

# Investigations on Detecting Potential Nuclear Material Diversion from a Pyroprocessing Facility

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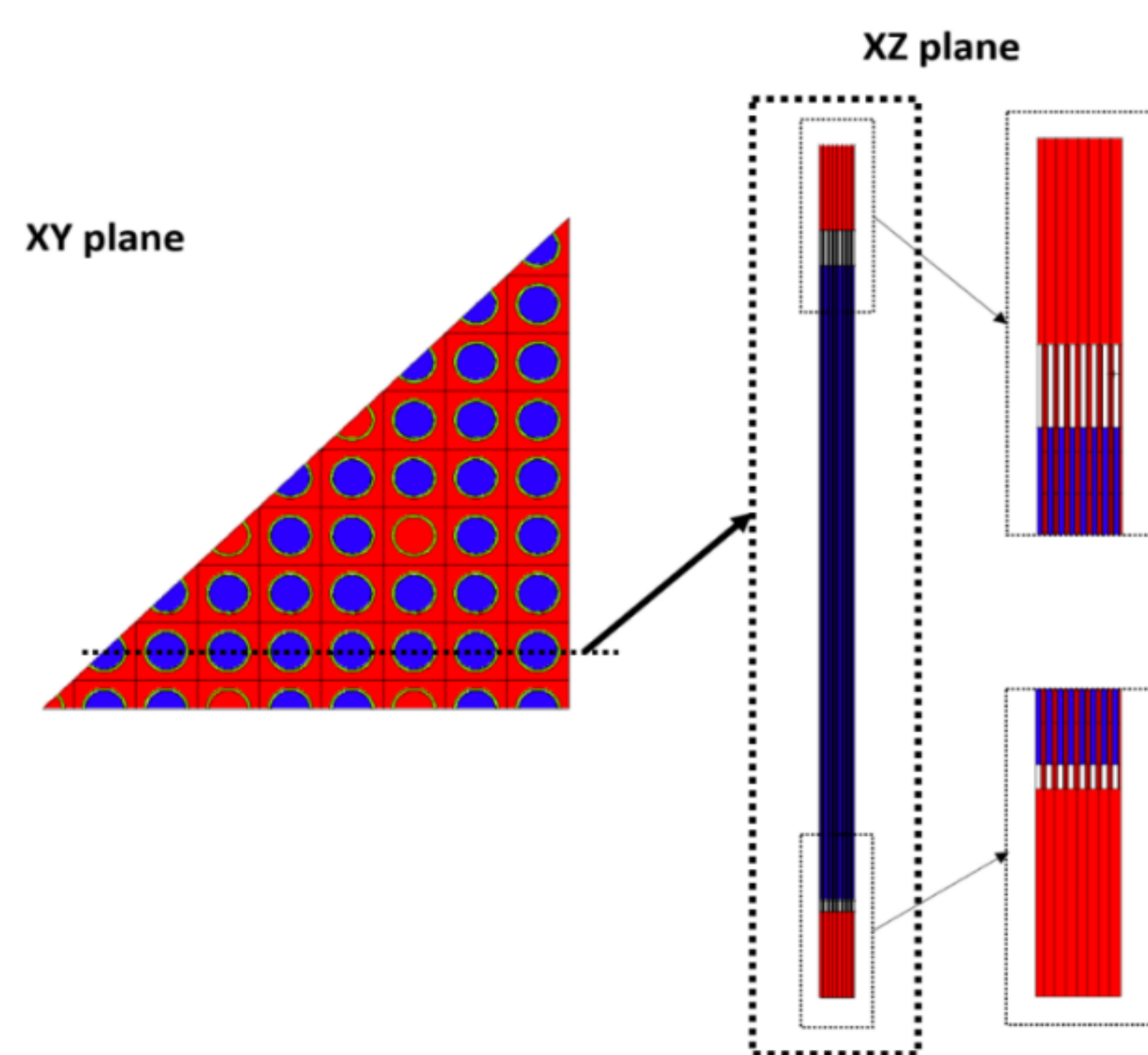
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## 1. Pyroprocessing technology

- Pyroprocessing produces TRU-U ingot & U ingot.
- TRU-U ingot contains depleted U, TRU elements.
- Proposed Nuclear material accountancy for TRU
  - ✓  $\gamma$ -ray detection system
  - ✓ Neutron detection system,
  - ✓ Nuclear Magnetic Resonance (NMR)

