Hybrid Accelerator-Heavy Water System for Production of a Reliable, Domestic Supply of Molybdenum-99 without the Use of Highly Enriched Uranium

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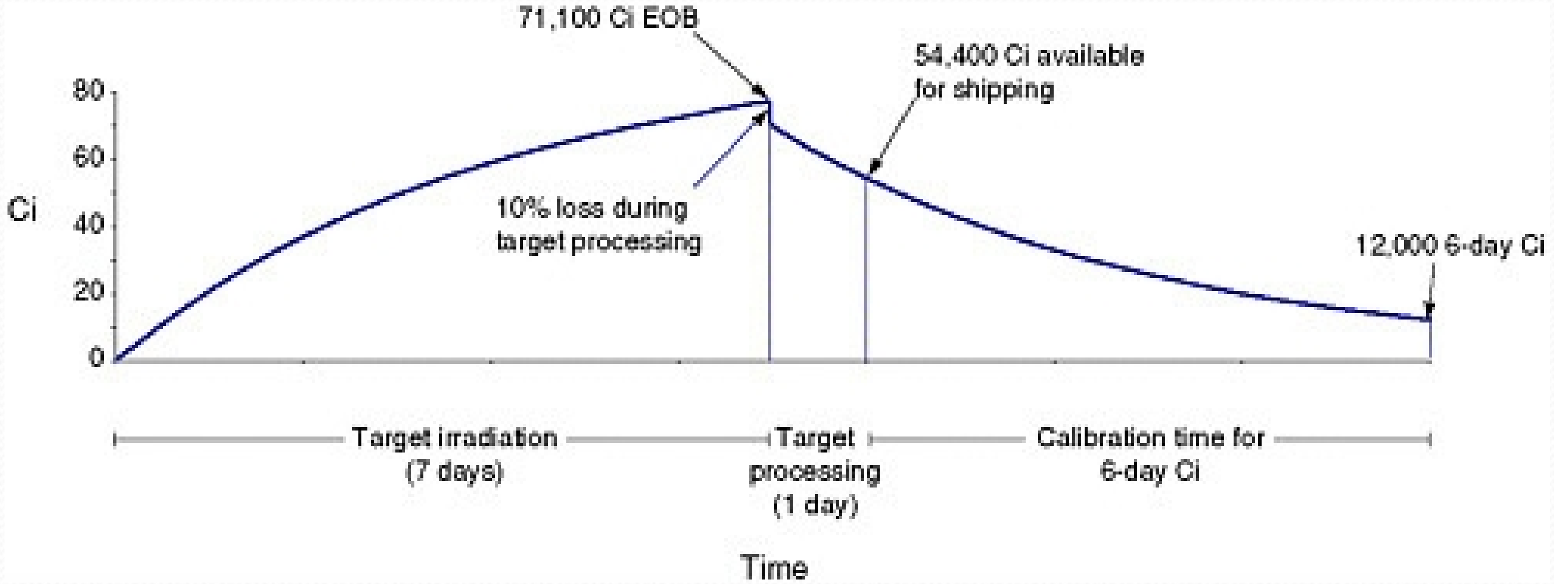
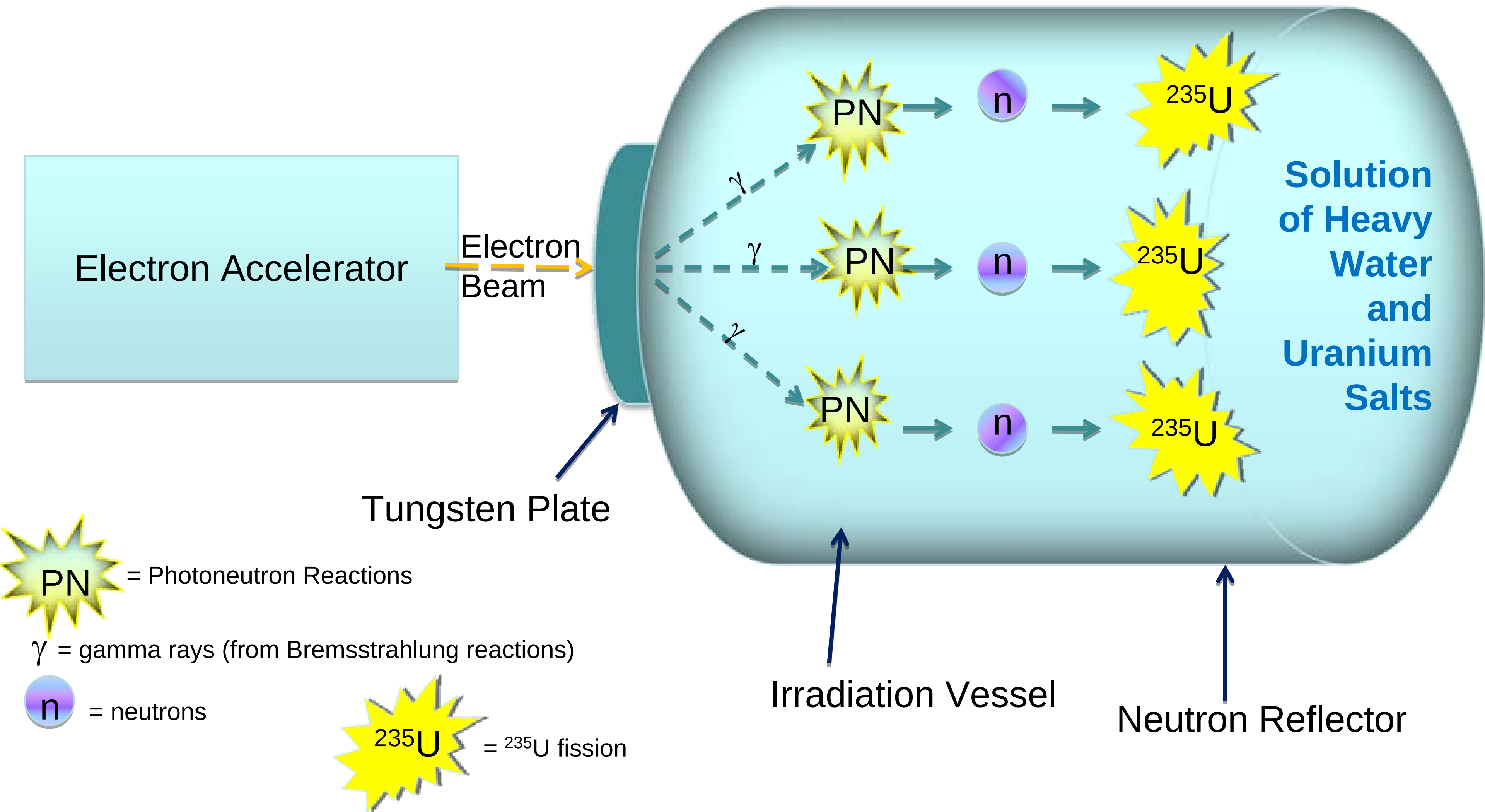
Mo-99 Demand

