Signatures of Weapon-grade Plutonium from Dedicated Production Reactors

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Revision 4

available at http://cstsp.aaas.org

Overview

Scope and Objective

Quantify the range of isotopic variations that can be expected
for plutonium produced with different types of dedicated production reactors

Understand the relative importance of
predictive versus *empirical* (isotopic) plutonium signatures

(relevant, in particular, for nuclear forensic analysis)

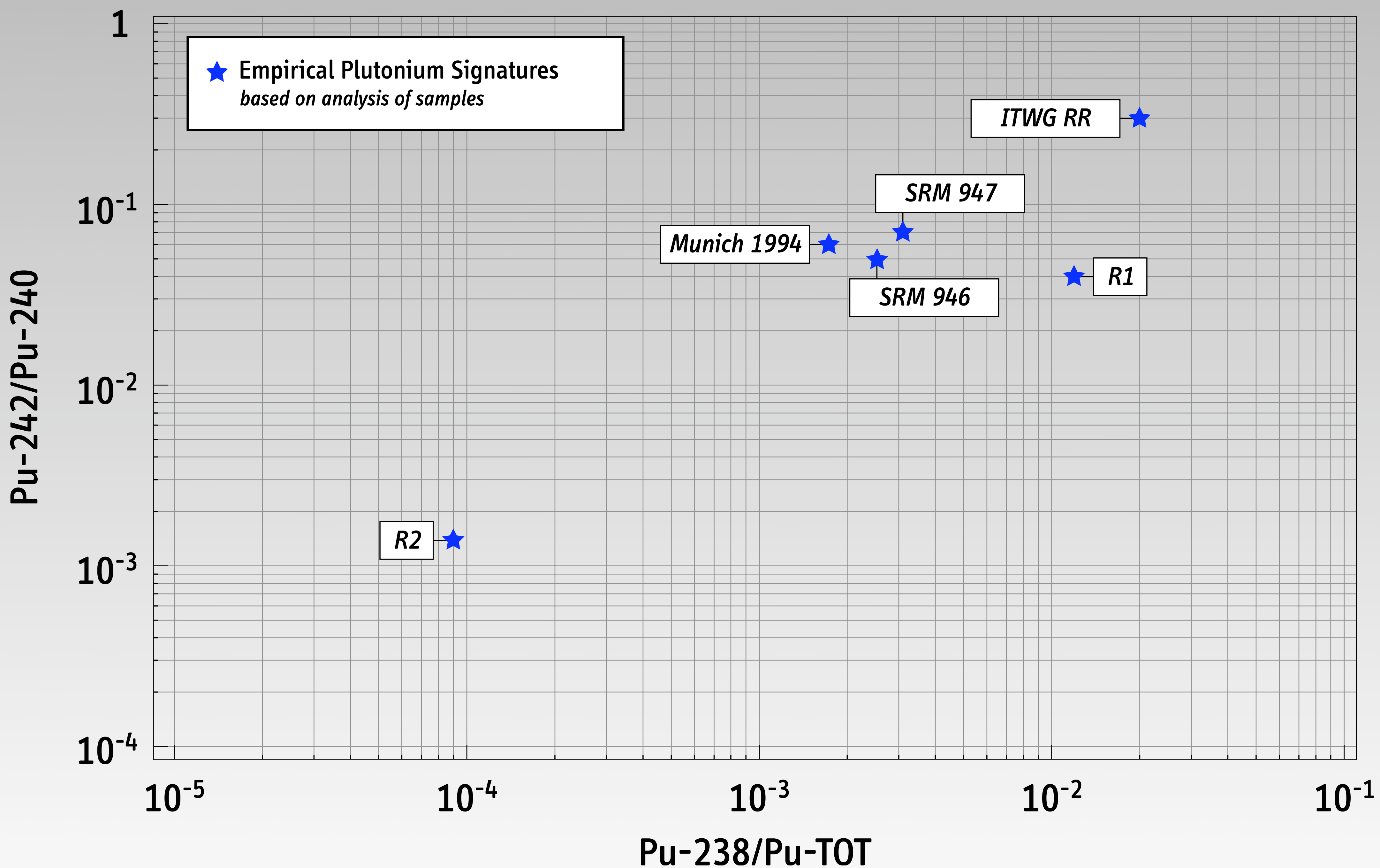
Methodology

Neutronics calculations for several important production reactor types

Using continuous-energy (MCNP) cross-section libraries
to generate spectrum-averaged one-group cross-sections for burnup calculations

*and to assure that differences between results are not due
to inconsistent cross-section data*

Isotope Ratio Correlations



K. Mayer, M. Wallenius, and I. Ray, "Nuclear Forensics – A Methodology Providing Clues on the Origin of Illicitly Trafficked Nuclear Materials," *Analyst*, Royal Society of Chemistry, 130 (2005), pp. 433–441

