Isotope Production at Oak Ridge National Laboratory

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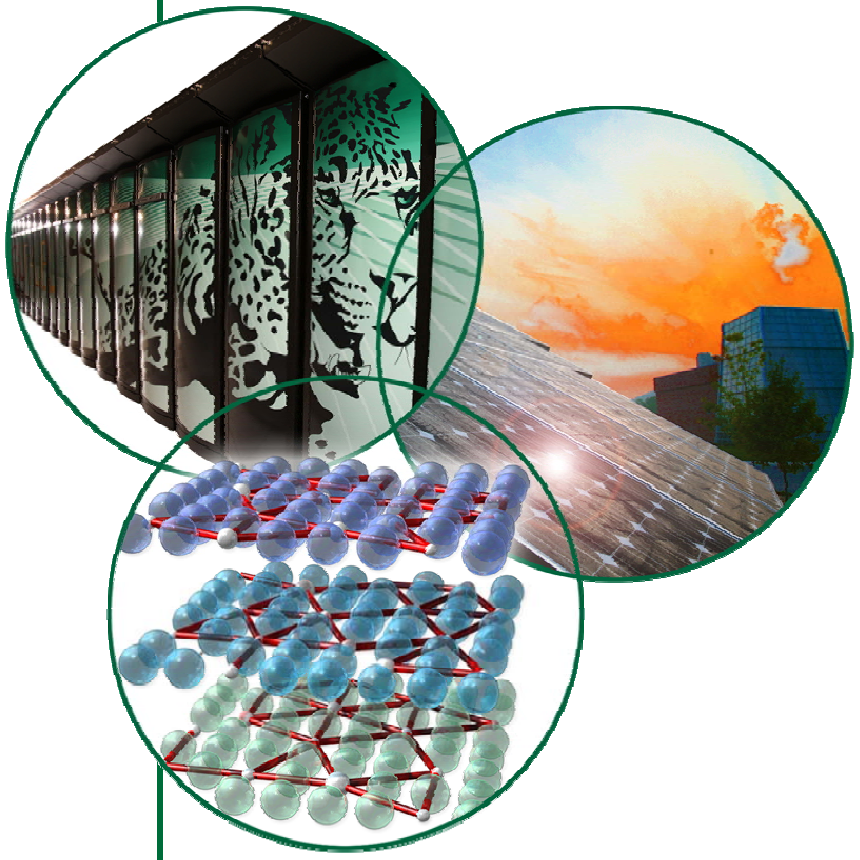
Idaho Falls, ID

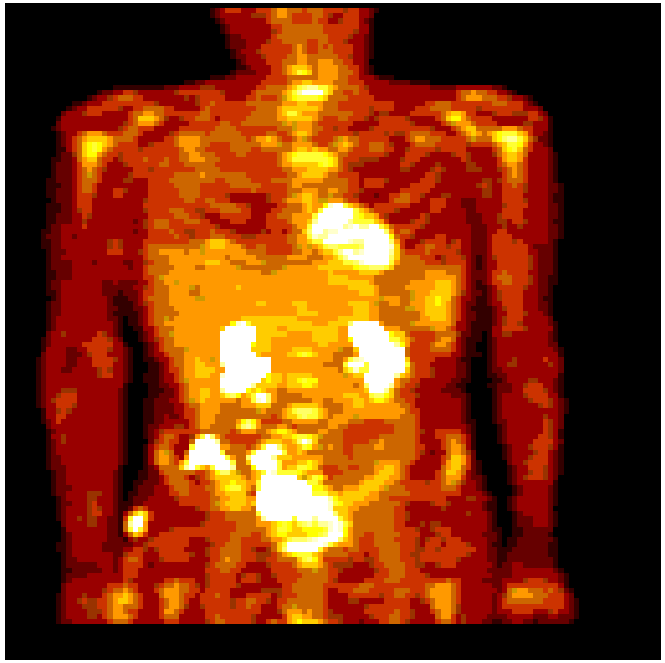


U.S. DEPARTMENT OF ENERGY

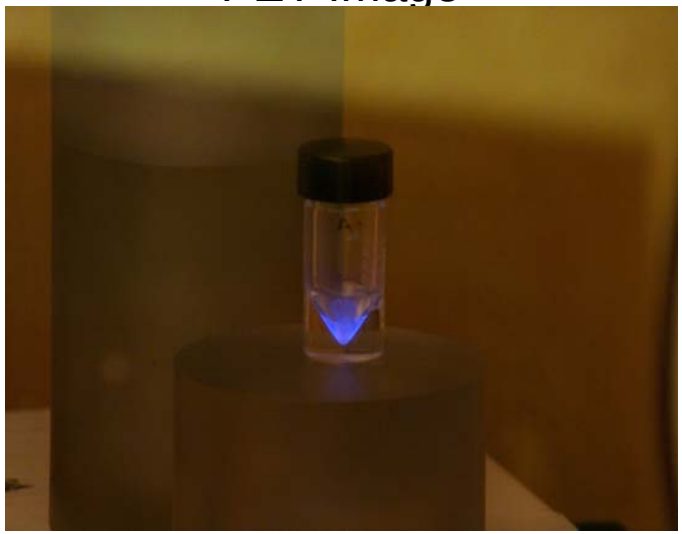
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Isotope Importance

- Medical
  - Imaging
  - Cancer Treatment
- Industrial
  - Well Logging
  - Material/Structural Inspection
  - Elemental Composition Determination
  - Sterilization
- Research
  - From Basic to Applied Research
  - Production and Application



PET Image



Ac-225 Shipment

ORNL/DOE Isotope Leadership

"If at some time a heavenly angel should ask what the laboratory in East Tennessee did to enlarge man's life and make it better, I daresay the production of radioisotopes for scientific research and medical treatment will surely rate as a candidate for the very first place."

