



**Pacific  
Northwest**  
NATIONAL LABORATORY

# Radon Emanation at Cryogenic Temperatures

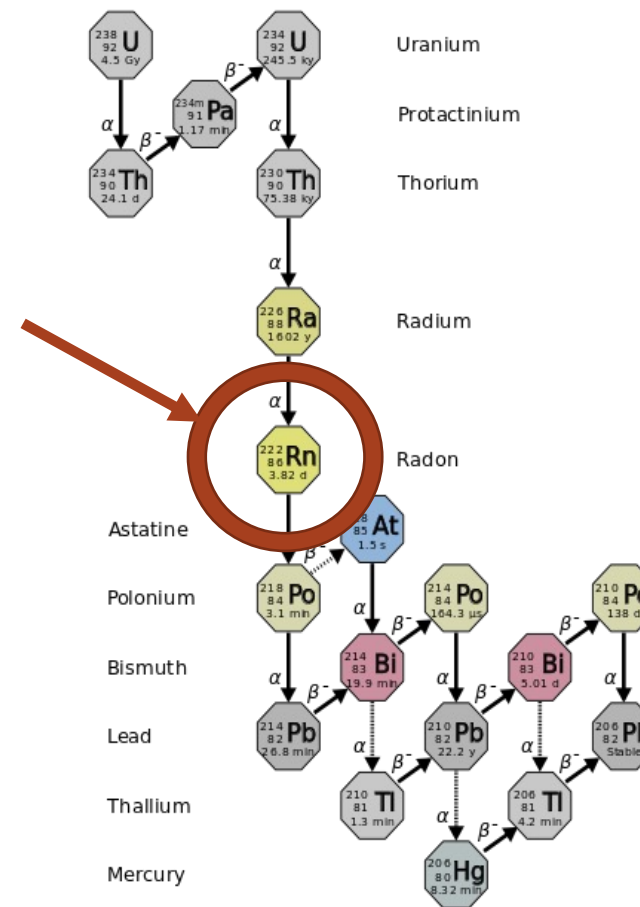
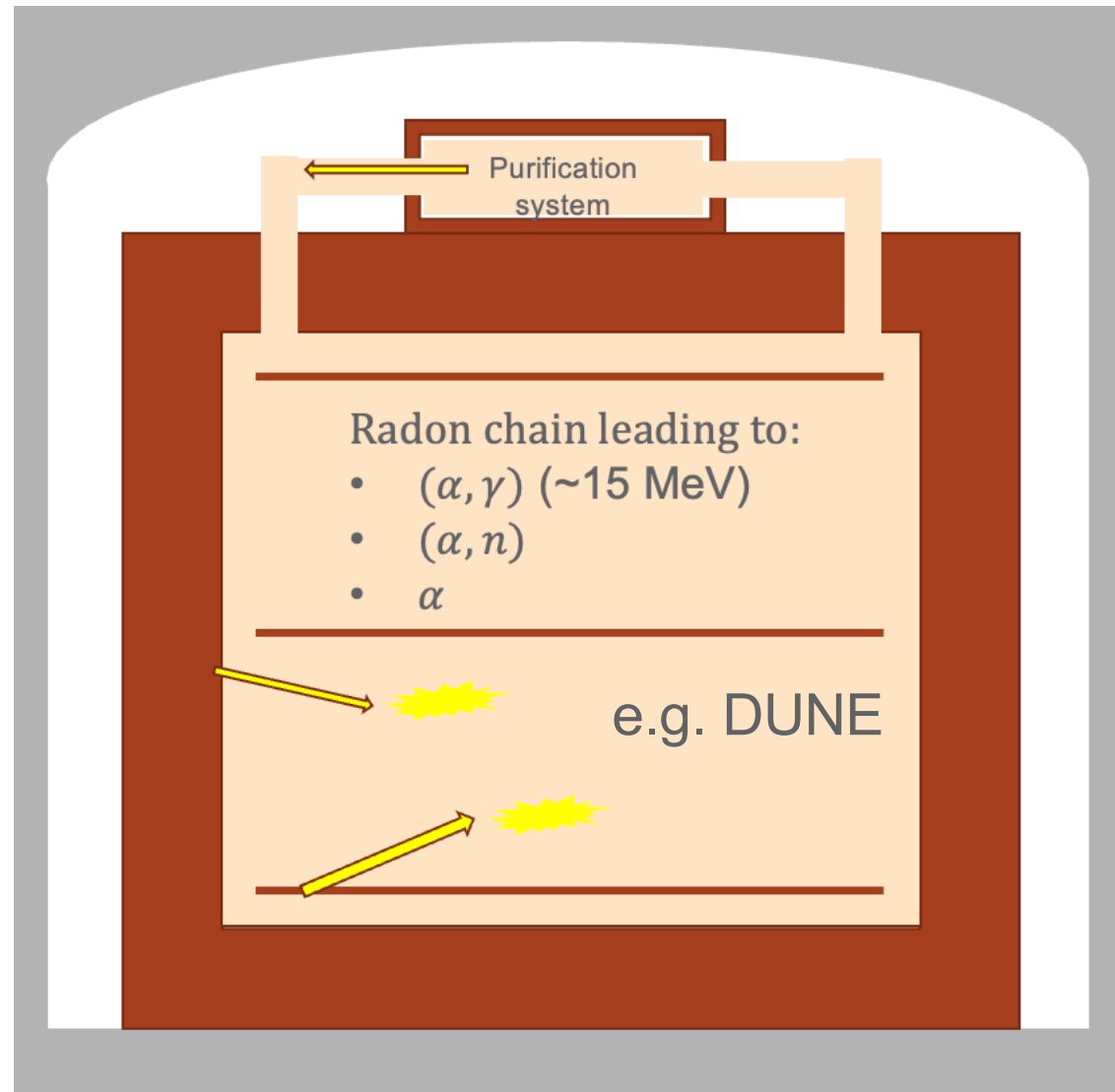
**Chris Jackson**  
PNNL

