New experimental data for GMAPy data base update since 2017 evaluation

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New experimental data available in the EXFOR DB and publications

Since Standards2017 more than 20 data sets can be retrieved from EXFOR and included in the GMAPy database.

The Table with ref. at the source of data and figures illustrating their consistency /discrepancies with Standards2017 evaluation are given.

Data sets obtained at the same installations (nTOF, NIFFTE TPC , CSNS Back-n) have components of uncertainties with the strong correlations which should be accounted.

The improvement of the standards can be expected in the fission cross sections, capture cross sections below 100 keV and in R-matrix evaluation for light element standards.

CSNS Back-n measurements for light elements standards

#	Reaction, Data Type	Energy Range	Ref.	Data available, status	Comments	Actions TBD
1	$^{10}B(n,a)/$ $^{6}Li(n,t)$ shape of ratio	1 eV – 2.4 MeV	Jie Liu, EPJ. A (2023) 59:106	Table 1, Final(?)	Shape of the ratio for angular distributions are available	To use in EDA and RAC fits if possible. Wait to EXFOR compilation
2	$^{10}B(n,a_0)/$ $^{6}Li(n,t)$ shape of ratio	1 eV – 0.9 MeV	Jie Liu, EPJ. A (2023) 59:106	Table 1, Final(?)	As above	As above
3	$^{10}B(n,a_1)/$ $^{6}Li(n,t)$ shape of ratio	1 eV – 0.9 MeV	Jie Liu, EPJ. A (2023) 59:106	Table 1 Final(?)	As above	As above

CSNS Back-n measurements for light elements standards

#	Reaction, Data Type	Energy Range	Ref.	Data available, status	Comments	Actions TBD
4	$^{6}Li(n,t)$ measured relative $^{235}U(n,f)$, including resonance range where $^{235}U(n,f)$ is not a standard	1 eV – 3 MeV	Huaiyong Bai, CPH/C,44, 014003, 2020	X4=32800	Cross sections measured with neutron flux monitored through $^{235}U(n,f)$ (CS from ENDF/B-VIII)	Can't be used in the GMA because primary measured quantities are ratios to $^{235}U(n,f)$, which was used as a neutron flux monitor (ratio was not given by the authors). These ratio data are redundant if sets 1 – 3 are used. Relative angular distribution can be used in EDA and RAC fits.

CSNS Back-n measurements for light elements standards

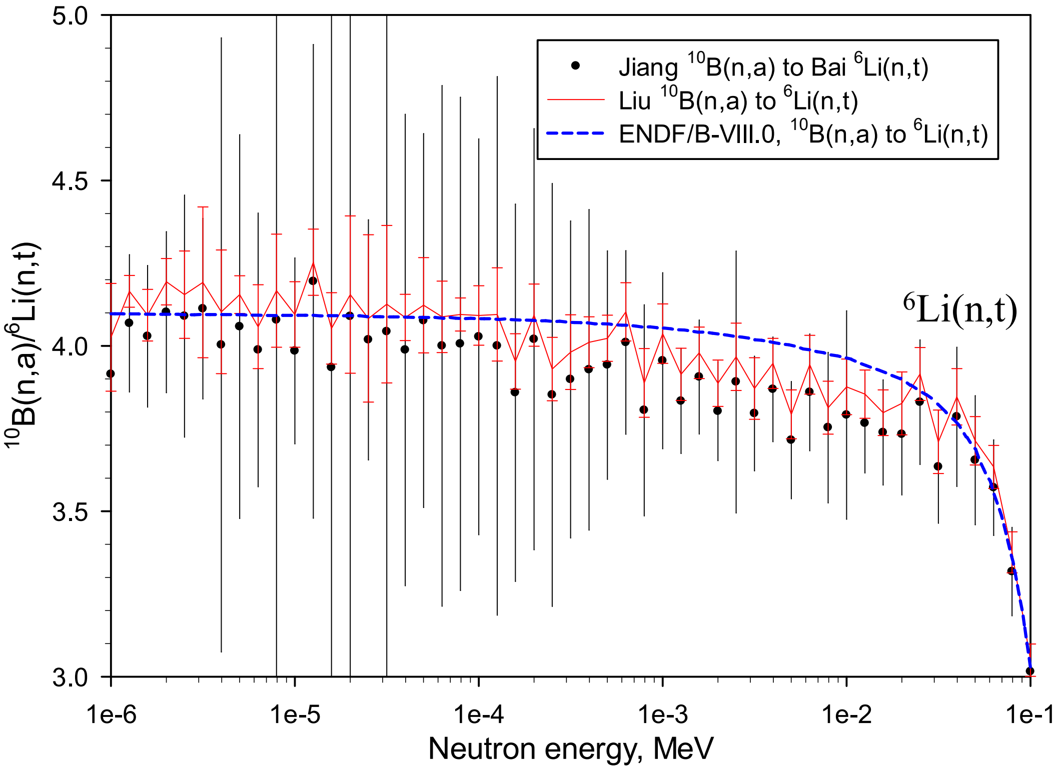
#	Reaction, Data Type	Energy Range	Ref.	Data available, status	Comments	Actions TBD
5	^{10}B(n,a) measured relative ^{35}U(n,f)	1 eV – 2.4 MeV	Haoyu Jiang, CPH/C,43,124002,2019	X4=32804002	Cross sections with neutron flux monitored with ^{235}U(n,f) (CS from ENDF/B-VIII.0)	Can't be used in the GMA, primary measured quantities are ratios to ^{235}U(n,f). Ratio is not given. These ratio data are redundant if set 1 is used
6	^{10}B(n,a$_0$) measured relative ^{35}U(n,f)	1 eV – 0.9 MeV	As above	X4=32804004	As above	As above. Relative angular distribution can be used in EDA and RAC fits.
7	^{10}B(n,a$_1$) measured relative ^{35}U(n,f)	1 eV – 0.9 MeV	As above	X4=32804004	As above	As above

CSNS Back-n measurements for light elements standards

#1,2,3,4,5,6,7 New analysis of ratio of boron alpha emission reactions to ^{6}Li(n,t) was done by Liu (2023). It is based at two separate results of measurements by Bai for ^{6}Li(n,t) (X4=32800, 2020) and by Jiang for ^{10}B(n, α_0), ^{10}B(n, α_1) and ^{10}B(n, α) (X4=32804, 2019). It was possible because ^{235}U(n,f) cross section was used in these two separate measurements for flux determination and it can be excluded in ratio.

The Liu ratio of the ^{10}B(n,a)/^{6}Li(n,t) integral in the energy range 1 eV – 1 keV from 2017 Standards (R=4.083) was used for ratio normalization. Due to this, the status of the data type is the shape of ratio.

CSNS Back-n measurements for light elements standards



Calculated ratio Jiang ^{10}B(n,α) (X4=32804002) to Bai ^{6}Li(n,t) (X4=32800002) is compared with ratio obtained in the analysis by Liu, normalized to the ENDF/B-VIII. The difference between Liu ratio normalized to Standards 2017 and ratio directly calculated from Jiang and Bai measurements is about 2%. There is more than 1 sigma difference in the shape of ratio near the 245 keV resonance in the ^{6}Li(n,t).

CSNS Back-n measurements for light elements standards

- **The results of Liu $^{10}B(n,a)$ and $^{10}B(n,a_0)$ to $^{6}Li(n,t)$ ratio analysis can be used in the GMA fit as shape of ratio data. To avoid double counting, the ratio $^{10}B(n,a_1)$/ $^{6}Li(n,t)$ should not be used in the fit. $^{10}B(n,a)$ is taken because it is presented up to 2.4 MeV.**
- **The partial uncertainties are not given at Liu ratios. The partial uncertainty for ratio can be estimated from components of the uncertainties given for ^{6}Li and ^{10}B measurements. Components of the uncertainties related to the flux and mass determination are not valid for shape of ratio data.**
- **The other problem is that the relative uncertainties given in Jiang (X4=32804) for $^{10}B(n,a)$, $^{10}B(n,a_0)$ and $^{10}B(n,a_1)$ for some components are identical what is not physical. Some points between 1 keV and 30 keV can be treated as outliers.**
- **Relative angular distributions for $^{10}B(n,a_0)$, $^{10}B(n,a_1)$ and $^{6}Li(n,t)$ could be used in the R-matrix fits.**

