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COMPARISON OF (n, 2n) AND (n, 3n) REACTION CROSS SECTIONS FOR FISSION PRODUCTS IN JENDL-3.2 WITH AVAILABLE EXPERIMENTAL AND OTHER EVALUATED CROSS SECTION DATA

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Comparison of (n,2n) and (n,3n) Reaction Cross Sections for Fission Products in JENDL-3.2 with Available Experimental and Other Evaluated Cross Section Data

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In this report, results of comparison of (n,2n) and (n,3n) reaction cross sections for 155 nuclei (Ge – Tb) in JENDL-3.2 with available experimental data, various evaluated data, and those estimated from systematics are summarized to assess validity of cross sections for threshold reactions for fission product nuclei in JENDL-3.2. Plots for comparisons are compiled and issues in cross section data in JENDL-3.2 are also discussed.

Keywords: JENDL-3.2, Fission Product Nuclei, (n,2n) Reaction, (n,3n) Reaction, Cross Section, Systematics, Intercomparison

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JENDL-3.2の核分裂生成物核種に対する(n,2n)及び(n,3n)反応断面積の実験データ及び他の評価済みデータとの比較

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JENDL-3.2に格納されている核分裂生成物核種のしきい反応断面積の妥当性検証のため、Ge～Tbの155核種について、(n,2n)及び(n,3n)反応断面積を、実験データ、様々な評価済み核データライブラリ、系統式による評価結果と比較した結果をまとめた。本レポートでは、断面積データの比較のためのプロット図をまとめるとともに、JENDL-3.2の断面積データの問題点についても議論した。

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1. Introduction

Nuclear data for fission product nuclei are of importance for design of nuclear reactors and assessment of safety of nuclear facility. The (n,2n) and (n,3n) reactions are most dominant cross sections among threshold reactions in fast neutron energy range. To assess validity of cross sections for threshold reactions of the fission product nuclei in JENDL-3.2 [1), 2)], comparison of the (n,2n) and (n,3n) reaction cross sections for 155 nuclei (Ge – Tb) in JENDL-3.2 with available experimental data as well as those estimated from the systematics [3)] and other evaluated data were carried out. In this report, plotted data for comparisons were compiled and issues in cross section data of JENDL-3.2 were also discussed. The data for Dy isotopes are also included in this report though there is no evaluation for that in JENDL-3.2.

2. Comparison of (n,2n) and (n,3n) Reaction Cross Section Data

Cross sections of (n,2n) and (n,3n) reactions in JENDL-3.2 were compared with those in ENDF/B-VI[4)], BROND-2 [5)], ADL-3 [6)], EAF-97 [7)]. Available experimental data were also considered in the comparison. Analysis of the cross sections by empirical systematics is an effective way to check differential data of cross sections for the fission product nuclei because measured cross section data are very limited for those nuclei. In the present comparison, Manokhin's systematics [3)], which can represent excitation function of threshold reactions, was adopted for comparison. Plots of cross sections using evaluated cross sections, systematics and available experimental data were drawn for comparison purpose. List of figures prepared in the present work is shown in Table 1. In the figures, cross sections calculated by the systematics [3)] are drawn by solid line and denoted by 'recom'. In addition to the work [3)], there is some information about the systematics used in the report [8)]. For some nuclei, data from JENDL Dosimetry File 99 (JENDL/D-99) [9)] are also plotted and refered as 'JDOS99'.

3. Results of Comparison

Results of comparison of the (n,2n) and (n,3n) reaction cross sections for fission product nuclei in JENDL-3.2 with other evaluated data and available experiment data are briefly described below.

(1) Se isotopes

^{77}Se(n,2n) and ^{79}Se(n,2n) reaction cross sections in JENDL-3.2 have larger cross section values than those in other evaluated data in the energy range from 8 to 11 MeV (Fig. 5, 9). Comparing with other evaluated data, ^{80}Se(n,2n) and ^{82}Se(n,2n) reaction cross sections in JENDL-3.2 rapidly decrease near 18 MeV (Fig. 11, 13).

(2) Kr isotopes

A shape of excitation function of ^{83}Kr(n,2n) reaction cross section in JENDL-3.2 slightly differs from data in the other evaluation: data in JENDL-3.2 are larger from 8 to 11 MeV and lower from 14 to 20 MeV (Fig. 21).

(3) Rb isotopes

^{87}Rb(n,2n) reaction cross section in JENDL-3.2 does not follow experimental data by Konno et al. [10], while ^{85}Rb(n,2n) reaction cross section in JENDL-3.2 represents the experimental data (Fig. 33, 29).

(4) Zr isotopes

^{90}Zr(n,2n) reaction cross section in JENDL-3.2 shows good agreement with experimental data (Fig. 46). Excitation function of ^{91}Zr(n,2n) reaction cross section in JENDL-3.2 has more steep curve near threshold energy than that calculated from the systematics (Fig. 49). $^{92, 93, 94, 95, 96}$Zr(n,2n) reaction cross sections in JENDL-3.2 rapidly decrease near 18 MeV compared with other evaluated data (Fig. 51, 53, 55, 57, 59).

(5) Mo isotopes

$^{95, 96, 97, 98, 99, 100}$Mo(n,2n) reaction cross sections in JENDL-3.2 rapidly decrease near 18 MeV compared with other evaluated data (Fig. 63, 65, 67, 69, 71, 73). For $^{95, 97, 100}$Mo(n,2n) reactions, excitation functions of JENDL-3.2 have more steep curve near threshold energy compared with other evaluated data. Rapid decrease of the (n,2n) cross sections of JENDL-3.2 for Mo isotopes from 18 MeV results in rather large values for (n,3n) reaction cross section compared with other evaluated data (Fig. 72).

(6) Ru isotopes

Excitation functions of $^{100, 101, 103}$Ru(n,2n) reactions in JENDL-3.2 have more steep curve near threshold energy compared with other evaluated data (Fig. 77, 79, 83). $^{102, 103, 104, 106}$Ru(n,2n) reaction cross sections in JENDL-3.2 give lower values than those in other evaluated data above 16 or 17 MeV (Fig. 81, 83, 85, 87). This tendency results in larger value for the (n, 3n) reaction cross sections in JENDL-3.2 (Fig. 82, 84, 86, 88).

(7) Rh isotopes

^{103}Rh(n,3n) reaction cross section in JENDL-3.2 does not follow experimental data by Veeser et al. [11] and gives larger cross section value than those in other evaluated data (Fig. 90), while ^{103}Rh(n,2n) cross section in JENDL-3.2 is in good agreement with available experimental data and other evaluated data (Fig. 89). Excitation function of ^{105}Rh(n,2n) reaction has more steep curve near threshold energy and rapidly decreases from 17 MeV compared with other evaluated data (Fig. 91). This tendency results in larger value for ^{105}Rh(n,3n) reaction cross section in JENDL-3.2 (Fig. 92).

(8) Pd isotopes

Excitation functions of $^{104, 105, 106, 107, 108}$Pd(n,2n) reactions in JENDL-3.2 have more steep curve near threshold energy and rapidly decrease from 17 or 18 MeV compared with other evaluated data (Fig. 93, 95, 97, 99, 101). This tendency results in larger value for the (n,3n) reaction cross sections of Pd isotopes in JENDL-3.2 (Fig. 94, 96, 98, 100, 102).

(9) Cd isotopes

Cross sections of $^{110, 111, 112, 113, 114, 116}$Cd(n,2n) reactions in JENDL-3.2 rapidly decrease from 17 or 18 MeV compared with other evaluated data (Fig. 109, 111, 113, 115, 117, 119). This tendency results in larger value for (n,3n) reaction cross sections of Cd isotopes in JENDL-3.2 (Fig. 110, 112, 114, 116, 118, 120).

(10) In isotopes

Cross section of ^{115}In(n,2n) reaction in JENDL-3.2 rapidly decreases from 18 MeV (Fig. 121) and that of (n,3n) reaction is larger than other evaluated data (Fig. 122).

(11) Sn isotopes

Cross sections of $^{115, 116, 117, 118, 119, 120, 122, 123, 124, 126}$Sn(n,2n) reactions in JENDL-3.2 rapidly decrease near 17 or 18 MeV compared with other evaluated data (Fig. 123, 125, 127, 129, 131, 133, 137, 139, 141, 145). This tendency results in larger value for (n,3n) reaction cross sections of Sn isotopes in JENDL-3.2 (Fig. 124, 126, 128, 130, 132, 134, 138, 140, 142, 146). Excitation functions of $^{115, 117, 119}$Sn(n,2n) reactions have more steep curve near threshold energy (Fig. 123, 127, 131).

(12) Sb isotopes

Comparing with available experimental data and evaluated data, peak energies of $^{121, 123}$Sb(n,2n) reaction cross sections in JENDL-3.2 are shifted to higher energy side and cross section values are larger (Fig. 147, 151).

(13) Te isotopes

Cross sections of $^{122, 123, 124, 125, 126, 128, 130}$Te(n,2n) reactions in JENDL-3.2 rapidly decrease near 17 or 18 MeV compared with other evaluated data (Fig. 161, 163, 165, 167, 169, 171, 173). This tendency results in larger value for the (n,3n) reaction cross sections of Te isotopes in JENDL-3.2. There exists structures in excitation functions of $^{123, 125}$Te(n,2n) reactions of JENDL-3.2 which cannot be found in other evaluated data (Fig. 163, 167).

(14) I isotopes

Cross sections of $^{127, 129, 131}$I(n,2n) reactions in JENDL-3.2 are larger near threshold energy and rapidly decrease from 17 MeV compared with experimental data and evaluated data (Fig. 177, 179, 183).

(15) Xe isotopes

Cross sections of $^{128, 129, 130, 131, 132, 133, 134, 135, 136}$Xe(n,2n) reactions in JENDL-3.2 rapidly decrease from 17 or 18 MeV compared with other evaluated data (Fig. 185, 187, 189, 191, 193, 195, 197, 199, 201). This tendency results in larger value for the (n,3n) reaction cross sections of Xe isotopes in JENDL-3.2 (Fig. 186, 188, 190, 192, 194, 196, 198, 200, 202). Excitation functions of the (n,2n) reactions for odd mass nuclei of Xe have structure which is not found in other evaluated data (Fig. 187, 191, 195, 199).

(16) Cs isotopes

Cross sections of $^{133, 134, 135, 136, 137}$Cs(n,2n) reactions in JENDL-3.2 rapidly decrease from 17 or 18 MeV compared with other evaluated data (Fig. 203, 205, 207, 209, 211). This tendency results in larger value for the (n,3n) reaction cross sections of Cs isotopes in JENDL-3.2 (Fig. 204, 206, 208, 210, 212) .

(17) Ba isotopes

Cross sections of $^{134, 136, 138}$Ba(n,2n) reactions in JENDL-3.2 rapidly decrease from 17 or 18 MeV compared with other evaluated data (Fig. 213, 217, 221). This tendency results in larger value for $^{134, 136, 138}$Ba(n,3n) reaction cross sections in JENDL-3.2 (Fig. 214, 218, 222).

(18) Pr isotopes

For the (n,2n) and (n,3n) reactions for ^{141}Pr, larger cross section values are given in JENDL-3.2 compared with other evaluated data (Fig. 241, 242).

(19) Nd isotopes

Shapes of excitation functions for $^{142, 143, 144, 145, 146, 147, 148, 150}$Nd(n,2n) reactions differ from those from other evaluated data and calculated data by the systematics (Fig. 245, 247, 249, 251, 253, 255, 257, 259).

(20) Pm isotopes

Cross sections of $^{147, 148, 149}$Pm(n,2n) reactions in JENDL-3.2 rapidly decrease from 14 MeV compared with other evaluated data (Fig. 261, 263, 265). This tendency results in larger values for the (n,3n) reaction cross sections for Pm isotopes in JENDL-3.2 (Fig. 262, 264, 266).

(21) Sm isotopes

Cross sections of $^{148, 150, 152, 154}$Sm(n,2n) reactions in JENDL-3.2 represent experimental data (Fig. 269, 273, 277, 281). ^{147}Sm(n,2n) reaction cross section in JENDL-3.2 gives lower values compared with other evaluated data (Fig. 267). Cross section of ^{149}Sm(n,2n) reaction has larger values near threshold energy compared with other evaluated data (Fig. 271). Excitation functions of the (n,2n) reaction for $^{151, 153}$Sm in JENDL-3.2 have structure which cannot be found in other evaluated data (Fig. 275, 279).

(22) Eu isotopes

Excitation functions of the (n,2n) reaction for $^{154, 155, 156}$Eu in JENDL-3.2 have structures which cannot be found in other evaluated data (Fig. 285, 287, 289).

(23) Gd isotopes

Cross sections of $^{154, 155, 156, 157, 158, 160}$Gd(n,2n) reactions in JENDL-3.2 were evaluated to follow experimental data, but the cross sections rapidly decrease above 16 MeV compared with other evaluated data (Fig. 291, 293, 295, 297, 299, 301). This tendency results in larger values for the (n,3n) reaction cross sections for Gd isotopes in JENDL-3.2 (Fig. 292, 294, 296, 298, 300, 302).

(24) Tb isotopes

Cross section of ^{159}Tb(n,2n) reaction in JENDL-3.2 rapidly decreases above 16 MeV (Fig. 303) and as the result ^{159}Tb(n,3n) reaction cross section in JENDL-3.2 has larger values than other evaluated data (Fig. 304).

(25) Ge, As, Br, Sr, Y, Nb, Tc, Ag, La, and Ce isotopes

There is no significant differences between data in JENDL-3.2 and those in other evaluated data for Ge, As, Br, Sr, Y, Nb, Tc, Ag, La, and Ce isotopes.

(26) Dy isotopes

No data is stored in JENDL-3.2.

4. Discussion

From the above described results of comparison, the following issues of the (n,2n) and (n,3n) reaction cross sections for fission product nuclei in JENDL-3.2 can be extracted: (1) some (n,2n) cross sections rapidly decrease above its maximum value, (2) some excitation functions of the (n,2n) reaction have steep curve near the threshold energy, (3) some (n,3n) cross sections are larger than other evaluated data in the energy range from the threshold energy to 20 MeV because the (n,2n) cross sections are small in the energy region where the (n,3n) reaction channel opens.

Most of data for fission product nuclei stored in JENDL-3.2 were evaluated by Fission Products Evaluation WG of Japanese Nuclear Data Committee [2] and most of the (n,2n) and (n,3n) reaction cross sections were evaluated by using the PEGASUS code [12] on the basis of the closed form exciton model preequilibrium theory and the multi-step evaporation theory. The calculated values were normalized to the cross sections at 14.5 MeV which were estimated from available experimental data or systematics by Bychkov et al.[13] Although comparison of the (n,2n) cross sections between JENDL-3.2 and experimental data around 14.5 MeV indicated that those data are in good agreement, it was found that there are above

mentioned issues in the cross sections for JENDL-3.2. To solve the discrepancies of data in JENDL-3.2 and other evaluated data, more sophisticated nuclear model analysis for some typical nuclei are recommended.

5. Summary

In this report, the present status of (n,2n) and (n,3n) reaction cross sections for fission product nuclei in JENDL-3.2 was studied by comparing them with other evaluated data and available experimental data. From the results of comparison, issues existing in the (n,2n) and (n,3n) reaction cross section for fission products nuclei in JENDL-3.2 were extracted.

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References

1) Nakagawa,T., Shibata, K., Chiba, S., Fukahori, T., Nakajima, Y., Kikuchi, Y., Kawano, T., Kanda, Y., Ohsawa, T., Matsunobu, H., Kawai, M., Zukeran, A., Watanabe, T., Igarasi, S., Kosako, K. and Asami, T.: "Japanese Evaluated Nuclear Data Library, Version 3, Revision 2: JENDL-3.2", J. Nucl.Sci. Technol., 32, 1259 (1995).
2) Kawai, M., Iijima, S., Nakagawa, T., Nakajima, Y., Sugi, T., Watanabe, T., Matsunobu, Y., Sasaki, M. and Zukeran, A.: "JENDL-3 Fission Product Nuclear Data Library", J. Nucl. Sci. Technol., 29, 195 (1992).
3) Manokhin, V. N.: "Some Criteria for Selection of Evaluated Threshold Reaction Excitation Functions", INDC(CCP)-397 (1997).
4) Rose, P.F. (Comp.): "ENDF-201: ENDF/B-VI Summary Documentation", BNL-NCS-17541 (1991).
5) Lemmel, H. D. and McLaughlin, P. K. : "BROND-2.2, Russian Evaluated Neutron Reaction Data Library, Summary Documentation", IAEA-NDS-90(rev.8) (1994).
6) Grudzevic, O.T., Zelenetskij, A.V., Ignatyuk, A.V. and Pashchenko, A.B.: "ADL-3, Nuclear Data Library for Activation and Transmutation Calculations", INDC(CCP)-386 (1995).
7) Sublet, J.-Ch., Kopecky, J. and Forrest, R.A.: "The European Activation File: EAF-97 - Cross Section Library" UKAEA-FUS-351 (1997).
8) Manokhin, V. N., Odano, N. and Hasegawa, A.: "Consistent Evaluation of (n,2n) and (n,np) Reaction Excitation Functions for Some Even-Even Isotopes Using Empirical Systematics", JAERI-Research 2001-013 (2001).

9) Kobayashi, K., Iwasaki, S., Odano, N., Iguchi, T., Uno, Y., Ikeda, Y., Nakagawa, T., Shibata, K., Sakurai, K., Aoyama, T., Shimakawa, S. and Nakazawa, M.: "Revision of JENDL Dosimetry File", Proc. 9th ASTM-Euratom Symposium on Reactor Dosimetry, p.457 (1998).

10) Konno, C., Ikeda, Y., Oishi, K., Kawade, K., Yamamoto, H. and Maekawa, H.: "Activation Cross Section Measurements at Neutron Energy from 13.3 to 14.9 MeV Using the FNS Facility", JAERI 1329 (1993).

11) Veeser, L.R., Arthur, E.D. and Young, P.G.: "Cross Sections for (n,2n) and (n,3n) Reactions above 14 MeV", Phys. Rev. C, 16, 1792 (1977).

12) Nakagawa, T., Iijima, S., Sugi, T. and Nishigori, T.: 'PEGASUS: A Preequilibrium and Multi-step Evaporation Code for Neutron Cross Section Calculation', JAERI-Data/Code 99-031 (1999).

13) Bychkov, V.M., Mankhin, V.M., Pashchenko, A.B. and Plyaskin, V.I.: 'Cross Sections for the (n,p), (n,alpha) and (n,2n) Threshold Reactions', INDC(CCP)-146/LJ (1980).

Table 1 List of figures

Figure No.	Reaction	Figure No.	Reaction	Figure No.	Reaction
1	^{76}Ge(n,2n)^{75}Ge	51	^{92}Zr(n,2n)^{91}Zr	101	^{108}Pd(n,2n)^{107}Pd
2	^{76}Ge(n,3n)^{74}Ge	52	^{92}Zr(n,3n)^{90}Zr	102	^{108}Pd(n,3n)^{106}Pd
3	^{75}As(n,2n)^{74}As	53	^{93}Zr(n,2n)^{92}Zr	103	^{109}Pd(n,2n)^{108}Pd
4	^{75}As(n,3n)^{73}As	54	^{93}Zr(n,3n)^{91}Zr	104	^{109}Pd(n,2n)^{107}Pd
5	^{77}Se(n,2n)^{76}Se	55	^{94}Zr(n,2n)^{93}Zr	105	^{109}Ag(n,2n)^{108}Ag
6	^{77}Se(n,3n)^{75}Se	56	^{94}Zr(n,3n)^{92}Zr	106	^{109}Ag(n,3n)^{107}Ag
7	^{78}Se(n,2n)^{77}Se	57	^{95}Zr(n,2n)^{94}Zr	107	^{111}Ag(n,2n)^{110}Ag
8	^{78}Se(n,3n)^{76}Se	58	^{95}Zr(n,3n)^{93}Zr	108	^{111}Ag(n,3n)^{109}Ag
9	^{79}Se(n,2n)^{78}Se	59	^{96}Zr(n,2n)^{95}Zr	109	^{110}Cd(n,2n)^{109}Cd
10	^{79}Se(n,3n)^{77}Se	60	^{96}Zr(n,3n)^{94}Zr	110	^{110}Cd(n,3n)^{108}Cd
11	^{80}Se(n,2n)^{79}Se	61	^{95}Nb(n,2n)^{94}Nb	111	^{111}Cd(n,2n)^{110}Cd
12	^{80}Se(n,3n)^{78}Se	62	^{95}Nb(n,3n)^{93}Nb	112	^{111}Cd(n,3n)^{109}Cd
13	^{82}Se(n,2n)^{81}Se	63	^{95}Mo(n,2n)^{94}Mo	113	^{112}Cd(n,2n)^{111}Cd
14	^{82}Se(n,3n)^{80}Se	64	^{95}Mo(n,3n)^{93}Mo	114	^{112}Cd(n,3n)^{110}Cd
15	^{81}Br(n,2n)^{80}Br	65	^{96}Mo(n,2n)^{95}Mo	115	^{113}Cd(n,2n)^{112}Cd
16	^{81}Br(n,2n)^{79}Br	66	^{96}Mo(n,3n)^{94}Mo	116	^{113}Cd(n,3n)^{111}Cd
17	^{82}Br(n,2n)^{81}Br	67	^{97}Mo(n,2n)^{96}Mo	117	^{114}Cd(n,2n)^{113}Cd
18	^{82}Br(n,3n)^{80}Br	68	^{97}Mo(n,3n)^{95}Mo	118	^{114}Cd(n,3n)^{112}Cd
19	^{82}Kr(n,2n)^{81}Kr	69	^{98}Mo(n,2n)^{97}Mo	119	^{116}Cd(n,2n)^{115}Cd
20	^{82}Kr(n,3n)^{80}Kr	70	^{98}Mo(n,3n)^{96}Mo	120	^{116}Cd(n,3n)^{115}Cd
21	^{83}Kr(n,2n)^{82}Kr	71	^{99}Mo(n,2n)^{98}Mo	121	^{115}In(n,2n)^{114}In
22	^{83}Kr(n,3n)^{81}Kr	72	^{99}Mo(n,3n)^{97}Mo	122	^{115}In(n,3n)^{113}In
23	^{84}Kr(n,2n)^{83}Kr	73	^{100}Mo(n,2n)^{99}Mo	123	^{115}Sn(n,2n)^{114}Sn
24	^{84}Kr(n,3n)^{82}Kr	74	^{100}Mo(n,3n)^{98}Mo	124	^{115}Sn(n,3n)^{113}Sn
25	^{85}Kr(n,2n)^{84}Kr	75	^{99}Tc(n,2n)^{98}Tc	125	^{116}Sn(n,2n)^{115}Sn
26	^{85}Kr(n,3n)^{83}Kr	76	^{99}Tc(n,3n)^{97}Tc	126	^{116}Sn(n,3n)^{114}Sn
27	^{86}Kr(n,2n)^{85}Kr	77	^{100}Ru(n,2n)^{99}Ru	127	^{117}Sn(n,2n)^{116}Sn
28	^{86}Kr(n,3n)^{84}Kr	78	^{100}Ru(n,3n)^{98}Ru	128	^{117}Sn(n,3n)^{115}Sn
29	^{85}Rb(n,2n)^{84}Rb	79	^{101}Ru(n,2n)^{100}Ru	129	^{118}Sn(n,2n)^{117}Sn
30	^{85}Rb(n,3n)^{83}Rb	80	^{101}Ru(n,3n)^{99}Ru	130	^{118}Sn(n,3n)^{116}Sn
31	^{86}Rb(n,2n)^{85}Rb	81	^{102}Ru(n,2n)^{101}Ru	131	^{119}Sn(n,2n)^{118}Sn
32	^{86}Rb(n,3n)^{84}Rb	82	^{102}Ru(n,3n)^{100}Ru	132	^{119}Sn(n,3n)^{117}Sn
33	^{87}Rb(n,2n)^{86}Rb	83	^{103}Ru(n,2n)^{102}Ru	133	^{120}Sn(n,2n)^{119}Sn
34	^{87}Rb(n,3n)^{85}Rb	84	^{103}Ru(n,3n)^{101}Ru	134	^{120}Sn(n,3n)^{118}Sn
35	^{86}Sr(n,2n)^{85}Sr	85	^{104}Ru(n,2n)^{103}Ru	135	^{121}Sn(n,2n)^{120}Sn
36	^{88}Sr(n,2n)^{87}Sr	86	^{104}Ru(n,3n)^{102}Ru	136	^{121}Sn(n,2n)^{119}Sn
37	^{89}Sr(n,2n)^{88}Sr	87	^{106}Ru(n,2n)^{105}Ru	137	^{122}Sn(n,2n)^{121}Sn
38	^{89}Sr(n,3n)^{87}Sr	88	^{106}Ru(n,3n)^{104}Ru	138	^{122}Sn(n,3n)^{120}Sn
39	^{90}Sr(n,2n)^{89}Sr	89	^{103}Rh(n,2n)^{102}Rh	139	^{123}Sn(n,2n)^{122}Sn
40	^{90}Sr(n,3n)^{88}Sr	90	^{103}Rh(n,3n)^{101}Rh	140	^{123}Sn(n,3n)^{121}Sn
41	^{89}Y(n,2n)^{88}Y	91	^{105}Rh(n,2n)^{104}Rh	141	^{124}Sn(n,2n)^{123}Sn
42	^{90}Y(n,2n)^{89}Y	92	^{105}Rh(n,3n)^{103}Rh	142	^{124}Sn(n,3n)^{122}Sn
43	^{90}Y(n,3n)^{88}Y	93	^{104}Pd(n,2n)^{103}Pd	143	^{125}Sn(n,2n)^{124}Sn
44	^{91}Y(n,2n)^{90}Y	94	^{104}Pd(n,3n)^{102}Pd	144	^{125}Sn(n,3n)^{123}Sn
45	^{91}Y(n,3n)^{89}Y	95	^{105}Pd(n,2n)^{104}Pd	145	^{126}Sn(n,2n)^{125}Sn
46	^{90}Zr(n,2n)^{89}Zr	96	^{105}Pd(n,3n)^{103}Pd	146	^{126}Sn(n,3n)^{124}Sn
47	^{90}Zr(n,2n)^{89g}Zr	97	^{106}Pd(n,2n)^{105}Pd	147	^{121}Sb(n,2n)^{120}Sb
48	^{90}Zr(n,2n)^{89m}Zr	98	^{106}Pd(n,3n)^{104}Pd	148	^{121}Sb(n,3n)^{119}Sb
49	^{91}Zr(n,2n)^{90}Zr	99	^{107}Pd(n,2n)^{106}Pd	149	^{122}Sb(n,2n)^{121}Sb
50	^{91}Zr(n,3n)^{89}Zr	100	^{107}Pd(n,3n)^{105}Pd	150	^{122}Sb(n,3n)^{120}Sb

Table 1 List of figures (Contd.)

Figure No.	Reaction	Figure No.	Reaction	Figure No.	Reaction
151	^{123}Sb(n,2n)^{122}Sb	201	^{136}Xe(n,2n)^{135}Xe	251	^{145}Nd(n,2n)^{144}Nd
152	^{123}Sb(n,3n)^{121}Sb	202	^{136}Xe(n,3n)^{134}Xe	252	^{145}Nd(n,3n)^{143}Nd
153	^{124}Sb(n,2n)^{123}Sb	203	^{133}Cs(n,2n)^{132}Cs	253	^{146}Nd(n,2n)^{145}Nd
154	^{124}Sb(n,3n)^{122}Sb	204	^{133}Cs(n,3n)^{131}Cs	254	^{146}Nd(n,3n)^{144}Nd
155	^{125}Sb(n,2n)^{124}Sb	205	^{134}Cs(n,2n)^{133}Cs	255	^{147}Nd(n,2n)^{146}Nd
156	^{125}Sb(n,3n)^{123}Sb	206	^{134}Cs(n,3n)^{132}Cs	256	^{147}Nd(n,3n)^{145}Nd
157	^{126}Sb(n,2n)^{125}Sb	207	^{135}Cs(n,2n)^{134}Cs	257	^{148}Nd(n,2n)^{147}Nd
158	^{126}Sb(n,3n)^{124}Sb	208	^{135}Cs(n,3n)^{133}Cs	258	^{148}Nd(n,3n)^{146}Nd
159	^{127}Sb(n,2n)^{126}Sb	209	^{136}Cs(n,2n)^{135}Cs	259	^{150}Nd(n,2n)^{149}Nd
160	^{127}Sb(n,3n)^{125}Sb	210	^{136}Cs(n,3n)^{134}Cs	260	^{150}Nd(n,3n)^{148}Nd
161	^{122}Te(n,2n)^{121}Te	211	^{137}Cs(n,2n)^{136}Cs	261	^{147}Pm(n,2n)^{146}Pm
162	^{122}Te(n,3n)^{120}Te	212	^{137}Cs(n,3n)^{135}Cs	262	^{147}Pm(n,3n)^{145}Pm
163	^{123}Te(n,2n)^{122}Te	213	^{134}Ba(n,2n)^{133}Ba	263	^{148}Pm(n,2n)^{147}Pm
164	^{123}Te(n,3n)^{121}Te	214	^{134}Ba(n,3n)^{132}Ba	264	^{148}Pm(n,3n)^{146}Pm
165	^{124}Te(n,2n)^{123}Te	215	^{135}Ba(n,2n)^{134}Ba	265	^{149}Pm(n,2n)^{148}Pm
166	^{124}Te(n,3n)^{122}Te	216	^{135}Ba(n,3n)^{133}Ba	266	^{149}Pm(n,3n)^{147}Pm
167	^{125}Te(n,2n)^{124}Te	217	^{136}Ba(n,2n)^{135}Ba	267	^{147}Sm(n,2n)^{146}Sm
168	^{125}Te(n,3n)^{123}Te	218	^{136}Ba(n,3n)^{134}Ba	268	^{147}Sm(n,3n)^{145}Sm
169	^{126}Te(n,2n)^{125}Te	219	^{137}Ba(n,2n)^{136}Ba	269	^{148}Sm(n,2n)^{147}Sm
170	^{126}Te(n,3n)^{124}Te	220	^{137}Ba(n,3n)^{135}Ba	270	^{148}Sm(n,3n)^{146}Sm
171	^{128}Te(n,2n)^{127}Te	221	^{138}Ba(n,2n)^{137}Ba	271	^{149}Sm(n,2n)^{148}Sm
172	^{128}Te(n,3n)^{126}Te	222	^{138}Ba(n,3n)^{136}Ba	272	^{149}Sm(n,3n)^{147}Sm
173	^{130}Te(n,2n)^{129}Te	223	^{139}Ba(n,2n)^{138}Ba	273	^{150}Sm(n,2n)^{149}Sm
174	^{130}Te(n,3n)^{128}Te	224	^{139}Ba(n,3n)^{137}Ba	274	^{150}Sm(n,3n)^{148}Sm
175	^{132}Te(n,2n)^{131}Te	225	^{140}Ba(n,2n)^{139}Ba	275	^{151}Sm(n,2n)^{150}Sm
176	^{132}Te(n,3n)^{130}Te	226	^{140}Ba(n,3n)^{138}Ba	276	^{151}Sm(n,3n)^{149}Sm
177	^{127}I(n,2n)^{126}I	227	^{139}La(n,2n)^{138}La	277	^{152}Sm(n,2n)^{151}Sm
178	^{127}I(n,3n)^{125}I	228	^{139}La(n,3n)^{137}La	278	^{152}Sm(n,3n)^{150}Sm
179	^{129}I(n,2n)^{128}I	229	^{140}La(n,2n)^{139}La	279	^{153}Sm(n,2n)^{152}Sm
180	^{129}I(n,3n)^{127}I	230	^{140}La(n,3n)^{138}La	280	^{153}Sm(n,3n)^{151}Sm
181	^{130}I(n,2n)^{129}I	231	^{140}Ce(n,2n)^{139}Ce	281	^{154}Sm(n,2n)^{153}Sm
182	^{130}I(n,3n)^{128}I	232	^{140}Ce(n,3n)^{138}Ce	282	^{154}Sm(n,3n)^{152}Sm
183	^{131}I(n,2n)^{130}I	233	^{141}Ce(n,2n)^{140}Ce	283	^{153}Eu(n,2n)^{152}Eu
184	^{131}I(n,3n)^{129}I	234	^{141}Ce(n,3n)^{139}Ce	284	^{153}Eu(n,3n)^{151}Eu
185	^{128}Xe(n,2n)^{127}Xe	235	^{142}Ce(n,2n)^{141}Ce	285	^{154}Eu(n,2n)^{153}Eu
186	^{128}Xe(n,3n)^{126}Xe	236	^{142}Ce(n,3n)^{140}Ce	286	^{154}Eu(n,3n)^{152}Eu
187	^{129}Xe(n,2n)^{128}Xe	237	^{143}Ce(n,2n)^{142}Ce	287	^{155}Eu(n,n2)^{154}Eu
188	^{129}Xe(n,3n)^{127}Xe	238	^{143}Ce(n,3n)^{141}Ce	288	^{155}Eu(n,3n)^{153}Eu
189	^{130}Xe(n,2n)^{129}Xe	239	^{144}Ce(n,2n)^{143}Ce	289	^{156}Eu(n,2n)^{155}Eu
190	^{130}Xe(n,3n)^{128}Xe	240	^{144}Ce(n,3n)^{142}Ce	290	^{156}Eu(n,3n)^{154}Eu
191	^{131}Xe(n,2n)^{130}Xe	241	^{141}Pr(n,2n)^{140}Pr	291	^{154}Gd(n,2n)^{153}Gd
192	^{131}Xe(n,3n)^{129}Xe	242	^{141}Pr(n,3n)^{139}Pr	292	^{154}Gd(n,3n)^{152}Gd
193	^{132}Xe(n,2n)^{131}Xe	243	^{143}Pr(n,2n)^{142}Pr	293	^{155}Gd(n,2n)^{154}Gd
194	^{132}Xe(n,3n)^{130}Xe	244	^{143}Pr(n,3n)^{141}Pr	294	^{155}Gd(n,3n)^{153}Gd
195	^{133}Xe(n,2n)^{132}Xe	245	^{142}Nd(n,2n)^{141}Nd	295	^{156}Gd(n,2n)^{155}Gd
196	^{133}Xe(n,3n)^{131}Xe	246	^{142}Nd(n,3n)^{140}Nd	296	^{156}Gd(n,3n)^{154}Gd
197	^{134}Xe(n,2n)^{133}Xe	247	^{143}Nd(n,2n)^{142}Nd	297	^{157}Gd(n,2n)^{156}Gd
198	^{134}Xe(n,3n)^{132}Xe	248	^{143}Nd(n,3n)^{141}Nd	298	^{157}Gd(n,3n)^{155}Gd
199	^{135}Xe(n,2n)^{134}Xe	249	^{144}Nd(n,2n)^{143}Nd	299	^{158}Gd(n,2n)^{157}Gd
200	^{135}Xe(n,3n)^{133}Xe	250	^{144}Nd(n,3n)^{142}Nd	300	^{158}Gd(n,3n)^{156}Gd

Table 1 List of figures (Contd.)

Figure No.	Reaction	Figure No.	Reaction	Figure No.	Reaction
301	^{160}Gd(n,2n)^{159}Gd	307	^{161}Tb(n,2n)^{160}Tb	313	^{162}Dy(n,2n)^{161}Dy
302	^{160}Gd(n,3n)^{158}Gd	308	^{161}Tb(n,3n)^{159}Tb	314	^{162}Dy(n,3n)^{160}Dy
303	^{159}Tb(n,2n)^{158}Tb	309	^{160}Dy(n,2n)^{159}Dy	315	^{163}Dy(n,2n)^{162}Dy
304	^{159}Tb(n,3n)^{157}Tb	310	^{160}Dy(n,3n)^{158}Dy	316	^{163}Dy(n,3n)^{161}Dy
305	^{160}Tb(n,2n)^{159}Tb	311	^{161}Dy(n,2n)^{160}Dy	317	^{164}Dy(n,2n)^{163}Dy
306	^{160}Tb(n,3n)^{158}Tb	312	^{161}Dy(n,3n)^{159}Dy	318	^{164}Dy(n,3n)^{162}Dy

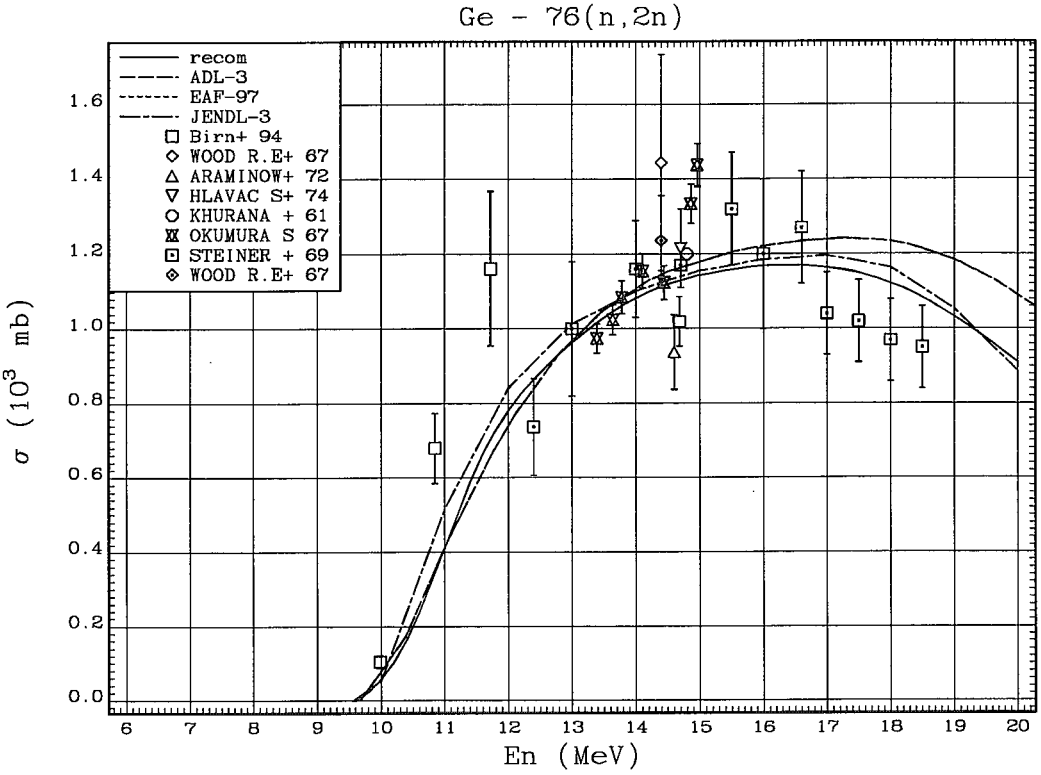

Fig.1. ^{76}Ge(n,2n)^{75}Ge reaction cross section.

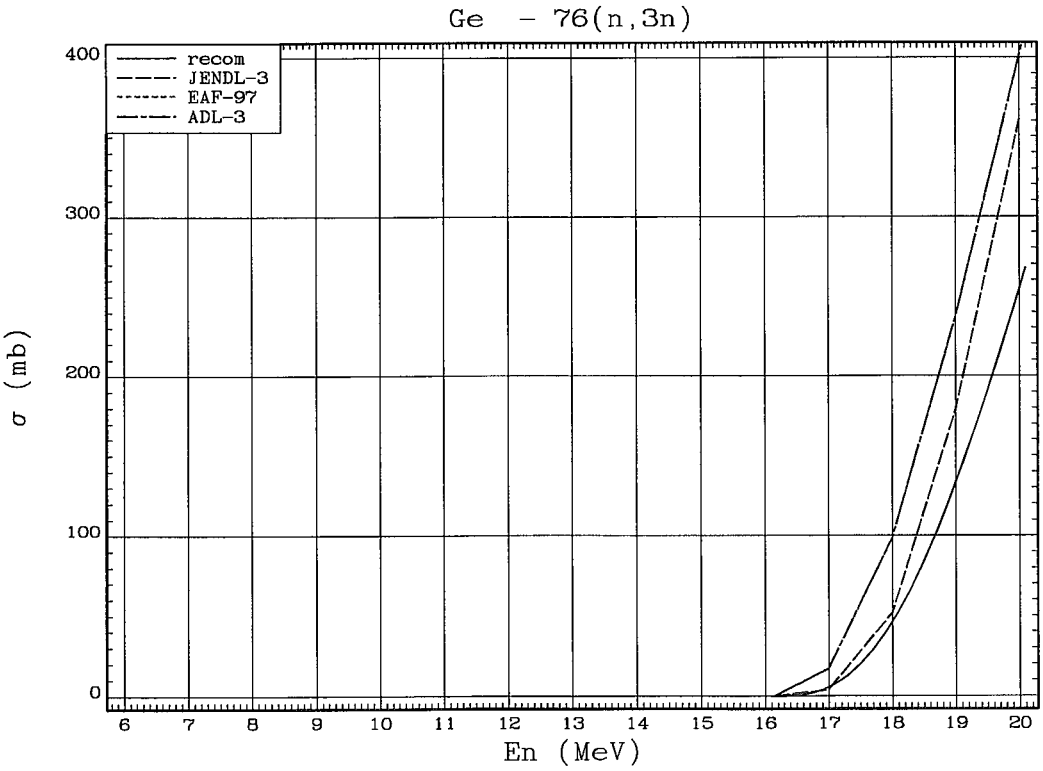

Fig.2. ^{76}Ge(n,3n)^{74}Ge reaction cross section.

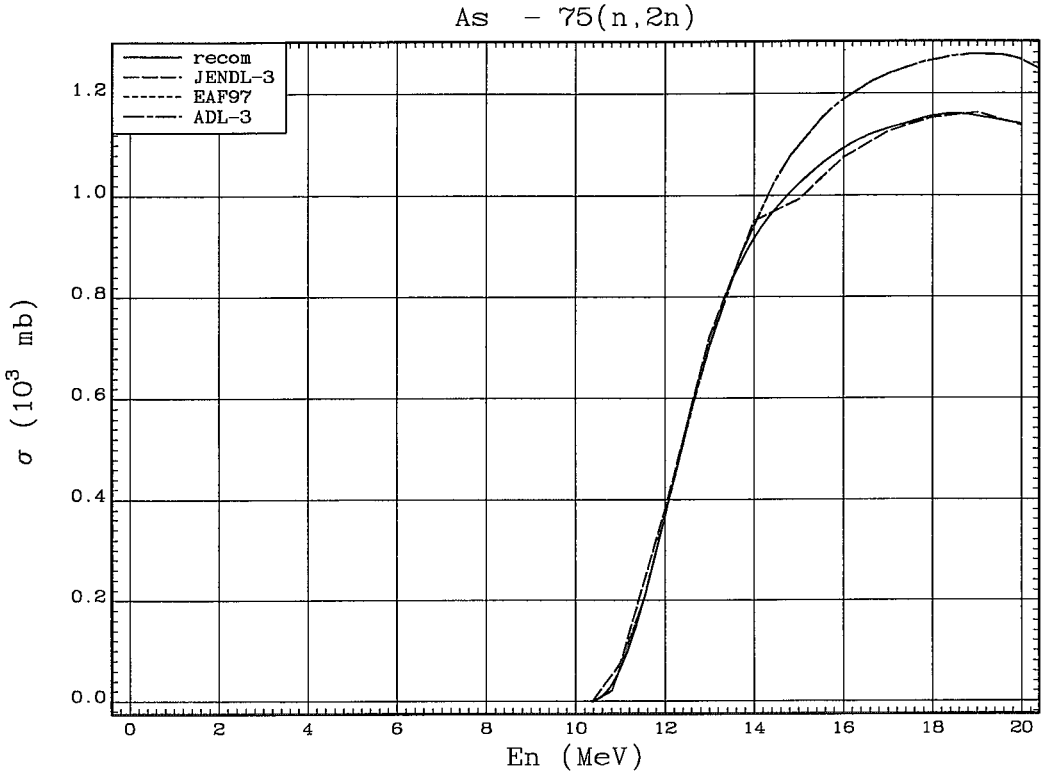

Fig.3. ^{75}As(n,2n)^{74}As reaction cross section.

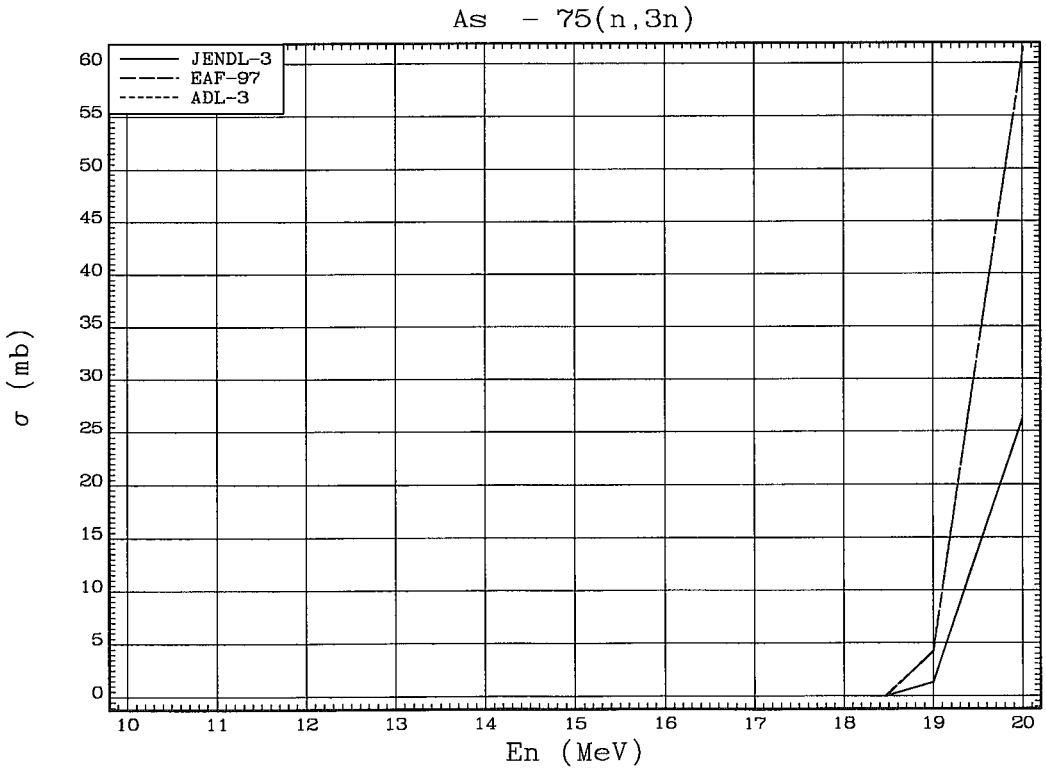

Fig.4. ^{75}As(n,3n)^{73}As reaction cross section.

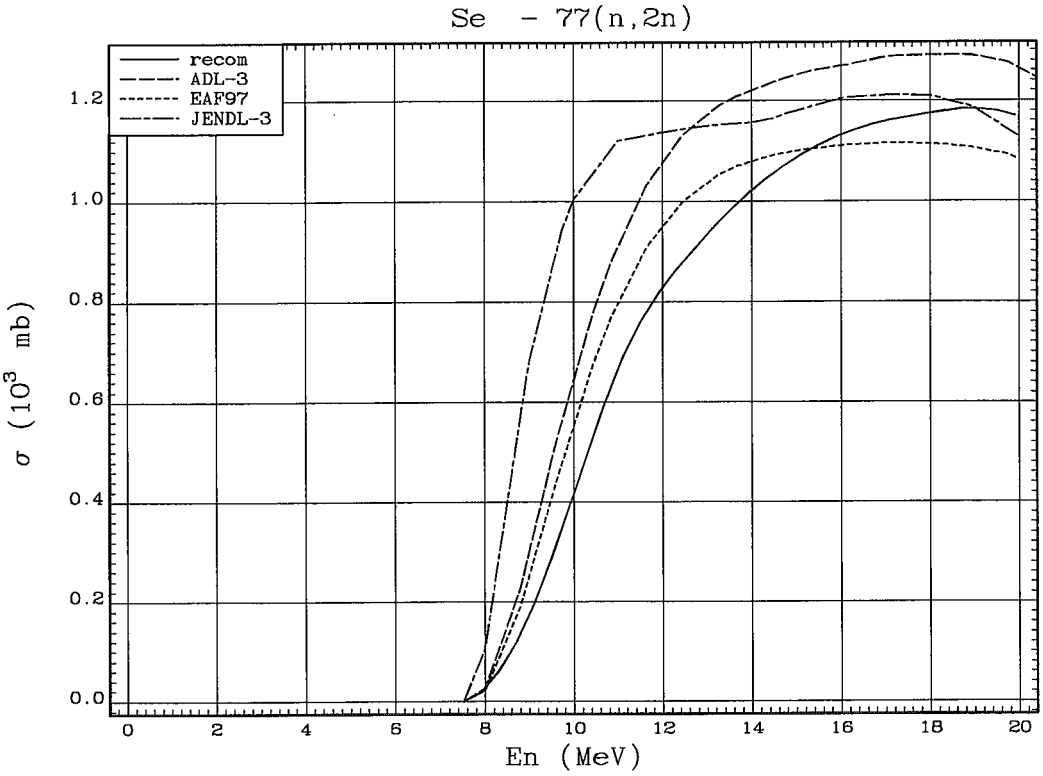

Fig.5. $^{77}Se(n,2n)^{76}Se$ reaction cross section.

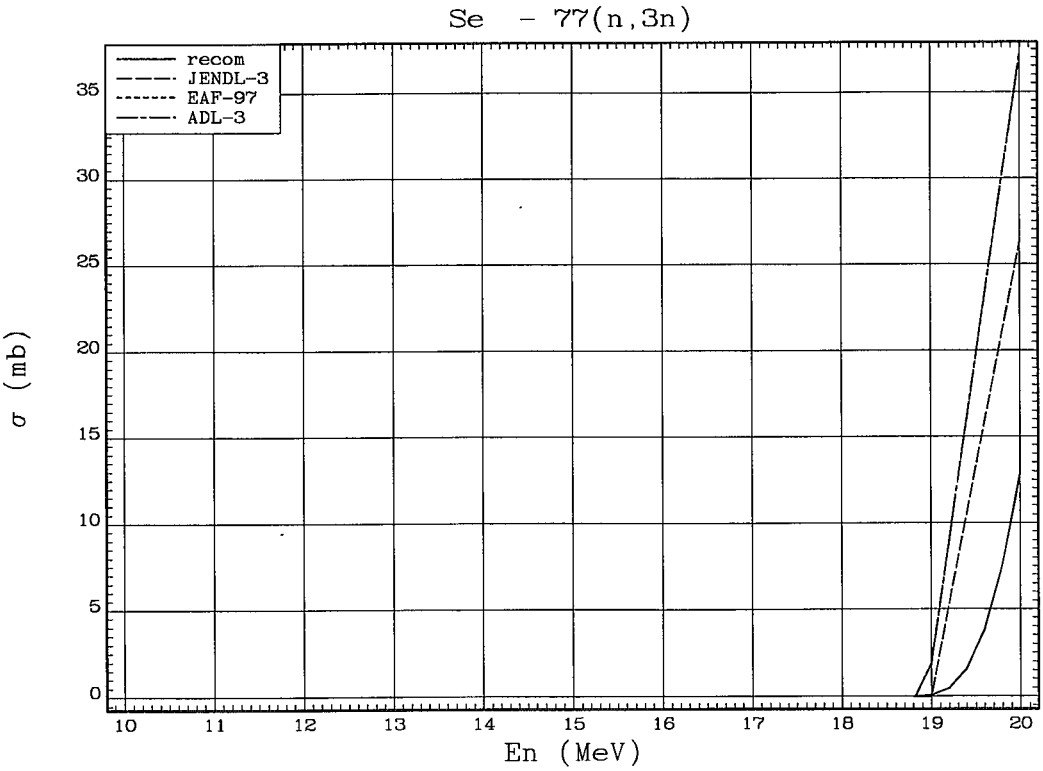

Fig.6. $^{77}Se(n,3n)^{75}Se$ reaction cross section.

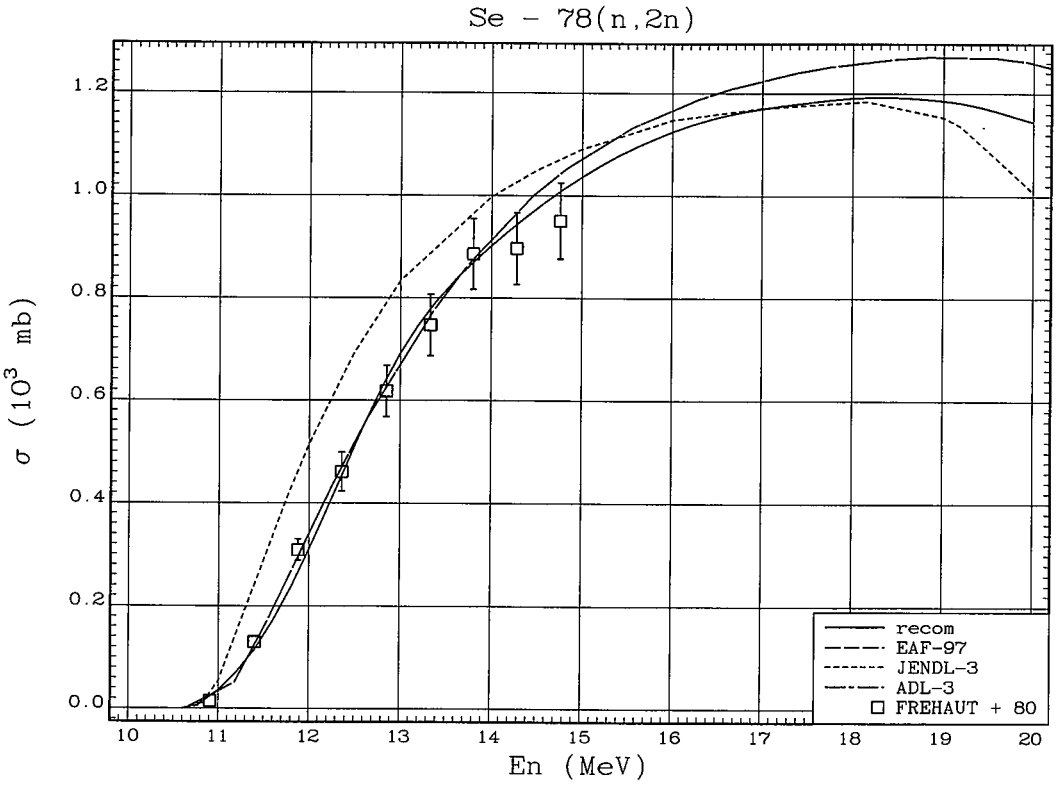

Fig.7. ^{78}Se(n,2n)^{77}Se reaction cross section.

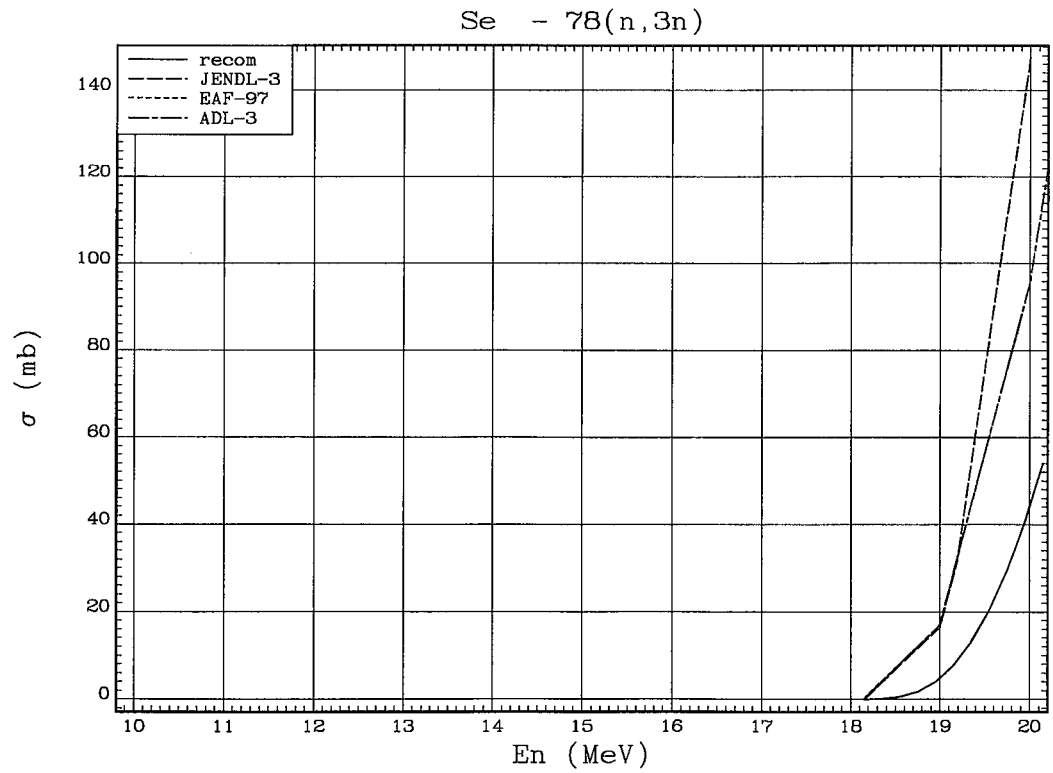

Fig.8. ^{78}Se(n,3n)^{76}Se reaction cross section.

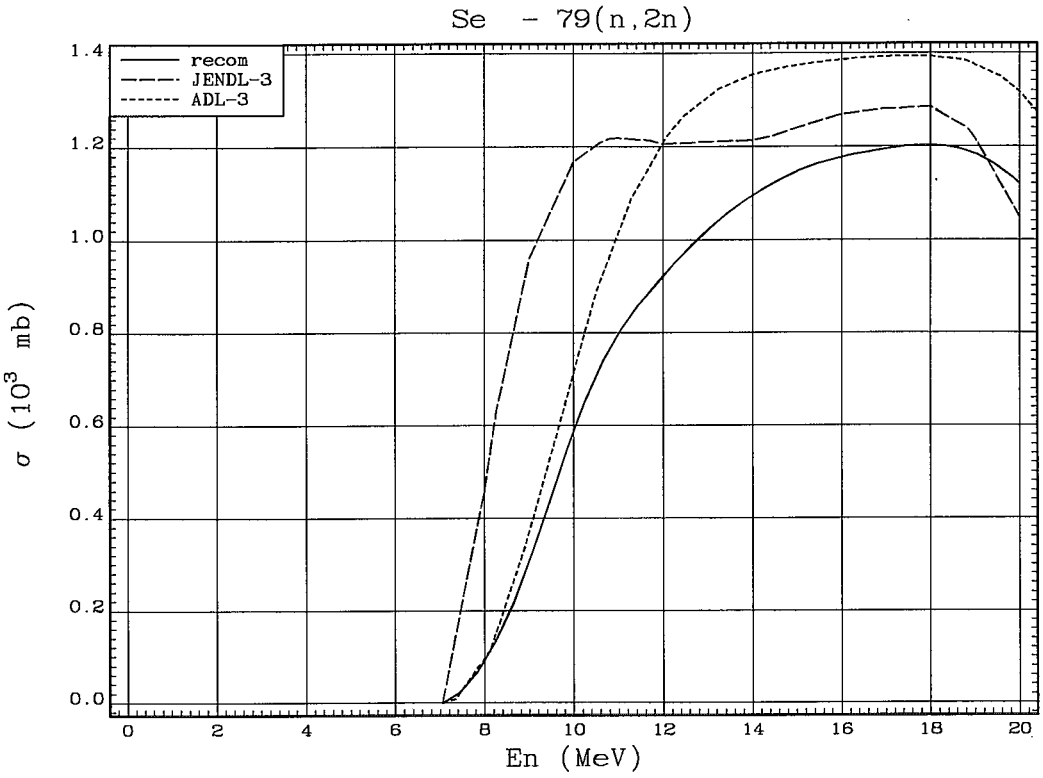

Fig. 9. ^{79}Se(n,2n)^{78}Se reaction cross section.

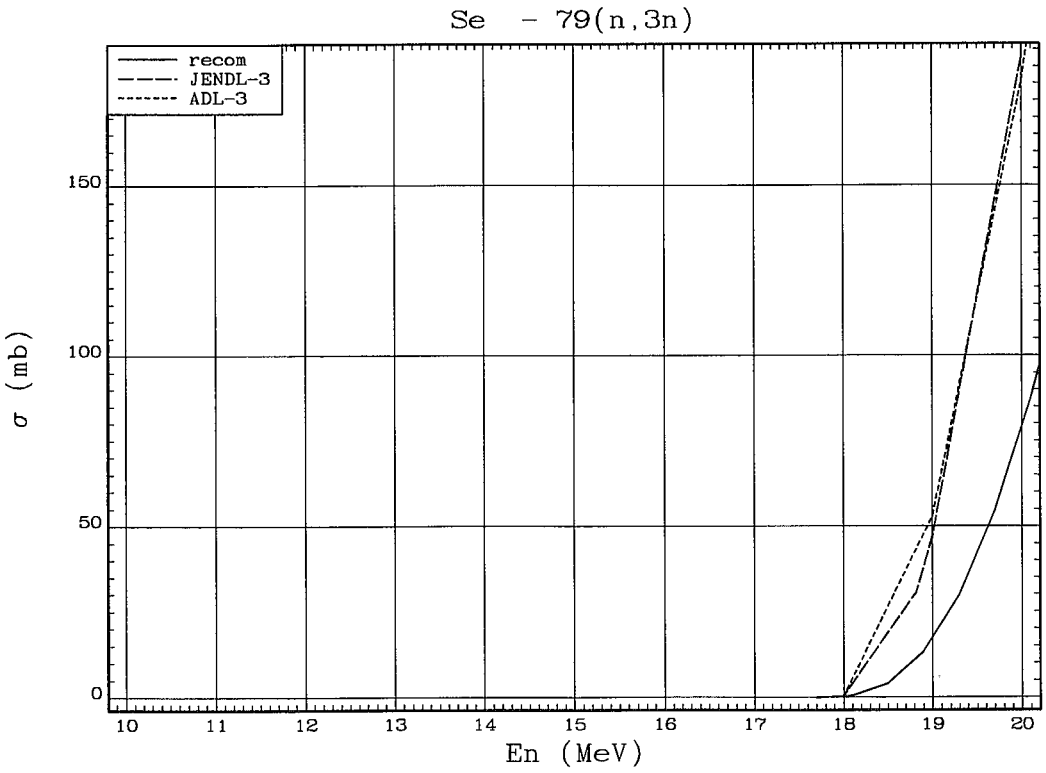

Fig.10. ^{79}Se(n,3n)^{77}Se reaction cross section.

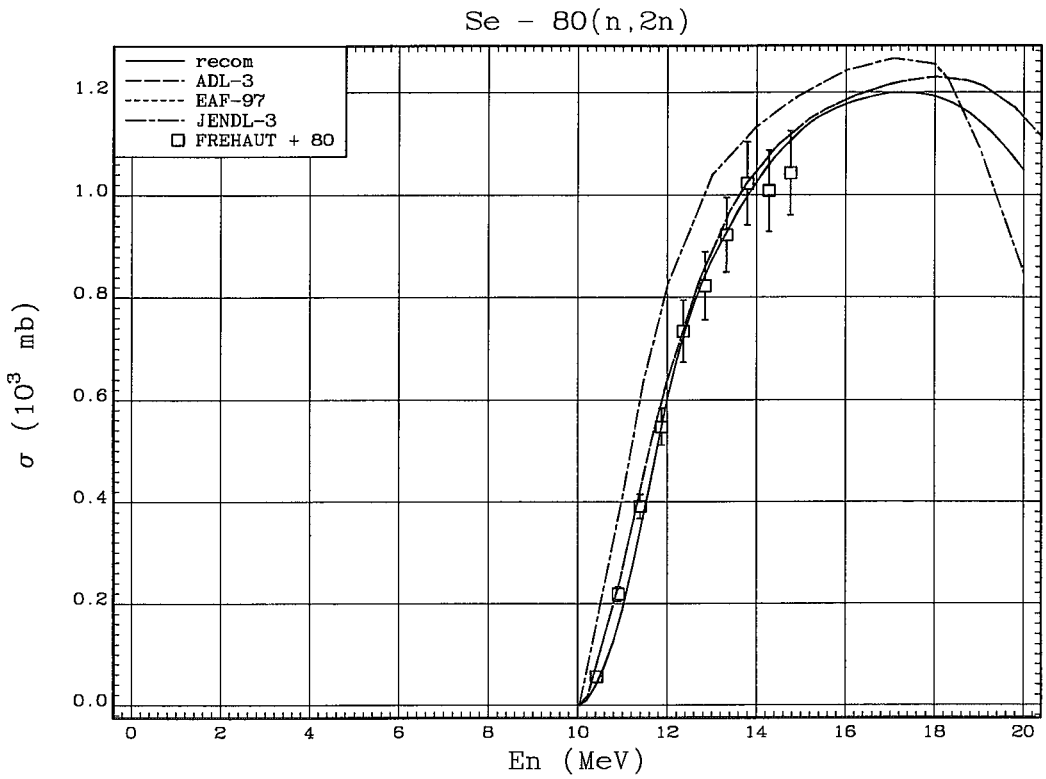

Fig.11. ^{80}Se(n,2n)^{79}Se reaction cross section.

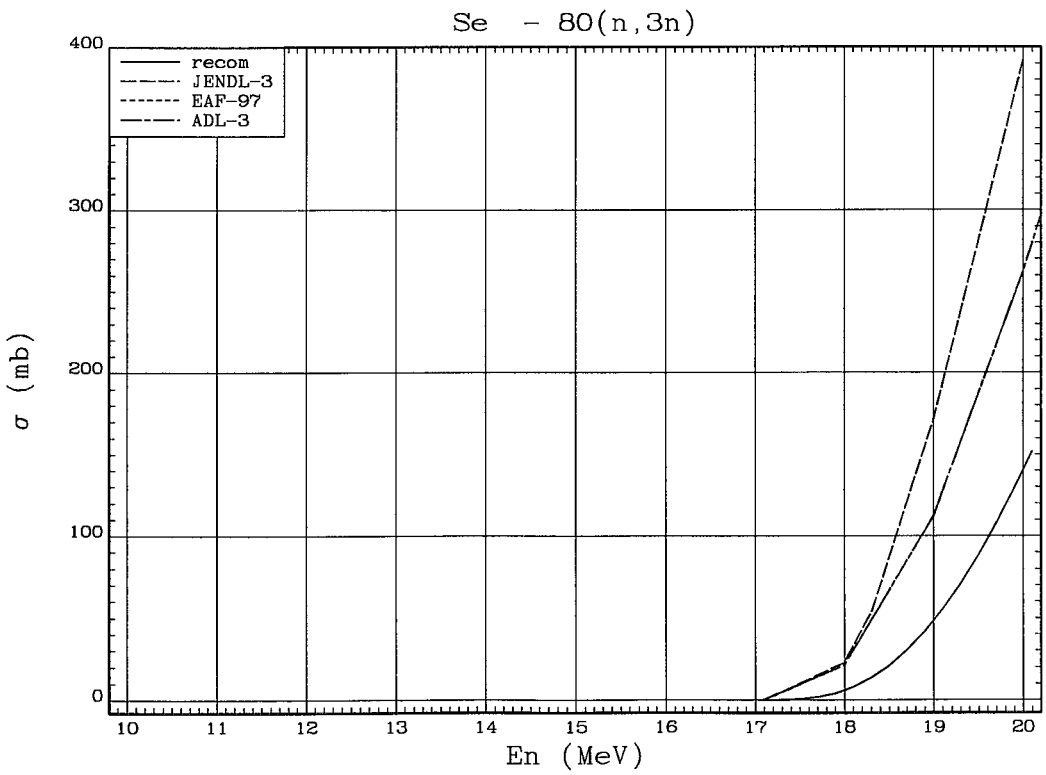

Fig.12. ^{80}Se(n,3n)^{78}Se reaction cross section.

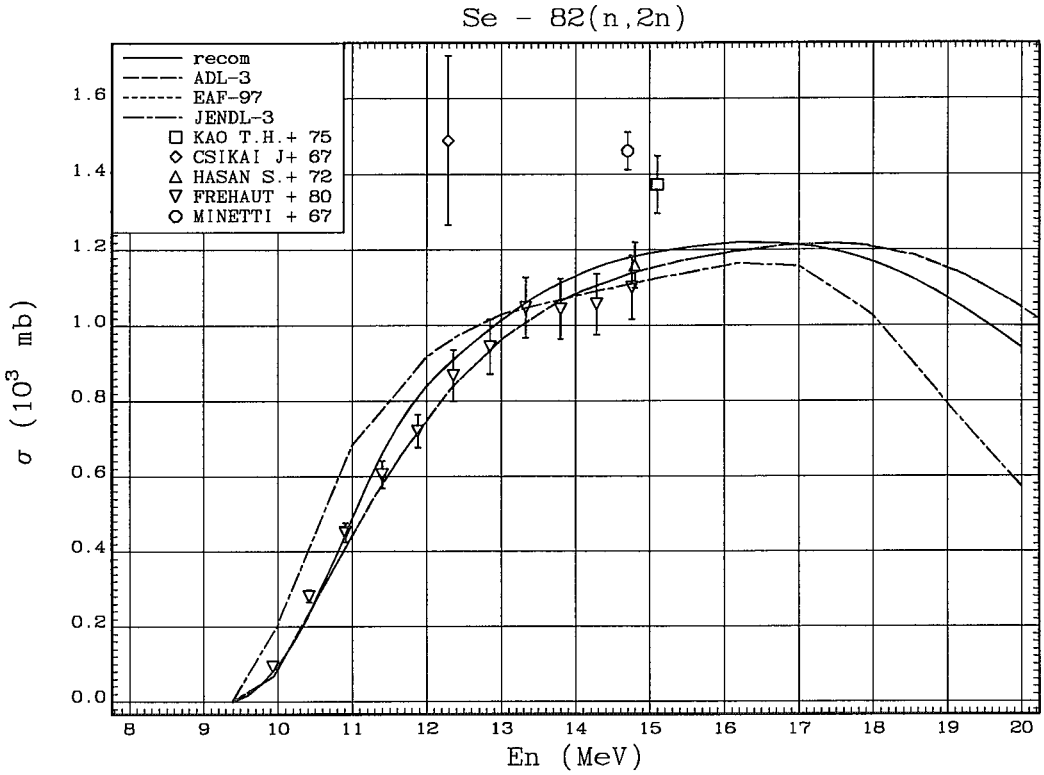

Fig.13. ^{82}Se(n,2n)^{81}Se reaction cross section.

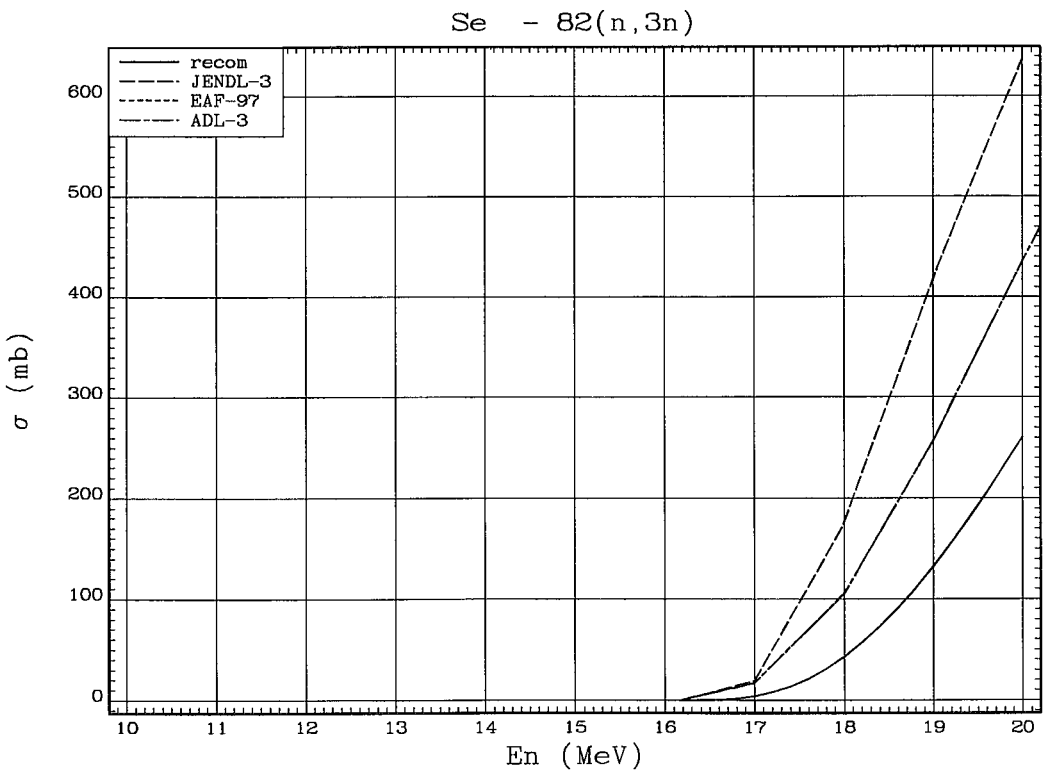

Fig.14. ^{82}Se(n,3n)^{80}Se reaction cross section.

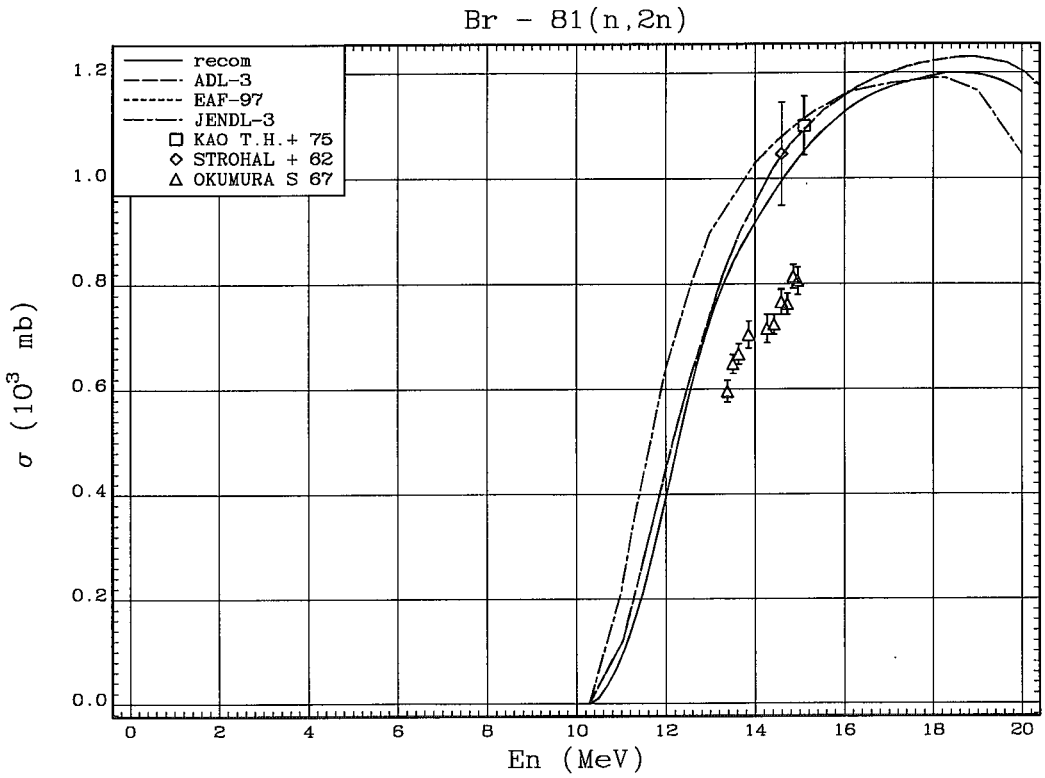

Fig.15. ^{81}Br(n,2n)^{80}Br reaction cross section.

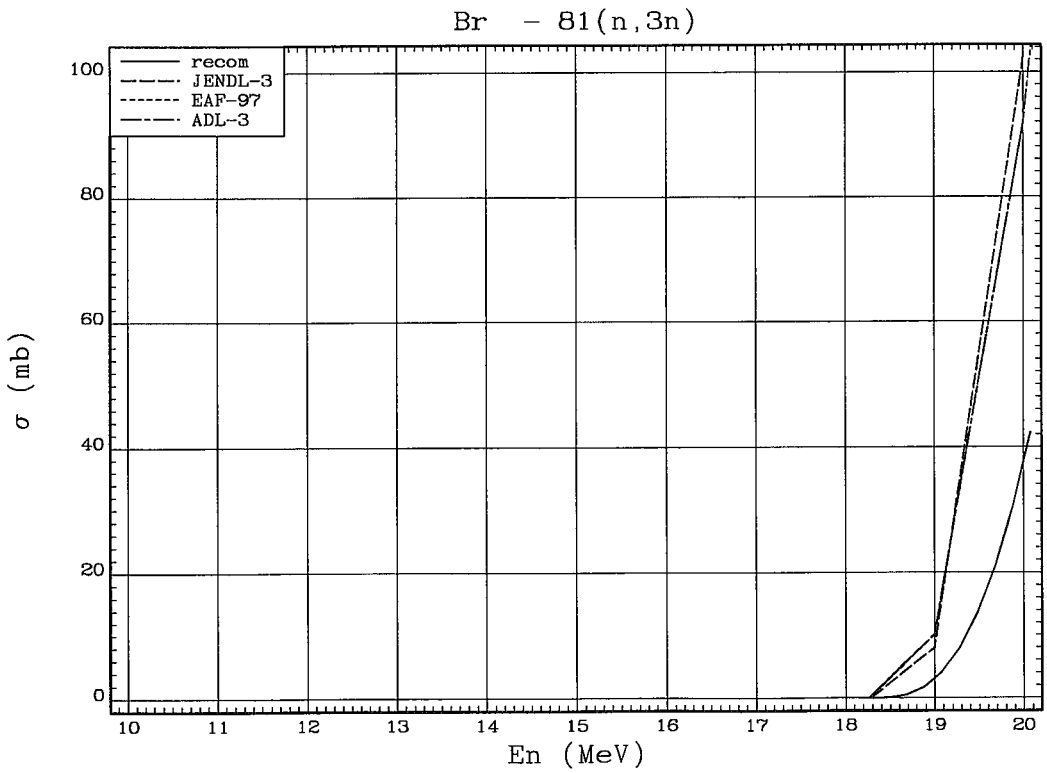

Fig. 16. ^{81}Br(n,3n)^{79}Br reaction cross section.

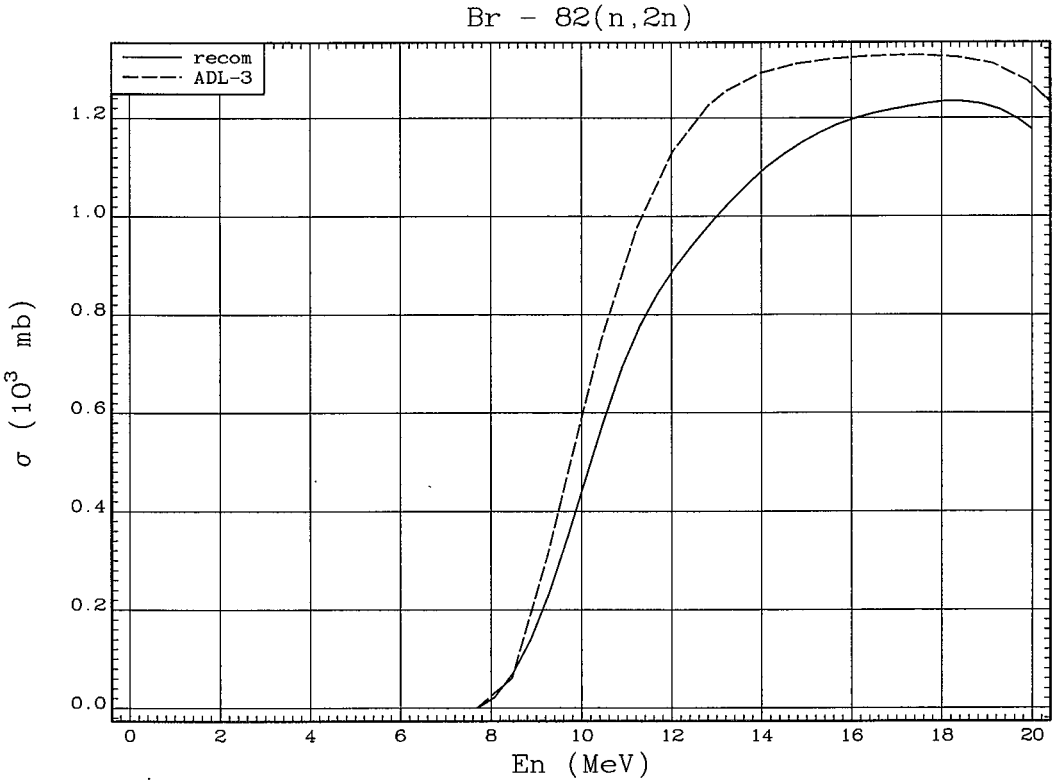

Fig. 17. ^{82}Br(n,2n)^{81}Br reaction cross section.

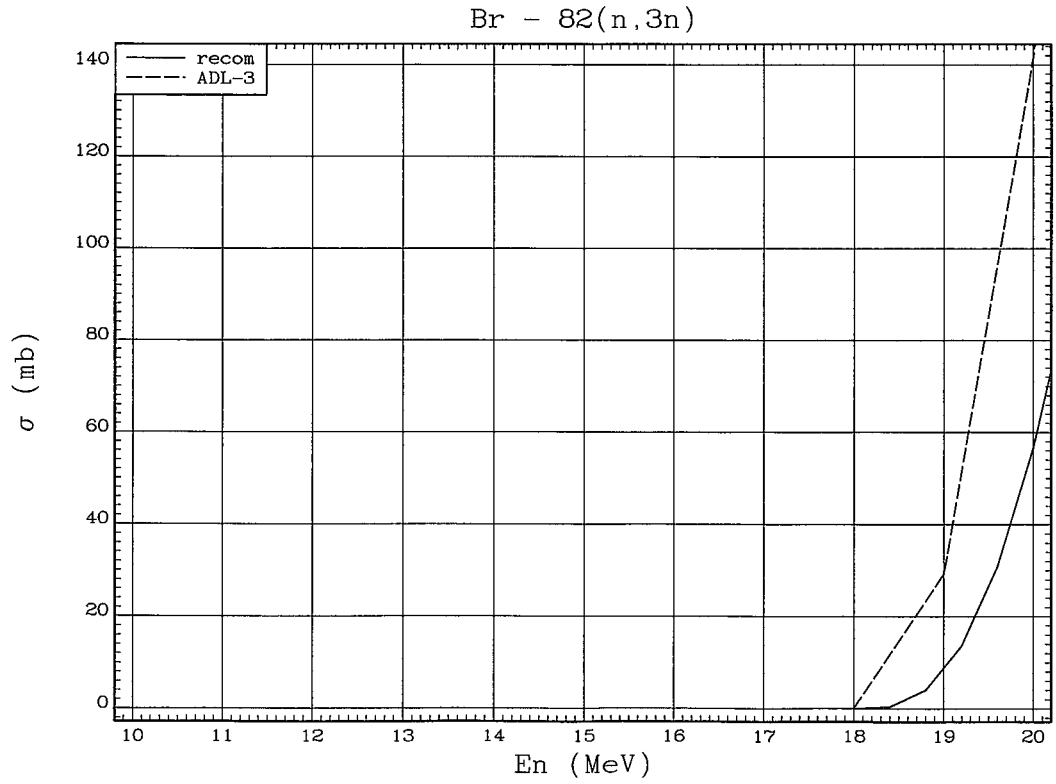

Fig.18. ^{82}Br(n,3n)^{80}Br reaction cross section.

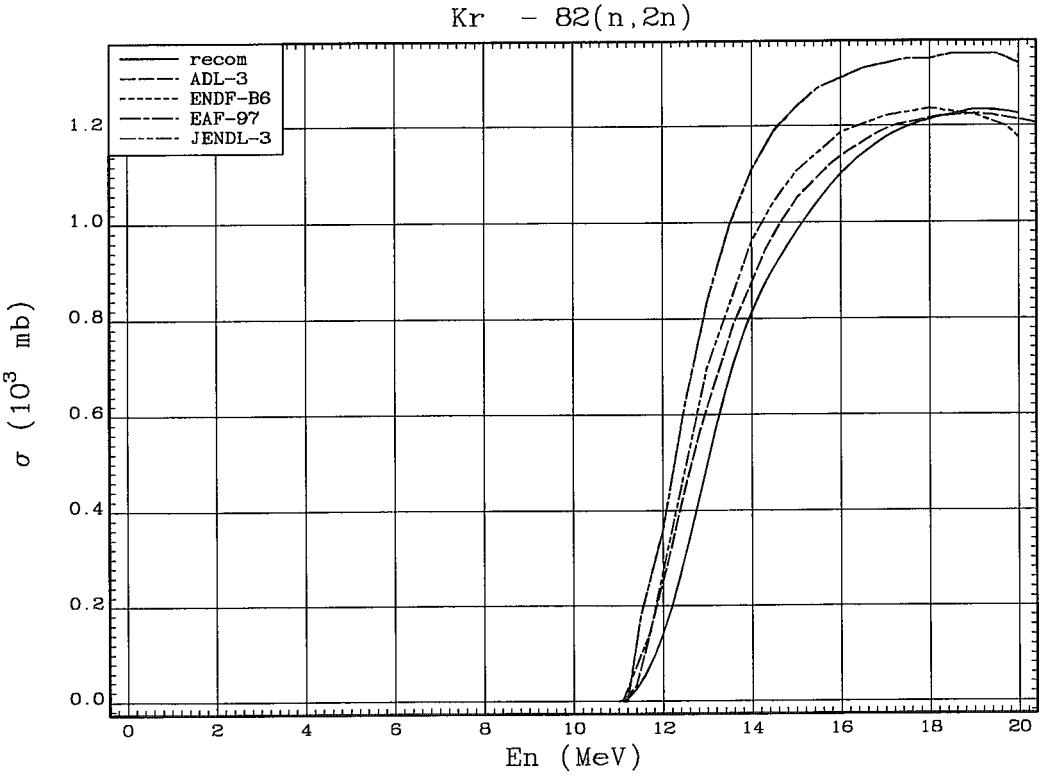

Fig.19. ^{82}Kr(n,2n)^{81}Kr reaction cross section.

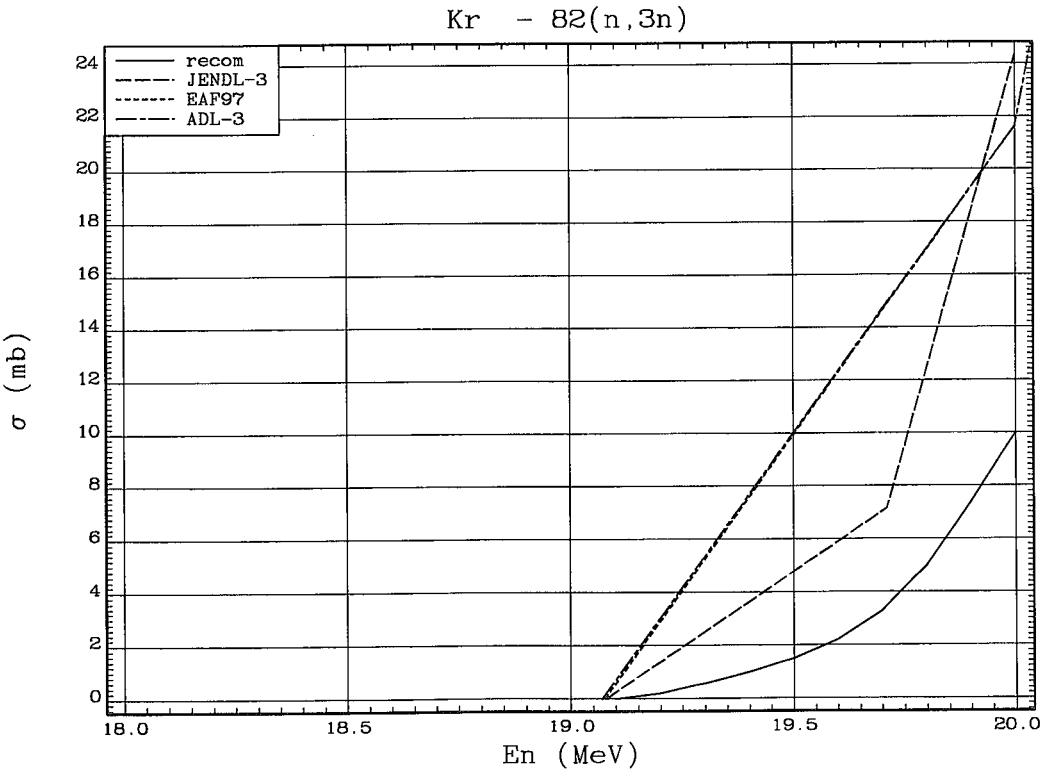

Fig.20. ^{82}Kr(n,3n)^{80}Kr reaction cross section.

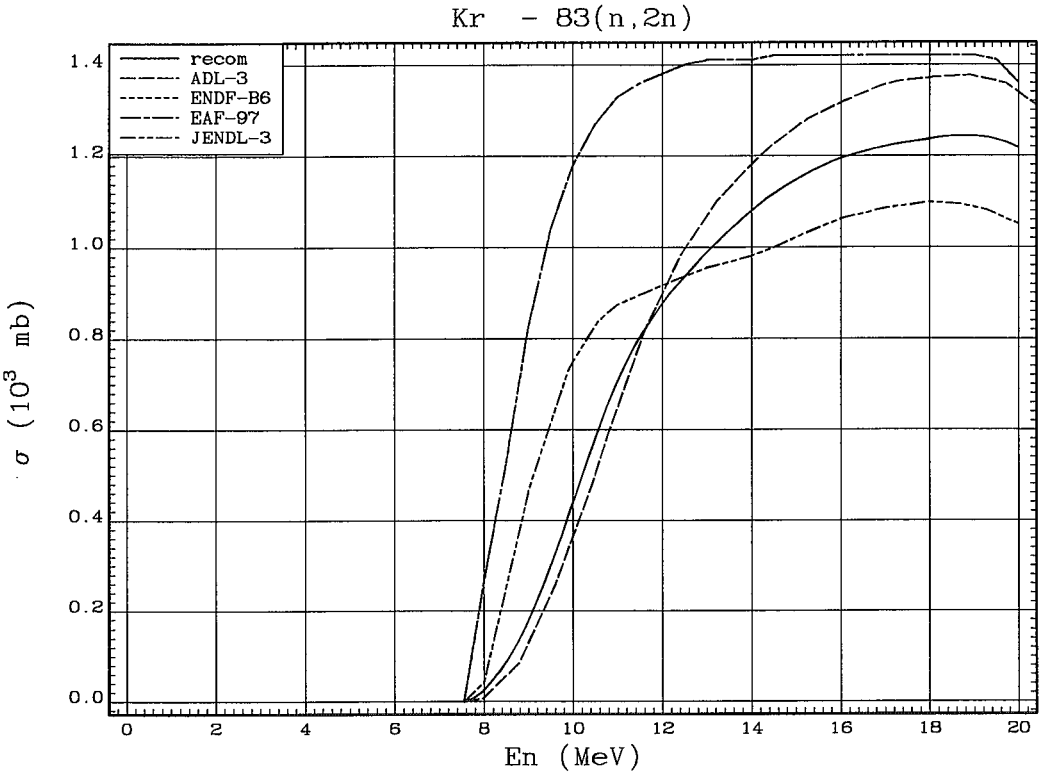

Fig.21. ^{83}Kr(n,2n)^{82}Kr reaction cross section.

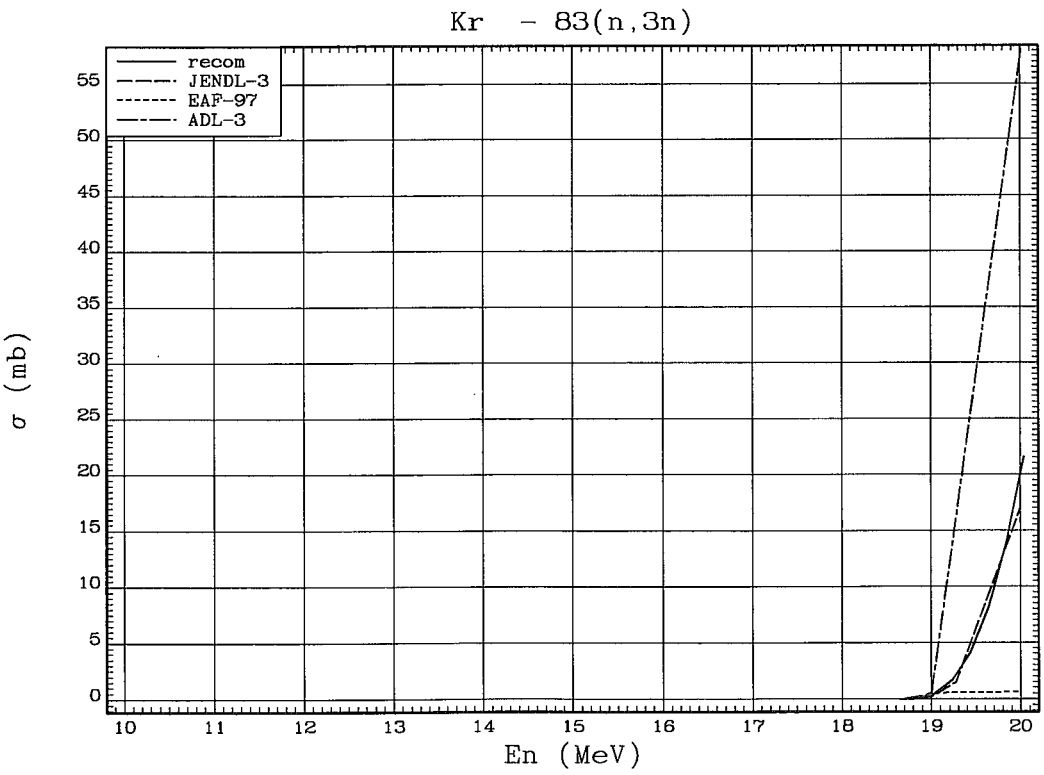

Fig.22. ^{83}Kr(n,3n)^{81}Kr reaction cross section.

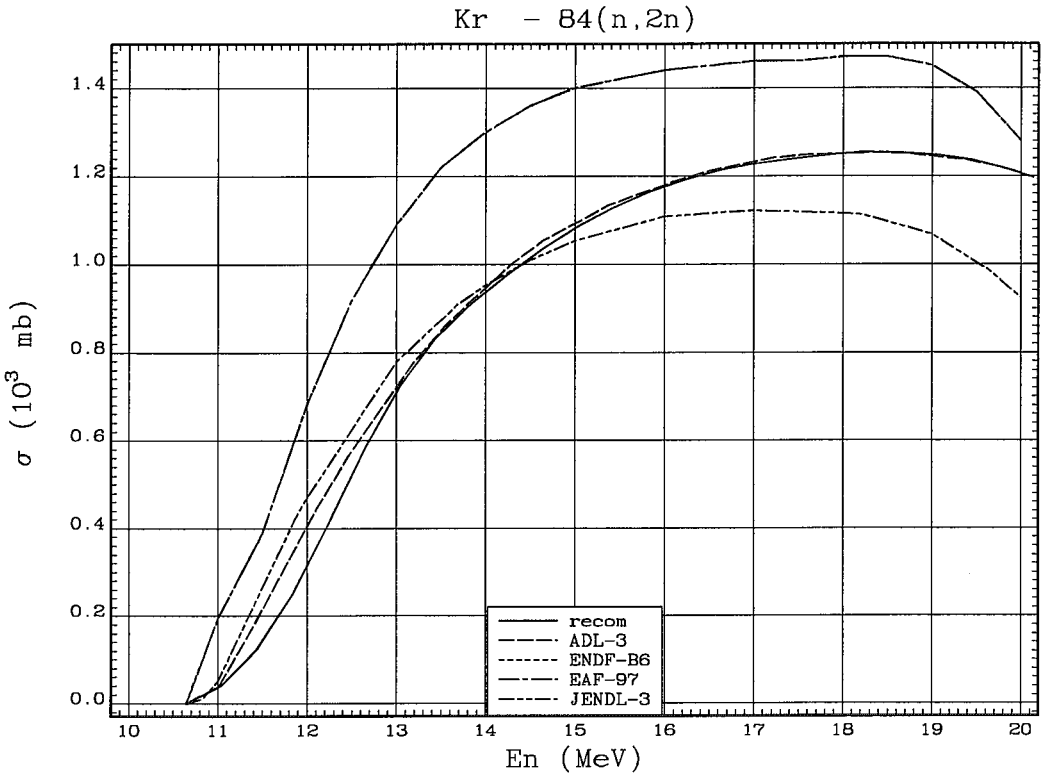

Fig.23. ^{84}Kr(n,2n)^{83}Kr reaction cross section.

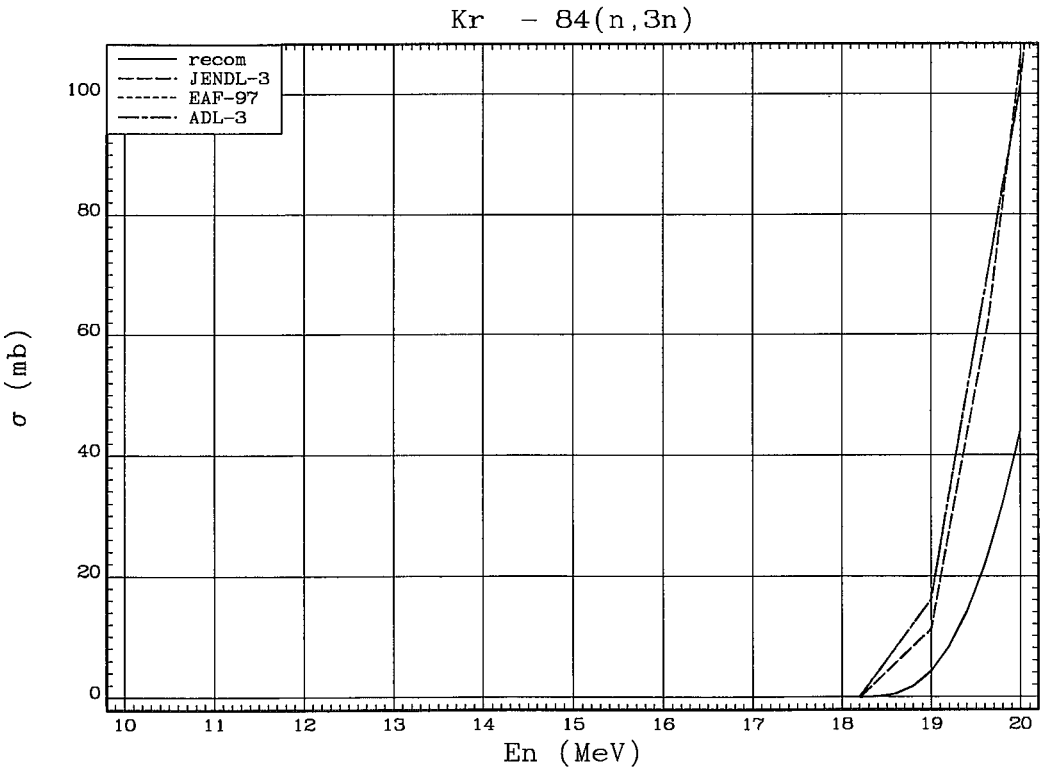

Fig.24. ^{84}Kr(n,3n)^{82}Kr reaction cross section.

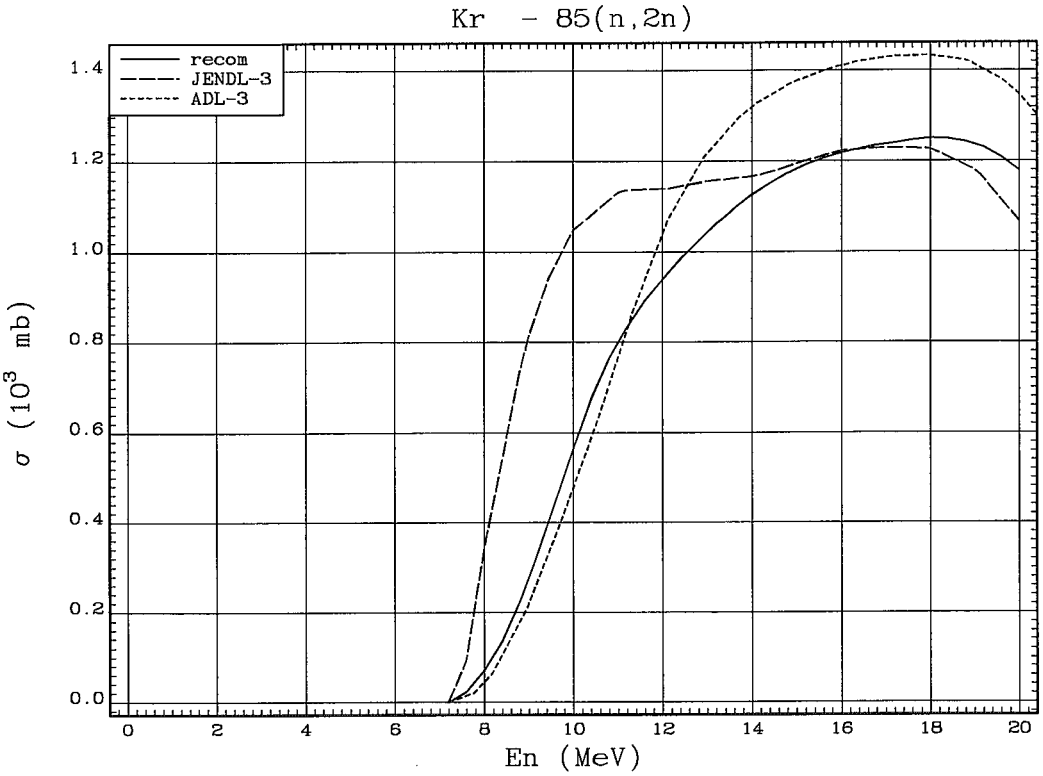

Fig.25. ^{85}Kr(n,2n)^{84}Kr reaction cross section.

