

SnT 2023

CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

HOFBURG PALACE - Vienna and Online

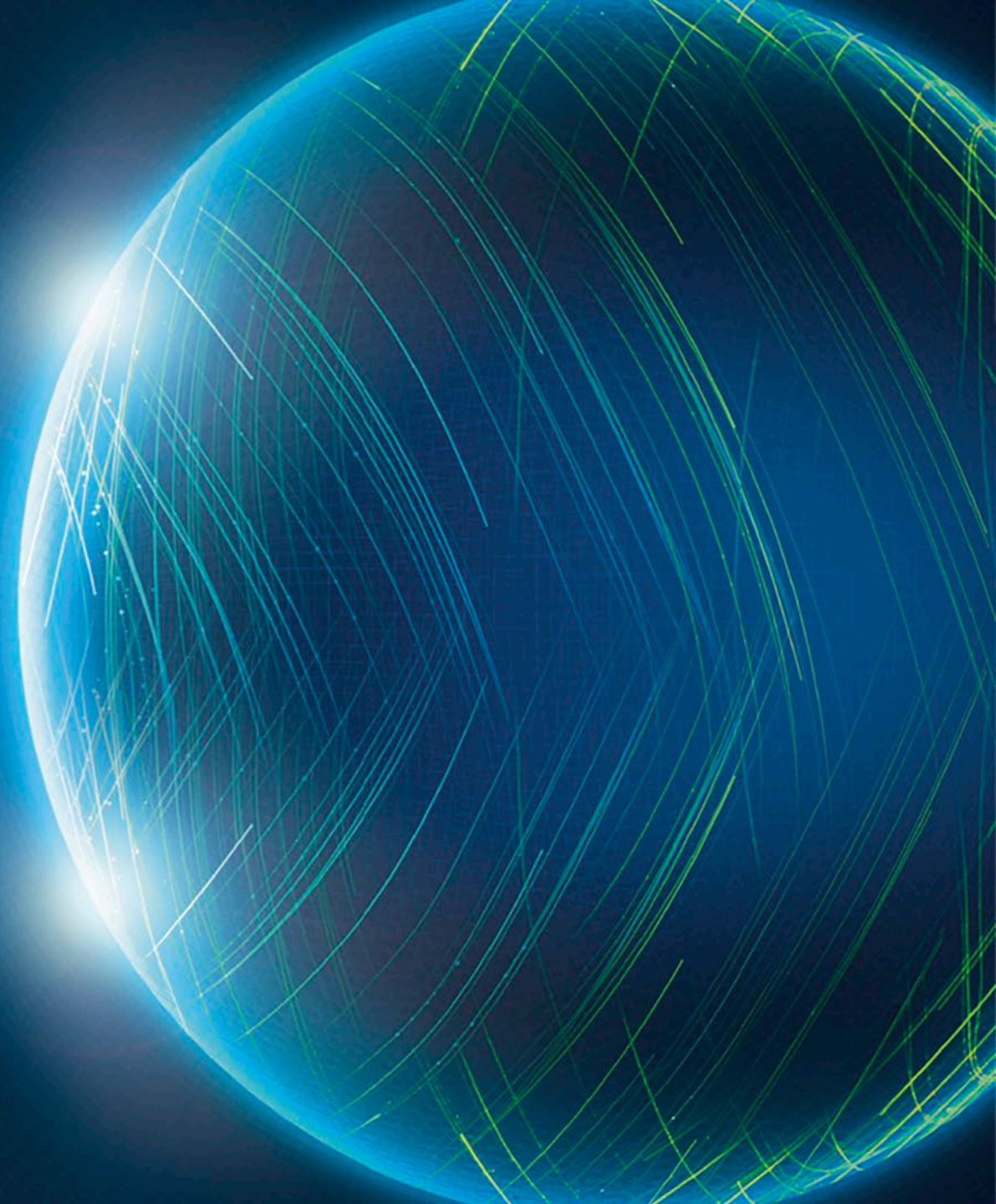
19 TO 23 JUNE

Ar-37 Field System Measurements

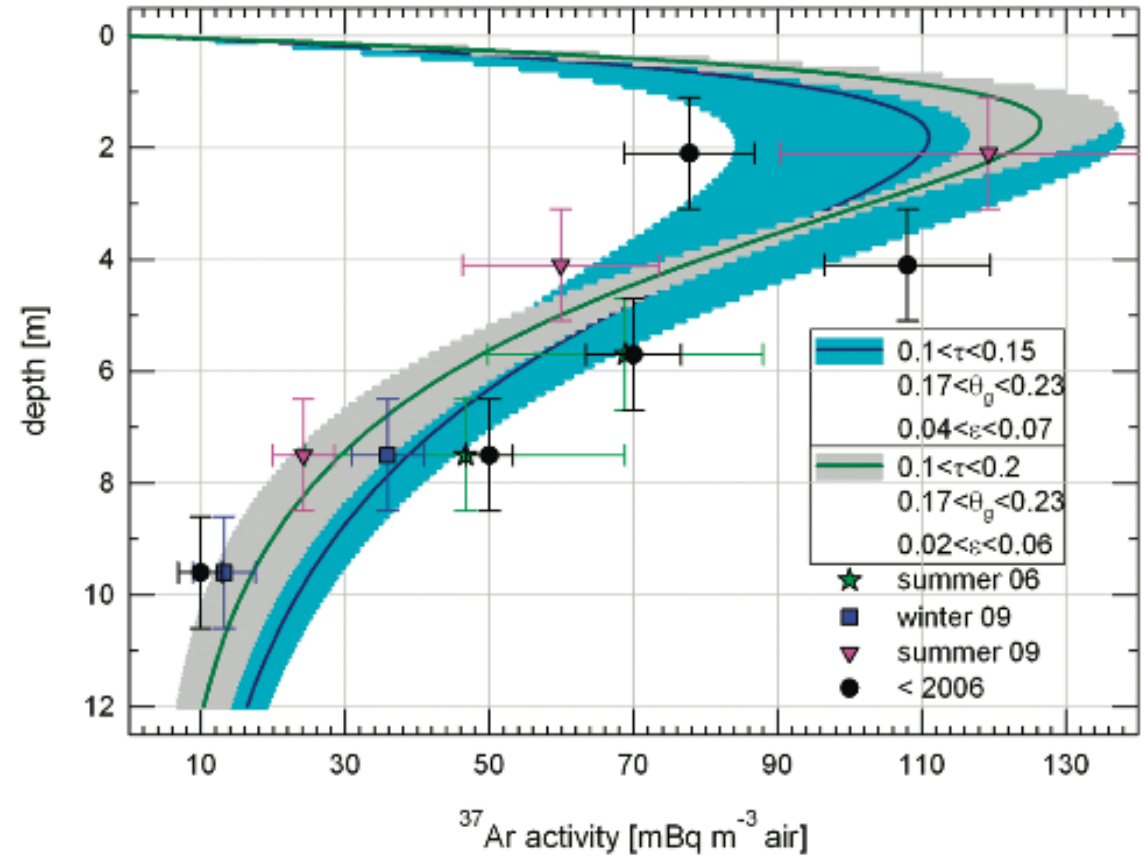
James Hayes, Tom Alexander,
Bradley Fritz, Mark Panisko
Pacific Northwest National Laboratory

