Advances in Large Grain Resonators

- material and fabrication aspects
- preparation and RF test results

Presented by W. Singer, DESY

Advances in Large Grain Resonators

Possible advantages (hope):

• Cost effective

• Higher purity. RRR=600 of ingot is achievable

• No danger that during many steps from ingot to sheet the material will be polluted.

• Simplified quality control (reduced number of measurements: grain size, eddy current scanning etc.)

• Higher thermal conductivity at low temperatures (phonon peak)

• Seems to be less susceptible to field emission (Univ. Wuppertal)

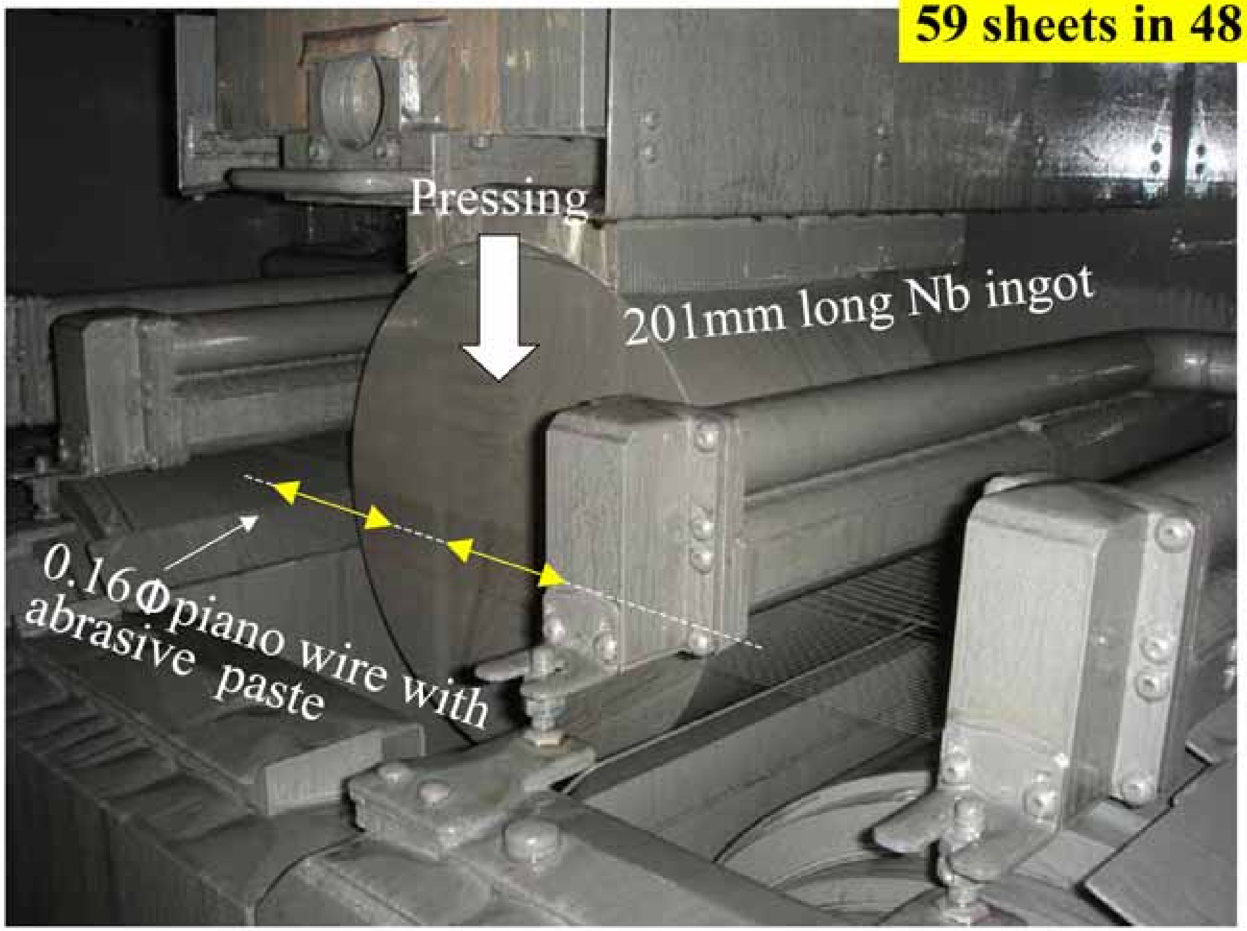
• Seems that the baking at 120°C works better after BCP (compare to fine grain BCP)

Discs Slicing:

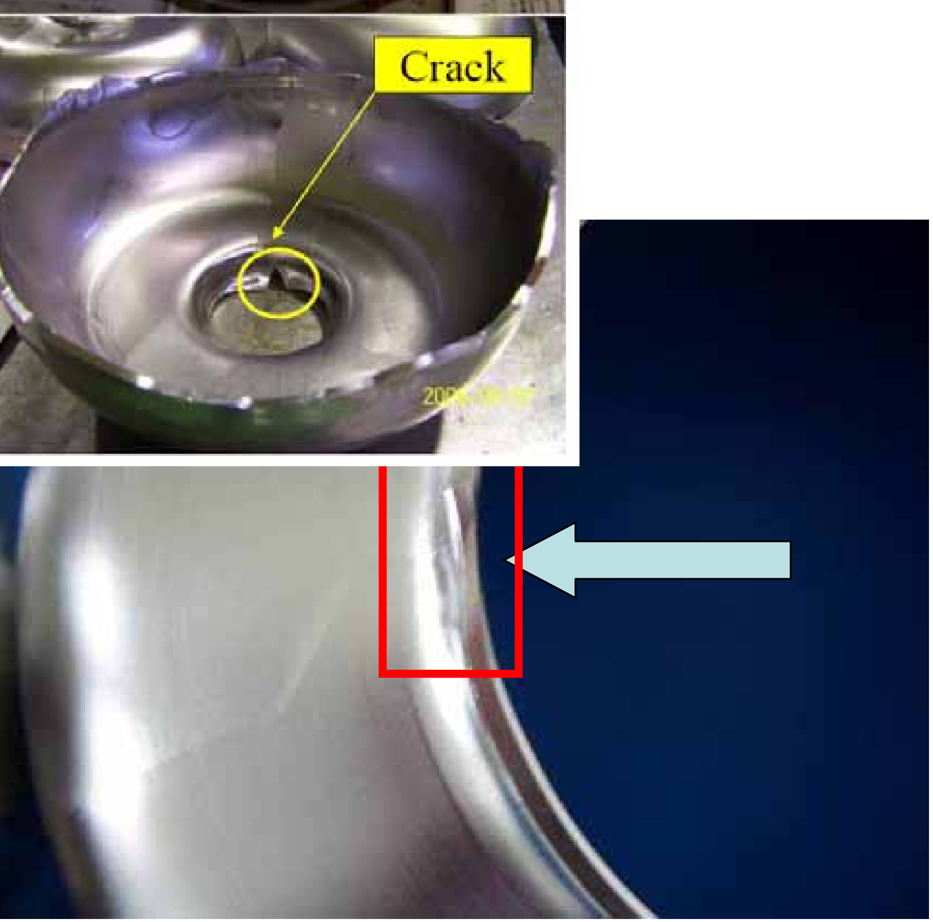
1. The multi - slicing of discs was done within the framework of the R&D program of DESY and the Co. W. C. HERAEUS (**B.Spaniol et al, LINAC 2006, TUP024**)

