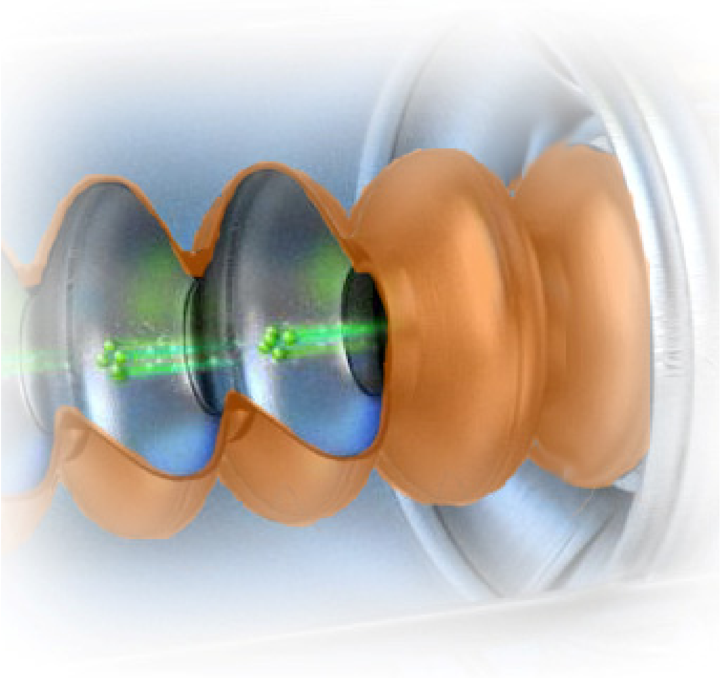
Progress With Nb Hipims Films on 1.3 GHz Cu Cavities

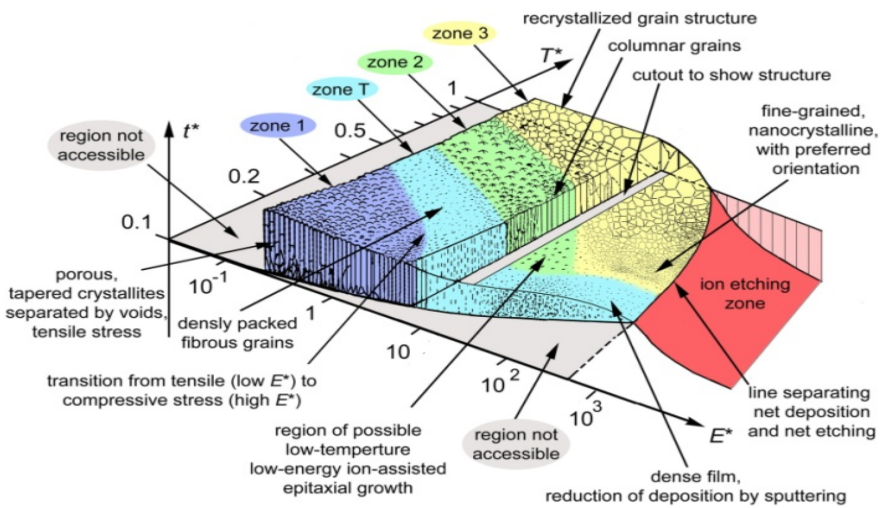


Matthew C. Burton

Presented by A.-M. Valente-Feliciano

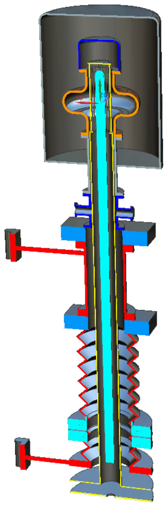
M.C. Burton, A.-M. Valente-Feliciano, A. D. Palczewski, C. E. Reece

Energetic Condensation via HiPIMS



Anders, André. "A structure zone diagram including plasma-based deposition and ion etching." *Thin Solid Films* 518.15 (2010): 4087-4090.

High Power Impulse Magnetron Sputtering (HiPIMS)



Requires working gas

Mulitply charged ions of Nb & Kr

Presence of neutrals

Controllable

deposition energy

with Bias voltage

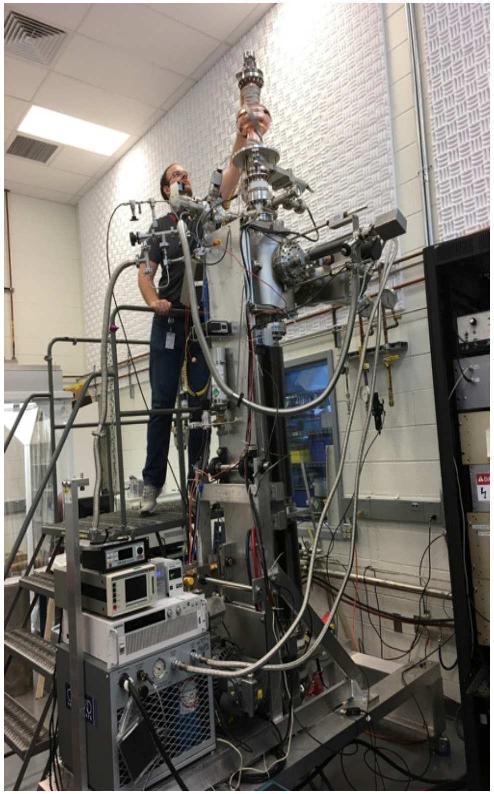
Excellent bonding

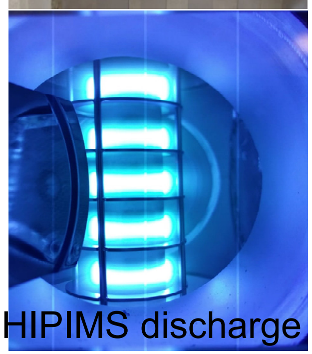
No macro particles

Ease of cavity configuration

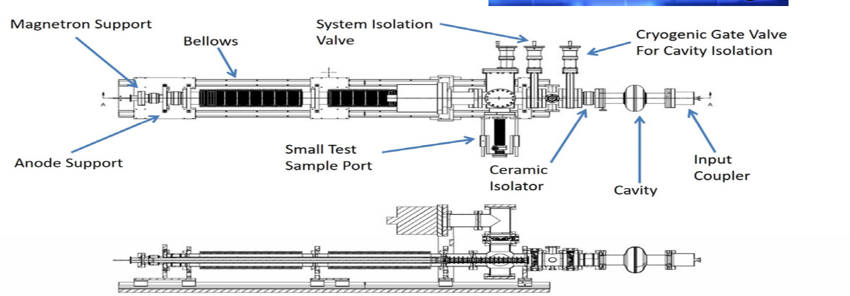
HiPIMS Cavity Coating System

Vertical coating system 1.3 GHz Nb/Cu cavity





HIPIMS discharge



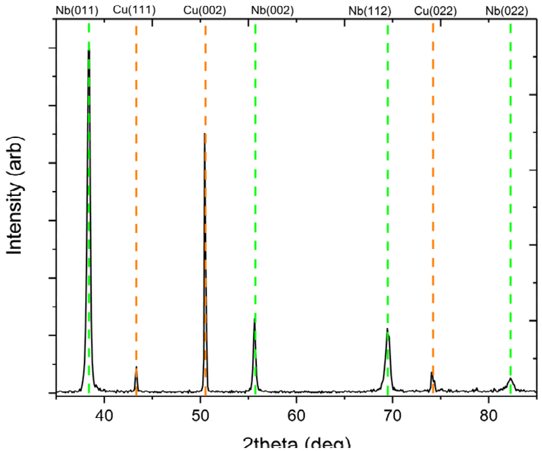
- Movable cylindrical Nb cathode
- Background pressure in 10^{-9}-10^{-10} Torr
- Coating temperatures up top 400 ° C under external nitrogen flow
- Kr atmosphere

