National Institute of Standards and Technology

Nuclear Data Verification and Standardization Program

PROGRESS REPORT

USNDP Meeting
Brookhaven National Laboratory
November 3-5, 2004

Staff (total of about 0.6 FTE):

•Allan Carlson, David Gilliam, and Alan Thompson

•NIST, independent of DOE funds, supplies almost half of the total support for the standards program.

•There is the equivalent of about 1 FTE working on the program.

Nuclear Structure Activities:

•None are supported by DOE funding.

•A modest effort (1 FTE) in structure and decay studies is supported by NIST funds.

Nuclear Reaction Activities:

•Neutron cross section standards:

•Significant improvements have been made in the standard cross section database.

- The emphasis has been on the H(n,n), ^{10}B(n,α), and fission standards.

•The standards are the basis for the neutron reaction cross section libraries.

•In response to requests for improvements in the standards:

- •The CSEWG formed a Task Force
- •The WPEC formed a subgroup
- •The IAEA formed a Coordinated Research Project (CRP)
- •NIST has maintained a leadership role in each of these groups

The International Neutron Cross Section Standards Evaluation

- WPEC and CSEWG
  - Encourage /motivate new measurements where necessary
  - Investigate experimental work to get better information on corrections and uncertainties
  - Mainly interested in the final product, the standards evaluation
- IAEA Coordinated Research Project
  - Refines/improves the evaluation process
  - Seeks to improve the understanding of the uncertainties
  - The focus is on the evaluation process

STANDARDS TO BE EVALUATED

Reaction	Energy Range
H(n,n)	1 keV to 200 MeV
^{3}He(n,p)	thermal to 50 keV
^{6}Li(n,t)	thermal to 1 MeV
^{10}B(n,α)	thermal to 1 MeV
^{10}B(n,$\alpha_1\gamma$)	thermal to 1 MeV
^{197}Au(n,γ)	thermal, 0.2 to 2.5 MeV
^{235}U(n,f)	thermal, 0.15 to 200 MeV
^{238}U(n,f)	2 to 200 MeV*

IAEA CRP
on
Improvement of the Standard Cross Sections for Light Elements

Objectives

• Improve the methods for determining the covariance matrix for R-matrix fits**.** Upgrade computer codes using this methodology.

• Study the reasons for uncertainty reduction in R-matrix fits.

• Evaluate cross sections and covariance matrices for neutron induced standard reactions for the light elements, H(n,n), ^{3}He(n,p), ^{6}Li(n,t), ^{10}B(n,α) and ^{10}B(n,$\alpha_1\gamma$)

• Establish the method and computer codes for combining the light element with the heavy element evaluations.

•Perform the combining procedure to obtain the standards evaluations.

CRP Activities

Three RCMs have been held

- Improvements to the experimental data in the standards database
- R-matrix evaluations are underway or completed for the H(n,n), ^{3}He(n,p), ^{6}Li(n,t), ^{10}B(n,$\alpha_1\gamma$), and ^{10}B(n,α) cross sections.
- Work on microscopic calculations leading to independent determinations of R-matrix poles
- Generalized least squares evaluations for the ^{6}Li(n,t), ^{10}B(n,α), ^{10}B(n,$\alpha_1\gamma$), Au(n,γ), ^{235}U(n,f), and ^{238}U(n,f) standard cross sections
- Combining of R-matrix and generalized least squares evaluations
- Studies of the effect of Peelle's Pertinent Puzzle (PPP) and its effect on the standards evaluation

CRP Activities (cont.)

- Studies of the small uncertainties resulting from evaluations

- Comparisons of R-matrix and model independent least squares codes for values of the cross sections and covariances produced

- Methods for handling discrepant data
  - Adding MERC components to discrepant data sets

- Methods for smoothing evaluated data
  - ^{6}Li(n,t), ^{10}B(n,α) and ^{10}B(n,α$_{1}$γ) data are basically smooth due to the dominance of the R-matrix fit.
  - A simple smoothing algorithm is used to remove fluctuations.
  - Models provide a method for removing unphysical effects.

Cross Section Results

- H(n,n)
  - An evaluation by Hale has been completed up to 30 Mev. It will be released only up to 20 MeV to ensure proper merging with the higher energy evaluation. The complete evalution which extends to 200 MeV should be released in February 2005.
  - This evaluation was used to renormalize all data relative to the hydrogen standard.
- ^{3}He(n,p)
  - This evaluation is nearly complete. It should be finished by Nov 30, 2004.

