How can large grain and single grain help the current yield problem from 35 MV/m for ILC cavities?

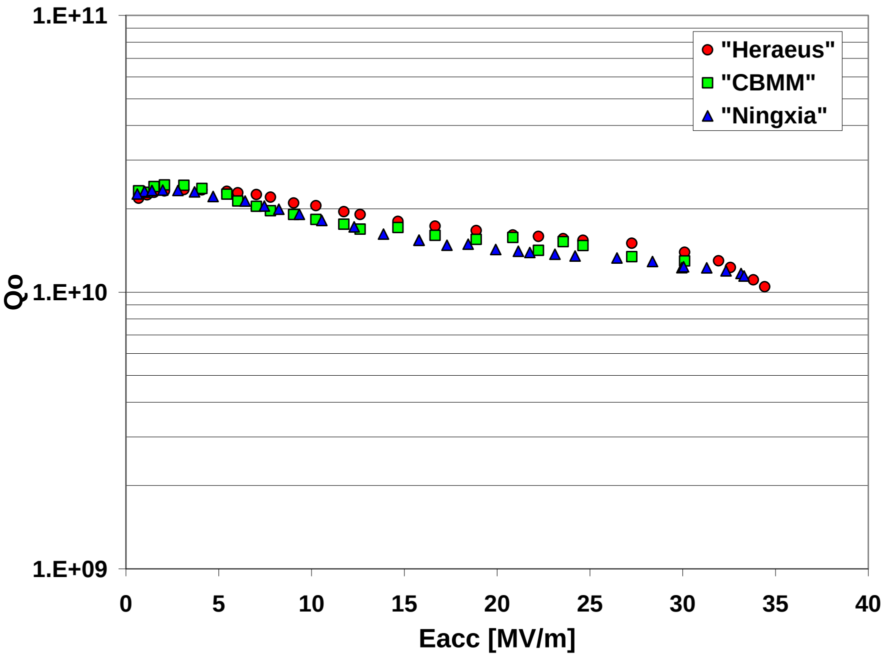
Why should the community support large grain niobium development?

Peter Kneisel, Jefferson Lab

Reproducibility Tests (1)

- Initially one single cell large grain niobium cavity each from CBMM, W.C.Heraeus and Ningxia showed reasonable agreements in performance after similar applied treatment (BCP only)

after post-purification



Supplier	As received H_{peak} [mT]	Post-purified H_{peak} [mT]
W.C.Heraeus	140	146
Ningxia	123	142
CBMM	133	131

Reproducibility(2)

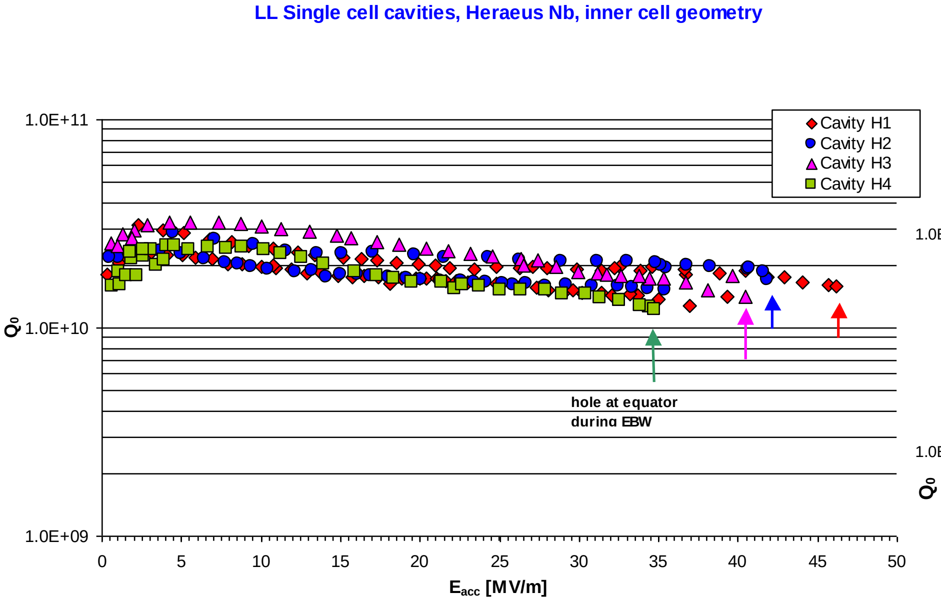
- Subsequently we fabricated 5 single cell cavities from these materials and additionally from Tokyo-Denkai large grain Nb
- W.C Heraeus and Ningxia cavities have had their initial test “as received” before and after “in-situ” baking
- CBMM and TD cavities in “cue” for testing (at least 20 tests)
- After post-purification all cavities are to be re-tested (at least 40 tests)
- Hopefully, a good statistic will be the result

