Improvements to the Coaxial Energetic Deposition process for Nb-on-Cu SRF Cavities

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Motivation and Status of AASC Activity

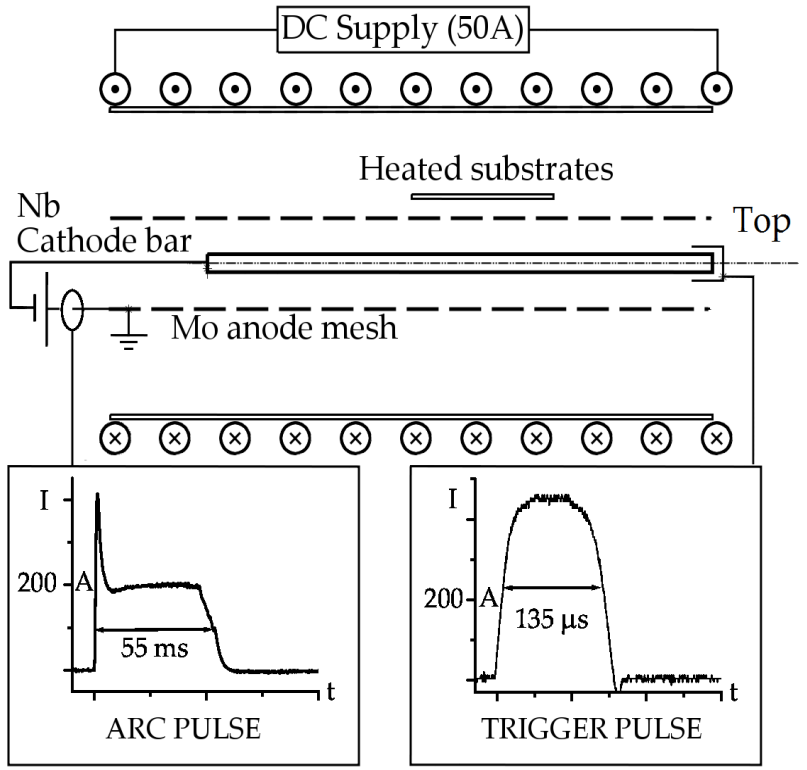
- AASC is developing Coaxial Energetic Deposition (CED) to coat Cu with Nb for SRF applications
- Research on Nb coated coupons shows CED has promise for SRF cavity coatings
- Achieving $Q_o > 10^{10}$ from coated cavities requires many iterations
- AASC has been coating 1.3 GHz Cu cavities and continues to improve the process
- Thank you to Charlie Reece, Larry Phillips, Ari Palczewski, Anne-Marie Valente-Feliciano and others at JLab for their enthusiastic collaboration

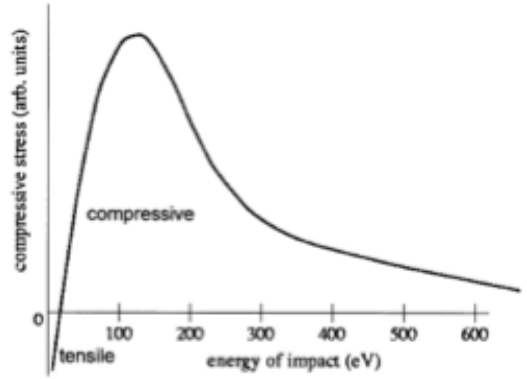
Outline

- Coaxial Energetic Deposition
- Baseline cavity coating in CED-2
- CED-U Coating chamber
- Results from first cavity coated in CED-U
- Improvements to CED-U and recent cavity coating

Coaxial Energetic Deposition (CED)

- CED uses 100V/200A power supply to drive cathodic arcs
- CED implants 60-120 eV Nb ions (avg charge +3) monolayers below the surface
- Ions shake up lattice promoting good adhesion and crystallinity
- Heat substrate to promote defect free crystal growth
- Adding -60 V bias gives 240 – 300 eV ions and reduces compressive stress



