LAUR-10-02501

Nuclear Data Evaluation Upgrades for ENDF/B-VII.1

Mark Chadwick, G. Hale,
P.G. Young, T. Kawano, P. Talou, S. Kahler, S. Holloway

June 22, 2010

Overview

- Status of work at LANL for ENDF/B-VII.1
- Observations from ND2010
- Action items in RED (especially new ones to add to our list).

What was Good About ENDF/B-VII.0

- Integrated munch information from nuclear theory and modeling, experimental measurements (fundamental data, and integral)
- Broad contribution from teams at many labs
- International engagement (e.g. Standards; Photonuclear; Validation testing)
- Much validation testing before release, leading to rapid adoption by users
    - LEU Solution criticals much better modeled
    - Fast and reflected fast criticals modeled well
    - …

<u>Some metrics. ENDF/B-VII.0 paper:</u>
Cited: 800 times (Google scholar)
Properly cited: 217 times
Google-hits: 167000
(for comparison, MCNP =118k)

Deficiencies in ENDF/B-VII.0

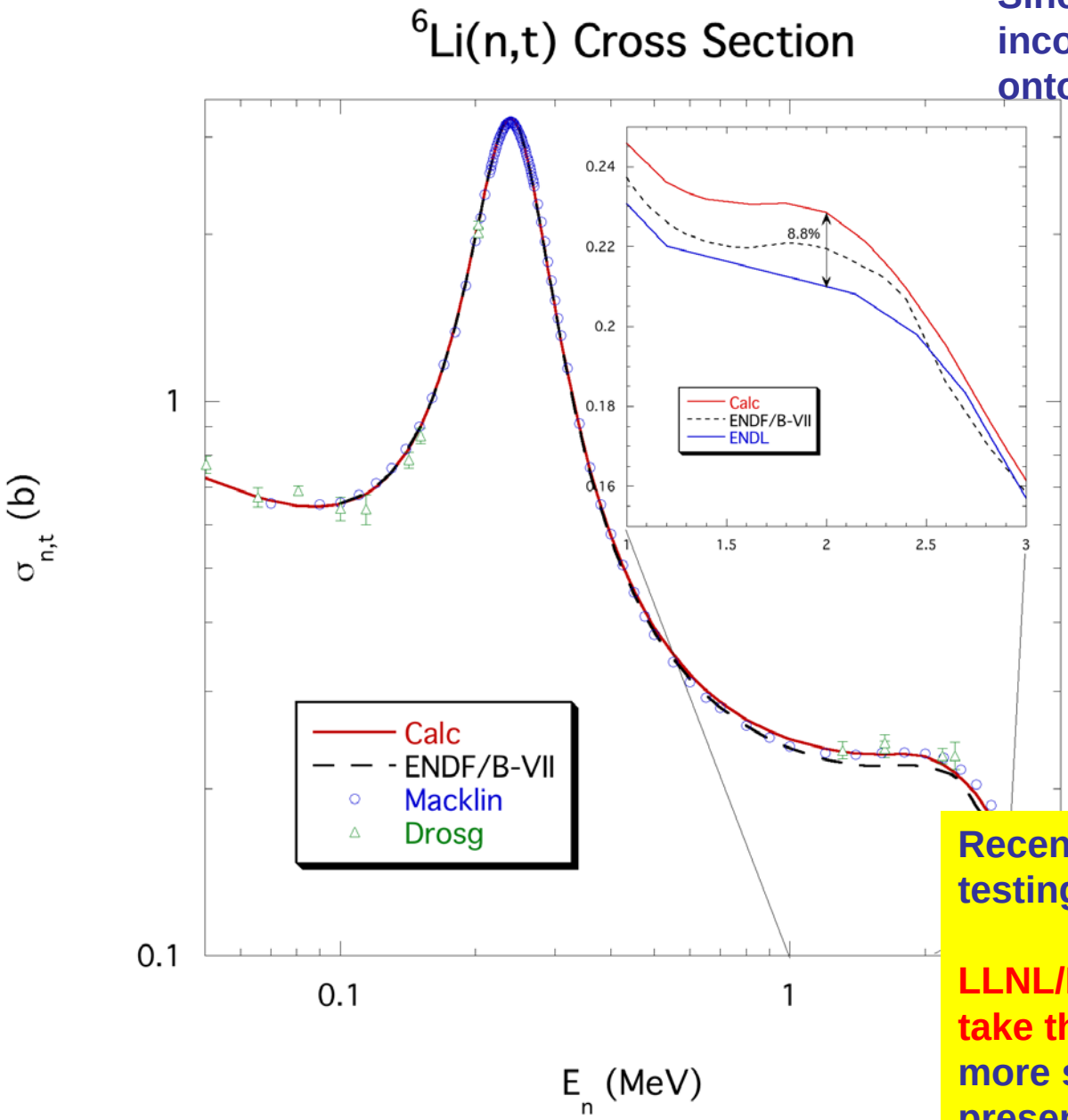
- Pu solution criticals overpredicted
- Many minor actinide evaluations deficient (e.g. see reviews by Ignatyuk, Maslov)
- Little covariance data
- Some problems with intermediate energy criticals (e.g. ZPRs)
- Some reflected critical problems, e.g. Be
- Little new work on fission neutron spectra
- No upgrades to fission product yields, …
- Problems reported with VII.1 delayed neutron data. People preferred older Keepin data. See Holloway talk.
- Chris Dean reported some problems with VII.0 FP evaluations in his testing – see his ND2007 paper he says
- *etc*

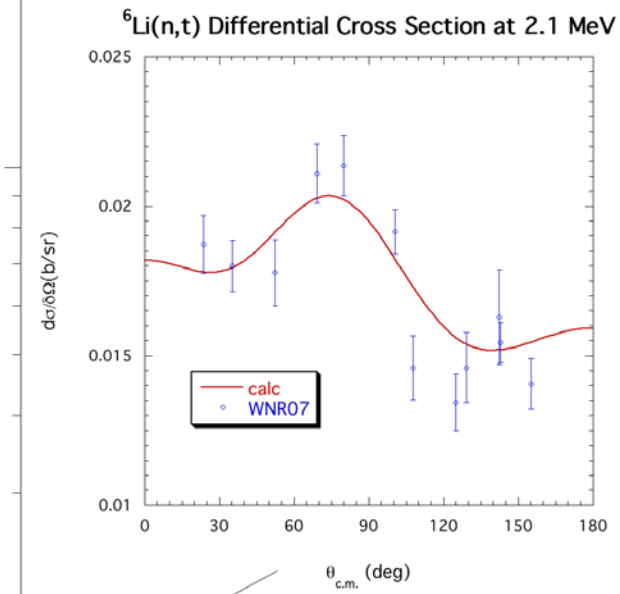
Principle Upgrades Planned for ENDF/B-VII.1

- Covariances – See Brookhaven talks
- Light nuclei based on R matrix work (6Li(n,t), 9Be, 16O …)
- Structural materials – supported by criticality safety
- Fission products (yields & delayed neutron, gamma data)
- Actinides – minor actinide improvements to fission, capture, n2n including much usage of feedback from critical assembly reaction rate data, and data from LANSCE, CERN *etc*
- Actinides – major:
    - Big issues in fission neutron spectra will take longer to resolve
    - We may have an updated 239Pu resonance evaluation (ORNL +Cadarache/CEA) but would like to see the good performance obtained by JEFF's recent work
    - We're interested in WPEC/Iwamoto conclusions re. 235U capture.
    - Need to fix DN problems reported

^{6}Li(n,t) Reaction - LANSCE data gives increase in 1-3 MeV range

Since this is a standard <1 MeV, we incorporate new results >1 MeV onto existing file.





