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RRDF-98
RUSSIAN REACTOR DOSIMETRY FILE

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Abstract

This document summarizes the contents and documentation of the new version of the Russian Reactor Dosimetry File (RRDF-98) released in December 1998 by the Russian Center on Nuclear Data (CJD) at the Institute of Physics and Power Engineering, Russian Federation. This file contains the original evaluations of cross section data and covariance matrixes for 22 reactions which are used for neutron flux dosimetry by foil activation. The majority of the evaluations included in previous versions of the Russian Reactor Dosimetry Files (BOSPOR-80, RRGF-94 and RRDF-96) have been superseded by new evaluations. The evaluated cross sections of RRDF-98 averaged over 252-Cf and 235-U fission spectra are compared with relevant integral data. The data file is available from the IAEA Nuclear Data Section on diskette, cost free.

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The file was revised to conform with ENDF/B format standards.. The merged file was corrected for format errors and processed through the code CHECKR to ensure, as far as possible, format compatibility.

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Introduction.

The 1998 version of the Russian Reactor Dosimetry File, RRDF-98, contains original evaluations of cross section data performed at the Institute of Physics and Power Engineering, Obninsk, for 22 neutron induced dosimetry reactions. The list of reactions is given in Table 1. The majority of evaluations included in previous versions of the Russian Reactor Dosimetry Files (BOSPOR-80, RRDF-94 and RRDF-96), which were issued in 1994 and 1996, respectively, have been superseded by new evaluations.

Evaluations.

The evaluation of excitation functions was performed on the basis of statistical analysis of corrected experimental data in the framework of generalized least squares method [1] and taking into account the results of optical-statistical STAPRE and GNASH calculations. The experimental cross section data including the most recent results were critically reviewed and processed in this study. If necessary, the data were normalized in order to make adjustments in relevant cross sections and decay schemes. In order to improve the accuracy and consistency of the experimental data, an update of the 1991 NEANDC/INDC Nuclear Standards Data File [2] was adopted for conversion of relative measured values.

The covariance matrixes were prepared and the evaluated cross section data are presented in ENDF-6 format (Files 3, 33). For estimation of correlations between experimental data the total uncertainties of measured cross sections have been separated into statistical and systematic parts and correlation coefficients between components of systematic parts were assigned according to information given in the original publications and EXFOR library. Then the correlation matrix of cross sections measured within one experiment was calculated and approximated by matrix with a constant (average) correlation coefficient. The overall correlation matrix was composed of such submatricies in the assumption that the cross sections measured in different experiments do not correlate with each other. It should be noted that such procedure of the statistical analyses guarantees positive definiteness of the covariance matrices of evaluated cross sections.

For convenience of the user the reactions are presented in order of increasing proton number (Z) of the target element, then in order of increasing mass number (A=Z+N) of the target nuclide. For the same target nuclide the order of reactions is as follows: (n,2n), (n,g), (n,p), (n,a) and (n,f). Each isotope in the RRDF-98 library starts with a brief description of the data and methods used in that particular evaluation (File 1). The RRDF-98 evaluations are compared with the IRDF-90 version 2 data, if available (or with the most recent new evaluations like JENDL-3.2, etc), and with experimental data in Figs. 1-22.

Table 1. RRDF-98. List of reactions

Isotope/Reaction	MAT	Threshold energy (MeV)	Authors	Date
$^{12}C(n,2n)^{11}C$	613	20.4095	K.I.Zolotarev, A.B.Pashchenko, M.V.Scripova	September 1998
$^{16}O(n,2n)^{15}O$	813	16.6481	K.I.Zolotarev, A.B.Pashchenko, M.V.Scripova	May 1998
$^{19}F(n,2n)^{18}F$	912	10.985	K.I.Zolotarev, A.B.Pashchenko	December 1993
$^{24}Mg(n,p)^{24}Na$	1225	4.9311	S.Badikov, K.I.Zolotarev	August 1994
$^{46}Ti(n,2n)^{45}Ti$	2212	13.4802	K.I.Zolotarev, S.Badikov, A.B.Pashchenko	January 1994
$^{46}Ti(n,p)^{46}Sc$	2212	1.6197	K.I.Zolotarev, S.Badikov, A.B.Pashchenko	January 1994
$^{47}Ti(n,x)^{46}Sc$	2222	9.0709	K.I.Zolotarev, A.B.Pashchenko,	October 1995
$^{48}Ti(n,p)^{48}Sc$	2232	3.2756	K.I.Zolotarev, A.B.Pashchenko	December 1993
$^{48}Ti(n,x)^{47}Sc$	2232	9.41396	K.I.Zolotarev, A.B.Pashchenko,	December 1993
$^{49}Ti(n,x)^{48}Sc$	2242	8.3077	K.I.Zolotarev, A.B.Pashchenko	November 1993
$^{51}V(n,\alpha)^{48}Sc$	2323	11.2688	K.I.Zolotarev, V.N.Manokhin, A.B.Pashchenko	November 1997
$^{54}Fe(n,2n)^{53m+g}Fe$	2613	13.6302	K.I.Zolotarev, A.B.Pashchenko, M.V.Scripova	August 1998
$^{54}Fe(n,\alpha)^{51}Cr$	2611	10^{-11}	K.I.Zolotarev	June 1996
$^{56}Fe(n,p)^{56}Mn$	2622	2.9709	K.I.Zolotarev	November 1992
$^{59}Co(n,\alpha)^{56}Mn$	2712	10^{-11}	K.I.Zolotarev	December 1997
$^{63}Cu(n,\alpha)^{60}Co$	2911	10^{-11}	K.I.Zolotarev	March 1997
$^{75}As(n,2n)^{74}As$	3312	10.3779	K.I.Zolotarev, V.N.Manokhin, A.B.Pashchenko	September 1994
$^{93}Nb(n,n')^{93m}Nb$	4112	0.03073	K.I.Zolotarev, S.Badikov	August 1996
$^{93}Nb(n,2n)^{92m}Nb$	4112	9.0523	K.I.Zolotarev, S.Badikov	August 1996
$^{103}Rh(n,n')^{103m}Rh$	4525	0.04	S.Badikov	August 1996
$^{115}In(n,n')^{115m}In$	4931	0.32	S.Badikov	August 1996
$^{141}Pr(n,2n)^{140}Pr$	5912	9.4607	K.I.Zolotarev, A.B.Pashchenko, M.V.Scripova	January 1994

Integral testing.

The RRDF-98 cross section data were averaged over the standard and reference neutron spectra and compared with relevant integral experimental results. The following neutron spectra were used: ^{252}Cf spontaneous fission spectrum [3], ^{235}U thermal fission spectrum [4], four fast reactor spectra ISSF, CERMF, ΣΣ, YAYOI and DT and LiD neutron fields. In the Table 2 the evaluated cross sections from RRDF-98 averaged over ^{252}Cf and ^{235}U fission spectra are compared with integral experimental data and respective data from IRDF-90 version 2 [5].

Table 2. Measured and calculated cross sections averaged over ^{252}Cf spontaneous fission and ^{235}U thermal fission neutron spectra

Reaction	^{252}Cf			^{235}U		
	RRDF-98	IRDF-90	Experiment	RRDF-98	IRDF-90	Experiment
	<σ>, mb	<σ>, mb	<σ>, mb	<σ>, mb	<σ>, mb	<σ>, mb
^{12}C(n,2n)^{11}C				4.1E-07		3.6-07±1.2E-07 [7]
^{16}O(n,2n)^{15}O				4.1E-06		4.5E-06±2.0E-06 [7]
^{19}F(n,2n)^{18}F	0.01679	0.017027	0.01628± 0.00054 [5]	0.00759	0.00772	
^{24}Mg(n,p)^{24}Na	2.1398	2.1564	2.005±0.048 [5]	1.5396	1.5517	1.50±0.06 [6]
^{46}Ti(n,p)^{46}Sc	13.354	12.313	14.20±0.24 [5]	11.090	10.252	11.6±0.4 [6]
^{48}Ti(n,p)^{48}Sc	0.3979	0.3864	0.428±0.008 [6]	0.2833	0.2749	0.302±0.010 [6]
^{51}V(n,α)^{48}Sc	0.03868	0.03872	0.03904± 0.00086 [6]	0.0245	0.0246	0.0241±0.009 [6]
^{54}Fe(n,α)^{51}Cr	1.1068			0.8420		0.850±0.050 *
^{56}Fe(n,p)^{56}Mn	1.4692	1.368	1.471±0.025 [6]	1.1070	1.0297	1.09±0.04 [6]
^{59}Co(n,α)^{56}Mn	0.2183	0.2159	0.2221±0.0039 [6]	0.1566	0.1549	0.161±0.007 [6]
^{63}Cu(n,α)^{60}Co	0.6803	0.6778	0.6897±0.0130 [6]	0.5228	0.5214	0.5271±0.0139 *
^{75}As(n,2n)^{74}As				0.310		0.309±0.019 *
^{93}Nb(n,2n)^{93m}Nb	0.7701	0.7773	0.749±0.038 [6]	0.4416	0.4459	0.4576±0.0226 *
^{93}Nb(n,n')^{92m}Nb	146.02	142.55	147.5±2.5 *	143.46	139.97	147.6±7.0*
^{103}Rh(n,n')^{103m}Rh	736.34	714.1		726.85	706.03	673.5±52.2 [8]
^{115}In(n,n')^{115m}In	190.4	189.7		187.20	186.35	190.3±7.3 [6]

* - evaluated by authors.

From the Table 2 it can be seen that, except for 3 reactions, the RRDF-98 evaluations are in good agreement with integral experimental data averaged over ^{235}U fission spectrum. However, the evaluations for ^{47}Ti(n,p)^{46}Sc and ^{48}Ti(n,p)^{48}Sc reactions disagree with the integral data for both spectra. Since these evaluations are based on the results of recent measurements the revision of the integral data is needed. The user of the RRDF-98 should pay attention to a large discrepancy which was discovered between the spectrum averaged calculated and experimental data for the ^{24}Mg(n,p)^{24}Na reaction. The integral value for this reaction seems to be erroneous. The comparison between the IRDF-90 evaluations and the RRDF-98 curves shows that the RRDF-98 data show a better agreement with the integral results for most reactions.

Concluding remarks.

The Russian Reactor Dosimetry File version 1998 is an updated and extended library which supersedes all previous Russian dosimetry files. The extension and improvement refer to the inclusion of "new" experimental data and the preparation of covariance matrixes for all dosimetry reactions included in the library. This version of RRDF comprises ENDF-6 formatted data for 22 reactions. The content of the library is not yet completed, several reactions important for neutron metrology work are not yet present. The authors plan to complete evaluations of cross sections and related uncertainty information for the following dosimetry reactions which are under preparation at the moment: 23-Na(n,γ)Na-24, 37-Cl(n,γ)Cl-38, 55-Mn(n,γ)Mn-56, 58-Ni(n,p)Co-58, 60-Ni(n,p)Co-60, 63-Cu(n,γ)Cu-64, 139-La(n,γ)La-140, 186-W(n,γ)W-187 and 241-Am(n,f).

