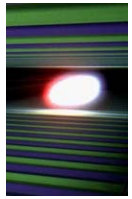


Material for European XFEL Cavity Production

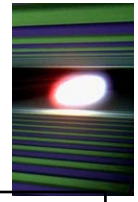
X. Singer, W. Singer,

Presented by Xenia Singer

Main issues

- Requirement to cavity material for XFEL
- Qualification of Nb suppliers for XFEL
- Current status of the material contract for XFEL cavity

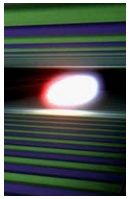
Technical Specification for High Purity Niobium for SC Cavities

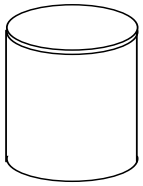


Concentration of impurities in wt.ppm				Mechanical properties	
Ta*	≤ 500	H*	≤ 2	Yield strength**, $\sigma_{0,2}$	$50<\sigma_{0,2}<100$ N/mm^2 (Mpa)
W*	≤ 70	N*	≤ 10	Tensile strength**	> 100 N/mm^2 (Mpa)
Ti*	≤ 50	O*	≤ 10	Elongation at break**	30 %
Fe*	≤ 30	C*	≤ 10	Vickers hardness** HV 10	≤ 60
Mo*	≤ 50	RRR*	≥ 300	Absence of foreign material inclusions*	Proven by scanning
Ni*	≤ 30	Recrystal. degree. Grain size* ,** ?	≈ 50 µm	Texture *, ** ?	

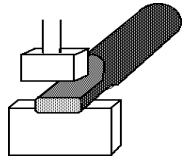
*** - relevant for performance ** - relevant for fabrication**

Fabrication schema of Nb sheets at Tokyo Denkai (courtesy of Tokyo Denkai)

