Niowave's Domestic Production of Mo-99 and other Fission Fragments from LEU without a Nuclear Reactor

Niowave, Inc.
Lansing MI

September 25, 2018
Presented at the Mo-99 Topical Meeting
Knoxville, TN

NIOWAVE
Accelerating Your Particles

Outline

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- Closed-loop fuel cycle
- Additional fission fragments (beta emitters)
- Status of technical work
  - Superconducting electron linac
  - Uranium Target Assembly
  - Radiochemistry and target fabrication
- Laboratory assistance
- Regulatory agencies
- Scale-up plans

Closed-Loop Fuel Cycle

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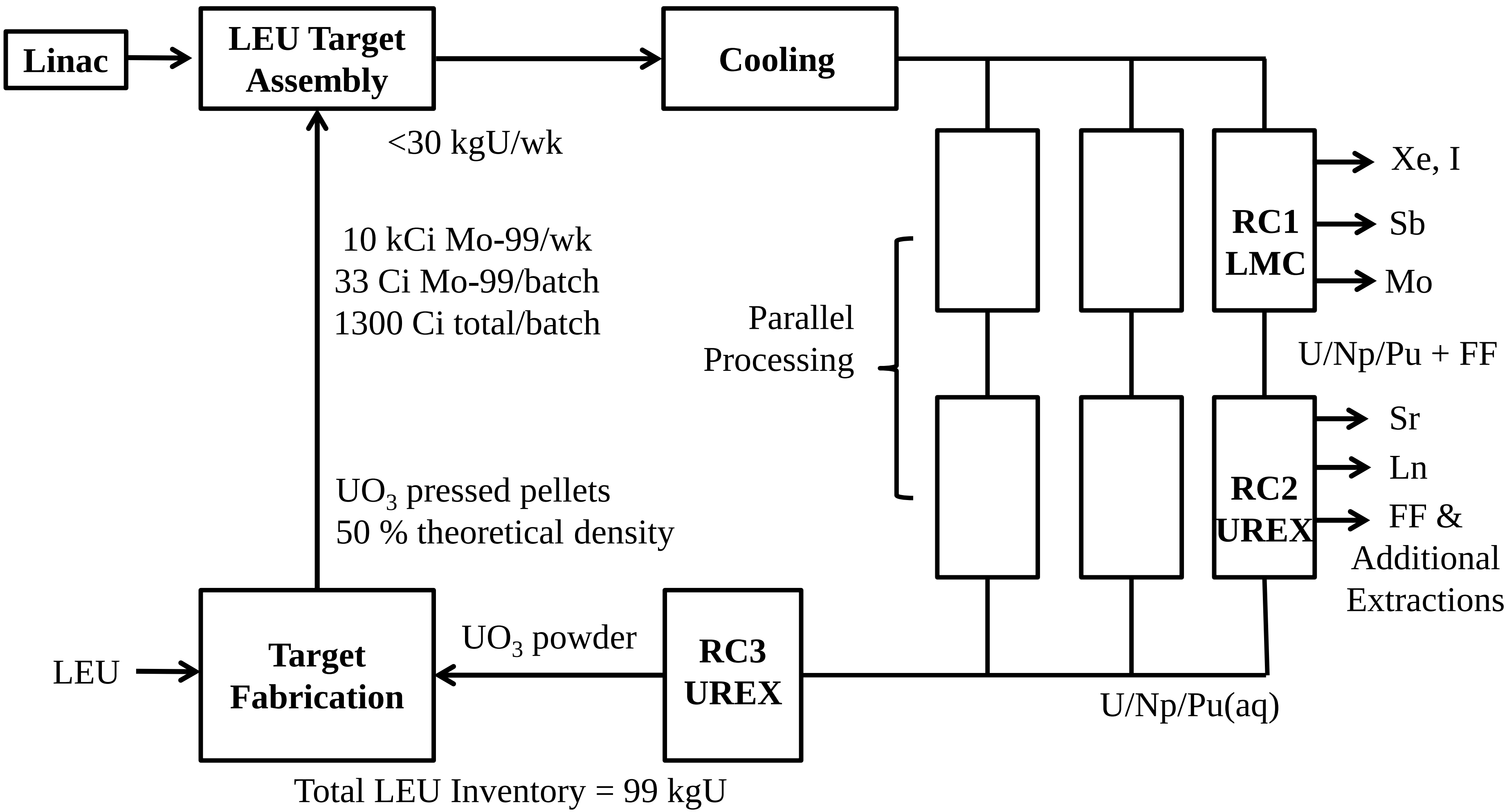

Niowave's Production Facility

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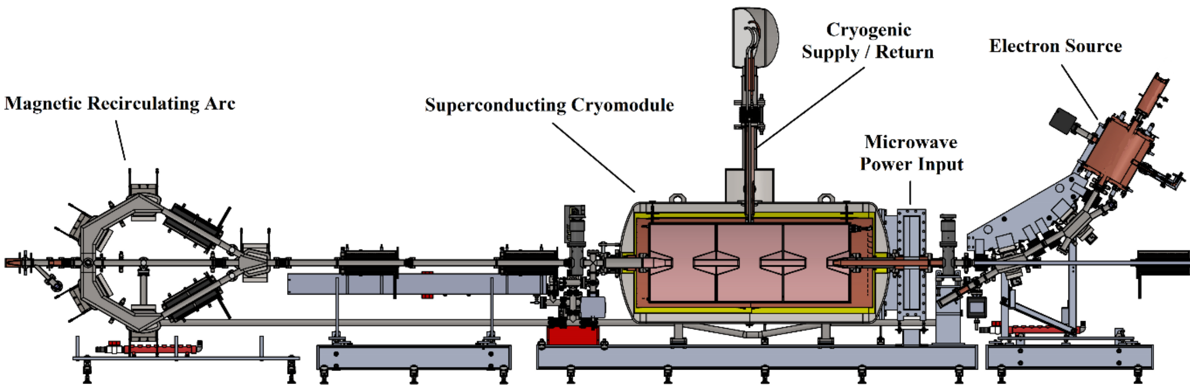
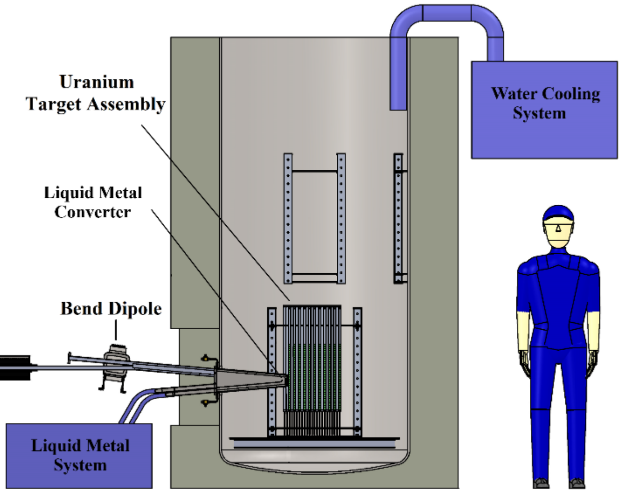
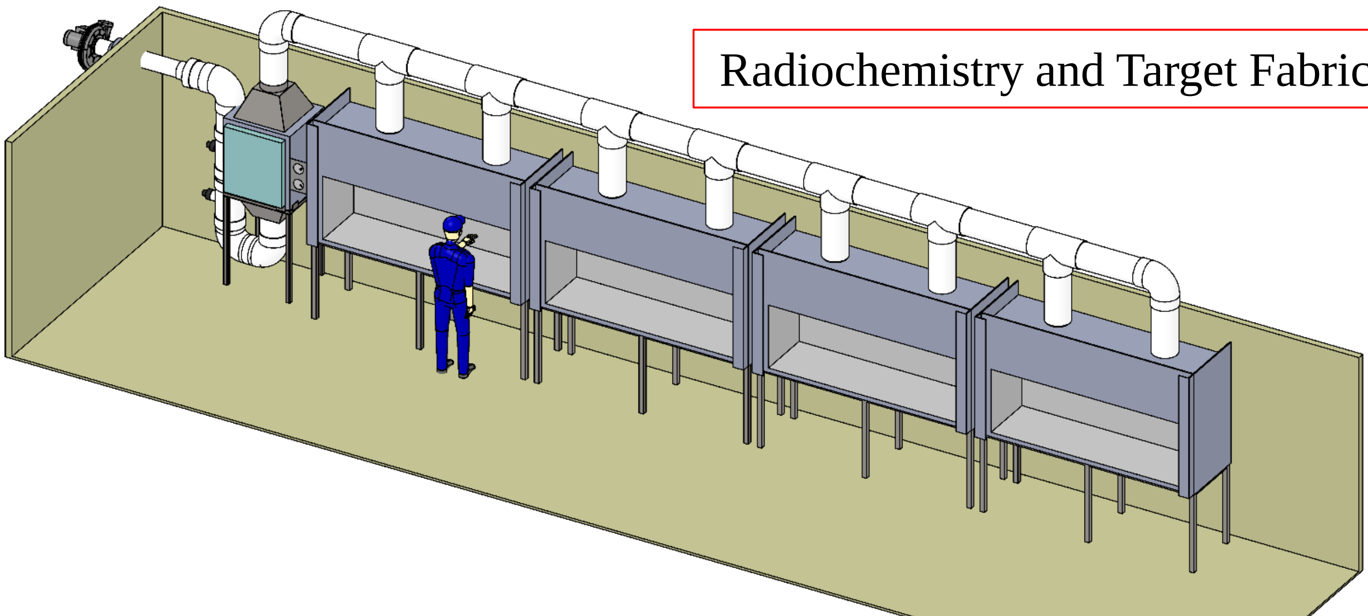
Superconducting Electron Linac



