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R-matrix Analysis of ^{239}Pu Neutron Cross-Sections in the Energy Range up to 1000 eV

H. Derrien
G. de Saussure

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R-MATRIX ANALYSIS OF ^{239}Pu NEUTRON CROSS-SECTIONS IN THE ENERGY RANGE UP TO 1000 eV

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ABSTRACT

The report is a description of the analysis of the ^{239}Pu neutron cross sections in the resolved resonance region using the multilevel-multichannel Reich-Moore code SAMMY. The resonance parameters were obtained in the energy range up to 1000 eV. The table of the resonance parameters is given with some statistical properties of the parameters. Tabulated and graphical comparisons between the experimental data and the calculated cross sections are given. The results are available in ENDF/B-V format and will be proposed for the evaluated data libraries JEF2 and ENDF/B-VI.

1. INTRODUCTION

In order to improve the representation of the ^{239}Pu cross sections by using a multilevel-multichannel formalism and to extend the resolved resonance range up to 1 keV, ^{239}Pu cross-section measurements were analyzed with the resonance analysis Bayesian code SAMMY[1] using the Reich-Moore R-matrix formalism. Preliminary results have been presented in the report ORNL/TM-10098[2] in which more information can be found concerning the purpose of the analysis, the data analyzed,[3−10] and the method of analysis. The aim of this report is to present: (1) the new set of resonance parameters obtained from complementary work performed in 1987 by using an updated version of SAMMY; (2) some properties of the resonance parameters and comparison to the results obtained at Saclay in 1973;[11] and (3) detailed graphical and tabular comparisons between the cross sections calculated from the resonance parameters and the experimental data analyzed. A more extensive study of the resonance properties and a discussion of their significance will be submitted for journal publication.

2. METHOD OF ANALYSIS

The list of the resonance parameters is given in ENDF/B format in Table 1. The cross sections in the energy range 0 to 1 keV are described by 393 resonances including four bound levels and three resonances in the energy range above 1 keV. The parameters of the seven fictitious outside resonances represent the contributions of the truncated external levels to the range of interest, in such a way that the cross sections could be properly described in the energy range up to 1 keV without the need of a smooth-file contribution and by using a constant effective radius $R' = 0.948$ fm. The value of R' is strongly correlated to the parameters of the fictitious resonances at 150 and 1100 eV and to the accuracy of the normalization coefficients of the experimental transmissions analyzed; R' is known with about 2% accuracy.

The new set of resonance parameters is improved in comparison to the values given in ORNL/TM-10098 in the following points:

1. More experimental data have been included in the thermal region and all the data were normalized to the ENDF/B-VI standard values at 2200 m/s. The standard values at 2200 m/s are reproduced by the resonance parameters within one standard deviation (see Table 9 page 29).

2. Some energy ranges above 300 eV containing broad resonances with large fission widths have been reanalyzed with respect to spin assignment. An attempt has been made to assign the spin 0^+ to all the broad resonances, since the fully open fission channel is a 0^+ fission channel. In the new set of parameters, only four broad resonances remain in the 1^+ spin group, against 20 in the previous set. This new spin assignment is more likely correct.

3. Some difficulties due to the exponential tail of the detector resolution function were encountered in the analysis of the high-energy range of the data. The so-called exponential folding width was previously taken as a constant in SAMMY. A careful least square shape analysis of some isolated resonances or well defined group of resonances has shown that this parameter varies roughly like $1/\sqrt{E}$ in the Harvey *et al.* transmission data. After updating SAMMY to take into account this variation, the transmission fits were greatly improved leading to more accurate values of the neutron widths.

4. Some bias was introduced in the parameters of the high-energy range analyzed, due to a lack of accuracy in SAMMY for the calculation of the Doppler and resolution broadening when the channel width of the experimental data is large compared to the natural width of the resonances. This was particularly true for the fission cross sections of Weston and Todd.[7] The updated version of SAMMY allows an

accurate calculation in each case by using an input parameter for the definition of the number of calcuated points in each resonance.

5. Above 500 eV no systematic search was made on the capture widths in the previous analysis. This was done in the new set of parameters and realistic values of Γ_γ were obtained for most of the well defined resonances. No attempt was made to constrain the value of Γ_γ of poorly resolved or wide resonances.

Table 1. Energy, angular momentum, neutron width, capture width, fission width (channel 1), fission width (channel 2) of Pu-239 resonances in ENDF/B-V format

9.42390+04	2.36999+02	0	0	1	0	9439	2151
9.42390+04	1.00000+00	0	1	1	0	9439	2151
1.00000-05	1.00000+03	1	3	0	0	9439	2151
5.00000-01	9.48000-01	0	0	1	0	9439	2151
2.36999+02	0.	0	0	2358	393	9439	2151
-1.5002E+02	1.0000E+00	4.2894E-01	4.4516E-02	1.9172E-01	0.0000E+00	9439	2151
-1.5465E+01	1.0000E+00	3.4883E-03	2.7501E-02	-2.5621E-06	0.0000E+00	9439	2151
-9.8675E+00	0.0000E+00	3.2139E-02	2.1105E-01	-8.8196E-01	7.1118E-01	9439	2151
-1.5188E-01	0.0000E+00	1.9694E-05	7.2302E-03	-3.8678E-02	-4.9336E-01	9439	2151
2.9568E-01	1.0000E+00	8.0088E-05	3.9333E-02	5.7571E-02	0.0000E+00	9439	2151
7.8158E+00	1.0000E+00	7.9204E-04	3.7754E-02	-4.4748E-02	0.0000E+00	9439	2151
1.0928E+01	1.0000E+00	1.7947E-03	4.0600E-02	-1.4948E-01	0.0000E+00	9439	2151
1.1898E+01	1.0000E+00	9.7513E-04	3.8568E-02	2.0104E-02	0.0000E+00	9439	2151
1.4329E+01	1.0000E+00	6.0470E-04	3.0932E-02	5.7316E-02	0.0000E+00	9439	2151
1.4678E+01	1.0000E+00	1.9105E-03	4.0051E-02	2.9561E-02	0.0000E+00	9439	2151
1.5417E+01	0.0000E+00	2.0042E-03	4.2000E-02	-7.5481E-06	7.5504E-01	9439	2151
1.7657E+01	1.0000E+00	1.8031E-03	3.9300E-02	-3.5342E-02	0.0000E+00	9439	2151
2.2266E+01	1.0000E+00	2.5877E-03	4.3416E-02	-6.1152E-02	0.0000E+00	9439	2151
2.3933E+01	1.0000E+00	8.5720E-05	3.6093E-02	2.5128E-02	0.0000E+00	9439	2151
2.6269E+01	1.0000E+00	1.5427E-03	4.0238E-02	3.9920E-02	0.0000E+00	9439	2151
2.7288E+01	1.0000E+00	1.4931E-04	3.8794E-02	2.7066E-03	0.0000E+00	9439	2151
3.2327E+01	0.0000E+00	8.4513E-04	4.2516E-02	8.1707E-03	-1.2785E-01	9439	2151
3.5486E+01	1.0000E+00	2.6981E-04	4.1027E-02	3.4438E-03	0.0000E+00	9439	2151
4.1457E+01	1.0000E+00	3.3035E-03	4.9118E-02	-6.2224E-03	0.0000E+00	9439	2151
4.1736E+01	1.0000E+00	9.3502E-04	3.9475E-02	5.9249E-02	0.0000E+00	9439	2151
4.4531E+01	1.0000E+00	6.1318E-03	4.0162E-02	-4.2461E-03	0.0000E+00	9439	2151
4.7534E+01	0.0000E+00	4.6984E-03	3.1464E-02	4.8148E-01	-1.2739E-07	9439	2151
4.9576E+01	0.0000E+00	4.1515E-03	4.2000E-02	-1.0493E+00	4.9827E-03	9439	2151
5.0144E+01	1.0000E+00	3.2536E-03	2.2649E-02	-4.8501E-03	0.0000E+00	9439	2151
5.2648E+01	1.0000E+00	9.4602E-03	4.4199E-02	-8.7811E-03	0.0000E+00	9439	2151
5.5704E+01	1.0000E+00	1.5078E-03	3.8263E-02	2.3565E-02	0.0000E+00	9439	2151
5.6924E+01	0.0000E+00	1.1362E-02	4.2000E-02	-2.2043E+00	2.5304E-02	9439	2151
5.9291E+01	1.0000E+00	4.4449E-03	3.6777E-02	9.5812E-02	0.0000E+00	9439	2151
6.1621E+01	0.0000E+00	2.7411E-02	4.2000E-02	7.0977E+00	6.6792E-03	9439	2151
6.3170E+01	1.0000E+00	6.2939E-04	3.7383E-02	7.0308E-02	0.0000E+00	9439	2151
6.5454E+01	0.0000E+00	4.0071E-03	2.4113E-02	4.5020E-01	-2.1169E-16	9439	2151
6.5793E+01	1.0000E+00	9.6909E-03	6.4784E-02	1.0596E-01	0.0000E+00	9439	2151
7.4167E+01	1.0000E+00	3.2109E-03	3.2080E-02	-2.8841E-02	0.0000E+00	9439	2151
7.4885E+01	0.0000E+00	2.8770E-03	4.2000E-02	1.2527E-03	-3.4027E-01	9439	2151
7.5034E+01	1.0000E+00	2.0886E-02	4.2752E-02	-8.6432E-02	0.0000E+00	9439	2151
7.9085E+01	1.0000E+00	4.2916E-05	4.2000E-02	6.0000E-03	0.0000E+00	9439	2151
8.0872E+01	0.0000E+00	4.6193E-03	4.2000E-02	1.8596E+00	-1.7602E-03	9439	2151
8.2774E+01	1.0000E+00	3.3118E-04	4.7000E-02	5.0000E-03	0.0000E+00	9439	2151
8.5507E+01	0.0000E+00	4.8833E-02	5.1000E-02	-1.8444E+00	3.0442E-03	9439	2151
8.5618E+01	1.0000E+00	8.1945E-03	2.6352E-02	5.6947E-03	0.0000E+00	9439	2151
9.0850E+01	1.0000E+00	1.2209E-02	3.4209E-02	7.1466E-03	0.0000E+00	9439	2151
9.3079E+01	1.0000E+00	6.7496E-04	3.7726E-02	-2.8135E-03	0.0000E+00	9439	2151
9.5509E+01	1.0000E+00	2.0784E-03	6.4127E-02	-3.2108E-02	0.0000E+00	9439	2151
9.6465E+01	0.0000E+00	6.6349E-03	4.2000E-02	1.5003E+00	-2.1350E-01	9439	2151

Table 1. Cont'd

```
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1.0314E+02 1.0000E+00 1.6464E-03 3.4626E-02 7.0250E-03 0.0000E+009439 2151
1.0546E+02 1.0000E+00 4.7159E-03 4.3650E-02 4.8470E-03 0.0000E+009439 2151
1.0683E+02 1.0000E+00 9.9439E-03 3.8191E-02-2.0920E-02 0.0000E+009439 2151
1.1055E+02 1.0000E+00 4.9620E-04 5.3818E-02 2.0372E-02 0.0000E+009439 2151
1.1442E+02 0.0000E+00 2.3513E-03 4.2000E-02-1.4574E+00 3.0317E-019439 2151
1.1532E+02 1.0000E+00 2.1667E-04 4.2000E-02 1.6000E-01 0.0000E+009439 2151
1.1619E+02 0.0000E+00 1.0055E-02 3.2644E-02-1.3959E-01-4.9309E-029439 2151
1.1900E+02 1.0000E+00 1.6904E-02 4.1217E-02-4.0865E-02 0.0000E+009439 2151
1.2118E+02 1.0000E+00 2.5735E-03 3.6094E-02 2.5628E-02 0.0000E+009439 2151
1.2362E+02 1.0000E+00 5.8035E-04 7.4979E-02-6.4558E-02 0.0000E+009439 2151
1.2639E+02 1.0000E+00 1.7424E-03 4.6630E-02-9.9365E-03 0.0000E+009439 2151
1.2772E+02 1.0000E+00 5.3777E-04 3.8339E-02 1.0836E-02 0.0000E+009439 2151
1.3177E+02 0.0000E+00 3.5654E-02 4.2000E-02 3.9491E+00-9.8495E-039439 2151
1.3398E+02 1.0000E+00 5.8612E-03 3.9457E-02-3.5603E-03 0.0000E+009439 2151
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1.4367E+02 1.0000E+00 4.5743E-03 4.0390E-02 3.0756E-02 0.0000E+009439 2151
1.4647E+02 1.0000E+00 7.3904E-03 4.0647E-02 7.9677E-03 0.0000E+009439 2151
1.4741E+02 0.0000E+00 4.9775E-03 4.2000E-02 2.4105E+00 1.6162E-039439 2151
1.4844E+02 1.0000E+00 3.3534E-04 5.0929E-02 3.3148E-02 0.0000E+009439 2151
1.4965E+02 1.0000E+00 1.6047E-03 3.6497E-02 2.4128E-02 0.0000E+009439 2151
1.5717E+02 1.0000E+00 1.2000E-03 4.2000E-02 6.0000E-03 0.0000E+009439 2151
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1.7081E+02 0.0000E+00 3.4950E-03 4.2000E-02-3.5961E-02 1.6240E+009439 2151
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1.7741E+02 1.0000E+00 3.6415E-03 4.3445E-02 6.6894E-03 0.0000E+009439 2151
1.7909E+02 1.0000E+00 1.2554E-03 3.3928E-02 9.0926E-03 0.0000E+009439 2151
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1.8847E+02 1.0000E+00 6.4878E-04 4.4492E-02 1.4782E-02 0.0000E+009439 2151
1.9084E+02 1.0000E+00 1.6801E-03 4.1694E-02-1.0894E-02 0.0000E+009439 2151
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1.9961E+02 1.0000E+00 9.0316E-03 4.7353E-02 7.1593E-02 0.0000E+009439 2151
2.0363E+02 1.0000E+00 1.7014E-03 2.3061E-02 2.2087E-02 0.0000E+009439 2151
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2.0760E+02 1.0000E+00 7.2268E-03 4.5715E-02 6.6815E-03 0.0000E+009439 2151
2.1100E+02 0.0000E+00 3.2460E-03 4.2000E-02-1.0688E-01 1.3248E+009439 2151
2.1350E+02 1.0000E+00 3.6061E-04 3.8250E-02 3.2153E-02 0.0000E+009439 2151
2.1465E+02 0.0000E+00 9.2960E-03 4.2000E-02 1.1171E+01-2.2798E-019439 2151
2.1550E+02 1.0000E+00 4.6000E-05 4.2000E-02 3.4000E-02 0.0000E+009439 2151
2.1677E+02 1.0000E+00 6.2371E-03 3.7331E-02 5.6296E-03 0.0000E+009439 2151
```

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2.2047E+02	1.0000E+00	7.7322E-03	3.9047E-02	-1.1407E-02	0.0000E+00	9439	2151
2.2341E+02	1.0000E+00	3.3835E-03	3.3574E-02	4.8768E-03	0.0000E+00	9439	2151
2.2513E+02	1.0000E+00	1.7305E-03	5.6842E-02	2.0835E-02	0.0000E+00	9439	2151
2.2651E+02	0.0000E+00	1.0648E-02	4.2000E-02	-1.4870E+00	-2.6981E+00	9439	2151
2.2814E+02	1.0000E+00	1.7830E-03	3.8809E-02	-1.6512E-02	0.0000E+00	9439	2151
2.3021E+02	0.0000E+00	5.5265E-03	4.2000E-02	3.0363E+00	-2.8453E-02	9439	2151
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2.3931E+02	1.0000E+00	5.5360E-03	4.1249E-02	-1.2130E-02	0.0000E+00	9439	2151
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2.5616E+02	0.0000E+00	1.6291E-03	4.1500E-02	8.7585E-01	1.0050E-03	9439	2151
2.5638E+02	1.0000E+00	5.5758E-03	4.2042E-02	-1.0544E-02	0.0000E+00	9439	2151
2.5926E+02	1.0000E+00	2.6400E-04	4.1500E-02	-3.6000E-02	0.0000E+00	9439	2151
2.6243E+02	0.0000E+00	8.2926E-02	4.2000E-02	-2.4749E+00	2.8448E+00	9439	2151
2.6301E+02	1.0000E+00	2.2718E-03	3.5444E-02	-8.0545E-03	0.0000E+00	9439	2151
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2.6984E+02	1.0000E+00	4.0898E-03	2.4755E-02	1.8413E-02	0.0000E+00	9439	2151
2.7291E+02	1.0000E+00	2.6410E-02	4.1396E-02	-4.2369E-02	0.0000E+00	9439	2151
2.7506E+02	0.0000E+00	3.8795E-02	4.2000E-02	8.7455E-02	8.6368E-01	9439	2151
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2.7619E+02	0.0000E+00	2.8489E-02	4.2000E-02	9.5666E+00	1.7832E-02	9439	2151
2.7986E+02	1.0000E+00	7.9042E-03	3.4171E-02	-2.8023E-02	0.0000E+00	9439	2151
2.8322E+02	1.0000E+00	2.7522E-02	3.9368E-02	5.9778E-03	0.0000E+00	9439	2151
2.8602E+02	1.0000E+00	2.0000E-04	4.1500E-02	1.0000E-02	0.0000E+00	9439	2151
2.8832E+02	1.0000E+00	9.3300E-05	4.1500E-02	-3.4000E-02	0.0000E+00	9439	2151
2.9184E+02	0.0000E+00	2.0972E-02	4.2000E-02	-6.3065E+00	1.6089E-02	9439	2151
2.9266E+02	1.0000E+00	3.5651E-03	2.7408E-02	2.1283E-02	0.0000E+00	9439	2151
2.9305E+02	0.0000E+00	5.0446E-04	4.2000E-02	1.0624E-04	-6.5534E-01	9439	2151
2.9680E+02	1.0000E+00	3.3737E-03	4.8793E-02	-3.2621E-02	0.0000E+00	9439	2151
2.9892E+02	1.0000E+00	1.0437E-02	5.0867E-02	2.7311E-02	0.0000E+00	9439	2151
3.0215E+02	1.0000E+00	1.8857E-02	4.7527E-02	-5.0214E-02	0.0000E+00	9439	2151
3.0858E+02	1.0000E+00	3.2501E-03	3.1956E-02	1.2687E-01	0.0000E+00	9439	2151
3.0935E+02	1.0000E+00	1.4019E-02	4.9404E-02	2.3430E-02	0.0000E+00	9439	2151
3.1122E+02	0.0000E+00	1.3702E-03	4.2000E-02	1.2968E+00	1.0069E-03	9439	2151
3.1150E+02	1.0000E+00	2.4156E-04	4.2000E-02	3.2000E-03	0.0000E+00	9439	2151
3.1397E+02	1.0000E+00	1.4691E-02	3.8948E-02	-1.0075E-02	0.0000E+00	9439	2151
3.1701E+02	1.0000E+00	5.6432E-03	3.8972E-02	2.1074E-02	0.0000E+00	9439	2151
3.2374E+02	1.0000E+00	1.8908E-02	8.3202E-02	-2.8154E-02	0.0000E+00	9439	2151
3.2422E+02	0.0000E+00	1.7234E-02	4.2000E-02	-2.1428E+00	-2.4099E+00	9439	2151
3.2566E+02	1.0000E+00	8.3350E-03	3.4172E-02	-1.9135E-02	0.0000E+00	9439	2151
3.2991E+02	0.0000E+00	5.3047E-03	4.2000E-02	1.6450E+00	-4.0261E-01	9439	2151
3.3430E+02	1.0000E+00	5.6422E-03	4.6151E-02	8.9325E-03	0.0000E+00	9439	2151

Table 1. Cont'd

3.3631E+02	1.0000E+00	1.4868E-02	4.5412E-02	-1.5871E-02	0.0000E+00	9439	2151
3.3834E+02	1.0000E+00	8.2000E-03	4.6842E-02	9.0499E-03	0.0000E+00	9439	2151
3.3963E+02	1.0000E+00	3.5036E-03	3.7815E-02	-1.6211E-02	0.0000E+00	9439	2151
3.4357E+02	1.0000E+00	1.6496E-02	3.5660E-02	2.0438E-02	0.0000E+00	9439	2151
3.4670E+02	0.0000E+00	1.0124E-02	4.2000E-02	-1.6845E-02	-1.1729E+00	9439	2151
3.5070E+02	1.0000E+00	2.1826E-02	3.8264E-02	3.0509E-02	0.0000E+00	9439	2151
3.5321E+02	1.0000E+00	3.9208E-03	3.6900E-02	1.5518E-02	0.0000E+00	9439	2151
3.5533E+02	1.0000E+00	3.5879E-04	4.2984E-02	1.6149E-02	0.0000E+00	9439	2151
3.6041E+02	1.0000E+00	1.1892E-03	7.7364E-02	-3.6870E-02	0.0000E+00	9439	2151
3.6172E+02	1.0000E+00	1.9142E-04	4.2500E-02	3.2000E-03	0.0000E+00	9439	2151
3.6540E+02	0.0000E+00	6.5964E-02	4.2000E-02	-2.8316E+01	7.5408E-01	9439	2151
3.6865E+02	1.0000E+00	2.6704E-04	4.2000E-02	1.5000E-02	0.0000E+00	9439	2151
3.6991E+02	0.0000E+00	3.7997E-03	4.1500E-02	1.2442E-03	1.0750E+00	9439	2151
3.7075E+02	1.0000E+00	3.0899E-03	7.3990E-02	2.7377E-02	0.0000E+00	9439	2151
3.7334E+02	0.0000E+00	3.0379E-03	4.2000E-02	2.7824E+00	1.7154E+00	9439	2151
3.7546E+02	1.0000E+00	2.7482E-03	2.9938E-02	2.8069E-03	0.0000E+00	9439	2151
3.7753E+02	1.0000E+00	1.7901E-03	4.0499E-02	-1.8794E-02	0.0000E+00	9439	2151
3.7848E+02	1.0000E+00	1.0435E-03	5.5527E-02	8.3916E-03	0.0000E+00	9439	2151
3.8282E+02	1.0000E+00	3.5140E-04	4.2566E-02	1.1424E-02	0.0000E+00	9439	2151
3.8471E+02	1.0000E+00	5.8363E-03	2.8604E-02	-2.7195E-02	0.0000E+00	9439	2151
3.8709E+02	1.0000E+00	2.2000E-04	4.2000E-02	1.5000E-02	0.0000E+00	9439	2151
3.8716E+02	0.0000E+00	3.5605E-03	4.2164E-02	4.7994E+00	-1.7975E+00	9439	2151
3.8998E+02	1.0000E+00	1.4433E-03	4.2542E-02	-1.3333E-02	0.0000E+00	9439	2151
3.9196E+02	1.0000E+00	1.0048E-03	6.0011E-02	3.1391E-02	0.0000E+00	9439	2151
3.9489E+02	1.0000E+00	6.8060E-03	5.1216E-02	-4.1151E-02	0.0000E+00	9439	2151
3.9735E+02	1.0000E+00	1.9223E-03	2.9428E-02	3.5285E-02	0.0000E+00	9439	2151
4.0207E+02	1.0000E+00	1.9064E-02	3.5091E-02	-1.8498E-01	0.0000E+00	9439	2151
4.0465E+02	1.0000E+00	2.2508E-02	3.8624E-02	-7.0010E-02	0.0000E+00	9439	2151
4.0652E+02	1.0000E+00	1.2395E-03	4.9859E-02	-1.0746E-02	0.0000E+00	9439	2151
4.0750E+02	1.0000E+00	8.1896E-04	3.0365E-02	1.4928E-01	0.0000E+00	9439	2151
4.0919E+02	1.0000E+00	1.1475E-03	6.1567E-02	-2.8898E-02	0.0000E+00	9439	2151
4.1279E+02	1.0000E+00	9.0126E-03	3.8622E-02	3.6871E-02	0.0000E+00	9439	2151
4.1616E+02	1.0000E+00	2.8995E-03	5.0431E-02	-6.2725E-03	0.0000E+00	9439	2151
4.1810E+02	1.0000E+00	1.2120E-03	5.8268E-02	-1.7538E-02	0.0000E+00	9439	2151
4.2024E+02	0.0000E+00	9.3578E-03	4.2000E-02	2.5013E-01	2.9407E+00	9439	2151
4.2033E+02	1.0000E+00	5.6119E-03	4.1683E-02	-2.8474E-02	0.0000E+00	9439	2151
4.2554E+02	0.0000E+00	1.8162E-02	4.2000E-02	1.5616E-01	8.4277E+00	9439	2151
4.2614E+02	1.0000E+00	2.8591E-04	4.1500E-02	2.1281E-02	0.0000E+00	9439	2151
4.3012E+02	1.0000E+00	3.4268E-03	5.8598E-02	6.4205E-01	0.0000E+00	9439	2151
4.3335E+02	1.0000E+00	6.2387E-04	4.1171E-02	-4.3066E-03	0.0000E+00	9439	2151
4.3394E+02	0.0000E+00	1.5106E-02	4.1500E-02	2.4012E+00	-2.8654E+00	9439	2151
4.3825E+02	1.0000E+00	2.8784E-03	3.7270E-02	-6.6911E-03	0.0000E+00	9439	2151
4.3930E+02	1.0000E+00	3.1583E-03	4.9825E-02	2.8784E-03	0.0000E+00	9439	2151
4.4072E+02	1.0000E+00	3.4403E-04	4.6000E-02	-1.3310E-01	0.0000E+00	9439	2151
4.4301E+02	0.0000E+00	2.1570E-02	3.8456E-02	-1.2445E-01	3.3484E-01	9439	2151
4.5033E+02	1.0000E+00	9.4711E-04	4.3623E-02	-3.9766E-02	0.0000E+00	9439	2151
4.5187E+02	1.0000E+00	1.4517E-02	2.8075E-02	2.4180E-03	0.0000E+00	9439	2151
4.5515E+02	1.0000E+00	4.1173E-04	4.0407E-02	-2.1127E-01	0.0000E+00	9439	2151
4.5631E+02	0.0000E+00	7.8792E-02	3.6237E-02	2.9552E-01	-8.1143E-02	9439	2151
4.5788E+02	1.0000E+00	7.1136E-03	6.3012E-02	-1.5855E-01	0.0000E+00	9439	2151
4.5938E+02	1.0000E+00	4.7598E-03	2.8197E-02	2.4155E-02	0.0000E+00	9439	2151

