R&D Cavity Testing and ILC Cavity Fabrication at Jlab

Peter Kneisel and Gianluigi Ciovati

Jlab

- Recent Single cell results with large grain niobium from CBMM, Heraeus, Ningxia
- Results from an investigation of influence of grain size on cavity performance
- Results from T-mapping tests with an anodized cavity to investigate “Q-drop”
- Status of 9-cell cavity fabrication

Evaluation of material from different vendors

Manufacturer	Ta Contents	RRR
CBMM	~800 ppm	~ 280
W.C.Heraeus	< 500 ppm	500
Ningxia	< 100 ppm	330

Fabrication and Treatment

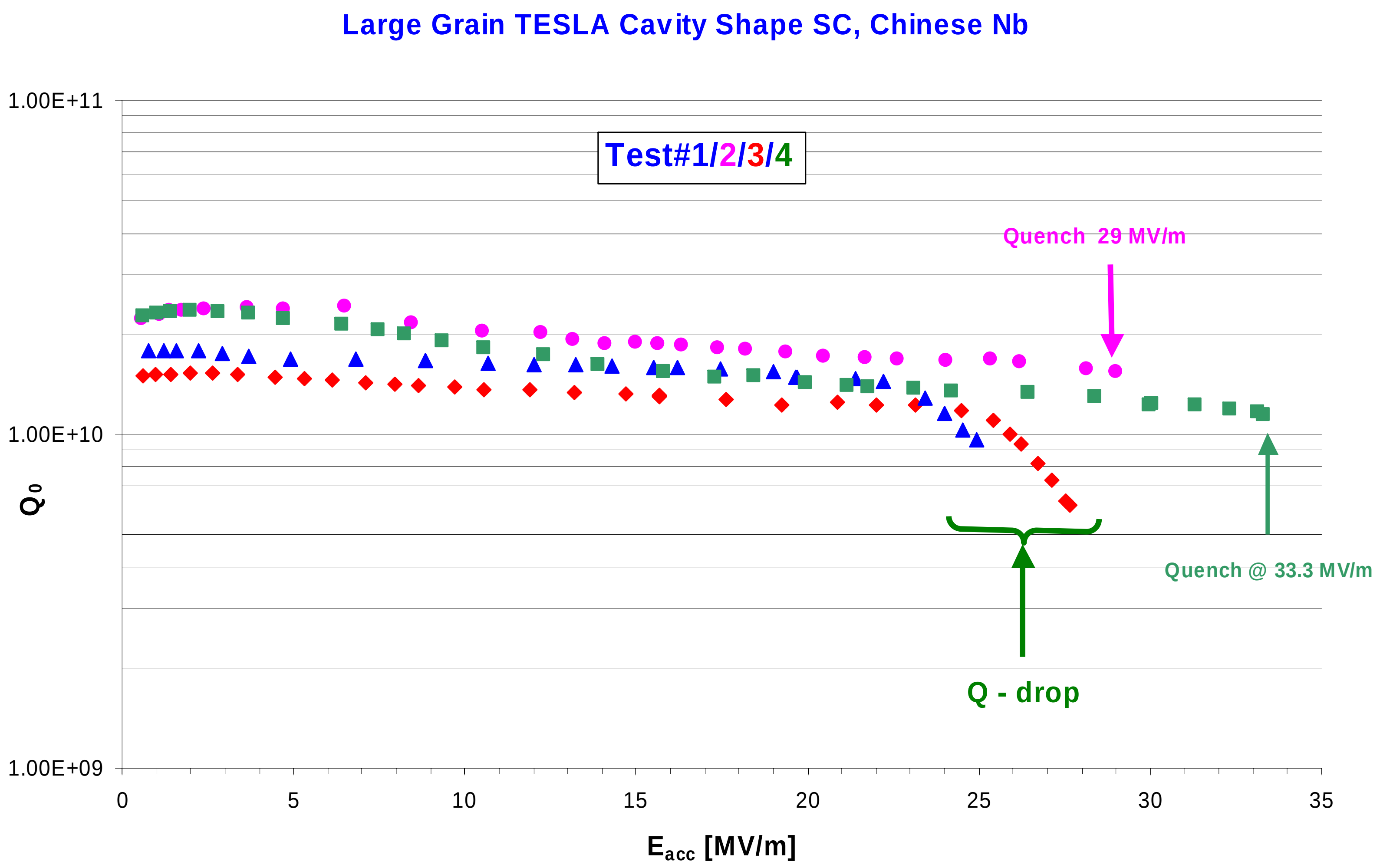
Fabrication

- Standard deep drawing after cutting of sheets (wire EDM/CBMM, saw cut/Ningxia, diamond saw/Heraeus)
- Machining
- Welding of beam pipes to half cell
- Mechanical grinding
- Equator weld

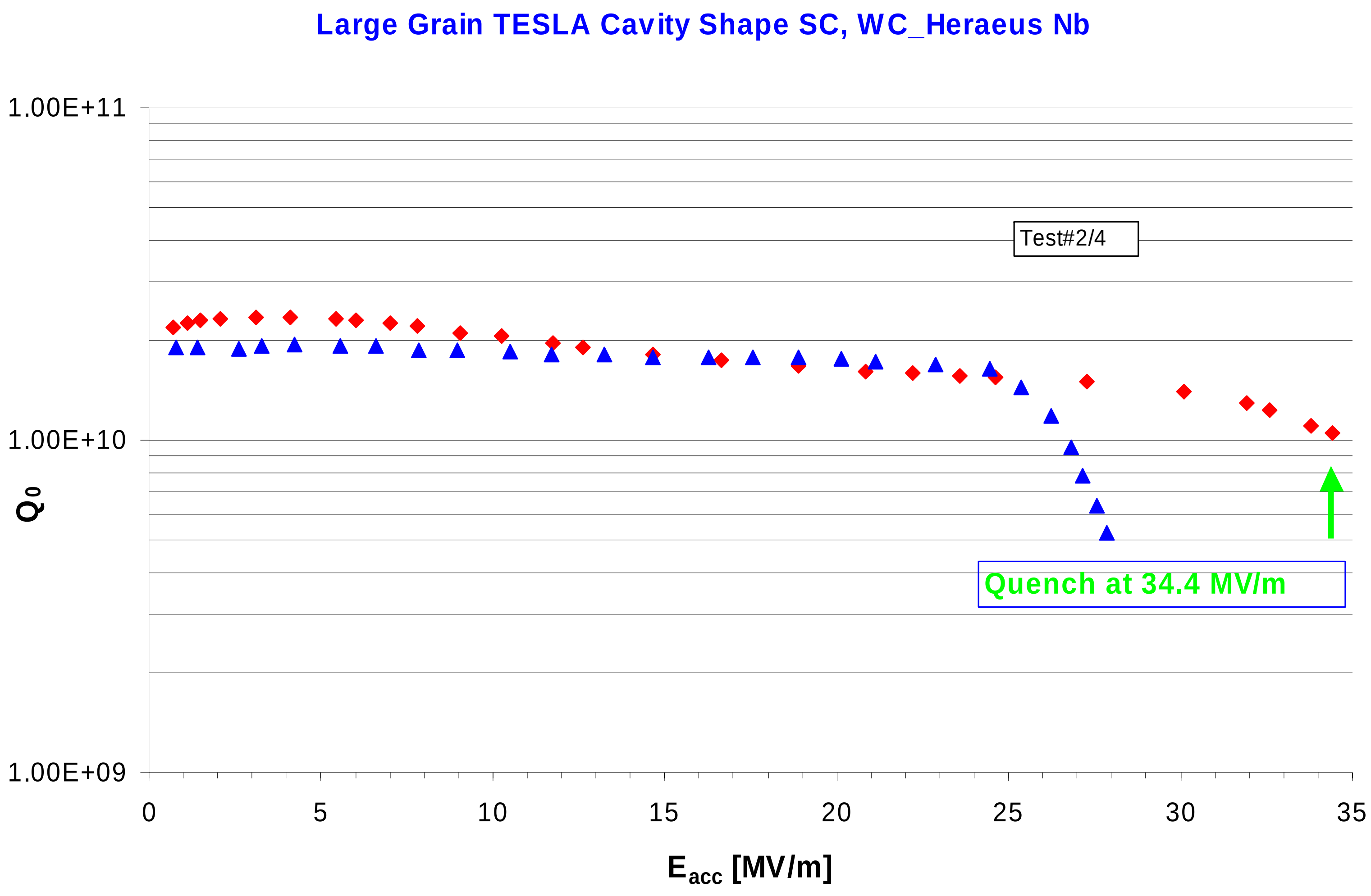
Surface Treatment

- ~ 50 micron bcp
- Hydrogen degassing at 600C for 10 hrs
- ~ 50 micron bcp, Test #1
- 12 hrs "in situ" baking at 120C for 12 hrs, Test #2
- 1200 C, 3 hrs post-purification with Ti
- ~ 50 micron bcp, Test #3
- 12 hrs "in situ" baking at 120C for 12 hrs,Test #4