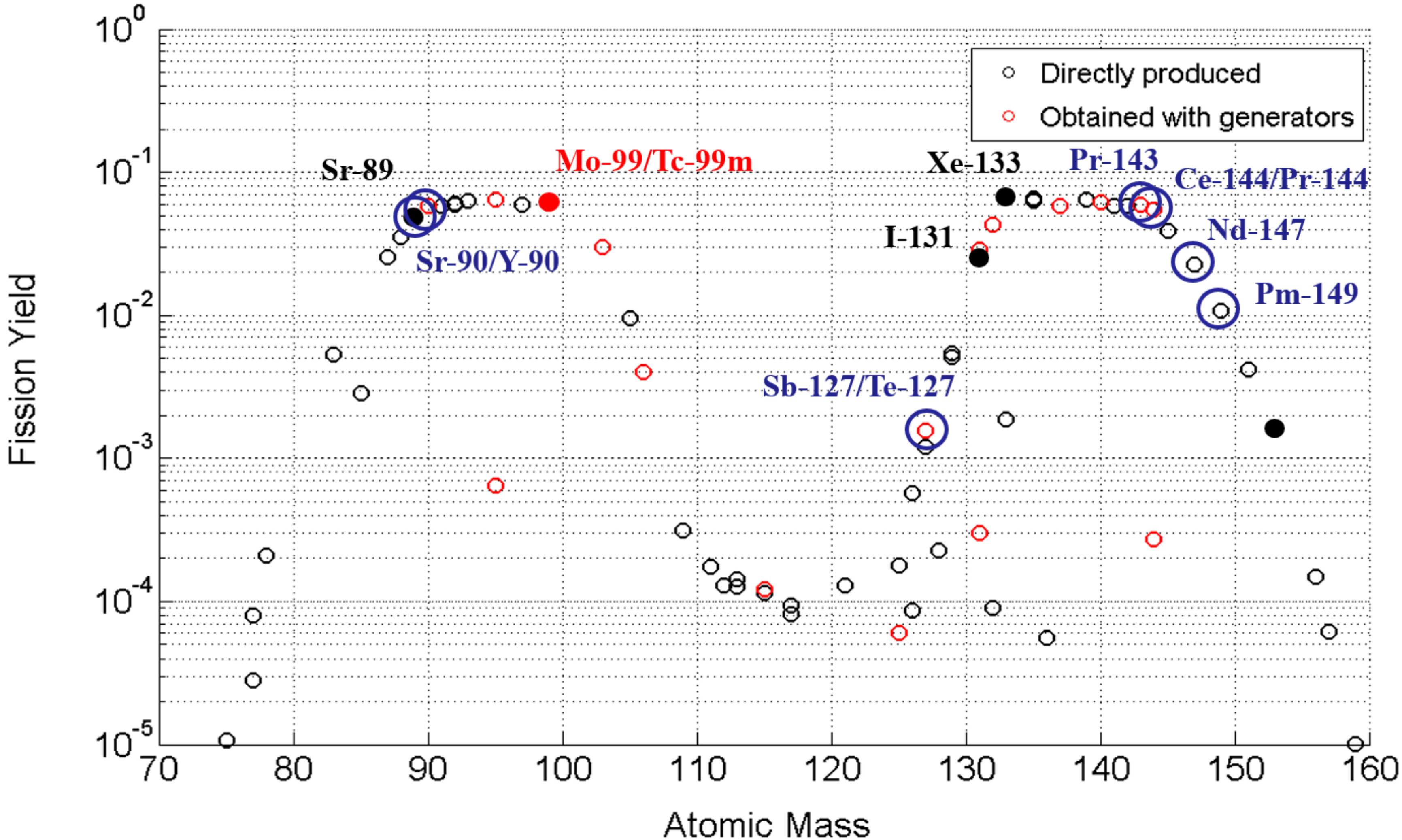
Uranium Target Assembly



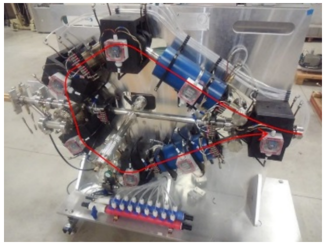
Radiochemistry and Target Fabrication

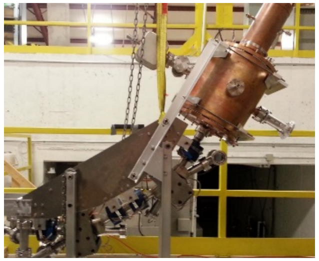


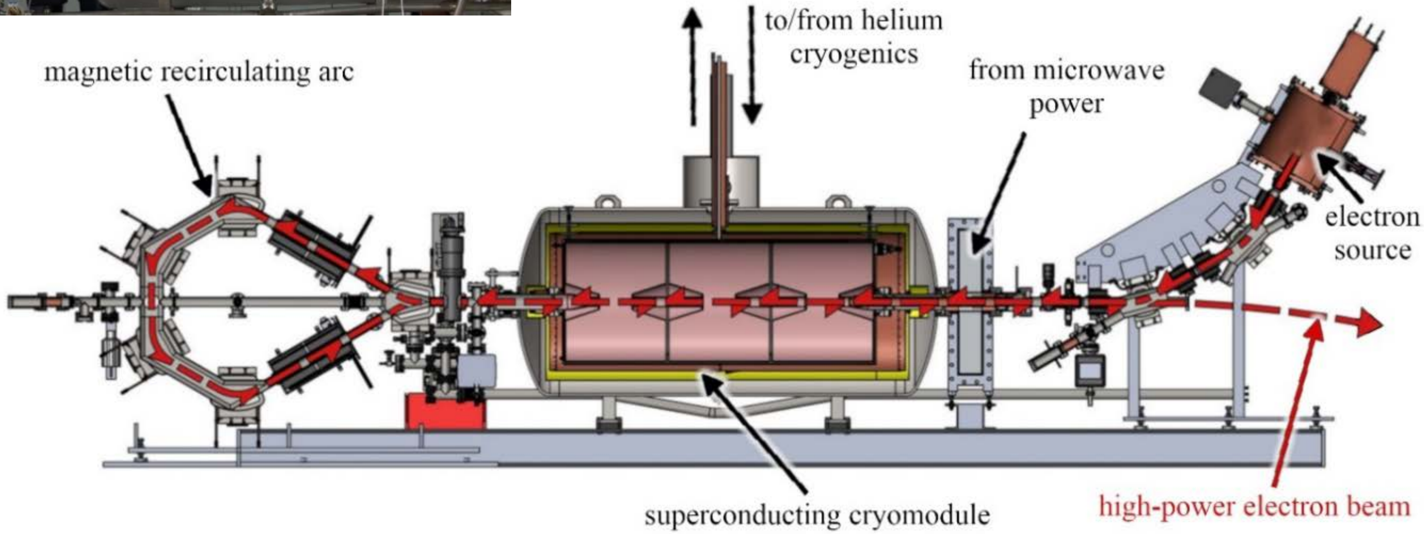
Beta Emitters for Nuclear Medicine



Superconducting Electron Linac







Advantages for isotope production

- stable operation at very high beam power
- efficient in converting wallplug electricity into beam power

Uranium Target Assembly