System upgrades

- Tripled Pulse Power Capability
- Permanent Vertical System Operation
- New Nb cathode with proper length
- Cavity support during bake-out

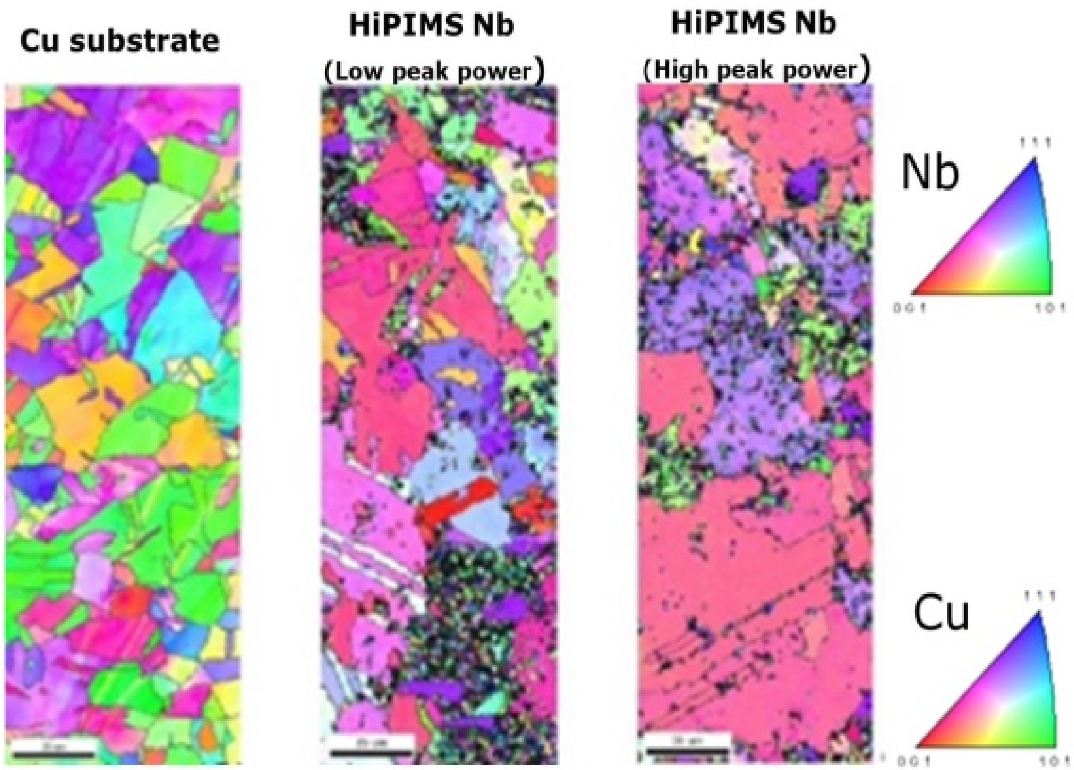
System re-commissioned June 2018

HiPIMS Nb films - Structure



Typical polycrystalline texture dominated by the Nb (011) phase. Average grain sizes determined with the Scherrer equation and the FWHM of the Nb (011) peak.

XRD

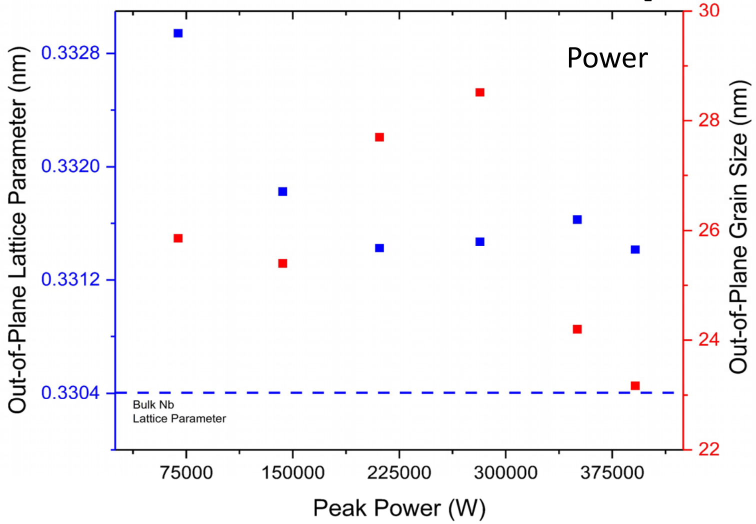


EBSD

HiPIMS Nb films – Structure & roughness

2 sample series performed to correlate deposition parameters to structure

- ❑Power series: 69 to 391 kW [Fixed bias -100 V]
- ❑Bias series: 0 to -300 V [Fixed peak power 220 kW]



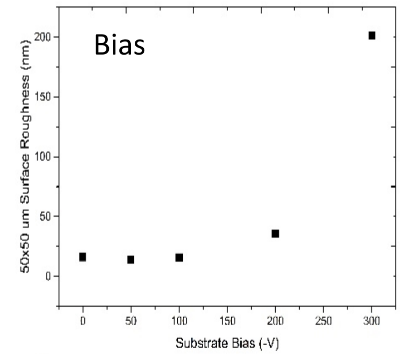
Both peak power and applied bias voltage series resulted with lattice parameters larger than bulk

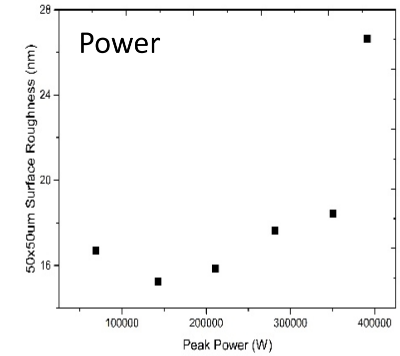
a decreasing trend with peak power and an increasing trend with bias.

