PAUL SCHERRER INSTITUT

PSI

eurad

European Joint Programme on Radioactive Waste Management

D. Rochman

EURAD WP8/Subtask 2.1: Status and plans

EURAD WP SFC – Work Package meeting, via remote connection,
28-30 September 2020

Zertifiziertes Managementsystem STARS ISO 9001

Summary

- Subtask 2.1: short recall (what and which participants)
- Current Status
- Plans/Conclusions

EUropean Joint Programme on RADioactive Waste Management

EURAD

5-year implementation phase 1 – EURAD-1

This project receives funding from the Euratom research and training programme under grant agreement No 847593.

Subtask 2.1: short recall

- Subtask 2.1: Theoretical study of SNF source terms
- Subtask leader: PSI
- Subtask contributors: CIEMAT, JSI, NAGRA, PSI, SCK.CEN, VTT, KIT, JRC-Geel, ENRESA
- Main responsible persons:
  - CIEMAT: Francisco Alvarez
  - JSI: Marjan Kromar
  - NAGRA: Ahmed Shama
  - PSI: Dimitri Rochman
  - SCK.CEN: Luca Fiorito
  - VTT: Silja Häkkinen
  - KIT: Ron Dagan
  - JRC-Geel: Peter Schillebeeckx
  - ENRESA: Ana Muñoz

Subtask 2.1: short recall

- Activities:

1. Select representative assemblies
2. Calculated quantities: isotopic concentrations, decay heat, gamma/neutron emissions
3. Cooling time: up to 1e5 years
4. Perform calculations (nominal and uncertainties/sensitivities/biases)
5. Identify relevant parameters
6. Summary of results
7. Workshop

Subtask 2.1: short recall

- Codes to be used and selected cases (as of today):

Institute	Code	Samples (planned)
PSI	CASMO, CASMO/SIMULATE/SNF	GU1, GU3, BM1
JSI	SERPENT2 ALEPH2 SCALE (TRITON/NEWT) POLARIS DRAGON	SKB-50 (JRC), S1.PWR, S2.PWR, NPP Krško fuel, SF95-5 REGAL (SCK)
SCK.CEN		
JRC Geel		
KIT	MCNP/CINDER, Nucleonica	SF95-5
NAGRA	SCALE POLARIS	SF95-5, BM1 Gundremmingen-7 (B23) ENRESA-BWR SKB-50
VTT	SERPENT2	Gundremmingen-7 (B23)
CIEMAT	EVOLCODE, MCNP/CINDER	S1.PWR, SF95-5
ENRESA	Define a BWR case	