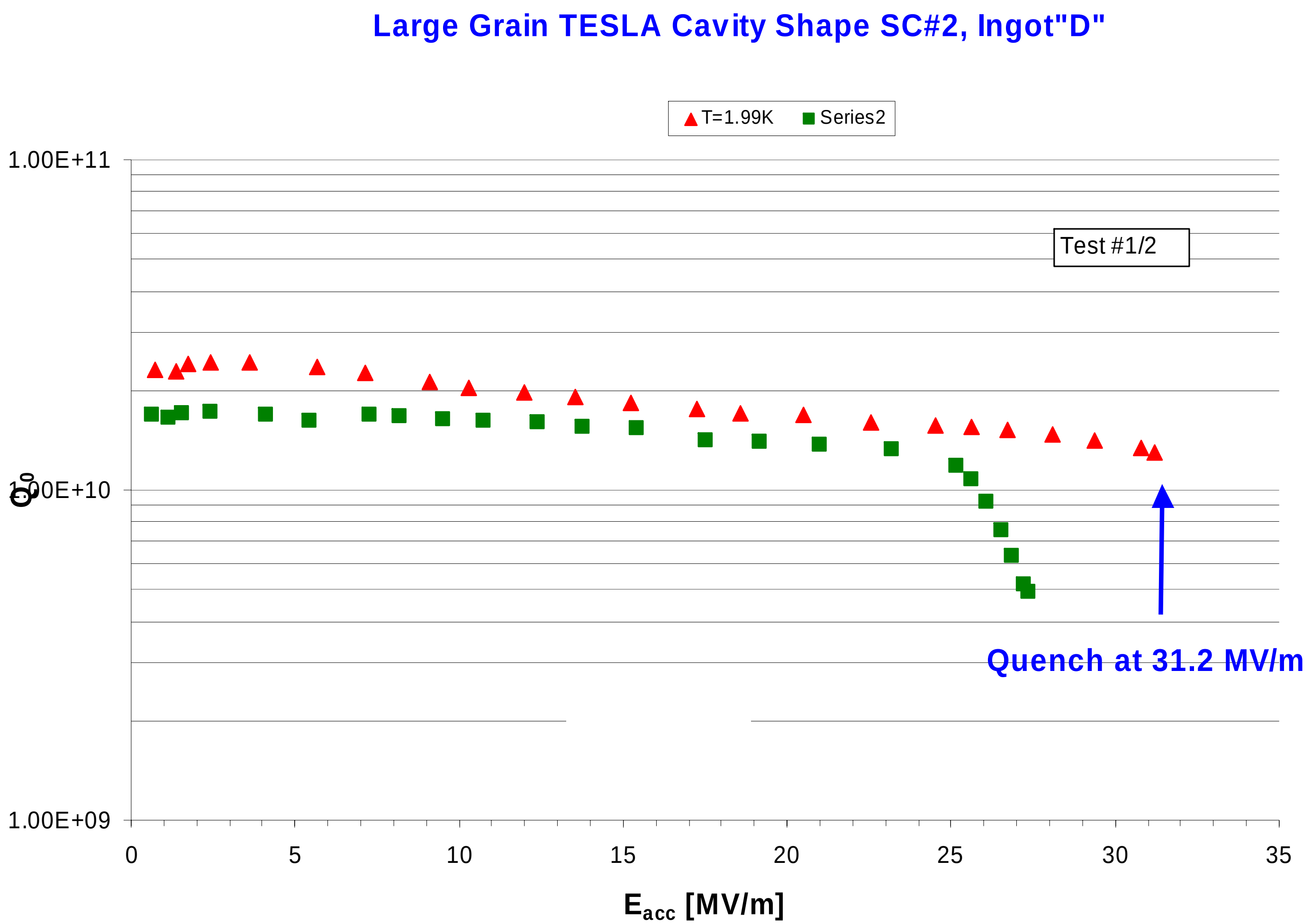
Ningxia Large Grain Nb



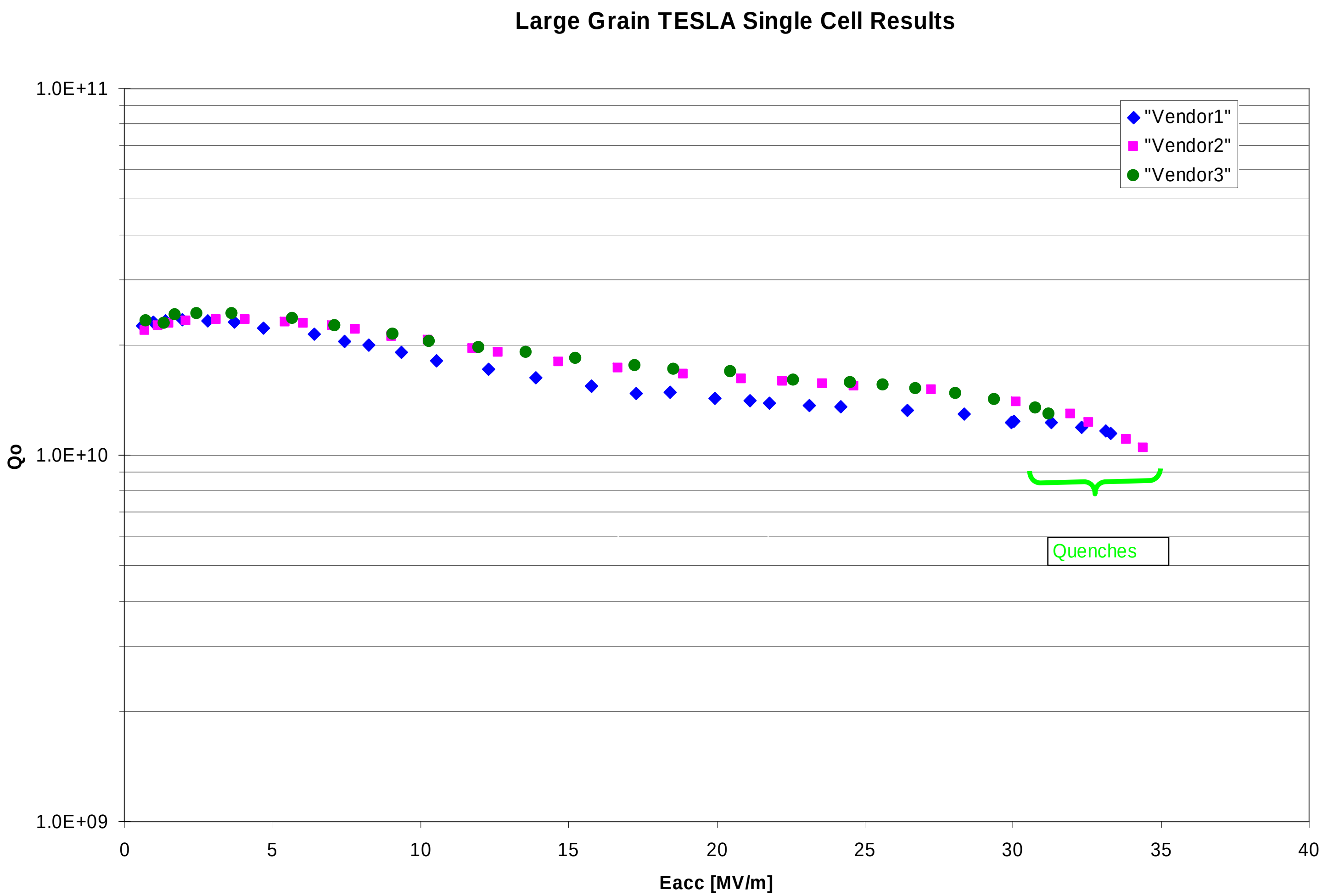
W.C.Heraeus Large Grain Nb



CBMM Large Grain Ingot"D"



Summary(1)



Large Grain TESLA Single Cell Results
1.0E+11
1.0E+10
1.0E+09
Qo
0
5
10
15
20
25
30
35
40
Eacc [MV/m]
"Vendor1"
"Vendor2"
"Vendor3"
Quenches

Summary (2)

- Materials with different properties (RRR,Ta..) and prepared by different cutting methods behaved very similar after BCP only
- It is not clear yet, what the important features for best performance are
- There is a significant price difference in the different materials
- We are going to fabricate 5 single cell cavities each from Ningxia and W.C.Heraeus material to get some statistics
- These materials have been ordered
- The 9-cell cavities for FNAL are being fabricated from CBMM large grain niobium

Multi-Cells

- We have fabricated a 7-cell ILC_LL shape cavity without stiffening rings
- We encountered difficulties in room temperature tuning and could tune the cavity to only ~ 75% of field flatness

- Initial tests gave gradients of ~ 20 MV/m (flat profile assumed), limited by rf power
- Stiffening rings are added to the structure
- A 7-cell HG cavity was fabricated from CBMM ingot”B”

  and is being evaluated. In initial test insufficient material was removed after fabrication and performance was mediocre.