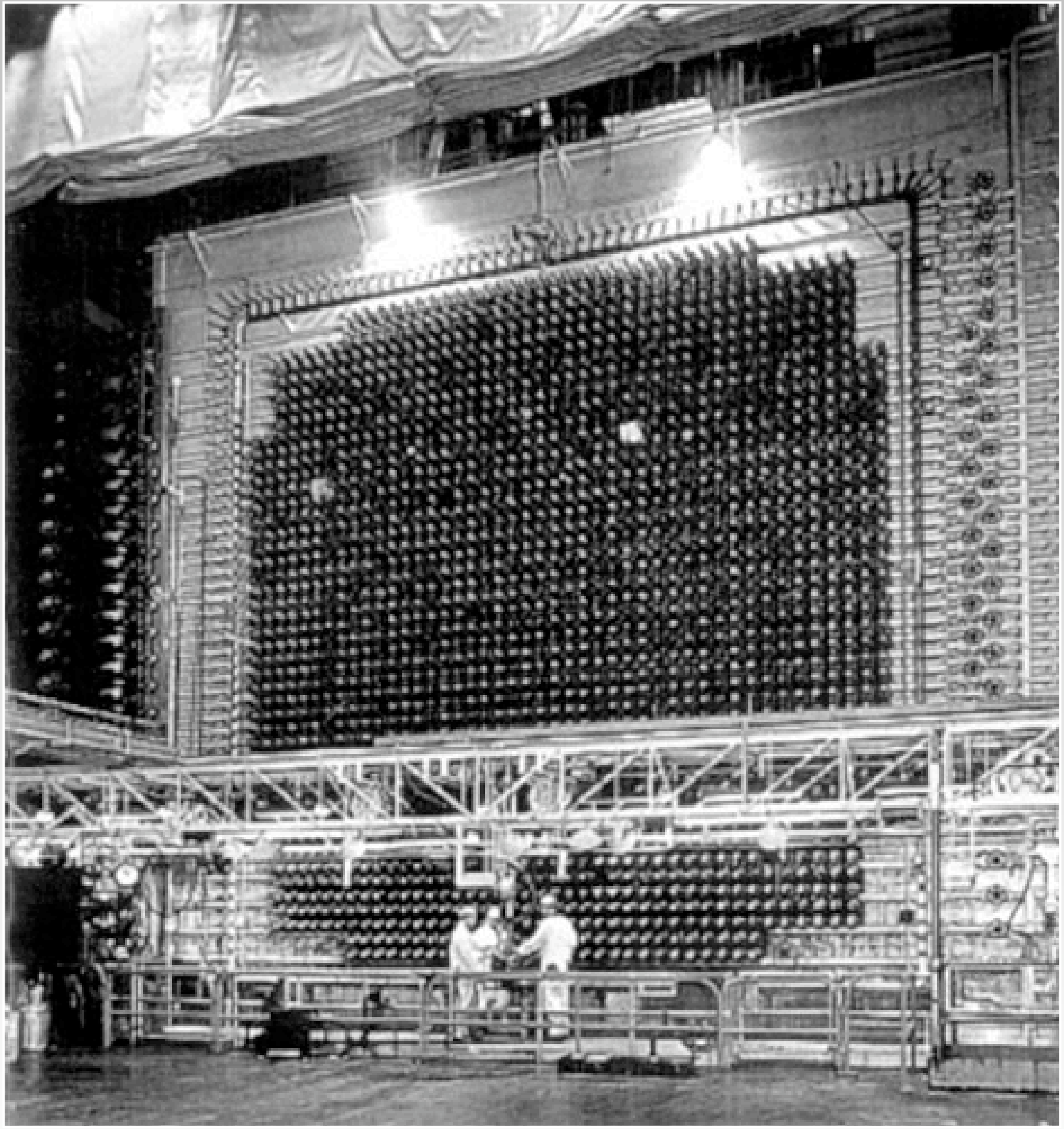
Production Reactor Types

Production Reactor Types

	Graphite moderated		Heavy-water moderated		Driver fuel with external DU targets
	H_2O cooled	CO_2 cooled	H_2O cooled	D_2O cooled	
United States	Hanford				Savannah River
Russia	"Tomsk-7"				
U.K.		Calder Hall			
France		G-Series			Célestin
China	"Jiuquan"				
Israel				Dimona	
India			Cirus/NRX	Dhruva	
Pakistan			Khushab		
DPRK		Yongbyon			