## 2. Depletion simulation – MCNP6



Element	Mass [g]
U-234	4.12E0
U-235	1.87E3
U-236	1.87E3
U-238	4.00E5
Np-237	2.38E1
Pu-238	8.34E1
Pu-239	1.72E3
Pu-240	1.10E3
Pu-241	3.94E2
Pu-242	3.42E2
Am-241	1.18E2
Cm-244	1.95E1
Total	4.07E5

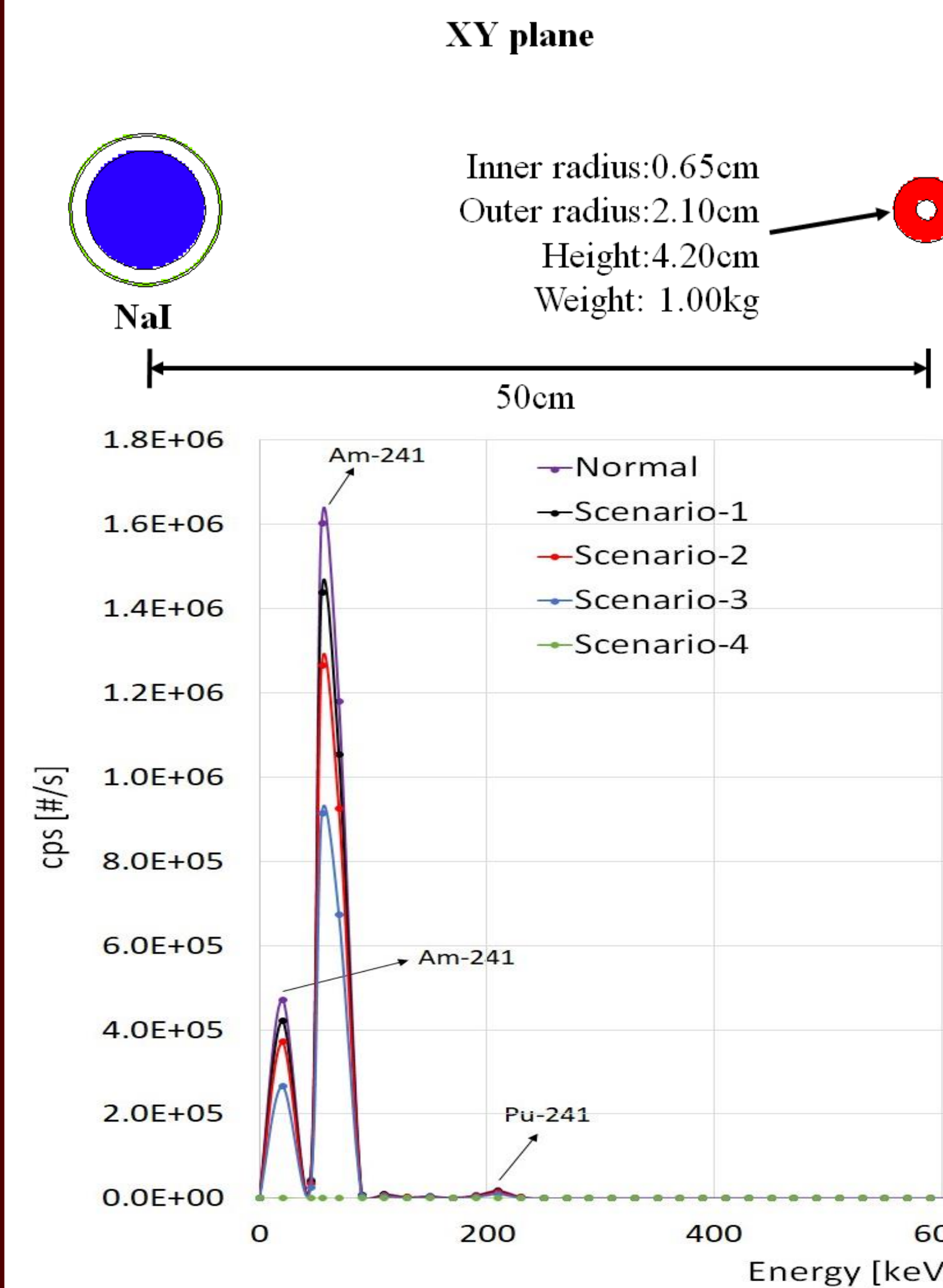
- Westinghouse FA (3.3w/o)
- No boron
- 2.21MWth/(1/8FA)
- 41GWd/MTU
- Reflective b/c
- 10000 (histories), 500 (active), 50 (inactive cycle)

