

Status of the XFEL test cavity program

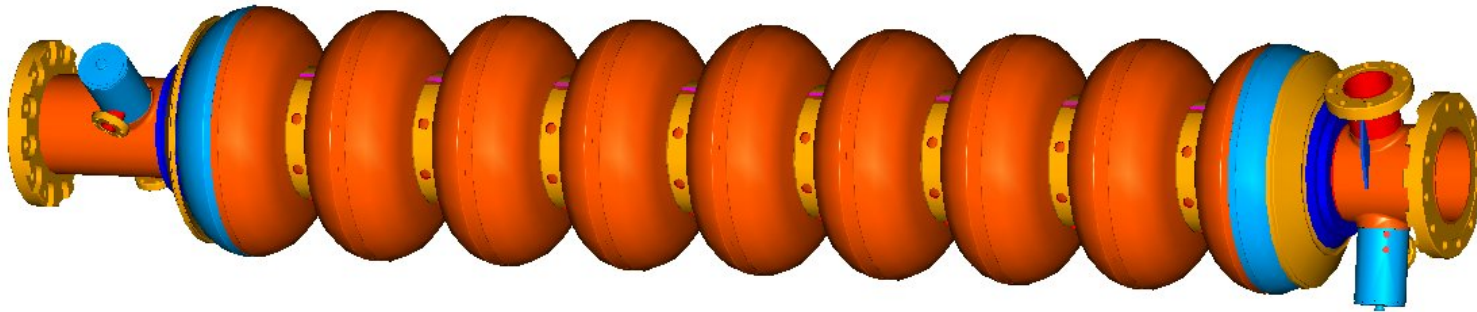
Detlef Reschke

for the test cavity program team

- Motivation
- Object of the program
- Status + Results
- Summary, next steps + some problems

Motivation

- XFEL will be based on today's nine-cell cavities (no super-structure, no major modifications of inter-cavity connection,..)



- Specification for cavity fabrication: **2006**

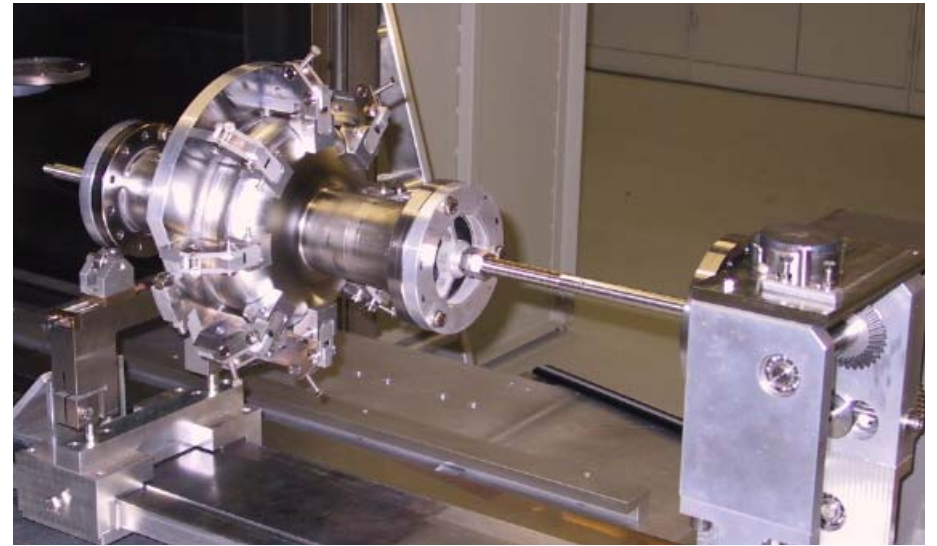
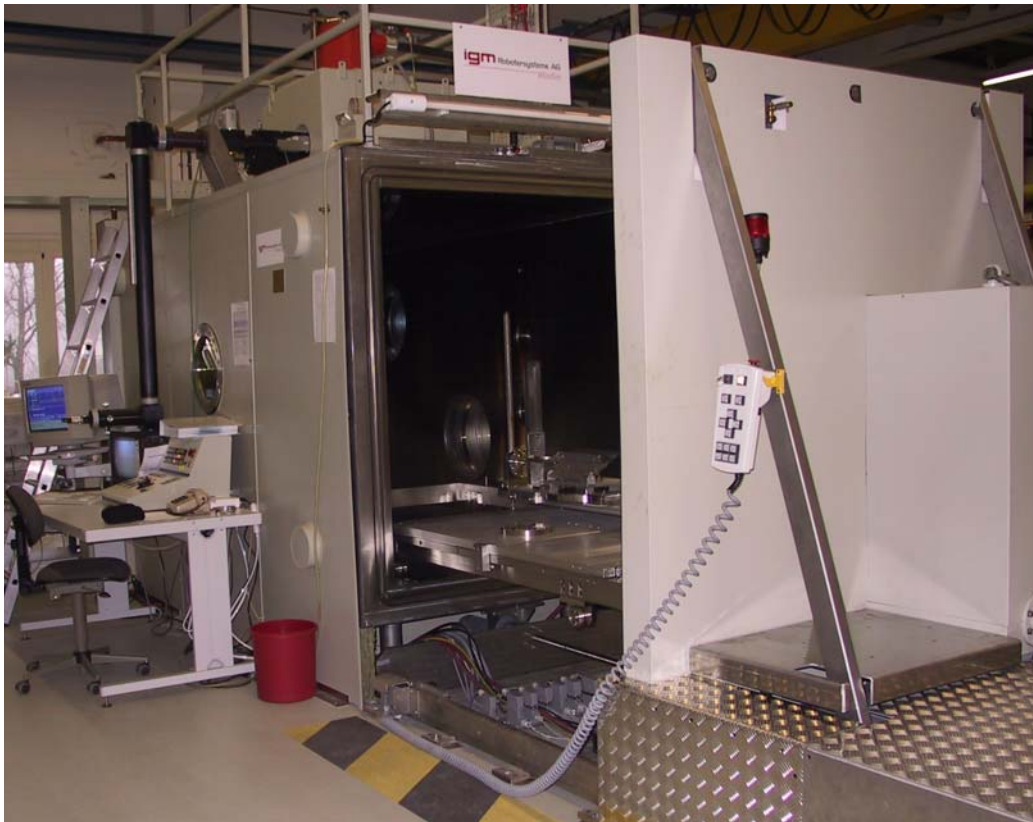
=> Qualification of modified fabrication parameters is urgent

=> Qualification of further Nb vendors

Object of the program

- Modification of present spec for welding preparation during cavity fabrication:
 - up to now:
max 8h between final etching of weld area and EB welding (“8h – Regel”)
=> restriction of cavity fabrication workflow
 - new:
test of storage of prepared (etched + dried) components for **1 week under vacuum and nitrogen** atmosphere

Electron beam welding at DESY



Object of the program (ctd.)

