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IRSN
INSTITUT DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

INTERNATIONAL BENCHMARK COMPARISON FOR NUCLEAR DATA AND CODE VALIDATION : OUTLOOK AND STATUS

IRSN-AM13/ORNL-AM10/LLNL-AM5/LANL-AM5/Y-12-AM1

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LLNL : S. McKinley, D. Heinrichs and J. Glesmann
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NCSP Technical Program Review - December 3-5 2024

MEMBRE DE
ETSON

Outline

- Project overview
- Summary of k_{eff} and β_{eff} comparisons
- Shielding comparisons (2024 work)
- Conclusion and prospects

Project overview

- Principle: calculate quantities of interest using multiple Monte-Carlo codes and nuclear data libraries.

- Objectives :
  - Check validation data base input decks
  - Cross-validate Monte Carlo codes :
    - ➢ for the same models, all codes/methodologies shall provide the same results (± 3σ) ;

      (source of discrepancies: errors or differences in the reference model (e.g. revision), nuclear data processing, etc.).
  - Have feedback on nuclear data libraries: methodology for assessing library quality and validation.

- Framework :
  - k_{eff} comparisons (2018-2022)
  - β_{eff} comparisons (2023)
  - Shielding comparisons (2024)

Topic of the day

Summary of previous results

- k_{eff} comparisons (2018-2022)
  - Report published under number IRSN/2024-00060
  - key findings :
    - quite good agreement between codes,
    - several corrections of input decks,
    - interesting feedback on JEFF-3.3, ENDF/B-VII.1 and ENDF/B-VIII.0, especially for reflectors.

- β_{eff} comparisons (2023)
  - Report published under number IRSN/2024-00488
  - key findings :
    - Correction on FCA cases data
    - Good agreement between code predictions and reference experimental values, regardless of the nuclear data library used
    - Trend to underestimate for all codes → Doubt on robustness of ZPPR-21B benchmark.
    - <u>Code to code comparison</u>:
      - Some codes are more consistent between them (COG11.3 and MORET6 versus SCALE6.3 and MCNP6.2)
      - Significant experimental uncertainties → impossible to determine a calculation method that outperforms the others
    - Need for new benchmarks with better experimental uncertainties (few pcm)

Shielding comparisons

- Two objectives:
  - Cross-validation of 5 Monte Carlo codes;
  - Feedback on 3 nuclear data libraries : ENDF/B-VIII.0, ENDF/B-VII.1 and JEFF-3.3.

MC codes	SERPENT2.2.1	SCALE6.3	MCNP6.3	COG11.3	MERCURY	MCNP6.2
Nuclear Data Librarie(s)	ENDF/B-VIII.0 JEFF-3.3	ENDF/B-VIII.0 ENDF/B-VII.1	ENDF/B-VIII.0	ENDF/B-VIII.0	ENDF/B-VIII.0 ENDF/B-VII.1	ENDF/B-VII.1
Processing Tool	GAIA1 (based on NJOY2016.35)	AMPX	NJOY	PREPRO	?	NDEX (based on NJOY2012)

Shielding comparisons

- Selection criteria:
  - Pure neutron problem (γ or n,γ to be considered later) → to compare one domain at once
  - Well-known source
  - Simple geometry (at least not too complicated)
  - Fixed source problem → to avoid another source of difference possible
  - Experimental measurements with response function known or easily comparable
  - Transport problem with different ray-matter interactions if possible

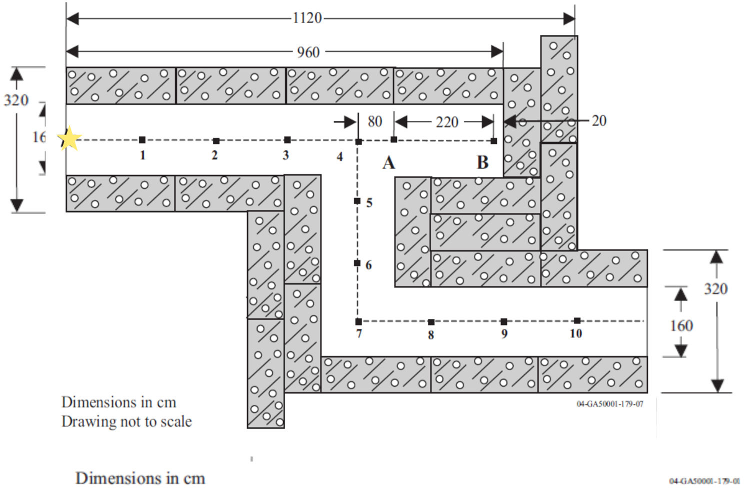
- Only one Benchmark identified, satisfying all criteria : → ALARM-CF-AIR-LAB-001 from ICSBEP

