Superconducting Deflecting Cavities for the Electron-Ion Collider and Large Hadron Collider

Dr. Terry Grimm
President & Senior Scientist

Jerry Hollister
Chief Operating Officer

October 1, 2012

Outline

NIOWAVE
www.niowaveinc.com

- Company Details & Leadership
- Superconducting Electron Linacs
- Applications of Superconducting Electron Linacs
- Successful Commercialization of DOE SBIRs
- Superconducting Deflecting Cavity for EIC
- Summary

Niowave, Inc.

NIOWAVE
www.niowaveinc.com

- Privately Owned
- 60,000 square feet
  - Engineering & design
  - Machine shop
  - Fabrication & welding
  - Chemistry facility
  - Class 100 Cleanroom
  - Cryogenic test lab
  - Accelerator test facility
    - 14,000 SF High Bay
    - 2.5 MW power
    - 4 K cryoplant

Lansing, Michigan Headquarters

Niowave Leadership

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Dr. Terry Grimm
President & Senior Scientist

- PhD from Massachusetts Institute of Technology
- 20 Years experience in Department of Energy
  - Superconducting Super-Collider
  - National Superconducting Cyclotron Laboratory at MSU
  - Numerous contracts with DOE at Niowave

Jerry Hollister
Chief Operating Officer

- Bachelors in Engineering from University of Michigan
- Active duty Naval Officer for 6 years
- Warranted Contracting Officer for US Navy
- Current Trustee at Lansing Community College

Mark Sinila
Chief Financial Officer

- Bachelors in Business Administration from Albion College Honors Program
- 20 years experience in business administration
- Prior CFO for multi-state manufacturer

Superconducting Electron Linacs

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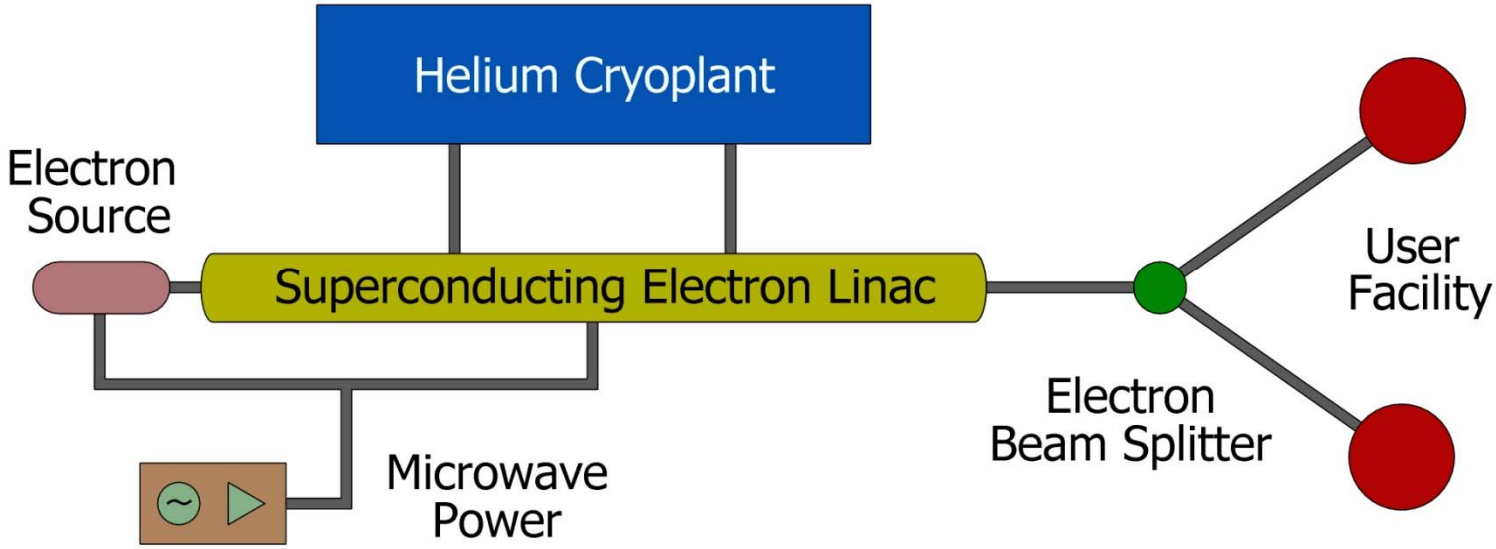

Turn-key Systems

- Superconducting Linac
- Helium Cryoplant
- Microwave Power
- Target / User Facility
- Licensing

Electron Beam Energy	**0.5 – 50 MeV**
Electron Beam Power	**1 W – 1 MW**
Electron Bunch Length	**~50 ps**