- World-Wide: 12,000 6-Day Curies (Ci)/week
- US: 6,000 6-Day Ci/week



Hybrid - Accelerator – Subcritical Vessel
^{99}Mo Production



AMIC-MU SYSTEM

- Rhodotrons produce Electron Beam that strike a dense target of tungsten or tantalum.

- The photons generated “shine” into a stainless steel tank containing a solution:

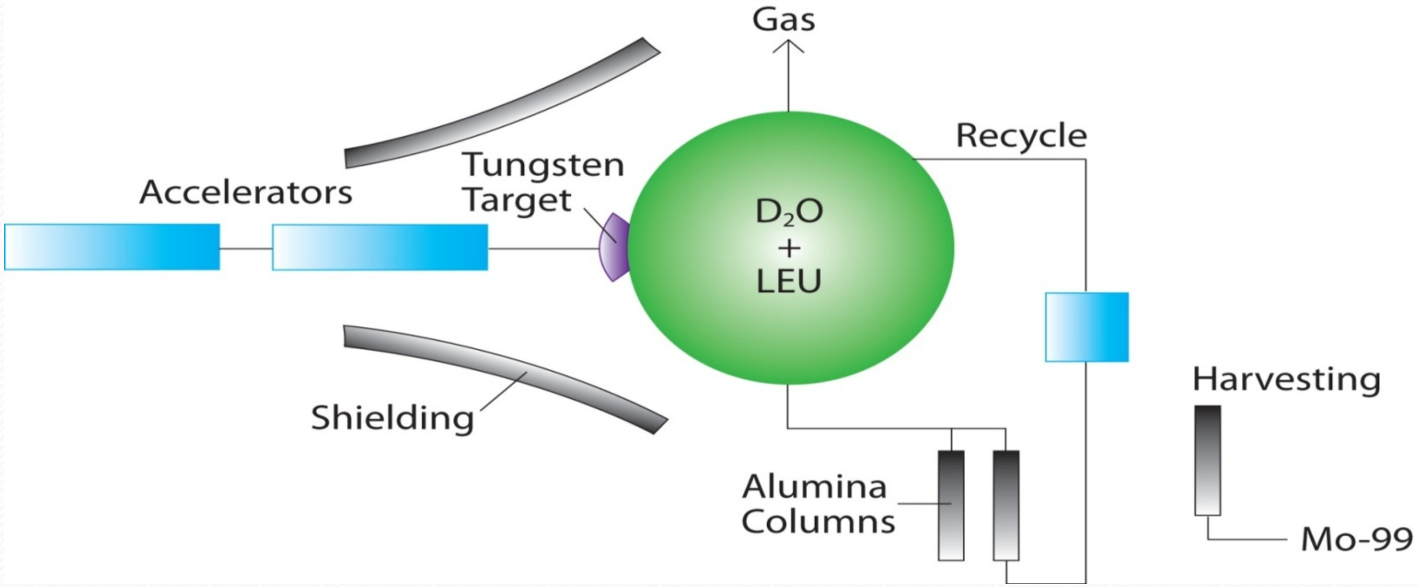
  - Heavy water, D_2O and
  - Dissolved low-enriched uranium (LEU) salt, such as uranyl nitrate.

- The photons eject neutrons from deuterium atoms in the D_2O that are thermalized.

AMIC-MU SYSTEM

- Subsequently, these thermal neutrons initiate fission in the LEU target material.
- This, in turn, provides a subcritical “boost” to the neutron population by contributing fission neutrons into the tank.
- The Mo-99 is extracted continuously during irradiation while recycling the solution back into the reaction chamber.
- After six days the batch is completed and the Mo-99 is then extracted from the collection columns to be purified.

Production Hardware



Electron Accelerator (Rhodotron)

AMIC calculations

- Over 4 years of effort by Dr. R. Schenter
- Using Computer Codes MCNP, MCNPX and CHAIN
- K_{eff} and Thermal Flux
- Mo-99 Production Activity and Specific Activity