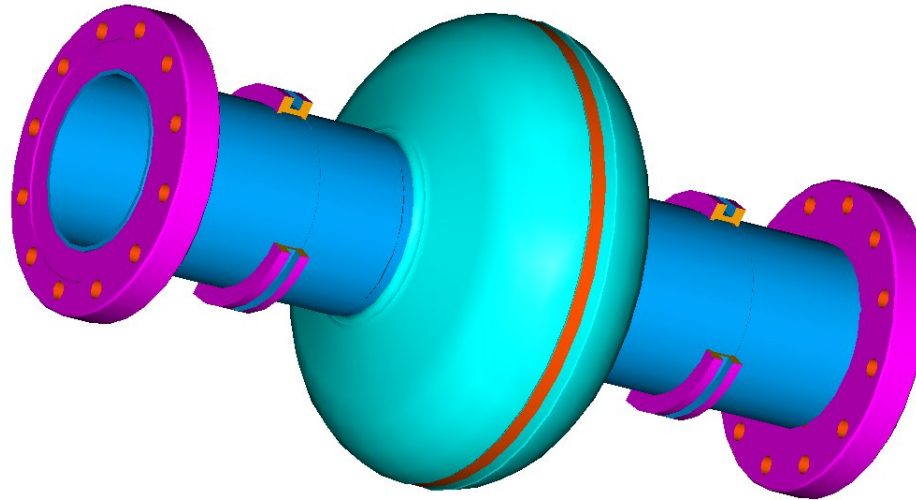
- Large grain niobium:
 - application of “large grain” (**cm-size**) niobium disks cut from ingot (instead of forged and rolled sheets with grain size of $\sim 100\mu\text{m}$)
 - **test of mono-crystal** niobium (one cavity)
- Qualification of further niobium vendors:
 - Heraeus stopped fabrication of Nb sheets; only ingots available
=> **sheets by Plansee Co. need to be qualified urgently**
 - check of chinese Ningxia niobium
 - check of Cabot niobium, but RRR spec not met
 - check of russian Giredmet niobium with high RRR + low tantalum
=> availability of large quantities??

Object of the program (ctd.)

- Comparison of EP processes at Henkel + DESY
 - different and complex behavior of electrolytic bath (1 part HF : 9 parts H_2SO_4)
=> study of parameters, electrolyte, set-up
- Development of dry-ice cleaning as additional cleaning process (CARE,...)
- Check + optimisation of “120C-bake” parameters
- Further activities:
 - second s.c. photo cathode gun cavity with 0.6-cells (Jacek Sekutowicz)
 - optional: extension to 1.6-cell s.c. gun cavity
 - prototype of three-cell cavity

Status and Results

- DESY standard single-cell cavity:



- 13 cavities at DESY completed:
 - machining, etching, EB welding + mechanical/optical checks inhouse
 - deep drawing of cups and electropolishing (EP) of cavities in industry
- 5 cavities at Accel Co. completed (large grain + mono crystal):
 - final mechanical/optical checks at DESY; EP at Henkel Co.

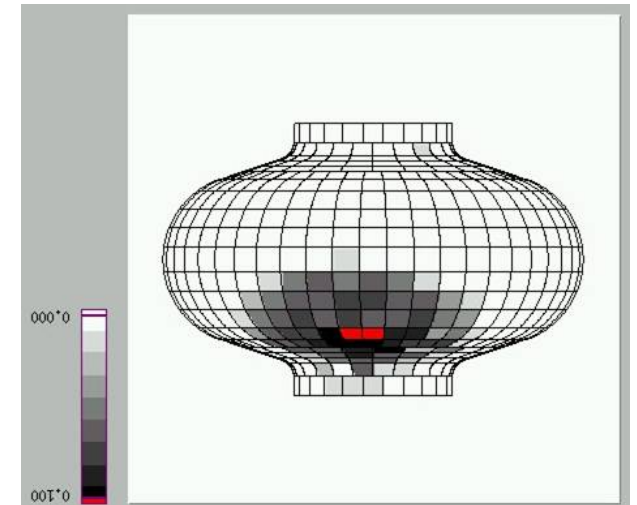
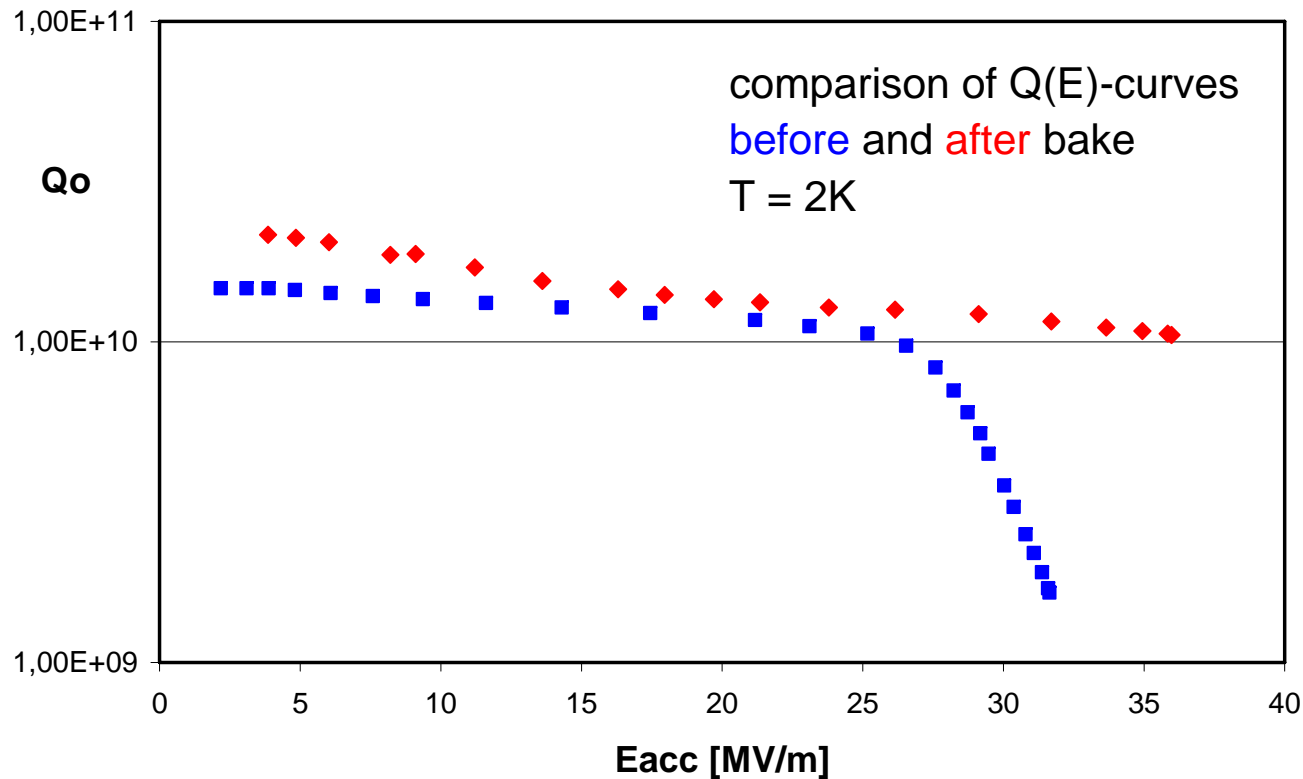
Status + Results: Qualification of DESY production

