Uncertainties in Plutonium multi-recycling scenarios

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IJCLab (2024-2027)

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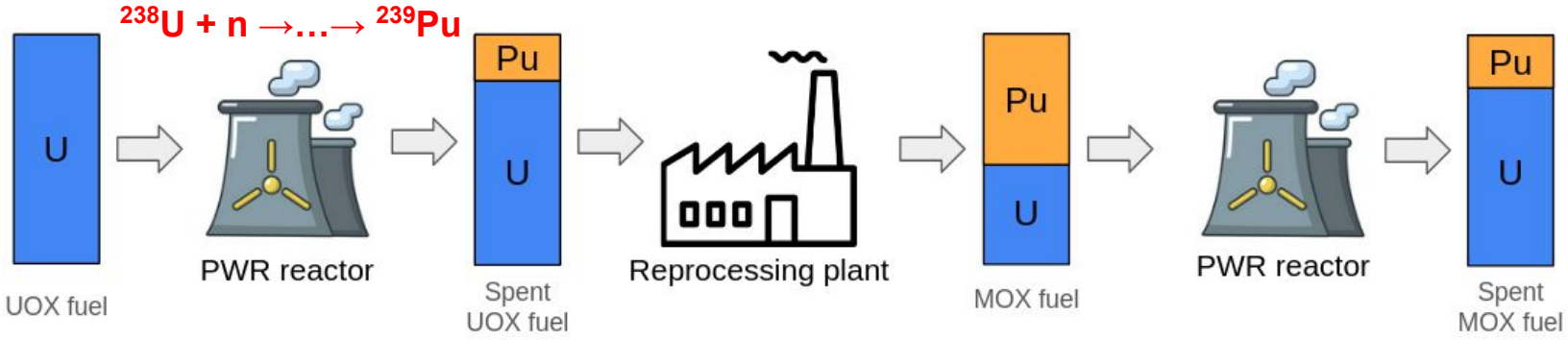
Agenda