2. **Successfully Multi-sliced 59 sheets (3.2t) from 201 mm long Nb Ingot**

59 sheets in 48 hr



More details in presentation of Kenji Saito (SRF2009)

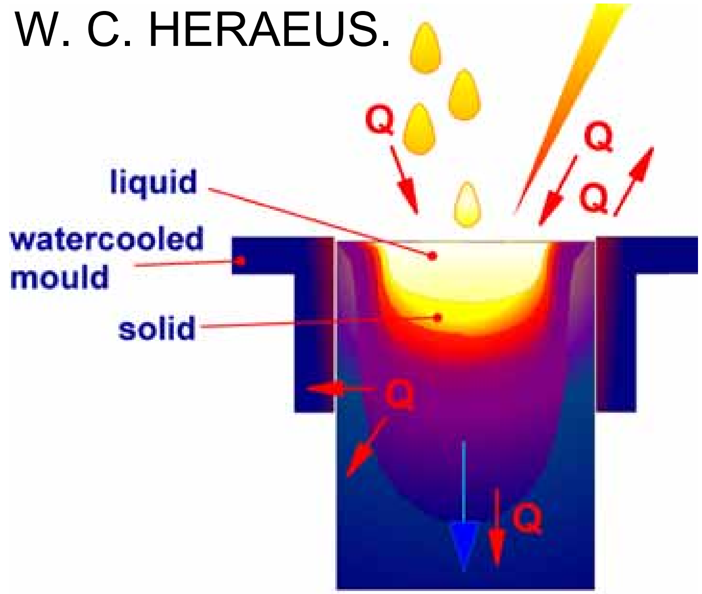


Thinning or ripping at grain boundary in iris if the grains “meet” in these areas

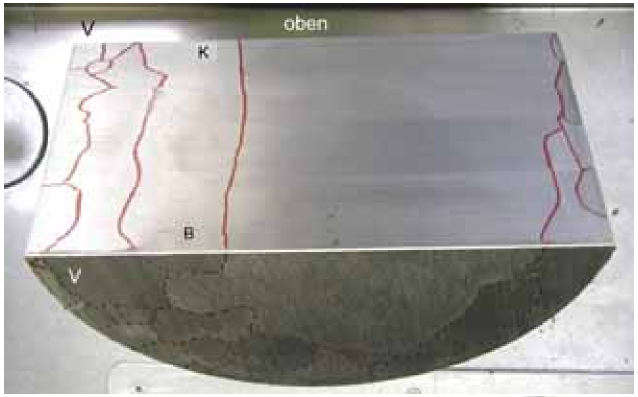
Safety margin is not big. Large central single crystal is very desirable

Ingot fabrication W.C. Heraeus:

Development of LG disc production was done within the framework of the R&D program of DESY and the Co. W. C. HERAEUS.



Energy exchange in the electron beam melted Niobium



Large Grain Nb

Melting-/cooling behavior was investigated: beam figures (different numbers, position und shape); energy entry (different focusing of the beam and stay time); refrigeration parameters (bottom, crucible wall, split).

The complete process is not sufficiently stable or reproducible in order to create a central crystal of big diameter and required orientation along the whole ingot.

JLab solution: deep draw.– annealing - second deep draw.

allows LG CV fabrication without big single crystal in the disc centre

Multi cell LG DESY: Fabricated 11 LG 9-cell cavities at ACCEL(RI) from HERAEUS material (AC112-AC114, AC151-AC158)

Fabrication:

- **Discs scanned only for two cavities.**
- **Deep drawing**
- **Machining**
- **EB welding**
- **Grinding of grain boundaries on 4 cavities for comparison**

Large single crystal in the centre of the LG disc was available

In discs for AC151-AC154, the main orientation of the central crystal is (100), for discs of AC155-AC158 (211) or (221). For the disc with (100) orientation, a more pronounced anisotropy and quadrangular shape after deep drawing was observed. The assembling of half cells and dumb-bells for welding have been done using a special tool

Multi cell LG activities: Several Labs are working on LG multi cell cavities

JLab: Two Jlab upgrade 7-cell cavities are completed from Ningxia/ CBMM large grain Nb

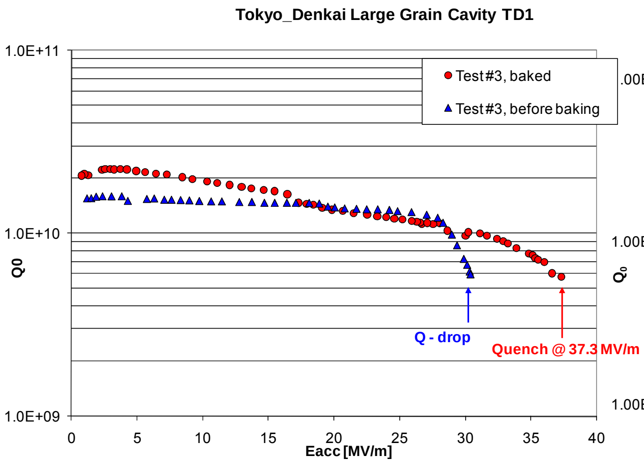
Jlab:Two LL/Ichiro 9-cell ILC cavities are in fabrication from Tokyo-Denkai and CBMM material

