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Title: Nuclear data needs associated with criticality monitoring during Fukushima Daiichi fuel debris retrieval operations

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Nuclear data needs associated with criticality monitoring during Fukushima Daiichi fuel debris retrieval operations

Jesson Hutchinson, Natalie Cannon, Cole Kostelac, George McKenzie, Jawad Moussa, Michael Rising, Lucas Rolison, and Nicholas Thompson

Figure 6. Bulky deposits (around point ① in Figure 5) [3]

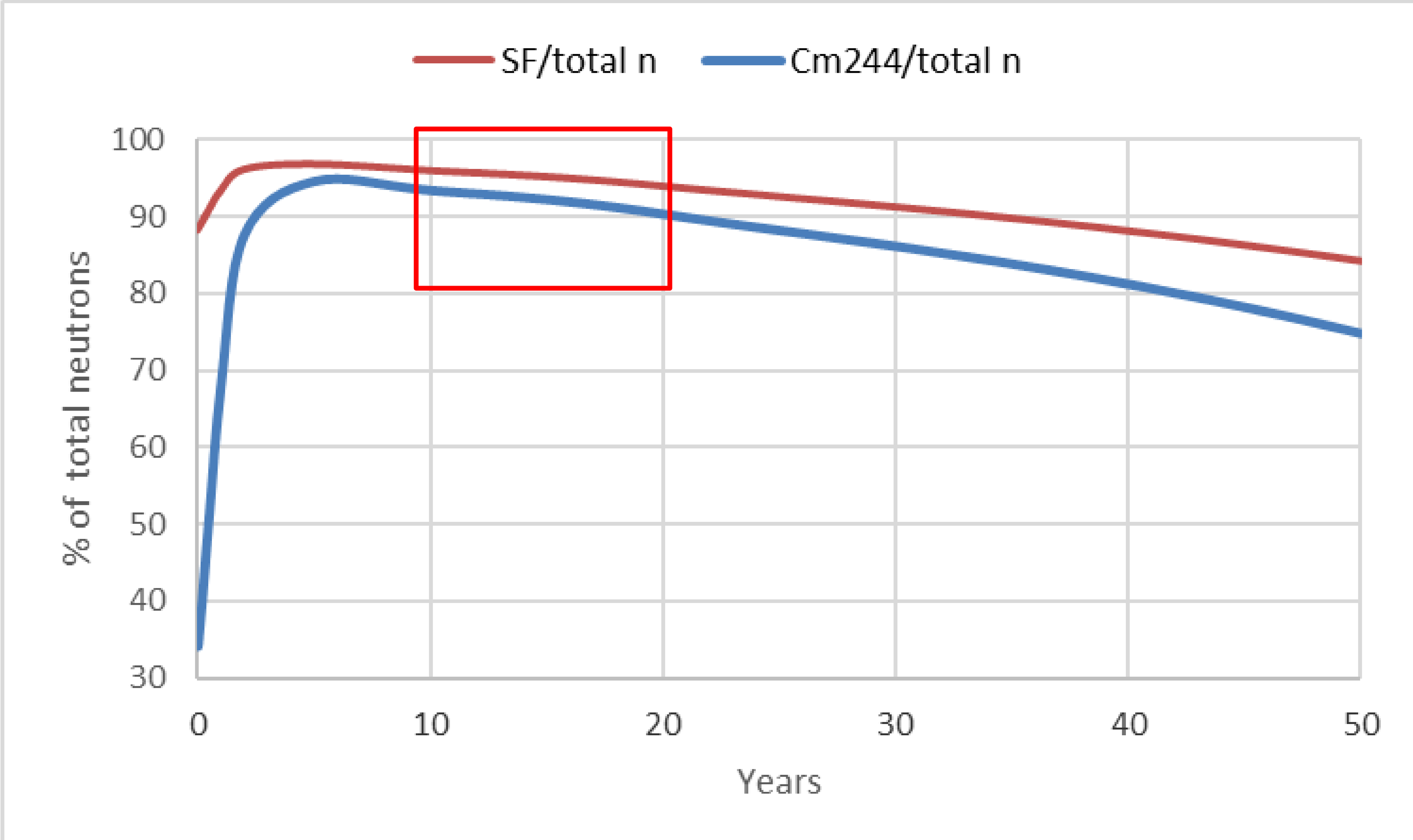
K. Owada, "Features of Fukushima Daiichi Nuclear Power Plant Accident and Information on Fuel Debris Obtained from PCV Internal Investigations," ICNC 2023.