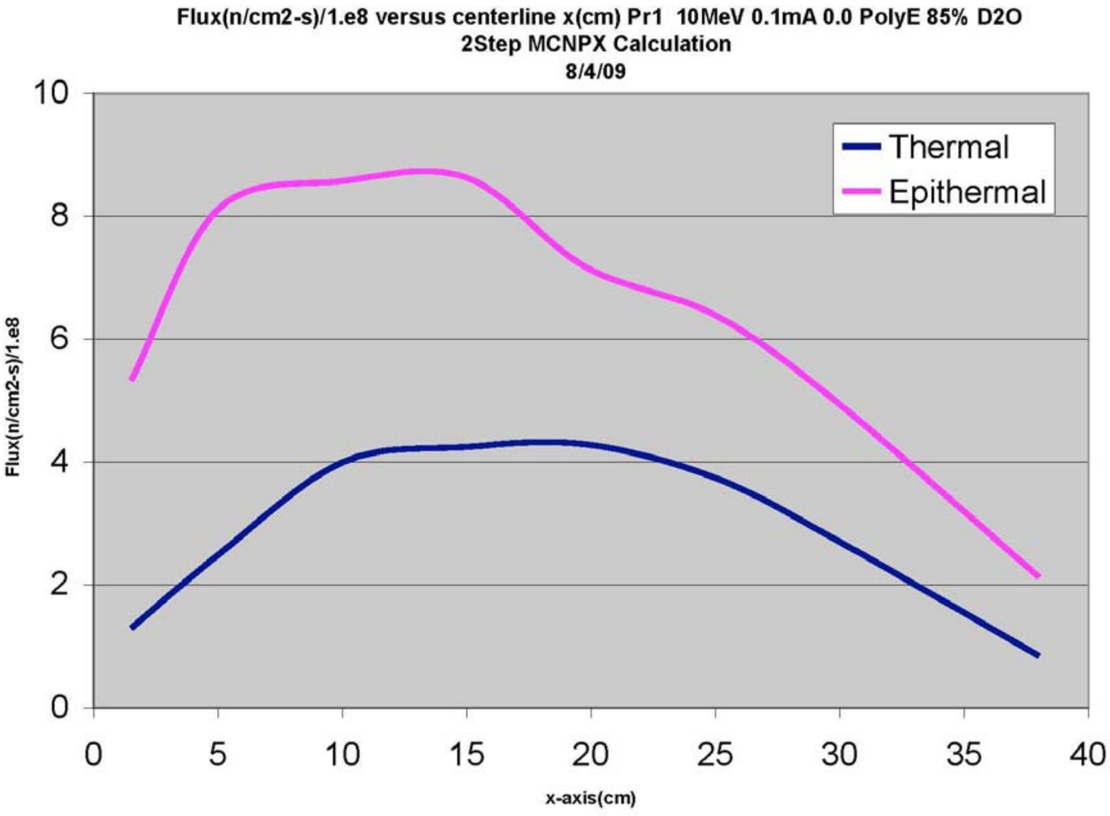
PR1 – First Prototype Test

- Test conducted at Idaho Accelerator Center July/Aug 2009

- Proof-of-Principle Experiments
  - Electron Beam Power : 428-1327 W (7-15 MeV)
  - Normal Water in SS tank (22 L)
  - Reflector (paraffin wax) thicknesses : 0-6 cm
  - Neutron Fluxes measured with Au and In foils (Cd covers)

- Conclusions:
  - Flux and Spectrum Matched Predictions (Calculations)
  - Confidence in Theoretical Modeling

