Pacific Northwest
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Underground Nuclear Explosion Signatures Experiment (UNESE) Phase 2: Gas migration studies in a tunnel test location

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U.S. DEPARTMENT OF ENERGY BATTELLE

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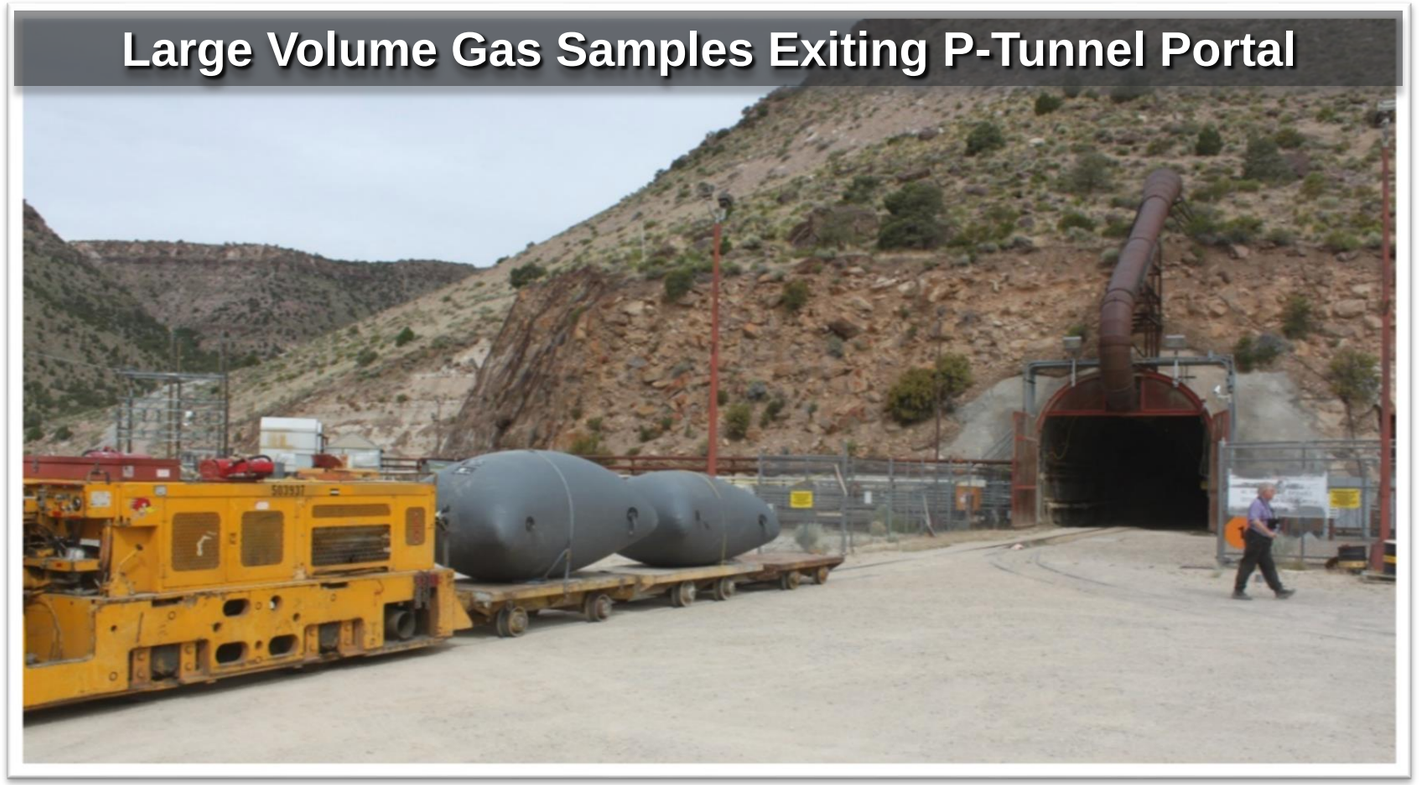
Outline

UNESE Phase 2: The goal of this experiment was to learn about radioactive gas transport around a historic, horizontally emplaced, underground nuclear explosion.

- History: UNESE Phase 1
- UNESE Phase 2 Injection
- Sampling
  - P-tunnel
  - Aqueduct Mesa
- Measurements results
  - P-tunnel
  - Aqueduct Mesa
- Future Work