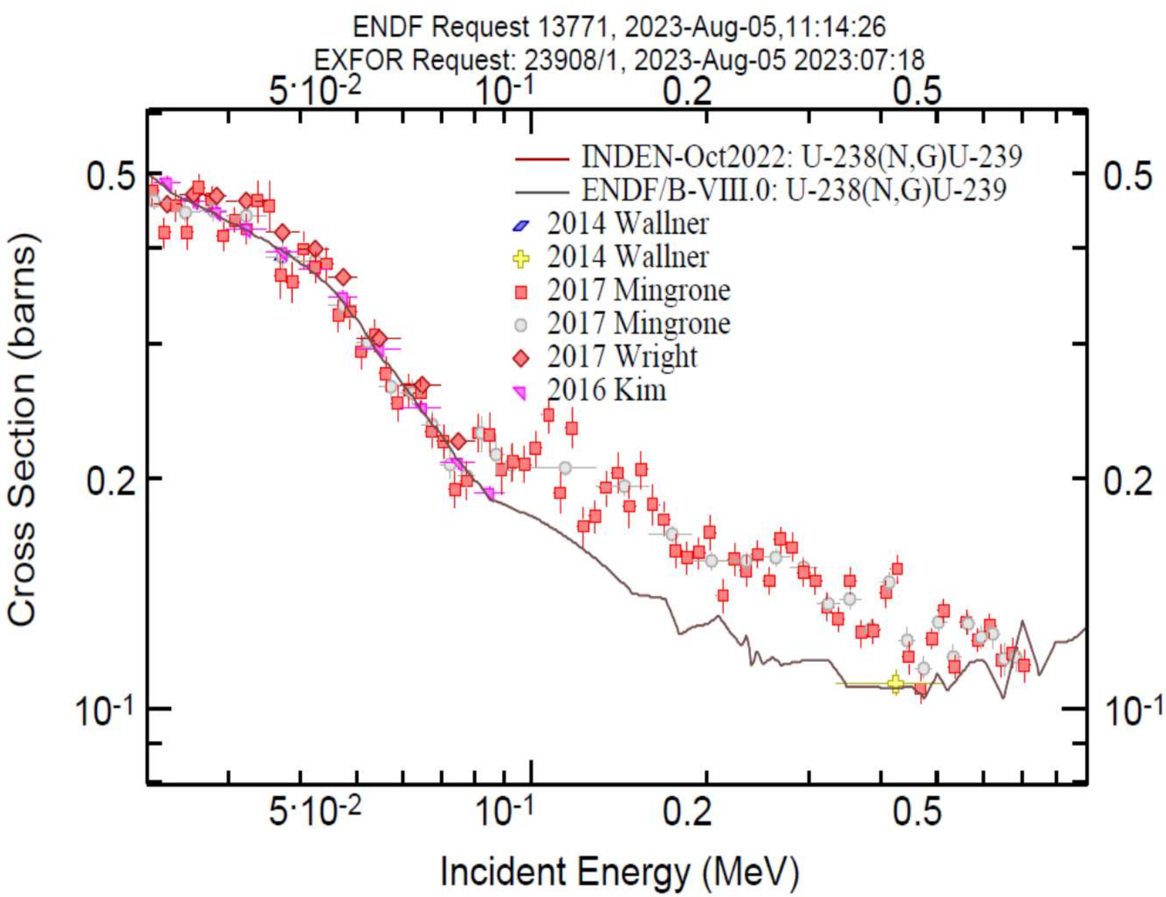
nTOF capture cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
8	$^{238}U(n,\gamma)$ nTOF measure-ments with C_6D_6 detector	3 – 700 keV	F.Mingrone, PR/C,95, 034604, 2017 X4=23234	Flux shape was monitored relative $^{6}Li(n,t)$, normalization – through nTOF proton current integration.	Data can be used as absolute data below 70 keV. Primarily measured ratio $^{238}U(n,\gamma)/^{6}Li(n,t)$ is not given but shape of $^{6}Li(n,t)$ is 1/v. Amount of aluminum in the windows of the beam line was not precisely known. This will require to increase the uncertainties near Al resonance at 34.2 keV.

nTOF capture cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
9	$^{238}U(n,\gamma)$ measured with BaF_2	1 eV – 77 keV	T.Wright, PR/C,96, 064601, 2017, X4= 23364004	Flux shape was monitored relative $^{6}Li(n,t)$, normalization – through nTOF proton current integration. Primarily measured ratio $^{238}U(n,g)/^{6}Li(n,t)$ is not given	Data can be used as absolute data because $^{6}Li(n,t)$ CS below 70 keV is very close to the 1/v. Amount of aluminum in the windows of the beam line was not precisely known. This will require to increase the uncertainties near Al resonance at 34.2 keV.

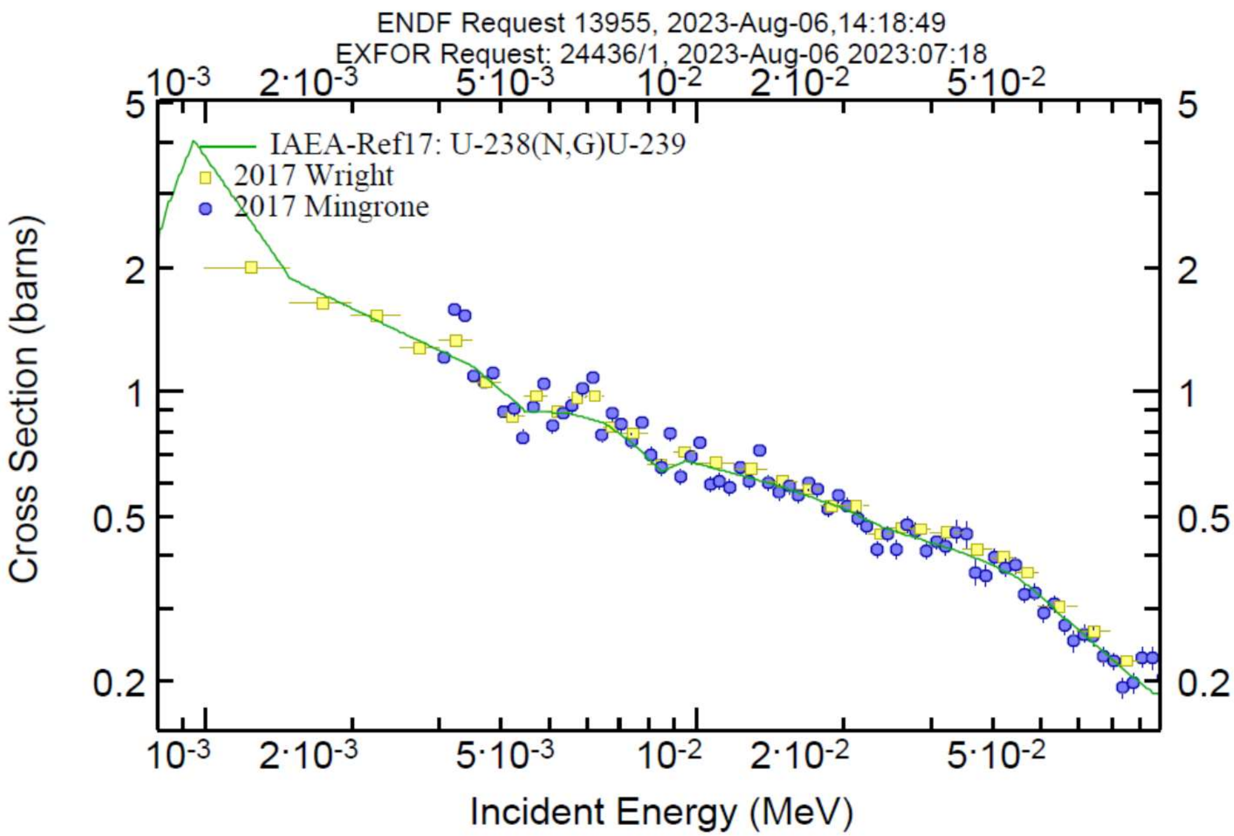
nTOF experimental data for $^{238}U(n,\gamma)$ reaction



The reason of discrepancy with Standards2017 above 70 keV is not clear.

The Mingrone's data above 70 keV should be excluded from the evaluation.

nTOF experimental data for $^{238}U(n,\gamma)$ reaction



Excellent consistency is observed between nTOF measurements done with 2 different detectors (C6D6 detector in the measurements by Mingrone and with BaF2 detector in the measurements by Wright.

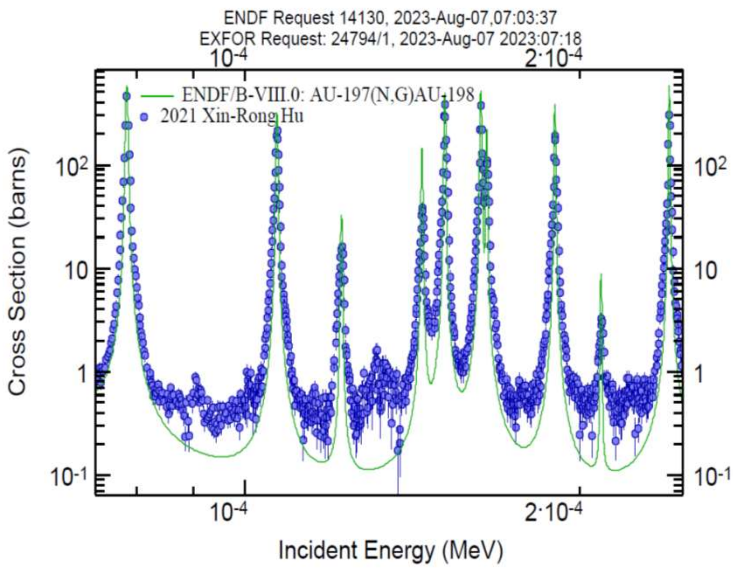
nTOF experimental data for $^{238}U(n,\gamma)$ reaction

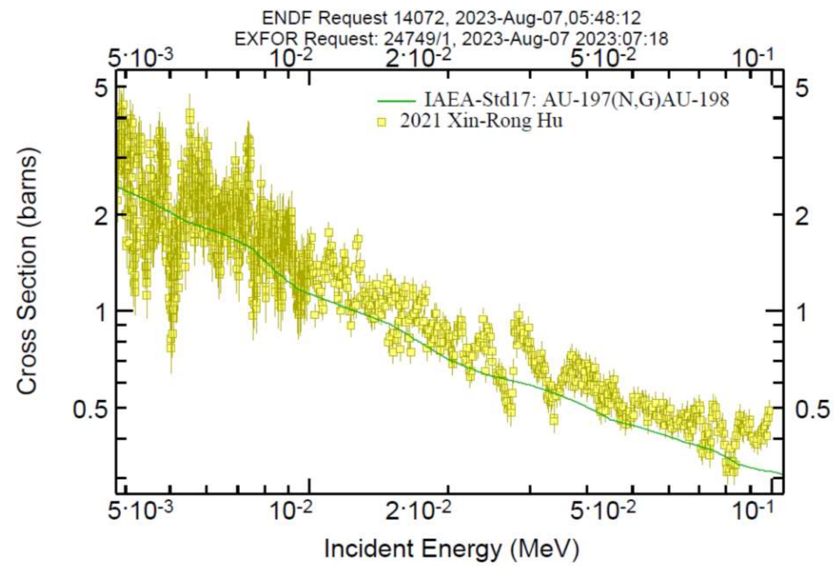
nTOF data sets #8 and #9 can be used as absolute data below 70 keV because their absolute flux normalization and its dominnce in 1/v range of $^{6}Li(n,t)$ reaction cross section below 70 keV

CSNS Back-n capture cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
10	^{197}Au(n,g) measured with C_6D_6	1 eV – 99.3 keV	Xin-Rong Hu, CNST, 32,101, 2021 X4= 32856002	Data in EXFOR presents the relative yields converted in the cross sections. Possible problems in the background separation and in multiple scattering correction account. As result, the background was not completely removed.	Data can't be used in the GMA database.

