



Coaching vendors on cavity processing

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Poland/WUST



Importance of clear expectations

- Experience from a number of both large and small projects highlights the importance of having **very clear expectations** with SRF cavity vendors.
- CEBAF 12 GeV Upgrade, ILC R&D, EXFEL, **LCLS-II**, **SNS PPU**, **LCLS-II HE**, CEBAF C75 cavities, ...
- It is very important to distinguish for each procurement whether one is
 - (a) "ordering up" the vendor's "standard" process without the requestor having to understand the details, **or**
 - (b) prescribing the detailed process that the vendor is then obligated to implement.
- The vendors are careful to not accept responsibility for "development".
 - They will in (a) repeat what they have done previously without thoughtful adaptation, or, in (b), implement and charge for doing what they are told to do.
 - *Vendor performance accountability is to the implementation of agreed processes, not to the eventual RF performance of delivered cavities.* [But incentive bonuses may help.]

Importance of clear expectations

- **Component mechanical specification** – dimensional tolerancing
 - Know what you want in detail, and communicate that unambiguously via drawings
- **Component mechanical fabrication** – dimensional and surface finish QA
 - Vendors will want flexibility in fabrication methods for their own efficiency
 - Check them – review their detailed procedures and dwgs and/or set key “hold point” acceptance checks. (Of course respect any proprietary aspects.) *“Coaching” opportunity*
- **Mid-fabrication processes**
 - Cleanliness of EB weld prep is **amazingly important**
 - Actual handling technique and tooling between parts etching/cleaning and EBW is critical
 - Individual personnel training and verification is indicated *“Coaching” opportunity*
 - Don’t rely on general training – technique QA is worth the effort

Importance of clear expectations

- **Cavity processing** – after mechanical fabrication
 - BCP, US, EP, HPR, HT, and “doping” are various items on the “menu”
 - The details of each are specific to each cavity geometry
 - Beware of simple extrapolations from processes used successfully on other geometries
 - Vendor and lab infrastructures are different, so processing procedures must be thoughtfully adapted to each circumstance *“Coaching” opportunity*
- **Cavity assembly for testing**
 - Final cleaning and clean assembly for delivery
 - Particulate free for field emission free cavity performance
 - Personnel technique is everything – component cleaning, disciplined motion habits, assembly sequence ... *“Coaching” opportunity*

For assured success with each new requirement, qualification runs are required, then Quality Assurance measures must be implemented to ensure that the applied processes are stable over time.

Importance of clear expectations

- **Example – electropolishing Nb cavities**

- EP of Nb cavities evolved empirically from its introduction on Tristan cavities at KEK, through successful use on EXFEL cavities and some ILC R&D cavities.
- Electrochemical research by Tian @ JLab and Eozénou @ CEA 2005-2010 clarified the basic process [refs. later]
- Implications for various applications have slowly propagated and been refined since then
- Note: There are no “Nb EP experts” in industry *“Coaching” opportunity*

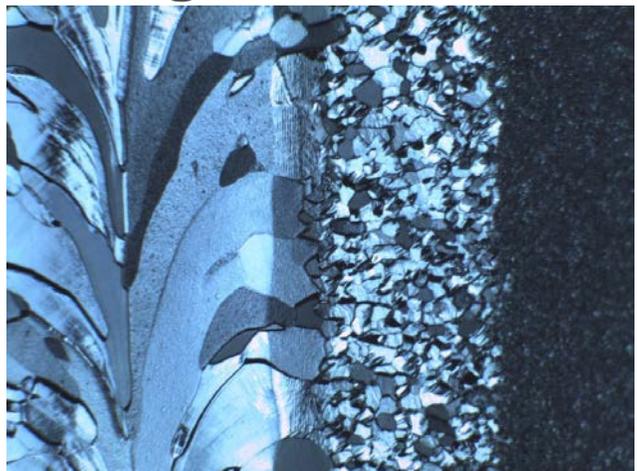
Importance of clear expectations

- Example – electropolishing Nb cavities
- **Why very geometry specific? - Basic highlights:**
 - Desired “EP” condition is “diffusion-limited”, not etching
 - Local current density depends only on HF concentration and local temperature
 - Local removal rate is thus very sensitive to local temperature
 - Local heat generation is inversely proportional to distance from cathode
 - Beampipes and iris will heat more, but polishing is most important at equators
 - Without external cooling, the acid also serves as process coolant
 - Non-uniform flow = non-uniform cooling = non-uniform temperature = non-uniform removal
 - Must find balance $\gg V$ high enough for equator EP, but not too high for iris removal
 - Total cavity current = total cathode current
 - Cathode polarization potential is proportional to cathode current density
 - Maximize cathode surface area – else generate Sulfur precipitation \gg FE source
 - Too low voltage operation loads cavity with H and etches equators
 - Creates both “Q disease” and “Q-slope” !!

