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Stable Isotope Enrichment Technology Development

1st Workshop on Isotope Federal Supply and Demand

January 11-12, 2012

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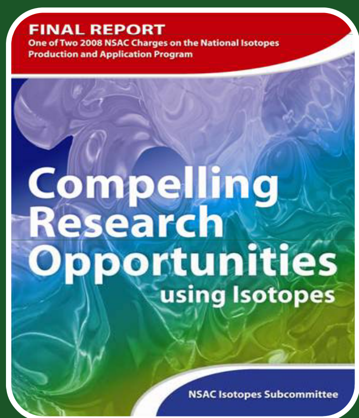
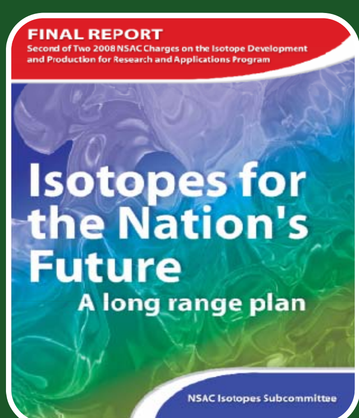
Office of Nuclear Physics, Isotope Production R&D

NSAC-I Report Recommendations



Recommendation 5

- R&D efforts should be conducted to prepare for the reestablishment of a domestic source of mass-separated stable and radioactive research isotopes



Recommendation III.1

- Construct and operate an electromagnetic isotope separator facility for stable and long-lived radioisotopes.

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Stable Nuclides with Very Limited Supply at ORNL

Isotope	Years Remaining (2008)	Years Remaining (2012)
Gd-157 (second pass)	0	0
Pb-204 (second pass)	0	0
Pb-205	*	0
Pb-207 (second pass)	0	0
Ru-96	0	0
Sm-150 (second pass)	0	0
Ta-181	0	0
V-51	0	0
W-180 (second pass)	0	0
Gd-157	0.2	0.5

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Stable Nuclides with <15 year Supply at ORNL

Isotope	Years Remaining (2008)	Years Remaining (2012)
Ni-62	3.9	4.5
Nd-150	7.9	4.8
Ga-69	3.7	5.9
W-183	*	7.6
W-182	*	9.9
Se-76	*	10.2
W-184	*	10.6
Cl-35	*	11.9
Mo-100	*	12.1
Pt-195	12.0	13.0
Ag-109	14.3	14.2

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Stable Nuclides with <20 year Supply at ORNL

Isotope	Years Remaining (2008)	Years Remaining (2012)
Mo-98	*	16.0
Ba-137	19.0	16.2
Ba-136	7.6	17.4
Zr-94	18.5	18.0
Sm-149	19.6	18.4
Tl-203	*	18.9