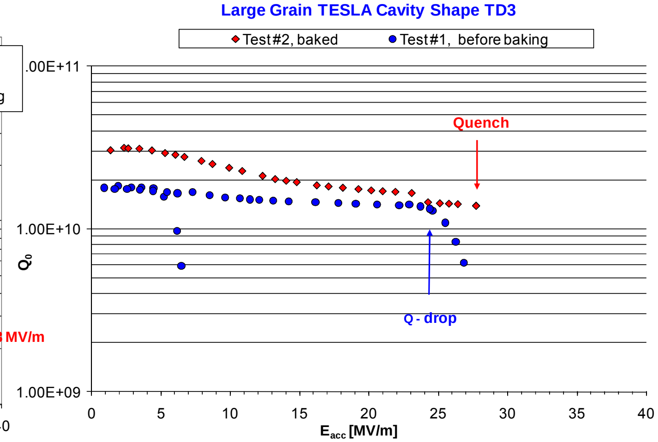
Pekin Univ: LG two cell cavity

SRF guns from LG: development of Pekin Univ. and BNL (SRF 2009 MOOBAU06 and MOOCAU01)

IHEP works on two 9-cell LG 1,3 GHz CVs

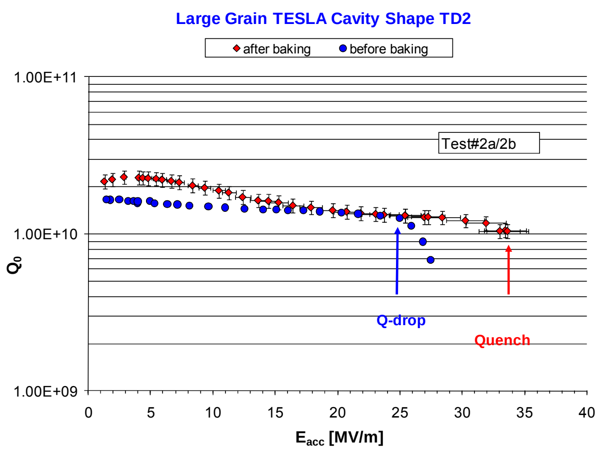
RF performance: reasonable Eacc and reproducibility is demonstrated on single cell LG cavities with BCP by JLAB, DESY, and KEK/IHEP

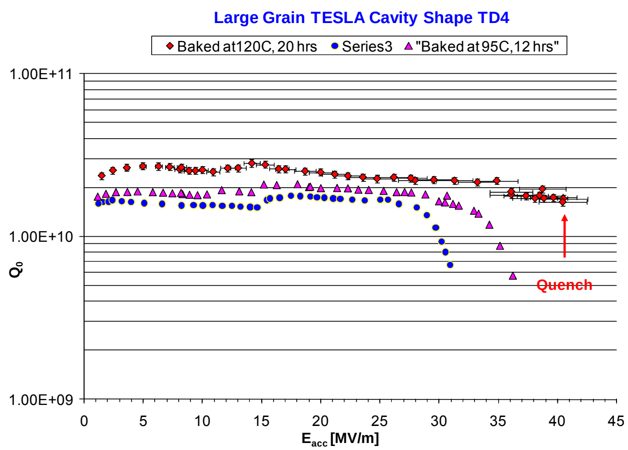


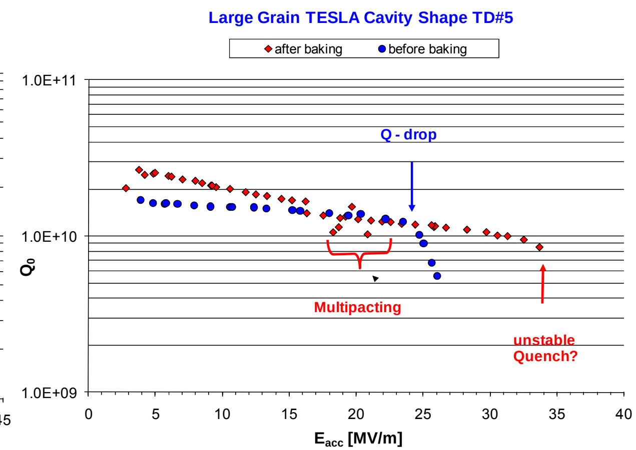


All cavities treated:

- 100 micron bcp (1:1:1)
- 600 C, 10 hrs
- 30 micron bcp, HPR
- RF-Test
- If no FE, baking at 120C for 20 hrs
- Re-testing