1- Fuel cycle and scenarios

2- Uncertainties in fuel cycle scenarios

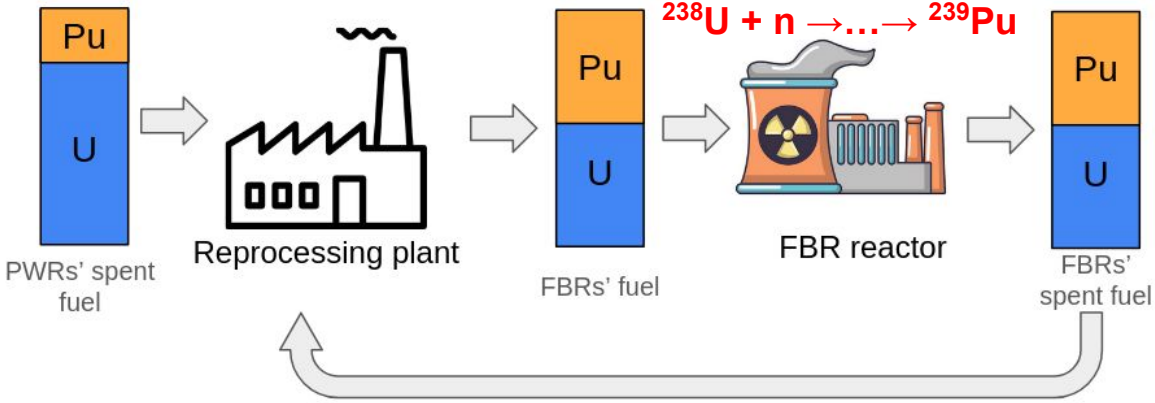
3- Uncertainties propagation examples

Current French fuel cycle



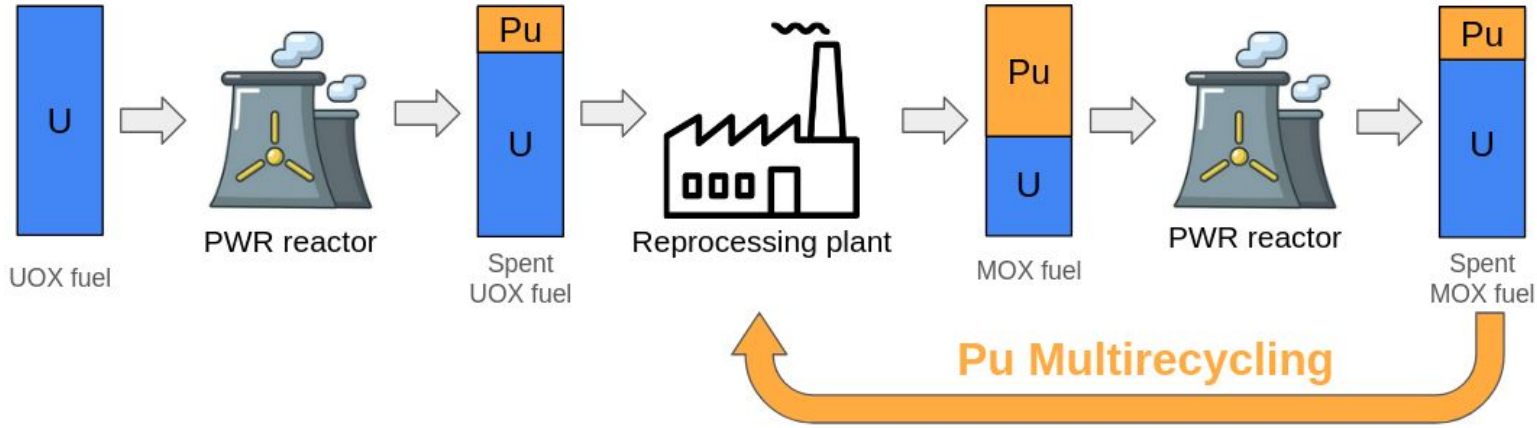
More plutonium is consumed than produced in a PWR

2100 French fuel cycle strategy



A FBR can consume as much plutonium as it produces:
no mining required

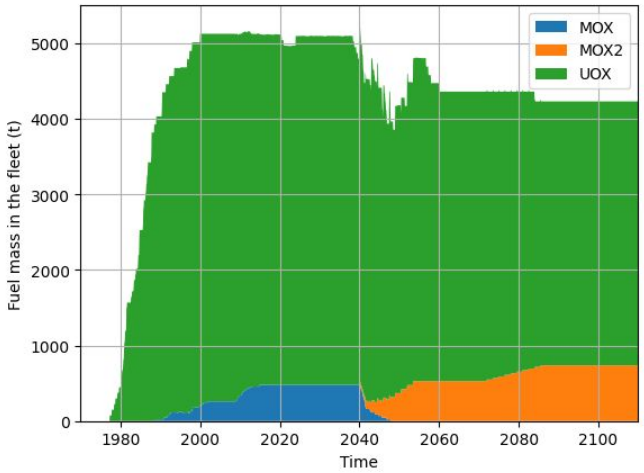
Mid-term French fuel cycle strategy: Pu multi-recycling in PWR



Pu multi-recycling in PWR can reduce spent fuel inventory but …
decrease Pu mass and quality

$^{238}U + n \rightarrow \ldots \rightarrow {}^{239}Pu$
$^{239}Pu + n \rightarrow {}^{240}Pu$
$^{240}Pu + n \rightarrow {}^{241}Pu$
$^{241}Pu \rightarrow {}^{241}Am\ (T_{1/2} = 14\ y)$
$^{241}Pu + n \rightarrow {}^{242}Pu$

Fuel cycle scenarios



Part of the definition of a multi-recycling scenario

A scenario explores possible futures to test assumptions, it is NOT a forecast

Fuel cycle simulation code

- CLASS code used, developed in CNRS
- Modelize fuel cycle facilities:
  - Reactors
  - Separation plant
  - Fabrication plant
  - Cooling pools …
- Outputs :
  - Spent fuel inventory
  - Spent fuel isotopy

