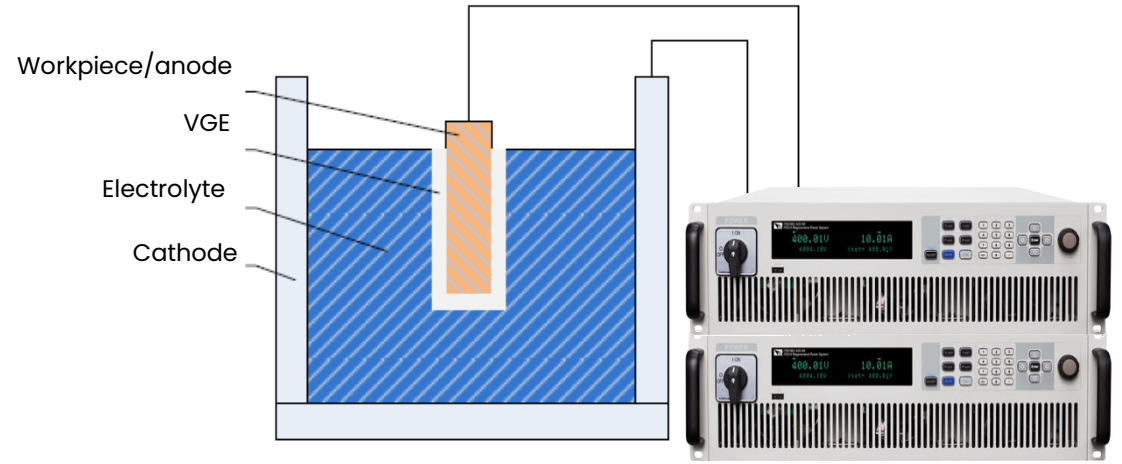
Cristian **Pira**

Plasma Electrolytic Polishing

TTC meeting 2023
Fermilab, 5 December 2023

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

Basics of PEP



Pira C. et. Al, SRF Proceeding 2021

	EP	PEP
Bath	Concentrated acid solutions	Diluted water-salt solutions
Area $_{\text{chatode: anode}}$	1:1	10:1
Working voltage	2-25 V	260 – 340 V
Current density	0,03 A/cm^2	0,2-0,8 A/cm^2
Temperature	4-60 C° (lower is better)	60-90 C°

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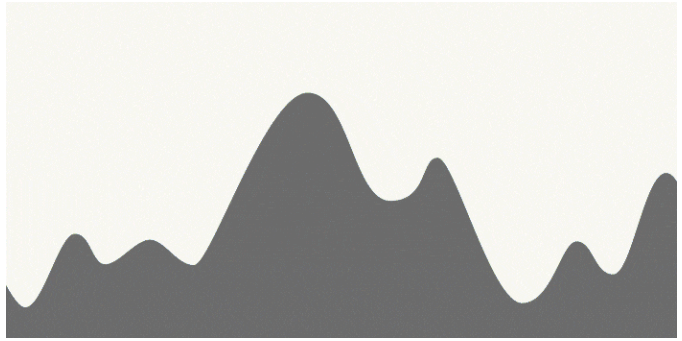
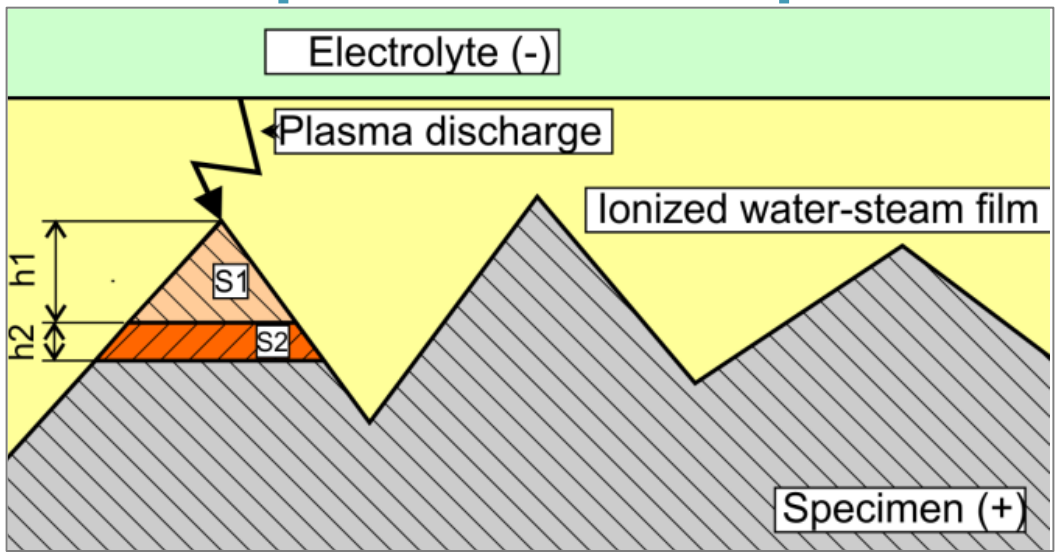
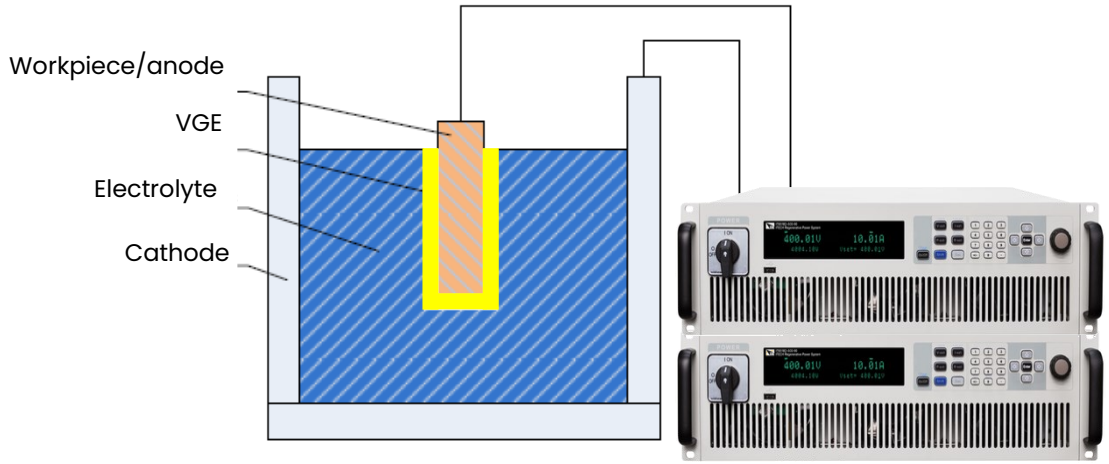


