Isotope Production Using a Superconducting Electron Linac

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Niowave, Inc.
Lansing MI

NP SBIR/STTR Exchange Meeting, Gaithersburg MD
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Outline

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- Key Personnel
- Key Participants
- Superconducting Linacs and Their Applications
- Mo-99 Production with Linacs
  - Conceptual Design
  - Superconducting Electron Linac
  - Intense Neutron Source
  - Mo-99 Production and Recovery
  - Uranium Target Recovery
- Licensing (NRC and State of Michigan)
- Niowave Facilities

Key Personnel

Dr. Terry Grimm
President & Senior Scientist
- PhD Nuclear Engineering, MIT
- Founded Niowave in 2005
- Over 25 years experience in superconducting accelerators

Dr. Chase Boulware
Accelerator Physicist
- PhD Physics, Vanderbilt
- Over 10 years experience in accelerator design and operation

Dr. Valeriia Starovoitova
Nuclear Physicist
- PhD Nuclear Physics, Purdue
- Researcher at Idaho Accelerator Center
- Over 10 years experience in nuclear physics

Jerry Hollister
Chief Operating Officer
- BS Engineering, Michigan
- Former Naval Officer & Warranted Contracting Officer

Dr. Mayir Mamtimin
Nuclear Physicist
- PhD Nuclear Physics, Idaho State
- Researcher at Idaho Accelerator Center

Stephen Barnard
Nuclear Engineer
- BS Engineering, Michigan

Superconducting Turnkey Electron Linacs

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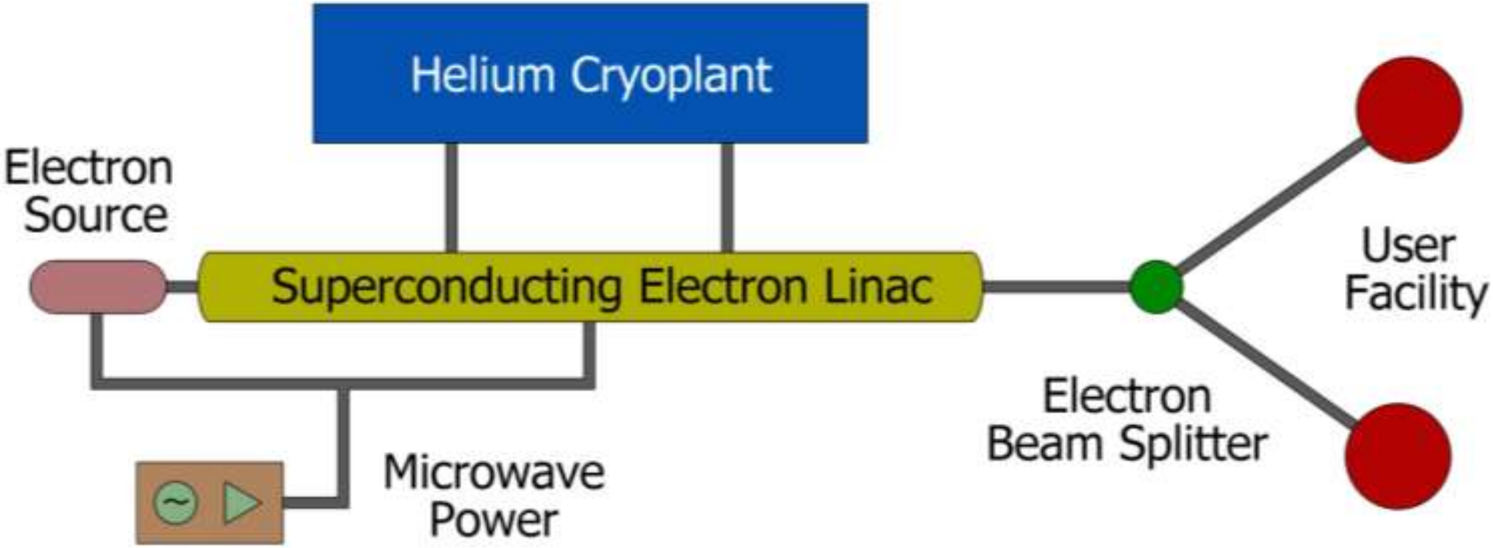
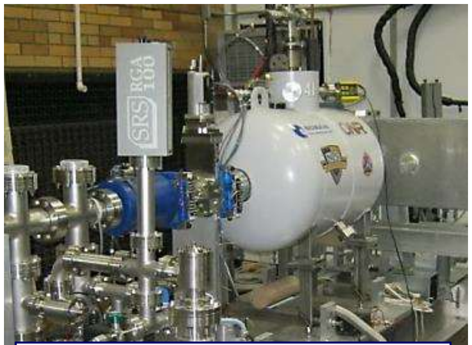


Turn-key Systems

- Superconducting Linac
- Helium Cryoplant
- Microwave Power
- Licensing

Electron Beam Energy	**0.5 – 80 MeV**
Electron Beam Power	**1 W – 400 kW**
Electron Bunch Length	**~5 ps**

