Advanced Quarter- and Half-Wave Resonator Development at ANL

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Acknowledgements

ANL SRF cavities benefit from many collaborations:

- FNAL: cavity surface processing and cavity design.
- AES: cavity fabrication and cavity design.
- Meyer Tool and Manufacturing: helium jackets.
- Argonne Central Shops: everything.
- Soreq-NRC: Cavity design.
- Many other vendors: EDM, precision machining, welding, brazing, baking etc…

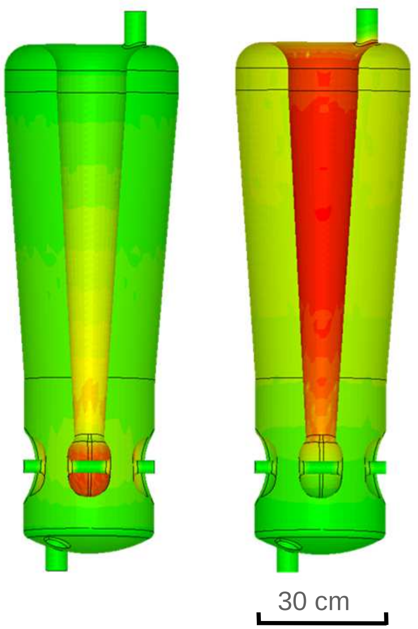
Thank you

Goals of ANL SRF Work

- We develop cost-effective ion linacs using:
  - Highly optimized compact lattice designs.
  - High-performance SRF cavities; including the RF design, cavity fabrication and processing.
  - High-performance compact magnet packages.
- For the remainder of this presentation the focus will be on SRF cavities:
  - Cavity design optimization.
  - Fabrication methodology and select techniques.
  - Cavity processing.
  - Recent cavity performance.
  - Current work status.
  - Future plans.

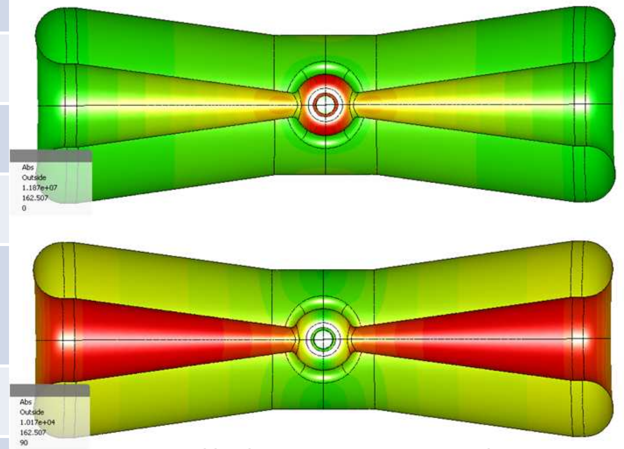
Cavity Design Optimization

β = 0.077 72 MHz
QWR Surface Fields



Cavity Type	QWR	HWR
Freq. (MHz)	72.75	162.5
β	0.077	0.112
l_{eff} (cm, βλ)	31.75	20.68
E_{pk}/E_{acc}	5.0	4.7
B_{pk}/E_{acc} (mT/(MV/m))	7.1	5.0
QR_s (Ω)	25.9	48.2
R_{sh}/Q (Ω)	568	271.5