Vapor Gas Envelope



Vana, D et. al, Int. J. Mod. Eng. Res. 2013



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PEP Advantages

Green

Diluted water solutions,
enviromentally friendly

Fast

The fastest
non-destructive polishing

Equal thickness removal yield
lowest roughness among
competitors

Efficient

Less sensitive to the
cathode shape!
AM compatible

Versatile

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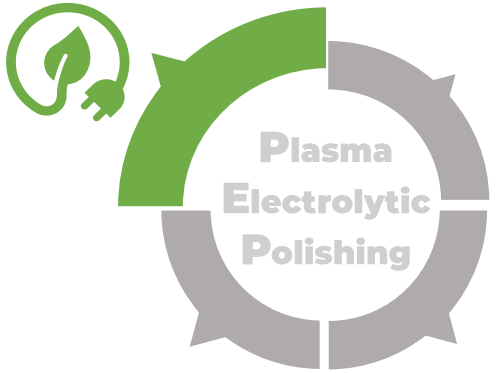
PEP is Green



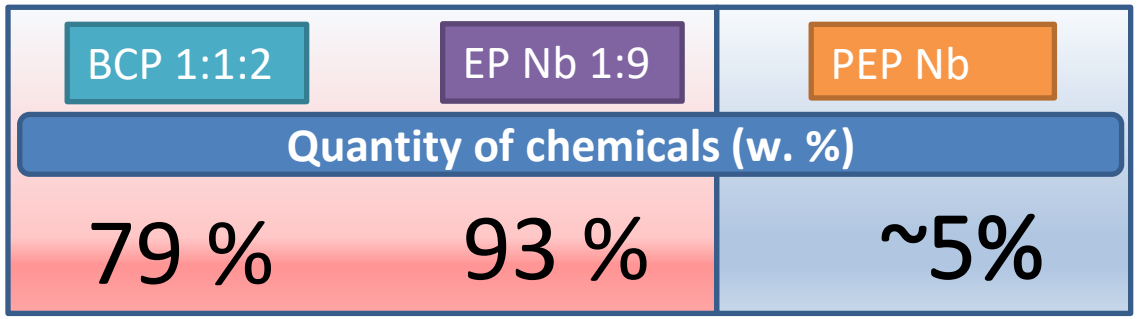
- Lower chemicals cost

  Roughly 5x cheaper per 1 L

- Easier storage
- Easier and cheaper wastes proceeding
- Less security risks

No Acids in the chemical bath!
No HF for Nb!

INFN PEP Patented Bath
Ammonium Fluoride NH_4F 2-6 %
Sodium Fluoride NaF 0,5 – 2 %



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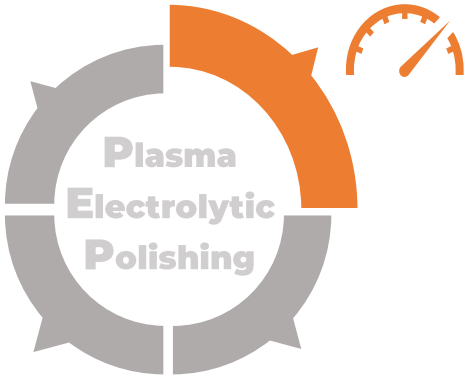
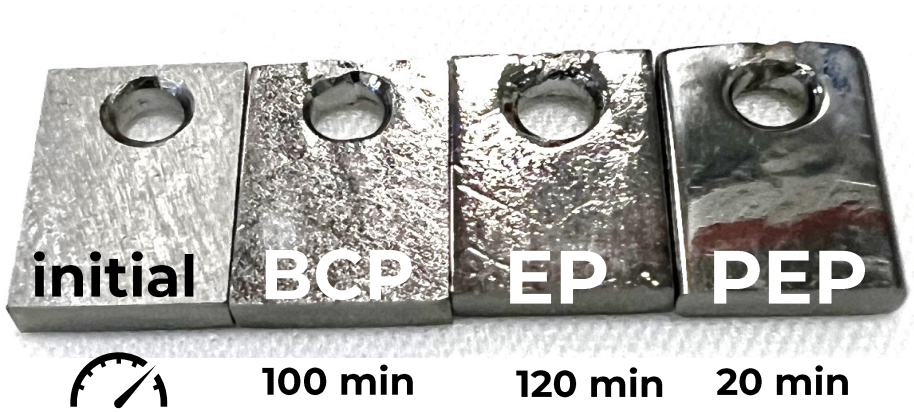
PEP is Faster



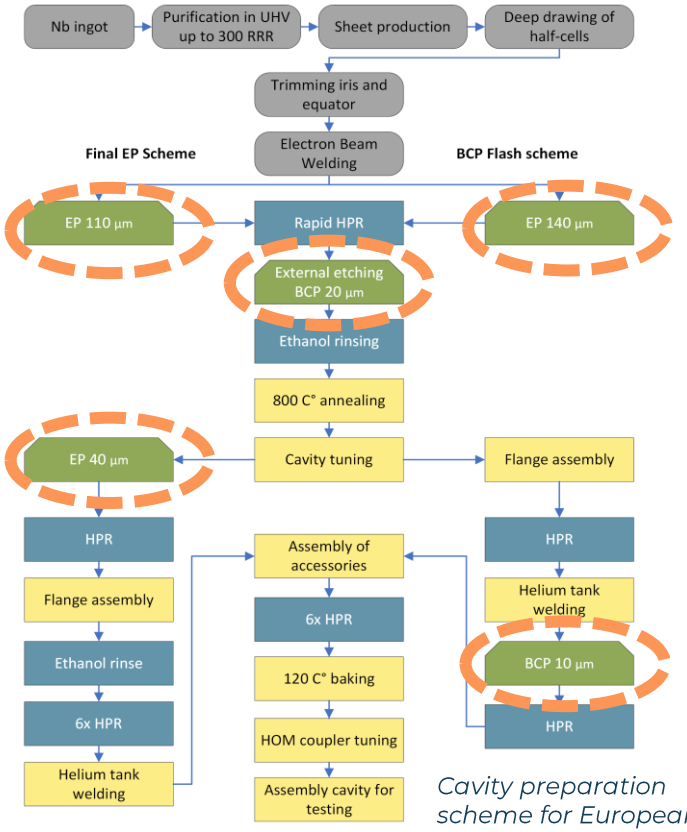
PEP is at least

6x times **faster** than EP!

