Pacific Northwest
NATIONAL LABORATORY

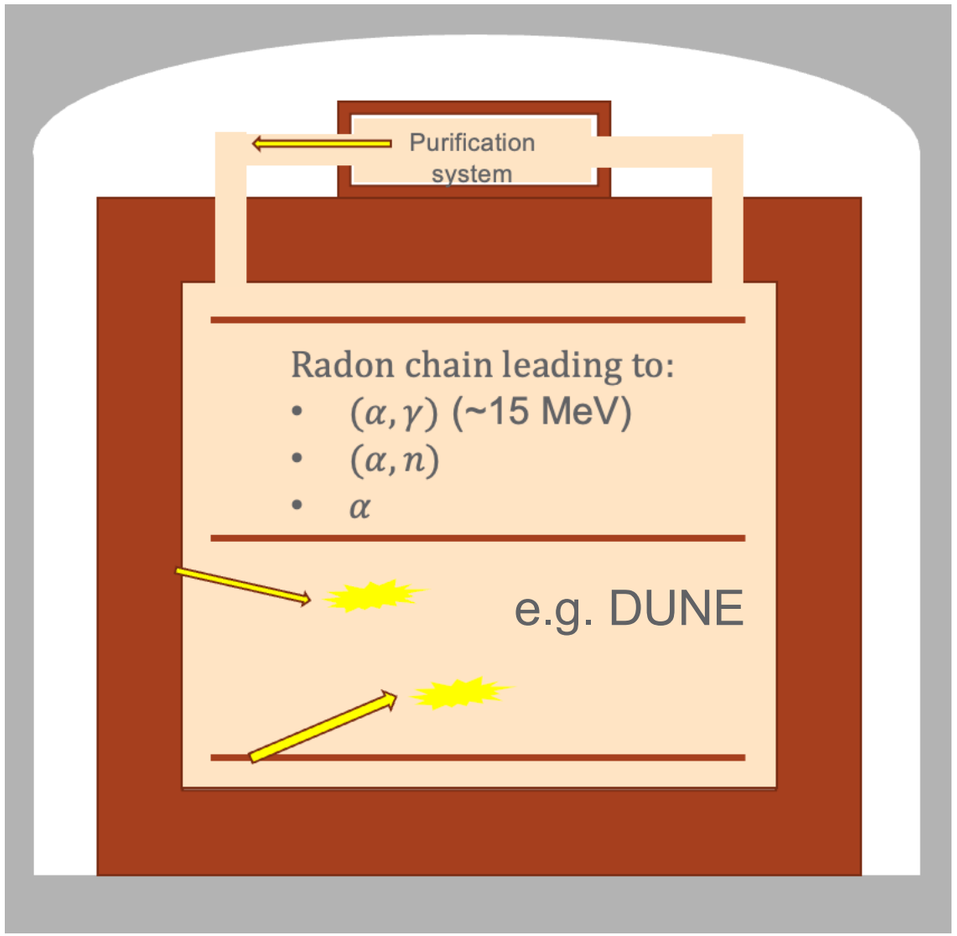
Radon Emanation at Cryogenic Temperatures