Subtask 2.1: short recall

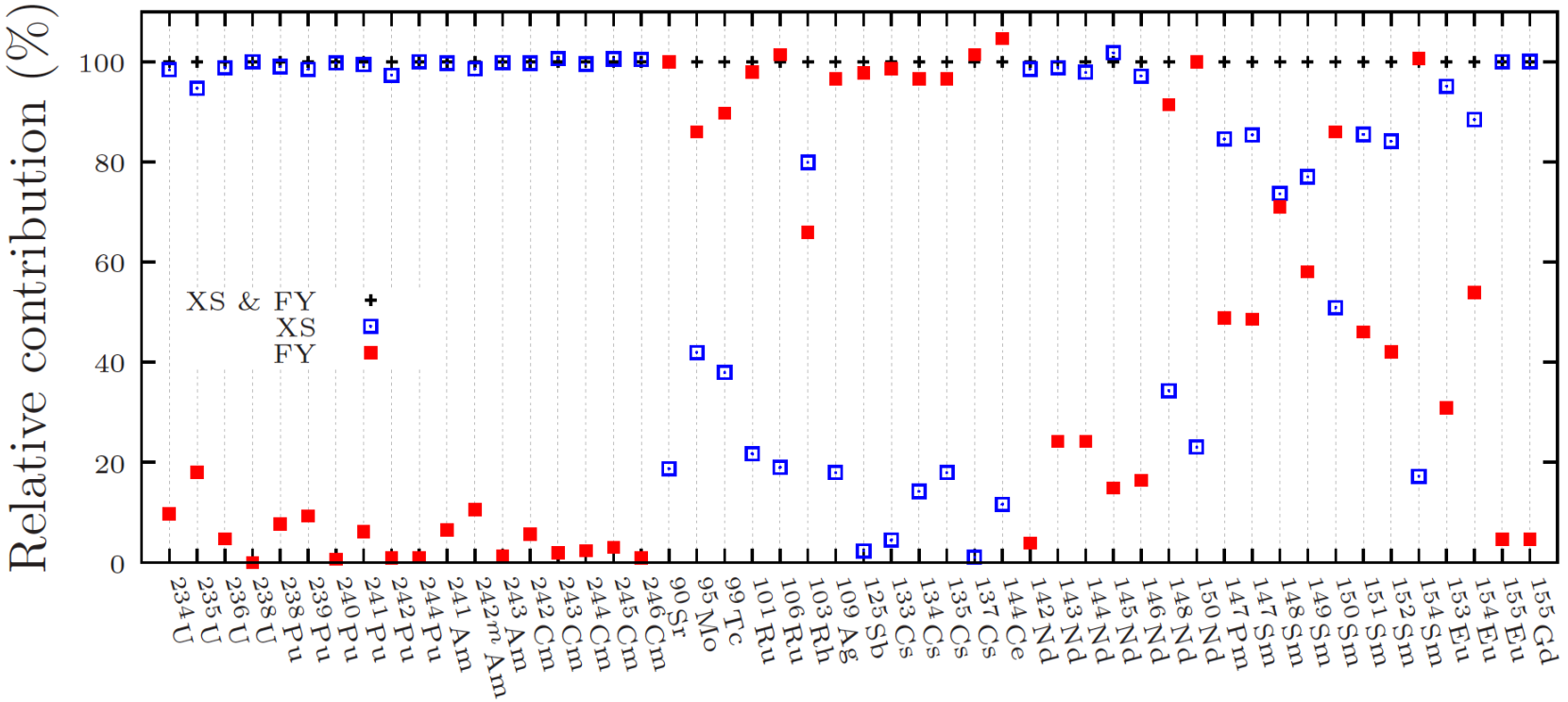
- Time frame

	Month 3 (Aug. 2019)	Month 7 (Dec. 2019)	Month 11 (April 2020)	Month 15 (Aug. 2020)	Month 19 (Dec. 2020)	Month 24 (May 2021)
Task Definition	PSI					
Simplified calculations		All				
Advanced calculations			All			
Sensitivity				All		
Uncertainties					All	
Report/workshop						PSI

Current status: PSI

- Three samples to be studied (GU1, GU3, BM1)
- GU1: done
- GU3: nominal done, nuclear data uncertainties started
- BM1: nominal done, nuclear data uncertainties not started

- GU1: publication under internal review:



Current status: JSI/SCK.CEN/JRC Geel

- S1.PWR:
  - Done with code comparisons (SERPENT2, ALEPH, POLARIS)
  - Nuclide vectors, decay heat
  - Effect of boundary conditions
- NPP Krško fuel assembly:
  - Done with TRITON/NEWT and ORIGEN+ARP
  - Nuclide vector comparison
  - Effect of simulation approximation (forced critical case)

