Summary report of the WPEC sub-group-22 « nuclear data for improved LEU-LWR reactivity prediction »

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Purpose of the working group

- Despite improvements in nuclear data evaluation (recent release of ENDFB/VI-8 – JEFF3.0 – JENDL3.3) significant underestimation of thermal LEU-LWR k_{eff} is observed
- Can we find « short term » solutions to fix the problem ?
- Possible sources of the calculation-experiment discrepancy
  - Evaluated nuclear data (exp. data, nuclear data model and code)
  - Nuclear data processing and Neutron transport code
  - Integral Experimental technique

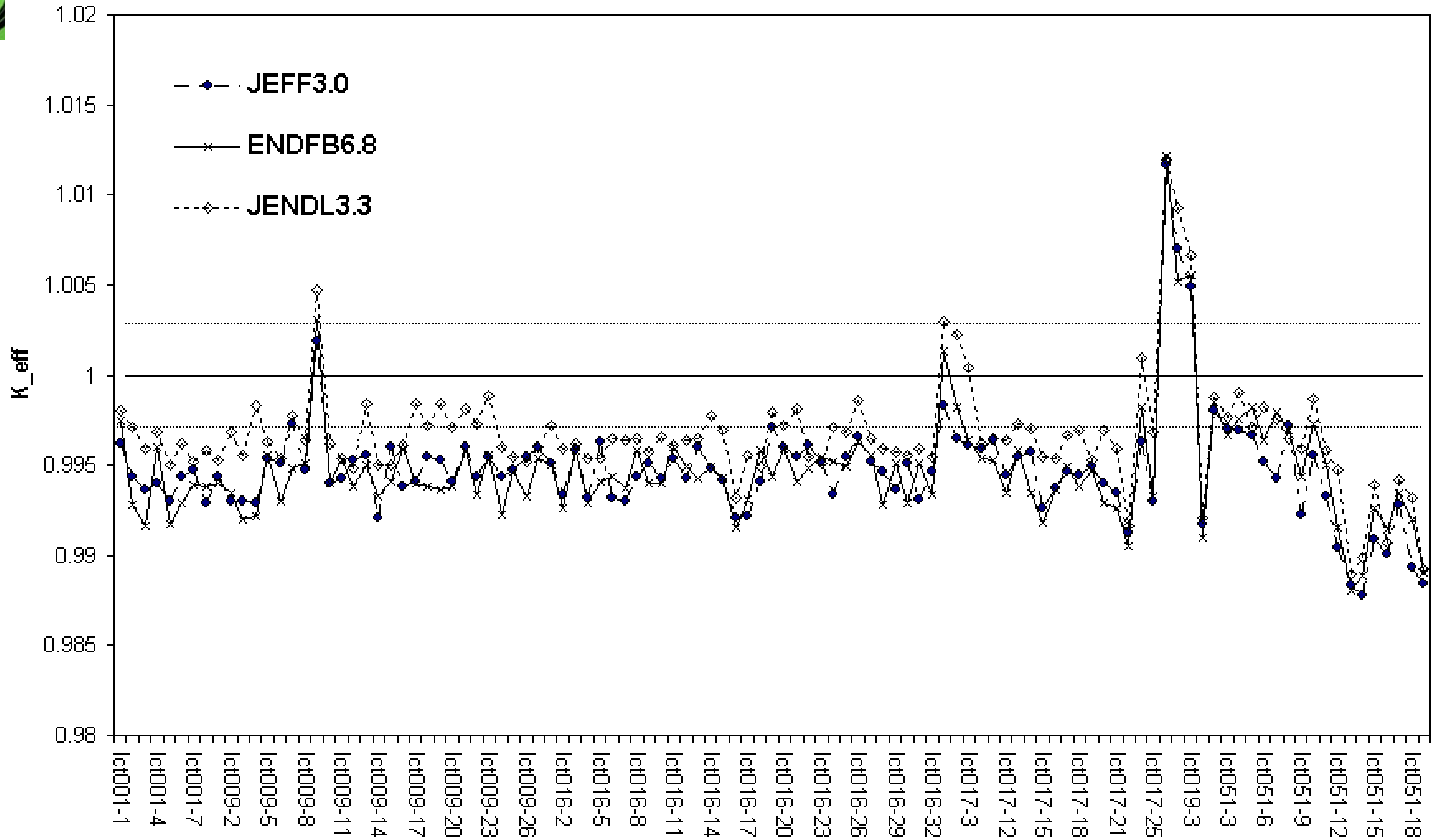
Subgroup-22 focused on evaluated nuclear data
U235 – <u>U238 </u>– H2O – O16

