IER-161, BeRP Ball Reflected by Nickel Benchmark Evaluation

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Subcritical Neutron Noise Measurements

An appropriate tool to improve criticality safety assessments ...

- Subcritical neutron noise measurement techniques can infer the multiplication and the reactivity of a nuclear assembly
- Easy way to provide a continuous monitoring during operations
- Validation of the computational schemes used in criticality safety assessment
  - Nuclear data
  - Codes and Methods

... Need for new subcritical benchmarks in the ICSBEP Database

Primary Objectives and Status

Provide a benchmark evaluation based on a set of subcritical experiments involving the Berp ball reflected by nickel shells

- Reactivity range: from $k_{eff} = 0.79$ to $k_{eff} = 0.92$
- 7 configurations: from the bare Berp to the 3” reflected case
- Experiments performed in September 2012 at NCERC

Efforts are provided to improve the restitution of MCNP microscopically -> Need for benchmarked experiments to support this work

- Necessity to go beyond k_{eff}
- Benchmark released in the ICSBEP handbook (September 2014) under the reference: **FUND-NCERC-PU-HE3-MULT-001**
- MCNP5/MCNP6 inputs available and ready to use

The Berp Ball: Overview

- α-phase plutonium sphere (93.7 wt.% of Pu 239)
- 4.5 kg, 3.0” diameter
- Encapsulated in a SS 304 cladding
- Machined in 1980

- Previous experiments:
  - Be reflected critical experiment (PU-MET-FAST-038)
  - HEU reflected "Rocky Flats Shells" critical experiment (MIX-MET-FAST-013)
  - CSDNA subcritical noise measurements with polyethylene reflection (SUB-PU-MET-FAST-001) and nickel reflection

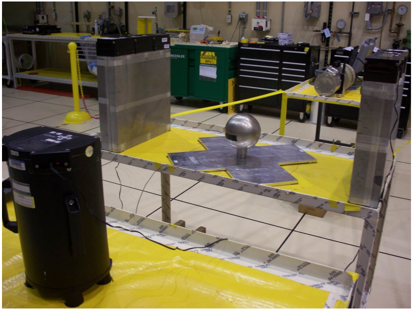
Nickel Shells

- 6 layers, each being 0.5” thick → maximum thickness: 3.0”
- Each layer is composed of 2 combined shells

Experimental Technique

Experimental configuration and instrumentation

- Two NPODs, aka *multiplicity counters*, 15 He3 tubes inside a polyethylene body which provide list-mode data
- Construction of the Feynman histograms to deduce the asymptotic counting rates R_1, R_2, (R_3 ...)
  - R_1: singles asymptotic counting rate (related to $\overline{\nu}$)
  - R_2: doubles asymptotic counting rate (related to $\overline{\nu(\nu-1)}$)
- 1 SNAP, aka *gross neutron counter*
- 1 HPGE, gamma detector



Benchmarked Quantities

- Must be deduced from well-known and fieldproven techniques
- Fundamental quantities having nevertheless a practical meaning
- Accessible and reliable uncertainty determination
- Must enable the discrimination without any ambiguity of each studied configuration

Selected quantities

- Directly deduced from the Feynman histogram:
  - R_1: singles asymptotic counting rate
  - R_2: doubles asymptotic counting rate
- M: neutron multiplication

The Neutron Multiplication

- Many kinds of neutron multiplications: total M_t and leakage M_l multiplications are mostly used
- Problem: both are difficult to benchmark
  - Effects coming from the variations of the spatial distribution of the importance function
  - Presence of a (α, n) neutron source

Use of the Hage-Cifarelli technique to get an **approximated leakage multiplication** $\widetilde{M_l}$

- Neglecting the (α, n) source strength in front of the spontaneous fissions source
- 3 equations $R_i = f(M_l, \epsilon, F_s, p(\nu))$
- Solve for M_l, ϵ and F_s

Codes and Methods

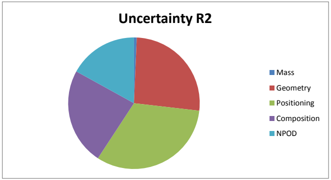
Steps	Experiment	Biases & Uncertainties	Simulation
Source setting	Berp Ball	Nuclear data & Sources4C	Sp. fission & (α, n) source strength SOURCEX routine / FMULT card
Transport	Nature	Model, MCNP & Nuclear data	Monte Carlo transport in MCNP
List mode data acquisition	2 NPODs	NPOD Model	TALLYX routine / PTRAC $\rightarrow$ detection events in He3 tubes
Solving Hage Cifarelli equations	ϵ deduced from calibration experiments $\rightarrow (M_l, F_s)$	Methodological bias (calibration)	F_s known (input parameter) $\rightarrow (M_l, \epsilon)$

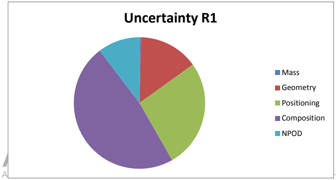
Sensitivity/Uncertainty Study - Experimental Data

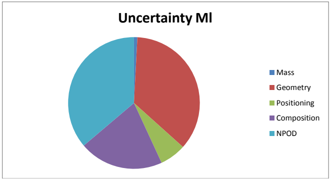
Illustration on the 3.0” thick reflected case