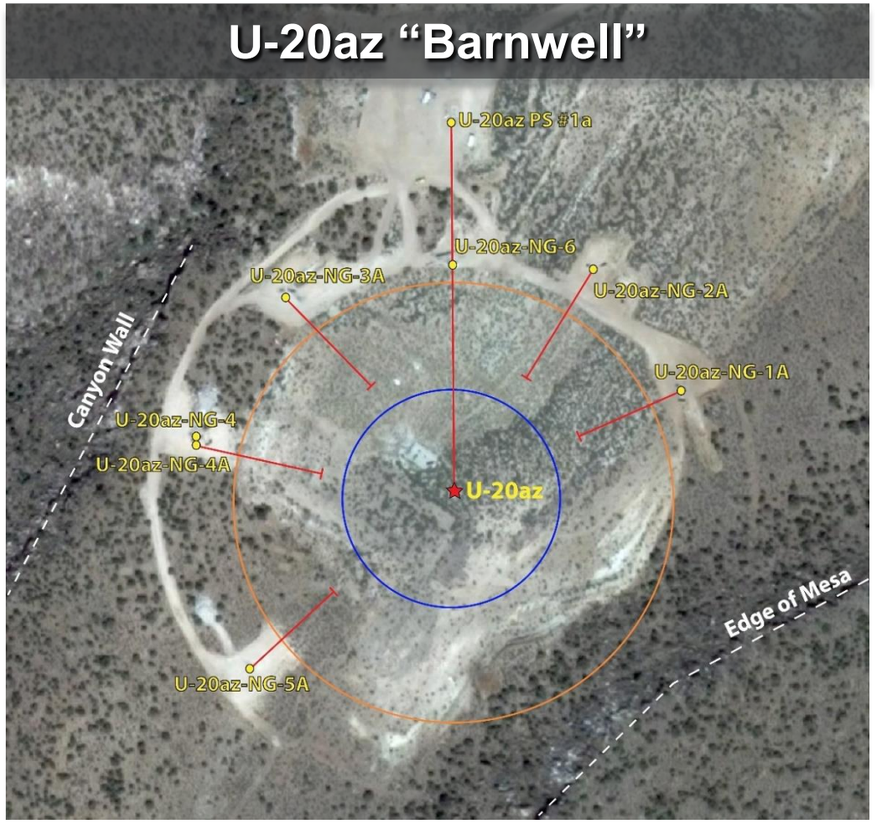
History: UNESE Phase 1

Noble Gas Migration Experiments 1 & 2

Emplacement:
- A vertically emplaced test
- Gaseous tracers placed within partially collapsed cavity

Experiment campaigns:
- 2012: Only surface sampling
- 2016: No cavity pressurization

Samples collected for 13 months after injection
- Large volume (2m^3) samples for radiotracers
- Small volume (~1L) samples for stable tracers



Experiment Results

In 2012 experiment, Xe and Ar were observed to behave similarly- both depleted with respect to SF_6

In 2016 experiment later samples were not depleted in Ar

Combination of factors needed to account for differences in observed gas arrivals.

Conclusions

1. **2012 results more representative of *bulk advective transport* from pressurization of remaining chimney gas**
2. **2016 results more representative of gas transported by *seepage flow***

UNESE Phase 2

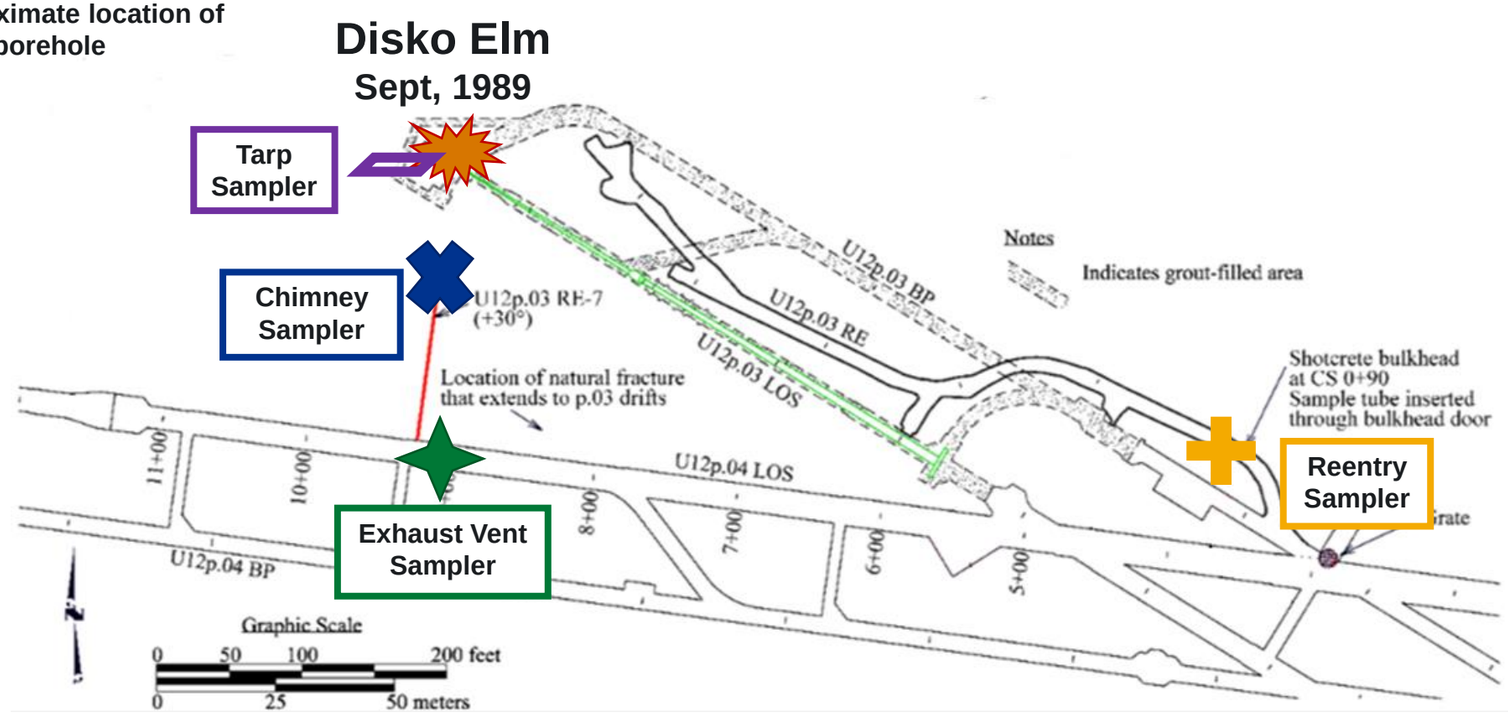
P-tunnel tracer experiments

Emplacement:
- A horizontally emplaced test
- Gaseous tracers placed within partially collapsed chimney

