Hanoi University of Science

Study on the impact of ENDF/B-VII.1 nuclear library uncertainty on the CERMET fueled ADS calculation result using Monte Carlo method

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Hanoi, December 10, 2021

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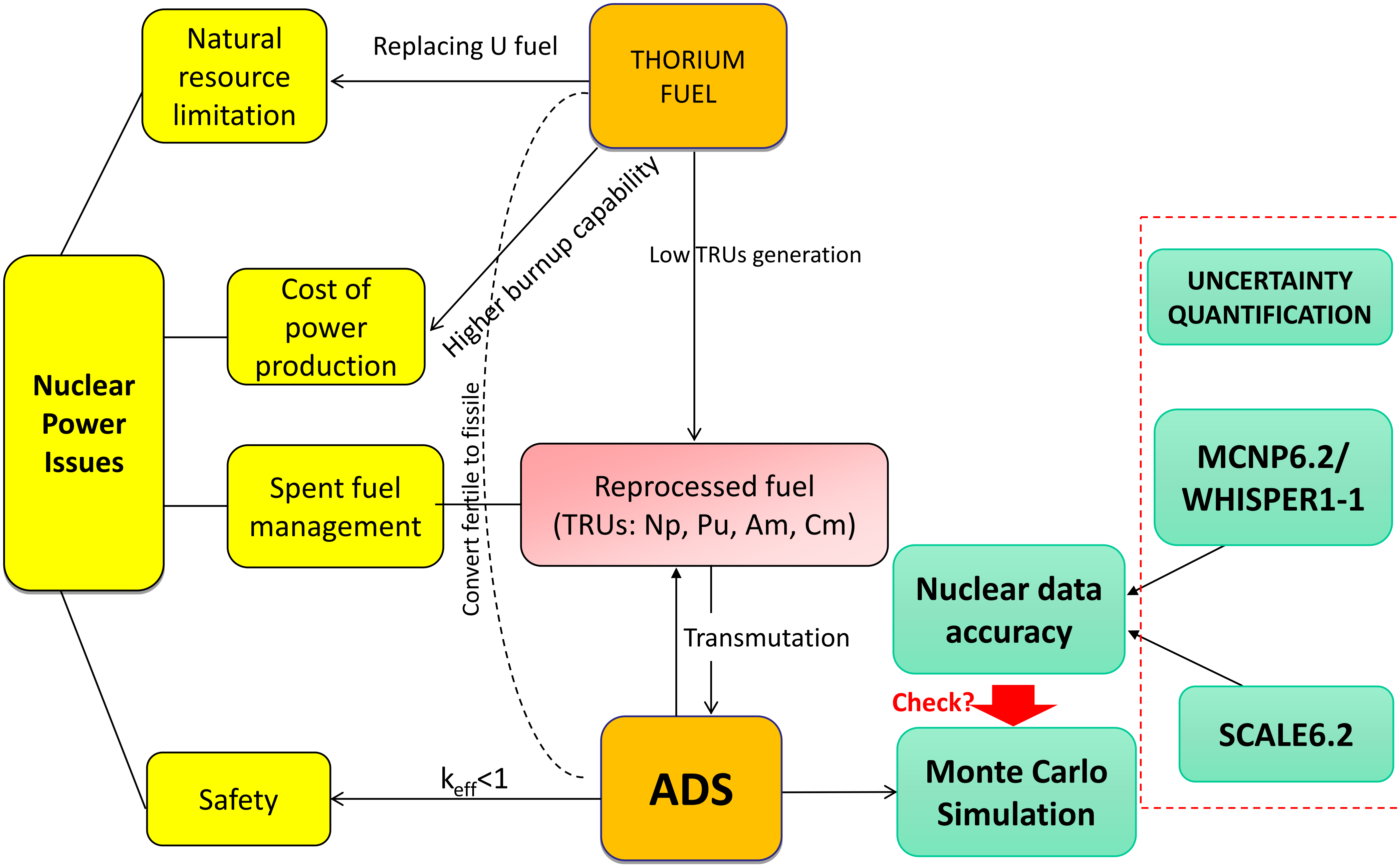
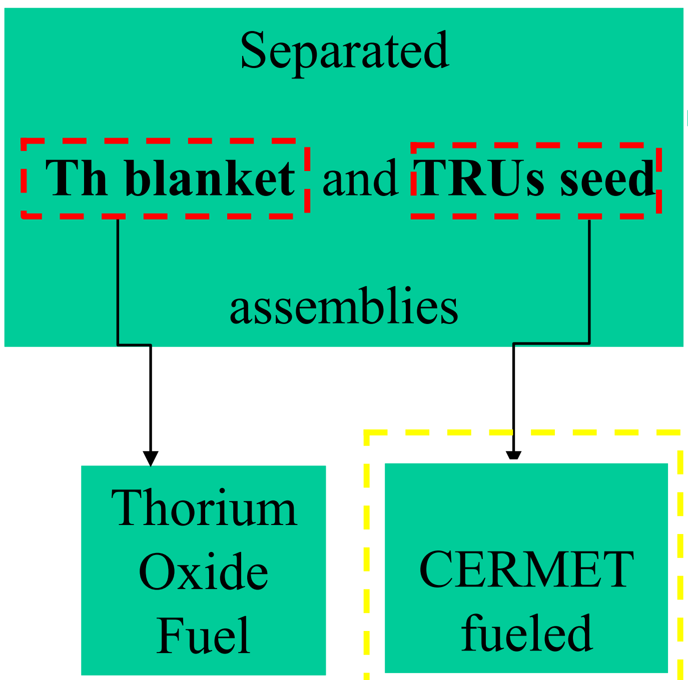
1. Motivation



2. Accelerator Driven System (ADS)

The accelerator-driven transmutation system includes 3 major components:

- □The neutron generated accelerator
- □The spallation target
- □The subcritical reactor core