NEUTRON FIELDS IN THREE-SECTION CONCRETE LABYRINTH FROM CF-252 SOURCE

Shielding comparisons : presentation of benchmark

- 3d concrete maze

- 12 different configurations
  - 2 for the source:
    - A : Bare source
    - B: thermalised source (CH_2 encased)
  - Different covering on the corners
    - 1 : no covering
    - 2: CH_2 and Cd
    - 3: CH_2
    - 4: Borated concrete plates
    - 5: transversal CH_2
    - 6: no covering but a dead end at first leg of the maze



- Neutron flux measurements using Bonner spheres at up to 12 location per configuration
  - 7 different sizes of Bonner spheres for each location

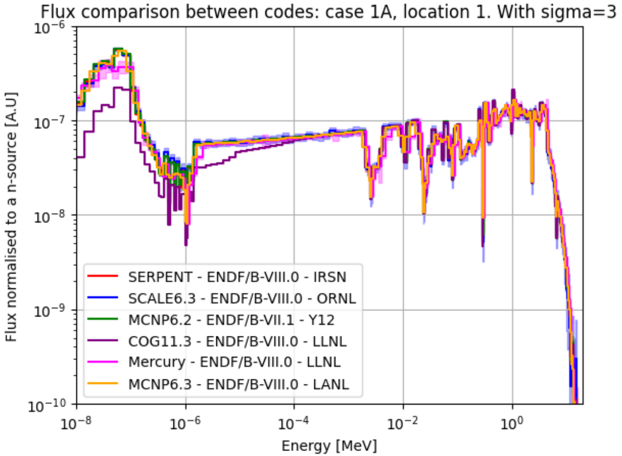
shielding comparisons : presentation of benchmark

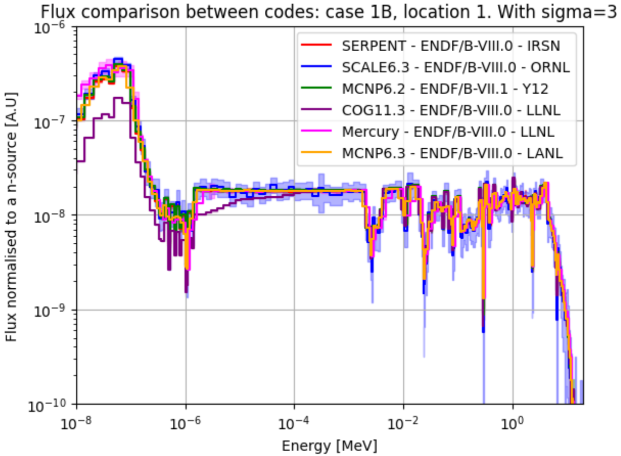
- 2 quantities to compare:
  - Flux at each position and for every configuration
    - Only code to code comparison
  - Response from Bonner sphere at each position and for every configuration
    - code to experiment comparison
    - code to code comparison

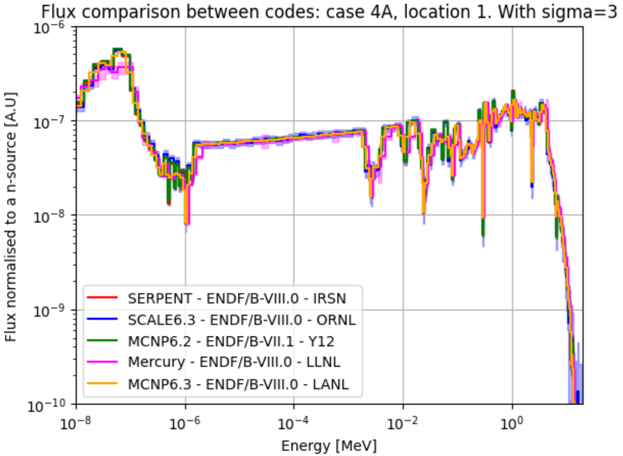
- Different methods to handle it:
  - 2-way approach: assessment of response function of detectors, then multiplied by flux to get response
  - Direct assessment of the detectors’ response
  - Semi-direct assessment of the detectors’ response in two times through « Source Write/Read » method