CSNS Back-n capture cross section measurements



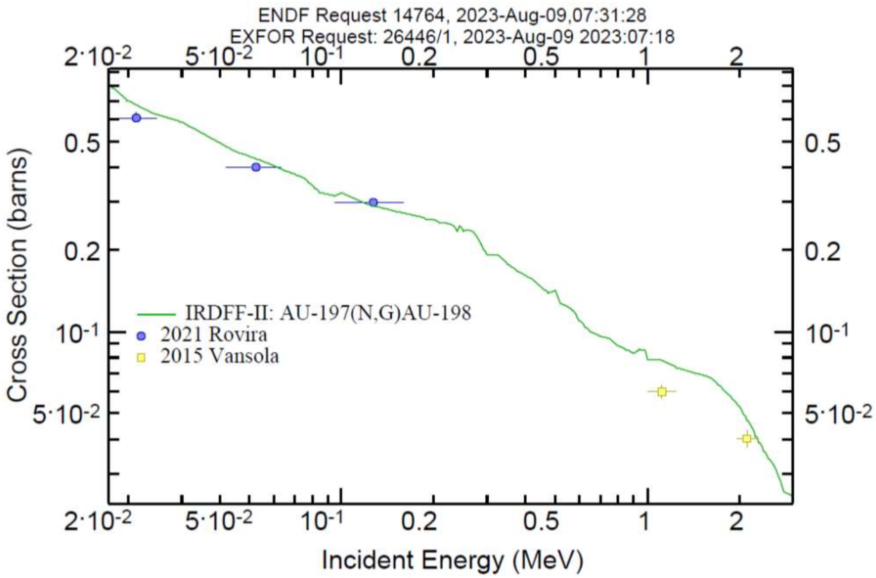


Derived cross sections shown are corrected at multiple scattering and background. But multiple scattering correction used in the resonance range is smooth. It should be resonance dependent and could be obtained from resonance capture area measurementsdone only with MC simulation. Average cross sections are 20-30% higher than Standards2017 in the URR.

ANNRI beam line capture cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
11	$^{197}Au(n,\gamma)$ measured at TOF+neut-ron filter with scintillator detector	23.5, 51.5 and 121.7 keV broad energy spectra	G. Rovira, NIM/A, 1003, 165318, 2021, X4= 23746002	Neutron flux was measured relative $^{6}Li(n,t)$ reaction. Absolute normalization was done using black resonance techniques. Double bunch mode expands substantially the energy resolution	Can be used in the standards evaluation with GMAPy as SACS. Filtered neutron spectra are given.

ANNRI beamline capture cross section measurements



Accelerator pulsed double bunch mode was used to increase statistics and obtain results with statisticalal uncertainty 1%. This led to double peaked wide resolution pulse. Can be used in GMAPy as SACS data. Spectra available through links: https://www-nds.iaea.org/exfor/servlet/X4sGetSubent?plus=1&sub=23746003 , …23746004, …23746005

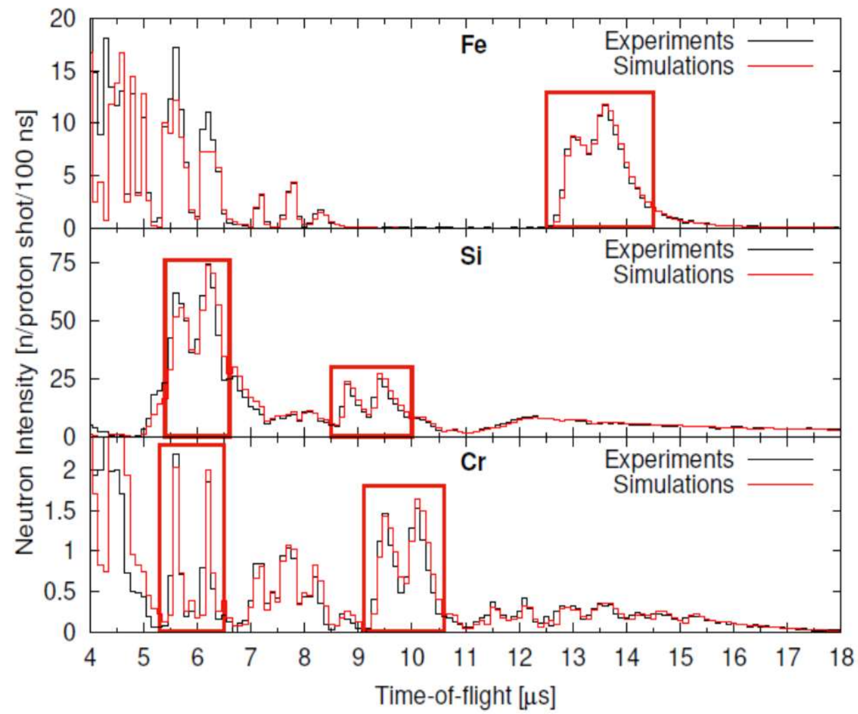
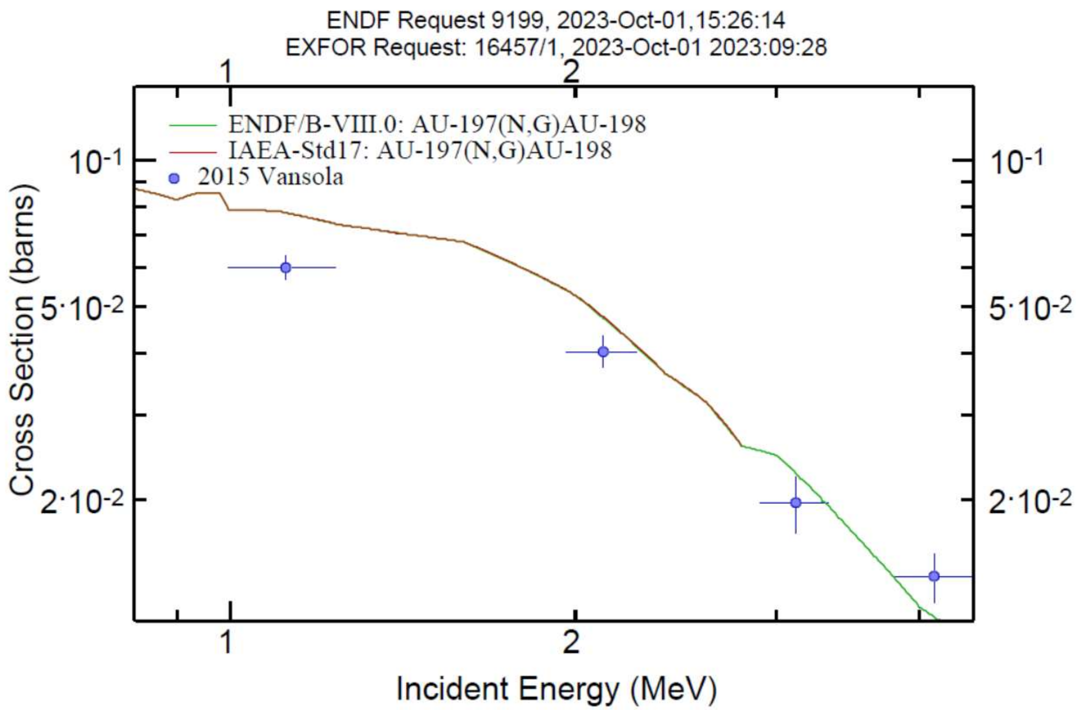


Figure 3. Filtered-neutron time distributions measured with the NaI(Tl) spectrometer (black) and obtained from simulations (red) for the filter configurations of 20 cm for Fe (top), 20 cm for Si (middle) and 15 cm for Cr (bottom).

Activation capture measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
12	^{197}Au(n,g) acvtivation measure-ments with p+^{7}Li neutron source	1.12, 2.12 MeV	V.Vansola, RCA,103, 817,2015 X4= 33096002	49-IN-115(N,G)49-IN-116-M,,SIG) was used as the monitor reaction	Can’t be used in the standards evaluation because ^{115}In(n,g)^{116m}In is not a reaction in the combined fit.