O2.4-846

Presentation Date: 20 June 2023

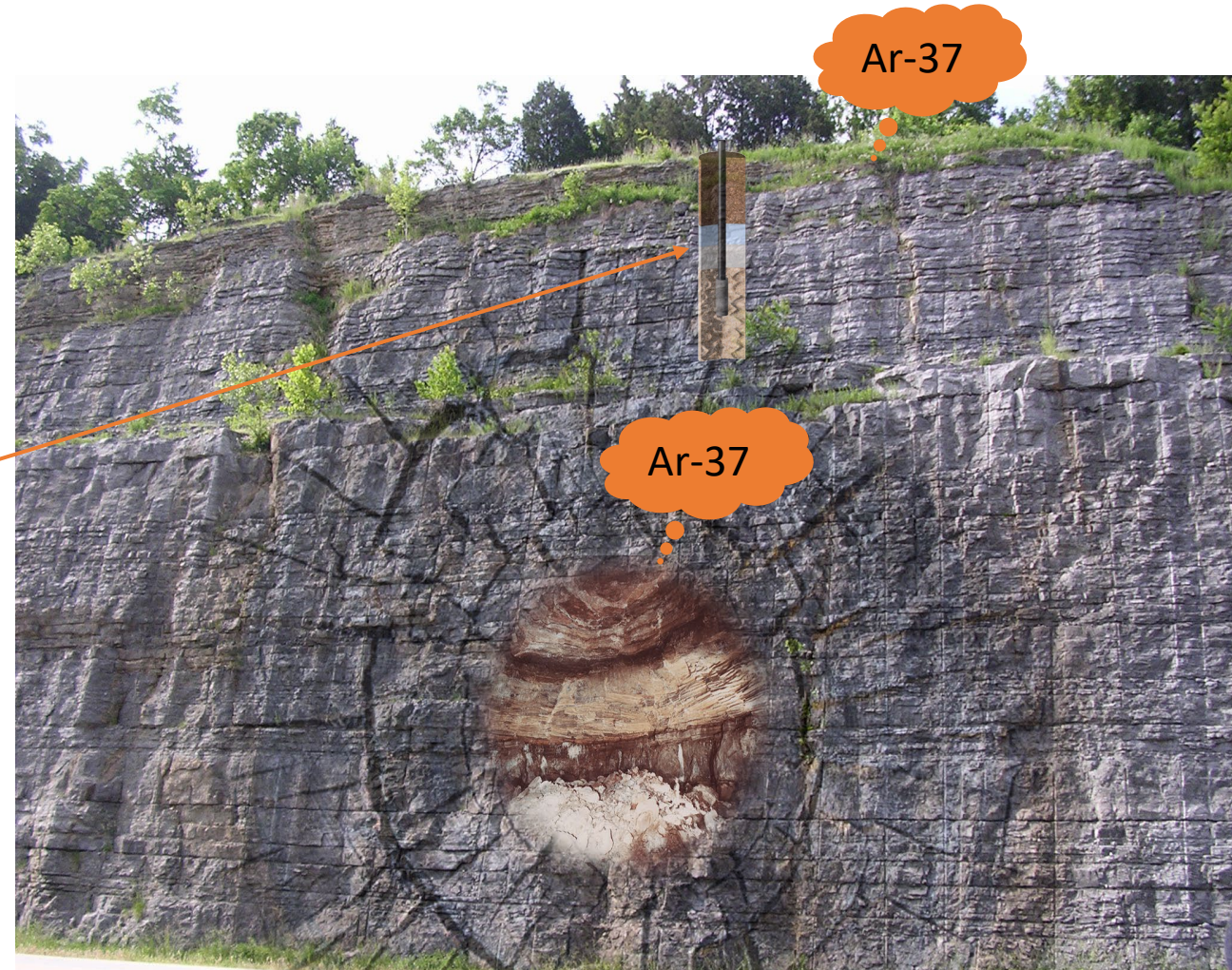
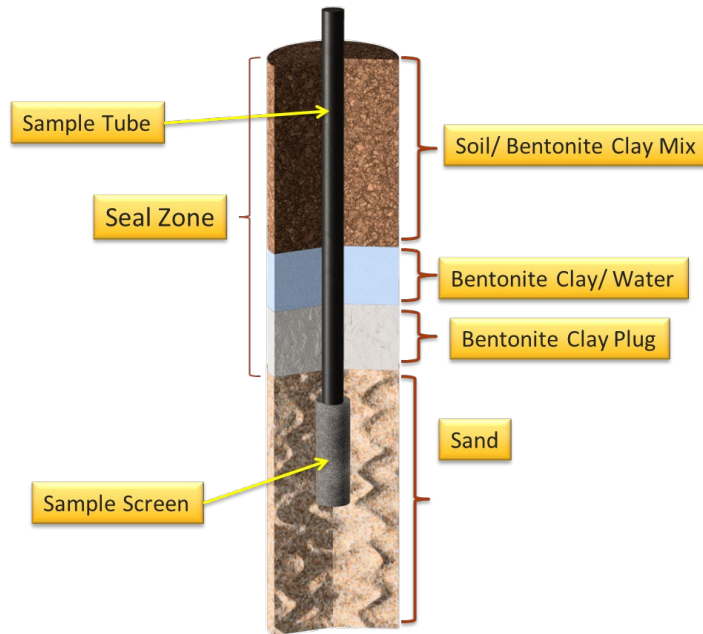


- Ar-37 is a nuclear signature that can help identify if an underground nuclear explosion occurred
- Ar-37 is produced when calcium in the ground is exposed to neutrons produced by an underground nuclear explosion: $^{40}\text{Ca}(n,\alpha)^{37}\text{Ar}$ reaction
- Ar-37 is produced in the atmosphere from $^{40}\text{Ar}(n,4n)^{37}\text{Ar}$
- Ar-37 measurable decay mode is a low-energy (2.8 keV) Auger electron with half-life of 35 days
- Argon makes up 1% of the atmosphere
 - 2 liters of argon needed for measurement requires ~300 – 400 liters of air (Xe requires many cubic meters of air)