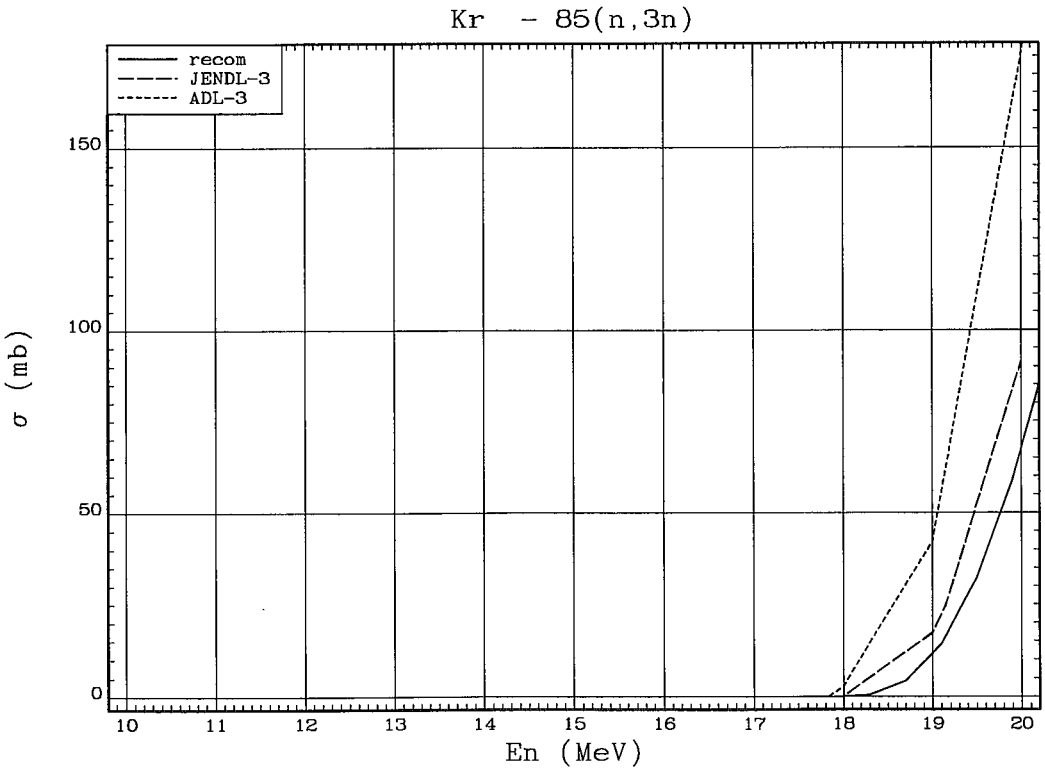

Fig.26. ^{85}Kr(n,3n)^{83}Kr reaction cross section.

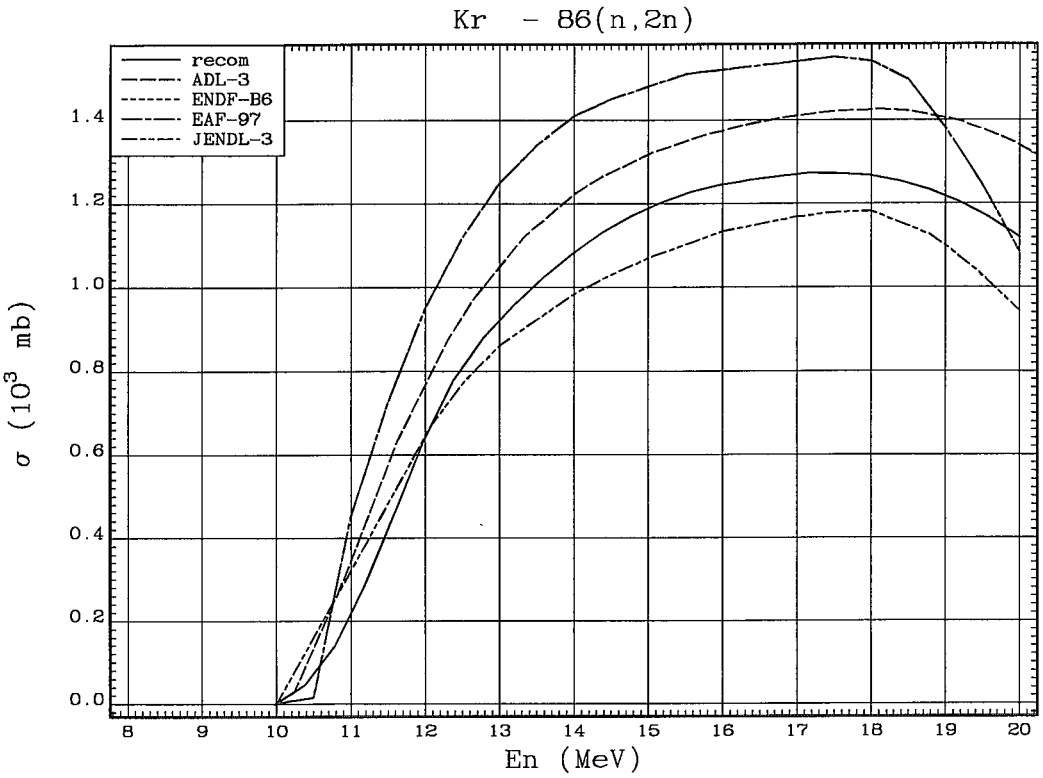

Fig.27. ^{86}Kr(n,2n)^{85}Kr reaction cross section.

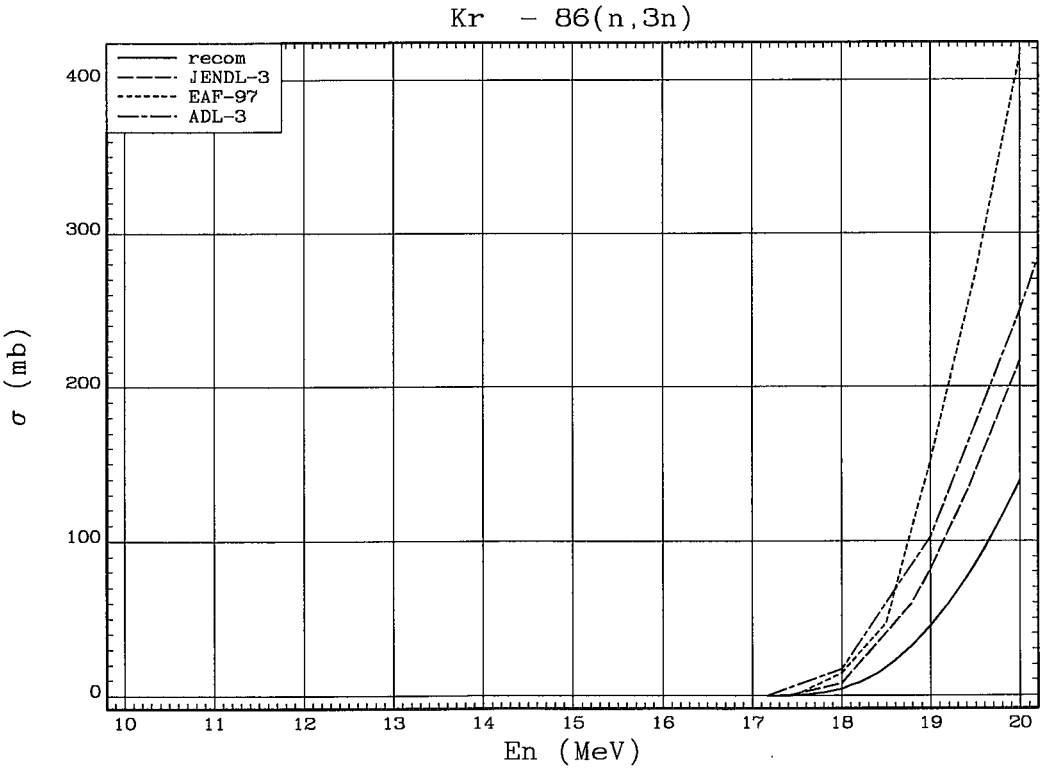

Fig.28. ^{86}Kr(n,3n)^{84}Kr reaction cross section.

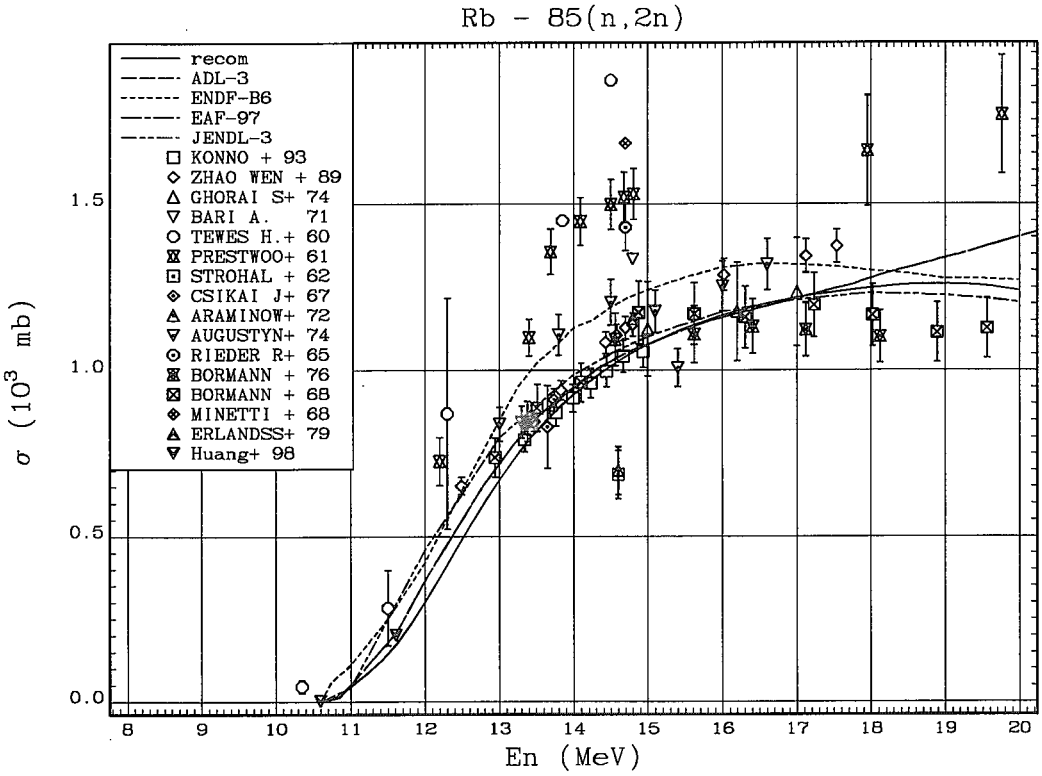

Fig.29. ^{85}Rb(n,2n)^{84}Rb reaction cross section.

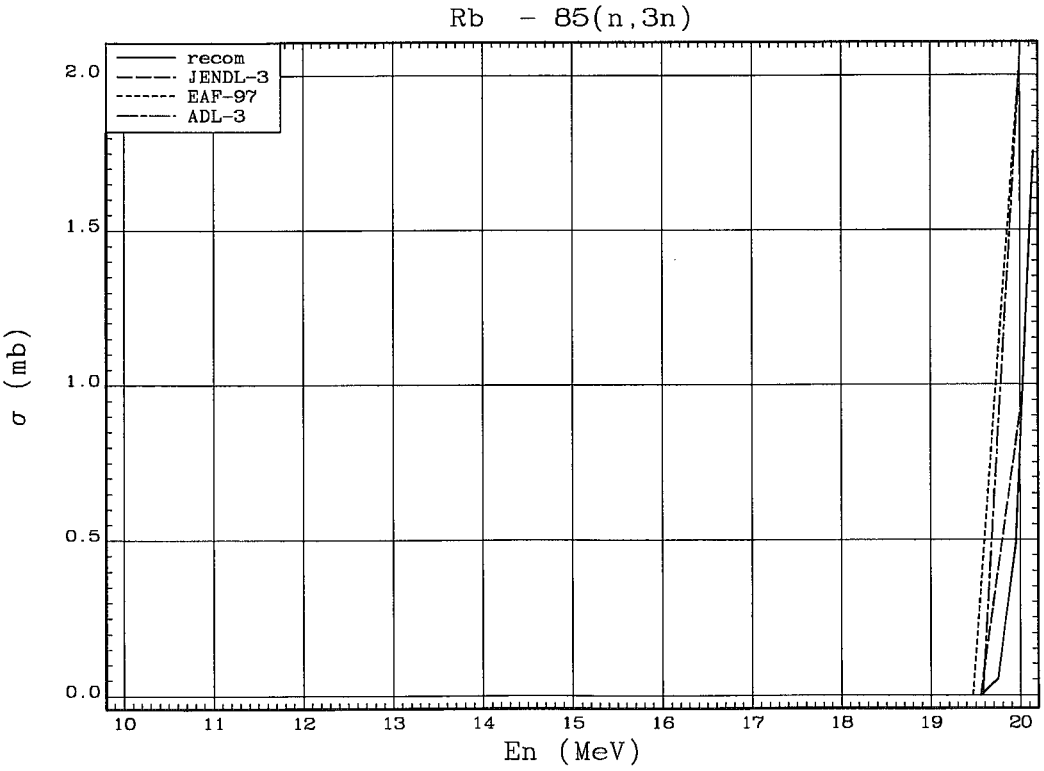

Fig.30. ^{85}Rb(n,3n)^{83}Rb reaction cross section.

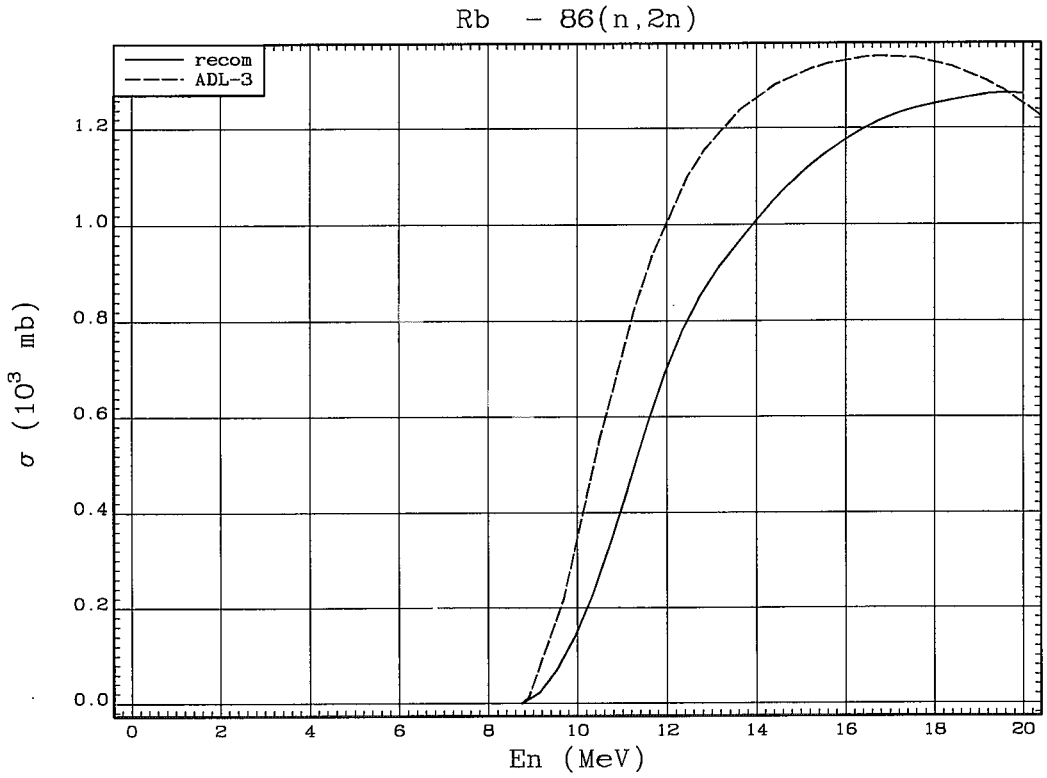

Fig.31. ^{86}Rb(n,2n)^{85}Rb reaction cross section.

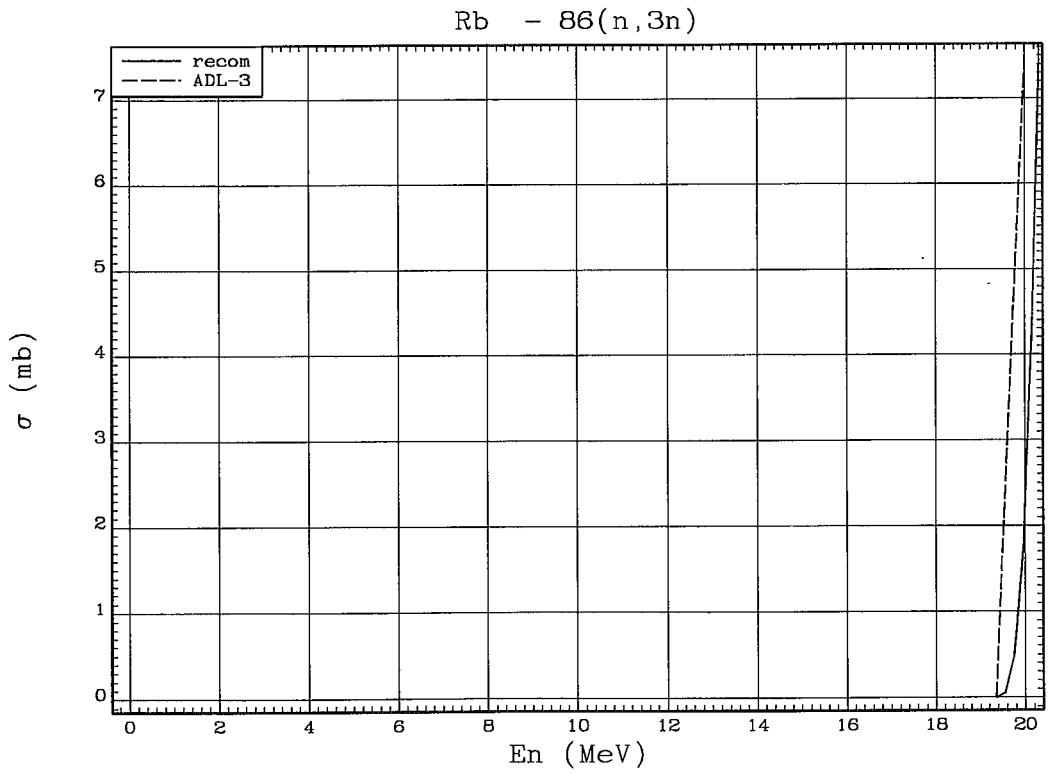

Fig.32. ^{86}Rb(n,3n)^{84}Rb reaction cross section.

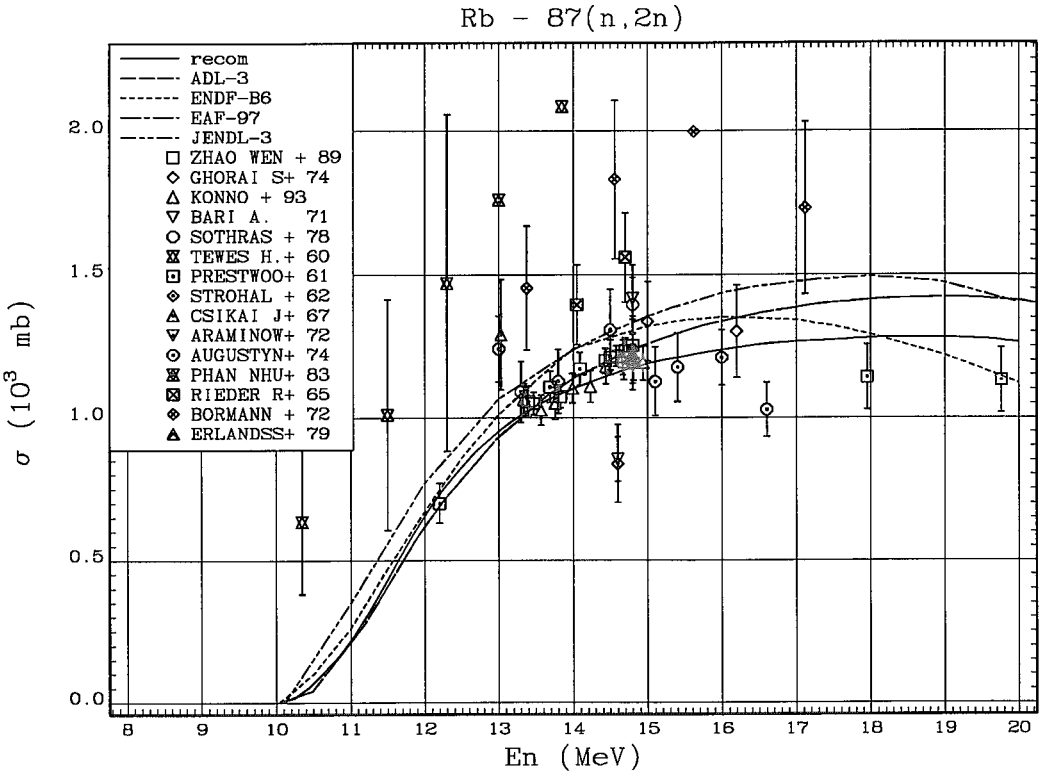

Fig.33. ^{87}Rb(n,2n)^{86}Rb reaction cross section.

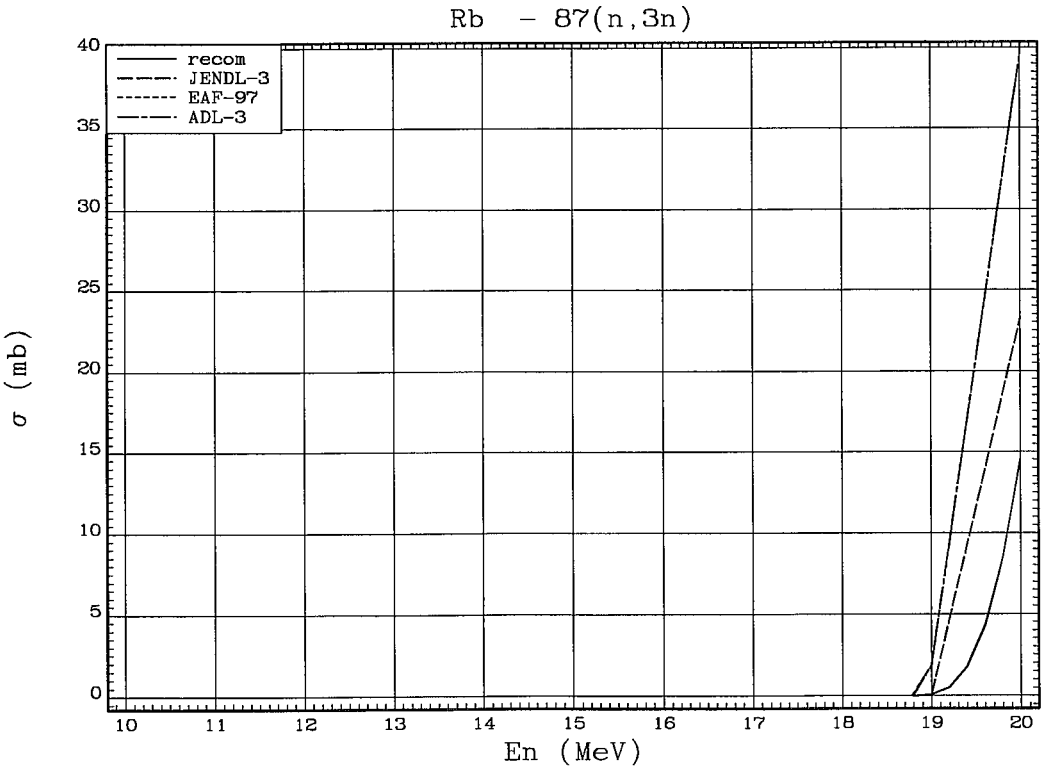

Fig.34. ^{87}Rb(n,3n)^{85}Rb reaction cross section.

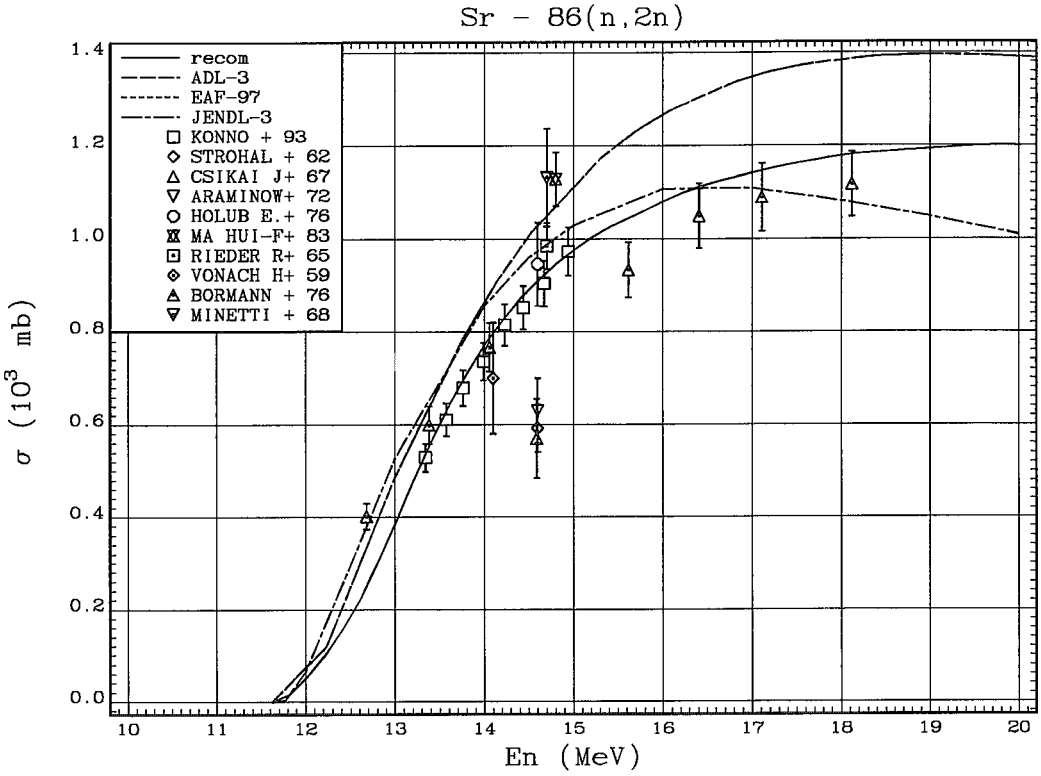

Fig.35. ^{86}Sr(n,2n)^{85}Sr reaction cross section.

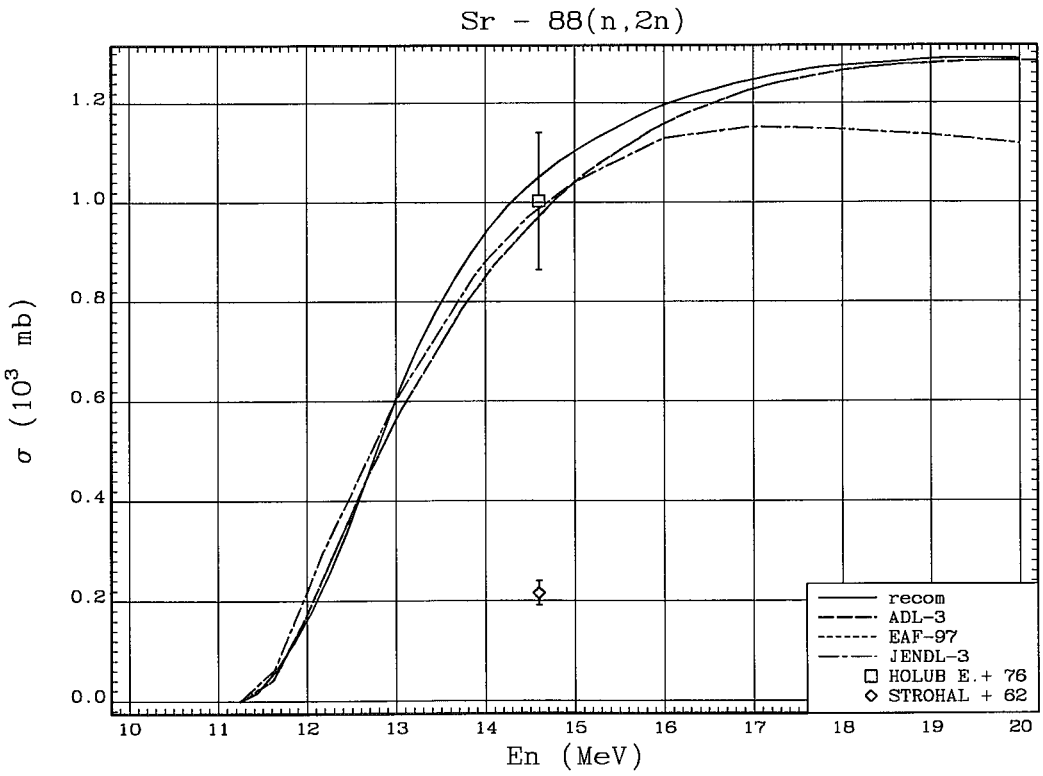

Fig.36. ^{88}Sr(n,2n)^{87}Sr reaction cross section.

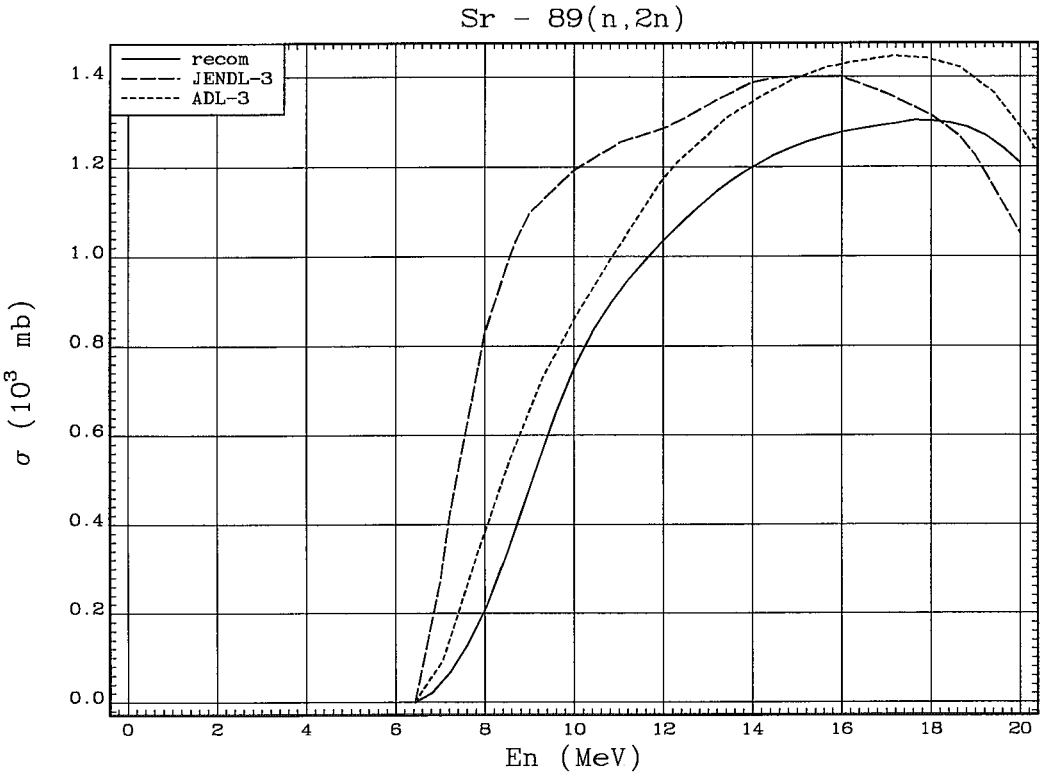

Fig.37. ^{89}Sr(n,2n)^{88}Sr reaction cross section.

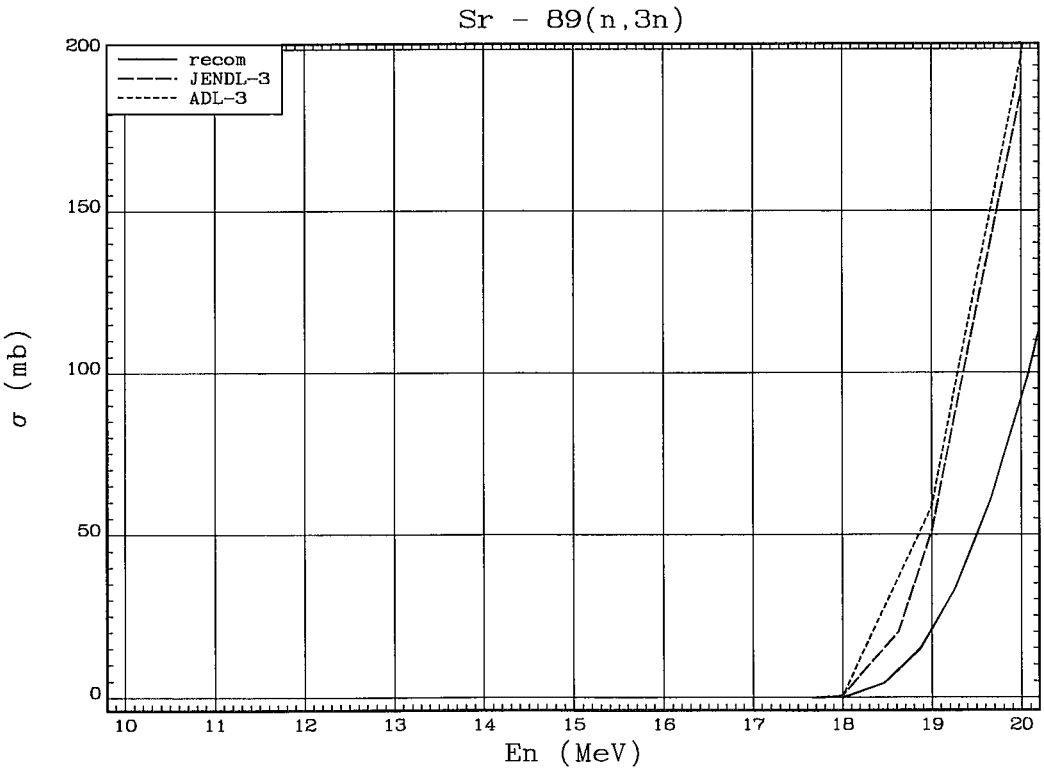

Fig.38. ^{89}Sr(n,3n)^{87}Sr reaction cross section.

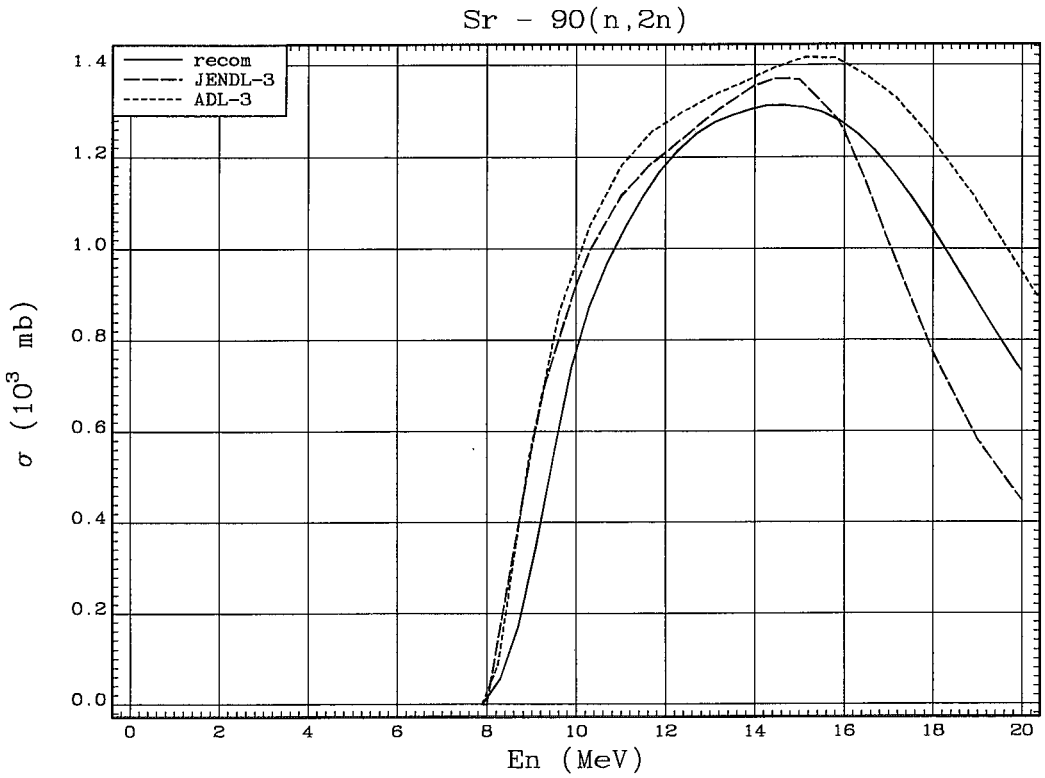

Fig.39. ^{90}Sr(n,2n)^{89}Sr reaction cross section.

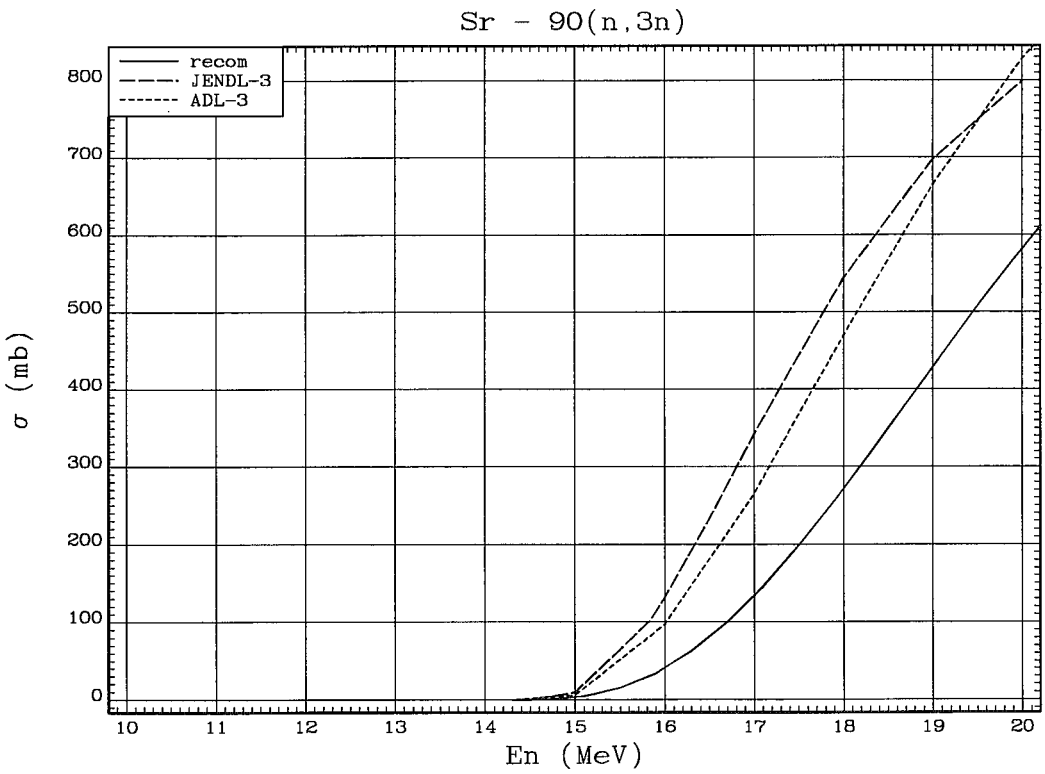

Fig.40. ^{90}Sr(n,3n)^{88}Sr reaction cross section.

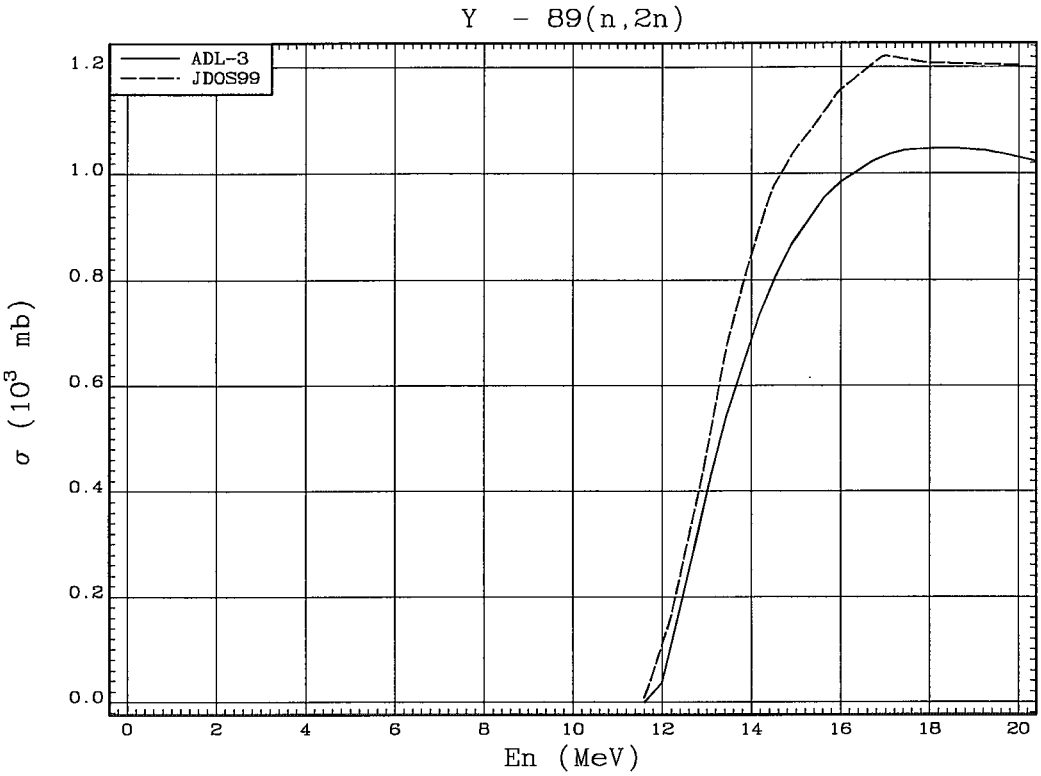

Fig.41. ^{89}Y(n,2n)^{88}Y reaction cross section.

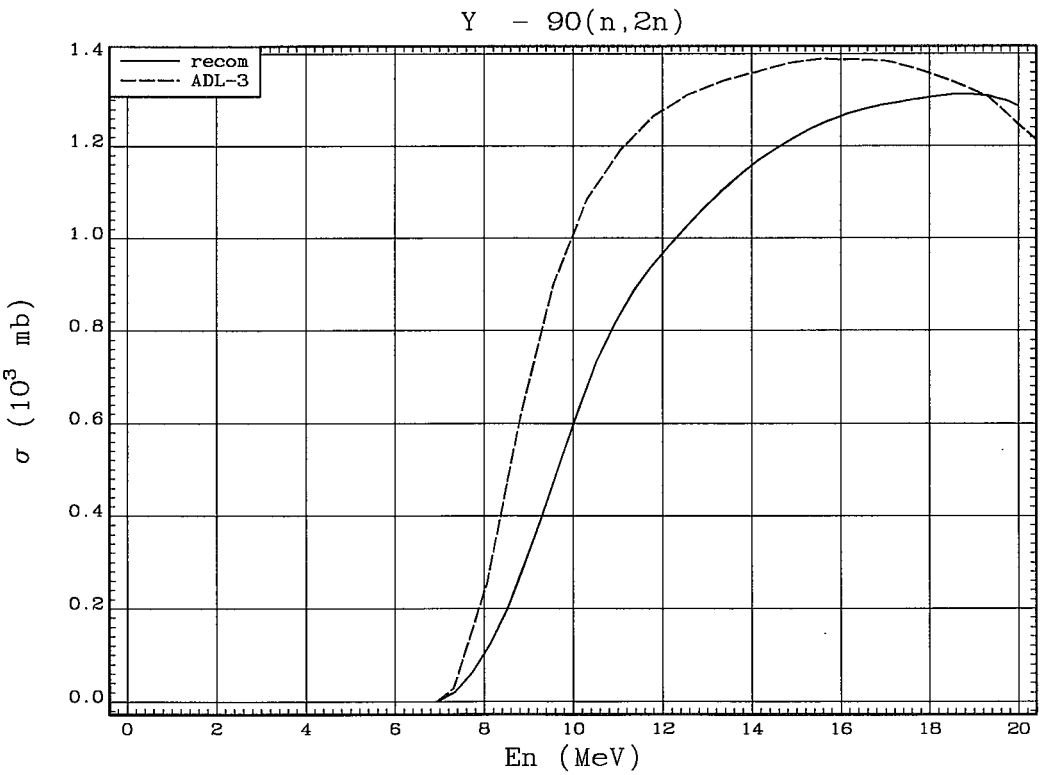

Fig.42. ^{90}Y(n,2n)^{89}Y reaction cross section.

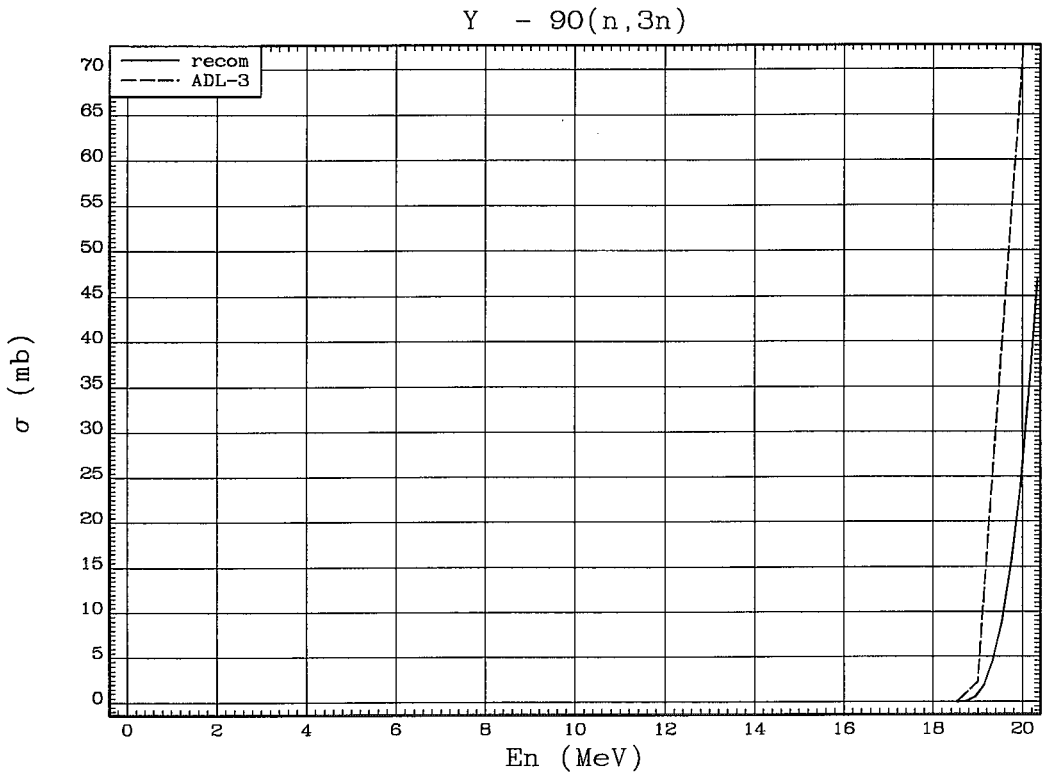

Fig. 43. $^{90}Y(n,3n)^{88}Y$ reaction cross section.

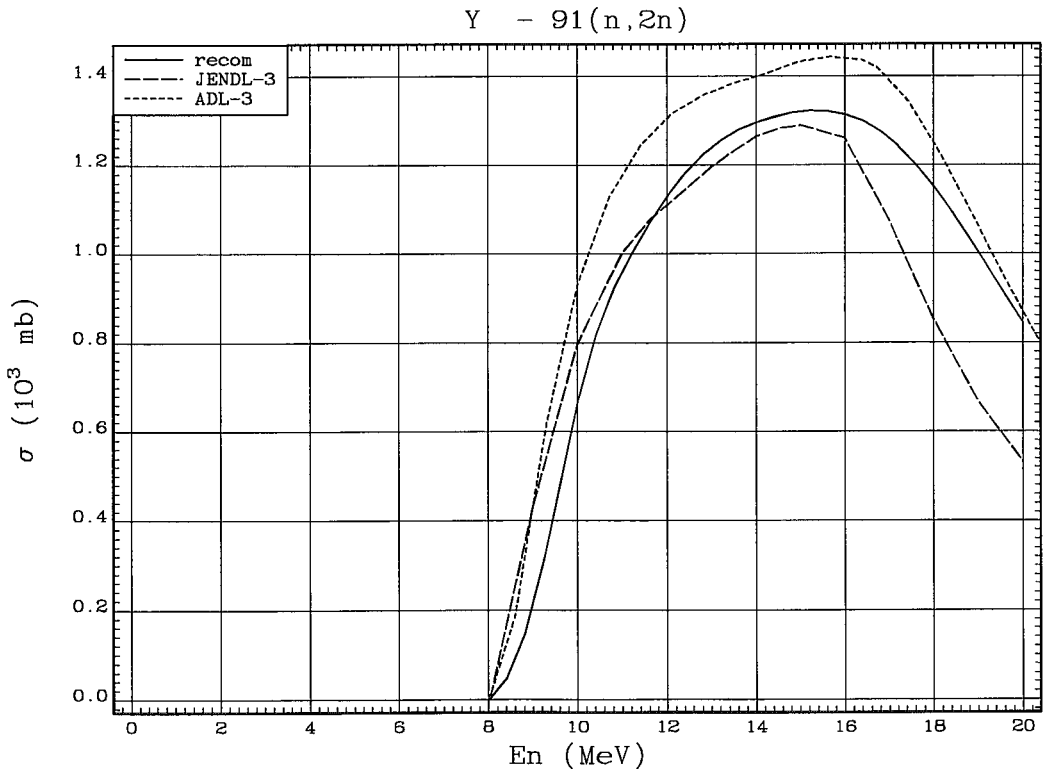

Fig.44. $^{91}Y(n,2n)^{90}Y$ reaction cross section.

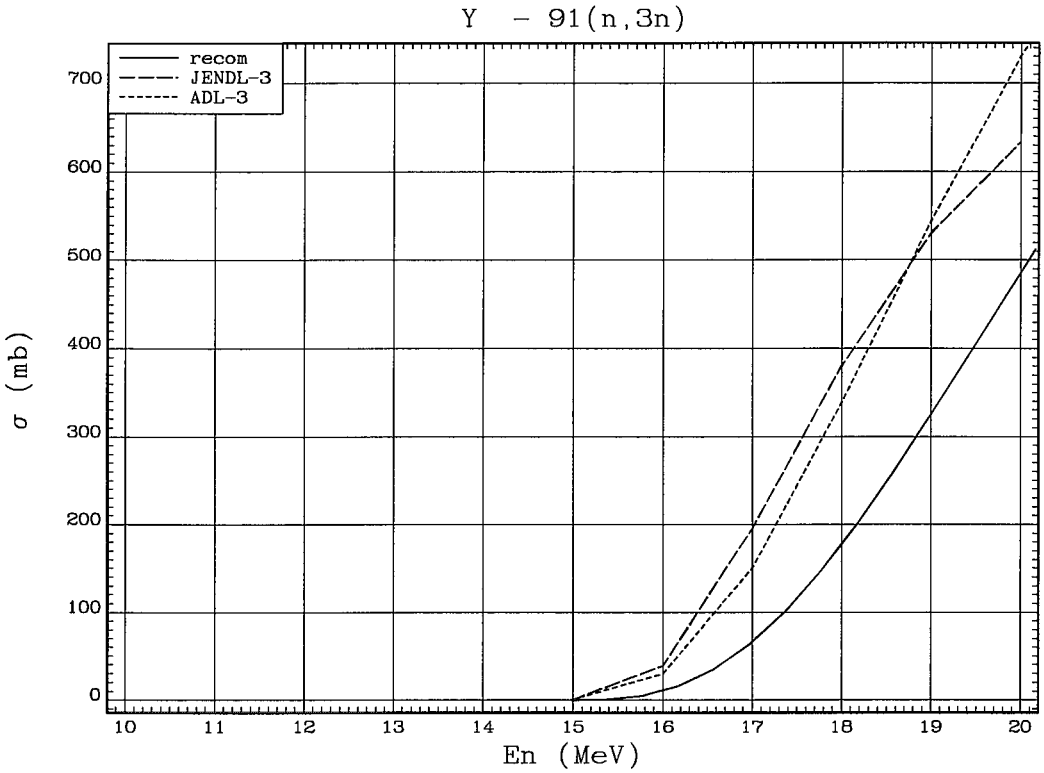

Fig.45. $^{91}Y(n,3n)^{89}Y$ reaction cross section.

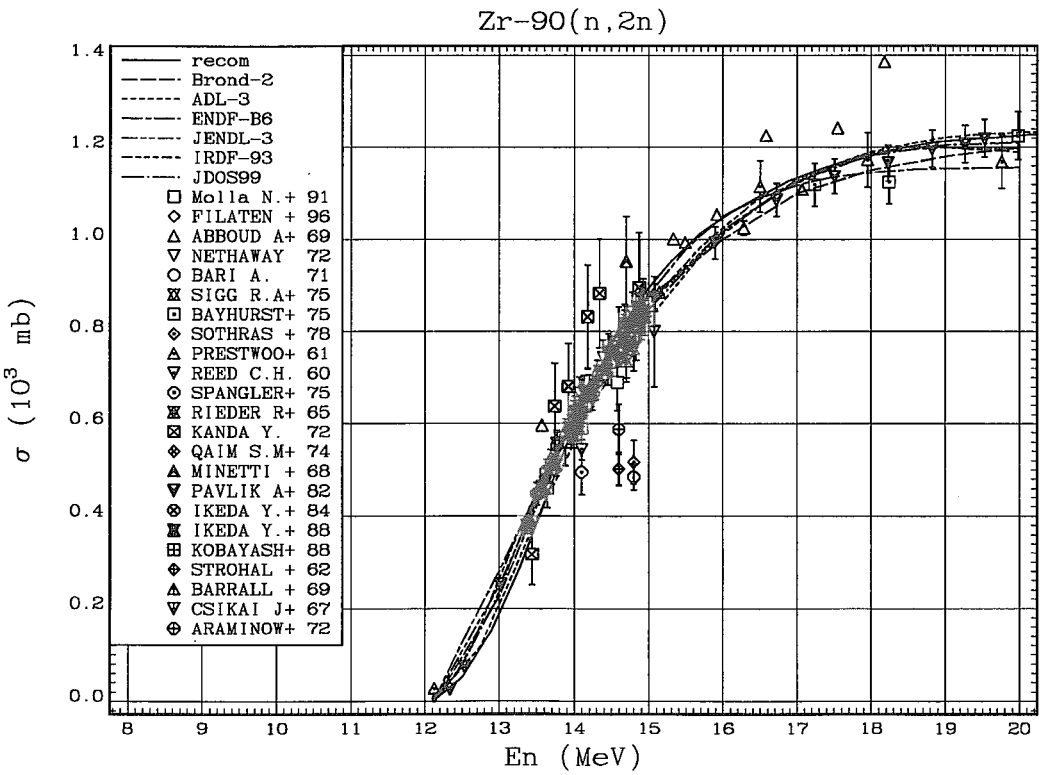

Fig.46. $^{90}Zr(n,2n)^{89}Zr$ reaction cross section.

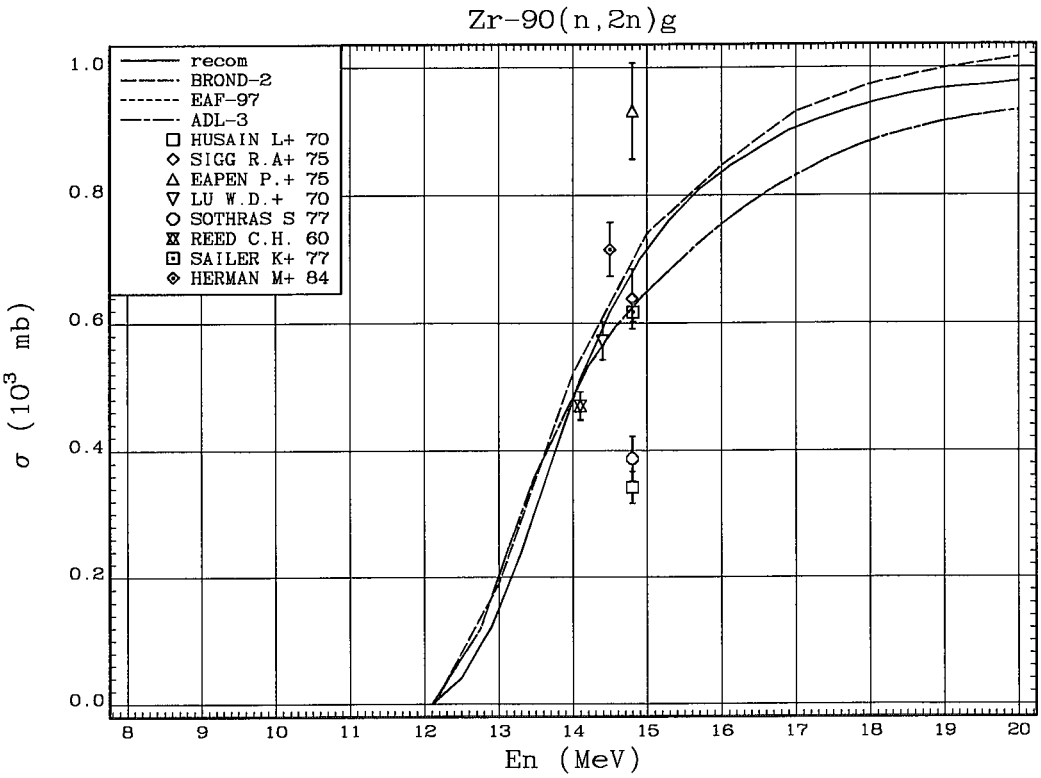

Fig.47. ^{90}Zr(n,2n)^{89g}Zr reaction cross section.

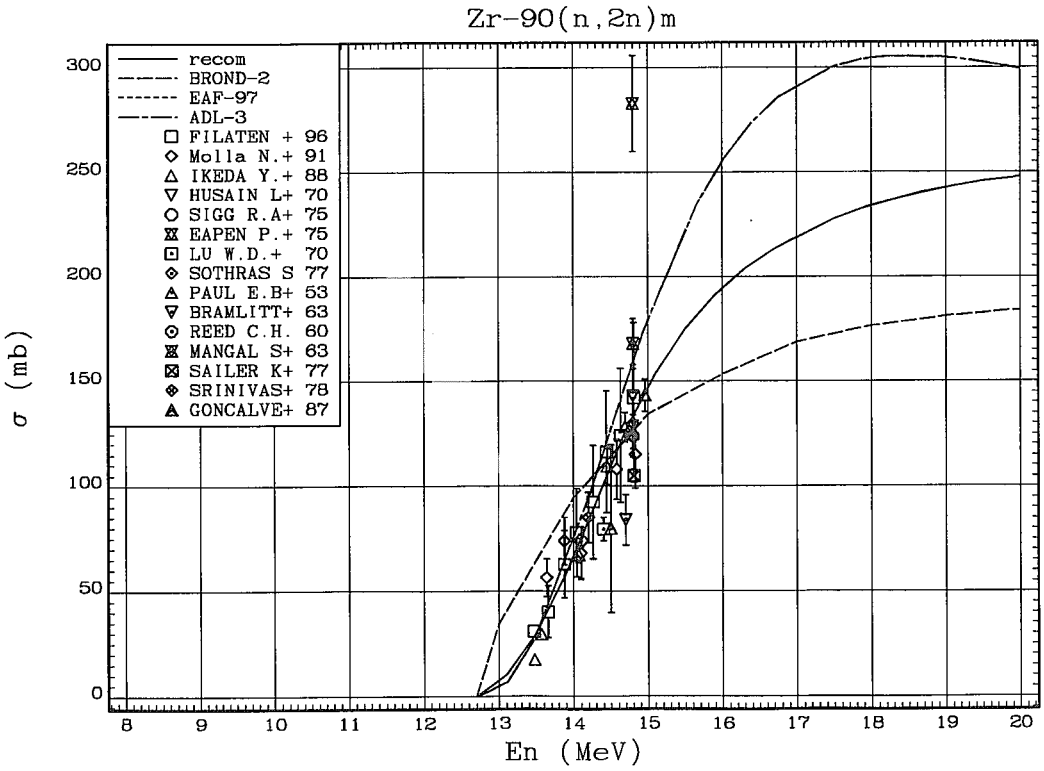

Fig.48. ^{90}Zr(n,2n)^{89m}Zr reaction cross section.

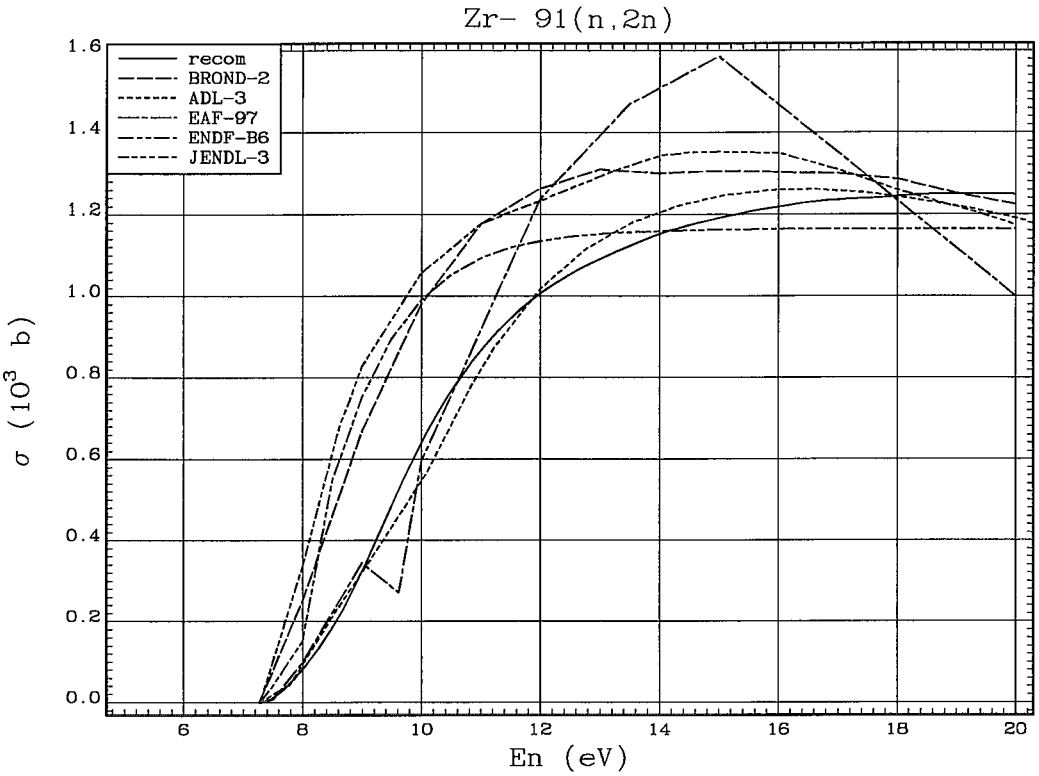

Fig.49. ^{91}Zr(n,2n)^{90}Zr reaction cross section.

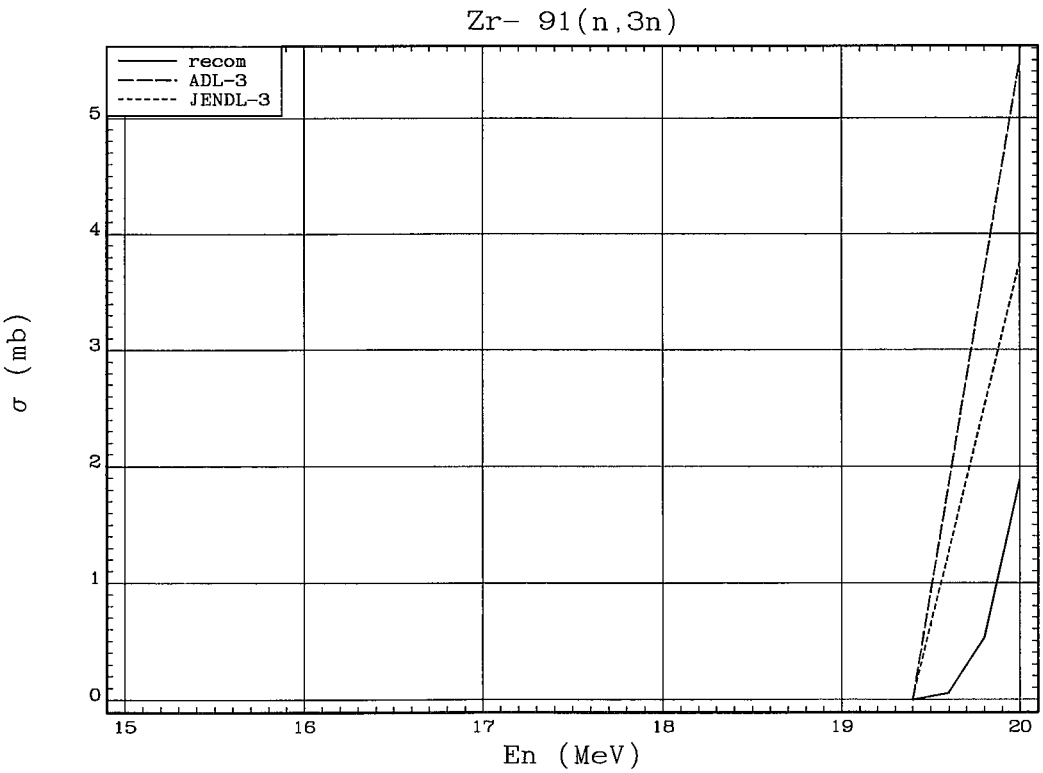

Fig.50. ^{91}Zr(n,3n)^{89}Zr reaction cross section.

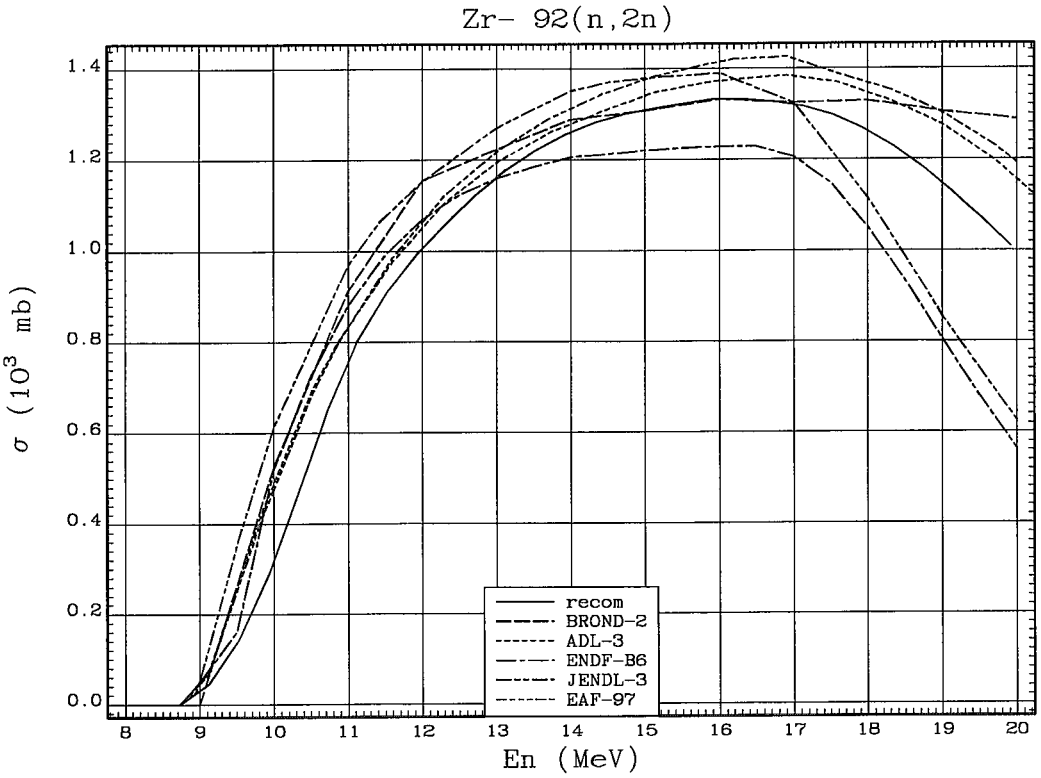

Fig.51. ^{92}Zr(n,2n)^{91}Zr reaction cross section.

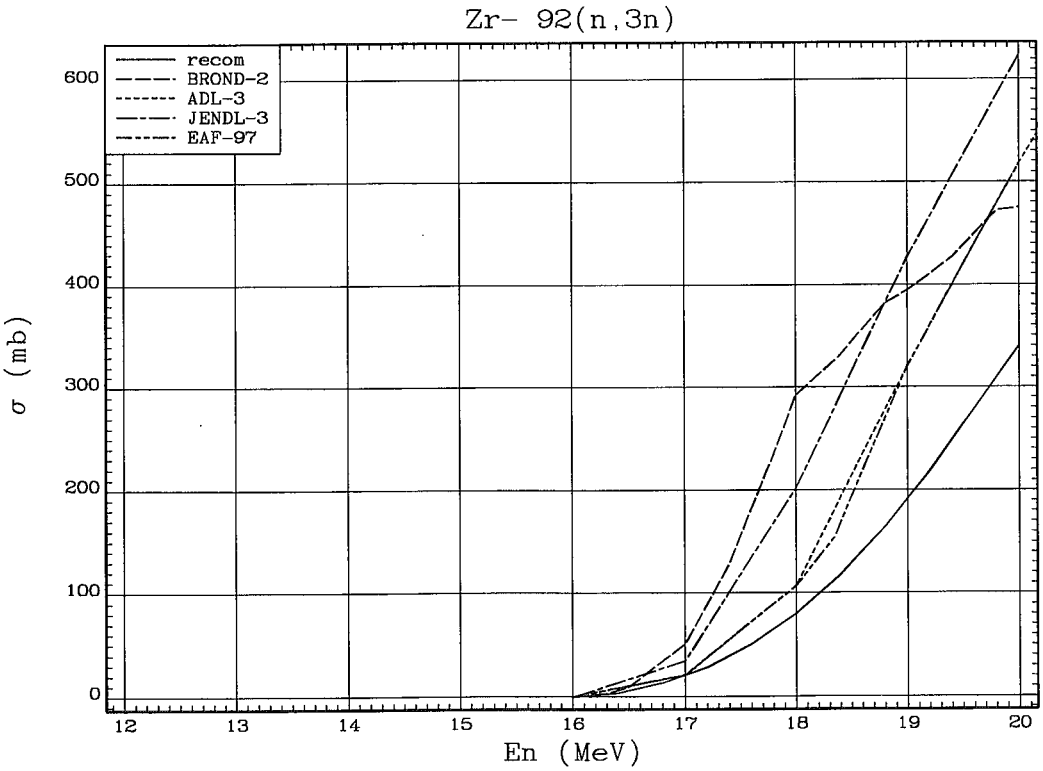

Fig.52. ^{92}Zr(n,3n)^{90}Zr reaction cross section.

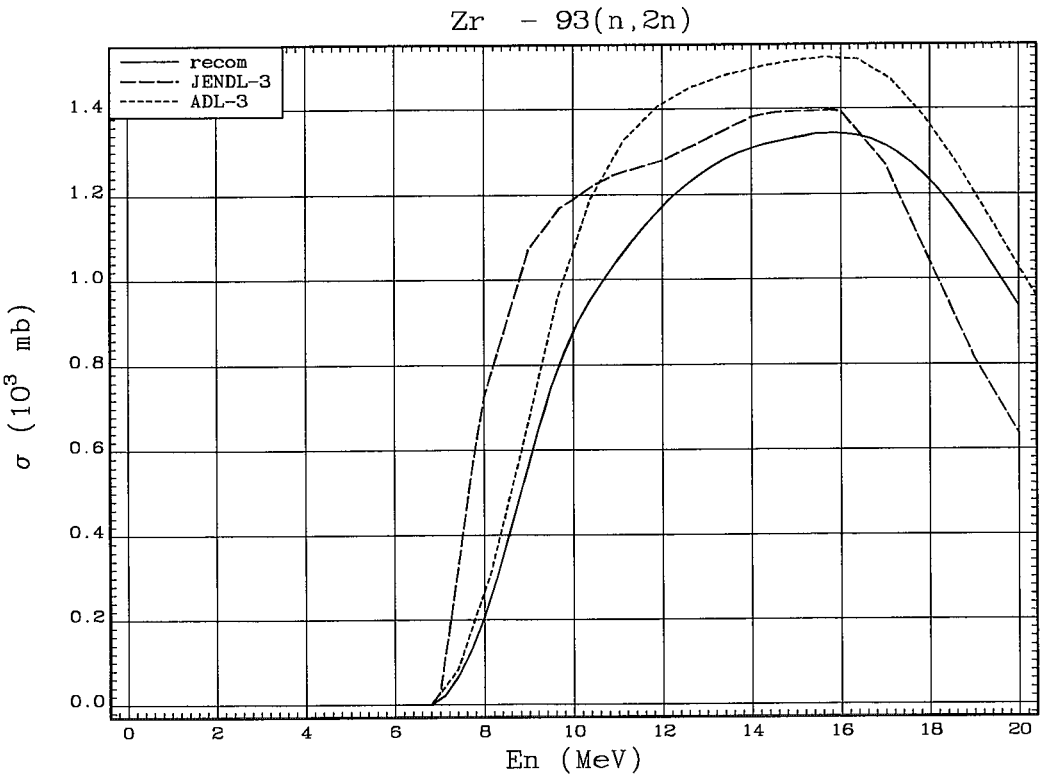

Fig.53. ^{93}Zr(n,2n)^{92}Zr reaction cross section.

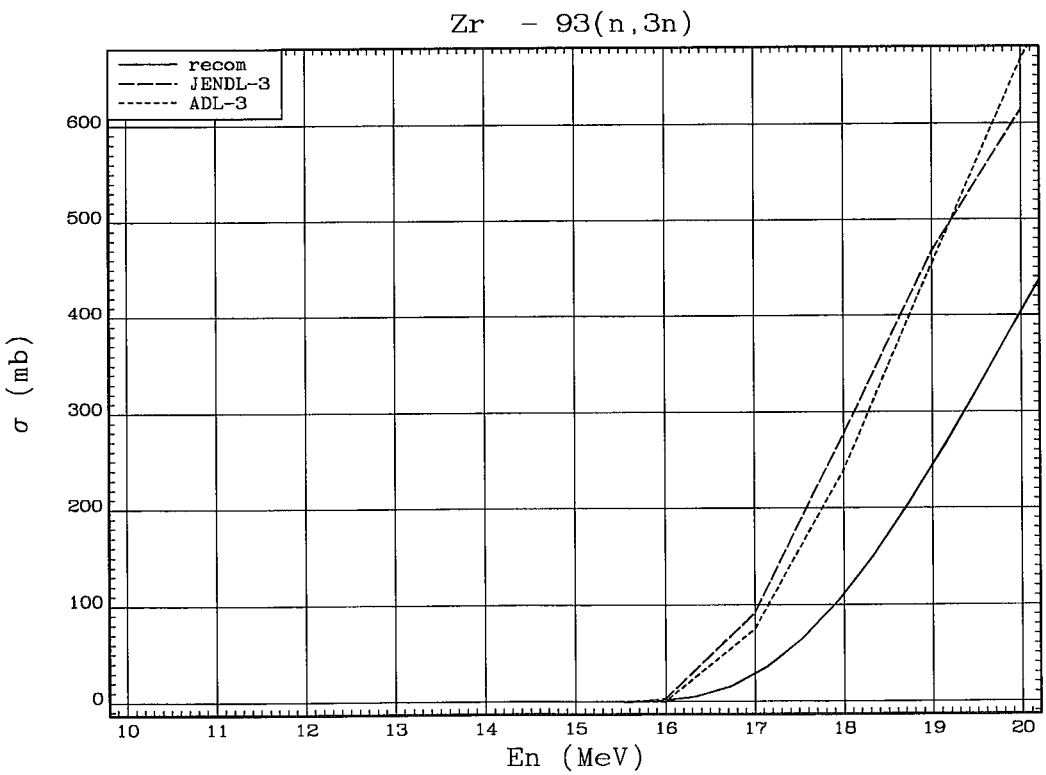

Fig.54. ^{93}Zr(n,3n)^{91}Zr reaction cross section.

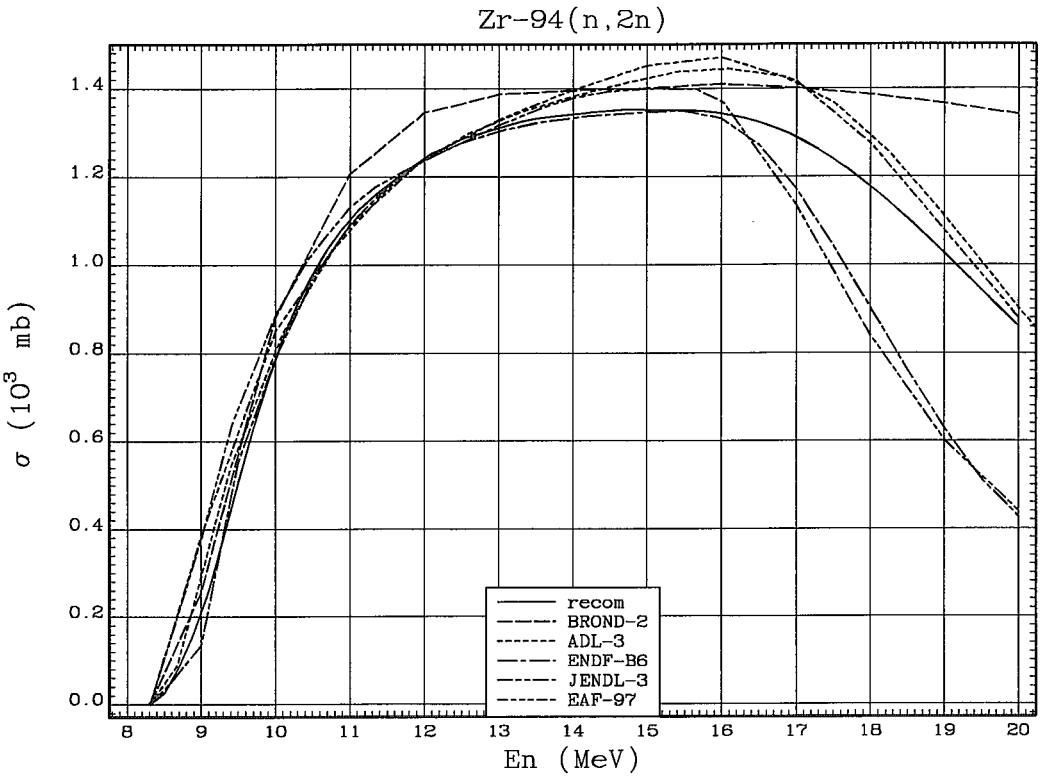

Fig.55. ^{94}Zr(n,2n)^{93}Zr reaction cross section.

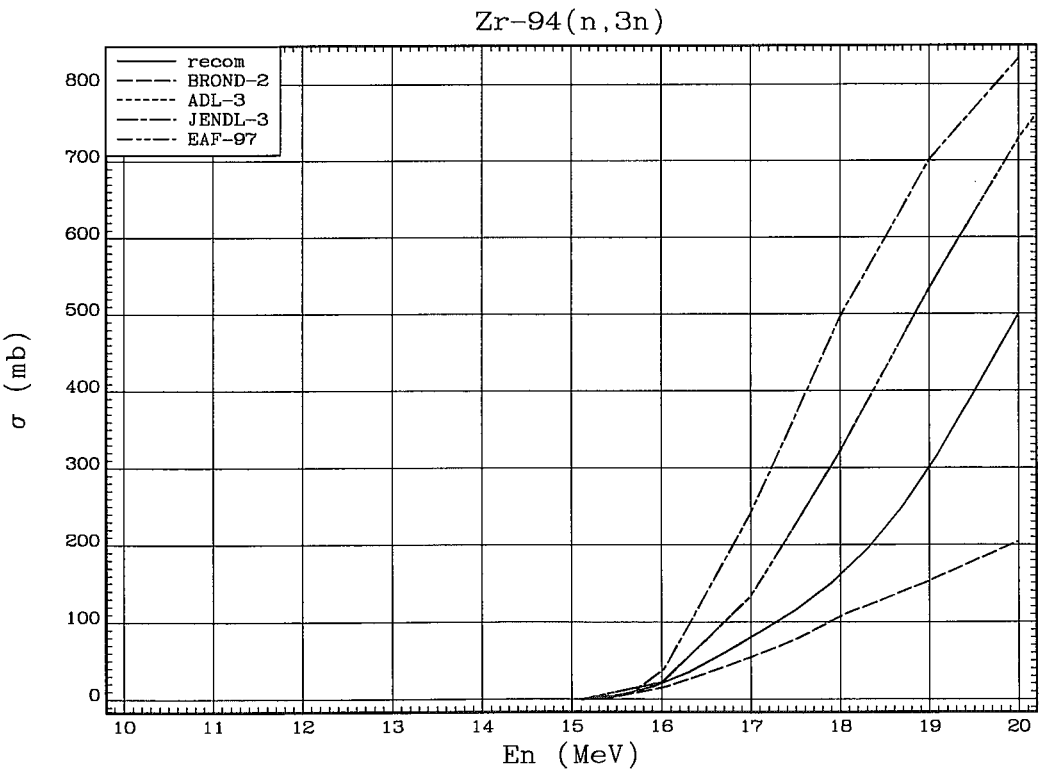

Fig.56. ^{94}Zr(n,3n)^{92}Zr reaction cross section.

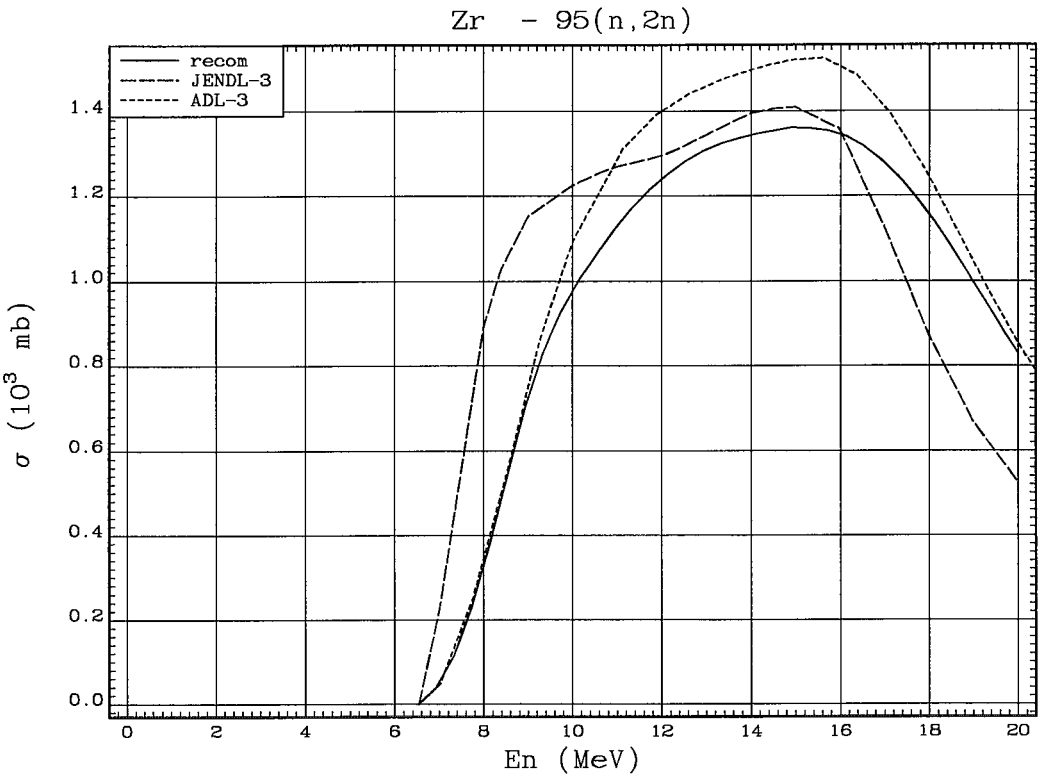

Fig.57. ^{95}Zr(n,2n)^{94}Zr reaction cross section.

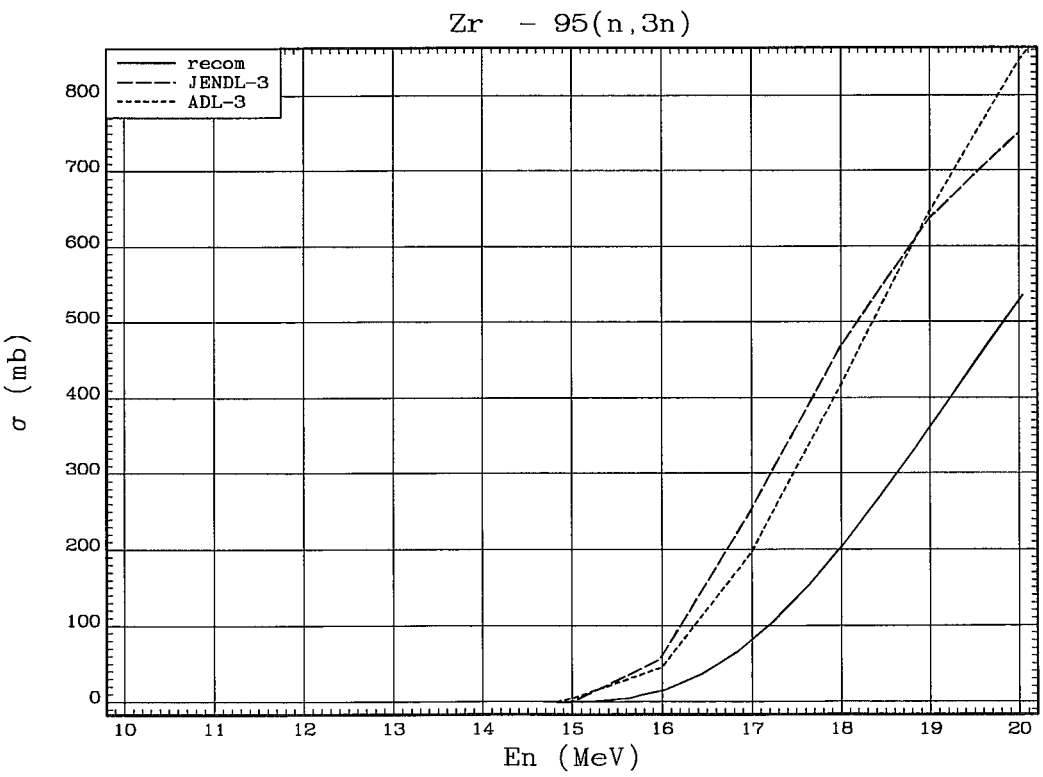

Fig.58. ^{95}Zr(n,3n)^{93}Zr reaction cross section.

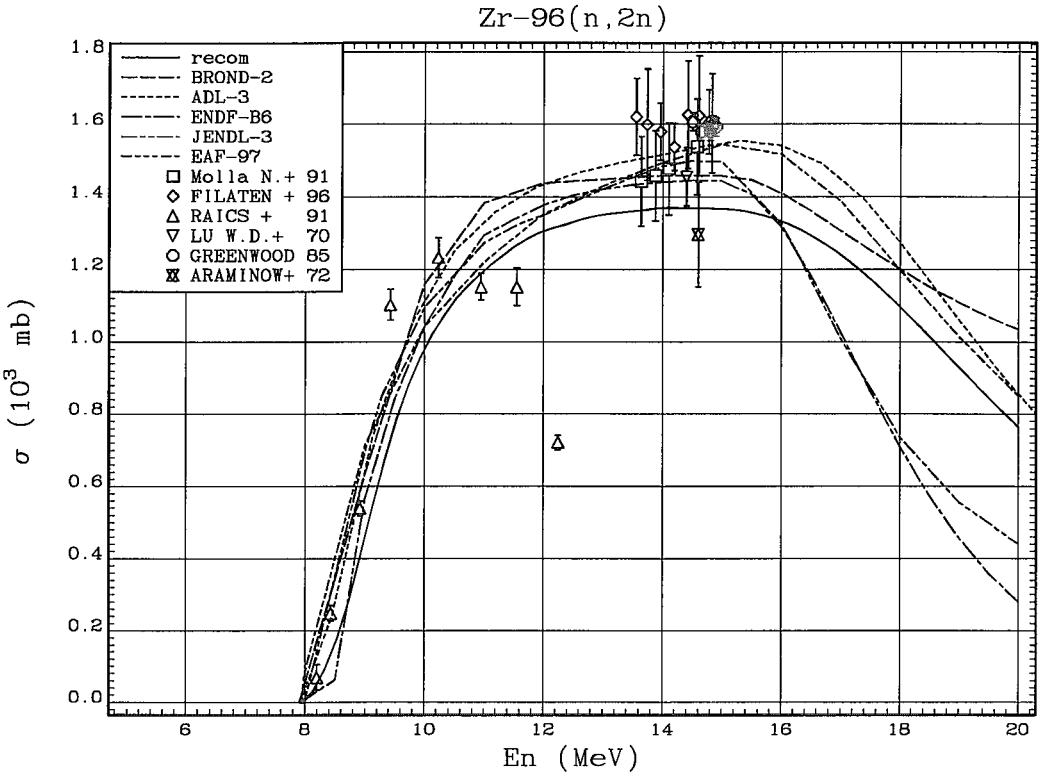

Fig.59. ^{96}Zr(n,2n)^{95}Zr reaction cross section.

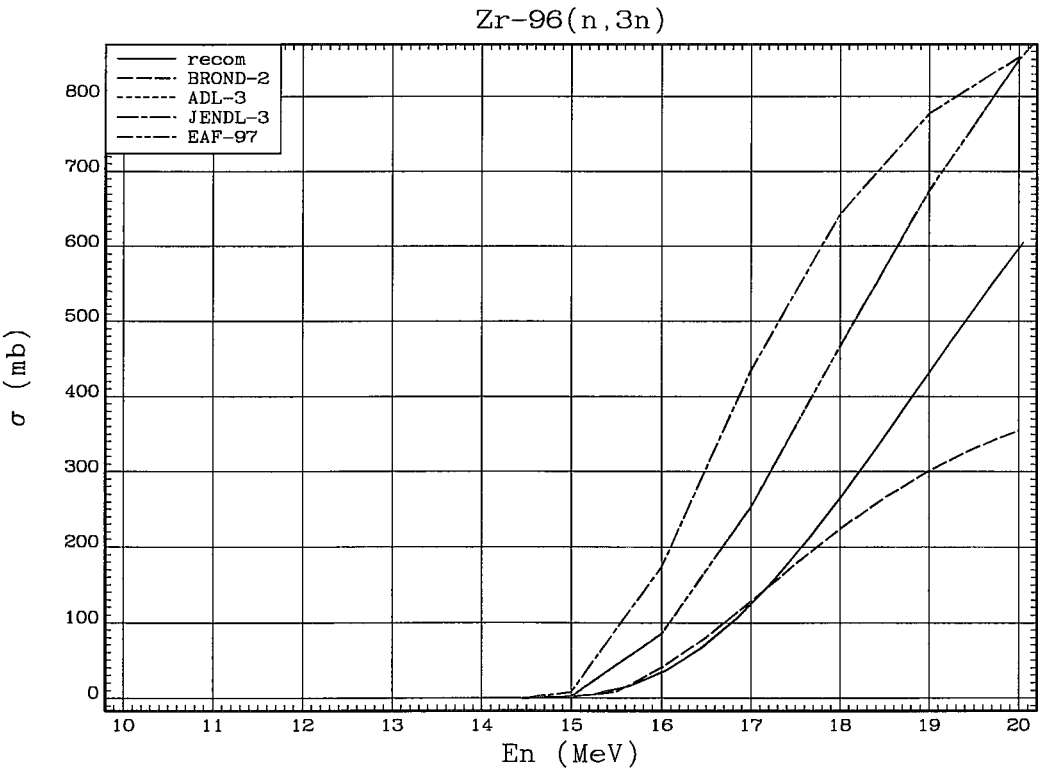

Fig.60. ^{96}Zr(n,3n)^{94}Zr reaction cross section.

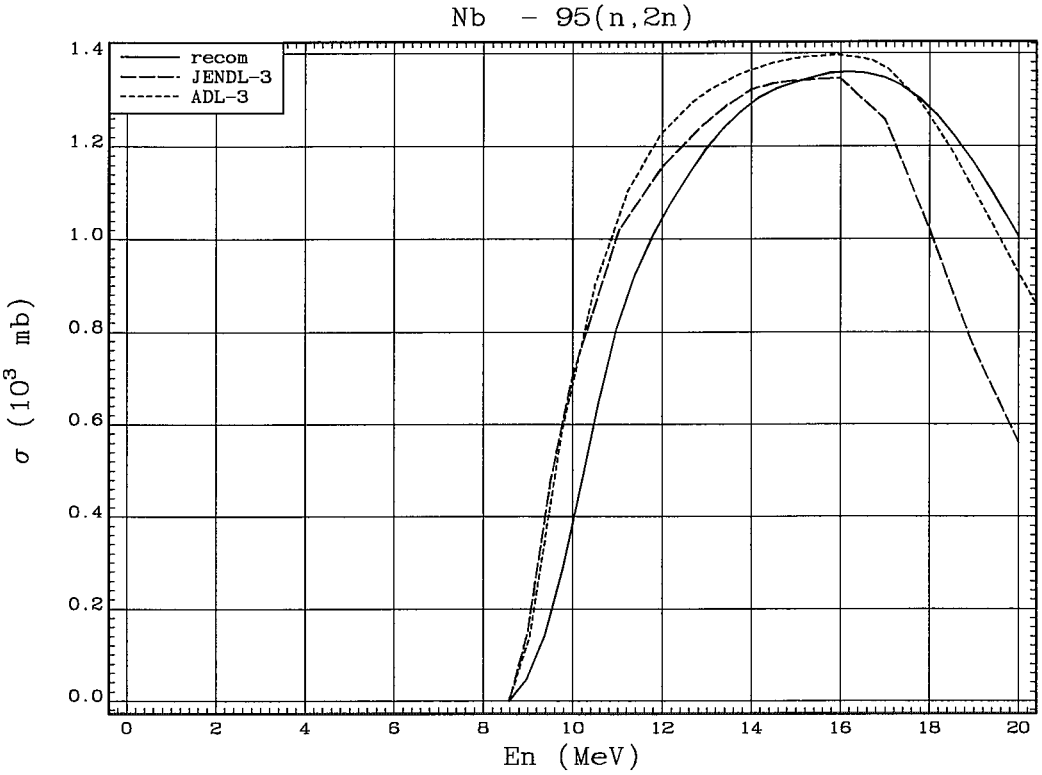

Fig. 61. ^{95}Nb(n,2n)^{94}Nb reaction cross section.

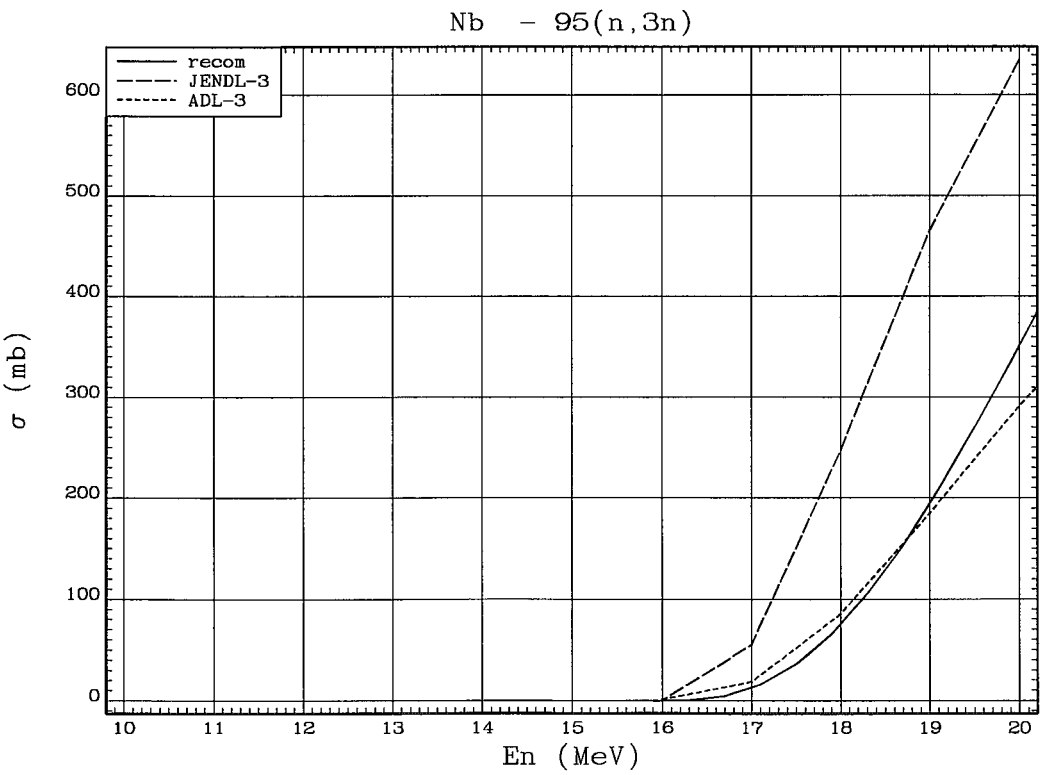

Fig. 62. ^{95}Nb(n,3n)^{93}Nb reaction cross section.

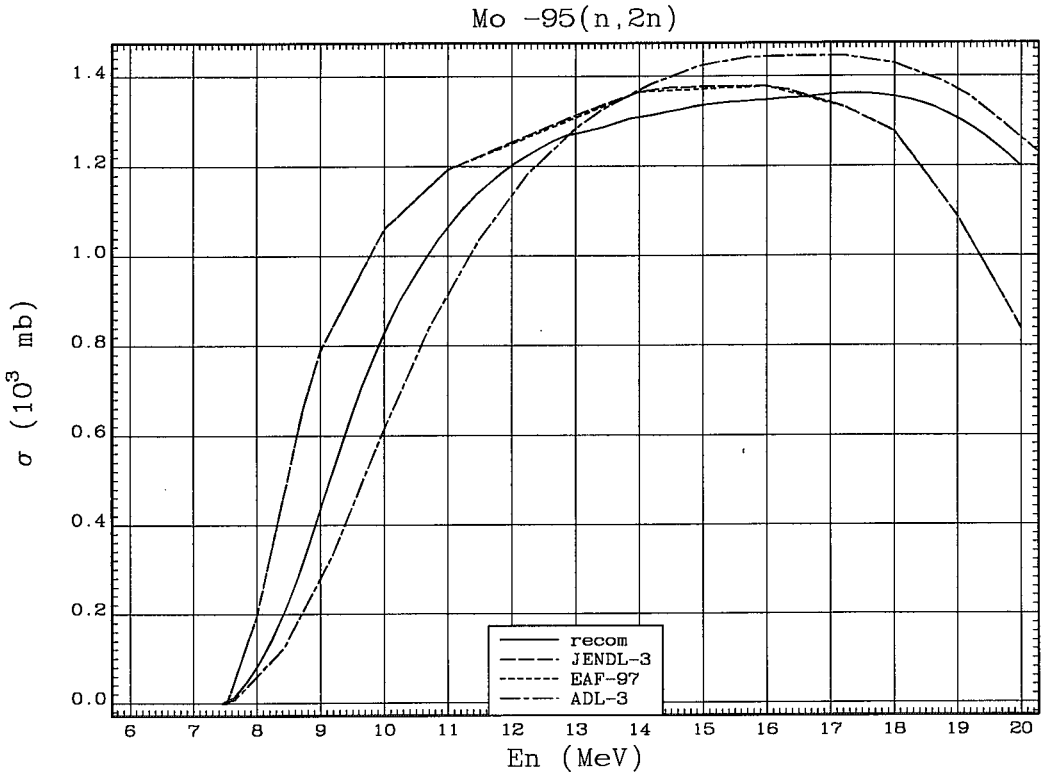

Fig. 63. ^{95}Mo(n,2n)^{94}Mo reaction cross section.