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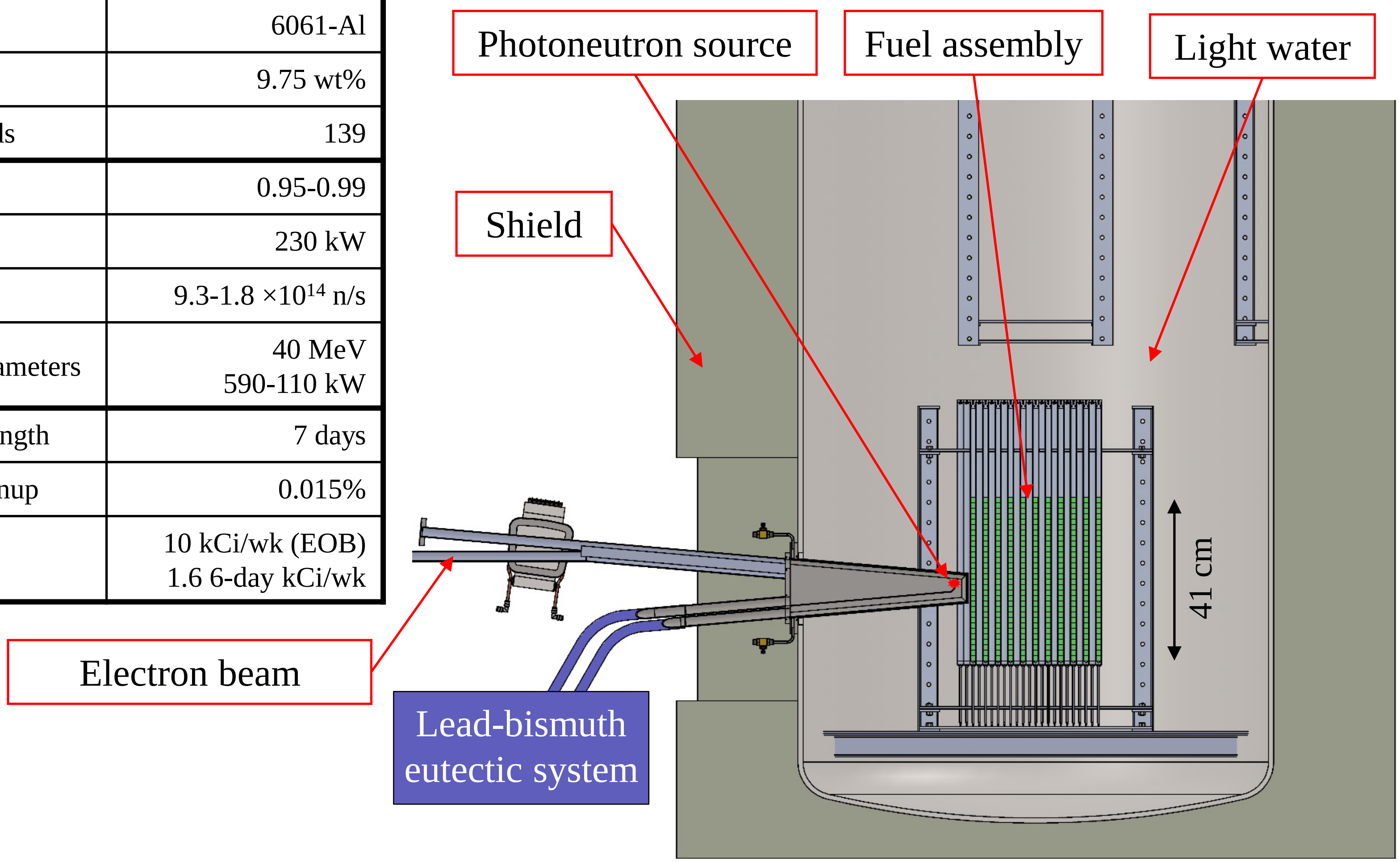
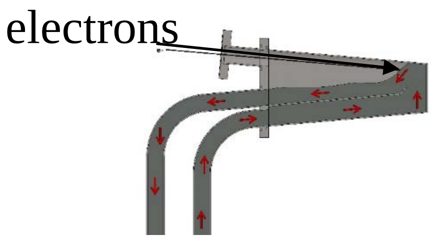
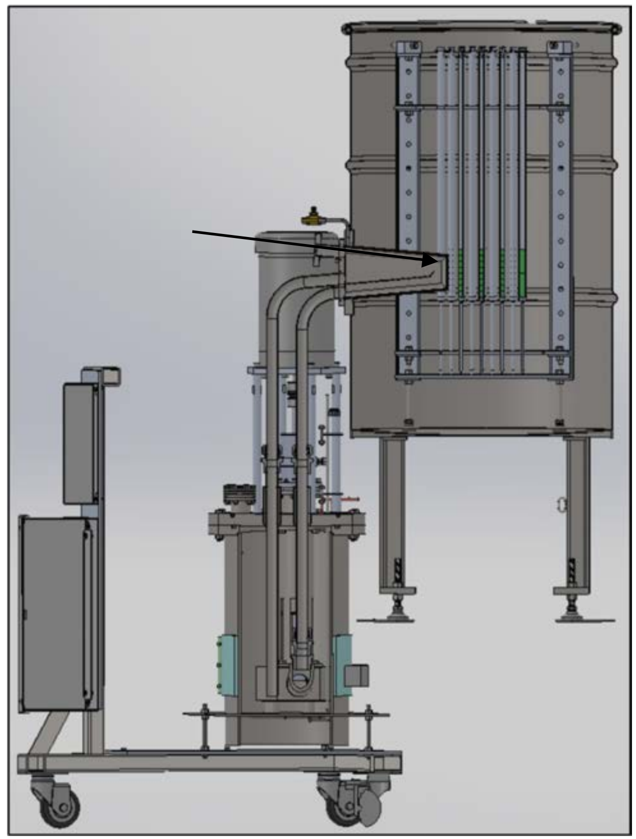
LEU fuel loading	27.4 kgU
Fuel type	UO_3
Cladding type	6061-Al
^{235}U enrichment	9.75 wt%
Number of fuel rods	139
k_{eff}	0.95-0.99
Fission power	230 kW
Neutron source	9.3-1.8 $\times 10^{14}$ n/s
Electron beam parameters	40 MeV 590-110 kW
Irradiation cycle length	7 days
Fractional fuel burnup	0.015%
Mo-99 activity	10 kCi/wk (EOB) 1.6 6-day kCi/wk

