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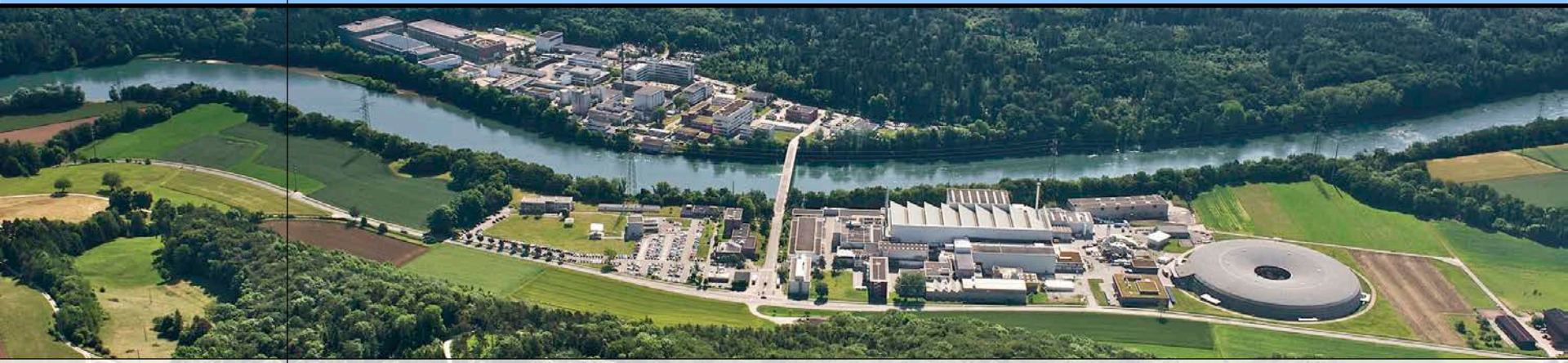

Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

Olivier Leray, D. Rochman, M. Hursin, H. Ferroukhi, A. Pautz

Propagation of FY uncertainties in the CASMO-5 deterministic code, application to PWR lattice.

WPEC-37 Meeting, May 18-19 2015

OUTLINE

1. Introduction
2. Case Description & Methodology
    1. The UAM Phase II benchmark
    2. Fission Yield perturbation methodology
3. Fission Yield Uncertainty propagation
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    2. On nuclide composition
4. Future Work
5. Conclusion

Introduction

- Nuclear Data Uncertainty Propagation at PSI for:
  - Safety Analysis (SWISS NPP)
  - Depletion Analysis (Burnup Credit, Heat Load)
- SHARK-X is the PSI Platform for Nuclear Data Uncertainty Quantification using Deterministic code (CASMO-5):
  - Direct Perturbation or Stochastic sampling methods
  - Cross-section, $\bar{\upsilon}$, χ, decay constants, energy per decay and Fission Yields perturbation
  - Using ENDF/B-VII.1 based library but propagation of uncertainty for various sources: ENDF/B-VII.1 (XS , $\bar{\upsilon}$, χ, dc, FY), SCALE-6.0 (XS , $\bar{\upsilon}$, χ), JEFF-3.1.1 (dc, FY)
- The OECD/NEA UAM benchmark is an ideal framework to compare methodologies and results

The UAM Phase II Benchmark (TMI-1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	g	-	-	-	-	-	-	-	-	-	-	-	g	-
3	-	-	-	-	-	G	-	-	-	G	-	-	-	-	-
4	-	-	-	G	-	-	-	-	-	-	-	G	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	G	-	-	G	-	-	-	G	-	-	G	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	I	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	G	-	-	G	-	-	-	G	-	-	G	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	G	-	-	-	-	-	-	-	G	-	-	-
13	-	-	-	-	-	G	-	-	-	G	-	-	-	-	-
14	-	g	-	-	-	-	-	-	-	-	-	-	-	g	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Figure 19: TMI-1 FA Pin Layout