Superconducting Test Facility

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July 3, 2012 Dedication
Niowave Test Facility

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Ilan Ben-Zvi

SEN Levin LK Len SEN Stabenow Jean Delayen

Admiral Klunder

Dedication Ceremony
July 3, 2012

L.K. Len SEN Levin

Ilan Ben-Zvi CDR Niles

Superconducting Linacs

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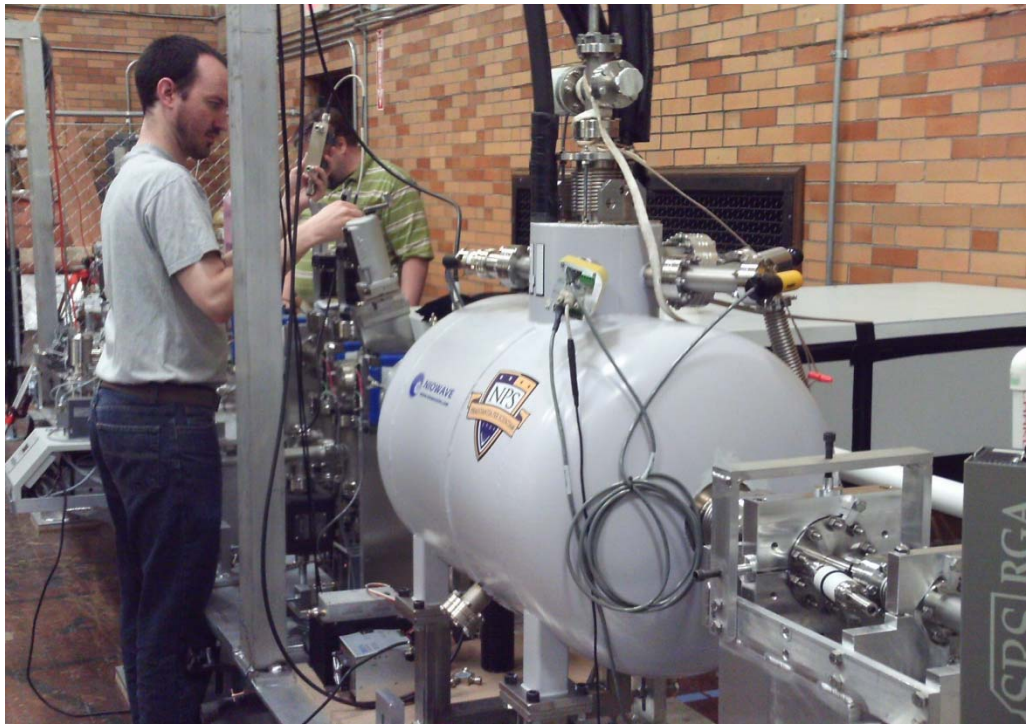
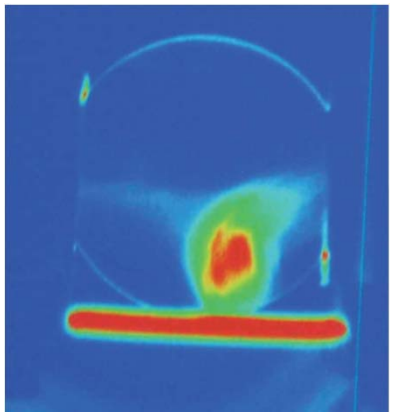
- NPS-Niowave SRF Injector Program
  - First superconducting linac designed, fabricated and tested entirely within industry
  - First delivered and operational SRF beam source at a US Navy facility
  - Second generation linac produced beam less than 2 years from first generation





High brightness photoelectron beam image on YAG scintillator.

Published Results: Harris, et al, "Design and operation of a superconducting quarter-wave electron gun," Phys Rev STAB 14 (2011)

