NIST Measurements and Standards Including Related Work at Other Facilities

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Presented at
The CSEWG Meeting
BNL
November 3, 2015

Motivation

- In order to improve the standards, it is essential to maintain an active program of measurements concerning the standards. Much of this work is supported under the IAEA Nuclear Data Development Project "Maintenance of the Neutron Cross Section Standards".

- Several libraries including ENDF/B and JEFF, will soon be producing new versions of their libraries. New and improved standards are needed for them.

- We have broadened the standards research effort by considering, in addition to the traditional activities related to standards, extending the energy ranges of the standards, including "reference data" that are not as well known as the standards but can be very useful in certain types of measurements, and certain neutron spectra data.

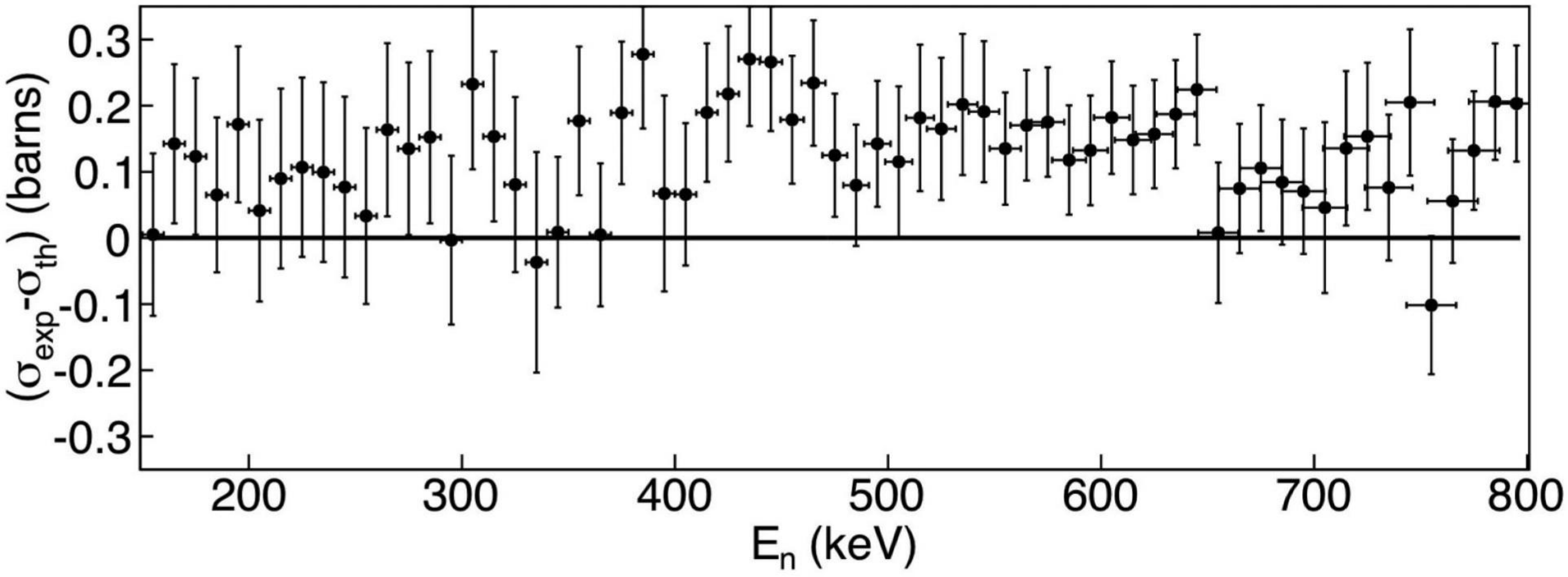
THE NEUTRON CROSS SECTION STANDARDS

Reaction	Energy Range
H(n,n)	1 keV to 20 MeV
$^{3}He(n,p)$	thermal to 50 keV
$^{6}Li(n,t)$	thermal to 1 MeV
$^{10}B(n,\alpha)$	thermal to 1 MeV
$^{10}B(n,\alpha_1\gamma)$	thermal to 1 MeV
C(n,n)	1 keV to 1.8 MeV
$^{197}Au(n,\gamma)$	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

H(n,n)H Standard Measurements

- Concerns about the hydrogen total scattering cross section at low neutron energies led to work at the University of Kentucky Van de Graaff by Daub *et al*. from 150 keV to 800 keV. The results are systematically slightly larger than the ENDF/B-VII values but generally within their uncertainties of 1.1 to 2%. (Phys Rev C87, 014005 (2013)). Including these data in the new hydrogen being done by Hale and Paris will cause a slight increase in the evaluated cross section. This would then lead to a somewhat better agreement with the Arndt evaluation. The Arndt evaluation is larger than ENDF/B-VII by about 0.1% at low energies and about 1% at about 12 MeV. Gerry however has found EDA normalizes these data down about 2%.

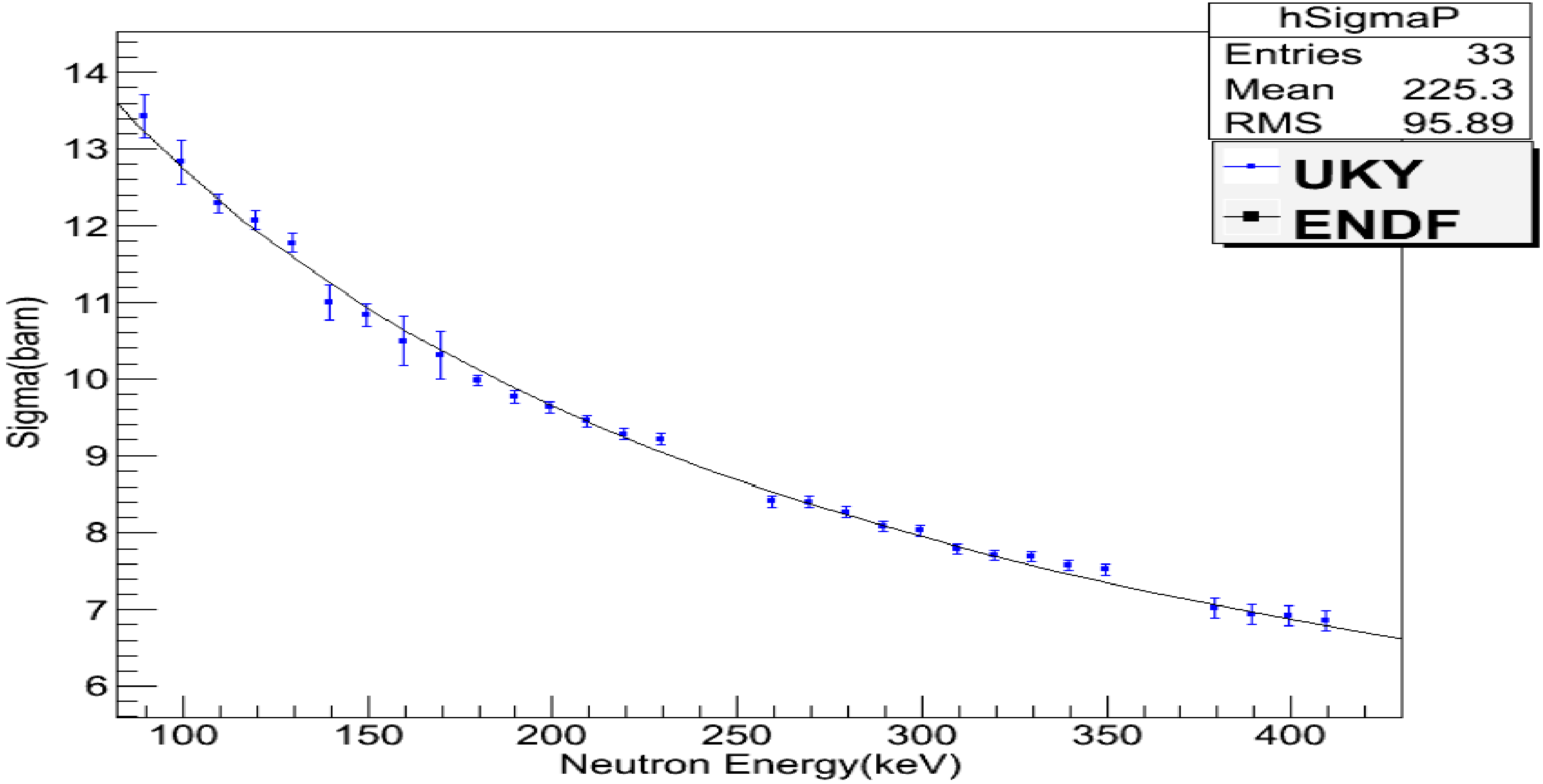
Daub *et al.* Hydrogen Total Cross Section-ENDF/B-VII Evaluation



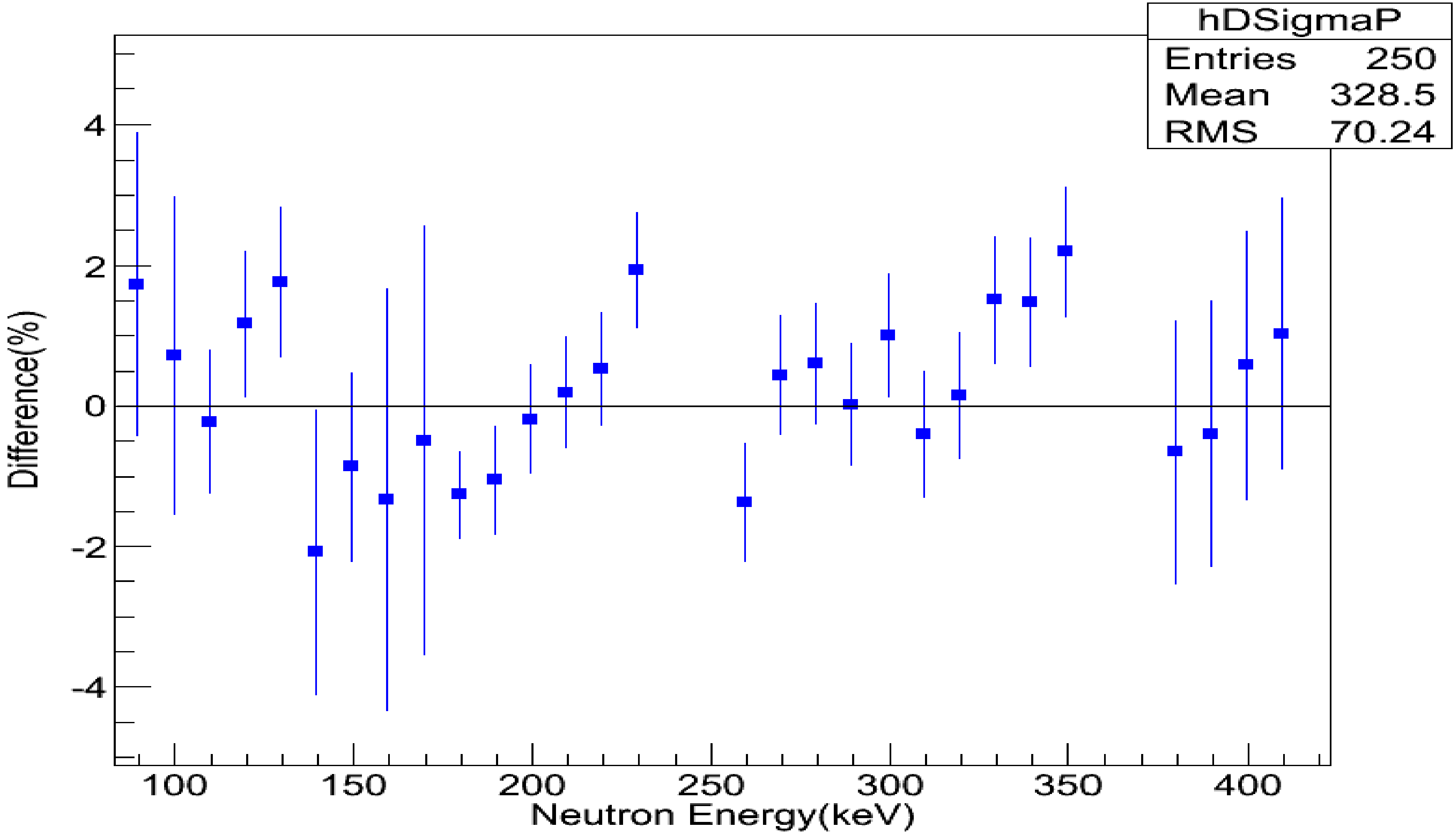
H(n,n)H Standard Measurements

- Additional total cross section work at Kentucky was done byYang as a thesis Project that was recently completed. The focus was getting to even lower energies than that obtained by Daub *et al*. The Van de Graaff data were obtained from 90 keV to 1.8 MeV with generally smaller uncertainties than those obtained by Daub *et al*. For these data it is not clear that the cross sections are slightly higher than ENDF/B-VII as was observed by Daub *et al*.

