Frequency and Q measurements on the TEVATRON RF spare cavity for different modes and temperatures.

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1 Introduction

The TEVATRON has eight RF cavities installed and operated in the F0 straight section. These cavities operate as two independent groups of four cavities, cavities 1-3-5-7 accelerating antiprotons and cavities 2-4-6-8 accelerating protons. A cavity contains two quarter-wave resonators placed back to back with a coaxial drift tube separating the two accelerating gaps by π radians. Each cavity has a Q of $\sim$6400, a shunt impedance of 1.2 MΩ and is capable of running cw with a peak accelerating voltage of 360 kV (180 kV per gap). A temperature control water system circulates tempered water through the drift tube to tune the cavities at the operation frequency of 53.104 MHz. Details on the TEVATRON High Level RF System can be found in reference [1].

We have undertaken a measurement of the frequency and quality factor Q of some of the main High Order Modes (HOMs) of the TEVATRON spare cavity with the motivation to monitor the dependence of these two parameters with respect to the temperature [2].

2 Experimental Results

The TEVATRON spare cavity, installed at the MI60 hall, is water cooled and under vacuum. The frequency and the quality factor of the main HOMs were measured for a cavity temperature of $T = 30°$, $T = 35°$ and $T = 40°$ and these measurements are reported in Tables 1, 2 and 3 respectively. The losses of the HOMs are also reported in the tables, which give an idea of their relative strength.

Measurements were done using a Network Analyzer (AGILENT 8753ES) in transmission S_{21}. The measurement of the full width at half height $\Delta\omega_H$ of the stored energy versus the excitation energy curve leads to the Q of the modes through the relation :

$$Q = \frac{w_0}{\Delta\omega_H} \tag{1}$$

The results presented in Tables 1 to 3 are reported in Figures 1 to 6. The interesting results shown by these Figures is that the shifts of the frequency, the quality factor and the losses of the HOMs due to the temperature do not follow the shift of the fundamental mode.

3 Conclusion

The fact that the frequency and quality factor dependence of the HOMs on the cavity temperature do not follow the one of the fundamental mode may explain some of the longitudinal instabilities observed with beam at the TEVATRON through the longitudinal beam impedance due to the HOMs in the cavity. Studies are in progress [2]. The measurement of the shunt impedance R/Q of the HOMs was not realized during these measurements since it would have required to brake the vacuum. Nevertheless we report in Table 4 the measurement done in 1995 by D. Sun for some of the modes. Figure 7 compare the Q measured in 1995 in good agreement with the ones measured at $T = 35$°C.

The author would like to thank J. Reid for changing the temperature of the cavity , T. Berenc for helping with the operation of the network analyzer and D. Sun for discussion on the measurements and for providing the 1995 RF measurements results of Table 4.

References

[1] Q. Kerns *et al.*, “Fermilab Tevatron High Level RF Accelerating Systems”, PAC 1985.

[2] Y. Alexahin, private communication.

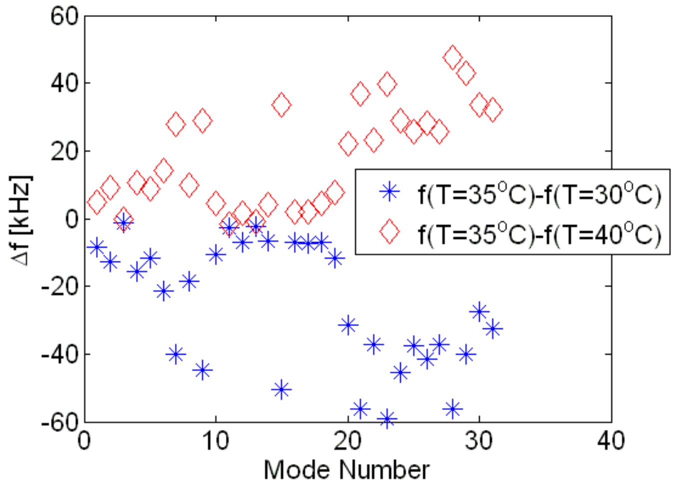

Figure 1: Frequency shift for the different modes for $T = 30°C$ and $T = 40°C$ with respect to $T = 35°C$. Mode #1 corresponds to the fundamental mode.

