OAK RIDGE National Laboratory

Targets for Radioisotope Production, Neutron Scattering, Nuclear Data Measurements, and Exploring the Periodic Table

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U.S. DEPARTMENT OF ENERGY

Bird's Eye View: Oak Ridge National Laboratory

Overview of ORNL activities related to nuclear target science and applications

Stable isotope targets covered by Zach, Conner, & Foster talks

Electrodeposition of Cf-251 targets for super heavy element studies

Targets for Neutron Scattering at ORNL Spallation Neutron Source (SNS)

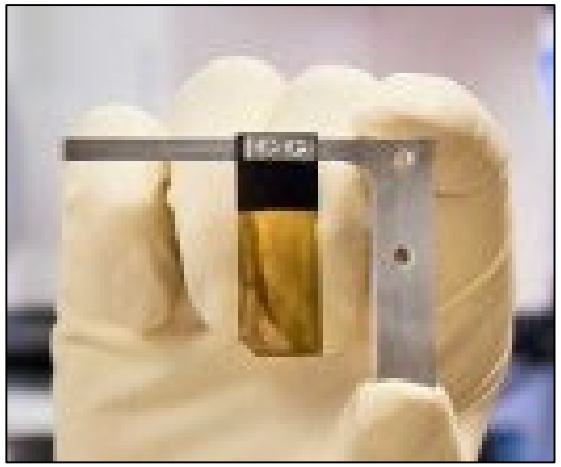
Ion Source produces 2.5 MeV H^- ions

Linear Accelerator increases H^- ion energy to 1 GeV

Proton Accumulator Ring bunches the H^- ions and passes them through diamond stripper foil

Spallation Target circulates 20 tons of mercury during irradiation with the 1.4 MW 60 Hz proton beam

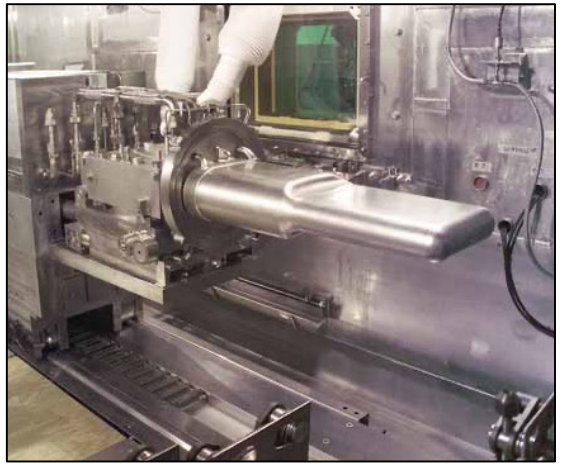
Future upgrades include power increase to 2.4 MW and a second target station

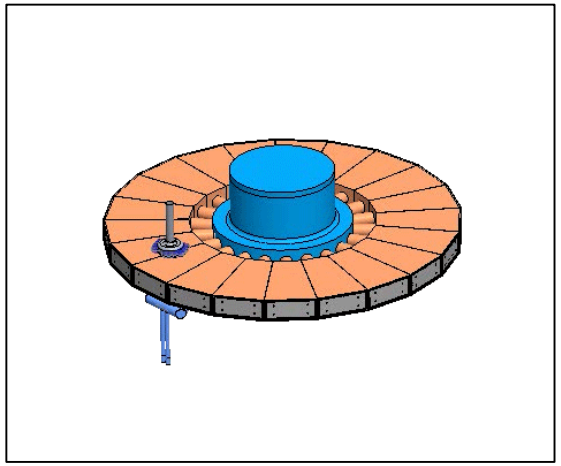


Mercury target used to produce neutrons

~1 μm thick diamond stripper foil used at SNS

ornl.gov/facility/cnms





Tungsten target concept for second target station

Images from: **neutrons.ornl.gov**

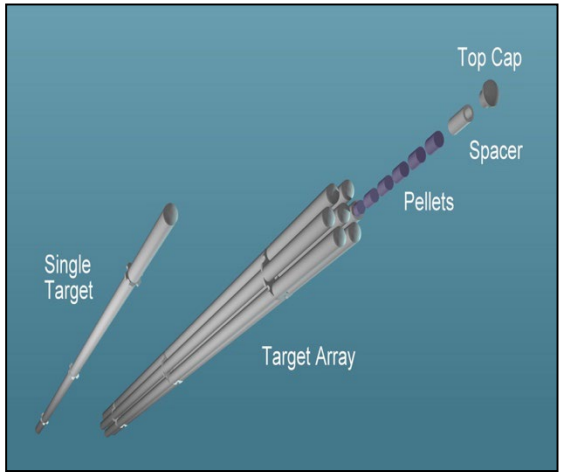
Radioactive Targets for Isotope Production

ORNL produces a variety of targets with radioactive material for isotope production in nuclear reactors

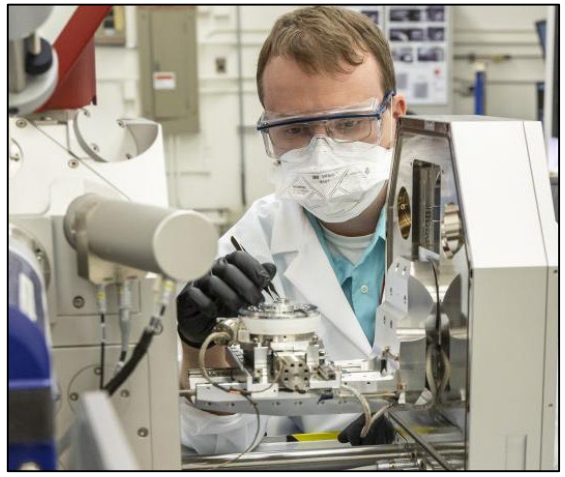
Target materials include **Ra, Np, & Cm** for Ac, Pu, and Cf isotope production

Automated and remote manufacturing are often required

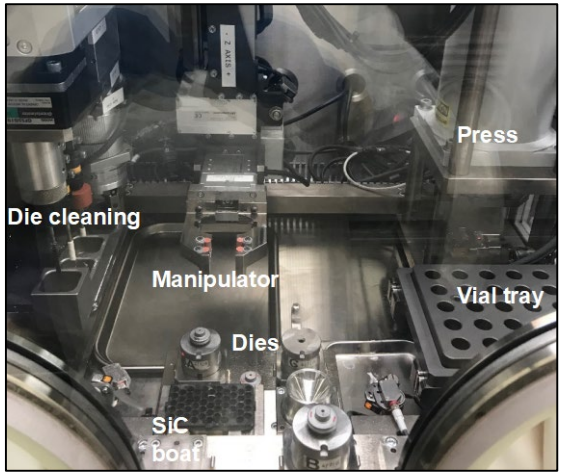
Post-irradiation characterization facilities are growing (for actinides too!)



Thousands of NpO2-Al pellets pressed per year with automated system in glovebox



Targets contain one or more pellets and often irradiated in arrays



Characterization techniques include nanoindentation, SEM, TEM, LECO, thermal desorption, and others

Actinide thin films for science and applications

ORNL primarily supplies raw radioisotope materials but can provide manufactured targets if needed

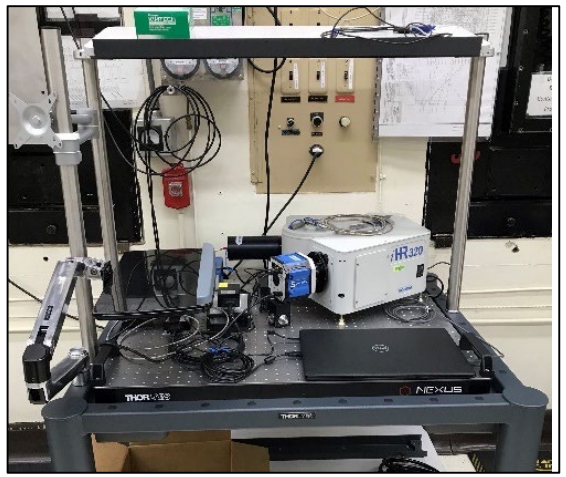
Isotopes have included Cf-251, Cf-252, and Am-241