Table 47: TMI-1 FA Pin Descriptions

Marker	Rod Type
g	2.0 w/o Gd 4.12% 235U pin
G	Guide Tube
I	Instrumentation Tube
-	4.12% 235U fuel pin

Table 48: TMI-1 FA Details

FA Pitch	218.1 mm
Active Height	3657.6 mm
# Guide Tubes	16
# Instrumentation Tubes	1
# 2.0 w/o Gd pins	4
# 4.12% 235U pins	204
Total rods/FA	225

Table 49: TMI-1 Fuel, Guide, and Instrumentation Rod Dimensions and Parameters

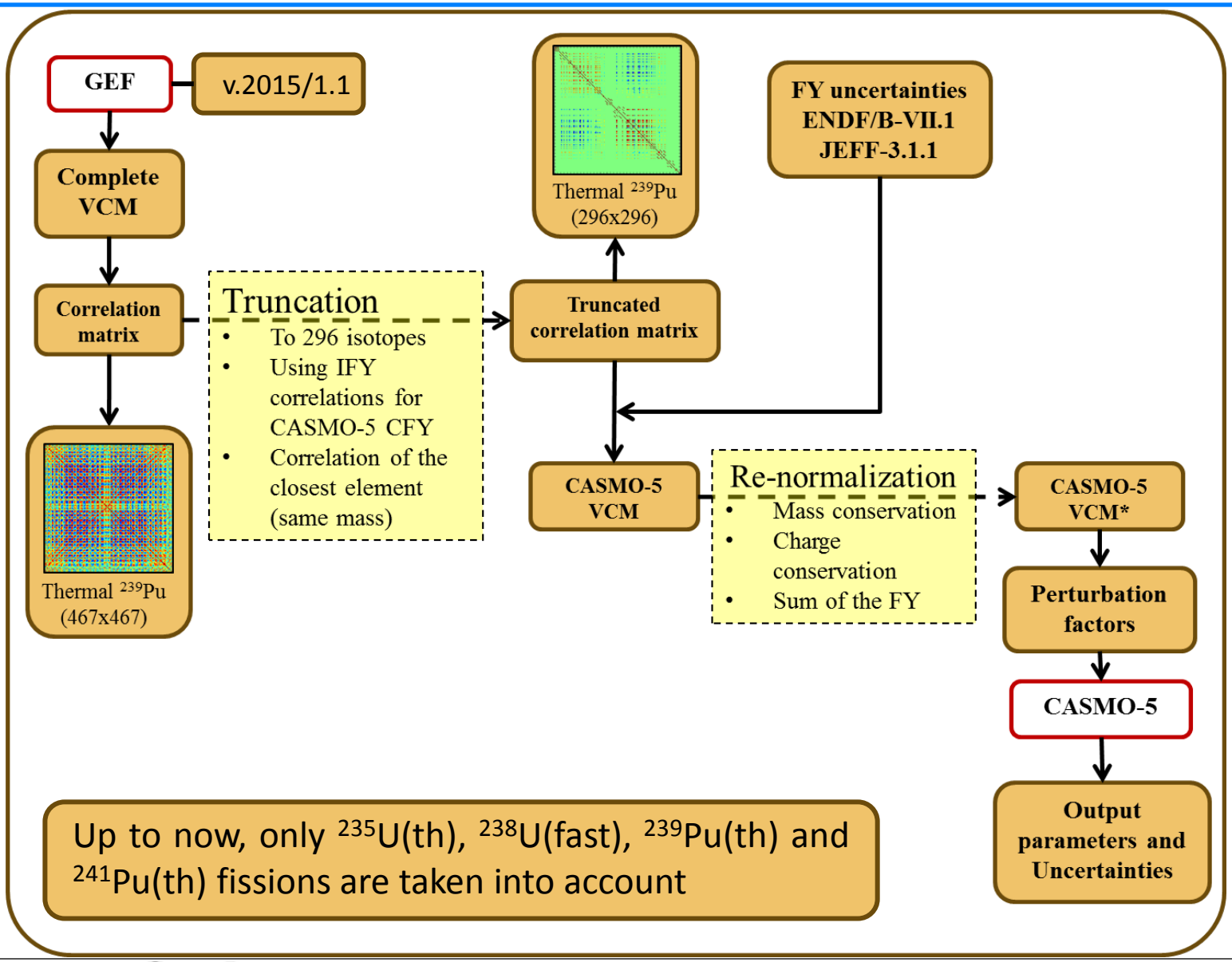
Cladding OD	10.922 mm
Cladding ID	9.58 mm
Cladding Thickness	0.673 mm
Pin Pitch	14.427 mm
Fuel Pellet OD	9.390 mm
Fuel Pellet Height	11.4 mm
% Density	93.8% TD
Guide Tube OD	13.462 mm
Guide Tube ID	12.649 mm
Instrumentation Tube OD	12.522 mm
Instrumentation Tube ID	11.201 mm

