Actinides, Covariances, Neutronics

Mark Chadwick, LANL

Nuclear Data: New ENDF/B-VII Library

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Nuclear data = Integration theme

Integrates NNSA, NE, Office of Science, …

Integrates experiment, theory, neutronics

Provides link to GNEP, AFC, GenIV simulations

Cross Section Evaluation Working Group

CSEWG is cooperative effort of the national laboratories, industry and universities in the United States and Canada, responsible for the production of the U.S. **E**valuated **N**uclear **D**ata **F**ile, ENDF.

Basic facts about CSEWG

- Established in 1966
- Currently ~ 60 scientists, vigorous and active collaboration
- 20 laboratories (LANL, BNL, ANL, LLNL, ORNL,…, Westinghouse, Bettis, …)
- National Nuclear Data Center coordinates, provides support, archives the library

Current funding of CSEWG, estimate

$ 1mil	DOE-SC, Office of Nuclear Physics, via US Nuclear Data Program, includes $200K allocated for AFC work in FY06
$ 7mil	DOE-NNSA (advanced simulation, criticality safety, nonproliferation), DOE-NE, also DOE naval reactor labs, NIST, industry, …
$ 1mil	International contribution (NEA Paris, IAEA Vienna, …)
$ 9 mil	

Evaluated Nuclear Data File, ENDF

Releases of ENDF library, historical perspective:

ENDF/B-I released	1968	-	CSEWG established in 1966
ENDF/B-II	1970	2y	
ENDF/B-III	1972	2y	
ENDF/B-IV	1974	2y	
ENDF/B-V	**1978**	**4y**	Early interest in covariances
ENDF/B-VI	**1990**	**12y**	Last update in 2001
ENDF/B-VII	**2006**	**16y**	40 years of CSEWG
ENDF/B-VIII	???	???	

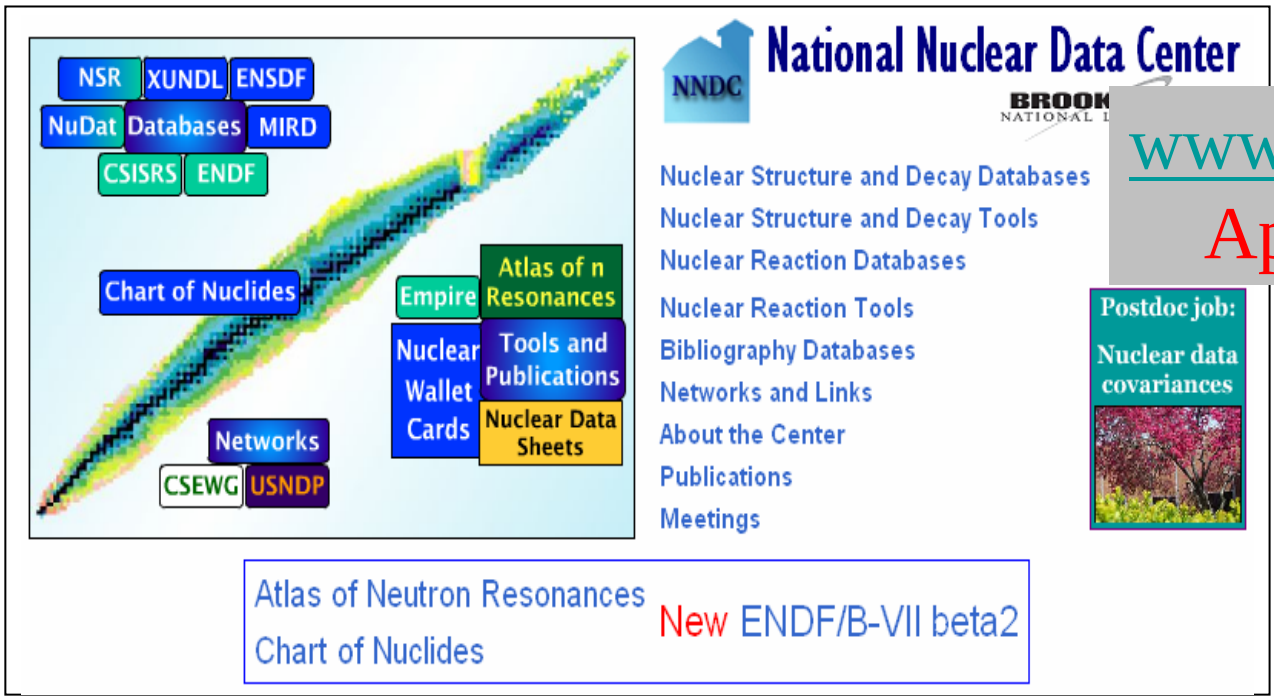
Development of the ENDF/B-VII library started modestly at the end of 2001.
No one assumed that there will be so much interest in its release in 2006.
ENDF data retrievals from the NNDC web service increased by **150%** in 2006.