Alvin Weinberg

US Isotope production snapshot

Missouri University Research Center	
Lutetium-177	• Ovarian and colon cancer treatment
Holmium-166	• Multiple myeloma and rheumatoid arthritis treatment
Phosporus-32	• SPECT imaging

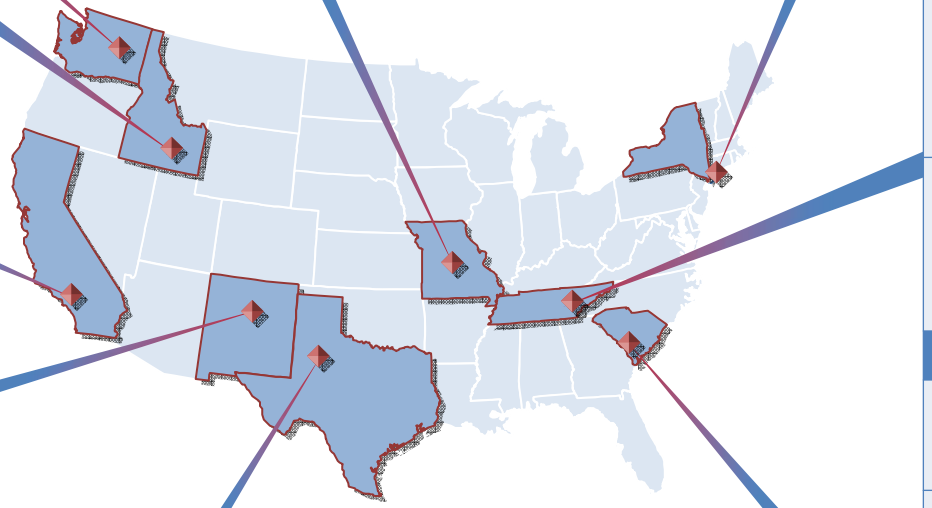
Brookhaven: BLIP	
Copper-67	• Antibody labeling for cancer therapy and imaging
Germanium-68	• Calibration sources for PET equipment; antibody labeling
Strontium-82	• Cardiac imaging

Pacific Northwest	
Strontium-90	• Parent for Y-90

Idaho	
Iridium-192	• Industrial nondestructive examination
Cobalt-60	• Surgical equipment and blood sterilization

UC David/McClellan	
Iodine-125	• Prostate cancer therapy

Los Alamos – LANSCE	
Aluminum-26	• Alzheimer's disease research • Acid rain research
Copper-67	• Antibody labeling for cancer therapy and imaging
Germanium-68	• Calibration sources for PET equipment; antibody labeling



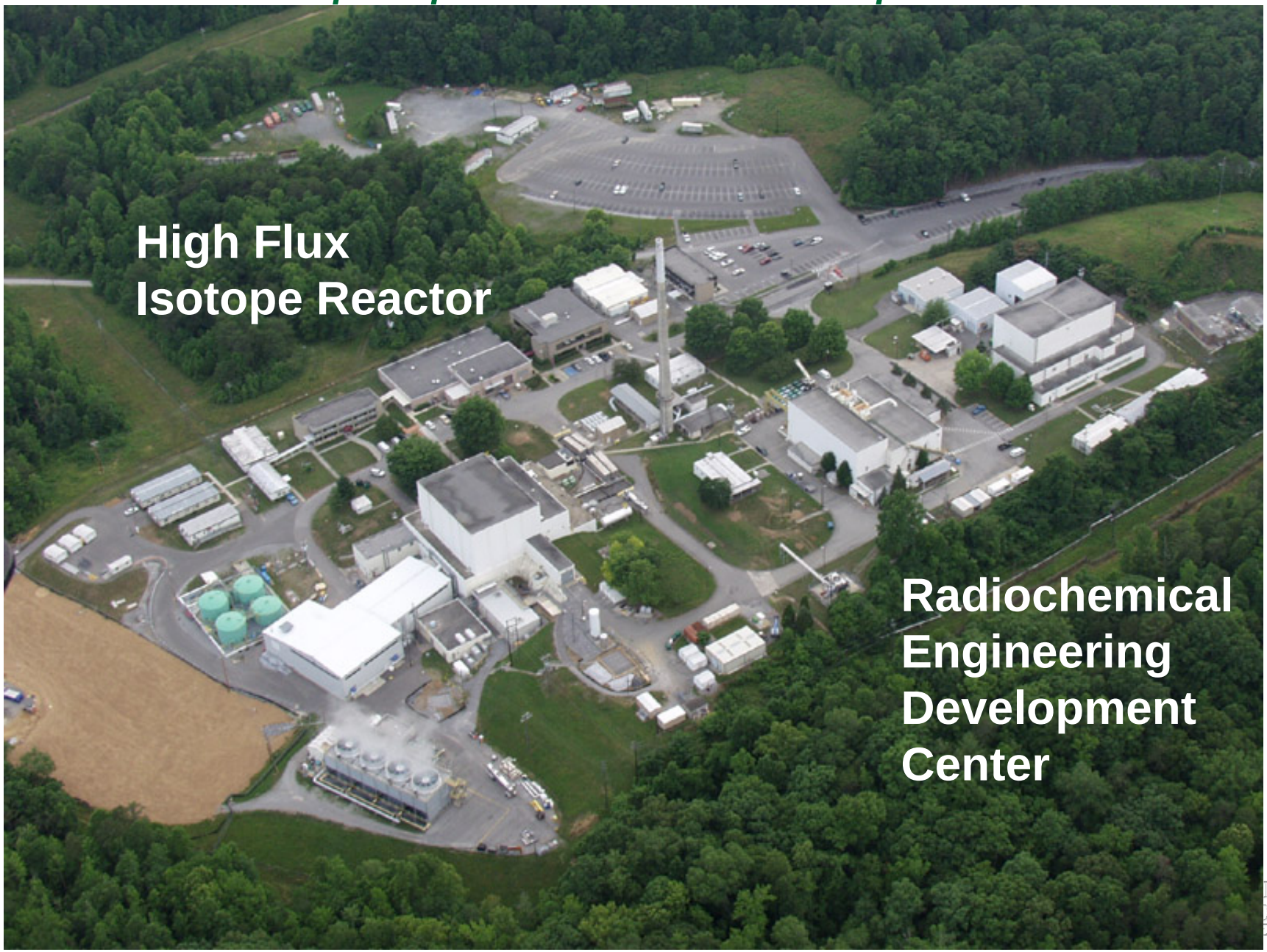
Denton, Texas	
Copper-67	• Cancer therapy
Thallium-201	• Cardiac imaging

