R&D towards Understanding the "Q-drop"

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and
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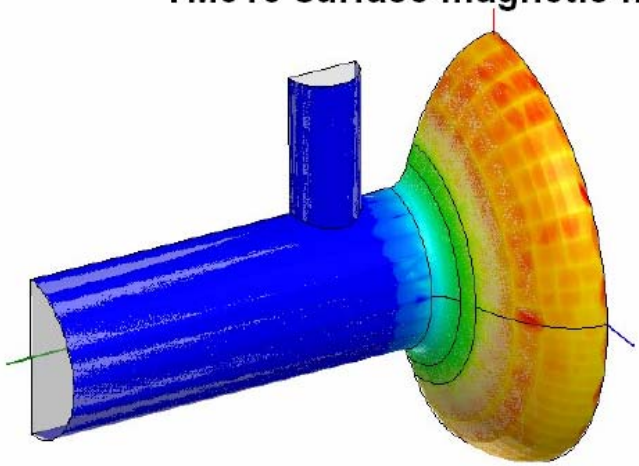
Issues/Work in progress

- Is the Q-drop an electric or magnetic field effect? TE/TM cavity, High Field Cavity
- Are grain boundaries the reason for the Q-drop?
  Cavities of different grain sizes, single crystal cavities
- What is the influence of the equator weld?
  Seamless cavities, NbCu, Nb
- Under which conditions can Q-drop be reduced/ eliminated? "in –situ" baking, EP vs BCP, T-mapping
- Is there a frequency dependence of the "Q-drop"?
  1300 MHz, 1500 MHz, 2300 MHz cavities
- Can one correlate rf performance with surface features? TE_{011} coaxial cavity with sample

TE/TM cavity: Q – drop(1)

TE011 vs. TM010 properties

TM010 surface magnetic field



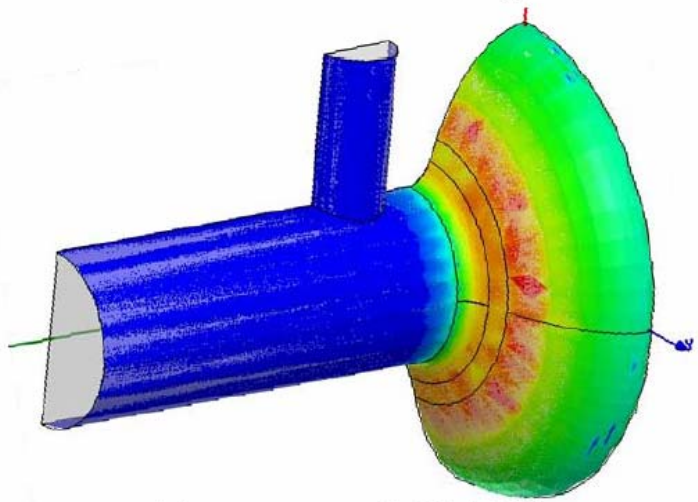
Frequency: 1.467 GHz

Geometry factor: 273 Ω

$B_p/\sqrt{U}$: 60.7 mT/√J

Effective area: 0.0586 m^2

TE011 surface magnetic field



Frequency: 2.824 GHz

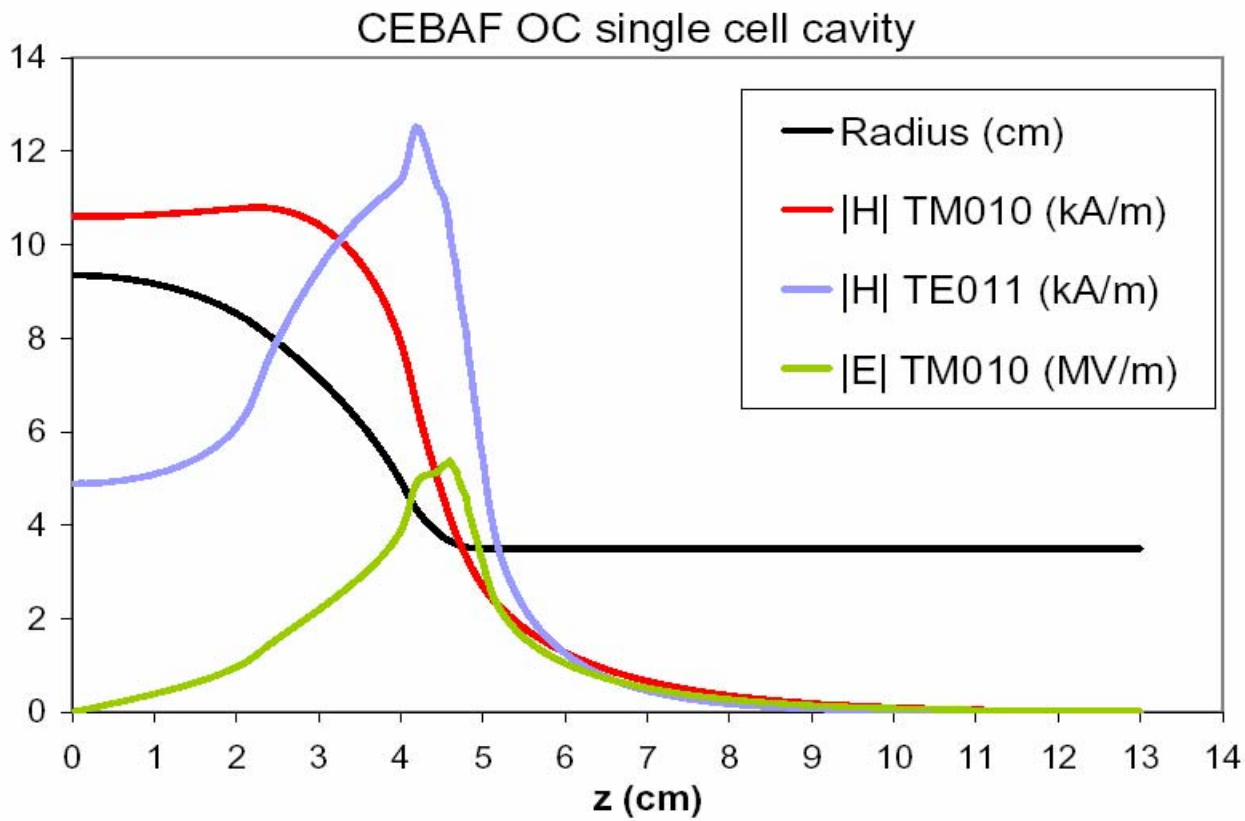
Geometry factor: 701 Ω

$B_p/\sqrt{U}$: 50 mT/√J

Effective area: 0.032 m^2

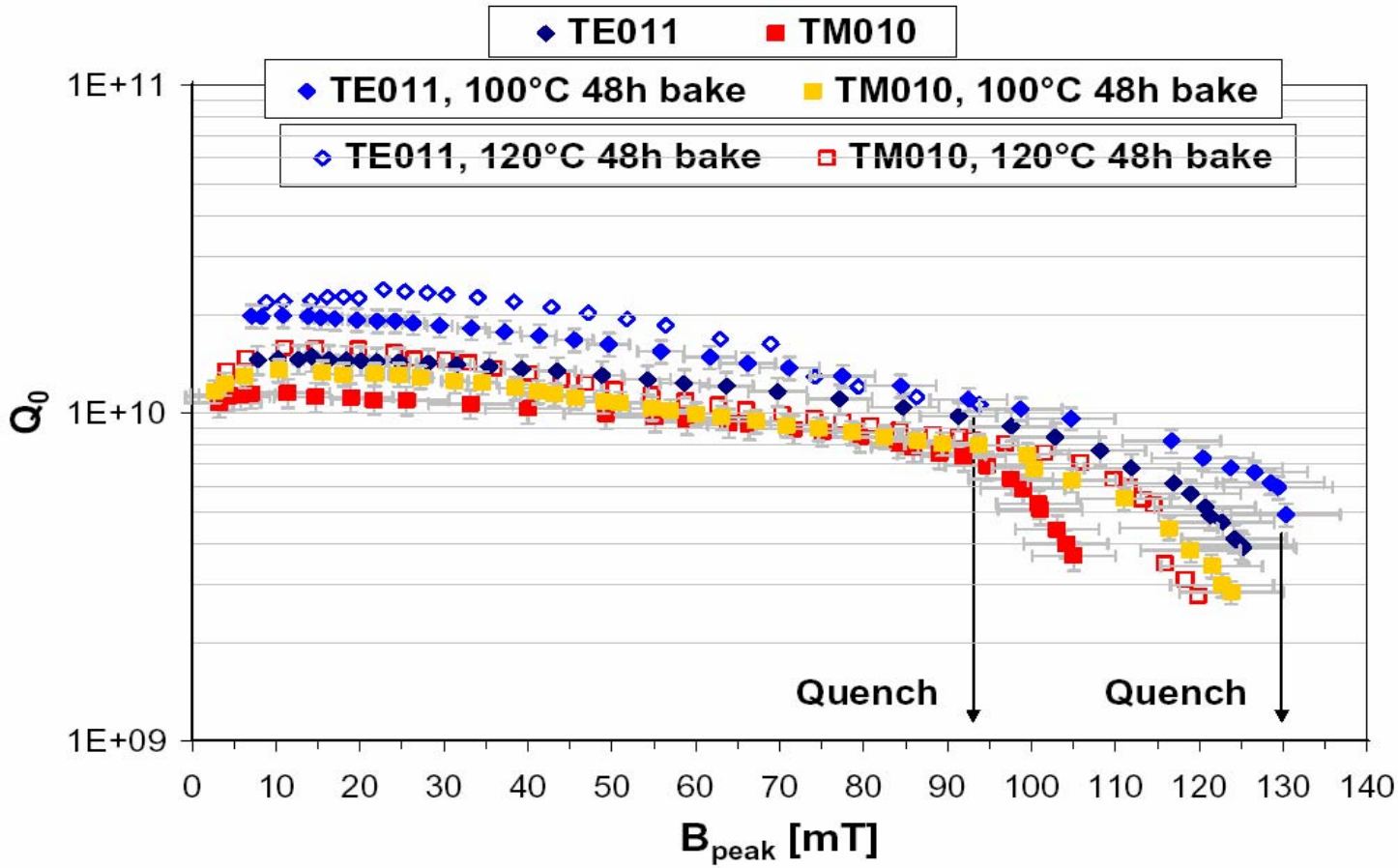
TE/TM cavity: Q – drop(2)

Surface fields distribution



TE011 has no electric field on the cavity surface

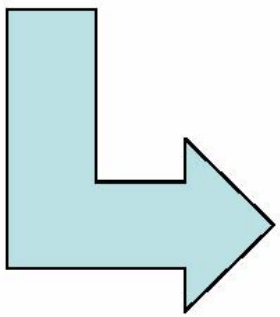
TE/TM cavity: Q – drop(3)



TE/TM cavity: Q – drop(4)

Conclusion (G. Ciovati)

- The same dependence R_s vs. B_p as seen in TM_{010} mode above 90mT was observed in TE_{011} mode at higher field, once the thermal conduc. was decreased by HT



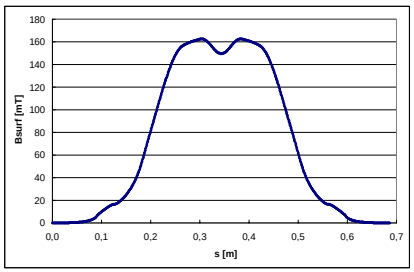
- Q-drop is more probable to be a magnetic field effect
- None of the present models explain all the experimental results

High Field Cavity (NbCu, seamless)

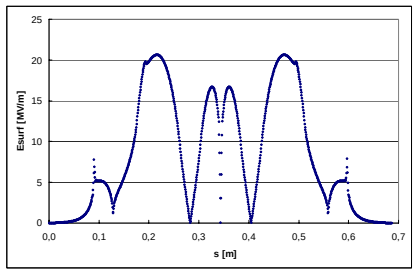
The cavity will be operated in two cylindrically symmetric modes (0 and π) of TM_{010} type.