Recent analysis of k_eff calculations

- Skip Kahler (RCP code) (November CSEWG 2002)
- Jim Weinman (RACER Code) (November CSEWG 2002)
- Dave Hanlon Christopher Dean (MONK Code) (JEFF meeting 2003)
- Steven Van Der Marck Alfred Hogenbirk (MCNP code) (JEFF Meeting 2003)
  - Previous studies led to the same conclusions

Use of Continuous Energy (or hyperfine group) Monte Carlo
comparison of codes in progress

Similar trends to keff underestimation with
ENDFB/VI-8 – JEFF3.0 –JENDL3.3

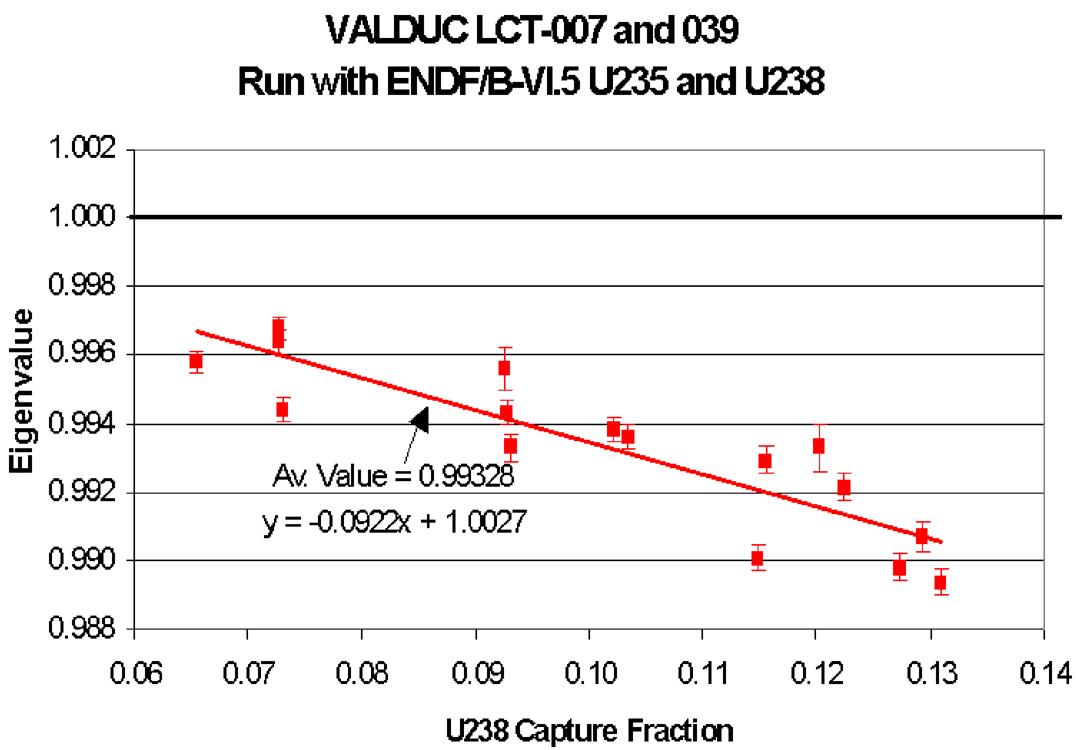


Steven van der Marck and Alfred Hogenbirk
JEFF Meeting April 2003 (MCNP4C)

reactivity bias trends (1)

- U238 capture fraction (Jim Weinman CSEWG 2003)
- Epithermal fission fraction (ATTF) (Skip Kahler CSEWG 2003)
- U8 and U5 capture and fission, (David Hanlon - Christopher Dean JEFF Meeting 2003)

