Status of the XFEL test cavity program

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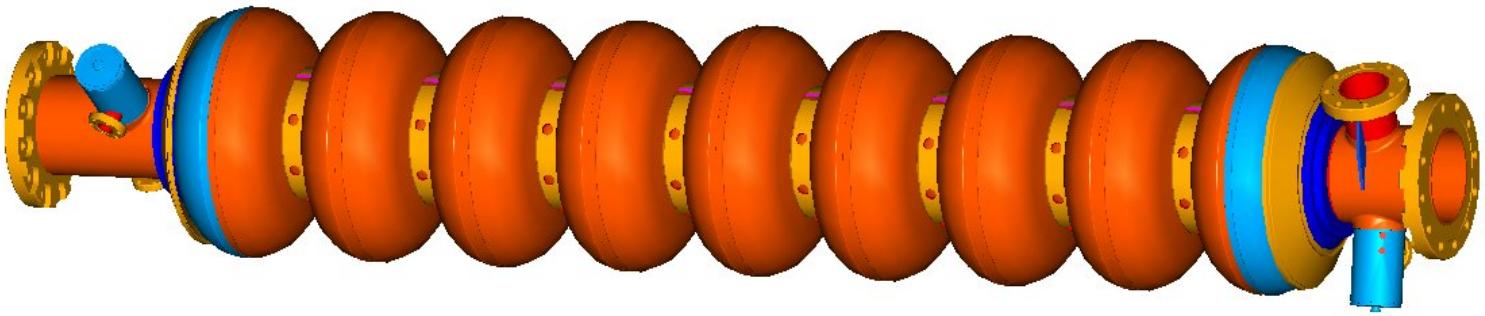
for the test cavity program team

- 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

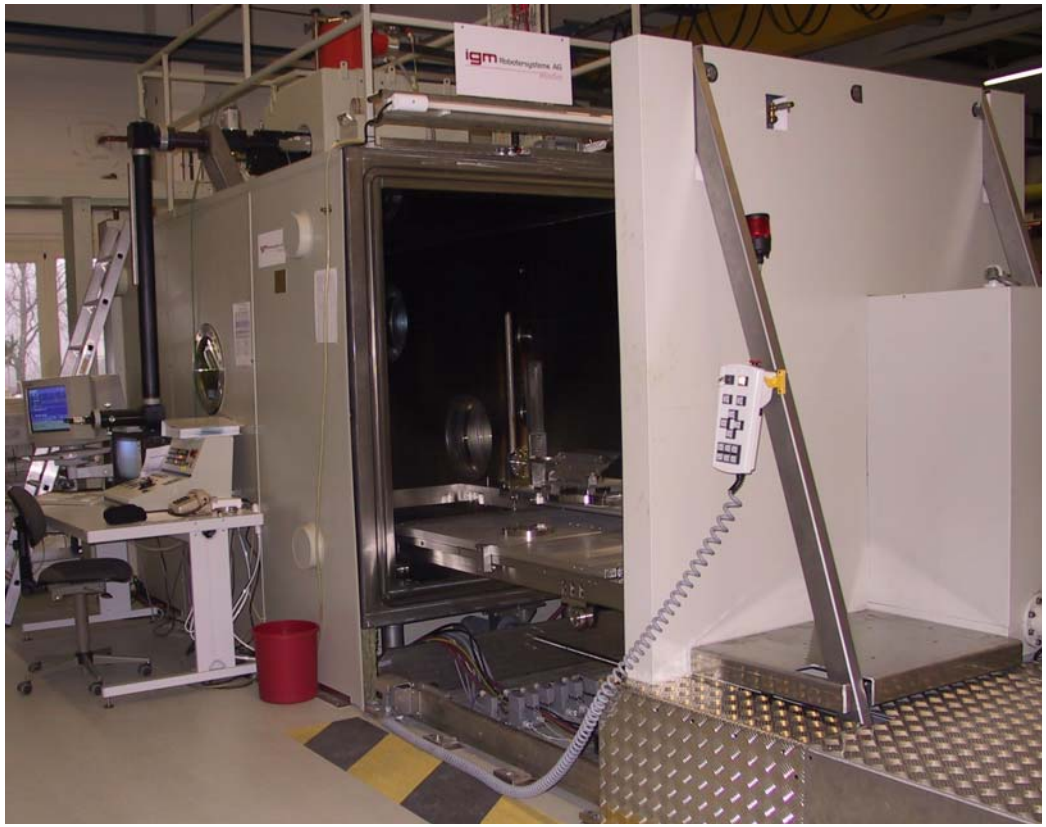
Object of the program

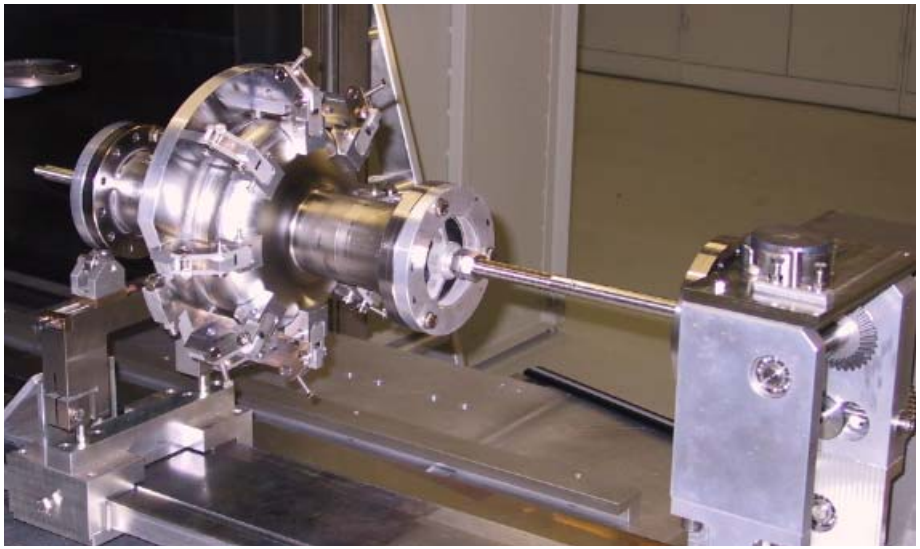
- Modification of present spec for welding preparation during cavity fabrication:

  - 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 ~ 100µm)

  - 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??