β = 0.11 162.5 MHz
HWR Surface Fields

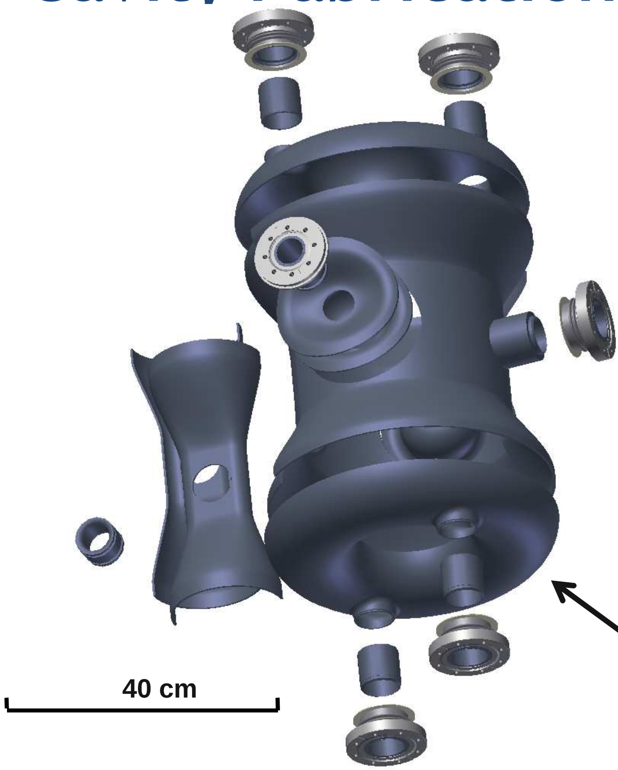


Collaboration with FNAL

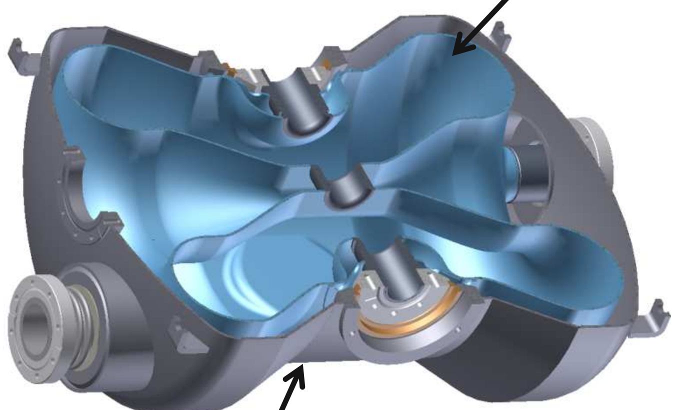
- Optimize RF parameters consistent with beam dynamics, mechanical design, fabrication, processing and cleaning.
- Tapered inner and outer conductors to minimize peak surface fields while maximizing real-estate gradient.
- Mechanical structure optimized to minimize RF power required for phase/amplitude stabilization of RF fields.

See for example: B. Mustapha et al., SRF2011, 192-194 (2012); B. Mustapha et al., IPAC12, 2289-2291, P.N. Ostroumov et al., IPAC12, 2295-2297 (2012); J.R. Delayan, NIM, A259, 341-357 (1987)

Cavity Fabrication



Nb Cavity (RRR > 250)



Stainless Steel

- Most Nb parts are formed (hydroforming or deep drawing).
- Electrostatic discharge machining (EDM).
- Helium jacket built around Nb cavity.
- Ports designed for polishing and cleaning.

Electrostatic Discharge Machining

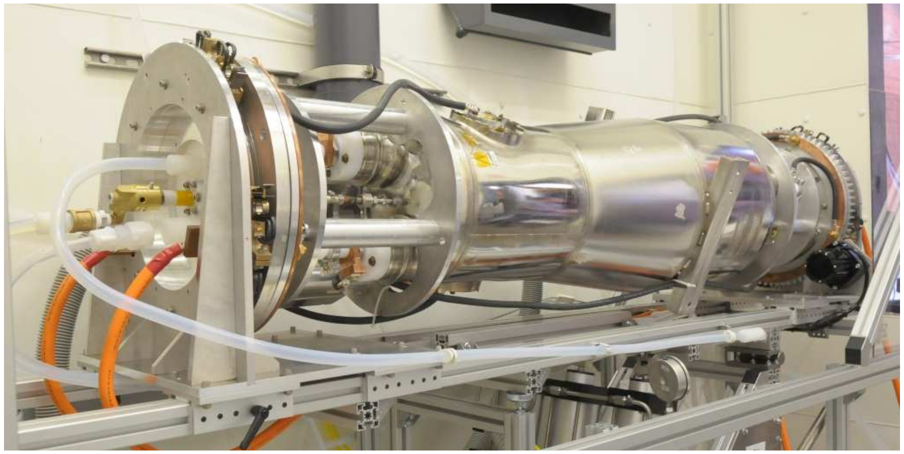
- EDM
  - No chance for cutting bit material inclusions.
  - Leaves a surface recast layer ~ 5 µm thick. BCP removes. EP does not.
  - Lower risk relative to conventional machining.
  - Cheap (~$400 per cut).
  - Simple.