Table 1. Cont'd

4.6179E+02	1.0000E+00	2.2596E-03	5.2287E-02	-1.1471E-01	0.0000E+00	9439	2151
4.6322E+02	1.0000E+00	6.3813E-04	2.8071E-02	2.4438E-02	0.0000E+00	9439	2151
4.6613E+02	1.0000E+00	7.6466E-05	4.6000E-02	3.6000E-02	0.0000E+00	9439	2151
4.6853E+02	0.0000E+00	2.1789E-02	4.6000E-02	-3.5998E+00	1.1033E-02	9439	2151
4.7366E+02	1.0000E+00	4.2038E-03	3.5486E-02	-3.2196E-03	0.0000E+00	9439	2151
4.7568E+02	0.0000E+00	2.9948E-02	4.6000E-02	3.9750E-03	3.0670E+00	9439	2151
4.7645E+02	0.0000E+00	3.7158E-03	4.6000E-02	3.6874E+00	5.5021E+00	9439	2151
4.7972E+02	1.0000E+00	1.5340E-04	4.6000E-02	2.0848E-02	0.0000E+00	9439	2151
4.8472E+02	1.0000E+00	2.4821E-03	2.7136E-02	-4.7428E-03	0.0000E+00	9439	2151
4.8829E+02	0.0000E+00	1.9272E-02	4.7300E-02	-1.7915E-02	7.8337E-01	9439	2151
4.9192E+02	0.0000E+00	3.7979E-02	4.6000E-02	1.6432E+00	1.1171E+00	9439	2151
4.9469E+02	1.0000E+00	5.1839E-03	3.9308E-02	-6.4862E-02	0.0000E+00	9439	2151
4.9622E+02	1.0000E+00	6.5329E-04	4.8004E-02	1.2668E-02	0.0000E+00	9439	2151
5.0112E+02	1.0000E+00	3.7758E-03	2.6656E-02	4.1372E-02	0.0000E+00	9439	2151
5.0345E+02	1.0000E+00	1.2322E-02	9.9586E-02	9.2351E-02	0.0000E+00	9439	2151
5.0646E+02	1.0000E+00	3.3210E-04	4.6000E-02	-1.2319E-01	0.0000E+00	9439	2151
5.1019E+02	0.0000E+00	5.7382E-05	4.6000E-02	7.2586E-01	3.0265E+00	9439	2151
5.1027E+02	1.0000E+00	3.2888E-02	4.2112E-02	-1.7123E-01	0.0000E+00	9439	2151
5.1051E+02	0.0000E+00	1.2835E-01	4.6000E-02	3.4115E-01	1.5967E+00	9439	2151
5.1571E+02	1.0000E+00	4.2593E-04	4.6000E-02	-1.2261E-02	0.0000E+00	9439	2151
5.1728E+02	1.0000E+00	6.4621E-05	4.6000E-02	5.9301E-02	0.0000E+00	9439	2151
5.1869E+02	1.0000E+00	6.9900E-04	4.6000E-02	-1.1083E-01	0.0000E+00	9439	2151
5.2085E+02	1.0000E+00	1.5203E-02	4.9896E-02	-3.1998E-02	0.0000E+00	9439	2151
5.2484E+02	1.0000E+00	3.8058E-02	2.3575E-02	-8.4195E-03	0.0000E+00	9439	2151
5.2584E+02	0.0000E+00	2.5121E-01	4.6000E-02	1.0661E+01	-5.3749E-01	9439	2151
5.2671E+02	1.0000E+00	1.1222E-03	4.6000E-02	2.4853E-03	0.0000E+00	9439	2151
5.2805E+02	1.0000E+00	1.4672E-03	4.6000E-02	1.9862E-02	0.0000E+00	9439	2151
5.2920E+02	1.0000E+00	8.0000E-04	4.6000E-02	3.0000E-03	0.0000E+00	9439	2151
5.3122E+02	1.0000E+00	5.5543E-02	4.0000E-02	-2.6800E-02	0.0000E+00	9439	2151
5.3140E+02	0.0000E+00	3.4500E-05	4.6000E-02	-1.6238E+00	5.0650E-02	9439	2151
5.3983E+02	1.0000E+00	1.2450E-02	2.2845E-02	2.5999E-03	0.0000E+00	9439	2151
5.4122E+02	1.0000E+00	1.4803E-03	4.6000E-02	-3.3950E-02	0.0000E+00	9439	2151
5.4218E+02	1.0000E+00	5.2424E-03	4.6000E-02	6.4731E-01	0.0000E+00	9439	2151
5.4376E+02	1.0000E+00	1.1828E-02	5.7182E-02	-8.8155E-03	0.0000E+00	9439	2151
5.4642E+02	0.0000E+00	3.5053E-02	4.6000E-02	-2.4185E-02	1.4113E+00	9439	2151
5.5034E+02	1.0000E+00	1.1620E-02	5.3797E-02	9.5329E-03	0.0000E+00	9439	2151
5.5426E+02	1.0000E+00	1.3317E-02	5.9412E-02	9.0566E-03	0.0000E+00	9439	2151
5.5492E+02	0.0000E+00	1.1328E-01	4.6000E-02	1.1063E+00	-5.7076E-01	9439	2151
5.5628E+02	1.0000E+00	1.2002E-03	5.5904E-02	-1.1926E-02	0.0000E+00	9439	2151
5.5984E+02	1.0000E+00	2.6992E-02	7.0403E-02	1.3442E-02	0.0000E+00	9439	2151
5.6348E+02	1.0000E+00	3.3288E-02	1.4685E-01	-4.1980E-01	0.0000E+00	9439	2151
5.6473E+02	1.0000E+00	7.2644E-03	7.5984E-02	3.2000E-03	0.0000E+00	9439	2151
5.6649E+02	1.0000E+00	9.4380E-03	5.8559E-02	-3.2000E-03	0.0000E+00	9439	2151
5.7178E+02	1.0000E+00	8.6654E-03	4.7945E-02	-6.1017E-02	0.0000E+00	9439	2151
5.7467E+02	0.0000E+00	1.5206E-01	3.5832E-02	5.2064E-02	1.3320E-01	9439	2151
5.7653E+02	1.0000E+00	4.2218E-02	3.5426E-02	7.7052E-03	0.0000E+00	9439	2151
5.7871E+02	1.0000E+00	1.8094E-03	4.6000E-02	3.2000E-03	0.0000E+00	9439	2151
5.7977E+02	1.0000E+00	6.5872E-03	4.1194E-02	6.2153E-03	0.0000E+00	9439	2151
5.8555E+02	1.0000E+00	6.6106E-04	4.6000E-02	-2.9789E-02	0.0000E+00	9439	2151
5.8882E+02	1.0000E+00	1.1549E-02	5.7995E-02	9.4038E-03	0.0000E+00	9439	2151
5.9069E+02	1.0000E+00	4.6689E-04	4.6000E-02	3.6000E-02	0.0000E+00	9439	2151

Table 1. Cont'd

5.9432E+02	1.0000E+00	1.6489E-03	5.3638E-02	1.0280E-02	0.0000E+00	9439	2151
5.9797E+02	0.0000E+00	3.0921E-02	4.6000E-02	3.9821E-02	5.5067E+00	9439	2151
5.9806E+02	1.0000E+00	8.1858E-03	2.6659E-02	-3.2555E-03	0.0000E+00	9439	2151
6.0474E+02	1.0000E+00	2.4029E-02	2.8362E-02	-2.7223E-03	0.0000E+00	9439	2151
6.0841E+02	1.0000E+00	9.7412E-03	2.4688E-02	-6.5632E-03	0.0000E+00	9439	2151
6.1004E+02	1.0000E+00	1.6009E-02	4.0333E-02	-5.9591E-03	0.0000E+00	9439	2151
6.1358E+02	1.0000E+00	5.5900E-03	3.4360E-02	-9.9296E-03	0.0000E+00	9439	2151
6.2160E+02	1.0000E+00	1.1235E-02	2.7340E-02	-4.5020E-03	0.0000E+00	9439	2151
6.2335E+02	1.0000E+00	8.8691E-03	4.5845E-02	7.4690E-03	0.0000E+00	9439	2151
6.2594E+02	1.0000E+00	7.3702E-03	2.2785E-02	-6.3839E-03	0.0000E+00	9439	2151
6.2895E+02	1.0000E+00	1.4510E-03	4.9006E-02	8.6448E-03	0.0000E+00	9439	2151
6.3358E+02	0.0000E+00	7.0841E-02	4.6000E-02	3.1626E-01	-3.8620E+00	9439	2151
6.3726E+02	1.0000E+00	4.3648E-03	8.2511E-02	1.3378E-02	0.0000E+00	9439	2151
6.4004E+02	1.0000E+00	8.5361E-03	2.7856E-02	8.6604E-03	0.0000E+00	9439	2151
6.4265E+02	1.0000E+00	2.3000E-04	4.6000E-02	1.0000E-02	0.0000E+00	9439	2151
6.4318E+02	0.0000E+00	5.4166E-03	4.6000E-02	9.1065E-03	3.5287E+00	9439	2151
6.4574E+02	1.0000E+00	5.9810E-03	2.9757E-02	4.4286E-03	0.0000E+00	9439	2151
6.4717E+02	0.0000E+00	4.5993E-03	4.6000E-02	1.6613E+00	9.4069E-02	9439	2151
6.4734E+02	1.0000E+00	4.0000E-04	4.6000E-02	1.0000E-02	0.0000E+00	9439	2151
6.5137E+02	1.0000E+00	2.5000E-04	4.6000E-02	1.0000E-02	0.0000E+00	9439	2151
6.5340E+02	1.0000E+00	2.0000E-04	4.6000E-02	1.0000E-02	0.0000E+00	9439	2151
6.5871E+02	0.0000E+00	4.1921E-02	4.8647E-02	-3.9061E-02	1.8988E-02	9439	2151
6.5936E+02	1.0000E+00	5.1496E-02	8.4387E-02	-1.3846E-02	0.0000E+00	9439	2151
6.6254E+02	1.0000E+00	3.7482E-04	4.6000E-02	3.0000E-02	0.0000E+00	9439	2151
6.6717E+02	1.0000E+00	2.0563E-03	4.0921E-02	-6.5085E-03	0.0000E+00	9439	2151
6.6991E+02	1.0000E+00	3.5813E-03	3.2364E-02	4.8724E-03	0.0000E+00	9439	2151
6.7215E+02	1.0000E+00	1.5913E-02	3.4909E-02	4.9918E-03	0.0000E+00	9439	2151
6.7357E+02	1.0000E+00	8.6380E-04	4.6000E-02	3.0000E-02	0.0000E+00	9439	2151
6.7507E+02	1.0000E+00	2.3780E-03	7.6728E-02	5.3295E-02	0.0000E+00	9439	2151
6.7630E+02	1.0000E+00	1.0991E-03	4.2325E-02	1.8186E-01	0.0000E+00	9439	2151
6.8172E+02	0.0000E+00	4.9330E-03	4.6000E-02	6.4356E-05	-1.0112E+00	9439	2151
6.8214E+02	1.0000E+00	2.7152E-03	6.9320E-02	-1.3699E-01	0.0000E+00	9439	2151
6.8395E+02	0.0000E+00	4.5058E-02	4.6000E-02	4.3979E-03	-3.3919E+00	9439	2151
6.8469E+02	1.0000E+00	7.9817E-03	4.3445E-02	2.7857E-03	0.0000E+00	9439	2151
6.8657E+02	1.0000E+00	5.6809E-04	4.0261E-02	3.2000E-03	0.0000E+00	9439	2151
6.8852E+02	1.0000E+00	1.4211E-02	2.2480E-02	7.3940E-03	0.0000E+00	9439	2151
6.9268E+02	1.0000E+00	5.5770E-03	7.8774E-02	1.1700E-01	0.0000E+00	9439	2151
6.9369E+02	0.0000E+00	8.9194E-03	4.9865E-02	6.9986E-01	1.1078E-02	9439	2151
7.0117E+02	0.0000E+00	5.8130E-03	4.6000E-02	1.5564E-02	-2.7122E+00	9439	2151
7.0708E+02	1.0000E+00	2.5879E-03	5.5755E-02	1.5755E-02	0.0000E+00	9439	2151
7.0768E+02	1.0000E+00	9.5335E-03	3.7637E-02	1.0996E-02	0.0000E+00	9439	2151
7.1050E+02	1.0000E+00	1.9000E-04	4.6000E-02	3.6000E-02	0.0000E+00	9439	2151
7.1320E+02	1.0000E+00	9.3806E-03	4.0634E-02	1.7198E-02	0.0000E+00	9439	2151
7.1401E+02	1.0000E+00	6.0112E-03	4.9313E-02	3.4838E-02	0.0000E+00	9439	2151
7.1747E+02	1.0000E+00	1.1297E-02	2.4333E-02	5.8322E-03	0.0000E+00	9439	2151
7.1884E+02	1.0000E+00	7.1714E-03	3.9242E-02	3.4041E-03	0.0000E+00	9439	2151
7.2082E+02	1.0000E+00	1.8779E-04	4.6000E-02	3.6000E-02	0.0000E+00	9439	2151
7.2785E+02	1.0000E+00	2.9752E-03	3.5089E-02	-1.5316E-02	0.0000E+00	9439	2151
7.3319E+02	1.0000E+00	8.1226E-03	8.4635E-02	1.2200E-02	0.0000E+00	9439	2151
7.3339E+02	0.0000E+00	1.9288E-02	4.6000E-02	-8.9511E-01	-1.4801E+00	9439	2151
7.3489E+02	1.0000E+00	6.6728E-04	4.6000E-02	3.0000E-02	0.0000E+00	9439	2151

Table 1. Cont'd

7.3795E+02	0.0000E+00	2.5630E-02	4.6000E-02	1.1393E+00	2.1880E-029439	2151
7.3956E+02	1.0000E+00	4.4709E-03	7.5214E-02	1.2009E-01	0.0000E+009439	2151
7.4464E+02	1.0000E+00	1.1790E-02	4.6341E-02	2.0374E-02	0.0000E+009439	2151
7.4705E+02	1.0000E+00	1.3434E-02	4.6054E-02	9.1451E-03	0.0000E+009439	2151
7.4931E+02	1.0000E+00	1.0560E-03	5.0108E-02	5.5687E-03	0.0000E+009439	2151
7.5080E+02	1.0000E+00	1.9244E-03	5.3543E-02	1.1738E-02	0.0000E+009439	2151
7.5343E+02	1.0000E+00	3.9481E-02	3.4281E-02	8.7146E-03	0.0000E+009439	2151
7.5536E+02	1.0000E+00	1.4469E-03	4.6000E-02	2.9547E-02	0.0000E+009439	2151
7.5769E+02	0.0000E+00	7.5608E-02	4.6000E-02-3.6041E-02		2.5714E+009439	2151
7.5808E+02	1.0000E+00	3.0587E-03	5.7300E-02	3.2203E-02	0.0000E+009439	2151
7.6475E+02	1.0000E+00	7.5953E-03	7.0799E-02-1.4739E-02		0.0000E+009439	2151
7.6713E+02	1.0000E+00	3.0315E-03	3.9258E-02	2.2226E-02	0.0000E+009439	2151
7.7386E+02	1.0000E+00	6.3369E-03	4.5620E-02	1.2965E-02	0.0000E+009439	2151
7.7577E+02	0.0000E+00	3.2323E-03	4.6000E-02	5.2535E-01	1.0591E-029439	2151
7.7767E+02	1.0000E+00	1.0023E-02	6.1353E-02	4.7888E-02	0.0000E+009439	2151
7.8102E+02	1.0000E+00	1.9041E-03	3.9142E-02	2.8013E-02	0.0000E+009439	2151
7.8180E+02	1.0000E+00	1.3458E-02	4.1921E-02	4.3533E-02	0.0000E+009439	2151
7.8262E+02	1.0000E+00	2.0658E-03	4.4550E-02	1.6331E-02	0.0000E+009439	2151
7.8470E+02	1.0000E+00	2.3098E-03	5.2689E-02	6.5944E-03	0.0000E+009439	2151
7.8714E+02	1.0000E+00	9.4892E-03	5.1000E-02	1.9364E-02	0.0000E+009439	2151
7.9050E+02	1.0000E+00	1.1595E-03	4.9238E-02	5.5356E-02	0.0000E+009439	2151
7.9577E+02	1.0000E+00	8.0436E-03	3.6299E-02	4.3475E-02	0.0000E+009439	2151
7.9797E+02	0.0000E+00	1.3331E-01	4.6000E-02-4.6100E+00		5.1266E+009439	2151
8.0095E+02	1.0000E+00	3.4193E-03	5.0639E-02	5.7010E-02	0.0000E+009439	2151
8.0503E+02	0.0000E+00	3.9599E-02	4.6000E-02-8.3486E-01		1.3220E+019439	2151
8.0531E+02	1.0000E+00	6.5917E-04	4.6000E-02	3.6000E-02	0.0000E+009439	2151
8.0702E+02	1.0000E+00	7.8059E-03	5.8322E-02	1.8236E-02	0.0000E+009439	2151
8.1099E+02	1.0000E+00	7.5843E-04	4.6000E-02	3.6893E-02	0.0000E+009439	2151
8.1664E+02	1.0000E+00	1.3312E-02	2.5821E-02	9.4502E-03	0.0000E+009439	2151
8.2066E+02	1.0000E+00	5.8822E-03	2.3415E-02	1.3918E-02	0.0000E+009439	2151
8.2381E+02	0.0000E+00	1.8351E-02	4.6000E-02-1.3966E+00		1.0232E+009439	2151
8.2520E+02	1.0000E+00	6.0492E-03	4.9624E-02-9.6419E-02		0.0000E+009439	2151
8.2977E+02	1.0000E+00	2.8890E-02	6.1145E-02	4.0558E-02	0.0000E+009439	2151
8.3191E+02	0.0000E+00	2.6920E-03	4.6000E-02	1.4328E+00	1.1770E+009439	2151
8.3300E+02	1.0000E+00	1.6856E-03	4.6000E-02	2.6591E-01	0.0000E+009439	2151
8.3613E+02	1.0000E+00	2.3836E-03	4.6226E-02	3.2000E-03	0.0000E+009439	2151
8.4351E+02	0.0000E+00	1.3100E-01	4.6000E-02	5.0285E-01	8.5366E+009439	2151
8.4375E+02	1.0000E+00	1.3815E-03	4.6000E-02	3.9432E-02	0.0000E+009439	2151
8.4556E+02	1.0000E+00	5.4191E-03	5.1553E-02-5.3643E-02		0.0000E+009439	2151
8.4820E+02	1.0000E+00	6.3836E-03	6.1252E-02	7.0237E-02	0.0000E+009439	2151
8.5360E+02	0.0000E+00	1.8952E-02	4.6000E-02	1.4052E+00	1.2244E+009439	2151
8.5398E+02	1.0000E+00	6.1233E-04	3.8858E-02	7.7711E-02	0.0000E+009439	2151
8.5593E+02	1.0000E+00	2.0332E-03	3.4158E-02	1.3753E-01	0.0000E+009439	2151
8.5870E+02	1.0000E+00	3.2987E-03	7.9075E-02	2.7146E-01	0.0000E+009439	2151
8.6147E+02	1.0000E+00	3.2282E-03	4.1419E-02	2.8908E-01	0.0000E+009439	2151
8.6594E+02	1.0000E+00	1.9196E-03	4.6000E-02	1.3762E-01	0.0000E+009439	2151
8.6745E+02	1.0000E+00	3.8798E-03	5.2426E-02	1.2870E-01	0.0000E+009439	2151
8.7014E+02	1.0000E+00	3.9928E-03	3.0070E-02	4.0866E-02	0.0000E+009439	2151
8.7440E+02	1.0000E+00	1.8112E-02	3.5951E-02	2.4064E-02	0.0000E+009439	2151
8.7565E+02	1.0000E+00	1.5052E-02	3.0047E-02	1.4188E-02	0.0000E+009439	2151
8.7858E+02	1.0000E+00	4.1016E-03	4.0254E-02	3.2301E-03	0.0000E+009439	2151

Table 1. Cont'd

8.8553E+02	1.0000E+00	1.1981E-02	4.8934E-02	1.0864E-02	0.0000E+00	9439	2151
8.8711E+02	0.0000E+00	9.4216E-03	4.6000E-02	8.4171E+00	-6.2861E-04	9439	2151
8.9191E+02	1.0000E+00	6.8314E-02	2.7803E-02	3.8696E-03	0.0000E+00	9439	2151
8.9586E+02	1.0000E+00	8.3745E-03	5.5581E-02	5.4718E-01	0.0000E+00	9439	2151
8.9660E+02	0.0000E+00	7.2308E-04	4.6000E-02	1.6696E+00	-4.2150E-02	9439	2151
8.9712E+02	1.0000E+00	7.4058E-03	6.0508E-02	7.7251E-02	0.0000E+00	9439	2151
9.0376E+02	1.0000E+00	1.0116E-02	3.6837E-02	-1.7509E-02	0.0000E+00	9439	2151
9.0447E+02	0.0000E+00	4.7275E-02	4.6000E-02	-4.8613E+00	1.2864E+00	9439	2151
9.0602E+02	1.0000E+00	4.1094E-03	4.1315E-02	-1.4001E-02	0.0000E+00	9439	2151
9.0851E+02	1.0000E+00	3.3634E-03	3.3162E-02	8.7105E-03	0.0000E+00	9439	2151
9.1094E+02	0.0000E+00	1.3092E-02	4.6000E-02	4.5577E+00	1.2542E-01	9439	2151
9.1266E+02	0.0000E+00	3.6954E-02	4.6000E-02	4.1538E-01	2.2307E+00	9439	2151
9.1619E+02	1.0000E+00	4.9970E-03	3.1397E-02	1.8934E-01	0.0000E+00	9439	2151
9.1994E+02	1.0000E+00	9.8750E-03	4.6000E-02	-1.7047E-01	0.0000E+00	9439	2151
9.2068E+02	1.0000E+00	9.9360E-03	4.6000E-02	2.1015E-02	0.0000E+00	9439	2151
9.2315E+02	1.0000E+00	2.5063E-02	3.0074E-02	5.8082E-03	0.0000E+00	9439	2151
9.2626E+02	0.0000E+00	7.4775E-03	4.6000E-02	6.8854E-01	1.0000E-02	9439	2151
9.2795E+02	1.0000E+00	3.8254E-03	4.6000E-02	2.6911E-02	0.0000E+00	9439	2151
9.2970E+02	1.0000E+00	1.3965E-03	4.6000E-02	2.5008E-01	0.0000E+00	9439	2151
9.3296E+02	1.0000E+00	1.2051E-02	5.1340E-02	-9.7008E-03	0.0000E+00	9439	2151
9.3759E+02	1.0000E+00	1.1249E-03	4.6000E-02	1.7540E-02	0.0000E+00	9439	2151
9.3823E+02	0.0000E+00	4.1517E-02	4.6000E-02	3.7460E+00	-1.3470E+00	9439	2151
9.3975E+02	1.0000E+00	1.3012E-02	7.9316E-02	1.3732E-01	0.0000E+00	9439	2151
9.4121E+02	1.0000E+00	9.3576E-03	6.8998E-02	5.0948E-02	0.0000E+00	9439	2151
9.4415E+02	1.0000E+00	8.2166E-03	6.1207E-02	2.3708E-02	0.0000E+00	9439	2151
9.4642E+02	1.0000E+00	7.9685E-03	5.3889E-02	-2.9670E-03	0.0000E+00	9439	2151
9.5170E+02	1.0000E+00	5.8144E-03	3.7289E-02	1.7635E-02	0.0000E+00	9439	2151
9.5500E+02	1.0000E+00	8.0271E-03	3.7606E-02	9.8835E-02	0.0000E+00	9439	2151
9.5890E+02	1.0000E+00	4.1059E-02	5.4297E-02	4.0545E-02	0.0000E+00	9439	2151
9.6637E+02	1.0000E+00	2.8623E-02	4.1617E-02	1.4251E-01	0.0000E+00	9439	2151
9.7185E+02	0.0000E+00	6.2197E-02	4.6000E-02	9.0917E-01	1.0358E-03	9439	2151
9.7442E+02	1.0000E+00	5.4043E-02	2.5735E-02	3.7846E-02	0.0000E+00	9439	2151
9.7813E+02	1.0000E+00	2.6224E-03	4.6000E-02	5.1269E-03	0.0000E+00	9439	2151
9.8063E+02	0.0000E+00	7.6450E-02	4.6000E-02	-4.2388E-01	1.3149E+00	9439	2151
9.8540E+02	1.0000E+00	7.7898E-02	3.1807E-02	-1.8559E-02	0.0000E+00	9439	2151
9.8956E+02	1.0000E+00	1.8919E-03	4.5565E-02	4.3517E-02	0.0000E+00	9439	2151
9.9081E+02	1.0000E+00	5.6616E-03	5.2874E-02	2.3628E-01	0.0000E+00	9439	2151
9.9428E+02	1.0000E+00	1.8441E-02	4.2773E-02	4.3104E-02	0.0000E+00	9439	2151
9.9795E+02	1.0000E+00	3.4997E-02	4.6000E-02	-1.5474E-01	0.0000E+00	9439	2151
9.9870E+02	1.0000E+00	3.4639E-02	4.6000E-02	-6.3158E-02	0.0000E+00	9439	2151
1.0050E+03	1.0000E+00	7.7227E-02	4.6000E-02	1.1953E-03	0.0000E+00	9439	2151
1.0100E+03	0.0000E+00	1.8505E-01	4.6000E-02	-4.9203E+00	2.0852E-02	9439	2151
1.1000E+03	1.0000E+00	1.2200E+00	4.6000E-02	4.6000E-02	0.0000E+00	9439	2151
0.	0.	0.	0.	0.	0.	9439	2 0