Neutron Flux – PR1



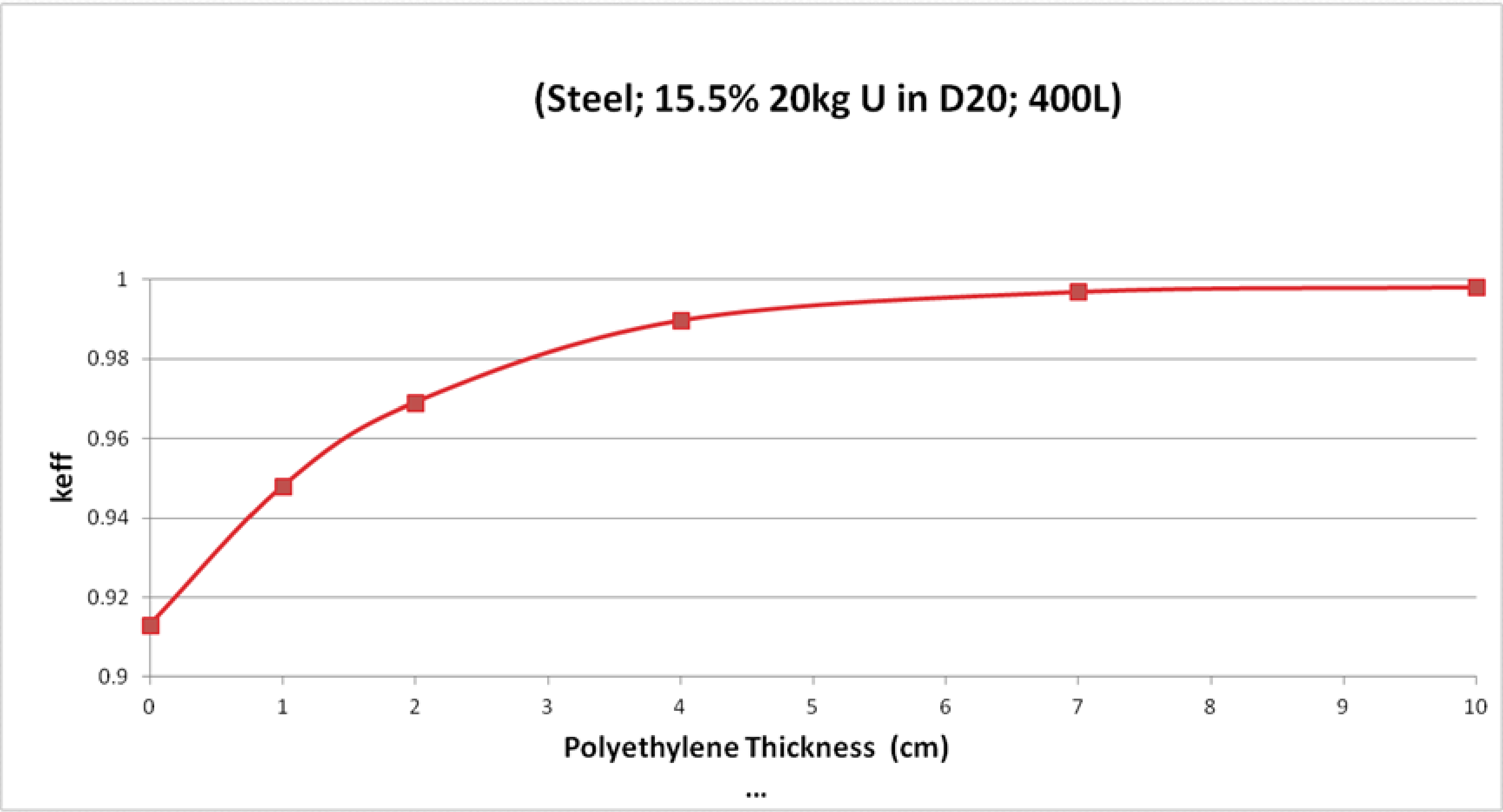
PR2 – Second Prototype Test

- Planned Extension of PR1:

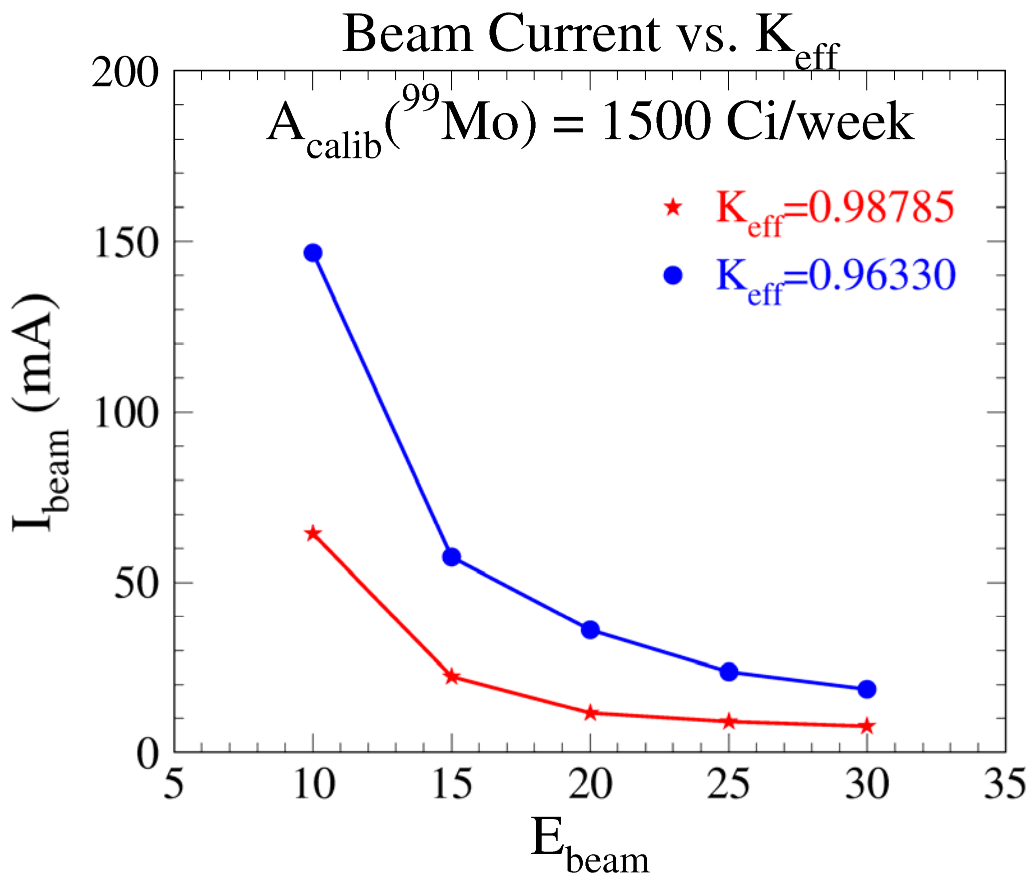
- Volume of water – 29.3 L
- Tank weight (filled) - 49 kg
- Tank OD 27.3 cm; ID 26.5 cm; length 52.9 cm
- LEU – 50 g/L
- U-235 – 276.76 g