Grain Size Dependence

- There has been a suspicion for some time that grain boundaries can contribute to performance limitations in niobium cavities
- We fabricated 4 single cell cavities of the TESLA shape scaled to 2.2 GHz
    - Single crystal from CBMM material (Ta 800 ppm, RRR~280)
    - Poly-crystalline from standard Wah Chang niobium (Ta < 500 ppm,RRR>300)
    - Two large grain (grain size ~ cm^2) cavities from Wah Chang ingot-top and bottom (Ta < 500 ppm,RRR>300)
- All cavities were tested before and after post-purification and before and after "in-situ" baking. Only BCP was applied

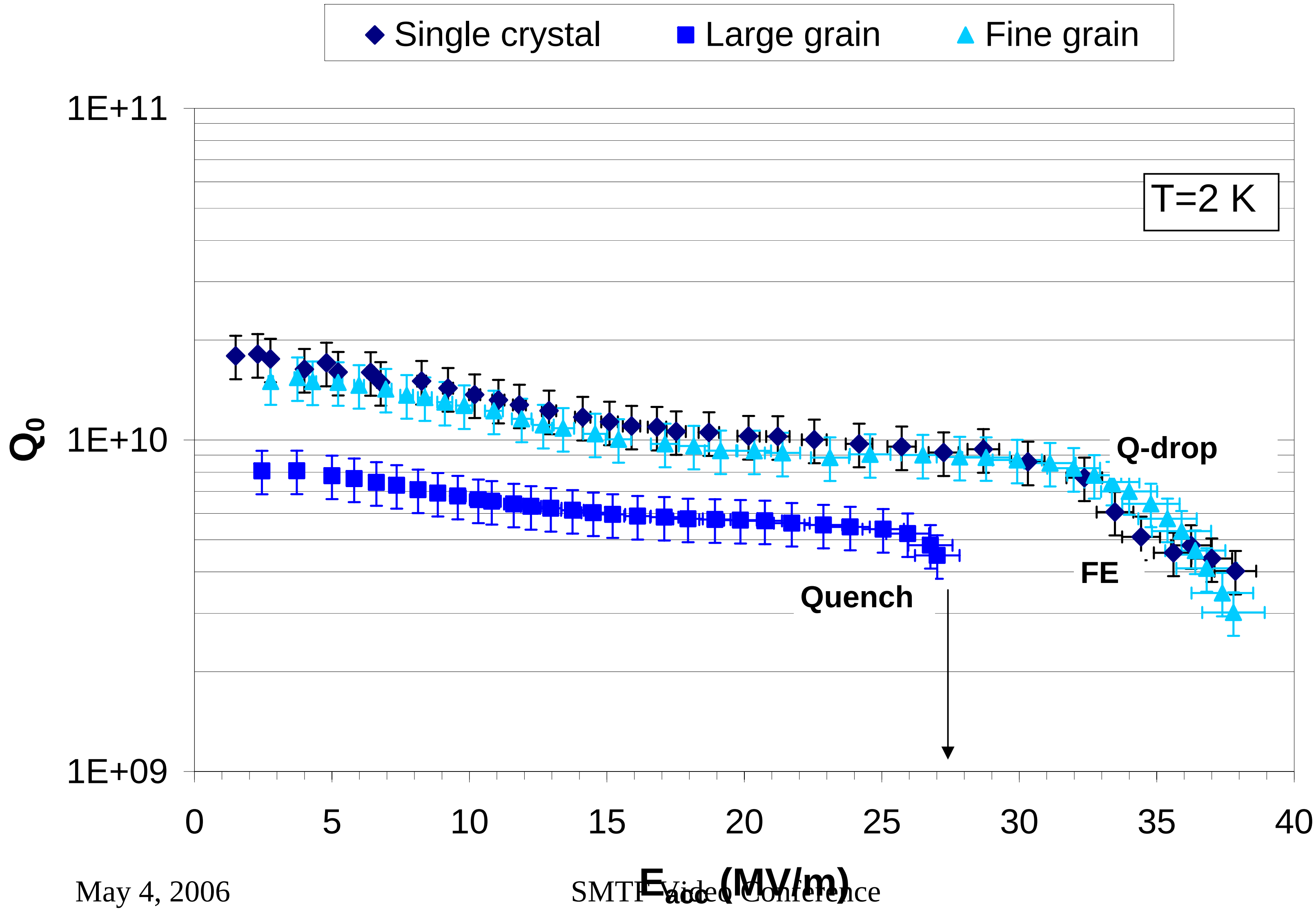
Cavity shape: HG scaled to 2.26 GHz

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

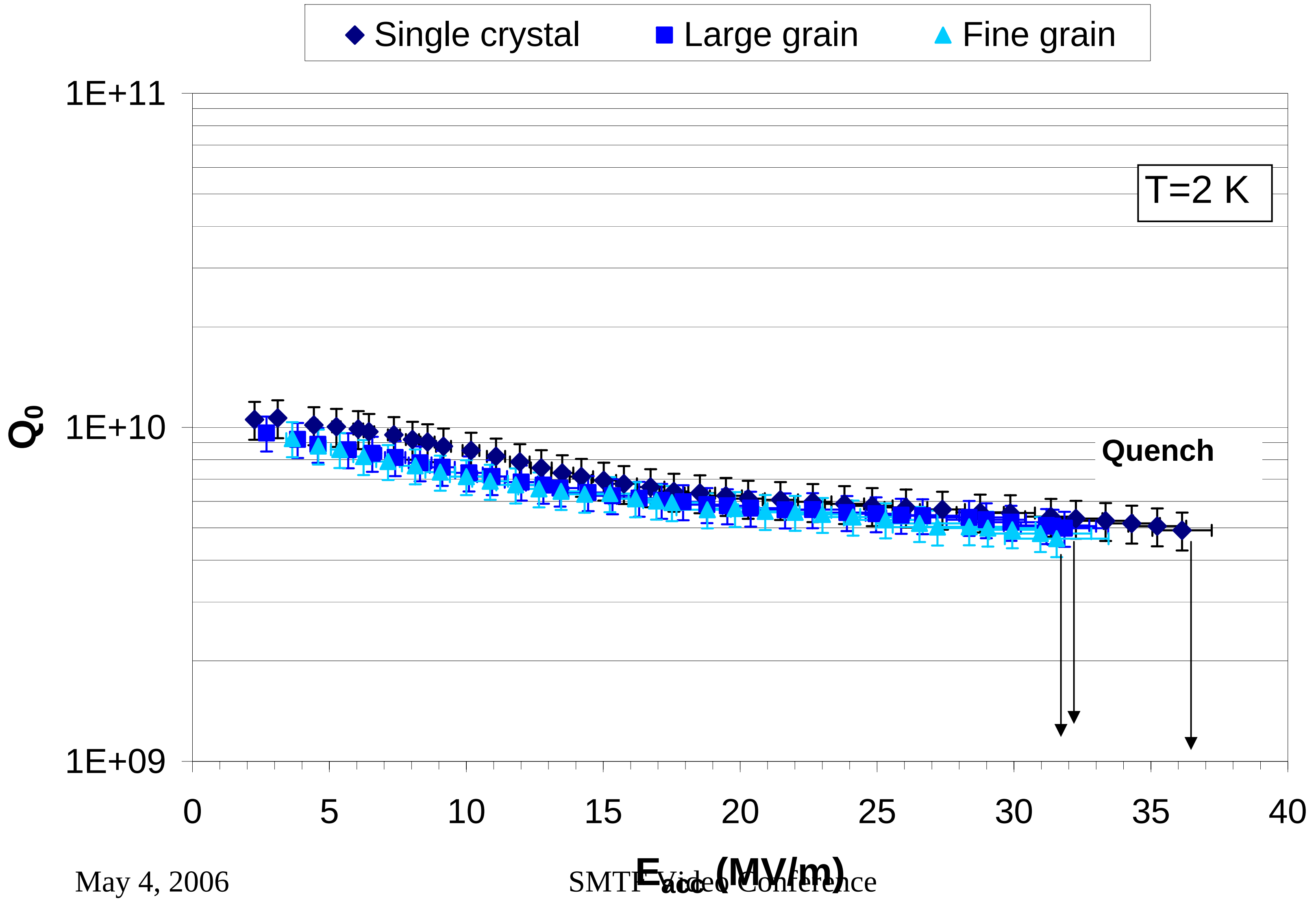
$B_{peak}/E_{acc} = 4.286$ mT/(MV/m)

