High-resolution evaluation of the $^{235}\text{U}(n,f)$ cross section from 3 keV to 30 keV

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Abstract. ^{235}U neutron-induced fission cross-section is commonly used as reference for determining other isotope fission cross-section. However, below 150 keV this cross section is only included as Standard at the thermal point and recently its integral value between 7.8 eV and 11 eV [1]. The resolved resonance region, spanning up to 2.25 keV, has been re-evaluated with high resolution in the last ENDF/B-VIII release [2] and a SAMMY resonance analysis was done by L. Leal et al. [3] including the CERN-nTOF experimental work of Paradela et al. [4] up to 10 keV, taken into account the IAEA Reference file.

In this work the $^{235}\text{U}(n,f)$ low-background and high-resolution experimental data obtained at the CERN-nTOF facility is combined with previous high-resolution experimental data, in order to produce a very fine grid dataset with normalisation to the IAEA Reference file. The extremely-high energy calibration required to reproduce the resonance sharp profiles is based on the nTOF DAQ system with a resolution below 0.1% with reference to the 8.78 eV resonance and to the sharp $\text{Al}(n,g)$ capture dip at 5.904 keV.

The comparison of the so-evaluated profile with the experimental data and with the evaluated ones will be discussed.

1 Introduction

Accurate data on the fission of heavy nuclei at energies beyond the resolved resonance region (RRR) are of a renewed interest for both fundamental and applied nuclear physics.

Most neutron cross section measurements are made relative to the neutron cross section standards, being so the basis for measurements and evaluations. Very few cross sections can be measured absolutely and in most cases cross sections are measured relative to the standards or to the data files retrieved from the evaluated libraries. An important point is that the accuracy of a cross section is limited by the uncertainty in the reference cross section relative to which it is measured. There is so a need for additional data related to standard isotopes used as reference and the extension in energy range of certain cross sections, as remarked in Ref [1].

Concerning the ^{235}U neutron-induced fission cross-section, below 150 keV this cross section is only included as Standard at the thermal point and recently its integral value between 7.8 eV and 11 eV [1]. The resolved resonance region, spanning up to 2.25 keV, has been re-evaluated in this energy range with high resolution in the last ENDF/B-VIII release [2] and a SAMMY resonance analysis was done by L. Leal et al. [3] after including the work of Paradela et al., presented at WONDER-2015 [4], and taken into account the IAEA Reference file. This result of L. Leal has been included in the last up-dating version

of JEFF (JEFF-3.3). Above 2.25 keV the current ENDF/B-VIII shows a coarse energy resolution, notwithstanding its integral mean values are in fine agreement with the point-wise dataset in the IAEA Reference file. JEFF-3.3 and JENDL-4.0, on the other hand, are giving only a smooth line.

$^{235}\text{U}(n,f)$ reaction has been amply measured and a bunch of entries can be retrieved at the EXFOR library, many of them consisting on single points, mean cross-section values in a broad energy interval or low energy resolution cross-section spectra. The aim of this work is to determine the shape of the $^{235}\text{U}(n,f)$ cross section with an improved energy resolution, in the energy region of the Unresolved Resonance Region (URR) up to 30 keV. So that, after inspection of the EXFOR library some selected datasets have been retained arriving to the conclusion that, besides the CERN-nTOF-PPAC results, the dataset of Weston and Todd [5] is the one having the best compromise between statistics and energy resolution, even though its bad energy calibration.

In the RRR, below 2.25 keV, most of the resonances found are of Class I, having so its energy intervals increasingly closer. On the other hand, in the transition from the RRR to the URR, the resonance structures due to the coupling of Class II states to Class I ones become more and more probable, resulting in a too high density of barrier transition states that make it almost impossible to resolve (for a detailed explanation see Ref. [6] and references therein). Above 3 keV, nevertheless, the cross-section spectrum is dominated by the grouping of the observed cross section peaks, pointing to the existence of resonance structures that have been so far not well resolved.

2 Evaluation procedure

When looking for the best energy achievable from the experimental data sets, only a few can be retrieved having both high statistics and an energy resolution high enough, as otherwise is difficult discerning statistical artifacts from real resonances. To overcome these difficulties different datasets must be compared between them, but only after a careful energy re-calibration and a suited re-normalisation. In Fig 1 can be seen some results from

Fig. 1. $^{235}\text{U}(n,f)$ experimental data from EXFOR. The ENDF/B-VIII, JENDL-3.2 and the IAEA evaluations are also included.