CSEWG understands historical opportunity, and long-term impact of ENDF/B-VII.
CSEWG is highly motivated to produce the best library ever.

But: Limited funding for AFC applications → Many AFC needs not addressed.

ENDF/B-VII: Status of the library

- April 2006: Beta2 version released, followed by extensive testing and validation against integral experiments
- June 2006: CSEWG validation meeting, major improvement compared to ENDF/B-VI
- Sep. 2006: Beta3 release, followed by the final round of testing
- Nov. 2006: Official release of ENDF/B-VII.0



www.nndc.bnl.gov

April 25, 2006

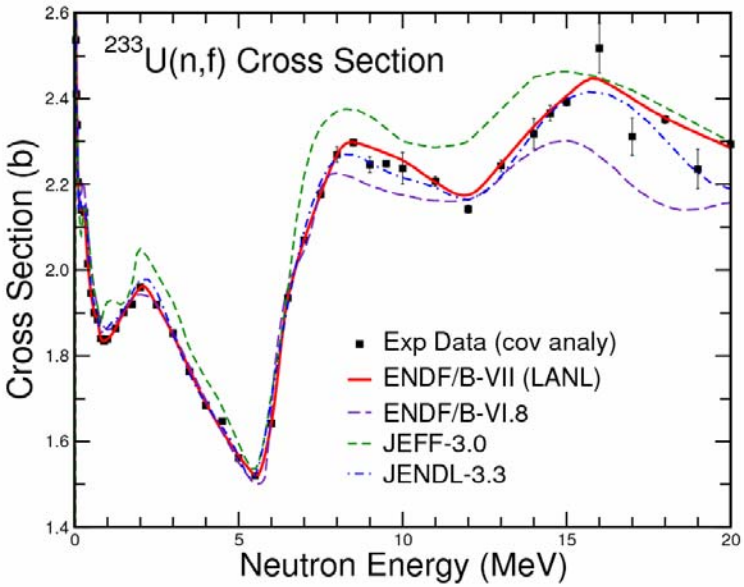
ENDF/B-VII: Contents of the library

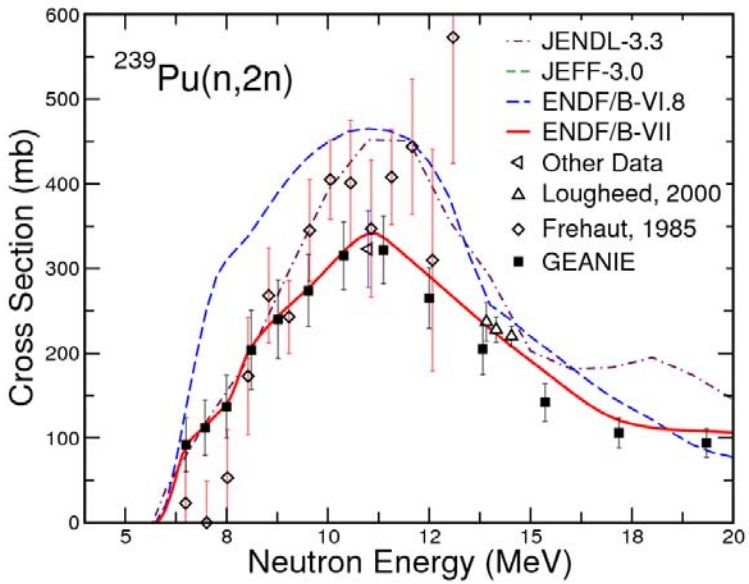
- General purpose library: Reactor design, advanced fuel cycles, waste transmutation, nonproliferation, national & homeland security, nuclear medicine, shielding, physics facility design, …