- ^{6}Li(n,t)
  - The evaluation is complete. These results were obtained by averaging EDA and RAC output which were then used as input to GMA. The upper energy bound is 1 MeV as it was for ENDF/B-VI. Users are cautioned about using this as a standard near the resonance at ~240 KeV due to the rapid change of the cross section with energy.

- ^{10}B(n,α) and ^{10}B(n,α$_{1}$γ)
  - These evaluations are not finished. It is anticipated that they will be finished by December 2004.

Cross Section Results (cont.)

- C(n,n)
  - This evaluation will be carried over from ENDF/B-VI. Very few new measurements have been made of this standard and those that were made agree very well with the ENDF/B-VI evaluation.

- Au(n,γ)
  - This evaluation is complete.

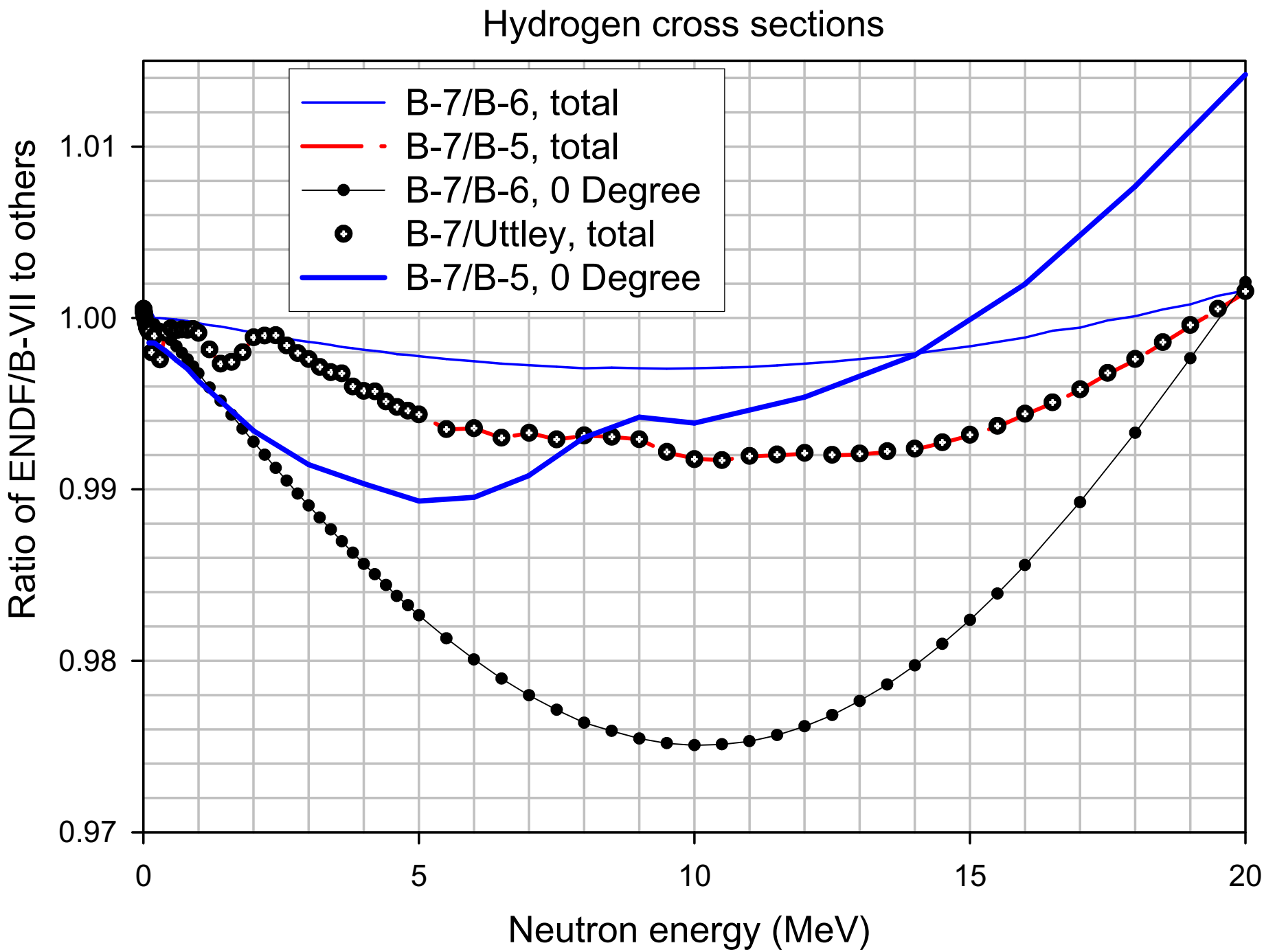
- ^{235}U(n,f)
  - The evaluation is complete to 20 MeV. It will be extended to 200 MeV when the hydrogen standard is available to that energy.
  - An improved K1 results from this evaluation.
    - New K1=721.6 b
      - 0.8 b increase from Arif coherent scattering data
      - 1.9 b increase from Gwin high accuracy ν data
    - Hardy K1 value=722.7 $\pm$ 3.9 b
  - Good agreement is expected with GODIVA
    - Calculations with preliminary results from this evaluation gave k_{eff} = 0.99971