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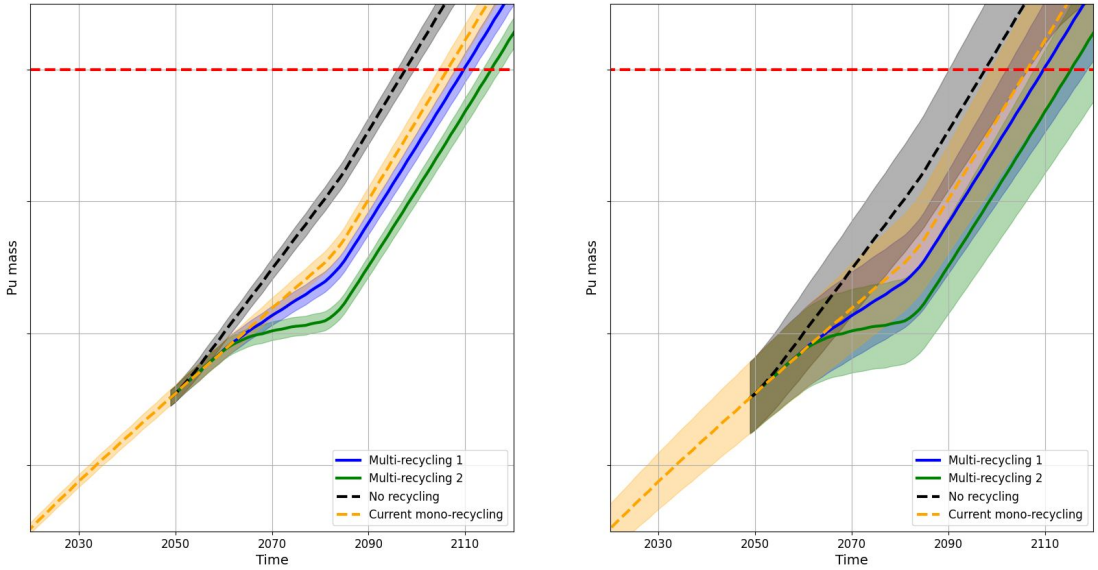
Uncertainties in nuclear scenarios

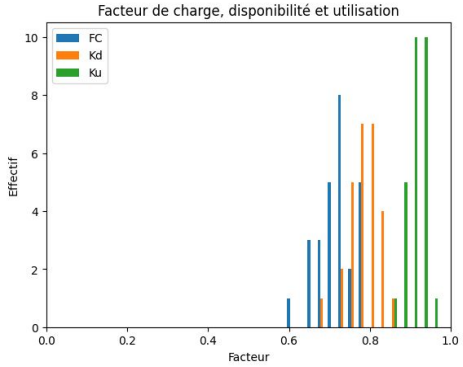


Plutonium mass evolution in different scenarios for two uncertainties magnitudes

What is the impact of Pu multi-recycling in PWR on the deployment of FBRs ?

What are the uncertainties?

Sources of uncertainty

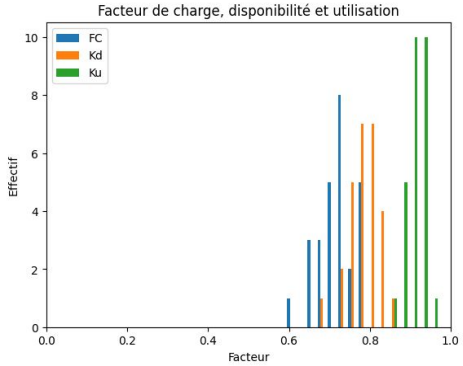


Data:IAEA PRIS

Operational parameters uncertainties (for past and future)

- Fuel discharge burn-ups
- Reactors load factor
- …

Sources of uncertainty



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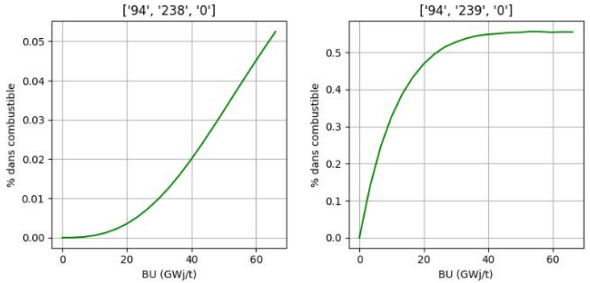