In cavity mass production
it would be huge advantage!



100 µm removed



Cavity preparation scheme for European XFEL facility

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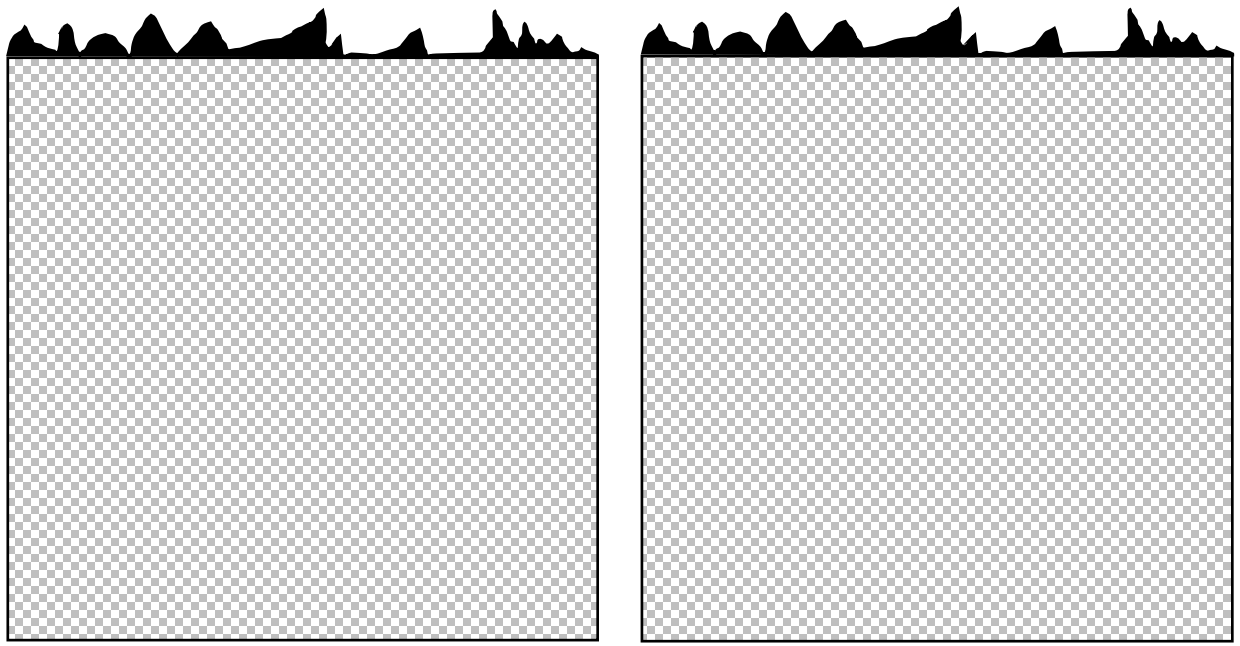
PEP is Efficient



Removal of equal quantity of materials leads to lower roughness comparing to other treatments

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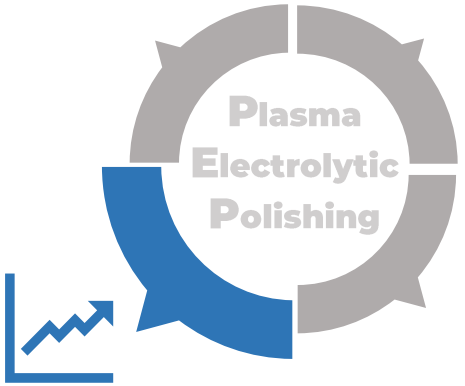
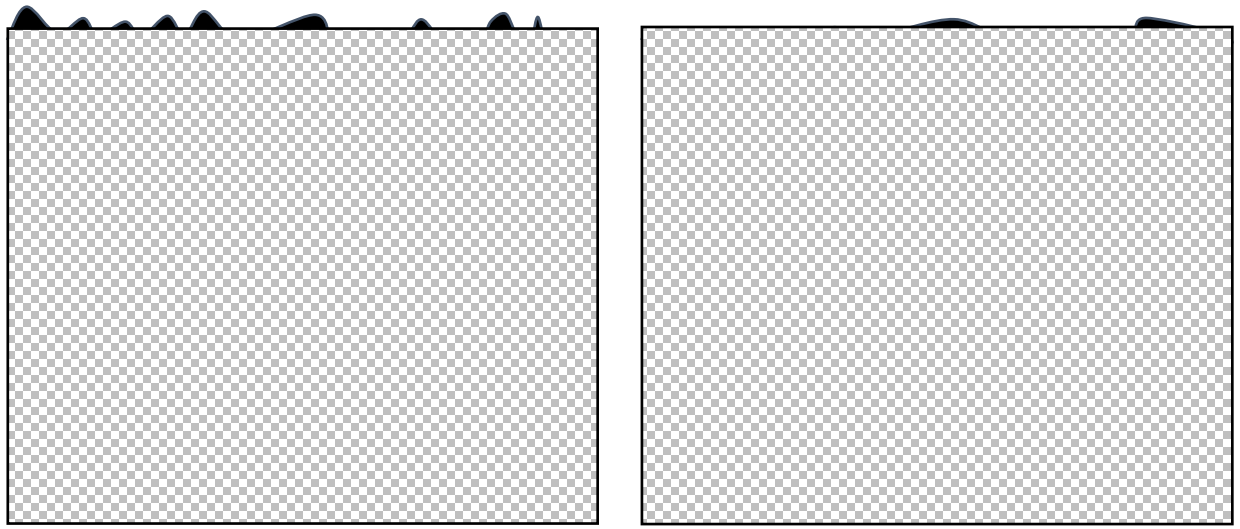
PEP is Efficient





