Real-time Primary Coolant Isotopic Trending using 3-D Pixelated CZT Spectrometers

Weiyi Wang, Ph.D.

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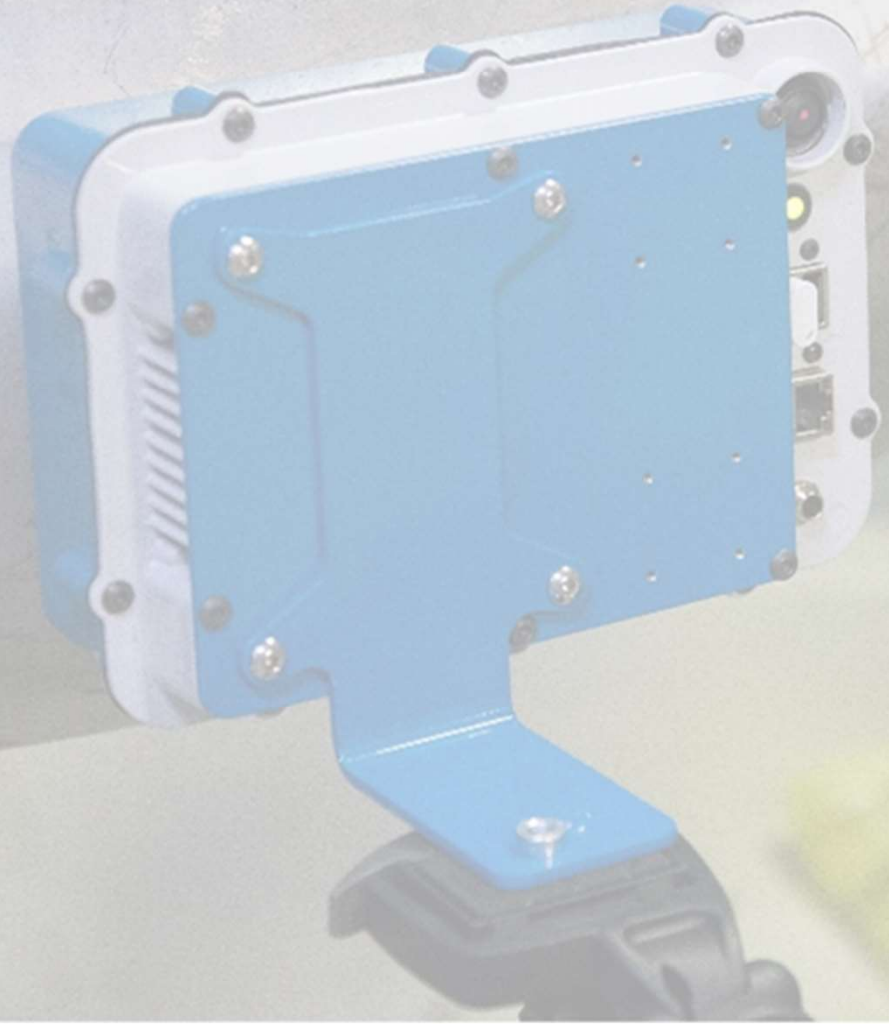
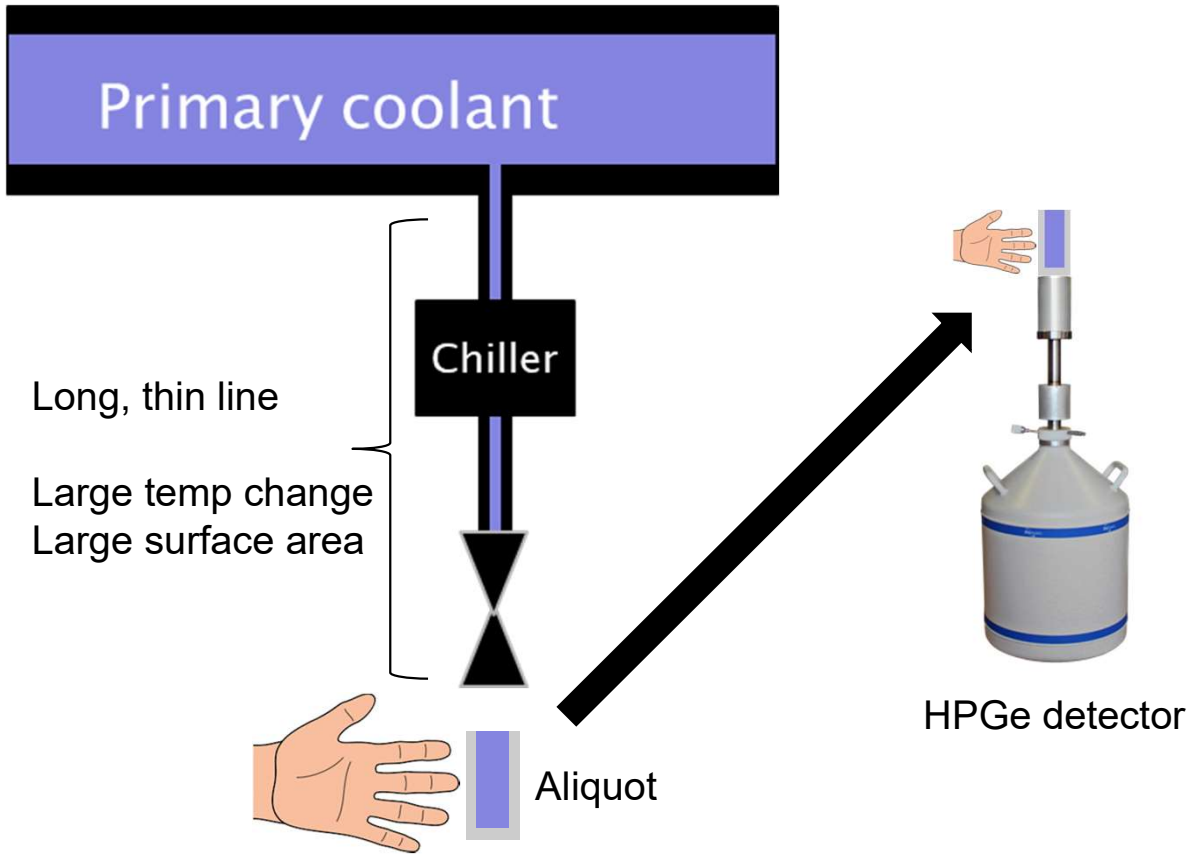
GammaTrend Introduction

- Field-deployable gamma spectroscopy and software tools to monitor radionuclide *trends* over time.
- Supplements traditional Chemistry water sampling:



- Minute-by-minute (continuous) results
- Much more data than manual sampling
- Detailed understanding of when changes occurred to facilitate learning
- Better understanding of how transport of radionuclides occurs, including differences in soluble and insoluble species

Traditional Coolant Sampling



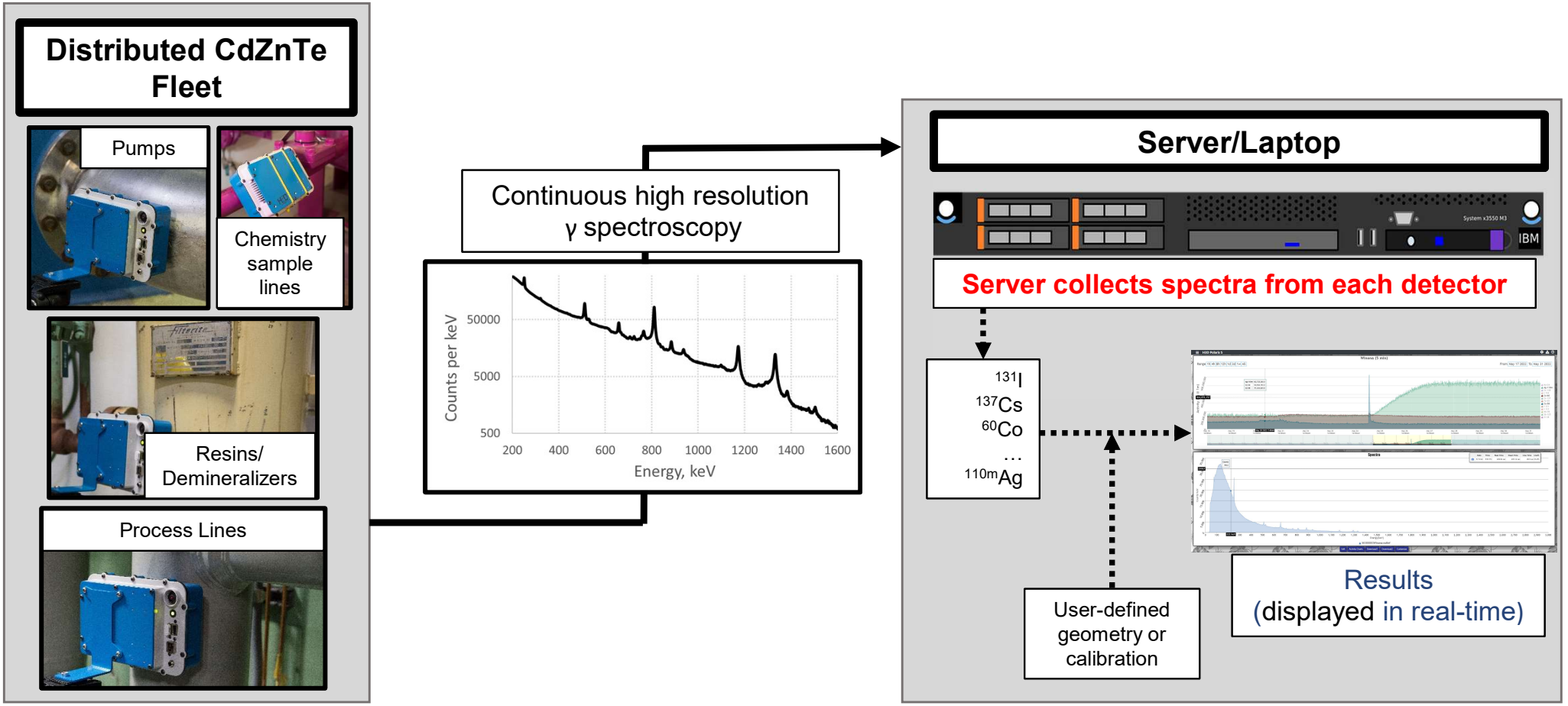
Pros:

- **Tradition**
- MDA (certain isotopes)
- Decay measurements to reduce impact of short-lived species
- Separate soluble from particulate (of the sample contents)