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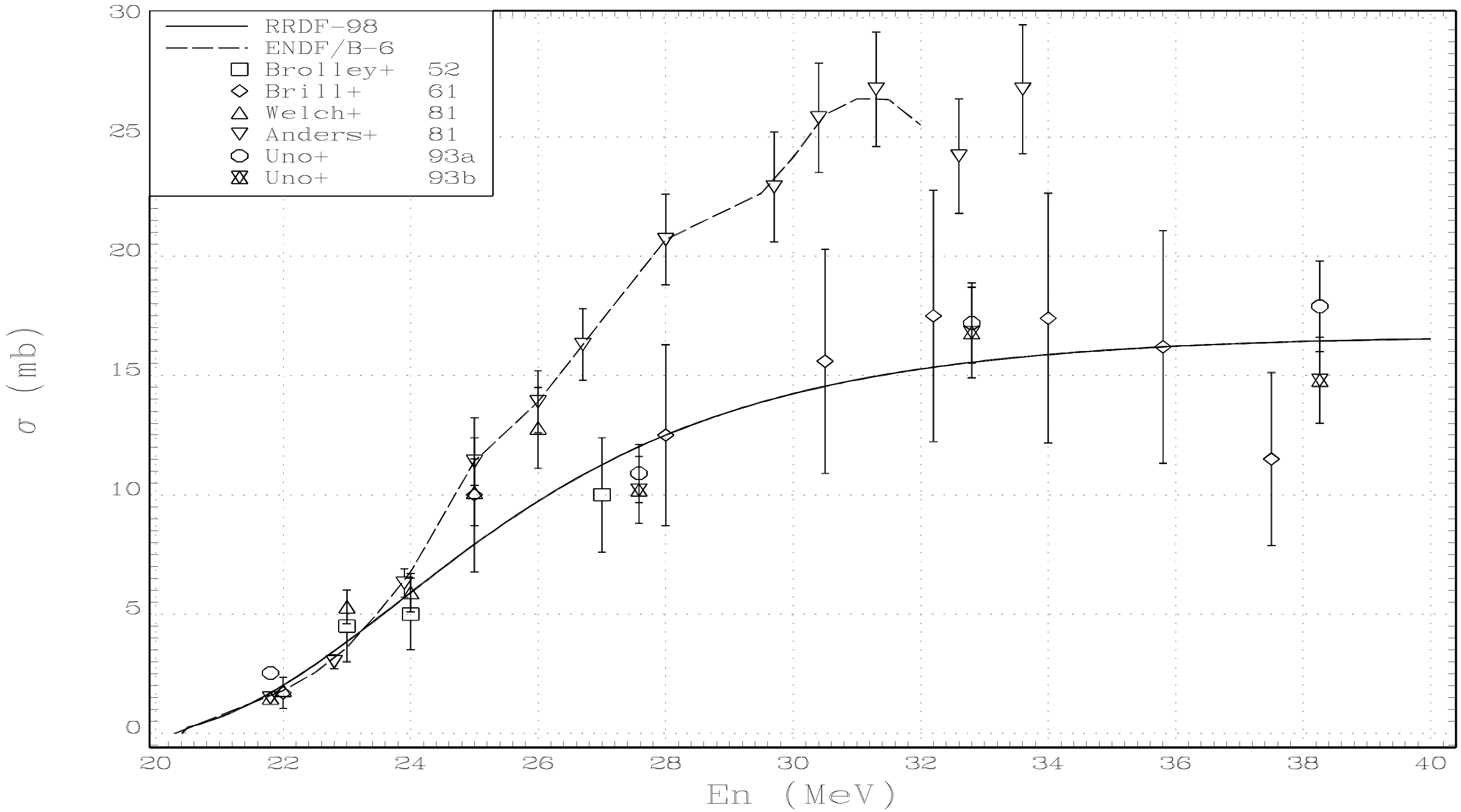

Fig.1. RRDF-98 evaluated excitation function for the $^{12}C(n,2n)^{11}C$ reaction in comparison with ENDF/B-VI curve and experimental data.

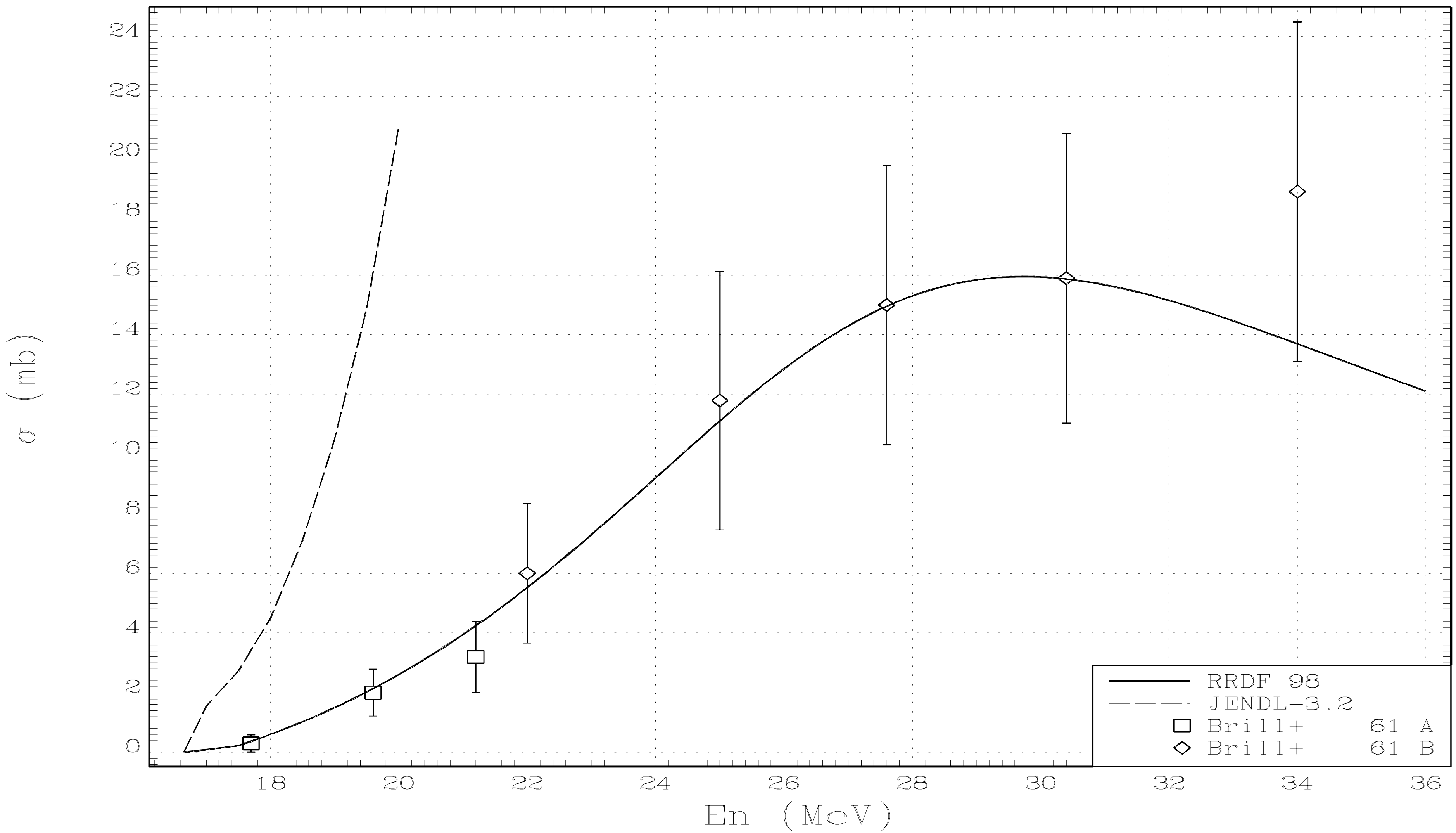

Fig.2. RRDF-98 evaluated excitation function for the $^{16}O(n,2n)^{15}O$ reaction in comparison with JENDL-3.2 curve and experimental

data.

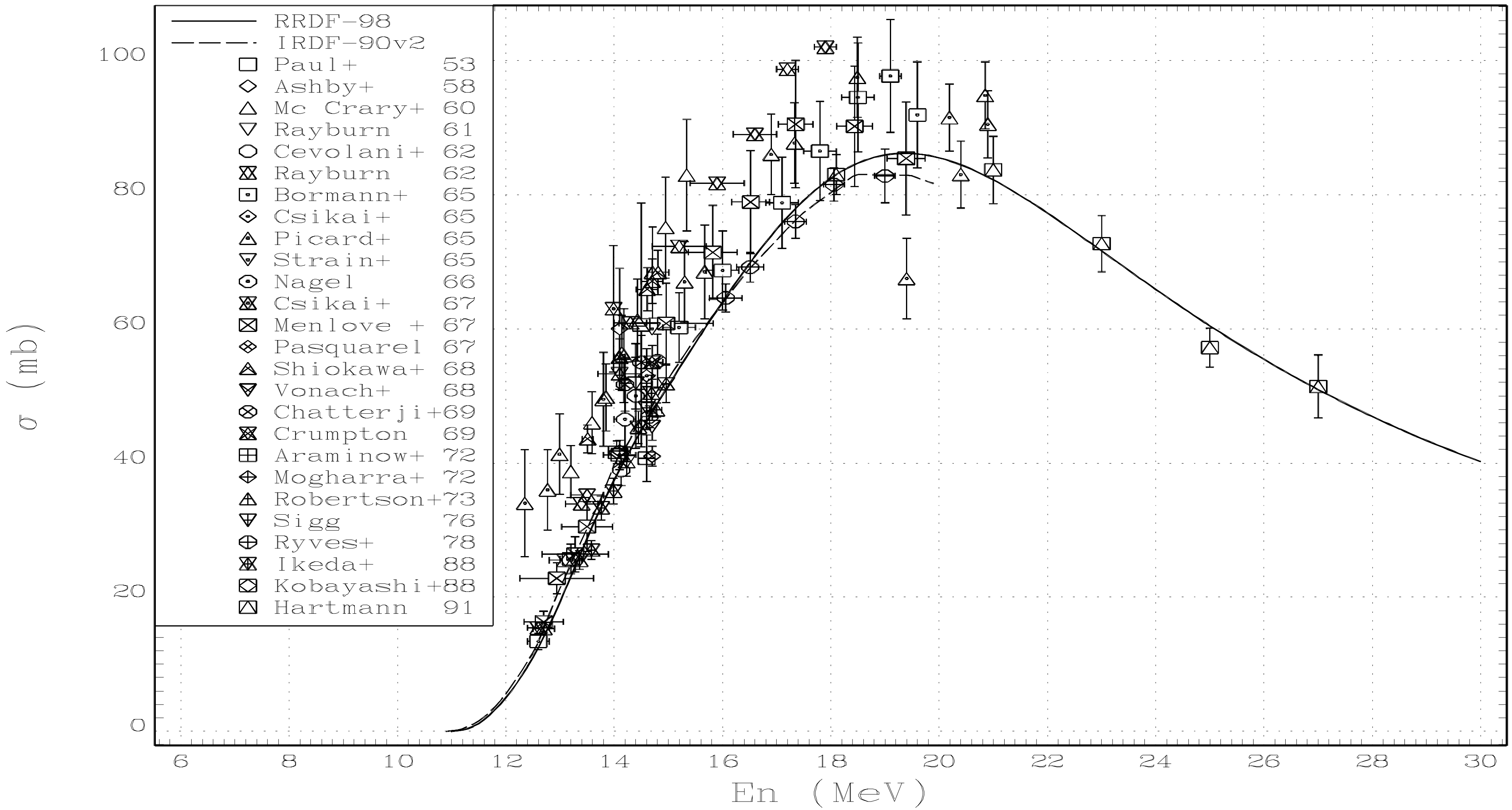

Fig.3. RRDF-98 evaluated excitation function for the $^{19}F(n,2n)^{18}F$ reaction in comparison with IRDF-90 (version 2) curve and experimental data.