Recent R&D is focusing on real time thickness, mass, and spectroscopy

Goal is to enable real time control and deeper understanding of process

Hot cell & glovebox Raman, absorption, & fluorescence systems

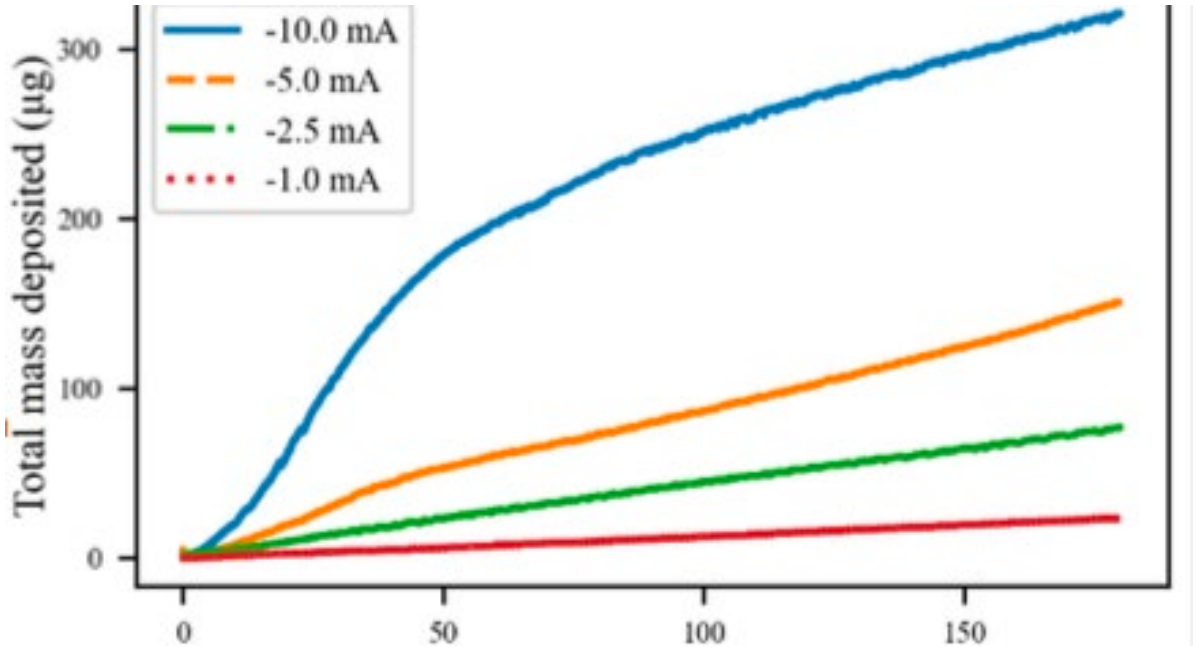
>1 Ci of Cf-252 electrodeposited for fission fragment source



Quartz Crystal Microbalance for real time mass data

Actinide thin films for science and applications

Example QCM data from La electrodepositions



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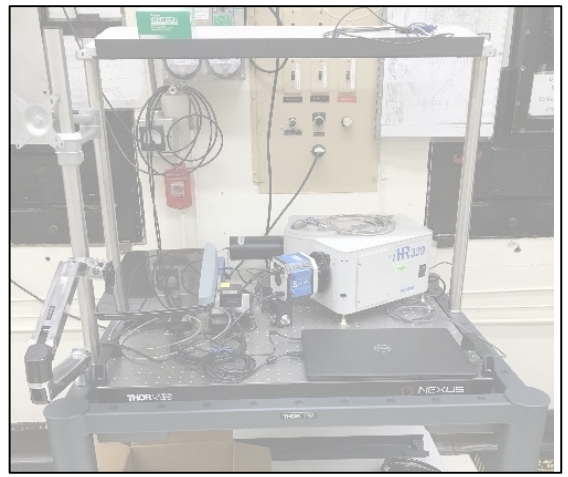
Hot cell & glovebox Raman, absorption, & fluorescence systems



Quartz Crystal Microbalance for real time mass data

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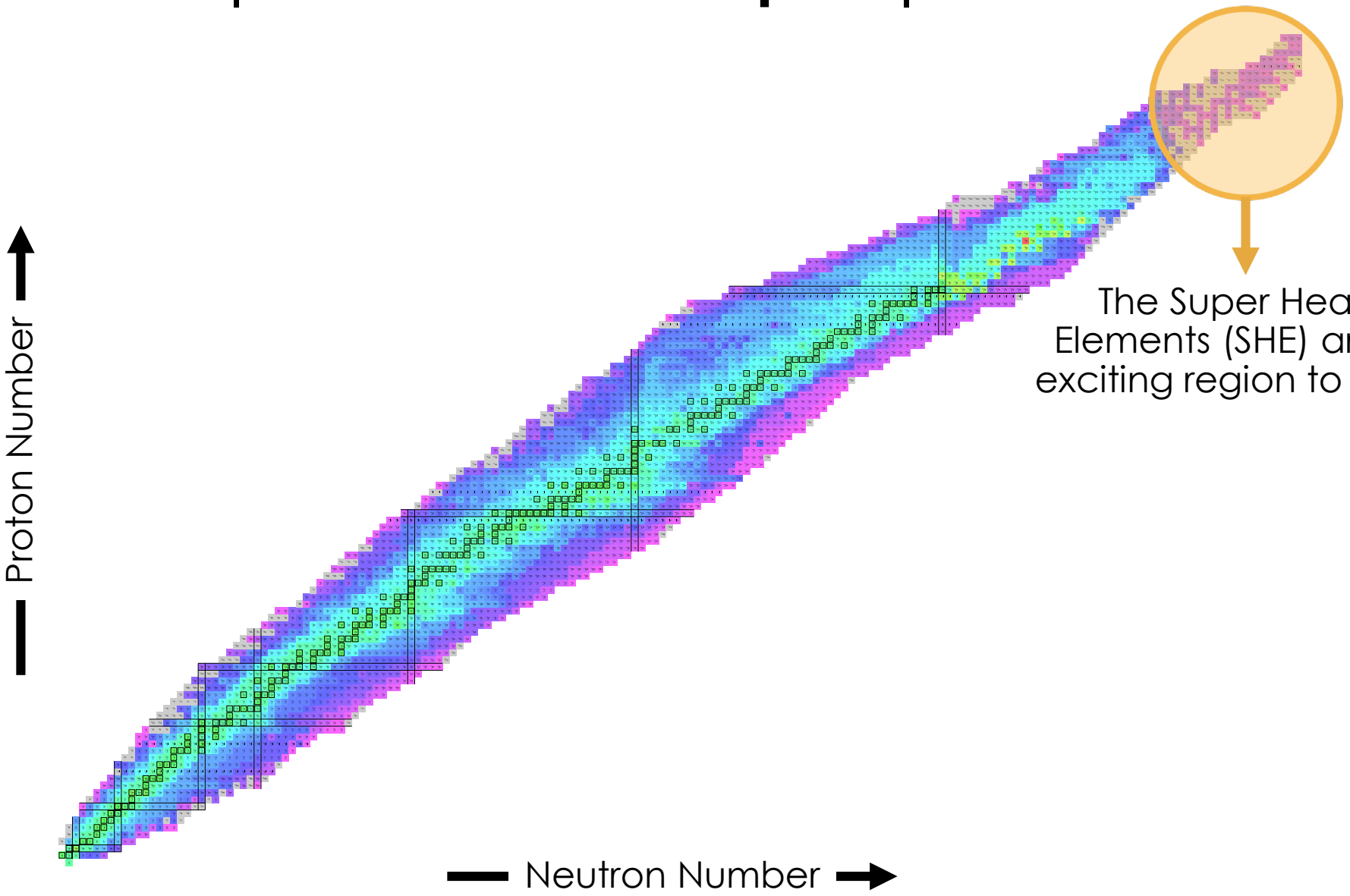
Electrodeposition of Cf-251 targets for super heavy element studies

