GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
POLITÉCNICA
UNIVERSIDAD POLITÉCNICA DE MADRID

Joint CIEMAT and UPM contribution: ASTRID, ESFR, ALFRED and MYRRHA

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WPEC SG 46 – OECD/NEA Headquarters, Paris (France), June 25th, 2019

Outline

1. Background
2. Models
3. S/U tools
4. S/U analyses
5. DA
6. Outlook

Outline

1. Background
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Background

Project information

ESNII PLUS

Grant agreement ID: 605172

Status
Closed project

Start date
1 September 2013

End date
31 August 2017

Funded under:
FP7-EURATOM-FISSION

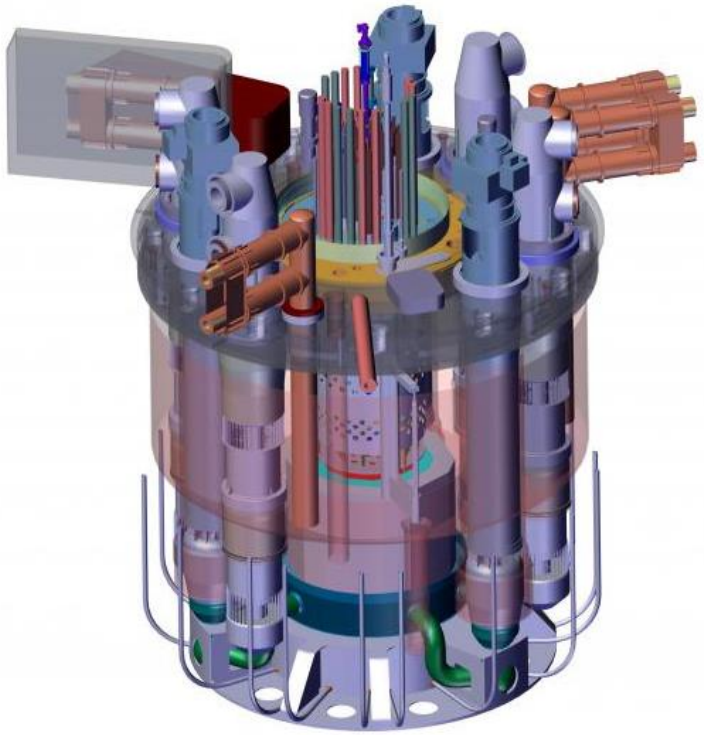
Overall budget:
€ 10 362 135,40

EU contribution
€ 6 455 000

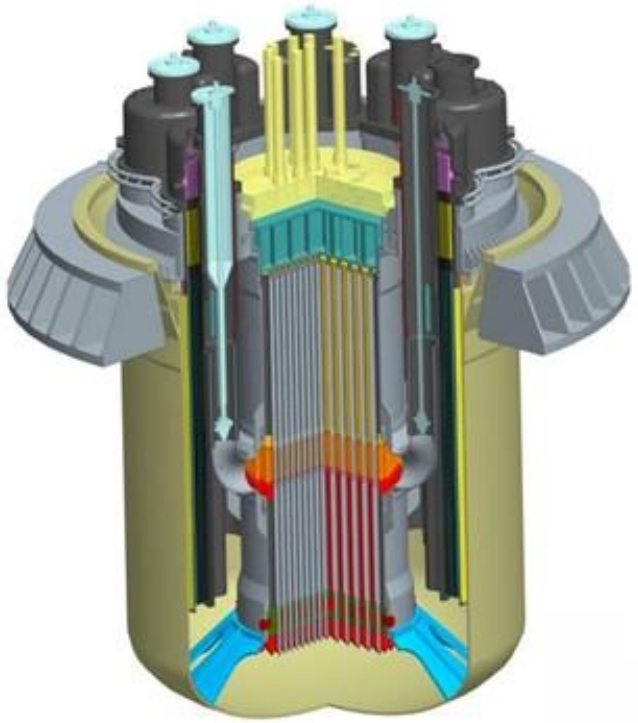
Coordinated by:
COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES
France

WP6: Core safety / T6.1. Core safety calculations for **ESNII reactors**

ASTRID



ALFRED



SEVENTH FRAMEWORK PROGRAMME

Background

Project information

CHANDA

Grant agreement ID: 605203

Status
Closed project

Start date
1 December 2013

End date
31 May 2018

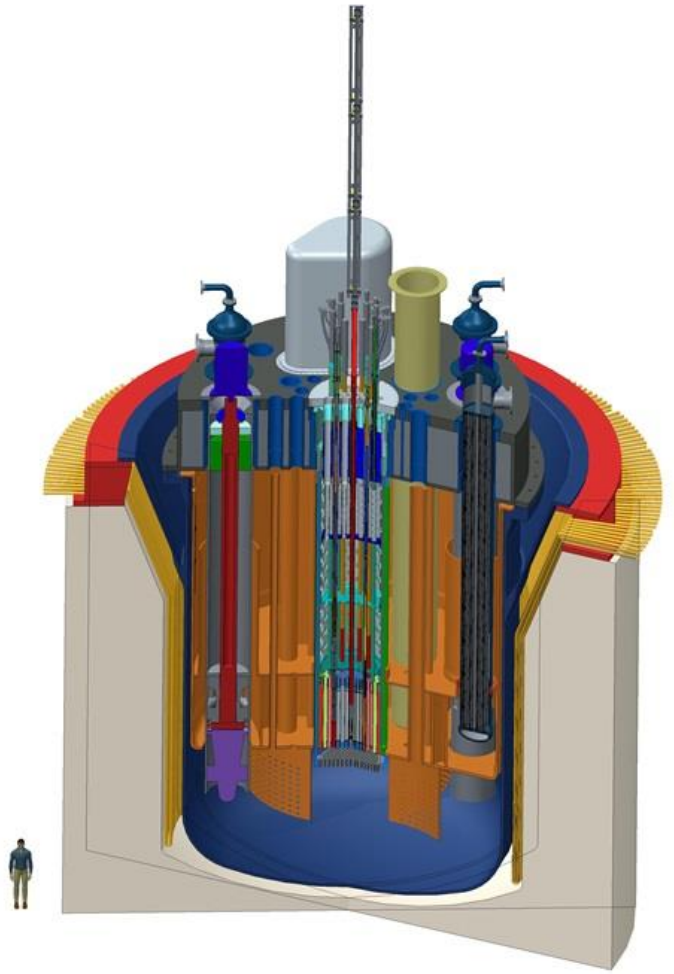
Funded under:
FP7-EURATOM-FISSION

Overall budget:
€ 9 237 814,64

EU contribution
€ 5 400 000

Coordinated by:
CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT
Spain

WP10: Development of nuclear data for **MYRRHA** reactor safety analyses



SEVENTH FRAMEWORK PROGRAMME

Background

Project information

ESFR-SMART

Grant agreement ID: 754501

Status
Ongoing project

Start date
1 September 2017

End date
31 August 2021

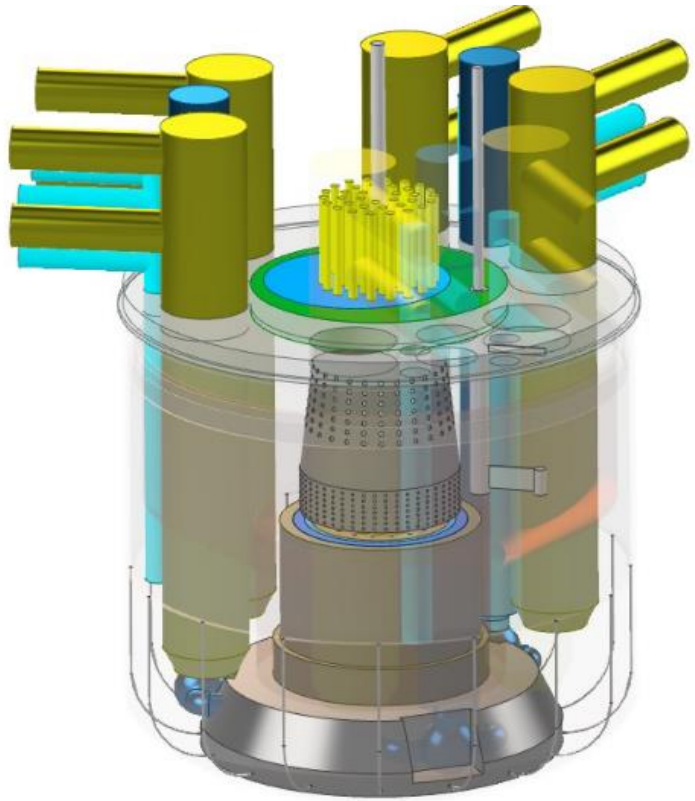
Funded under:
H2020-Euratom-1.1.