3. SOME COMMENTS ON THE RESONANCE PARAMETERS

3.1 THE RESONANCE SPIN

The repartition between the two possible spins, 0^+ and 1^+, is roughly the same as in Ref. 11. The fission width distribution (Fig. 6) shows evidence of two families of resonances corresponding to two different average fission widths. One family is characterized by a small average value of about 30 meV and the other by a large value of about 2500 meV. The first family should correspond to a partially open 1^+ fission channel and the second to the 0^+ fully open fission channel. One estimates from the fission width distribution that almost all of the resonances having a fission width larger than 300 meV are 0^+ resonances, and about 95% of the resonances having a fission width smaller than 300 meV are 1^+ resonances. Several authors have assigned the spin 0^+ to some of the narrow resonances, mainly from scattering measurements.[12–14] There are a few differences between the spin assignments made in the present work and those found in the literature. These differences correspond to resonances located mainly in energy regions where the shape of the cross sections is rather complicated and where the resonance analysis does not provide a unique description.

3.2 THE LEVEL SPACING

The spacing stairstep histogram, shown in Fig. 1., is linear in the energy range 0 to 480 eV with an average level spacing of 2.40 eV. Between 480 and 1000 eV the spacing stairstep is still linear but with an average level spacing of 2.71 eV, suggesting that, compared to the energy range 0 to 480 eV, there is a constant fraction of 17% of missed levels in the energy range 480 to 1000 eV. A progressive loss of levels with increasing energy is the expected effect of the resolution in the experimental data. The neutron width distribution suggests that a non-negligible fraction of the levels could also be missed in the low energy part of the data, as will be shown in the next section.

3.3 THE NEUTRON WIDTHS AND THE S-WAVE STRENGTH FUNCTION

The cumulative reduced neutron width stairstep histogram is shown in Fig. 2. The s-wave strength function in the energy range 0 to 1000 eV is given by the average slope of the histogram, and is equal to the following value:

$$S_o = \left(\sum_{E_1}^{E_2} g\Gamma_n^{\circ} \right) / (E_2 - E_1) = (1.145 \pm 0.082) \times 10^{-4}$$

With $E_1 = 0$ eV and $E_2 = 1000$ eV

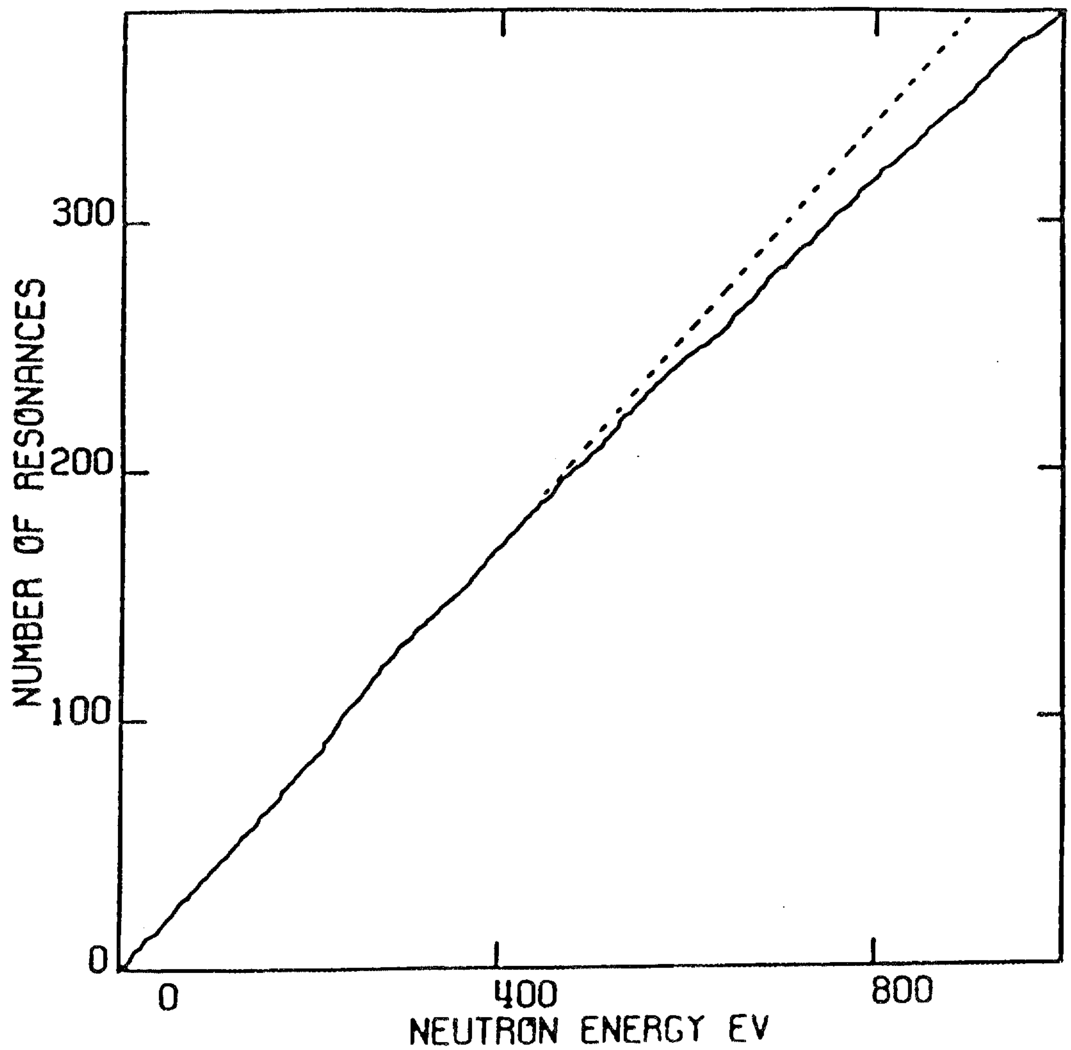

Fig. 1. Spacing stairstep histogram in the neutron energy range 0 to 1000 eV. The dashed line corresponds to an average level spacing of 2.40 eV. Compared to the energy range 0 to 480 eV, 17% of levels are missing in the energy range 480 to 1000 eV.

The local values of the strength function fluctuate strongly as is shown in Table 2. The largest value, $(1.99 \pm 0.45) \times 10^{-4}$, is obtained in the 500- to 600-eV interval and the smallest value, $(0.72 \pm 0.16) \times 10^{-4}$, in the 400- to 500-eV interval. The fractional uncertainty in the strength function is taken as $(2/N)^{1/2}$ where N is the number of resonances in the interval. These strong fluctuations suggest a nonstatistical effect in the entrance channel.

Table 2 shows a comparison with the results obtained at Saclay[11] from similar transmission data in the energy range 0 to 600 eV. The Saclay neutron widths were

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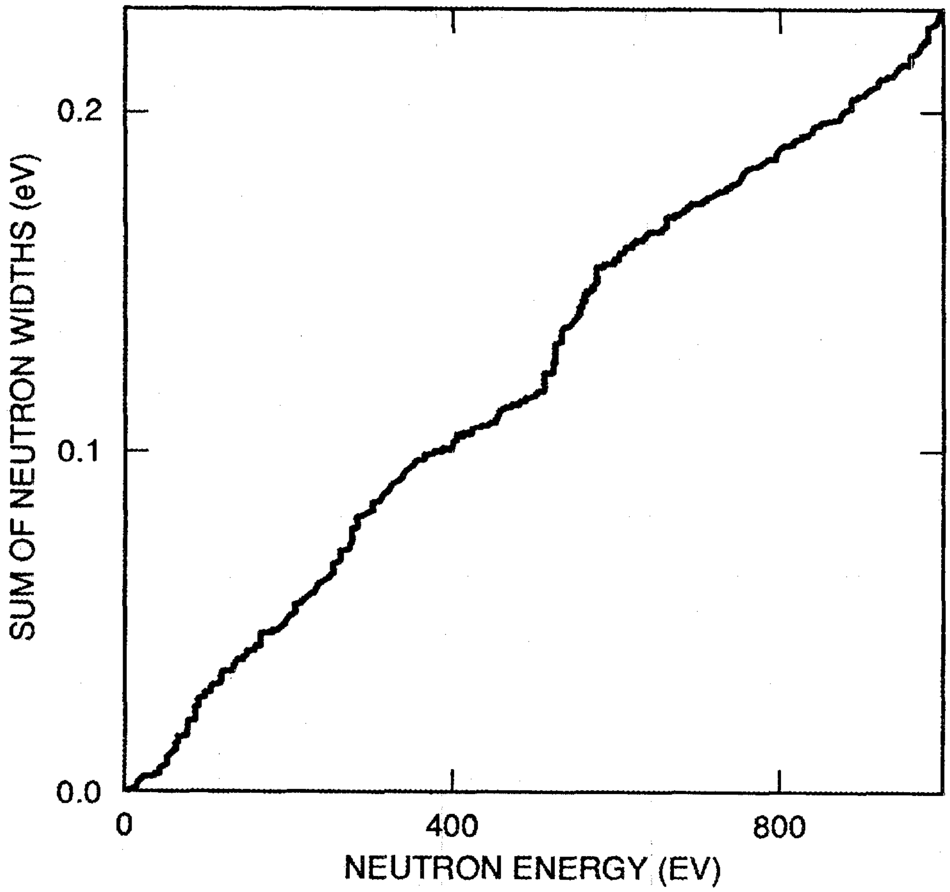

Fig. 2. $\sum_o^E 2g\Gamma_n^o$ histogram in the energy range 0 to 1000 eV, showing strong fluctuations in the local s-wave strength functions.

used as prior information in SAMMY with uncertainty estimates ranging from 20% to 50%. There is an overall few percent agreement between the ORNL and Saclay results. However, one should note some local deviations, particularly in the energy ranges 300 to 400 eV and 500 to 600 eV where the Saclay strength function is 6% to 7% smaller. These differences are due to the very wide 0^+ resonances at 365.40 and 510.51 eV which were not included in the Saclay analysis. As a matter of fact, the multilevel Breit-Wigner formalism used in the Saclay analysis was much less accurate for the representation of the 0^+ resonances than the SAMMY Reich-Moore multilevel-multichannel formalism used in the present work. The agreement is much better for the narrow resonances for which the multilevel Breit-Wigner formalism is equivalent to the Reich-Moore formalism. A comparison is given in Table 3 for the individual $g\Gamma n$ value of the narrow resonances in the energy range 500 to 600 eV.

The integral distributions of the reduced neutron widths are shown in Fig. 3 for the energy range 0 to 480 eV and in Fig. 4 for the energy range 0 to 1000 eV.

Table 2. Pu-239 s-wave strength functions in 100 eV intervals[a]

	$S_o \times 10^4$		S_o (narrow) $\times 10^4$	
Energy range (eV)	ORNL	Saclay	ORNL	Saclay
0 – 100	1.470	1.520 (–3.4%)	1.046	1.068 (–2.0%)
100 – 200	1.103	1.072 (+2.9%)	0.787	0.777 (+1.3%)
200 – 300	1.531	1.515 (+1.0%)	1.093	1.087 (+0.6%)
300 – 400	0.912	0.856 (+6.5%)	0.765	0.764 (+0.1%)
400 – 500	0.723	0.741 (–2.4%)	0.413	0.423 (–2.4%)
500 – 600	1.992	1.864 (+6.9%)	1.387	1.379 (+0.6%)
600 – 700	0.807			
700 – 800	0.786			
900 – 1000	1.290			
0 – 600	1.289	1.261 (+2.2%)	0.915	0.916 (–0.1%)
0 – 1000	1.141			

[a]Pu-239 s-wave strength functions in several energy intervals in the incident neutron energy range 0 to 1000 eV. The values calculated from the resonance parameters of Table 1 (ORNL) are compared to the values obtained in Ref. 11 (Saclay). The figures between parentheses are the percentage deviations between ORNL and Saclay. So (narrow) are the values obtained from the resonances for which the fission width is smaller than 300 meV (mainly 1^+ resonances). The differences of 6.5% and 6.9% in the energy ranges 300 to 400 eV and 500 to 600 eV are due to the inadequacy of the Breit-Wigner formalism used at Saclay to represent accurately the shape of the broad resonances (0^+ resonances).

Though the fraction of missed levels is larger in the second sample than in the first, both distributions have the same behavior. The experimental distribution is poorly described by a Porter-Thomas distribution. Apparently about 15% of small $g\Gamma_n^o$ values are missing in the energy range 0 to 470 eV and a correct value of the average s-wave level spacing could be (2.10 ± 0.20) eV.

3.4 THE FISSION WIDTHS

At least one fully open fission channel is available for the low-energy neutron induced reaction on ^{239}Pu. It is a 0^+ fission channel corresponding to the fundamental rotational band of the ^{240}Pu compound nucleus. Since the average level spacing of the 0^+ resonances is about 9 eV, the corresponding average fission width, $< \Gamma_f >= D/2\pi$, could be as large as 1.5 eV, justifying that one should *a priori* assign the spin 0^+ to the broad resonances. Other 0^+ collective states could exist in the spectrum of the highly deformed nucleus, justifying that at least two 0^+ fission

Table 3. Comparison of neutron widths[a]

	Γ_n (meV)			Γ_n (meV)	
Resonance energy (eV)	Saclay	ORNL	Resonance energy (eV)	Saclay	ORNL
500.50	3.40 ± 0.90	3.78	562.84	35.73 ± 2.68	33.29
502.96	11.87 ± 0.90	12.32	564.03	6.53 ± 1.07	7.26
509.74	52.13 ± 2.70	57.39	565.81	9.47 ± 0.80	9.44
520.22	14.93 ± 1.21	15.20	571.11	8.60 ± 0.60	8.67
524.21	30.60 ± 3.22	25.12	574.00	159.00 ± 4.02	152.10
530.52	42.52 ± 3.41	55.54	575.77	39.80 ± 3.75	42.22
539.17	11.40 ± 2.01	12.45	579.04	6.87 ± 0.60	6.59
543.08	11.73 ± 2.01	11.83	588.09	11.27 ± 0.80	11.55
549.67	11.80 ± 1.01	11.62	593.52	2.13 ± 0.34	1.65
559.16	27.20 ± 1.61	26.99	597.35	8.60 ± 1.01	8.19

[a]Comparison between the neutron widths obtained in the present evaluations (ORNL) with those obtained in Ref. 11 (Saclay) in the energy range 500 to 600 eV. The average values agree within 1.5%.

channels should be used in the Reich-Moore calculations. Since the fission widths of the 1^+ resonances are relatively important, a 1^+ fission channel is expected close to the neutron binding energy, yet no 1^+ transition state could be found among the low lying collective states of the even-even compound nucleus. This led J. J. Griffin[15] to postulate a 1^+ transition state combining the collective states formed from the mass-assymetry and bending vibrations. Based on the average fission width of the 1^+ resonances obtained from early data of Fraser *et al.*[12] on the ^{239}Pu resonance spin assignments, Griffin was led in 1965 to place this fission channel near 500 keV below the neutron binding energy. More recent work[23] suggests that the average fission width of the 1^+ resonances is smaller than expected in 1965 and smaller than 40 meV, corresponding to a fission threshold for the 1^+ states at about 300 keV above the neutron binding energy.

The integral distributions of the total fission widths in the energy ranges 0 to 480 eV and 0 eV to 1 keV are shown in Figs. 5 and 6, respectively. They are similar to those in Ref. 11. The existence of two families of resonances is obvious. As mentioned above, the shape of the distribution was used for a prior assignment of the resonance spins. The width of the $(n, \gamma f)$ process, which was found to be equal to about 3 meV by several authors,[16,17] is not negligible compared to the average fission width of the 1^+ resonances. A constant value of 3 meV was subtracted from all the fission widths in Figs. 5 and 6. A good description of the shape of the distributions is obtained by a sum of two χ^2 distributions, $P(\nu, x)$, with the average parameters given in Table 4. The average value of the fission widths of the narrow resonances obtained in the energy range 0 to 1000 eV is 37.0 meV [or 34.0 meV without the $(n, \gamma f)$ process]. For the broad resonances, the average value is 2800 meV which corresponds to an effective number of fission channels,

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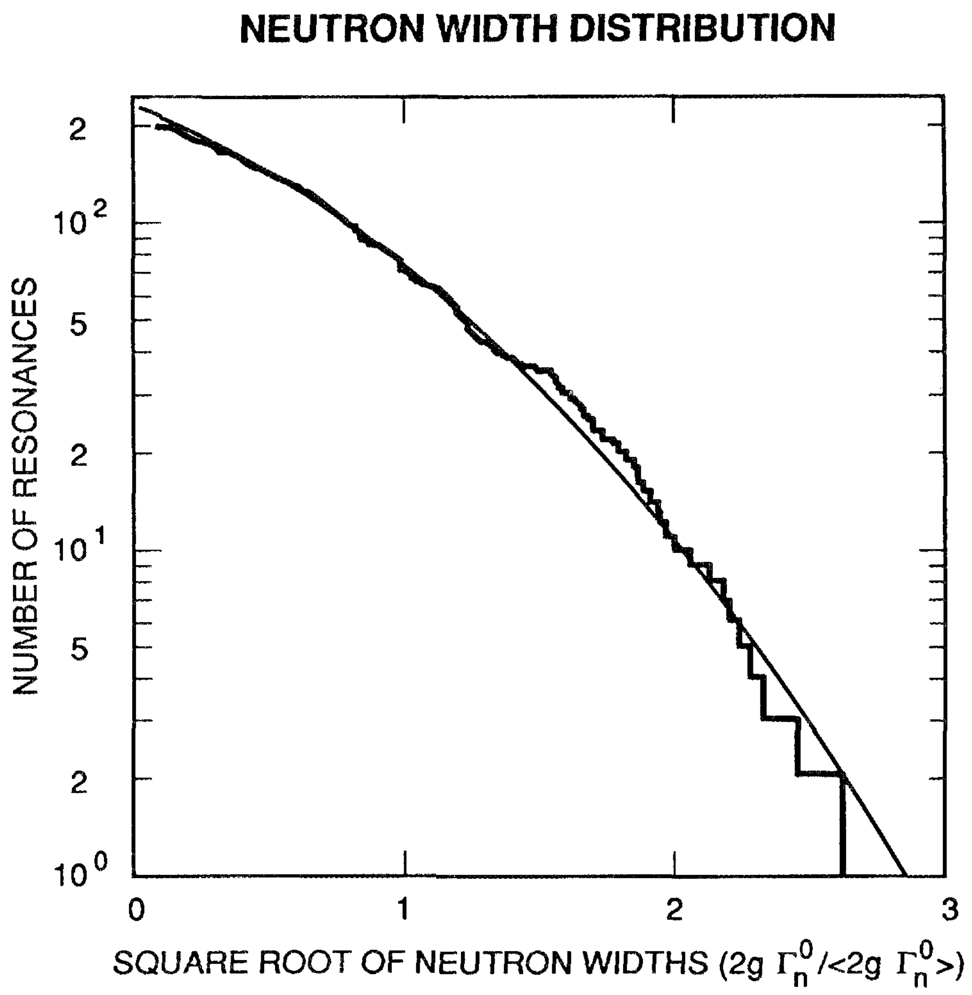

Fig. 3. Histogram of the integral distribution of the reduced neutron widths for the resonances of the energy range 0 to 480 eV. The curve is the Porter-Thomas distribution normalized to 230 resonances, assuming that about 30 small $2g\Gamma_n^o$ values could be missed.

$N_{eff} = 2\pi < \Gamma f > / < D >$, of about 2. Due to this large value, in addition to the fully open 0^+ channel, more than one partially open 0^+ channel could exist with average fission widths of several hundred meV. Therefore, the splitting of the 0^+ fission widths in only two components is questionable and has probably no physical meaning, more especially as equivalent solutions could be found by rotation of the fission vectors in the channel space configuration. In this regard, the results obtained in the energy range 0 to 200 eV in Ref. 11, for the 0^+ fission channel properties, should be revised.

The 1^+ fission component corresponds to a partially open fission channel. An intermediate structure, due to a double humped fission barrier, could exist in this component. A detailed study of the average 1^+ fission width is found in Ref. 11 where it was concluded that the small value of the average fission width of the narrow resonances in the 110-eV energy interval centered at 610 eV cannot be explained by

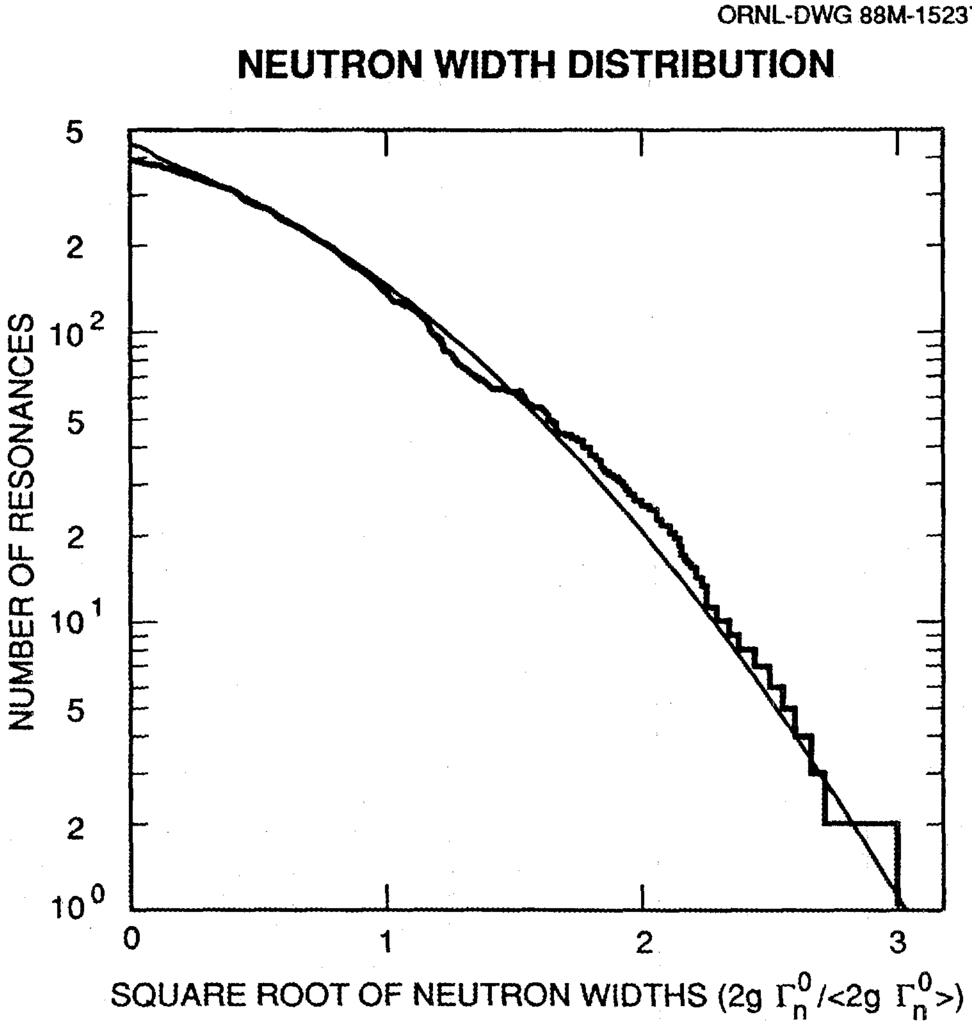

Fig. 4. Histogram of the integral distribution of the reduced neutron widths for the resonances of the energy range 0 to 1000 eV. The curve is the Porter-Thomas distribution normalized to 480 resonances, assuming that 65 small $2g\Gamma_n^0$ values could be missed.

the usual Porter-Thomas fluctuations of the parameters. The results of the present work confirm the small average value in the energy interval 550 to 660 eV as shown in Table 5. However, such nonstatistical behavior is not apparent in Table 6 where the average parameters are given in energy interval of 100 eV from 0 to 1000 eV.