- Scaled down version of Commercial System
- Quantify the subcritical multiplication/amplification ($1.0/(1.0-k_{eff})$) effect.
- Specific activity, purity and by-product profiles

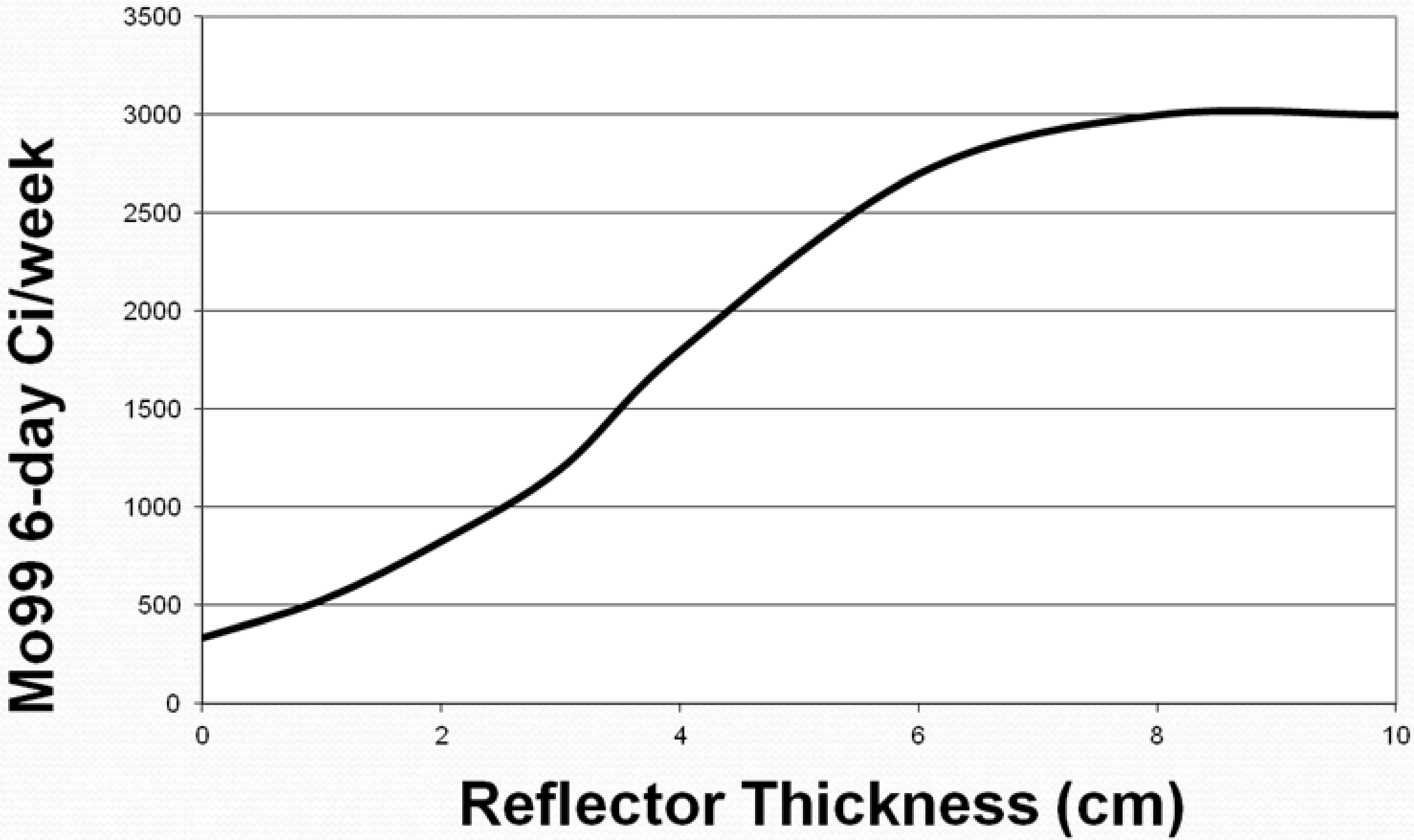
Effect of Reflector Thickness



Production Rate



Mo-99 Production



Beam Parameters

- Optimized beam design parameters: 24 MeV, 350 kW, and 14.6 mA
- The system design is flexible and can function well in a range between 15 to 40 MeV and 150 to 400 kW
- Achieving thermal flux levels equal to 1.23 E+12 is necessary to reach the Mo-99 production goals of 1500 6-day Curies per system at a specific activity of 50,000 Ci/g
- Optimization of the MCNXP calculations achieves more than twice that flux, which would produce at least 3000 6-day Curies/week (50% of US needs)