Niowave Systems for Superconducting Electron Linacs

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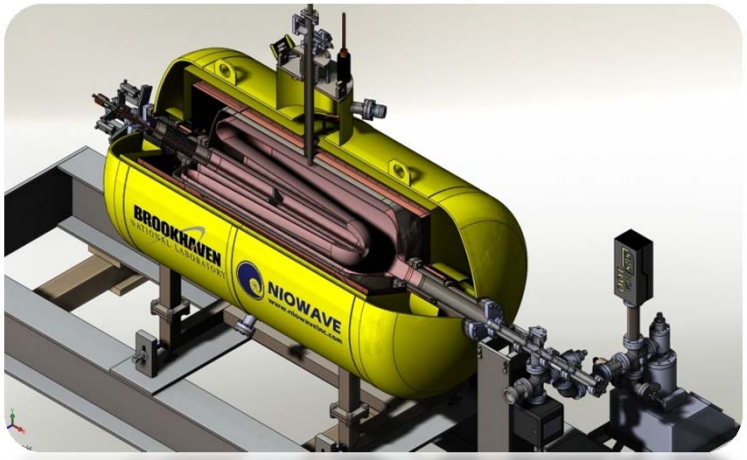
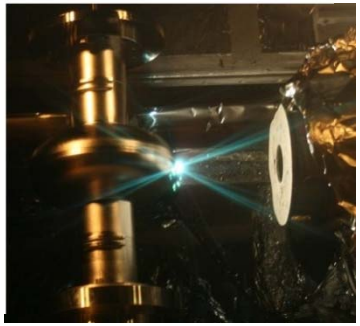


- Electron Guns & Injectors

•4 K Cryogenic Systems

- Niobium (In Stock)



- Niobium Superconducting Cavities

Superconducting Cavities

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Niowave produces superconducting cavities at a broad range of frequencies and geometries, and will customize to meet specific applications.

- Elliptical cavities
- Quarter-wave cavities
- Deflecting structures
- Single and multi-spoke cavities

700 MHz Multi-Spoke for Electron Linacs

56 MHz Quarter-Wave Resonator for RHIC

400 MHz Deflecting Cavity for the LHC

1.3 GHz 9-cell cavities for ILC

Cavity frequencies
28 MHz to 9.5 GHz

Commercial Applications of Superconducting Electron Linacs

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- Radioisotope production
  - Medical and Industrial
- Free electron lasers
  - Defense, Medical and Industrial
- X-ray sources
  - Defense, Medical and Industrial
- Large accelerators
  - Current DOE projects: Brookhaven, Fermi, Jefferson Lab, Large Hadron Collider
  - Future: FRIB, eRHIC, Project-X, ILC & many more

Commercialization of SBIRs at Niowave

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DOE Office	Phase I Selections	Phase II Selections	Phase III Commercialization to date
Nuclear Physics	6	5	$11,754 K
Basic Energy Sciences	6	3	$356 K
High Energy Physics	5	1	$399 K
Other	1	0	$0
TOTAL	18	9	$12,509 K

112 MHz electron gun

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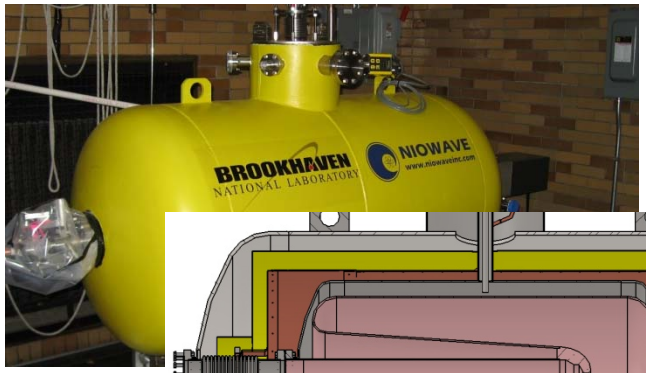
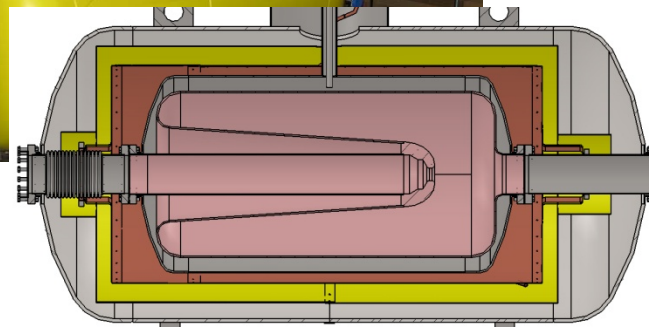
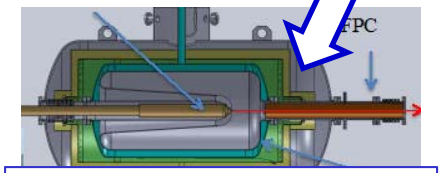
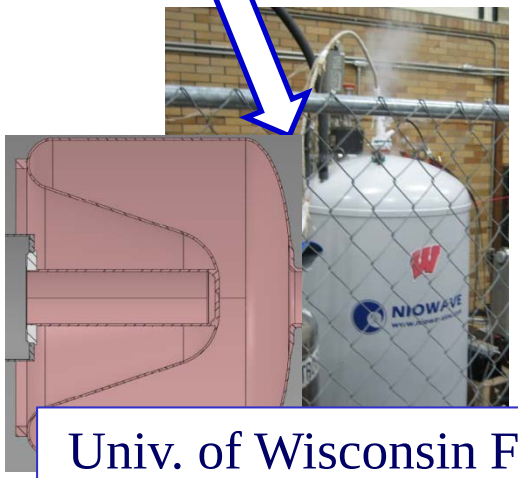




