Preliminary Results from 650MHz Single Cell beta =0.61 Prototype Cavities for ProjectX

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Webex FNAL

Cavity Design

- Cavity was designed by F.Marhauser as an Alternative to an existing FNAL design
- Details can be found in Jlab Tech. Note Jlab-TN- 10- 042

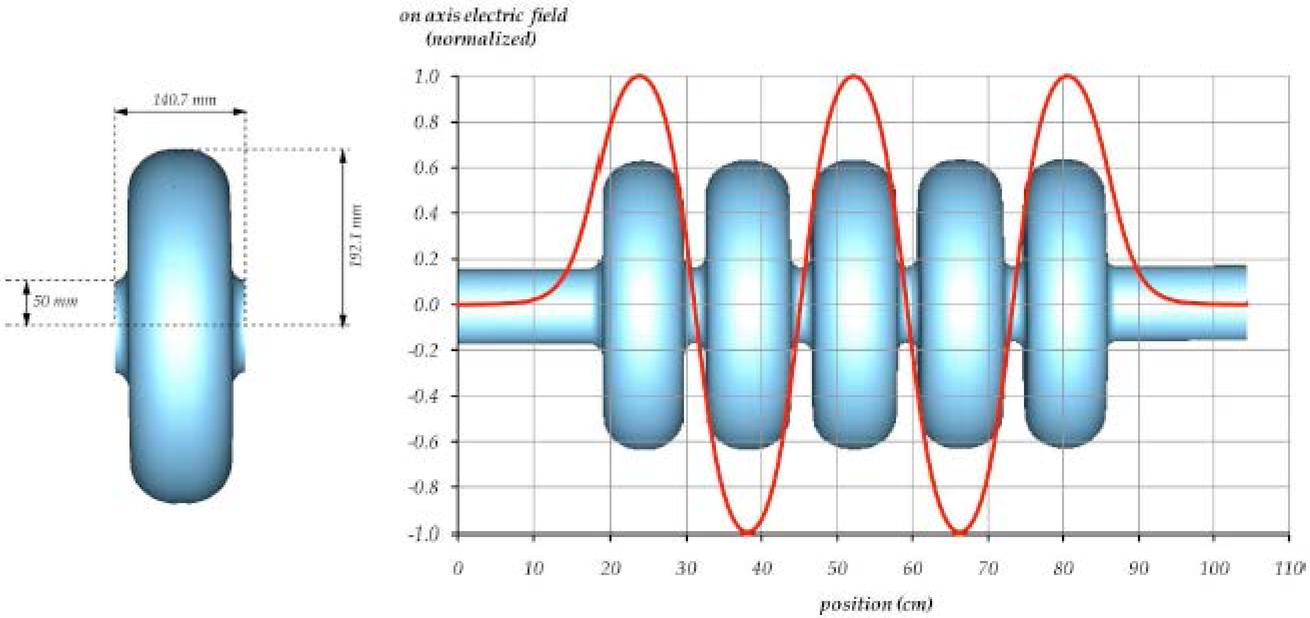


Figure 4: Medium-beta ($\beta = 0.61$) 650 MHz cavity mid cell layout (left) and five-cell cavity design.

Cavity Design: increase beam aperture

Benefits:

1) improved ability for chemical etching (BCP and/or EP) at the cell equators (electron beam welded "heat-affected" zone)
2) improved mechanical stability with respect to cell deformations including a reduction of microphonics and the Lorentz-force detuning coefficient
3) increase of the cell-to-cell coupling
   a) reduced sensibility of fundamental field flatness on cell imperfections
   b) reduced amount of required bench tuning
   c) reduced potential for trapped HOM field configurations
   d) reduced potential for tilted HOM field configurations (for symmetrical cavity design)

Cavity Design

Table II: Comparison of RF parameters for five-cell $\beta = 0.61$ cavities with iris aperture 100 mm (JLAB design) and 83 mm (Fermilab design [2]).

parameter	unit	Project-X JLAB	Project-X Fermilab
$\beta = v/c$		0.61	0.61
frequency	MHz	650	650
active length (iris-to-iris)	mm	694	705
equator diameter E	mm	380.4	389.9
iris aperture A	mm	100	83
tube diameter	mm	ditto	ditto
E/A		3.84	4.70
A/λ		0.217	0.180
cell-to-cell coupling	%	1.40	0.75
R/Q	Ω	296.6	378
G	Ω	190	191
R/Q·G	Ω^2	56466	72198
U_{eff}	MV	12	12
E_{acc}	MV/m	17.3	17.0
E_{peak}/E_{acc}		2.71	2.26
B_{peak}/E_{acc}		4.78	4.21
B_{peak}	mT	82.6	71.6
E_{peak}	MV/m	46.9	38.4
Q_0 assumed at 2K		1.72e10	1.72e10
P_{cav}	W	28.2	22.0

Cavity Fabrication and Treatment

- Two single cell cavities (“A” and “B”) were fabricated from RRR> 300 high purity Nb of 4 thickness by standard technique:
- Deep drawing of half cells, trimming of half cells for equator butt weld,
- beam tube/flange/half cell subassembly was welded first
- Subassembly was mechanically polished to remove surface imperfections
- Equator weld after cleaning of subassemblies by bcp
- Between all manufacturing steps the mechanical dimensions and frequencies were monitored
- After completion of cavities, bulk bcp was performed prior to hydrogen degassing at 600C for 10 hrs

Final Treatment before Test #1, cavity "A"

- Measurement of material thickness
- Degreasing
- 50 micron bcp
- Rinsing with cold and hot water
- High pressure rinsing for 2 hrs, 2 passes
- Drying in class 10 clean room for 12 hrs
- Assembly in class 10 clean room
- Attachment to test stand and evacuation for >12 hrs
- Prior to cooldown for test #1, the cavity vacuum was $\leq$ 1.2e-8 mbar; at 4.2K : p< 5e-9 mbar
- Cryogenic measurements consisted of R(T) between 4.2K and 2K, pressure sensitivity, Q vs Eacc at 2K and Lorentz Force Detuning