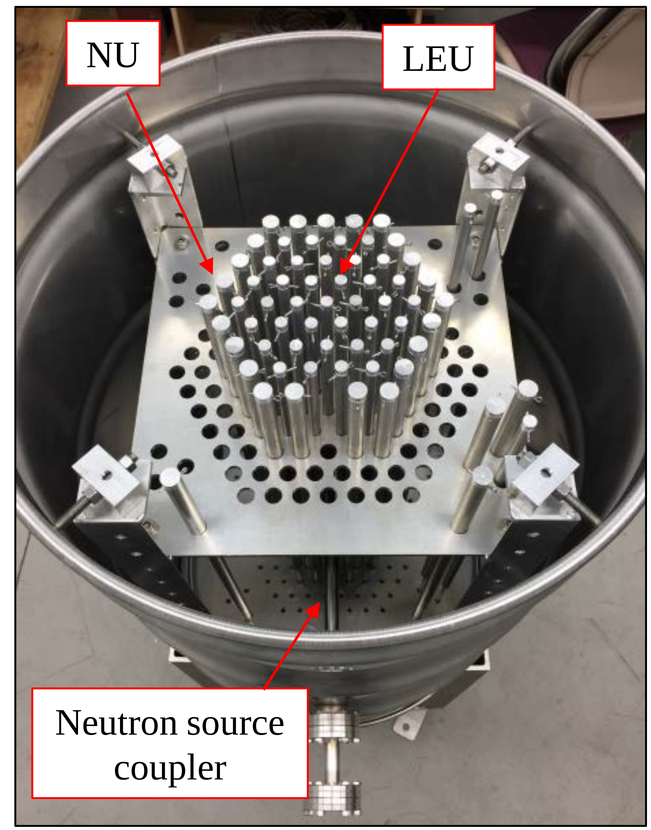
The Uranium Target Assembly (UTA) is a subcritical assembly, open-pool type LWR



Neutron Source and UTA







- Windowless liquid Lead-Bismuth Eutectic (LBE)

UTA Loading and Testing

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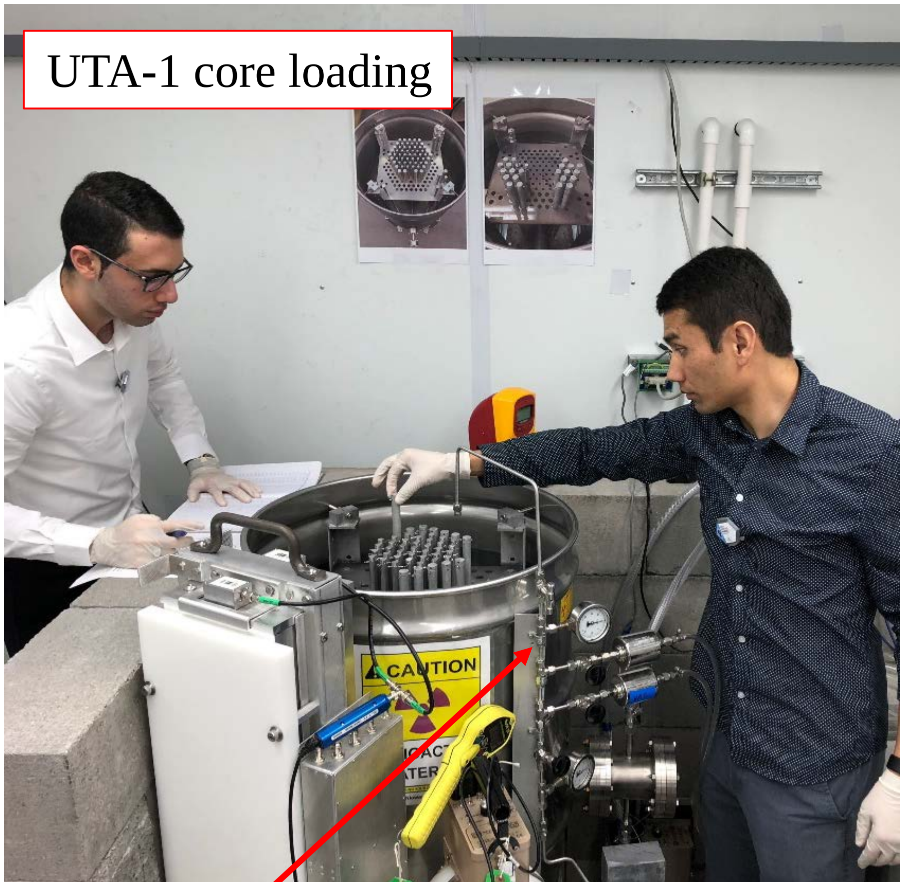
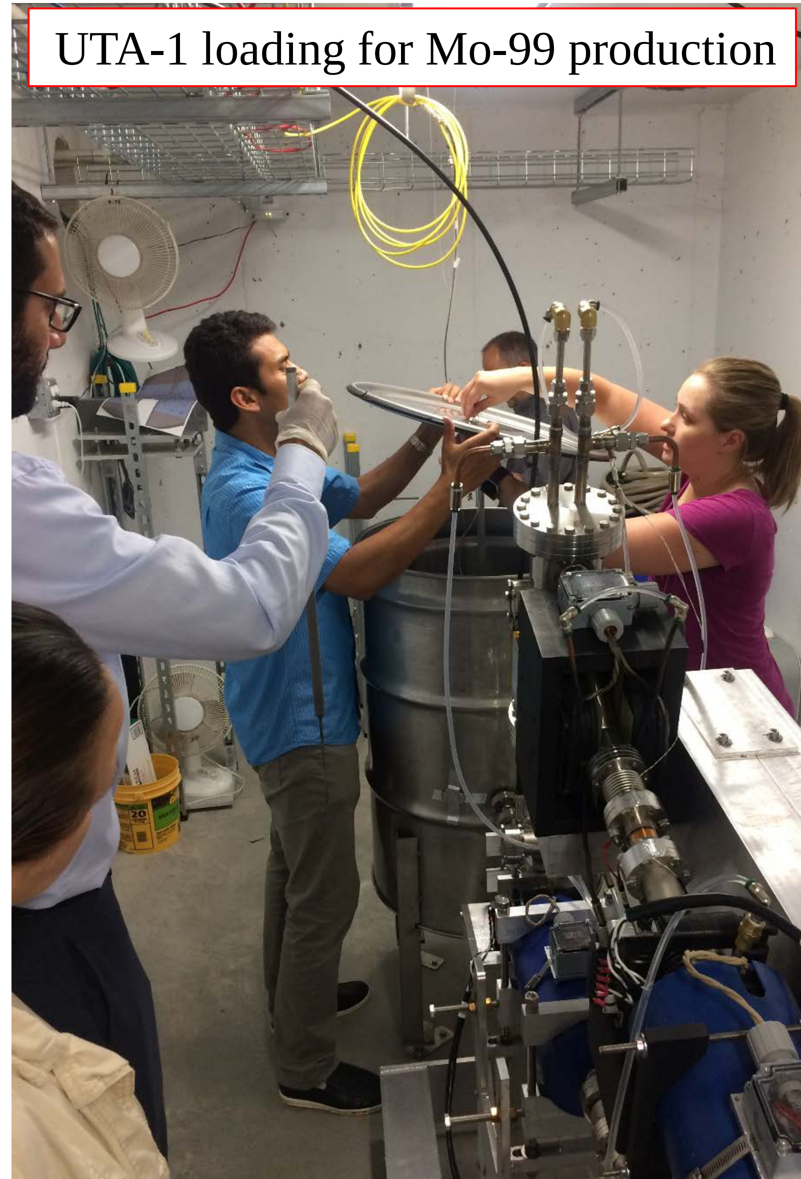