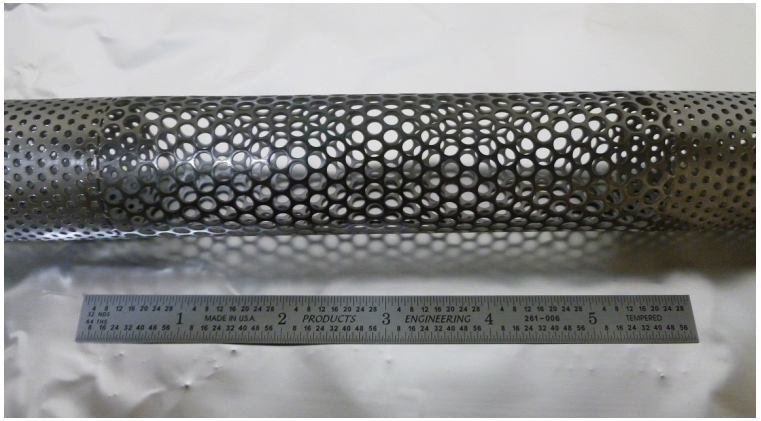


Internal stress as a function of incident ion energy*

*M. M. M. Bilek, D.R. McKenzie, R.N. Tarrant, S.H.M. Lim, D.G. McCulloch, Surface and Coatings Technology 156 (2002)

Control Coating Parameters

- Ensure thickness uniformity with variable transmission anode
- 23% in beam pipe, 63% in ellipse
- Number of pulses determines thickness
- Heat substrate: 150 – 350 °C
- Bias substrate: -60 – 0 V

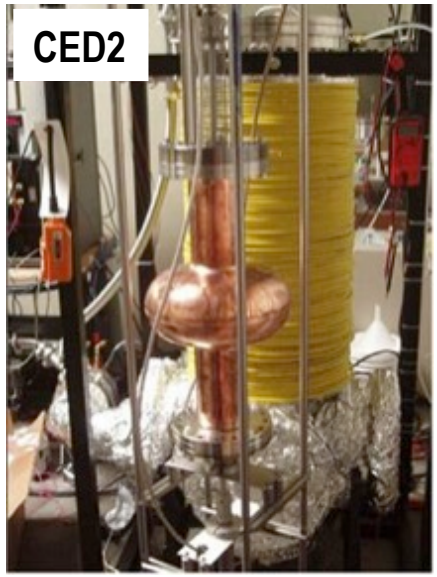


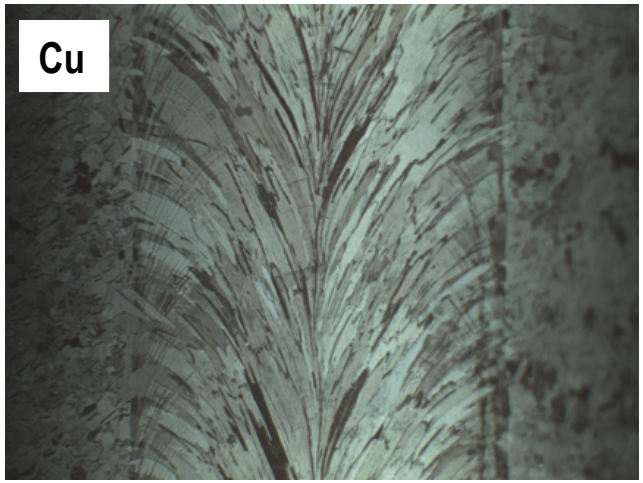
Measure	Value		Unit
Coating pulse width	0.285		s
Arc velocity	4		m/s
coated length	114		cm
Arc current	135		A
Charge per pulse	38.5		C
Erosion rate	25		µg/C
Eroded mass per pulse	9.60E-04		g
Substrate radius	3.9	10	cm
Anode Transparancy	23%	63%	
Fluence at substrate	7.9E-08	8.4E-08	g/cm^2
Nb density	8.57		g/cc
Thickness per pulse	9.2E-09	9.8E-09	cm
# of pulses	25000		
Film Thickness	2.30	2.46	µm
Average Film Thickness	2.38±0.08		µm