Injection
- Two tracer injections
- Stable tracers
- Radioactive tracers injected with constant activity/time

Sampling
- Three sampling locations in tunnel
- Four sampling location zones in borehole from surface
- Surface sampling outside tunnel portal and on mesa top

Approximate location of mesa borehole



P-tunnel sampling locations

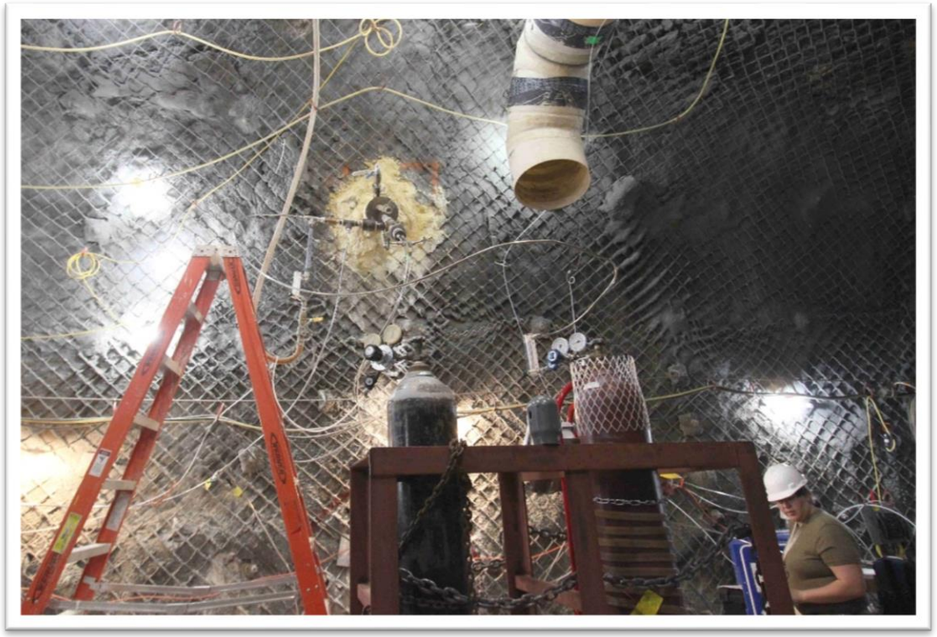
Radionuclide and stable gas injection

Chimney injection (location ✖) lasted 4.5 hours on the morning of June 20, 2018.
3 tracers injected

Mixed ^{127}Xe and ^{37}Ar (shown below in shielded canisters) injected with air.

- Approximately 20 GBq of each isotope
- Constant activity injection

Stable SF_6 (~50 kg) injected with the mixed radiotracers.
Cylinder containing SF_6 connected to the injection borehole shown below.



