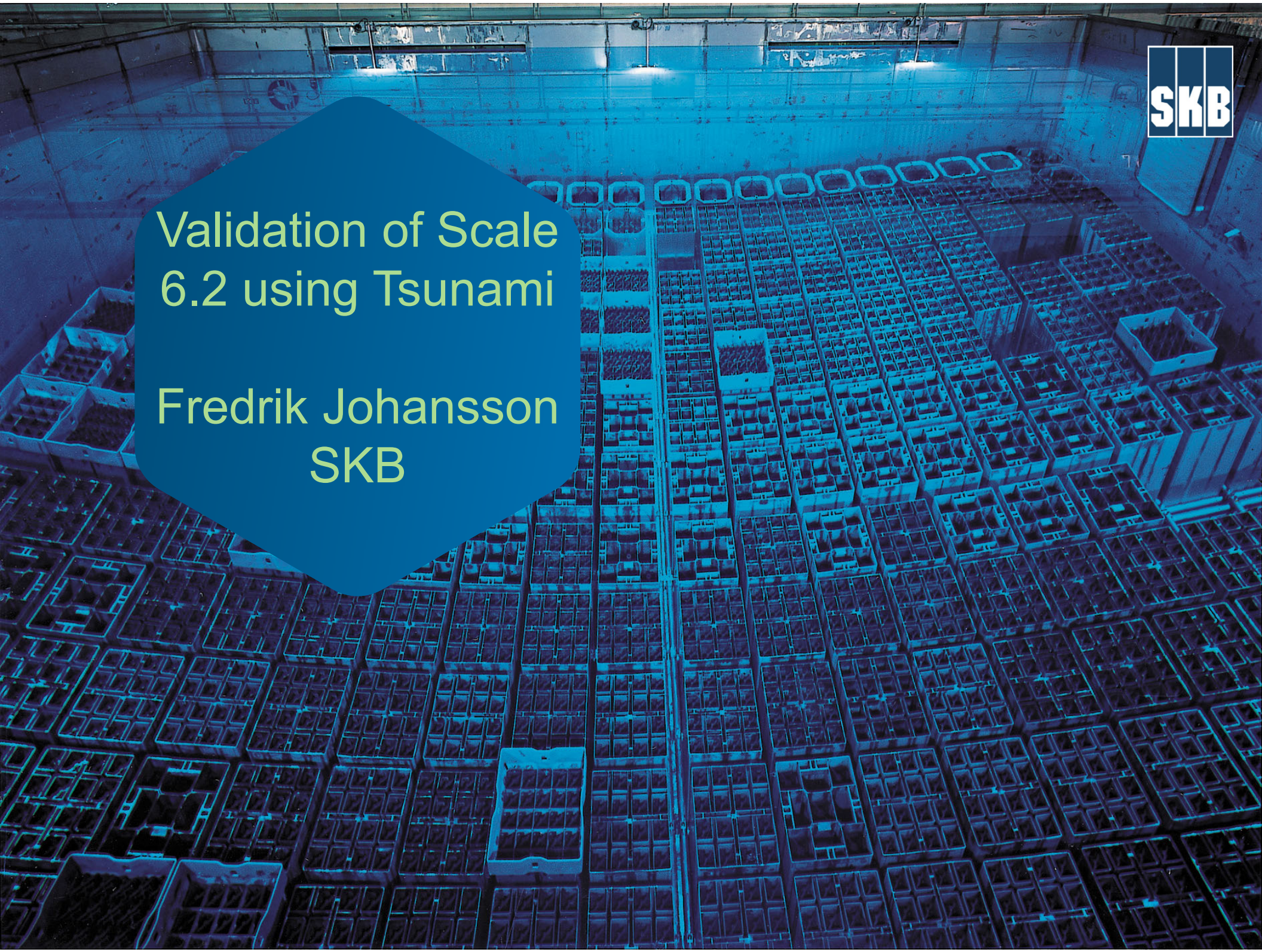

Validation of Scale 6.2 using Tsunami