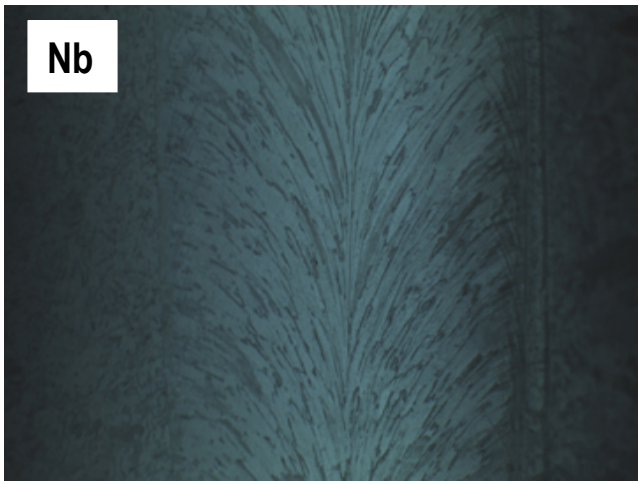
LSFC-B Coating inside CED-2 vacuum chamber

LSFC-B

- Base vacuum pressure 7e-7
- Cavity heated to 275 °C
- No bias voltage
- 2 μm film deposited
- Optical inspection shows Nb inherits crystallinity of Cu substrate