Current status: JSI/SCK.CEN/JRC Geel

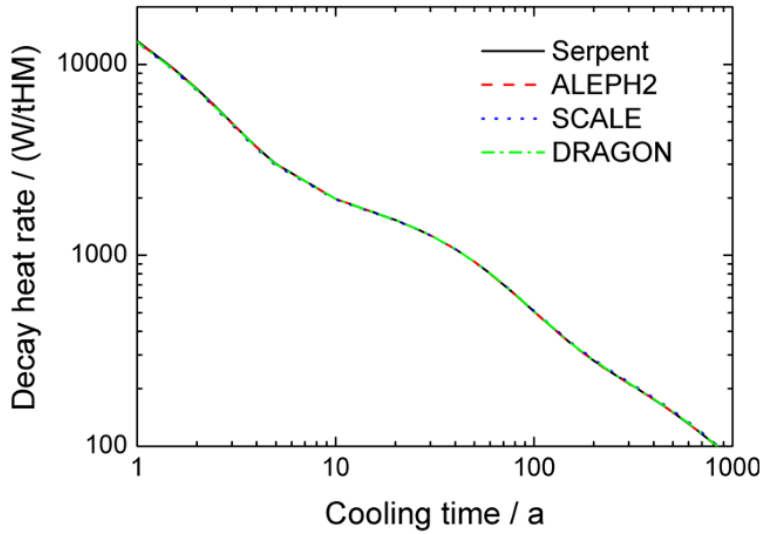
- S1.PWR: (similar results for neutron/gamma emission)

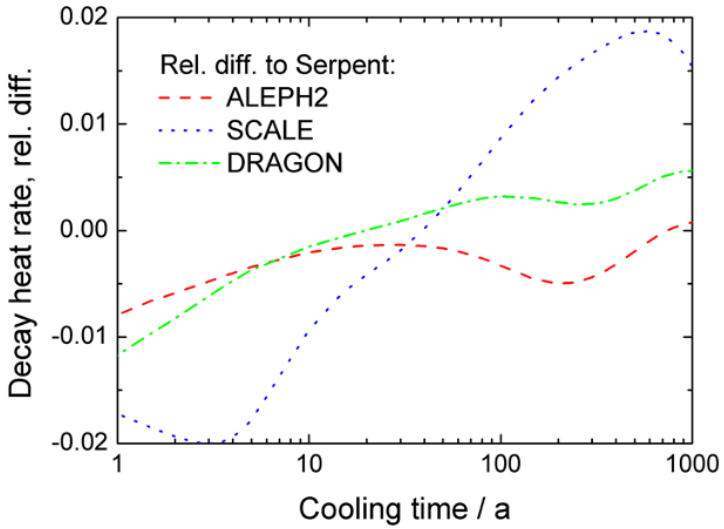
Code comparison: decay heat rate

Decay heat rate: $H(t) = \sum_j H_j(t)$

$H_j(t) = N_j(t)\lambda_j E_{rd,j}$

- λ - decay constant
- E_{rd} - recoverable energy per decay
- N - number density