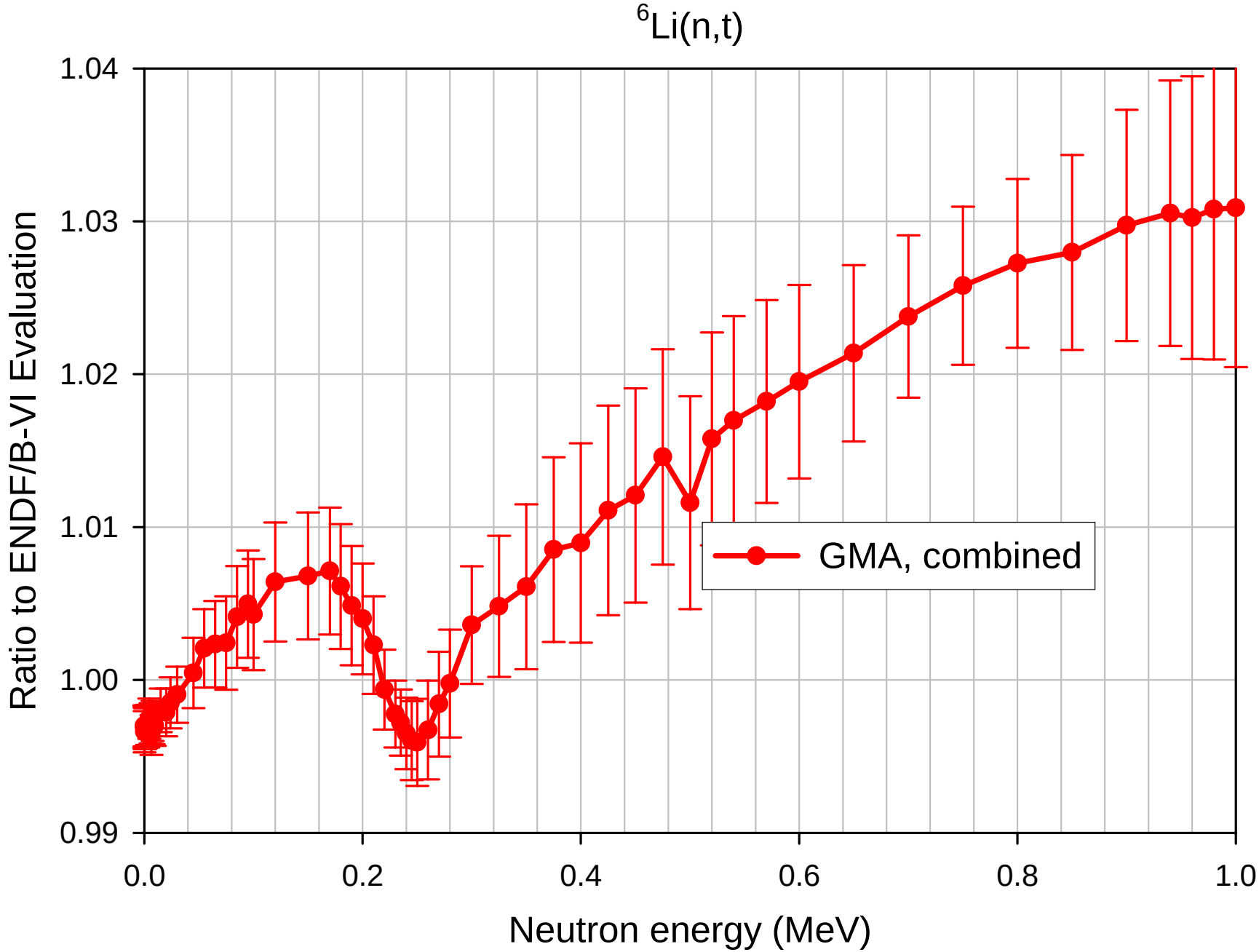
Cross Section Results (cont.)

