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Some reflexions concerning ^{239}Pu fission cross-sections

Herve Derrien
Japan Atomic Energy Research Institute
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A new set of fission cross-sections of ^{239}Pu was available in 1984 from a measurement performed at ORNL by L.W.Weston and J.H.Todd[1]. The results were quite surprising: the data, independently normalized at thermal to the accepted standard value, were much lower than the average of the previous measurements. The differences between ENDF/B-V and the new results varied from 1% at 60 eV to 10% at 100 keV. In the same time, the sub-group for ENDF/B-VI standard evaluation was performing an important work on the fission standard data and very accurate values of the fission cross-section of ^{239}Pu were proposed from a simultaneous analysis of an exhaustive set of experimental fission data and other related data (ratio of fission cross-sections, α, η, etc.)[2]. The fission data of Weston were 4% lower than the standard evaluation. The situation was not acceptable from the point of view of accurate modern evaluation (Bayesian simultaneous fit of all the experimental data) and of accurate modern fission experiment (low experimental background, improved fission detector, etc.)

Very high resolution transmission experiments of ^{239}Pu were also performed by J.A.Harvey et al. in 1984 at ORNL[3]. Therefore, a simultaneous fit of the new fission of Weston and of the transmissions of Harvey could be performed in the resolved resonance energy range in order to obtain a new set of resonance parameters on an extended energy range. A new code was available at ORNL for this purpose: the Reich-Moore Bayesian SAMMY code[4]. This analysis, by checking the consistency (or inconsistency) between the transmissions of Harvey and the fission of Weston, could also provide a good test on the accuracy of the fission of Weston.

In 1985, I receive an invitation from G.de Saussure to come to ORNL to take the responsability of this analysis. G.de Saussure should be considered as the initiator of the important work performed at ORNL since 1985 leading to a tremendous improvement in the resonance parameter evaluation of the fissile isotopes ^{235}U, ^{239}Pu and ^{241}Pu. The analysis of the ^{239}Pu data was started in 1985 and completed in 1987 in the energy range from thermal to 1.0 keV[5]. The data from Harvey and Weston were the basis of the analysis, but the high resolution measurement of Blons[6] was also included in the experimental data base. A very good consistency was found between Harvey transmission and Weston fission without any modification of the background and of the normalization in both sets of data. Such consistency was not found for the data of Blons which showed large cross-sections between resonances due to an underestimation of the experimental background (fig.1). In view of these results, I strongly supported the data of Weston at least in the resonance region arguing that the results of the standard group evaluation could be biased by Blons data and other similar data. Finally, the results of the SAMMY analysis were accepted for ENDF/B-VI, JENDL-3 and JEF-2; but the standard data were taken in the high energy ranges. A discrepancy was stated and an international group was established as a sub-group of the NEA International Evaluation Cooperation in order to resolve the discrepancy.

In the meantime, I was obliged to retire from the French Atomic Energy Commission and I took a sabbatical year in my hometown in Brittany (west part of France) building a new house. But I knew that there was a possibility for me to come back to the evaluation work by accepting a JAERI research fellowship at JAERI Nuclear Data Center headed by Y.Kikuchi (to whom I am grateful). When I left Oak-Ridge in November 1989, I was sad knowing I was going to retire leaving a non finished job; though I realize several months later that I was on the list of the international working group in charge of the discrepancy of the ^{239}Pu fission! I am at JAERI since March 1991 and I completed a ^{239}Pu resonance analysis in the energy range 1.0 keV to 2.5 keV by using a version of SAMMY made available on the FACOM-M 780 by T.Nakagawa, almost forgetting that something could be wrong in the 1984 fission data of Weston!

The news came on 15th of December 1991, on a BITNET message from Larry Weston[10]: following a recommandation of the sub-group of the NEA International Evaluation Cooperation in a meeting at Saclay in December 1990, a new measurement was performed by Weston; the very preliminary results were that the 1984 data of Weston should be renormalized by about +3%, resulting of a careful examination of the data at 0.0253 eV; but the low cross-section between resonances were confirmed. I was not ready to accept such "bad news" from the results which were going to destroy the high quality of the resonance parameters in the energy range from thermal to 2.5 keV. I spent several days on the data, trying to renormalize Weston 84 data by several ways. I used the data in the low energy range overlapping with Weston data, particularly the new data published by Wagemans at MITO in 1988[7]. I followed the recommandations of Wagemans to normalize all the data in the energy range 0.1 eV to 0.5 eV to a fission integral of 470.0 b.eV[8]. But this kind of normalization is very traitorous, depending on the interval of energy choosen for the normalization (Table 1). I reached the conclusion that the data I used in my 1987-1989 analysis could indeed be renormalized but not by more than 1.5% with 2% accuracy and will be in good agreement with Wagemans 80 data[9] below 1 keV.

January 7th 1992, I received another message from Larry Weston[11]. He completed the evaluation of his new experiment with a definitive renormalization of +2.3% on the data I used in my 1987-1989 analysis, and achieving a 0.5% agreement with the standard data of Poenitz in the energy range 0.1 keV to 100 keV. Weston could conclude: "I really do not think there is a discrepancy anymore". This renormalization will bring the data only 1.3% higher than the renormalized Wagemans 80 data,which could not be considered as a discrepancy. The remaining discrepancy with the data of Blons (2.2%) is due to large experimental background in a massive detector system used to cool the sample down to the liquid nitrogen temperature[11].

