HOM calculations and cavity measurements.

1. Cavity modeling.

1.1. Cavity HFSS calculations of the model with all couplers.

1.2. Single and double full size Cu cavity HOM measurements.

1.3. Analysis of the calculations and measurements.

2. 3 cell cavity tuning and cold tests.

3. Nb 9cell cavity RF QC during and after production.

3.1. Half cells and Dumbbells RF QC.

3.2. Incoming RF QC.	1 day
3.2. Main RF tuning after basic (80 micron) BCP.	4 days
3.3 Final RF QC on dressed cavity.	1 day

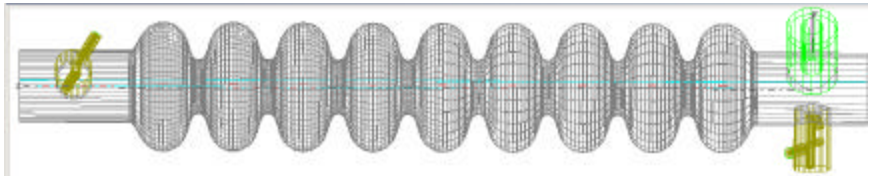
4. Cold tests.

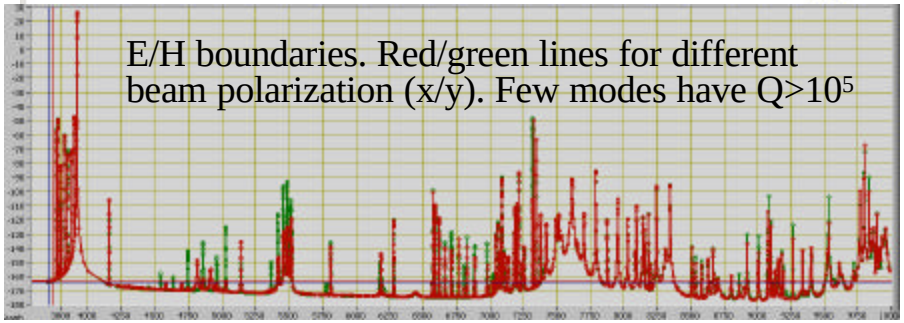
4.1. Vertical tests, Q vs. T (design Q>2e9 at 1.8K), Q vs. E (E_{acc}>15 MV/m)	4 days
4.1. Horizontal test.	4 days

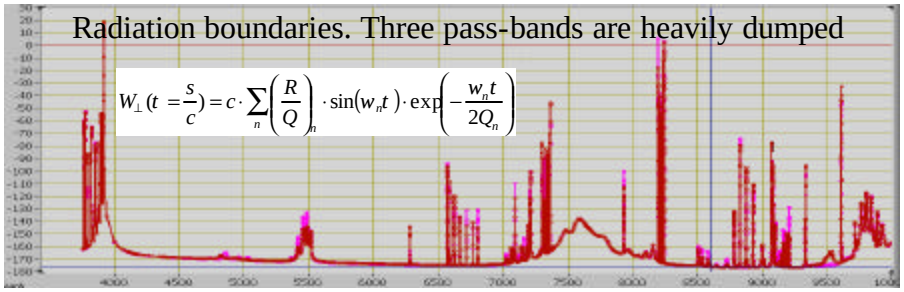
Cavity HFSS calculations of the model with all couplers.

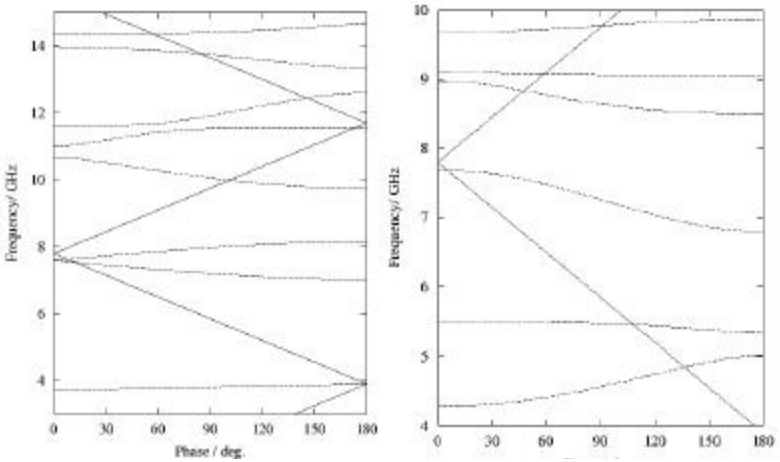
HFSS 3D 9 cells cavity model with:
- 2 High Order Mode (HOM) couplers,
- matched Main coupler port,
- different type of beam pipe terminations,
- distributed and phased current sources.