$G = 270\ \Omega$

Q_0 vs. E_{acc} after 120 °C baking



Q_0 vs. E_{acc} after post-purification and baking



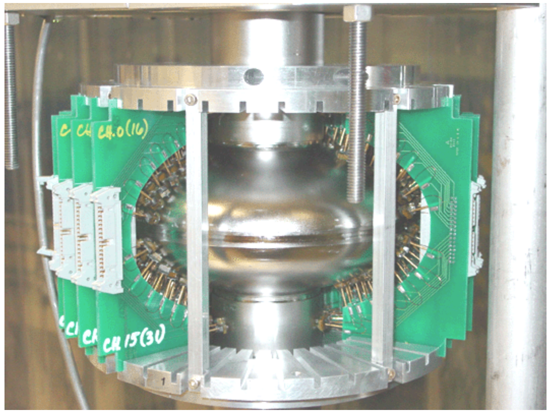
Conclusions

- No clear dependence of cavity performance to grain size was observed before post-purification
- After post-purification, the single crystal cavity clearly achieved the best performance
- The 2 large grain cavities behaved very consistently with each other but
  - R_{res} was higher than typically observed on other large grain cavities
  - they did not achieve higher fields than the fine grain one
- Baking works best in recovering from Q-drop in large grain/single crystal cavities treated by BCP than for fine grain ones
- It is not clear yet, which property of the material is important for best performance (grain size,impurity content, RRR…

Anodizing Tests: Understanding the "Q-drop"

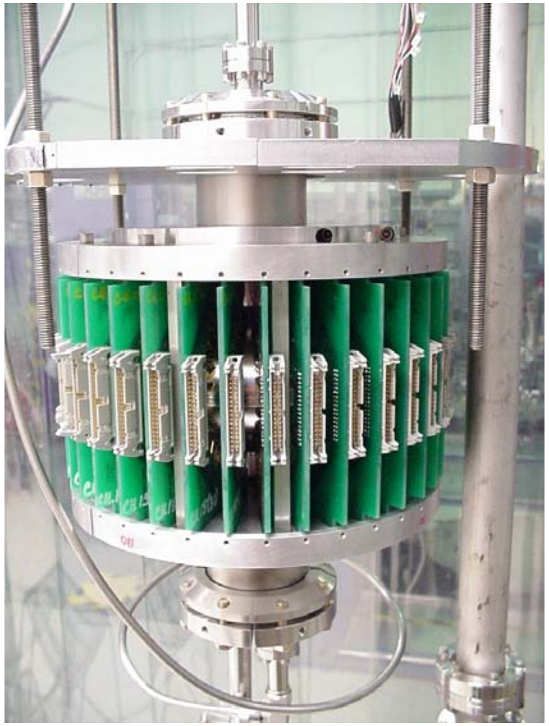
- Initial report about such tests with a large grain cavity from Chinese niobium given at Frascati meeting:
  - "Q-drop" free Q vs E_{acc} performance (BCP only) turned into Q-drop after anodization of ~ 40 nm
  - Recovery from Q-drop after "in-situ" baking for 12 hrs at 120C
  - This behaviour was reproducible
  - Material parameters such as Δ/kT_C and mean free path as well as residual resistance were changing with treatment
- This test series was repeated with T-mapping on the same cavity