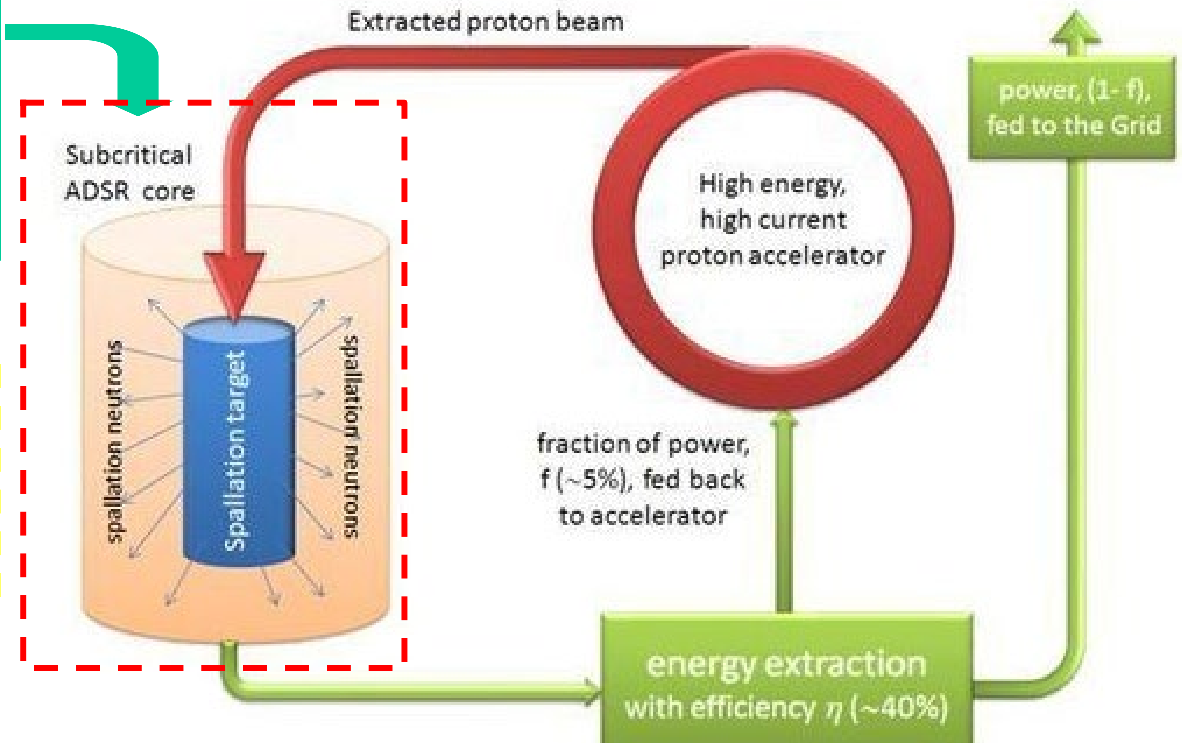
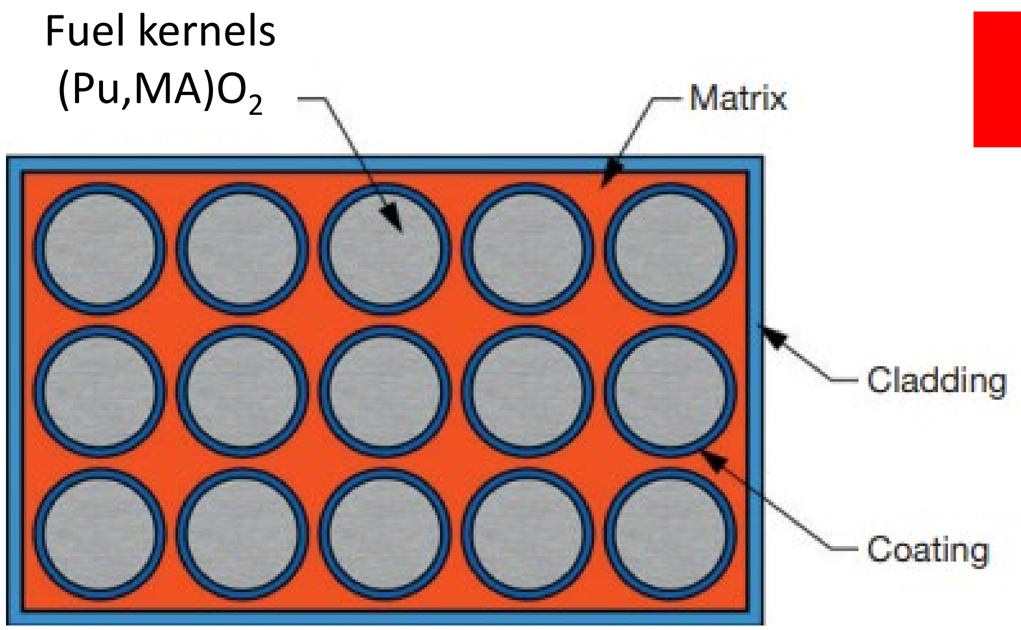


Fig. 2. 1. Schematic view of main components of an ADS

(1) T-M Vu, Study on seed and blanket ADS for transuranic elements transmutation using thorium-reprocessed fuel and its application in Vietnam, Doctoral Dissertation, Osaka University, 2014