Jim Weinman
CSEWG 2002



Status of U235 cross-section impacting LEU-LWR

- In the resolved range, U235 evaluation from ORNL (adopted in ENDFB/VI.8 JEFF3.0 JENDL3.3) extensively tested (see WPEC/Sub-group-18 report by Cecil Lubitz)
- Improvement of prediction for highly enriched systems, U236 build-up in reactor with U235 ORNL.
- revision of U235 neutron fission multiplicity, fission spectrum and U235 standards could have a significant impact on thermal uranium benchmark.
- U235 urr and fast range data are not sensitive data for LEU-LWR (not true for U238) but new evaluations need to be tested.

Integral trends on U238 capture

- The history of U238 capture is long : from the *1975 U8 capture conference in Brookhaven* to *1991 summary report of U238 task force,* extensive work to remove longstanding integral-differential discrepancies

Does U238 still overabsorb in reactor calculations ?

- **Subgroup is investigating C/E values of :**
  - « old » measurements of effective U8 resonance integral
  - Integral measurements of U238 capture rate (spectral indices, conversion ratios)
  - Pu239 formation in reactor

Analyses of Hellstrand correlations

- U238 effective (shielded) resonance integral measurements compiled by E. Hellstrand (*1966 San Diego conference*)

  ⇒ compilation of 4 measurements

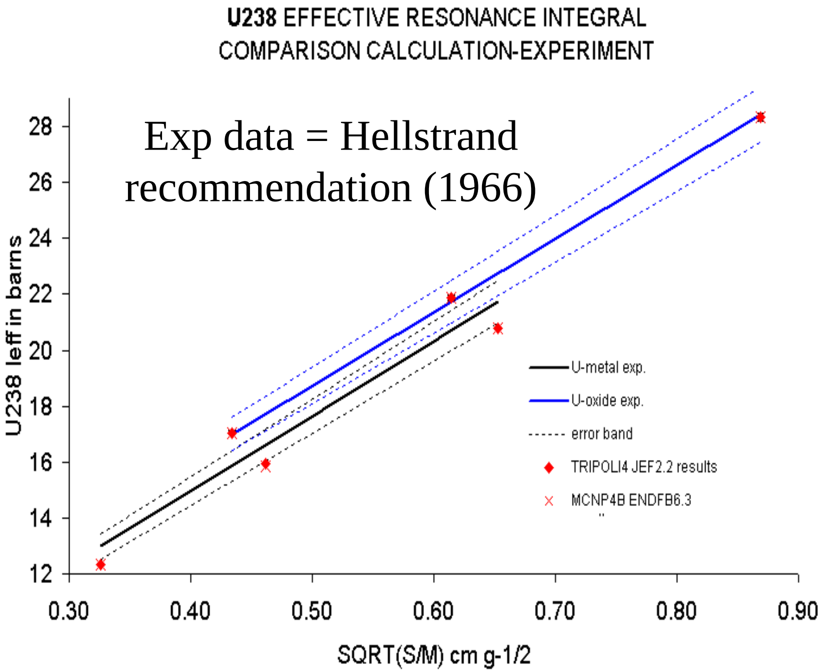
  ⇒ recommendations for U-metal and UO2 : I = a * sqrt(S/M) + b

- According to Hellstrand :