## 3. Diversion scenarios

Isotope	Mass [g]				
	Normal	Scen-1	Scen-2	Scen-3	Scen-4
U-234	5.12E-3	5.68E-3	6.25E-3	7.38E-3	1.02E-2
U-235	2.32E+0	2.57E+0	2.83E+0	3.34E+0	4.63E+0
U-236	2.32E+0	2.58E+0	2.84E+0	3.35E+0	4.65E+0
U-238	4.96E+2	5.50E+2	6.05E+2	7.15E+2	9.91E+2
Np-237	2.36E+1	2.10E+1	1.84E+1	1.31E+1	0.00E+0
Pu-238	1.03E+1	9.20E+0	8.06E+0	5.77E+0	0.00E+0
Pu-239	2.13E+2	1.89E+2	1.66E+2	1.19E+2	0.00E+0
Pu-240	1.37E+2	1.22E+2	1.07E+2	7.63E+1	0.00E+0
Pu-241	4.89E+1	4.35E+1	3.81E+1	2.73E+1	0.00E+0
Pu-242	4.24E+1	3.77E+1	3.30E+1	2.36E+1	0.00E+0
Am-241	1.46E+1	1.30E+1	1.13E+1	8.12E+0	0.00E+0
Cm-244	2.42E+0	2.15E+0	1.88E+0	1.35E+0	0.00E+0
Total	9.92E+2	9.93E+2	9.94E+2	9.96E+2	1.00E+3

- Scenario-1: 50g Pu diversion
- Scenario-2: 100g Pu diversion
- Scenario-3: 200g Pu diversion
- Scenario-4: 452g Pu diversion
- ➔ Other TRU elements also removed proportionally

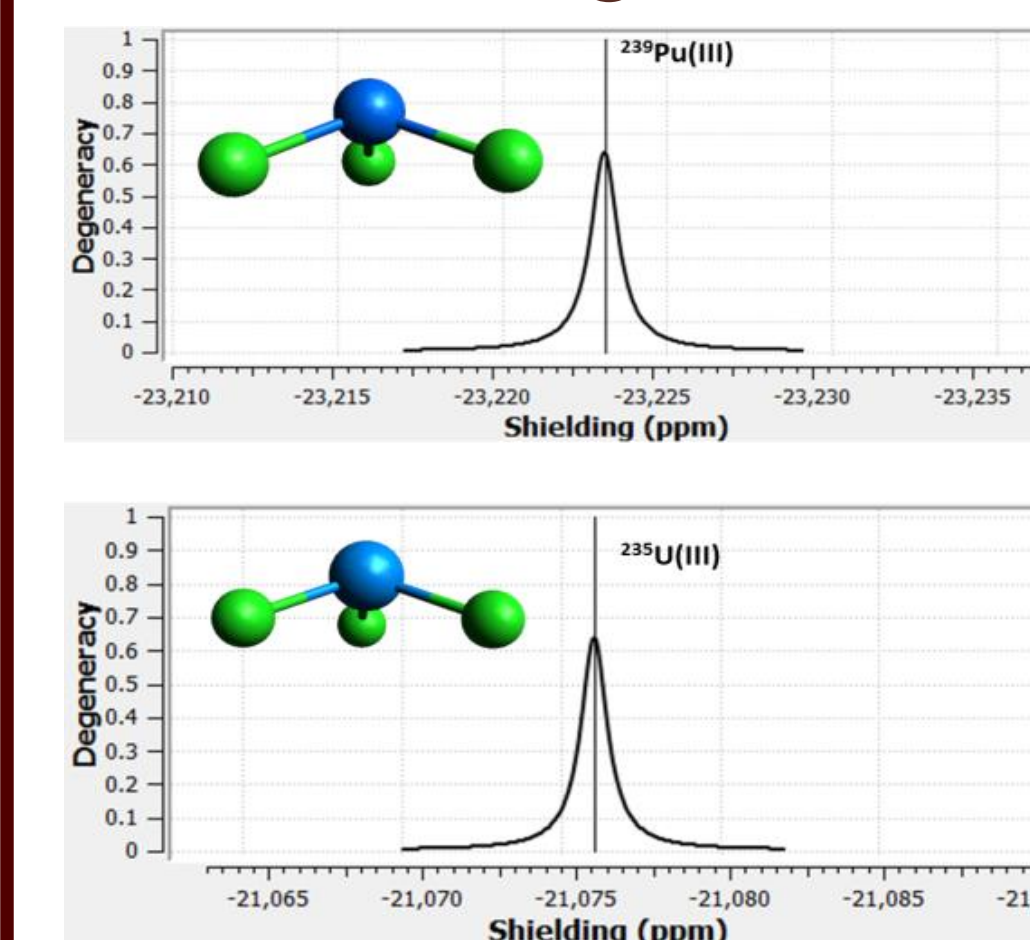
## 4. NaI $\gamma$ -ray detection system-MCNP6