- First step: Qualification of DESY in-house production:
 - 3 single-cells of well-known Nb quality (Heraeus 1999)
 - deepdrawing of cups at Zanon Co.
 - All electropolishing at Henkel Co.
 - Assembly, HPR and tests at hall NO
- all cavities exceed 30 MV/m at high Q-value limited by Quench
- Example for cavity data presentation

1DE1: First DESY-Cavity successful

- First Cavity of DESY inhouse fabrication
- 150 μm EP@Henkel, 800C, 130 μm EP@Henkel, HPR, 127C bake, HPR
(i) 130 μm EP due to grinding; ii) add. HPR after bake necessary due to field emission)

$$E_{\text{acc}} = 36 \text{ MV/m @ } Q_0 = 1 \cdot 10^{10}; \text{ no FE; limited by BD; few MP}$$

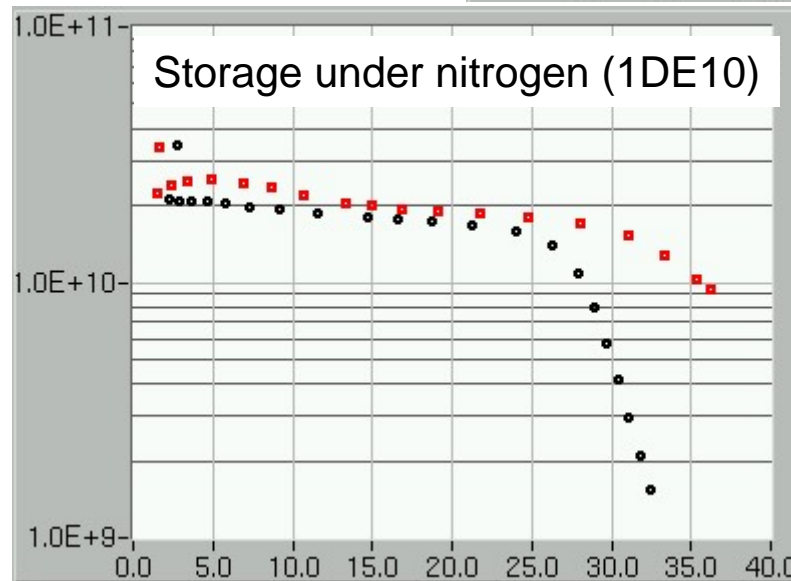
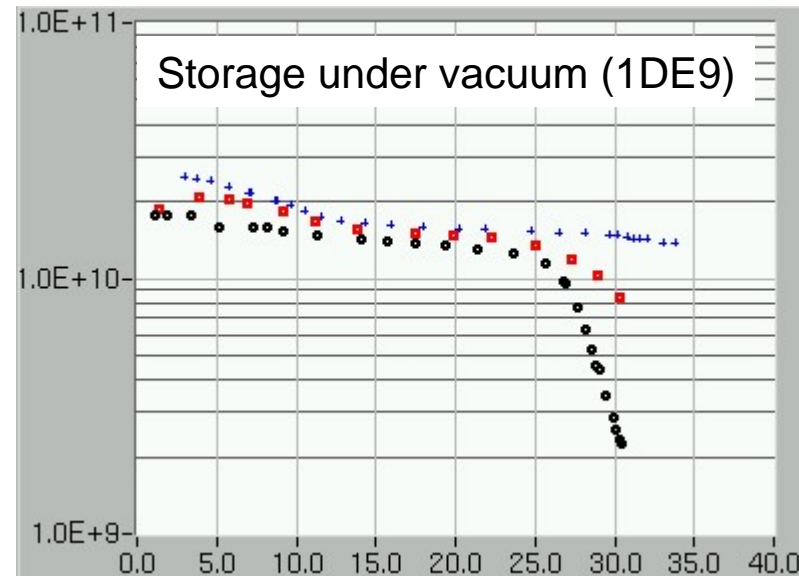
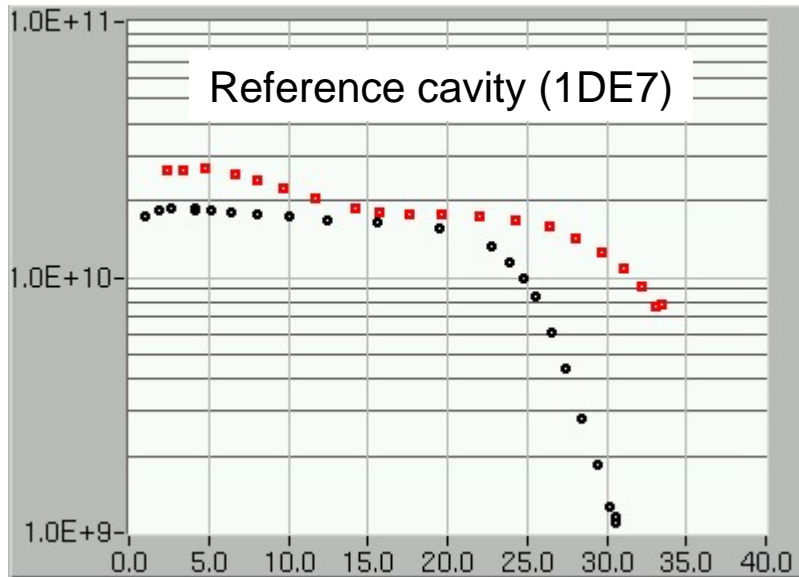