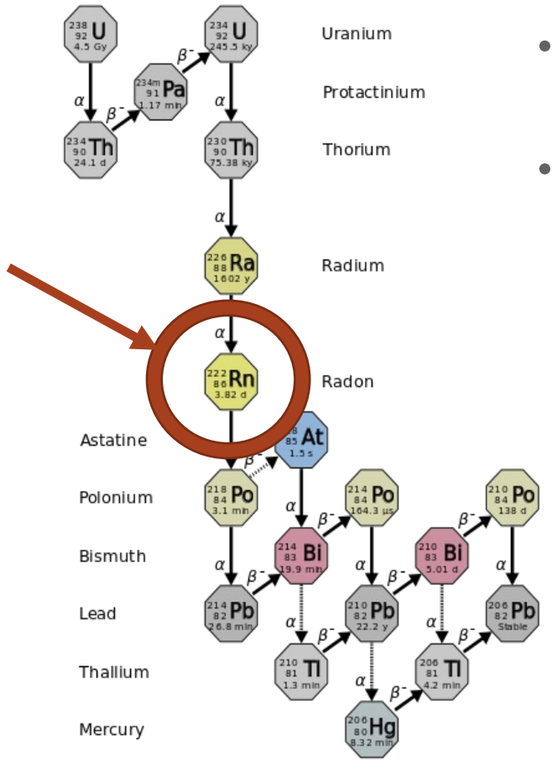
Chris Jackson
PNNL

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

Radon is a problematic background

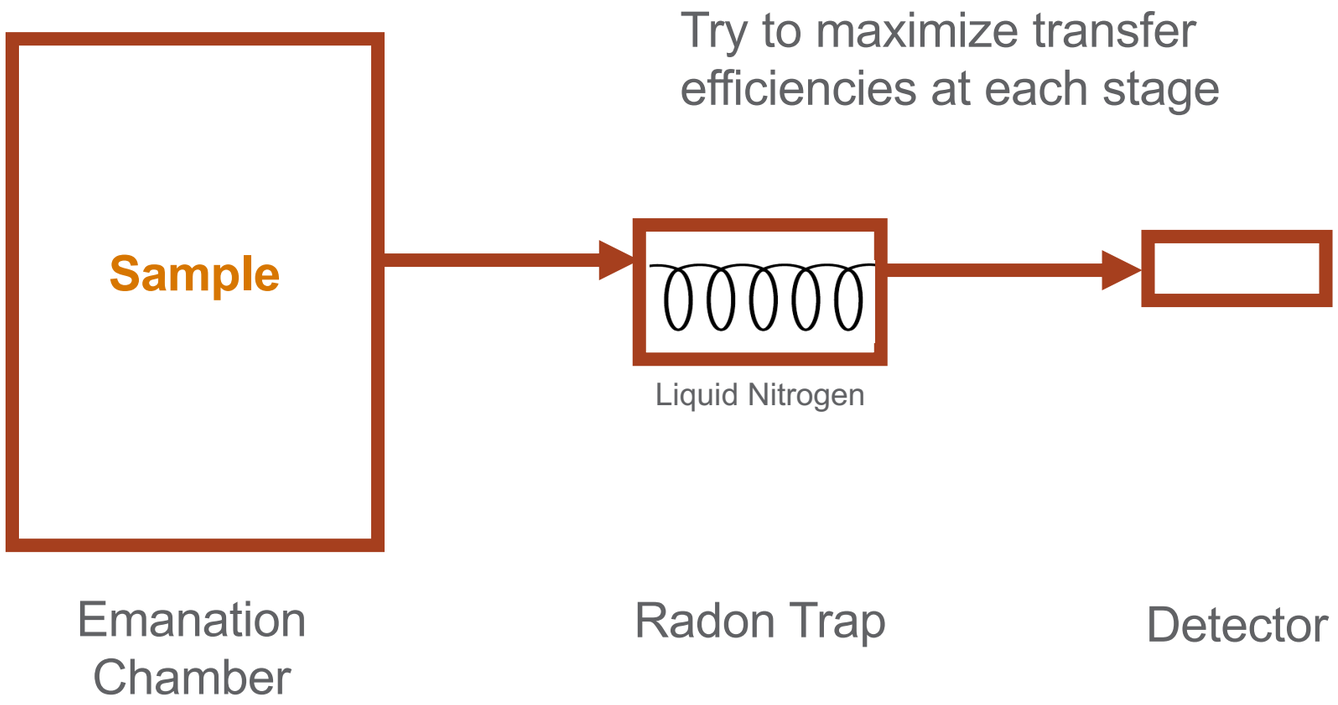




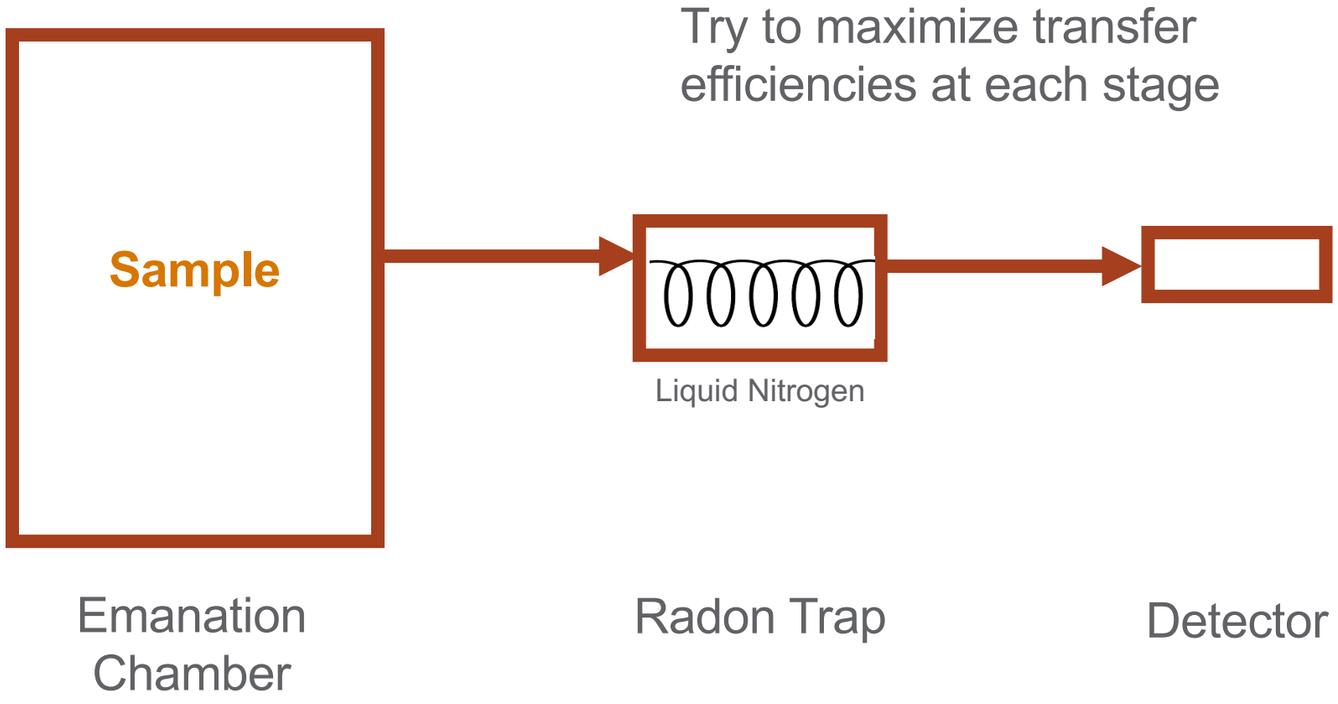
- Ra decay daughter
- Highly mobile, diffuse throughout detector
- Can plate out on surfaces

