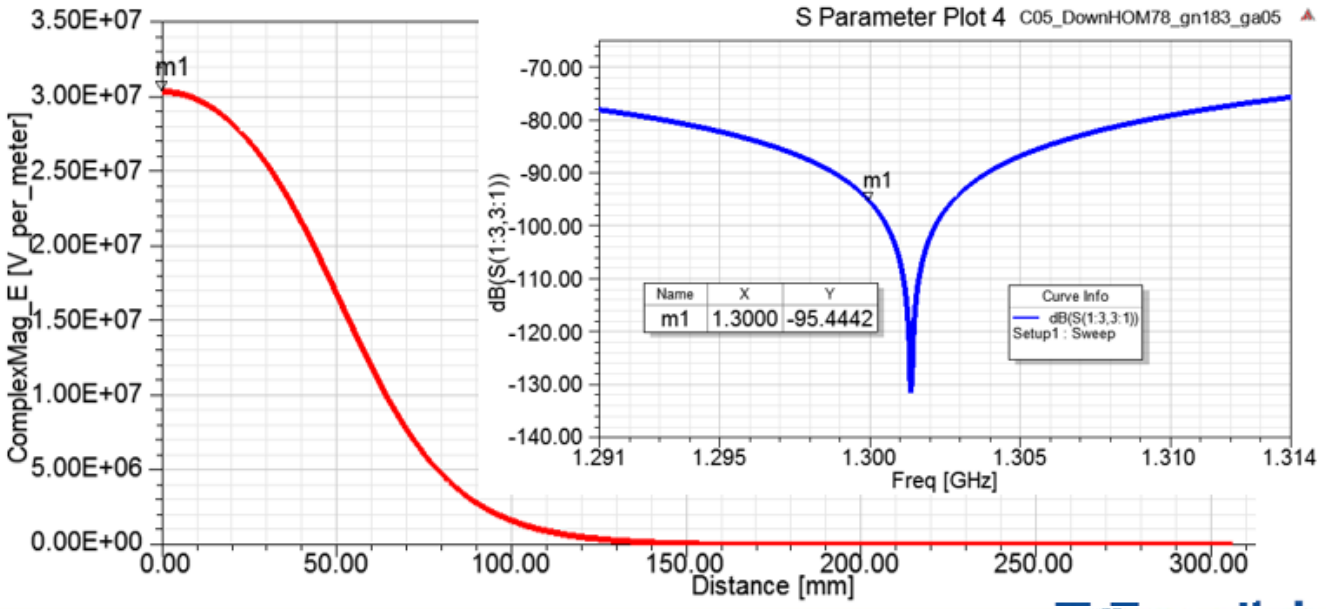
E_{max} = 30.3 MV/m



P_{out} @ 16MV/m = 0.6 W

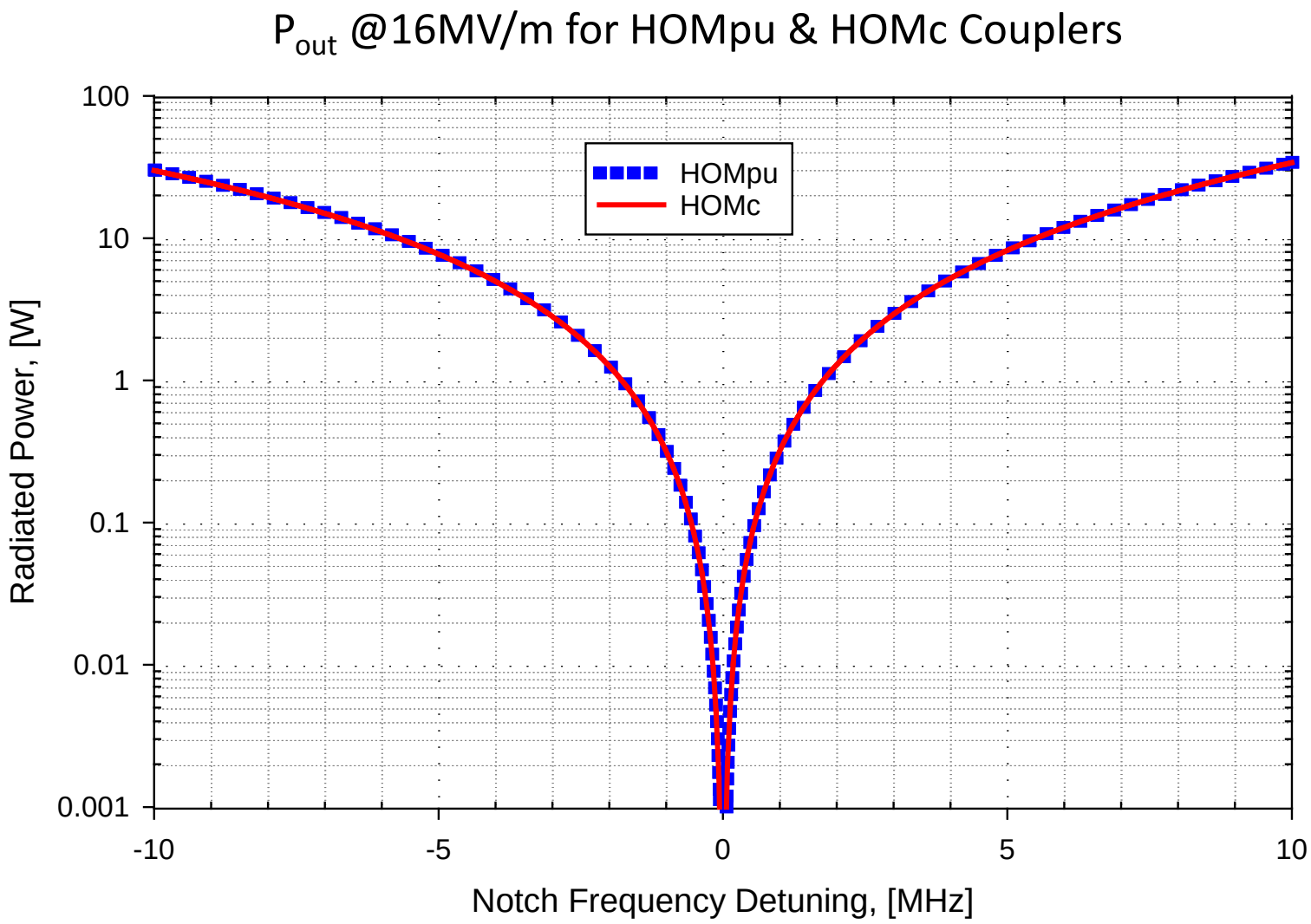
Calibration:

P_{out} = 0.6 W
S_{12} = -95.4 dB



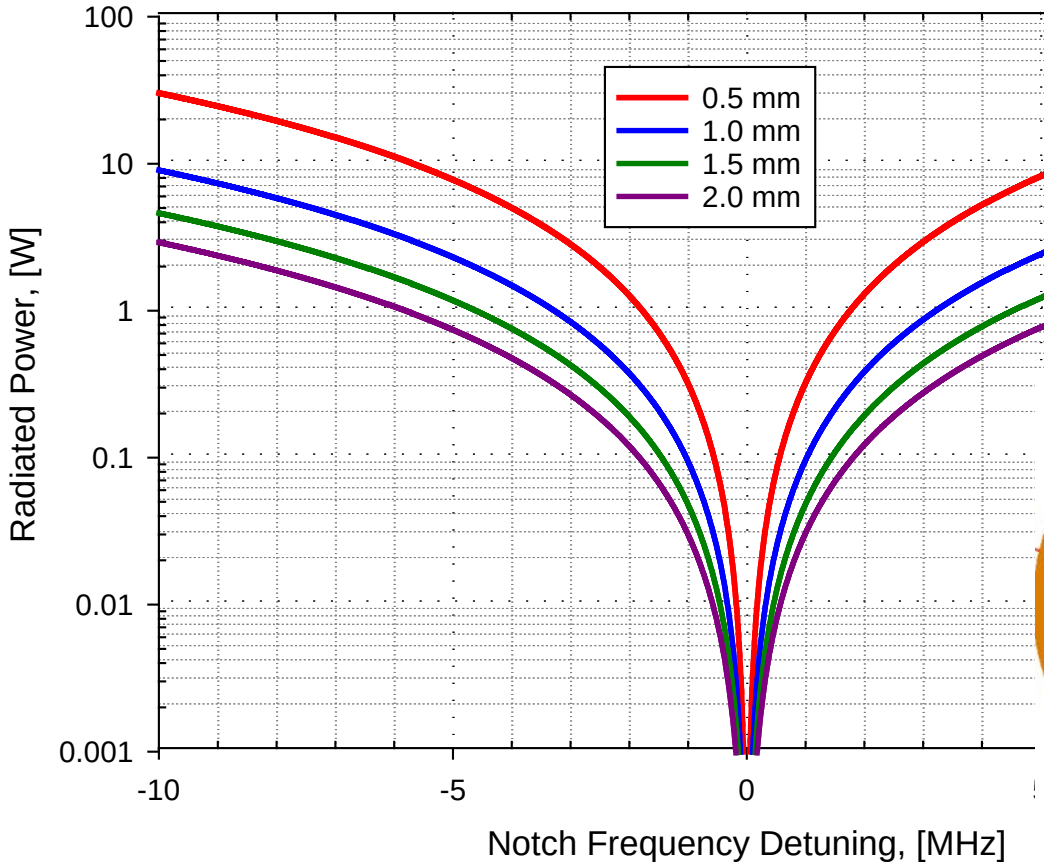
Simulations

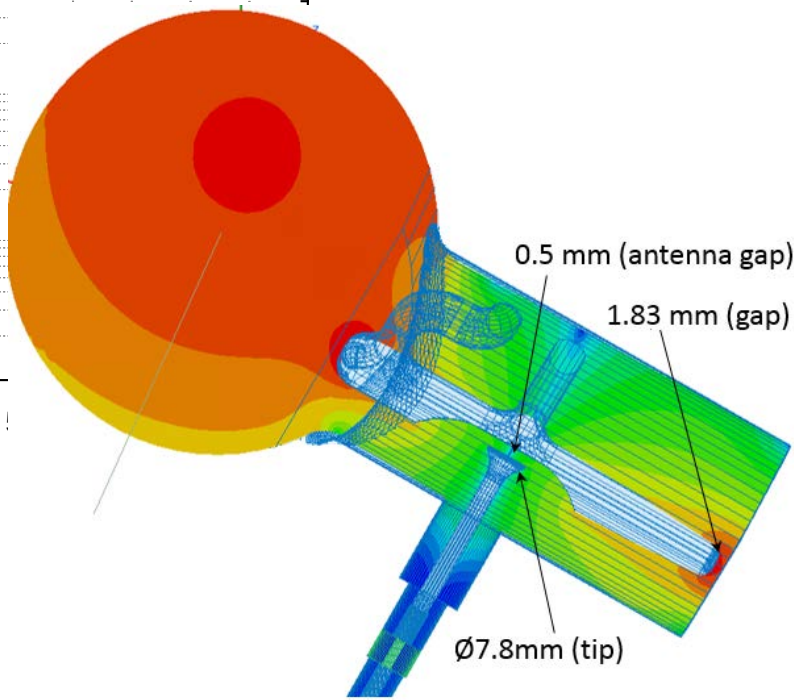
By A. Lunin



Simulations

By A. Lunin





P_{out} @16MV/m versus pickup antenna gap

Capacitance measurements at WS2

CM01	WS2	
	HOM1, pF	HOM2, pF
TB9AES021	5.60	5.52
TB9AES019	5.42	5.50
TB9AES026	5.50	5.40
TB9AES024	5.58	5.57
TB9AES028	5.31	5.40
TB9AES016	5.73	5.44
TB9AES022	5.35	5.47
TB9AES027	5.36	5.33
Aver.	**5.48**	**5.45**

CM02	WS2	
	HOM1, pF	HOM2, pF
CAV0008	5.58	5.61
CAV0003	5.68	5.74
CAV0006	5.76	5.81
CAV0007	5.07	5.73
CAV0016	5.90	6.11
CAV0013	5.55	5.88
CAV0011	5.79	5.95
CAV0015	5.61	5.68
Aver.	**5.62**	**5.81**

CM03	WS2	
	HOM1, pF	HOM2, pF
CAV0034	5.61	5.76
CAV0039	5.76	6.29
CAV0040	5.59	5.41
CAV0026	5.59	5.63
CAV0027	5.64	5.60
CAV0029	5.71	5.68
CAV0042	5.71	5.59
CAV0032	5.70	5.65
Aver.	**5.66**	**5.70**

CM04	WS2	
	HOM1, pF	HOM2, pF
CAV0052	5.58	5.61
CAV0036	5.68	5.74
CAV0019	5.76	5.81
CAV0041	5.07	5.73
CAV0030	5.90	6.11
CAV0020	5.55	5.88
CAV0051	5.79	5.95
CAV0221	5.61	5.68
Aver.	**5.62**	**5.81**

CM05	WS2	
	HOM1, pF	HOM2, pF
CAV0045	5.61	5.76
CAV0038	5.85	5.80
CAV0047	5.80	6.15
CAV0050	5.80	5.75