3.5 THE CAPTURE WIDTHS

The capture width appears explicitly in the reduced R-matrix expression of the Reich-Moore formalism. The derivatives of all the cross sections can be calculated with respect to the capture widths and search on the capture widths could be made even if the cross-section sample analyzed does not include experimental capture data. In this case, if the results obtained for the capture widths are consistent

Table 4. Parameters of the χ^2 distributions[a]

Energy range (eV)	Spin	N	$< \Gamma_f >$	ν
0 - 480	0^+ 1^+	62 154	3.000 0.030	1.3 1.0
0 - 1000	0^+ 1^+	105 300	2.800 0.034	1.5 0.0

[a]Parameters of the χ^2 distribution $P(\nu, x)$ used in Figs. 5 and 6. N is the number of levels used for the normalization of the distributions. The average fission widths are given in eV. A value of 3.0 meV was subtracted from the fission widths to take into account the $n(\gamma, f)$ reaction.

(reasonable fluctuations about a constant average value for all the resonances in all energy intervals), one could expect that the cross-section sample analyzed is also consistent and that adequate width and shape of the resolution function have been used. In the present work, experimental capture cross sections were used only below 30 eV. In the 0- to 1000-eV energy range, search on Γ_γ have been made on 64% of the identified resonances. The fluctuations observed in the results are as large as 40% with respect to the average value. These fluctuations are present mainly in the small or poorly resolved resonances, in correlation with the corresponding poor accuracy obtained on the fission widths. The average values over 100-eV energy intervals are shown in Table 6. Below 500 eV, the data are quite consistent and one obtains $< \Gamma_\gamma > = 41.14$ meV, in very good agreement with the result obtained in Ref. 11. Above 500 eV, the data are still consistent, but the average value of 45.75 meV is 10% higher; mainly due to the increasing number of nonresolved multiplets when the neutron energy increases.

3.6 THE CORRELATION MATRICES

Due to computer time and space limitations, the full correlation matrix for the nearly 1600 parameters used for the calculation of the cross sections in the energy range 0 to 1000 eV was not obtained. The SAMMY calculations were performed separately in the nine energy intervals shown in Table 11 on page 34. The totality of the parameters were used in each energy interval, but the Bayes equations were solved only for the resonance parameters of the energy interval analyzed. The partial correlation matrices are available and should be associated to the parameters of Table 1 for the evaluation of the errors. Some sample of correlation matrices are given in Table 7 and Table 8 for the energy ranges 30 to 153 eV and 770 to 900 eV. The errors on the resonance parameters are quite small; they should be increased to take into account some systematic experimental effects not included in SAMMY and the difficulties in fitting the data for small or poorly resolved resonances.

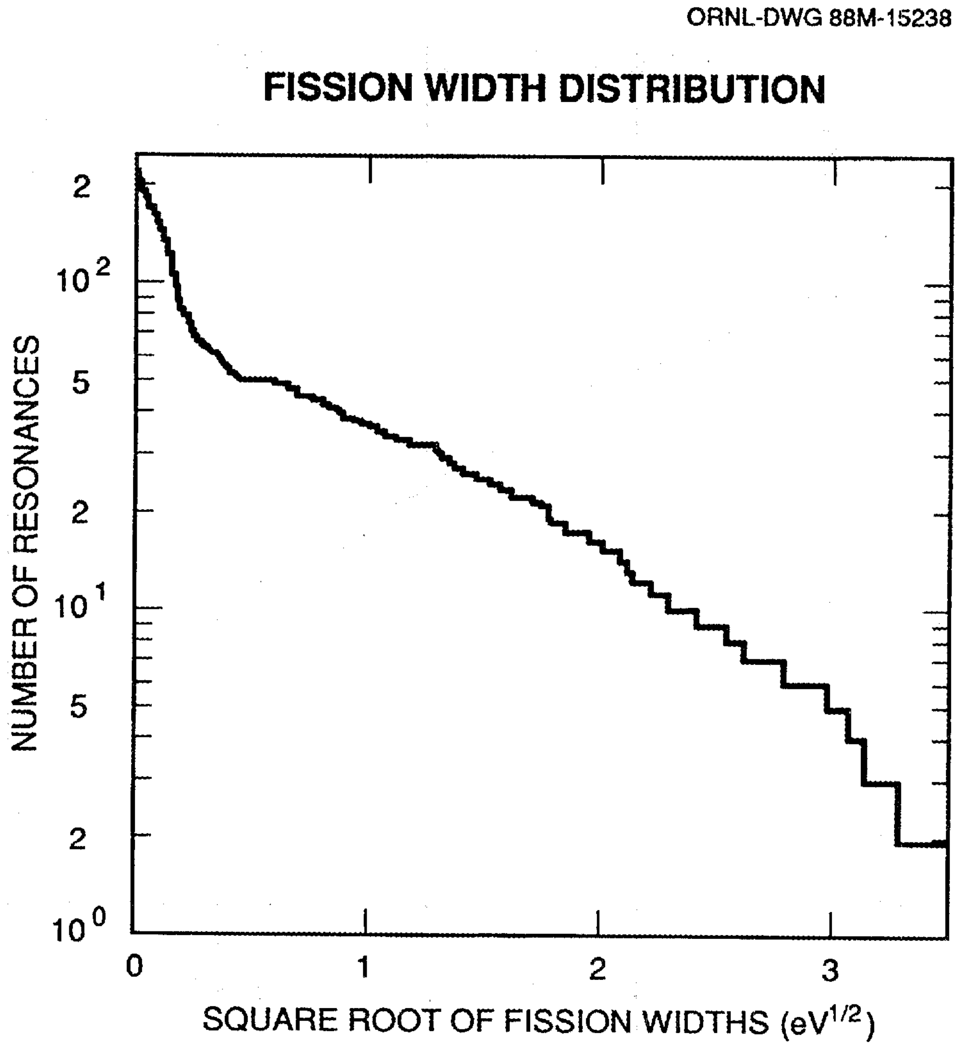

Fig. 5. Integral distribution of the fission widths for the resonances of the energy range 0 to 480 eV. The shape of the distribution corresponds to a sum of two χ^2 distributions, $P(\nu, x)$, representative of the 1^+ fission channel (small average value of the fission widths) and of the 0^+ fission channels (large average values of the fission widths). The crosses correspond to a sum of two distributions with the parameters given in Table 4.

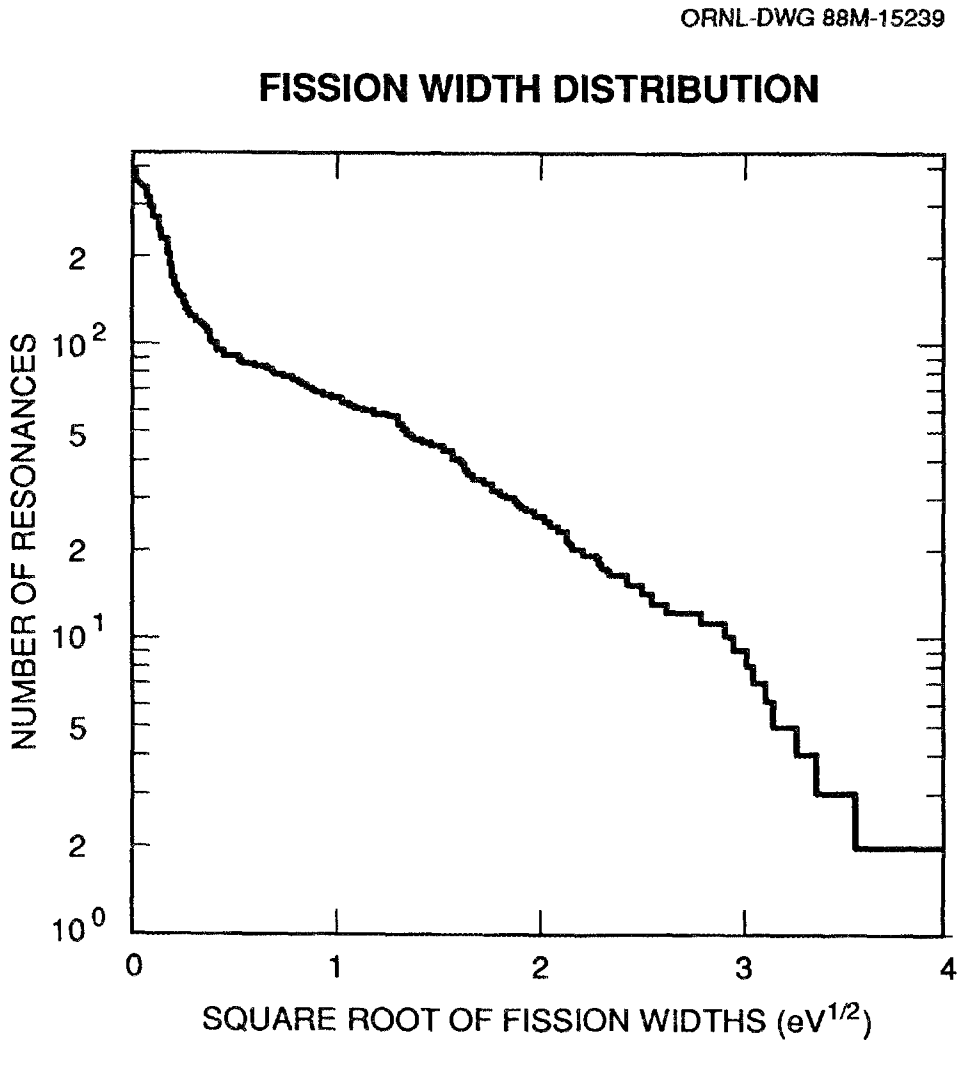

Fig. 6. **Integral distribution of the fission widths for the resonances of the energy range 0 to 1000 eV.** The shape of the distribution corresponds to a sum of two χ^2 distributions, $P(\nu, x)$, representative of the 1^+ fission channel (small average value of the fission widths) and of the 0^+ fission channels (large average values of the fission widths). The crosses correspond to a sum of two distributions with the parameters given in Table 4.

Table 5. Pu-239 average fission widths of the narrow resonances

	Average fission widths (meV)		
Energy range (eV)	ORNL (EXP)	Saclay (EXP)	Saclay (THE)
0 – 110	31.75 (32)	35.3 (29)	41.0
110 – 220	23.92 (35)	38.1 (26)	30.0
220 – 330	26.20 (37)	33.8 (27)	22.0
330 – 440	25.23 (35)	60.2 (25)	43.0
440 – 550	50.36 (30)	41.4 (19)	38.0
550 – 660	8.28 (31)	7.2 (23)	5.4
0 – 660	27.36 (200)	36.13 (149)	30.0

[a]Pu-239 average fission widths of the narrow resonances (mainly 1^+ resonances) for six energy intervals in the incident neutron energy range 0 to 600 eV, as obtained in the present work (ORNL) and in Ref. 11 (Saclay). The numbers between parenthesis are the number of resonances in the averaged sample. A value of 3 meV corresponding to the $n(\gamma, f)$ process has been subtracted from all the average values. Saclay (TH) are the values obtained by fitting the fission width distributions in the corresponding energy ranges. These values are in better agreement with ORNL (EXP) than Saclay (EXP), because they take into account the small values which are missing in the Saclay (EXP) samples.

Table 6. Pu-239 average fission and capture widths[a]

Energy range (eV)	Average fission widths (meV)	Average capture widths (meV)
0 – 100	37.22 (29)	39.66 (29)
100 – 200	26.66 (32)	41.15 (30)
200 – 300	26.28 (35)	39.59 (29)
300 – 400	23.40 (30)	44.55 (27)
400 – 500	52.55 (27)	40.98 (27)
500 – 600	31.15 (31)	48.06 (21)
600 – 700	25.40 (28)	43.75 (23)
700 – 800	25.52 (30)	46.26 (25)
800 – 900	75.28 (26)	45.57 (21)
900 – 1000	68.44 (27)	45.13 (19)
0 – 1000	37.05 (295)	
0 – 500		41.14 (142)
500 – 1000		45.75 (109)

[a]Pu-239 average fission widths and capture widths obtained from the parameters of the narrow resonances (mainly 1^+ resonances) in the energy range 0 to 1000 eV. The figures between parentheses are the number of resonances in the averaged samples.

Table 7a. Partial correlation matrix of ^{239}Pu resonance parameters[a]

			26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
107	9.6068E-04	.000	-1	5	1	2	-4	3	5	3	0	0	-2	-3	0	0	2	1	-1	1	-2	-3	0	0	0	-1	0
108	0.7376	.023	2	-19	21	2	0	2	3	2	3	0	-3	-2	-4	-2	7	4	-1	9	-7	-1	-2	3	1	1	-2
109	3.8823E-02	.012	0	16	-4	0	-4	-1	-2	-2	-1	1	1	1	2	1	-4	-2	1	-5	5	1	2	-1	0	0	1
110	0.9406	.033	2	-26	26	2	-2	3	4	3	4	0	-4	-2	-5	-2	8	5	-2	11	-9	-2	-3	3	1	1	-2
111	1.6221E-03	.000	0	-85	4	1	12	-1	-7	-5	0	0	2	1	1	0	-5	-3	1	-3	5	3	2	-1	0	1	0
112	0.7103	.017	-3	37	15	2	-44	1	5	4	-3	1	-2	-1	4	2	-4	-2	1	-9	6	-3	4	-2	-1	-1	3
113	0.1934	.009	-1	11	-43	0	22	0	-1	-1	-1	-2	-2	2	2	1	0	-1	-1	-1	-1	-1	-1	0	0	-1	2
114	1.294	.015	-6	3	-15	5	-9	5	11	7	-4	2	-2	-6	5	3	-4	-3	1	-9	8	-6	6	-2	-1	-2	3
115	3.5824E-03	.000	0	0	0	0	0	3	3	-1	0	1	-2	-1	0	0	0	0	0	0	0	0	1	0	0	0	0
116	9.6247E-03	.029	0	0	0	0	0	-8	-13	-13	-1	-9	2	-6	0	-1	2	1	0	2	-2	-2	-1	0	0	0	0
117	2.0278E-03	.000	0	0	0	0	0	-2	-4	-4	0	-11	3	-1	-1	0	2	1	0	2	-1	-2	0	0	0	0	0
118	1.672	.063	0	-2	-4	0	-4	-5	-7	1	1	-2	-20	20	-1	-1	2	1	1	4	-4	0	-4	0	-1	0	-2
119	0.2504	.031	0	2	0	0	3	-11	-5	6	-2	-12	-20	20	3	0	0	0	0	2	-4	2	-1	1	0	0	1
120	0.3991	.070	-1	-3	-3	0	-4	-9	-11	3	1	-2	-23	30	-1	-1	3	1	1	5	-5	0	-6	0	-1	0	-4
121	7.9960E-04	.000	0	0	0	0	0	2	2	0	0	1	1	-4	1	-2	2	2	-1	2	-2	2	-1	1	1	1	-1
122	0.8096	.024	1	0	-1	1	-1	6	7	2	0	4	-5	-9	4	-2	4	3	-4	3	-5	9	-8	1	0	2	-4
123	0.1684	.014	0	1	1	0	2	-6	-5	-1	-1	-2	7	8	-1	-1	0	0	4	5	-3	-5	3	1	1	-1	2
124	0.2071	.029	1	0	-1	1	-1	6	7	2	0	4	-6	-9	4	-2	3	3	-4	1	-3	9	-7	1	0	2	-4
125	1.6356E-03	.000	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-1	1	1	0	0	0	0	0	0	0
126	2.283	.061	0	0	1	0	0	0	1	0	0	-1	0	-1	1	-1	4	3	-1	5	-5	1	-2	1	1	1	-1
127	1.0568E-02	.016	0	0	1	0	1	-1	0	1	-1	0	1	1	1	-4	4	3	2	9	-7	1	-4	1	1	1	-1
128	0.2039	.072	0	1	2	0	2	-2	-1	1	-1	-1	2	3	2	-7	4	4	4	13	-11	3	-7	2	2	2	-2
129	1.3148E-03	.000	0	0	0	0	-1	0	0	-1	0	2	-1	0	-1	12	-5	-7	-4	-6	3	-2	0	-1	-2	0	0
130	1.960	.031	-2	0	2	0	0	-2	-2	0	0	6	1	3	-2	13	-15	-19	4	-4	3	-6	-2	-2	-2	0	-1
131	2.6395E-02	.013	-1	-1	0	0	-1	-1	-1	-1	1	6	-1	1	-2	14	-14	-18	0	-10	8	-5	1	-3	-3	-1	0
132	1.310	.041	-2	-1	2	0	0	-3	-3	-1	1	8	0	4	-3	17	-24	-28	7	-10	9	-8	-1	-5	-4	0	-1
133	1.1217E-03	.000	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1	-1	-1	0	0	-1	0	0	0	0	0
134	1.451	.042	-1	-1	-2	0	-1	0	-1	0	0	2	0	-1	0	0	-8	-3	2	-13	4	0	-2	0	-3	0	-6
135	1.9744E-02	.012	0	0	0	0	0	0	0	0	0	1	0	0	0	1	-4	-2	0	-7	1	0	-4	0	-2	0	-3
136	0.3362	.048	-1	0	-2	0	-1	-1	-1	1	0	3	0	-1	0	0	-10	-4	3	-18	5	0	-3	0	-4	0	-8
137	8.8267E-04	.000	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	1	1	0	2	0	0	0	1
138	1.144	.026	0	-1	-1	0	0	0	0	0	0	1	0	0	0	2	-3	-3	-1	-8	0	-1	-6	0	-1	1	-4
139	5.6138E-02	.012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	-1	2	-1	0	-1	0	1	0	2
140	0.1690	.035	0	0	-1	0	0	-1	0	0	0	1	0	0	0	3	-3	-4	-2	-9	-1	-1	-8	1	-2	1	-6
141	7.8697E-04	.000	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	-1	-1	-3	0	-4	1	1	1	-2
142	0.7159	.019	0	0	2	0	2	-1	0	0	-1	-1	0	1	0	2	3	-2	-5	-2	-9	-3	-15	3	4	6	-3
143	0.1256	.013	1	0	-1	0	0	1	1	0	0	1	0	-1	0	0	1	1	-1	3	2	0	3	0	0	-2	5
144	0.5601	.027	0	0	2	0	1	-1	0	0	-1	-1	0	1	1	2	2	-2	-4	-3	-8	-2	-13	2	3	5	-5
145	1.9056E-03	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
146	2.663	.049	1	0	0	0	1	0	0	0	0	-1	0	0	0	1	4	1	-4	2	-7	-2	-7	0	8	3	7
147	8.1610E-03	.016	0	0	0	0	1	0	0	0	0	0	0	0	0	1	3	1	-2	2	-5	-1	-5	0	6	2	7
148	1.094	.054	1	0	0	0	1	-1	0	0	0	-1	0	1	0	2	7	2	-5	5	-10	-2	-11	0	12	4	11
149	8.3115E-04	.000	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	-1	0	-1	0	-1	-1	0
150	0.6201	.015	1	0	1	0	2	2	3	-1	0	0	-1	0	1	1	1	-1	-1	0	-4	-2	-6	-12	-21	-13	-5
151	0.1882	.011	0	0	-1	0	-1	-1	0	1	0	1	0	0	-1	0	0	0	0	0	3	-1	4	8	13	6	1
152	0.8946	.022	1	0	1	0	2	2	2	-1	0	0	-1	0	1	1	1	-1	-1	0	-5	-1	-6	-13	-22	-13	-5
153	1.1284E-03	.000	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	-1	-1	-1	-1	-3	-2	-1
154	1.076	.030	2	0	0	0	1	2	3	-1	0	1	-2	-1	0	2	5	1	-3	3	-6	-4	-5	-1	-9	-8	-4
155	2.7356E-02	.011	0	0	0	0	0	1	1	0	0	1	0	0	0	1	1	0	-1	1	-1	-1	-1	-1	-4	-3	-2
156	0.8519	.033	2	0	0	0	1	2	4	-1	0	1	-2	-1	0	2	6	1	-3	4	-7	-5	-5	0	-9	-8	-4
157	2.5561E-03	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
158	3.439	.046	1	0	1	0	1	2	3	0	0	1	-1	-1	0	1	3	0	-1	2	-3	-3	-2	0	-5	-6	-2
159	1.0340E-02	.018	1	0	1	0	1	2	3	-1	0	1	-1	-1	0	1	4	0	-2	3	-4	-4	-2	0	-6	-6	-3
160	3.082	.048	1	0	1	0	1	3	5	-1	0	2	-2	-2	0	2	5	0	-2	4	-6	-6	-3	1	-8	-9	-4
161	1.3572E-03	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
162	1.854	.040	0	0	1	0	0	1	1	0	0	1	-1	-1	0	0	1	0	0	1	-1	-2	0	1	-1	-3	0
163	2.0280E-02	.012	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	-1	-1	0	1	0	-2	0
164	0.4467	.065	0	0	1	0	1	2	2	0	0	1	-1	-1	0	1	3	0	-1	2	-2	-3	0	2	-2	-4	-1
166	2.625	.068	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-1	-1	0	0	0	-1	0
167	1.1075E-02	.021	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	-1	1	-1	-1	0	2	0	-1	0
168	0.7685	.071	0	0	0	0	0	1	1	0	0	1	-1	0	0	1	3	1	-1	2	-2	-2	0	3	0	-2	0
169	1.1243E-03	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0

[a]Part of the correlation matrix obtained from SAMMY fit in the energy range 30 to 150 eV. The absolute and relative errors on the parameters are also given (columns 2 and 3). The numbers in column 1 and line 1 of the table are the parameter numbers as they appear on Table 8 bis. The correlation coefficients are given in percentage units. The correlation coefficients are signficiant only for the neighboring resonances.