EXFOR [5] and [7-12] for two energy ranges. In both panels can be perceived that an evident correlation exists, even though the scatter of the points due to not having a correct calibration. It is worth of mention the coarse miscalibration of the Bowman's dataset [7] shown in the left panel (light blue).

The low-background and high-resolution $^{235}\text{U}(n,f)$ experimental data obtained at the CERN-nTOF facility can not be taken alone because of its limited statistics. We started so by combining different data sets from measurements done with different detector setups but having the same time-to-energy calibration. The CERN-nTOF facility is described in detail

in Refs. [13] and [14], and the data analysis is described in Refs [4] and [15 - 17]. We take advantage of the very high stability of both the neutron flux and the DAQ system timing that having a clock frequency of 2 GHz gets an energy resolution well below 0.1%, all along this energy range,

2.1 Data reduction and conditioning

As above mentioned, there is in EXFOR many entries for the $^{235}\text{U}(\text{n},\text{f})$ reaction measurements, but only a few having both high statistic and fine energy resolution. So that, this work is based in only those susceptible of passing a suited filter without loss of the required information. Every dataset was managed to have around 2000 bin/decade in order to cope with the extremely-high energy calibration required to reproduce the resonance sharp profiles. Then a triangular Barlett filter was applied in order to reduce the statistical scatter without reducing the binning. The nTOF energy calibration has been taken as reference with reference to the $^{235}\text{U}(\text{n},\text{f})$ 8.775(3) eV resonance and to the sharp $\text{Al}(\text{n},\text{g})$ capture dip at 5.904(5) keV. In Fig 2 (left) is shown the nTOF data (in blue) matching the ENDF/B-VIII evaluation and in the right plot is the dip produced by the capture and by the

Fig. 2. $^{235}\text{U}(\text{n},\text{f})$ peak at 8.773 eV and $\text{Al}(\text{n},\text{tot})$ dip at 5.904 keV used as time references in this work.

scattering of neutrons produced in the windows of the neutron-beam vacuum pipe. In this way we know that the accuracy of the energy calibration is below 0.1% in all the energy range. The cross section of the nTOF datasets has been normalised in order to match the IAEA standard value of the cross section integral in the energy interval 7.8 to 11 eV ($247.5 \text{ b} \cdot \text{eV}$), as recommended in [1]. Then, both the energy calibration and the cross section normalisation of the nTOF datasets were kept untouched along the rest of the procedure.

Once the nTOF dataset was accurately calibrated, different resonance peaks along the energy range were used to re-calibrate and re-normalise the datasets of Weston and Bowman. It is worth to mention that whereas the Weston data were quite fine calibrated (a few percent both in energy and in cross section) the Bowman data required severe shifts (the original energy calibration was found to be non-linear) and the cross section normalisation do not match correctly all along the energy range, as it will be shown later.

The thereafter called USC-Eval file was then built starting by introducing points (energy-cross section) at those resonances having maxima and minima clearly seen in both the PPACs nTOF dataset and the Weston dataset, because these data files are the most reliable. Plotting the USC-Eval together with the experimental profiles, more points were added in an iterative process, in order to reproduce as close as possible both experimental datasets.

At this point, we realised that number of resonance peaks were composed of two or even few peaks not being resolved in one or other data files. This ambiguity required the comparison with other experiments and so the Bowman data [7], and sometimes also the Lemley data [8], were used to cross-check the assignment of the peaks. Moreover, the data

from an experiment performed at CERN-nTOF using a FIC detector has been used too, as it can be taken as an independent experiment. The analysis of this experiment [18] is not yet finished but it shows a very high energy resolution and has been useful to prove the existence of some doubtful peaks. So that, every peak introduced in the USC-Eval file required to be present in at least two different experiments and having some trace in others. It is worth to mention that, after the correct calibration of all the datasets, the grade of coincidence has been surprisingly high, as it will be shown in the next section.

Finally, the whole USC-Eval dataset was normalised in order to fit with the point-wise values recommended by the IAEA Reference file [19]. This result is shown in Table 2, at the end of the text, compared with the recent evaluations.

Fig. 3. Comparison of the USC-Eval with experimental datasets at different energy intervals.