Single Cell Cavity Test Set Up

Geometry Factor: G = 181.4 Ohm

Shunt Impedance: R/Q = 60 Ohm

Cavity Length: L = 0.1388 m

E_{peak}/E_{acc} = 2.71

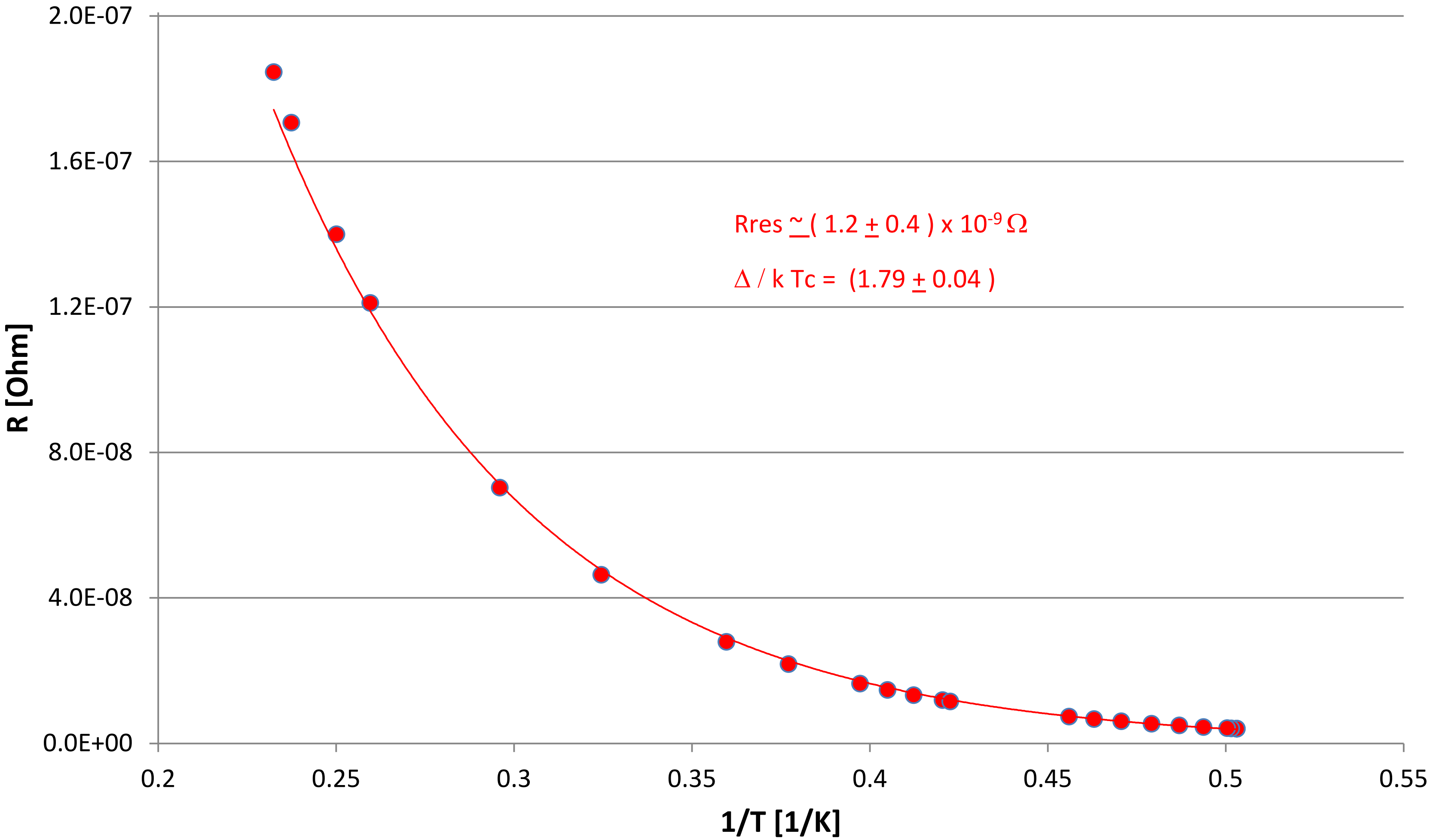
B_{peak}/E_{acc} = 4.78 [mT/MV/m]