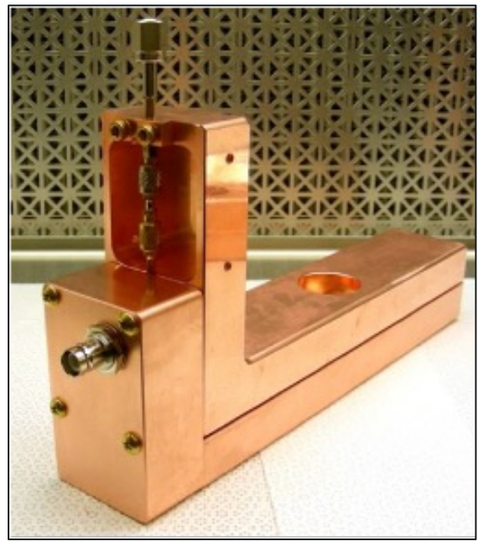
- An issue for next generation low-energy neutrino, dark matter and neutrinoless double beta decay experiments

Radon Emanation Measurements



Radon Emanation Measurements

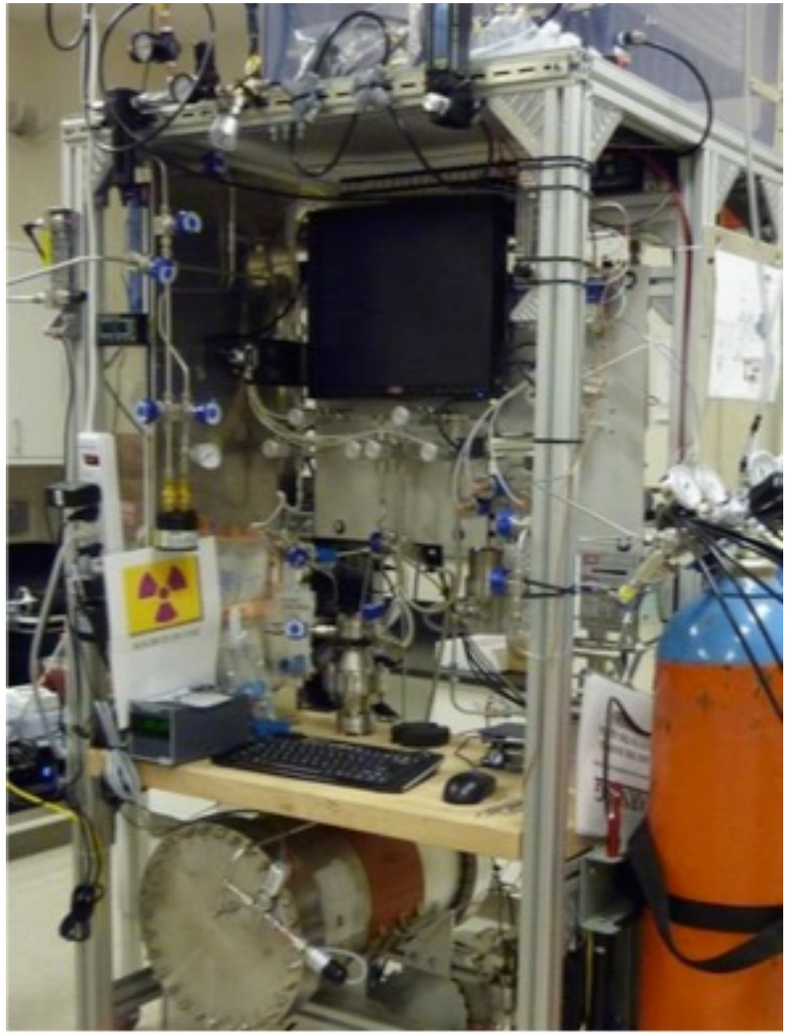




- Take advantage of PNNL ultralow background proportional counters to count radon
- Use ultrapure electroformed copper

Aalseth, C.E., et al., Design and construction of a low-background, internal-source proportional counter. Journal of Radioanalytical and Nuclear Chemistry, 2009. 282(1): p. 233-237