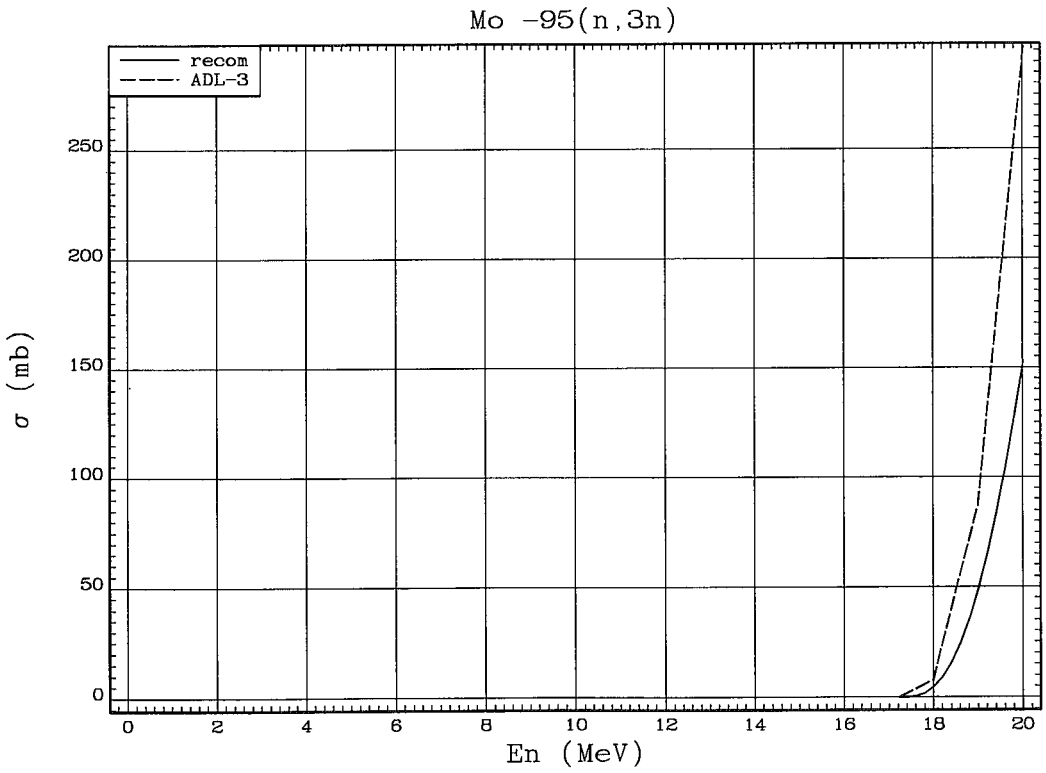

Fig. 64. ^{95}Mo(n,3n)^{93}Mo reaction cross section.

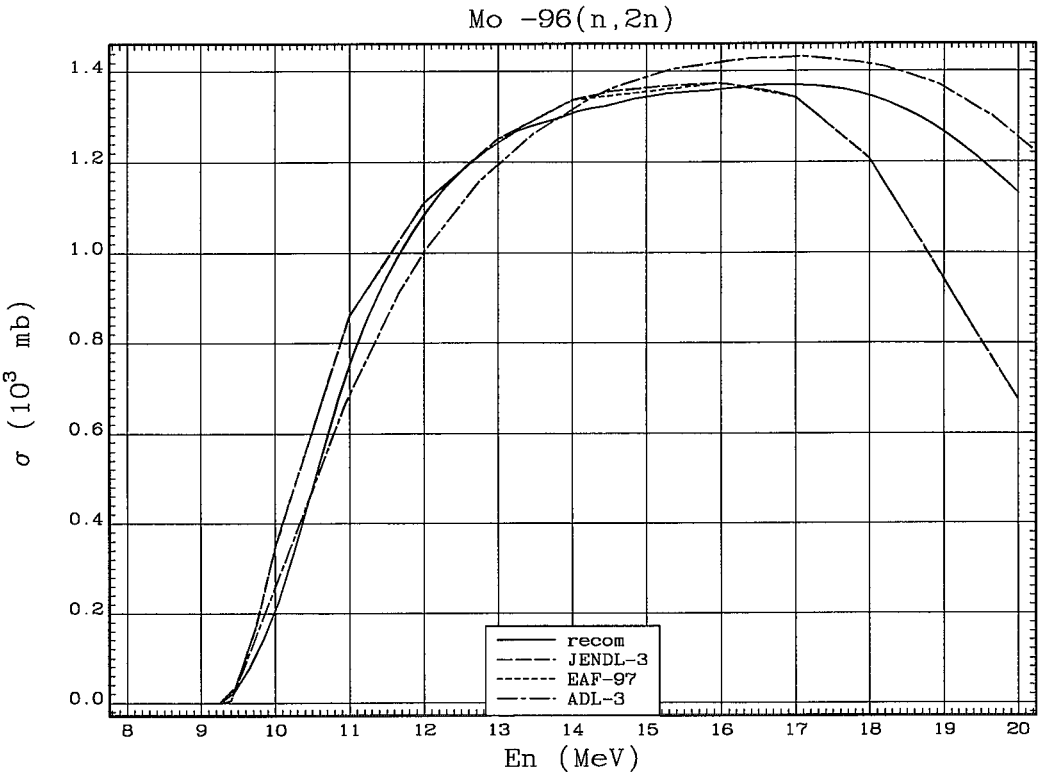

Fig.65. ^{96}Mo(n,2n)^{95}Mo reaction cross section.

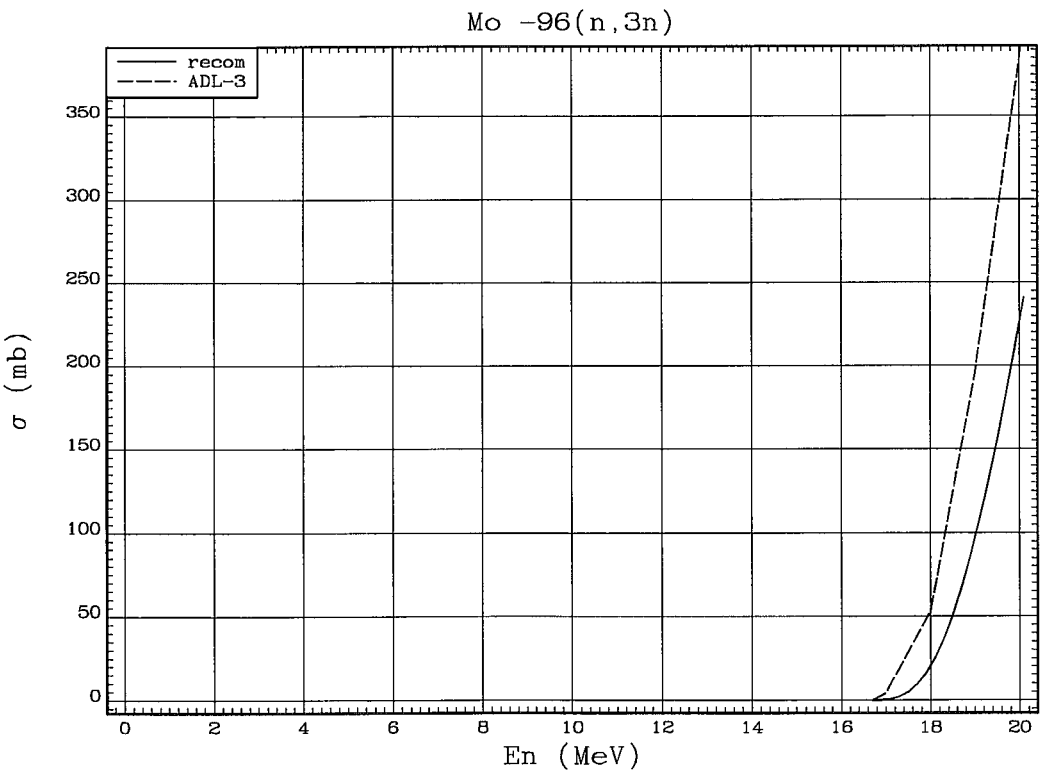

Fig.66. ^{96}Mo(n,3n)^{94}Mo reaction cross section.

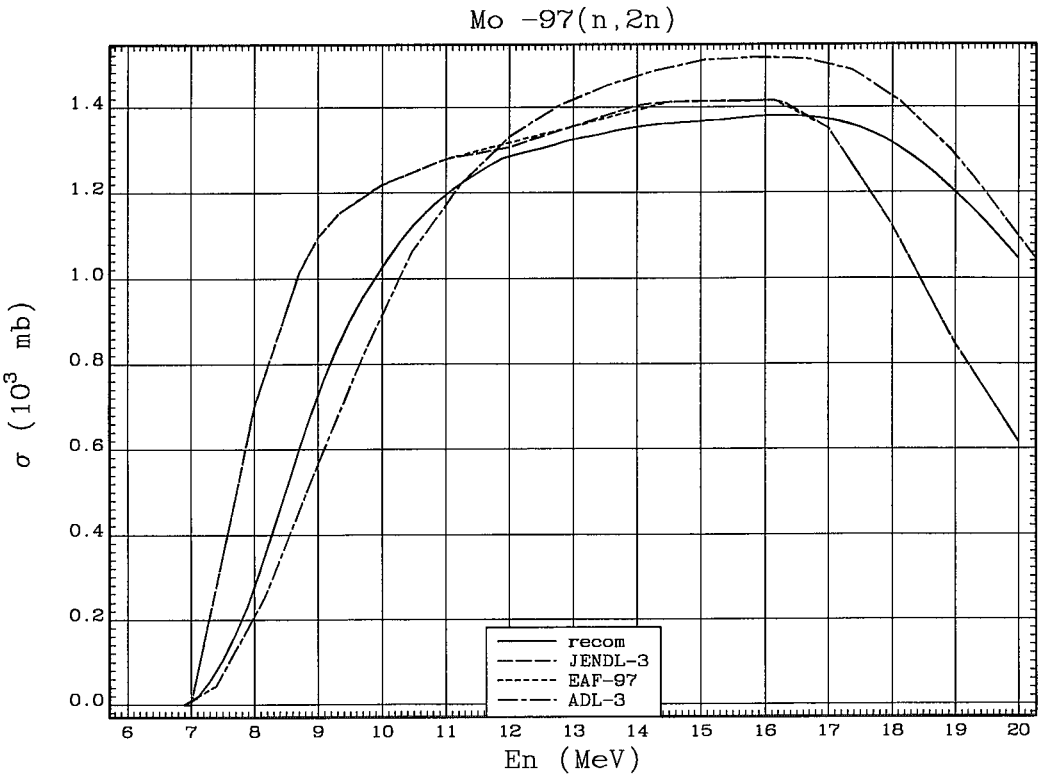

Fig. 67. ^{97}Mo (n, 2n) ^{96}Mo reaction cross section.

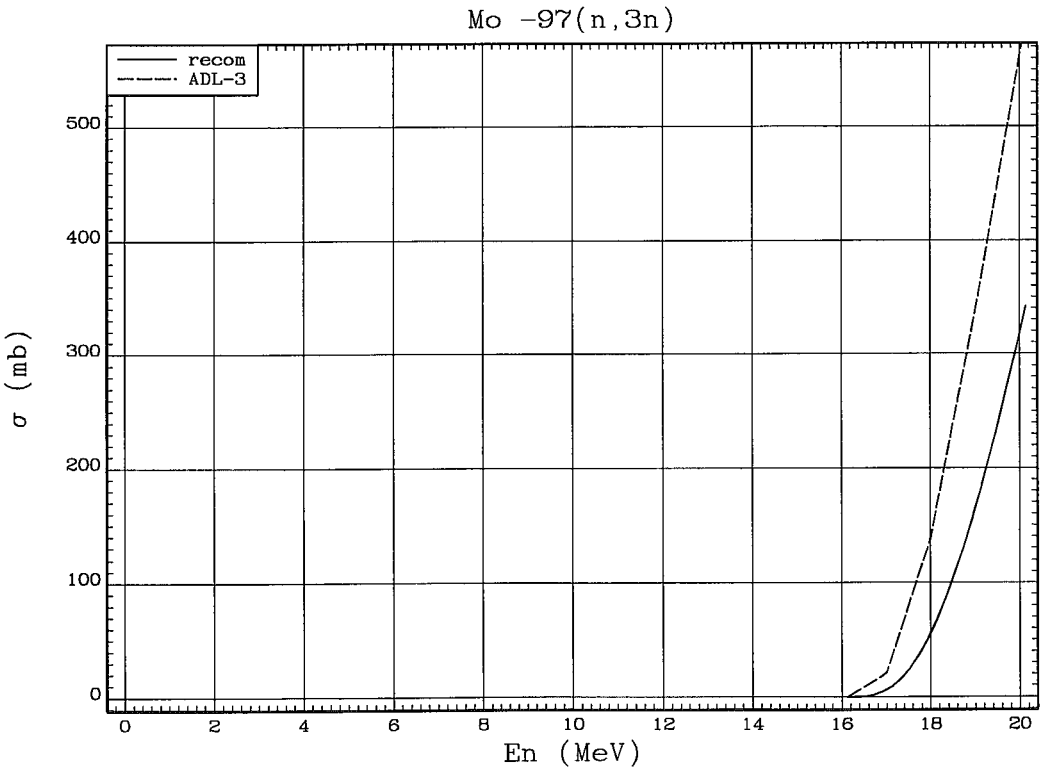

Fig. 68. ^{97}Mo (n, 3n) ^{95}Mo reaction cross section.

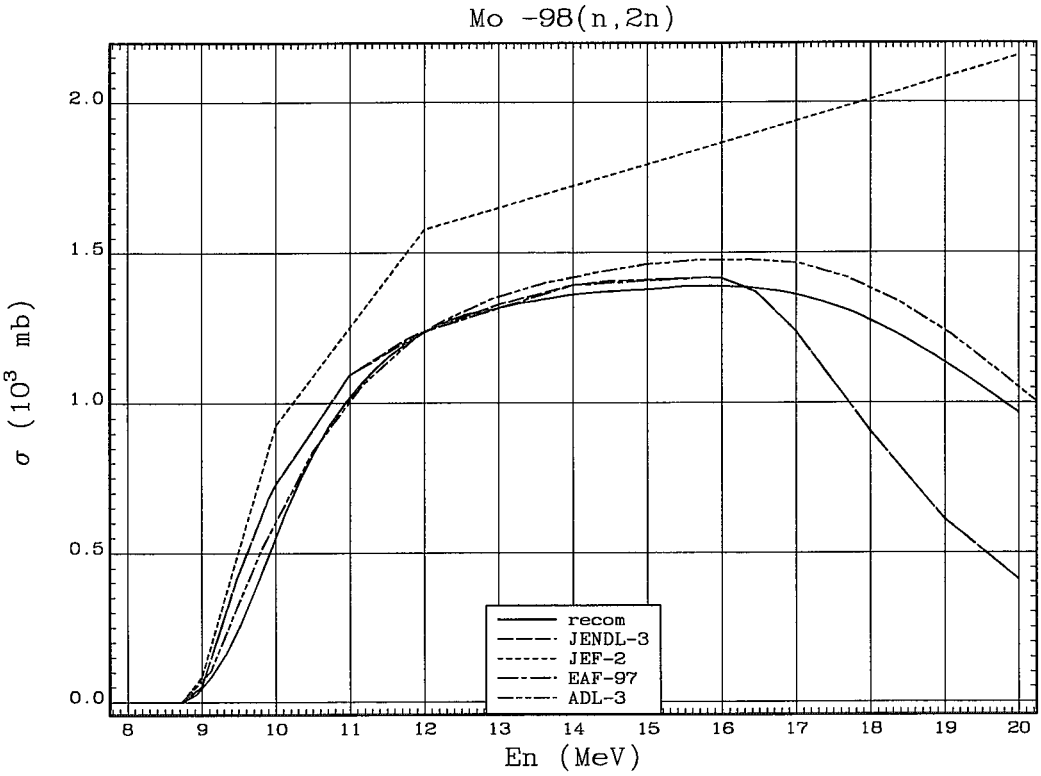

Fig.69. ^{98}Mo(n,2n)^{97}Mo reaction cross section.

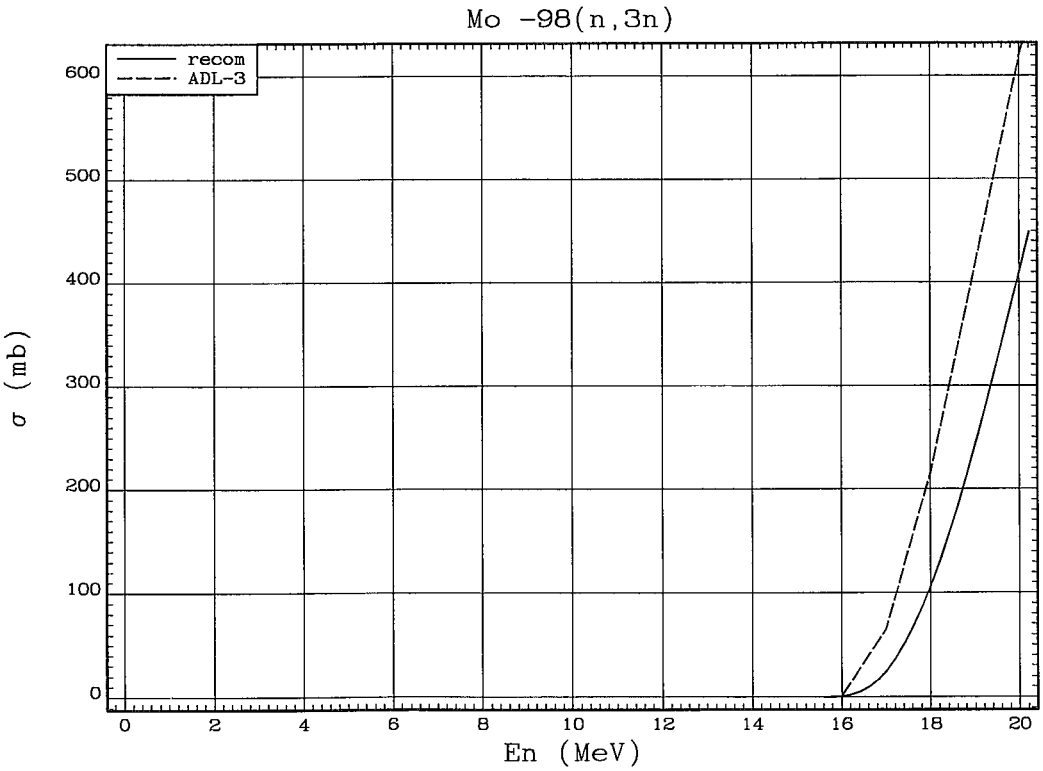

Fig.70. ^{98}Mo(n,3n)^{96}Mo reaction cross section.

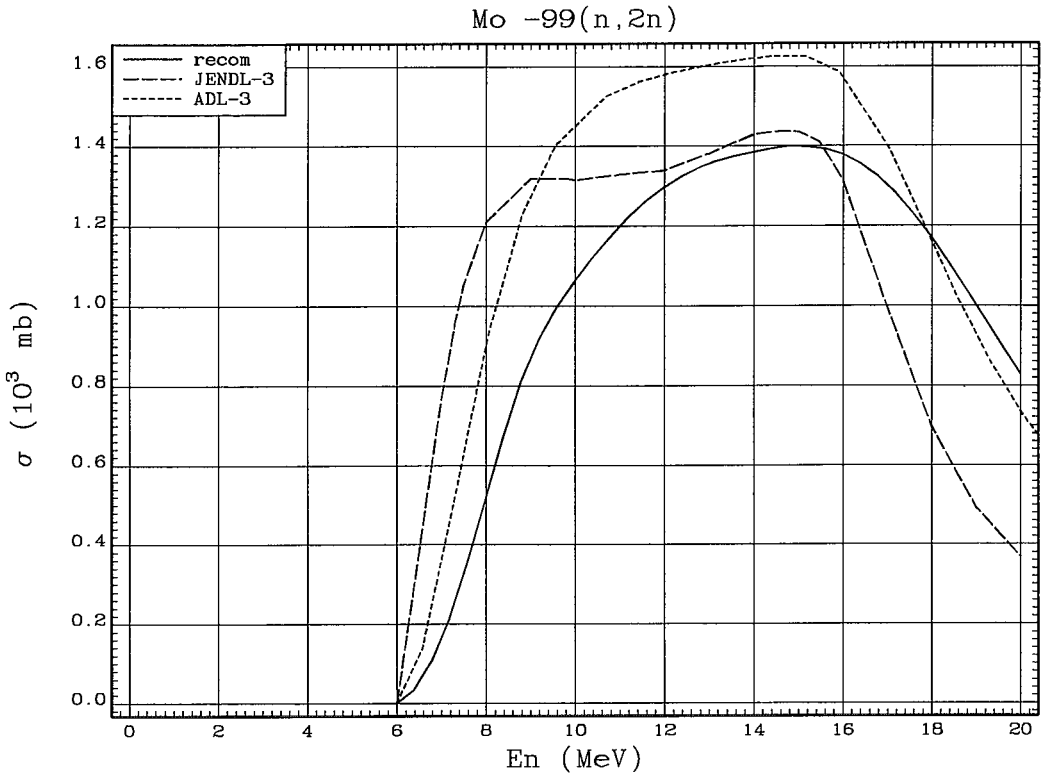

Fig.71. ^{99}Mo(n,2n)^{98}Mo reaction cross section.

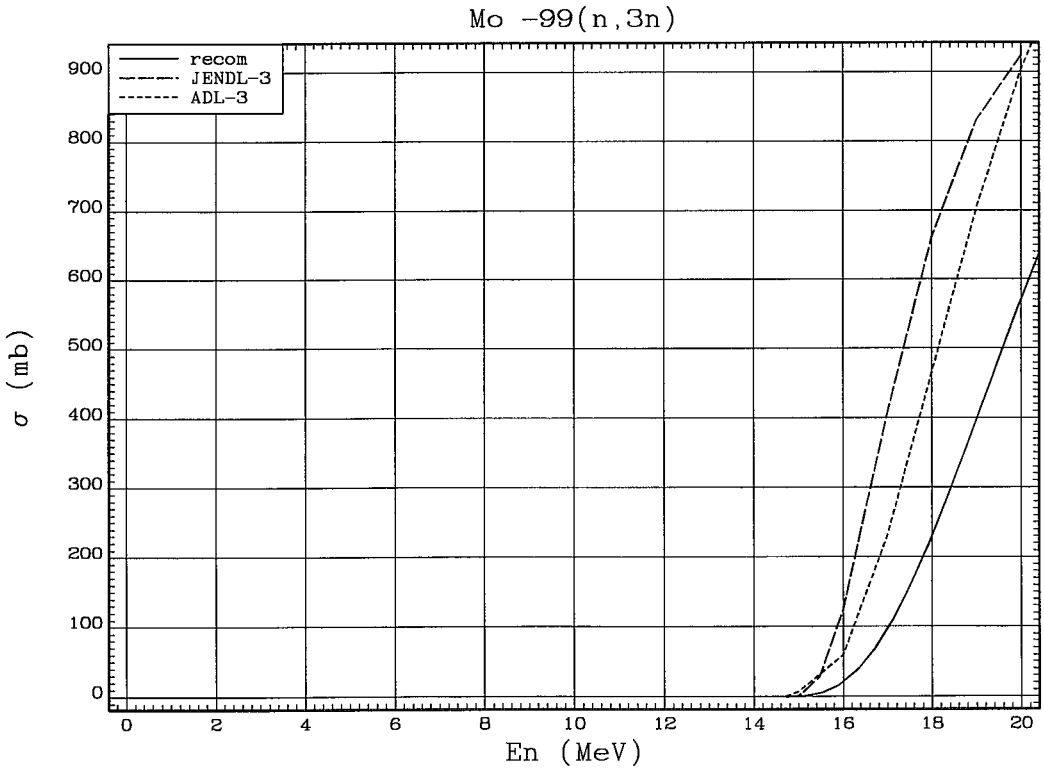

Fig.72. ^{99}Mo(n,3n)^{97}Mo reaction cross section.

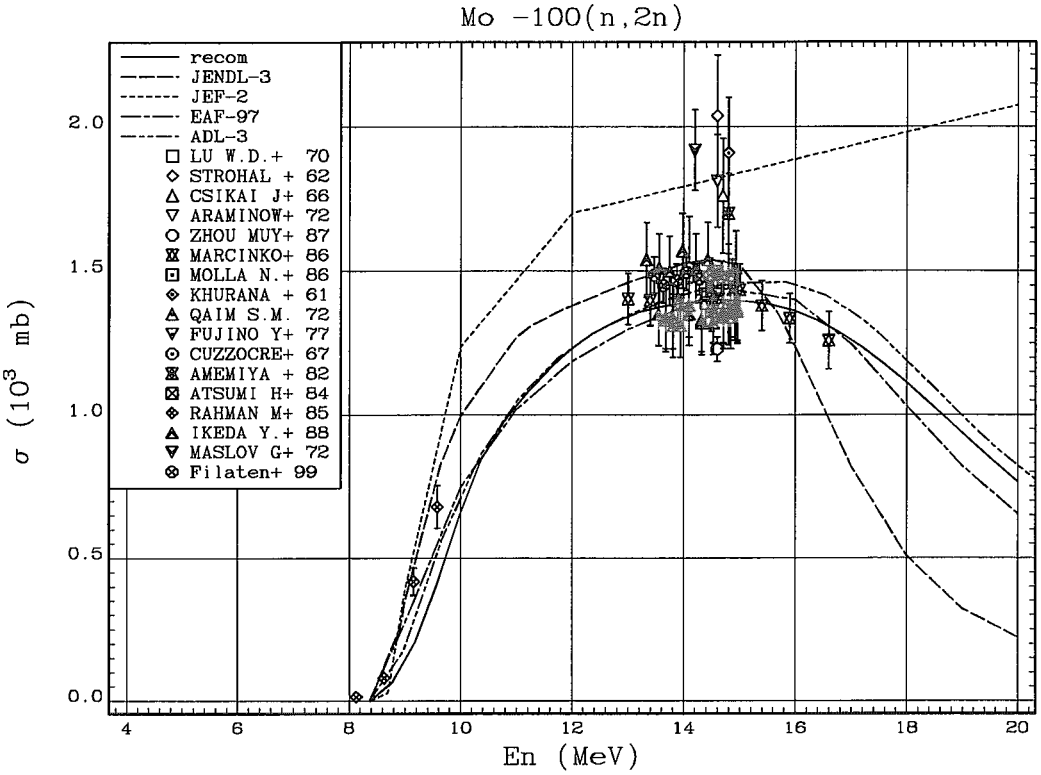

Fig. 73. ^{100}Mo (n, 2n) ^{99}Mo reaction cross section.

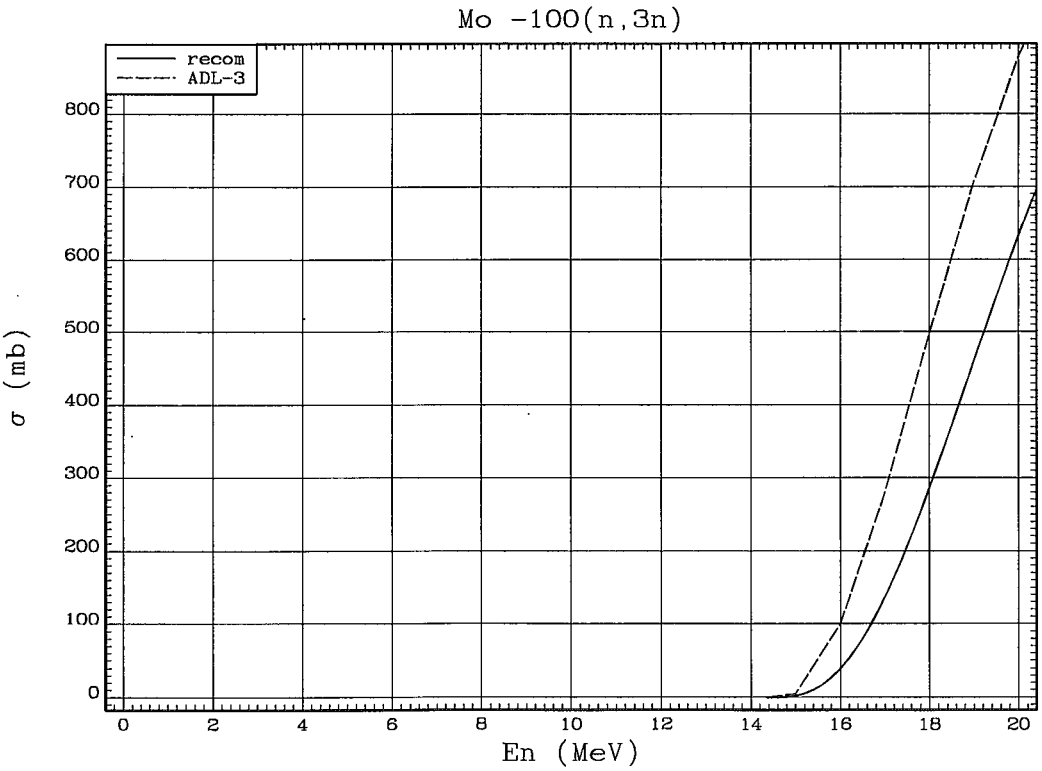

Fig. 74. ^{100}Mo (n, 3n) ^{98}Mo reaction cross section.

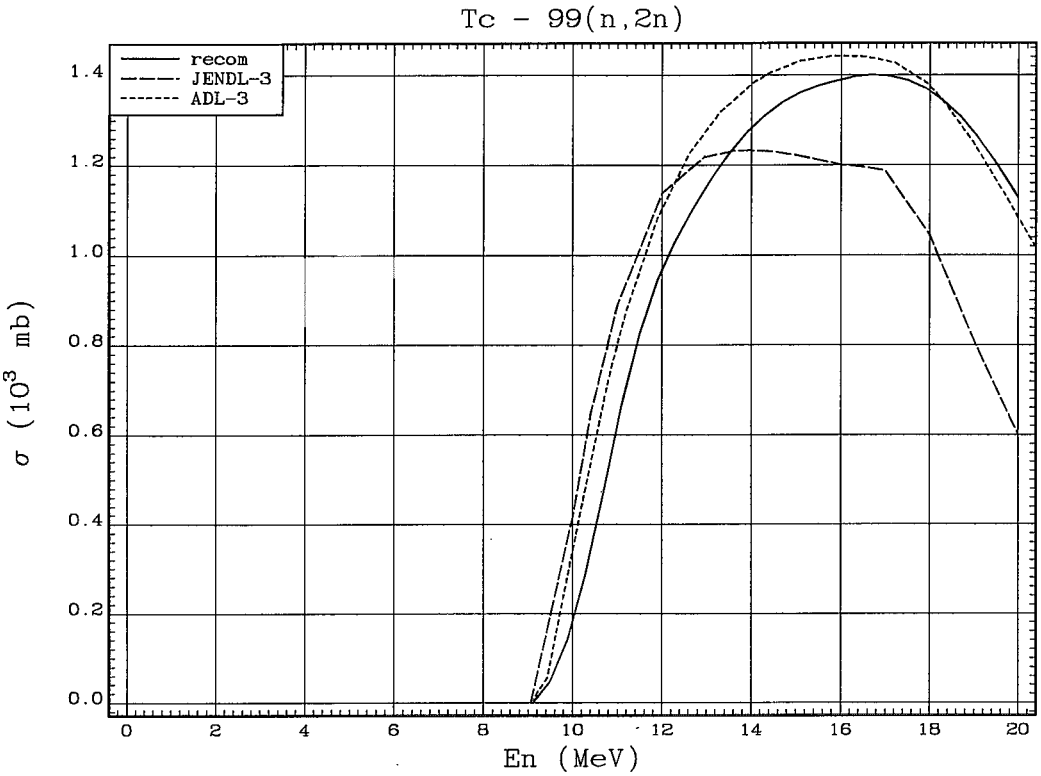

Fig.75. ^{99}Tc(n,2n)^{98}Tc reaction cross section.

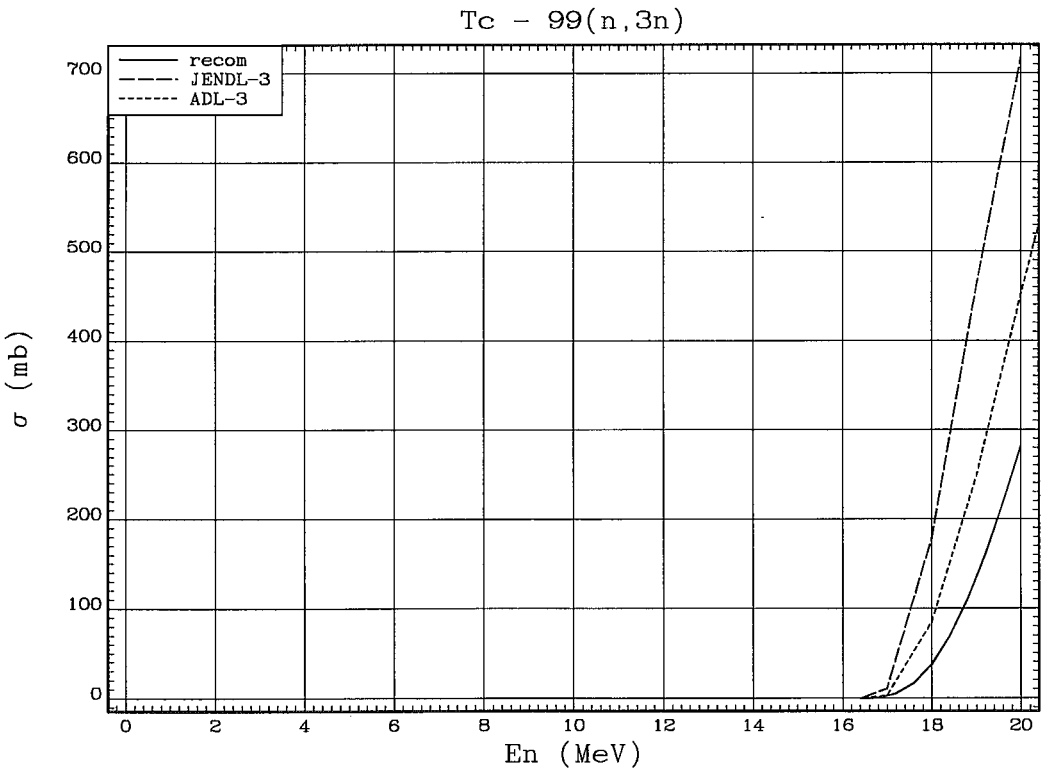

Fig.76. ^{99}Tc(n,3n)^{97}Tc reaction cross section.

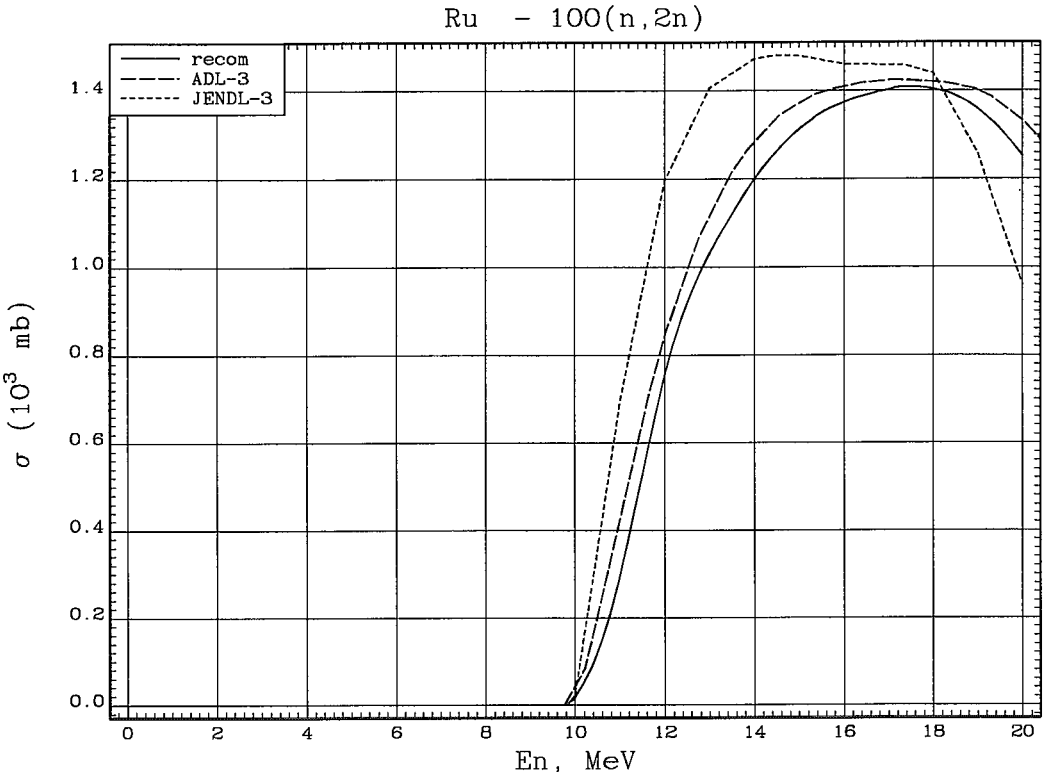

Fig.77. ^{100}Ru(n,2n)^{99}Ru reaction cross section.

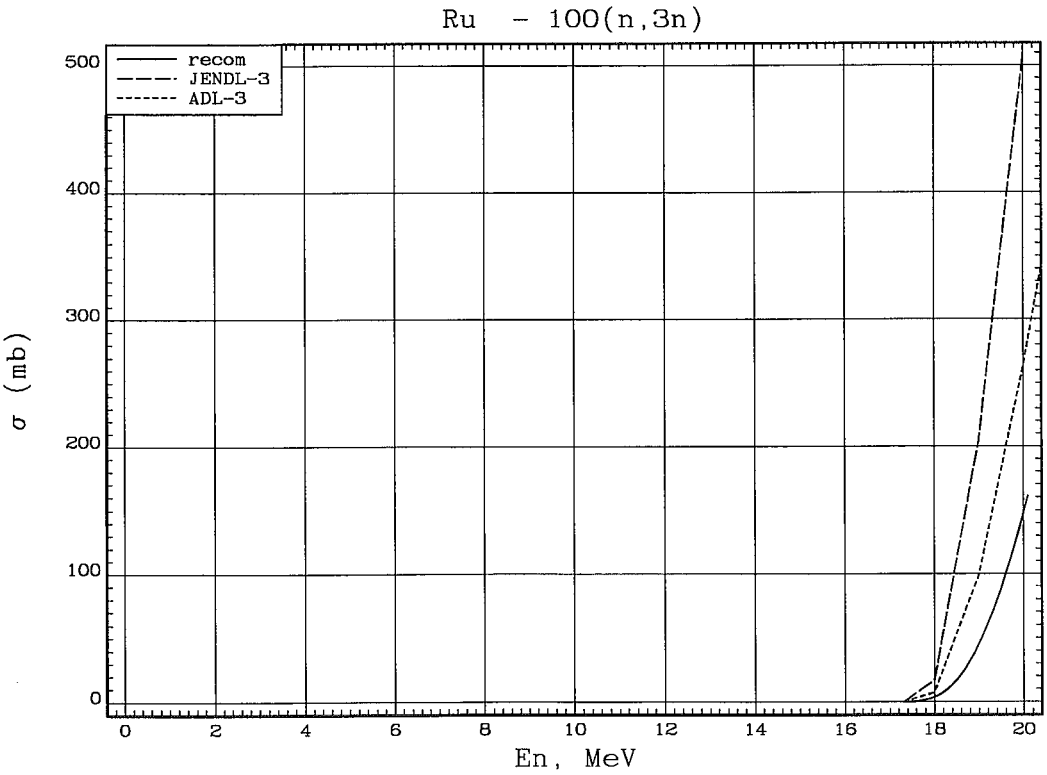

Fig. 78. ^{100}Ru(n,3n)^{98}Ru reaction cross section.

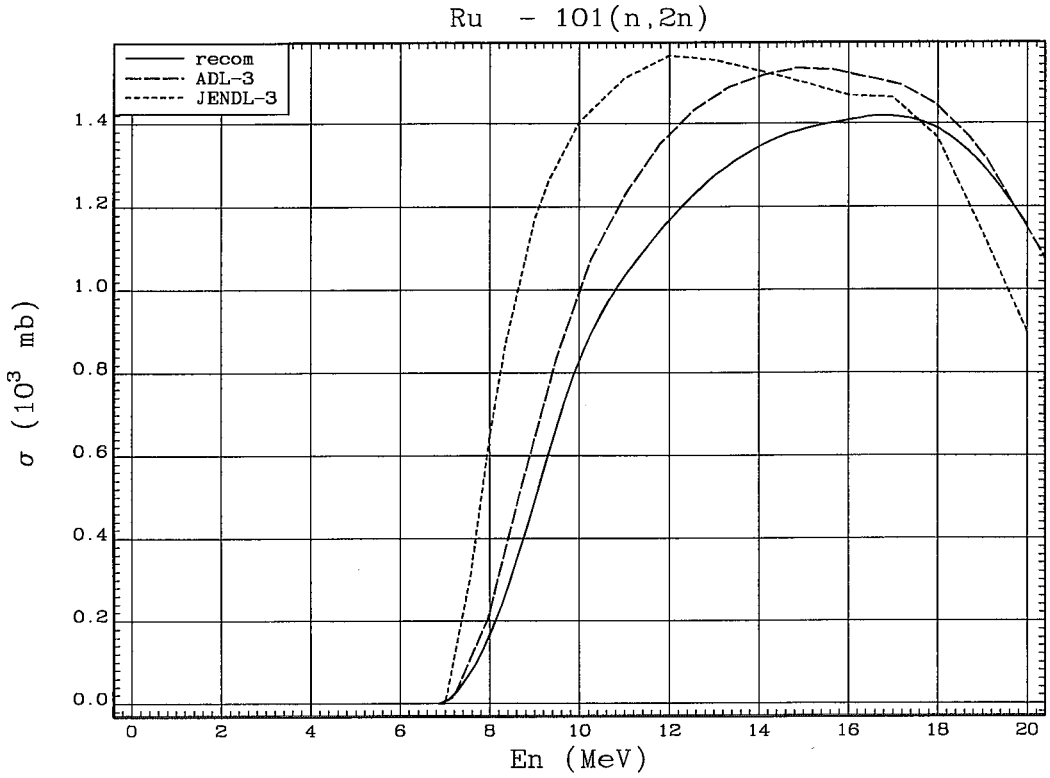

Fig. 79. ^{101}Ru(n,2n)^{100}Ru reaction cross section.

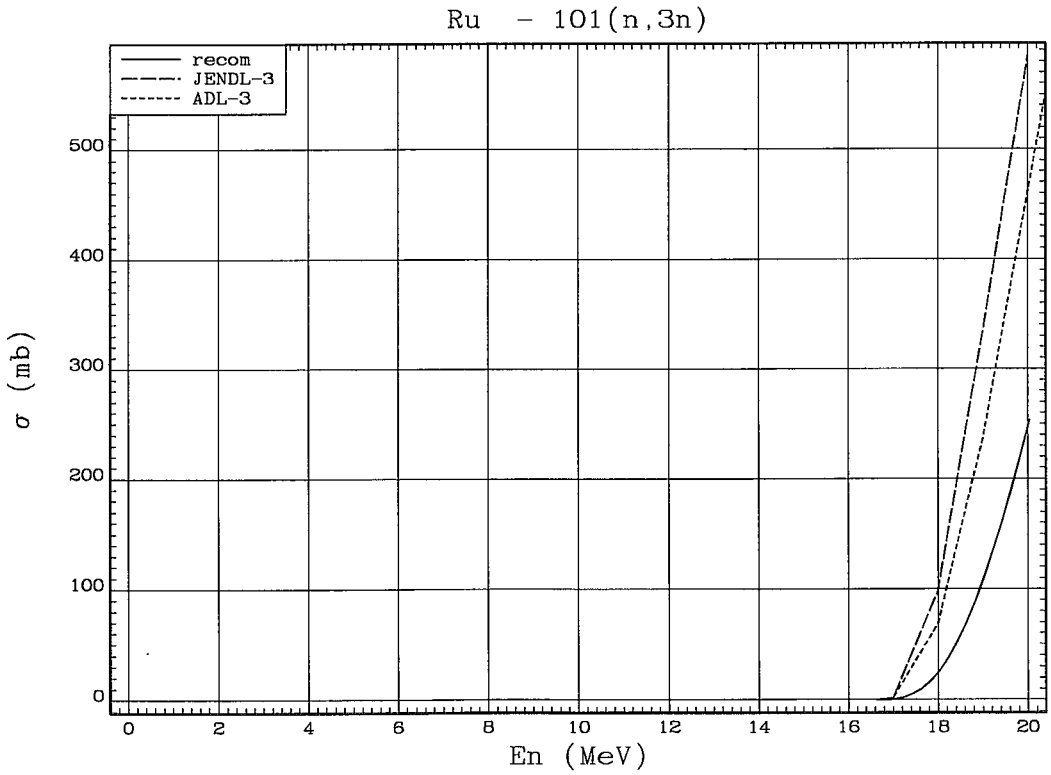

Fig. 80. ^{101}Ru(n,3n)^{99}Ru reaction cross section.

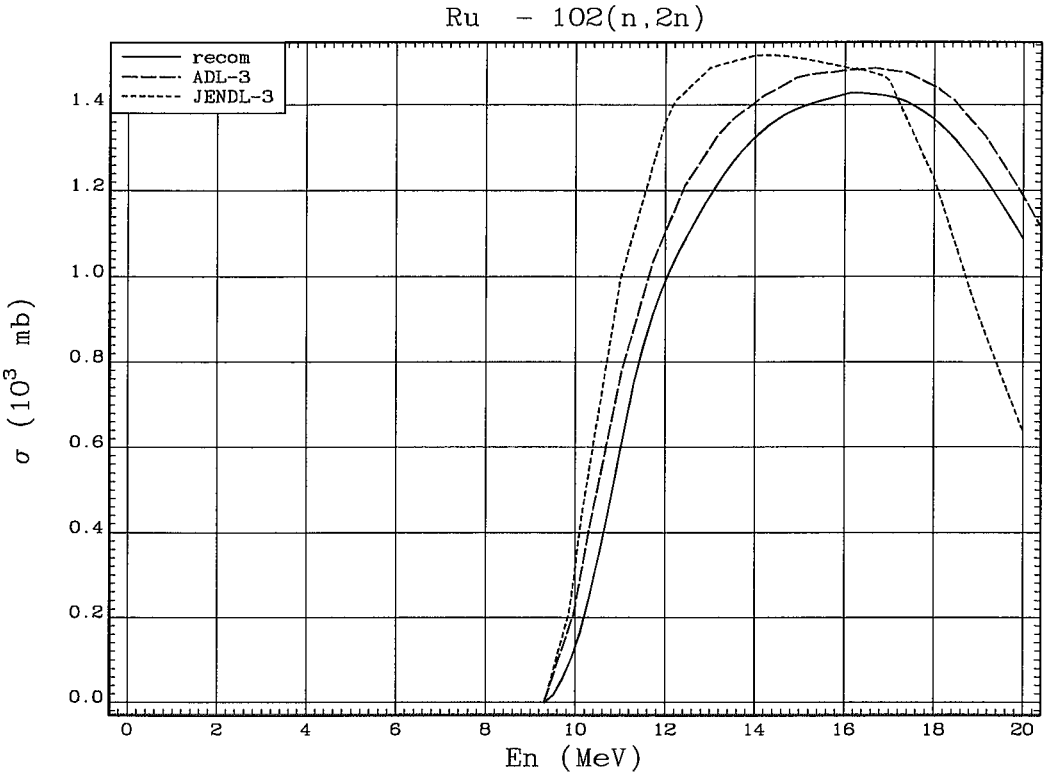

Fig. 81. ^{102}Ru(n,2n)^{101}Ru reaction cross section.

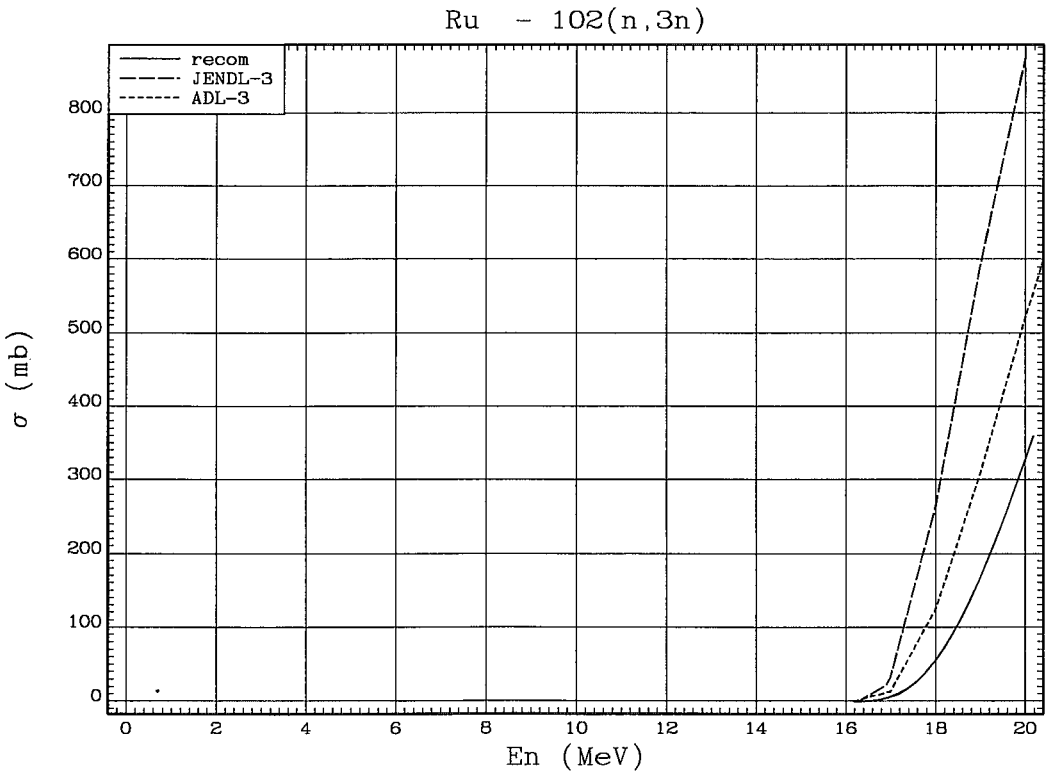

Fig. 82. ^{102}Ru(n,3n)^{100}Ru reaction cross section.

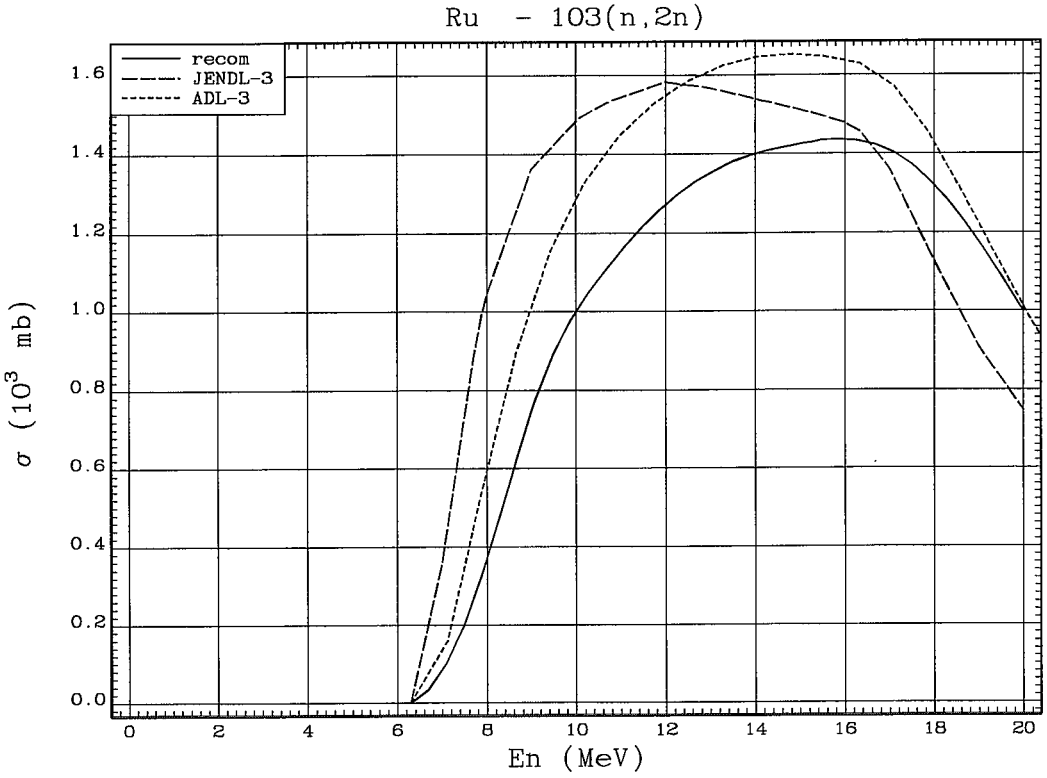

Fig. 83. ^{103}Ru(n,2n)^{102}Ru reaction cross section.

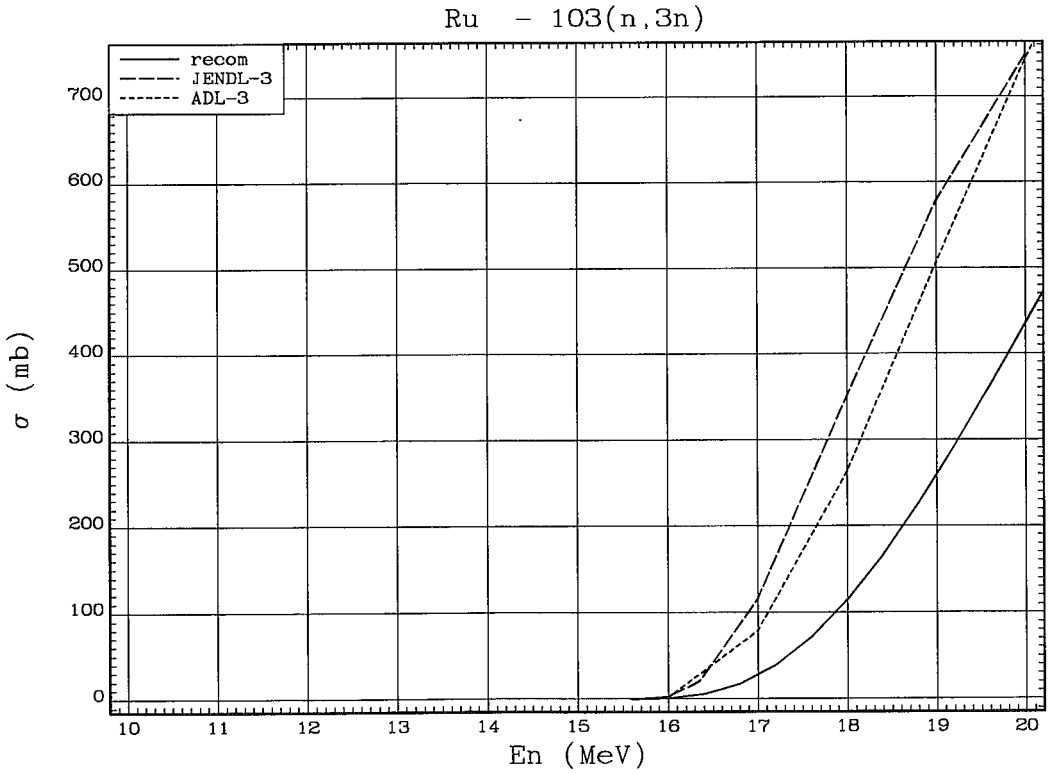

Fig. 84. ^{103}Ru(n,3n)^{101}Ru reaction cross section.

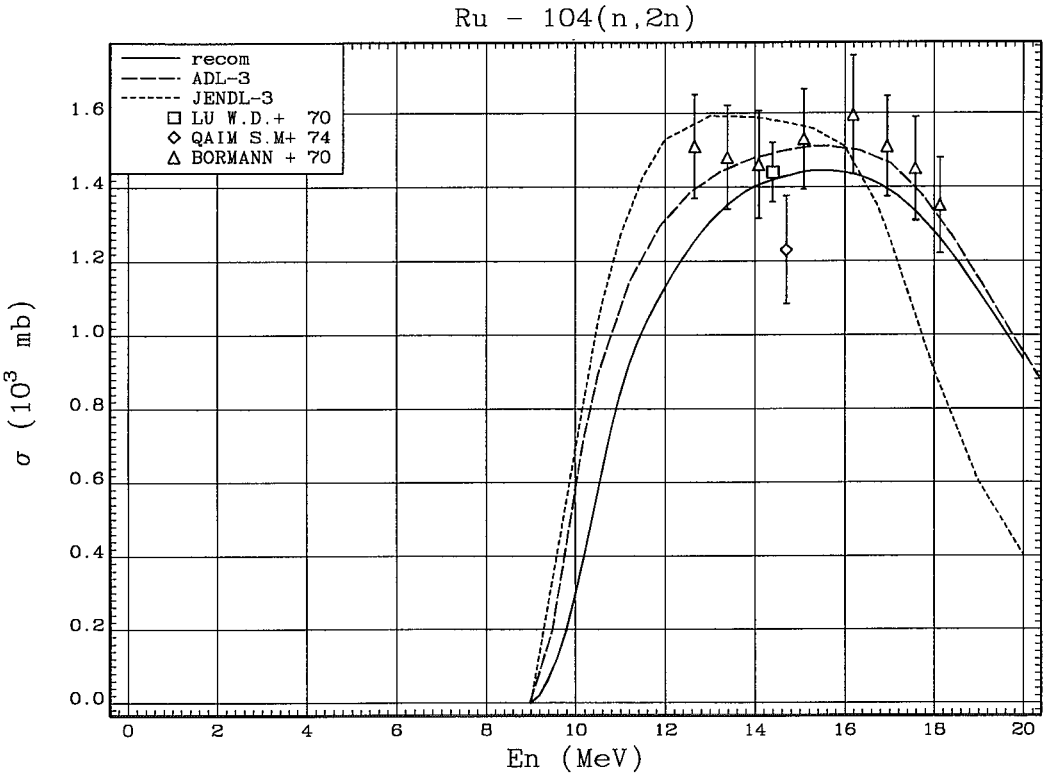

Fig. 85. ^{104}Ru(n,2n)^{103}Ru reaction cross section.

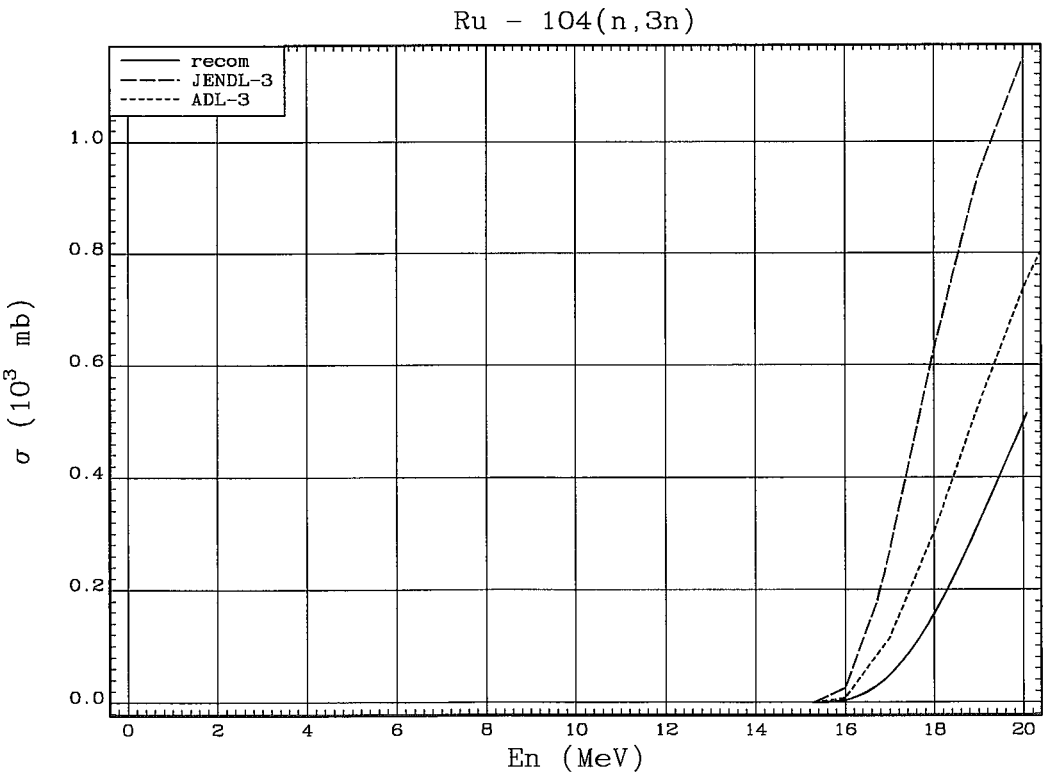

Fig. 86. ^{104}Ru(n,3n)^{102}Ru reaction cross section.

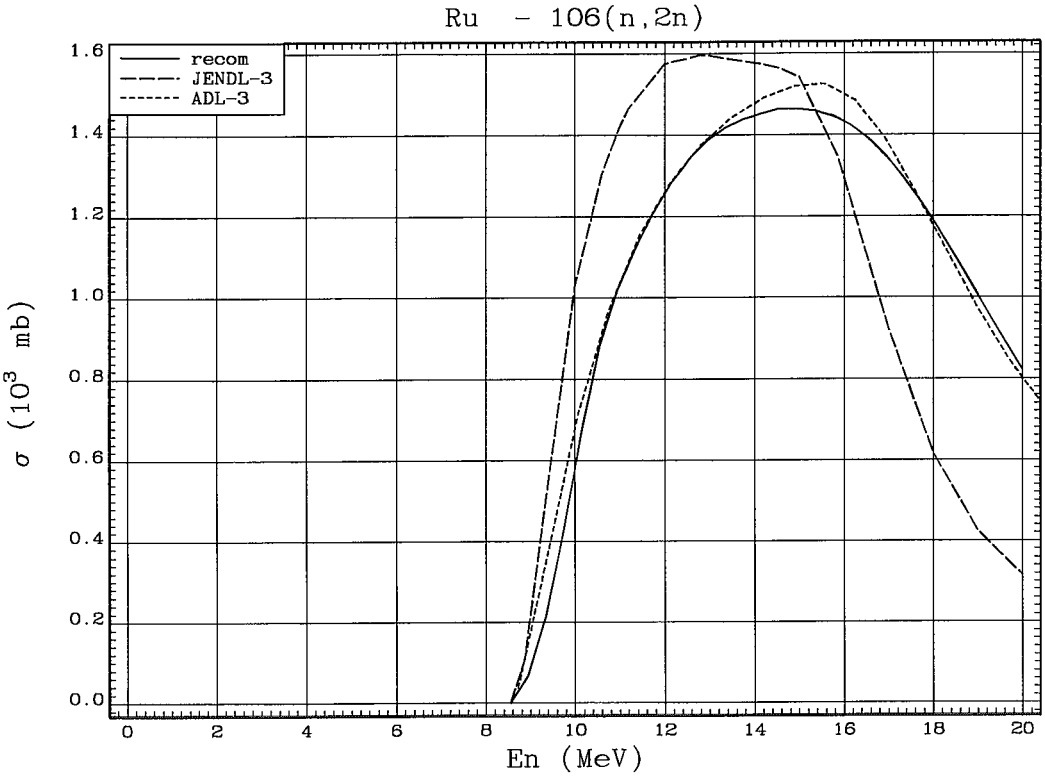

Fig. 87. ^{106}Ru(n,2n)^{105}Ru reaction cross section.

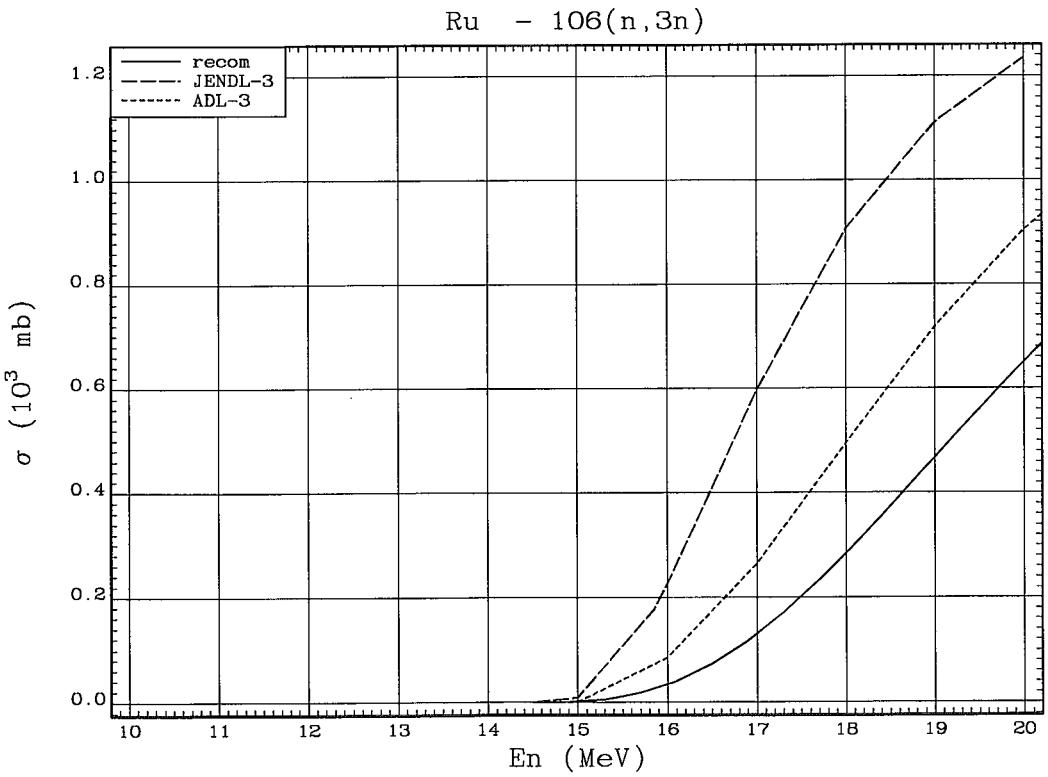

Fig. 88. ^{106}Ru(n,3n)^{104}Ru reaction cross section.

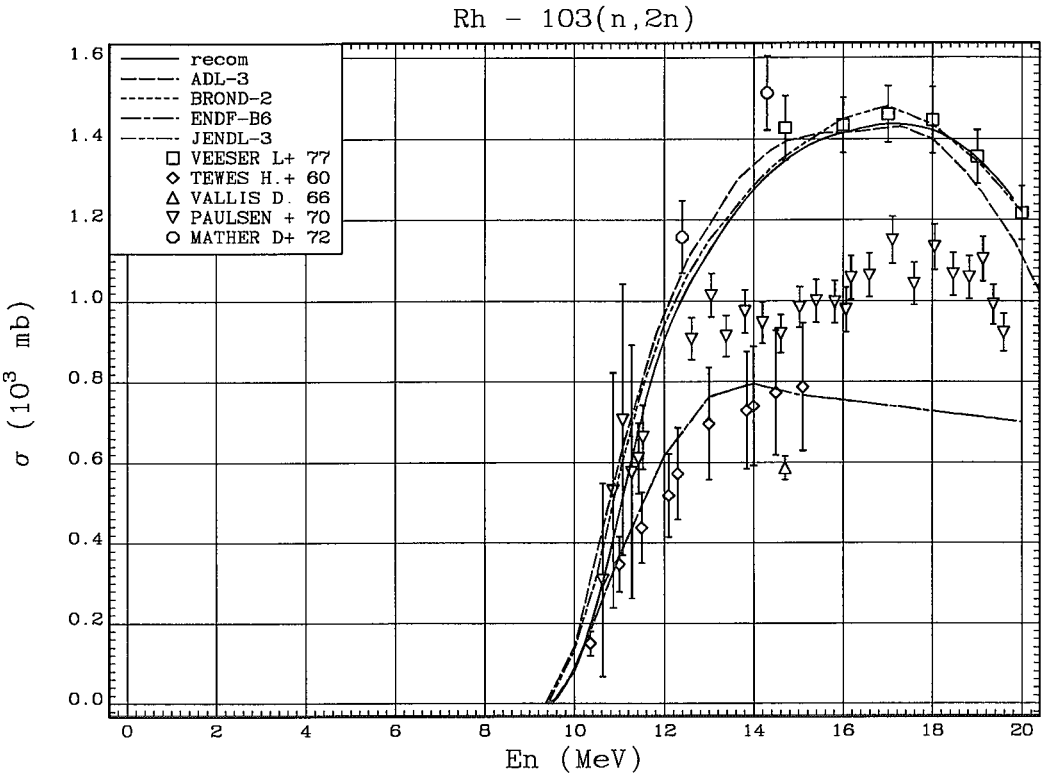

Fig. 89. ^{103}Rh(n,2n)^{102}Rh reaction cross section.

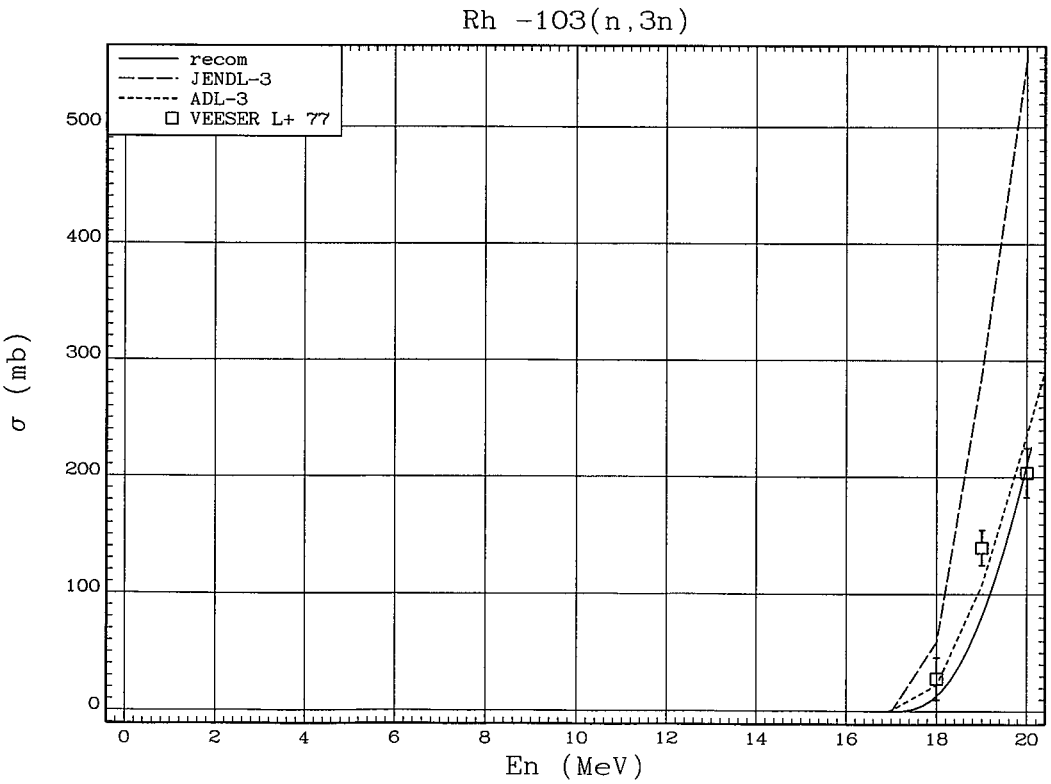

Fig. 90. ^{103}Rh(n,3n)^{101}Rh reaction cross section.

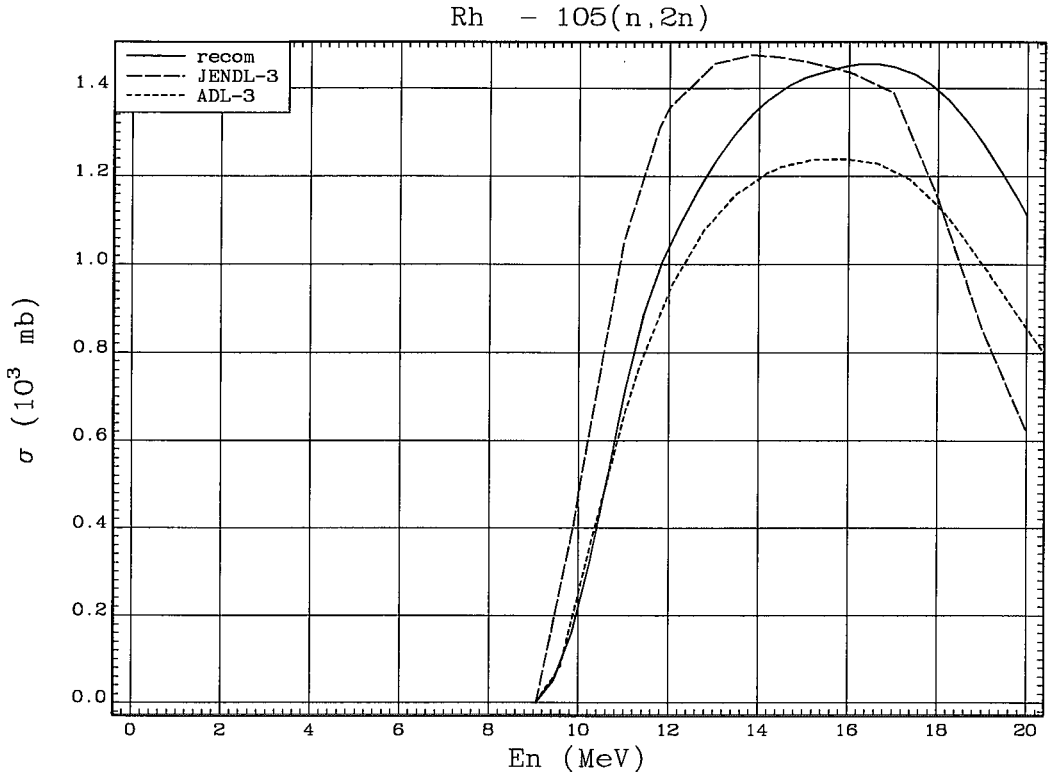

Fig. 91. ^{105}Rh(n,2n)^{104}Rh reaction cross section.

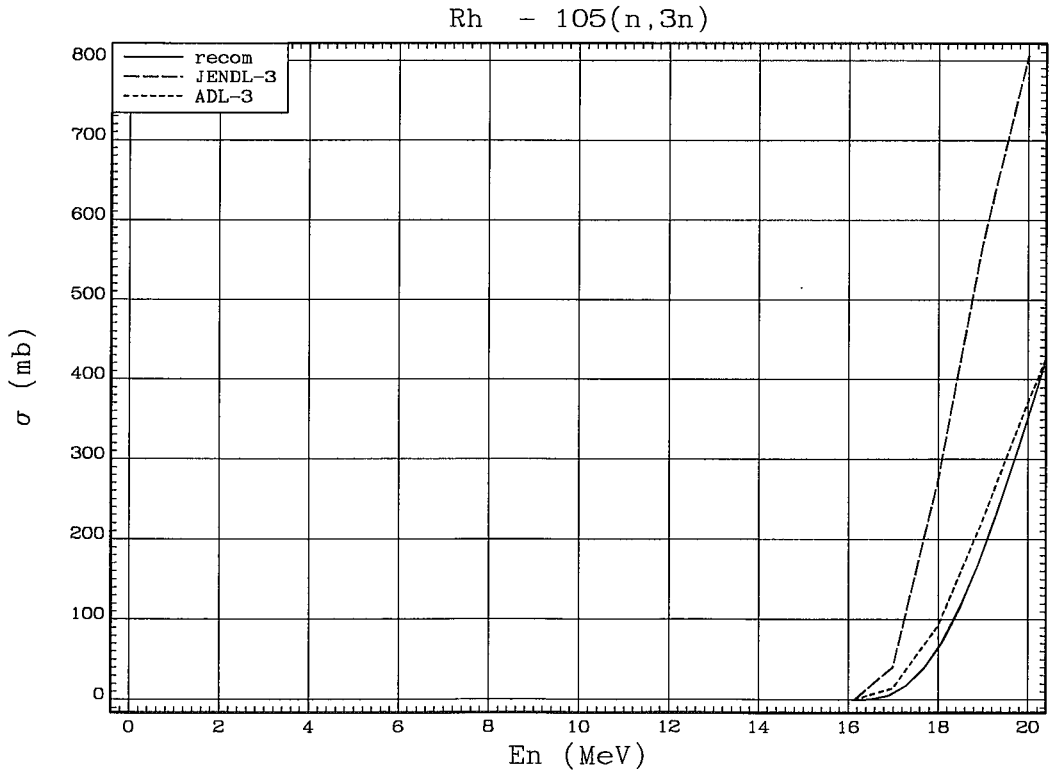

Fig. 92. ^{105}Rh(n,3n)^{103}Rh reaction cross section.

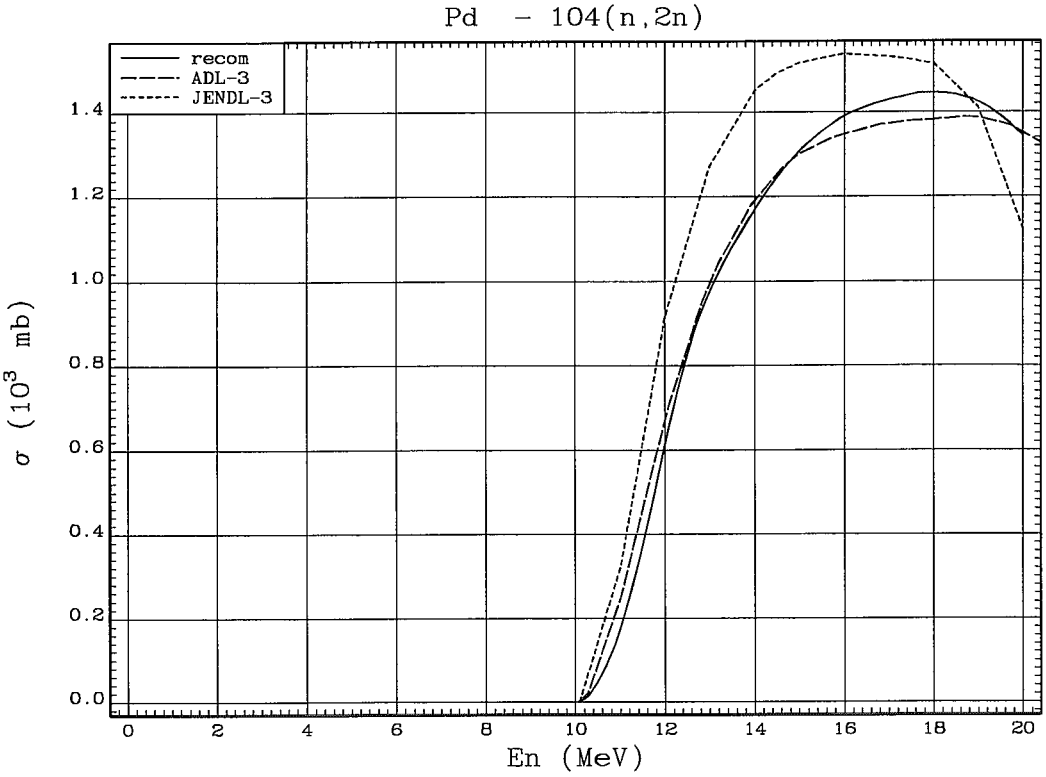

Fig.93. ^{104}Pd(n,2n)^{103}Pd reaction cross section.

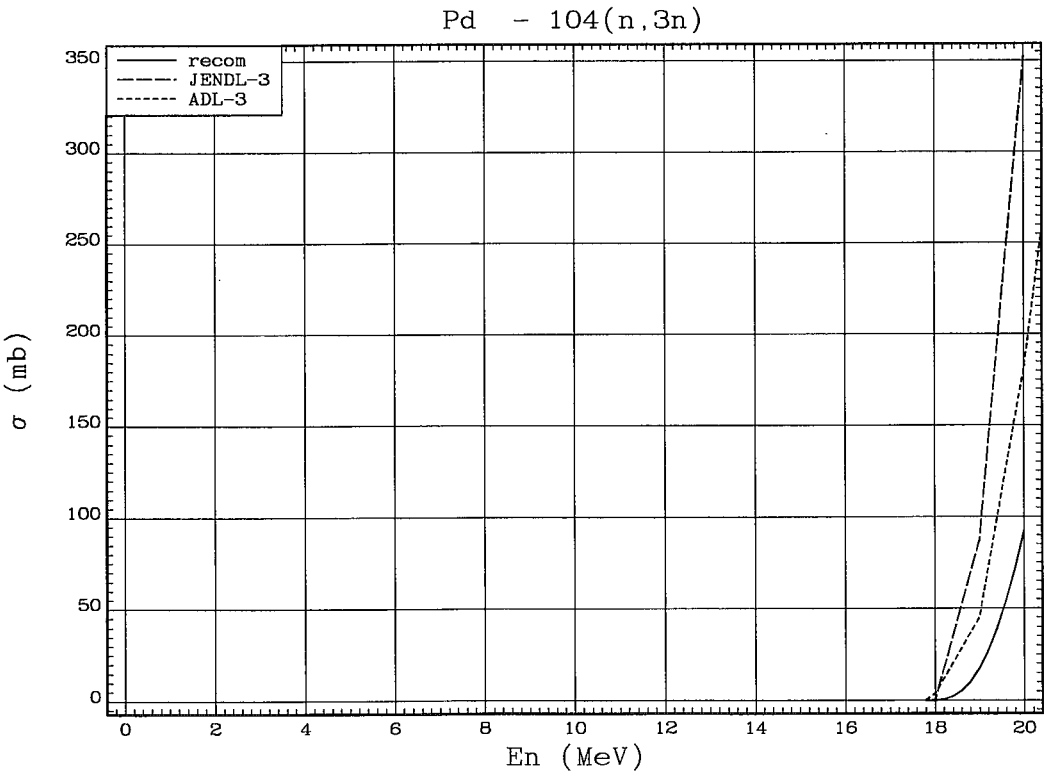

Fig.94. ^{104}Pd(n,3n)^{102}Pd reaction cross section.

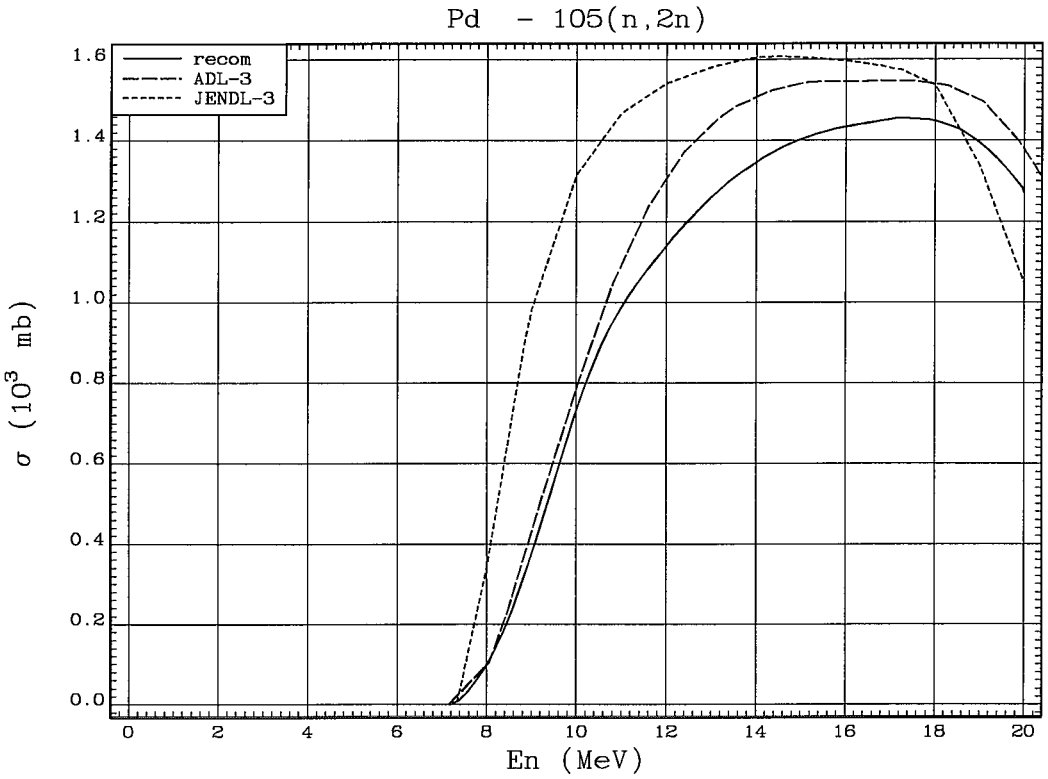

Fig.95. ^{105}Pd(n,2n)^{104}Pd reaction cross section.

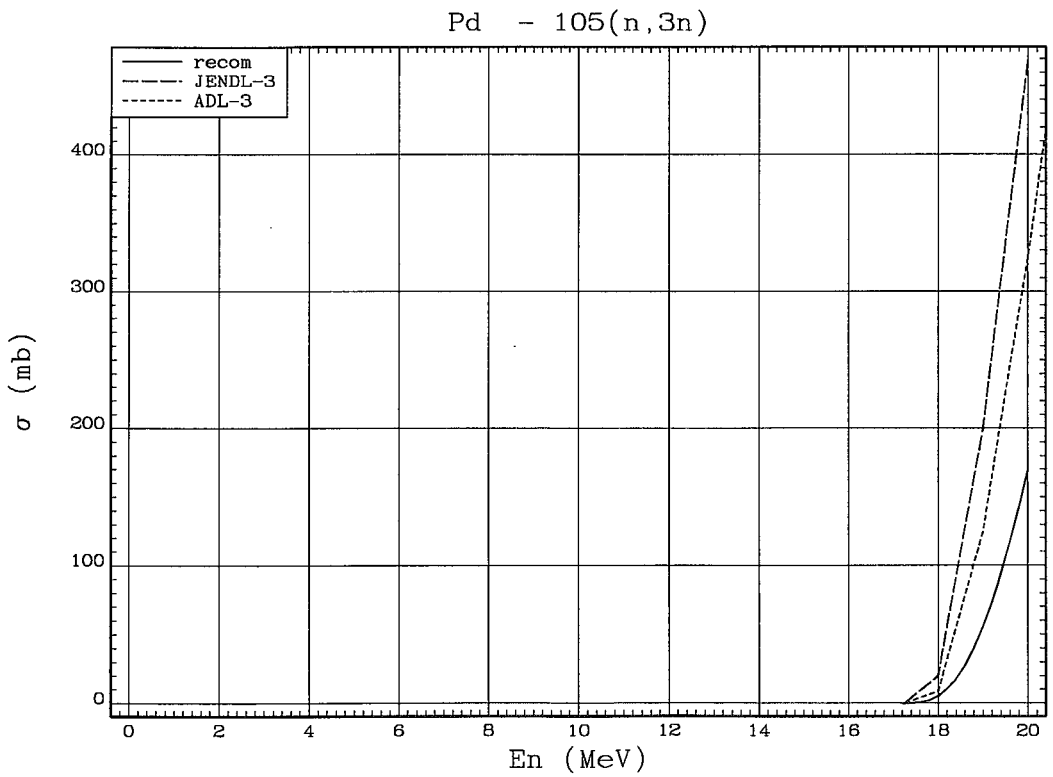

Fig.96. ^{105}Pd(n,3n)^{103}Pd reaction cross section.

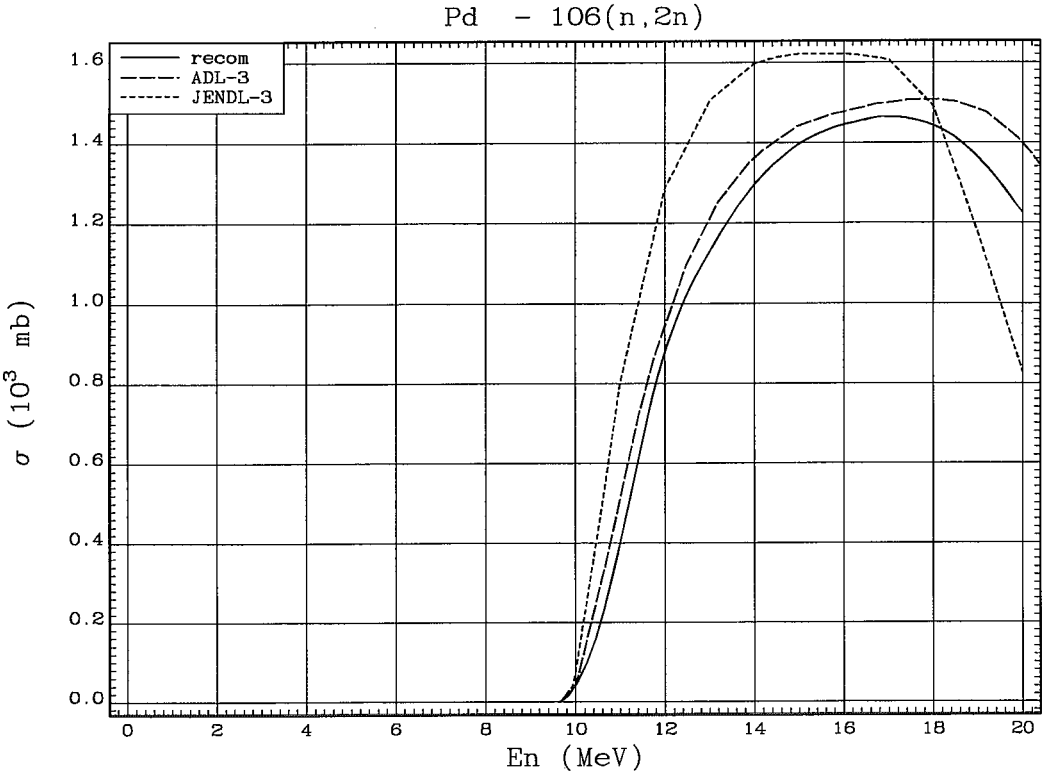

Fig.97. ^{106}Pd(n,2n)^{105}Pd reaction cross section.

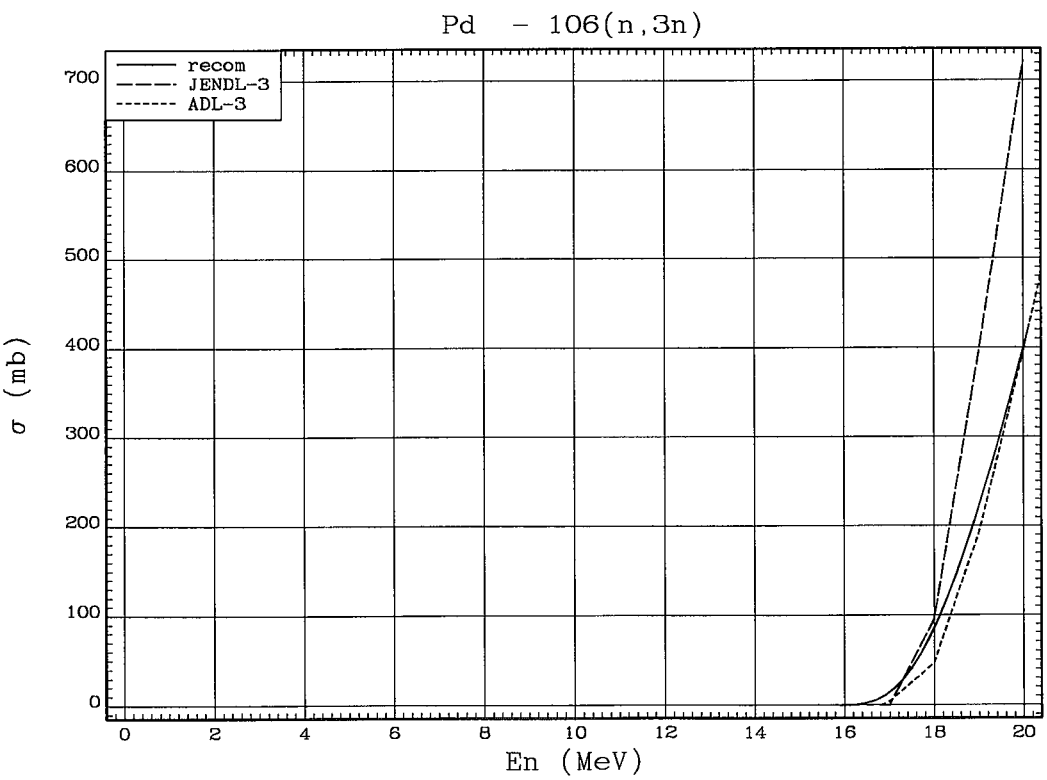

Fig.98. ^{106}Pd(n,3n)^{104}Pd reaction cross section.

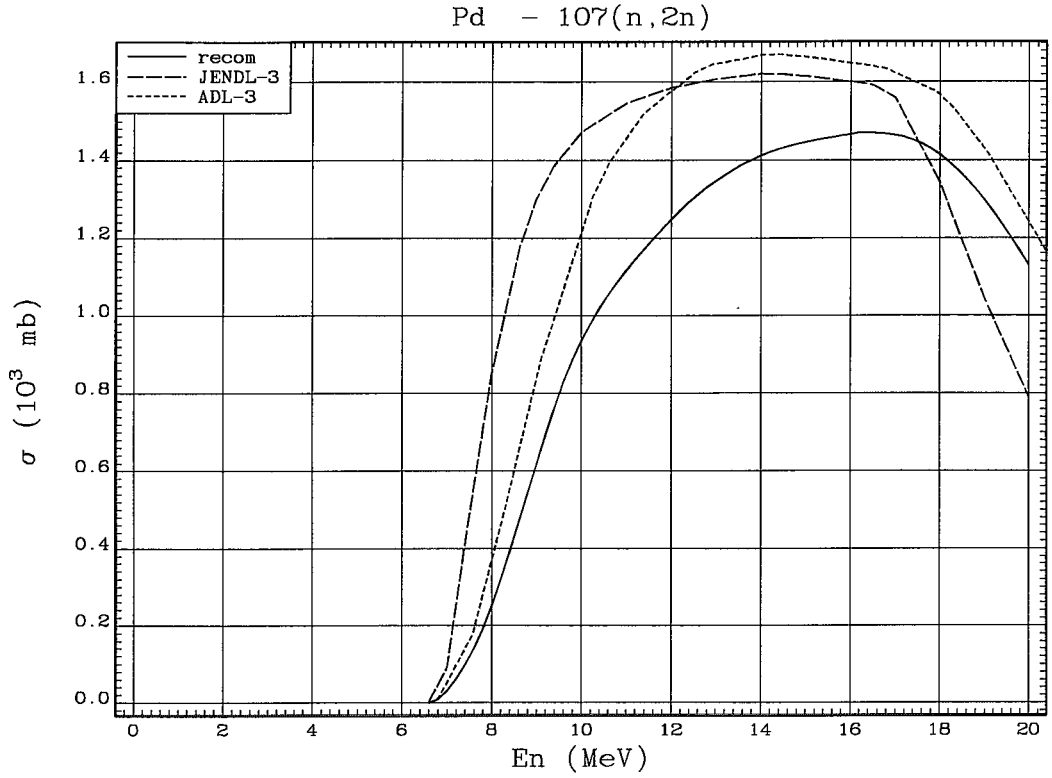

Fig.99. ^{107}Pd(n,2n)^{106}Pd reaction cross section.

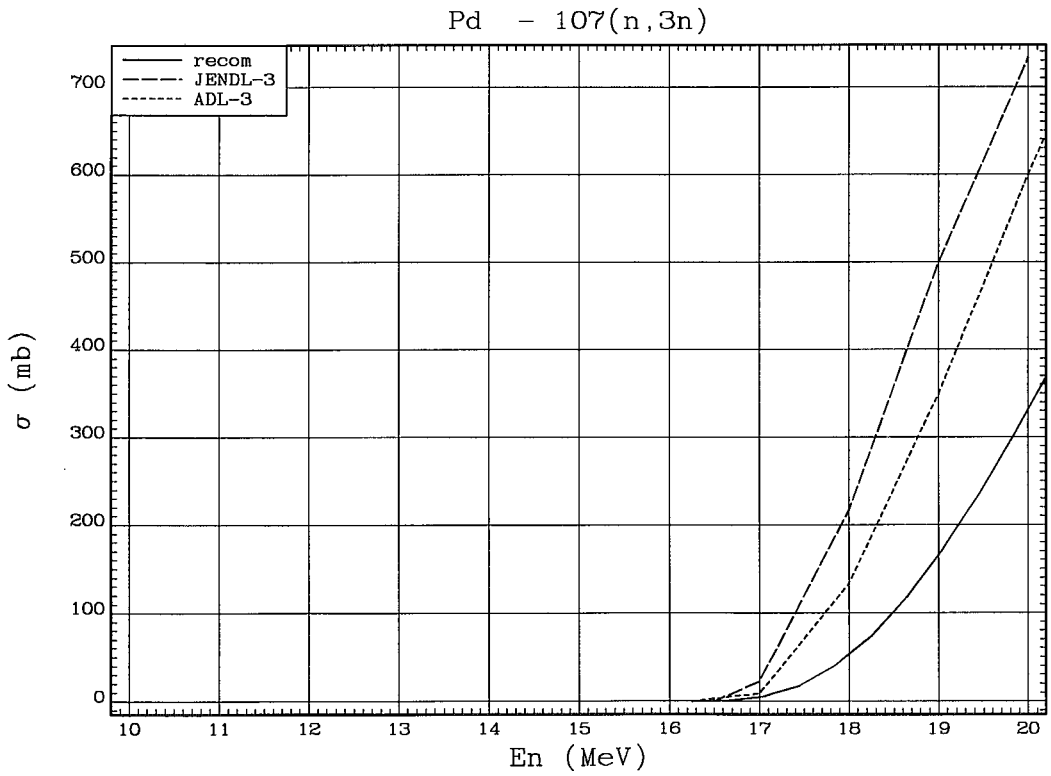

Fig.100. ^{107}Pd(n,3n)^{105}Pd reaction cross section.

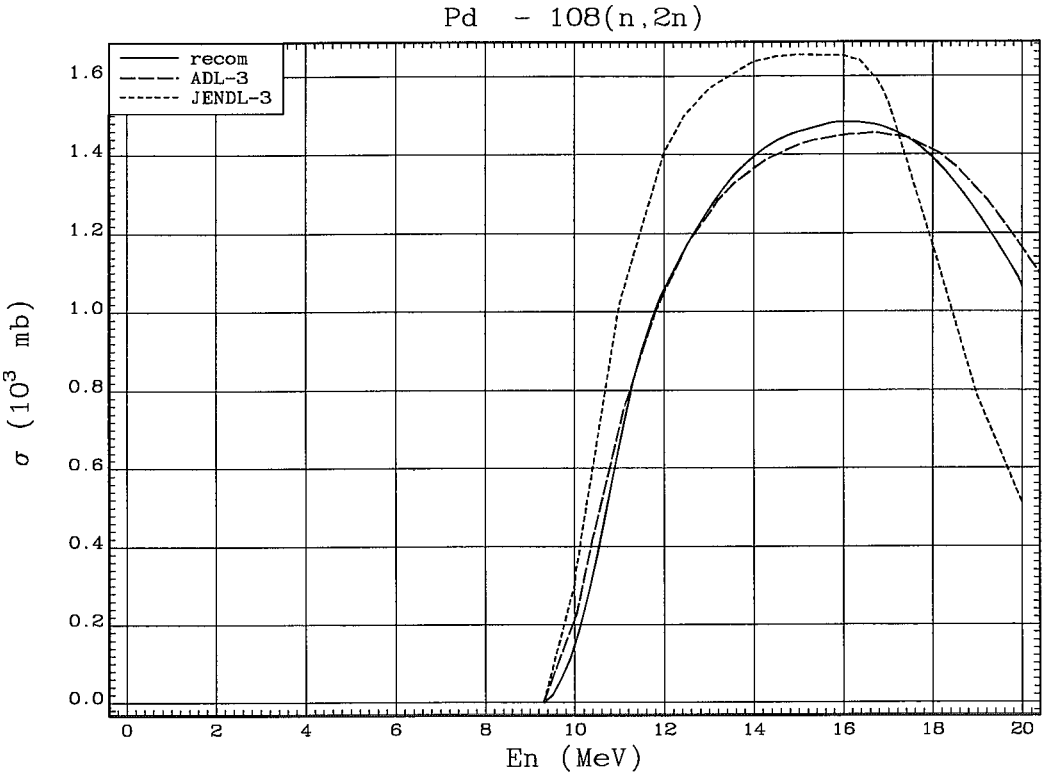

Fig.101. ^{108}Pd(n,2n)^{107}Pd reaction cross section.

