R&D PROGRESS IN SRF SURFACE PREPARATION WITH CENTRIFUGAL BARREL POLISHING (CBP) ON NIOBIUM AND COPPER – TUI0B01

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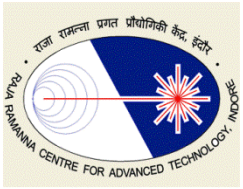
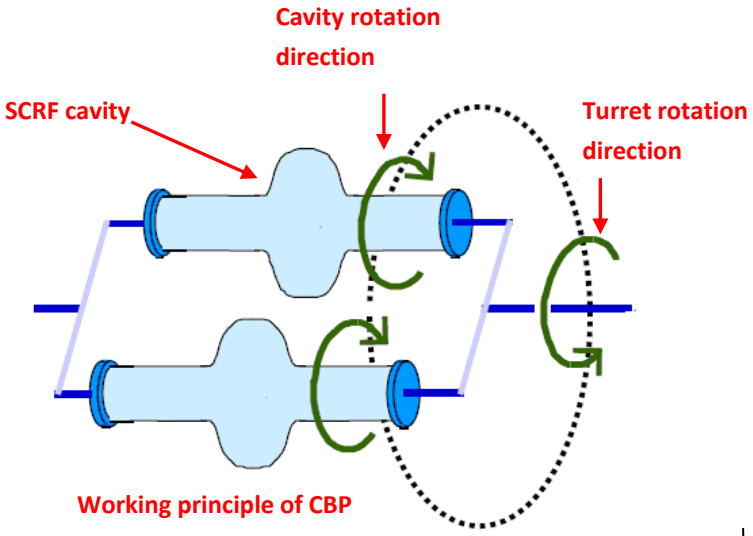


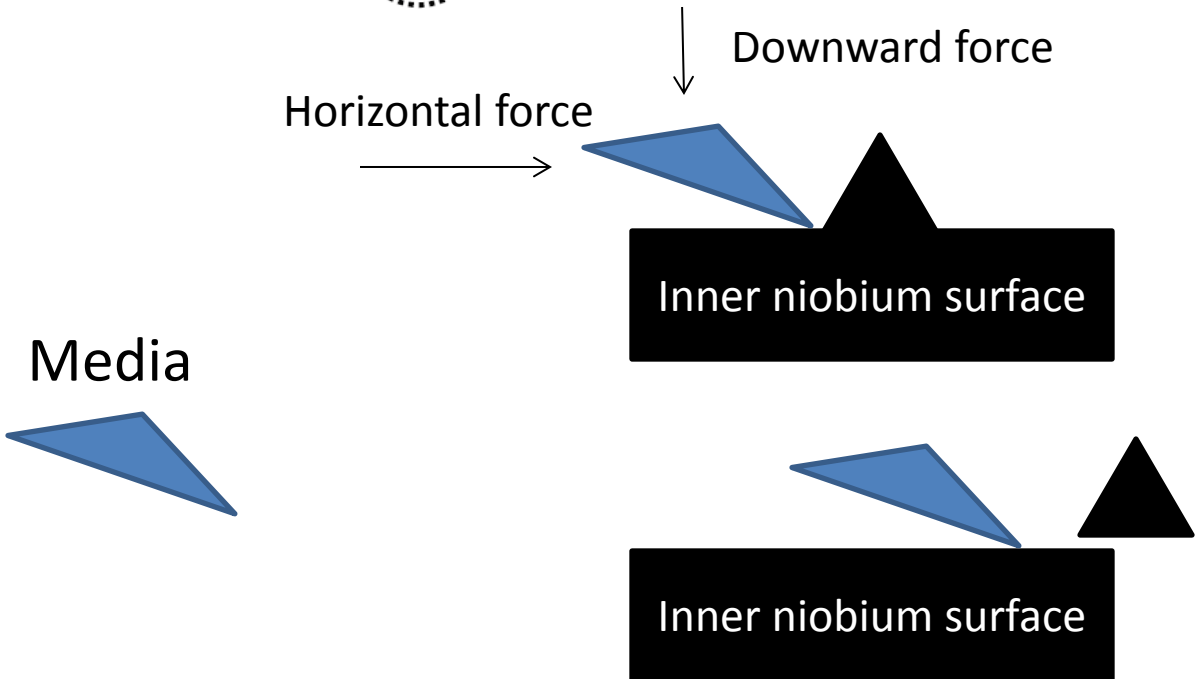
Sept. 24th 2014 – SRF2013 Paris

Progress and Updates from 2011 by Cooper et al. **CENTRIFUGAL BARREL POLISHING OF CAVITIES WORLDWIDE -** WEIOA02

CBP process

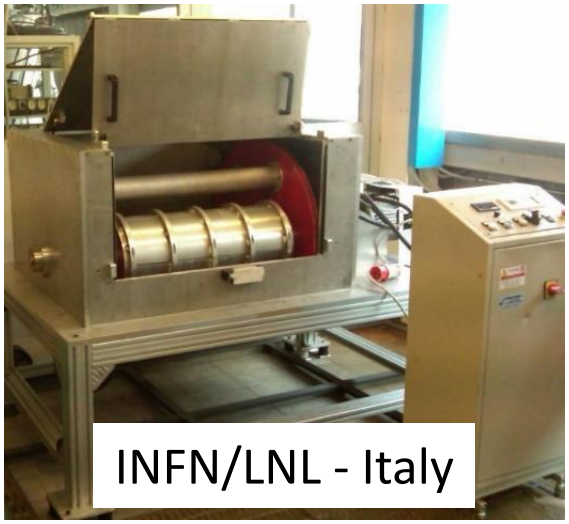


- Fill cavity with abrasive median and usually a liquid
- Hermitically seal the cavity - run in machine for a set time
- Clean cavity (water rinse, ultrasonically clean, HPR ….)
- Reduce media grit size and repeat



CBP Machines

Custom built for 1.3 and 6GHz



INFN/LNL - Italy

Mass finishing HZ for 1.3GHz

JLAB, FNAL, Cornell – USA
DESY - Germany

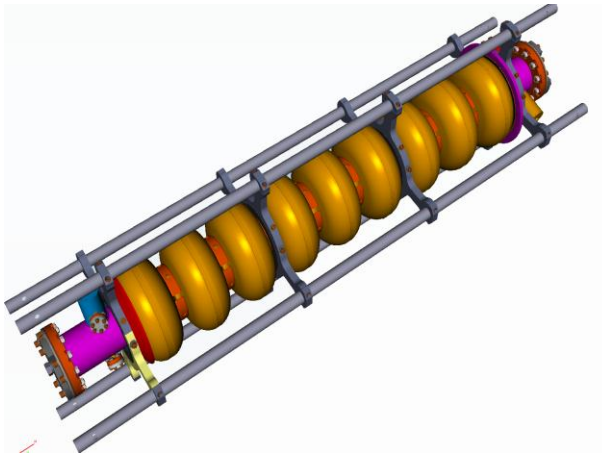
1.3GHz

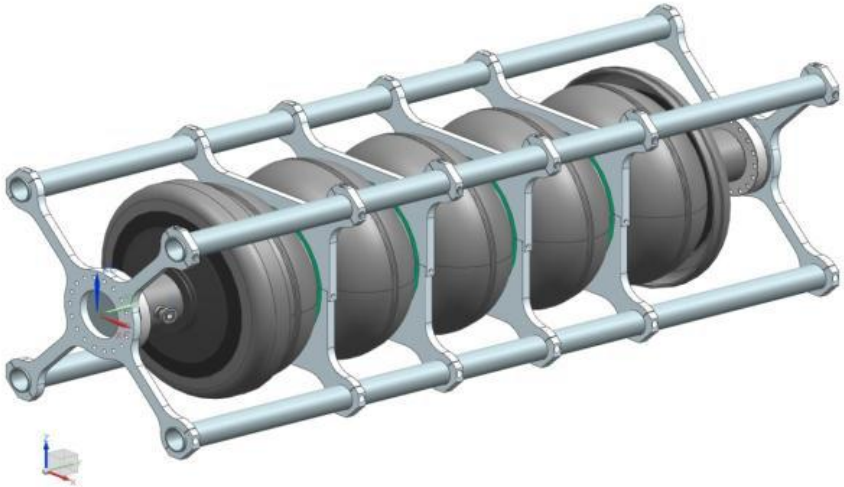
RRCAT - INDIA

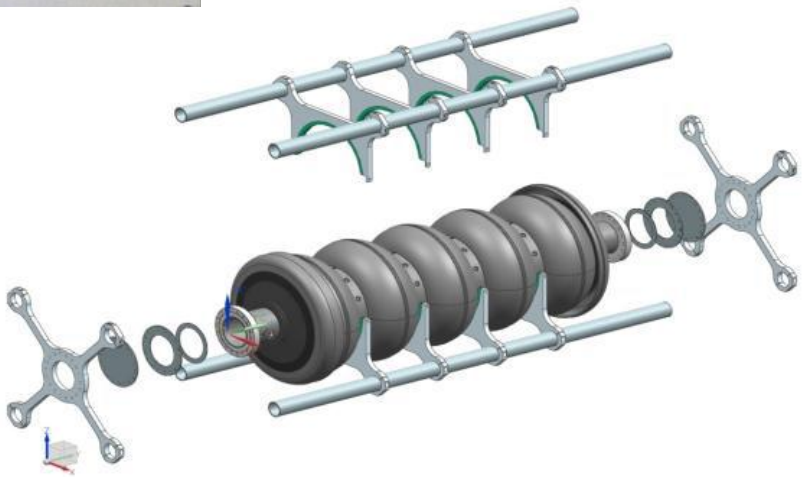
Mass finishing HZ for 0.65 and 1.3GHz

FNAL

CBP brackets
“iris clamping spider system”





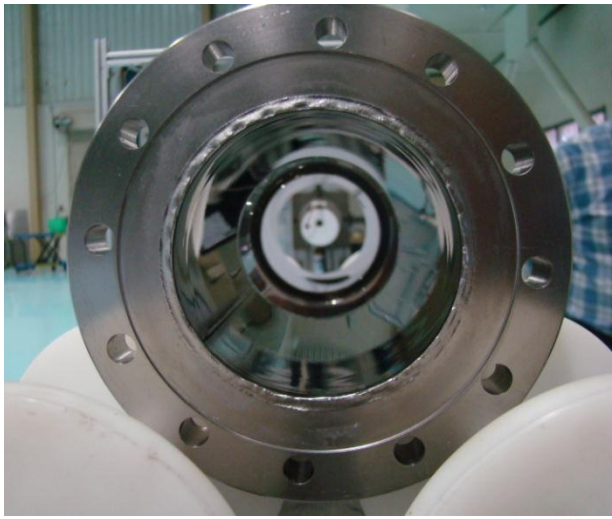


“Standard Mirror finish” CBP recipe (FNAL modified)

Course (variable ~10 hours)
K&M ceramic

Medium (10 to 20 hours)
RG-22 cones

Polish 1 (30 to 40 hours) 800 mesh powder & carrier - hard wood block/corn cobs



Polish 2 (40 to 200 hours) 40 nm colloidal silica & carrier - hard wood block/corn cobs

“Standard Mirror finish” CBP recipe (FNAL modified)

Course (variable ~10 hours)
K&M ceramic

Polish 1 (30 to 40 hours) 800 mesh powder & carrier -
hard wood block/corn cobs

90 to 300 hours machine run time
About 10-20 man hours depending on cleaning and machine maintenance

Medium (1
RG-22 cone

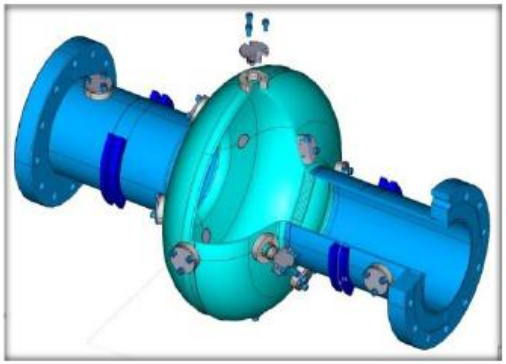
New CBP research highlights since 2011

- Many more groups running CBP machines and many more cavities processed (over 50)
- CBP removal rates by cavity type and material
- CBP copper
- Zero post chemistry CBP
- Other mechanical polishing – resonate vibration

Cavities CBP's since SRF2011

FNAL

•Nine Cell (TB9XXXX)
–7 different cavities, some multiple passes
–ACC015, NR002, AES006, AES012, AES016
–AC114 – Large Grain
–IHEP02 – Large Grain – Low Loss Shape
•Single Cell (TE1XXXX)
–JL001, JL002, ACC001, ACC004, ACC006, CAT001-CAT004, CATLZW001, PAV001, PAV005, PAV007, PIPPS03, AES008-AES011,
–1DE20, IHEPLG01 – Large Grain
–RICU001 (several others as well) – Copper
–CAT05 – Aluminum (contact Cooper first to do)
•Coupon Cavity
–TACAES001 & 002 (~40 runs)