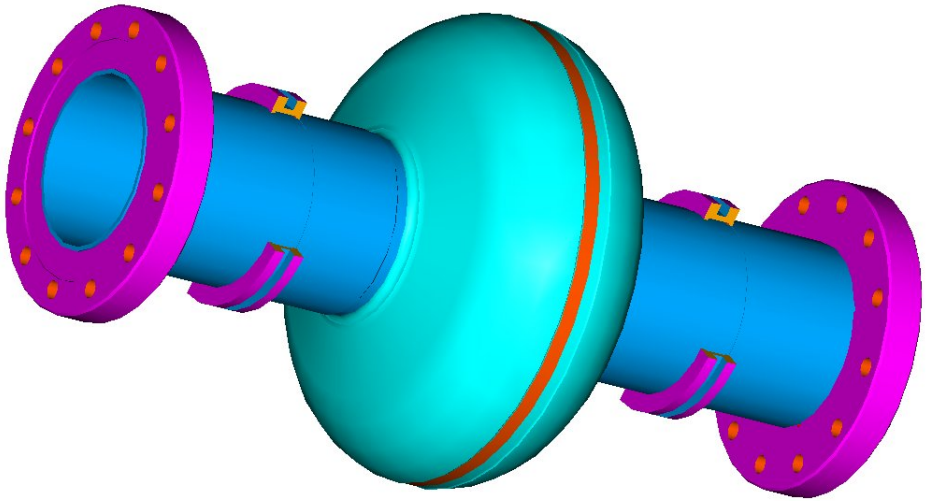
Object of the program (ctd.)

- 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

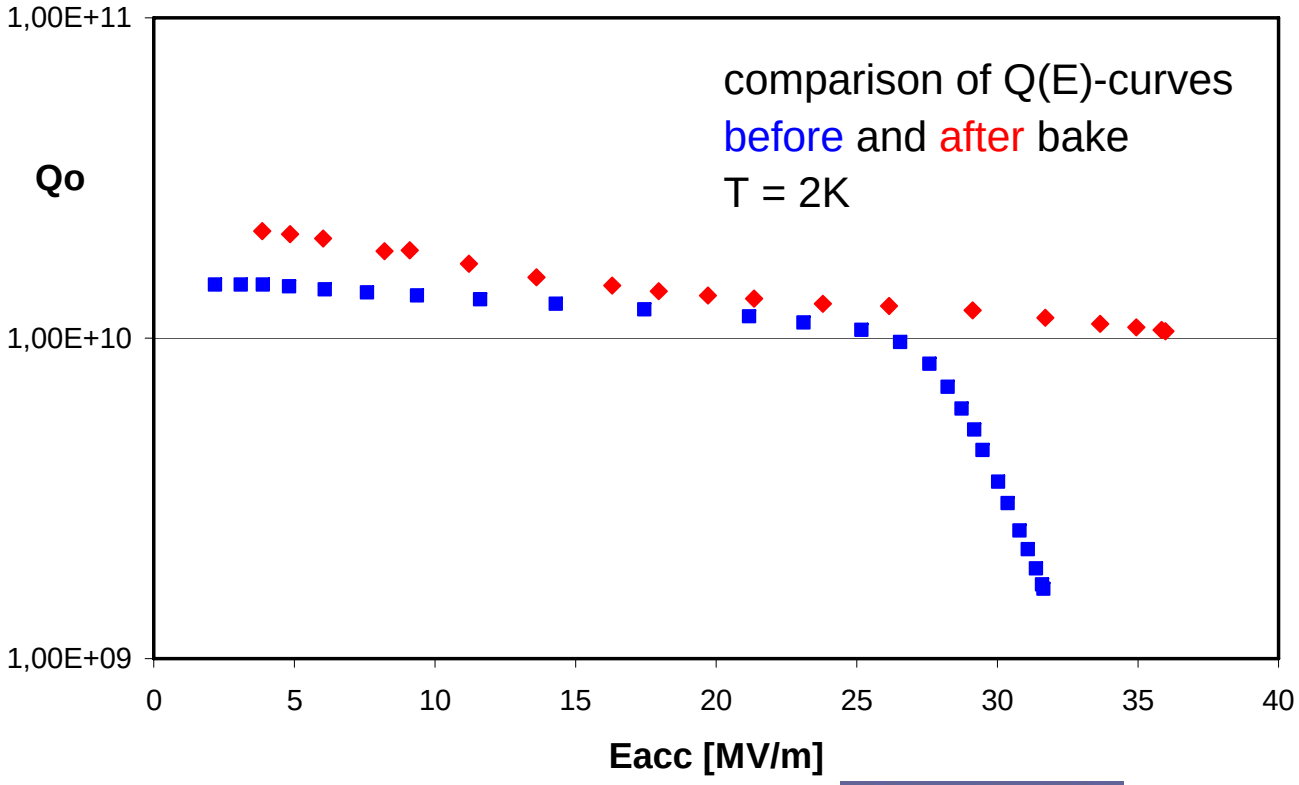
- First step: Qualification of DESY in-house production:
  - 3 single-cells of well-known Nb quality (Heraeus 1999)
  - deepdrawing of cups at Zanon Co.
  - All electropolishing at Henkel Co.
  - Assembly, HPR and tests at hall NO