U.S. DEPARTMENT OF  
**ENERGY** **BATTELLE**

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

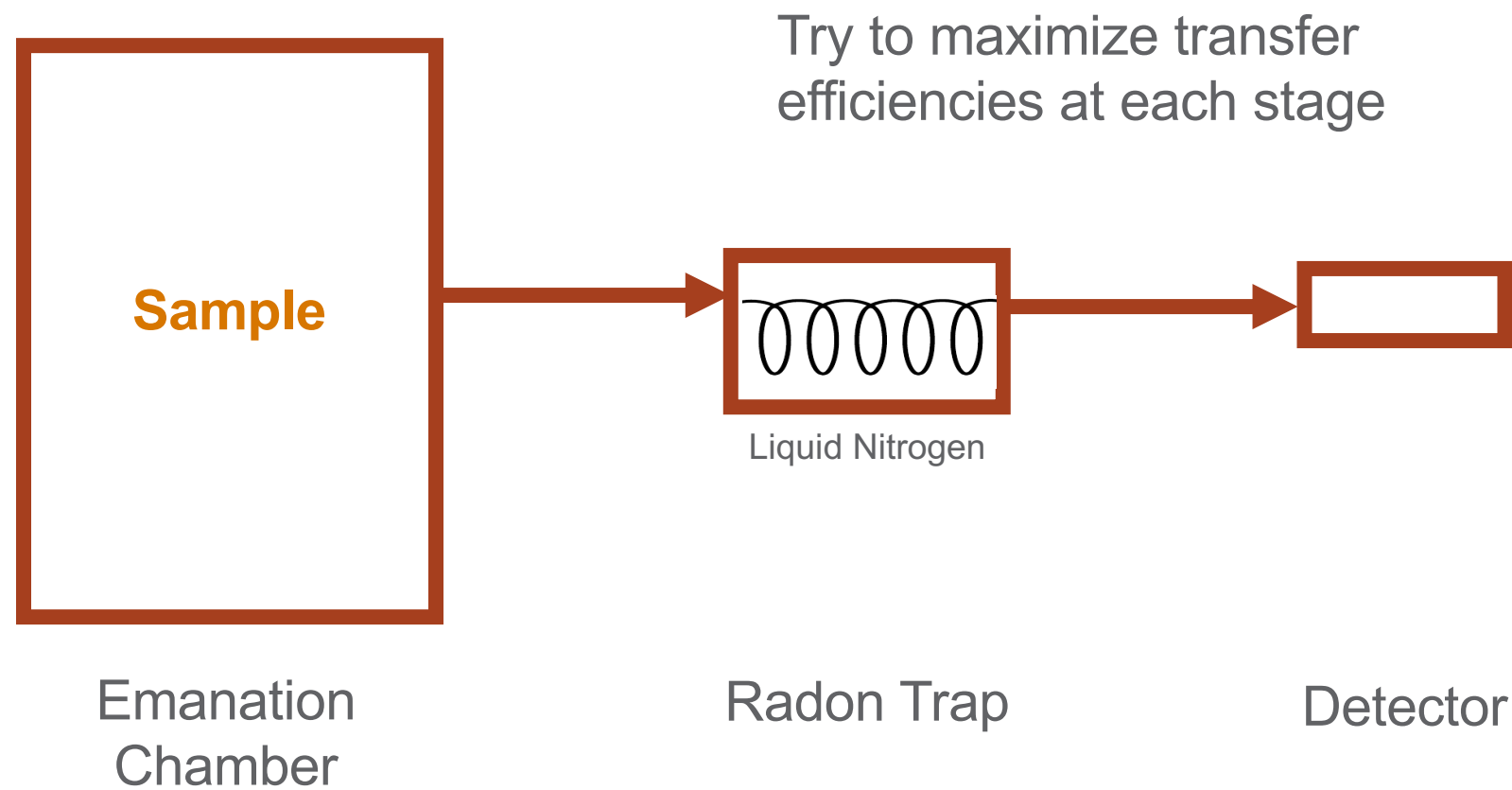


# Radon is a problematic background

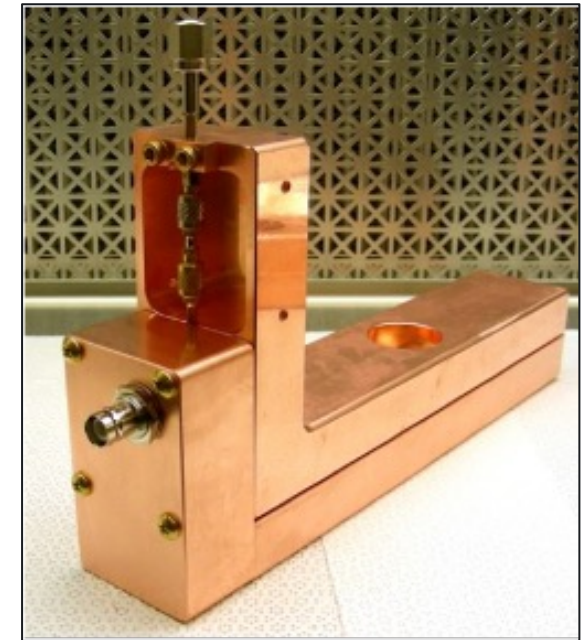