2.1. CERCER/CERMET fuel and ADS core configuration



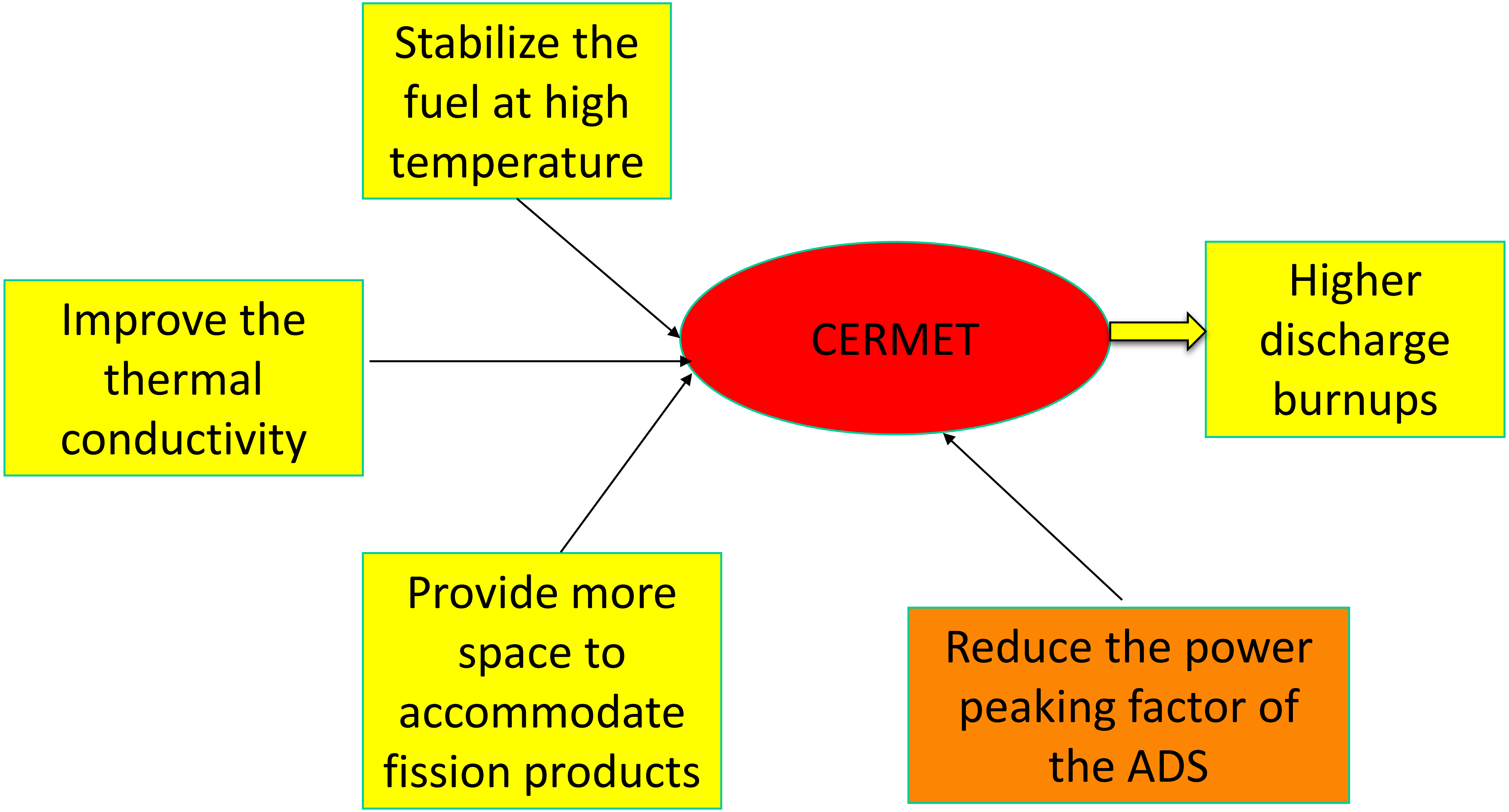
Matrix
Mo

Schematic representation of inert matrix fuel[2]

CERMET
(Pu,MA)O2-xM

(2) M. K. Meyer, Composite Fuel (cermet, cercer), Idaho National Laboratory 2012

3. CERMET fuel and ADS core configuration



3. CERMET fuel and ADS core configuration

Table 1. The composition of CERMET fuel

Isotopes	CERMET fuel weight fraction (%)	Isotopes	CERMET fuel weight fraction (%)
^{237}Np	10.35	^{24}Mg	-
^{238}Np	3.27E-9	^{25}Mg	-
^{239}Np	2.18E-6	^{26}Mg	-
^{238}Pu	0.48	^{92}Mo	7.11
^{239}Pu	11.76	^{94}Mo	4.53
^{240}Pu	4.91	^{95}Mo	7.88
^{241}Pu	1.90	^{96}Mo	8.34
^{242}Pu	1.26	^{97}Mo	4.82
^{244}Pu	3.88E-5	^{98}Mo	12.31
^{241}Am	10.27	^{100}Mo	5.02
^{242}Am	0.02		
^{243}Am	2.53		
^{242}Cm	4.68E-5		
^{243}Cm	6.49E-3		
^{244}Cm	0.59		
^{245}Cm	0.04		
^{246}Cm	3.70E-3		
^{247}Cm	0.00		
^{16}O	5.89		

3. CERMET fuel and ADS core configuration

- Lead-bismuth eutetic (LBE) target
- 1 GeV proton beam
- Thorium-reprocessed fuel subcritical reactor core

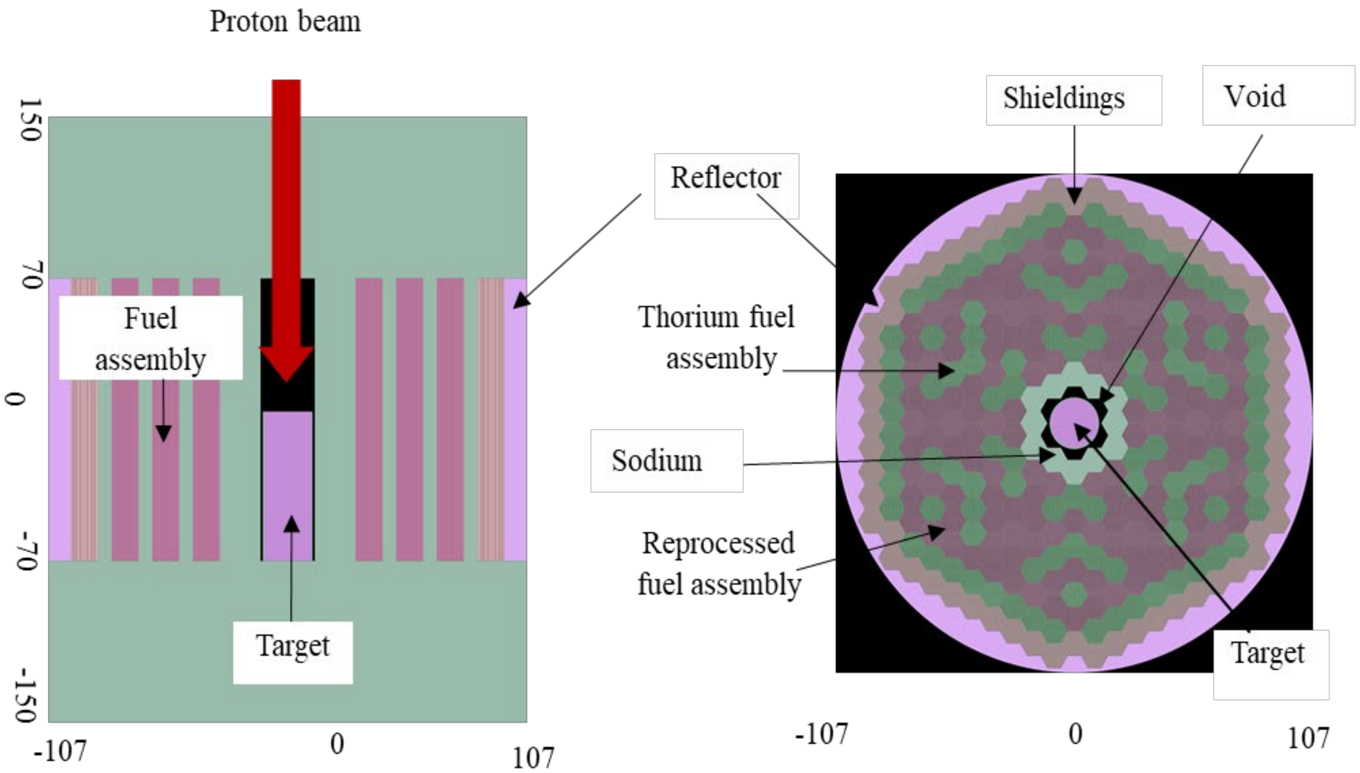


Fig.2. Vertical and horizontal sectional views of the seed and blanket thorium – reprocessed (TRUs) fuel ADS design (Scale is given in cm*)*