0 - Mode

B - field

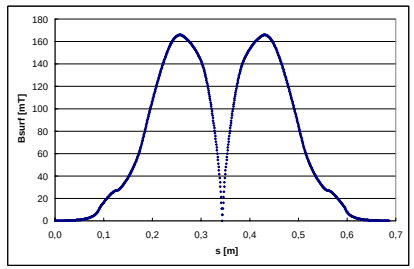


E - field

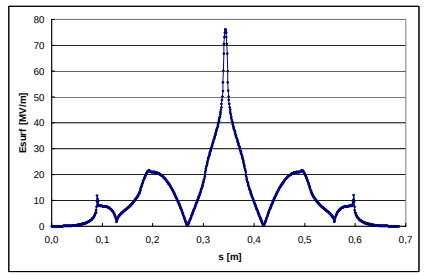


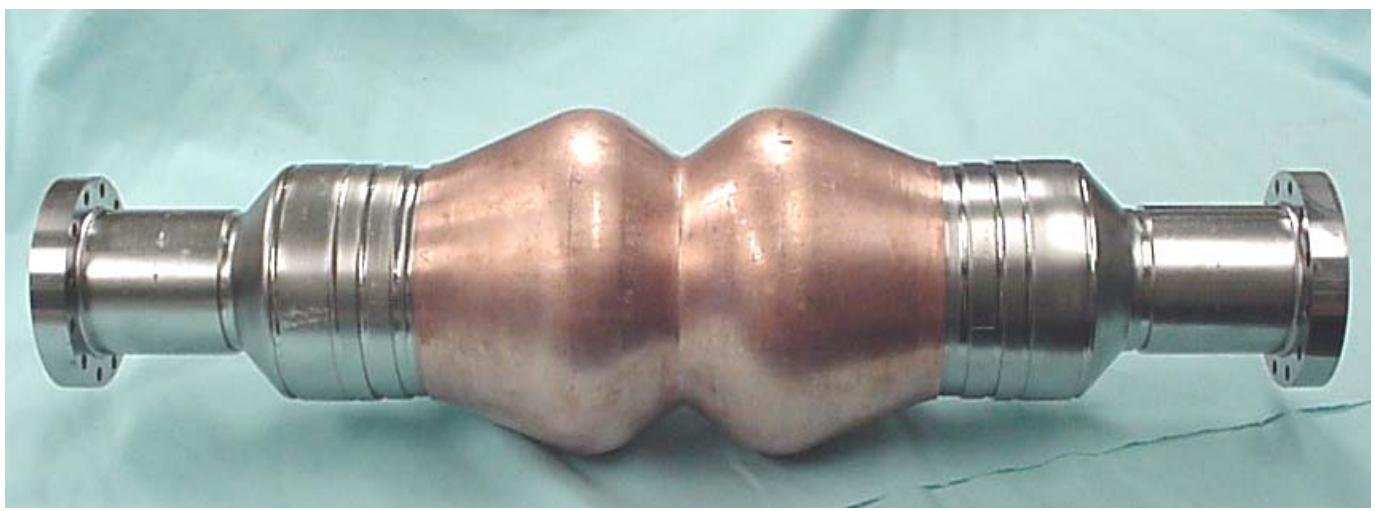
π - Mode

B - field

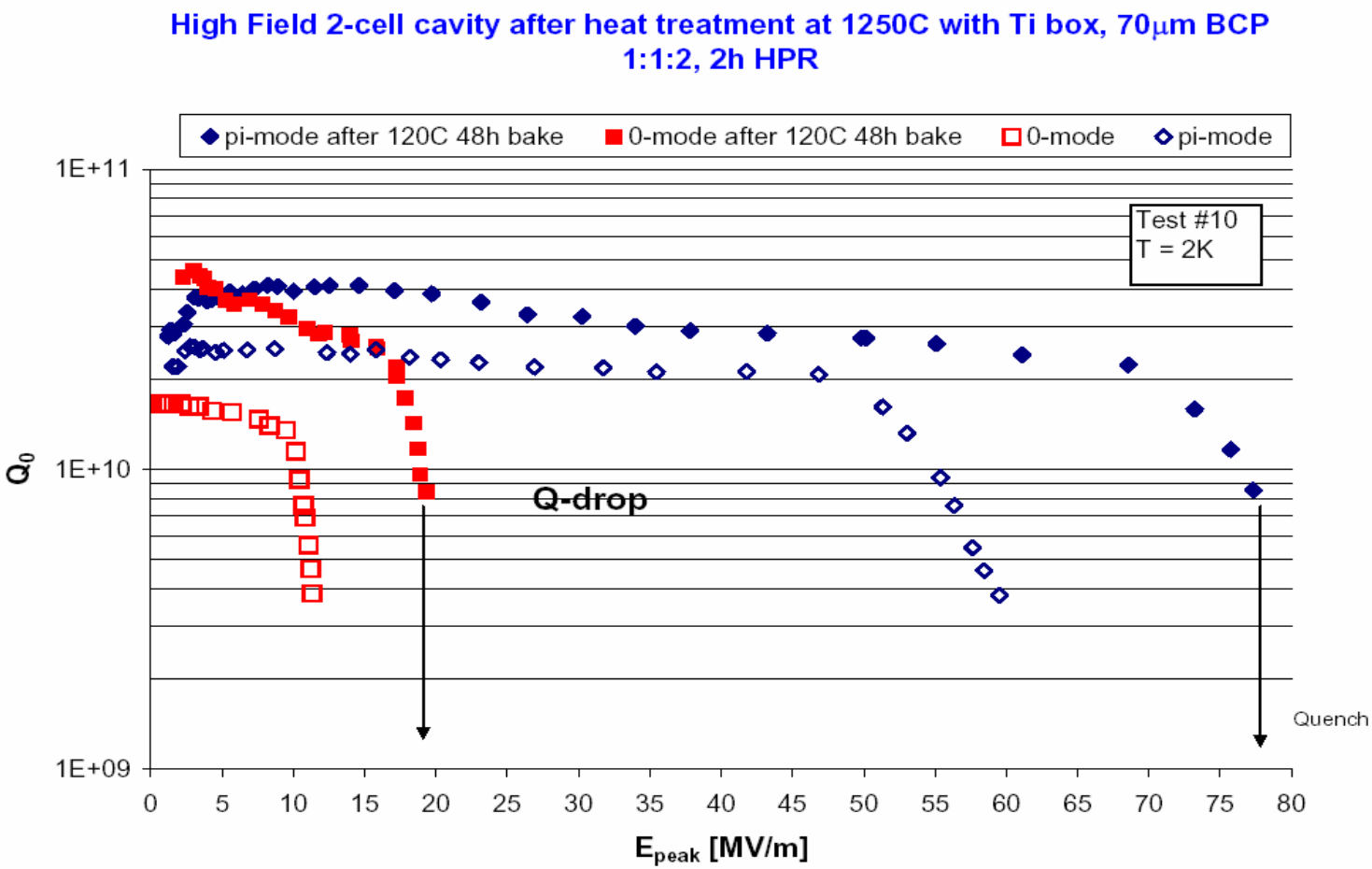


E - field

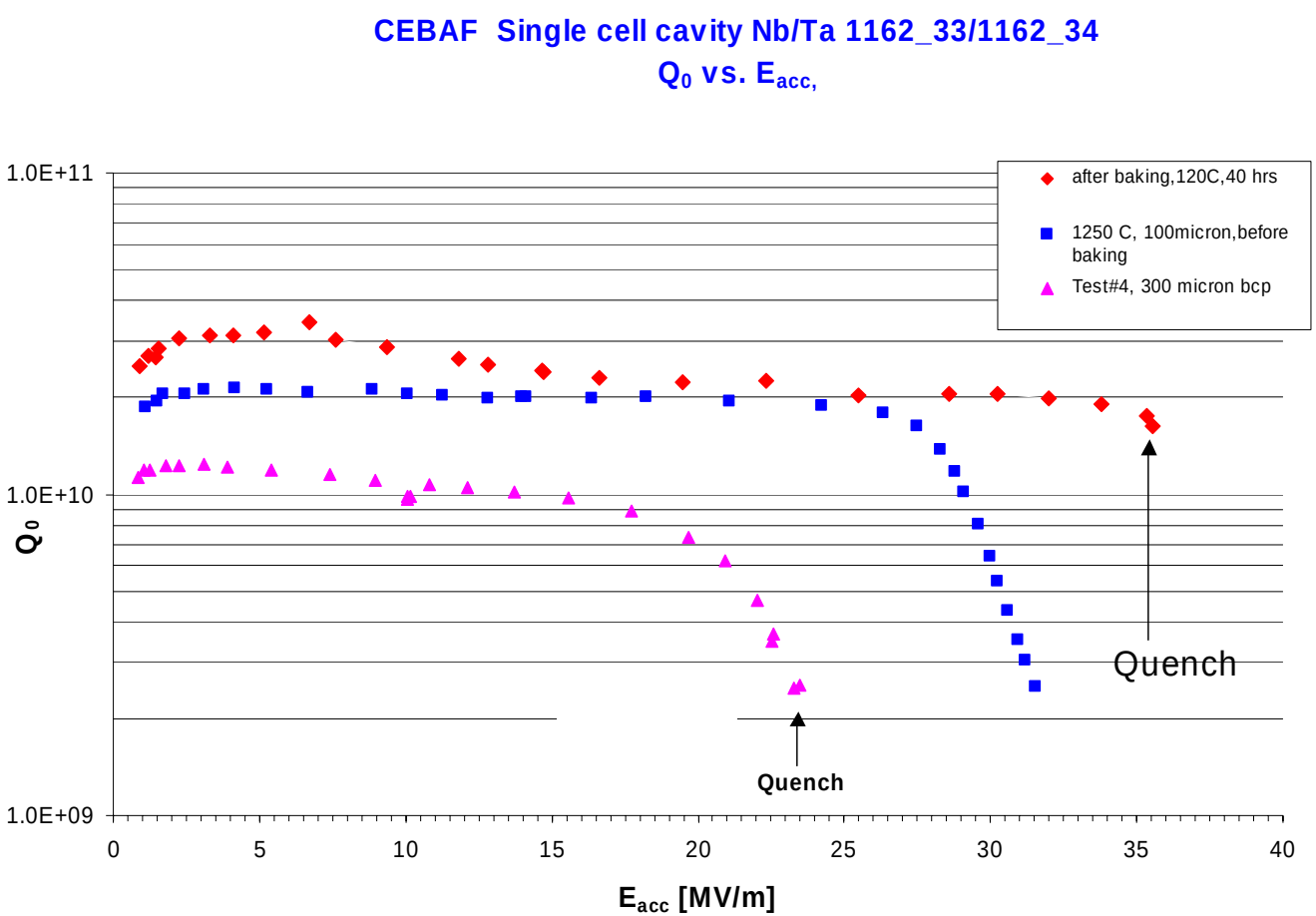




High Field Cavity (Niobium)

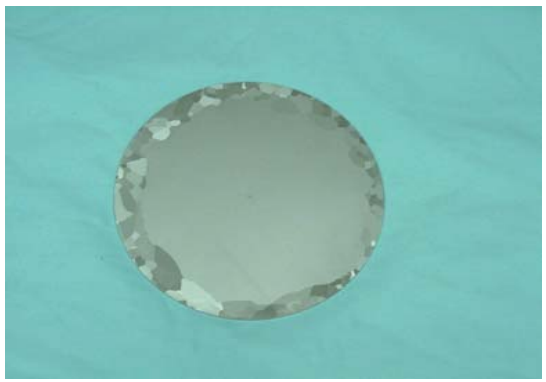


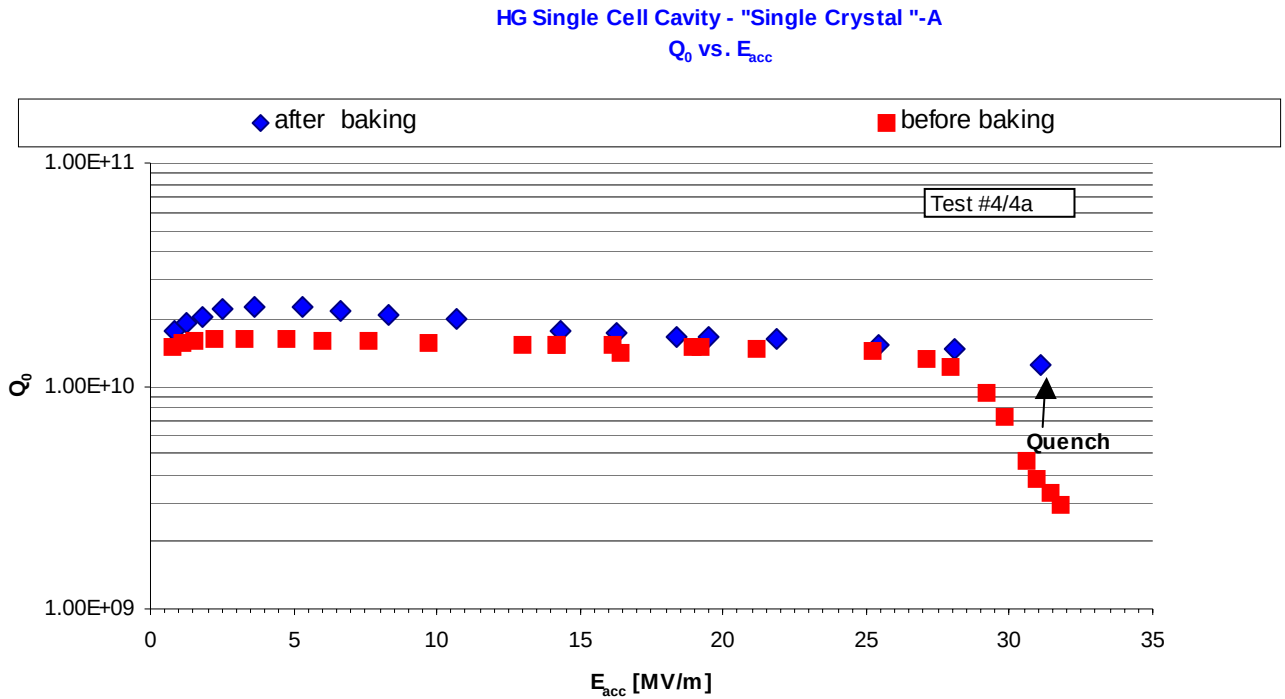
Nb of different Ta contents(2):600 ppm



To Item 1: large grain cavities(2)

