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Ultra-sensitive gamma-spectrometry measurements of environmental samples from the Hartlepool Nuclear Power Station

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POSTER

P2.4-308

BATTELLE

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EDF ENERGY

AWE

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ABSTRACT

Two ultra-sensitive gamma-spectrometry systems are being used to measure environmental samples collected from the Hartlepool Nuclear Power Station in the United Kingdom. The work is being performed as part of the Xenon Environmental Nuclide Analysis at Hartlepool (XENAH) collaboration between Pacific Northwest National Laboratory (PNNL, USA), the Atomic Weapons Establishment (AWE, UK) and EDF Energy (UK). The coincidence-based gamma-spectrometry systems are located at the Shallow Underground Laboratory (USA) and Boulby Underground Laboratory (UK), and they are being used to measure radionuclides that are relevant for nuclear explosion monitoring purposes. Stack filters for particulate fission and activation products, charcoal cartridges for gaseous iodine, and other environmental samples are being collected and measured. The advanced systems have detection sensitivities some orders of magnitude better than standard laboratory systems (e.g., for ^{106}Ru/^{106}Rh, ^{134}Cs, ^{144}Ce), and they shall improve the understanding of the trace-level radionuclide emissions of the Advanced Gas-cooled Reactor (AGR) at Hartlepool. This is important for interpreting the radionuclide measurements performed at International Monitoring System (IMS) stations and determining whether detections are attributable to civilian nuclear sources or nuclear explosive tests.

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COLLABORATION

- Research undertaken as part of the Xenon Environmental Nuclide Analysis at Hartlepool (XENAH) collaboration
  - Pacific Northwest National Laboratory (PNNL, USA)
  - EDF Energy (UK)
  - Atomic Weapons Establishment (AWE, UK)
  - Swedish Defense Research Agency (FOI)

XENAH

- The goal is to better understand how radionuclide emissions from a nuclear power reactor might impact the International Monitoring System
  - 2-year measurement campaign at Hartlepool Nuclear Power Station, UK
  - See B. Milbrath poster (P2.4-206)

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HARTLEPOOL

- The Hartlepool Nuclear Power Station began generating electricity in 1983
  - Operated by EDF Energy, it is licensed until 2024
- It consists of two Advanced Gas Reactors (AGRs)
  - Each reactor provides 650 MW of electrical power (1570 MW thermal), or 2% of the UK's electricity

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SAMPLING

- Samples are being collected from stacks attached to the facility
- They include activated charcoal maypacks for gaseous radionuclides (e.g. ^{131}I) and filter papers for particulate radionuclides (e.g. ^{60}Co)
- Additional environmental samples will also be measured in the next stages of the study including soil and biota

Stack samplers	Other samples
R1 + R2 common blowdown	Herbage
Tritiated water storage tank	Soil/core
Fuel handling block	Tacky shades
Additional fuel storage facility	Marine samples (seaweed, fish, sediment)
R6	Water (sea and fresh)
Gas circulator maintenance facility	
R12	

Samples prepared for gamma-spectrometry measurement

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MEASUREMENT

- Ultra-sensitive gamma-spectrometry systems are being used to measure the environmental samples
  - Systems located at the Shallow Underground Laboratory (SUL, PNNL, USA) and Boulby Underground Laboratory (AWE, UK)
- These systems have detection sensitivities some orders of magnitude better than standard systems
  - Used to measure treaty relevant radionuclides (e.g. ^{106}Ru/^{106}Rh, ^{134}Cs, ^{144}Ce)

The SUL at PNNL. Located at 38 Meters Water Equivalent (MWE) it provides a 100x reduction in fast neutrons and 6x reduction in muons. Combined with low background detector components and optimized shielding, this results in gamma-spectrometry systems with 100x lower backgrounds.