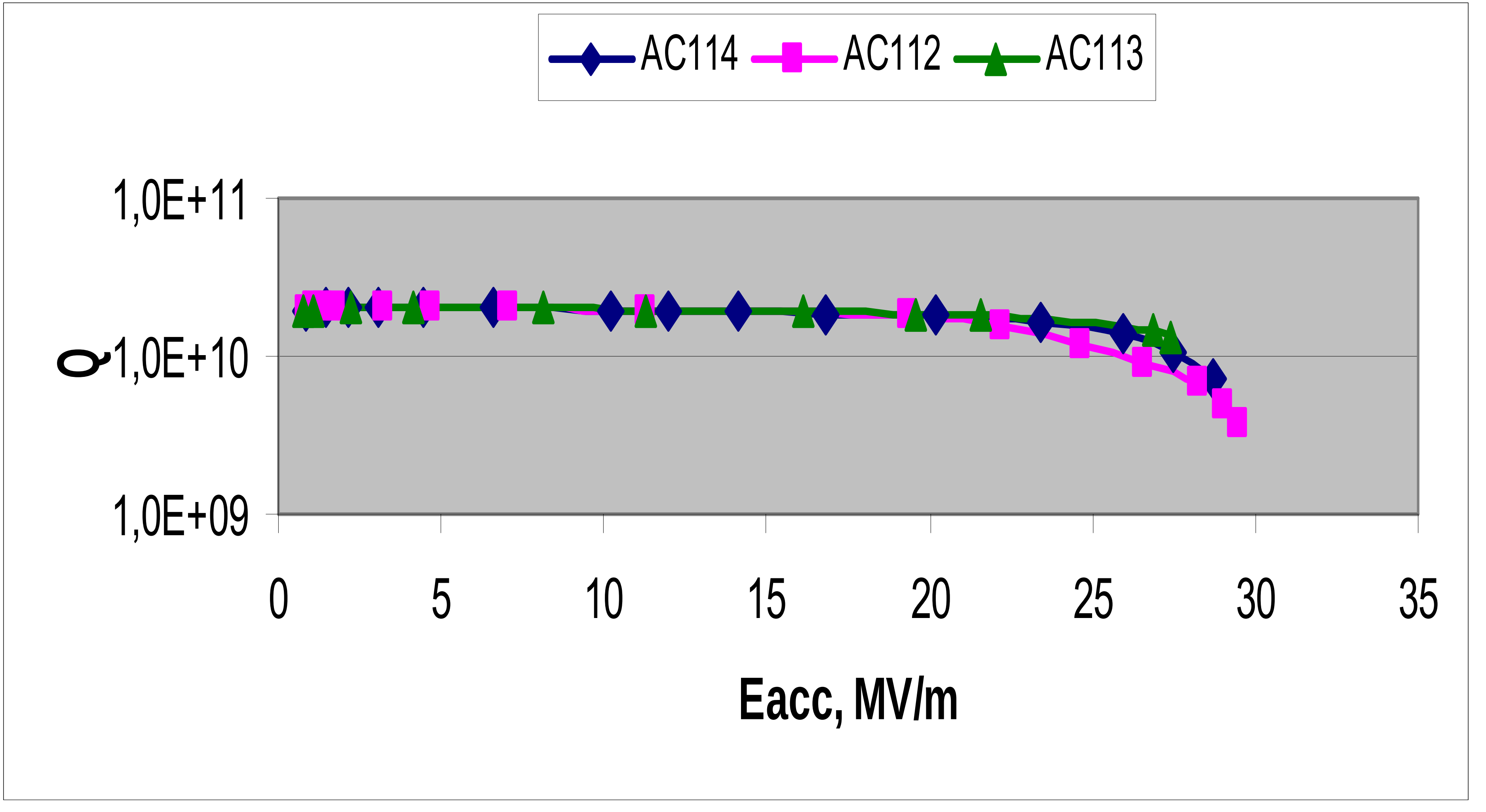


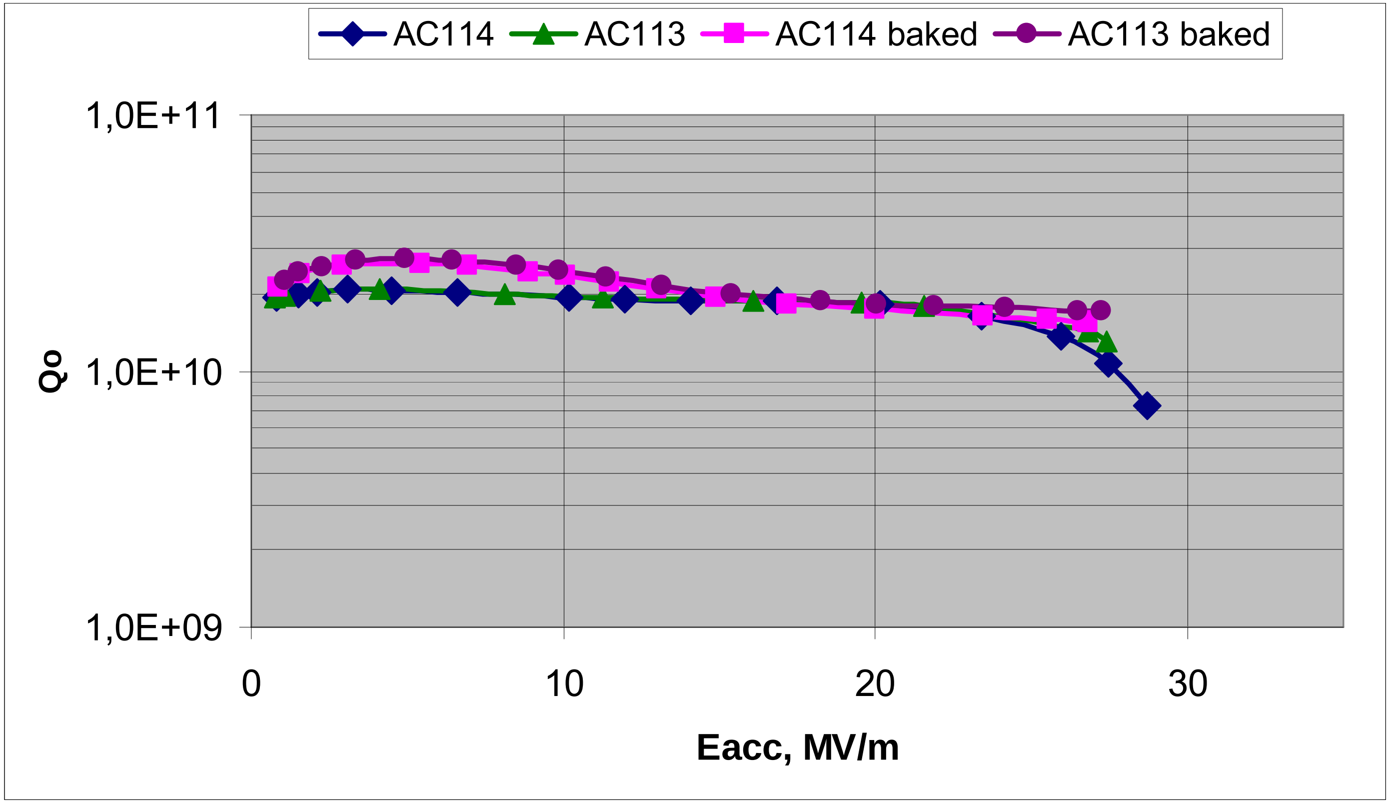




Reproducibility Tests of LG Niobium Cavities (P. Kneisel, JLab). Baking works

DESY: BCP of first three 9-cell LG cavities (100 μm rough BCP, annealing at 800°C for 2h followed by fine BCP of 20 μm). The same BCP treatment is now applied to the recently fabricated 8 LG cavities AC151-AC158. 100 μm BCP done at Company RI. RF test is ongoing.





