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XENAH: Xenon Environmental Nuclide Analysis at Hartlepool

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XENAH - Overview

Scientists from the U.K., U.S., and Sweden are performing measurements involving a suite of radionuclide monitoring techniques in order to better understand radionuclide emissions from a nuclear power reactor and how those might affect the International Monitoring System. The Xenon Environmental Nuclide Analysis at Hartlepool (XENAH) collaboration will perform these measurements utilizing the Hartlepool Power Reactor in northeast England with cooperation of the reactor operator, EDF Energy

XENAH

- Reactor stack monitoring for radio xenon measurement at the source
- Stand-off measurements of radioxenon after several km of atmospheric transport and dispersion
- Radionuclide measurement of environmental and regulatory samples taken at or near the power station (including in-core coolant activity monitoring)

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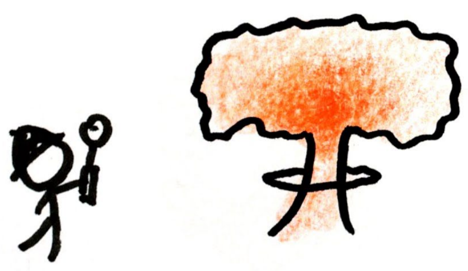
CTBT & IMS Overview

- The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is a multilateral treaty that would ban nuclear weapons test explosions and any other nuclear explosions, for both civilian and military purposes, in all environments. It was adopted by the United Nations General Assembly on 10 September 1996. 185 States have signed the treaty. 172 States have ratified, though the Treaty has not yet entered into force.

- The International Monitoring System (IMS) is part of the verification regime for the CTBT and consists of four technologies to detect telltale indications of nuclear explosion: Seismology, Hydroacoustics, Infrasound and **Radionuclides**

- When complete, the IMS will consist of 337 facilities including 80 radionuclide monitoring stations and 16 radionuclide laboratories

- The IMS successfully detected all six of the DPRK nuclear tests



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Hartlepool Power Station

Overview of an Advanced Gas-cooled Reactor and its operation

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Hartlepool Power Station

- 2 Advanced Gas-cooled Reactors
- Generates ~ 600 MW(e) each, enough to power 1.5 million homes
- Employs ~500 full time staff members and ~200 full time contract partners
- Has been supplying safe, clean, secure energy since 1983
- Currently licenced until April 2024

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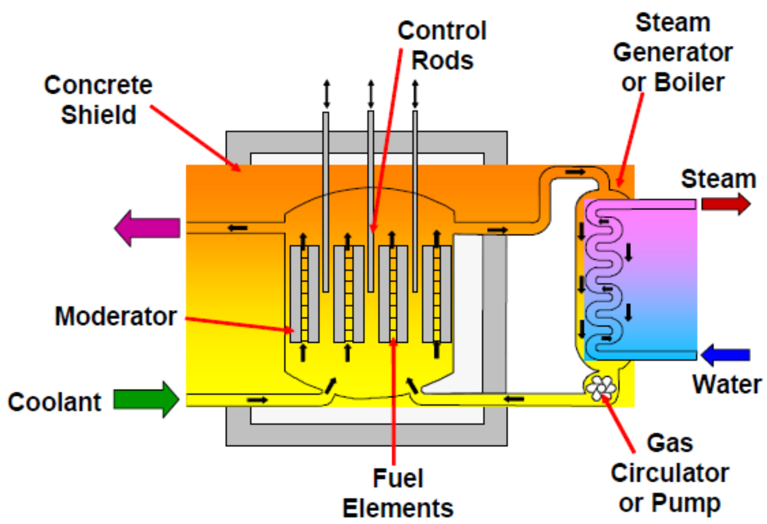
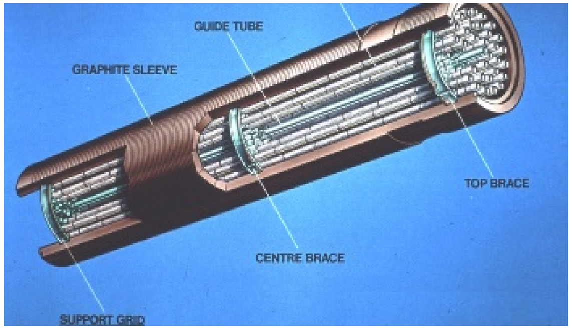
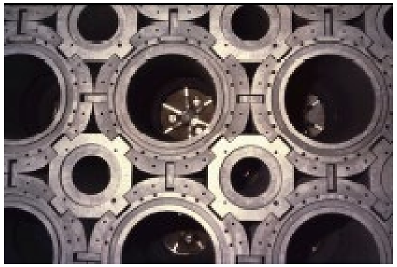
Advanced Gas-cooled Reactor Design