Table 50: TMI-1 Core Boundary Conditions

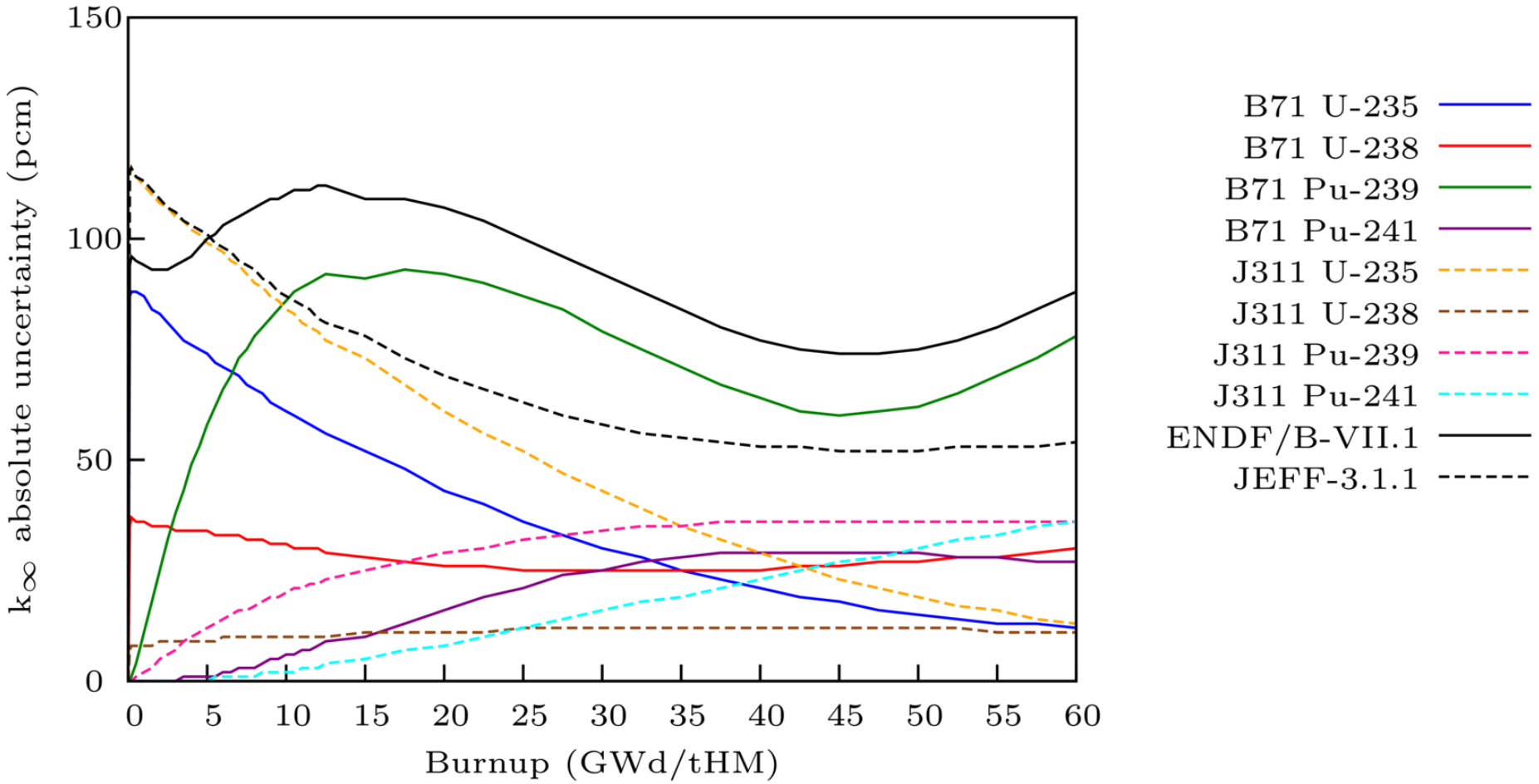
Core Power	2772 MWt
Coolant Temperature	578 K
Core Pressure	15.51 MPa
Core Coolant Flow Rate	16052.4 kg/sec