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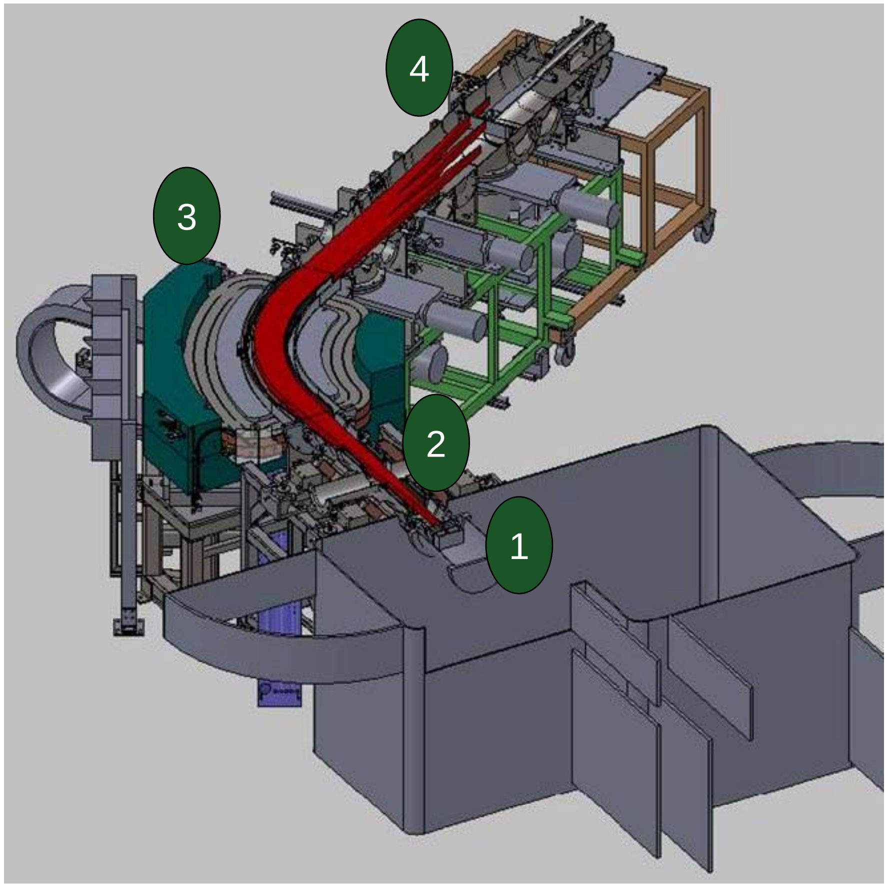
ORNL Separator Project

- **Design, fabricate, and test one research capable EMIS device with minimum on-collector ion-current of 10 mA.**
- **Engineering evaluation of gas-centrifuge-based enrichment system for select stable isotopes (Mo, W, Ni, Ge).**
- **Conceptualize a facility integrating EMIS technologies to provide enrichment capability equivalent to 3 to 6 Calutron EMIS systems.**
  - Three production scale 100 mA EMIS
  - Small modular centrifuges
- **Optimize to produce targeted isotopes at high rates, reasonable cost, scale as needed.**
- **Project commenced October, 2009**

EMIS Design



1. **Ribbon-shaped ion beam**
   - 100 mm max height
   - Freeman ion source
   - 1200^{o} C oven
2. **Magnetic quadrupole doublet for beam focus**
3. **60^{o} sector magnet for separation**
4. **Standard collector pockets**
   - Re-useable graphite lined
   - Viable for most stable elements

EMIS Commissioned December 15, 2011

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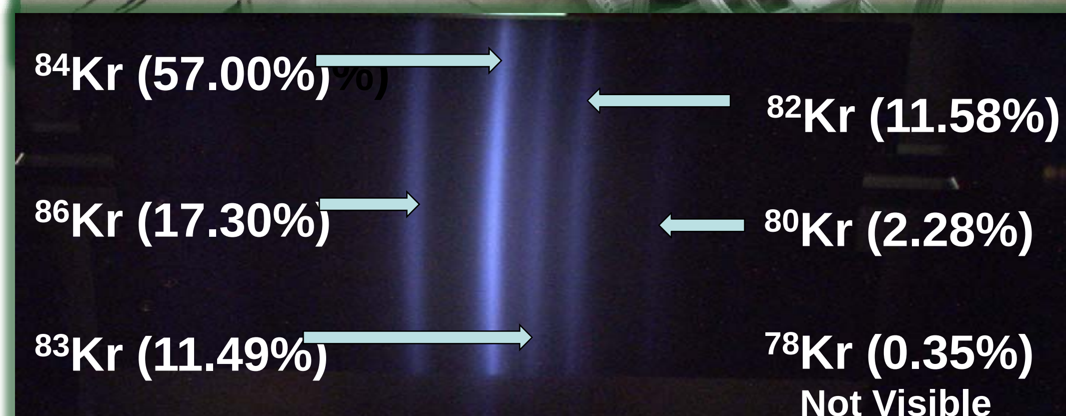
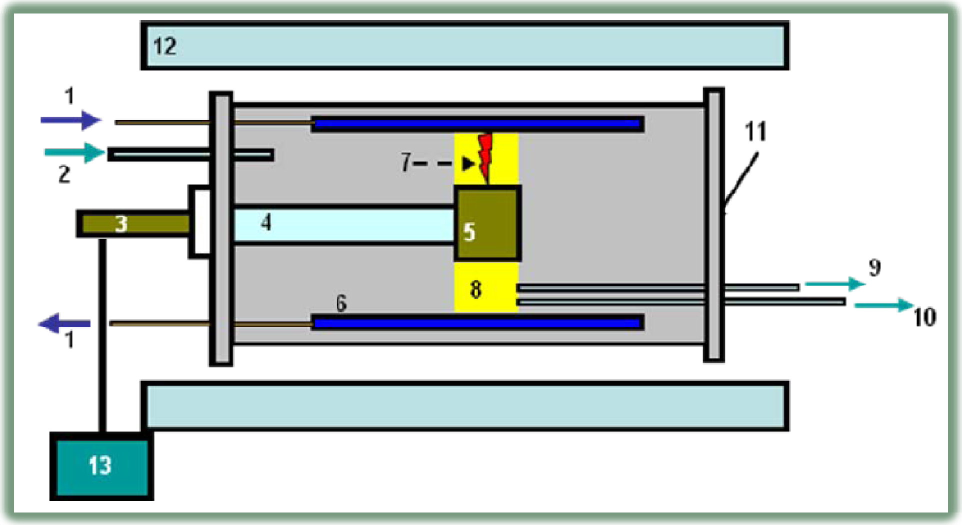