Reactor	
Moderator	Graphite
Primary Coolant	CO_2 @ 41 bar, 3623 kg/s
Number of Fuel Channels	324 with 460mm pitch
Number of Control Rods	81
Active Core Dimensions	9.3m x 8.2m
Mean Temps	T1: 286 °C, T2 648 °C

Fuel design	
Material	UO_2, 3.2 – 3.78% enriched, 130 tonnes per reactor
Disposition	36 pin cluster, graphite sleeve. 8 elements per fuel channel
Cladding	Stainless steel, 0.37mm thick
Average discharge irradiation	30 GWd/tU





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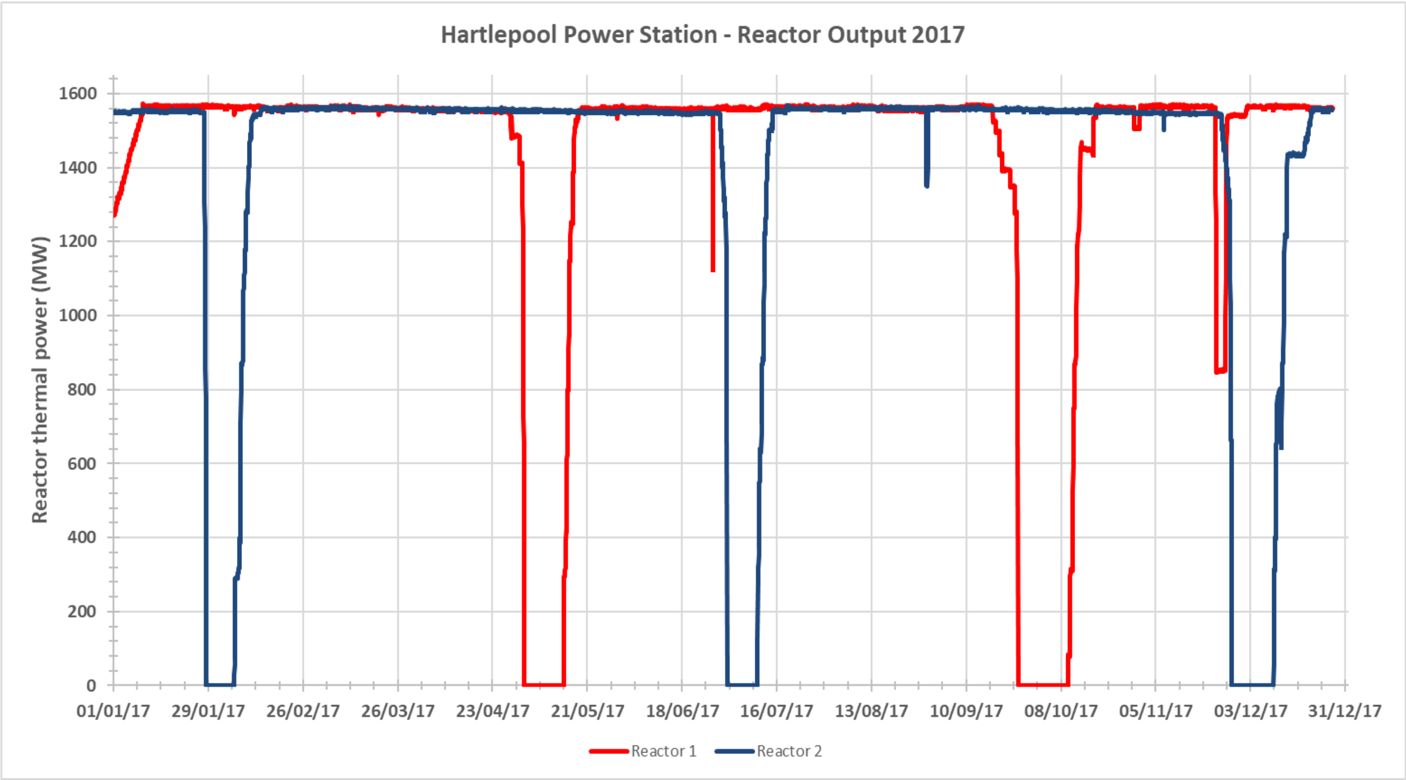
Hartlepool power station operation