Yang Hydrogen Total Cross Section



Yang Hydrogen Total Cross Section-ENDF/B-VII Evaluation



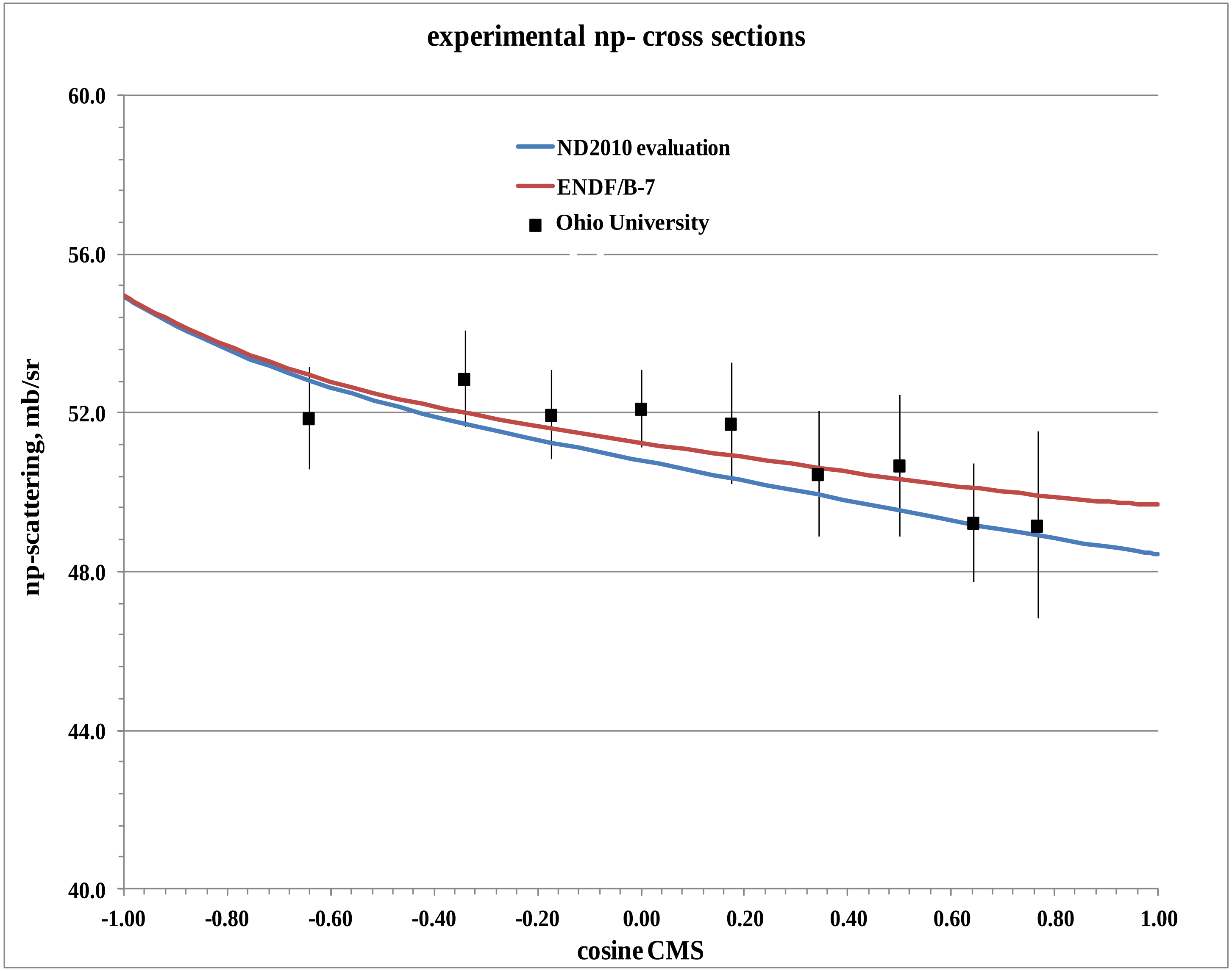
H(n,n)H Angular Distribution Measurements

- There is a problem with the quality of data at small CMS angles for hydrogen scattering. In order to improve the database of measurements at smaller scattering angles an experiment has been designed where the primary objective is detection of the scattered neutron instead of the scattered proton.

- The work was done at the Ohio University accelerator facility. Preliminary measurements have been made at laboratory neutron scattering angles from 20 degrees to 65 degrees in 5 degree steps for 14.9 MeV incident neutrons. The plan is to increase the accuracy of the measurements and extend the angular range so that data are obtained from 15 to 70 degrees. Plans have also been made to do similar measurements for 10 MeV neutrons. For this work the ^{252}Cf neutron spectrum standard was used to determine the efficiency of the neutron detector.

(collaboration of Ohio University, NIST, LANL and the University of Guelma)

14.9 MeV Hydrogen Angular Distribution Measurements



H(n,n)H Angular Distribution Measurements

- To obtain the higher accuracy needed for this work, the neutron detector efficiency must be determined more accurately.

- For our work, the detector efficiency is well known below about 6 MeV. For neutron detector efficiency determinations above that energy, a technique using reactions where the projectile and target are identical is being used. Because they are identical, the angular distribution **must** be symmetrical in the CMS. So the neutron yield at an angle Θ must be the same as that at 180- Θ in the CMS. But the energies of the neutrons are different in the LAB system. Thus in the LAB system, for a bombarding energy such that the backward portion of the angular distribution falls in the energy range below 6 MeV where the efficiencies are well known, we can deduce the efficiency for the higher energy group in the forward hemisphere.

- Many possible reactions were studied. D(d,n) turned out to be the best reaction and will be used for 10 MeV neutrons. A gas cell will be used. The Q value of 3.3 MeV will allow data to be taken at small angles for 10 MeV neutrons.

- Studies using MCNP in an effort to optimize the experiment are now underway.

(collaboration of Ohio University, NIST, LANL and the University of Guelma)

$^{6}Li(n,t)$ Measurements

- At the NIST Neutron Center for Neutron Research a measurement was made by Yue *et al*. of the $^{6}Li(n,t)$ cross section standard. The value obtained is 2563.3 ± 7.7 b for a neutron energy of 3.3245 ± 0.0016 meV.

- This is the first direct and absolute measurement of this cross section in this neutron energy range using monoenergetic neutrons.

- A primary effort was focused on measuring the neutron fluence accurately. It was determined with an uncertainty of 0.06%.

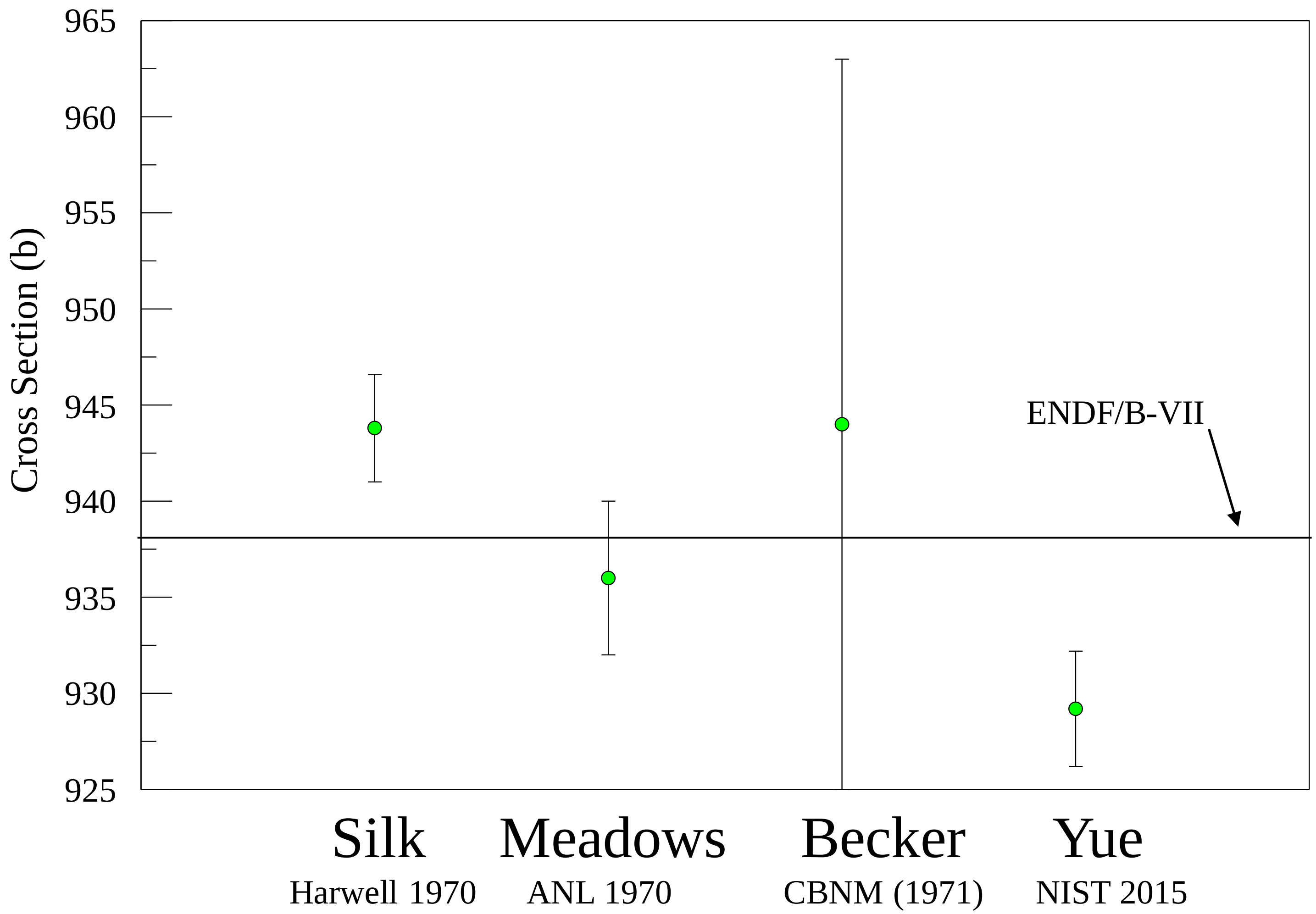
- Much investigation has gone into the uncertainty of this result. The uncertainty is mainly from the uncertainty in the ^{6}Li mass. The initial value obtained was in excellent agreement with the ENDF/B-VII standards evaluation. It was recently found that the mass reported by IRMM was in error. Using the new mass value produces a cross section value with an uncertainty of 0.3% that is 1% lower than the ENDF/B-VII value.

- **The low energy (thermal) cross section ENDF/B-VII value is largely determined by measurements made in 1970-1971.**
  - It is not clear how well they determined their ^{6}Li masses.

(collaboration of NIST with the University of Tennessee and Tulane University)

Thermal Measurements of the ^{6}Li(n,t) cross section

(The Yue value is converted to thermal energy)



$^{6}Li(n,t)$ Measurements

- Measurements have been made of the $^{6}Li(n,t)$ cross section by Devlin et al. at LANL. This work was initiated to improve the cross section in the 2 MeV energy region where the uncertainties in this cross section are large. This work includes angular distribution data obtained from 0.2 to 10 MeV at eight laboratory angles using four E-ΔE telescopes. These data are absolute ratios to the $^{235}U(n,f)$ cross section and also the hydrogen scattering cross section. The uncertainties are about 5%. These data have been added to the existing R-matrix database used by Hale for a new "independent evaluation" of the $^{6}Li(n,t)$ cross section. The new Hale evaluation is consistent with the Devlin et al. data.

^{6}Li(n,t) Measurements (cont.)

- It should be noted that the ENDF/B-VII.0 evaluation for the ^{6}Li(n,t) cross section up to 2.6 MeV is obtained from the international standards evaluation. But the cross section is a standard only up to 1 MeV. The result from the new "independent evaluation" by Hale including the results from the Devlin et al. data is about 4% higher than ENDF/B-VII.0 at 2 MeV.

- Thus the Devlin et al. data had an important impact on the new Hale evaluation.

- At 1 MeV, the highest energy where ^{6}Li(n,t) is a standard, the uncertainty is 1%. The difference between the "independent evaluation" by Hale and the previous standards evaluation is about 3%.

- It is still not clear what result will come from the present evaluation process but we must be concerned when very large changes occur relative to uncertainties for the standards!

$^{6}Li(n,t)$ Measurements (cont.)

- At the IRMM Van De Graaff facility Giorginis and Bencardino have made $^{6}Li(n,t)$ cross section measurements at the IRMM Van De Graaff facility. They are using a Time Projection Chamber that was designed and fabricated at IRMM. They are characterizing the ^{6}LiF samples with Thermal Neutron Depth Profiling. They obtained $^{6}Li(n,t)$ cross section data at 1.9, 2.0 and 2.1 MeV These data should overlap the GELINA data to be obtained from 1 to 3 MeV. The ^{6}Li deposits for both the GELINA and Van De Graaff measurements were made at IRMM. The data agree well with the ENDF/B-VII evaluation.

Results of the $^{6}Li(n,t)/^{238}U(n,f)$ cross section ratio measurement in the 2 MeV energy region at IRMM.
G. Giorginis, R. Bencardino, EC/JRC/IRMM, Geel, Belgium.
Private communication, 29 NOV 2014.

E_n(MeV)	$R=\sigma_{Li}/\sigma_U$	$(\Delta R/R)_{stat}$	$(\Delta R/R)_{sys}$	$(\Delta R/R)_{tot}$	σ_{Li}(b)	$\sigma_{7.1}$(b)	$\Delta\sigma/\sigma_{7.1}$
1.9	0.447	0.056	0.014	0.051	0.229	0.230	-0.004
2.0	0.430	0.009	0.014	0.020	0.230	0.228	+0.009
2.1	0.406	0.040	0.014	0.034	0.221	0.225	-0.018

In the above table the symbols have the following meanings:

-$(\Delta R/R)_{stat}$ stays for statistical (random) uncertainty.

-$(\Delta R/R)_{sys}$ stays for systematic uncertainty. It was obtained by quadratic addition of the uncertainties listed below together with their sources:

1. Number of ^{238}U atoms in the $^{238}UO_4.H_2O$ sample $\rightarrow$ $(\Delta R/R)_1 = 0.006$
2. Number of ^{6}Li atoms in the ^{6}LiF sample $\rightarrow$ $(\Delta R/R)_2 = 0.007$
3. Fission fragment loss in the $^{238}UO_4.H_2O$ sample $\rightarrow$ $(\Delta R/R)_3 = 0.001$
4. Hidden $^{6}Li(n,t)$ events $\rightarrow$ $(\Delta R/R)_4 = 0.001$
5. Manual ROI definition in $^{6}Li(n,t)$ and FF spectra $\rightarrow$ $(\Delta R/R)_5 = 0.01$

-$(\Delta R/R)_{tot}$ stays for total uncertainty. It was obtained by quadratic addition of $(\Delta R/R)_{stat}$ and $(\Delta R/R)_{sys}$.

No correlation analysis was performed for the calculation of $(\Delta R/R)_{sys}$ and $(\Delta R/R)_{tot}$. They are indicative uncertainty values.

The fission fragment loss ε, used as correction for the production of the σ_{Li}/σ_U ratio, was calculated by using an analytical relation taking into account the effects of sample thickness, momentum transfer and angular distribution. The obtained ε values as function of energy are: $\varepsilon=0.056$ for $E_n=1.9$ MeV, $\varepsilon=0.054$ for $E_n=2.0$ MeV and $\varepsilon=0.052$ for $E_n=2.1$ MeV.

Backgrounds were determined by performing measurements with beam OFF and beam ON with substrate blanks in the position of the ^{6}Li and ^{238}U samples.

Other backgrounds such as those induced by scattered neutrons were not taken into account.

