

NIOWAVE
Accelerating the Fight Against Cancer



High-power Two-pass Superconducting Electron Linac for Medical Radioisotope Production

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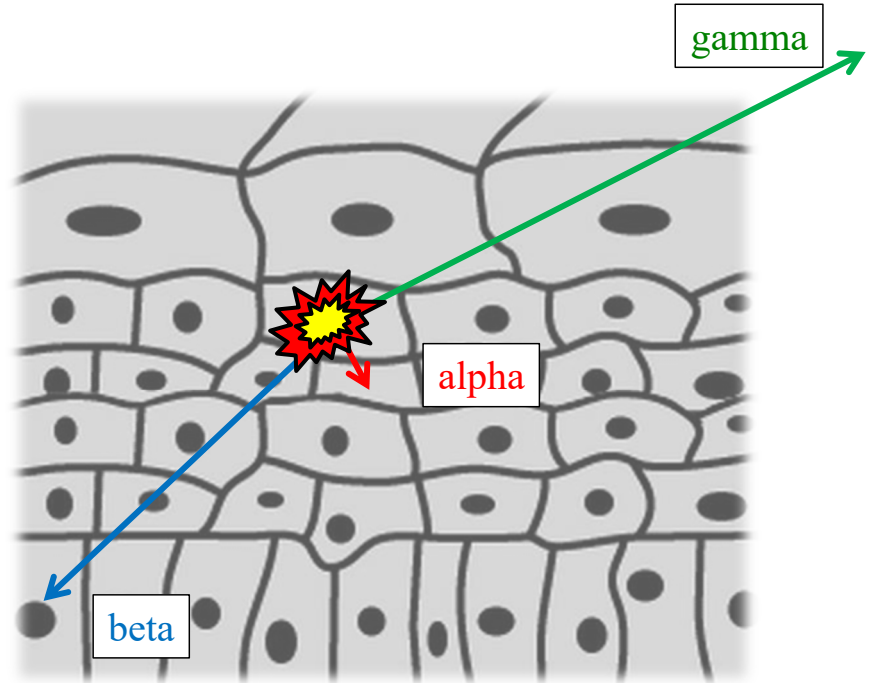
High-Power SRF Accelerator for Radioisotopes

- Radioisotope production with high-power electron beams
 - Diagnostic and therapeutic isotopes
 - Niowave isotope programs
- Commercial SRF accelerator technology
 - SRF Cavities and Cryomodules
 - Liquid helium refrigerators
 - Microwave power
 - Thermionic-cathode electron guns for high duty cycle
 - Recirculating beamline designs
 - Isotope production targets for high average power



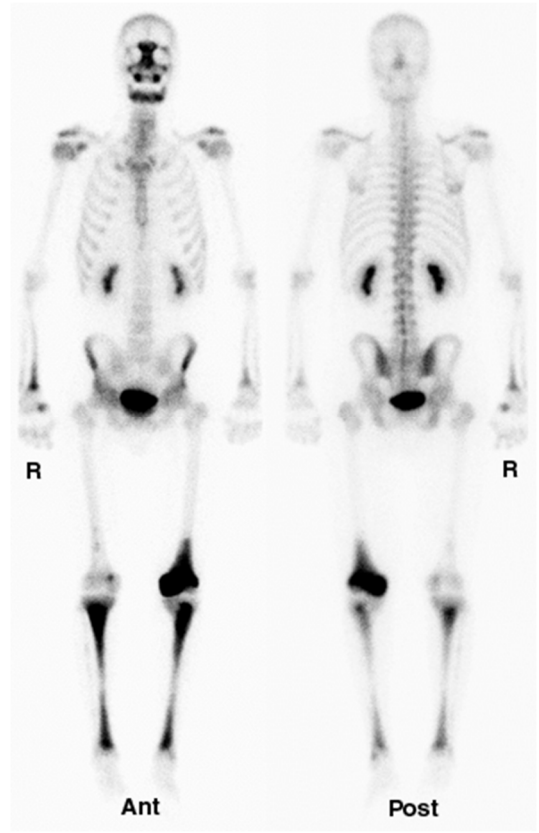
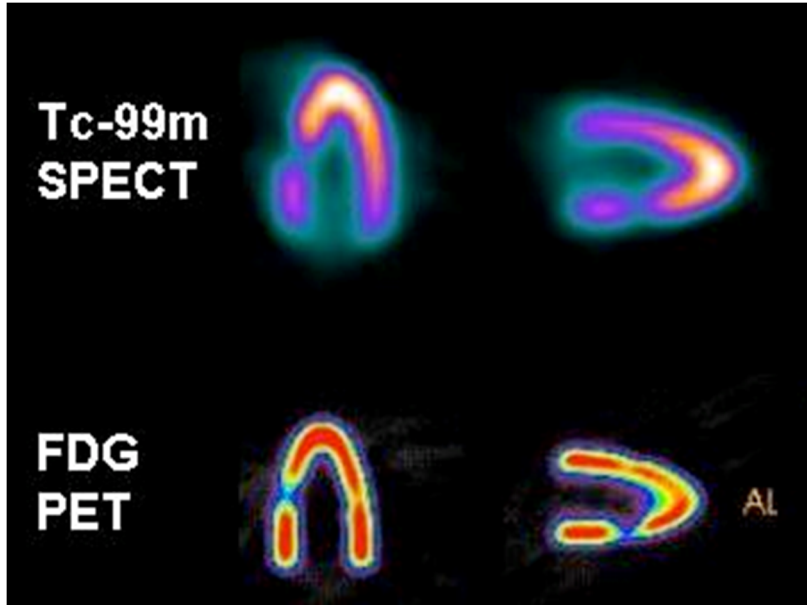
Radioisotopes in the body

