2019 Technical Workshop on Nuclear Fuel Cycle Simulation

The FIT Project: Improving confidence in fuel cycle model

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OUTLINE

1. Présentation of the FIT Project

a. Framework of the project
b. Goals and intended impacts of the project

2. Fuel Loading Model versus Fixed Fraction

a. What is a functionality?
b. Exercice design and methodology

3. Contributions and output analysis

a. Contributions
b. Output analysis

4. Results analysis

a. Estimator building
b. Estimators #1 for PWR

Conclusions and Perspectives

Part 1 : Presentation of the FIT Project

1.1 Framework of the project

- Fuel Cycle Simulators (FCS) are developed for many purposes
  - Study existing nuclear fleet in support for industrial operation optimization
  - Study and analysis of electro-nuclear future trajectories for prospective reflexions
  - Verification and/or assessment of nuclear fleets by safety authorities
  - Training and educational tool for the fuel cycle understanding

- FCS confidence outputs is a major issue

- FCS bias & uncertainty
  - Reactor simplifications
    - ➡ System simulations
    - ➡ Nuclear Data
  - Scenario simplifications
    - ➡ Technical parameters
    - ➡ Facility operating hypothesis
  - FCS use
    - ➡ Problem definition
    - ➡ Problem solving method

- Reactors studies
  - Code development and qualification
  - Benchmarks
  - Precise reactor coupling with FCS

- Fuel cycle studies
  - Functionality testing → FIT Project
  - Global benchmarks

- FCS use
  - Sociology related question

- Animate a community of fuel cycle specialist on confidence in outputs

ANICCA	TRACTEBEL (BEL)	CLASS	CNRS / IN2P3 (FRA)
	Univ. Catlica del Maule (CHL)	DYMOND	Argonne National Lab (USA)
CYCLUS	Univ. of Wisconsin Madison (USA)	JOSSETTE	BME (HUN)
	Univ. of Illinois (USA)	ORION	Oak Ridge National Lab (USA)
Tr_Evol	CIEMAT (ESP)	VISION	Idaho National Lab (USA)

- What is the minimum level of details in fuel cycle simulations required as a function of the study and the wanted confidence level?
  - ➡ Help developers/users to define priorities for the FCS they develop
  - ➡ Help users to decide which FCS to use according to their needs
  - ➡ Evaluate weak/strong points related to fuel cycle studies

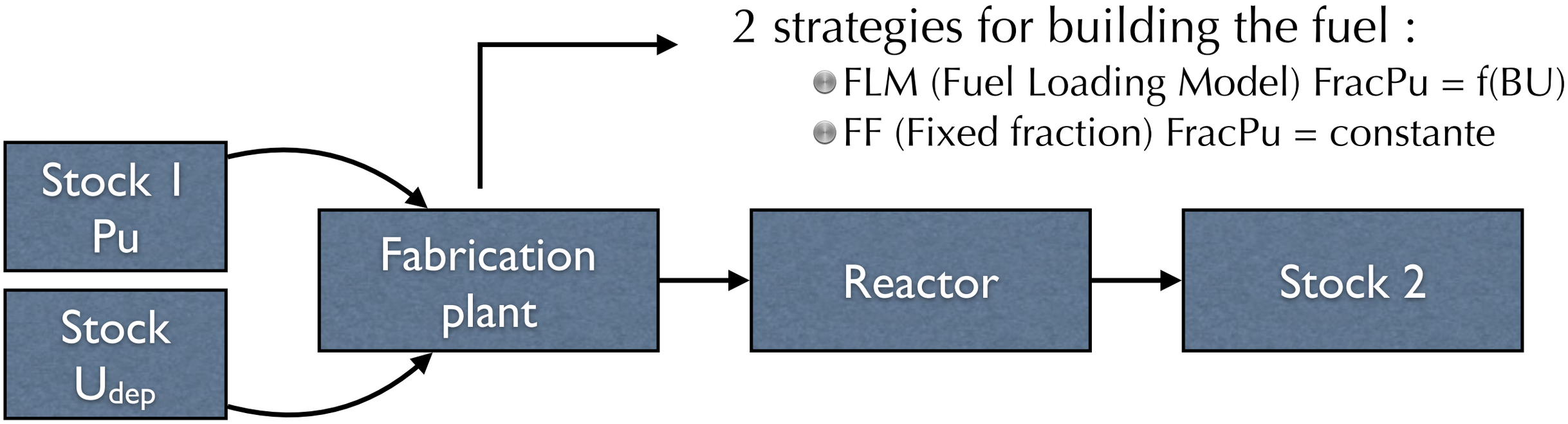
- A fuel cycle code functionality is the translation into computer software language of a physical or technical process related to nuclear facilities.

Reference	Functionality to develop
At each reactor loading, the reactor fresh fuel composition is constant	At each reactor loading, the reactor fresh fuel composition depends on available material isotopic composition
The reactor load factor is constant over the reactor lifetime	The reactor load factor takes into account precise industrial constraints, such as partial refueling
The mean cross sections used to perform the fuel evolution in reactor are calculated at BOC and kept constant during the cycle	The mean cross sections used to perform the fuel evolution in reactor are updated according to fuel composition
The reactor first cycles composition is not taken into account and is assumed to be the steady states composition	The exact reactor first cycles composition is used

Table 1: Examples of simplified and more complex functionalities.

Fresh fuel @ B.O.C.

- FF (Fixed Fraction)
  - Fissile fraction is constant
- FLM (Fuel Loading Model)
  - Reactor requirements
  - Available isotopes stock



Wide Parametric Sweeping method:

- Two simulation groups
  - PWR MOx
  - SFR MOx
- For each reactor type
  - Random compositions
  - 1 cycle simulation / composition
  - N runs for FLM
  - N identical runs for FF

Isotope	Min. wgt. Fraction	Max. wgt. Fraction
^{238}Pu	0	10
^{239}Pu	25	90
^{240}Pu	10	40
^{241}Pu	0	25
^{242}Pu	0	30
^{241}Am	0	10

Data are stored in a GitHub repo:

- Project documents
- Output Data for exercice #1
- Draft of the first FIT paper

Impact of the Fresh Fuel Loading Management in Fuel Cycle Simulators In The Framework Of The FIT Project