Activation capture measurements

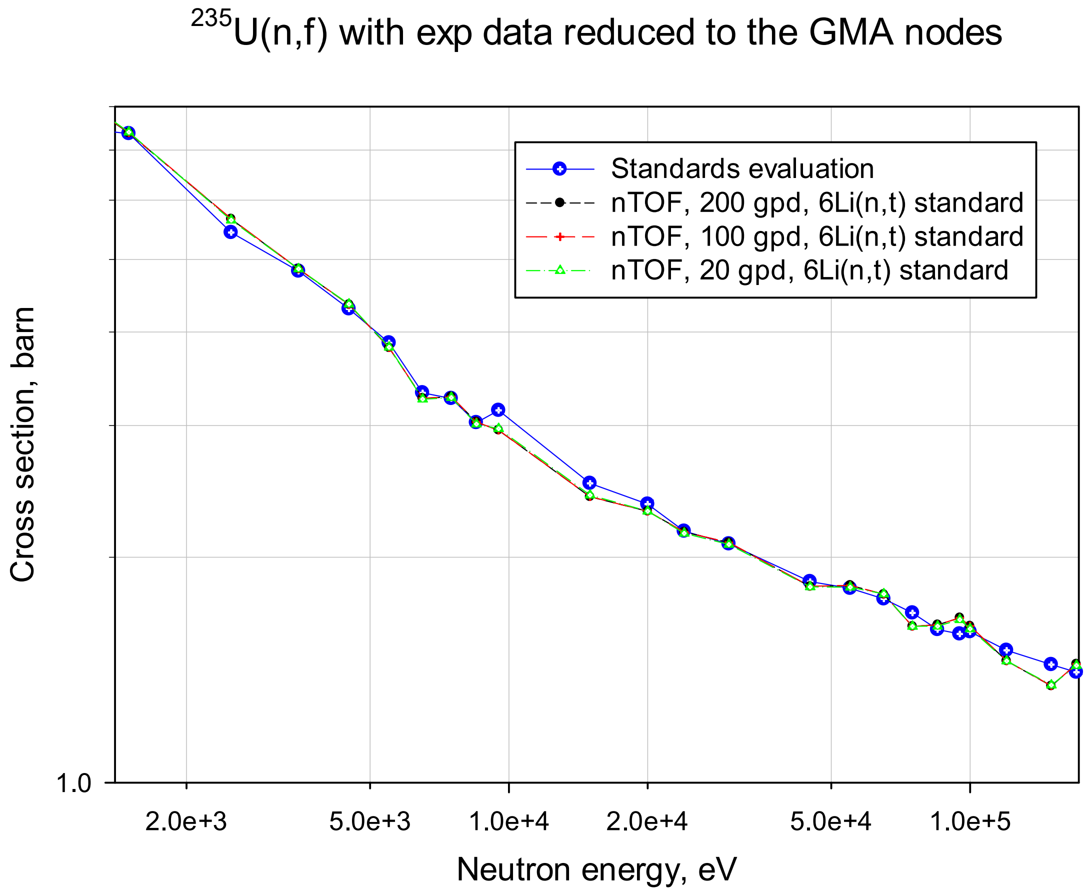


Measured relative 49-IN-115(N,G)49-IN-116-M,,SIG) it has also large deviations from Standards2017. Can not be used in the Standards evaluation.

nTOF fission cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
13	$^{235}U(n,f)$ /$^{6}Li(n,t)$ shape of ratio	0.0178 eV – 178 keV	S.Amaducci, EPJ/A55,120, 2019; EPJ/A58, 147,2022; X4=23453002	Presence of the Al, Mn, Pb causes sharp variations of the neutron flux, what should increase the uncertainty of measurements in the regions of the resonances	Data with 20 gpd can be used in the standards evaluation as shape of ratio data with USU component added if it will be required.
14	$^{235}U(n,f)$ /$^{10}B(n,a)$ shape of ratio	As above	As above, but X4= 23453003	As above	As above

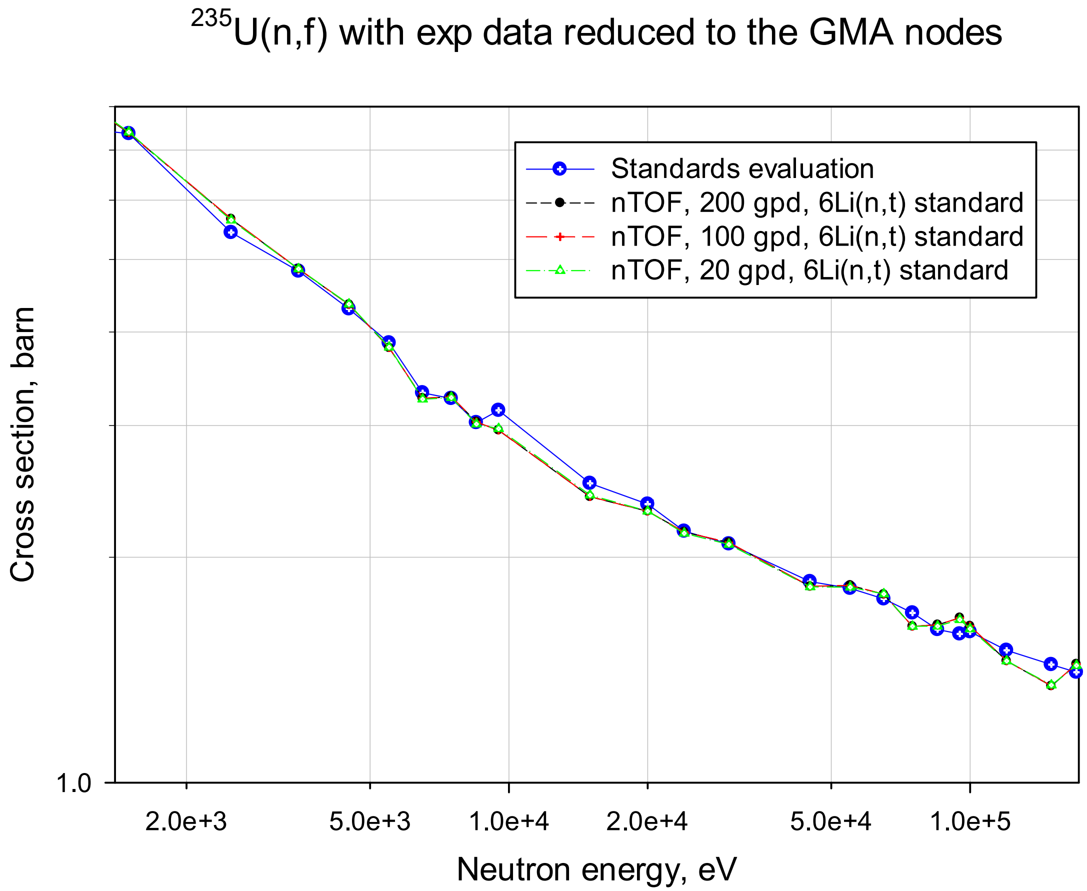
nTOF fission cross section measurements



nTOF measurements of ^{235}U(n,f) were done relative ^{6}Li(n,t) and ^{10}B(n,α) in in the same neutron beam run. The ratios were normalized using Standards (2017) ratios ^{235}U(n,f/)/^{6}Li(n,t) and ^{235}U(n,f/)/^{10}B(n,a) in the energy range 7.8 eV – 11 eV.

Because of this, they can be used only as shape of ratio measurements A visible differences with Standards (2017) are observed at 9, 15 and above 70 keV

nTOF fission cross section measurements

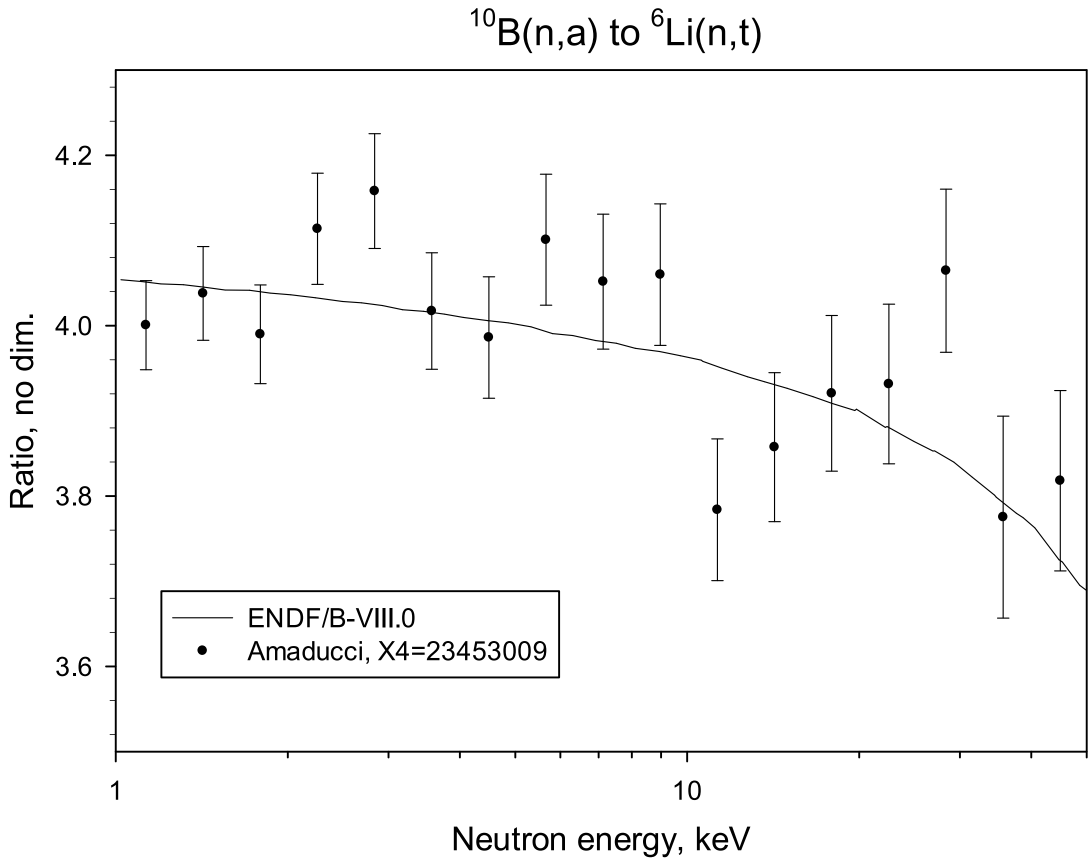


nTOF measurements of ^{235}U(n,f) were done relative ^{6}Li(n,t) and ^{10}B(n,α) in in the same neutron beam run. The ratios were normalized using Standards (2017) ratios ^{235}U(n,f/)/^{6}Li(n,t) and ^{235}U(n,f/)/^{10}B(n,a) in the energy range 7.8 eV – 11 eV.