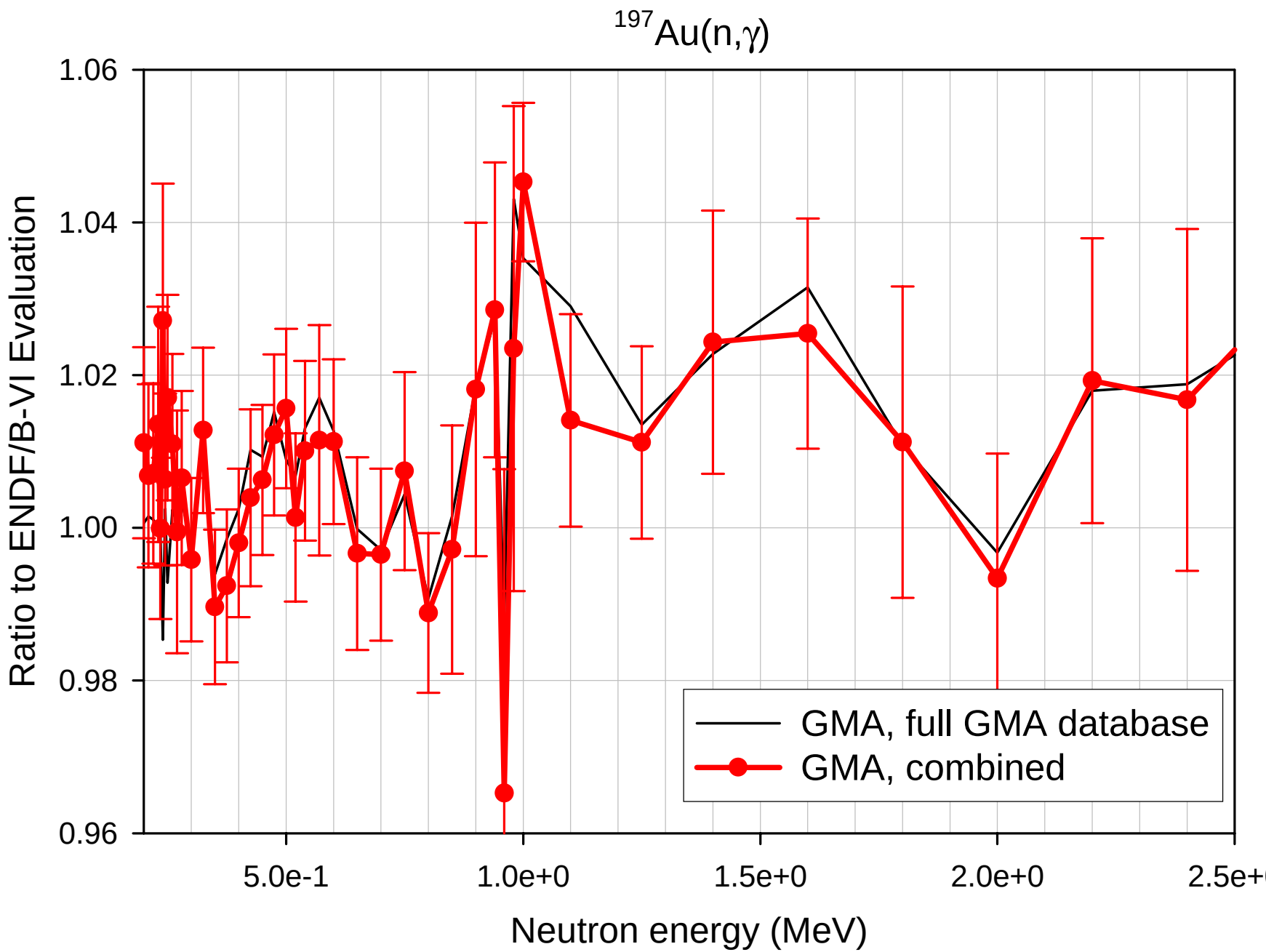
- ^{238}U(n,f)
  - This evaluation is complete to 20 MeV. It will be extended to 200 MeV when the hydrogen standard is available to that energy.
  - It is recommended that this cross section be accepted as an ENDF standard.
  - It is recommended that the lower energy bound for use as a standard be changed to 2 MeV