- Diagnostics
 - need information out
 - radiation must escape the body
 - gamma rays
- Therapeutics
 - kill cancer cells
 - radiation needs to be absorbed locally
 - alpha or beta particles



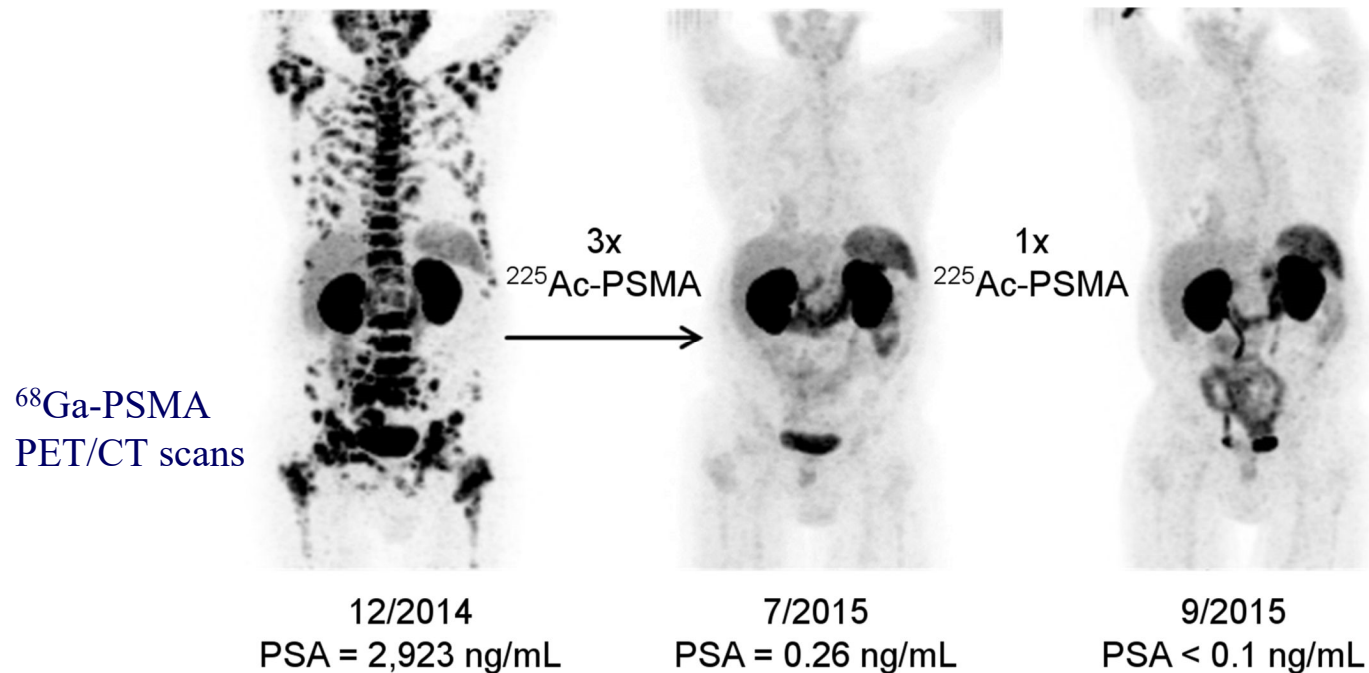
Mo-99 / Tc-99m

About 80% of nuclear medicine diagnostic procedures (tens of million exams annually) are performed with Tc-99m labeled radiopharmaceuticals.



