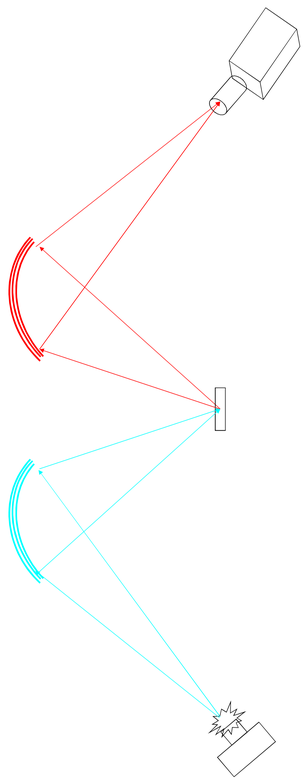
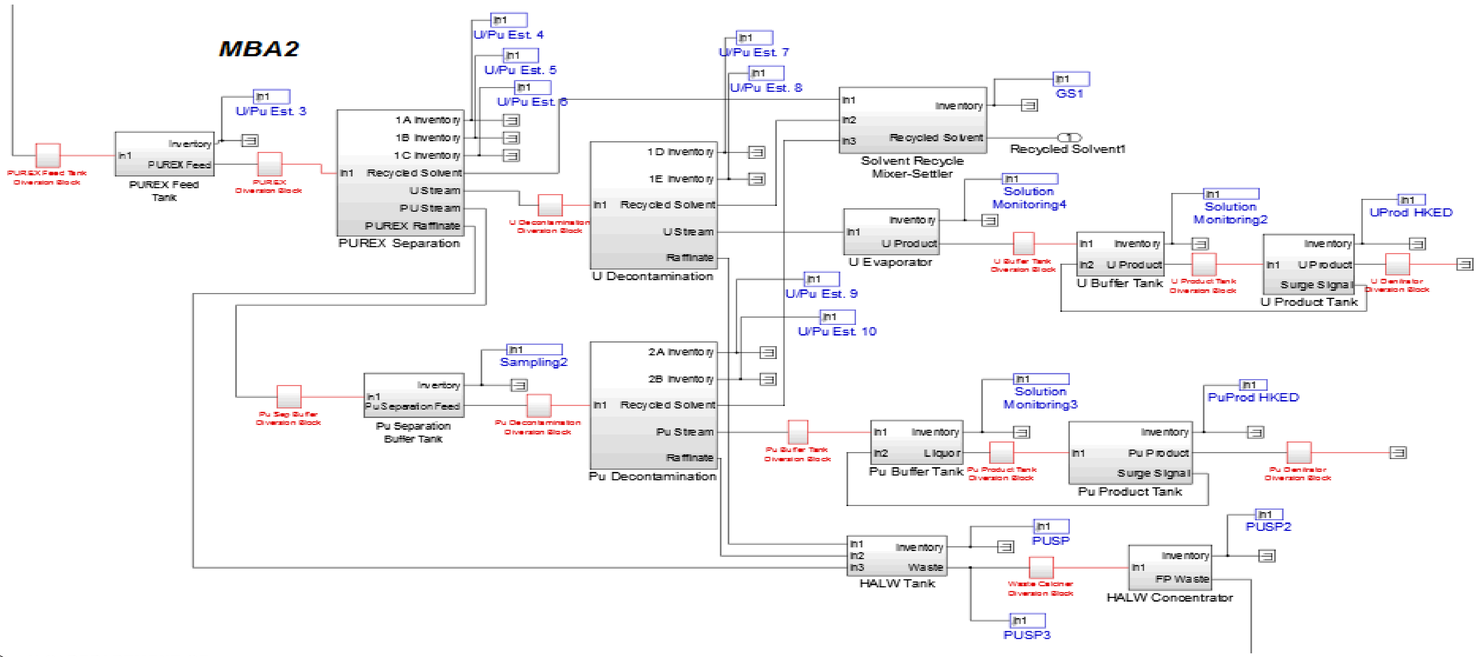
Symposium on International Safeguards: Linking Strategy, Implementation and People



Improving Materials Accountancy for Reprocessing using HiRX

Ben Cipiti, Mike McDaniel, George Havrilla, Michael Collins

High Resolution X-Ray (HiRX) could potentially replace HKED for routine accountancy measurements in reprocessing—modeling was used to examine overall improvement to safeguards performance.



