A New Electropolishing System For Low-β SC Cavities

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Outline

1. BCP or EP
2. Brief History of EP at ANL
3. New Low-β SC Cavity EP Tool
4. Summary
BCP or EP

Max gradient ~ 25-30 MV/m

L. Lilje et al., DESY
BCP or EP

Max gradient ~ 35-40 MV/m

L. Lilje et al., DESY
BCP or EP

~20% higher than BCP
BCP or EP

- EP produces higher average gradients than BCP in elliptical cell cavities
- The effect is likely fundamental and similar for low-β cavities
- Other benefits:
  - EP can be repeated without making surface progressively worse
  - Offers long term cost benefit for next generation machines by maximizing real estate gradient

D. Reschke – TUPO046
R.L. Geng – TUPO049
S. Aderhold – WEIOB05
J. Halbritter – THPO004
K. Saito – THPO013
A. Romanenko – THPO022
C. Xu – THPO046
EP at ANL

SPLIT RING – 1976

SPLIT RING - 1976

TRIPLE SPOKE – 2004

QUARTER-WAVE – 2004

HALF-WAVE – 2004
EP at ANL - ATLAS Energy Upgrade

- Unique cathode design minimized EP to only two major assemblies
- Integrated direct water cooling
- Still needed one final E-beam closure weld followed by flash BCP
EP at ANL - Global ILC Effort

- Horizontal EP
- Teflon rotary lip seals
- Custom rotating copper/carbon brush electrical slip ring assembly
- Adjustable to allow EP of single to 9-cell cavities

- Pivots to vertical position to drain acid and water rinse
- Continuous \( \text{N}_2 \) flow to evacuate hydrogen
- User friendly; short installation times
- Many good 9-cell cavities to date
EP at ANL - Global ILC Effort

TB9RI022 - Q vs E

Tested 03/08/11 - Light EP, HPR/Assy @ ANL, 120C Bake @ IB1

Gradient (MV/m) vs Radiation (mR/hr) for Q0.
New Low-\(\beta\) SC Cavity EP Tool
New Low-\(\beta\) SC Cavity EP Tool

Design Goals

- Ability to EP a complete, fully jacketed cavity
- Direct water cooling through cavity LH\text{e} jacket (while cavity is rotating!)
- Two electrical slip ring assemblies to allow rotation of both anode and cathodes
- Enough cathodes to provide adequate polishing
- Cathode loading system to ensure correct cathode alignment inside cavity
- Ability to circulate acid during EP
- Nitrogen purge to evacuate hydrogen
- Within budget (yet still needs to work!)
New Low-\(\beta\) SC Cavity EP Tool

- Designed and built over 8 months for ~$95k and with 4 man-months effort
- Four cathodes which are used to flow both acid and \(N_2\) to evacuate \(H_2\)
- Cathode loading done via plastic port flanges
- Direct water cooling achieved by using rotary water feedthroughs and Teflon lip seals
- Load/unload time is ~ 1 hour
New Low-\(\beta\) SC Cavity EP Tool

HORIZONTAL SECTION VIEW

VERTICAL SECTION VIEW
New Low-\(\beta\) SC Cavity EP Tool

- All acid wetted parts are made from HDPE, UHMWPE, Teflon, Viton, and 3003 series aluminum
- “Bookends” and end groups share many of the same parts
New Low-β SC Cavity EP Tool

ELECTRICAL SLIP RING

ELECTRICAL SLIP RING
New Low-β SC Cavity EP Tool

BEARING ASSEMBLY

BEARING/GEAR ASSEMBLY
New Low-\(\beta\) SC Cavity EP Tool

TEFLON LIP SEALS

TEFLON LIP SEALS
New Low-\(\beta\) SC Cavity EP Tool
New Low-β SC Cavity EP Tool

ROTARY WATER FEEDTHROUGH

ROTARY WATER FEEDTHROUGH
New Low-\(\beta\) SC Cavity EP Tool

ACID DAM

ACID HEIGHT IS ~ 60% CAVITY INNER DIAMETER
New Low-$\beta$ SC Cavity EP Tool

Cathode Loading

- Integrated cathode loading
- Precision HDPE port flanges allow cathode loading and set cathode angles inside cavity during EP
- Eliminates need for special cathode loading device when dealing with complex cavity geometries
- No cathode bag
New Low-β SC Cavity EP Tool
H₂O Flow

- Chilled water is circulated through the LHe space to control cavity temperature
- Offers an improvement over our elliptical cell EP setup which chills the acid in order to control temperature
New Low-\(\beta\) SC Cavity EP Tool

H\(_2\)O Flow

- Chilled water is circulated through the LHe space to control cavity temperature
- Offers an improvement over our elliptical cell EP setup which chills the acid in order to control temperature
New Low-\(\beta\) SC Cavity EP Tool
H\(_2\)O Flow

- Chilled water is circulated through the LHe space to control cavity temperature
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New Low-β SC Cavity EP Tool

H₂O Flow

- Chilled water is circulated through the LHe space to control cavity temperature
- Offers an improvement over our elliptical cell EP setup which chills the acid in order to control temperature
Low acid flow rate (0.19 LPM)
- Acid flow only needed to refresh acid, not to maintain temperature
- Rotates at 0.5 RPM
New Low-\(\beta\) SC Cavity EP Tool
Operation Data for 72 MHz QWR EP

- CAVITY TEMPS (C)
- CURRENT (A)
- OPERATING VOLTAGE (V)
- ACID DUMP TANK TEMP (C)
- ACID RETURN LINE TEMP (C)
- WATER RETURN TEMP (C)
New Low-β SC Cavity EP Tool
Before and After EP

BEFORE EP

AFTER 12HRS OF EP
150μm Nb REMOVED
New Low-β SC Cavity EP Tool Results

$E_{PEAK}$ (MV/m)

$B_{PEAK}$ (mT)

$Q$

X-ray yield (mR/h)

$V_{ACC}$ (MV)

$E_{ACC}$ (MV/m)

$I_{eff} = 31.75 \text{ cm}$

$T = 1.8 \text{ K}$

$T = 4.6 \text{ K}$

X-rays

$P_{in} = 5 \text{ Watts}$

MIKE KELLY: THIOB04
Summary

- EP with this method is the *final* step in cavity fabrication.
- Unlike BCP, EP can be repeated, if necessary, without degradation of surface.
- Once the tool is built, EP with this method is simple to use and cost effective.
- The EP tool is broadly useful for various cavity geometries, including any type of quarter-wave or half-wave cavity.
- Our goal is to use this method of EP to maximize real estate gradient for ATLAS as well as the next generation of SC ion linacs.