Overall budget:
€ 9 911 150

EU contribution
€ 5 000 000

Coordinated by:
PAUL SCHERRER INSTITUT
Switzerland

WP2: Normal operation/ T1.2.2. Uncertainties in the mapping of Doppler and void reactivity for **ESFR** reactor



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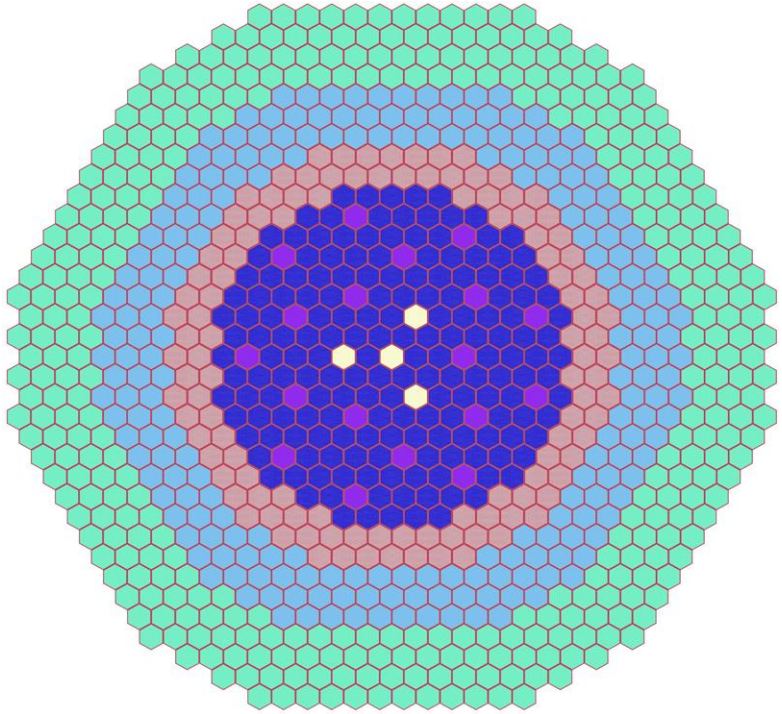
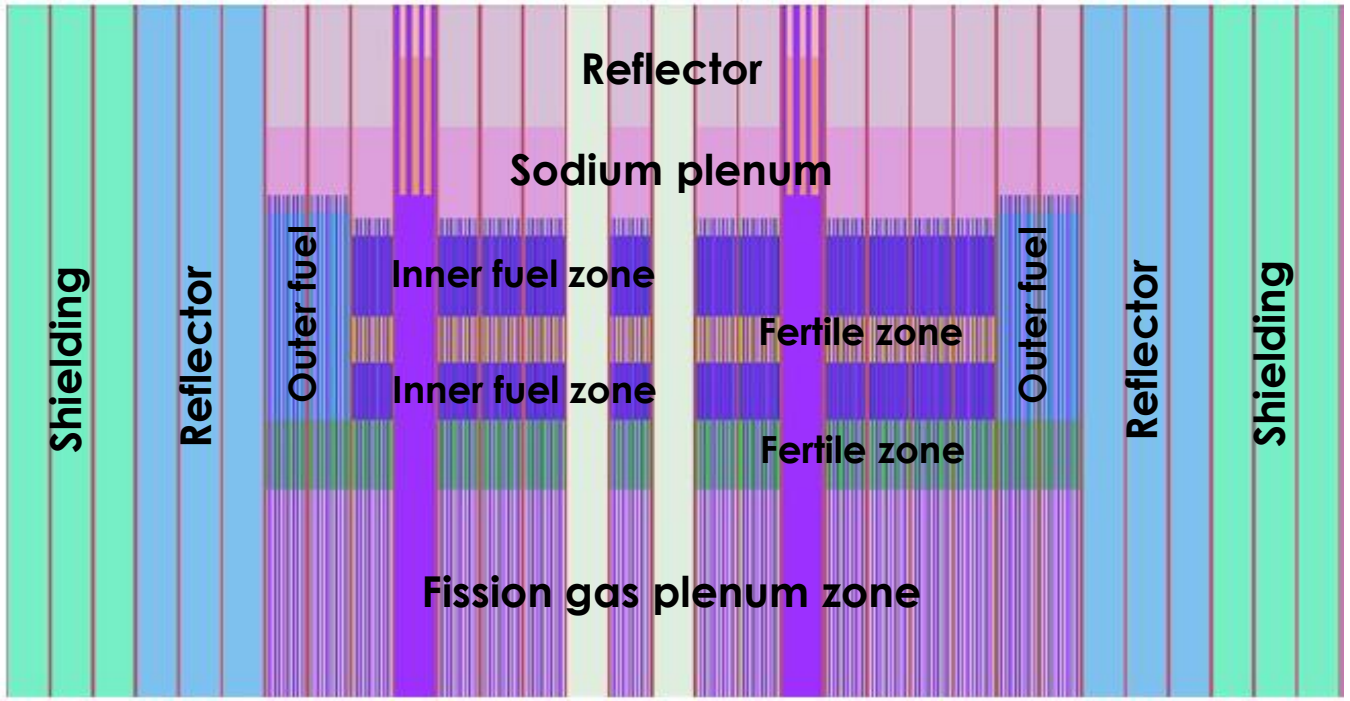
ASTRID

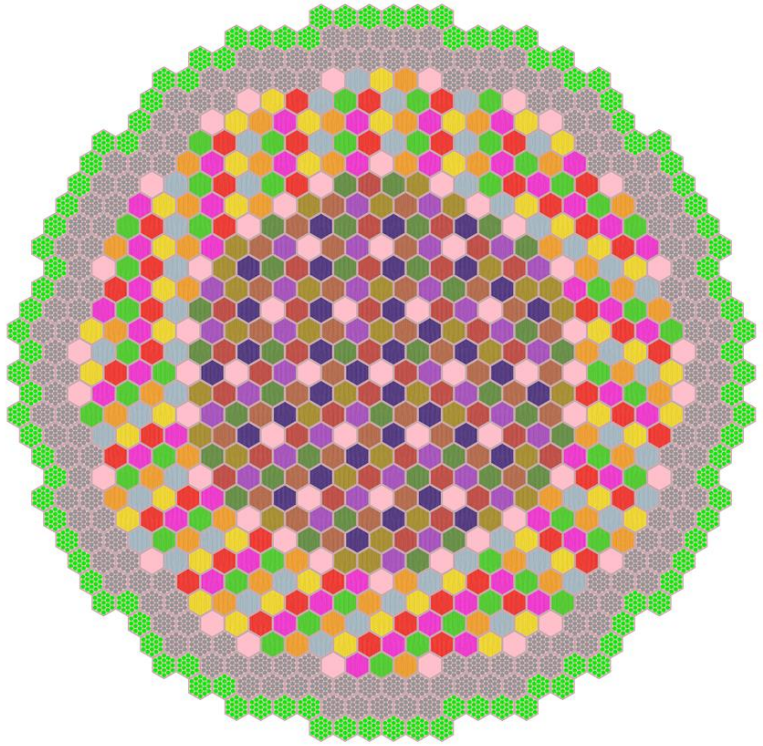
- **Reference:** P. Sciora, ESNII+ deliverable D6.1.1-1
- **Date:** 12/06/2014
- **Codes:** MCNP and SCALE
- **Conditions:** EoC