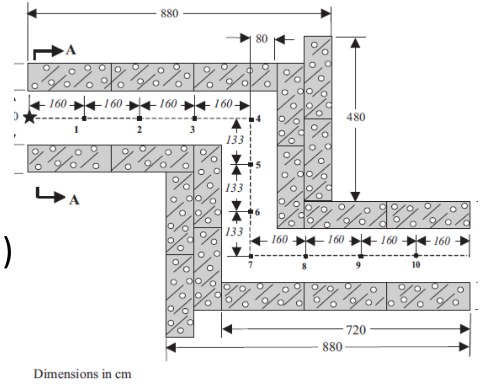
/	SERPENT2.2.1	SCALE6.3	MCNP6.3	COG11.3	Mercury	MCNP6.2
Method used	Semi-direct	2-way	2-way	-	2-way	Direct

Shielding comparisons – Flux comparisons



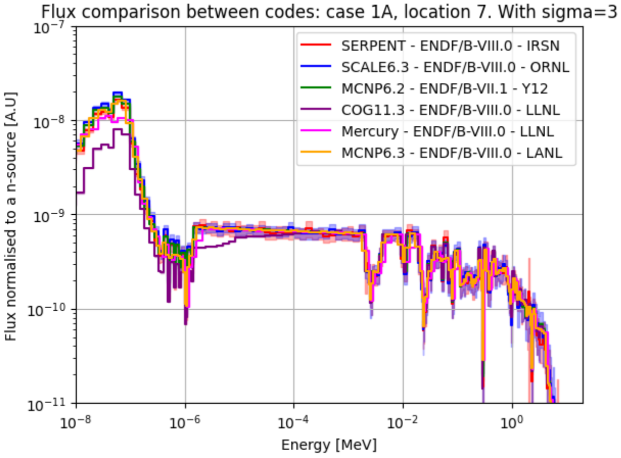


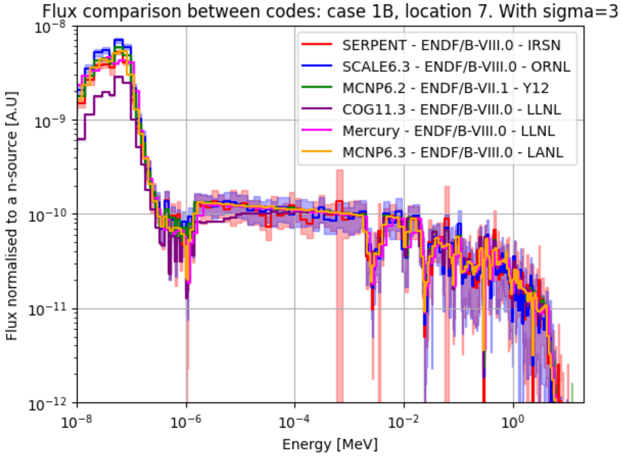


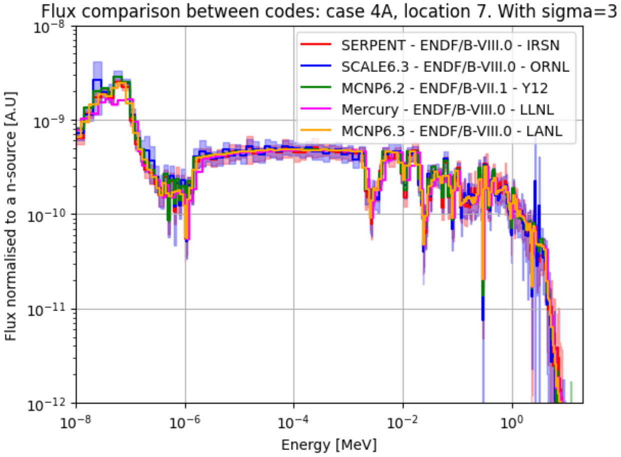


- Location 1 (very beginning of the maze) ➔ very few interactions
- Codes consistent between them, with small discrepancies
  - Except for COG's results. ➔ under investigation (probably due to source description)