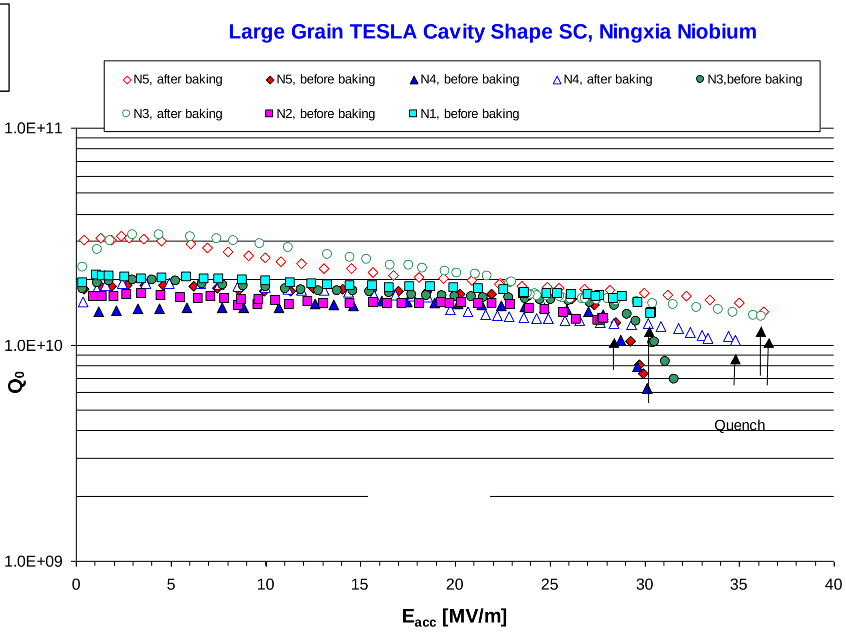
Reproducibility (3)

W.C.Heraeus

LL shape (ACD)

Ningxia (BCD)