3. CERMET fuel and ADS core configuration

Table 2. Main design parameters of CERMET fueled ADS

Reactor parameter	
Thermal power (MW_{th})	**500**
Fuel temperature (K)	900
Coolant temperature (K)	600
Structure material temperature (K)	600
Fuel type Thorium TRUs	 **Oxide** **CERMET**
Coolant	Sodium
Number of thorium /reprocessed assemblies	**144/102**
Core diameter (cm)	214
LBE target radius (cm)	15
Core length (cm)	300
Number of pins per assembly	271
Length of pin (cm)	140
Fuel pin radius (cm)	0.372
Pitch of pin (cm)	0.89
Pitch of assembly (cm)	14.71

3. CERMET fuel and ADS core configuration

❖ **Neutron spectra**

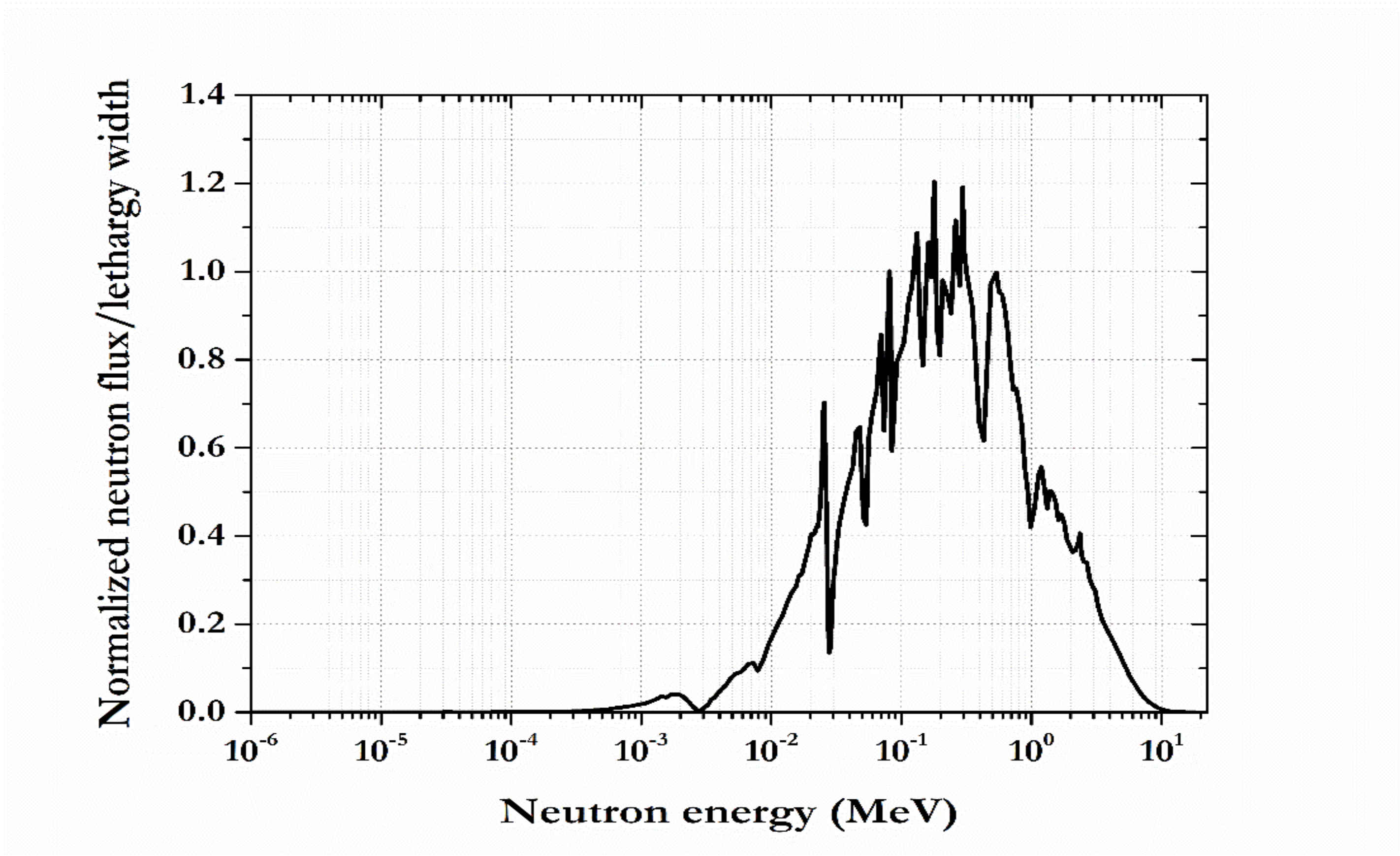


Fig.3. Neutron spectra of CERCER and CERMET fueled small power ADS at normal condition

4. Calculation methods

Uncertainty Quantification:

The **uncertainty for the system k_{eff}** due to the changes in the neutron cross-section data are produced using Sandwich rule as follows:

$$\sigma_k^2 = S_k C_{\Sigma\Sigma} S_k^T$$

where T indicates a transpose.

With the elements of S_k are:

$$(S_{k,\Sigma_{x,g}^i}) = \frac{\Sigma_{x,g}^i}{k}\frac{\partial k}{\partial \Sigma_{x,g}^i}$$

From Monte Carlo codes

and the elements of $C_{\Sigma\Sigma}$ are:

$$(C_{\Sigma_{x,g}^i \Sigma_{y,g'}^j}) = \frac{COV(\Sigma_{x,g}^i \Sigma_{y,g'}^j)}{\Sigma_{x,g}^i \Sigma_{y,g'}^j}$$

From Nuclear data libraries

where i and j are varied over all isotopes, x and y are varied over all reactions for each isotope and g and g' are varied over all energy groups.