Operational parameters uncertainties (for past and future)

- Fuel discharge burn-ups
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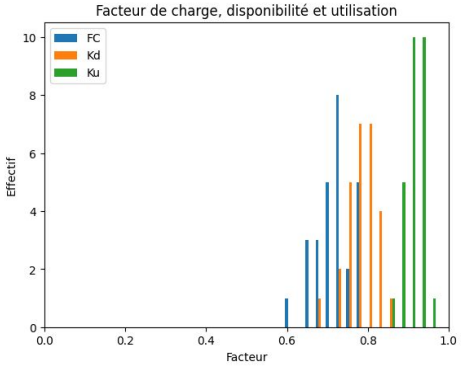
Uncertainties in fabrication and depletion of the fuel

- Nuclear data
- Computational schemes
- Fabrication criteria
- …

Sources of uncertainty



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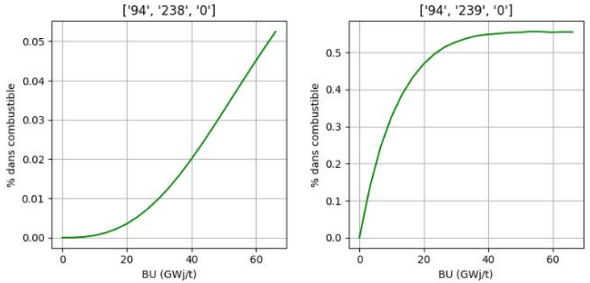

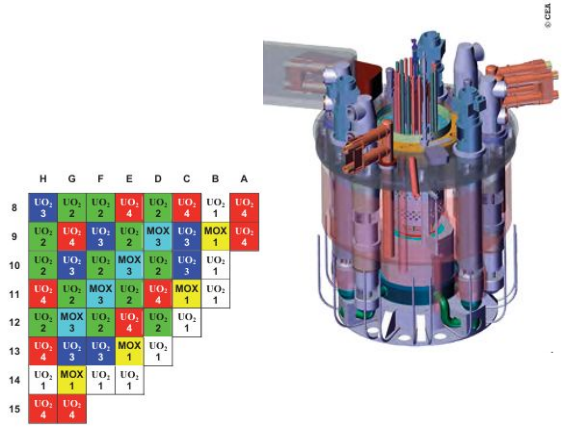

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Future choices for the cycle

- Loading pattern
- Reactors lifetime
- FBRs design
- …

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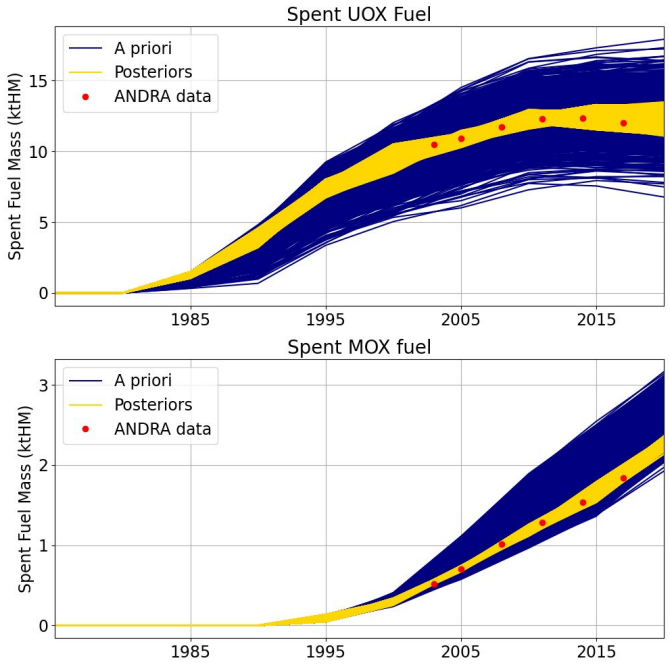
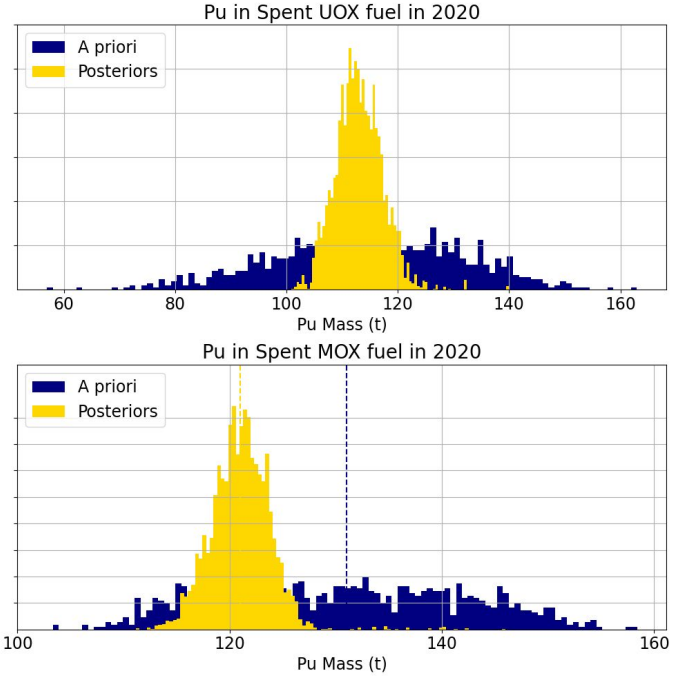
First example: Bayesian uncertainties reduction for historical fleet