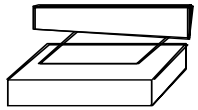




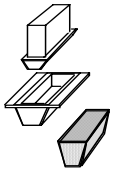
Mother material



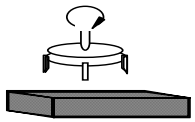
Forging



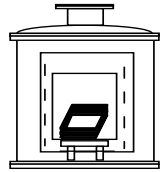
Cutting



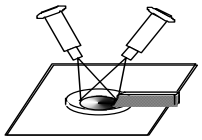
Pressing



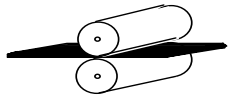
Milling



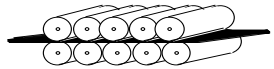
Annealing



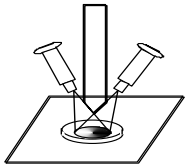
1st EB melting



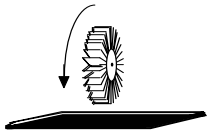
Rolling



Levering

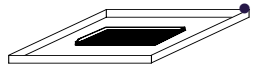


2nd, 3rd etc. EB melting

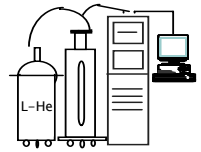


Polishing

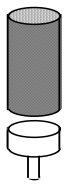
Chemical polishing



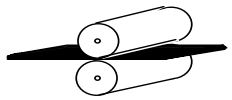
Inspection



- ICP-AES
- Gas Analysis
- RRR
- Grain size
- Hardness
- Tensile tests



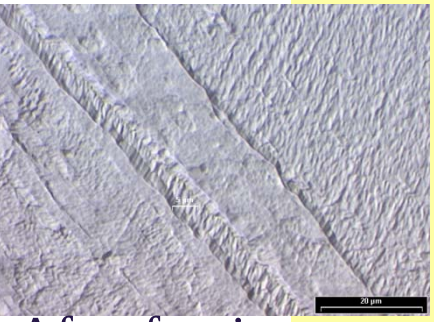
Separate from base plate



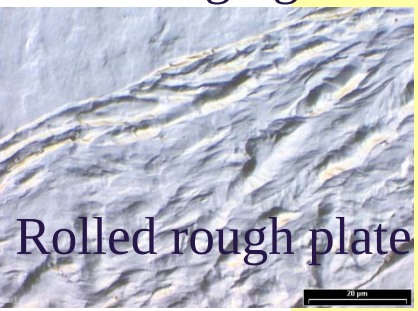
Rolling

In the final sheet the purity of niobium should be not inferior as in the ingot

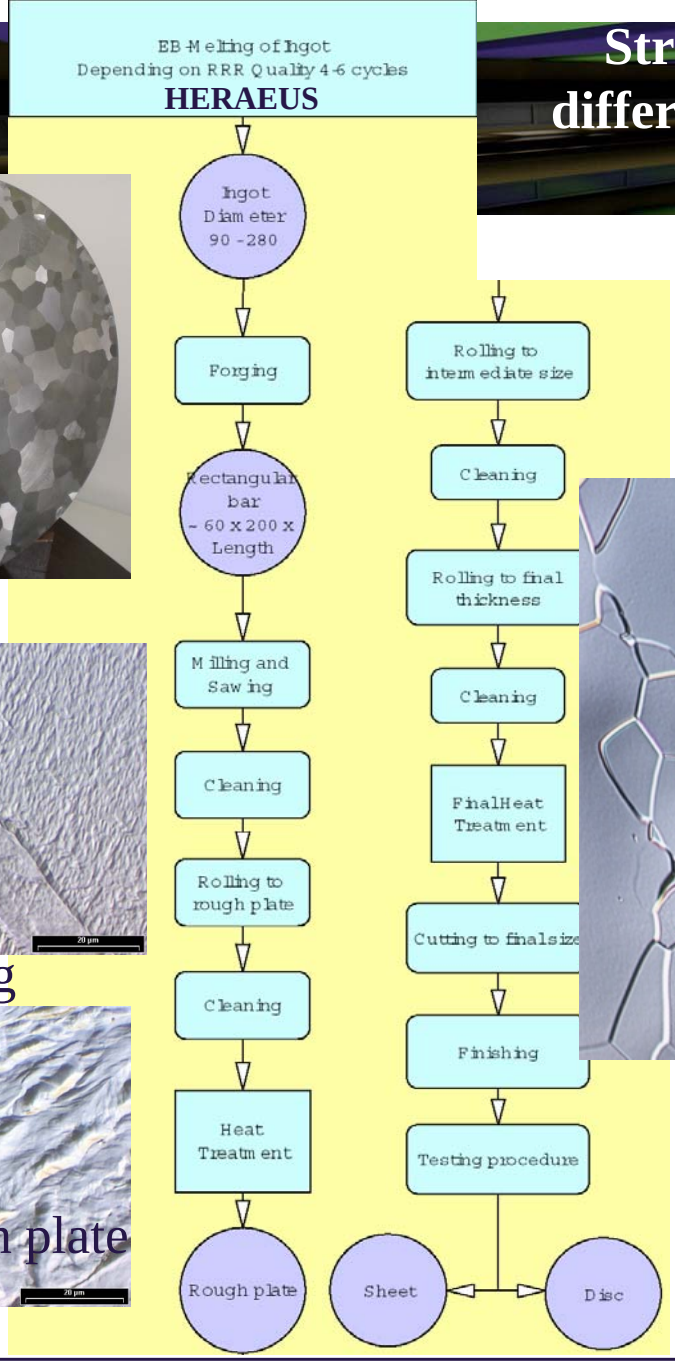
Ingot

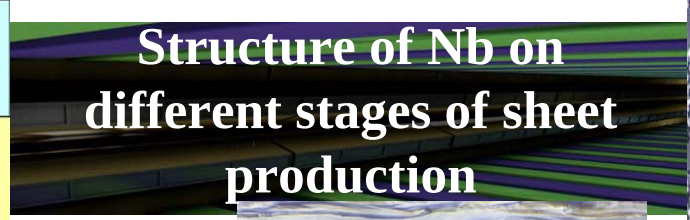


After forging

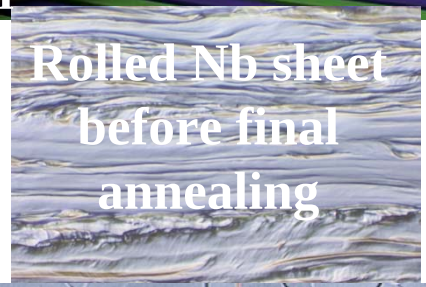


Rolled rough plate



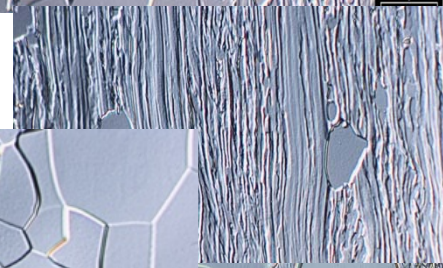


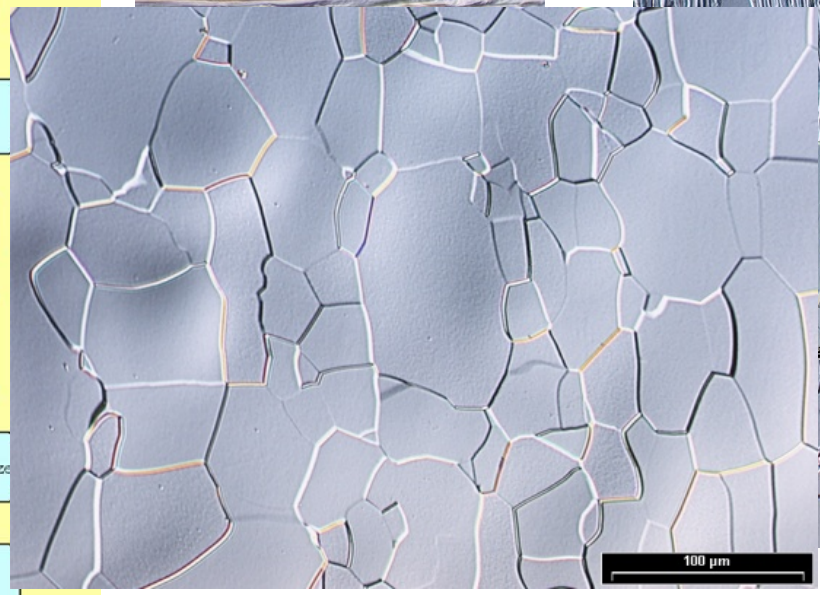
Structure of Nb on different stages of sheet production

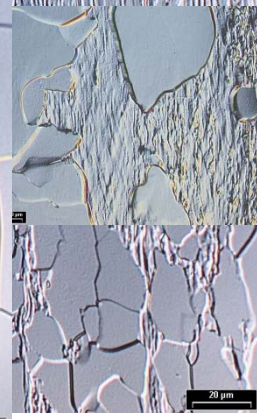


Rolled Nb sheet before final annealing

Examples of bad recrystallization







Recrystallized niobium sheet

Task: starting with cm size grain of ingot finish with ca. 50 µm uniform grain without contamination of Nb

The world's largest niobium deposit is located in **Araxá, Brazil** (CBMM). The mining of weathered ore, running between 2.5 and 3.0% Nb_2O_5, is carried out by open pit mining. 85 to 90% of the niobium industry obtains its niobium ores.

European XFEL

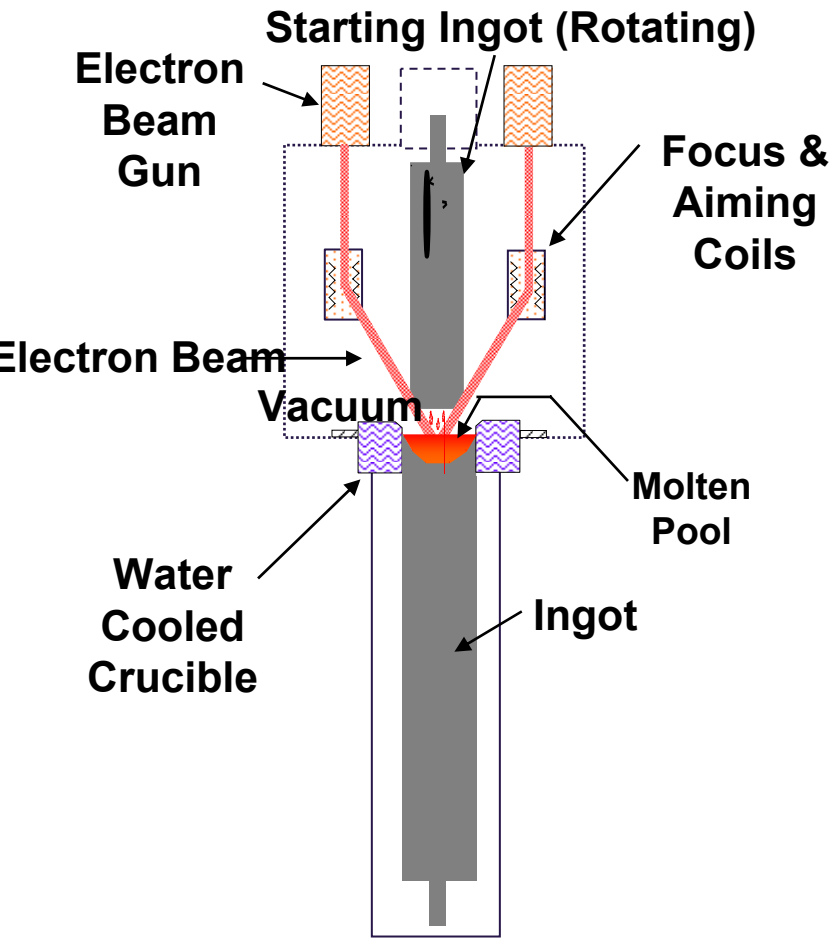
There are several companies, which can produce high purity Nb in larger quantities: Wah Chang (USA), W.C.Heraeus (Germany), Tokyo Denkai (Japan), Ningxia (China), CBMM (Brasil),