Recent Bethe sphere integral testing successful

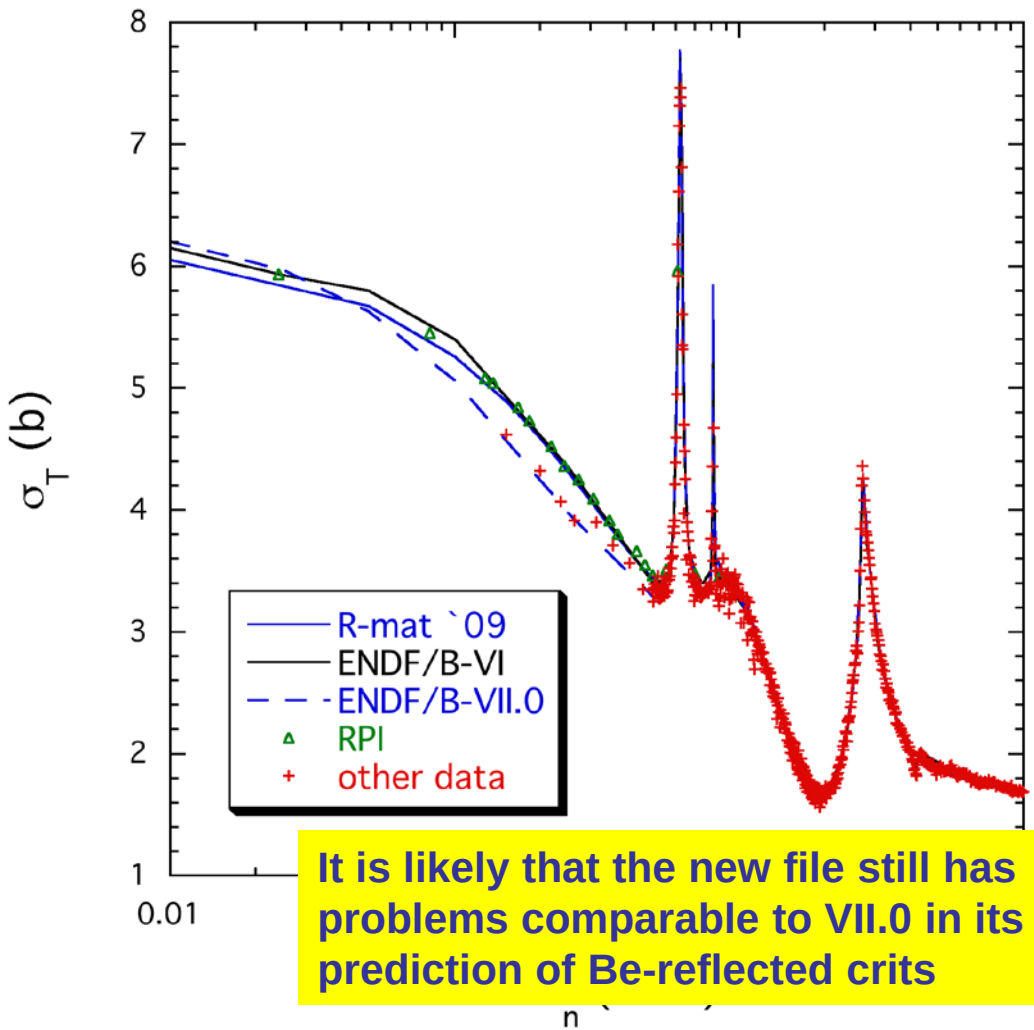
LLNL/David Brown has offered to take this file and reformat using more standard formats (though the present file does process OK)

n+^{9}Be Total Cross Section – New RPI Data

Shown is Hale's latest 9Be evaluation - different to B-VII because RPI data included (looks more like B-VI at low energies, but now higher than most other data there).

To do:
Test performance in critical assemblies:
-try to resolve discrepant info on feedback from LANL and LLNL Be reflected crits
- study what is the problem with the 233U Be reflected crits

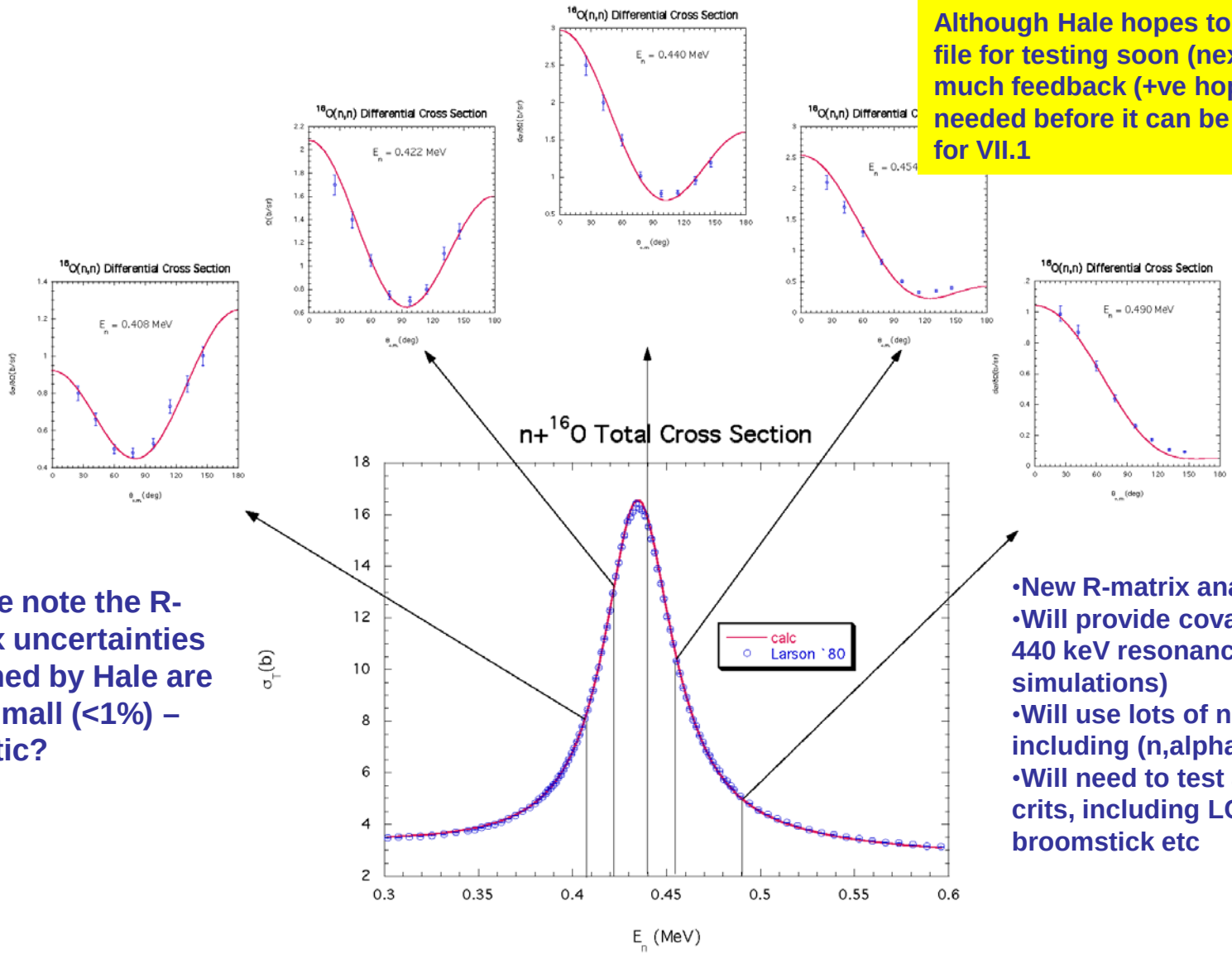
-(ENDF/B/VII.0 performed better for some crits!)



