TTC 2018 RIKEN

OPTIMIZING TEM MODE CAVITY PERFORMANCE

Z.A. CONWAY
Physics Division
Argonne National Laboratory

26 June 2018
Argonne, Illinois 60439

OPTIMIZING TEM MODE PERFORMANCE

Overview

- **What?**
- **Design examples.**
- **Summary.**

162.5 MHz $\beta = 0.112$
Half-Wave Resonator (HWR)

48" (122cm)

162.5 MHz, $\beta = 0.112$
Half-Wave Resonator Niobium Parts

95 cm

ATLAS Positive Ion Injector Cryomodule

PEOPLE WHO DESERVE CREDIT

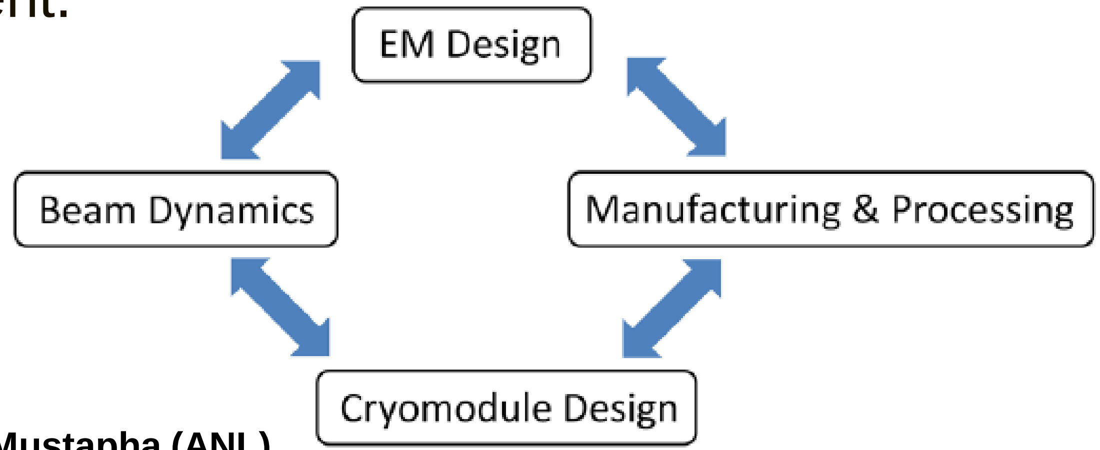
Many thanks to my close friends and collaborators.

- **ANL:**
  - **PHY: M. Kelly, B. Guilfoyle, M. Kedzie, J. Kilbane, B. Mustapha, T. Ng and T. Reid.**
  - **NE: A. Barcikowski, G. Cherry and R. Fischer.**
  - **APS: W. Jansma.**
- **TechSource: K.W. Shepard.**

QWR, HWR AND SPOKE RESONATOR DESIGN

TEM-class cavity complexity

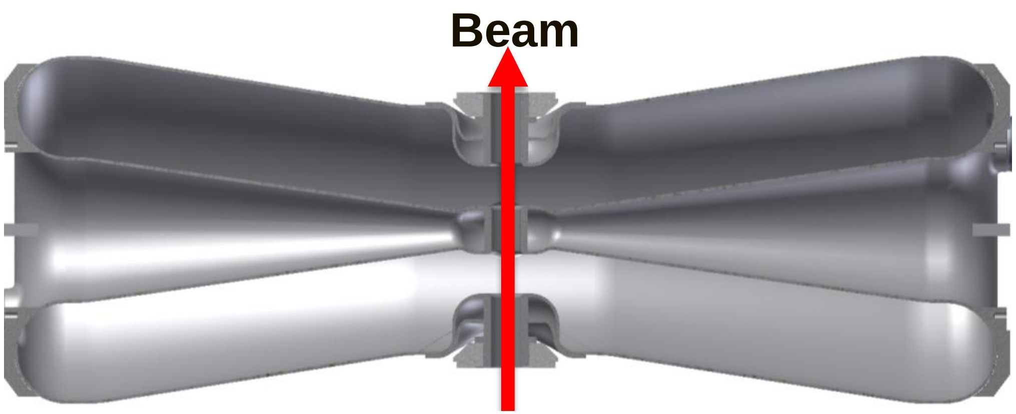
- Want to reduce the length and cost of low-beta accelerators.
- The approach is two-fold:
  - **Substantially increase the performance of low-β cavities.**
    - **Geometry optimization for both processing and electromagnetics.**
    - **Quality control; apply/improve upon methods developed for β = 1 cavities**
    - **Discussed in this presentation.**
  - Optimize the accelerator lattice geometry for maximum real-estate gradient.