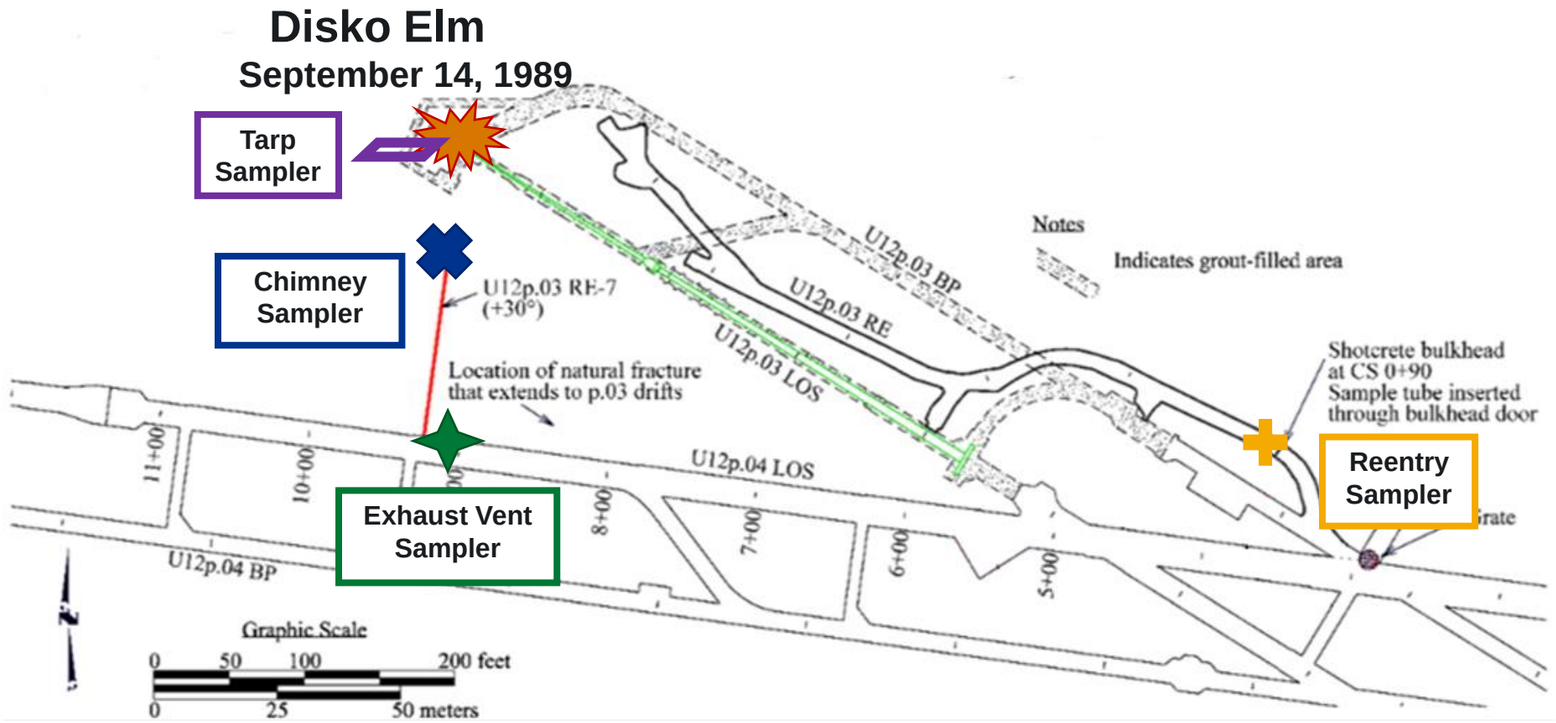
P-tunnel sampling locations

Approximate location of mesa borehole

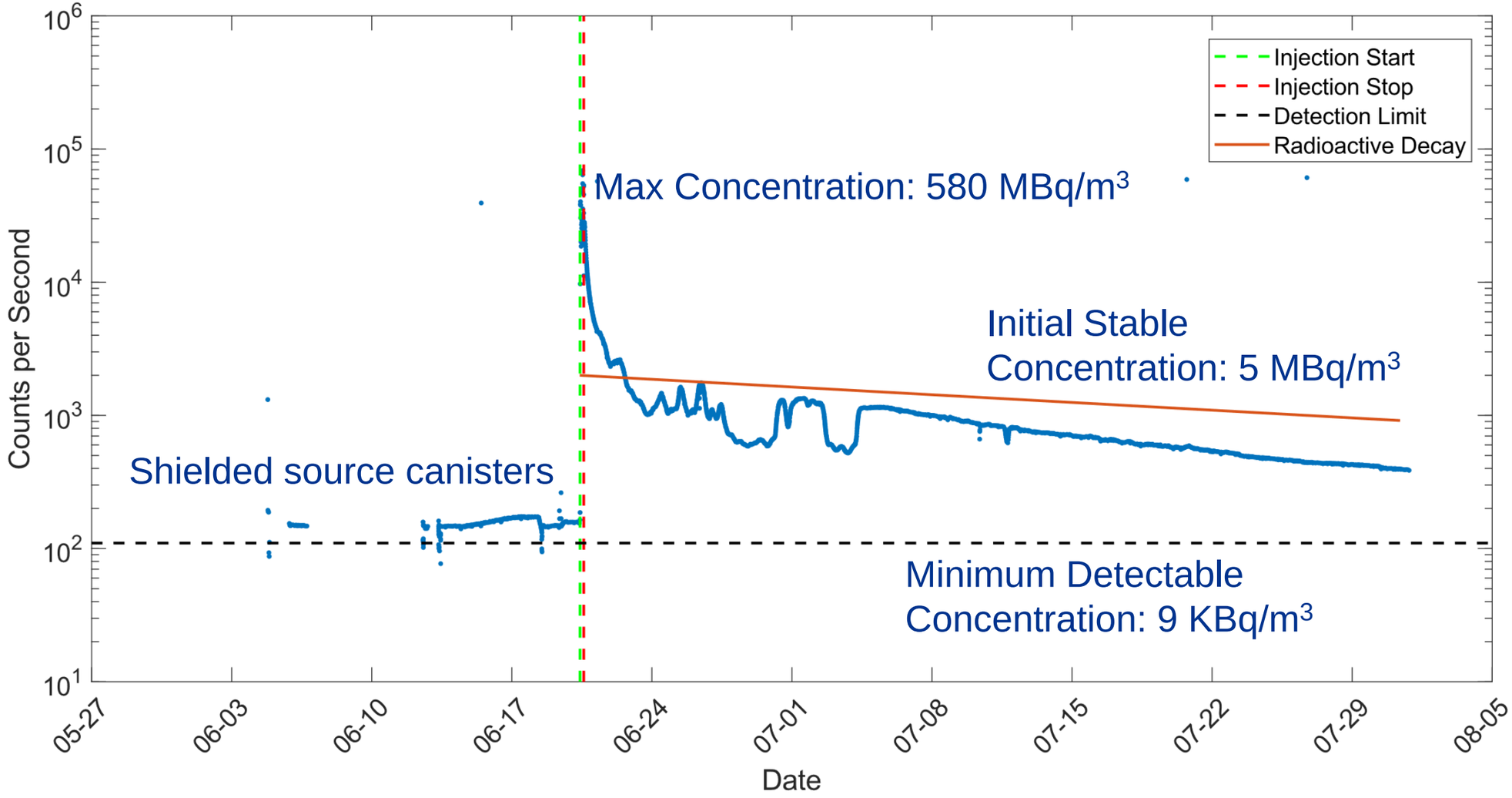
Chimney Sampler:
- Recirculating gas sampler
- Near-continuous ^{127}Xe detection with NaI detector surrounded by gas volume
- Small samples collected from recirculation line