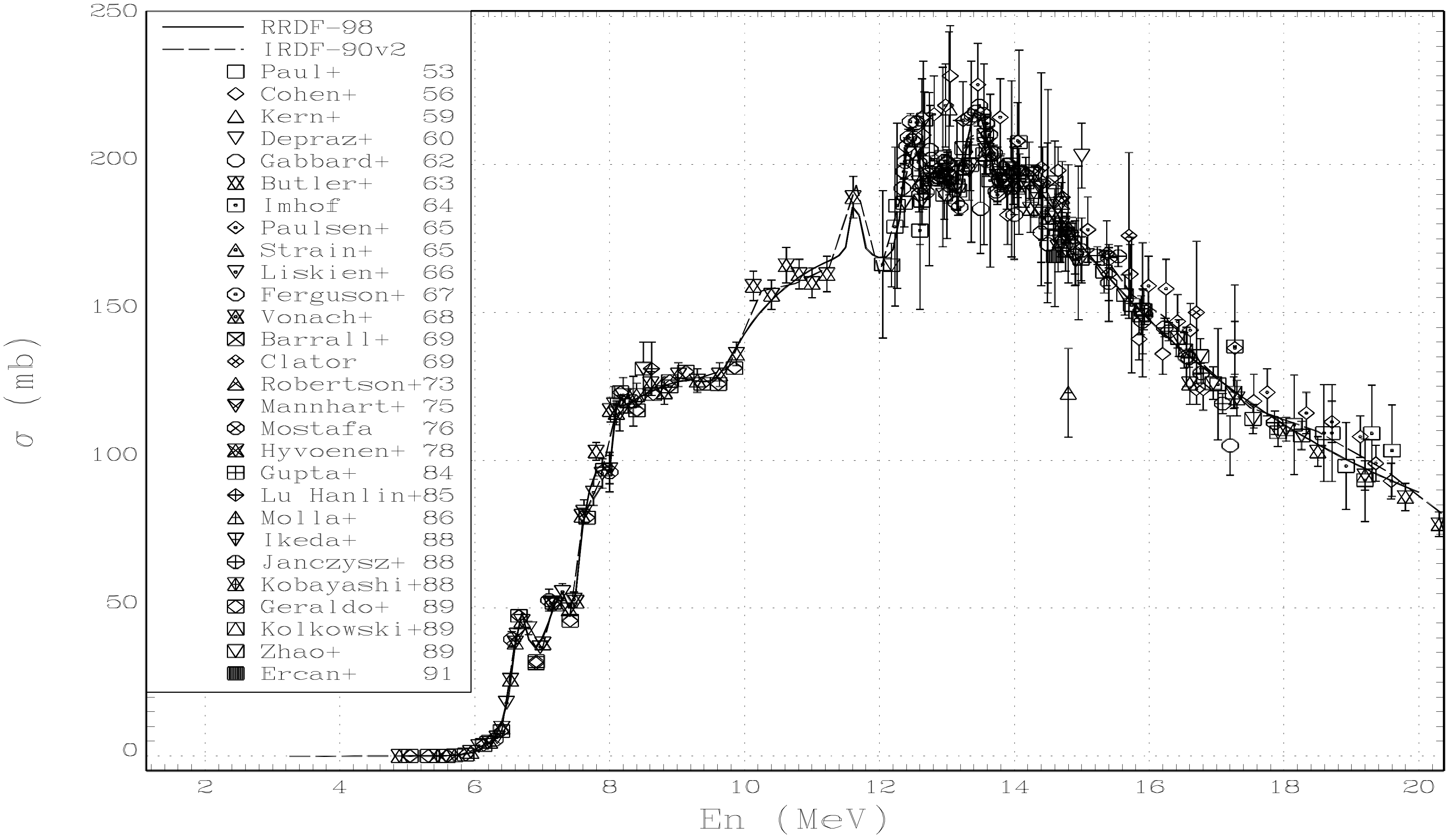

Fig.4. RRDF-98 evaluated excitation function for the $^{24}Mg(n,p)^{24}Na$ reaction in comparison with IRDF-90 (version 2) curve and

experimental data.

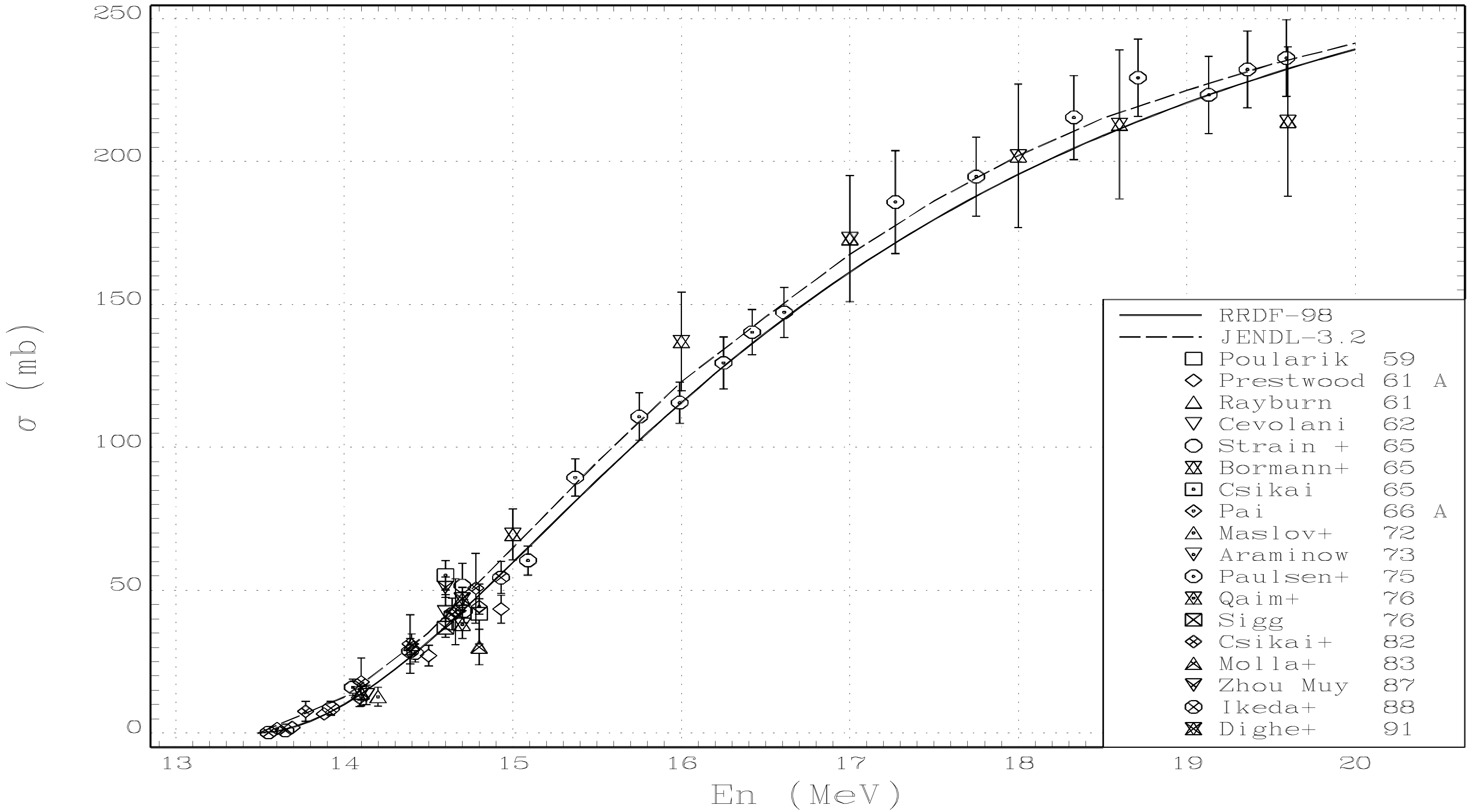

Fig.5. RRDF-98 evaluated excitation function for the ^{46}Ti(n,2n)^{45}Ti reaction in comparison with JENDL-3.2 curve and experimental

data.

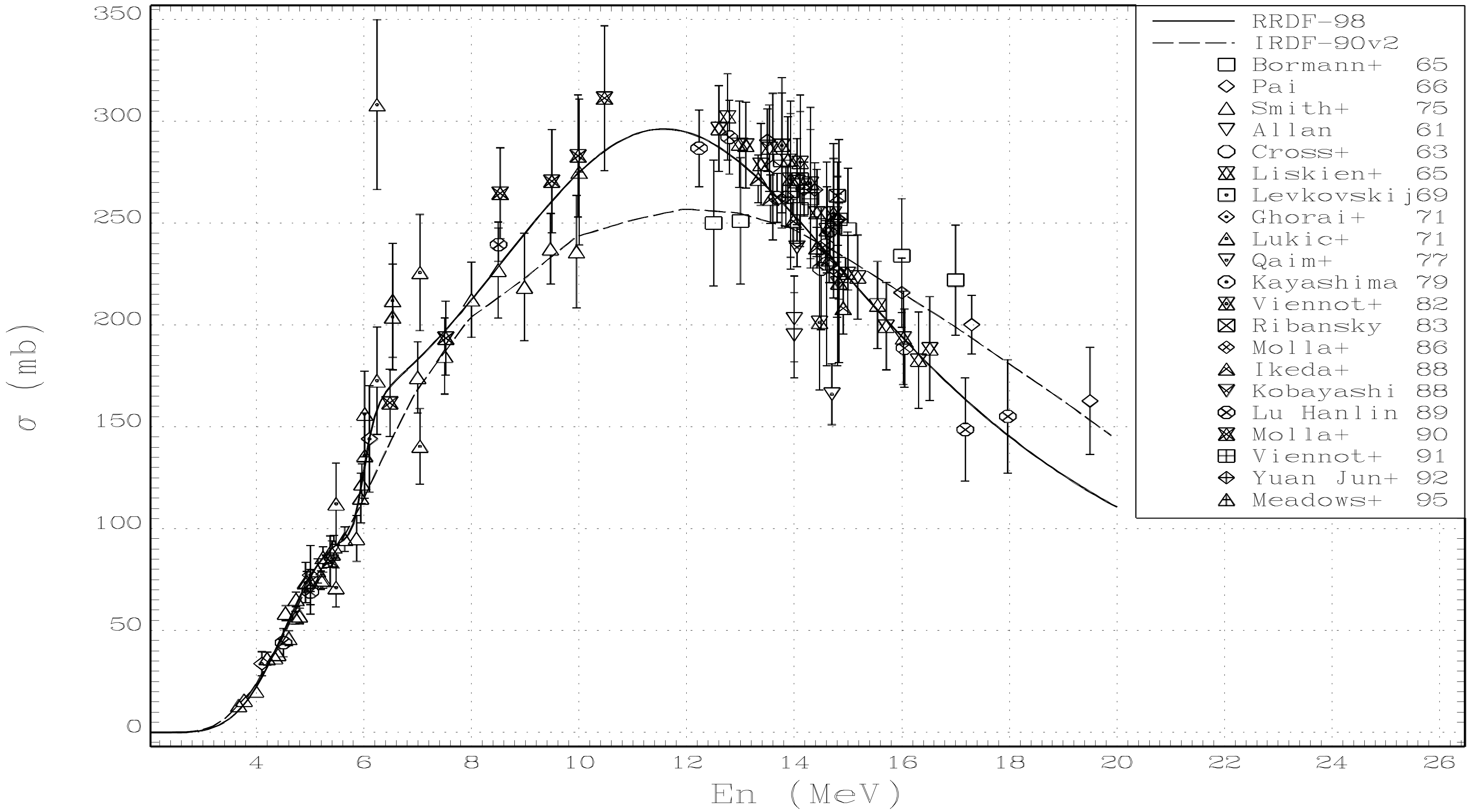

Fig.6. RRDF-98 evaluated excitation function for the $^{46}Ti(n,p)^{46}Sc$ reaction in comparison with IRDF-90 (version 2) curve and

experimental data.

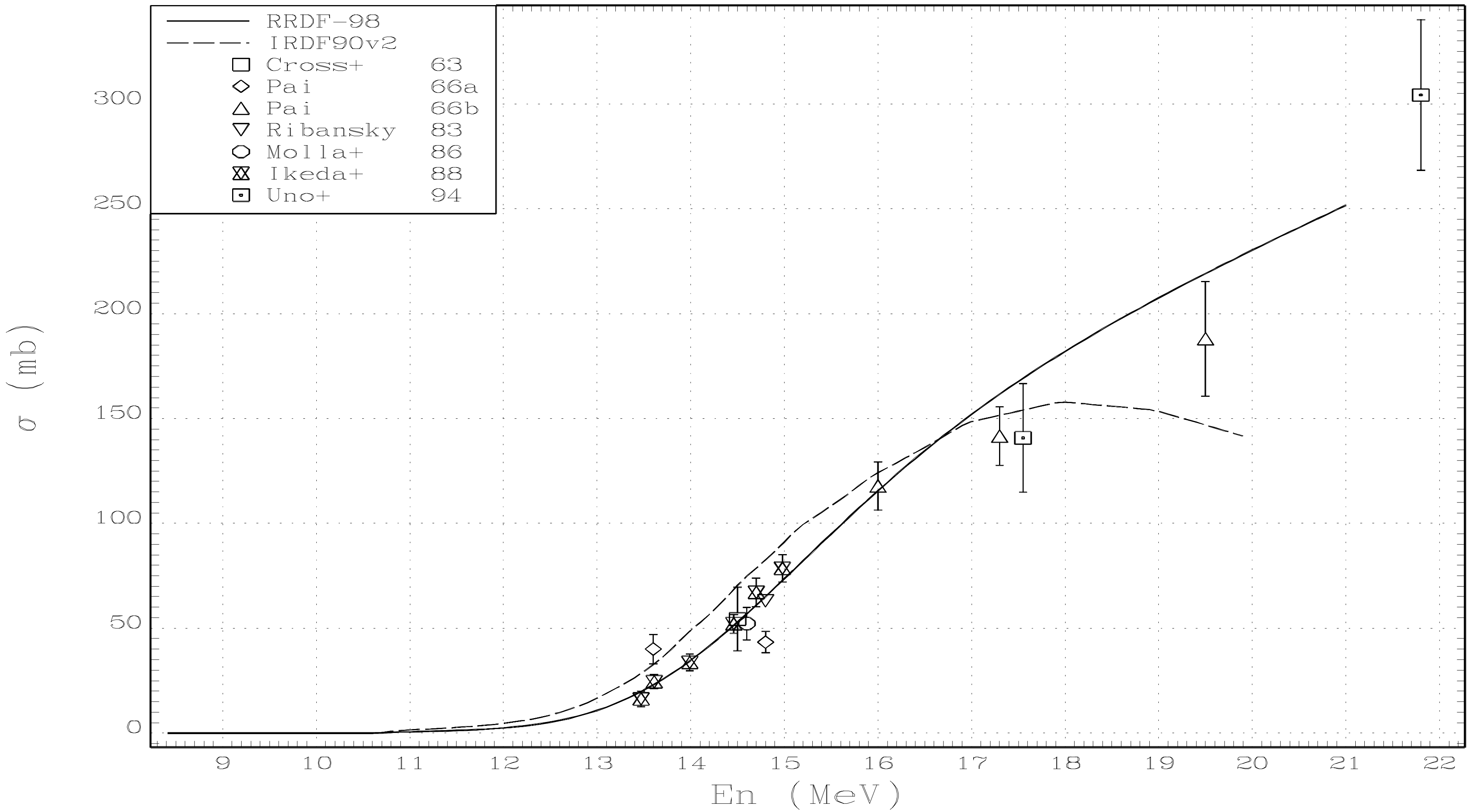

Fig.7. RRDF-98 evaluated excitation function for the $^{47}Ti(n,x)^{46m+g}Sc$ reaction in comparison with IRDF-90 (version 2) curve and