Savannah River: Helium-3	
Helium-3	• Helium-lithium and helium-neon lasers • Fuel source for fusion reactors • Research on properties of superfluids

Oak Ridge: ~233 Stable isotopes in inventory	
Calcium-42	• Calcium retention studies
Calcium-43	• Nutrition
Calcium-44	• Bone growth
Calcium-45	• Nucleosynthesis
Calcium-48	• Nuclear physics
Strontium-88	• Reactor targets for Sr-89 (for bone cancer therapy and monoclonal antibody labeling)
Thallium-203	• Targets for production of Tl-201 (for cardiac imaging) in accelerators

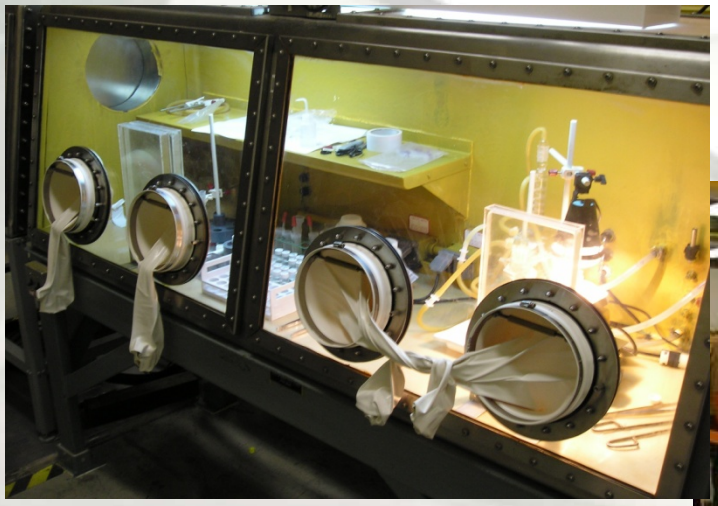
Radioisotopes	
Selenium-75	• Industrial nondestructive examination
Nickel-63	• Explosives detection
Californium-252	• Industrial source
Tungsten-188	• Cancer therapy
Actinium-225	• Cancer therapy

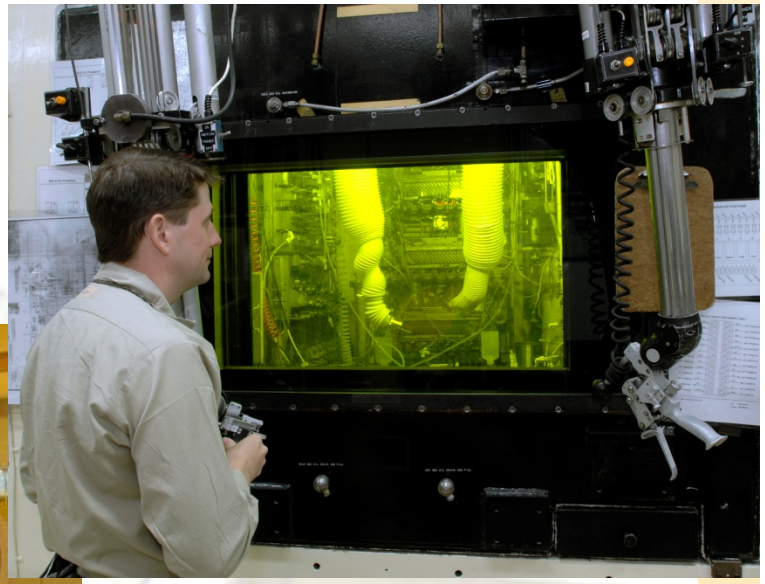
ORNL Isotope production capabilities



ORNL Nuclear Facilities: Unique National Capabilities

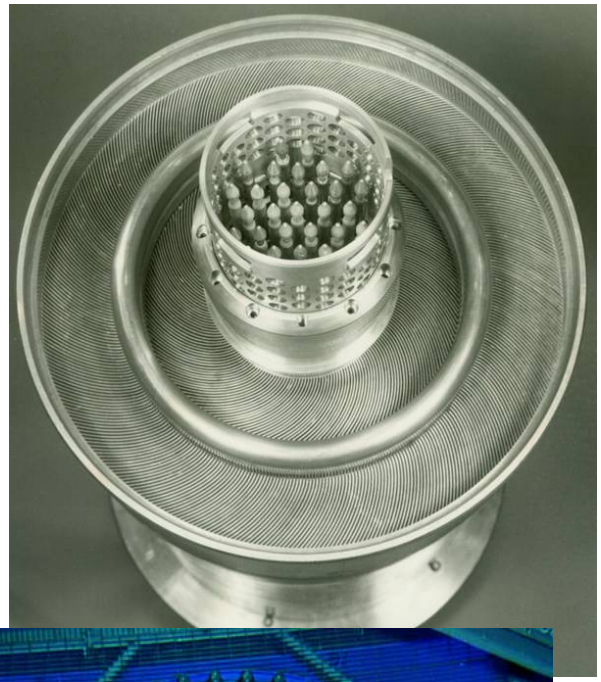
- 4 active facilities – glovebox to heavily shielded
  - Target Fabrication and Processing
  - Radiochemical separations
  - On-site shipment