Exhaust Vent Sampler:
- Small samples collected from exhaust intake

Reentry Sampler:
- Recirculating gas sampler
- Near-continuous ^{127}Xe detection with CsI detector surrounded by gas volume
- Small samples from parallel sampling line



^{127}Xe within the chimney ✖ (About 30m from WP)



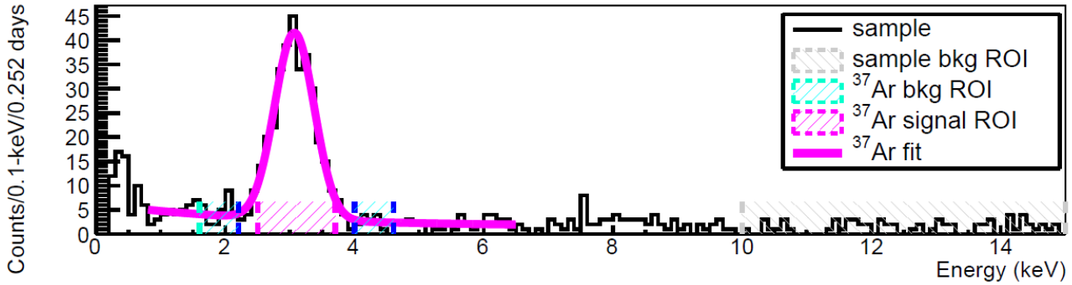
Measurements of ^{37}Ar in P-tunnel

Initial measurements of ^{37}Ar made rapidly on-site with a field deployable ^{37}Ar detector system

- All P-tunnel samples collected after injection had a volume of 1 L

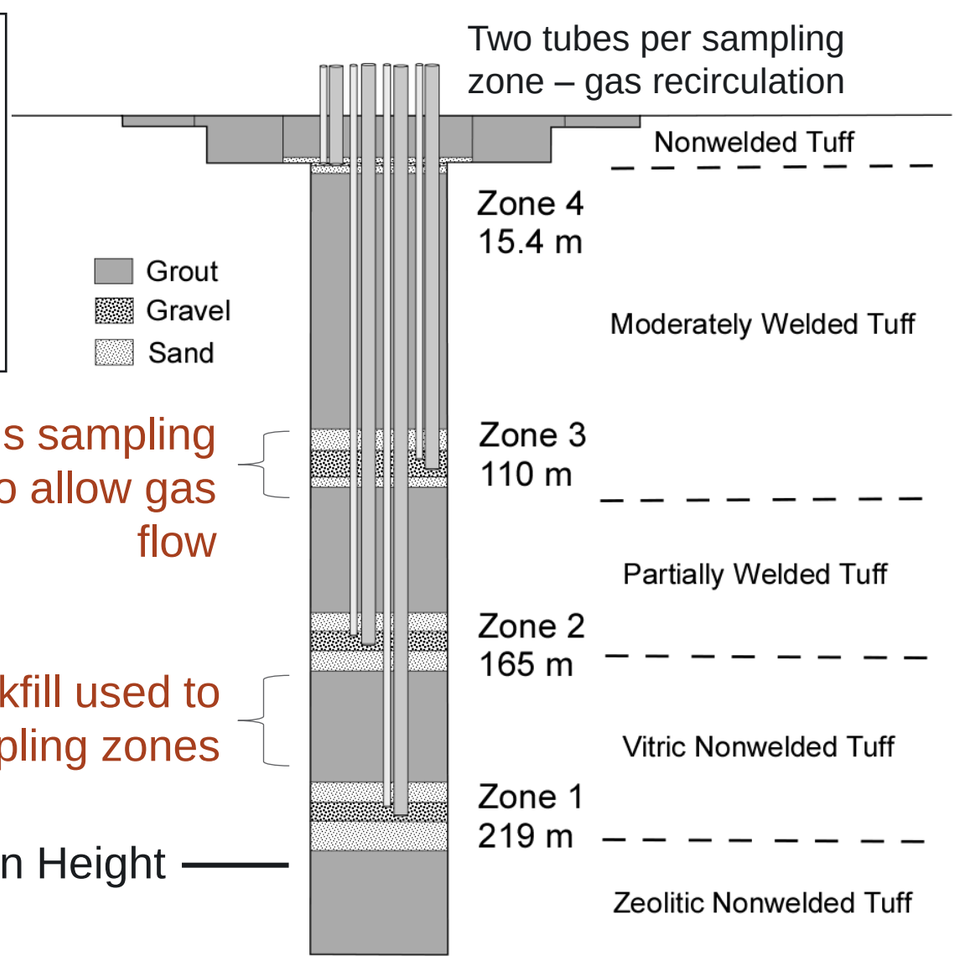
- Injected ^{37}Ar was detected in P-tunnel ventilation
  - possibly leakage from the injection borehole
- No ^{37}Ar was detected in re-entry drift