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SAND2014-17669PE

HiRX Modeling Topics

- Technical background on HiRX measurement technology
- Separation and Safeguards Performance Model (SSPM) details and modeling assumptions.
- Modeling results, showing the improvement factor to safeguards performance.
- Economic analysis comparing HiRX to HKED

Improving Materials Accountancy for Reprocessing using HiRX

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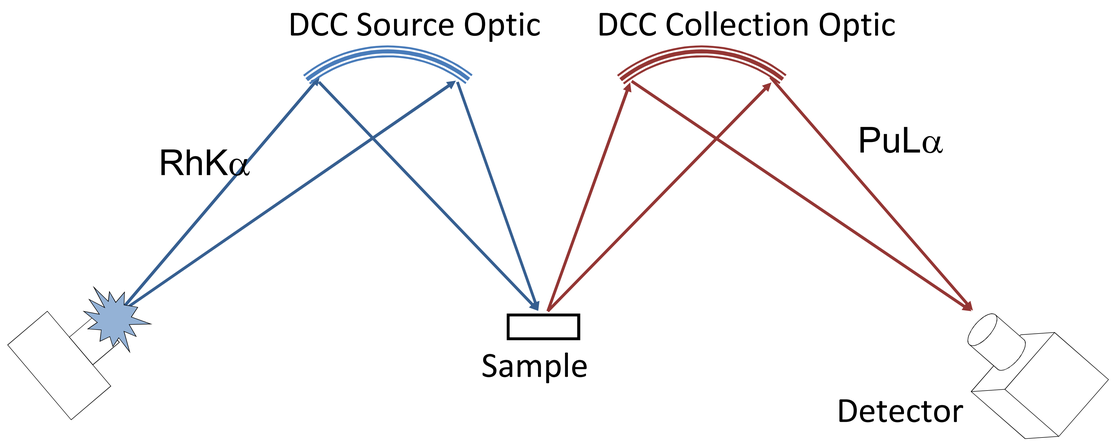
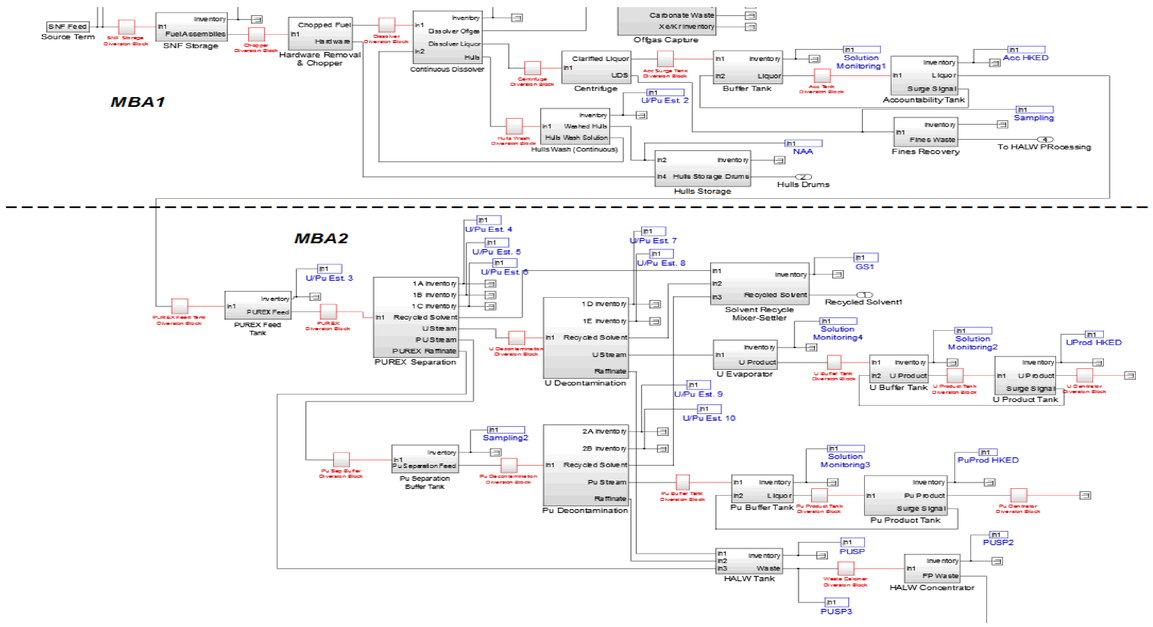
Objective: Determine the safeguards improvement if the High Resolution X-Ray (HiRX) technology replaces HKED for routine accountancy measurements in reprocessing.