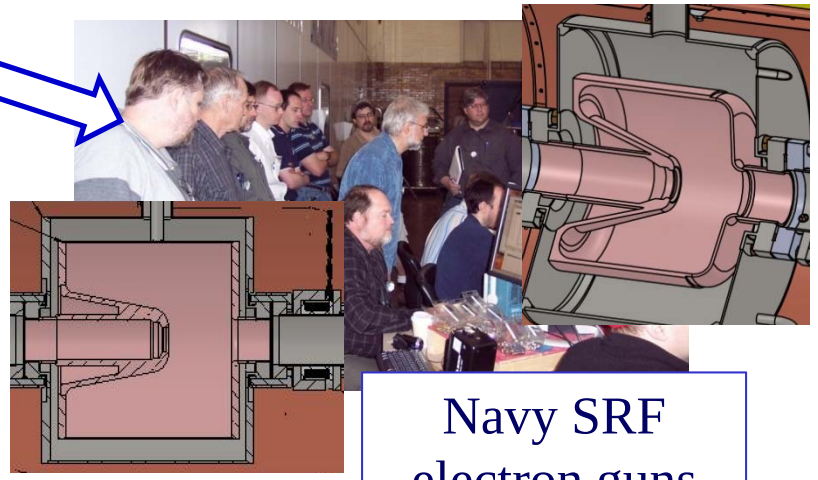
- First PhII SBIR for Niowave, 2008
- By the Office of Nuclear Physics
- Collaboration with BNL (Ilan Ben-Zvi)
- **Has led to ($10.7 M in contracts to date (DOE, DOD, universities)**



e- source for Coherent Electron Cooling at RHIC



Univ. of Wisconsin FEL electron gun



Navy SRF electron guns

Spoke cavity for electrons

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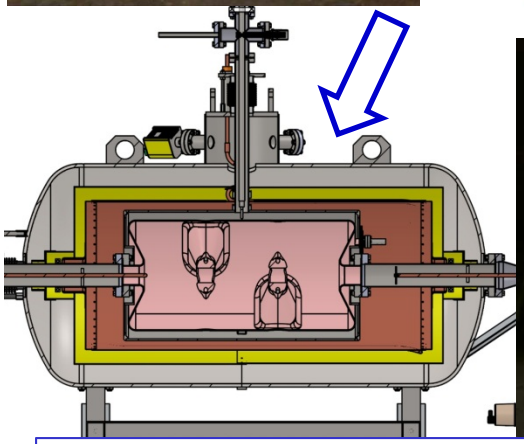
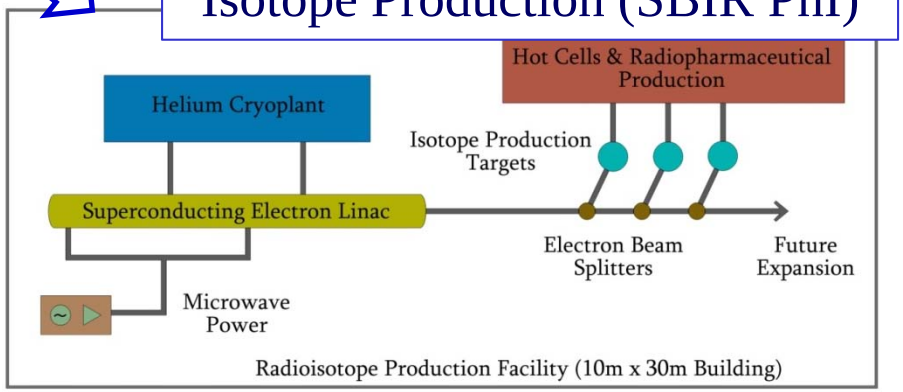


700 MHz Double Spoke for Joint Technology Office (DOD)

- PhII SBIR for Niowave, 2009
- By the Office of Nuclear Physics
- Collaboration with Old Dominion University (Jean Delayen)
- **Niowave now building spokes for Navy and isotope production linacs ($1 M in contracts to date)**

Linear accelerator for Medical Isotope Production (SBIR PhI)



