XFEL/ILC HiGrade program

R&D program @ DESY derived from global effort for ILC and well in phase with effort elsewhere

- Our goal
- European XFEL/ILC-HiGrade program
- Results of cold RF test of the first XFEL/ILC-HiGrade cavity
- Additional R&D instruments to be applied
  - Centrifugal Barrel Polishing
  - OBACHT optical inspection
  - Second sound upgrade
  - Local grinding
  - Replica
- HiGrade Lab

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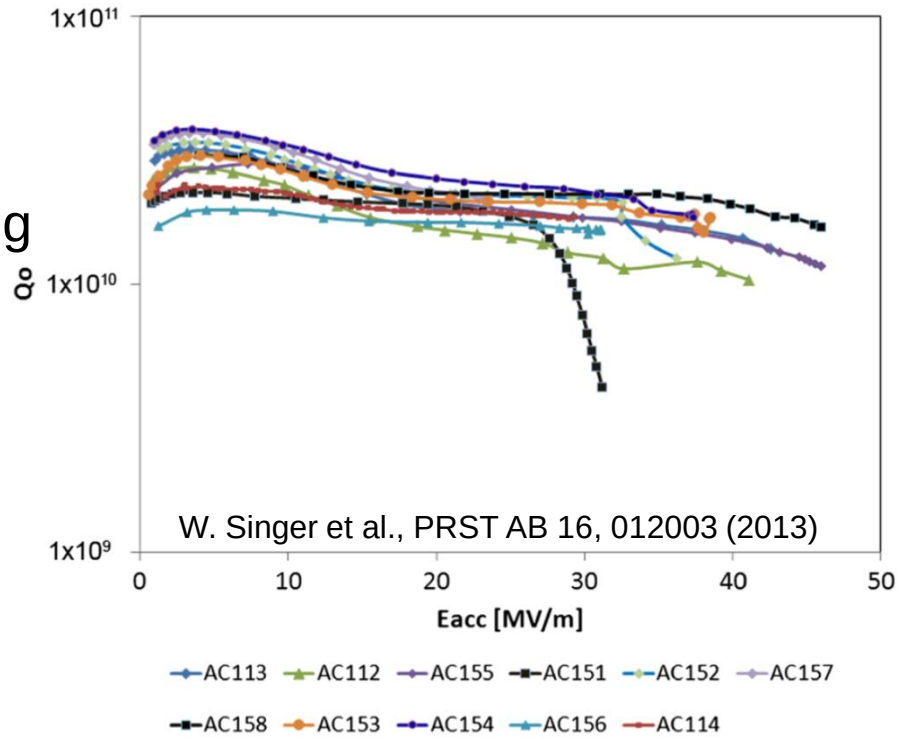
HELMHOLTZ ASSOCIATION · ilc higrade · SEVENTH FRAMEWORK PROGRAMME · CRISP · Bundesministeriu für Bildung und Forschung · Alexander von Humboldt Stiftung/Foundation

Goal of the R&D program @ DESY

- Solid understanding/control of the industrial mass-production process (*good statistics* with 800 XFEL cavities)

- **Influence/feedback** to the XFEL production
- Clear **identification** of the **gradient limiting factors**
- **Elaboration** of cavity treatment providing at least **E_{acc} > 35 MV/m** @ **>90% yield**



W. Singer et al., PRST AB 16, 012003 (2013)

45 MV/m already shown!

Yield?

European XFEL/ILC-HiGrade programme

XFEL order includes 24 cavities as a part of the ILC-HiGrade program:

- Initially, serve as **quality control (QC)** sample for the ***XFEL***
  - extracted regularly, ~**one cavity/month:** **first cavity arrived!**
  - after the **normal acceptance test** will be **taken out** of the production flow:

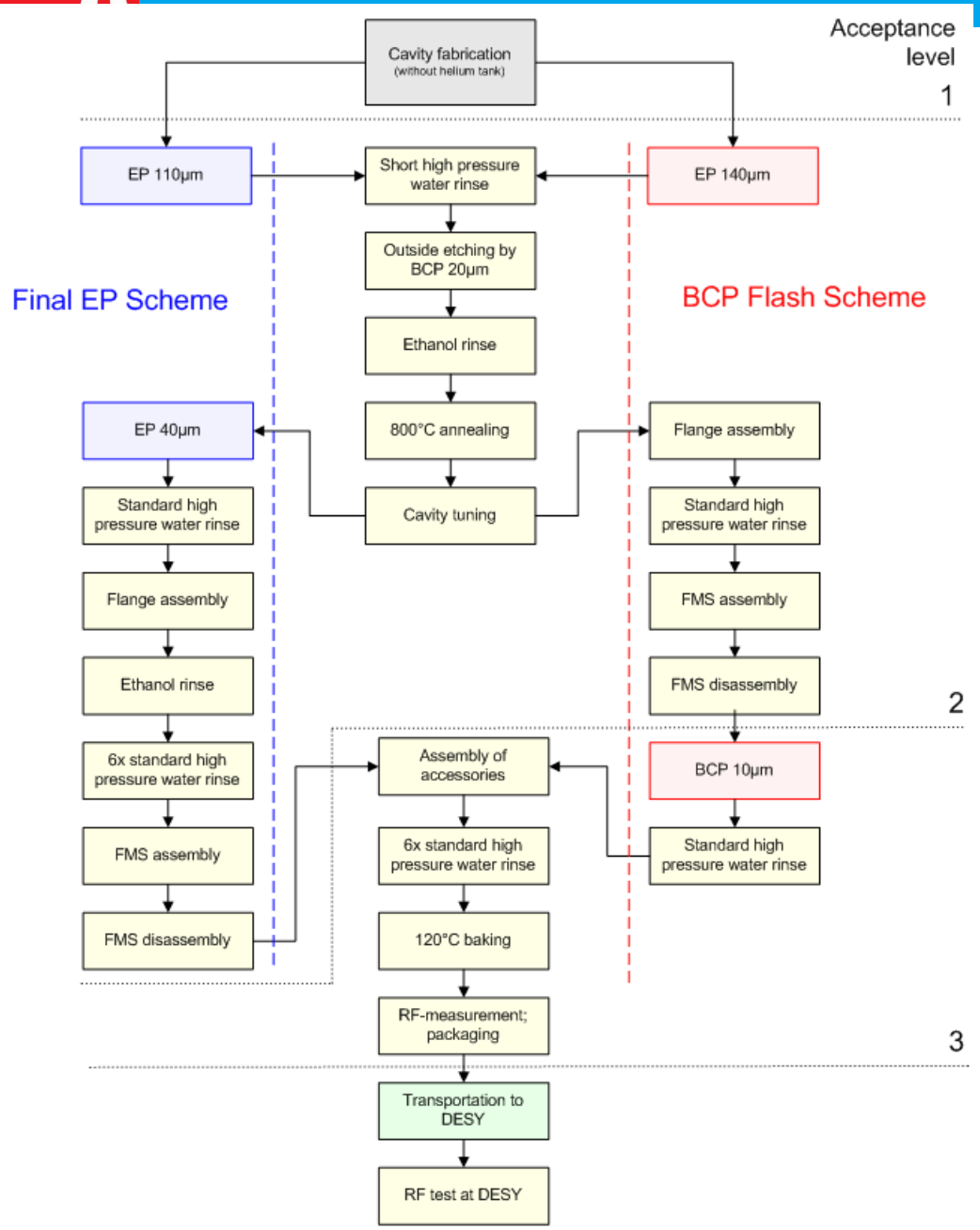
    --> **judgement** about actual cavity fabrication (even in **advance**)
    --> additional **R&D** possible

- Delivered with **full treatment** (identical to XFEL cavities) but **no helium tank**
  -> **maximize** the data output from the test

- R&D within **ILC-HiGrade/CRISP** **as feasibility study** for **ILC goal**:
  - surface mapping from the 2nd cold RF test
  - optical inspection (OBACHT) and replica
  - second pass EP/BCP
  - Centrifugal Barrel Polishing
  - Local Grinding repair