Because of this, they can be used only as shape of ratio measurements.

A visible differences with Standards (2017) are observed at 9, 15 and above 70 keV. This difference is not related with the data reduction to the nodes.

nTOF fission cross section measurements

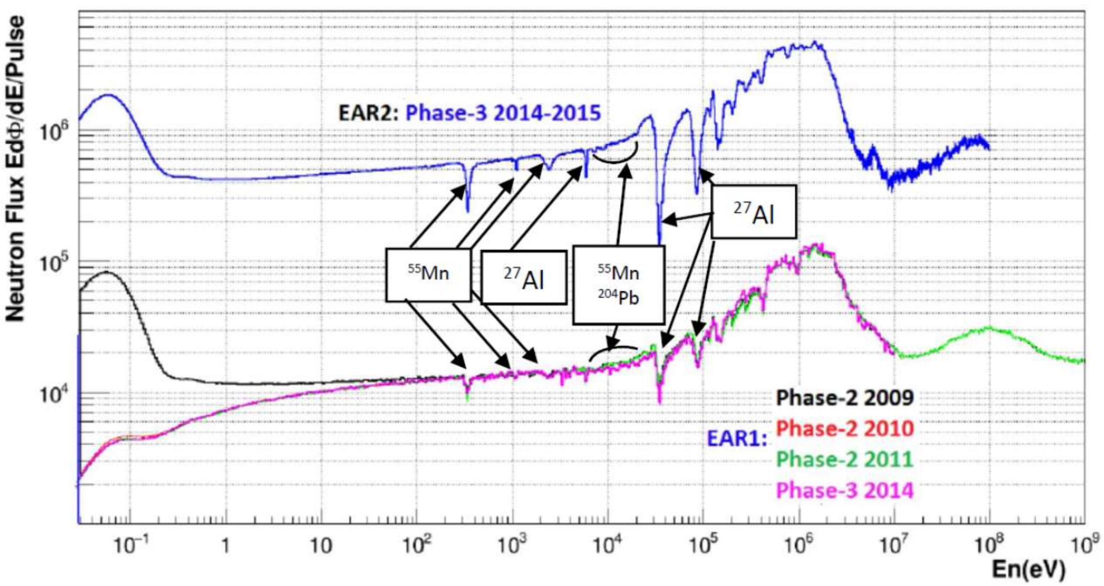


The measurements were done relative ^{6}Li(n,t) and ^{10}B(n,α) in in the same neutron beam run. Ratio ^{10}B(n,α)/ ^{6}Li(n,t) has strong fluctuations.

There is 7.4% increase between 11.3 and 28.4 keV in the measurements, but 2.5% decrease for the same energies in the evaluations.

Is this play of statistics or presence of unaccounted material in the sample/detector system?

nTOF fission cross section measurements

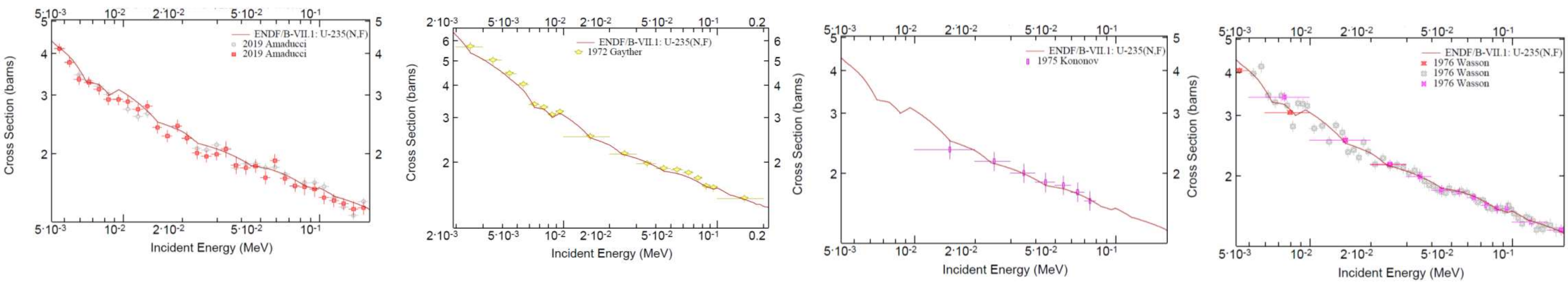


The measurements were done at the EAR2 ("short") flight path. The neutron flux was not smooth because of presence of structural materials in neutron source, windows and sample backings (not shown).

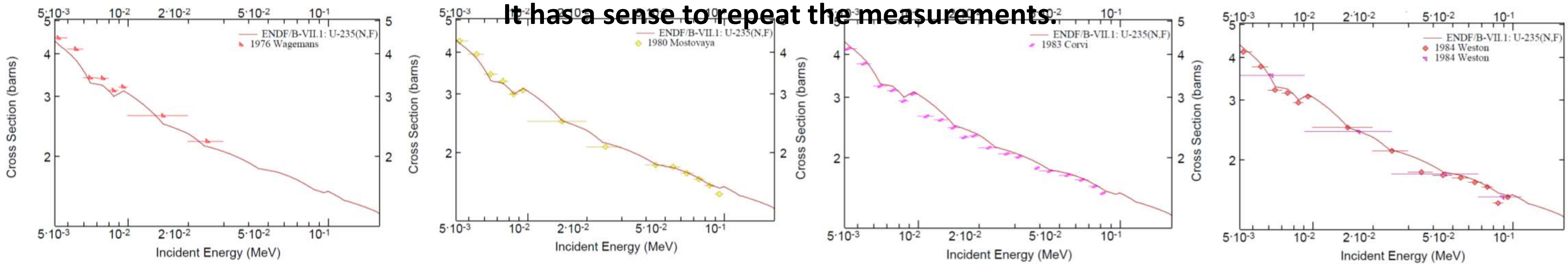
This "non-smoothness" may contribute in the uncertainty of the determined cross sections near neutron flux dips.

Latest upgrade reduces the parasitic materials from the neutron beam.

nTOF fission cross section measurements



It has a sense to repeat the measurements.

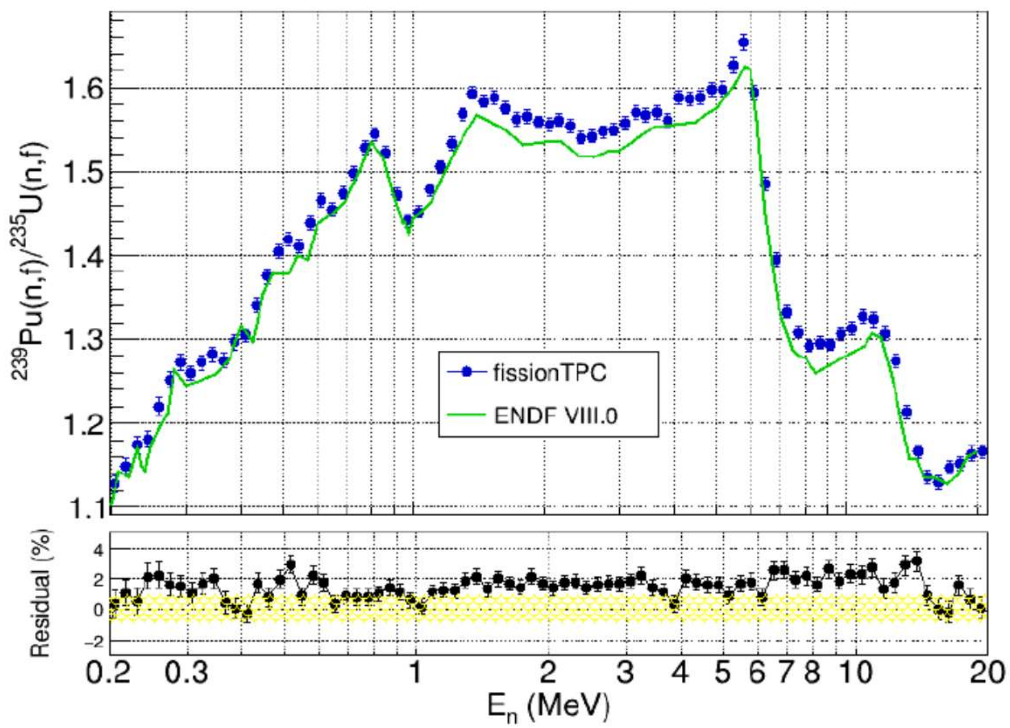


It has a sense to repeat the measurements at the upgraded neutron beam with more attention at the presence of the parasitic materials at the beam line and detector system. Present data can be used in the GMA fit with treating of the discrepant data as values with USU.