Ac-225 – A Cure for Cancer

PSMA – prostate-specific membrane antigen, a biomarker that often appears on prostate cancer cells



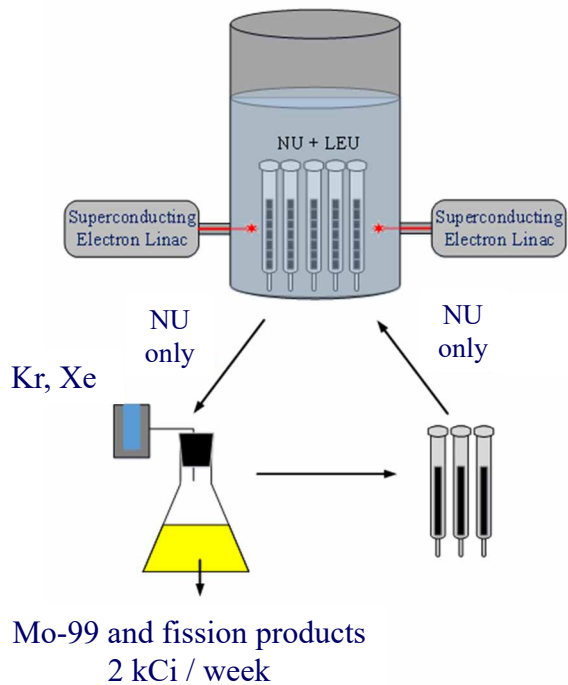
PSA – prostate-specific antigen, a chemical marker of prostate cancer measured in a routine blood test



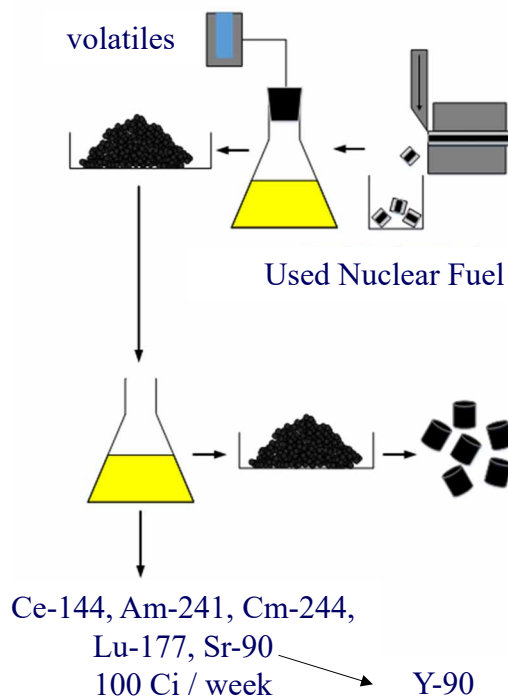
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Niowave Isotope Programs