EP PEP

Removal of equal quantity of materials leads to lower roughness comparing to other treatments

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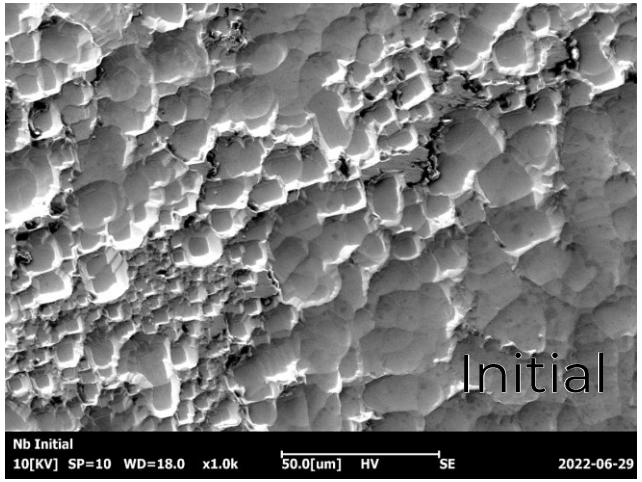
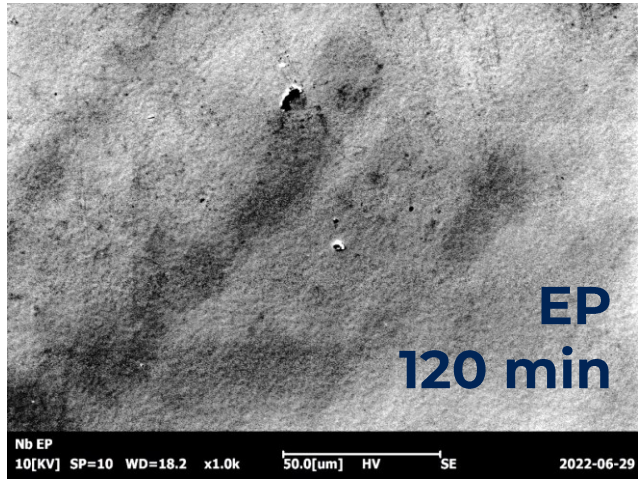
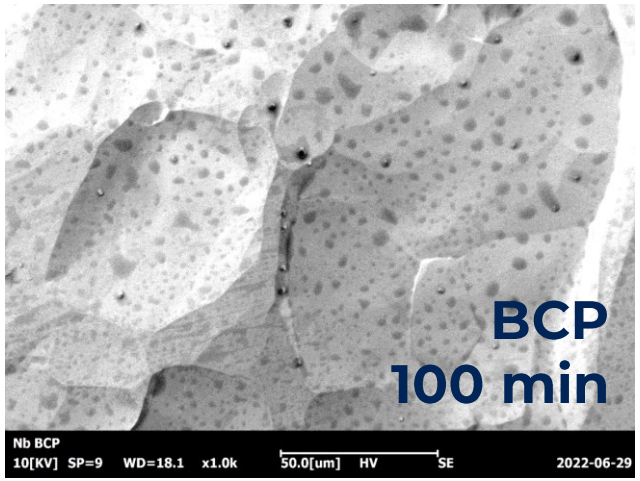
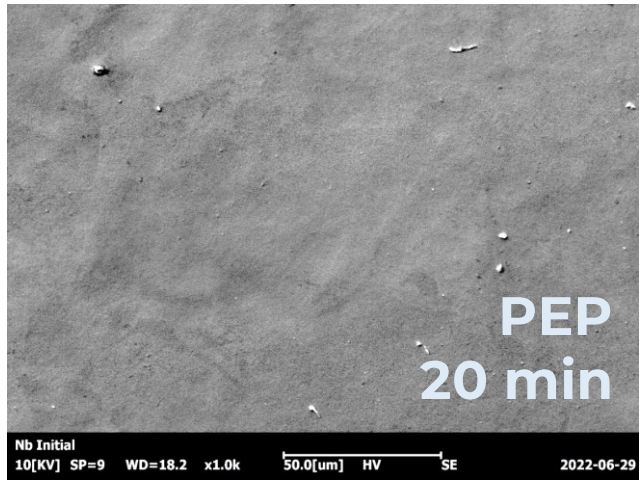
PEP is Efficient