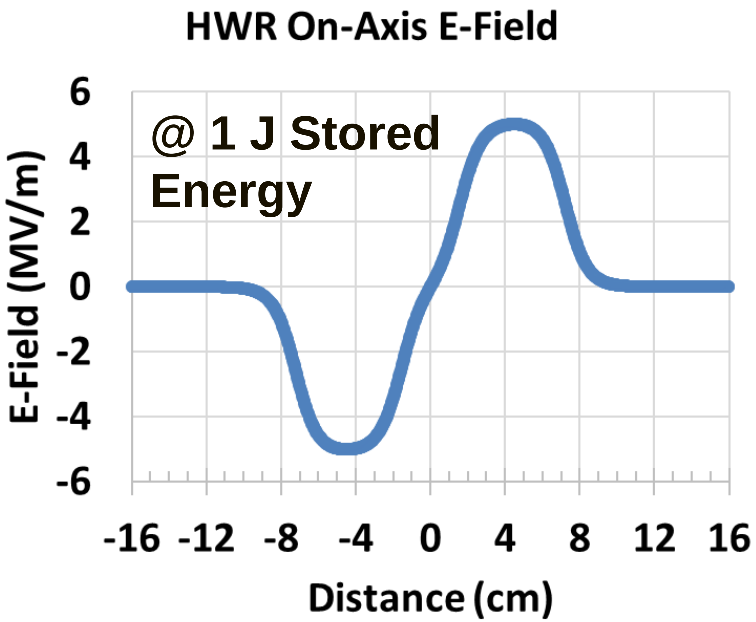


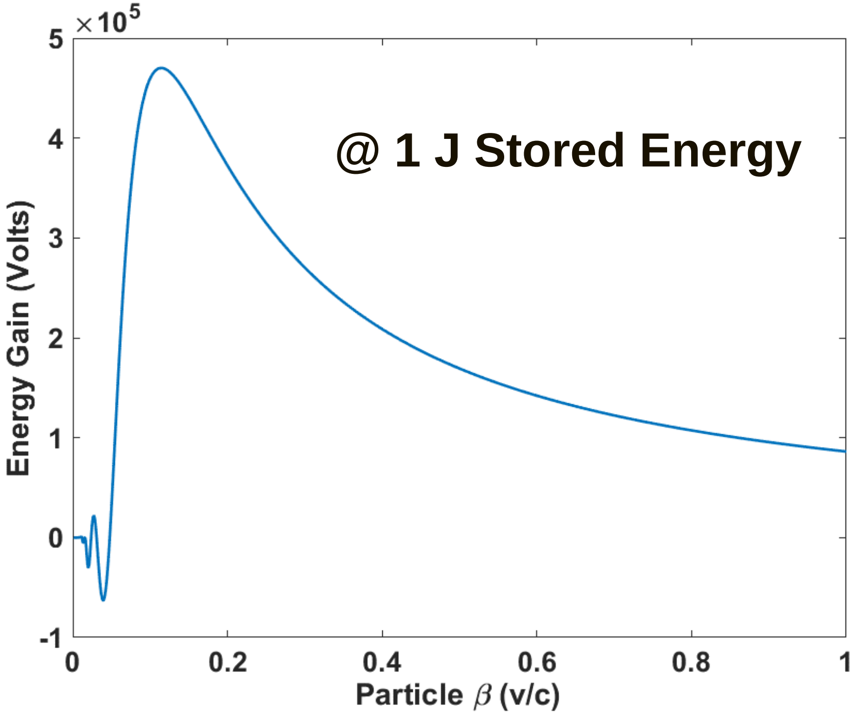
Picture courtesy of B. Mustapha (ANL)