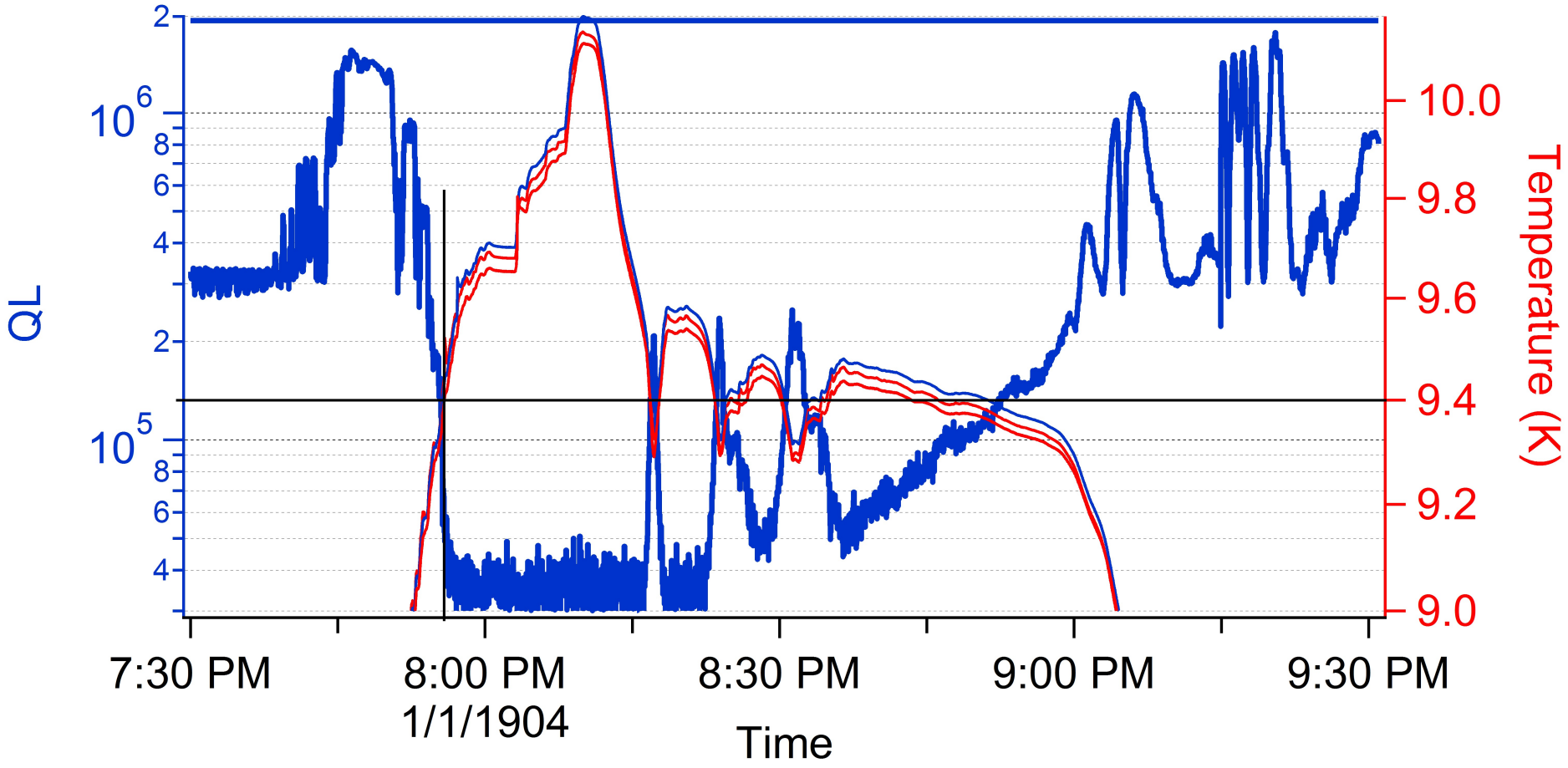




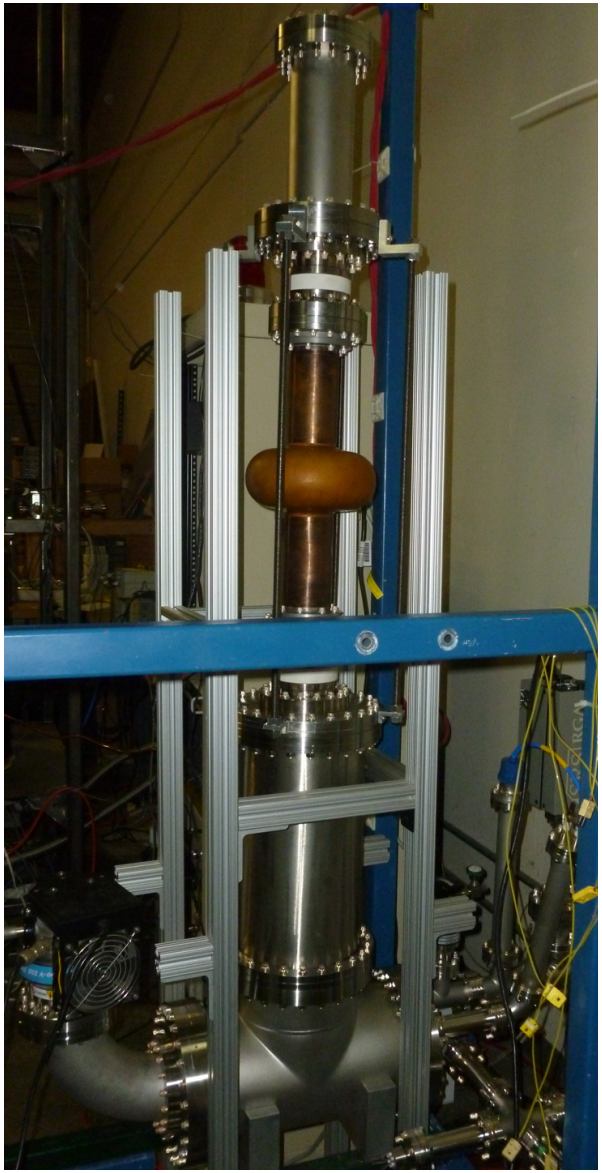


RF Test results are disappointing

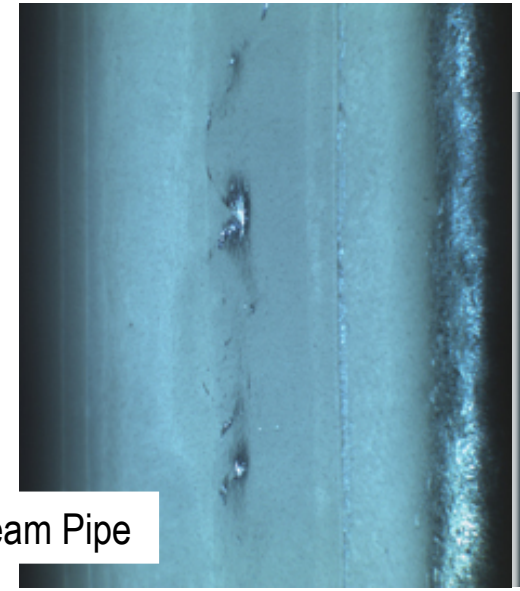
- Clear T_c at 9.4 K
- Q_o limited to 1.5E8
- Results independent of temperature (2 or 4 K) or cooling speed



