PROGRESS TOWARD 2 K HIGH PERFORMANCE HALF-WAVE RESONATORS AND CRYOMODULE

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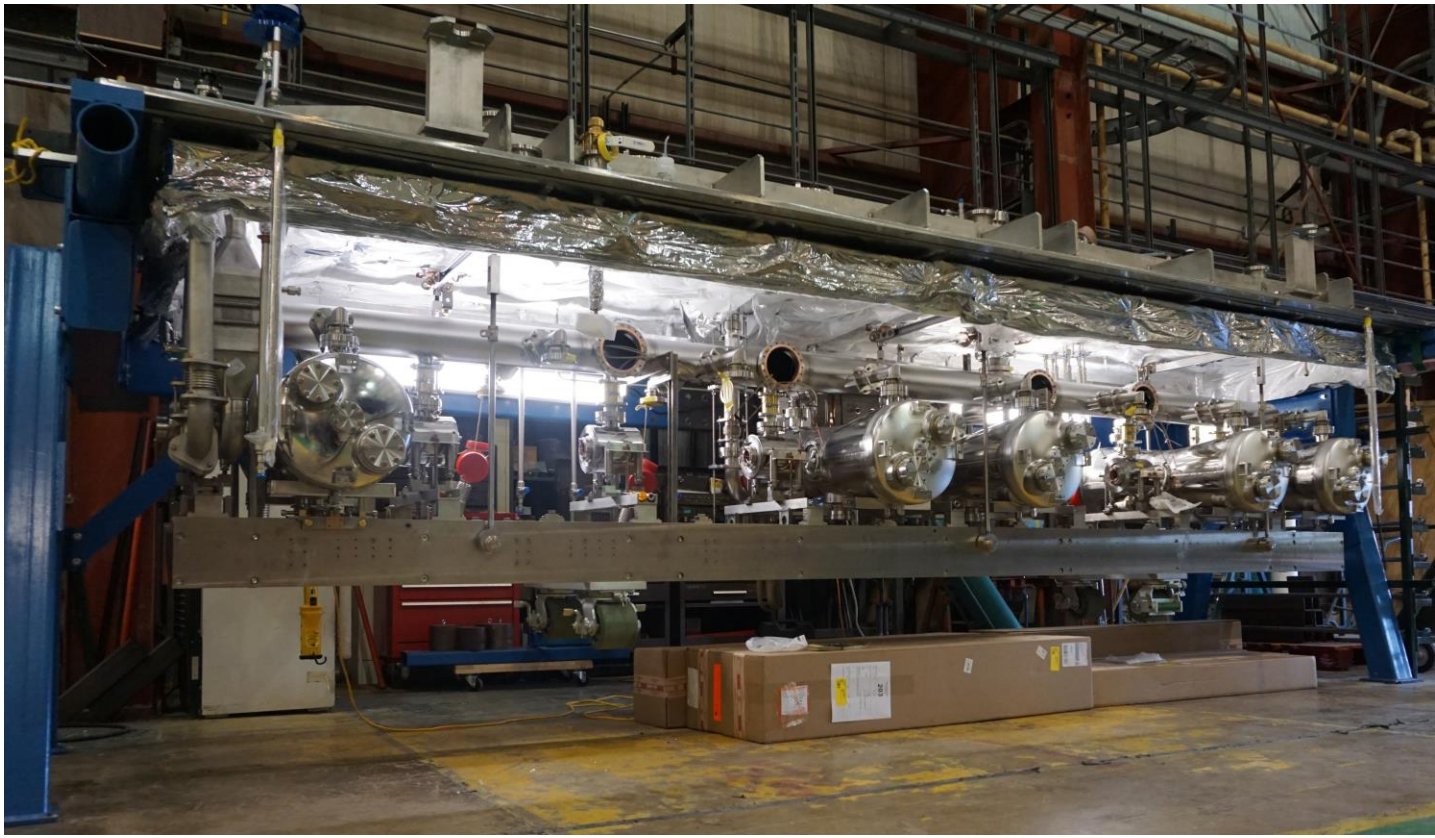
OUTLINE

- Half-Wave Resonators
- Cryomodule Overview
- Half-Wave Resonator Processing and Testing
- Future Work

Test Assembly of the HWR Cryomodule Cold Mass/Lid



For FNAL's Proton Improvement Plan II's (PIP-II) Project details refer to MOYA05, M.P. Kelly & A. Rowe's "SRF Technology for PIP-II and III"

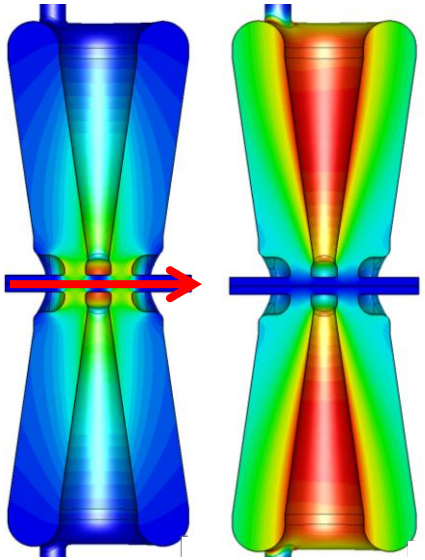
For power coupler details look forward to FRXBA03, M.P. Kelly's Presentation "Coaxial Power Coupler Development at ANL"

HALF WAVE RESONATOR DEVELOPMENT

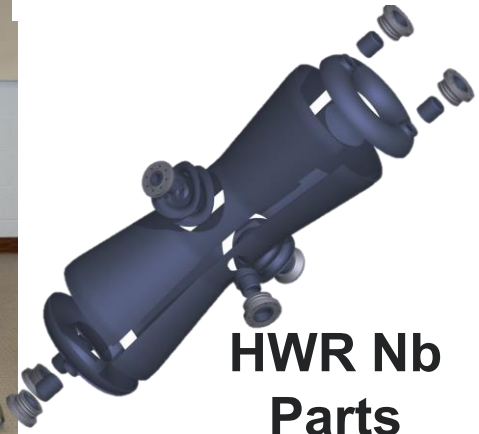
- SRF 2015:
  - Two prototypes finished and tested.
  - Low field R_{res}~2.5 nΩ.
  - Peak surface fields ~ 90 MV/m and 95 mT, electric and magnetic respectively.
- Now:
  - Finished fabrication and processing of 7 production HWRs.
  - 2.0 K testing of 5 of the 7 finished.
  - Low field R_{res}~2.5 nΩ.
  - Reaching higher peak surface fields.