Experimental setup



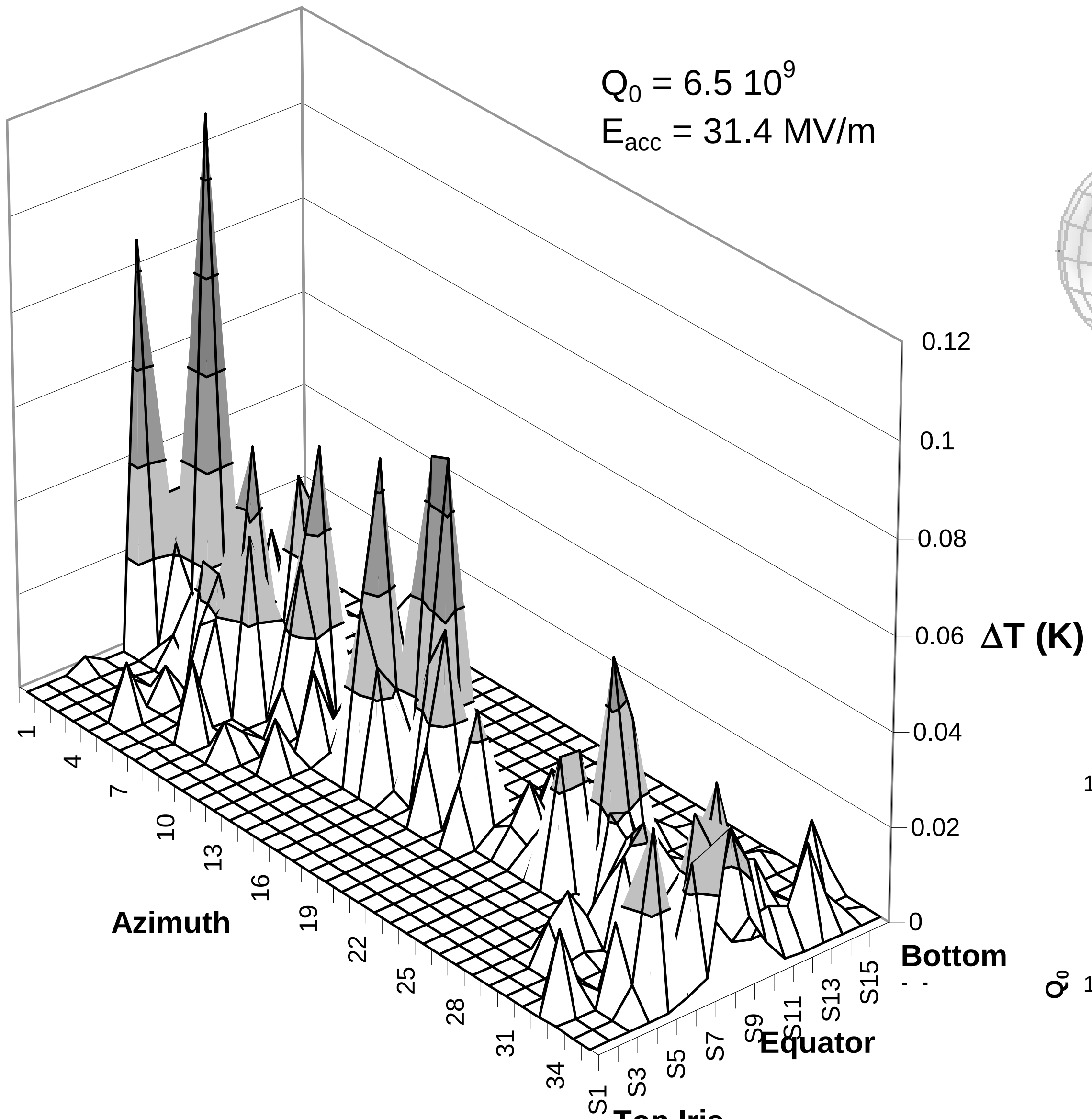
16 x 36 Carbon-resistors

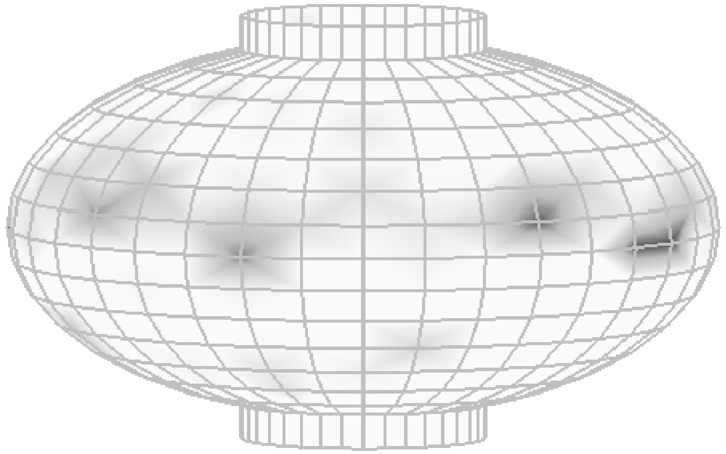
Allen-Bradley, 100Ω–1/8W

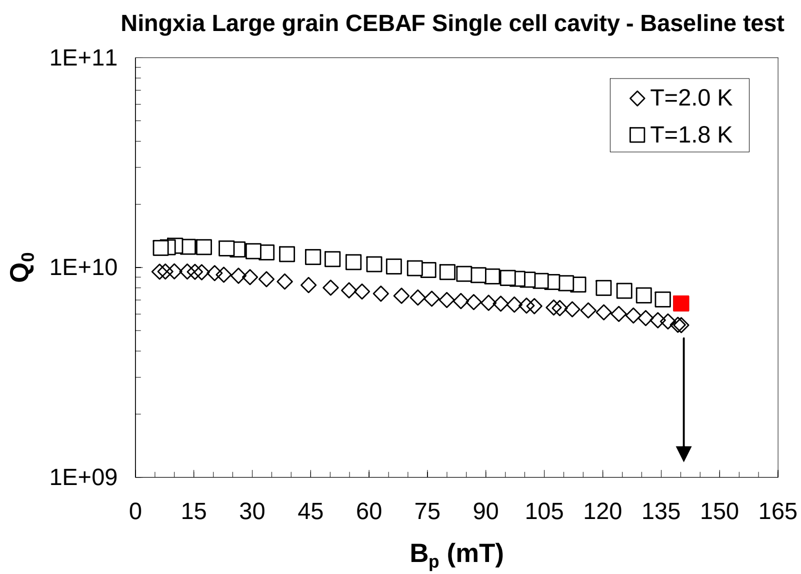


- Cavity made from Ningxia (RRR~330, Ta content ≤ 100 ppm), Nb sheets were saw-cut from the ingot
- Cavity shape: OC CEBAF, 1.476 GHz