Irradiation up to 60 GWd/tHM
Calculation with CASMO-5,
19 Energetic Groups perturbation
Hot Full Power

Fission Yield Perturbation Methodology



Uncertainty on k-inf



- Fission Yield uncertainty (ENDF/B-VII.1 and JEFF-3.1.1) propagation on k-inf (500 samples)
- Uncertainty breakdown by ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu
- Very strong contribution from ^{239}Pu in the ENDF/B-VII.1 case

Uncertainty on Nuclide Composition

isotope	ENDF/B-VII.1	JEFF-3.1.1
Sr-90	0.48%	1.19%
Mo-95	0.64%	0.66%
Tc-99	1.41%	2.40%
Ru-101	2.81%	1.49%
Ru-106	1.27%	2.62%
Ag-109	23.91%	3.54%
I-129	2.67%	2.91%
Xe-131	1.08%	1.64%
Xe-135	9.75%	1.76%
Cs-133	20.64%	1.43%
Cs-134	16.28%	1.37%

isotope	ENDF/B-VII.1	JEFF-3.1.1
Cs-137	7.72%	3.46%
Ce-144	0.38%	0.60%
Nd-142	0.51%	0.65%
Nd-143	0.59%	0.72%
Nd-144	0.25%	0.51%
Nd-145	0.34%	0.70%
Nd-146	0.33%	0.57%
Nd-148	0.37%	0.62%
Sm-147	1.08%	1.09%
Sm-149	1.00%	1.02%

isotope	ENDF/B-VII.1	JEFF-3.1.1
Sm-150	1.06%	0.93%
Sm-151	1.46%	2.76%
Sm-152	1.25%	2.62%
Eu-153	1.11%	2.55%
Eu-154	1.15%	2.43%
Eu-155	1.02%	2.97%
Gd-155	1.01%	2.28%
Gd-156	1.38%	3.06%
Gd-157	2.43%	5.08%
Gd-158	0.72%	1.88%

- Burnup: 60 GWd/tHM
- Important Uncertainty on Cs isotopes, Xe-135 and Ag-109 with ENDF/B-VII.1
- Same order of magnitude of the uncertainty on Nd, Sm, Eu, Gd between ENDF/B-VII.1 and JEFF-3.1.1
- Trend of slightly higher uncertainties with JEFF-3.1.1 on Nd, Sm, Eu, Gd

Breakdown of the uncertainty: who between U-235, U-238, Pu-239 or Pu-241 is the main contributor ?