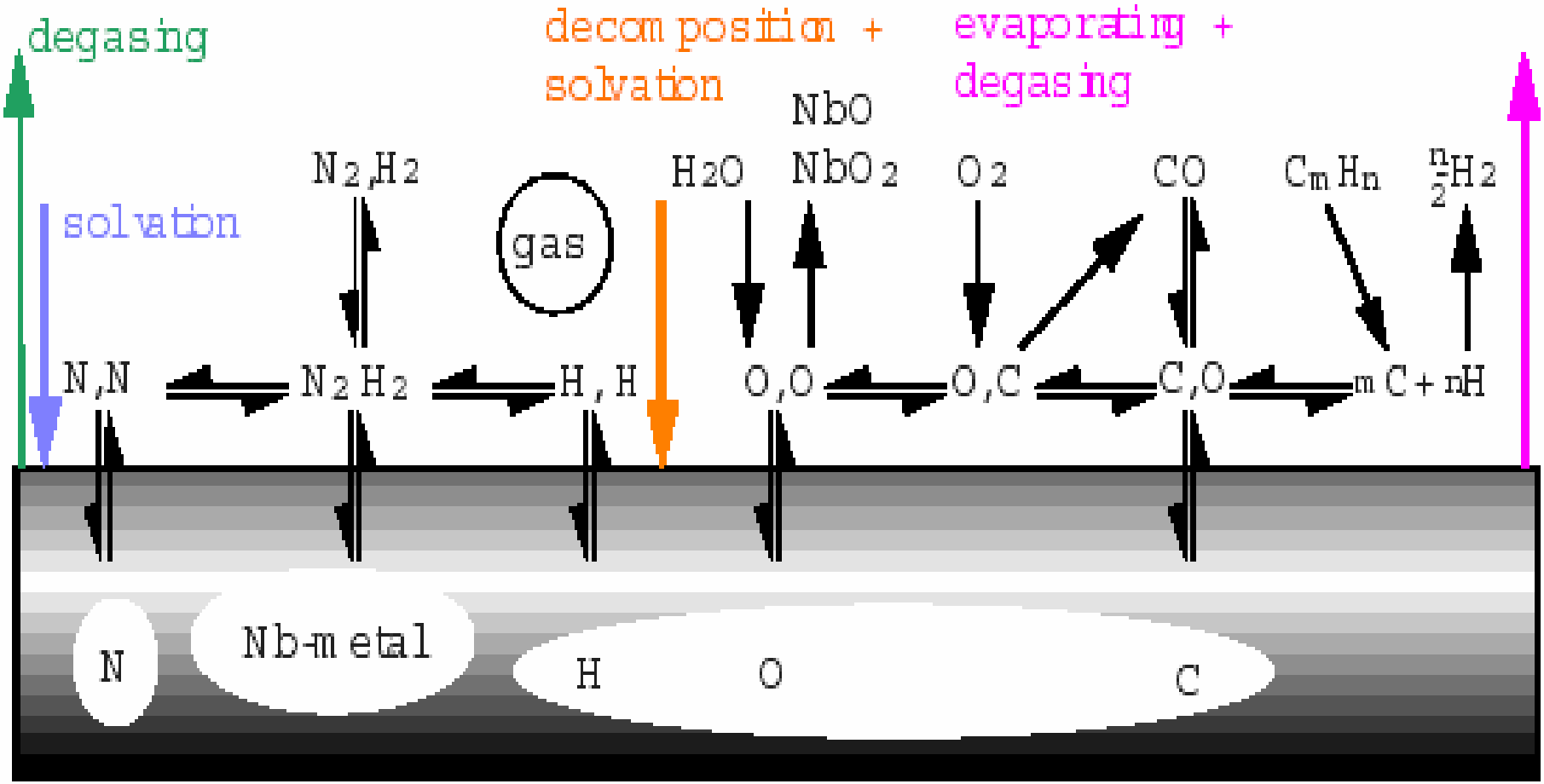
Control room (Wah Chang)

EB melting after liquid-liquid extraction and ATR (aluminum thermal reduction

Electron beam melting furnace of CBMM (Brazil)

Electron Beam Melting of Niobium





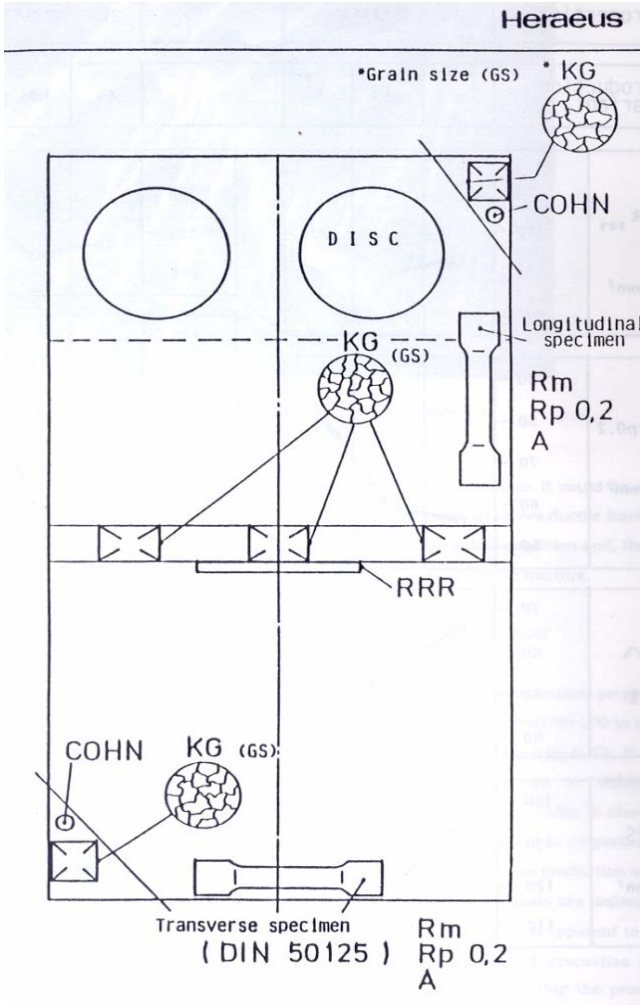
The melting temperature is a compromise between the maximization of purification and minimization of the material losses by evaporation.