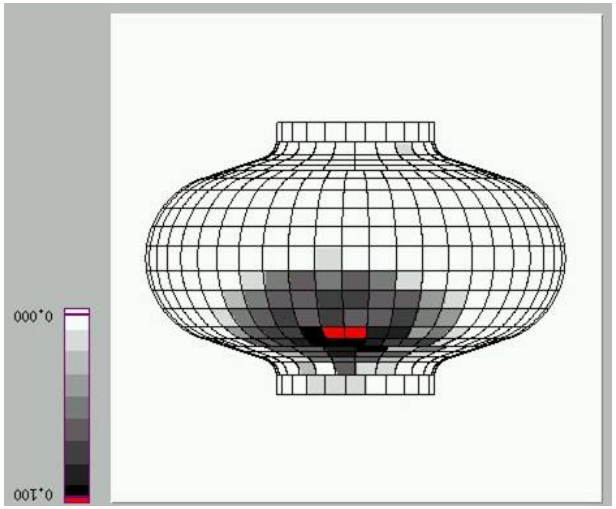
- all cavities exceed 30 MV/m at high Q-value limited by Quench

- Example for cavity data presentation

1DE1: First DESY-Cavity successful

- First Cavity of DESY inhouse fabrication
- 150µm EP@Henkel, 800C, 130µm EP@Henkel, HPR, 127C bake, HPR
  (i) 130µm EP due to grinding; ii) add. HPR after bake necessary due to field emission)
  E_{acc} = 36 MV/m @ Q_0 = 1 ·10^{10}; no FE; limited by BD; few MP





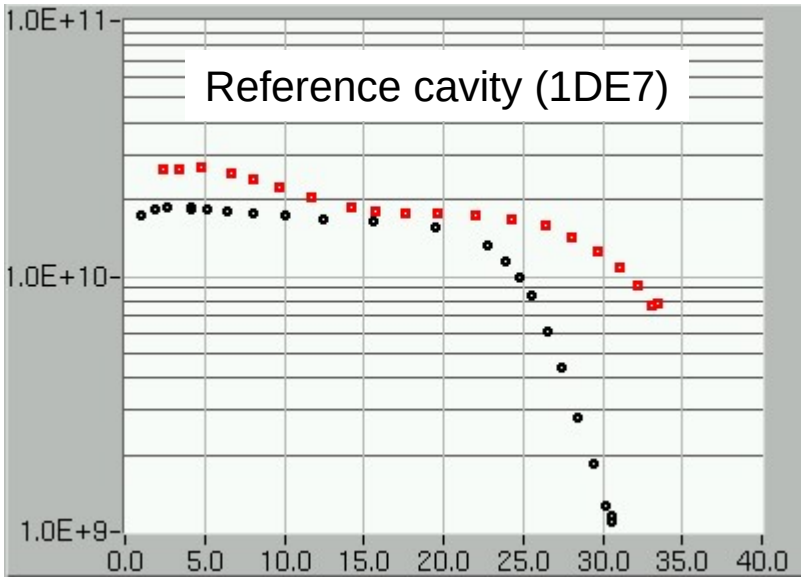
Quench location far off the equator

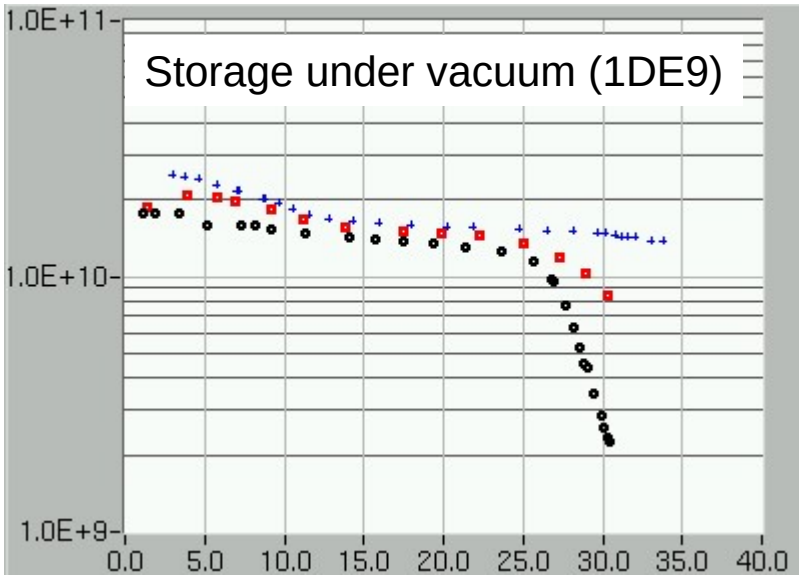
Status and Results: Welding preparation

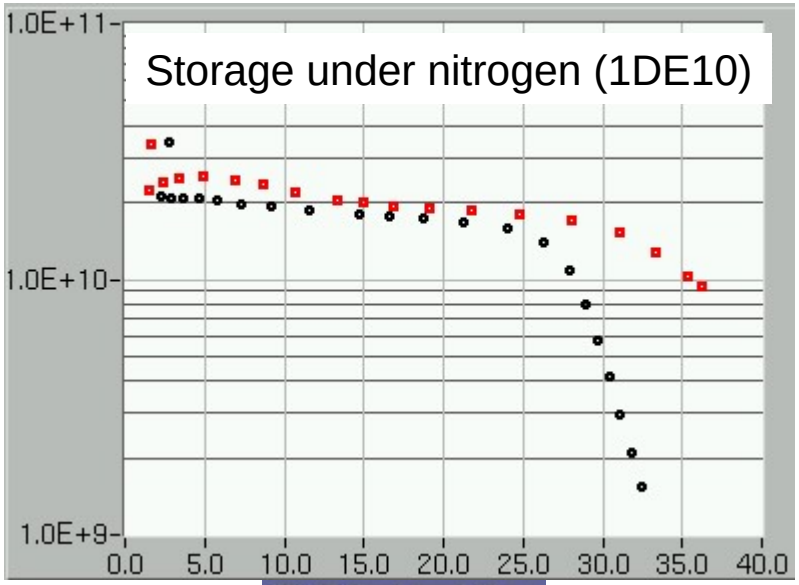
- Modification of present spec for welding preparation during cavity fabrication:
  - 1x reference cavity: max 8h between final etching of weld area and EB welding; (tested)
  - 2x cavities with 168h storage under vacuum of components after final etch of weld area; (1x tested, 1x ready for test)
  - 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