Quench location far off
the equator

Status and Results: Welding preparation

- Modification of present spec for welding preparation during cavity fabrication:
 - 1x reference cavity: max 8h between final etching of weld area and EB welding; (tested)
 - 2x cavities with **168h storage under vacuum** of components after final etch of weld area; (1x tested, 1x ready for test)
 - 2x cavities with **168h storage under nitrogen atmosphere** of components after final etch of weld area; (1x tested; 1x completed)
- **No difference in cavity performance!!**

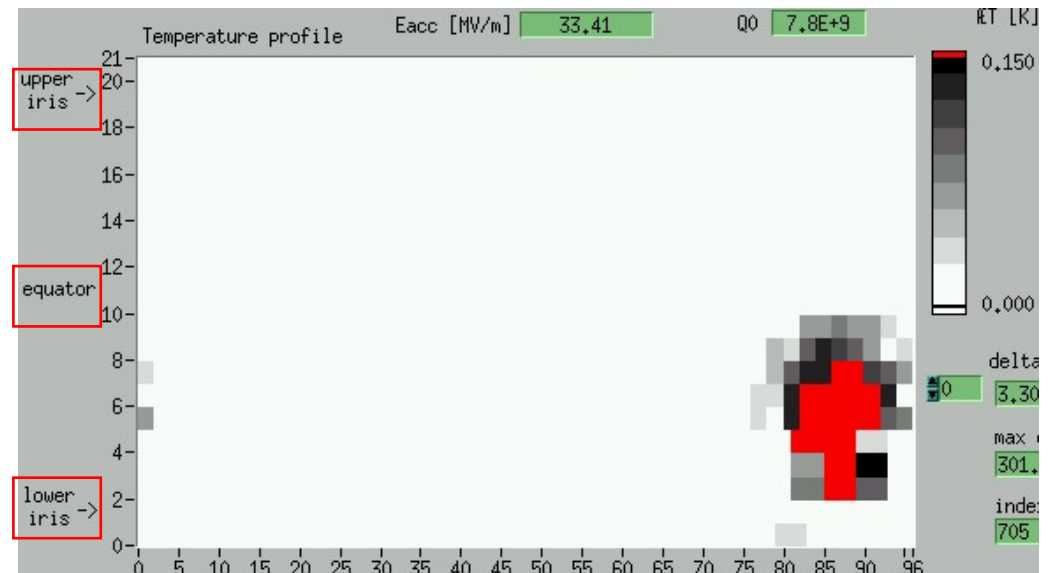
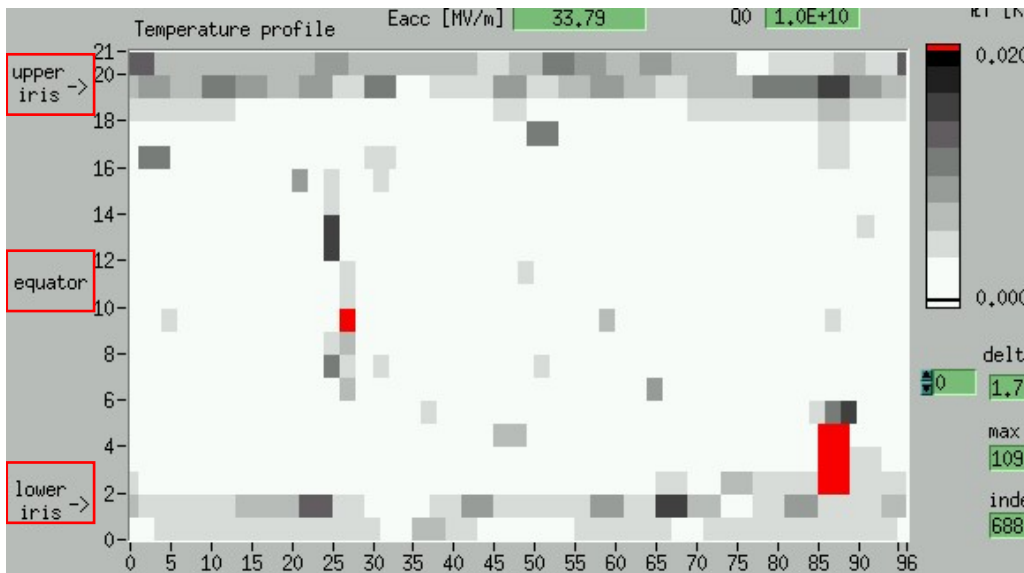
Status and Results: Welding preparation II



Q(E)-curves at 2K
before and after bake

Quench location (1DE7, 1DE9)

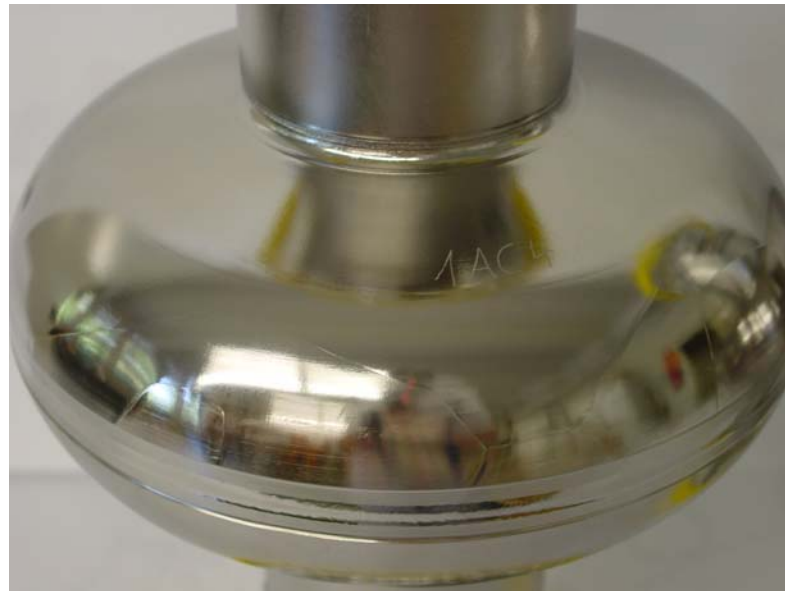
- Reference cavity 1DE7: T-Maps after bake (test 2):
 - T-Mapping shows remaining field emission and pre-cursor of quench
 - T-Map during quench at 33,5 MV/m; quench located well-off the equator