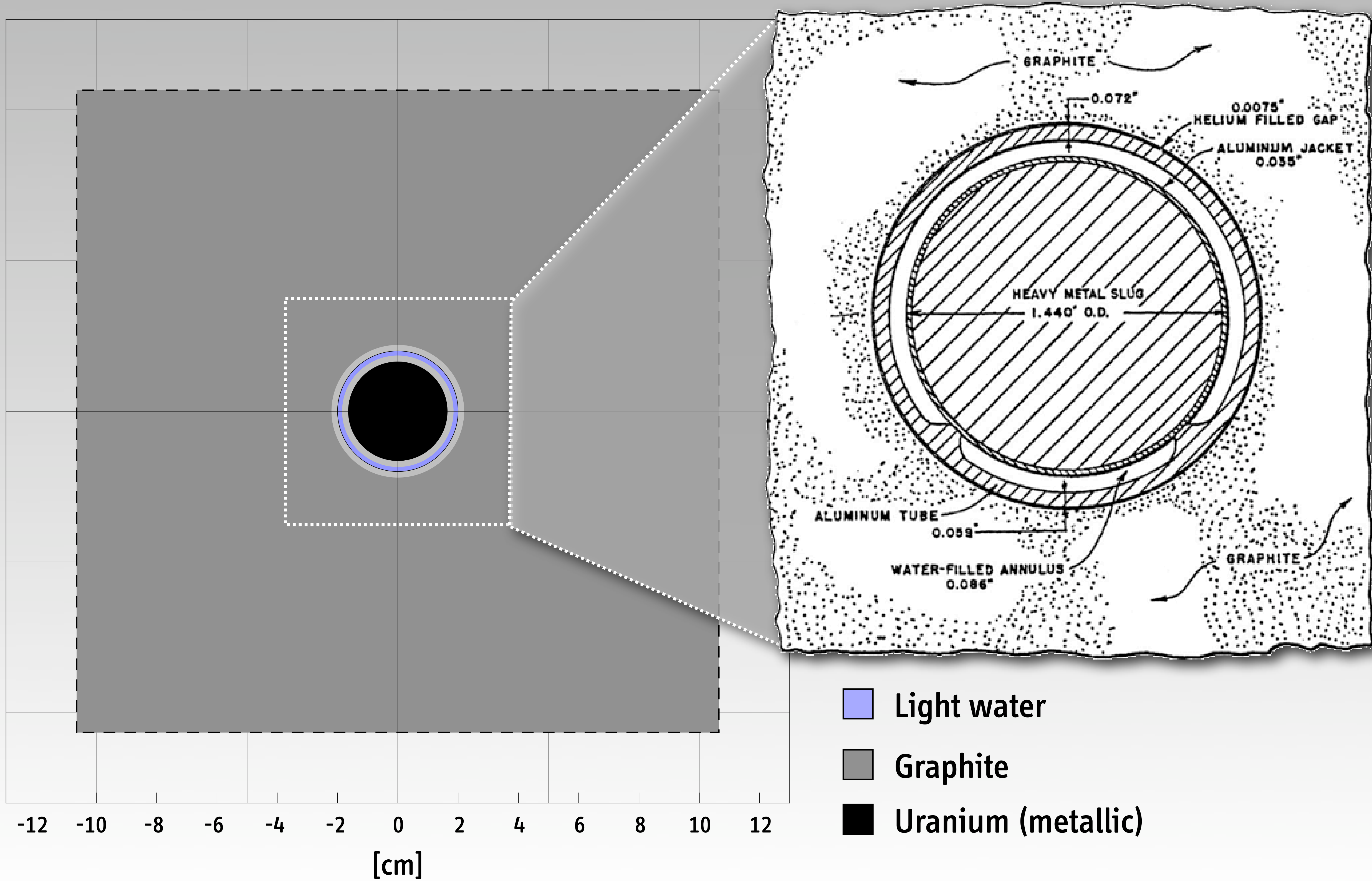
Hanford B Reactor

(United States, 1944-1968)