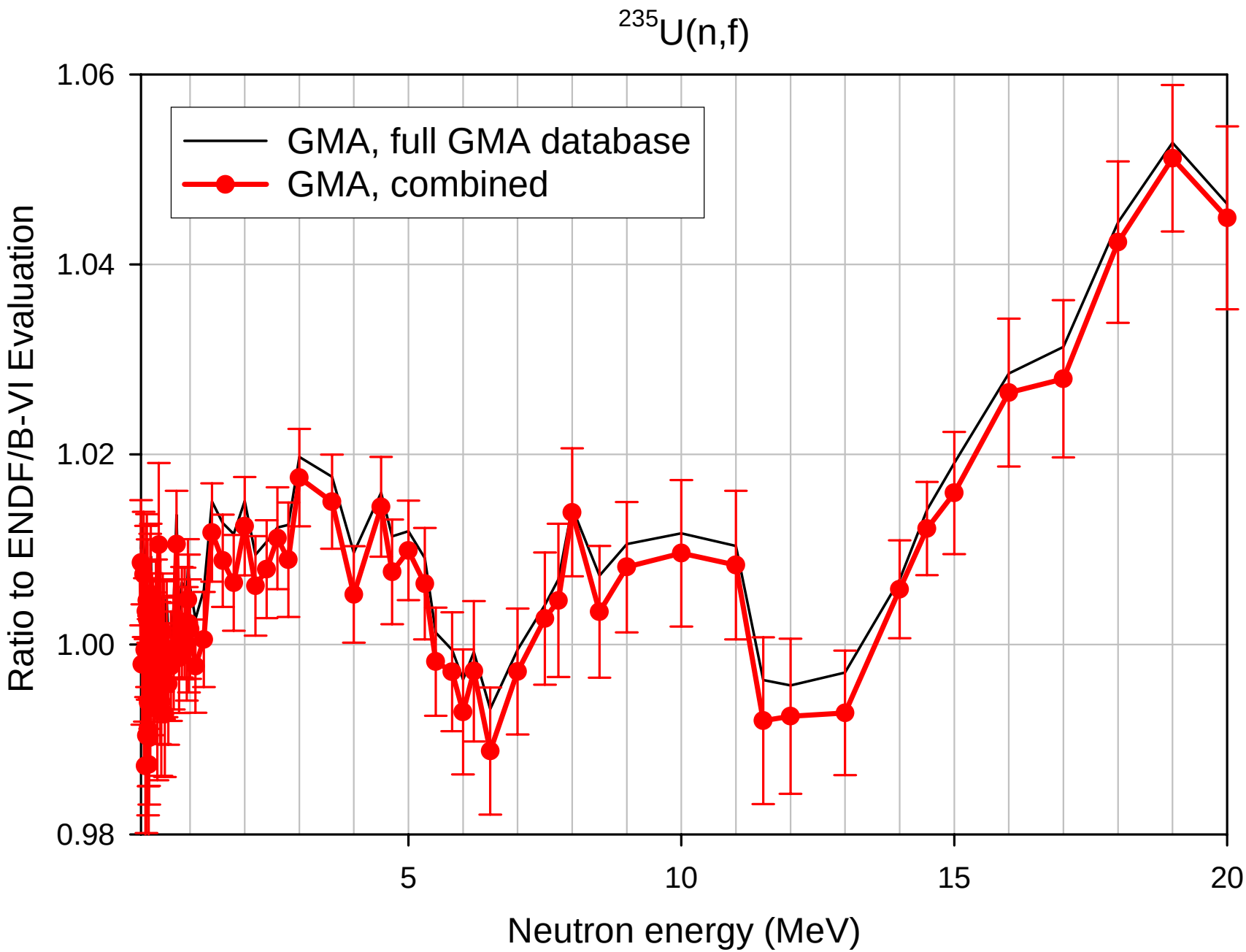
- ^{239}Pu(n,f)
  - This evaluation is complete to 20 MeV. It will be extended to 200 MeV when the hydrogen standard is available to that energy.
  - This is not a standard cross section.