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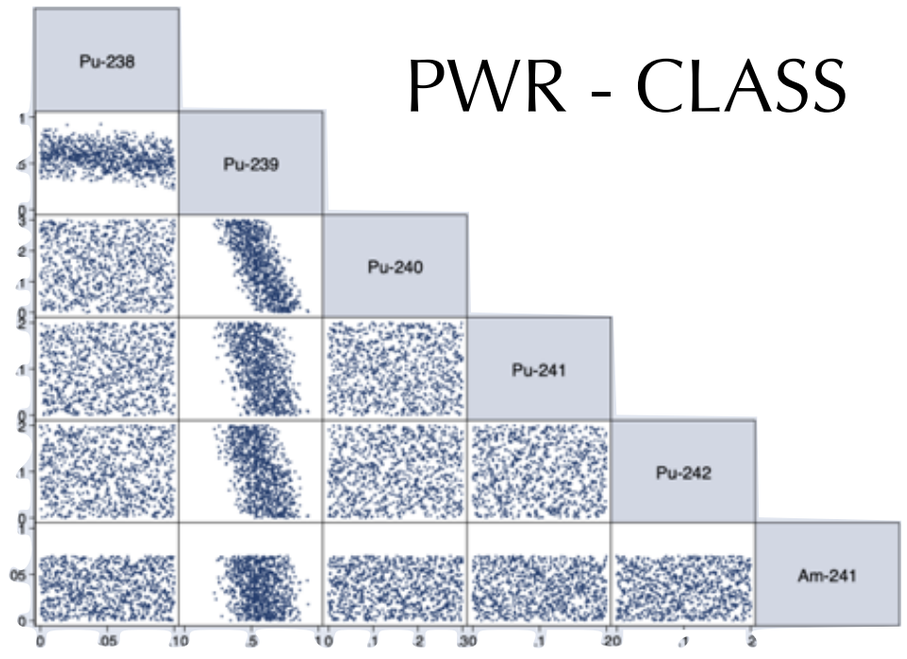
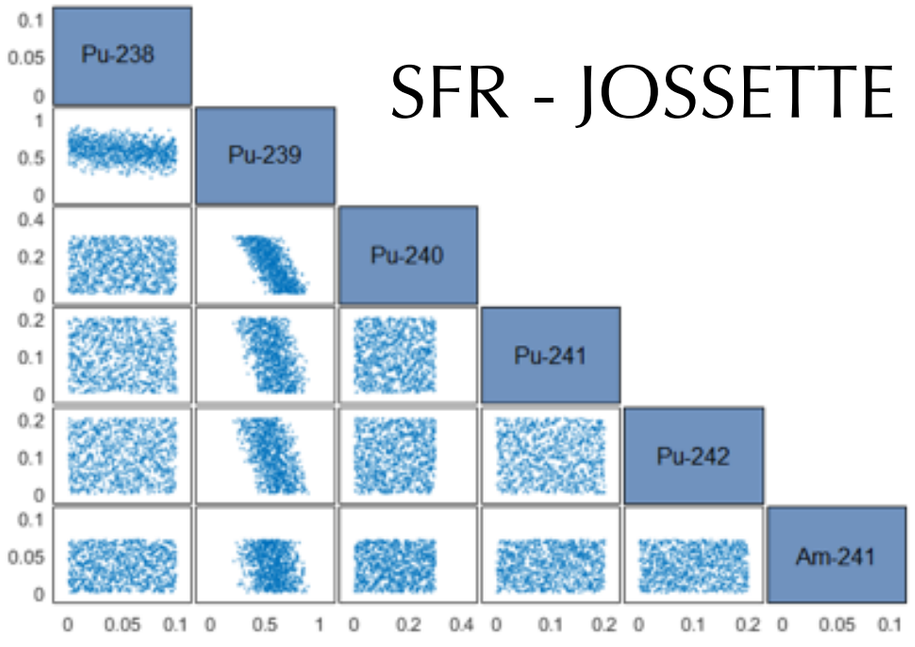
Contributions for this exercise

