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Ultra Sensitive Measurements of Airbourne Nuclear Debris

Richard Britton, Ashley Davies, Nikolaus Hermanspahn

CTBTO

INTRODUCTION AND MAIN RESULTS

The Comprehensive Nuclear Test-Ban Treaty (CTBT) International Monitoring System (IMS) is designed to provide a network of 80 Radionuclide detection systems, strategically positioned around the globe to detect particulate radionuclide emissions from nuclear explosions.

The implementation of ultra-sensitive monitoring systems to the IMS, incorporating gamma coincidence measurements into routine operations, provides both redundancy of the Treaty measurement and the potential to detect radionuclides at a threshold 100x lower than the current systems.

Progress towards the implementation, and benefits of the work, are discussed.

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Detecting UGTs on the IMS

IMS particulate (P) monitors typically achieve μBq.m^{-3} detection limits, which is ~1000 times more sensitive than Noble Gas (NG) monitors. The IMS has automated and manual stations, each providing 24/7 monitoring within an 80 station network design. Currently there are 73 P & 26 NG stations certified.

Gamma coincidence systems are widely used in both IMS laboratories and in the field. Applying this technology to current P monitoring stations can improve the sensitivity by up to 100x, pushing the MDCs down into the nBq.m^{-3} regime.

Such an advance brings numerous benefits, including the sensitivity to measure a UGT with a prompt vent beyond what is possible using the NG network, despite the fact that the major particulate signature is a ^{140}Xe (Noble Gas) decay product.

Station mode MDA [mBq]	^{140}Ba	^{99}Mo	^{140}La	^{131}I
IMS station - RN67	142	281	66	46
VIP00 system - station mode - singles	141	439	66	38
VIP00 system - station mode - dual	99	310	46	27
VIP00 system - station mode - $\gamma-\gamma$	84	44	7	49

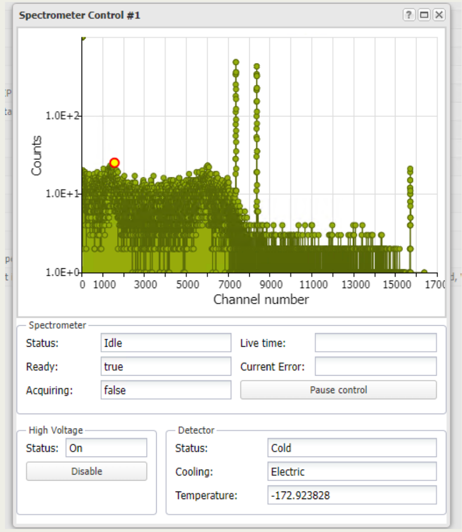
Laboratory mode MDA [mBq]	^{140}Ba	^{99}Mo	^{140}La	^{131}I
IMS laboratory - highest	79	5657	62	50
IMS laboratory - lowest	19	170	9	17
IMS laboratory - average	43	1636	26	27
VIP00 system - lab mode - singles	60	3648	23	29
VIP00 system - lab mode - dual	42	2561	16	21
VIP00 system - lab mode - $\gamma-\gamma$	11	491	9	67