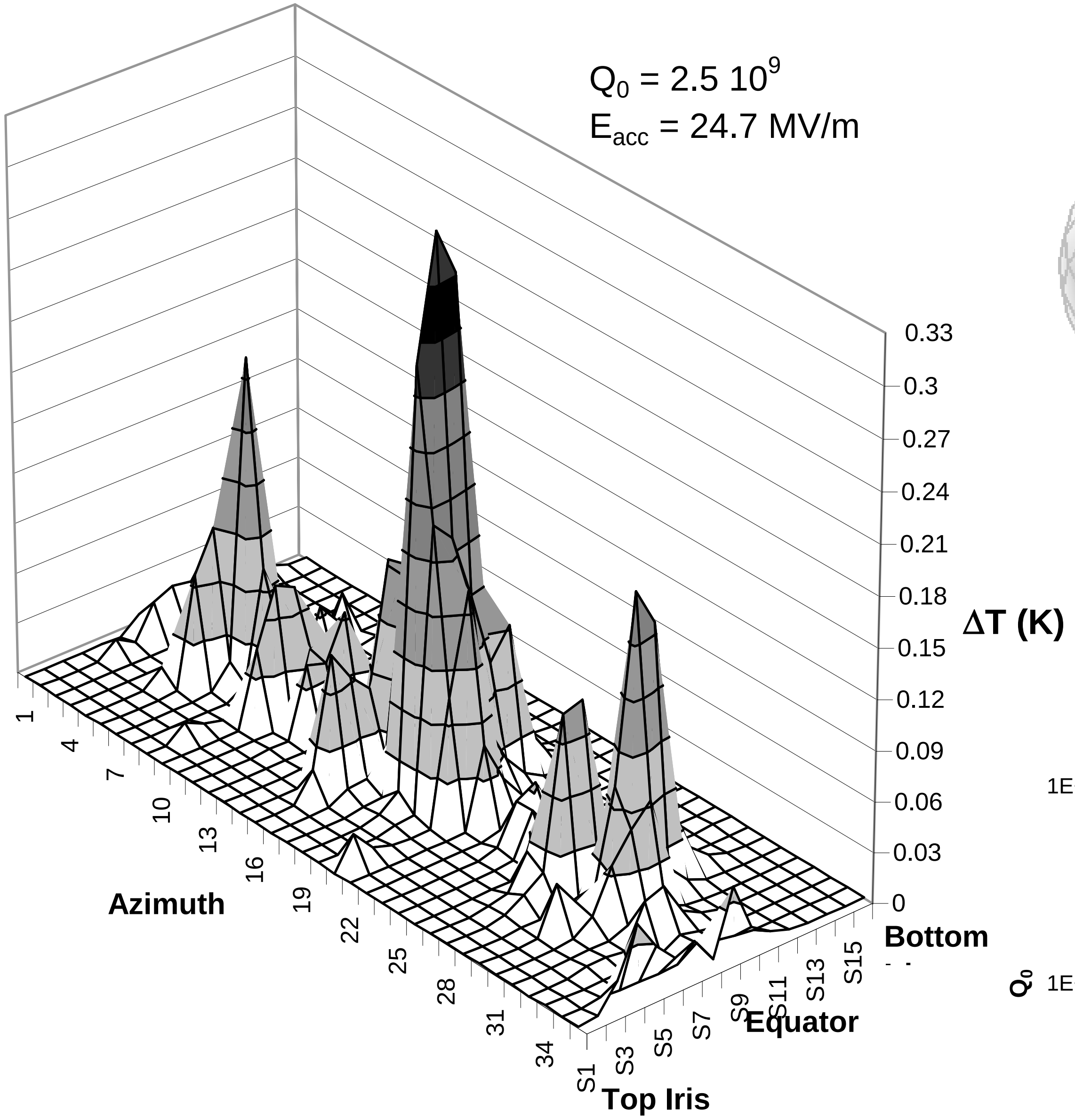
Before Anodization



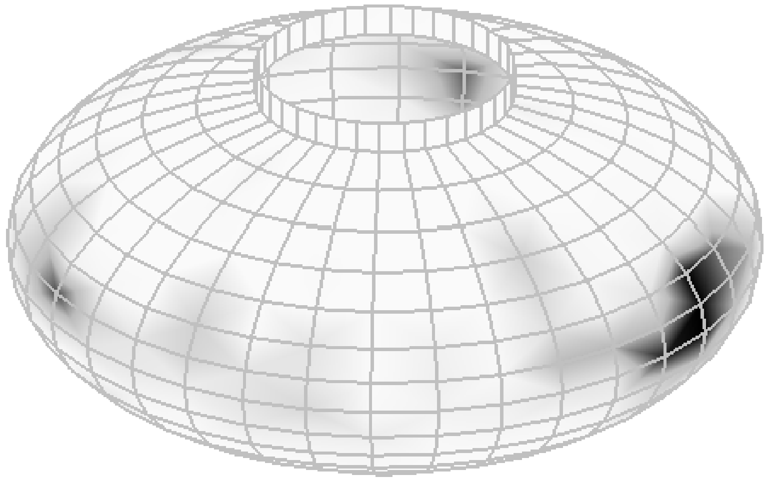


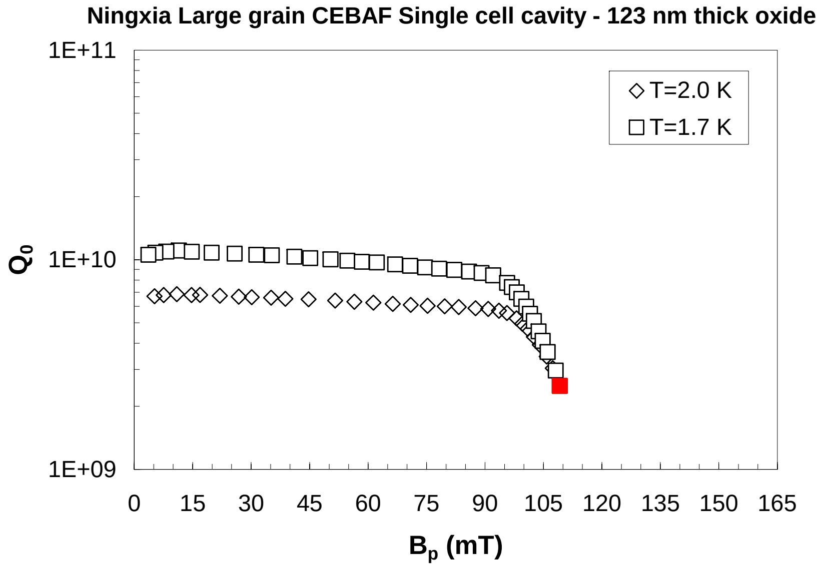


Quench in the region around #150-8

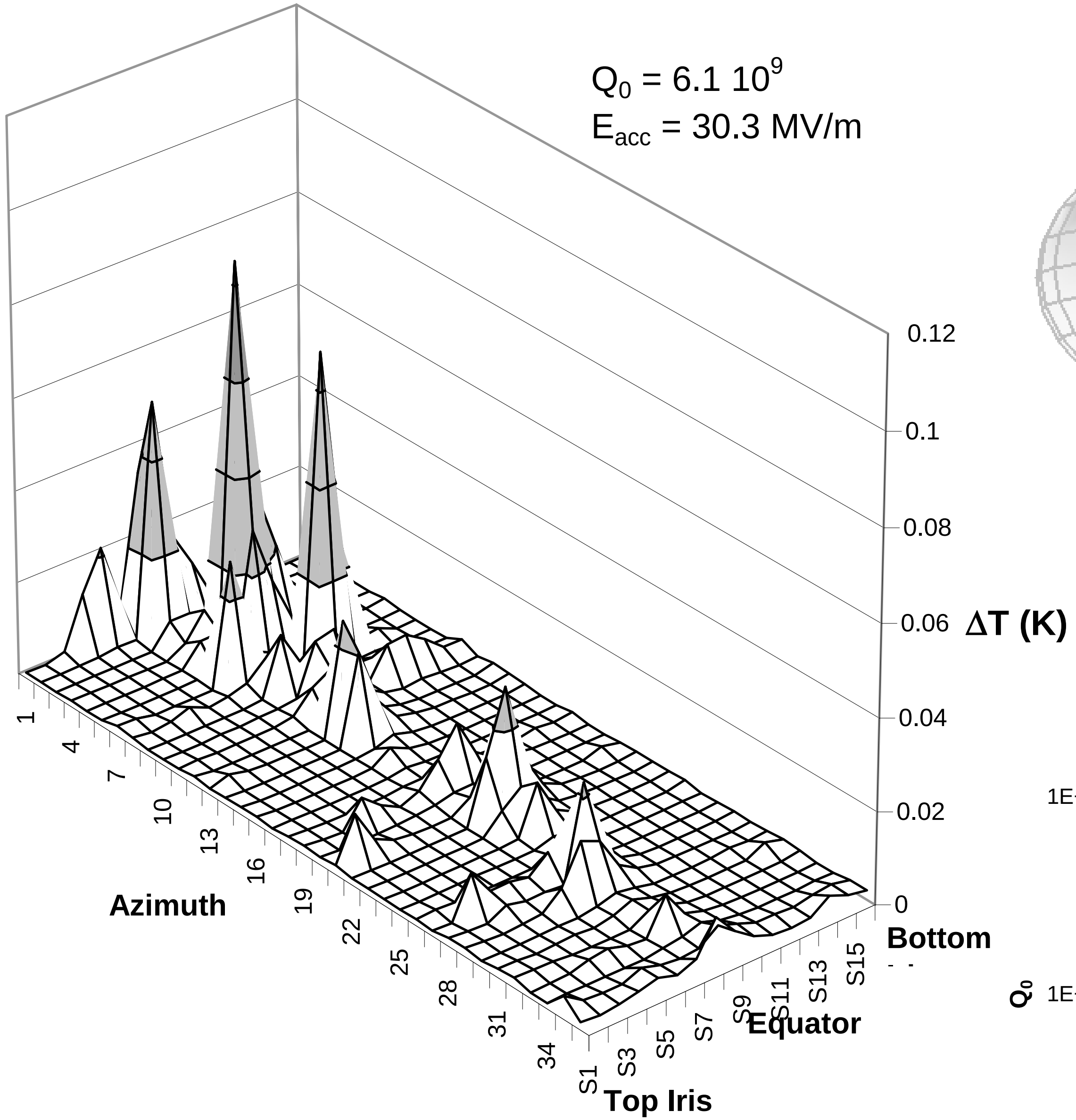


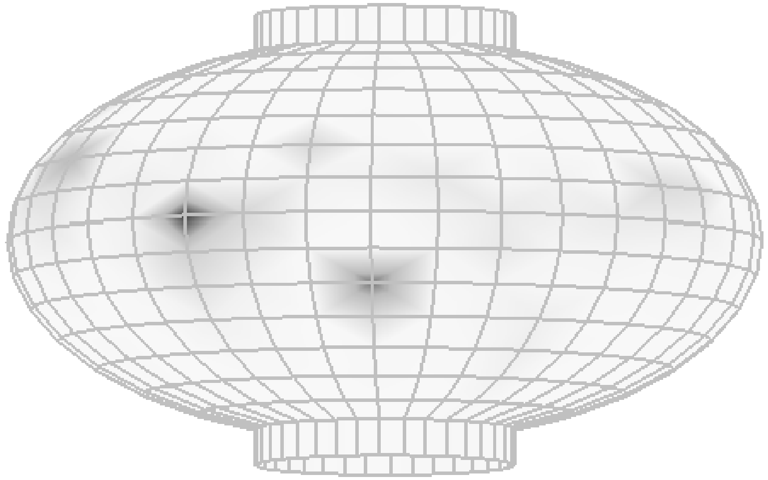
$Q_0 = 2.5\ 10^9$
E_{acc} = 24.7 MV/m
ΔT (K)
0.33
0.3
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0
Azimuth
1
4
7
10
13
16
19
22
25
28
31
34
S1
S3
S5
S7
S9
S11
S13
S15
Top Iris
Equator
Bottom

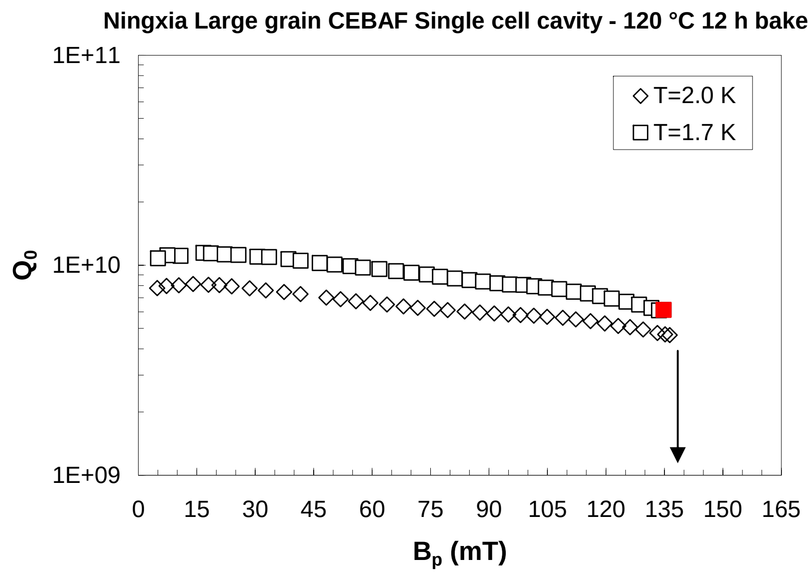




Ningxia Large grain CEBAF Single cell cavity - 123 nm thick oxide
1E+11
1E+10
1E+09
Q_0
◇ T=2.0 K
□ T=1.7 K
0
15
30
45
60
75
90
105
120
135
150
165
B_p (mT)