It is likely that the new file still has problems comparable to VII.0 in its prediction of Be-reflected crits

n+^{16}O Cross Sections Across the 440-keV Resonance: Important Data for Studies Quantifying Reactor Criticality Uncertainty

Although Hale hopes to have a new file for testing soon (next week!), much feedback (+ve hopefully) is needed before it can be considered for VII.1



But we note the R-matrix uncertainties obtained by Hale are very small (<1%) – realistic?

- **New R-matrix analysis begun**
- **Will provide covariances, eg for 440 keV resonance (for reactor simulations)**
- **Will use lots of new data, including (n,alpha)**
- **Will need to test against many crits, including LCTs, and broomstick etc**

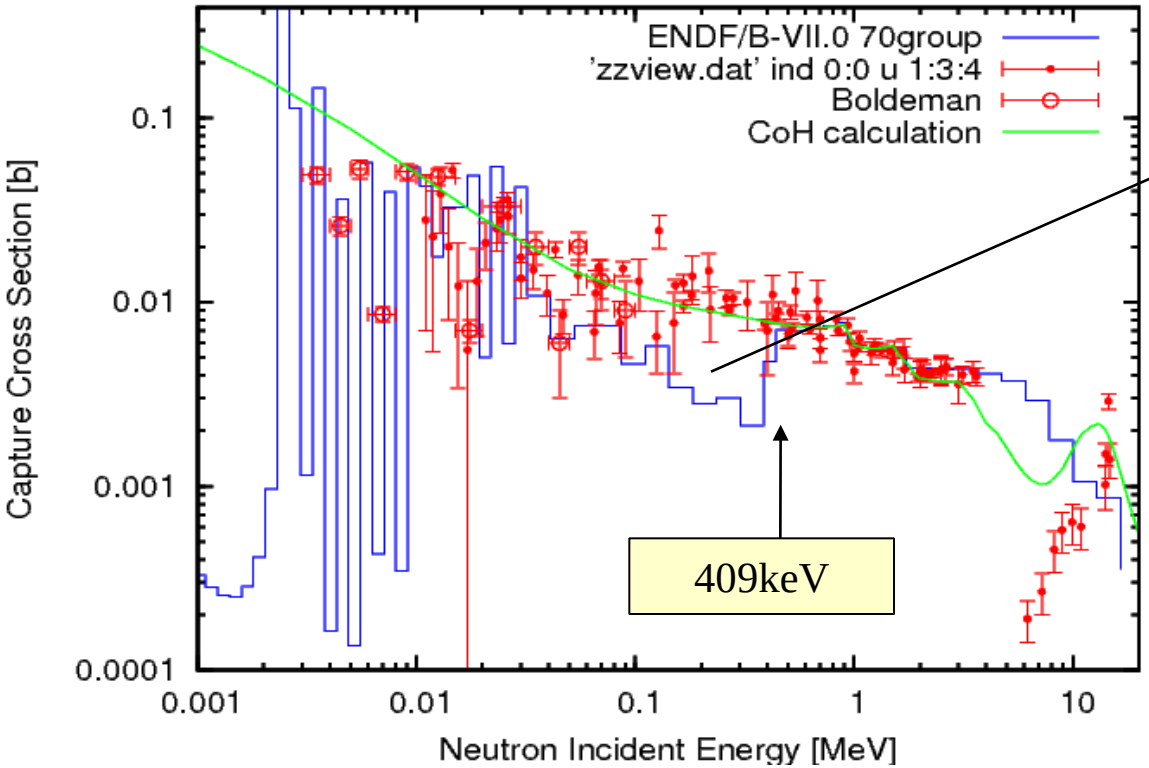
Elements in Medium Mass Range

- Ti isotopes
  - New evaluations from LANL and ORNL
    - I think we are waiting to include new resonance parameter covariances from ORNL (retroactive, using LANL resonances)
    - γ-production for some isotopes (^{47}Ti fixed by LLNL)
- ^{58}Ni(n,α),^{56}Fe(n,α) < 20 MeV
  - work in progress (Holloway, Kawano) using LANSCE data
  - Goal – do by next CSEWG.

(Mn, Cr isotopes coming…)

- ^{63,65}Cu
  - Mosteller tested new CENDL-3 data, and new JENDL data
    - Zeus benchmark testing not so satisfactory – like B-.VII.0, but perhaps this is a 235U(n,g) issue instead near 1 keV – more testing needed
- ^{89}Y
  - capture data fixed at low energies (Kawano)

Y-89 Capture 70 Group Cross Section: Thanks to Ignatyuk for noting a problem!



d- f-wave contributions are missing ?

Gamma width
ENDF 134meV
RIPL-3 130meV
D0
ENDF 4.4keV (approx)
RIPL-3 3.7keV

Change the upper limit to 30keV or so, or
Increase the radiative width to match the Hauser-Feshbach calculation

Major Actinides

- ^{238}U: New Wallner capture data validates VII.0 evaluation.

- 235U: We are monitoring the WPEC/Iwamoto work, and may want to adopt their result (lower capture in the 0.5-4 keV region). Some may view the lower energy boundary for the resonance region a drawback. Much validation testing will be needed.

- ^{239}Pu. Inelastics – VII.0 based on old evaluation. Maslov argues that total inelastic is too high in the fast region. Kawano will assess and initiate a new effort to model and evaluate inelastic reactions – but for an ENDF upgrade beyond VII.1. Kahler continues to test ORNL/CEA new resonance region work, including interplay of fission spectrum shape and other data in solution criticals.

Patrick has refined the grids for the major actinide fiss spec > 10 MeV out; He is also using the LANL model to create fiss spec for minor actinides, some of which we could use for VII.1.