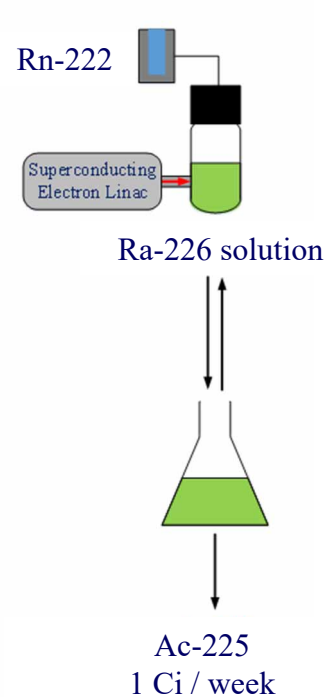
Mo-99 Program



Reactor Program



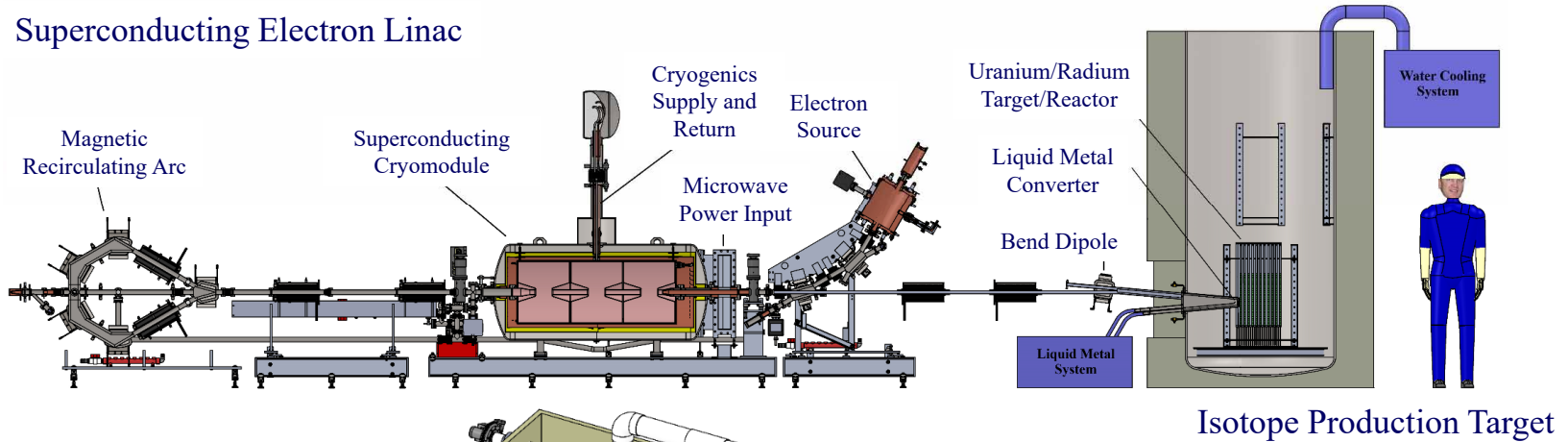
Ac-225 Program



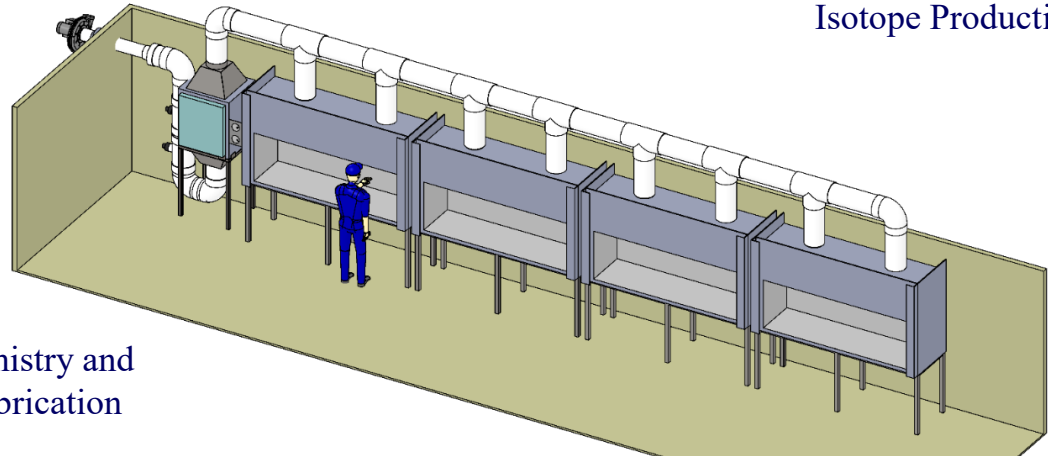
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Radioisotope Production