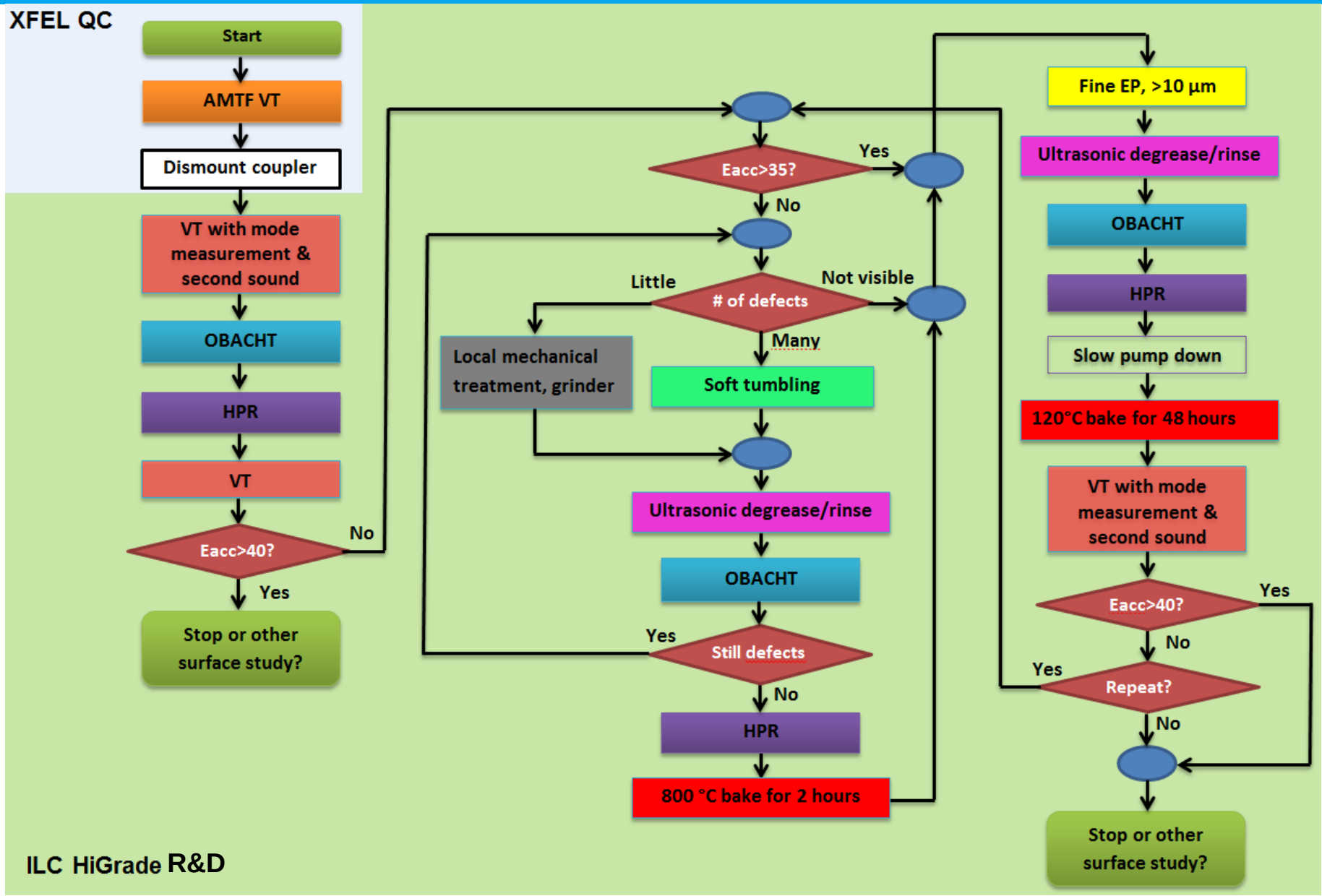
- Aim for **3 world record modules** from the **24 ILC-HiGrade cavities**

HiGrade cavities: fabrication

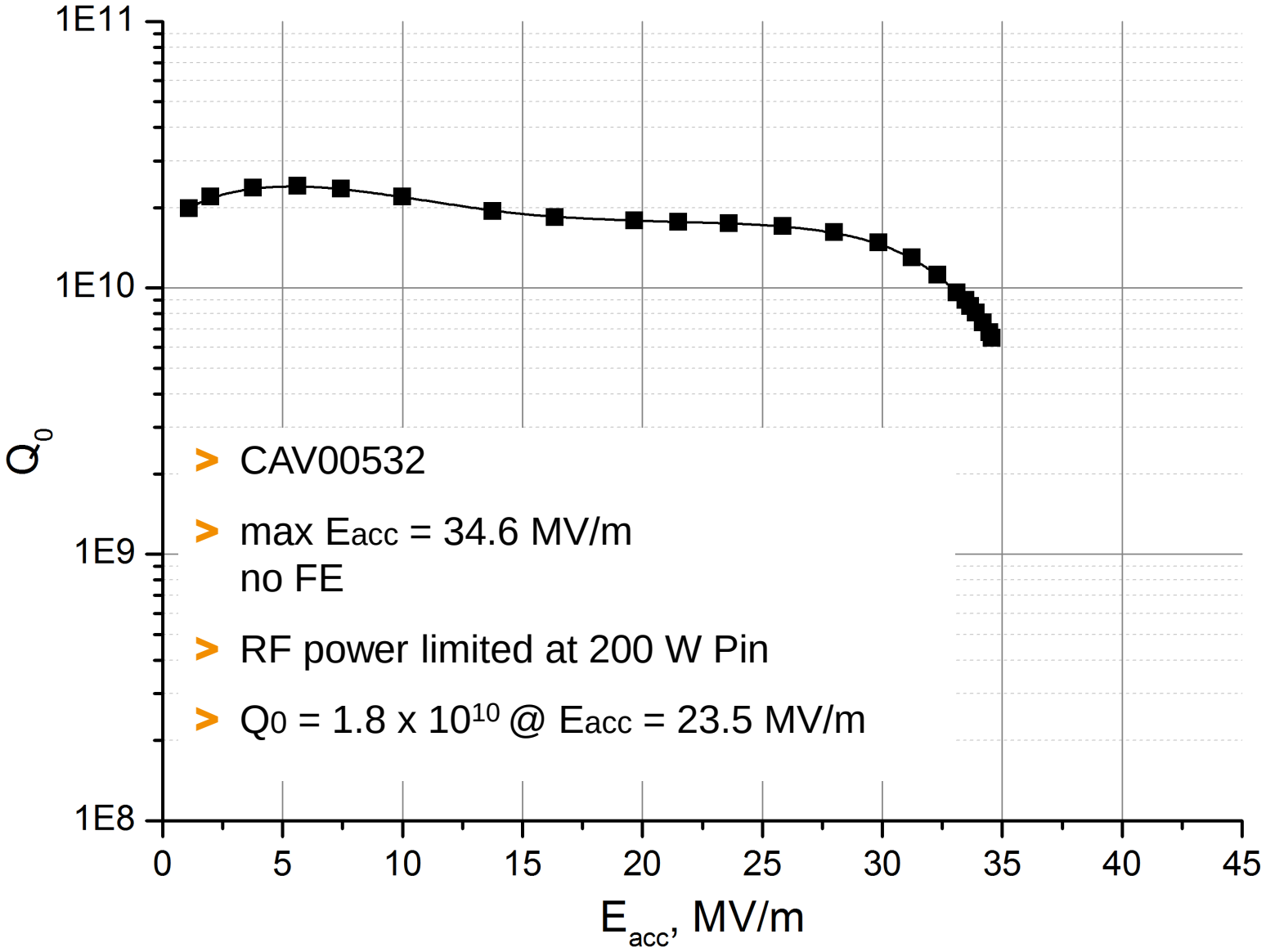


- Includes all processing steps of the XFEL cavities **except** helium tank welding
- After the RF test -> **out of flow** Components (e.g. fixed power coupler) **disassembled** and **returned** to the contractor as for the XFEL cavities
- Further handling is within the frame of the ILC-HiGrade/CRISP program in close **collaboration** with the XFEL experts