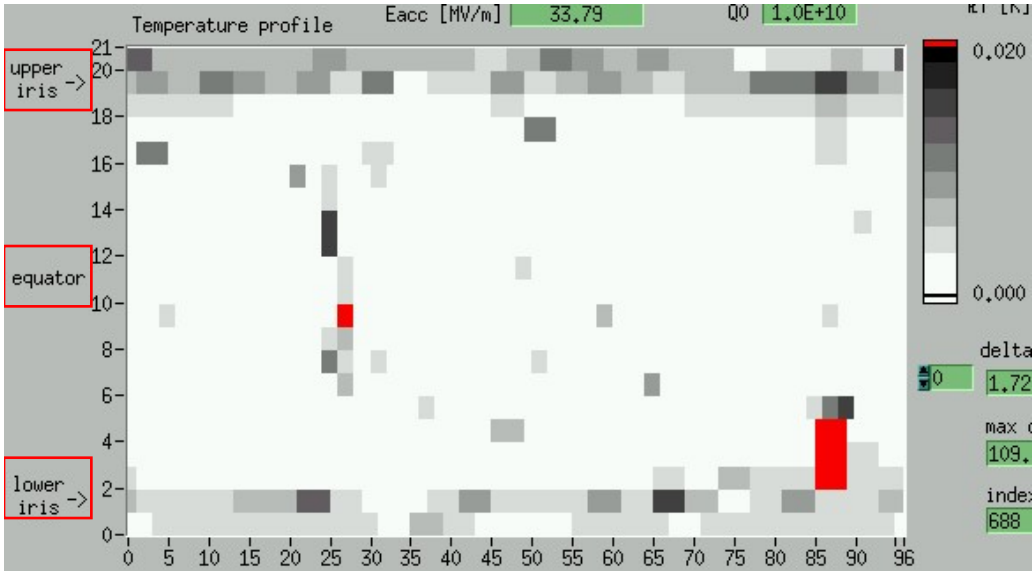


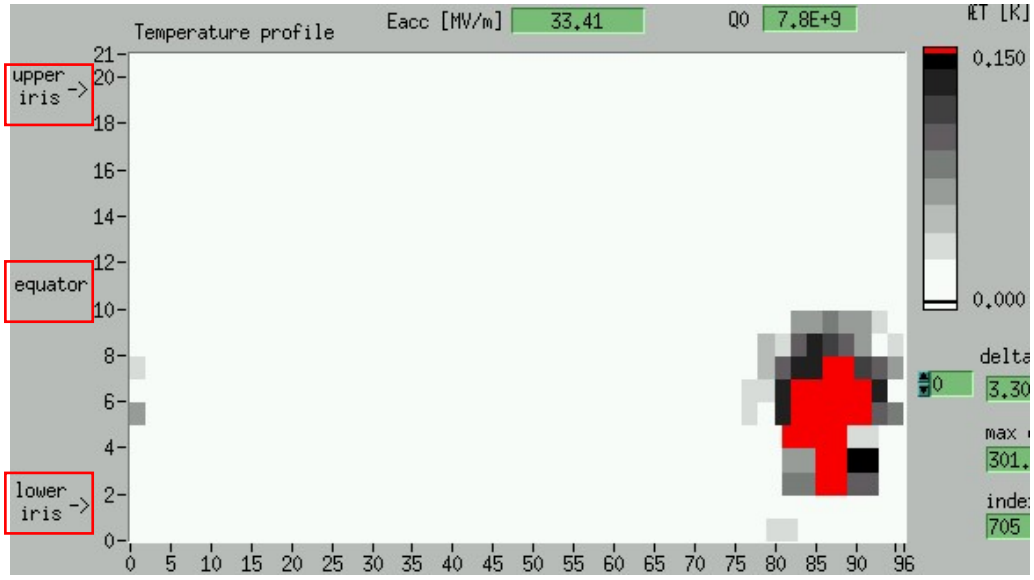


Q(E)-curves at 2K
before and after bake

Quench location (1DE7, 1DE9)

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





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

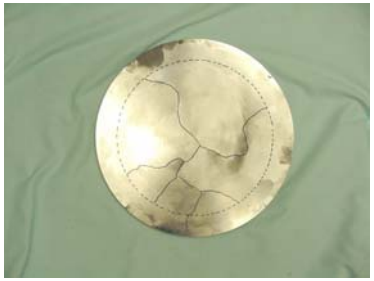
Status and Results: Large grain material

- 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) MV/m

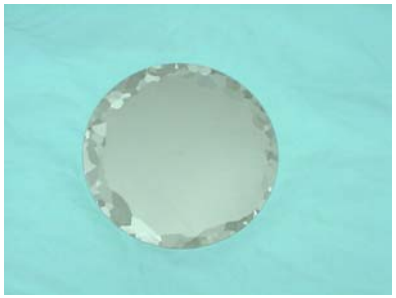
Courtesy by Peter Kneisel

Large Grain/Single Crystal Niobium[2]