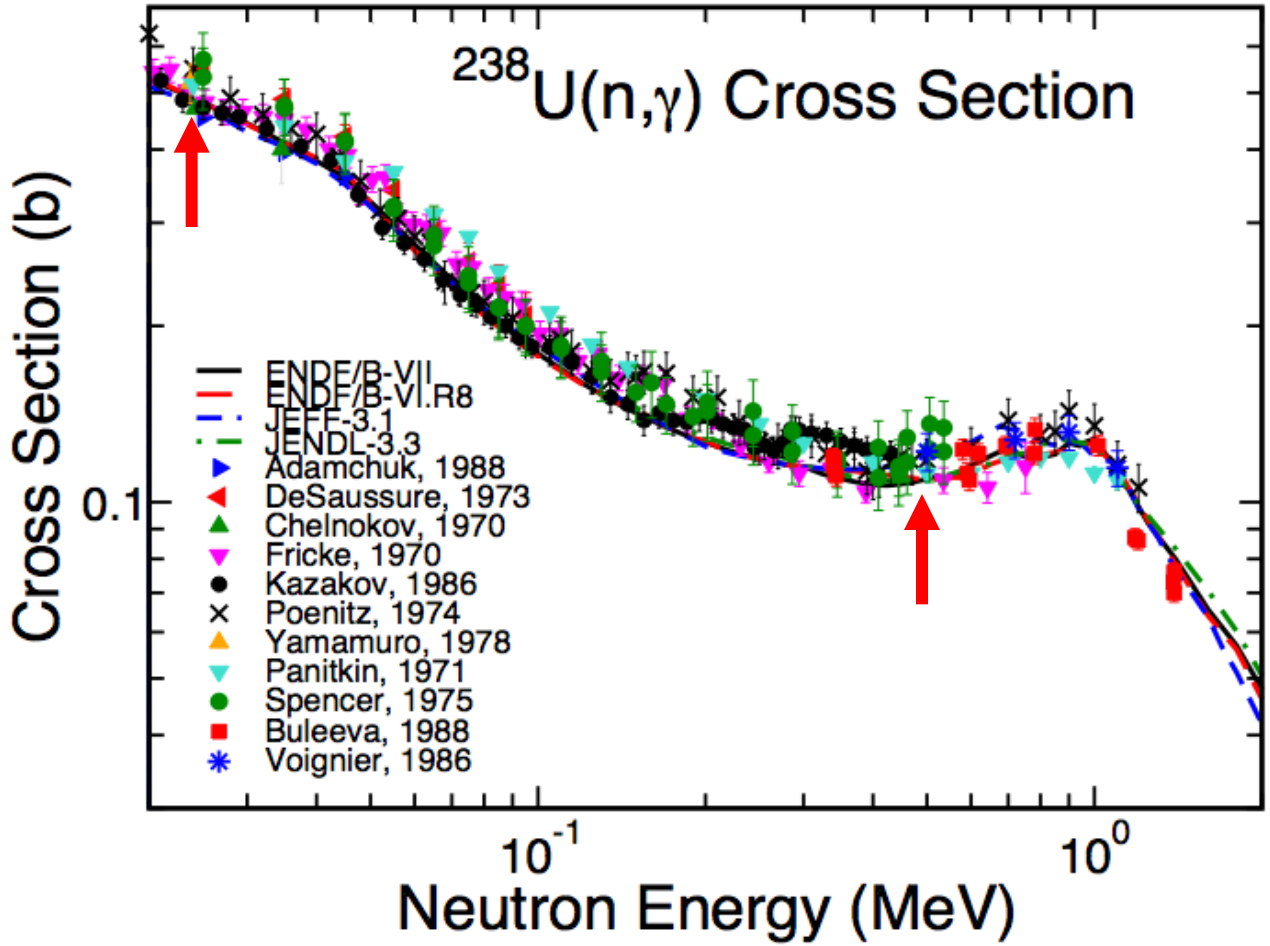
238U capture: ~ We're Monitoring Wallner expt.

As part of an IAEA CRP, Toni Wallner (Vienna) is measuring 238U(n,γ)

Irradiation at Karsruhe, at ~25 and ~500 keV. with acc. mass spectrometry.

First results now available – CONFIRM B-VII.0 (and JEFF differs by ~ 10%!)

IAEA/CSEWG standard, in line with earlier WPEC group, concluded that most measurements suffer from multiple scattering & are too high. Evaluation unc. claimed to be small (~2% or less)



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Minor Actinides

- ^{233}U
  - delayed neutron typo, E-02 -> E-03, confirmed
- ^{236}U ^{241}Am
  - small adjustment of fission cross sections in the sub-threshold region
  - capture calculated for better production of integral data
- ^{240}Pu
  - adopt LANL new evaluation
    - comparison of resonance region reported by R. Cullen
    - P. Young and O. Bouland will review this again
- ^{237}U
  - new evaluation – work esp. on fission cross section (crits perform well)
- ^{237}Np
  - (n,2n) new evaluation by Holloway underway, taking account of isomeric state production cross section – adopting insights by Maslov. New data testing of (n,f) and (n,g) against crit data (Bigten, as well as hotter) good.
- ^{238}Pu
  - New work underway and will be completed soon. But our calculations overpredict new LANSCE/CEA fission data, and agree well with new LLNL surrogate data (not yet understood way recent CEA calculations differ). (n,3n) at 14 MeV is 85 times smaller than VII.0!
  - We also plan to fix 243Am(n,2n) – Maslov feedback

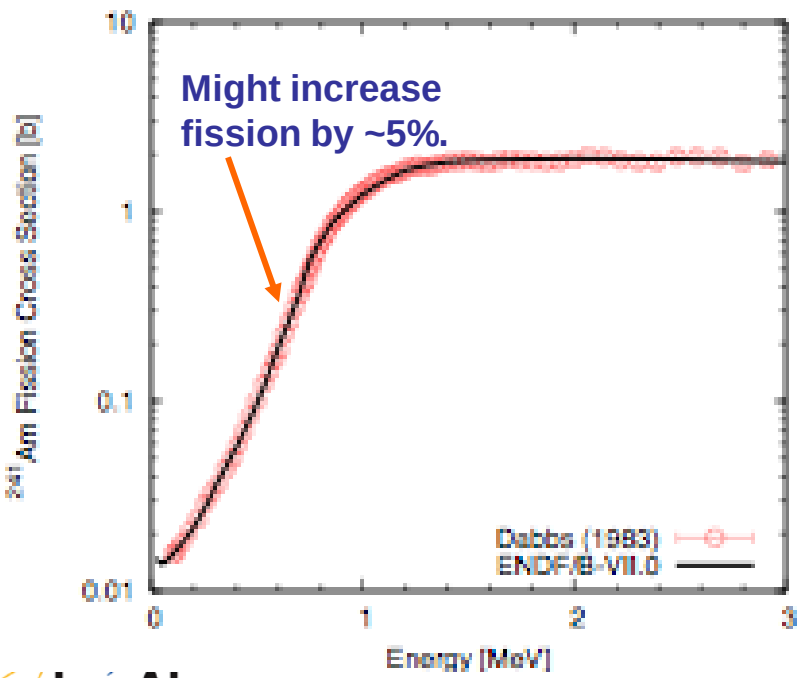
FPY : Fast neutrons on 239Pu, 235U, 238U

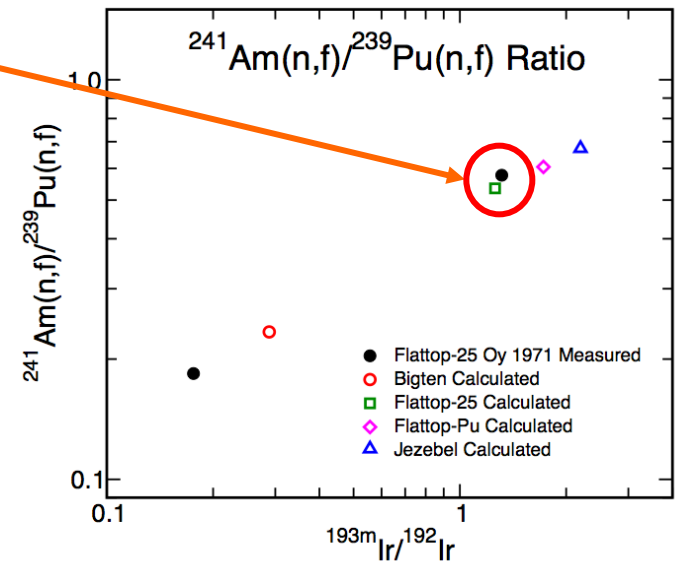
- The longstanding discrepancy between LANL and LLNL has been resolved, for the few key FPs using for monitoring fissions. LLNL estimates now agree with LANL.
- Our results are supported by an external “Expert Panel” review
- 3 papers being finalized for NDS Dec 2010
- To do – finalize evaluated numbers, and include in upgraded FPY evaluation. Extend work to include energy deposition for all FPY in fast region. E.g. augment current fast ENDF FPY data (at ~”0.5 MeV”) with another suite at 2.0 MeV, Will require some work (Kawano, Lestone, MBC,… + BNL).