Comparision with EP and BCP

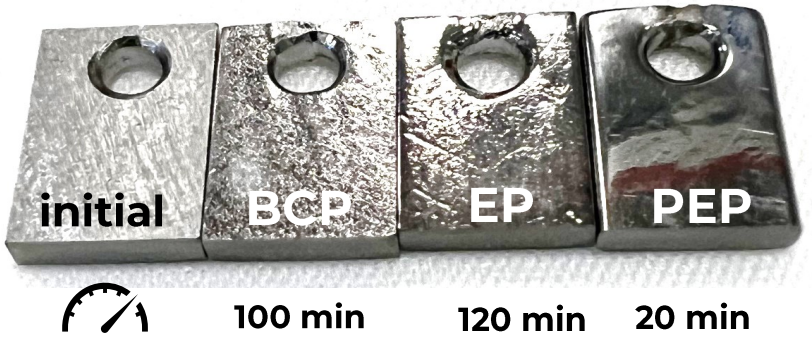








Nb, Magnification **1000x**;
100 µm Removal



Both micro and macro **roughness is improved significantly**

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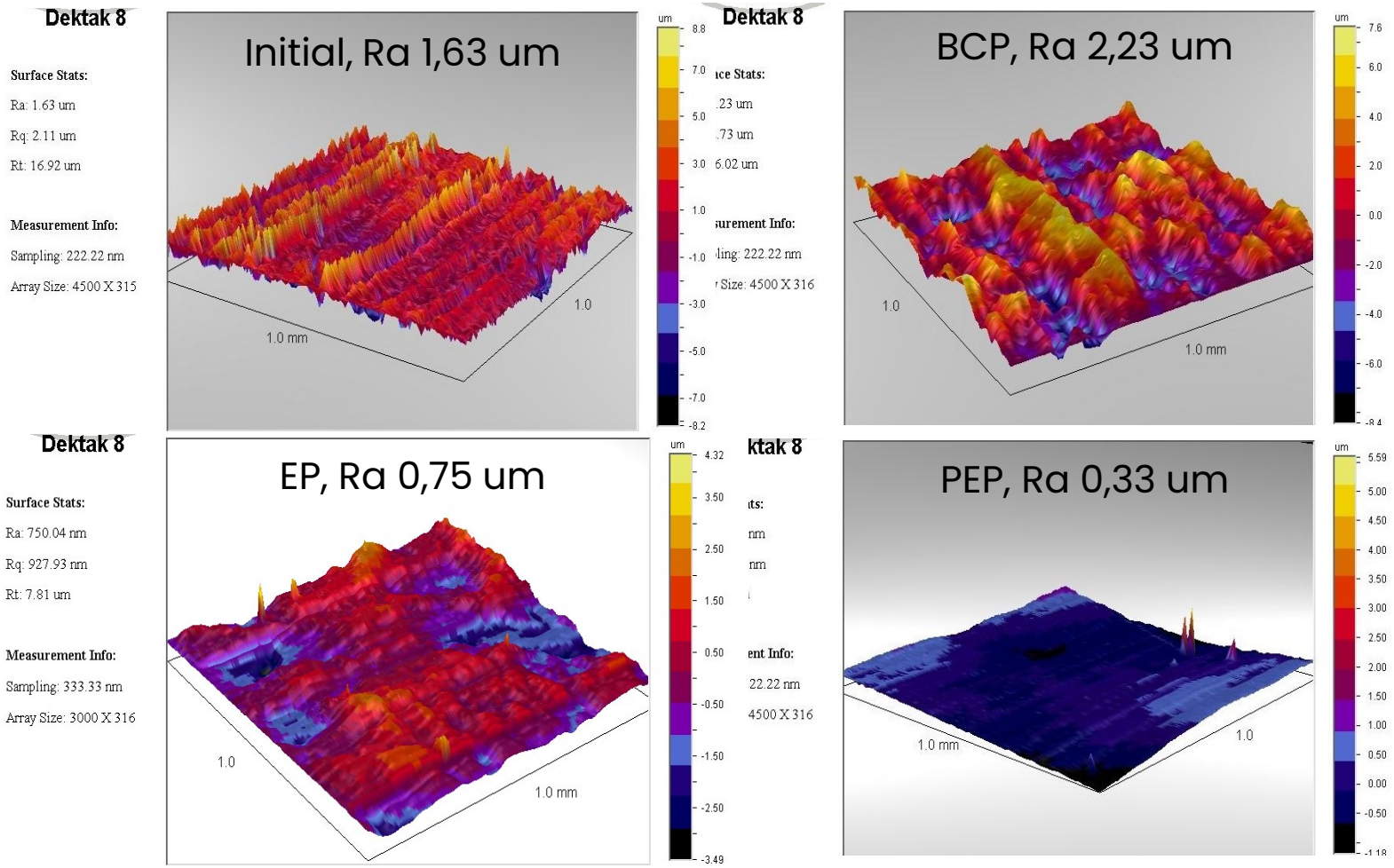
PEP is Efficient

Comparision with EP and BCP



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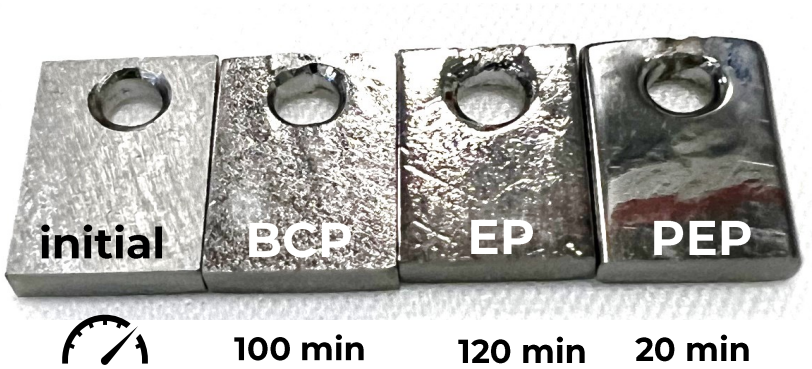

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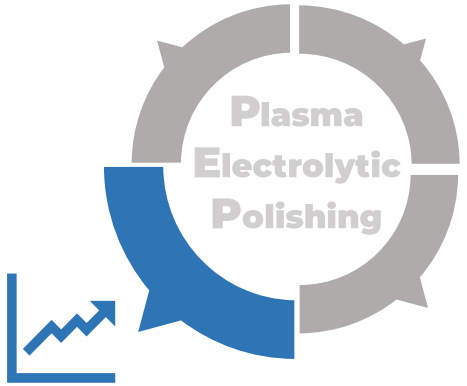
PEP is Efficient