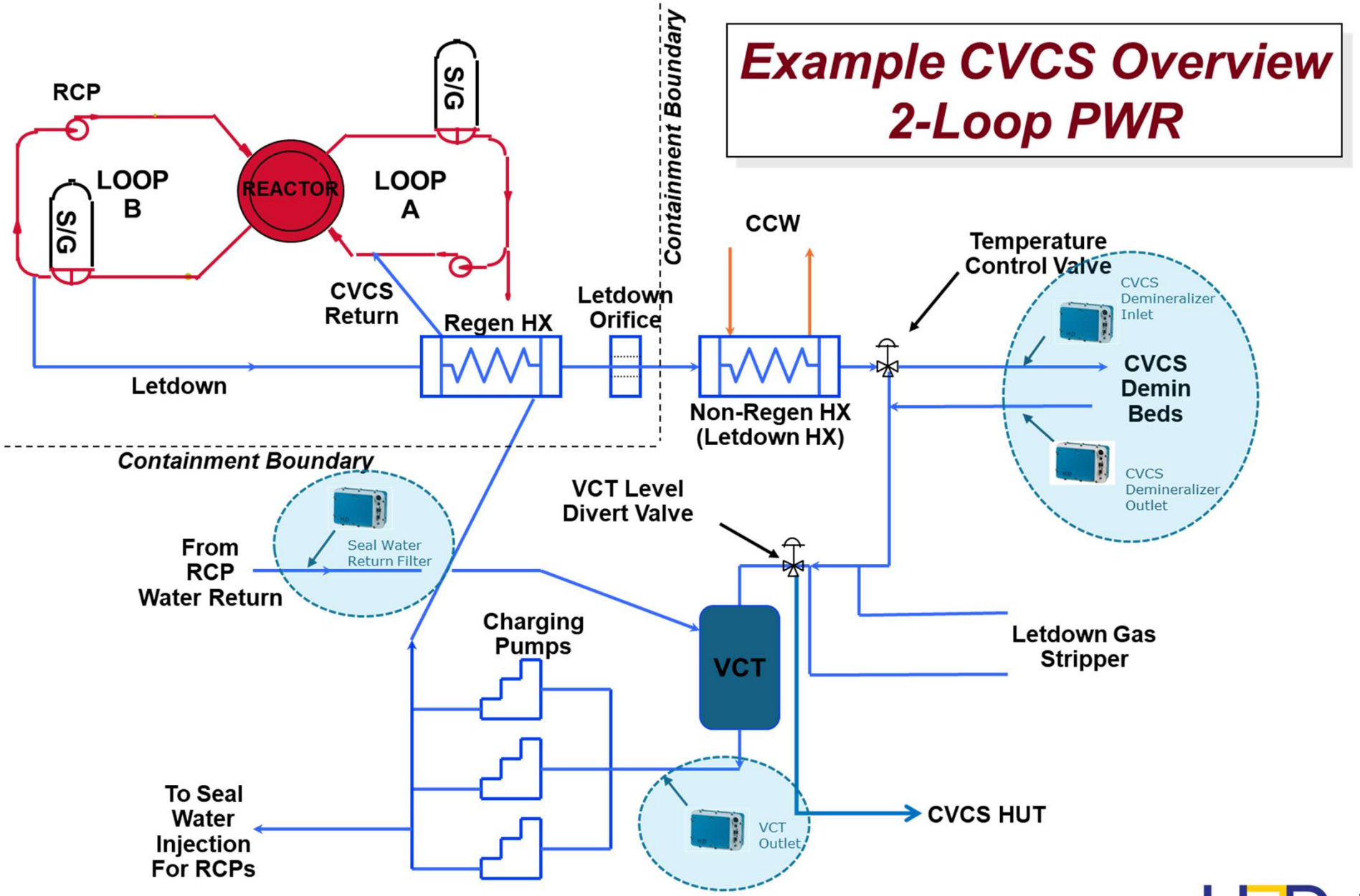
Cons:

- **Cost** (labor)
- **Dose** (valve in radiological area)
- Significant time between samples
- Limited number of sampling locations
- **Insoluble particulate may not make it into the sample**

Real-Time Process Monitoring/Trending



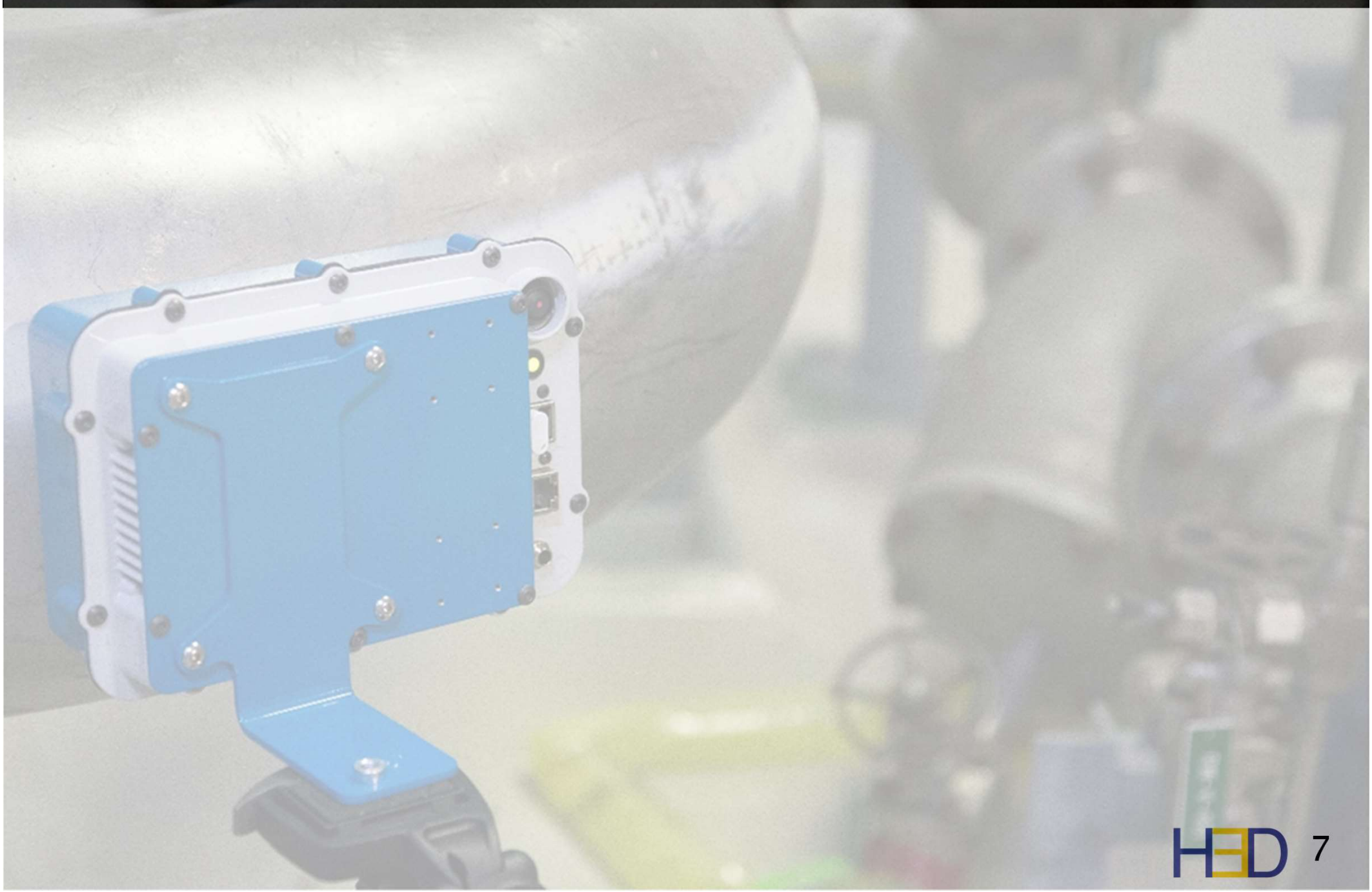
Typical Measurement Strategy



Multiple Use Cases for Real-Time Spectrometry

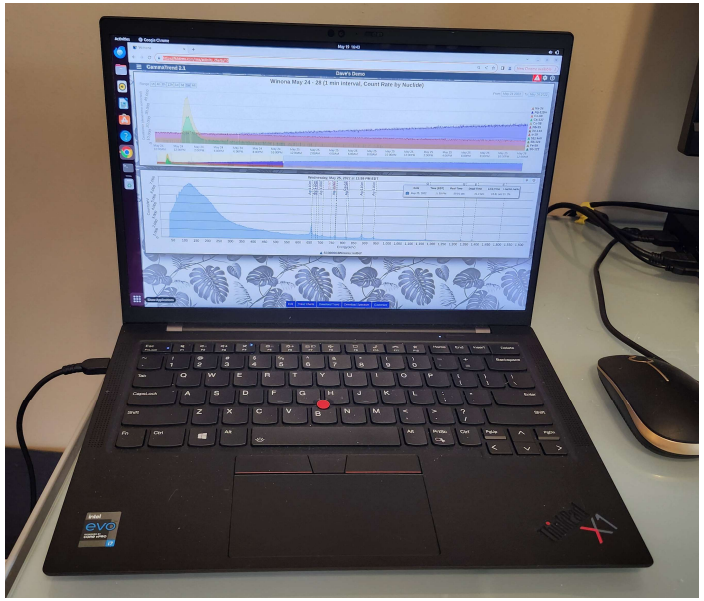
- Monitoring Forced Oxidation and Hydrazine Additions During Outages (CRUD-burst monitoring at Pressurized Water Reactors)
- Online Xenon Monitoring for Fuel Defects
- Inputs into Strategic Source Term Evaluations (Comparisons between Operating Cycles, Units, Sites)
- Investigating Impacts of Planned Changes in Reactor Water Chemistry (for instance, Piloting KOH vs. LiOH in US PWRs)