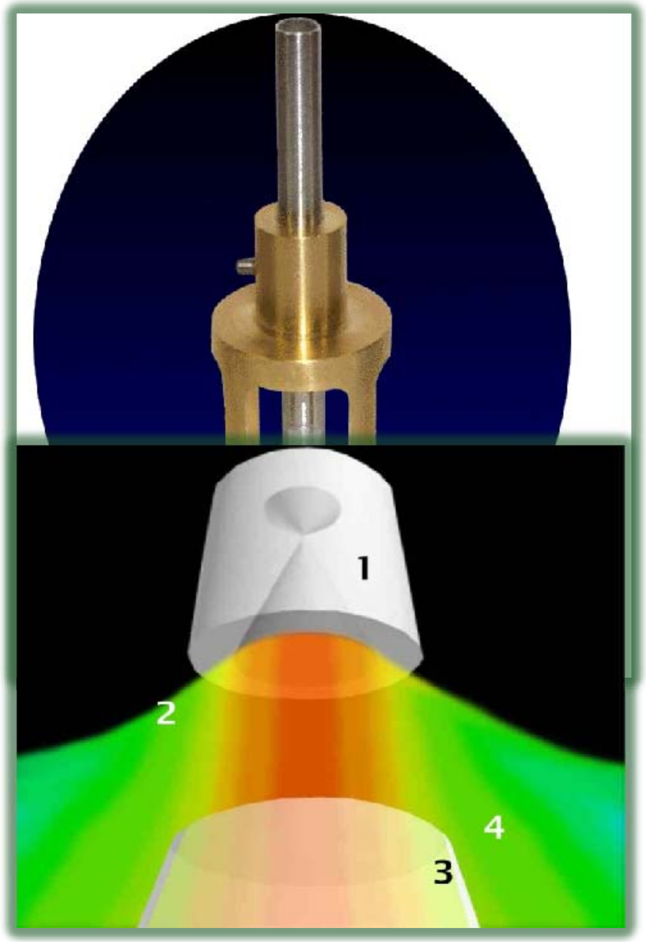
- **Commissioned with noble gases**
  - Focused Ar-40 beam on collector showing shape/size in agreement with 3D Lorentz simulations
  - Separated krypton beam
- **Testing continues**
- **Design studies to scale up ion source to 100 mA on collector**