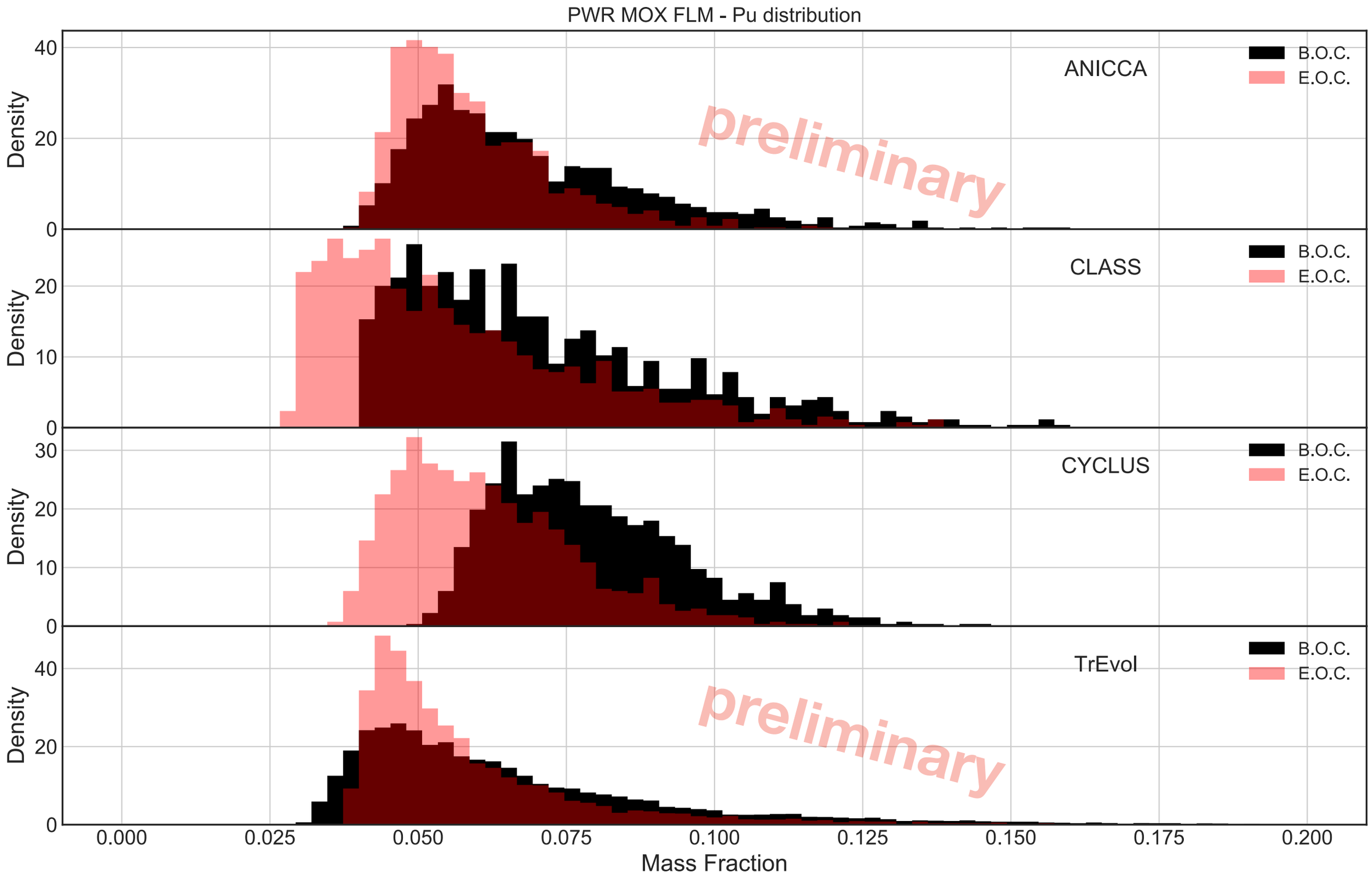
Code	PWR	SFR
ANICCA	X	X
CLASS	X	X
CYCLUS	X	-
JOSSETTE	-	X
TR_EVOL	X	-

PWR - CLASS



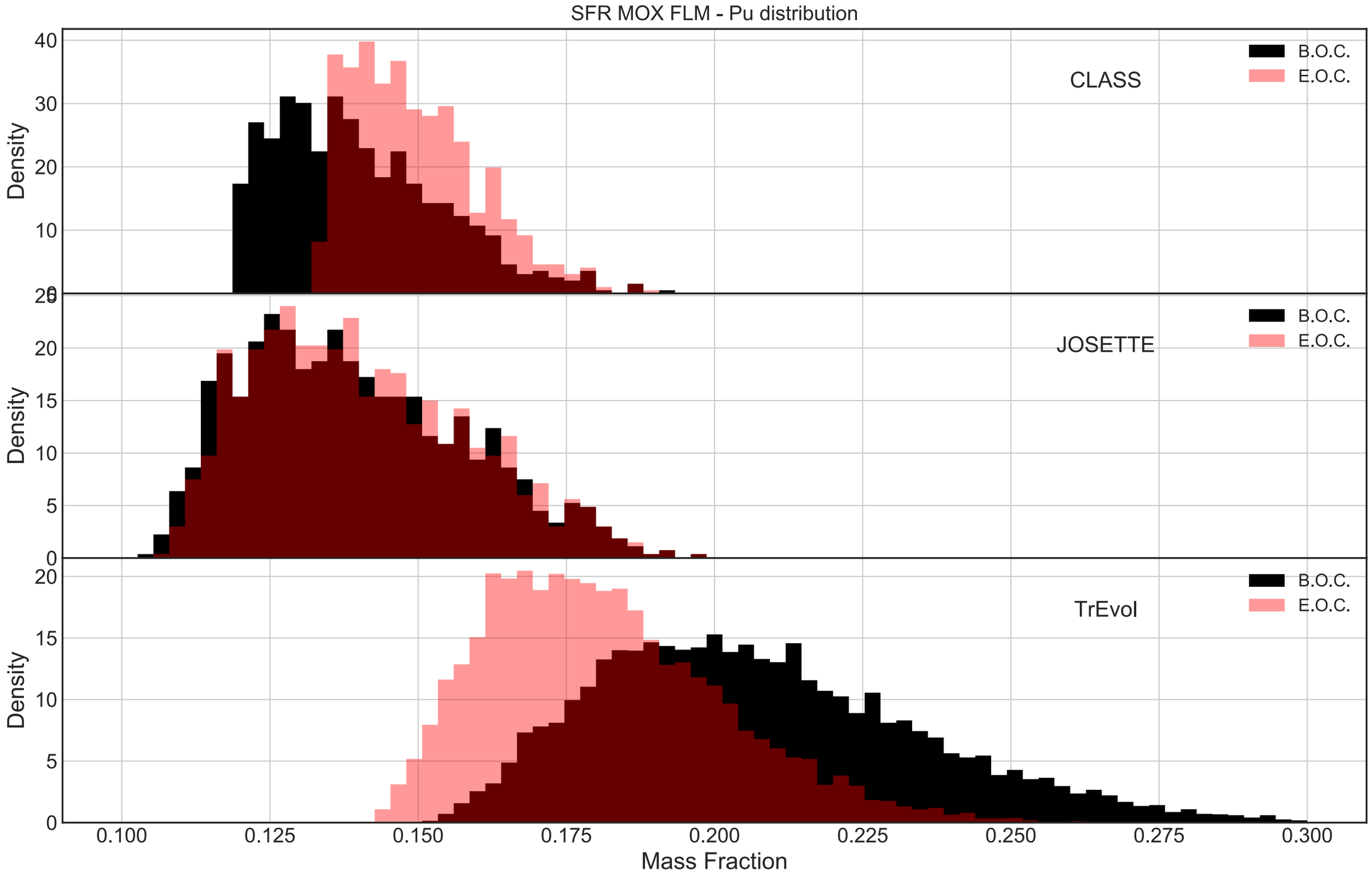
SFR - JOSSETTE



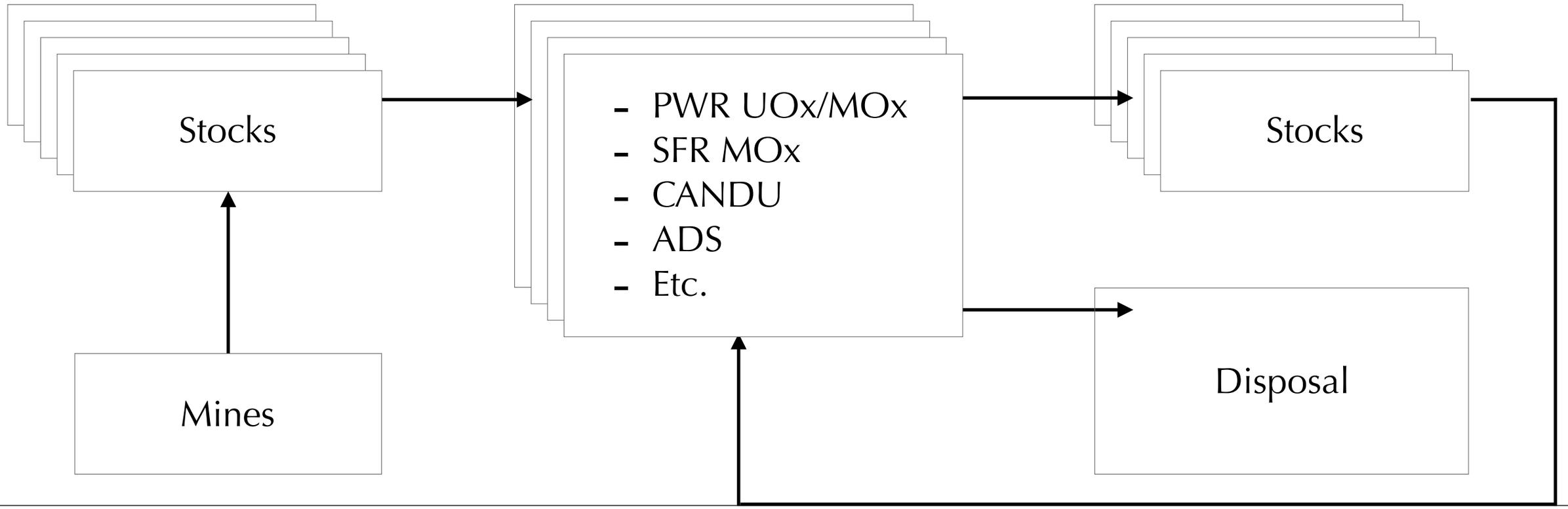

PWR MOX FLM - Pu distribution
ANICCA
CLASS
CYCLUS
TrEvol
B.O.C.
E.O.C.
Density
Mass Fraction
preliminary
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200