Cavity Type	HWR
Freq. (MHz)	162.5
β	0.112
l_{eff} (cm, βλ)	20.68
E_{pk}/E_{acc}	4.7
B_{pk}/E_{acc} (mT/(MV/m))	5.0
QR_s (Ω)	48.1
R_{sh}/Q (Ω)	272

Electromagnetic Field Intensity

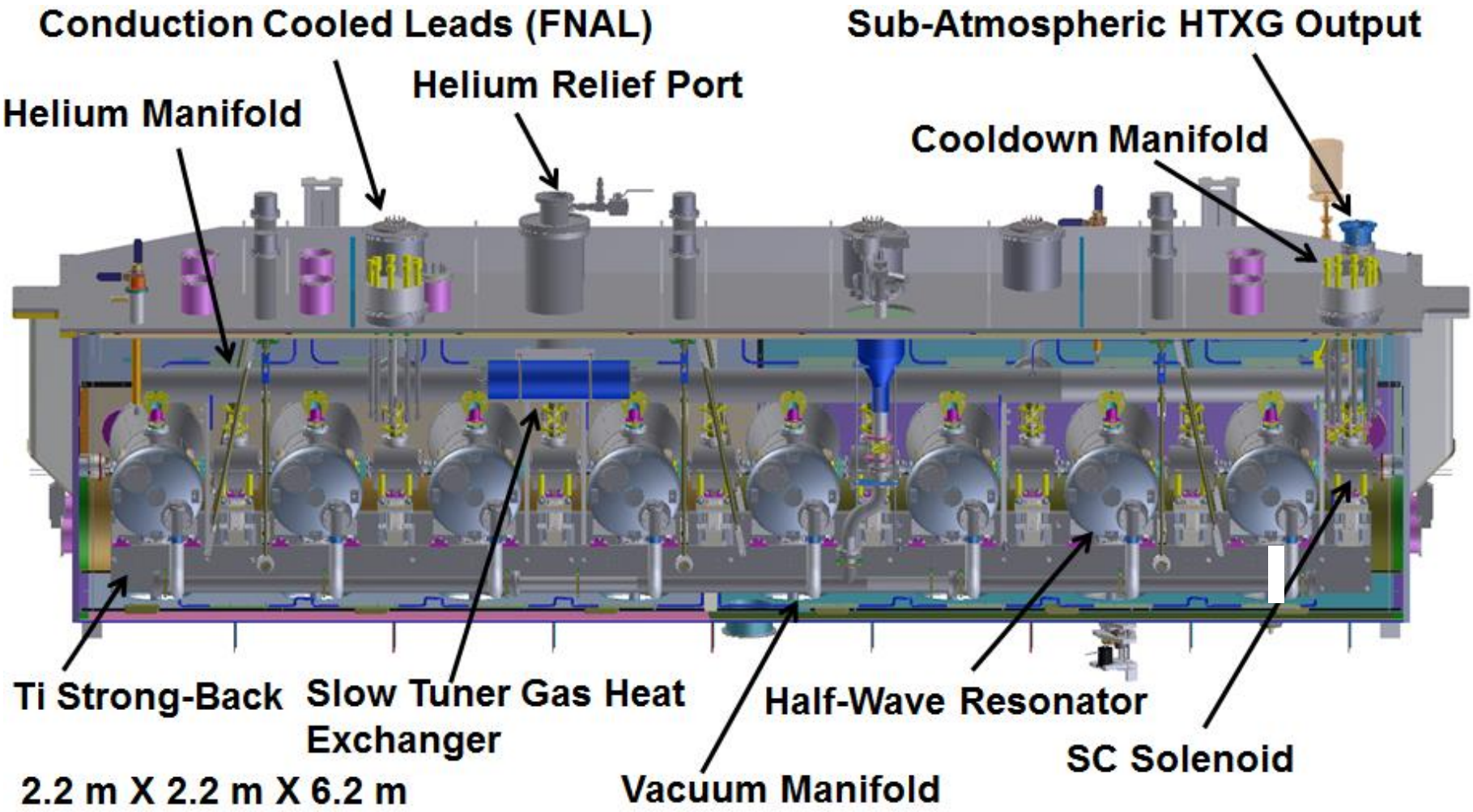


E-Field H-Field



HWR Nb Parts

2.0 K HWR CRYOMODULE OVERVIEW

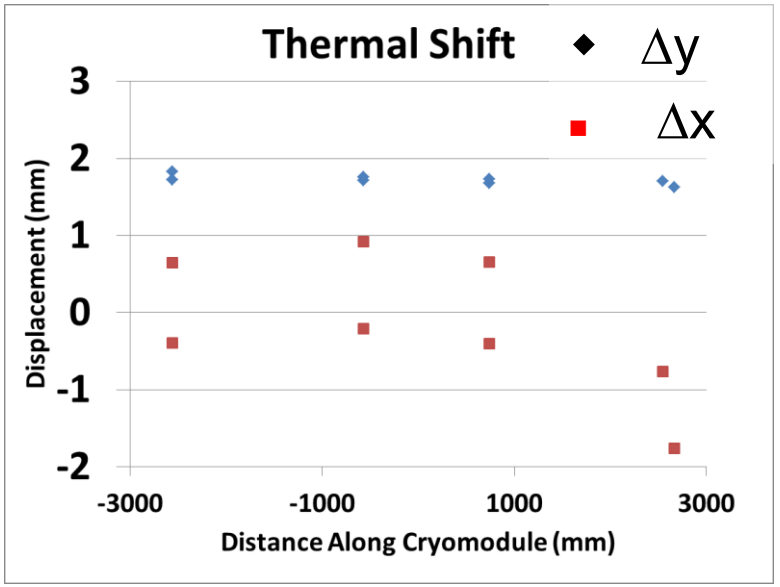


- 2 MV with < 2 W dynamic thermal load per HWR.
- ANL designed & fabricated for PIP-II @ FNAL.
- Continued ANL/FNAL collaboration: low-particulate cleaning, hydrogen degassing, sub-atmospheric heat exchanger, precision alignment, etc

80 K ENGINEERING COOLDOWN

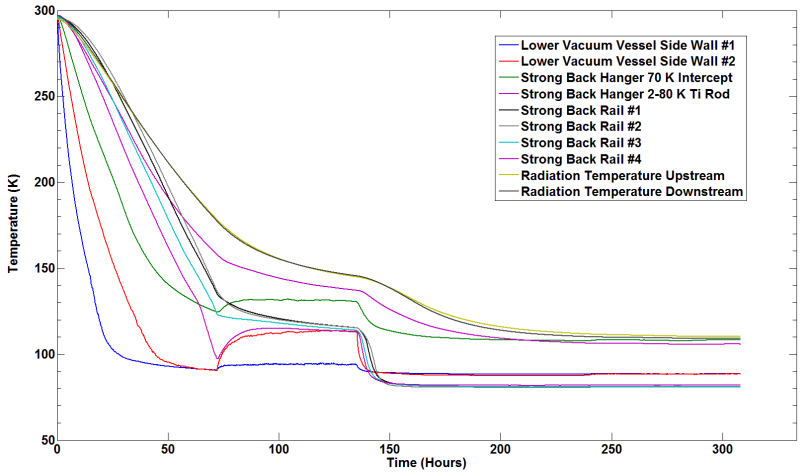