European Commission

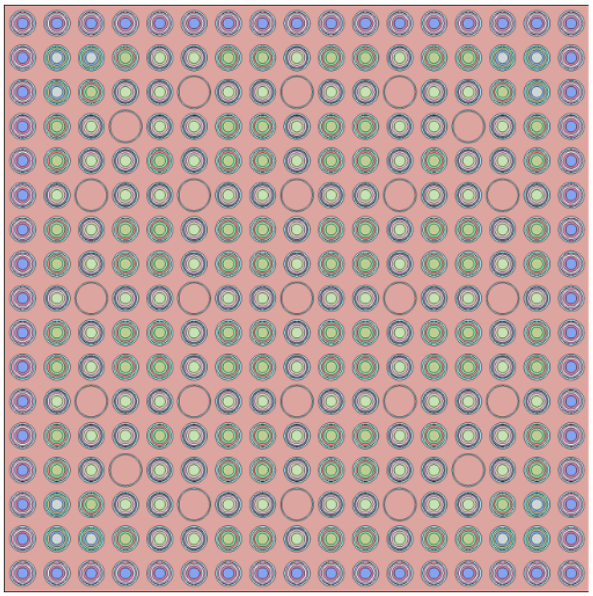
SCK·CEN

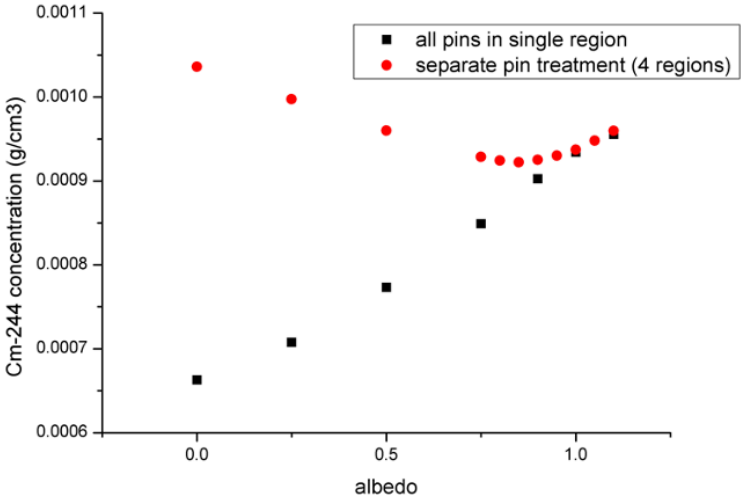
Current status: JSI/SCK.CEN/JRC Geel

- S1.PWR:

Sensitivity study: spatial discretization

- 4 radial depletion zones required for ^{244}Cm conc. within 0.5%
- Importance of separate pin treatment depends on the boundary conditions





European Commission

SCK•CEN

Current status: KIT

- SF95-5:
  - Started with MCNP/CINDER and Nucleonica
  - Calculations with MURE and KAPROS
  - Code comparison between high fidelity (Monte Carlo) and simplified deterministic approach.
  - Study of isotopic composition in the fuel and in the cladding (*e.g*. impurities)
  - Contribute to the question “how much simulation efforts are meaningful ?”

Current status: NAGRA

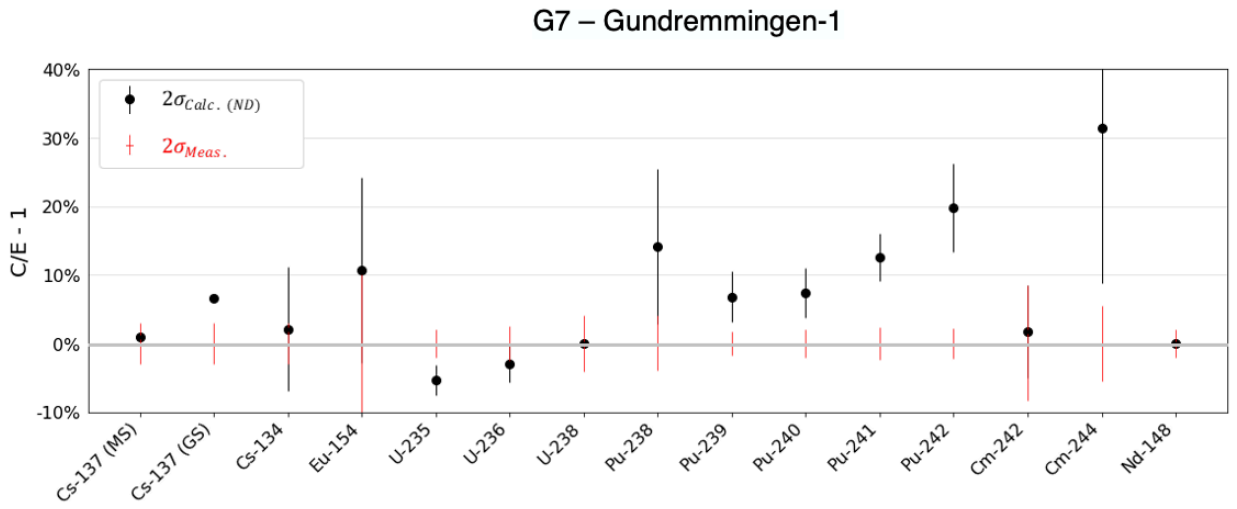
- BM1, SF95-5 and Gundremmingen-7
  - Performed with SCALE/Polaris, isotopic vectors (PIE)
- SKB-50
  - Ringhals-2 and -3 under study

PIE Calculations

- C/E of:

☑ KKB (BM1) ☑ Takahama-3 (SF95-5) ☑ Gundremmingen-1 (G7) ENRESA (Ongoing)