Use Case: Real-Time CRUD Burst Monitoring

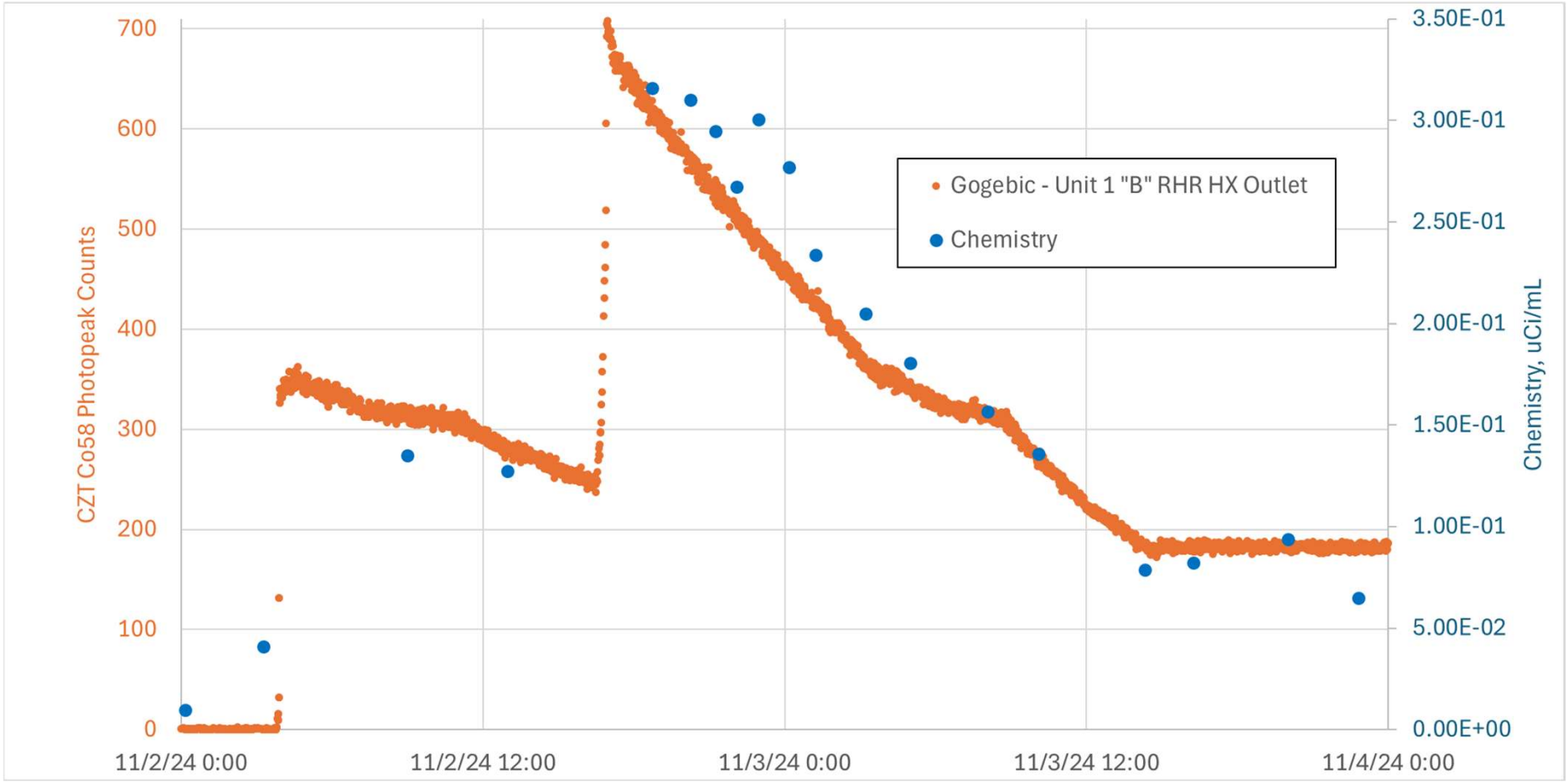


Use Case: Real-Time CRUD Burst Monitoring

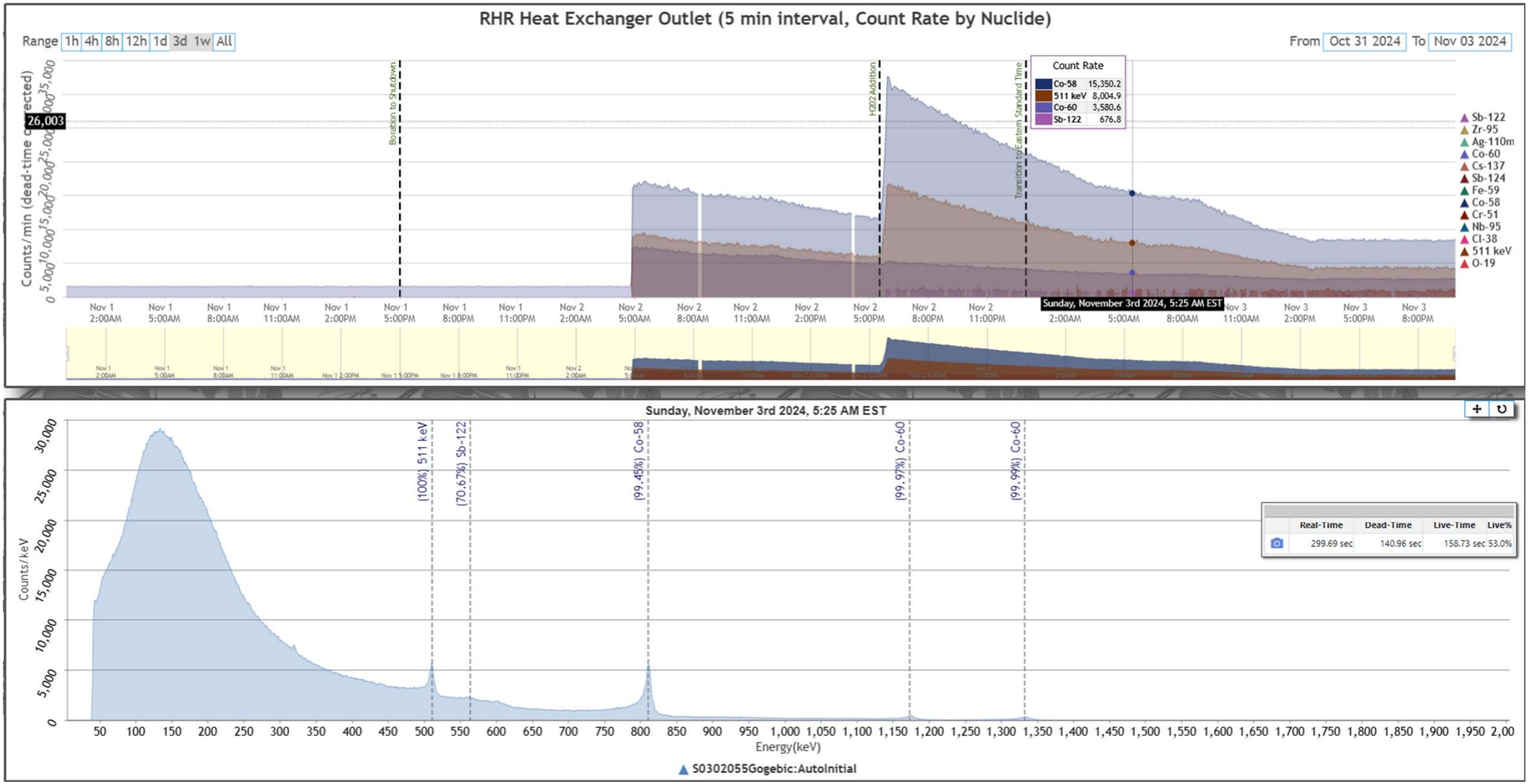
- Installed real-time in-field gamma spectrometers for a Fall 2024 refueling outage
- Four S100 instruments were installed at:
  - Letdown heat exchanger outlet
  - 1B RHR heat exchanger outlet
  - RCS Filter Outlet
  - Pipe Chase
- Detectors collected continuous (1-minute duration) gamma spectra from each location.
- Data transmitted via Xbee radio to H3D-provided server laptop
  - Real-time display
  - Analysis tools