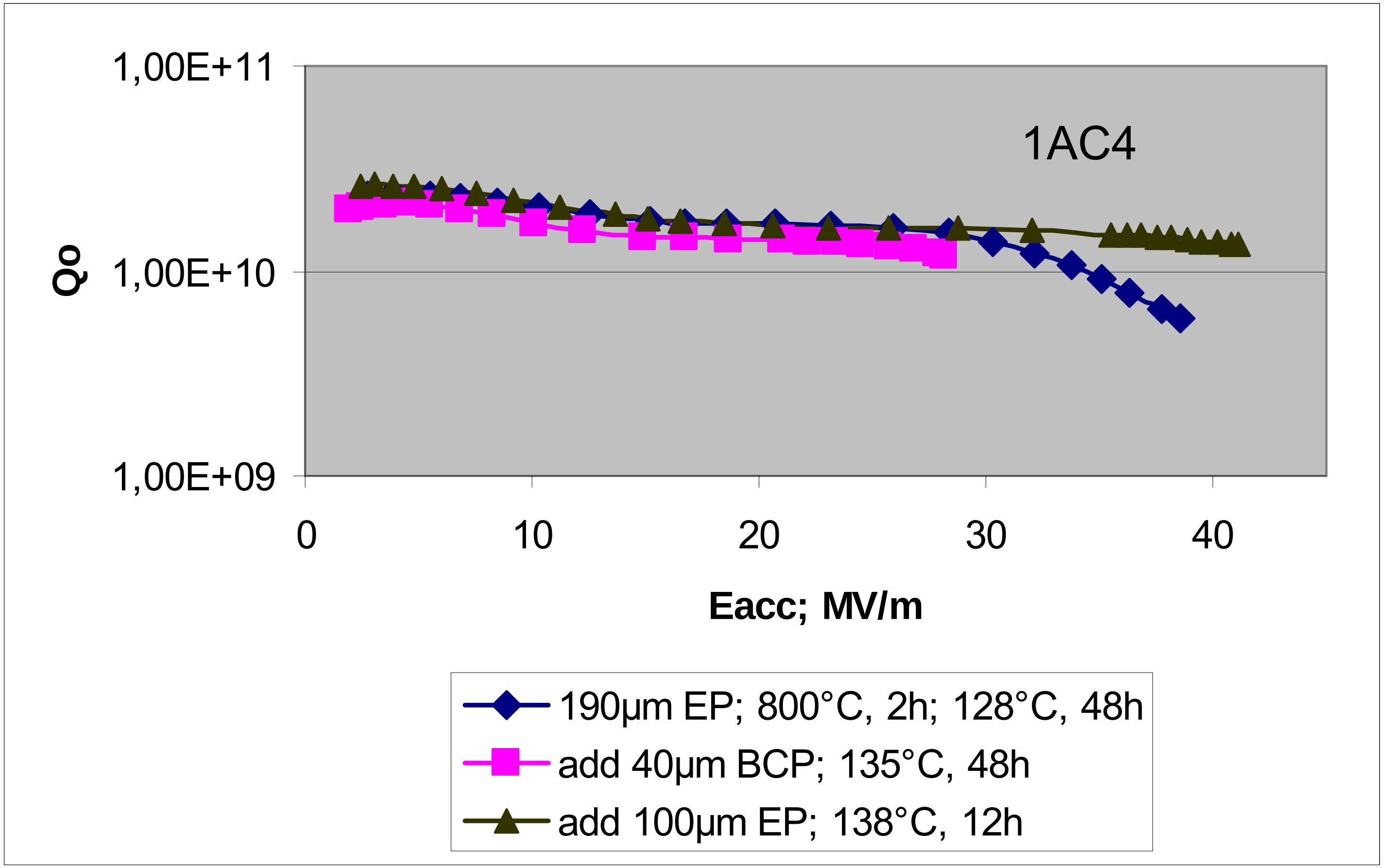
DESY: Q(Eacc) curve of the LG nine cell cavities AC113-AC114 at 2K after additional 20-30 µm BCP and 125°C, 50 h baking