Uncertainty on Nuclide Composition

	ENDF/B-VII.1					JEFF-3.1.1			
isotope	U-235	U-238	Pu-239	Pu-241	isotope	U-235	U-238	Pu-239	Pu-241
Sr-90	0.39%	0.08%	0.27%	0.04%	Sr-90	1.12%	0.18%	0.34%	0.12%
Mo-95	0.57%	0.10%	0.27%	0.09%	Mo-95	0.51%	0.12%	0.37%	0.16%
Tc-99	0.50%	0.20%	1.27%	0.30%	Tc-99	0.64%	0.28%	2.25%	0.48%
Ru-101	0.67%	0.29%	2.68%	0.43%	Ru-101	0.71%	0.16%	1.28%	0.26%
Ru-106	0.07%	0.12%	1.06%	0.68%	Ru-106	0.12%	0.43%	1.37%	2.19%
Ag-109	0.58%	1.97%	18.04%	15.55%	Ag-109	0.07%	0.21%	1.98%	2.92%
I-129	0.54%	0.89%	0.93%	2.28%	I-129	1.28%	0.70%	1.72%	1.83%
Xe-131	0.48%	0.16%	0.47%	0.83%	Xe-131	0.77%	0.39%	1.27%	0.56%
Xe-135	0.50%	1.57%	9.04%	3.24%	Xe-135	0.67%	0.36%	1.47%	0.61%
Cs-133	0.90%	4.60%	19.71%	3.91%	Cs-133	1.00%	0.27%	0.93%	0.29%
Cs-134	1.00%	4.07%	15.53%	2.53%	Cs-134	1.11%	0.24%	0.74%	0.19%
Cs-137	5.28%	0.16%	5.62%	0.42%	Cs-137	2.52%	0.05%	2.34%	0.38%
Ce-144	0.27%	0.12%	0.20%	0.13%	Ce-144	0.42%	0.24%	0.22%	0.27%
Nd-142	0.33%	0.19%	0.34%	0.03%	Nd-142	0.65%	0.01%	0.04%	0.02%
Nd-143	0.48%	0.07%	0.30%	0.12%	Nd-143	0.64%	0.18%	0.24%	0.16%
Nd-144	0.21%	0.07%	0.13%	0.04%	Nd-144	0.47%	0.14%	0.12%	0.07%
Nd-145	0.23%	0.05%	0.24%	0.08%	Nd-145	0.50%	0.34%	0.31%	0.17%
Nd-146	0.24%	0.06%	0.21%	0.07%	Nd-146	0.38%	0.27%	0.26%	0.20%
Nd-148	0.22%	0.07%	0.27%	0.09%	Nd-148	0.36%	0.18%	0.35%	0.31%
Sm-147	0.69%	0.14%	0.79%	0.19%	Sm-147	0.86%	0.21%	0.54%	0.33%
Sm-149	0.30%	0.25%	0.78%	0.48%	Sm-149	0.28%	0.33%	0.66%	0.66%
Sm-150	0.78%	0.24%	0.61%	0.27%	Sm-150	0.60%	0.30%	0.52%	0.39%
Sm-151	0.46%	0.22%	1.25%	0.57%	Sm-151	0.34%	0.20%	0.70%	2.64%
Sm-152	0.45%	0.21%	1.04%	0.48%	Sm-152	0.28%	0.19%	0.73%	2.50%
Eu-153	0.48%	0.21%	0.93%	0.30%	Eu-153	0.24%	0.14%	0.69%	2.44%
Eu-154	0.53%	0.22%	0.96%	0.27%	Eu-154	0.27%	0.14%	0.70%	2.31%
Eu-155	0.50%	0.20%	0.81%	0.31%	Eu-155	0.24%	0.12%	0.58%	2.91%
Gd-155	0.56%	0.15%	0.78%	0.23%	Gd-155	0.32%	0.13%	0.50%	2.20%
Gd-156	0.54%	0.44%	1.16%	0.29%	Gd-156	0.24%	0.18%	0.86%	2.92%
Gd-157	0.38%	0.41%	1.96%	1.31%	Gd-157	0.21%	0.16%	1.16%	4.94%
Gd-158	0.24%	0.19%	0.64%	0.13%	Gd-158	0.16%	0.11%	0.47%	1.81%

- Main contributors: U-235 and Pu-239
- FY uncertainties on Pu-241 from JEFF-3.1.1 contribute a lot on Sm, Eu and Gd
- The trend of slightly higher uncertainties with JEFF-3.1.1 on Sm, Eu and Gd is coming from Pu-241, for Nd is due to U-235
- Concerning ENDF/B-VII.1, huge uncertainty on Ag-109 due to Pu-239 and Pu-241, on Xe-135, Cs-133 and Cs-134 due to Pu-239