Ingot "A"





Single Crystal Niobium Cavity (1)

Discs from Ingot

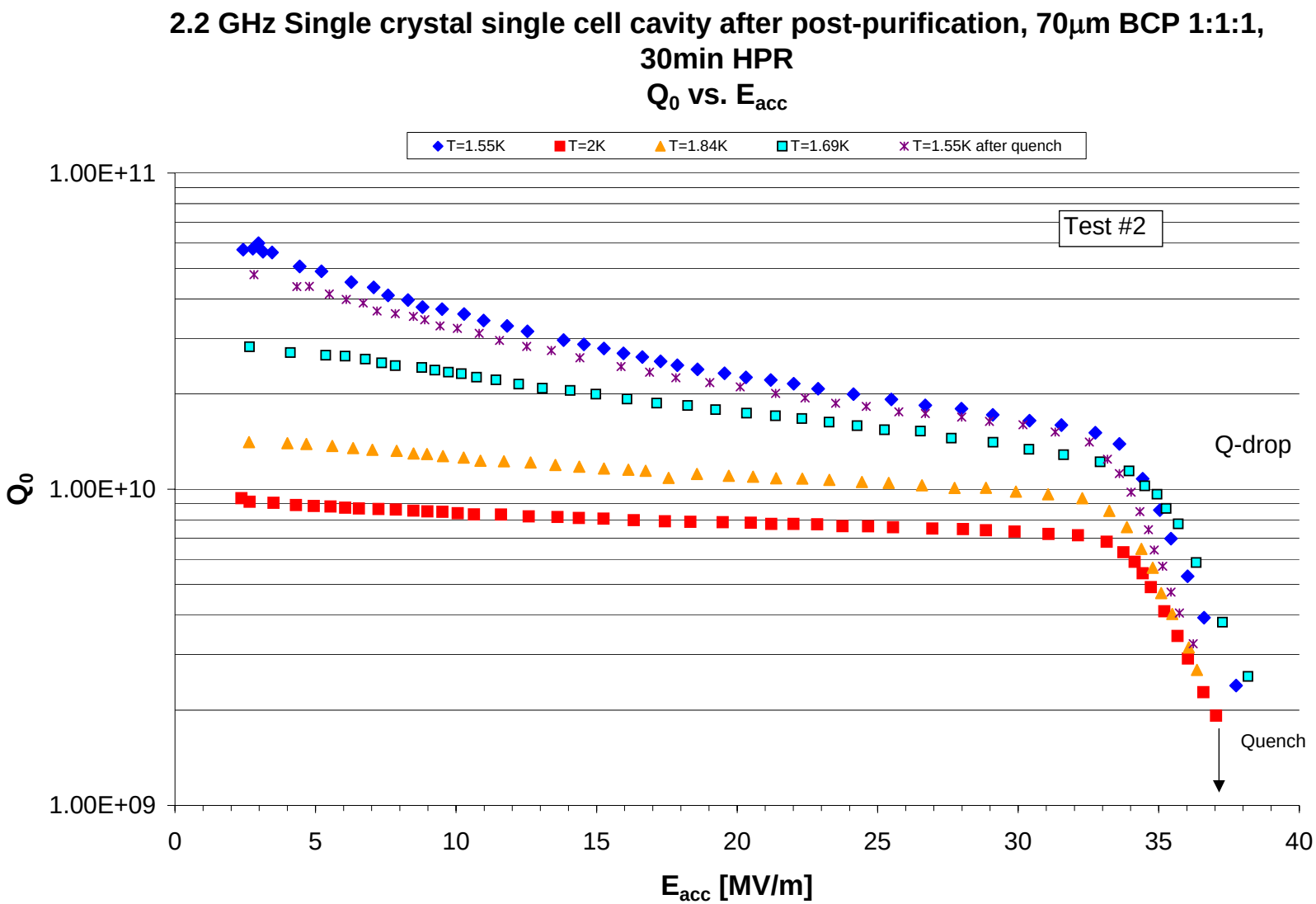
Cavity

$E_{peak}/E_{acc} = 1.674$

$H_{peak}/E_{acc} = 4.286$ mT/MV/m

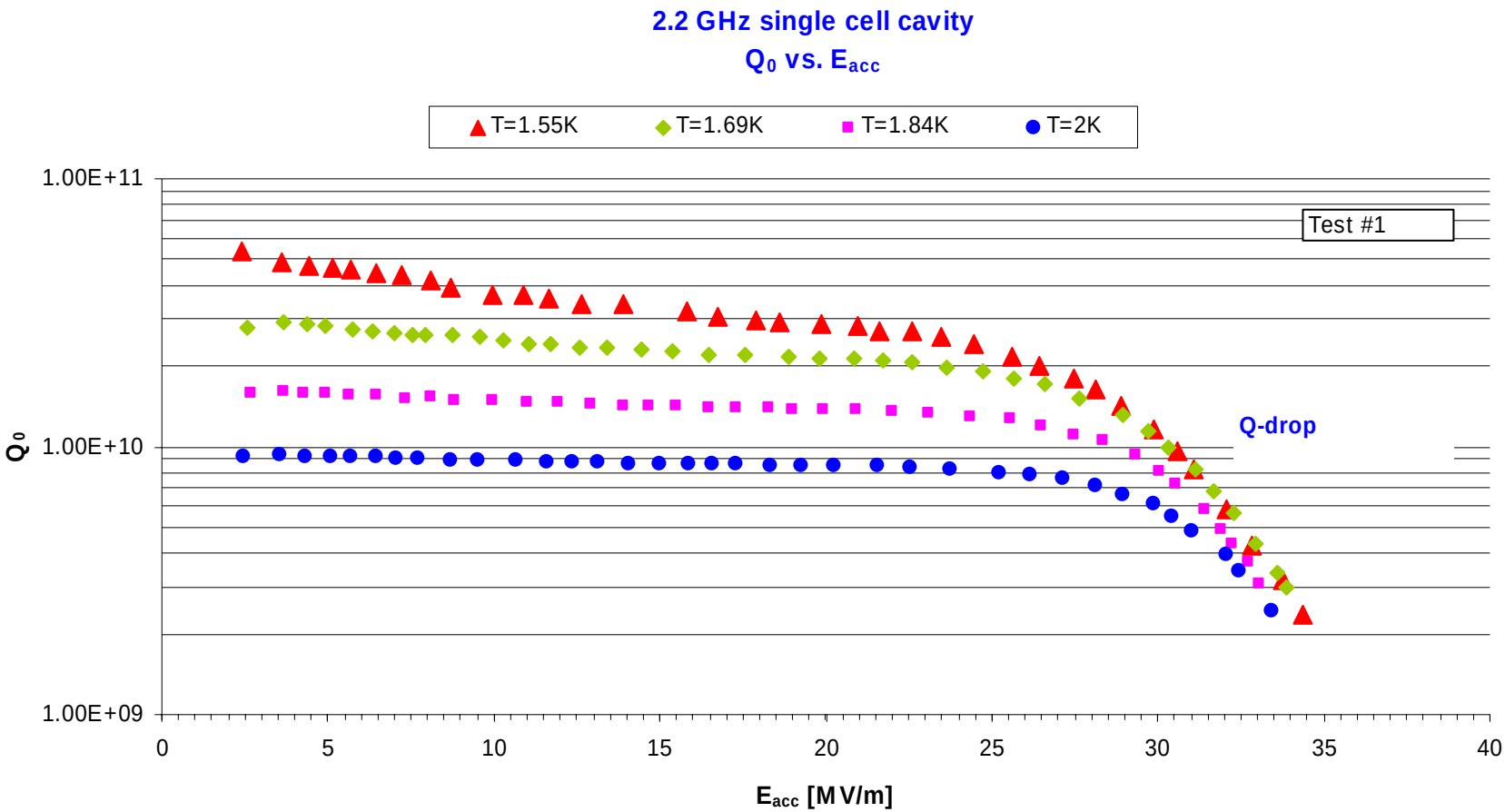
Single Crystal Niobium Cavity (4)

Test #2(before baking)