-Very similar behavior, good reproducibility

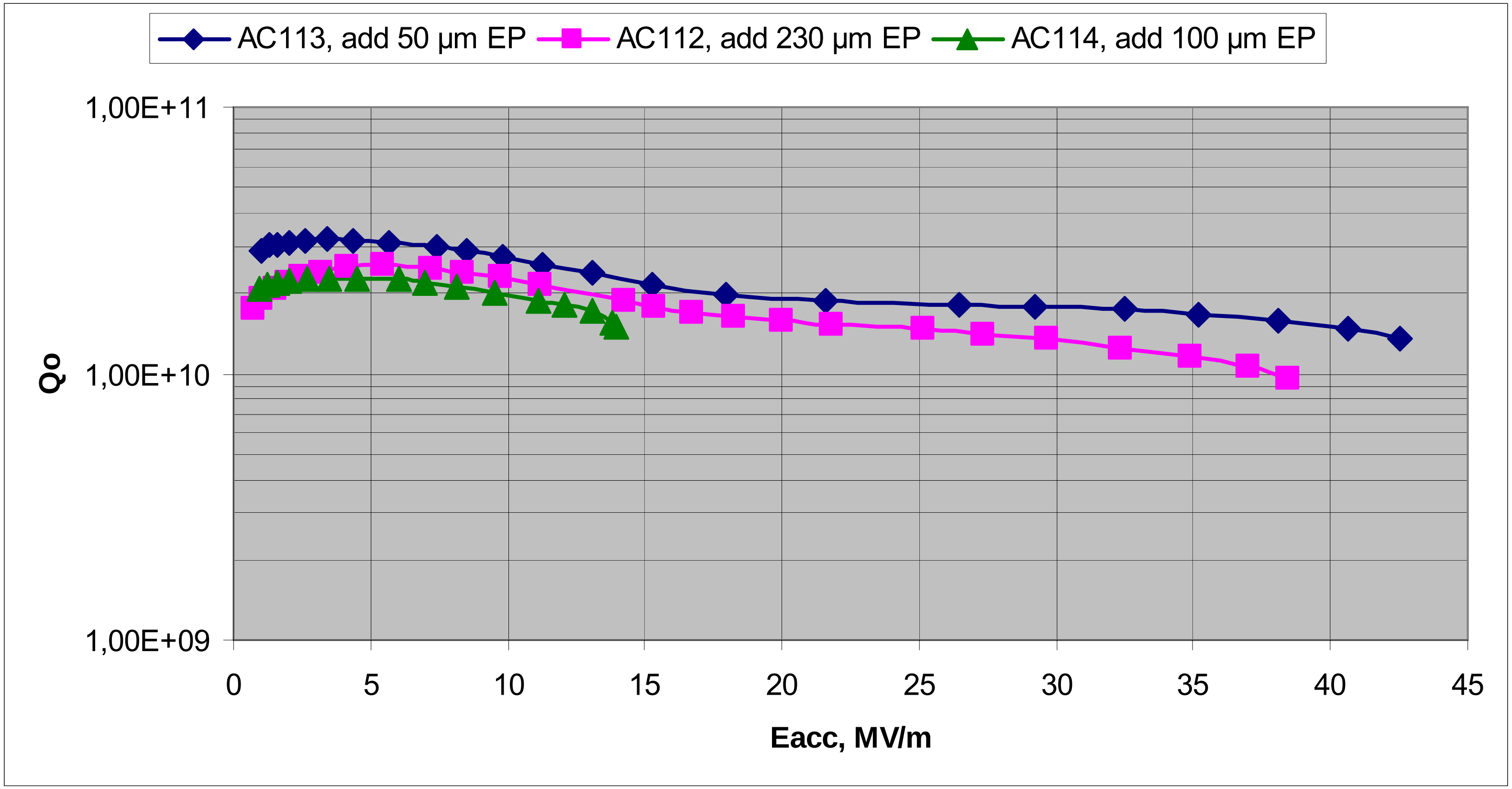
- Baking does not work?? More results needed. New 8 LG CVs in work

What treatment EP or BCP??

DESY data on single cell cavities; it seems that EP works better

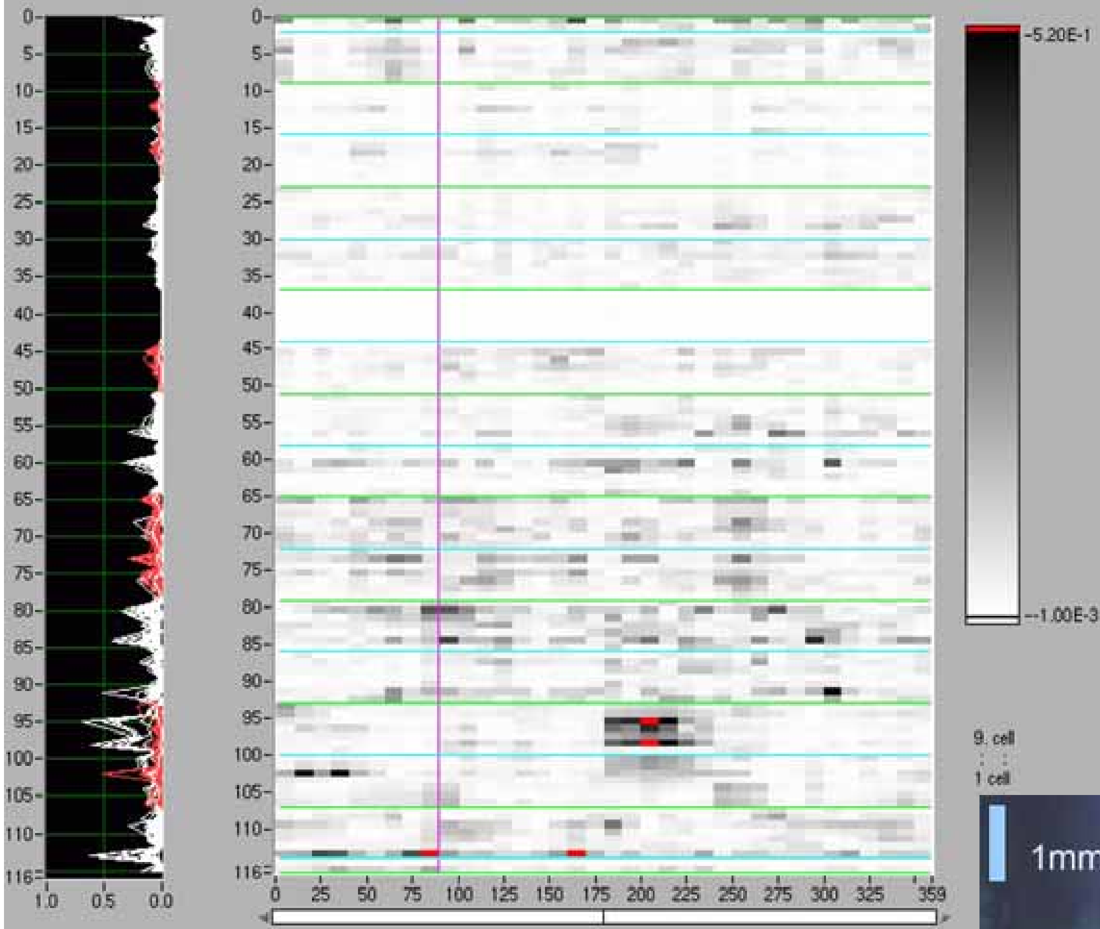


DESY: Q(Eacc) curve of the LG single cell cavity1AC4 after EP and BCP treatment. EP at Henkel, preparation at DESY (D. Reschke et al)