Methods: The Separation and Safeguards Performance Model (SSPM) was used to examine the safeguards improvement if a 0.1-0.2% measurement uncertainty could be obtained.

Economics: An economic analysis examined the costs of HiRX as compared to HKED--lower costs are expected due to the simplicity of operation.

	HiRX Cost Compared to HKED	Notes
Equipment	lower	HiRX cost could be 1/3 of HKED due to smaller x-ray source, no moving parts, less shielding
Labor	lower	Potentially quicker measurement time, less training requirements
Utility	much lower	Less electricity, no water cooling, no cryogenic cooling
Waste	much lower	Smaller sample chips, much less sample volume, less equipment/repair waste
Facility	same	Similar sample transportation, similar overhead costs
Shielding	much lower	Much smaller sample volume may allow measurements in a glove box instead of a hot cell, much less shielding for personnel required
Repair	same	Similar repair costs

	Reduction in σ_{MUF} from Baseline
0.2% Measurement on Accountability Tanks	**40% Reduction**
0.1% Measurement on Accountability Tanks and Random Sampling	**60% Reduction**

Results: The modeling showed a 2-3 fold improvement in the overall safeguards performance of a plant if a 0.1-0.2% measurement uncertainty can be achieved.

Conclusion: HiRX has the potential to provide an improvement to overall safeguards performance with lower cost if a low measurement uncertainty can be demonstrated.

PUREX Separation and Safeguards Performance Model (SSPM)

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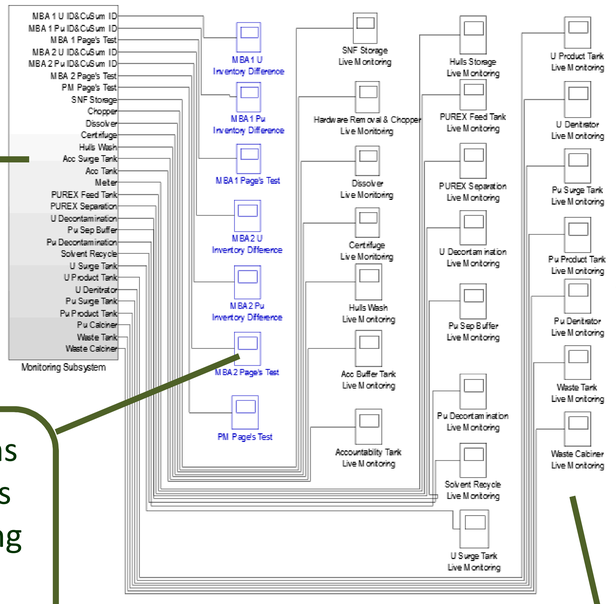
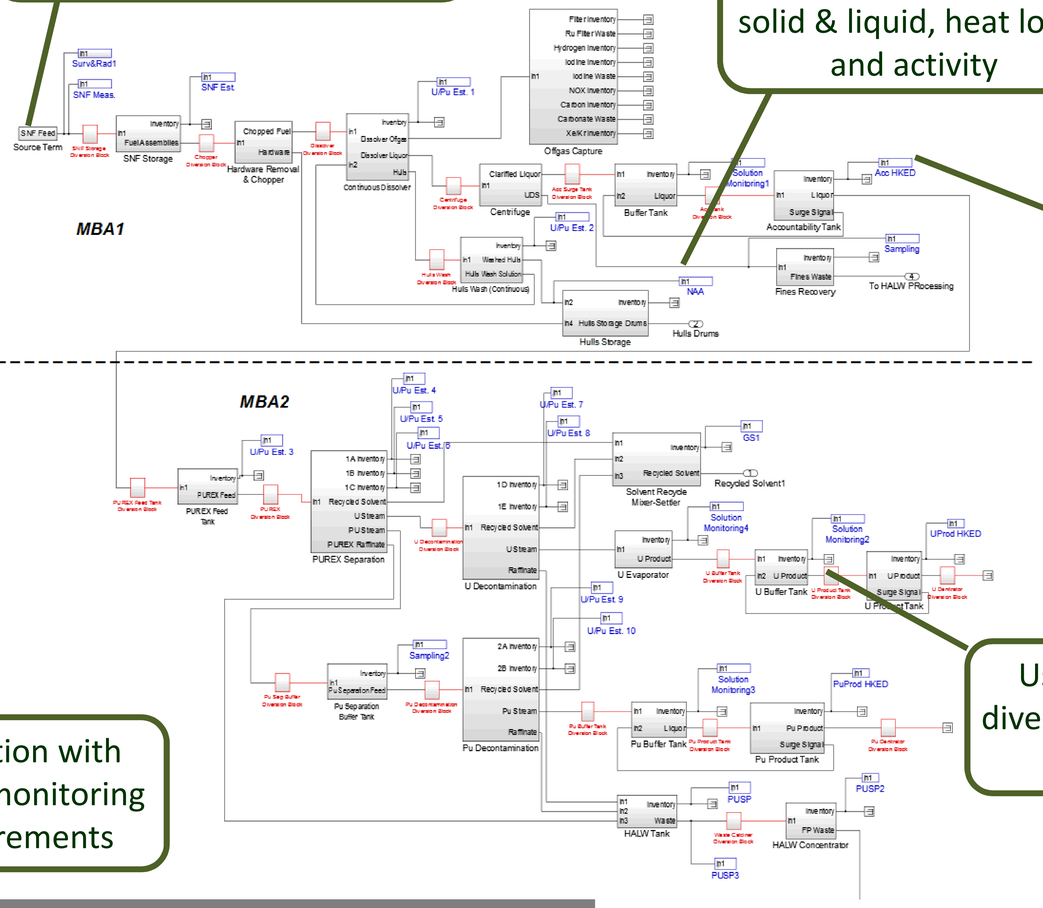
The Matlab Simulink environment is used to model material flows and measurements used in reprocessing.

