Advances in Large Grain/Single Crystal Resonators at DESY *

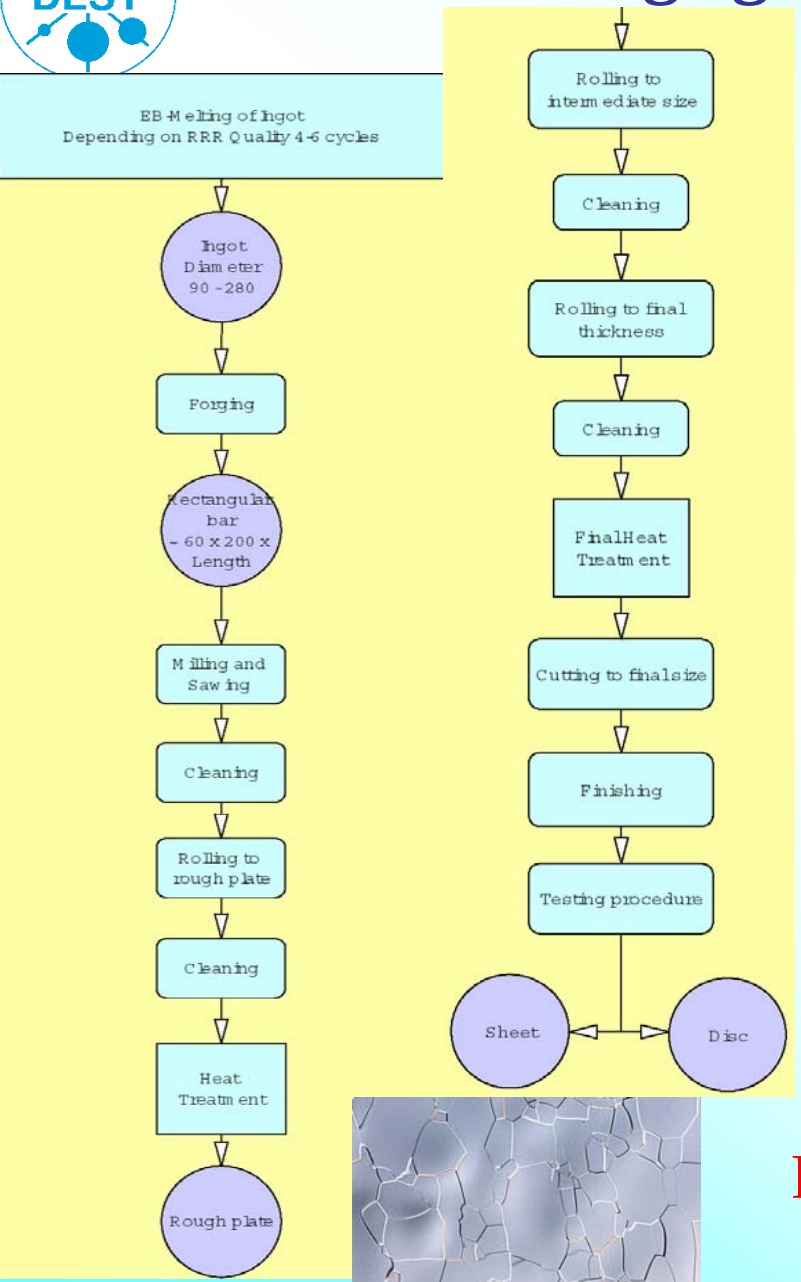
Presented by Waldemar Singer

DESY

- material and fabrication aspects
- preparation and RF test results
- perspectives

* Supported in part by European CARE program

Large grain cavity (LG)



Proposed by

G.Rao,

P.Kneisel,

T.Carneiro

Possibly

- **Cost effective**
- **Higher purity as in the sheet. RRR=600 of ingot is achievable**
- **More predictable behavior for fabrication (spring back for deep drawing etc.)**
- **Less susceptible to field emission (higher field emission onset)**

Fine grain Nb sheet - GB length ~ 3000 m,
LG Nb disc- GB length ~ 3 m

Material and fabrication aspects

Fabrication:

- **disc of HERAEUS cut by diamond saw (B.Spaniol,LINAC 2006, TUP024)**
- **Deep drawing**
- **Machining**
- **EB welding**
- **No grinding of grain boundaries**

- No problems at EB welding
- Very smooth (shiny) surface in grain areas after BCP;
- the steps at grain boundaries are more pronounced as in polycrystalline material

DESY fabricated three LG 9-cell and several single cell cavities at ACCEL from HERAEUS material

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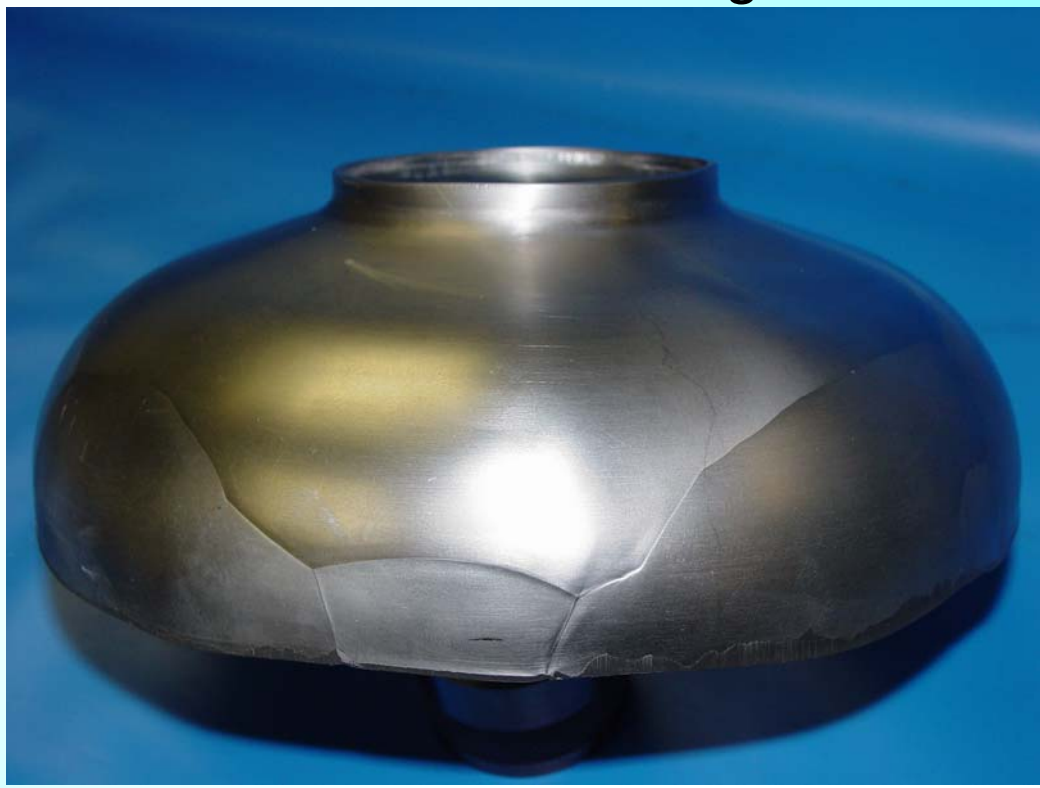
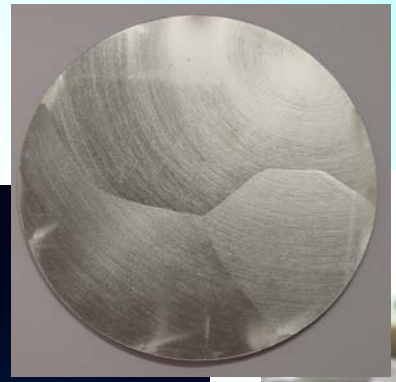
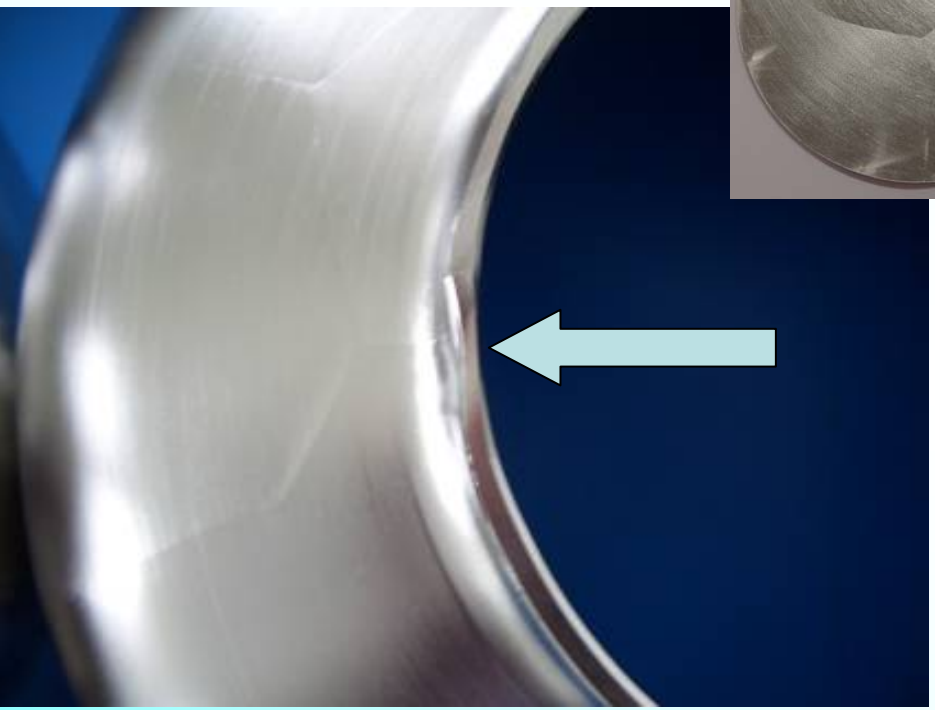
- Some spring back after the deep drawing, making the half cells “oval”
- The same happens after the trimming for EBW
- Assembly for EBW some more difficult as with fine grain material.