CAV0070	5.90	5.75
CAV0223	6.05	6.00
CAV0069	6.05	5.90
CAV0037	5.85	5.85
Aver.	**5.86**	**5.87**

CM06	WS2	
	HOM1, pF	HOM2, pF
CAV0064	5.67	5.68
CAV0081	5.68	5.72
CAV0077	5.68	5.72
CAV0074	5.71	5.51
CAV0078	5.69	5.61
CAV0086	5.72	5.42
CAV0085	5.74	5.36
CAV0058	5.67	5.69
Aver.	**5.70**	**5.59**

CM07	WS2	
	HOM1, pF	HOM2, pF
CAV0058	5.53	5.62
CAV0084	5.57	5.68
CAV0098	5.66	5.73
CAV0091	5.61	5.65
CAV0111	5.63	5.78
CAV0262	5.71	5.73
CAV0105	5.60	5.73
CAV0076	5.60	5.51
Aver.	**5.61**	**5.68**

Summary

- HOM notch frequencies are tuned with accuracy of <200 kHz at room temperature in WS3 when cavities are backfilled
- Pumping down of the cavity volume shifts notch frequency down by 200-800 kHz
  - 1 bar pressure difference inside and outside of the cavity shifts HOM notch frequency in range 600-1200 kHz
  - Notch frequency tuning is preferred at equal pressure
- Notch frequency spread increases after cooling down.
- Power leak for operating mode is more from HOM2 compared to HOM1 for same detuning of notch frequency
  - Simulations did not confirmed this difference
  - Difference of antenna gap also not explain this difference
  - Additional study needed