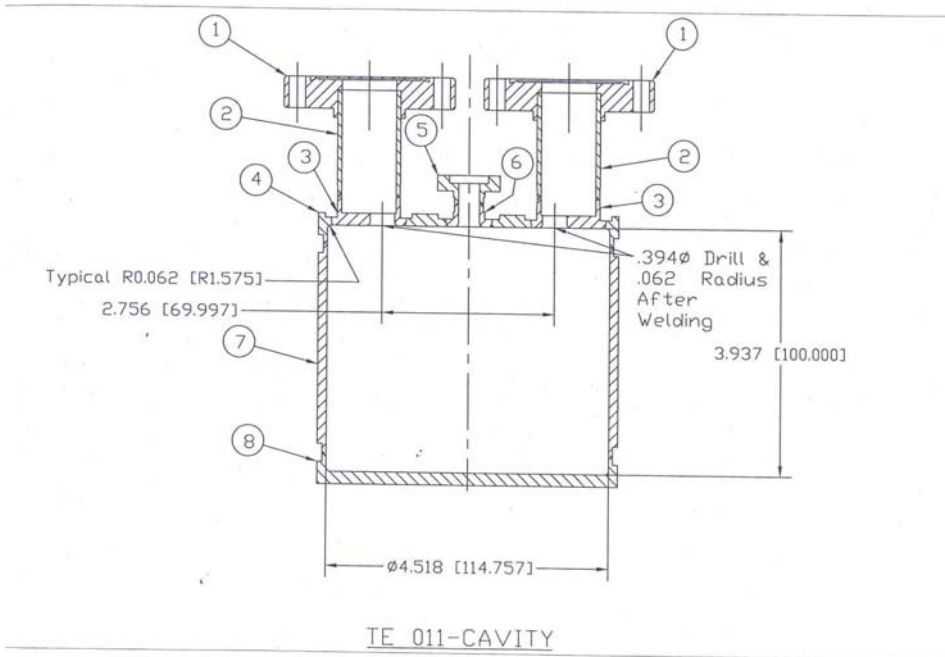
Standard Material: 2.2 GHz

Test #1:~ 100 mm bcp, 800C, 3 hrs,~ 80 mm bcp

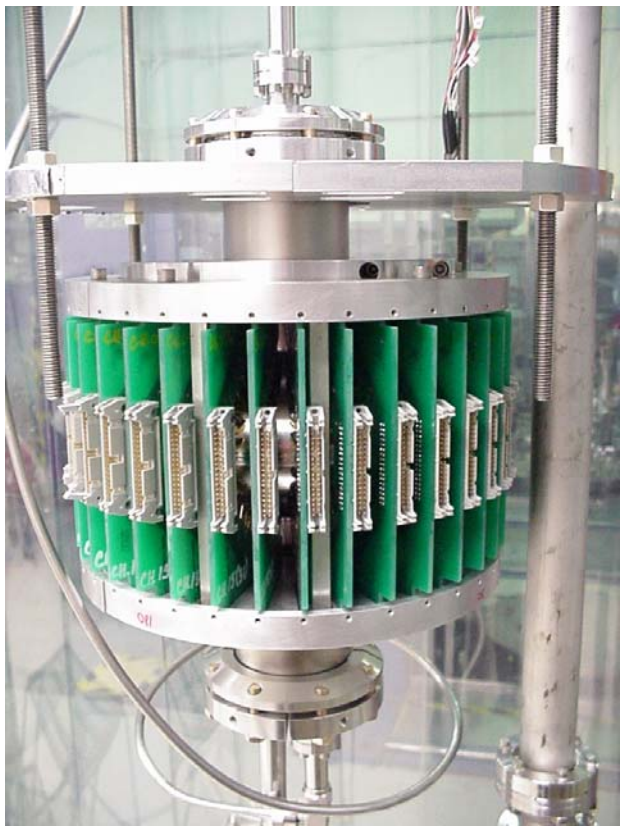


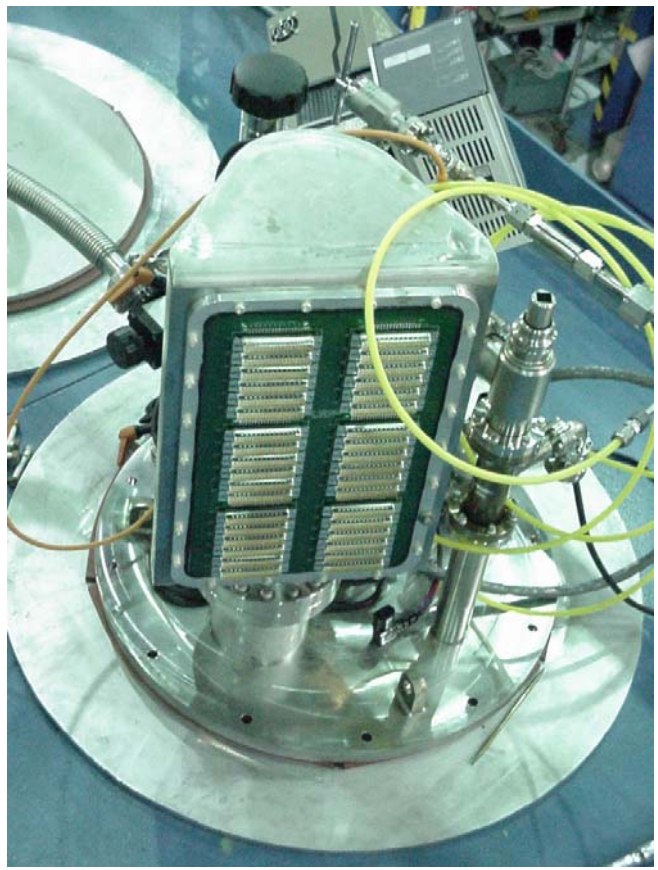
TE_{011} Coaxial Cavity

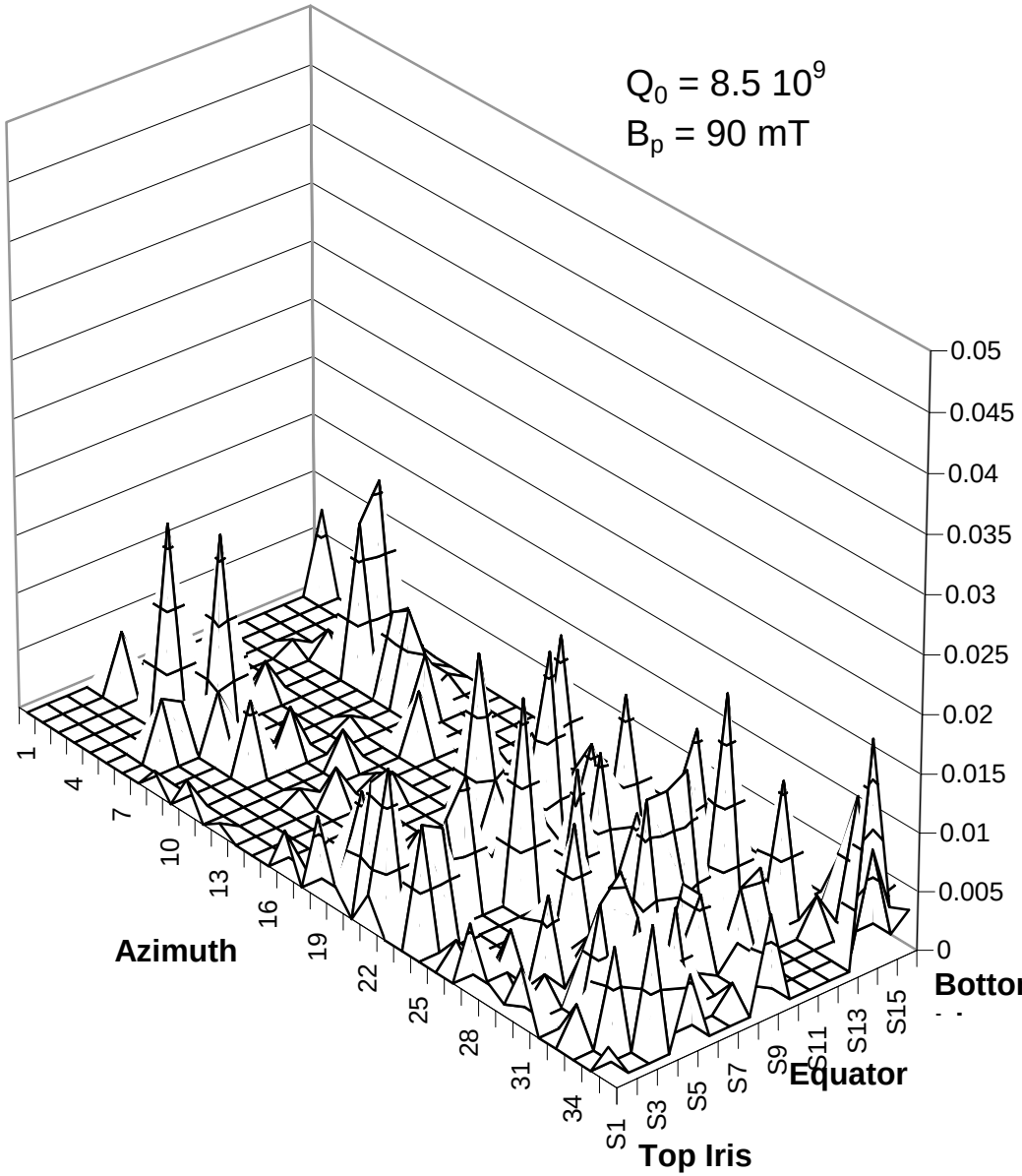
H-field on sample 2x higher than anywhere on cavity wall

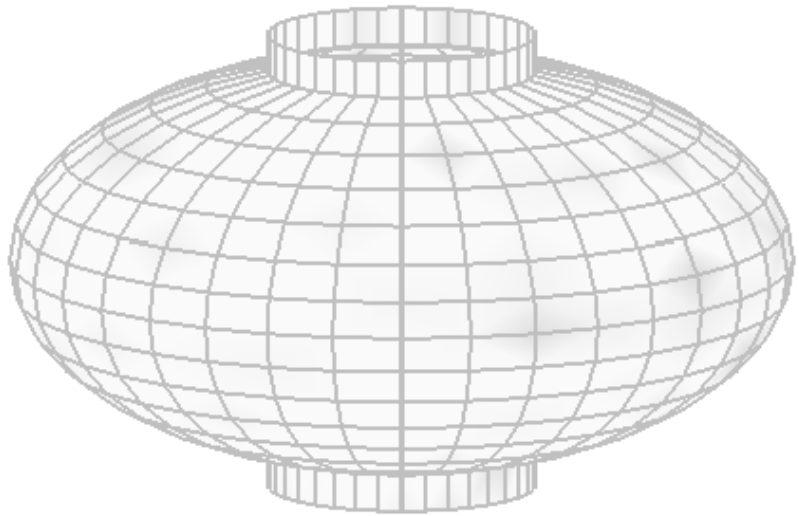


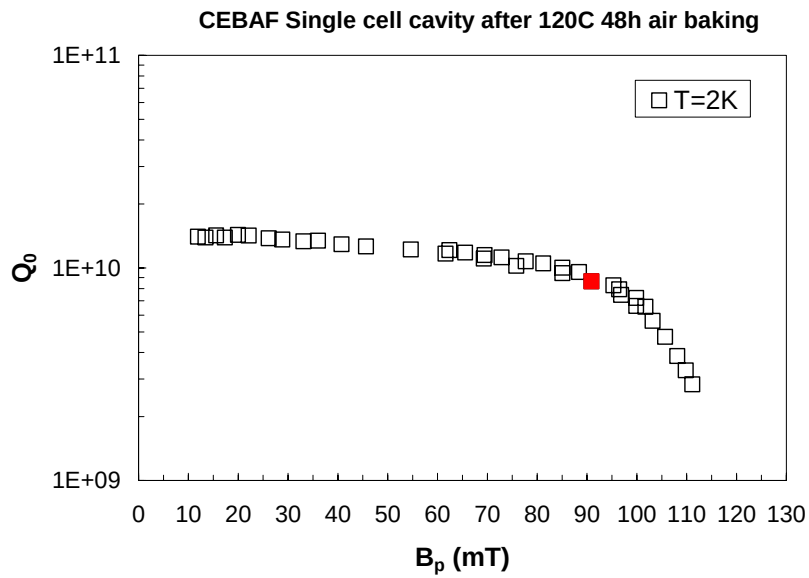
T- Mapping(1)