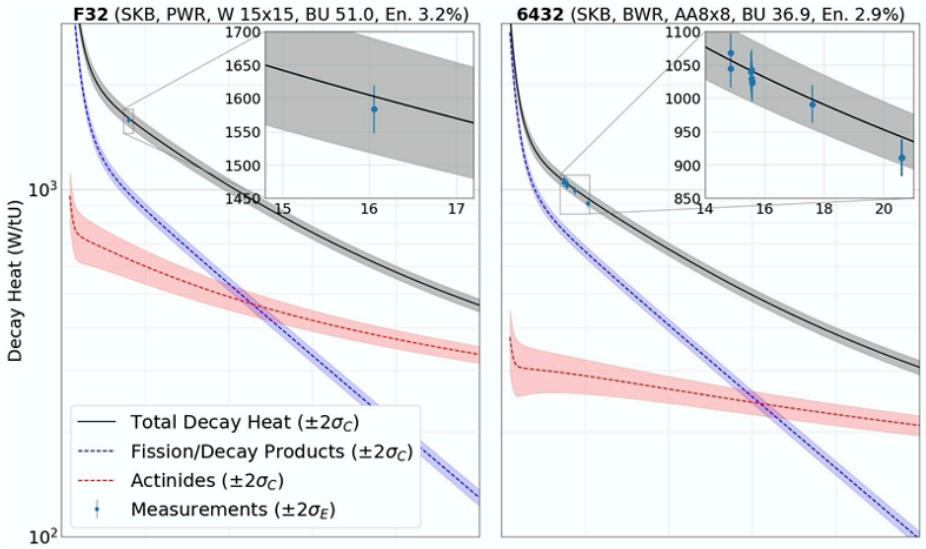
- Simplified calculations using SCALE/Polaris (2D along with ND based on ENDF/B-VII.1)
- Burnup normalized to the measured Nd-148 in all samples
- Sensitivity analyses (started)
- Uncertainty analyses (started)

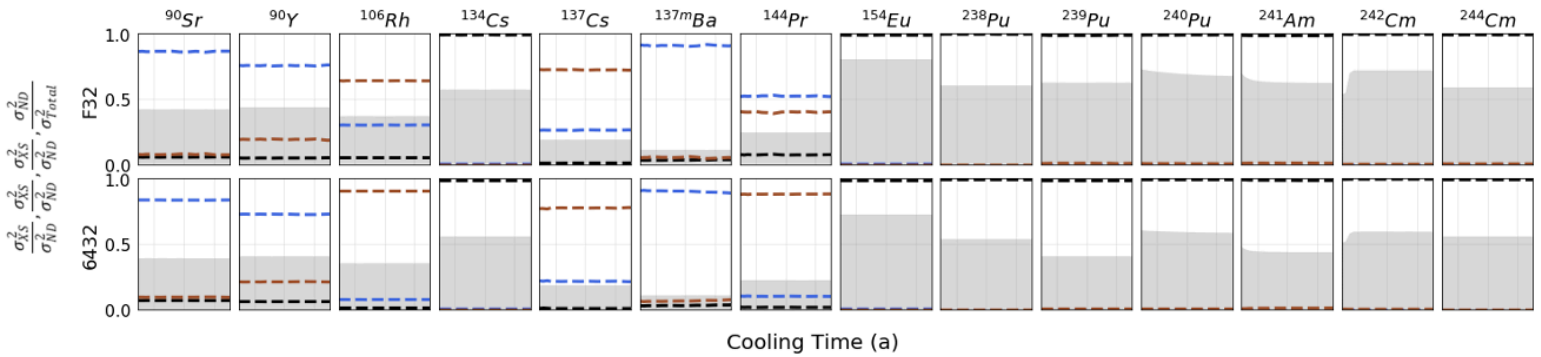


Current status: NAGRA

Decay Heat Calculations

- Two SNFs: PWR F32 (Ringhals-2) & BWR 6432 (Ringhals-1)
- C/E Calculations using SCALE (Polaris and ORIGEN-ARP)
- Uncertainty Propagation (ND and model variables)
- Contributions to uncertainties from XS, FY and DY data