Crab Cavity for the LHC

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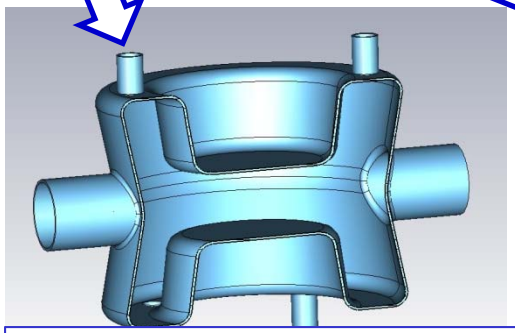
- PhII SBIR for Niowave, 2010
- By the Office of High Energy Physics
- Collaboration with Old Dominion University (Jean Delayen)
- **Niowave now building three LHC crab cavity designs**

4-bar Crab for LHC (Daresbury)



Quarter-Wave Crab for LHC (BNL)

499 MHz Deflecting Cavity (ODU/Niowave PhI STTR, then built at JLab)

Electron-ion collider at JLab

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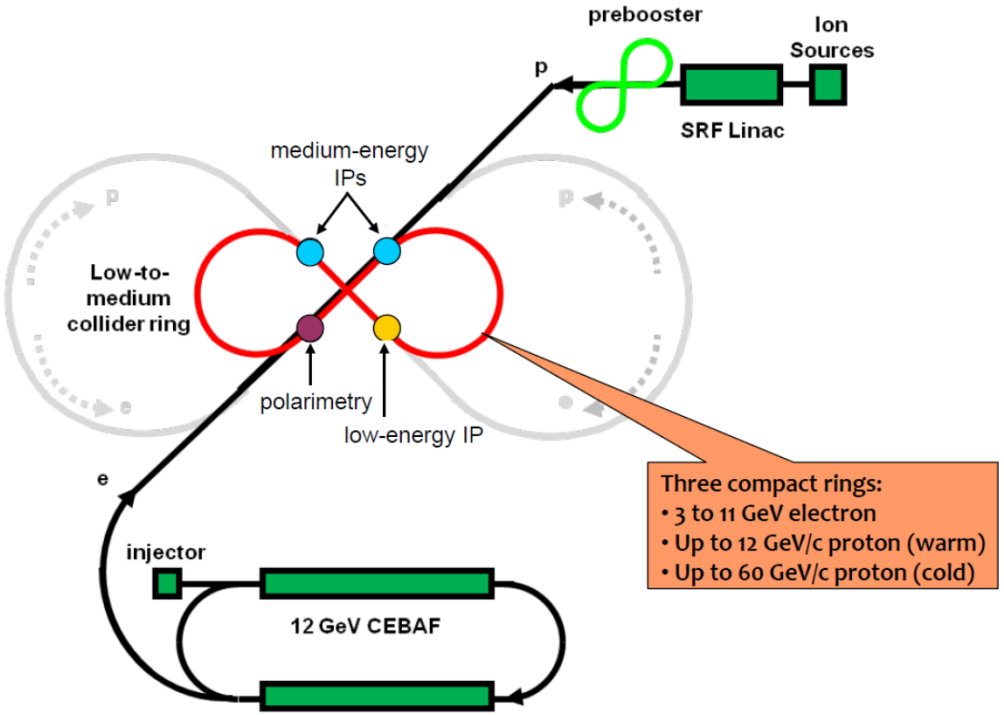
A proposed electron-ion collider at Jlab will use the 12 GeV electron beam from CEBAF and inject it into collider rings where it would be brought to collide with a high-energy proton beam.



Reaching the luminosity of the designed machine will require crab cavities to collide the beams head-on while preserving the crossing angle at the interaction point.

750 MHz SRF Crab Cavity

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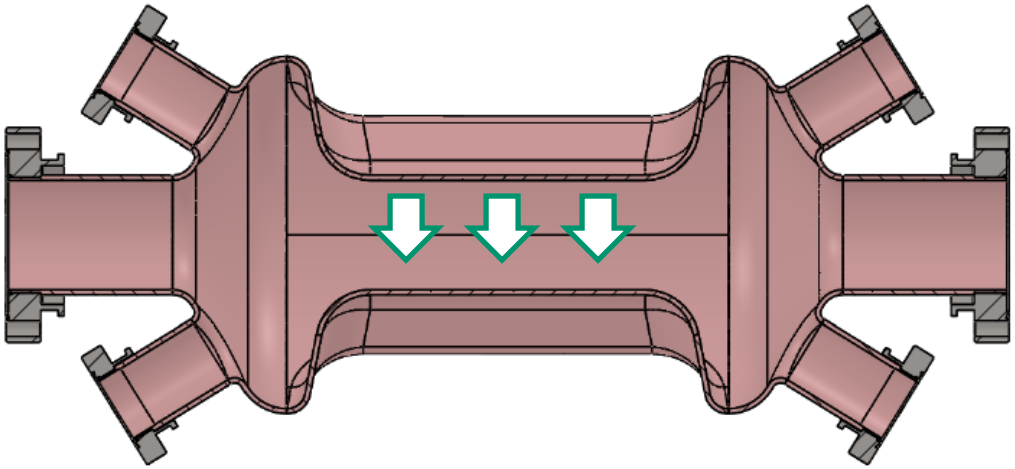