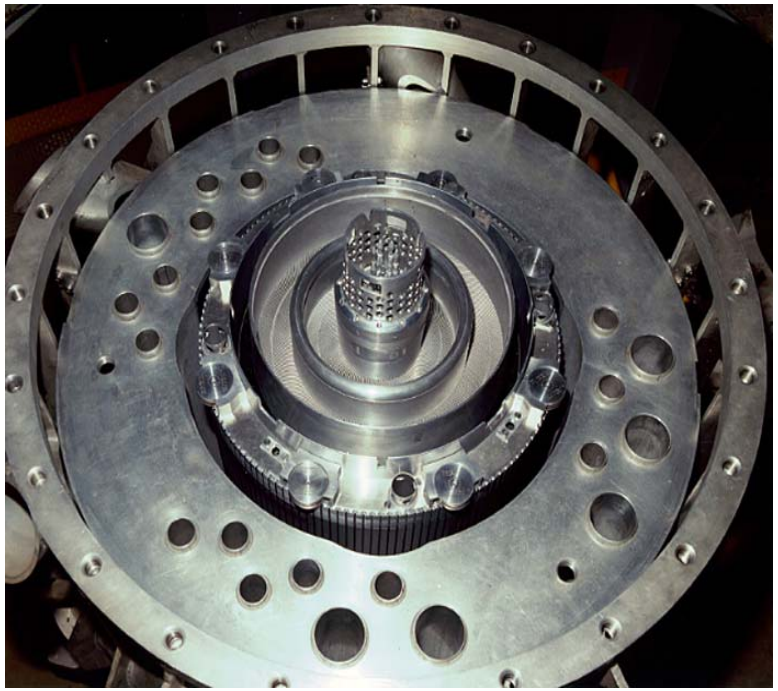


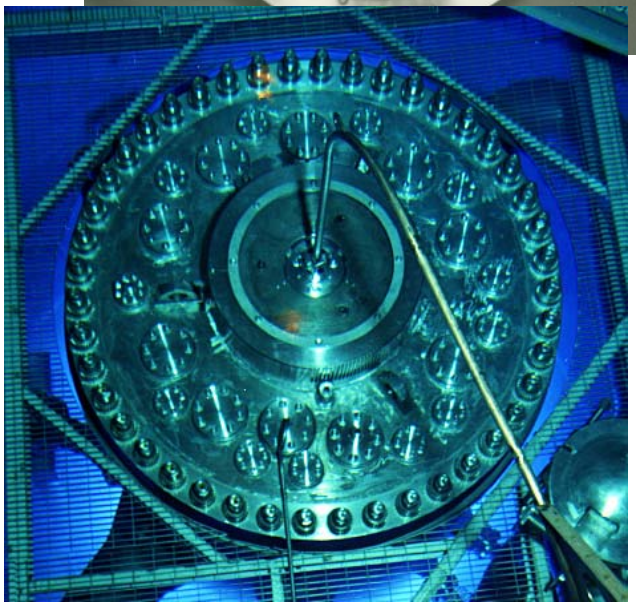


Reactor isotope production at the HFIR

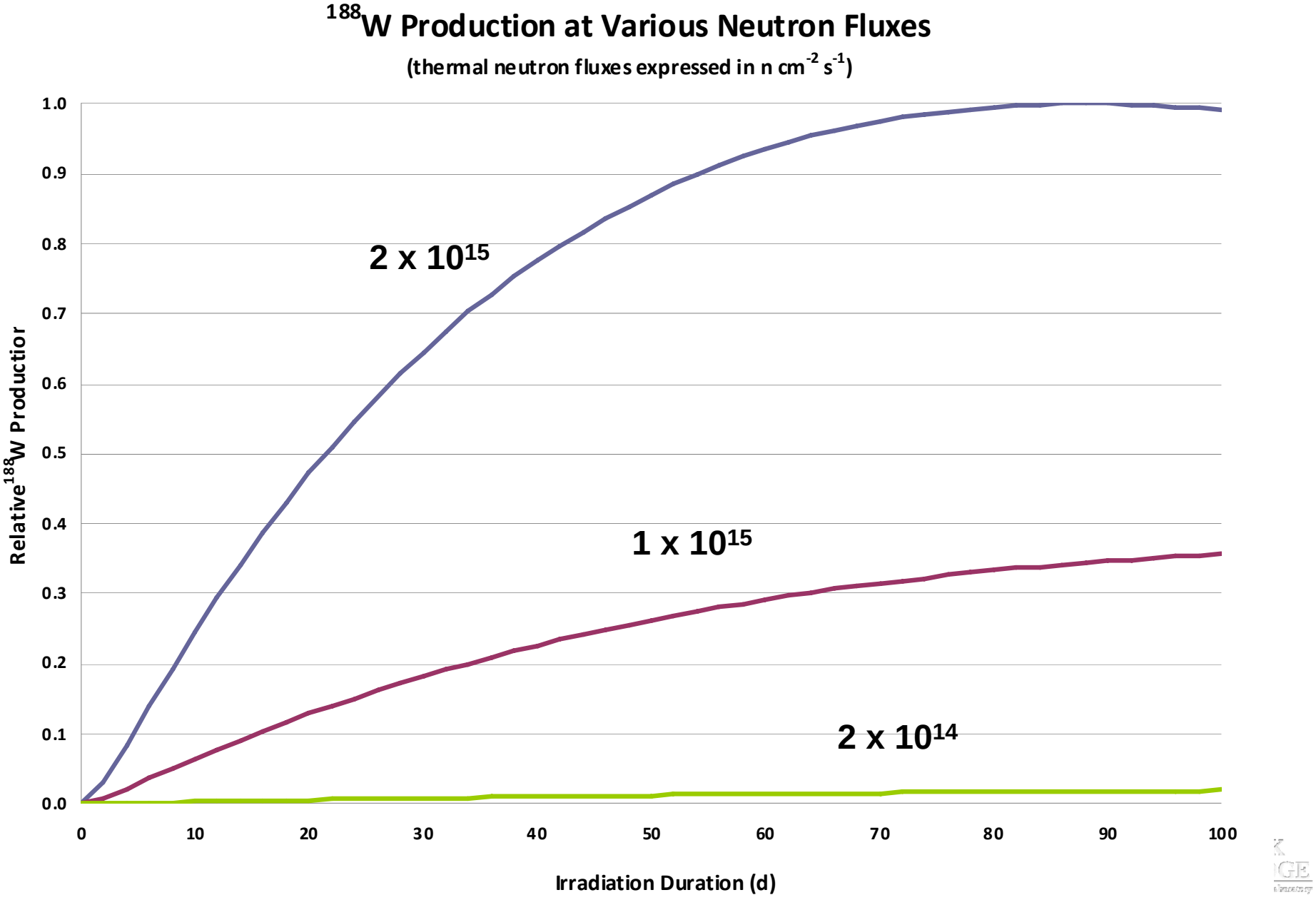
- Flux trap – steady state thermal neutron flux 2.5 x 10^{15} n.cm^{-2}.s^{-1}
- Peripheral target positions
- Hydraulic tube