Importance of clear expectations

- Example – electropolishing Nb cavities

HB EP development cavity test at JLab for PPU



HB-71 equator views with Kyoto camera

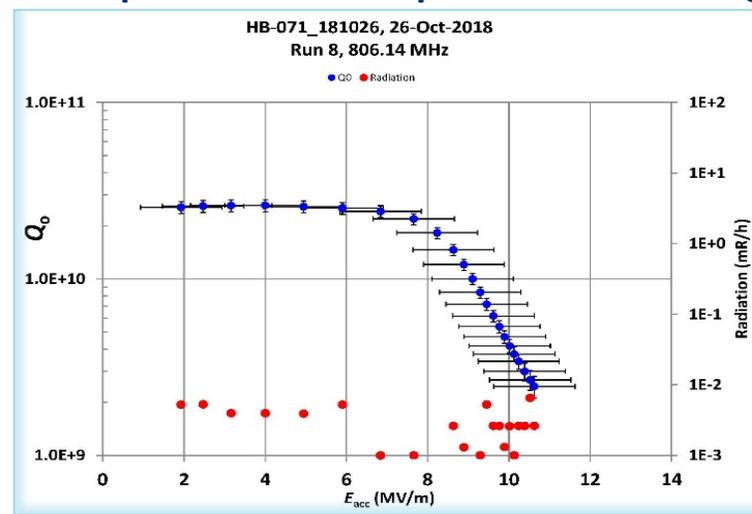


V=17 V, plenty high

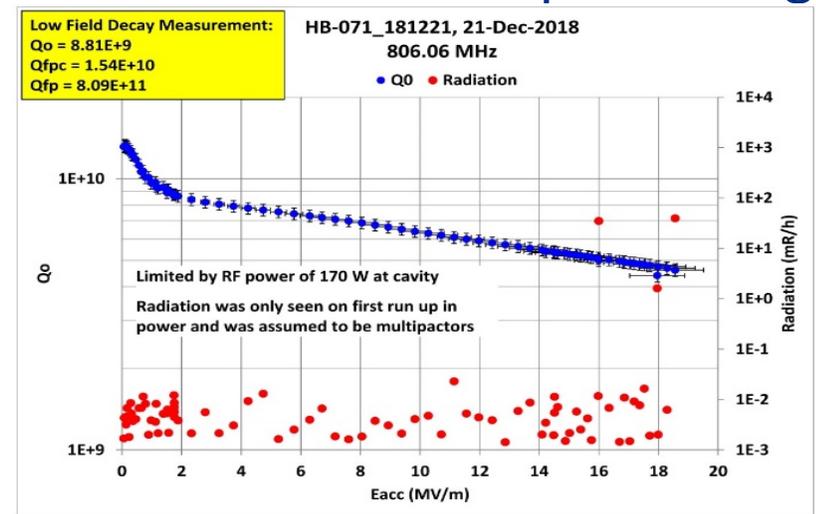


$\beta = 0.81, 805 \text{ MHz}$

“Q-slope” from equator etching



“Q-disease” from 1st processing



Importance of clear expectations

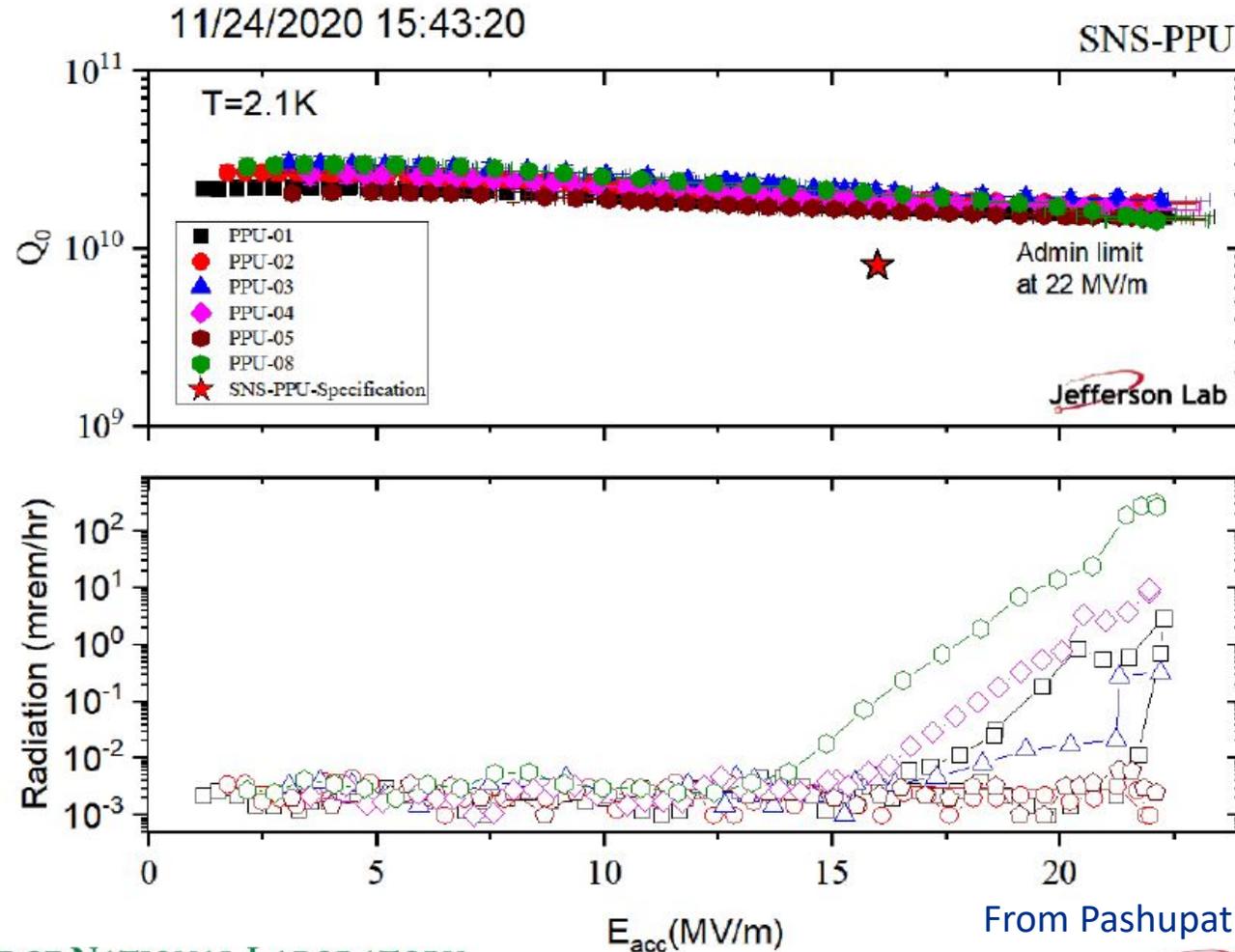
- Example – electropolishing Nb cavities
 - Based on lessons learned, we **coached** PPU cavity vendor during development run at their site to find an implementation on their particular equipment which provided ~uniform temperature and adequate voltage setting for assured polishing at HB cavity equators.

Importance of clear expectations

CAVITY PERFORMANCE

Example:

- PPU production cavities
- Vendor electropolishing 805 MHz SNS HB cavities for PPU
- After coaching regarding acid temperature, flow rate, and applied voltage.
- Excellent $Q \propto v E$.
- Further coaching for FE reduction was required.



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From Pashupati Dhakal

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- It is very important to distinguish for each procurement whether one is
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 - (b) prescribing the detailed process that the vendor is then obligated to implement.
- There must be detailed involvement with your project's specific implementation details, if you require the best final performance.
- Don't miss your ***“Coaching” opportunities*** when launching vendor work, then follow up with Quality Assurance monitoring.

References for Nb Electropolish

USPAS 2015 EP tutorial:

<https://indico.jlab.org/event/98/contributions/7440/attachments/6311/8359/13T - BCP and EP for Nb Cavities v2.pdf>

Papers:

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