Part 3 : Contributions and output analysis

3.2 Output analysis

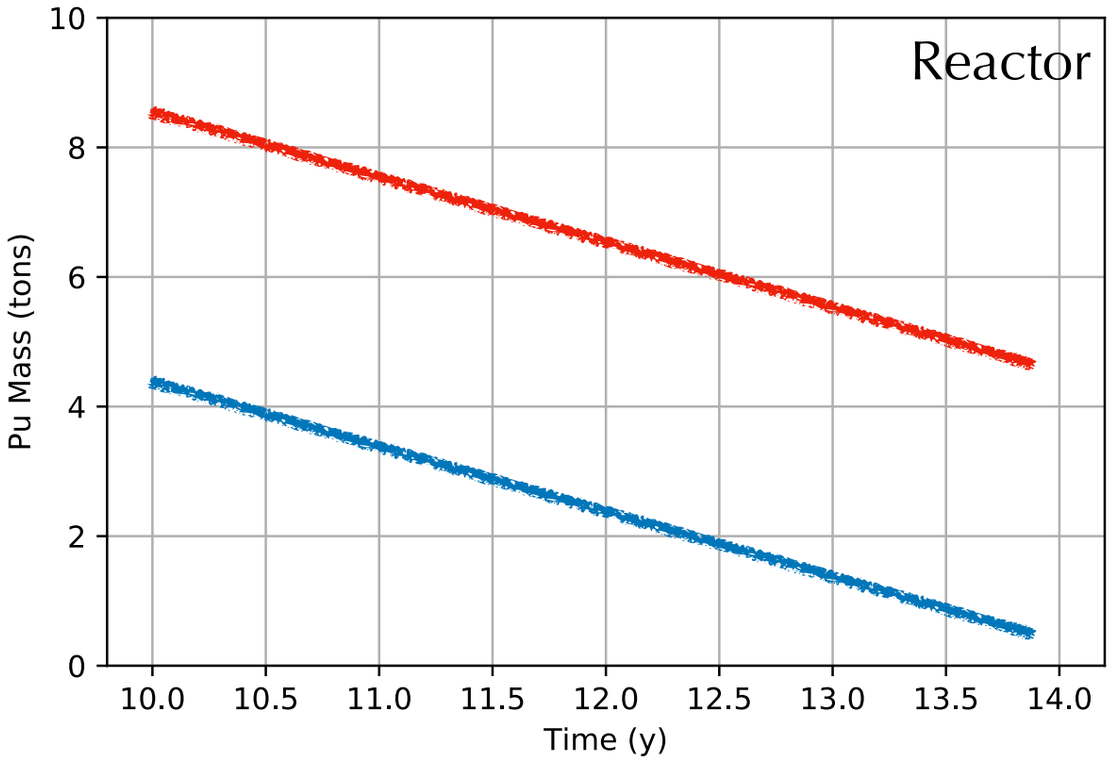


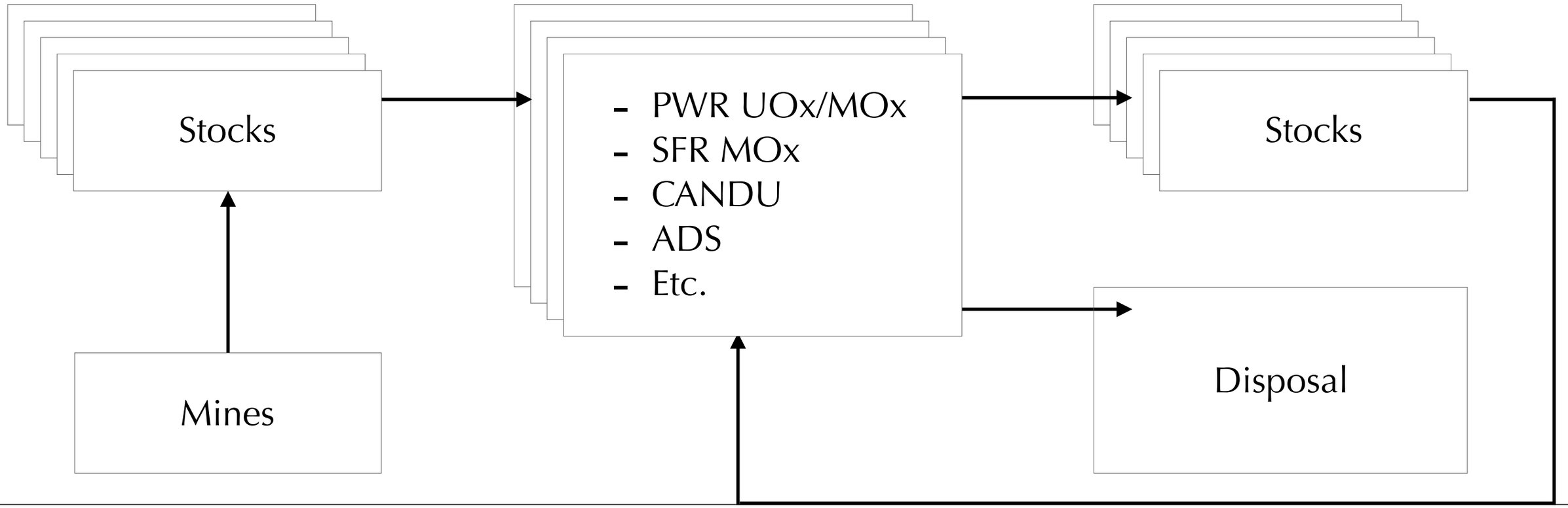
- How to build relevant estimators for direct outputs data from FCS?
  - A local effect means that there is an impact on a specific facility
  - A global effect means that there is an impact on a total inventory



Part 3 : Results analysis

3.1 Estimator building





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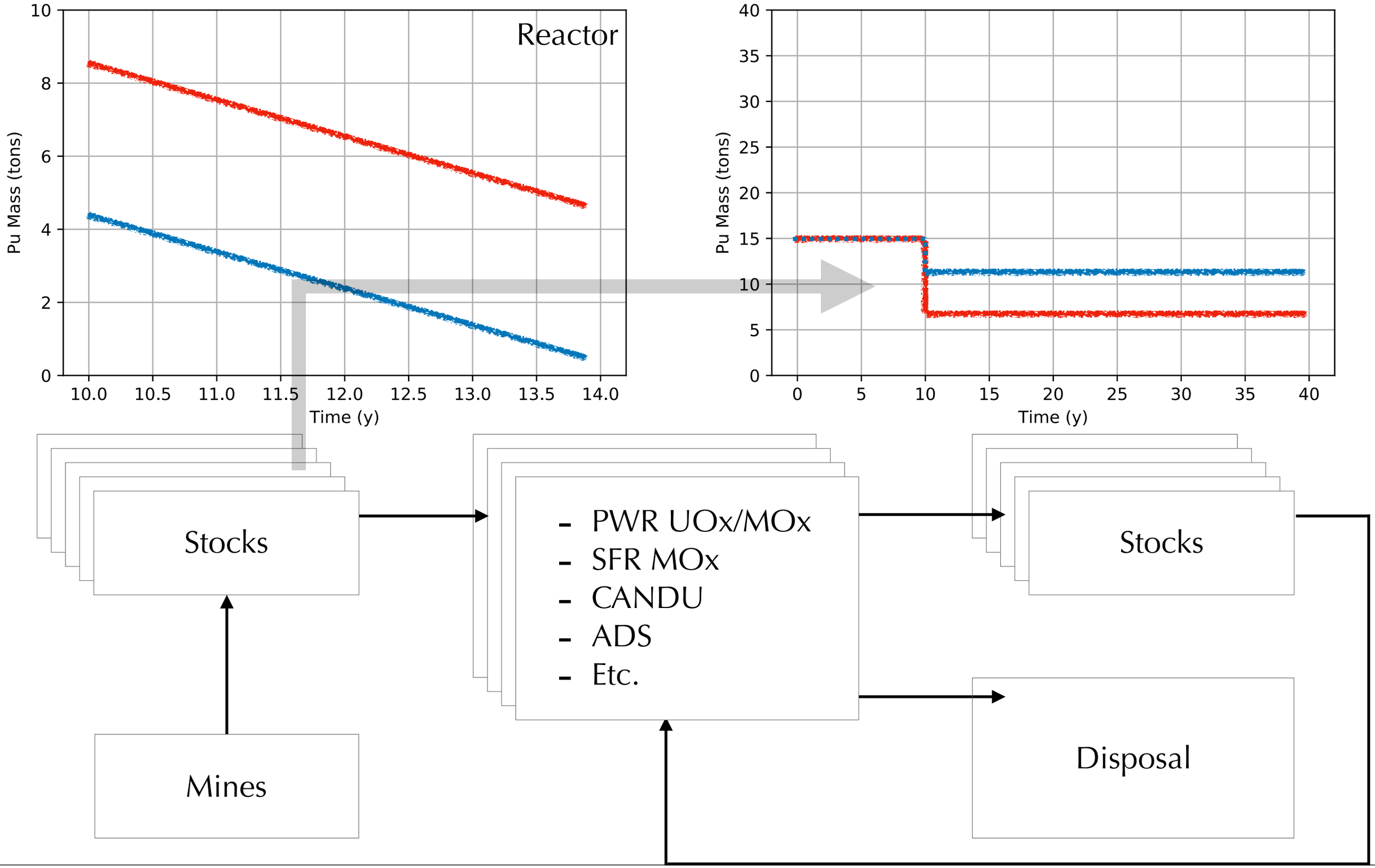