JLAB

•Multicell
TB9NR001
DESY 3.5GHz gun cavity
•Single cell
RDT4-7
LSF-1,2,3 (copper)
G1G2
F1F2
PS-1307
6 sets of beam pipes (Cu and Nb)

RRCAT

•Multiple single cell

INFN

•Over 10 6 GHz (resonate vibration)

Cornell

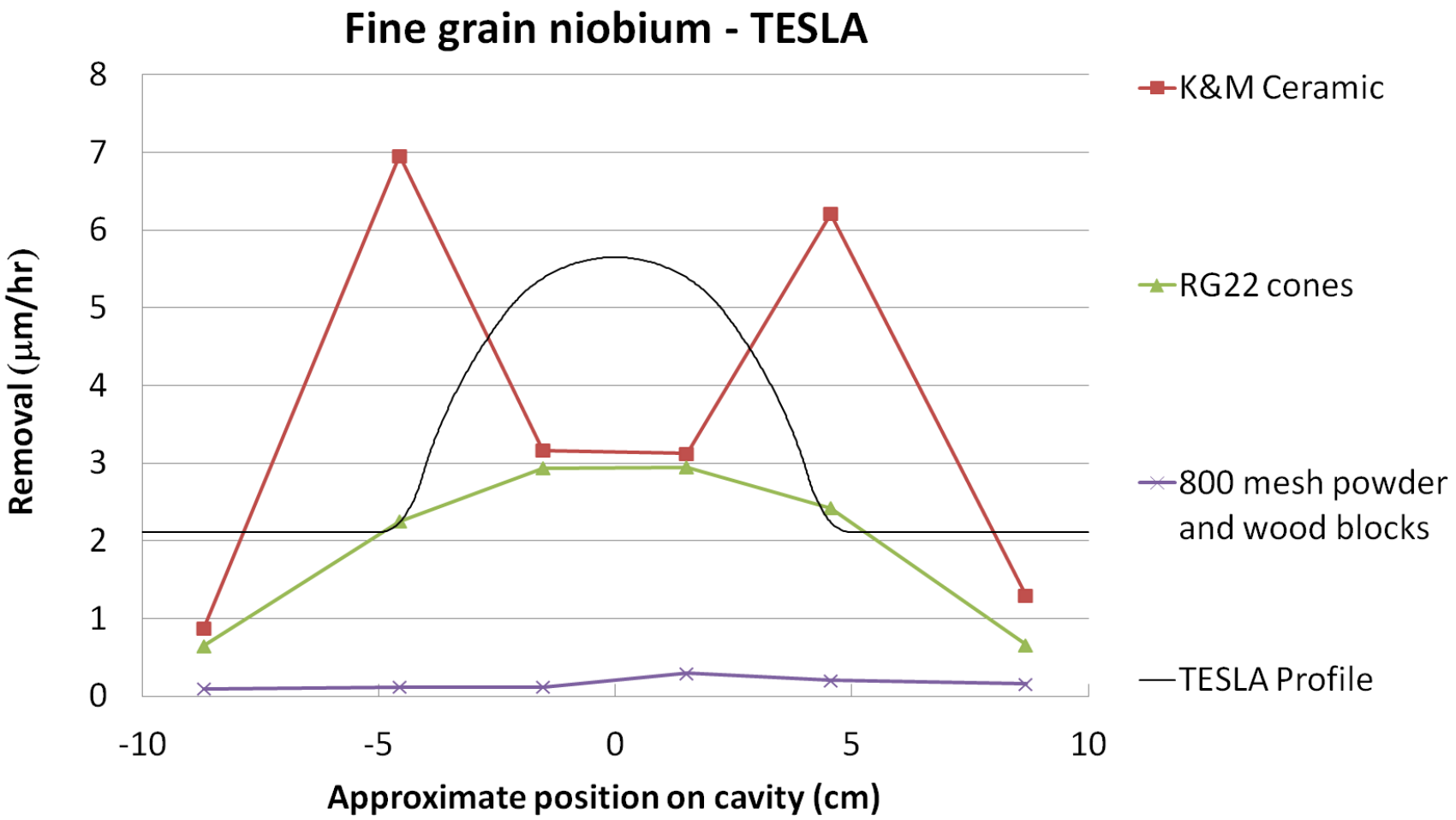
•Beginning to process muti-cell cavities

DESY

•Machine setup and beginning to process

CBP REMOVAL RATES

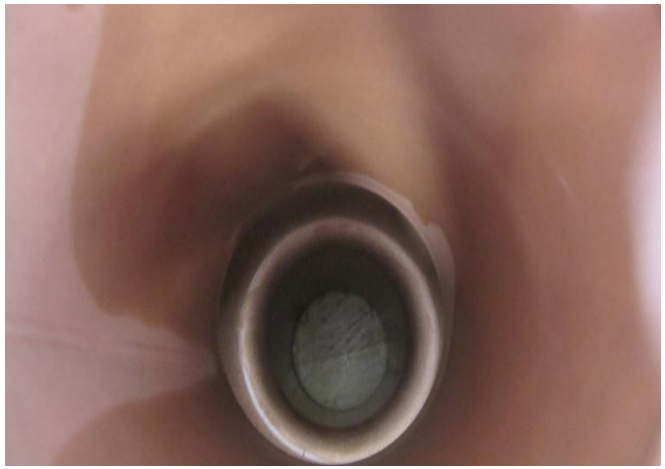
CBP removal rates - niobium



More information -Palczewski et al. **poster TUP062**

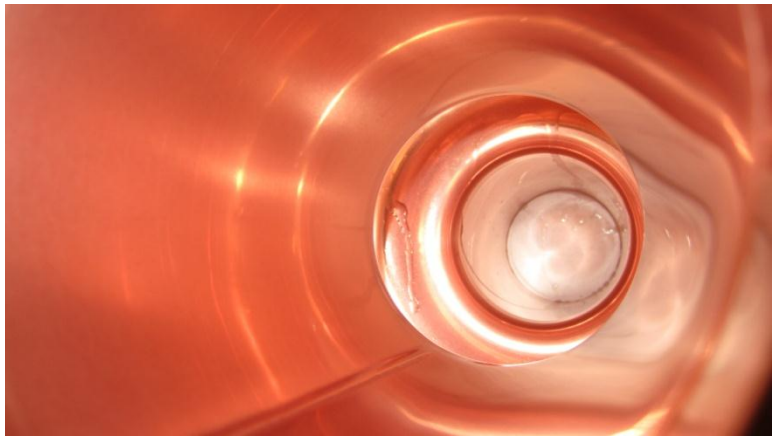
CBP - COPPER CAVITIES

First copper cavity (LSF1-1Cu) modified niobium recipe

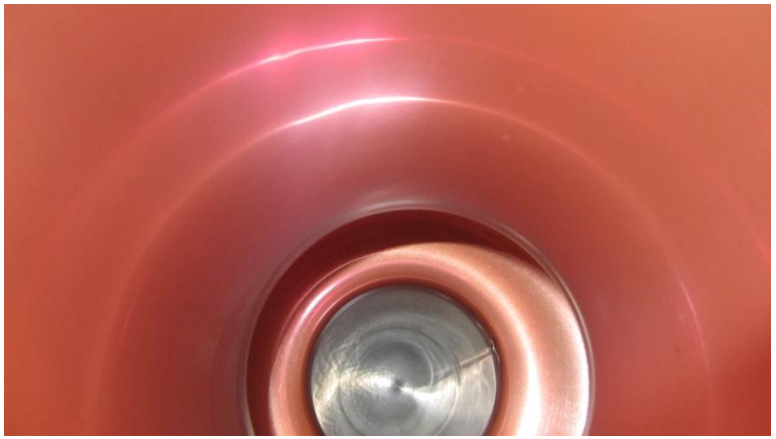


20 hours -K&M ceramic triangles

16 hours - RG22 cones

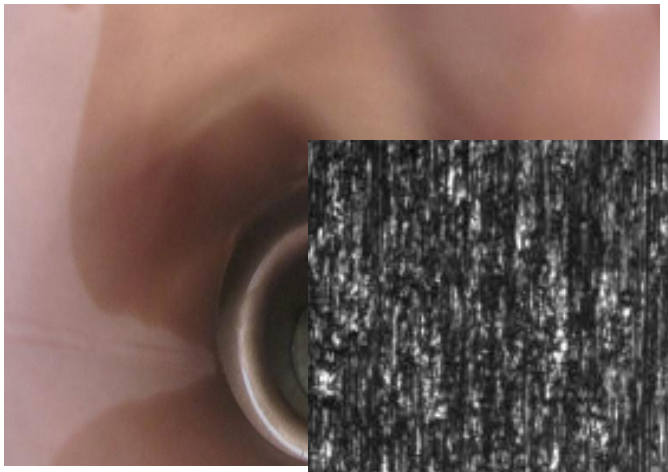


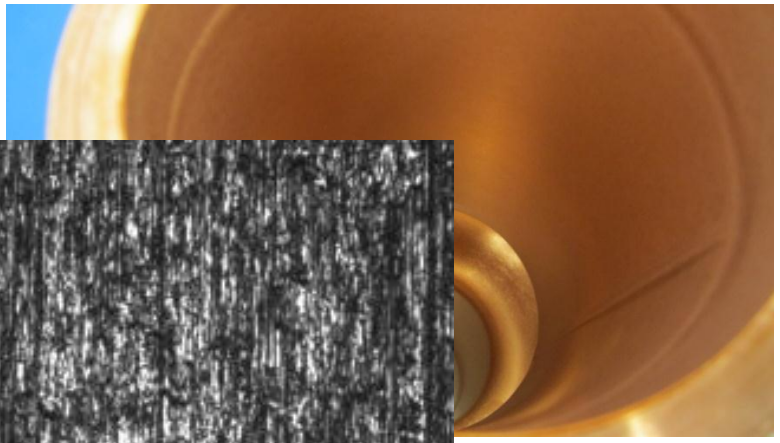
30 hours – 3 micron diamond and wood blocks