Calculations in driven mode.

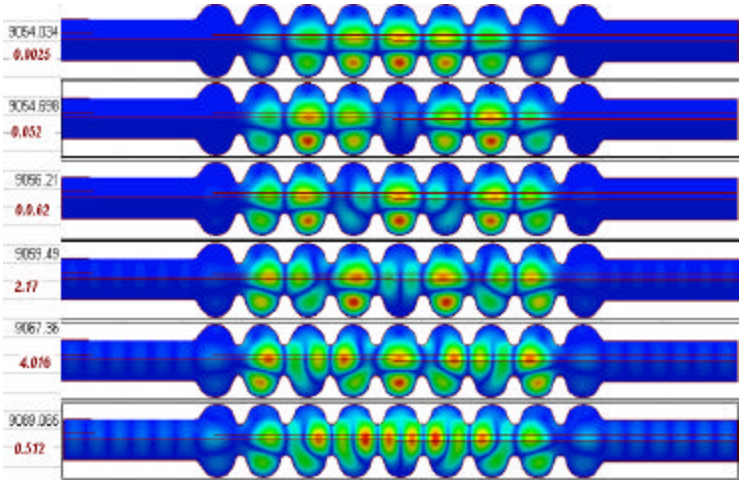








Monopole(left) and Dipole (right) passbands for mid-cell of the 3rd harmonic cavity



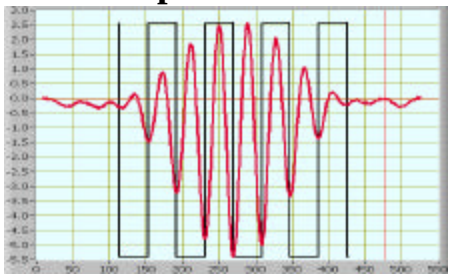
Trapped modes in 5th dipole passband

Single and double full size Cu cavity HOM measurements.

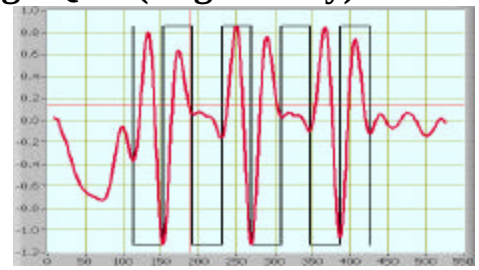
9 cells Cu cavity measurements with:
- 2 High Order Mode (HOM) couplers,
- Main coupler port with matched termination,
- Beam pipes with metal plates,
- Excitation and pick-up from different ports.

Bead-pull and S-parameter measurements for single cavity and double cavity system.

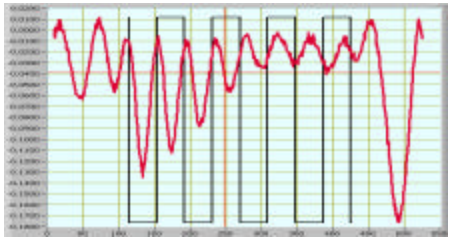
Dipole modes with high Qext (single cavity).



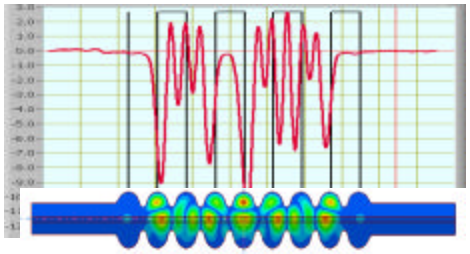
2-nd dipole band “Pi” mode.
F=5325.2 MHz. Q=14000.



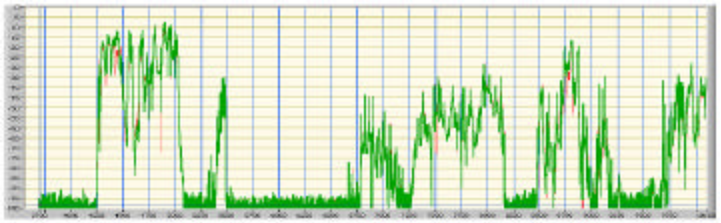
2-nd dipole band “6/9Pi” mode.
F=5418.7 MHz. Q=11600.