4. Calculation methods

- **SCALE6.2**

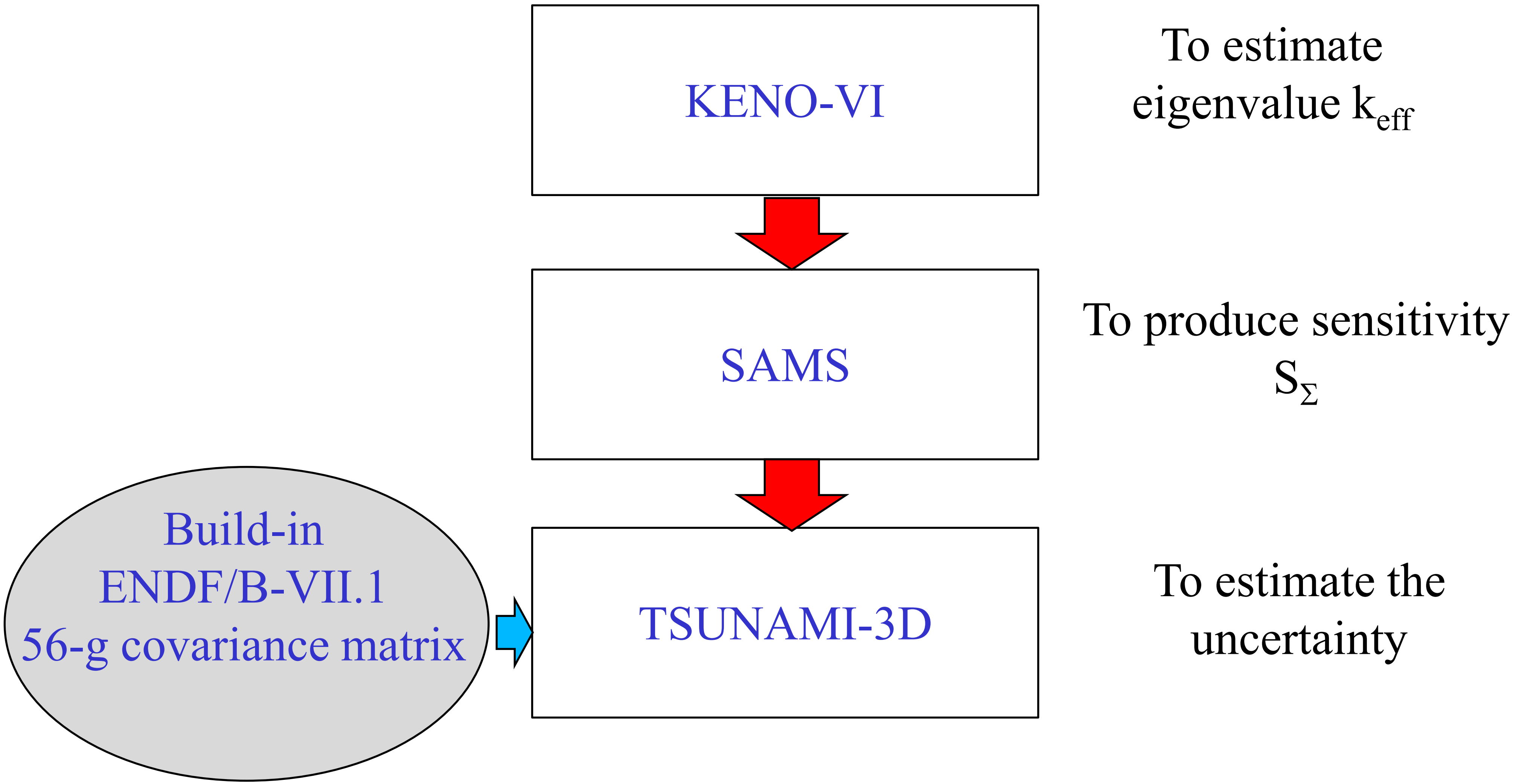


Fig.4. Calculation algorithm flowchart in SCALE6.2 code

4. Calculation methods

- **MCNP6/WHISPER1-1**

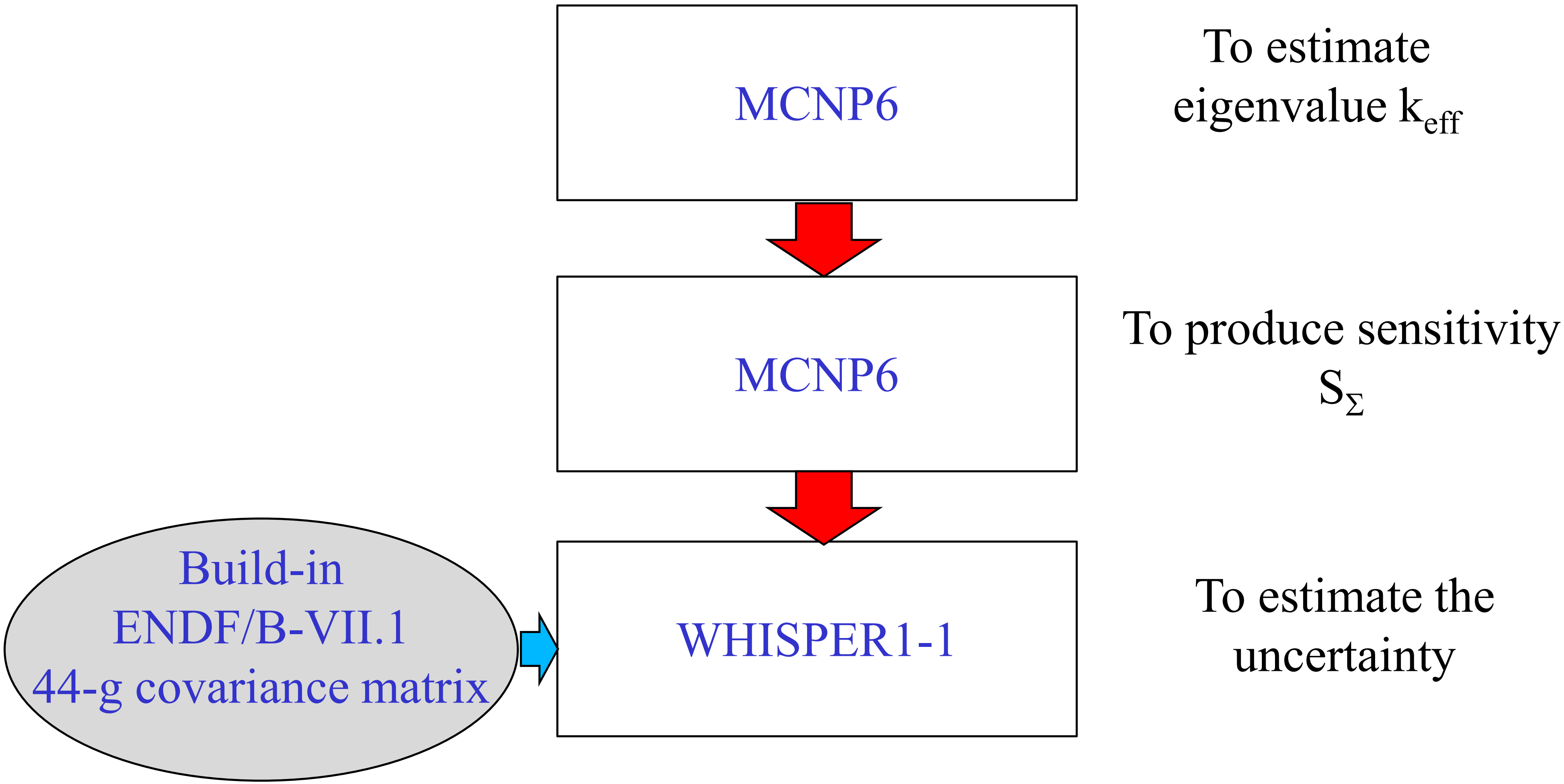


Fig.5. Calculation algorithm flowchart in MCNP6/WHISPER1-1

5. Results and discussion

Table 3. Uncertainty results of CERMET ADS obtained by WHISPER-1.1 [illegible]d SCALE6.2 using ENDF/B-VII.1

Characteristics	MCNP6.2-Whisper-1.1		[illegible].2	