- Test Set-up

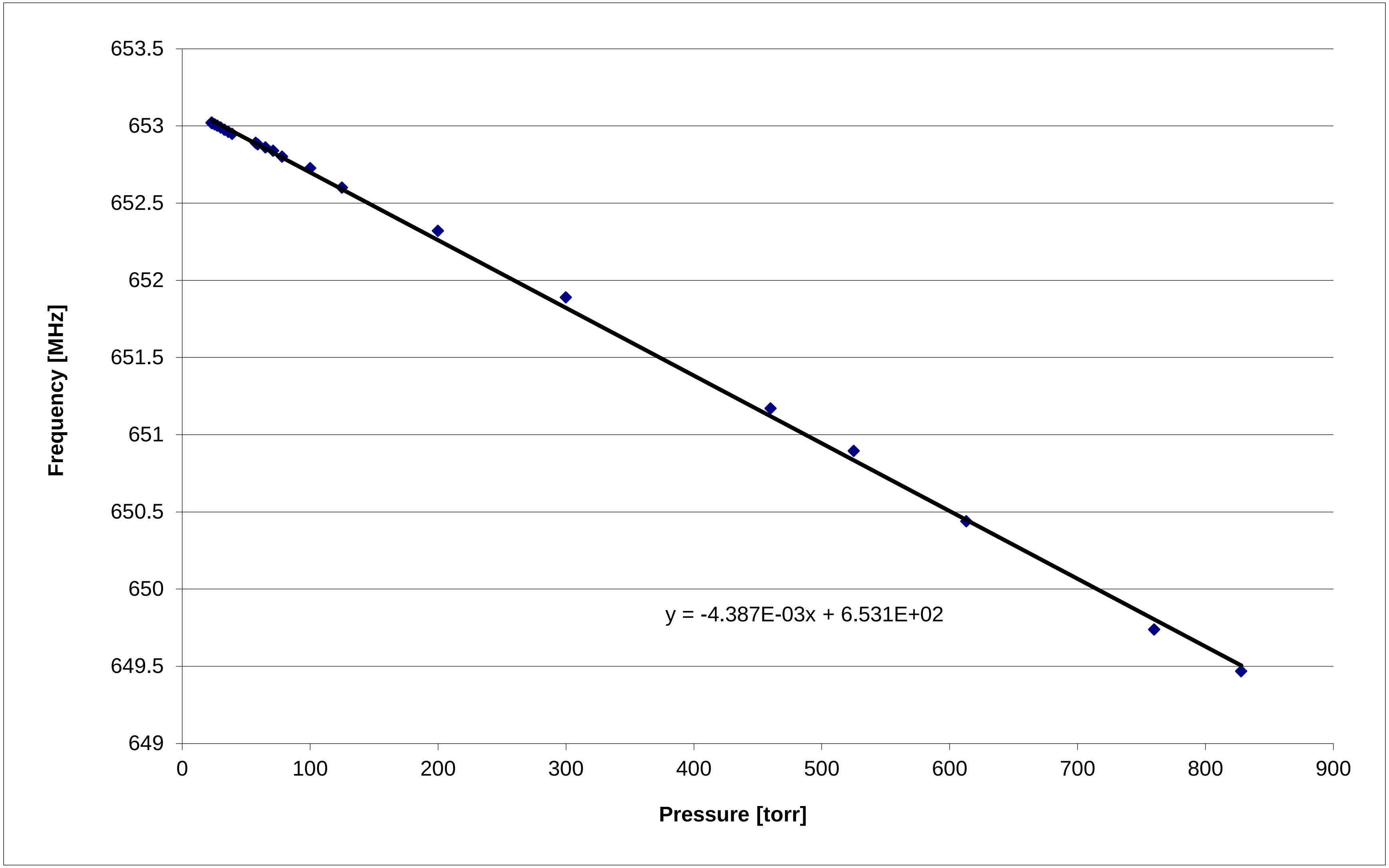
Test #1, cont'd

- By some reason the input Qext was very high and accordingly the coupling was weak.
- That made the measurements very difficult, in particular because of large frequency shifts due to He pressure changes
- Additionally, the decay times became quite long at lower temperatures (at 2K, $\tau = 6755$ msec, delta f ~ 0.015 Hz)
- However, because of the weak coupling (beta (2K) ~ 0.5) the error in the Q-measurement is small and the high Q-values/ low residual resistance is "real".