Background

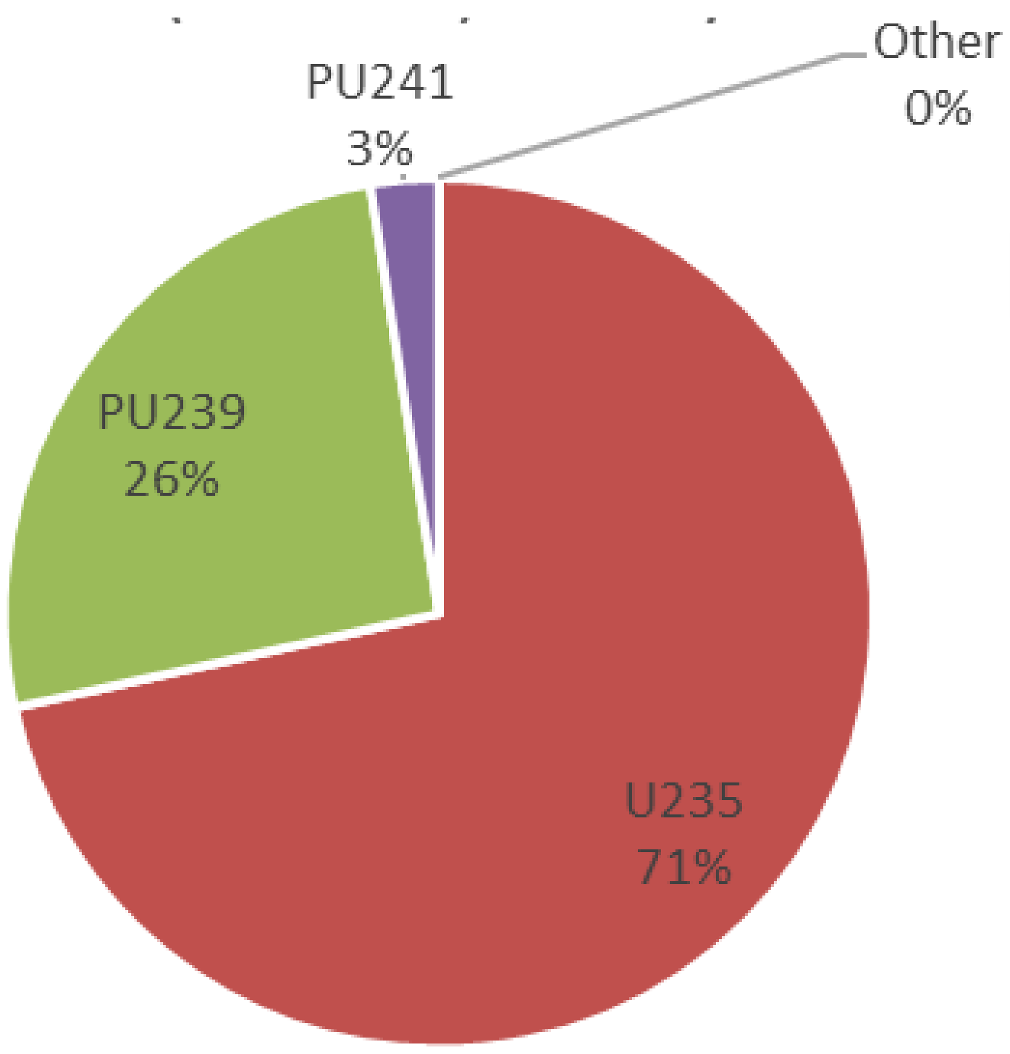
- Fuel debris removal operations at the Fukushima-Daiichi Nuclear Power Station (1F) present significant complexities in many engineering disciplines
- One among them is monitoring of neutron multiplication
- Subcriticality must be maintained at 1F, even though there is unknown composition and distribution of the fuel debris
- Multiple parameters of criticality can change simultaneously
- Could result in increase in system multiplication
- Measurement of neutron multiplication, therefore, is an important component of decommissioning the 1F to ensure safety and maximize efficiency

1FRAME project

- 1FRAME (1F Fuel Retrieval and Monitoring Experiments) funded by the DOE Nuclear Criticality Safety Program (DOE-NCSP)
- Collaboration with Japanese organizations and ASNR France
- Project objective: advancing R&D related to neutron detection, analysis, and simulations
- **Focus of this work: nuclear data needs associated with 1F fuel debris retrieval, with an emphasis on needs within the next decade**
- Largest sources of uncertainty are not nuclear data, but still worth looking into
  - All 3 units had been run at power for months prior to shutdown
  - Actinide buildup makes neutron detection more difficult
  - Also results in induced fission in Pu239
  - Molten Core Concrete Interaction (MCCI) also creates challenges



Fraction of spontaneous fission to all starter neutrons and Cm244 to all starter neutrons



Induced fission by nuclide in Unit 1 at 20 years

Wt.% of top nuclides in Unit 1 at 10 and 20 years. Does not include MCCI

Total	10.0YR	20.0YR
U238	70.7%	70.7%
O16	10.0%	10.0%
ZR90	7.6%	7.6%
ZR94	2.7%	2.7%
ZR92	2.6%	2.6%
ZR91	1.7%	1.7%
U235	1.2%	1.2%
ZR96	0.4%	0.4%
PU239	0.3%	0.3%
U236	0.3%	0.3%
XE136	0.1%	0.1%
PU240	0.1%	0.1%

Methods/Results

- Composition of nuclides within 1F is obtained from previous simulation efforts performed Japan Atomic Energy Agency (JAEA) and other references
- Focus of results:
  - Time: 10-20 years (currently 14 years since 2011)
  - Location: unit 1 (arbitrarily chosen)
- Starter neutron population is currently dominated by Cm244 spontaneous fission (SF): 90-93% of all starter neutrons
  - Currently (α,n) is not a large contributor
- Beneficial for detection if the majority of starter neutrons are from the same nuclide
- For induced fission (IF), both U235 and Pu239 are important
  - In the fast region U238 is also important

Future work

- Model 1F units (upcoming NCSD 2025 conference)
- Research on neutron detection and analysis for neutron multiplication and neutron mapping at 1F

Conclusions

- Starter neutrons: both spontaneous fission and (α,n) neutron investigated. Cm244 to dominate starter neutrons for the next decade
- Induced fission: split between U235 (~71%) and Pu239 (~26%) for thousands of years
- Core materials: U, O, Zr, Pu, Xe
- Fission product inventory: not investigated in detail, part of future work
- Molten Core Concrete Interaction (MCCI): Si, Ca, C, H, Al, Fe, Cr, Ni
- Interested in talking about nuclear data needs for any/all of these!

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NCERC NATIONAL CRITICALITY EXPERIMENTS RESEARCH CENTER
NCSP NUCLEAR CRITICALITY SAFETY PROGRAM