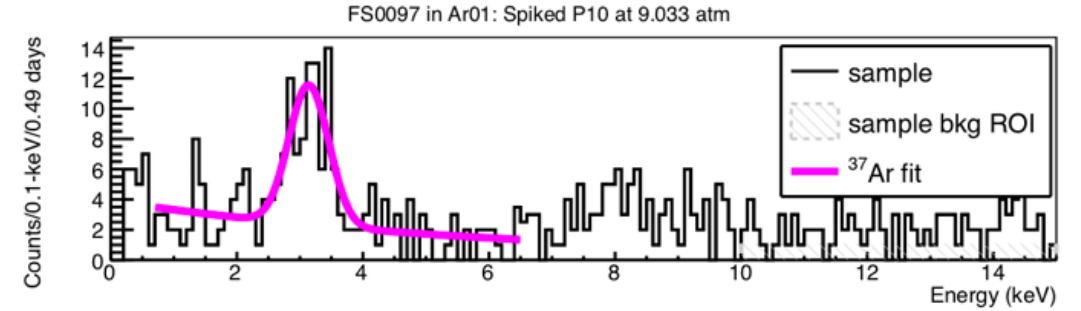
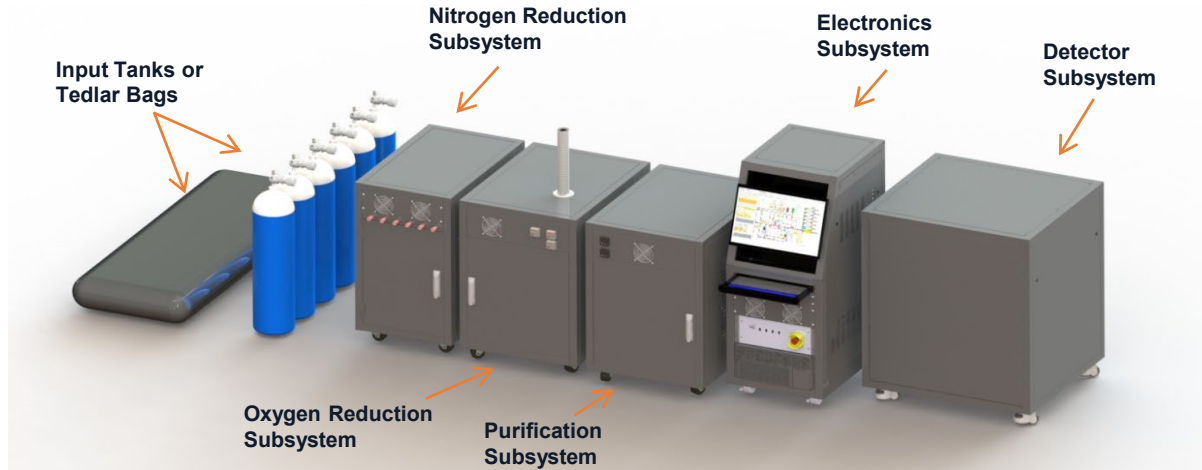


Riedmann & Purtschert (2011)

Radioactive argon atoms diffuse toward the ground surface where they are optimally collected in a soil sample to prevent air interference



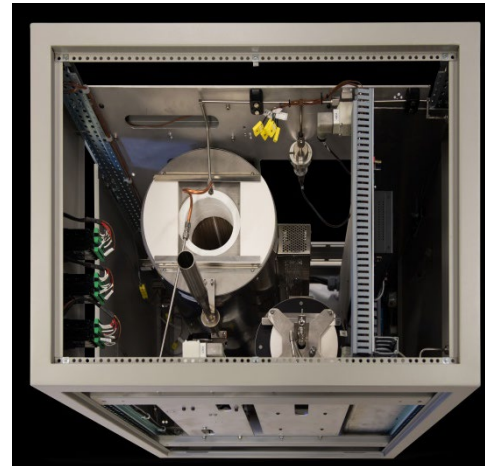
Radioactive argon can also release into the atmosphere



Gas process consists of a combination of methods to separate and purify argon from air. The primary steps are to remove nitrogen, remove oxygen, then purify argon before delivery to a nuclear detector.