B-Reactor in 1998

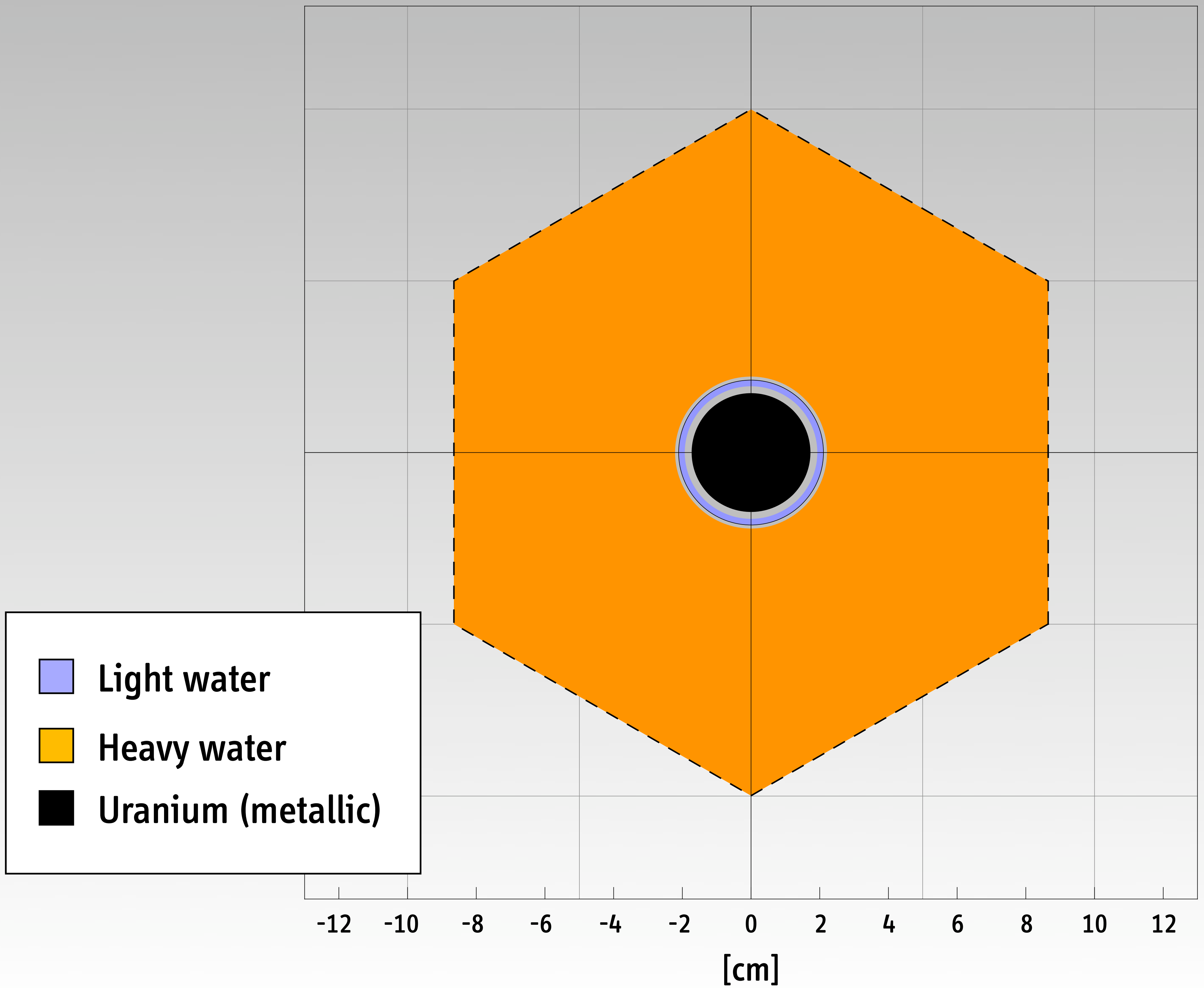
Unit Cell of Hanford B Reactor



NRX / Cirus Reactor

(Canada / India)

Unit Cell of NRX / Cirus Reactor



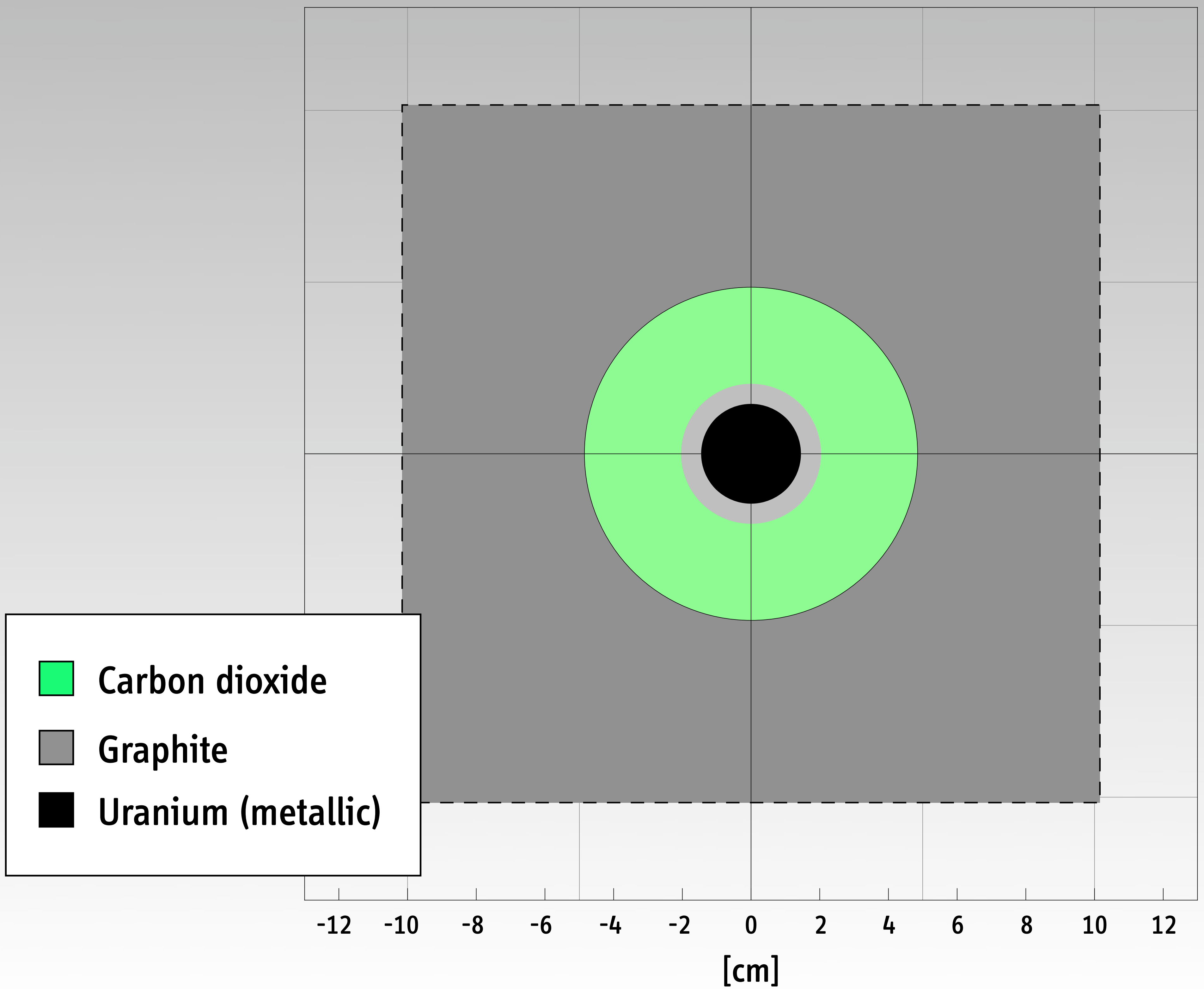
Calder Hall Reactor

(United Kingdom)