T-maps just before (left) and during (right) quench

Status and Results: Large grain material

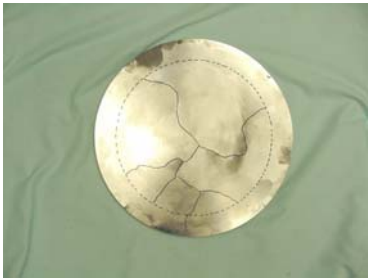
- Four cavities fabricated at Accel Co. of “large grain”-Nb by Heraeus with RRR = 500 (2x tested after EP, 1x ready for test after EP, 1x completed)
- First tests after electropolishing due to
 - i) availability of BCP vs. EP facilities
 - ii) comparison to P.Kneisel’s large grain results after BCP
 - CBMM, Wah Chang + Ningxia niobium at 2,2GHz / 1.5GHz / 1.3GHz
 - 8 – 10 cavities of different cavity shapes => $E_{acc} = (25 - 34) \text{ MV/m}$



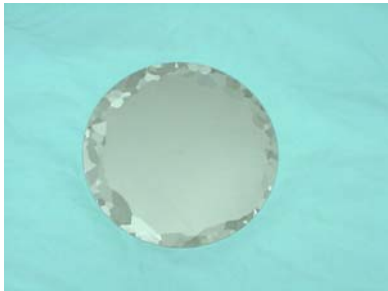
Courtesy by Peter Kneisel

Large Grain/Single Crystal Niobium[2]

CBMM



Ingot "D", 800 ppm Ta



Ingot "A", 800 ppm Ta



Ingot "B", 800 ppm Ta

Ninxia



Wah Chang



Heraeus



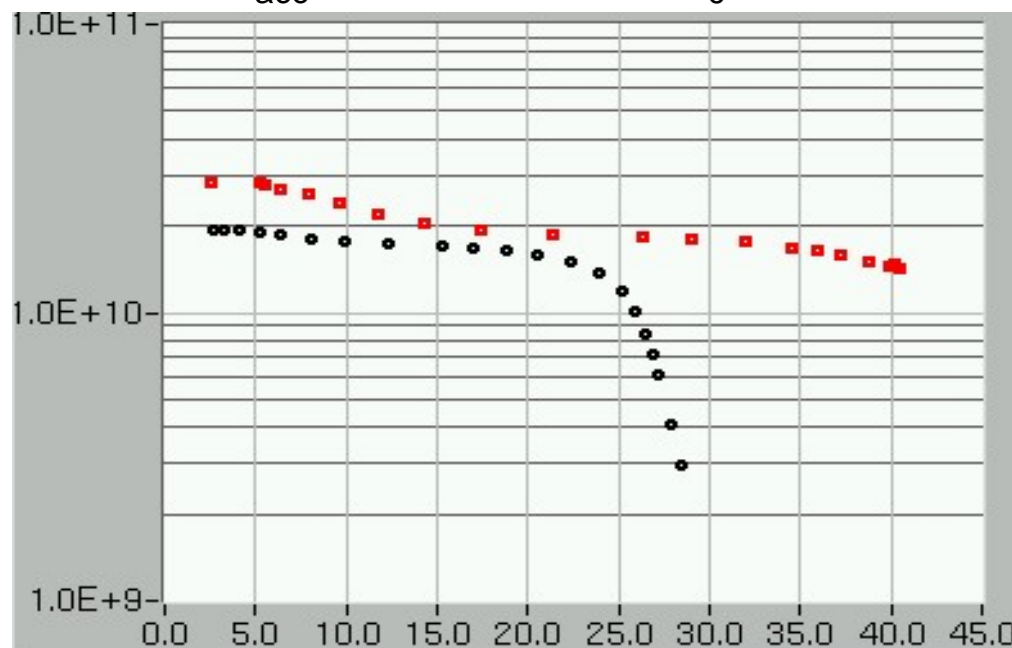
Ingot "C", 1500 ppm Ta



26.04.2006

Summary of large grain cavity 1AC3

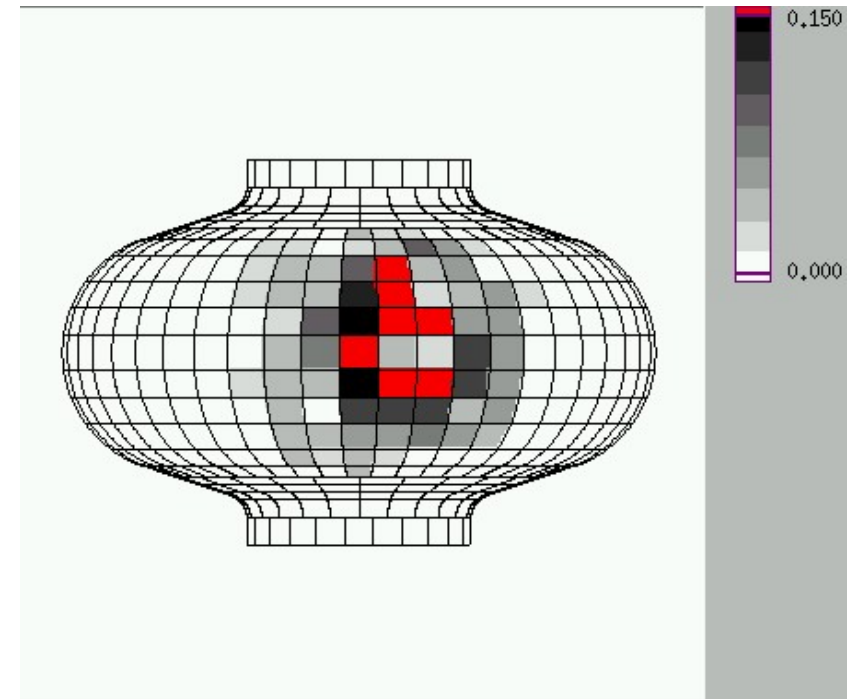
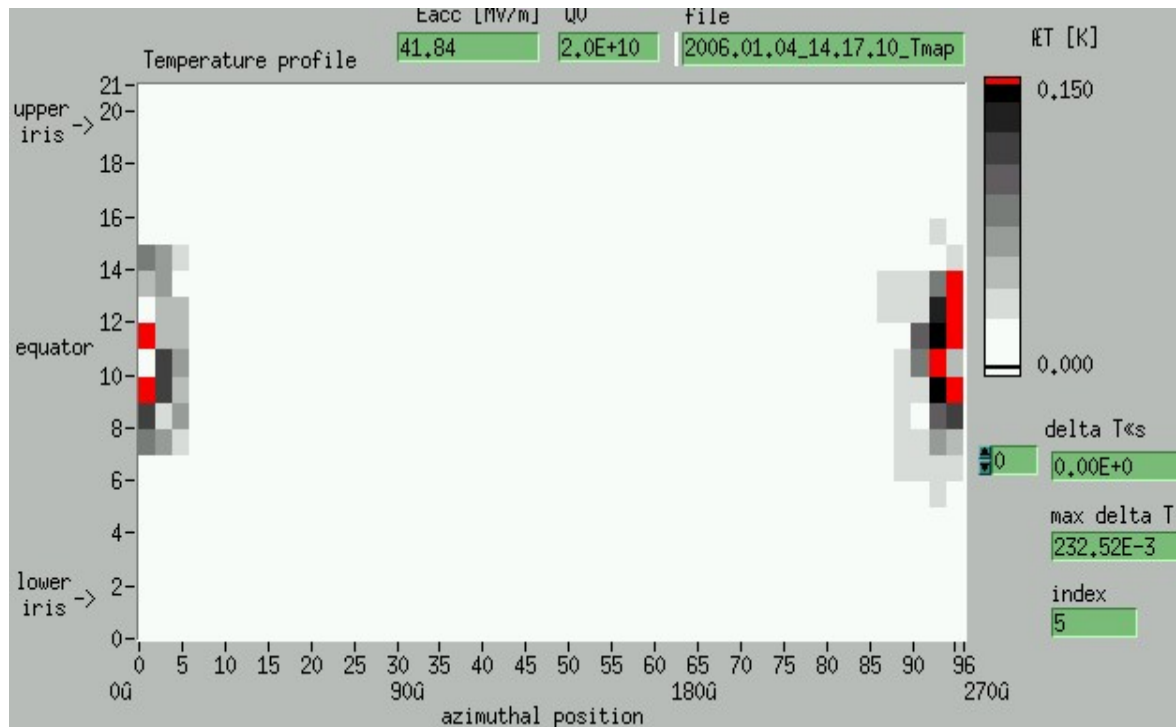
- large grain Heraeus Nb RRR 500 cut from ingot; fabrication at Accel Co.
- Test 1: 150 μ m EP@Henkel, 800C, 40 μ m EP, HPR:
 $E_{acc} = 28,4$ MV/m @ $Q_0 = 3 \cdot 10^9$; **FE** (>25 / n.a.MV/m) ; limited by pwr
- Test 3: baking at 120C,48h + add. HPR (test 2 limited by field emission):
 $E_{acc} = 41$ MV/m @ $Q_0 = 1,4 \cdot 10^{10}$; **no FE** ; limited by bd