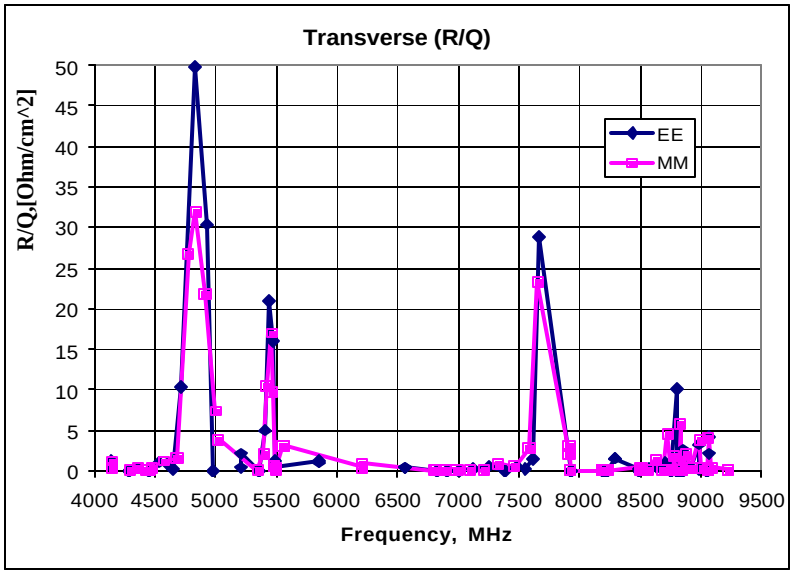
1st dipole band.
F=4979.6 MHz. Q=2200

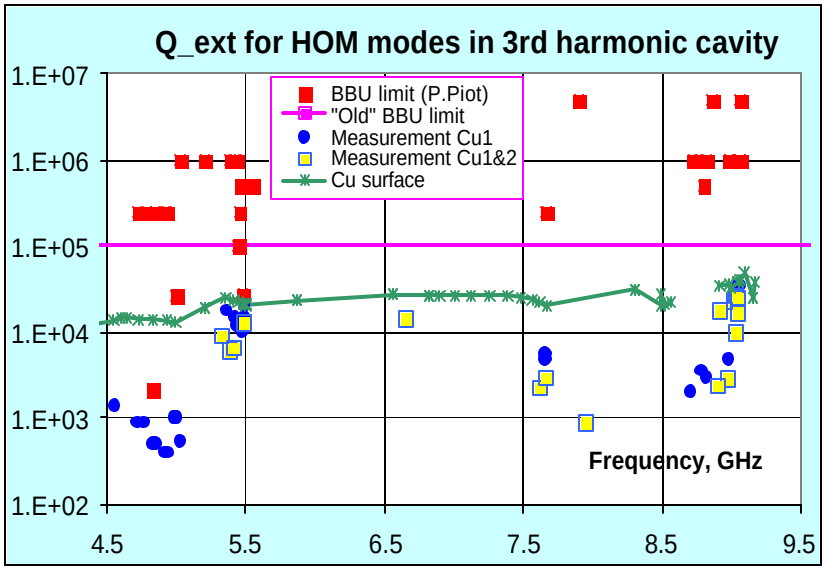


5-th dipole band.F=9029.1 MHz. Q=32000.



Analysis of the calculations and measurements.





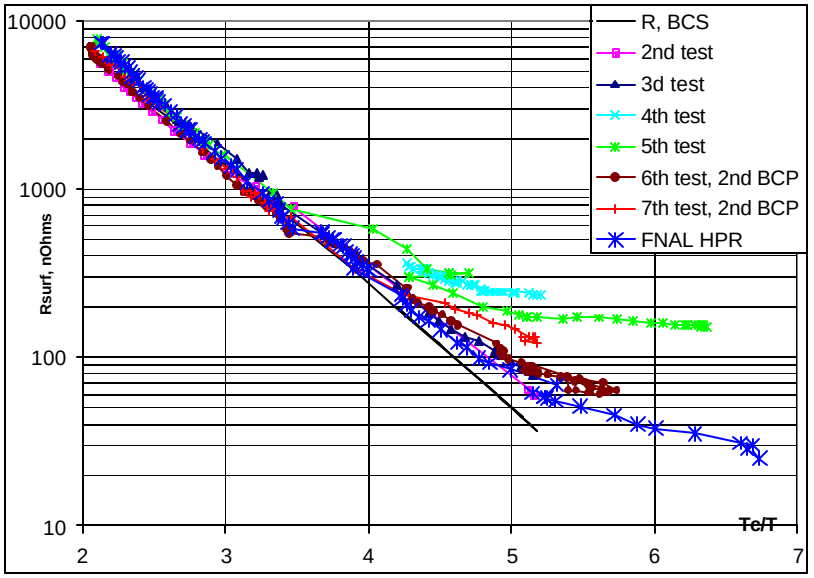
Calculated R/Q (above) and measured Q-value for the dipole modes in a single Cu cavity (blue) or string of two cavities (yellow). Red markers show upper limit for Q, calculated from BBU instability. Measured Q-value is limited by Cu surface resistance (green).