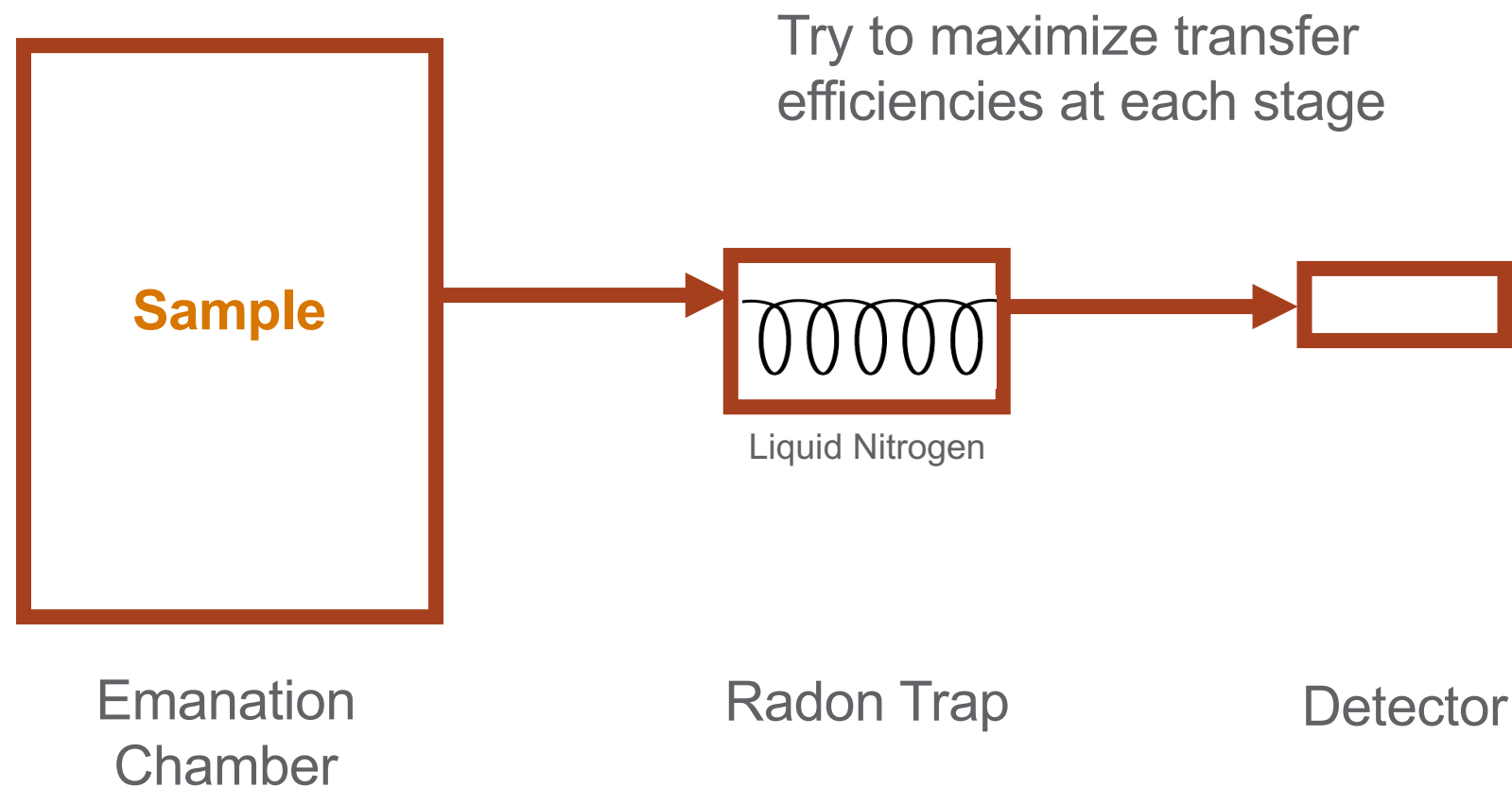


- Ra decay daughter
- Highly mobile, diffuse throughout detector
- Can plate out on surfaces
- An issue for next generation low-energy neutrino, dark matter and neutrinoless double beta decay experiments