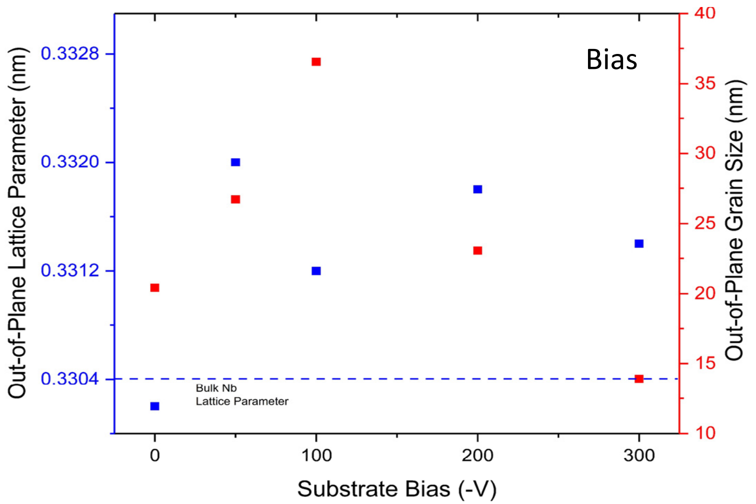
0 V bias leads to a smaller than bulk lattice parameter (0.3304 nm) flipping the stress present in the film?

RMS roughness

50×50 µm scale







increasing surface roughness with increasing power and **bias** independently

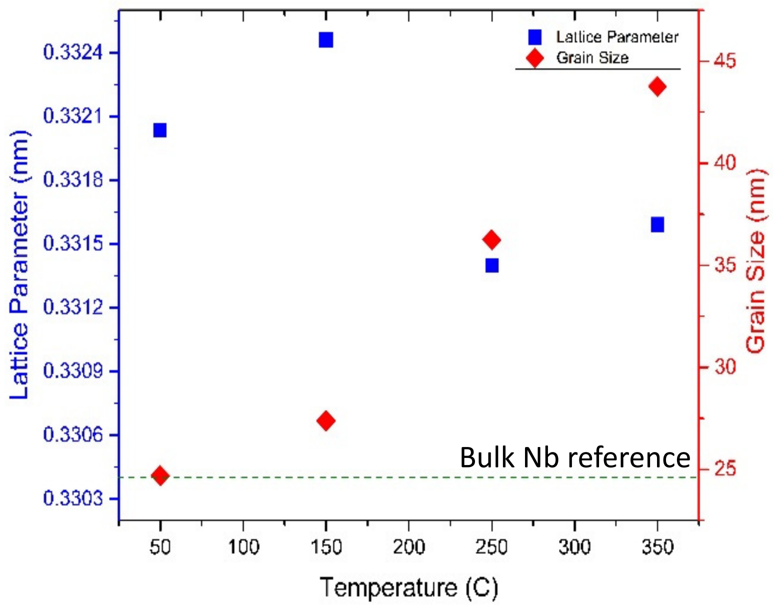
Results indicate ability/need to engineer film properties throughout growth

Optimized bias will have to be a compromise for ion energy high enough to insure good adhesion while keeping control over final RF surface roughness

HiPIMS Nb films - Structure

- Temperature series: 50 to 350 °C [Fixed bias -25-35 V, power 350-400 kW]

Temperature (C)	Peak Power (kW)	Applied Substrate Bias Voltage (V)	Out-of-Plane Lattice Parameter (nm)	Out-of-Plane Grain Size (nm)
350	332	25	0.3316	43.77
250	360	35	0.3314	36.24
150	377	25	0.3325	27.38
50	400	25	0.3320	24.69



Consistency with previous sample series

Reproducible film quality

1.3 GHz Nb/Cu Cavity Procedure

Surface Preparation

- SUBU 5
- 15 to 30 µm removal
- HPWR
- Drying with methanol sheeting
- Assembly in ISO-4 clean room
- Slow pump down
- Bake-out 24 h

Coating

- $T_{bake/coating}$ = 350 or 150 °C
- Target-substrate distance = 10 cm
- [samples & equator]
- Film thickness ~ 1.5 µm
- f = 83 Hz
- Pulse width = 110 µs
- P_{Kr}= 4.2 mTorr
- Bias = -100 V or -25 V
- Peak power = 220 kW

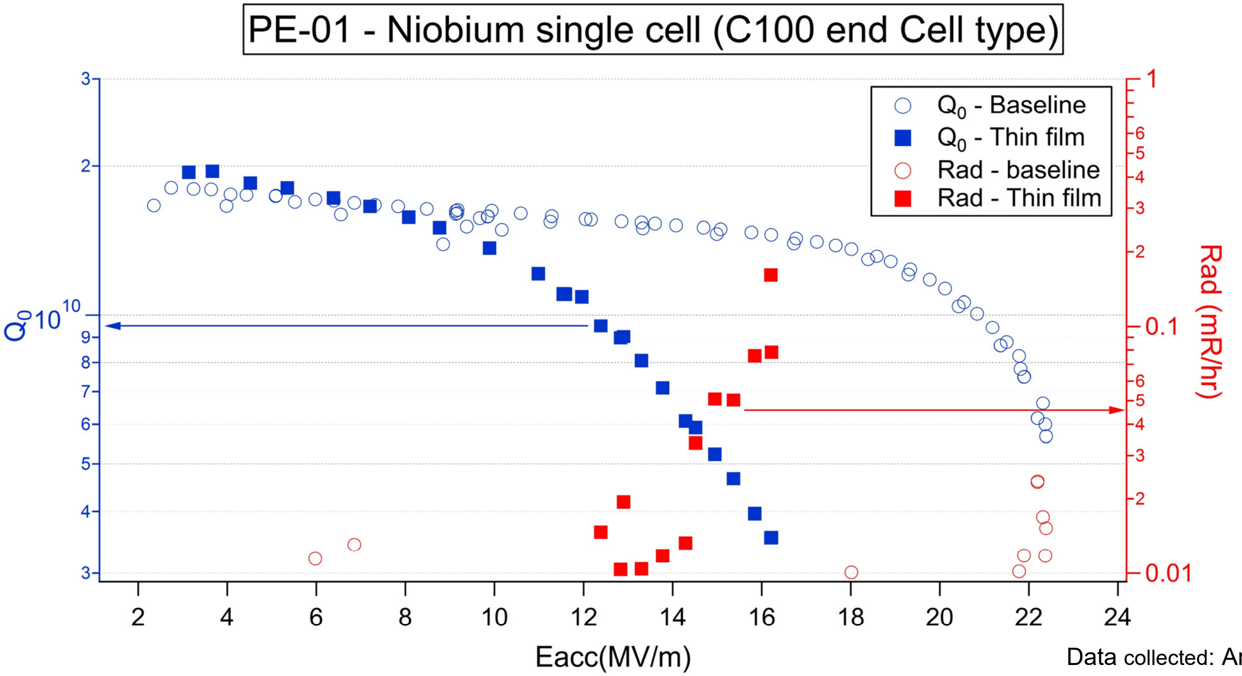
Preparation for RF test

- HPWR
- Drying in ISO-4 cleanroom
- Assembly in ISO-4 clean room
- Assembly on test stand
- Slow pump down