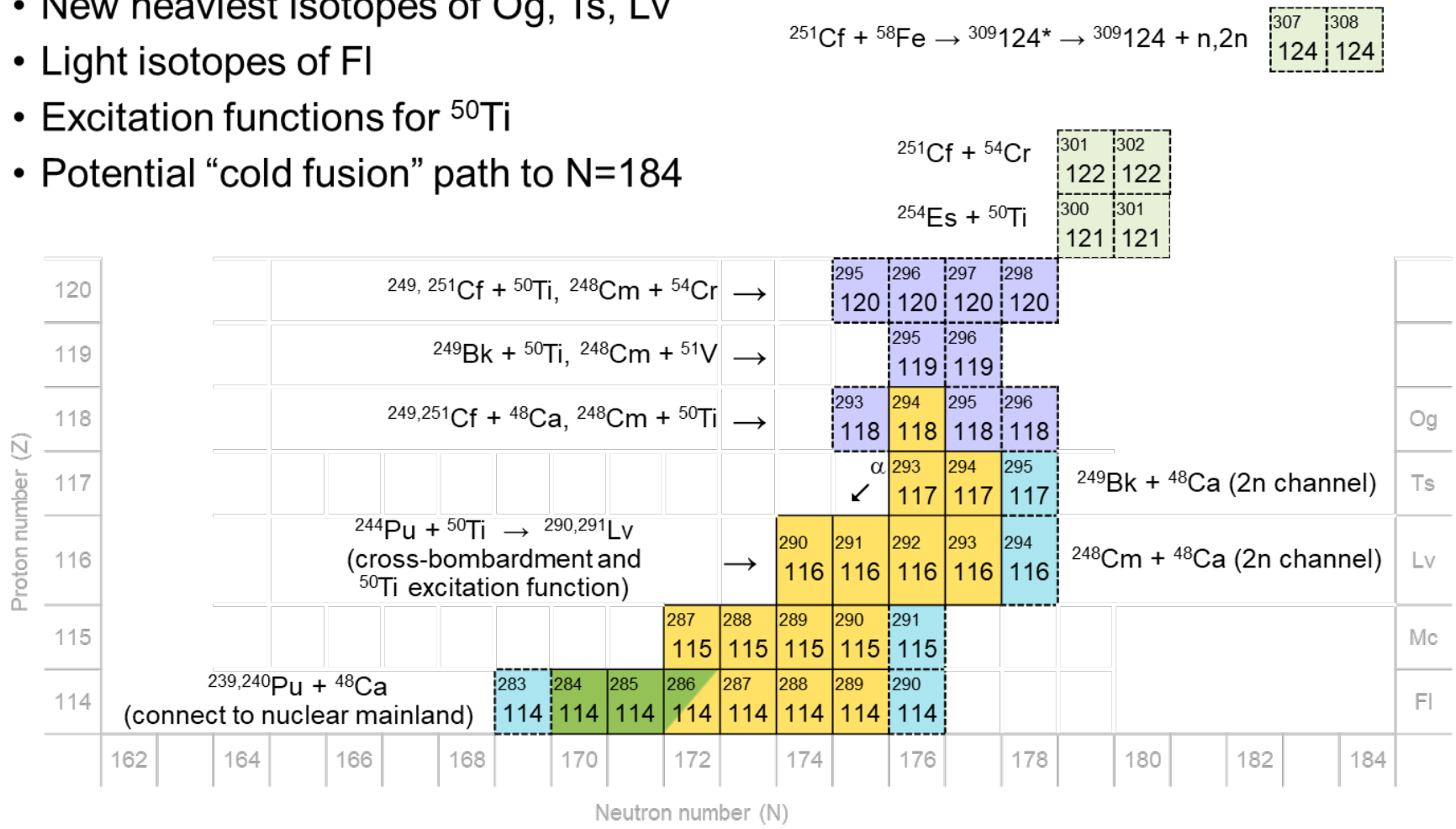
118 elements | 254 stable isotopes | >3000 radioisotopes



https://people.physics.anu.edu.au/~ecs103/chart/

Significant SHE research opportunities exist using actinide targets

- New elements 119 and 120
- New heaviest isotopes of Og, Ts, Lv
- Light isotopes of Fl
- Excitation functions for ^{50}Ti
- Potential “cold fusion” path to N=184

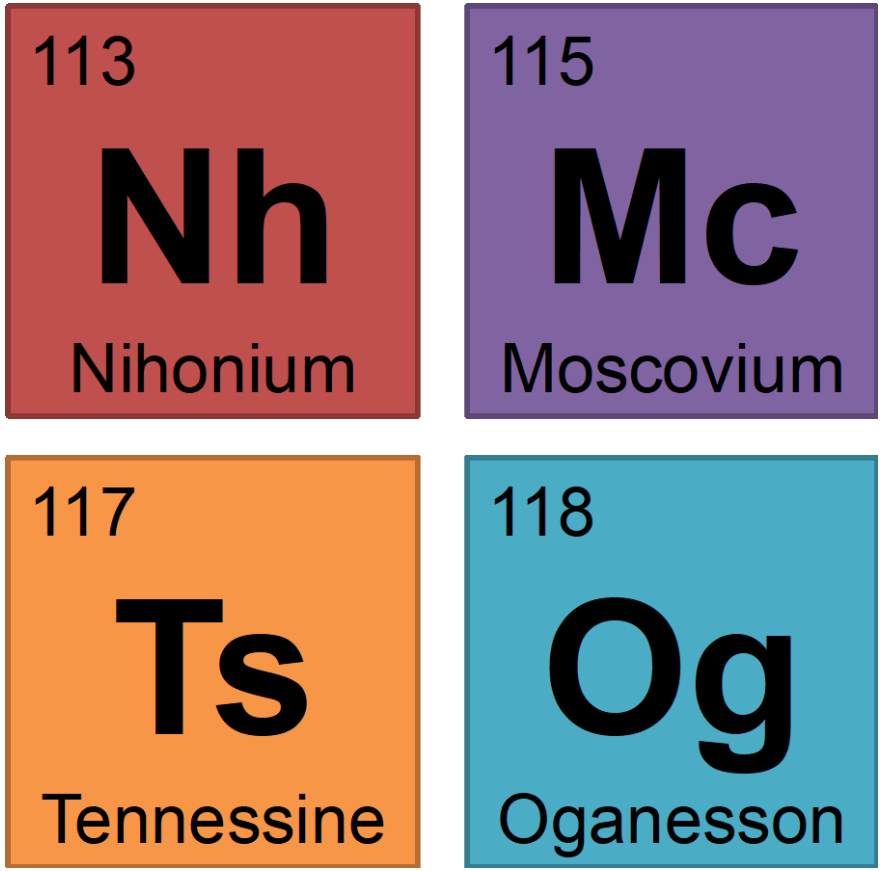


Graphic curtesy of James Roberto

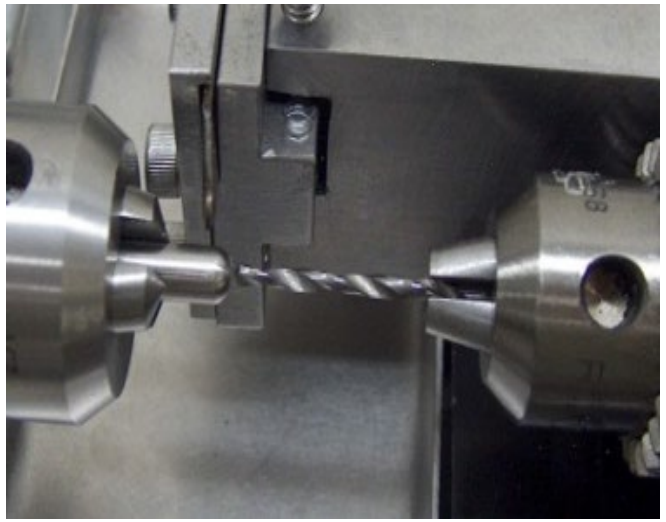
Challenges of pushing beyond element 118