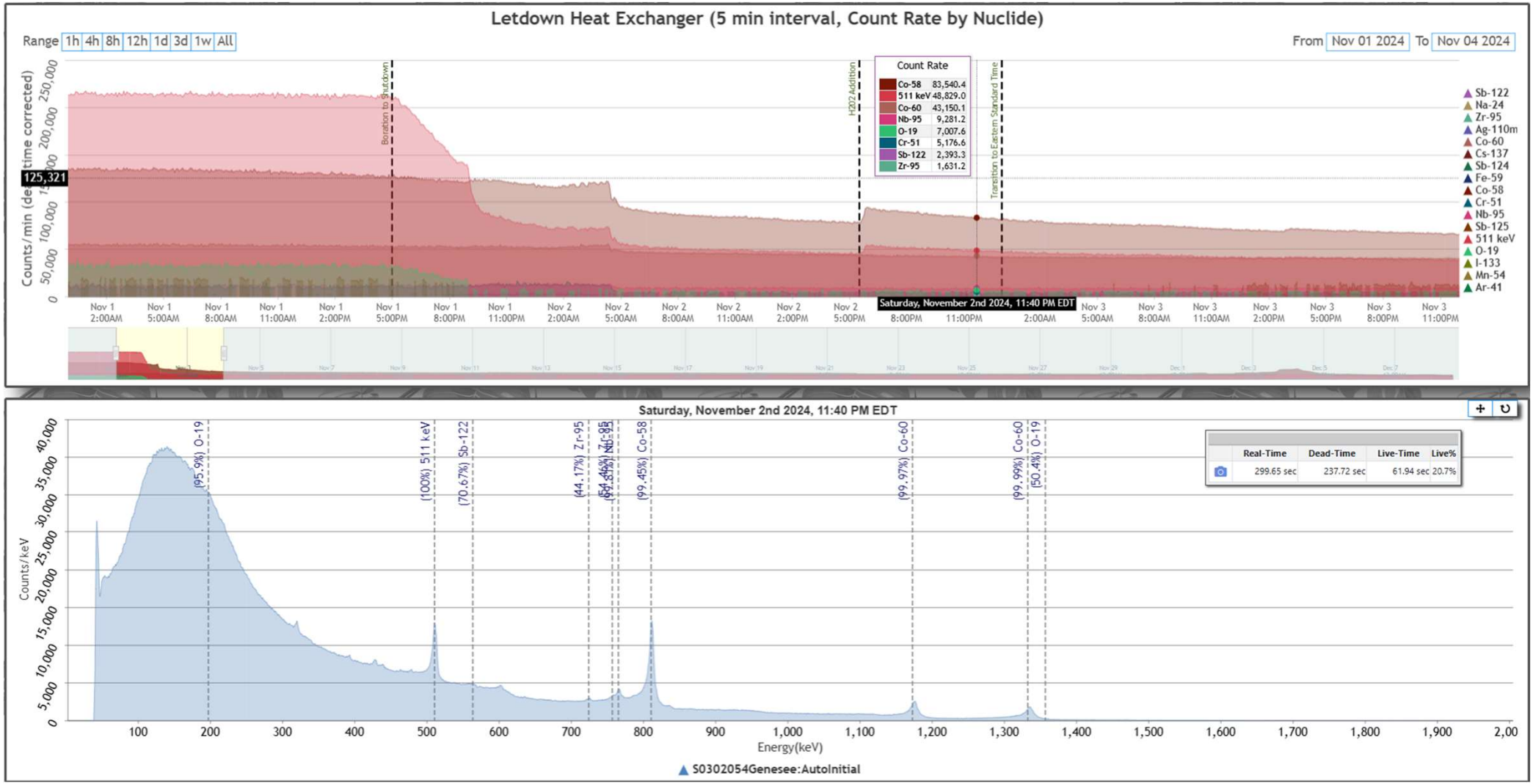
Results during Forced Oxidation



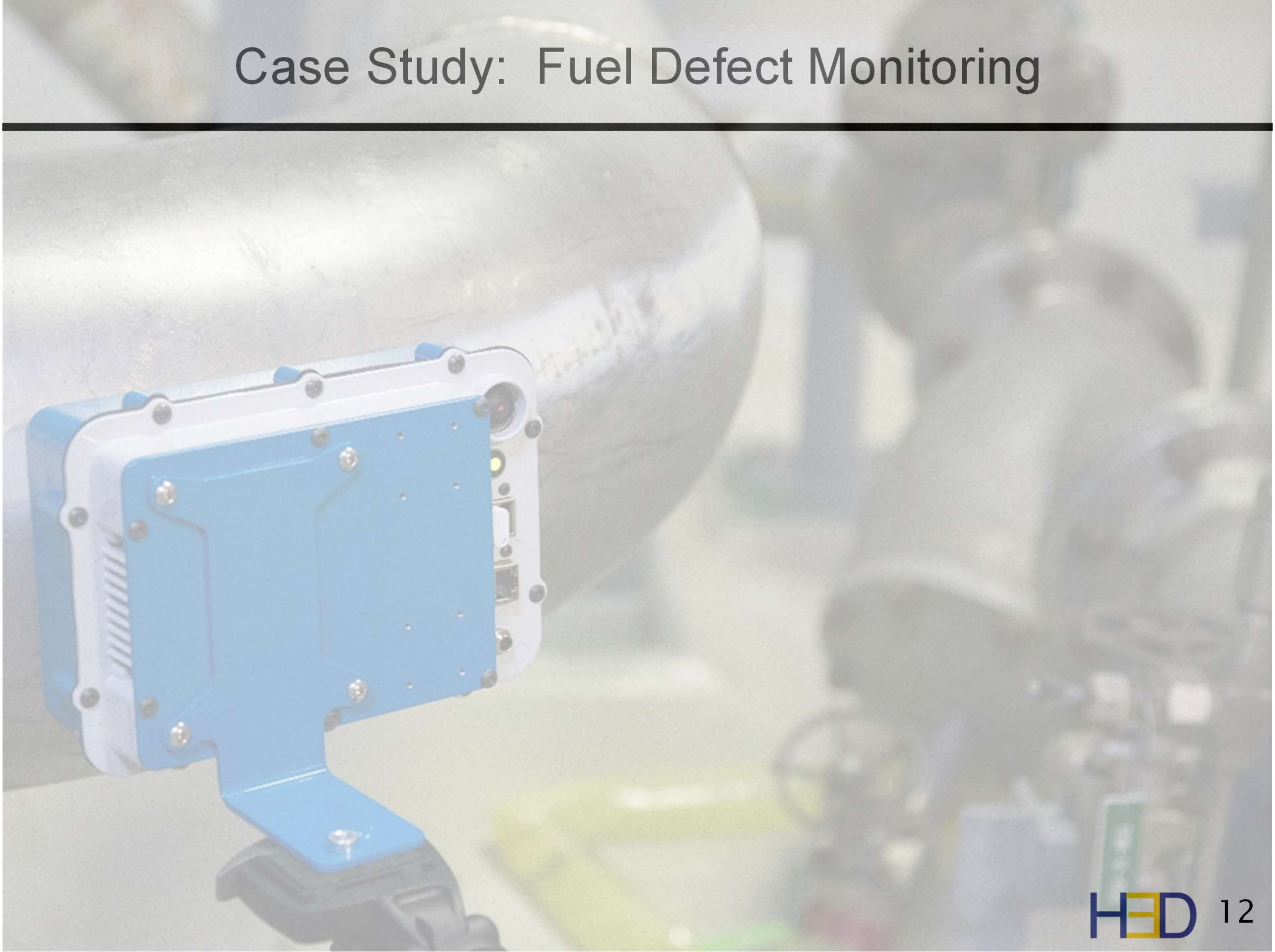
Forced Oxidation Period (Residual Heat Removal System)



Forced Oxidation Period (Letdown System)



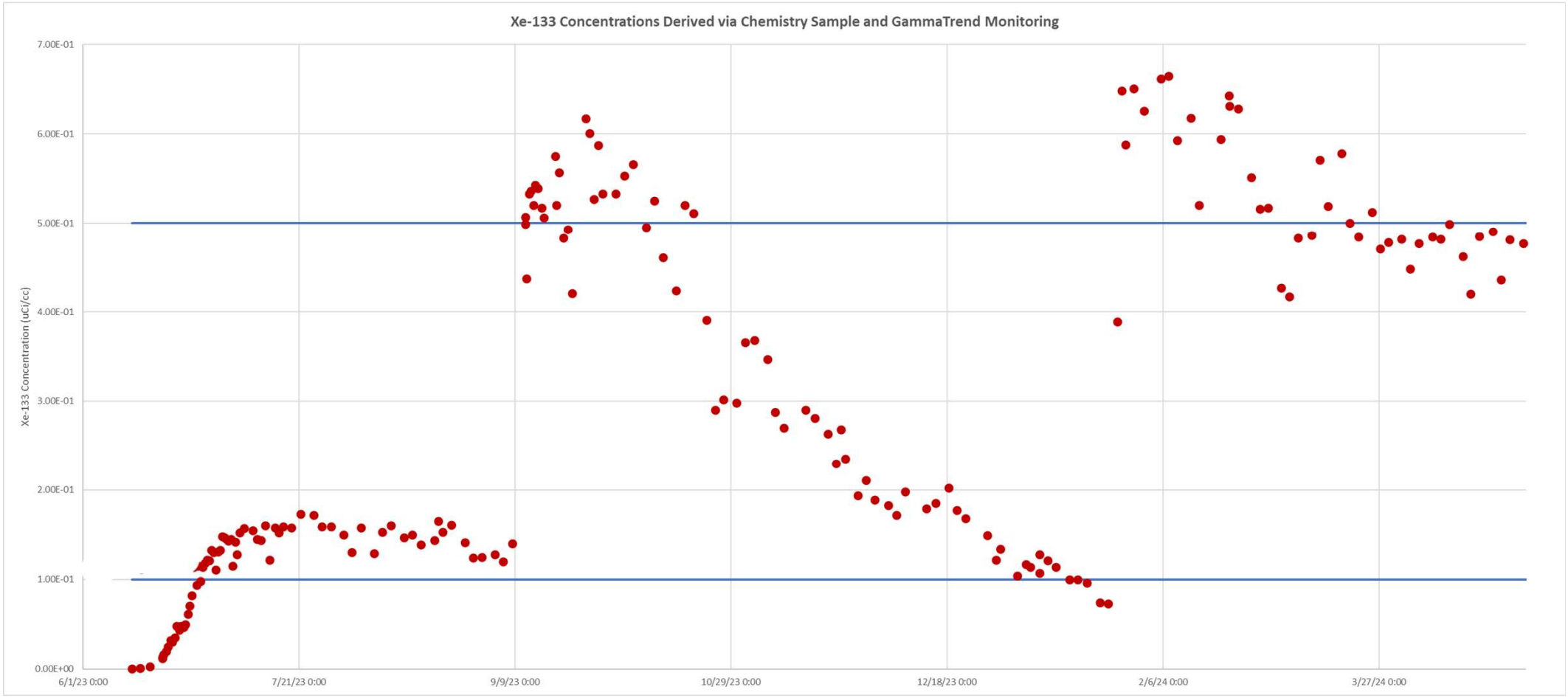
Case Study: Fuel Defect Monitoring



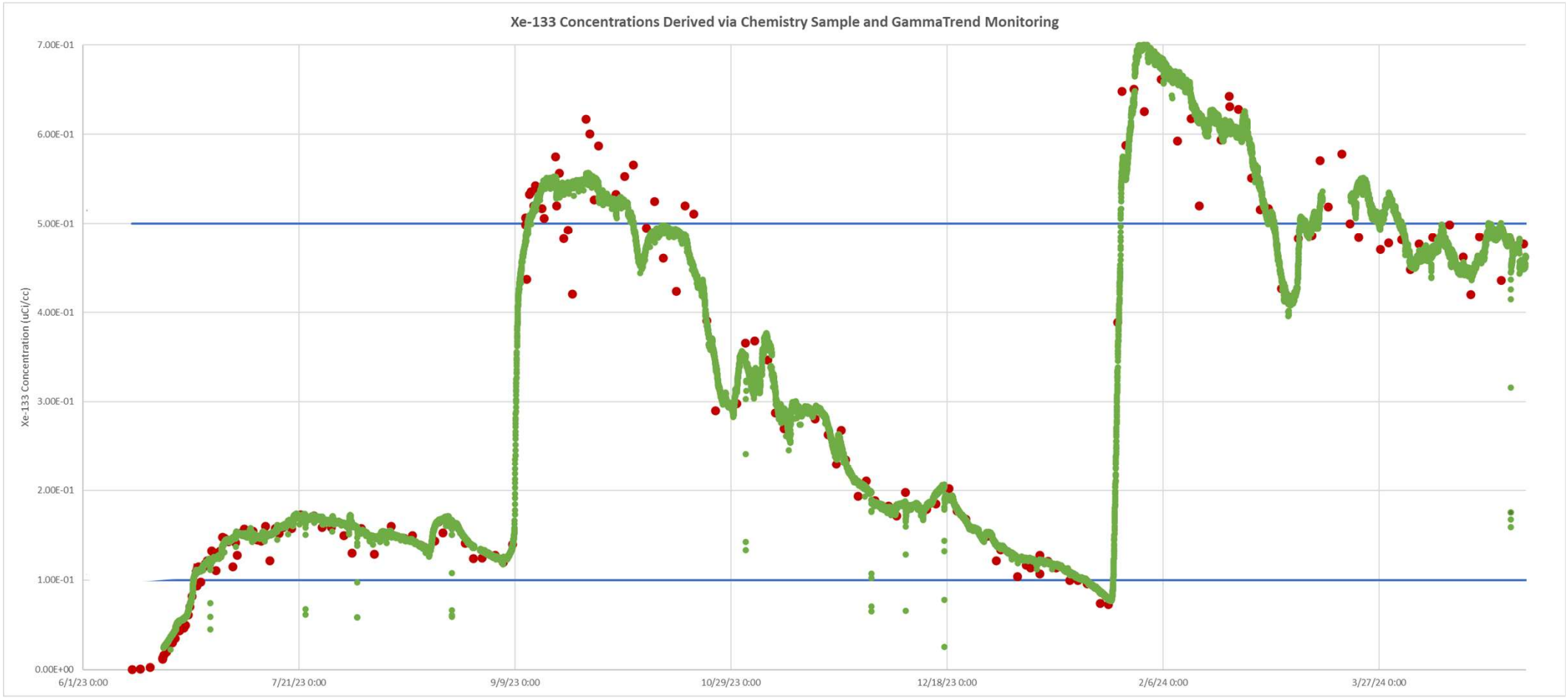
Case Study: Fuel Defect Monitoring

- 2023 Implementation of field spectrometers prior to refueling outage
- Monitoring performed continuously during outage and subsequently during plant operation

Xe-133 Trend


Xe-133 Concentrations Derived via Chemistry Sample and GammaTrend Monitoring
Xe-133 Concentration (uCi/cc)
7.00E-01
6.00E-01
5.00E-01
4.00E-01
3.00E-01
2.00E-01
1.00E-01
0.00E+00
6/1/23 0:00
7/21/23 0:00
9/9/23 0:00
10/29/23 0:00
12/18/23 0:00
2/6/24 0:00
3/27/24 0:00