HiGrade cavities: QC and R&D

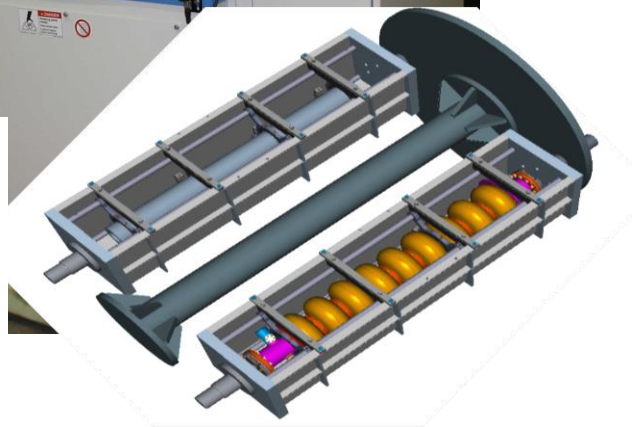


First QC test results of XFEL/HiGrade cavities



Centrifugal Barrel Polishing (CBP) of Nb cavities

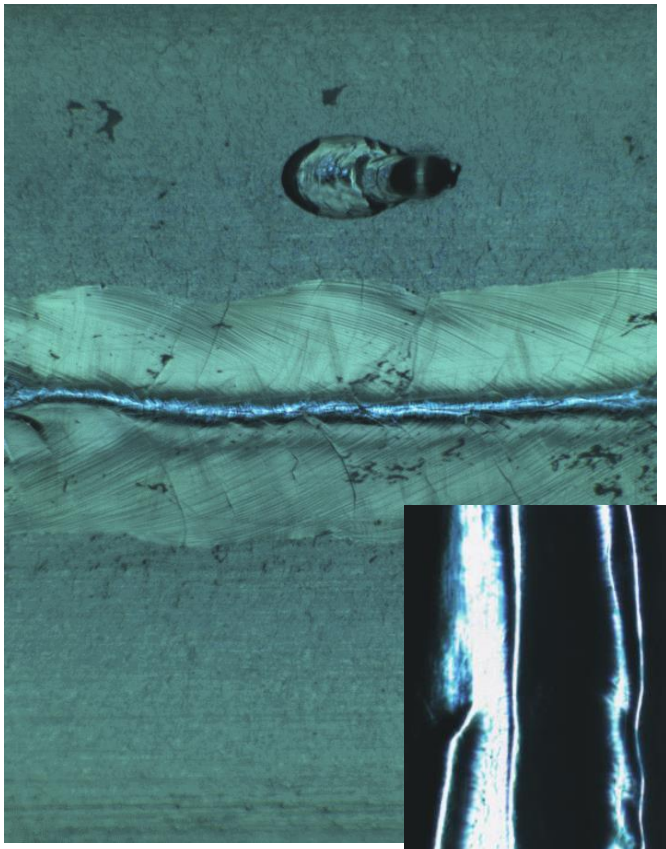
- CBP is an ***acid-free*** surface polishing technique using abrasive media
  - **reduce chemistry** amount, only light electropolishing (EP) (~10 µm) finally required [1]
  - **~10x smaller** surface **roughness** compare to chemistry alone [2] with mirror-like surface
  - **better Q_0** and **E_{acc}** might be achieved
- CBP machines in use at FNAL [2], Cornell, and JLab
- Identical machine ***has been ordered*** **by Uni Hamburg** and made available at DESY HiGrade Lab for:
  - **serial tests** of the polishing procedure (partially with **ILC-HiGrade cavities**) as feasibility study for meeting the ILC performance goal
  - **further optimizations/understand.** of the process (H-free polishing, time, etc.)
  - Study of CBP as **cavity repair** and possibly **preparation technique**

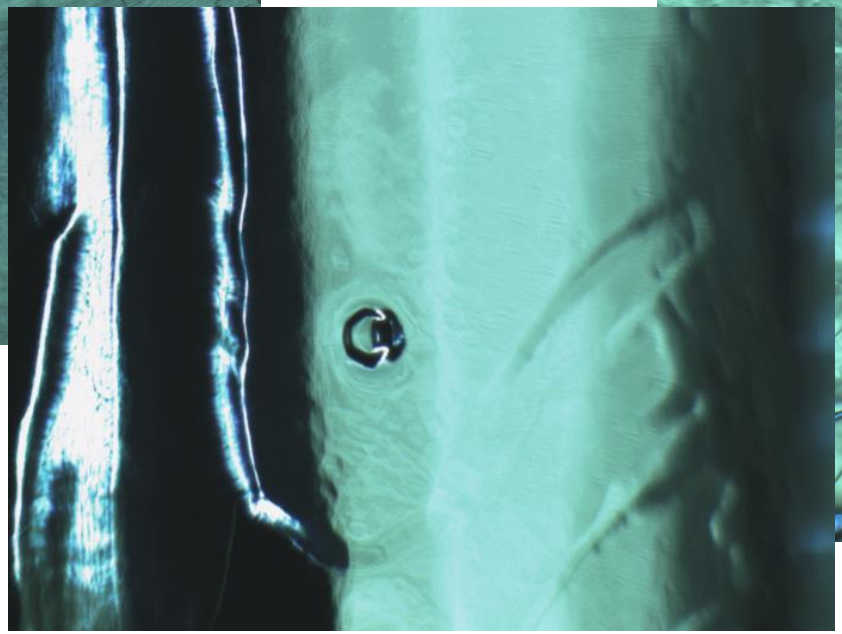


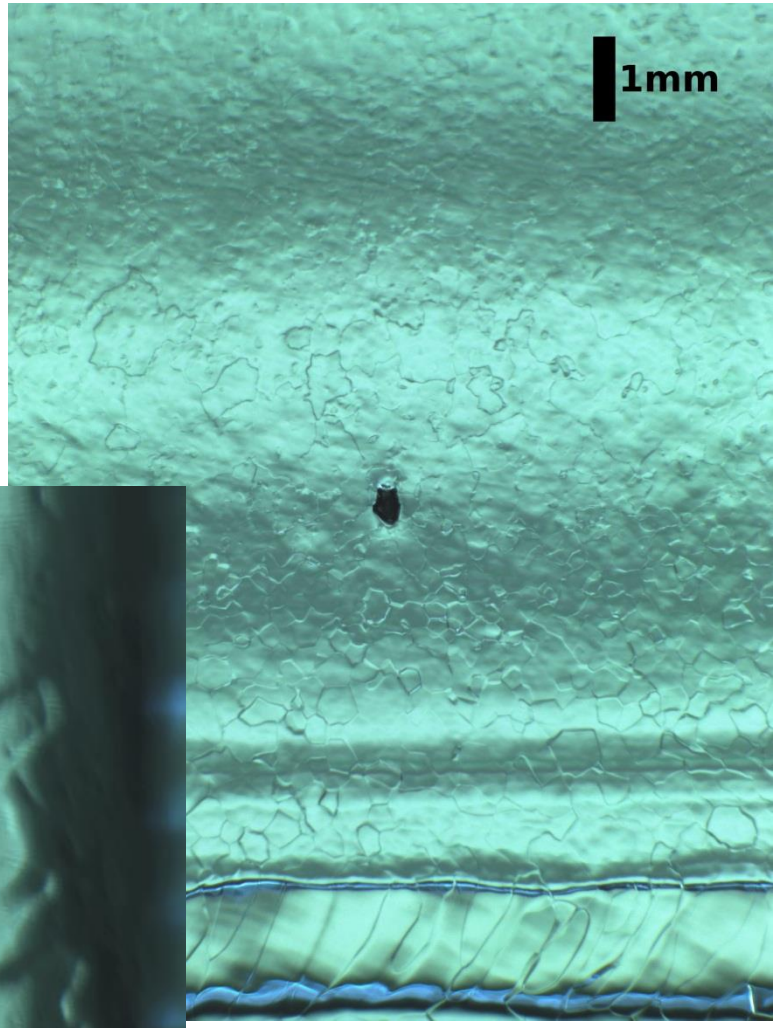
Individual Barrels rotate ~100 RPM in opposite direction to main shaft