Cryomodule Alignment

Alignment Measurements



Cryomodule Assembly

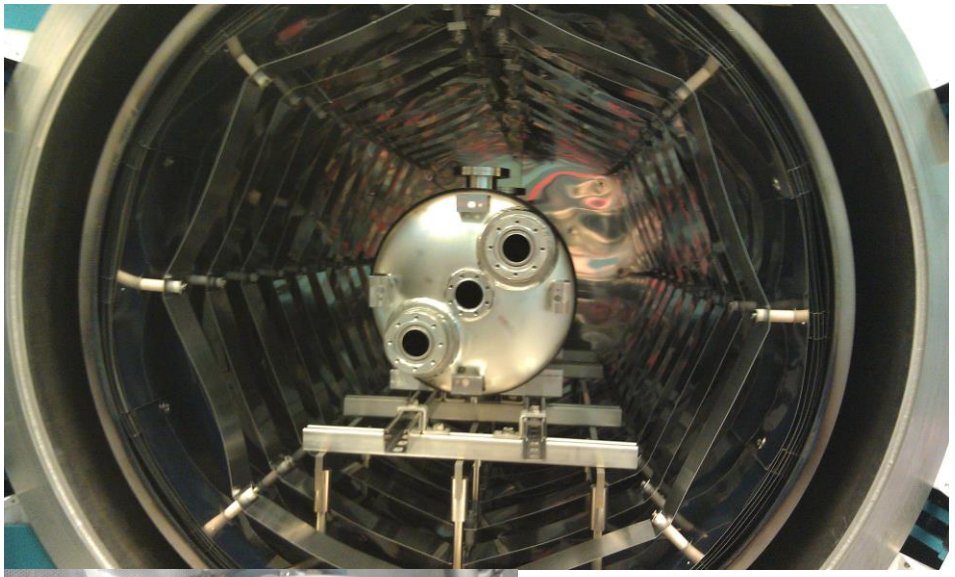
Cool Down Data

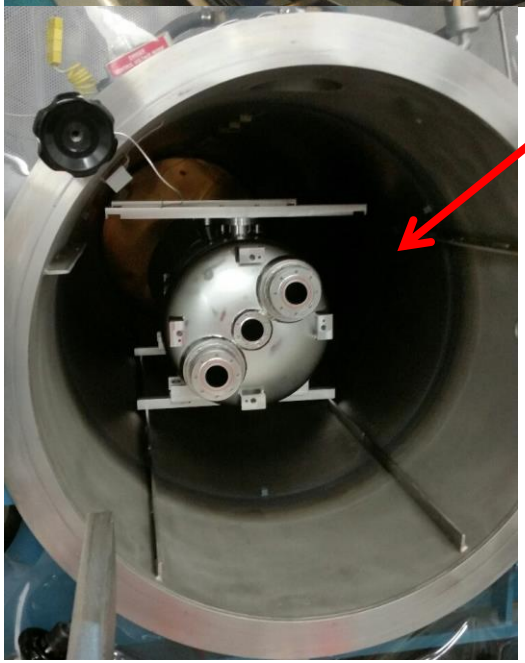


HWR FABRICATION

- Careful electrostatic discharge and conventional machining.
- Niobium sheet used to form reentrant noses (high E_{peak}) had scratches and dents removed via hand polishing prior to forming.
- All high field surfaces polished with 60, 120, 240, 300 and 400 grit sandpaper.
- BCP polished parts for 5-10 minutes at T < 25 C prior to welding. Not just the weld seam but the heat affected zone +.
- Post fabrication chemical polishing.