	Reactivity	Uncertainty	[illegible]	Uncertainty
k_{eff}	0.97162±0.00002	0.01353	[illegible]0±0.00016	0.00916

Target accuracy: 300 pcm

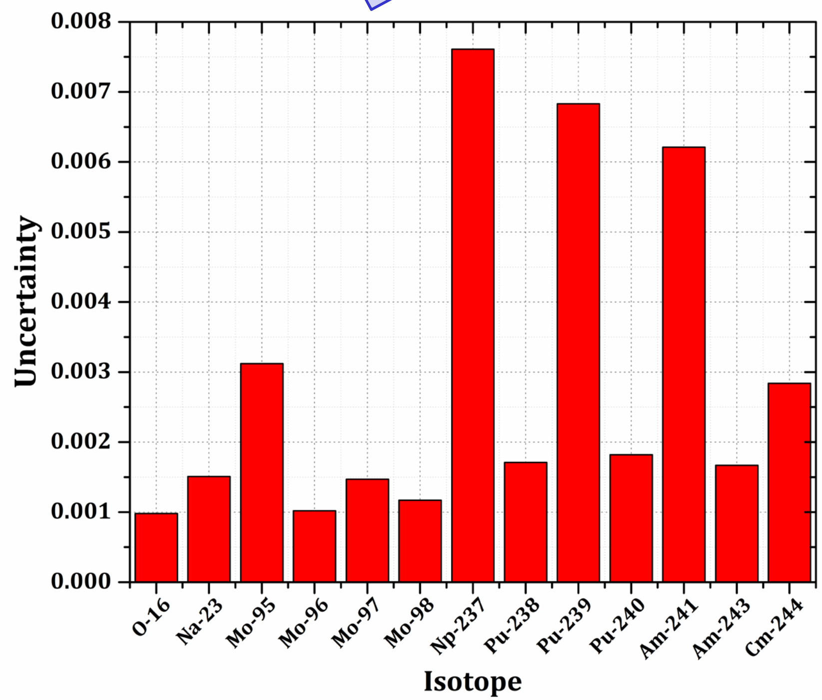


Fig. 6. Isotopes-wise uncertainty contribution to change in k_{eff} for CERMET ADS obtained by Whisper-1.1

M. Salvatores et al., *"Uncertainty And Target Accuracy Assessment For Innovative Systems Using Recent Covariance Data Evaluations," International Evaluation Co-operation, Volume 26, NEA/WPEC-26, 2008.*