Superconducting Electron Linac



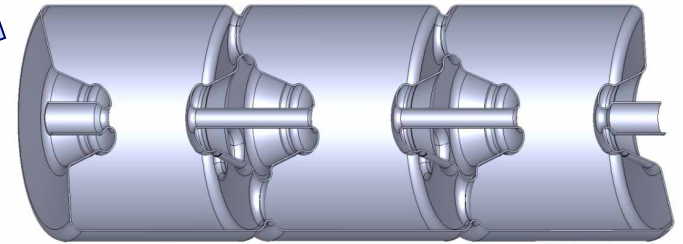
Electron beam
energy: 18-40 MeV
Beam power:
several kW to 200 kW
Duty cycle: 10-40%



Radiochemistry and
Target Fabrication

Commercial SRF: Cavities and Cryomodules

Niowave cavity design developed from experiences building a wide variety of structures for the SRF community



3-gap reentrant cell cavity

350 MHz and 4 K operation



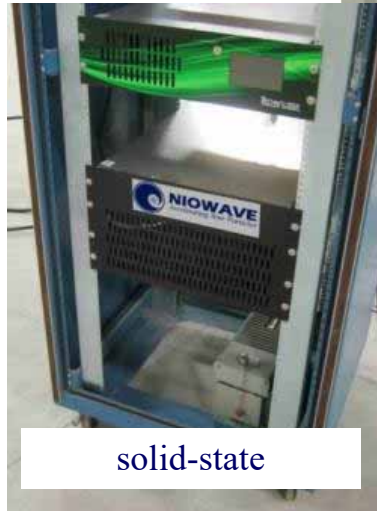
Liquid helium refrigerators

- 114 W capacity at 4.5 K
(100 kW wallplug power)
- Developed with Linde
 - Collins cycle
 - robust reciprocating piston expander
- Helium lines above atmospheric pressure
(He leaks out, contaminants do not leak in)
- Long term operation ready:
 - 5000 hr. major maintenance interval
 - No warmup for short term maintenance



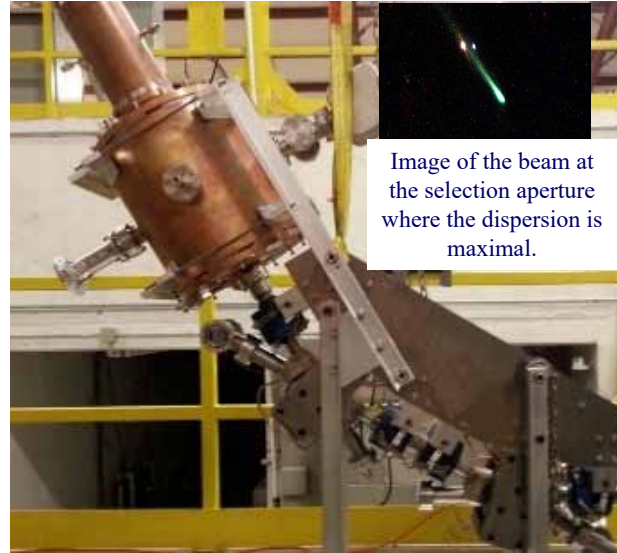
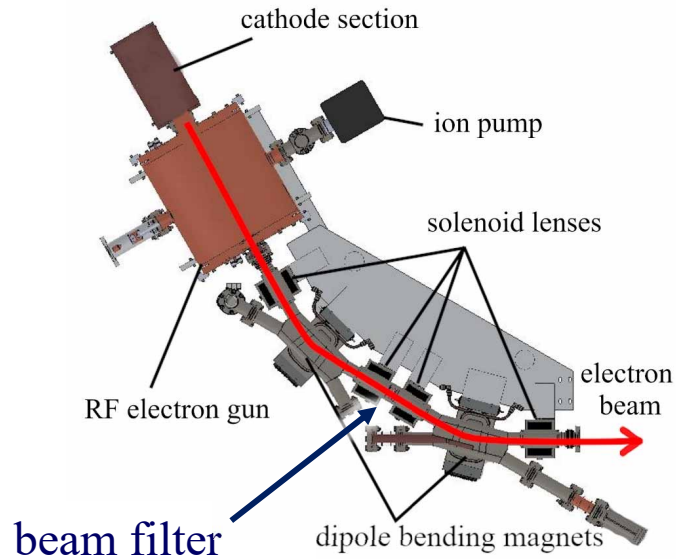
Microwave power