Spent fuel library with a range of initial enrichment, burnup, and cooling time

Mass tracking of elements 1-99, bulk solid & liquid, heat load, and activity

Automated calculation of Material Unaccounted For (MUF) and σ_{MUF} in real-time

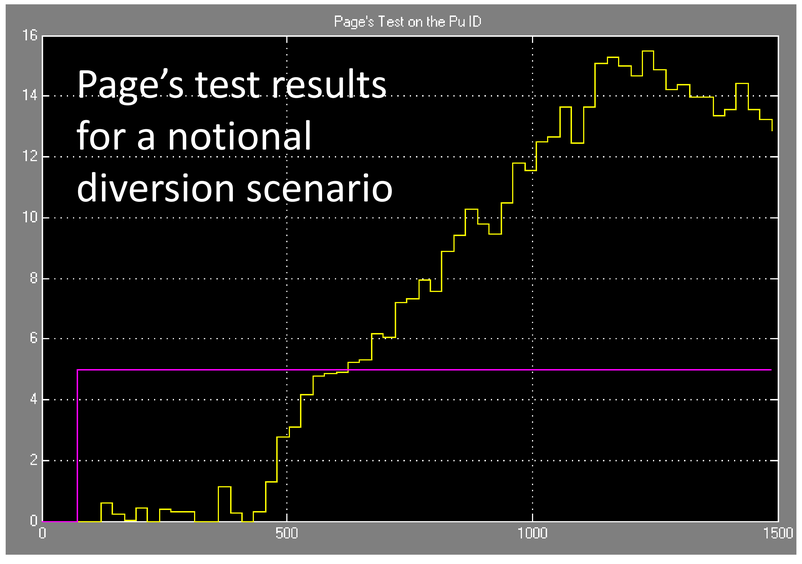


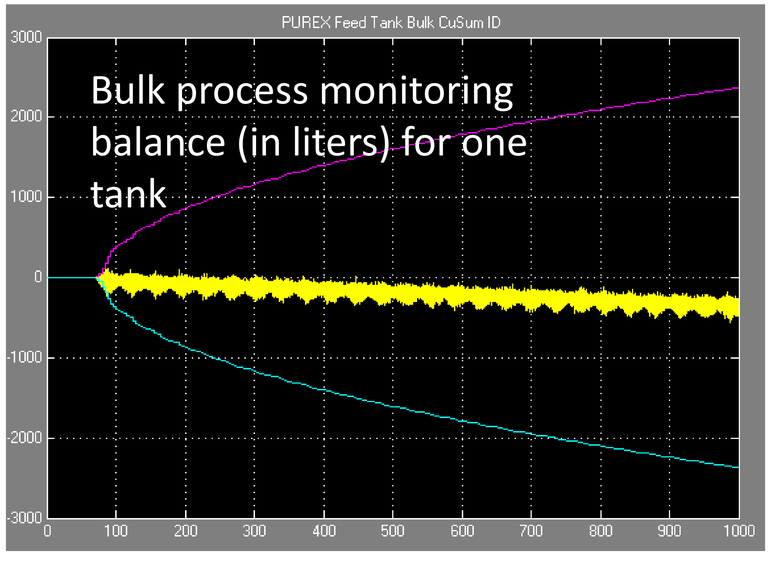


Alarm conditions for material loss determined using Page's test on SITMUF

Integration with process monitoring measurements

User-defined diversion scenario analyses





The Separation and Safeguards Performance Model (SSPM) was used to examine the safeguards improvement if a 0.1-0.2% measurement uncertainty can be obtained using HiRX.

HiRX Modeling Results

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Model Results:

- The use of HiRX (with 0.2% measurement uncertainty) at the Input Accountability Tank only led to a 30% reduction in σ_{MUF} from the baseline.
- The use of HiRX (with 0.2% measurement uncertainty) at the Input and Output Accountability Tanks led to a 40% reduction in σ_{MUF} from the baseline.
- The use of HiRX (with 0.1% measurement uncertainty) for Input and Output Accountability and all internal random sampling led to a 60% reduction in σ_{MUF} compared to the baseline.

The use of HiRX could potentially lead to a *two or three-fold improvement* in the safeguards performance of the separations area of the plant.

The modeling depends on the ability to achieve a 0.1-0.2% measurement uncertainty, which has not been demonstrated yet.

Measurement Assumptions

Location	Baseline		HiRX Case 1 IAT only		HiRX Case 2 IAT & OAT		HiRX Case 3 Best Case	
	RE	SE	RE	SE	RE	SE	RE	SE
Accountancy Tank (HKED)	0.8%	0.5%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%
PUREX Feed Tank (Sampling-IDMS)	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%
PUREX Separation (Calculation)	3%	3%	3%	3%	3%	3%	3%	3%
U Decontamination (Calculation)	3%	3%	3%	3%	3%	3%	3%	3%
U Evaporator (Sampling-IDMS)	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%
U Buffer Tank (Sampling-IDMS)	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%
U Product Tank (HKED)	2%	2%	2%	2%	2%	2%	0.1%	0.1%
Recycle Mixer-Settler (Calculation)	7%	7%	7%	7%	7%	7%	7%	7%
Pu Sep. Buffer Tank (Sampling-IDMS)	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%
Pu Decontamination (Calculation)	3%	3%	3%	3%	3%	3%	3%	3%
Pu Buffer Tank (Sampling-IDMS)	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%
Pu Product Tank (KED)	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%
HALW Tank	7%	7%	7%	7%	7%	7%	7%	7%
HALW Concentrator	7%	7%	7%	7%	7%	7%	7%	7%