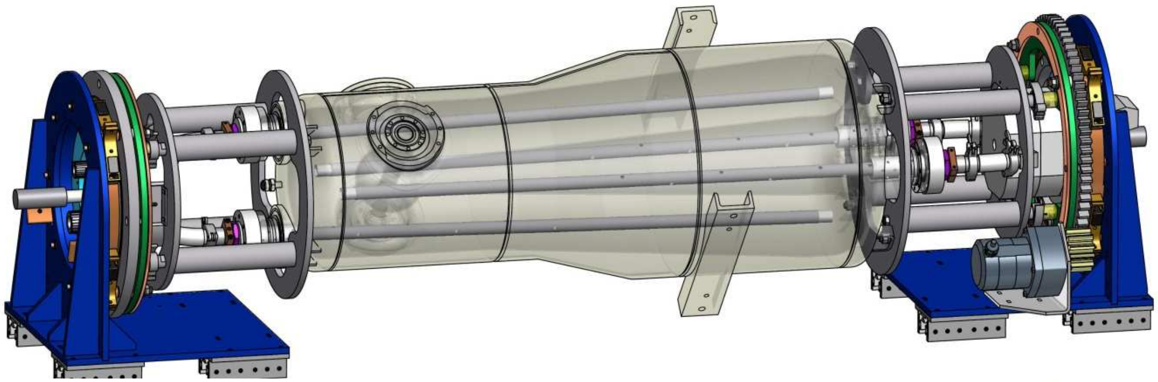
- Details:
  - Brass alloy wires are typically. Other materials are used.
  - 0.0001” tolerances.
  - 0.012” thick wire. 0.016” cut width.
  - Cut speed depends upon setup and machine type. Cost not driven by speed.