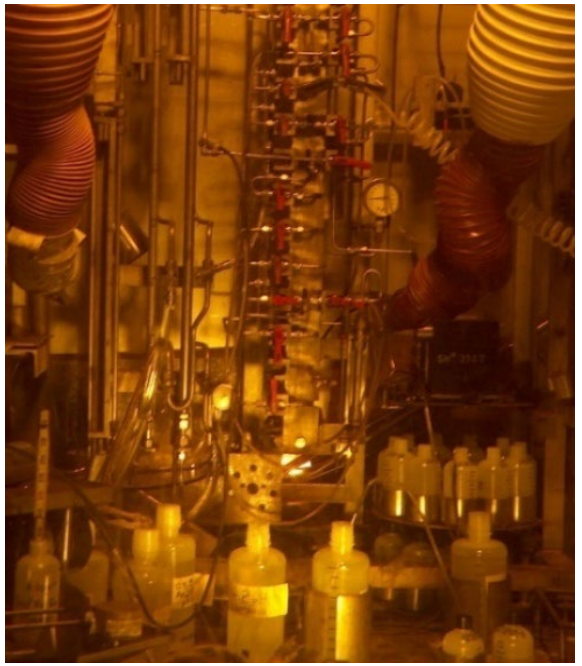
- Cross-sections are decreasing
- Beam intensities are increasing
- Heavier ions are needed
- Target materials are often limited

All aspects of SHE research must be advanced to continue discovery science



In 2014, rare mixed californium isotope material was recovered from decayed ^{252}Cf sources at REDC

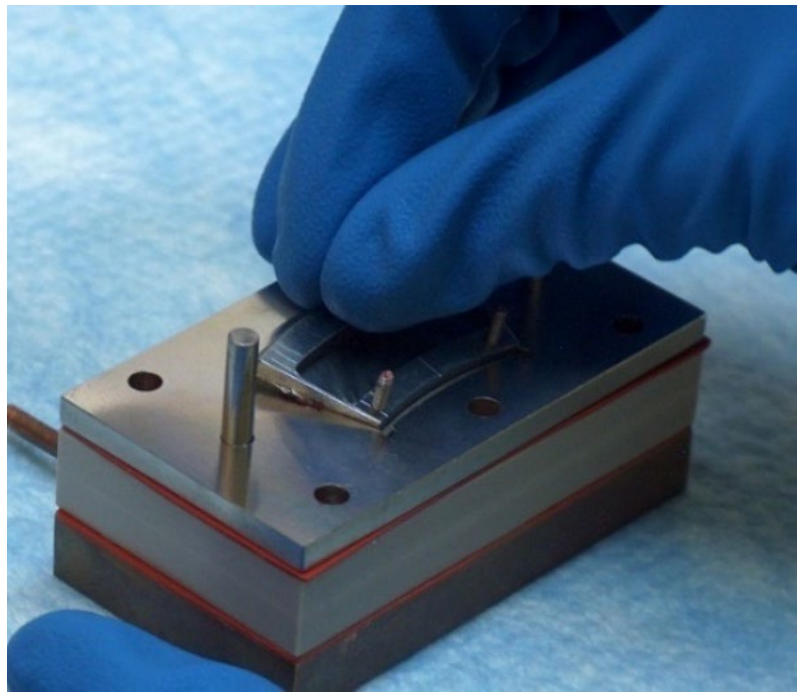


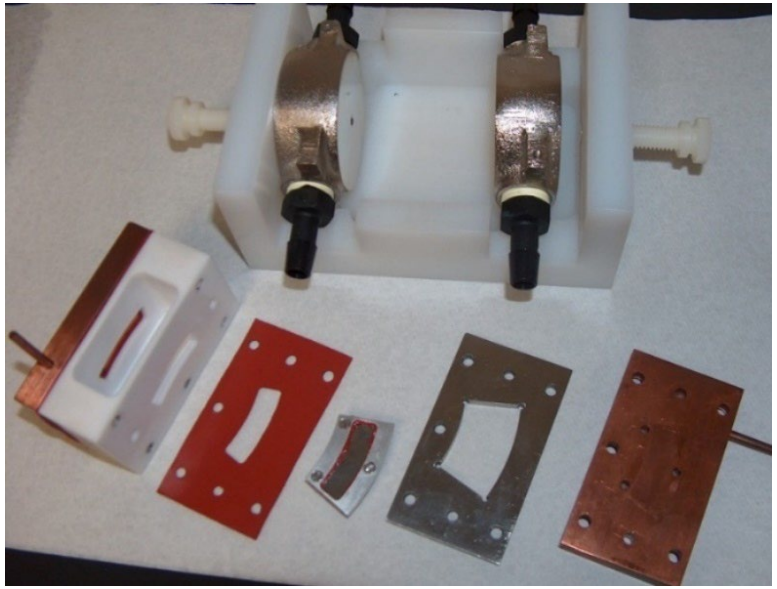


~16 mg of californium was recovered

Target material isotopics	
^{249}Cf	48.1%
^{250}Cf	15.6%
^{251}Cf	36.3%
^{252}Cf	0.01%

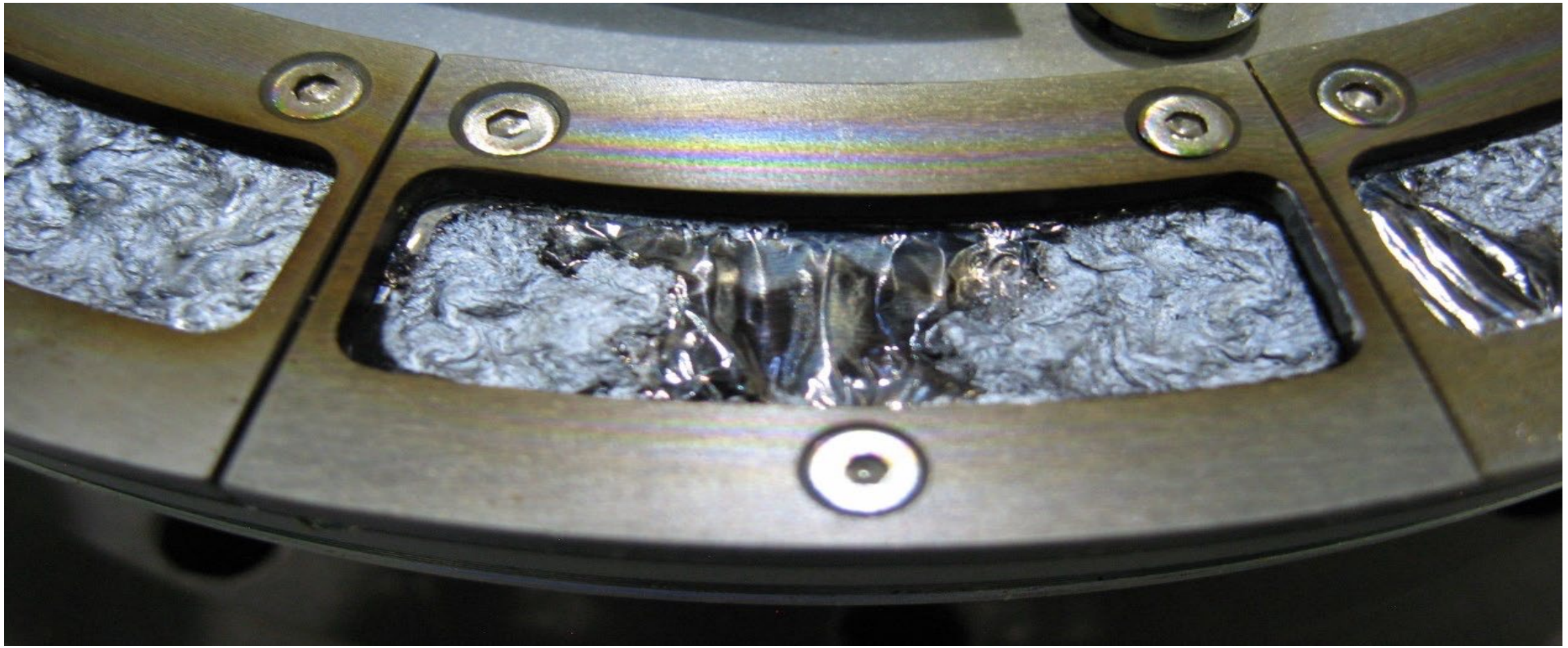
Twelve ^{251}Cf enriched target segments were produced at ORNL using the isopropanol-isobutanol molecular plating technique