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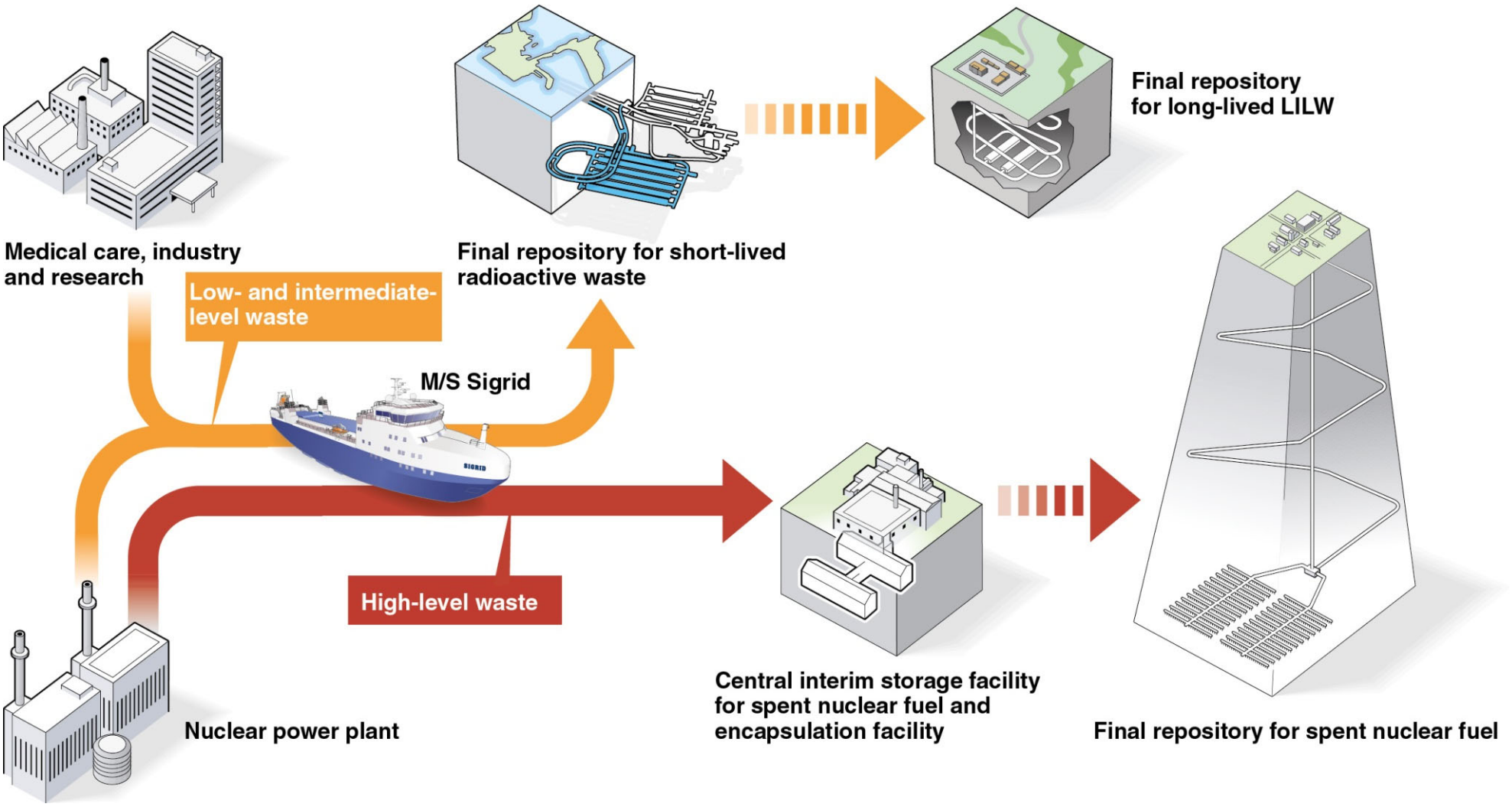
Outline