HALF WAVE RESONATOR

More Figures of Merit







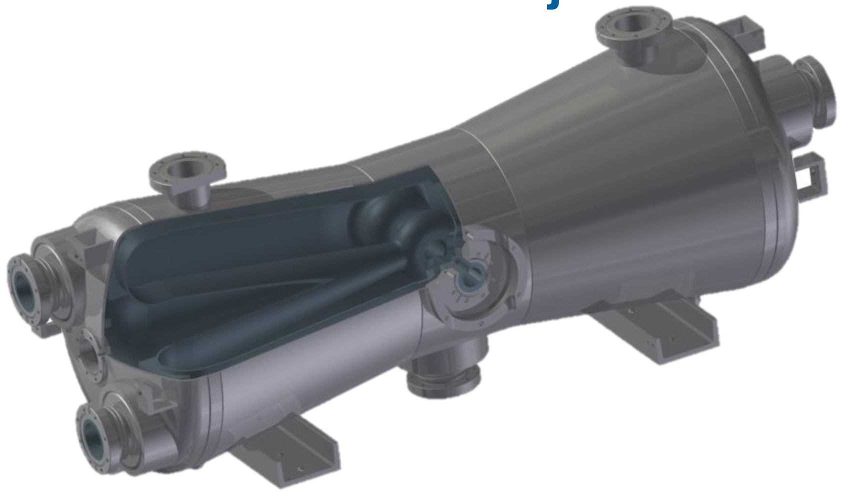
$$V_{acc} = \mathrm{Re}\left(\int_{-b}^{b} \vec{E}\,(beam\ axis, t) \cdot d\vec{l}\right)$$

$$\frac{R_{shunt}}{Q} = \frac{V_{acc}^2}{\omega_0 U_0} = \frac{V_{acc}^2}{Q * P}$$