# Radon Emanation Measurements



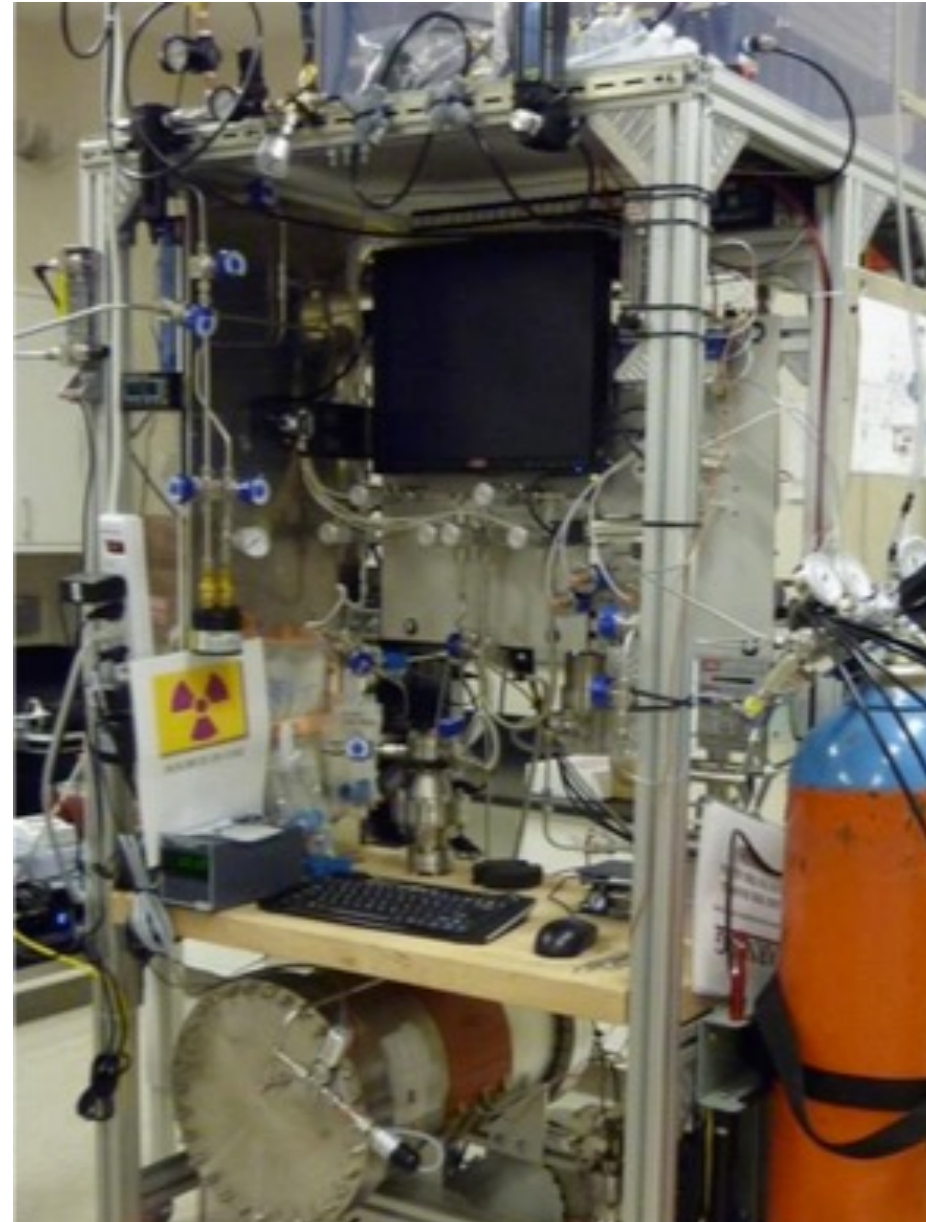
# Radon Emanation Measurements



- 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

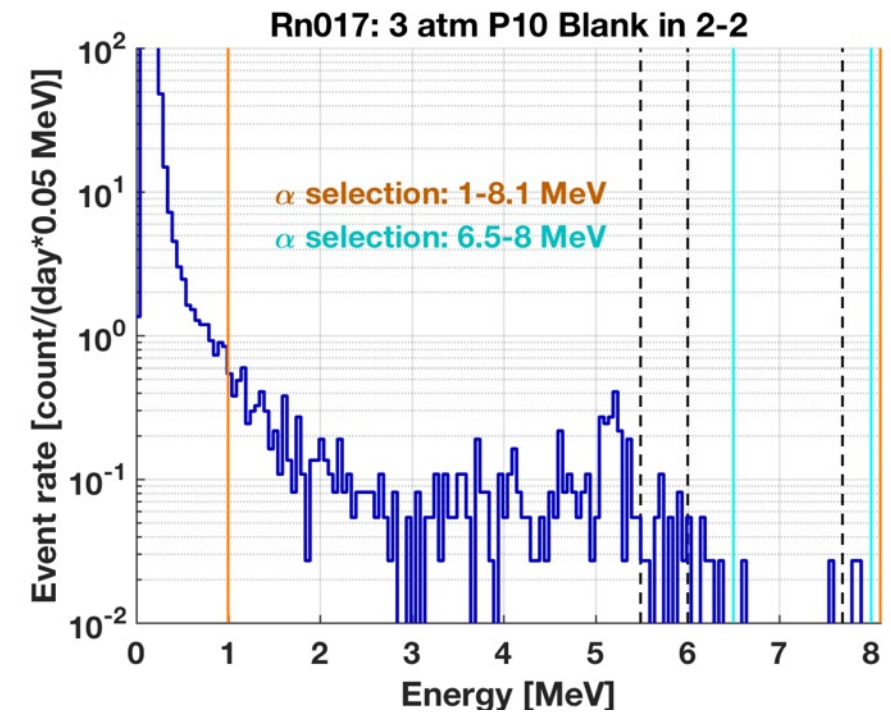
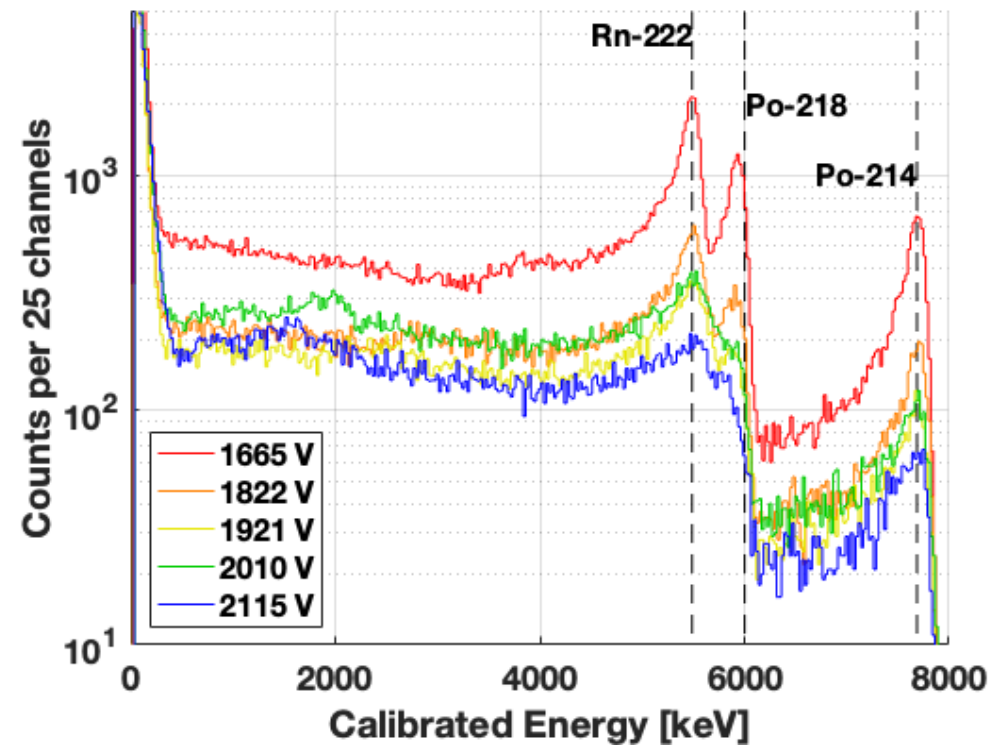
# PNNL Emanation Bench