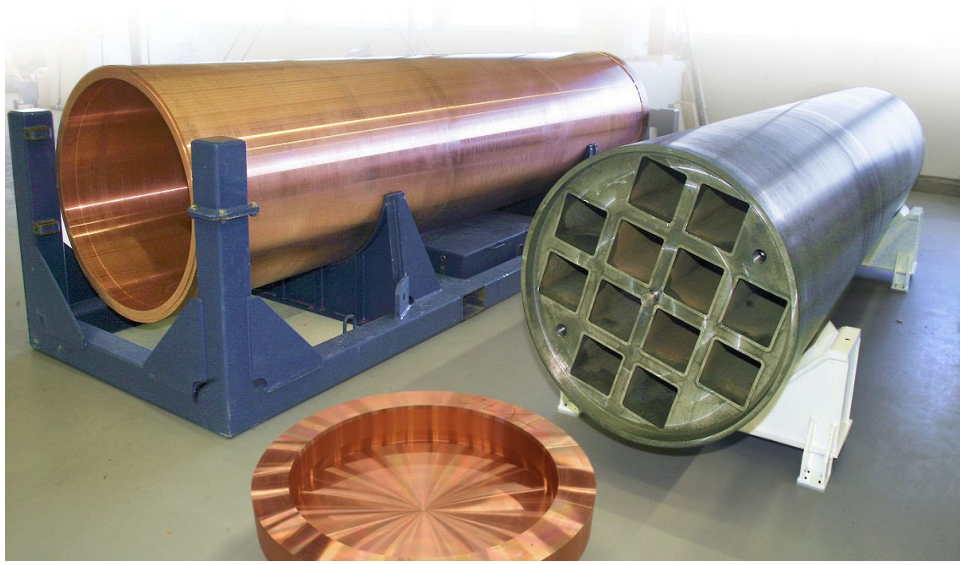
- SKB and scope of validation
- Background
- Methodology
- Results
- Conclusion

The Swedish system for Spent Nuclear Fuel and Waste



Scope of validation

- Several different storage canisters
  - Normal BWR
  - Compact BWR and PWR
  - Transfer BWR and PWR
  - Disposal BWR and PWR (Copper)
- Several different fueltypes
  - 15x15 PWR
  - 17x17 PWR
  - 8x8 BWR
  - 10x10 BWR
  - 4x(5x5) BWR
- Several different nuclear designs
  - Enrichment between 0.7-5 %
  - Gd-content between 4x1.5% to 14x5.5%.



Background - 1

- In 2011 SKB applied for a permit to build a final repository for spent fuel in Forsmark, and a Encapsulation Plant in Oskarshamn. This application contained among many reports also a critical safety analysis.
- 2013 the Swedish Radiation Safety Authority (SSM) made several critical remarks on this report. One of them concerned the methodology to choose experiments for the validation suite.
- During 2014 SKB did a validation of Scale-6.1 with cross-section library ENDF/B-VII.0 (238 group) using Tsunami to chose experiments who had a neutron characteristic similar to our safety cases. (This was presented in the ANS meeting in Wilmington.)

Background – 2

- Based on tis validation SKB complemented the application with a new criticality safety analysis.
- In the review of this SSM remarked that there was quite a large change in the uncertainty for the Pu cross sections, between ENDFB/VII.0 and ENDFB/VII.1. This will impact the Tsunami ck-value, and hence the choice of expriment for the validation suite.
- We answered, and promised to investigate this further in future validation.
- This year (2018) the validation was updated using Scale 6.2.2 with the cross-section library ENDF/B-VII.I (252 group).

Methodology base

- Following the ANS/ANSI standards 8.24 and 8.27.
- One validation for fresh fuel and one for depleted fuel.
- Credit of actinides and fission products, following the recomendations in NUREG-7901 and NRC ISG-8.
- BUC for PWR, Burnable absorber credit for BWR (peak reactivity).

Methodology for chosing experiment

- The tool Tsunami in the Scale code package was used to select experiments from the handbook of criticality experiment (IHECSBE). Using sensitivity files SKB evaluated more than 2000 experiments and the experiments that most resembled our safety cases were selected.
- The sensitivity coefficient, ck, from Tsunami was used to evaluate the similarity between the experiments and the applications. A ck over 0.8 was considered as “good enough” similarity between the experiment and our evaluated safety cases.
- To make sure the validation covers all materials and required physical parameters of the target system gap analysis was made using engineering judgement by criticality safety experts judgement.