Uncertainty on Nuclide Composition

- Comparison with results on the TMI-1 pincell (UAM Phase I) from:
  O. Cabellos, D.Piedra, C.J. Diez and L. Fiorito "Impact of the Fission Yield Nuclear Data Uncertainties in the Pin-Cell Burn-Up OECD/NEA UAM Benchmark", Proc. Of the Int. Conf. PHYSOR 2014, Kyoto, Japan, 2014

- Nuclide Composition uncertainty due to Fission yields (U-235 and Pu-239) with and without correlations and comparison with GRS methodology (Table 1).

- 1000 samples

- Correlations added using a Bayesian/General Least Square Method (Katakura)

- ENDF/B-VII.1 fission yields uncertainties

- GRS used XSUSA/SCALE6.1/ORIGEN-S without correlation (ENDF/B-VII.1)

Uncertainty on Nuclide Composition

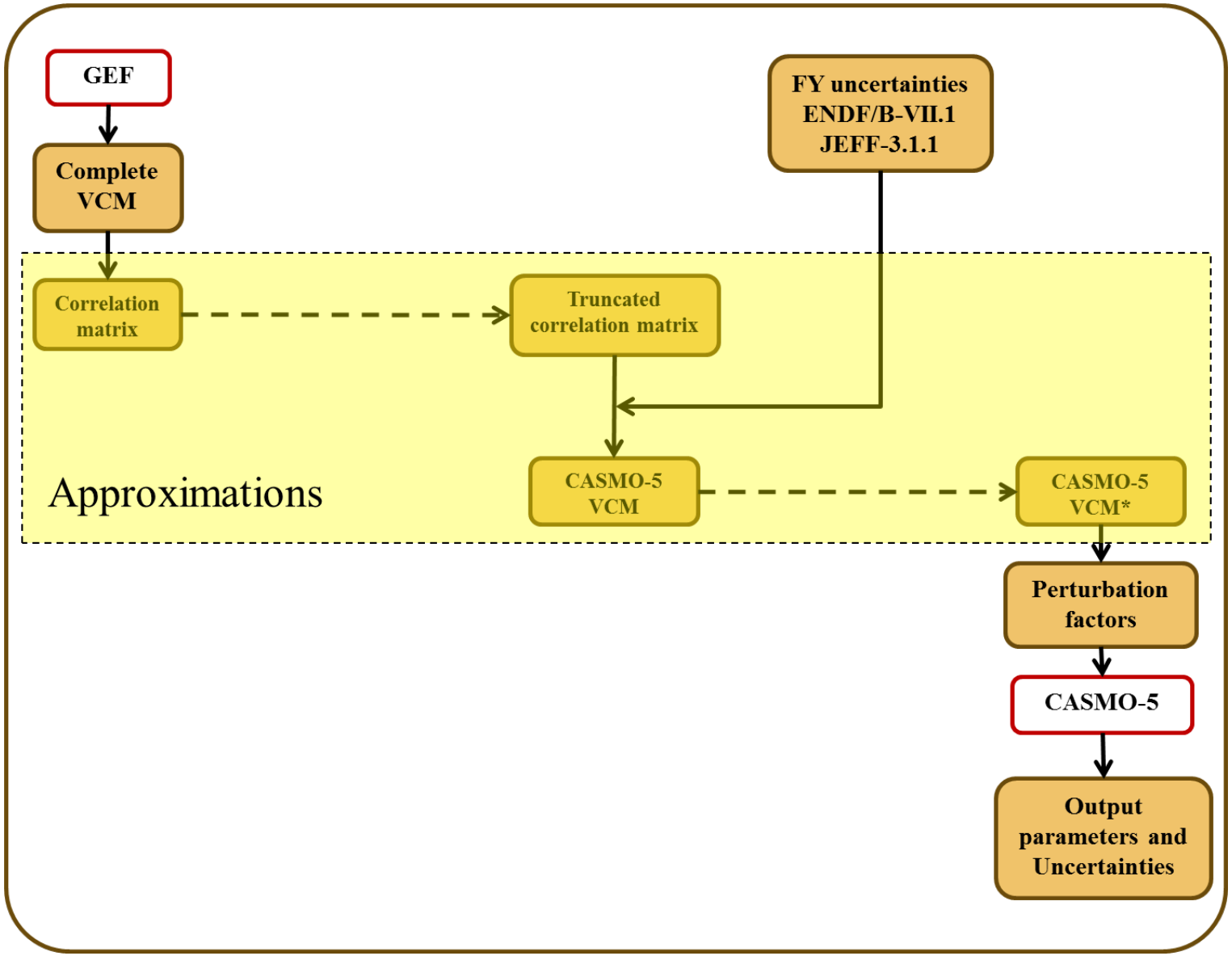