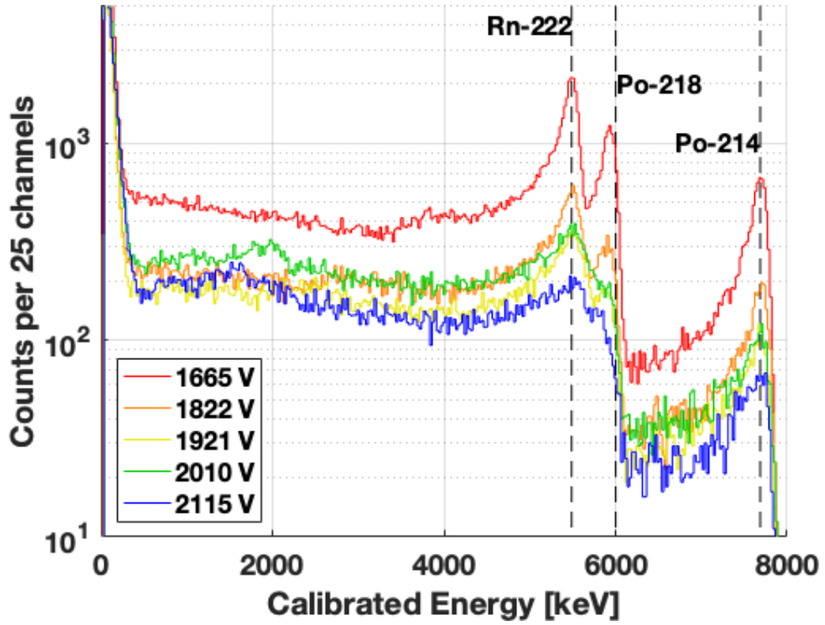
PNNL Emanation Bench

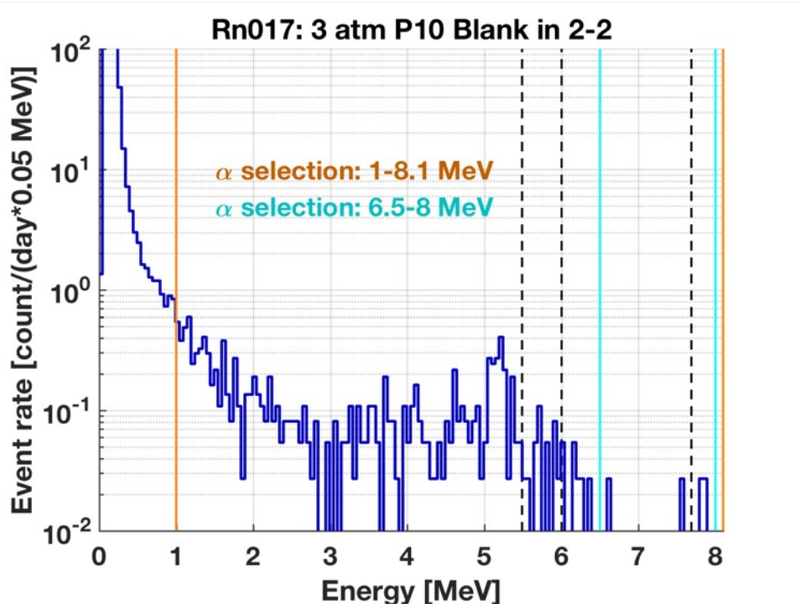


System as constructed at PNNL

Work by Ray Bunker and Dan Jardin (SCGSR)

PNNL Emanation Bench

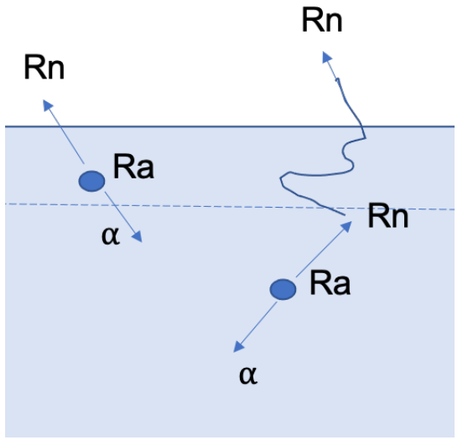




- Calibration with radon source sample using alphas

- Count radon rate using Po-214 alpha peak
  - 0.1 background events/per day in ^{214}Po ROI
  - <100 μBq background rate