System as constructed at PNNL

Work by Ray Bunker and Dan  
Jardin (SCGSR)

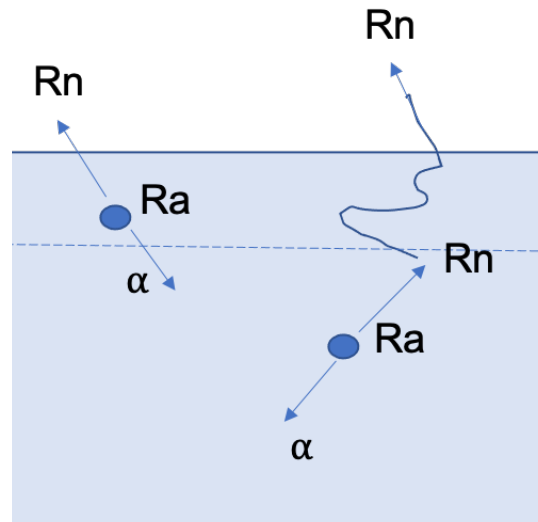
# PNNL Emanation Bench



- Calibration with radon source sample using alphas

- Count radon rate using Po-214 alpha peak
  - 0.1 background events/per day in  $^{214}\text{Po}$  ROI
  - $<100 \mu\text{Bq}$  background rate

## Emanation in materials and cold



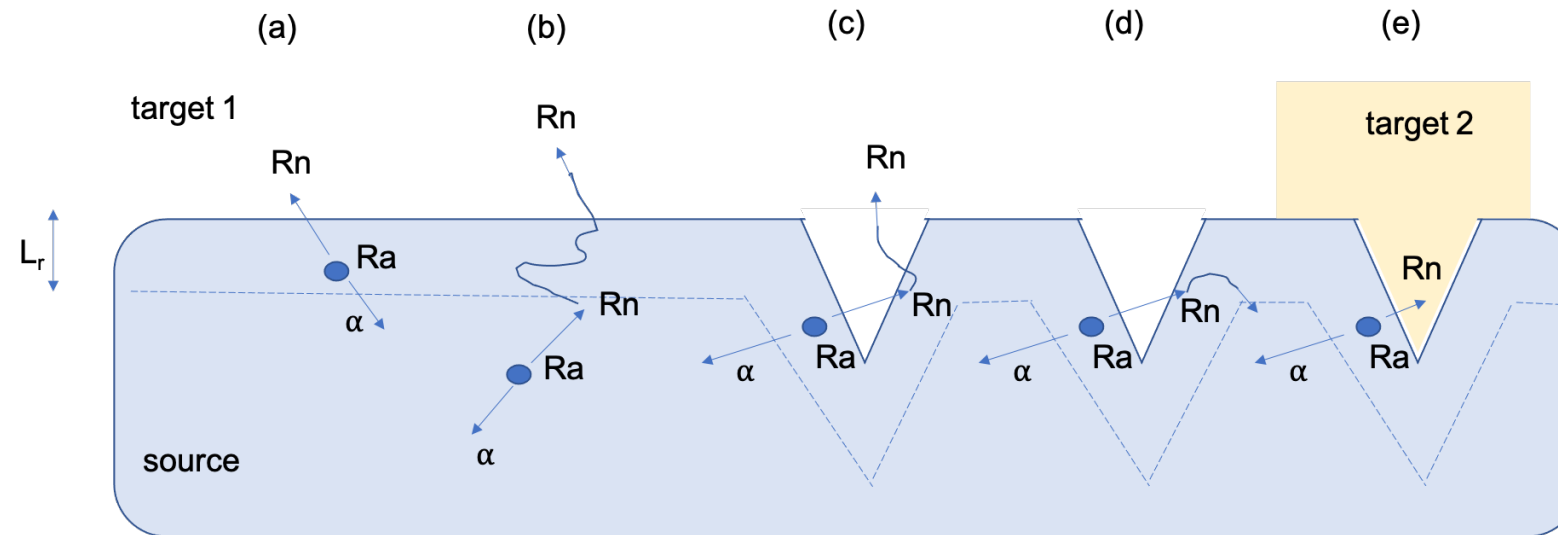
- Total radon emanation is the sum of two distinct components:
  - Recoil induced emanation
  - Bulk diffusion
- Different materials contain varying rates of both processes

- 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  $^{222}\text{Rn}/^{222}\text{Rn}$  at cryogenic temperatures  
*AIP Conf. Proc.* 1338, 156–160 (2011)

- What are the rates in cryogenic liquids?