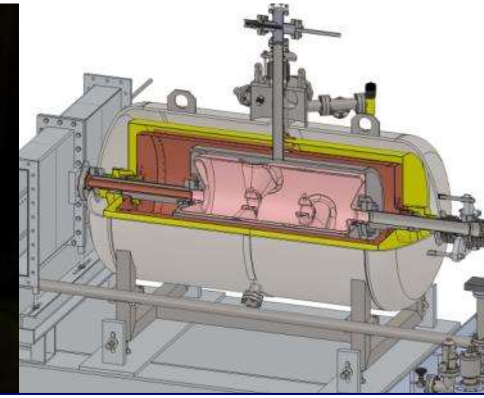
Turnkey Linac Subsystems



RF electron guns

High-power couplers

Solid-state and tetrode RF amplifiers (up to 60 kW)



Superconducting cavities and cryomodules

Commercial 4 K refrigerators (rugged piston-based systems, 100 W cryogenic capacity)

2 & 10 MeV Injectors

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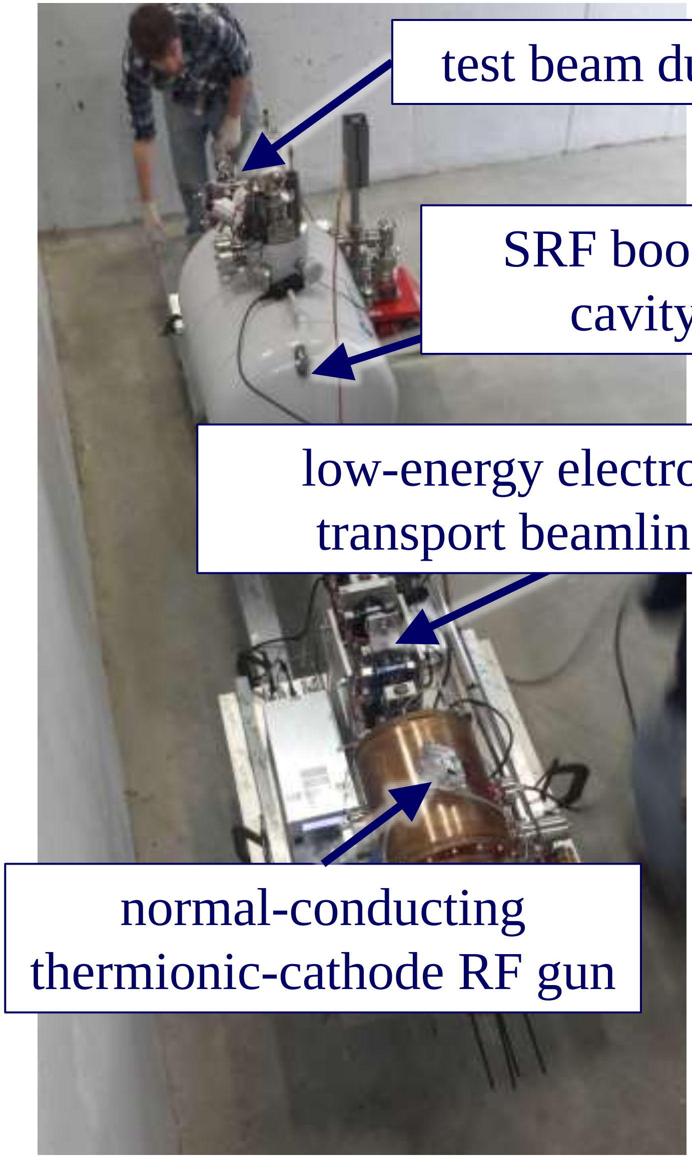

Parameter	2 MeV	10 MeV
cathode type	thermionic	thermionic
NCRF electron gun energy	100 keV	100 keV
SRF booster cavity energy	2 MeV	10 MeV
bunch repetition rate (gun, booster frequency)	350 MHz	350 MHz
transverse normalized rms emittance	3-5 mm mrad	3-5 mm mrad
bunch length @ 2 MeV	2-5 ps	2-5 ps
average beam current	2 mA	1-2 mA

Commercial Uses of Superconducting Electron Linacs

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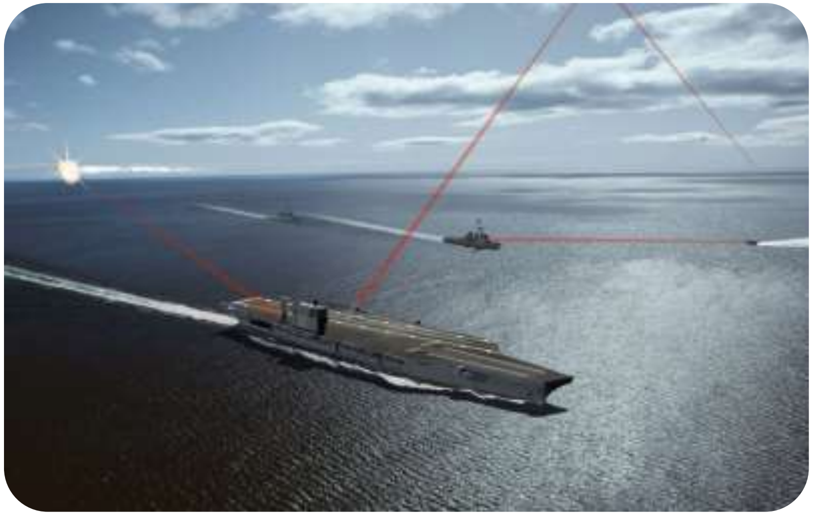
High Power X-Ray Sources