- Contents: 14 sublibraries (2 - new, 7 - many improvements, 5 – unchanged)

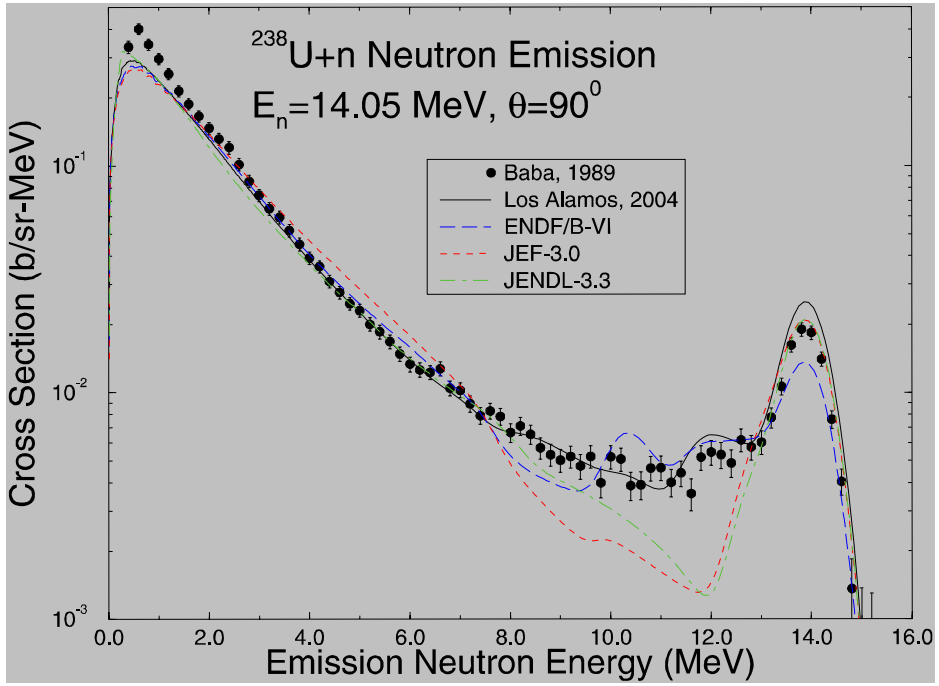
No.	Sublibrary	Materials in B-VII	Materials in B-VI	Comment
1	Photonuclear reactions	**163**	-	**New sublibrary**
2	Photo-atomic	**100**	100	Taken from VI.8
3	Radioactive decay	**3830**	979	**New evaluations**
4	Spontaneous fission yields	**9**	9	Taken from VI.8
5	Atomic relaxation	**100**	100	Taken from VI.8
6	**Neutron reactions**	**387**	**328**	**Many new evaluations**
7	Neutron fission yields	**31**	31	Taken from VI.8
8	Thermal neutron scattering	**20**	15	**Some new evaluations**
9	Standards	**8**	8	**New evaluations**
10	Electro-atomic	**100**	100	Taken from VI.8
11	Proton reactions	**48**	35	Some new evaluations
12	Deuteron reactions	**5**	2	Some new evaluations
13	Triton reactions	**3**	1	Some new evaluations
14	He-3 reactions	**2**	1	Some new evaluations
	Full library	**4812**	1709	