Emanation in materials and cold

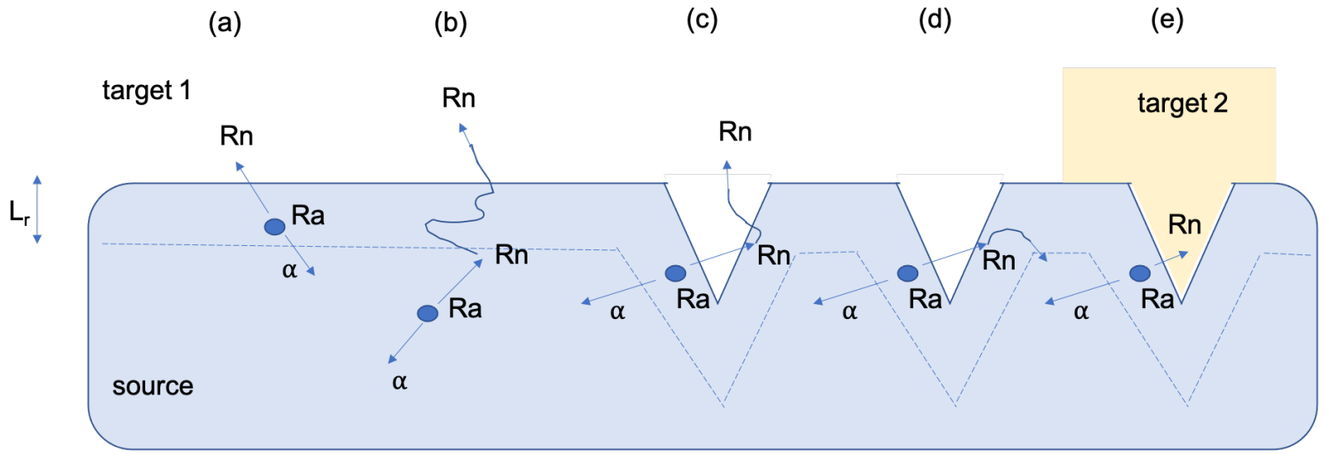


- Total radon emanation is the sum of two distinct components:
  - Recoil induced emanation
  - Bulk diffusion
- Different materials contain varying rates of both processes

- At cold temperatures, the diffusion term is suppressed
- However, in liquids the recoil term is enhanced

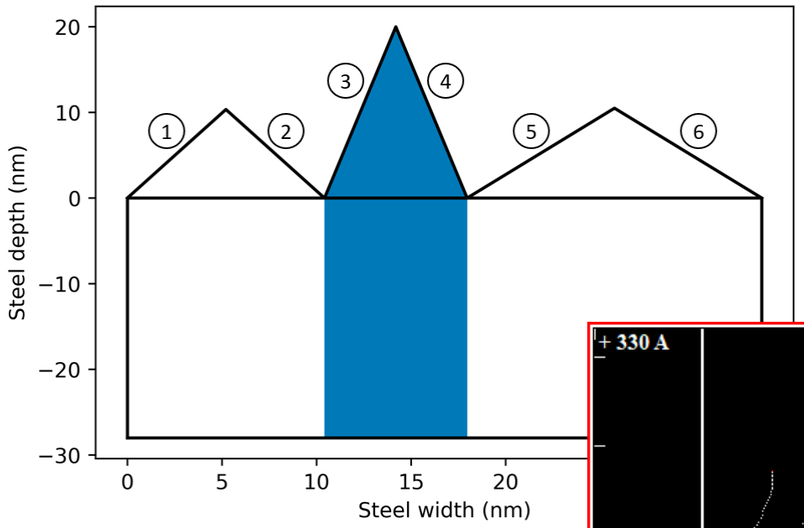
  e.g. Sebastian Lindemann; Hardy Simgen; Grzegorz Zuzel, Behaviour of 222Rn/222Rn at cryogenic temperatures *AIP Conf. Proc.* 1338, 156–160 (2011)
- What are the rates in cryogenic liquids?

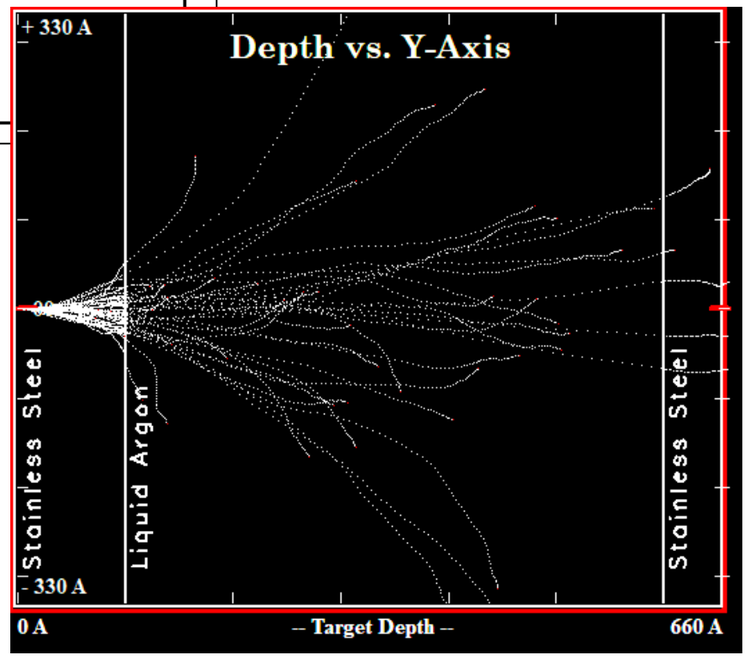
Simulation of Emanation in Cryogenic Liquids