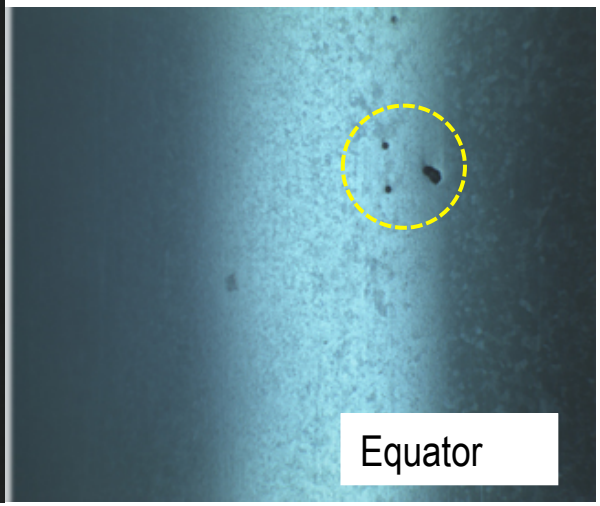
CED-U Chamber Pumps on Cavity



- Removes potential contaminants
- Use sub-chamber to coat coupons
- JLab LSFC-3 cavity coated using -40 V bias at 200 °C
- Base vacuum of 5E-8
- 1.8 um film