experimental data.

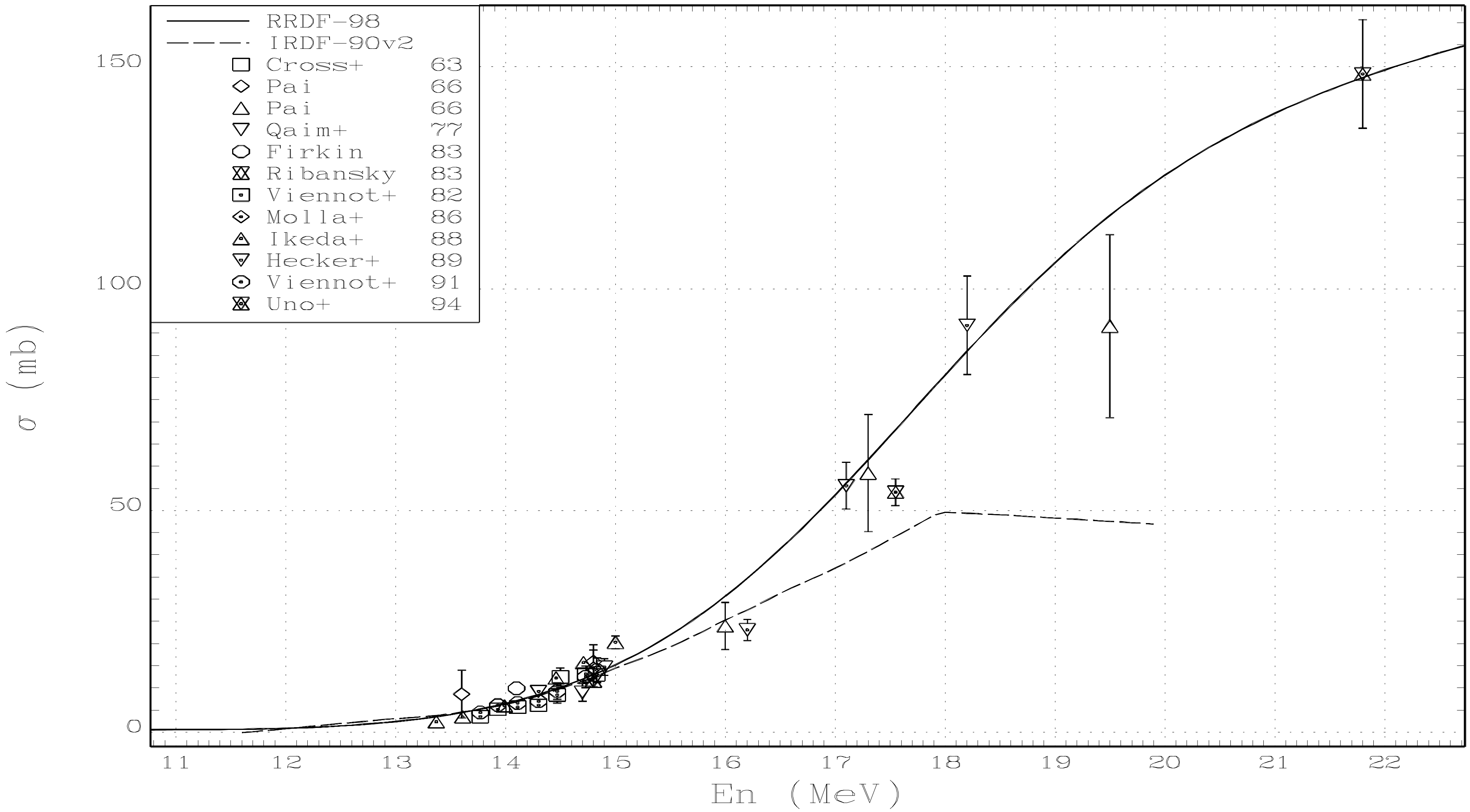

Fig.8. RRDF-98 evaluated excitation function for the $^{48}Ti(n,x)^{47}Sc$ reaction in comparison with IRDF-90 (version 2) curve and

experimental data.

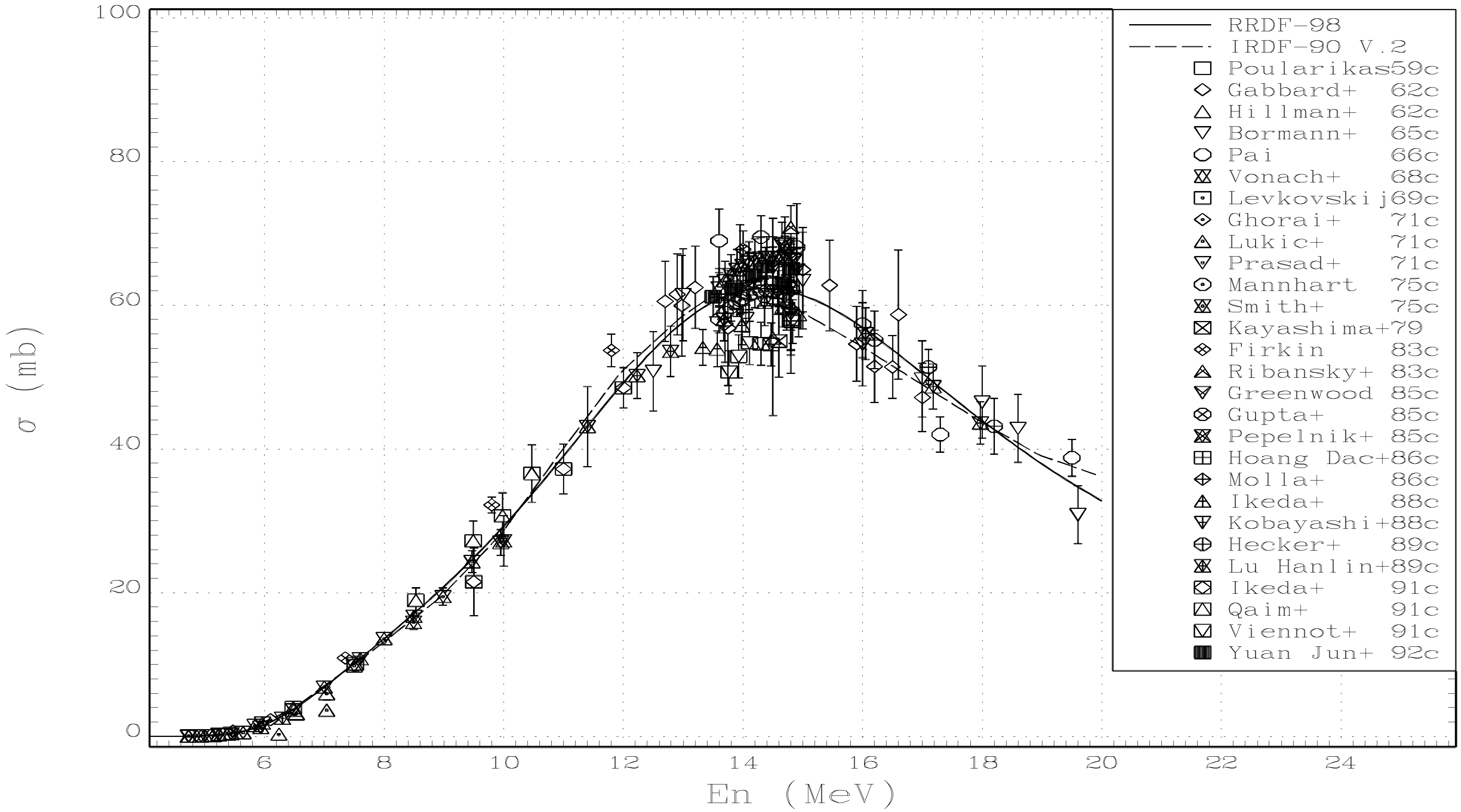

Fig.9. RRDF-98 evaluated excitation function for the $^{48}Ti(n,p)^{48}Sc$ reaction in comparison with IRDF-90 (version 2) curve and

experimental data.

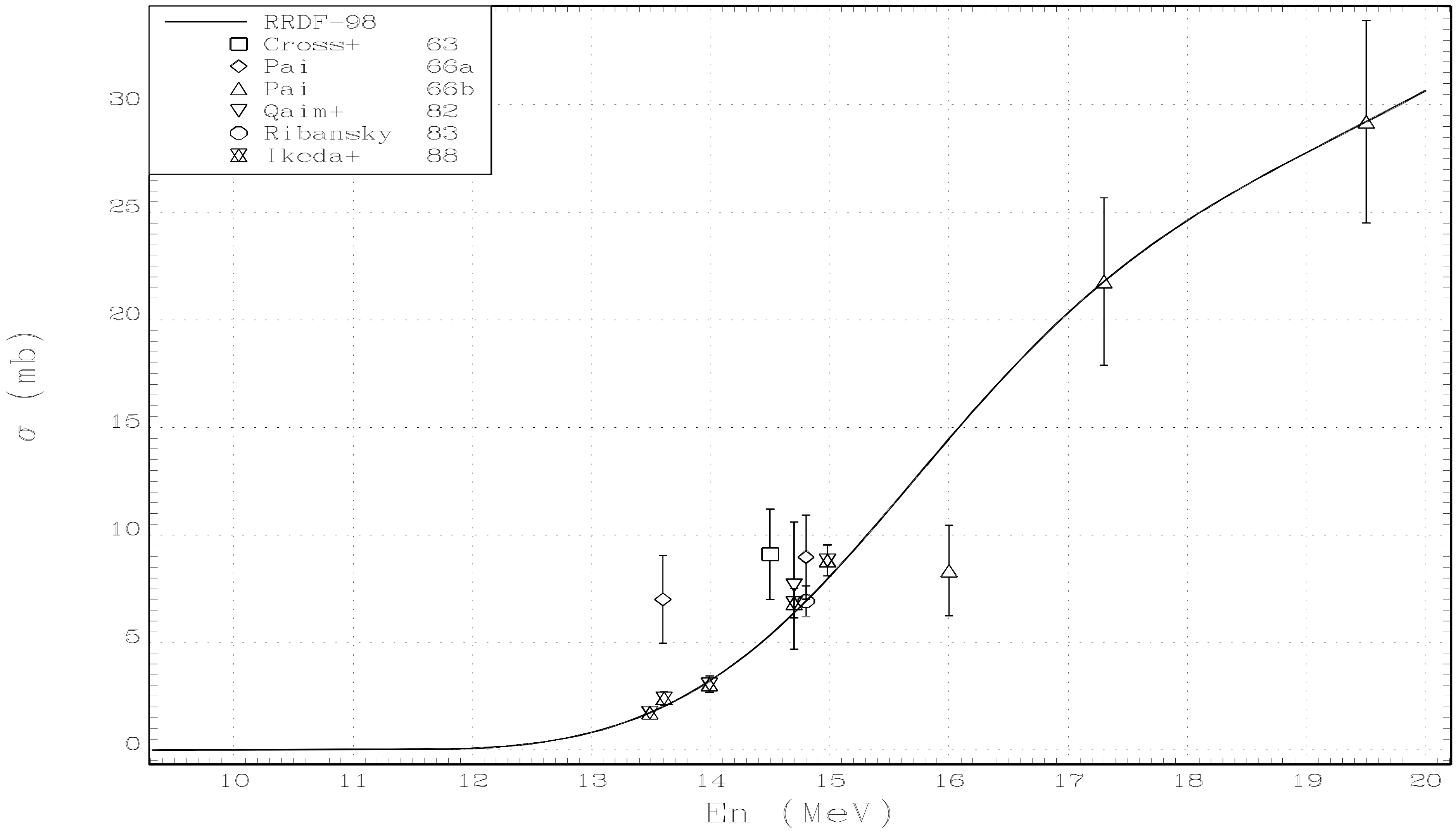

Fig.10. RRDF-98 evaluated excitation function for the $^{49}Ti(n,x)^{48}Sc$ reaction in comparison with the experimental data.