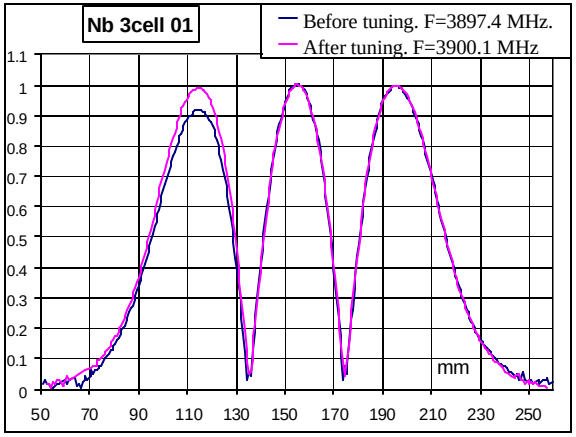
Summary of HOM studies

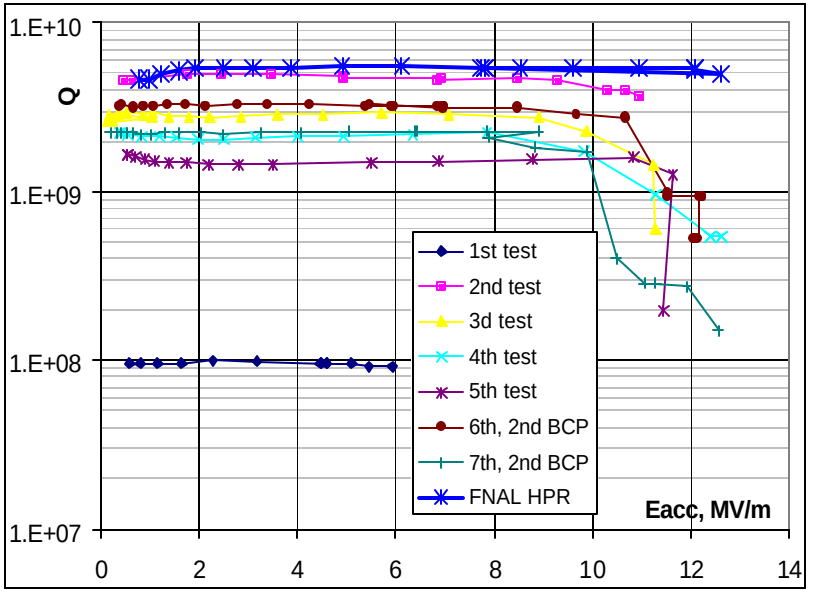
- ✓ 1st passband – No problem. High R/Q, but all modes are dumped well below BBU limit.
- ✓ 2nd – No problem. Only pi-mode has high Q, but low R/Q.
- ✓ 3rd – No problem. Dumped well below of the limit
- ✓ 4th – No problem. Low R/Q and good damping.
- ✓ 5th – Narrow band. Modes are really trapped in cavity (see picture), but most of them have low R/Q. Distribution very sensitive to errors in cell dimensions.

3 cell cavity tuning and cold tests.

- Tuning of the cavity to 3.9 GHz. 1st cold test before BCP.
- External 20µm BCP. Internal 20 µm BCP. Heat treatment 10 hours at 600°C.
- Internal 83µm BCP. High pressure rinsing (HPR) with 1200 psi for 15 min.
- 2nd cold test. Rres=40 nOhms. Eacc=11.5 MV/m. Field emission (X-rays).
- 3rd cold test. Rres=70 nOhms. Eacc=11.5 MV/m. Field emission (X-rays).
- 4th cold test. Rres=200 nOhms. Eacc=12 MV/m. Field emission (X-rays). Degradation of the surface resistance indicates surface cleanness problem.
- 5th cold test. Rres=140 nOhms. Eacc=12 MV/m. Field emission (X-rays).
- Additional internal BCP and HPR at JLAB.
- 6th cold test. Rres=50 nOhms. Eacc=12 MV/m. Field emission (X-rays).
- 7th cold test. Rres=120 nOhms. Eacc=12 MV/m. Field emission (X-rays).
- 8th cold test after 2h HPR at FNAL. Rres=20 nOhms. Eacc=12.5 MV/m. No field emission (X-rays).