Xe-133 Trend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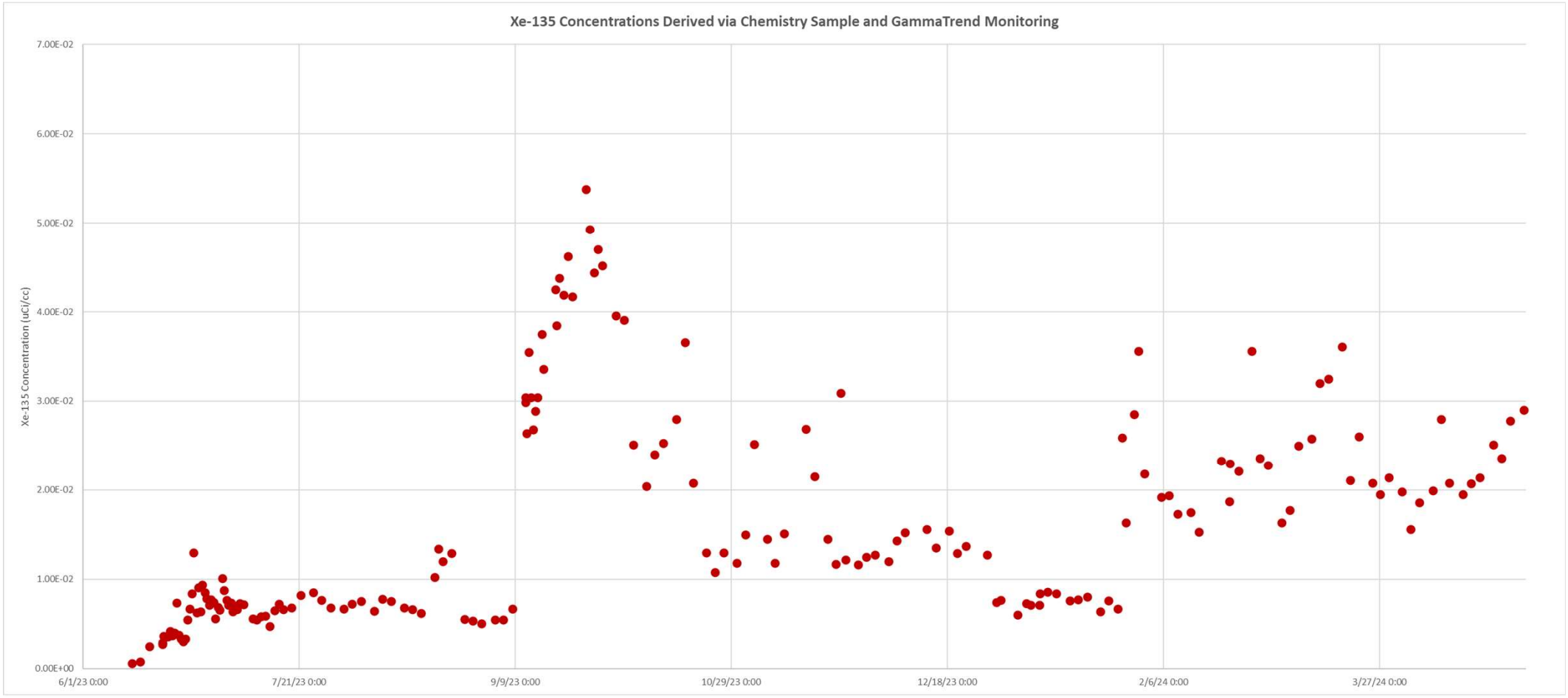
10/29/23 0:00
12/18/23 0:00
2/6/24 0:00
3/27/24 0:00

Xe-135 Trend


Xe-135 Concentrations Derived via Chemistry Sample and GammaTrend Monitoring
Xe-135 Concentration (uCi/cc)
7.00E-02
6.00E-02
5.00E-02
4.00E-02
3.00E-02
2.00E-02
1.00E-02
0.00E+00
6/1/23 0:00
7/21/23 0:00
9/9/23 0:00
10/29/23 0:00
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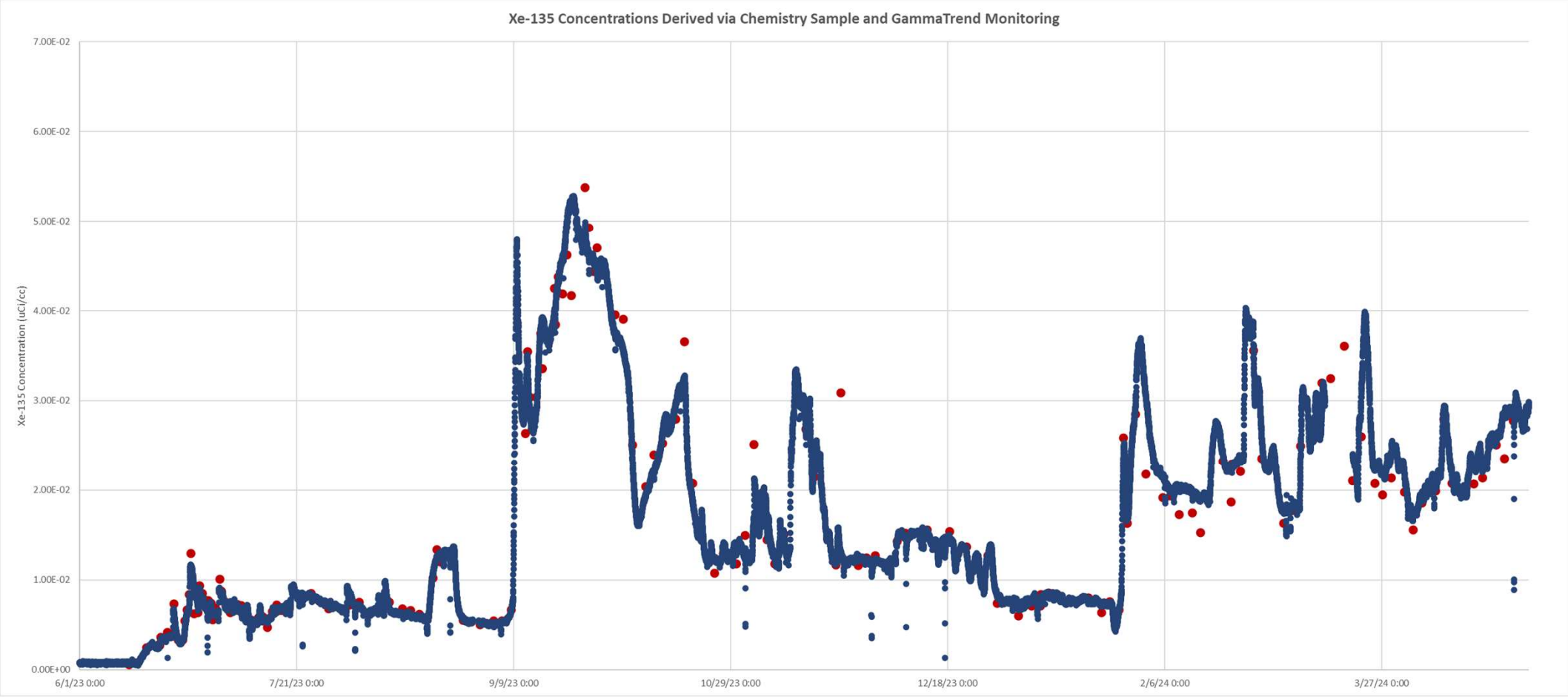
3/27/24 0:00

Xe-135 Trend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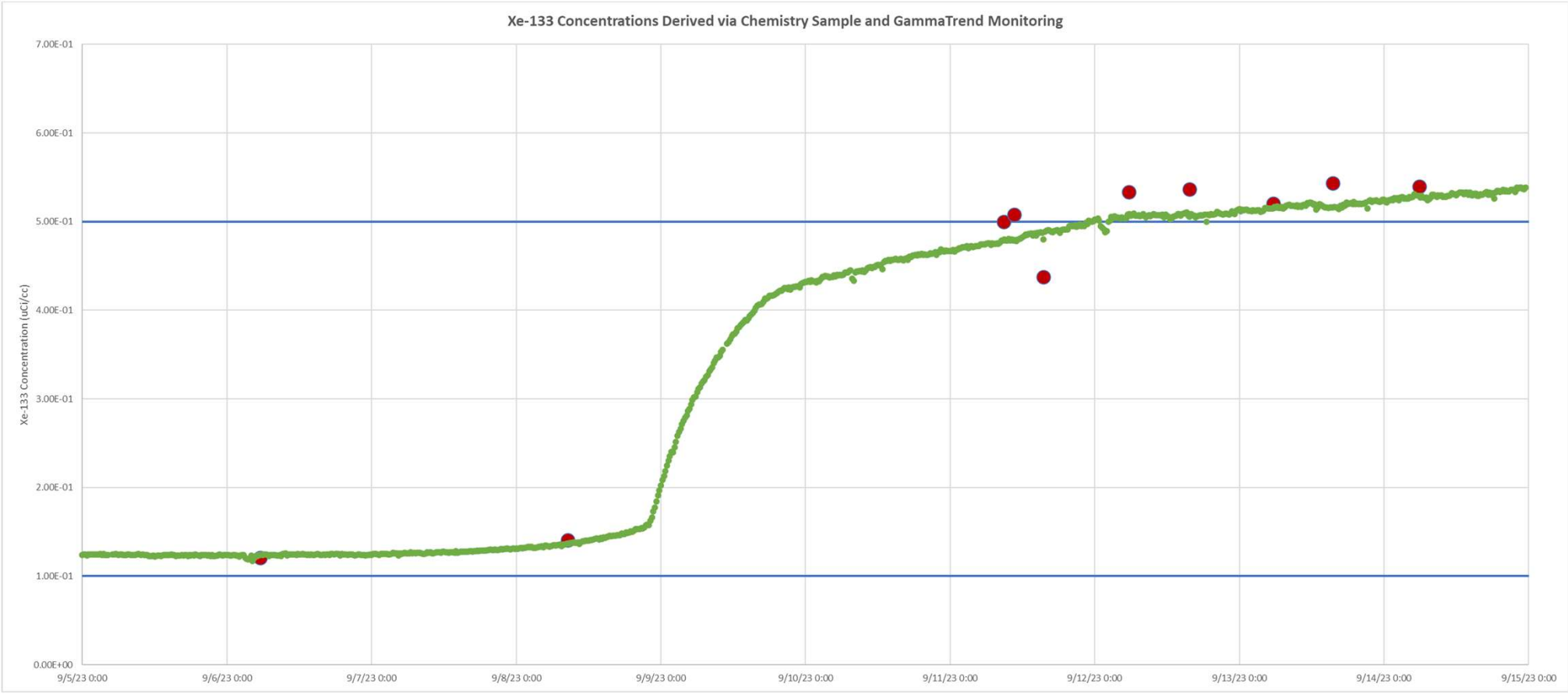
Xe-133 Trend (Initial Step Change)



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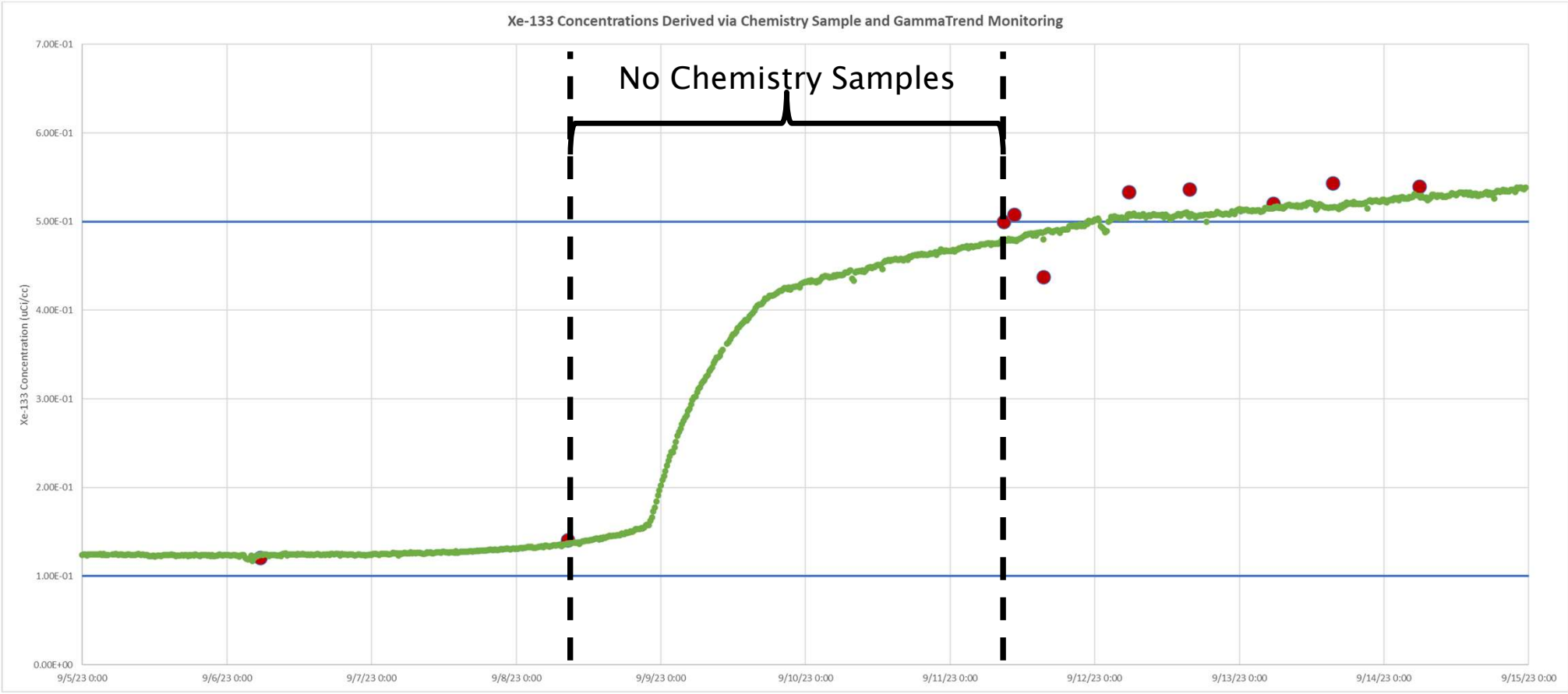