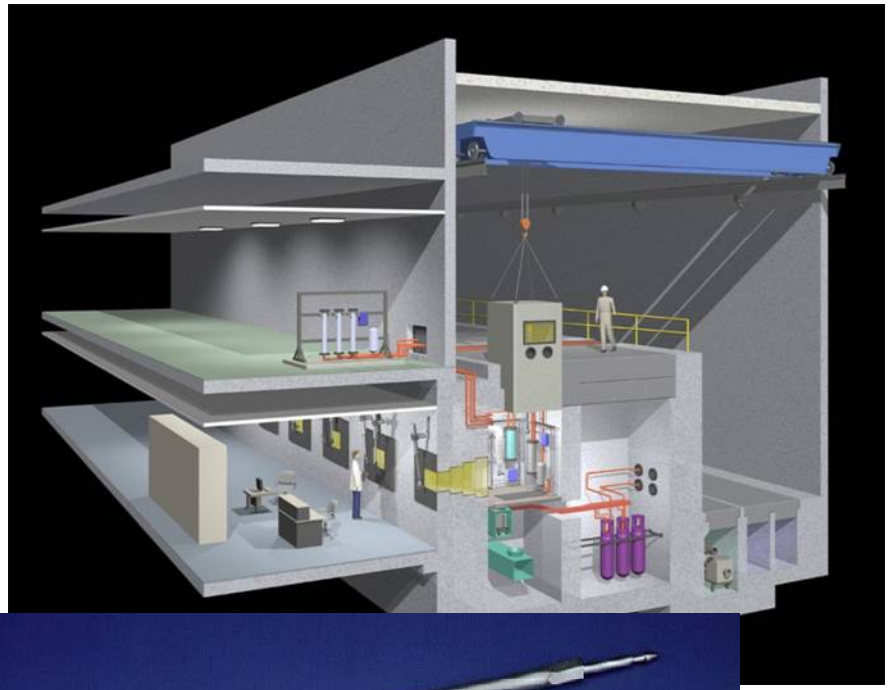


Impact of High Flux on Production Rates



Target Fabrication and Processing in the Hot Cells

- Heavily shielded hot cells
  - Dedicated to pellet production and target fabrication
  - Chemical processing
  - Sample analysis
  - Waste handling
- Shielded caves and glovebox labs for product purification and R&D
- Radiochemical analytical labs

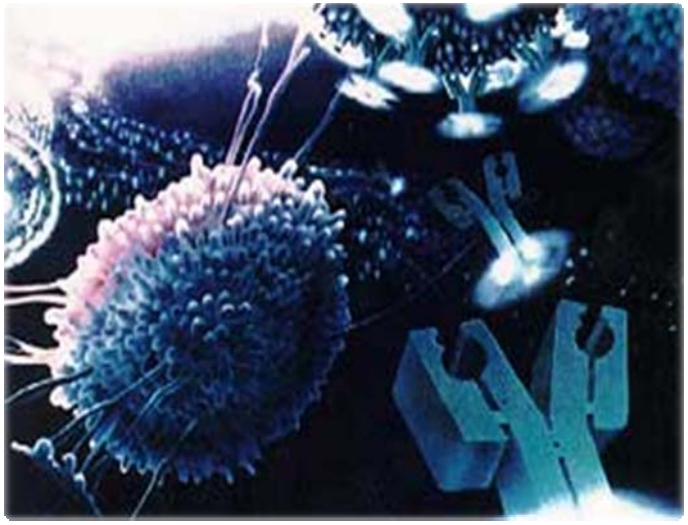


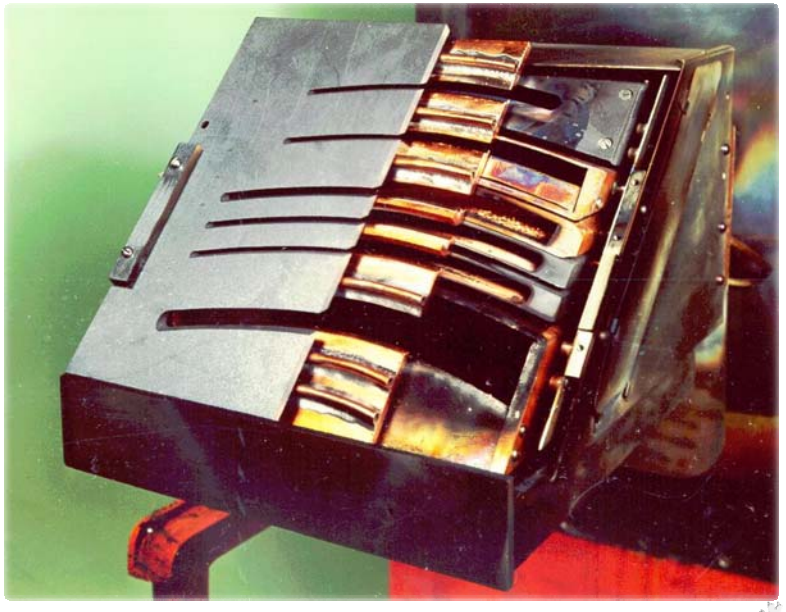
Isotope Dispensing and Shipping

- Radiochemical grade product ready for pharmaceutical applications
  - Ac-225
  - W-188
- Transcurium shipments
  - Special form Encapsulation
- Stable isotope custom processing and dispensing

Current Areas of Focus

- Expanded or large-scale targeted alpha therapy for cancer treatment
  - Radium irradiations
  - Extraction of Th-229 from U-233
- Beta emitting isotopes
- Expanded transcurium production
  - Cf, Bk, Es, Fm
  - Processing improvements
- Stable isotope enrichment capability