HiPIMS Cavities - 1st RF Tests on bulk Nb

- Test of deposition system capabilities

Coated 1.5 GHz C100 end cell bulk Nb cavity

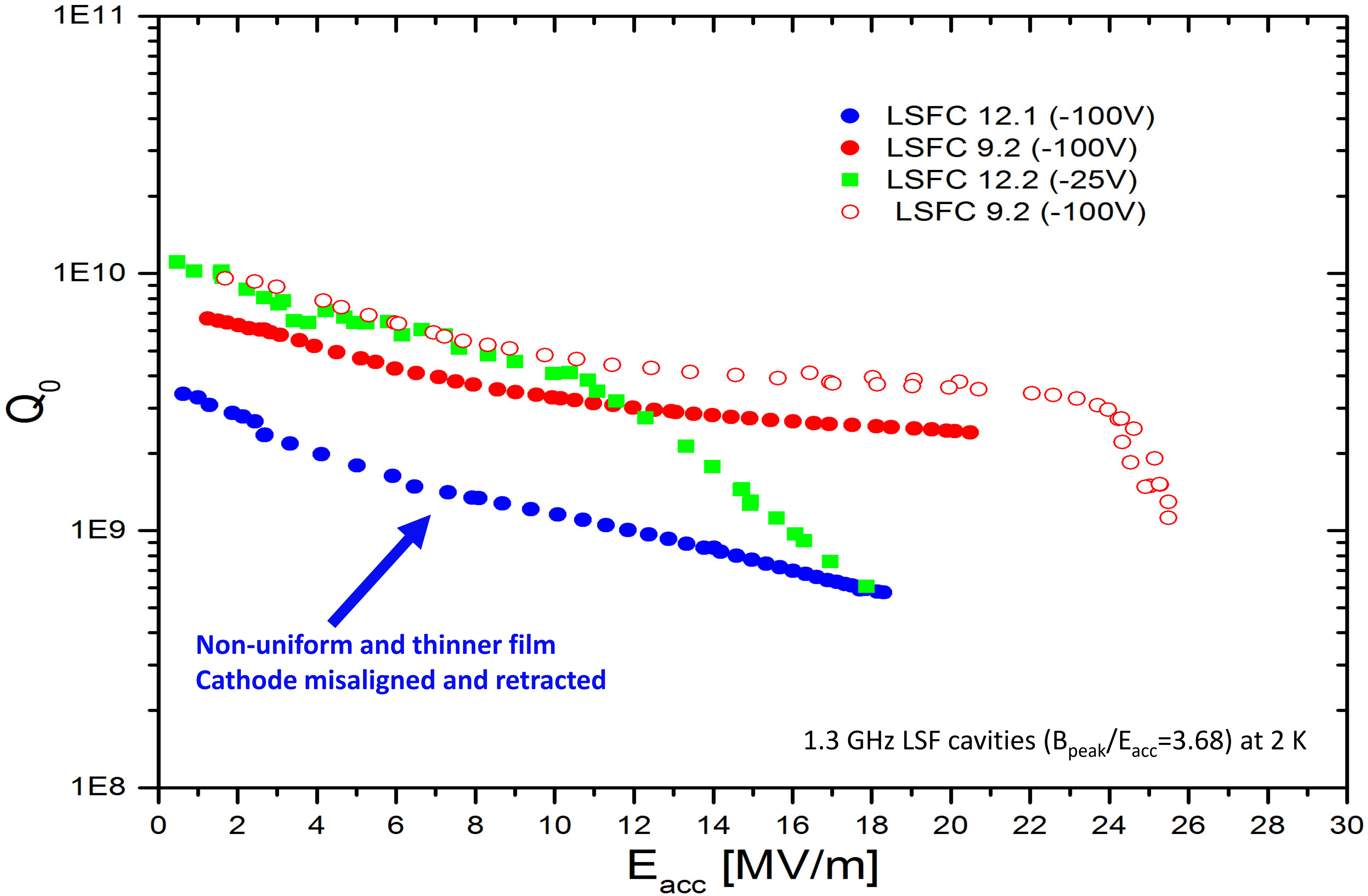


Data collected: Ari Palczewski, JLab

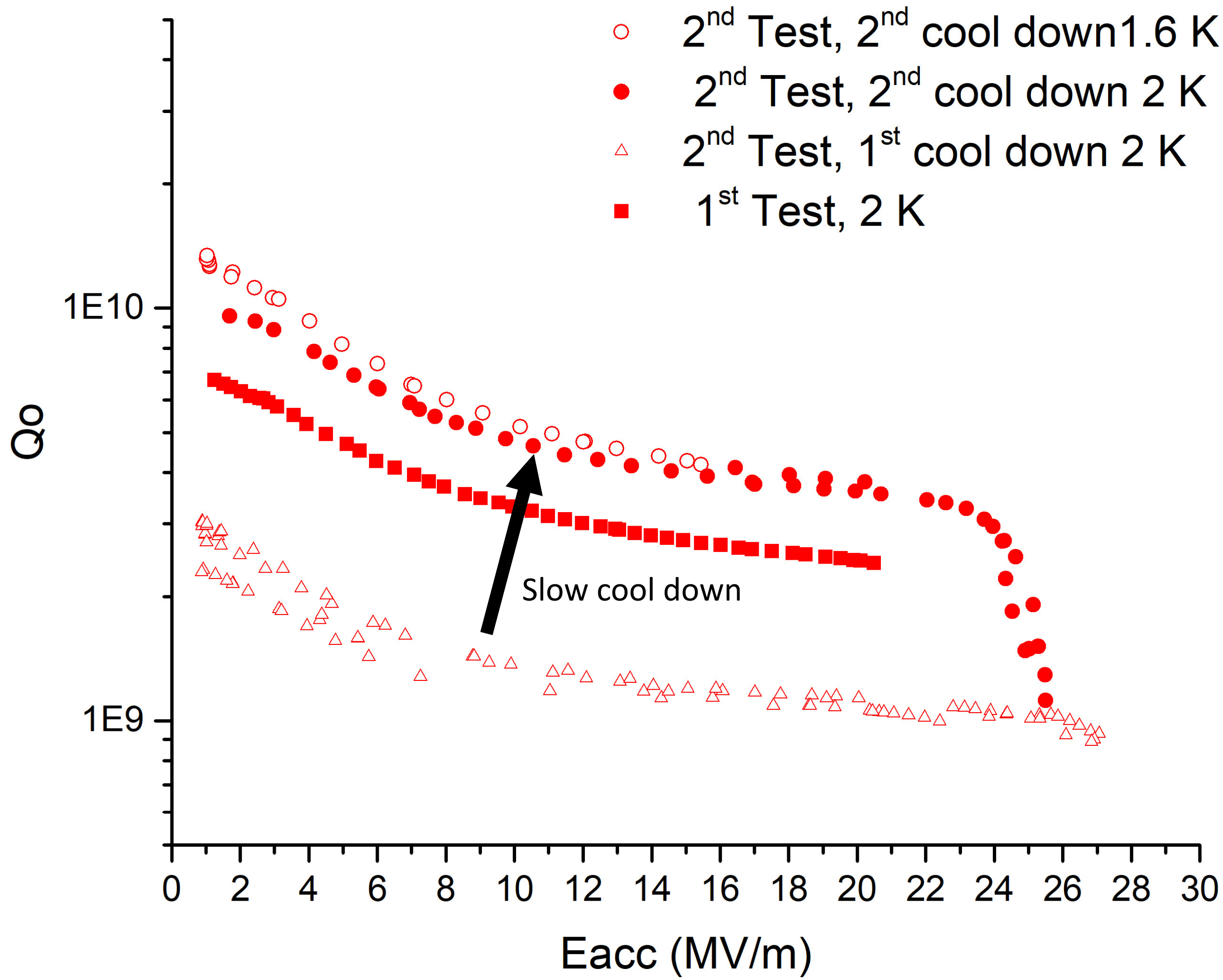
- 1st coatings (no HPR before RF test)
  - comparable to bulk performance up to 10 MV/m then heavy field emission