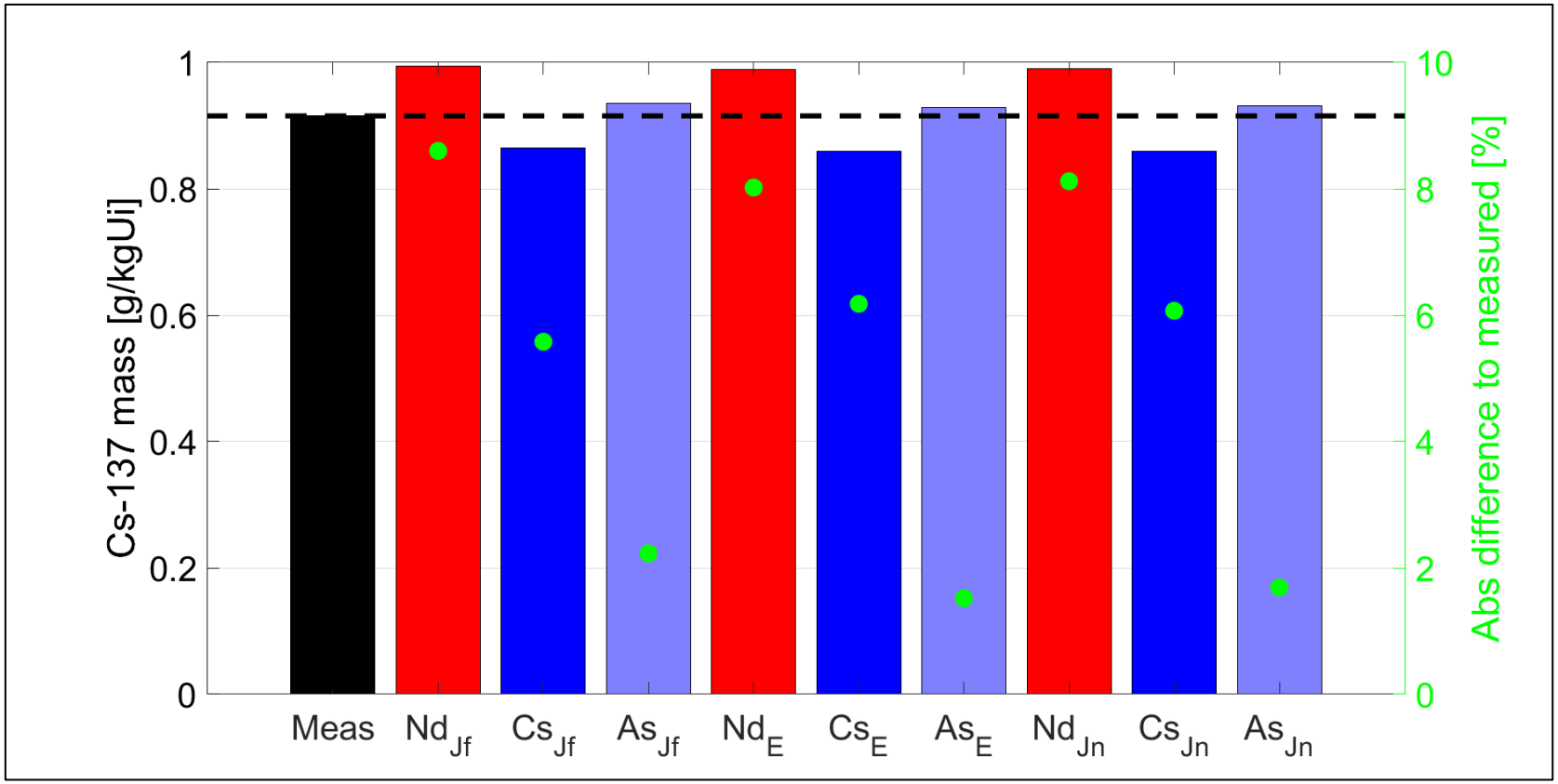


Current status: VTT

- Gundremmingen-7 with SERPENT2
  - Simplified and advanced (3D) calculations done
  - Sensitivity calculations to be started
  - The calculations were normalized to power density calculated from sample or assembly burnup and effective full power days
  - Two different sample burnup values based on Nd-148 (Nd) and Cs-137 (Cs) measurements and assembly burnup (As) were used in three independent calculations.
  - The different power densities have a significant effect on the results.