$^{6}Li(n,t)$ Measurements

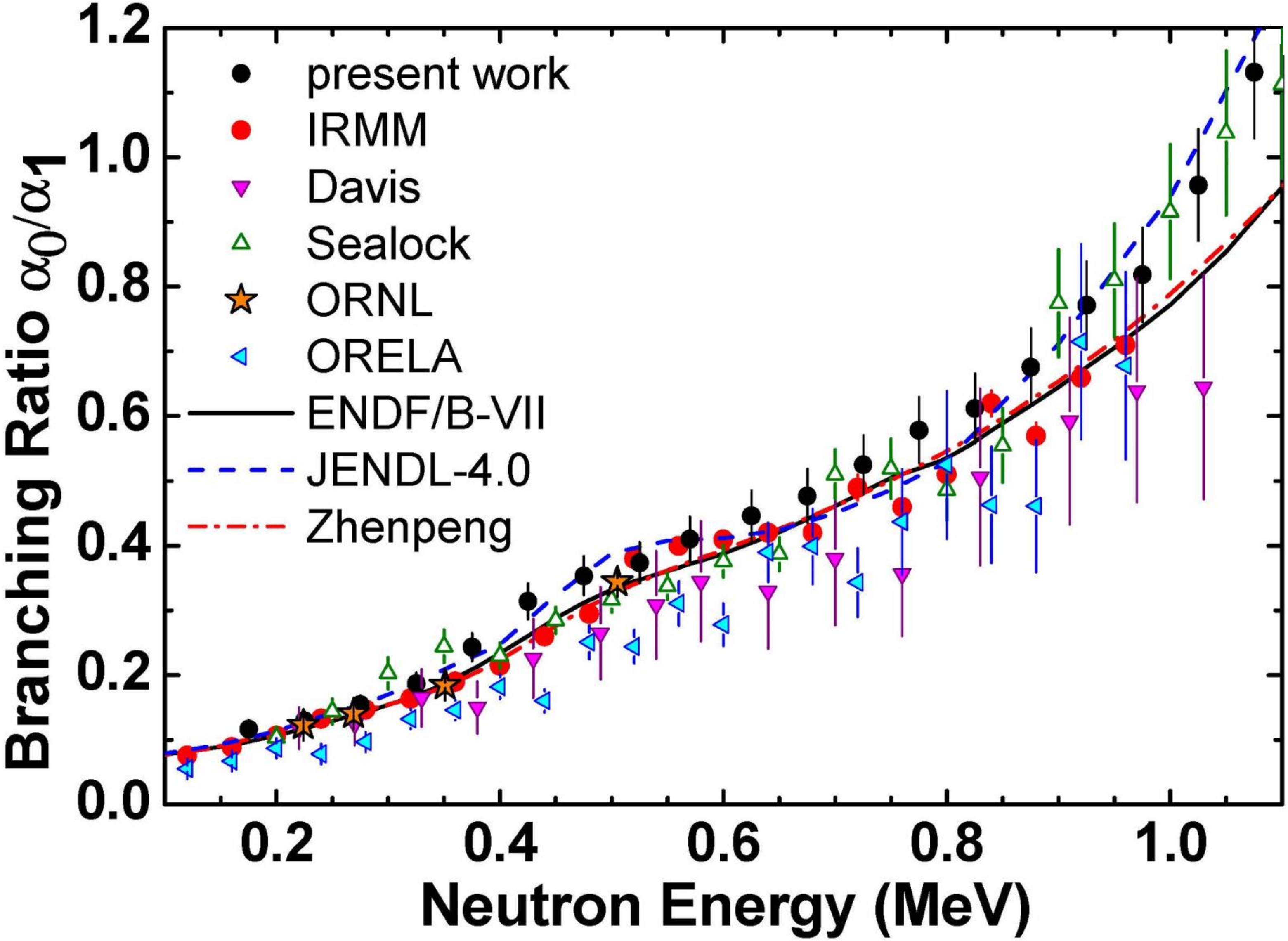
- At the GELINA linac, Hambsch plans angular distribution and cross section measurements for the $^{6}Li(n,t)$ reaction. The cross section data will be relative to the $^{235}U(n,f)$ standard. This work will extend from a few keV to about 3 MeV so the resonances at 0.25 and the weak one at about 2 MeV will be covered. The ^{6}Li samples were supposed to be made last year. They are using a digital data acquisition system for these experiments.

$^{10}B(n,\alpha)$ Measurements

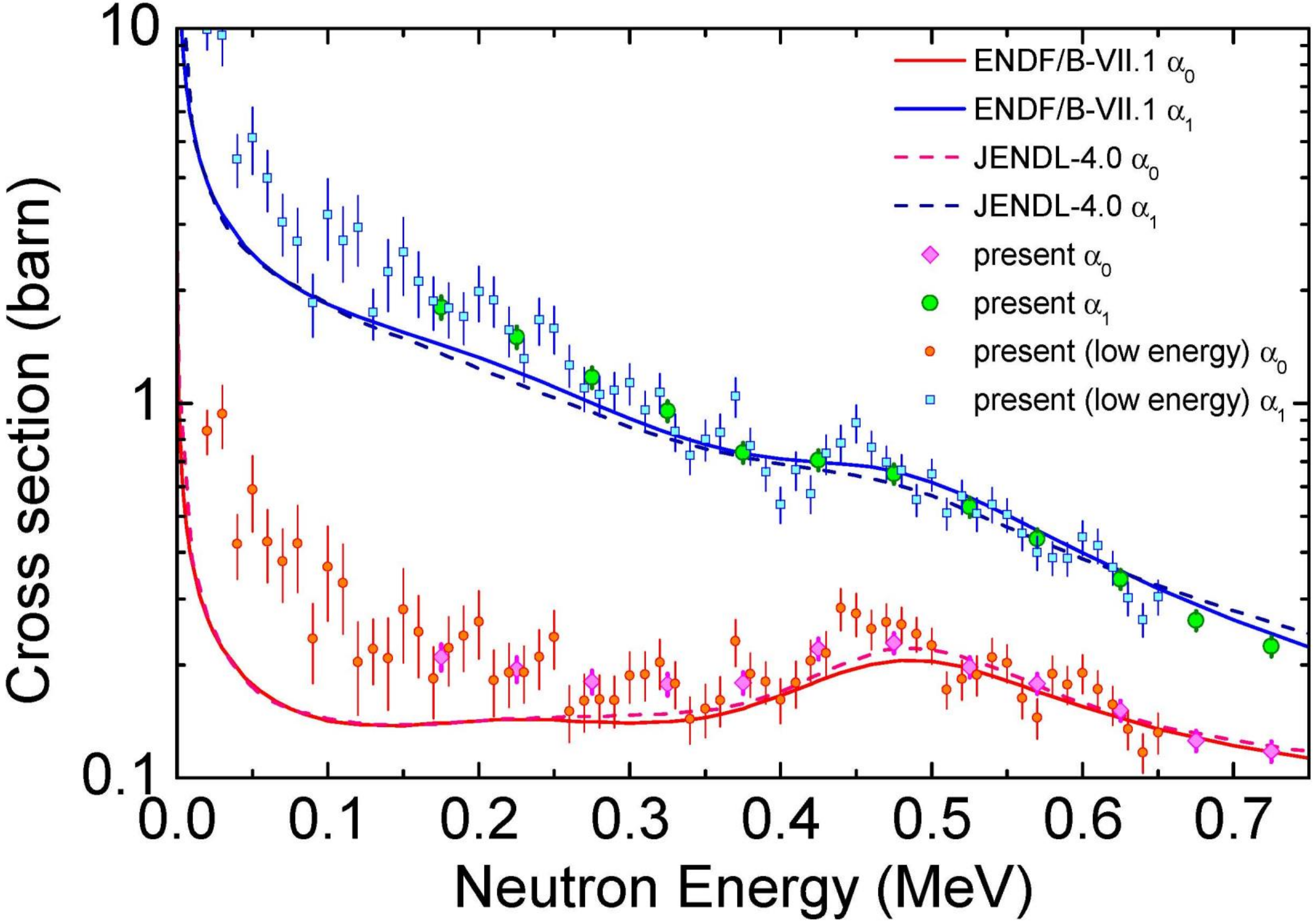
- Hambsch continues to accumulate data on the branching ratio, the angular distribution and the $^{10}B(n,\alpha)$ and $^{10}B(n,\alpha_1\gamma)$ cross sections relative to the $^{235}U(n,f)$ standard up to about 3 MeV. This work is being done at the 60m station of GELINA at IRMM. He has taken data with very good statistics that cover that energy region.   In the energy region below 1 MeV, the new branching ratio measurements look reasonable but the $^{10}B(n,\alpha)$ and $^{10}B(n,\alpha_1\gamma)$ cross sections used to make that ratio are strange below 0.5 MeV. It could be something in common such as the fluence determination.

- Additional analysis and work at a shorter flight path are planned

IRMM Preliminary Measurements of the $^{10}B(n,\alpha)$ Branching Ratio



IRMM Preliminary Measurements of the $^{10}B(n,\alpha_0)$ & $^{10}B(n,\alpha_1)$ Cross Sections

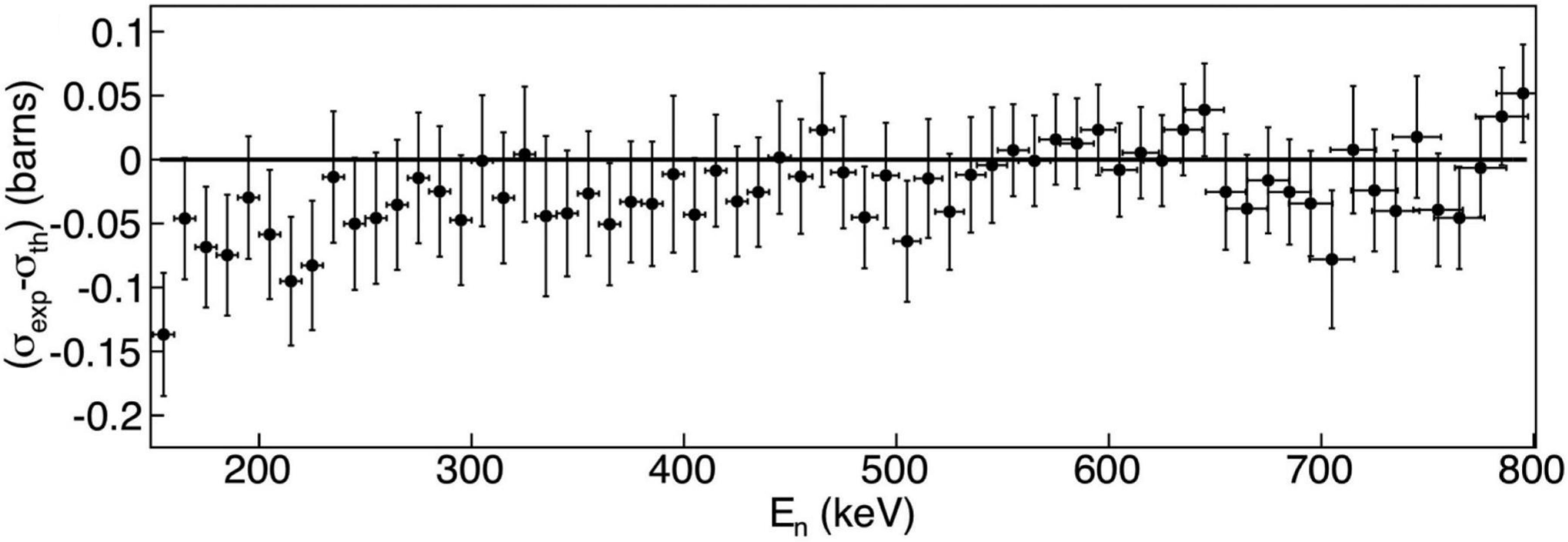


C(n,n) Data

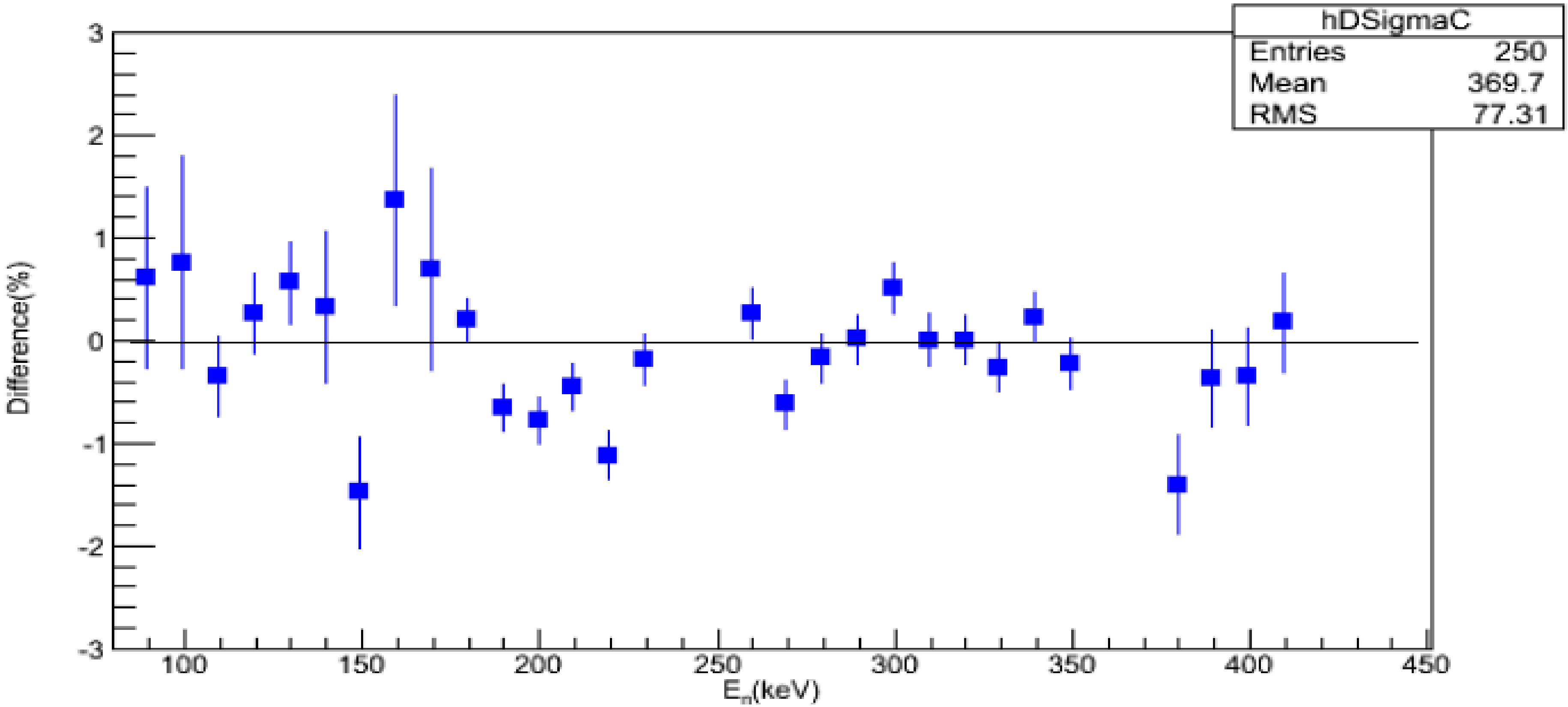
- In addition to their work on the hydrogen total cross section, Daub *et al.* also made very accurate measurements of the carbon total cross section from 150 keV to 800 keV. The results were systematically very slightly lower than the ENDF/B-VII values values but generally within their uncertainties of 1.1 to 2%.