Results - Comparison 6.2 vs 6.1

- Using Tsunami in Scale 6.2 validation for fresh fuel the results were quite similar to the Scale 6.1 validation,
- but for the depleted fuel the ck values for the MOX experiments were much lower, creating a brand new ck ranking list,
- and for the copper canister no experiments at all qualified in as “good enough” (ck above 0.8) for high burnups.

Results - explanation

- The difference between ENDF/B-VII.0 and ENDF/B-VII.I considering covariance data for ^{239}Pu is quite large. ENDF/B-VII.0 had a much larger uncertainty for ^{239}Pu.
- So when the uncertainty decreases for ^{239}Pu it will have less impact on ck.
- In the old validation it was basically enough to have experiment with a good mixture of ^{235}U, ^{238}U and ^{239}Pu to receive a ”good enough” ck. This was not longer the case.
- For the copper canister, looking at the ck-contribution from different reactions, it could be concluded that to be able to reach a ck value of 0.8, experiments with both ^{239}Pu and a lot of ^{56}Fe were needed.

Results - Comparison

- The most important reactions to receive a high ck-value for the different target systems were:
- **Compact storage and transfer racks:**
- - u-238 n,gamma
- - u-235 nubar
- - u-238 n,n'
- - pu-239 fission

- **Copper disposal canister**
- - u-238 n,gamma
- - fe-56 n,gamma
- - u-235 nubar
- - pu-239 fission

Results – The way out

- We looked at the result from Tsunami for the contribution to ck of individual nuclear reactions,

Copper disposal canister, MWd/kgU	45	fe-56 n,gamma fe-56 n,gamma	0.1926
		u-238 n,gamma u-238 n,gamma	0.1625
		pu-239 fission pu-239 fission	0.1246
		u-235 nubar u-235 nubar	0.0922
		u-238 n,n' u-238 n,n'	0.0463
		pu-239 n,gamma pu-239 n,gamma	0.0449
		pu-241 fission pu-241 fission	0.0369
		fe-56 elastic fe-56 elastic	0.0368
		pu-239 fission pu-239 n,gamma	0.0327
		pu-239 n,gamma pu-239 fission	0.0327
		h-1 n,gamma h-1 n,gamma	0.0277
		pu-239 nubar pu-239 nubar	0.0207
		h-1 elastic h-1 elastic	0.0172
		u-238 nubar u-238 nubar	0.0171
		u-235 fission u-235 fission	0.0144
		u-235 n,gamma u-235 n,gamma	0.0141
		nd-143 n,gamma nd-143 n,gamma	0.0134

- and then we based the selection of experiments to thoose with similar sensitivity contributions to c(k)

Results

- We have a validation suite for the copper canister who are covering all the important nuclear reactions, (however not in the same experiment).

- We don’t covered the nd-143 n,gamma reaction. There is no benchmark experiment that cover this reaction among the available experiments.
- The validation suite for the copper disposal canister does not have any experiments with copper.

Final USL results

- The concluding USL results are summarized below:
- Scale 6.1 fresh fuel **0.99026**
- Scale 6.2 fresh fuel **0.98922**
- Scale 6.1 depleted fuel **0.98529**
- Scale 6.2 depleted fuel (Clab) **0.98680**
- Scale 6.2 depleted fuel (Canister) **0.98688**

Conclusions

- The first conclusion is that the Scale code system predicts the keff value well with good accuracy. Different versions of the code and the cross-section library, different choice of experiments from the handbook results in just a slight difference in the concluding USL-results.
- The second conclusion is that the uncertainty in the cross-section libraries and our methodology to use Tsunami as a tool for choosing experiments for the validation suite needs to mature. It does not build confidence in the methodology that a change in the covariance data between two versions results in a completely new set of experiments in the validation suite.
- With this in mind we're looking forward to the release of ENDF/B-VIII.