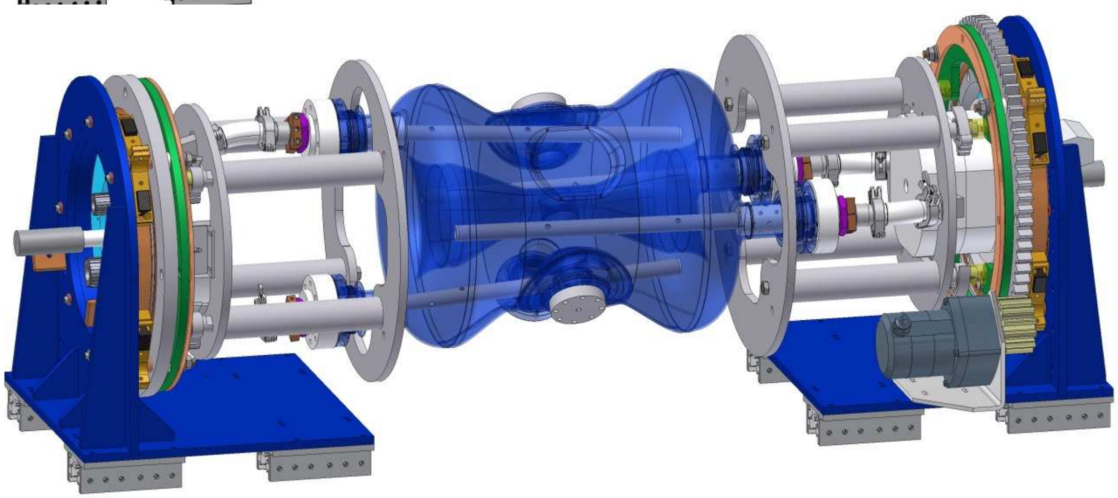
Reentrant Nose Bore EDM

Center Conductor EDM

Cavity Processing: Electropolishing

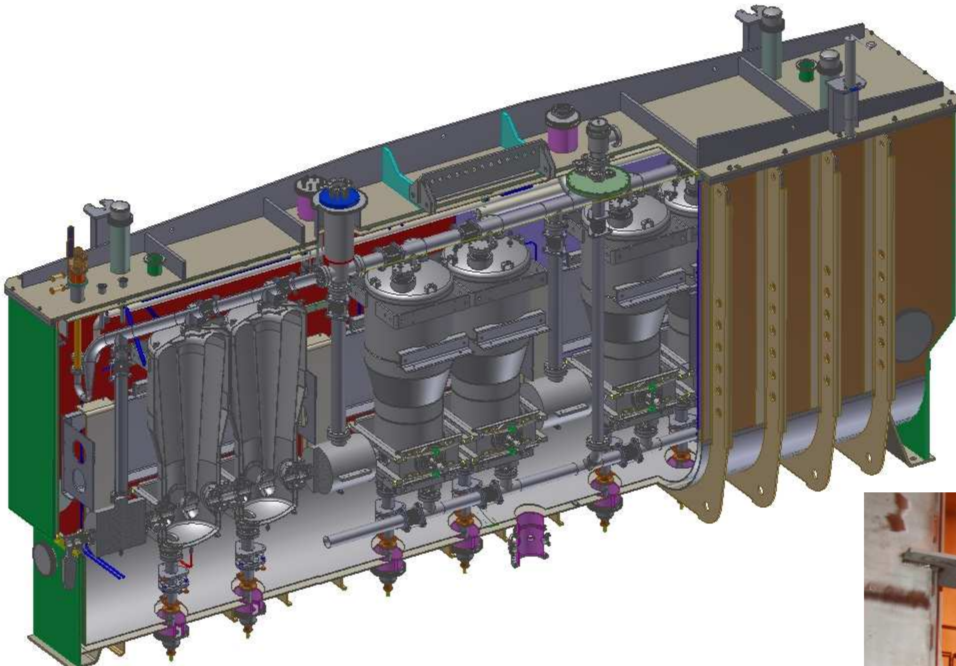




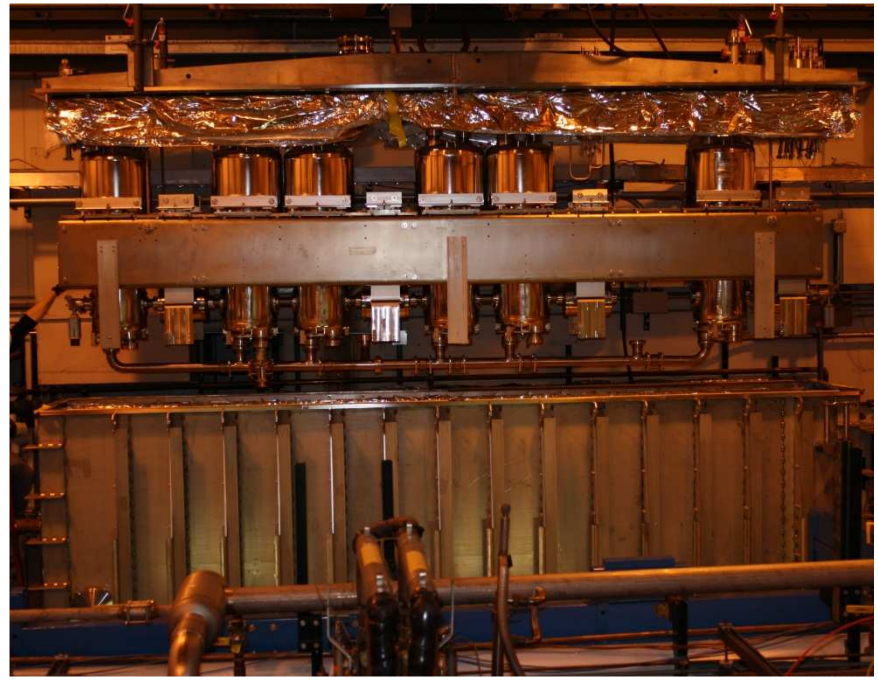


S.M. Gerbick et al., SRF2011, 576-578 (2012)