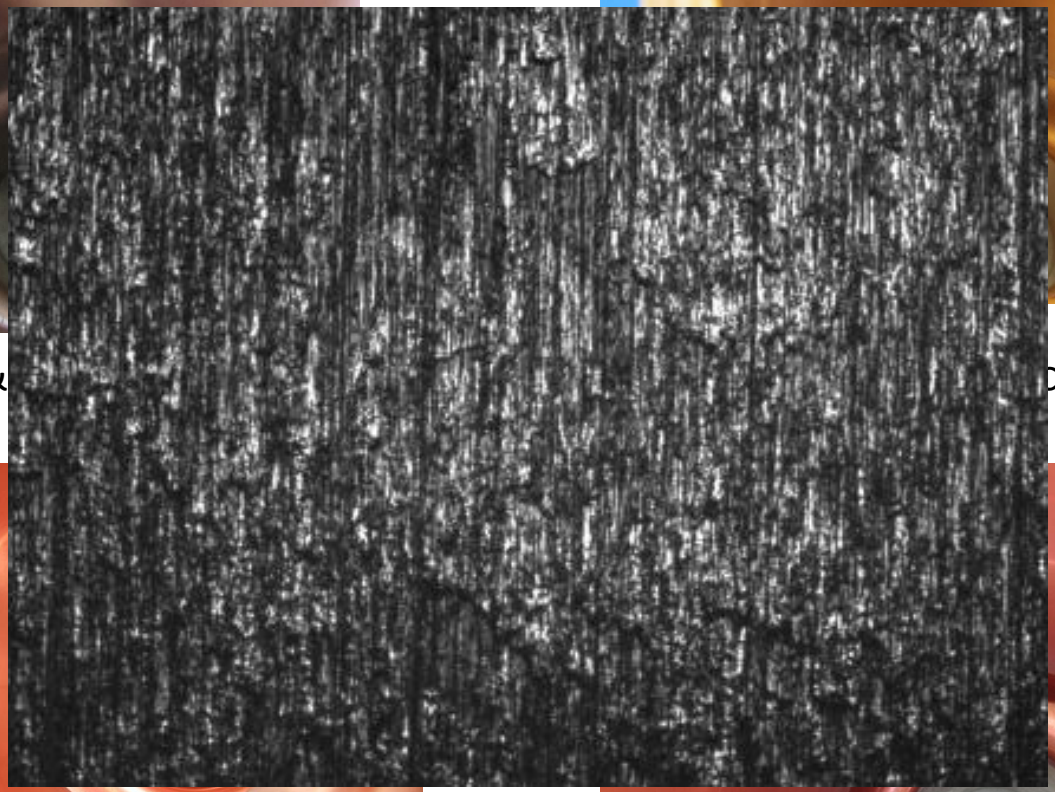


40 hours -40mn colloidal silica and wood blocks - oxidized

First copper cavity (LSF1-1Cu) modified niobium recipe

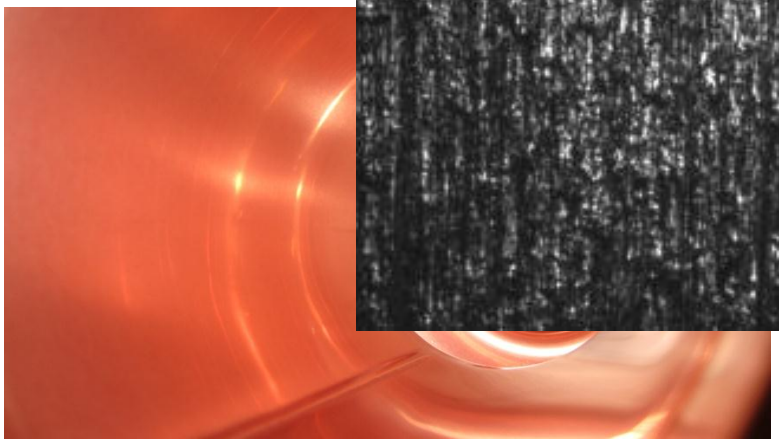


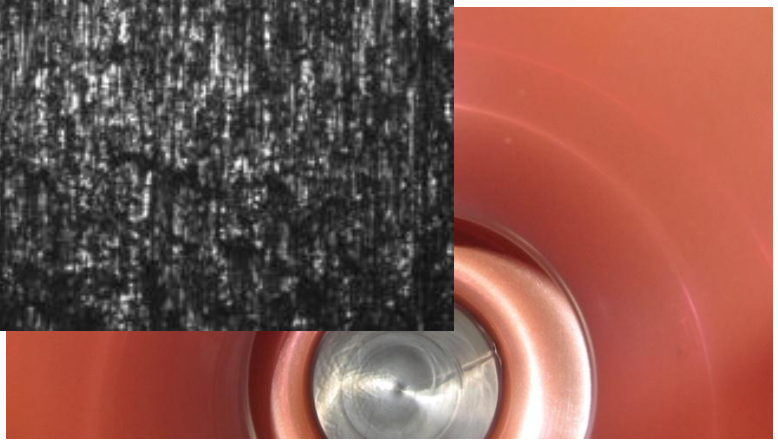




20 hours -K&

cones





30 hours – 3 micron diamond and wood blocks

40 hours -40mn colloidal silica and wood blocks - oxidized

First copper cavity (LSF1-1Cu) modified niobium recipe

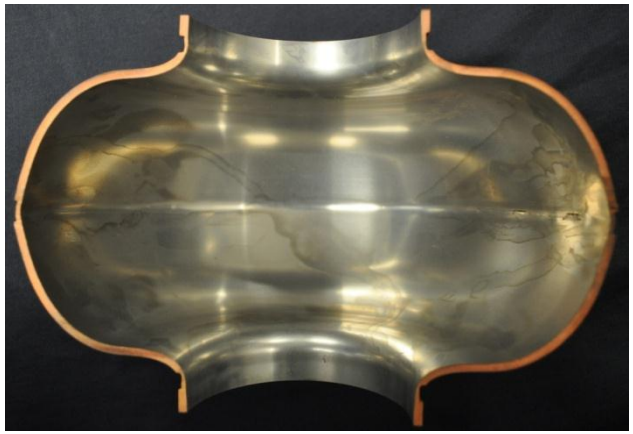
40 nm media + hardwood blocks scratched/smeared the surface

i.e. can't use JLAB's niobium recipe on Copper!

30 hours – 3 micron diamond and wood blocks

40 hours -40mn colloidal silica and wood blocks - oxidized

Thin film coating copper LSF1-1Cu

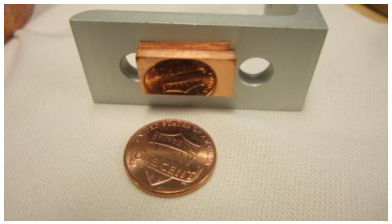


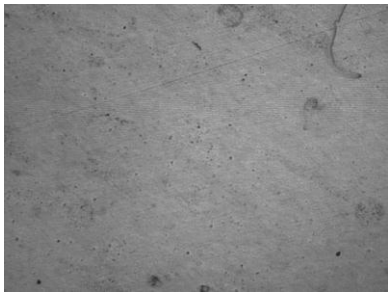
- No chem between CBP and coating, only 400C heat treatment.
- Good adhesion even after 3 HPR and cryo test
- Weld pores found which were uncoated

Xin Zhao, Rong-Li Geng, Ari D. Palczewski, and Yongming Li- **see poster TUP083** (RF tests and surface analysas)

JLAB copper surface finish - lapped coupon vs. CBP (beam tube)

1 inch Copper coupon

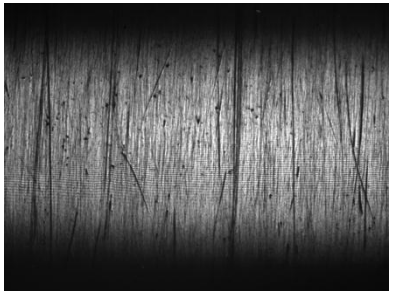




~1.6mm (CYCLOPS)

(FYI $600 -$1000 gallon)

3 inch Copper beam pipe



~1.6mm (CYCLOPS)

Lapping step

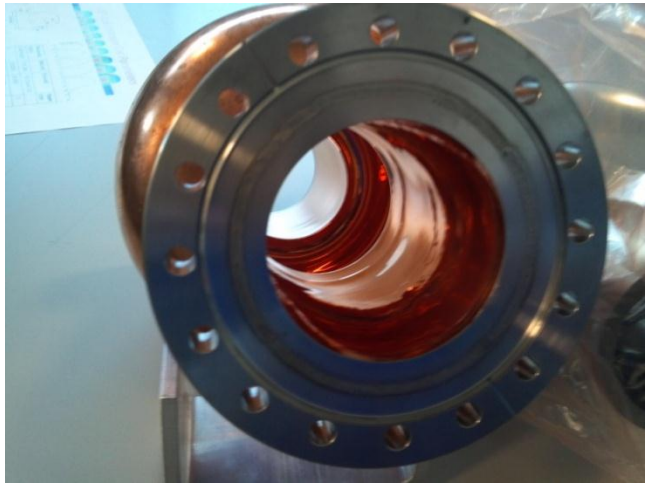
120 grit alumina oxide paper
320 grit alumina oxide paper
400 grit alumina oxide paper
600 grit Silicon Carbide paper
3µm polycrystalline colloidal diamond

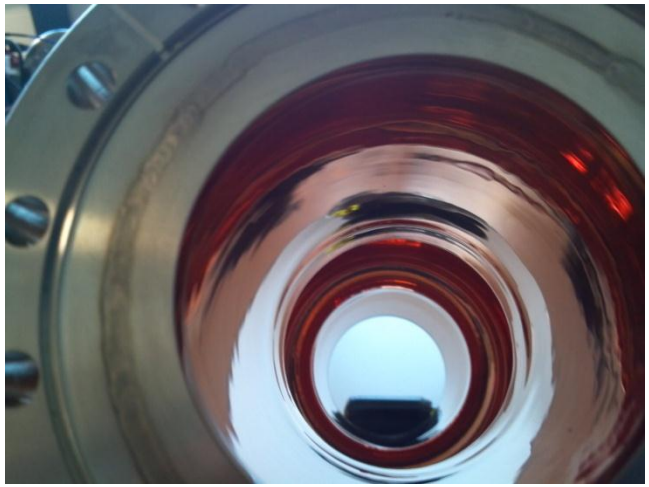
CBP steps

RG22 cones
800 mesh alumina and wood blocks
3µm polycrystalline colloidal diamond and wood blocks

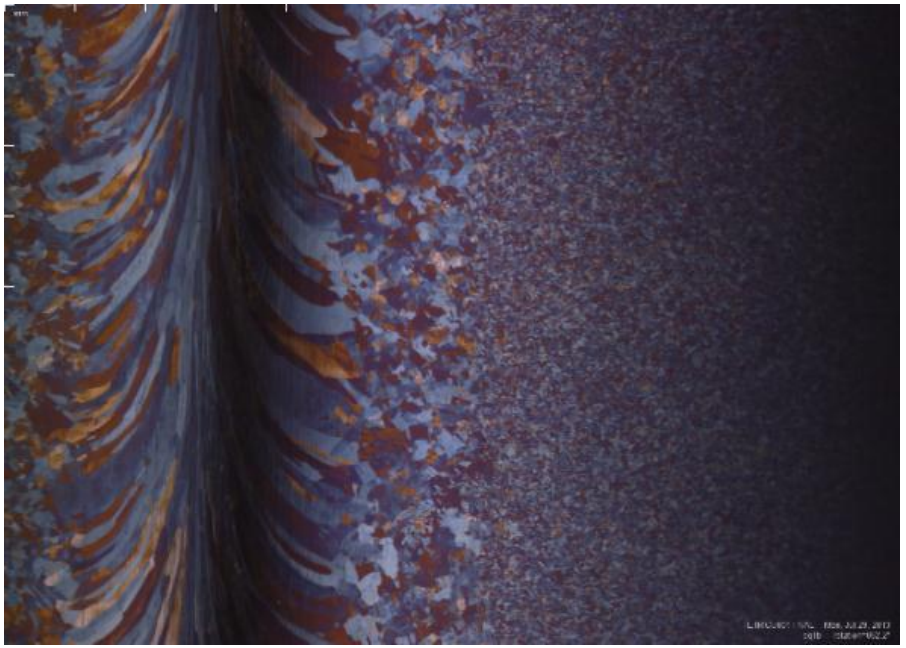
Copper CBP - other

JLAB LSF1-3Cu (still small scratches) – no oxidation





FNAL - Copper cavity, shown with no chemistry (equator optical inspection, surface with thick oxidized [not from CBP])