Source: BNFL

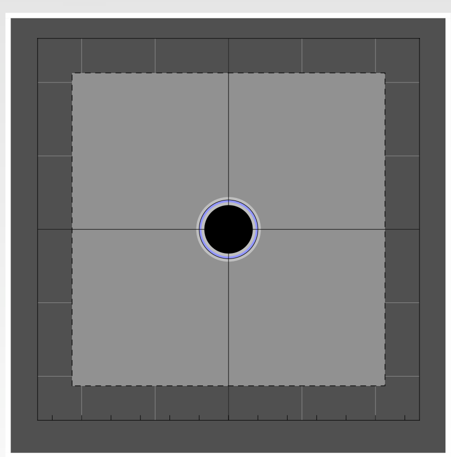
Demolition of Calder Hall (A) Towers
September 29, 2007

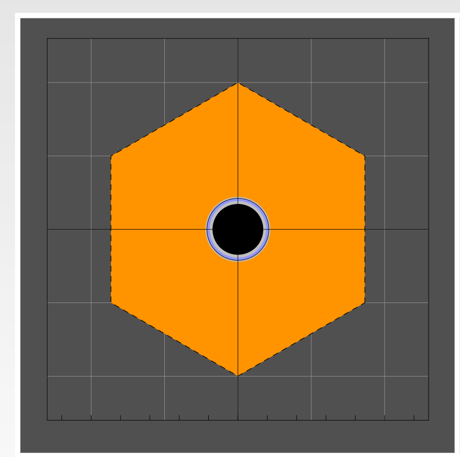
Unit Cell of Calder Hall Reactor

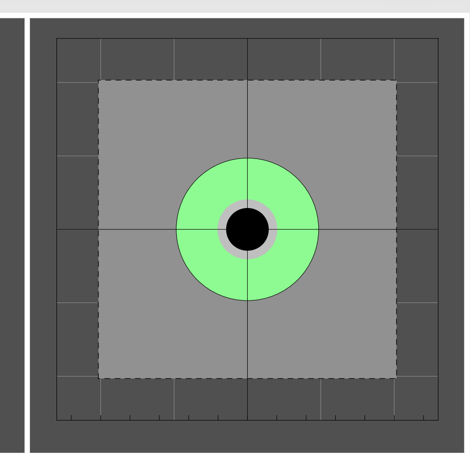


Summary of Basic Design Data

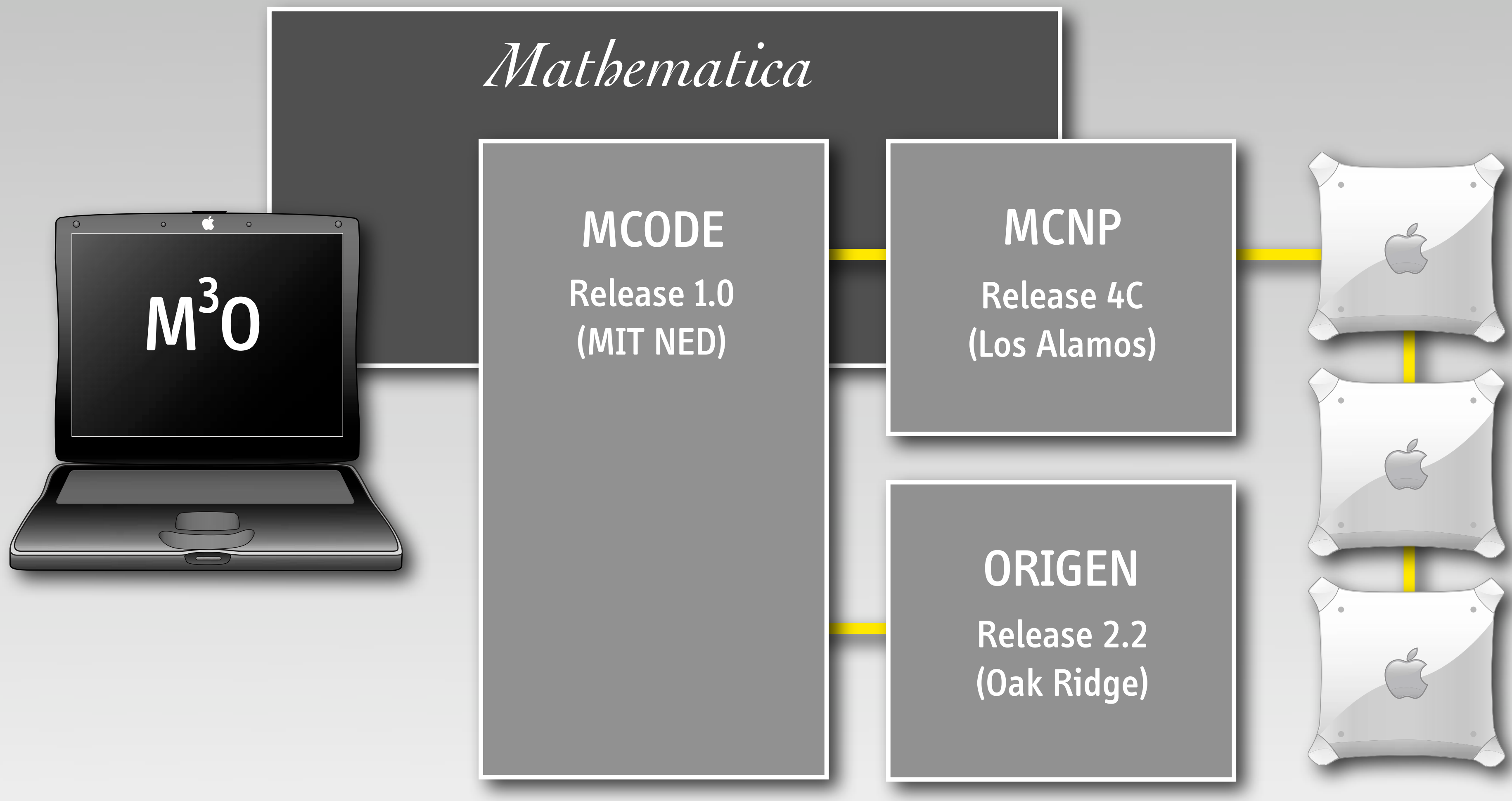
	Hanford B	"Tomsk 7"	NRX/Cirus	Calder Hall
Uranium Slug Diameter	3.48 cm	3.40 cm	3.46 cm	2.92 cm
Cladding Thickness	0.09 cm	0.10 cm	0.20 cm	0.58 cm
Width of Cooling Channel	0.22 cm	0.20 cm	0.18 cm	2.81 cm
Flow Tube Diameter	4.10 cm	4.00 cm	4.22 cm	9.70 cm
Aluminum Tube Thickness	0.15 cm	0.16 cm	0.10 cm	-
Lattice Pitch	21.27 cm	20.00 cm	17.30 cm	20.32 cm