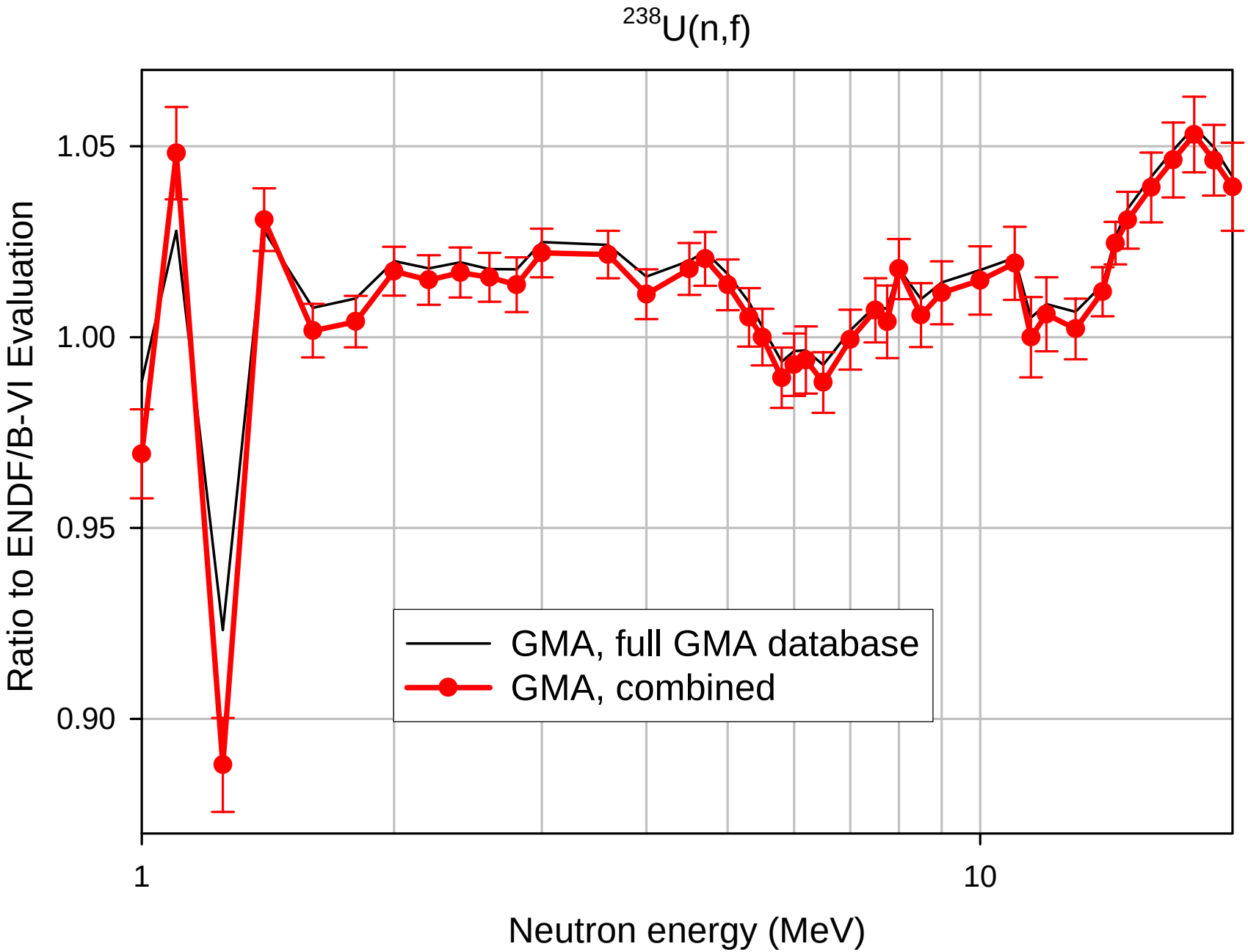
- ^{238}U(n,γ)
  - This evaluation is complete.
  - This is not a standard cross section.