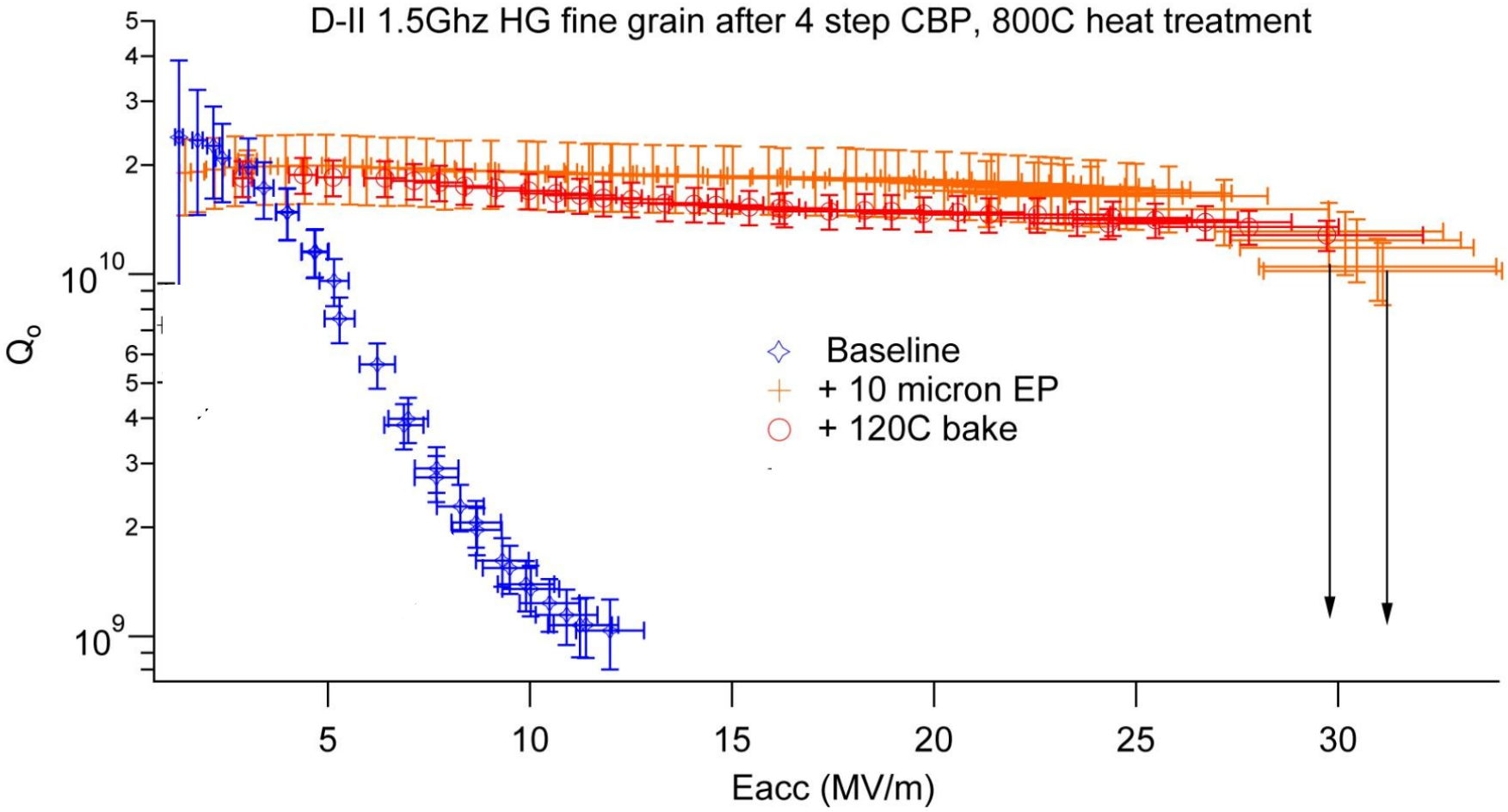


ZERO POST CHEMISTRY CBP

CBP with no chemistry

IPAC 2012 - WEPPC094

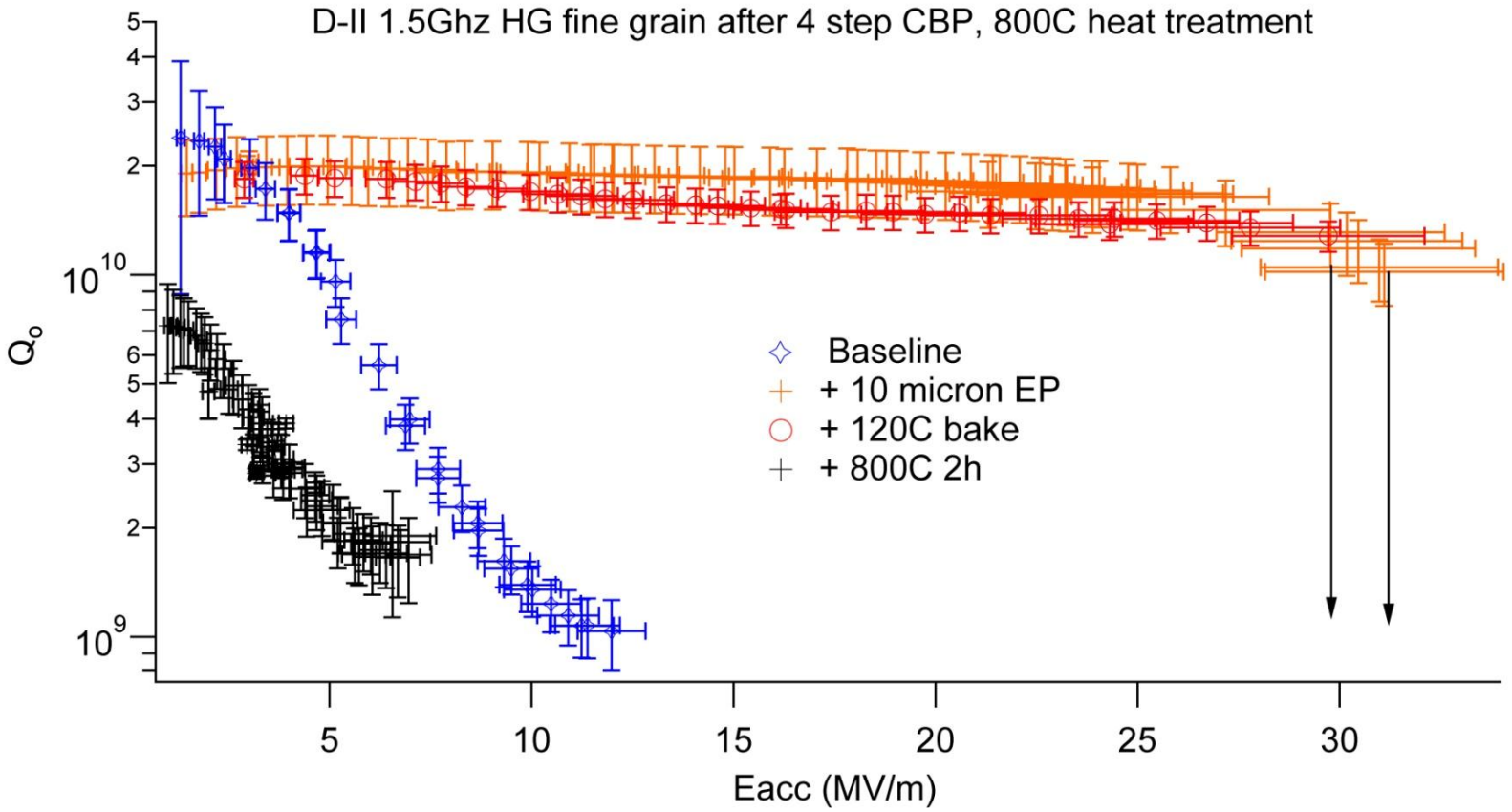
At time we thought initial Q slope was caused by damaged surface from CBP, yet shape of slope seemed strange



CBP with no chemistry

IPAC 2012 - WEPPC094

Now know initial slop is probably from heat treatment in “dirty furnace (not designed for)” which caused the Q slop without chem.D



CBP with no chemistry

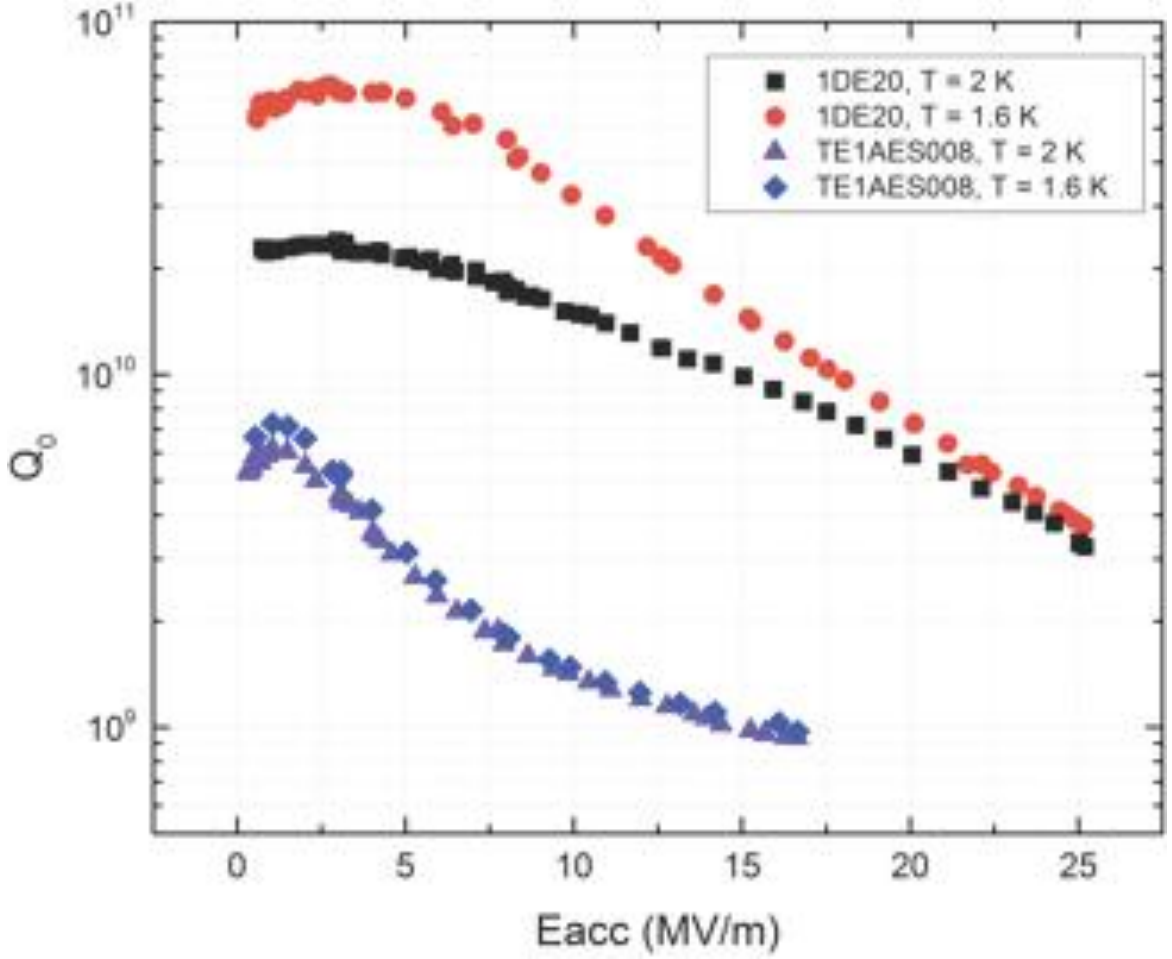
–**See TUP030 (Grassellino FNAL)**

TE1AES008 – fine grain

1DE20 – Large grain

4 step CBP + 800C heat treatment (without end caps)

Q slope limited



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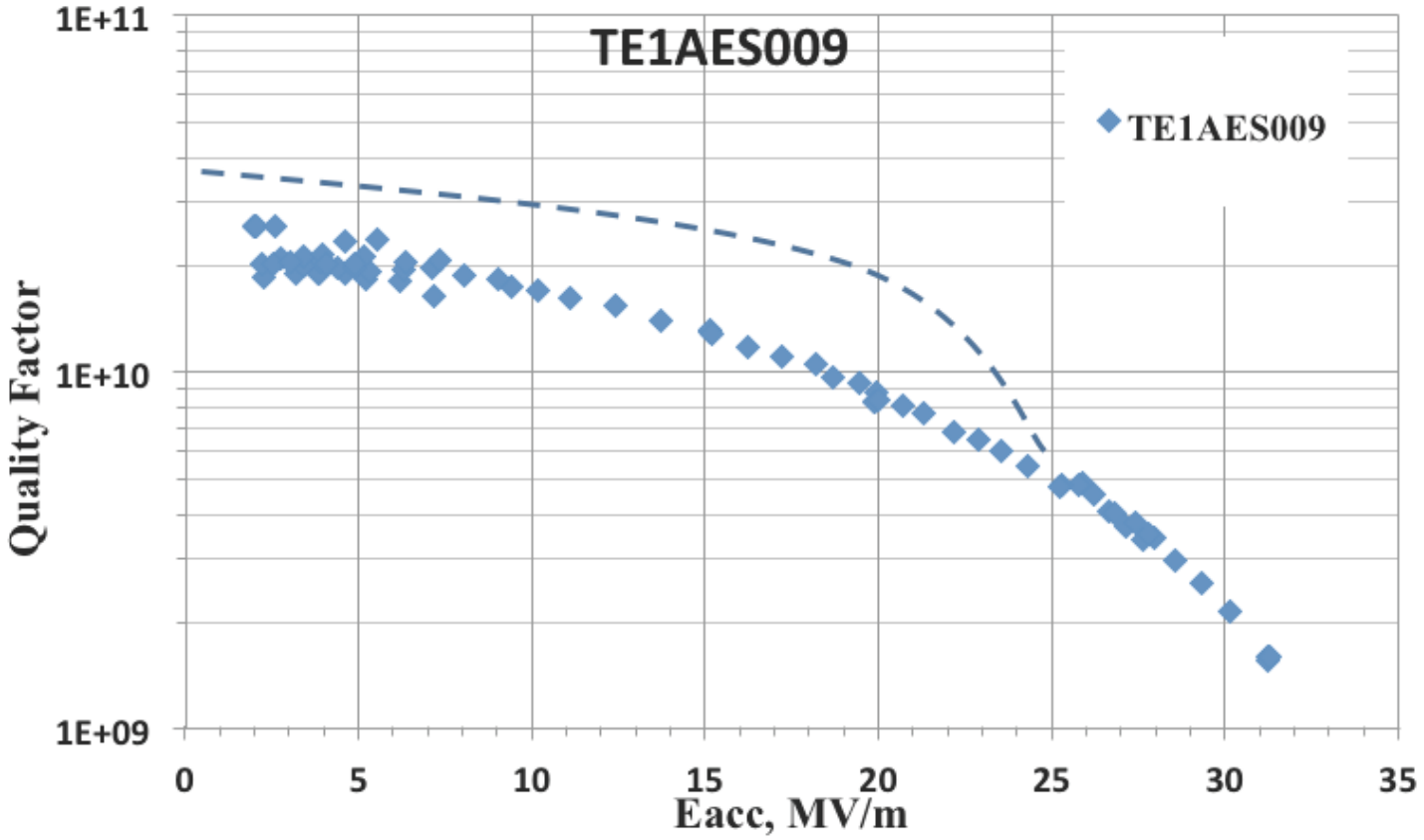
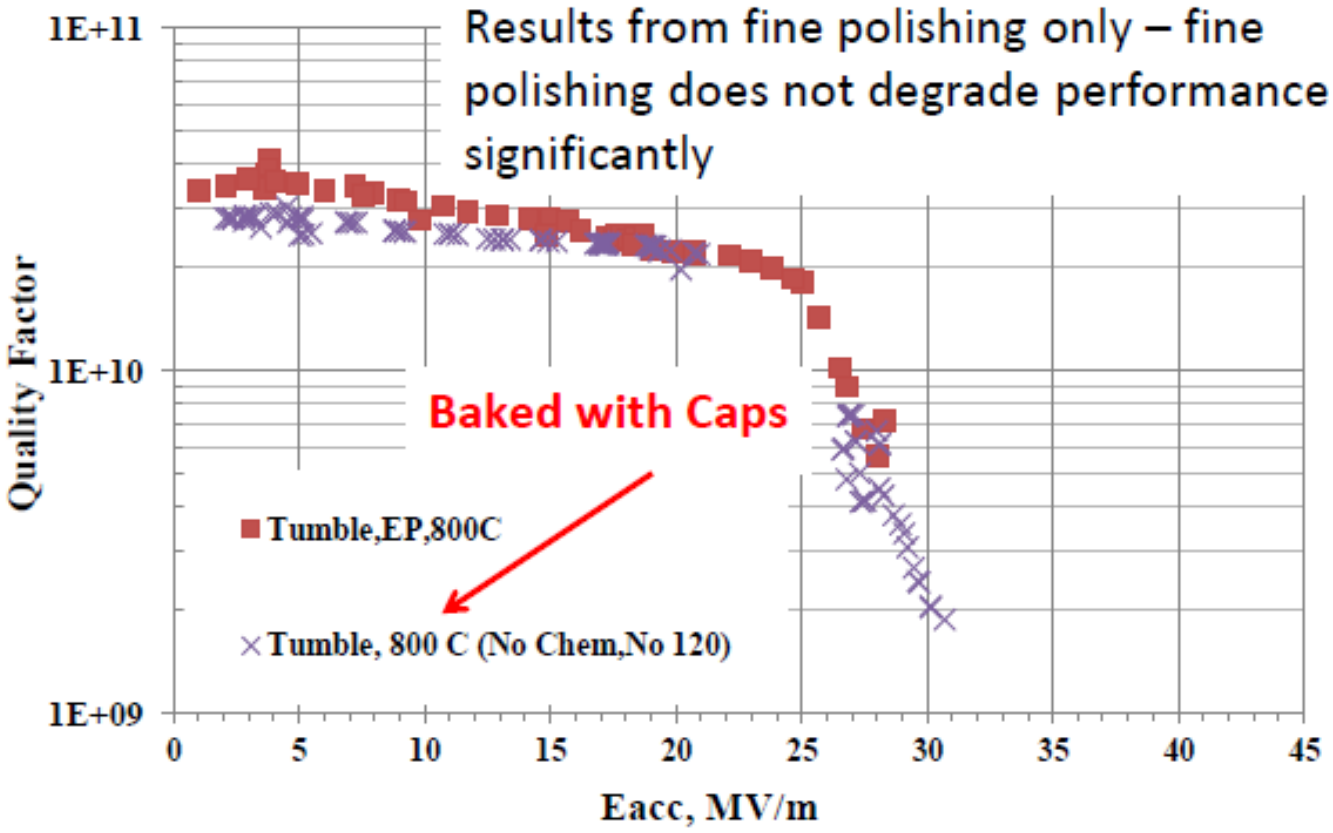