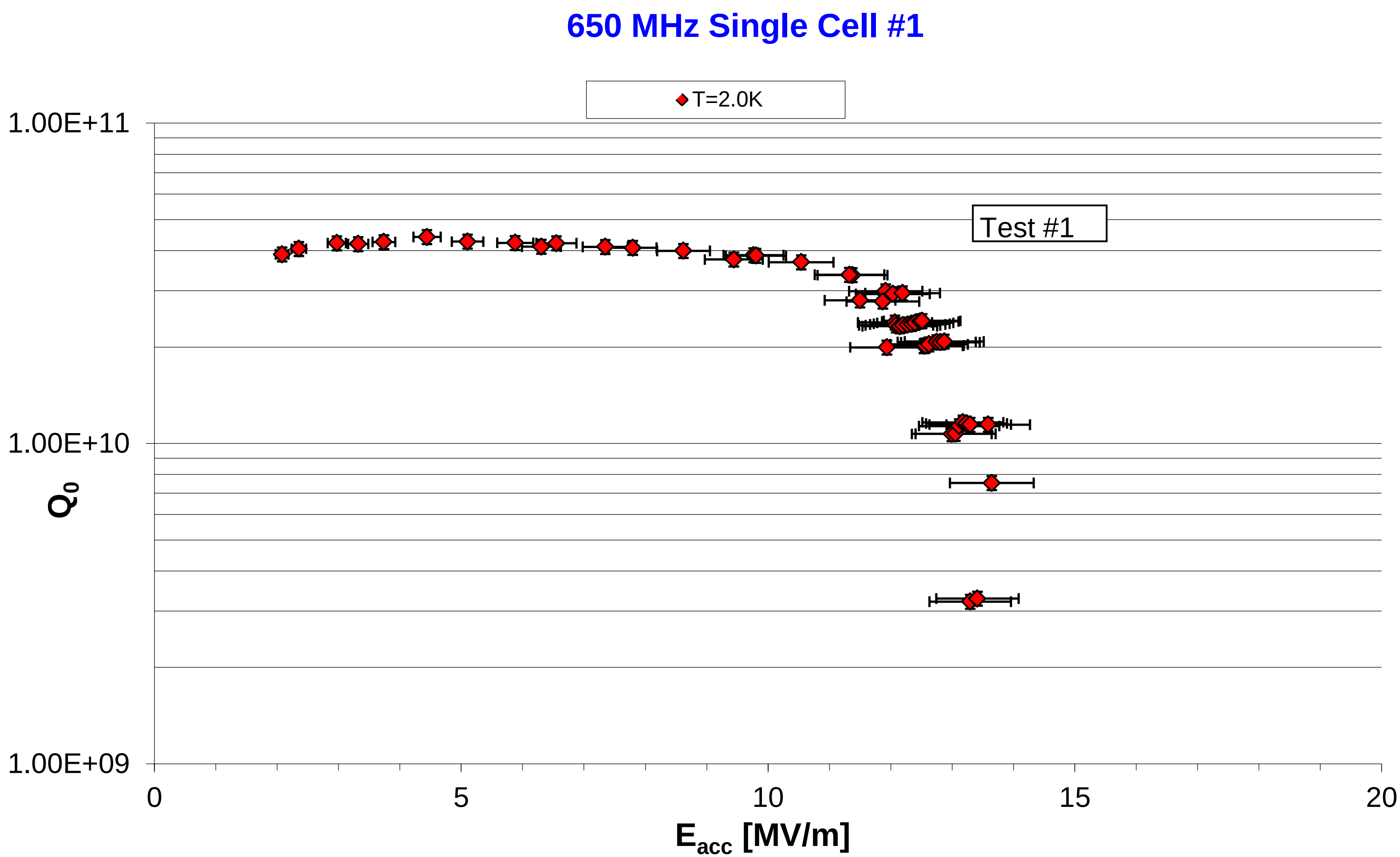
Temperature Dependence



Pressure Sensitivity

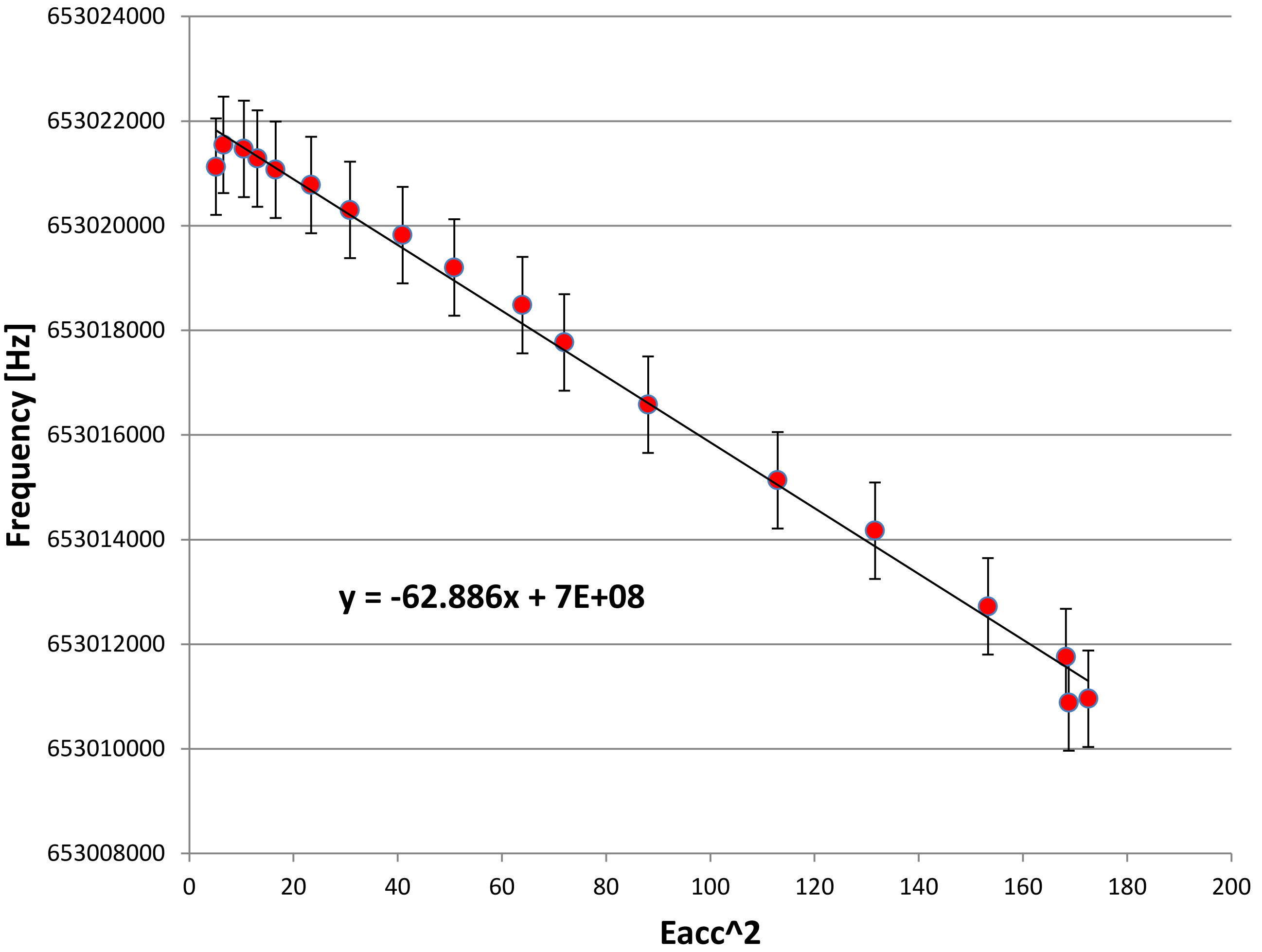


Test #1



650 MHz Single Cell #1
T=2.0K
Test #1
1.00E+11
1.00E+10
1.00E+09
Q_0
0
5
10
15
20
E_{acc} [MV/m]

Lorentz-Force Detuning



Test #1, cont'd

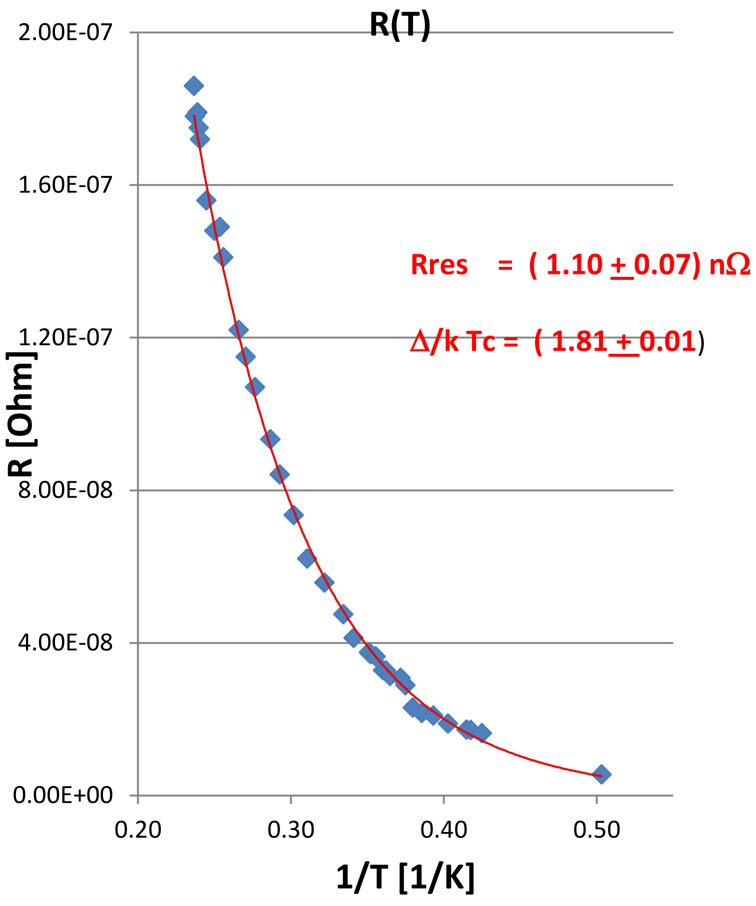
- During the Q vs E_{acc} measurement a limitation was encountered as shown on the graph caused by strong FE
- This limitation did not disappear after 1.5 hrs of processing rf; it was most likely very ineffective because of the weak input coupling
- Possibly it could also be enhanced by an insufficient He- level in the dewar such that parts of the beam pipes were not covered
- Because of other tests planned for this particular dewar the test was stopped and for the next test a stronger input coupling was adjusted