	E [keV]	A [ $\gamma$ /g/s]
U-234	120.9	9.35E4
U-235	143.8	8.40E3
	185.7	4.32E4
U-238	766.4	2.57E1
	1001.0	7.34E1
Pu-238	152.7	5.90E6
	766.4	1.39E5
Pu-239	129.3	1.44E5
	413.7	3.42E4
	45.2	3.80E6
Pu-240	160.3	3.37E4
	642.5	1.04E3
Pu-241	148.6	7.15E6
	208.0	2.04E7
Am-241	59.5	4.54E10
	125.3	5.16E6

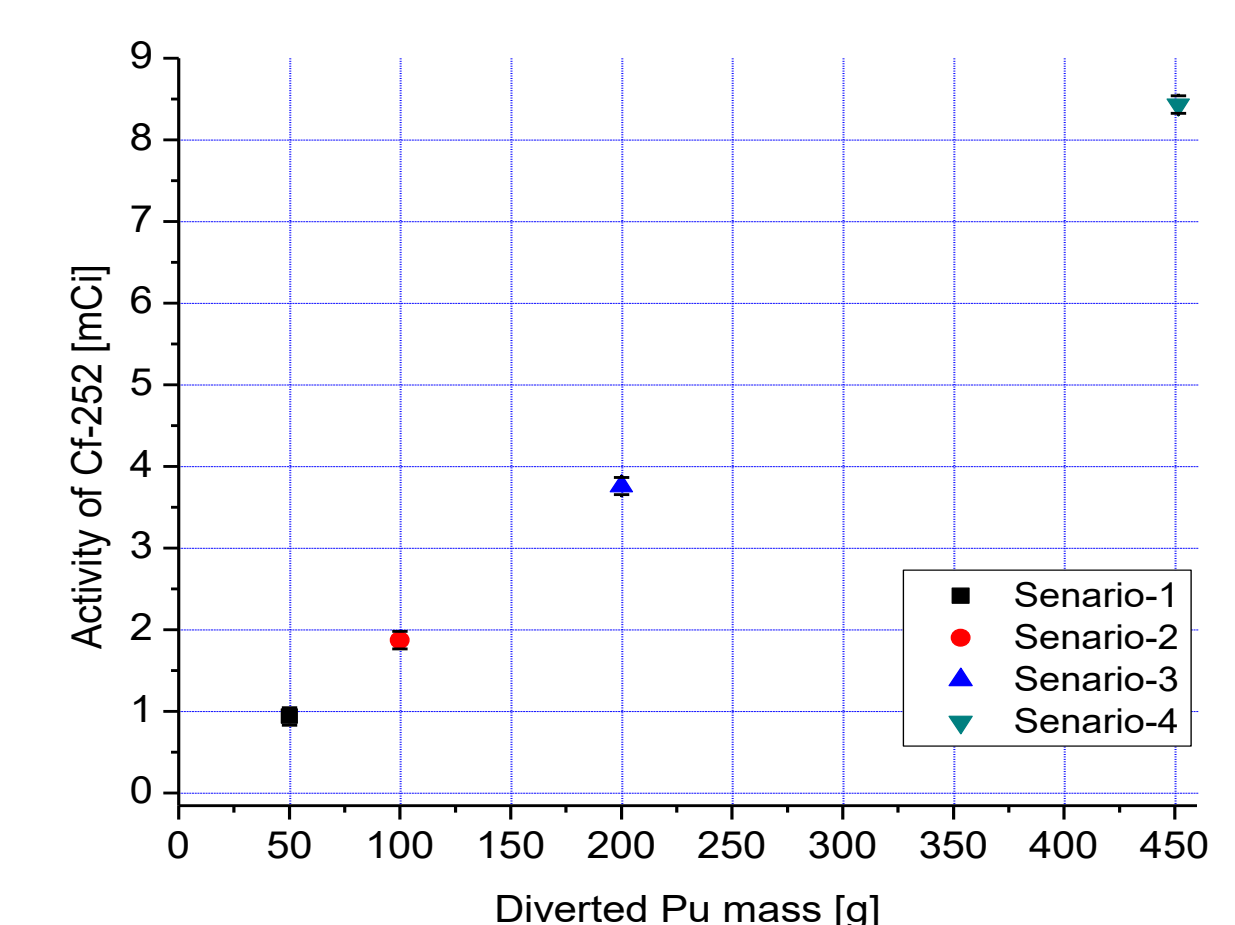
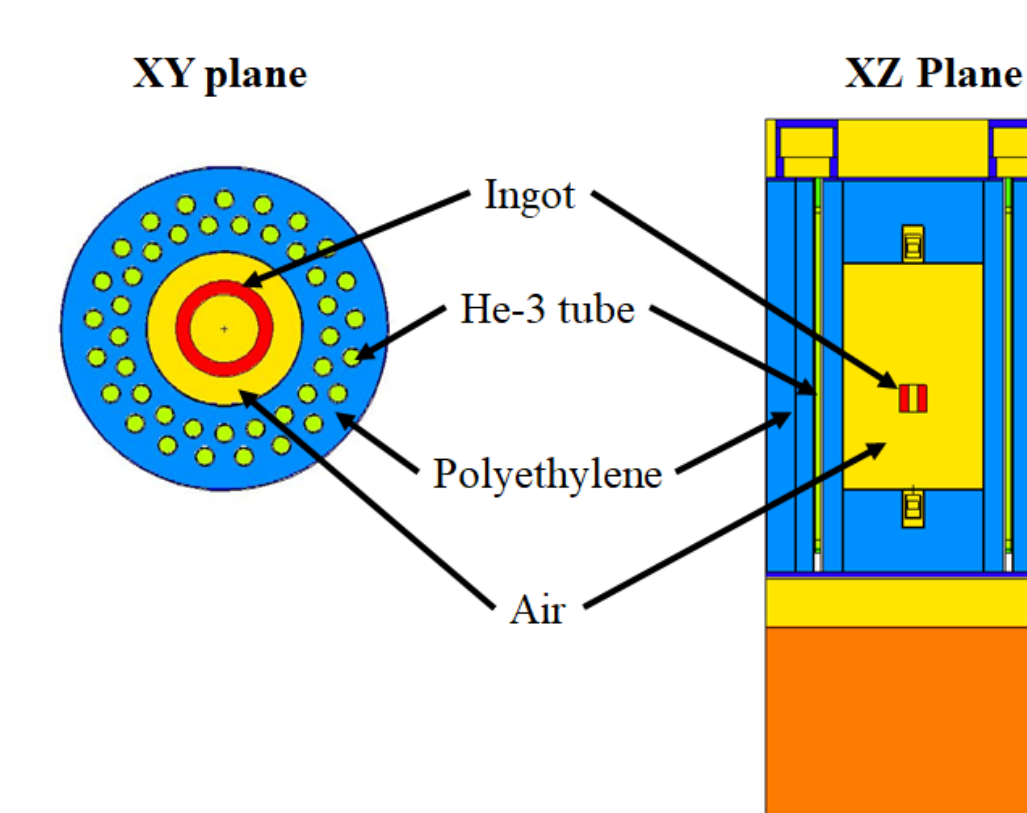
- Loss of Pu ➔ **Detectable**
- Loss of U ➔ **Not detectable**

## 5. NMR detection system-DFT



- NMR application for NMA
- UCl<sub>3</sub> and PuCl<sub>3</sub> used for DFT
- NMR peaking at different level of freq. and ppm for Pu-239 and U-235
- Loss of Pu ➔ **Detectable**
- Loss of U ➔ **Detectable**

## 6. Coincidence neutron detection system-MCNP6



- A necessary activity of Cf-252 to fake the coincidence neutron detection system depending on the scenarios
- However, loss of Pu ➔ detectable by  $\gamma$ -ray detector

## 7. Conclusion

- Assumption ➔ No rare earth (RE) in TRU-U ingot
- Existing RE ➔ reducing material attractiveness
- Non-existing RE ➔ Possible to direct measure Pu
- A combination of detection system ➔ enhancing NMA for safeguarding pyroprocessing

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