The quench is located around 180/9, where the Q-drop was

Conclusion

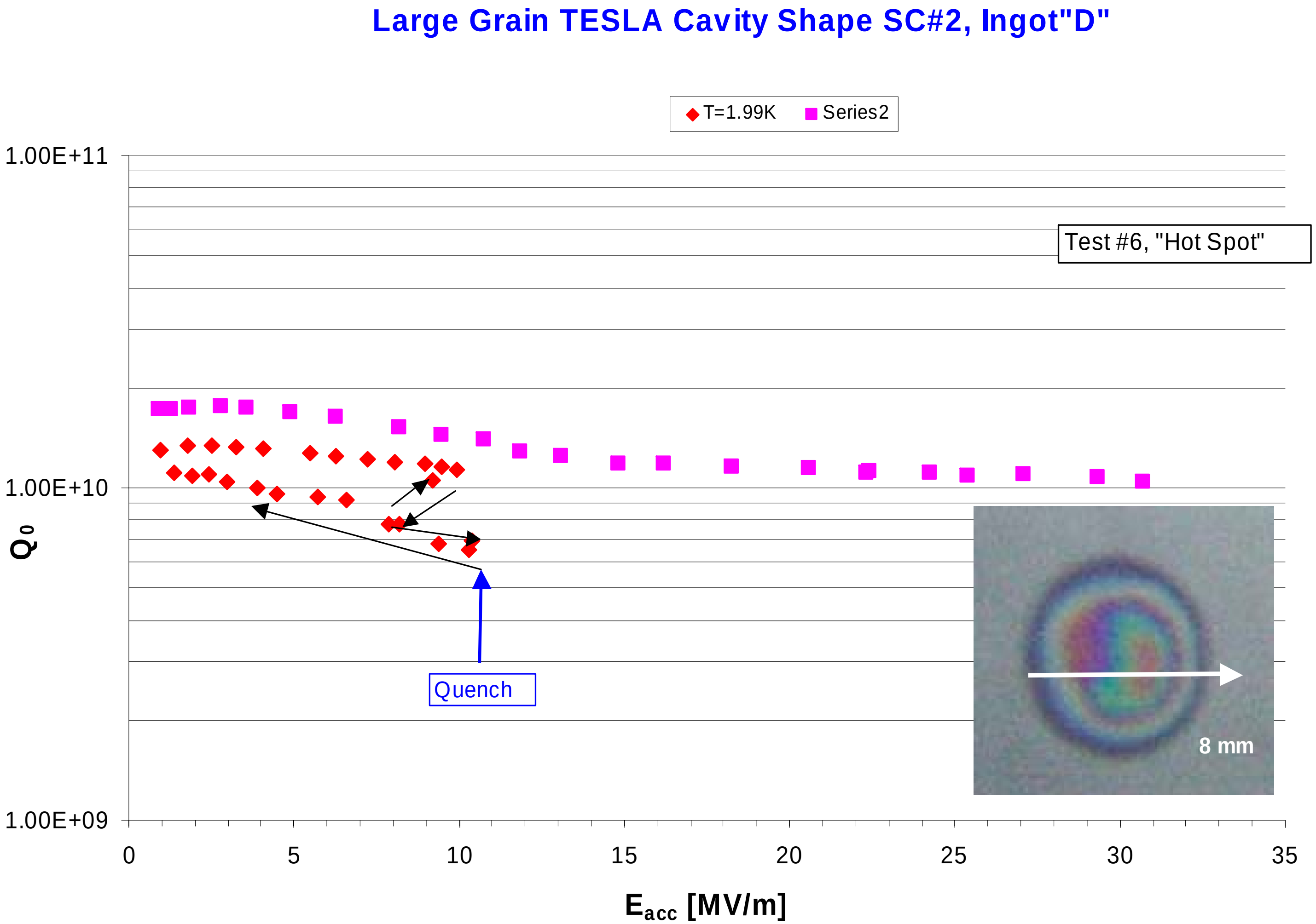
- Q-drop and "hot spots" can be generated and eliminated by anodization and "in situ" baking
- There is strong evidence that oxygen diffusion is involved in the Q-drop phenomenon
- The question then is:

Can one generate a single "hot spot" by generating an area on a cavity surface with increased oxygen concentration?

And if so, can this "hot spot" be eliminated/reduced by "in situ" baking?

“Hot Spot” ?

A concentrated water jet generates an oxidized area on niobium



ILC Cavity Fabrication (MOU with FNAL)

- **Fabricate and test a prototype TESLA cavity from polycrystalline RRR niobium**
- **Fabricate 2 modified TESLA/ILC 9-cell cavities from large grain niobium with shorter beam pipe and possibly modified HOM couplers (tests on a single cell with a modified HOM coupler showed improved thermal stability)**

Status

- **Dumbbells for all 3 cavities have been welded**
- **"Grooving" for stiffening rings will start this week**
- **Flanges (beam line, HOM, FPC, field probe) are completed**
- **HOM coupling loops are completed**
- **Other parts (He vessel end dish and end disc flange) are in fabrication and aluminum models have been completed**
- **Beam pipes have been rolled, welded and nipples have been pulled**
- **A deep drawing die for back extrusion of HOM cans will be completed and tried out next week.**