HWR @ FNAL for H-Degassing





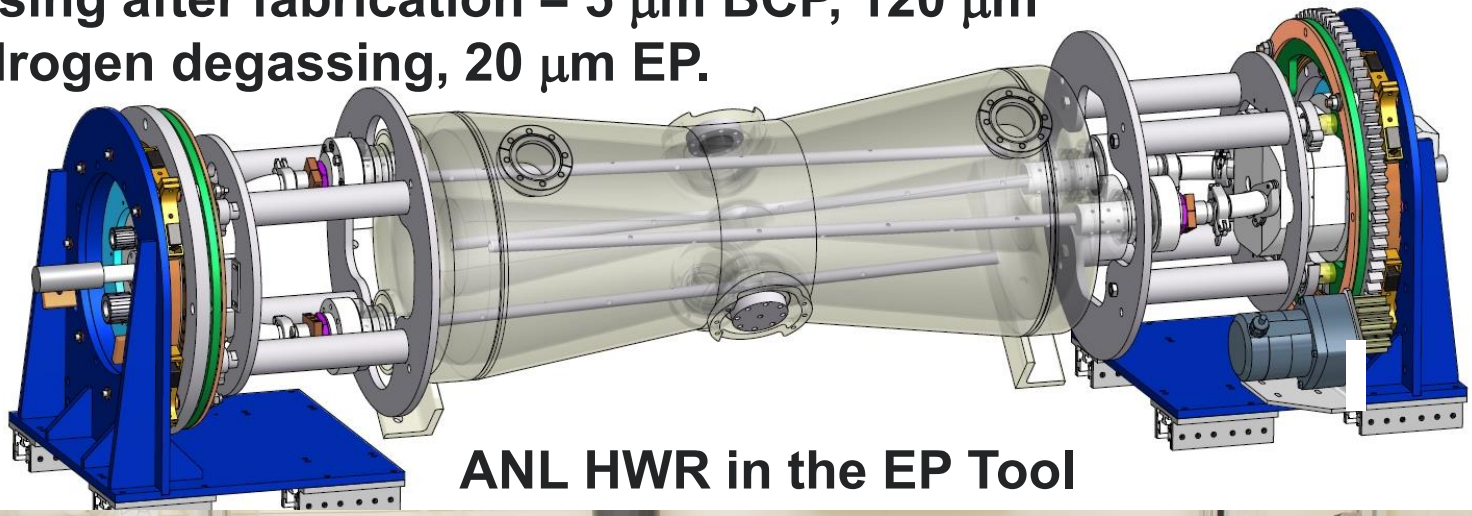
HWR @ BNL for H-Degassing

Many thanks to FNAL (A. Rowe, M. Merio) and BNL (S. Seberg, K. Smith, W. Xu) for hydrogen degassing.

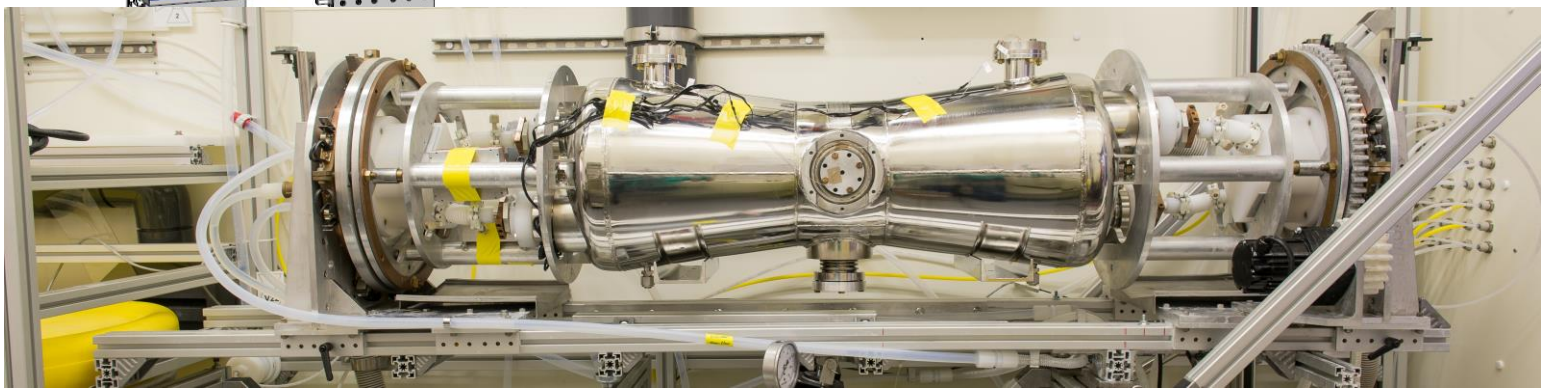
HWR POLISHING

- All processing done in the joint ANL-FNAL surface processing facility.
  - M.P. Kelly and T.C. Reid 2017 Supercond. Sci. Tech. 30 043001
- Processing after fabrication = 5 μm BCP, 120 μm EP, hydrogen degassing, 20 μm EP.