- Additional total cross section work at Kentucky was done by Yang as a thesis Project that was recently completed. The focus was getting to even lower energies than that obtained by Daub *et al.* The Van de Graaff data were obtained from 90 keV to 1.8 MeV with generally smaller uncertainties than those obtained by Daub *et al.* For these data it is not clear that the cross sections are slightly lower than ENDF/B-VII as was observed by Daub *et al.*

Daub *et al.* Carbon Total Cross Section



Yang Carbon Total Cross Section - ENDF/B-VII Evaluation



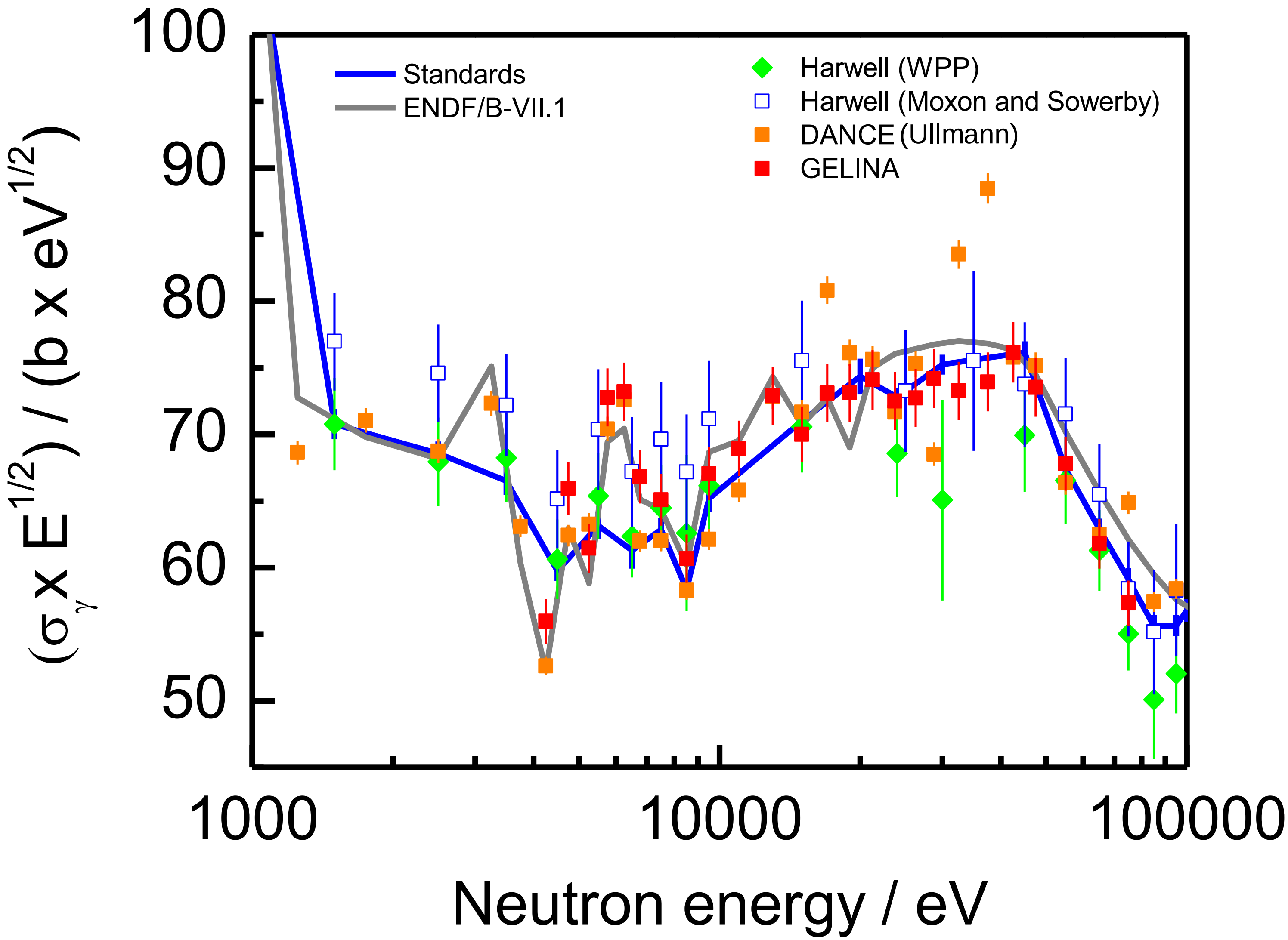
Au(n,γ) and ^{238}U(n,γ) Measurements

- Wallner (U. of Vienna) made measurements of the ^{238}U(n,γ)/^{197}Au(n,γ) cross section ratio at 426 keV. Accelerator mass spectrometry was used to measure the ^{239}Pu resulting from the ^{239}U. Activation was used for the gold measurements. The measurement has a large (150 - 200 keV FWHM) energy spread. That ratio, 0.99± 0.04, compared with the standards evaluation is in excellent agreement.

$^{238}U(n,\gamma)$ Measurements

- Ullmann et al. made measurements of the $^{238}U(n,\gamma)$ cross sections using the DANCE (160 BaF_2 crystals) detector at LANSCE. The neutron beam was monitored with a ^{235}U fission chamber, a BF_3 counter, a ^6Li F detector and a ^3He detector. Small ^{238}U samples could be used due to the high neutron intensity at DANCE. This reduces the uncertainty due to multiple scattering. Though the data could be made absolute, they are normalized to capture in the 80 and 145 eV resonances. Since the data are normalized in this manner, not to a standard set of reactions, they will be used as shape data in the evaluation. They associate a 2 percent uncertainty to this normalization. The energy range is 10 eV to 500 keV. In the evaluation, the data will be used up to 10 keV and above 200 keV because of an apparent contribution from aluminum resonances from the encapsulation of the sample.

Measurements of the $^{238}U(n,\gamma)$ Cross Section



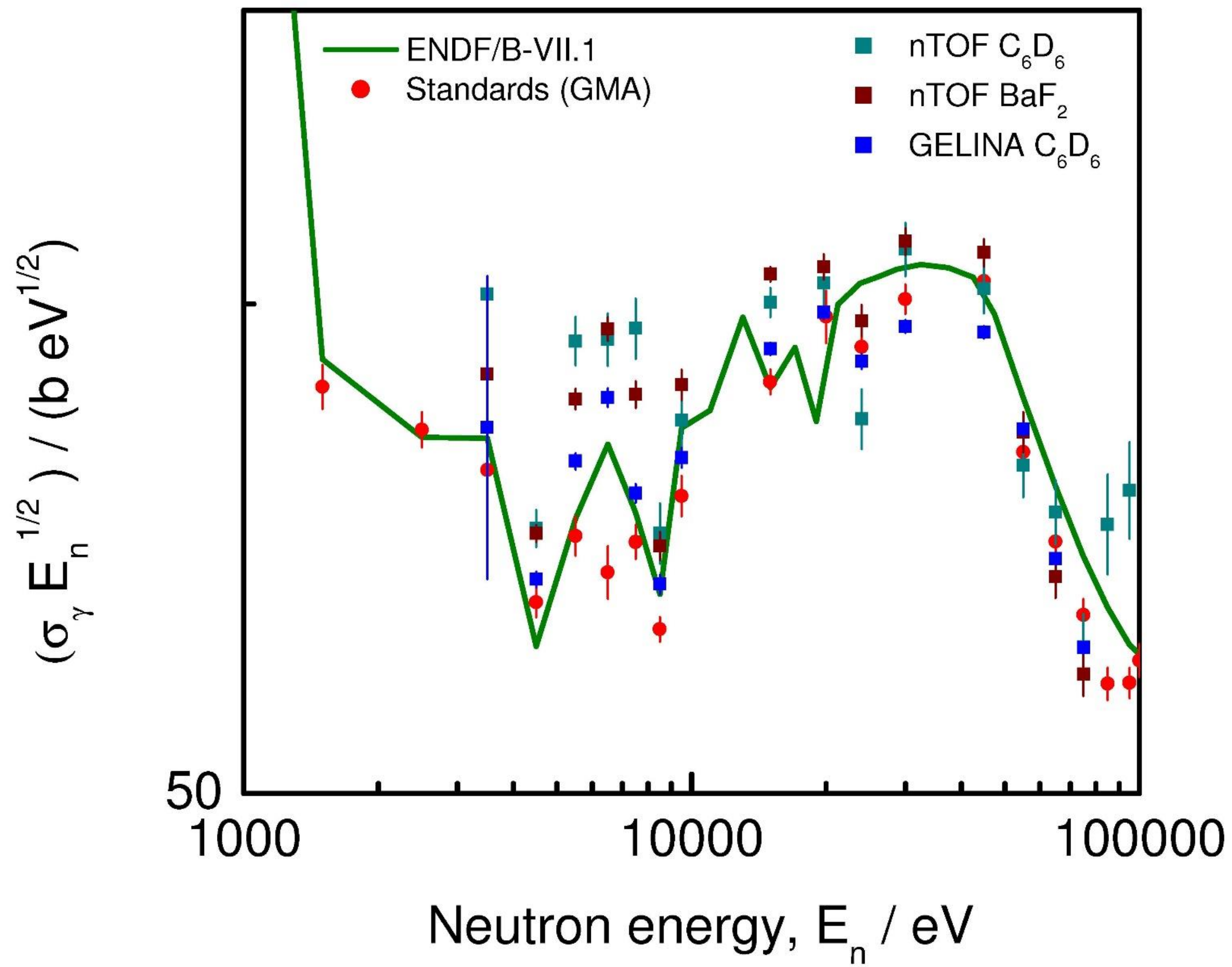
$^{238}U(n,\gamma)$ Measurements

Measurements have been made recently at GELINA and n_TOF using the same sample.

- At GELINA measurements were made using a C_6D_6 detector. ND2013 paper with Lampoudis et al. as authors

- At n_TOF, measurements were made with a C_6D_6 detector by Mingrone et al. and with a BaF_2 detector by Wright. They have an ND2013 paper

Recent Measurements of the $^{238}U(n,\gamma)$ Cross Section



^{235}U(n,f) Measurements

- There have not been any new measurements. However work at the_TOF facility in a publication by Barbagallo has raised some concerns about the cross section in the energy region from about 10 to 30 keV (not in the standards energy region).

- Their work compared fluence determinations based on ^{10}B(n,α), ^{6}Li(n,t) and two ^{235}U(n,f) based detectors.

- The two ^{235}U(n,f) based detectors agreed with each other but were about 10% lower from about 10 keV to 30 keV than the ^{10}B(n,α) & ^{6}Li(n,t) detectors.

- This could indicate a problem with the ^{235}U(n,f) cross section or a problem with the n_TOF data.

- This requires more investigation.

$^{238}U(n,f)/^{235}U(n,f)$ Measurements

- Four measurements of the $^{238}U(n,f)/^{235}U(n,f)$ cross section ratio were made at the n_TOF facility.

  - Fission chamber measurements were made (by Calviani).

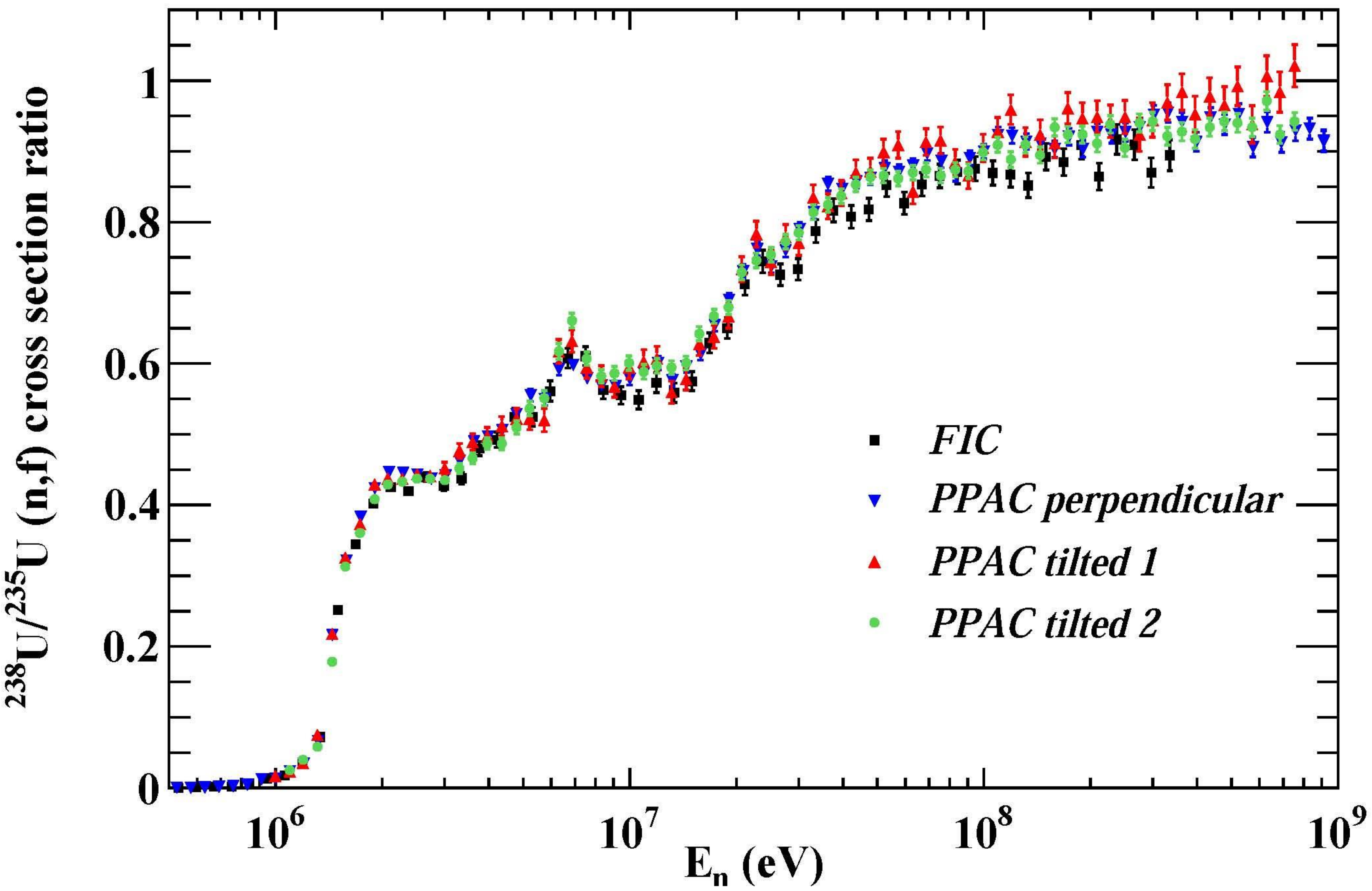
  - Parallel plate avalanche counters were used for 3 sets of measurements (all formerly associated with Audouin).