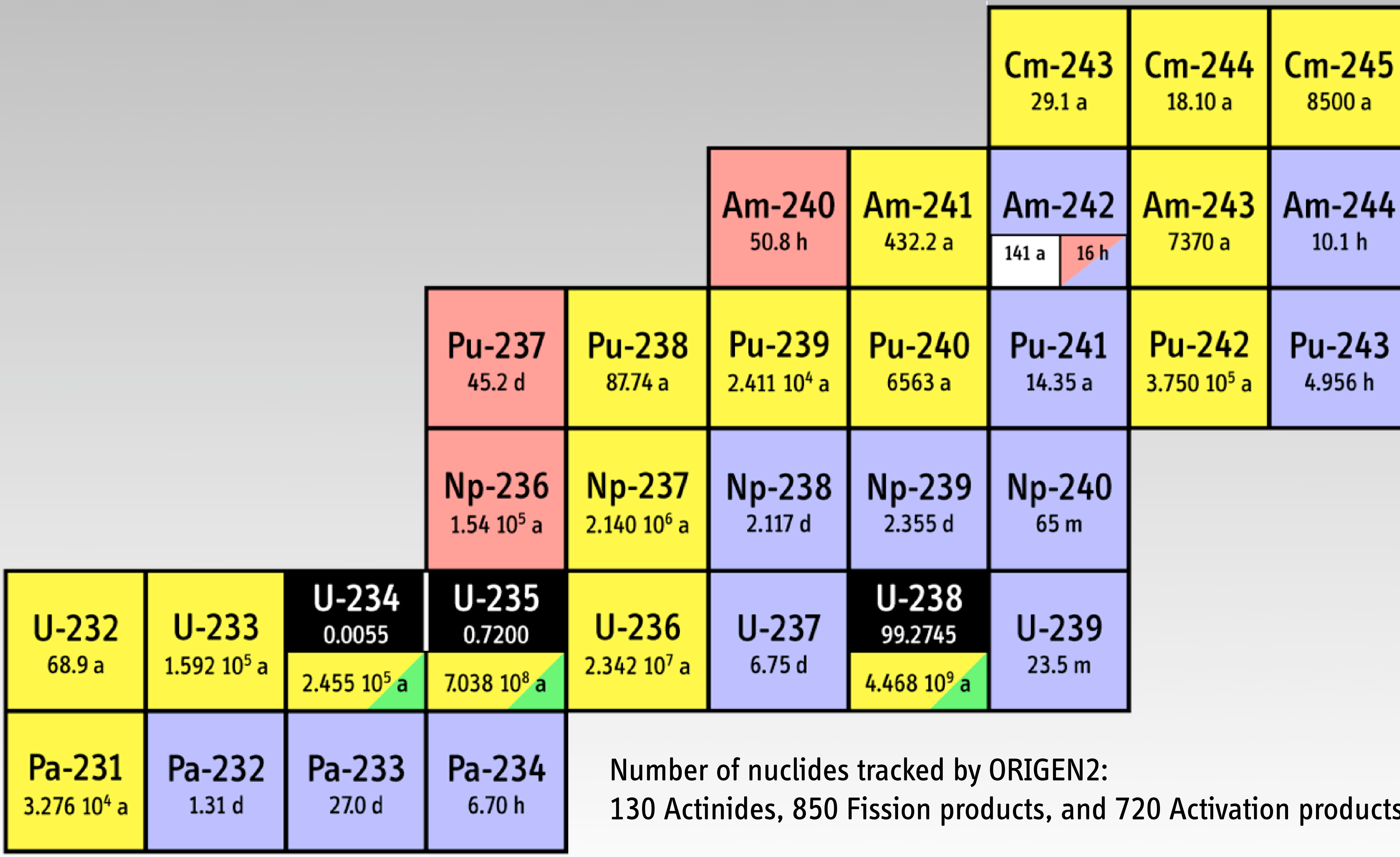


System for Neutronics Calculations



A. Glaser, *Neutronics Calculations Relevant to the Conversion of Research Reactors to Low-Enriched Fuel*
Ph.D. Thesis, Department of Physics, Darmstadt