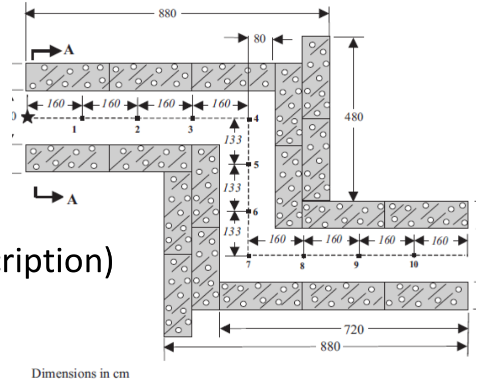
shielding comparisons – Flux comparison







- At location 7: 2nd leg of the maze ➔ after all variations
- Codes consistent between them, with small discrepancies (mostly under 1σ unc.)
  - Except for COG's results. ➔ under investigation (probably on source description)
- For some codes, uncertainties become important for distant locations



shielding comparisons – Flux comparison – preliminary conclusion

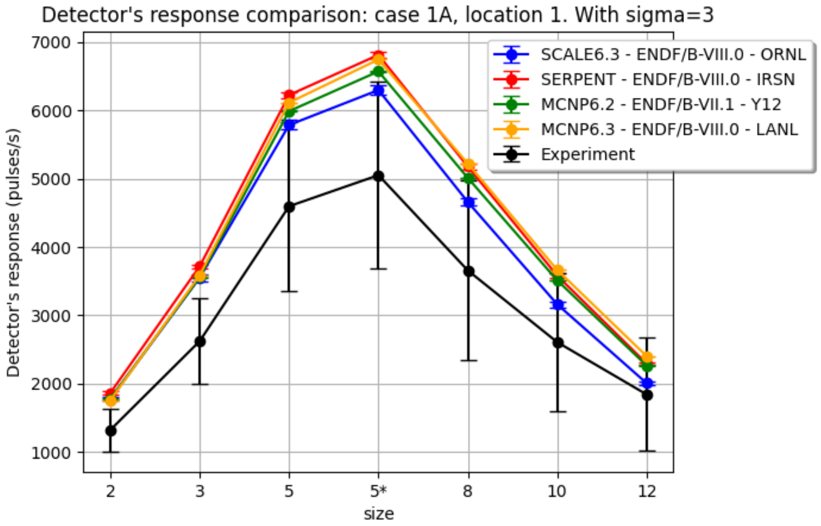
- Agreement between all codes above 10 keV.

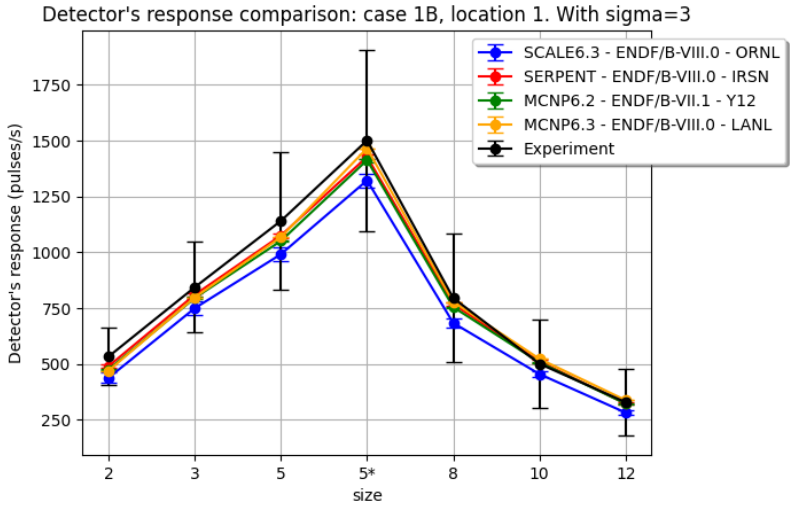
- Below 10 keV, discrepancies between COG's results to the others
  - Probably due to source description

- Most of the time, discrepancies rely within 3-σ experimental uncertainty range.