Nitrogen Reduction Module



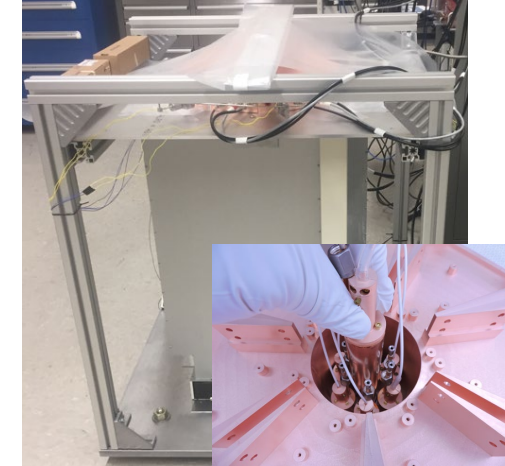
Oxygen Reduction Module



Purification Module

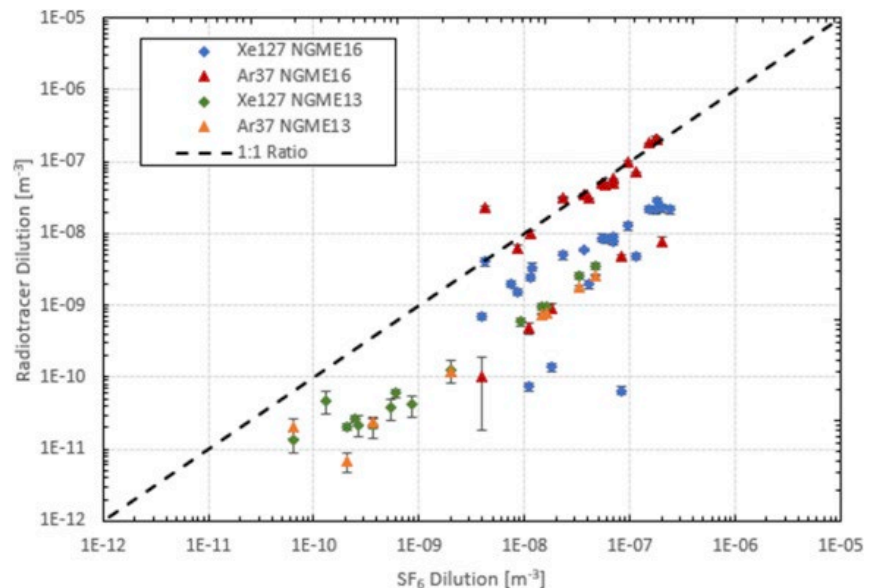


Control Module



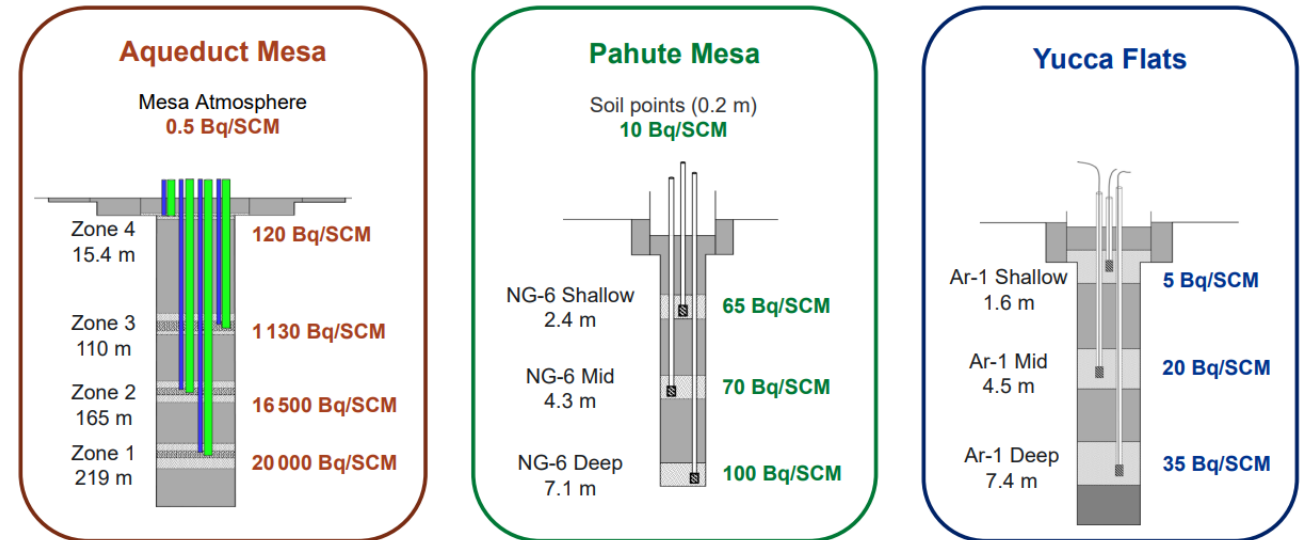
Detectors

- 2013 Injection of Ar-37, Xe-127, and SF₆ into UNE chimney (U20az) over 45 days
 - Ar-37 (orange) and Xe-127 (green) tracked well, but suppressed wrt SF₆
- 2016 injection allowed to migrate naturally
 - Ar-37 (red) tracked well with the stable SF₆, Xe-127 (blue) was suppressed WRT the SF₆



Ar-39 Subsurface Measurements at NNSS

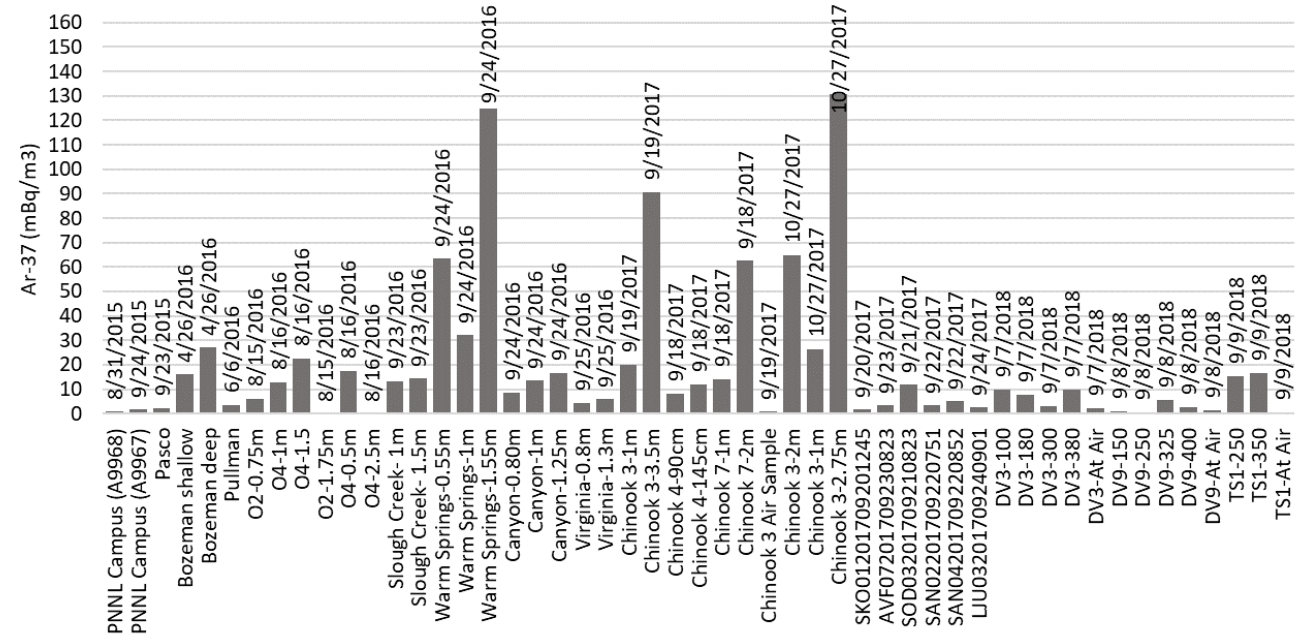
- The A-39 signature at legacy test sites has been measured to be many times greater than background levels 30+ years after a UNE
- Ar-39 conc. overtakes Ar-37 conc. after 3 years and remains a persistent signal for decades after a UNE



McIntyre, *et al.*, "Measurements of Argon-39 at the U20az underground nuclear explosion site", JER, **178**, p. 28-35, 2017

Background Ar-37 in Soil Gas

- Concentrations generally less than 20 mBq/m³
- Some samples greater than 100 mBq/m³
- Wider range of background makes identification of non-natural concentrations more difficult