ENDF/B-VII: Neutron cross sections

Major improvements in actinides (LANL – fast neutrons, ORNL – resonances)



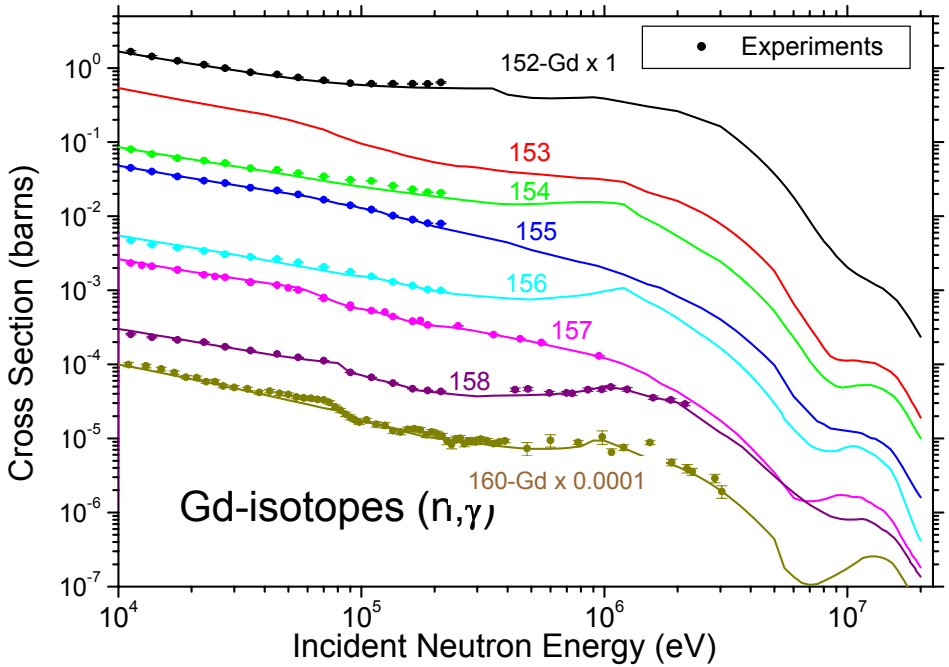


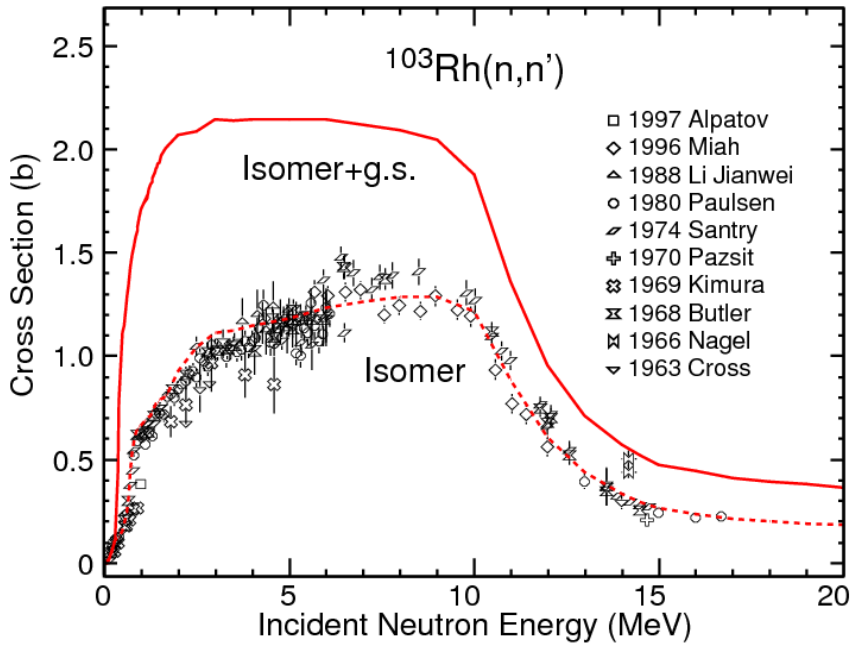


233U: Fission much improved
238U: Neutron spectrum much improved below elastic peak
239Pu: (n,2n) problem solved
Many other improvements, based on advanced modeling, …