Q(E)- curves at 2K before and **after** bake

1AC3: T-Maps of Test 3

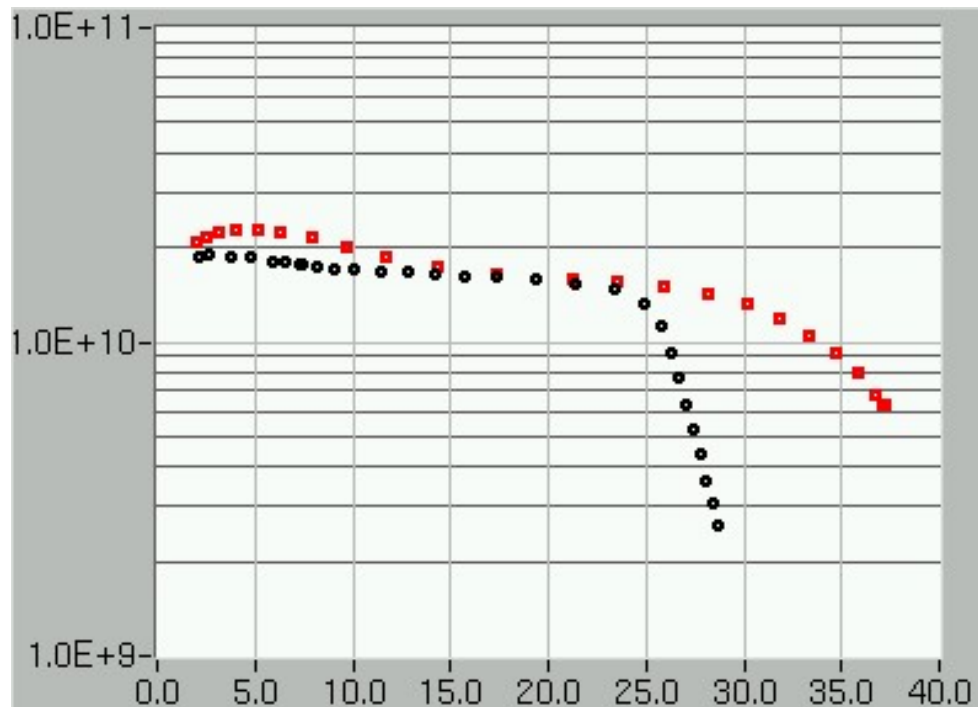
- Test 3: T-Maps at 1.8K **during** quench
 $E_{\text{acc}} = 41 \text{ MV/m}$ @ $Q_0 = 2,0 \cdot 10^{10}$