HiRX Measurement Technology

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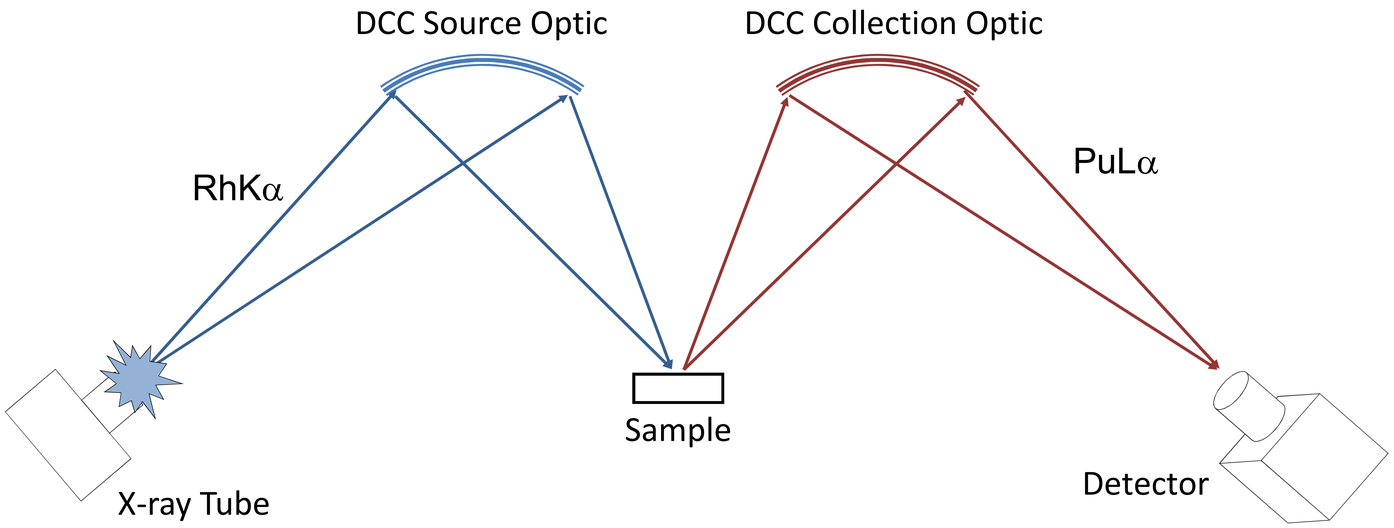


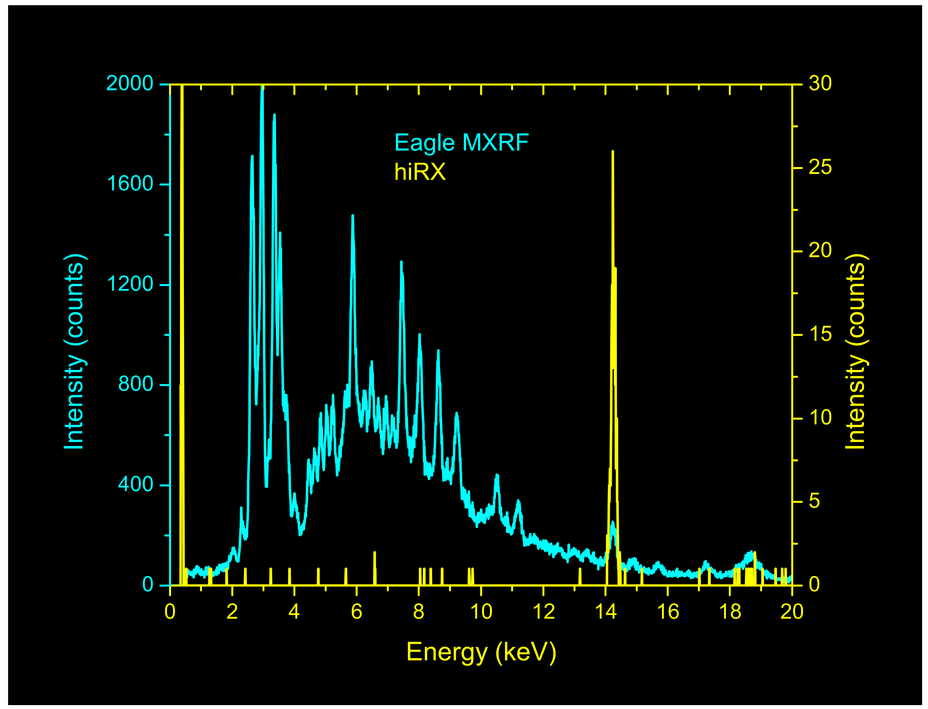
HiRX uses a low energy x-ray tube with doubly curved crystal optics to create a monochromatic x-ray source for exciting x-ray fluorescence in a sample.

A second doubly curved crystal optic is used to collect and focus emitted x-rays of a specific energy (unique to the element of interest) onto a detector.

HiRX Prototype

Experiments at Los Alamos National Laboratory have consistently attained better than 10 ppm detection limits with small sample sizes (100 μL or less).

It is expected that HiRX can improve both the input and output accountability measurement for Pu in reprocessing solutions with an error of 0.1% and with rapid turn-around time, but this uncertainty has not been achieved yet.



The result is a spectrum that exhibits a prominent x-ray peak specific to one element with negligible background.