Gas extraction module



Mo-99 and Xe-133 Production

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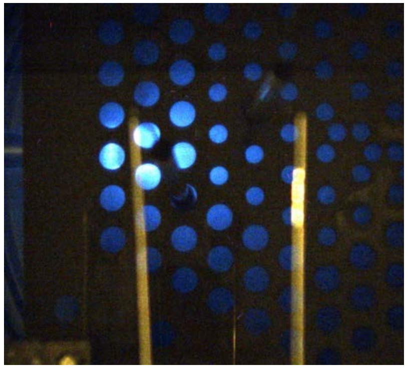
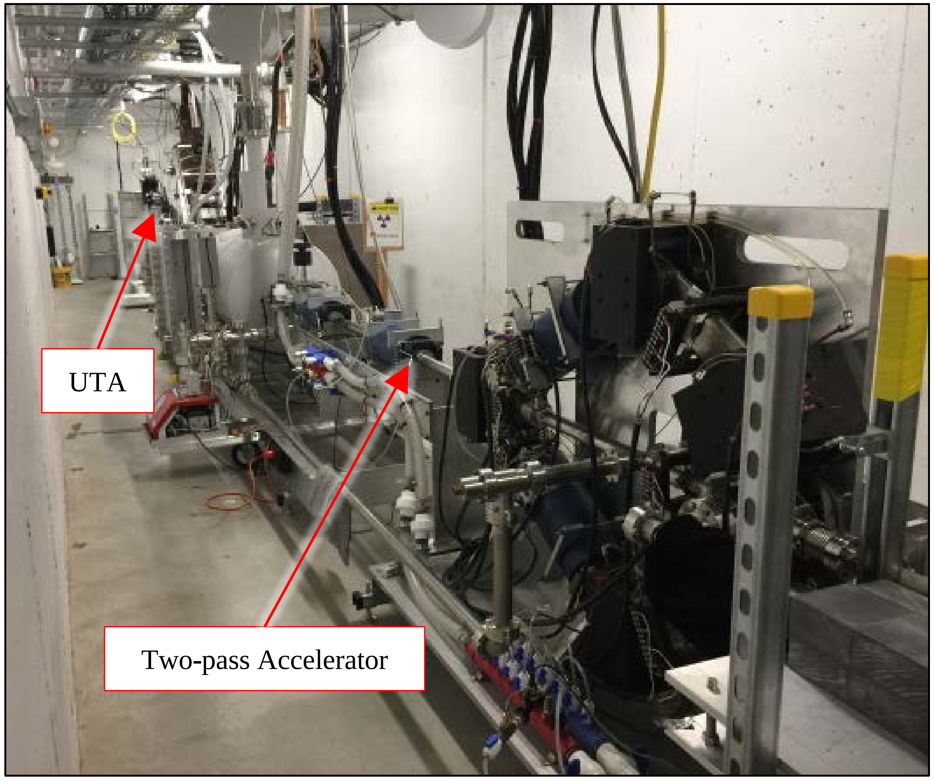
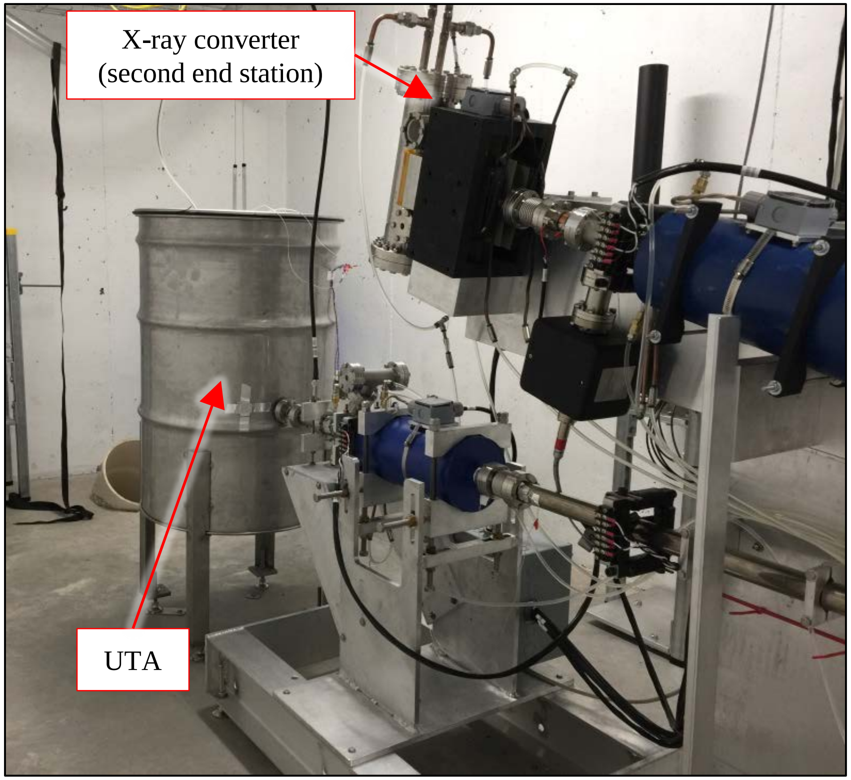
Successfully operational fully coupled system:

- Superconducting linac coupled to UTA
- Neutron production verified and validated
- Mo-99 and other FF are produced