CBP with no chemistry

-See TUP060 (Cooper et al. FNAL)

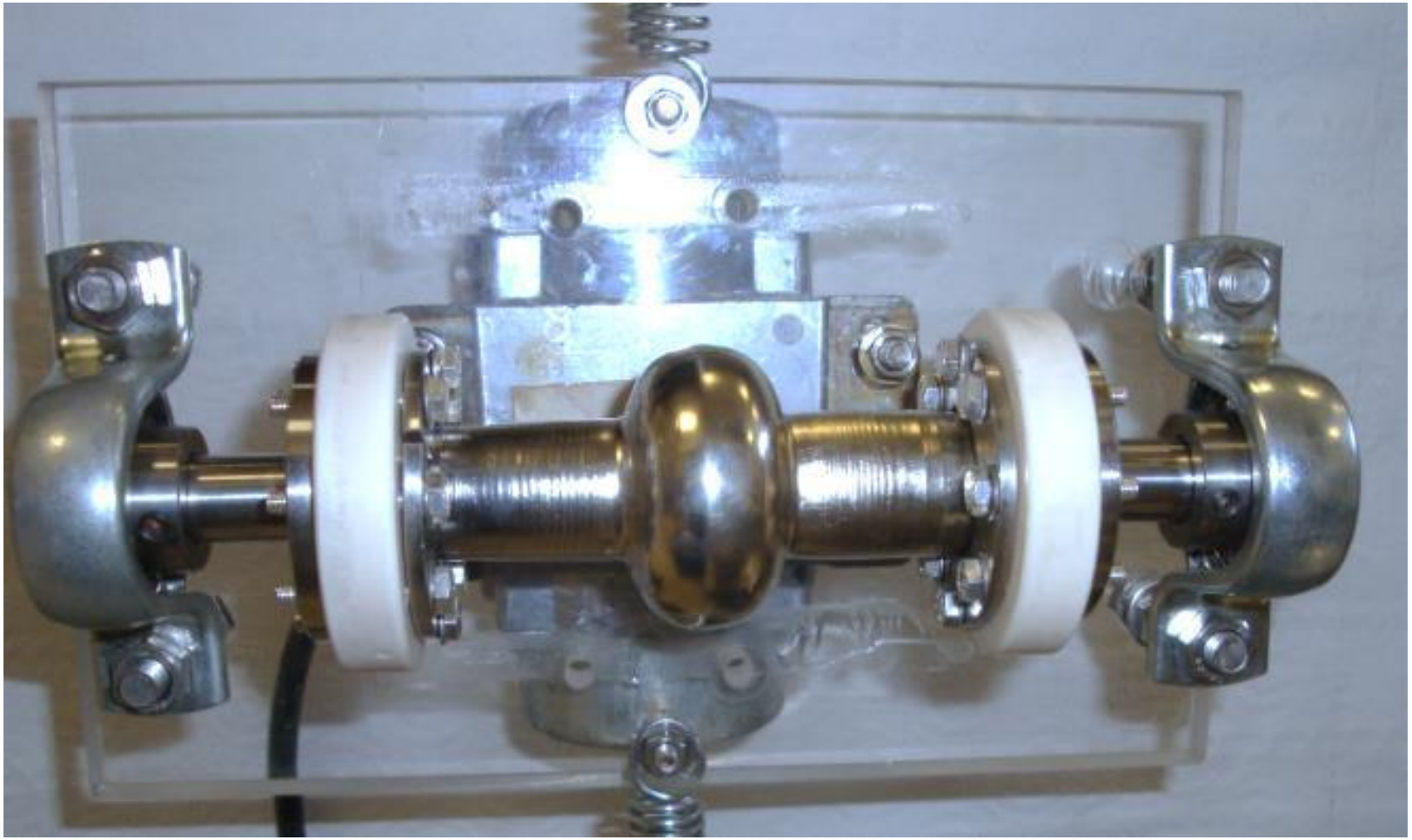
Large grain single cell

CBP final step with 800C does not effect surface on large grain



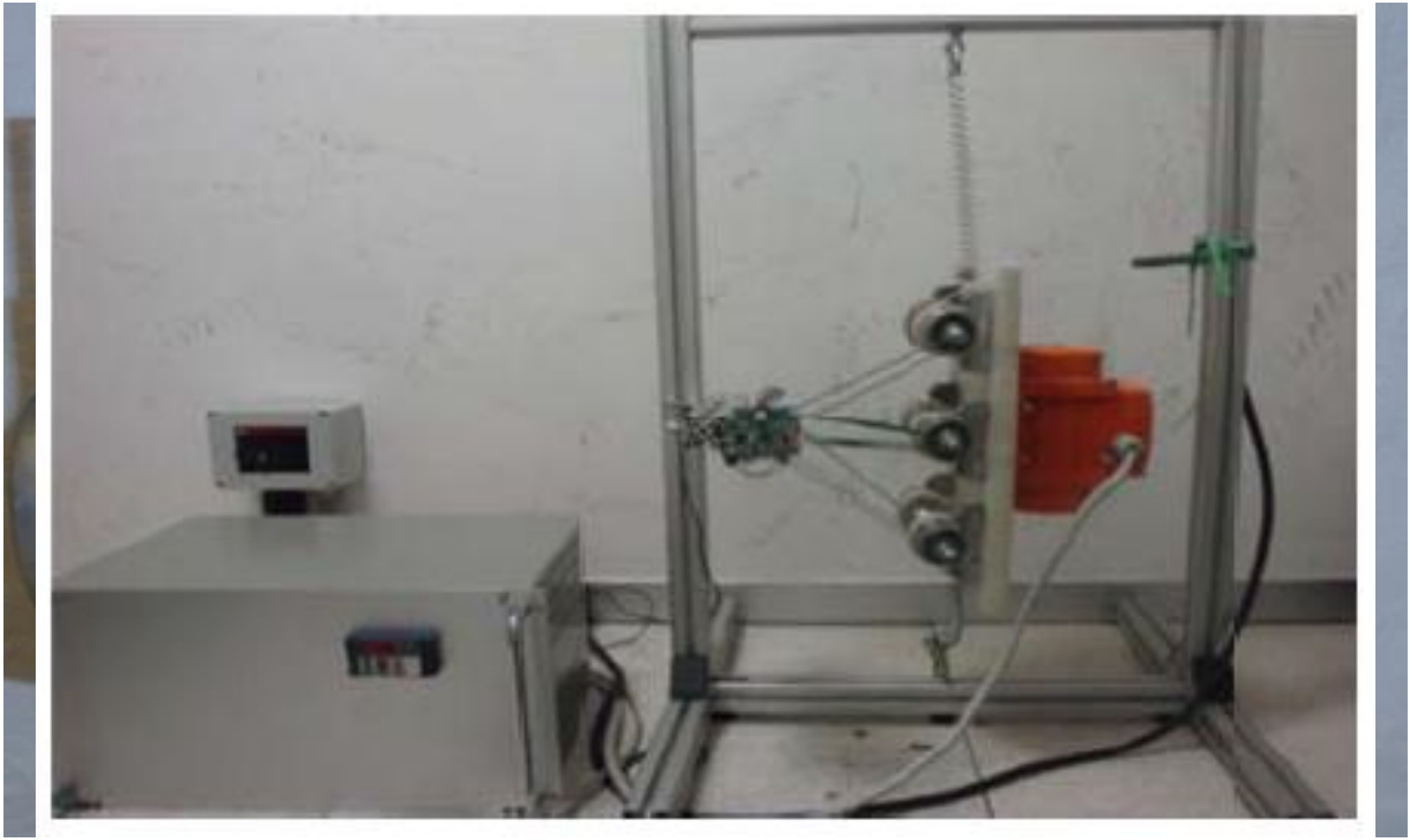
SIDE NOTE FOR CBP – RESONATE VIBRATING SYSTEM

Resonate Vibrating System



Yu Guolong (thesis), Ram-Krishna THAKUR (thesis), A.A. Rossi . And V. Palmieri [INFN/LNL]