One discrepancy remains which is my concern: the cross-sections calculated from the resonance parameters in the energy range from thermal to 1.0 keV (parameters used in ENDF/B-VI, JENDL-3 and JEF-2) are 1% (accepted fit accuracy) on the average smaller than the experimental data from which they were inferred. Now, these cross-sections will be at 3.3% below the new Weston data. This discrepancy should not be left like that and a new SAMMY analysis should be performed. However, this analysis will not take too much time by starting from the existing covariance matrices. But a severe inconsistancy could show up between the new fission data of Weston and the transmission of Harvey in the wide J=0 resonances, where the fission width is nearly equal to the total width.

As said Larry Weston in his last message: "As always, there is never a clear solution to a problem".

References

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Table 1 Comparison of average fission cross sections

Energy range(eV)	WAG88[7] (748 b)+	WEST84[1] (748 b)+	GWIN76[11]	GWIN84[12]	WAG80[9]	WAG80/WEST84
0.01-0.02	9.73			9.88		
0.02-0.10	44.93			45.51		
0.10-0.50	470.00		470.00	470.00	470.00	
0.50-1.00	39.66			38.85	38.82	
1.00-10.0	252.50		261.55	254.90	252.20	
10.0-20.0	1063.00	1014.75	1052.43	1070.00	1025.70	1.0109
0.10-20.0	1825.16			1833.75	1786.72	
20.0-30.0		319.23	329.04	322.00	318.67	0.9982
30.0-60.0		1023.12	1019.55		1005.20	0.9823
60.0-100.		2118.08	2164.13		2153.10	1.0167
100.-1000		9071.12	9404.32		9154.00	1.0092
10.0-100.		4475.19	4565.15		4502.70	1.0062
10.0-1000		13546.39	13969.47		13656.70	1.0082
1000-1900		4119.45	4411.00		4316.50	1.0483
1900-3000		3390.22			3577.13	1.0555

+ : normalization at 0.0253 eV.

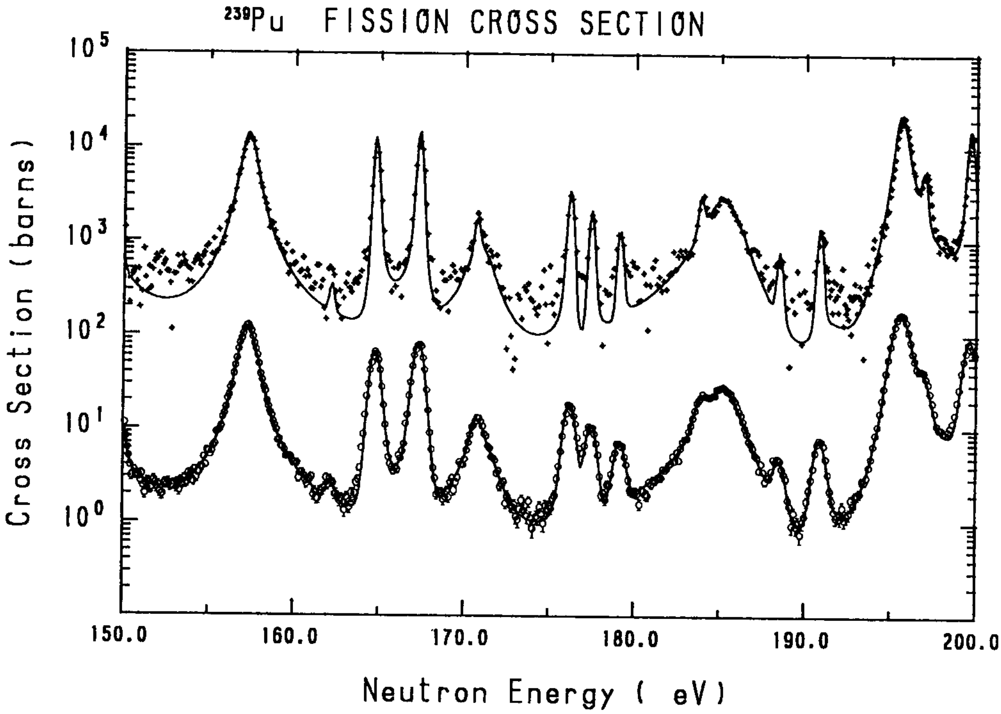

Fig.1 The fission cross-section of ^{239}Pu in the energy range from 150 eV to 200 eV. The upper part of the figure shows the experimental data of Blons (displaced by two decades). The lower part shows the 1984 experimental data of Weston. The curves represent the cross-sections calculated with the resonance parameters obtained from a consistent fit of the transmissions of Harvey and the fission of Weston. A discrepency of about 2 barns is seen between resonances when comparing the data of Weston and those of Blons; this discrepency is more than 10% of the average calculated cross-section (16.35 b) in the energy range from 150 eV to 200 eV.