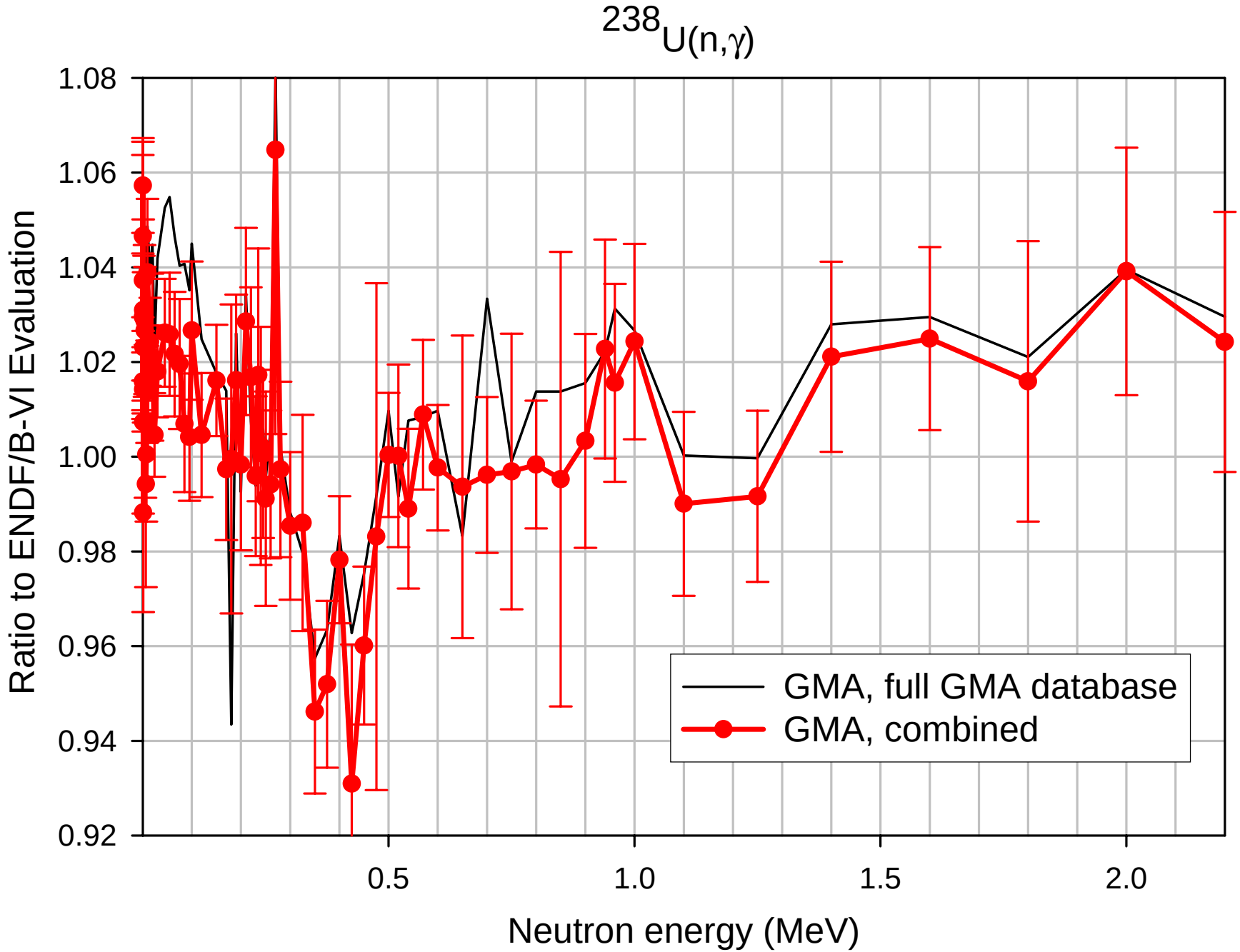

Hydrogen cross sections
B-7/B-6, total
B-7/B-5, total
B-7/B-6, 0 Degree
B-7/Uttley, total
B-7/B-5, 0 Degree
Ratio of ENDF/B-VII to others
1.01
1.00
0.99
0.98
0.97
0
5
10
15
20
Neutron energy (MeV)