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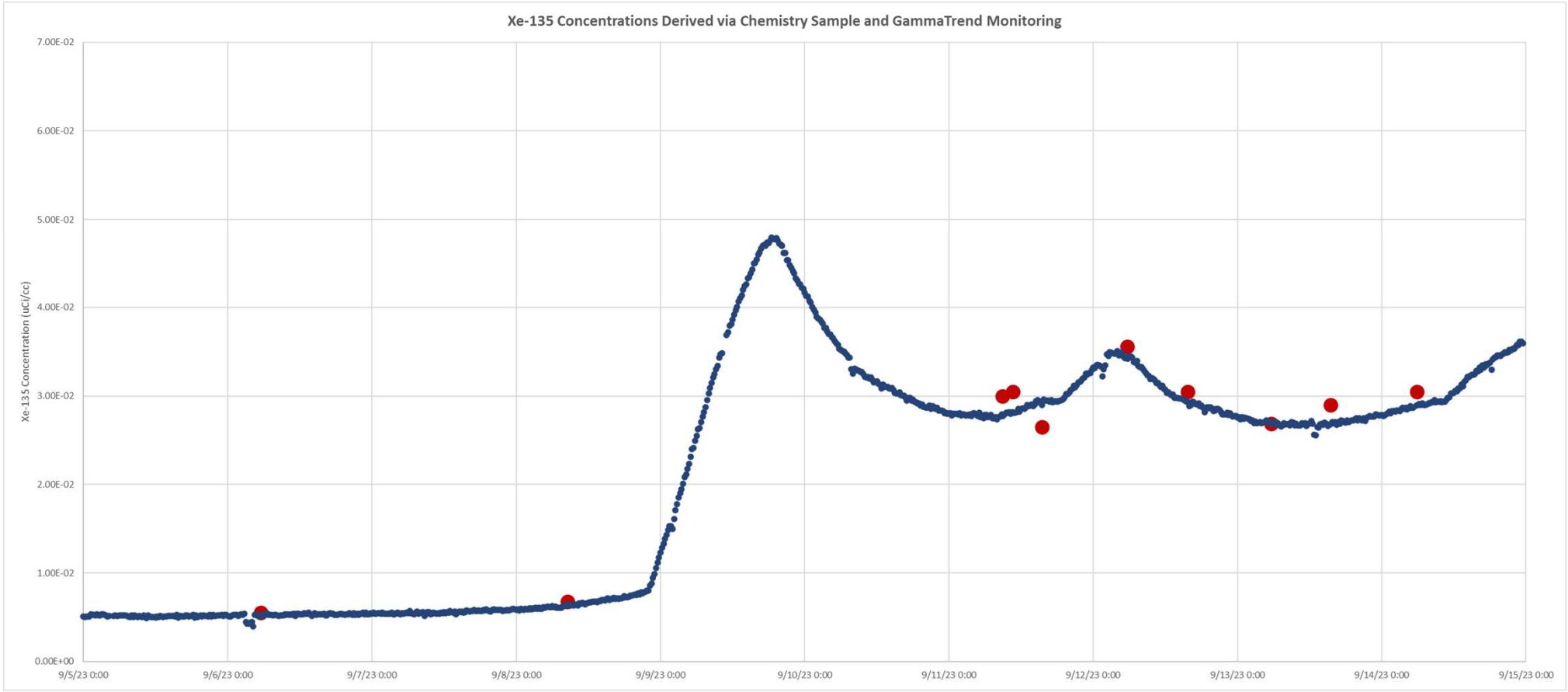

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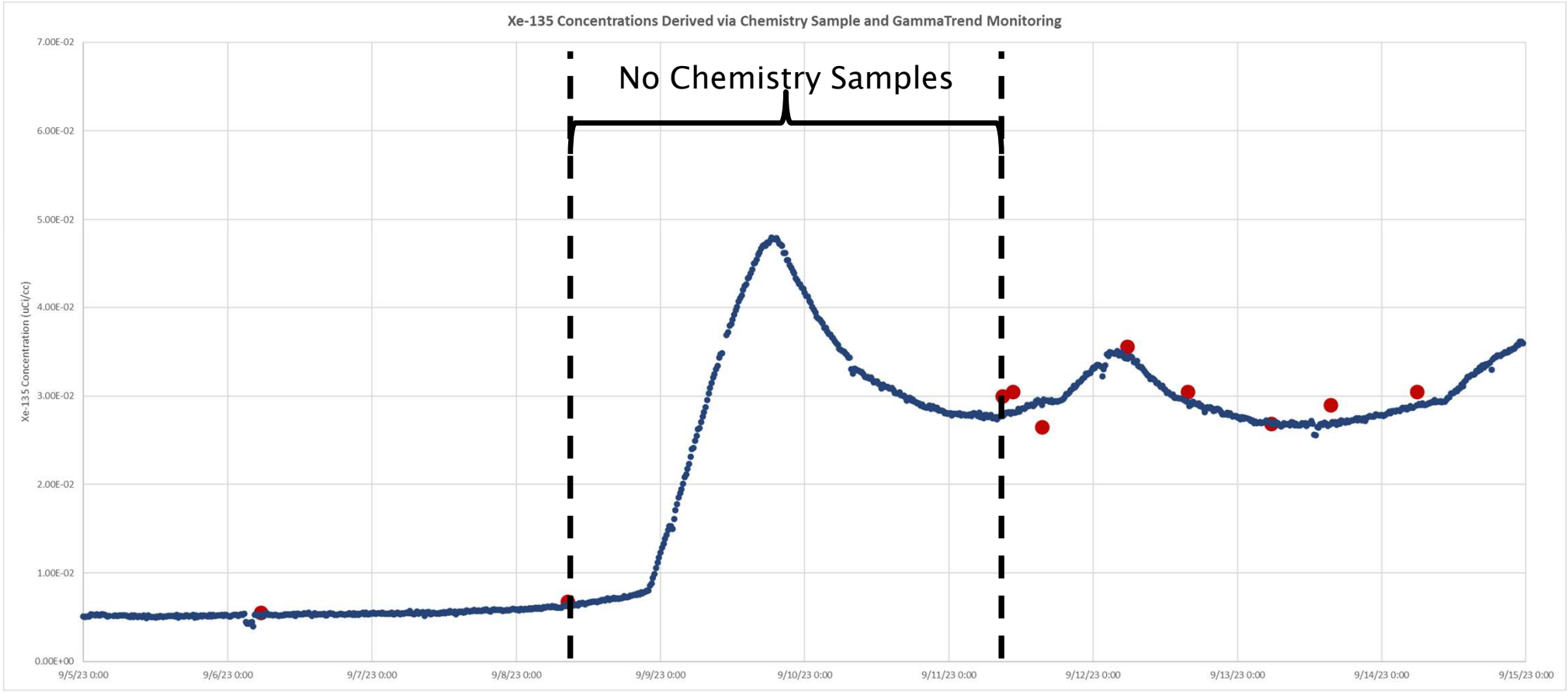
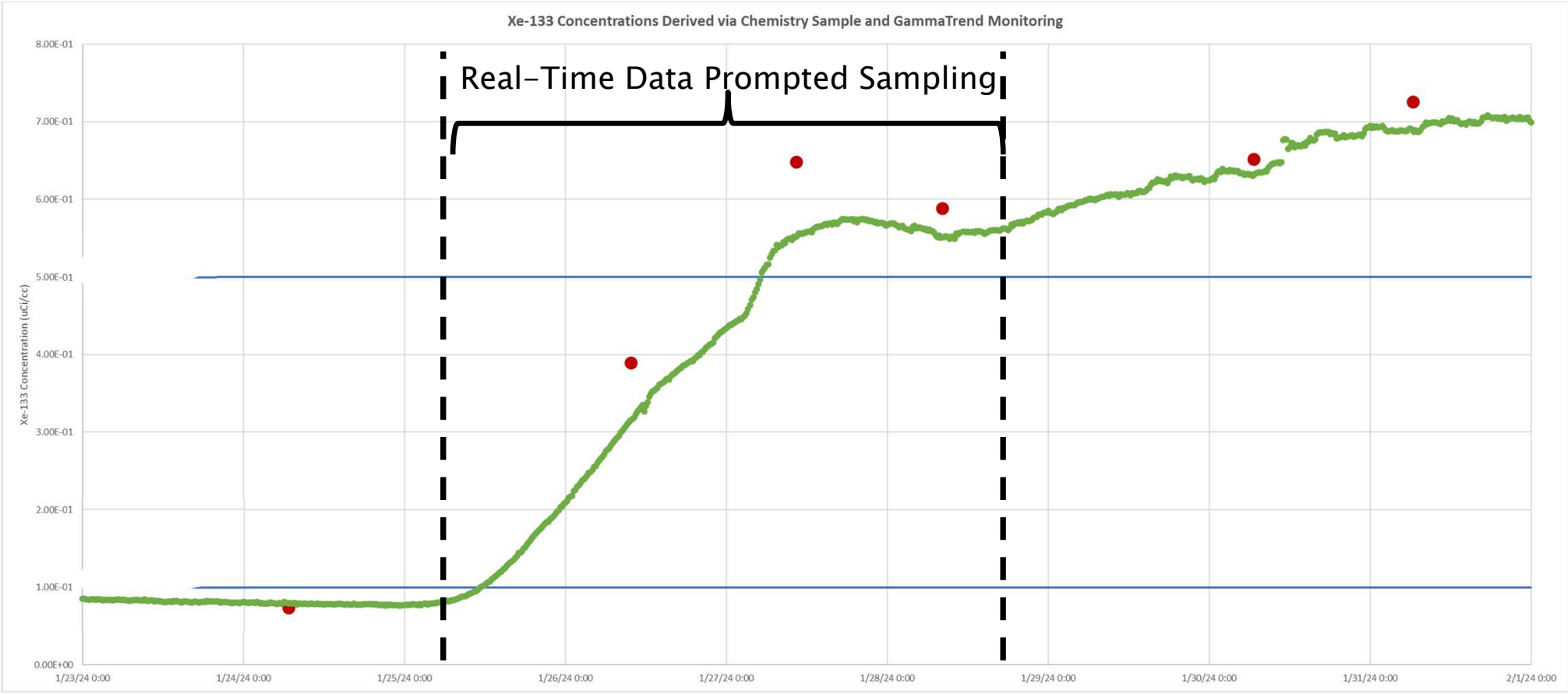
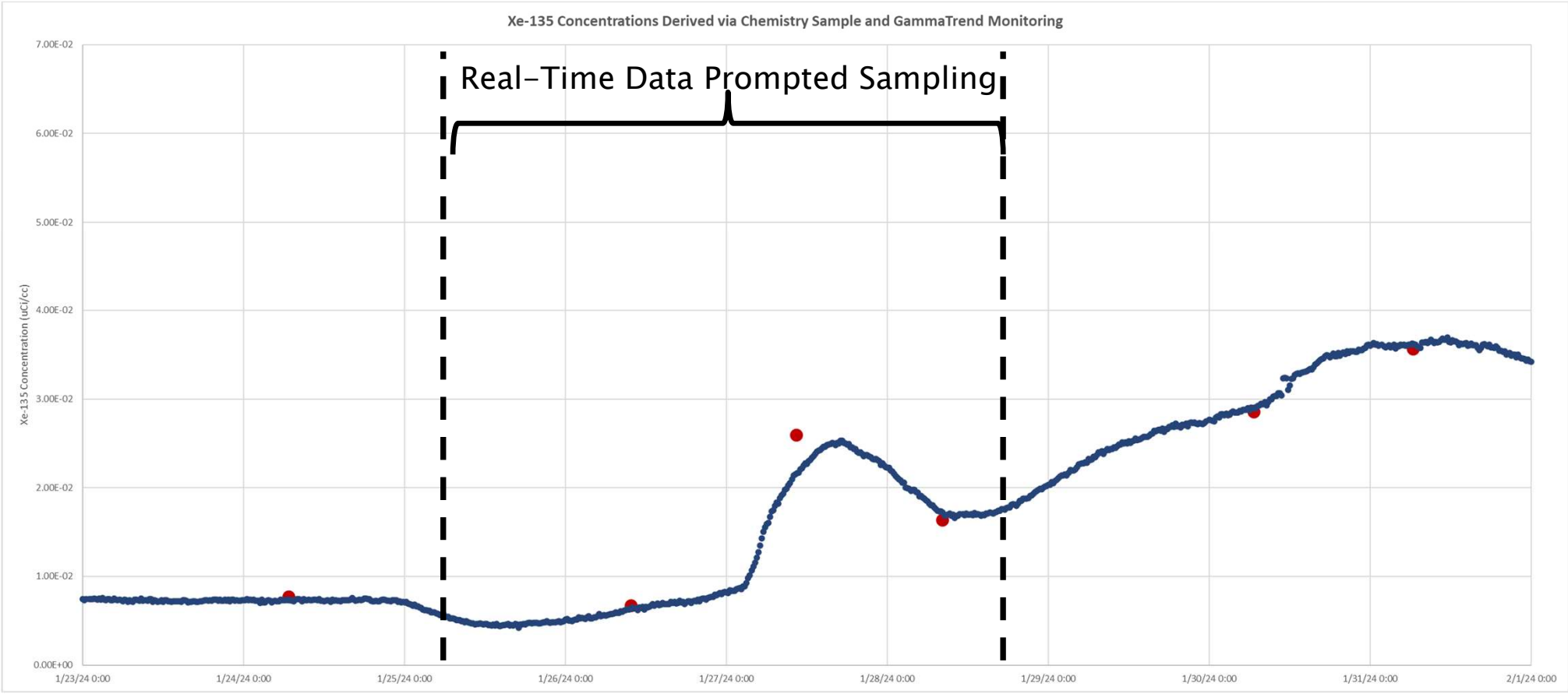