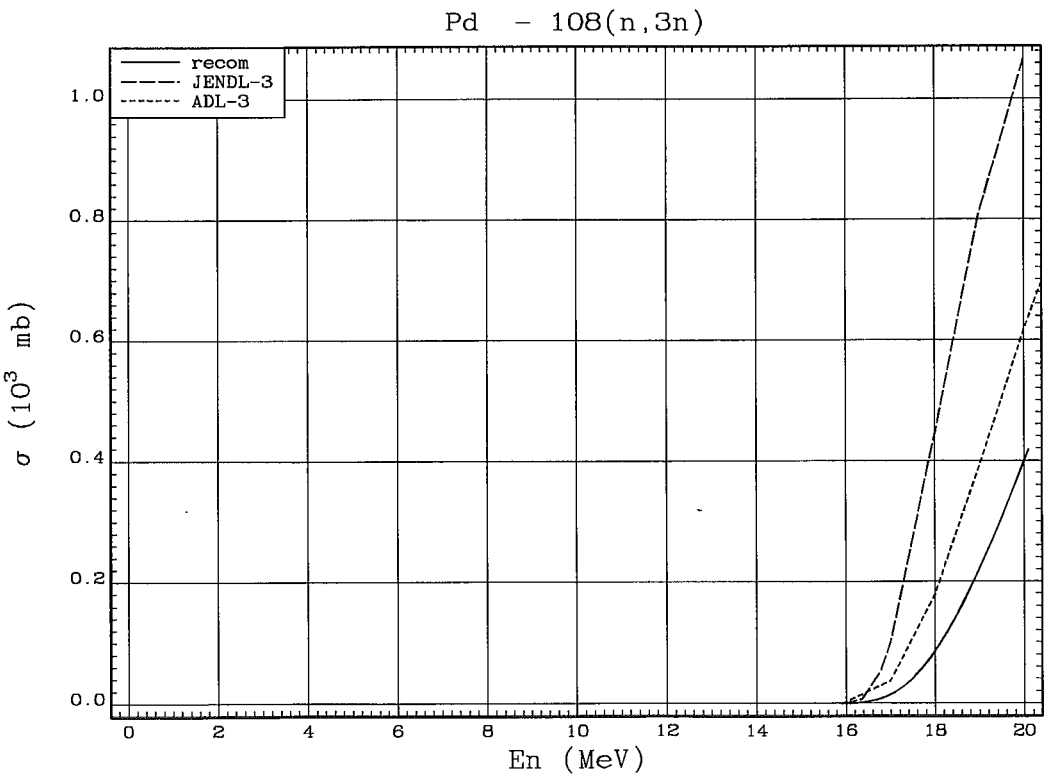

Fig.102. ^{108}Pd(n,3n)^{106}Pd reaction cross section.

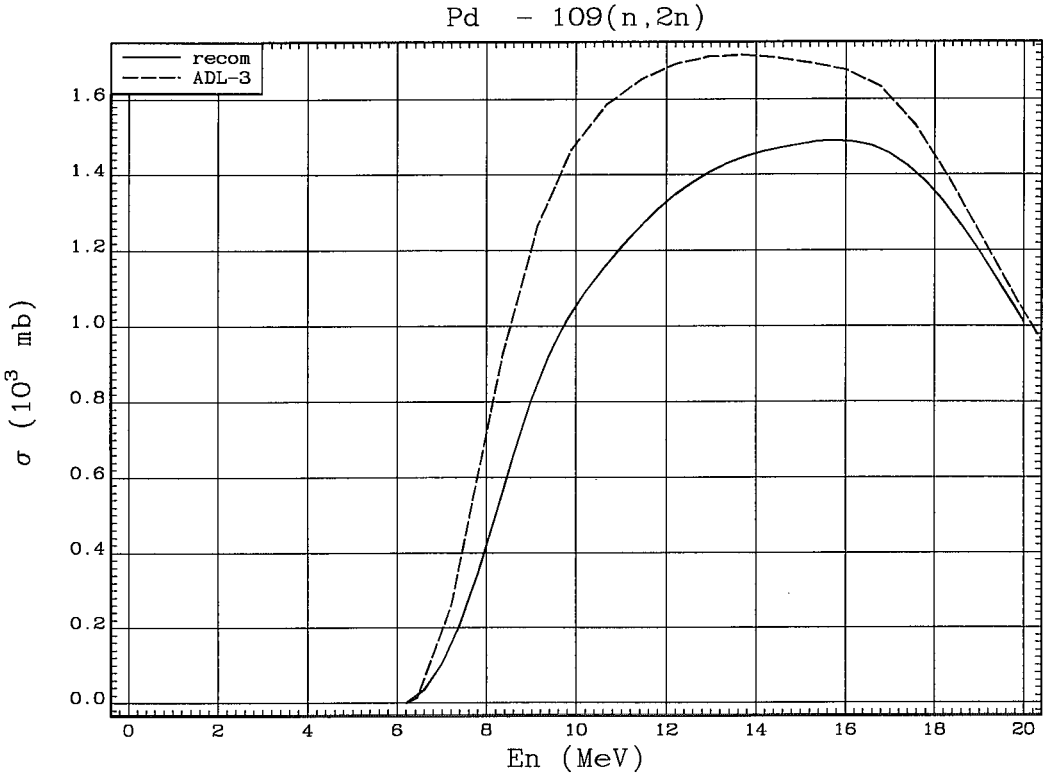

Fig.103. ^{109}Pd(n,2n)^{108}Pd reaction cross section.

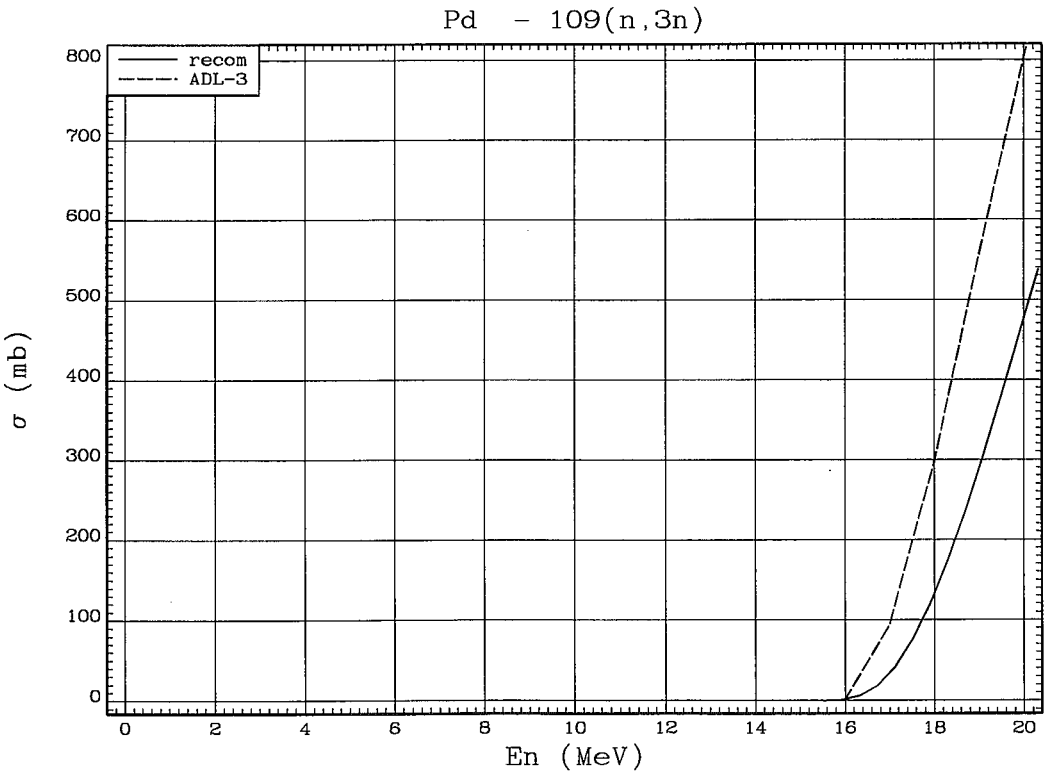

Fig.104. ^{109}Pd(n,3n)^{107}Pd reaction cross section.

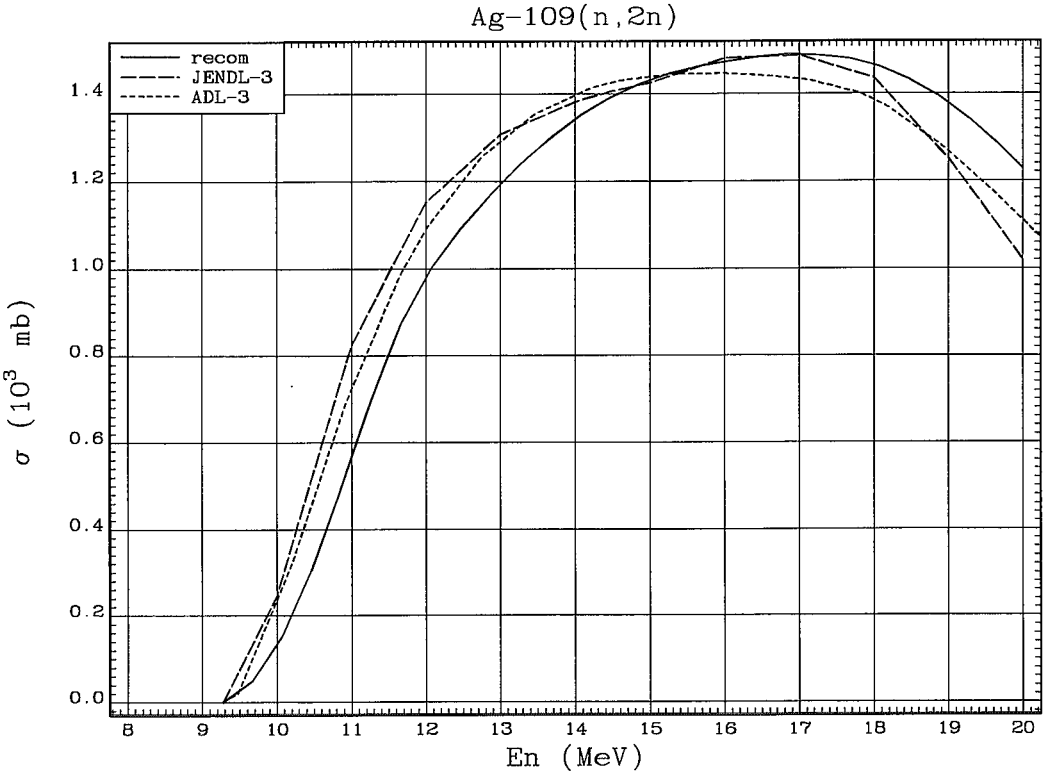

Fig.105. ^{109}Ag(n,2n)^{108}Ag reaction cross section.

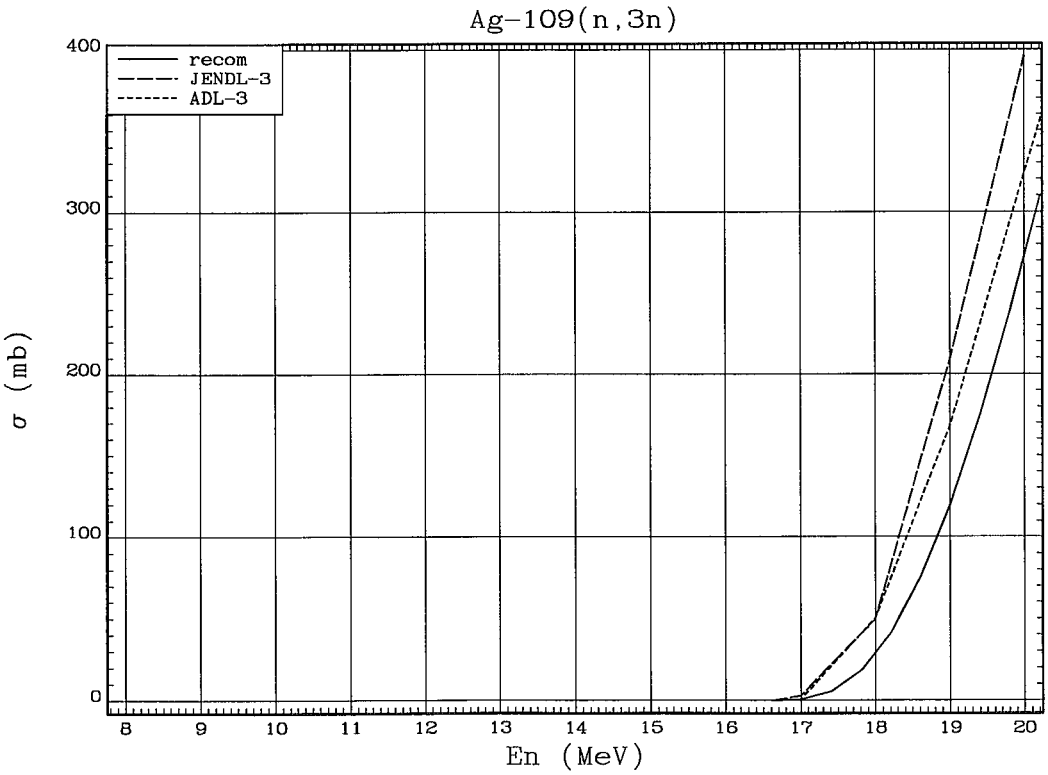

Fig.106. ^{109}Ag(n,3n)^{107}Ag reaction cross section.

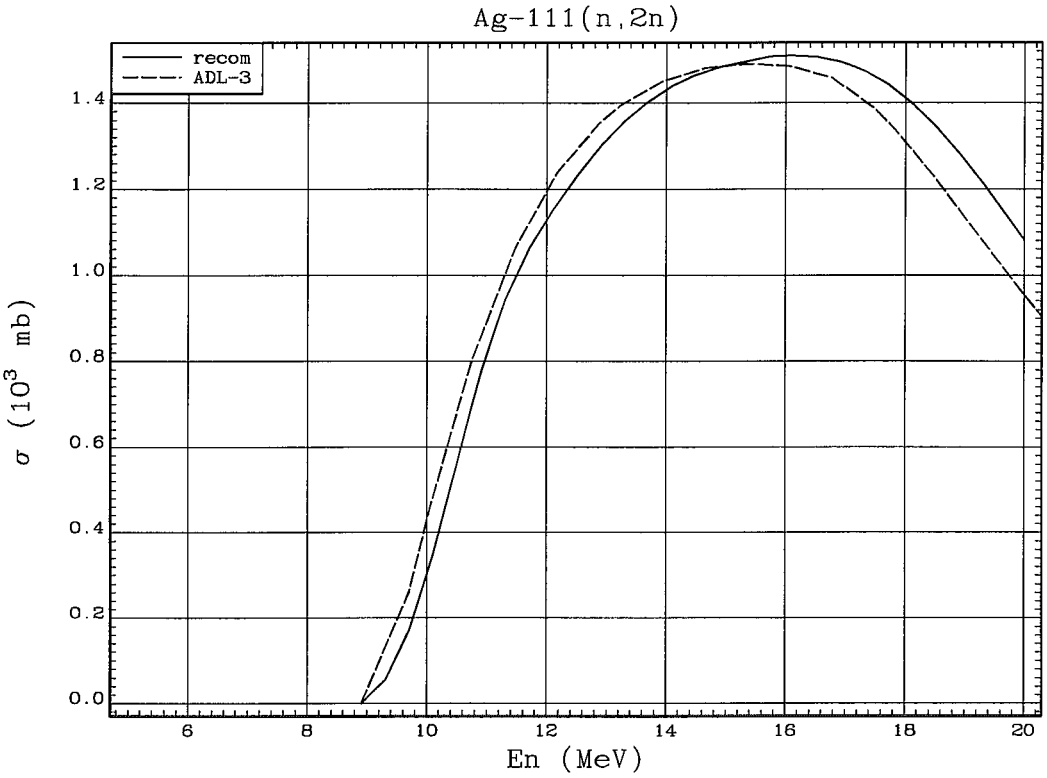

Fig.107. ^{111}Ag(n,2n)^{110}Ag reaction cross section.

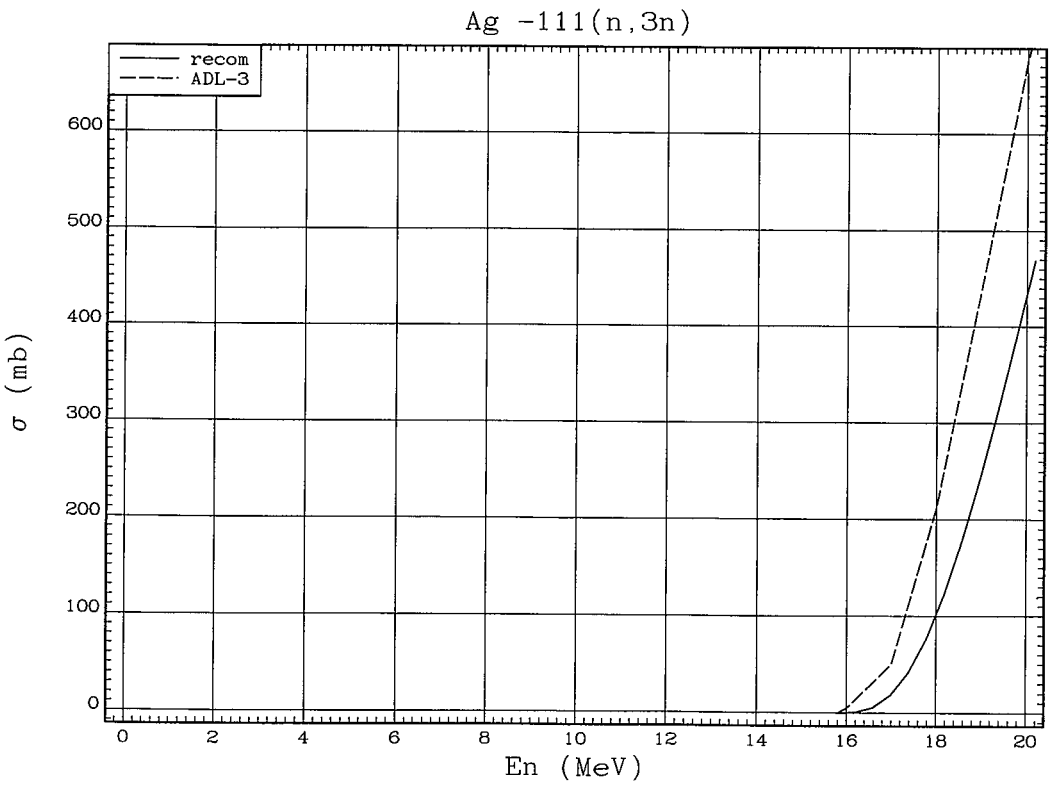

Fig.108. ^{111}Ag(n,3n)^{109}Ag reaction cross section.

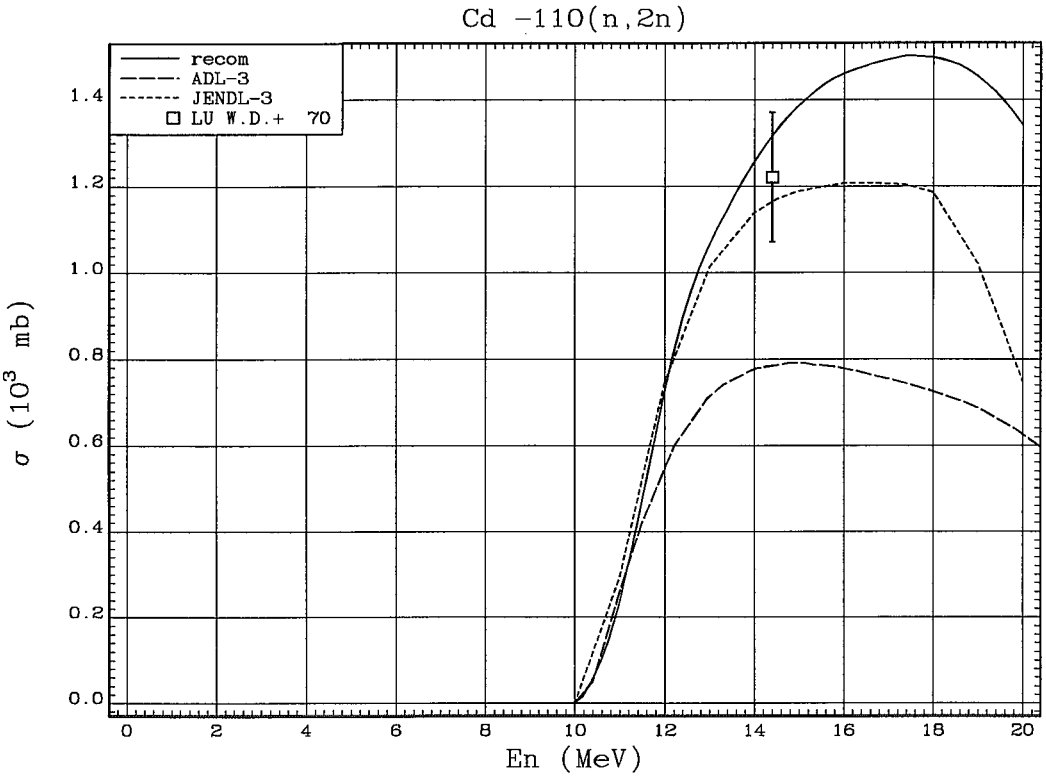

Fig.109. ^{110}Cd(n,2n)^{109}Cd reaction cross section.

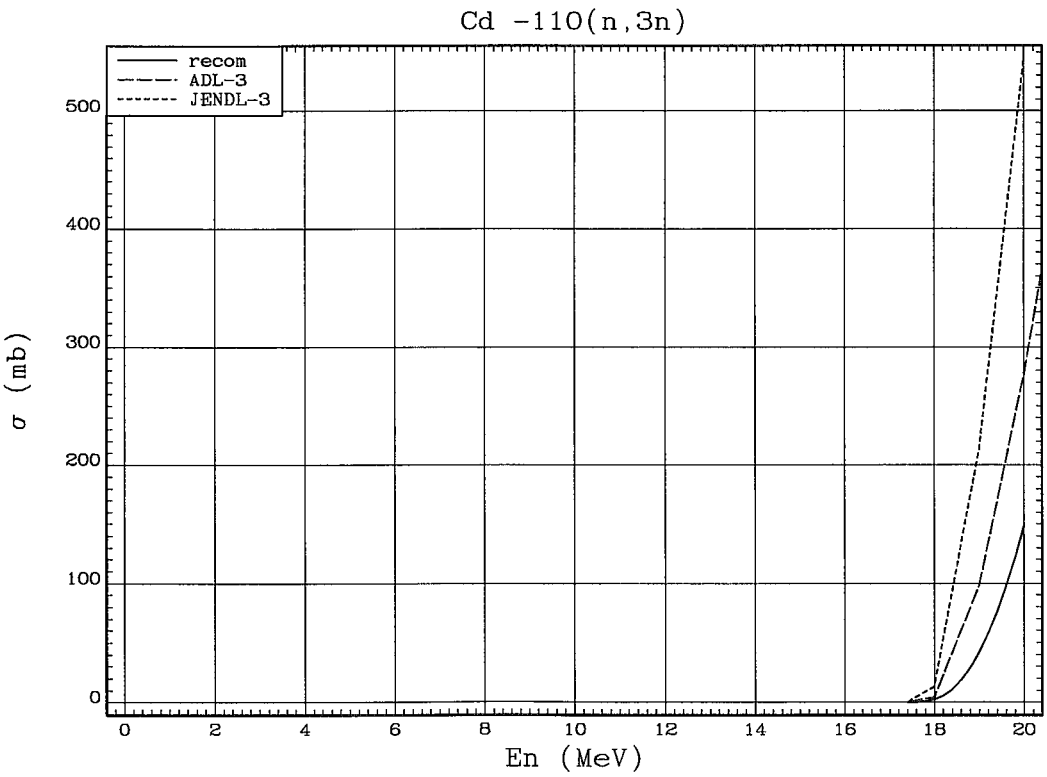

Fig.110. ^{110}Cd(n,3n)^{108}Cd reaction cross section.

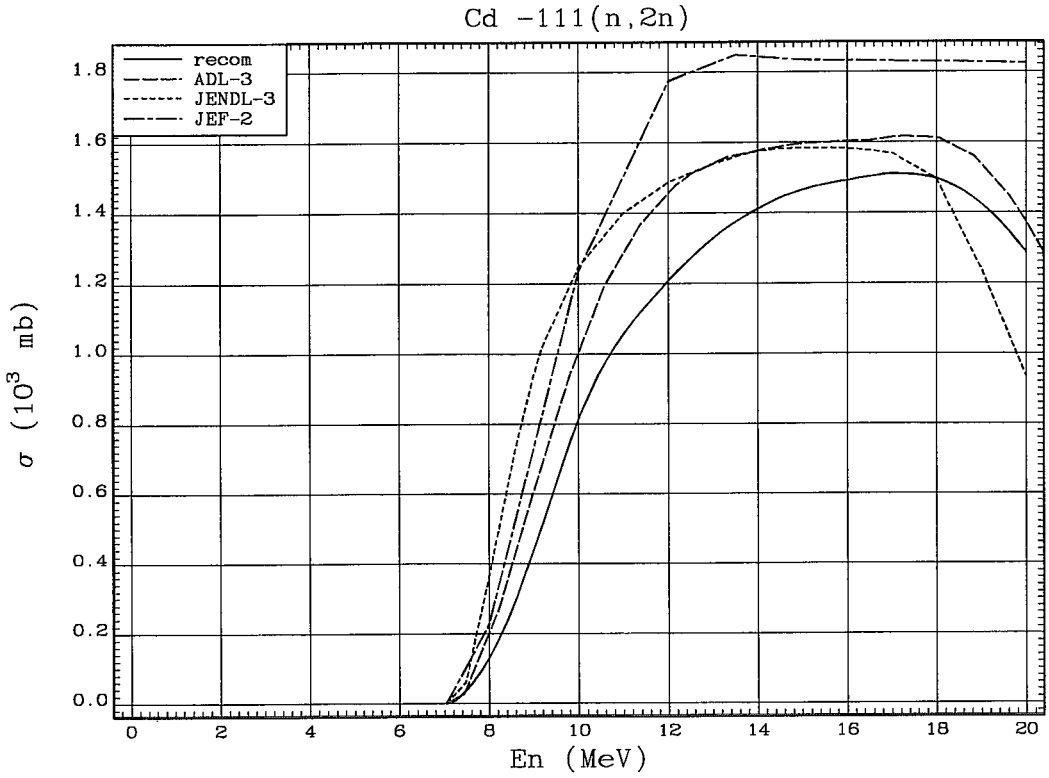

Fig.111. ^{111}Cd(n,2n)^{110}Cd reaction cross section.

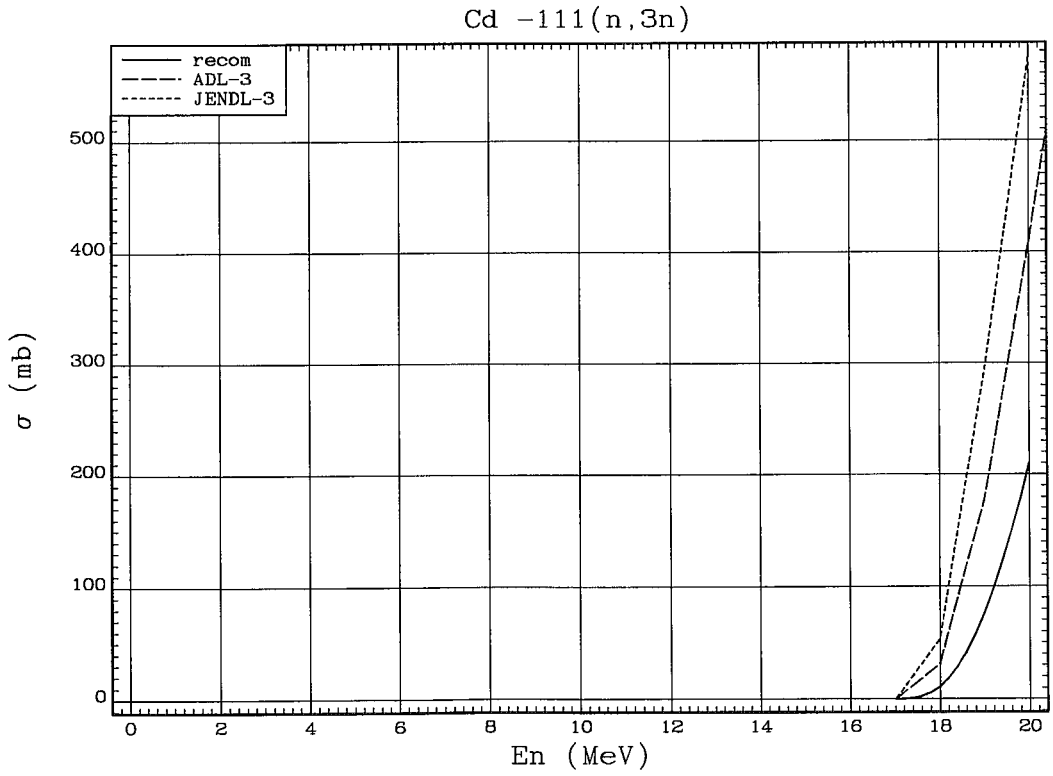

Fig.112. ^{111}Cd(n,3n)^{109}Cd reaction cross section.

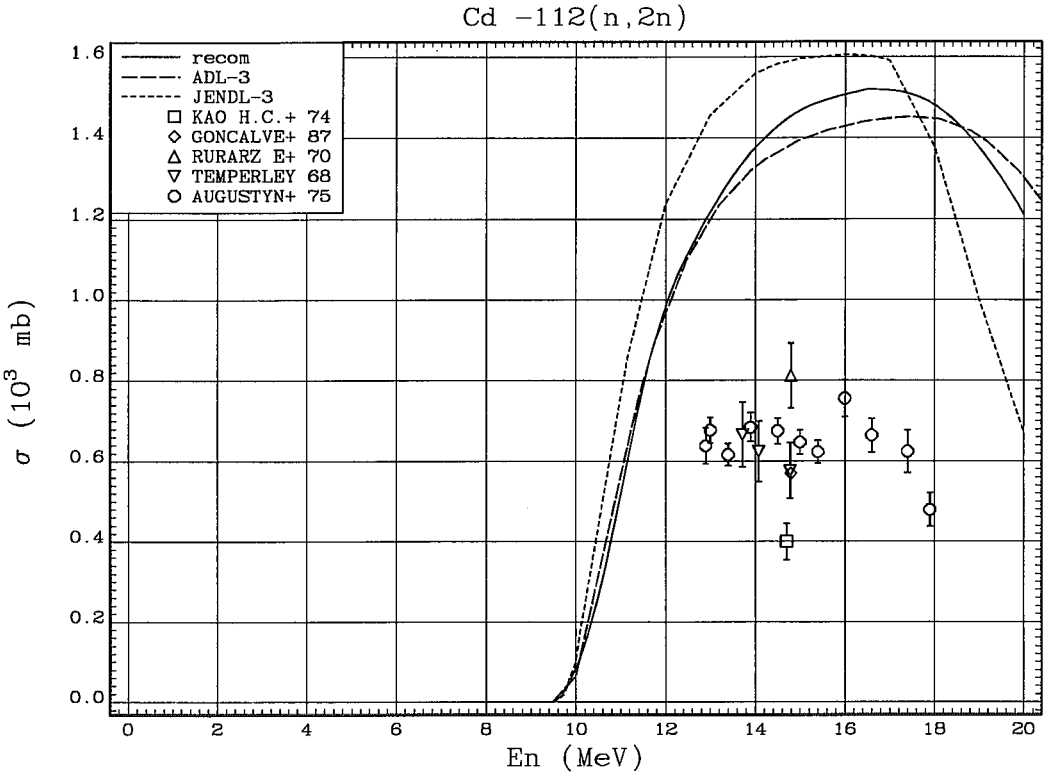

Fig.113. ^{112}Cd(n,2n)^{111}Cd reaction cross section.

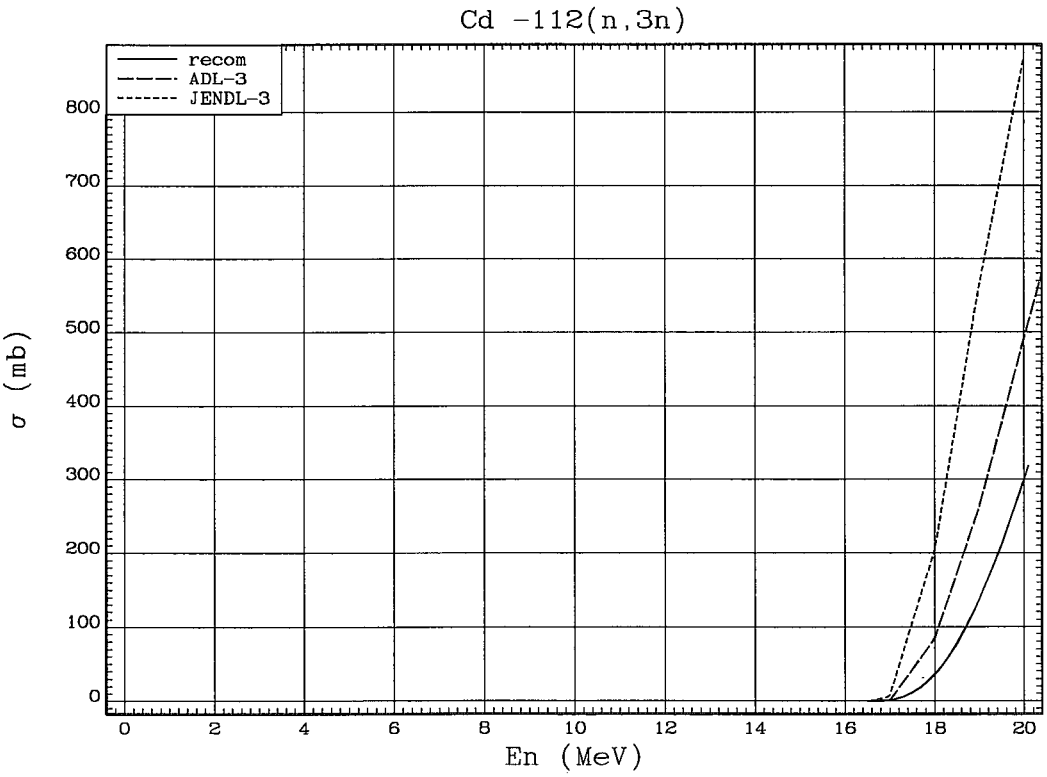

Fig.114. ^{112}Cd(n,3n)^{110}Cd reaction cross section.

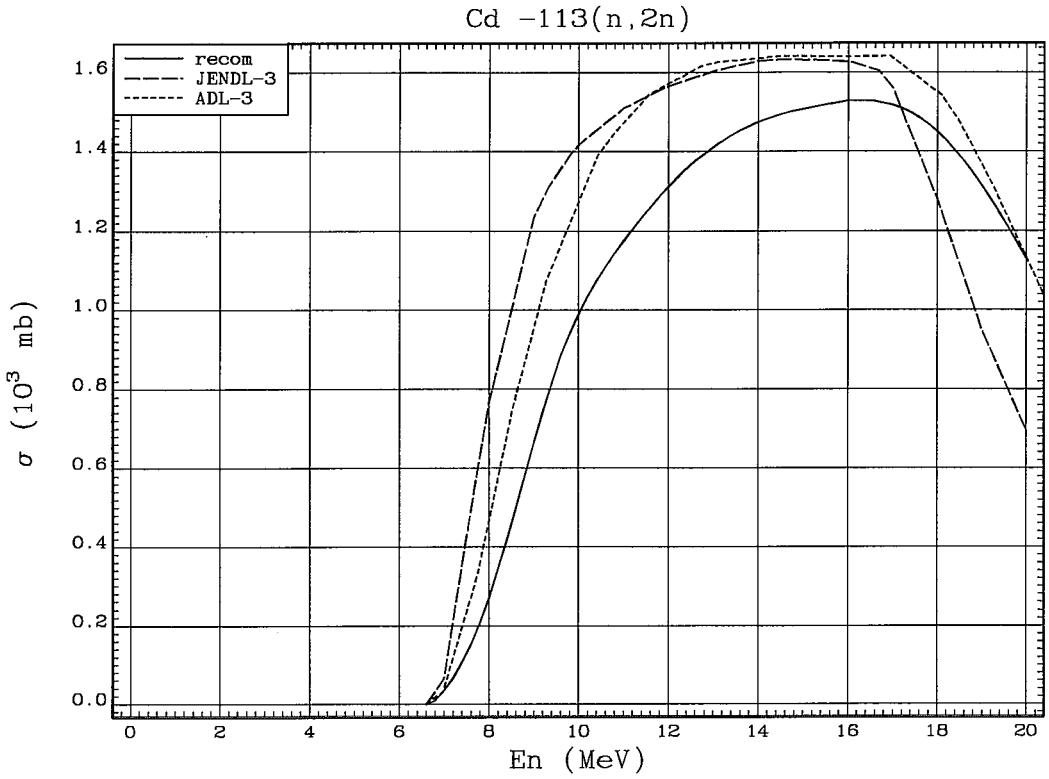

Fig.115. ^{113}Cd(n,2n)^{112}Cd reaction cross section.

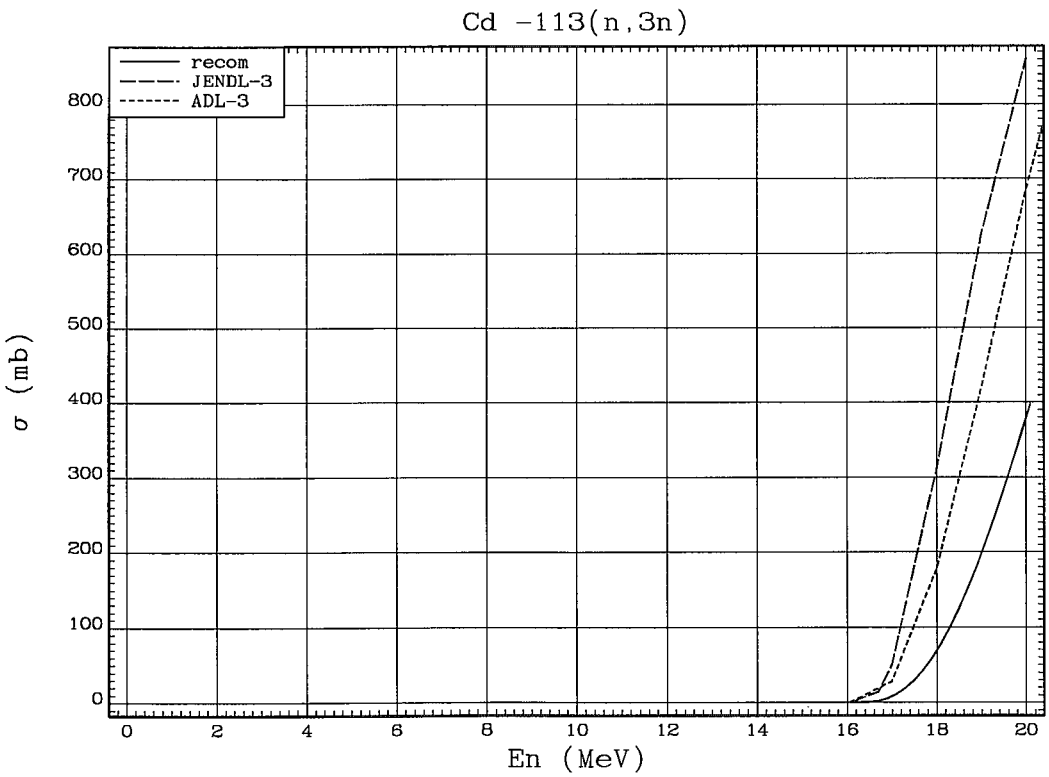

Fig.116. ^{113}Cd(n,3n)^{111}Cd reaction cross section.

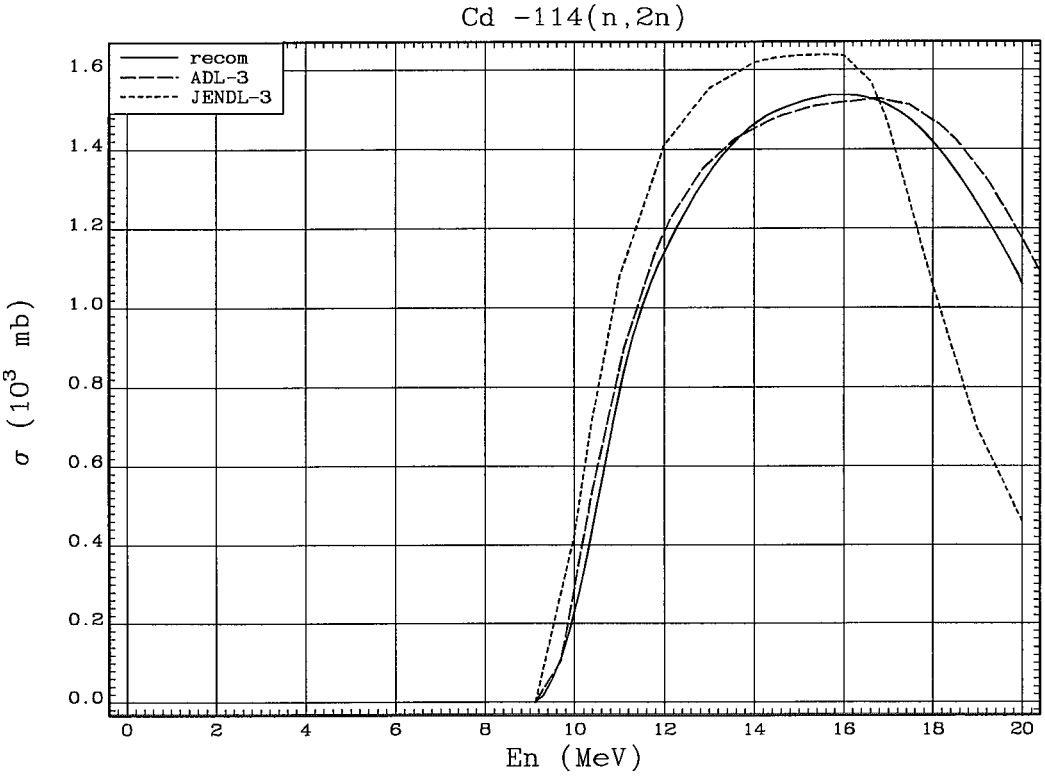

Fig.117. ^{114}Cd(n,2n)^{113}Cd reaction cross section.

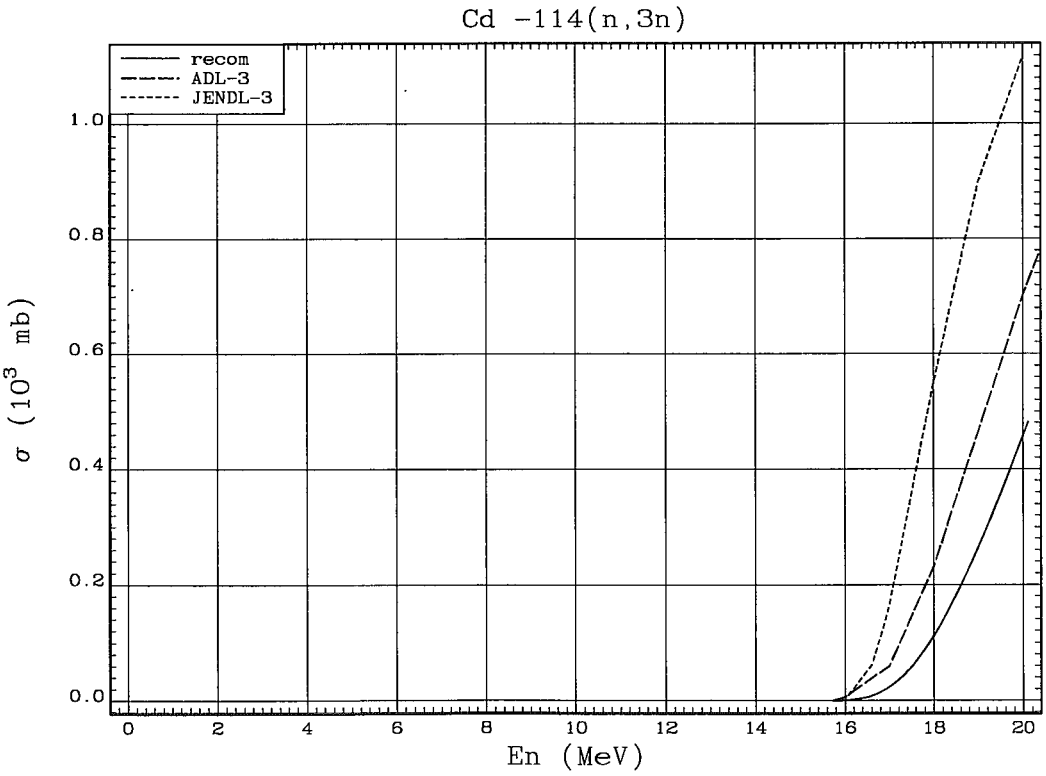

Fig.118. ^{114}Cd(n,3n)^{112}Cd reaction cross section.

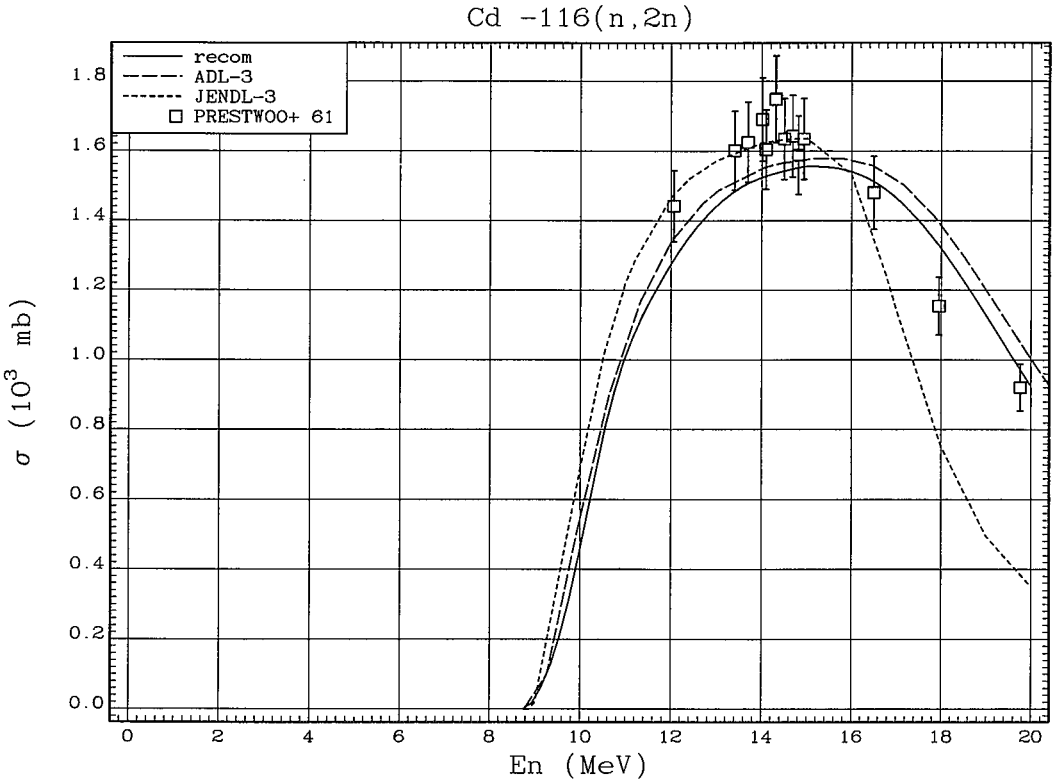

Fig.119. ^{116}Cd(n,2n)^{115}Cd reaction cross section.

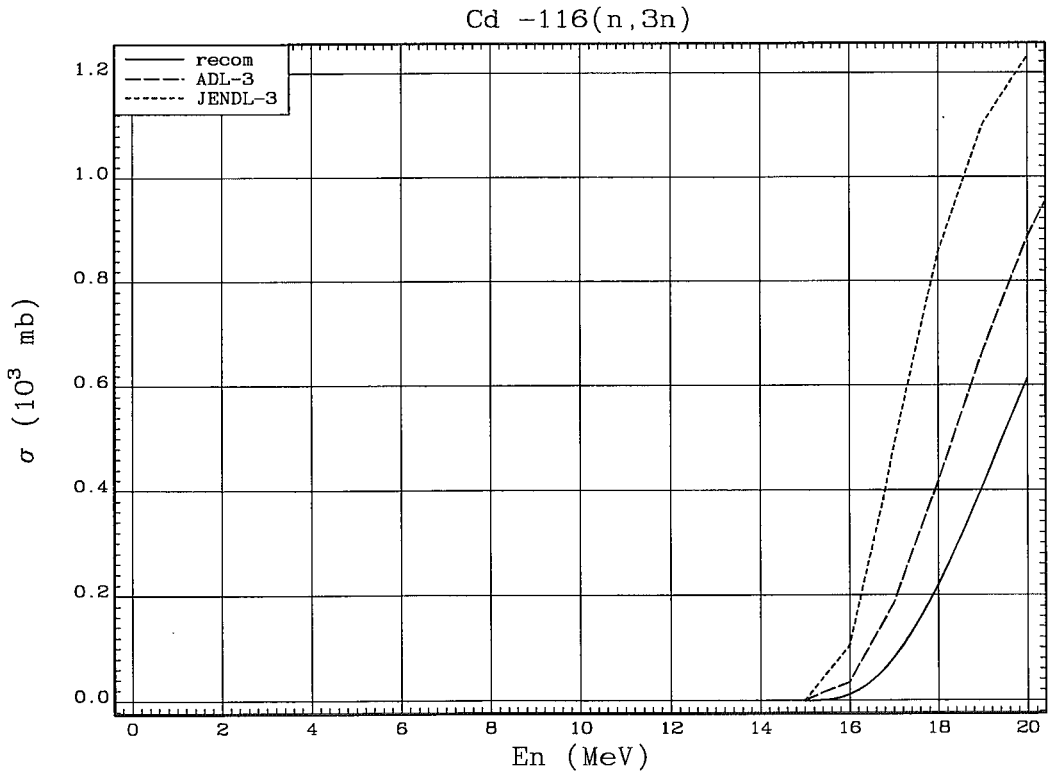

Fig.120. ^{116}Cd(n,3n)^{114}Cd reaction cross section.

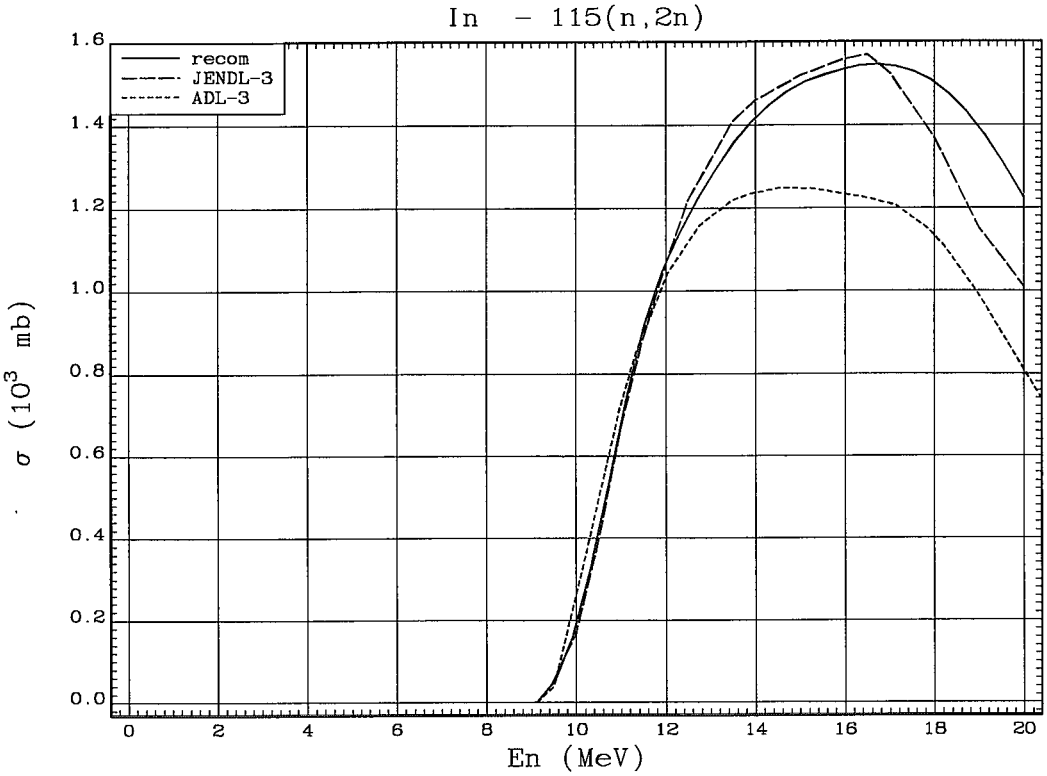

Fig.121. ^{115}In(n,2n)^{114}In reaction cross section.

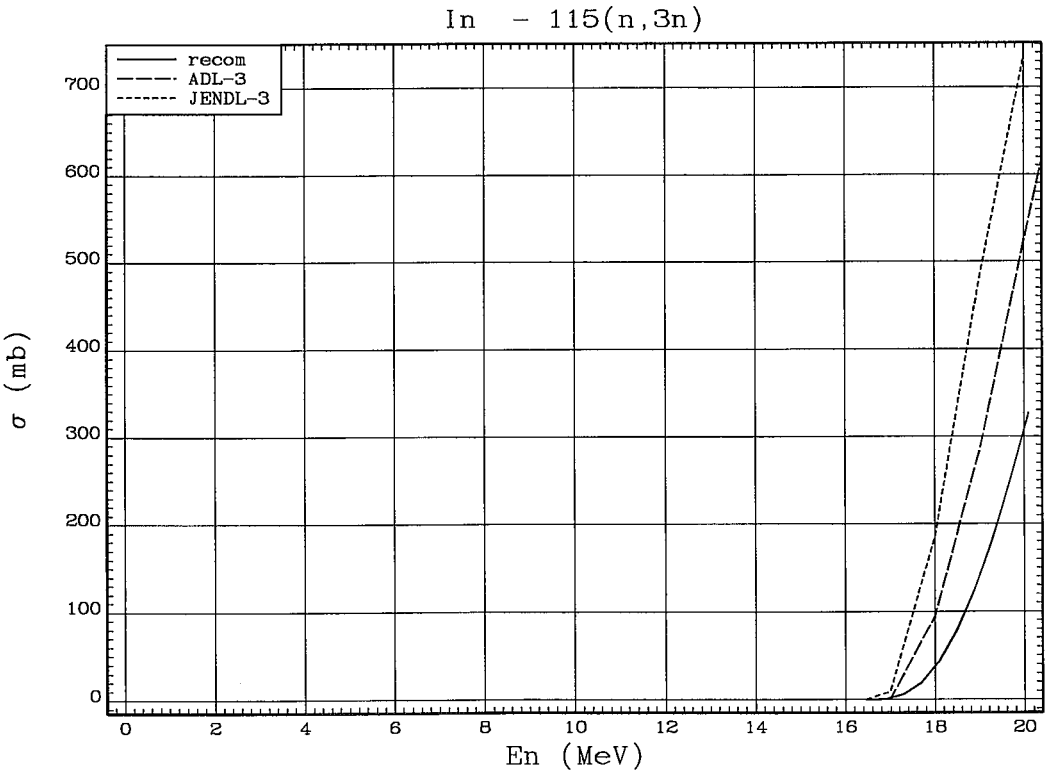

Fig.122. ^{115}In(n,3n)^{113}In reaction cross section.

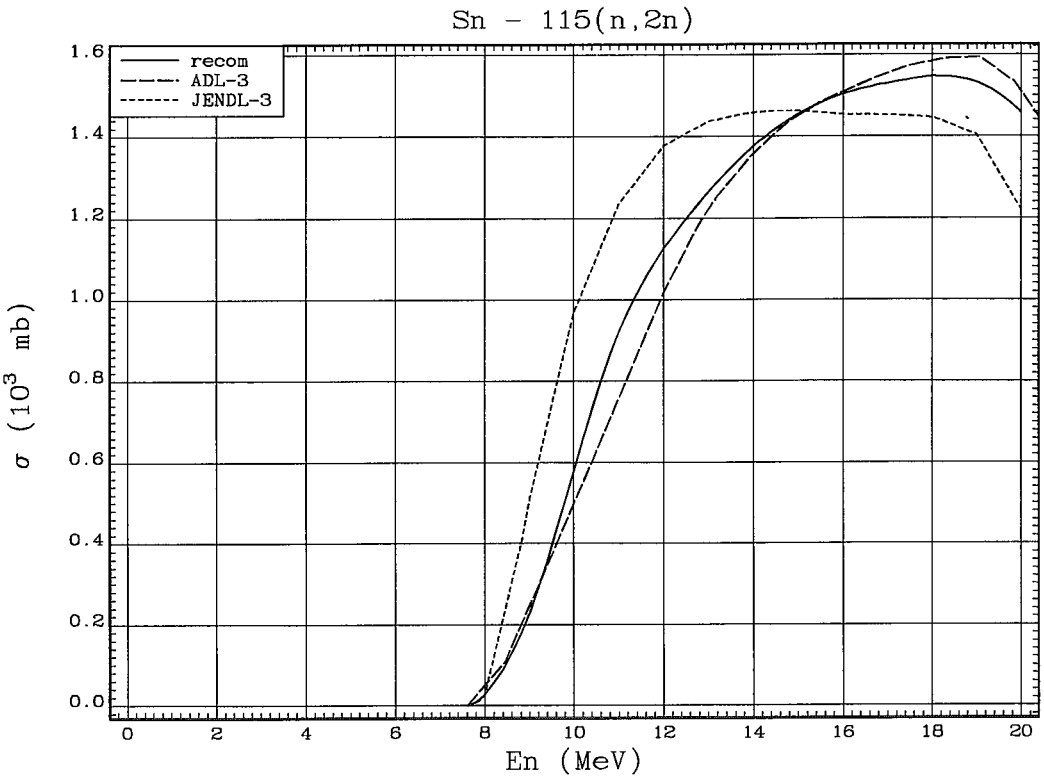

Fig.123. ^{115}Sn(n,2n)^{114}Sn reaction cross section.

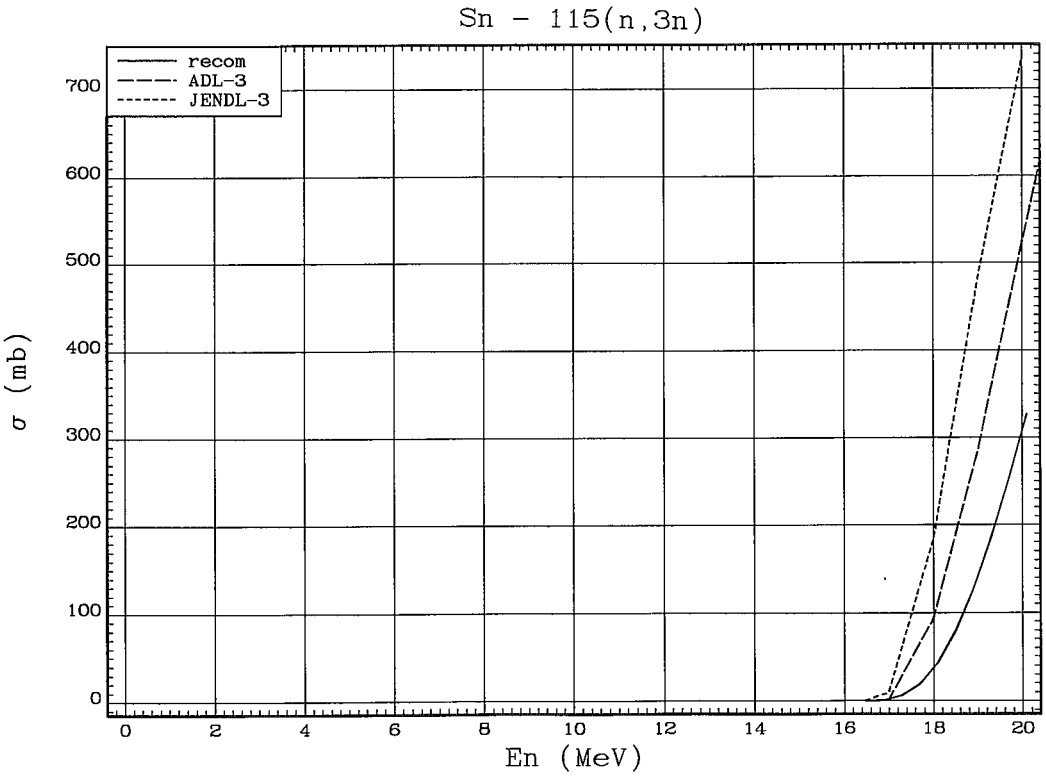

Fig.124. ^{115}Sn(n,3n)^{113}Sn reaction cross section.

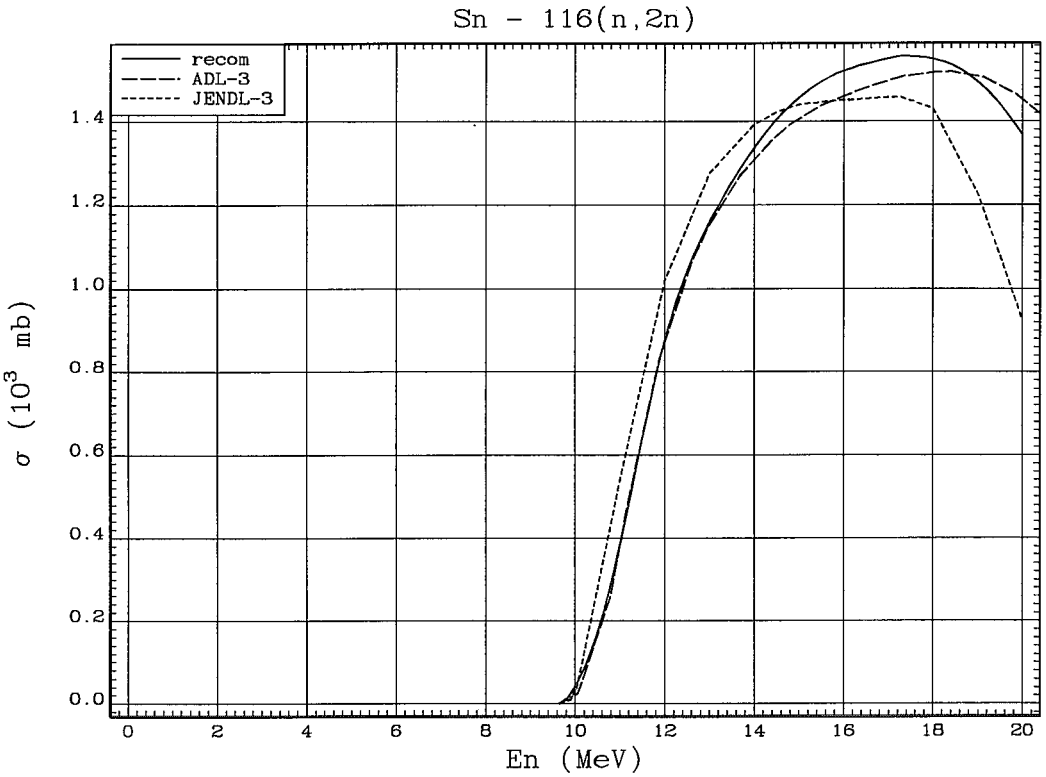

Fig.125. ^{116}Sn(n,2n)^{115}Sn reaction cross section.

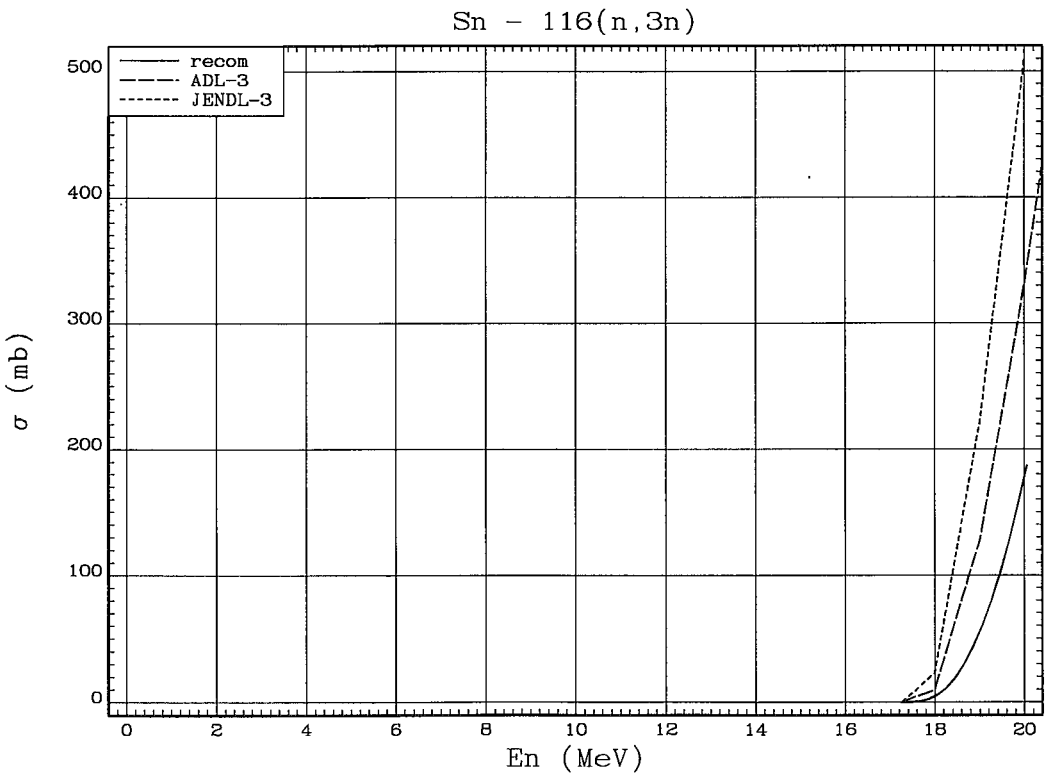

Fig.126. ^{116}Sn(n,3n)^{114}Sn reaction cross section.

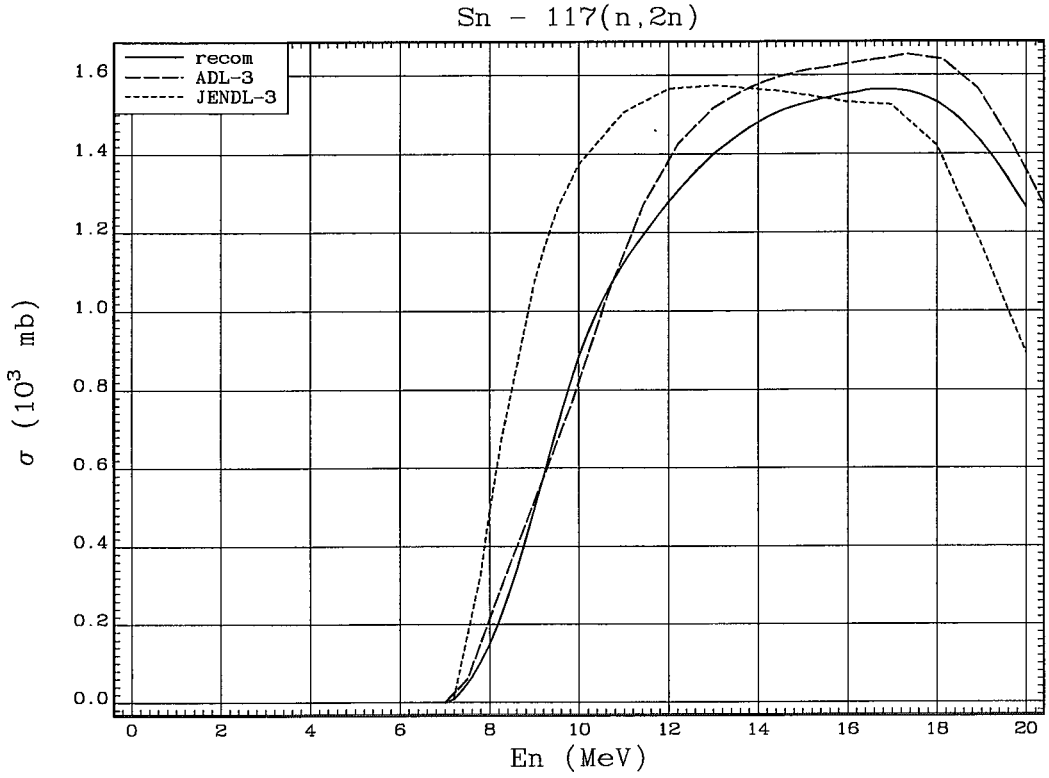

Fig.127. ^{117}Sn(n,2n)^{116}Sn reaction cross section.

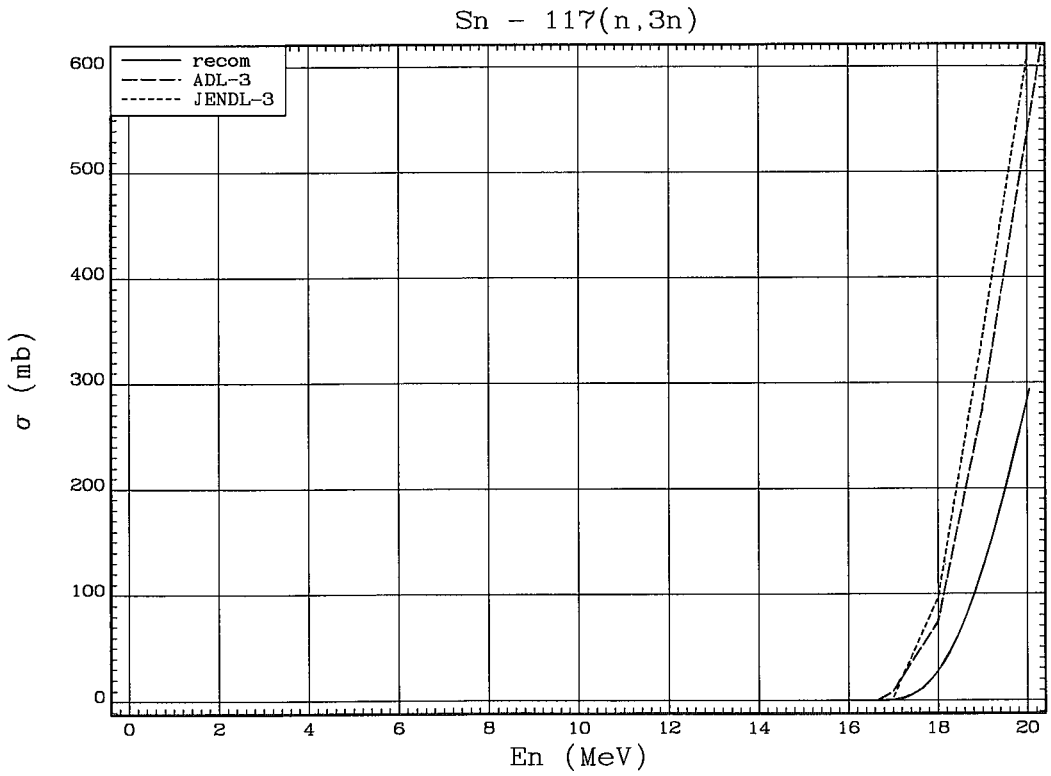

Fig.128. ^{117}Sn(n,3n)^{115}Sn reaction cross section.

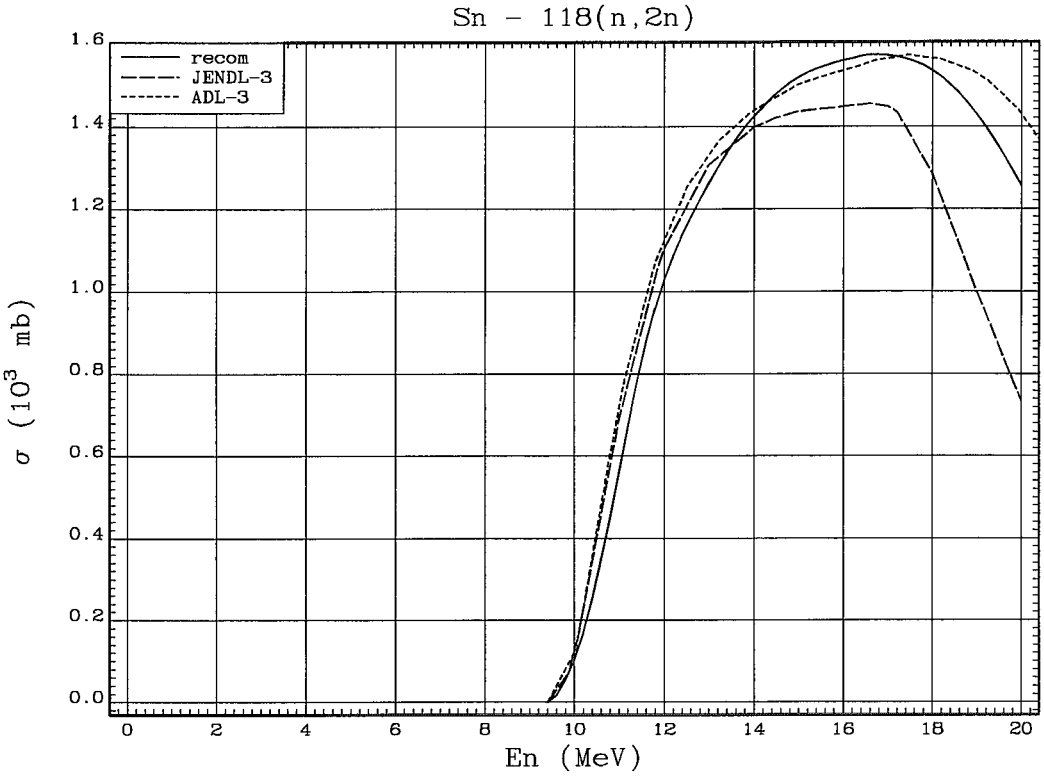

Fig.129. ^{118}Sn(n,2n)^{117}Sn reaction cross section.

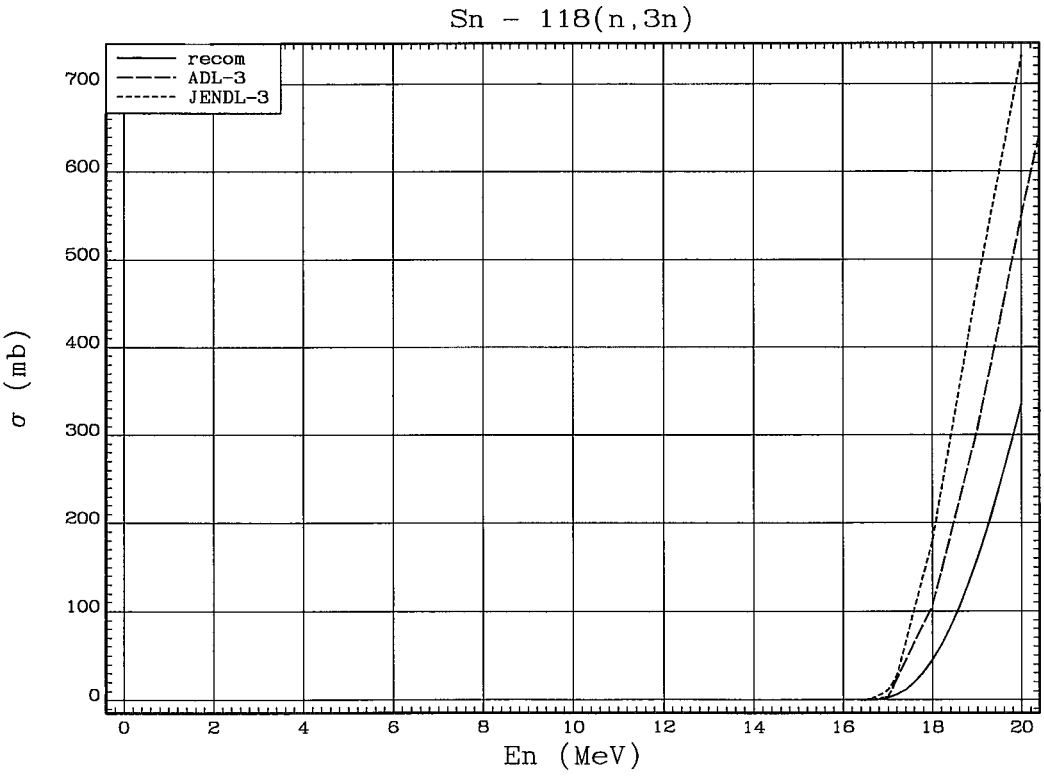

Fig.130. ^{118}Sn(n,3n)^{116}Sn reaction cross section.

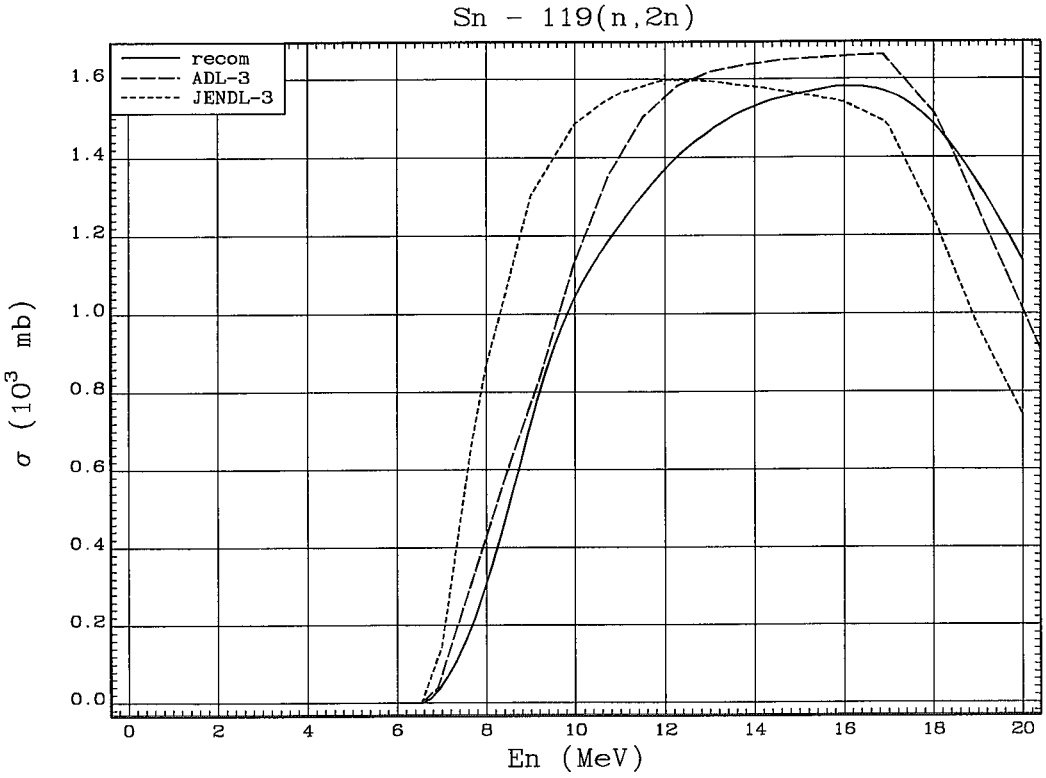

Fig.131. ^{119}Sn(n,2n)^{118}Sn reaction cross section.

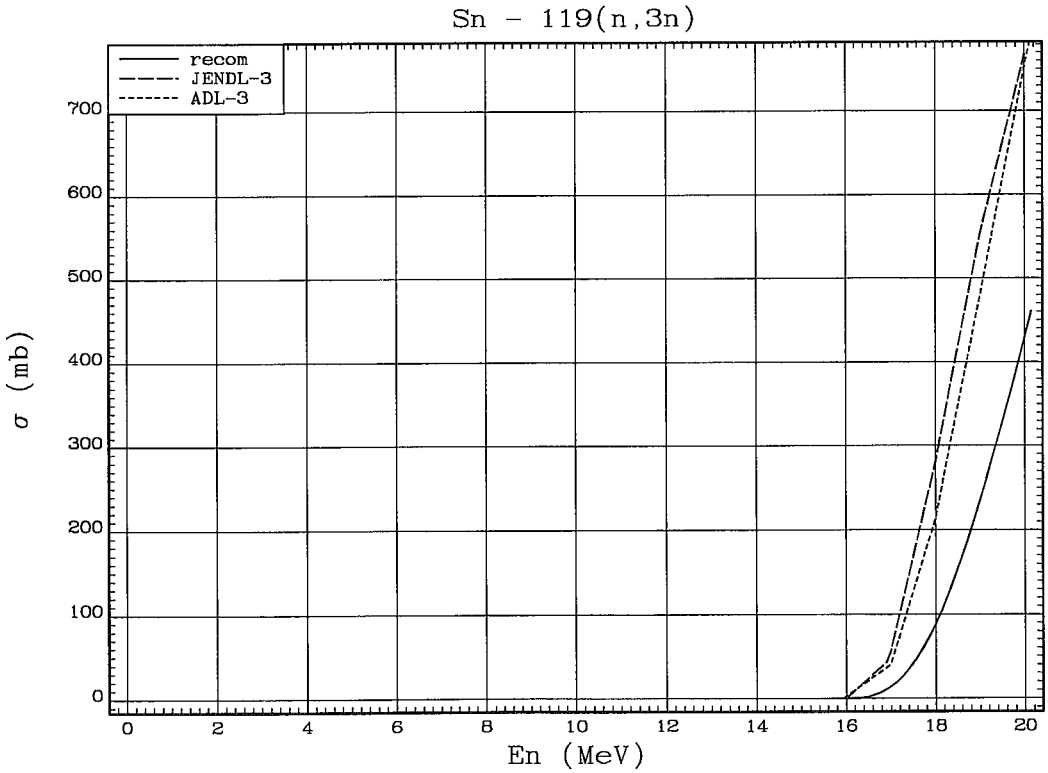

Fig.132. ^{119}Sn(n,3n)^{117}Sn reaction cross section.

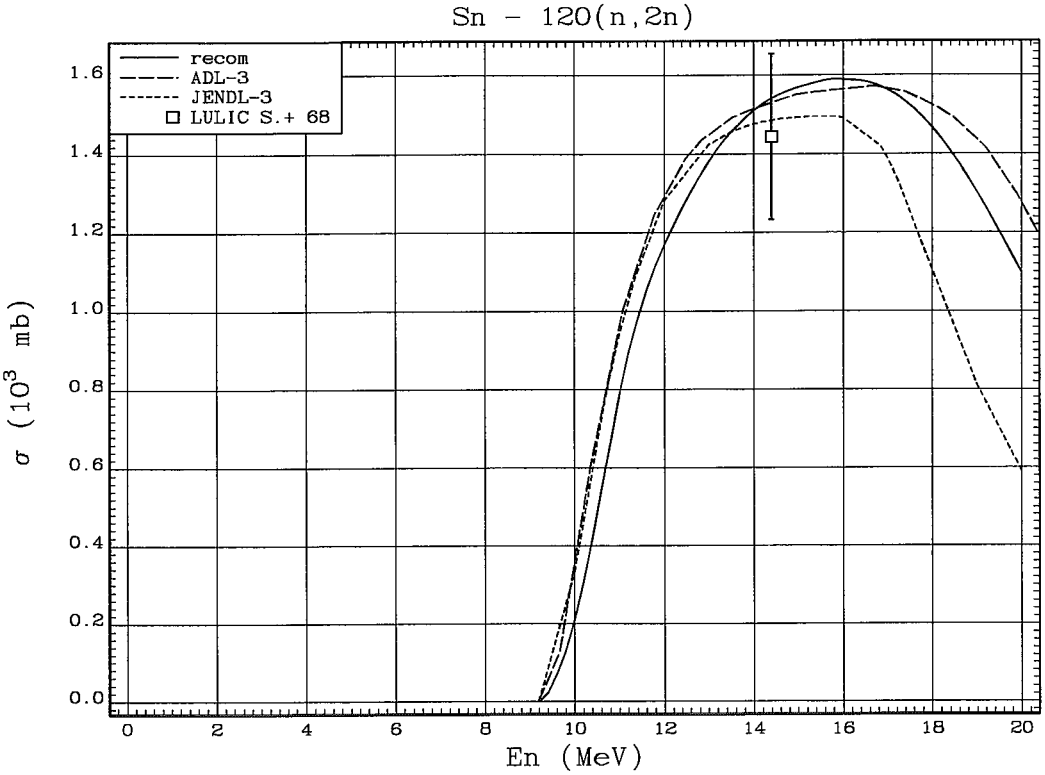

Fig.133. ^{120}Sn(n,2n)^{119}Sn reaction cross section.

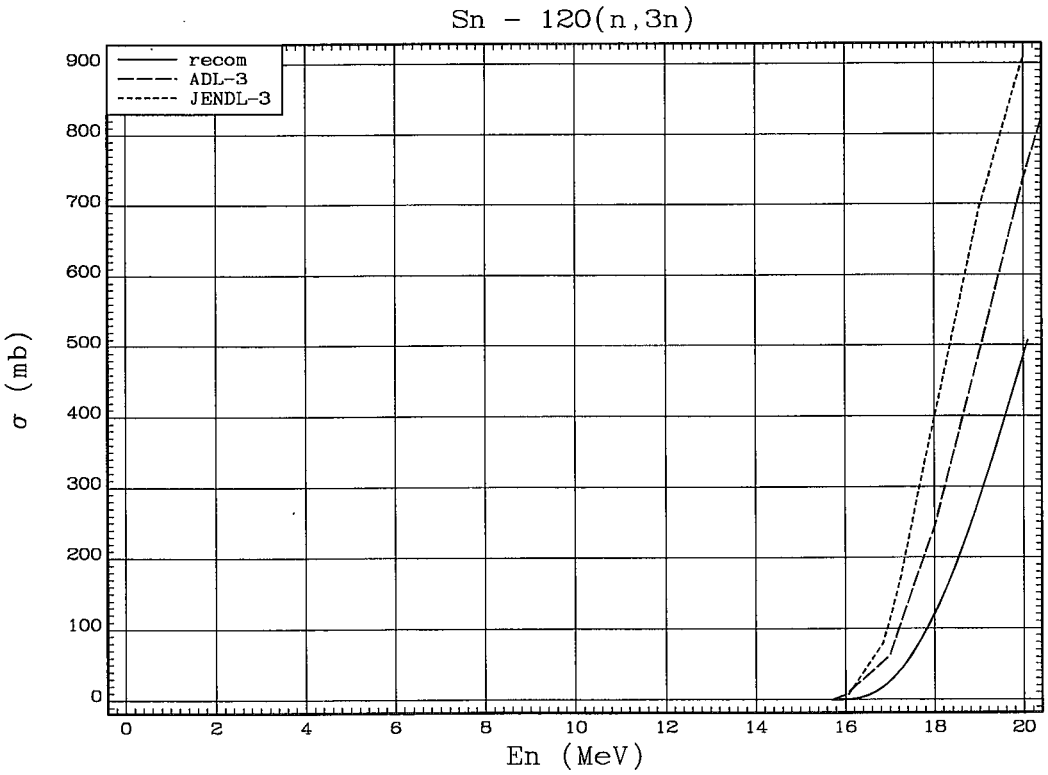

Fig.134. ^{120}Sn(n,3n)^{118}Sn reaction cross section.

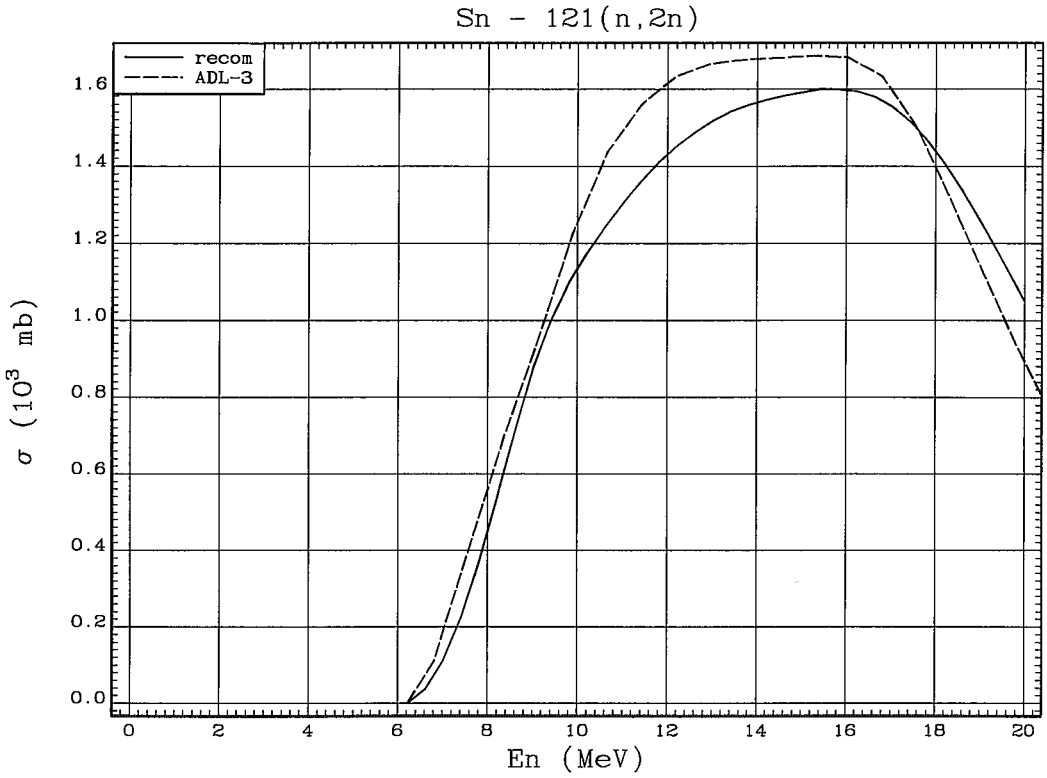

Fig.135. ^{121}Sn(n,2n)^{120}Sn reaction cross section.

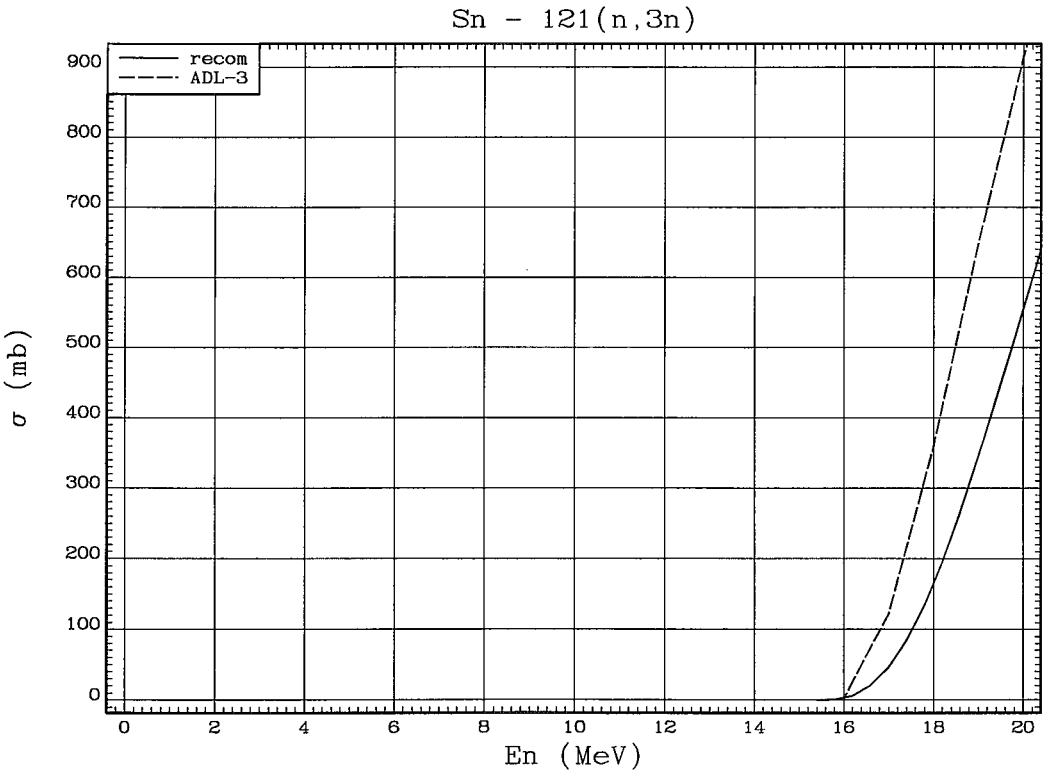

Fig.136. ^{121}Sn(n,3n)^{119}Sn reaction cross section.

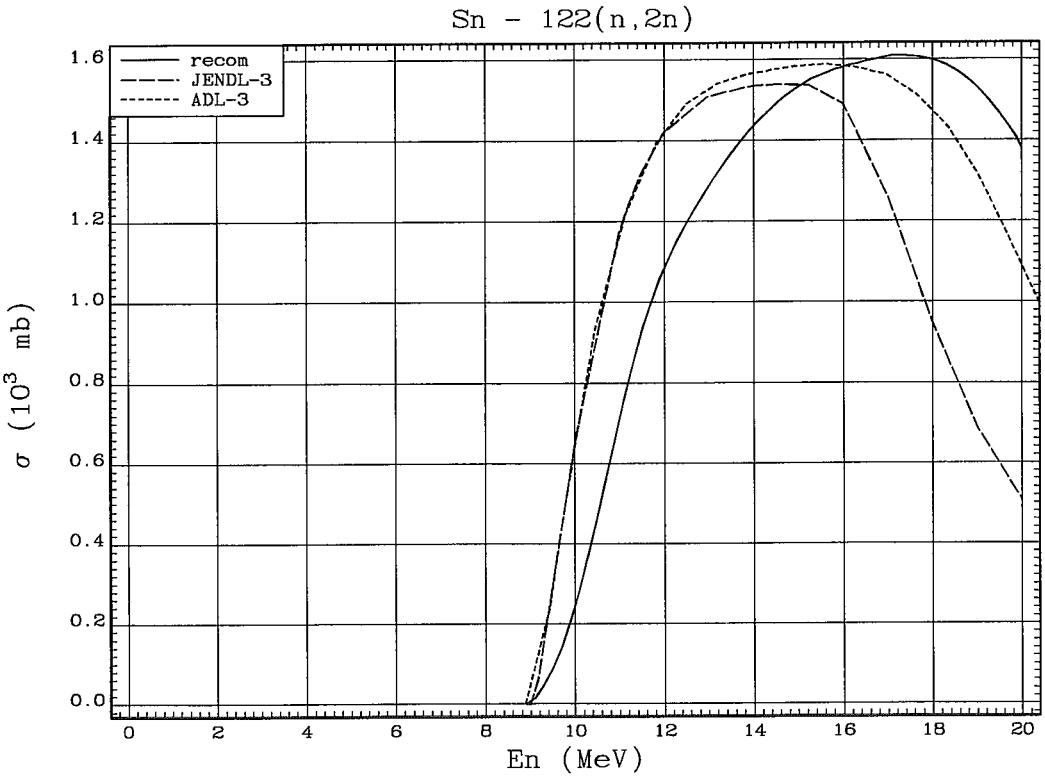

Fig.137. ^{122}Sn(n,2n)^{121}Sn reaction cross section.

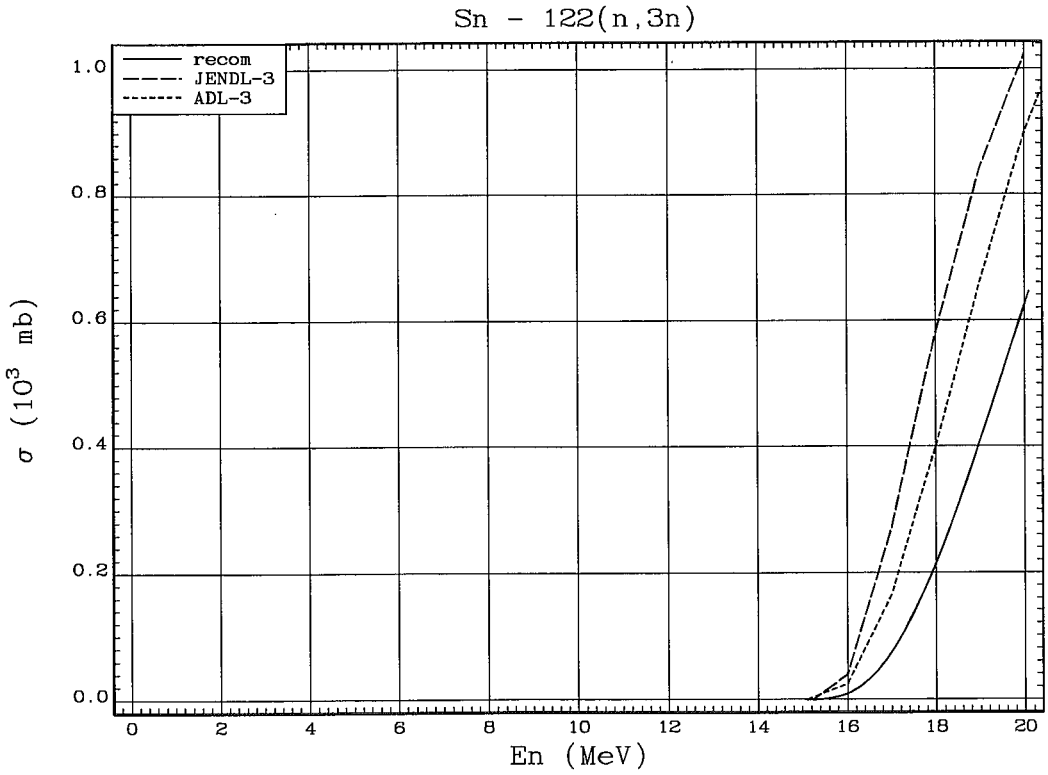

Fig.138. ^{122}Sn(n,3n)^{120}Sn reaction cross section.

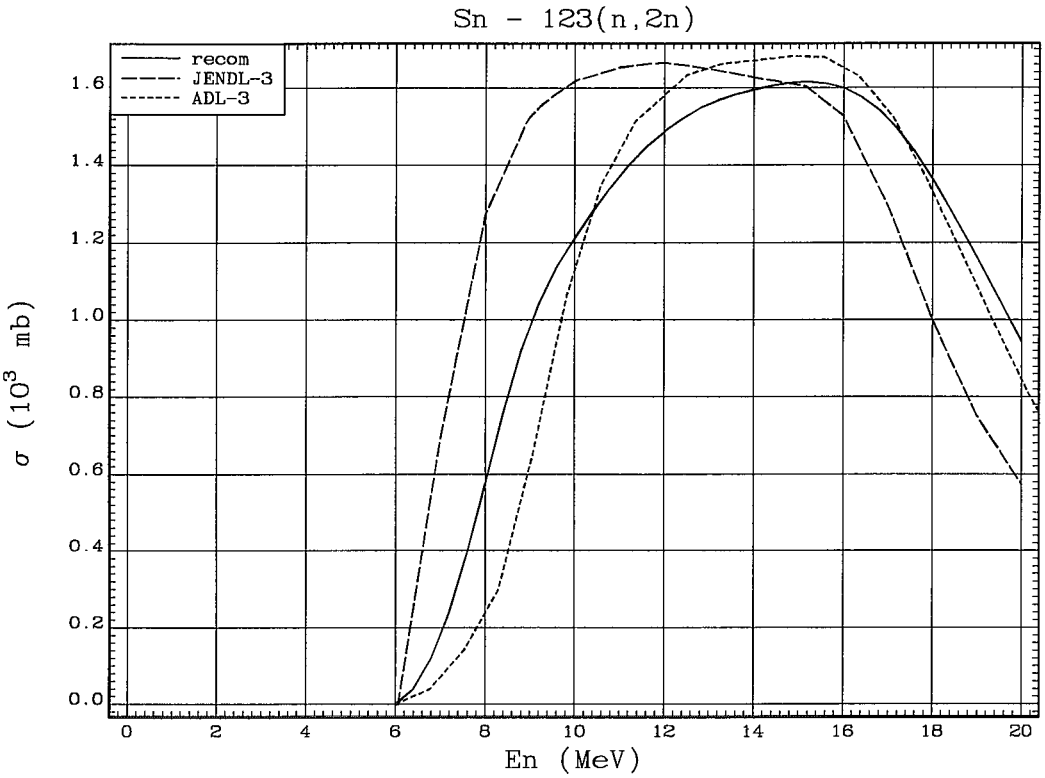

Fig.139. ^{123}Sn(n,2n)^{122}Sn reaction cross section.