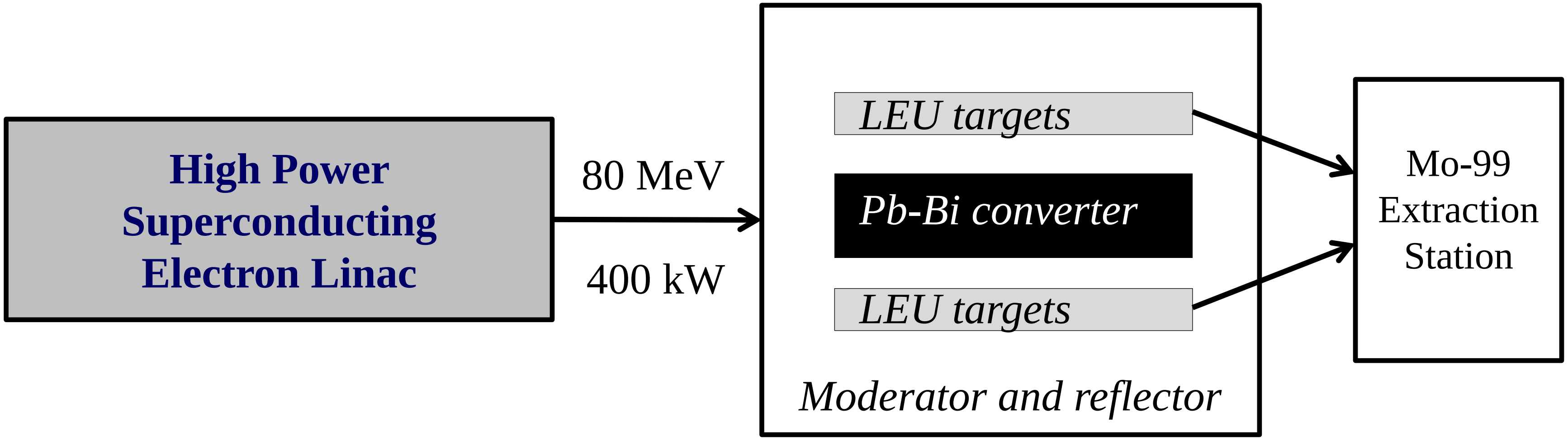
Radioisotope Production



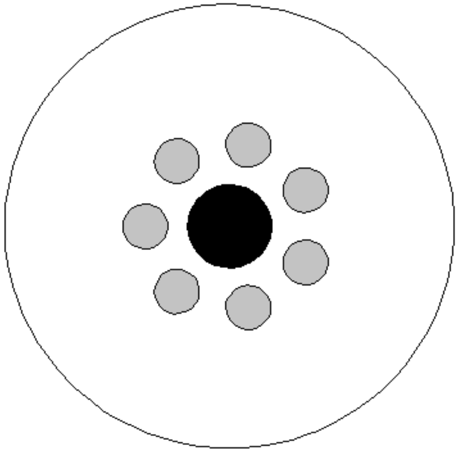
Free Electron Lasers

High Flux Neutron Sources

Conceptual Design [1]



- Pb-Bi converter is used to produce n and γ
- Uranium (in LEU targets) is fissioned by both n and γ
- Mo-99 is one of the fission products



Conceptual Design [2]

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- Using LEU we plan to produce ~9 kCi of Mo-99 (~1,500 six-day curies) weekly at each of the 80 MeV 400 kW facilities