Table 7b. Partial list of ^{239}Pu input resonance parameters[a]

Resonance Energy	Capture Width	Neutron Width	Fission Width Channel 1	Fission Width Channel 2
3.23276E+01(1)	4.2850E+01(2)	8.4410E-01(3)	8.1644E+00(4)	-1.2763E+02(5)
4.75362E+01(6)	3.2116E+01(7)	4.6977E+00(8)	4.7951E+02(9)	-1.2741E-04(10)
4.95701E+01(11)	4.2000E+01	4.1105E+00(12)	-1.0522E+03(13)	5.3343E+00(14)
5.69259E+01(15)	4.2000E+01	1.1248E+01(16)	-2.1899E+03(17)	2.8973E+01(18)
6.16096E+01(19)	4.2000E+01	2.7340E+01(20)	7.0756E+03(21)	6.8264E+00(22)
6.54791E+01(23)	2.7269E+01(24)	4.2072E+00(25)	4.7212E+02(26)	-2.1169E-13
7.49717E+01(27)	4.2000E+01	2.8344E+00(28)	1.2358E+00(29)	-3.2693E+02(30)
8.08674E+01(31)	4.2000E+01	4.5849E+00(32)	1.8700E+03(33)	-1.6794E+00(34)
8.55081E+01(35)	5.1000E+01	4.8769E+01(36)	-1.8560E+03(37)	3.1327E+00(38)
9.64781E+01(39)	4.2000E+01	6.4325E+00(40)	1.4622E+03(41)	-2.1756E+02(42)
9.93364E+01(43)	4.2000E+01	2.7552E+01(44)	-1.1557E+02(45)	9.9647E+03(46)
1.14409E+02(47)	4.2000E+01	2.3356E+00(48)	-1.4801E+03(49)	2.9161E+02(50)
1.16191E+02(51)	3.3299E+01(52)	1.0063E+01(53)	-1.3613E+02(54)	-5.0190E+01(55)
1.31771E+02(56)	4.2000E+01	3.5899E+01(57)	3.9954E+03(58)	-1.0513E+01(59)
1.36942E+02(60)	3.4718E+01(61)	1.1005E+01(62)	3.5063E-01(63)	-9.0487E+01(64)
1.47393E+02(65)	4.2000E+01	5.0545E+00(66)	2.4293E+03(67)	1.6683E+00(68)
3.54863E+01(69)	4.1016E+01(70)	2.6954E-01(71)	3.4108E+00(72)	
3.83360E+01	3.6558E+01	1.0259E-02	0.0000E+00	
4.14603E+01(73)	4.9118E+01	3.3937E+00(74)	-6.0765E+00(75)	
4.17339E+01(76)	3.9475E+01	9.2768E-01(77)	6.0619E+01(78)	
4.45312E+01(79)	4.0145E+01(80)	6.1192E+00(81)	-4.2232E+00(82)	
5.01445E+01(83)	2.4507E+01(84)	3.1800E+00(85)	-5.3664E+00(86)	
5.26498E+01(87)	4.3545E+01(88)	9.5464E+00(89)	-8.5185E+00(90)	
5.57040E+01(91)	3.8258E+01(92)	1.5087E+00(93)	2.3121E+01(94)	
5.92916E+01(95)	3.7807E+01(96)	4.4840E+00(97)	9.3520E+01(98)	
6.31697E+01(99)	3.9349E+01(100)	6.3546E-01(101)	7.2130E+01(102)	
6.57930E+01(103)	6.5258E+01(104)	9.6837E+00(105)	1.0506E+02(106)	
7.41671E+01(107)	3.2974E+01(108)	3.2268E+00(109)	-2.9399E+01(110)	
7.50286E+01(111)	4.3276E+01(112)	2.1243E+01(113)	-8.3082E+01(114)	
7.90850E+01	4.2000E+01	4.2916E-02	6.0000E+00	
8.27735E+01(115)	4.7000E+01	3.3203E-01(116)	5.0000E+00	
8.56173E+01(117)	2.6761E+01(118)	8.2809E+00(119)	5.7076E+00(120)	
9.08502E+01(121)	3.3291E+01(122)	1.2315E+01(123)	6.8851E+00(124)	
9.30789E+01(125)	3.8461E+01(126)	6.7282E-01(127)	-2.7397E+00(128)	
9.55102E+01(129)	6.2868E+01(130)	2.0897E+00(131)	-3.1239E+01(132)	
1.03145E+02(133)	3.4717E+01(134)	1.6443E+00(135)	6.9248E+00(136)	
1.05458E+02(137)	4.4006E+01(138)	4.7194E+00(139)	4.8289E+00(140)	
1.06834E+02(141)	3.6887E+01(142)	1.0094E+01(143)	-1.9800E+01(144)	
1.10551E+02(145)	5.1602E+01(146)	4.9245E-01(147)	1.9352E+01(148)	
1.15320E+02	4.2000E+01	2.1667E-01	1.6000E+02	
1.19001E+02(149)	4.1345E+01(150)	1.6914E+01(151)	-4.0270E+01(152)	
1.21179E+02(153)	3.7883E+01(154)	2.5640E+00(155)	2.6495E+01(156)	
1.23622E+02(157)	7.0664E+01(158)	5.7353E-01(159)	-6.0176E+01(160)	
1.26392E+02(161)	4.5699E+01(162)	1.7379E+00(163)	-9.5489E+00(164)	
1.27721E+02(165)	3.9550E+01(166)	5.3574E-01(167)	1.0774E+01(168)	
1.33984E+02(169)	3.8724E+01(170)	5.8374E+00(171)	-3.3855E+00(172)	
1.39450E+02	4.2000E+01	9.0429E-02(173)	-1.9300E+01	
1.43156E+02(174)	2.7942E+01(175)	3.2510E+00(176)	4.5142E+01(177)	
1.43676E+02(178)	4.2279E+01(179)	4.5660E+00(180)	3.1873E+01(181)	
1.46471E+02(182)	3.9564E+01(183)	7.4138E+00(184)	7.6543E+00(185)	
1.48441E+02(186)	5.0687E+01(187)	3.3268E-01(188)	3.2550E+01(189)	
1.49645E+02(190)	3.6069E+01(191)	1.6005E+00(192)	2.3525E+01(193)	

[a]SAMMY input resonance parameters in the energy range 30 to 150 eV. The figures between parenthesis are the number of the parameter for the interpretation of the covariance matrix of Table 7. The resonances with two fission channels are 0^+, the others are 1^+.

Table 8a. Partial correlation matrix of ^{239}Pu resonance parameters[a]

			26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
27	119.1	.085	44	100																							
28	90.42	.076	44	-1	100																						
29	0.4413	.000	-2	-11	11	100																					
30	0.5239	.056	-1	-1	-3	35	100																				
31	509.4	.061	2	0	-1	12	53	100																			
32	6.2809E-02	.100	0	0	0	1	0	0	100																		
33	0.2732	.000	-1	-1	-1	-16	-18	-22	0	100																	
34	6.7102E-02	.093	0	-1	0	1	-5	-9	0	5	100																
35	161.5	.097	0	-1	0	-6	-8	-2	0	-25	-1	100															
36	4.206	.100	0	0	0	0	-1	-1	0	-1	0	0	100														
38	3.532	.077	0	0	0	1	0	0	0	0	0	0	0	4	100												
39	0.1735	.027	0	0	0	-1	1	0	0	0	0	0	0	-3	17	100											
40	0.9443	.073	1	1	-1	-2	1	0	0	0	0	0	0	9	70	-18	100										
41	8.4766E-03	.000	0	0	0	-1	0	0	0	0	0	0	0	0	-2	0	0	100									
42	4.473	.073	0	0	0	0	0	0	0	0	0	0	0	1	0	-3	-2	9	100								
43	0.2369	.024	1	1	0	-2	1	1	0	0	0	0	0	0	2	0	0	-13	23	100							
44	3.453	.072	1	1	0	-2	1	1	0	0	0	0	0	1	0	-3	-1	9	72	-19	100						
45	3.1123E-02	.000	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-1	1	-3	0	-3	100					
46	3.777	.096	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	-2	-1	0	-2	100				
47	0.1186	.062	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	44	2	100			
48	2.759	.098	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	2	0	0	12	6	7	100		
49	1.1337E-02	.000	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	1	-3	0	-2	48	-6	58	4	100	
50	0.3374	.025	0	0	0	-1	0	0	0	0	0	0	0	0	0	2	1	0	2	3	3	-30	4	-20	-4	-2	100
51	2.121	.049	1	1	0	-2	1	1	0	0	0	0	0	0	-1	0	1	-1	0	2	2	10	19	-7	-19	-3	-53
52	3.4002E-02	.000	0	0	0	-1	0	0	0	0	0	0	0	0	-1	1	1	1	-1	1	0	13	-2	20	1	41	28
53	4.352	.098	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	3	2	0	-2	7	2
54	0.1366	.066	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	-18	-1	-24	0	-51	-33
55	1.601	.098	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-2	-2	-1	2	-4	-3
56	2.0224E-02	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
57	4.954	.094	0	0	0	1	0	0	0	0	0	0	0	0	0	-1	-1	0	0	-1	-1	2	1	0	-1	3	-1
58	0.1064	.046	1	1	0	-2	1	0	0	0	0	0	0	0	-1	1	2	1	0	1	3	-1	-1	1	1	-1	-2
59	0.6525	.099	0	0	0	-1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	-1	-1	-1	1	-2	1
60	8.6672E-03	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-1	0	0	0	0	0	0
61	3.876	.076	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	-1	-1	1	0	-1	0	1	-2
62	0.2436	.026	0	0	0	-2	0	0	0	0	0	0	0	0	0	1	2	1	1	2	2	-1	0	2	1	1	0
63	1.398	.072	1	1	0	-2	1	1	0	0	0	0	0	0	-1	1	2	1	0	2	2	0	0	1	0	2	2
64	4.0096E-02	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0
65	4.718	.096	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	-1	-1	0	0	-1	0	0	-1
66	7.6199E-02	.066	1	0	0	-1	0	0	0	0	0	0	0	0	-1	1	2	1	0	2	3	-1	0	2	1	1	2
67	5.386	.097	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	1	1
68	1.1035E-02	.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-1	-1	-1	0	0	0	0	0	0
70	0.2435	.030	-1	0	-1	1	-1	0	0	0	0	0	0	0	1	-1	-2	0	0	-1	-1	0	0	0	0	0	0
71	3.412	.078	0	0	-1	1	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	-1	1	0	0	0	1	0
72	2.1399E-02	.000	-2	1	-2	0	-1	1	0	0	0	0	0	0	1	-1	-2	0	0	0	-1	0	0	0	0	0	-1
74	0.2005	.059	0	1	-1	0	0	1	0	-1	0	0	0	0	1	-1	-1	0	0	0	0	0	0	0	0	0	0
75	5.211	.091	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
76	1.0280E-02	.000	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	4.586	.079	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
78	0.2221	.028	1	1	-1	1	0	0	0	0	0	0	0	0	0	-1	-1	0	0	-1	-1	1	0	0	0	0	-1
79	1.405	.077	1	1	0	1	0	0	0	0	0	0	0	0	0	-1	-1	0	0	-1	-1	1	0	-1	0	0	0
82	0.2988	.022	-1	-1	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0.5683	.060	0	-1	1	0	-1	-1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
84	1.0751E-02	.000	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	1.893	.081	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0.1722	.029	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87	0.9688	.070	0	-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	1.3483E-02	.000	0	-1	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
89	4.088	.082	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0.2124	.035	0	0	0	-3	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[a]Part of the correlation matrix obtained from SAMMY fit in the energy range 770 to 900 eV. The absolute and relative errors on the parameters are also given (columns 2 and 3). The numbers in column 1 and line 1 of the table are the parameter numbers as they appear on Table 8 bis. The correlation coefficients are given in percentage unit. The correlation coefficients are significant only for the neighboring resonances.

Table 8b. Partial list of ^{239}Pu input resonance parameters[a]

Resonance Energy	Capture Width	Neutron Width	Fission Width Channel 1	Fission Width Channel 2
7.75803E+02(1)	4.6000E+01	3.1120E+00(2)	5.5000E+02(3)	1.0506E+01(4)
7.98048E+02(5)	4.6000E+01	1.2923E+02(6)	-4.3500E+03(7)	4.9921E+03(8)
8.05155E+02(9)	4.6000E+01	3.7984E+01(10)	-8.1783E+02(11)	1.2127E+04(12)
8.23847E+02(13)	4.6000E+01	1.7639E+01(14)	-1.3606E+03(15)	1.0058E+03(16)
8.32010E+02(17)	4.6000E+01	2.5443E+00(18)	1.3982E+03(19)	1.1759E+03(20)
8.43493E+02(21)	4.6000E+01	1.2944E+02(22)	4.9173E+02(23)	8.4202E+03(24)
8.53594E+02(25)	4.6000E+01	1.8846E+01(26)	1.3528E+03(27)	1.2504E+03(28)
8.87136E+02(29)	4.6000E+01	8.3263E+00(30)	8.2654E+03(31)	-6.2822E-01(32)
8.96254E+02(33)	4.6000E+01	7.0838E-01(34)	1.7034E+03(35)	-4.2120E+01(36)
7.73862E+02(37)	4.4159E+01(38)	6.4070E+00(39)	1.3345E+01(40)	
7.77676E+02(41)	6.0368E+01(42)	1.0098E+01(43)	4.8778E+01(44)	
7.81010E+02(45)	3.8949E+01(46)	1.9253E+00(47)	2.8146E+01(48)	
7.81799E+02(49)	4.1921E+01	1.3564E+01(50)	4.4024E+01(51)	
7.82624E+02(52)	4.4376E+01(53)	2.0906E+00(54)	1.6413E+01(55)	
7.84698E+02(56)	5.1784E+01(57)	2.3700E+00(58)	6.7385E+00(59)	
7.87133E+02(60)	5.0209E+01(61)	9.6296E+00(62)	2.0102E+01(63)	
7.90507E+02(64)	4.8383E+01(65)	1.2155E+00(66)	5.6518E+01(67)	
7.95768E+02(68)	3.6422E+01(69)	8.0355E+00(70)	4.3344E+01(71)	
8.00945E+02(72)	5.1134E+01(73)	3.4013E+00(74)	5.6778E+01(75)	
8.05310E+02	4.6000E+01	6.5917E-01	3.6000E+01	
8.07022E+02(76)	5.8290E+01(77)	7.7730E+00(78)	1.8181E+01(79)	
8.10990E+02	4.6000E+01	7.5843E-01	3.6893E+01	
8.16637E+02(80)	2.5473E+01(81)	1.3349E+01(82)	9.5951E+00(83)	
8.20665E+02(84)	2.3409E+01(85)	5.8878E+00(86)	1.3916E+01(87)	
8.25197E+02(88)	4.7868E+01(89)	6.1452E+00(90)	-9.7611E+01(91)	
8.29775E+02(92)	6.0559E+01(93)	2.8921E+01(94)	4.0794E+01(95)	
8.32992E+02(96)	4.6000E+01	1.6650E+00(97)	2.6052E+02(98)	
8.36129E+02(99)	4.5399E+01(100)	2.4013E+00(101)	3.2000E+00	
8.43750E+02	4.6000E+01	1.3815E+00	3.9432E+01	
8.45554E+02(102)	5.1712E+01(103)	5.4336E+00(104)	-5.3842E+01(105)	
8.48200E+02(106)	6.0602E+01(107)	6.4507E+00(108)	7.1090E+01(109)	
8.53980E+02	3.8858E+01	6.1233E-01	7.7711E+01	
8.55933E+02(110)	3.4142E+01(111)	2.0436E+00(112)	1.3695E+02(113)	
8.58697E+02(114)	7.8322E+01(115)	3.3481E+00(116)	2.7378E+02(117)	
8.61455E+02(118)	4.1098E+01(119)	3.2640E+00(120)	2.8491E+02(121)	
8.65940E+02	4.6000E+01	1.9196E+00	1.3762E+02	
8.67435E+02(122)	5.1736E+01(123)	3.9141E+00(124)	1.2992E+02(125)	
8.70138E+02(126)	3.0374E+01(127)	3.9895E+00(128)	4.0585E+01(129)	
8.74405E+02(130)	3.5872E+01(131)	1.8118E+01(132)	2.4283E+01(133)	
8.75652E+02(134)	3.0138E+01(135)	1.5053E+01(136)	1.4136E+01(137)	
8.78580E+02	4.0254E+01	4.1192E+00(138)	3.2301E+00	
8.85529E+02(139)	4.7425E+01(140)	1.2070E+01(141)	1.1370E+01(142)	
8.91911E+02(143)	2.8214E+01(144)	6.6306E+01(145)	4.0662E+00(146)	
8.95865E+02(147)	5.3739E+01(148)	6.3651E+00(149)	4.9374E+02(150)	
8.97113E+02(151)	5.7773E+01(152)	7.3439E+00(153)	7.5119E+01(154)	

[a]SAMMY input resonance parameters in the energy range 770 to 900 eV. The figures between parenthesis are the number of the parameters for the interpretation of the covariance matrix of Table 8. The resonances with two fission channels are 0^+, the others are 1^+.

4. THE CROSS SECTIONS

4.1 THE THERMAL RANGE

The cross sections at 0.0253 eV are estimated to be known with an accuracy better than 1%, (0.25% for fission, 0.8% for capture and 0.5% for total cross sections); they were obtained by the ENDF/B-VI standard evaluation committee from an experimental data base including all the available experimental data and the correlation coefficients for all the fissile isotopes.[18] Since recommendations have been made to avoid the use of a background file in the evaluated data files, one should reproduce these accurate values with the evaluated resonance parameters. For this purpose, a SAMMY fit was performed in the energy range 0.01 to 5 eV using as input the resonance parameters obtained by fitting the higher energy region up to 1 keV. The experimental data base was Gwin *et al.* fission, capture, and absorption cross sections[3,5,8] published in 1971, 1976, and 1984, and Spencer *et al.* transmission data.[9] All the data were renormalized in the energy range 0.02 to 0.06 eV to an average cross-section value equivalent to the new standard value at 0.0253 eV. A renormalization of the energy scale on Spencer transmission data was also performed by a preliminary fit on the 0.29 eV resonance for each separated data set. The adjustment on the standard values in SAMMY calculations was obtained by varying only the parameters of three negative energy resonances and the parameters of the 0.29 eV resonance. The cross sections obtained at 0.0253 eV from the resonance parameters and using the Leal-Hwang method[24] are shown in Table 9. They agree well with the experimental standard values.

Table 9. Pu-239 cross sections at 0.0253 eV

	Calculated values (barn)		
	300 K	0 K	Proposed standard values (barn) (18)
Fission	747.34	746.66	747.99 ± 1.87
Capture	270.49	270.03	271.43 ± 2.14
Scattering	8.85	8.83	7.88 ± 0.97
Absorption	1017.83	1016.69	1019.42 ± 4.00
Total	1026.68	1025.52	1027.30 ± 5.00
GF	1.0543		1.0563 ± 0.0022
GA	1.0786		1.0782 ± 0.0024

The average cross sections in the energy range 0.02 to 0.65 eV over the 0.29-eV resonance are shown in Table 10. ORNL-RPI data are consistent within about 1% with the calculated values. Data from Deruytter and Wagemans[19] and Wagemans *et al.*,[6] which were not included in the SAMMY fit, are also shown in Table 10.

When normalized to the same thermal standard value, they are 2% to 3% larger over the 0.29-eV resonance. New results obtained recently by Wagemans *et al.*,[20] show an agreement better than 1% with 1984 data of Gwin *et al.* These new results of Wagemans *et al.* should be in good agreement with the present evaluation.

Figures 7 and 8 illustrate the results of the SAMMY fit in the low energy region.

4.2 CROSS SECTIONS IN THE RESOLVED RESONANCE REGION

4.2.1 Background and Normalization Problems

In ORELA transmission measurements, the normalization coefficients are known with better than 1% accuracy. The error due the background corrections is also very small. Therefore, the scattering radius and the contribution of the nonidentified external resonances should be carefully chosen to avoid a nonrealistic variation of the residual background and normalization correction parameters in the SAMMY calculation. (For a definition of these correction parameters, see Ref. 1.) Starting from guessed parameters for the external resonance contributions and a value of 9.50 fm for the scattering radius, a preliminary SAMMY fit was performed on the experimental transmissions in nine energy intervals by searching on the normalization and residual background parameters. The values obtained for these parameters are shown in Table 11. The residual background corrections are very small, as expected. But the normalization corrections vary from −2% in the lower energy range to 5% in the higher energy range, which suggests that one should decrease the contribution of the external resonances. Starting with a new set of external resonance parameters, chosen to minimize the above corrections, a second series of SAMMY fits was performed leading to the normalization and residual background corrections parameters shown in Table 12. These corrections were considered small enough to provide a good starting point for the final fit including the fission data.

Some *a priori* information on the normalization and residual background are also needed for the experimental fission cross sections. The fission cross sections are generally normalized on the same standard at thermal energy. But discrepancies could appear even at energies not far from the normalization region, as was shown above when comparing ORELA and Geel Data in the low-energy range (see Table 10). In the present work, only the 1984 fission measurements of Gwin *et al.*,[8] and of Weston and Todd,[7] and the 1973 fission measurement of Blons[4] have been considered in the resolved resonance region. The fission cross sections were renormalized to the 2200 m/s ENDF/B-VI standard values shown in Table 9; the energy scales were aligned on the transmission measurements of Harvey *et al.*; no corrections were made for changes in the $^{10}B(n,\alpha)$ cross sections with respect to which the flux were measured. However, the ORELA measurements used the ENDF/B-V $^{10}B(n,\alpha)$ cross-section evaluation which differs from ENDF/B-VI by less than 1% below 1 keV. The $^{10}B(n,\alpha)$ model used by Blons also agrees to better than 1% with ENDF/B-VI up to 1 keV. The 1984 ORELA data have been obtained with very good experimental background conditions. Blons 1973 data were obtained in better resolution conditions (longer flight path and sample cooled down to liquid

Table 10. Average ^{239}Pu cross sections at low energy (b)

	0.02 to 0.06 eV		0.02 to 0.65 eV	
Reference	Measured	Calculated	Measured	Calculated
Fission				
Gwin *et al.* (1971)	631.41[a]		843.71	
Gwin *et al.* (1976)	631.41		838.39	
Gwin *et al.* (1984)[b]	631.41	631.59	837.18	838.46
Deruytter *et al.* (1970)	631.41		859.43	
Wagemans *et al.* (1980)	631.41		862.56	
Capture				
Gwin *et al.* (1971)	243.84	243.12	524.75	517.79
Absorption				
Gwin *et al.* (1976)[b]	875.90	874.71	1359.96	1356.25
Total				
Spencer *et al.* (1987)[b]	883.20	883.47	1361.69	1367.96

All partial cross sections renormalized at 2200 m/s.

[a]The value of 631.41 b for all the experimental fission data in the energy 0.02 to 0.06 eV corresponds to the renormalization of all experiments to 748.0 ± 1.0 b at 0.0253 eV.

[b]These data had the largest weight in the thermal fit.

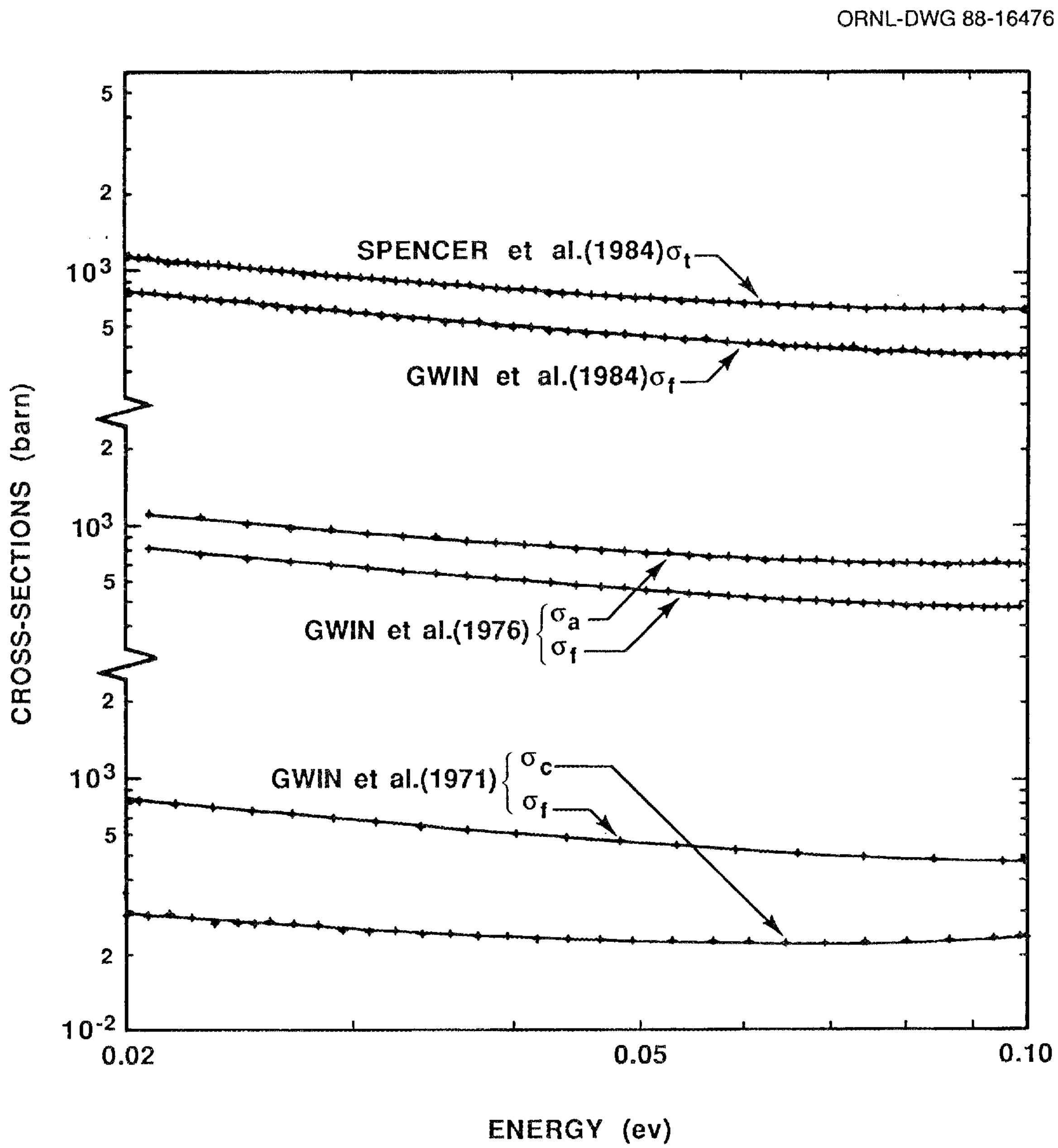

Fig. 7. Comparison between the calculated cross sections (curve) and the experimental data (cross) in the energy range 0.02 to 0.10 eV.