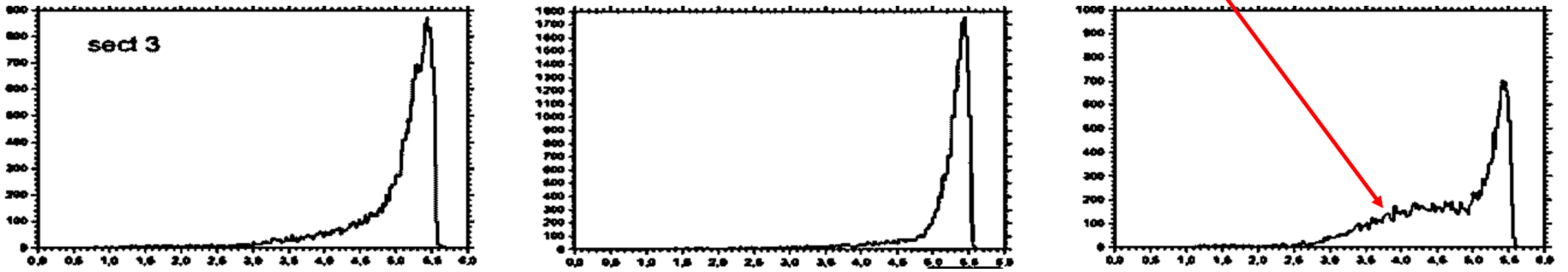
Deposition method adapted from **A. Vascon, et al., Nucl. Instr. And Meth. 655 (2011) 72**

An unknown film formed on the targets during irradiation at the Joint Institute for Nuclear Research (JINR)



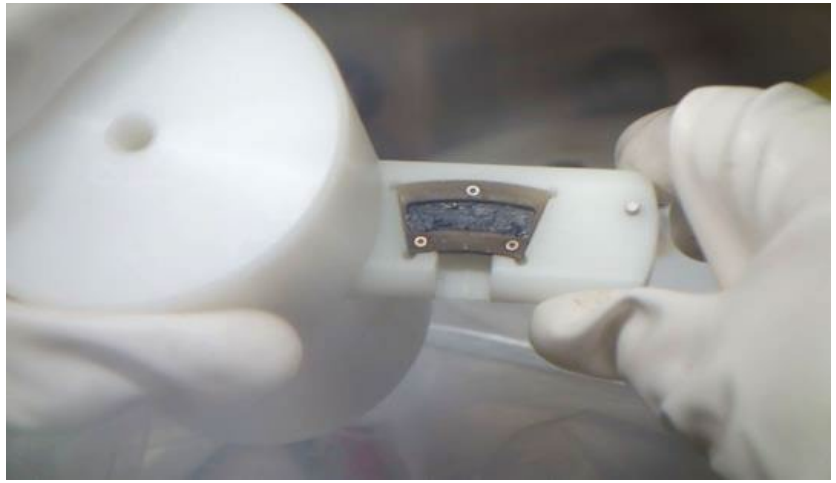
Alpha spectroscopy showed the degrading quality of the targets during irradiation

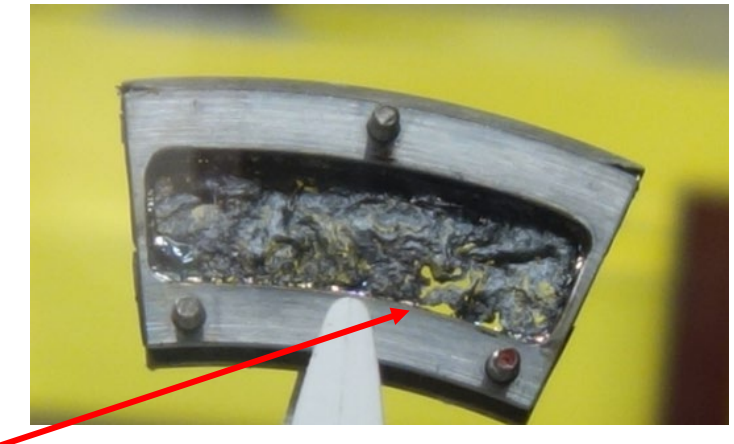
Low-energy tail indicates loss of alpha energy from attenuation



Data provided from Vladimir Utyonkov at JINR

In 2016, the targets were shipped back to ORNL for recovery of the californium material and reproduction of the target segments for continued studies