ANL ATLAS Intensity Upgrade Cryomodule

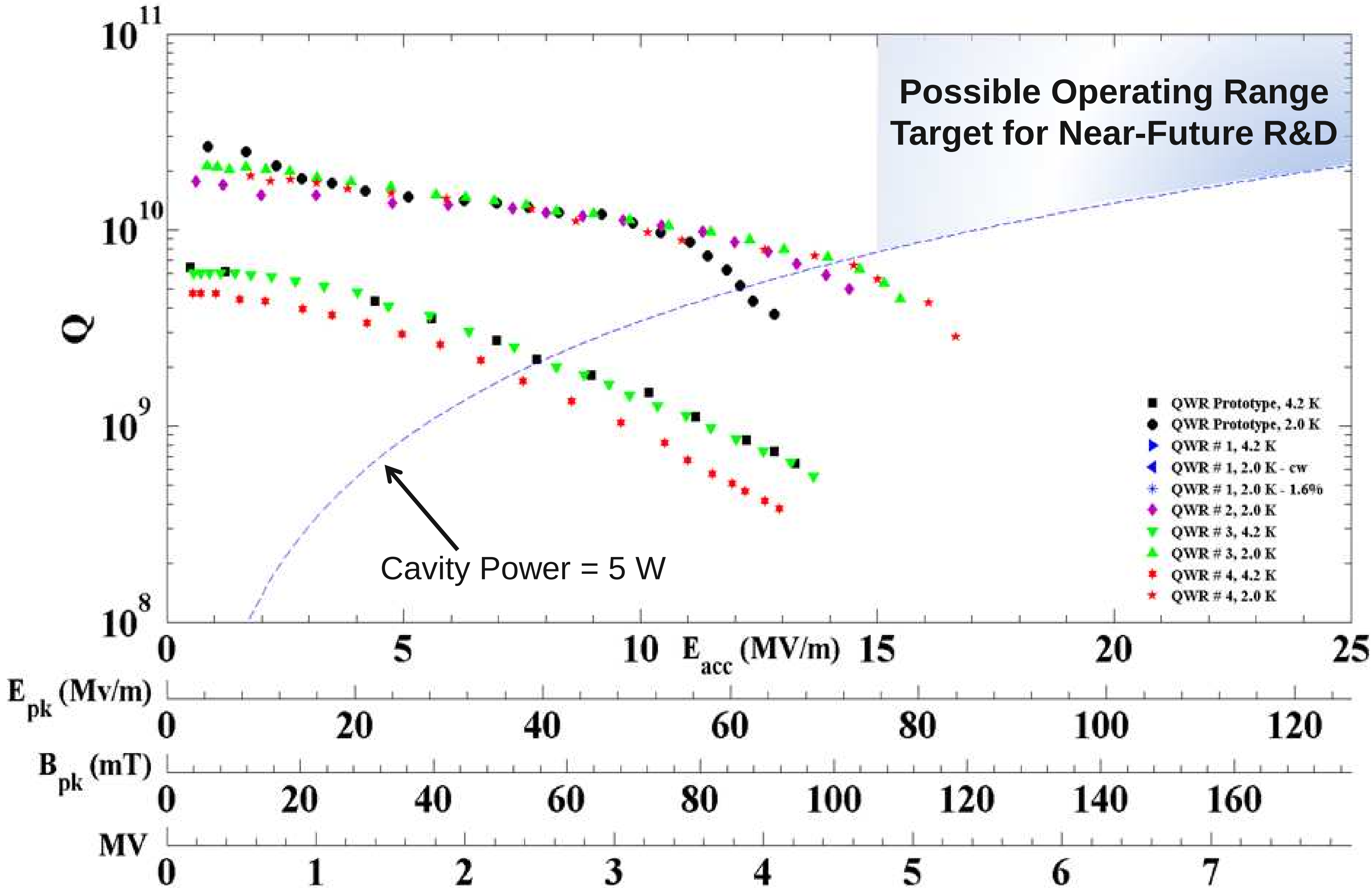


5.2 m long x 2.9 m high x 1.1 m wide