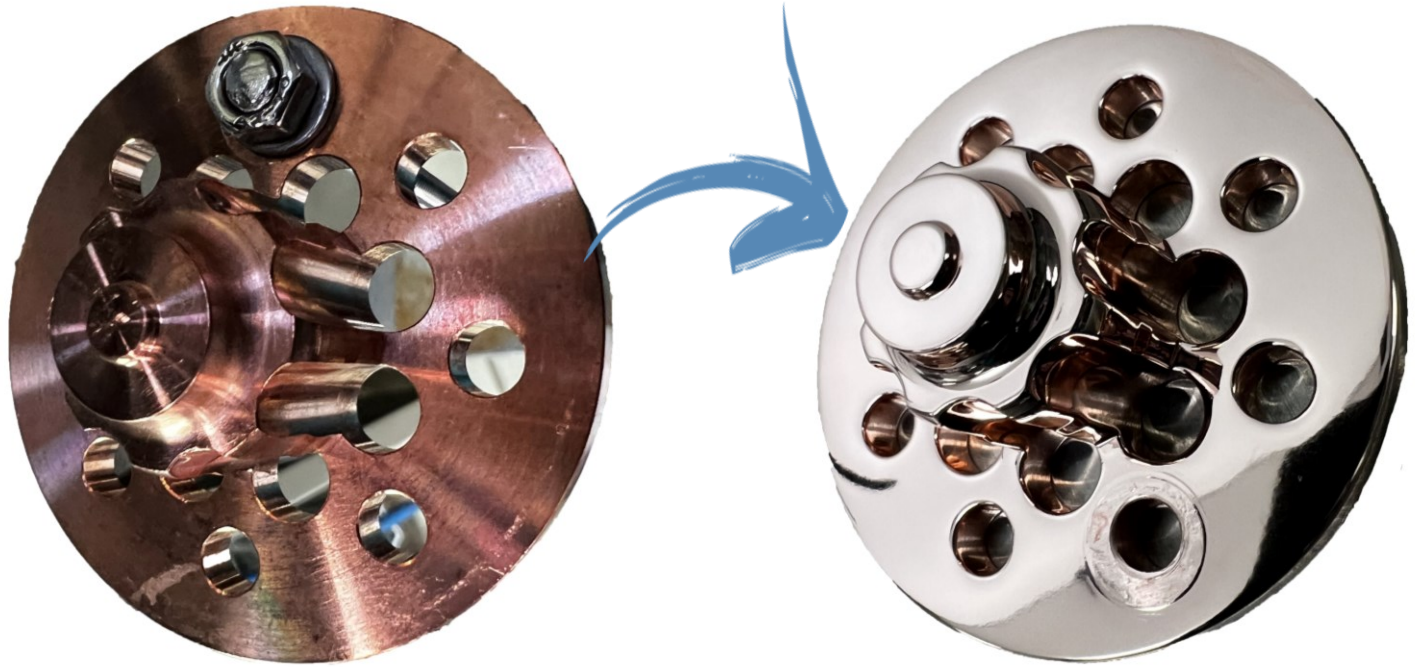
Real Example: Photocathode

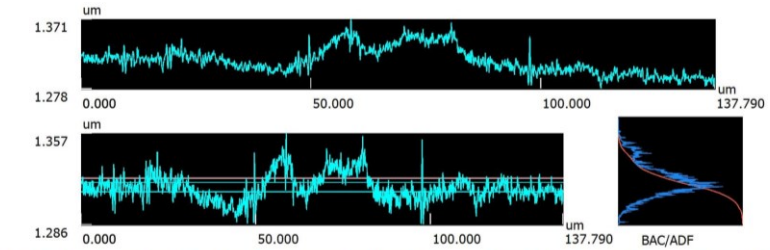
In collaboration with DESY.



Initial

After 4 min PEP





Profile1	Horz. dist.	Rp	Rv	Rt	Rz	Rc	Ra	Rq
All	137.790um	0.042um	0.029um	0.071um	0.071um	0.063um	0.008um	0.010um

Profile1
Line type : Set 2pt.
Ave: None
Correction : Smooth intensity None, DCL/BCL None, Smooth height None, Correct tilt None
JIS B0601:2001(ISO 4287:1997)
Cutoff : Roughness λs None, λc 0.08mm
Stylus mode : OFF

Item	Description
File name	Copper Catode INFN polished PEP 100X 1X.rpt
Measurement date	6/6/2023
Measurement time	2:16:42 PM
Objective lens	Standard lens 100.0x
NA	0.950
Size	Super fine
Mode	Surface profile
RPD	ON
Quality	High accuracy
Pitch	0.08 um
Z measurement distance	2.635 um
Double scan	ON
Brightness1	6500
ND filter	Intensity3%, Intensity100%
Fine mode	ON
Head type	VK-X110

Ra ~ 8 nm!!!

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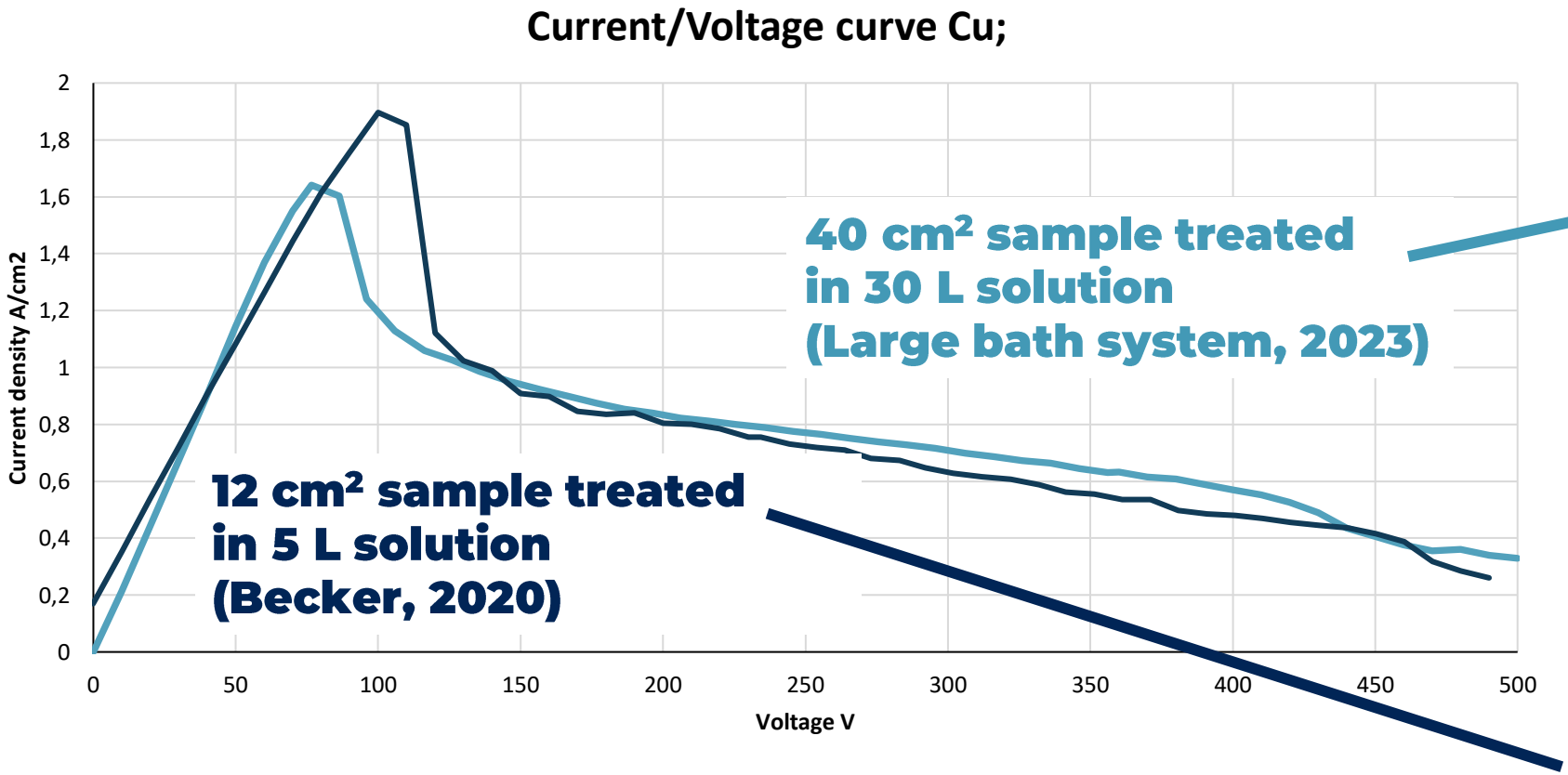
PEP is Versatile