^{37}Ar in Ventilation Exhaust



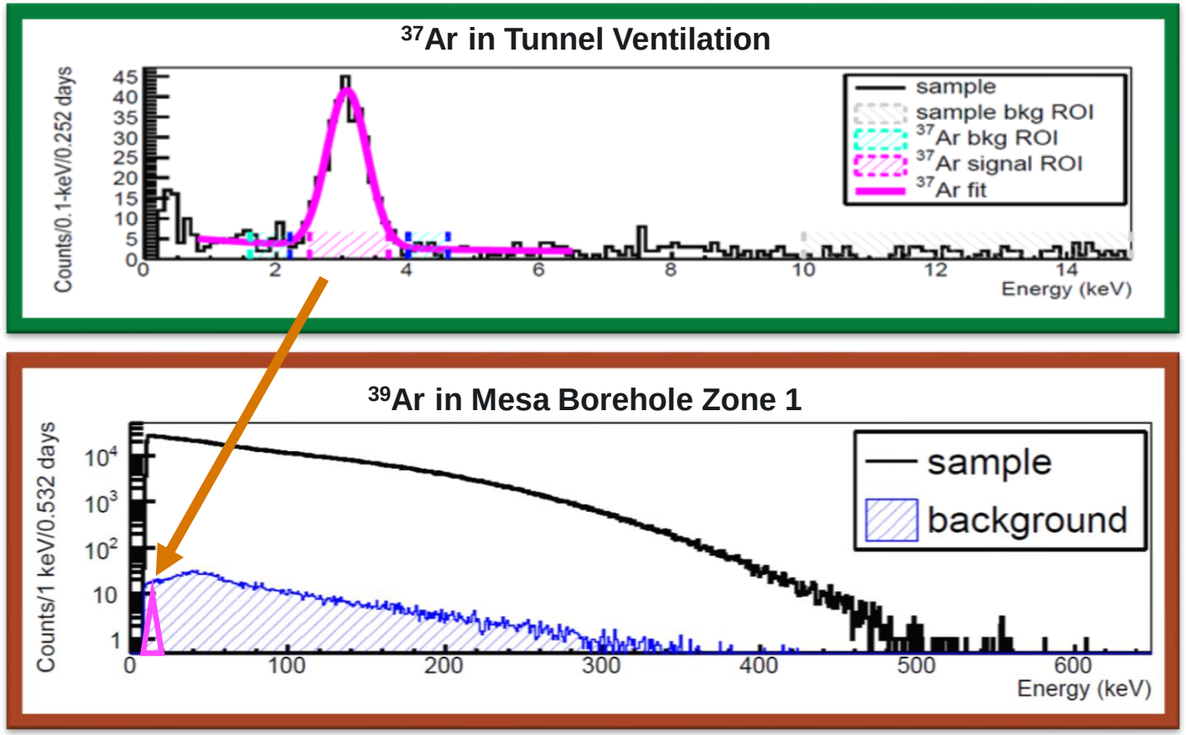
Aqueduct Mesa Sampling

- Over 200 samples collected
  - 50 large volume (2 m^3)
  - 165 small volume (1 L)
- 100 samples analyzed for stable tracers
- 20 samples analyzed for Xe
- 30 samples analyzed for Ar



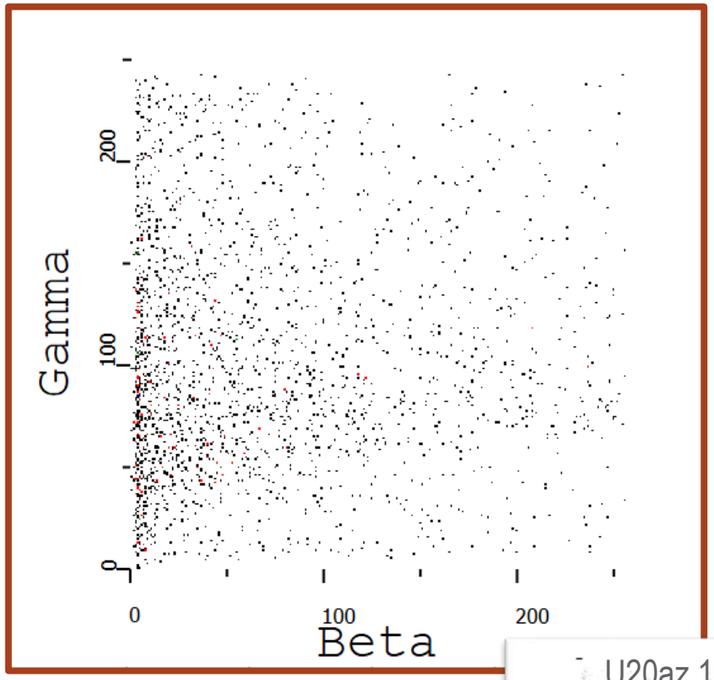
Measurements on Aqueduct Mesa

High levels of ^{39}Ar impact ^{37}Ar detection limits in the mesa borehole samples