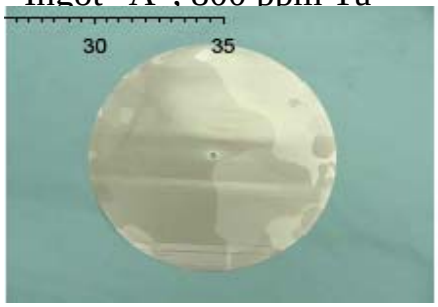
CBMM



Ingot “D”,800 ppm Ta



Ingot “A”, 800 ppm Ta



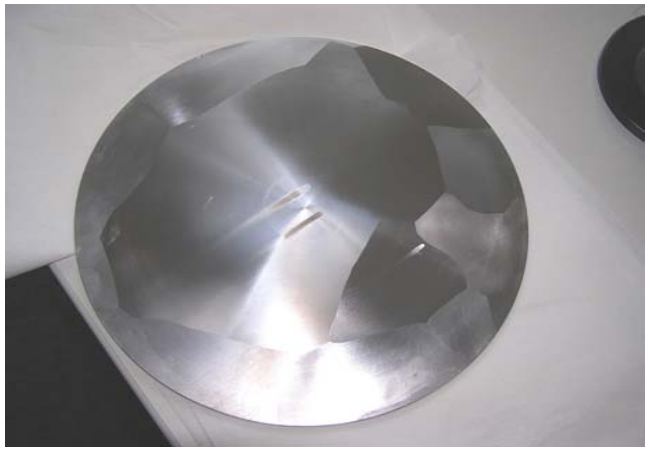
Ingot “B1”, 800 ppm Ta

Ninxia

Wah Chang

Heraeus

Ingot “C”, 1500 ppm Ta

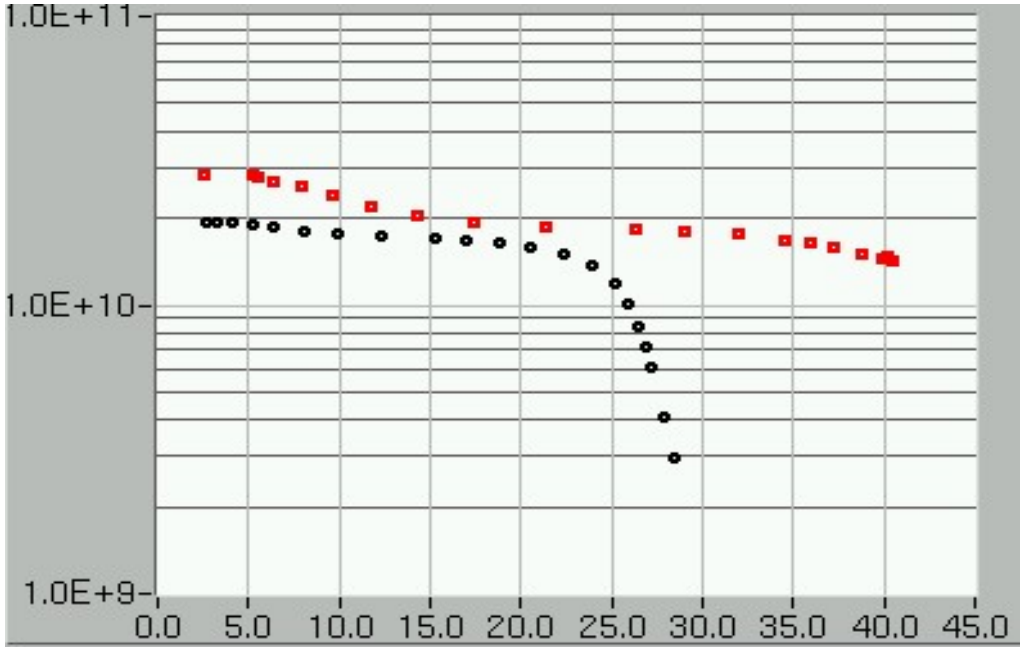


Peter Kneisel

XFEL
X-Ray Free-Electron Laser

Summary of large grain cavity 1AC3

- large grain Heraeus Nb RRR 500 cut from ingot; fabrication at Accel Co.
- Test 1: 150µm EP@Henkel, 800C, 40µm 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