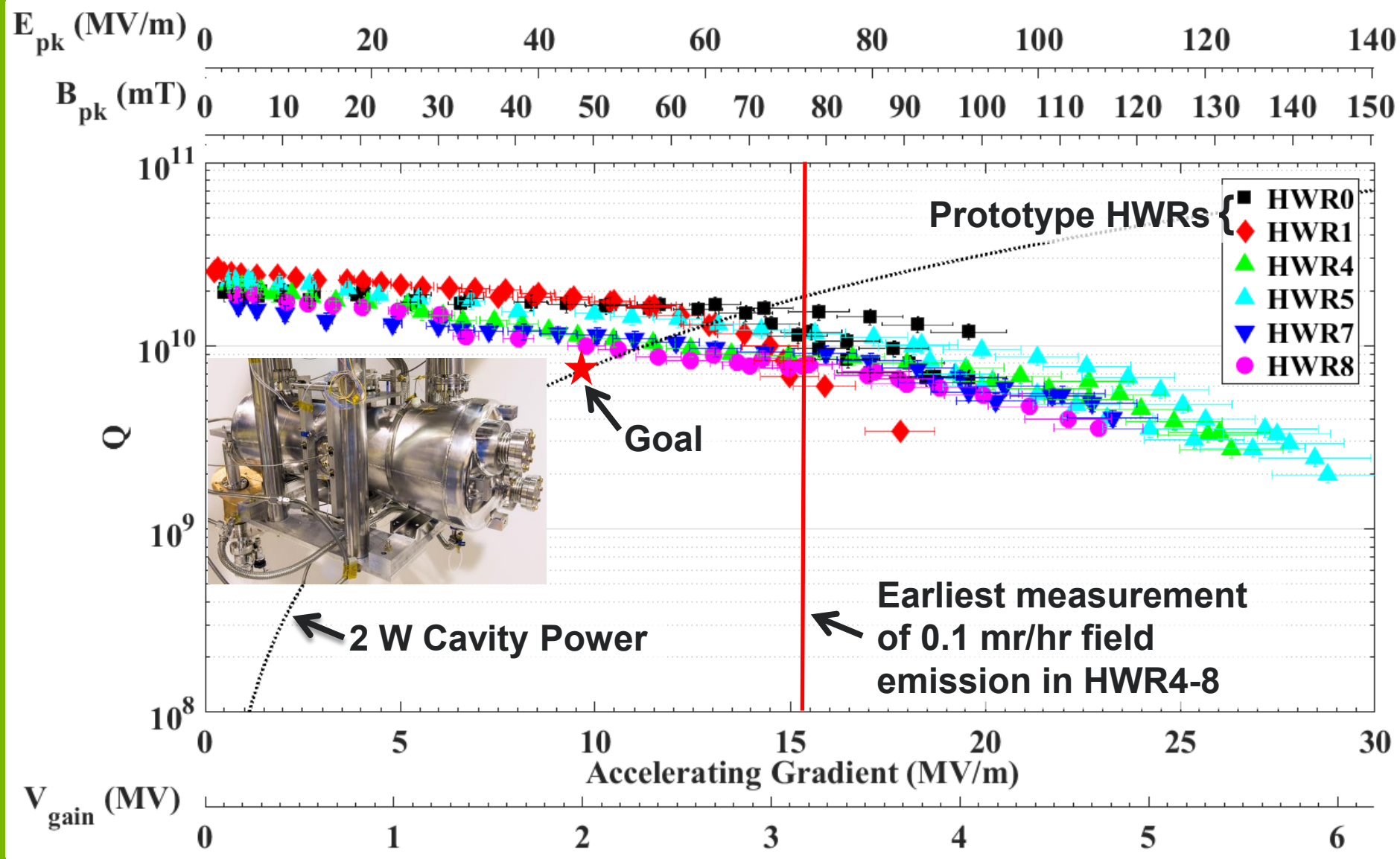
Post EP HWR Interior



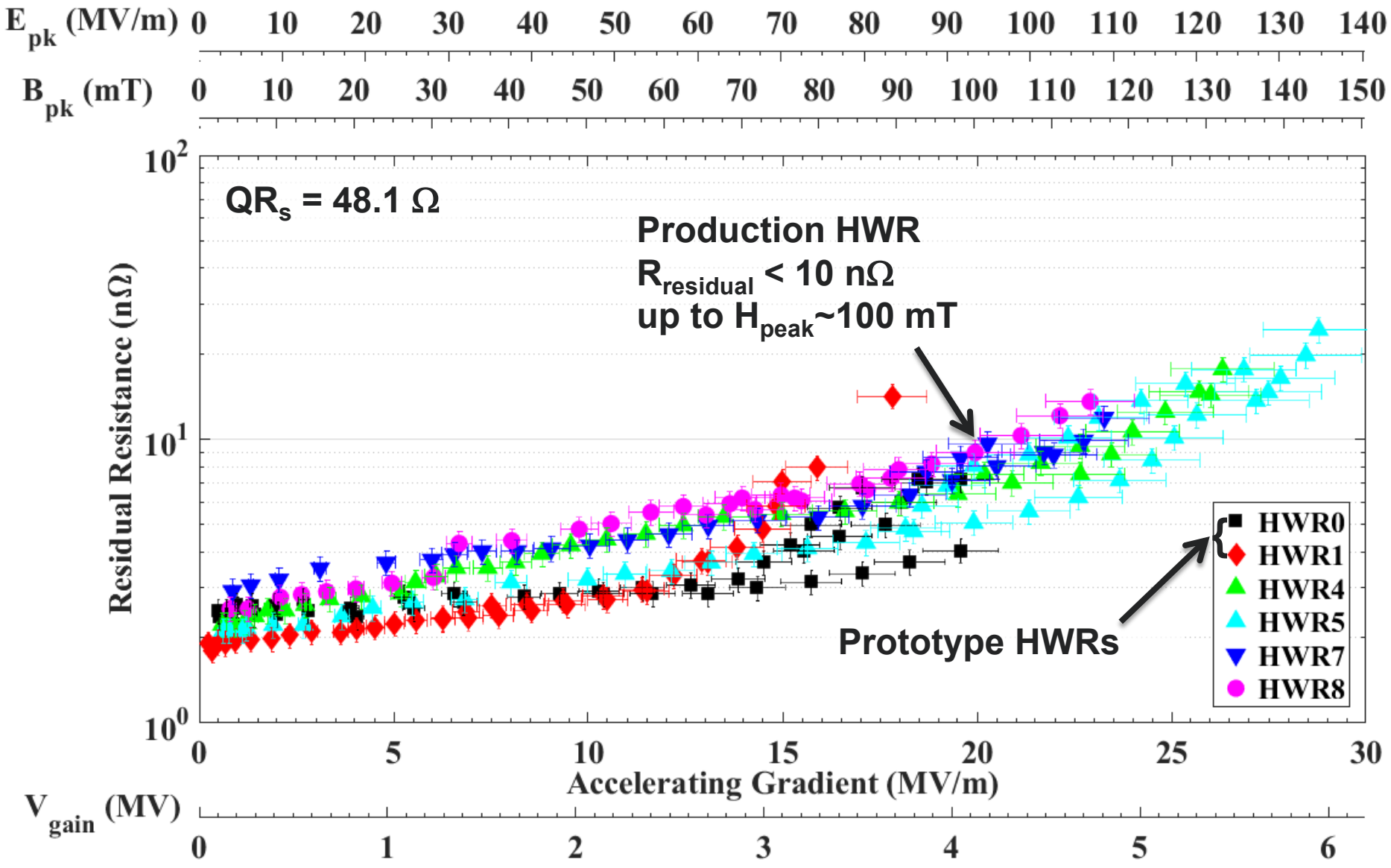
ANL HWR in the EP Tool



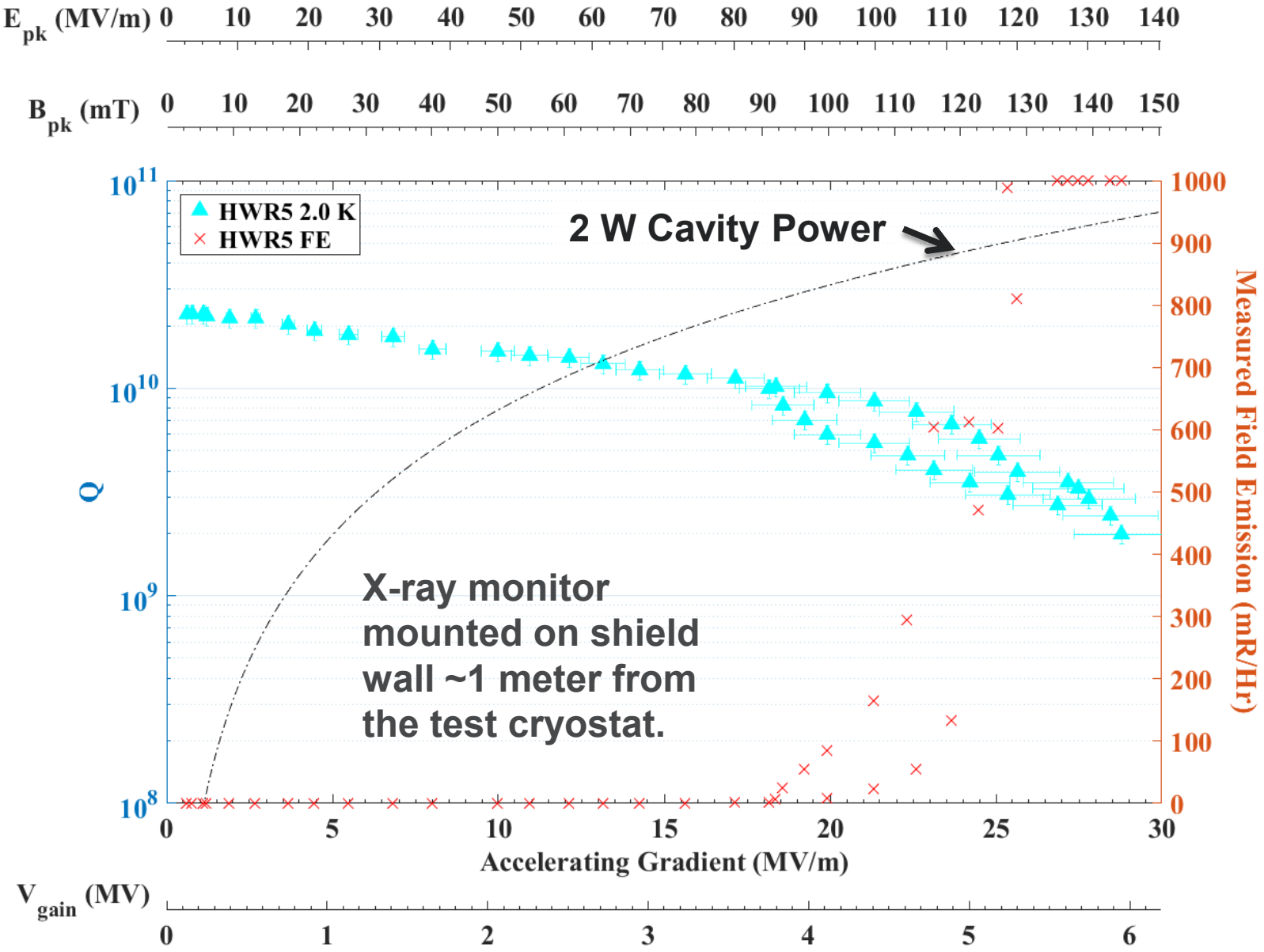
HWR 2.0 K OFFLINE RESULTS



2.0 K HWR RESIDUAL RESISTANCE



EXAMPLE: HWR5 FIELD EMISSION