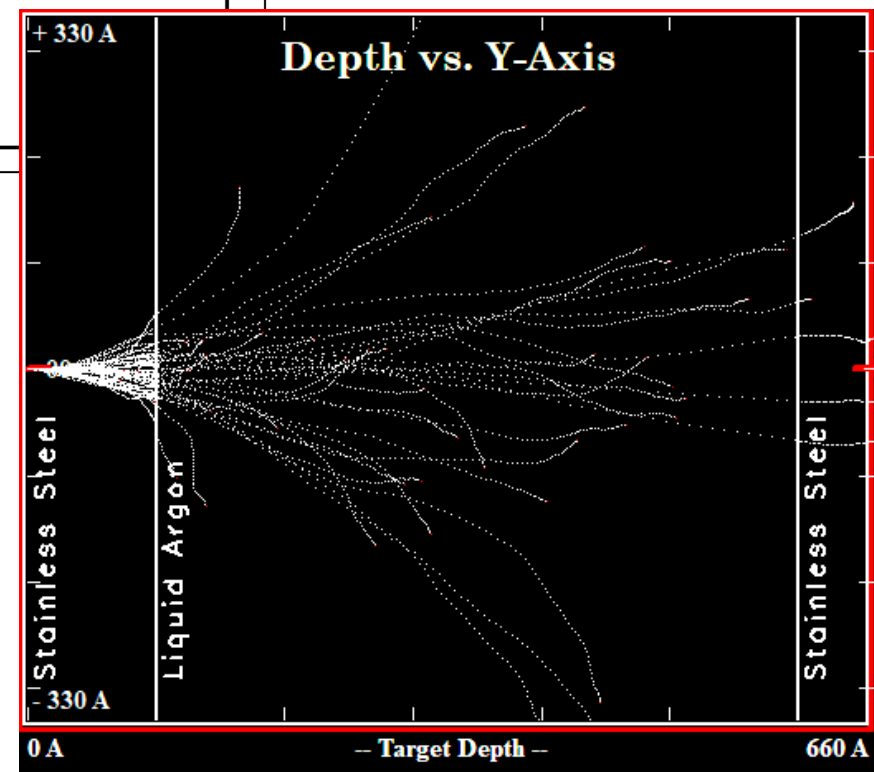
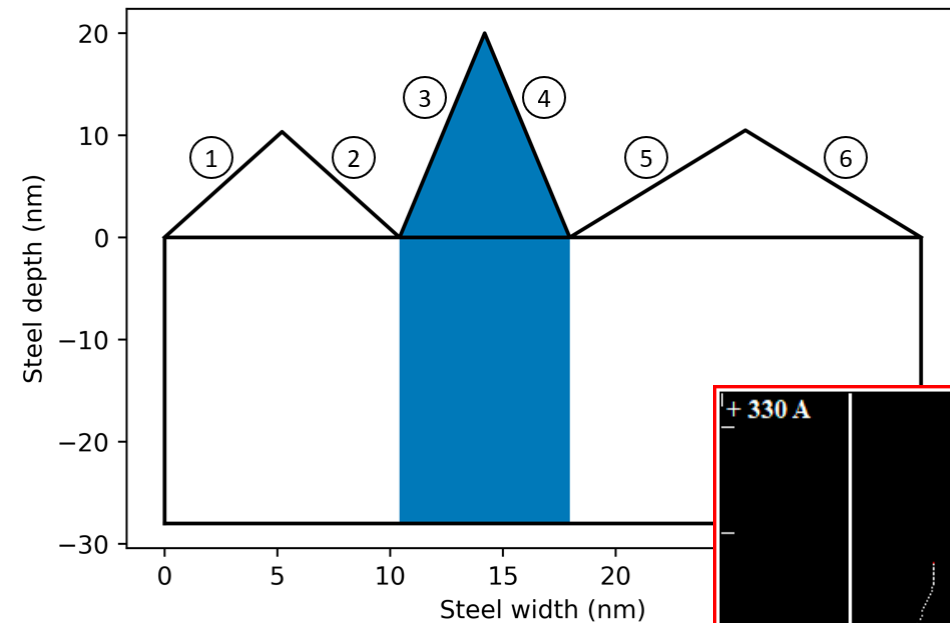
# Simulation of Emanation in Cryogenic Liquids