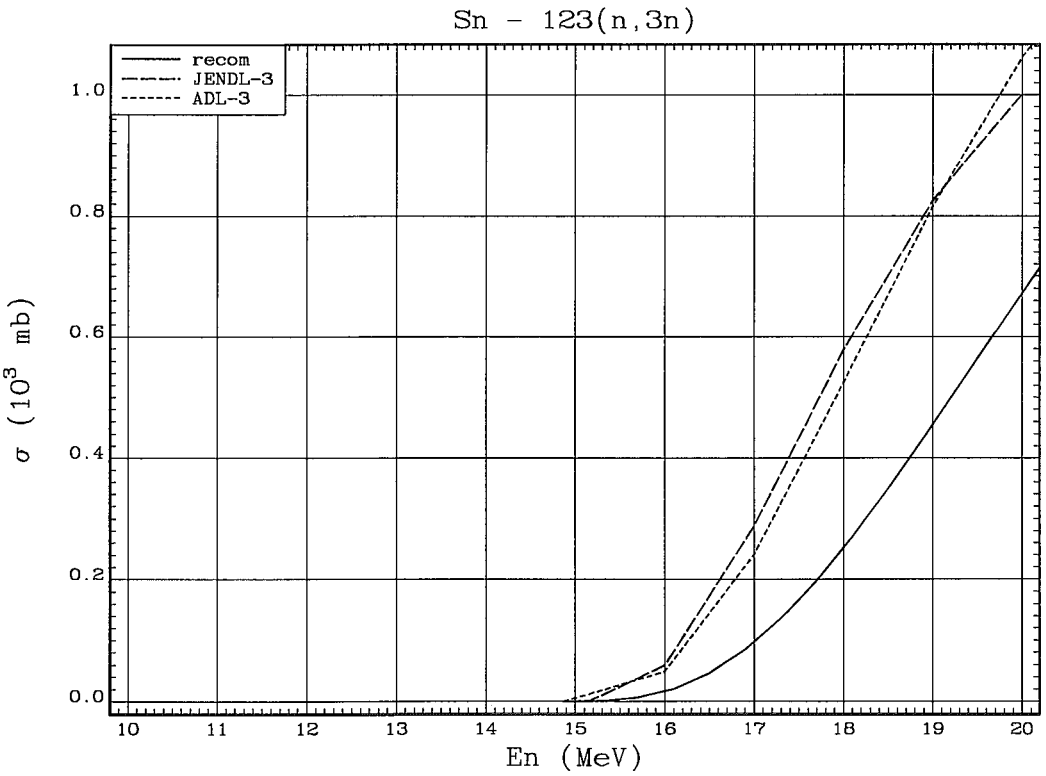

Fig.140. ^{123}Sn(n,3n)^{121}Sn reaction cross section.

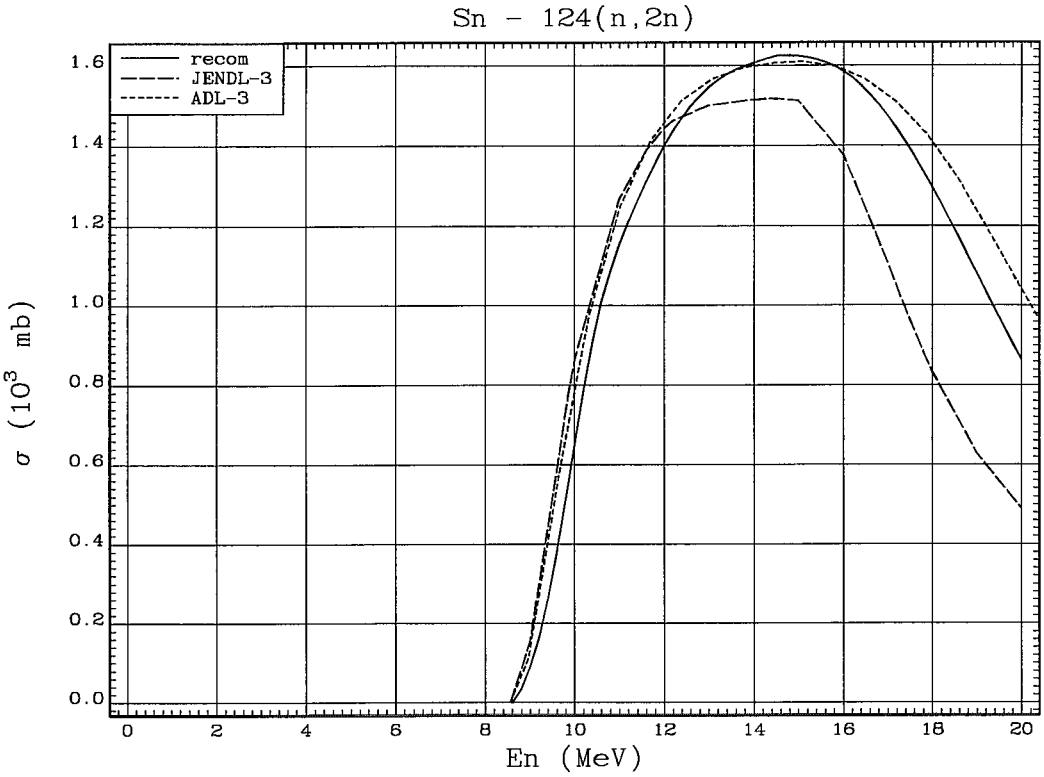

Fig.141. ^{124}Sn(n,2n)^{123}Sn reaction cross section.

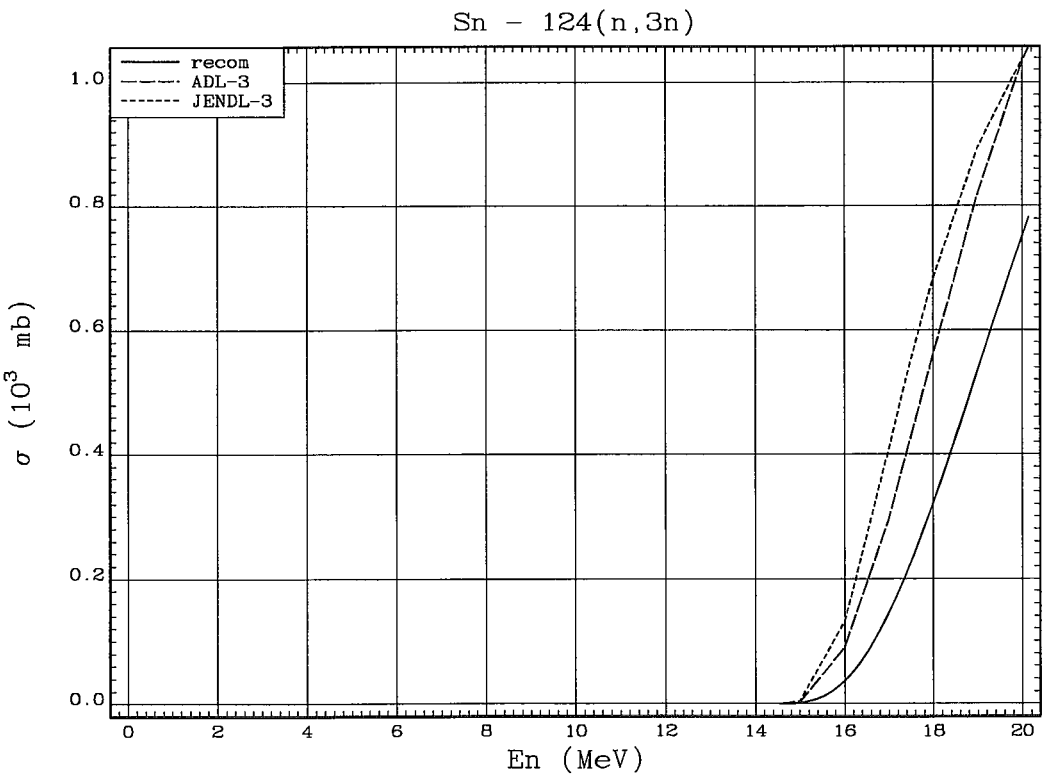

Fig.142. ^{124}Sn(n,3n)^{122}Sn reaction cross section.

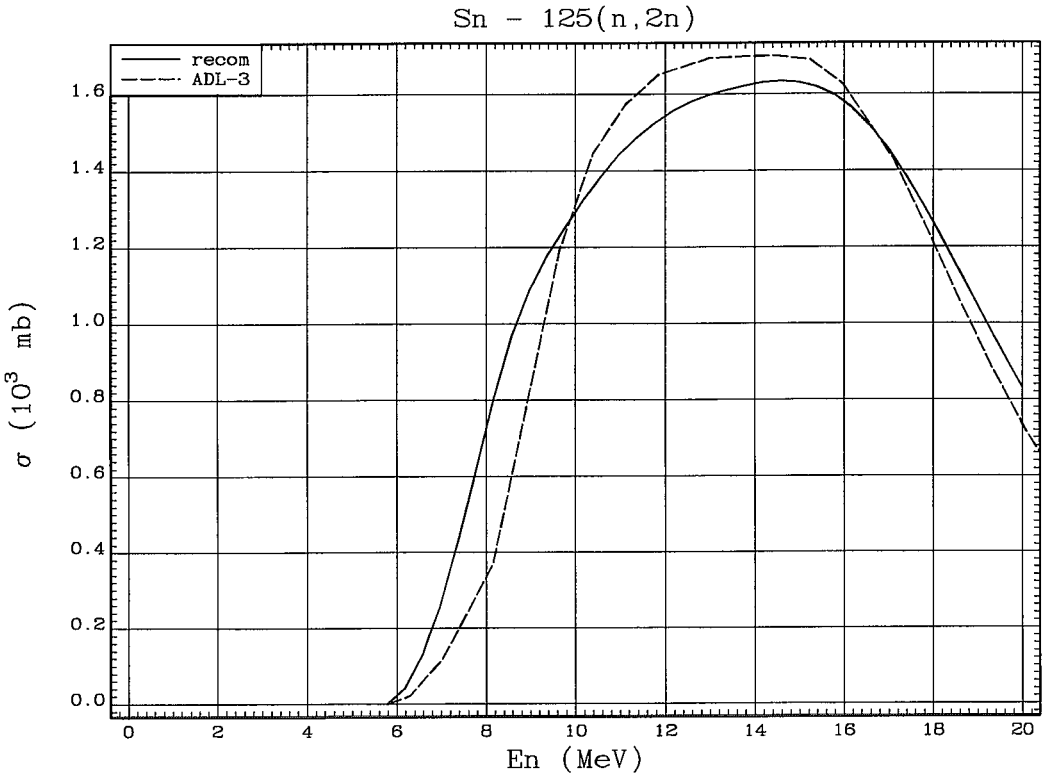

Fig.143. ^{125}Sn(n,2n)^{124}Sn reaction cross section.

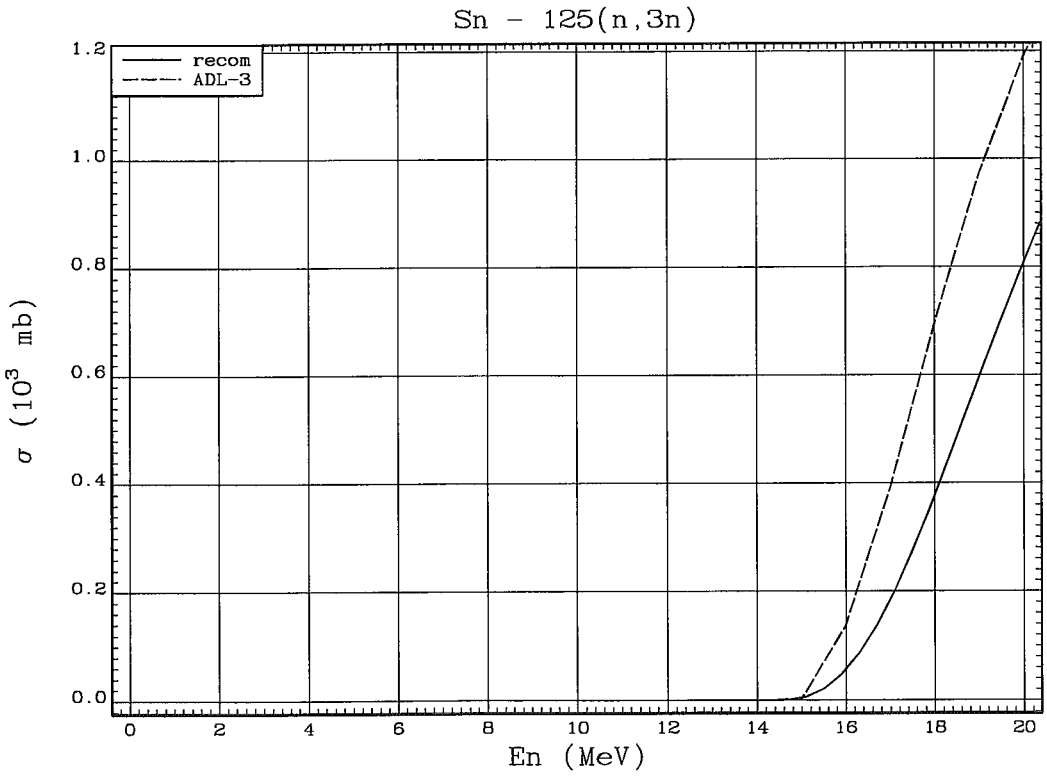

Fig.144. ^{125}Sn(n,3n)^{123}Sn reaction cross section.

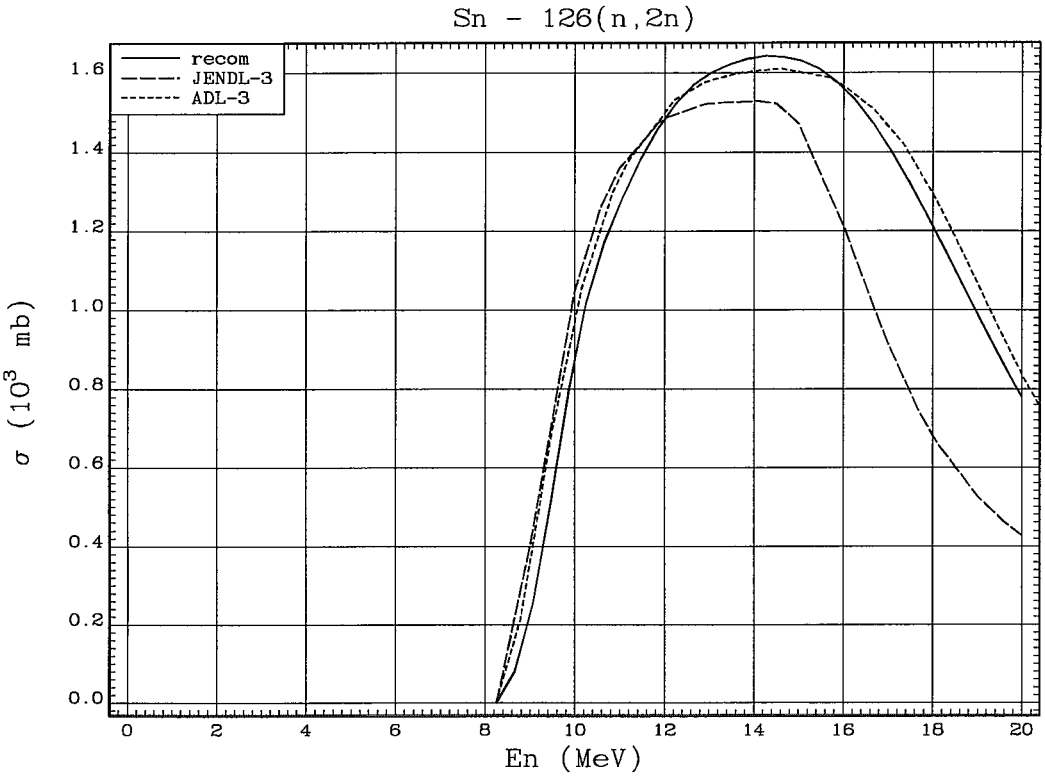

Fig.145. ^{126}Sn(n,2n)^{125}Sn reaction cross section.

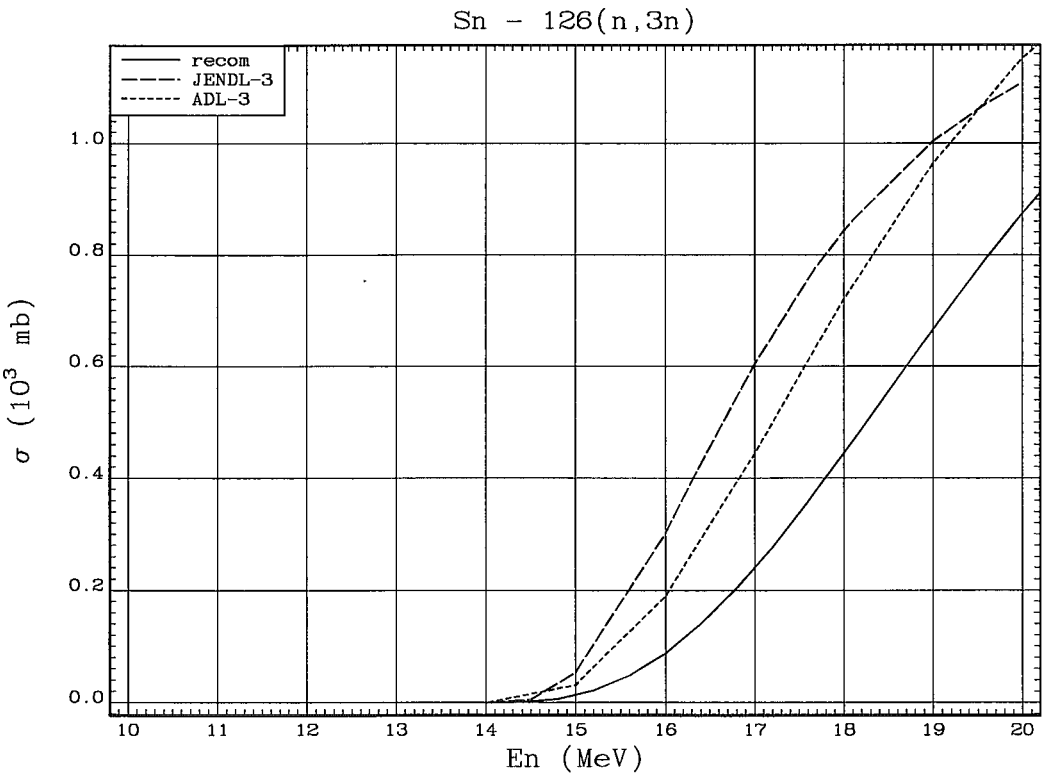

Fig.146. ^{126}Sn(n,3n)^{124}Sn reaction cross section.

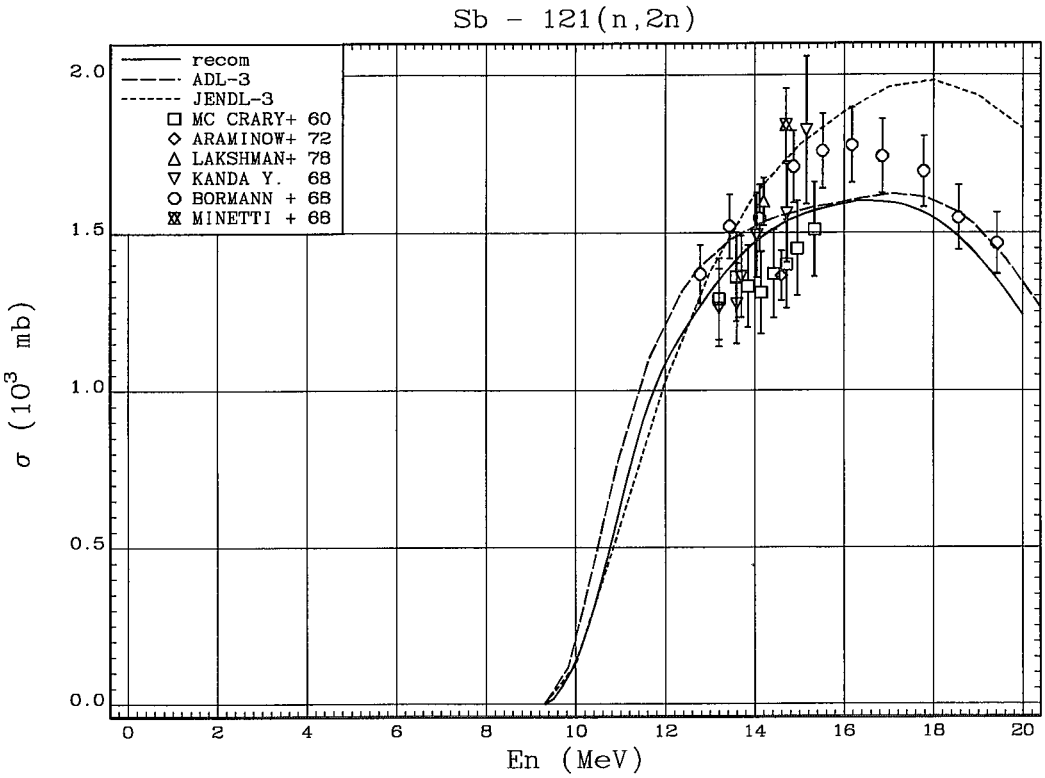

Fig.147. ^{121}Sb(n,2n)^{120}Sb reaction cross section.

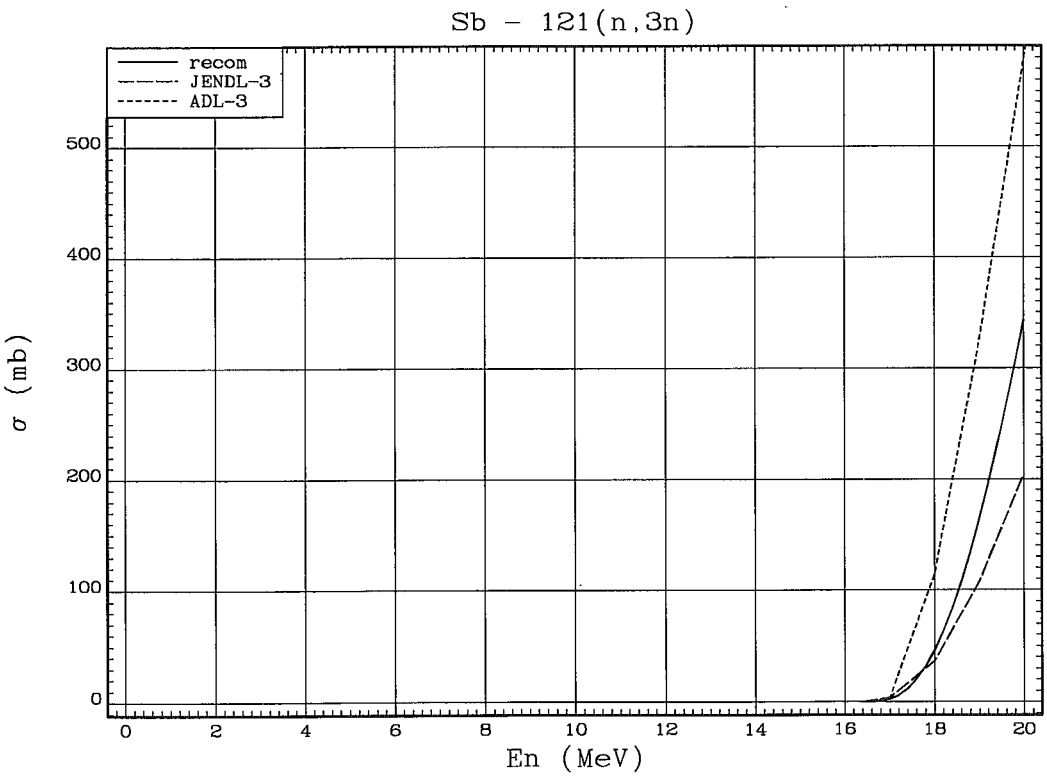

Fig.148. ^{121}Sb(n,3n)^{119}Sb ^{120}Sb reaction cross section.

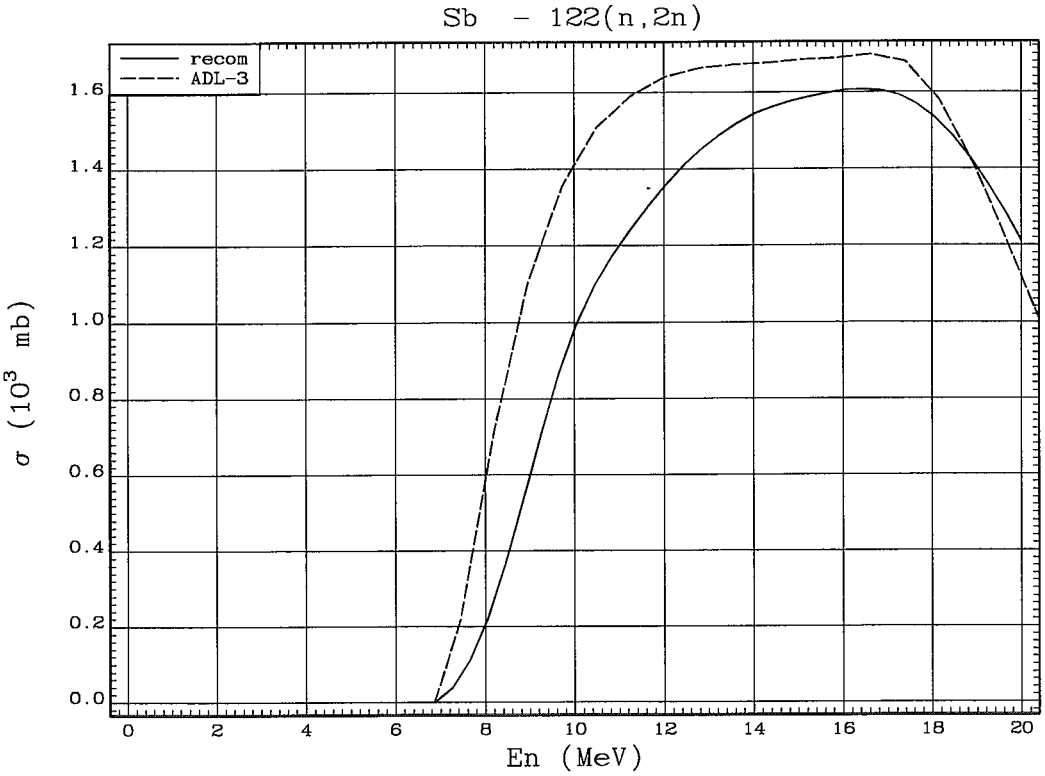

Fig.149. ^{122}Sb(n,2n)^{121}Sb ^{120}Sb reaction cross section.

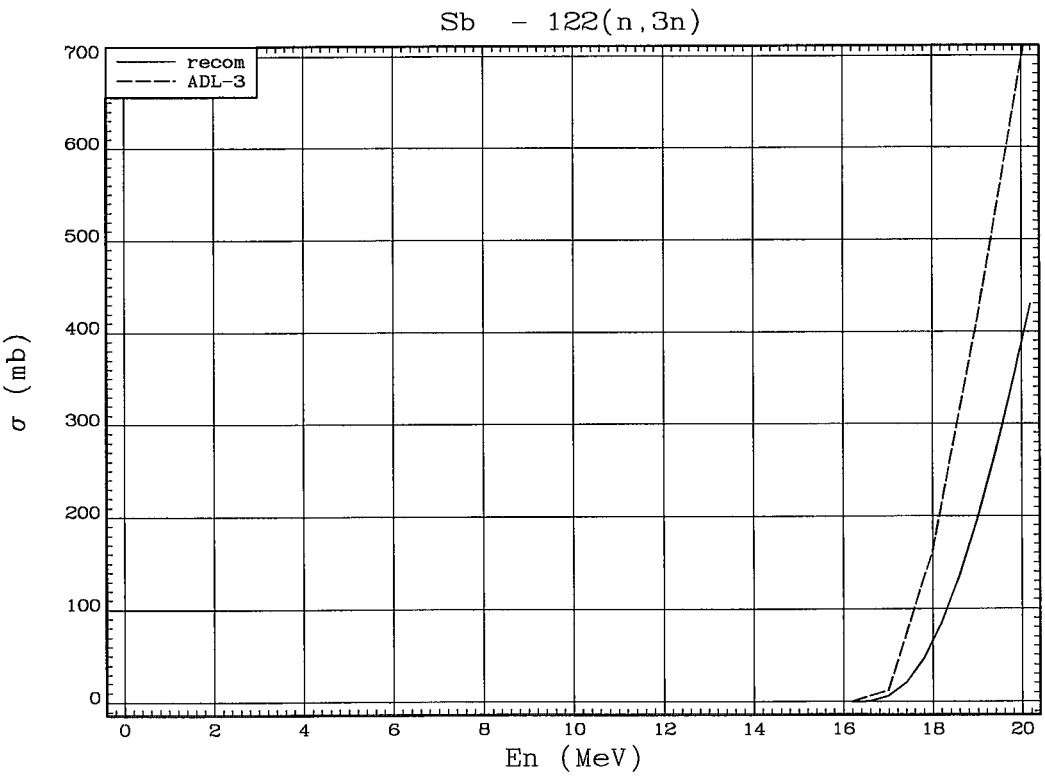

Fig.150. ^{122}Sb(n,3n)^{120}Sb reaction cross section.

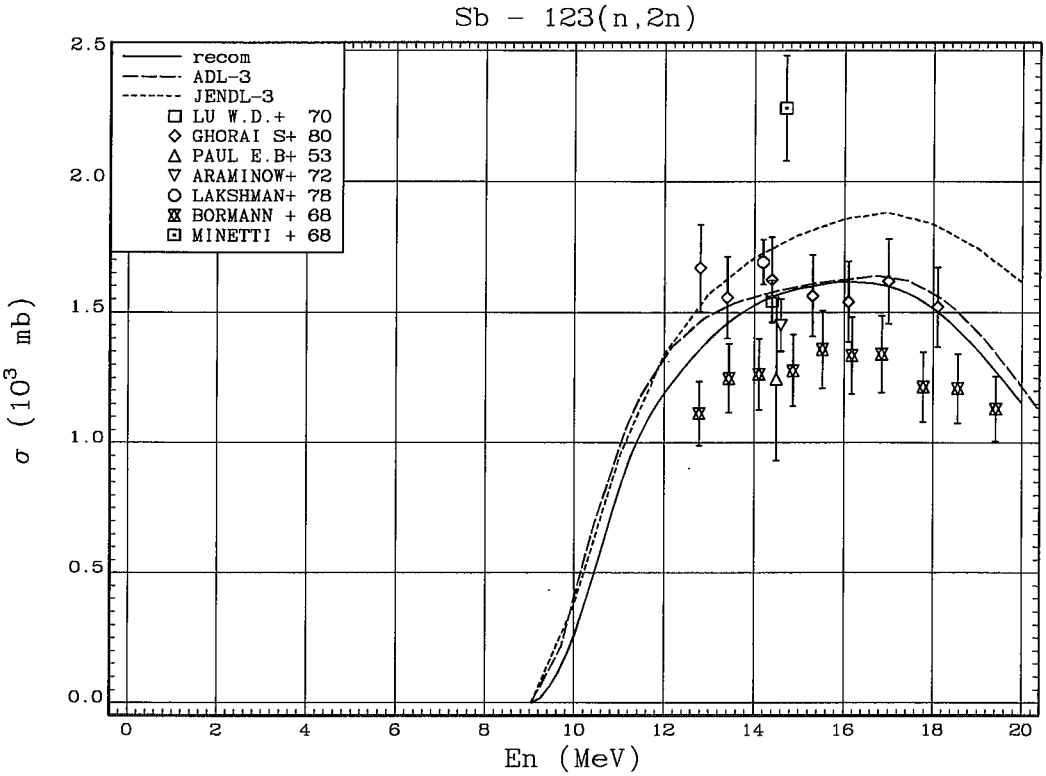

Fig.151. ^{123}Sb(n,2n)^{122}Sb reaction cross section.

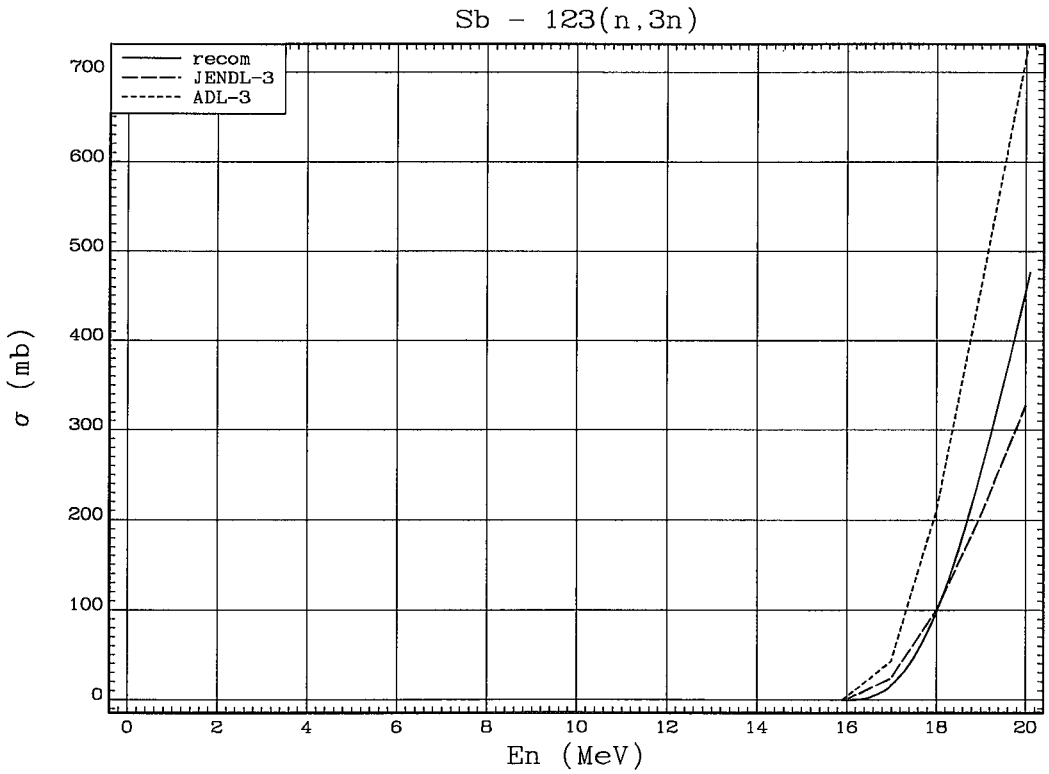

Fig.152. ^{123}Sb(n,3n)^{121}Sb reaction cross section.

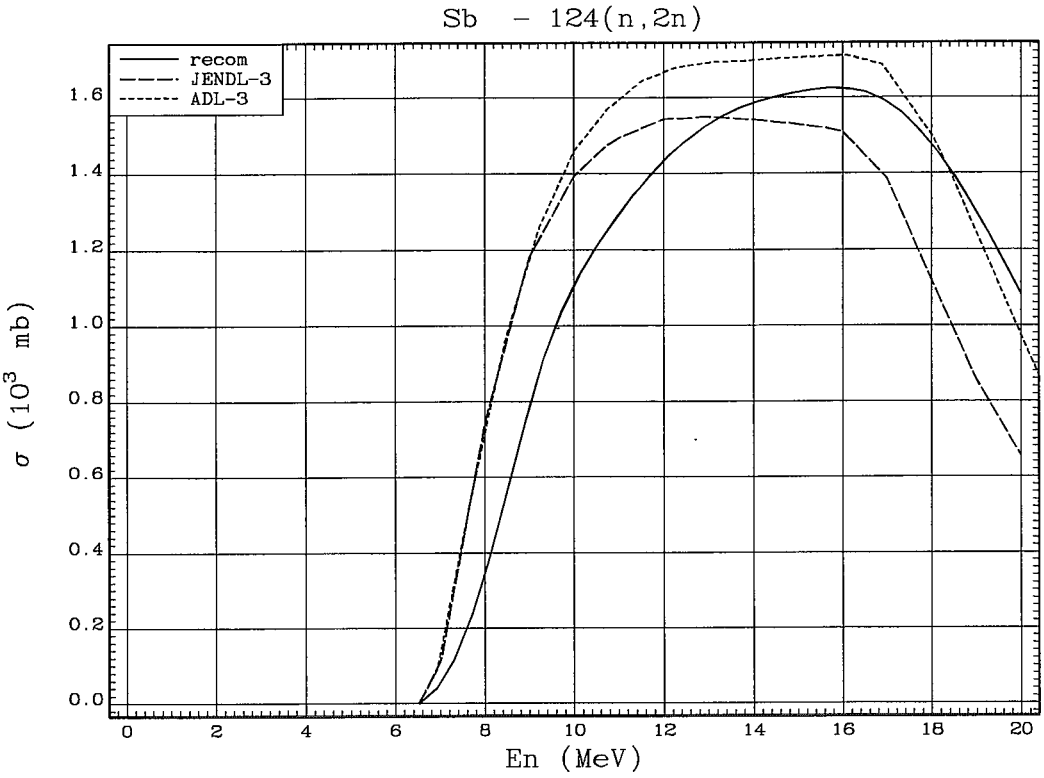

Fig.153. ^{124}Sb(n,2n)^{123}Sb reaction cross section.

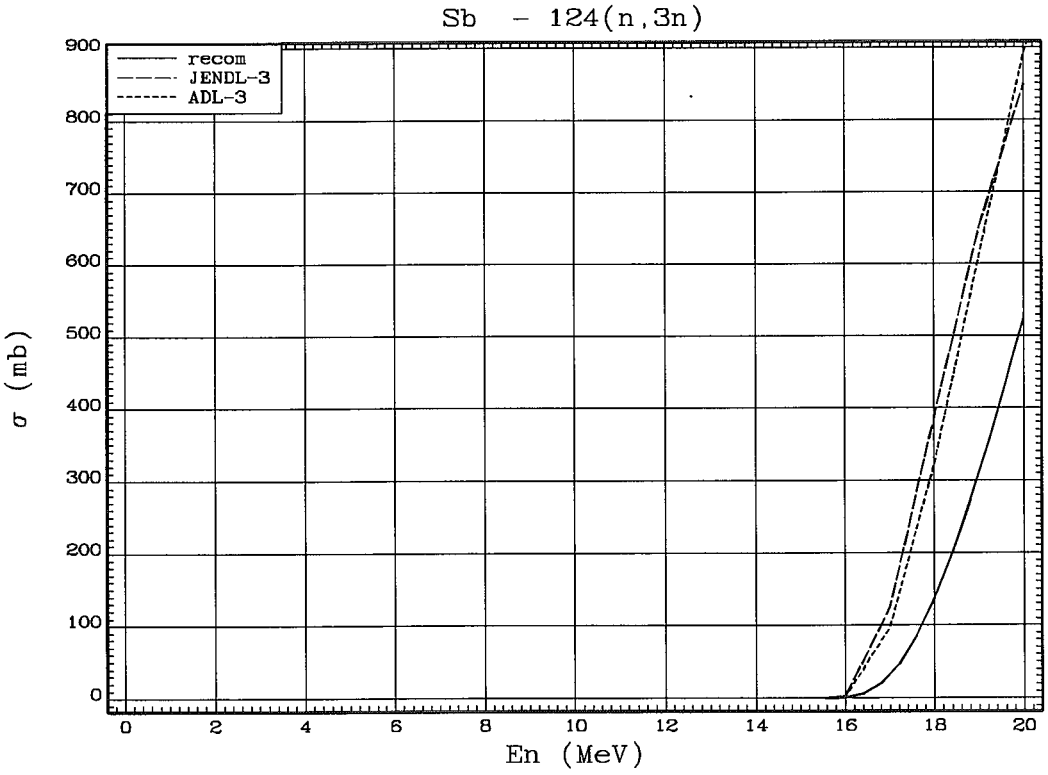

Fig.154. ^{124}Sb(n,3n)^{122}Sb reaction cross section.

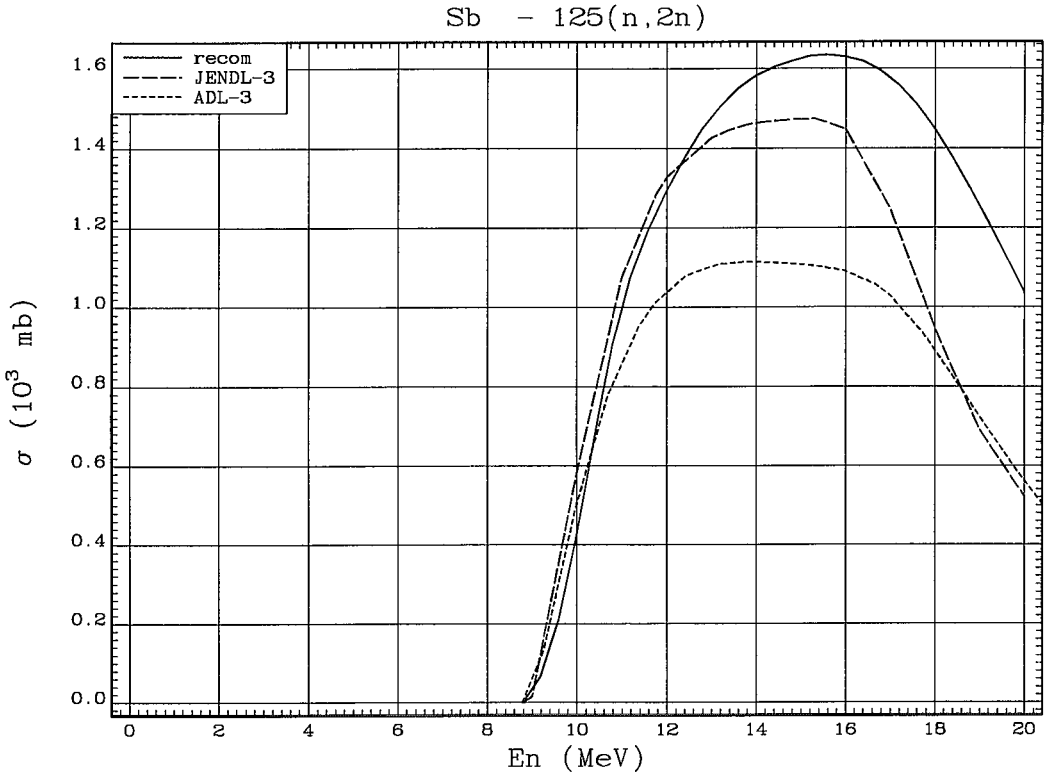

Fig.155. ^{125}Sb(n,2n)^{124}Sb reaction cross section.

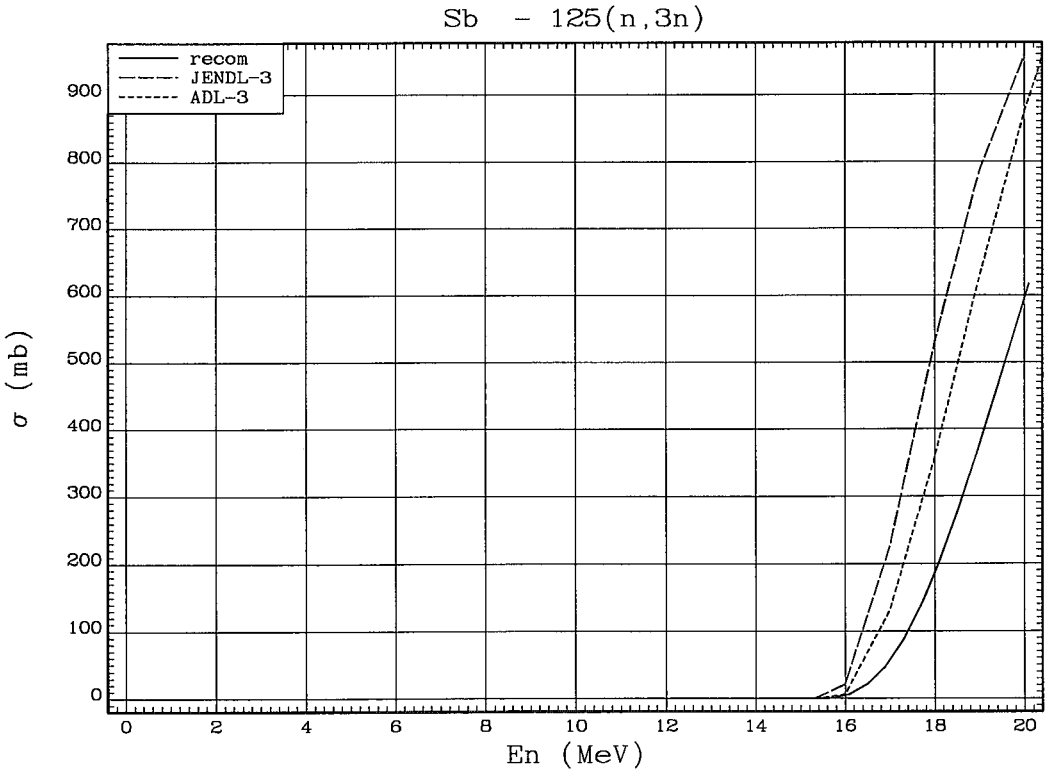

Fig.156. ^{125}Sb(n,3n)^{123}Sb reaction cross section.

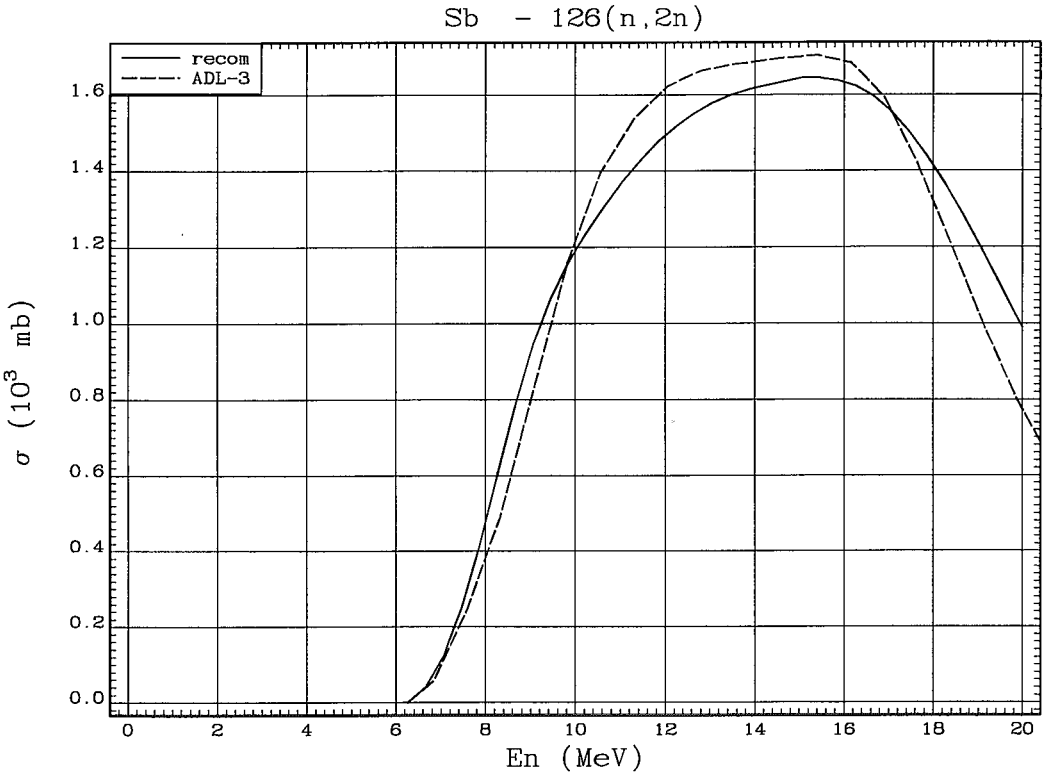

Fig.157. ^{126}Sb(n,2n)^{125}Sb reaction cross section.

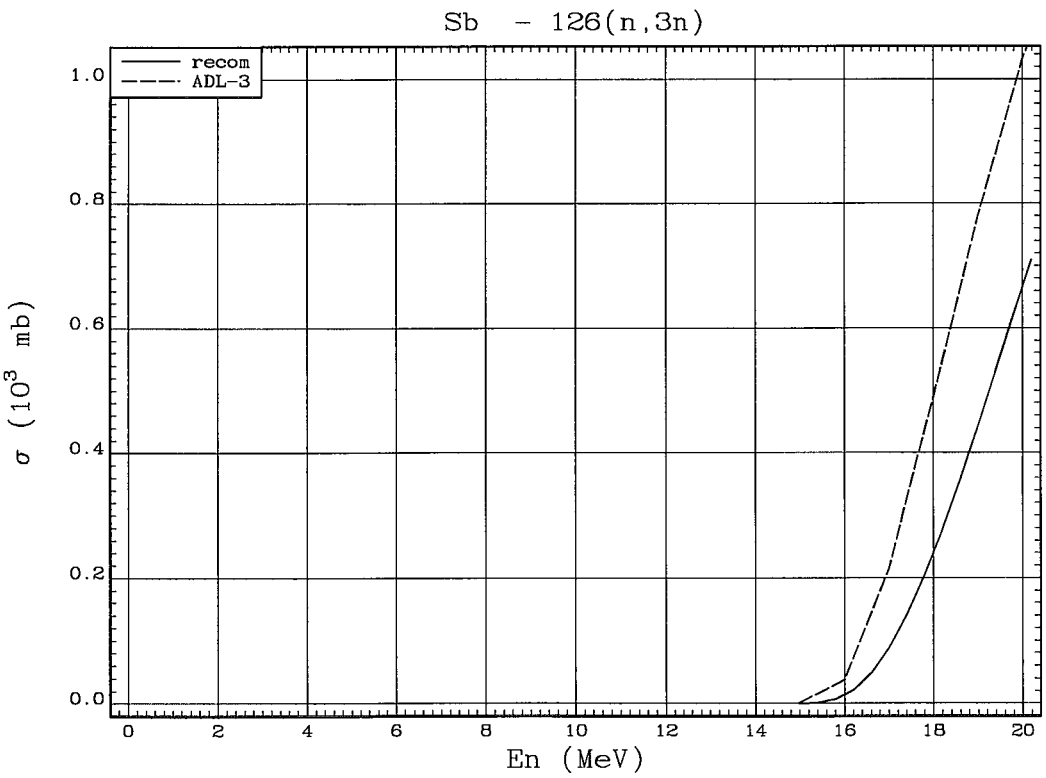

Fig.158. ^{126}Sb(n,3n)^{124}Sb reaction cross section.

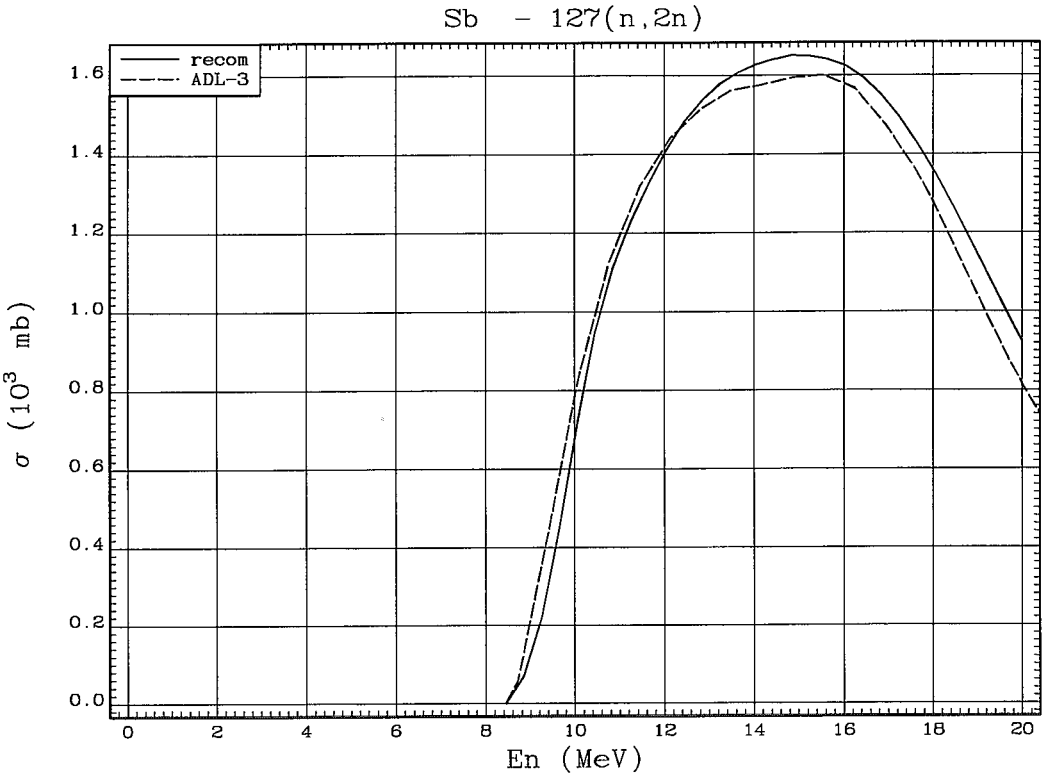

Fig.159. ^{127}Sb(n,2n)^{126}Sb reaction cross section.

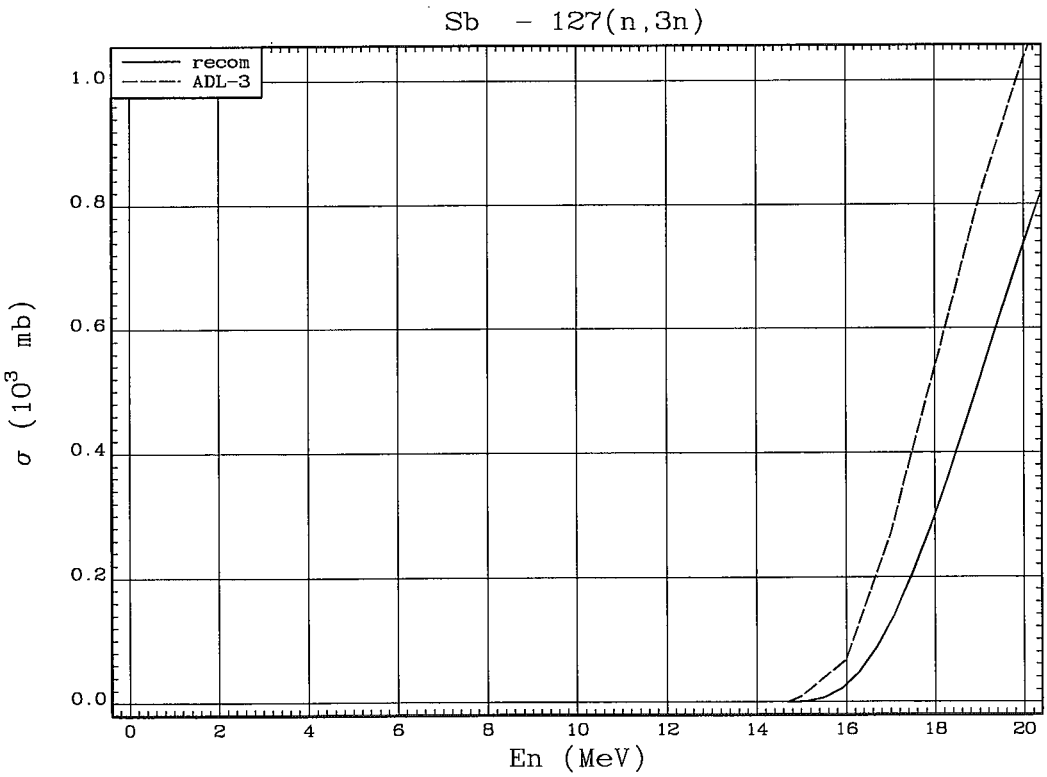

Fig.160. ^{127}Sb(n,3n)^{125}Sb reaction cross section.

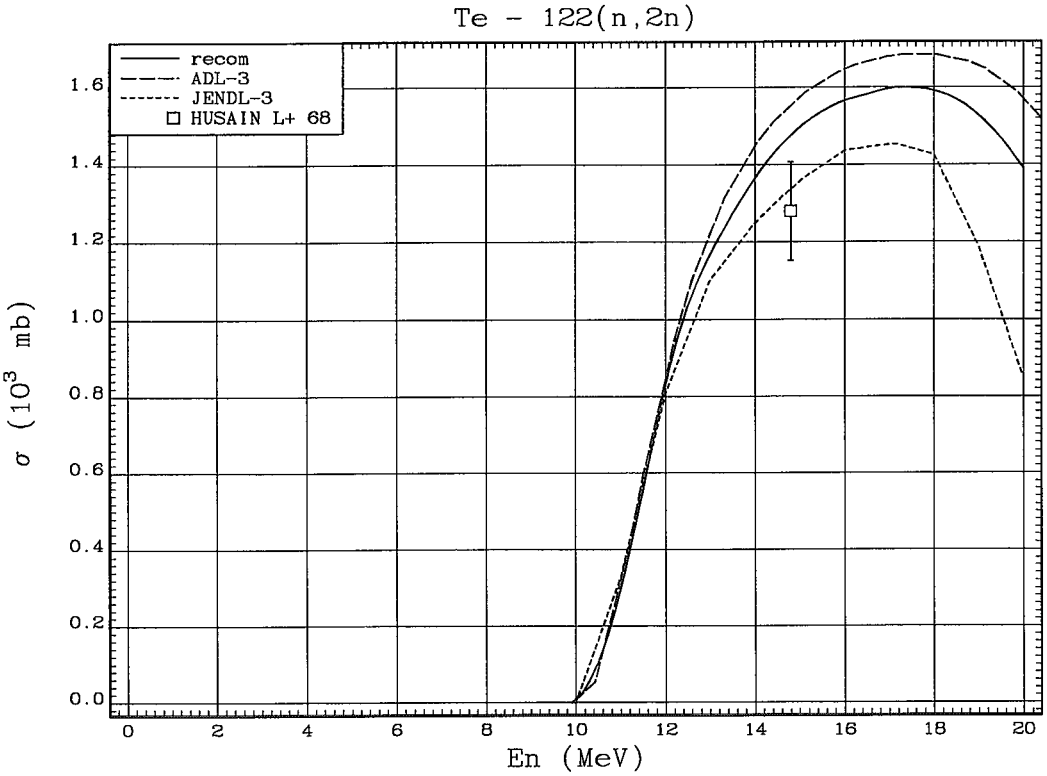

Fig.161. ^{122}Te(n,2n)^{121}Te reaction cross section.

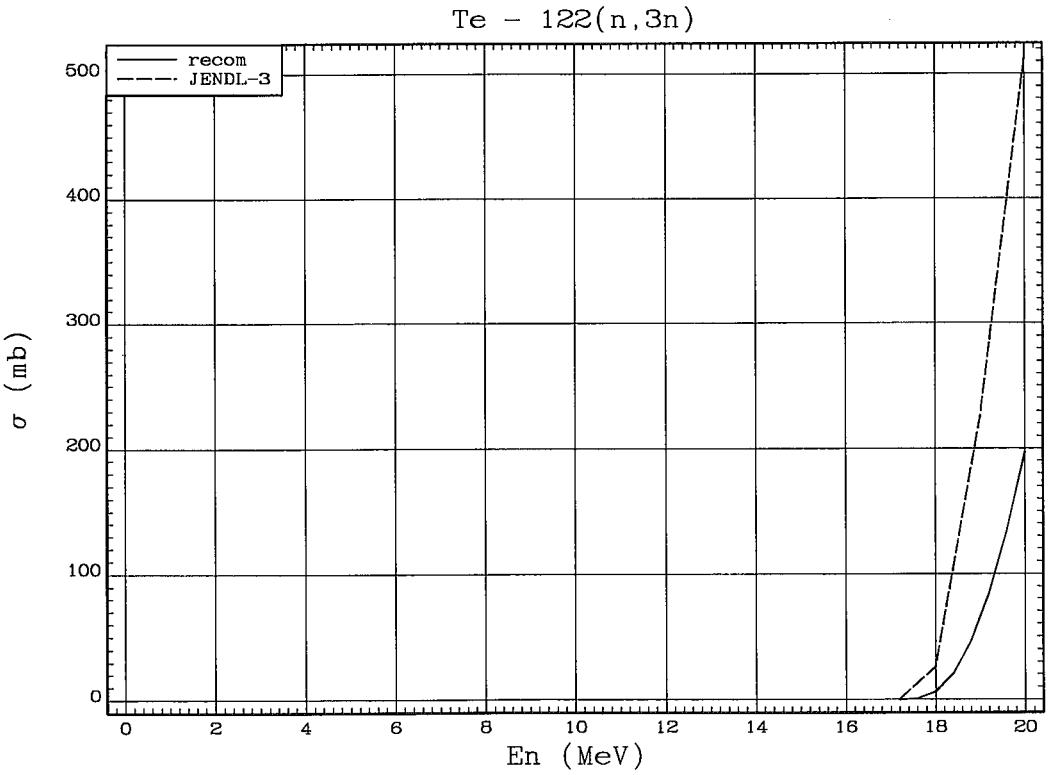

Fig.162. ^{122}Te(n,3n)^{120}Te reaction cross section.

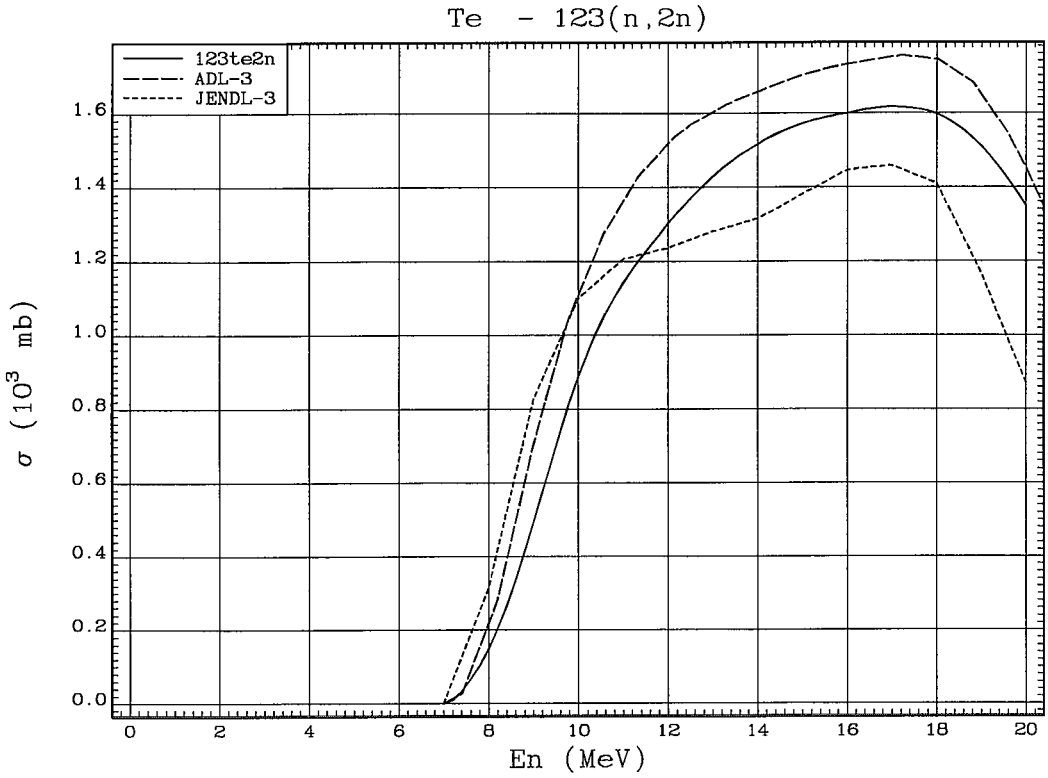

Fig.163. ^{123}Te(n,2n)^{122}Te reaction cross section.

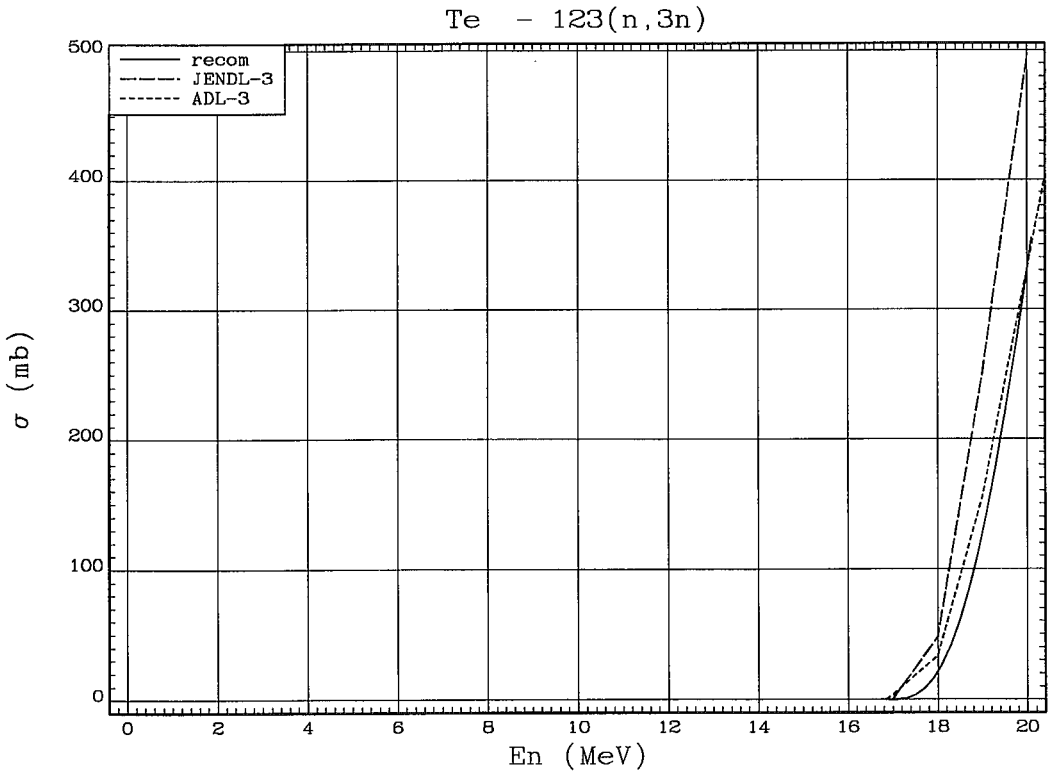

Fig.164. ^{123}Te(n,3n)^{121}Te reaction cross section.

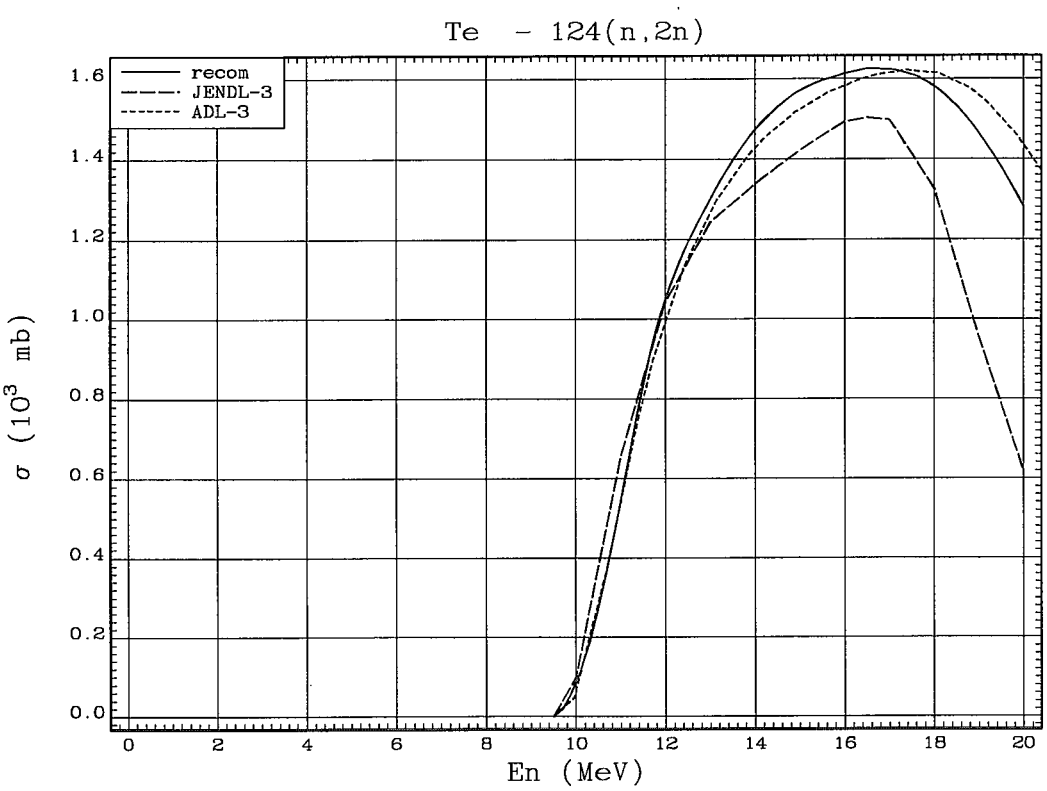

Fig.165. ^{124}Te(n,2n)^{123}Te reaction cross section.

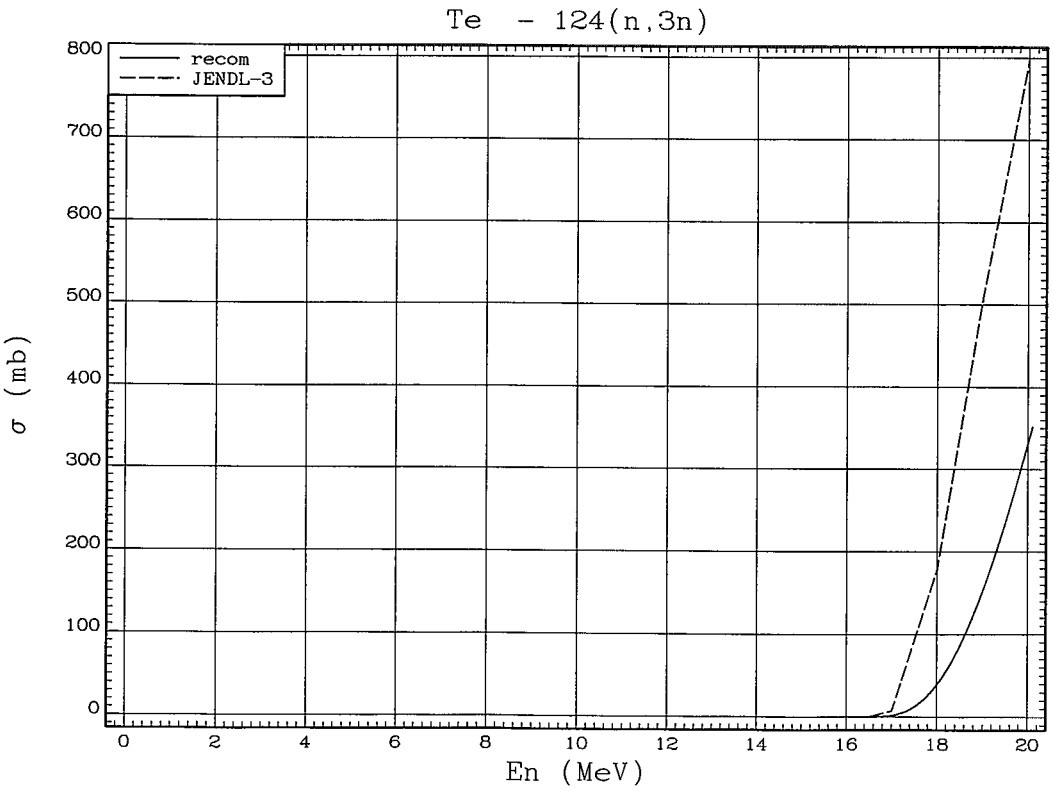

Fig.166. ^{124}Te(n,3n)^{122}Te reaction cross section.

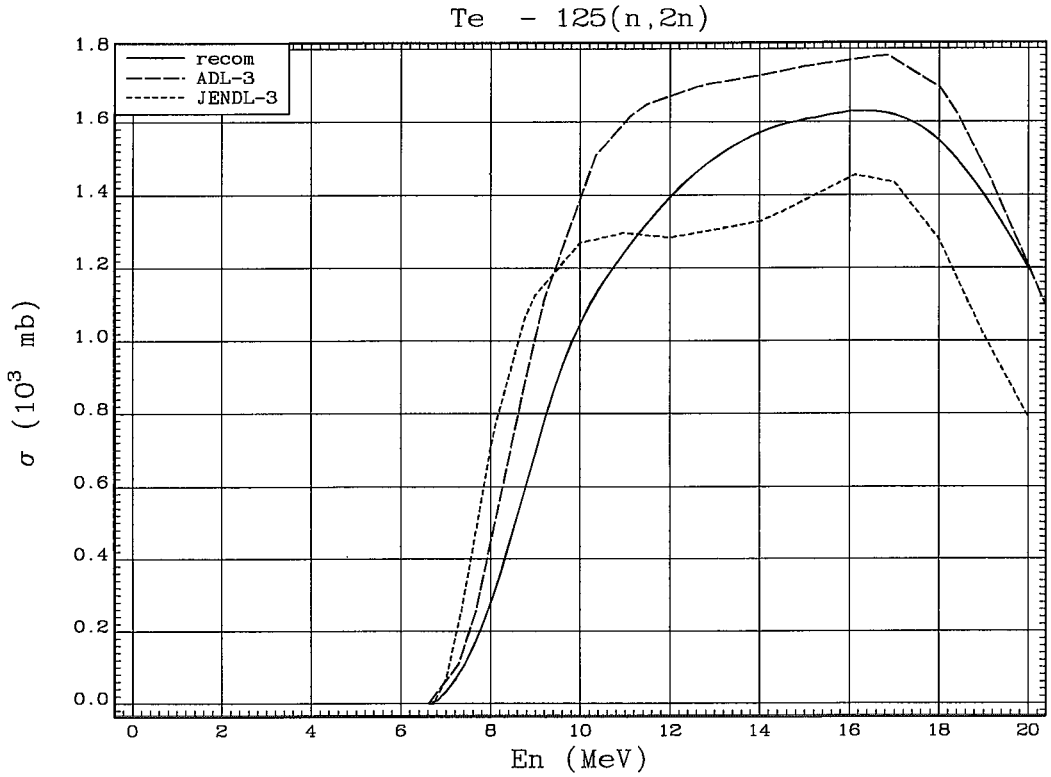

Fig.167. ^{125}Te(n,2n)^{124}Te reaction cross section.

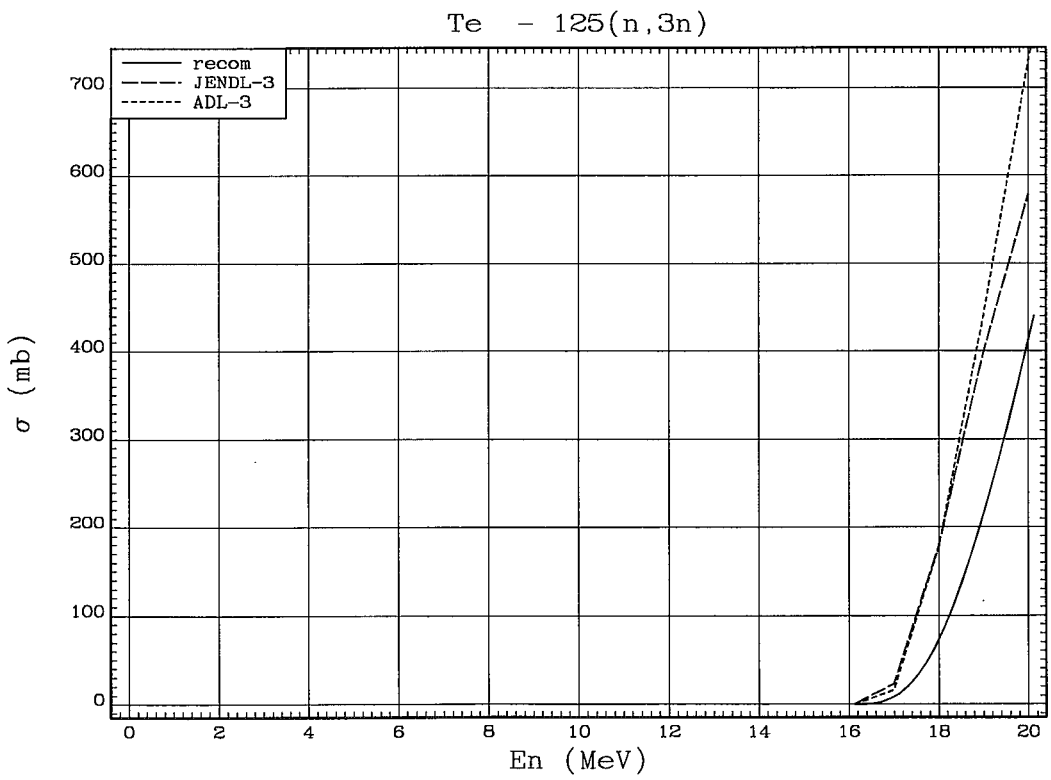

Fig.168. ^{125}Te(n,3n)^{123}Te reaction cross section.

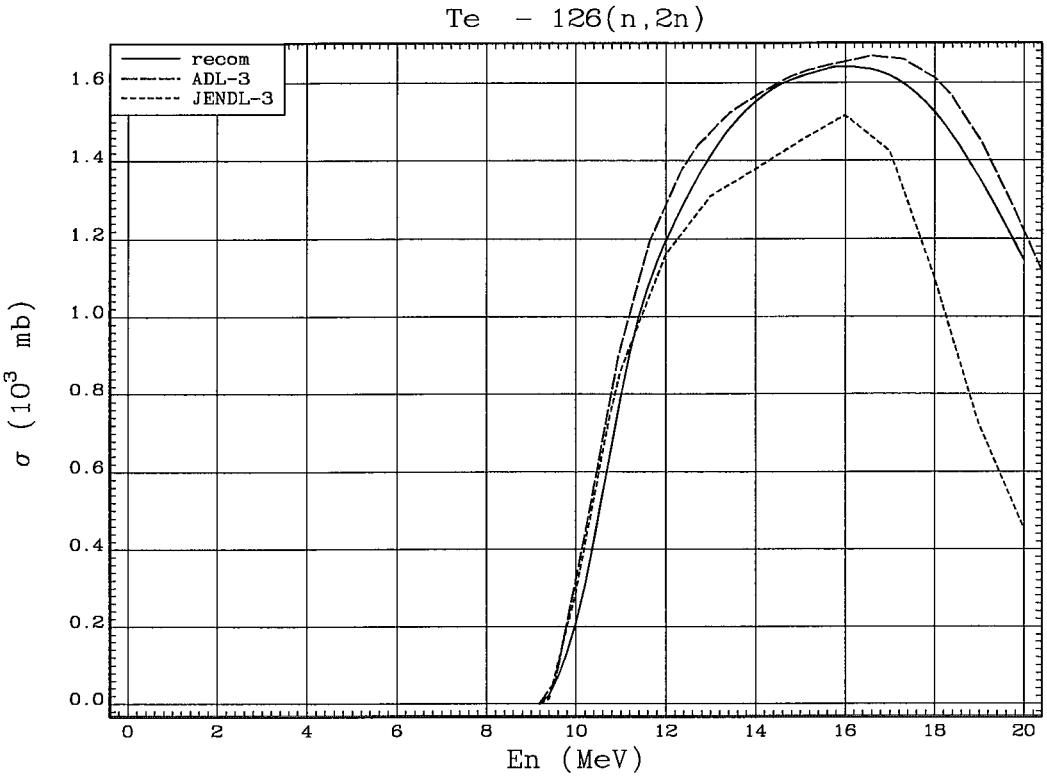

Fig.169. ^{126}Te(n,2n)^{125}Te reaction cross section.

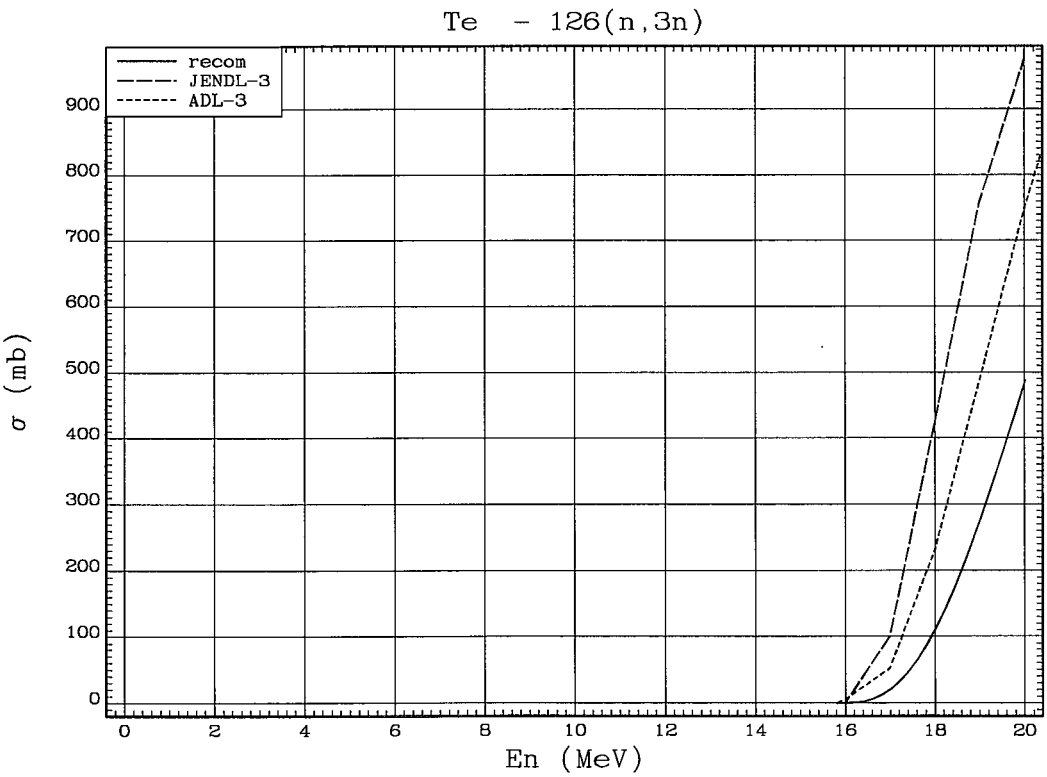

Fig.170. ^{126}Te(n,3n)^{124}Te reaction cross section.

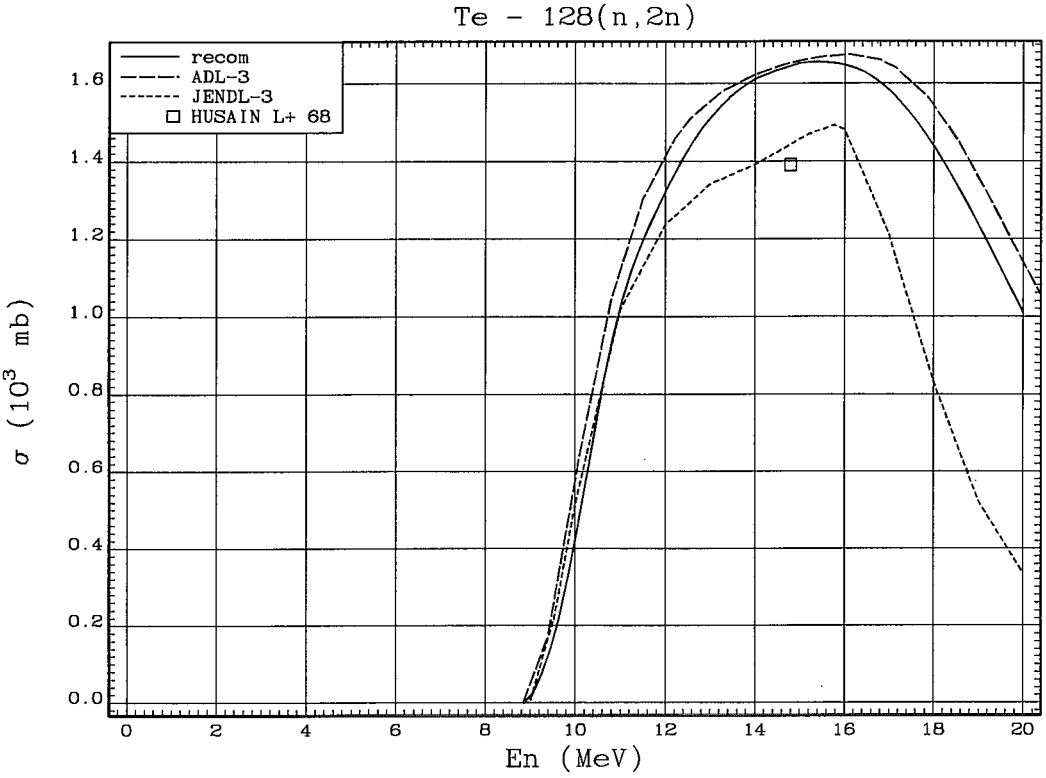

Fig.171. ^{128}Te(n,2n)^{127}Te reaction cross section.

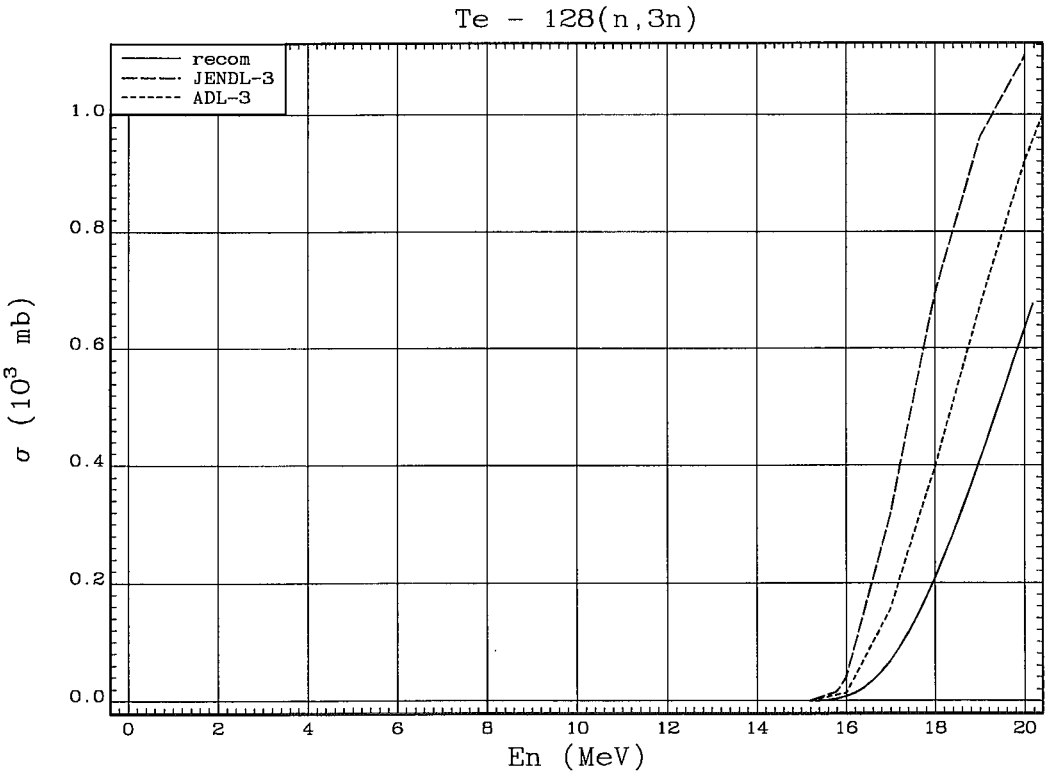

Fig.172. ^{128}Te(n,3n)^{126}Te reaction cross section.

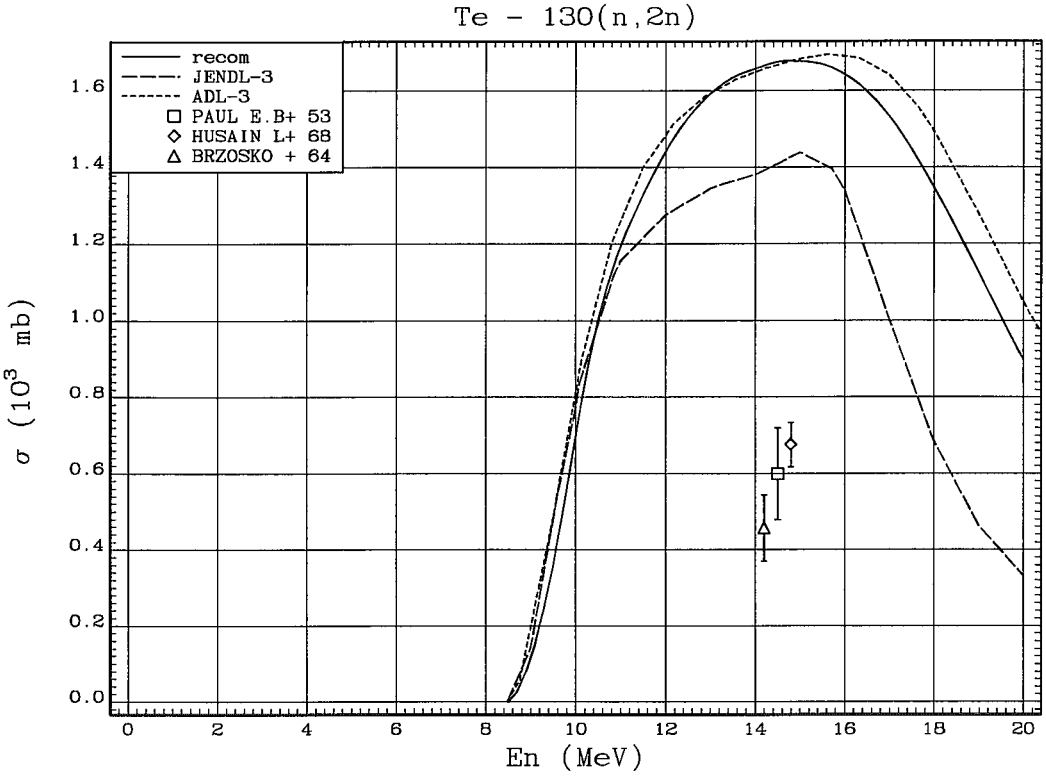

Fig.173. ^{130}Te(n,2n)^{129}Te reaction cross section.

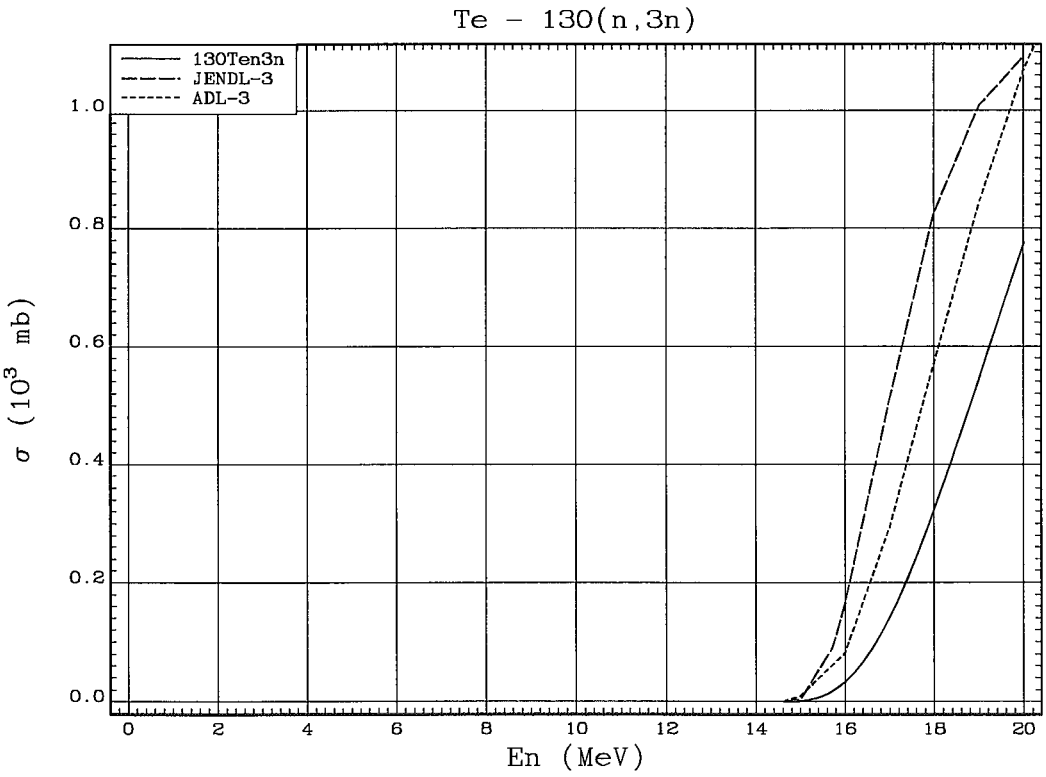

Fig.174. ^{130}Te(n,3n)^{128}Te reaction cross section.

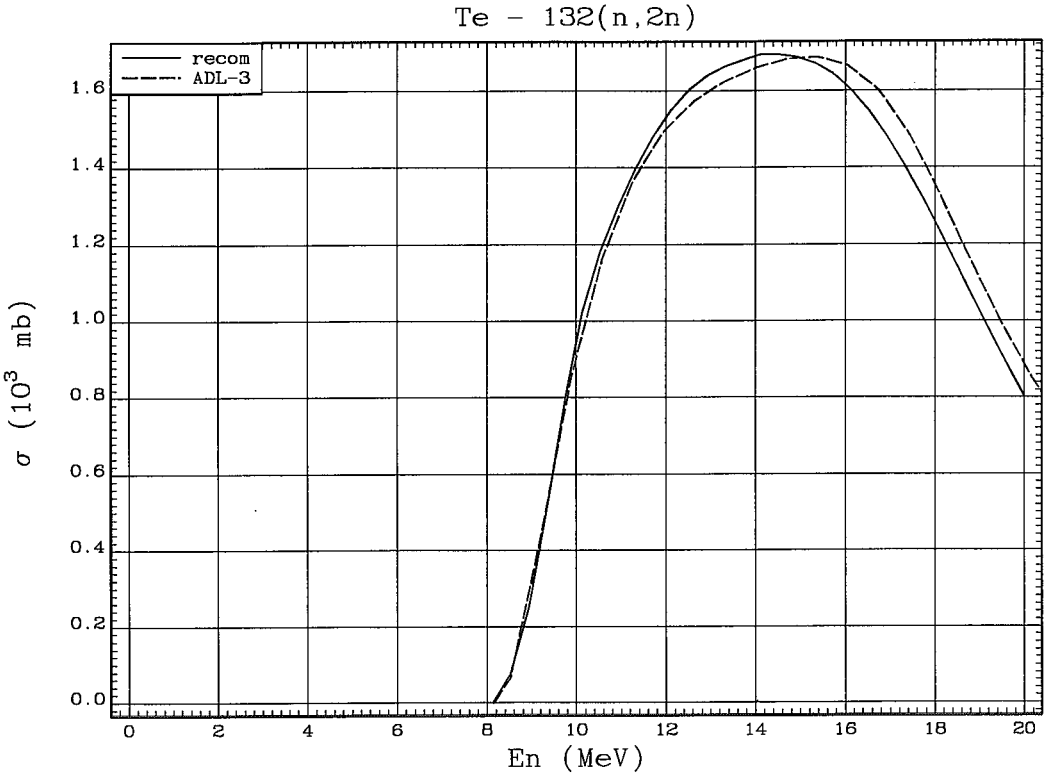

Fig.175. ^{132}Te(n,2n)^{131}Te reaction cross section.

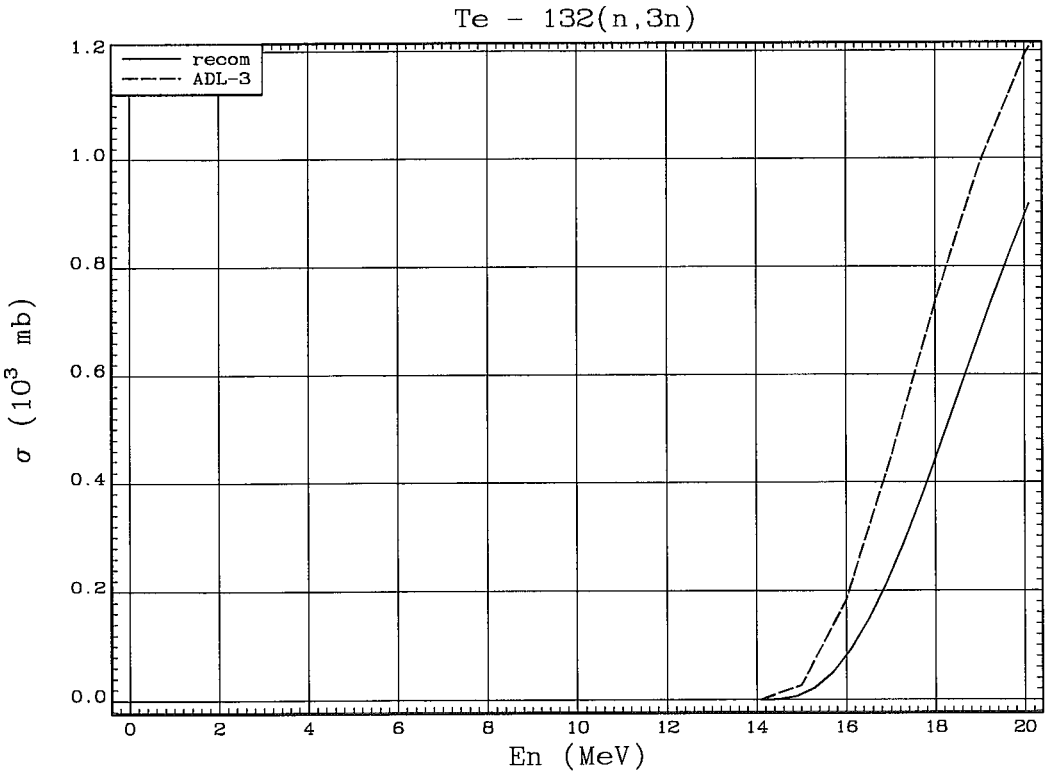

Fig.176. ^{132}Te(n,3n)^{130}Te reaction cross section.

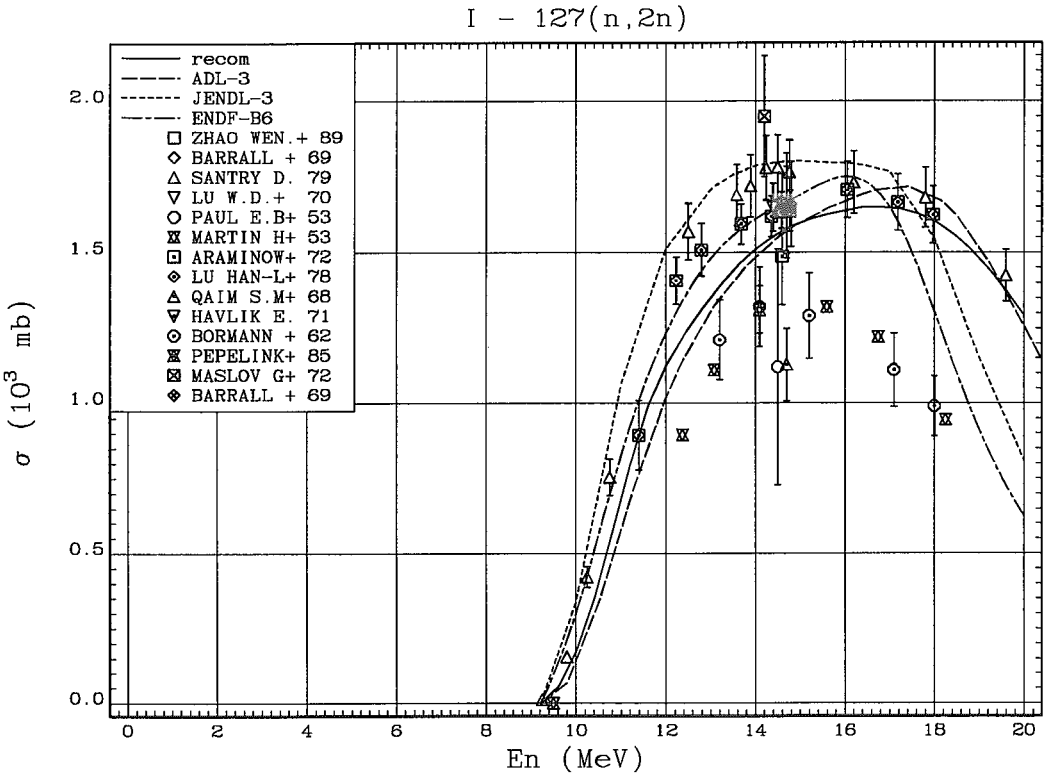

Fig.177. $^{127}I(n,2n)^{126}I$ reaction cross section.