Integrated Spin System (ISS) Plasma Separator

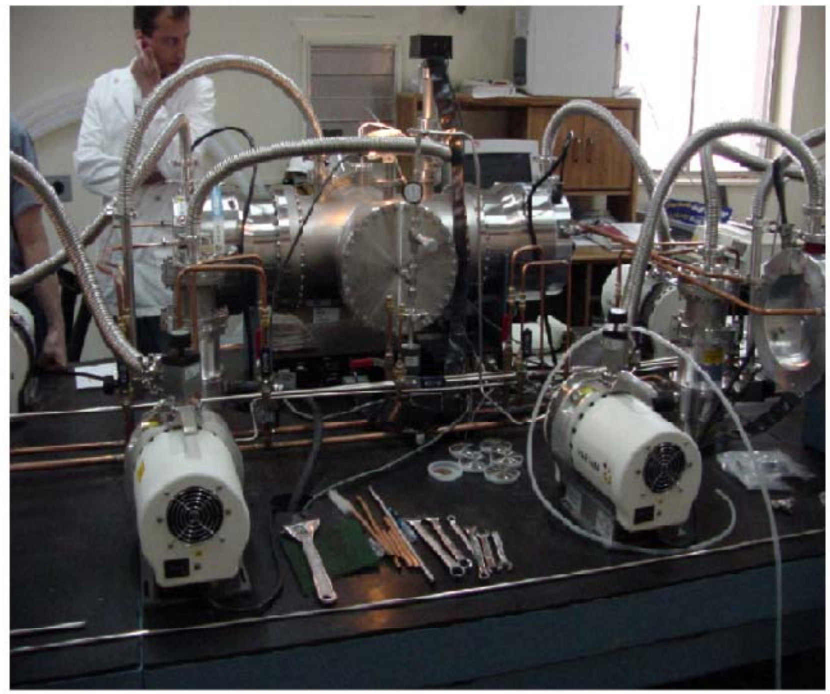


Consecutive frames from high speed camera (45000 frames per second) showing ~17000 rpm rotation of argon plasma.