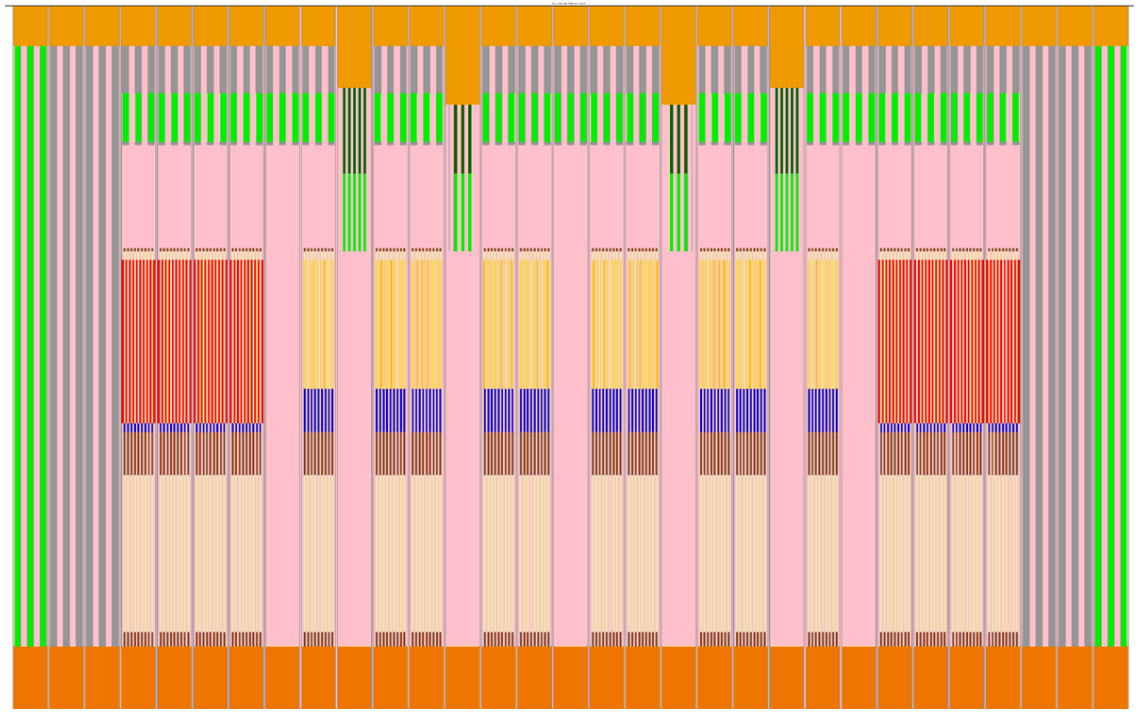


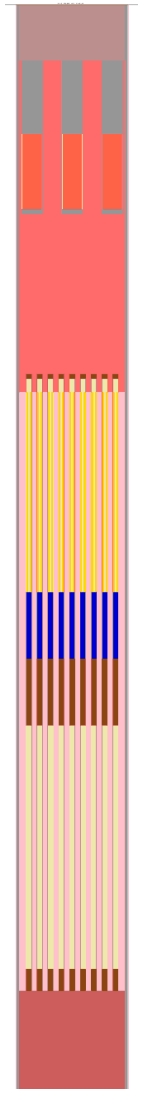


ESFR

- **Reference:** A. Rineiski et al., ESFR-SMART deliverable D1.1.2
- **Date:** 23/04/2018
- **Codes:** MCNP and SCALE
- **Conditions:** EoC