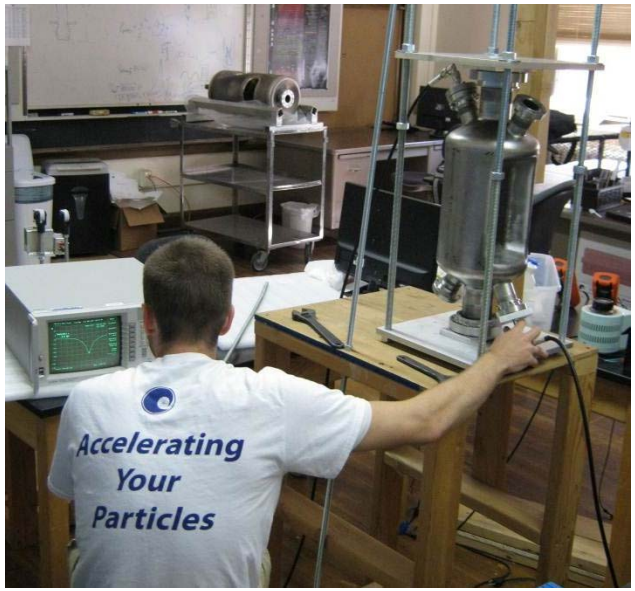

OLD DOMINION UNIVERSITY

The SRF Crab Cavity designed and built by the ODU-Niowave collaboration in this DOE STTR uses strong transverse electric fields to provide a linear deflection of the particle beam.

750 MHz Crab Cavity Test Setup

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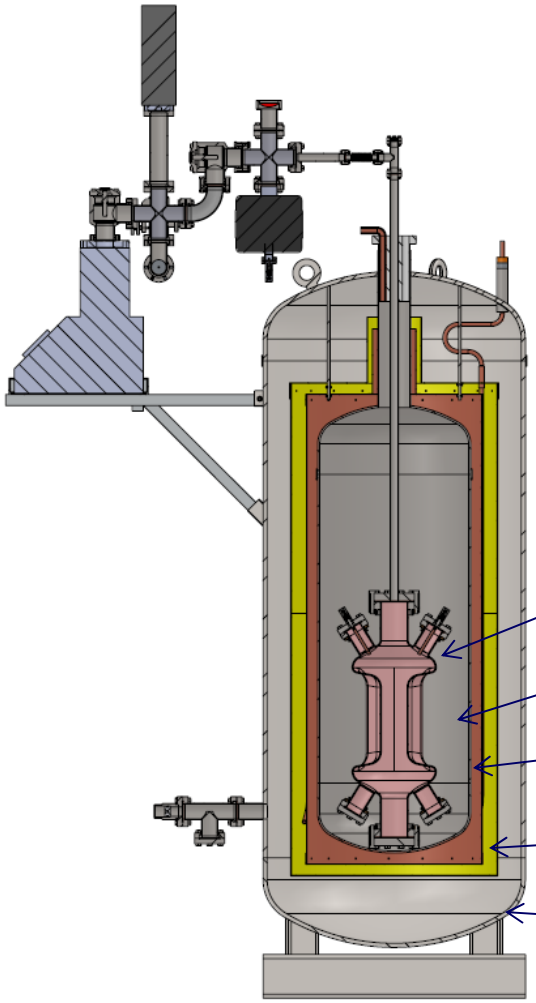
The 750 MHz crab cavity has now been tested in a vertical test cryostat at Niowave. The test setup is as shown at left.