- In vacuum or gases surface effects can lower the radon emanation rates
  - Emitted radon can return to the material it came from
- This effect is suppressed in liquid
  - Denser liquid stops radon more easily before it returns to the material it came from

Simulation of Emanation in Cryogenic Liquids



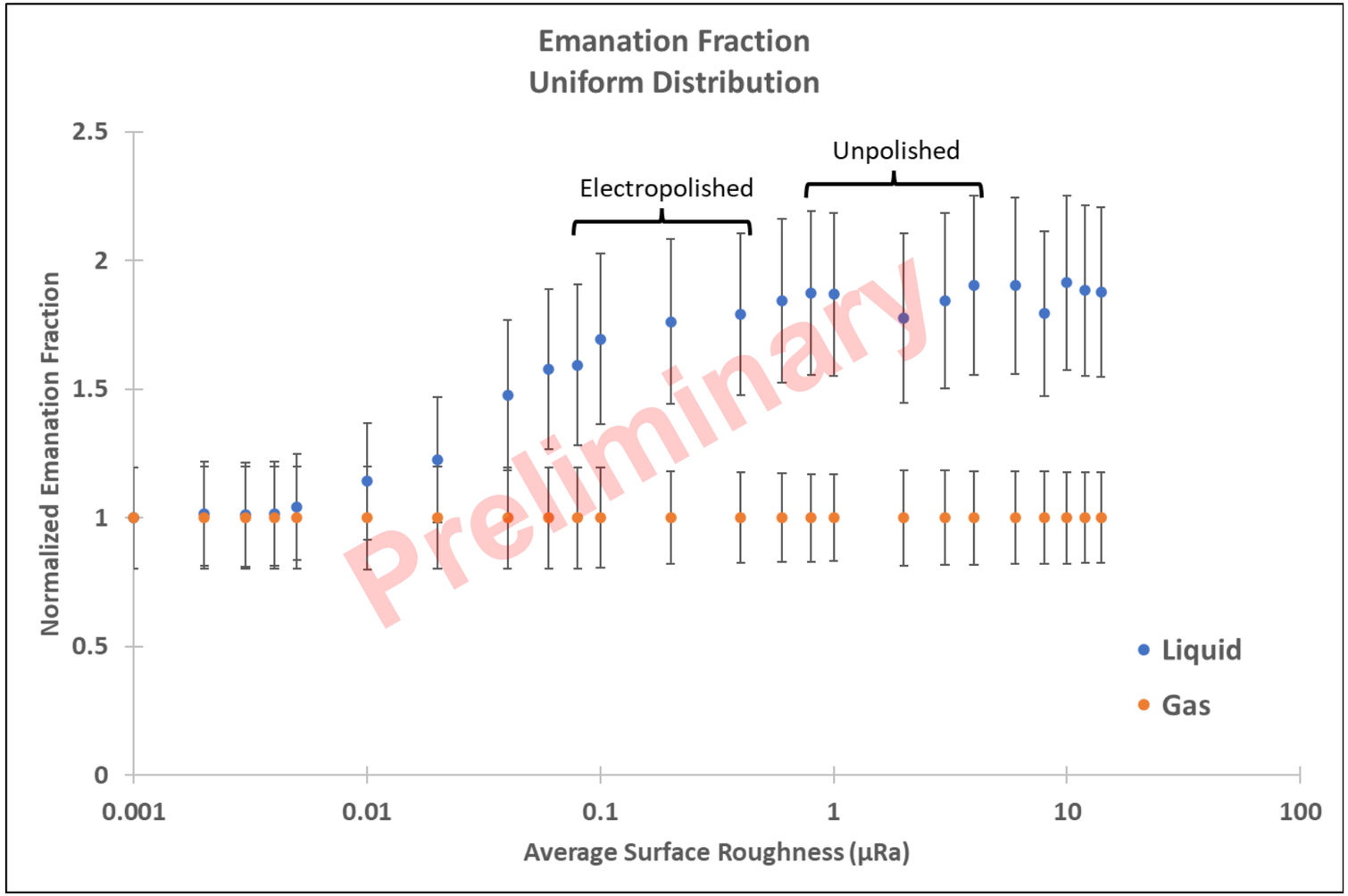


- Have created a Monte Carlo model to estimate the surface-shape contribution to emanation
- Consists of:
  - 2D geometric model of surfaces dependent of measured ‘roughness parameters’
  - SRIM based simulation of average propagation depths through materials
    - ✓ Argon and stainless steel so far