Current status: VTT

- Gundremmingen-7 with SERPENT2
  - Example on Cs137 concentrations for different libraries and sample burnup
  - Ambiguous measurement data / operating history data can yield to very different calculation results



Current status: CIEMAT

- SF95-5
  - Calculations planned to be finished mid-2020 with EVOLCODE and MCNP/CINDER
  - Sensitivity, uncertainty calculations started

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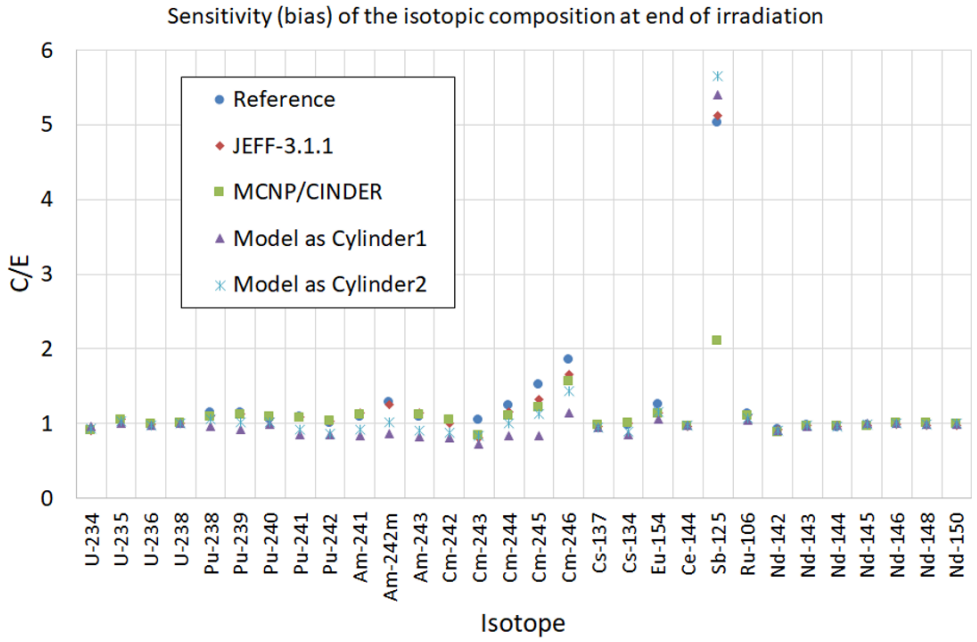
CIEMAT activities in EURAD WP8 Task 2.1

CIEMAT effort: 10.79 PM. Task already initiated at CIEMAT.

Isotopic composition of the SF95-5 sample is being calculated with EVOLCODE (reference with JEFF-3.3, squared model of the sample as a pin).

Bias (Calculation/Experimental) and uncertainty propagation estimations are ongoing.



Preliminary results, isotopic composition for the moment but planned to obtain decay heat, and neutron and photon emission rates, for the isotopes and times agreed.

Current status: CIEMAT

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CIEMAT activities in EURAD WP8 Task 2.1

Uncertainty propagation estimations include uncertainties coming from nuclear data (cross sections, fission yields, decay data) and from modelling/fabrication: power, irradiation time, enrichment, etc.

Hybrid method EVOLCODE-ACAB. Special effort in gaining computational speed with EVOLCODE (a factor of 10-30 times faster for SF95-5). Parallelization planned to increase speed even more: brute Monte Carlo will be possible so other variables' uncertainties can be propagated (geometry, materials, etc.).