5. Sensitivity and Uncertainty of CERMET ADS

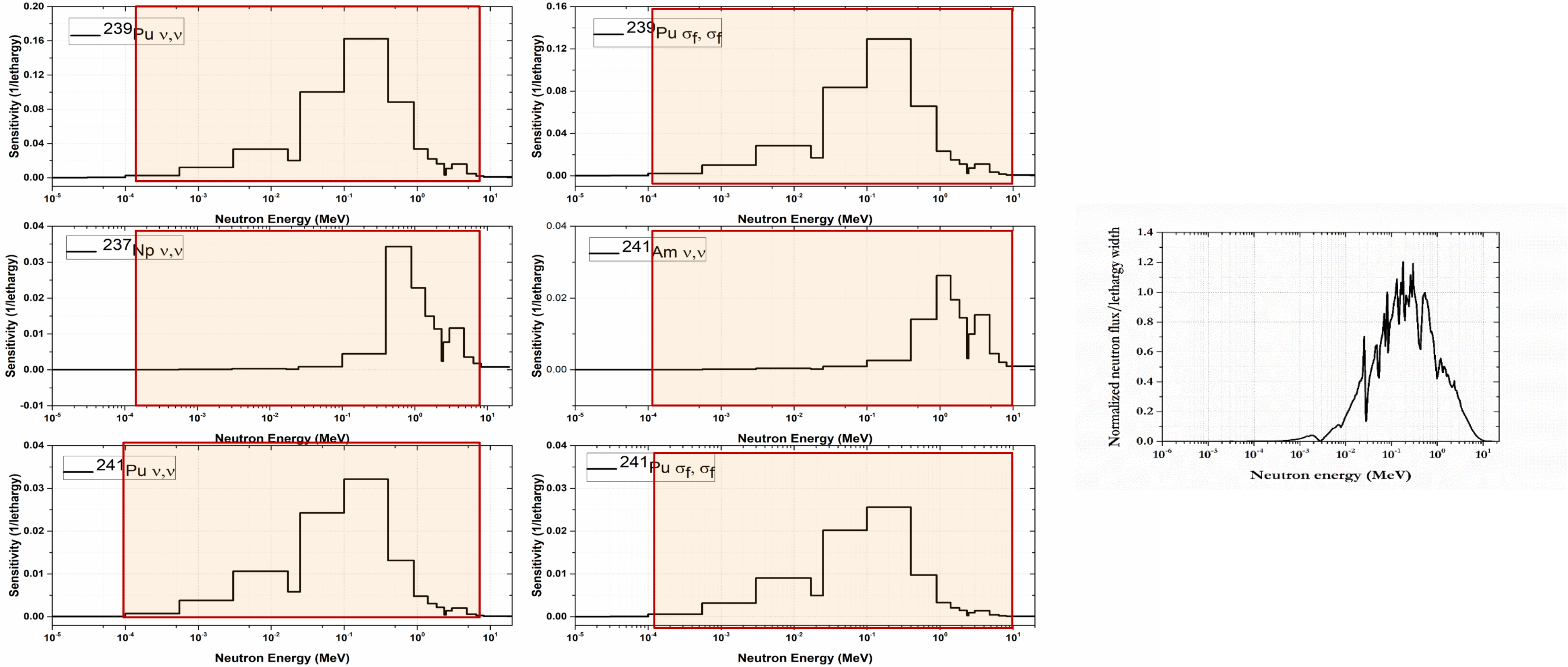
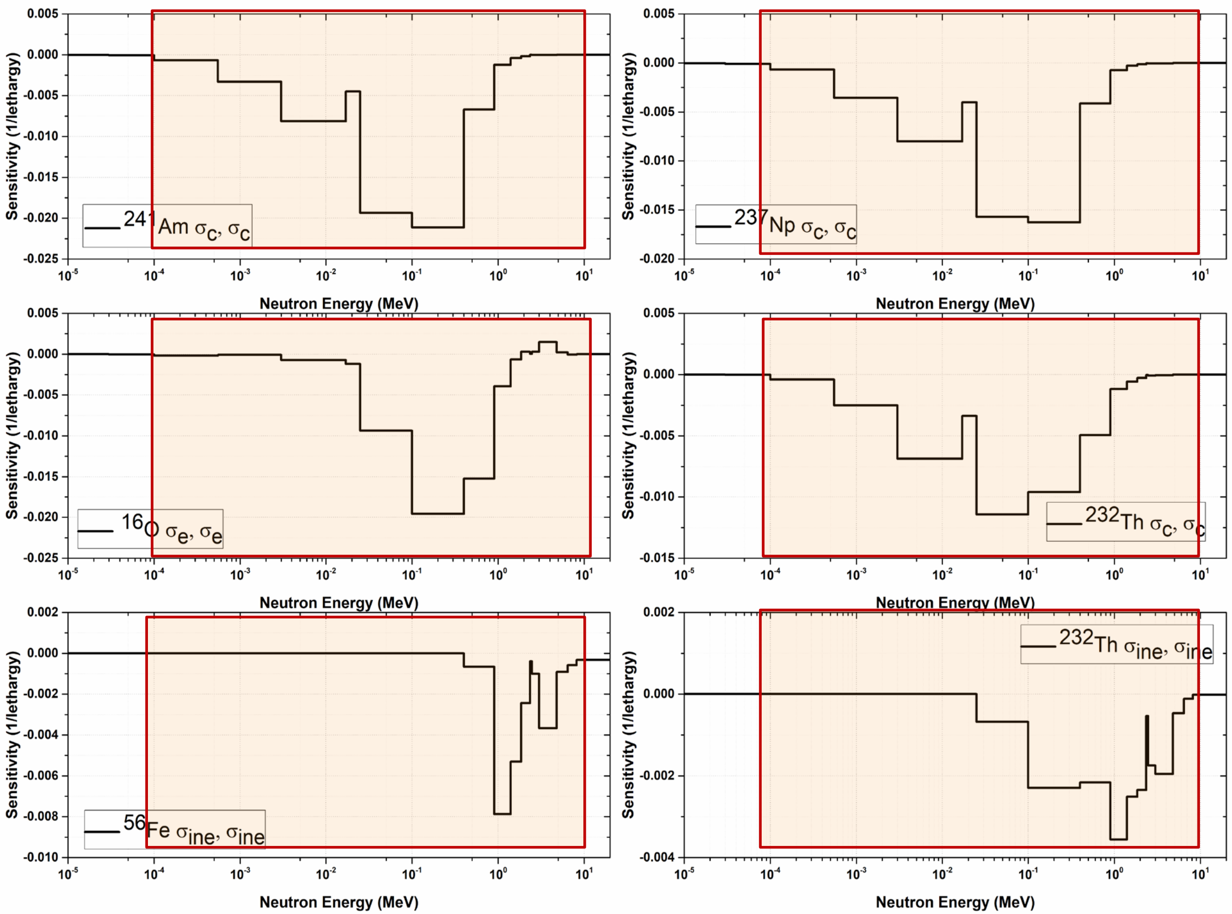


Fig. 7 . Energy-dependent sensitivities of k_{eff} for CERMET fueled ADS (positive contributions)

5. Sensitivity and Uncertainty of CERMET ADS



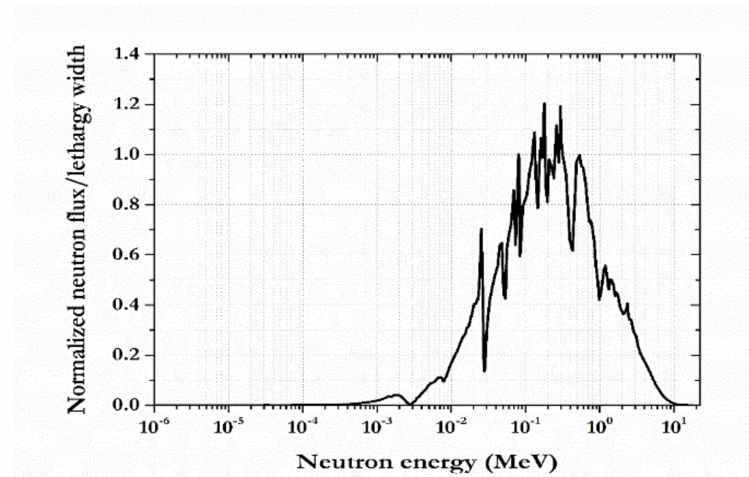


Fig. 8 . Energy-dependent sensitivities of k_{eff} for CERMET fueled ADS (negative contributions)