Fabrication Team

Bob Manus

Larry Turlington

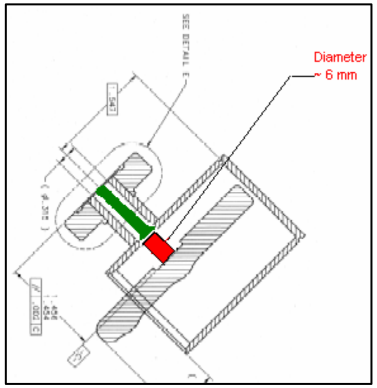
Steve Manning

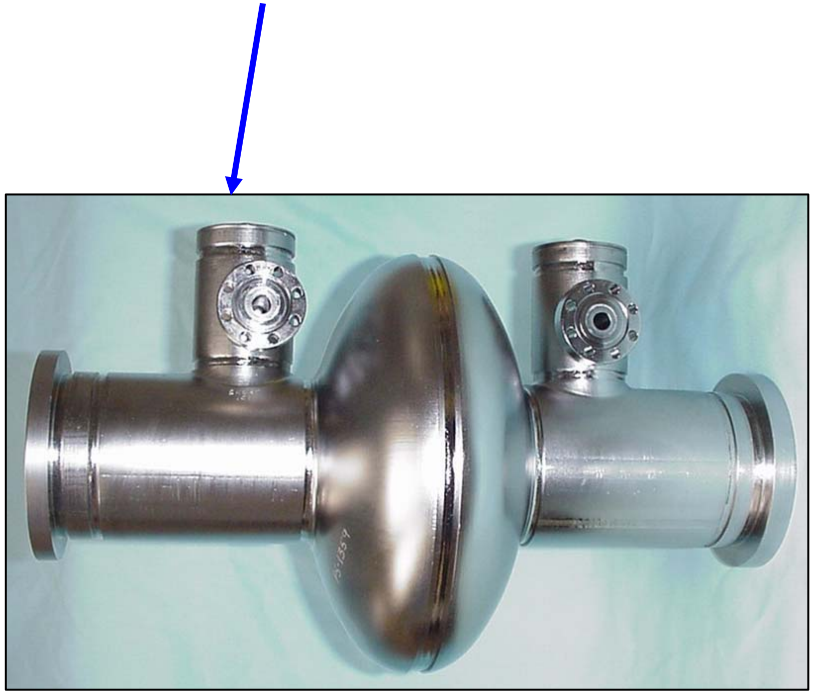
Gary Slack

Gigi Ciovati

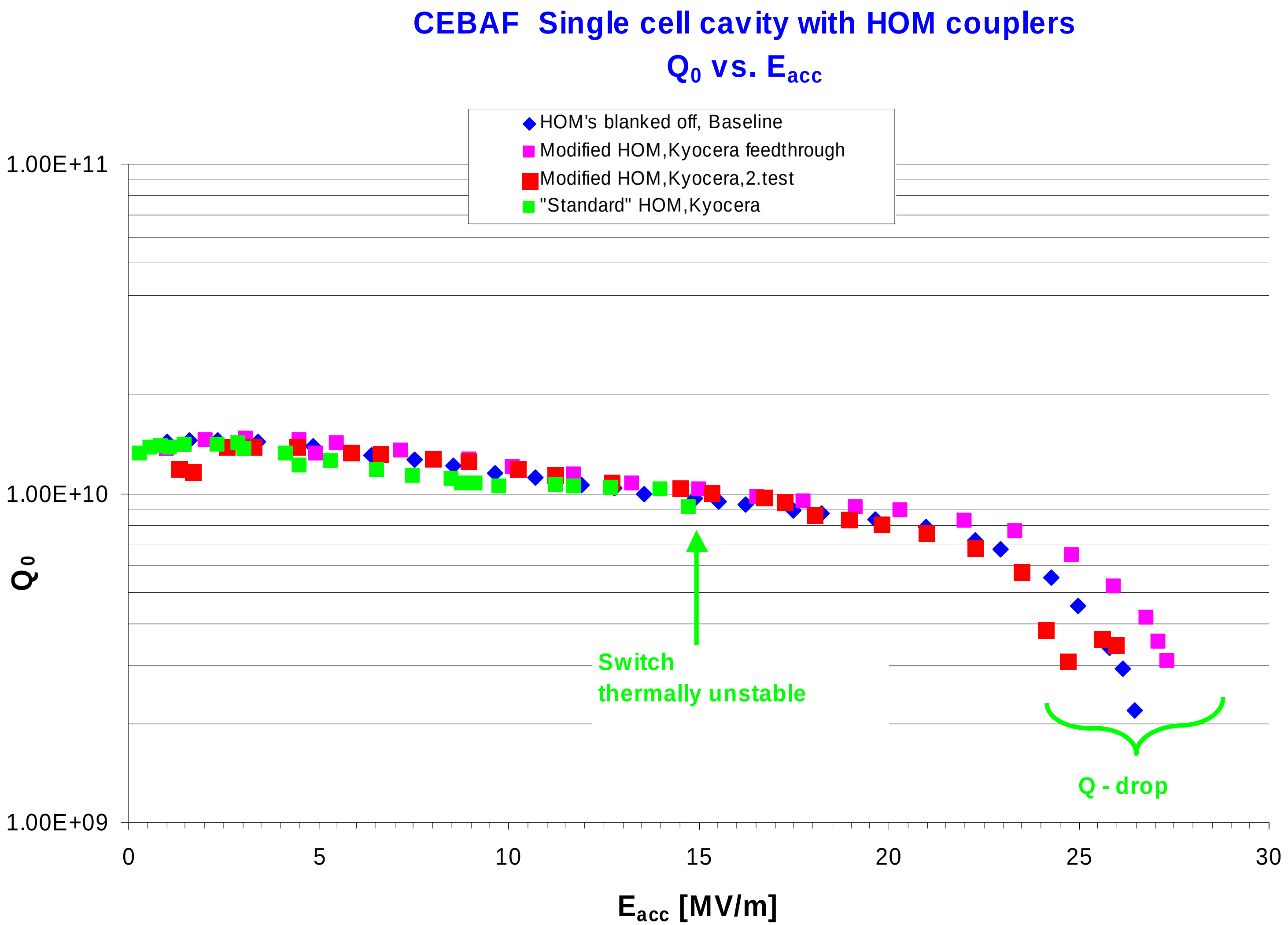
Peter Kneisel

Modified HOM Coupler Tests





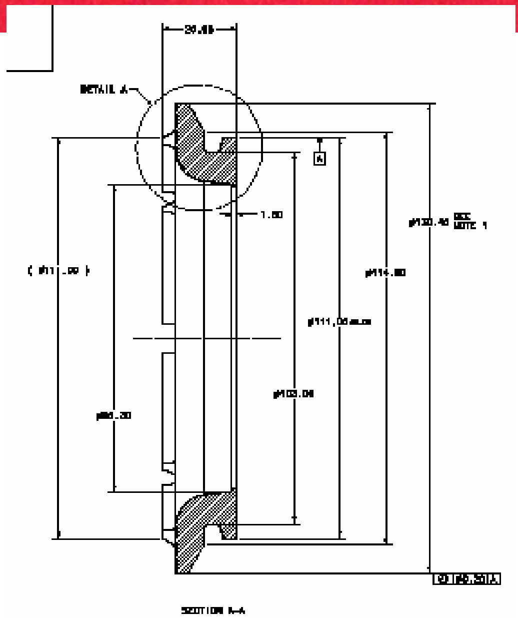
Modified HOM Coupler Tests

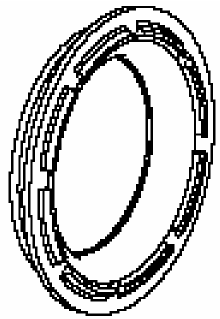


ILC Cavity Fabrication:Large Grain Dumbbells

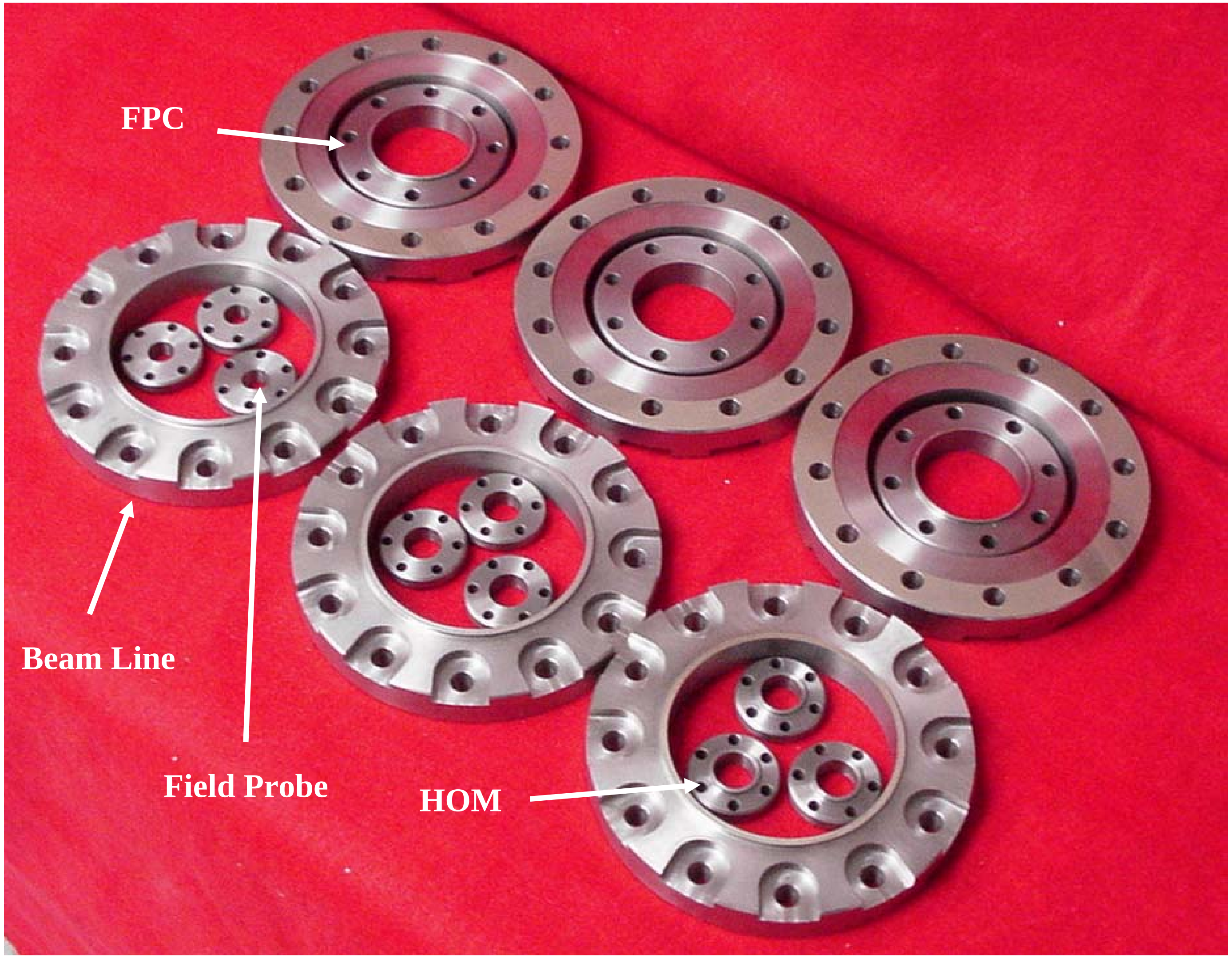
HOM Coupler Loops

He-vessel end dishes/End disc flange





Flanges



HOM Can Deep Drawing Die