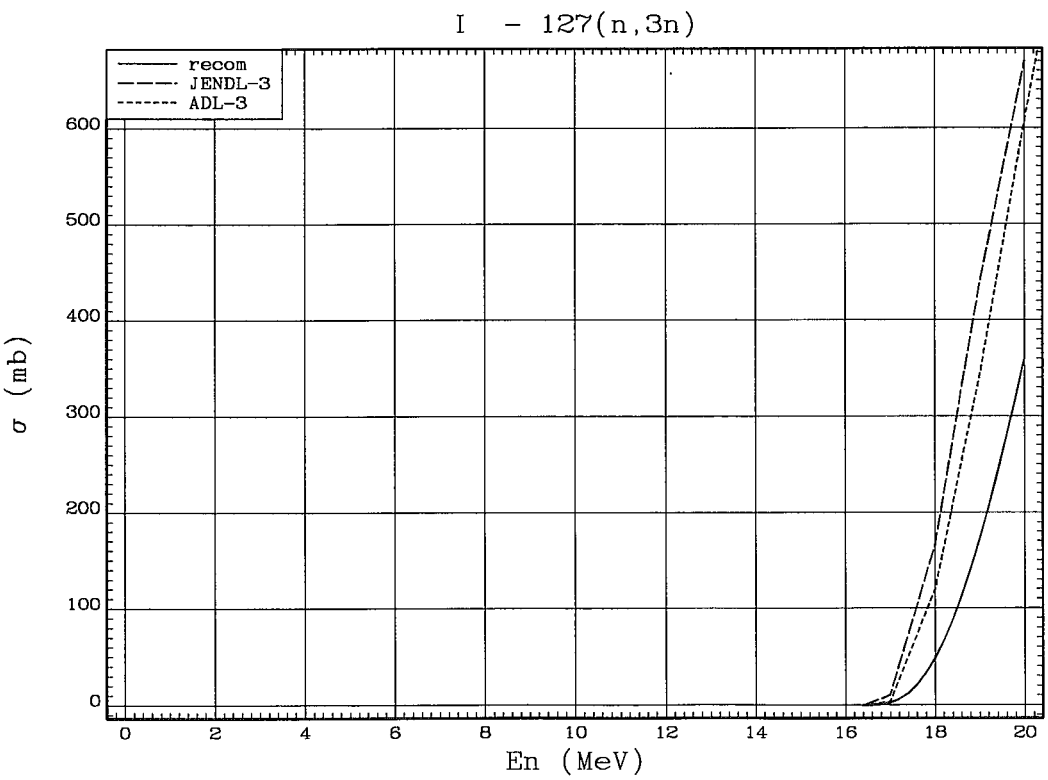

Fig.178. $^{127}I(n,3n)^{125}I$ reaction cross section.

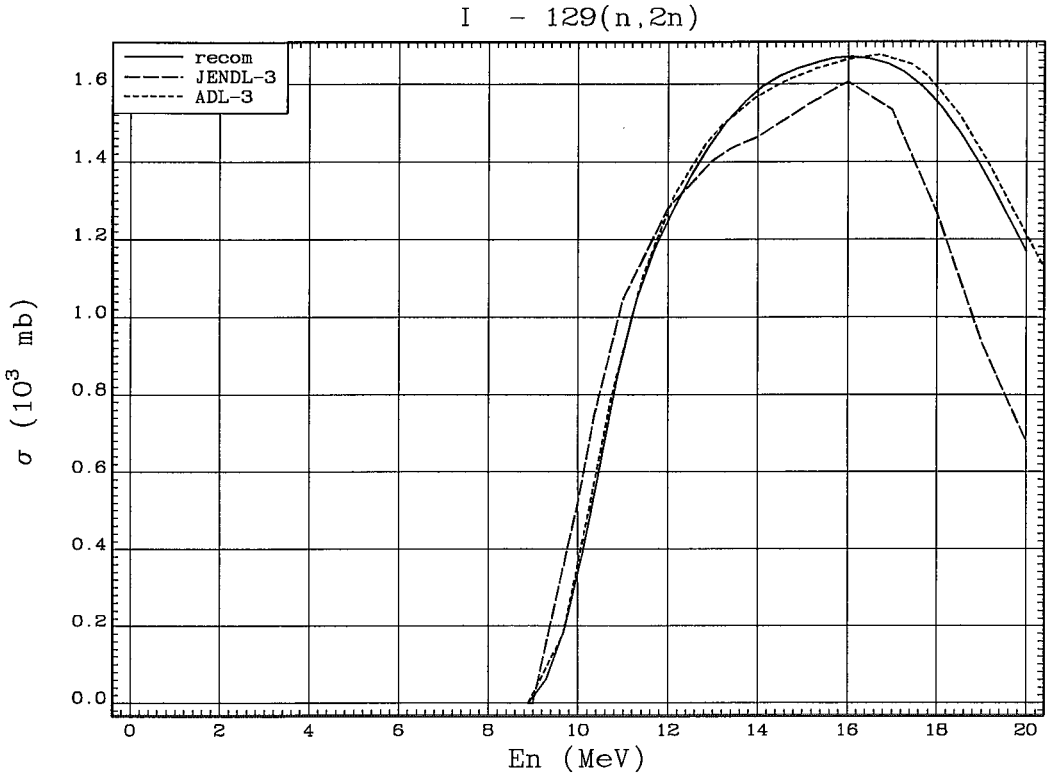

Fig.179. $^{129}I(n,2n)^{128}I$ reaction cross section.

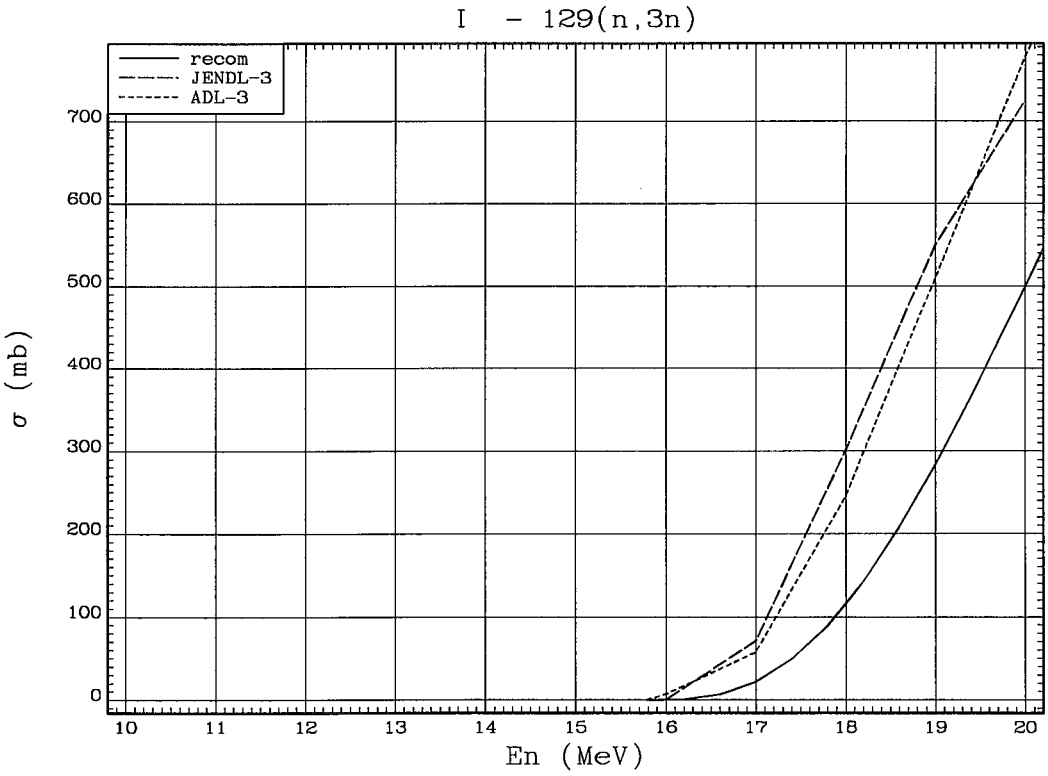

Fig.180. $^{129}I(n,3n)^{127}I$ reaction cross section.

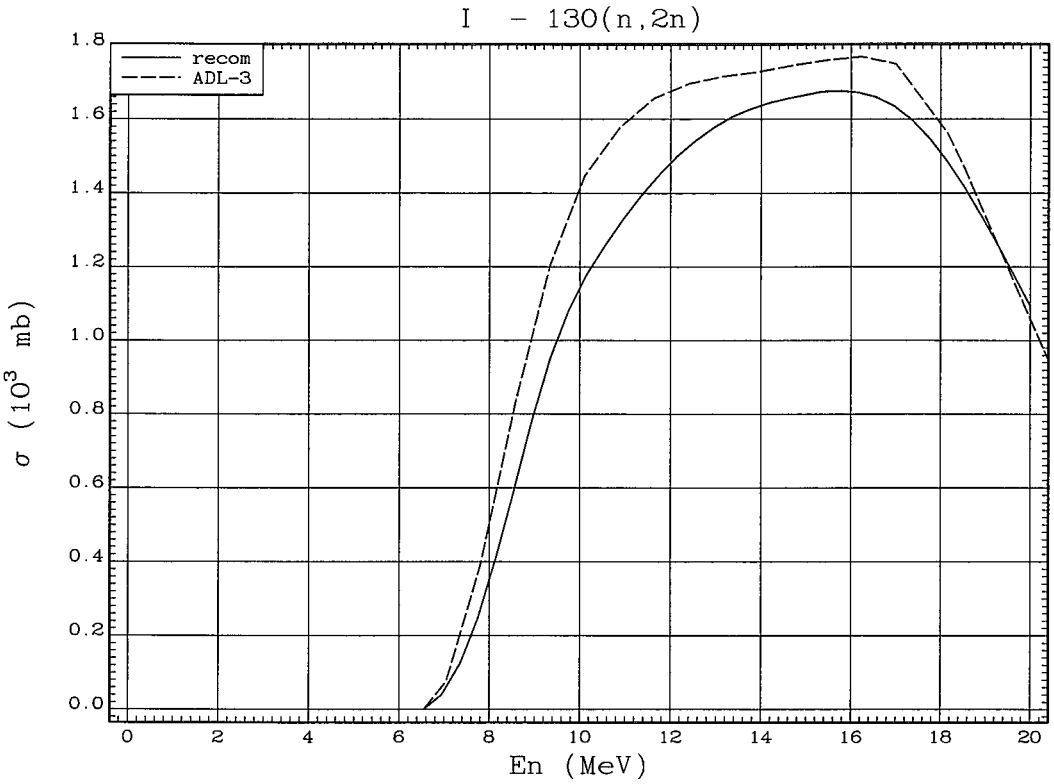

Fig.181. $^{130}I(n,2n)^{129}I$ reaction cross section.

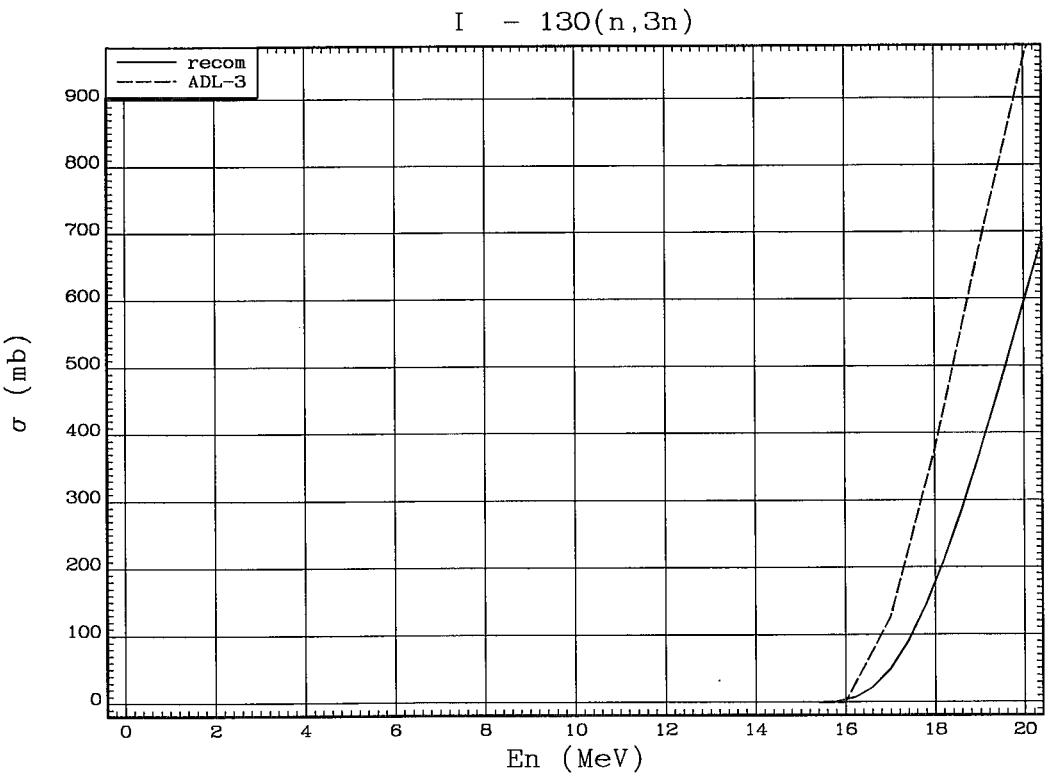

Fig.182. $^{130}I(n,3n)^{128}I$ reaction cross section.

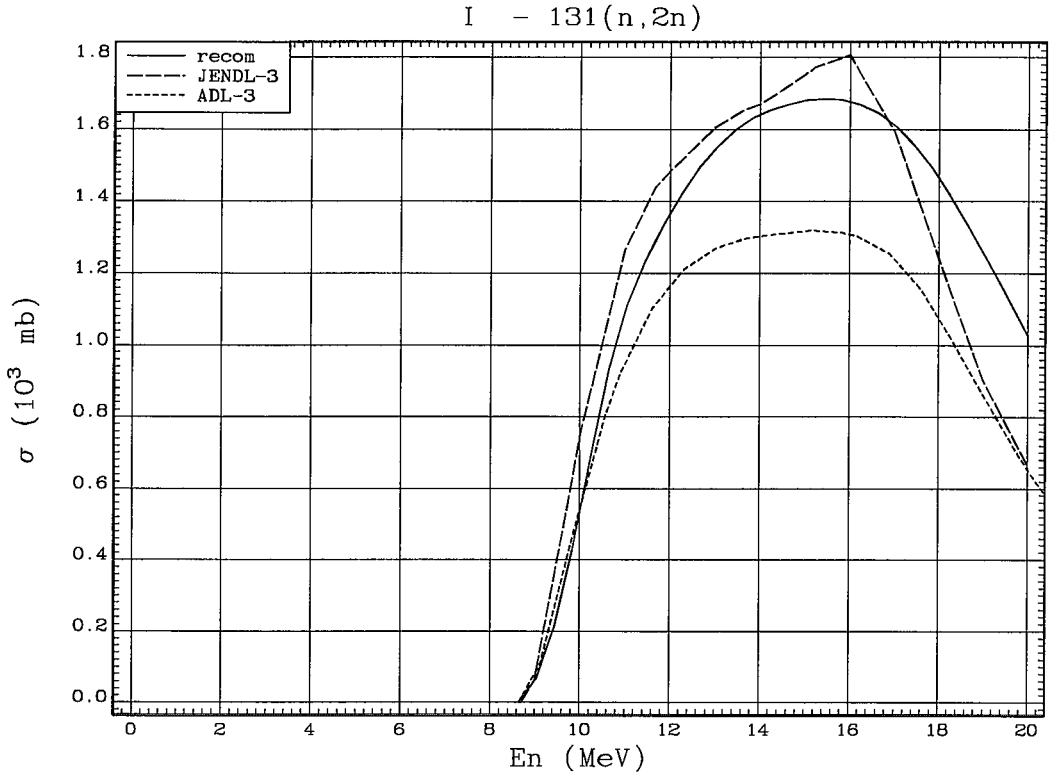

Fig.183. $^{131}I(n,2n)^{130}I$ reaction cross section.

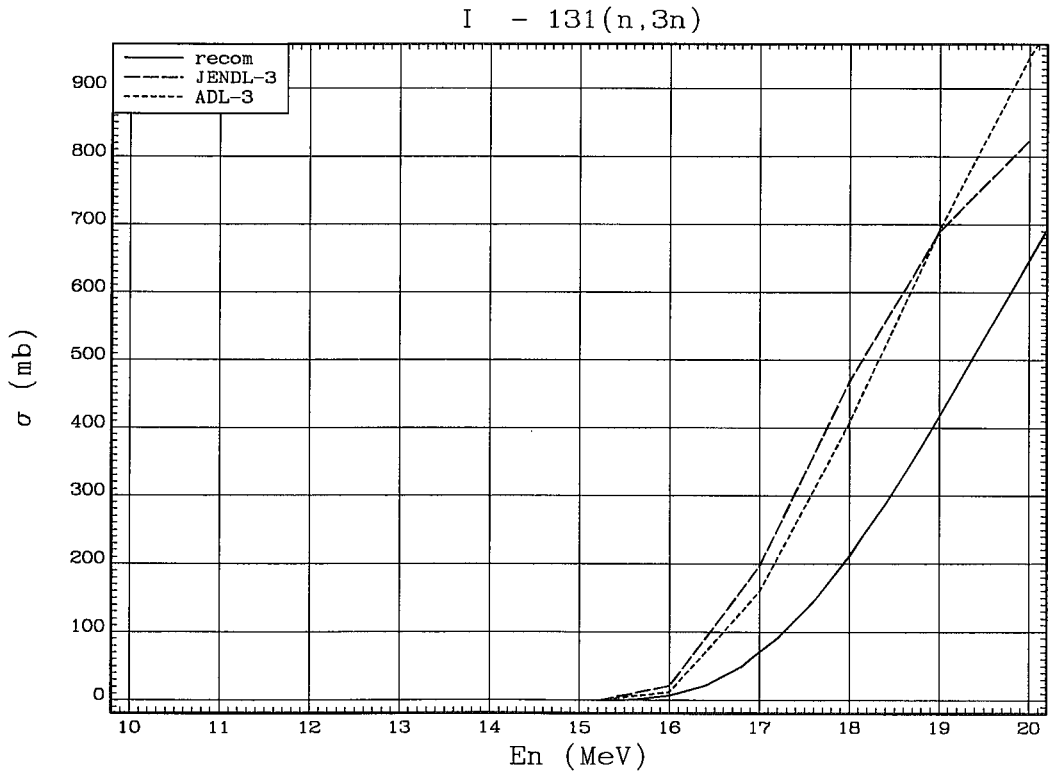

Fig.184. $^{131}I(n,3n)^{129}I$ reaction cross section.

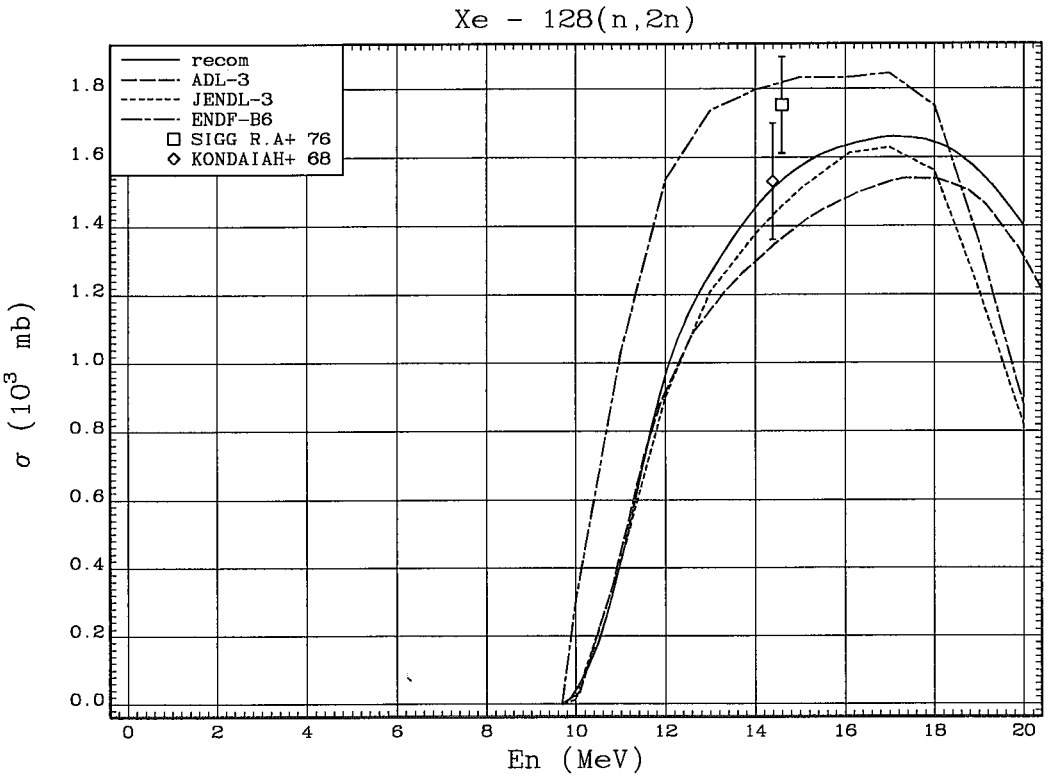

Fig.185. ^{128}Xe(n,2n)^{127}Xe reaction cross section.

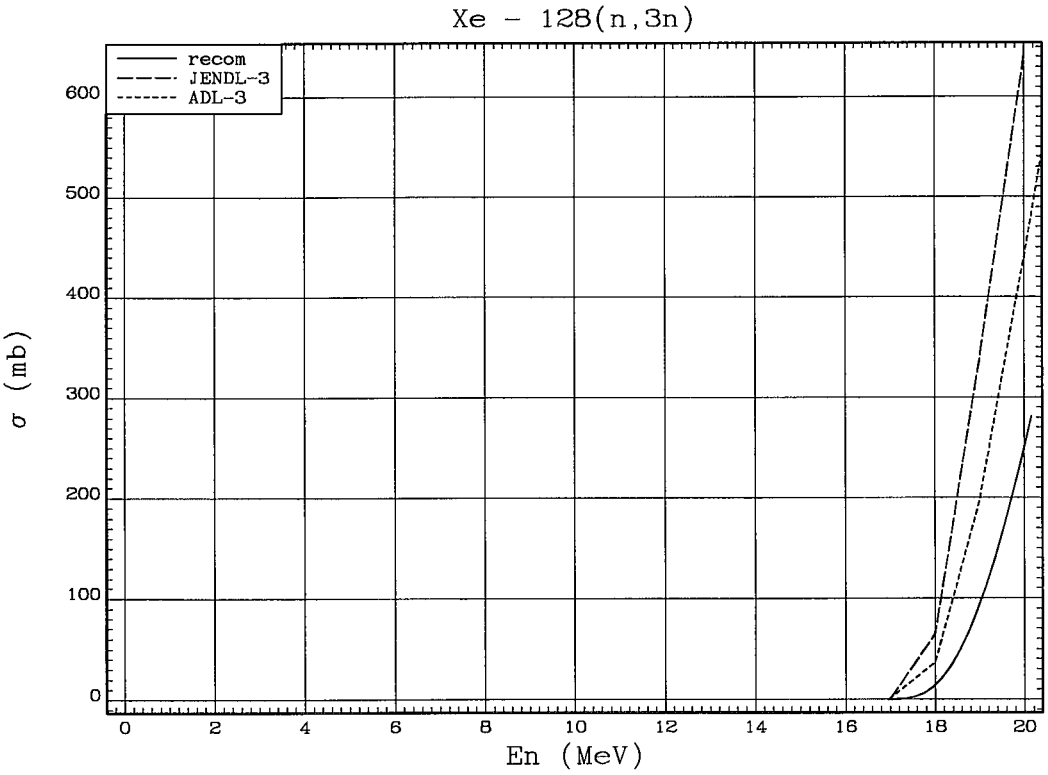

Fig.186. ^{128}Xe(n,3n)^{126}Xe reaction cross section.

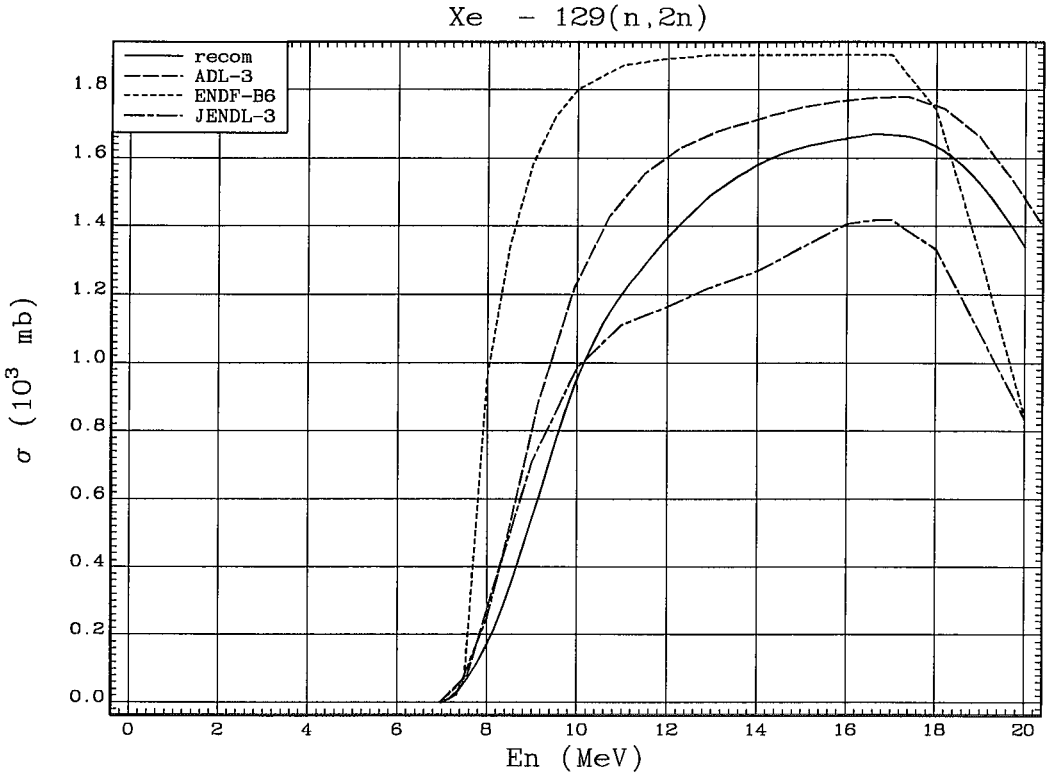

Fig.187. $^{129}Xe(n,2n)^{128}Xe$ reaction cross section.

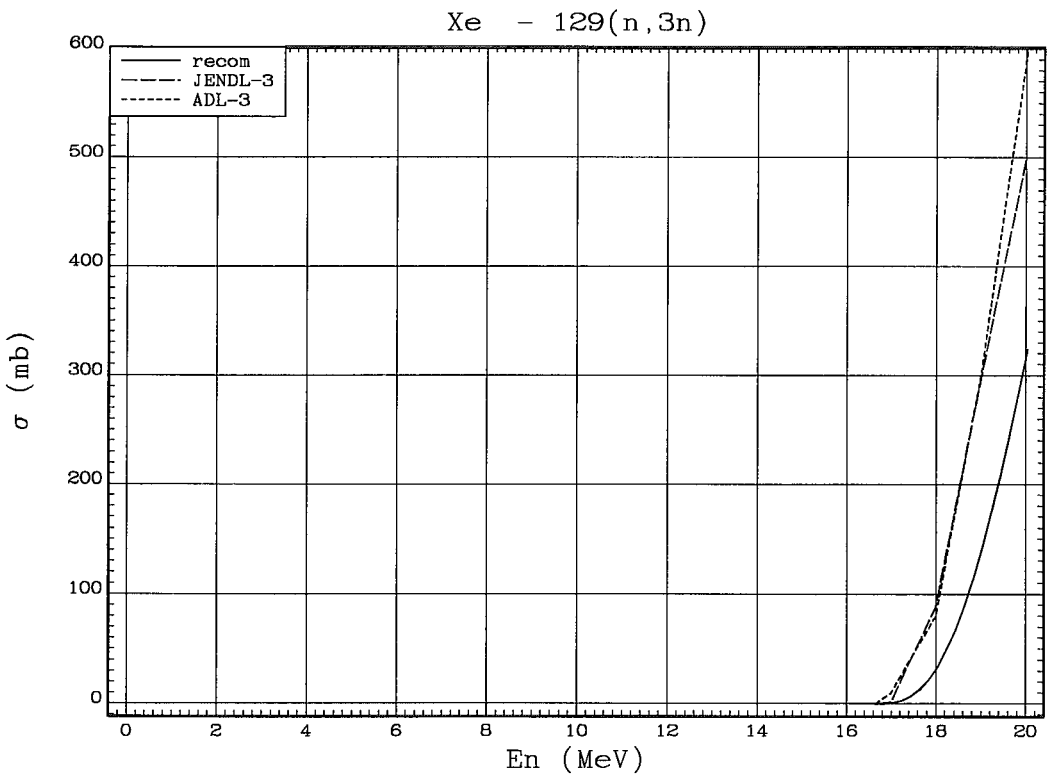

Fig.188. $^{129}Xe(n,3n)^{127}Xe$ reaction cross section.

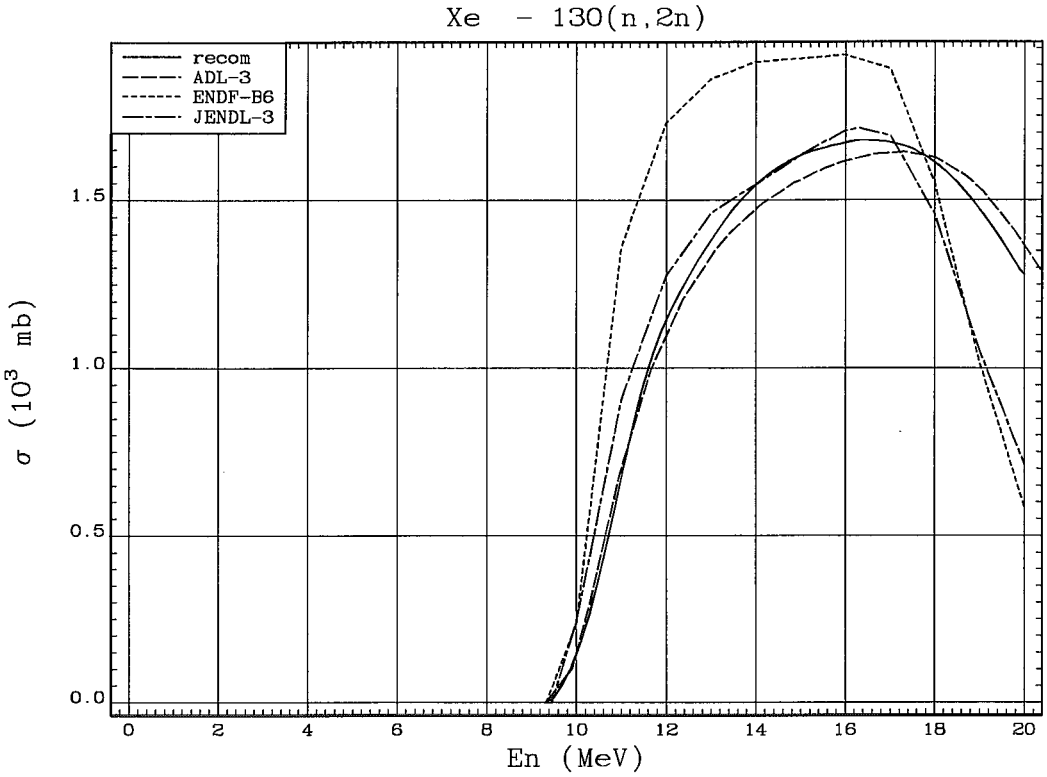

Fig.189. ^{130}Xe(n,2n)^{129}Xe reaction cross section.

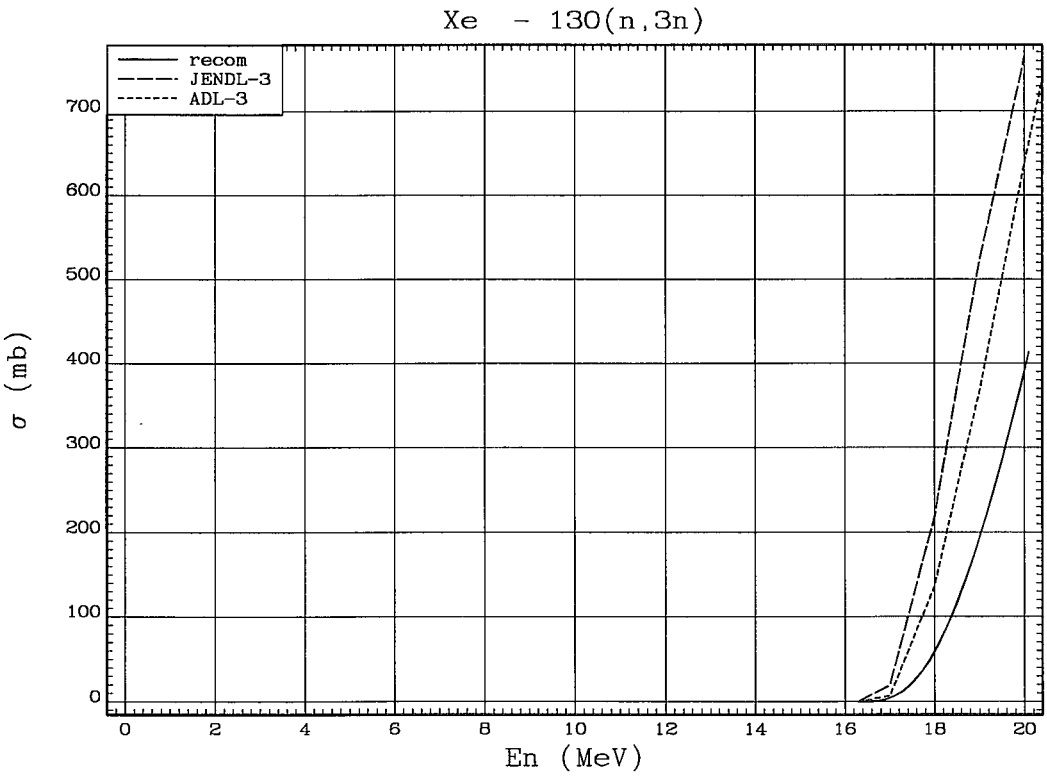

Fig.190. ^{130}Xe(n,3n)^{128}Xe reaction cross section.

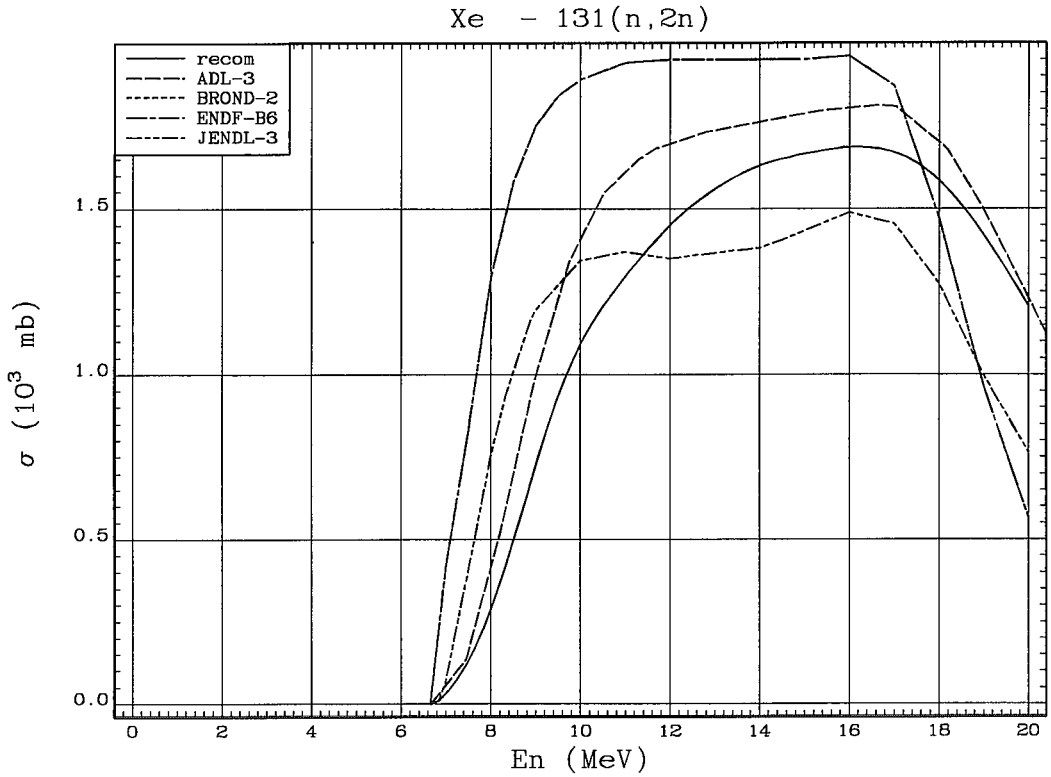

Fig.191. ^{131}Xe(n,2n)^{130}Xe reaction cross section.

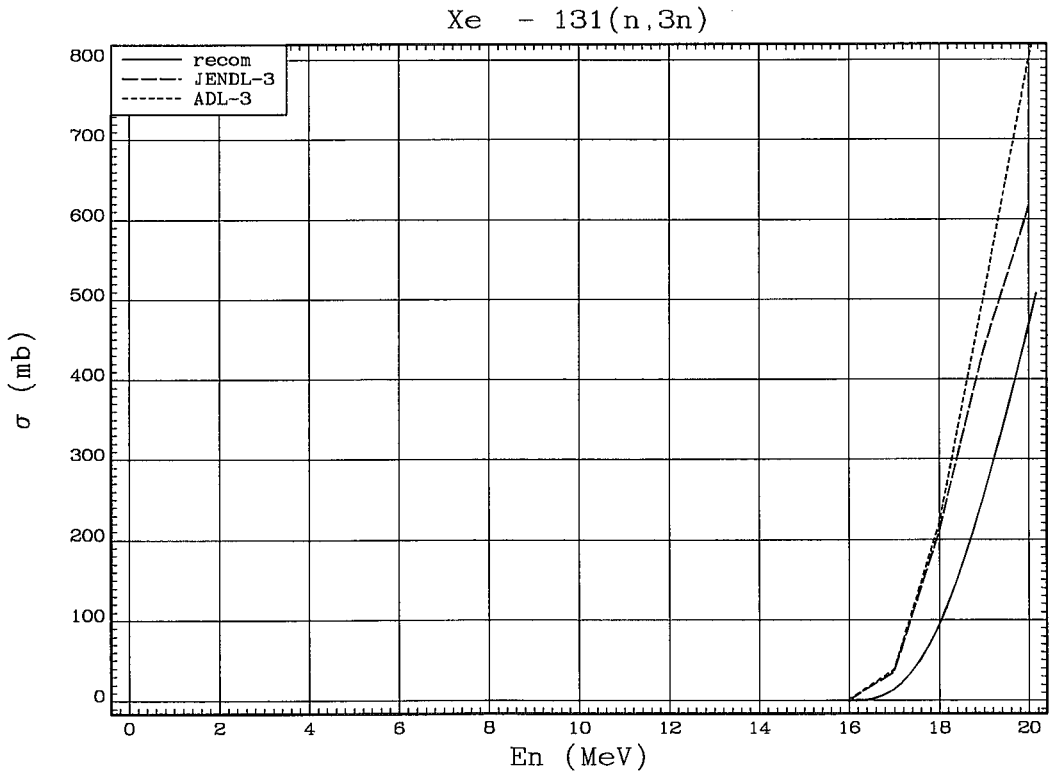

Fig.192. ^{131}Xe(n,3n)^{129}Xe reaction cross section.

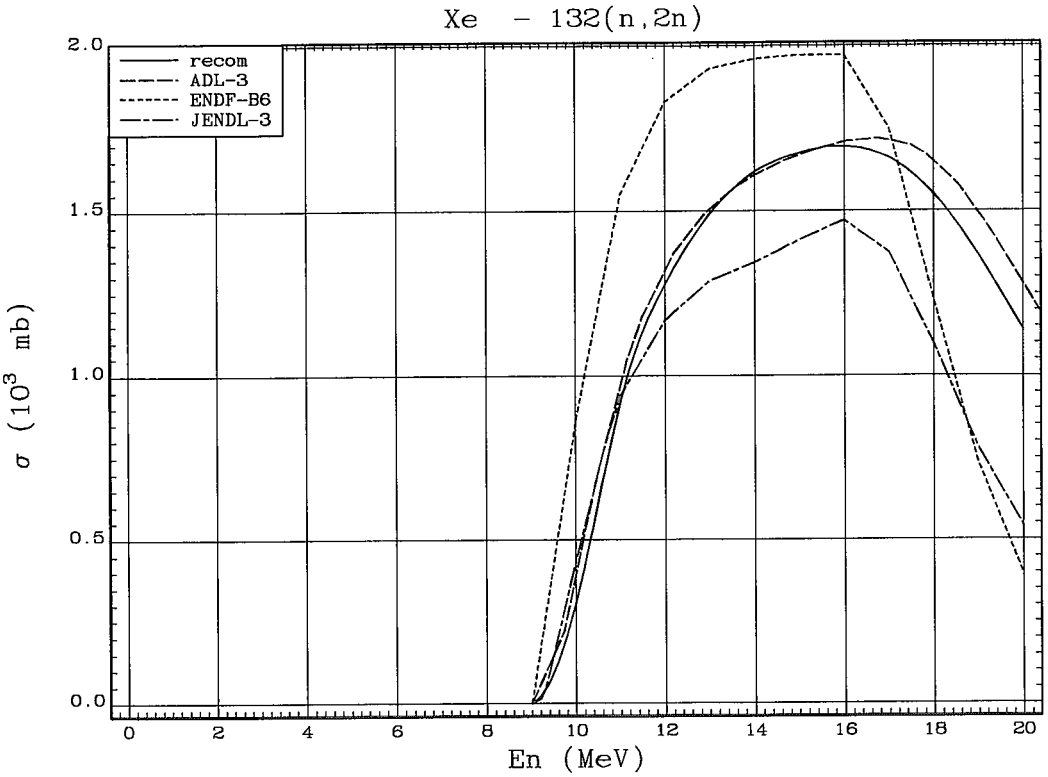

Fig.193. ^{132}Xe(n,2n)^{131}Xe reaction cross section.

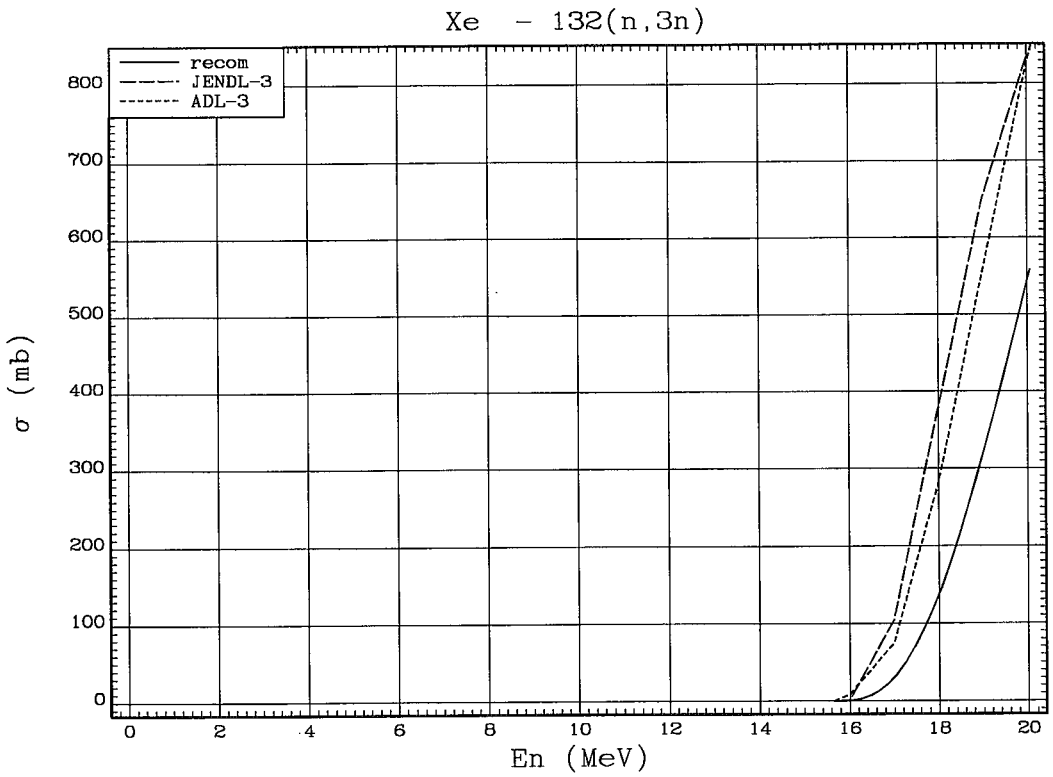

Fig.194. ^{132}Xe(n,3n)^{130}Xe reaction cross section.

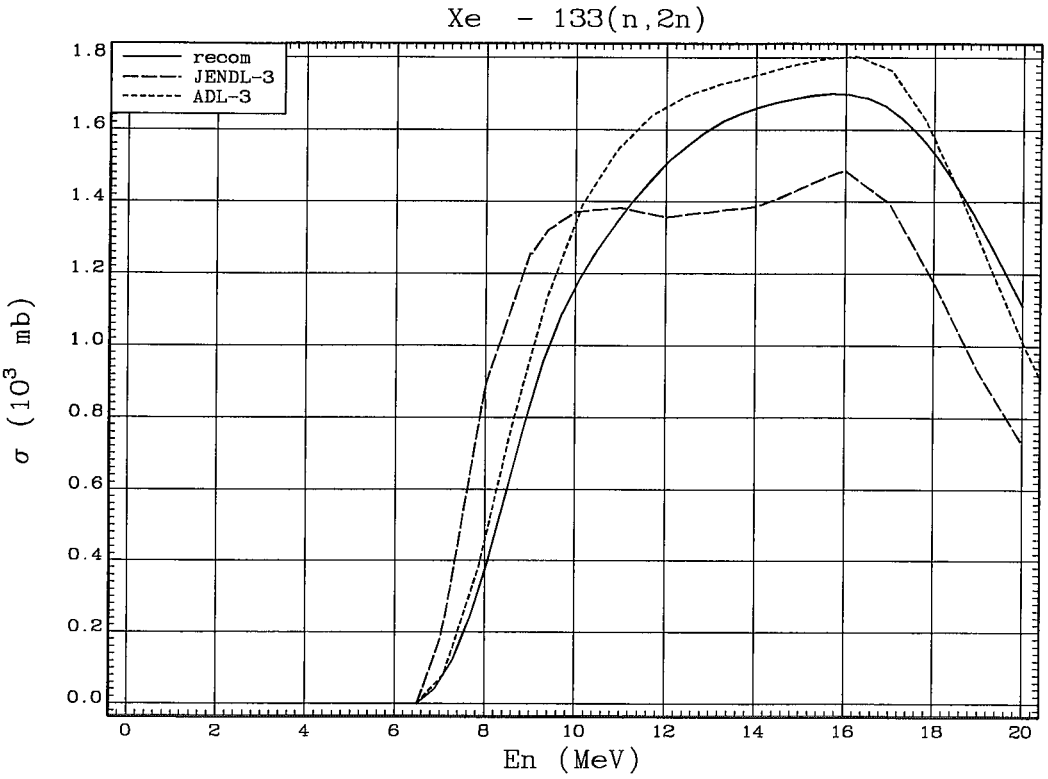

Fig.195. ^{133}Xe(n,2n)^{132}Xe reaction cross section.

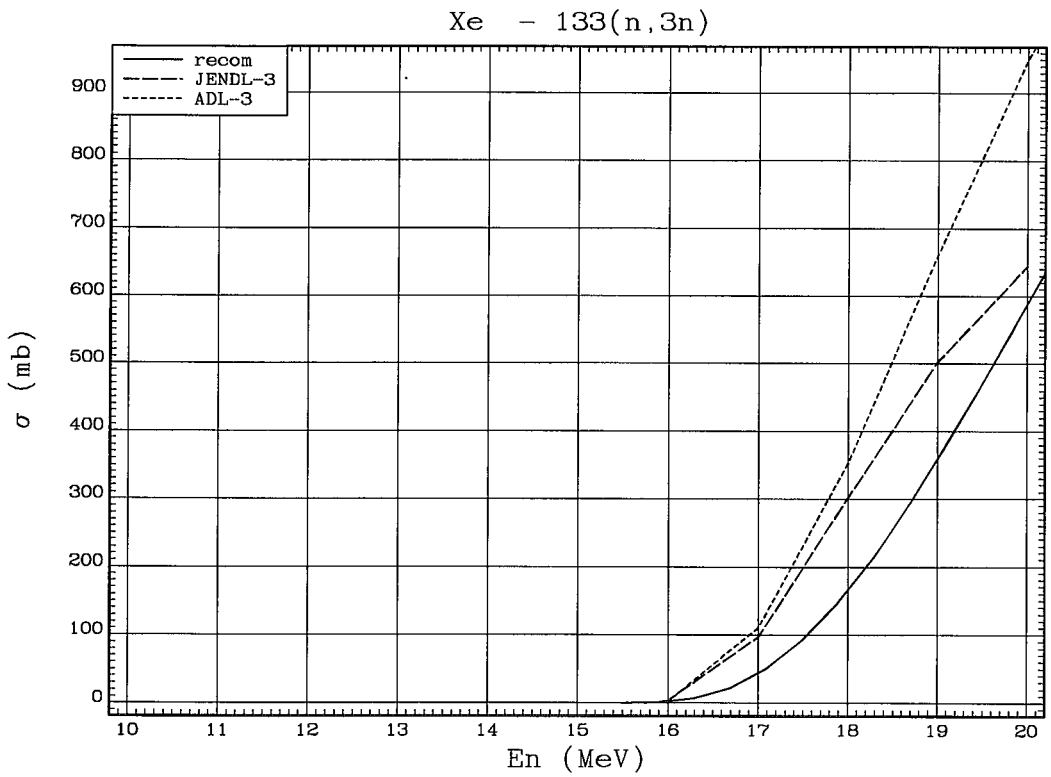

Fig.196. ^{133}Xe(n,3n)^{131}Xe reaction cross section.

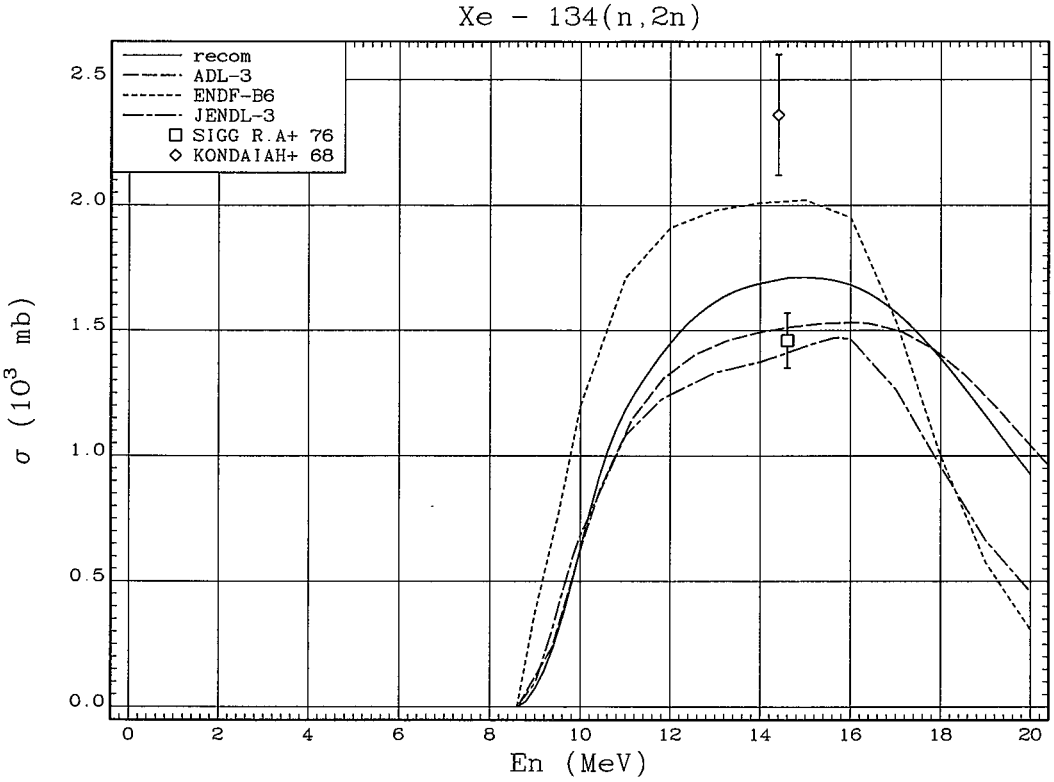

Fig.197. ^{134}Xe(n,2n)^{133}Xe reaction cross section.

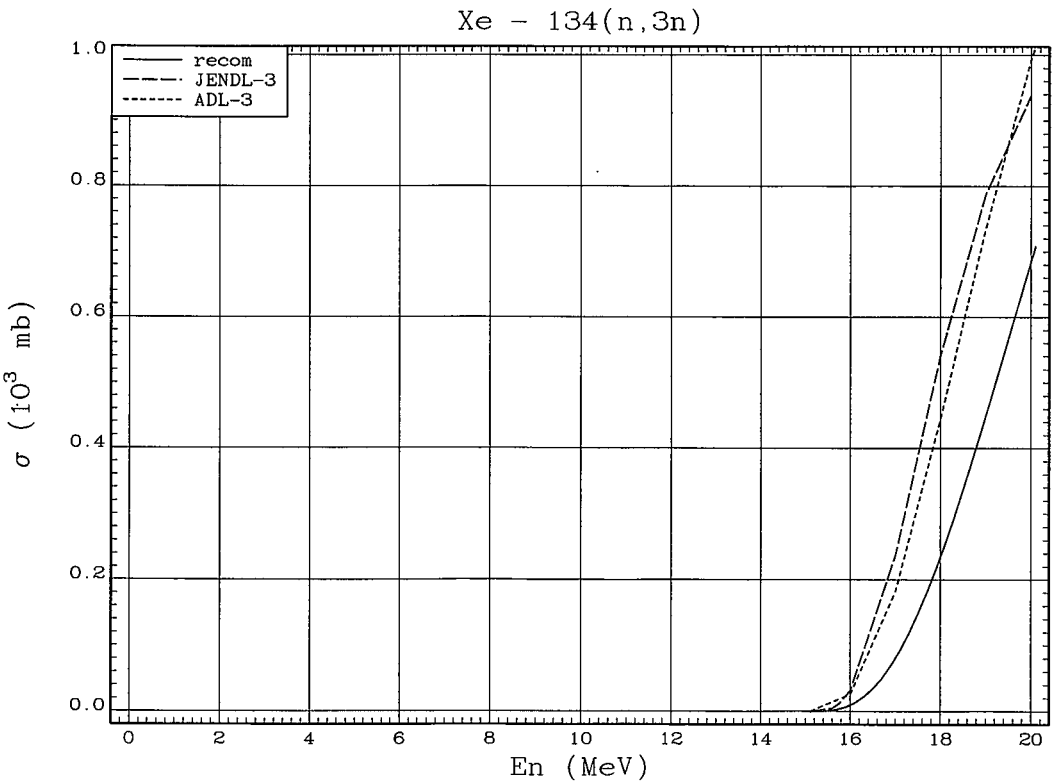

Fig.198. ^{134}Xe(n,3n)^{132}Xe reaction cross section.

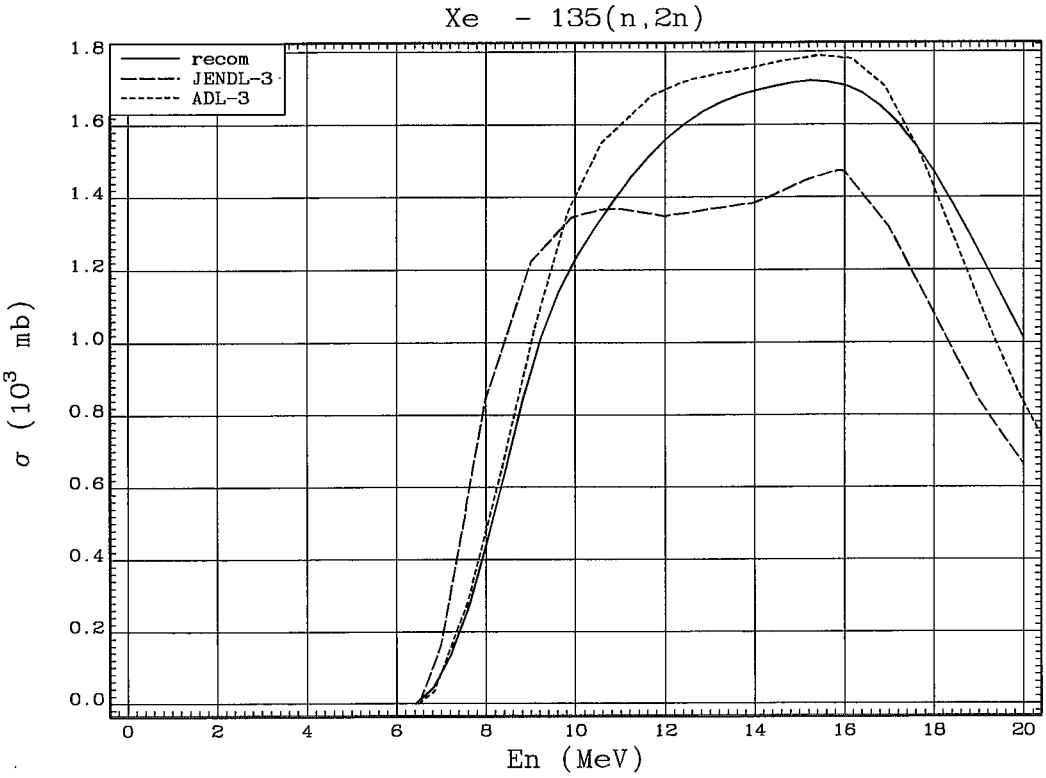

Fig.199. ^{135}Xe(n,2n)^{134}Xe reaction cross section.

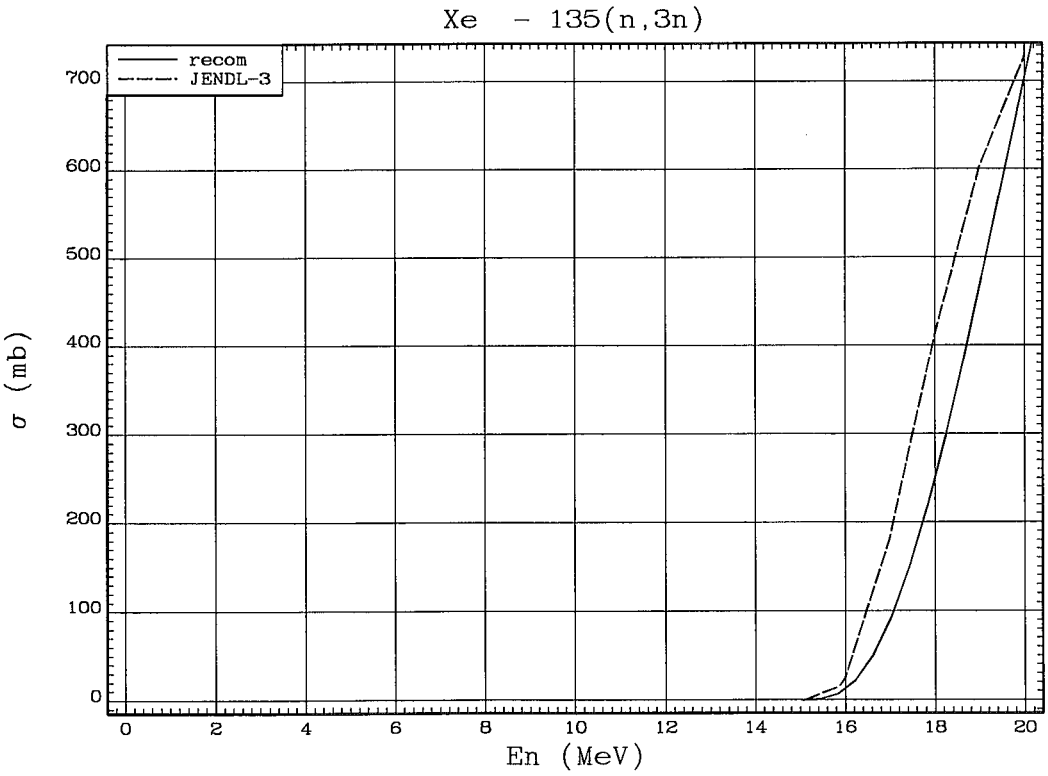

Fig.200. ^{135}Xe(n,3n)^{133}Xe reaction cross section.

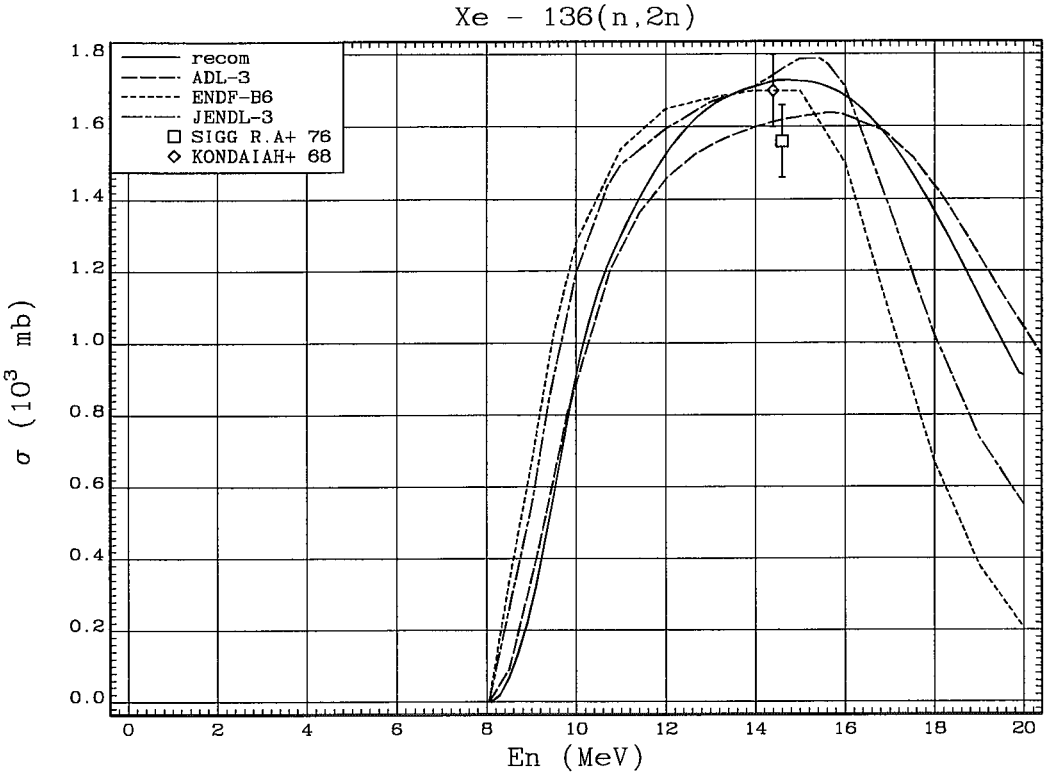

Fig.201. ^{136}Xe(n,2n)^{135}Xe reaction cross section.

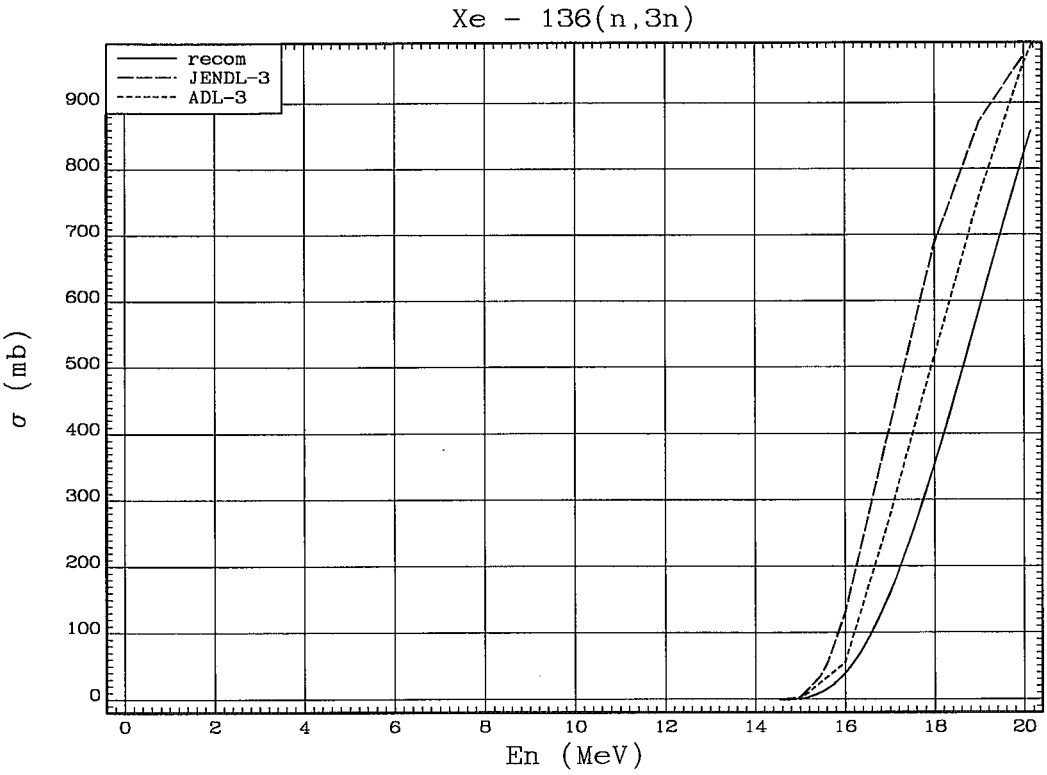

Fig.202. ^{136}Xe(n,3n)^{134}Xe reaction cross section.

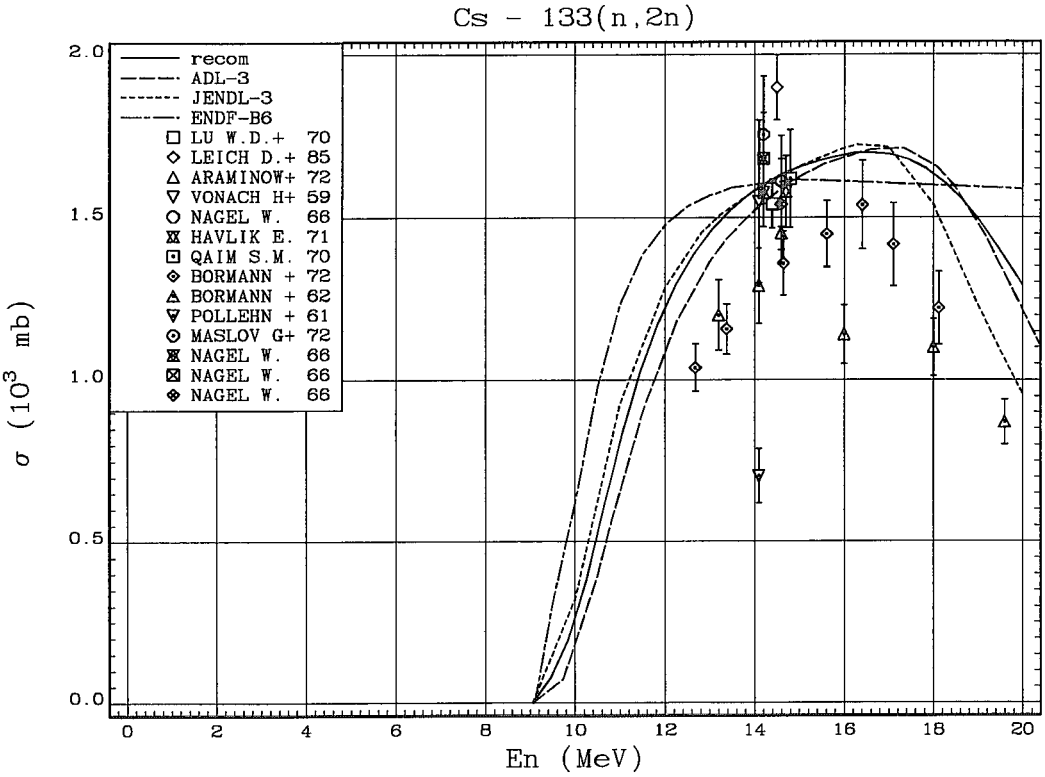

Fig.203. ^{133}Cs(n,2n)^{132}Cs reaction cross section.

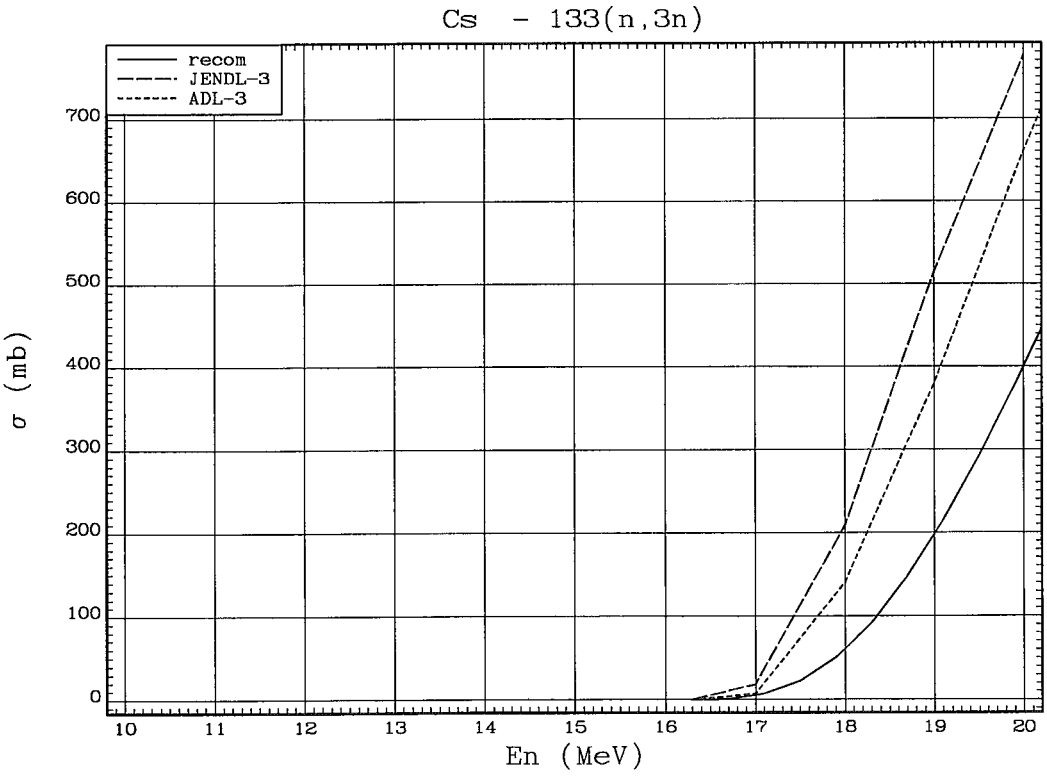

Fig.204. ^{133}Cs(n,3n)^{131}Cs reaction cross section.

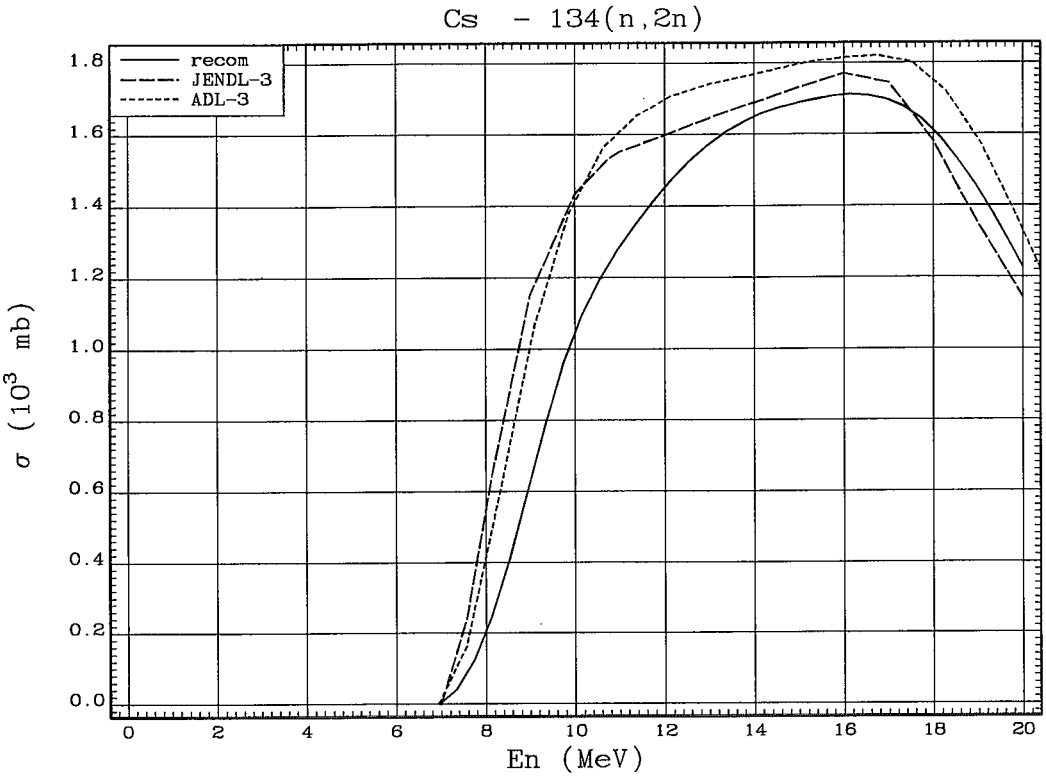

Fig.205. ^{134}Cs(n,2n)^{133}Cs reaction cross section.

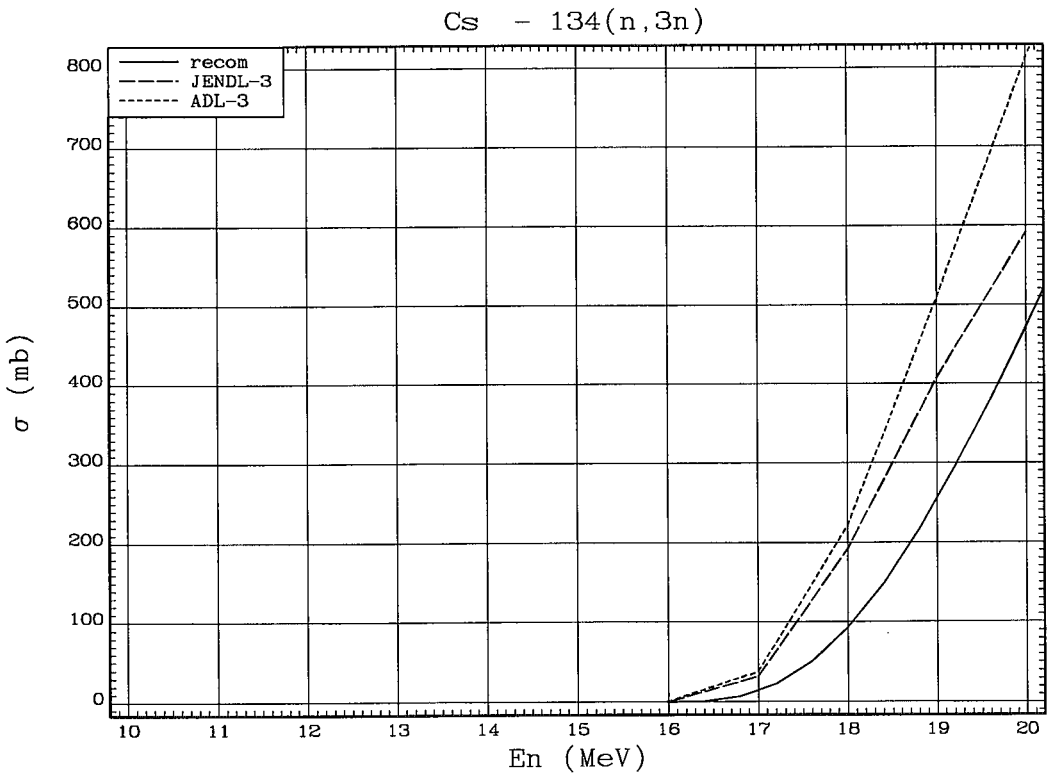

Fig. 206. ^{134}Cs(n,3n)^{132}Cs reaction cross section.

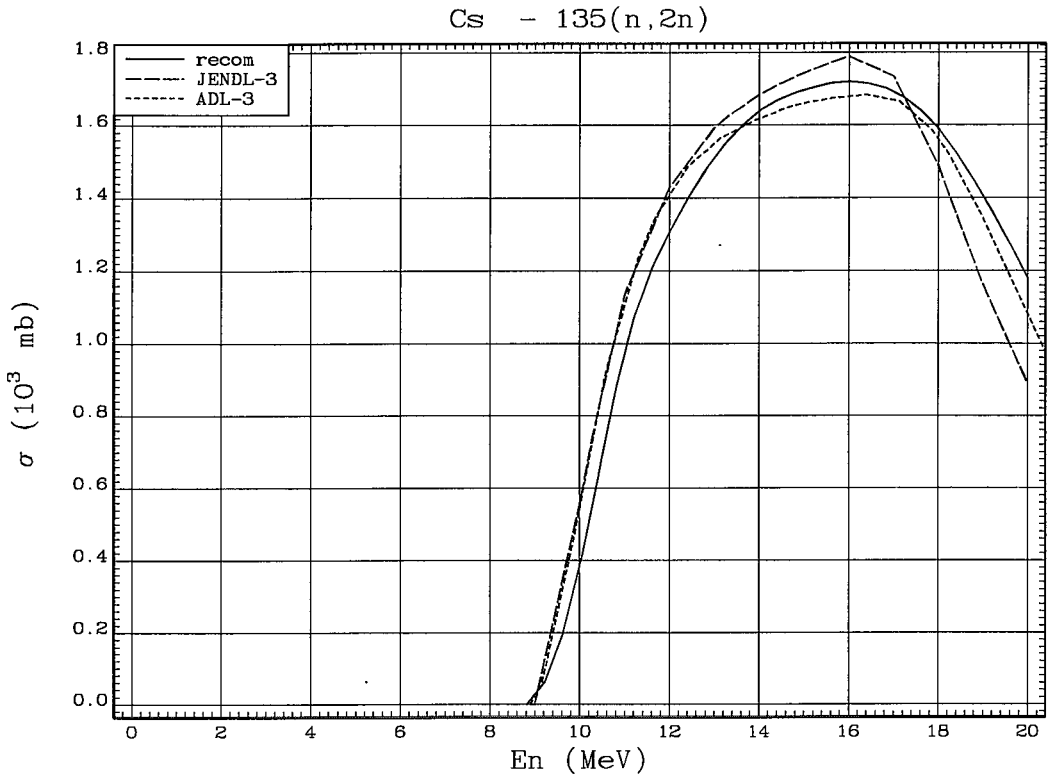

Fig.207. $^{135}Cs(n,2n)^{134}Cs$ reaction cross section.

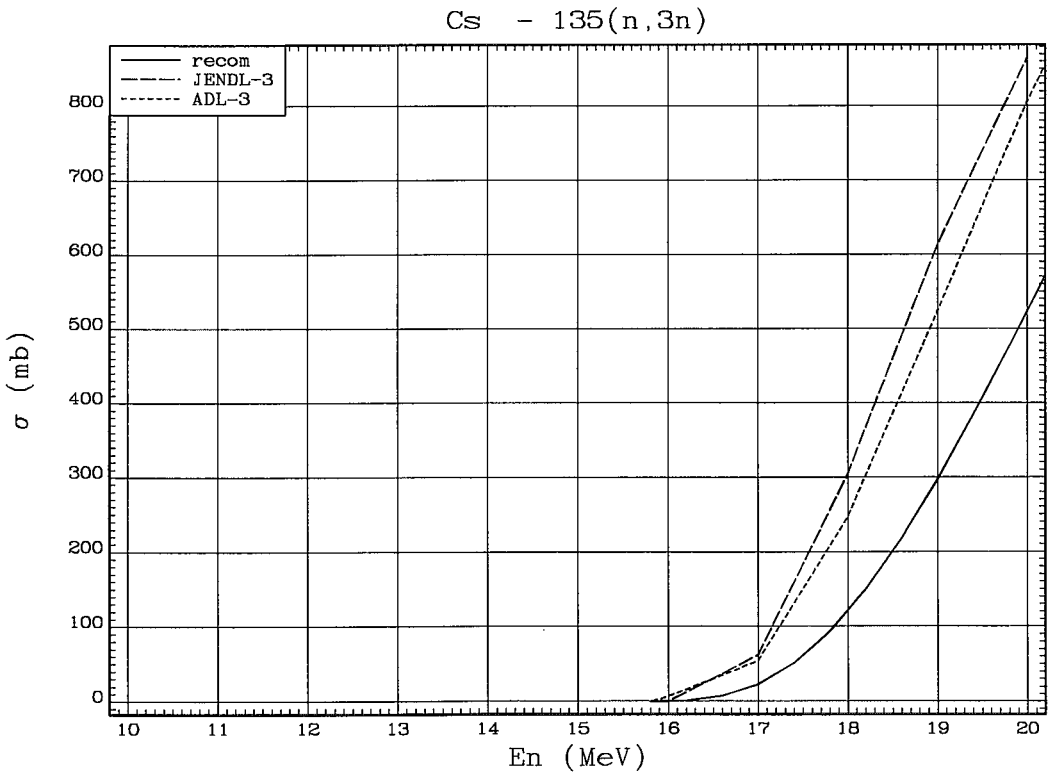

Fig.208. $^{135}Cs(n,3n)^{133}Cs$ reaction cross section.

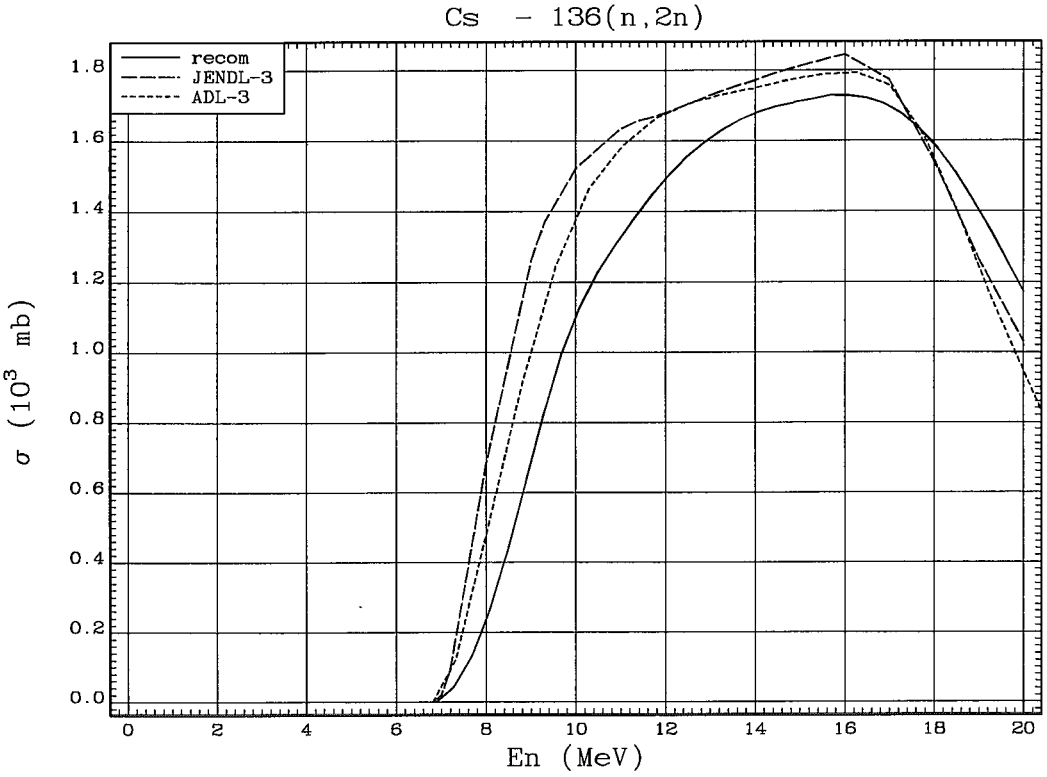

Fig.209. ^{136}Cs(n,2n)^{135}Cs reaction cross section.

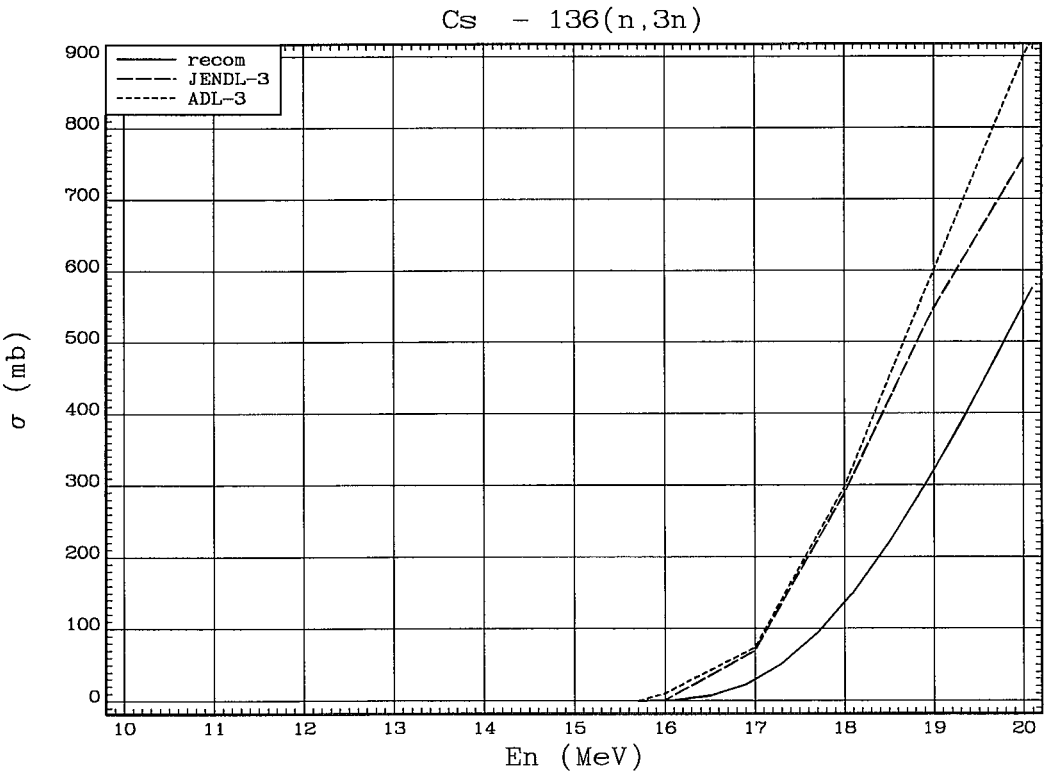

Fig.210. ^{136}Cs(n,3n)^{134}Cs reaction cross section.

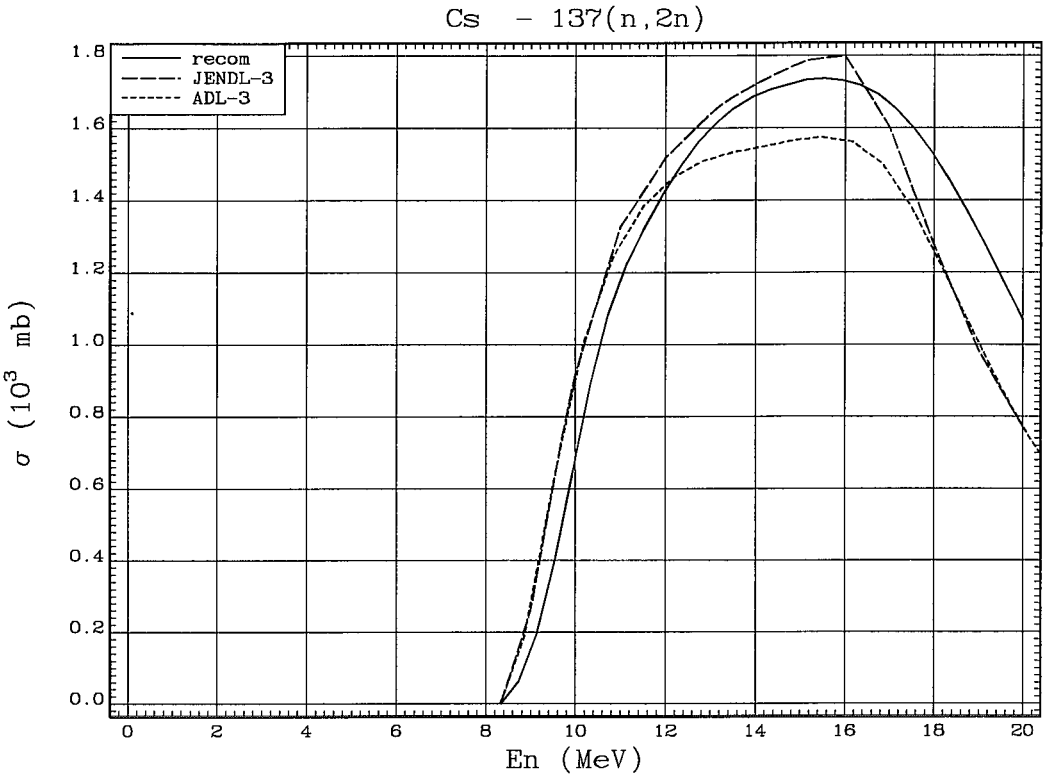

Fig.211. ^{137}Cs(n,2n)^{136}Cs reaction cross section.

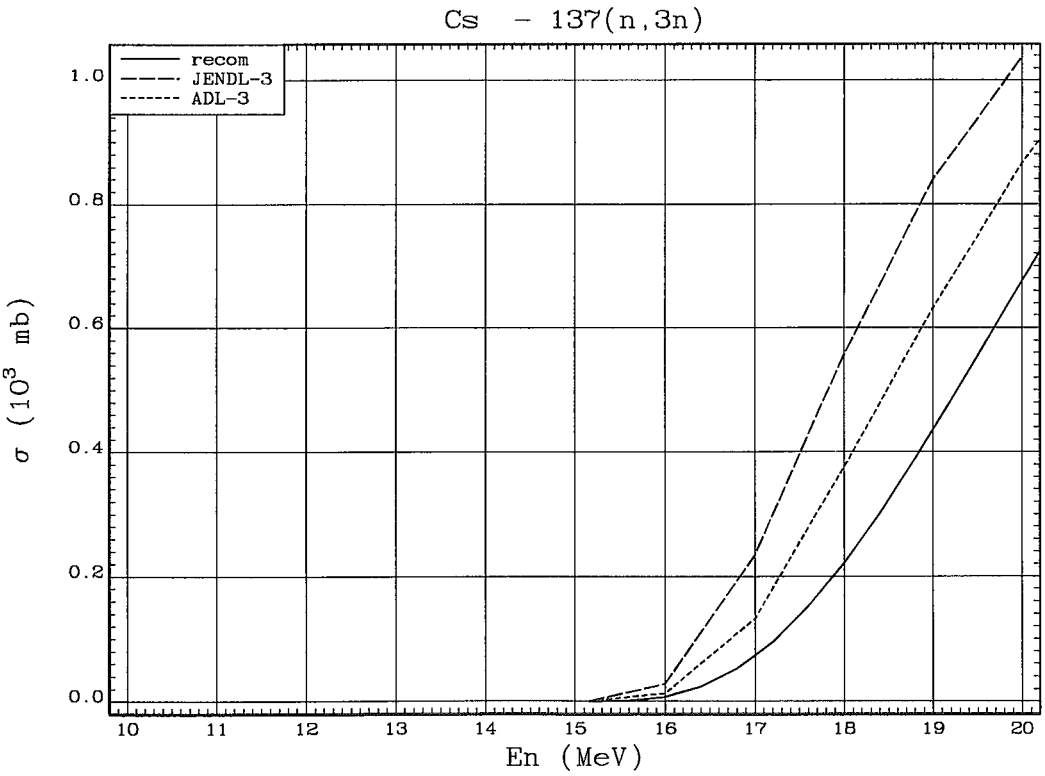

Fig.212. ^{137}Cs(n,3n)^{135}Cs reaction cross section.

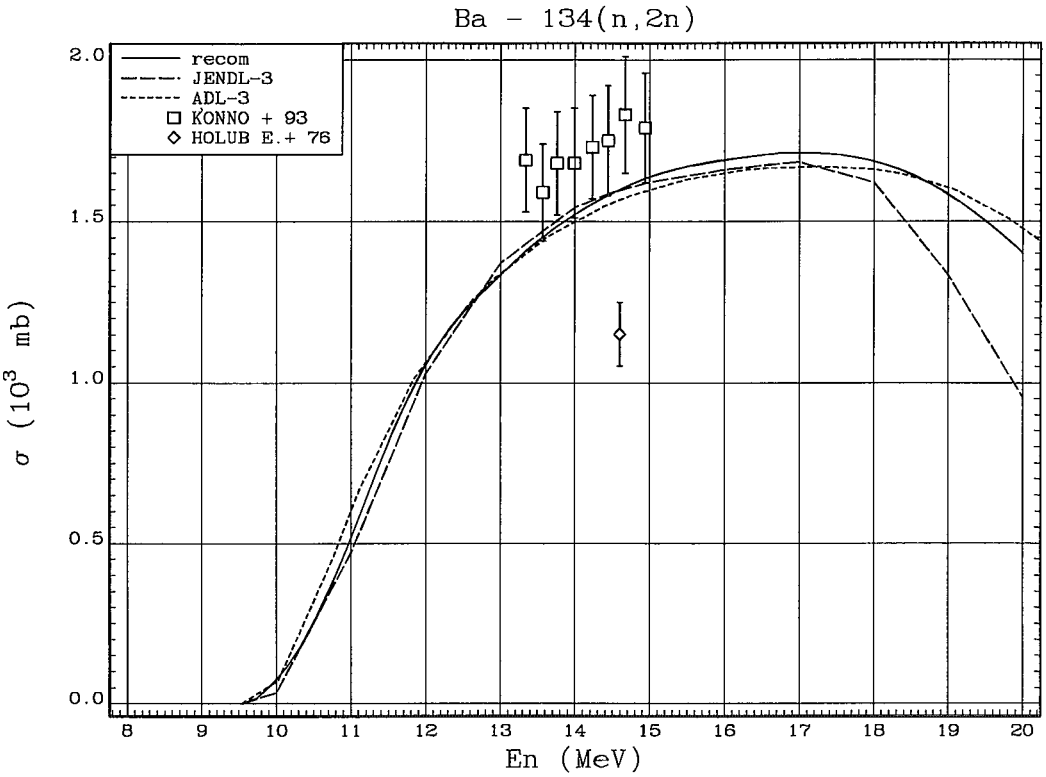

Fig.213. ^{134}Ba(n,2n)^{133}Ba reaction cross section.

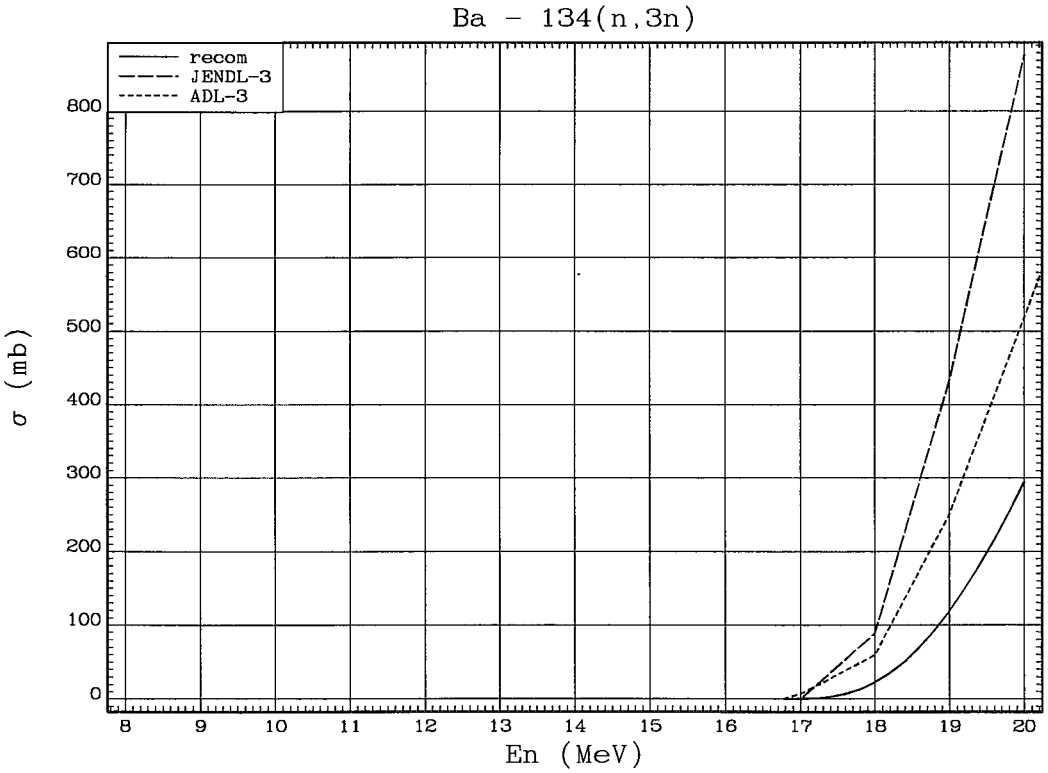

Fig.214. ^{134}Ba(n,3n)^{132}Ba reaction cross section.

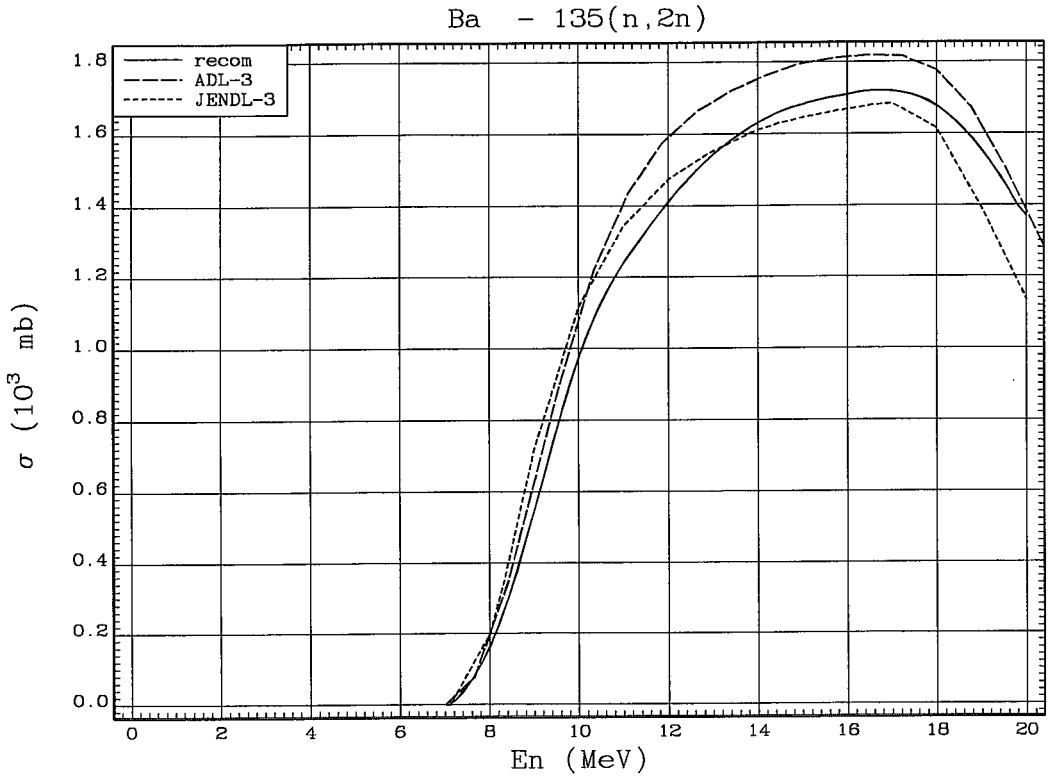

Fig.215. ^{135}Ba(n,2n)^{134}Ba reaction cross section.