RRR=300-500 are reachable currently

Independent from company QC and acceptance on company site are indispensable

In House (DESY)

- RRR
- Scanning - Apparatus
- Interstitial impurity analysis (H,N,O, C)
- Metallic impurities analysis (another RM, Fe, Ni etc.)
- Metallography
- Tensile test
- Hardness, HV
- Surface roughness
- Thermal conductivity



Scheme of QC of Nb sheets

Outsource

- NAA Neutron Activation Analysis
- Radiation Fluorescence Analysis
- SEM, EDX
- SIMS, XPS, AUGER
- X-ray radiography
- Neutron radiography
- Texture analysis
- Bulging test

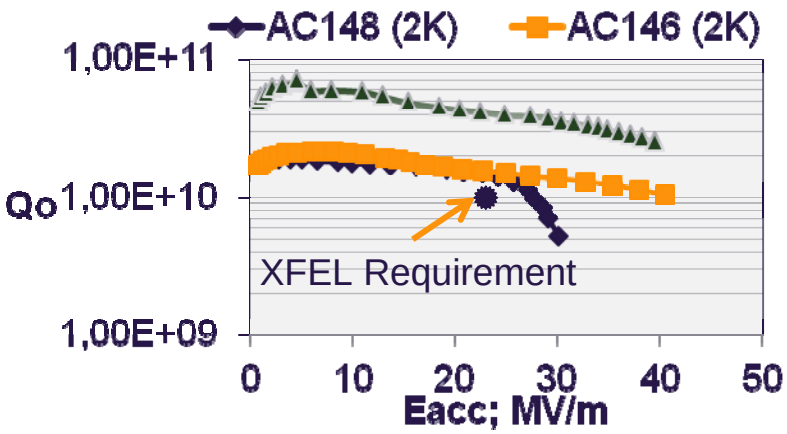
Qualification of Nb suppliers for XFEL
Three qualification steps

Step 1. Material testing (RRR, Microstructure, Eddy current scanning, Tensile test, HV, Impurity content, Surface conditions etc.).

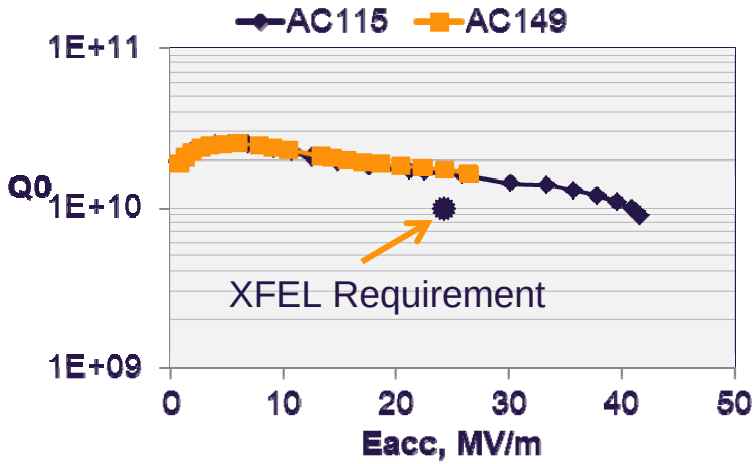
Step 2. Single cell cavity fabrication, treatment and RF tests at DESY.

Step.3. 9-cell cavity fabrication at Industry, treatment at DESY and RF tests.

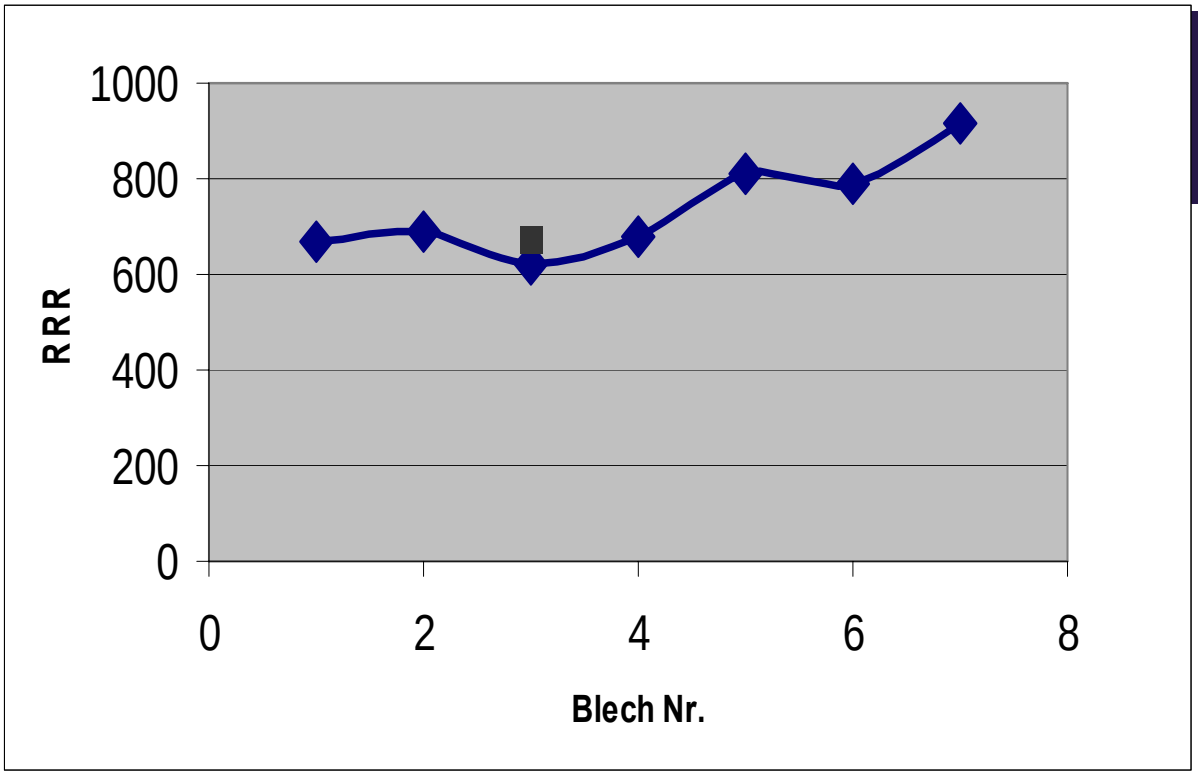
OTIC Ningxia



Plansee



RF test results of 9 cell cavities produced from material of Plansee (Austria) and Ningxia OTIC (China). Only this companies successfully passed all qualification steps. **5 qualified suppliers now.**



RRR values of Nb produced at **GIREDMET (Russia)**

Chemical analysis:

Ta = 6 wt. ppm,

N = 1 wt. ppm, O = 5 wt. ppm,

W, Ti, Fe, Si, Mo, Ni < 5 wt. ppm all together

The EB melting technique in combination with advanced Nb -Ta separation allows to reach very high RRR values (700-1000)

Status: Material for XFEL Cavities

Material for 800 Cavities will be provided by DESY to RI and E.ZANON

Mid 2011 – Mid 2013

Contracted to companies:

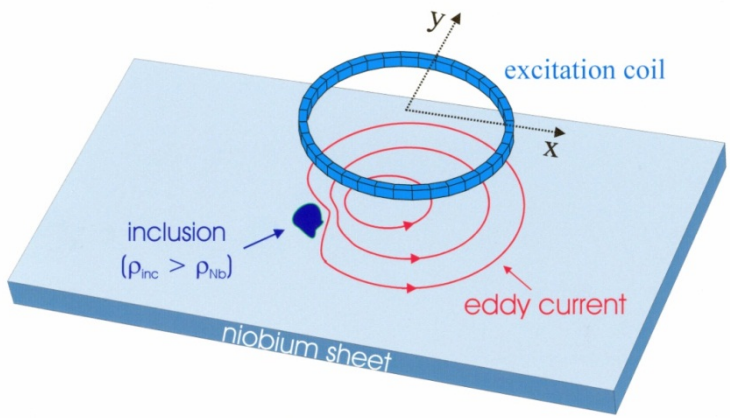
- W.C. Heraeus (Germany)
- Tokyo Denkai (Japan)
- OTIC Ningxia (China)
- SE Plansee (Austria)

>20 000 pieces of semifinished products (sheets, tubes, etc.)