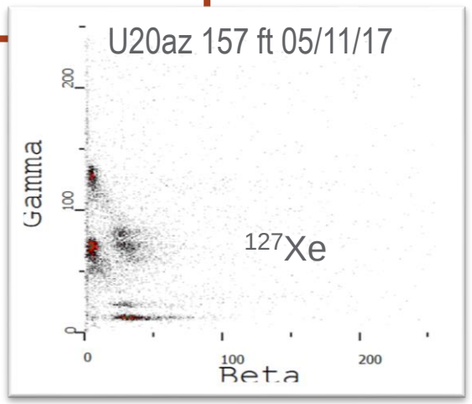


No detections of injected tracers in the deep borehole as of October 2018

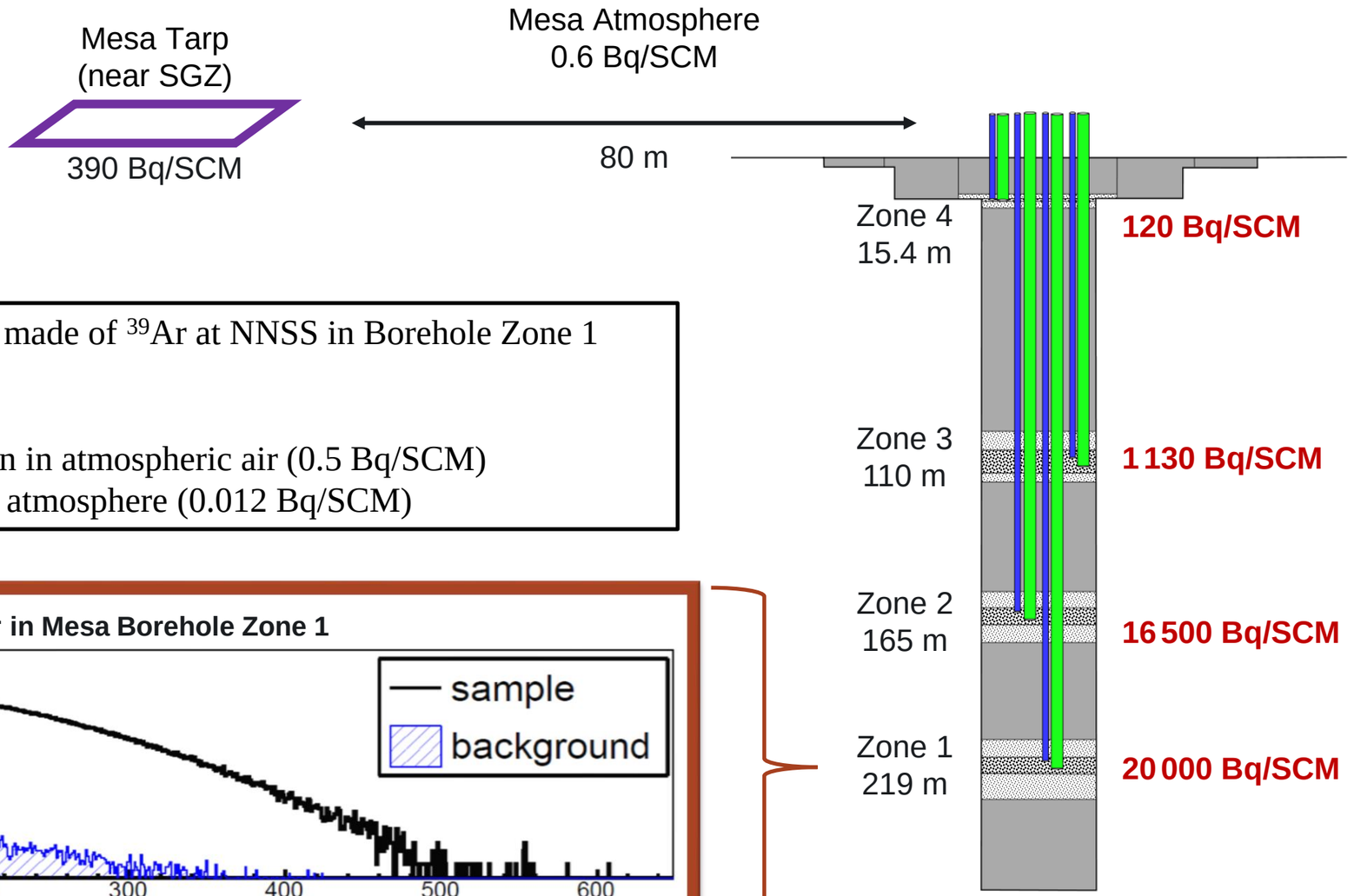
Borehole Zone 1 10/15/18



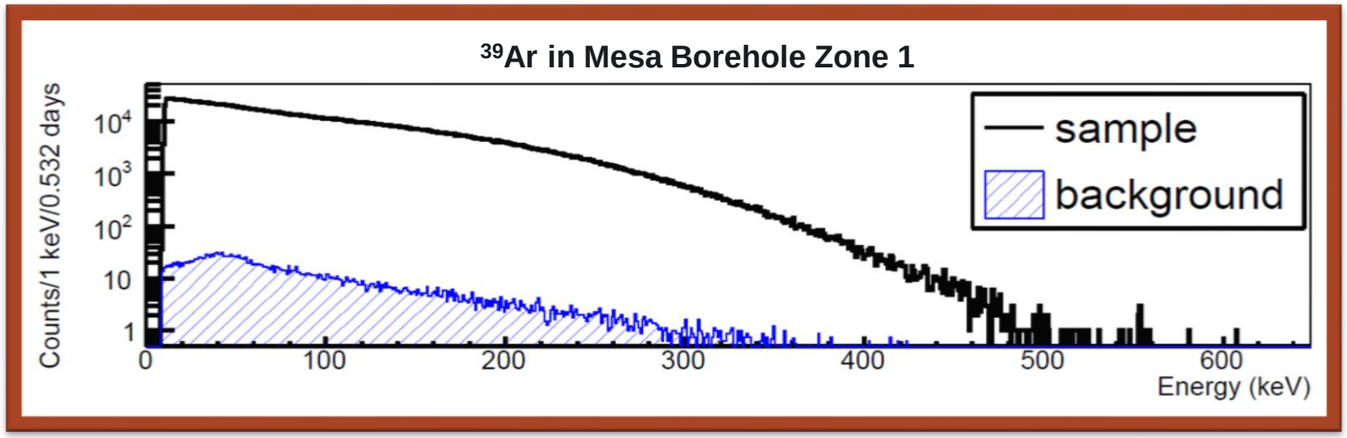
For comparison…



Measurements of ^{39}Ar on Aqueduct Mesa

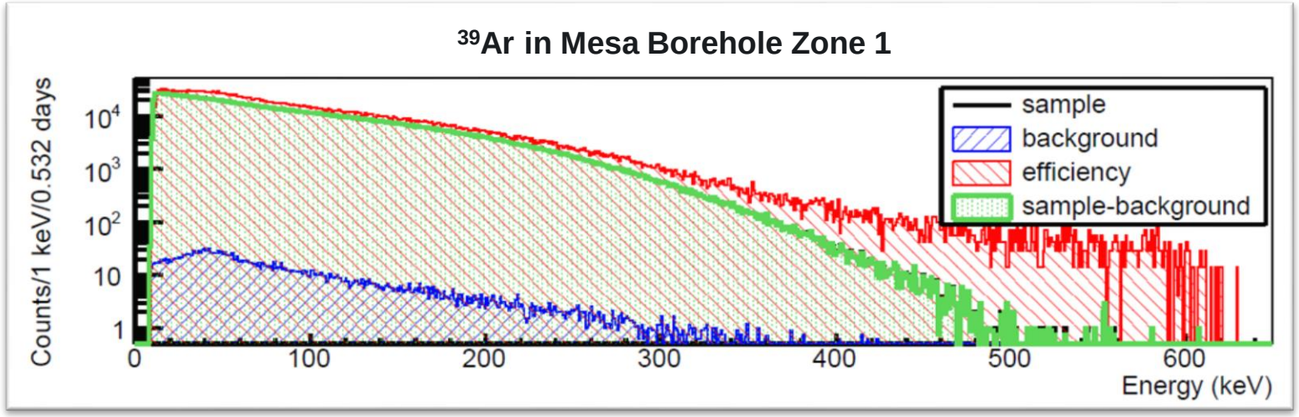


- Highest measurements yet made of ^{39}Ar at NNSS in Borehole Zone 1
  - **20 000 Bq/SCM!**
- Elevated levels of ^{39}Ar seen in atmospheric air (0.5 Bq/SCM)
  - Over 30 times typical atmosphere (0.012 Bq/SCM)



Summary

- **Key finding**: natural transport mechanisms not sufficient to force transport of injected tracers from injection point to deep borehole in a four month period
- Demonstrated ability to utilize small volume samples (1 L) for measurement of radioactive argon and stable gases
- **Key finding**: **the activation product ^{39}Ar is present in significant quantities in the subsurface 30 years after a UNE**.
  - This impacts ^{37}Ar detection limits – ^{39}Ar acts as a background
  - Near surface ^{39}Ar measurements of nearly 400 Bq/m^3 air
  - Above ground measurements of ^{39}Ar on Aqueduct Mesa greater than 30 times average atmospheric levels
  - Highest ^{39}Ar measurement yet at NNSS: 20 000 Bq/m^3 air



Ongoing Work

- Large volume samples are still being analyzed for ^{127}Xe and radioargon
- Small volume samples are being sent out for higher fidelity (ppt) analysis of Freon and SF_6
- Follow-on work: Enhanced Noble Gas Signatures Study
  - Developing model of ^{39}Ar transport in a range of geologies
  - Improve analysis fidelity of ^{127}Xe and ^{39}Ar
  - Developing model of P-tunnel which will be used to simulate both gas injections

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The Underground Nuclear Explosion Signatures Experiment (UNESE) was created to apply a broad range of research and development (R&D) techniques and technologies to nuclear explosion monitoring and nuclear nonproliferation. It is a multi-year research and development project sponsored by NNSA DNN R&D, and is collaboratively executed by Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Mission Support and Test Services, Pacific Northwest National Laboratory, and Sandia National Laboratories.

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Thank you