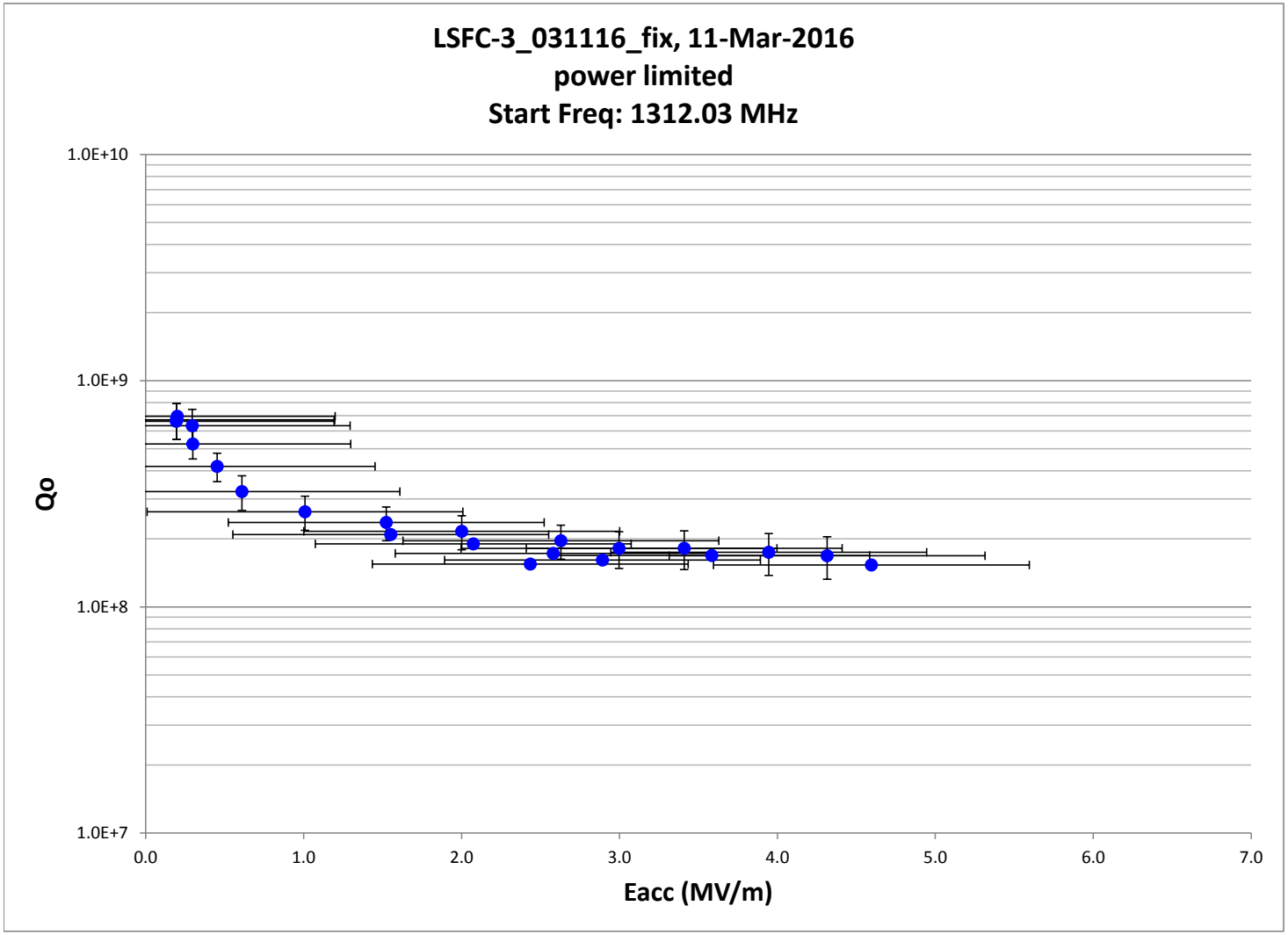
Beam Pipe



Equator

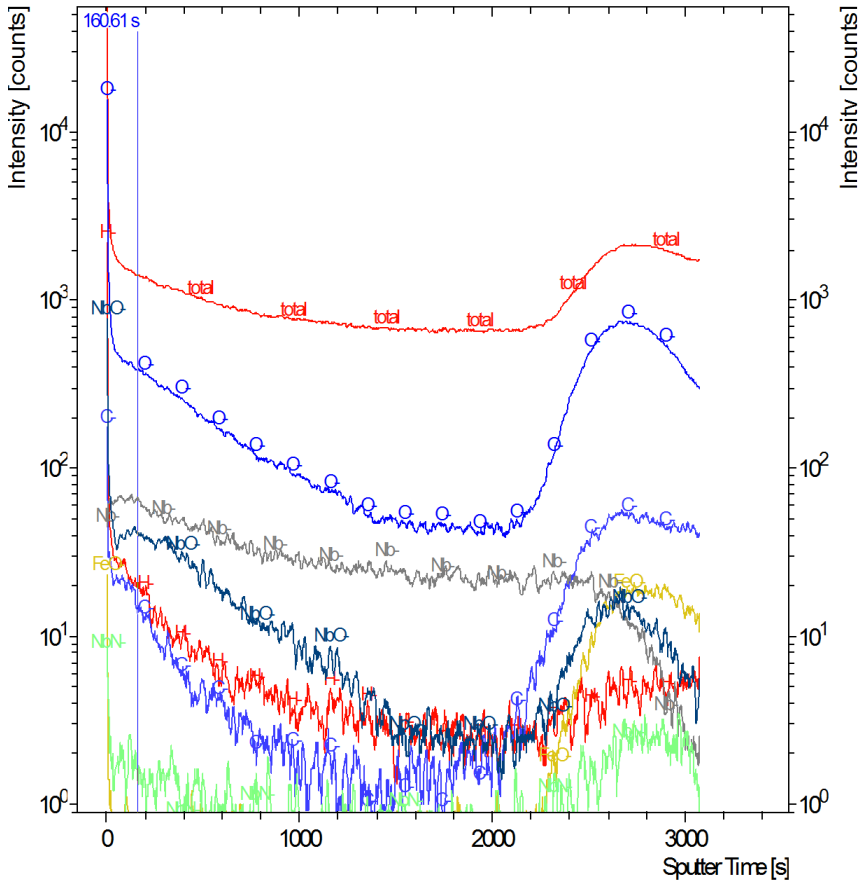
CED-U sees improvement in RF performance