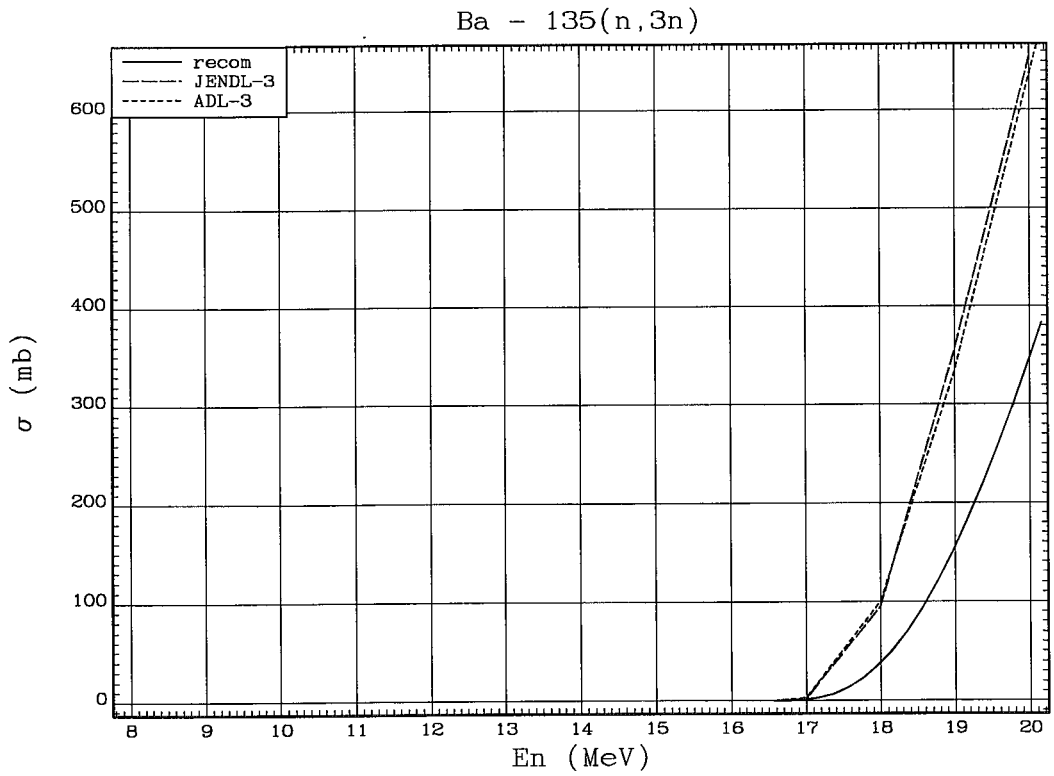

Fig.216. ^{135}Ba(n,3n)^{133}Ba reaction cross section

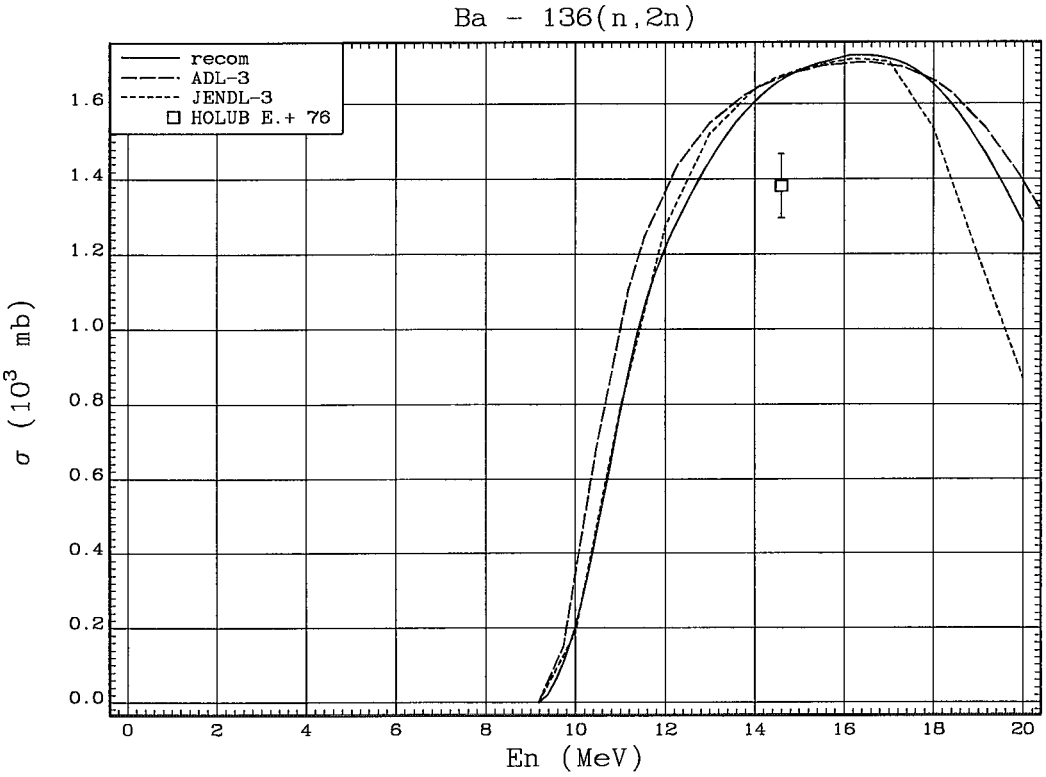

Fig.217. ^{136}Ba(n,2n)^{135}Ba reaction cross section.

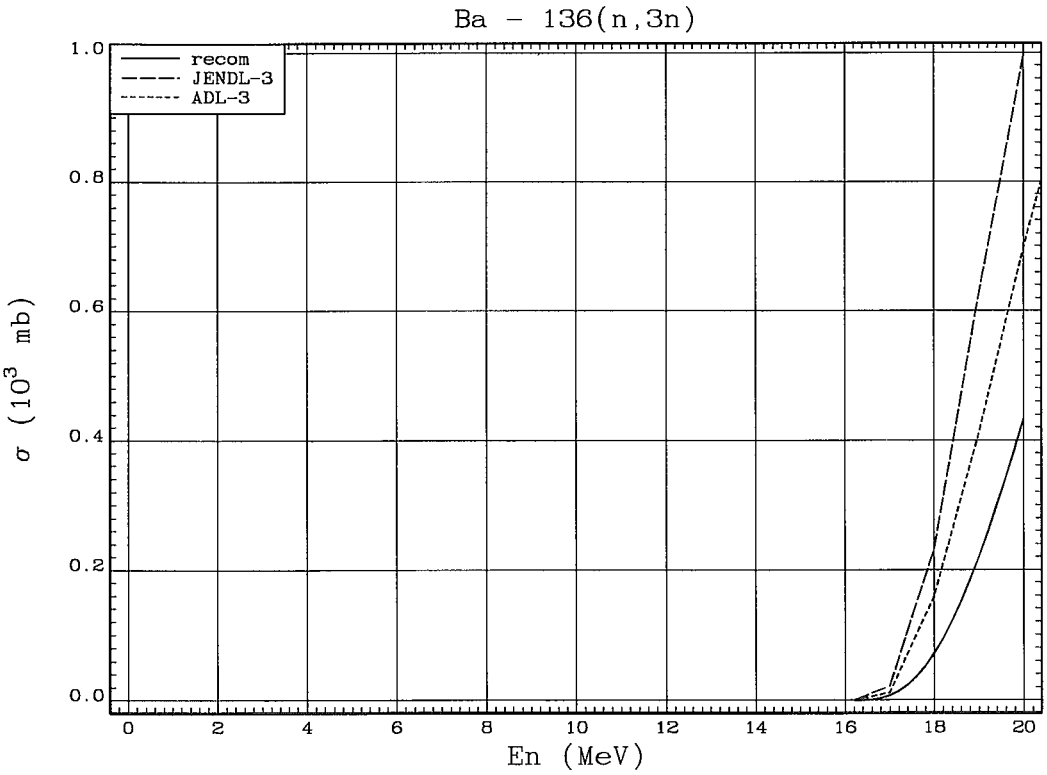

Fig.218. ^{136}Ba(n,3n)^{134}Ba reaction cross section.

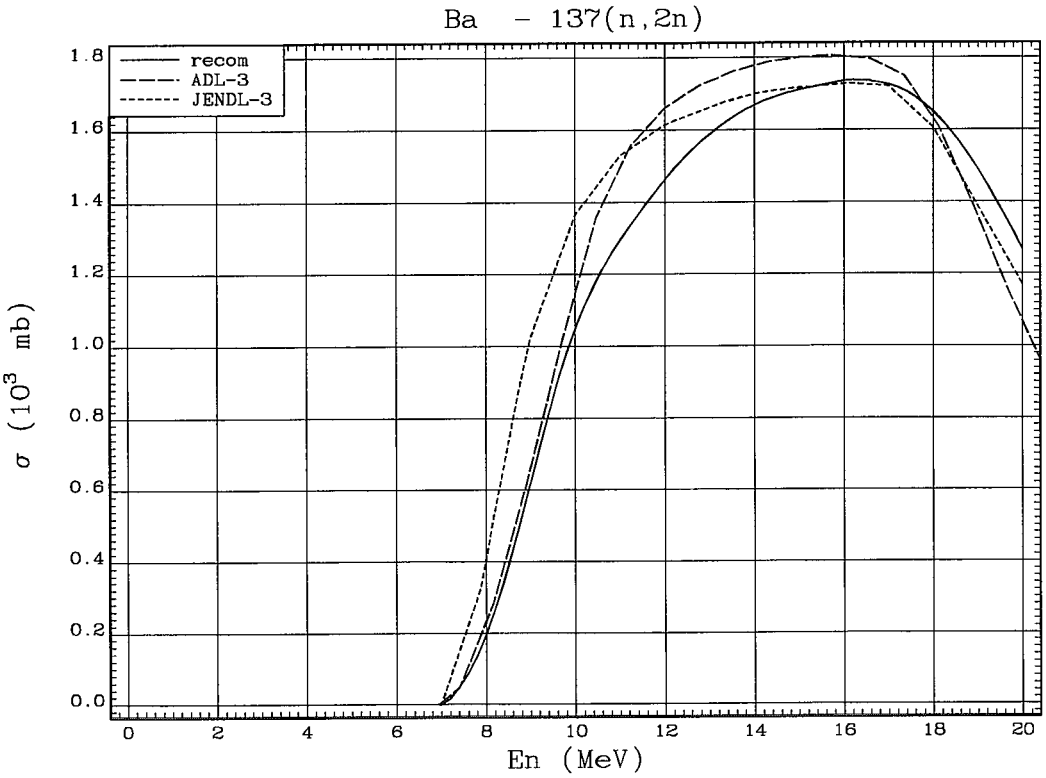

Fig.219. ^{137}Ba(n,2n)^{136}Ba reaction cross section.

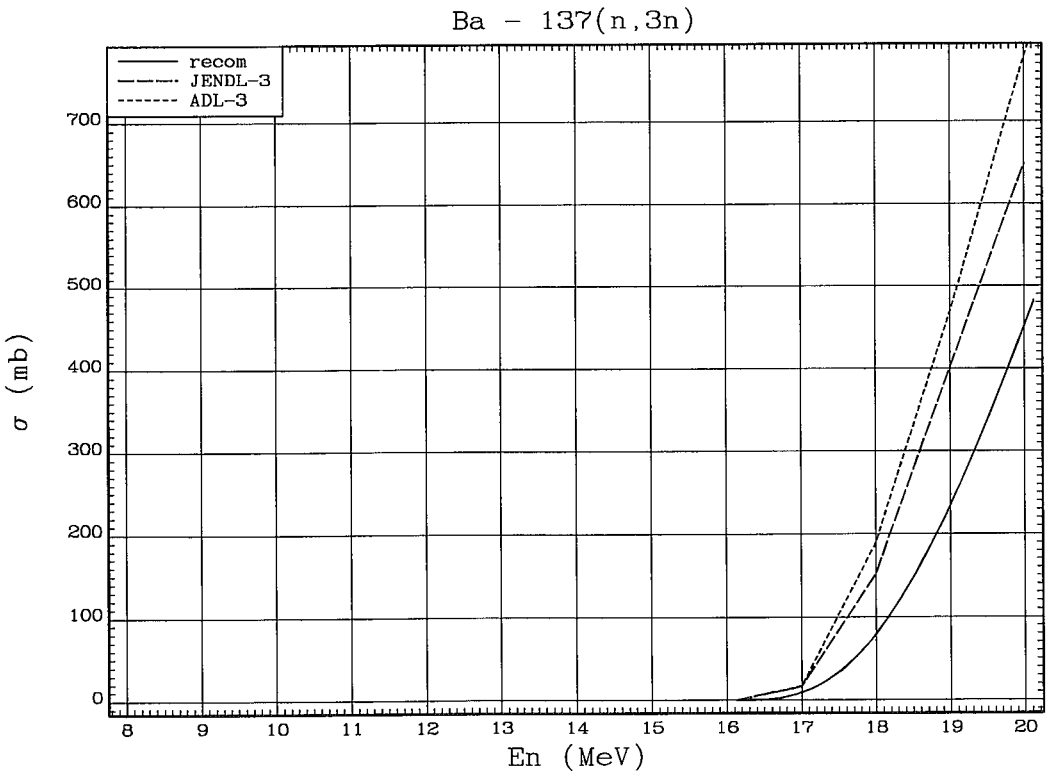

Fig.220. ^{137}Ba(n,3n)^{135}Ba reaction cross section.

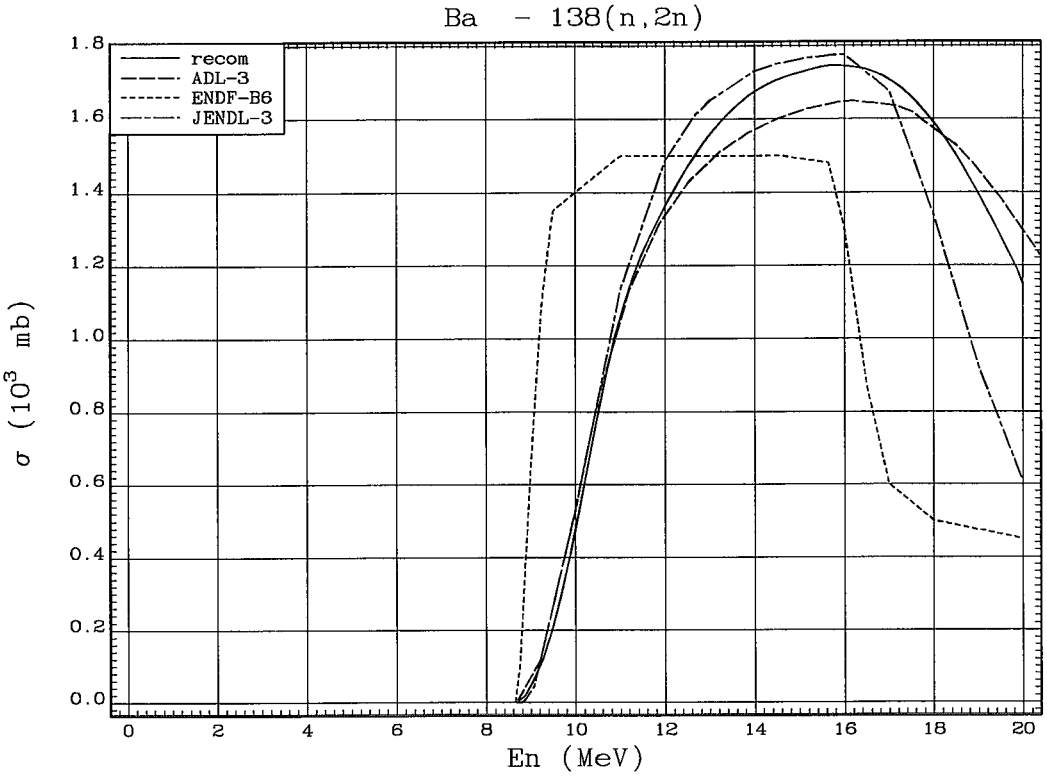

Fig.221. ^{138}Ba(n,2n)^{137}Ba reaction cross section.

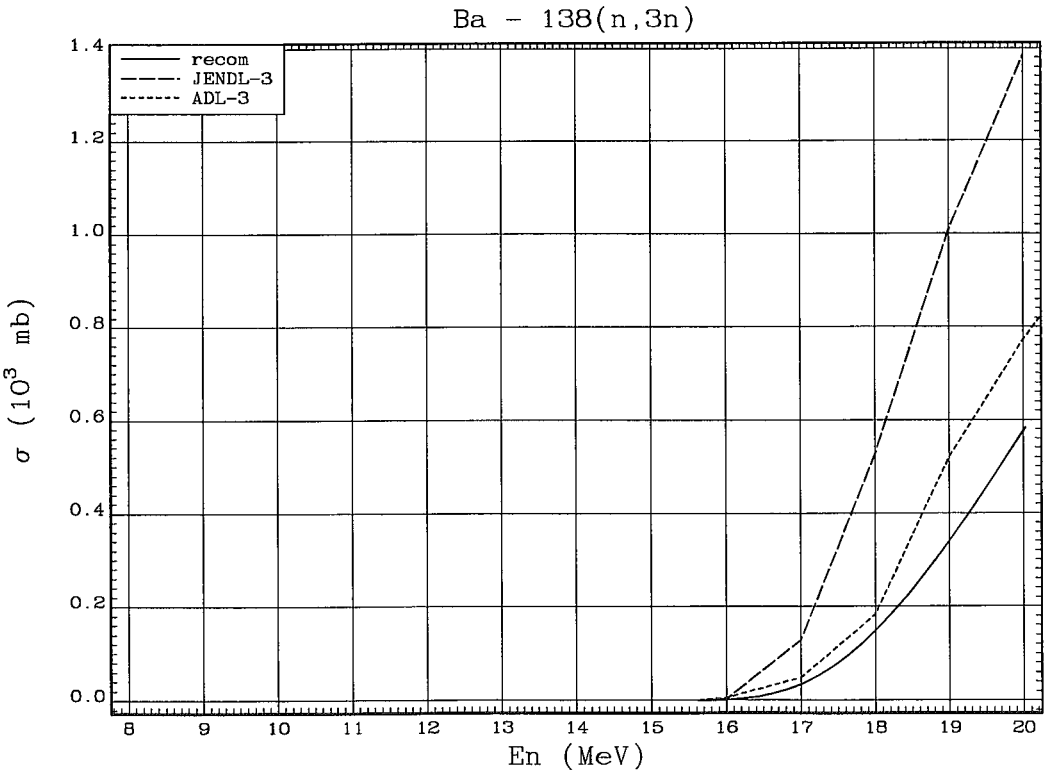

Fig.222. ^{138}Ba(n,3n)^{136}Ba reaction cross section.

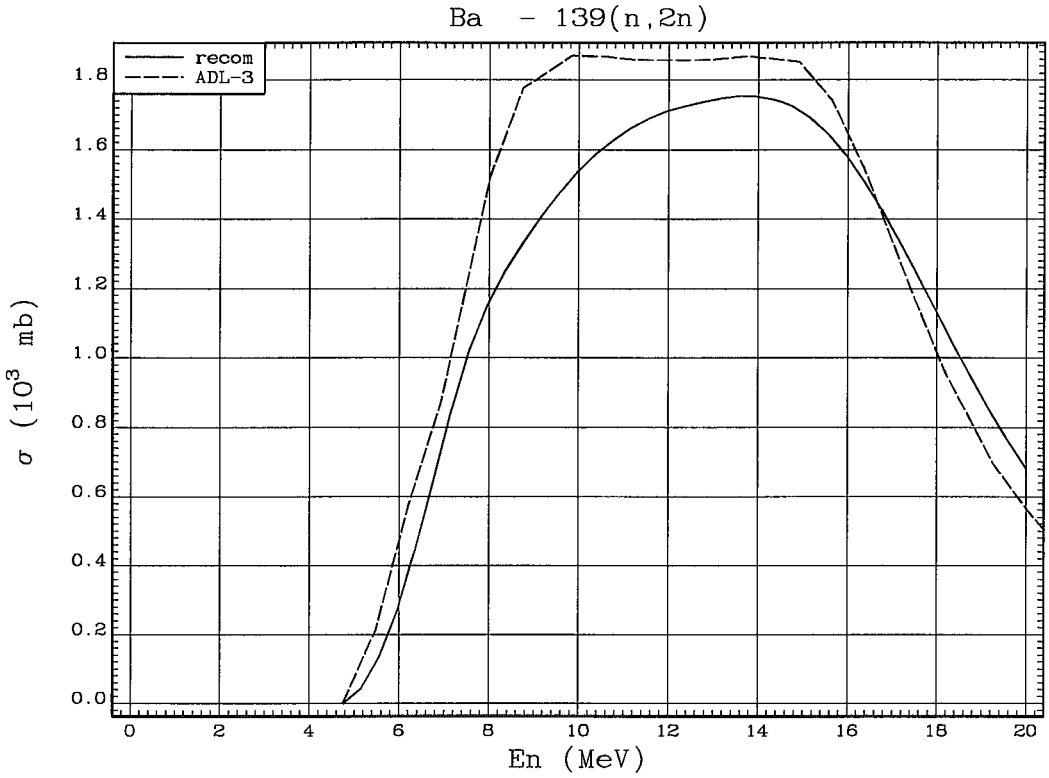

Fig.223. ^{139}Ba(n,2n)^{138}Ba reaction cross section.

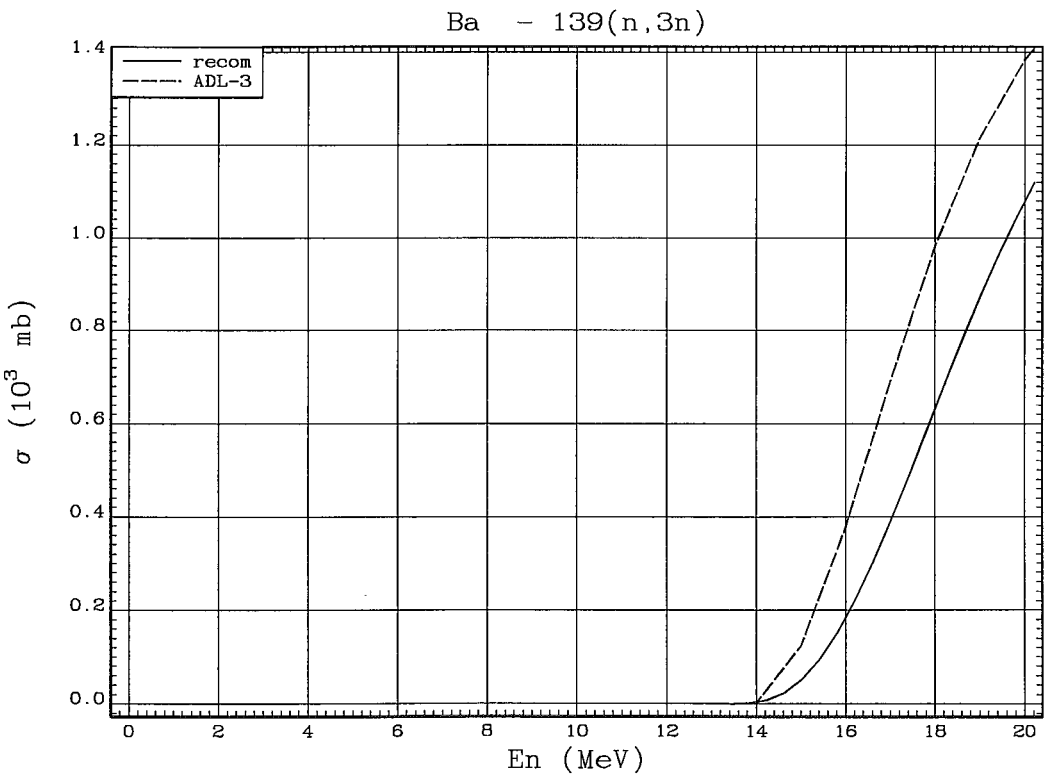

Fig.224. ^{139}Ba(n,3n)^{137}Ba reaction cross section.

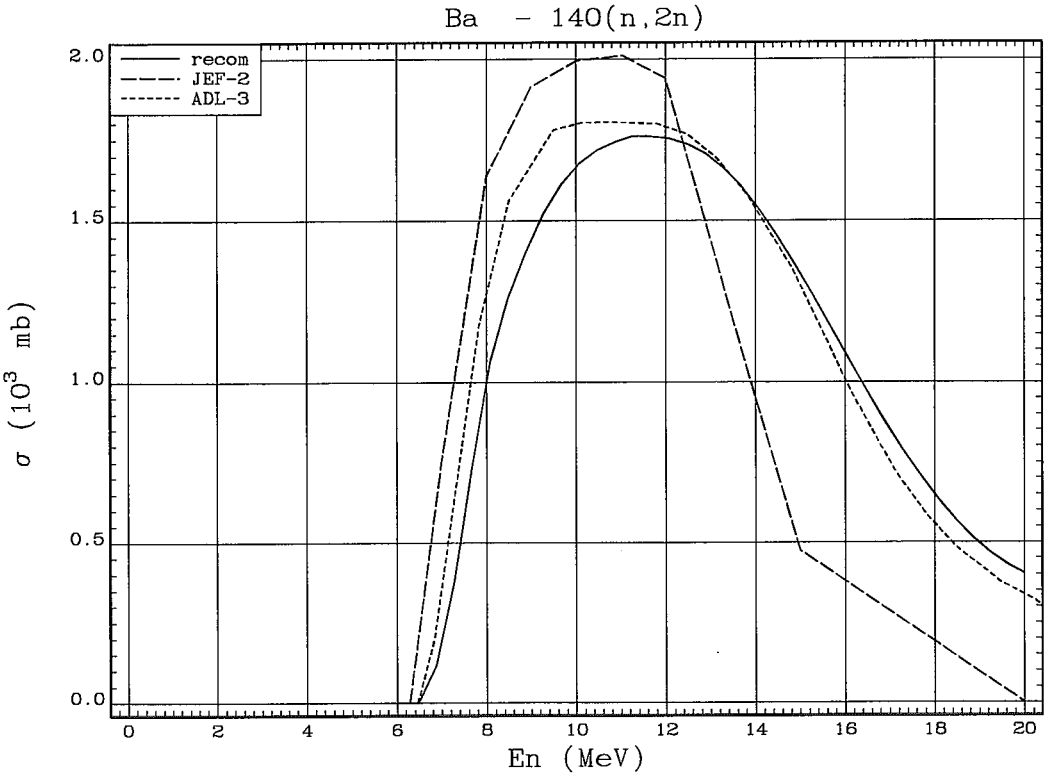

Fig.225. ^{140}Ba(n,2n)^{139}Ba reaction cross section.

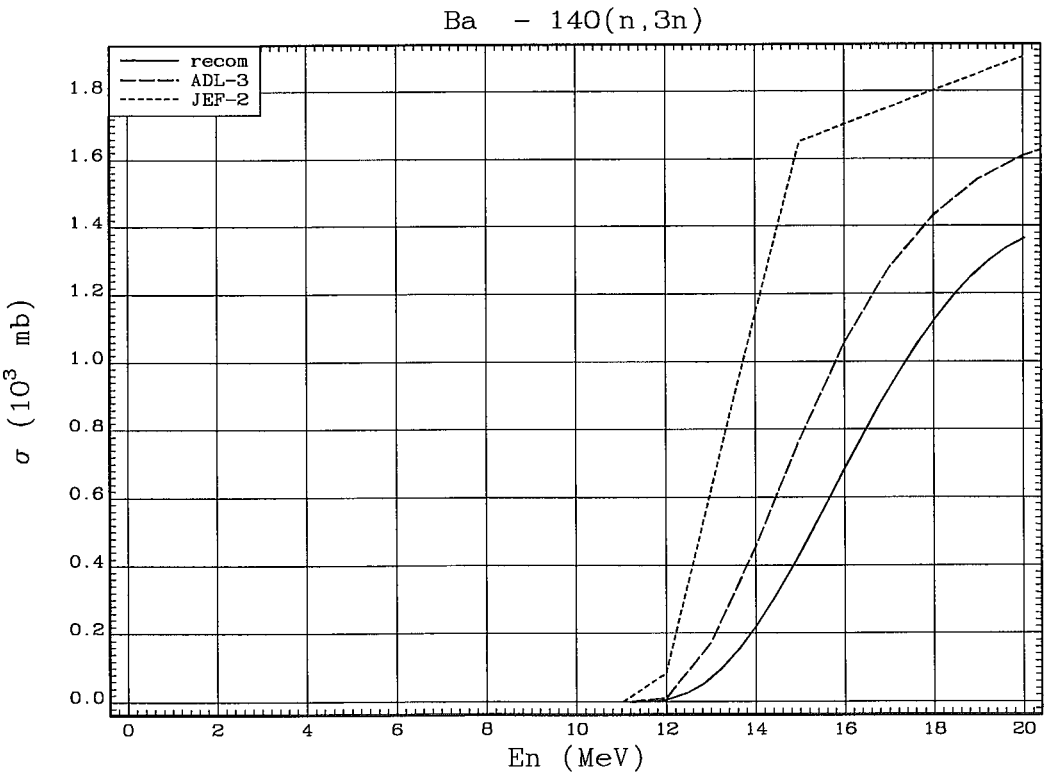

Fig.226. ^{140}Ba(n,3n)^{138}Ba reaction cross section.

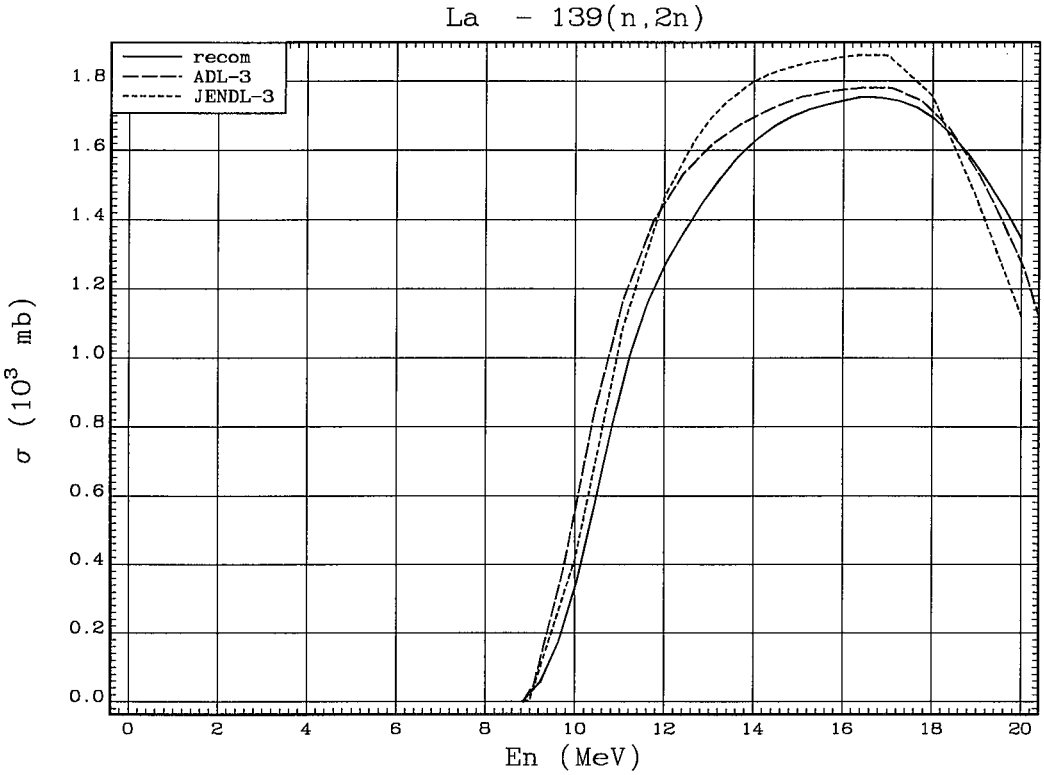

Fig.227. ^{139}La(n,2n)^{138}La reaction cross section.

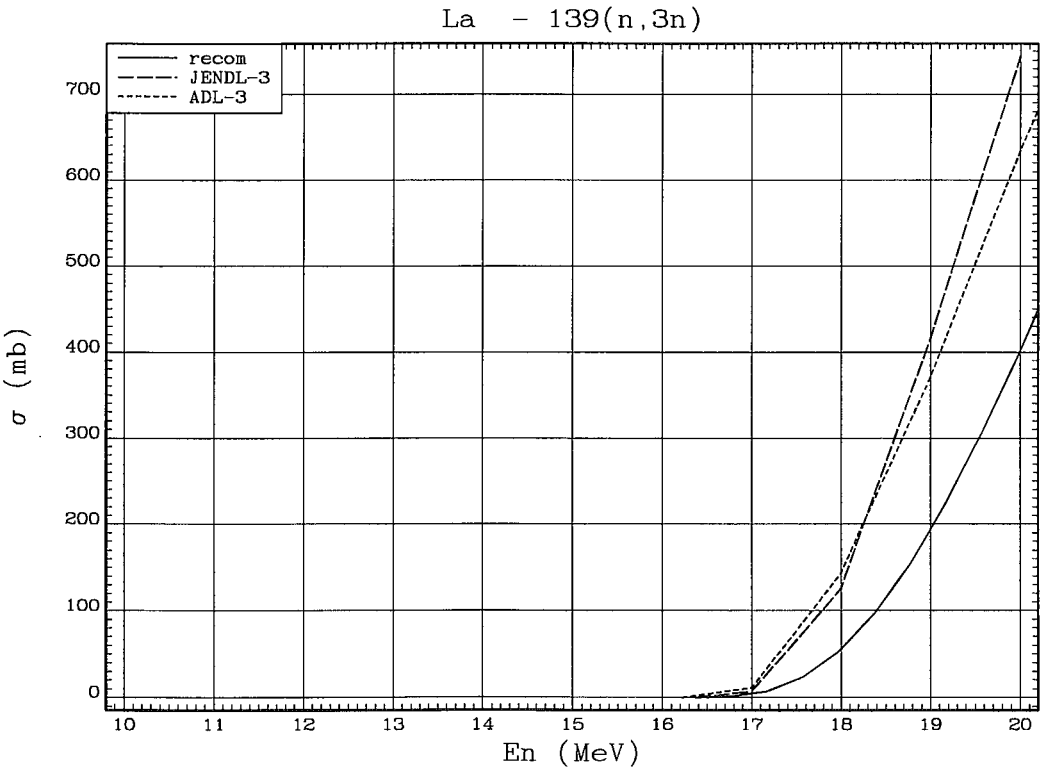

Fig.228. ^{139}La(n,3n)^{137}La reaction cross section.

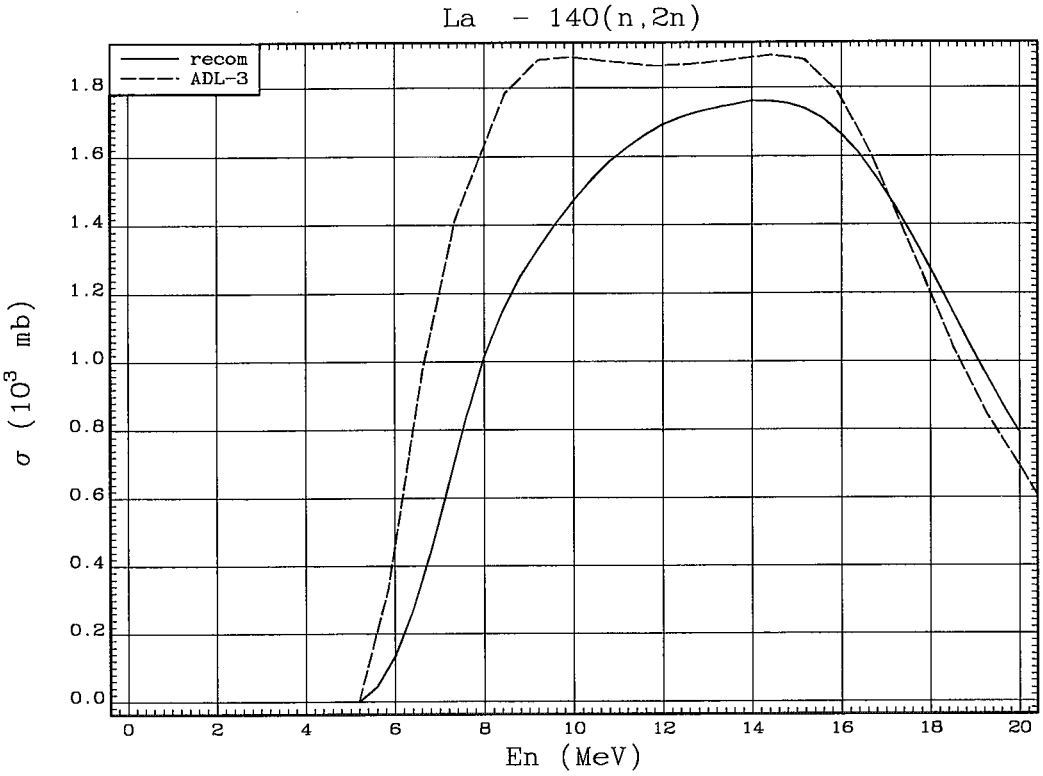

Fig.229. ^{140}La(n,2n)^{139}La reaction cross section.

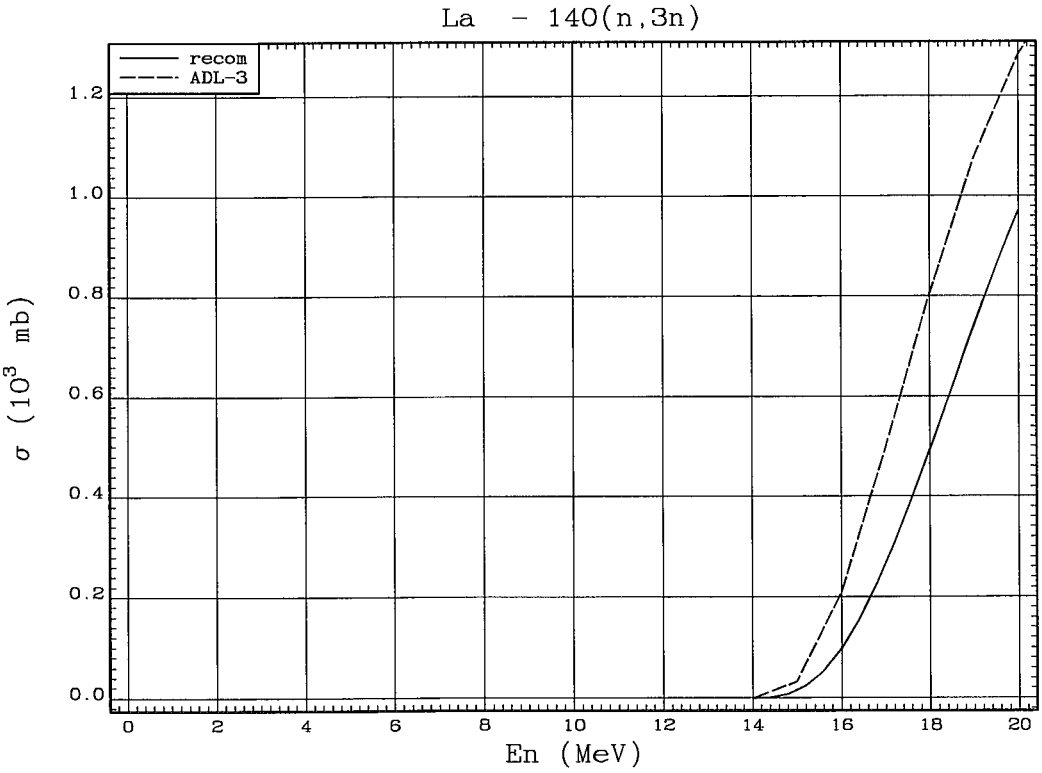

Fig.230. ^{140}La(n,3n)^{138}La reaction cross section.

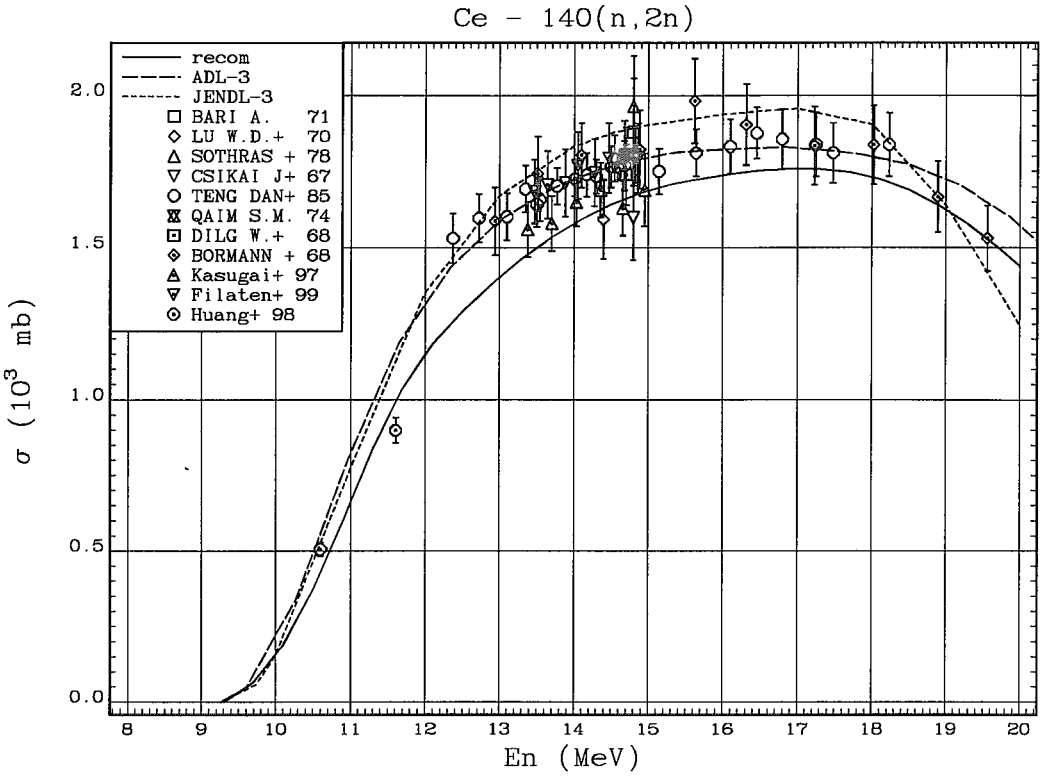

Fig.231. ^{140}Ce(n,2n)^{139}Ce reaction cross section.

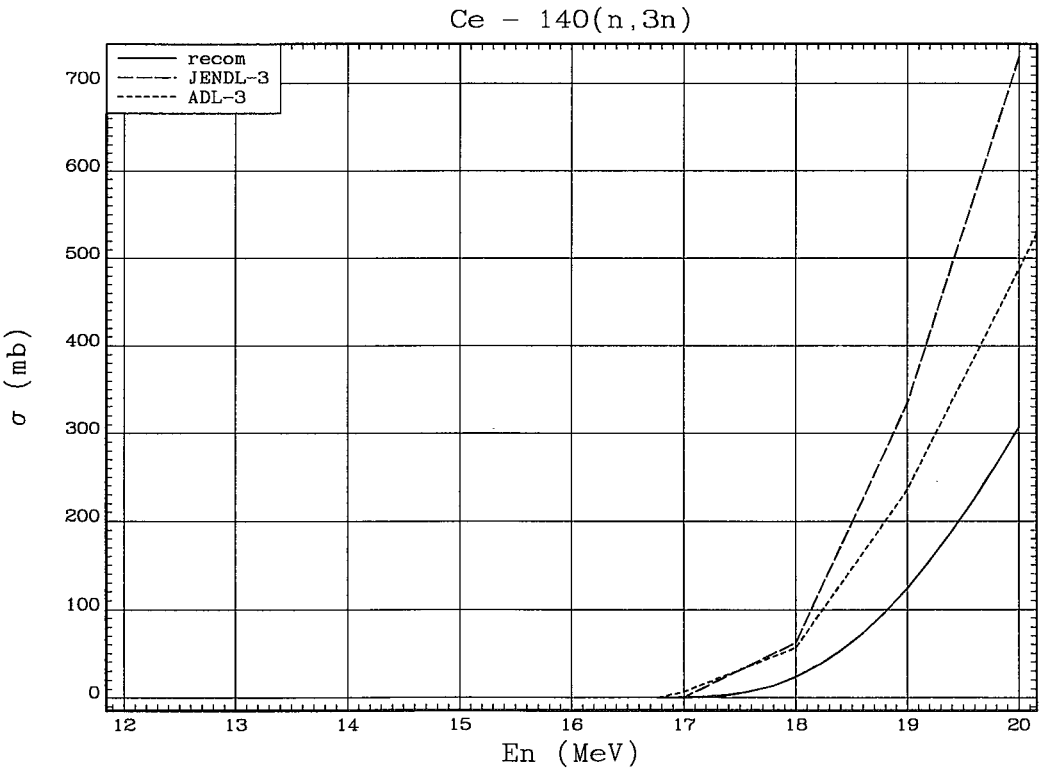

Fig.232. ^{140}Ce(n,3n)^{138}Ce reaction cross section.

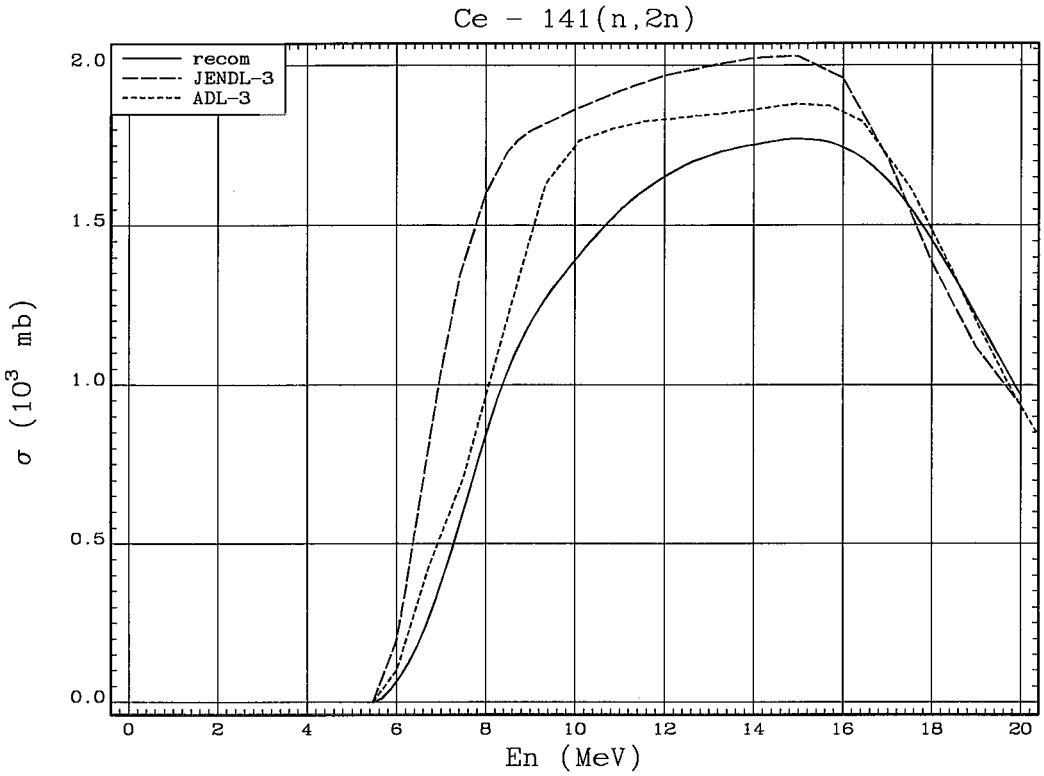

Fig.233. ^{141}Ce(n,2n)^{140}Ce reaction cross section.

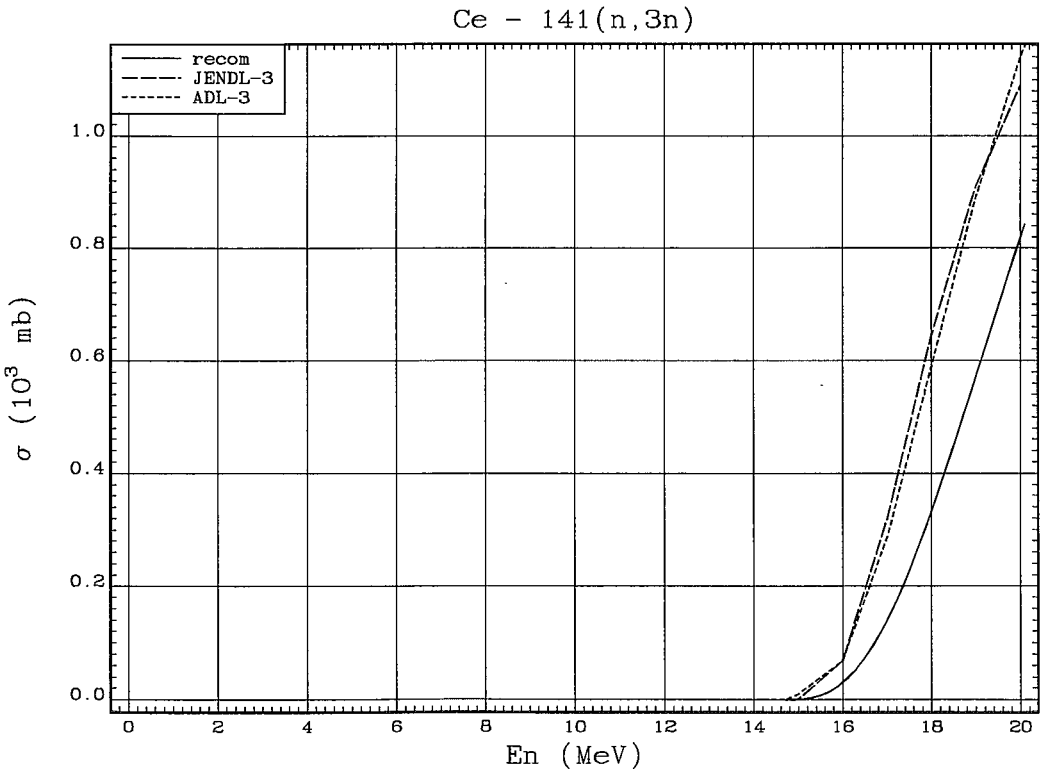

Fig.234. ^{141}Ce(n,3n)^{139}Ce reaction cross section.

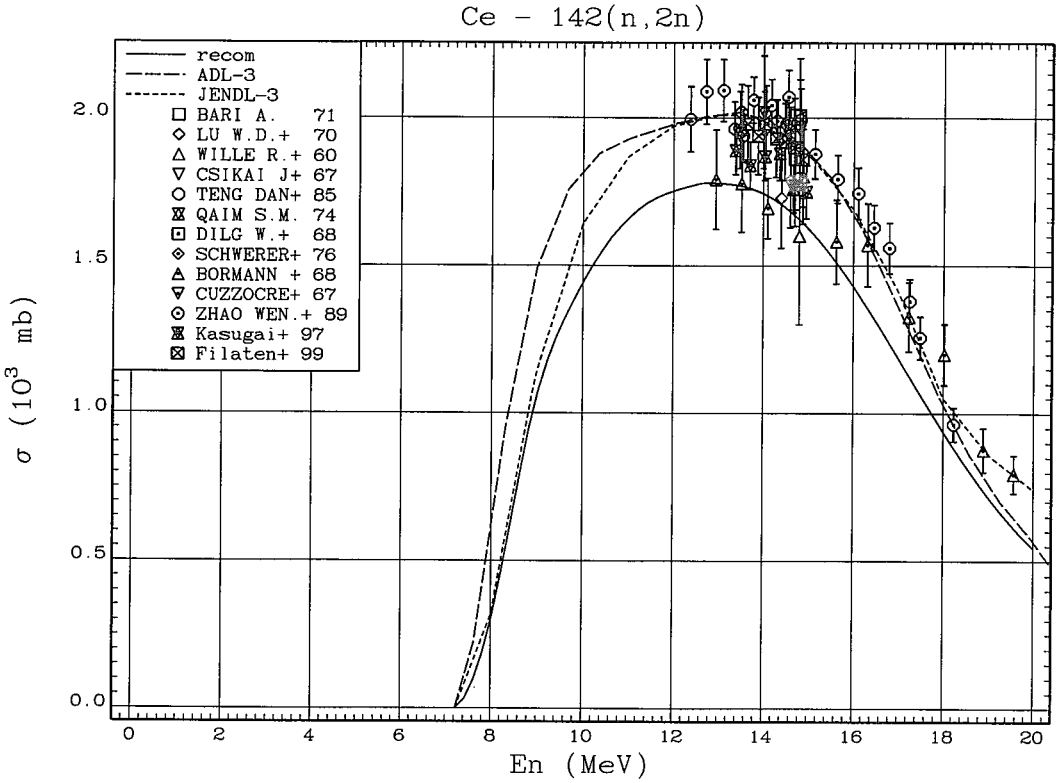

Fig.235. ^{142}Ce(n,2n)^{141}Ce reaction cross section.

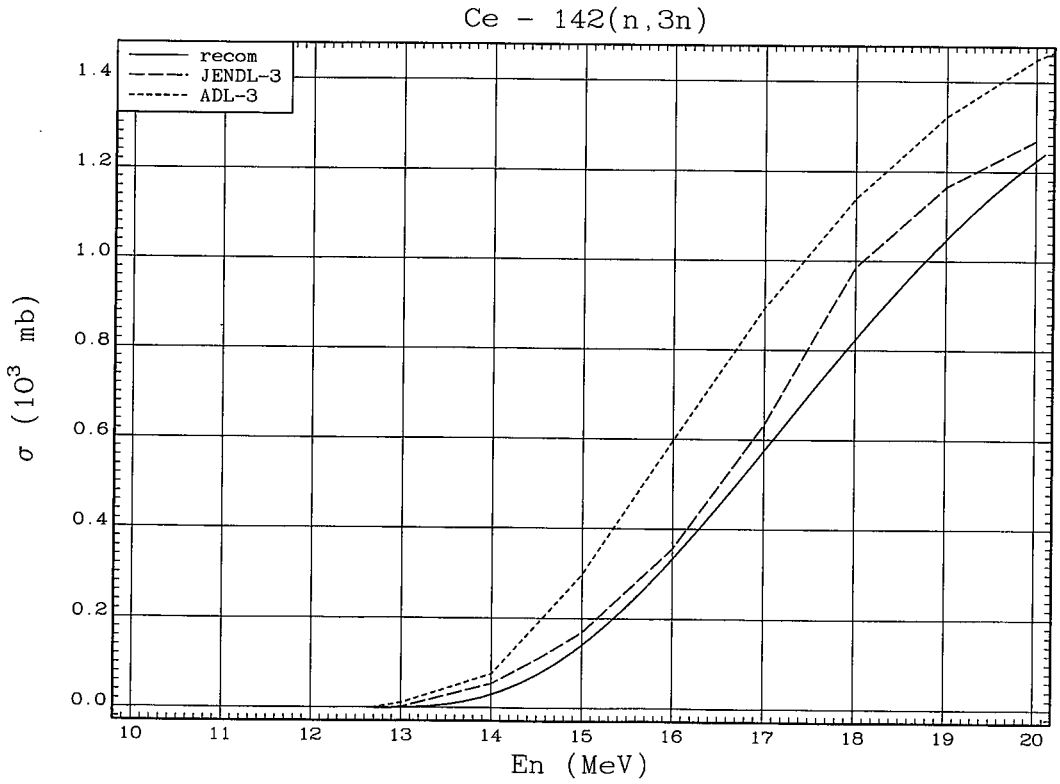

Fig.236. ^{142}Ce(n,3n)^{140}Ce reaction cross section.

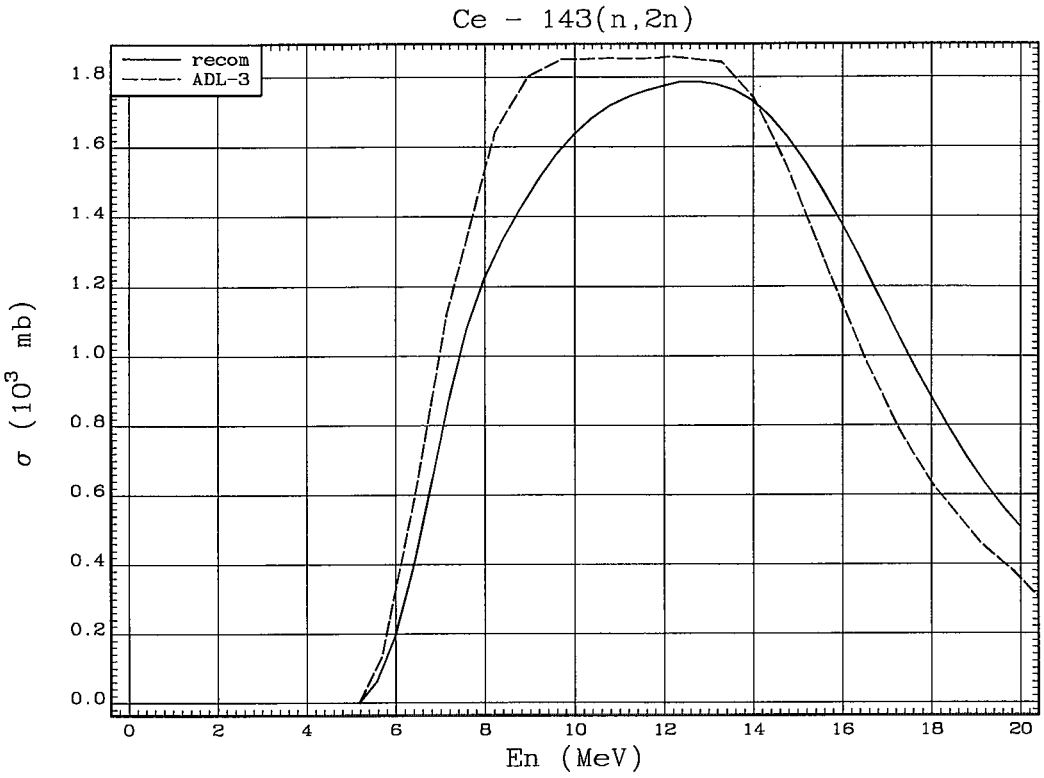

Fig.237. ^{143}Ce(n,2n)^{142}Ce reaction cross section.

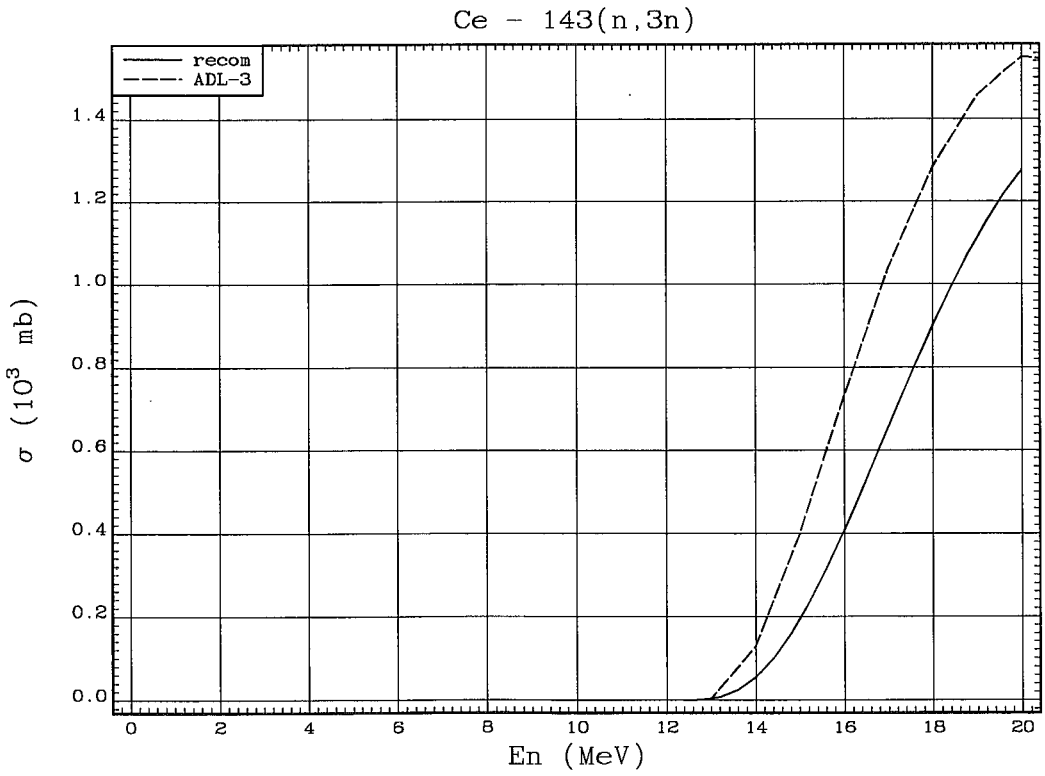

Fig.238. ^{143}Ce(n,3n)^{141}Ce reaction cross section.

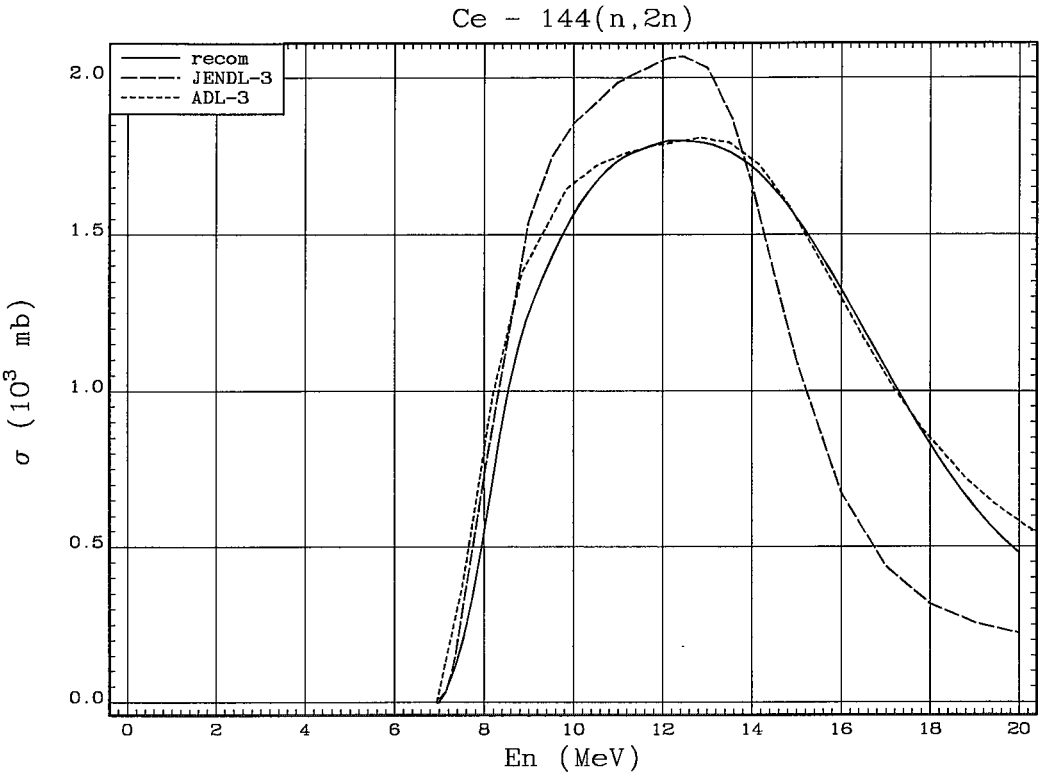

Fig.239. ^{144}Ce(n,2n)^{143}Ce reaction cross section.

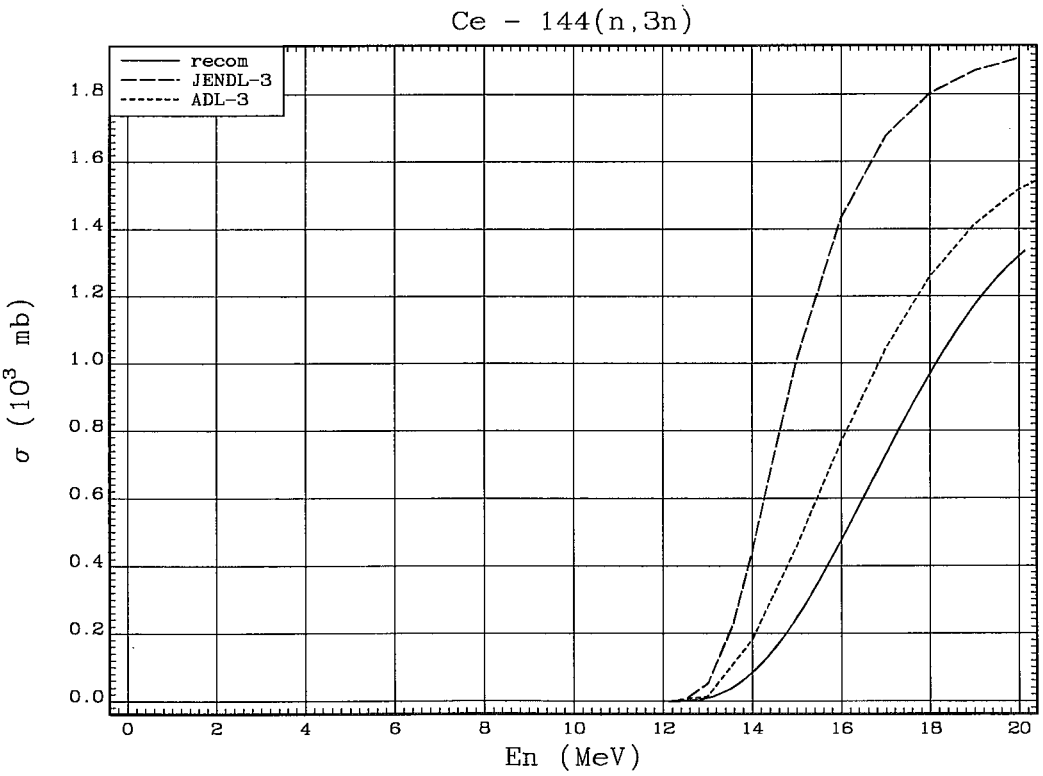

Fig.240. ^{144}Ce(n,3n)^{142}Ce reaction cross section.

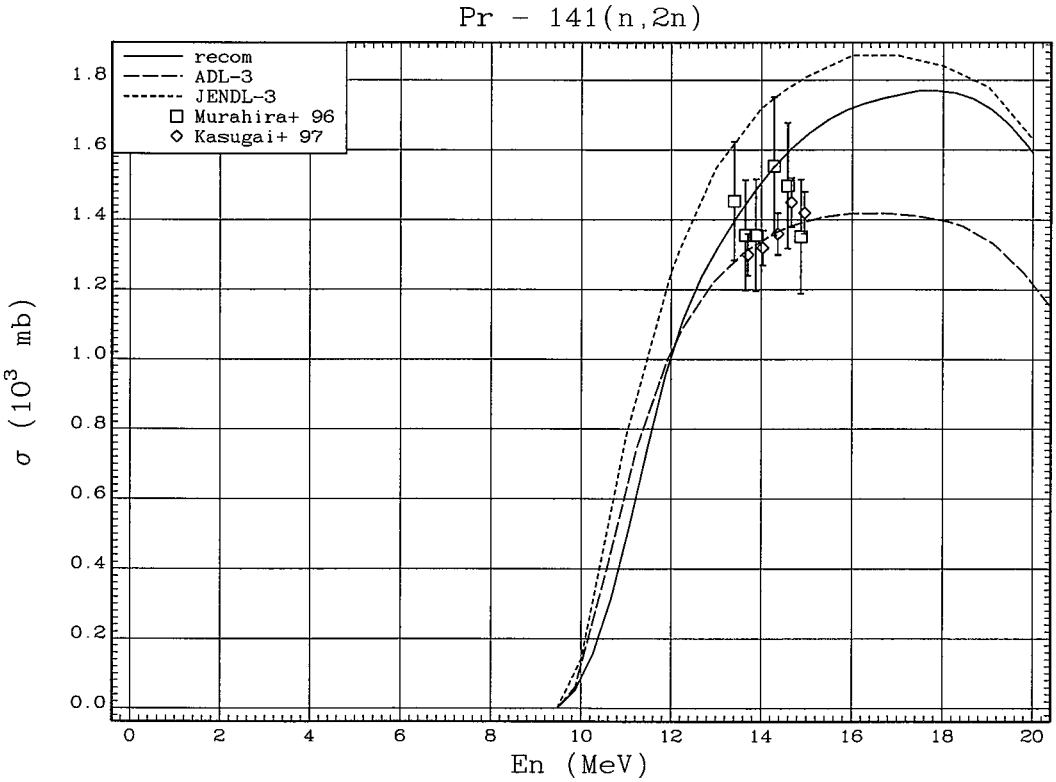

Fig.241. ^{141}Pr(n,2n)^{140}Pr reaction cross section.

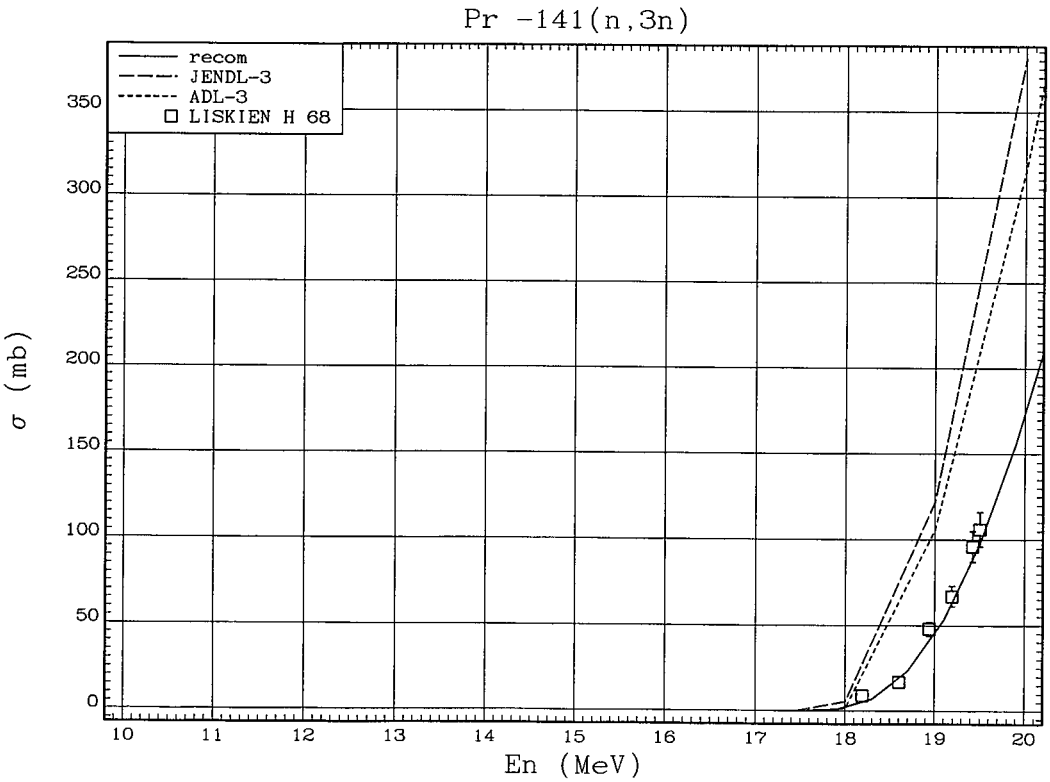

Fig.242. ^{141}Pr(n,3n)^{139}Pr reaction cross section.

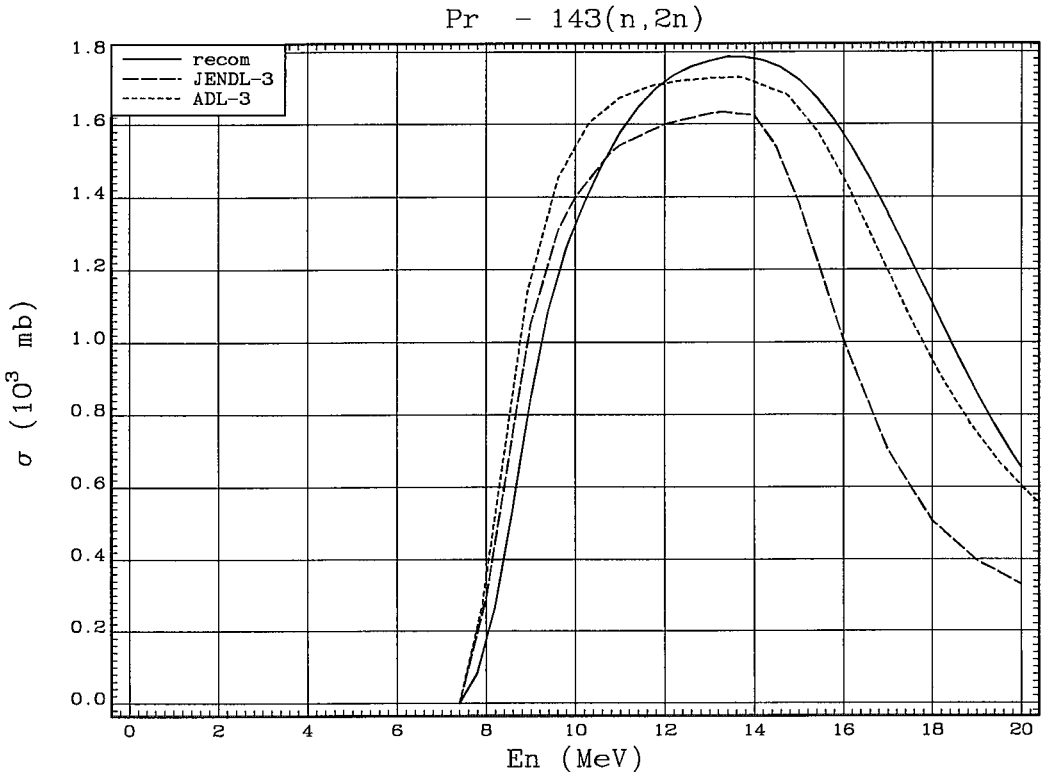

Fig.243. ^{143}Pr(n,2n)^{142}Pr reaction cross section.

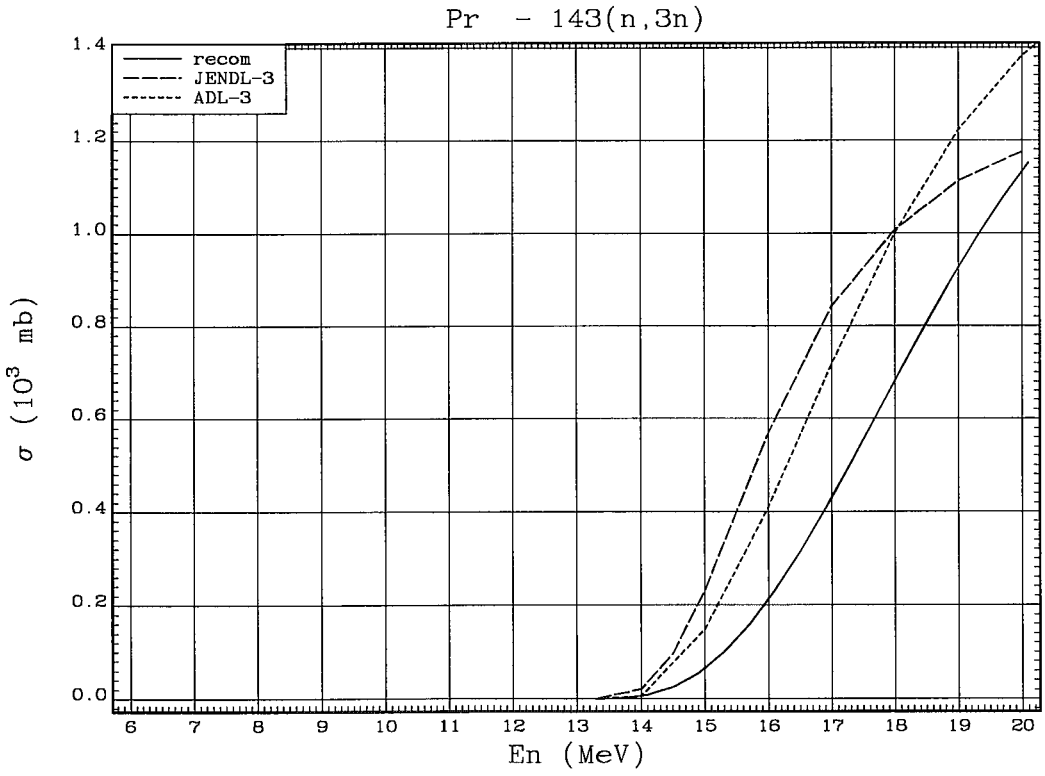

Fig.244. ^{143}Pr(n,3n)^{141}Pr reaction cross section.

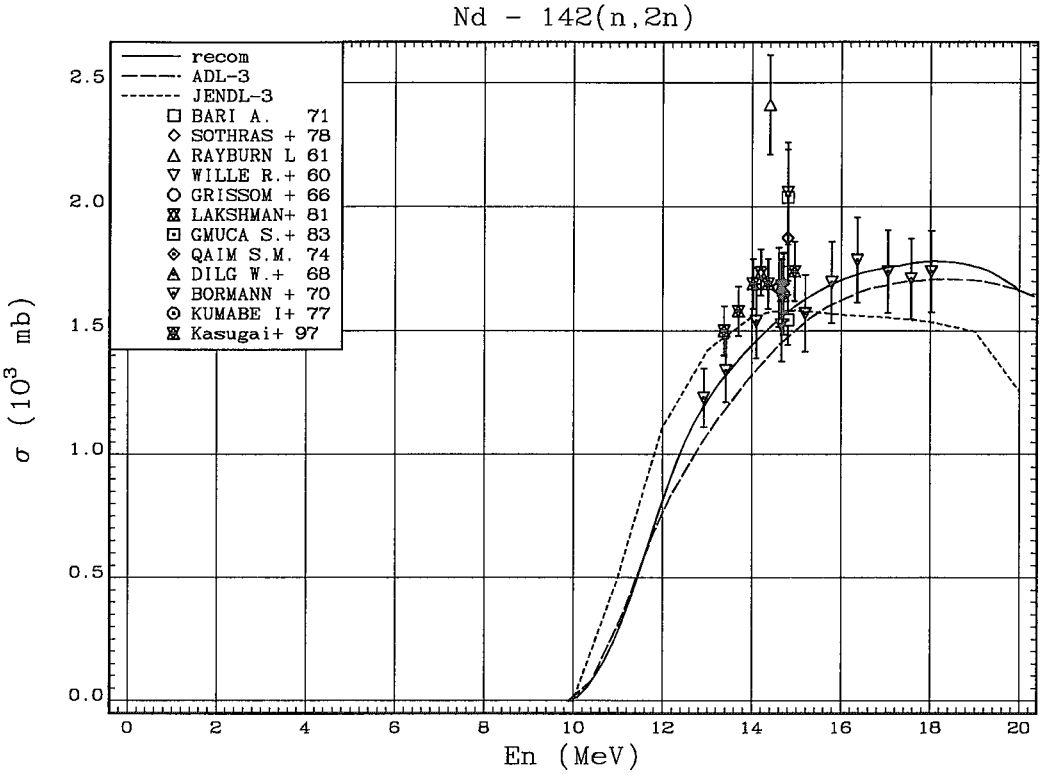

Fig.245. ^{142}Nd(n,2n)^{141}Nd reaction cross section.

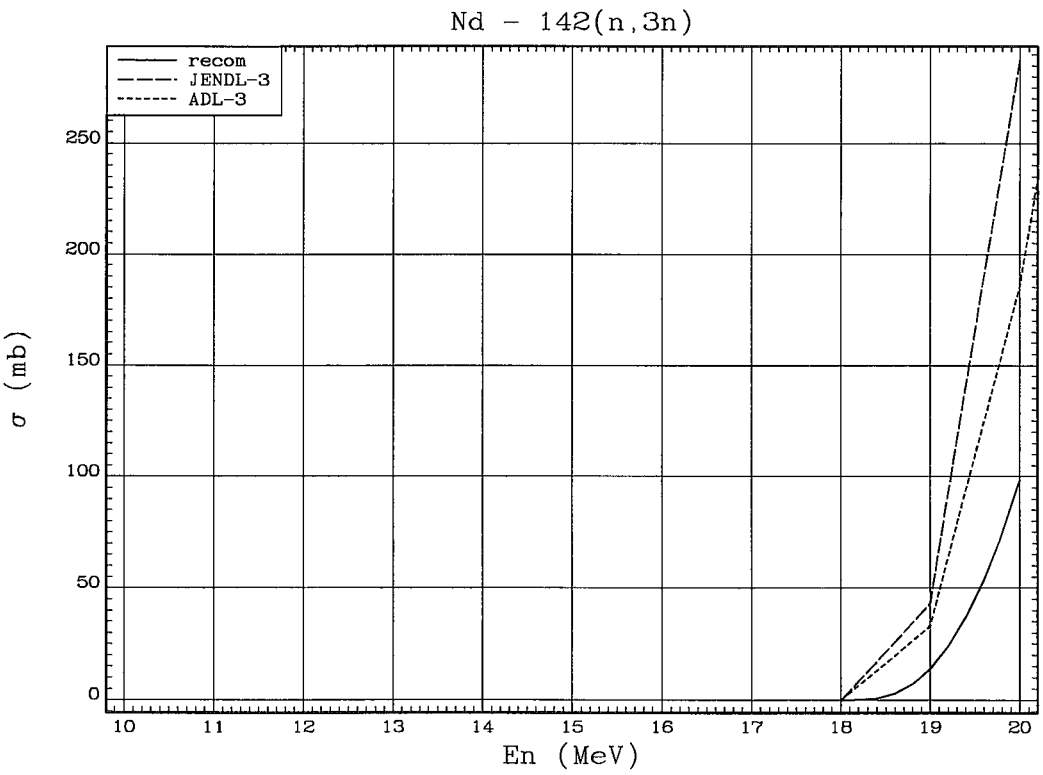

Fig.246. ^{142}Nd(n,3n)^{140}Nd reaction cross section.

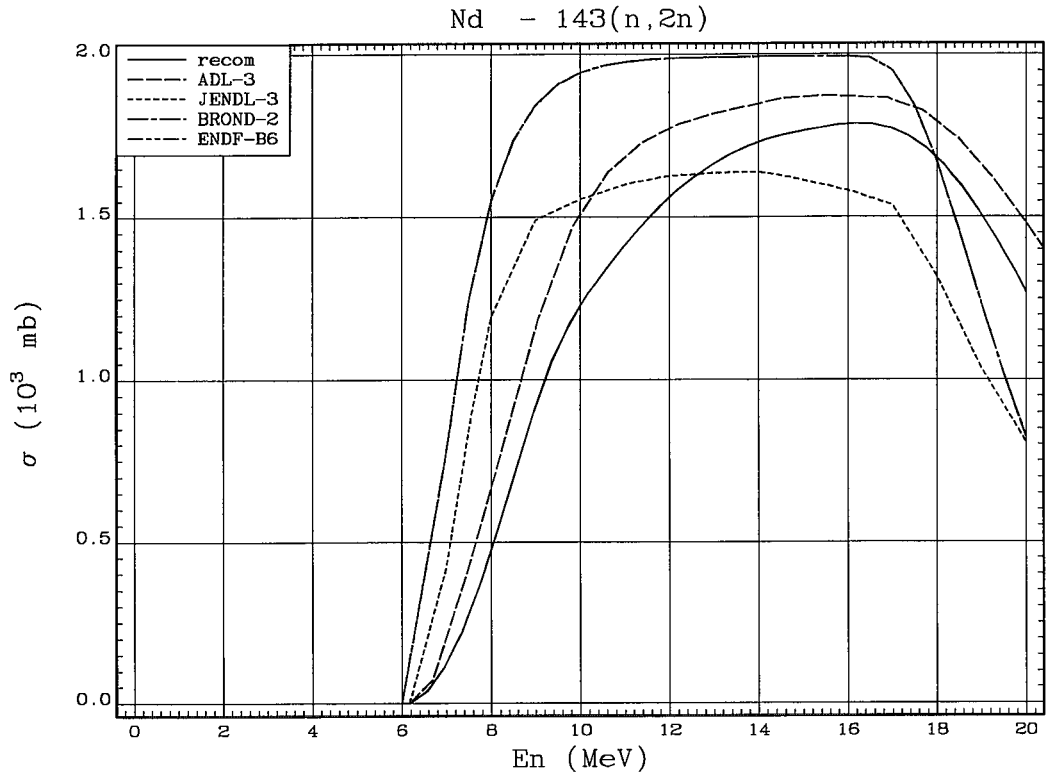

Fig.247. ^{143}Nd(n,2n)^{142}Nd reaction cross section.

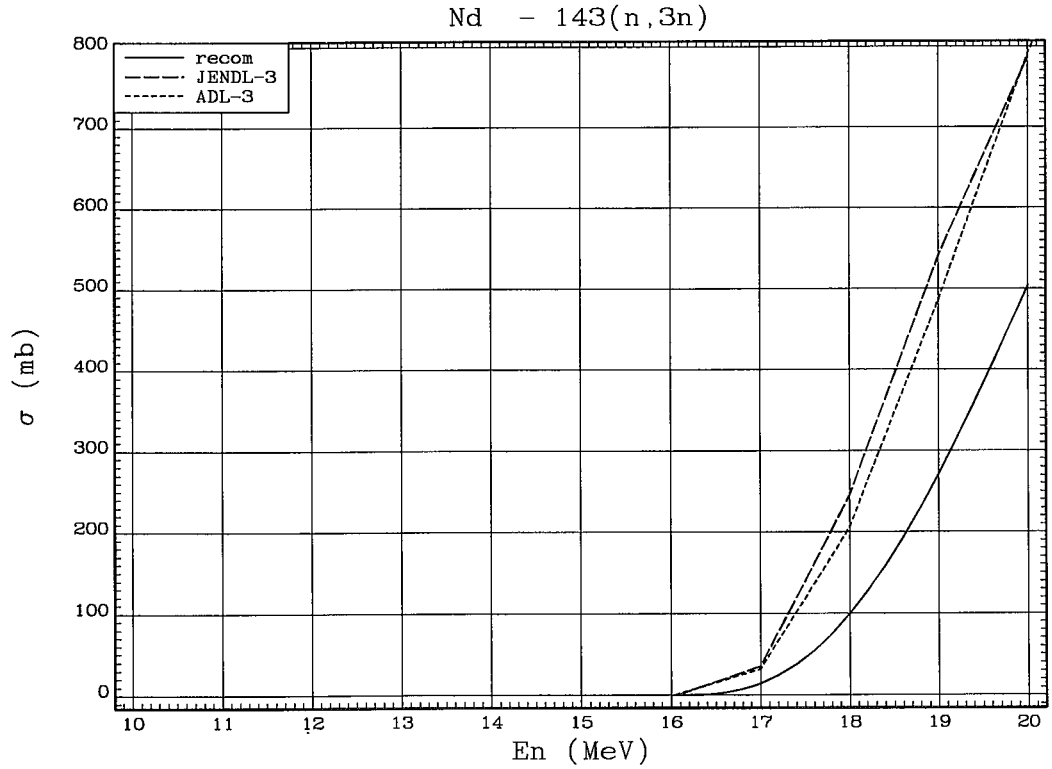

Fig.248. ^{143}Nd(n,3n)^{141}Nd reaction cross section.

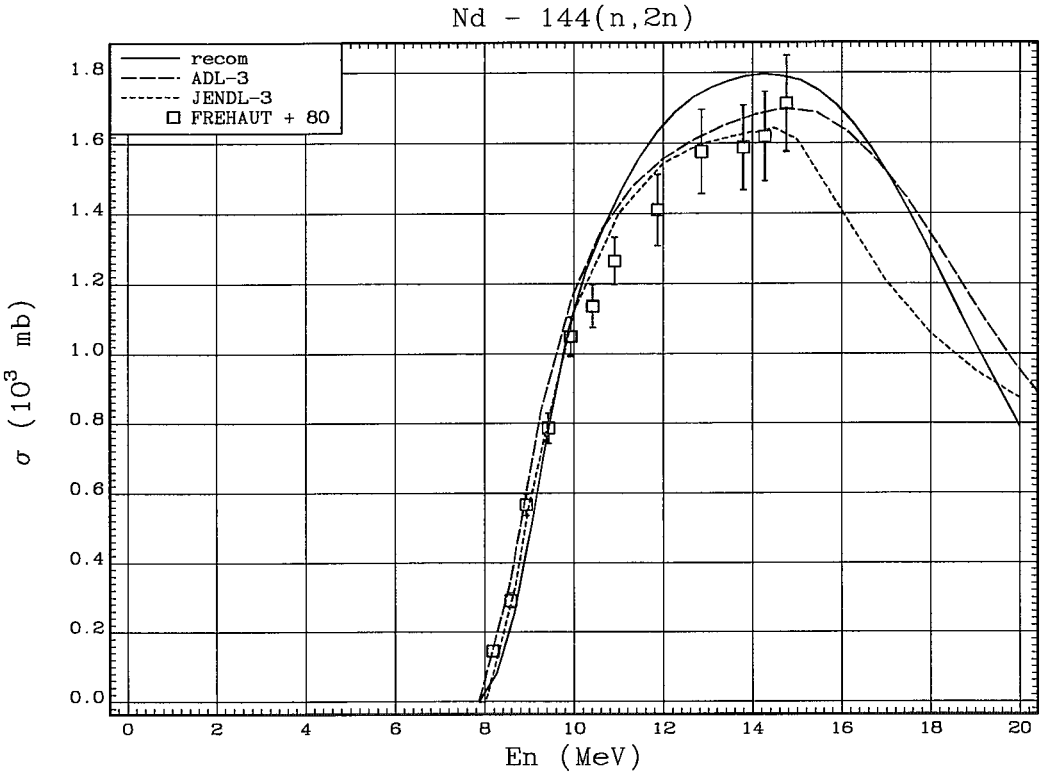

Fig.249. ^{144}Nd(n,2n)^{143}Nd reaction cross section.

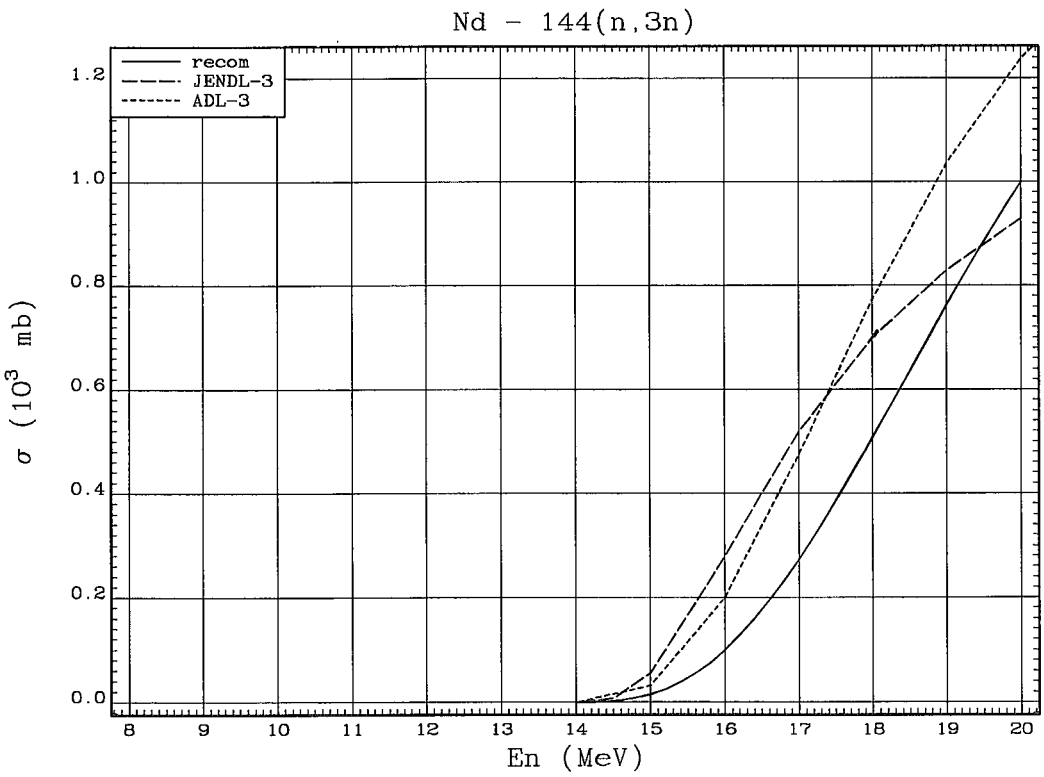

Fig.250. ^{144}Nd(n,3n)^{142}Nd reaction cross section.

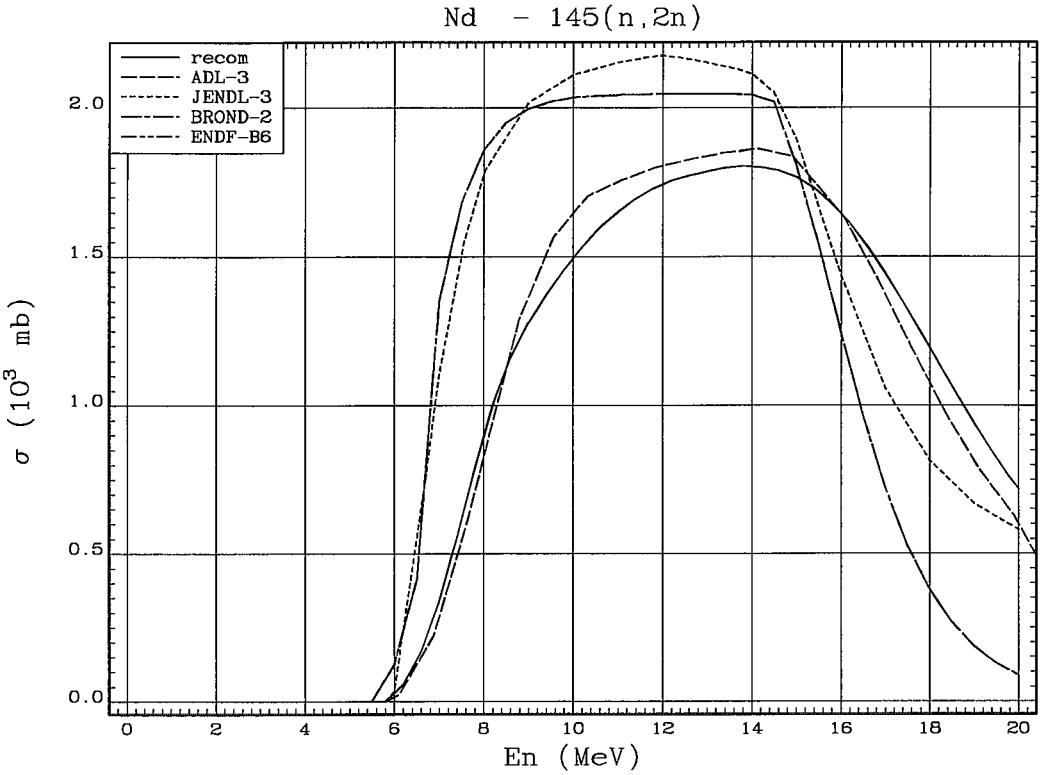

Fig.251. ^{145}Nd(n,2n)^{144}Nd reaction cross section.

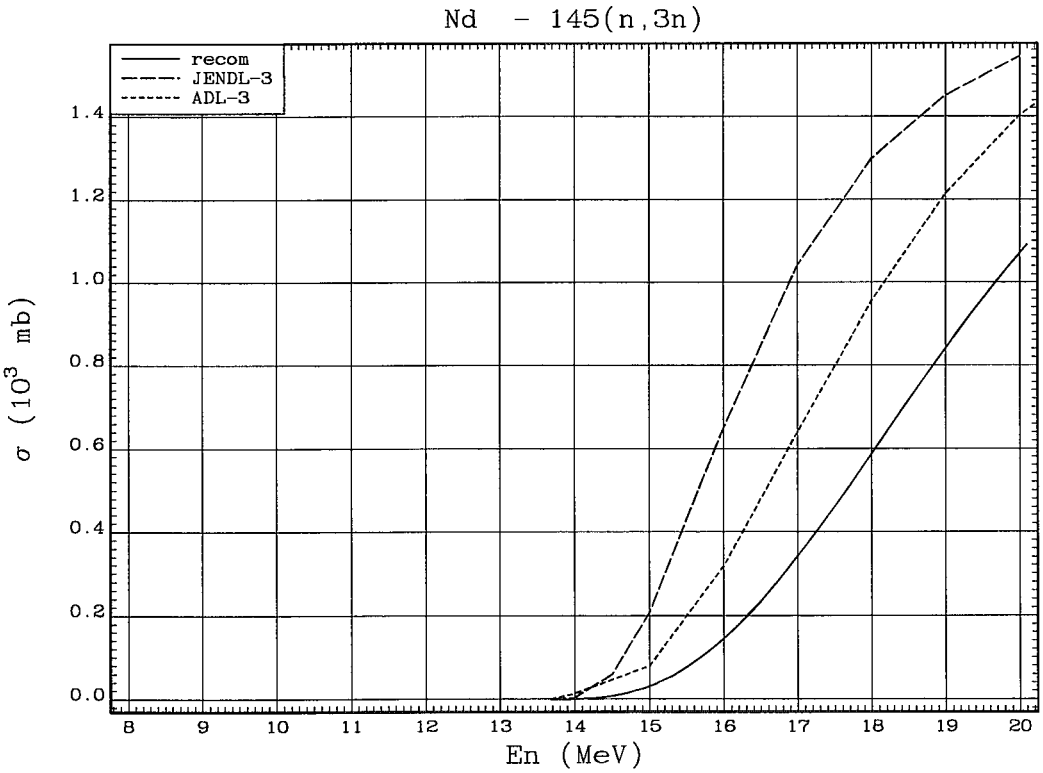

Fig.252. ^{145}Nd(n,3n)^{143}Nd reaction cross section.

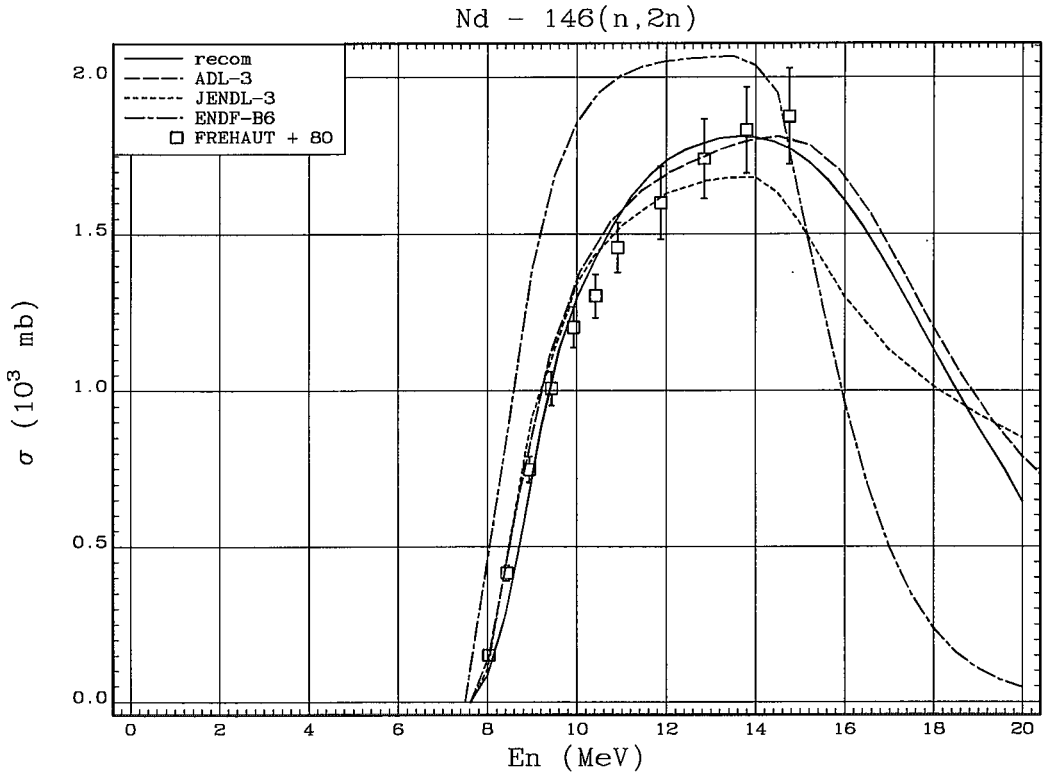

Fig.253. ^{146}Nd(n,2n)^{145}Nd reaction cross section.

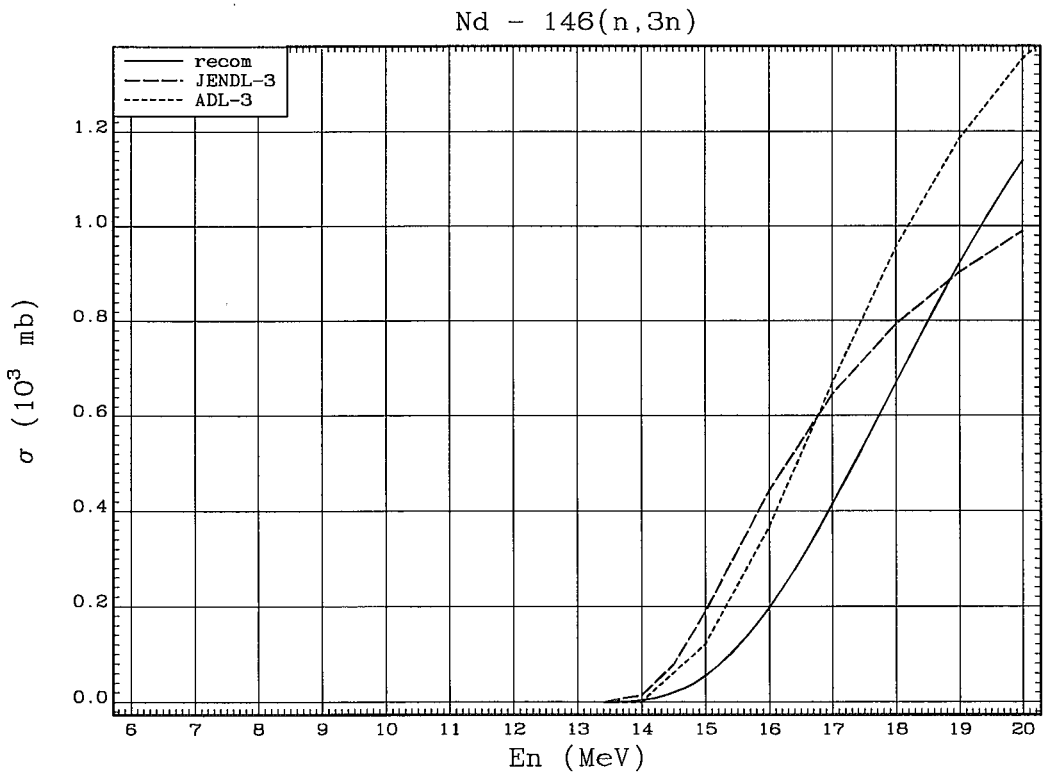

Fig.254. ^{146}Nd(n,3n)^{144}Nd reaction cross section.