3 Results

In this section are shown the results of the $^{235}\text{U}(n,f)$ evaluation based on the CERN-nTOF PPACs experiments, combined with the Weston data and compared to the ones of Bowman, Lemley and Furman. In this way we can say that the shape of the cross section spectrum reproduce well the experimental datasets and, on the other hand, its integral mean values

are in a fair agreement with the GMA nodes used by the IAEA for the Reference files. In Fig.3 are shown some plots comparing the result of our evaluation with the experimental data at different energy intervals. In Fig 4 are summarised the statistics of such a comparison for the four experimental datasets: namely: nTOF-PPACs, nTOF-FIC, Weston and Bowman. In the left panel is the histogram of the energy residuals, showing that after the energy re-calibration the dispersion of the energy at the resonance peaks is 0.11% which is compatible with the energy resolution of each individual setup. In the right is the histogram with the residual of the cross-section values at the peaks with a RMS dispersion of 5.2% with maximum values of 20%. As the evaluated values are a compromise between the experimental ones, the differences from experiments to evaluation are lower than the differences between experiments. It must be noted that this differences arose because most resonances have a very narrow peak, depending so its apparent height on the energy binning.

Fig. 4. Statistics of the energy and cross section values of the resonance peaks, taken as the differences between evaluation and experiments in percent.

3.1 Main findings

The high degree of coincidence found between the Paradel data at CERN-nTOF and those of Weston at ORNL is confirmed by other high-resolution datasets. More than 280 peaks have been unambiguously identified, distributed as follows: 70 from 3 to 5 keV; 73 from 5 to 8 keV; 56 from 8 to 13 keV; and 82 from 13 to 30 keV. The position in energy of these points is statistically distributed with a RMS of 1.1 % (Fig. 3-left).

In a recent paper of G.F. Bertsch *et al.* [20] the authors examine the autocorrelation function of the $^{235}\text{U}(n,f)$ reaction with a view to quantify the presence of intermediate structures in the cross section. Finally they claim that the apparent fluctuations due to compound nucleus resonances, on the order of the eV energy scale, do not present structure but in the region around 20 keV. They based the study mainly in the Perez data from ORNL [21], discarding among others the Weston data, with the argument that the Perez dataset has a superior energy resolution, what it is false in the range below 30 keV (from the information available in EXFOR). This bad choice is leading us to criticize the Bersch assertion. In Fig. 5 is presented the smoothed USC-Eval which suggests the existence of correlated peaks on the scale of 1 keV, that have the same profile as the 22 keV structure analysed in [20]. That structure shape can be suspected around 9 keV, 15 keV, and 19 keV, for instance. The existence of narrowest structures is also suggested below 9 keV in the plots presented in Fig. 3.

Fig. 5. Smoothed profile of the $^{235}\text{U}(n,f)$ cross section

3.2 Numerical results

The numerical values of the USC-Eval data file are at the end, in Table 1. The uncertainty in energy is 0.1 % and in the cross section it can be estimated to be 2.6 %, assuming that the evaluated values are the mean of the experimental data with an energy binnig of 2000 bin / decade. In Table 2 are the integral mean values compared with last evaluated libraries

4 Conclusions

An evaluation of the $^{235}\text{U}(n,f)$ reaction has been made in the energy range from 3 keV to 30 keV, comparing datasets from different experiments having high statistics and a fine energy resolution. The very high coincidence between those experimental datasets allow us to unambiguously assign the energy and cross section value at the identified peaks with the resolution equivalent to 2000 bin/decade, with an uncertainty in energy below 0.1% and in cross section of 2.6%.

The shape of the cross section suggest the existence of resonance structures paving the way to a further understanding of the compound nucleus fission barriers.

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Table 1. USC-Eval [Energy in eV – Cross section in barn]