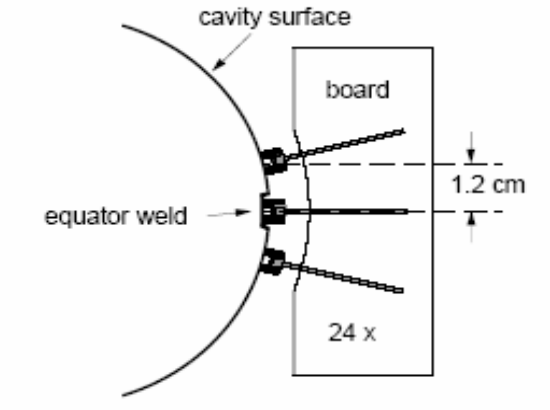
Eddy current scanning

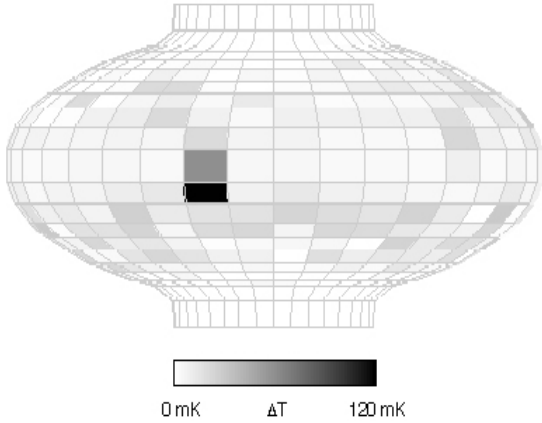
Equipment for eddy current scanning of ca. 16.000 XFEL niobium sheets at DESY

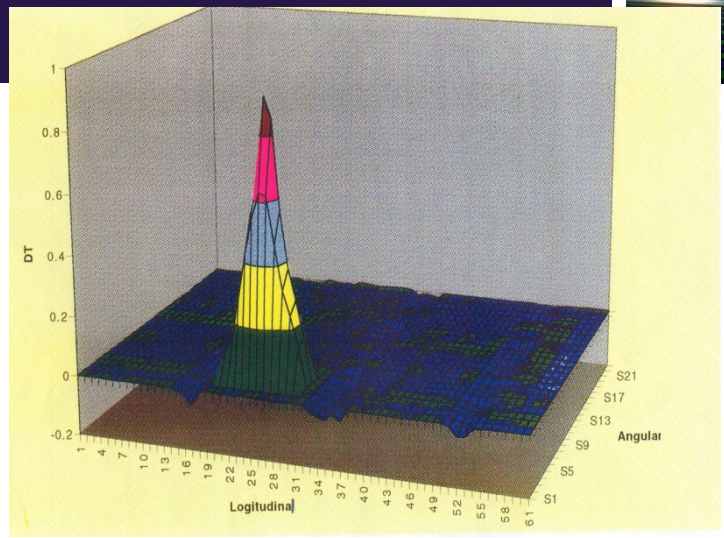
Principle of eddy current measurement



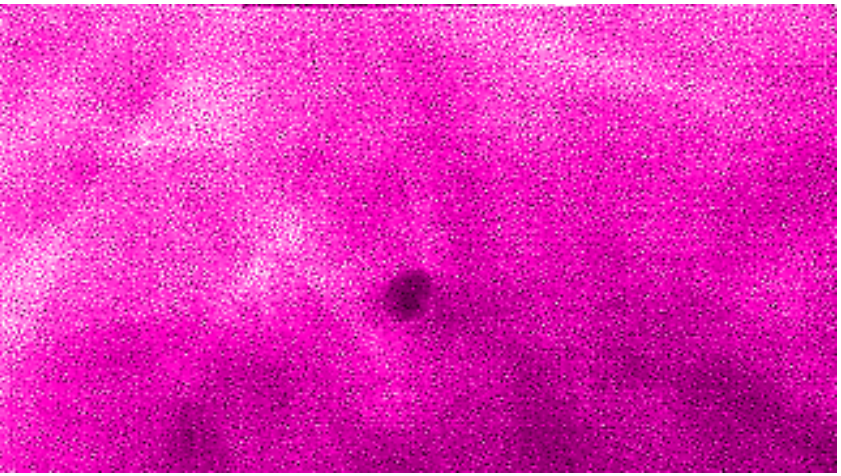
Foreign material inclusions in the cavity