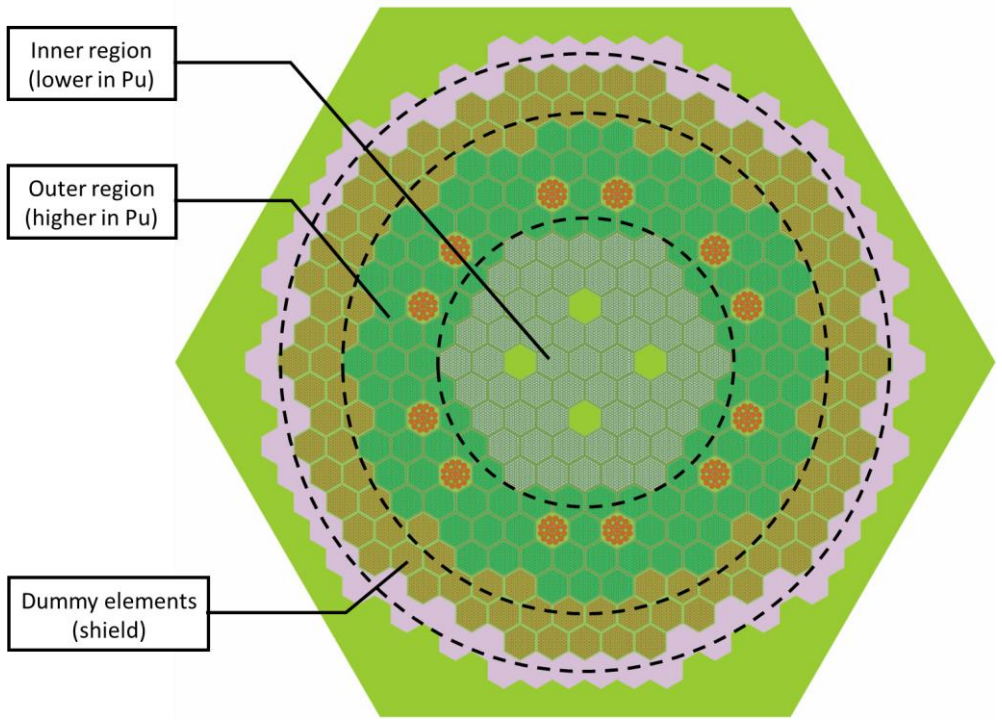


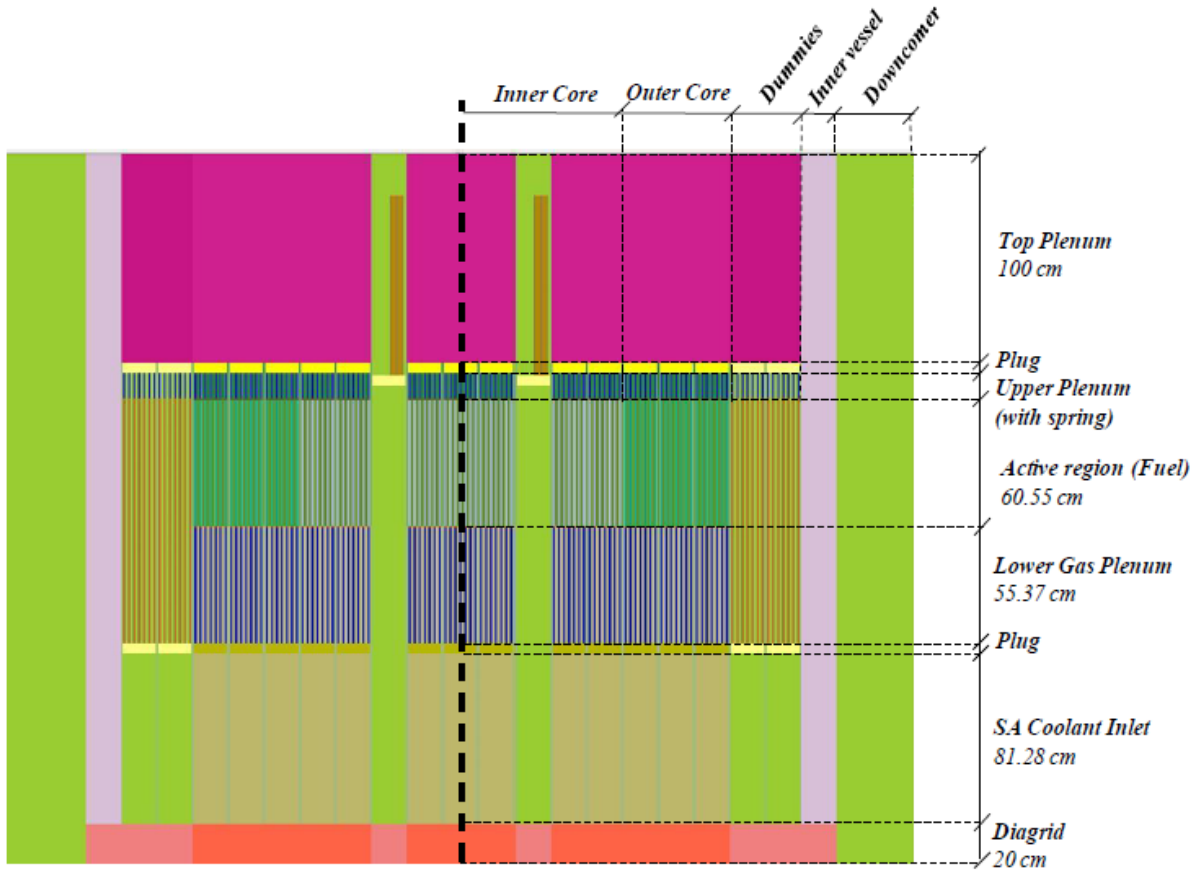




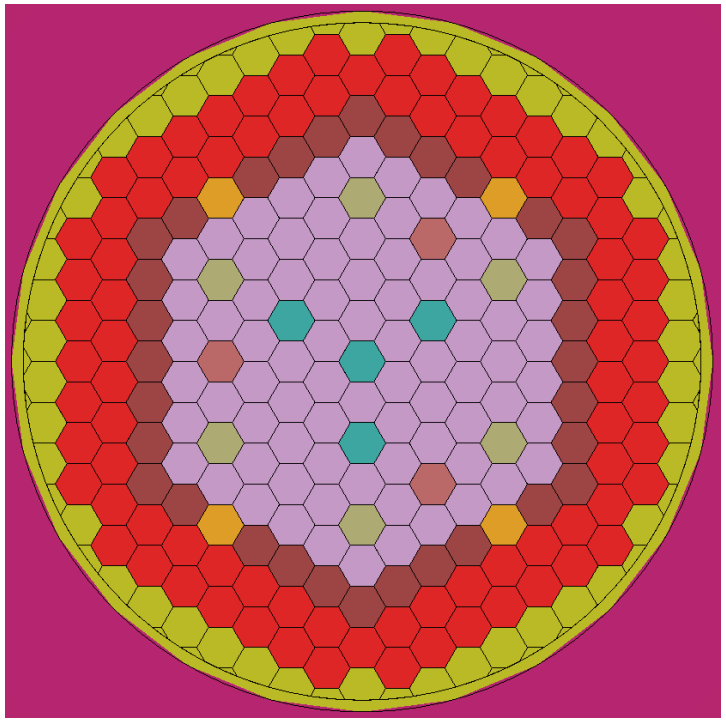
ALFRED

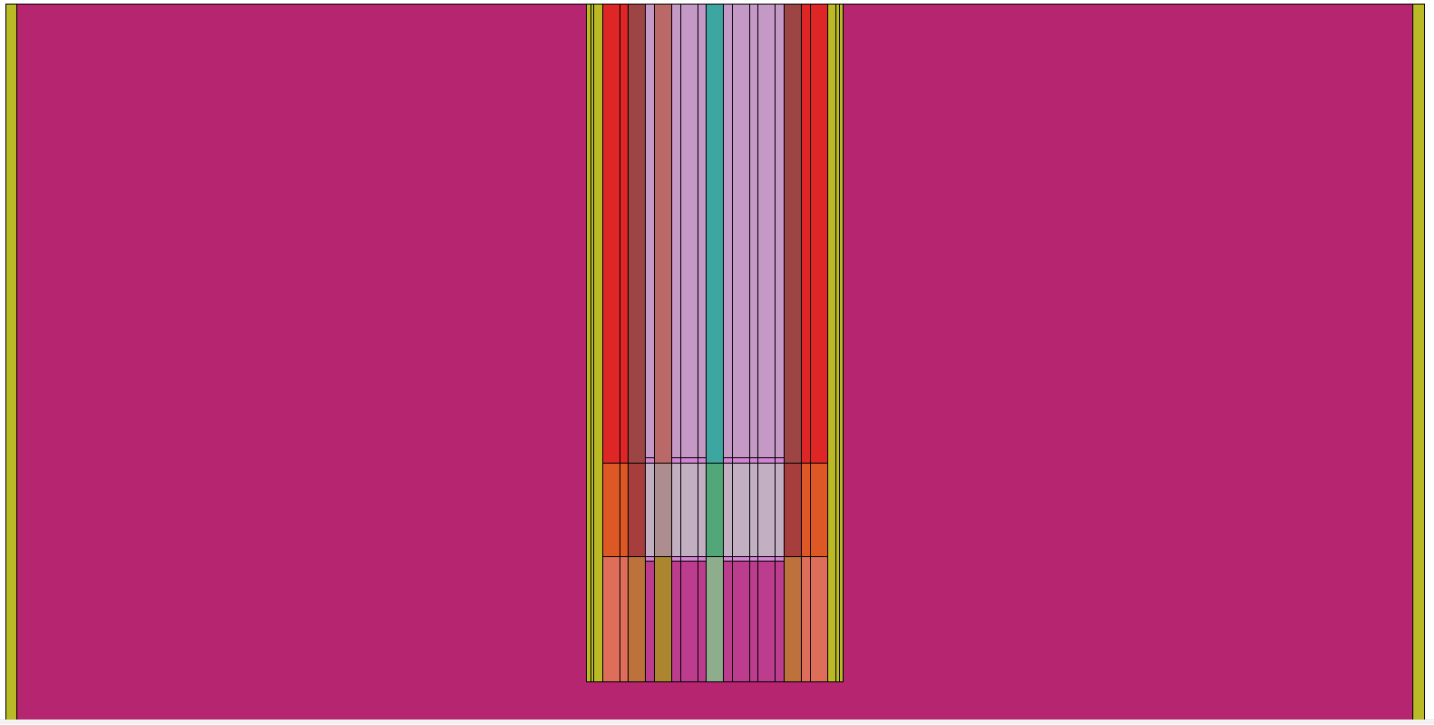
- **Reference:** G. Grasso et al., ESNII+ deliverable D6.1.1-3
- **Date:** 20/11/2014
- **Codes:** MCNP and SCALE
- **Conditions:** BoL, BoC and EoC





- **Reference:** A. Stankovskiy et al., SCK•CEN report SCK•CEN/44638036
- **Date:** 29/08/2014
- **Codes:** MCNP (SCK•CEN) and SCALE (UPM/CIEMAT)
- **Conditions:** BoL





Outline

1. Background
2. Models
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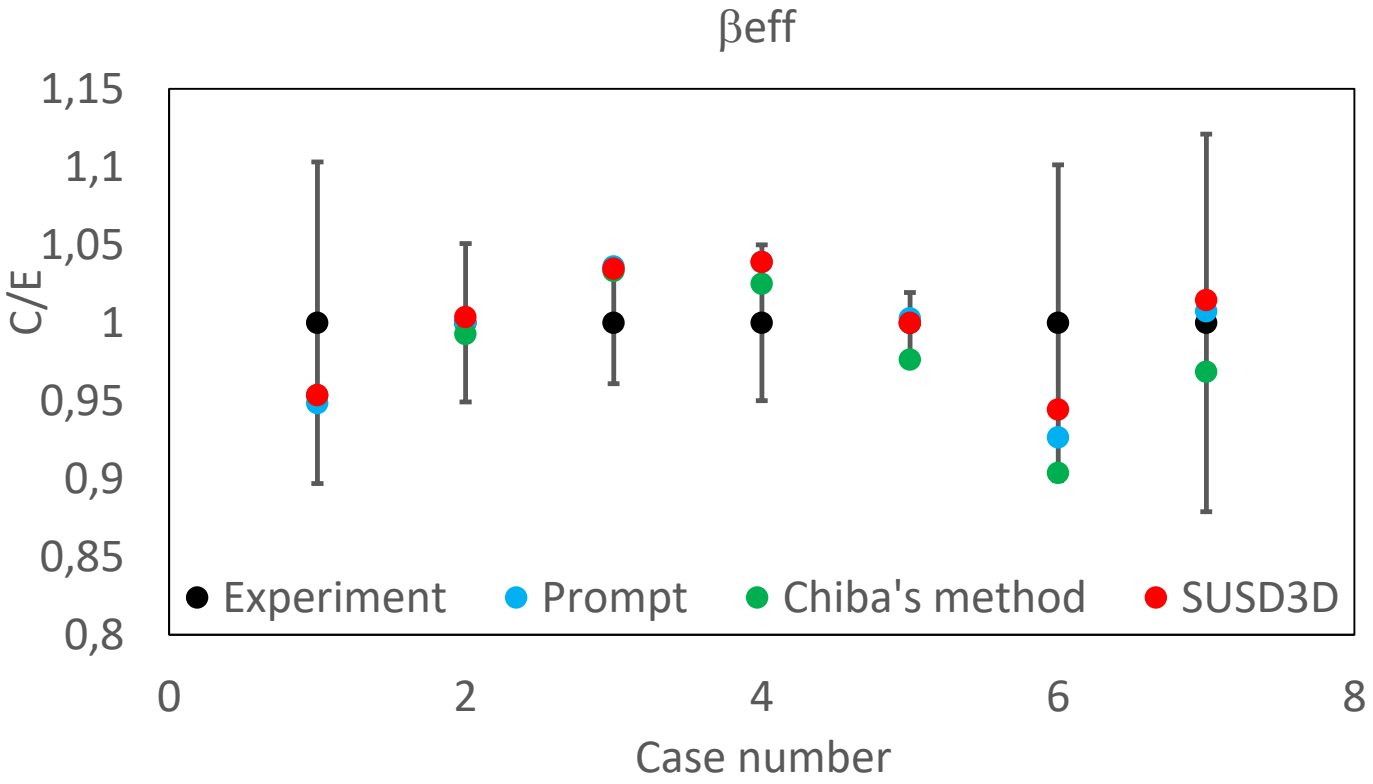
UPM/SCALE