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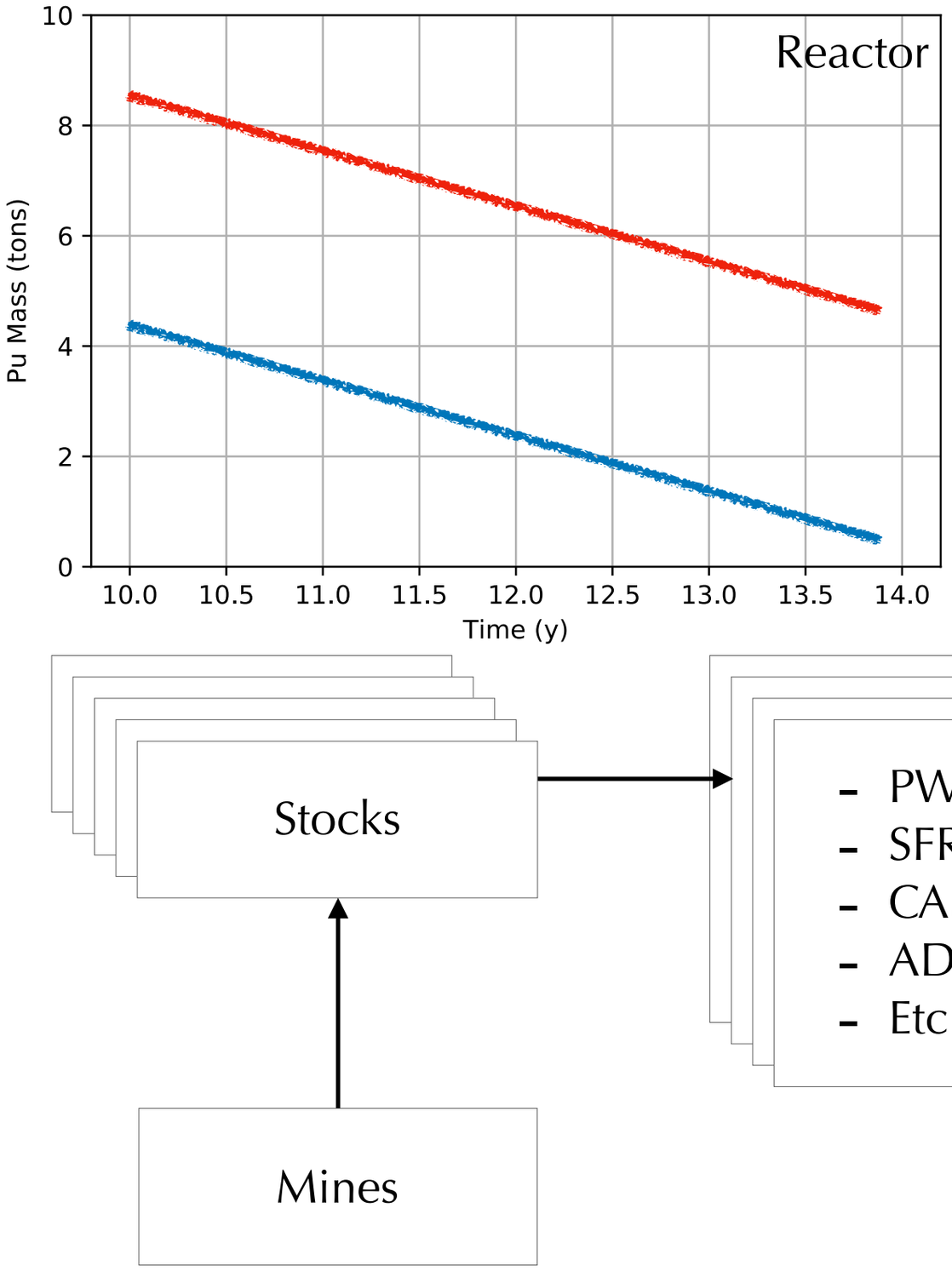