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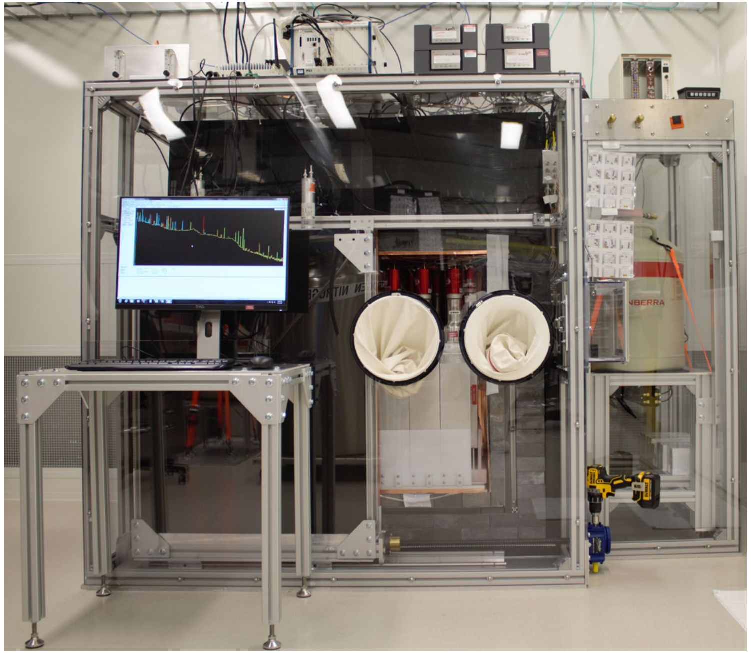
ARGO

- The Advanced Radionuclide Gamma-spectrOmeter (ARGO) is optimized for trace radionuclide measurements
  - Combines low background measurements, cosmic veto, Compton suppression and coincidence functionality
  - It consists of two broad energy germanium (BEGe) gamma-spectrometers
  - It can simultaneously perform singles, combined and coincidence measurements
- It is supported by other detectors in the SUL
  - A small anode germanium (SAGe) well-detector
  - A novel dual BEGe system (see M. Sharma poster, P3.1-312)

The ceramic SAGe well-detector used for measuring Hartlepool filter samples



The ARGO at PNNL

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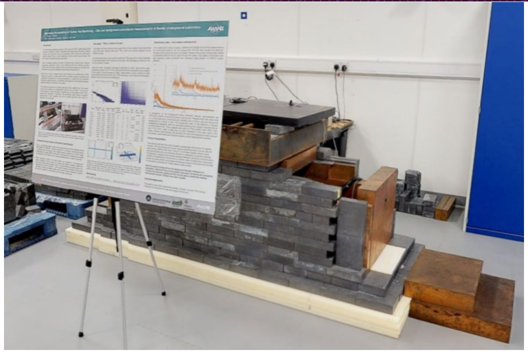
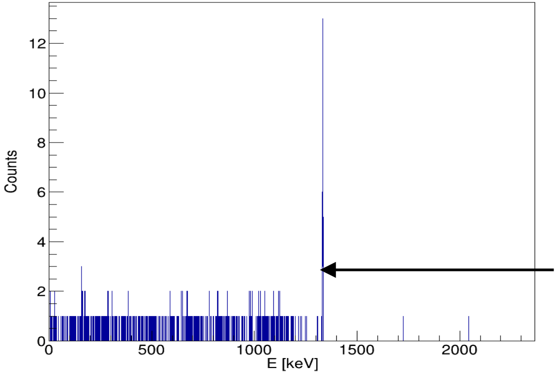
AWE-BOULBY

- The AWE-Boulby system is designed for trace measurements
  - The system is located within the Boulby Underground Laboratory to reduce cosmic background radiation
  - It consists of two BEGe gamma-spectrometers
- The system will be upgraded to include new detectors and a modified shield (see A. Davies poster, P3.1-303)

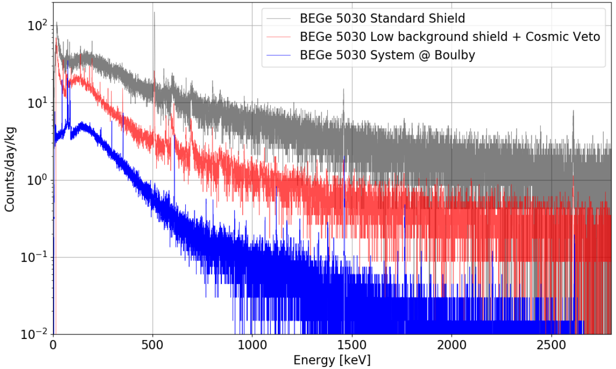


The AWE-Boulby system



R12 Charcoal measurement using γ-γ coincidence system. Spectrum projected using a 1173 keV energy gate.