ENDF/B-VII: Neutron cross sections

Major improvements in fission products (BNL, international)





Gd-isotopes: New evaluations for criticality safety applications, include covariances by BNL-LANL-ORNL.

70 materials (^{103}Rh, …): New evaluations, advanced modeling.

Other materials: Best non-US evaluations adopted.

ENDF/B-VII: From physics to applications

Old nuclear data dilemma

Too applied for basic nuclear science, too scientific for applied technology.

ENDF/B-VII is based on the best physics available, reflects low-energy nuclear physics in its entirety, relies on cutting edge experiments, incorporates the best nuclear reaction theory (R-matrix, quantum mechanical multi-step models, advanced fission, …).

ENDF/B-VII serves as an interface between basic nuclear physics science and applications, it should be viewed as an *example par excellence* of nuclear science output for nuclear technology.

ENDF/B-VII: Quality Assurance

Quality Assurance is of key importance in the library development, it is done by careful comparison of the library against hundreds of integral benchmark experiments (benchmarking and validation).

Criticality benchmarks:

- main fissionable isotope (low enriched U, high enriched U, …)
- physical form of fissile material (metal, compound, solution)
- neutron spectrum (thermal, intermediate, fast)

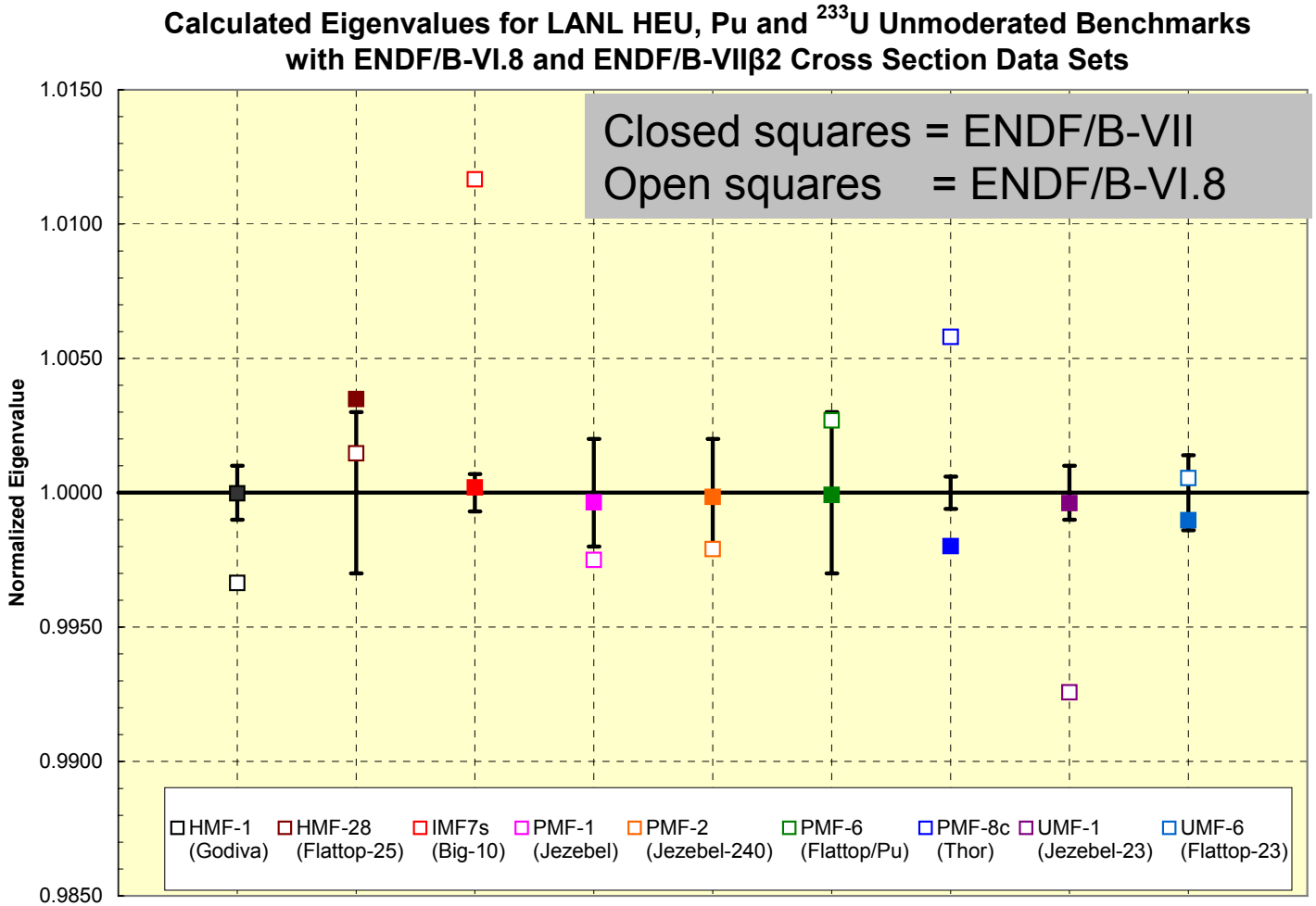
Validation is complex process, multiple pathways:

- US laboratories (LANL, KAPL, ANL, …, Westinghouse, Bettis,…)
- Europe (Petten, Cadarache), independent testing
- Use of independent tools (simulation codes MCNP – Los Alamos, TRIPOLI - Cadarache)

Preliminary results are encouraging, some statements:

"… major improvement…, significantly improved…, better than any previous data set…, mother of all nuclear data libraries…"

Quality Assurance: Example of Integral Validation



Fast U and Pu benchmarks:

Considerable improvement for all benchmarks.

ENDF/B-VII: Covariance data

Although very important for simulations, little covariance data are available

Covariances

Covariances are given in a form of matrix that include uncertainties (e.g., for cross section at a given incident neutron energy) and correlations (e.g, between cross sections at different neutron incident energies).

ENDF/B-VII should contain quality covariances only:

Covariances mostly produced in1970-ties for ENDF/B-V, little done since then.
CSEWG decided to keep quality data only.
About 90% of old covariances were removed, based on ANL analysis.
Only partial covariances for 13 materials migrated from B-VI to ENDF/B-VII.

New covariances for 9 materials:

152,153,154,155,156,157,158,160-Gd (produced by BNL-LANL-ORNL)

232-Th (IAEA international project, resonance region by ORNL)

ENDF/B-VII: Covariances only for 22 materials out of total 393 materials.

What should be done for AFC?

Cross sections needed for simulation of
- Nuclear criticality and transmutation rates (burnup)
- Radiation damage and heating

1. Precise cross sections for minor and major actinides

Minor actinides (Np, Am, Cm)
- Experiments with tiny radioactive targets, LANL; surrogate reactions, LLNL
- Theory can be used to predict unknown fission and capture
- Integral validation provides very accurate quality check

Major actinides
- ^{239}Pu, ^{235,238}U have high impact on AFC because of their abundance
- Significant uncertainties (> 10%) in fast neutron region for capture

2. Covariance data
- There is huge demand for covariances from many applications
- AFC needs include major and minor actinides, structural materials, coolants, …

More discussion on actinides and covariances – Mark Chadwick, LANL