Resonate Vibrating System



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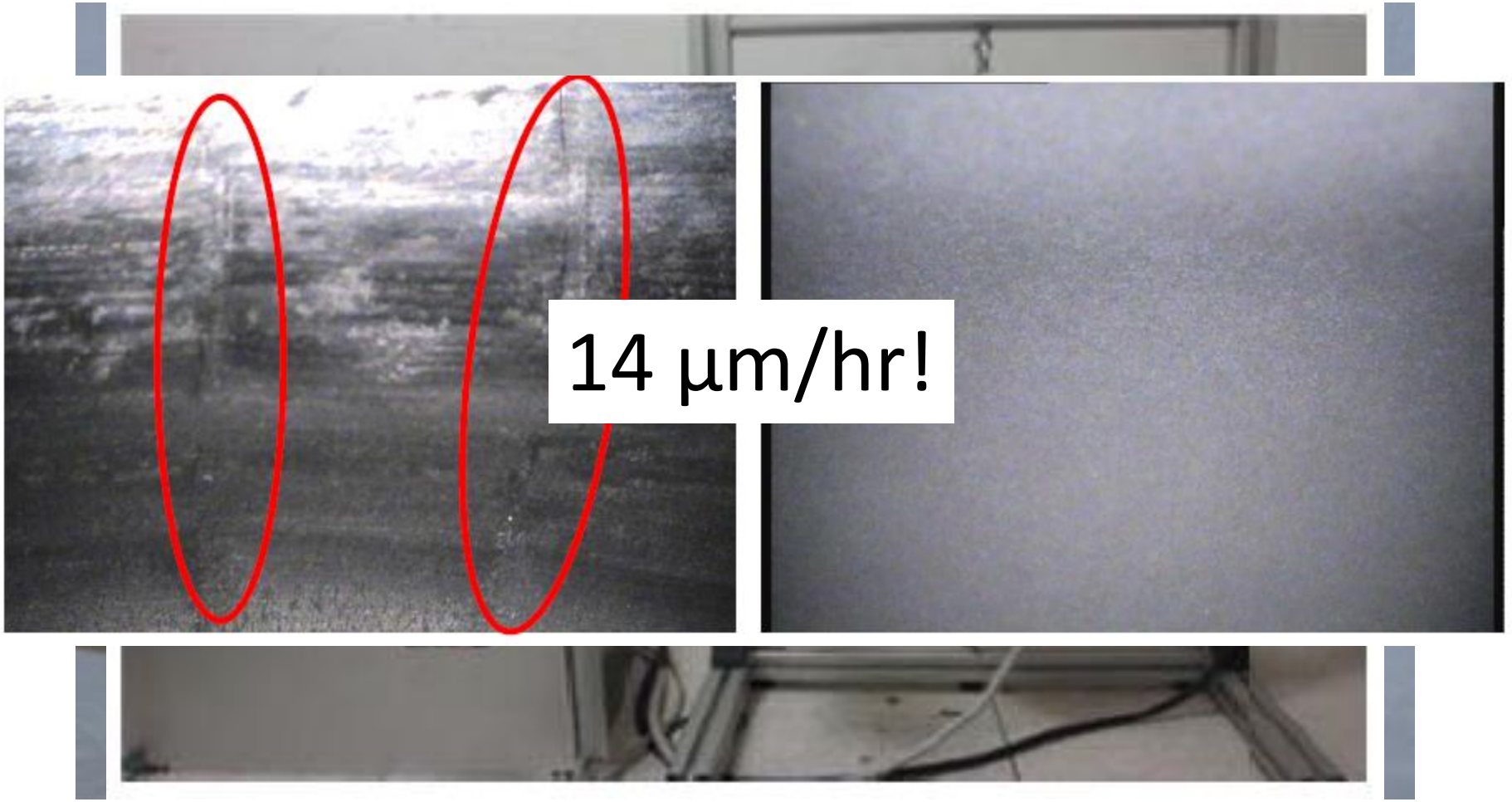
Resonate Vibrating System



Yu Guolong (thesis), Ram-Krishna THAKUR (thesis), A.A. Rossi . And V. Palmieri [INFN/LNL]

CBP at SRF 2013 and thanks

- **MOP050** R&D on Cavity Treatments at DESY towards the ILC Performance Goal
- **MOP071** IHEP Large Grain Low Loss 9-cell Cavity Processing and Test
- **TUIOB01** R&D Progress in SRF Surface Preparation With Centrifugal Barrel Polishing (*CBP*) for Both Nb and Cu.
- **TUP028** Post-Annealing Losses in SRF Niobium Cavities Due to Furnace Contamination and the Ways to Its Mitigation
- **TUP058** Acid Free Centrifugal Barrel Polishing R&D
- **TUP062** Exploration of Material Removal Rate of SRF Elliptical Cavities as a Function of Media Type and Cavity Shape on Niobium and Copper Using Centrifugal Barrel Polishing
- **TUP081** Materials Analysis of CED Nb Films Being Coated on Bulk Nb SRF Single Cell Cavities
- **THP008** High Voltage Cavity R&D at Cornell, RE and ICHIRO
- **TUIOC05** An Innovative Purification Technique of 6 GHz Tesla Type Nb Mono Cell Seamless Superconducting Cavities in UHV System
- **TUP083** Film Deposition, Cryogenic RF Testing and Materials Analysis of a Nb/Cu Single Cell SRF Cavity
- **TUP068** Laser Polishing of Niobium for SRF Applications
- *Sorry for the one's I missed*

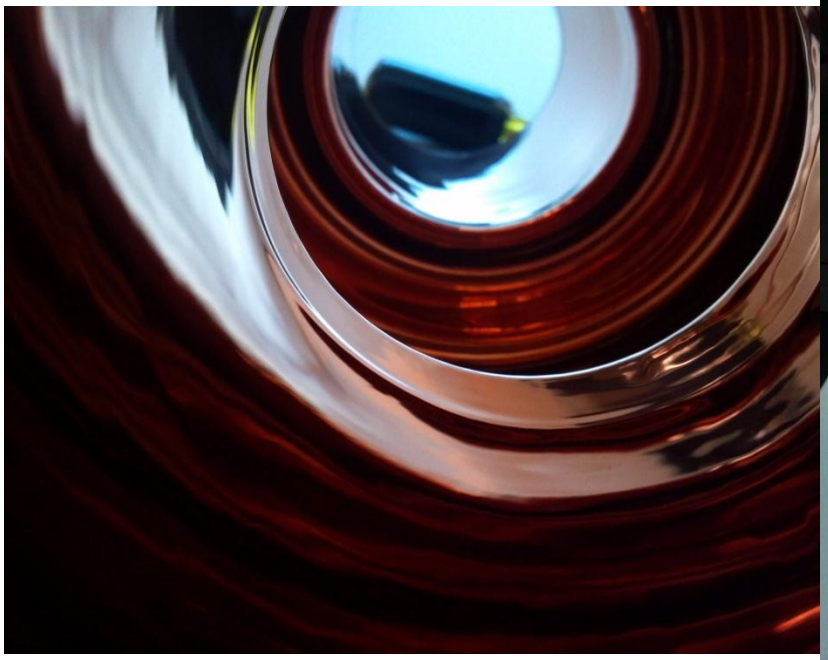
Backup slides

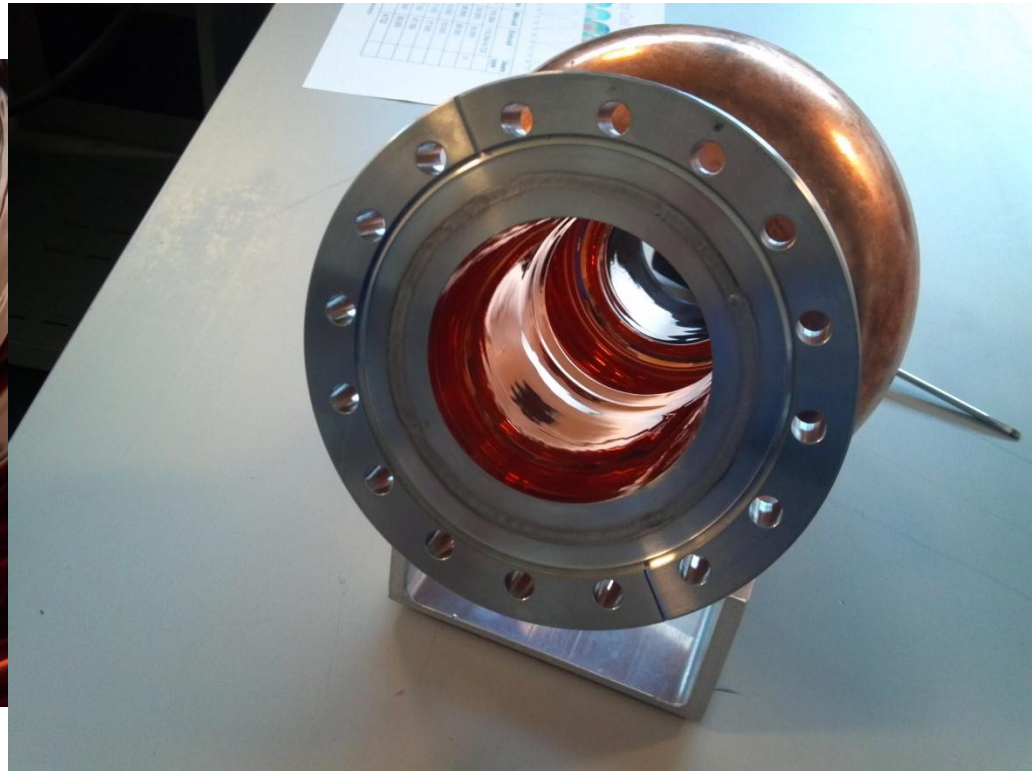
Resonate vibration Removal Rate

Cavity Number	Initial mass (gm)	Final mass (gm)	Total removal (gm)	Removal/hr (mg)
127	191.352	181.142	10.21	216
128	177.775	167.365	10.4	415
129	184.483	174.383	10.10	249
130	170.209	159.937	10.27	312
131	175.812	165.686	10.13	242
132	167.890	157.82	10.07	379
133	174.381	164.285	10.1	200
134	168.378	158,386	10.05	226

Yu Guolong (thesis), Ram-Krishna THAKUR (thesis), V. Palmieri, V. Palmieri

Copper cavity finishes – LSF1-3 Cu

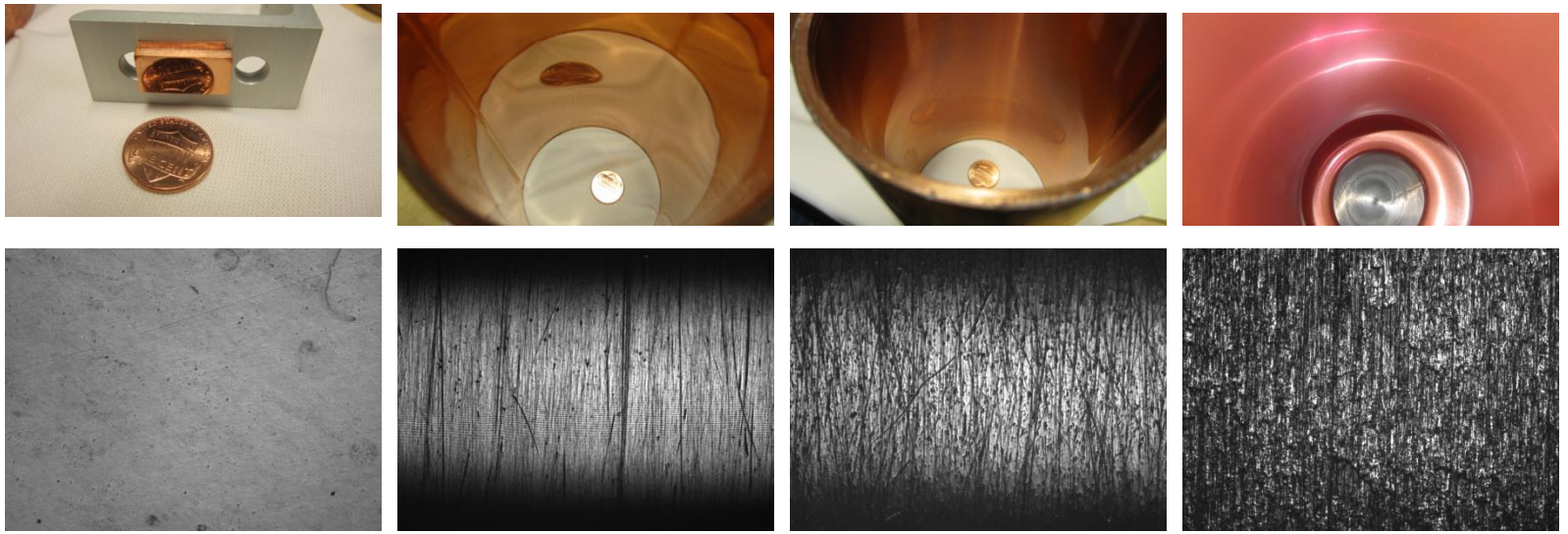




Using glycerol based colloidal diamond allows the surface to CBP'ed without a thick oxide

Copper surface final finish – beam tubes

3 µm diamond | 3 µm diamond | 1 µm diamond paste | 40nm colloidal silica

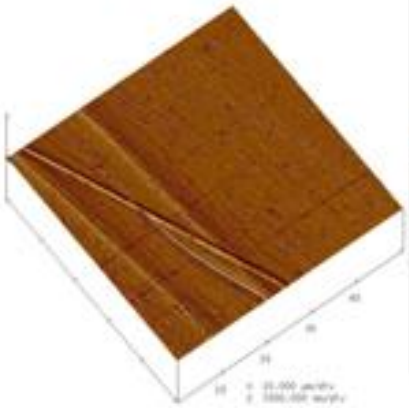


@ Jlab we have found media below 3 micron scratches the cavity – intrinsic or extrinsic from using wood blocks????