Jefferson Lab

HiPIMS Cavities RF Behavior

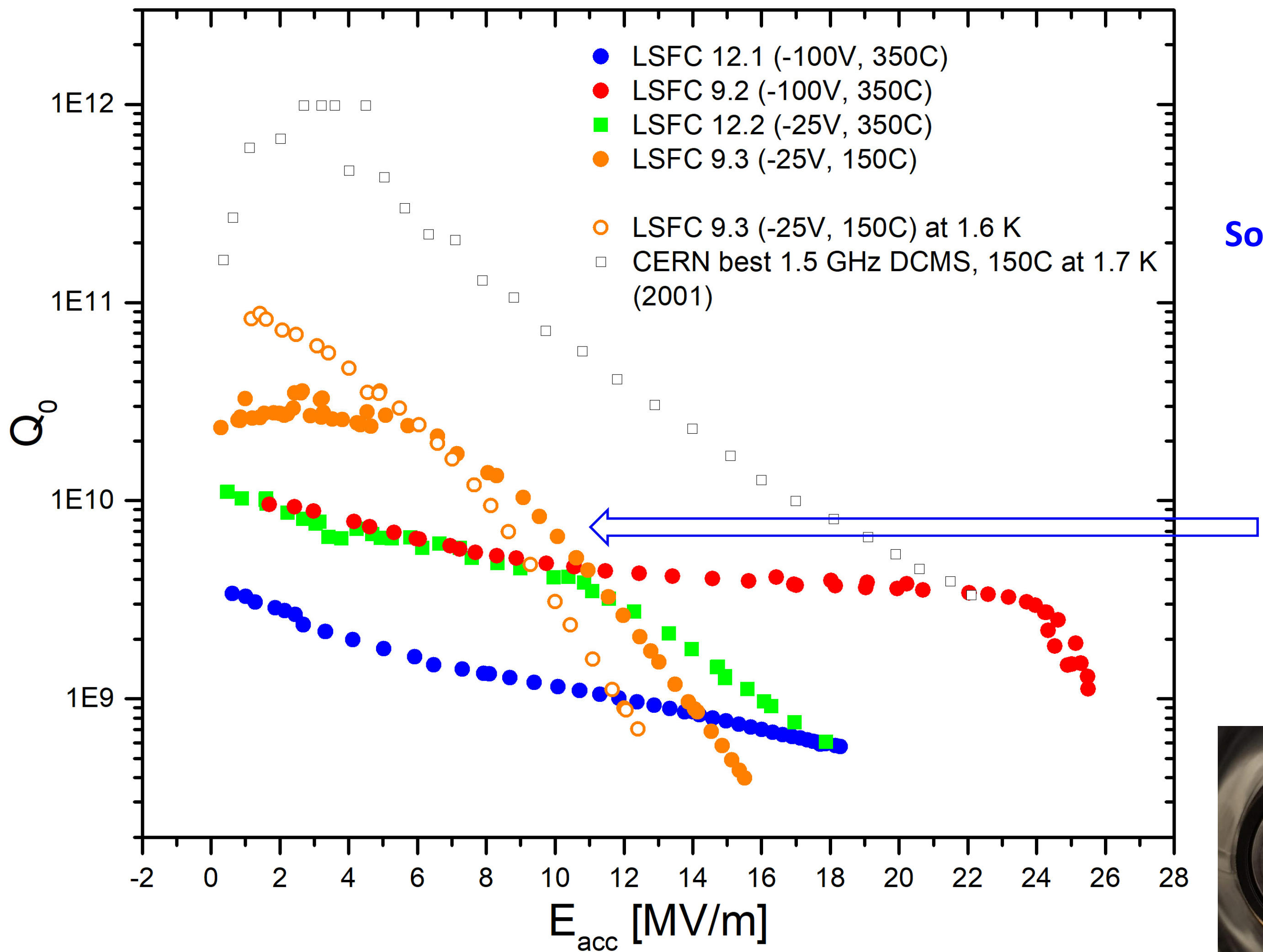


HiPIMS Cavities RF Behavior



Cool down has significant influence on losses – flux pinning

HiPIMS Nb/Cu Film RF Results on 1.3 GHz cavities

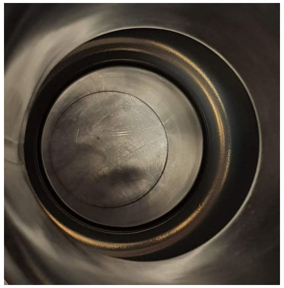


6 cavities coated
11 RF test cycles

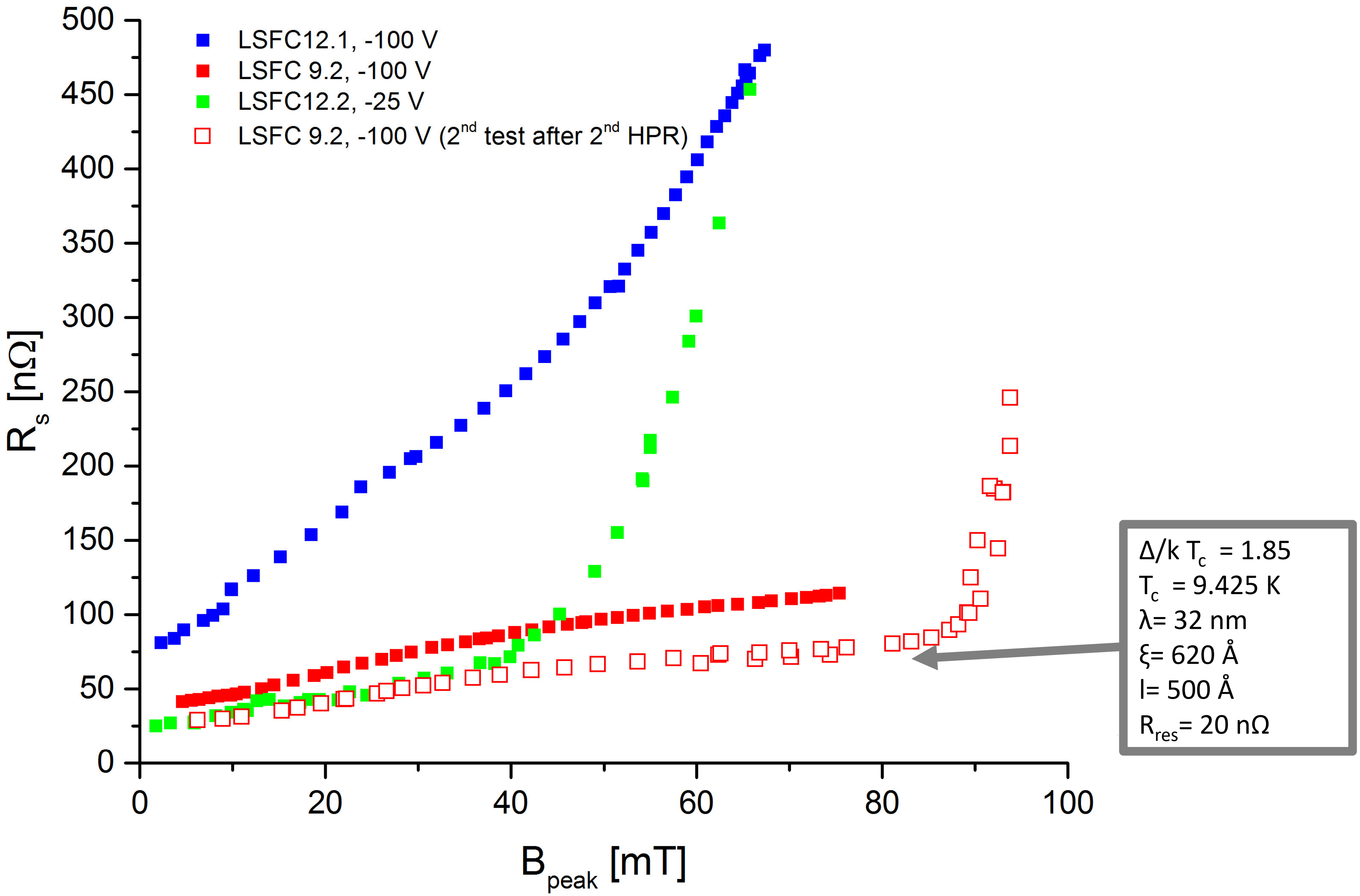
Films sustain HPR at full pressure