    - The same deposits were used for both the PPAC perpendicular (by Paradela) and the PPAC tilted 1 (by Tarrio) measurements. The difference was that the perpendicular measurements were made with the deposits perpendicular to the beam direction whereas the tilted 1 measurements were made with the deposits at 45° to the beam direction.

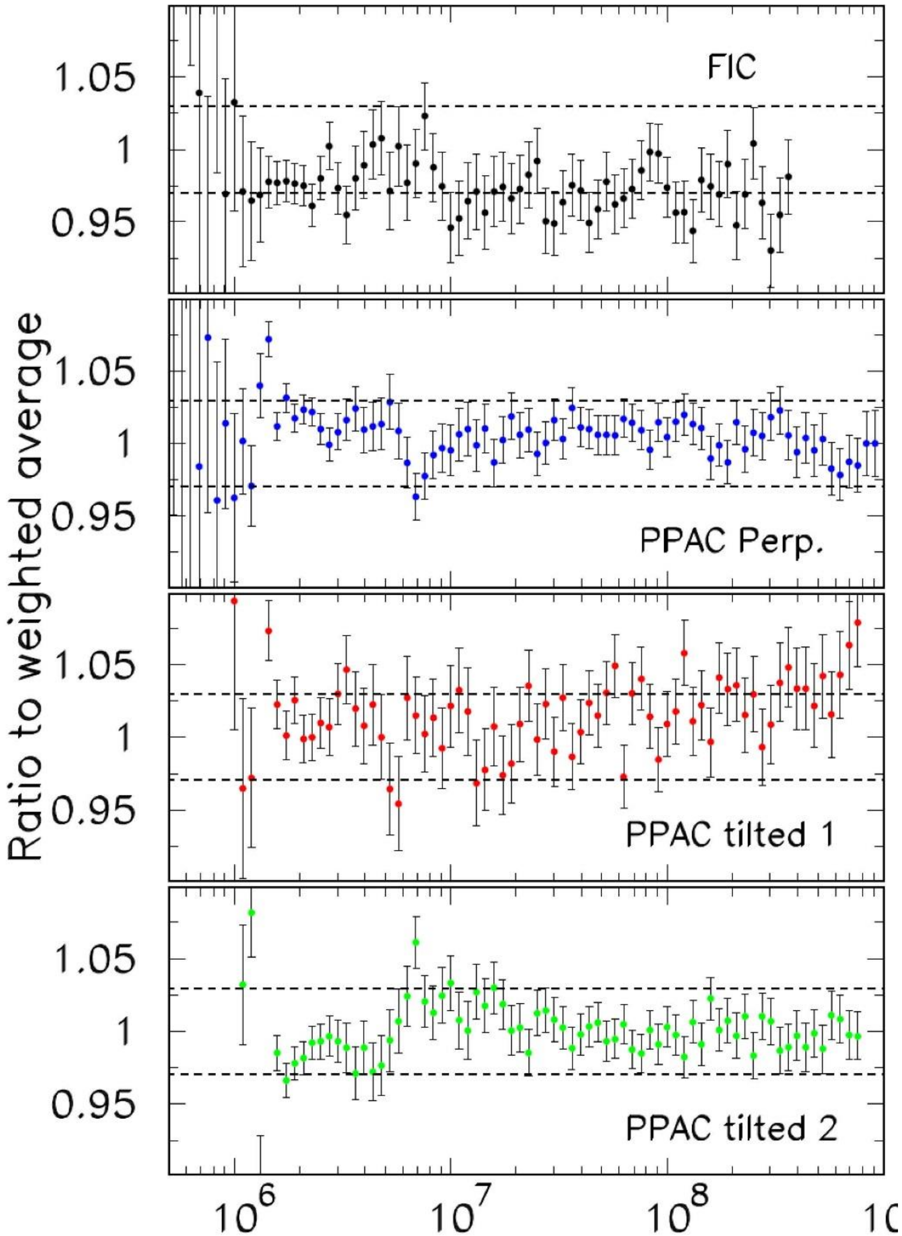
    - The third setup for the PPAC detectors, PPAC tilted 2 (by leal-chidoncha), again were made with the deposits at 45° to the beam direction, were not as well characterized as the other deposits so they were normalized to ENDF/B-VII.1 between 3 and 5 MeV.

- The PPAC sets are about 3% higher than the fission chamber data but they agree within their uncertainties. They all agree well with the standards evaluation.

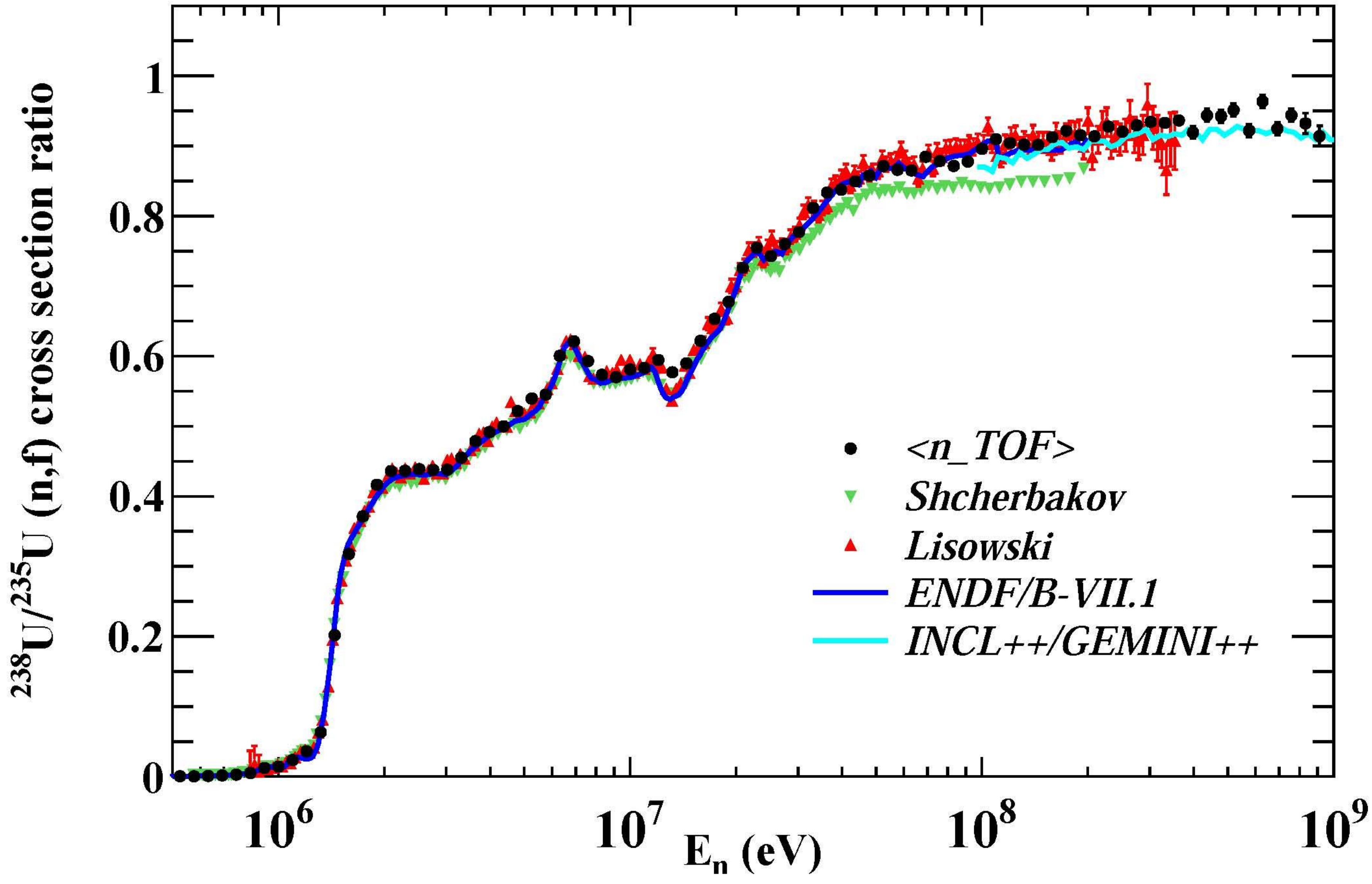
$^{238}U(n,f)/^{235}U(n,f)$ n_TOF Measurements



n_TOF - Comparison of Results With Each Detector



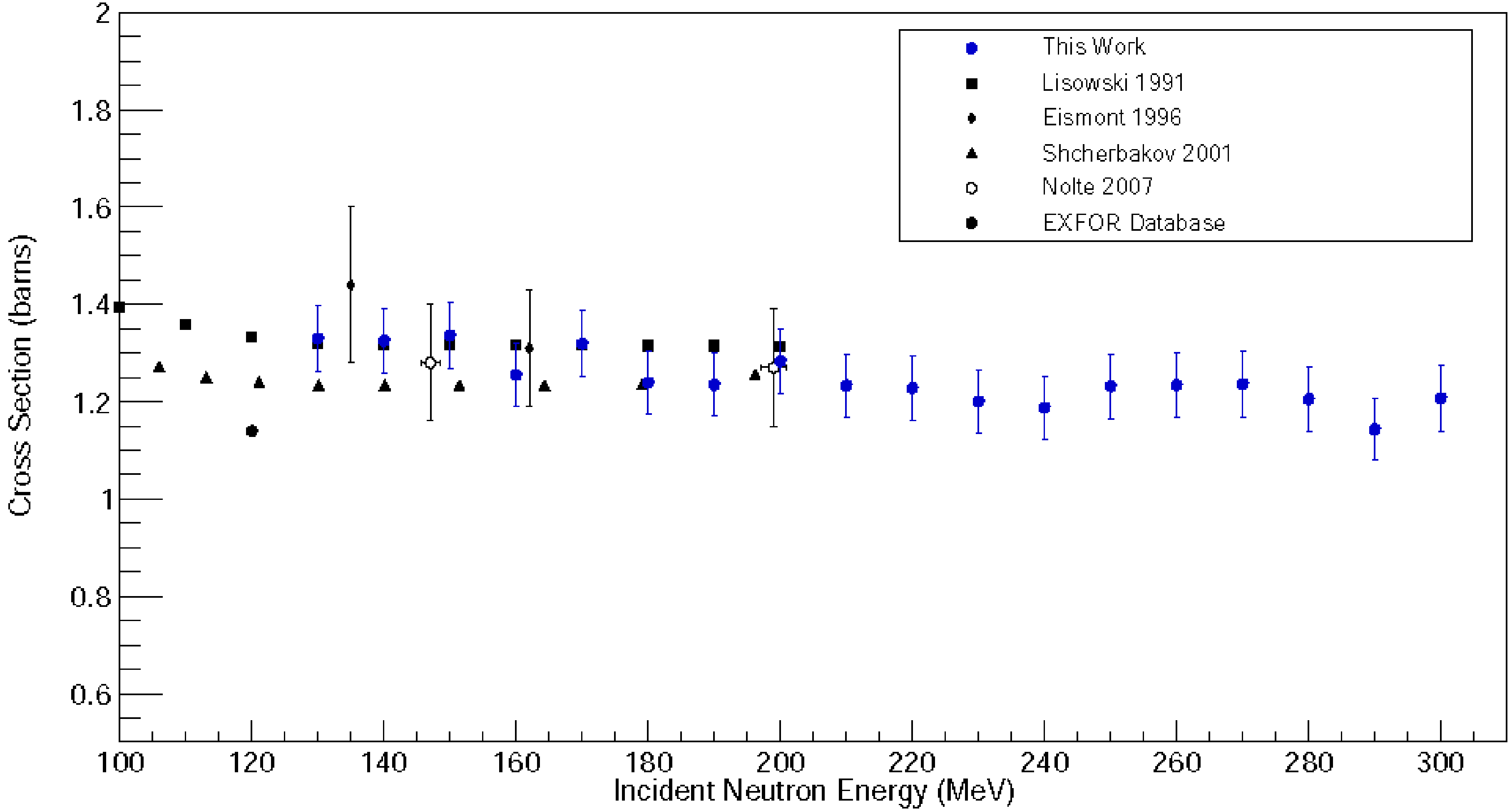
$^{238}U(n,f)/^{235}U(n,f)$ Measurements and Evaluations



$^{238}U(n,f)$ Measurements

- Measurements have been completed and analyzed by Miller from the University of Kentucky of the $^{238}U(n,f)$ cross section relative to hydrogen scattering. The absolute data are shape measurements extending from 100 to 300 MeV. The data were obtained at the LANL WNR facility. There may be some very minor changes to the Data.

Measurements of the $^{238}U(n,f)$ Cross Section by Miller



^{239}Pu(n,f) Measurements

- The most recent ^{239}Pu(n,f) cross section measurements were made by Tovesson and Hill at WNR-LANL.