5. Sensitivity and Uncertainty of CERMET ADS

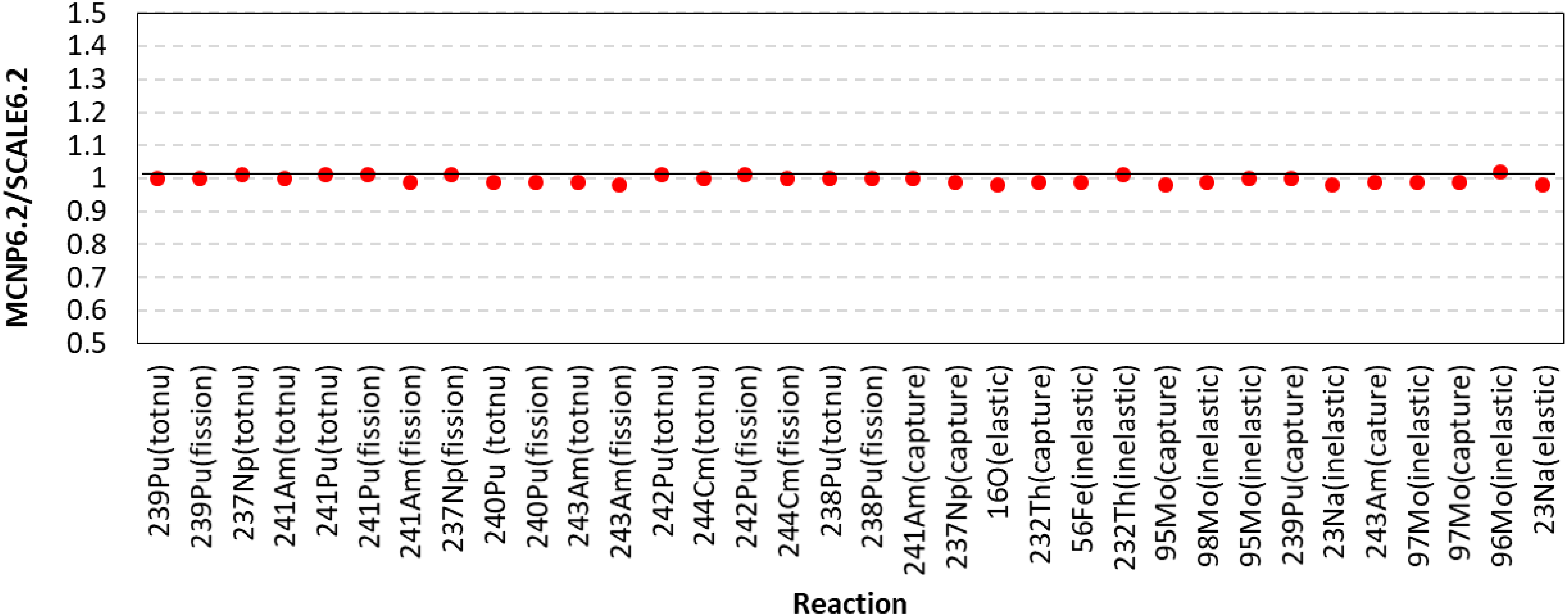
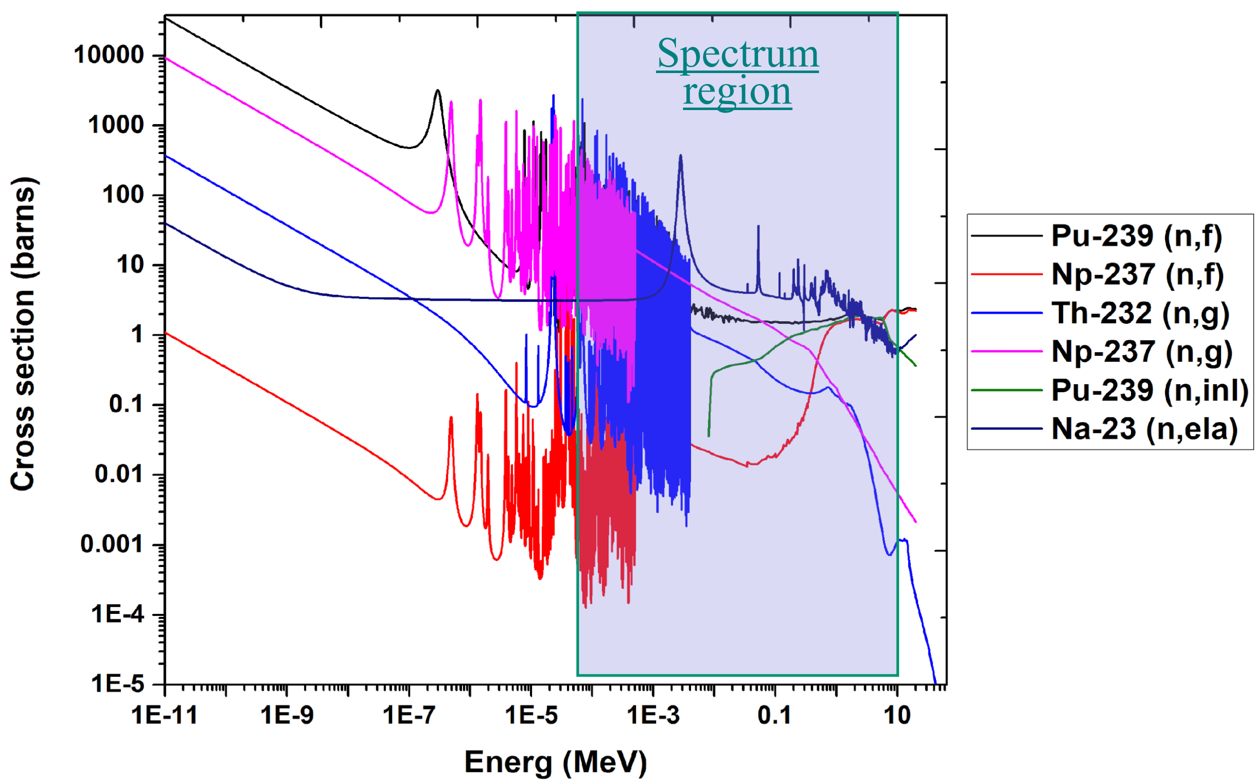


Fig. 9. Comparison of sensitivity coefficients of k_{eff} CERMET fueled ADS S obtained by MCNP6.2 and SCALE6.2

6. Conclusions

- The impact of ENDF/B-VII.1 nuclear library **uncertainty on the CERMET fueled ADS cores reactivity calculation** were investigated using MCNP6.2/Whisper-1.1 and SCALE6.2 codes.
- The uncertainty of k_{eff} originating from ENDF/B-VII.1 is about **1000 pcm** for CERMET. From the sensitivity analysis, **total ν and (n, fission) reaction of ^{239}Pu; total ν and (n, fission) reaction of ^{241}Pu, total ν of ^{241}Am, (n, gamma) reaction of ^{241}Am, ^{237}Np, ^{232}Th, ^{239}Pu and elastic scattering of ^{16}O** at the fast neutron energy region are highly recommended to be adjusted to provide more reliable results on reactivity calculation.

Thank you for your kind attention!



Cross sections of 239Pu (n,f), 232Th (n,g), 237Np (n,f), 237Np (n,g), 239Pu (n,inl) and 23Na (n,ela) reactions