- Reactors nominally produce ~1560 MW thermal power each
- Usually 5 refuelling outages per year across the two reactors, lasting 10 - 14 days each
- Off-load, depressurised, batch refuelling
- ~20 channels refuelled during each outage
- During depressurisation, estimated 11.7 GBq of ^{133}Xe released over a 24 hour period



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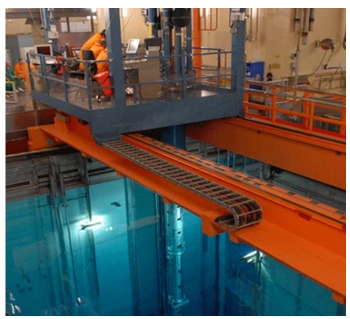
Journey of the nuclear fuel



- Fuel spends ~ 8 years in the reactor
- Once out of the reactor, fuel must be below 16 kW before it can be dismantled at the IFDF – this typically takes around 2 weeks, during which the fuel is housed in special 'buffer stores'
- Once below 16 kW, fuel is dismantled at the IFDF and sent to the cooling ponds
- Fuel must cool to < 12 kW decay heat and spend at least 90 days within the ponds
- Fuel elements are placed in a 'flask' for transport
- Flask with irradiated fuel is transported by train to Sellafield for reprocessing and long-term storage

Wherever nuclear fuel is handled, active Heating and Ventilation (H&V) is discharged through a filtered route

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XENAH Project Workstreams

What we aim to achieve and where we currently are

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XENAH - Workstreams

- Reactor stack monitoring for radio xenon measurement at the source (STAX)
- Stand-off measurements of radio xenon after several km of atmospheric transport and dispersion
- Radionuclide measurement of environmental and regulatory samples taken at or near the power station (including in-core coolant activity monitoring)

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Reactor stack monitoring for Xenon emissions

NGM-2000 System by VF Nuclear

- 30% HPGe detector
- MDC 270 Bq/m^3 for ^{133}Xe
- Flow through system: 1.25 m^3/hr
- Continuous monitoring (15 minute acquisitions, looped)

- Typical of STAX systems employed at Medical Isotope Production facilities

- System's primary aim is to measure radioxenon isotopes, but is sensitive to all gamma-emitting gaseous fission products

- Air extracted from stack flows through Marinelli beaker. Measured concentration is adjusted by total stack flow.

- Stack flow peaks around 1400 m^3/hr during blowdowns

- System installed at R6 tower (main blowdown route)

- Some issues with data transfer (sneakernet) which have (hopefully) now been resolved

- **Has measured most recent blowdown**

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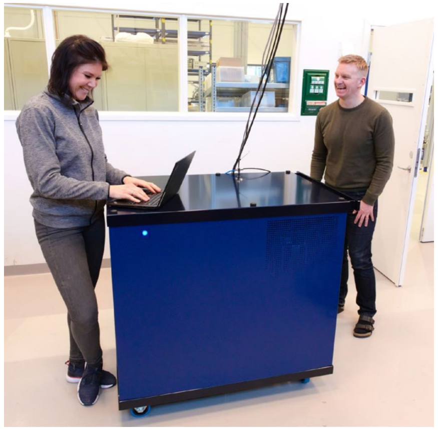
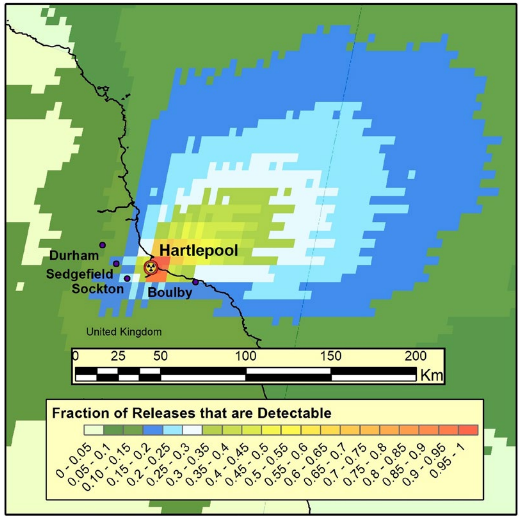
Stand-off measurements – 3 SAUNA detector array