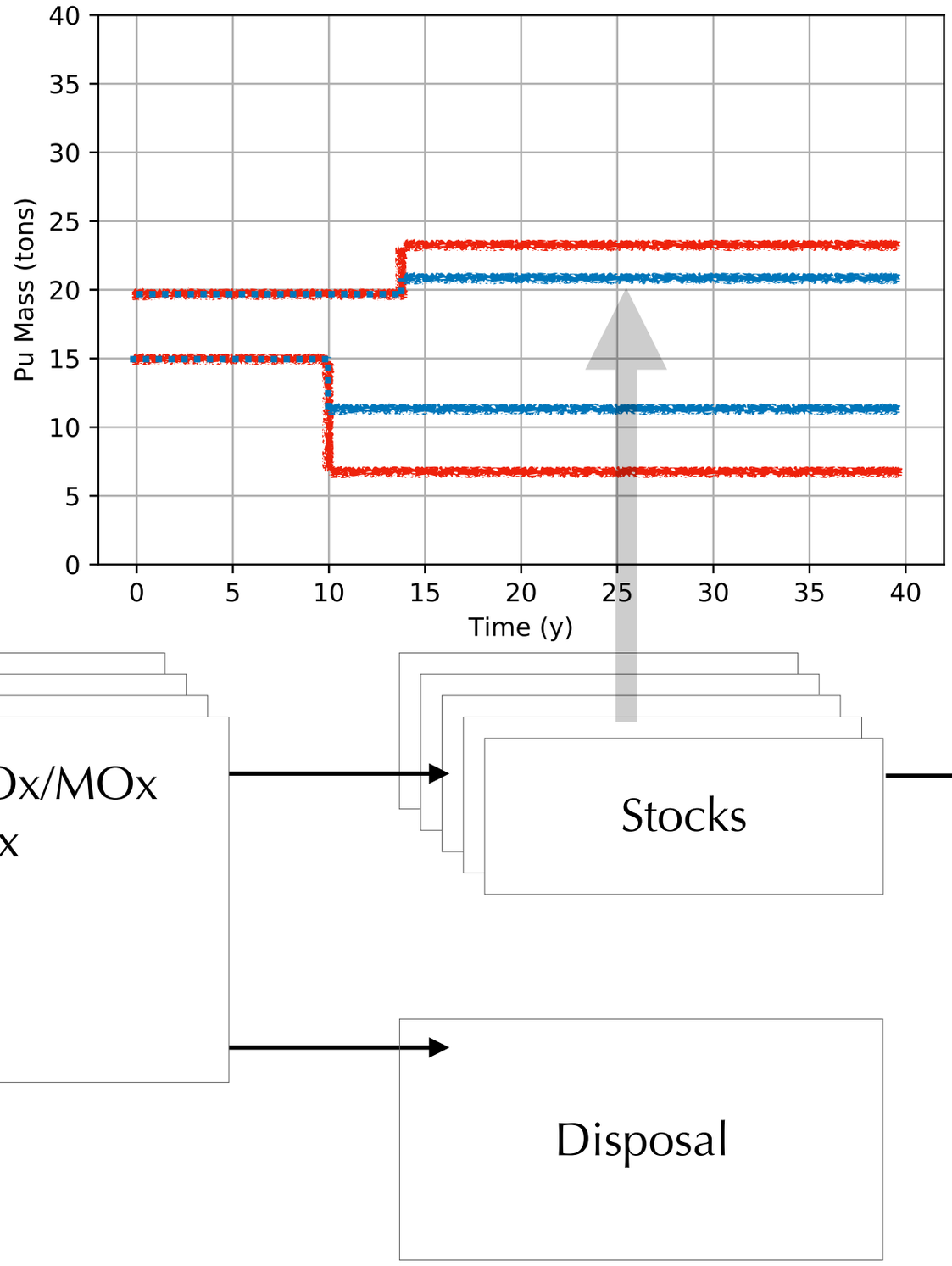
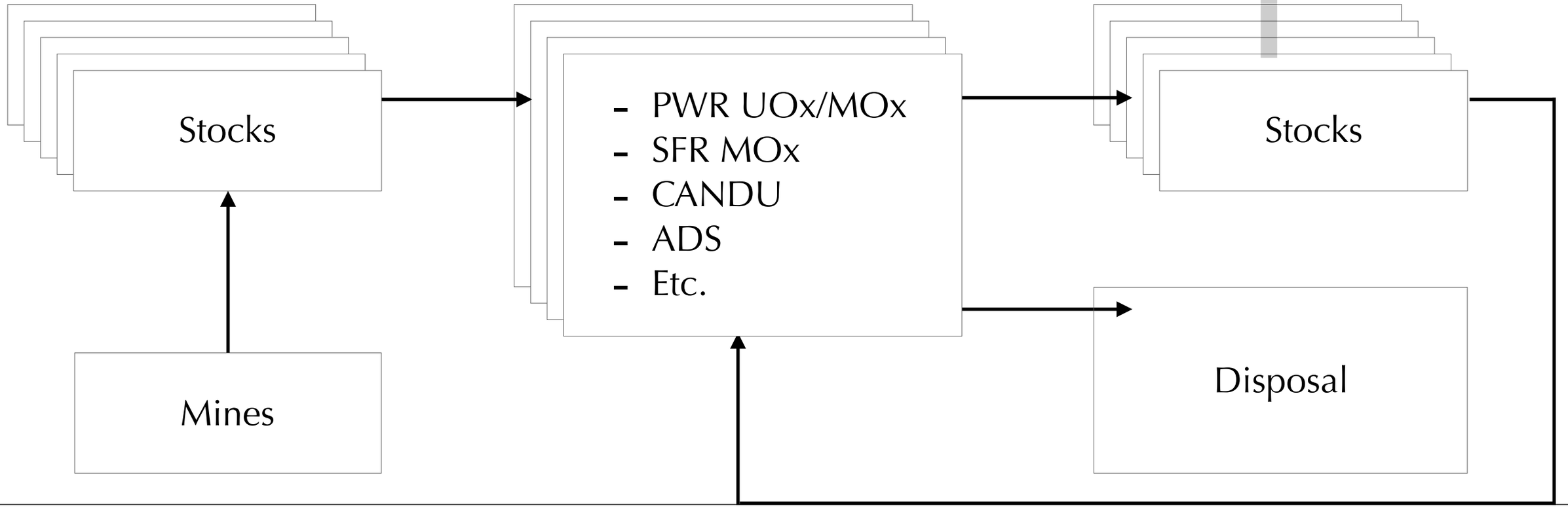
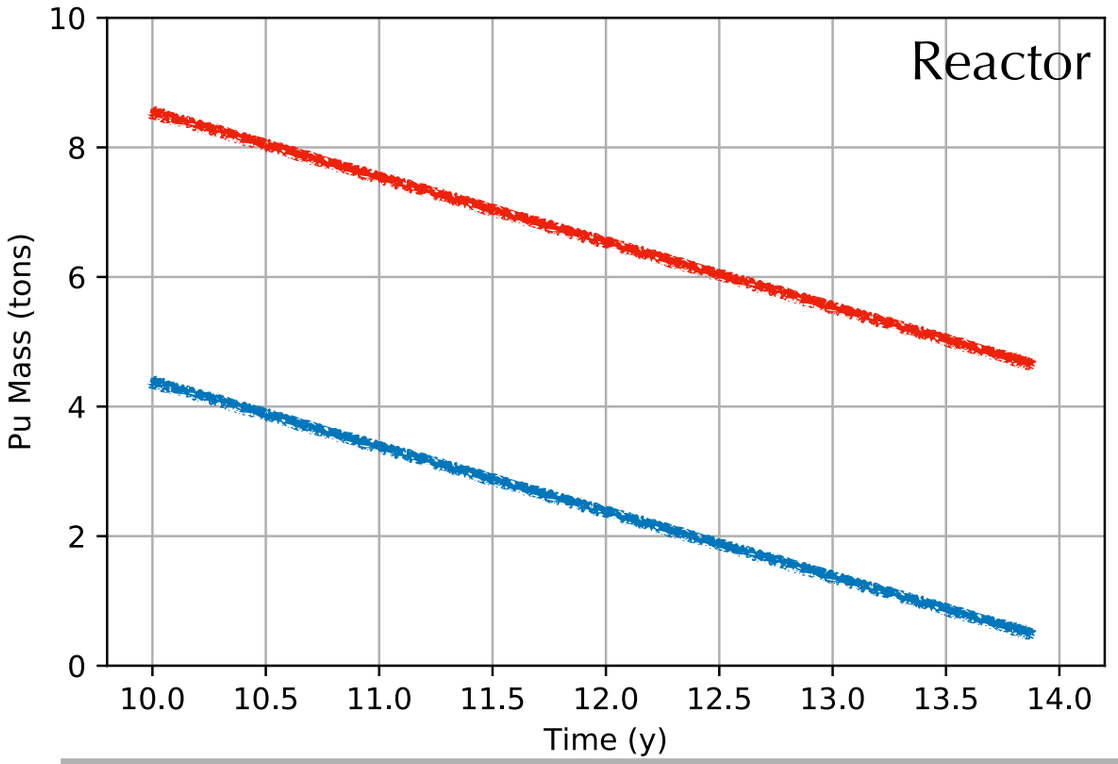