Xe-133 Trend (Next Step Change)



Xe-135 Trend (Next Step Change)



Case Study: Strategic Source Term Reduction

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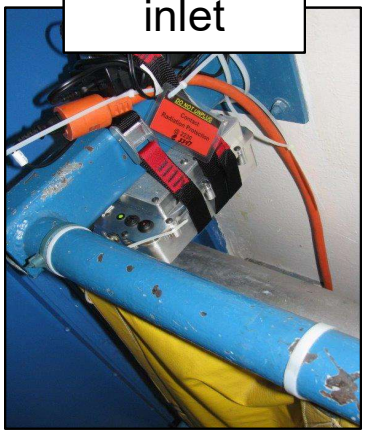
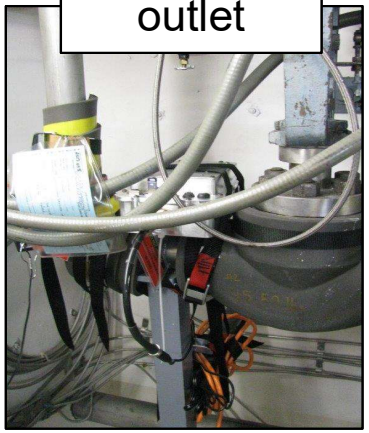
- Traditionally a very high source-term plant
  - Highest dose rates (and worker dose) of all Pressurized Water Reactors in the United States
- Installed four real-time spectrometers along the charging/letdown systems as part of R&D effort

Charging inlet

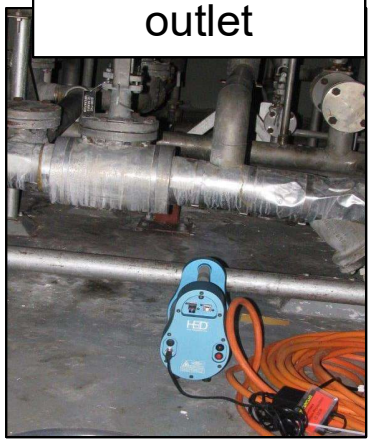


Charging outlet



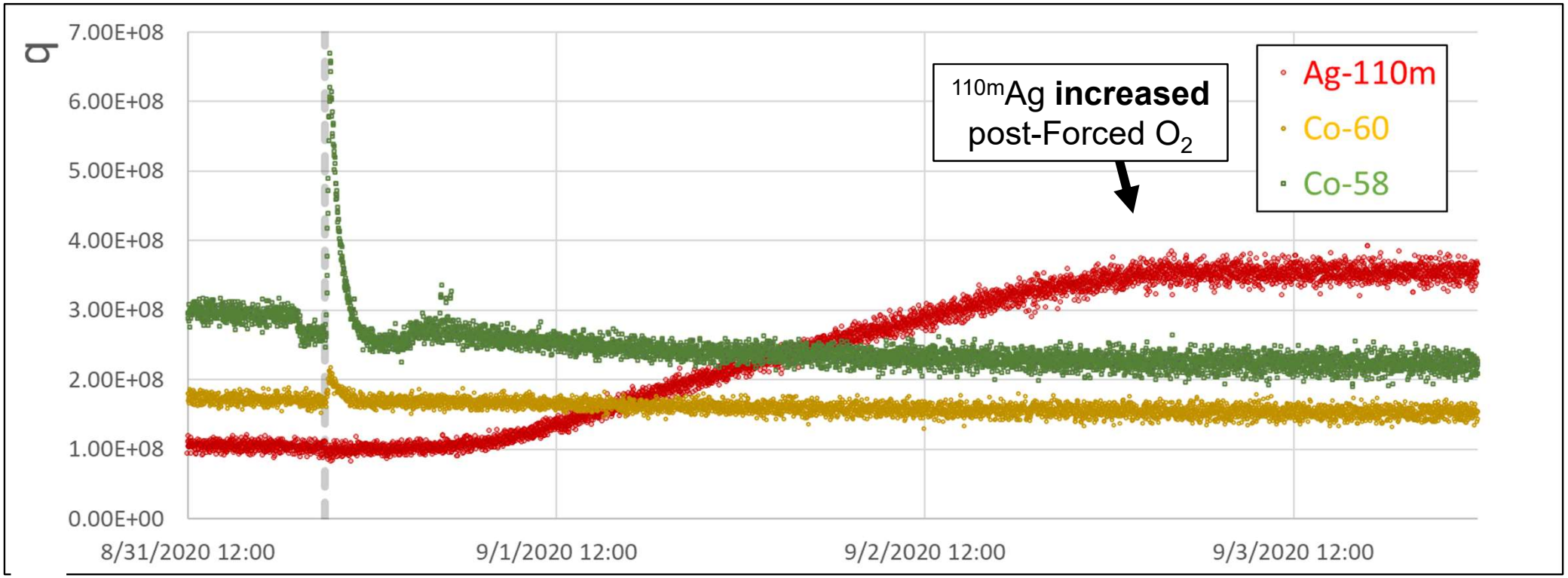
Demineralizer inlet

Demineralizer outlet



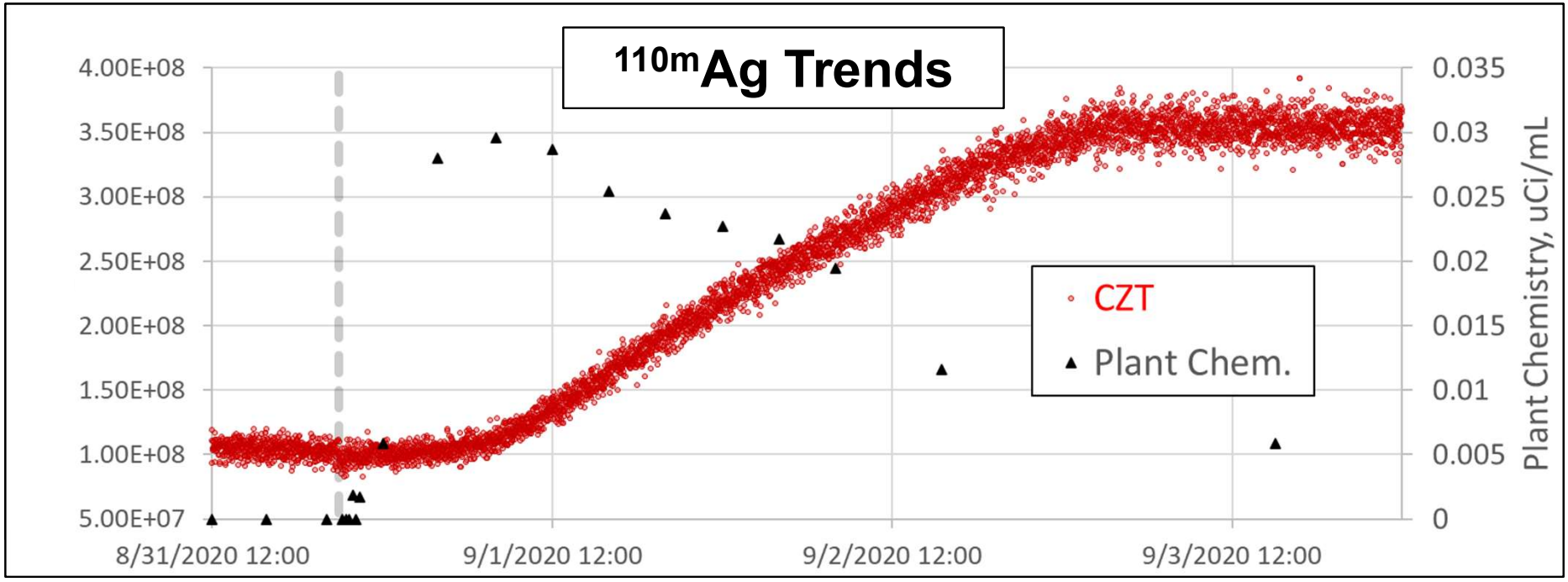
Charging Pump Inlet during Forced Oxygenation