Field Campaigns

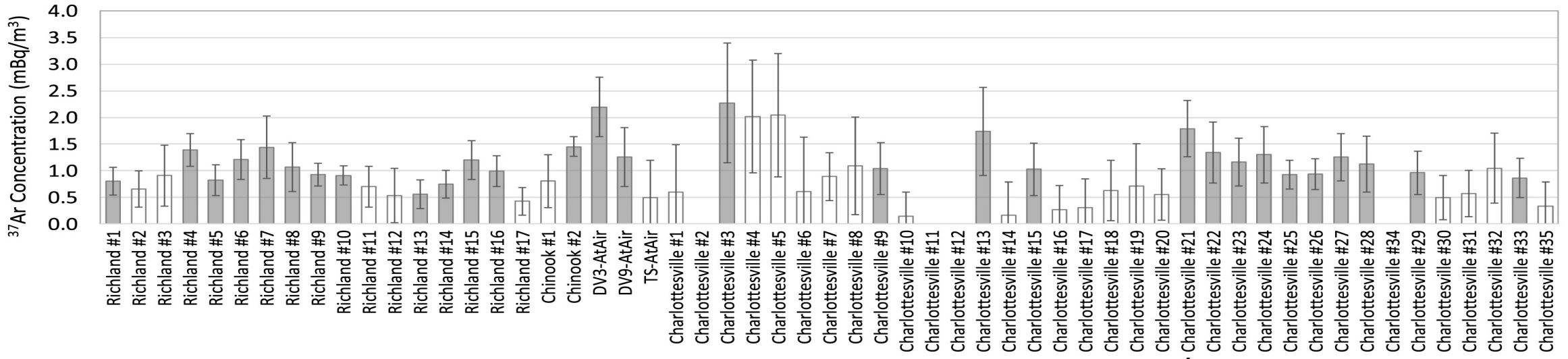
- Richland, Washington State
- Cascade Mountains, Washington State
- Washington State University
- Montana State University
- Olympic National Park
- Yellowstone National Park
- Death Valley National Park
- Tule Springs National Monument
- Virginia (IMS Station RN75)
- Tennessee (TBE)

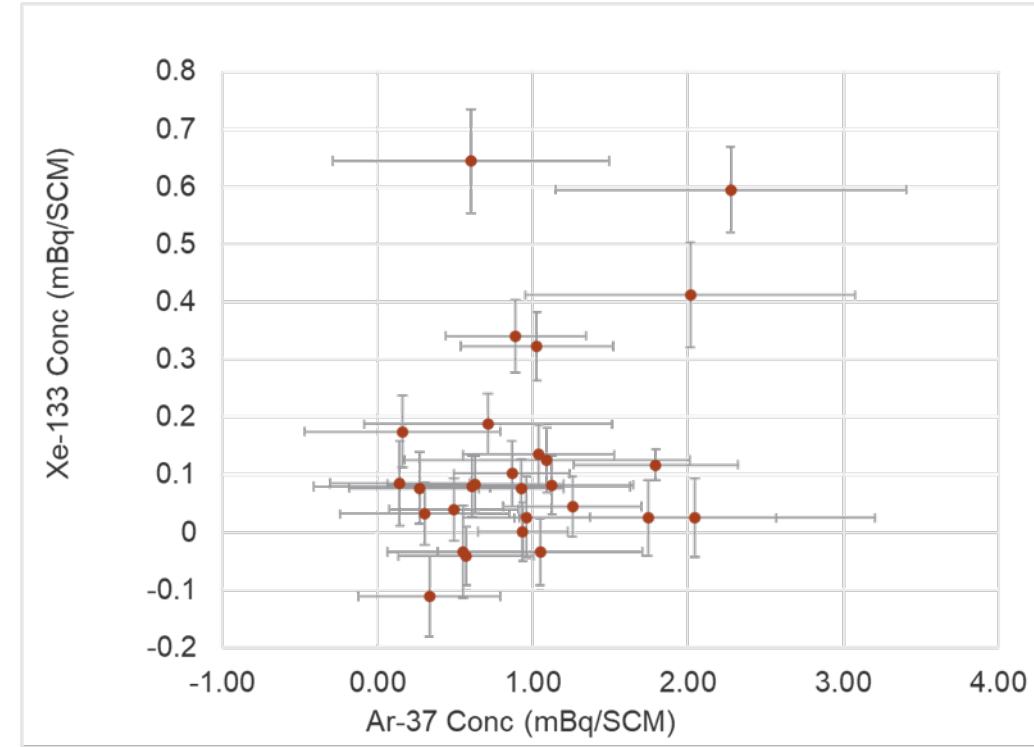
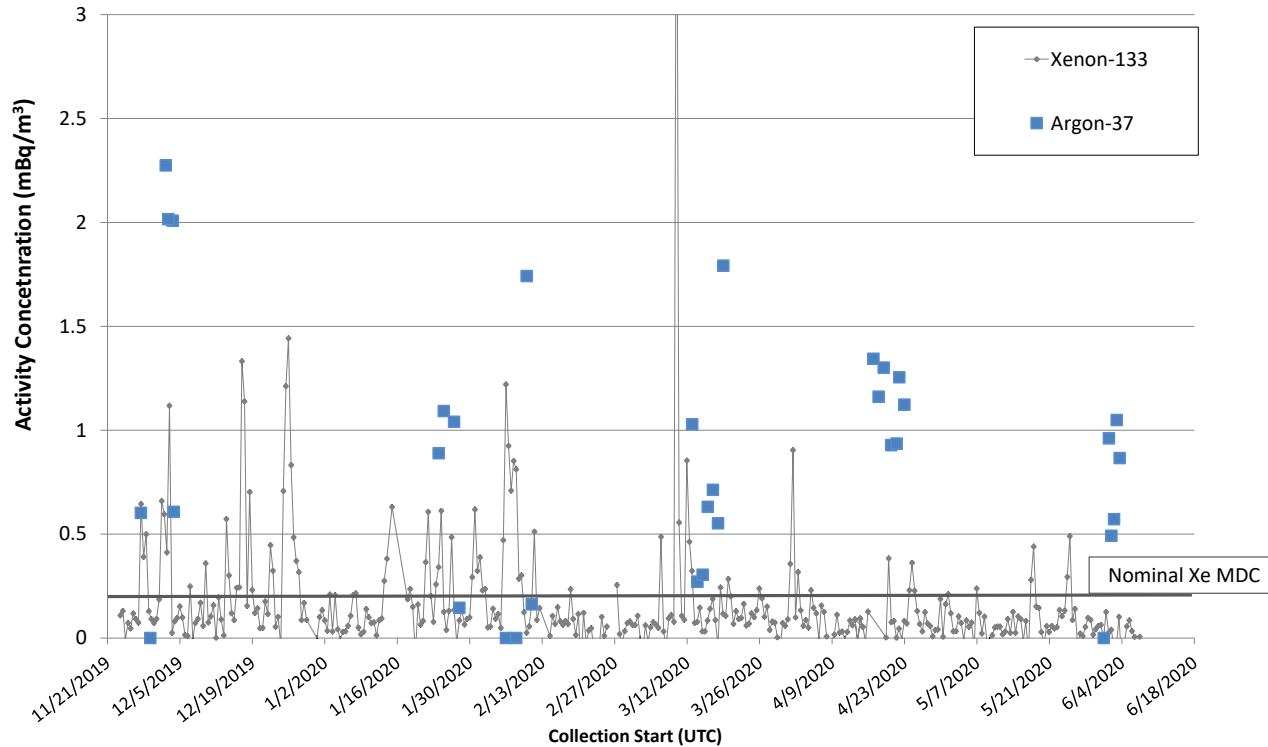
Soil gas samples (all locations)