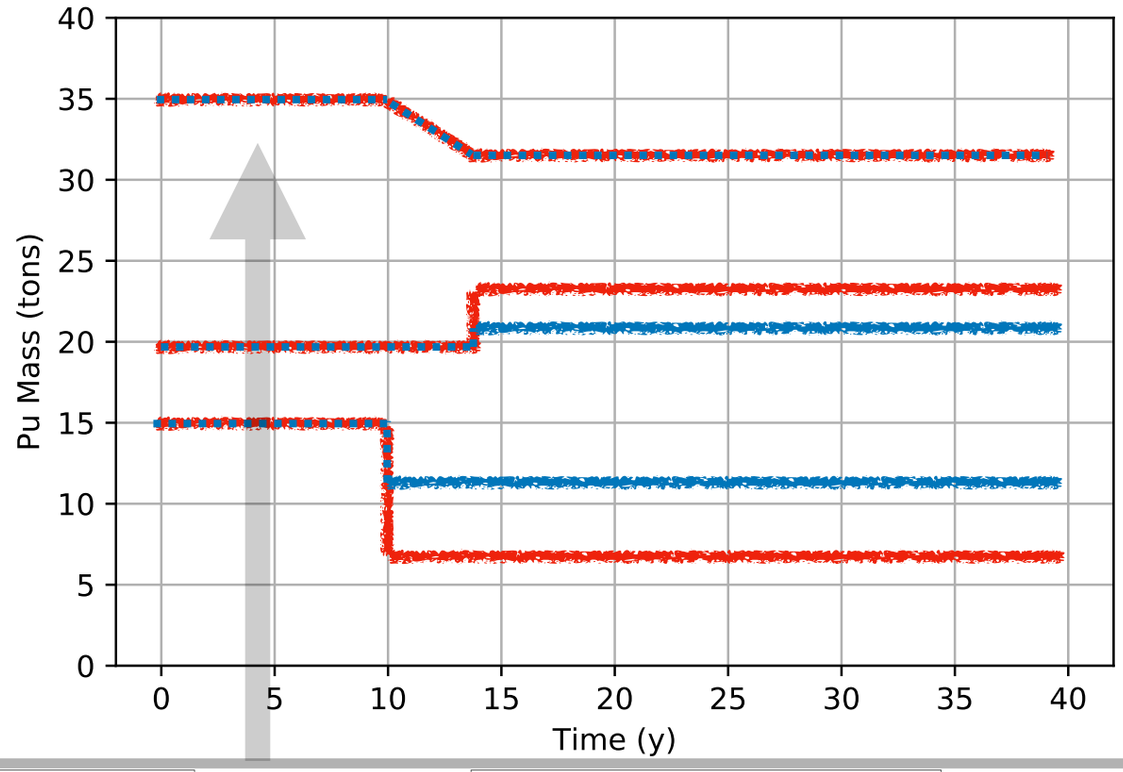


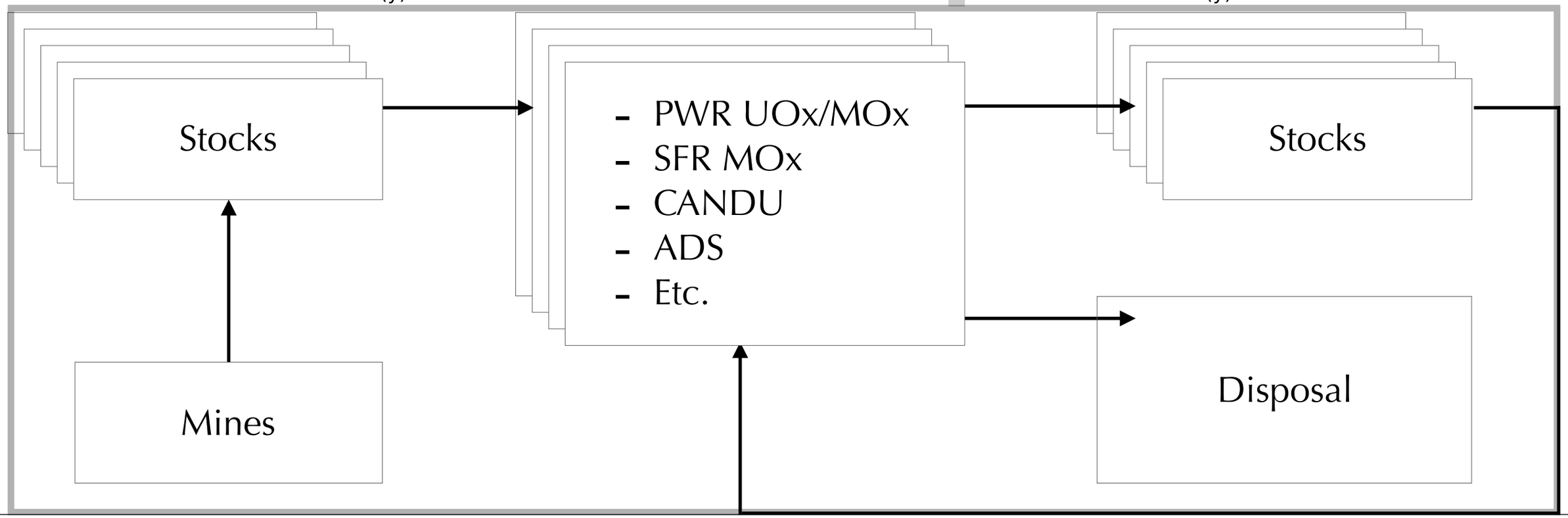


Part 3 : Results analysis

3.1 Estimator building







Part 3 : Results analysis

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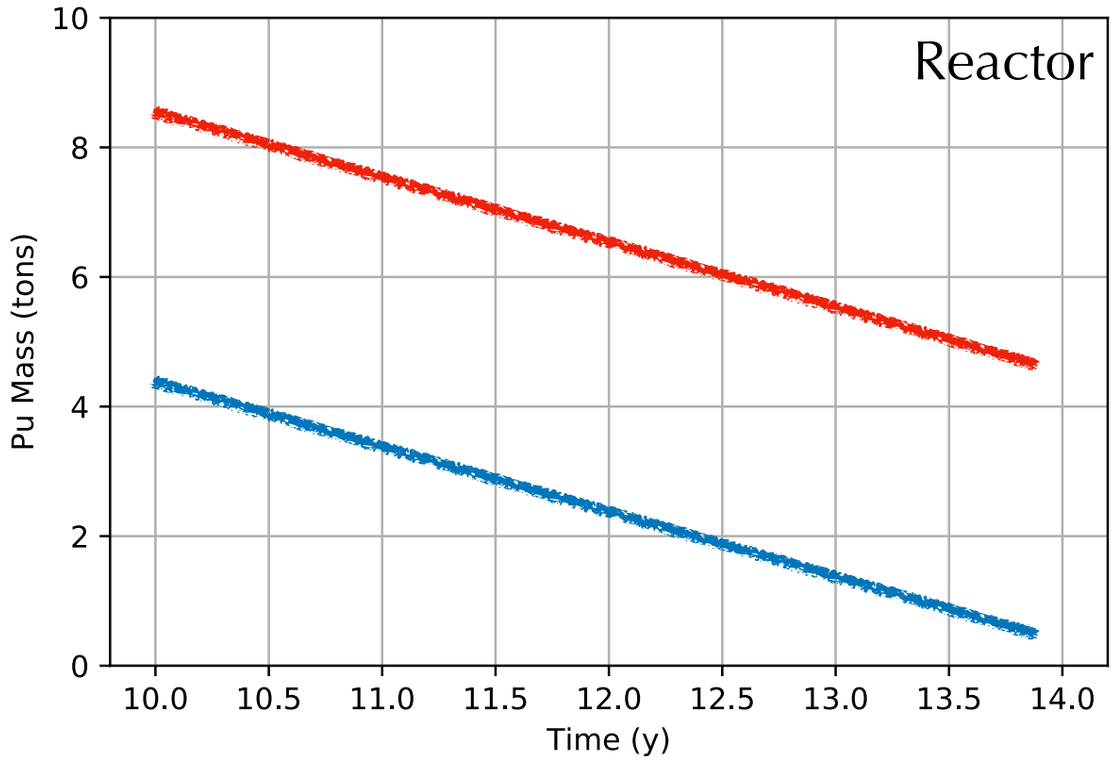
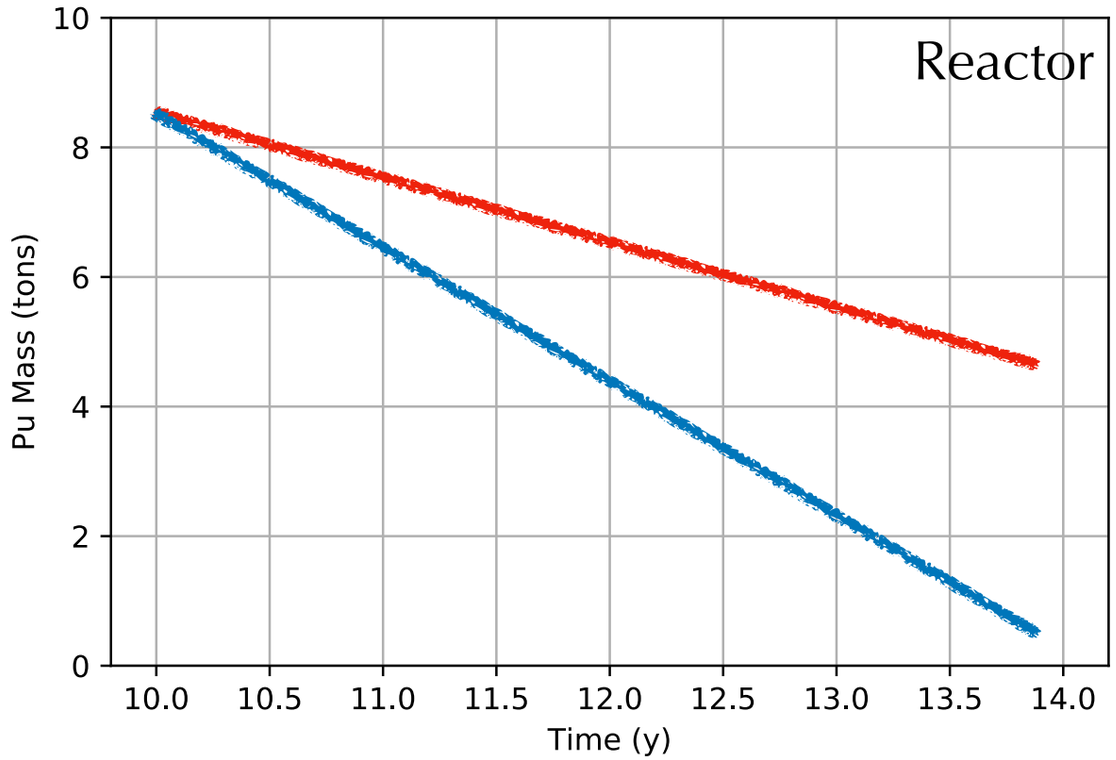