- 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

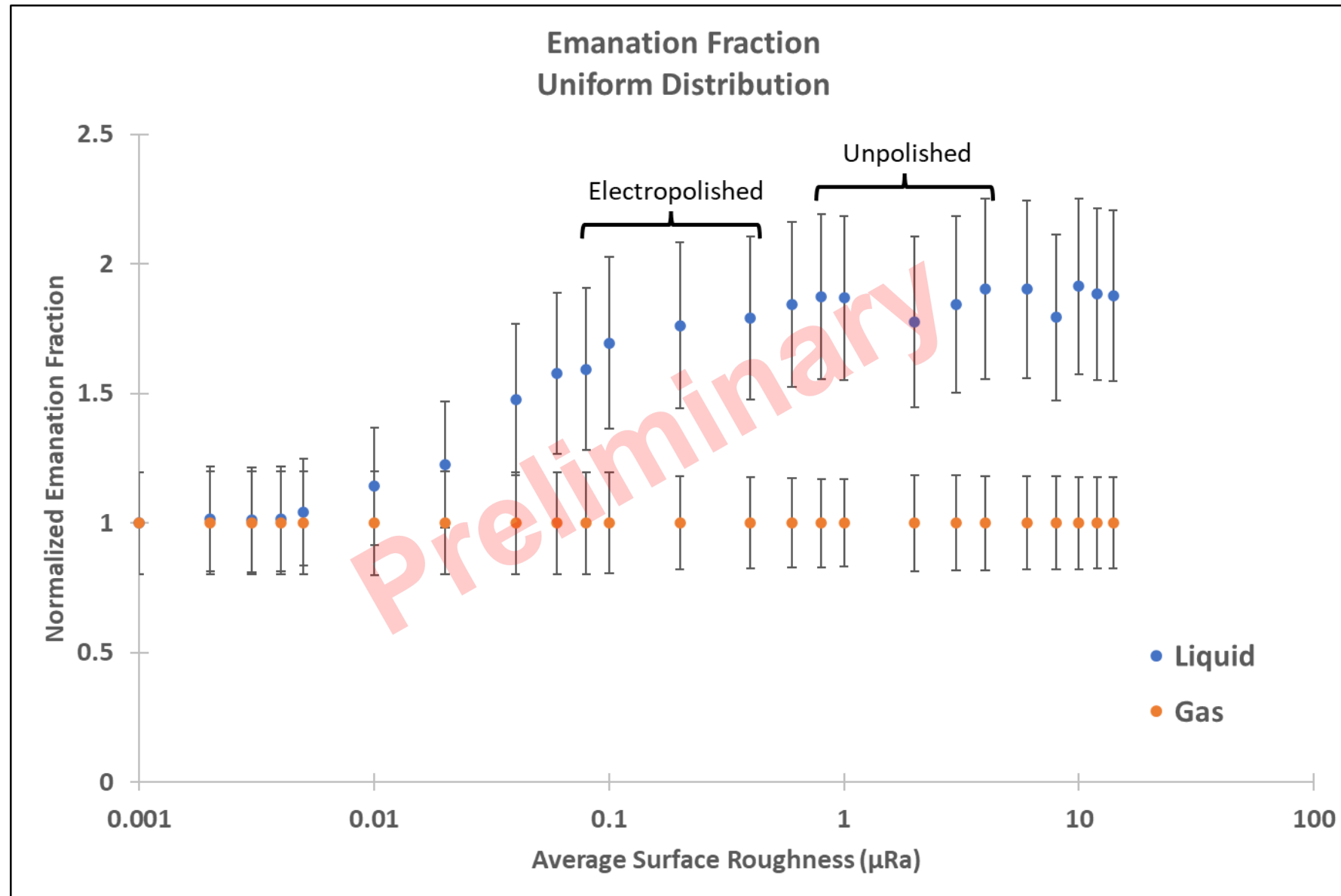


- Have created a Monte Carlo model to estimate the surface-shape contribution to emanation
- Consists of:
  - 2D geometric model of surfaces dependent of measured 'roughness parameters'
  - SRIM based simulation of average propagation depths through materials
    - ✓ Argon and stainless steel so far

Work by Aaron Hellinger and  
Brienne Hackett

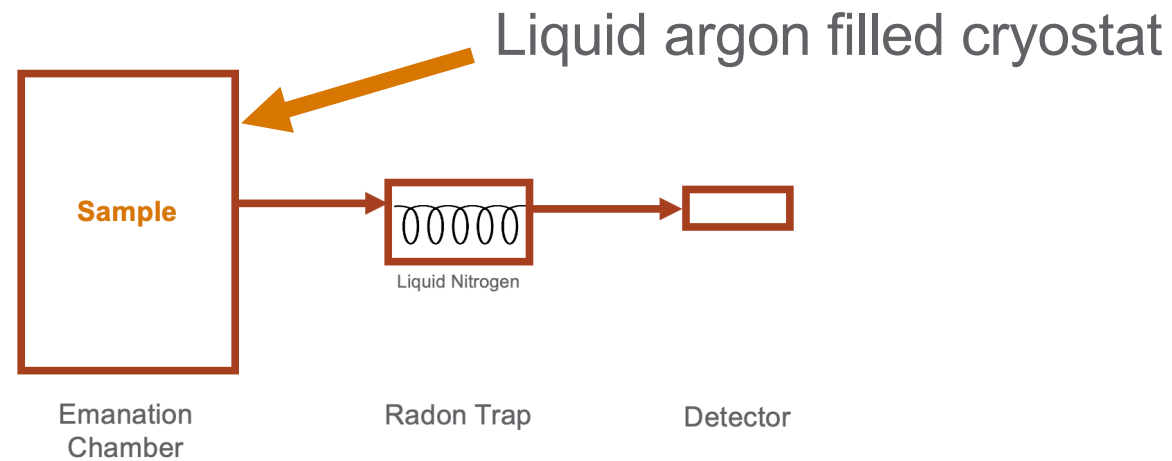
Ziegler, J.F., Ziegler, M.D., Biersack, J.P.; SRIM - The stopping and range of ions in matter (2010). Nuclear Instruments and Methods in Physics Research Section B, Volume 268, Issue 11-12, p. 1818-1823.