Mo-99 Extraction

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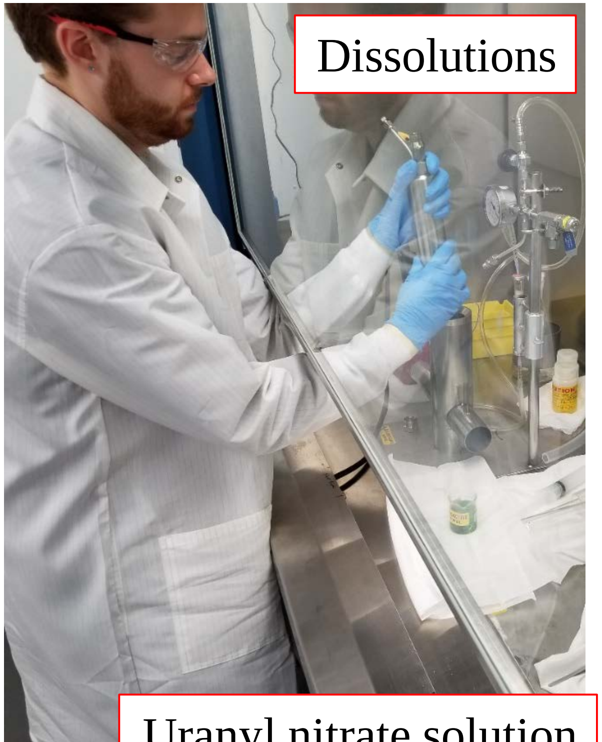
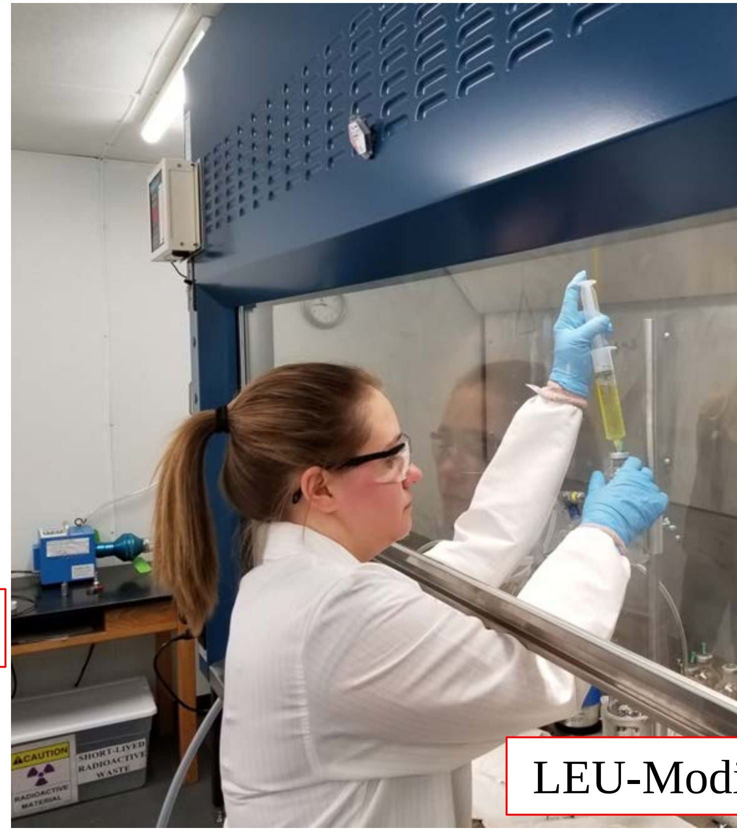


Dissolutions

Uranyl nitrate solution



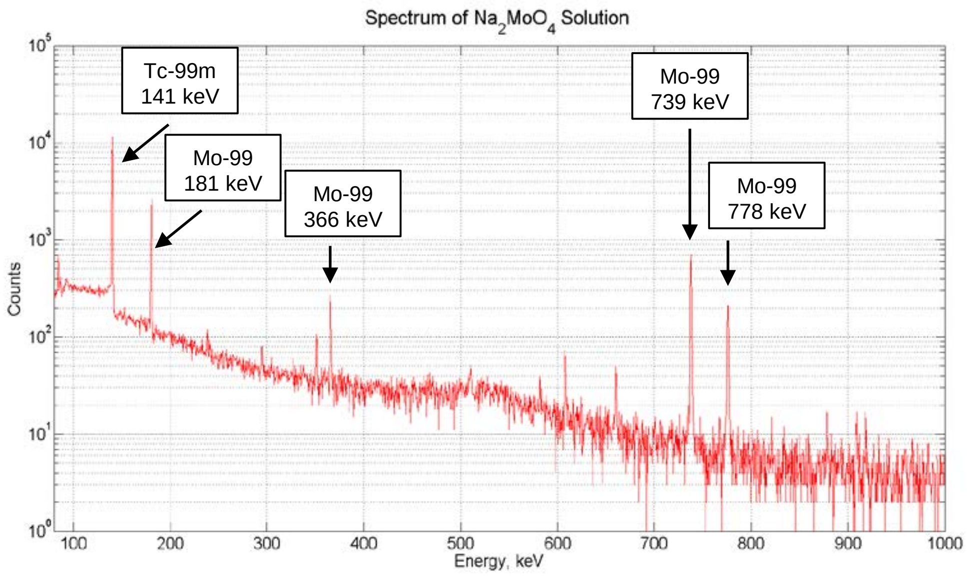
LEU-Modified Cintichem Process

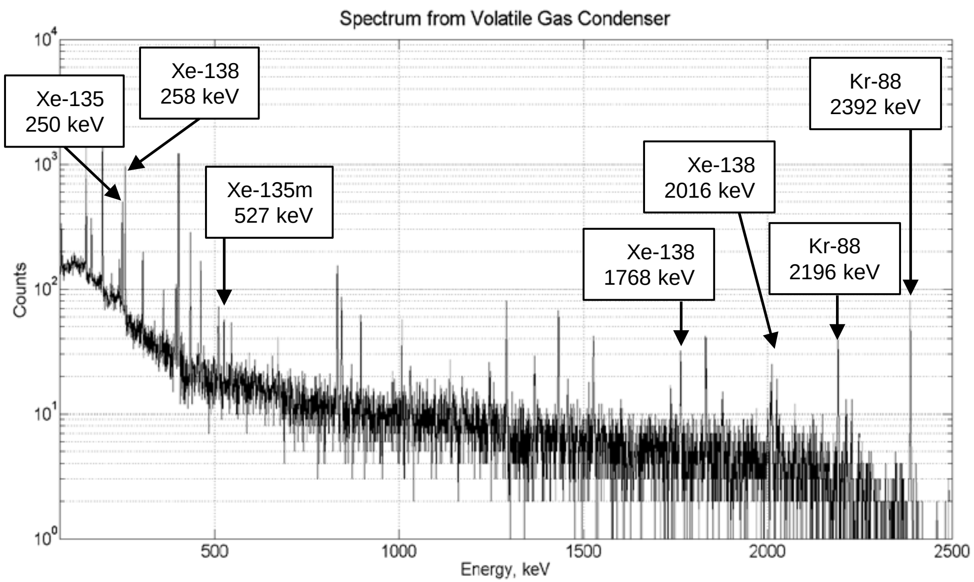
Poster Tuesday 3:30 PM, *Progress Toward an LEU Fuel Cycle for Domestic Radioisotope Production from Fission Fragments* (Dr. Kristin Shannon, Niowave)