- H_2O_2 add at 8/31/2020 20:55
  - Before H_2O_2 : 170 μSv/h After H_2O_2: **270 μSv/h**



Charging Pump Inlet (In-situ vs RCS Sampling)

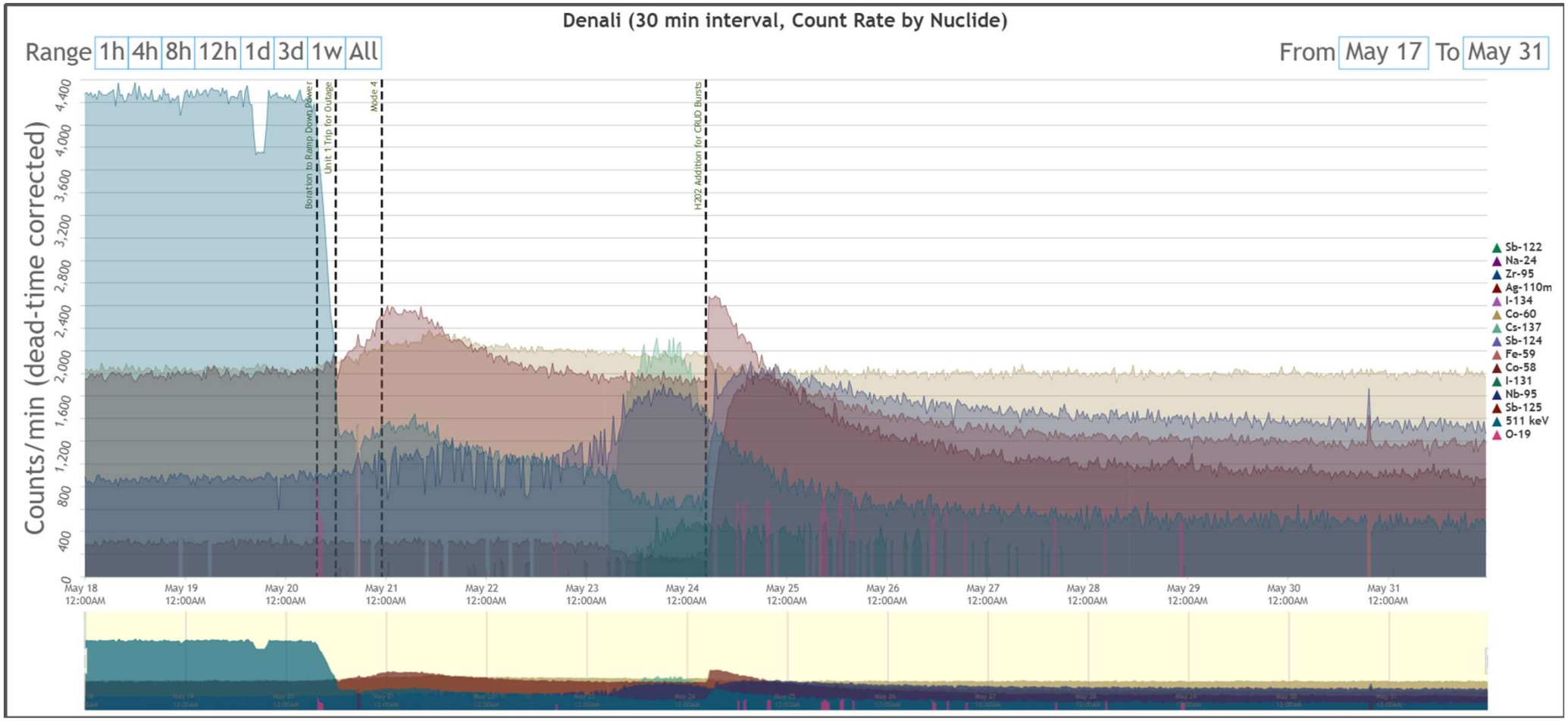
- Water sampling shows that ^{110m}Ag is **decreasing**
- Yet local dose rates (trended by CZT) increased **3.5x**



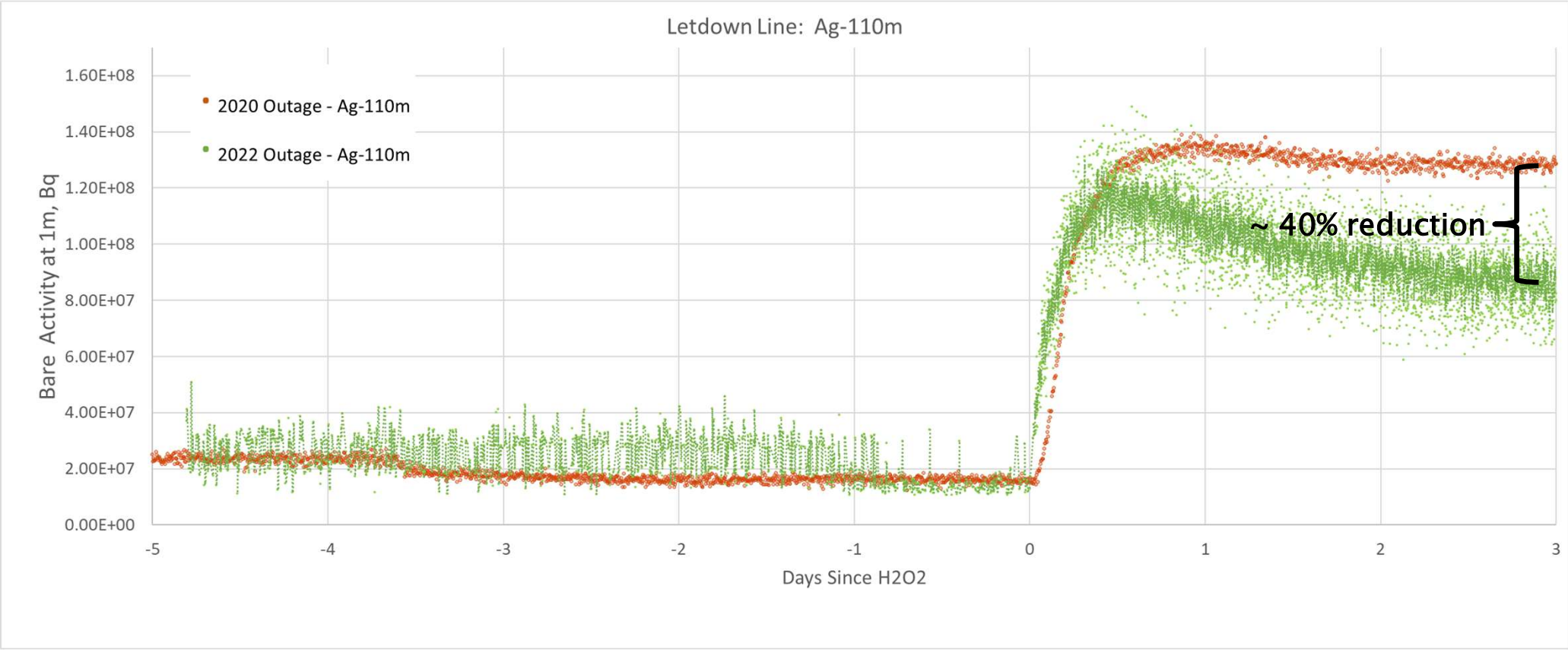
Case Study: Strategic Source-Term Reduction

- Data provided input for a revised Source Term Reduction strategy:
  - Spectrometer trends and sample data were reviewed
  - Industry expertise sought for silver/cobalt mitigation
  - Final cycle strategy included:
    - Increased end-of-cycle boron concentration (earlier coastdown)
    - Use of longer acid-reducing period at start of defuel outage
    - Higher concentration of hydrogen peroxide during forced oxygenation
    - Higher primary coolant temperature during forced oxygenation (to promote better cleanup and mitigate silver insolubility challenges)
    - Changes in demineralizer usage during 1R27 hydrazine add

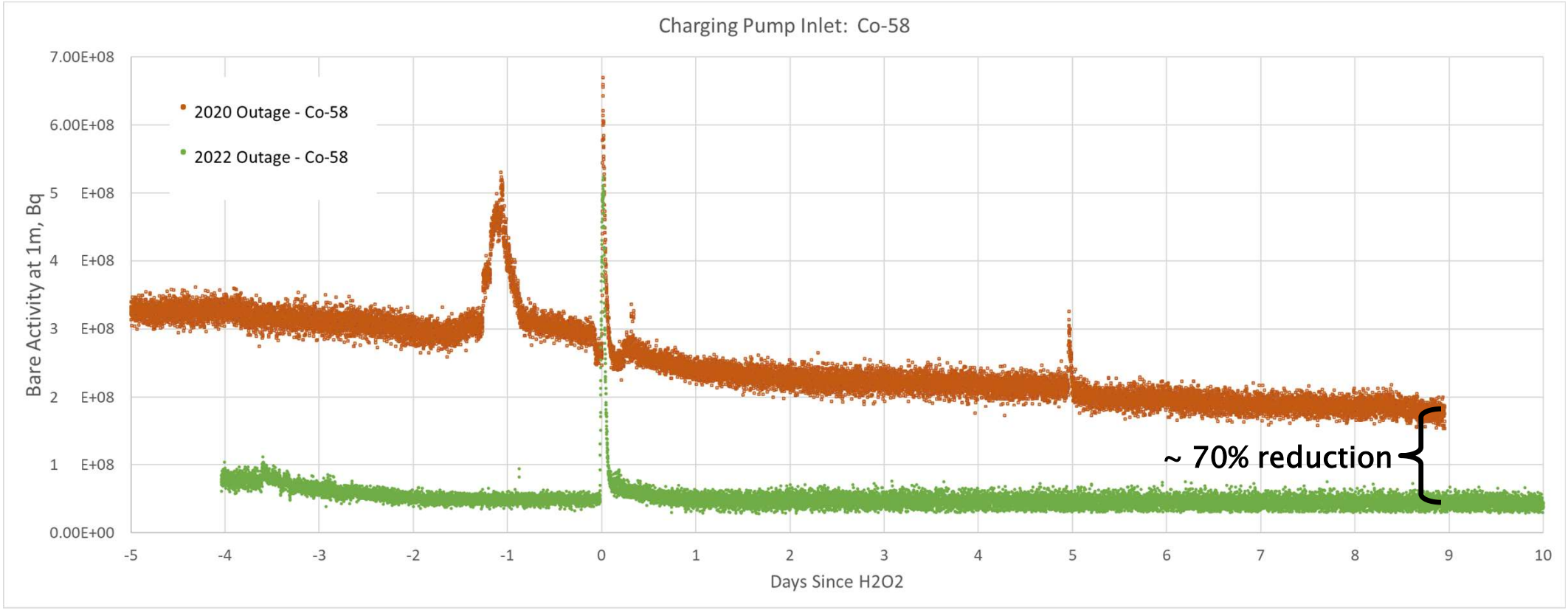
Outage Trends



Ag-110m Results: 2022 vs 2020



Co-58 Results: 2022 vs 2020



Questions?