Example: Operating Parameters

- 400L Spherical Reaction Vessel
- 380 kW Electron Beam
- 24 MeV (2 coupled TT300 Rhodotrons)
- 20 kg of 15.5% Enriched LEU
  - 3.7cm reflector PolyE
  - Zr .625cm vessel material
  - D2O/uranyl density = 1.183g/cc
  - 6 day irradiation
  - W target 0.3cm thick; diameter 8cm
  - Electron beam spread 2cm diameter
  - Keff=.991
- → 3000 6-Day Ci/week

Commercial System

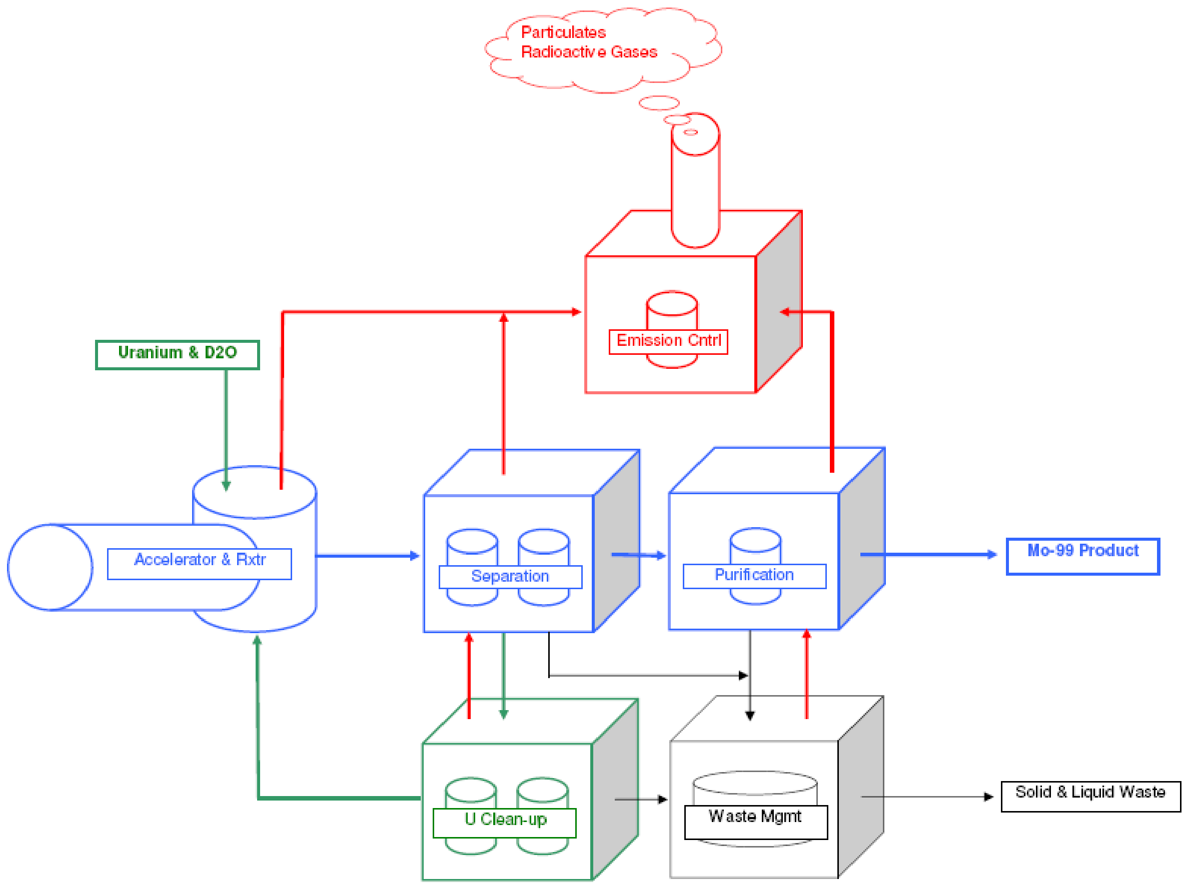
- Rhodotrons (Two Coupled TT300) & Metal Target System(s) - IBA
- Operating Parameters & Design – AMIC
- Production Scheme – Energy Solutions
- Solution Reactor – MU
- Chemistry – AMIC & others