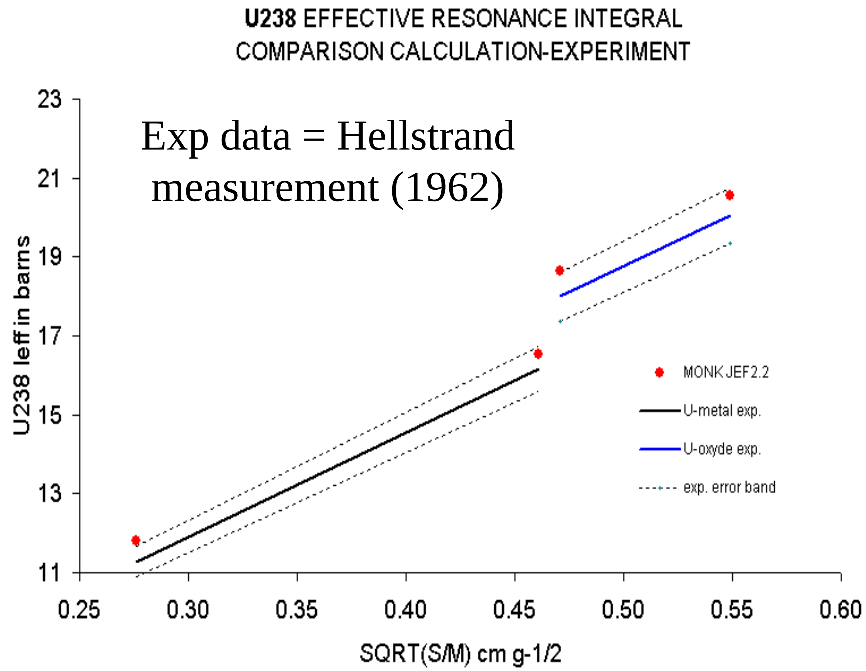
  « *limits of error below 3.5% could scarcely be obtained* »

- 2 different studies with MC codes :
  - Set-up of a simplified benchmark (*A. Courcelle et al. H. C. Huria et al.*) and comparison with Hellstrand recommendations (1966)
  - Detailed modelling of one particular experiment : Hellstrand et al. In 1962 (*David Hanlon and Christopher Dean*)

A. Courcelle H.C. Huria et al.



David Hanlon Christopher Dean



- Hellstrand et al. measurement (1962) different from Hellstrand recommendation (1966) based on 4 different experiments
- Calculations within the experimental error bands (±3.5%)
- Given the large exp. Unc., insufficient evidence to indicate a problem with U238 capture

U238 Spectral indices

- EOLE (Physor 2002)

exp.	Meas.	C/E
– Mistral 1	C8/F	+2.2% ± 2.0%
– Mistral 2	C8/F	+2.3% ± 2.0%
– Erasme-S	C*=C8/F5	+1.6% ± 2.3%
– Erasme-R	C*=C8/F5	-0.2% ± 2.2%

- IPEN/MB01 (Physor 2002)

ρ28	+2.3% ± 0.9%
C*=C8/F5	+2.4% ± 1.2%
C8/F	+0.9% ± 1.1%
(C8/F)epi	-2.7% ± 1.0%

- Calculated U238 capture rate in reactor <u>within exp. error band</u>
- Pu239 build-up overestimated by 1% in French PIE (JEFF Meeting 2002)
- Slight reduction of U8 (n,γ) compatible with these results.

- Recommendation : Analysis of U238 capture ratios (CSEWG benchmarks, TRX, MIT DIMPLE..) is strongly needed. SG22 is looking for volounteers !

Analysis of the present U238 evaluations (thermal – resolved range)

- Present U238 resonance parameters (up to 10 keV) from Mick Moxon et al. (U238 task force extensive work) with REFIT code

Improvements ?

- Thermal capture value
- Solid state effect (first 3 resonances)
- New evaluation (ORNL) with SAMMY
- Measurements
- Other effects (multiple scattering in capture exp., Reich-Moore approx, direct capture)

U238 Thermal capture value

- JEFF/ENDFB/JENDL value : 2.719 b
- CSEWG recommendations (based on GMA 1985 adjustment) : 2.708 b
- Mughabghab 2003 : 2.680 +/- 0.019 b (Poenitz et al. 1981 meas.)
- Latest measurements : 2.750 +/- 0.055 b (F. De corte et al. 1988)
  - Only 4 measurements since 1969 that disagree (from 2.68 to 2.77 b) !
  - Significant correction of published values (renormalisation, experimental corrections)
  - Work in progress to provide a recommended value

Need for accurate U238 thermal capture measurements

LEU-LWR multiplication factor is not very sensitive to U238 σ_0
but 1% accuracy is required by reactor physicists
(1% modification = about 50 pcm max)

Analysis of the present U238 evaluations Solid state effect

- Resonance parameters set derived with Free gas Model (adjusted effective temperature for solid state effect).