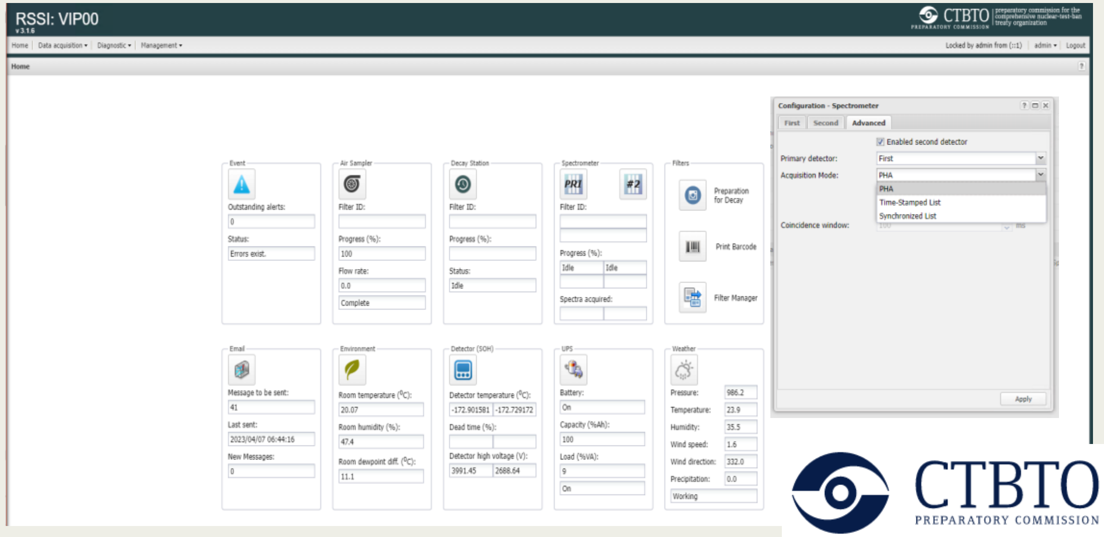
Above – MDAs for a range of nuclei, demonstrating the significant improvements in sensitivity that are possible with a dual detector system.

CURRENT IMPLEMENTATION AT VIP00

Clockwise from the left:
- Dual system at VIP00
- MCAs used and tested (LYNX 1&2)
- Snow White sampler on the roof of the VIC
- RSSI2 station software, with easy switching between single, dual and synchronised operations
- RSSI2 spectra diagnostics for real-time updates

Modified station configuration with dual detector setup (two electrically cooled HPGe, with LYNX2 MCAs:
- Improved reliability (one detector failure does not compromise treaty measurement)
- Simplified setup using COTS components
- Additional Measurement capability (Pulse Height, List-mode, Synchronized List mode)
- Improved Data Availability
- Fully integrated in the latest version of RSSI
- Data compatible with F&P Rev8
- Improved analysis potential for NDC's
- Best use of spare detector, which should be kept cold and operational to prolong its useful life





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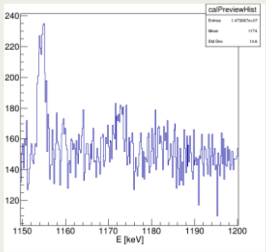
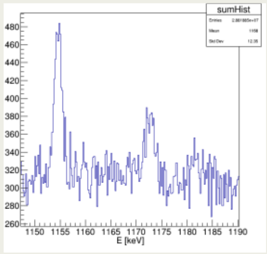
γ–γ COINCIDENCE MEASUREMENTS – EXAMPLE SCENARIOS

Eliminating false positives

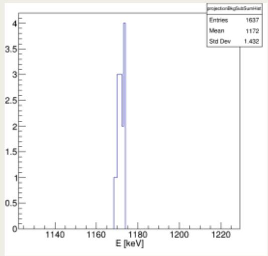
- false positives create significant additional work for both IDC and NDC analysts
- dual systems provide a big step forward – coincidence systems a giant leap