isotope	PSI	UPM Corr.	UPM No corr.	GRS
Sr-90	0.5	0.8	6.2	-
Mo-95	0.6	0.5	8.4	7.9
Tc-99	1.4	0.8	10.0	9.5
Ru-101	2.8	0.7	4.6	5.0
Ru-106	1.1	1.2	13.7	14.1
Ag-109	18.1	10.9	17.8	14.8
I-129	1.1	2.7	20.7	-
Xe-131	0.7	0.4	6.9	-
Xe-135	9.1	0.4	5.1	-
Cs-133	19.7	0.3	3.4	3.3
Cs-134	15.6	0.3	3.0	2.9
Cs-137	7.7	0.5	1.5	1.7
Ce-144	0.3	0.2	8.0	8.4
Nd-142	0.5	0.8	3.5	3.5
Nd-143	0.6	0.4	6.5	5.9
Nd-144	0.2	0.2	3.9	-
Nd-145	0.3	0.4	7.1	6.7
Nd-146	0.3	0.7	10.8	9.5
Nd-148	0.4	0.8	13.7	13.0
Sm-147	1.1	0.5	9.4	8.4
Sm-149	0.8	0.6	12.2	10.6
Sm-150	1.0	0.6	10.3	9.3
Sm-151	1.3	0.7	12.1	10.9
Sm-152	1.1	0.6	11.3	8.8
Eu-153	1.0	0.8	9.9	8.3
Eu-154	1.1	0.8	10.4	8.7
Eu-155	1.0	1.0	9.5	8.1
Gd-155	1.0	1.0	10.5	8.8
Gd-156	1.3	1.2	9.0	7.8
Gd-157	2.0	1.3	9.5	-
Gd-158	0.7	2.3	11.3	9.9