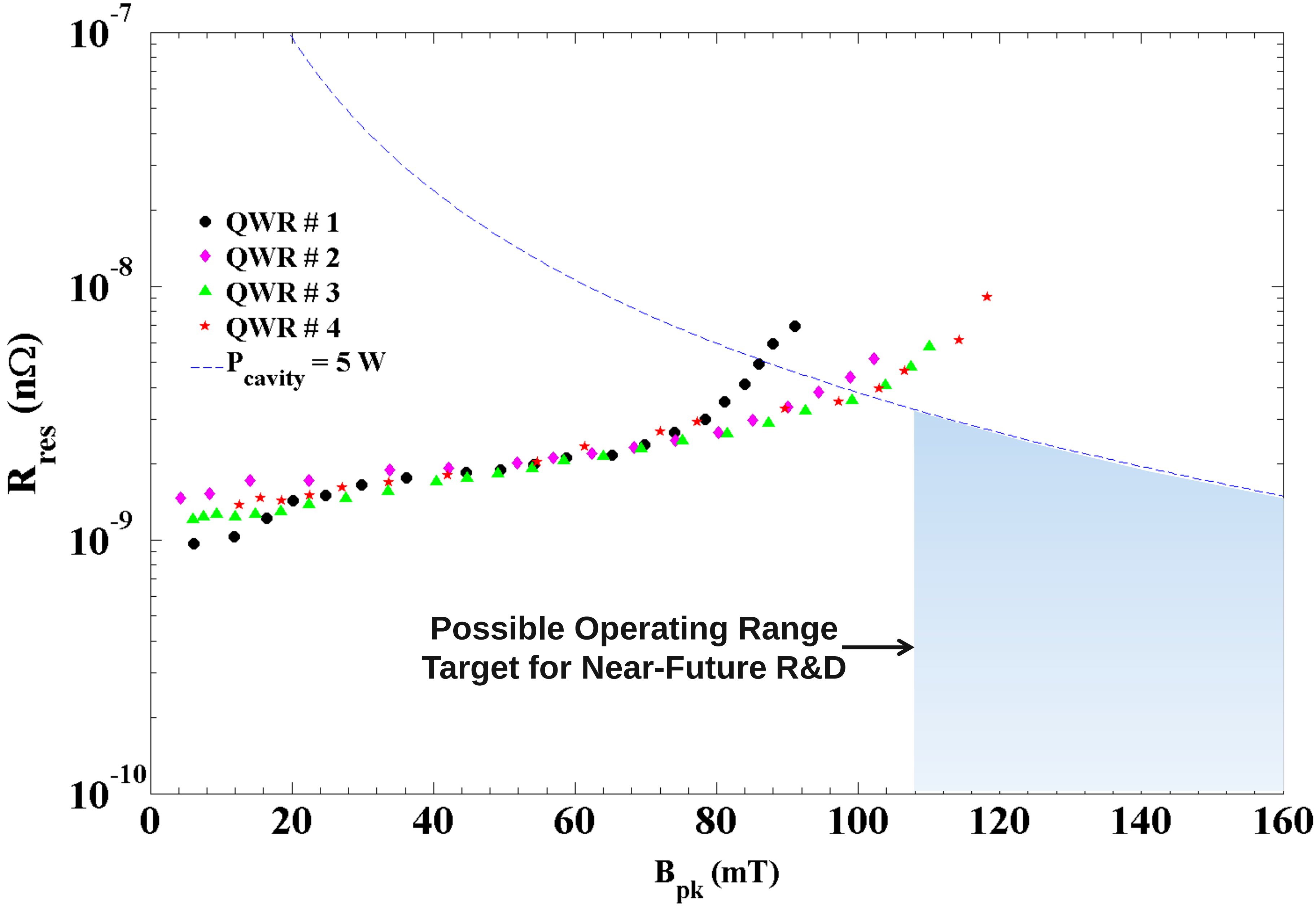


- 4 superconducting solenoids.
- 7 β = 0.077 72.75 MHz quarter-wave cavities.
- Work will be complete soon.