Supersonic Fluid Dynamics, SBIR Funded

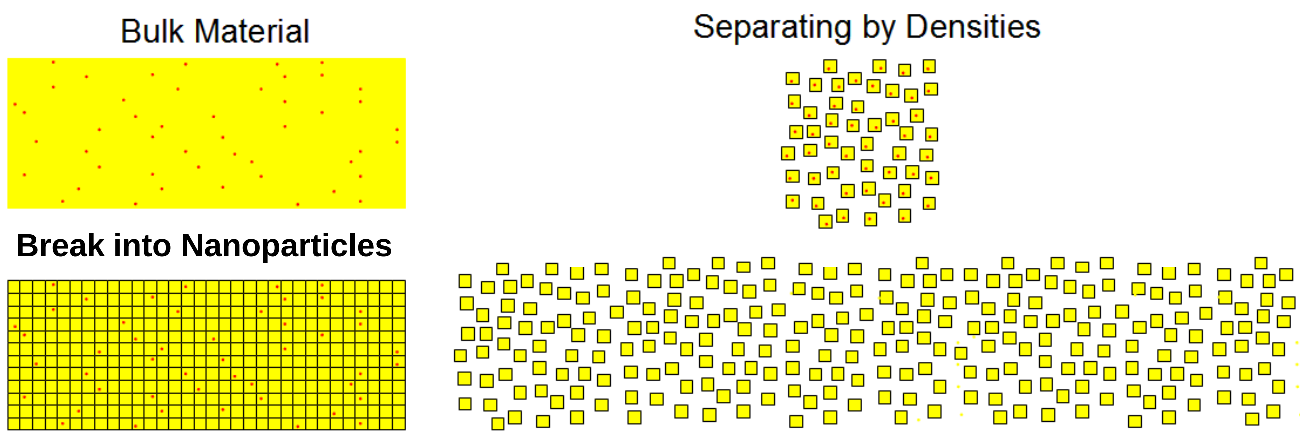


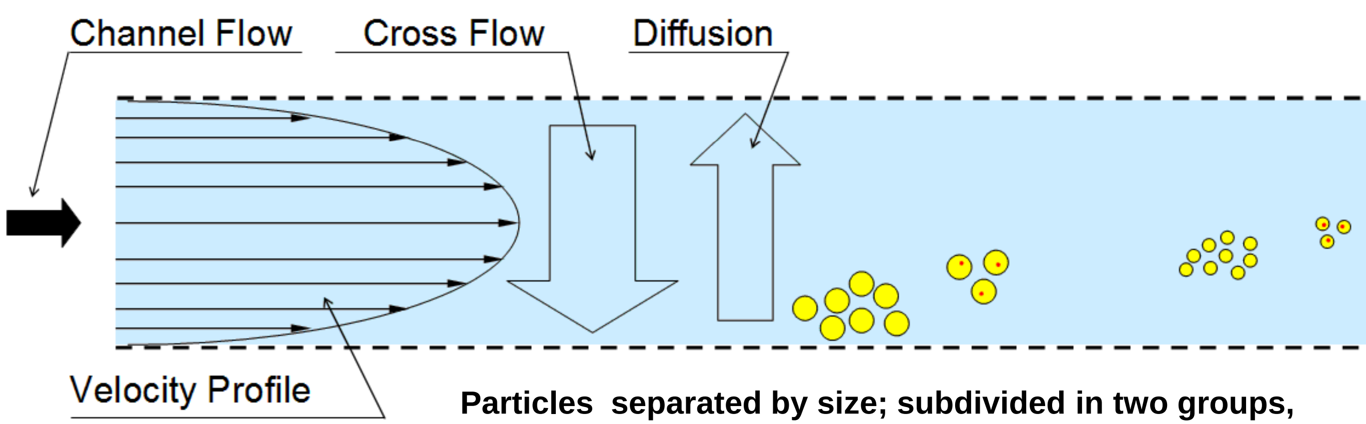
Principle of the Nozzle Separation



Single stage separator = ~$2M

Nanoparticle Formation/ Assymetric Cross-Flow





Particles separated by size; subdivided in two groups, depending on the presence of the less abundant isotope.

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FY10 Funded Project, UPR, Mayagüez

- **Applicable to elements with two naturally occurring isotopes of widely disparate abundance**
  - Modest enrichment of isotope of low abundance
  - High enrichment of isotope of high abundance
- **Vanadium (Natural: V-50(0.25%) and V-51(99.75%)**
  - Theoretical enrichments: V-50 (3.5%) and V-51 (99.99%)
  - V-51 used as a reference material for solid-state NMR analysis (currently 0 years of remaining DOE inventory)
- **Uranium (Natural: U-235(0.72%) and U-238(99.27%)**
  - Maximum theoretical enrichments: U-235 (~5.8%) and U-238 (99.99%)
  - “Safely” produces LWR reactor grade U-235
  - Highly enriched U-238 useful for physics targets for production of neutron rich heavy isotopes