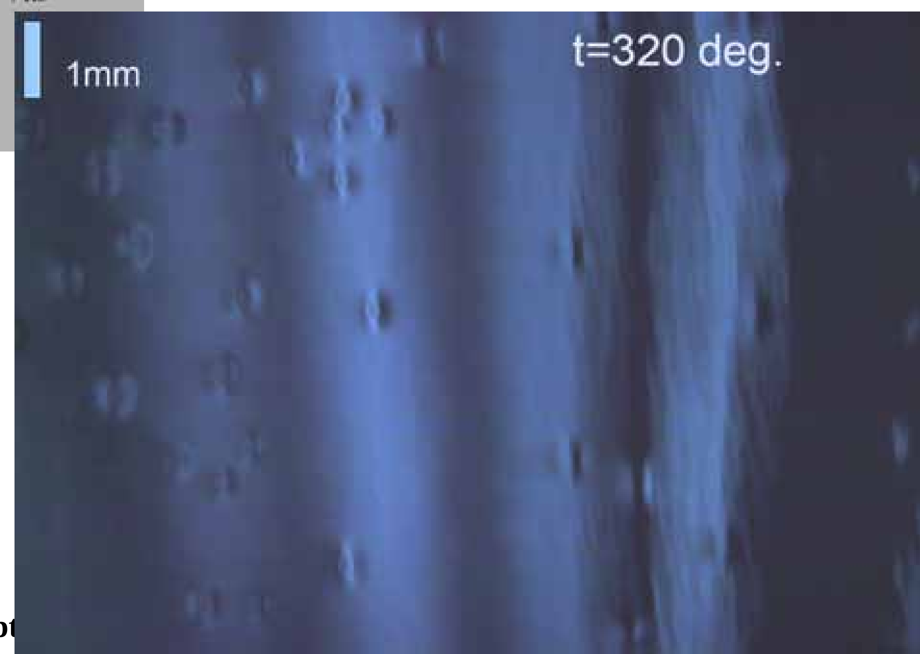
DESY 3 LG cavities: additional EP of 50 -100 µm, combined with additional “in situ” baking. Enhancing the acceleration gradient by approx. 10 MV/m can be seen on two cavities (AC112 and AC113). AC113 installed into cryomodule PXFEL1 (SRF2009 MOOAAU02, H. Weise)

Surprisingly, significant degradation of Eacc from 28 to 14 MV/m for the cavity AC114 (quench without field emission)



T-maps of AC114: for π-mode, the quench in cell 2 above and near equator. In other modes, quench was also found in cell 1 and 9. In addition, many other smaller hot spots were found.

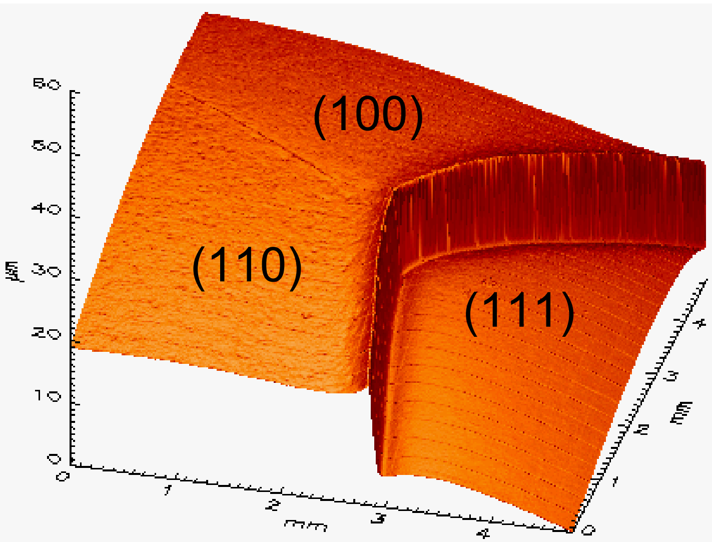
Large groups of small craters on the entire surface of all cells found by optical inspection with high resolution camera in AC114



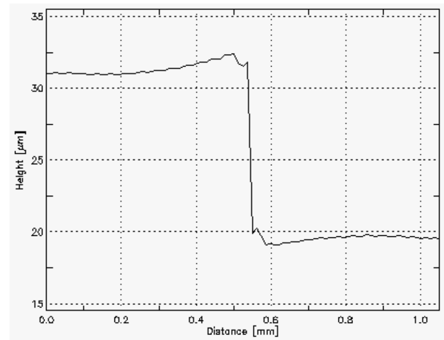
Depends the pits creation on the crystal orientation?

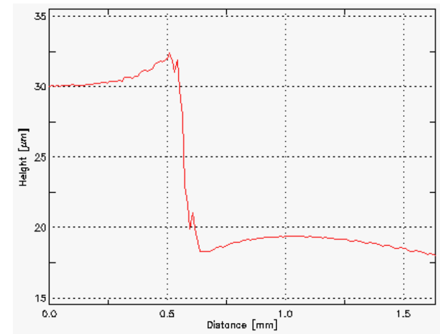
More results needed. New 8 LG CVs in work

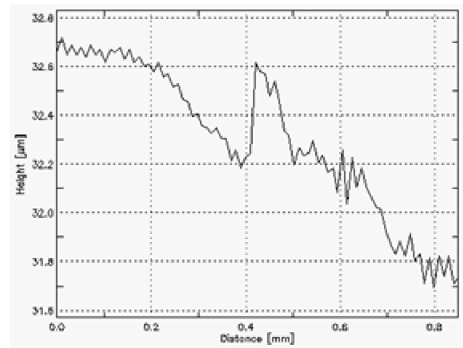
Is LG good enough, or do we have to have single grain?