Deep drawn half cell of HERAEUS large grain niobium; Large single crystal at centre, no problems on iris area

Deep drawn half cells of another LG Nb supplier

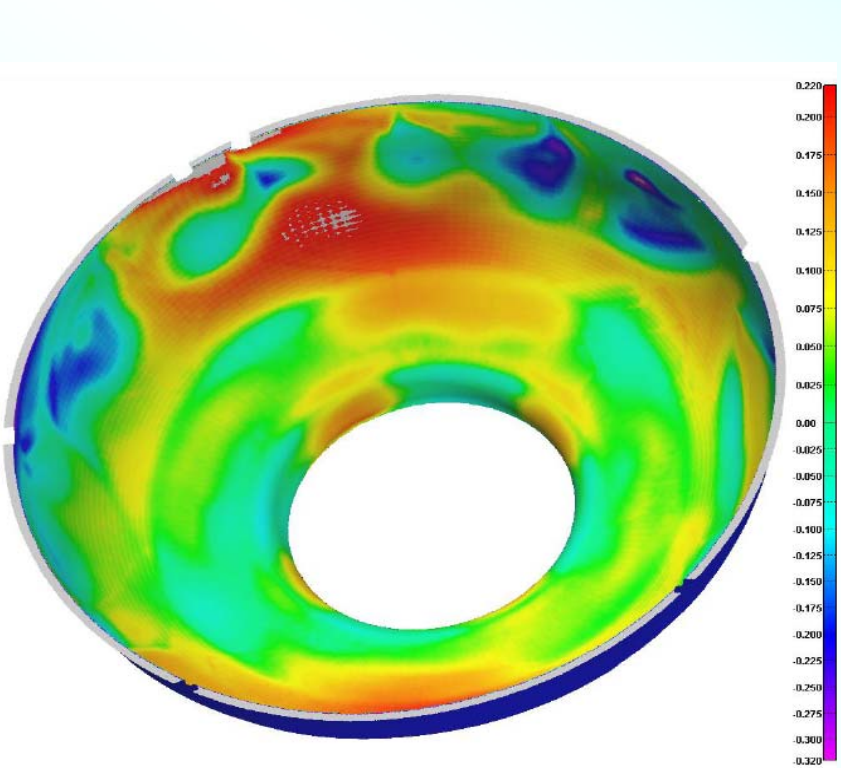


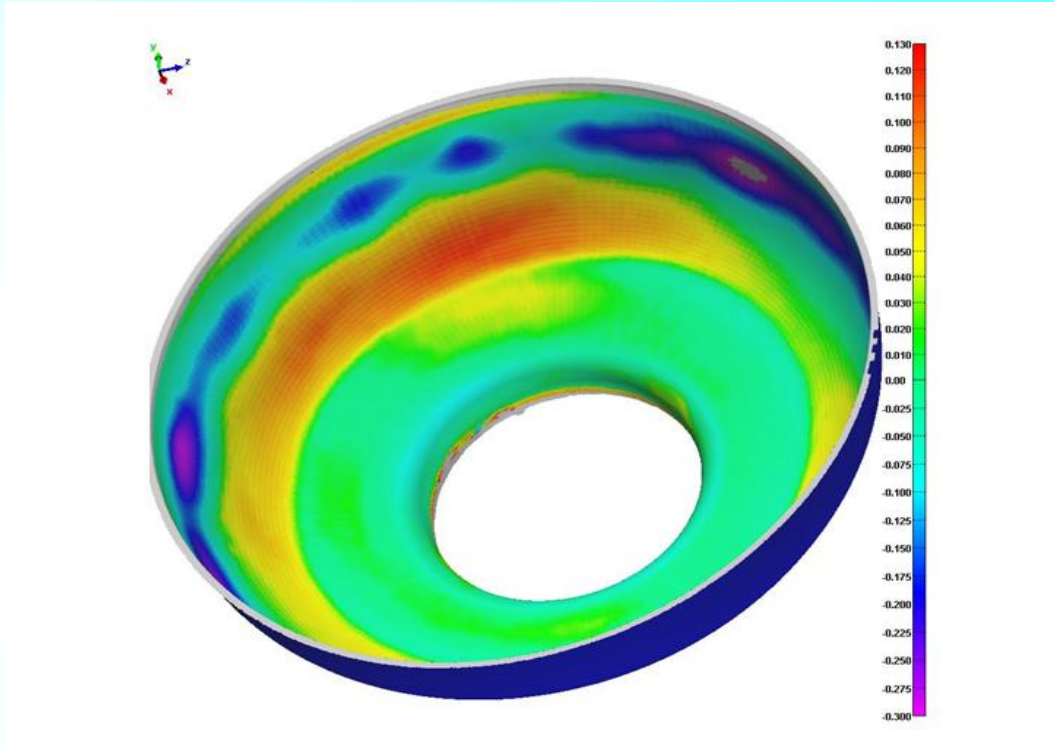


- thinning or ripping at grain boundary in iris if the grains “meet” in these areas

- Strong earing and grain steps at equator region if the grain are not sufficiently big