# Simulation in Cryogenic Liquids

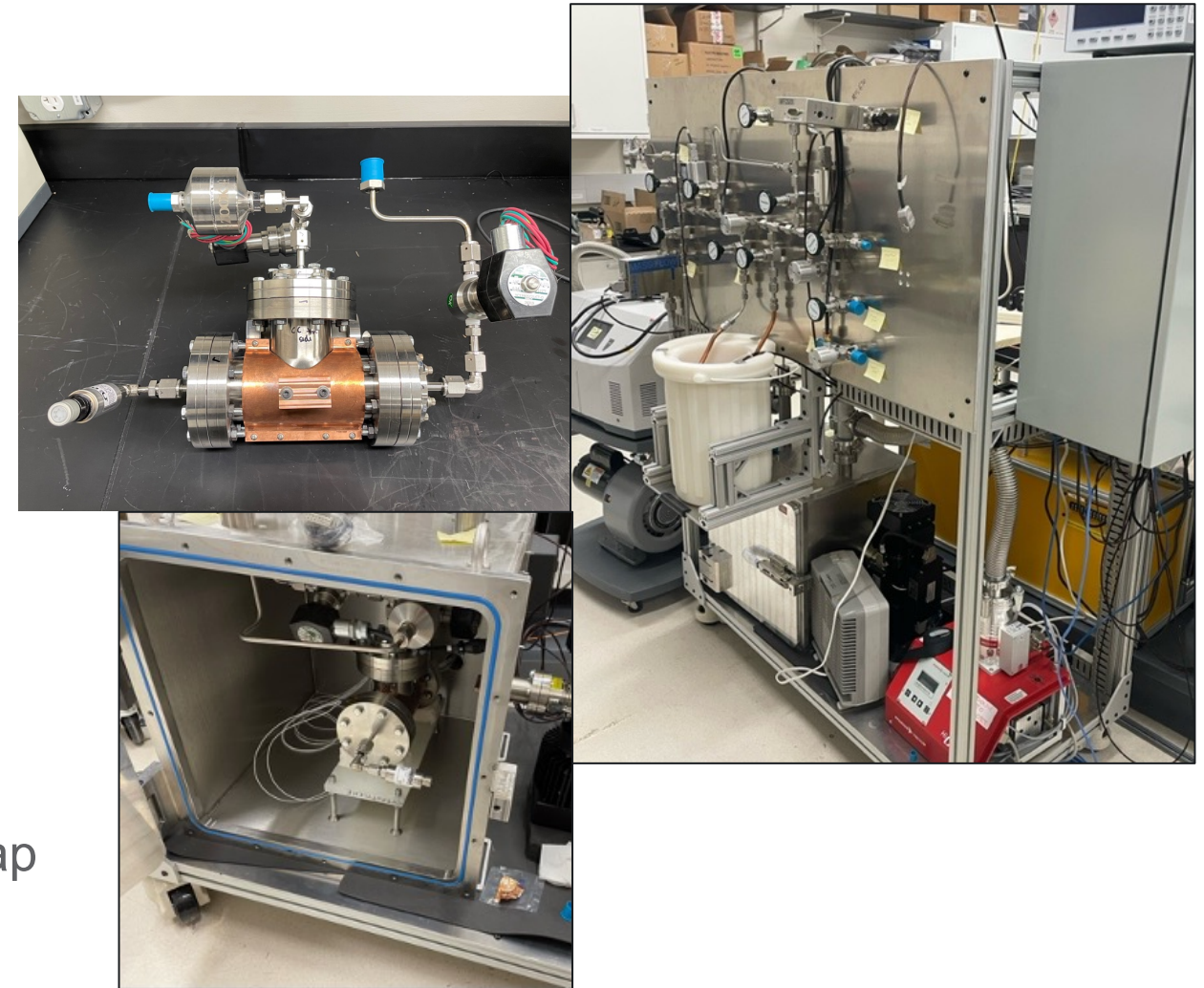


- Preliminary simulation results show factor two difference in emanation rates between emanation into liquid and gas at cryogenic temperatures
- This does not include effect of diffusion, going from room temperature to cryogenic temperatures

# 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

- 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](http://www.radiopurity.org)
- Feedback? Data to share? [radiopurity@snolab.org](mailto:radiopurity@snolab.org)

## Radiopurity.org Materials Database Development

Chris Jackson

### What is radiopurity.org?

A database to track and share radioactive assay results

### What is the aim?

Support the fundamental physics community designing and building low background experiments

### What is the framework?

- Material Assay Data Format (MADF)
  - Standardized, but flexible, json format
- Database Assistant
  - Open-source format for storing, displaying and manipulating MADFs
- Public Instance
  - Maintained by SNOLAB
  - Can share results easily with community when ready

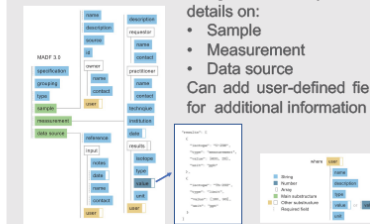


### Data format:

MADF is a data format designed for assays. Tracks details on:

- Sample
- Measurement
- Data source

Can add user-defined fields for additional information



### Visit the site:

[www.radiopurity.org](http://www.radiopurity.org)



### Feedback? Data to share?

[radiopurity@snolab.org](mailto:radiopurity@snolab.org)

### Download the open-source code:

[github.com/pnnl/Radiopurity-database-assistant](https://github.com/pnnl/Radiopurity-database-assistant)

### How to use:



Search from homepage

Advanced search

### Recent development:

- Search improvements
- Search all, summary Information
- New synonym capability (e.g. Cu/copper)
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### Backend Development:

- New modern MongoDB database, replacing deprecated CouchDB tools
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### Coming soon:

- Docker tools for easy database deployment
- Dedicated radiopurity.org for your experiment, institution, group
- Allows easy option to share data (when ready)
- Cloud-based website deployment
- Full uptime for database

### Future plans:

- Federated database structure. Simple sharing of data when ready to share.
- Supporting the low background RDC collaborations

What else would help your experiment? Let us know?

### Development and Support Team:



Original radiopurity.org by:

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M. Al-Rammah, C. Cacciatore, C.M. Jackson  
S. Scorza, S. Sekula

# 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.



# 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