- SCALE version: 6.1.3 / 6.2.3
- **TSUNAMI-3D MG** module or **TSUNAMI-3D CE**
  - k_{eff} sensitivity: 1st order perturbation theory
- **TSAR** module:
  - Reactivity response sensitivity: eigenvalue-difference response + 1st order perturbation theory
- **SAMS** module:
  - Uncertainties: propagation of moments ("Sandwich rule")
- **ND libraries**:
  - XS: ENDF/B-VII.0, ENSDF/B-VII.1, JEFF3.1
  - Covariances: SCALE6.1-44g (ENDF/B-VII.0 based), SCALE6.2-56g (ENDF/B-VII.1 based)

CIEMAT/SUMMON

- **SUMMON developed by CIEMAT**
- Based on the use of KSEN card of MCNP6
- **S/U analysis of integral-safety related parameters**:
  - k_{eff} — Iterated Fission Probability
  - β_{eff} — Prompt method & Chiba's method
  - Λ_{eff} — Perturbation method
  - Reactivity coefficients — Eigenvalue-difference response
  - Uncertainty — Propagation of moments ("Sandwich rule")
- **ND libraries**:
  - ND and covariances: **all**

- **Validation & Verification**:
  - International Criticality Safety Benchmark Evaluation Project (ICSBEP)
  - Consolidated codes: SCALE & SUSD3D & SERPENT



Outline

1. Background
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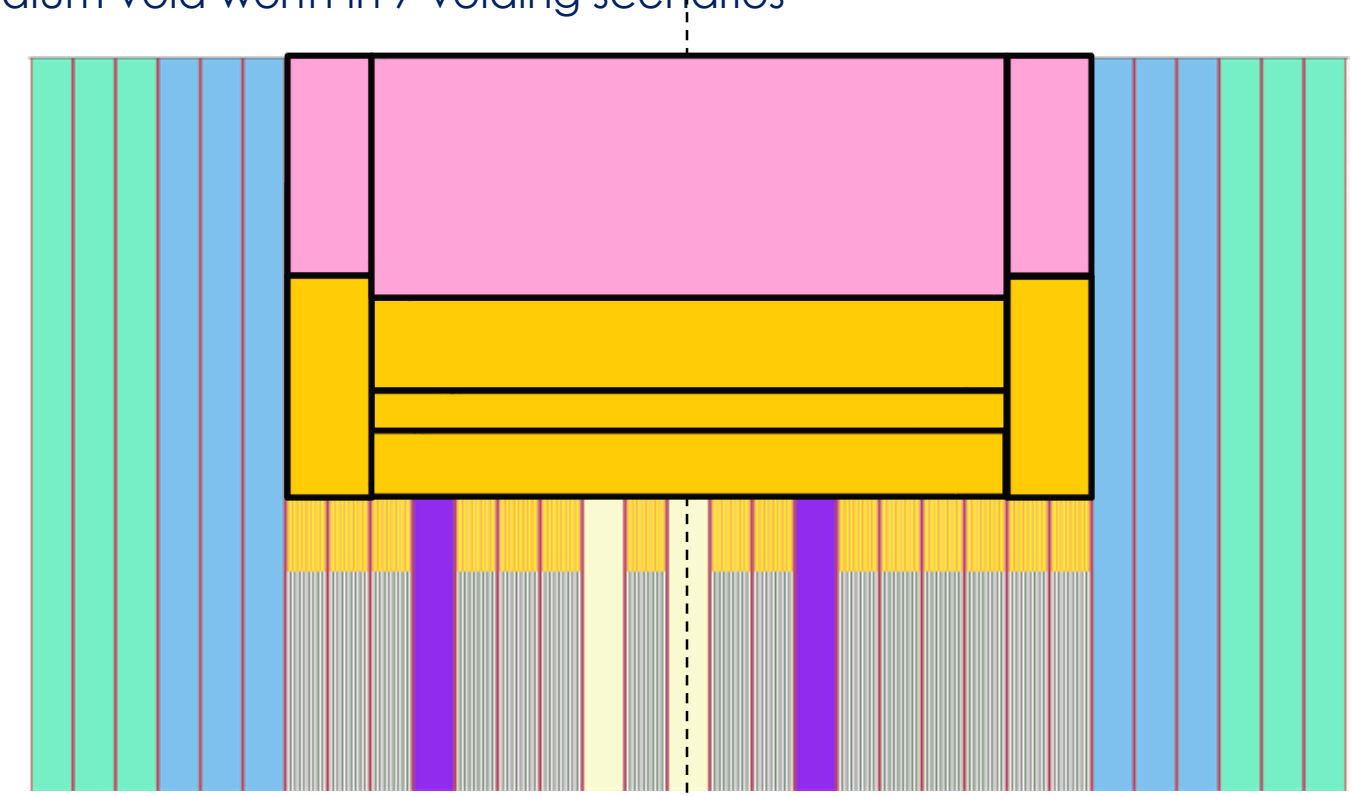
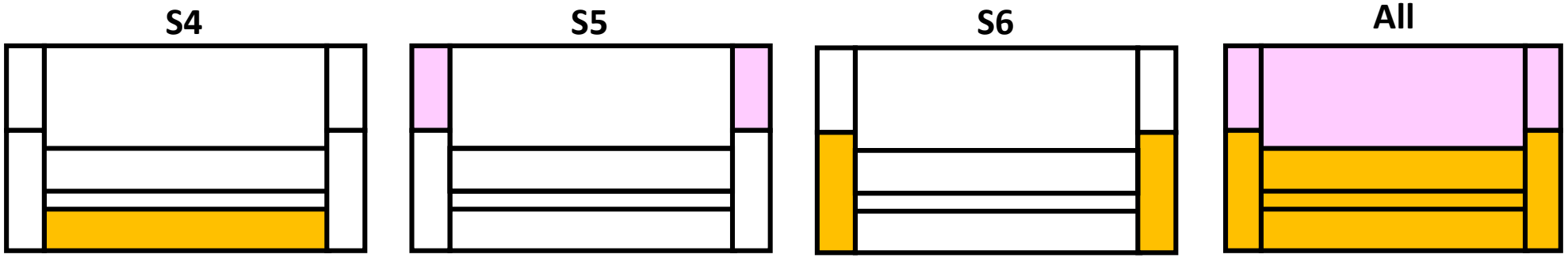
ASTRID

- **Condition:** EoC
- **Code:** SCALE6.1.3
- **XS:** ENDF/B-VII.0
- **Covariances:** SCALE6.1-44g (ENDF/B-VII.0), SCALE6.2-56g (ENDF/B-VII.1)
- **Parameters:** k_{eff}; sodium void worth in 7 voiding scenarios