Test #2

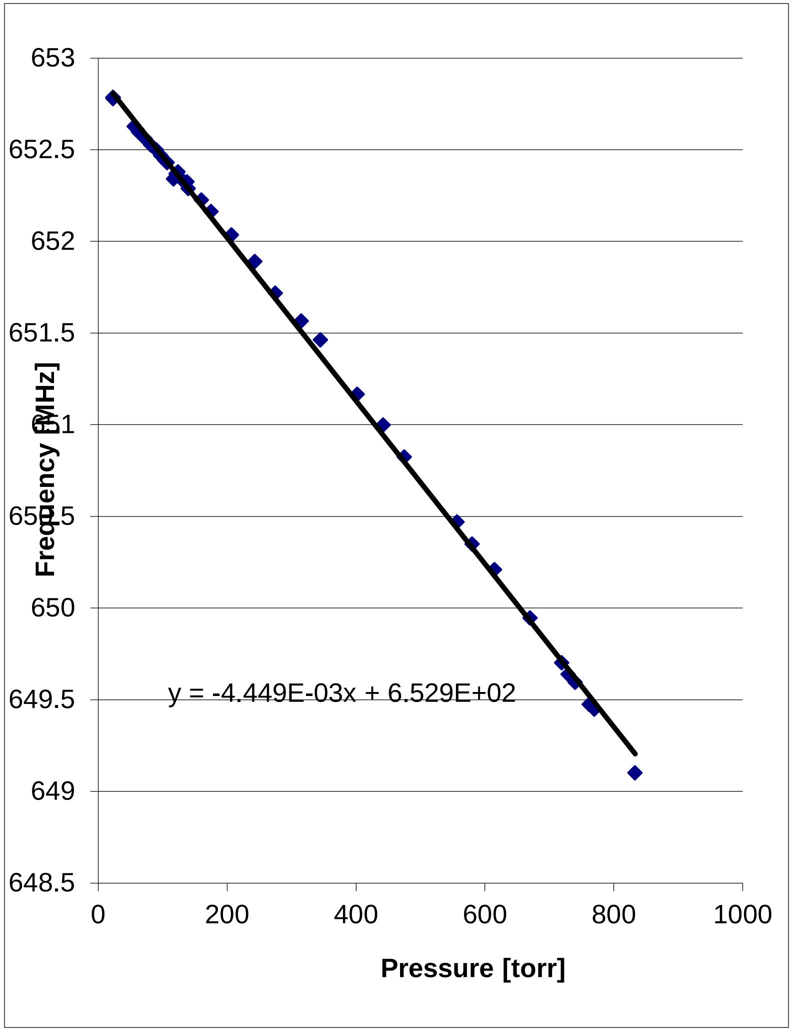
- Prior to test #2 the input coupling Q_{ext} was increased
- The cavity was degreased, then high pressure rinsed and subsequently dried for 12 hrs in the class 10 clean room
- Cavity was assembled with input and output probes and attached to test stand; evacuated for > 12 hrs
- Prior to cooldown the cavity vacuum was 1.2×10^{-8} mbar, it improved to $p < 5 \times 10^{-9}$ mbar at 4.2K
- The same data were taken as in test #1; in addition Q vs E_{acc} was measured also at 1.8K and 1.6K
- To validate the data taken with the R&D rf system, the same measurements were made with the 805 MHz SNS rf system

Test #2, cont'd

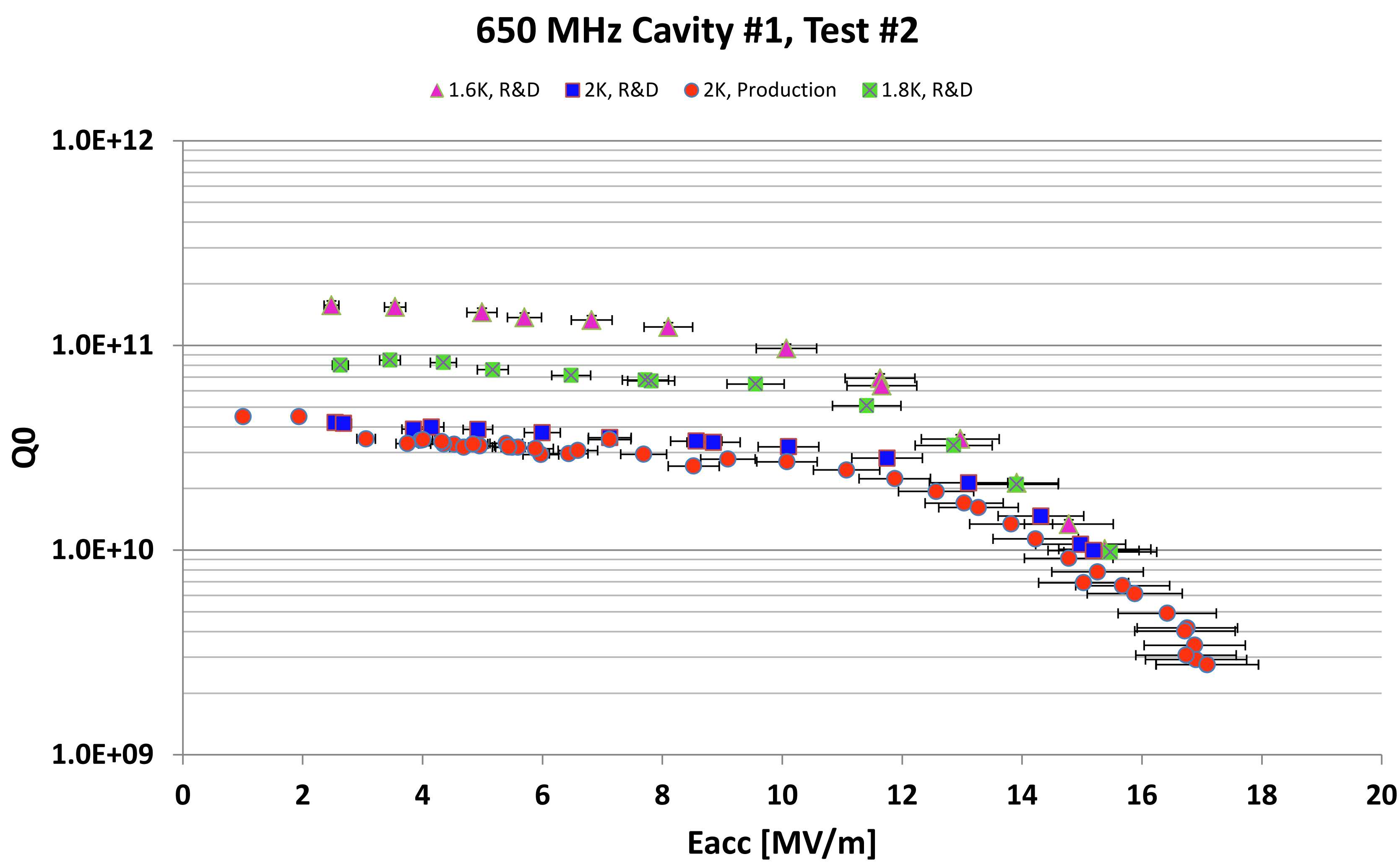
R(T)