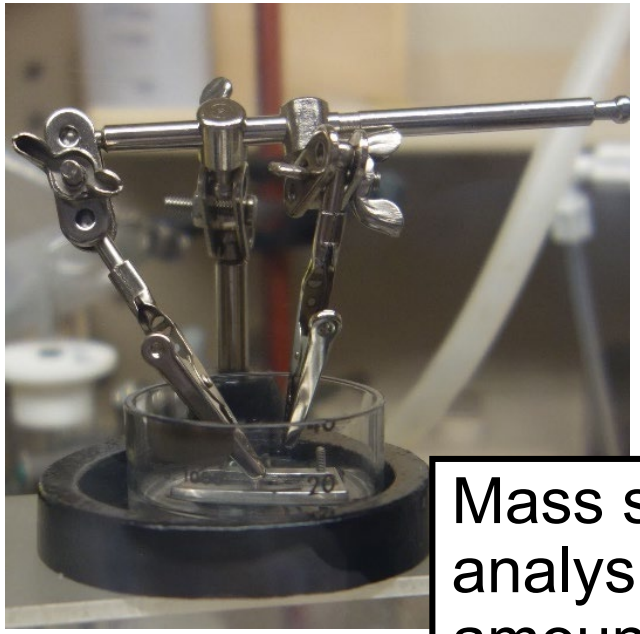


Large areas of the foils were missing

Target segment dissolution and analysis

Several 0.1 *M* HNO_3 rinses

- Film mostly dissolved

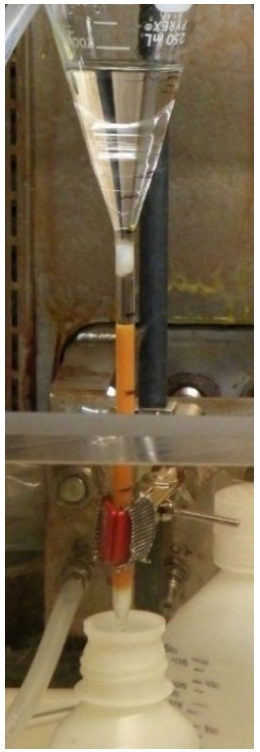


Few drops of conc. HF

- Residual solids dissolved

Cation column purification

- 73% of original californium mass recovered

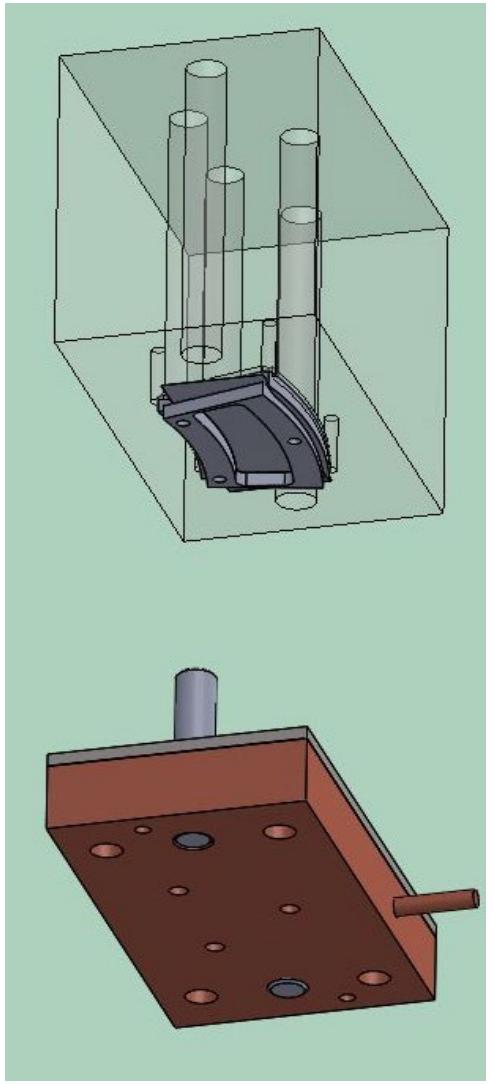


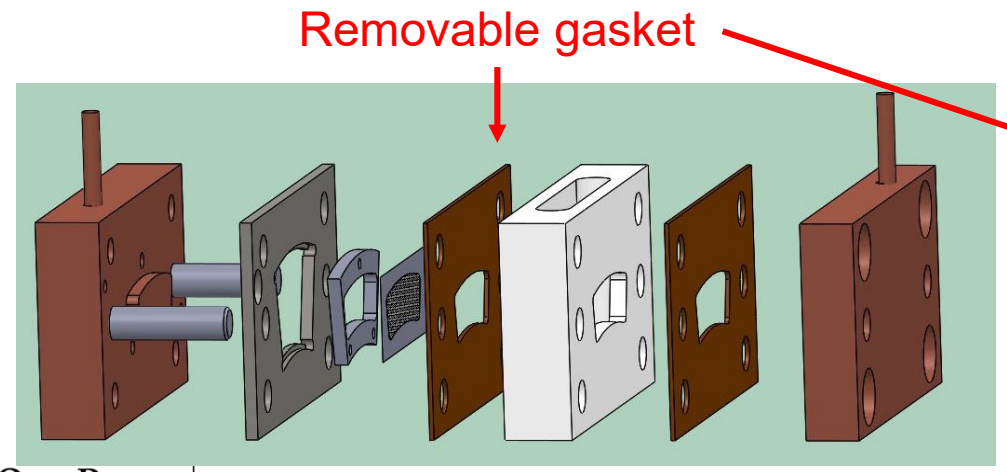
Mass spectrometry analysis showed large amounts of silicon in the solid films

New production method that results in an all-metal support structure for the actinide film was developed

Electrodeposition redesign includes

- 1.5 µm thick Ti foil is attached to unit with double-sided tape
- Graphite powder used to ensure the gasket does not stick to the titanium foil when removed
- Front frame section will be screwed onto disassembled portion and guided onto the titanium foil for assembly

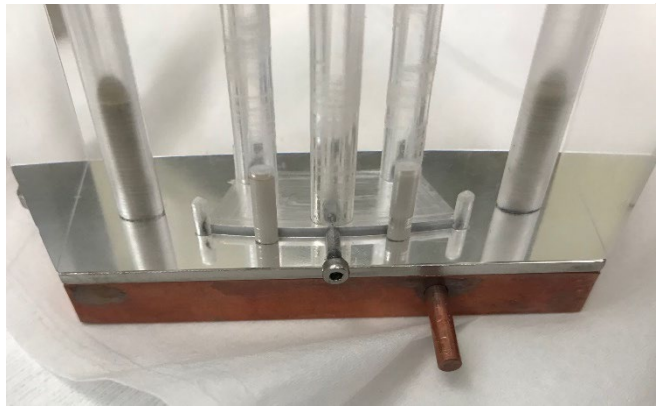




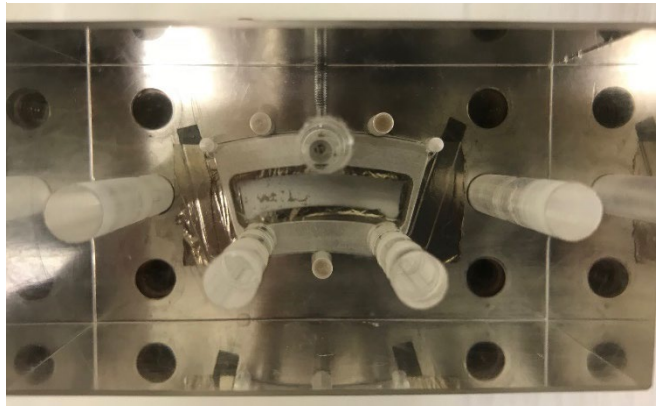
New production methodology (continued)