Sampled at Charlottesville (RN75) and Richland, Washington

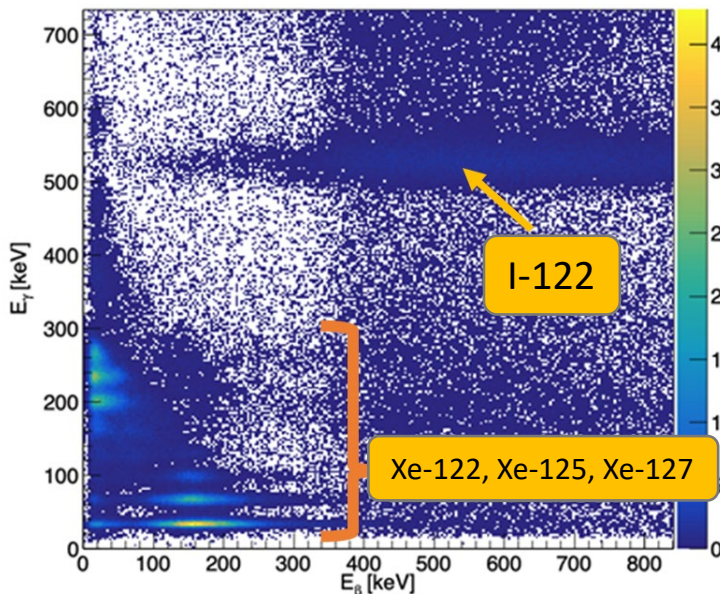
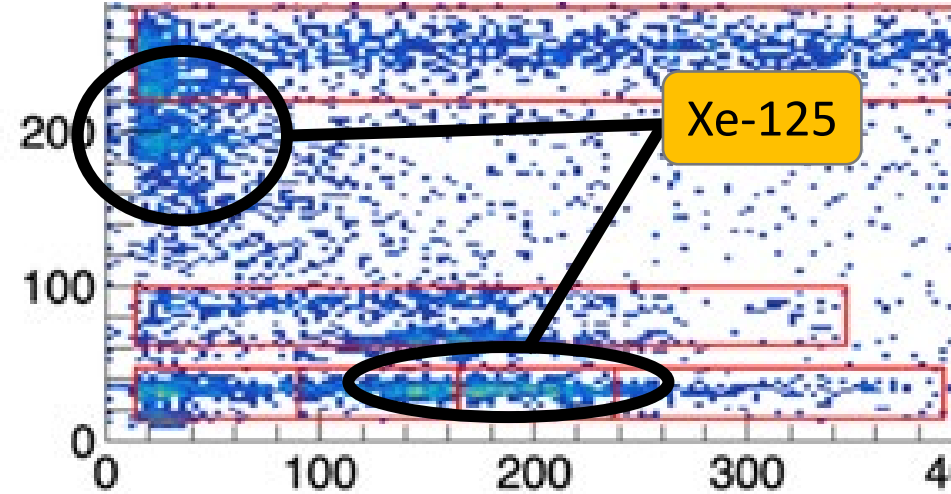
- Natural production
 - $^{40}\text{Ar}(n,4n)^{37}\text{Ar}$ produced in air (air activation)
- Manmade production
 - Anywhere there are Ca atoms and neutrons: nuclear reactors, neutron generating facilities
- Air sent back to PNNL to be processed and measured on the Ar-37 Field System
 - Typical sample size 2 liters counted for several days