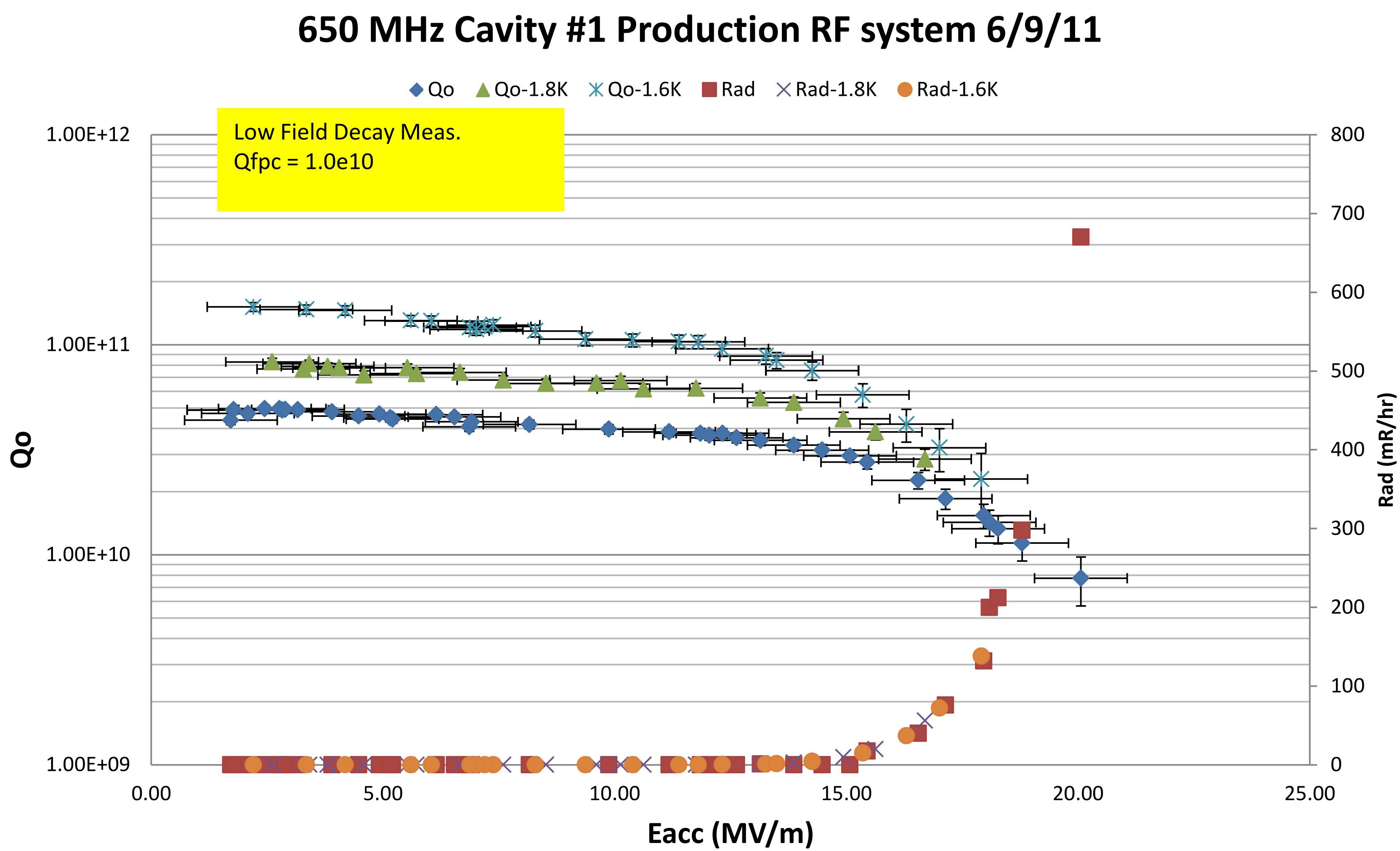
Pressure Sensitivity



Test #2, cont'd, Test with R&D system



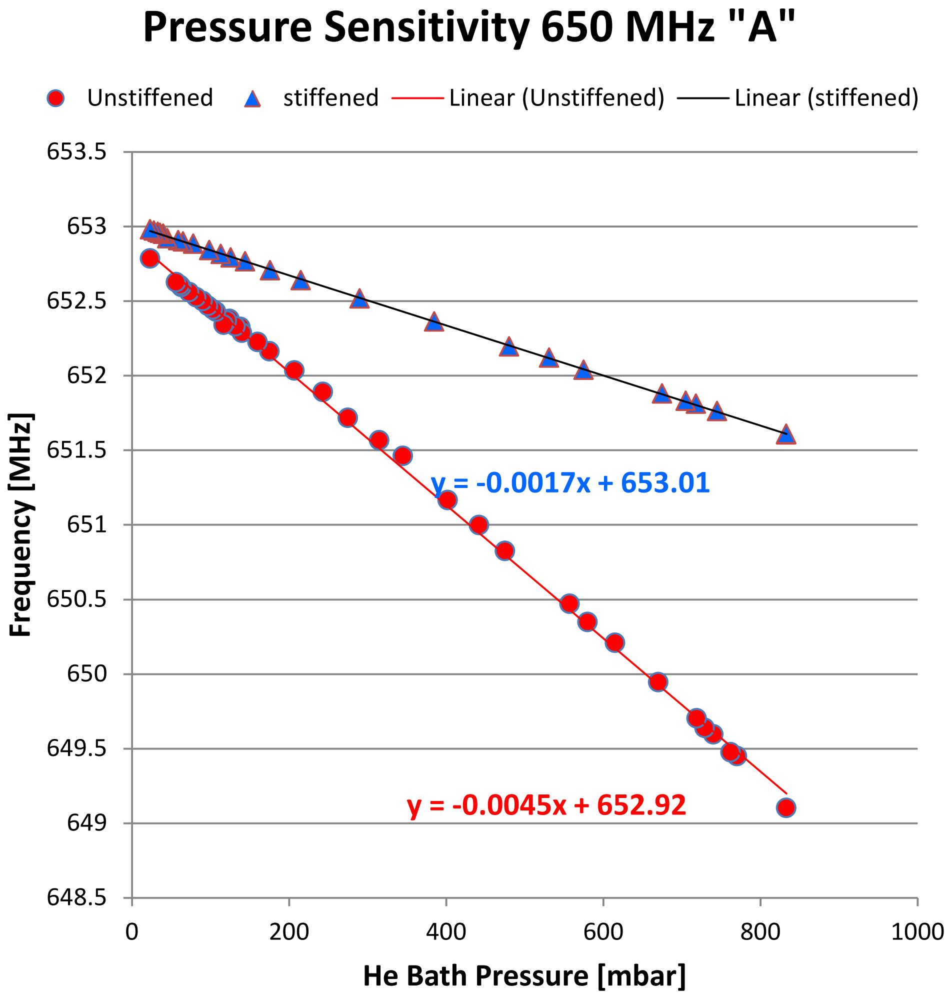
Test #2, cont'd, Test with 805 MHz system