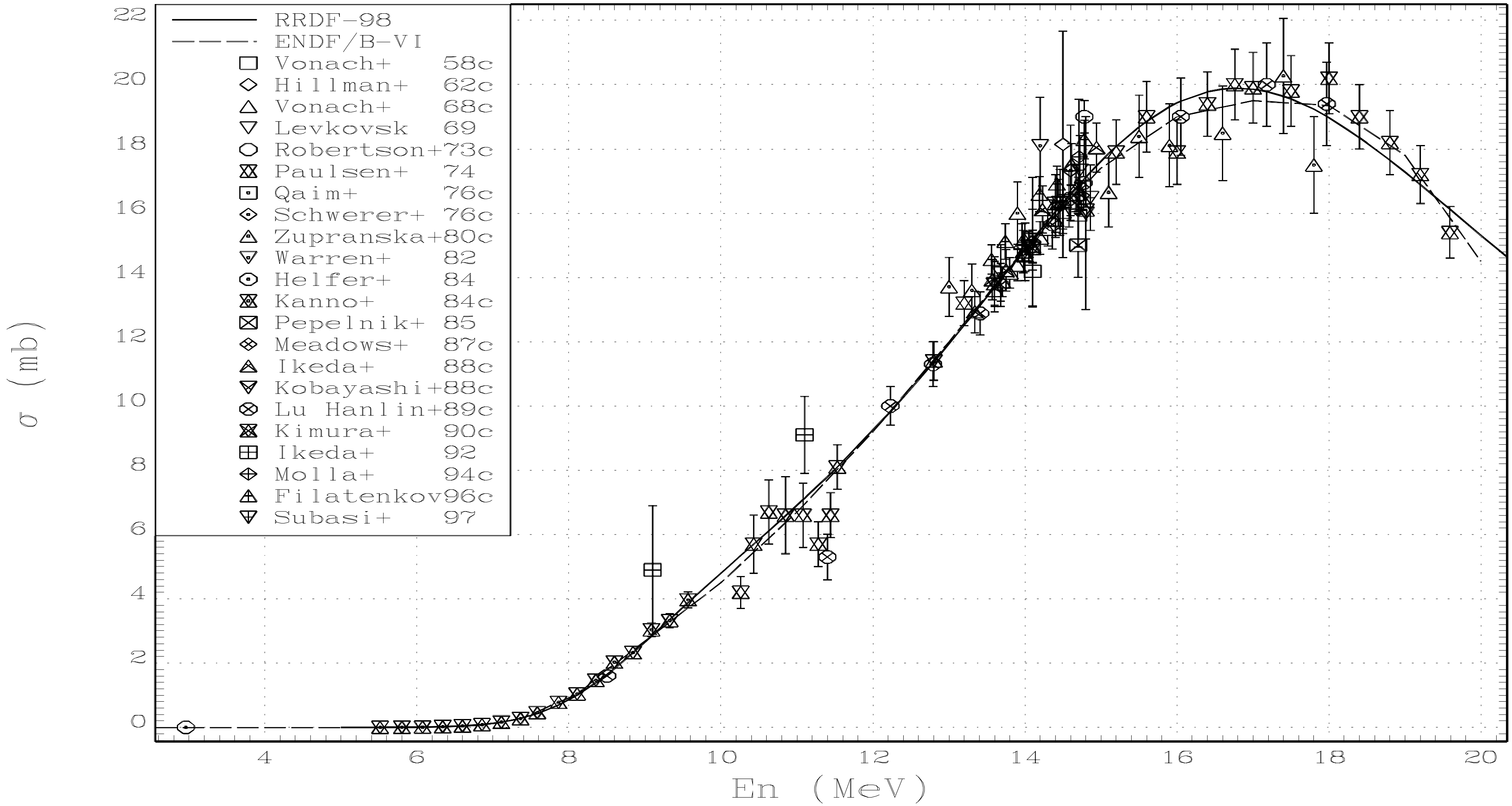

Fig.11. RRDF-98 evaluated excitation function for the $^{51}V(n,\alpha)^{48}Sc$ reaction in comparison with ENDF/B-VI curve and experimental

data.

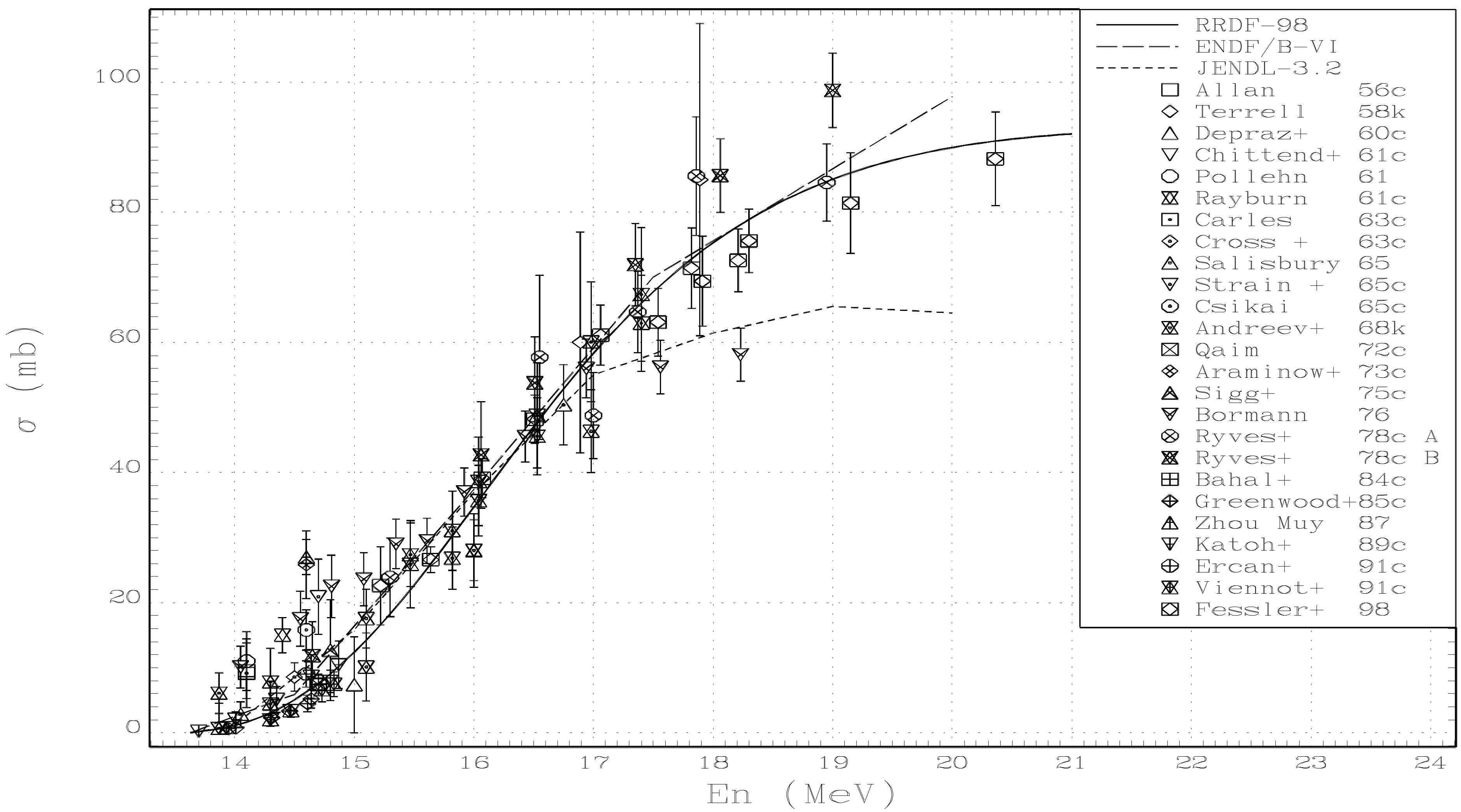

Fig.12. RRDF-98 evaluated excitation function for the $^{54}Fe(n,2n)^{53m+g}Fe$ reaction in comparison with ENDF/B-VI and JENDL-3.2

curves and experimental data.

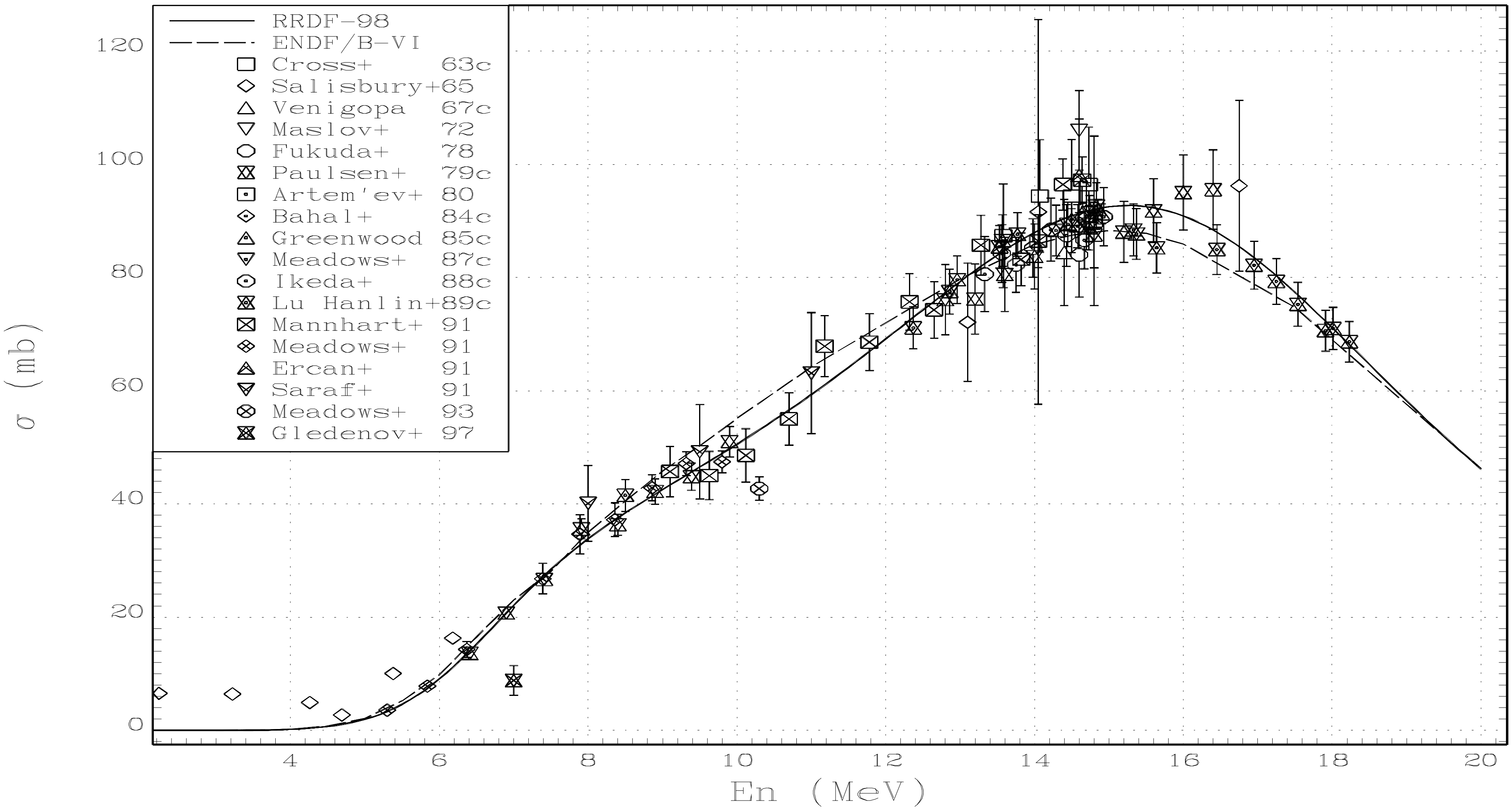

Fig.13. RRDF-98 evaluated excitation function for the $^{54}Fe(n,\alpha)^{51}Cr$ reaction in comparison with ENDF/B-VI curve and experimental data.