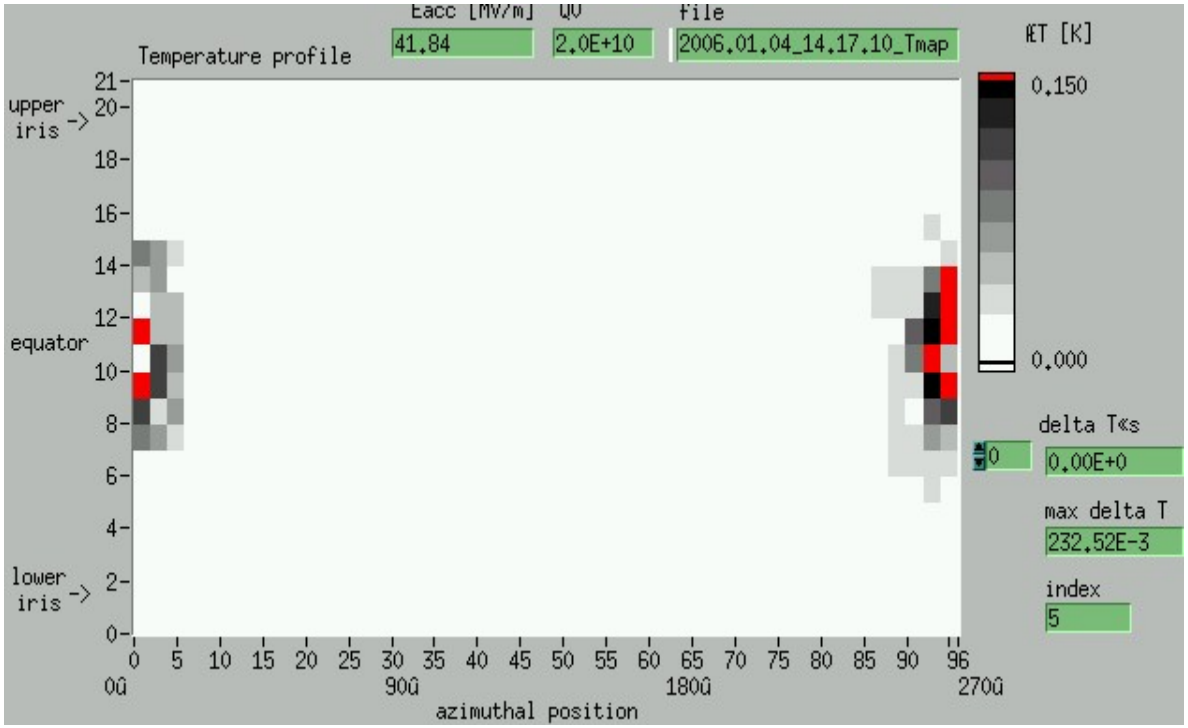


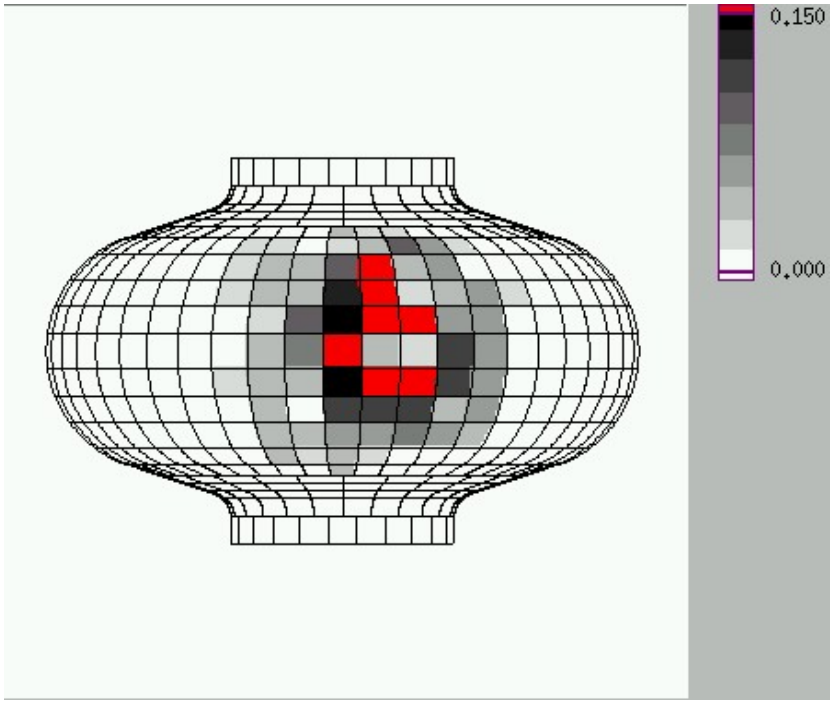
Q(E)- curves at 2K before and after bake