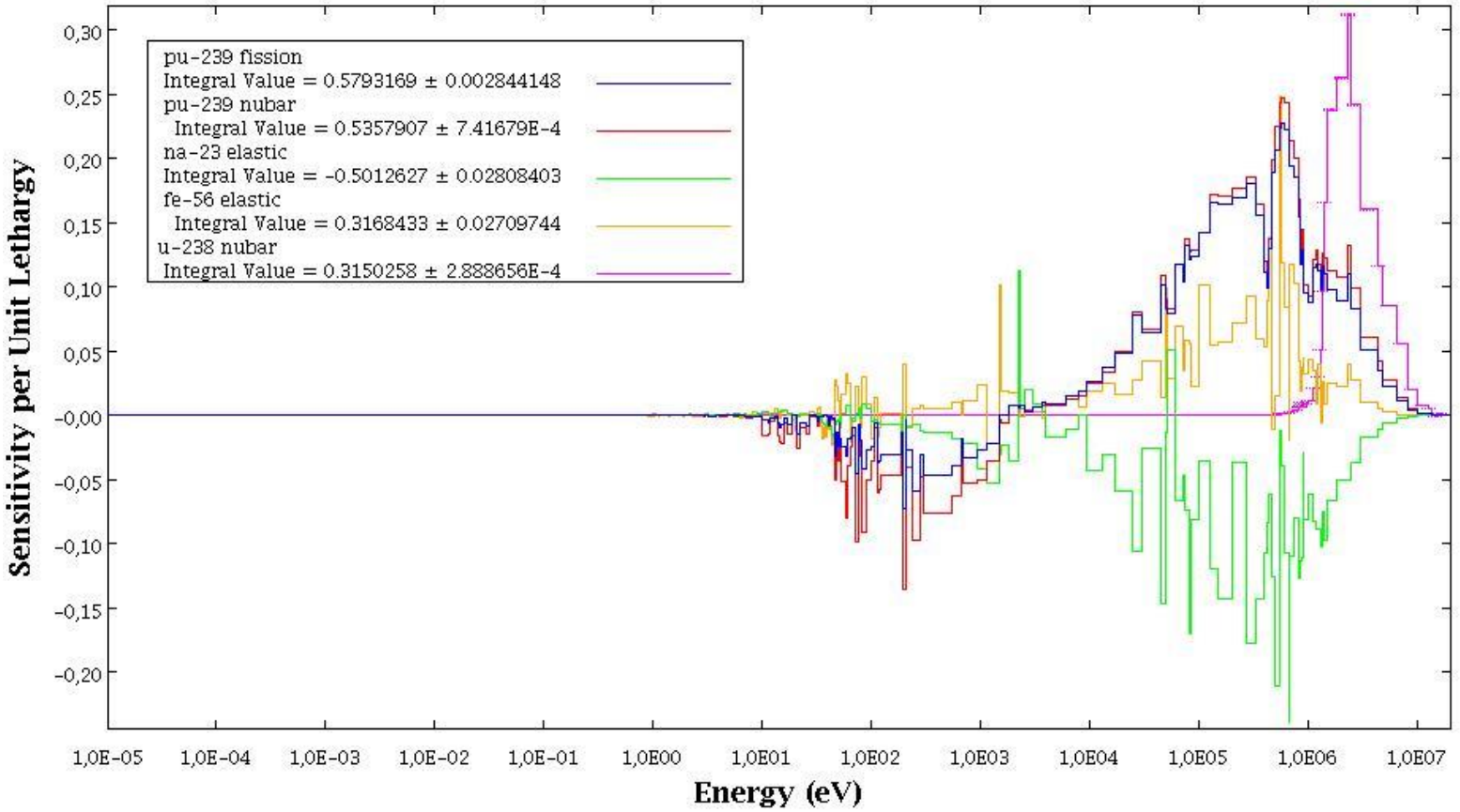
Spatial distribution of the Na void worth uncertainties

	S1	S2	S3
Void worth (pcm)	-1413 ± 13	439 ± 13	326 ± 12
44gCOV Unc. (pcm)	43 ± 0.8 (3%)	29 ± 0.5 (7%)	16 ± 0.7 (5%)



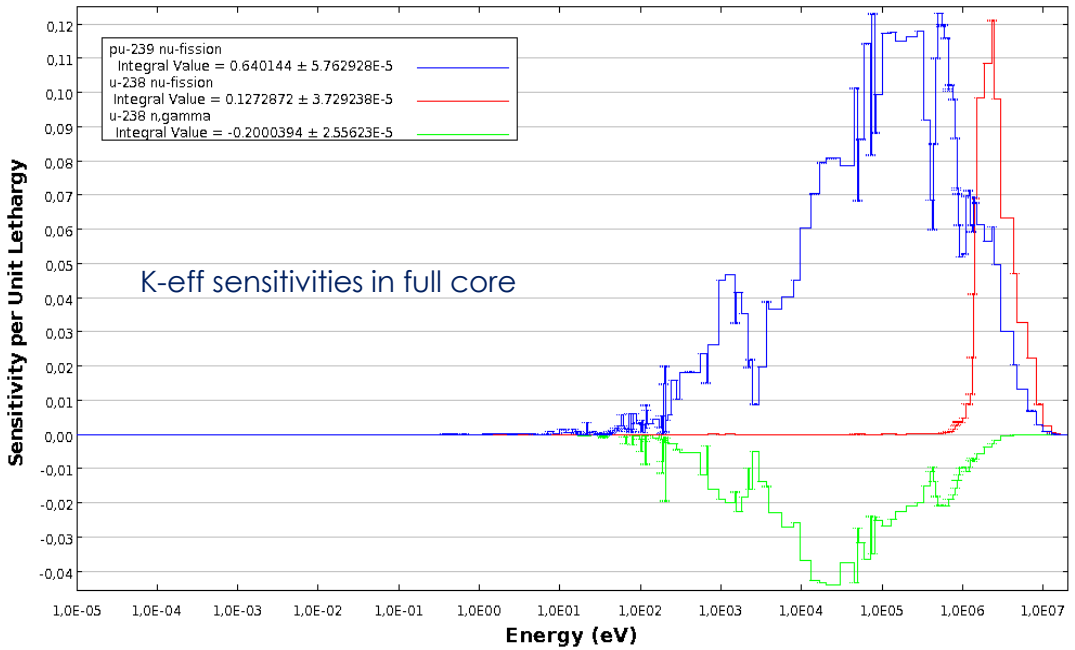
	S4	S5	S6	All
Void worth (pcm)	219 ± 12	-264 ± 11	203 ± 12	-536 ± 12
44gCOV Unc. (pcm)	15 ± 0.6 (7%)	8 ± 0.9 (3%)	23 ± 0.5 (11%)	112 ± 0.6 (21%)

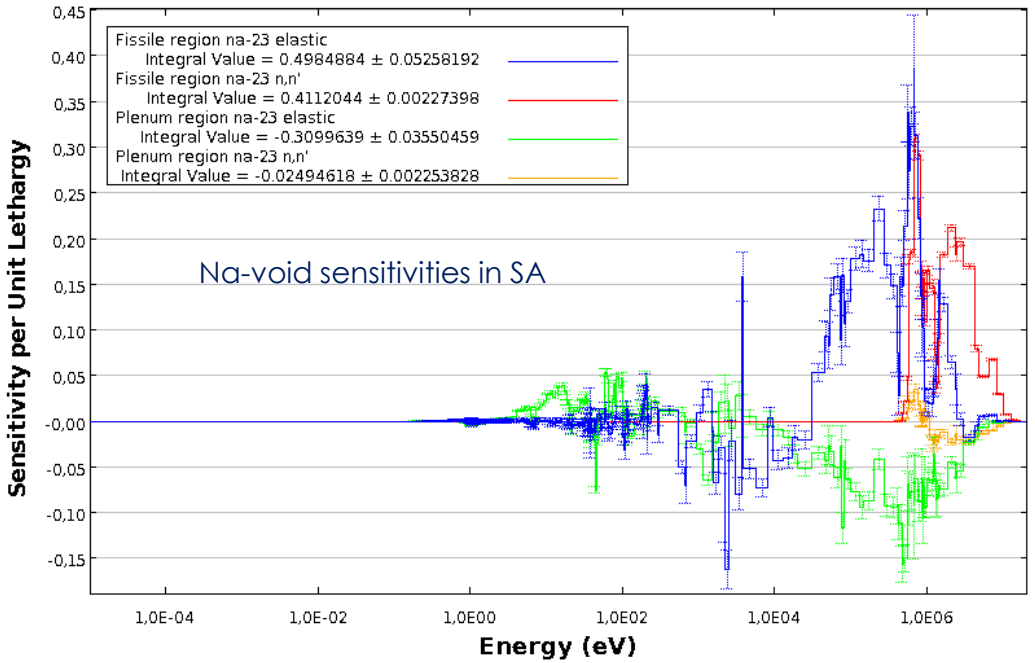
Na void worth sensitivities for Scenario 1