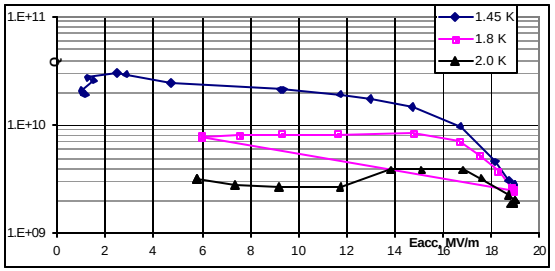


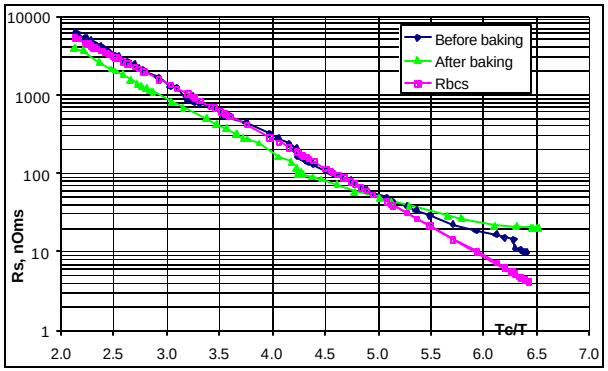




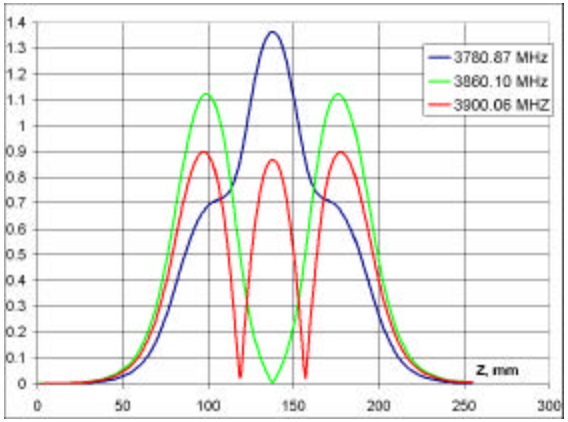
3 cell cavity tuning and cold tests.

In multiple cold tests, after HPR at FNAL more than 2 hours, Rres < 20 nOhms, Eacc=19MV/m and Bmax=105 mT repeatedly achieved.

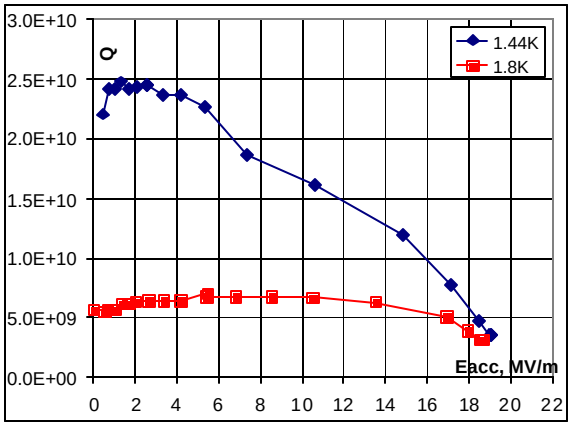




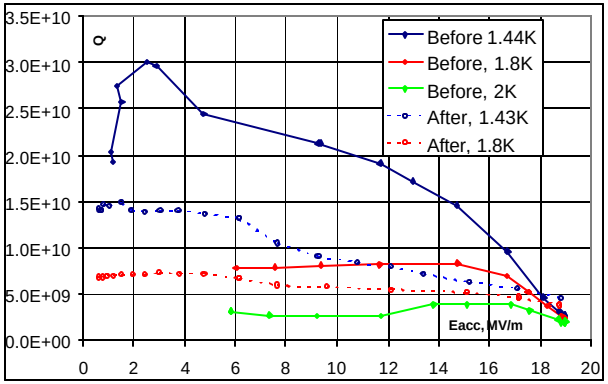
2005.03.31. BCS part after backing lower. Residual part after backing higher.



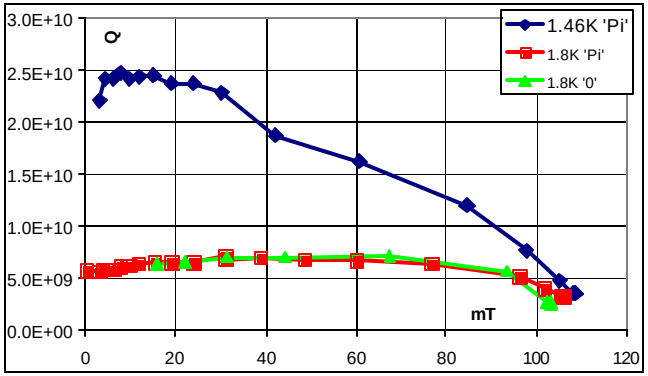
Electric field in cavity axes.