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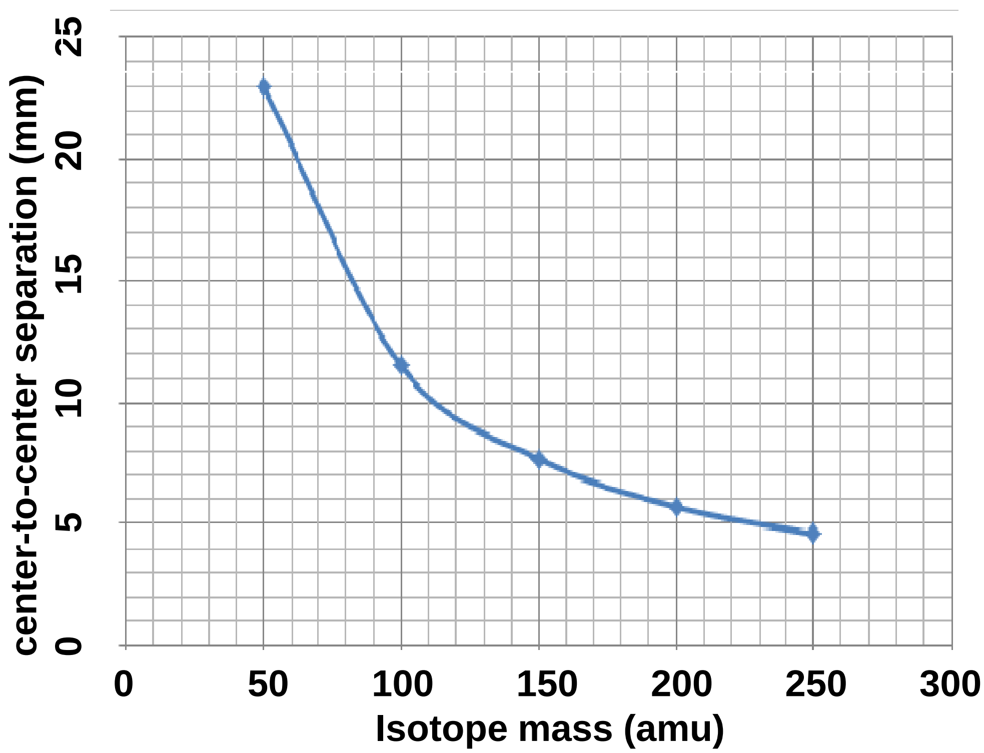
Conclusion

- The NP Isotope Program takes seriously the recommendation to develop new isotope separation capability.
- Ongoing promising R&D gives reason to be optimistic that a viable new technology will emerge.

Questions?

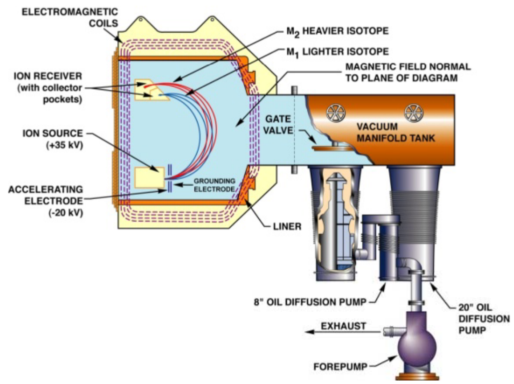
Mass Dispersion, Current Configuration

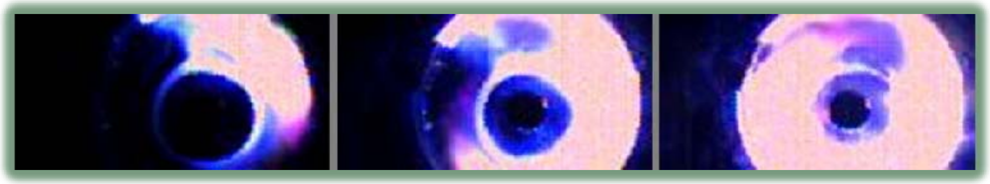


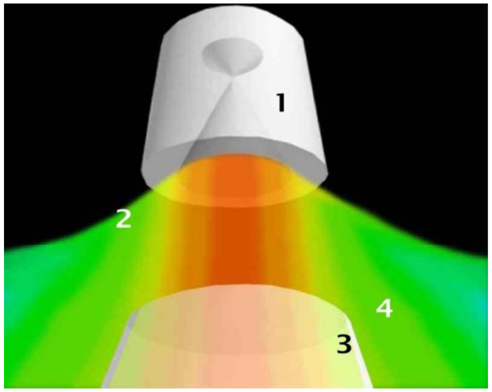
- Magnet designed for 20 amu < A < 208 amu
- Optimized for a A = 100 amu as mid-point
- Magnet capable of bending the path for A up to 450 amu
- Slight amount of distortion in the magnetic field for masses above 250
- Can make adjustments in the flight path to increase the separation for heavier isotopes