750 MHz Crab Cavity Test

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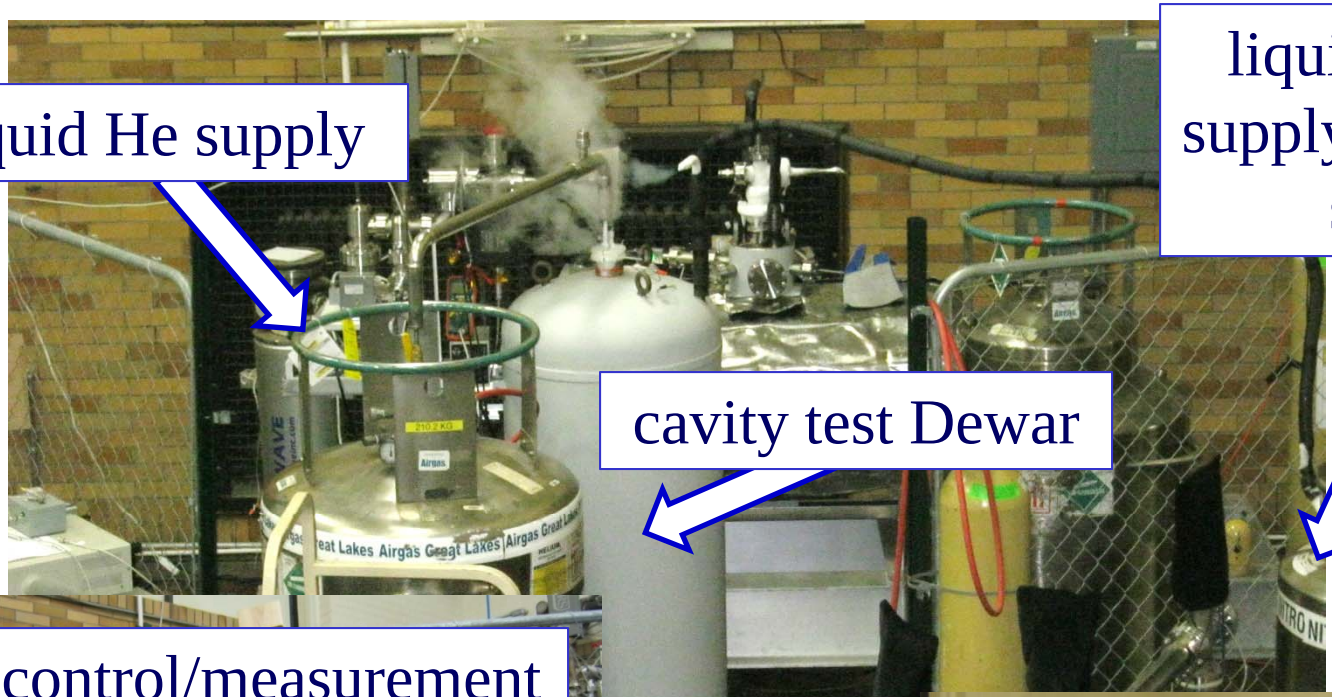