[1] A. D. Palczewski et.al, WEPPC094 , IPAC2012
[2] C. A. Cooper et.al http://lss.fnal.gov/archive/2011/pub/fermilab-pub-11-032-td.pdf

Defects unavoidable by the current technique







Polishing media and processing time

Step 1
Cutting,
~8 hours

+ Soap &
Ultrapure
Water

Step 2
Intermediate
polishing, ~15 hours

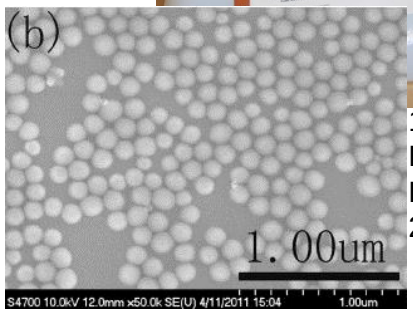
+ Soap &
Ultrapure
Water

Step 3
Intermediate polishing,
~30 hours

Water +
15 μm
Alumina

Step 4
Final polishing,
40+ hours

Colloidal
Silica –
0.04 μm

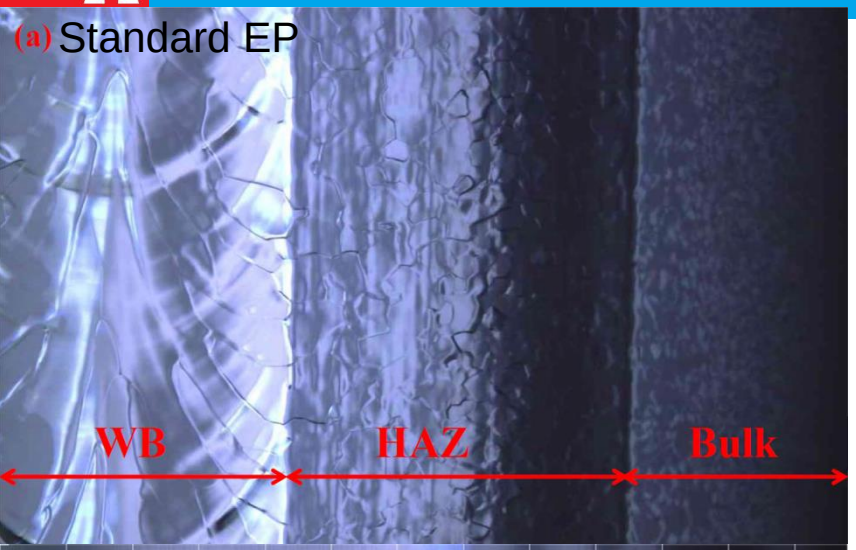


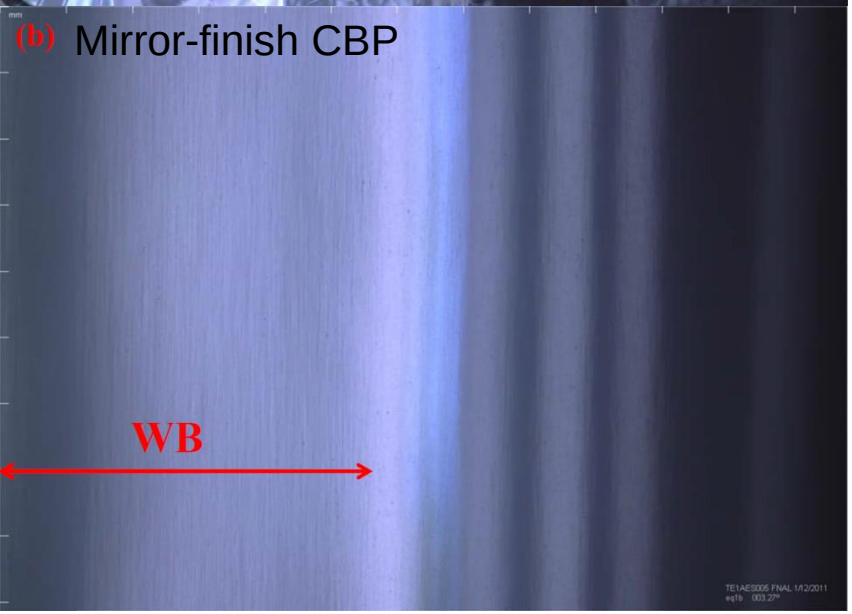
119 nm SiO_2,
Example from
L. Zhang et.al. ASS,
258, (2011) p.1217.

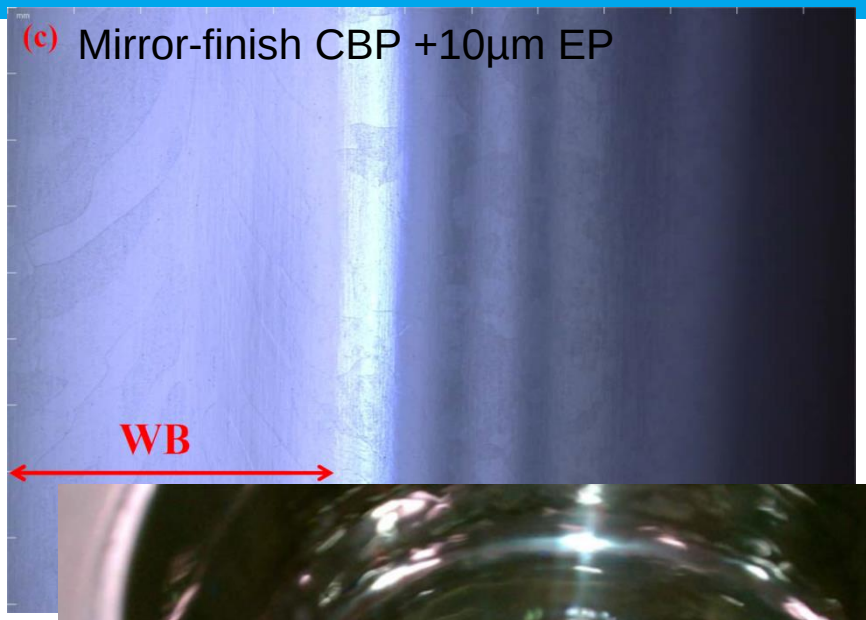
Step 5
Final EP
>10 μm

HF : H_2SO_4
1 : 9

CBP vs. standard EP [1]