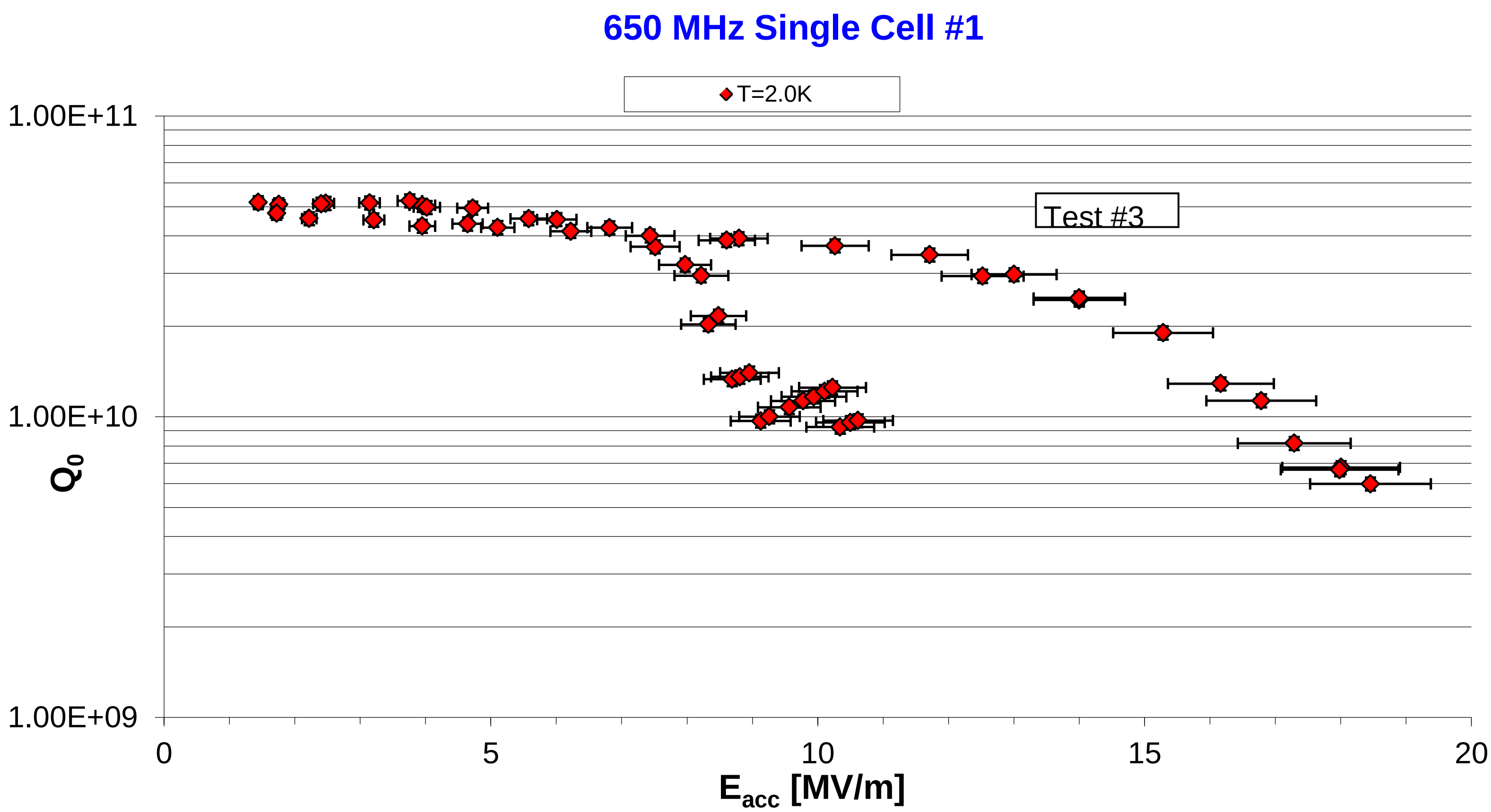
Conclusion

- Both rf systems give similar results
- However, because of a highly overcoupled cavity at the lower temperatures, the errors are quite high
- The cavity is "flimsy" as indicated by a large pressure sensitivity coefficient and a large Lorentz force detuning coefficient; in both cases the measurements are difficult
- Therefore in test #3: adjust the input coupler to Qext ~ 4 $x10^{10}$ and stiffen up the cavity, only HPR

Cavity "A", Test #3



Cavity “A”, Test #3



Cavity “B”, Test #1

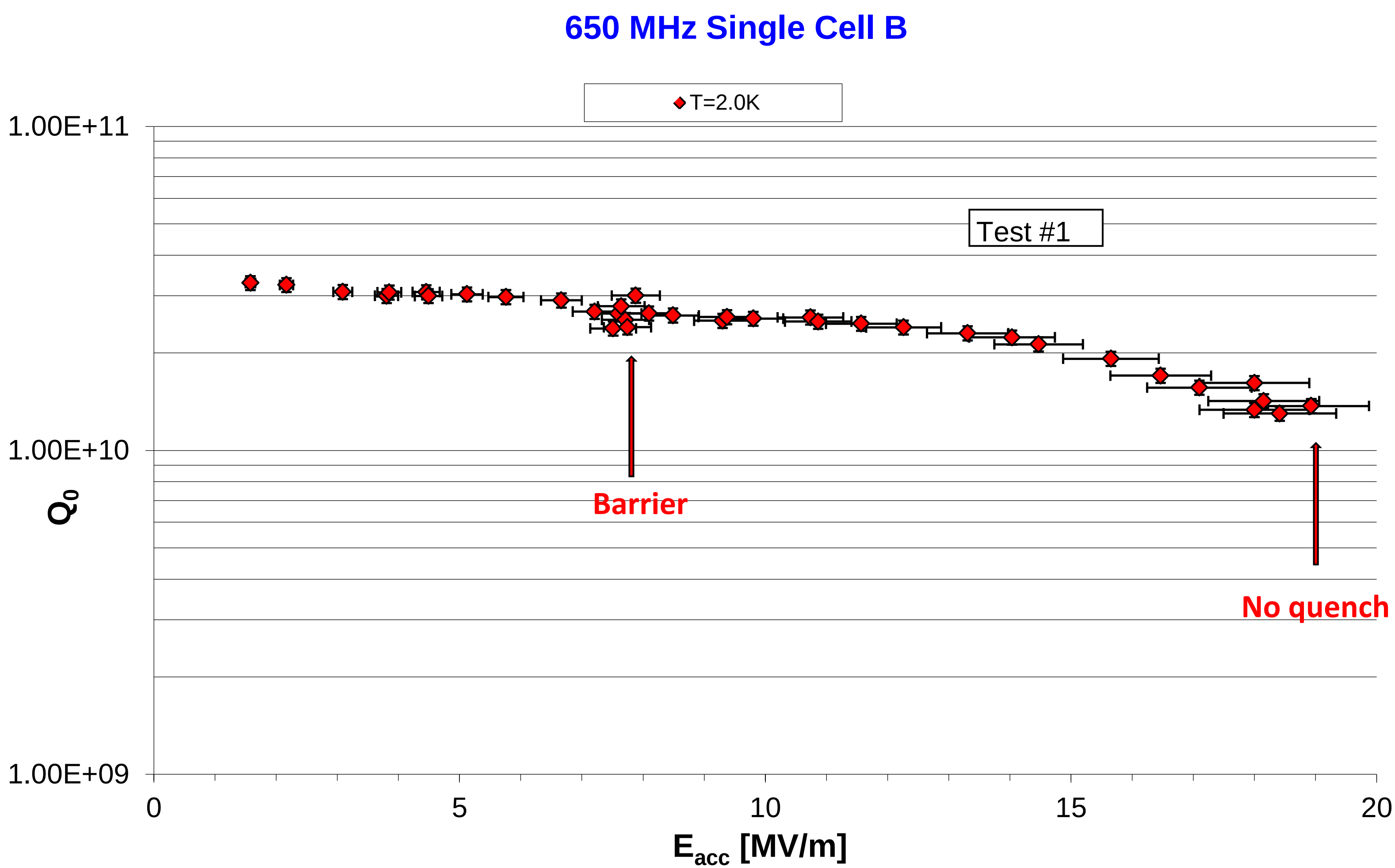
- Cavity received similar final treatment as cavity “A”
- App. 50 micron bcp after hydrogen degassing
- HPR, drying in class 10 for >12 hrs, assembly with stiffener and evacuation
- Prior to cooldown, $p \leq 1.2 \times 10^{-8}$ mbar
- At 4.2K, $p < 5 \times 10^{-9}$ mbar
- Because of weaker coupling than in “A”, no R(T), but immediately to 2K
- Pressure sensitivity measured during pumpdown