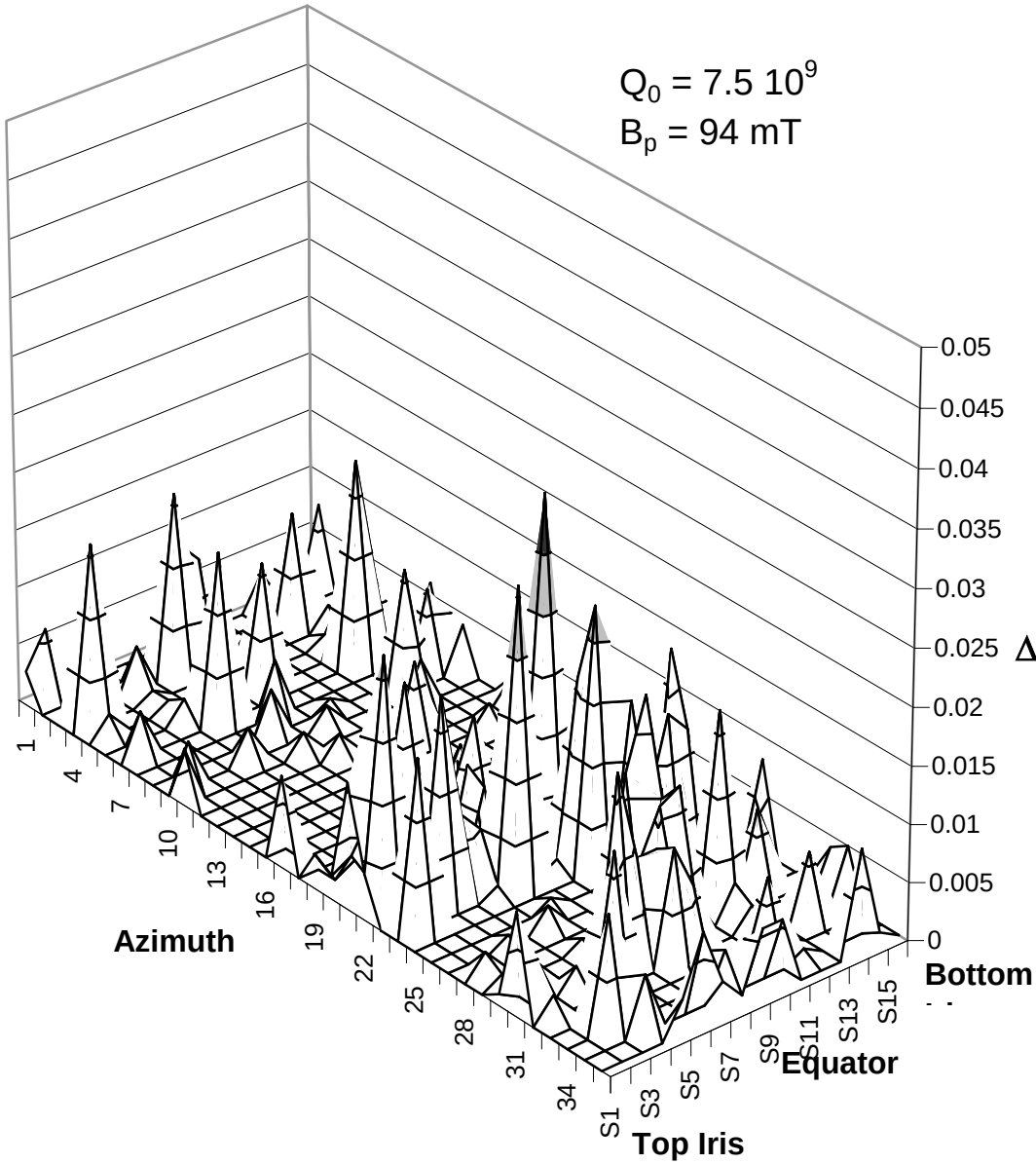


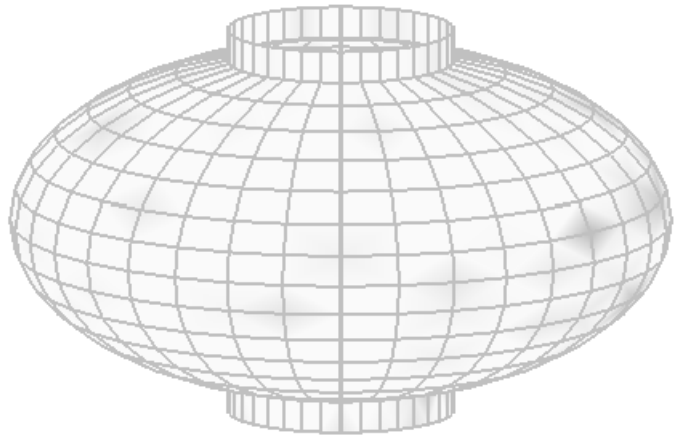


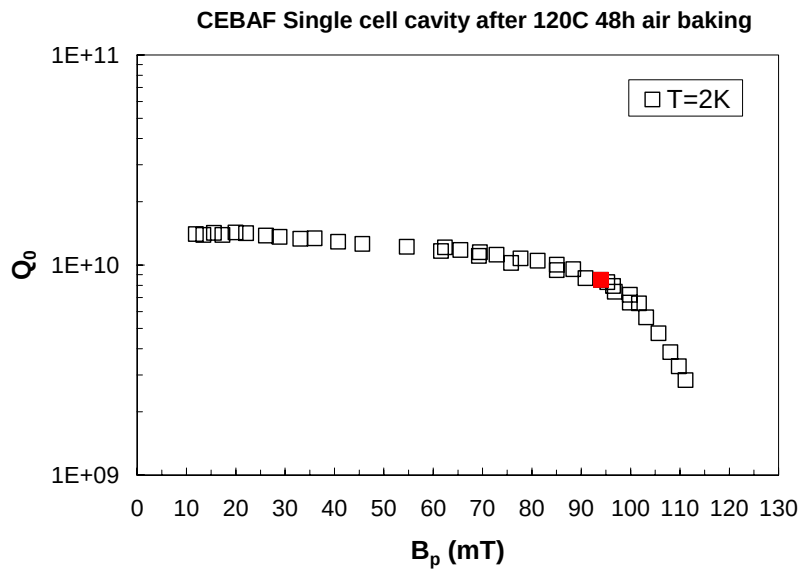

$Q_0 = 8.5\ 10^9$
$B_p = 90$ mT
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
ΔT (K)
1
4
7
10
13
16
19
22
25
28
31
34
Azimuth
S1
S3
S5
S7
S9
S11
S13
S15
Equator
Bottom
Top Iris

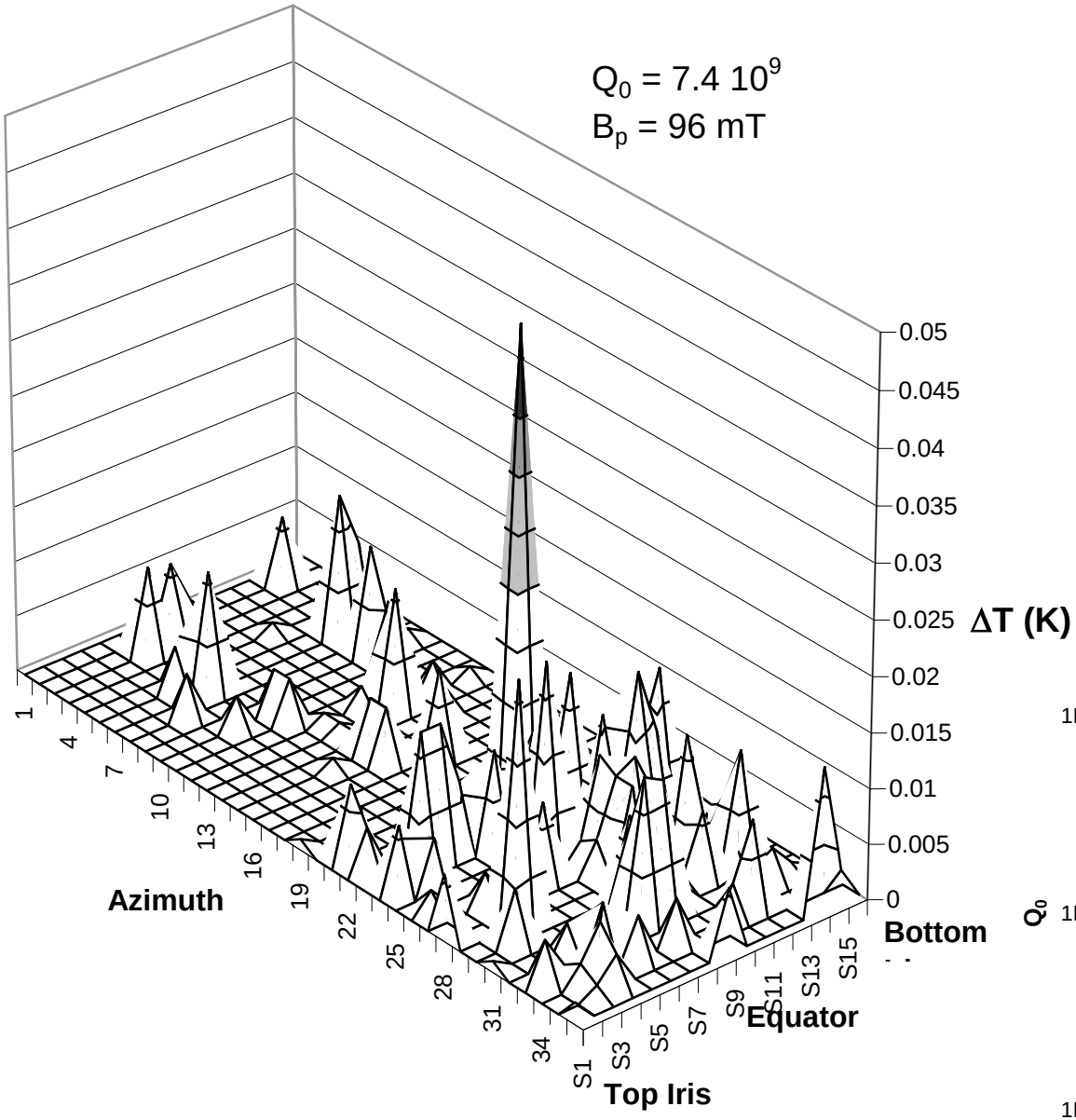


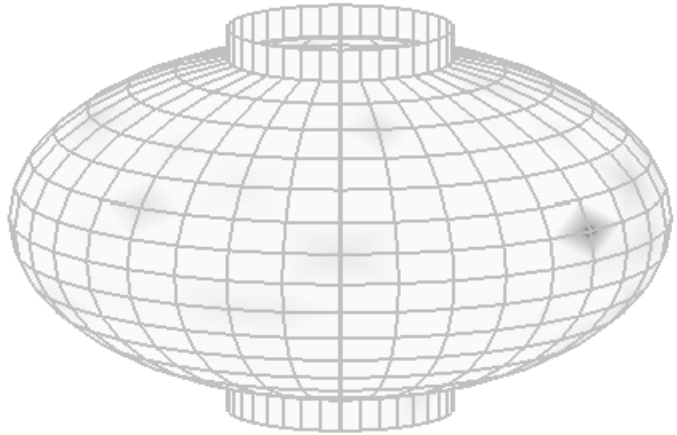

CEBAF Single cell cavity after 120C 48h air baking
T=2K
1E+11
1E+10
1E+09
Q_0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
B_p (mT)

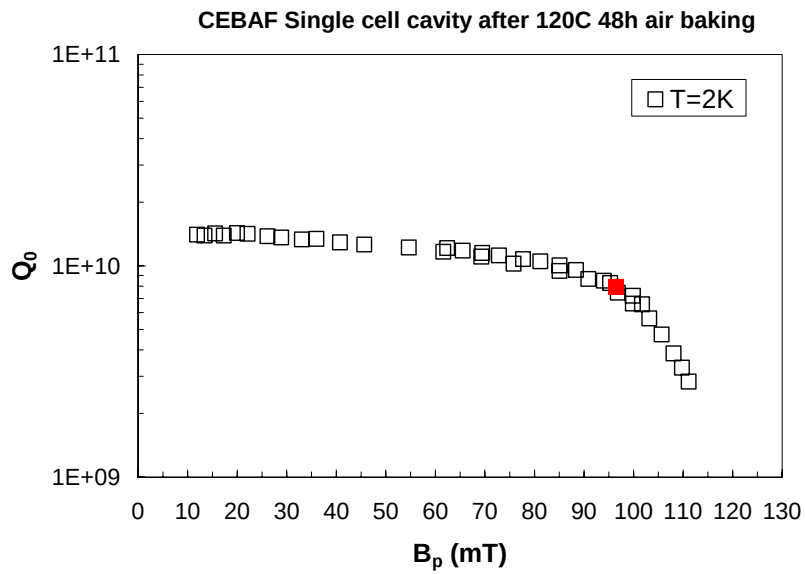

$Q_0 = 7.5\ 10^9$
$B_p = 94$ mT
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
ΔT (K)
1
4
7
10
13
16
19
22
25
28
31
34
Azimuth
S1
S3
S5
S7
S9
S11
S13
S15
Equator
Top Iris
Bottom