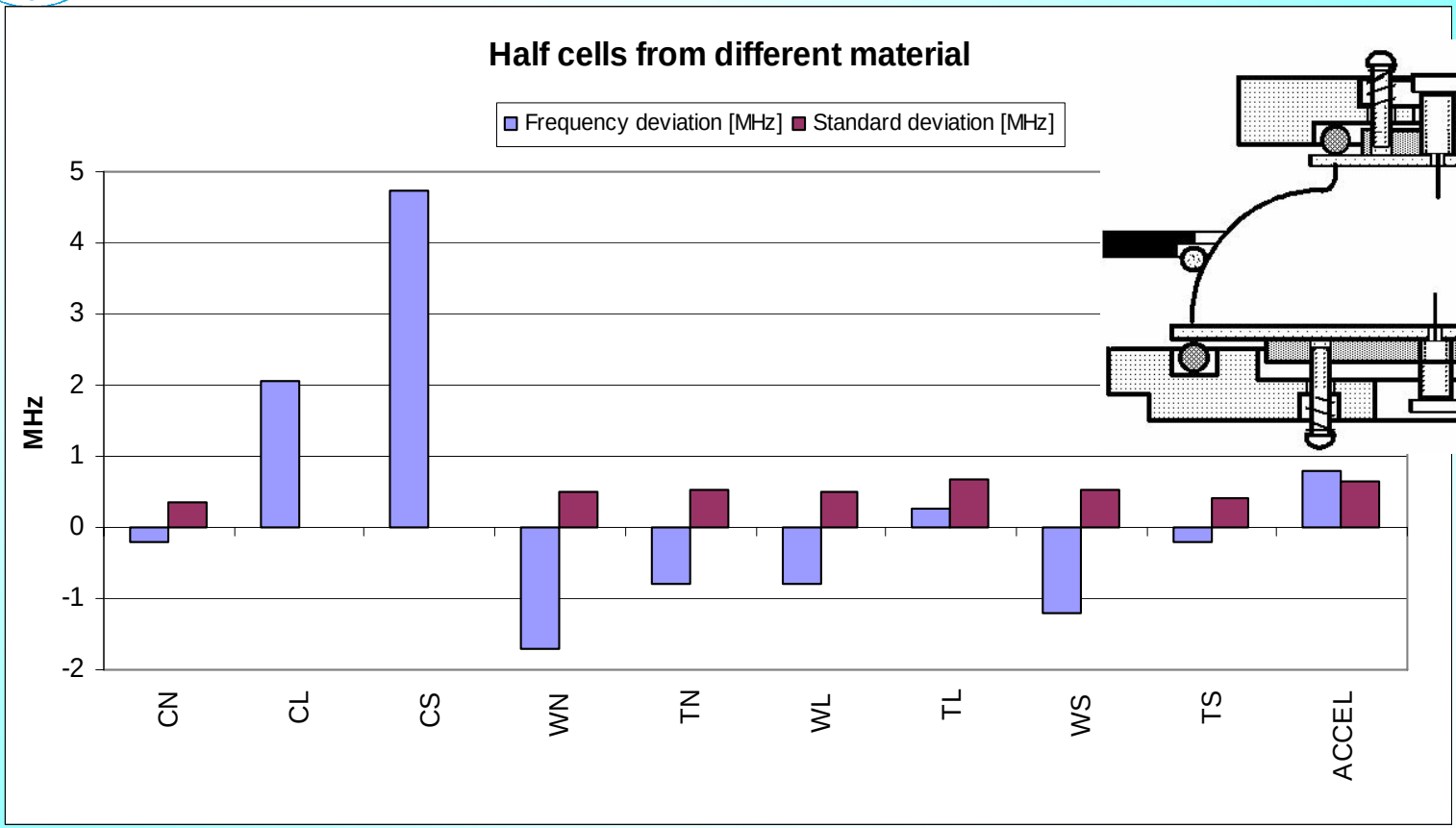
Shape accuracy: 3D profile measurement





3D Image of the optical measurement of the shape on large grain half cell (left; realized accuracy +0,22 / -0,32 mm) in comparison with a fine grain half cell (right; realized accuracy +0,13 / -0,30 mm). The large grains are fractionally pronounced. The variation of the large grain half cell shape is somewhat larger

Shape accuracy: frequency measurement



Frequency measurement of 6 end half cells (L and S) and 48 middle half cells (N) for cavities AC112-114. C - large crystal, W - Wah Chang, T - Tokyo Denkai. The shape conformity of half cells from large grain material is lower as of conventional fine grain (could be improved by correction of the tools), the uniformity of the half cells from large grain material is better.

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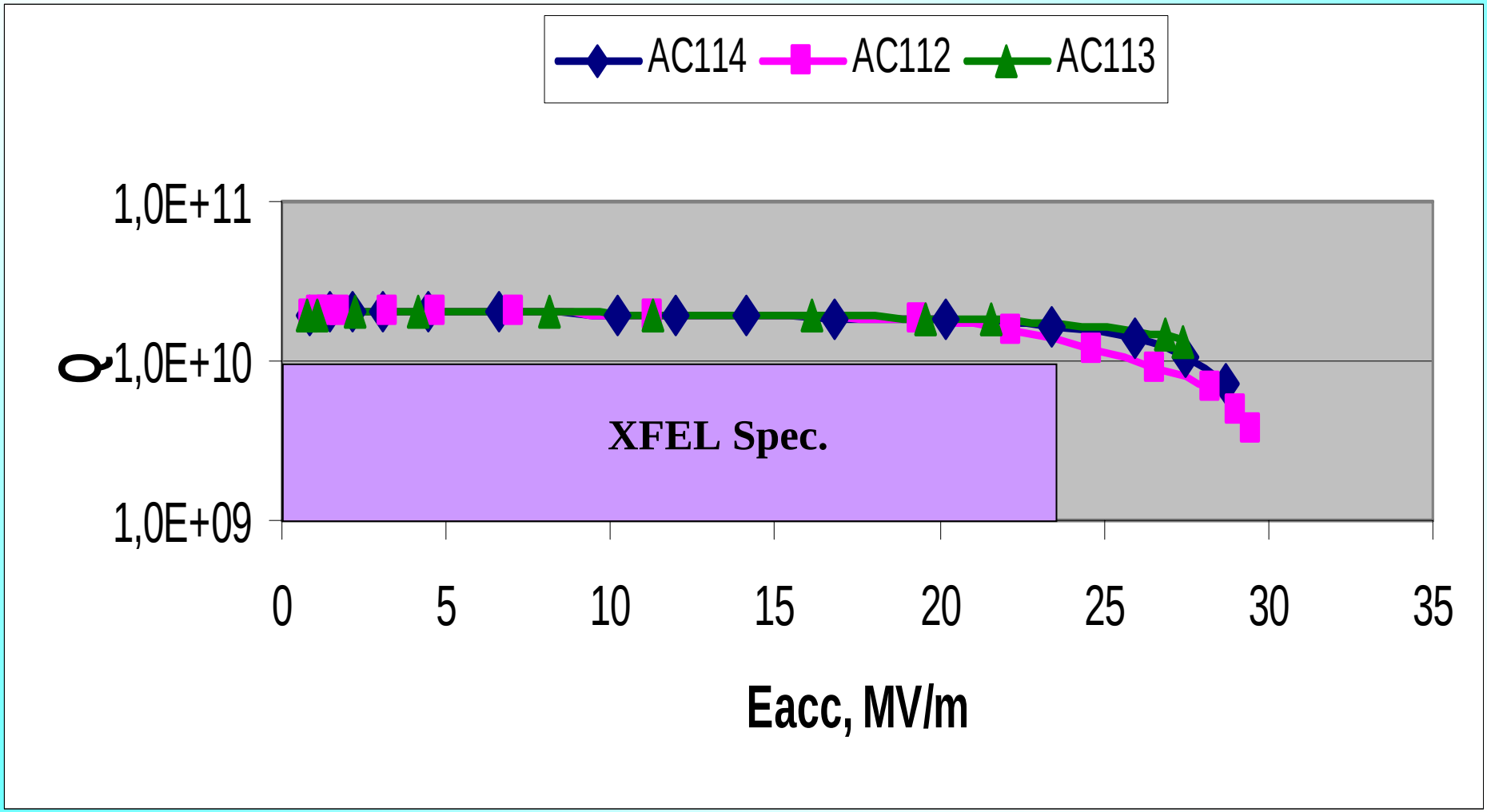
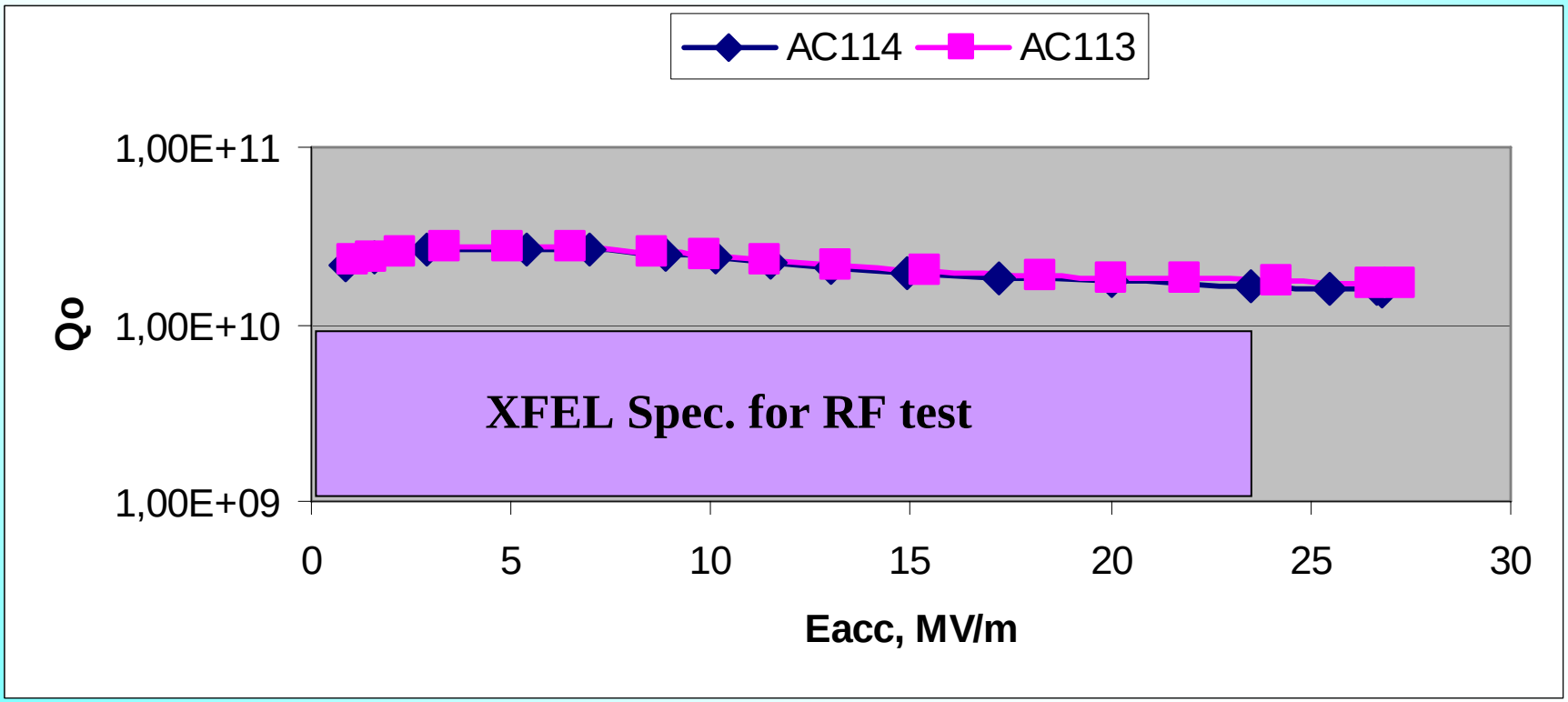
Preparation and RF tests