- At first glance:
  - no identification of possible misbehavior of codes
  - no grouping of codes

shielding comparisons – Detectors response

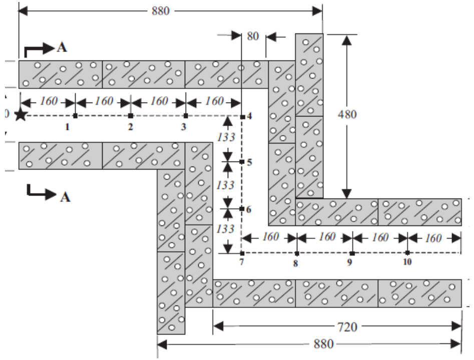




- Location 1 (very beginning of the maze) ➔ very few interactions

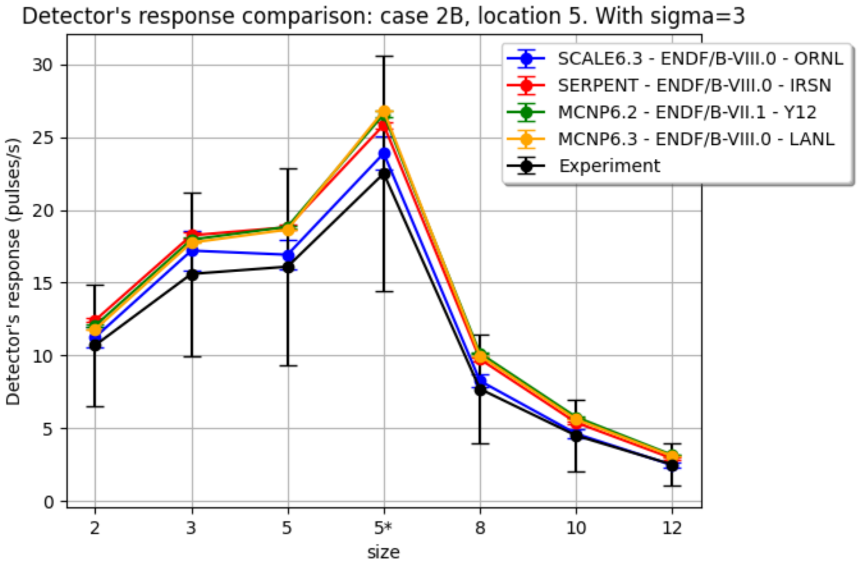
- Codes consistent between them, with small discrepancies

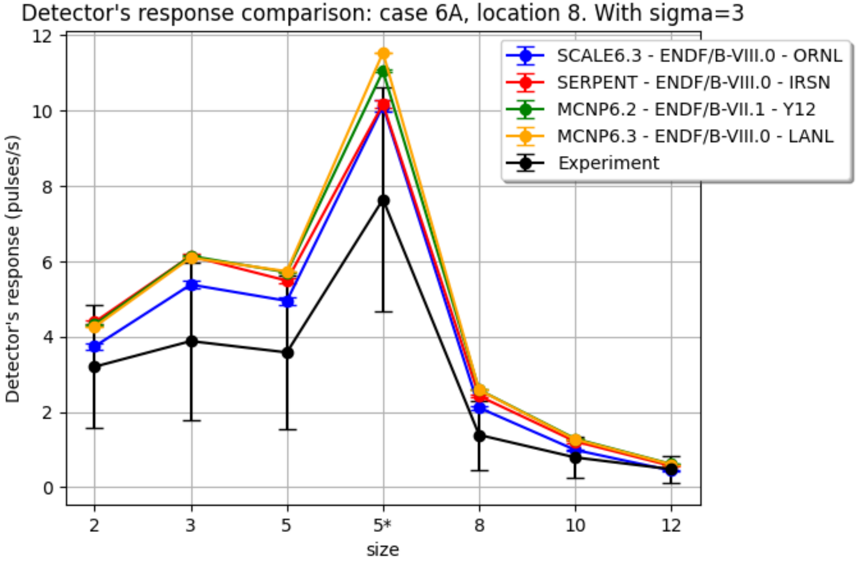
- Bare source description seems to have been inadequately described in Benchmark
  - discrepancies between experiment and all codes, for all *A cases
  - Same discrepancies for other locations