- Tetrode amplifier supplies the superconducting cavity
 - 350 MHz
 - 60 kW CW (100 kW pulsed)
 - very reliable and tough
 - can be operated without a circulator (but we use one)
- Solid-state amplifiers for the electron gun
 - 2.5 kW for the main fields (350 MHz)
 - 200 W for the harmonic gating (700 MHz)



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Thermionic-cathode RF gun and double-bend achromat

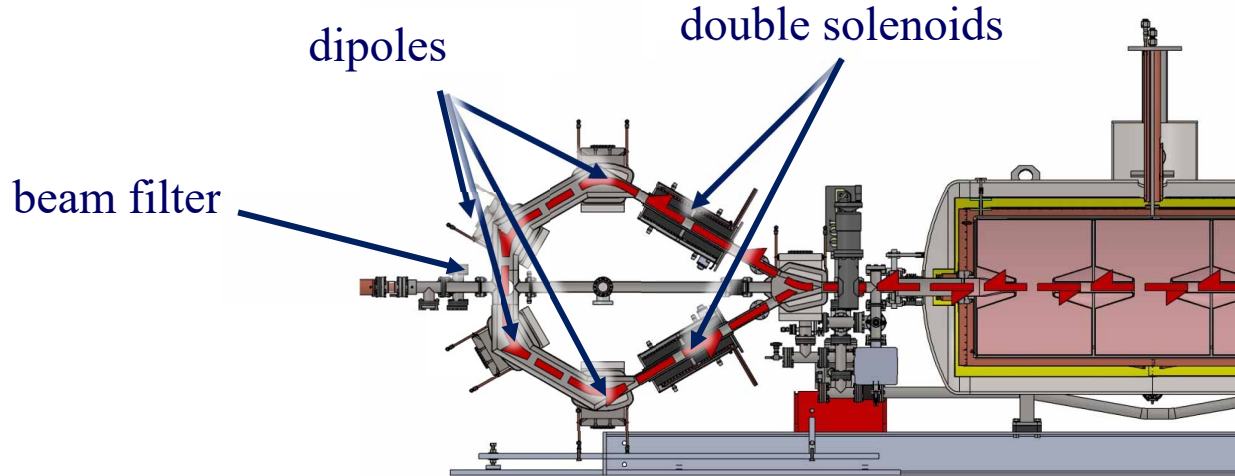


- thermionic cathode takes advantage of high-duty cycle SRF operation (10%-100%)
- electron bunches from the cathode are shortened by gating fields (DC, fundamental RF, harmonic RF) at the cathode



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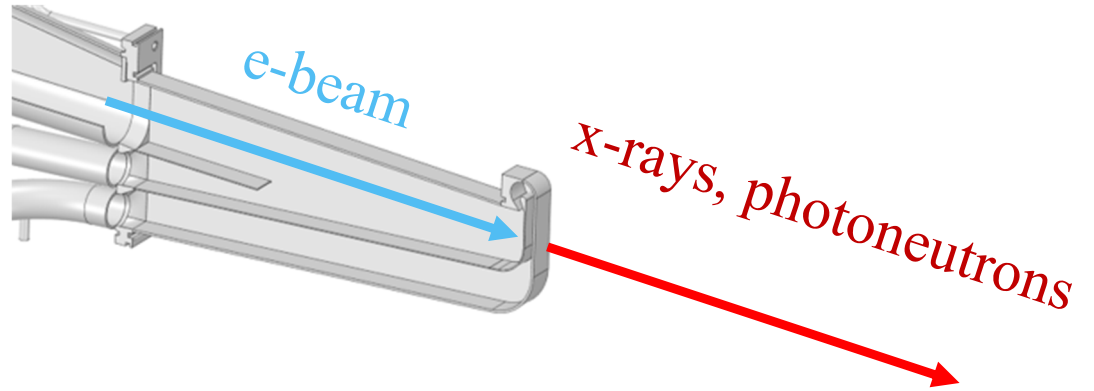
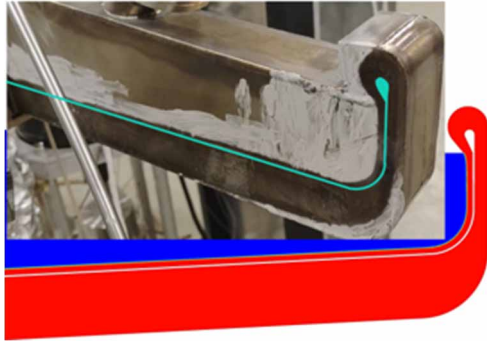
Magnetic Recirculating Arc