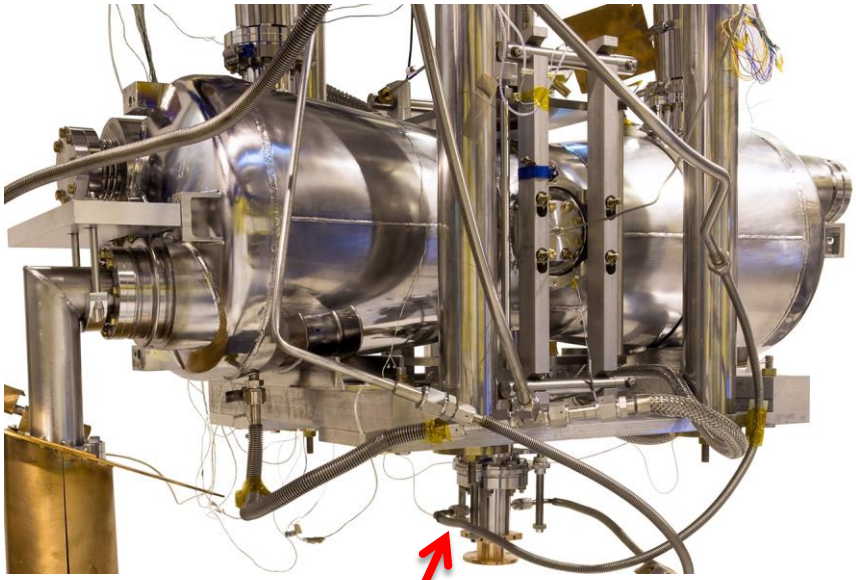
HWR PROCESSING AND TESTING ISSUES

Not every process was smooth:

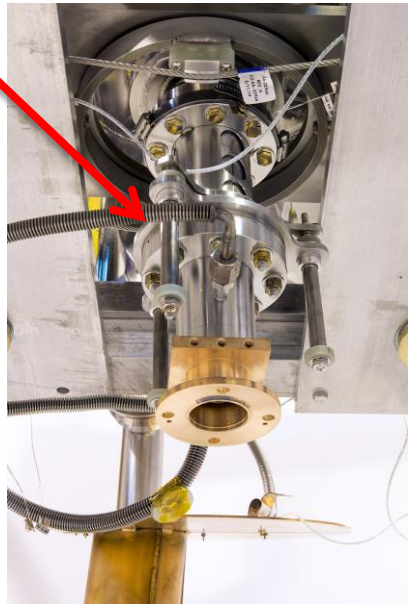
- **During first HWR4 test a glow discharge was initiated in the power coupler.**

- **During first HPR of HWR5 the HPR water hose cracked and HPR pressure was very low.**
  - **First test was poor, E_{acc}<6 MV/m.**
  - **Second test was shown on the previous slide.**

- **During bulk EP of HWR6 an aluminum cathode was improperly inserted into the cavity. An electrical arc occurred early in the EP process.**