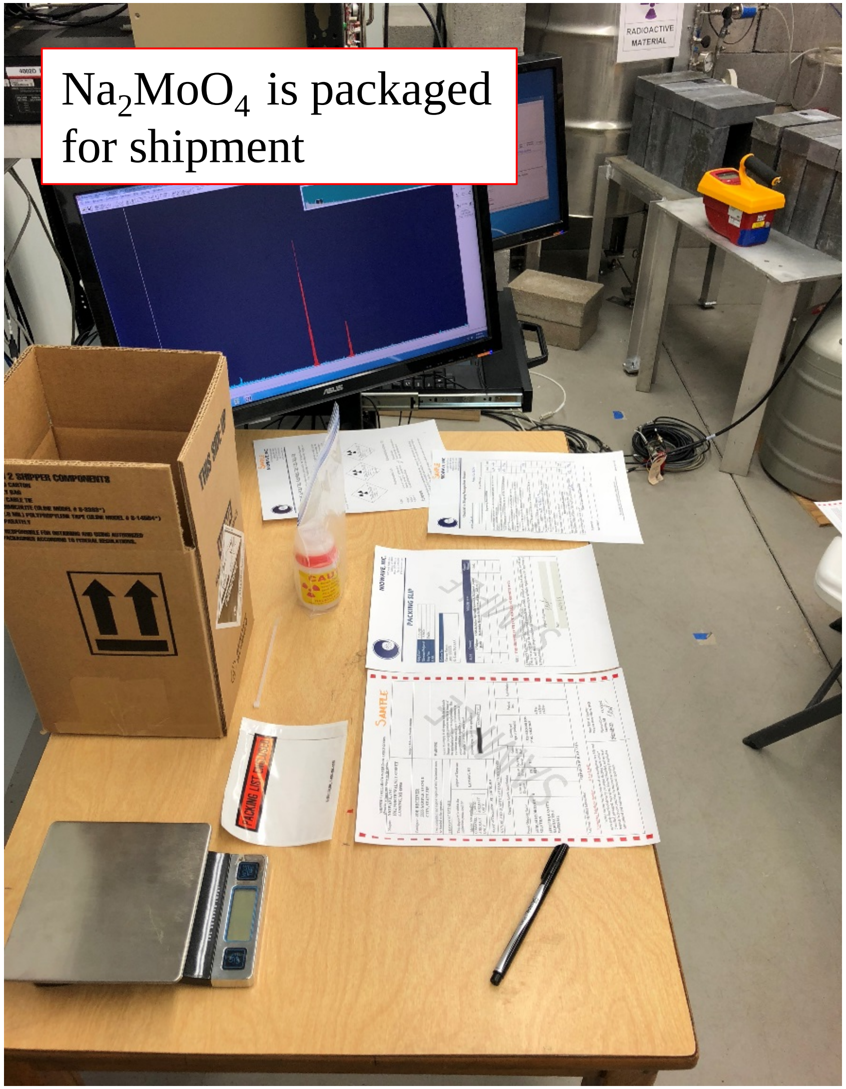
Partnering with Argonne

- Working with Argonne since 2015
- Optimization of dissolution
- Design, fabrication & testing of the automated LMC

Na_2MoO_4 and Xe Samples







Uranium Recovery and Target Preparation

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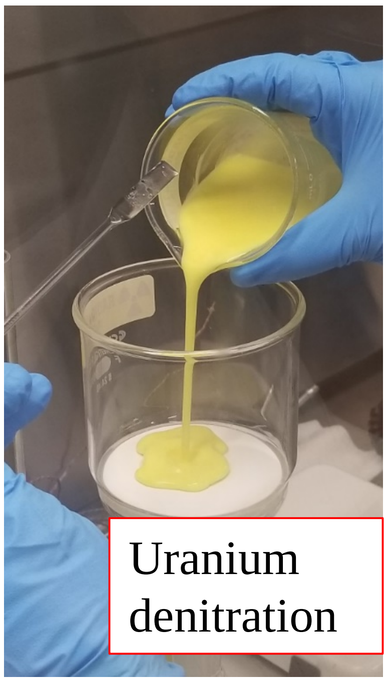
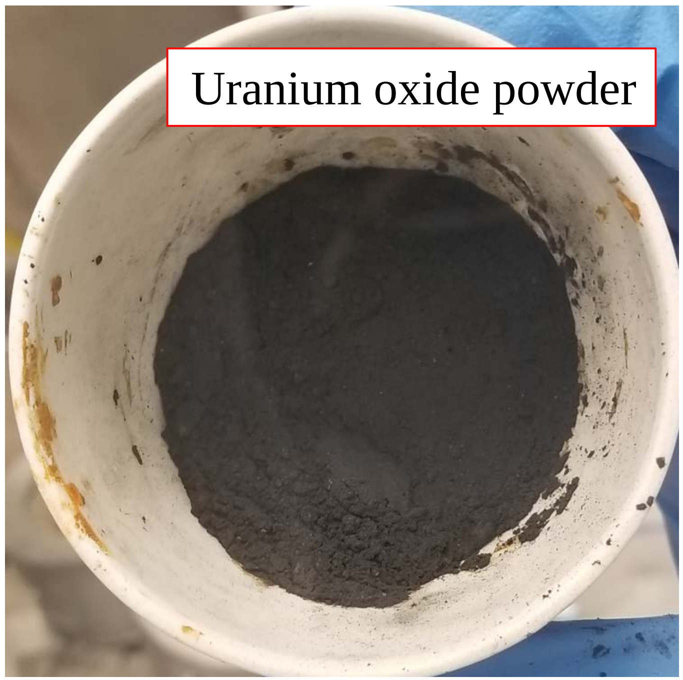
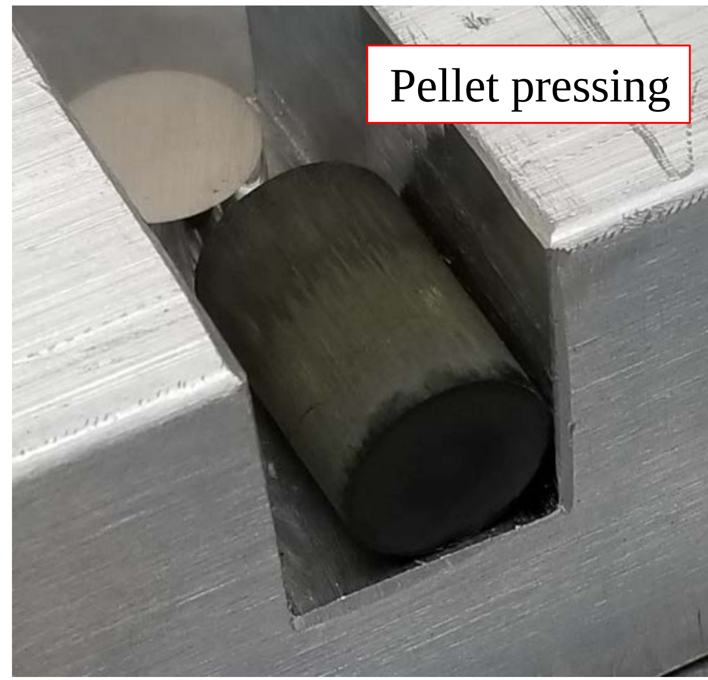
- UREX
- Mechanical pressing of uranium oxide powder