- Passing the beam through the SRF cavity twice reduces the required voltage by 2 and cryogenic load by 4
- Like the double-bend achromat, the solenoids cancel the dispersion from the dipoles



High-power liquid metal targets



0.5 gpm



1.4 gpm



2.0 gpm

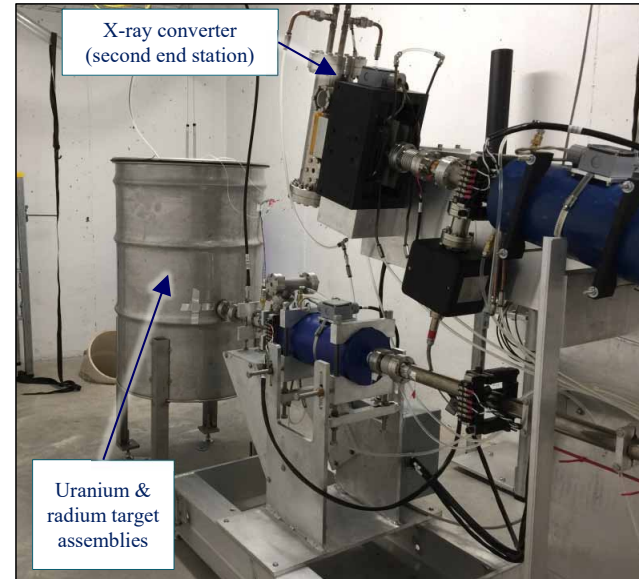
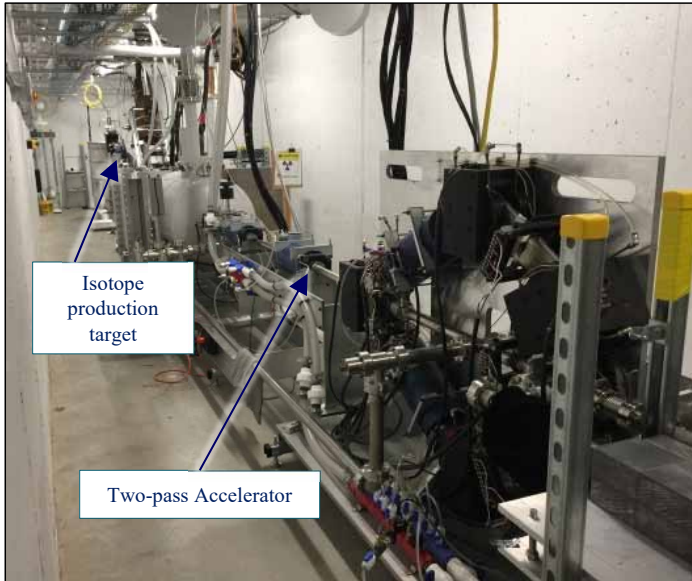
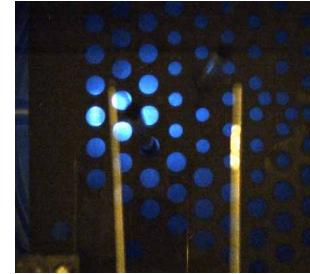


2.7 gpm

Accelerator Isotope Production

Production systems have now come online

- Superconducting linac coupled to uranium and radium targets
- Benchmarks of isotope production for Mo-99, Ac-225
- Ac-225 shipped to radiopharmaceutical partners



Facilities

Walnut St. school

- headquarters
- offices
- cleanroom
- test facility



Lansing airport production facility

- accelerator
- radiochemistry



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www.niowaveinc.com

We manufacture radioisotopes to cure cancer and save lives.

- Small superconducting RF accelerators have found a viable market application in the production of isotopes.
- Niowave, Inc. is focused on using SRF electron machines to drive radioisotope production targets and make Mo-99 (and other fission fragments) and Ac-225. Also producing Y-90 without accelerator.
- **WE ARE HIRING FOR A VARIETY OF PRODUCTION, RESEARCH, AND MANAGEMENT POSITIONS.**