1. Deposition unit disassembled

2. Top frame holder lowered



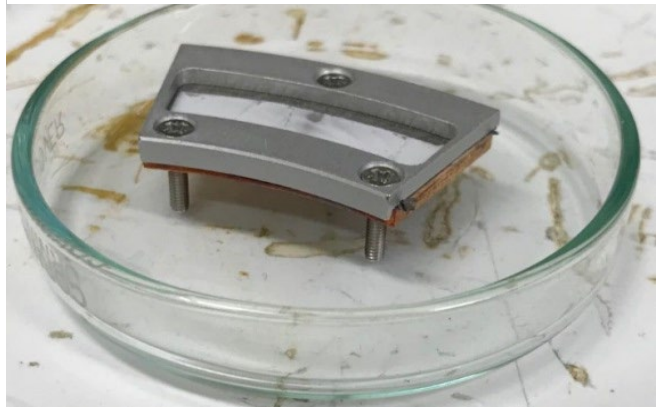
3. Frame screwed together



4. Sides of foil cut

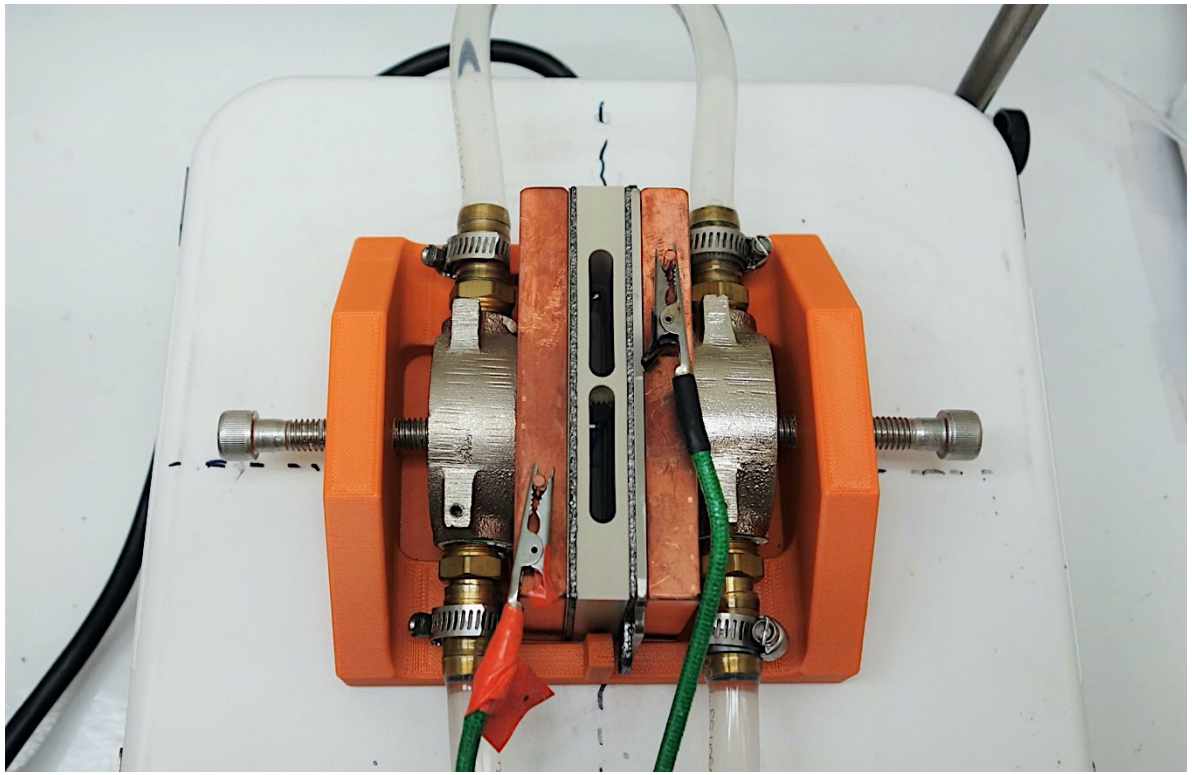
5. Assembled target removed

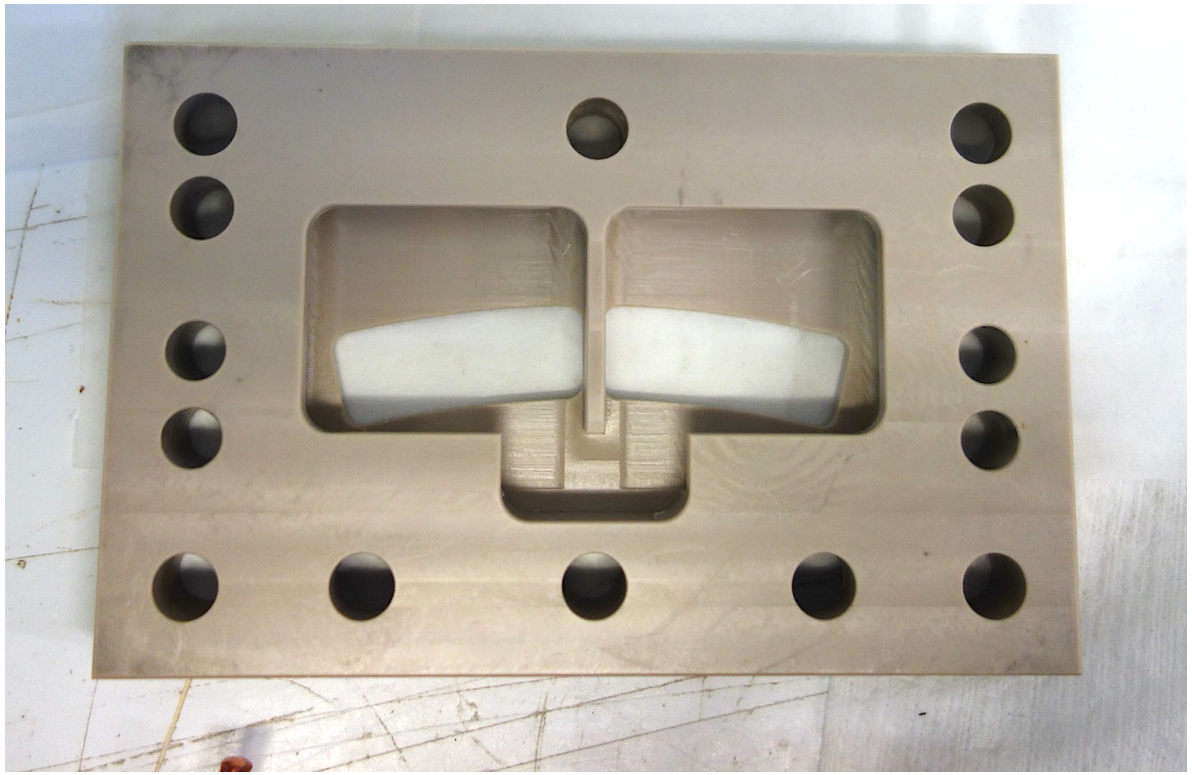
6. Target completed



Team decided double sector targets were needed, requiring further refinement of production methodology

Redesign of the well was critical to ensure distinct deposition regions



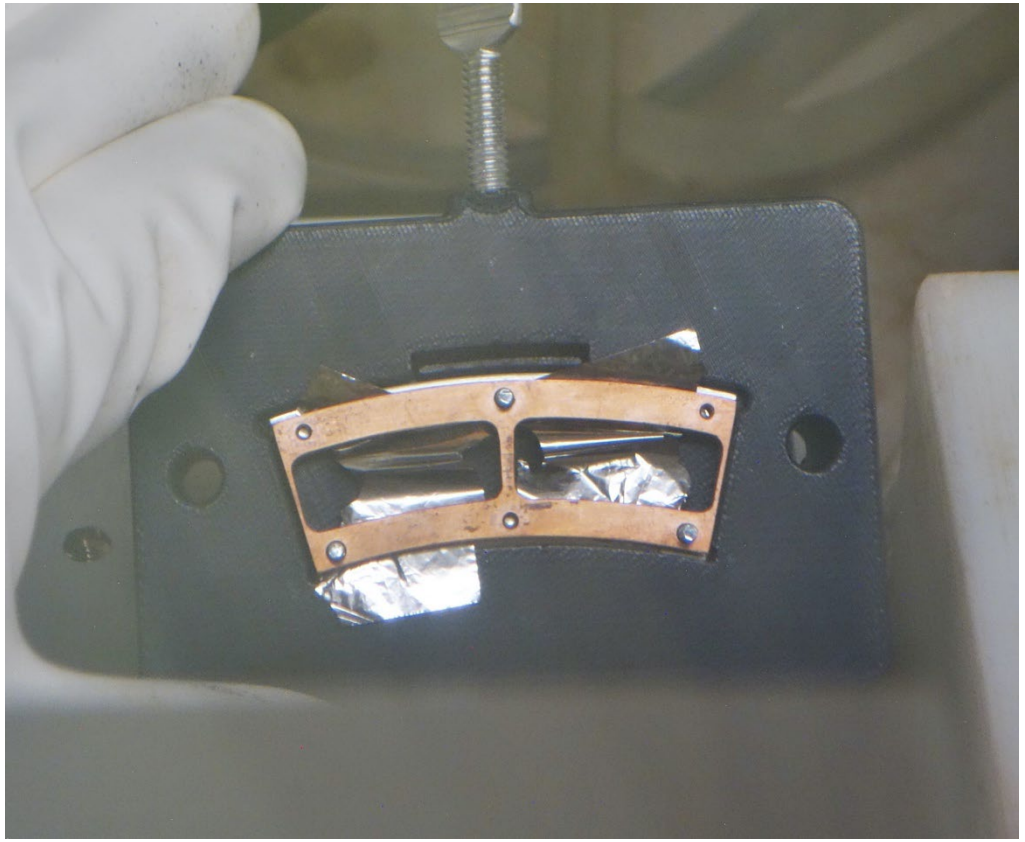


After successful non-radioactive Sm tests on the bench and in the glovebox,

we were ready to produce the Cf targets!

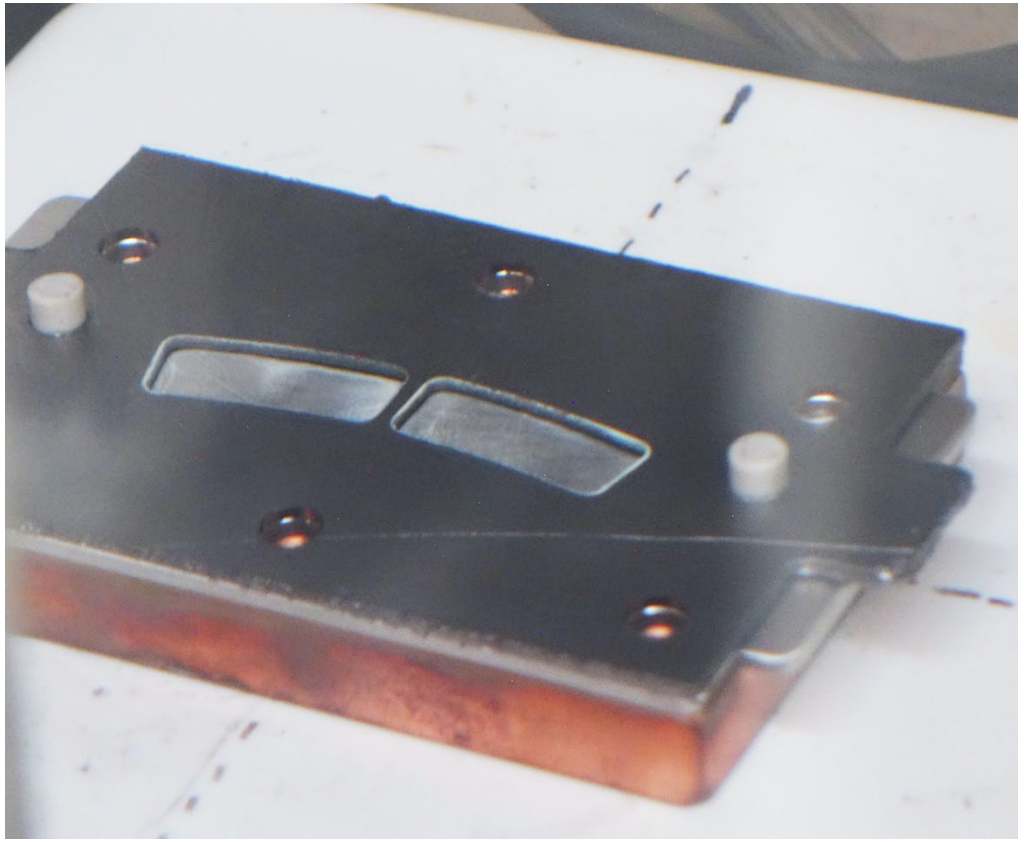
But then… two disasters…

First Cf target broke during assembly



Frame holder mechanism found to be too fragile for repeated use

Second Cf target had low yield (22%)