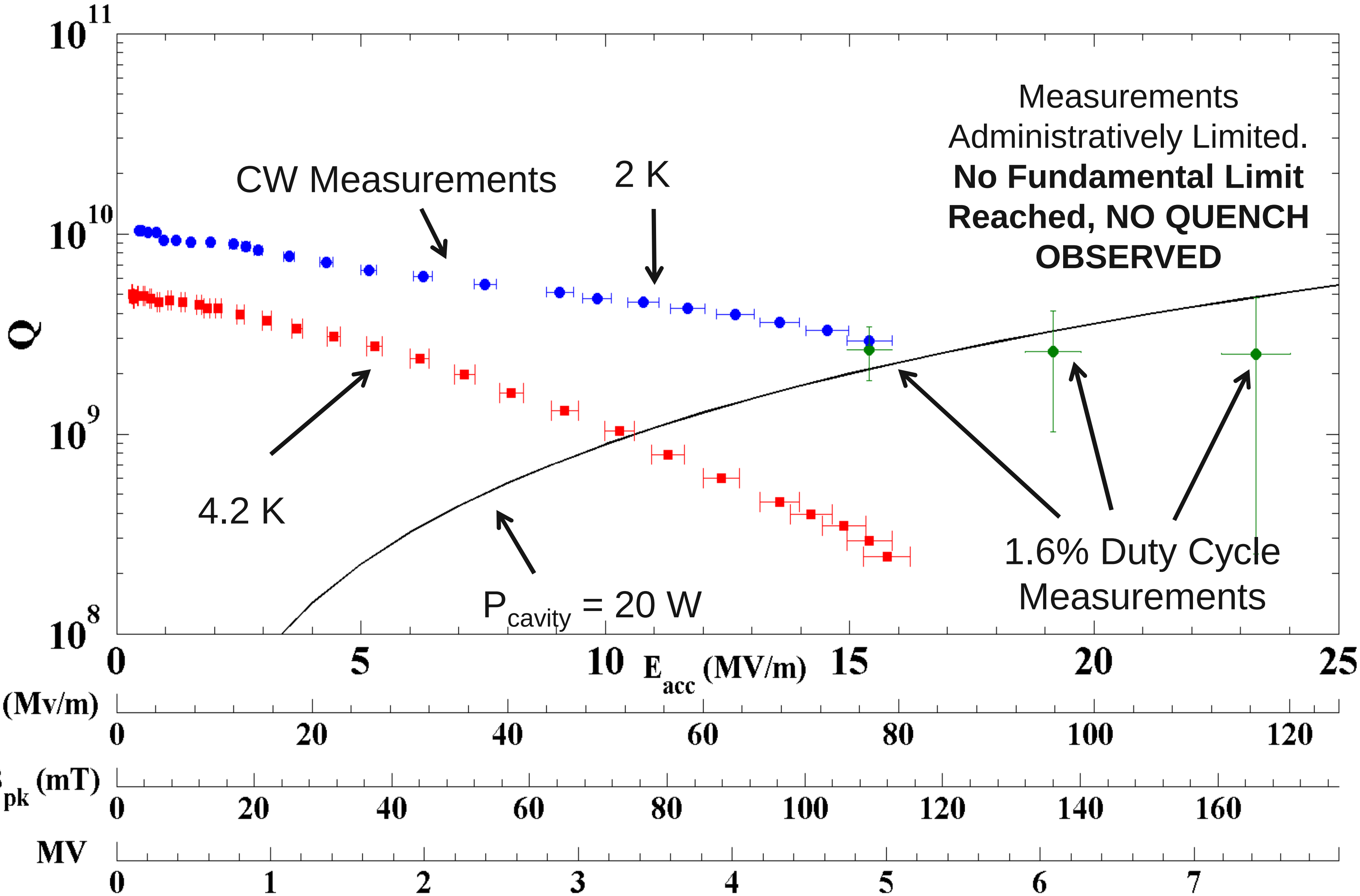
ANL Intensity Upgrade QWR Q-Curves



ANL Intensity Upgrade QWR Residual Resistance



High Peak Field Development: Not the same cavity.



Impact

- **Higher accelerating gradients and lower residual resistances = shorter cheaper accelerators.**
- **Work is proceeding to simultaneously increase the peak fields and quality factors of reduced-beta cavities at ANL.**
- **Enables new applications where SC Linac technology was too expensive to propose or support in the past:**
  - Future Basic Science Applications and Upgrades.
  - National Security.
  - Nuclear Medicine (Medical Isotope Production).
  - Waste Transmutation.
  - Accelerator Driven Systems.
- **Improved techniques for all SC niobium accelerator cavities.**
  - Electrostatic Discharge Machining.
  - Final EP after fabrication is finished.