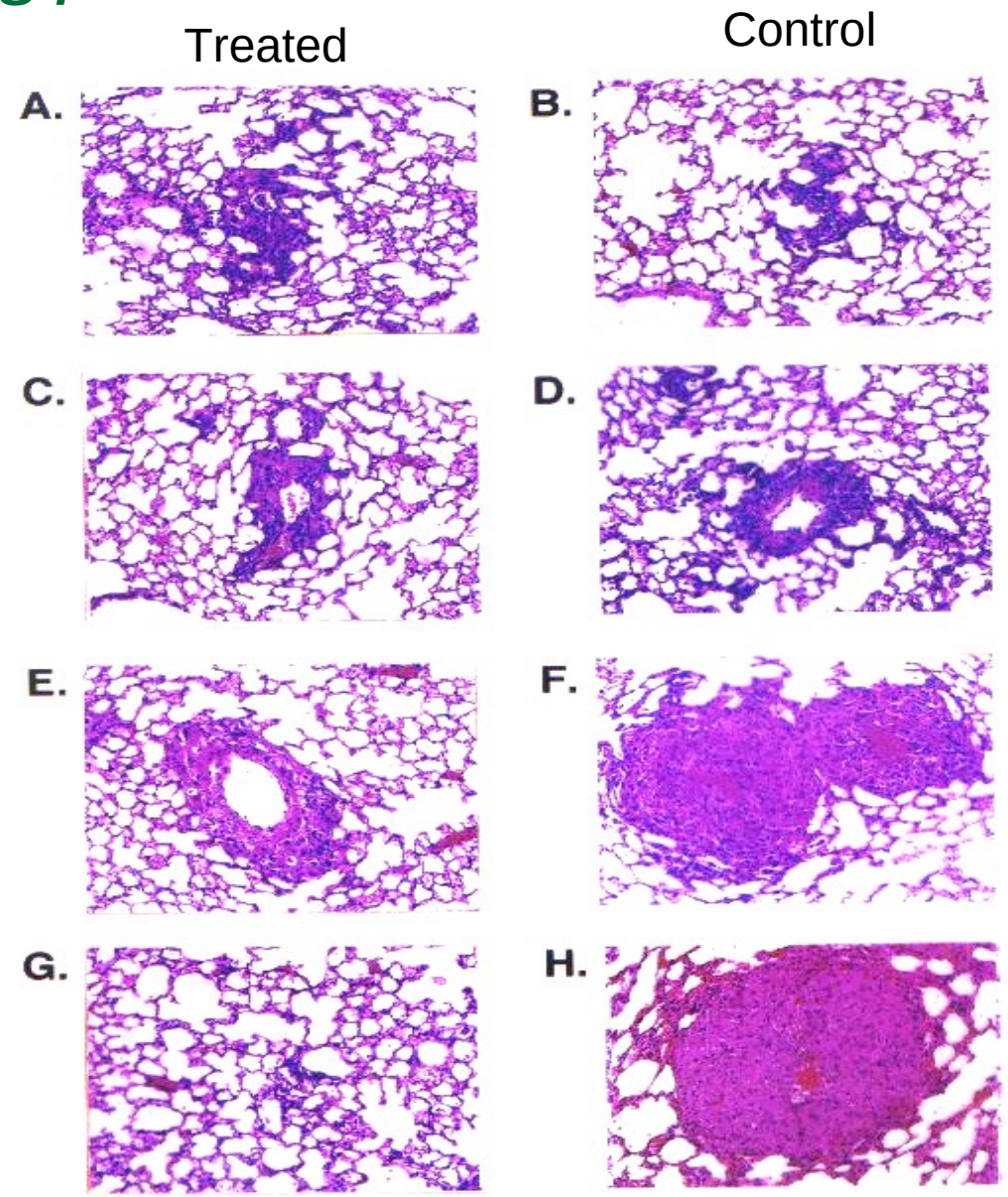




Why Alpha Emitters?

- Alpha particle have short range but high linear energy transfer (LET) radiation
- Alphas kills all cells in short path (~100 µm)

  (^{213}Bi, 8 MeV, 6-10 cell layer)
- Isotope is attached to tumor cell targeting antibody
- Short half-life alpha emitters
  - immediate effects, vascular, external cell
- Longer half-life alpha emitters
  - nanogenerator systems, internal cell, multi-alphas

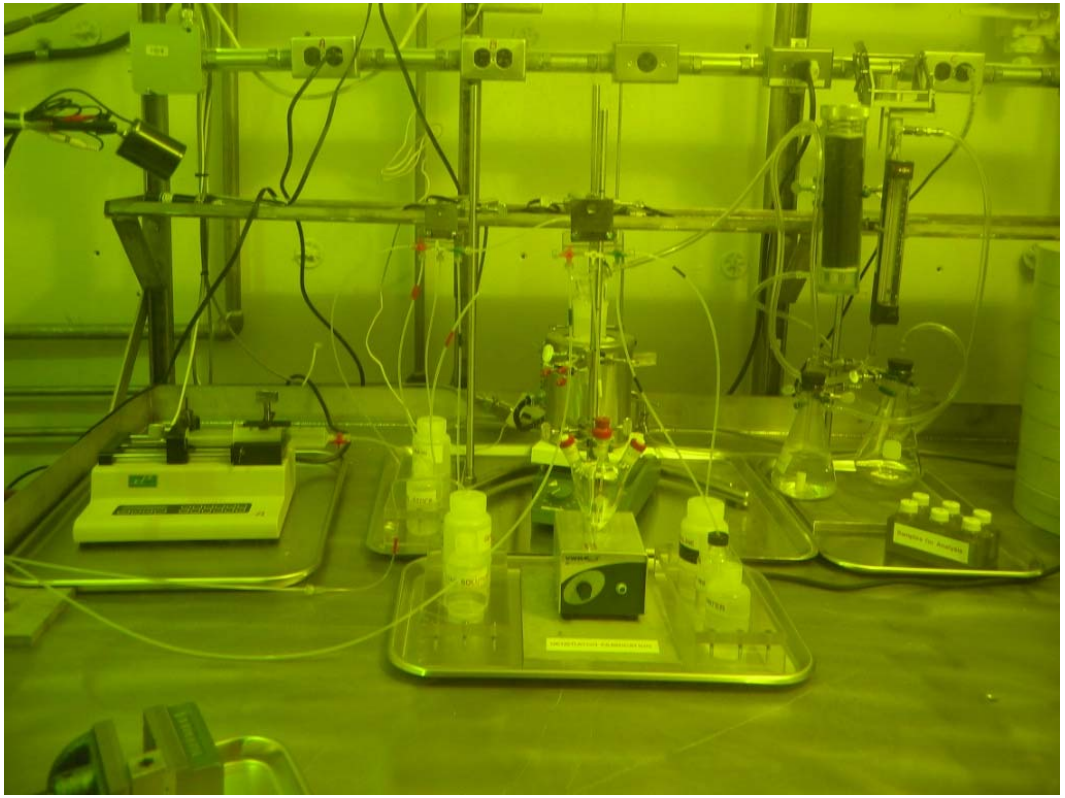


Alpha Production – Current Focus

- Facility requirements radium/daughters
- Target fabrication
- Post-irradiation target processing
- Routine product separation and distribution
- Very limited supply of purified ^{229}Th