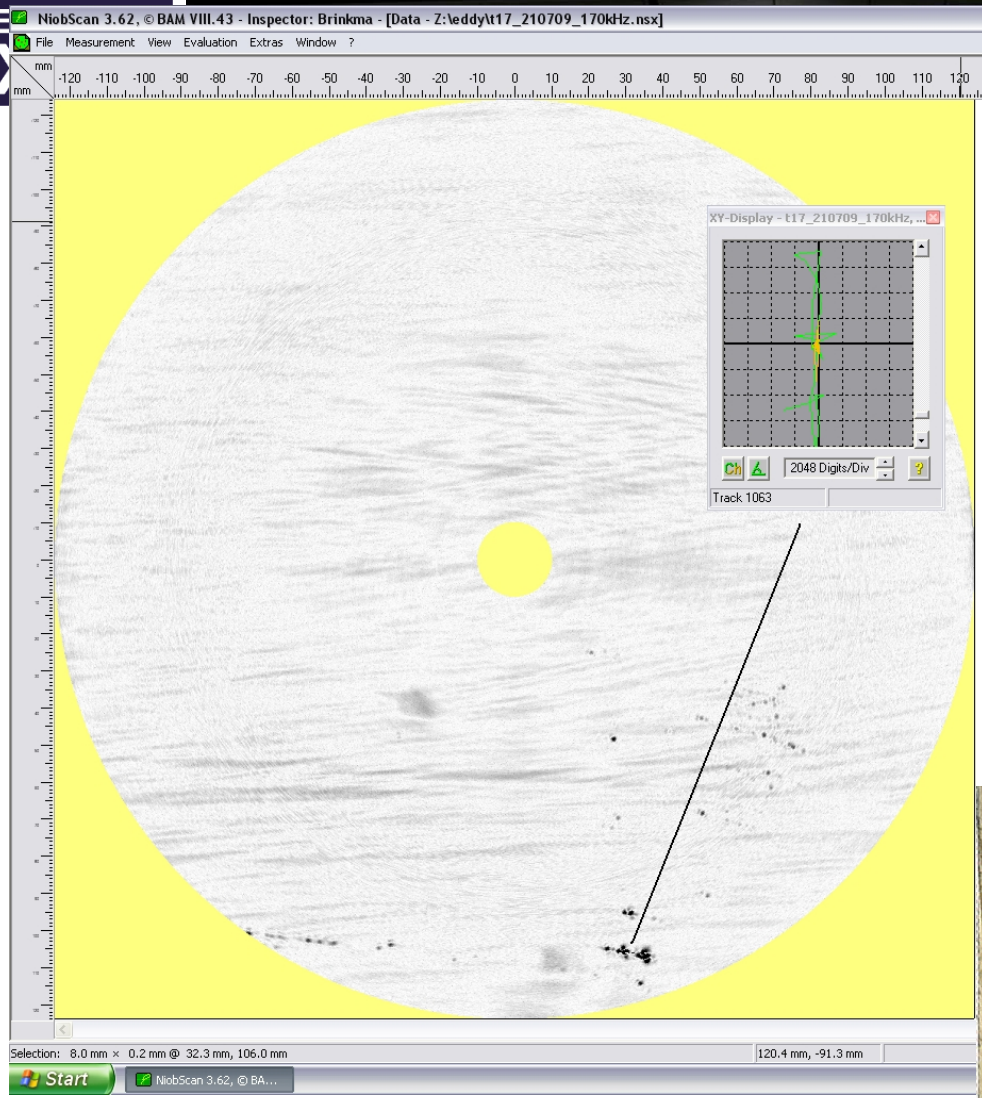


Temperature mapping: Cavity D6 with Eacc=13 MV/m shows excessive heating at a localized spot

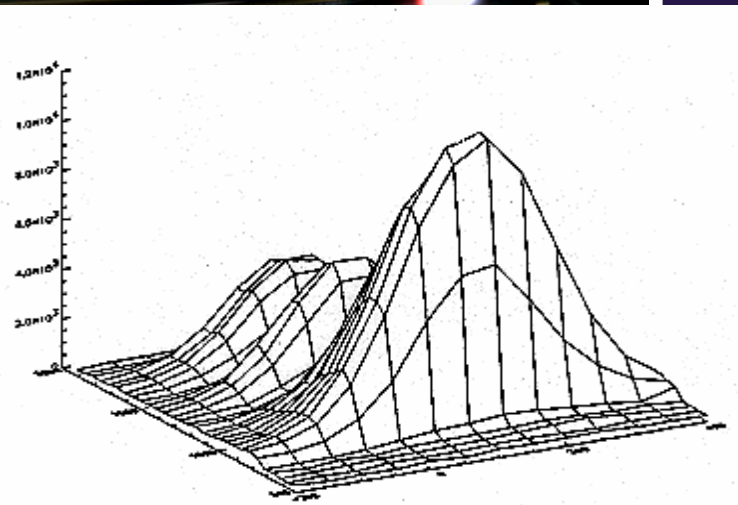


Positive print of a X-ray radiograph (X-Ray irradiation and imaging) showing the “hot spot” as a dark point (0.2 mm large Ta inclusion).

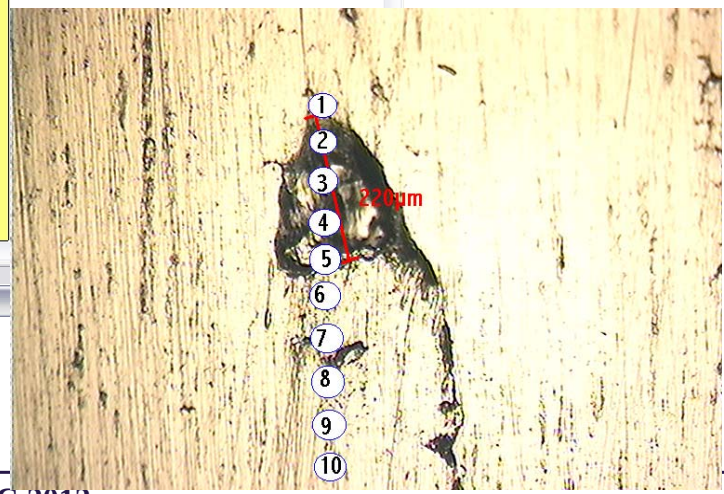
Local defects



Iron particles, probably imbedded during rolling T17



Iron signal distribution in one of the locations of the Nb sheet T17 measured Synchrotron Radiation Fluorescence Analysis (SURFA) and defects image.



Status Niobium and NbTi material for XFEL Cavities

Equipment for tactile 3D dimension measurement

Equipment for sheets marking

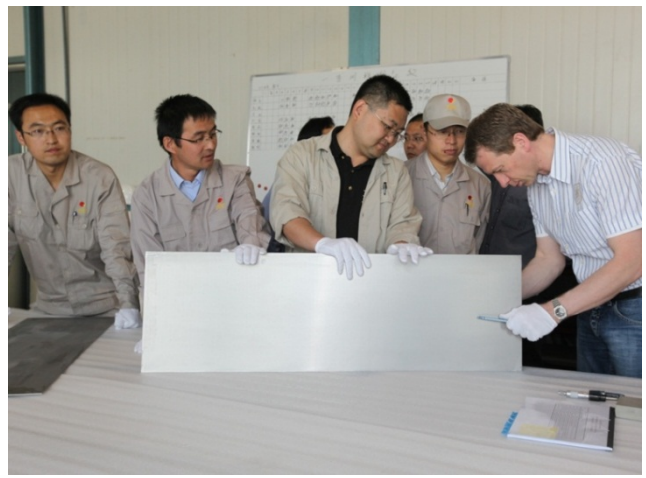
- Four previously qualified companies (Heraeus, Tokyo Denkai, Ningxia OTIC and Plansee) are contracted for cavity material supply
- Supervision of production at companies; incoming control, scanning, documentation and delivery to RI and EZ of cavity material is task of DESY.
- (status 3/2012). >70% of all niobium incl. sheets, tubes etc. delivered to cavities vendors
- Material for Option 80+160 cavities contracted.

Material PED (Pressure Equipment Directive) activities

The cavity and helium tank material **has to be produced** according PED/97/23/EC

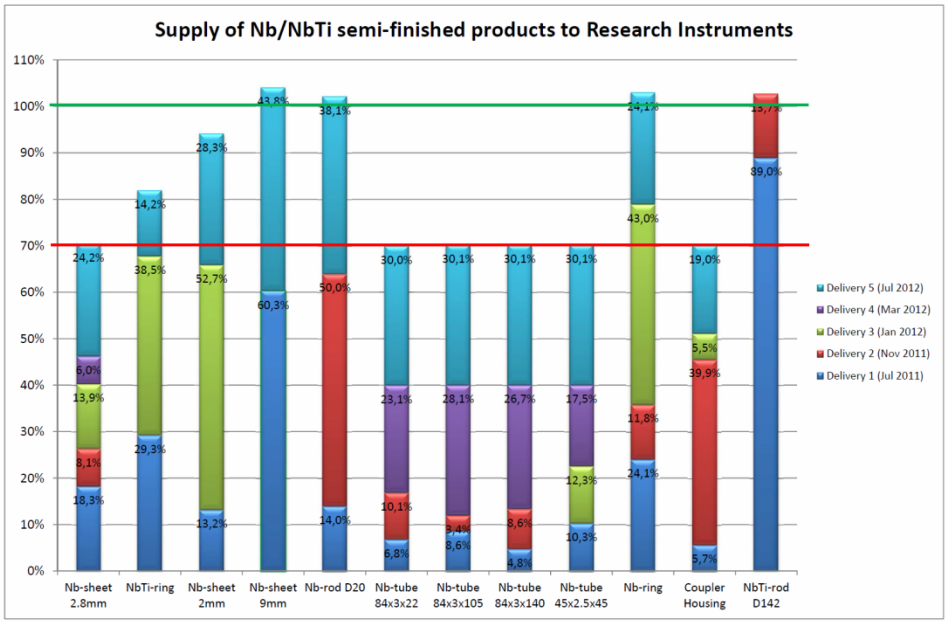
PED Activities on Material for Cavities and Helium Tanks