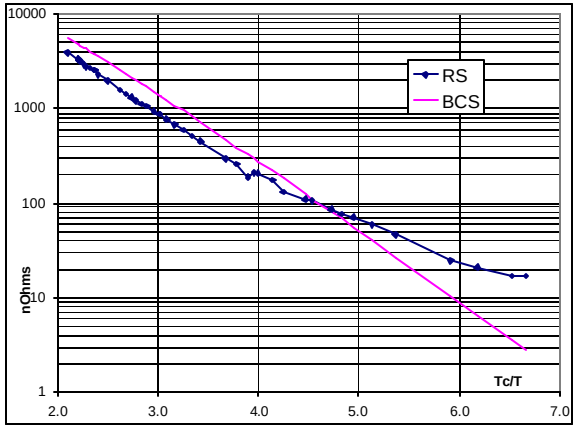
2005.09.08 test. 1.46K test done first. 1.8K test without multipacting and X-rays.



2005.03.31. Q vs E for before and after baking.



2005.09.08. Surface magnetic field. “0” and “Pi” modes.



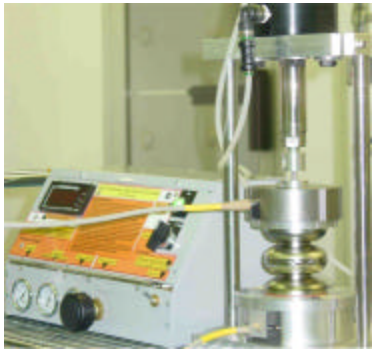
2005.09.30 test. Rres=14 nOhms.

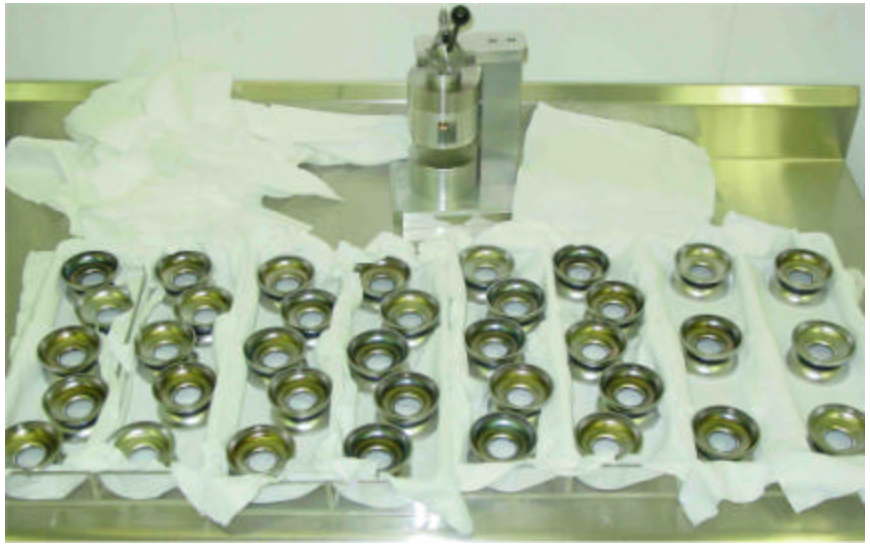
History of the 3-cell accelerator cavity.

Where	BCP	HT	HPWR	Test Date	Test results
FNAL	No	No	No	01/21/04	Rres = 2000nW Ea=5.6 MV/m; Hpk(p /0)~30/60 mT
JLAB 02/25/04	Extrn~20mm Int ~140mm	2hrs@500 C 10hrs@600C	JLAB 15'@2 loc	03/17/04 04/19/04	Rres=60nW → 200nW (after FE) Ea=11.5 MV/m; Hpk =60mT; Heavy X-ray
JLAB 06/10/04	Intern: ~30 mm	No	JLAB 30'@3 loc	07/02/04 07/19/04	Rres =70nW→130nW (after HG) E=12.5 MV/m, Hpk(pi/0)=70/110mT; X-ray
FNAL 10/10/04	No	No	~1 hrs, movable	10/14/04	R_res=60 nW, E=12.8 MV/m, No X-ray
JLAB 10/26/04	Intern: 20mm	No	JLAB 90'@7 loc	11/10/04 12/16/04	E= 5MV/m – vacuum leak E=15MV/m coupler problem
FNAL 01/30 /05	Internal: ~5mm	No	~2hrs movable	02/08/05 02/21/05	R_res=6 nW, E=19MV/m, Hpk=105mT, No X-ray
FNAL 05/25/05	No	48hrs@120C	No	03/31/05	R_res = 16 nW, E=19MV/m, Hpk=105mT, No X-ray
ANL 06/01/05	1:1:2 12min(15C)	No	FNAL ~2.5hrs	06/09/05	R_res= 58 nW, E=12MV/m, Hpk(pi/0)=62/104mT; X-ray
FNAL 06/25/05	No → (HPWR 3hrs after BCP) →	No	~6.5 hrs movable	07/05/05	R_res=10nW, E~19MV/m, No X-ray