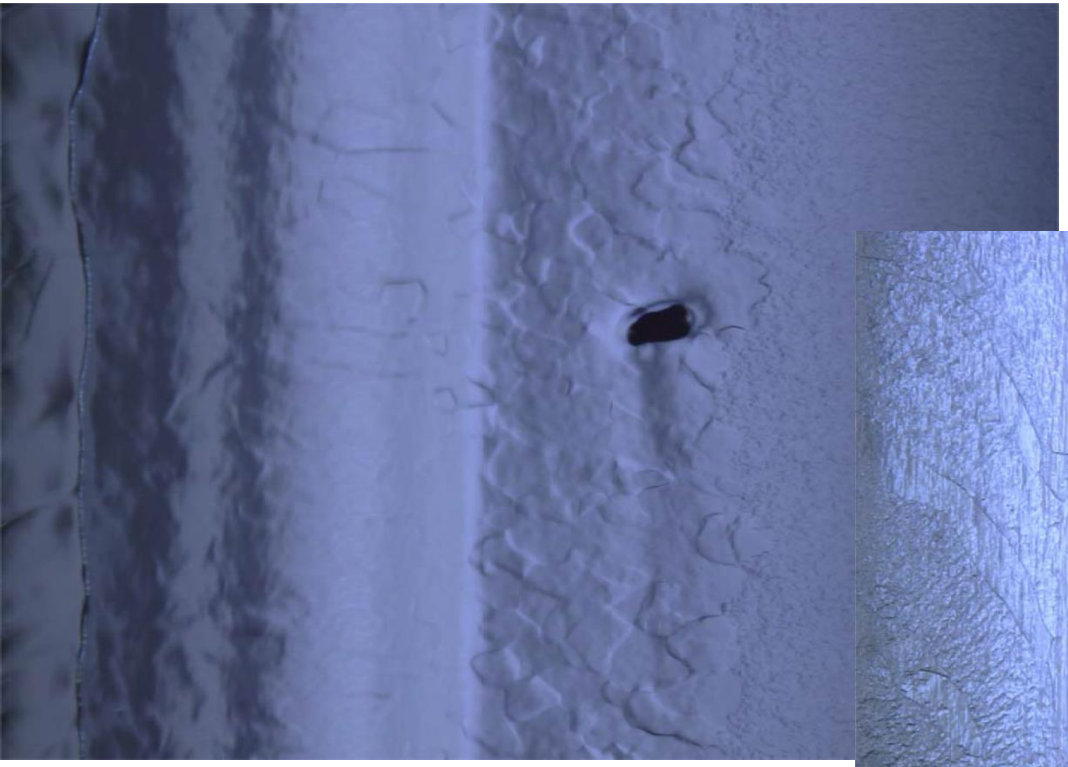




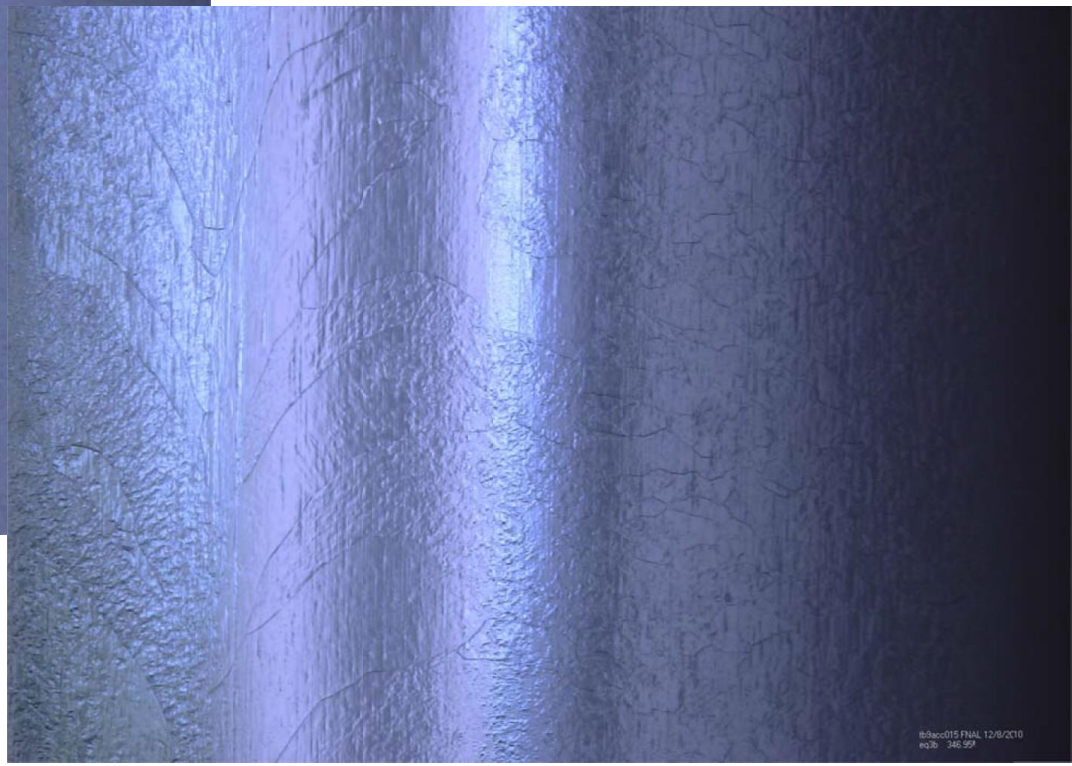
[1] C.A. Cooper, L.D. Cooley, Supercond. Sci. Technol. **26** (2013) 015011

Defect removal by CBP [1]

After standard EP



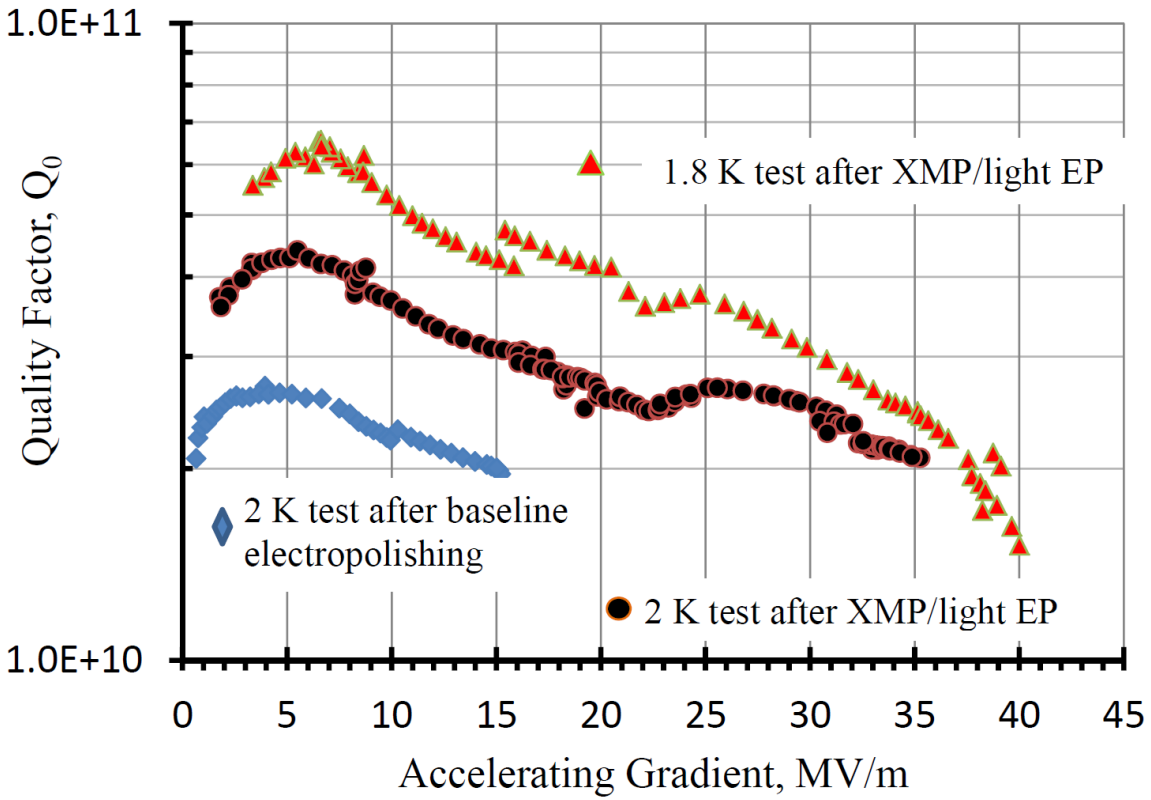
After CBP + 60 µm final EP



> **Removal** of defects unaffected by the standard EP process

[1] C. A. Cooper, L.D. Cooley, Supercond. Sci. Technol. **26** (2013) 015011

Cold test results after CBP [1]