$$P = \frac{1}{2}\int_s R_s(\vec{x}, t)\left|\vec{H}(\vec{r}, t)\right|^2 da$$

ANL HALF-WAVE RESONATORS

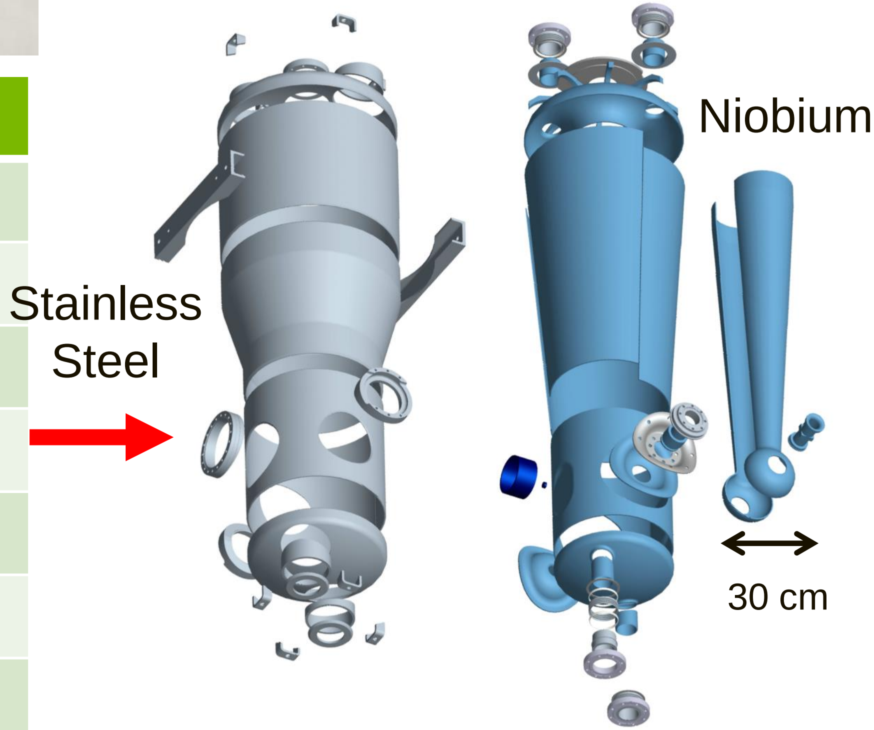
For the FNAL PIP-2 Project



Cavity Type	HWR
Freq. (MHz)	162.5
β	0.112
l_{eff} (cm, $\beta\lambda$)	20.68
E_{pk}/E_{acc}	4.7
B_{pk}/E_{acc} (mT/(MV/m))	5.0
QR_s (Ω)	48.1
$R_{sh}/Q = V^2/P = V^2/\omega_0 U_0$ (Ω)	272

ANL QUARTER-WAVE RESONATORS

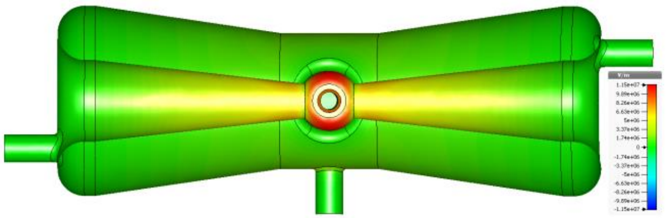
ATLAS Upgrades



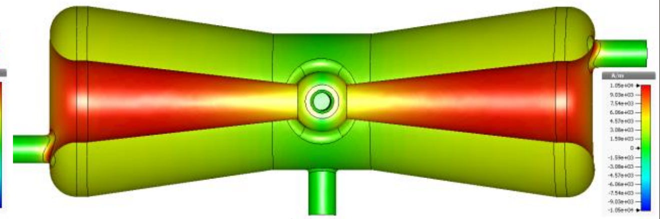
Cavity Type	QWR
Freq. (MHz)	72.75
β	0.077
l_{eff} (cm, βλ)	31.75
E_{pk}/E_{acc}	5.2
B_{pk}/E_{acc} (mT/(MV/m))	7.6
QR_s (Ω)	26.4
$R_{sh}/Q = V^2/P = V^2/\omega_0 U_0$ (Ω)	587