Work by Aaron Hellinger and Brianne Hackett

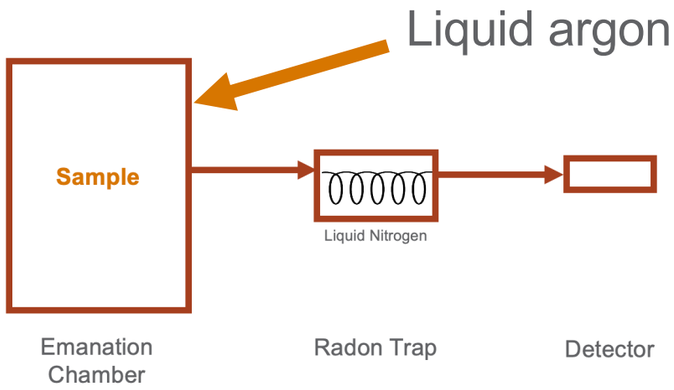
Ziegler, J.F., Ziegler, M.D., Biersack, J.P.; SRIM - The stopping and range of ions in matter (2010). Nuclear Instruments and Methods in Physics Research Section B, Volume 268, Issue 11-12, p. 1818-1823.

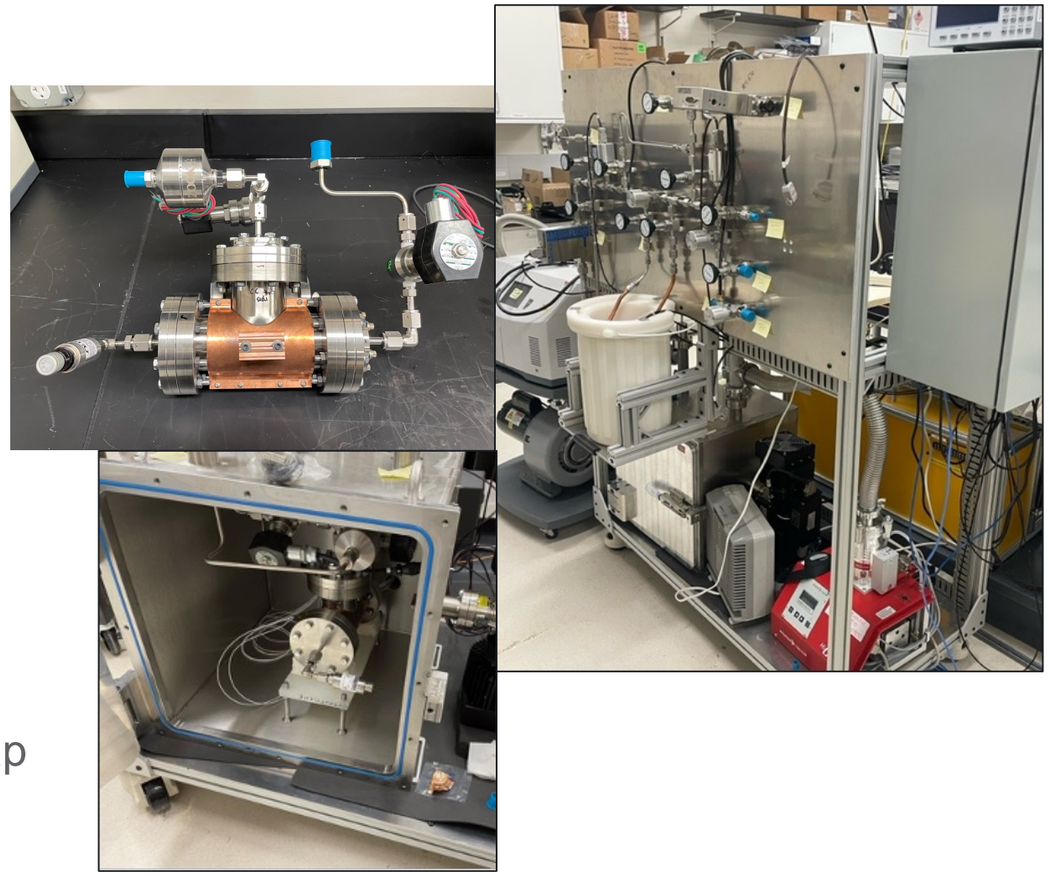
Simulation in Cryogenic Liquids



- Preliminary simulation results show factor two difference in emanation rates between emanation into liquid and gas at cryogenic temperatures
- This does not include effect of diffusion, going from room temperature to cryogenic temperatures