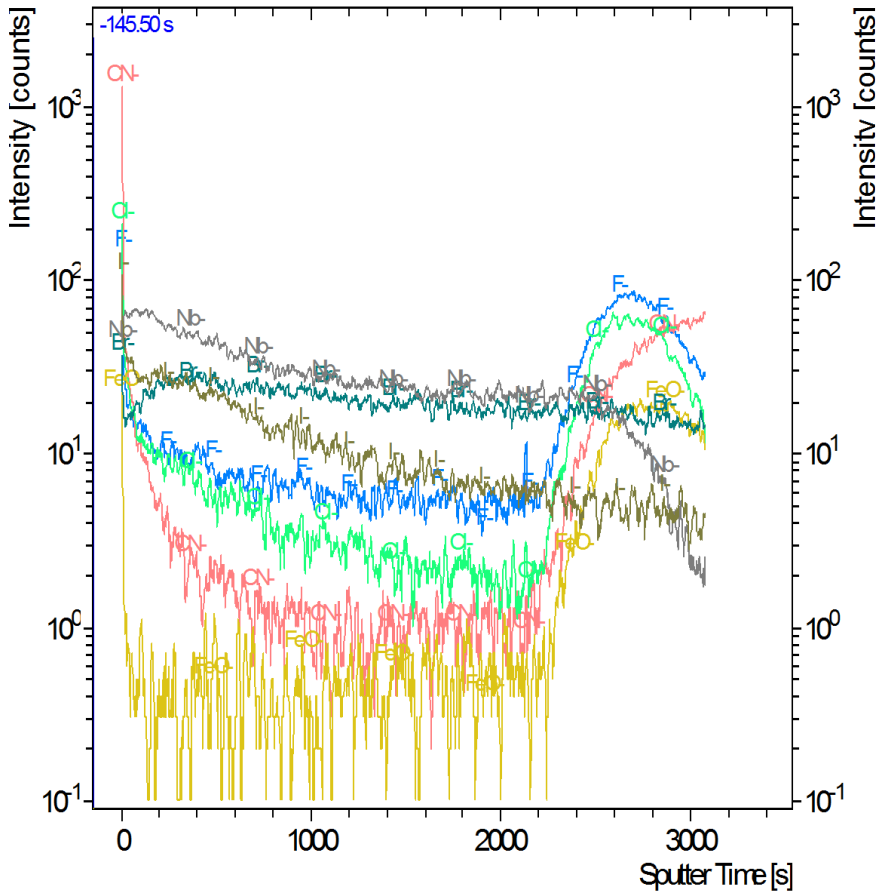
- Zero field Q_0 ≈ 1E9. Highest in CED cavity.
- Q_0 quickly falls to 2E8



SIMS data from Negative Ion Spectrum

- Stainless Steel coupons sent to NCSU for TOF SIMS
- Presence of Halides (F, Cl, Br, I) is puzzling
- Impurities decrease from surface through bulk
- No Ta or W