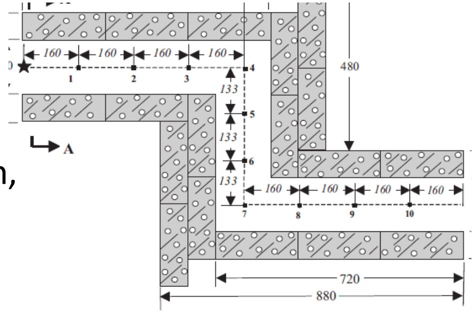
Dimensions in cm

shielding comparisons – Detectors response

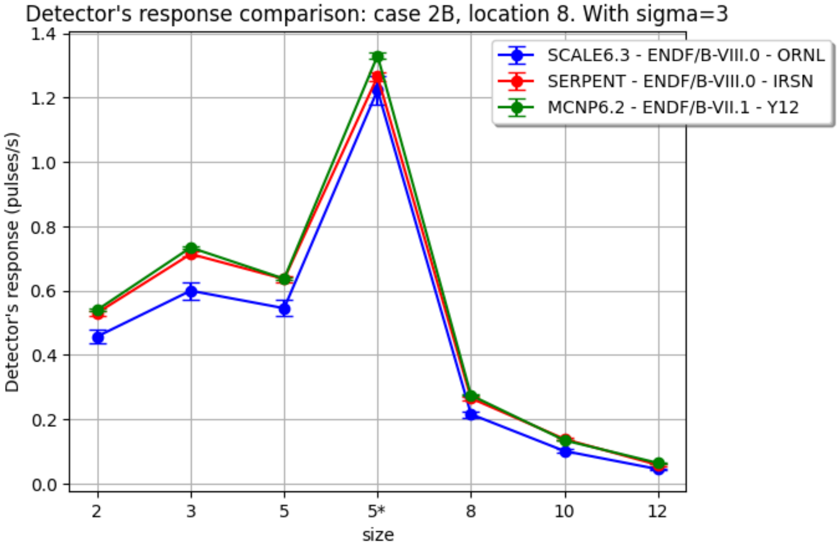


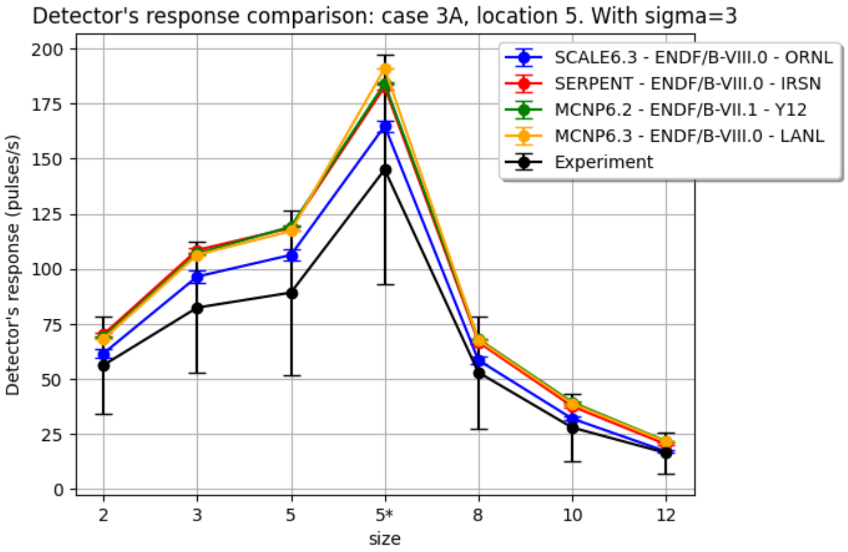


- For all *B cases (thermalised source of ^{252}Cf)
- Codes consistent with experiments (*i.e. discrepancies < 3sigma*$_{exp}$) and between them, whatever the location is