Cryogenic Liquid Radon Emanation Measurement Bench



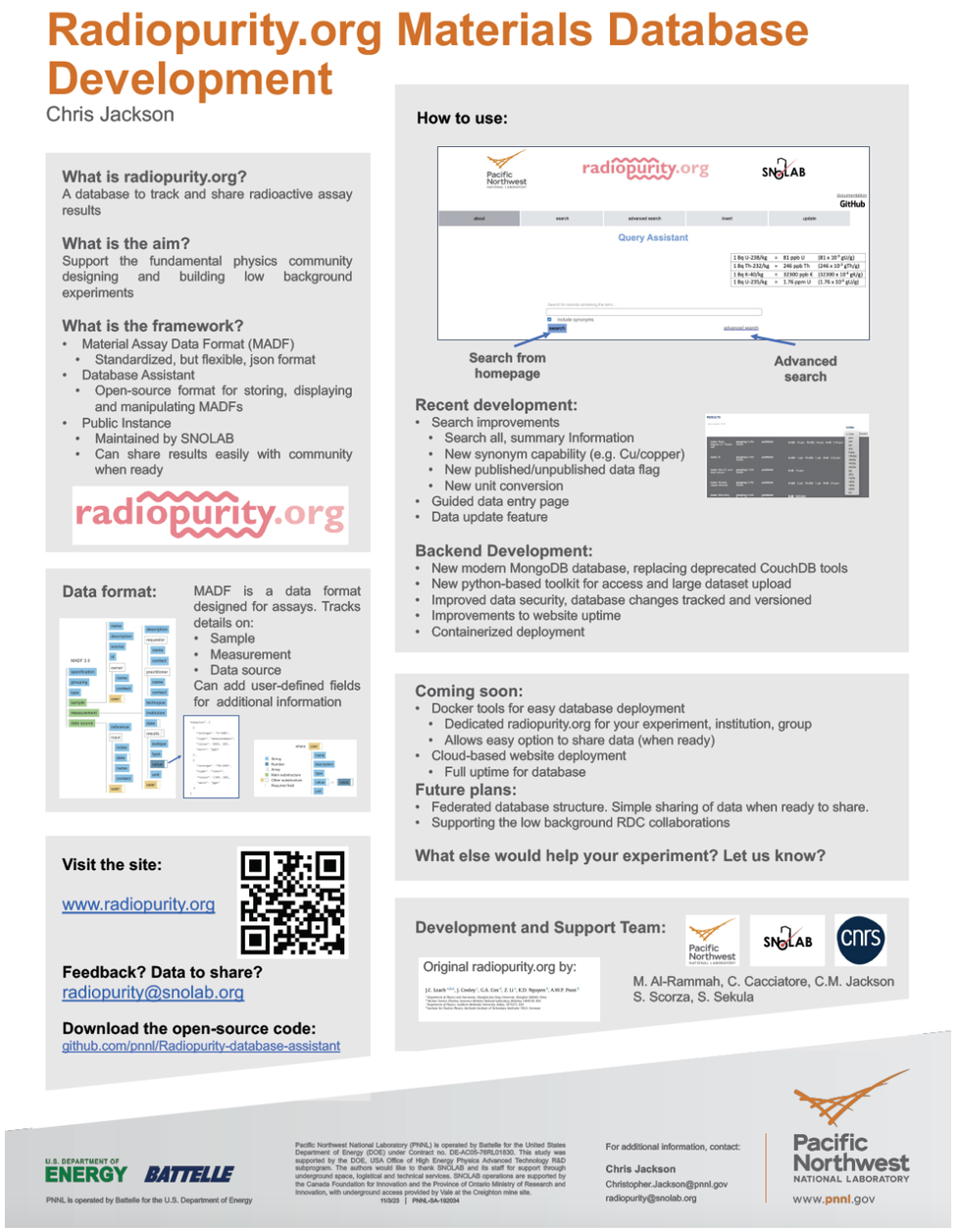


- Testing is underway of system to validate these results
- Designed to maintain stable 1-liter liquid argon radon emanation volume using cold head(1-week timescales)
- Liquid argon then boiled off through dry ice (above argon freezing point, below radon freezing point) filled radon trap
- Control/monitoring system testing completed, leak tests ongoing, first cool down in next weeks
- System can be upgraded for larger emanation chambers

Work by Gabe Ortega

Radiopurity.org

- **Recent development:**
  - Search improvements
    - ✓ Search all, summary Information
    - ✓ New synonym capability (e.g. Cu/copper)
    - ✓ New published/unpublished data flag
    - ✓ New unit conversion
  - Guided data entry page
  - Data update feature
- **Backend Development:**
  - New modern MongoDB database, replacing deprecated CouchDB tools
  - New python-based toolkit for access and large dataset upload
  - Improved data security, database changes tracked and versioned
  - Improvements to website uptime
  - Containerized deployment
- **Visit the site:** www.radiopurity.org
- **Feedback? Data to share?** radiopurity@snolab.org



Poster at this conference

Conclusions

- Radon emanation is a key problem for low background physics experiments such as low-energy neutrino measurements, dark matter searches and neutrinoless double beta decay
- Measurement capability constructed at PNNL:
  - Comparable to best sensitivity in the world
  - Use ultralow background proportional counter capability
- Temperature and emanation media (gas/liquid) can affect emanation rates
- SRIM-based simulation developed to evaluate surface roughness effects on emanation
- Cryogenic liquid radon emanation capability being tested to validate this model and evaluate emanation rates for next-generation noble liquid experiments in realistic conditions.

Pacific Northwest
NATIONAL LABORATORY

Thank you

Pacific Northwest National Laboratory (PNNL) is operated by Battelle for the United States Department of Energy (DOE) under Contract no. DE-AC05-76RL01830. This work was supported by the DOE, USA Office of High Energy Physics Advanced Technology R&D subprogram