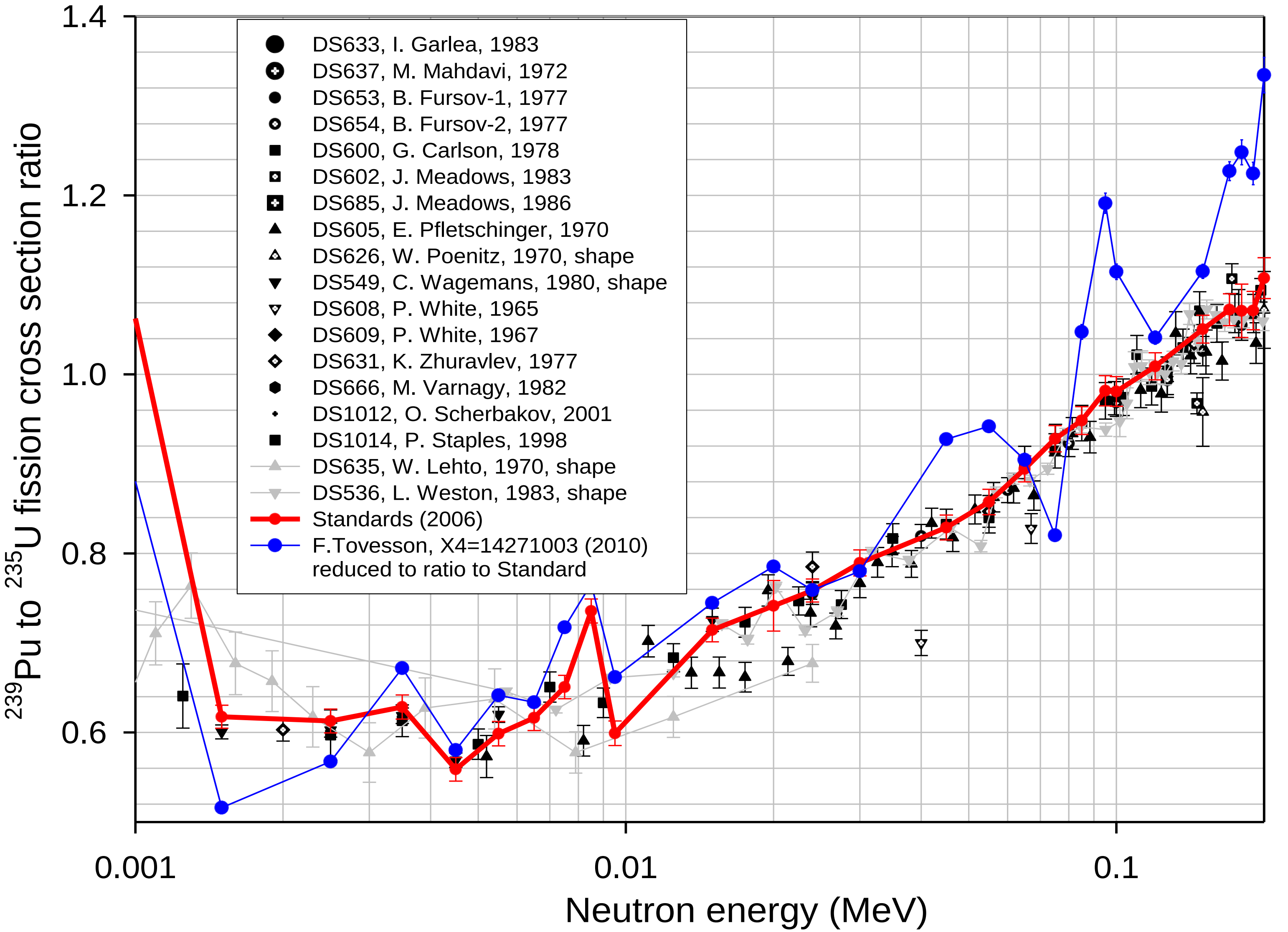
- The data are actually two separate measurements, one for energies from 0.01 eV to 200 keV and one for 200 keV to 200 MeV.

- In the low energy experiment, structure not present in other experiments, is present. Only the data below 30 keV will be used in the next evaluation of the standards

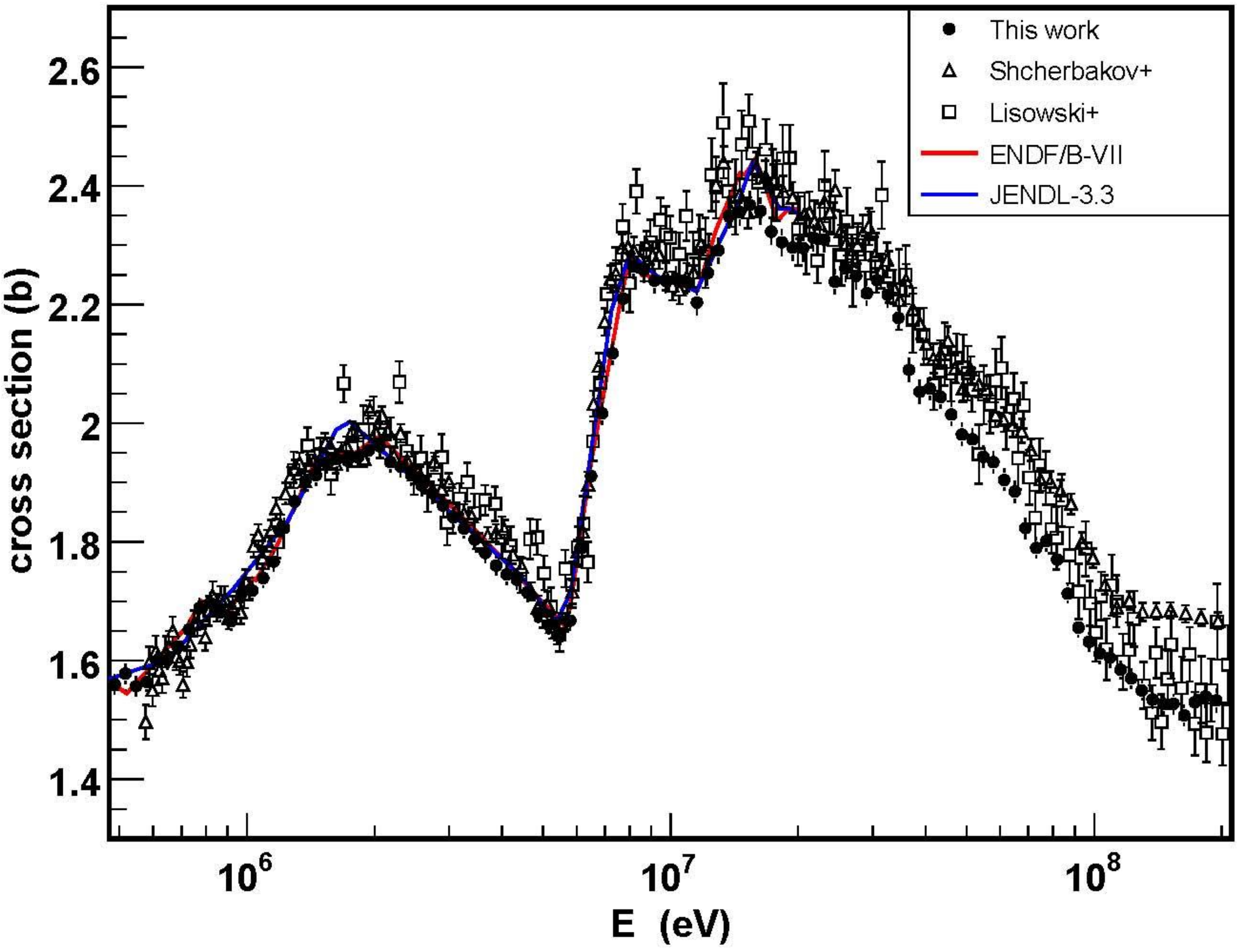
- For the high energy experiment, it agrees reasonably well with the ENDF/B-VII standards evaluation and the Lisowski *et al.* and Shcherbakov *et al.* measurements up to about 10 MeV. The new measurements have somewhat smaller uncertainties than these other two data Sets.

- Above 10 MeV the measurements fall somewhat lower than the ENDF/B-VII evaluation and the Lisowski et al. and Shcherbakov *et al.* measurements except above about 100 MeV where they agree with the Lisowski et al. data.

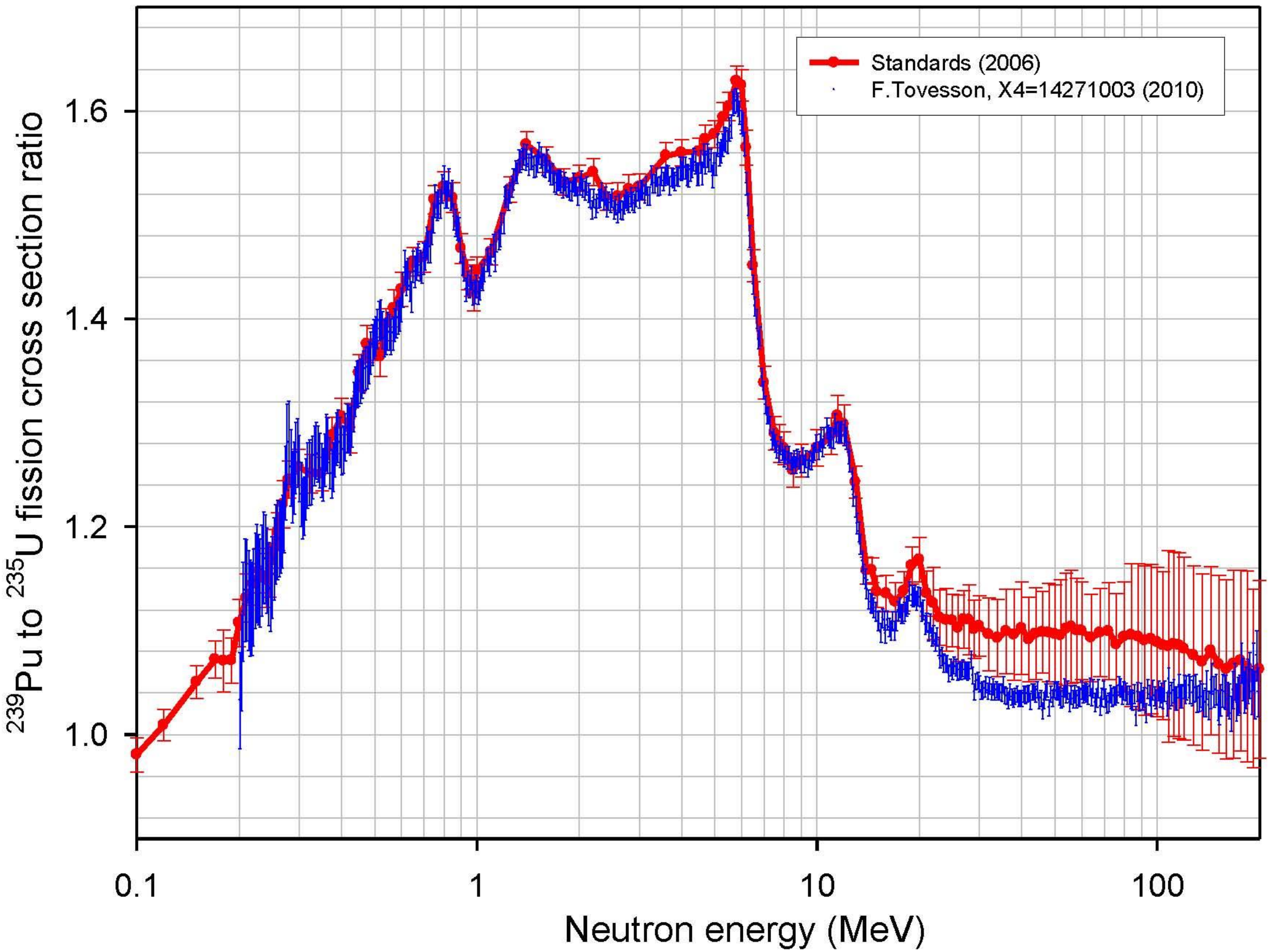
Low Energy Measurements of the ^{239}Pu(n,f) Cross Section



Measurements of the ^{239}Pu(n,f) Cross Section by Tovesson & Hill (labelled "This work"), Shcherbakov et al. and Lisowski et al. Compared With the ENDF/B-VII Evaluation



Measurements of the ^{239}Pu(n,f)/ ^{235}U(n,f) Cross Section by Tovesson and Hill Compared with the Standards



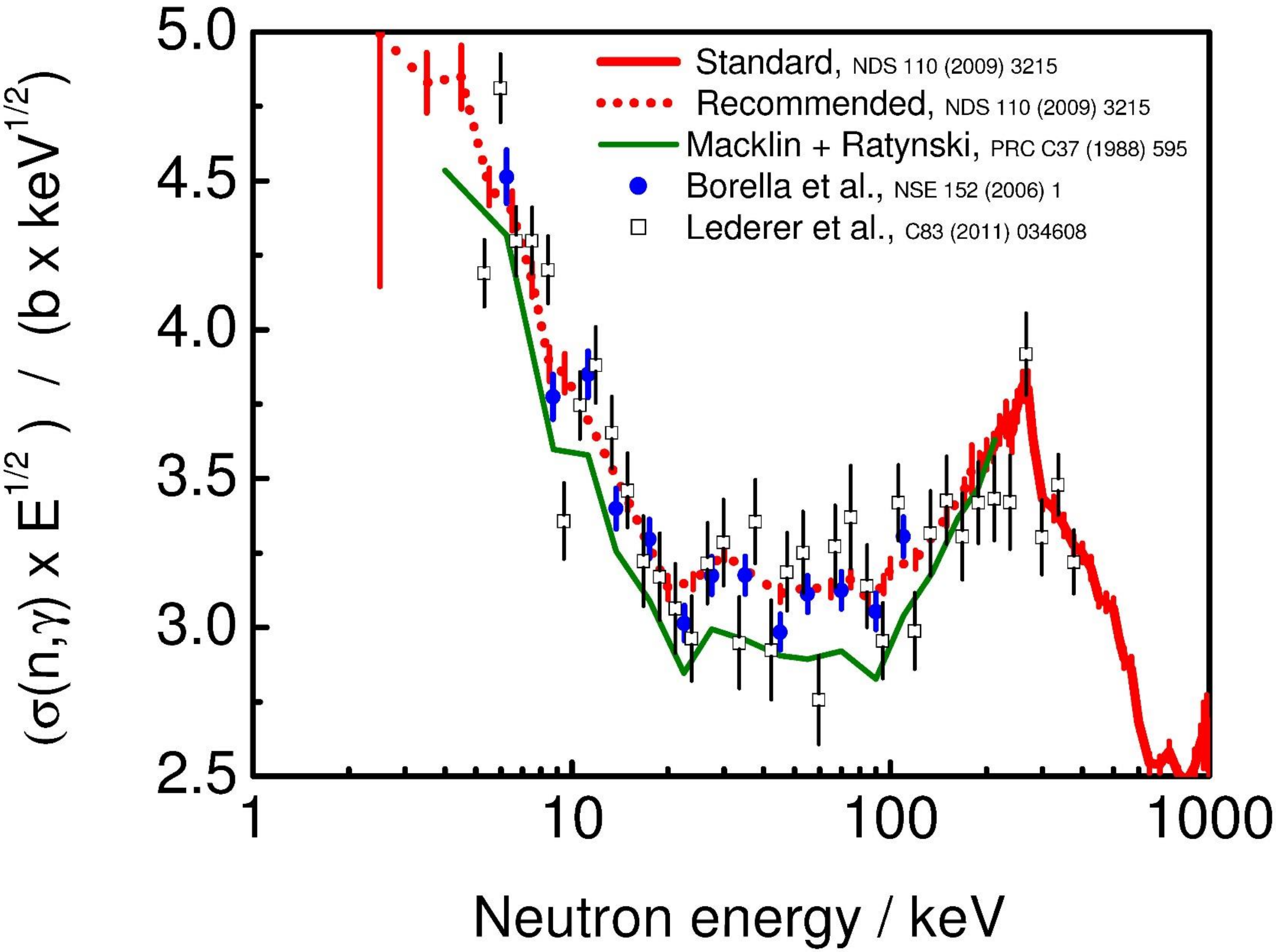
Additional Standards Work

- In order to improve the standards on a continuing basis, an IAEA Nuclear Data Development Project “Maintenance of the Neutron Cross Section Standards” was initiated.
  - This project has pursued improvements in the experimental database, considered additional standards, maintained evaluation codes and will periodically update the standards so they are available for new versions of data libraries. In addition to the conventional standards:
    - Work has been done on the gold cross section at energies below where it is considered a standard.
    - Reference cross sections for prompt gamma-ray production in fast neutron-induced reactions have been studied and the best candidates have been suggested.
    - An effort was directed at improvements in the evaluations of the ^{252}Cf spontaneous fission neutron spectrum and the ^{235}U thermal neutron fission spectrum

Au(n,γ) Data at Low Neutron Energies

- Au(n,γ) reference cross section for capture cross section measurements for astrophysics (below the standards energy region)
  - The measurements cited below all support the results of the standards evaluation. They indicate the Ratynski and Käppeler results are low by about 5-7% from 15 to 25 keV.
    - Wallner using AMS with a simulated Maxwellian neutron source spectrum of 25 keV mean energy obtained a ratio to the standards evaluation for gold capture of 1.04 ± 0.05
    - Lederer reanalyzed n_TOF gold capture data of Massimi and folded a simulated Maxwellian neutron source spectrum of 25 keV mean energy into that data. The result was 564 ± 23 mb compared with the standards evaluation of 575 mb. That is a 2% difference with an uncertainty of 4%.
    - The Au(n,γ) cross section measurements of Borella et al. support the standards evaluation. Schillebeeckx repeated that experiment of Borella et al. with considerable concern about corrections to the data. The new results support the standards results.