Enrichment Technologies

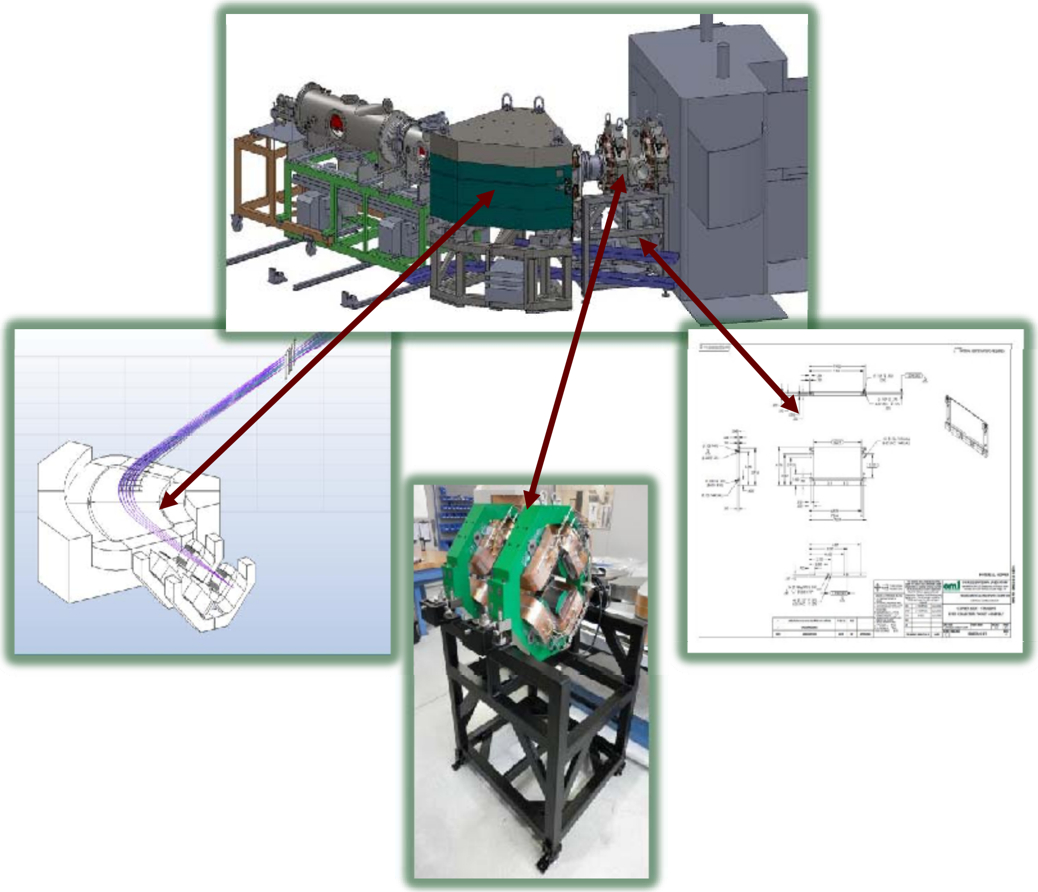
- **Electromagnetic separation**
- **Centrifugal separation**
  - Gas centrifuge
  - Spin System Plasma
- **Distillation**
- **Diffusion**
  - Gaseous
  - Thermal
  - Barrier
- **Supersonic fluid dynamics**
- **Laser**
- **Chemical/physical kinetic isotope effect**







Project Risk Mitigation



- Master 3D CAD model directly linked to simulation software and fabrication drawings.
- Components ORNL designed. Manufactured in four different countries.   Seamlessly fit together with the use of highly accurate CAD models.
- Measured magnetic field data imported into simulations to verify accuracy of design and fabrication before shipment.
- Separator fully operable on the day the last component (sector magnet) was installed.