1332 keV
^{60}Co



Reductions in detector background at the Boulby mine

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO PrepCom

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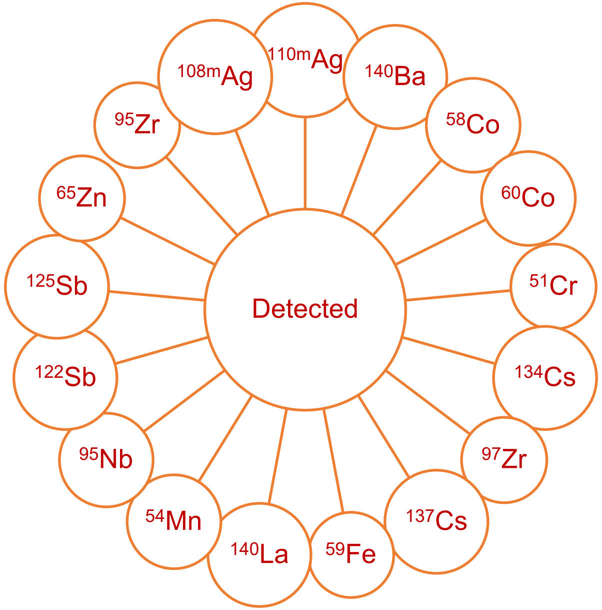
DETECTIONS

- Prior to measurement at PNNL and AWE, each sample is measured using conventional gamma-spectrometry systems at EDF Energy
- Due to the distance of PNNL from Hartlepool, PNNL analysis focused on longer-lived radionuclides (e.g. ^{54}Mn, ^{58}Co, ^{60}Co, ^{137}Cs)
  - AWE focused on shorter-lived radionuclides (e.g. ^{131}I)
- The ultra-sensitive measurements have identified trace levels of fission and activation products, including ^{108m}Ag, ^{110m}Ag, ^{51}Cr, ^{54}Mn, ^{58}Co, ^{60}Co, ^{97}Zr and ^{137}Cs.
- As measurements continue, we shall develop a radionuclide fingerprint of an operational nuclear power reactor



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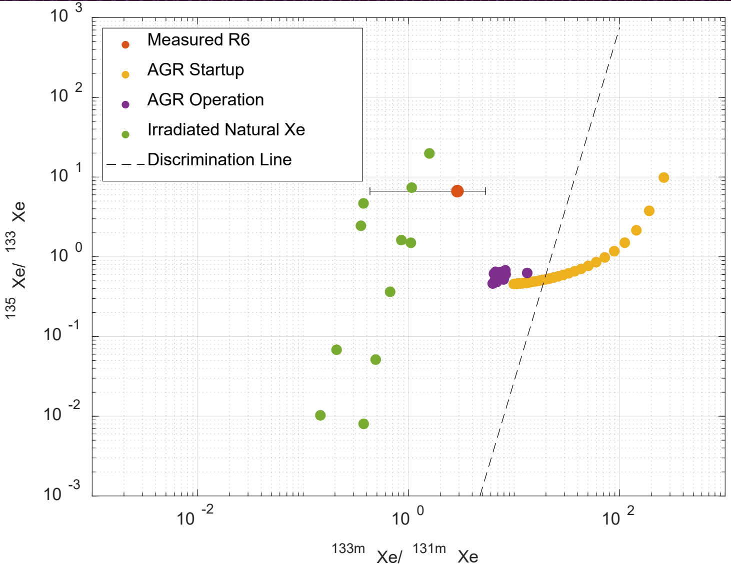
MODELLING

- AGR modelling simulations were performed to better understand the radionuclide detections using the ORIGEN/SCALE software
  - Estimates the production of relevant radionuclides in the AGR fuel during operation
- Has provided insight into radioxenon measurements made by EDF Energy
  - The isotopic composition of R6 stack sampler measurements appears like activated natural xenon in air rather than from fission in AGR fuel



Calculation of the radioxenon isotope ratios shows values right of the nuclear explosion discrimination line [1] during AGR start-up and left during routine AGR operation. R6 stack measurements are also like activated natural xenon in air [2].

[1] Kalinowski, M. et al. (2010). Pure and Applied Geophysics 167(4);
[2] Klingberg, F. et al. (2013). Journal of Radioanalytical and Nuclear Chemistry 296.

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SUMMARY

- ❑ Ultra-sensitive gamma-spectrometry measurements began this year and will continue until September 2022
- ❑ As the number of samples increases, becoming more representative of reactor operations, future work will aim to establish a radionuclide fingerprint for the AGR
- ❑ This will be correlated with other tasks of the XENAH collaboration, including stack monitoring and stand-off measurements for radioxenon emissions

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Thank You!

For additional comments or questions….
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