French spent nuclear fuel evolution

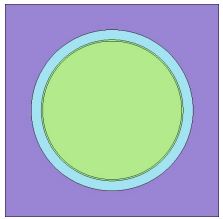
Bayesian framework:

Metropolis-Hastings algorithm



Pu distribution in spent fuel in 2020

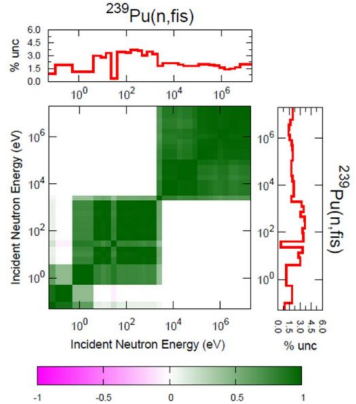
Second example: Nuclear data uncertainties propagation



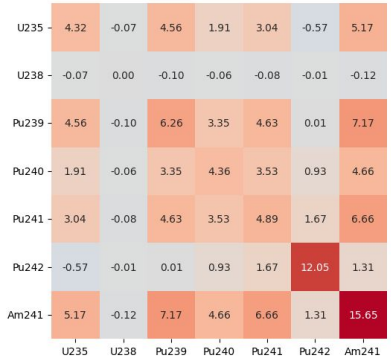
Fuel pin simulations

$$\frac{\partial N_i}{\partial \sigma}$$

Sensibility coefficients

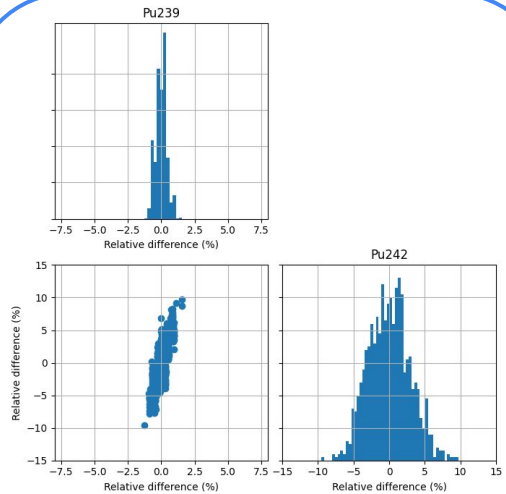


Nuclear data covariance matrix



Isotopic error covariance matrix

Errors sampling



Pu239 and Pu242 distribution

Conclusion

- Identification of sources of uncertainty
- Implementation of appropriate propagation methods for different sources of uncertainties

Perspectives

- Continue to implement uncertainty propagations
- Propagate all uncertainty sources in a multi-recycling scenario