241Am fission: ~5% increase near 500 keV?

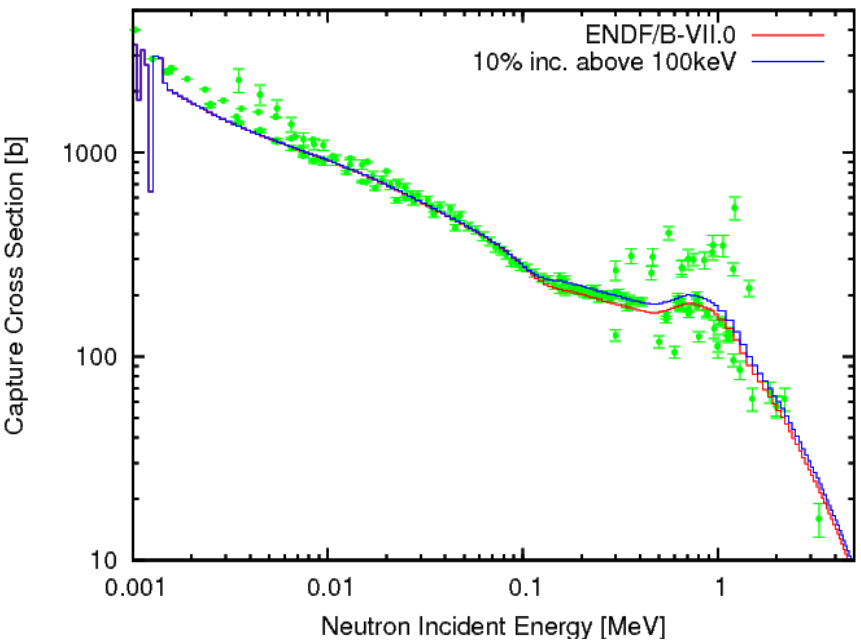
Japanese FCA data testing suggest that B-VII needs increasing 3-6% in the ~ 500 keV region