$$\Delta f / \Delta p = 1.75 \quad \text{k Hz / mbar}$$

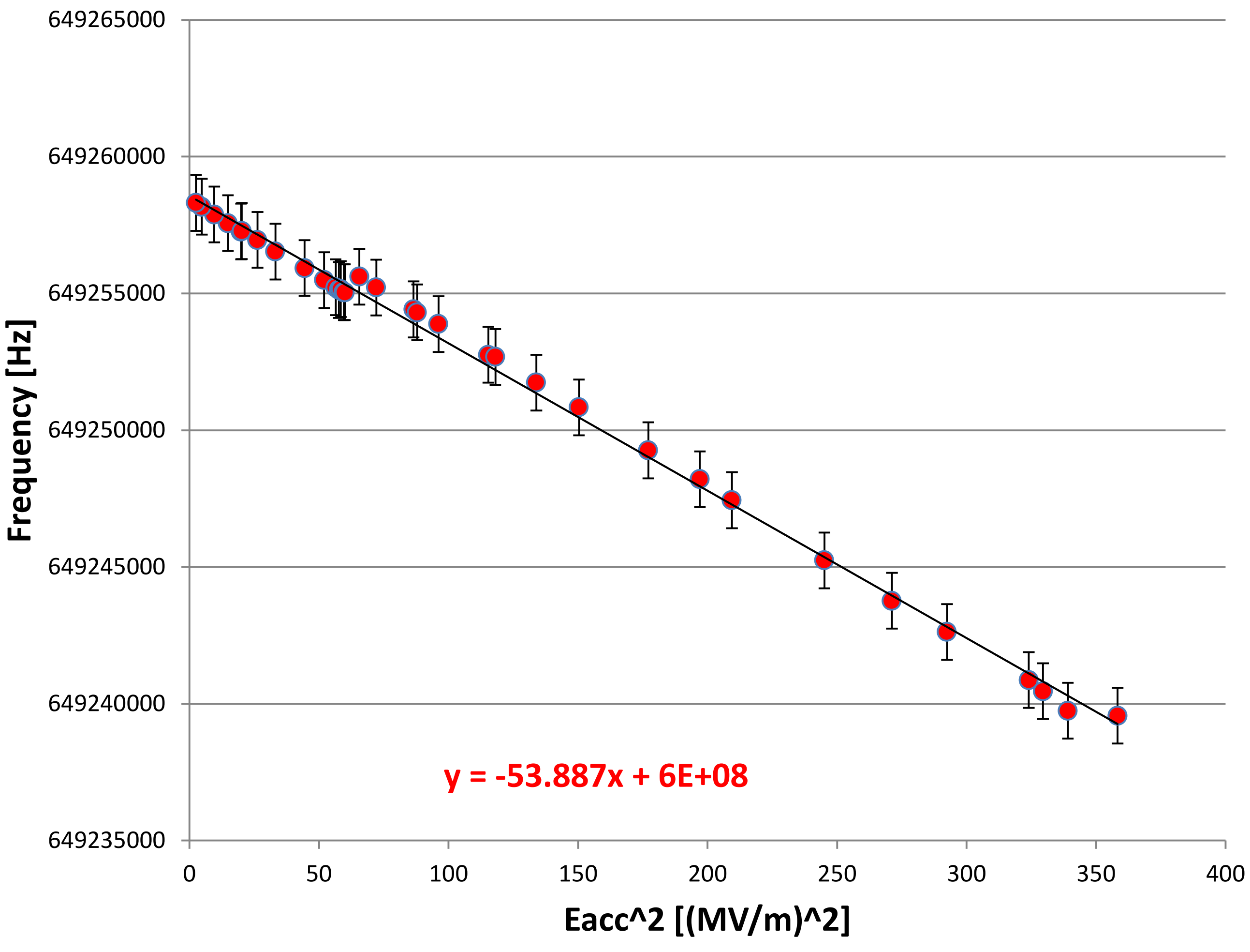
- Test carried out yesterday, will continue after baking

  data preliminary

Cavity "B", Test #1, cont'd



Cavity “B”, Test #1,Lorentz Force Detuning



Summary

- Both cavities had rather high low field Q-values, corresponding to residual resistances of $1.5\ \text{n}\Omega \leq \text{Rres} \leq 3\ \text{n}\Omega$
- Without stiffening on the cells the single cell cavities are quite "flimsy", resulting in large frequency shifts with He bath pressure and fields in the cavity ("Lorentz Force Detuning")
- Presently the gradients are limited by FE – better cleaning/assembly is desirable
- The max. gradients of ~ 18 – 19 MV/m correspond to peak electric fields of ~ 50 MV/m
- There is a weak MP barrier around 8 – 10 MV/m