First test Q(Eacc) curve of the LG nine cell cavities AC112- AC114 at 2K after 100µm BCP, 800°C 2h, 20µm BCP, HPR

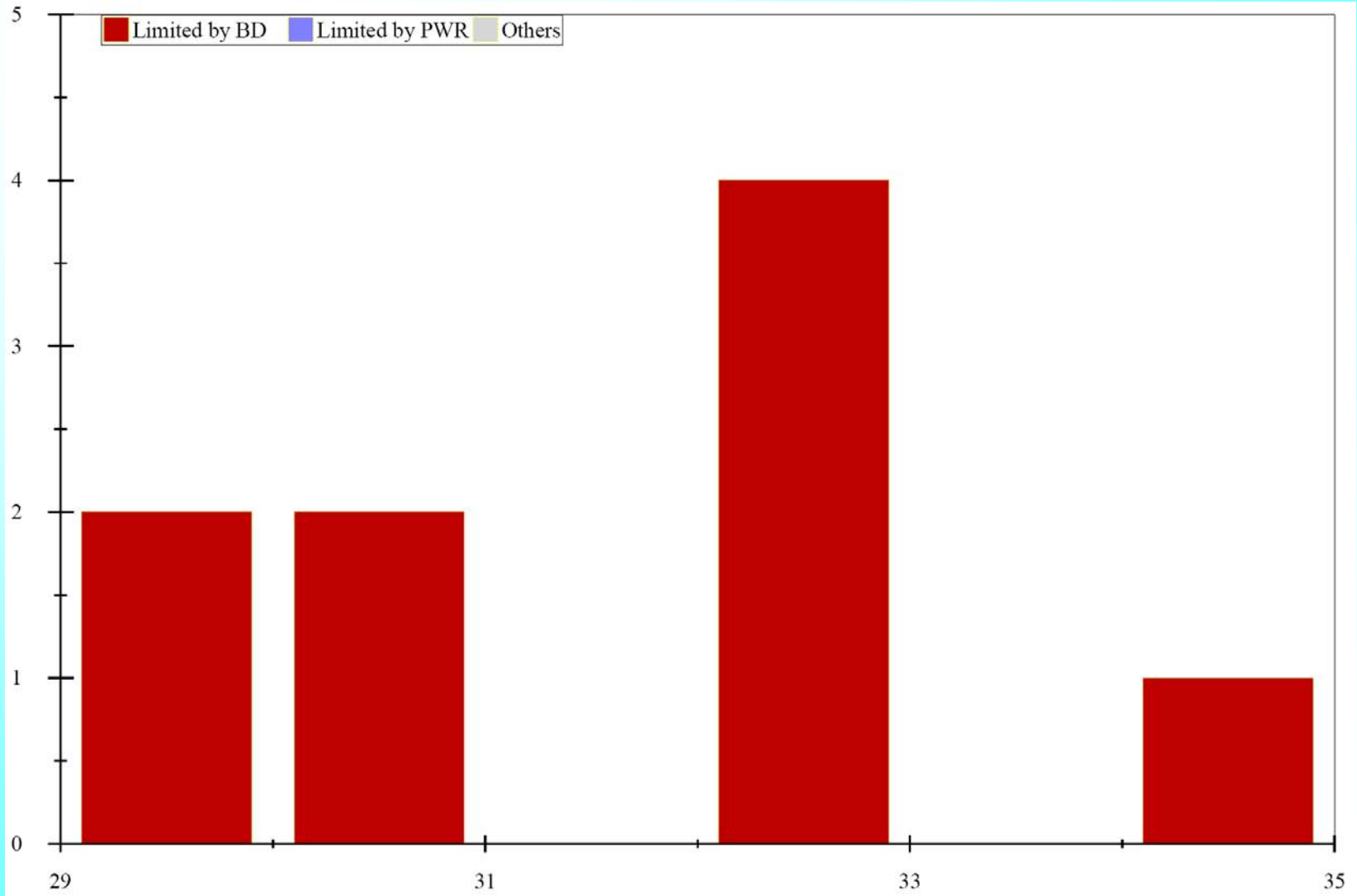


Second test Q(Eacc) curve of the LG nine cell cavities AC113- AC114 at 2K after additional 20-30 µm BCP and 125°C, 50 h baking