^{60}Co / standard detector
Analyst: Inconclusive



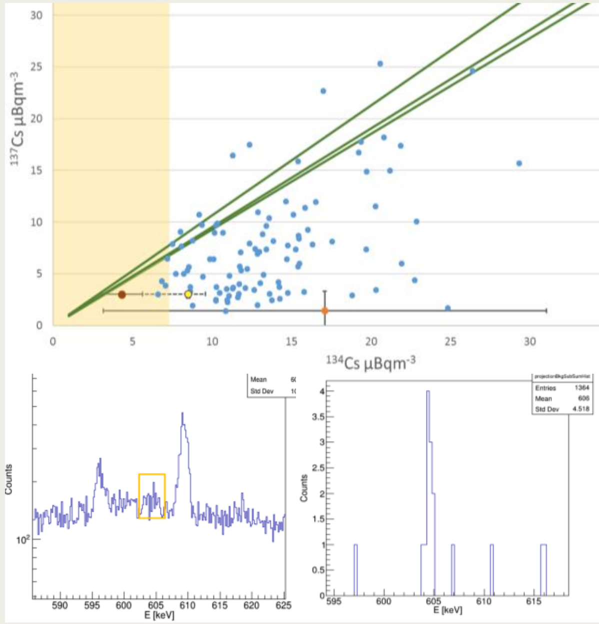
^{60}Co / dual detector mode
Analyst: Probable



^{60}Co / coincidence mode
Analyst: Indisputable

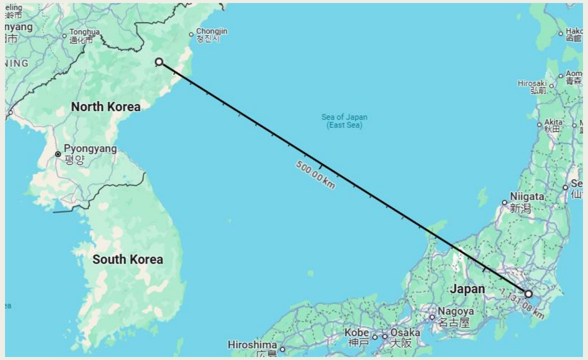
Improved results, better verification

- post Fukushima, IMS detections were often seen with a potential excess of ^{134}Cs
- bias mostly seen at low ^{134}Cs concentrations, typically due to poor peak fitting and low statistics
- with dual detector systems, measured values fall much closer to the theoretical decay corrected ^{134}Cs/^{137}Cs ratio
- [1] Based on the ^{137}Cs/^{134}Cs expected from fuel compositions in Fukushima-Daiichi nuclear power plant. JAEA-Data/Code 2012-018, Japan Atomic Nishihara, K., Iwamoto, H. and Suyama, K. (2012)



Spiked sample to mimic a typical measurement that could occur from a UGT

- prompt gas release of 0.025% ^{140}Xe from a 1 kT device
- dilution factor of 10^{17}, to mimic typical transport across ~1000 km
- ^{140}Xe promptly decays into ^{140}Ba/La, providing a clear signature and nuclear clock with which to calculate fission zero time
- this scenario would go undetected on the current IMS
- using a dual detector system, you could measure it and get a zerotime
- <u>using a dual system in coincidence, you could measure a signal 10x smaller (less release, or smaller UGT)</u>



Mode	Energy	Signal (MDA), mBq	Zero time	Conclusion
Current IMS	^{140}Ba (537keV)	MDA (190-610)	Not Determined	No Detection
IMS (RN67)	^{140}Ba (537keV)	216 (142)	Not Determined	Detection, no zero time
Dual System (Sum)	^{140}Ba (537keV) ^{140}La (487keV)	153 (99) 66 (46)	18/3/2020 17:01	Detection and zero time
Dual System (coincidence)	^{140}Ba (305keV gate 162keV) ^{140}La (487keV gate 328keV)	156 (84) 67 (7)	18/3/2020 17:33	Detection and zero time

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γ–γ COINCIDENCE MEASUREMENTS – REFERENCES AND LINKS

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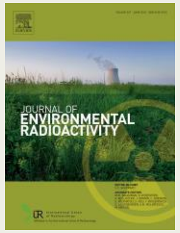

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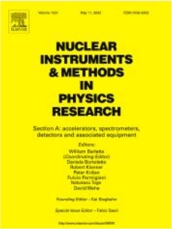

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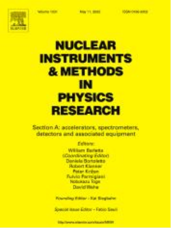

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