- 4-5 such facilities will satisfy North America's demand of Mo-99

9

High Power X-Ray Converter

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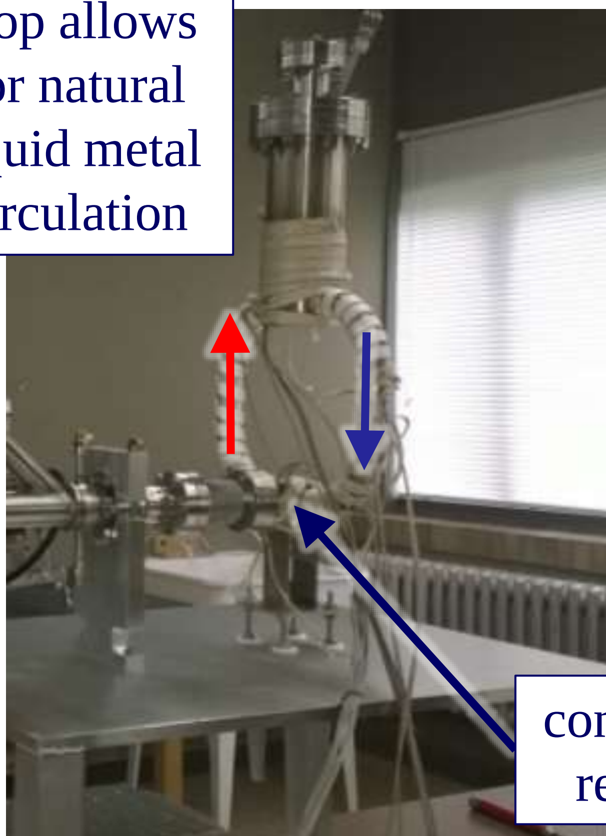
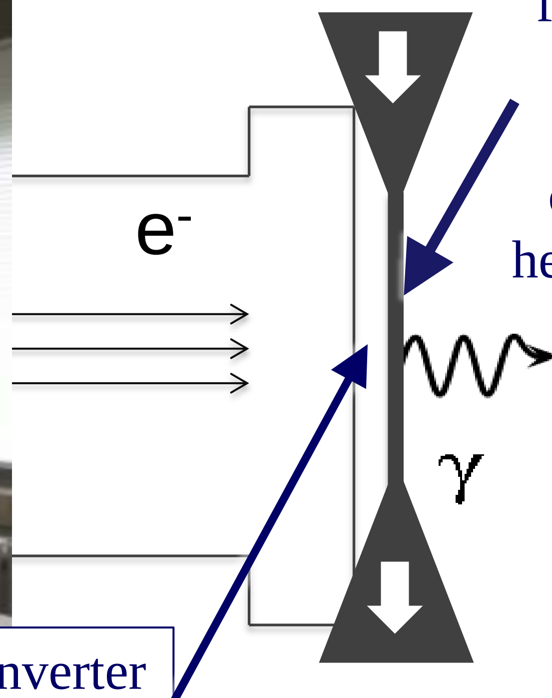
Electrons strike high-Z target (liquid PbBi eutectic) and produce bremsstrahlung photons

loop allows for natural liquid metal circulation



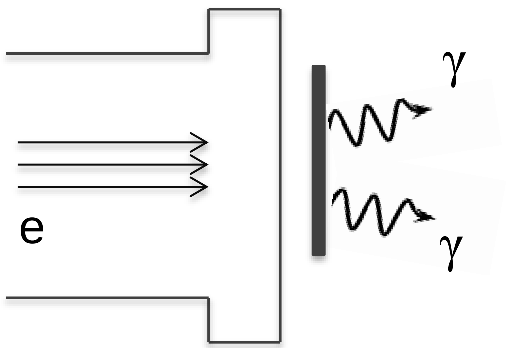
converter region



flowing liquid metal carries heat away

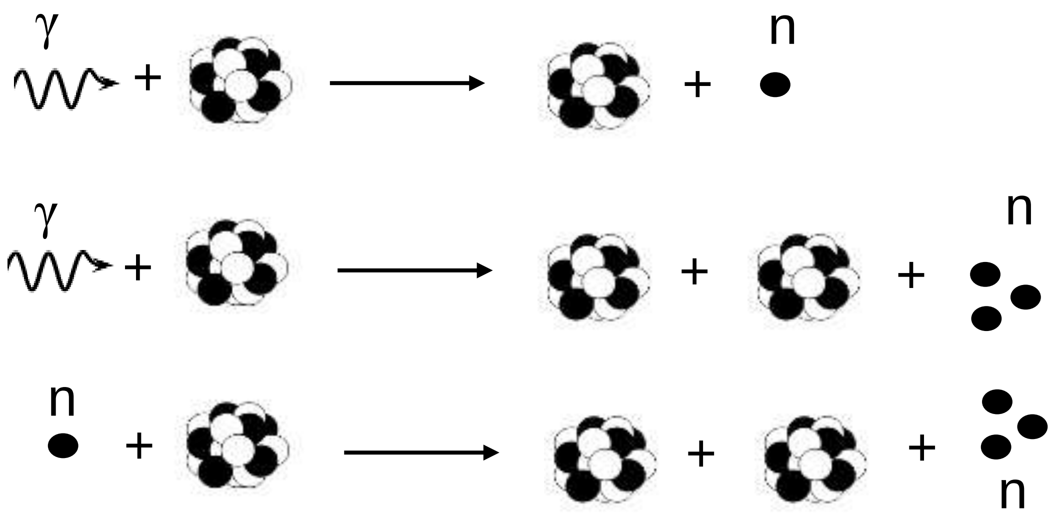
tested with partners at Idaho Accelerator Center (40 MeV beam, produced Cu-67 and Zn-65)

Intense Neutron Source [1]



Electrons are accelerated

Electrons brake and produce photons



Neutrons are generated by:

a) (γ,n) reactions

b) Photo-fission

c) Neutron-induced fission

Intense Neutron Source [2]