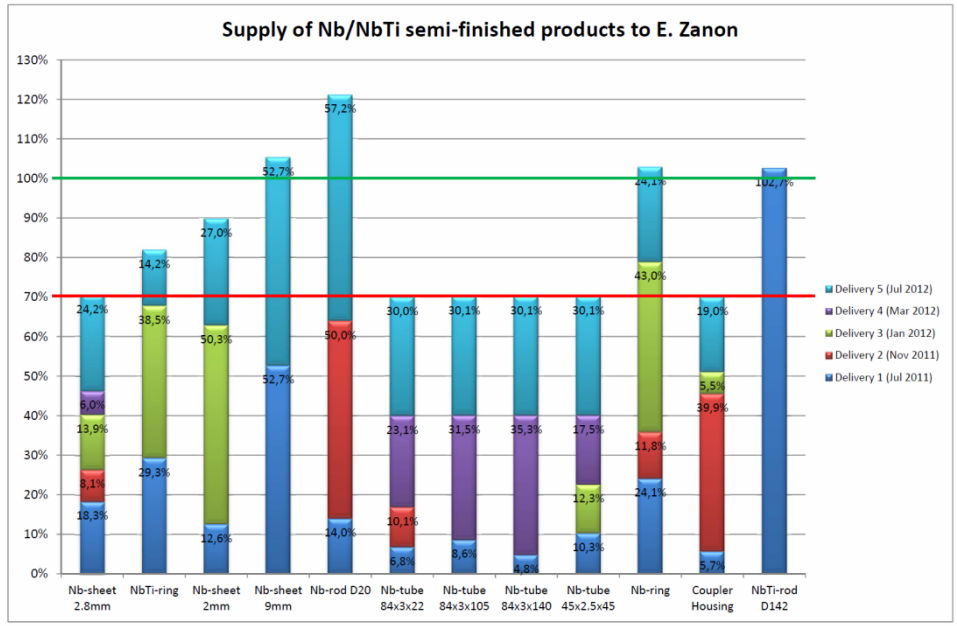
- Qualification of cavity material Nb40, Nb300, NbTi, Ti1, Ti2 (creation the particular material appraisal (PMA) by notified body).
- Certification of QM system at the companies (producing cavity material). Tokyo Denkai and Ningxia OTIC certified by TUEV NORD.
- Certification of QM system at the company Skodock (producing bellows for helium tank) by TUEV NORD.
- Supervising of the semi finished material products procurement (traceability, marking, 3.1 test certificates).



Acceptance of Nb sheets at Ningxia OTIC (courtesy of NOTIC)

Status of material shipment from DESY to RI and E.Zanon

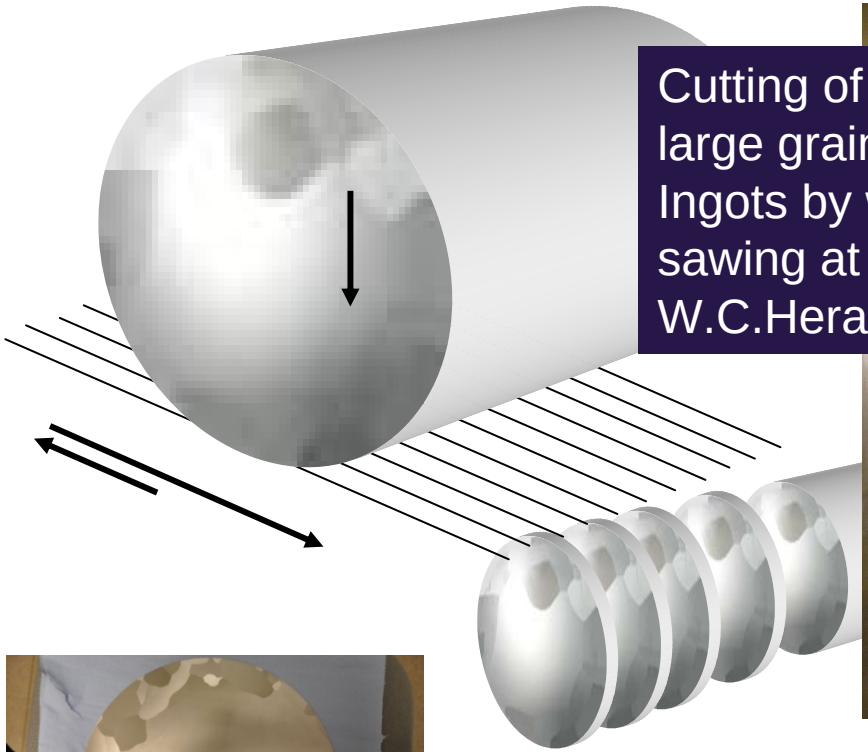




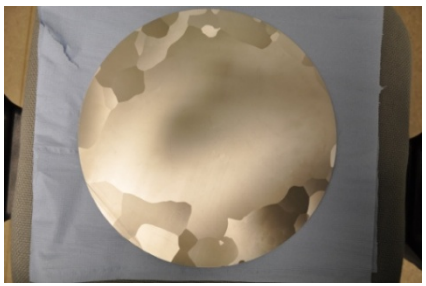
Example of first shipment to E.Zanon/RI Mid July 2011 (55 boxes) Shipment status end of July 2012