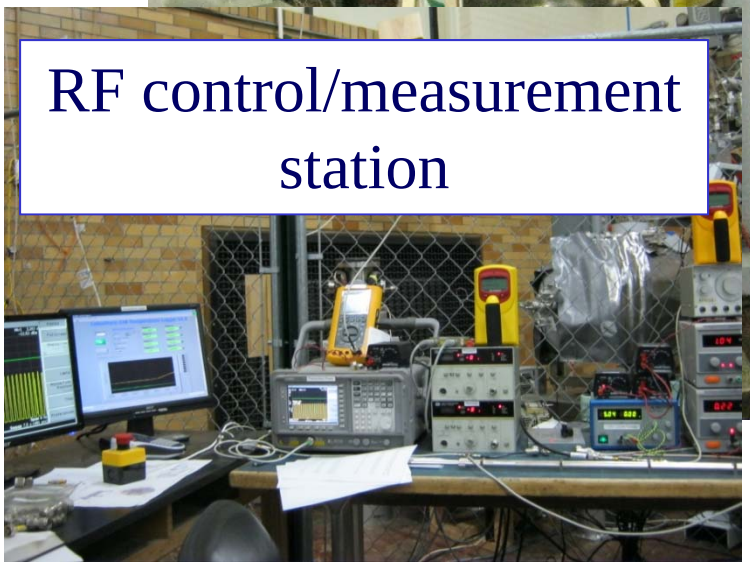

750 MHz Crab Cavity Test Results

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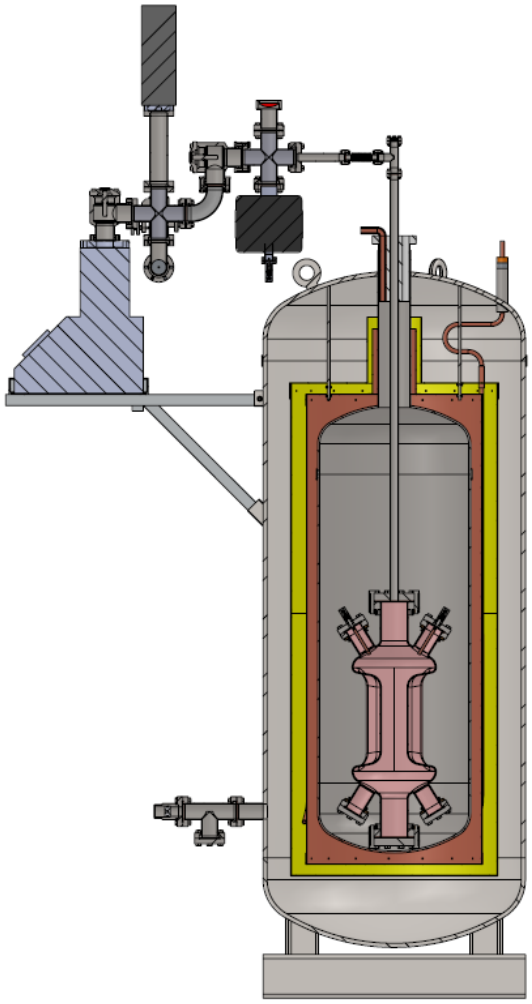
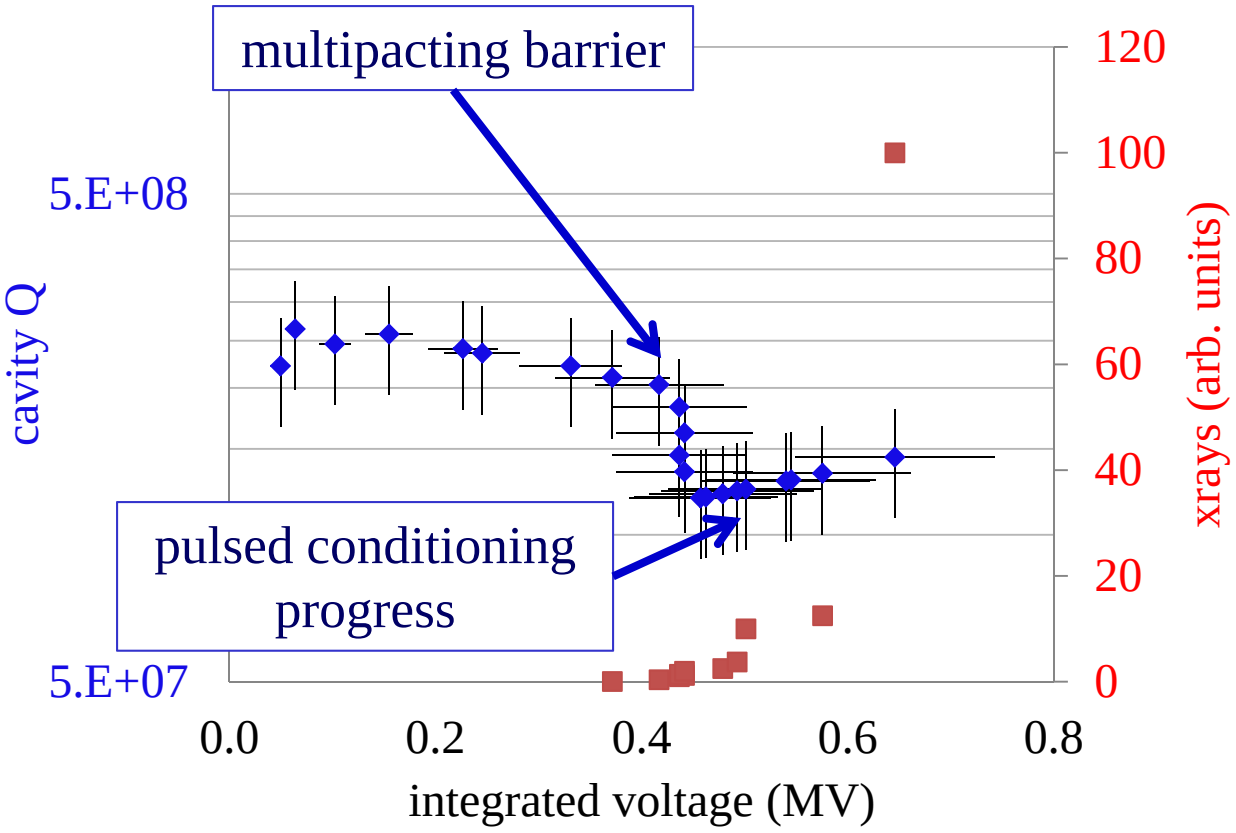


The 750 MHz crab cavity reached an estimated maximum deflecting voltage >0.6 MV.



Summary

NIOWAVE
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- **Niowave supplies full 4K superconducting electron linacs for numerous commerical applications**
  - Radioisotope Production
  - Free Electron Lasers
  - X-Rays
- **These commercial applications are a direct result of the SBIR program**
  - DOE Lab collaborations (intellectual support)
  - R&D funding