3000	5.167	3005	6.420	3009	6.802	3013	6.144	3019	5.288
3023	4.650	3030	5.192	3036	6.134	3041	4.765	3046	4.483
3053	4.804	3058	3.884	3065	5.757	3070	7.204	3077	6.199
3084	5.112	3091	4.757	3098	5.027	3102	5.116	3110	4.683
3116	4.029	3119	3.681	3124	4.426	3131	5.244	3135	6.976
3142	5.375	3149	4.262	3156	4.883	3163	4.198	3168	3.201
3172	2.652	3185	4.157	3193	6.153	3201	5.032	3204	3.485
3208	4.038	3211	3.060	3223	4.332	3231	6.026	3238	5.726
3245	6.115	3253	5.203	3260	4.954	3268	5.202	3275	4.673
3283	6.220	3290	5.699	3297	7.358	3301	8.489	3309	7.811
3317	5.043	3321	4.551	3332	4.678	3335	5.133	3344	4.501
3352	4.343	3360	3.561	3367	2.780	3373	2.761	3383	3.510
3391	4.940	3399	5.620	3407	5.633	3416	5.877	3423	5.581
3431	4.407	3438	3.401	3446	3.121	3454	3.626	3462	4.510
3470	4.933	3478	4.587	3486	4.230	3495	5.028	3503	6.374
3511	6.069	3518	4.464	3525	3.758	3535	4.255	3543	5.168
3551	5.124	3559	4.049	3566	4.021	3576	5.467	3582	5.978
3592	5.060	3600	5.330	3608	5.835	3617	4.668	3625	3.717
3631	3.707	3641	4.466	3650	4.749	3658	4.153	3667	3.870
3675	3.772	3684	3.876	3692	4.536	3701	5.046	3709	4.690
3718	3.812	3725	3.438	3735	3.772	3744	4.227	3752	4.469
3761	4.810	3770	5.367	3776	5.494	3787	5.102	3796	4.791
3805	4.816	3813	5.216	3820	5.738	3830	5.545	3839	5.791
3846	6.151	3854	5.060	3861	3.859	3873	3.865	3883	3.905
3892	3.535	3901	3.214	3911	3.276	3920	3.836	3926	4.374
3939	4.424	3949	5.280	3956	5.872	3966	5.815	3973	6.035
3981	5.249	3991	4.096	4000	4.288	4008	4.894	4014	4.375
4021	4.759	4030	4.213	4039	4.716	4041	4.832	4053	4.482
4068	4.788	4077	3.961	4088	4.221	4099	3.926	4103	4.068
4116	4.131	4125	3.871	4130	3.604	4144	3.613	4154	3.722
4162	3.993	4172	3.939	4183	3.923	4191	4.753	4199	5.377
4211	4.900	4220	4.309	4230	4.145	4240	4.824	4250	6.391
4258	6.601	4269	5.551	4279	5.155	4290	5.524	4299	5.388
4307	4.846	4318	4.754	4328	4.488	4338	3.970	4345	3.819
4358	4.797	4370	5.168	4380	5.482	4387	5.569	4398	4.551
4409	3.835	4419	3.378	4429	3.385	4439	4.484	4447	5.641
4460	5.563	4470	4.870	4480	4.911	4489	5.641	4491	5.656
4508	4.981	4513	4.926	4521	4.394	4533	4.334	4543	4.479
4552	4.179	4564	3.444	4570	3.729	4585	4.002	4594	4.732
4603	4.888	4615	4.162	4626	3.779	4637	3.744	4649	3.137
4660	3.267	4669	4.219	4672	4.773	4691	4.361	4701	3.820
4712	3.391	4724	2.891	4736	3.168	4745	3.649	4757	3.627
4769	3.687	4778	4.240	4786	3.924	4802	3.714	4812	3.052
4822	3.291	4834	3.840	4845	3.869	4854	3.820	4868	4.050
4879	4.625	4890	5.480	4896	5.765	4912	4.487	4924	3.067
4935	2.670	4947	2.951	4958	3.171	4965	2.918	4972	2.428