Significant bias on resonance parameters ?

- Study by Dimitri NaberejneV et al. with DOPUSH code (Nucl. Sci. Eng. Eng. 131, 222-229 (1999) $\Rightarrow$ possible overestimation by 1% of shielded U238 capture resonance integral with u-metal samples

- Recent Implementation in REFIT and SAMMY (Nancy Larson 2002) of solid state model based on DOPUSH. Work in progress to test it

U238 resonance parameters adjustment

- Adjustment of resonance parameters proposed by C. Lubitz (2002) for sensitivity analyses :
  - Decrease by 1.35% of U238 s-waves average $\Gamma\gamma$: 22.96 $\rightarrow$ 22.65 meV deduced from Frohner unresolved range analysis. Γn slightly adjusted
  - Effective U238 capture resonance integral decreased by 0.7% (compatible with U238 reaction rate ratio meas. in reactor)
  - Improvement of thermal benchmarks reactivity prediction (effect from 50 to 200 pcm (Andrej TrkoV Jim Weinman).
  - Adjustment of the radiation widths is considered less desirable than an equivalent reduction in the neutron width
- Equivalent adjustment of gamma-n has been submitted to ueval (same resonance integral and thermal cross section).

U238 resonance parameter evaluation in progress at ORNL (CSEWG 2002)

- Analysis with SAMMY (Luiz Leal, Hervé Derrien et al. ORNL).
- Preliminary set of resonance parameters from thermal to 20 keV

- Extension of the resolved range up to 20 keV using J. Harvey transmission measurements (MITO 1988)
  – Average capture cross-section calculated with resonance parameters smaller than experimental values by 10 to 15% (4 keV – 20 keV)
  – This problem exists with the Moxon et al. evaluation
  – Missed p resonances or underestimation of Γn for p ?

Preliminary Integral tests will start soon

Role of U238 inelastic data in thermal benchmark eigenvalue calculation

- Significant effect on thermal benchmarks when only U238 (n,n') are changed A TrkoV (JEFF Meeting 2002), Jim Weinman (2002)
- New U238 (n,n') evaluations available (soon) : LANL, CEA, Maslov etc.
- Preliminary test with new U235-U238 « above urr » evaluation from LANL by Bob Mc Farlane (April 2003).

Assembly	Keff ENDFB/VI.5	Keff new evals
LCT001-1	0.9948	0.9992
LCT002-2	0.9925	0.9978
LCT002-4	0.9943	0.9991
BAPL-1	0.9965	0.9979

Significant increase of keff
Why ?
Solution ?

O16 (n, α)

- Large differences between evaluations ($\approx$ 50% in the range 3-6 MeV)
- Experimental database discrepant : O16 (n, α) deduced by reciprocity from C13(α,n) measurements
- **O16 (n, α) measurements** in the 3-6 MeV region would help
- Needs to evaluate the impact of O16 **(n, α)** changes on thermal benchmark.

Other candidates ?

ISOTOPE	NUCLEAR DATA	ENERGY RANGE
	Very sensitive	
U235	(n, γ) , (n,f), ν, fission spectrum	Thermal, resolved range
U238	(n, γ) , (n,n)	Thermal, resolved range (urr)
H1 – H2O	(n, γ) , (n,n) thermal data	Thermal
	Less sensitive but high level of uncertainty or discrepant evaluations	
U238	(n,n')	keV to MeV
O16	(n,α)	MeV

Conclusions and future work

- LEU-LWR keff is underestimated by c.e.m.c calculations with ENDFB/VI-8, JEFF3.0 and JENDL3.3)
- Overestimation of U238 (n,γ) is still not firmly demonstrated : futher work is needed (interpretation of integral capture measurements)
- New evaluations (U238 resolved range and U238 (n,n') fast range) are expected to improve the situation
- Influence of other nuclear data and revisions : Standards, U235 fission spectrum, O16 to be studied
- Any comments ? !Use ueval mailing list ! : ueval@nea.fr

    http://www.nea.fr/lists/ueval.html