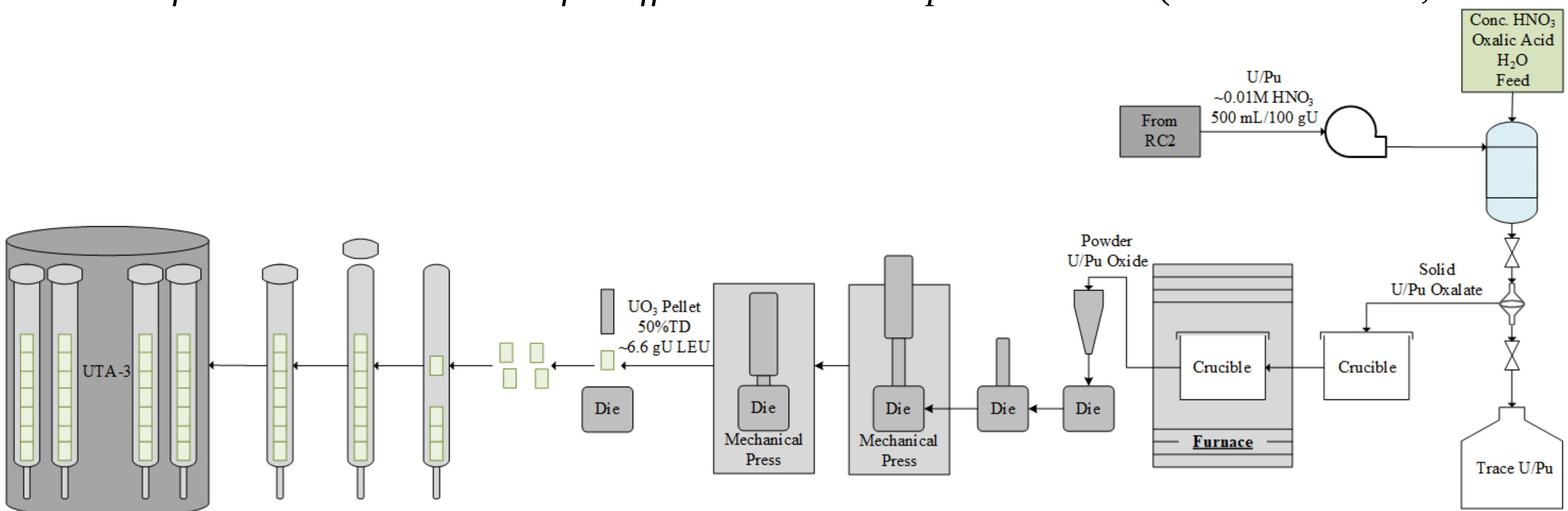
Pressed pellets are loaded for re-irradiation

Partnering with Y-12

Posters Tuesday 3:30 PM

Optimizing Extraction Processes and Fuel Fabrication for Mo-99 Production (Kaara Patton, CNS Y-12)

Fabrication of Uranium Oxide Pellets for Efficient Radioisotope Production (Nathan Johnson, Niowave)



LEU Acquisition and Target Preparation

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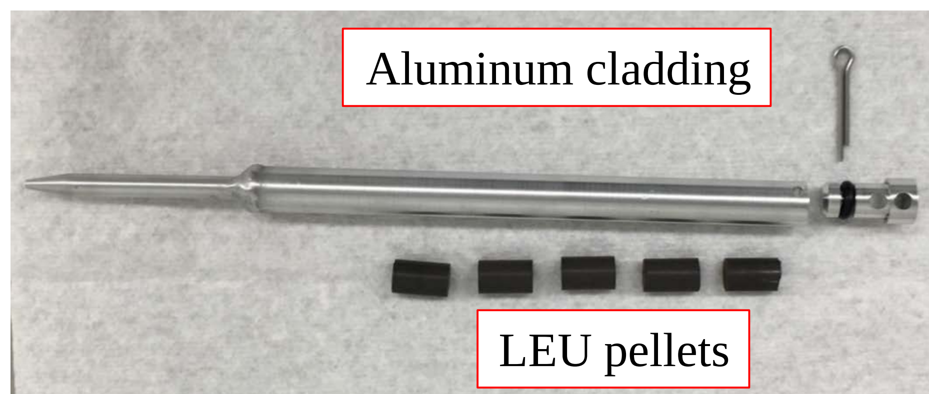
Natural uranium

– 345 kgU (metal and oxide) at Niowave

Low Enriched Uranium (<20 wt% ^{235}U)

– 1.8 kgU oxide at Niowave

– 18 kgU metal purchased from Y-12/NNSA



Regulatory Plans

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- State of Michigan
  - 40 MeV, 100 kW electron linacs
- NRC
  - Materials license
- FDA
  - Active pharmaceutical ingredient
  - Facility registration & Drug Master File
- DOT
  - Have shipped excepted, Type A, & Type B packages
- Waste
  - 3rd party broker

NRC Licensing Strategy

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1. Materials license

   Not “utilization” or “production” facility (10 CFR 50.2)

   - $k_{eff} < 1$ (not a reactor)
   - Limiting batches to < 100 g LEU (Cintichem process)
   - Components & processes are proven & benchmarked

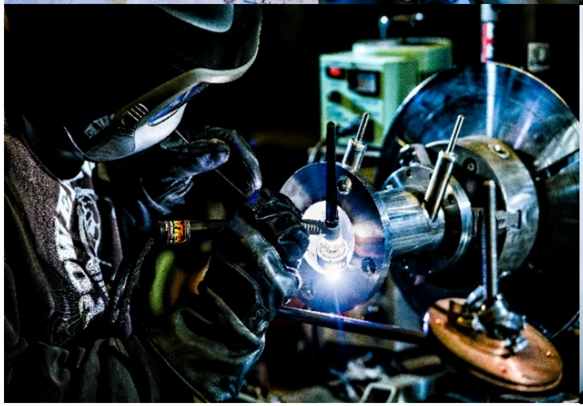
2. Once > 7 kg LEU on-site
   - Establish a criticality safety program

3. Max LEU on-site < 100 kg LEU
   - Keeps us below “SNM of low strategic significance”

4. Processing LEU requires an environmental impact statement

Facilities [1]

HQ (2006)
R&D (2012)



Facilities [2]

Pilot Production Facility (2014)
Lansing International Airport
Foreign Trade Zone

Fall 2014

Fall 2015

Mo-99 Program Overview

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Category	Phase 1	Phase 2	Phase 3	Phase 4
Production Level	Demo	Pilot	Commercial	Commercial – 2nd Site
Fission Power	23 mW	230 W	230 kW	2 × 230 kW
Activity Produced[1]	1 mCi batches	10 Ci/week 1.55 6-dCi/week	10 kCi/week 1,550 6-dCi/week	20 kCi/week[2] 3,100 6-dCi/week
Radiochemicals Produced	Mo-99→Tc-99m Xe-133	Sr-89, I-131 Pr-143, Nd-147, Pm-149	Sr-90→Y-90 Sb-127→Te-127 Ce-144→Pr-144	TBD
Location	HQ	HQ / Airport	TBD	TBD
Completion Date	Dec 2018	Dec 2020	Dec 2025	Dec 2027
Budget	$15M	$35M[3]	$85M	$63M

[1]10 kCi/week Mo-99 EOB = 1,550 6 day Ci/week Mo-99
[2]Two facilities, each operating at 10 kCi/week
[3]Includes DOE-NNSA Mo-99 contribution