R&D: Large Grain LG Cavity for European XFEL

LG ingot and disc fabrication

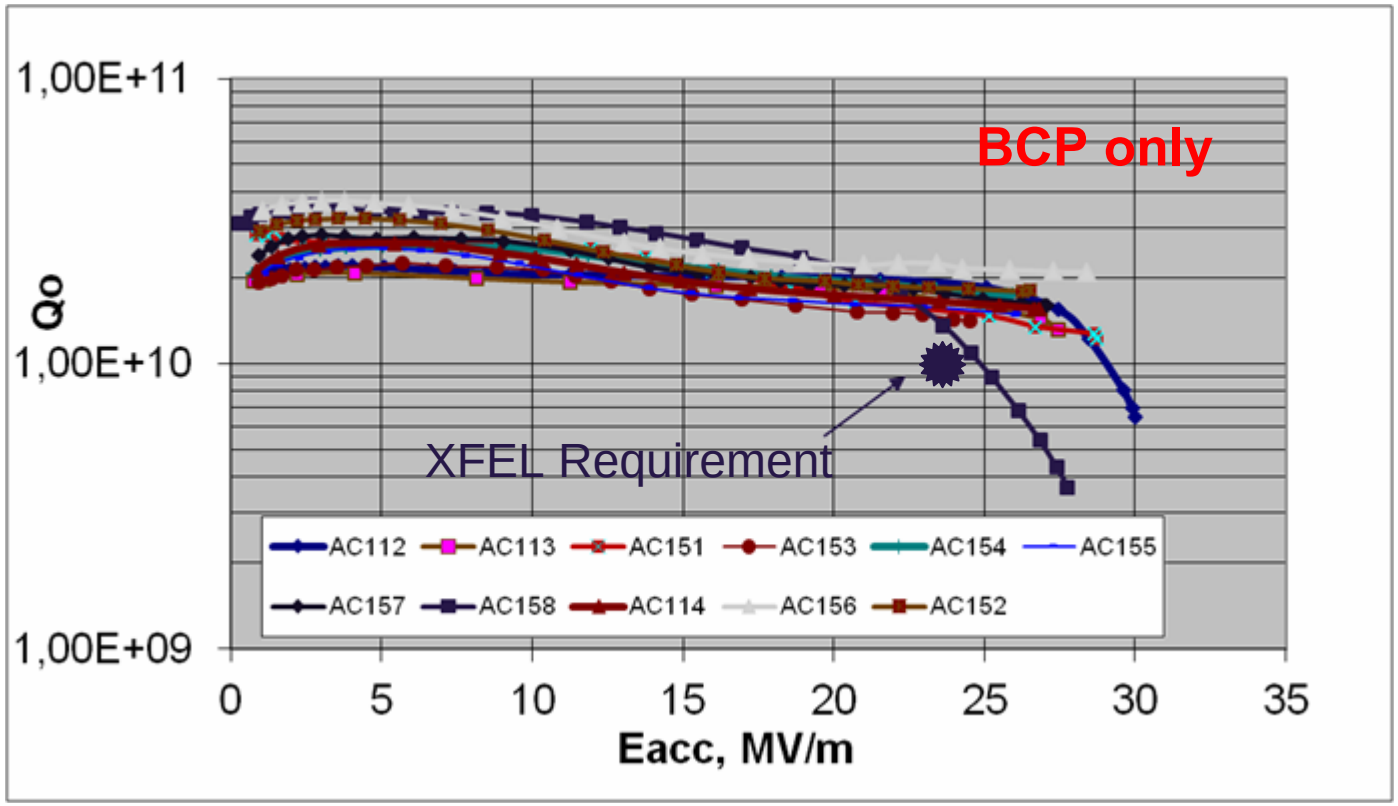


Cutting of the large grain Ingots by wire sawing at W.C.Heraeus



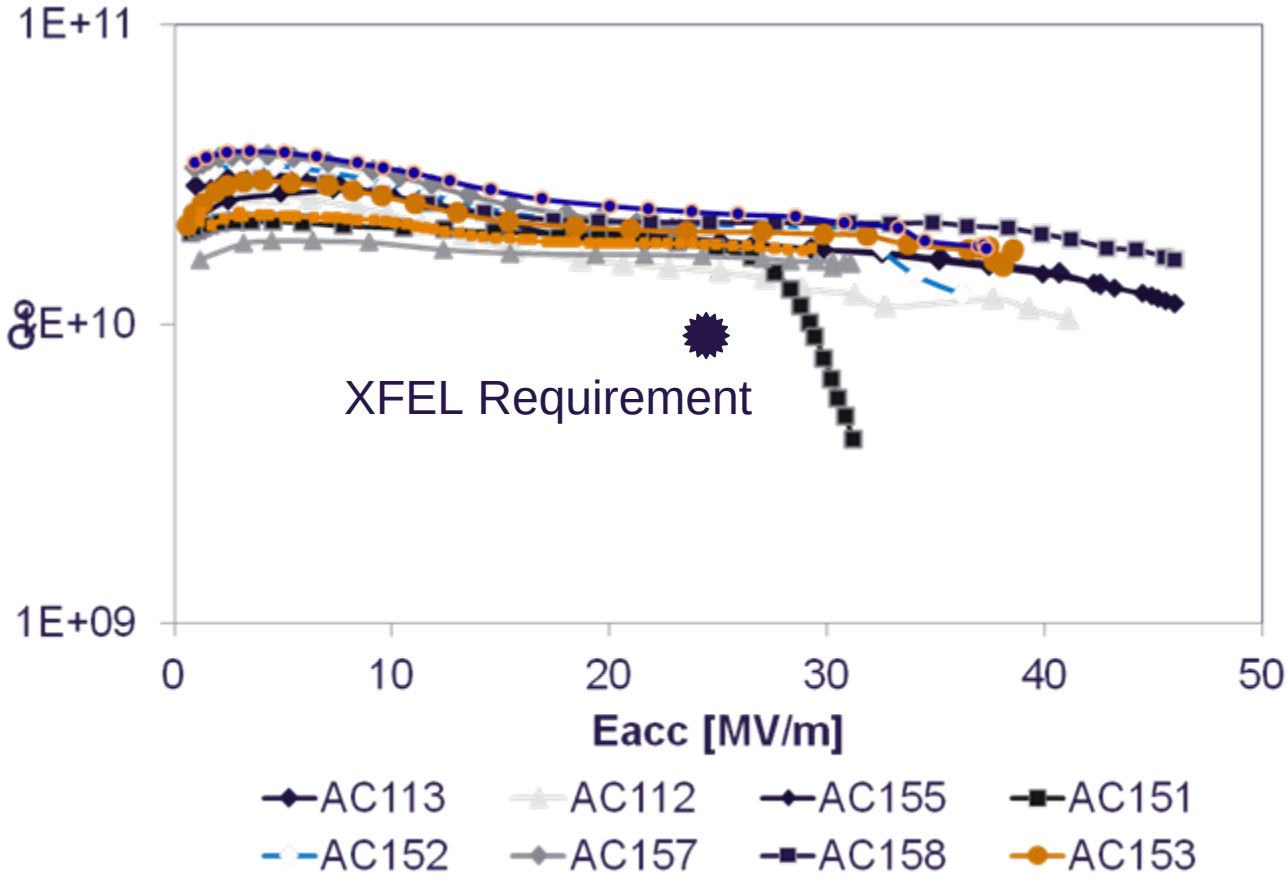
Development of LG disc production was done within the framework of the XFEL R&D program of DESY and the W. C. HERAEUS.

R&D: Large Grain LG Cavity for XFEL.
The R&D must be completed before TT starts



11nine-cell DESY cavities from LG Nb of Fa. HERAEUS are fabricated at Fa. RI Treatment: 100µm BCP, 800°C 2h, 20µm BCP, HPR and 125°C, 50 h baking.

Eacc up to 45 MV/m after add. EP
World record



Encouraging results, but the time was not sufficient to finish R&D. One cryo-module with 8 LG Cavities will be produced for European XFEL

Thank you