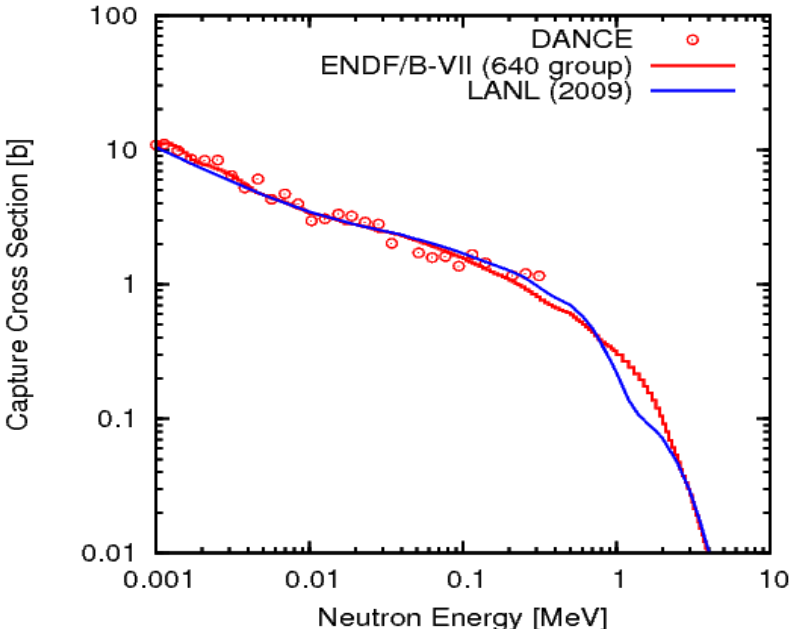
~ Similar to LANL results





U-236 and Am-241 Capture Cross Section



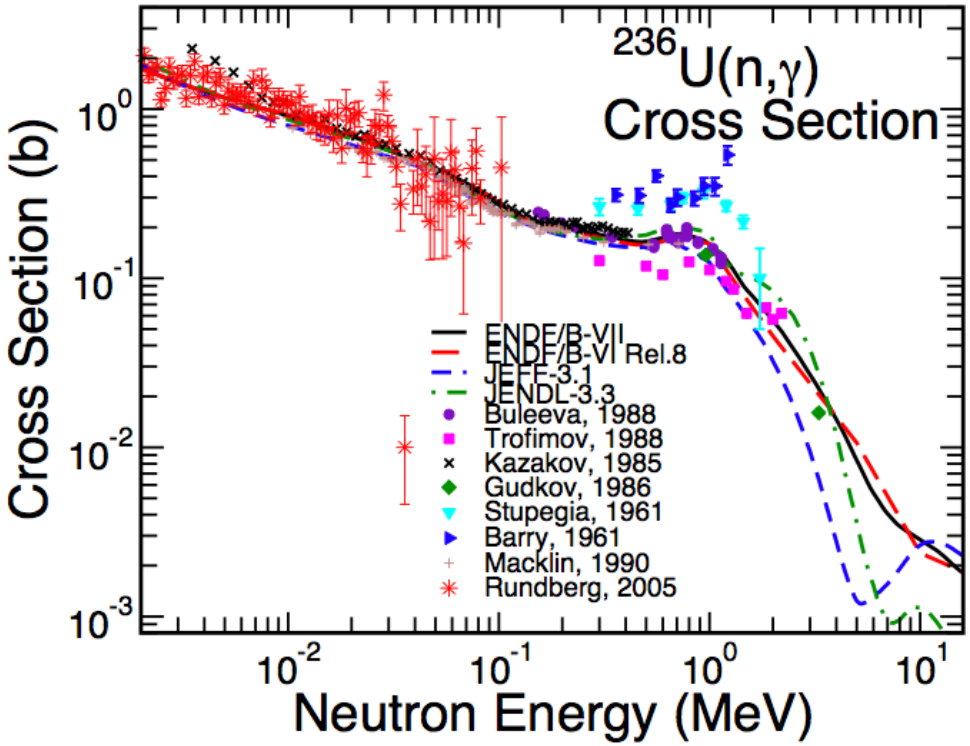


M. Jandel et al.
Phys. Rev. C, 78 034609 (2008)

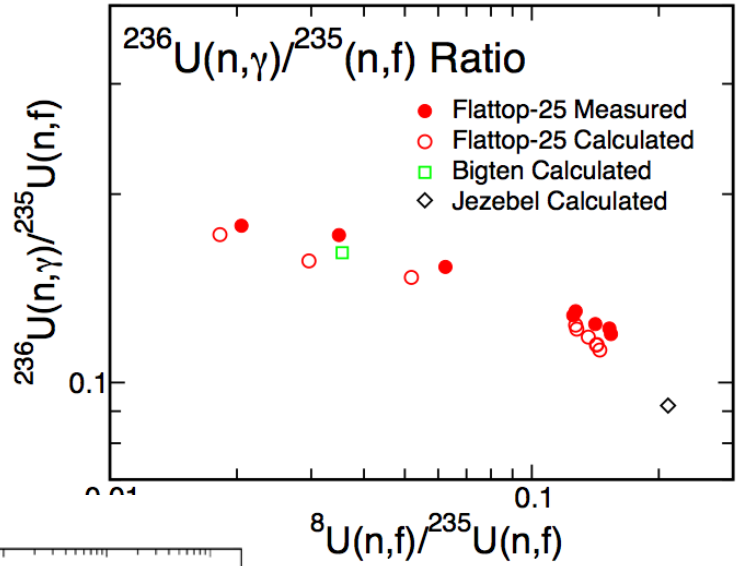
Increase capture cross sections slightly for better reproduction of critical assembly data (See Kahler's talk)

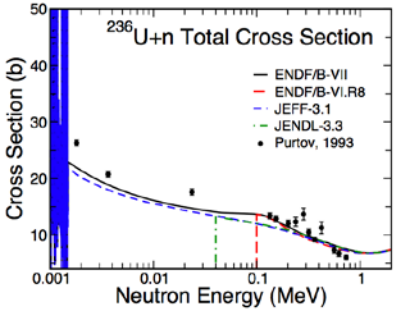
236U - Possible ~10% increase to capture

Spread in measured data would allow an increase in capture

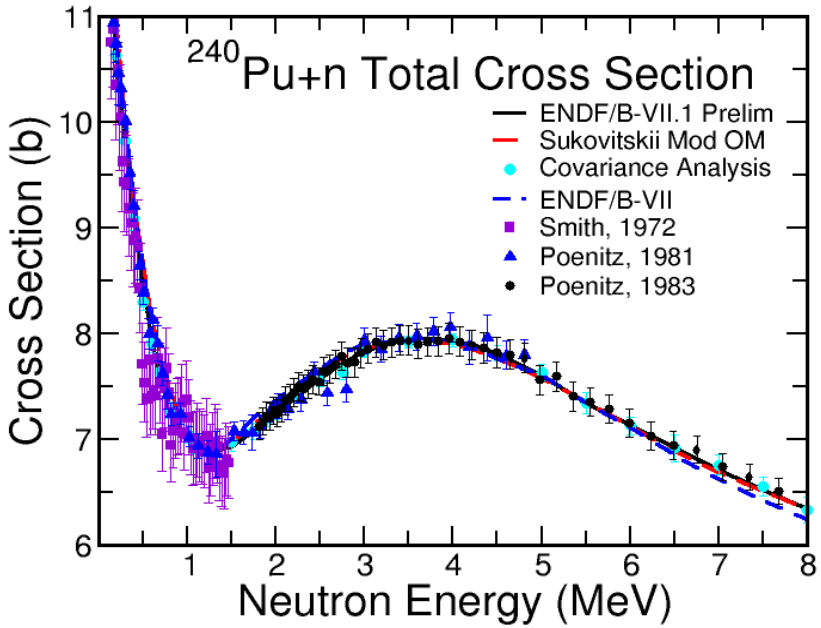


Testing of capture cross section suggests ~ 10% increase needed in 10kev - 1-2 MeV region. (critical assemblies here have most neutrons >10 keV)



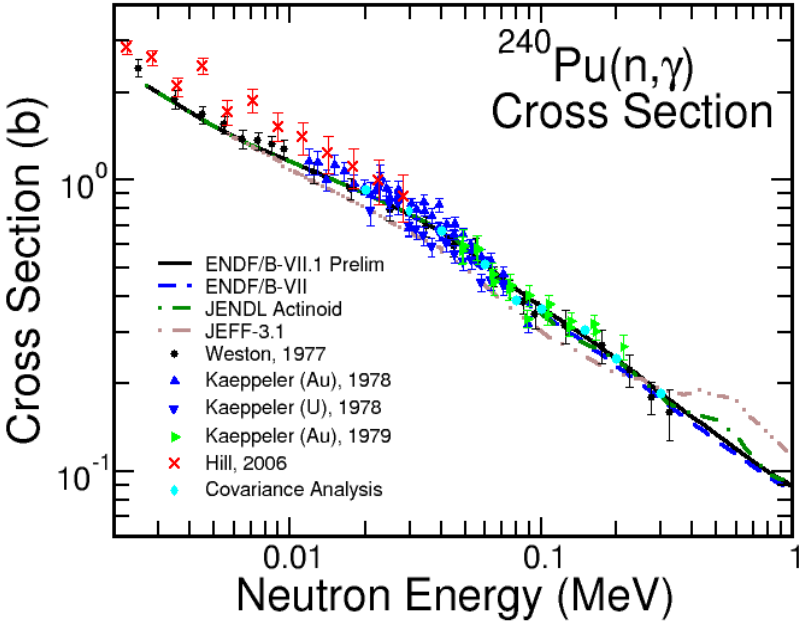


Pu-240 LANL Evaluation - Total and Capture,



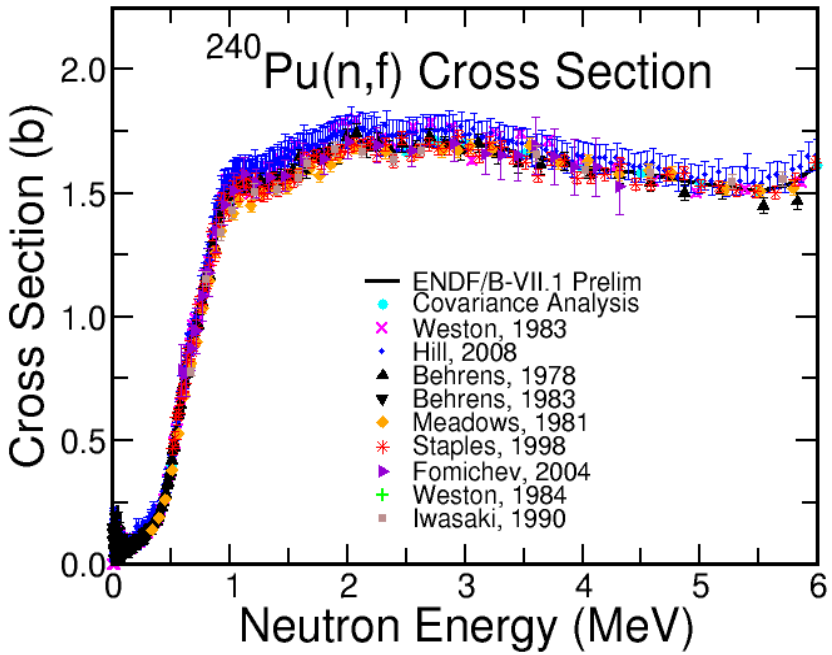
Total Cross Section
modified Sukovitskii optical potential