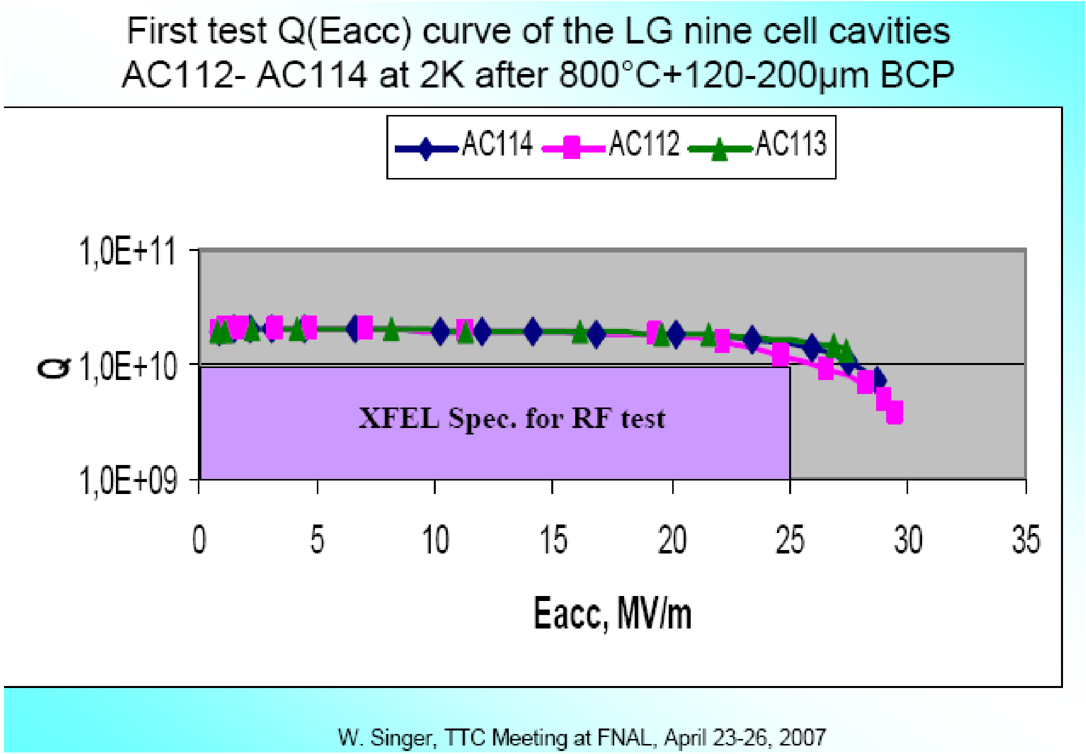




Project	E_{acc} [MV/m]	H_{max} [mT]
XFEL	28	119
ILC(BCD)	35	149
ILC (ACD)	45	162

DESY Experience with 9-cell Cavities

- Three TESLA-type 9-cell cavities were fabricated from large grain Heraeus niobium by ACCEL
- Only the sheets for 1 cavity were eddy current scanned and no defects were found. No further scanning
- The cavities were tested at DESY after 800C degassing and BCP surface treatment



Possible Causes for Performance Variations

- Material with defects (sheet forming → eddy current scanning)
- Manufacturing defects (embedded materials, EBW..)
- Surface preparation (chem. residue, sulfur, particulate contamination, grain boundary contamination…)
- Assembly (re-contamination, multipacting, field emission…)
- “Environmental” influences (vacuum, cables, couplers..)
- Large grain material might have some advantages with respect to defect density, length of grain boundaries, EBW

Advantages (1): grain boundaries?

- A 9-cell cavity made from large grain niobium has ~ 7 m of grain boundaries
- A 9-cell cavity made from poly-crystalline niobium has ~ 1000m of grain boundaries
- An accelerator such as ILC has ~ 20 000 km of grain boundaries, more than half the equator length
- Grain boundaries can be "weak links" because of preferential impurity segregation[G. Mueller, CARE2007]; they can also be pinning centers for vortices [A.Gurevich, G.Ciovati]
- LG/SC niobium samples (bcp ~100 micron) show less FE than FG(EP) [A.Dangwal, UniWuppertal, Thesis];
- From RRR – measurements at grain bounderies [H.Safa et al] it was concluded that EP,BCP is affecting the grain boundary resistance to a deeper depth than the resistance at the surface of a grain.

Advantage 2:Defect Density?

- The manufacturing process for sheets is significantly simplified: no forging, rolling, heat treatments, machining...

- Multi-wire cutting from ingot as developed by K.Saito gives good surface finish (~ 6 μm) and tight thickness tolerances and clean surfaces; it is economical: relatively short cutting time, no waste and the need for eddy current scanning/squid scanning (with limited resolution) is eliminated

Advantages (3): Electron Beam Welding

- The Kyoto optical inspection system and other followers have often found features (“cat eyes”, pits..) in the heat affected zone of the equator weld
- It is being “speculated” [1] that these features could be missing grains, which are ejected during cooldown of the weld due to large thermal stresses
- So far on a few sample cavities from large grain no such features have been seen (most likely not enough inspections).
- The grains in the equator region of a large grain cavity are of the order of cm^2, therefore it seems unlikely that grains can “pop out”

[1] Y. Iwashita et al.; EPAC 2008, paper WEOBM03

Final Comment

- For ILC at E_{acc} = 35 MV/m one needs to produce app. 2 football fields of defect-free niobium cavity surface
- For my taste, these field requirements are too close to the fundamental magnetic field limits of the material
- If one would not only concentrate on "ILC/TESLA-type" cavities, but would give the "LL/Ichiro" shape a better chance

  for development at E_{acc} = 35 MV/m , the required magnetic field stability would be reduced to "only" H_{peak} = 126 mT,

  much further away from the fundamental limit
- This is one of the reasons, why we are in the process of fabricating two 9-cell Ichiro-type cavities at Jlab with large grain niobium , combining the shape "advantages" and the material "advantages".
- We will use our best practices, which we have learnt during the previous cavity manufacturing