NIFFTE TPC LANL fission cross section measurements

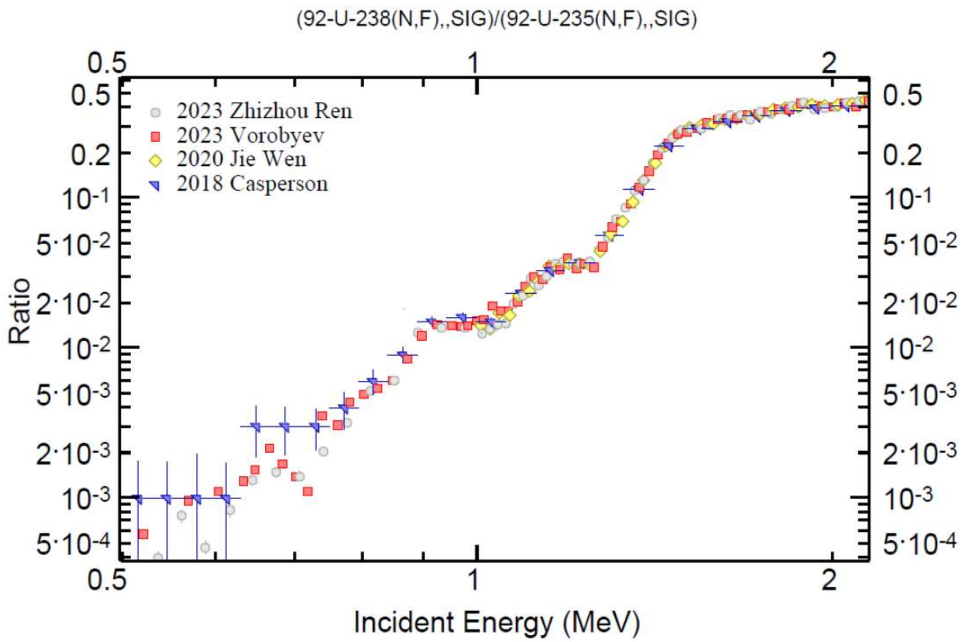
#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
15	^{239}Pu(n,f) /^{235}U(n,f) NIFFTE TPC LANL	0.1-100 MeV	L.Snyder, NDS,178,1,2021; X4=14721	Correlation matrix of total uncertainty for shape of ratio data is given under COVARIANCE	Correlation matrix for total uncertainty of the shape of ratio measurement given under COVARIANCE in subent 14721002 should be used
17	^{238}U(n,f)/ ^{235}U(n,f) NIFFTE TPC LANL	0.5- 30 MeV	R.J.Casperson, PR/C,97,034618,2018; X4=41756	Correlation matrix of total uncertainty for shape of ratio data is given under COVARIANCE	As above, COVARIANCE in subent 14498002 should be used

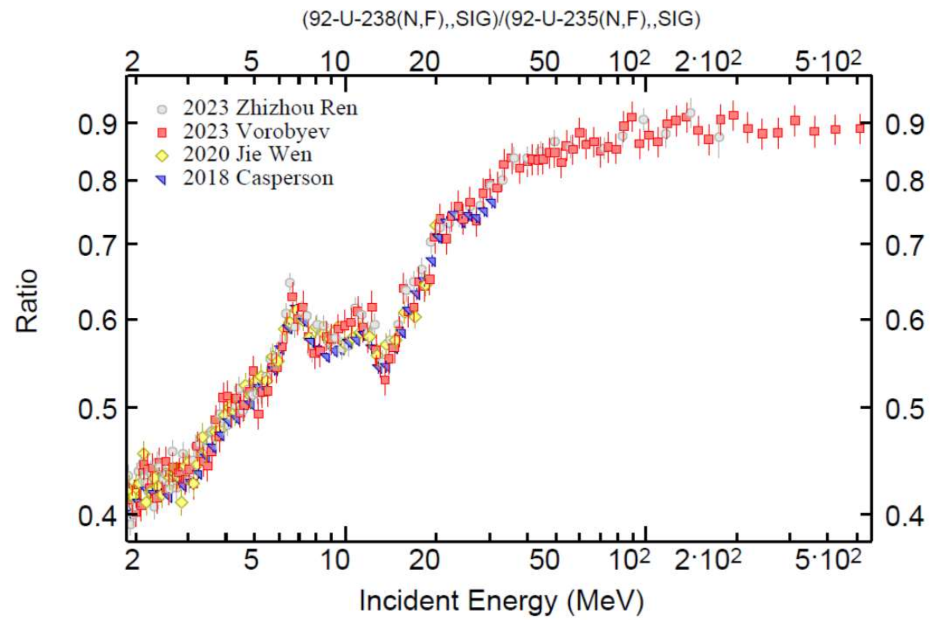
NIFFTE TPC LANL fission cross section measurements



#15 ^{239}Pu(n,f)/^{235}U(n,f). It was previously discussed and consensus was found to use these data as a shape of ratio measurements due to the possible problem with a sample mass determination.

NIFFTE TPC LANL fission cross section measurements





Reaults of latest measurements by TOF technique (LANL – Casperson, PNPI – Vorobyev and CSNS - Zhizhou Ren and Jie Wen) are very consistent.
#17 ^{238}U(n,f)/^{235}U(n,f) by Casperson et al. can be used as shape of ratio data because they are normalized to the ENDF/B-VIII.beta3 ratio at 14.5 MeV .

nTOF fission cross section measurements

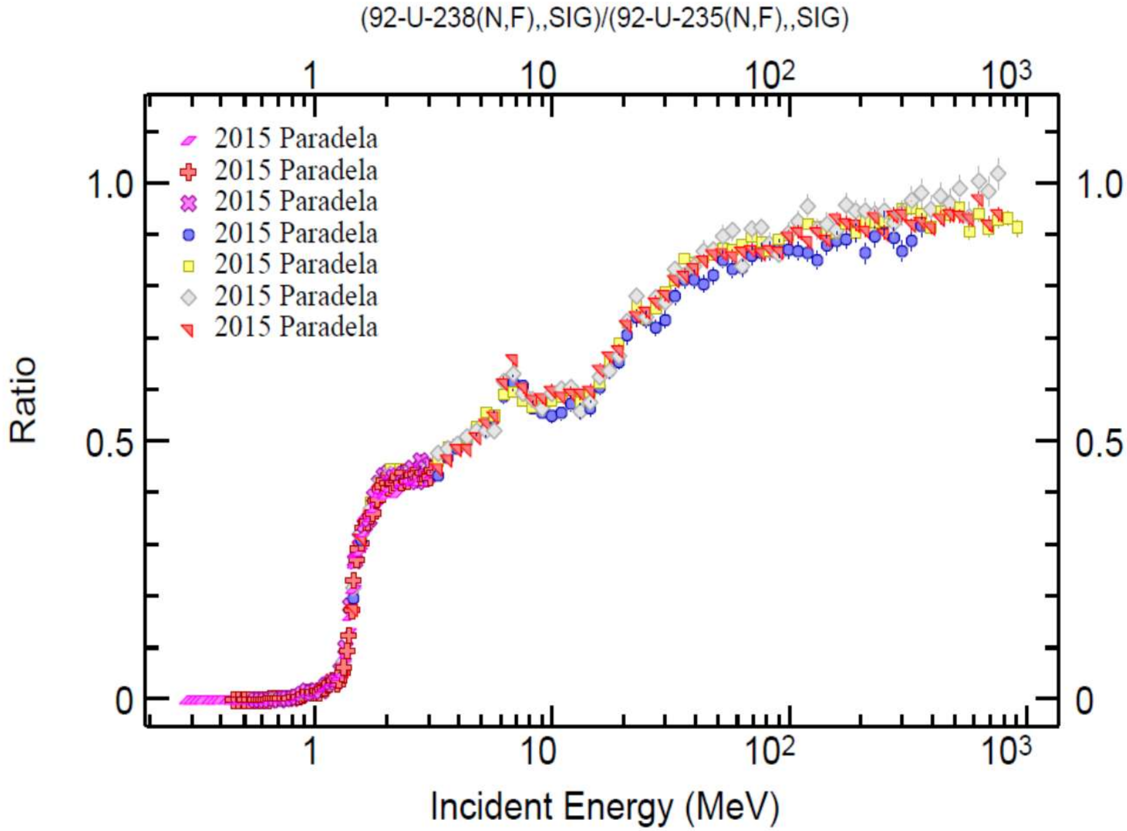
#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
16	$^{238}U(n,f)/^{235}U(n,f)$ nTOF measurements final data	0.29-870 MeV	C.Paradela, PR/C,91,024602,2015; EPJ/CS,111, 02002,2016; X4=23269	Data sets from subentries 2 – 4 and 6 – 8 are correlated because common samples, detectors are used	Absolute cross section ratio measurements. 6 correlated data sets should be used replacing preliminary data in Standards2017 evaluation

nTOF fission cross section measurements

.Seven nTOF results of ratio measurements numberde from top to down in the legend above:

1. with two fast ionization chambers (FIC1, FIC2) and single fragment registration (X4=23269002)
2. with parallel plate avalance counter mounted perpendicular to the beam and two fission fragments registration in the coincidence; samples different from 1. (X4=23269003)
3. with parallel plate avalance counter mounted 45 deg to the beam and two fission fragments registration in the coincidence; samples as in 2. (73 bins, X4=23269004)
4. as in 3. but normalized to ENDF/B-VII.1 ratio between 3 and 5 MeV (X4=23269005)
5. with one (FIC0, two 235U and one 238U sample) fast ionization chamber and single fragment registration (X4=23269006)
6. with one (FIC2, two 235U and one 238U sample) fast ionization chamber and single fragment registration (X4=23269007)

nTOF fission cross section measurements



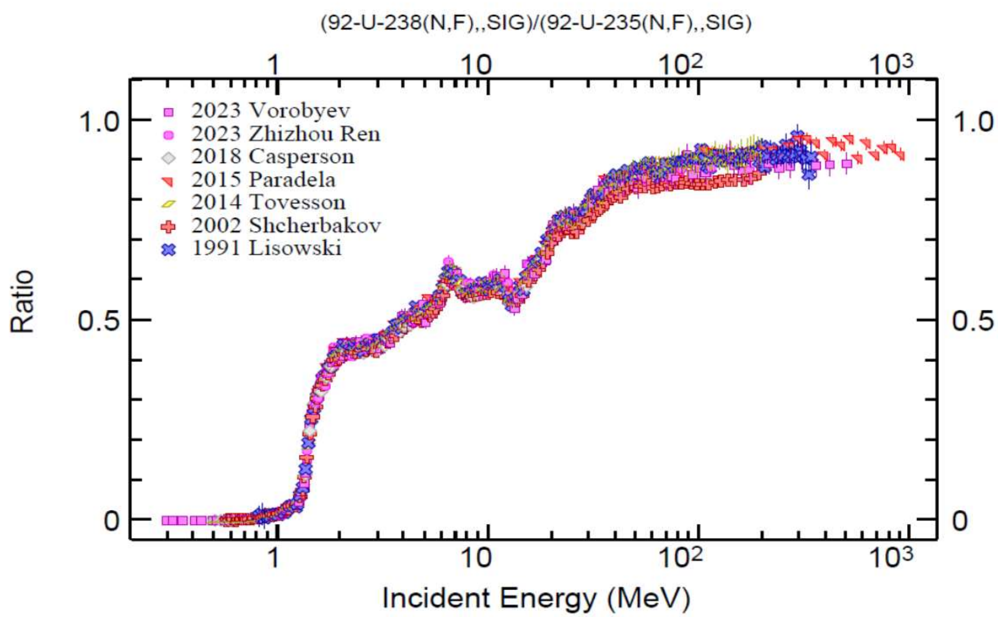
#16 nTOF ^{238}U(n,f)/^{235}U(n,f). Detailed measurements including 9 data sets obtained with different samples and detectors.

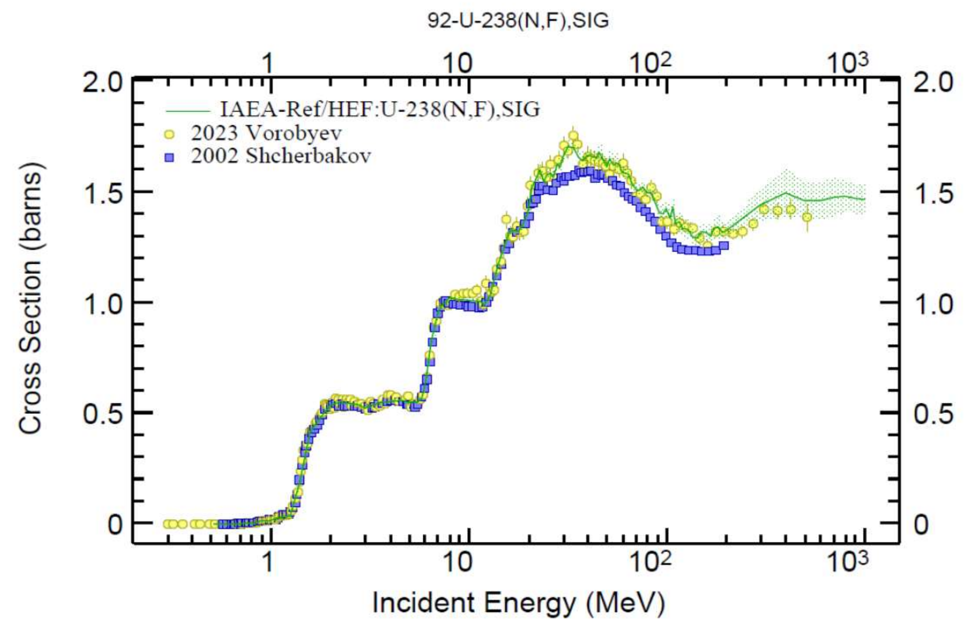
The data spread (up to 5% at high energy demonstrates the systematic uncertainties due to variation of the measurements conditions.

PNPI fission cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
18	^{238}U(n,f)/ ^{235}U(n,f) absolute ratio measurement	0.3-500 MeV	A.S.Vorobyev JEL,117,557,2023; ZEP,117,561, 2023; X4=41756	Uncertainty of the specific samples nuclides ratio determination is 1.5%. This reduces uncertainty for samples density ratio (7.5%) at 5 times	All components of the uncertainties are given and should be used for constructing of the covariance matrix

PNPI fission cross section measurements



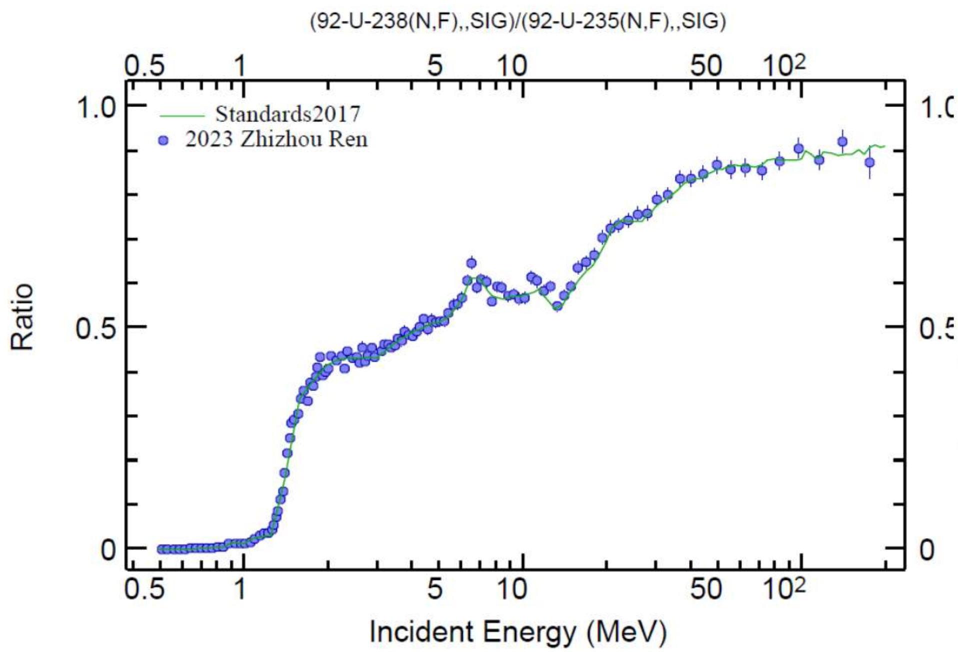


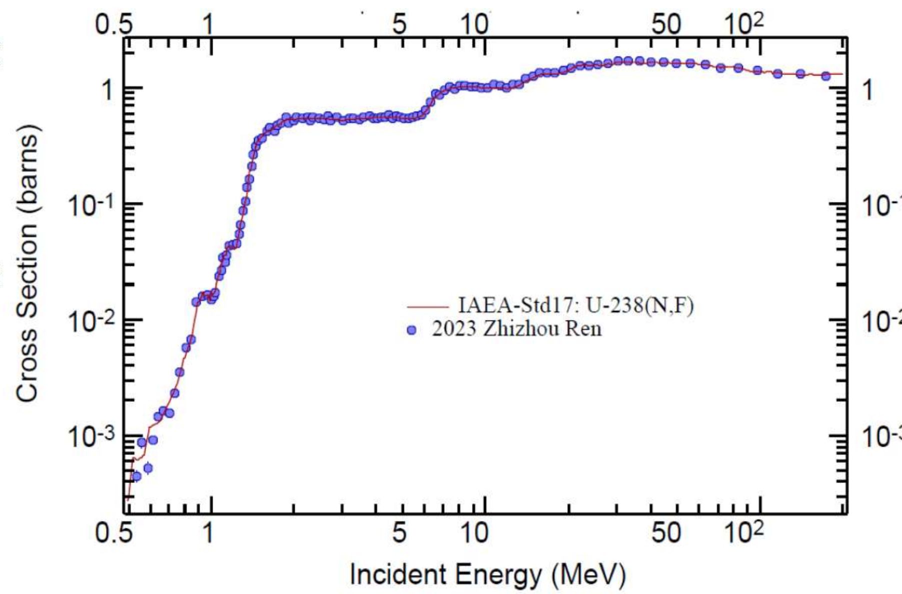
#18 TOF ^{238}U(n,f)/^{235}U(n,f) measurements available in EXFOR. There is good consistency with Standards2017 evaluation below 200 MeV. Above 200 MeV ^{238}U(n,f) calculated with using ^{238}U(n,f) Standards2017 recommended cross section235 are 5% below the present recommended high energy IAEA evaluation.