T-Map at 1.8K

Summary of large grain cavity 1AC4

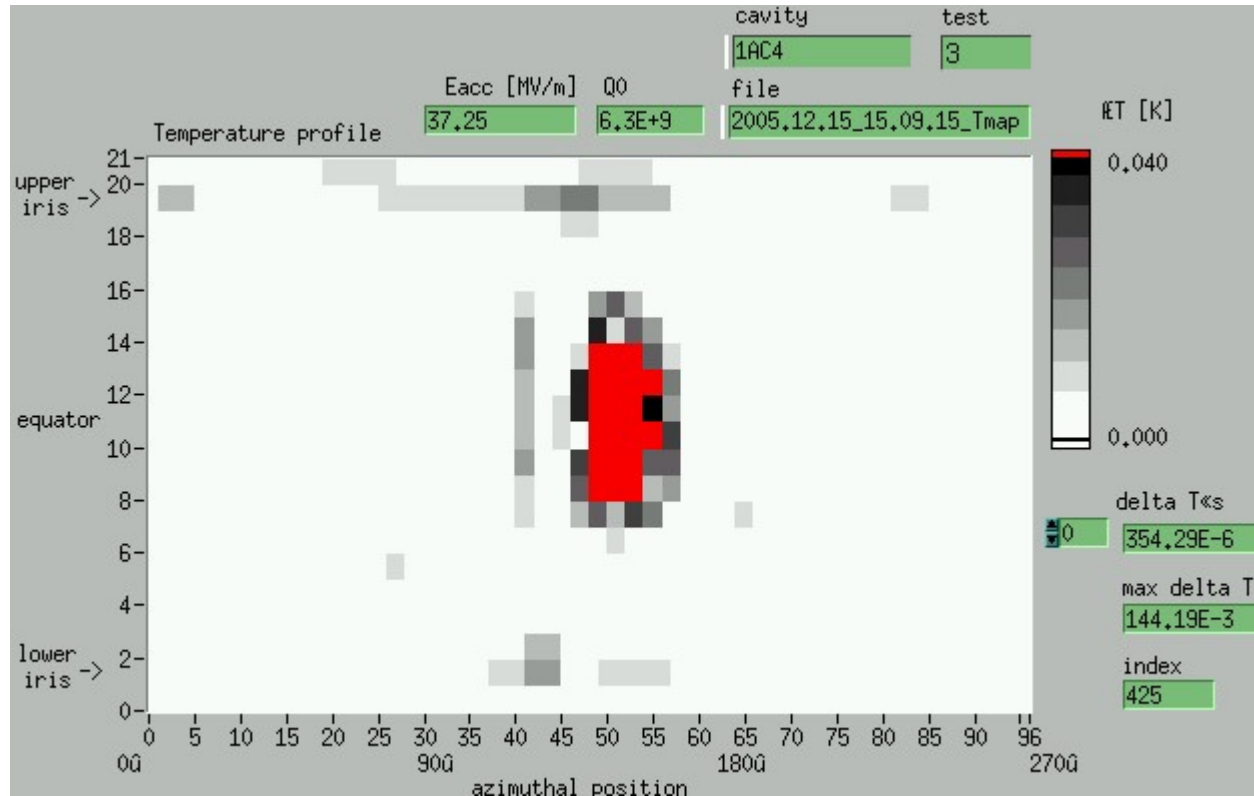
- large grain Heraeus Nb RRR 500 cut from ingot; fabrication at Accel Co.; EP at Henkel Co.
- Test 2: 150 μ m EP, 800C, 40 μ m EP, HPR (test 1 stopped due to cryostat problem)
 $E_{acc} = 29$ MV/m @ $Q_0 = 3 \cdot 10^9$; no FE, no MP, limited by pwr
- Test 3: baking at 128C, 48h:
 $E_{acc} = 37,2$ MV/m @ $Q_0 = 6,3 \cdot 10^9$; FE (>28 / 36MV/m); limited by quench



Q(E) - curves at 2K
before and **after** bake

1AC4: T-Maps of test 3

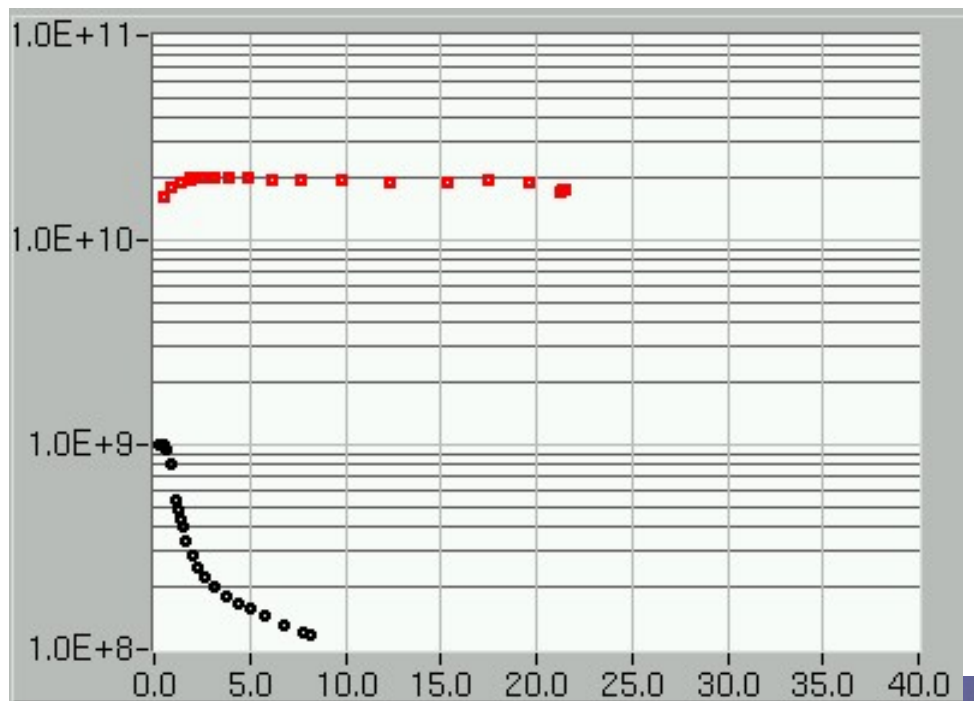
- T-Map no. 13 of test 3 at 37 MV/m during Quench:



- quench location around the equator dominating
- trace and hot spots of field emission clearly visible

Mono-crystal cavity (1AC6)

- Single crystal CBMM Nb with RRR 200; fabrication at Accel Co.
- Test 1: 140 μ m BCP, HPR:
 $E_{acc} = 8 \text{ MV/m @ } Q_0 = 1,2 \cdot 10^9$; **strong Q-disease due to EDM cutting**
- Test 2: add. 750C heat treatment, 30 μ m BCP, HPR:
 $E_{acc} = 21,5 \text{ MV/m @ } Q_0 = 1,8 \cdot 10^{10}$; **limited by quench**, no FE



=> next test after more BCP

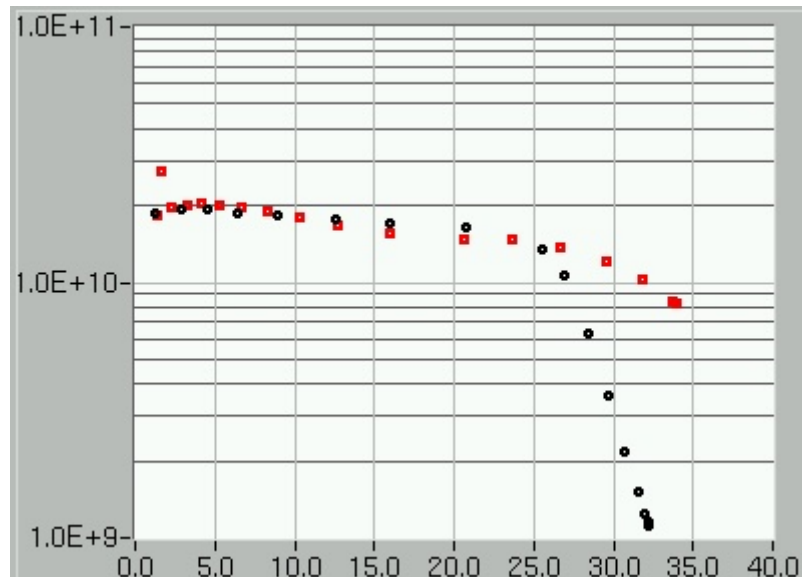
Q(E) - curves at 2K before
and **after** 750C + 30 μ m BCP