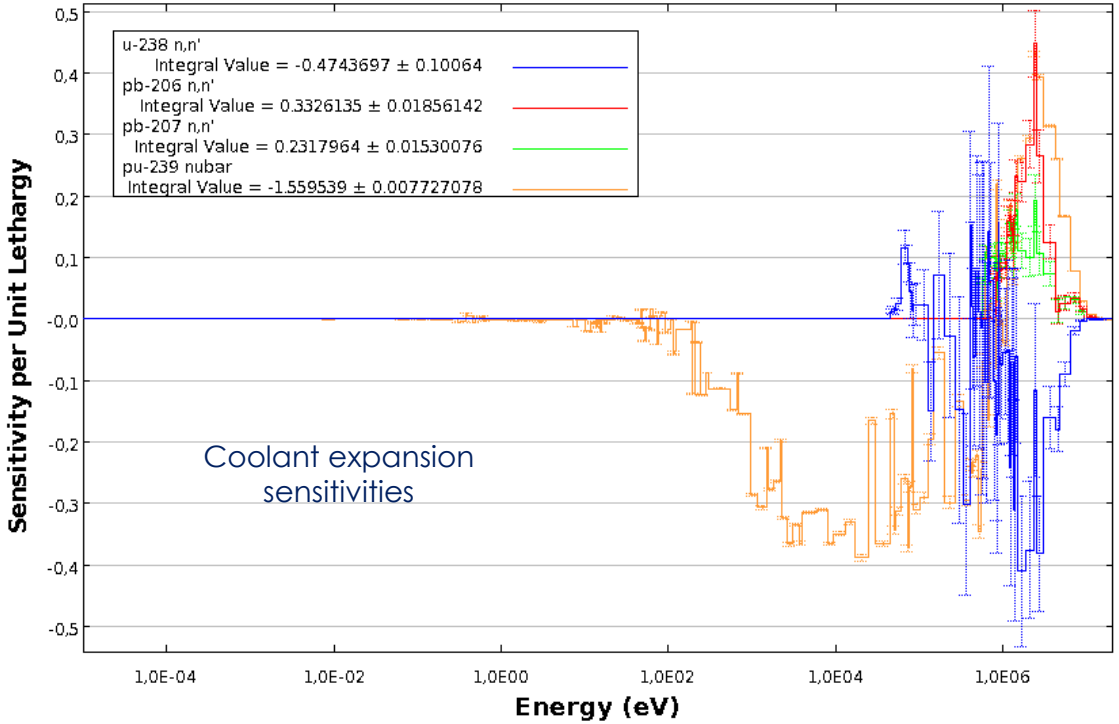
ESFR

- **Condition:** EoC
- **Code:** SCALE6.2.3 (TSUNAMI-3D CE)
- **XS:** JEFF-3.1
- **Covariances:** -
- **Parameters:** k_{eff}; sensitivities of detailed mapping of Doppler and sodium void ongoing

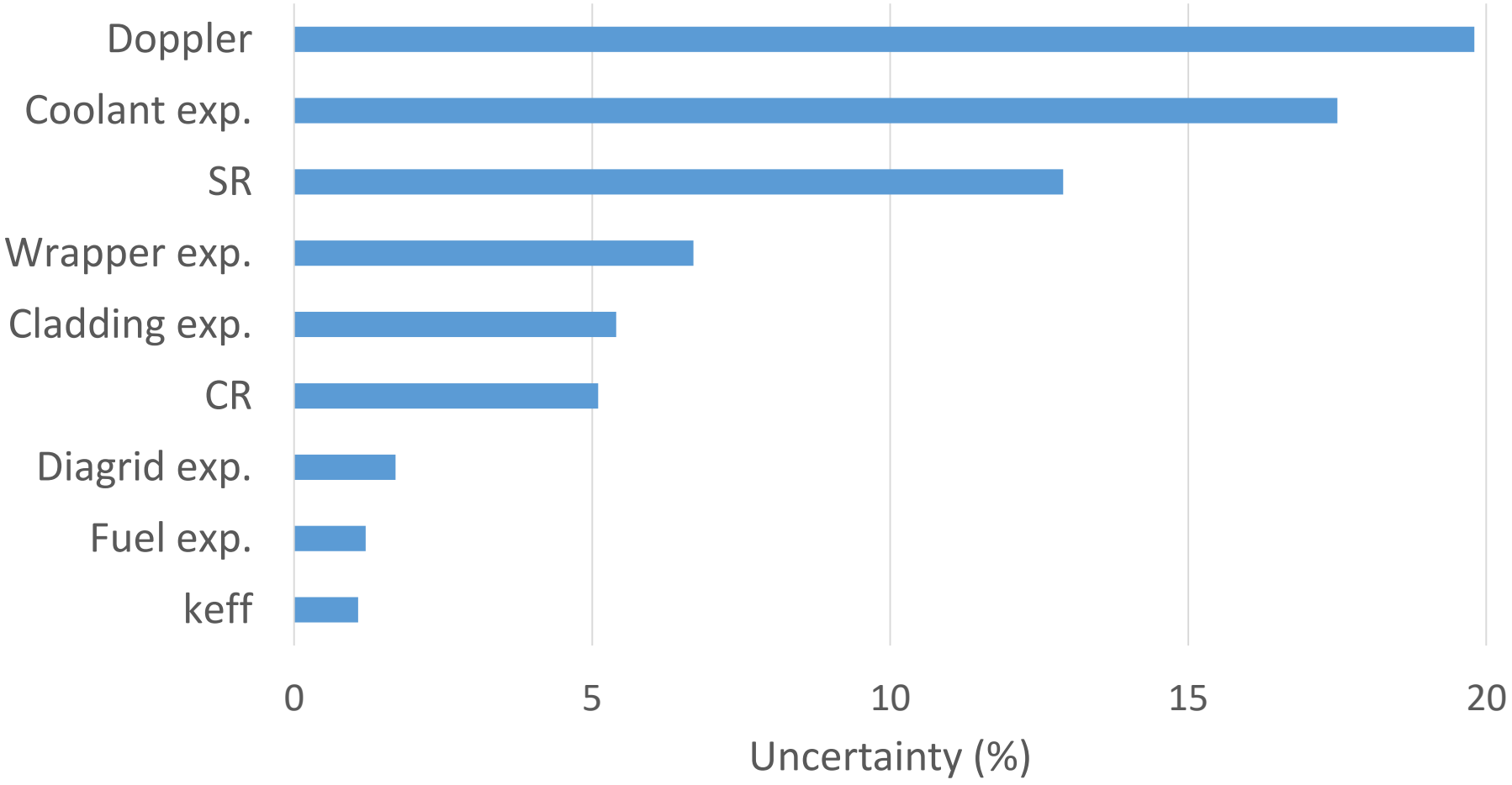




- **Condition:** BoC
- **Code:** SCALE6.1.3
- **XS:** ENDF/B-VII.0
- **Covariances:** SCALE6.1-44g (ENDF/B-VII.0), SCALE6.2-56g (ENDF/B-VII.1)
- **Parameters:** k_{eff}; Doppler; coolant, clad, wrapper, fuel and diagrid expansion; CR and SR shift