Surface roughness before and after light EP

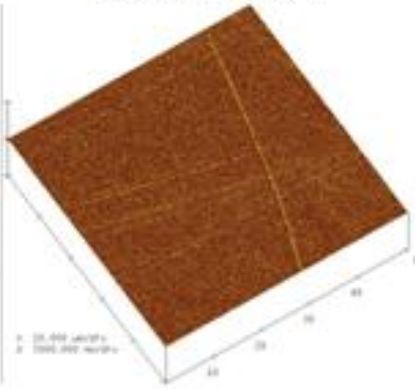
Sample 7–step 5 of CBP

After CBP-step 5



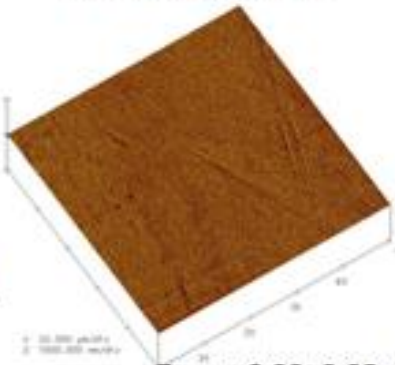
Zmax=0.21±0.05 µm
Rms=4.86±1.55 nm

After EP with 5 µm

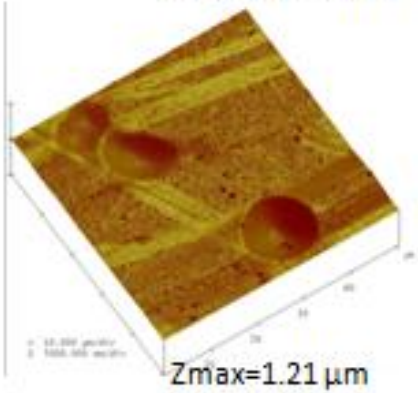


Zmax=0.18±0.02 µm
Rms=7.1±1.5 nm

After EP with 10 µm

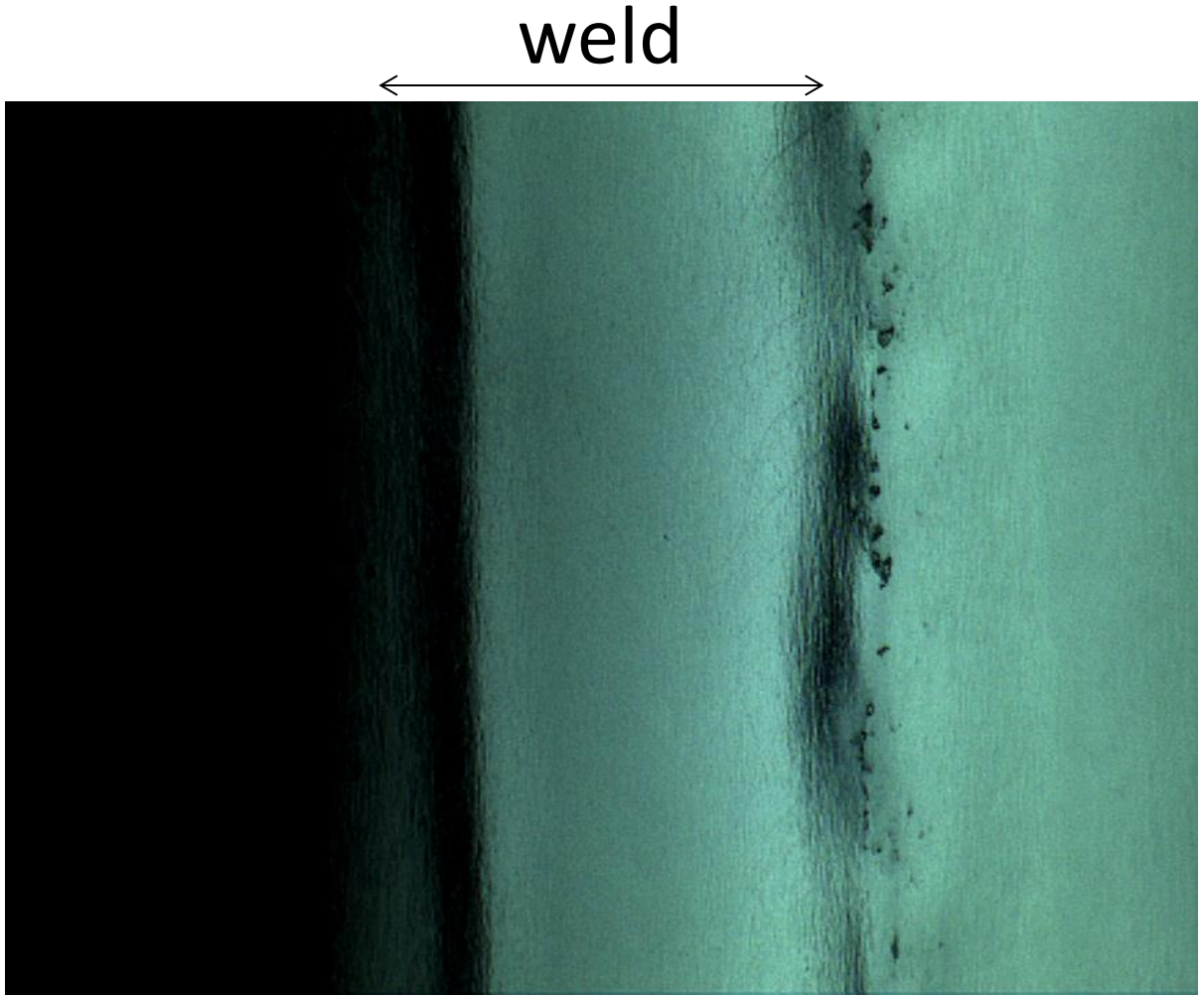


Zmax=0.22±0.08 µm
Rms=4.5±1.2 nm



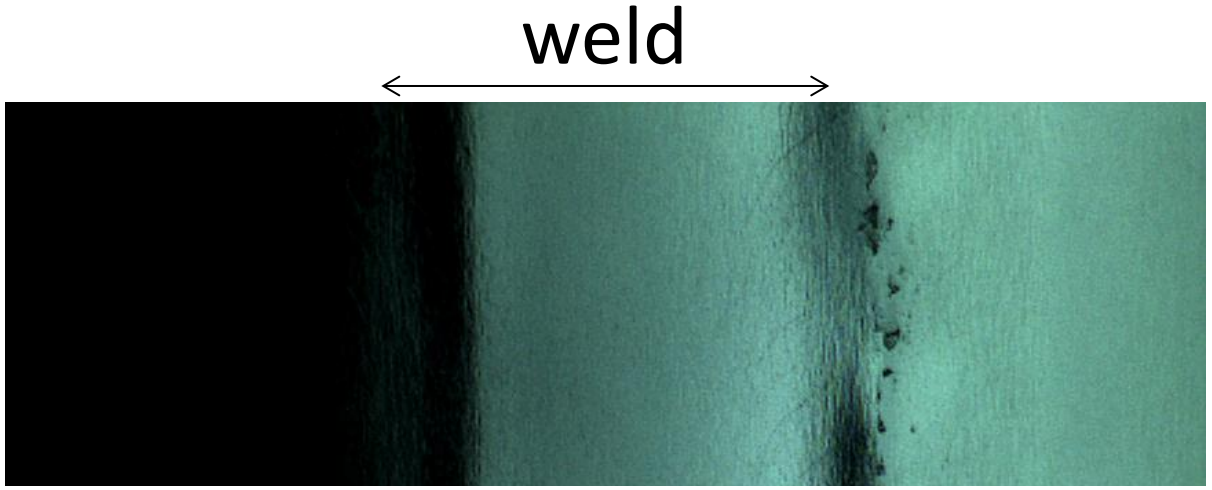
Zmax=1.21 µm
Rms=132 nm

CBP - uncovering weld porosity?

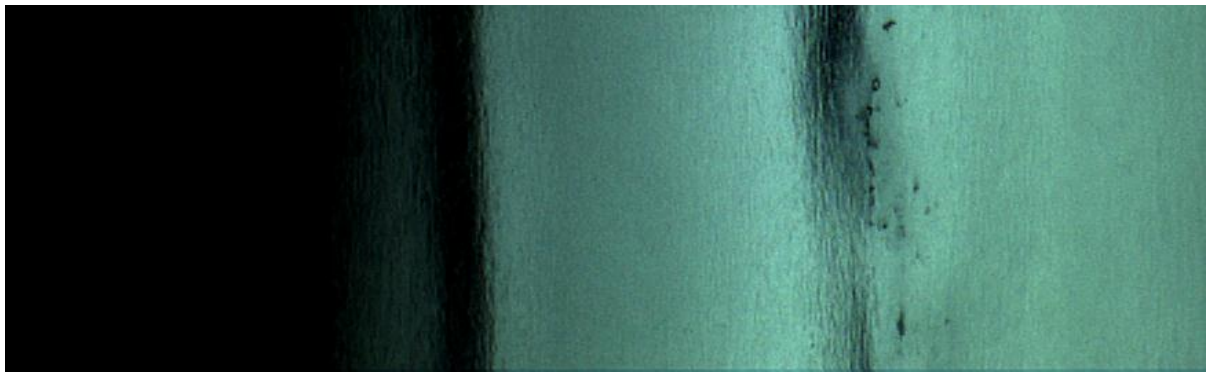


RDT-5 – 200 micron removed by CBP

CBP - uncovering weld porosity?



Add 10 micron EP - Eacc=35MV/m



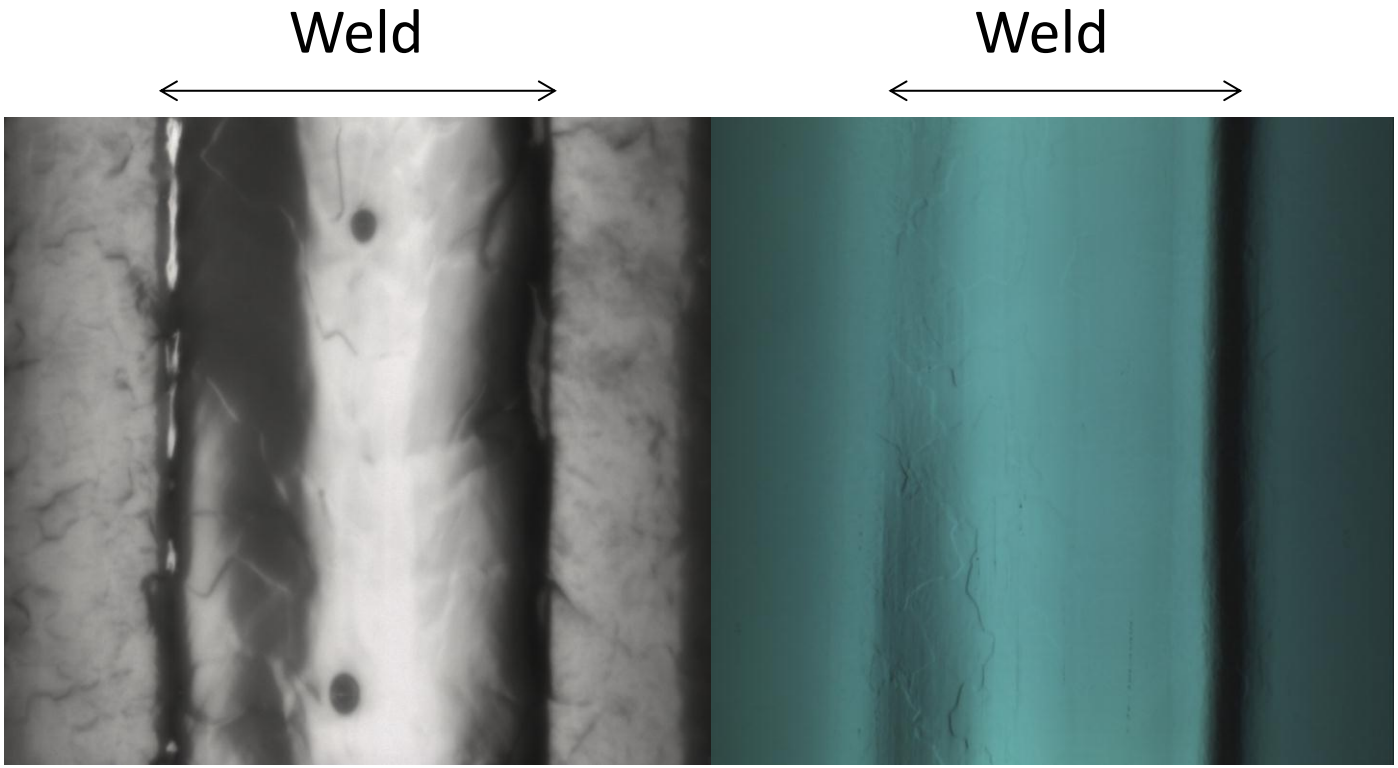
RDT-5 – 200 micron removed by CBP

Why CBP

- Surface uniformity – yes
- Defect removal – yes
- Loosen welding tolerance – many be
- Q enhancement (mechanism?) - maybe
- Create low Surface roughness - yes
- Reduce cost, industrialization – maybe
- Remove chemistry - maybe