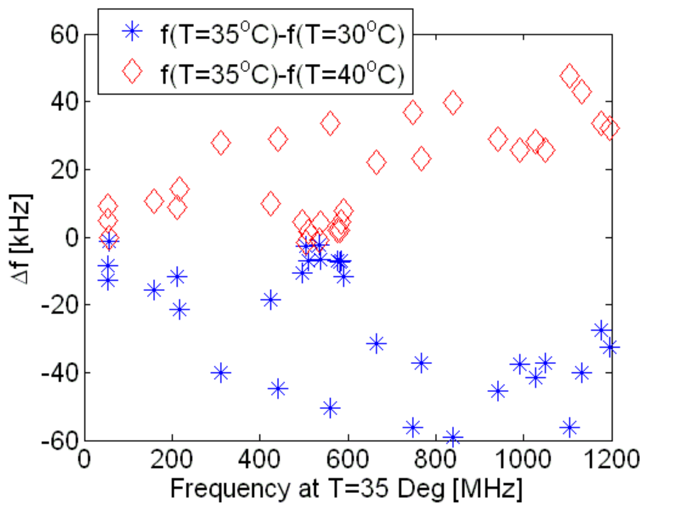

Figure 2: Same as Figure 1 with frequency of the different modes at $T = 35°C$ in the X-axis.

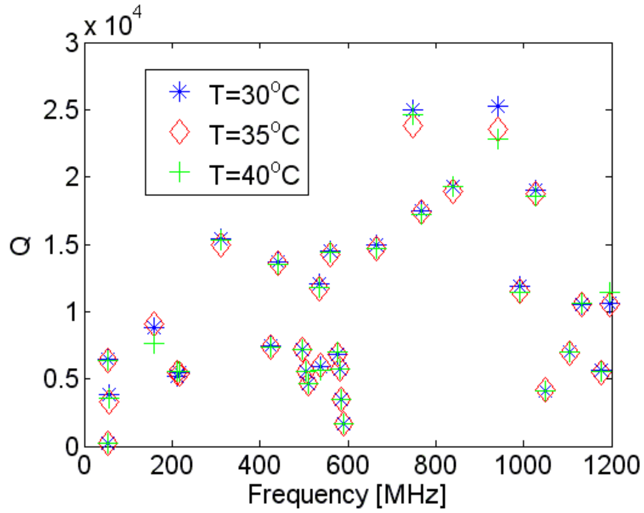

Figure 3: Quality Factor Q for the different modes for $T = 30°$C, $T = 35°$C and $T = 40°$C.

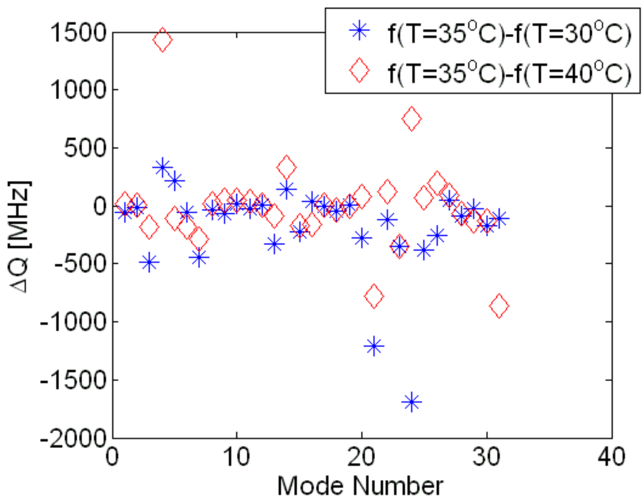

Figure 4: Quality Factor shift for the different modes for $T = 30°$C and $T = 40°$C with respect to $T = 35°$C. Mode #1 corresponds to the fundamental mode.

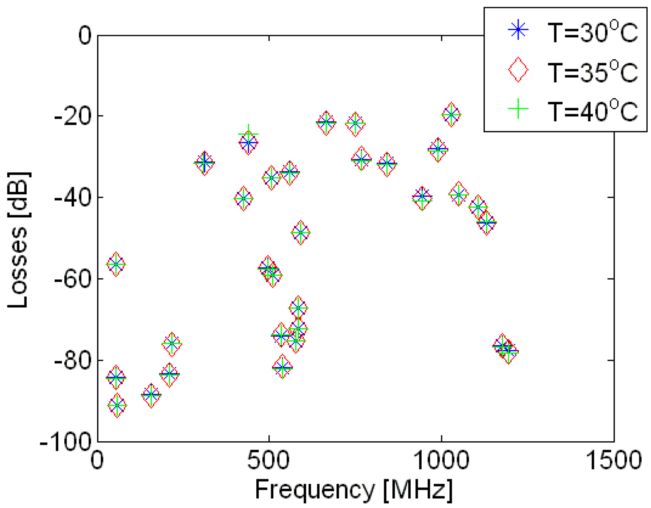

Figure 5: Losses for the different modes for $T = 30°$C, $T = 35°$C and $T = 40°$C.