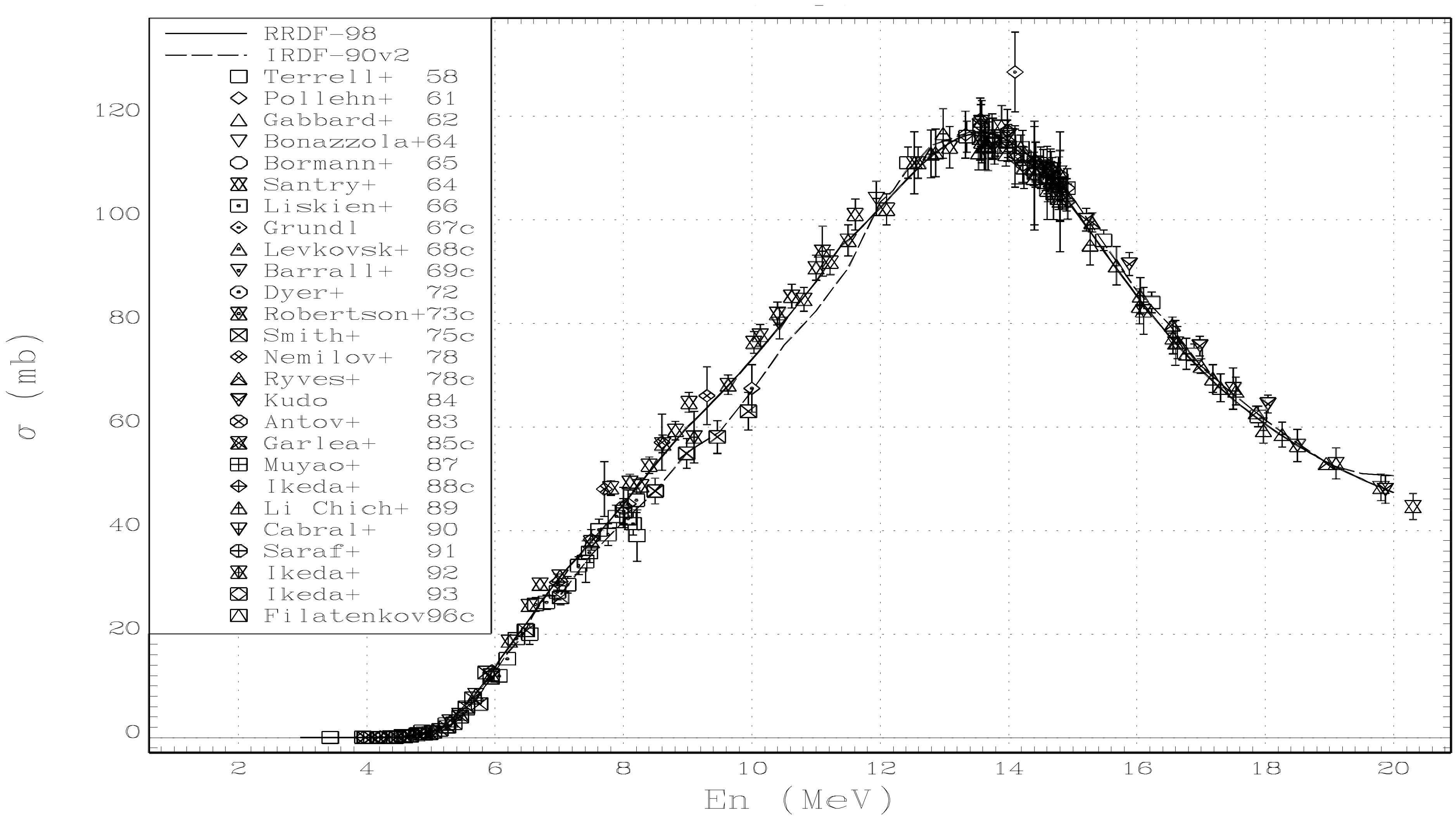

Fig.14. RRDF-98 evaluated excitation function for the $^{56}Fe(n,p)^{56}Mn$ reaction in comparison with IRDF-90 (version 2) curve and experimental data.

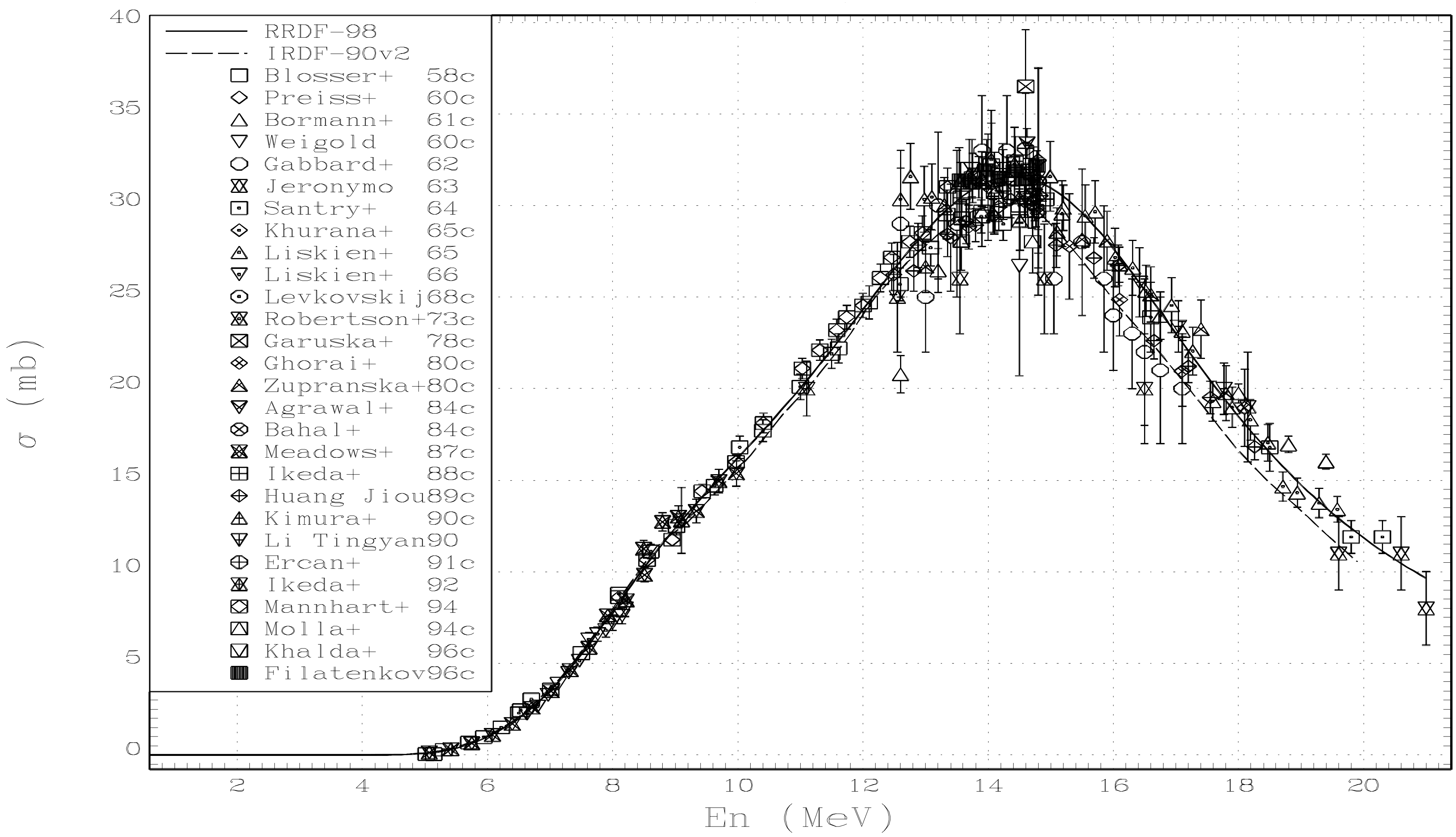

Fig.15. RRDF-98 evaluated excitation function for the $^{59}Co(n,\alpha)^{56}Mn$ reaction in comparison with IRDF-90 (version 2) curve and experimental data.

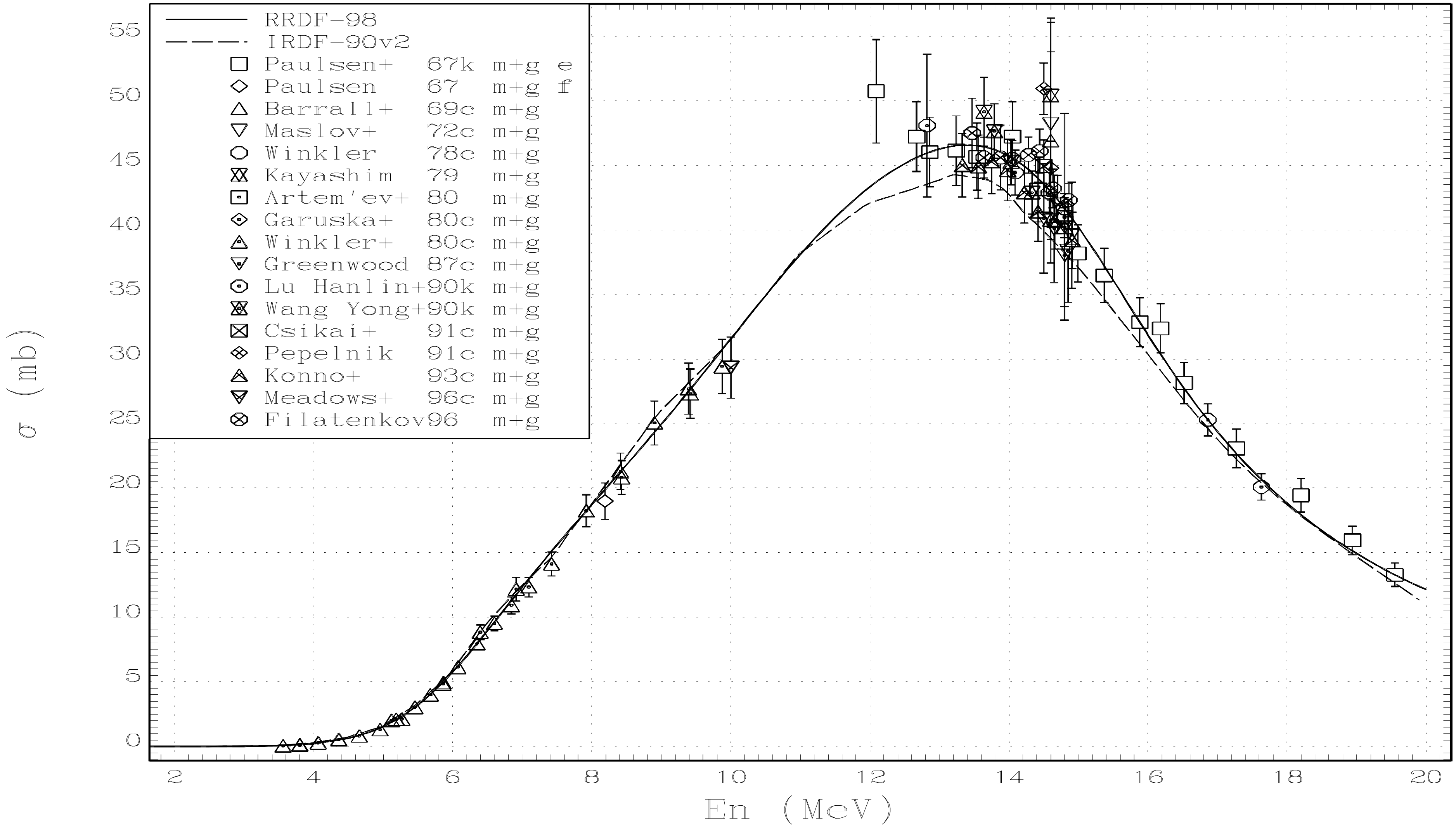

Fig.16. RRDF-98 evaluated excitation function for the $^{63}Cu(n,\alpha)^{60m+g}Co$ reaction in comparison with IRDF-90 (version 2) curve and experimental data.