Defect removal

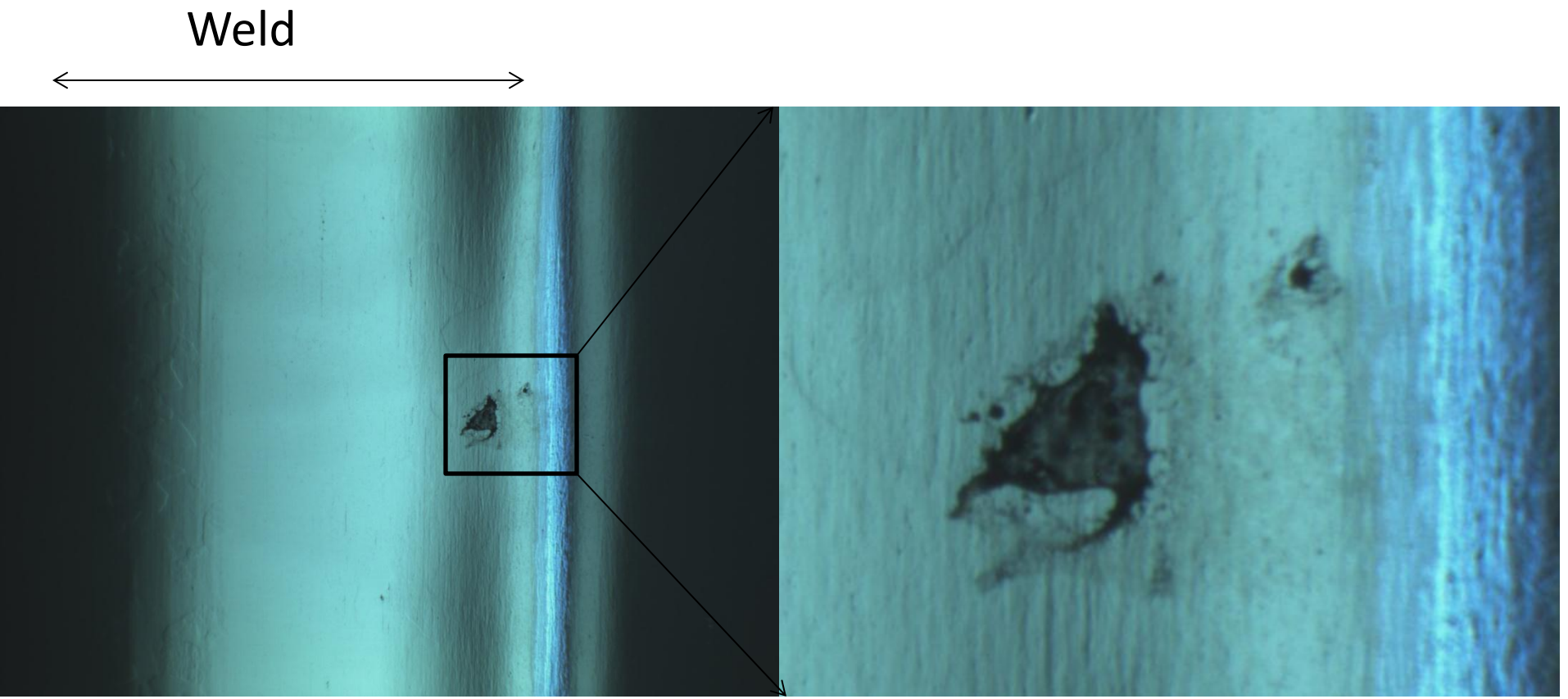
TB9NR001 – dual cat eye defect (cell 5) 17 to 35MV/m after EP



Cell 5 Before CBP

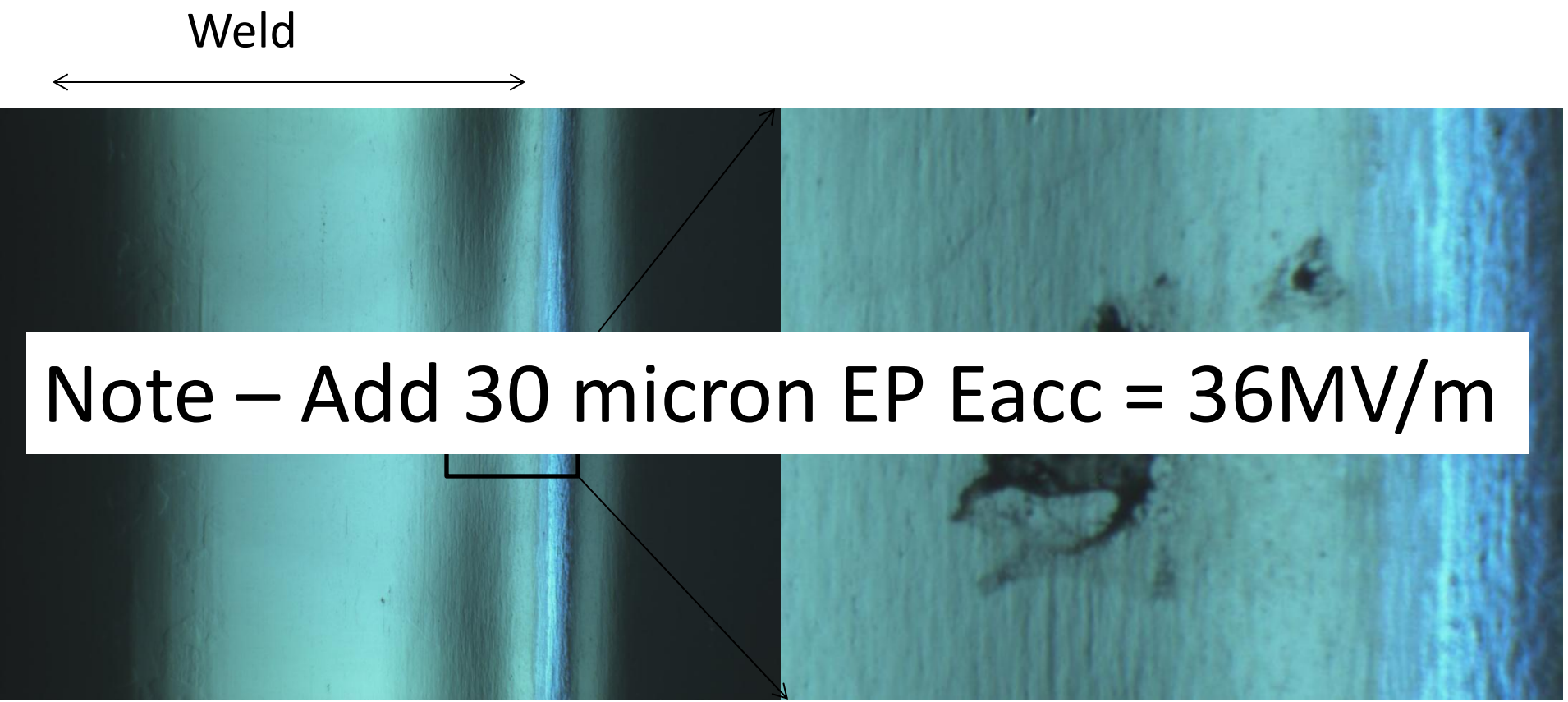
Cell 5 After CBP

CBP - uncovering weld porosity?



TB9NR001 – cell (10 to 12 microns deep measured by CYCLOPS interferometer)

CBP - uncovering weld porosity?

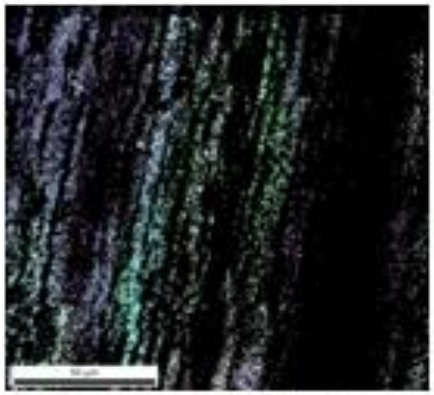


TB9NR001 – cell (10 to 12 microns deep measured by CYCLOPS interferometer)

First signs of chemistry free CBP possible at JLAB

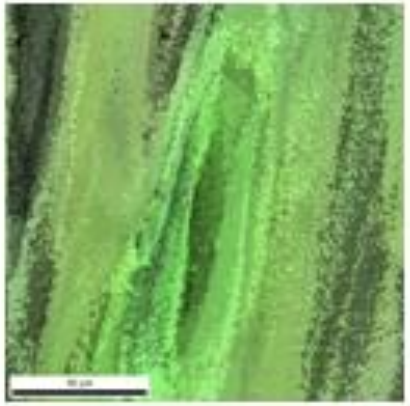
Sample 7–step 5 of CBP

After CBP-step 5



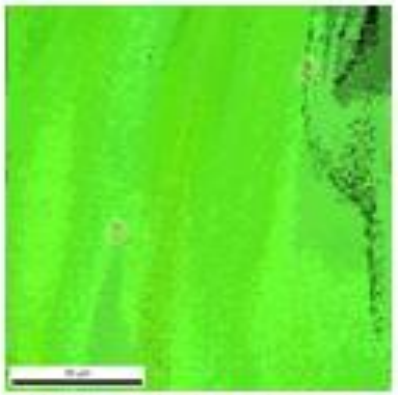
Average C.I. <0.2

After EP with 5 µm

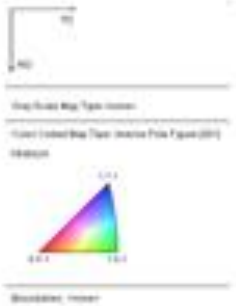


Average C.I. =0.53

After EP with 10 µm



Average C.I. =0.88



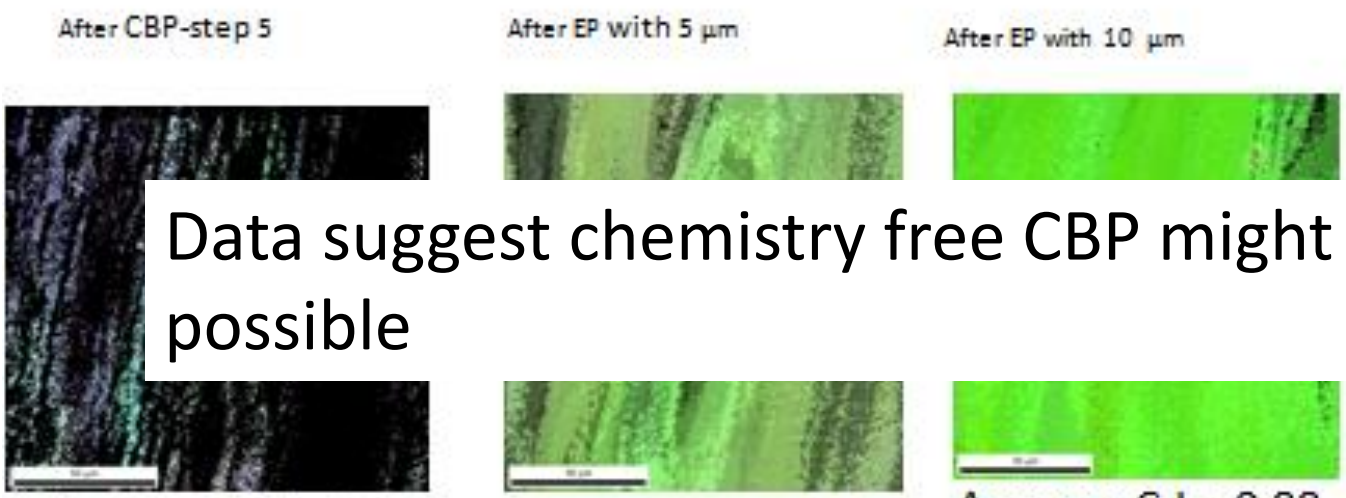
It suggest the thickness of the disruptive crystal structures after step 5 CBP ~ (10 µm)

5 step CBP (FNAL original recipe) on large grain coupons in stainless steel sample holder

Last step 40 hours

First signs of chemistry free CBP possible at JLAB

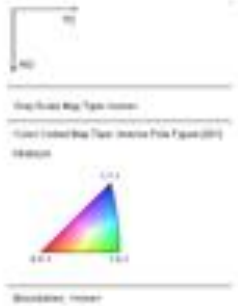
Sample 7–step 5 of CBP



Data suggest chemistry free CBP might be possible

5 step CBP (FNAL original recipe) on ain coupons ess steel holder

Last step 40 hours



It suggest the thickness of the disruptive crystal structures after step 5 CBP ~ (10 µm)