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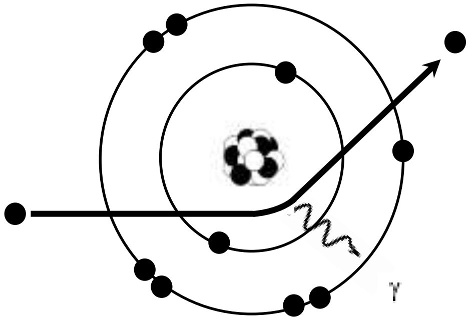
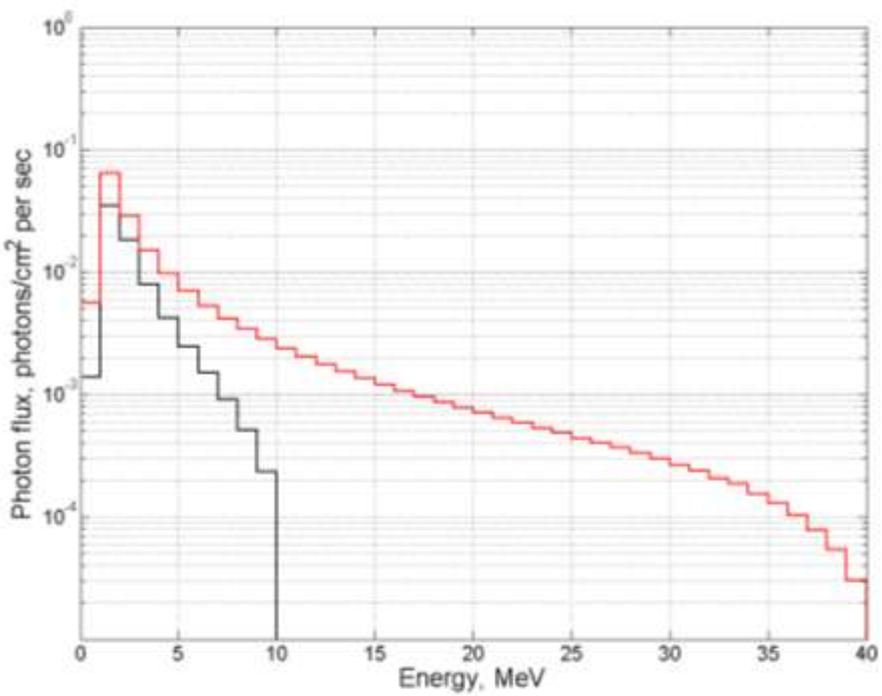
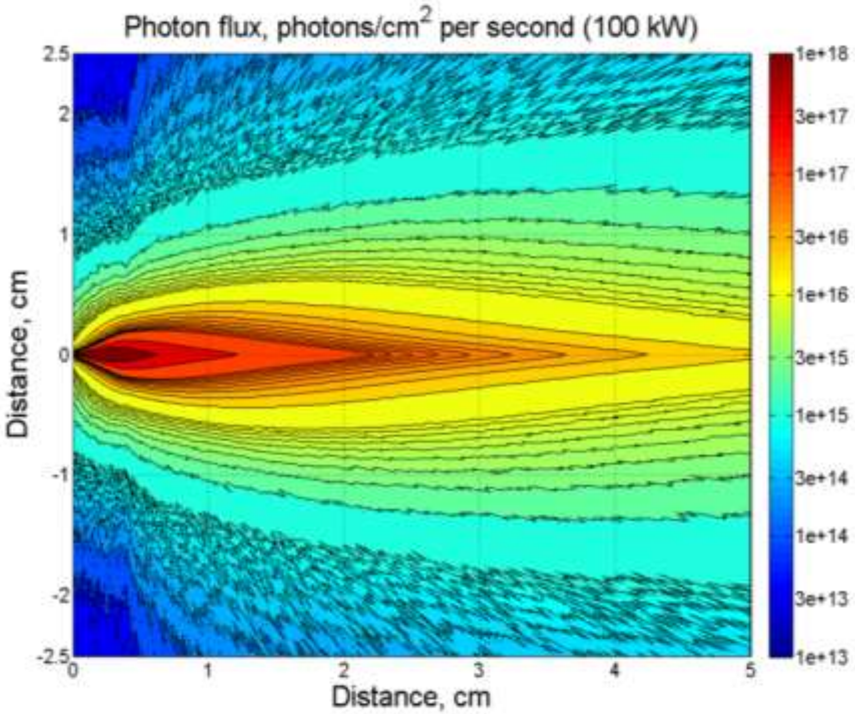
Braking radiation (bremsstrahlung photons):







Intense Neutron Source [3]