Low Energy Au(n,γ) Cross Section Measurements and Evaluations



Reference Cross Sections

- Reference cross section are not standards but they are used in some applications as effective standards. There are generally some limitations on them compared with the traditional standards. It is preferred that the standards community review and evaluate them.

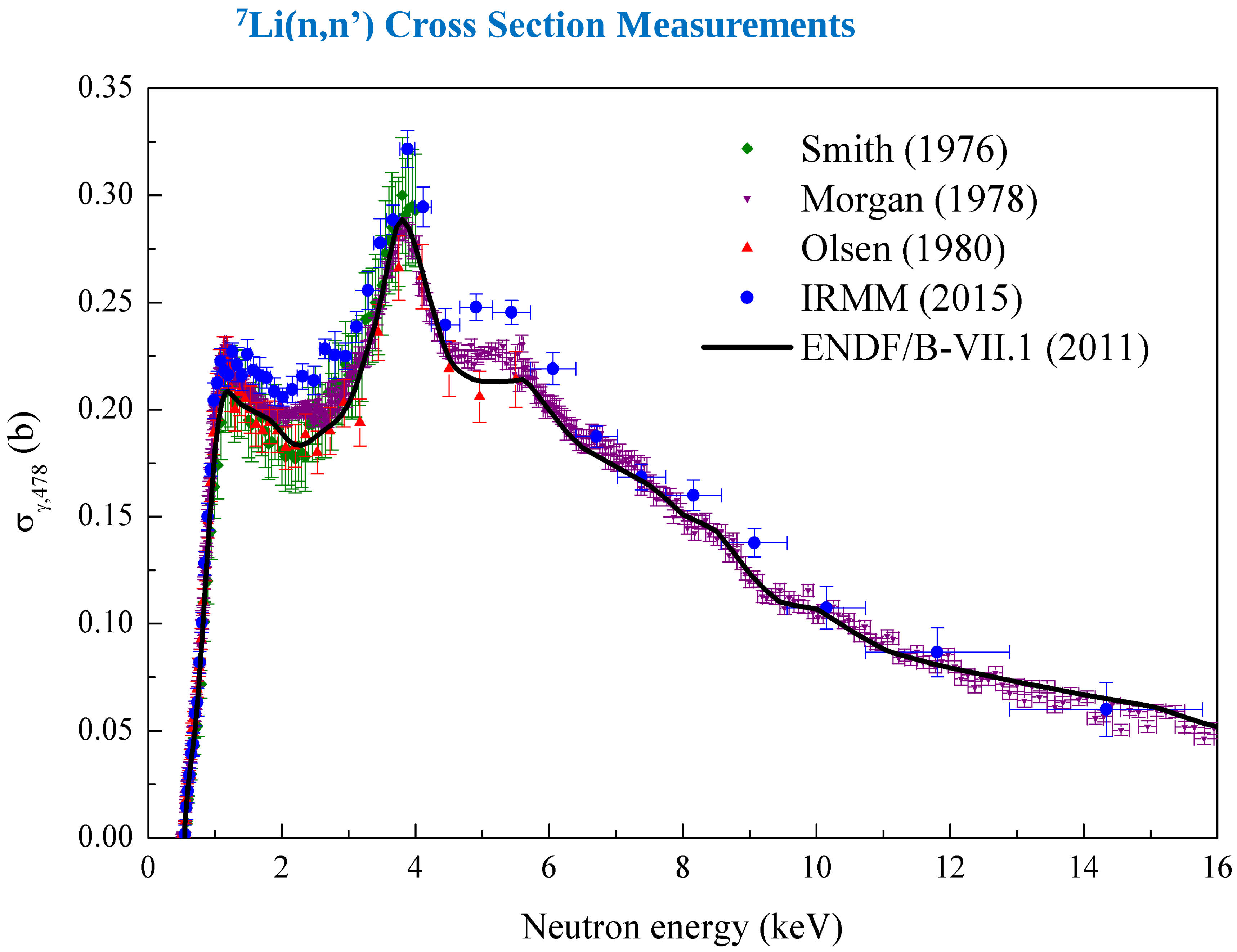
  - Desired properties of reference standards (similar to those for the traditional standards)
    - Accurately known.
    - Large cross section.
    - Suitable physical/chemical properties.
    - Relatively smooth cross section as a function of incident neutron energy and angle. Best if the cross section is almost constant and the angular distribution is isotropic.
    - Small backgrounds from materials in the experiments
    - Small activation gamma problems
    - Other cross sections for the material should be well known so corrections for scattering can be made accurately.
    - High energy gamma-ray, well separated from background gamma rays.

Reference cross sections for measurements of prompt gamma-ray production cross sections

- The existing $^{10}B(n,\alpha_1\gamma)$ standard cross section with a 478 keV gamma-ray can be used for the energy range from 10^{-5} eV to 1 MeV.

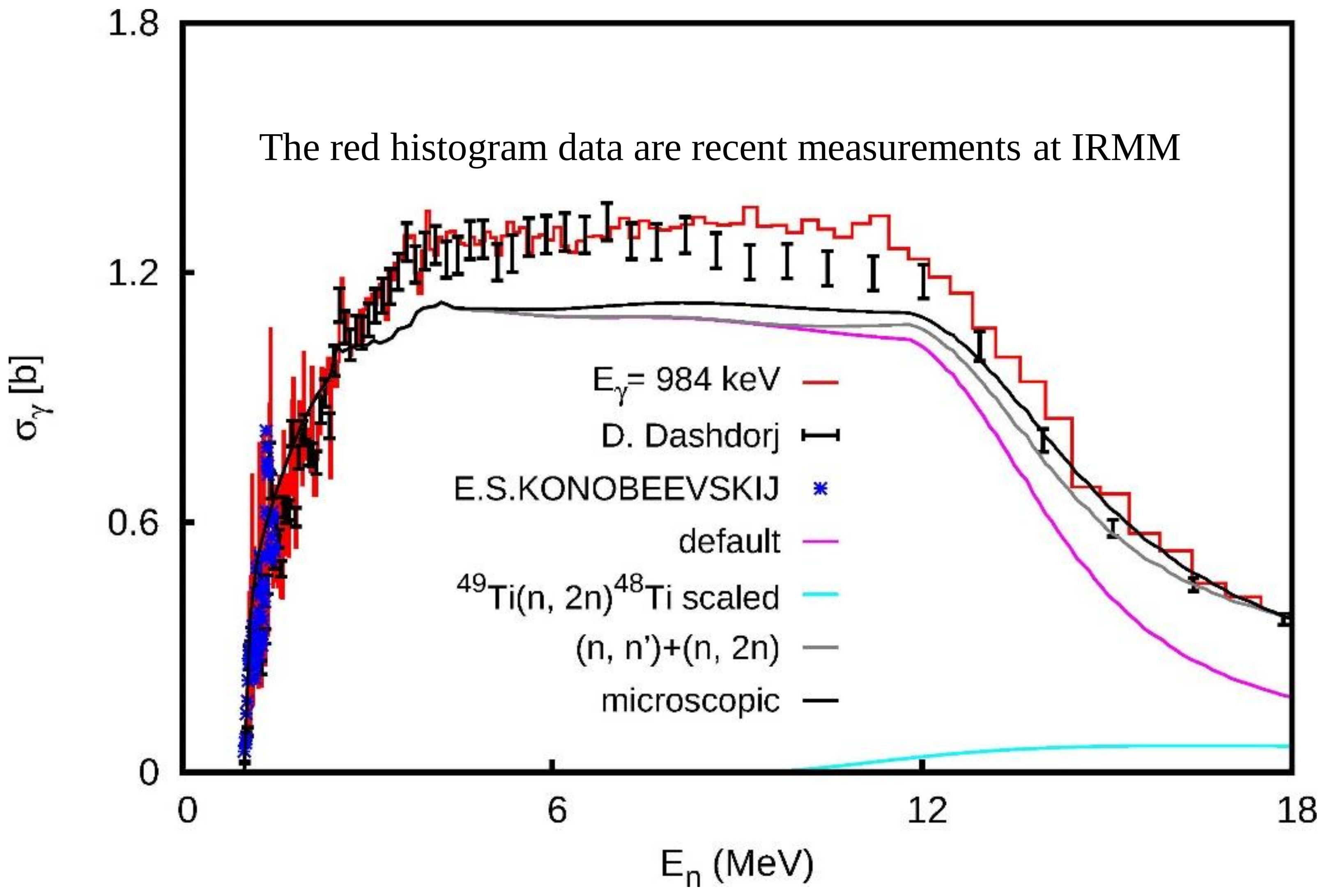
- The $^{7}Li(n,n'\gamma)$ cross section with a 478 keV gamma-ray is suggested as a reference cross section for the energy range from about 1 MeV – 5 MeV.
  - New measurements have been made by Nelson with GEANIE
  - There are IRMM data.
  - More work should be done at higher neutron energies.

- The $^{48}Ti(n,n'\gamma)$ cross section with a 984 keV gamma-ray is suggested as a reference cross section for the energy range from 3-15 MeV. More work needs to be done to improve the experimental database.
  - New measurements by Nelson using GEANIE have been made and are being analyzed.
  - IRMM data are being prepared for publication.
  - An improved evaluation by Simakov has been done.

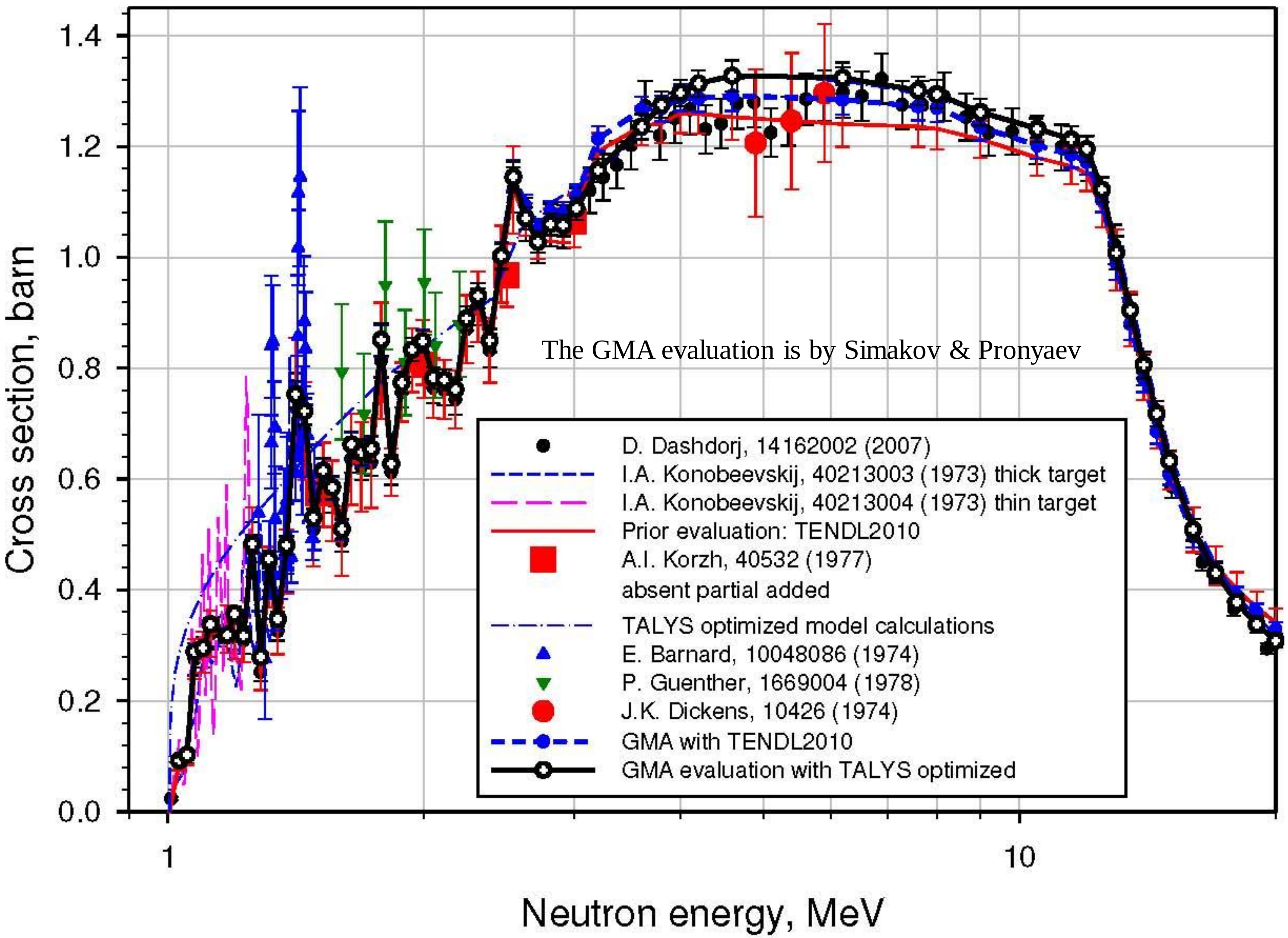


^{7}Li(n,n') Cross Section Measurements
Smith (1976)
Morgan (1978)
Olsen (1980)
IRMM (2015)
ENDF/B-VII.1 (2011)
$\sigma_{\gamma,478}$ (b)
Neutron energy (keV)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0
2
4
6
8
10
12
14
16