Preliminary results

Uncertainty in decay heat from nuclear data at EOL (%)				
Isotope	X sections	Fis. yields	Decay data	Total
U-233	1.9	0.0	0.4	2.0
U-234	5.5	0.0	0.1	5.5
U-235	1.5	0.0	3.5	3.8
U-236	1.6	0.0	4.5	4.8
U-238	0.3	0.0	0.7	0.8
Np-237	2.7	0.0	0.5	2.7
Pu-238	3.6	0.0	0.6	3.6
Pu-239	2.3	0.0	0.2	2.3
Pu-240	3.5	0.0	0.7	3.6
Pu-241	3.5	0.0	1.0	3.6
Pu-242	3.8	0.0	0.4	3.8
Am-241	4.1	0.0	0.5	4.2
Am-242m	6.7	0.0	5.7	8.8
Am-243	4.5	0.0	8.0	9.2
Cm-242	4.3	0.0	1.4	4.6
Cm-243	9.3	0.0	6.7	11
Cm-244	5.0	0.0	0.6	5.1
Cm-245	5.5	0.0	2.4	6.0
Cm-246	5.8	0.0	3.4	6.9

Uncertainty in decay heat from nuclear data at EOL (%)				
Isotope	X sections	Fis. yields	Decay data	Total
C-14	2.1	19	0.5	19
Sr-90	1.3	5.9	0.4	7.0
Tc-99	1.8	7.1	3.9	8.6
Ru-106	2.2	11	1.0	11
Ag-110m	22	8.9	0.5	25
Sb-125	2.2	8.9	0.6	9.4
I-129	2.1	7.6	4.6	9.3
Cs-134	2.7	6.0	0.1	6.5
Cs-137	1.8	8.0	0.5	8.3
Ce-144	1.7	8.3	0.9	8.5
Nd-144	2.0	6.1	6.8	9.8
Nd-148	1.8	6.2	0.1	6.8
Nd-150	1.9	9.5	24	26
Pm-147	1.9	7.6	0.2	8.3
Sm-147	1.9	7.2	1.8	8.2
Sm-148	2.3	7.2	29	30
Sm-149	2.0	7.2	0.1	8.4
Sm-151	2.7	6.9	6.7	10
Sm-153	1.9	4.6	2.0	5.9
Eu-154	13	4.7	0.4	15
Eu-155	11	6.4	1.7	13
Total	**1.4**	**2.5**	**0.5**	**3.0**

Current status: ENRESA

- ENRESEA delivered the BWR assembly specifications on June 2020

EXECUTIVE SUMMARY

The document INF-TD-010032 revision 0 comprises the data of the experimental program carried out to measure isotopic compositions of samples from a GE14 high burnup fuel, developed several years ago by the Spanish consortium of Enresa, Enusa and CSN.

The measurements represent an important contribution to isotopic data for BWR fuel designs and expand validation data to include modern and complex designs with enrichments and burnup values representative of currently operating reactors.

Current status: ENRESA

- ENRESEA delivered the BWR assembly specifications on June 2020

enusa

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The report compiles the results of the isotopic composition measurements of eight GE14 high burnup samples taken from the GN592 fuel assembly manufactured by ENUSA and irradiated in Forsmark 3 during 4 cycles up to a rod average burnup of 41 MWd/kgU and peak burnup of 54 MWd/kg. The experimental measurements were carried out by Studsvik Nuclear and include more than 60 isotopes.

The data is provided in the report INF-TD-010032 as follows:

- Samples characteristics are included in chapter 2.
- The mechanical and nuclear design of the GN592 bundle is described in section 3.2.
- The irradiation history of the bundle is included in section 3.3
- The isotopic composition experimental results separated by experimental technique are presented in section 4.1
- Finally, the burnup estimation of each sample is included in section 4.2.

Plans/conclusions

- All participants have started their calculations
- We follow the schedule as planned
- Collection of all results: end 2020/beginning of 2021
- Expected draft report: mid 2021
- Workshop: place and date to be defined in 2021

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