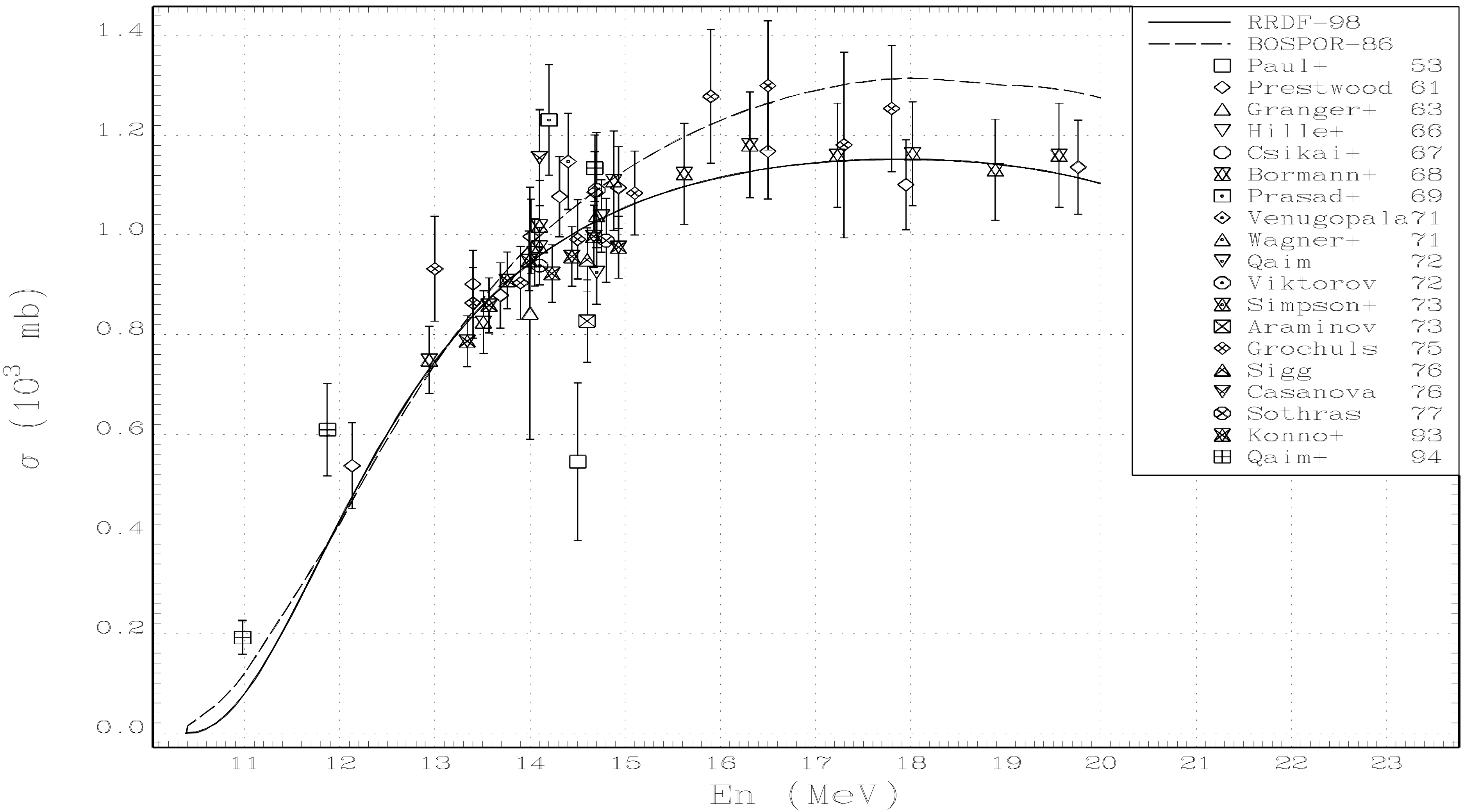

Fig.17. RRDF-98 evaluated excitation function for the $^{75}As(n,2n)^{74}As$ reaction in comparison with BOSPOR-86 curve and experimental data.

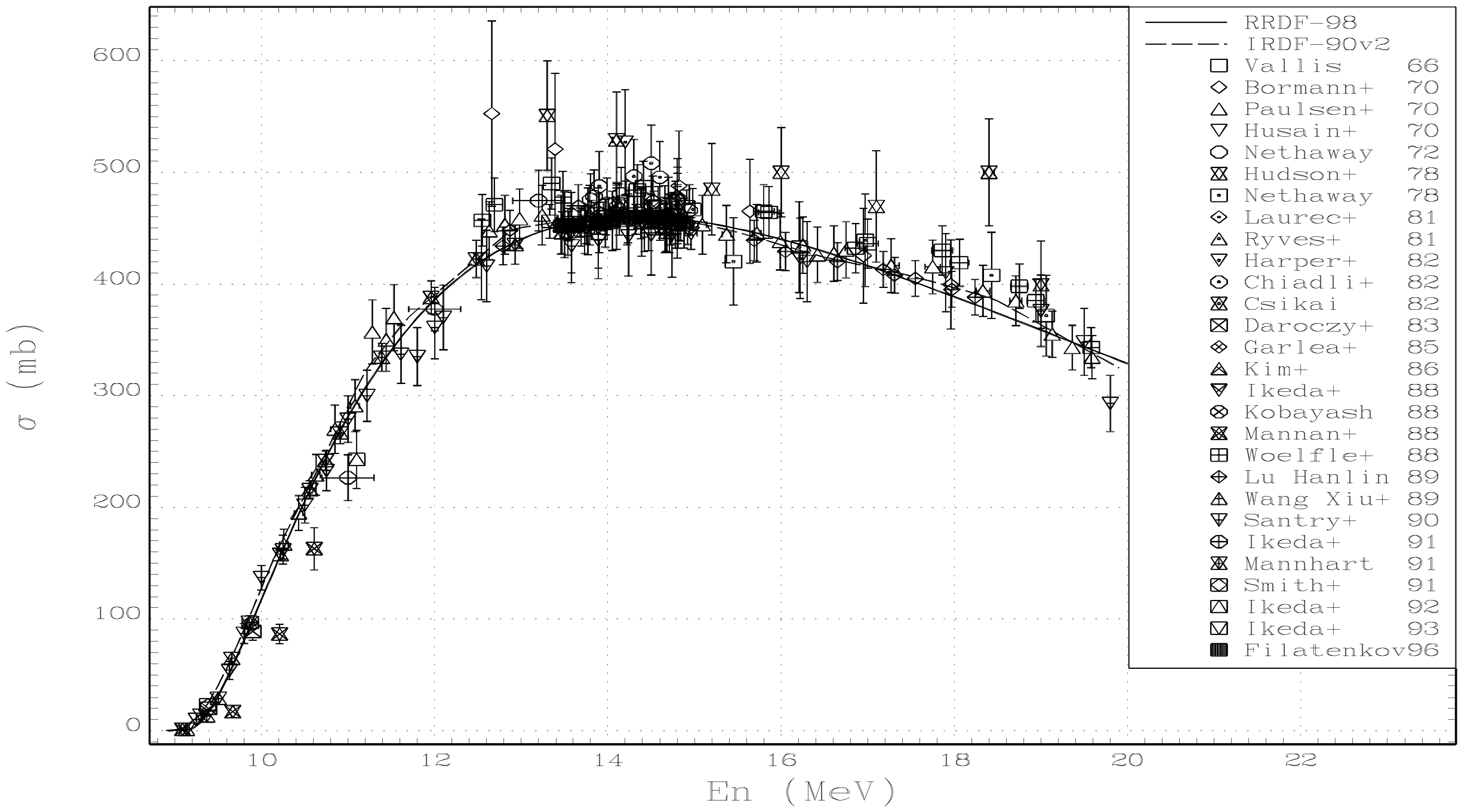

Fig.18. RRDF-98 evaluated excitation function for the $^{93}Nb(n,2n)^{92m}Nb$ reaction in comparison with IRDF-90 (version 2) curve and experimental data.

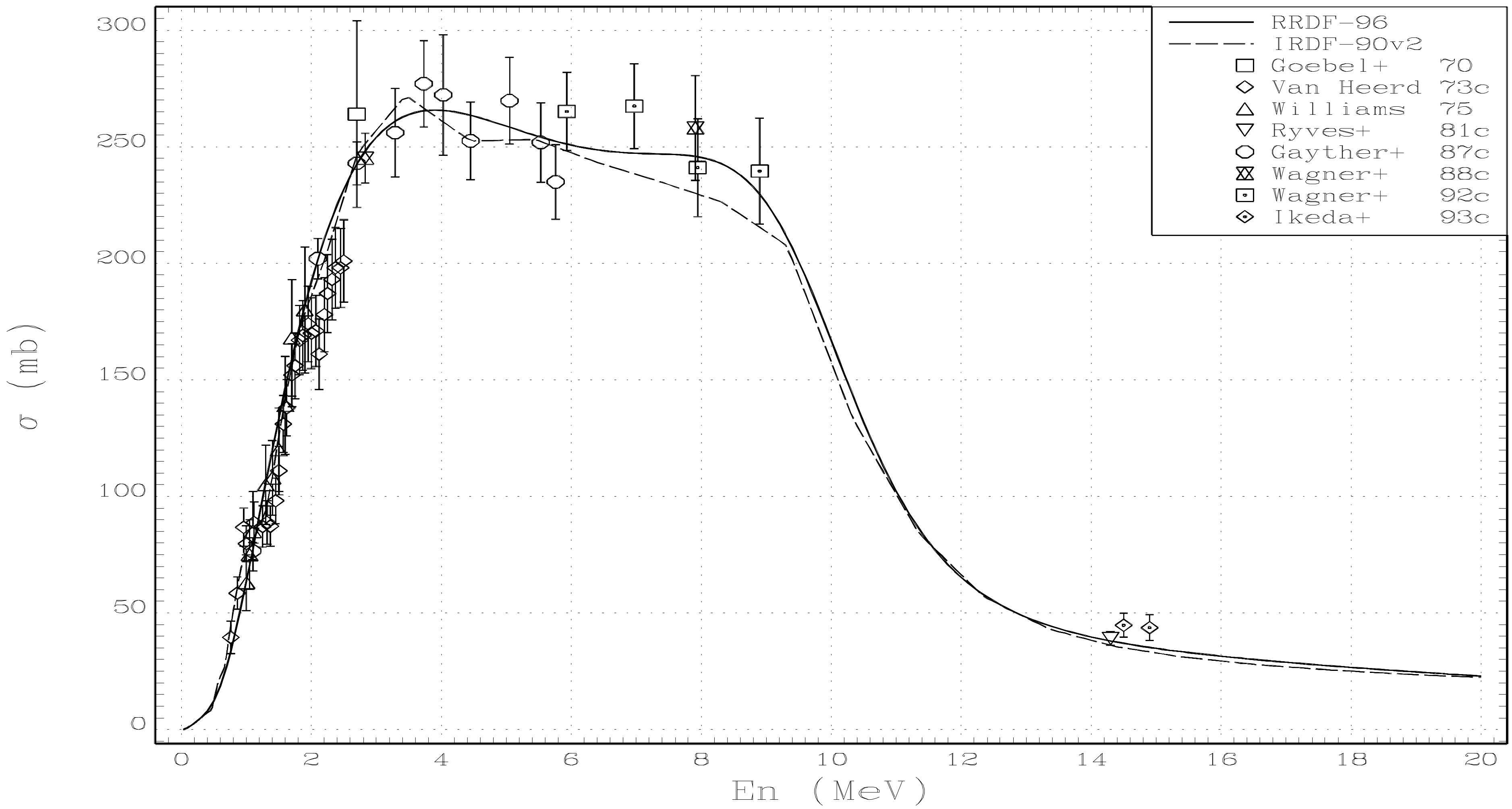

Fig.19. RRDF-98 evaluated excitation function for the $^{93}Nb(n,n')^{93m}Nb$ reaction in comparison with IRDF-90 (version 2) curve and experimental data.