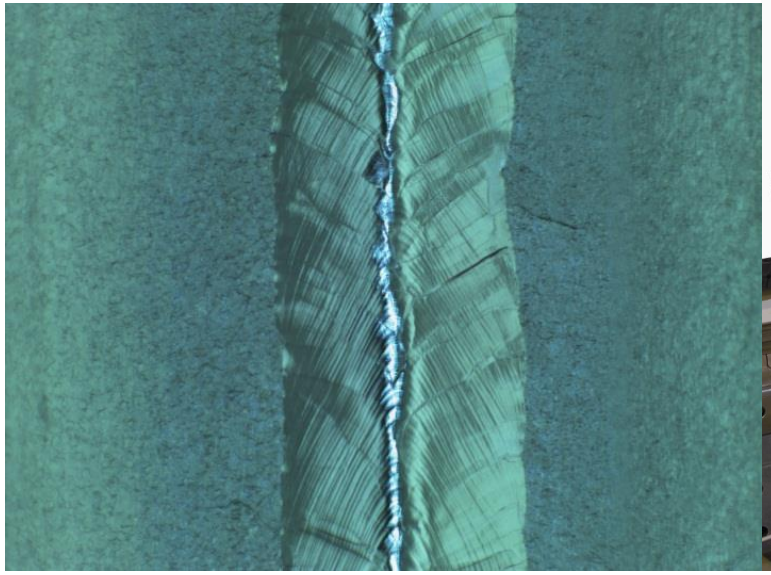


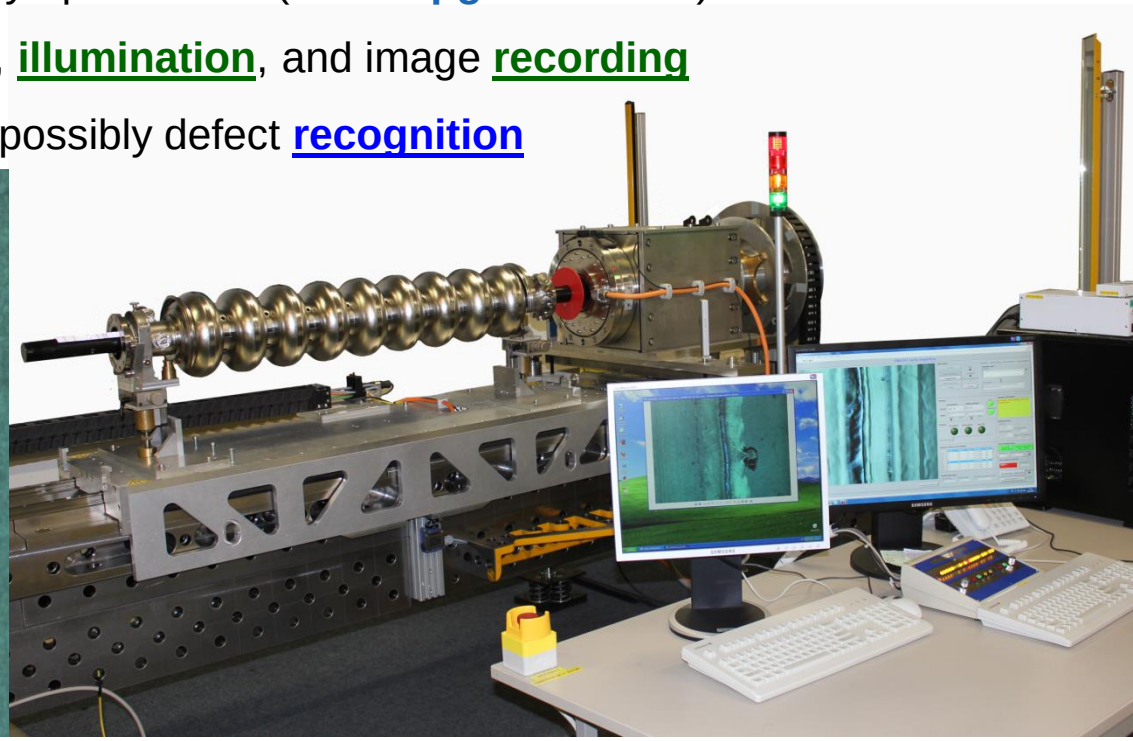
- **Improvement** of the accelerating gradient from 15 to 35 MV/m
- ***CBP process*** is able to overcome some major manufacturing defects like shown

[1] C. A. Cooper, L.D. Cooley, Supercond. Sci. Technol. **26** (2013) 015011

OBACHT – Optical Bench for Automated Cavity Inspection with High Resolution on Short Time Scales

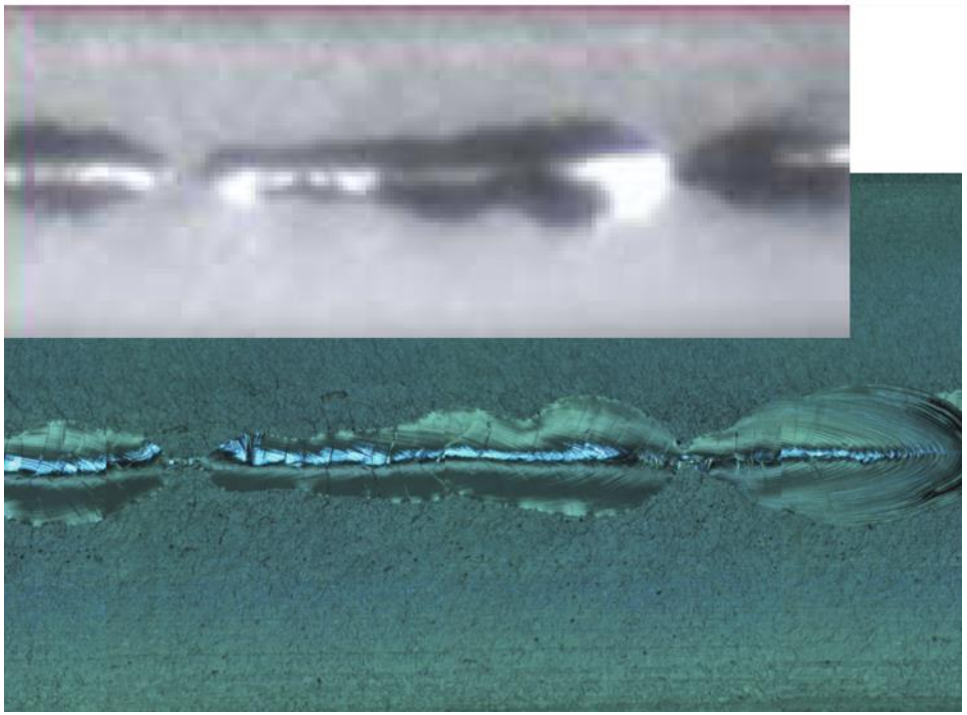
- **Large amount** of cavities (also dressed) can be **inspected**: ILC-HiGrade, (European XFEL)
- **Fully automated** (LabView) cavity inspection with Kyoto Camera System yields
  - 2790 pictures in ~8 hours: welding seems of equator (iris) every 4°(10°) + equator left/right
  - ~12 x 9 mm pictures (2488 x 2616 pixels, ~10 µm/pixel) in *.bmp, *.png and/or *.jpg
- Movable sled with cavity (axial posit. ~10 µm) and Kyoto camera (angular posit. ~0.01°),
- Collision free movements assured by optical tests (**to be upgraded now**)
- Fully **automatic** cavity **positioning**, **illumination**, and image **recording**
- **Automatic** image **processing** and possibly defect **recognition**



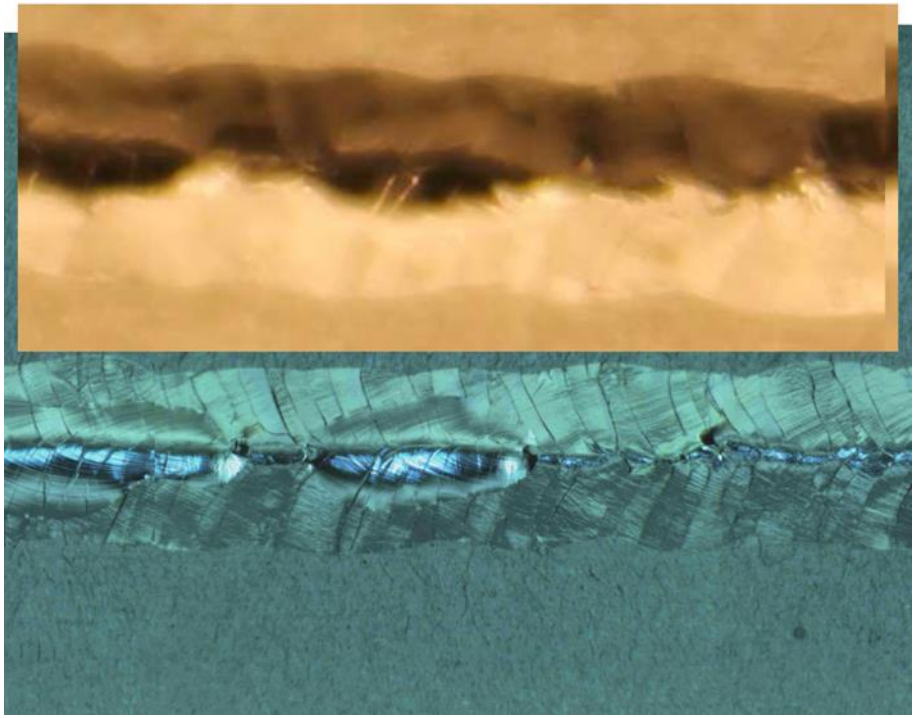


Examples of the OBACHT tests

> **Optimization** of equator welding parameters:



Initial, **not optimized**
→ **e^- -beam not penetrated everywhere**
→ **strong variation of the seem- width**

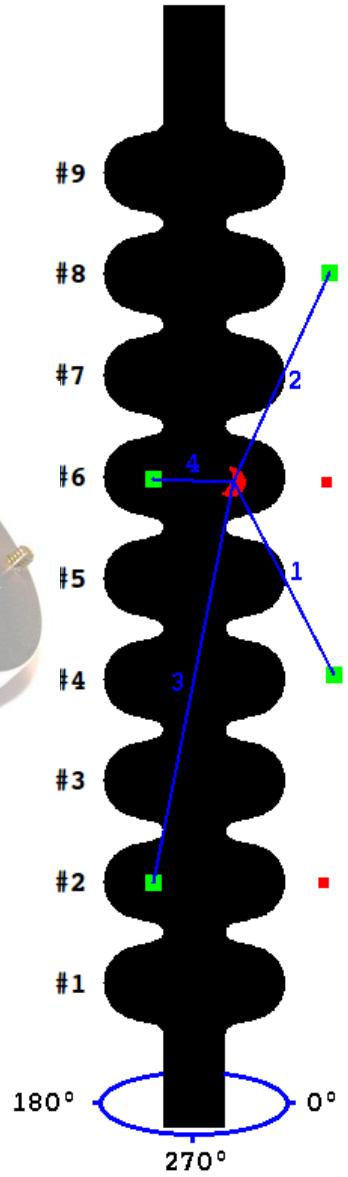


Final, **optimized**
→ **e^- -beam fully penetrated**
→ **homogeneous welding seem**

> **OBACHT** provides much **better resolution and image quality** as compared to the conventional **endoscopes** (see upper images)

Upgrade of „Second sound“ quench detection system

- **Currently** all VT inserts @ DESY equipped with 8 OSTs to detect „second sound“
- **Upgrade** to 16 OSTs for the ILC-HiGrade cavity tests:
  - Better localization accuracy (< cm)
  - Allow additional R&D

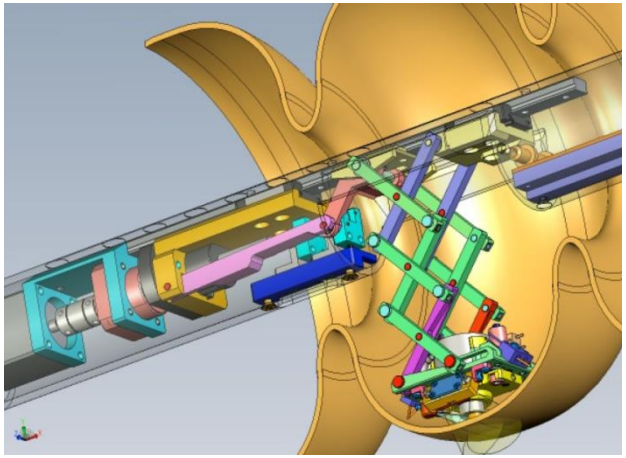


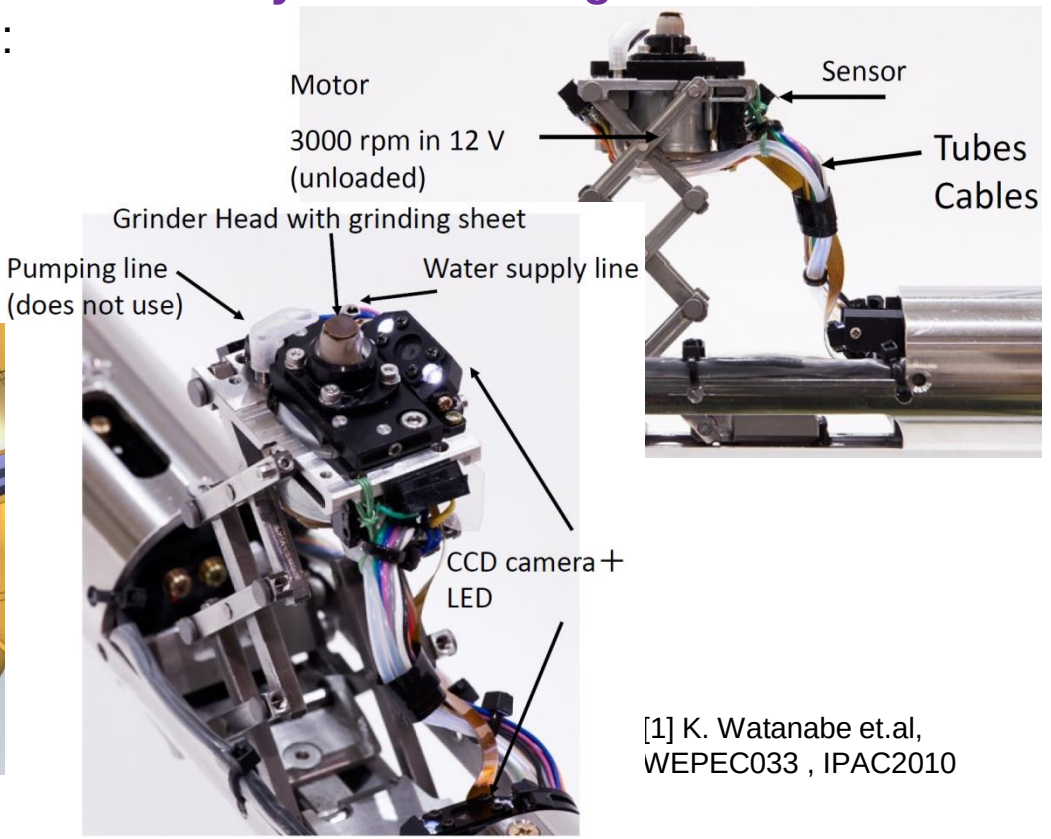
Required modification:

- New DAQ with more channels
- More feedthroughs on the cryomodule inserts
- Update of the evaluation software with better accounting of the cavity shape and wave propagation in Nb

Local grinding as repair technique for cavities

- **Local grinder** is a mechanical polishing technique used for **local** defects removal
- Defects unaffected by standard chemical polishing can be eliminated [1]
- Local grinder in use at KEK (shown below [1]) and deliver very promising results
- Similar machine ***is planned to been ordered*** **by Uni Hamburg/DESY** and made available at DESY HiGrade Lab for:
  - **serial tests** of the repair procedure (partially with **ILC-HiGrade cavities**) as feasibility study for meeting the ILC performance goal
  - **further optimizations** of the process