Some HiPIMS Nb/Cu cavities show mitigation of the characteristic Q-slope

Contamination in system can rapidly degrade RF performance (From $>10^{10}$ to $5x10^{8}$, then $6x10^{7}$...)



HiPIMS Cavities – Substrate Quality Issues



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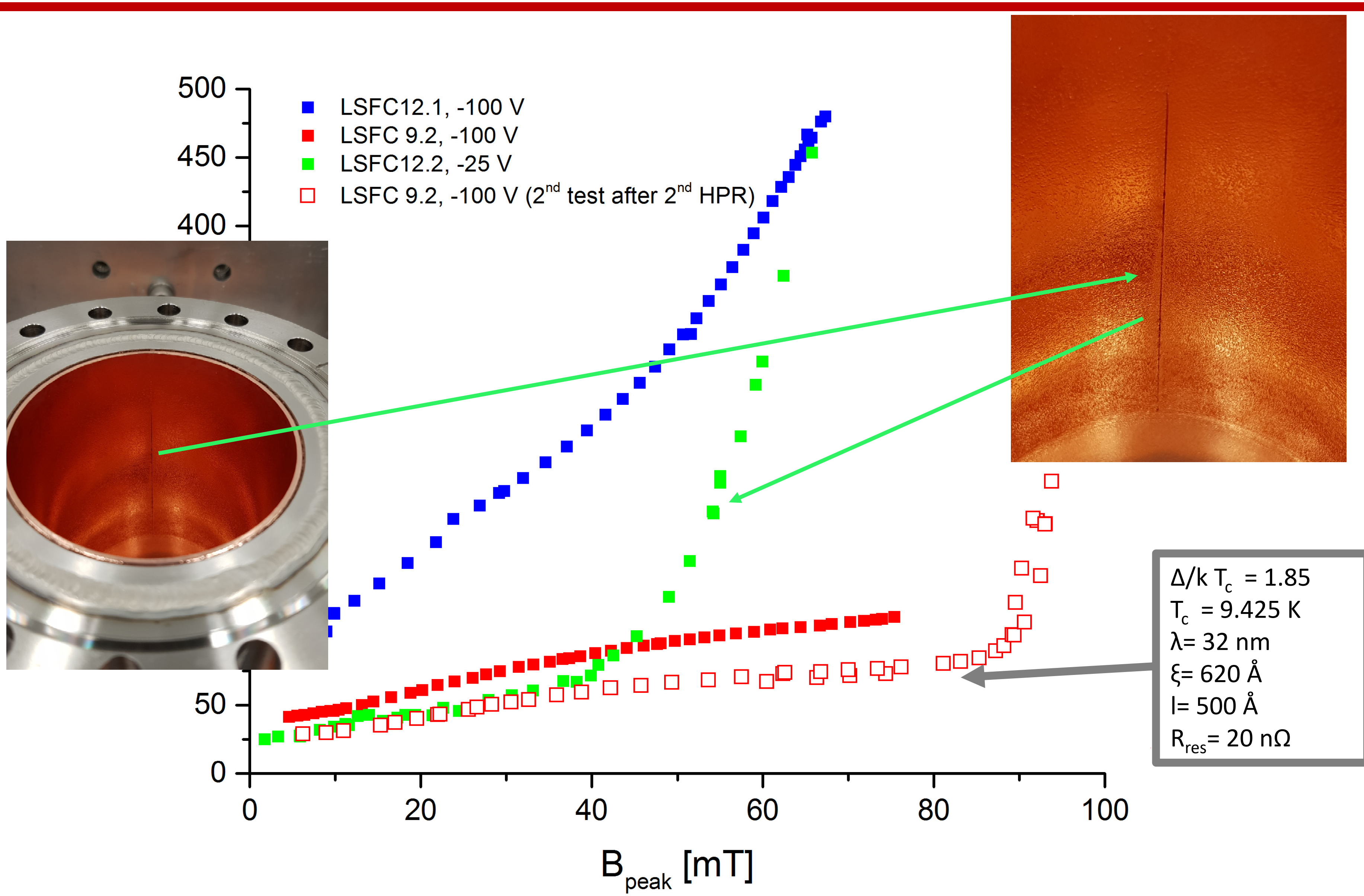
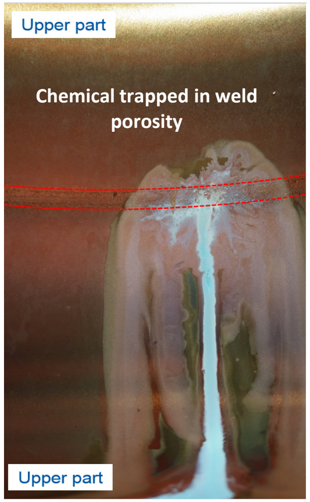