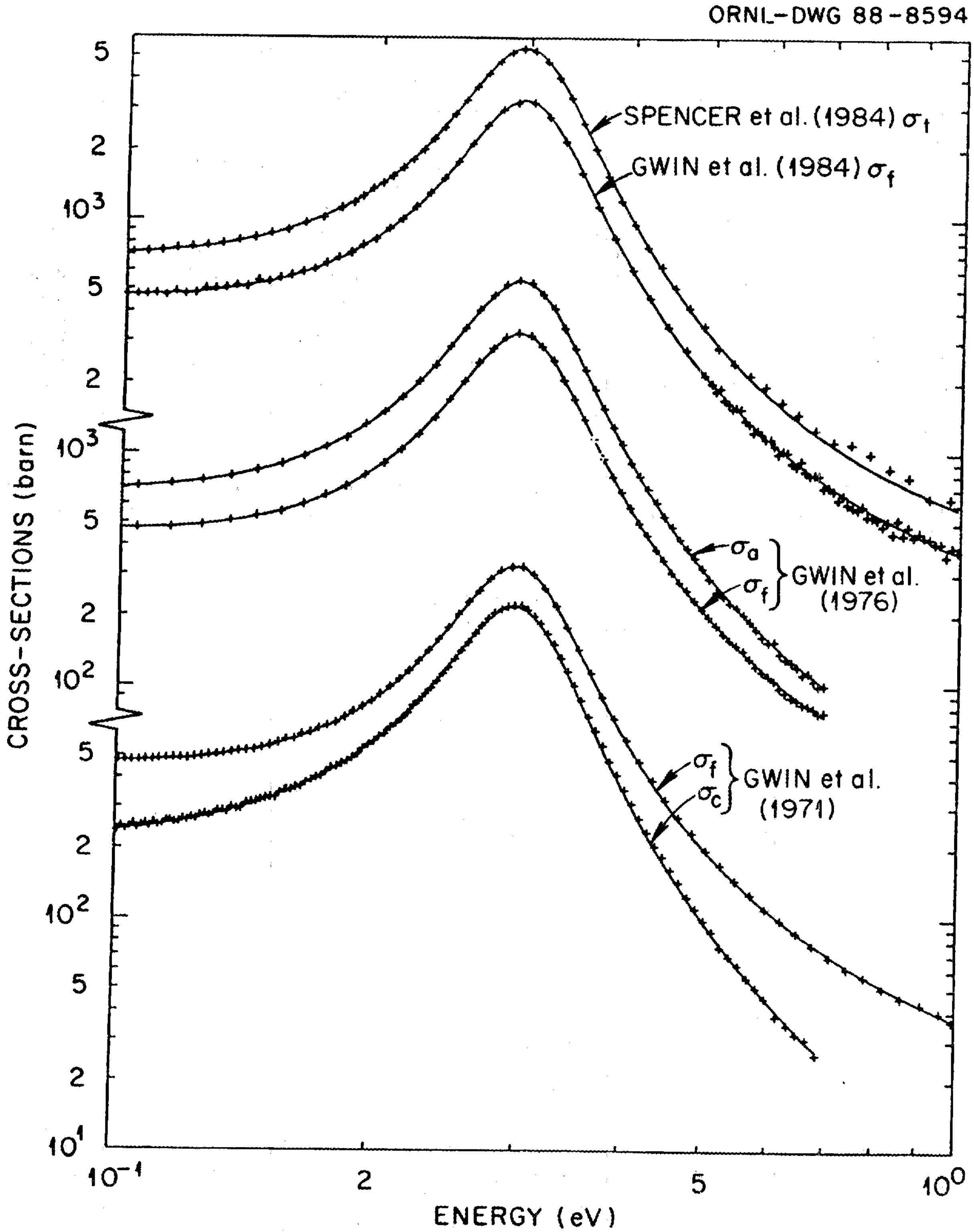

Fig. 8. Comparison between the calculated cross sections (curve) and the experimental data (cross) in the energy range 0.10 to 1.0 eV.

Table 11. Local normalization and background corrections[a]

	Thick sample (0.0747 at/b)		Medium sample (0.01825 at/b)		Thin sample (0.00646 at/b)	
Energy range (eV)	NORM	BG	NORM	BG	NORM	BG
100 – 153	0.979	0.0012	0.994	0.0043	0.994	0.0048
153 – 210	0.977	0.0005	0.994	0.0032	1.003	−0.0016
210 – 253	0.984	0.0005	0.991	0.0047	0.988	0.0089
253 – 305	0.996	0.0002	0.999	0.0027	0.995	0.0043
305 – 447	0.989	0.0024	0.993	0.0037	1.002	−0.0032
447 – 617	1.000	0.0020	0.998	0.0043	0.997	0.0029
617 – 770	1.010	0.0018	0.997	0.0075	0.997	0.0039
770 – 900	1.029	−0.0018	1.007	−0.0009	1.009	−0.0046
900 – 1000	1.052	−0.0015	1.010	0.0031	1.000	0.0007

[a]Normalization (NORM) and background (BG) corrections obtained in the first preliminary SAMMY runs of the transmission data of Harvey *et al.* (For a definition of these corrections see Ref. 1.)

Table 12. Local normalization and background corrections[a]

Energy range (eV)	NORM	BG
30 – 150	0.995	−0.00050
150 – 300	0.993	−0.00099
300 – 450	0.997	−0.00003
450 – 600	0.997	0.00096
600 – 770	0.990	0.00066
770 – 900	1.000	0.00210
900 – 1000	1.000	0.00190

[a]Normalization (NORM) and background (BG) corrections obtained in the second preliminary SAMMY runs of the thick sample transmission data of Harvey *et al.* (For a definition of these corrections see Ref. 1.)

nitrogen temperature); but an accurate evaluation of a large background in the experimental data was difficult both in the fission rate measurements and in the neutron flux measurements.[21] Starting from this prior information (small corrections on the data of Weston and Todd and larger corrections on Blons data), and with the covariance matrices obtained in the second fit of the transmissions mentioned above, a series of SAMMY fits were performed on the data of Weston and Todd and of Blons with a search on the normalization and residual background corrections. The results are shown in Table 13, suggesting the following:

1. A rather stable normalization correction of 1.2% on average and small residual background corrections are obtained in data of Weston and Todd. The agreement between the calculated and experimental cross sections is excellent (better than 0.5%). Blons normalization corrections, about 5% on average, vary strongly and are strongly correlated to a rather high residual background corrections; in spite of the fact that large variations were allowed on the correction parameters, larger deviations are observed between the calculated cross sections and the experimental data.

2. The last line of Table 13 is an example of results which would be obtained if the same constraints were applied to the data of Blons and of Weston and Todd (small variations allowed on the normalization and residual background corrections). The correction parameters obtained for Blons data are surprisingly very small but the discrepancy between the calculated and the experimental cross sections is very important (more than 10%). The conclusion is that, at least in the energy range considered, it is impossible to find a consistent fit of the data of Harvey *et al.,* Weston and Todd, and Blons without allowing a large variation of the residual background correction in the data of Blons.

3. The search on normalization and residual background corrections was made before renormalizing data of Weston and Todd on the new thermal standard. The renormalization results in an increase of 0.85% on fission and the average variation of normalization on Table 13 should decrease to 0.37%.

In conclusion, 1984 fission data of Weston and Todd and transmissions of Harvey *et al.* are consistent with no or small normalization and background adjustment. Blons data are not consistent with data of Weston and Todd and of Harvey *et al.* and need important correlated normalization and background adjustment. In the energy range 30 to 1000 eV, the final SAMMY runs were performed on the renormalized Weston and Todd fission and on Harvey *et al.* transmission with the external resonance parameters obtained in the preliminary calculations and no background or normalization adjustment. In the energy range below 30 eV, Gwin *et al.* 1984 data were also included in the fit. The resonance parameters obtained are representative of ORELA cross-section measurements.

4.2.2 Presentation of Some Results

Table 14 shows the average fission cross sections calculated with the resonance parameters and the values given by the ENDF/B-VI standard evaluation committee.[18] These values were obtained from a large experimental data base including all the correlated standard cross sections. The small errors on the values are due to a statistical processing of a large number of experimental data and the

Table 13. Local normalization and background corrections[a]

	Normalization		Background (barn)		(EXP-CAL)/CAL	
Energy range (eV)	Weston and Todd	Blons	Weston and Todd	Blons	Weston and Todd	Blons
30 - 150	0.9895	0.9996	−0.190	1.713	−0.55%	+0.5%
150 - 300	0.9865	0.9432	0.005	1.233	−0.27%	−1.0%
300 - 450	0.9822	0.9279	−0.024	1.012	−0.20%	−1.6%
450 - 600	0.9763	0.9317	0.104	0.964	−0.13%	−2.0%
600 - 770	0.9887	0.9566	0.062	0.742	+0.17%	−1.1%
780 - 900	0.9944	0.9347	0.150	0.875	−0.11%	−0.1%
900 - 1000	1.0040	0.9133	0.171	1.159	−0.46%	+1.4%
750 - 900	0.9874	1.0071	0.162	0.005	+0.30%	+10.5%

[a]Normalization and background corrections resulting from a SAMMY fit including the transmissions data of Harvey *et al.* and the fission data of Weston and Todd and of Blons. The input uncertainty on the background correction was 0.05 b for Weston and Todd and 0.5 b for Blons. In the fit corresponding to the last line, Blons background input uncertainty was also 0.05 b. (For a definition of the normalization and background corrections, see Ref. 1.)

Table 14. Comparison of average ^{239}Pu fission cross sections (b)

Energy (eV)	Calculation	ENDF/B-VI Standard Committee[a]	Blons (1973)	Weston and Todd (1984)
100– 200	18.135	18.66 ± 0.13	18.93	18.095
200– 300	17.312	17.88 ± 0.12	17.79	17.441
300– 400	8.080	8.43 ± 0.06	8.91	8.130
400– 500	9.389	9.57 ± 0.07	9.71	9.337
500– 600	15.062	15.56 ± 0.11	15.51	15.170
600– 700	4.129	4.46 ± 0.04	4.63	4.192
700– 800	5.323	5.63 ± 0.04	5.94	5.385
800– 900	4.729	4.98 ± 0.04	5.11	4.765
900–1000	8.223	8.30 ± 0.07	8.57	8.165
100–1000	10.043	10.39	10.57	10.075

[a]The uncertainties on these values are tentative (see Ref. 18).

systematic uncertainties were also considered by the standard evalution committee as statistical errors with zero mean. The calculated cross sections and the cross sections of Weston and Todd are on average 3.5% and 3.1% smaller than those obtained in the standards effort; Blons data are on average 1.7% larger. As has been explained above, the systematic errors on the cross sections of Weston and Todd are quite small, but could be very large on Blons data. The authors of the present work have the feeling that many of the experimental fission cross sections suffer from an underestimation of the experimental background, leading to systematic overestimation of the cross sections. That is particularly true for the Blons data. The values obtained by the standard's group could be wrong by about +3% in the resolved resonance region, which is in conflict with the tentative 0.7% to 0.8% uncertainties quoted.

Because of the large statistical uncertainties and contamination by chemical or isotopical impurities, the direct capture or absorption measurements were not included in the SAMMY fit. Accurate absorption cross sections should be calculated by the parameters obtained from the analysis of the transmission and fission experimental data. Table 15 shows the average calculated values of the absorption, and alpha compared to Gwin *et al.* 1976 data. Below 500 eV the calculated absorption agrees quite well with Gwin *et al.* 1976 data. Above 500 eV, they are on average 4.5% lower, and the calculated alpha values are also on average 4.5% lower. In the energy range 100 to 1000 eV, the calculated alpha values agree very well with Weston and Todd 1972 evaluation.[22]

The fission and capture resonance integrals are compared to ENDF/B-V on Table 16. The fission and capture integrals calculated from the present evaluation are respectively 1.95% and 5.03% smaller than ENDF/B-V values.

Figures 9 to 21 provide a detailed graphical comparison between the results of several measurements and the corresponding quantities as computed from the resonance parameters of Table 1. The curves represent the calculated values; the crosses or the vertical bars (one standard deviation) represent the measured values. Most of the figures indicate that Blons fission cross sections are much larger than Weston and Todd values in the valleys between resonances, suggesting a remaining background of about 2 barns at 40 eV (Fig. 10), 1.5 barn at 150 eV (Fig. 13), 0.7 barn at 500 eV (Fig. 17) and 850 eV (Fig. 20) in Blons data.

Figure 22 shows an example of the differences between the shape of the fission cross sections calculated from ENDF/B-V and in the present evaluation. ENDF/B-V calculations were displaced by one decade. The experimental data are from Weston and Todd 1984. This figure illustrates the improvement obtained in the representation of the fission cross section shape by the Reich-Moore code SAMMY, compared to the Breit-Wigner representation in ENDF/B-V. Similar comparisons are shown in the same energy interval for the capture cross section in Fig. 23. In the valleys between resonances there are large differences between SAMMY calculations and ENDF/B-V calculations; the ENDF/B-V representation often results in an unphysical structure as would be expected because of the nonphysical formalism used: between resonances the cross sections are mostly determined by the "smooth background" File 3. More comparisons between SAMMY calculations and ENDF/B-V representation can be found in ORNL/TM-10098.

Table 15. ^{239}Pu average absorption cross section and alpha

Energy (eV)	Calculated		Measured; Gwin *et al.* (1976)	
	Absorption (b)	Alpha	Absorption (b)	Alpha
7.3 – 16.0	194.82	0.682	208.00	0.74[a]
16.0 – 37.5	44.79	0.891	46.50	0.89[a]
37.5 – 50.0	69.27	2.389	83.15	2.96[a]
50.0 – 100.00	91.25	0.602	92.84	0.63
100.0 – 200.00	33.88	0.868	33.66	0.87
200.0 – 300.00	33.32	0.925	34.69	0.94
300.0 – 400.00	17.73	1.194	18.31	1.16
400.0 – 500.00	13.28	0.414	13.56	0.44
500.0 – 600.00	25.82	0.714	26.54	0.72
600.0 – 700.00	10.60	1.566	11.57	1.54
700.0 – 800.00	10.13	0.904	10.52	0.97
800.0 – 900.00	8.26	0.746	9.30	0.82
900.0 – 1000.00	13.29	0.615	13.23	0.70

[a]From Gwin *et al.* (1971).

Table 16. Comparison of ^{239}Pu resonance integrals

Energy range (eV)	Fission (b)		Capture (b)	
	This work	ENDF/B-V	This work	ENDF/B-V
0.5– 5.0	85.67	86.02	28.64	32.21
5.0– 10.0	25.06	26.03	19.04	20.14
10.0– 50.0	96.84	100.25	77.38	78.66
50.0– 100.0	40.42	40.32	25.66	27.23
100.0– 301.0	19.67	19.98	17.94	19.52
301.0–1000.0	10.04	10.15	8.34	8.54
1 keV–20 MeV	(21.07)	21.07	(7.80)	7.80
0.5 eV–20 MeV	298.77	303.82	184.80	194.10
Mughabghab (1984)	301 ± 10		200 ± 20	

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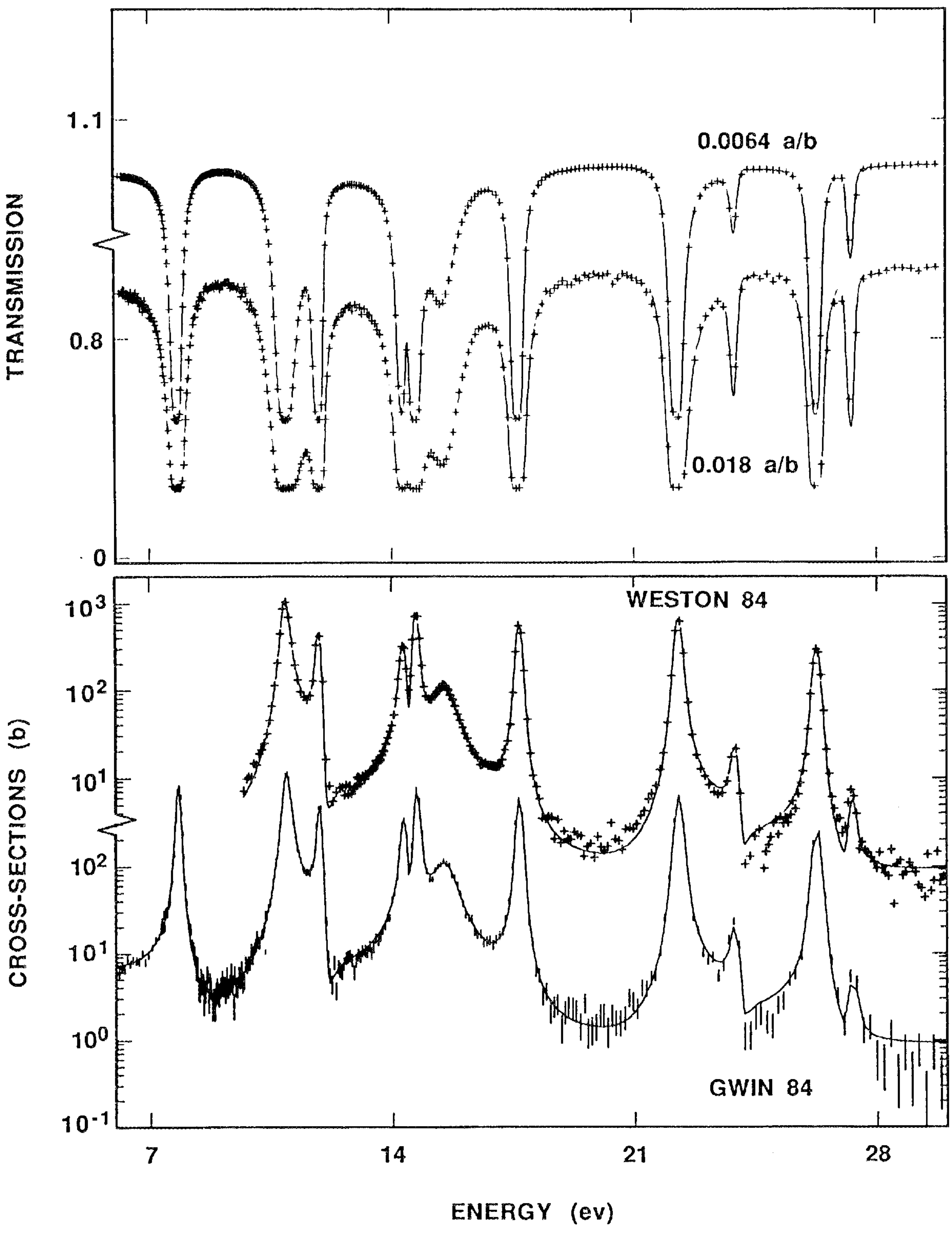

Fig. 9. Experimental and calculated data in the energy range 6 to 30 eV.

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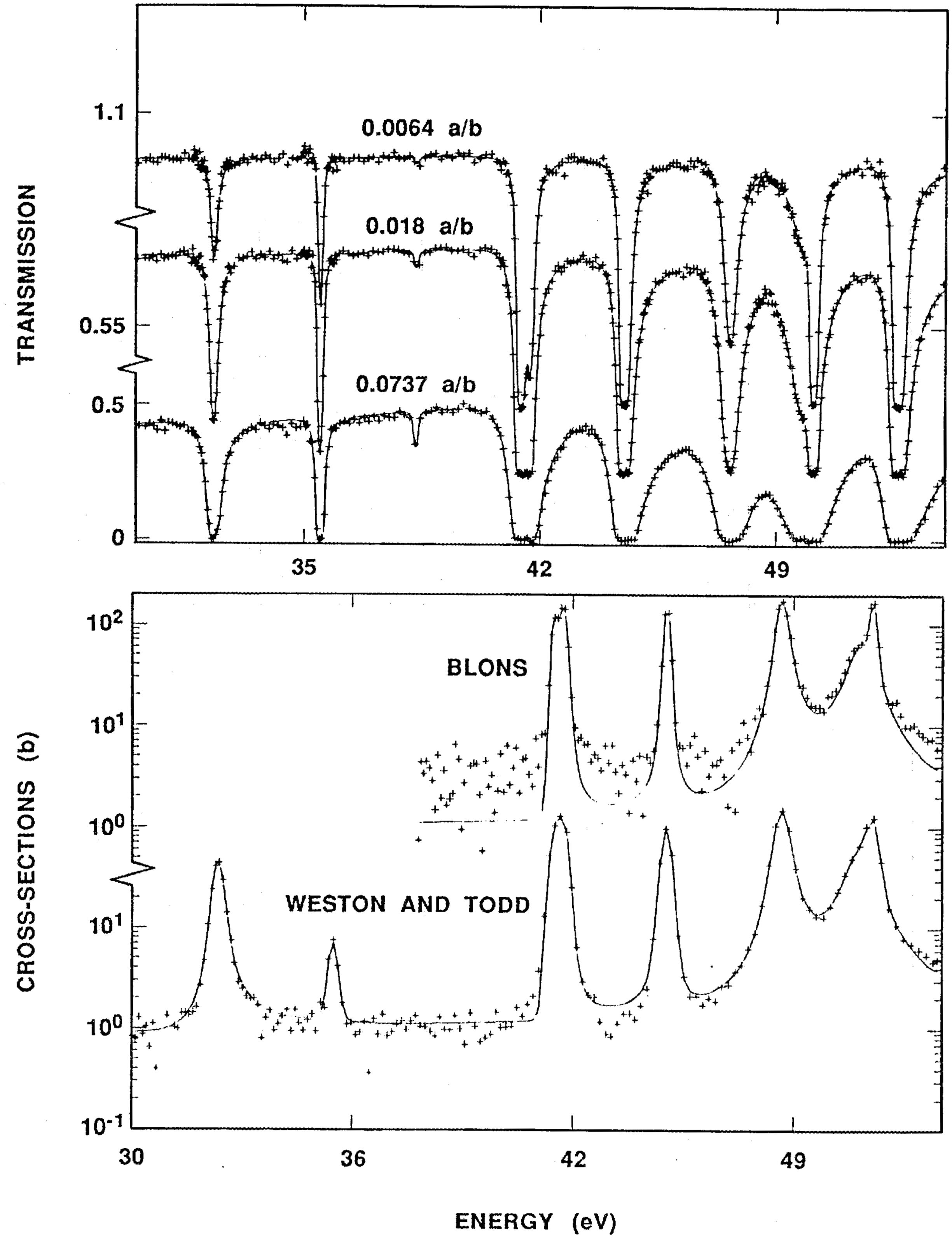

Fig. 10. Experimental and calculated data in the energy range 30 to 50 eV.