SRF RESONATOR FIELDS

Half-Wave Resonator

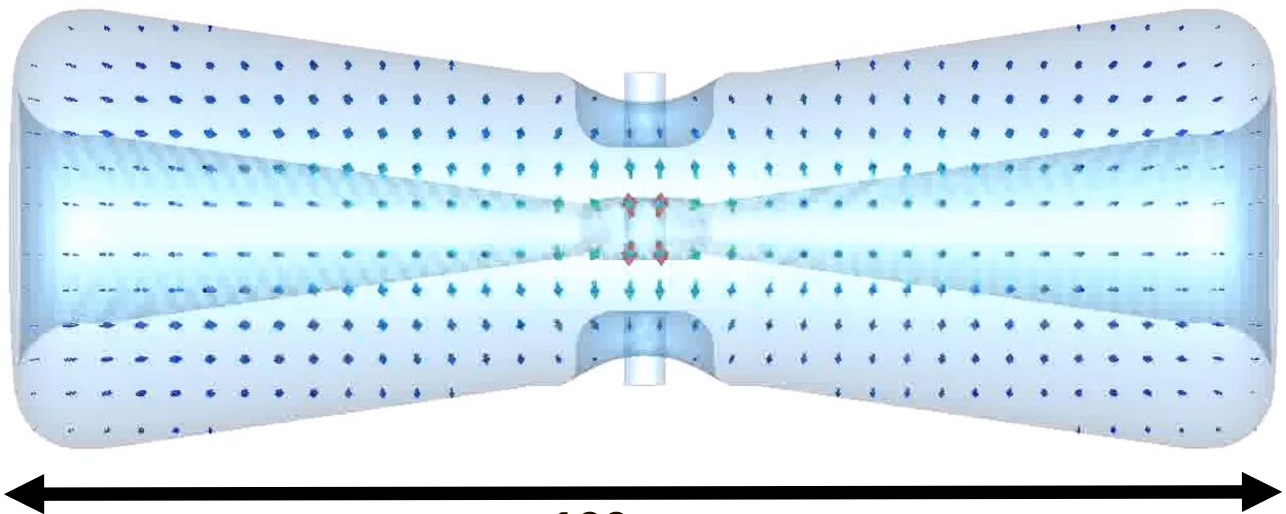


Surface-E

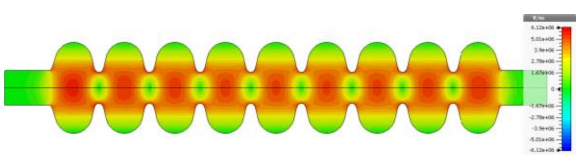


Surface-H

Animated E-Field in HWR



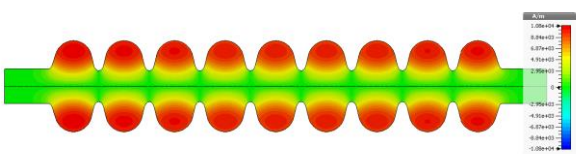
100 cm



Volume-E

ECR

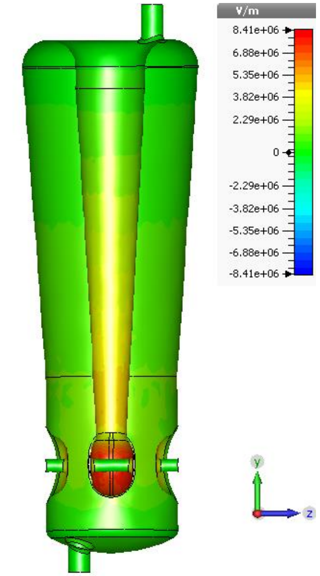
TM_{010}



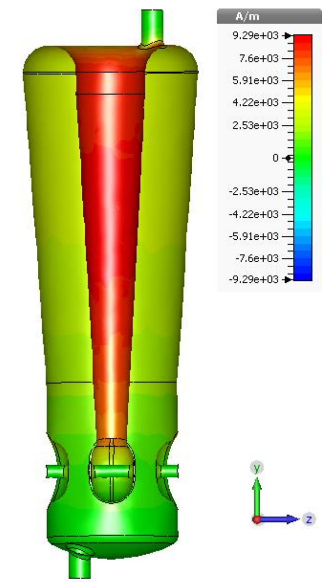
Volume-H

Quarter-Wave Resonator

Surface-E