Cavity Manufacturing Issues

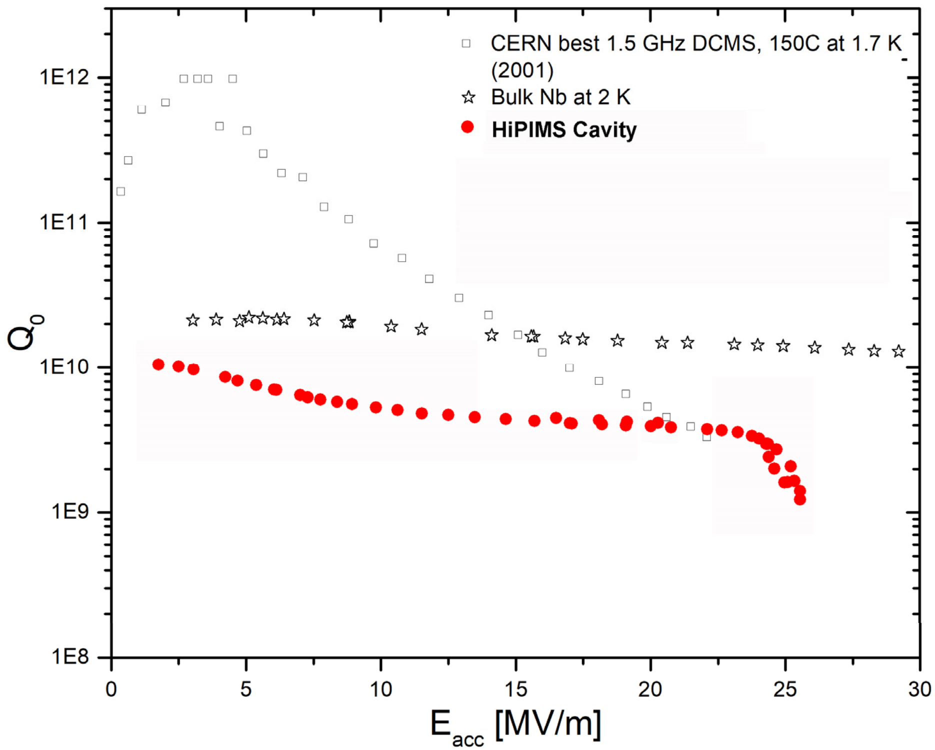
- Cracks on Seam Welds
  - Not visible after welding or CBP
  - Exposed after multiple acid etching cycles

- Effect on Films
  - ❖ Acid trapped potentially leading to film poisoning, delamination …
  - ❖ Cracks could cause locally thinner films
  - ❖ In extreme cases films so thin that Cu may be uncovered to RF field or film thin enough that RF field can probe Cu underneath



CONCLUSION & Future Work

- Mitigation of Q-slope for HiPIMS Cavities



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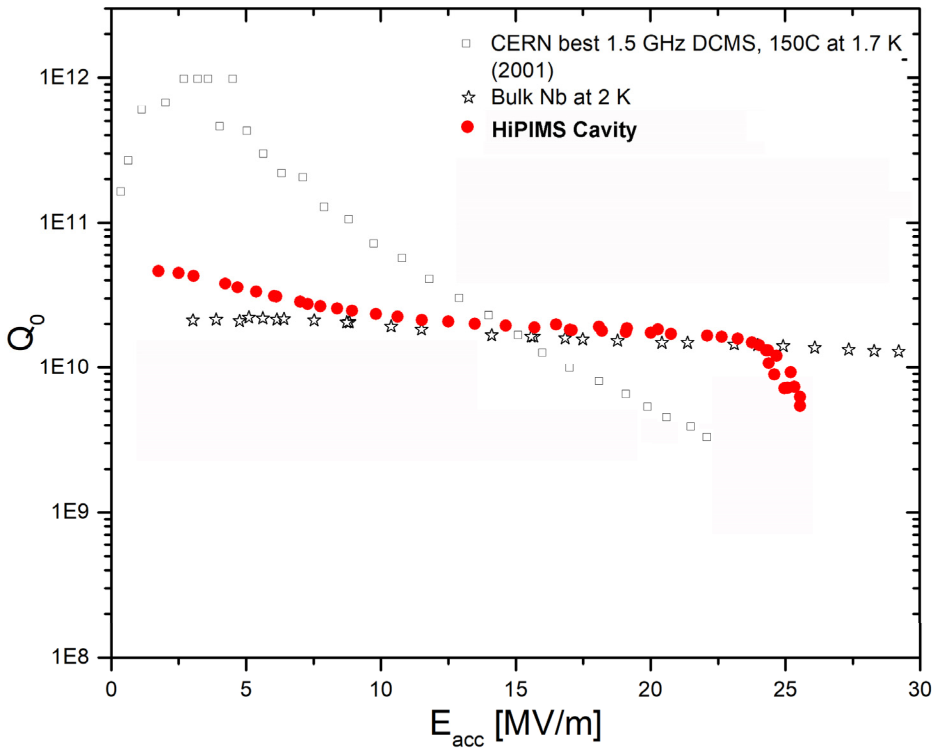

CONCLUSION & Future Work

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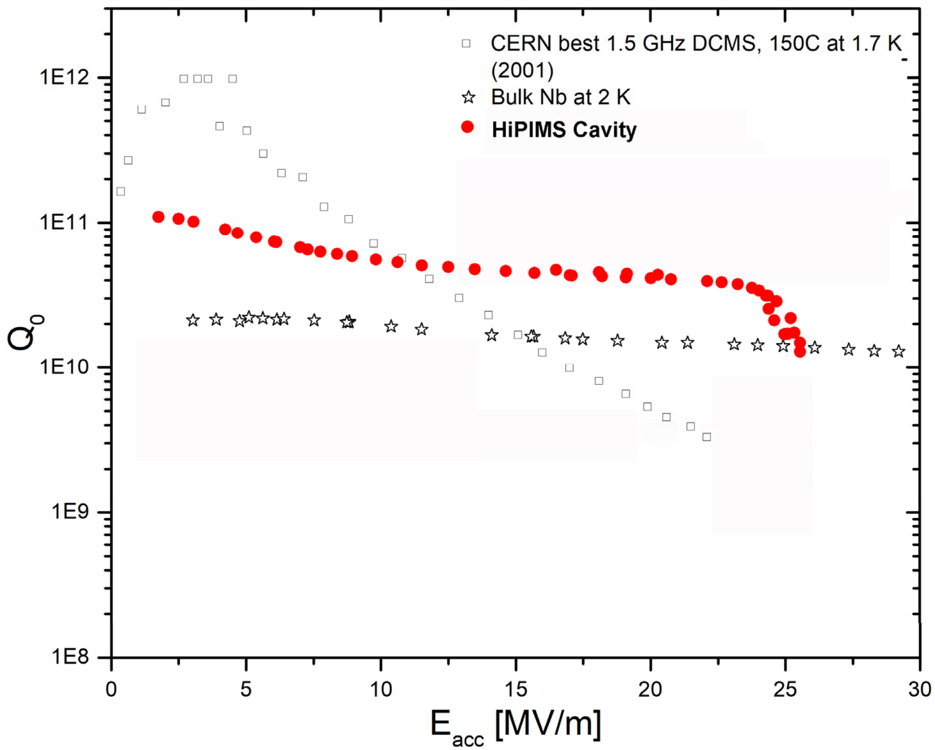