Agreement:

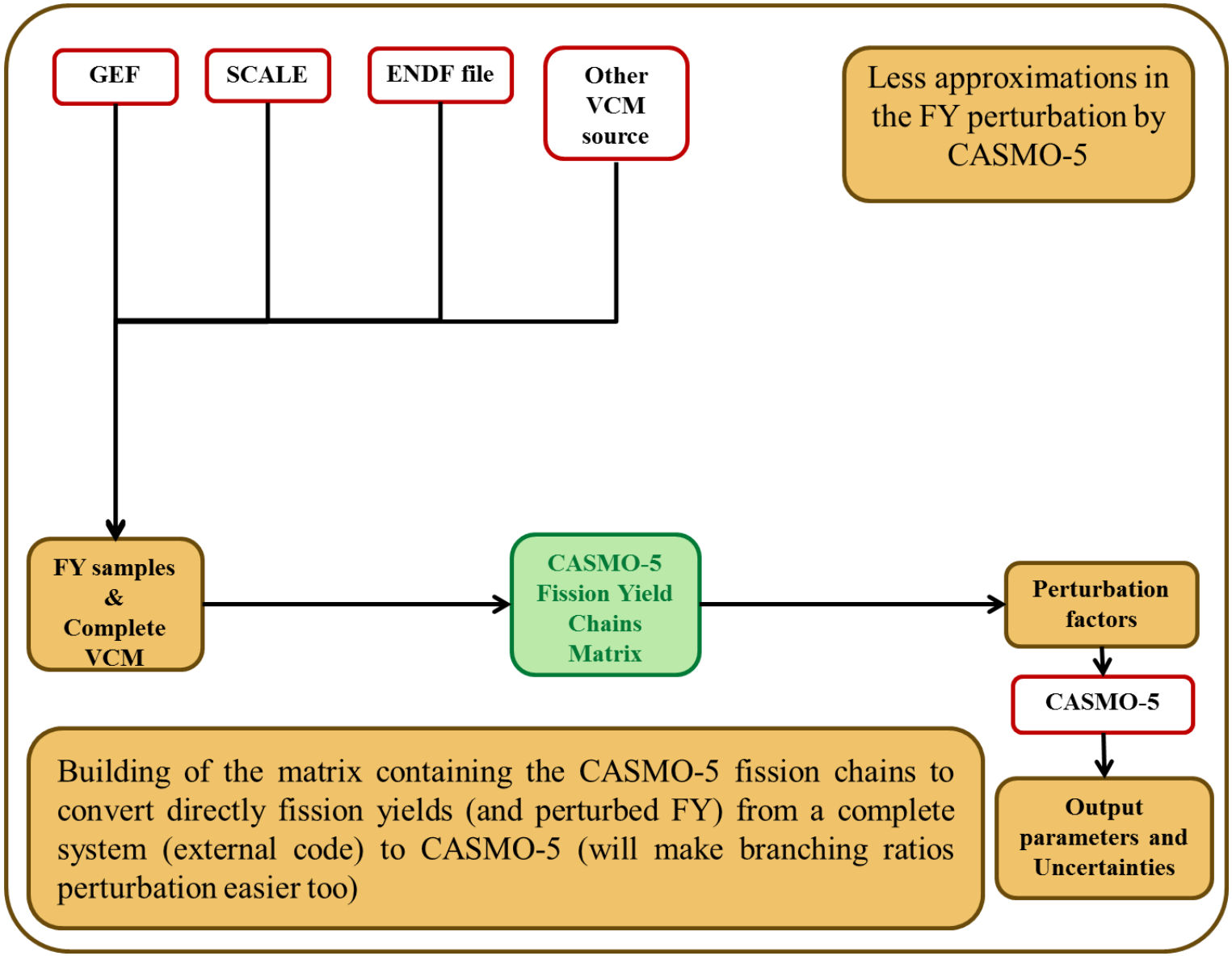
Good
Bad

- Relatively good agreement for Nd, Sm, Eu and Gd isotopes
- Overestimation of the uncertainty on Xe-135 and Cs isotopes ?
- High uncertainty on Ag-109 in all cases (In CASMO-5, adjustment of the FY leading to Pd-109: then impacts Ag-109)
- Uncertainties are smaller when correlations are used
- Not the same source of correlations: GEF (PSI) and SCALE (UPM)

Future Developments



Future Developments



Conclusion

- Fission Yield Uncertainty propagation performed on Kinf and nuclide composition
  - Using U-235, U-238, Pu-239 and Pu-241
  - Correlations from GEF
  - Approximations are made to use CASMO-5

- Except on some nuclides (Cs-133, Cs-134, Cs137, Xe-135 and Ag-109), there is the same order of magnitude on the nuclide composition uncertainties between JEFF-3.1.1 and ENDF/B-VII.1: The main contributors are U-235 and Pu-239.
- Pu-241 has an important role on Sm, Eu and Gd when JEFF-3.1.1 is used
- Good agreement with previous work (UPM), except on Cs-133, Cs-134, Cs137, Xe-135 !

- Future Work
  - Improvement of the methodology to use different sources of Correlations
  - Continue contribution to the UAM benchmark (next meeting: 20-22 May 2015, Madrid)

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Thank you for your attention