Scaling to large area



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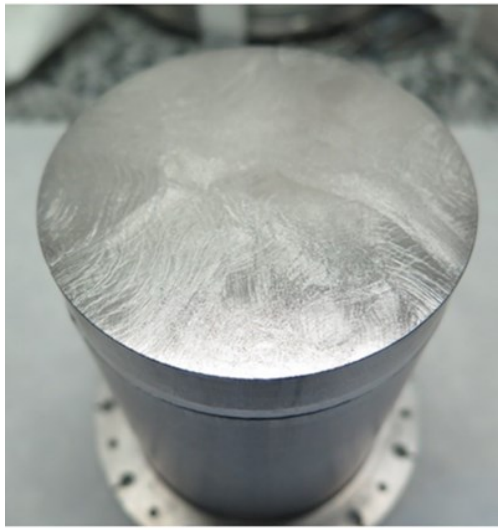
PEP is Versatile

Scaling Nb is a challenge

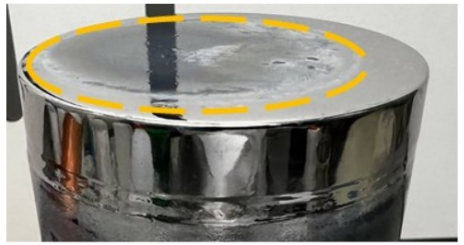
In collaboration with

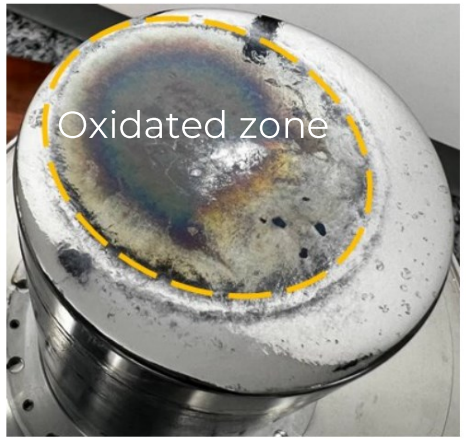
HZB Helmholtz Zentrum Berlin



Initial
(Bad BCP)

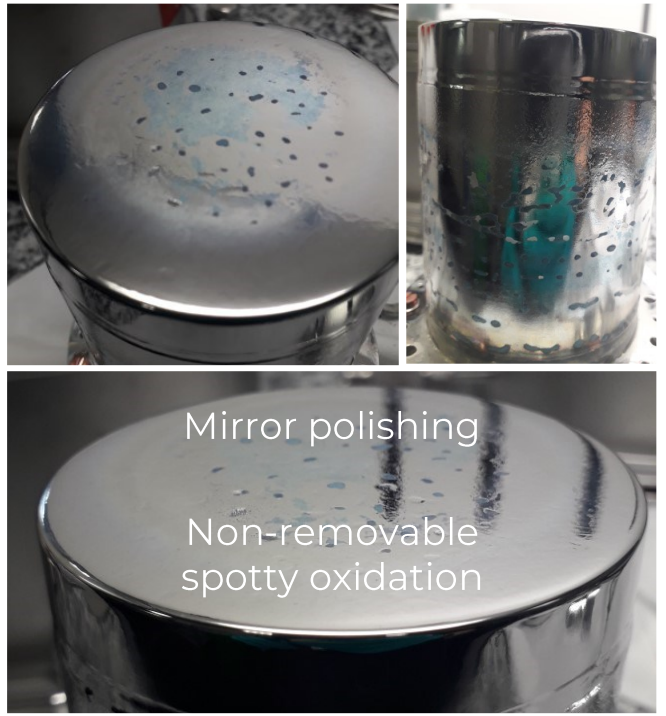
300 V
30 min





First run

300 V
30 min



Second run

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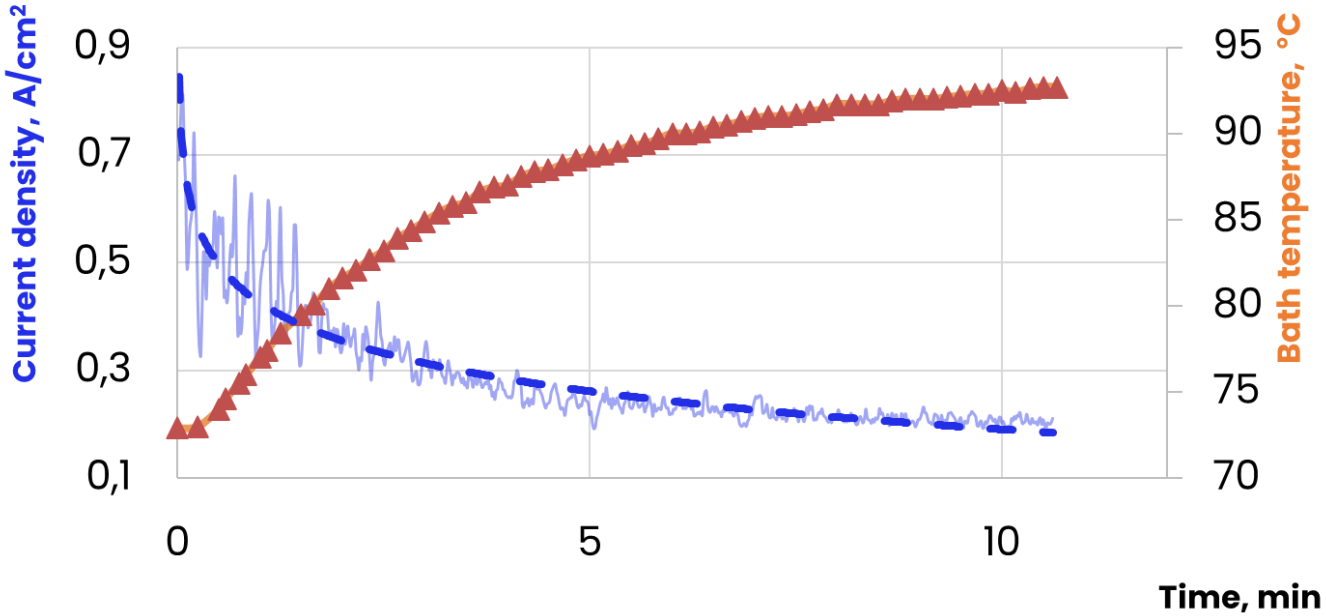
PEP is Versatile