System Modules

1) Accelerator and reaction vessel
2) Mo-99 separation and purification
3) Uranium nitrate recycle
4) Waste management
5) Airborne emissions treatment

Each system has been through a pre-conceptual design. Conceptual design and targeted engineering module demonstration projects are planned to reduce any risks of schedule delay

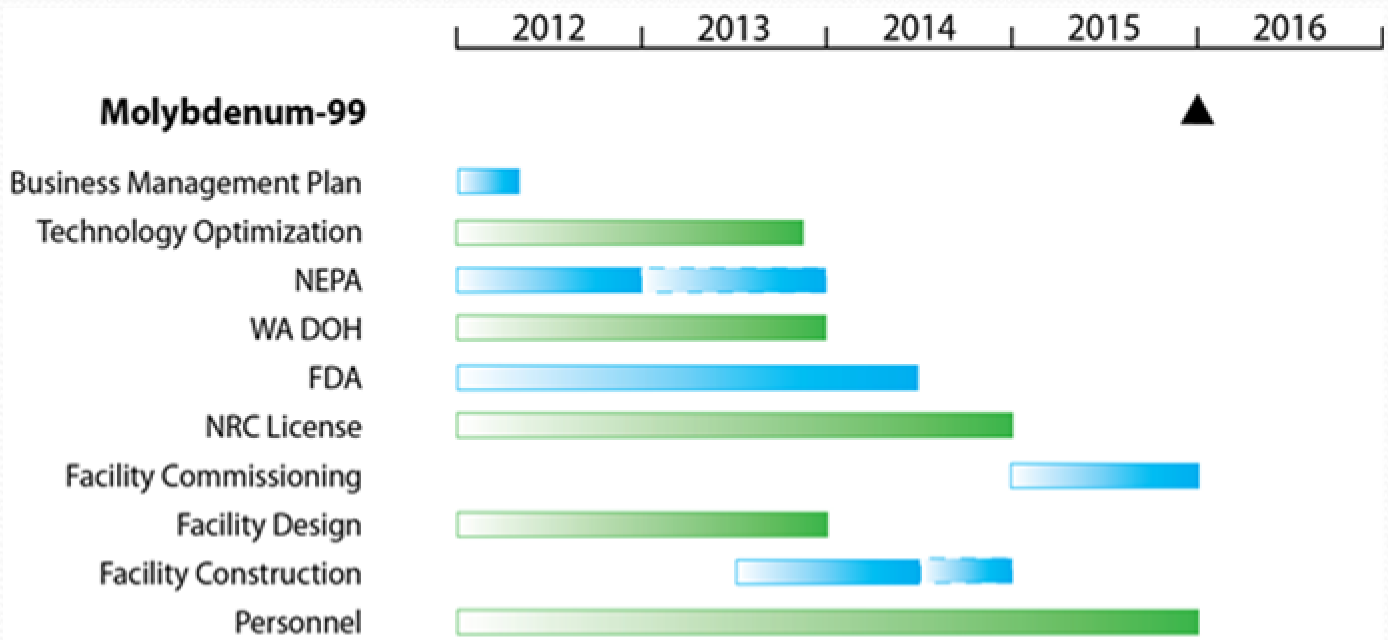
Production Scheme



Integrated System Design

- Primary functional design criteria:
  - Ensure a stable non-critical system under all scenarios
  - Ensure employee safety and insignificant environmental impacts
  - Maximize the production rates
  - Produce the lowest cost and most reliable system that satisfies, at least, 50% of the US needs

Schedule


2012
2013
2014
2015
2016
Molybdenum-99
Business Management Plan
Technology Optimization
NEPA
WA DOH
FDA
NRC License
Facility Commissioning
Facility Design
Facility Construction
Personnel

AMIC-MU Mo-99 Production Method Conclusion-Summary

- Large Scale Production-3000 6day-Ci/Week
- SPA Greater than 10,000Ci/gram at Hospital

- Electron Accelerator-Based
- Turn on and off with a switch

- LEU Solution Target
- System Components are all “Established Technology”

- “Cannot Go Critical”

Questions?