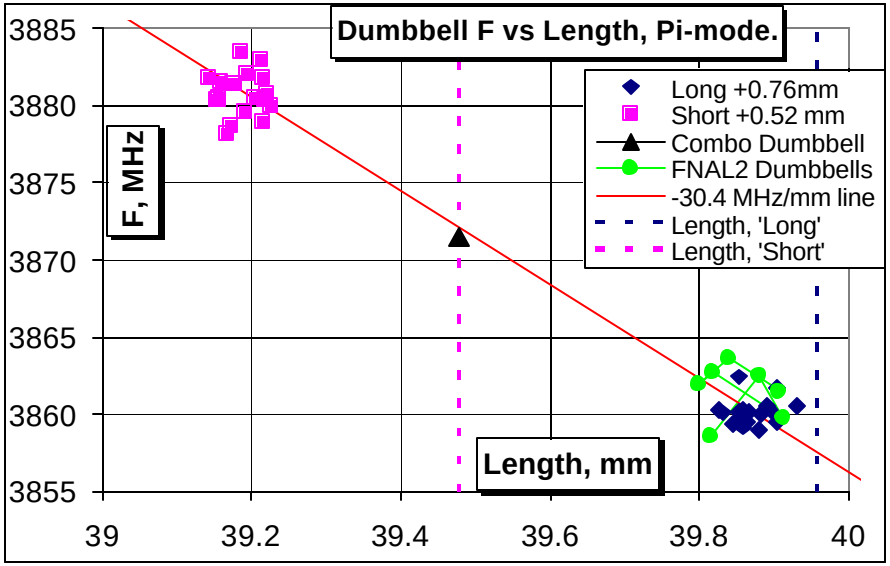
Half cells and dumbbells RF QC.

RF QC sequence:
- Half cells frequency measurements
- Trim before welding if dF>5MHz.
- Dumbbell F_0 and F_{pi} measurements.
- Trim to make equator end flat.
- F_0 and F_{pi} measurements.
- Final trim.

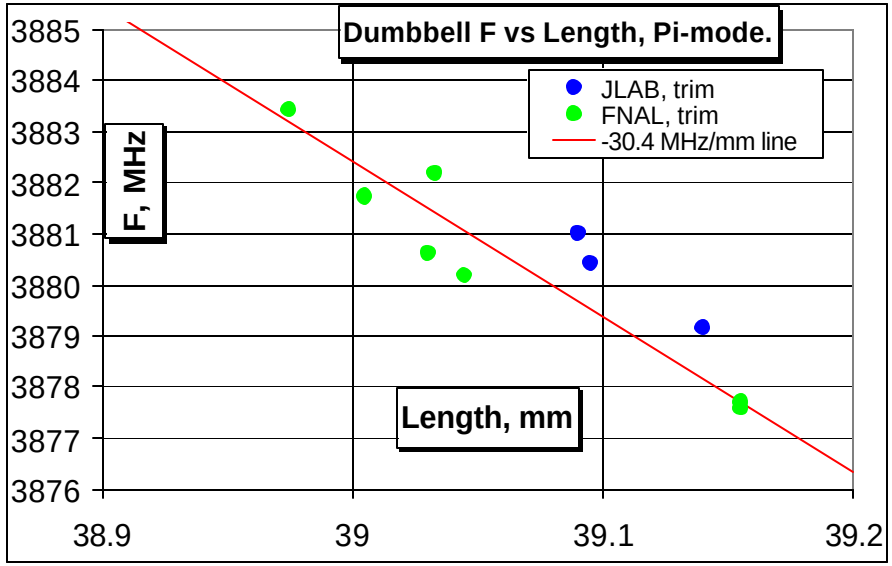




36 JLAB Dumbbells.



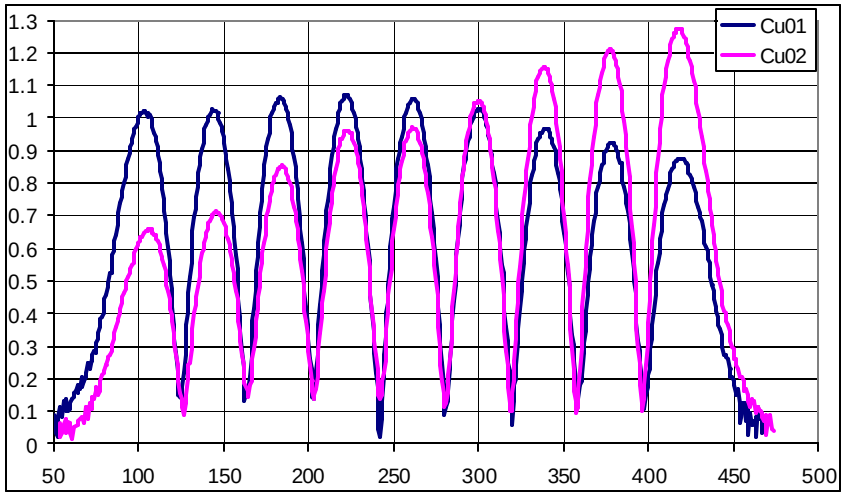
7 FNAL and 36 JLAB Dumbbells after welding. dF<5 MHz