- Very similar behavior, good reproducibility

Cavity AC114 after baking; Mode measurement



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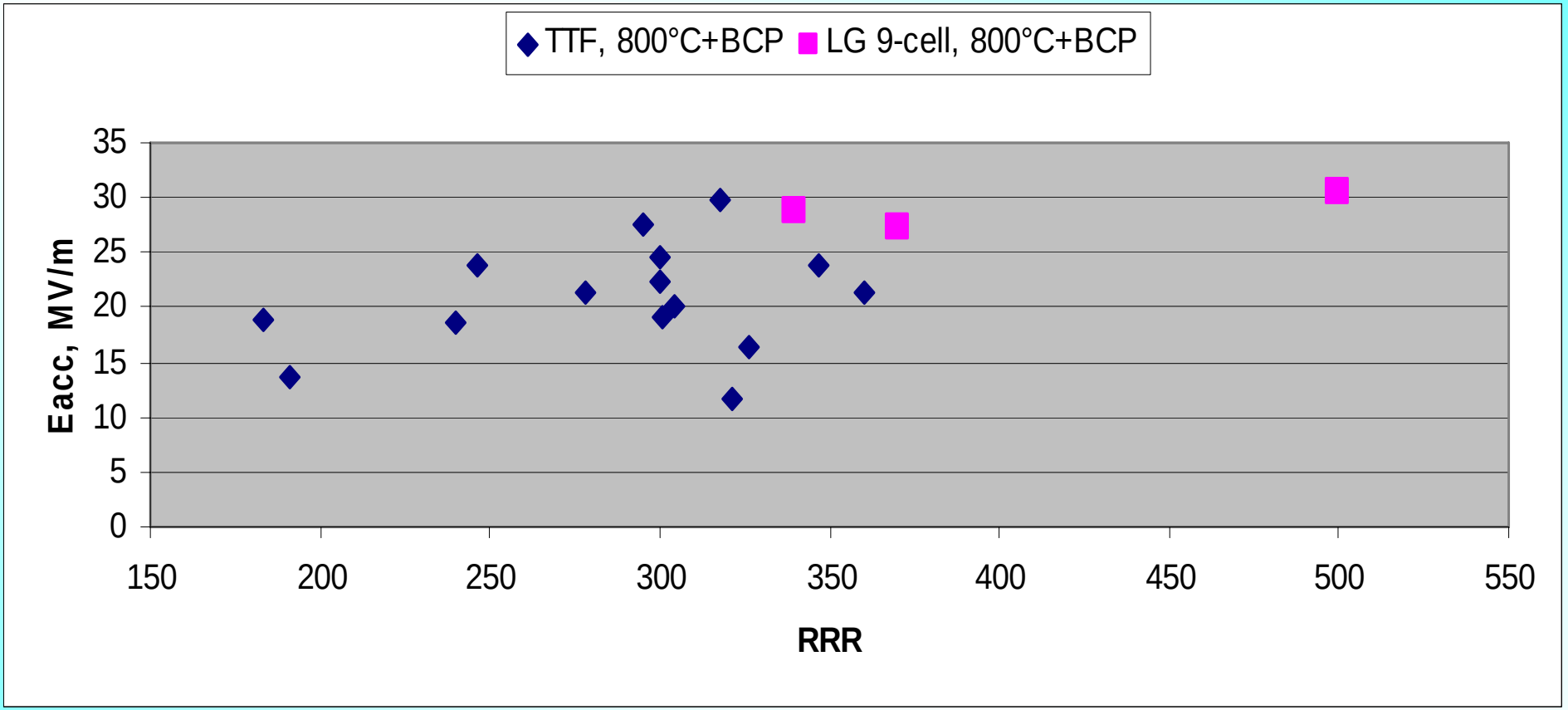

Comparison of the Eacc performance of large grain (LG) 9-cell cavities with similarly treated fine grain TTF cavities

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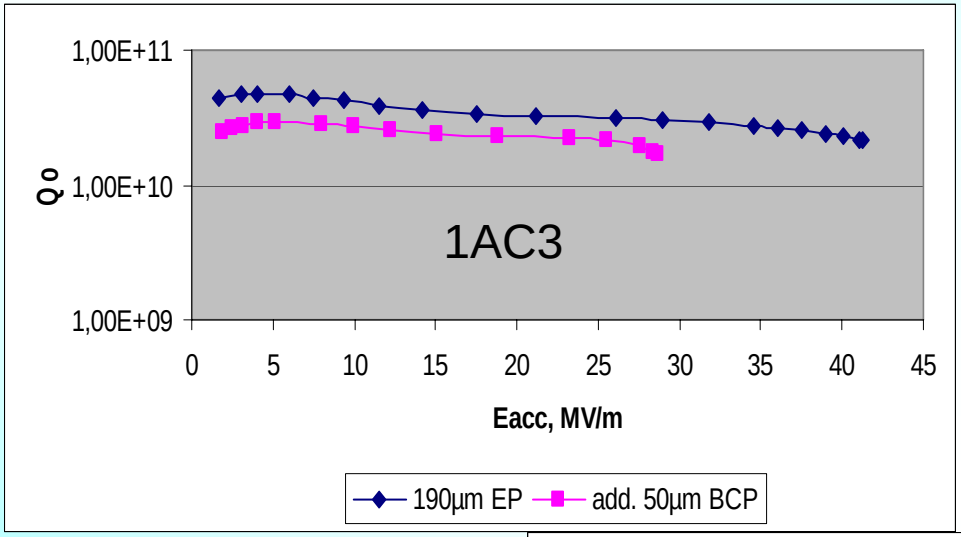
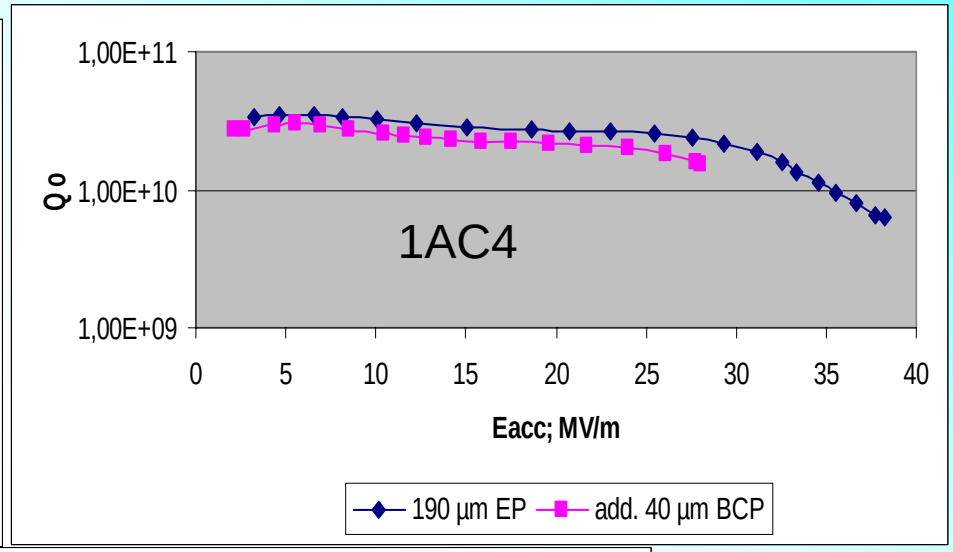
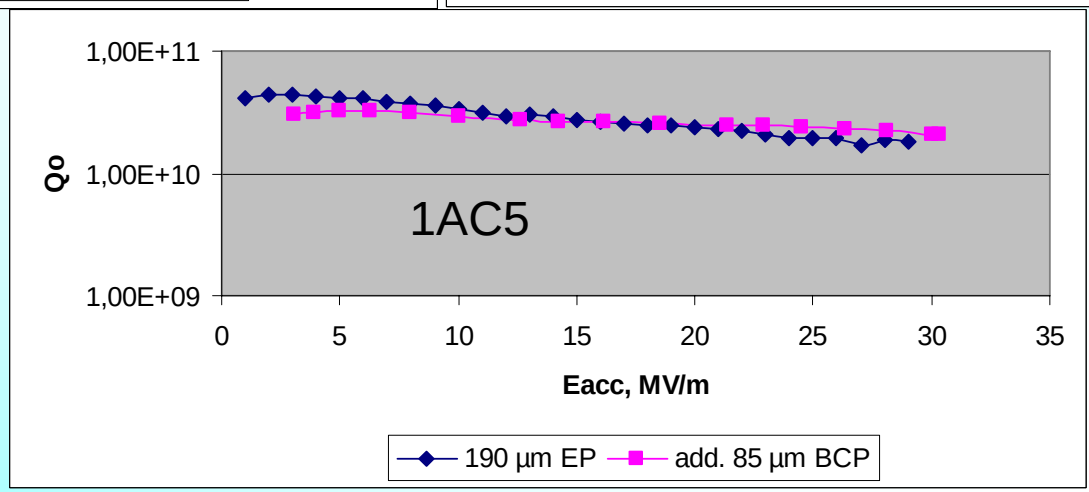
- EP is planned as the next step for LG AC112-AC114 cavities