Large grain material: Summary

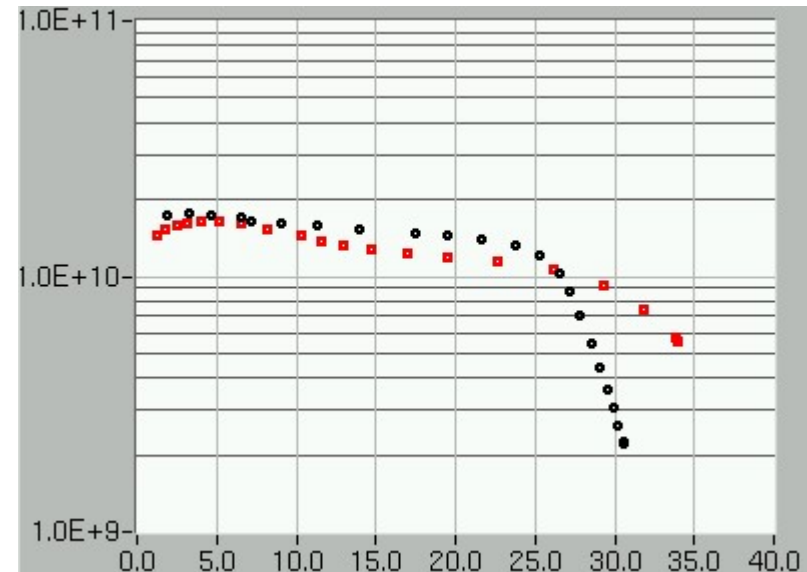
- Electropolished Heraeus “large grain”- niobium gives comparable performance to the best “fine grain”- Nb cavities
- **Q-disease check is missing**
- Next tests after etching (BCP)
 - 2x cavities in two steps; 1x cavity one step
 - new cavity only BCP
- Three nine-cell cavities under fabrication (Accel Co., delivery in May 06)
- Mono-crystal cavity:
 - next test after add. Etching
 - poor result compared to P.Kneisel (>38 MV/m in two cavities at 2.3 GHz)

Status and Results: Giredmet Nb

- Three cavities fabricated in-house of russian Giredmet Nb with RRR > 600 (2x completed)
- Preparation: 150 μ m EP, 800C firing, 40 μ m EP, HPR, (add. HPR or add. 130C/136C bake)
- Qualification successful !!



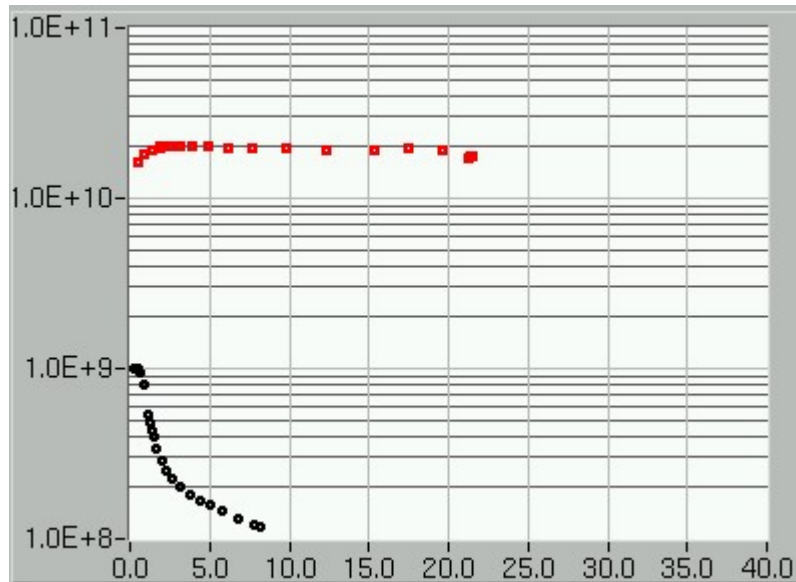
Q(E)-curves of 1DE4 before and after bake
(some FE present before and after bake)



Q(E)-curves of 1DE5 before and after bake
(some FE present before and after bake)

Q-disease

- Q-disease after Henkel EP:
- No Q-disease found after EP at Henkel Co. up to now (not all cavities checked!)
- URGENT: Q-disease check of “large grain”-niobium cavities!!!
- Example for Q-disease: mono-crystal cavity after heavy grinding + BCP



1AC6: Q(E)-curves at 2K before and after 750C + 30 μ m BCP

Summary, next steps and some problems

- Qualification of DESY in-house cavity fabrication successful
=> reproducible gradients above 30MV/m
- Modified welding preparation gives good results
=> complete cavity tests for changed welding preparation (“8h-Regel”)
=> application to next single-cells for more statistics
- “Large-grain” show excellent results after EP
=> tests after BCP of existing “large grain” cavities
=> comparison between BCP and EP on “large grain” Nb material
- New BCP preparation of the mono-crystal cavity
- Complex behavior of electrolytic bath of the EP process
=> study about electrolyte management starts now (Henkel Co., DESY)
=> 2 single-cells treated with different electrolytes (waiting for final measurement)

Summary, next steps and some problems

- Fabrication, preparation and test of Plansee niobium cavities (summer 06)
- Fabrication, preparation and test of Ningxia niobium cavities (summer 06)
- Fabrication, preparation and test of “large grain” niobium cavities at DESY (autumn 06)
- Fabrication, preparation and test of “large grain” 9-cell cavities
- Upcoming presentation:
 - Test and improvement of parameters of dry-ice cleaning
 - Analysis of “120C bake” procedure
- Workflow at DESY needs further optimisation
- Etching and electropolishing facilities at DESY are overloaded with nine-cells

Thanks!

- Thanks to all colleagues for their support:
 - MVP, MVA, MKS, MHF-sl, ZM, V4, AV, Henkel Co. + all others
- Thanks to J. Iversen + W.Singer

Addendum:

- Additional transparencies for explanation!

Q-disease II

- Q-disease after Henkel EP:
- No Q-disease found after EP at Henkel Co. up to now (not all cavities checked!)
- URGENT: Q-disease check of “large grain”-niobium cavities!!!

- Some examples:
 - 1AC2: no Q-disease after 40h at 115 -125K (between tests, april 05)
 - 1DE4: no Q-disease after 18h at 100-120K
 - 1DE9: no Q-disease after 15h at 80 -100 K (between tests)
 - 1DE10: no Q-disease after parking at 75 – 90K over night (before test)

Courtesy by Peter Kneisel

Update since Snowmass(2)

Large grain Ingot "D" from CBMM