Estimator for local effect :

$$\delta\lambda(i) = \frac{\left(\lambda_{\mathrm{Pu}}^{BOC}(i)\right)_{FML} - \left(\lambda_{\mathrm{Pu}}^{BOC}(i)\right)_{FF}}{\left(\lambda_{\mathrm{Pu}}^{BOC}(i)\right)_{FF}}$$

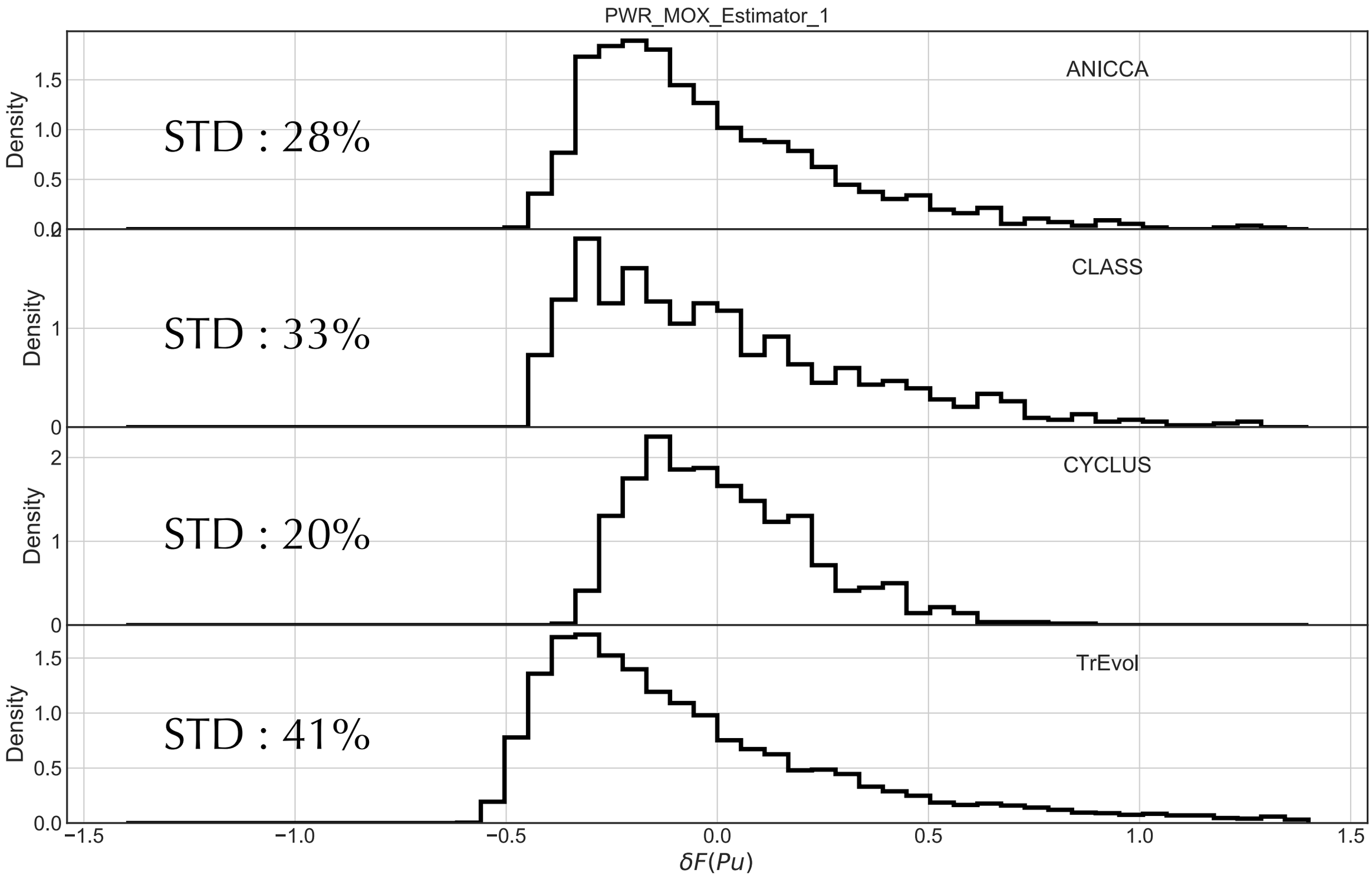
Estimators for global effects :

$$\delta\frac{\Delta M}{M}(i) = \frac{\left(\frac{\Delta M}{M}(i)\right)_{FML} - \left(\frac{\Delta M}{M}(i)\right)_{FF}}{\left(\frac{\Delta M}{M}(i)\right)_{FF}}$$

$$\delta\frac{\Delta M}{T}(i) = \frac{\left(\frac{\Delta M}{T}(i)\right)_{FML} - \left(\frac{\Delta M}{T}(i)\right)_{FF}}{\left(\frac{\Delta M}{T}(i)\right)_{FF}}$$

Part 3 : Results analysis

3.2 Estimators #1 for PWR



Conclusions and Perspectives

- FIT Project is an open framework to improve FCS output confidence

- FIT success lies on a high number of participants/codes and exercise
- Anyone can join the effort to access data, propose and/or solve exercise
  - Target is 1 exercise solving and paper / year
  - https://github.com/FuelCycleFIT/FITProject
  - Contact me if you need informations or help on including data

- A first functionality (FLM versus FF) has been tested
  - The FIT method can provide estimations on functionality impact
  - A draft of paper is in progress
  - The impact of FLM is around 30% on Pu fraction @ BOC => Local impact
  - The impact of FLM is around 10% on Pu fraction evolution => Global impact

- Extend output analysis for the first exercise
  - Impact of FLM versus FF on plutonium isotopic composition
  - Impact on minor actinides, etc.

- Next step is to test new functionality
  - Discussions between participants