CSNS fission cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
19	$^{238}U(n,f)/^{235}U(n,f)$ absolute ratio measurement at CSNS Back-n source	0.5-175 MeV	Zhizhou Ren, EPJ/A,59,5,2023; X4=32886	Absolute ratio measurements with uncertainty of samples nuclides ratio determination in 1.5%	All components of the uncertainties are given and should be used for construction of the covariance matrix
20	$^{238}U(n,f)/^{235}U(n,f)$ as above	1 - 20 MeV	Jie Wen, ANE,140,107301,2020; X4=32798	As above	As above. Some components of the uncertainties should be strongly correlated wit the same in #19

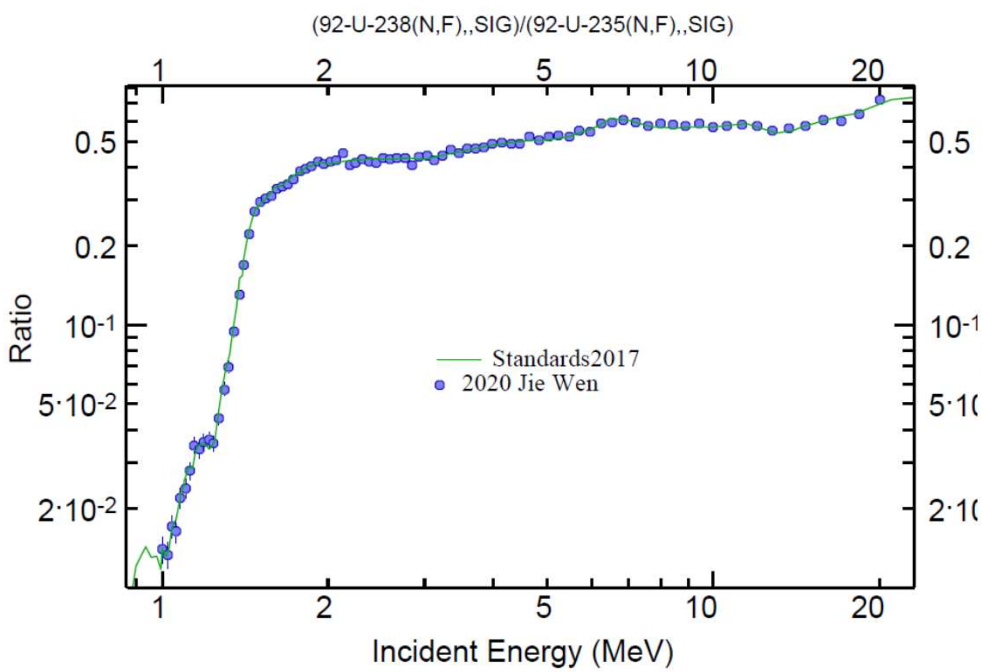
CSNS fission cross section measurements

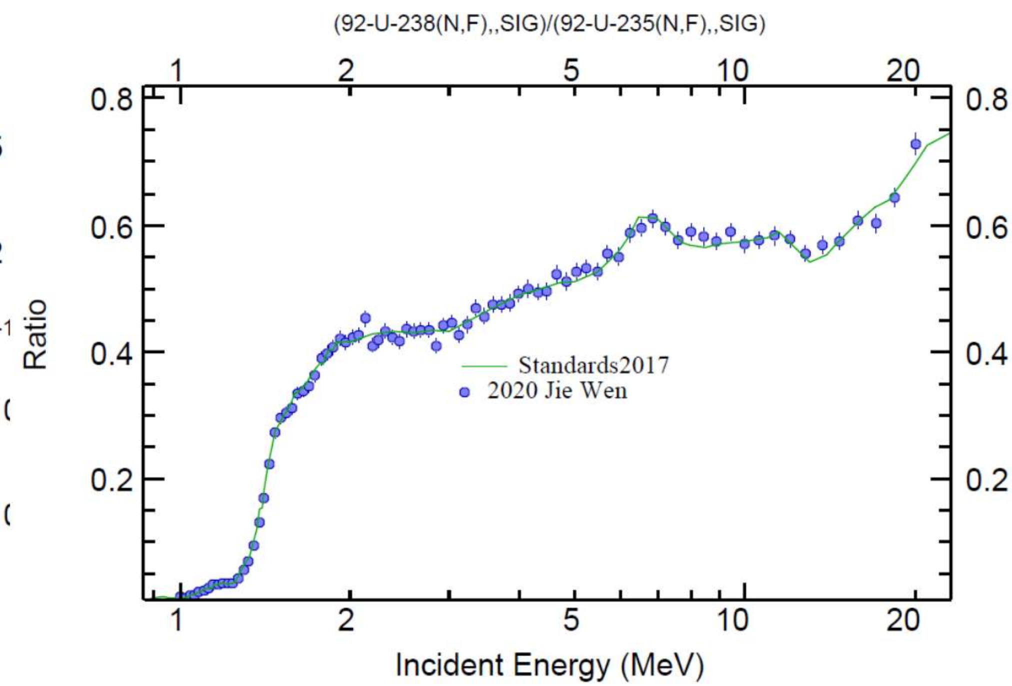




#19 CSNS $^{238}U(n,f)/^{235}U(n,f)$. Good consistency with Standards2017 evaluation and other experimental data in the all energy range. The total uncertainty is below 3% in the energy range between 1.5 and 150 MeV

CSNS fission cross section measurements



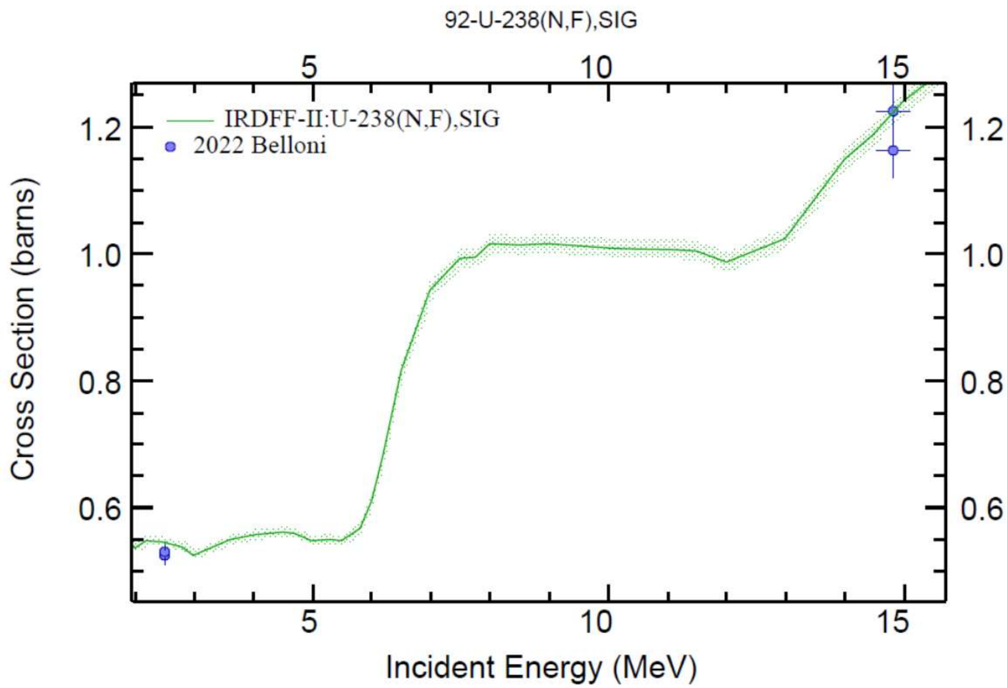


#20 CSNS ^{238}U(n,f)/^{235}U(n,f). Average discrepancy with the Standards2017 evaluation is between 1,9 – 2.6 %, due to mostly statistical spread of experimental values. The relative experimental uncertainty for En > 1.4 MeV is between 2.3 – 3.6%.

PTB-GEEL absolute fission cross section measurements

#	Reaction, Data Type	Energy Range	Ref.	Comments	Actions TBD
21	$^{238}U(n,f)$ absolute measurement relative PTB hydrogen long counter used as German primary standard for neutron flux measurement	2.51 $\pm$0.14 MeV, 14.83 $\pm$0.57 MeV	F.Belloni, EPJ/A,58, 227,2022; X4=23653	Absolute measurements relative hydrogen. Results for two fission chamber are different at 2% at 2.51 MeV and at 5% at 14.53 MeV	There are common components of the uncertainties and correlated components of the uncertainties for 4 experimental values with 2 chambers at energies.

PTB-GEEL absolute fission cross section measurements



#21 Two identical fission chambers with slightly different loads of ^{238}U gives 2% difference at 2.51 MeV and 5% at 14.53 MeV in the determined fission cross section. This shows that at least some part of the differences is not related to the uncertainties in the mass of the ^{238}U samples.

This part may be related with the difference in the kinematics (if not accounted) and anisotropy (if not accounted) of fission fragment yields at two energies. Both factors increase the yield of fission fragments under forward angle relative neutron beam at 14.53 MeV in comparison with 2.51 MeV neutron energy. As result the relative absorption of fission fragments in thick of ^{238}U sample is decreased with increase of neutron energy from 2.51 MeV to 14.53 MeV At least effect of anisotropy in fission fragment yields is not mentioned in short publication

New experimental data available in the EXFOR DB and publications: conclusion

New experimental data obtained since Standards2017 evaluation and still not included in the GMA database may contribute in the improvement of the evaluation even if they are consistent with the Standards2017 evaluation.