1AC3: T-Maps of Test 3

- Test 3: T-Maps at 1.8K during quench

  E_{acc} = 41 MV/m @ Q_0 = 2,0 ·10^{10}

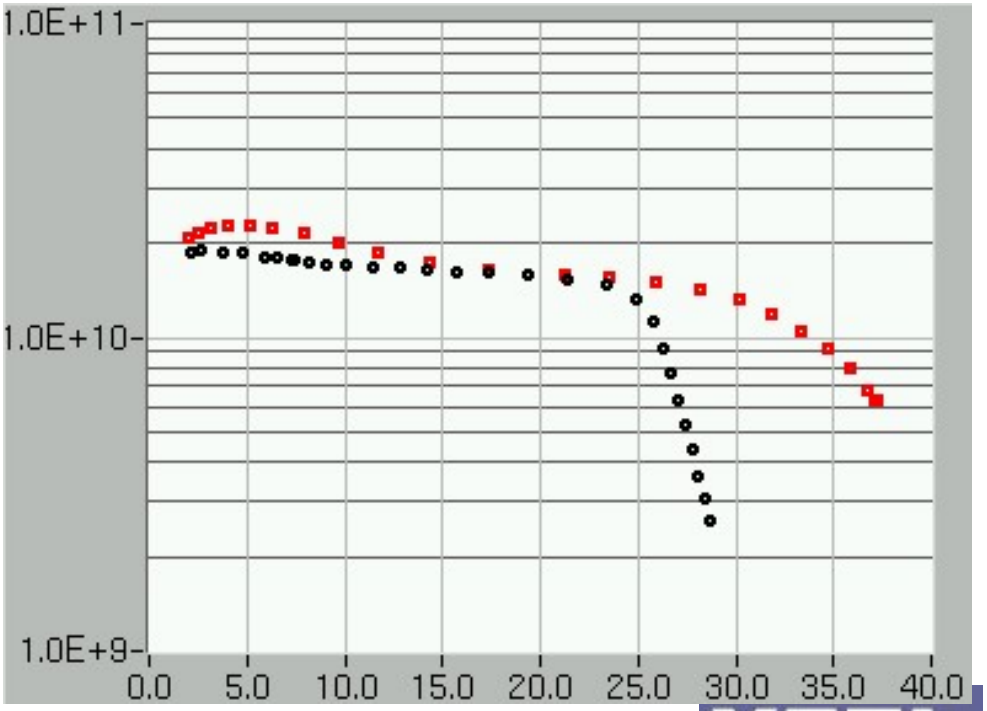




T-Map at 1.8K

Summary of large grain cavity 1AC4

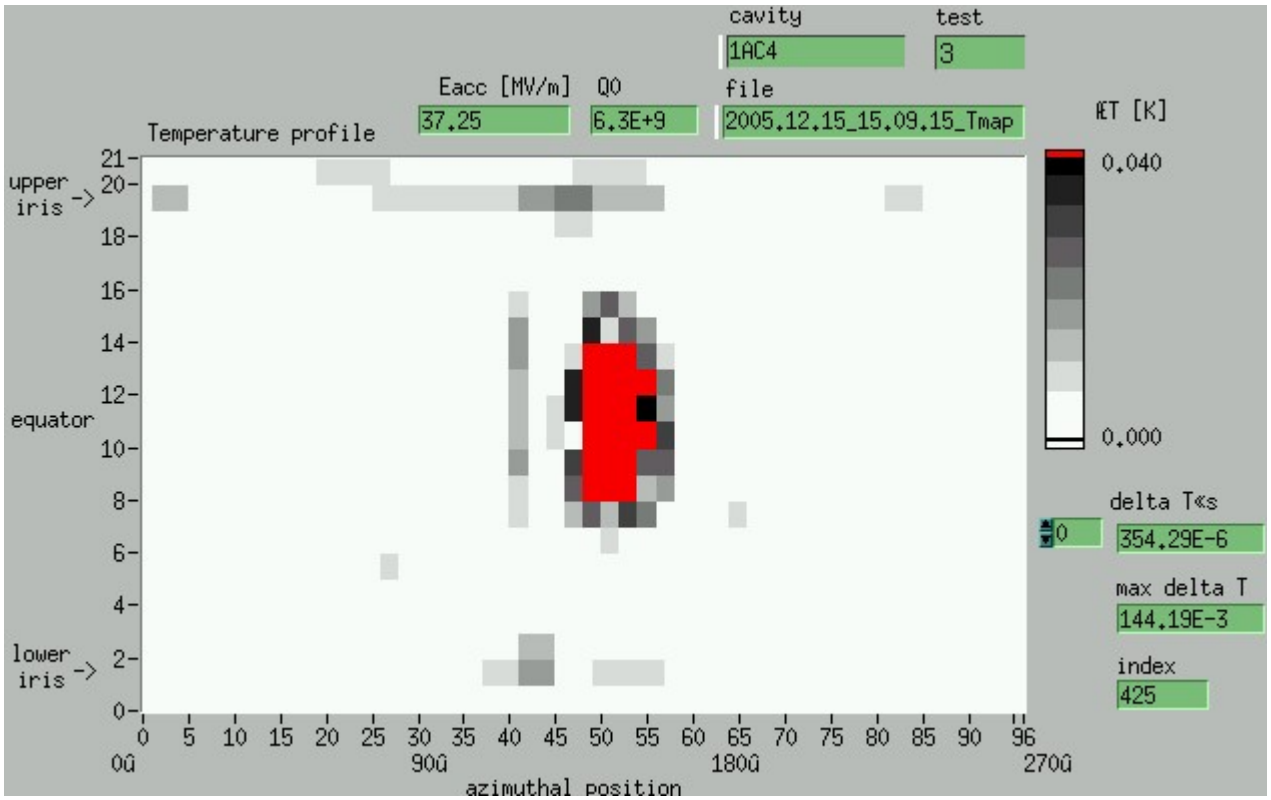
- large grain Heraeus Nb RRR 500 cut from ingot; fabrication at Accel Co.; EP at Henkel Co.
- Test 2: 150µm EP, 800C, 40µm EP, HPR (test 1 stopped due to cryostat problem)
  E_{acc} = 29 MV/m @ $Q_0 = 3 \cdot 10^9$; no FE, no MP, limited by pwr
- Test 3: baking at 128C, 48h:
  E_{acc} = 37,2 MV/m @ $Q_0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

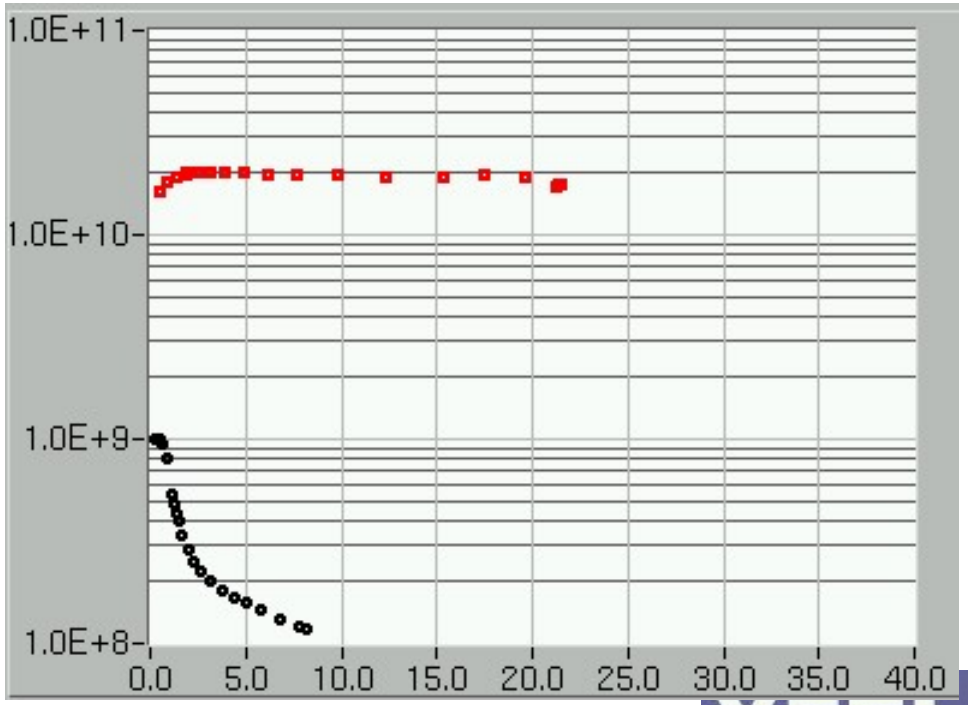


i) quench location around the equator dominating

ii) 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: 140µm BCP, HPR:
  E_{acc} = 8 MV/m @ Q_0 = 1,2 ·10^9; strong Q-disease due to grinding
- Test 2: add. 750C heat treatment, 30µm BCP, HPR:
  E_{acc} = 21,5 MV/m @ Q_0 = 1,8 ·10^{10}; limited by quench, no FE