4986	3.508	5000	4.415	5021	3.502	5038	4.040	5046	5.045
5055	4.172	5061	4.517	5079	3.471	5092	3.877	5109	3.309
5127	4.344	5148	3.187	5166	3.502	5178	3.167	5195	3.816
5215	3.278	5235	3.706	5242	3.136	5254	3.502	5265	3.238
5282	4.314	5301	3.542	5323	4.688	5345	3.705	5355	4.009
5366	3.400	5383	4.507	5405	3.410	5421	4.415	5437	3.400
5455	3.532	5470	2.944	5490	4.283	5512	5.228	5526	3.938
5542	4.689	5552	4.375	5562	5.085	5600	3.116	5634	4.649
5664	3.055	5686	3.816	5706	3.025	5723	3.542	5742	3.055
5772	4.796	5796	3.715	5810	4.141	5818	3.705	5838	4.517
5852	4.111	5872	4.892	5902	3.014	5931	3.502	5945	3.133
5975	3.918	5992	3.217	6000	3.512	6025	3.715	6041	3.502
6055	3.827	6066	3.252	6071	3.370	6078	3.268	6093	3.228
6106	2.994	6120	3.258	6135	2.791	6148	3.228	6171	2.649
6191	2.964	6199	2.933	6224	3.674	6242	2.994	6278	3.360
6299	2.830	6336	3.735	6351	3.238	6373	3.745	6385	3.390
6396	3.380	6411	3.998	6424	3.502	6432	3.735	6447	3.228
6464	3.725	6488	2.852	6511	3.248	6520	3.055	6535	3.288
6557	2.750	6581	3.705	6598	3.471	6614	3.502	6632	2.771
6647	3.441	6661	2.700	6675	2.751	6693	2.984	6707	2.771
6728	2.558	6745	3.075	6761	3.258	6773	3.552	6792	3.675
6810	3.938	6825	3.563	6838	2.446	6850	2.548	6866	3.461
6884	2.954	6899	3.471	6915	3.217	6952	4.425	6971	3.319
6986	3.745	7000	3.502	7014	3.197	7041	4.659	7053	4.172
7060	3.918	7076	4.111	7089	3.837	7109	3.055	7125	3.573
7158	2.598	7200	3.647	7225	2.751	7245	2.984	7257	2.832
7270	3.685	7285	3.107	7305	3.258	7324	2.755	7333	2.517
7351	3.593	7369	3.644	7387	4.395	7399	4.841	7415	3.877
7438	2.548	7461	2.923	7470	2.883	7505	3.776	7522	3.461
7540	3.705	7570	2.497	7595	2.842	7610	3.218	7625	2.801
7645	3.461	7661	3.177	7677	3.471	7698	2.923	7712	2.960
7741	2.252	7770	3.157	7786	3.685	7824	2.588	7859	3.918
7875	3.461	7904	2.619	7940	3.146	7970	2.598	8000	2.820
8018	2.870	8032	2.710	8059	3.235	8073	3.013	8087	3.490
8115	3.207	8138	2.513	8169	2.659	8200	2.487	8227	2.669
8260	2.311	8290	2.954	8320	2.823	8356	3.127	8377	2.811
8400	3.278	8429	3.146	8458	3.623	8485	3.532	8503	2.766
8520	2.827	8548	2.750	8570	3.239	8595	3.230	8618	3.718
8655	3.623	8685	3.146	8708	3.090	8735	3.796	8765	3.755
8795	2.943	8817	2.883	8832	3.126	8845	3.146	8875	2.436
8895	2.492	8930	2.334	8960	2.545	8990	2.420	9000	2.298
9010	2.385	9047	3.018	9086	2.953	9110	3.700	9130	3.684
9144	3.859	9170	3.654	9206	3.136	9230	3.126	9257	3.497
9312	2.994	9340	3.009	9365	2.842	9402	3.360	9443	3.644
9466	3.323	9501	3.319	9534	2.831	9561	2.893	9590	2.817
9620	2.944	9650	2.842	9679	2.984	9711	2.710	9757	3.547
9783	3.197	9802	3.329	9852	2.908	9892	3.040	9916	3.027
9951	3.345	9970	3.197	10000	2.517	10026	2.465	10055	2.487
10090	2.740	10120	2.730	10150	3.207	10192	2.548	10228	2.710
10275	2.538	10300	2.771	10378	2.509	10410	2.598	10442	2.522
10474	2.750	10533	2.603	10591	2.841	10646	2.791	10699	3.233
10744	2.952	10764	2.599	10840	2.690	10890	2.455	10941	2.690
10997	2.386	11080	3.274	11115	3.128	11151	2.801	11187	2.832
11224	2.690	11252	2.791	11320	3.146	11345	3.288	11375	2.984
11415	2.559	11460	3.004	11530	2.639	11570	2.720	11643	2.279
11711	2.456	11782	2.416	11854	3.141	11892	2.817	11951	2.450
11990	2.499	12010	2.700	12060	2.781	12092	2.937	12130	2.750
12170	2.548	12220	2.619	12275	2.131	12308	2.064	12355	2.460
12405	2.416	12460	2.213	12510	2.508	12545	2.483	12595	2.559
12620	2.355	12682	2.492	12715	2.386	12744	2.201	12777	2.345
12819	2.512	12882	2.264	13008	2.908	13023	2.802	13075	2.455
13164	2.853	13210	2.898	13240	3.100	13293	2.705	13333	2.994