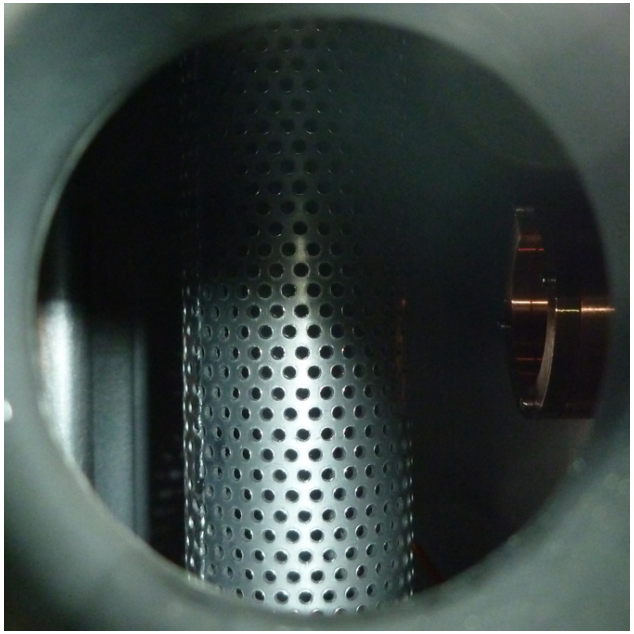




CED-U needed improvements

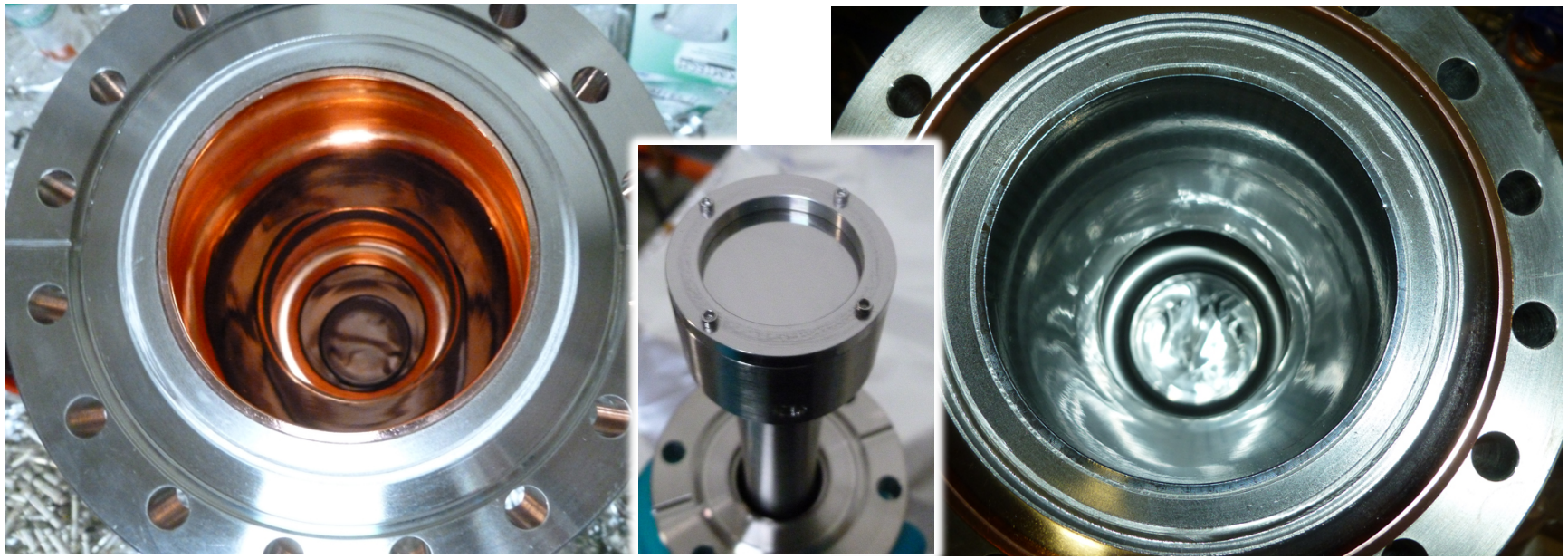
- LSFC-3 had HF rinse to remove surface layer and was retested at Q_0 ~ 1e7
- Are impurities at interface degrading performance?

- Install gas line to flush cavity with high pressure gas before sealing chamber
- Add feedthroughs to heat coupons from outside



CEDU needs further improvements

- LSFC-2 coated at 170 °C and -60V with 2 μm and base vacuum of 1E-8 torr
- Flushed chamber with 50 psi of purified N_2 for 10 minutes before final vacuum seal
  - Results soon
  - PLAN B – assemble CED-U in clean room at JLab



Summary

- CED-U is an upgraded CED coating system that directly pumps on a cavity to allow heating from outside and removes potential sources of impurities
- First cavity coated in CED-U had highest Q_o measured using Coaxial Energetic Deposition
- Improvements decreased base vacuum and hopefully removed surface particulates before coating
- Improvements are being made in cavity manufacture
- Next steps may include assembly in JLab clean room
- AASC's new research grant is to test a seamless Cu cavity