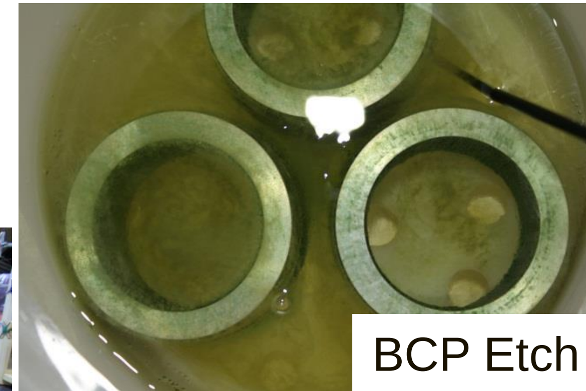
Surface-H



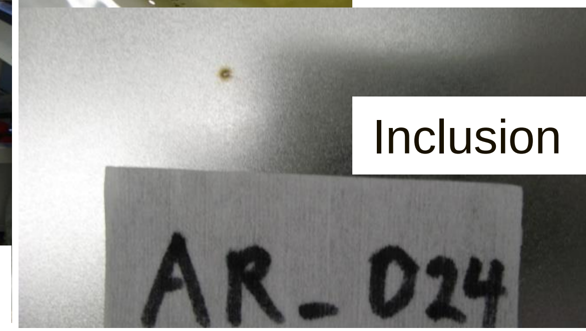
SURFACE PREPARATION

Sheet Inspection

Surface Preparation



BCP Etch

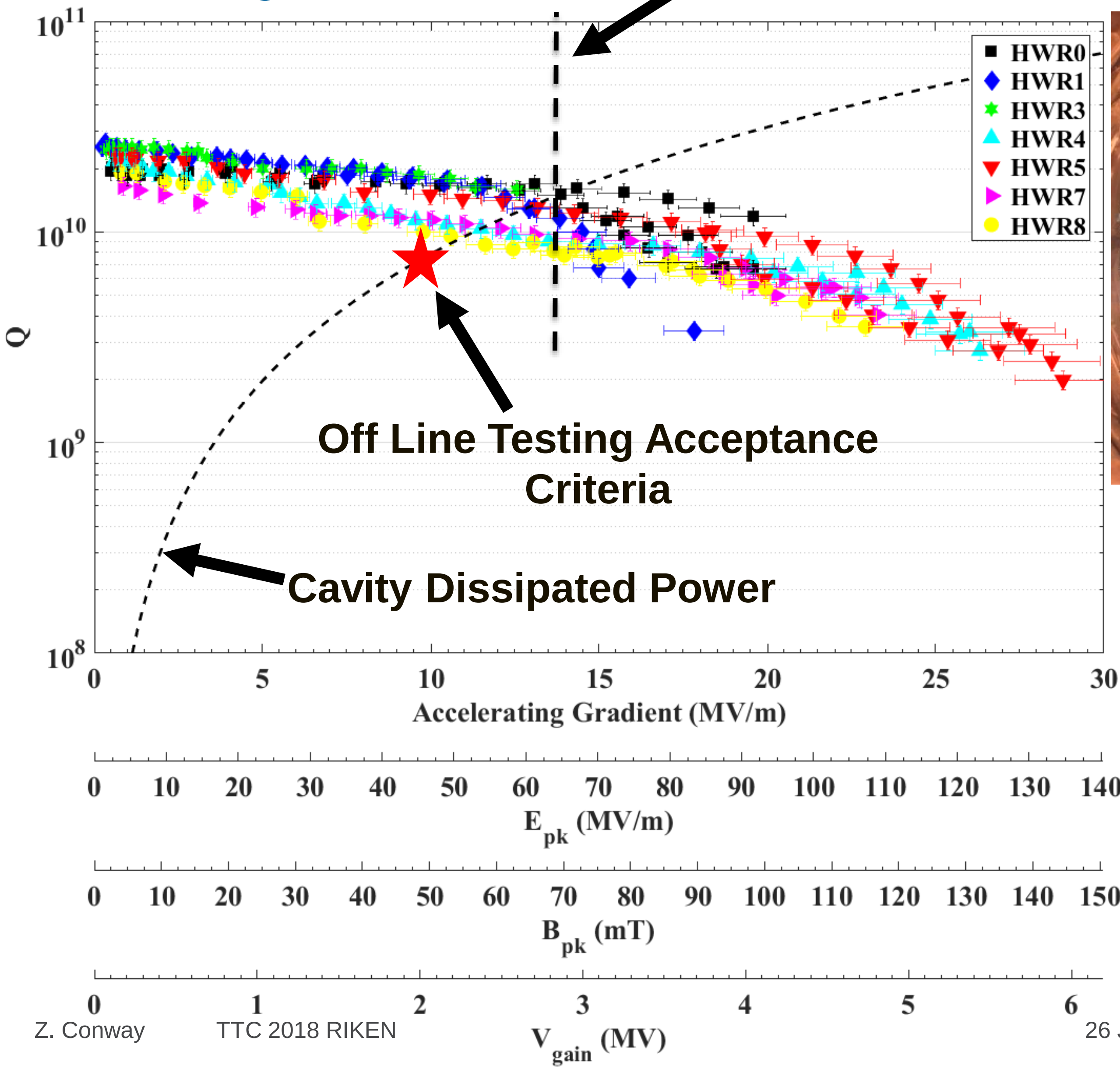


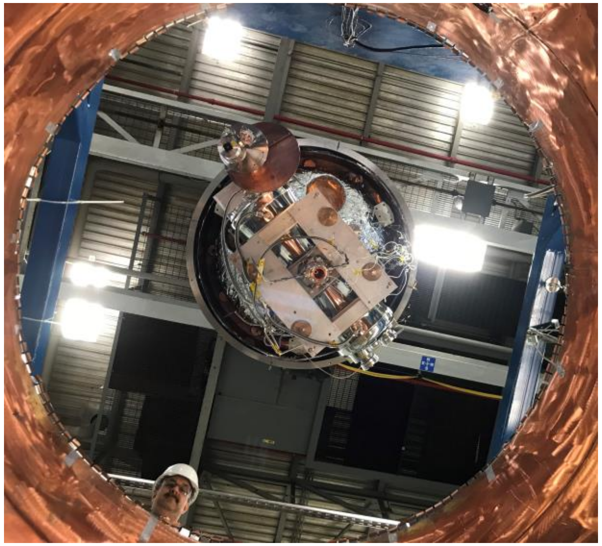
Inclusion

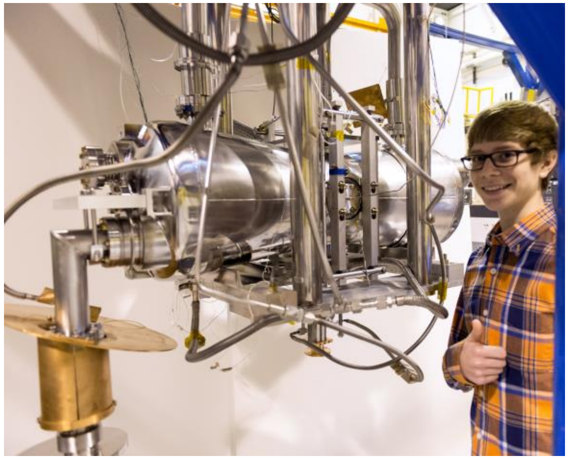
- Soak parts to find iron inclusions.
- BCP etch parts prior to welds:
  - T , 18^0C.
  - Limits hydrogen absorption of Nb.
- High pressure rinse with ultra –high purity water prior to welding.
- Post-etch part work is performed in a clean room
- BCP etch (~10μm) interior and exterior of all parts & finally the interior of finished cavity.
- Electropolish, ~120μm @ T < 30^0C, finished cavity
- Bake @ 600^0C to degas hydrogen
- Light electropolish, ~20μm @ T < 25^0C
- Cleaning & testing follow