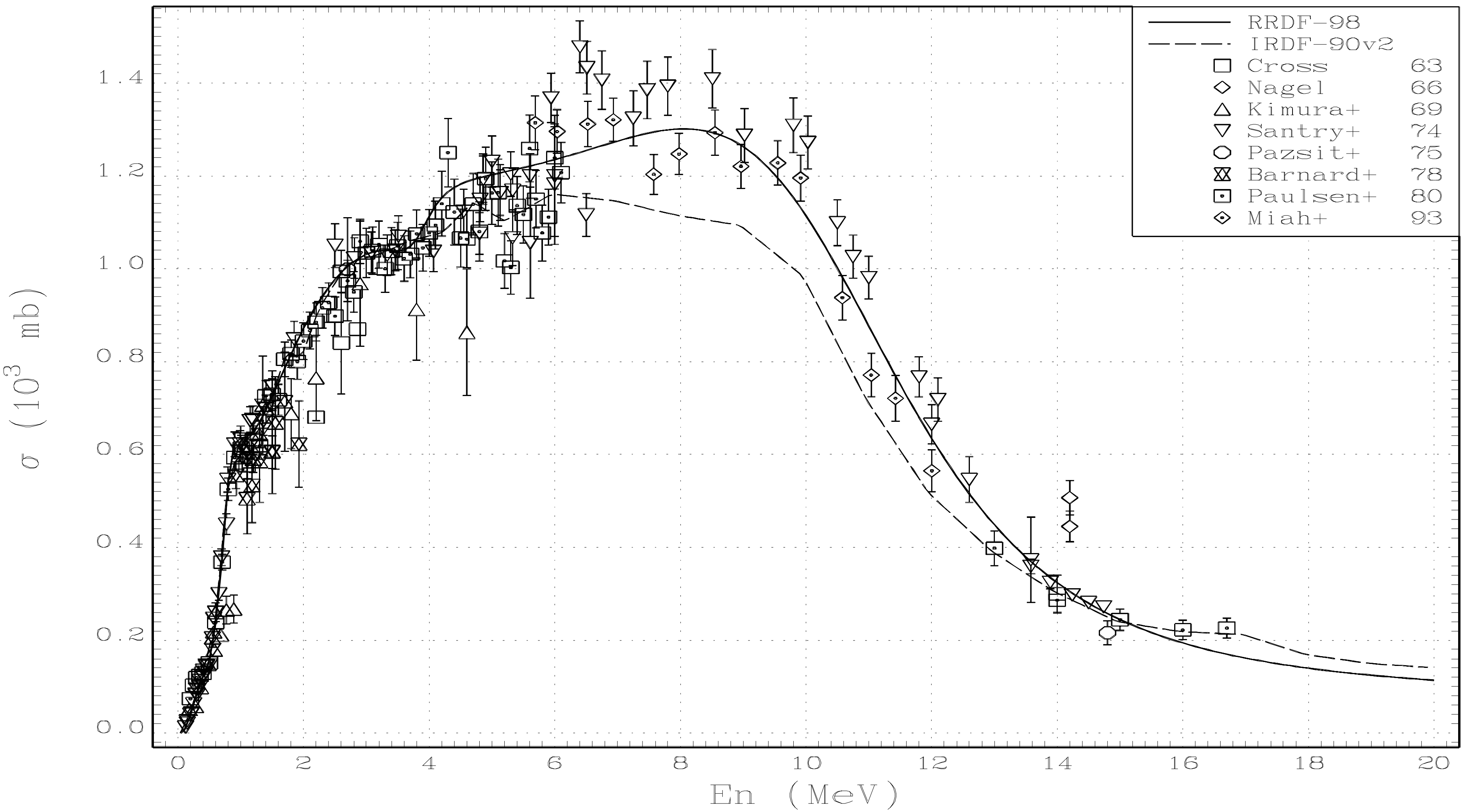

Fig.20. RRDF-98 evaluated excitation function for the ^{103}Rh(n,n')^{103m}Rh reaction in comparison with IRDF-90 (version 2) curve and experimental data.

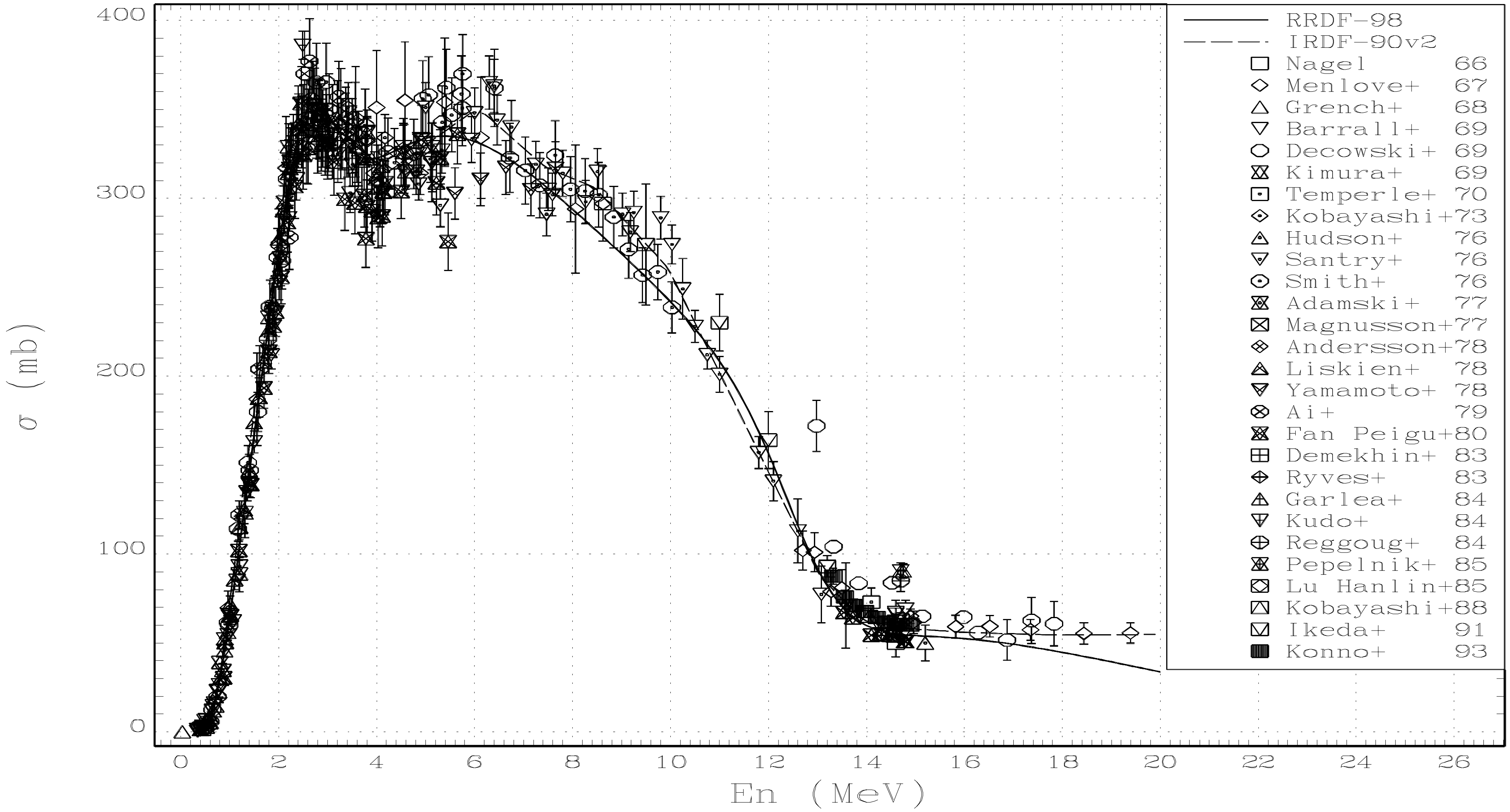

Fig.5. RRDF-98 evaluated excitation function for the $^{115}In(n,n')^{115m}In$ reaction in comparison with IRDF-90 (version 2) curve and experimental data.

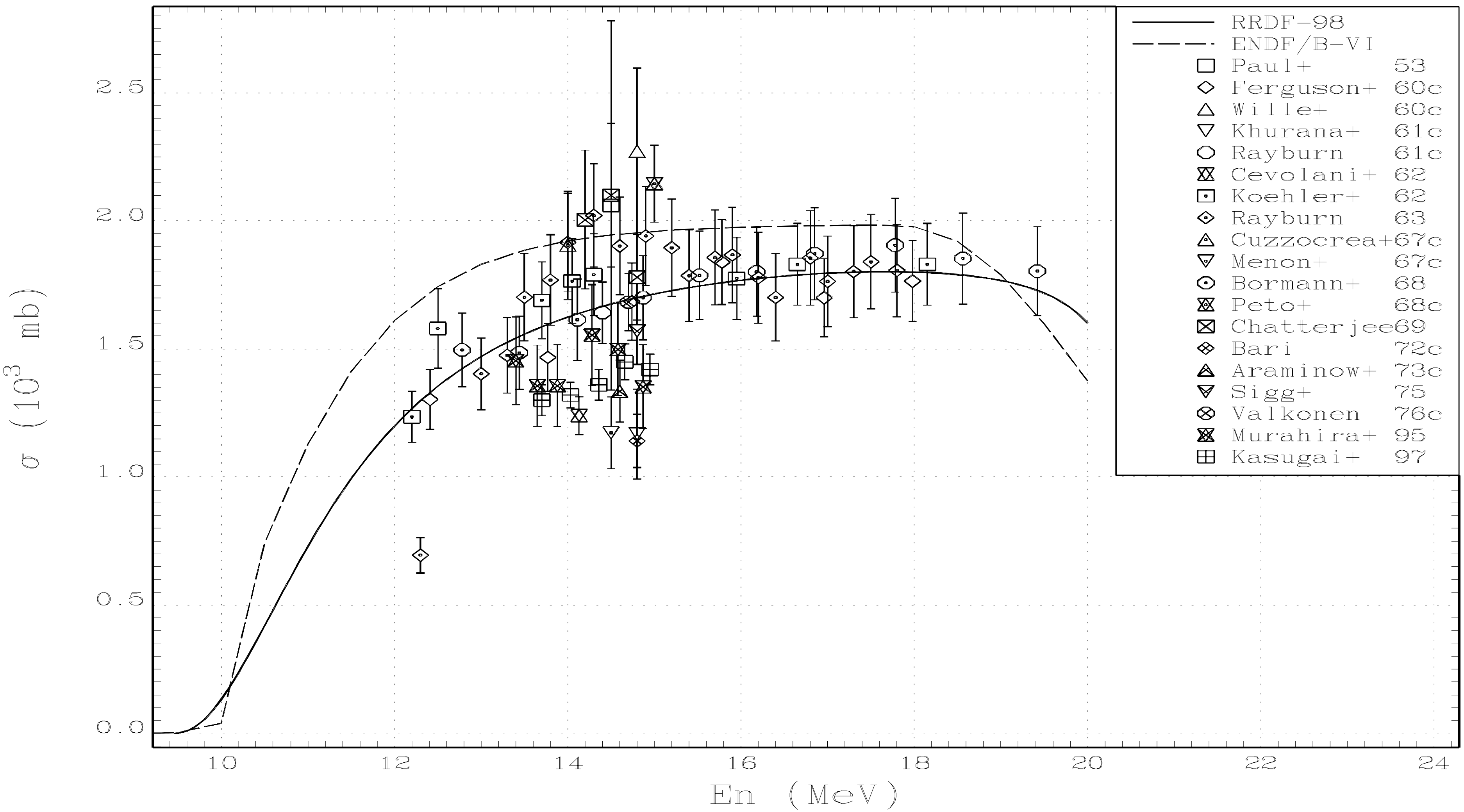

Fig.22. RRDF-98 evaluated excitation function for the $^{141}Pr(n,2n)^{140}Pr$ reaction in comparison with ENDF/B-VI curve and experimental data.