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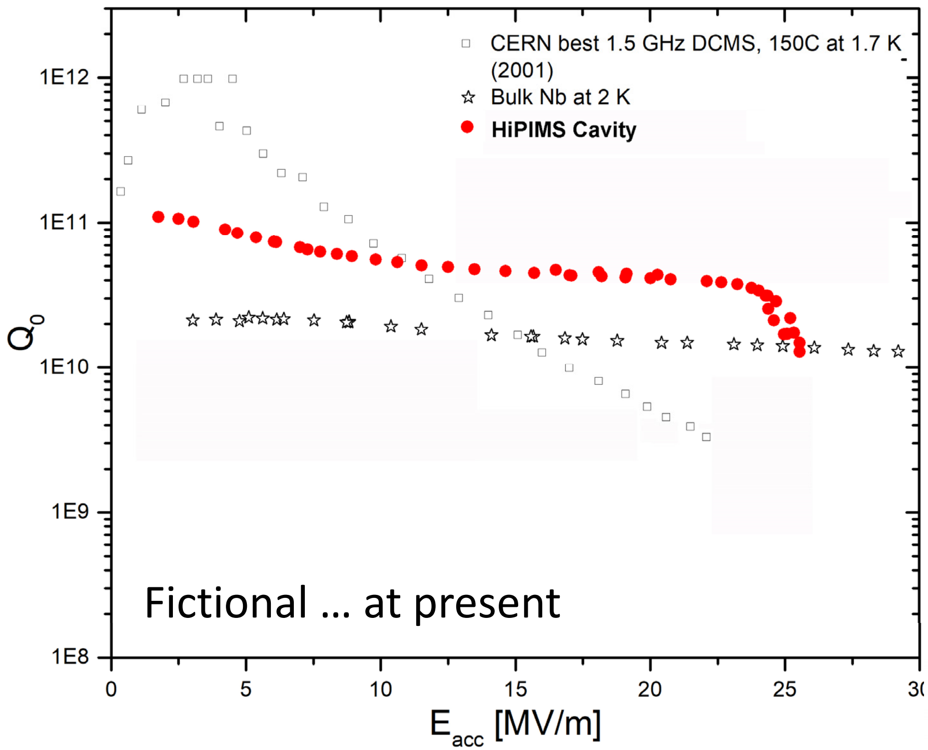

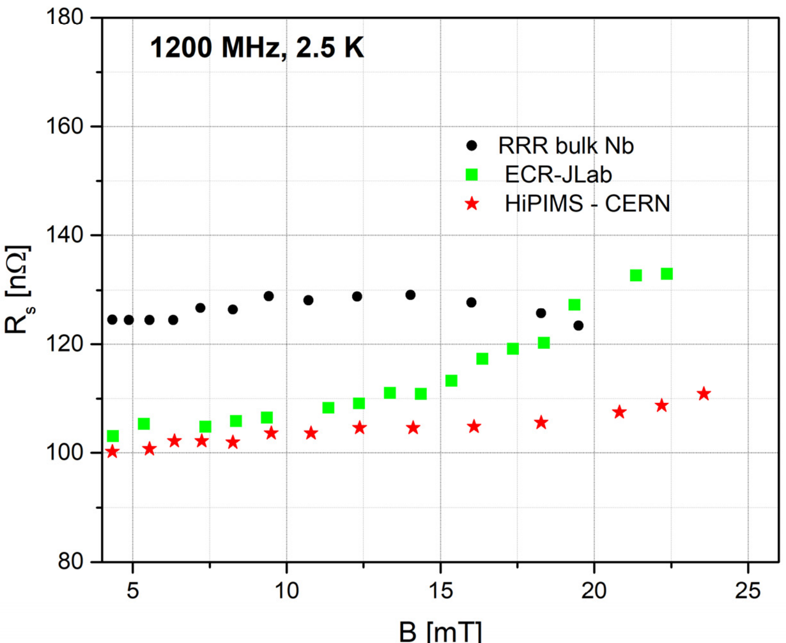

Courtesy M. Arzeo, G. Rosaz

CONCLUSION & Future Work

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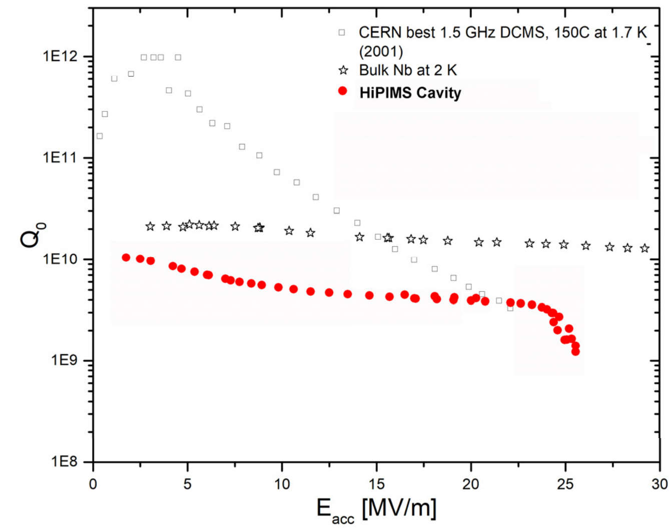
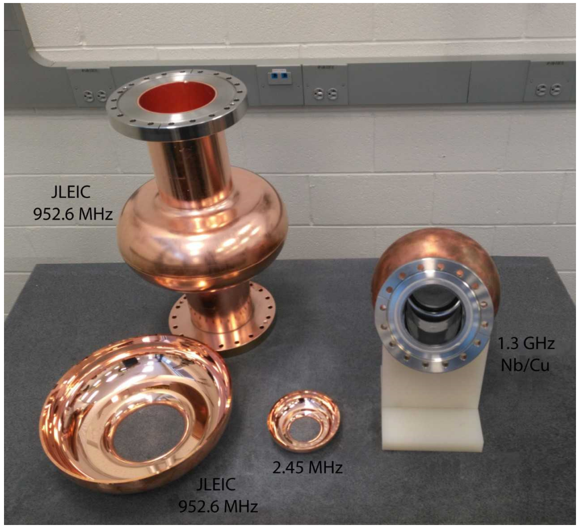


Principal challenges at present

- ❑ Establish adequate process controls
- ❑ **Need better substrates** see MOP007 (O. Azzolini), FRCAB2 (G. Rosaz)
- ❑ **Need better chemical processes**
  - ➡ EP development
- ❑ "Turn the knobs" to truly engineer the SRF surface by manipulating the film growth conditions
- ❑ Deposition on JLEIC cavities (952.6 MHz)



DANKE
THANK YOU