University of Technology, April 2005

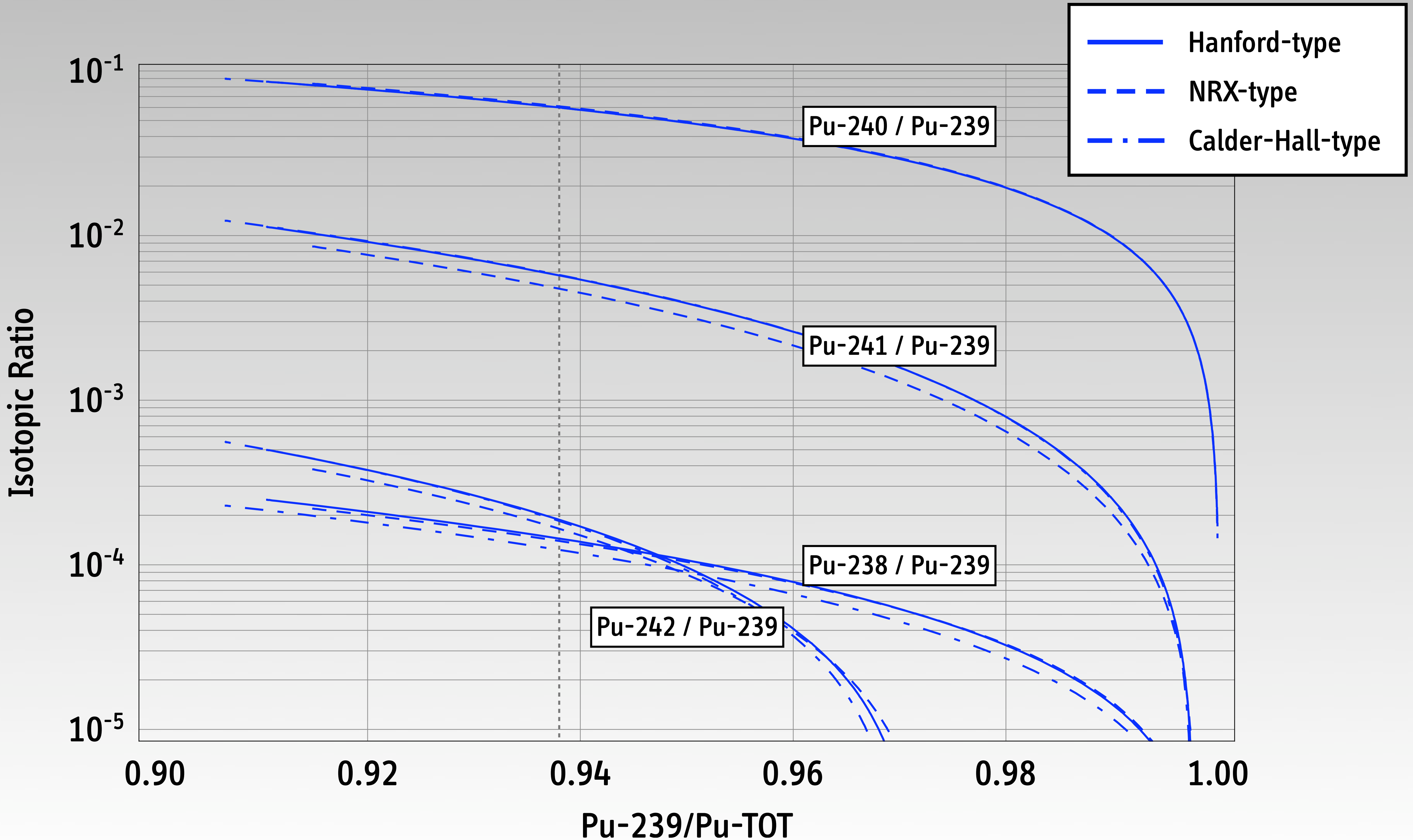
Nuclides in Burnup Calculations



Number of nuclides tracked by ORIGEN2:
130 Actinides, 850 Fission products, and 720 Activation products