- Experiences on single cell LG cavities; it seems that EP works better







Q(Eacc) curve of the single cell cavities 1AC3 -1AC5 after EP and BCP treatment

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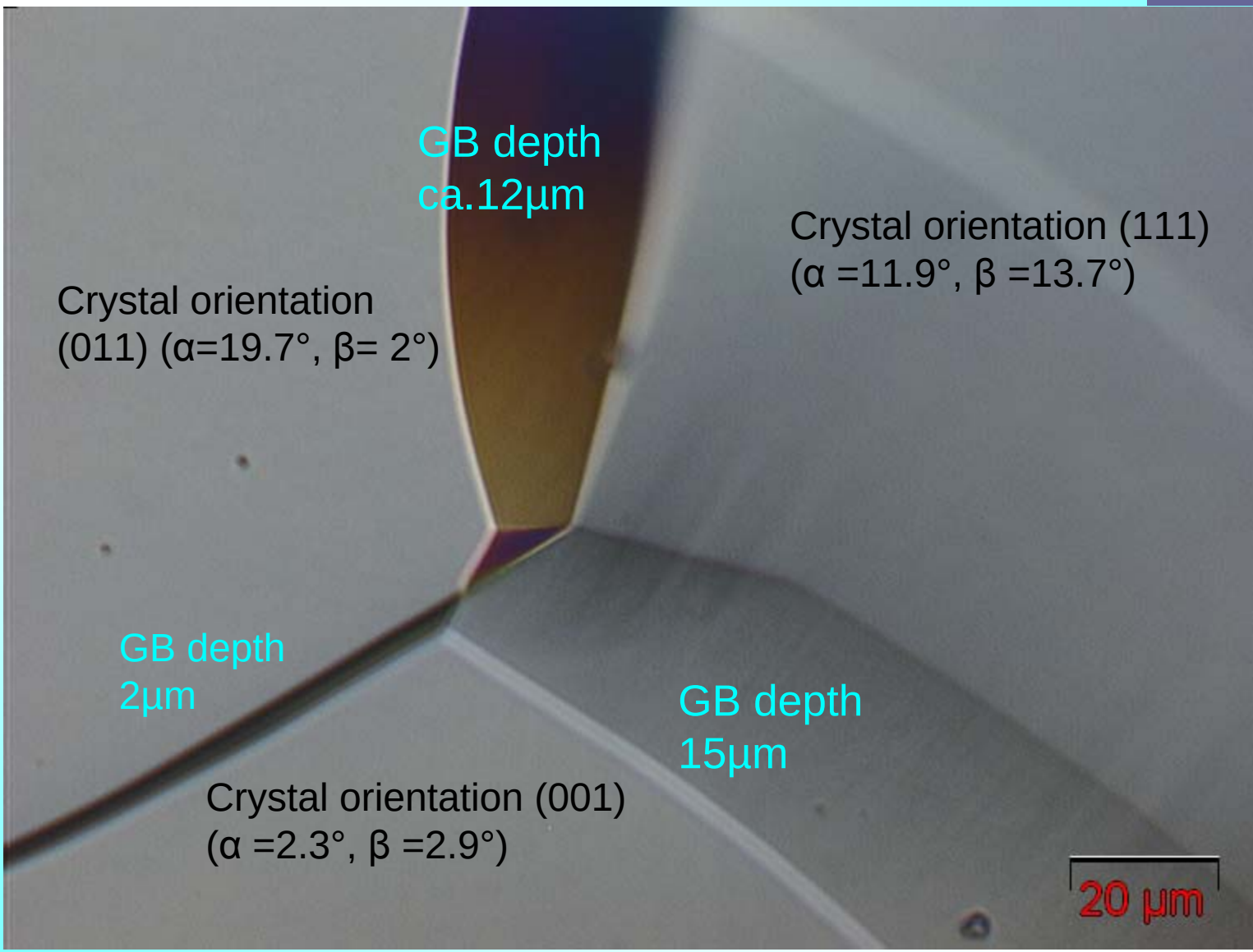

Light microscope image of LGs sample after 100 µm BCP

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Grain boundaries GBs contribute to reduction of the cavity performance

- responsible for magnetic field enhancement (steps on GBs after BCP)
- make easier the penetration of external magnetic field (GBs are planar weak links with reduced critical current density)
- additional RF resistance due to vortices penetrating along the grain boundary (reduce the quality factor Qo)
- make easier the hydrogen absorption and diffusion
- gathered impurities (reduced RRR)
- reduce the thermal conductivity at low temperatures (reduced phonon contribution)
- possibly make worse the baking (oxides and impurities in grain boundaries)
- possibly make worse high pressure water rinsing (enhance the surface roughness)

Single Crystal Option

Better not to have the grain boundaries at all

(successful experiments at JLab on small SC cavities).

Fabrication of TESLA shape single crystal single cell cavities was proposed at DESY after

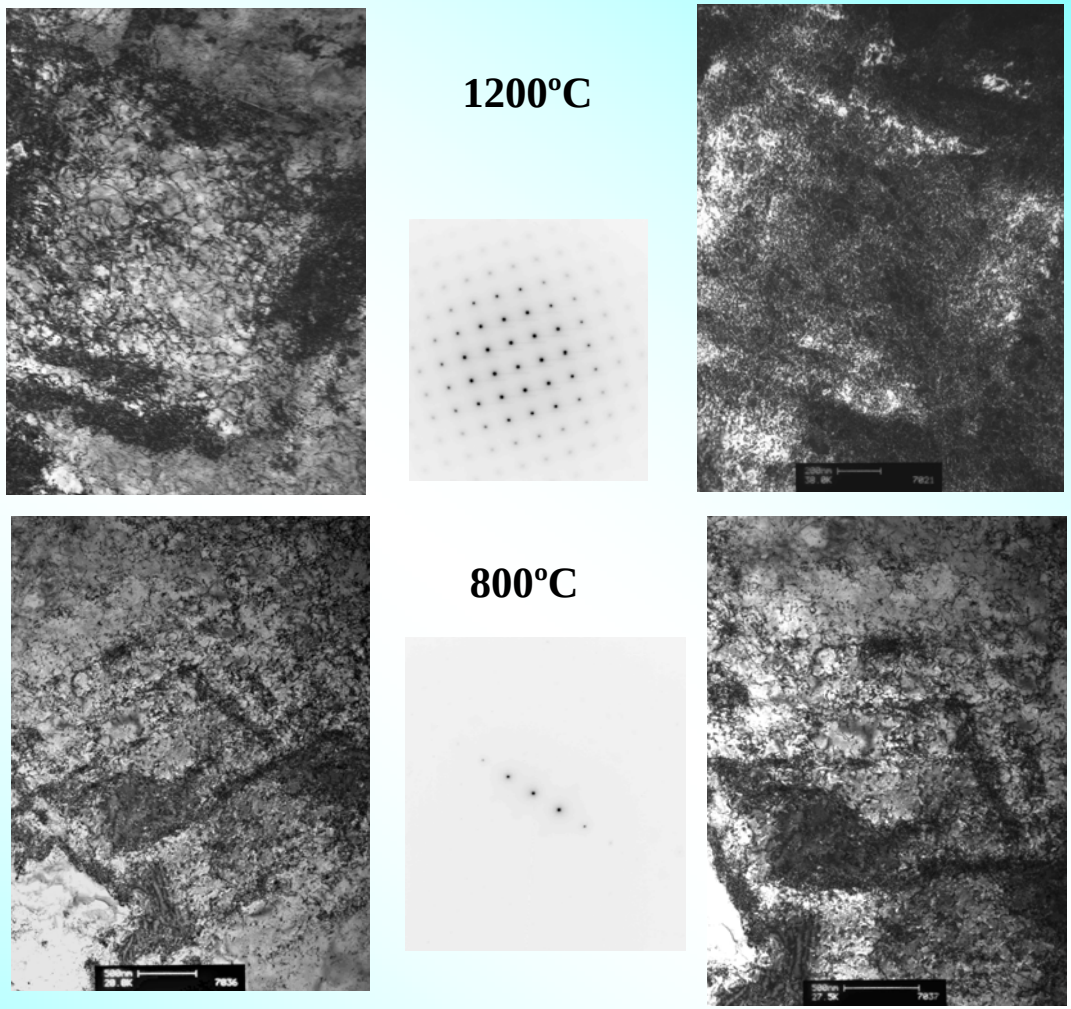
Following aspects have been investigated and taken into consideration during cavity fabrication

- Definite enlargement of the discs diameter is possible without destroying the single crystal structure in an existing state.
- Appropriate heat treatment will not destroy the deformed single crystal
- The single crystals keep the crystallographic structure and the orientations after deep drawing and annealing at 800°C
- Two single crystals will grow together by EB welding, if the crystal orientations is taken into account.