Scienta SAUNA Qb specs

- Intakes atmospheric sample and produces ~1.3 cm^3 of xenon per period
- Sample time of 12 hours (includes gas conditioning)
- Qb consists of single $\beta-\gamma$ detector consisting of 18ml plastic scintillator detector inside a 4 inch NaI crystal
- ^{133}Xe MDC ~ 0.4 mBq/m^3





Hysplit simulations using one year of metrological data archived on a 25 km, 3 hr basis

Locations and goals

- 3 detectors (1 each from U.K., U.S. and Sweden) at different locations a few 10's of km around Hartlepool: **Boulby, Durham, Leeds**
- Comparisons of the stand-off measurements with predictions based on atmospheric transport of stack monitor results are a key measurement goal of the project
- Evaluate advantages of an array network over single station and how this could improve the IMS
- **System running at all 3 locations during March Blowdown**

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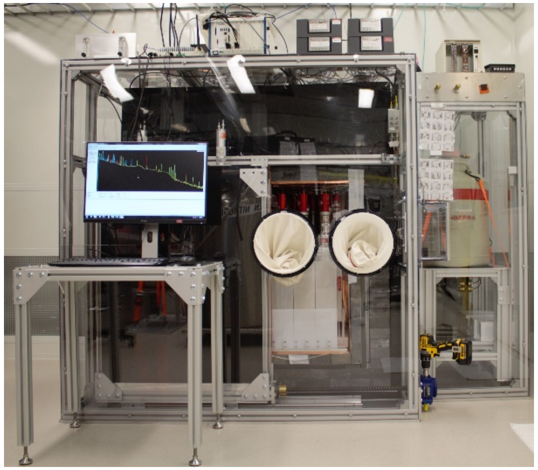
In-Core and Environmental sample analysis

In-Core measurements

- Gaseous Activity Monitoring (GAM) measures in-core coolant activity to assess fuel condition
- 40% HPGe detector feeding MCA for isotopic analysis and NIM modules for analogue Central Control Room (CCR) indications and alarms
- 1 hour acquisition, continuous flow of 1 litre/s
- Used to monitor for fuel performance – particularly during blowdowns
- **March Blowdown monitored**

Environmental measurements

- Maypack charcoal and paper filters provided from various locations at Hartlepool (pond stack, R6 blowdown Stack, GCMF etc)
- Samples measured at Boulby underground laboratory and the Shallow Underground Laboratory at PNNL
- Laboratories able to perform ultra-sensitive $\gamma-$ray spectroscopy. Usually used to measure treaty-relevant radionuclides
- ARGO at PNNL combines low background, cosmic veto, Compton suppression and coincidence functionality