Beta Emitting Medical Radioisotopes

- W-188/Re-188 Generator
  - New processing system
  - Drug Master File (DMF)
  - current Good Manufacturing Practice (cGMP) quality system
- Lutetium-177
  - Dedicated hotcell
  - New processing system



Vision of a Unified Heavy Element Production Program

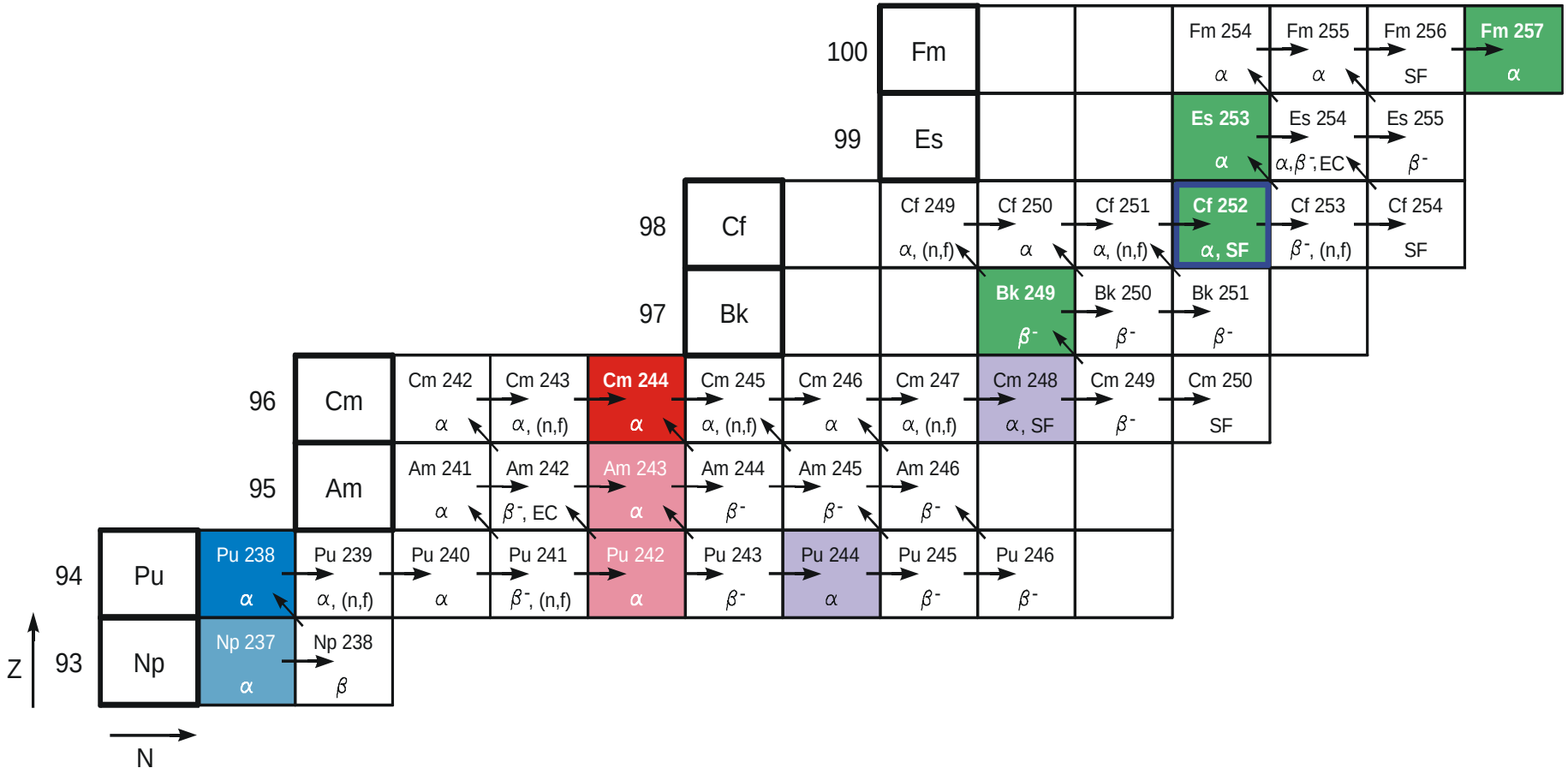
The field of new transuranium elements is entering an era where the participating scientists in this country cannot go much further without some unified national effort, which can only be authorized and coordinated by the Atomic Energy Commission itself.

- *The future progress in this area depends on substantial weighable quantities (say milligrams) of berkelium, californium, and einsteinium. The acquiring of this depends upon our country's entrance into a two-fold program.*
- *The irradiation of substantial quantities of ^{239}Pu as reactor fuel element, and the reirradiation of the products...to form hundred gram amounts of ^{244}Cm and higher curium isotopes...*
- *The irradiation of the curium in the suggested "very high flux reactor."*

G. T. Seaborg

Berkeley, October 24, 1957

Heavy Element Pathways



Major Scientific Impacts of the Heavy Element Products

- *Discovery of new heavier elements and isotopes*
- *Basic research on the physics of heavy elements;*
  electron behavior in orbitals,
  nuclear properties,
  nuclear reactions.
- *Discovery of bimodal fission in some nuclides with $Z \geq 100$.*
- *Basic research on the chemistry of heavy actinides;*
  chemically stable compounds,
  crystal structure of salts,
  solution chemistry, spectroscopy.