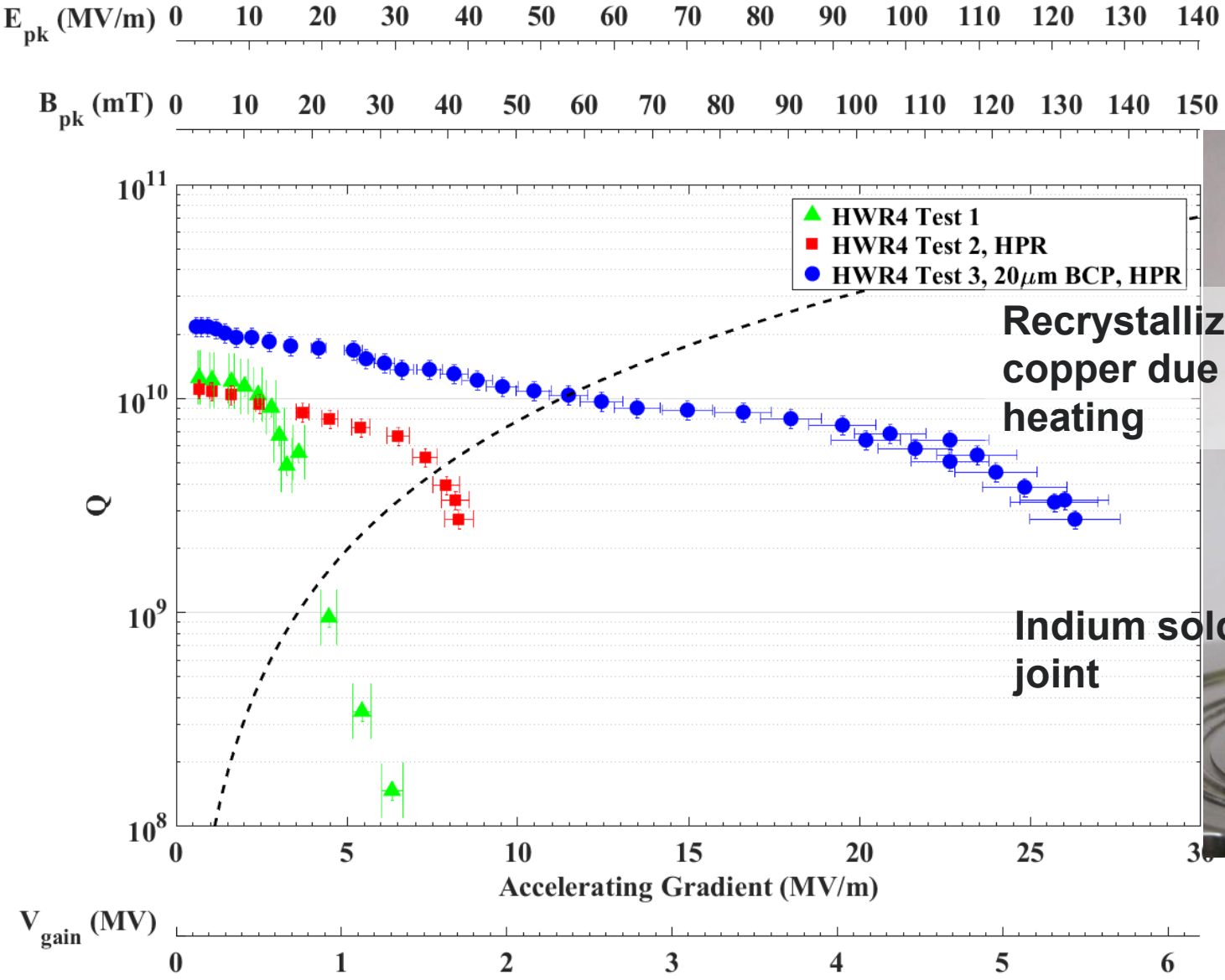


Power Coupler

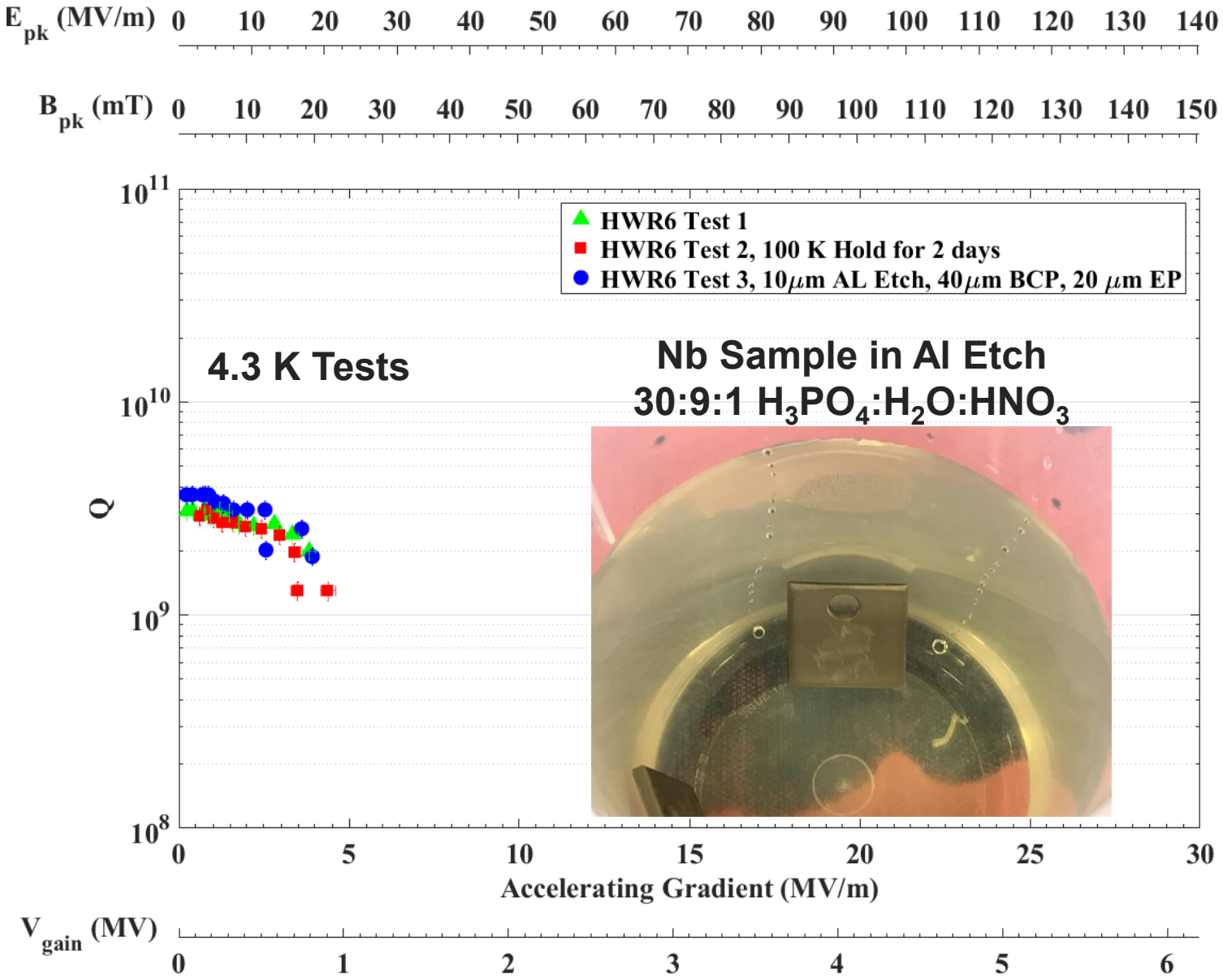


1) Broken vacuum pump.
2) Bad cavity vacuum.
3) Coupler discharge during 1st test.

HWR4 TEST ING AND PROCESSING HISTORY



HWR6 TEST AND PROCESSING HISTORY



FUTURE WORK

- 6 of 8 HWRs ready for installation in the cryomodule.
- The last 2 HWRs have been processed and are ready for 2.0 K testing.
- 1 HWR requires more diagnostics.
- 134 MV/m and 144 mT peak surface electric and magnetic fields, respectively, achieved in recent HWR testing.
  - Special attention to surface cleaning and surface roughness.
- How to go to higher E_{peak}?
  - Increased HPR water pressure is marginal.
  - Smoother surface?
    - Already mirror smooth after EP.
  - Alternative surface cleaning process?
- <u>Assemble and commission the cryomodule.</u>