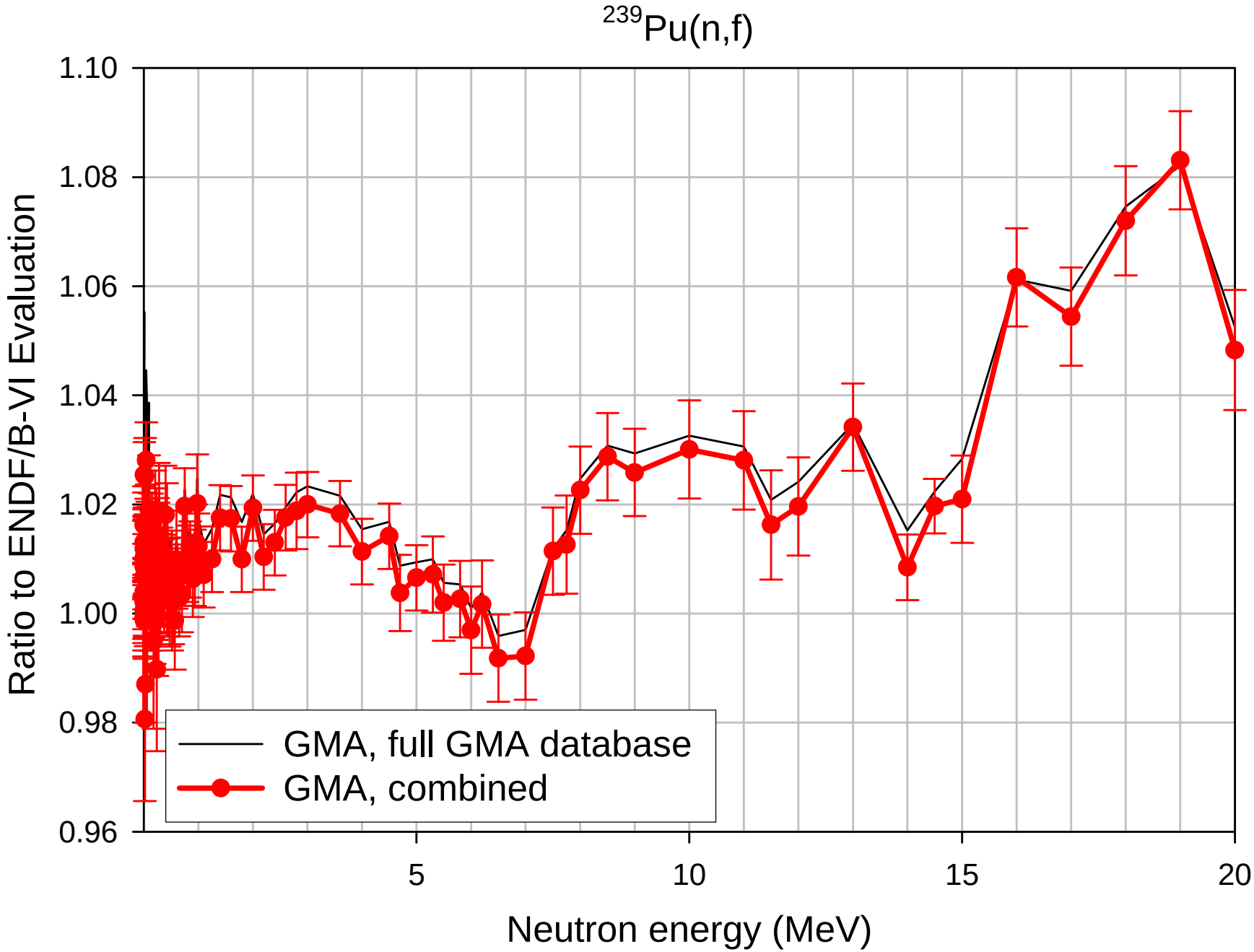

^{6}Li(n,t)
Ratio to ENDF/B-VI Evaluation
1.04
1.03
1.02
1.01
1.00
0.99
0.0
0.2
0.4
0.6
0.8
1.0
Neutron energy (MeV)
GMA, combined


^{197}Au(n,γ)
Ratio to ENDF/B-VI Evaluation
1.06
1.04
1.02
1.00
0.98
0.96
5.0e-1
1.0e+0
1.5e+0
2.0e+0
2.5e+
Neutron energy (MeV)
GMA, full GMA database
GMA, combined


^{235}U(n,f)
GMA, full GMA database
GMA, combined
Ratio to ENDF/B-VI Evaluation
1.06
1.04
1.02
1.00
0.98
5
10
15
20
Neutron energy (MeV)


^{238}U(n,f)
Ratio to ENDF/B-VI Evaluation
1.05
1.00
0.95
0.90
1
10
Neutron energy (MeV)
GMA, full GMA database
GMA, combined


^{238}U(n,γ)
Ratio to ENDF/B-VI Evaluation
1.08
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.5
1.0
1.5
2.0
Neutron energy (MeV)
GMA, full GMA database
GMA, combined


239Pu(n,f)
Ratio to ENDF/B-VI Evaluation
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
5
10
15
20
Neutron energy (MeV)
GMA, full GMA database
GMA, combined

Uncertainties

Though there is some uncertainty information available at this time, such data will not be released until further investigation has been completed for the entire evaluation. It is anticipated that covariance and variance data will be available early next year. The importance of considering the covariances not just the variances is stressed for any discussion of uncertainties.

Experimental and other work

•The analysis of measurements of the ^{10}B total cross section has been completed and made available for the standards evaluation.

•Hydrogen scattering angular distribution measurements at 15 MeV neutron energy are underway.
(collaboration with Ohio University and LANL)

• The NIST National Repository for Fissionable Isotope Mass Standards continues to acquire and monitor samples.

• Measurements have been made of the coherent scattering lengths for H and ^{3}He that are used in the evaluation of the H(n,n) and ^{3}He(n,p) cross sections.

• Improvements continue on a measurement of the ^{6}Li(n,t) cross section standard at ~ 4 meV neutron energy.