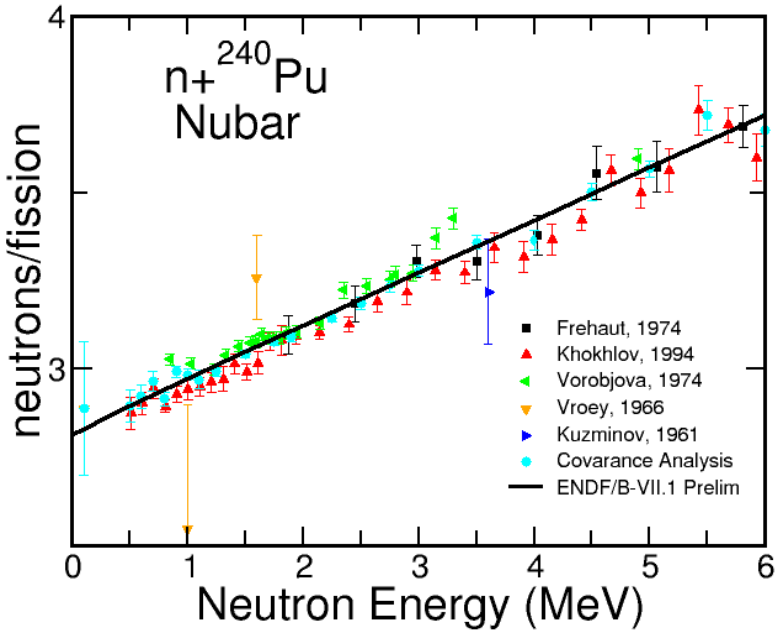
Fission Cross Section
GLUCS analysis
and JENDL/AC (up to 30keV)



Pu-240 LANL Evaluation, Fission

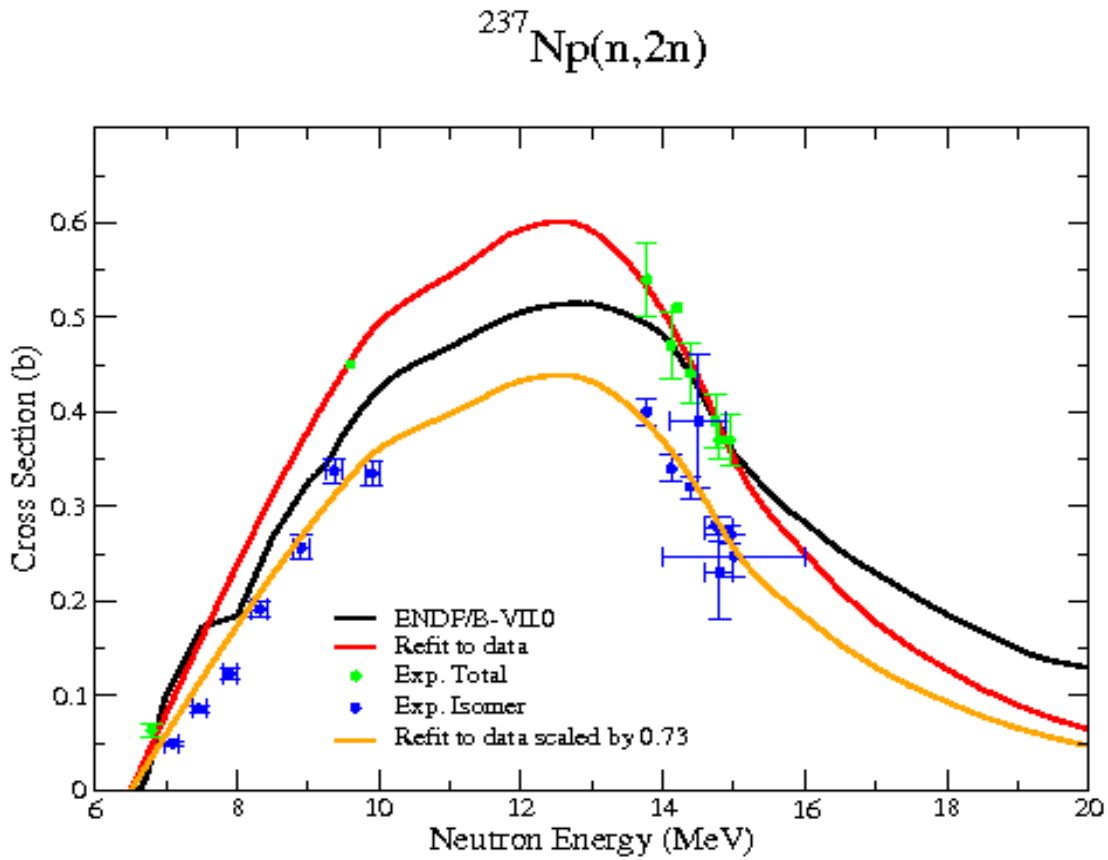
When we model Pu crits with high 240Pu content,
we now believe we get the right answer for the right reason!





Covariance data are also provided

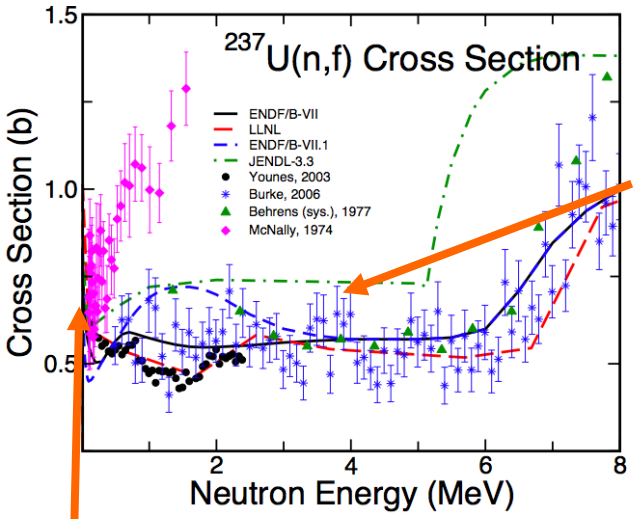
Np-237 – Focus on (n,2n) Improvements. We use Maslov's predicted m/tot isomer ratio



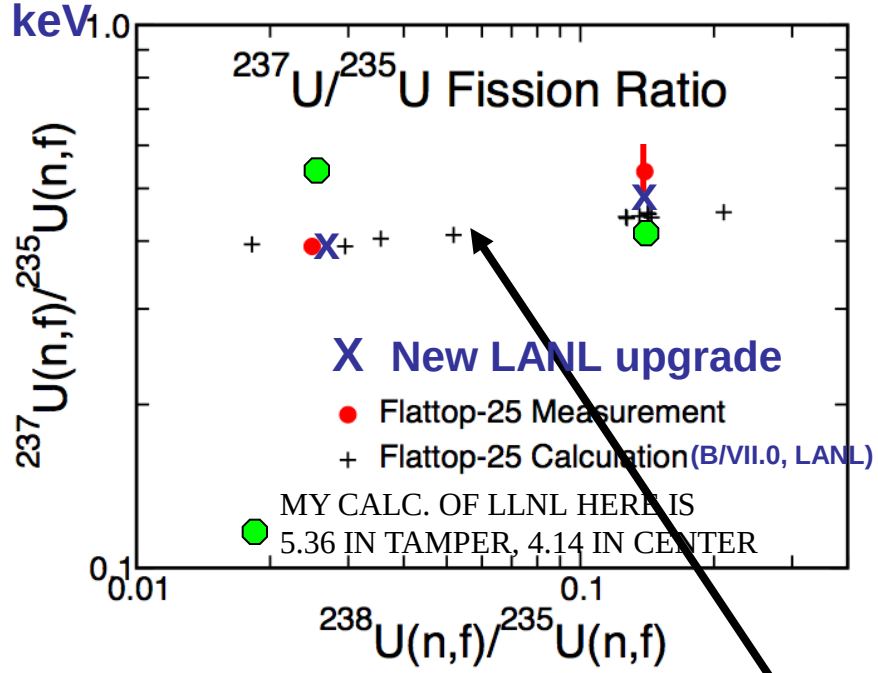
(n,2n) upgraded based on total and isomer production data