7 FNAL and 3 JLAB Dumbbells after trim.

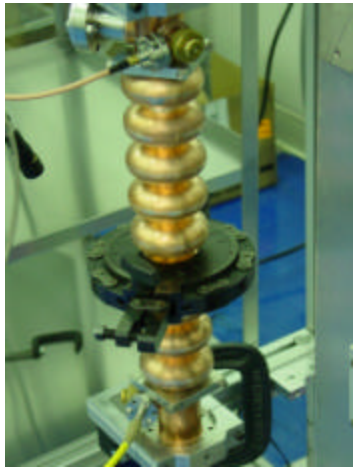
Cavity tuning.

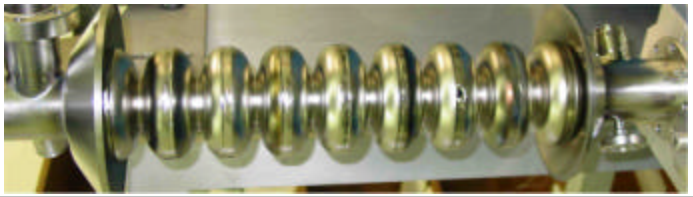
2 Cu 9cell cavities tuned. For Nb cavities F0=3900-7.5(cool+vac.)+13(BCP)=3905.5 MHz – expected cavity room temperature frequency before BCP.

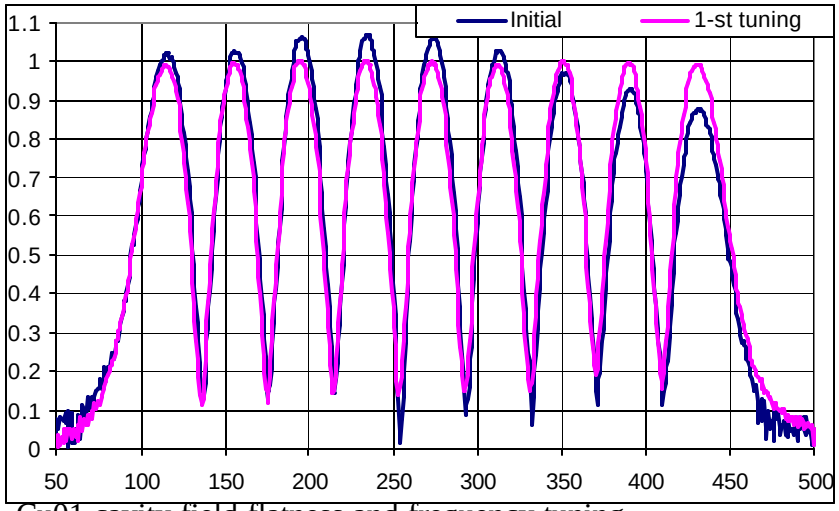


Cu01. F=3895.41 MHz. Cu02. F=3908.99 MHz. After brazing

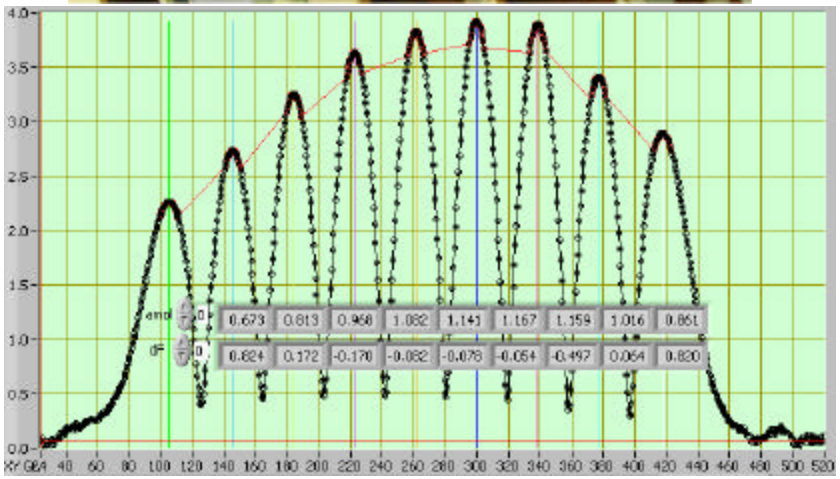
Tuning tools.







Cu01 cavity field flatness and frequency tuning.



Cell N=7, with hole, about 4 MHz higher frequency.