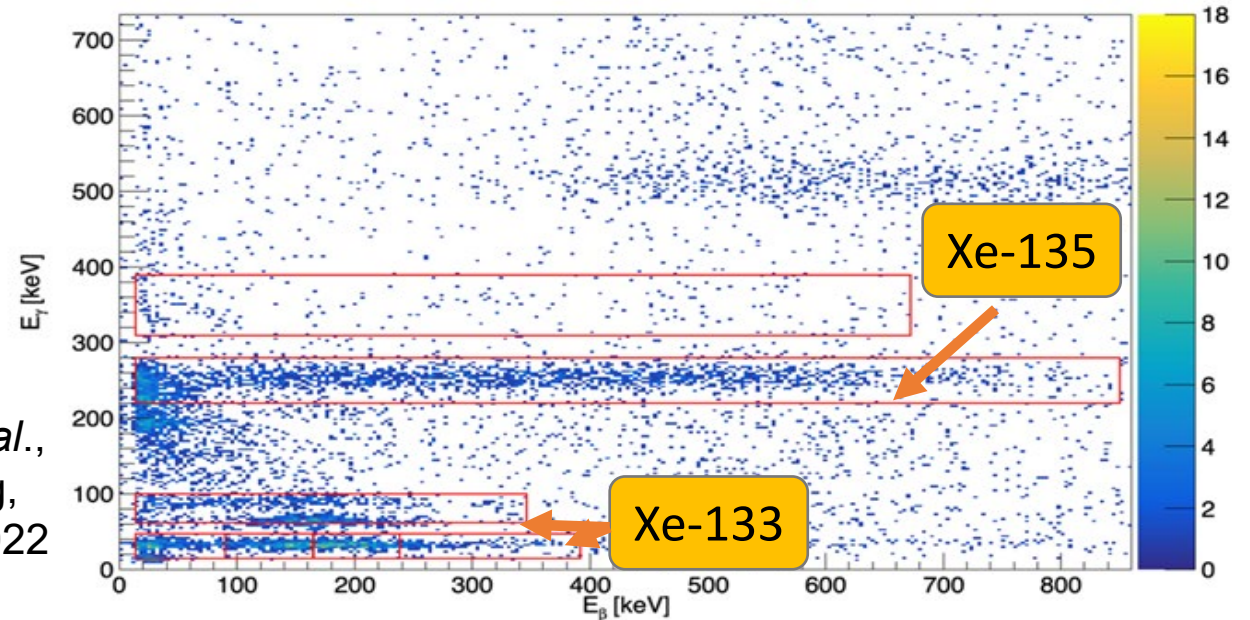


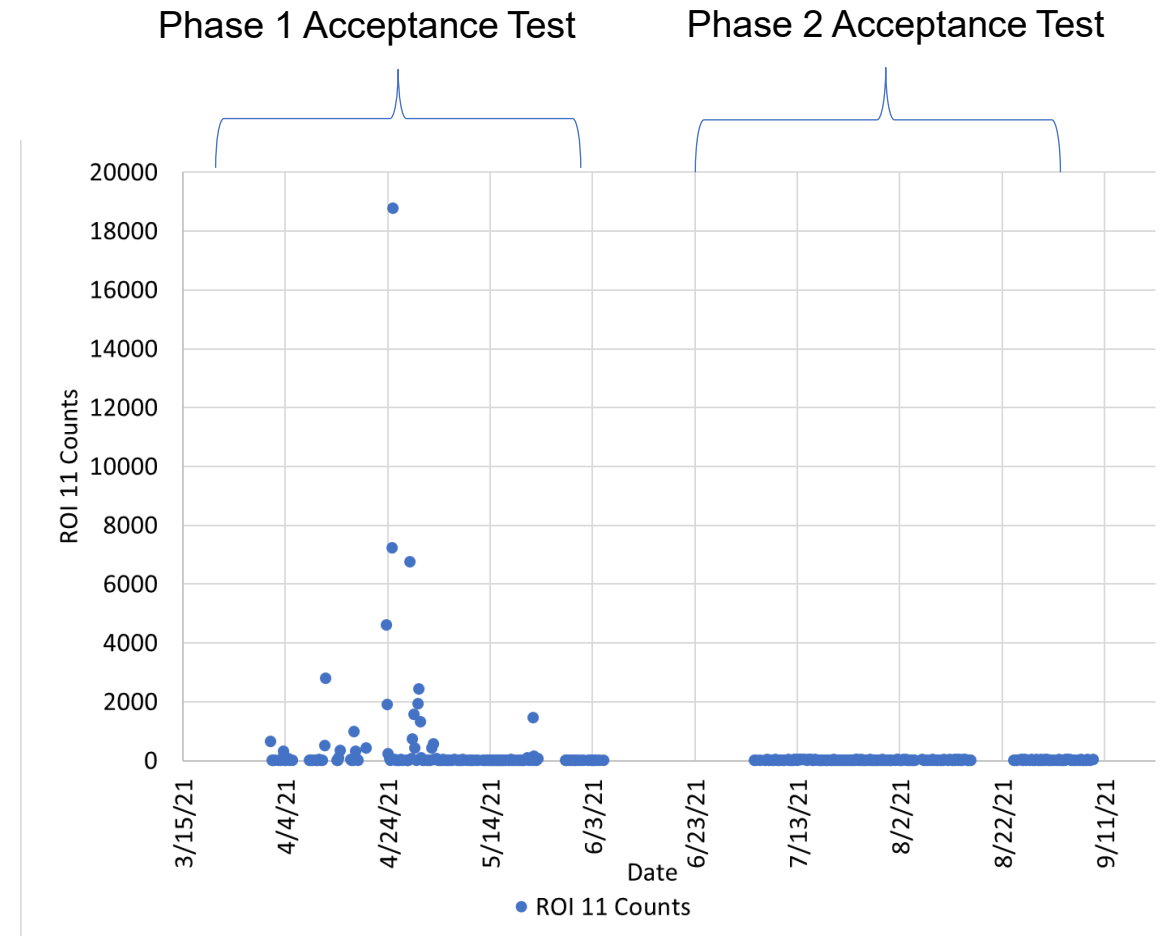
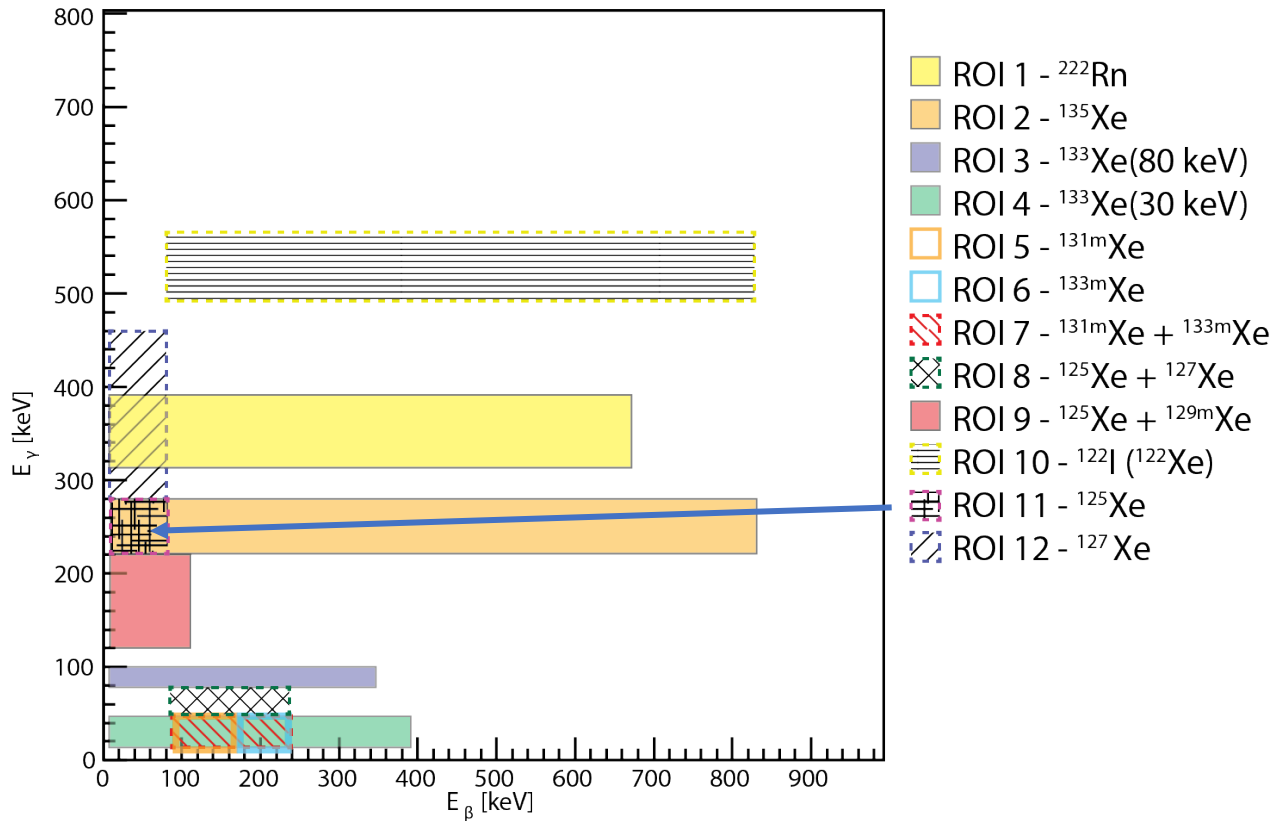
- Correlation plot of Charlottesville data (RN75) between Ar-37 and Xe-133 concentrations
- 1-sigma uncertainty bars
- Xe-133 minimum-detectable-concentration (MDC) ~2.5 times 1-sigma uncertainty
- Assuming an equal multiplier for the Ar-37 concentrations implies no Ar-37 measurement was above the Ar-37 MDC
- Initially gives a < 5% overlap with this data