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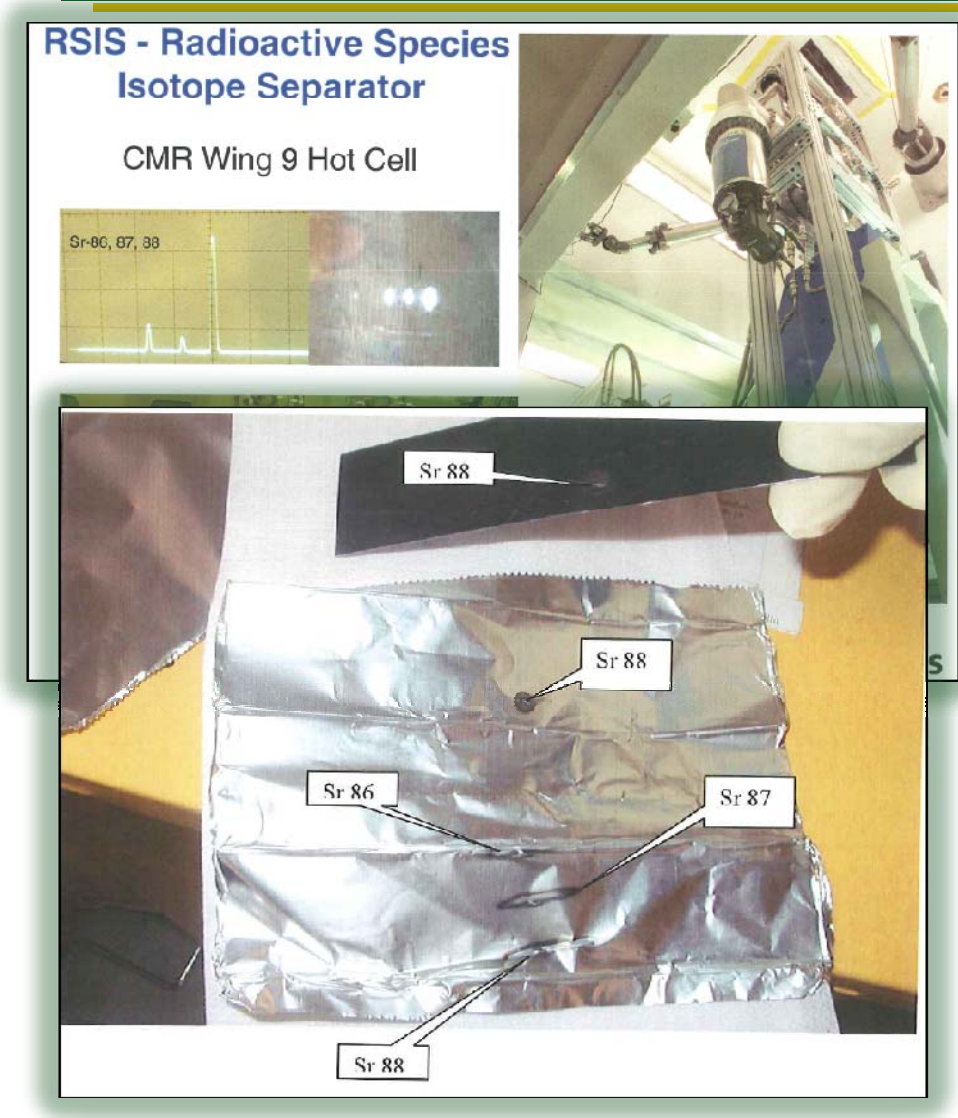
LANL Radioactive Sample Isotope Separator (RSIS)



- **Built, hot-cell installed by Isotope Program in late 1990s for strontium radioisotope separations**
- **Commissioned 2003 with stable strontium**
- **Cold stand-by since 2004.**
- **LANL proposing to up-date and restart for radioisotope separation.**

Advantage of ISS Technology

- Electromagnetically generate a rotating plasma, with very high rotation velocity
- Introduce material to be isotopically separated at center of plasma
- Separation occurs with strong dependence on rotational velocity and temperature

$$q(r) + 1 = \exp\left(\frac{\omega^2 r^2 \Delta m}{2kT}\right)$$

- Rotational velocities exceeding 1.4 x 10^3 m/s (cf 600 m/s for classical gas centrifuge separation)
- Can be applied to non-gaseous forms of material
- Potentially highly efficient (kg quantities)