Grey deposit was found on the rim of the graphite gasket

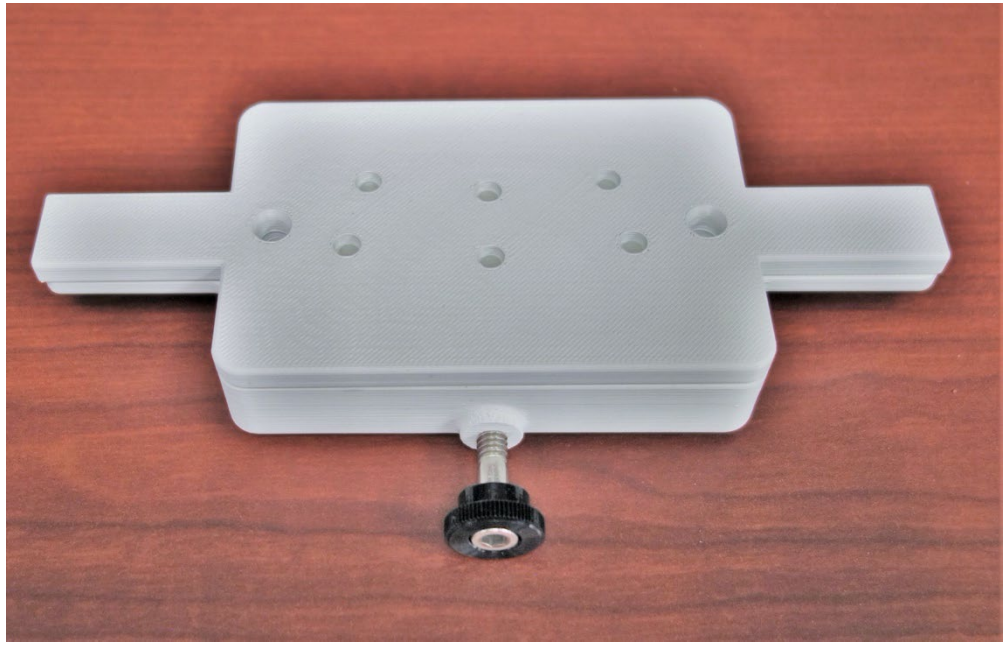
Solution one: design a new target frame holder

Top of view of holder

Push guide

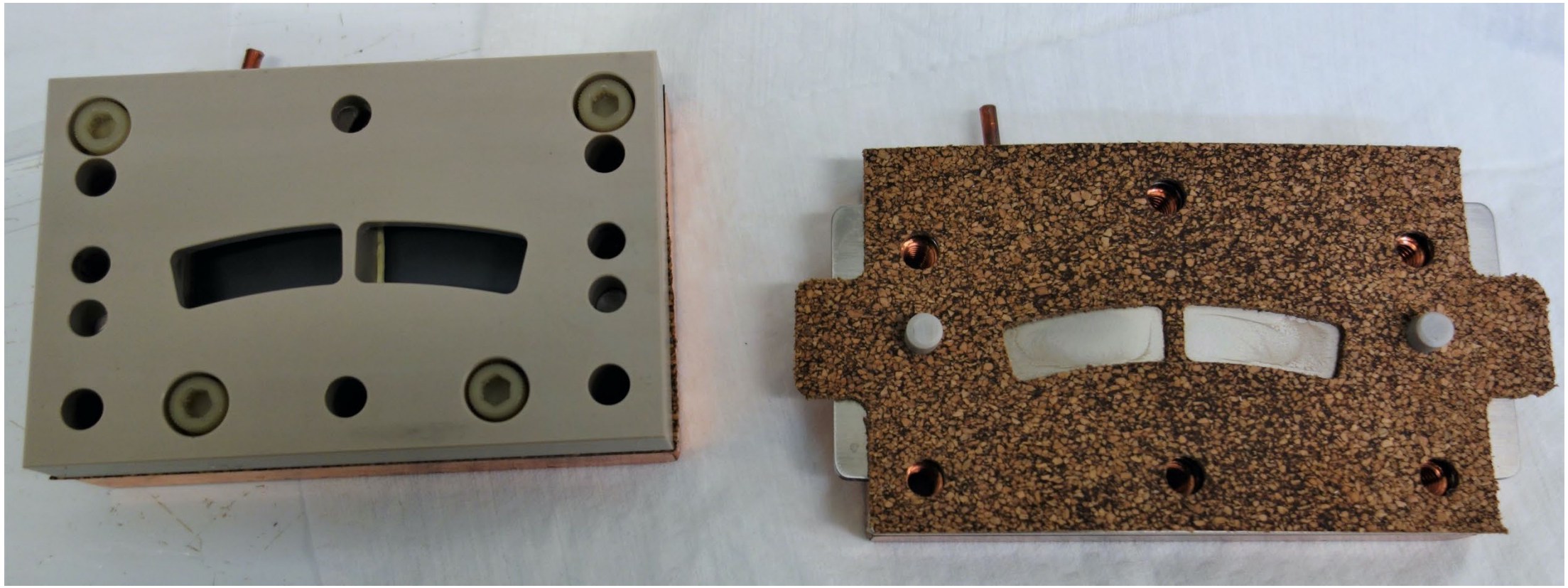
Bottom view of holder

Holder with push guide inserted



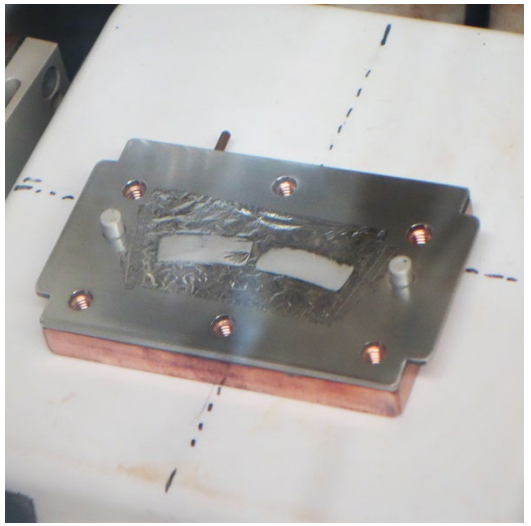
Small details were critical to success, including magnetic screwdriver, guides for screws, and push guide for target disengagement.

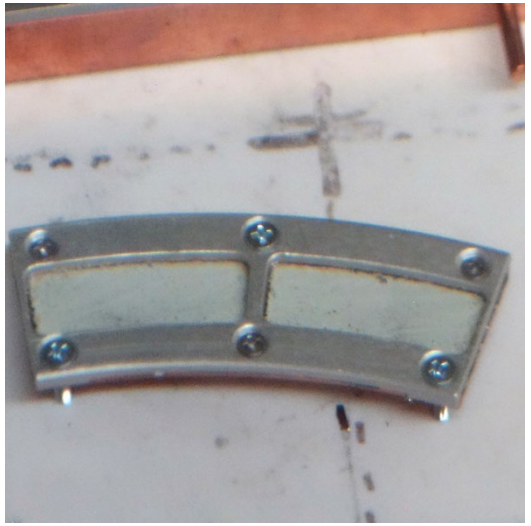
Solution two: use a cork gasket



Six Cf targets were successfully produced with an average deposition yield of 94%

Deposition Number	Percent Yield	Mass of Mixed Californium
1	Broken Target	n/a
2	22%	0.42 mg
3	97%	1.85 mg
4	98%	1.89 mg
5	90%	1.73 mg
6	94%	1.81 mg
7	88%	1.68 mg
8	95%	1.82 mg





Summary

- ORNL is involved in a wide range of target production activities and eager to collaborate
- One of ORNL's roles in the Super Heavy Element community is to provide transuranic material and, in some cases, transuranic targets
- Six Cf-251 targets were produced at ORNL to help discover new nuclides of the heaviest elements
  - Production process has faced separation and fabrication challenges
  - Californium has been cleaned up successfully
  - Challenges to fabricating targets without a gasket in the final assembly were overcome
  - Average percent deposition was 94% for six consecutive targets

Acknowledgments

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Questions?

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