Scaling Nb is a challenge

Initial	70 °C	75 °C	85 °C
Average	80 °C	85 °C	88 °C

TFSRF'22 Chyhyrynets et.al.

Current density is inversally proportional to Temperature



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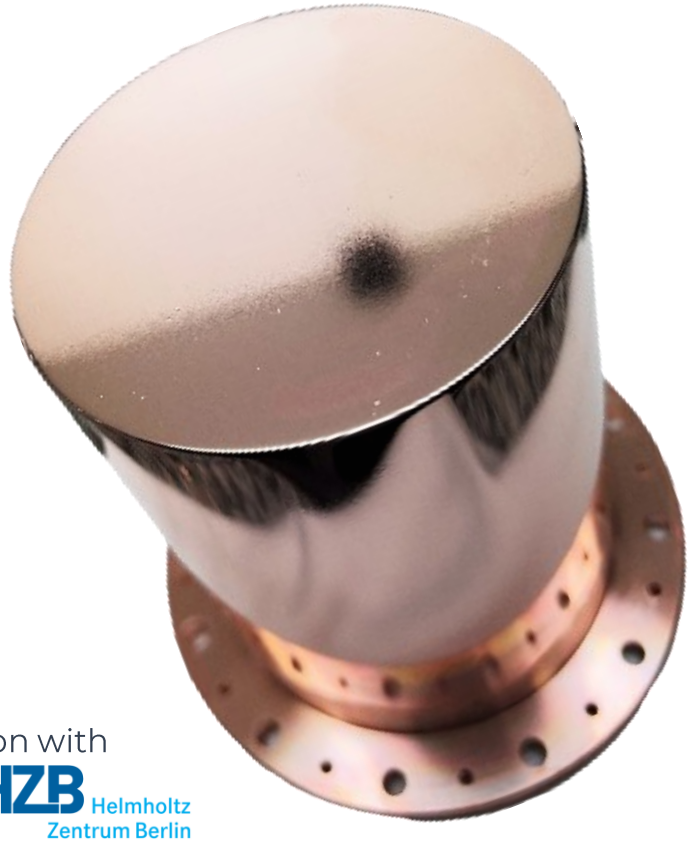
PEP is Versatile

Cu has no scaling problem



In collaboration with HZB Helmholtz Zentrum Berlin

The solution used for Cu PEP is **SUBU5**

Double effect: **PEP+Chemical Polishing**

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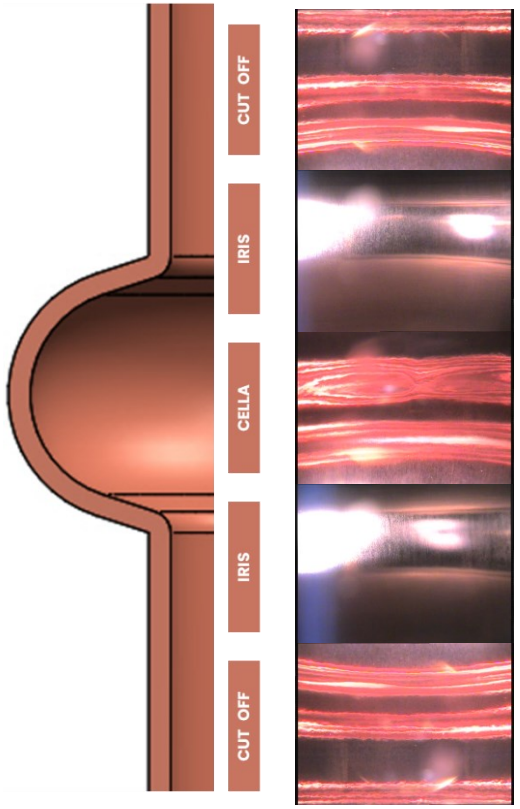
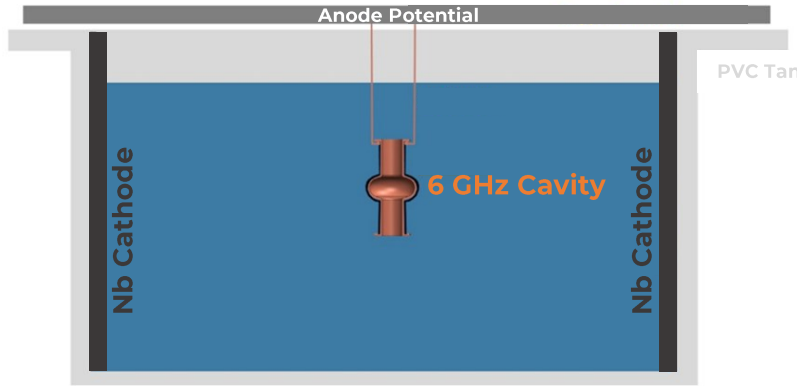
PEP is Versatile

Cu 6 GHz cavity succesfully polished

70 µm removed in 10 minutes
30 A (100 cm^2 → 1.3 GHz ~ 300 A)



No internal cathode, Only external cathode!



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Conclusions

- **PEP** is a promising **alternative** polishing technique **for SRF**
- **Greener, Faster, More Efficient** and versatile than EP and BCP
- **Scaling Nb** PEP to large area **is challenging**
  (Temperature gradients must be avoided)
- **PEP on elliptical cavity** geometry **proved** on Cu

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Thank you!