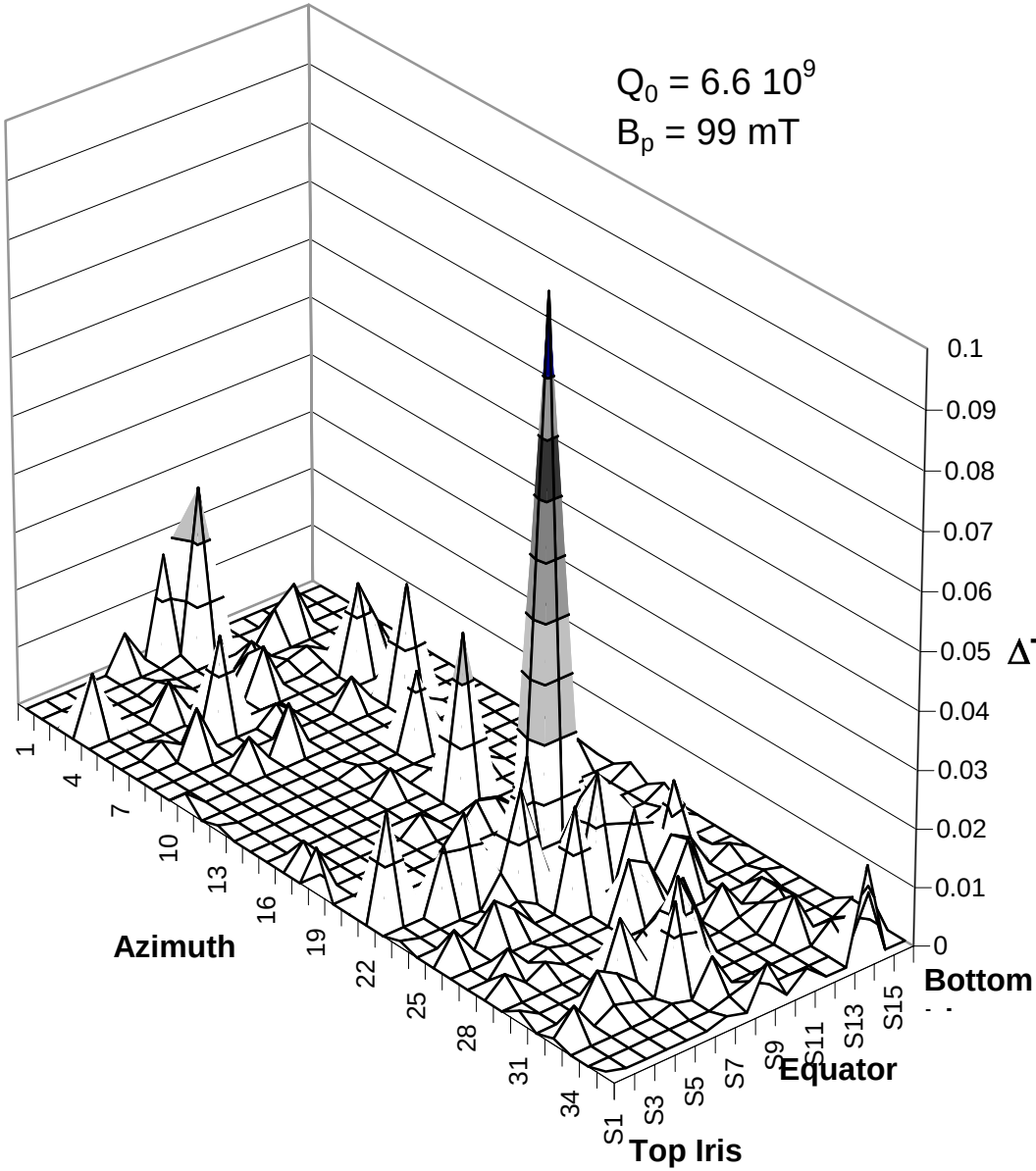


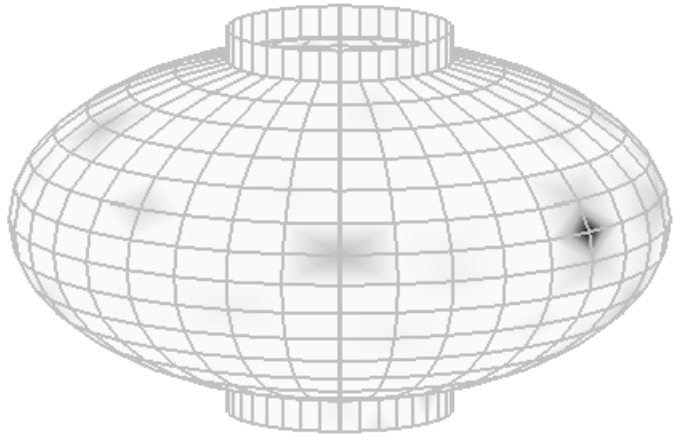

CEBAF Single cell cavity after 120C 48h air baking
T=2K
1E+11
1E+10
1E+09
Q_0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
B_p (mT)

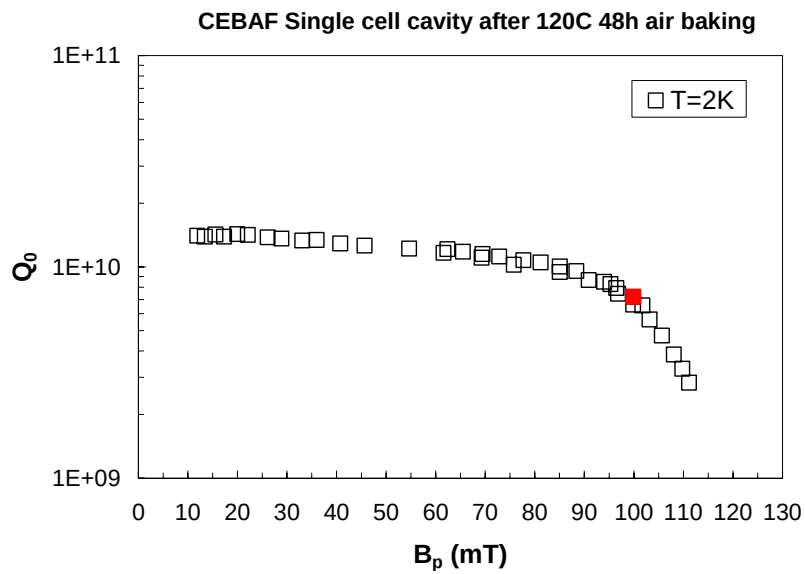

$Q_0 = 7.4\ 10^9$
$B_p = 96$ mT
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
ΔT (K)
Azimuth
1
4
7
10
13
16
19
22
25
28
31
34
Top Iris
S1
S3
S5
S7
S9
S11
S13
S15
Equator
Bottom




CEBAF Single cell cavity after 120C 48h air baking
T=2K
Q_0
1E+11
1E+10
1E+09
0
10
20
30
40
50
60
70
80
90
100
110
120
130
B_p (mT)

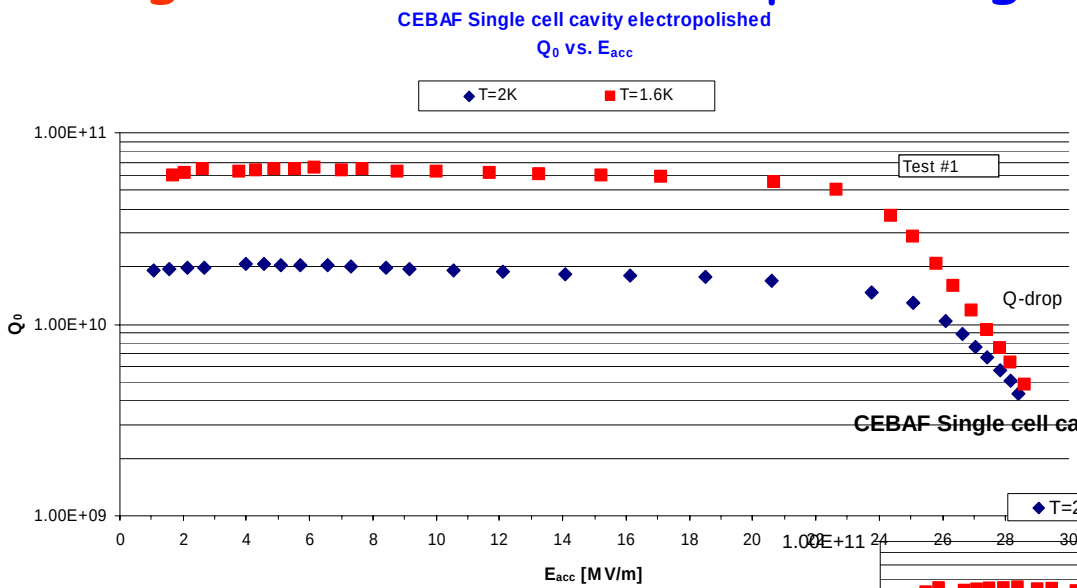

$Q_0 = 6.6\ 10^9$
$B_p = 99$ mT
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
ΔT (K)
1
4
7
10
13
16
19
22
25
28
31
34
Azimuth
S1
S3
S5
S7
S9
S11
S13
S15
Equator
Bottom
Top Iris

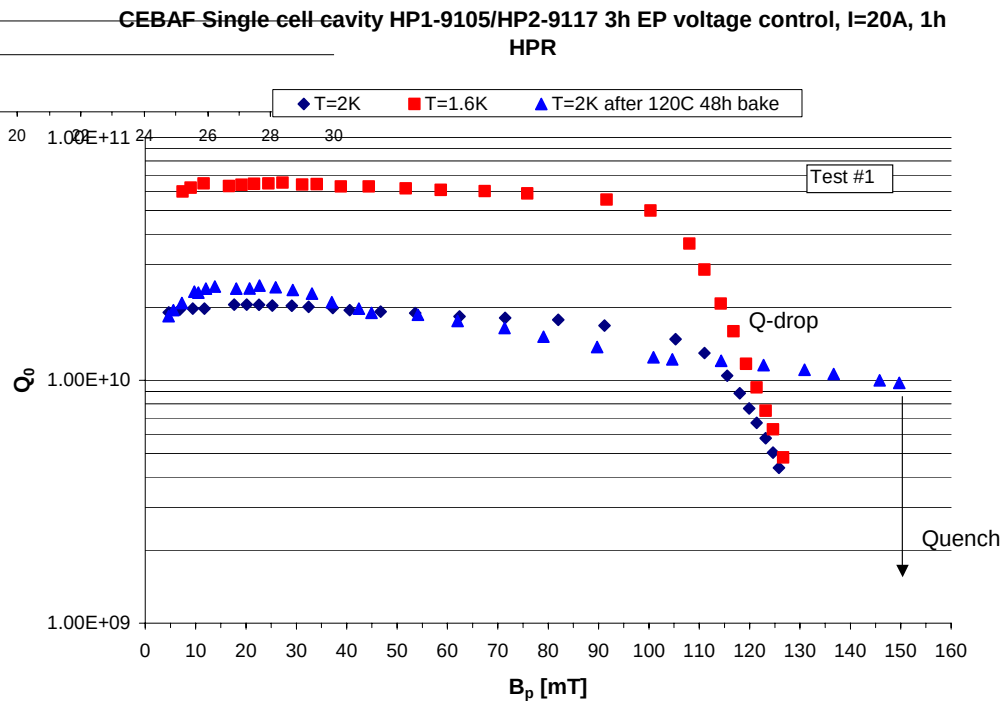



CEBAF Single cell cavity after 120C 48h air baking
T=2K
Q_0
1E+11
1E+10
1E+09
0
10
20
30
40
50
60
70
80
90
100
110
120
130
B_p (mT)

Electropolishing

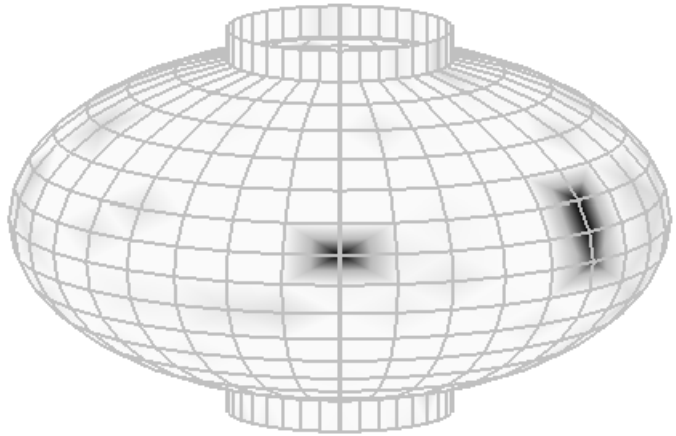
Single cell:3 hrs, 20 Amp, Voltage control