Aim is to provide radionuclide fingerprint of an operating AGR

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XENAH Preliminary results

Measurements of recent emissions from Hartlepool

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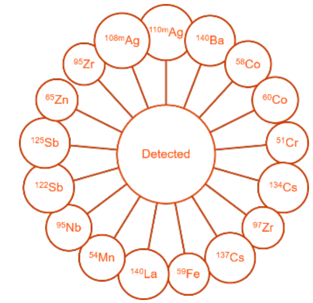
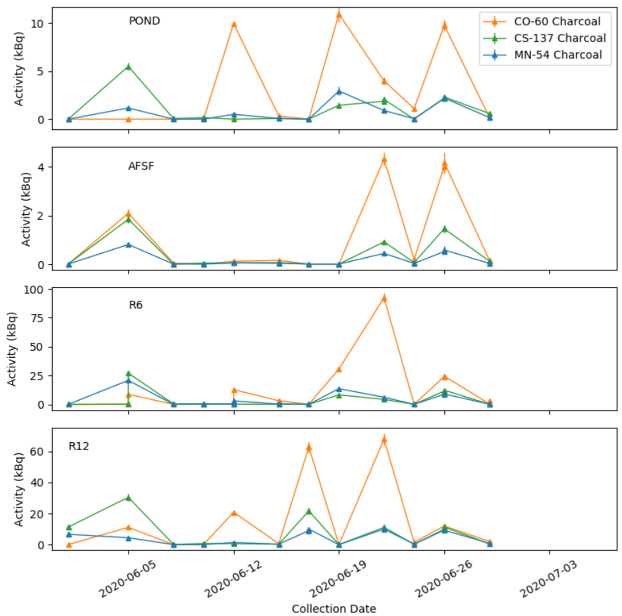
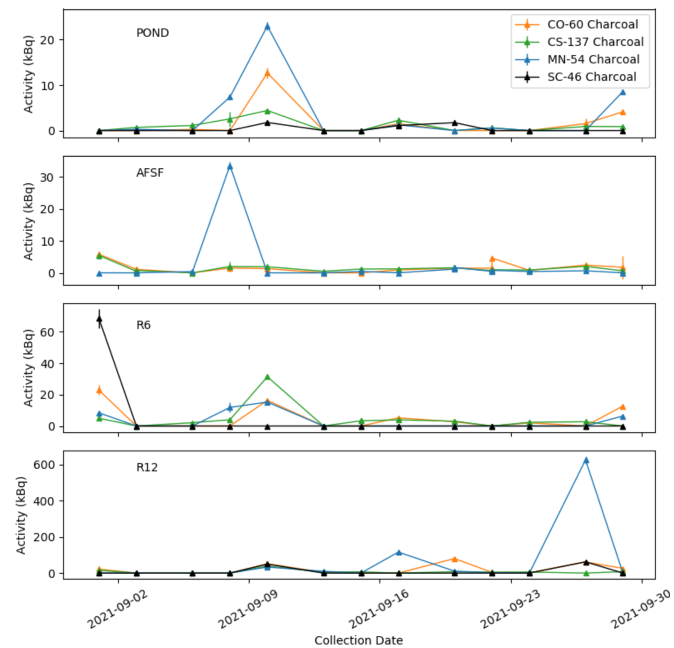
Ultra-sensitive sample analysis







- Prior to measurement at PNNL and AWE, each sample is measured using conventional gamma-spectrometry systems at EDF Energy for environmental compliance
- 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., **many of these are sometimes seen in IMS data**
- Analysis focused on longer-lived radionuclides (e.g. ^{54}Mn, ^{58}Co, ^{60}Co, ^{137}Cs) at fuel handling locations
- **Measurements reveal increases in radionuclide activities during fuel handling**
- Information from activation-product discharges could possibly infer if a facility is handling nuclear material