=> next test after more BCP

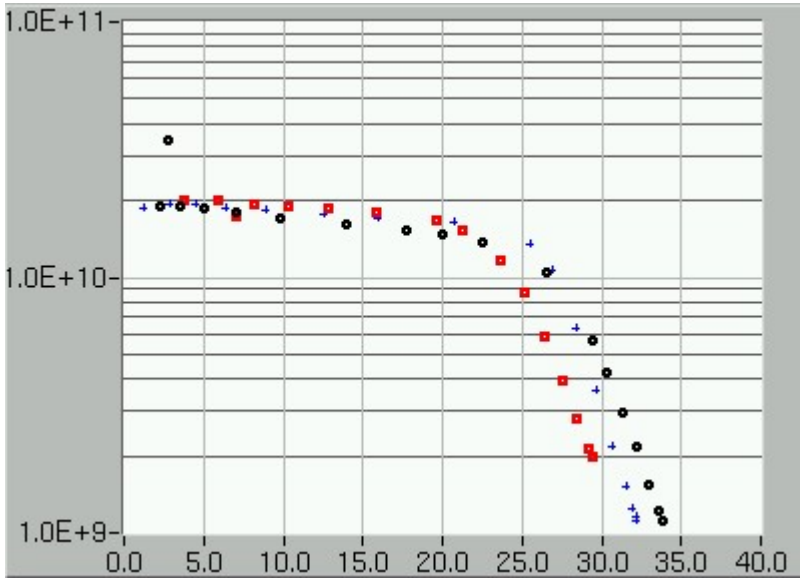
Q(E) - curves at 2K before
and after 750C + 30µm BCP

Large grain material: Summary

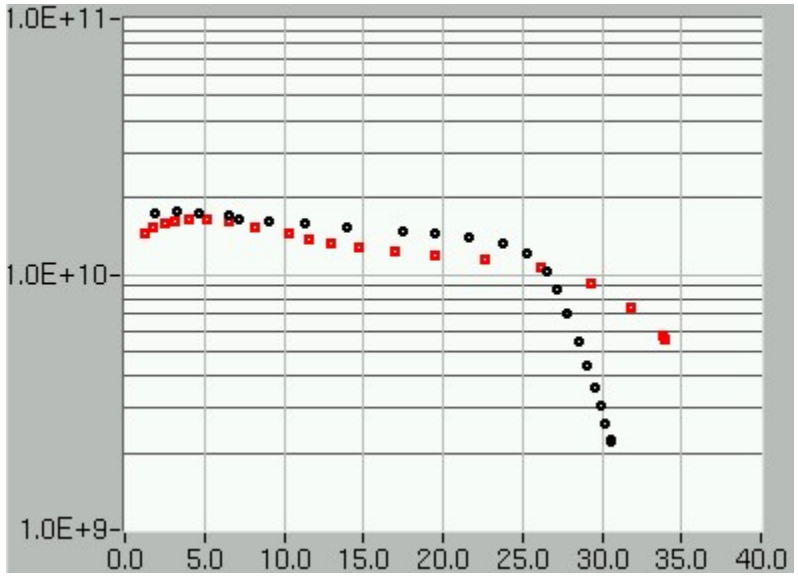
- Electropolished Heraeus “large grain”- niobium gives comparable performance to the best “fine grain”- Nb cavities
- Q-disease check is missing
- Next tests after etching (BCP)
  - 2x cavities in two steps; 1x cavity one step
  - new cavity only BCP
- Three nine-cell cavities under fabrication (Accel 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 tested after EP, 1x completed)
- Preparation: 150µm EP, 800C firing, 40µm EP, HPR, (add. HPR or add. 136C bake)
- Qualification successful !!



Q(E)-curves of 1DE4 before bake
(different treatments due to field emission)

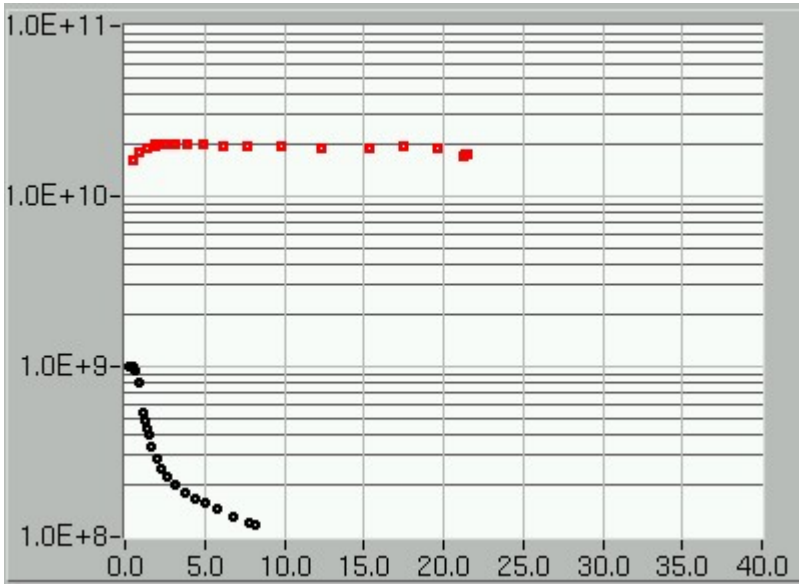


Q(E)-curve of 1DE5 before and after bake

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 + 30µm 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 electolytic 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!

Courtesy by Peter Kneisel

Update since Snowmass(2)

Large grain Ingot “D” from CBMM