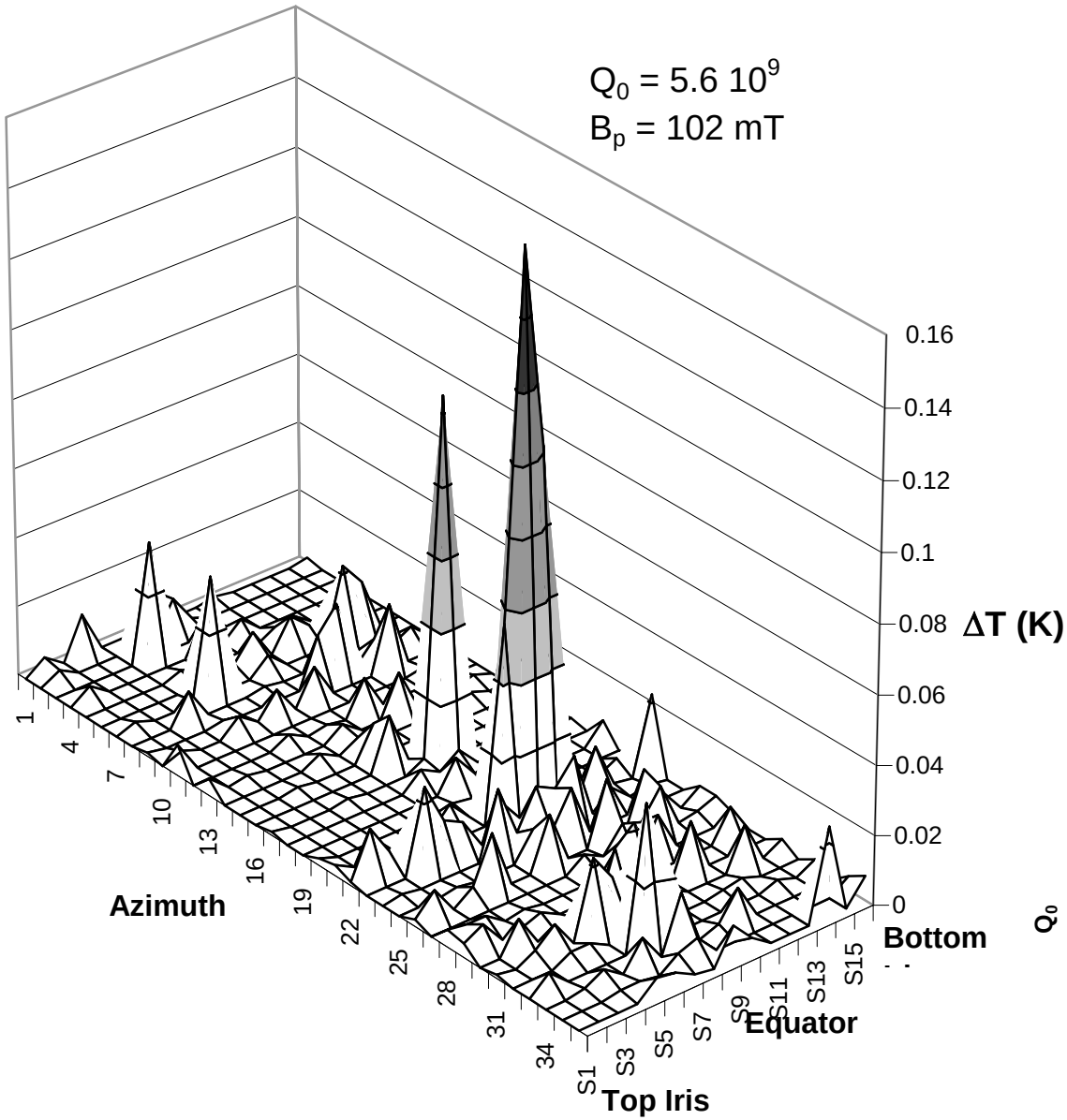


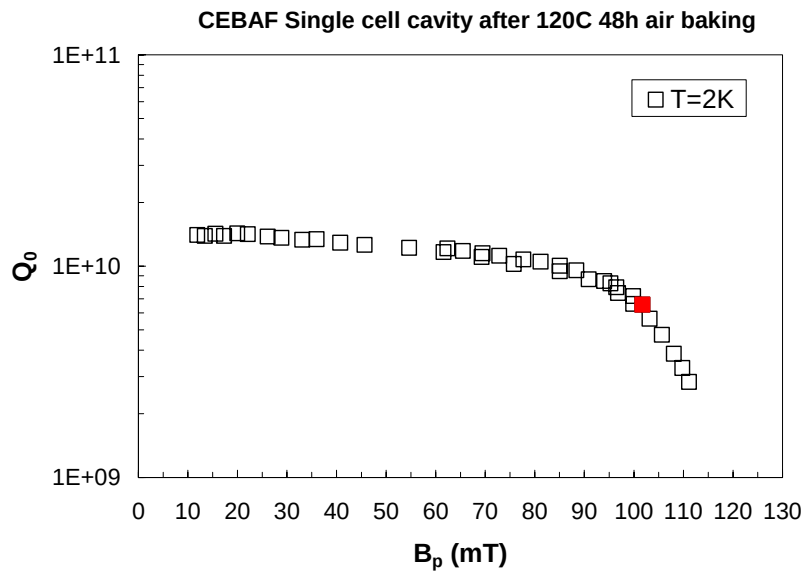


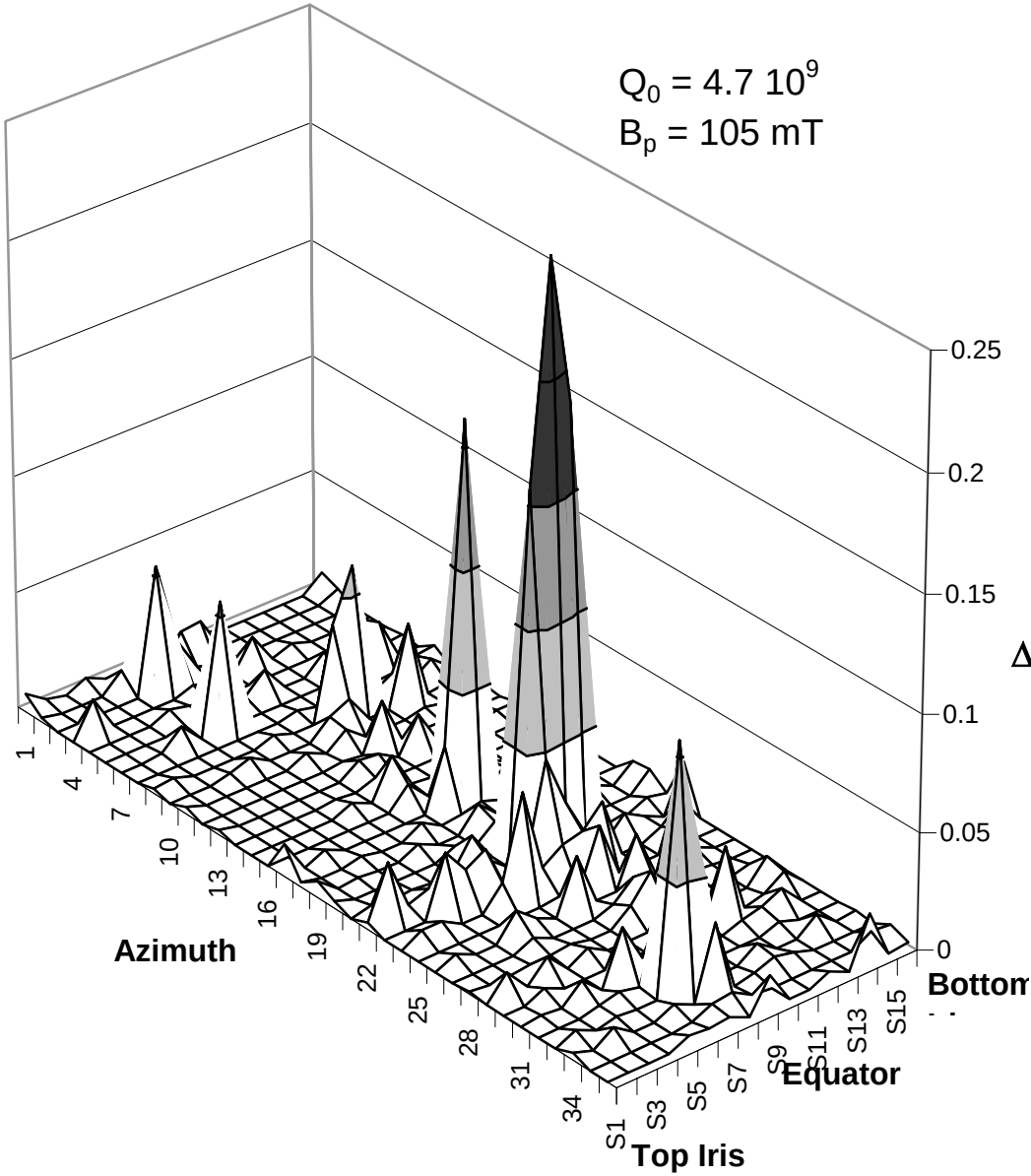
$Q_0 = 5.6\ 10^9$

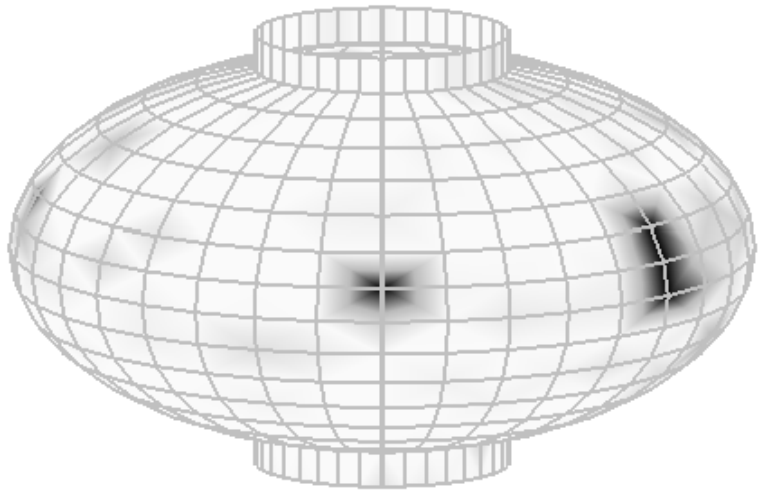
$B_p = 102$ mT

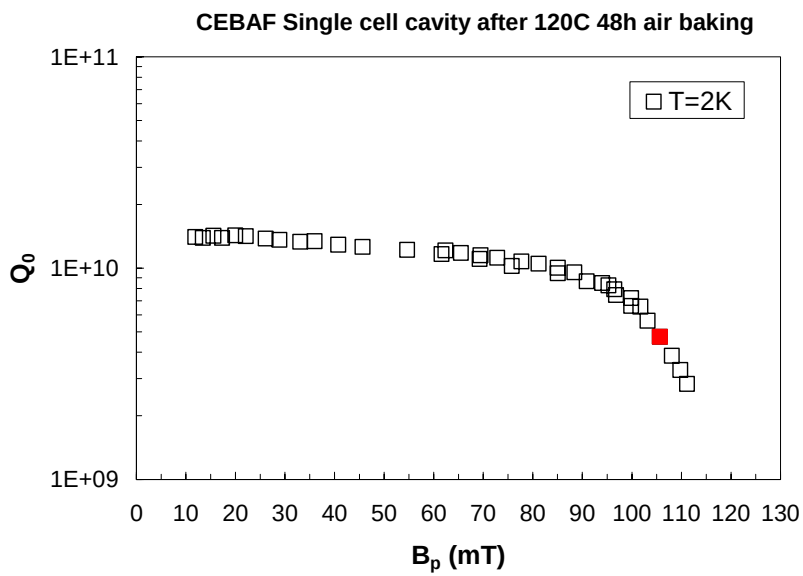


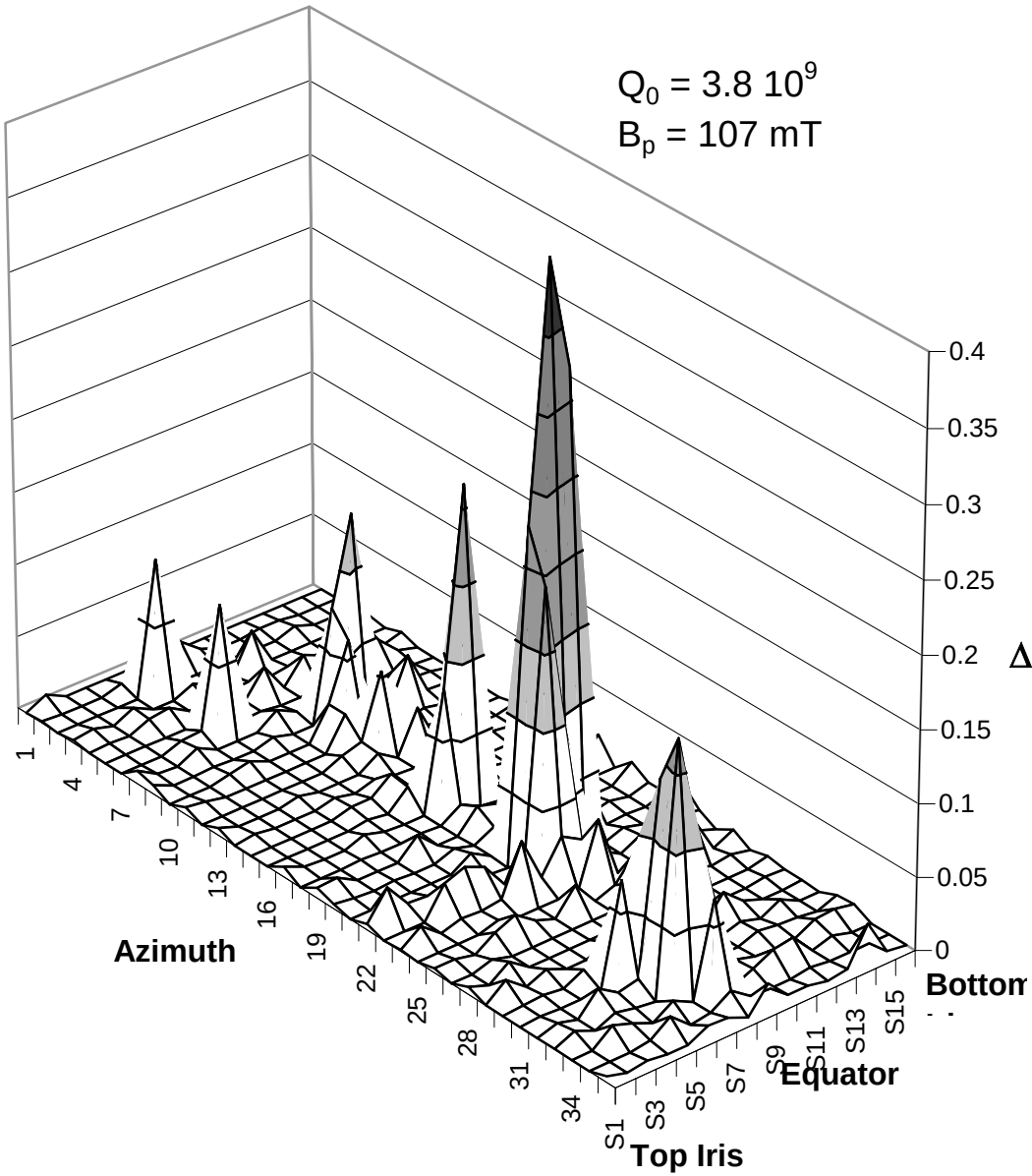


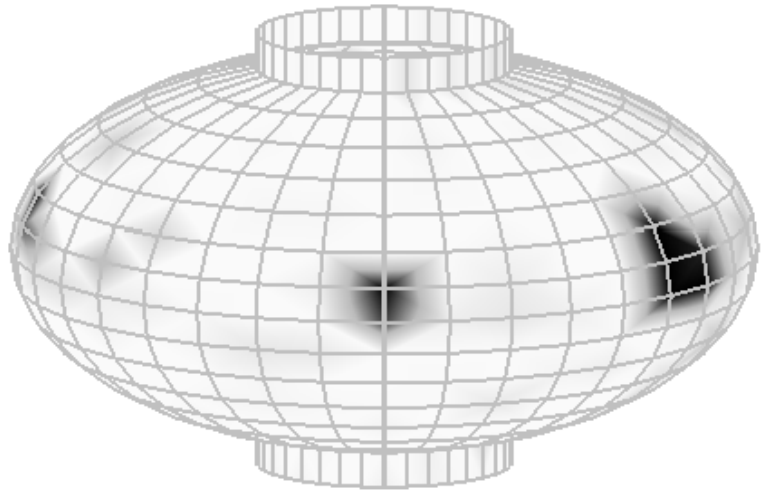


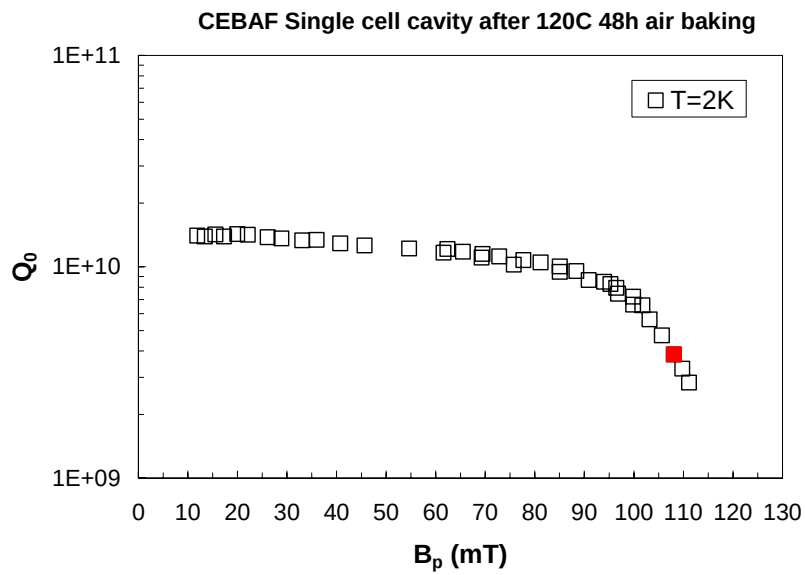

$Q_0 = 4.7\ 10^9$
$B_p = 105$ mT
0.25
0.2
0.15
0.1
0.05
0
ΔT (K)
Azimuth
1
4
7
10
13
16
19
22
25
28
31
34
Equator
S1
S3
S5
S7
S9
S11
S13
S15
Bottom
Top Iris

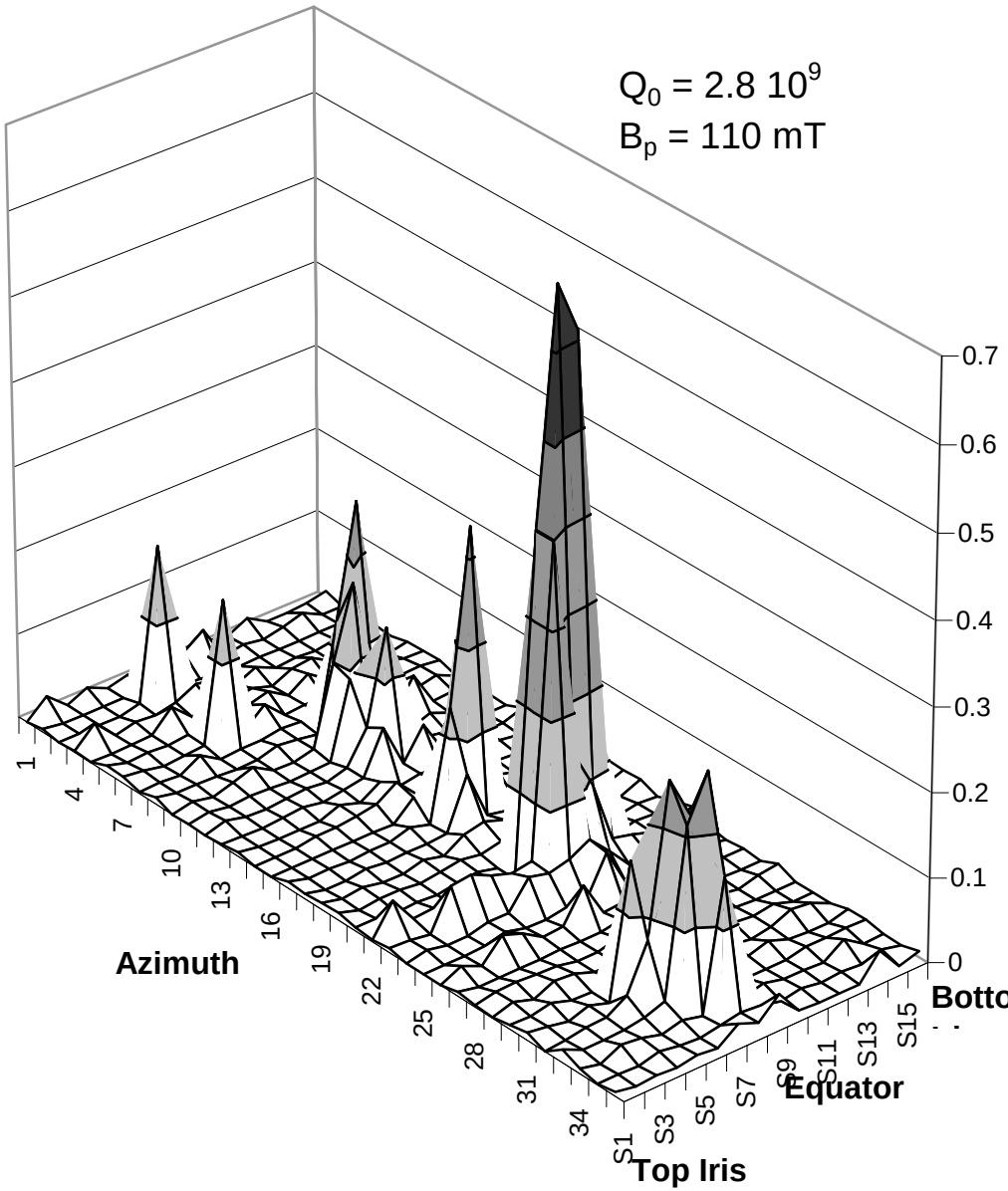


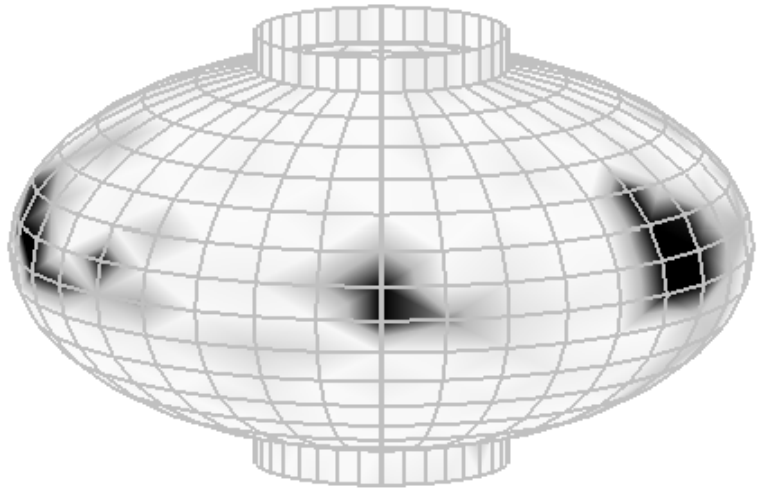

CEBAF Single cell cavity after 120C 48h air baking
T=2K
1E+11
1E+10
1E+09
Q_0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
B_p (mT)

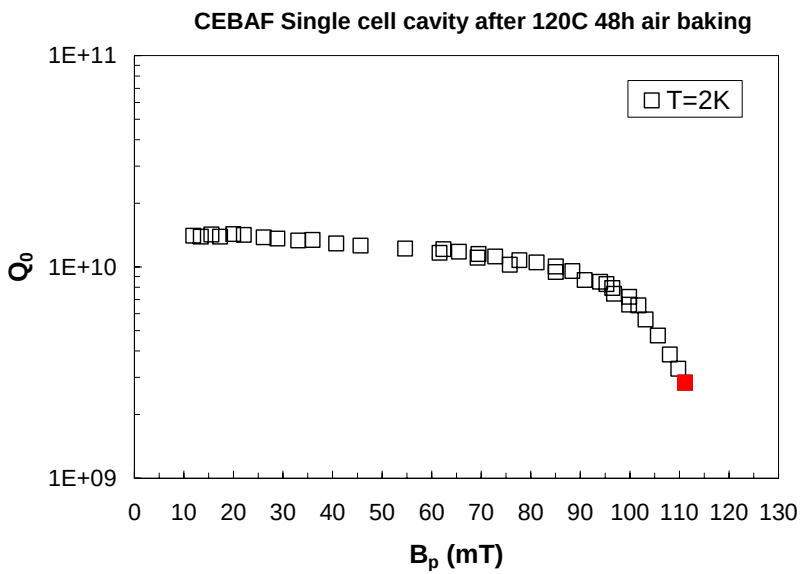

$Q_0 = 3.8\ 10^9$
$B_p = 107$ mT
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
ΔT (K)
Azimuth
1
4
7
10
13
16
19
22
25
28
31
34
Equator
S1
S3
S5
S7
S9
S11
S13
S15
Top Iris
Bottom




CEBAF Single cell cavity after 120C 48h air baking
T=2K
Q_0
1E+11
1E+10
1E+09
0
10
20
30
40
50
60
70
80
90
100
110
120
130
B_p (mT)


$Q_0 = 2.8\ 10^9$
$B_p = 110$ mT
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ΔT (K)
Azimuth
1
4
7
10
13
16
19
22
25
28
31
34
Top Iris
S1
S3
S5
S7
S9
S11
S13
S15
Equator
Bottom




CEBAF Single cell cavity after 120C 48h air baking
T=2K
1E+11
1E+10
1E+09
Q_0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
B_p (mT)

Q-drop: recent observations

- Q-drop is most likely a magnetic field effect
- Heating observed near equator with T-maps
- Is the electron beam weld/contaminated area around weld responsible? (oxide clusters, reduced H_c)
- Elimination of grain boundaries does not eliminate Q – drop, but seem to shift it to larger H_{peak}
- At higher frequencies Q-drop seems to start at higher H_{peak}
- "In situ" baking of EP and BCP cavities reduces Q-drop
- Optimal baking conditions for single crystal/large grain material might need to be adjusted (sometimes increase in R_{res})