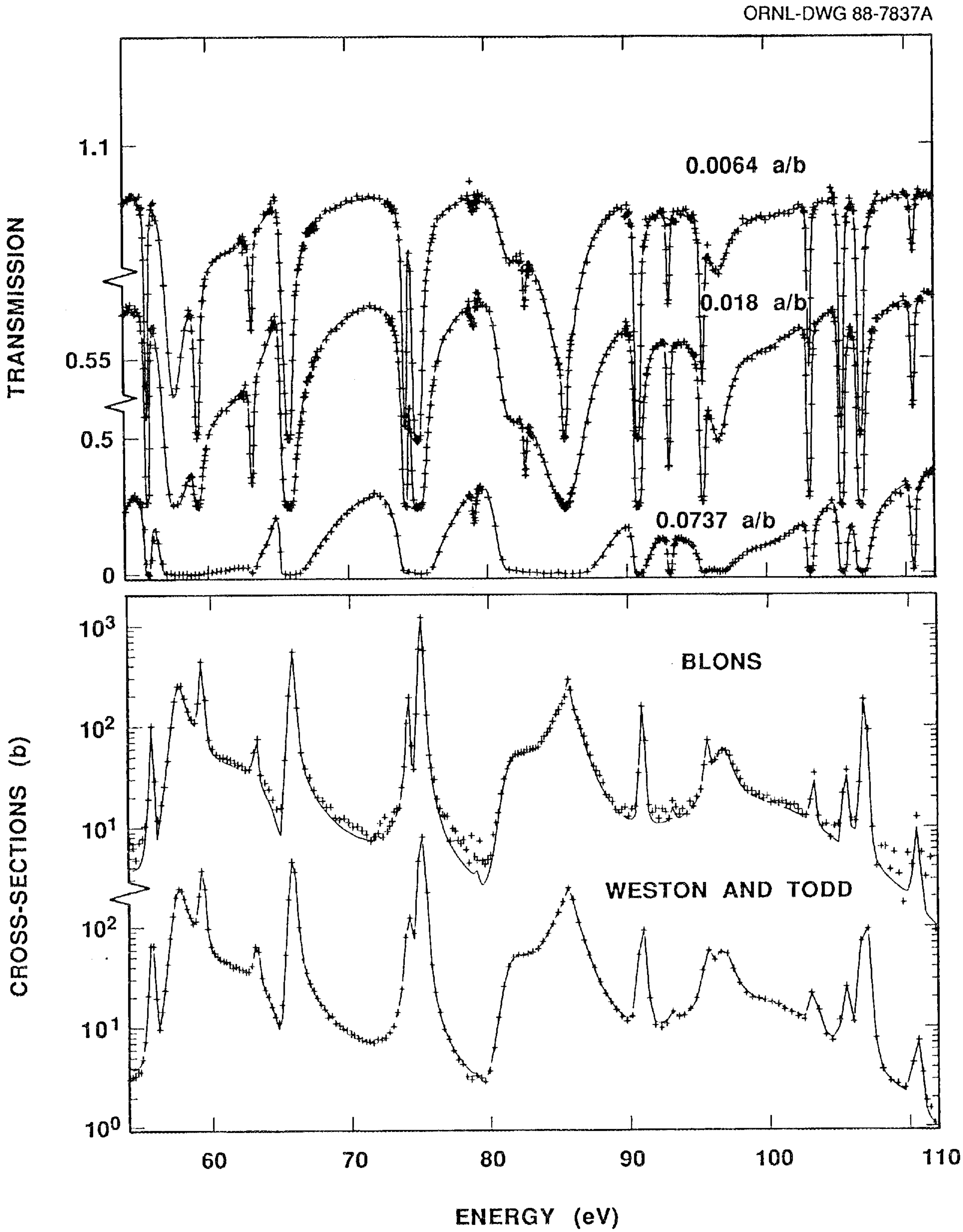

Fig. 11. Experimental and calculated data in the energy range 50 to 110 eV.

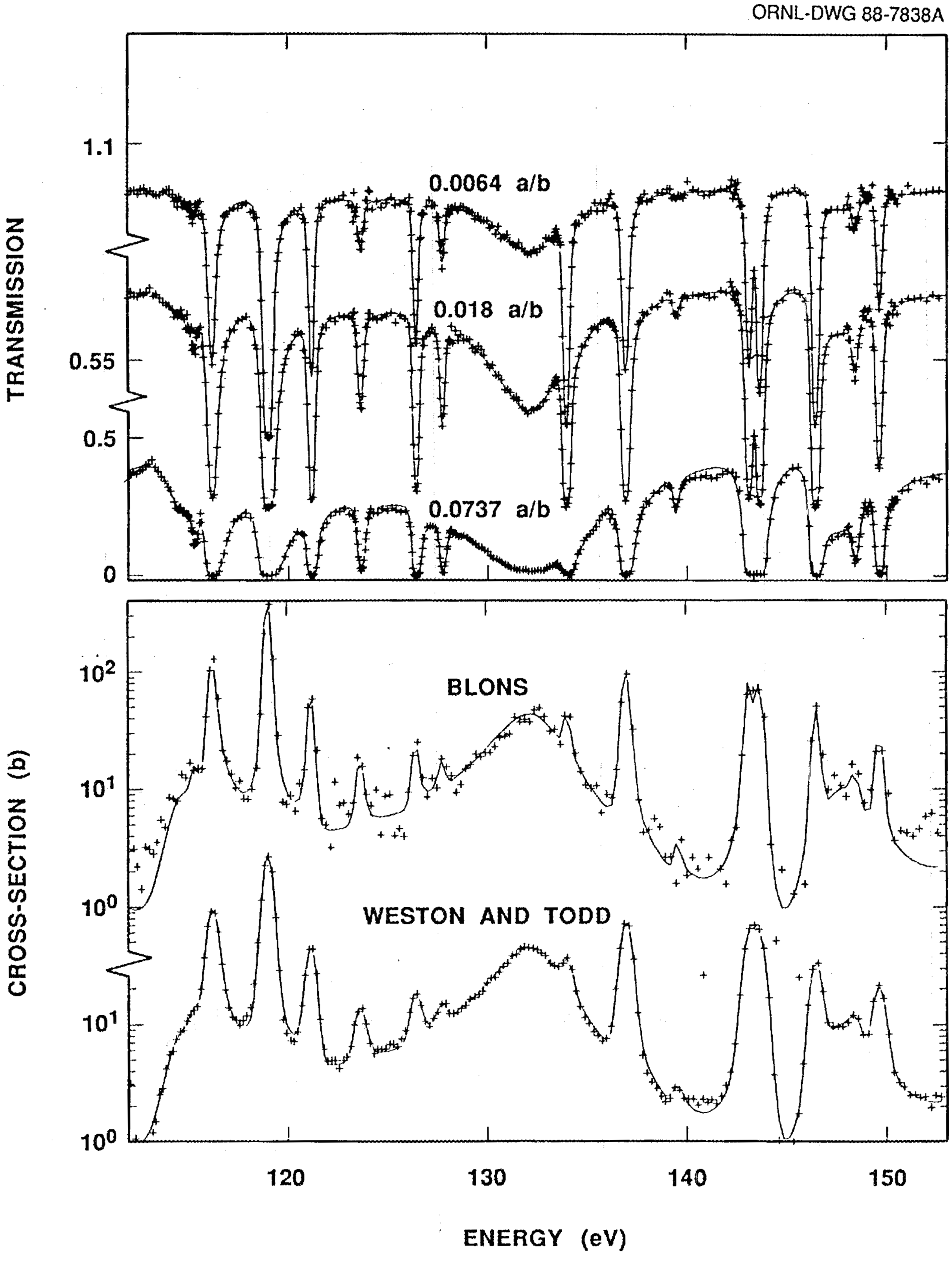

Fig. 12. Experimental and calculated data in the energy range 100 to 153 eV.

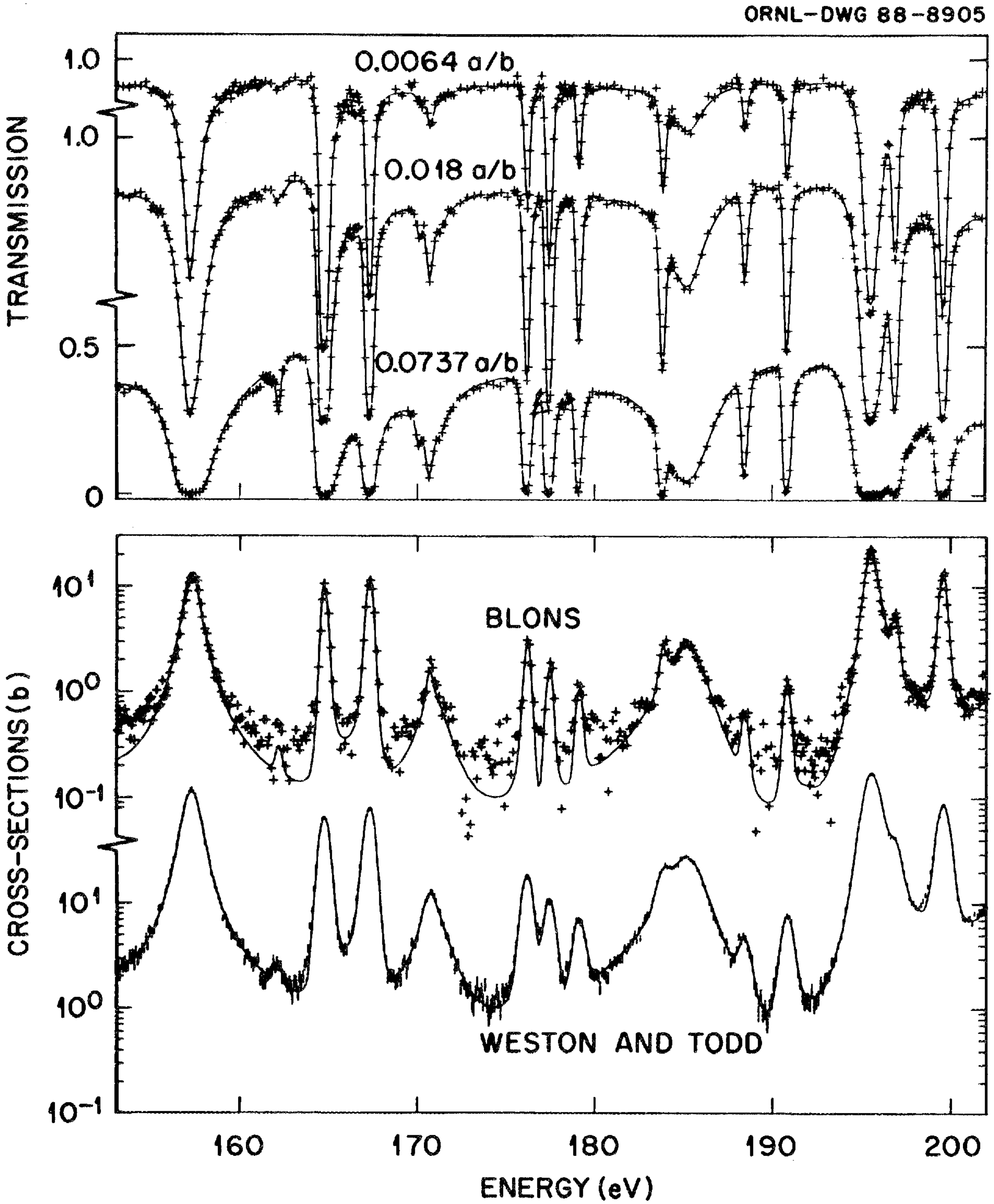

Fig. 13. Experimental and calculated data in the energy range 150 to 210 eV.

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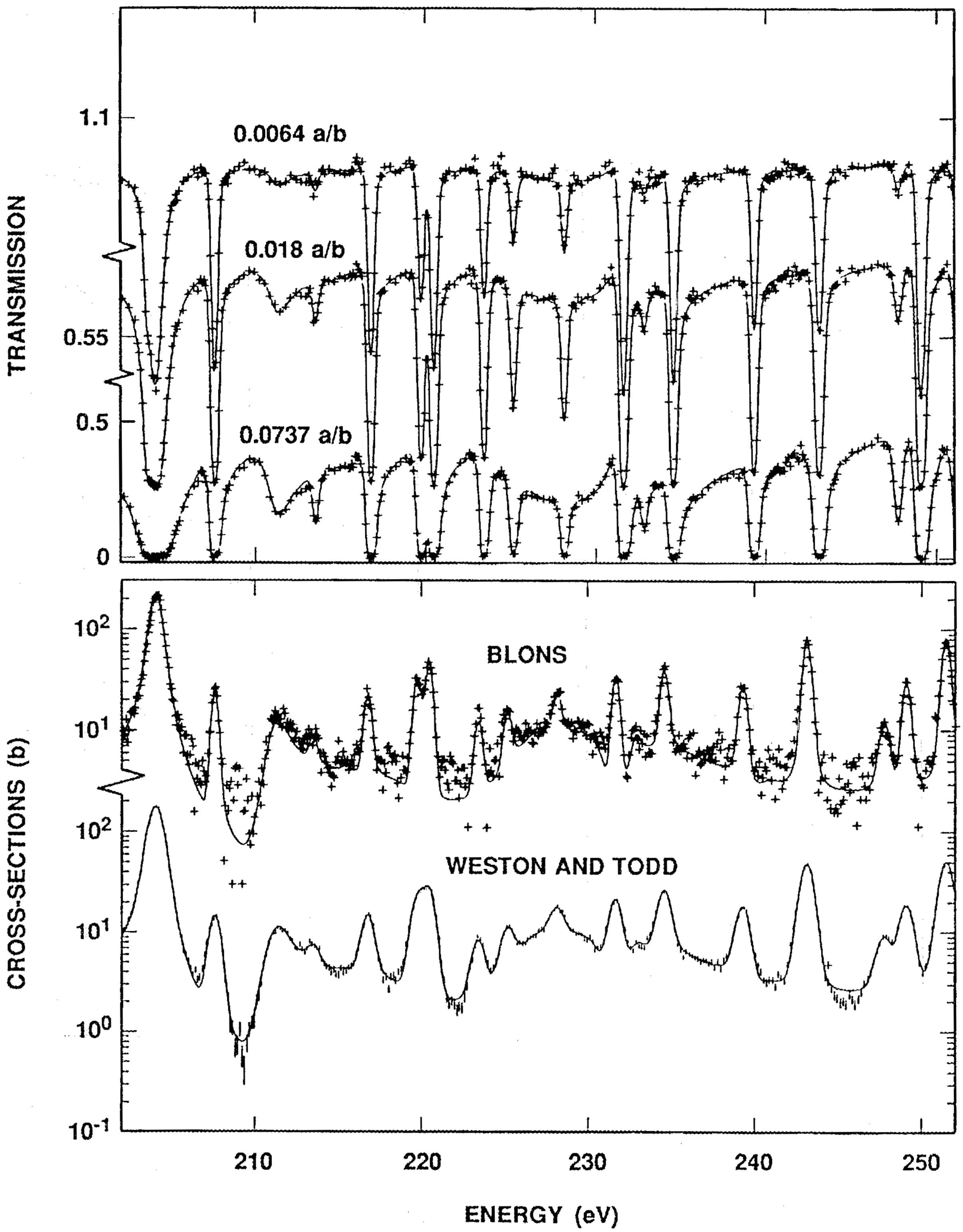

Fig. 14. Experimental and calculated data in the energy range 190 to 253 eV.

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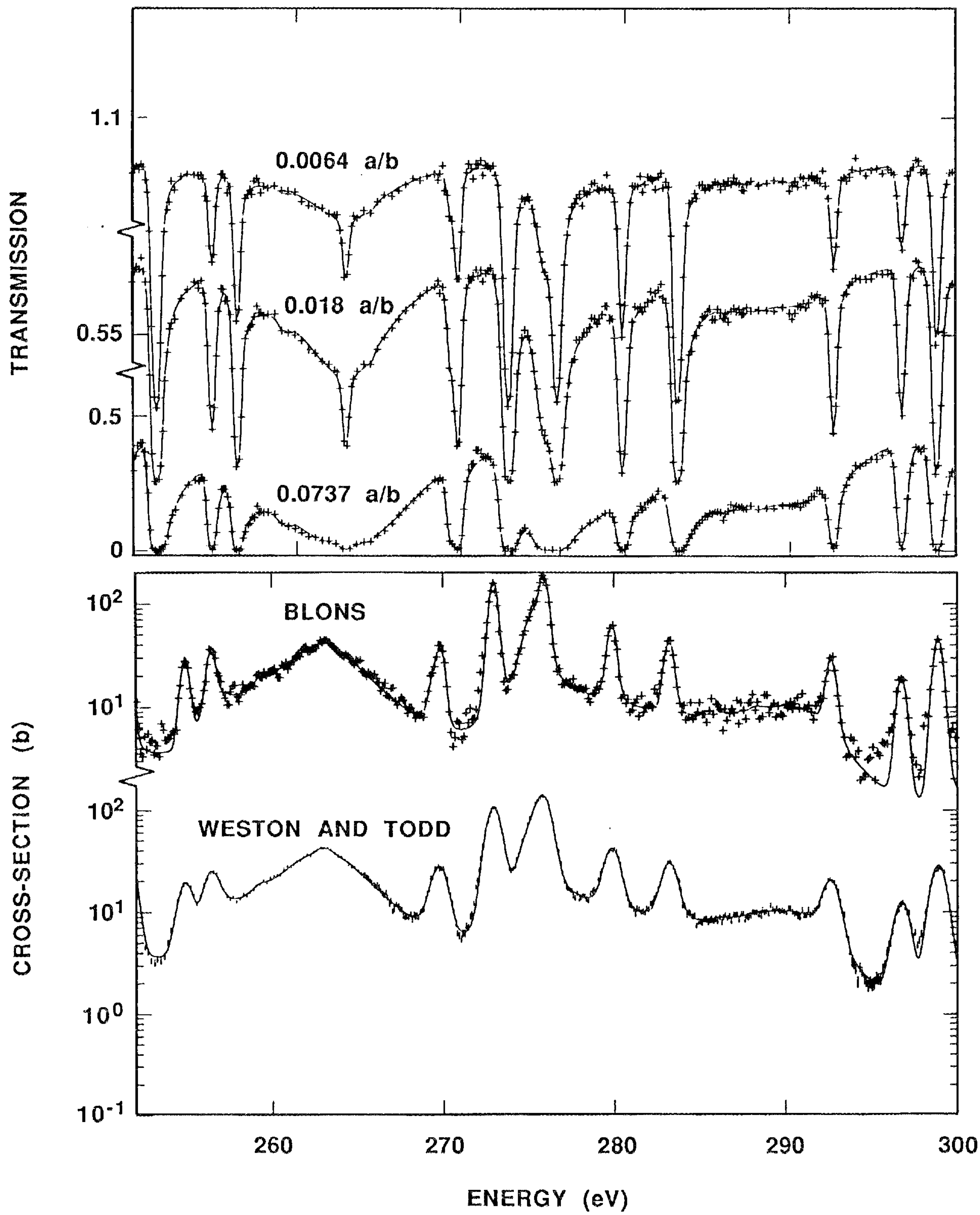

Fig. 15. Experimental and calculated data in the energy range 250 to 300 eV.

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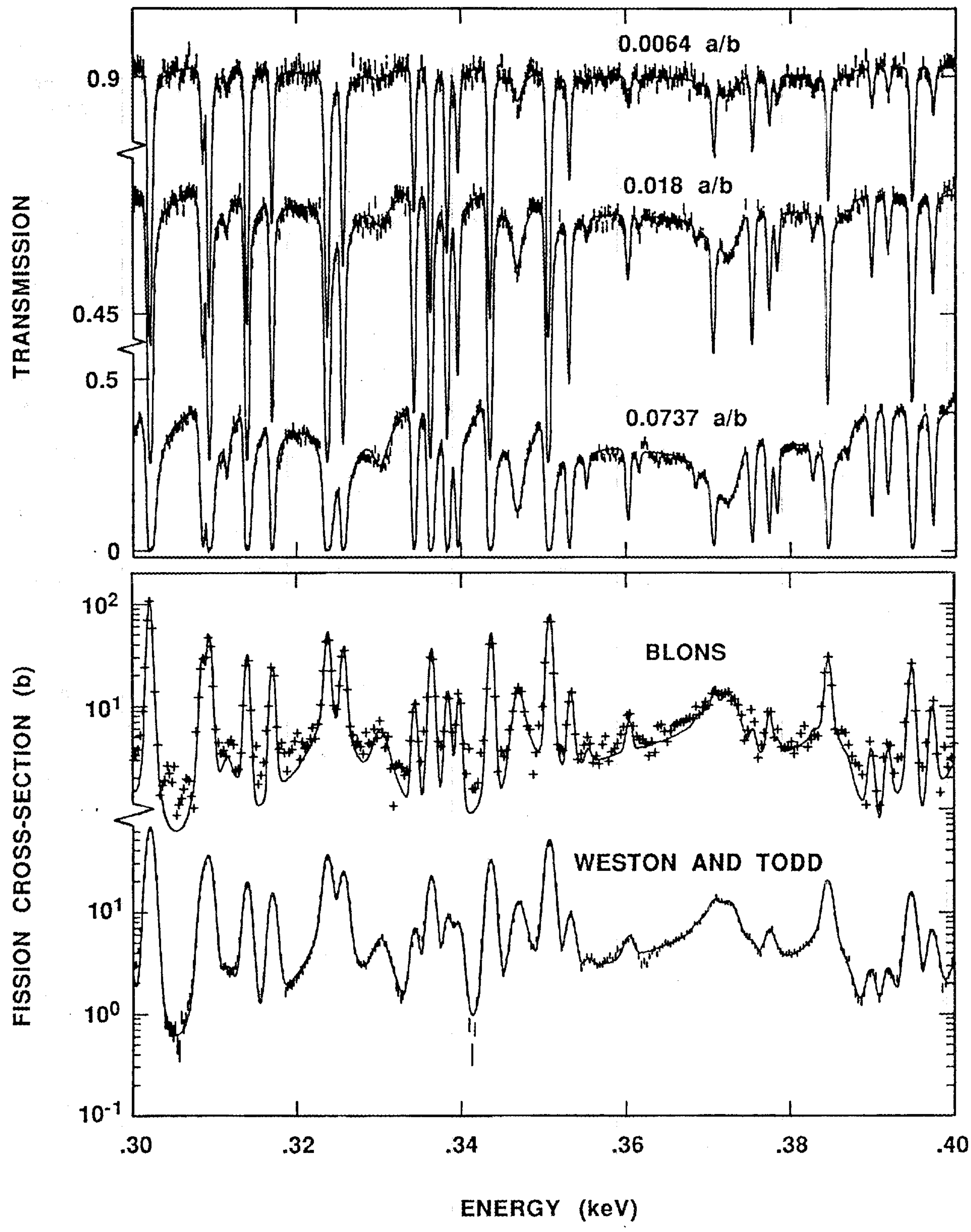

Fig. 16. Experimental and calculated data in the energy range 0.30 to 0.40 keV.

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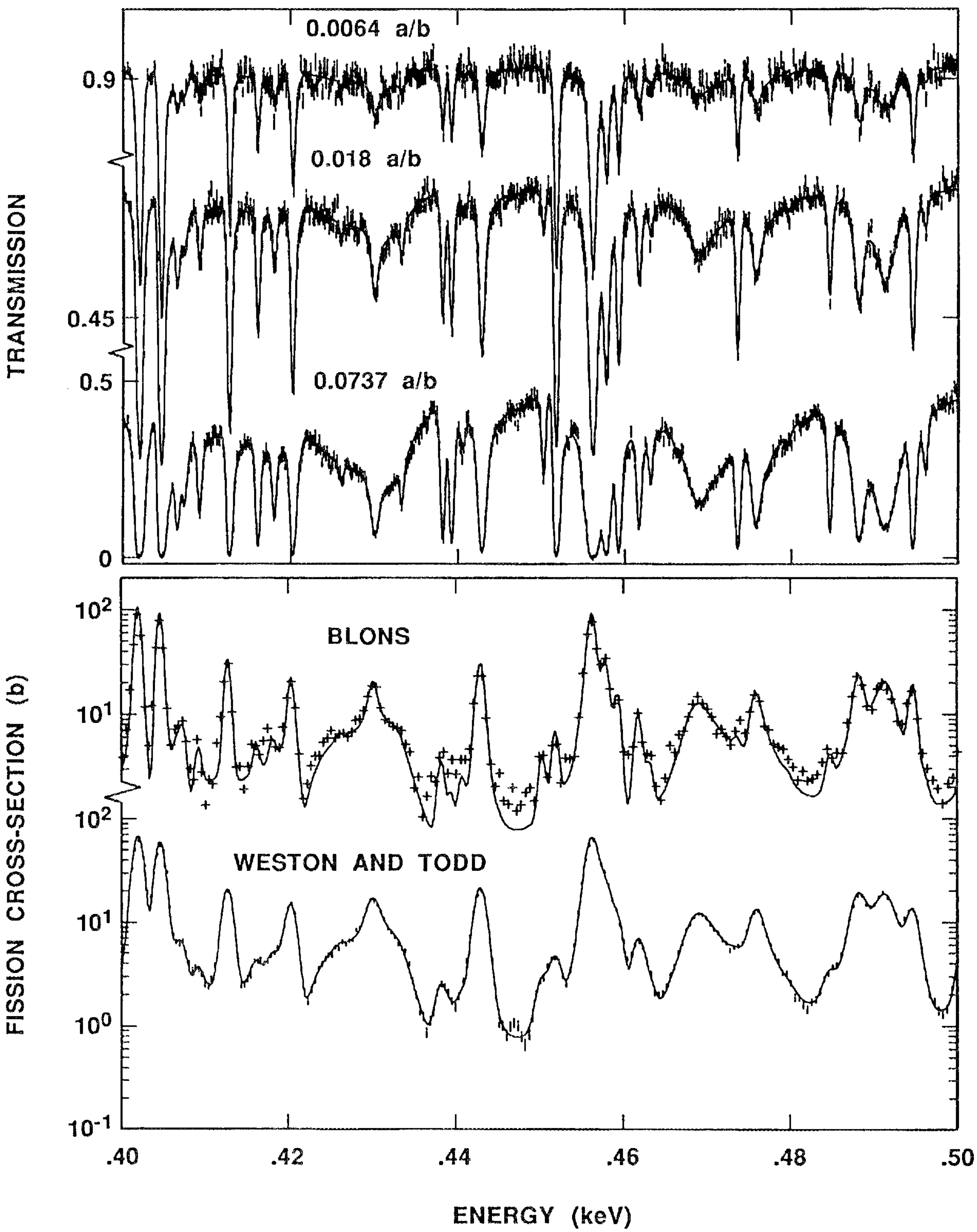

Fig. 17. Experimental and calculated data in the energy range 0.40 to 0.50 keV.