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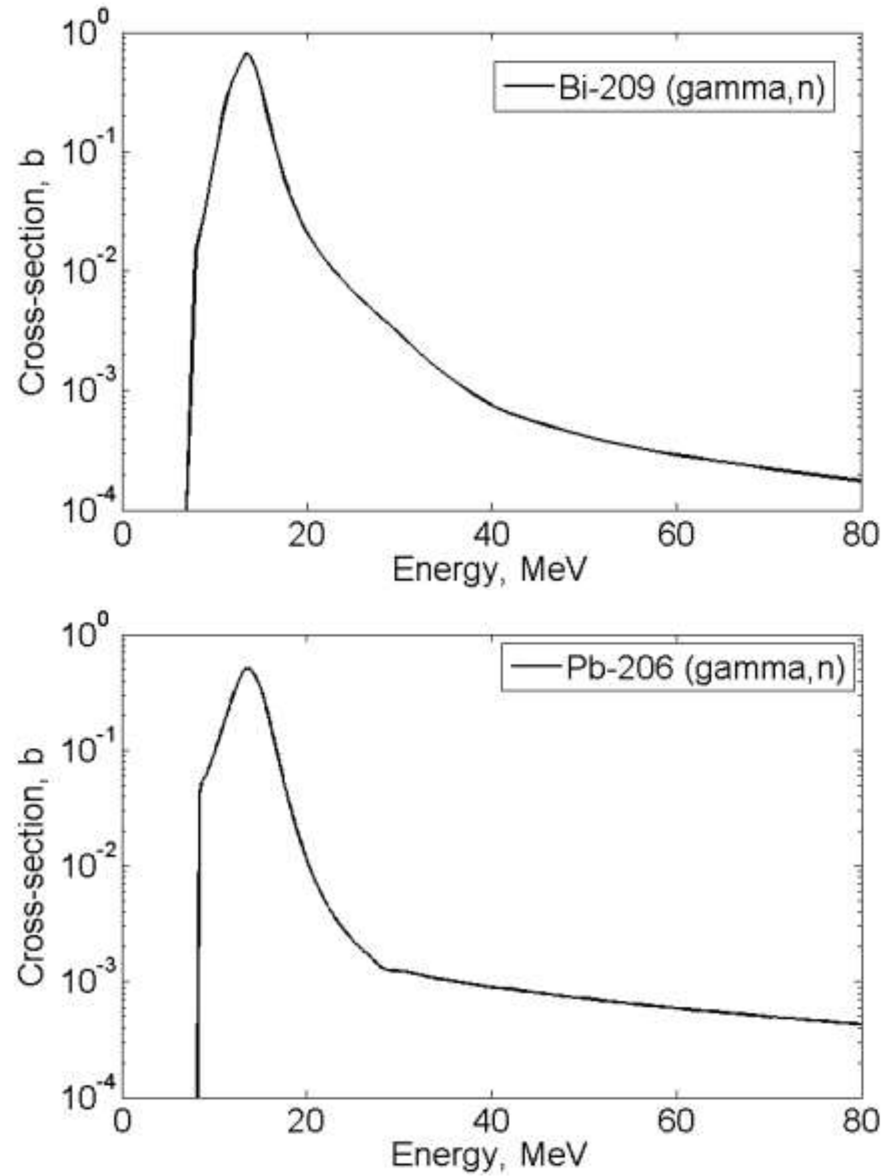
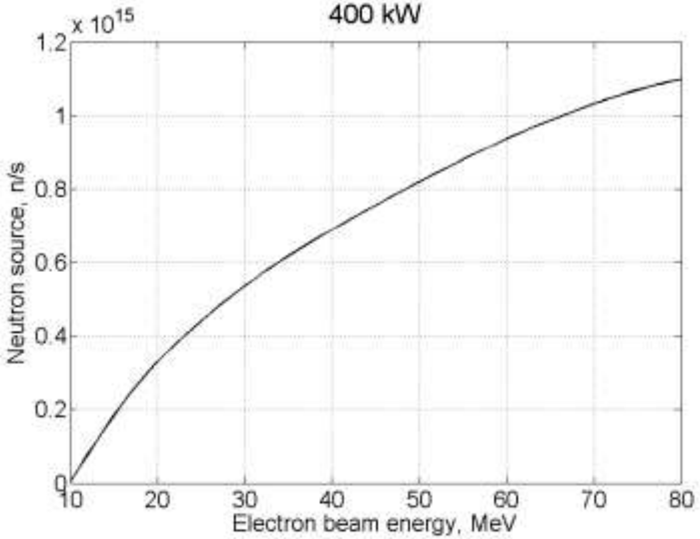
Lead-Bismuth Eutectic (PbBi):

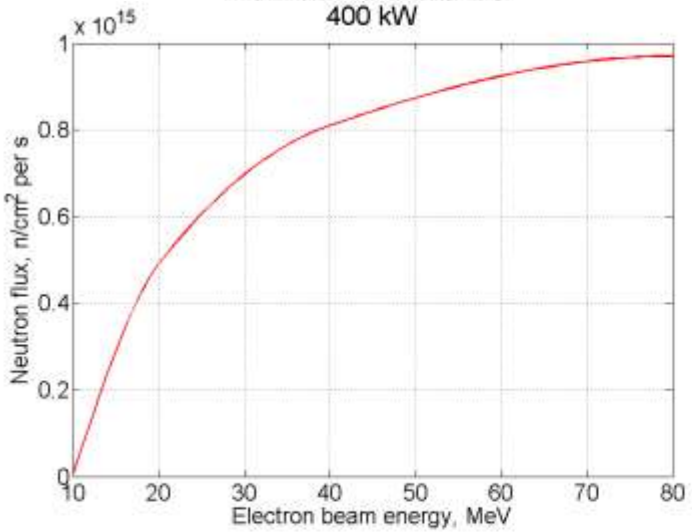
- High conversion efficiency (Z=82,83)
- Low melting point (124°C)
- High boiling point
- (1670 °C)