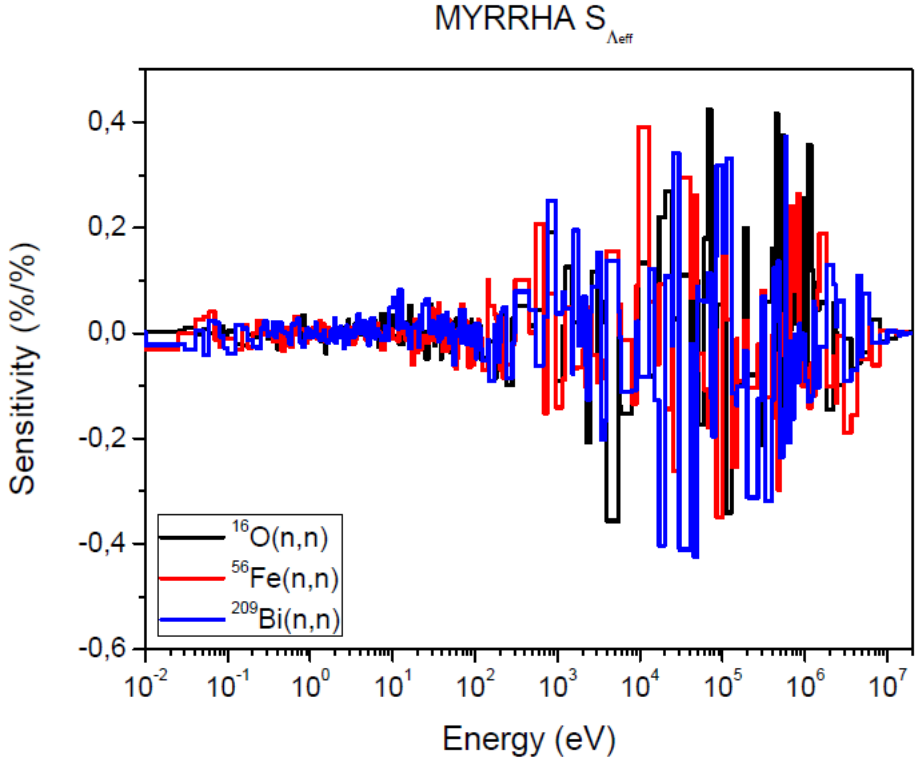


ALFRED


Doppler
Coolant exp.
SR
Wrapper exp.
Cladding exp.
CR
Diagrid exp.
Fuel exp.
keff
0
5
10
15
20
Uncertainty (%)

MYRRHA

- **Condition:** BoL
- **Code:** SUMMON
- **XS:** JEFF-3.3
- **Covariances:** JEFF-3.3
- **Parameters:** k_{eff}; β_{eff}; Λ_{eff}; Doppler; coolant expansion; CR shift



Parameter	TA (%)	Unc. (%)
k_{eff}	0.3	**0.8**
β_{eff}	3	**1.1**
Λ_{eff}	-	20.8
Doppler coefficient (+400 K)	7	**9.1**
Coolant density coefficient (-5%)	7	**20.3**
Control rod worth	7	**1.8**

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1. Background
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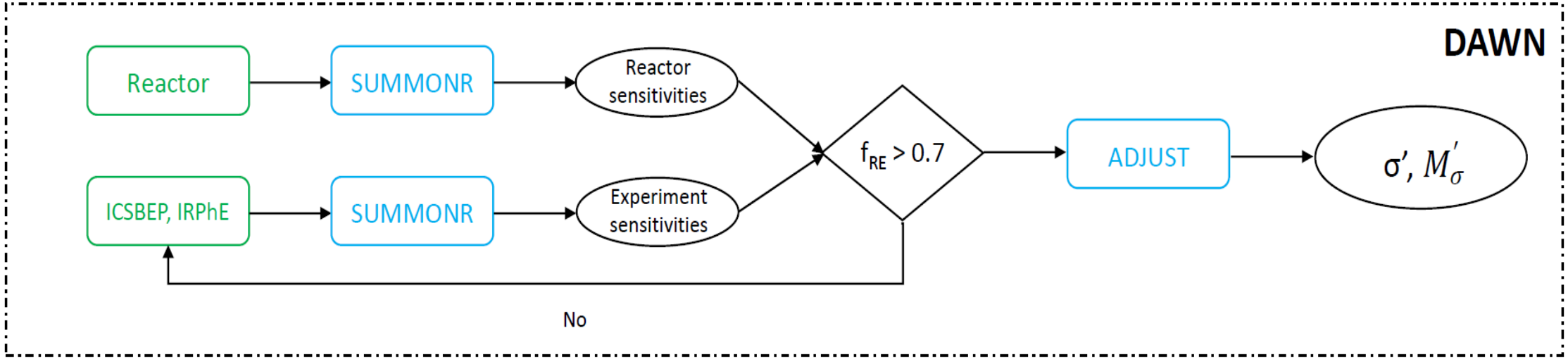
- Based on **GLS technique**
- **Representativity factor** to identify similar experiments in ICSBEP and IRPhE
- Pre-adjustment: **AM**, $\mathbf{X^2_{diag}}$ and **IS**
- **PIA** & **REWIND** (finishing implementation)
- Post-adjustment: $\mathbf{X^2_{con}}$



- **Assimilation**:
  - Major contributors to the uncertainty in k_{eff}, Doppler and coolant density
  - Critical mass experiments from ICSBEP
  - **Individual adjustments**
- **Selected integral experiments**:

f_{RE}	MYRRHA
ALFRED	0.97
HMF010	0.39
PMF028	0.42
HMF064	0.56
PMF006	0.81
PMF001	0.82
PMF002	0.94

Integral experiment	E	U_E (%)	C	U_c (%)	U_{EC} (%)	U_σ (%)	AM (%)
HMF010	1.00000	0.10	0.99728	0.001	0.10	0.01	-0.17
PMF028	1.00000	0.24	0.99906	0.001	0.24	0.41	0.56
HMF064	0.99960	0.10	1.00318	0.001	0.10	0.33	0.08
PMF006	1.00000	0.30	1.00334	0.001	0.30	0.75	0.72
PMF001	1.00000	0.11	1.00019	0.001	0.11	0.66	0.75
PMF002	1.00000	0.20	1.00128	0.001	0.20	0.84	0.91

- **Total uncertainties after assimilation with PMF002:**

A PRIORI					A POSTERIORI				
Quantity				$\Delta k_{eff}/k_{eff}$ (%)	Quantity				$\Delta k_{eff}/k_{eff}$ (%)
^{240}Pu	(n,f)	^{240}Pu	(n,f)	0.543	^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.291
^{240}Pu	(n,f)	^{240}Pu	(n,γ)	-0.420	^{239}Pu	χ	^{239}Pu	ν_p	-0.268
^{239}Pu	ν_p	^{239}Pu	ν_p	0.321	^{239}Pu	ν_p	^{239}Pu	ν_p	0.254
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.295	^{239}Pu	χ	^{239}Pu	χ	0.187
^{239}Pu	χ	^{239}Pu	χ	0.261	^{239}Pu	(n,f)	^{239}Pu	(n,γ)	0.173
^{240}Pu	(n,γ)	^{240}Pu	(n,γ)	0.197	^{238}U	(n,γ)	^{238}U	(n,γ)	0.167
^{239}Pu	(n,f)	^{239}Pu	(n,γ)	0.174	^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.151
^{238}U	(n,γ)	^{238}U	(n,γ)	0.167	^{239}Pu	ν_p	^{239}Pu	(n,f)	-0.137
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.151	^{240}Pu	(n,f)	^{240}Pu	(n,f)	0.135
^{238}U	(n,n')	^{238}U	(n,f)	-0.138	^{239}Pu	χ	^{239}Pu	(n,f)	-0.132
Total uncertainty in k_{eff}				**0.772**	**Total uncertainty in k_{eff}**				**0.529**

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Outlook

- Collapse existing sensitivity coefficients to energy grid defined for SG 46
- Process covariances of another ND library to 7g structure
- Other parameters could be derived with SUMMON
- Repeat calculations with SUMMON and another ND
- Update models
- S/U for ESFR ongoing in ESFR-SMART project
- S/U for several reactor designs in starting SANDA project