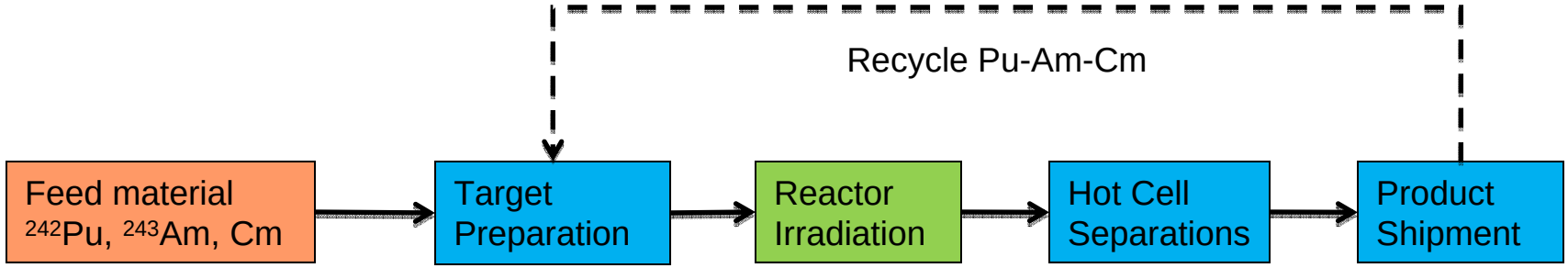
Es-253 (0.17 mg, self-illuminated)

Applications of ^{252}Cf Neutron Sources

Applications

- Reactor startup sources
- Fuel-rod Scanners, Neutron radiography
- Calibration standards
- Neutron Activation Analysis (NAA)
- Prompt Gamma Neutron Activation Analysis (PGNAA) for on-line monitoring of coal, cement, etc.
- Waste analysis (fissile and transuranic materials)
- Measurements for corrosion (bridges, highway infrastructure)

Heavy Element Production for DOE Research Programs and ^{252}Cf Neutron Sources



SRS

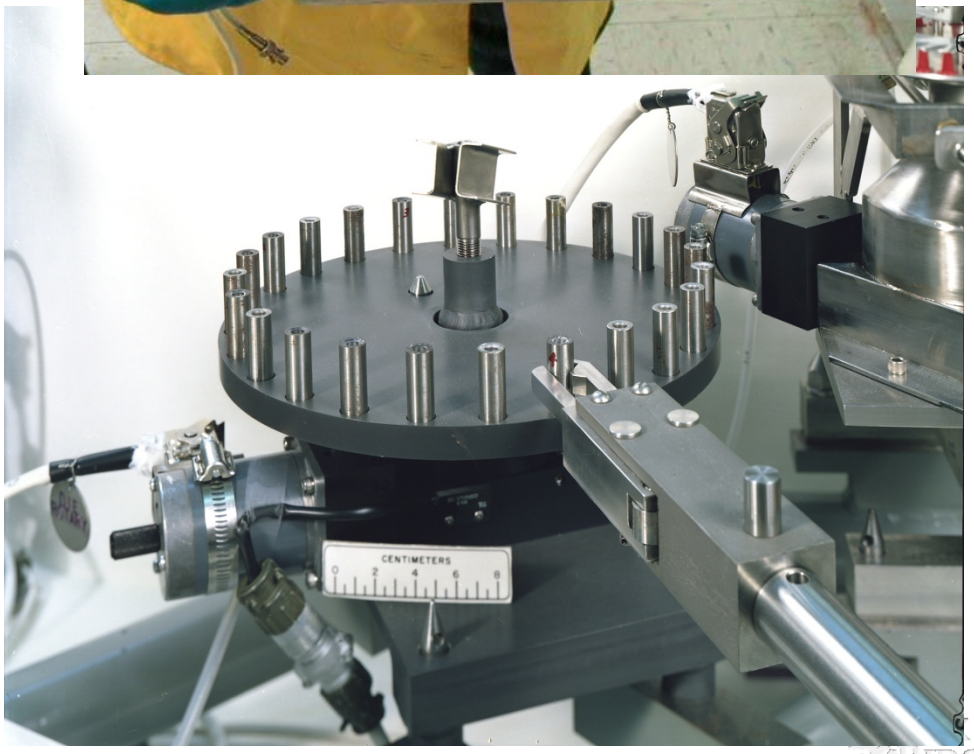
REDC

HFIR

	1st Campaign (1967)	Campaign 73 (2003)	Campaign 74 (2009)
^{249}Bk	0.34 mg	45 mg	22 mg
^{252}Cf	5.6 mg	350 mg	220-240 mg
^{253}Es	14 µg	1.7 mg	N/A

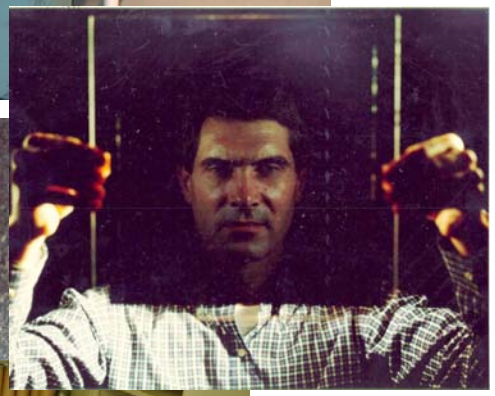
Heavy Elements – Current Focus

- Facility requirements for short lived isotopes
  - Iodine retention
- More efficient separations chemistry
- Improved target concepts
- Equipment Improvement
  - Target fabrication
  - Source fabrication



Stable Isotope Enrichment – Current Focus

- Custom product and services capabilities exist
- R&D to large-scale quantity enrichment capabilities needed
- Infrastructure needs common to any enrichment technology
  - High power/cooling demands
  - Chemical and materials expertise covering most of the Periodic Table
  - Ability to handle large amounts of a wide variety of hazardous materials and waste
  - High security requirements
  - Diverse technical staff disciplines



ORNL Isotope Initiatives

- Maintain and Grow Heavy Element Program
- Establish Isotope R&D Portfolio
- Expand production of Alpha and Beta emitters
- New or Refreshed capabilities
  - New Stable Enrichment