Recent Measurements of the $^{48}Ti(n,n'\gamma)$ cross section



Measurements of the $^{48}Ti(n,n'\gamma)$ Cross Section and Evaluations

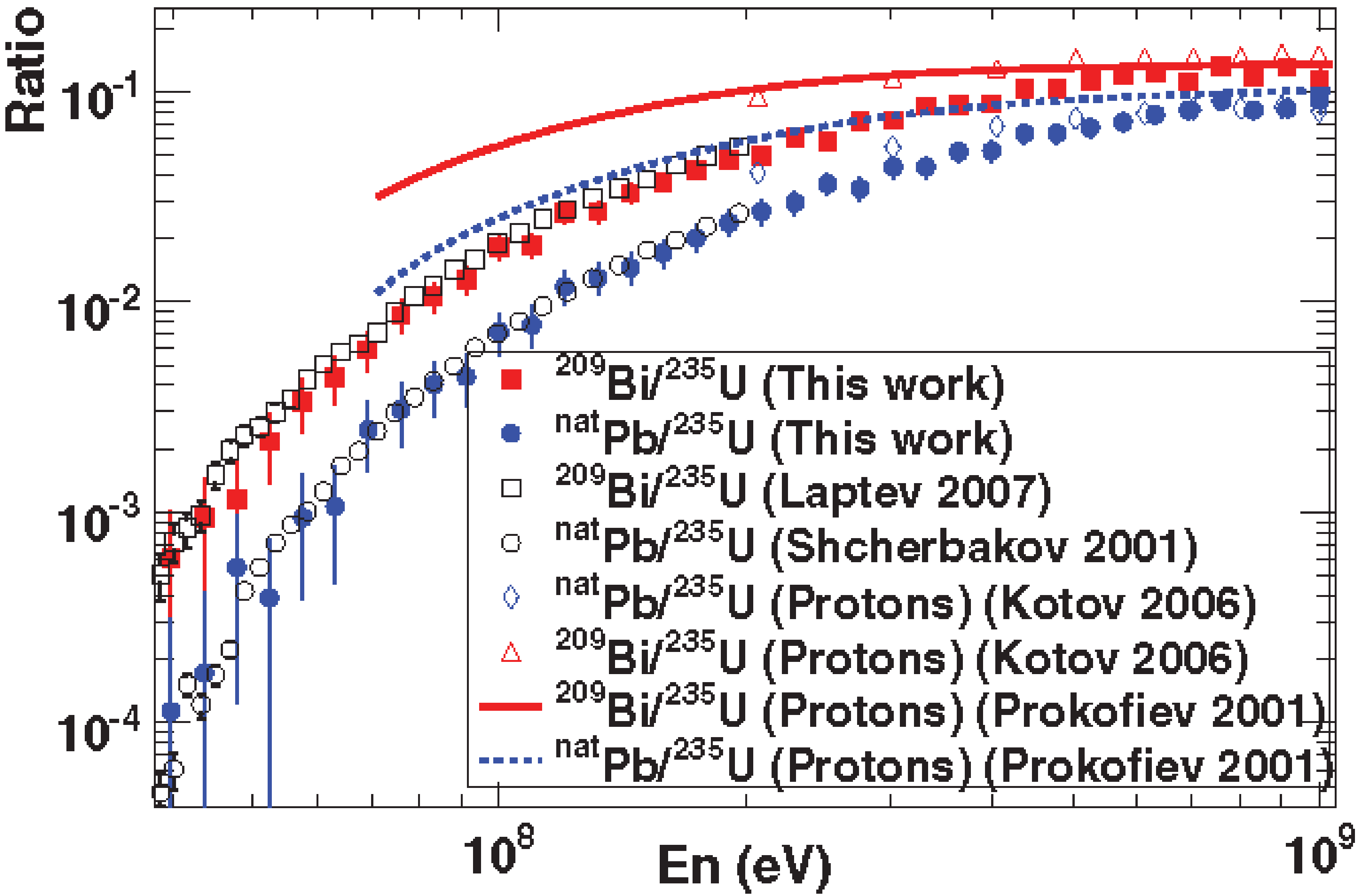


^{209}Bi(n,f) & Pb(n,f) as Reference Cross Sections

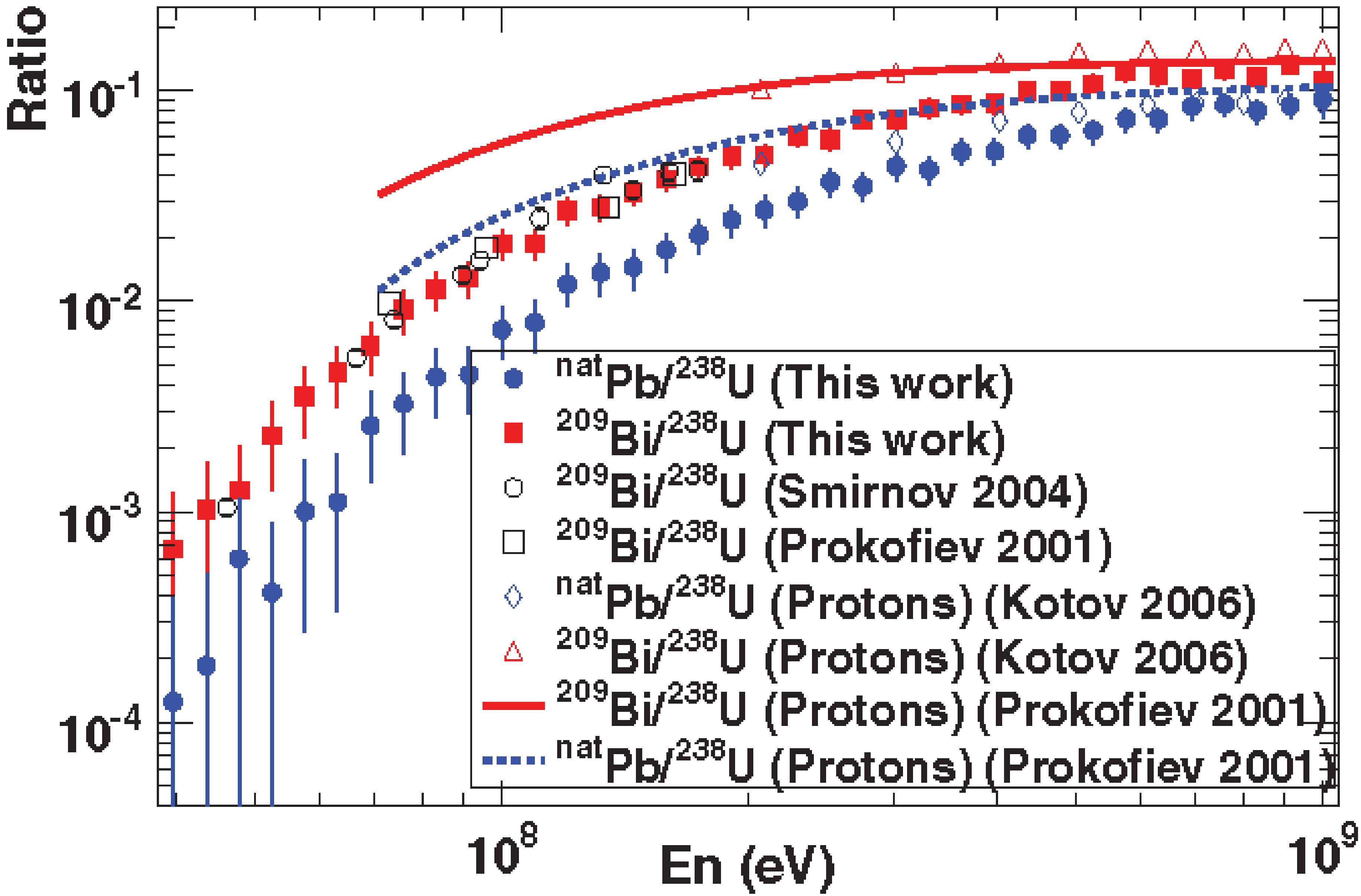
- The ^{209}Bi(n,f) & Pb(n,f) reactions have been suggested as reference cross sections. Such data are useful for dosimetry and the development of accelerator-driven systems. These cross sections may useful references in the neutron energy region above 20 MeV since the excitation functions have thresholds above that energy which eliminates the influence of low energy neutrons.

- Preliminary IAEA evaluations by Marcinkeviciu, Simakov and Pronyaev are available. They continue to review the available experimental data and improve on the evaluations.

^{209}Bi(n,f) and ^{nat}Pb(n,f) Measurements Relative to ^{235}U(n,f)
"This work" is Tarrio (n_TOF)



^{209}Bi(n,f) and ^{nat}Pb(n,f) Measurements Relative to ^{238}U(n,f)
"This work" is Tarrio (n_TOF)



Fission Measurements of Tarrio (n_TOF)

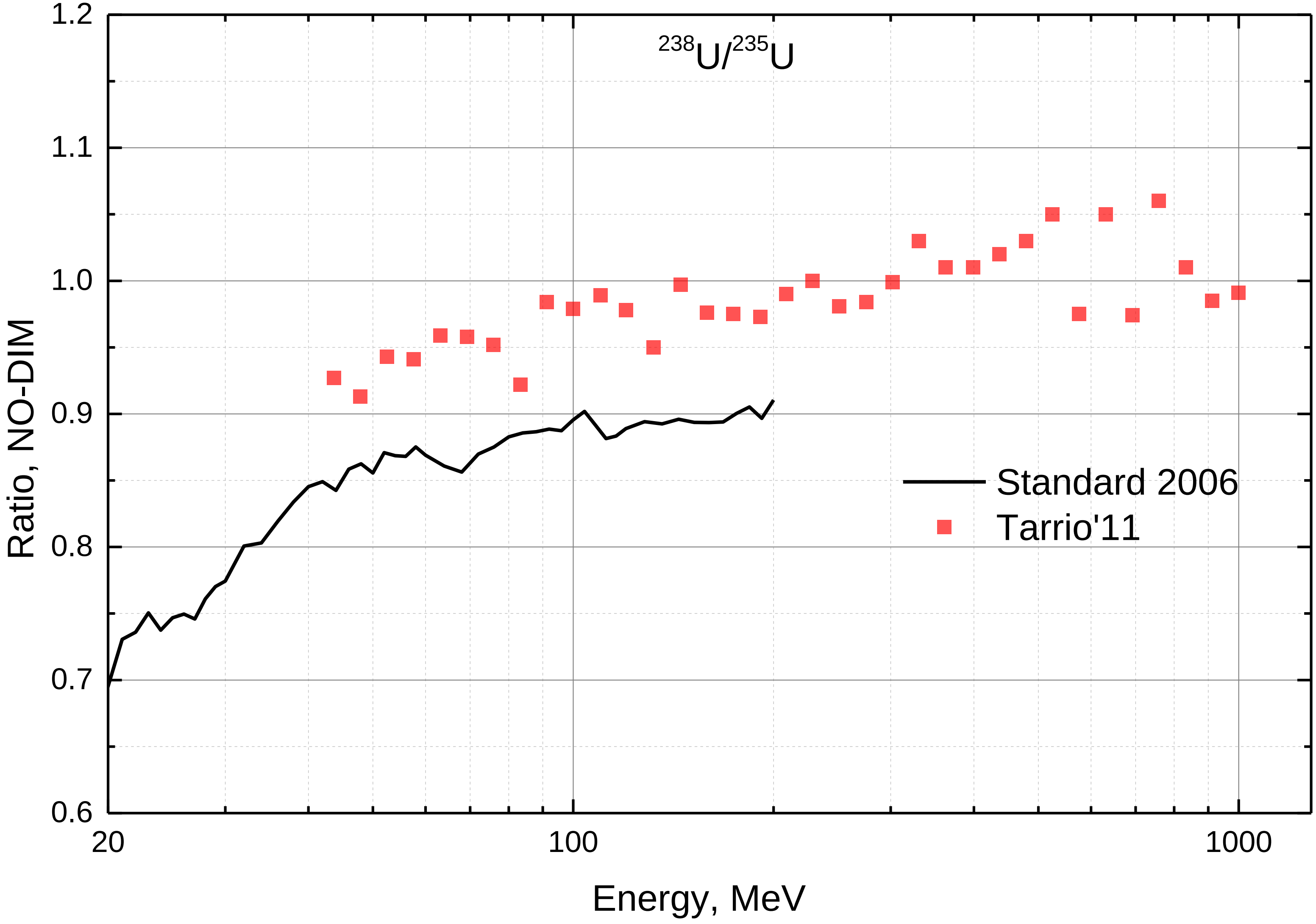
- Tarrio *et al.* made measurements of the ^{209}Bi(n,f)/^{238}U(n,f) and ^{209}Bi(n,f)/^{235}U(n,f) cross section ratios. From these data ^{238}U(n,f)/^{235}U(n,f) cross section ratios can be Obtained.

- Tarrio *et al.* also made measurements of the Pb(n,f)/^{238}U(n,f) and Pb(n,f)/^{235}U(n,f) cross section ratios. From these data ^{238}U(n,f)/^{235}U(n,f) cross section ratios can also be Obtained.

- These ratios are in excellent agreement with each other.

- However they are higher than the results from the standards evaluation. Possibly due to a problem with the mass determinations of the samples. But they agree in shape and will be used as a shape ratio in the evaluation.

Derived $^{238}U(n,f)/^{235}U(n,f)$ Measurement of Tarrio (n_TOF)



Neutron Spectra

- The most recent measurements of the $^{235}U(n_{th},f)$ neutron spectrum have been made with a ^{252}Cf source located outside the beam. Thus ratio measurements of these spectra were obtained.

- The GMA code used in the standards evaluation that can properly evaluate ratio data was used to simultaneously evaluate these two fission spectra. Then there is an impact on both quantities in the ratio.

- An independent Bayesian evaluation was also done by Mannhart.

Conclusions

- Recent experimental activity has improved the quality of the standards database.
- In most cases the data are in reasonable agreement with the evaluation.
- Areas of concern are:
  - H(n,n) at small angles in the CMS near 15 MeV
  - H(n,n) at intermediate and high energies where data are sparse and typically not available for a large angular range.
  - Both ^{6}Li(n,t) and the ^{10}B standards need additional work as the emphasis is on extending the energy range to higher energies
  - Additional work should be done in the high energy region on the ^{235}U(n,f), ^{238}U(n,f) and ^{239}Pu(n,f) cross sections to support of the needs for better standards in that energy region .
  - More work should be done on prompt gamma-ray reference, ^{nat}Pb(n,f) and ^{209}Bi(n,f) cross sections.
- **The standards should be at the forefront, producing high accuracy cross sections including energy regions that may shortly require improved standards. It is short sighted to not have quality standards whenever they may be needed.**