TEM, (001), Cross-rolled, Strain 50%, Annealed

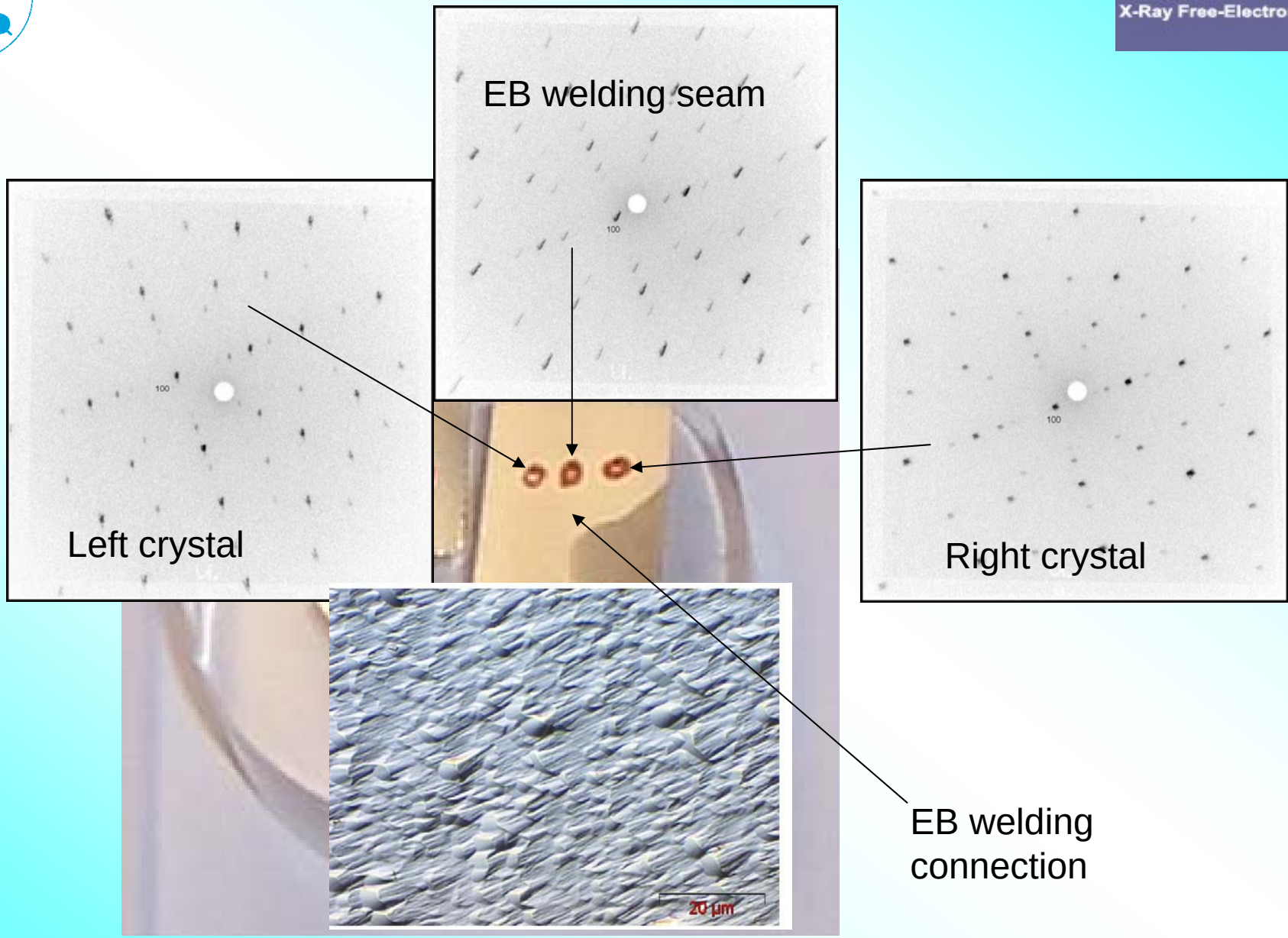
Niobium (Heraeus) single crystal cold cross rolling (001)<110> , 50% reduction. Annealing for 3 hours at 1200ºC (top); at 800ºC (bottom).

Neither cell nor subgrain formation is observed



Vladimir Levit, Peter Collins, Babu Viswanthan, Hamish L Fraser
Waldemar Singer and Xenia Singer. **SRF Materials Workshop, May 23-24, 2007 FERMILAB**

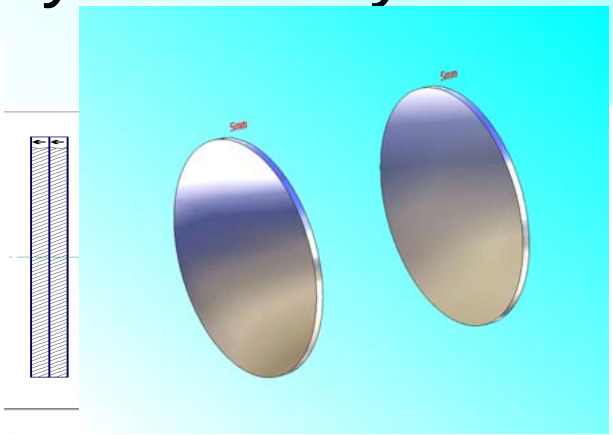
In the EB welding the single crystals grow together



X-Ray reflexes are the same in both welded together crystals and in the welding seam