13407	2.730	13442	2.852	13505	2.799	13540	2.850	13580	2.537
13610	2.791	13650	2.487	13678	2.669	13710	2.601	13780	2.212
13810	2.253	13850	2.548	13892	2.477	13942	2.563	13990	2.431
14044	2.678	14140	2.295	14218	2.588	14250	2.527	14325	2.619
14420	2.275	14495	2.722	14528	2.676	14572	2.741	14619	2.443
14677	2.835	14760	2.639	14795	2.619	14874	3.050	14921	2.806
14975	2.999	15011	2.761	15047	2.259	15081	2.155	15118	2.154
15118	2.154	15193	2.369	15264	2.246	15338	2.330	15381	2.249
15460	2.365	15527	2.162	15645	2.516	15712	2.372	15777	2.400
15822	2.285	15895	2.507	15992	2.224	16065	2.604	16119	2.142
16182	2.527	16220	2.436	16290	2.603	16362	2.497	16441	2.603
16535	2.154	16615	2.608	16672	2.497	16755	2.575	16825	2.152
16863	2.350	16922	2.220	17022	2.355	17066	2.254	17137	2.445
17217	2.183	17295	2.214	17389	1.940	17460	2.123	17560	2.021
17625	2.386	17690	2.455	17780	2.436	17855	2.391	17944	2.471
18056	2.274	18095	2.487	18200	2.426	18250	2.426	18309	2.222
18360	2.380	18405	2.334	18470	2.578	18514	2.375	18562	2.367
18632	2.284	18820	2.588	18930	2.426	19030	2.829	19075	2.741
19111	2.771	19241	2.224	19325	2.341	19412	2.045	19560	2.443
19590	2.385	19690	2.091	19760	2.139	19830	2.099	19870	2.172
19920	2.101	20000	2.395	20055	2.520	20090	2.299	20160	2.335
20220	2.110	20325	2.113	20385	1.942	20406	1.896	20520	1.912
20580	2.102	20715	1.944	20808	2.222	20909	2.071	21007	2.192
21205	1.829	21230	1.928	21325	1.918	21430	2.273	21580	2.055
22612	2.049	22670	2.190	22715	2.199	22800	2.011	22880	2.040
22960	1.979	23040	2.020	23136	1.866	23230	1.939	23330	2.050
23395	2.005	23460	2.070	23580	1.839	23740	2.249	23850	2.293
23980	1.989	24105	2.010	24185	1.879	24375	2.243	24458	2.281
24620	2.064	24790	2.184	24910	2.081	25040	2.116	25150	1.959
25270	2.133	25380	2.090	25499	2.212	25620	2.017	25730	2.113
25858	1.855	25950	1.887	25980	1.989	26130	2.121	26225	2.250
26330	2.106	26420	2.152	26560	2.035	26660	2.142	26850	2.040
27000	2.274	27120	2.137	27250	2.213	27410	2.035	27488	2.028
27590	2.296	27724	2.233	27890	2.416	27990	2.345	28080	2.360
28270	2.142	28390	2.289	28475	2.228	28605	2.396	28730	2.162
28980	2.410	29070	2.375	29240	2.451	29395	2.162	29520	1.979
29660	2.060	29890	1.837	29910	1.847	29955	1.908	30000	2.040

Table 2. Integral mean values compared with last evaluated libraries.
E_n is in keV and the cross section in barn.
In brackets are the ratios of the USC-Eval to the evaluated libraries

E _{ini}	E _{fin}	EvalUSC	ENDF-VIII	JEFF-3.3	IAEA[Ref 19]
3.00	4.00	4.802	4.804 (1.00)	4.653 (1.03)	4.792 (1.00)
4.00	5.00	4.286	4.294 (1.00)	4.273 (1.00)	4.268 (1.00)
5.00	6.00	3.850	3.842 (1.00)	3.823 (1.01)	3.847 (1.00)
6.00	7.00	3.270	3.368 (0.97)	3.352 (0.98)	3.298 (0.99)
7.00	8.01	3.253	3.229 (1.01)	3.215 (1.01)	3.242 (1.00)
8.00	9.00	3.015	3.062 (0.98)	3.094 (0.97)	3.014 (1.00)
9.00	10.0	3.117	3.219 (0.97)	3.064 (1.02)	3.130 (1.00)
10.0	12.0	2.720	2.928 (0.93)	2.950 (0.92)	
12.0	14.0	2.568	2.715 (0.95)	2.722 (0.94)	
14.0	16.0	2.482	2.591 (0.96)	2.536 (0.98)	
16.0	18.0	2.365	2.370 (1.00)	2.432 (0.97)	
18.0	20.0	2.378	2.440 (0.97)	2.369 (1.00)	
20.0	25.0	2.164	2.234 (0.97)	2.227 (0.97)	
25.0	30.0	2.175	2.153 (1.01)	2.121 (1.03)	