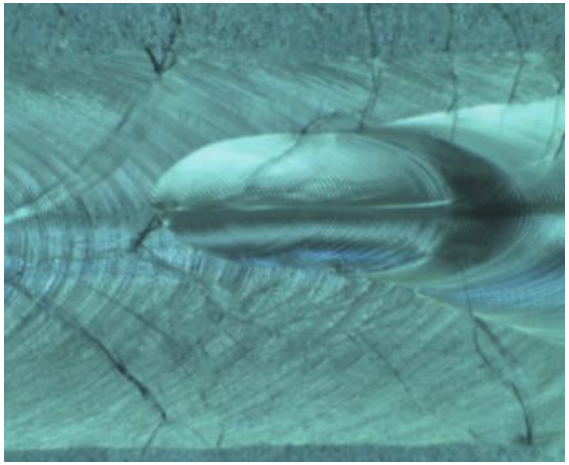


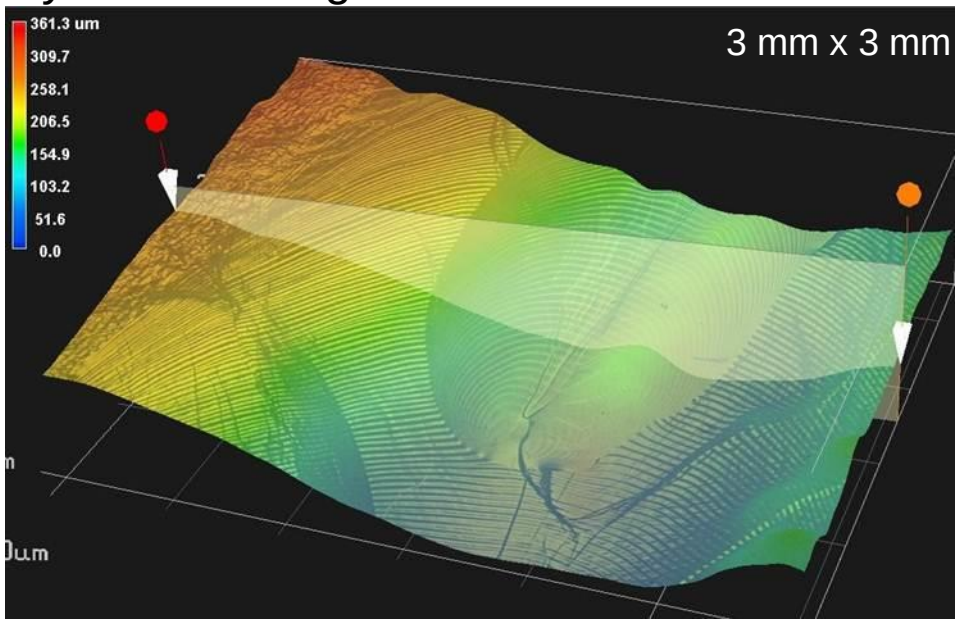


[1] K. Watanabe et.al, WEPEC033 , IPAC2010

Replica as additional surface study technique for cavities

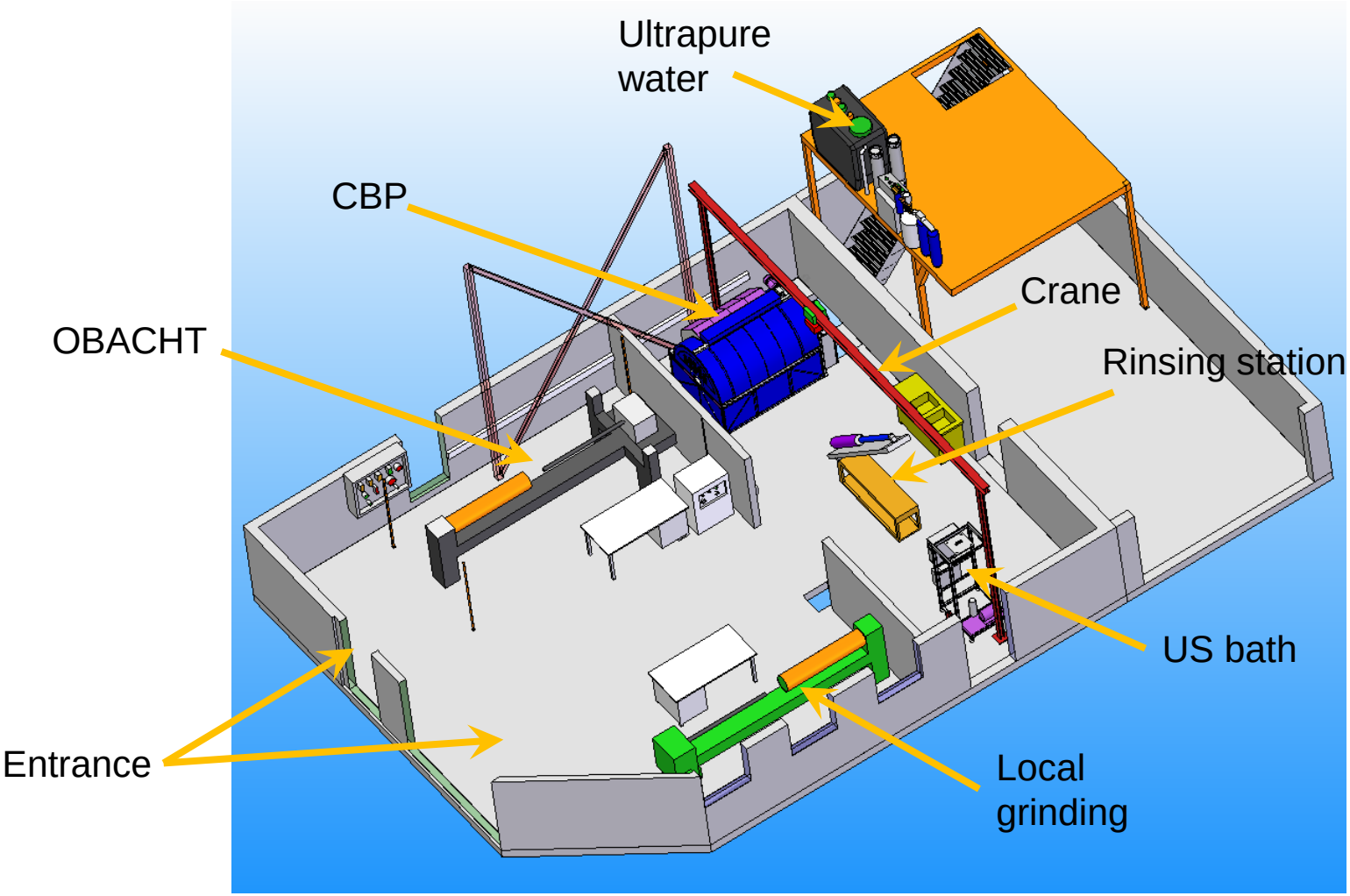
- **Replica** is non-destructive testing tool of inner cavity surface
  - helps analyse 3D geometry of defects
  - deliver resolution down to 1 µm
  - do not leave residues on the surface if done correctly (at least after HPR)
  - no cavity performance degradation
- **Replica** in use at KEK [1], Fermilab [2], CEA/DSM/DAPNIA [3] etc.
- Similar technique ***is in use at*** **DESY** for:
  - **tests** of the surface defect geometry
  - **correlation** between 3D topography and 2D images from OBACHT





[1] K. Watanabe, et. al, TTC2010.
[2] M. Ge et. al, SRF2009, TUPPO064.
[3] S. Berry et. al, EPAC04, TUPKF018

HiGrade Lab



- ~150 m^2
- 2 laboratory rooms + 1 storage/technical room
- to be ready around August 2013

HiGrade Lab

Thank you for your attention !

Acknowledgements:

- **FLA/ILC group** (Eckhard Elsen, Brian Foster, Egor Tamashevich, Ricarda Laasch, Marc Wenskat, Lea Steder, Sebastian Aderhold, Jörn Schaffran, Uwe Cornett, Gert Falley, Agnessa Guddat) & all **DESY colleagues,** especially ones participating in the XFEL cavity fabrication, treatment and tests
- **FNAL colleagues** (Charlie Cooper, Lance D. Cooley, David A. Burk, Anthony C. Crawford) for great help with the CBP technique
- Colleagues from **KEK** & **Kyoto University** (Hitoshi Hayano, Yoshihisa Iwashita, Ken Watanabe, Takayuki Saeki etc.) for collaboration regarding optical inspection system, local grinding, replica etc.

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