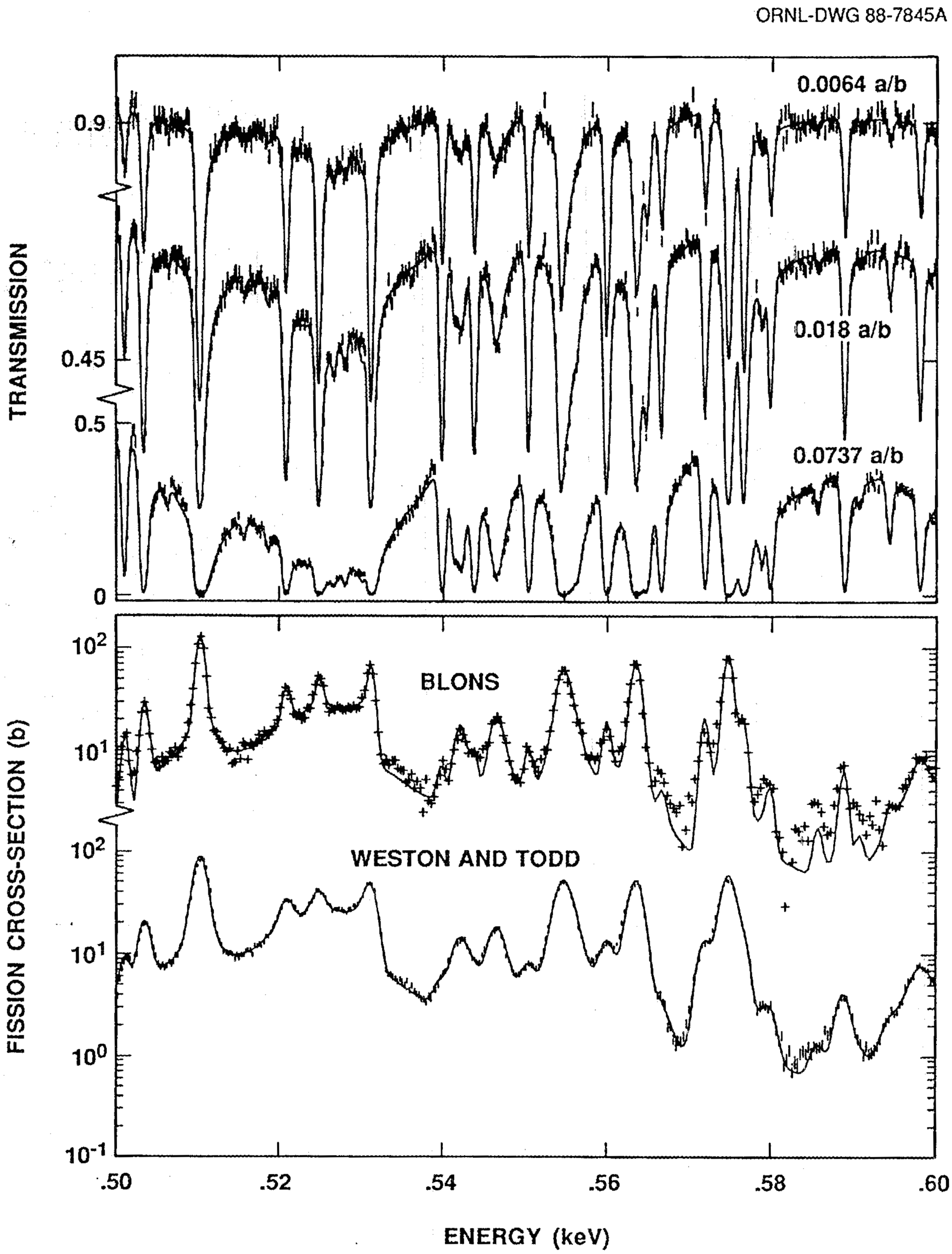

Fig. 18. Experimental and calculated data in the energy range 0.50 to 0.60 keV.

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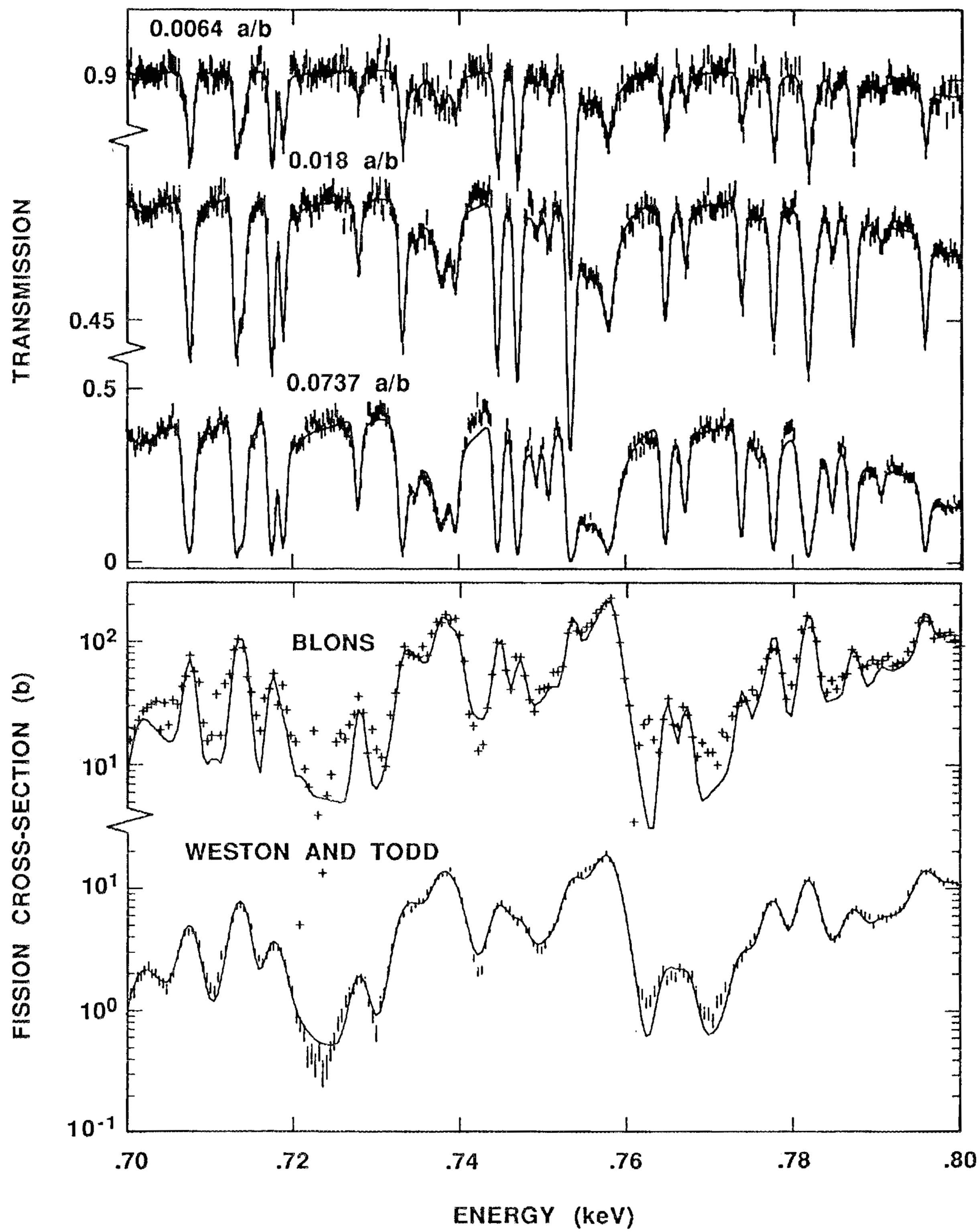

Fig. 19. Experimental and calculated data in the energy range 0.70 to 0.80 keV.

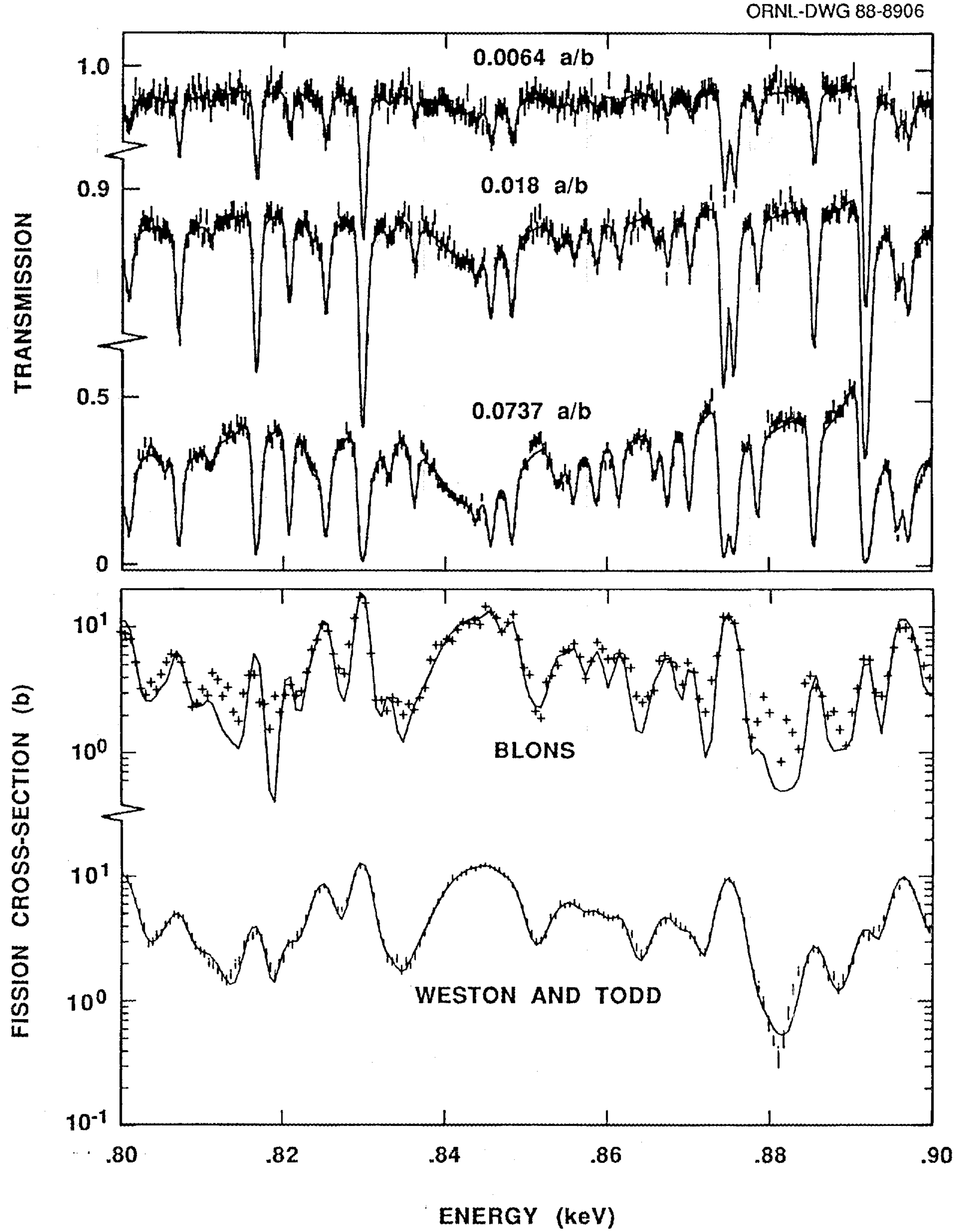

Fig. 20. Experimental and calculated data in the energy range 0.80 to 0.90 keV.

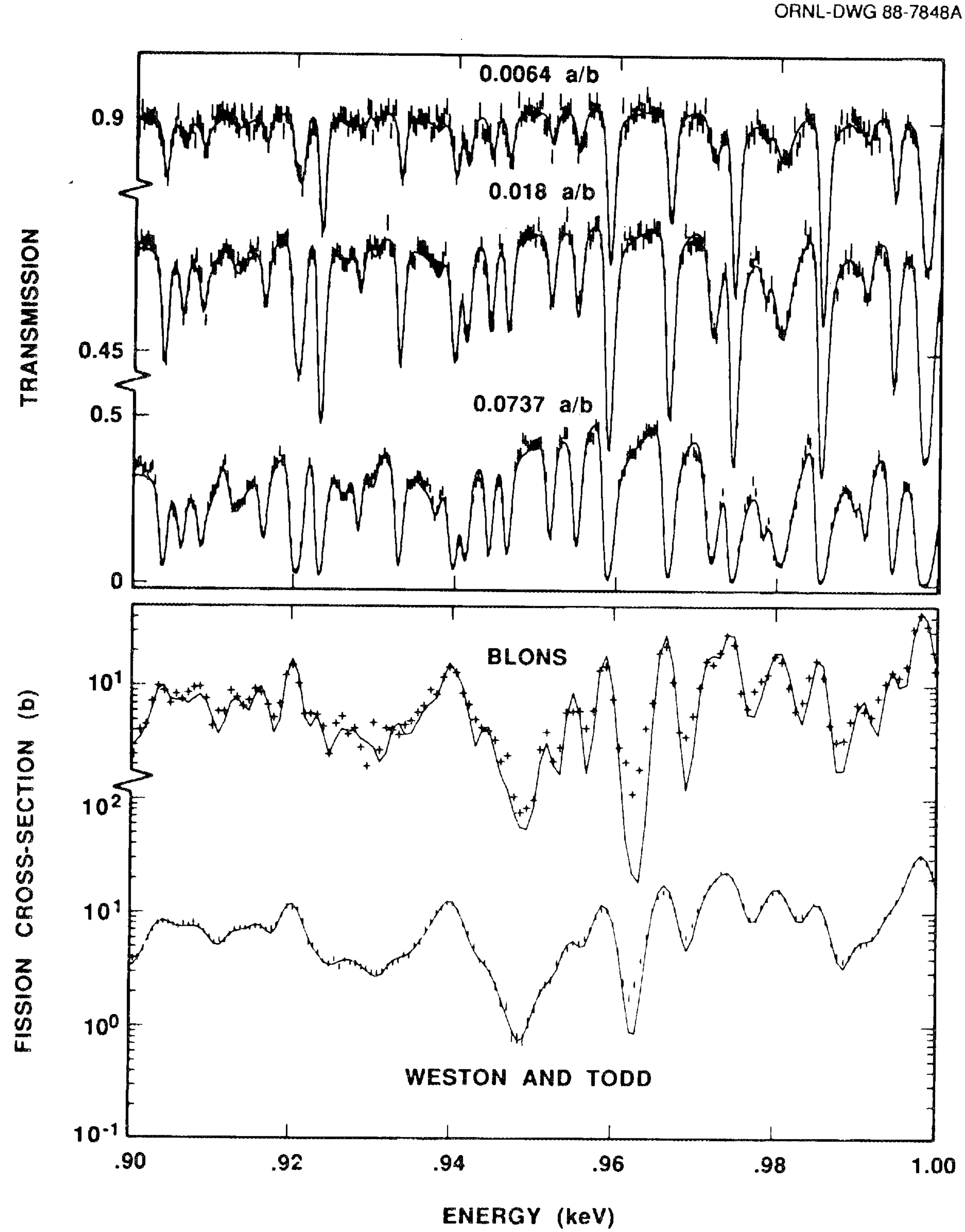

Fig. 21. Experimental and calculated data in the energy range 0.90 to 1.00 keV.

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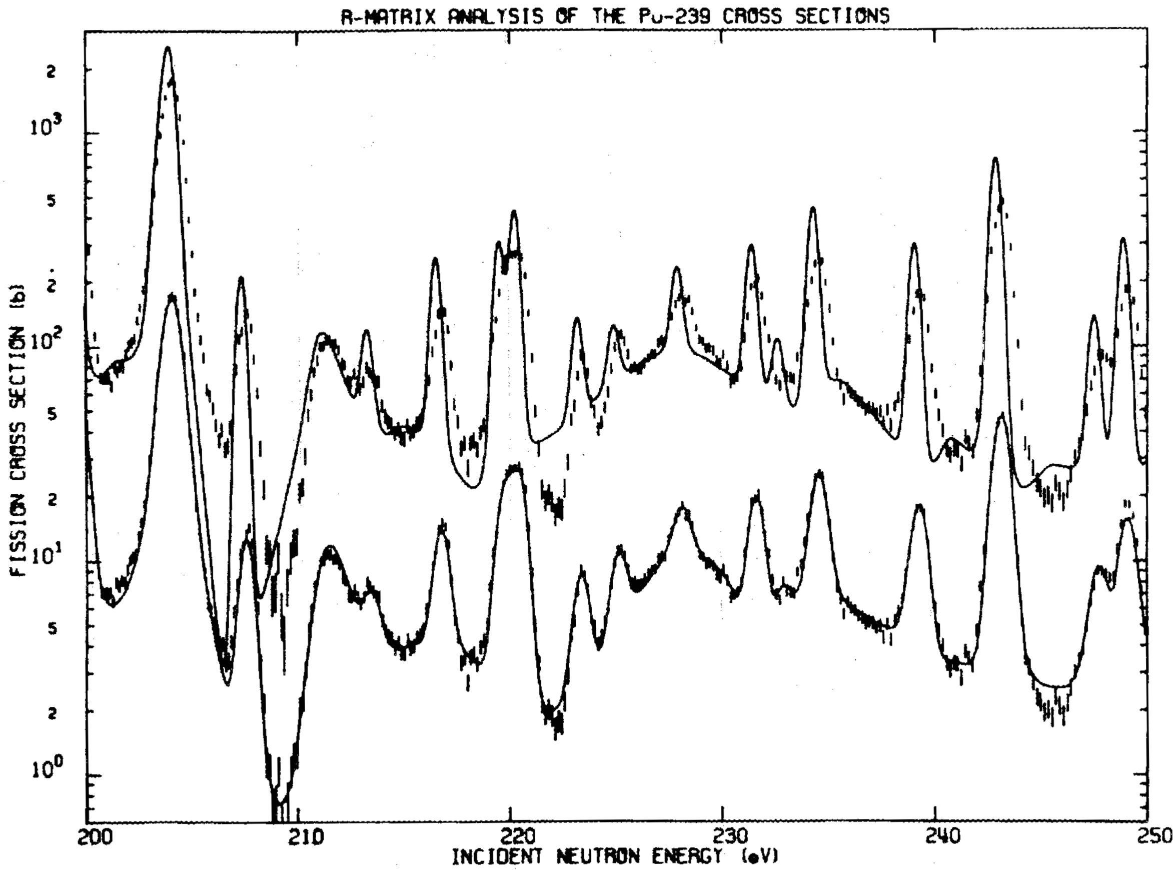

Fig. 22. Comparison of the fission cross section computed with the resonance parameters of Table 1 (lower solid line) and with ENDF/B-V (upper solid line), with the data from Weston 84, in the energy range 200 to 250 eV. The ENDF/B-V calculation and corresponding set of data were displaced up by one decade for clarity.

ORNL-DWG 86-11955

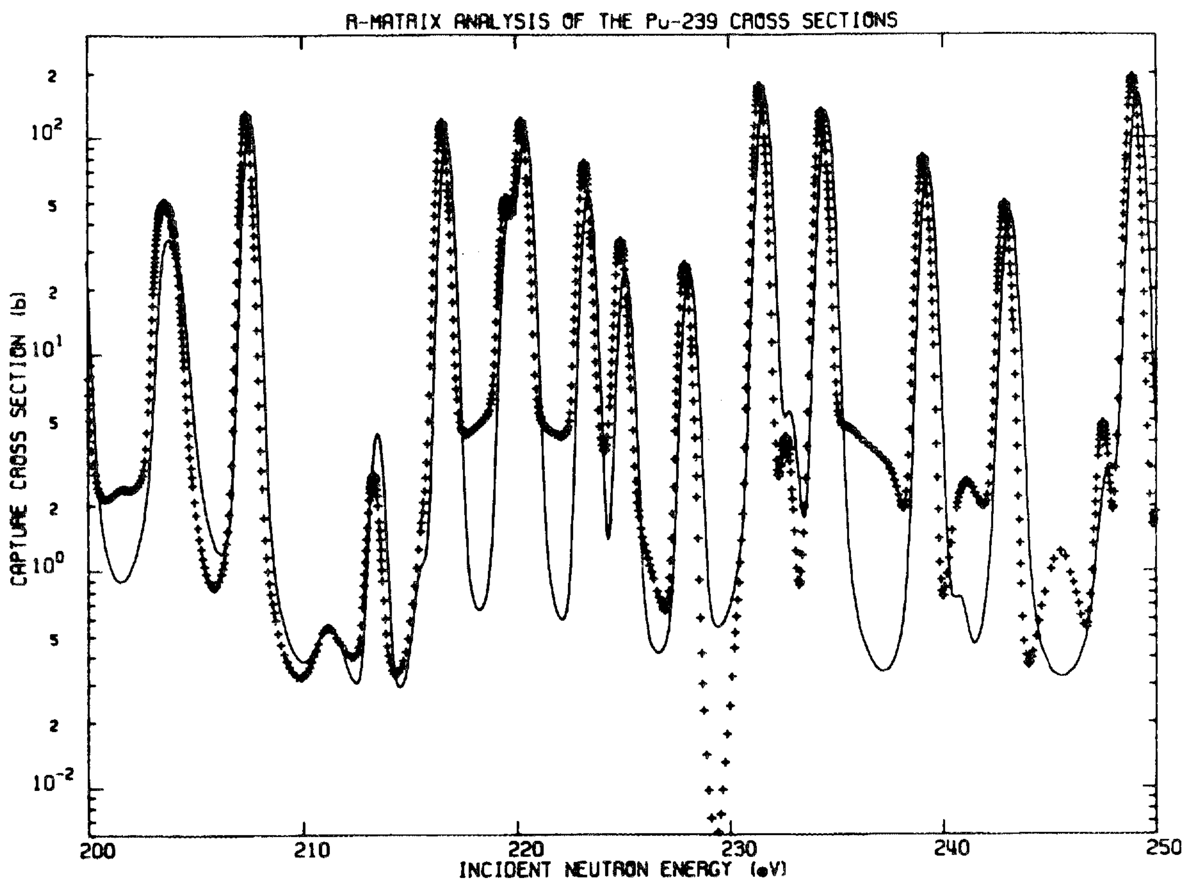

Fig. 23. Comparison of the capture cross section computed with the resonance parameters of Table 1 (solid line), with ENDF/B-V (crosses) over the neutron energy range 200 to 250 eV.

5. SUMMARY AND CONCLUSIONS

Several sets of ^{239}Pu neutron cross-section data, both recent and older, have been analyzed using R-matrix theory combined with Bayesian equations, a technique which provides a powerful tool for cross-section evaluation procedures. This analysis provides a consistent and precise description of various sets of fission, capture, and transmission data. The evaluation also provides an accurate method for cross-section interpolation at the valleys between resonances where the capture and fission cross sections are exceedingly small, making accurate measurements difficult, and where the single-level formalisms grossly misrepresent the data. The present analysis is a great improvement over previous evaluations in that it provides a good and consistent representation of the high resolution transmission ratios of Harvey *et al.* and the high accuracy recent fission measurements of Weston and Todd and Gwin *et al.*

6. ACKNOWLEDGEMENTS

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