44 independent uncertainties on experimental data divided in 4 broad categories

	R_1	R_2	M_l
Combined uncertainties	2.19 %	3.49 %	0.76 %







Models for the Berp Ball Assembly

Detailed model

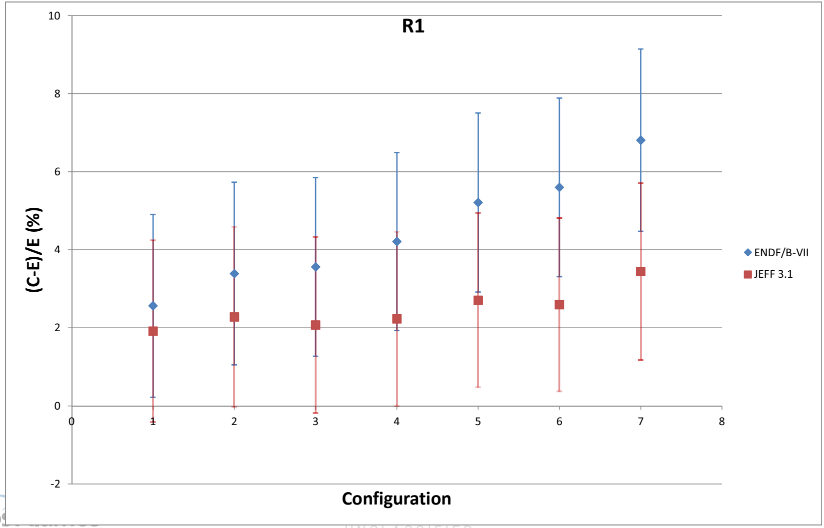
- As close as possible to engineering specifications
- Impurities are modeled
- Expensive simulations (3.0-in / 2 hours / 128 proc. / MCNP5-Moonlight)

Simplified model

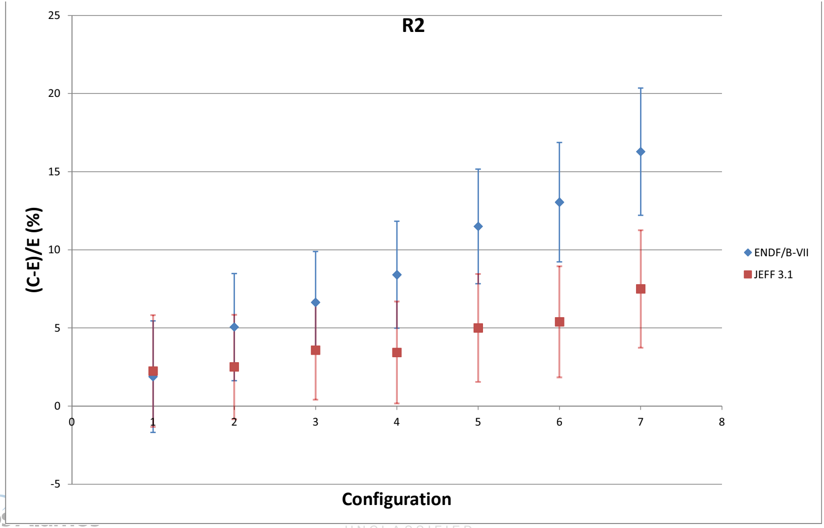
- Simplified geometry
  - BERP ball
  - Detectors
- No impurities
- Concrete walls removed
- Large improvements in computational time (3.0-in / 15 min. / 128 proc. / MCNP5-Moonlight)

Global/individual simplification biases have been estimated and are included in the evaluation

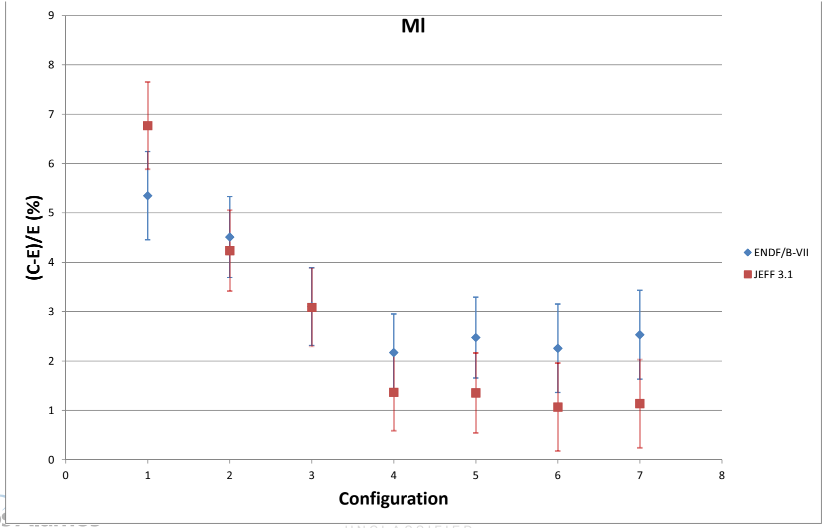
Comparison Experiment-Simulation on R_1



Comparison Experiment-Simulation on $\mathcal{R}_2$



Comparison Experiment-Simulation on M_l



Conclusion & Future Work

- Criteria are met to make this benchmark acceptable, for the three benchmarked quantities
- Results can still be improved:
  - Methodological biases induced by calibration experiments
- Preliminary results for the W benchmark are encouraging: submission next year
- Good starting point to go beyond: inference model benchmark
- Study of the response given by the Gamma detector (gamma coincidences)

Acknowledgments

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