Results

Plutonium Isotope Ratio Correlations

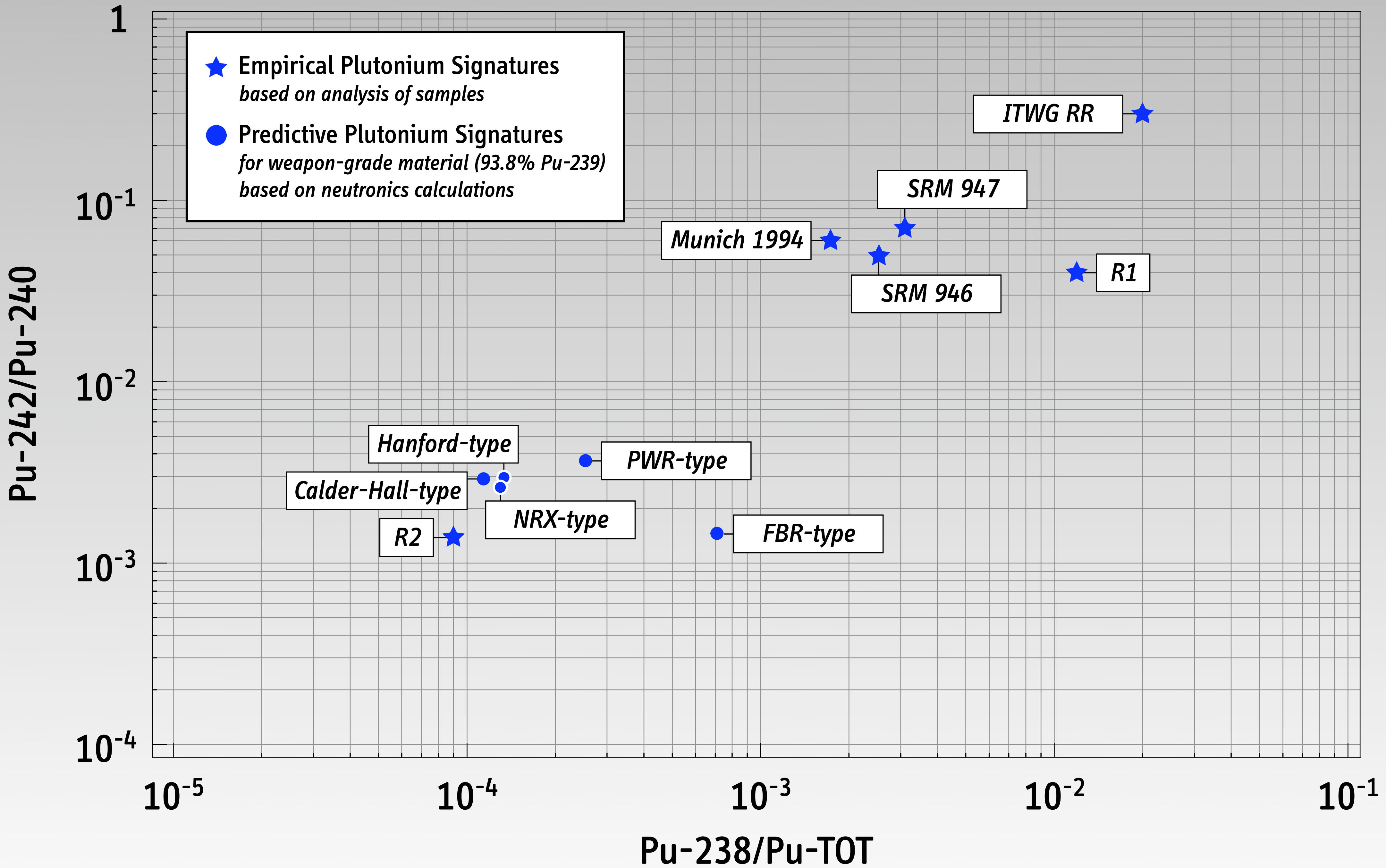


Plutonium Isotopics and Production Rates

(for target burnup achieving 93.8 wt% Pu-239)

	Hanford B	NRX/Cirus	Calder Hall	PWR
Pu-238	0.013%	0.013%	0.011%	0.0252%
Pu-239	93.8%	93.8%	93.8%	93.8%
Pu-240	5.64%	5.73%	5.64%	5.24%
Pu-241	0.53%	0.44%	0.53%	0.91%
Pu-242	0.017%	0.015%	0.017%	0.019%
Plutonium Production Rate	0.83 g/MWd	0.76 g/MWd	0.85 g/MWd	0.47 g/MWd

Isotope Ratio Correlations



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Summary and Conclusion

Results

Weapon-grade plutonium compositions from some basic reactor types can be distinguished based on computer simulations (i.e., based on predictive signatures)

In contrast, isotopics from dedicated production reactors using natural uranium fuel are very similar

Isotopic Signatures and Nuclear Forensics

Predictive signatures of plutonium are generally too weak for a robust nuclear forensic analysis (if source-attribution is pursued)

To perform task with confidence, empirical signatures (samples) are required

Importance of comprehensive (international) databases for nuclear forensics

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