237U - LANL new evaluation

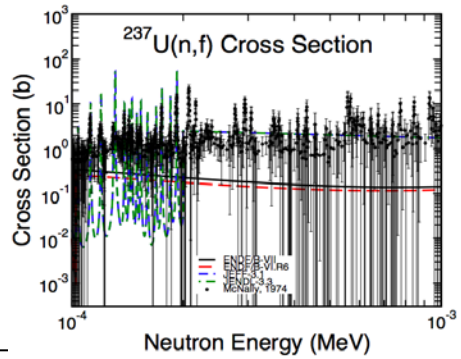
LANL/ENDF 237 fission ~ poor below 10 keV (used old ENDF res. Parameters). We propose:
-LANL + JENDL3.3 at lower energies for B-VII.1
-LANL - longer term, use LANL/LSD expt ~ 1 keV

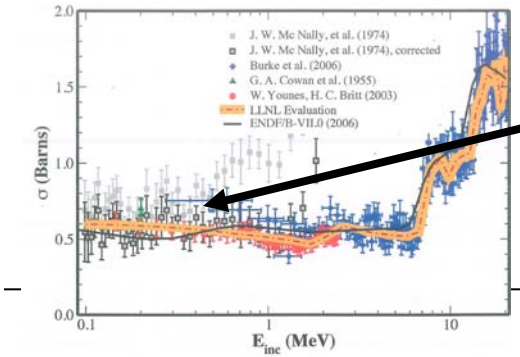


LANL VII.1 proposal
Higher here to better match:
a) Crit assembly data
b) Behrens systematcis
c) Lynn-Hayes calc.



Experiment at LANSCE being planned below 1 keV





Slope dictated by fission x/s slope

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Okajima Physor08 FCA data testing of fission

Japanese testing of ENDF/B-VII.0 fission:

237Np - good
241Am, 243Am - C/E is 3-6% low
238Pu - good, maybe 2% low
242Pu - 4-8% too high
244Cm - 0-7% too high

Table 2
C/E values of CFRRs for TRU in FCA cores

$^{237}Np/^{235}Pu$

Core	Nuclear data libraries		
	JENDL-3.3	ENDF/B-7.0	JEFF-3.1
IX-1	1.05 ±2%	1.03 ±3%	1.00 ±5%
IX-2	1.00 ±2%	1.03 ±2%	1.01 ±2%
IX-3	1.02 ±1%	1.00 ±1%	1.01 ±1%
IX-4	1.03 ±2%	1.03 ±2%	1.03 ±2%
IX-5	1.02 ±1%	1.01 ±1%	1.02 ±1%
IX-6	1.00 ±1%	1.01 ±2%	1.00 ±1%
IX-7	1.01 ±1%	1.00 ±1%	1.00 ±1%
X-1	1.00 ±2%	0.98 ±2%	1.00 ±2%

$^{241}Am/^{239}Pu$

Core	Nuclear data libraries		
	JENDL-3.3	ENDF/B-7.0	JEFF-3.1
IX-1	1.00 ±2%	0.97 ±3%	0.95 ±5%
IX-2	0.94 ±2%	0.96 ±2%	0.95 ±2%
IX-3	0.98 ±1%	0.96 ±1%	0.97 ±1%
IX-4	0.97 ±2%	0.96 ±2%	0.97 ±2%
IX-5	0.97 ±1%	0.96 ±1%	0.97 ±1%
IX-6	0.96 ±2%	0.97 ±2%	0.95 ±2%
IX-7	0.95 ±1%	0.94 ±1%	0.93 ±1%
X-1	0.94 ±2%	0.91 ±2%	0.94 ±2%

$^{238}Pu/^{239}Pu$

Core	Nuclear data libraries		
	JENDL-3.3	ENDF/B-7.0	JEFF-3.1
IX-1	1.00 ±2%	1.00 ±3%	1.15 ±5%
IX-2	-	-	-
IX-3	1.00 ±1%	0.99 ±1%	1.04 ±1%
IX-4	0.99 ±1%	0.98 ±1%	1.01 ±1%
IX-5	0.99 ±1%	0.98 ±1%	1.00 ±1%
IX-6	0.98 ±1%	0.97 ±1%	0.99 ±1%
IX-7	0.98 ±1%	0.97 ±1%	0.99 ±1%
X-1	0.97 ±1%	0.97 ±1%	1.01 ±1%

$^{243}Am/^{239}Pu$

Core	Nuclear data libraries		
	JENDL-3.3	ENDF/B-7.0	JEFF-3.1
IX-1	0.98 ±2%	0.95 ±3%	0.92 ±5%
IX-2	0.93 ±2%	0.96 ±2%	0.94 ±2%
IX-3	0.97 ±1%	0.95 ±1%	0.96 ±1%
IX-4	0.95 ±2%	0.94 ±2%	0.95 ±2%
IX-5	0.96 ±1%	0.94 ±2%	0.96 ±1%
IX-6	0.95 ±2%	0.95 ±2%	0.93 ±2%
IX-7	0.95 ±1%	0.94 ±1%	0.93 ±1%
X-1	0.92 ±2%	0.89 ±2%	0.92 ±2%

$^{242}Pu/^{239}Pu$

Core	Nuclear data libraries		
	JENDL-3.3	ENDF/B-7.0	JEFF-3.1
IX-1	1.10 ±2%	1.08 ±3%	1.08 ±5%
IX-2	1.05 ±2%	1.08 ±2%	1.10 ±2%
IX-3	1.08 ±1%	1.06 ±1%	1.11 ±1%
IX-4	1.07 ±2%	1.08 ±2%	1.12 ±2%
IX-5	1.08 ±1%	1.08 ±1%	1.12 ±1%
IX-6	1.06 ±2%	1.07 ±2%	1.09 ±2%
IX-7	1.06 ±1%	1.05 ±1%	1.09 ±1%
X-1	1.05 ±2%	1.04 ±2%	1.09 ±2%

$^{244}Cm/^{239}Pu$

Core	Nuclear data libraries		
	JENDL-3.3	ENDF/B-7.0	JEFF-3.1
IX-1	1.02 ±2%	1.00 ±3%	0.99 ±5%
IX-2	1.01 ±2%	1.04 ±2%	1.03 ±2%
IX-3	1.05 ±1%	1.03 ±1%	1.06 ±1%
IX-4	1.05 ±2%	1.06 ±2%	1.07 ±2%
IX-5	1.05 ±1%	1.05 ±1%	1.07 ±1%
IX-6	1.05 ±1%	1.07 ±1%	1.07 ±1%
IX-7	1.04 ±1%	1.03 ±1%	1.04 ±1%
X-1	1.01 ±2%	1.00 ±2%	1.02 ±2%