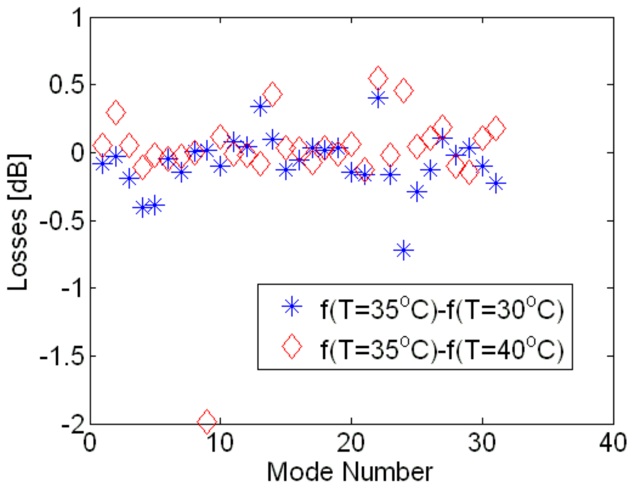

Figure 6: Losses shift for the different modes for $T = 30°$C and $T = 40°$C with respect to $T = 35°$C. Mode #1 corresponds to the fundamental mode.

	$T = 30°$C		
	f [MHz]	Q	Losses [dB]
Fundamental Mode f_0	53.121108	6468.7	-56.357
Mode #2	54.498597	264.41	-84.190
Mode #3	56.617297	3826.3	-91.027
Mode #4	157.735874	8770.4	-88.407
Mode #5	210.178431	5225.5	-83.924
Mode #6	218.266180	5421.8	-76.041
Mode #7	310.651430	15445	-31.429
Mode #8	424.311317	7411.8	-40.156
Mode #9	439.771282	13648	-26.493
Mode #10	496.113798	7201.1	-57.296
Mode #11	504.711560	5572.9	-35.156
Mode #12	510.191172	4646.8	-59.124
Mode #13	534.115817	12060	-74.107
Mode #14	538.941097	5877.3	-81.739
Mode #15	558.865004	14481	-33.766
Mode #16	575.610228	6777.9	-75.226
Mode #17	582.381984	5743.1	-67.276
Mode #18	585.295053	3491.0	-72.320
Mode #19	591.334842	1668.2	-48.772
Mode #20	664.854942	14995	-21.522
Mode #21	748.491138	25028	-21.715
Mode #22	767.576021	17503	-30.783
Mode #23	840.111757	19311	-31.695
Mode #24	942.837607	25237	-39.590
Mode #25	990.249087	11917	-28.129
Mode #26	1027.465091	18987	-19.483
Mode #27	1049.975043	4154.6	-39.249
Mode #28	1105.249688	6992.2	-42.469
Mode #29	1131.542068	10516	-46.144
Mode #30	1176.118368	5030.1	-76.499
Mode #31	1195.518274	10660	-77.801

Table 1: RF measurements for $T = 30°$C.

	$T = 35°$C		
	f [MHz]	Q	Losses [dB]
Fundamental Mode f_0	53.112558	6415.3	-56.440
Mode #2	54.485981	249.3	-84.216
Mode #3	56.615905	3342.9	-91.219
Mode #4	157.720184	9106.2	-88.810
Mode #5	210.166673	5443.0	-83.791
Mode #6	218.244644	5362.4	-76.091
Mode #7	310.611421	14997	-31.575
Mode #8	424.292639	7381.7	-40.151
Mode #9	439.726561	13577	-26.474
Mode #10	496.103261	7219	-57.397
Mode #11	504.708837	5552.1	-35.075
Mode #12	510.184303	4651.3	-59.081
Mode #13	534.113306	11728	-73.766
Mode #14	538.934296	6018	-81.641
Mode #15	558.814406	14257	-33.889
Mode #16	575.603335	6819.1	-75.278
Mode #17	582.374755	5738.7	-67.241
Mode #18	585.287998	3449.9	-72.308
Mode #19	591.323306	1679.0	-48.738
Mode #20	664.823471	14724	-21.665
Mode #21	748.435012	23823	-21.881
Mode #22	767.538742	17381	-30.381
Mode #23	840.052588	18966	-31.857
Mode #24	942.792041	23549	-40.306
Mode #25	990.211538	11532	-28.414
Mode #26	1027.423450	18728	-19.609
Mode #27	1049.938005	4199.9	-39.145
Mode #28	1105.193620	6900.3	-42.487
Mode #29	1131.501988	10487	-46.110
Mode #30	1176.090981	5463.7	-76.595
Mode #31	1195.485692	10549	-78.023

Table 2: RF measurements for $T = 35°$ C.