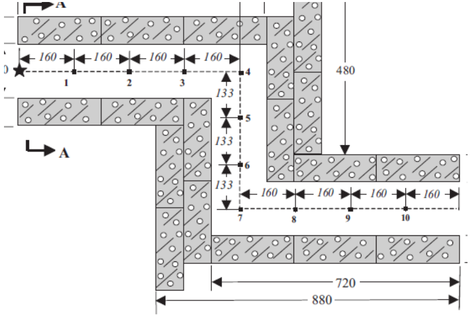


shielding comparisons – Detectors response

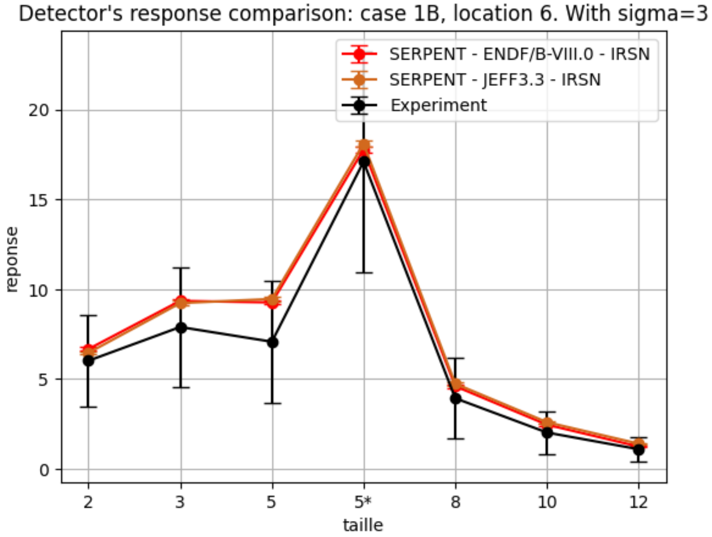


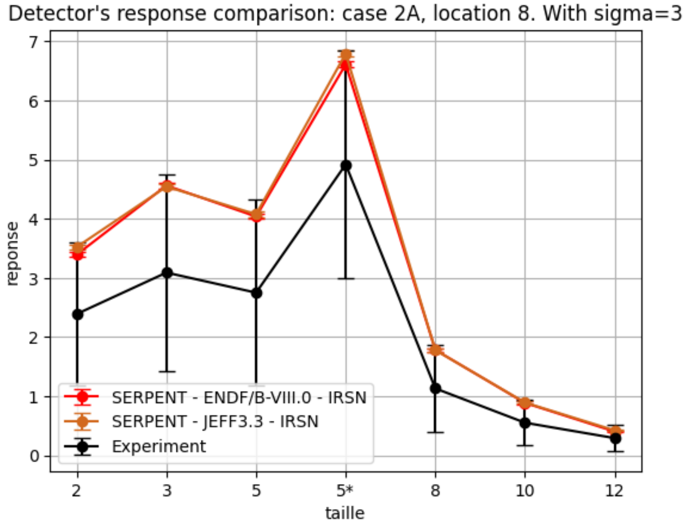


- In most configurations and locations, MCNP6.2, MCNP6.3 and SERPENT align more closely with each other than with SCALE.

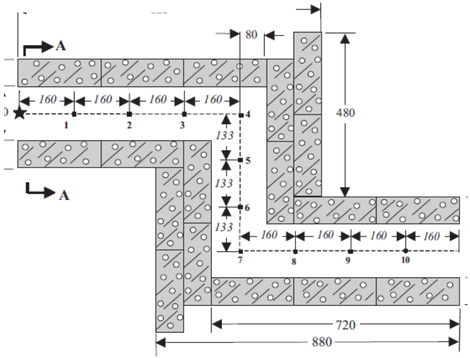


shielding comparisons – Detectors response





- Very few dicrepancies between JEFF3.3 and EDNDF/B-VIII.0 results with SERPENT
- Large experimental uncertainties ➔ Impossible to say which library performs the best



Conclusion

- Key findings on shielding :
  - Disagreement between all codes and experiments for all *A cases
    - Strong assumption on bad source description from Benchmark
  - Overall good consistency between code predictions
  - important experimental uncertainties do not allow to identify problems in ND libraries when comparing ENDF/B-VIII.0 and JEFF3.3 (SERPENT's results) and ENDF/B-VIII.0 and ENDF/B-VII.1 (MCNP's respective results from LANL and from Y12; and MERCURY's results).

- Report on shielding intercomparison is currently being written at IRSN (draft version expected in April 2025).

- Intercomparison exercises are a very efficient way to improve the reliability of calculation database and provide interesting feedbacks on codes, processing tools and nuclear data libraries.

Prospects

- Planned : report on shielding calculations in Q2 2025.

- New task for FY2025 : intercomparison exercise on nuclear data processing
  - Feedback on processing tools, options and methods.
    - Modeling of **simple cases** to avoid compensation effects ;
    - Use of the same nuclear data evaluation and Monte-Carlo code (and the same input file).

- Acknowledgment
  - IRSN thanks the NCSP for supporting this action on analytical methods and all the partners for this exercise.

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