ARGONNE HALF-WAVE RESONATOR PERFORMANCE

So far so good

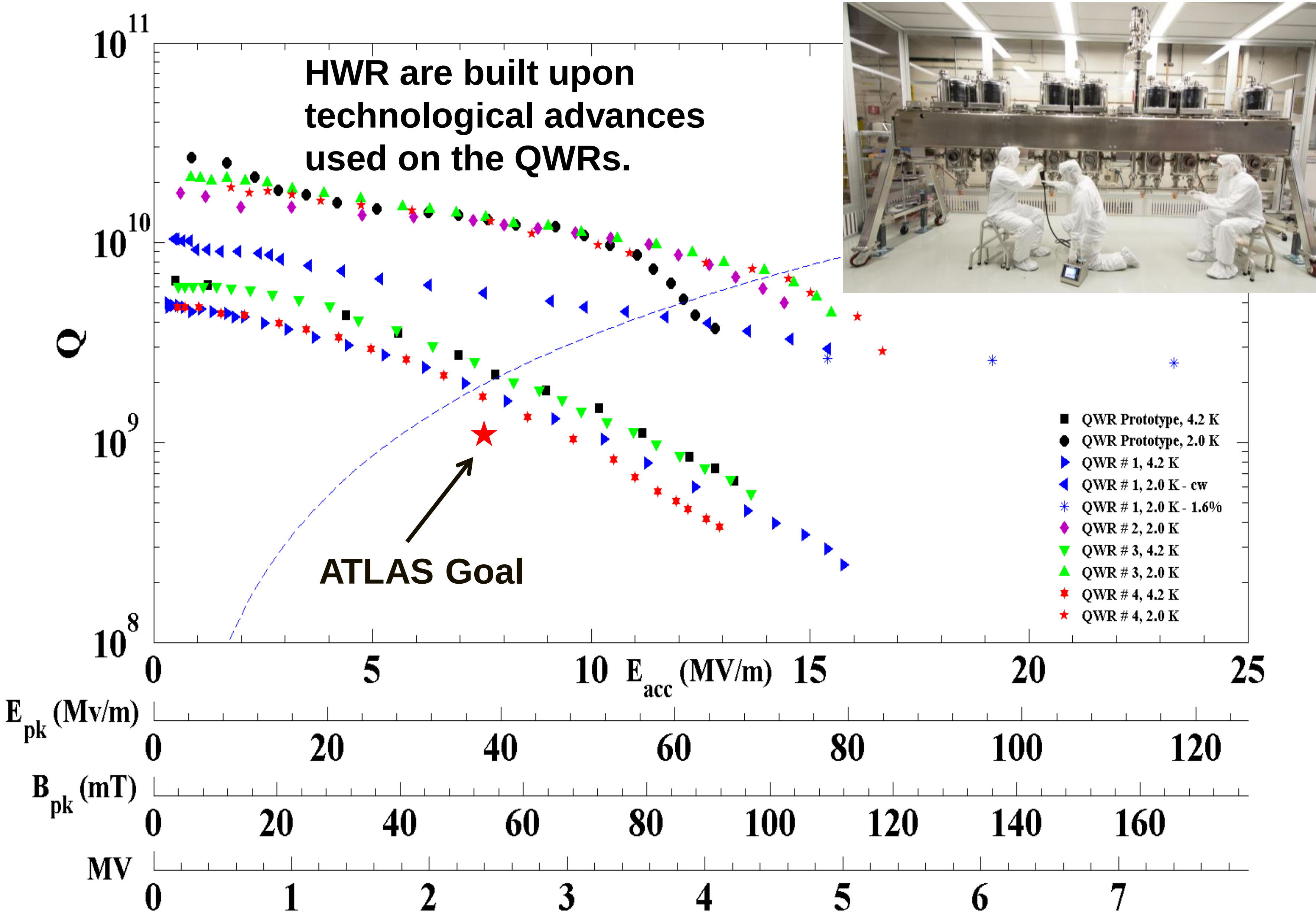






ANL QUARTER WAVE RESONATORS

HWR are built upon technological advances used on the QWRs.



See M. Kelly et al, LINAC12.

ANL HWR CRYOMODULE

HOW TO CONTINUE IMPROVEMENT

Path Forward

- Improved design/optimization:
  - Neural networks @ JLAB/ODU
  - Complex algorithms work as well as a graduate student.
- Reduce field emission.
  - Improve/compliment high pressure water rinsing.
- Reduce medium field Q-slope.
- Electropolish more TEM-class resonators.