	$T = 40°$C		
	f [MHz]	Q	Losses [dB]
Fundamental Mode f_0	53.107538	6398.5	-56.490
Mode #2	54.476917	238.36	-84.513
Mode #3	56.615933	3528.3	-91.275
Mode #4	157.709452	7674.4	-88.705
Mode #5	210.157997	5556.0	-83.771
Mode #6	218.230273	5542.6	-76.041
Mode #7	310.583671	15281	-31.548
Mode #8	424.282751	7361.2	40.153
Mode #9	439.697687	13532	-24.483
Mode #10	496.098786	7174.3	-57.510
Mode #11	504.710468	5516.2	-35.063
Mode #12	510.182777	4642.5	-59.064
Mode #13	534.114064	11811	-73.680
Mode #14	538.930290	5687.5	-82.073
Mode #15	558.780964	14432	-33.922
Mode #16	575.601352	6982.3	-75.302
Mode #17	582.372878	5731.2	-67.172
Mode #18	585.283358	3488.6	-72.339
Mode #19	591.315481	1680.6	-48.731
Mode #20	664.801470	14649	-21.724
Mode #21	748.398308	24598	-21.751
Mode #22	767.515521	17255	-30.928
Mode #23	840.013053	19317	-31.835
Mode #24	942.763018	22797	-40.760
Mode #25	990.185714	11467	-28.459
Mode #26	1027.395286	18532	-19.717
Mode #27	1049.912209	4110.6	-39.336
Mode #28	1105.146054	6971.7	-42.391
Mode #29	1131.459069	10621	-45.961
Mode #30	1176.057224	5591.5	-76.698
Mode #31	1195.453702	11416	-78.205

Table 3: RF measurements for $T = 40°$ C.

	Measurements 1995			Measurements 2005		
	f [MHz]	Q	R/Q	f[MHz]	Q	Losses [dB]
Fundamental Mode f_0	53.11375	6523	109.6	53.112558	6415.3	-56.440
Mode #2	56.50625	3620	18.81	56.615905	3342.9	-91.219
Mode #3	158.2325	6060	11.68	157.720184	9106.2	-88.810
Mode #4	310.6775	15923	7.97	310.611421	14997	-31.575
Mode #5	424.24875	6394	1.28	424.292639	7381.7	-40.151
Mode #6	439.7725	13728	5.23	439.726561	13577	-26.474
Mode #7	498.4975	8326	< 0.01	496.103261	7219	-57.397
Mode #8	559.4825	13928	6.73	558.814406	14257	-33.889
Mode #9	583.39375	8986	0.11	582.374755	5738.7	-67.241
Mode #10	592.39375	10402	0.21	591.323306	1679.0	-48.738
Mode #11	664.7125	13763	0.35	664.823471	14724	-21.665
Mode #12	748.1800	13356	10.90	748.435012	23823	-21.881
Mode #13	768.030	16191	2.47	767.538742	17381	-30.381

Table 4: Comparison of RF measurements done in the TEVATRON spare cavity in 1995 and 2005.

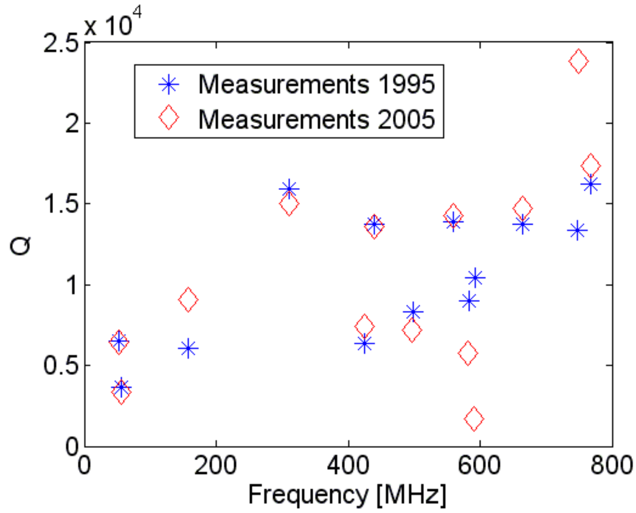

Figure 7: Comparison of the quality factor for different modes measured in 1995 and 2005. Datas from Table 4.