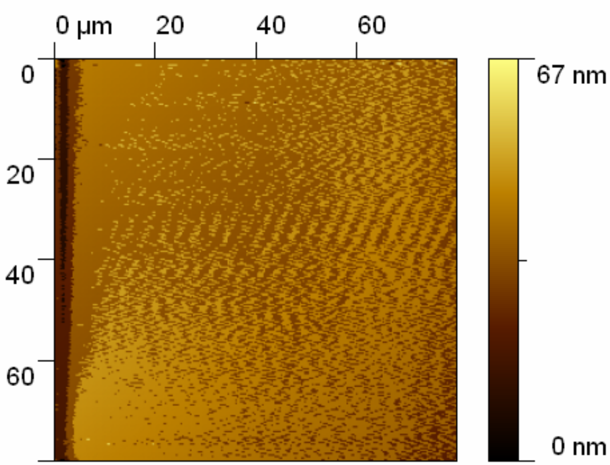
AFM image of LG Nb,
BCP etched up to 100 µm

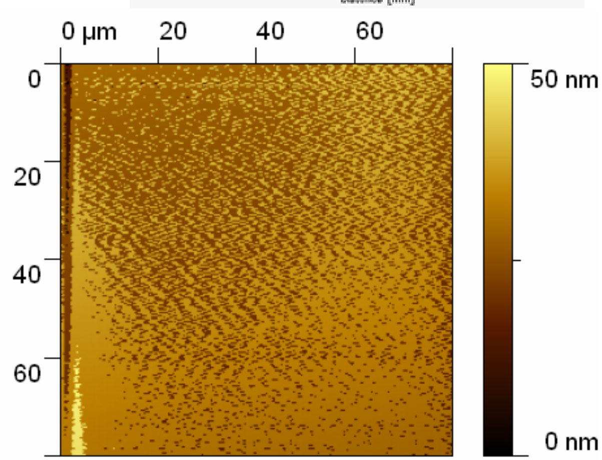


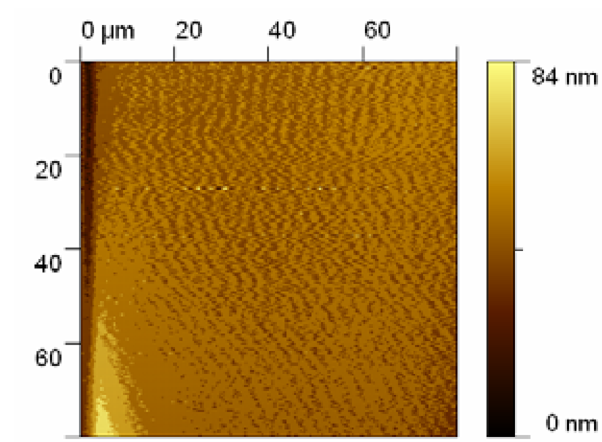




Profile and step heights of the three grain sample at the grain boundary intersection







AFM roughness measurement (X. Singer, A. Dangwal-Pandey). Roughness of fine grain Nb after EP is 251 nm (A. Wu) .

One large grain (single crystal) is still a very perspective option that allows stably reach very high gradient by simple BCP treatment

Summary of test results on single crystal single cell cavities

P. Kneisel et al EPAC2008

Cavity #	$E_{acc,max}$ (MV/m)	$B_{peak,max}$ (mT)	$Q_0(B_{peak,max})$	Treatment
1	38	162	4×10^{9}	200μm BCP, 800°C 3h, HPR, 120°C 48h
2	45	160	7×10^{9}	200μm BCP, 800°C 3h, HPR, 120°C 24h
3 (1AC6)	41	177	1.2×10^{10}	250μm BCP, 750°C 2h, 120μm EP, HPR, 135°C 12h
4 (1AC8)	38.9	168	1.8×10^{10}	216μm BCP, 600°C 10h, HPR, 120°C 12h
5	38.5	166	7.6×10^{9}	170μm BCP, HPR, 120°C 12h

Single Crystal Cavity option is going on

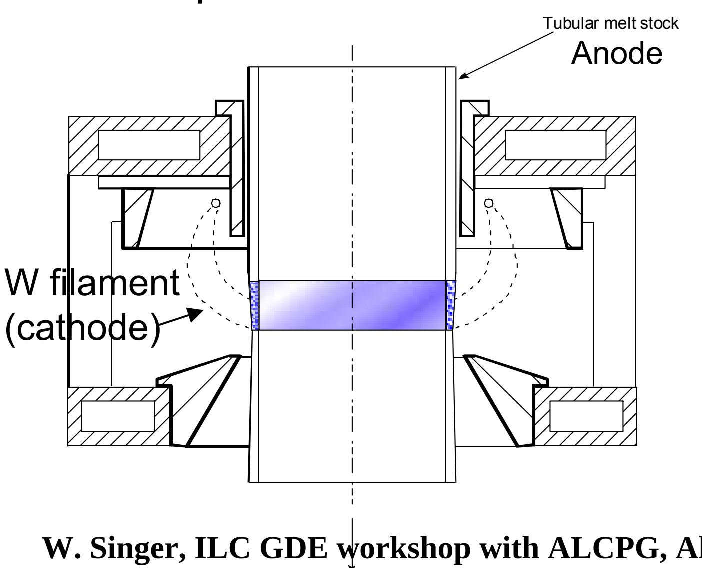
JLAB: Three single cell single crystal cavities of three different crystal orientation have been fabricated from enlarged by DESY method single crystals of CBMM niobium and are in the "pipeline" for testing

Single Crystal Cavities with
three different crystal orientation

Alternative ideas: Cavity fabrication from single crystal tubes

Single crystal cavity fabrication from single crystal tubes produced by EB floated zone method

- EBFZ on tubular melt stock (or inductive melting)
- May be able to produce a single crystal tube
- Thin wall contains molten zone
- Surface tension may be able to support molten metal column
- Benefits of zone refining
- Tube could be hydroformed or spun to cavity shape



The single crystal tube of 4mm diameter and 2 mm wall thickness exists

More Information by Chris. Compton (MSU)

Thank you to all colleagues who provided me with information for this summary