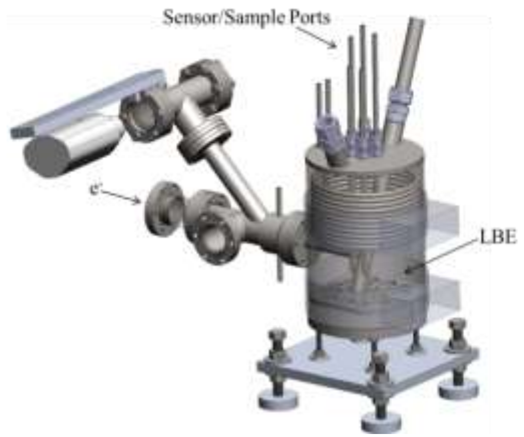


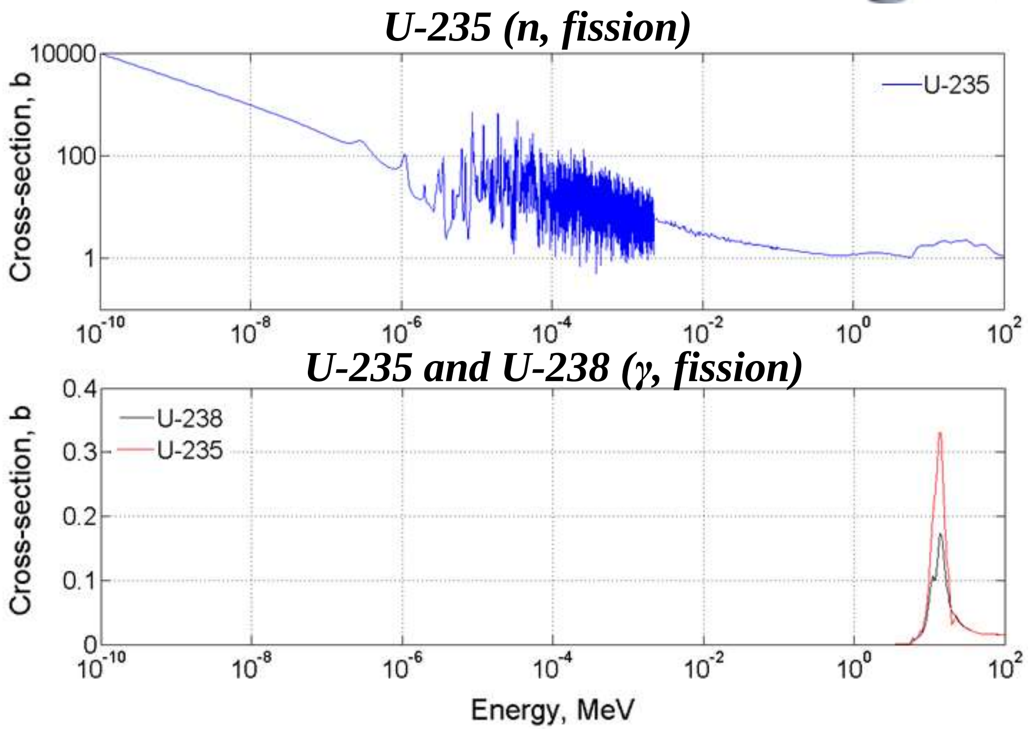
Intense Neutron Source [4]

PbBi source intensity & flux:

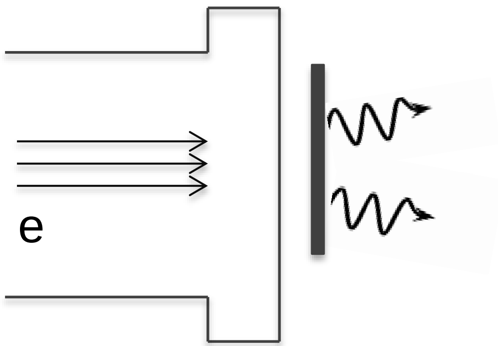


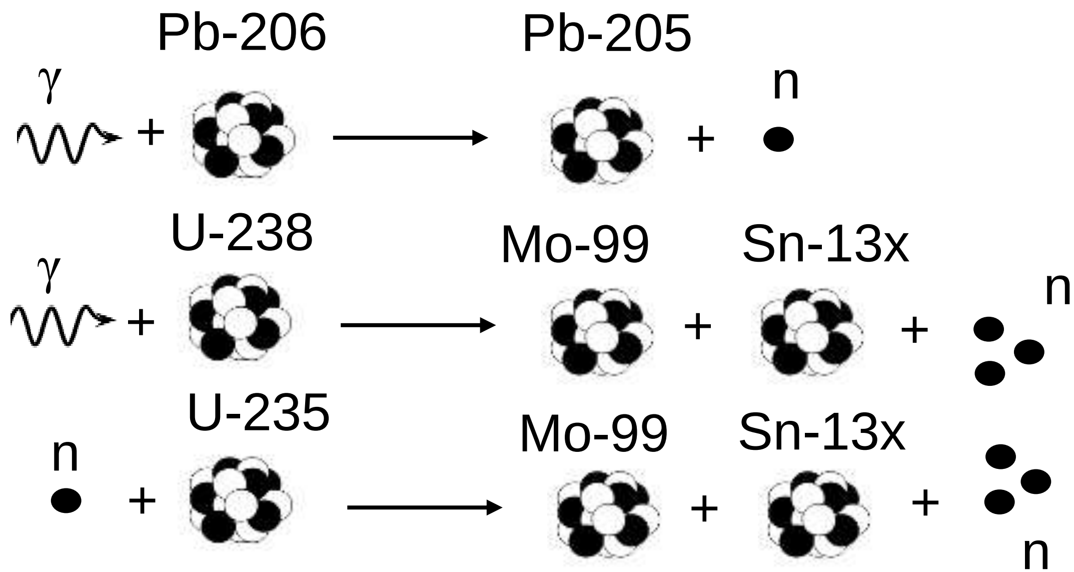


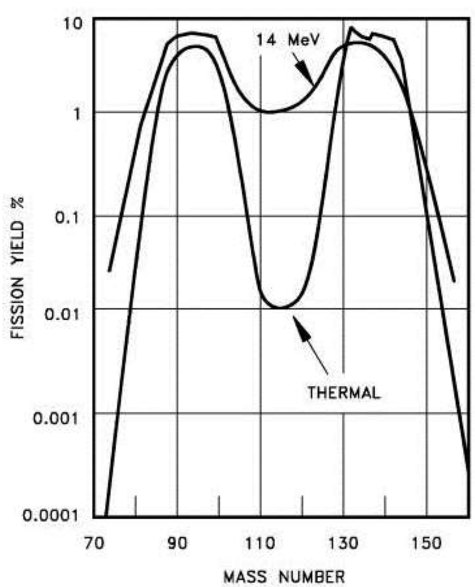




Mo-99 Production







- Time of irradiation – 1 week
- Mo-99 activity per rod – 0.1 kCi
- Total Mo-99 produced – 9 kCi/week

Mo-99 Recovery

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- Twelve rods will be processed daily
- Mass of each LEU rod – 99g
  - If the batch mass is less than 100 g of <20% LEU (<20 g U-235), than Part 30 Byproduct from accelerators applies
- Produce up to 9,000 Ci/wk (1,500 6-day Ci/wk)
- Molybdenum recovery
  - Uranium target dissolution with HNO_3
  - Molybdenum adsorption on ion exchange resin
- Standard Tc-99m generators
  - Capable of using the existing supply chain

Uranium Target Recovery

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- Extract additional isotopes of commercial value
  - ^{140}La, ^{133}Xe, ^{132}Te, etc
- Extract uranium for reuse
- Waste consolidated and shipped to LLW/HLW repositories

Licensing Plan

- Plan to scale up production and processing as technical and financial milestones are met
- Phased approach to production and processing

PHASE I
Feasibility Demo
150 6-day Ci/wk
<700 g of U-235

→

PHASE II
Full Scale Demo
1,500 6-day Ci/wk
<10,000 g of U-235

→

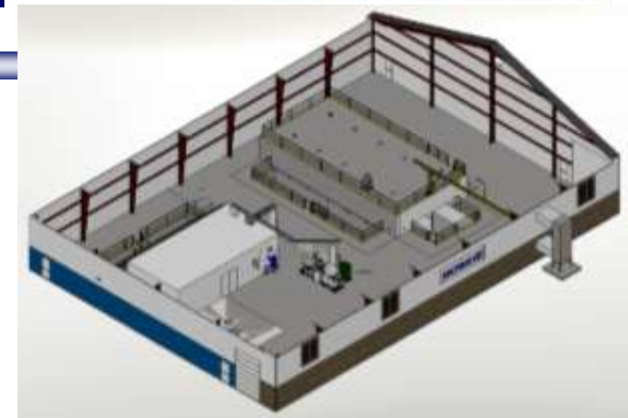
PHASE III
Full Production
4-5 facilities in U.S.
6,000 6-day Ci/wk

Niowave Facilities [1]

- **60,000 square feet**
  - Engineering & design
  - Machine shop
  - Fabrication & welding
  - Chemistry facility
  - Class 100 Cleanroom
  - Cryogenic test lab
  - Two operating 100 W cryoplants
- **Test Facilities (2)**
  - 3 megawatts power available at both
  - Licensed to operate up to 40 MeV and 100 kW

Lansing, Michigan Headquarters

Niowave Facilities [2]



- Headquarters test facility
  - Prototype and commission
  - 40 MeV superconducting electron linac
- 2012 Dedication of test facility at headquarters
  - Keynote speakers: Senator Carl Levin, Senator Debbie Stabenow, Rear Admiral Matthew Klunder and MSU Provost Kim Wilcox

Niowave Airport Facility

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- Production & processing facility
  - Occupancy Jan 2015
  - 24/7 operation
  - Isotopes, x-rays, etc.
- Lansing International Airport
  - Foreign Trade Zone

Phase II SBIR Summary

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- 40-80 MeV accelerator designed, hardware development path started
- Prototype converter/target unit built and used for photonuclear isotope production test
- Dedicated production facility ready at Lansing International Airport (accelerators licensed both for R&D at headquarters and airport location)
- NRC licenses allow:
    - Possession, machining, and distribution of source material (natural/depleted uranium and thorium)
    - Production of certain isotopes from stable targets and uranium (including LEU)