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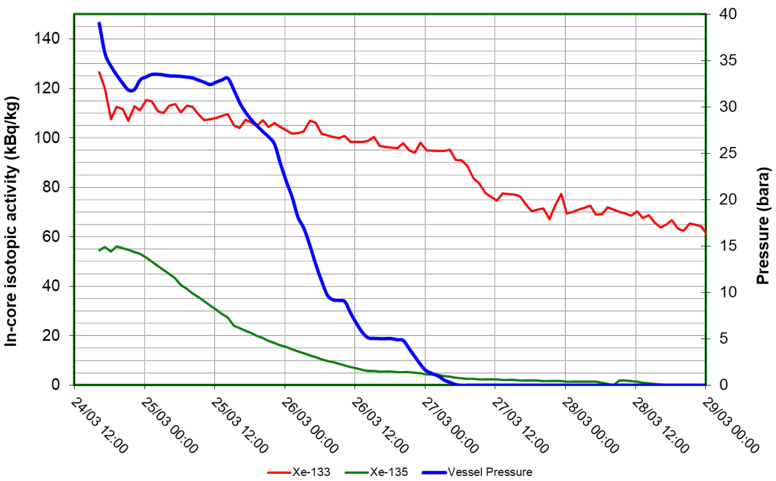
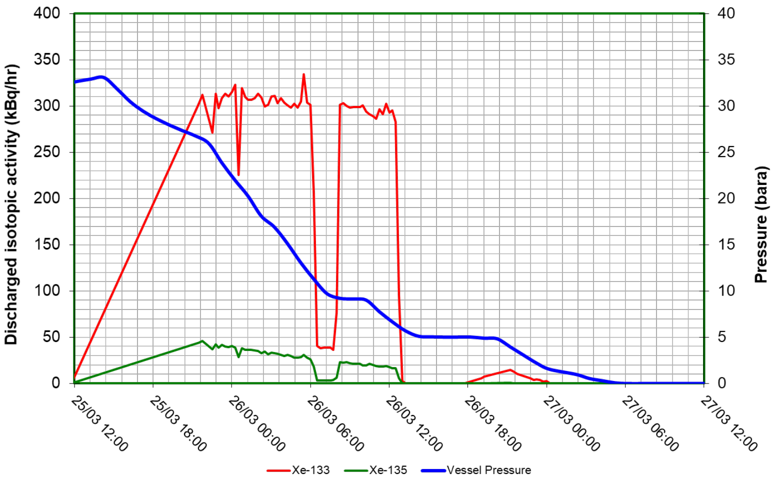
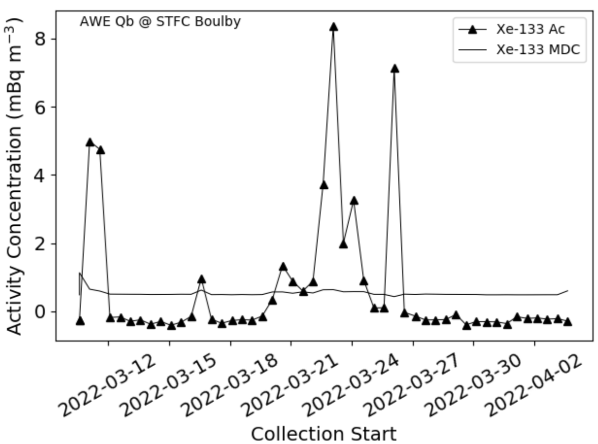
Radio-xenon measurements of March blowdown







- GAM system measured ^{133}Xe and ^{135}Xe activity during depressurisation with a typical profile observed
- Stack monitor detected xenon isotopes going up through the stack. Some data drop outs during blowdown
- Boulby Qb also detected an above-background ^{133}Xe signature during period of blowdown

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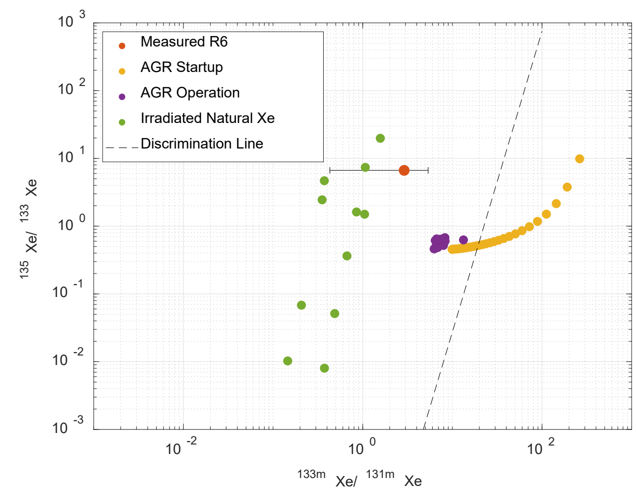
Next Steps…

- Measure next major emission in June looking at correlations in core data, stack data and Qb data
- Analyse current data sets from March blowdown looking particularly at xenon ratios, comparing with Kalinowski plot
- Submit paper to PAGEOPH covering Environmental sample analysis
- **Analyse 5 years worth of in-core coolant activity specifically xenon ratios**
- Obtain/produce AGR ‘fingerprint’ from emissions data
- Compare Qb array performance and detections to ATM predictions
- **Produce over-arching paper covering in-core -> Stack - > atmosphere emissions from an operating nuclear facility**

XENAH



Calculation of the radioxenon isotope ratios shows values right of the nuclear explosion discrimination line during AGR start-up and left during routine AGR operation.

- Hartlepool is also collaborating with the AIT-WATCHMAN project to assess anti-neutrino emissions from a nuclear facility for non-proliferation purposes.

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Thank You

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