- Unusual radioxenon detections during Xenon International Phase 1 Acceptance Test at Teledyne Brown Engineering in Knoxville, TN **
 - Likely from air activation by strong neutron source (SNS)
 - Xe-122, Xe-125, Xe-127, Xe-129m, and daughter products I-122, and I-125



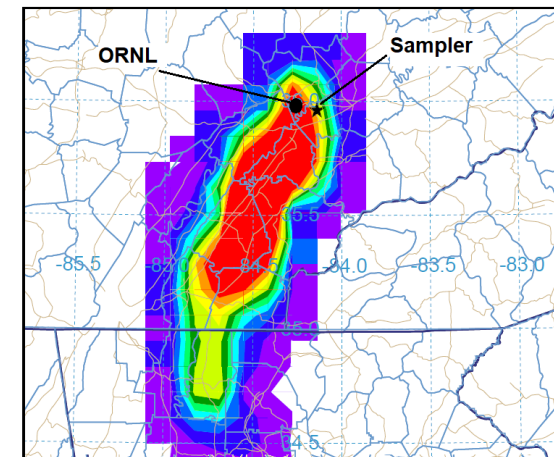
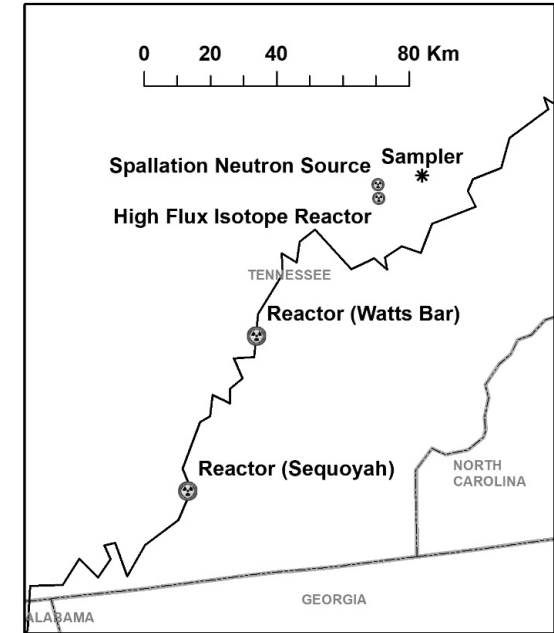
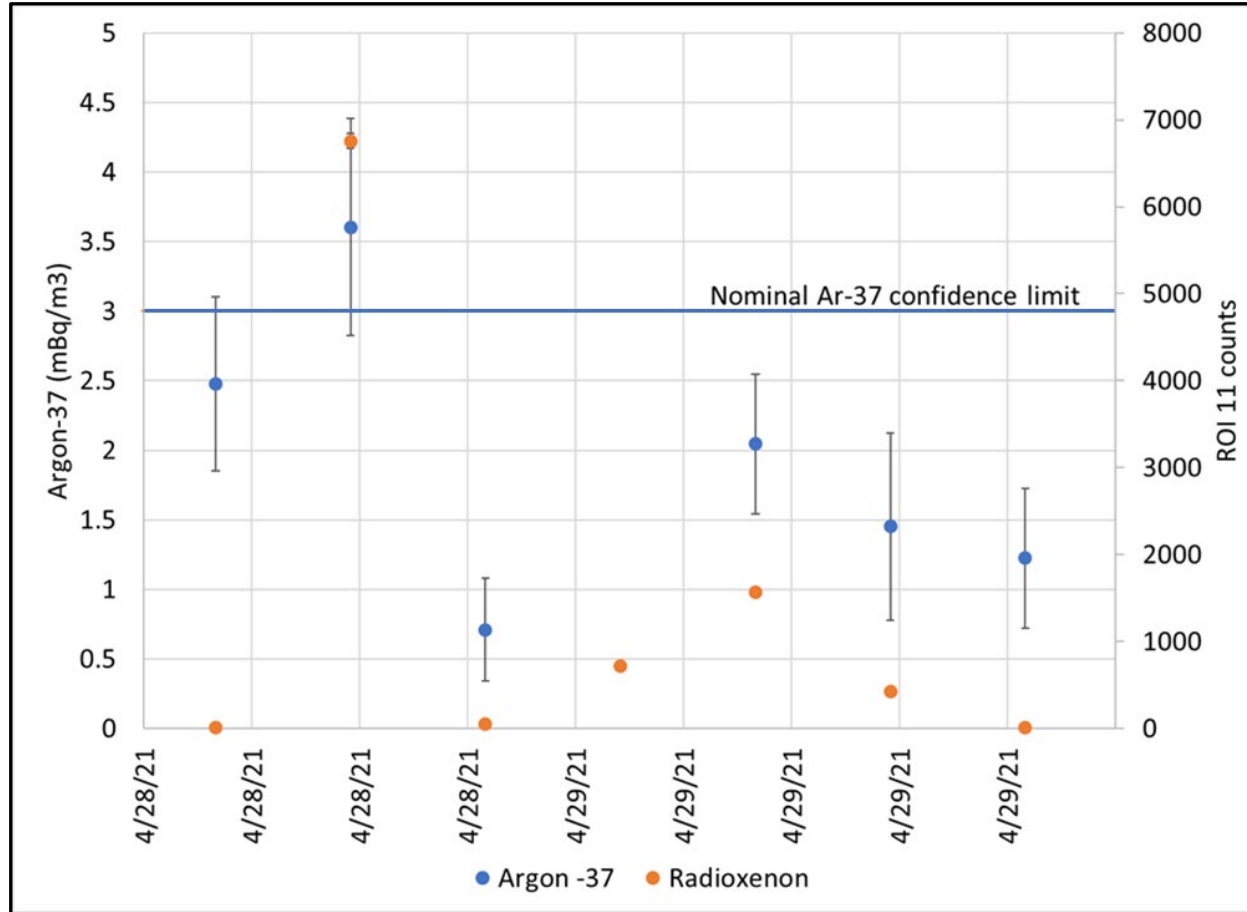
Cooper, M.W. *et al.*,
 AGU Fall Meeting,
 p. A55R-1367, 2022





- Plotting all Xenon International samples shows strong detections in April.
- No detections in Germany during Phase 2 testing.

- Several Ar-37 measurements were made from air at TBE that coincided with Xenon International measurements.
- Data shows there may be a correlation between “new” xenon isotopes and Ar-37. Just need more data...
- Initial modeling indicates air mass comes from direction of neutron source.



Thank You!