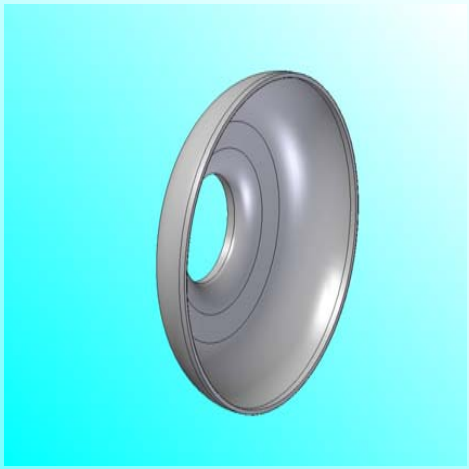
Single crystal cavity fabrication

1. Take out central single crystal of definite thickness

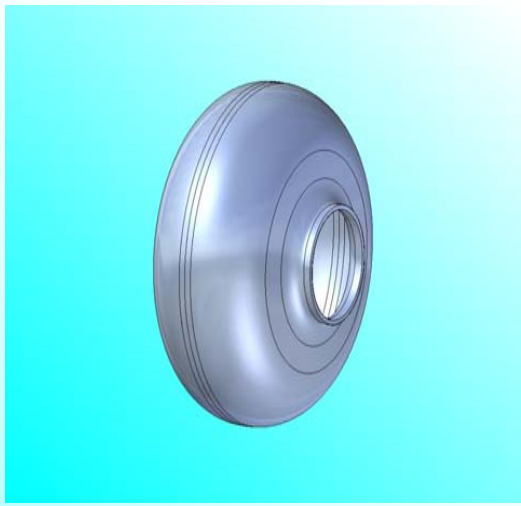


2. Cutting through the disc

3. Increasing of diameter by special rolling with an intermediate annealing



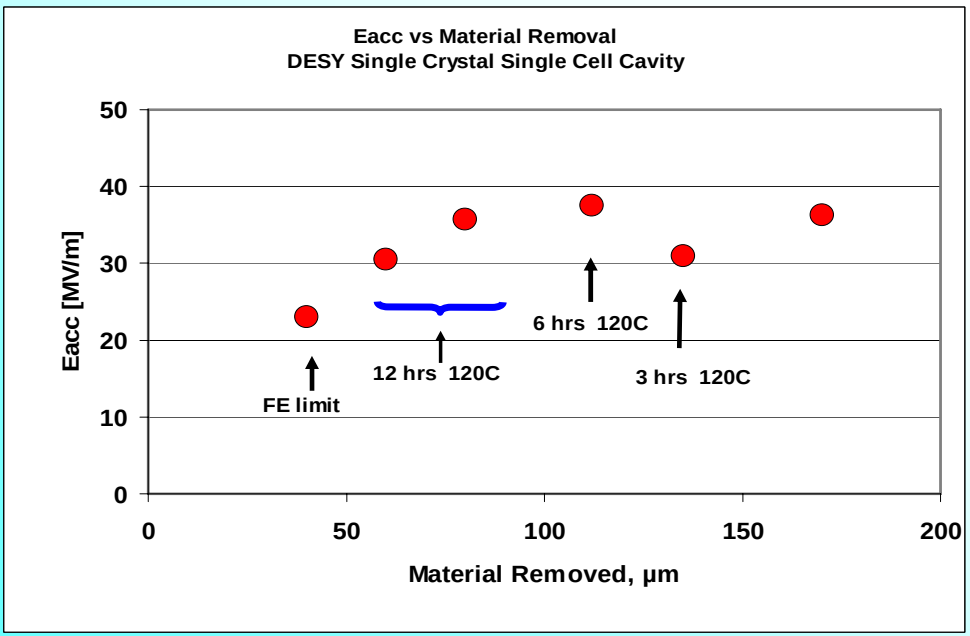
4. Deep drawing

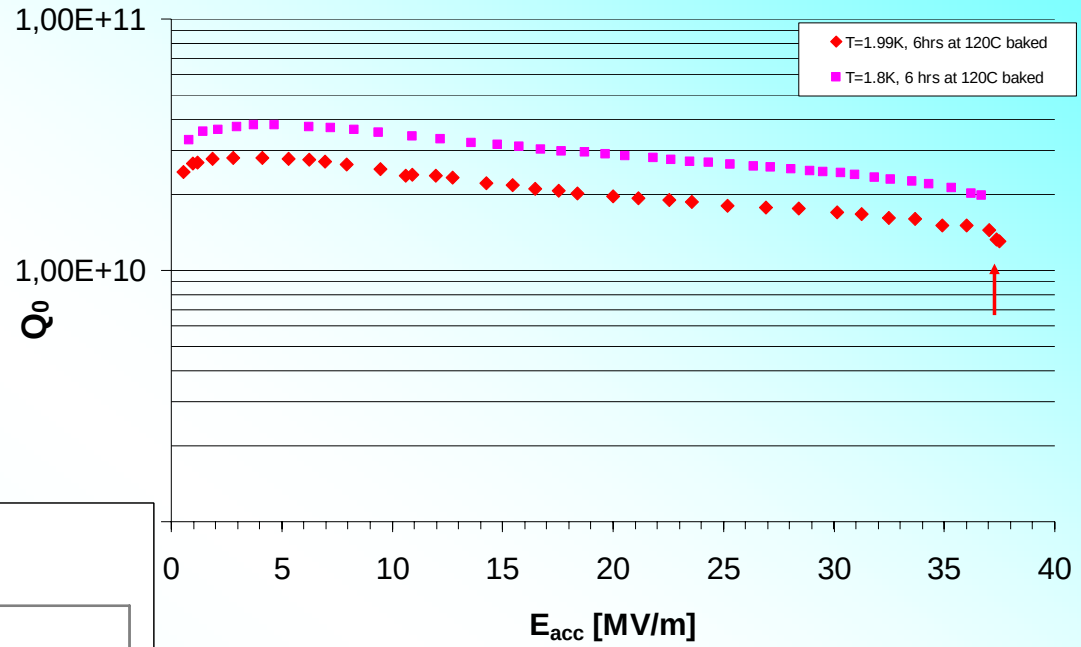


5. EB welding considering the crystal orientation

Single crystals after deep drawing at ACCEL

DESY single crystal cavity 1AC8 build from Heraeus disc by rolling at RWTH, deep drawing and EB welding at ACCEL



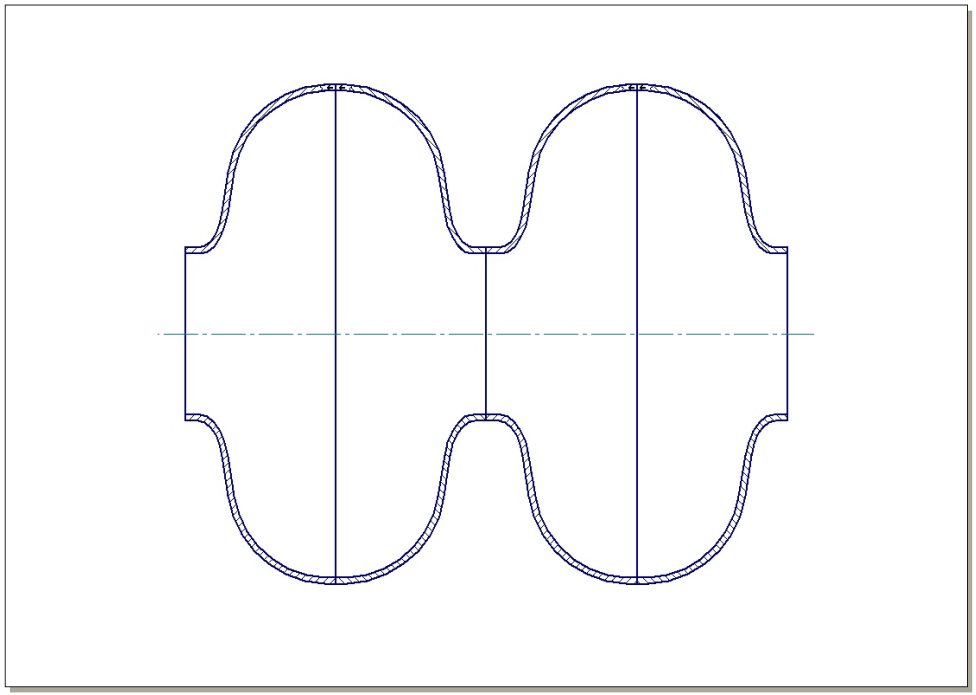


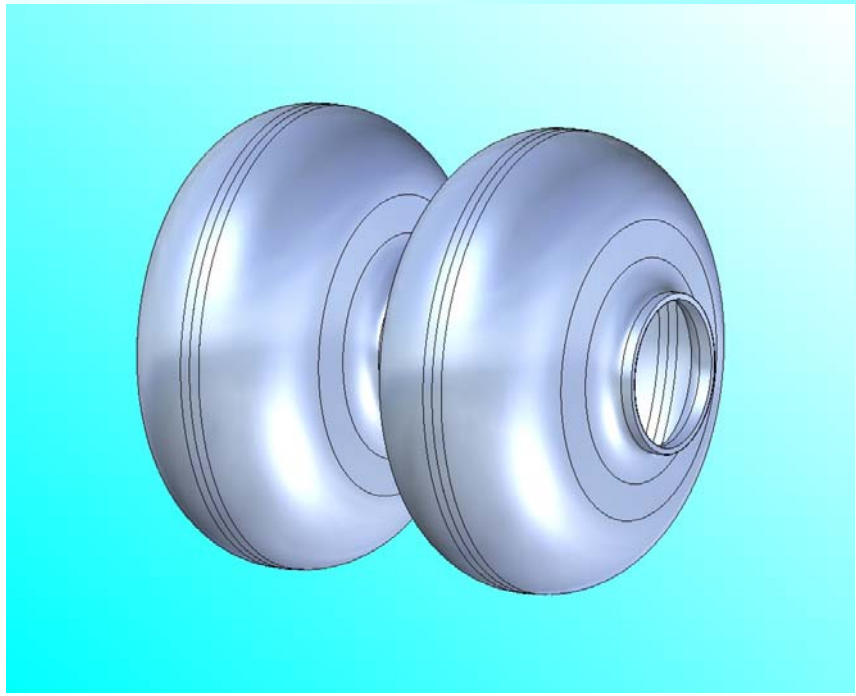
Q(Eacc) curve after 112 µm BCP and in situ baking 120°C for 6 hrs.

Eacc vs. material removal on single crystal single cell cavity (left).

Preparation and RF tests of P.Kneisel, JLab

SC. It works. The proposed method can be extended on fabrication of multi cell cavities.





It is worthwhile to check the single crystal option for fabrication of multi cell cavities

Outlook

Fabrication of multi cell cavities from large grain niobium by deep drawing and electron beam welding is feasible. Big central single crystal in the disc seems to be mandatory

Performance up to 30 MV/m can be achieved on the nine cell cavity after only BCP treatment.

EP preparation on multi-cell LG cavities is ongoing. Up to 41 MV/m was measured on a LG single cell cavities after EP.

Fabrication of several new 9 cell LG cavities is in progress

First single crystal single cell cavity of TESLA shape are build with very encouraging results. It is worthwhile to check the SC option for fabrication of multi cell cavities

Acknowledgement

This work would be not possible without support of: colleagues of DESY HASYLAB and DESY M-groups -MHF-SL-, -MKS-, -MPL-,- MVA-, - MVP-, -ZM-

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