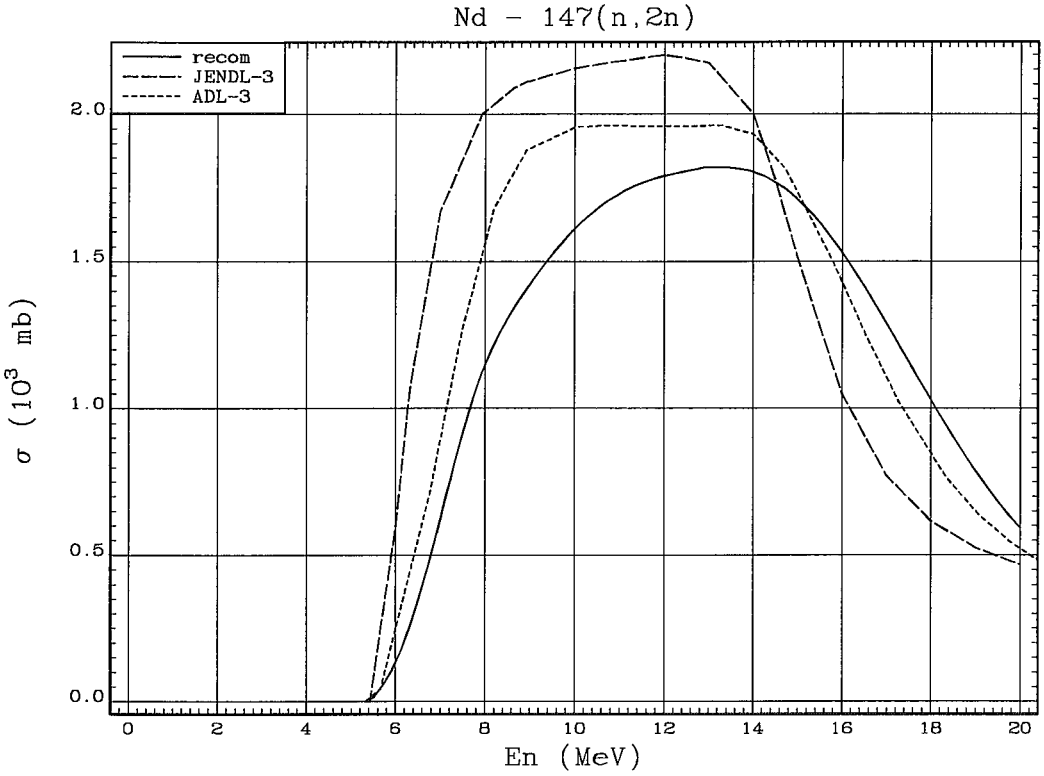

Fig.255. ^{147}Nd(n,2n)^{146}Nd reaction cross section.

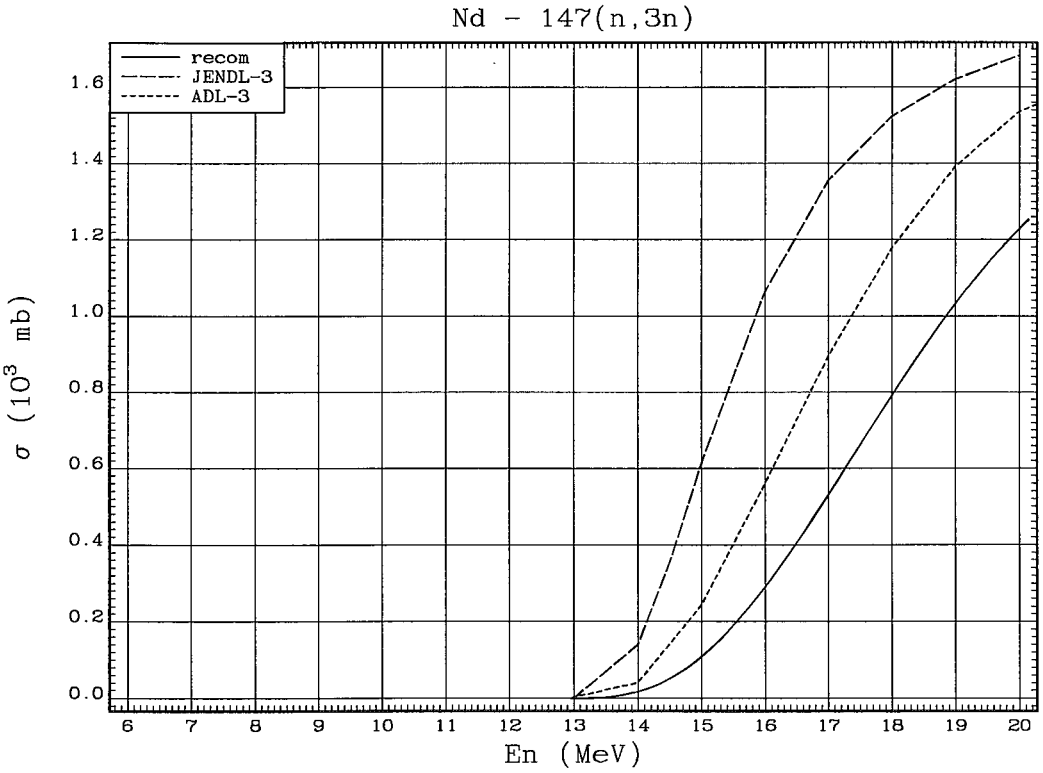

Fig.256. ^{147}Nd(n,3n)^{145}Nd reaction cross section.

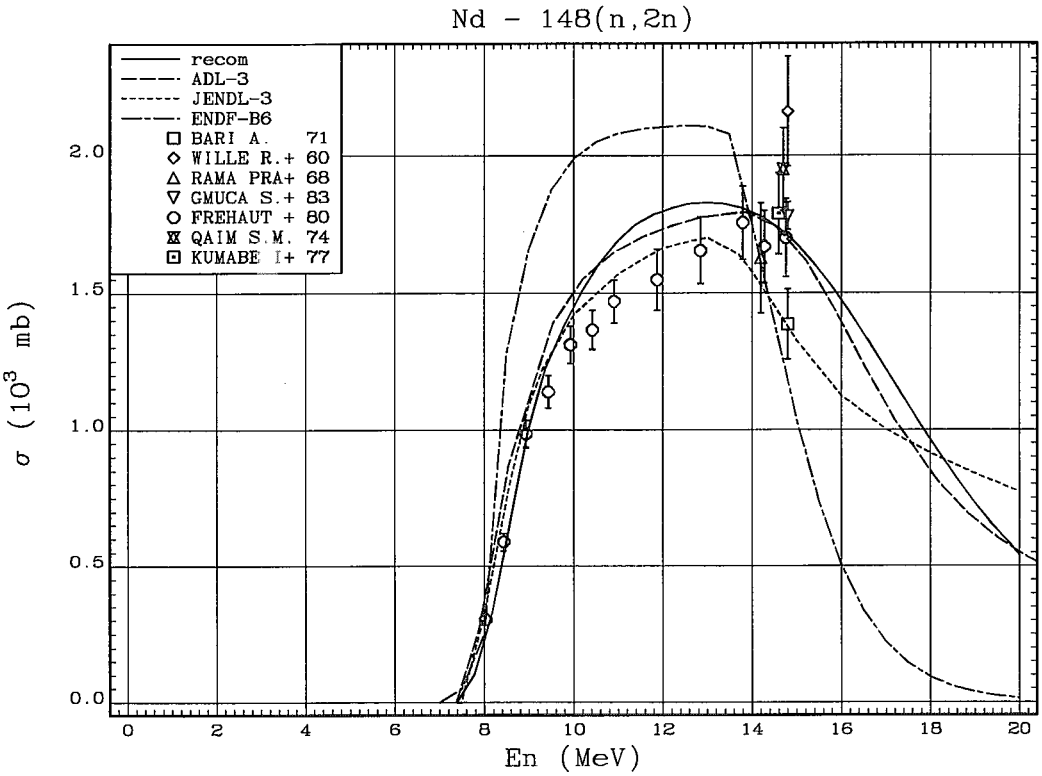

Fig.257. ^{148}Nd(n,2n)^{147}Nd reaction cross section.

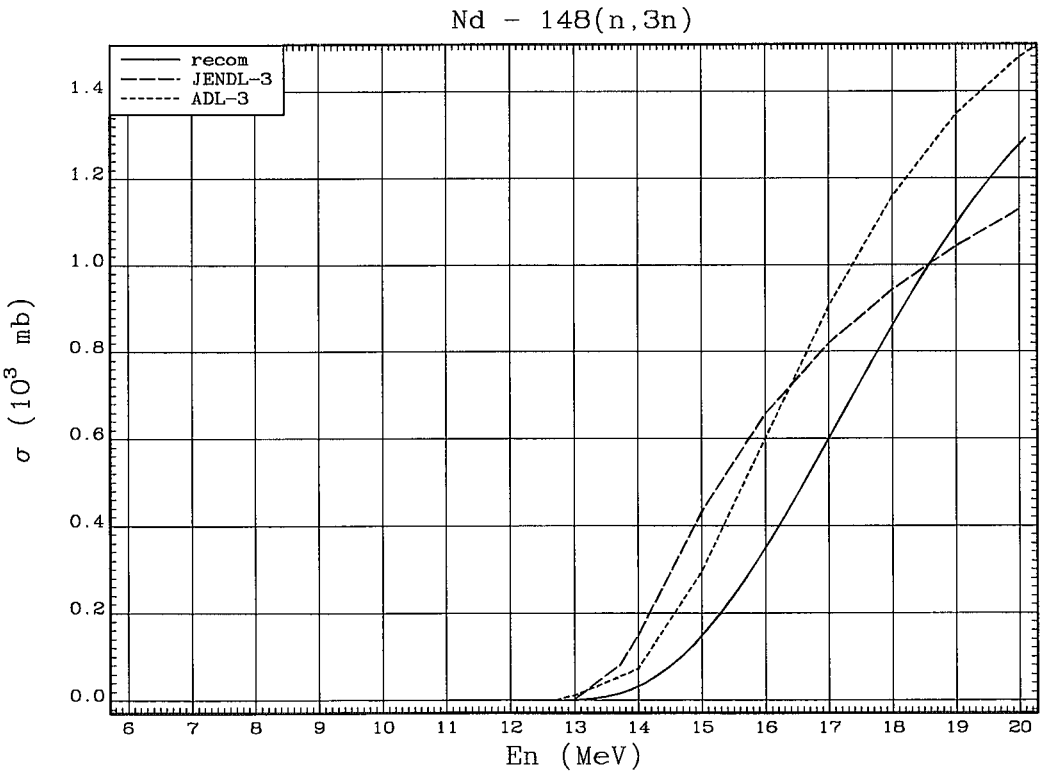

Fig.258. ^{148}Nd(n,3n)^{146}Nd reaction cross section.

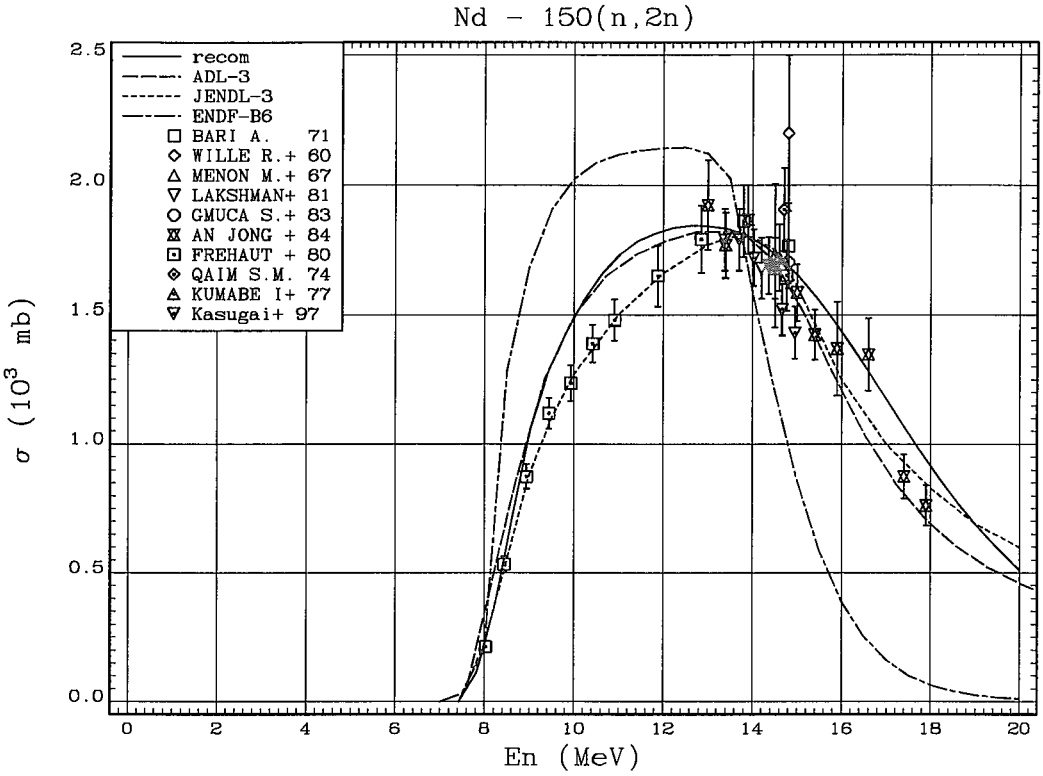

Fig.259. ^{150}Nd(n,2n)^{149}Nd reaction cross section.

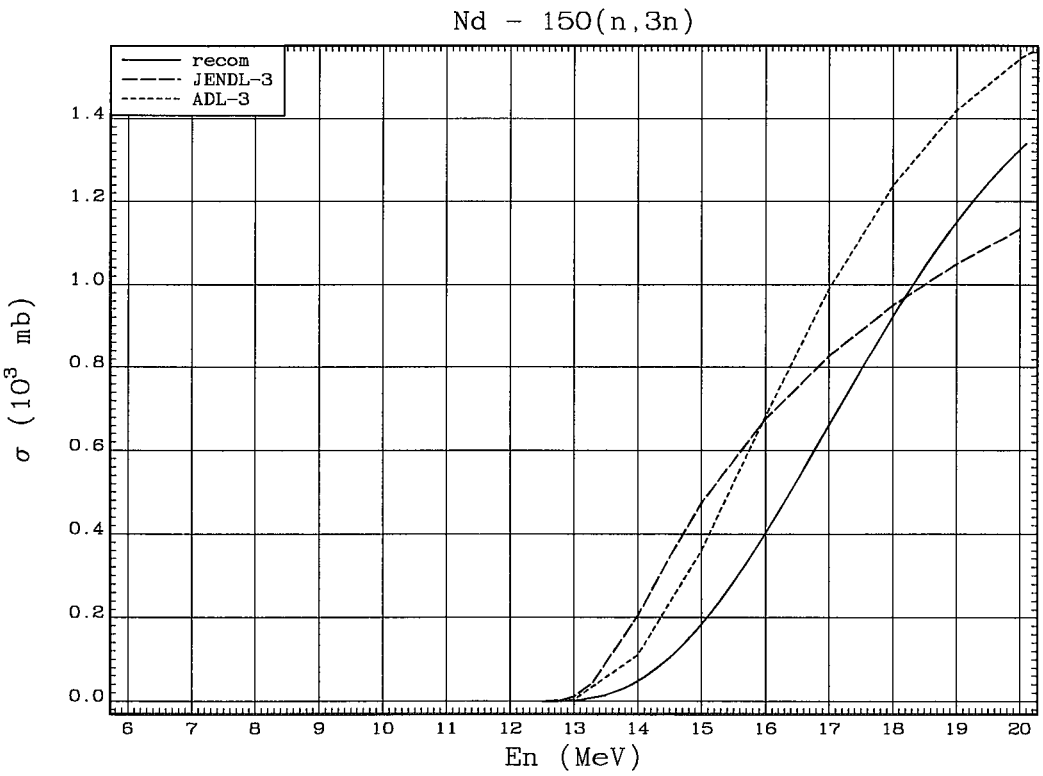

Fig.260. ^{150}Nd(n,3n)^{148}Nd reaction cross section.

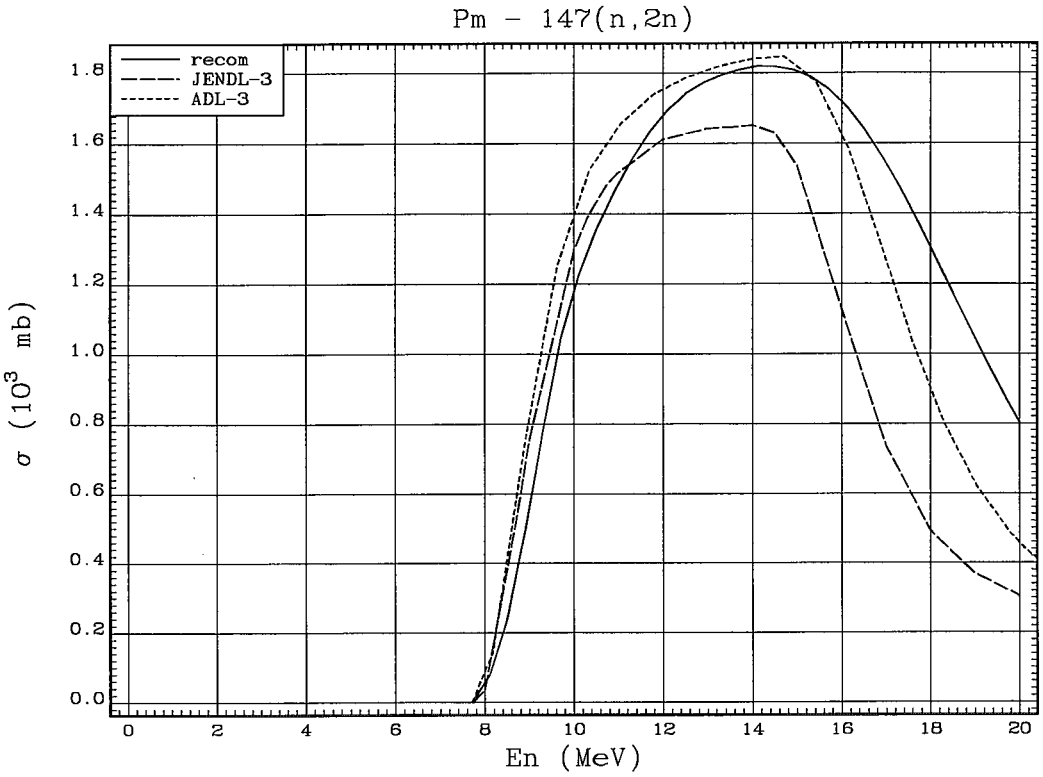

Fig.261. ^{147}Pm(n,2n)^{146}Pm reaction cross section.

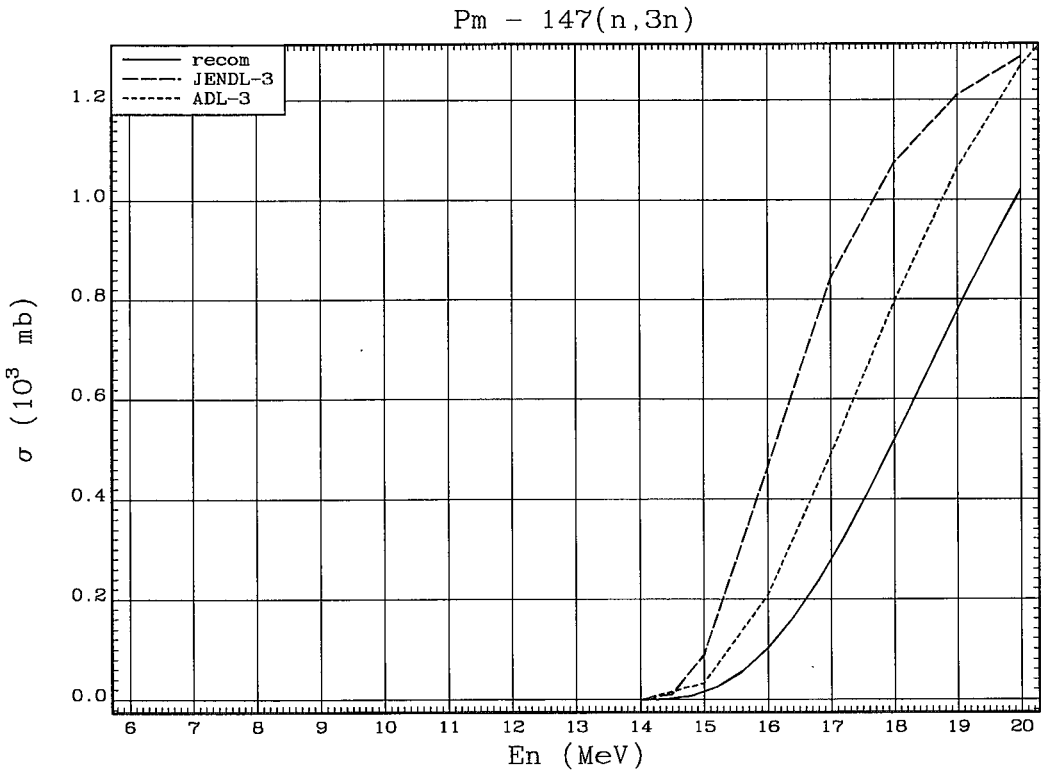

Fig.262. ^{147}Pm(n,3n)^{145}Pm reaction cross section.

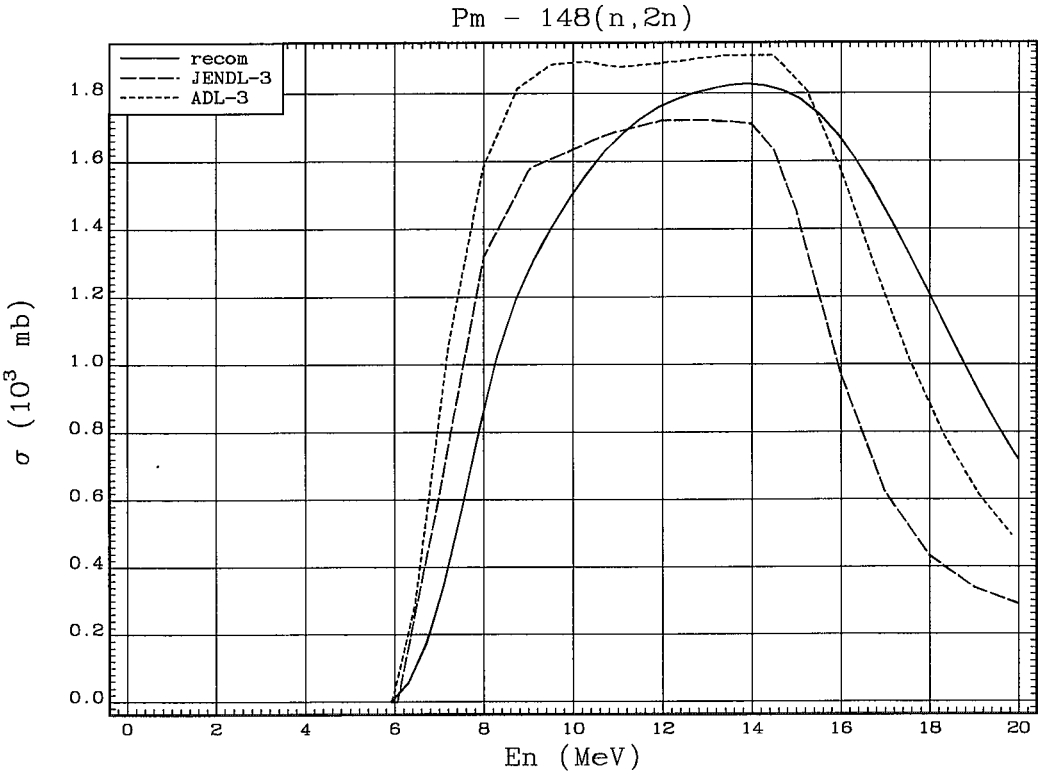

Fig.263. ^{148}Pm(n,2n)^{147}Pm reaction cross section.

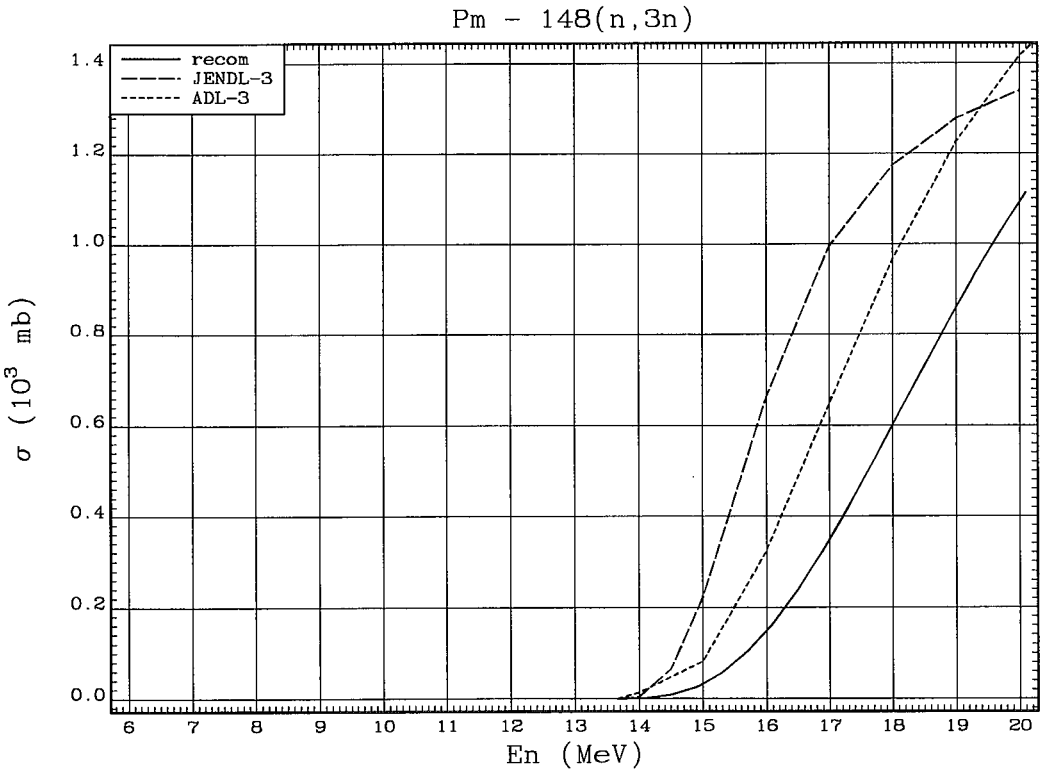

Fig.264. ^{148}Pm(n,3n)^{146}Pm reaction cross section.

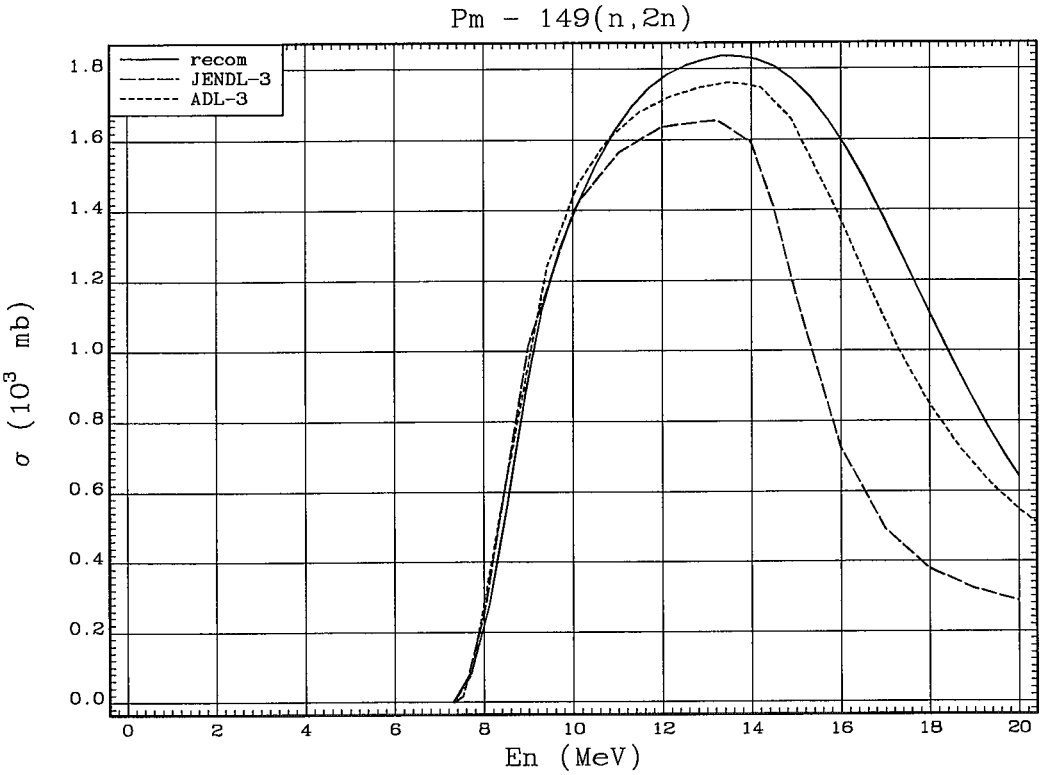

Fig.265. ^{149}Pm(n,2n)^{148}Pm reaction cross section.

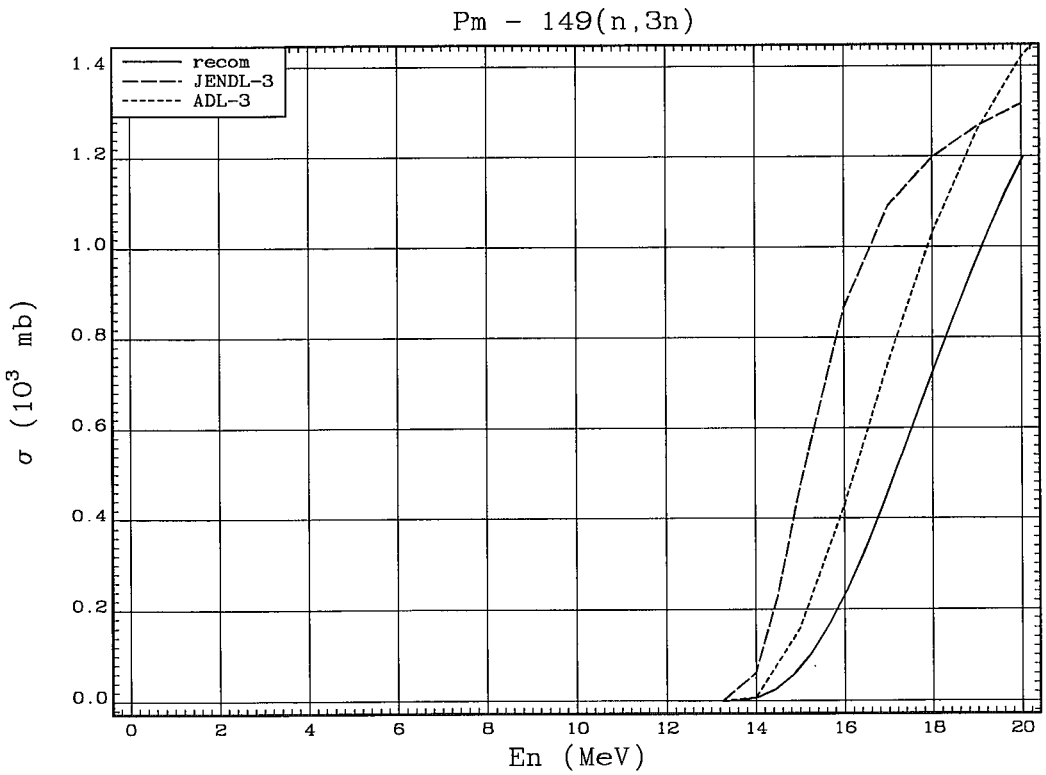

Fig.266. ^{149}Pm(n,3n)^{147}Pm reaction cross section.

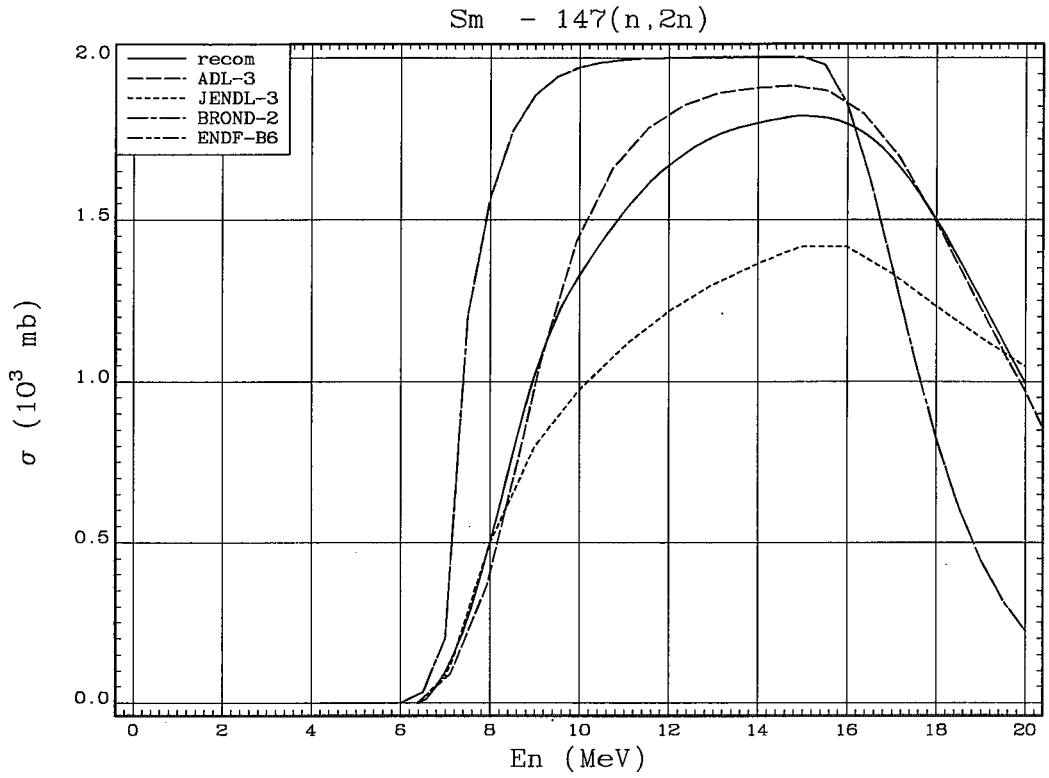

Fig.267. ^{147}Sm(n,2n)^{146}Sm reaction cross section.

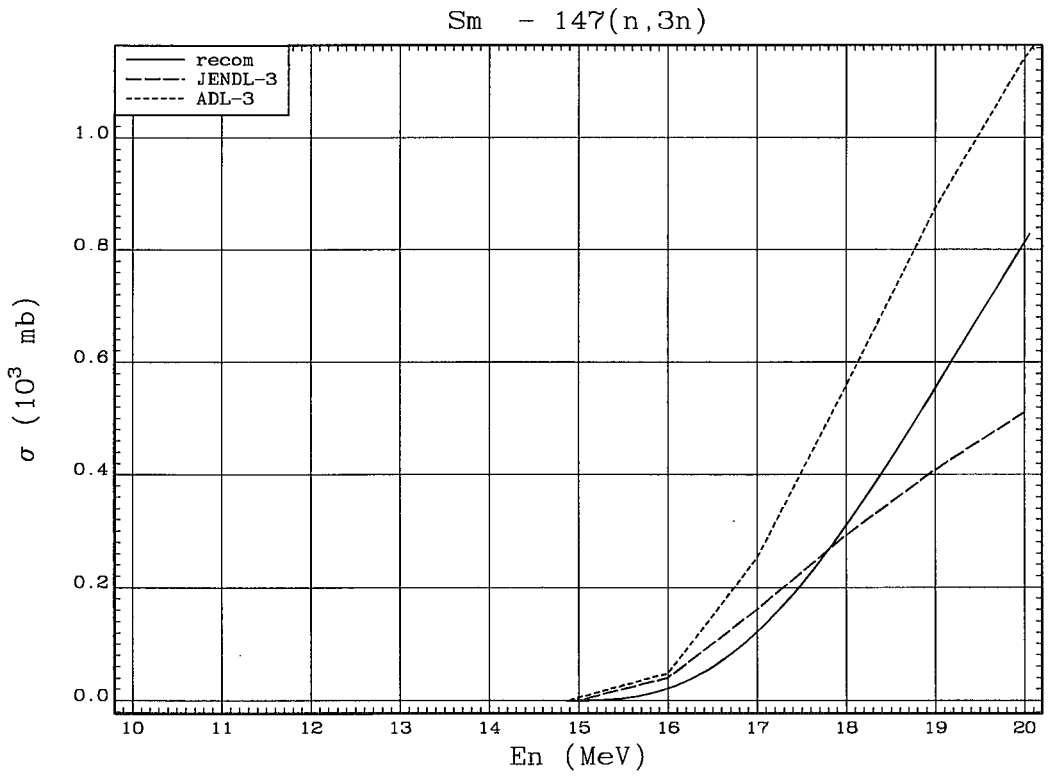

Fig.268. ^{147}Sm(n,3n)^{145}Sm reaction cross section.

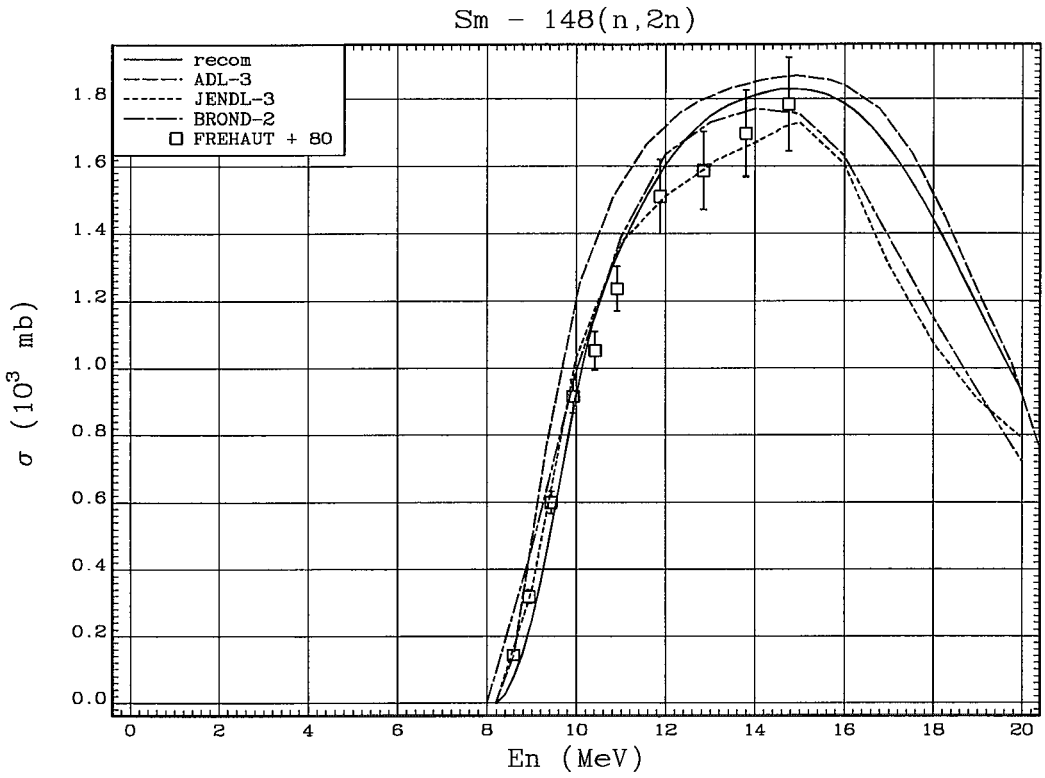

Fig.269. ^{148}Sm(n,2n)^{147}Sm reaction cross section.

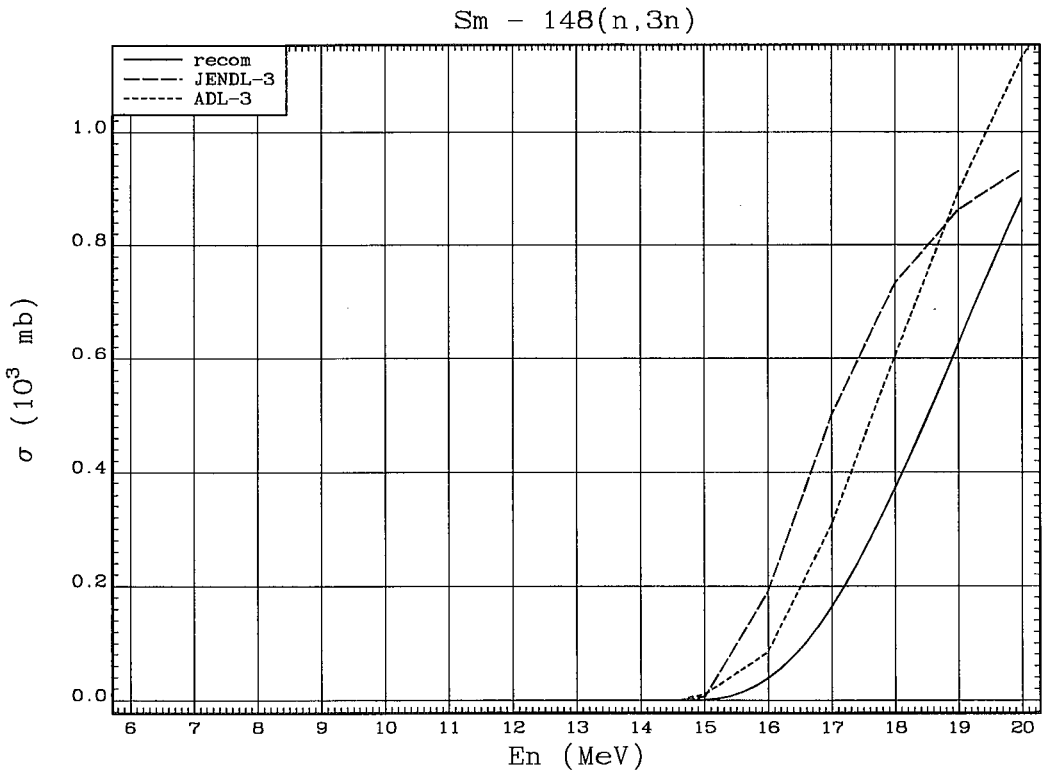

Fig.270. ^{148}Sm(n,3n)^{146}Sm reaction cross section.

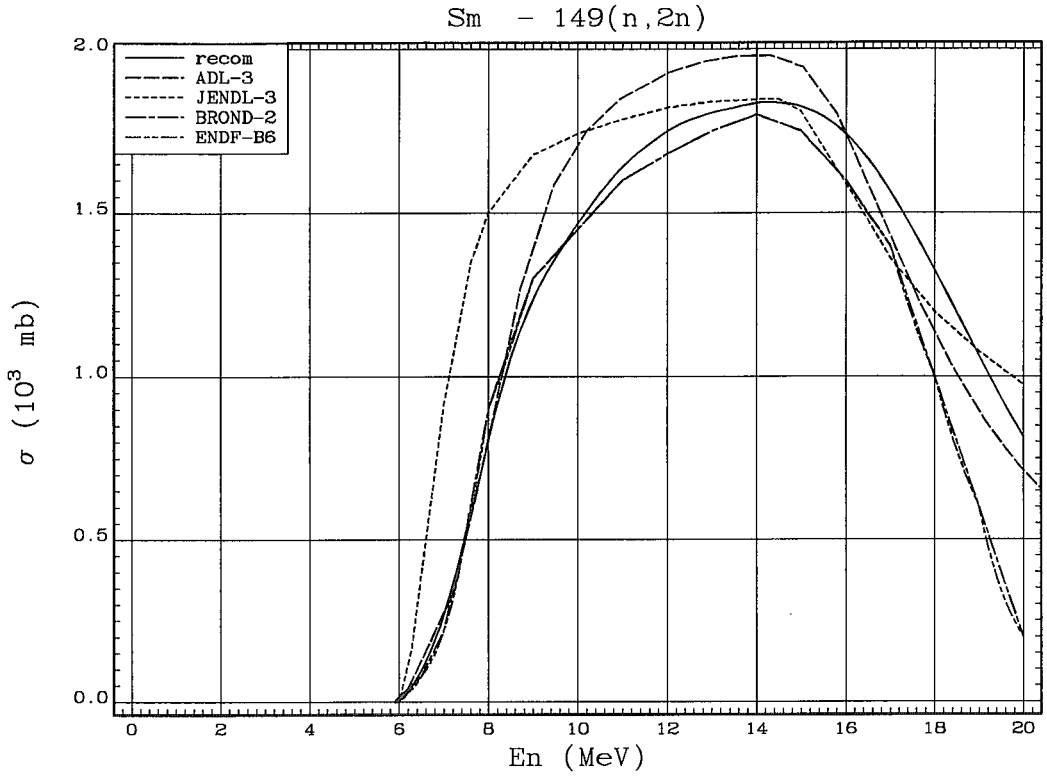

Fig.271. ^{149}Sm(n,2n)^{148}Sm reaction cross section.

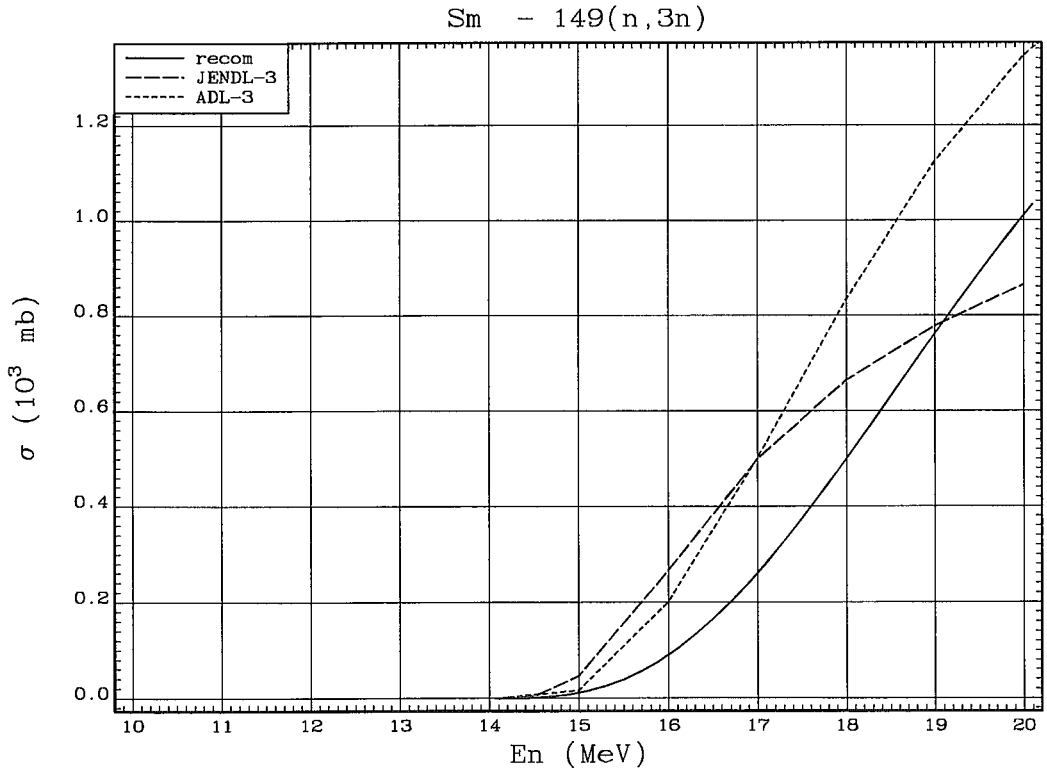

Fig.272. ^{149}Sm(n,3n)^{147}Sm reaction cross section.

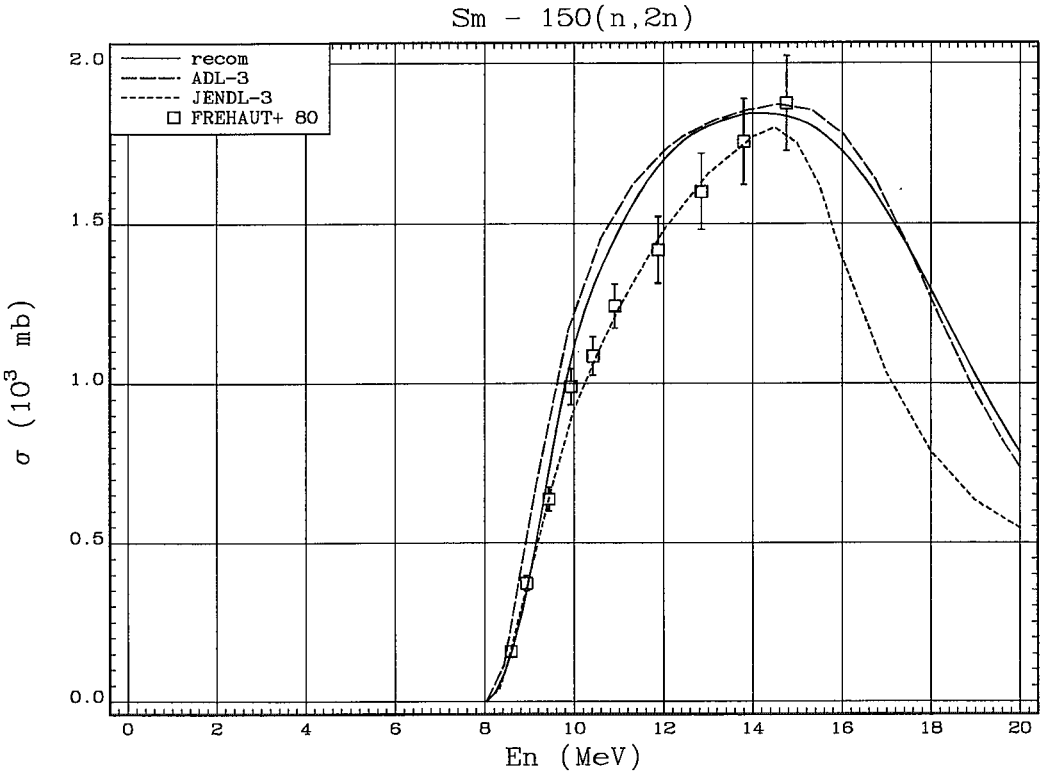

Fig.273. ^{150}Sm(n,2n)^{149}Sm reaction cross section.

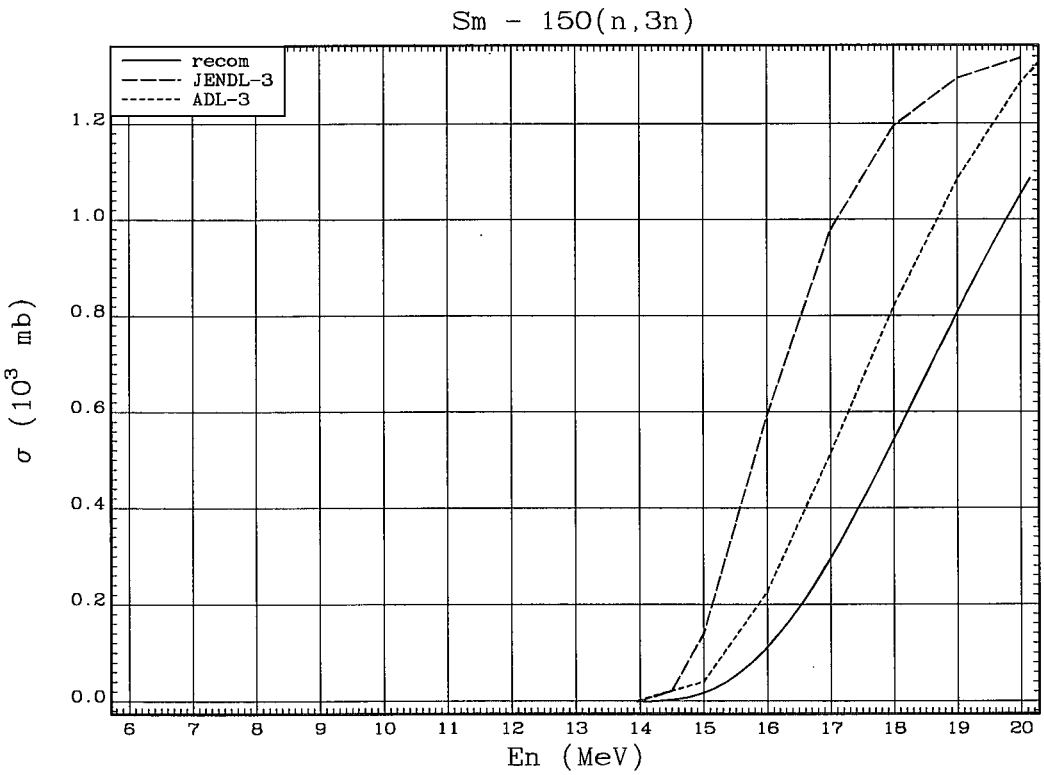

Fig.274. ^{150}Sm(n,3n)^{148}Sm reaction cross section.

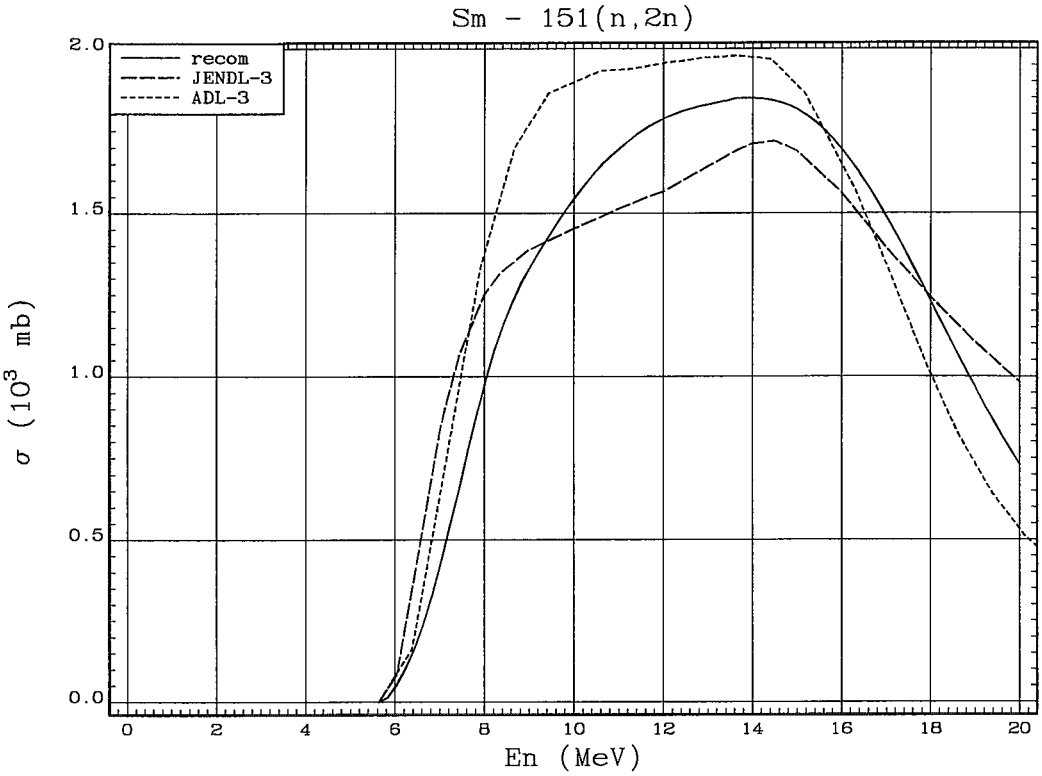

Fig.275. ^{151}Sm(n,2n)^{150}Sm reaction cross section.

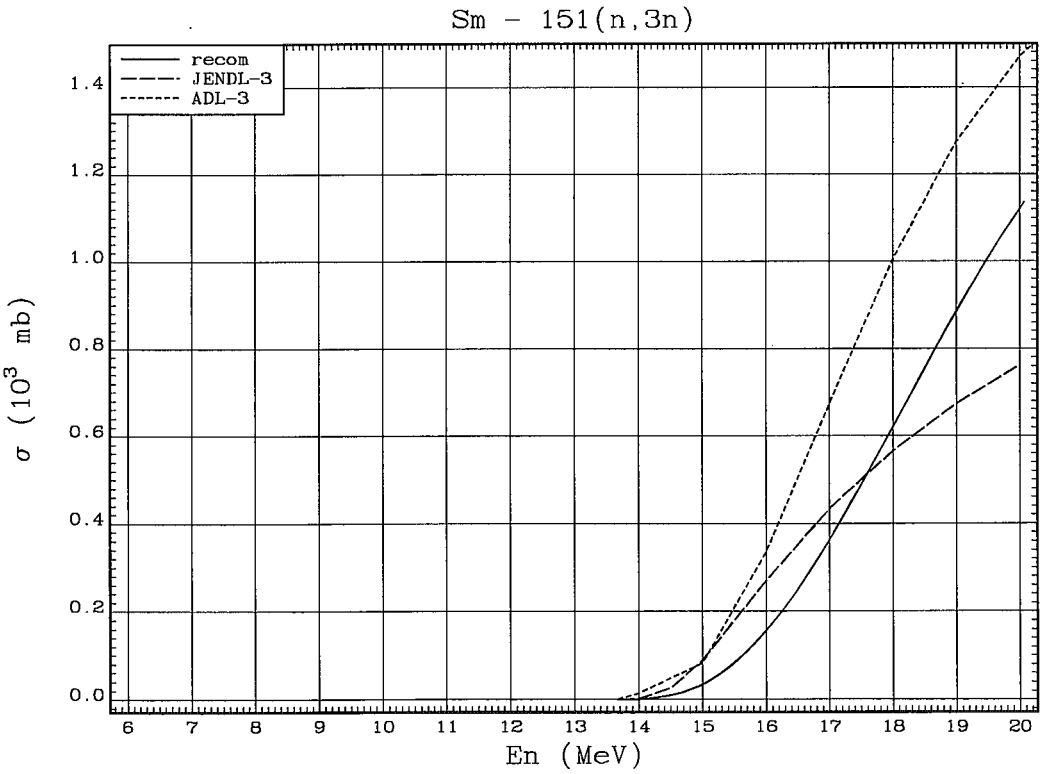

Fig.276. ^{151}Sm(n,3n)^{149}Sm reaction cross section.

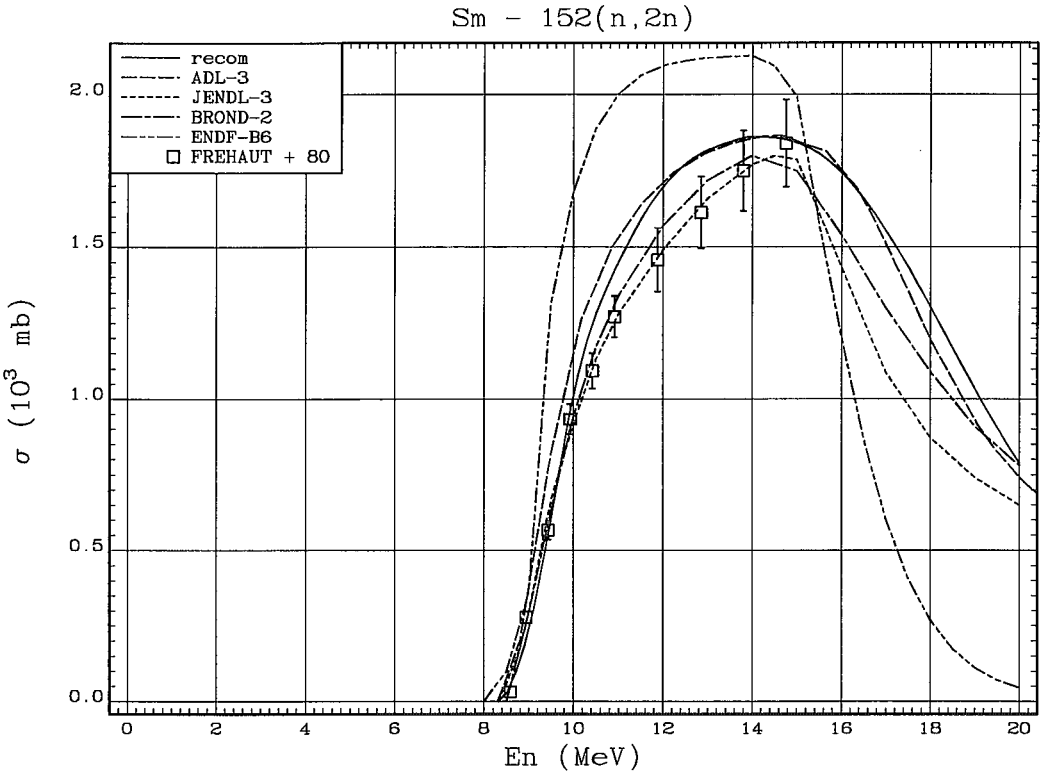

Fig.277. ^{152}Sm(n,2n)^{151}Sm reaction cross section.

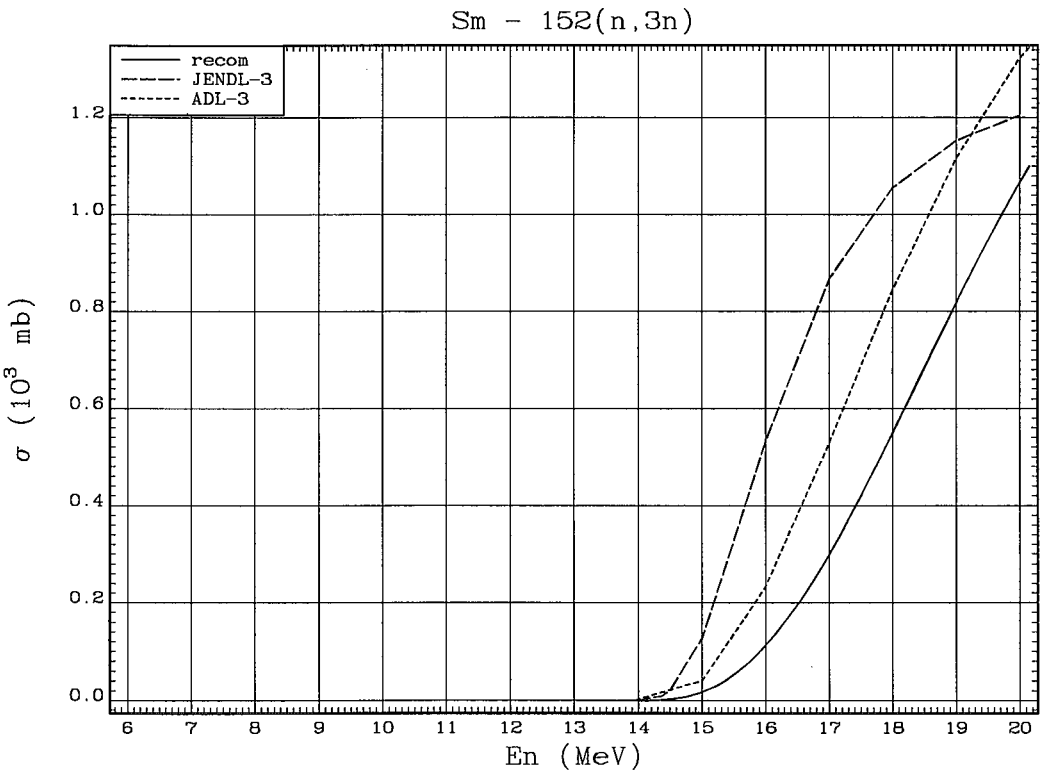

Fig.278. ^{152}Sm(n,3n)^{150}Sm reaction cross section.

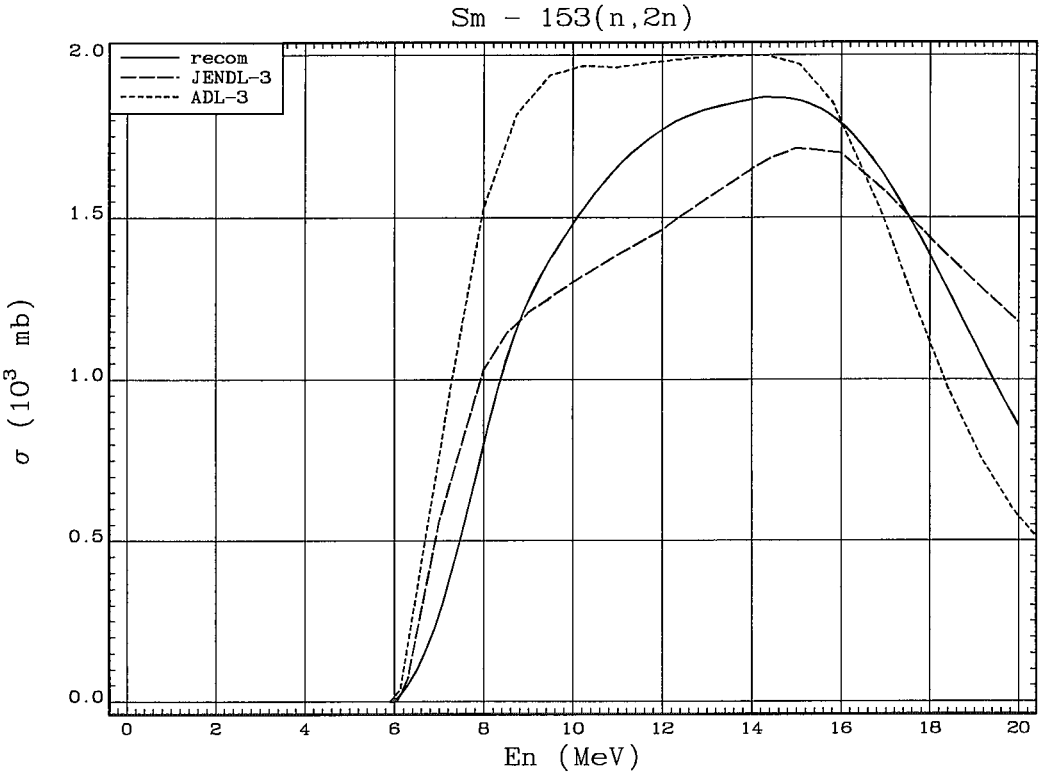

Fig.279. ^{153}Sm(n,2n)^{152}Sm reaction cross section.

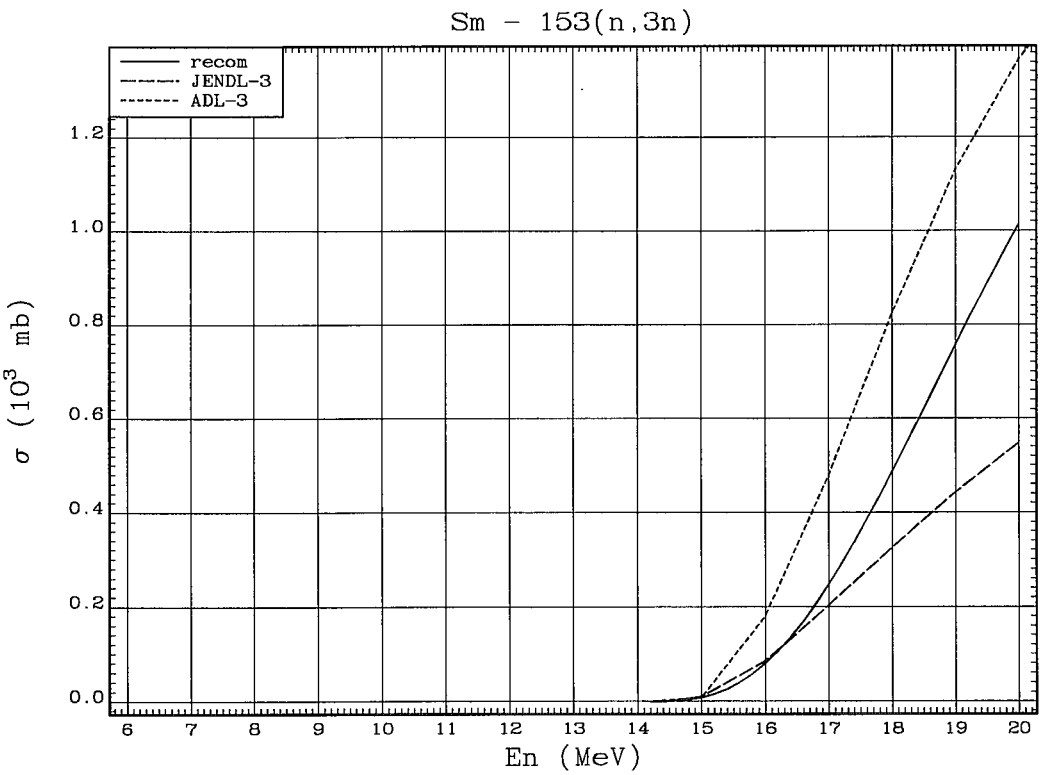

Fig.280. ^{153}Sm(n,3n)^{151}Sm reaction cross section.

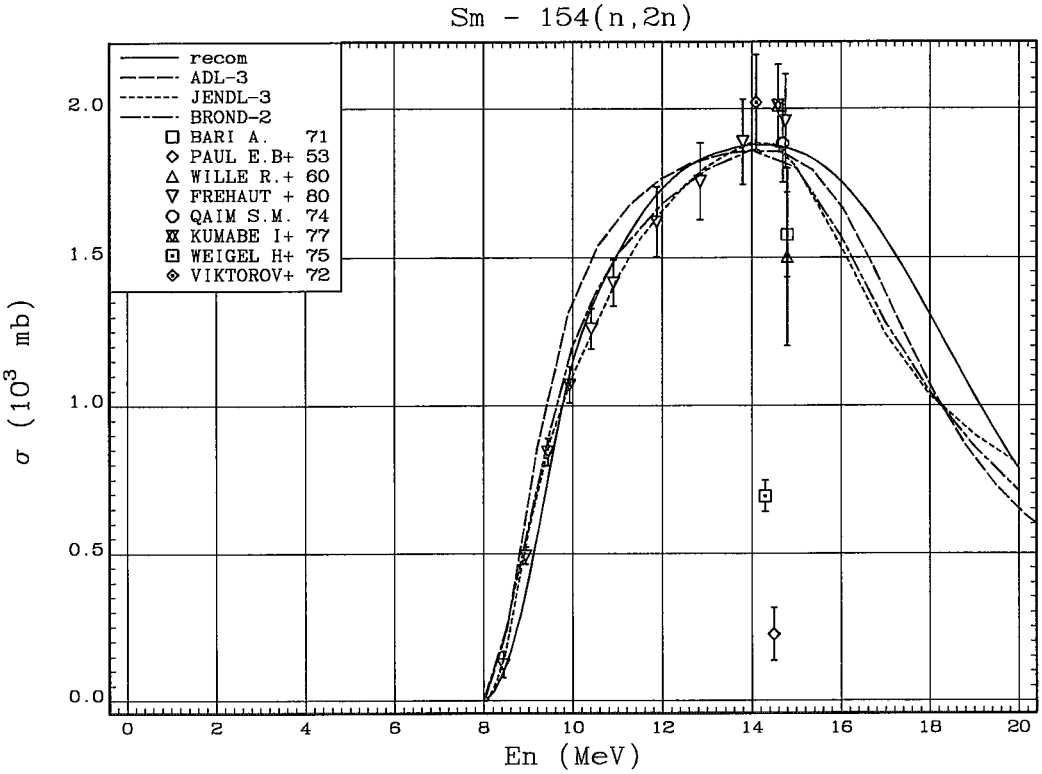

Fig.281. ^{154}Sm(n,2n)^{153}Sm reaction cross section.

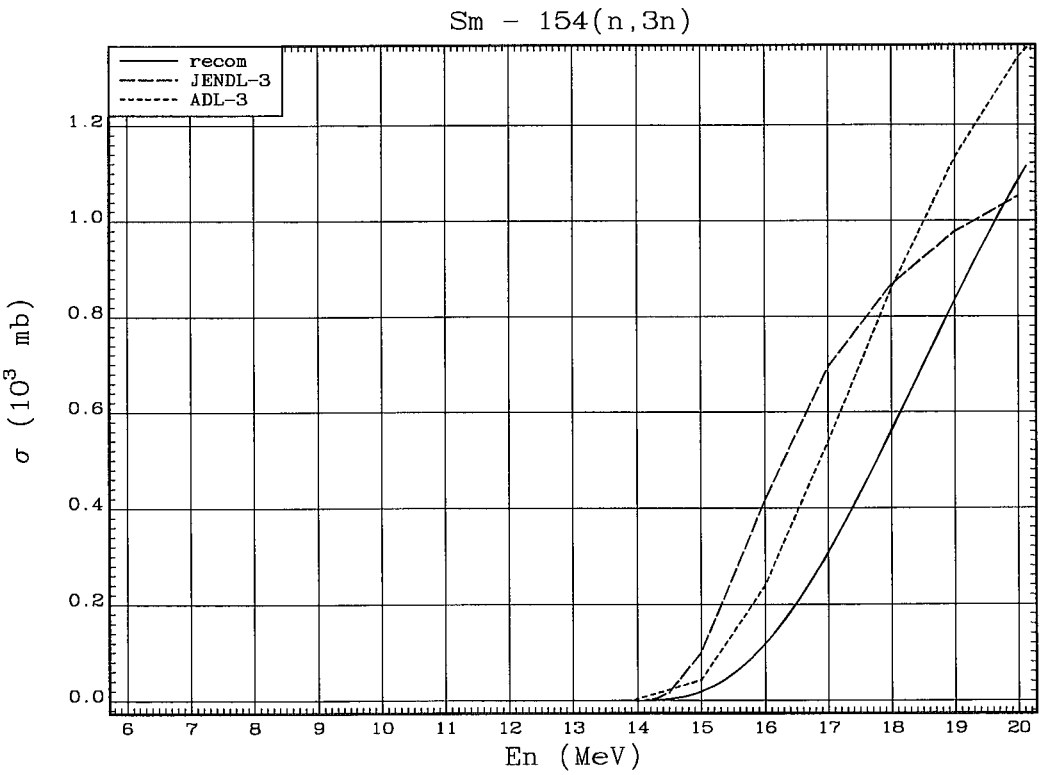

Fig.282. ^{154}Sm(n,3n)^{152}Sm reaction cross section.

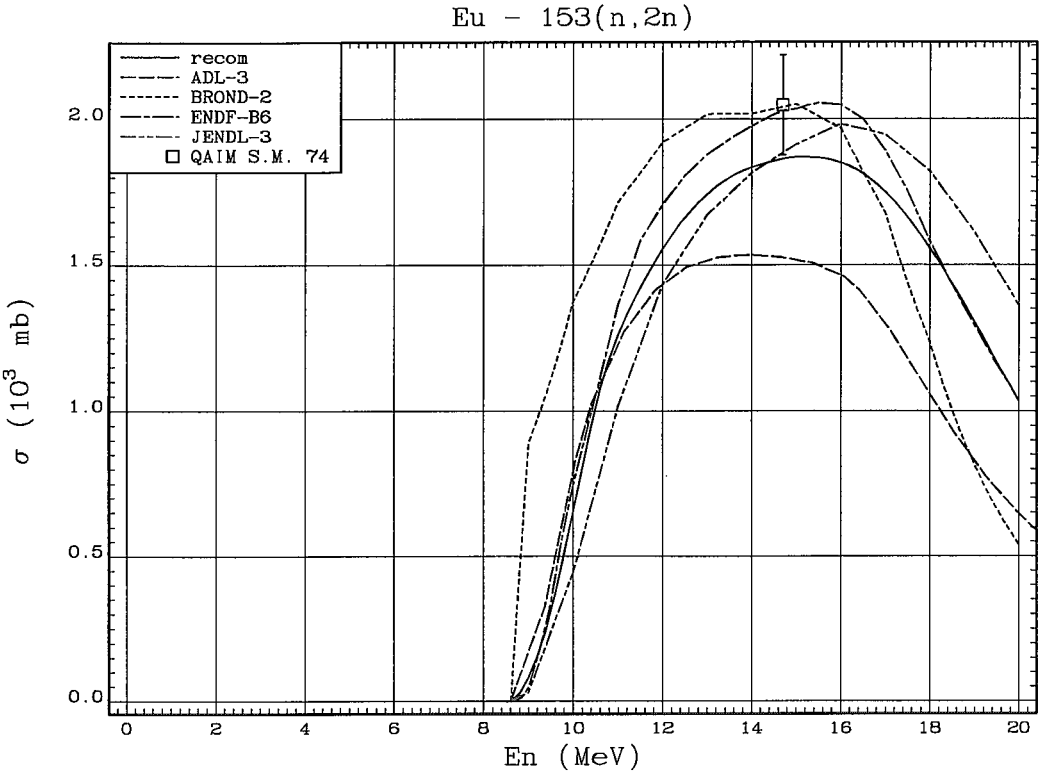

Fig.283. ^{153}Eu(n,2n)^{152}Eu reaction cross section.

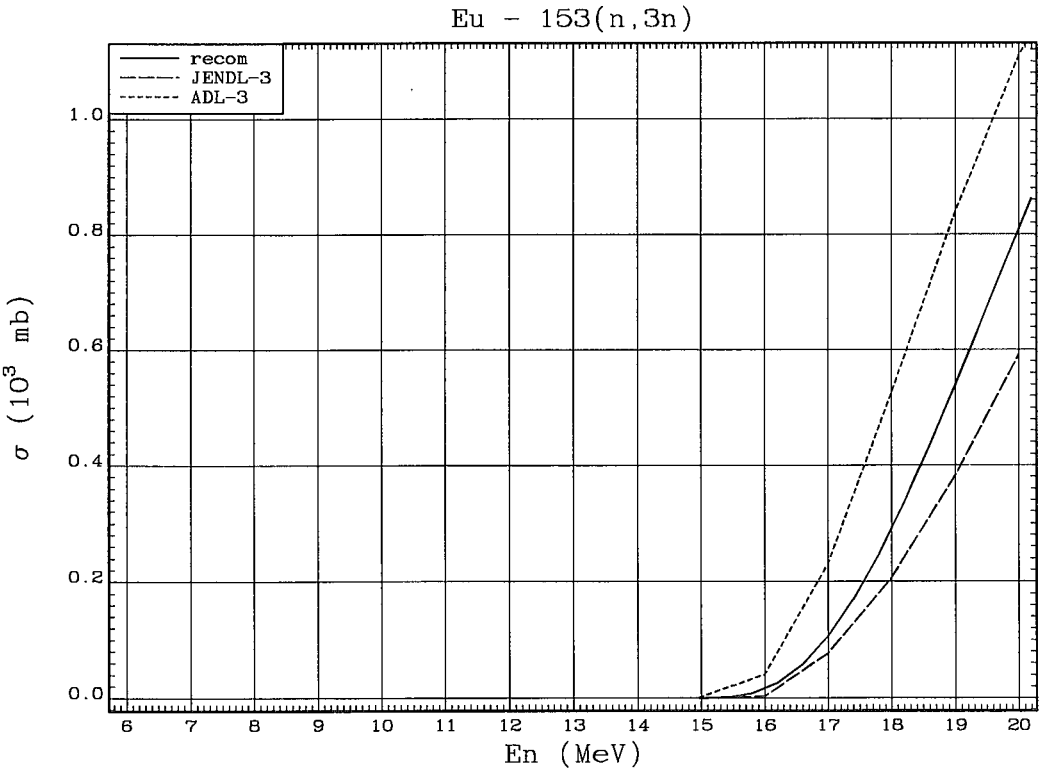

Fig.284. ^{153}Eu(n,3n)^{151}Eu reaction cross section.

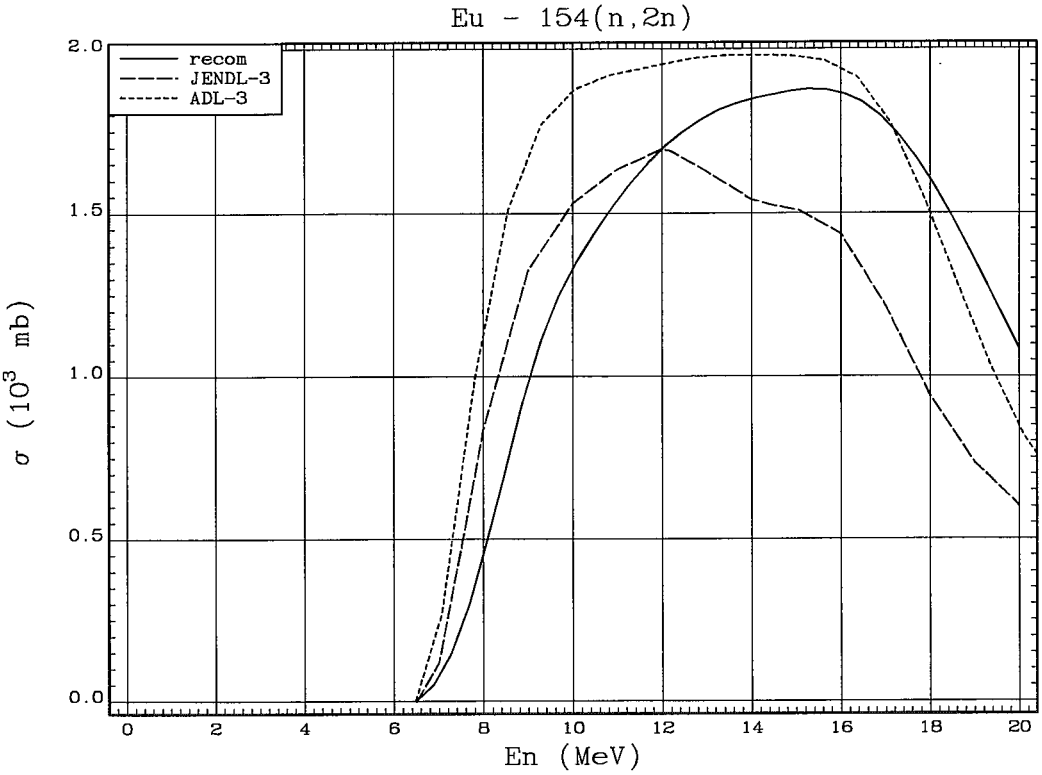

Fig.285. ^{154}Eu(n,2n)^{153}Eu reaction cross section.

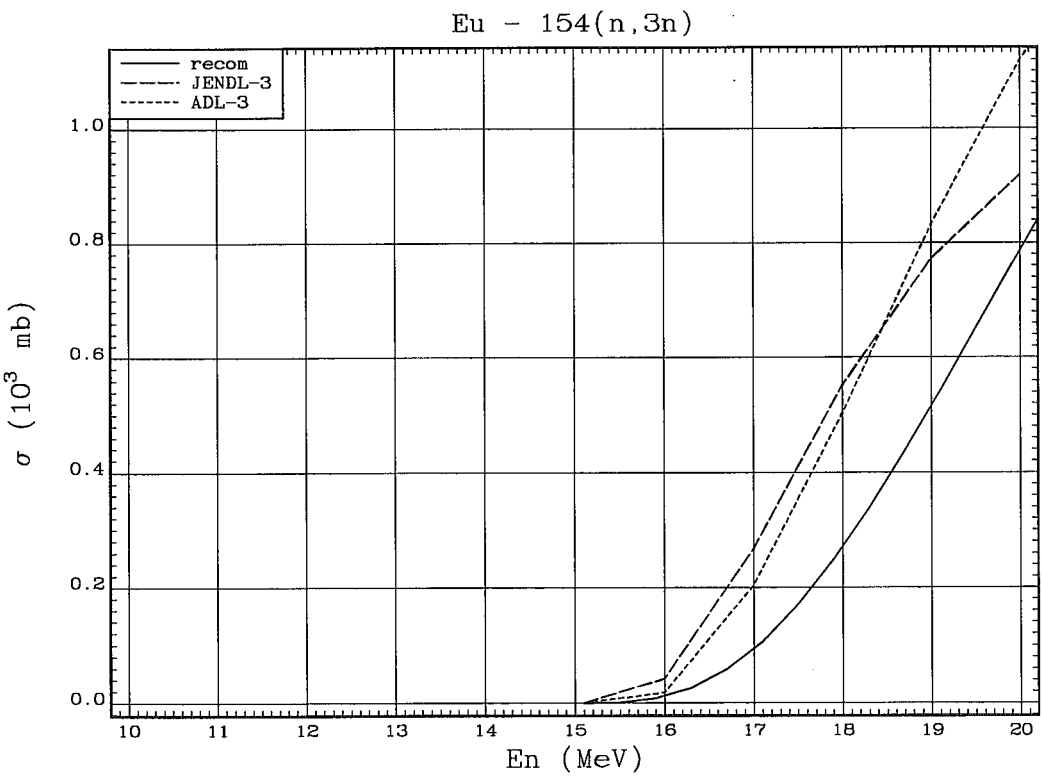

Fig.286. ^{154}Eu(n,3n)^{152}Eu reaction cross section.

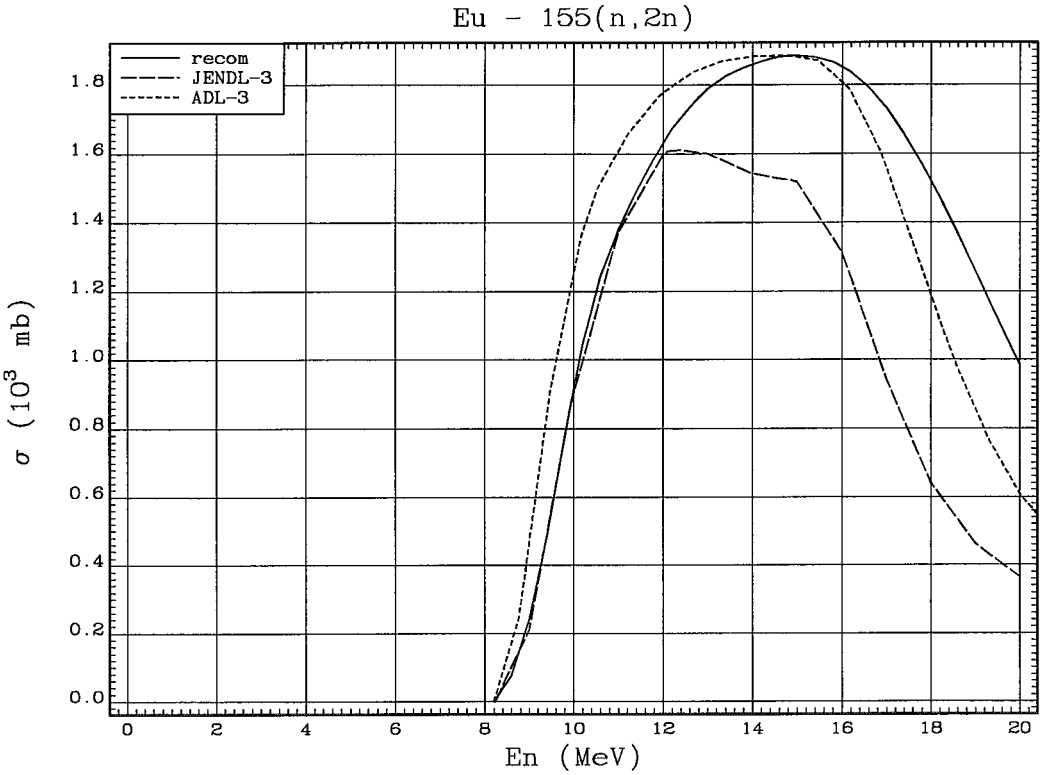

Fig.287. ^{155}Eu(n,2n)^{154}Eu reaction cross section.

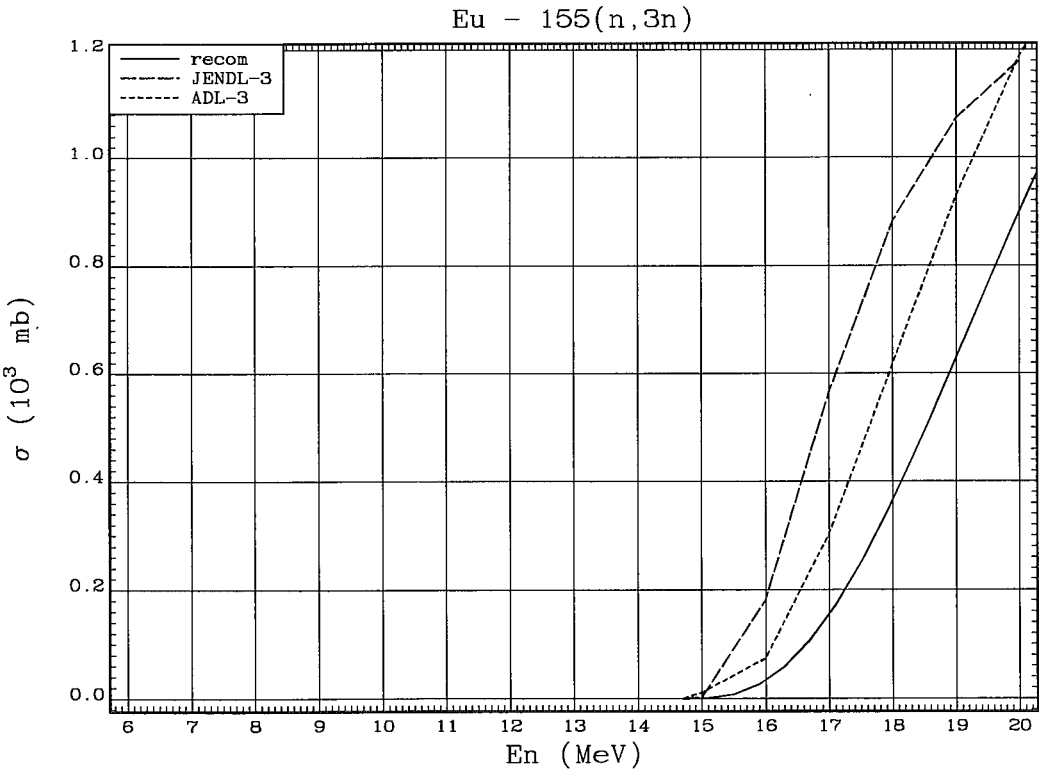

Fig.288. ^{155}Eu(n,3n)^{153}Eu reaction cross section.

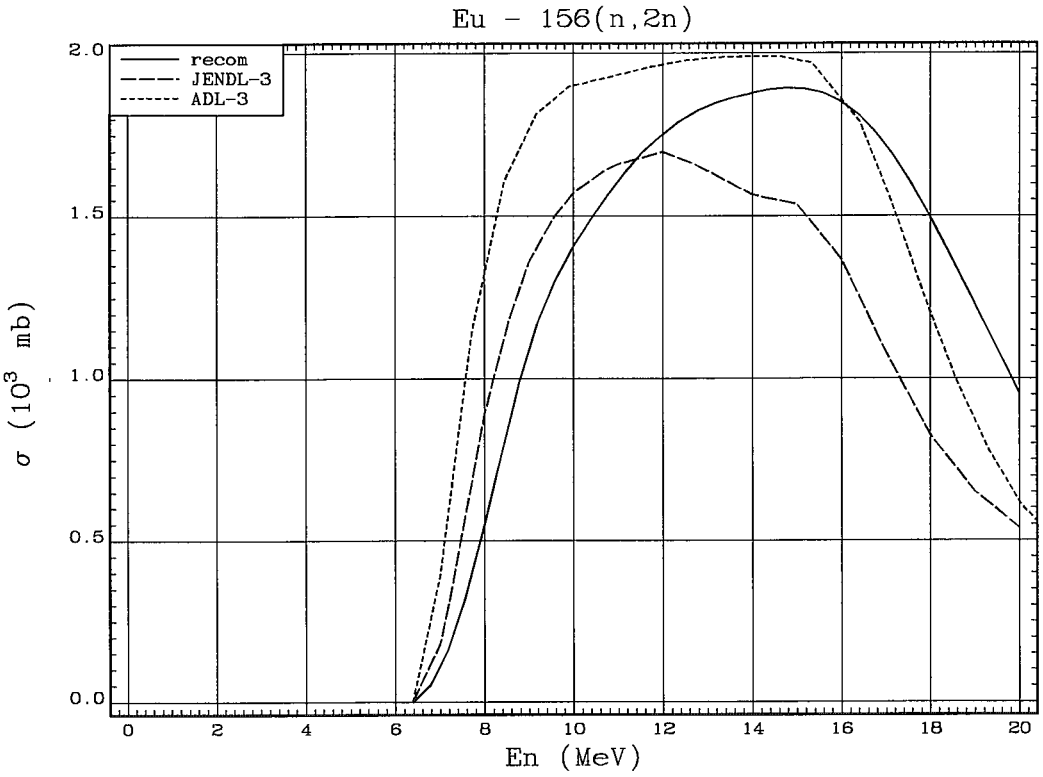

Fig.289. ^{156}Eu(n,2n)^{155}Eu reaction cross section.

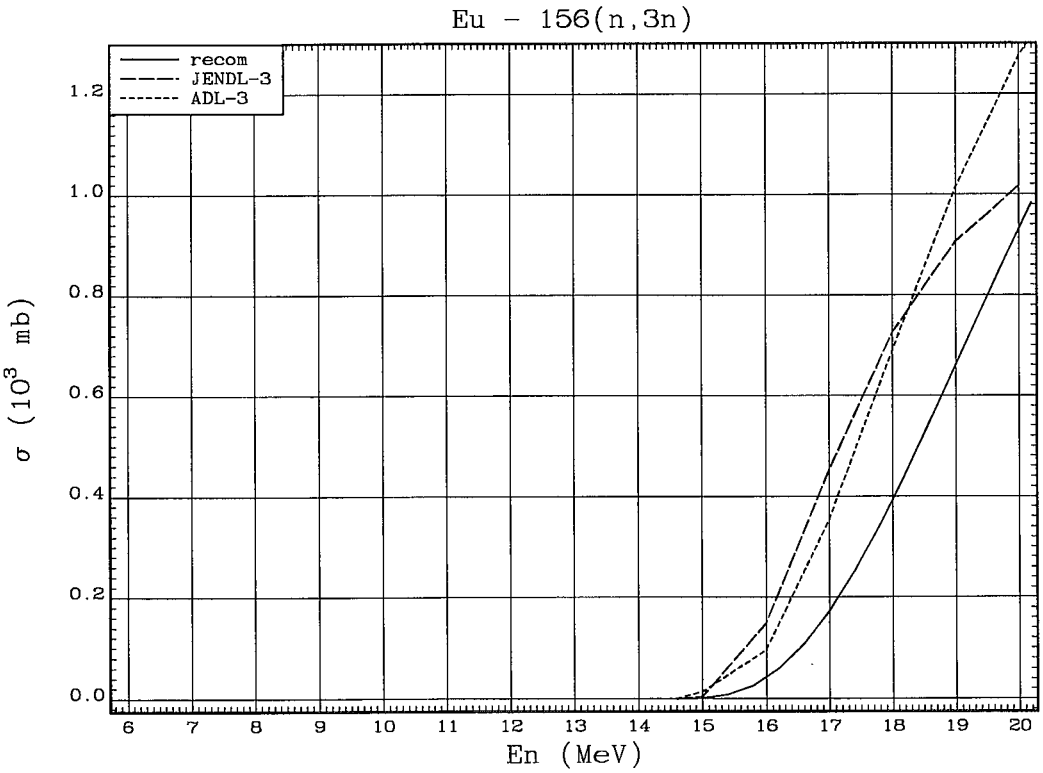

Fig.290. ^{156}Eu(n,3n)^{154}Eu reaction cross section.

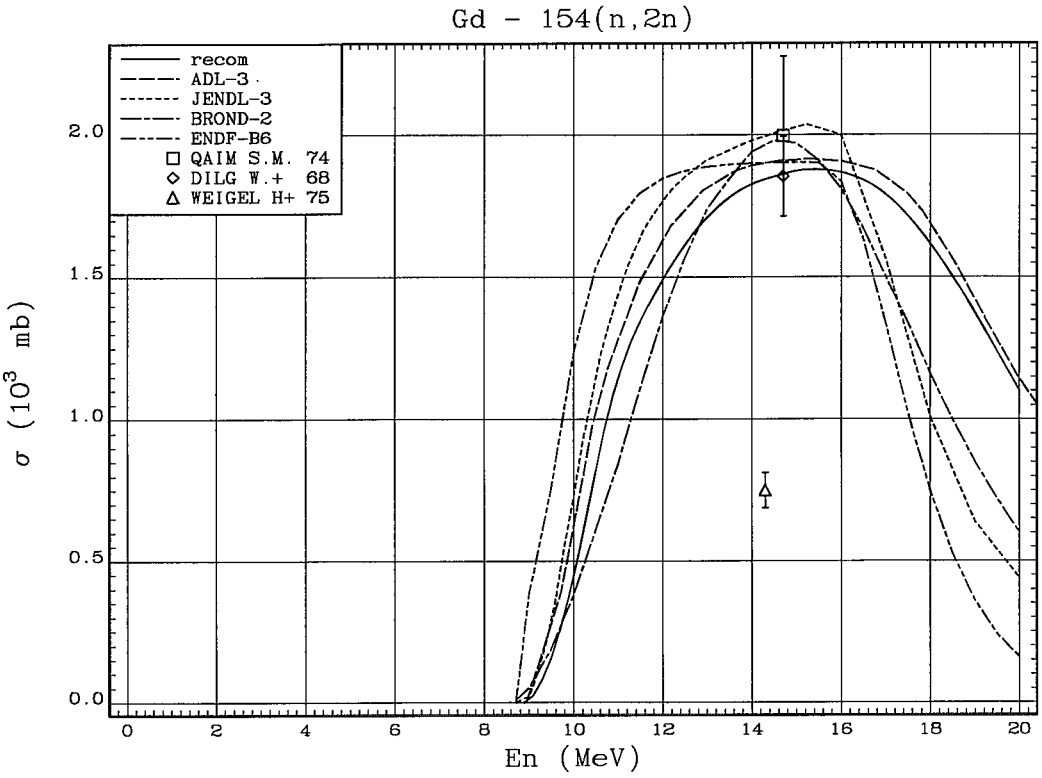

Fig.291. ^{154}Gd(n,2n)^{153}Gd reaction cross section.

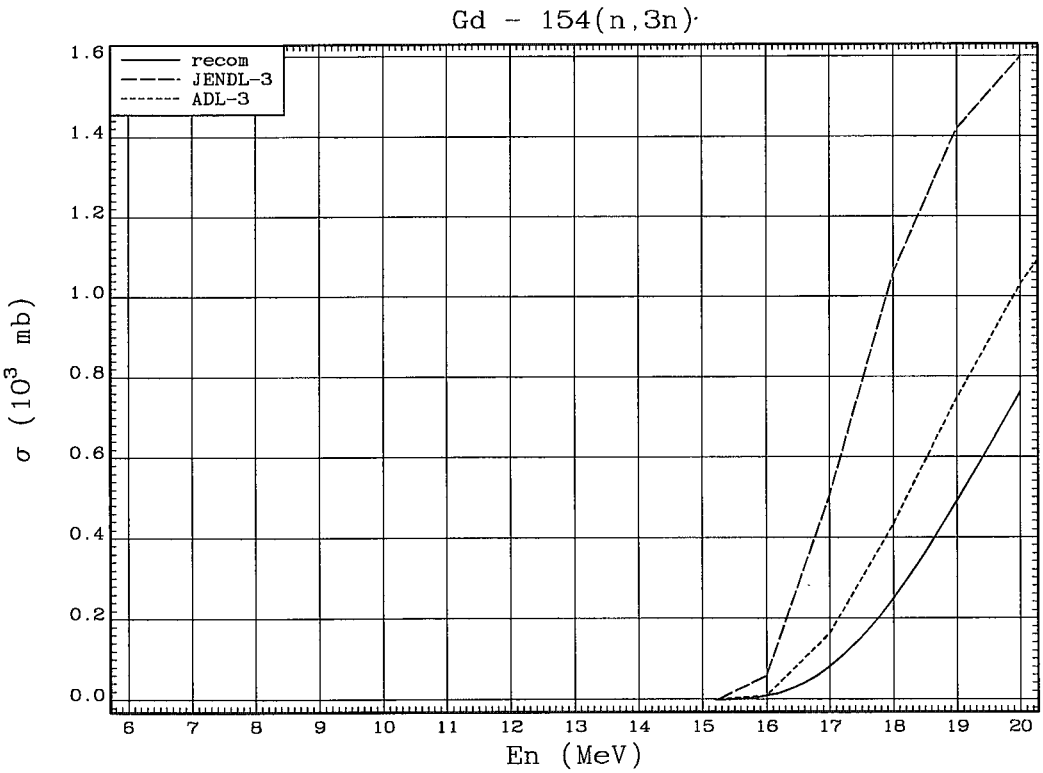

Fig.292. ^{154}Gd(n,3n)^{152}Gd reaction cross section.

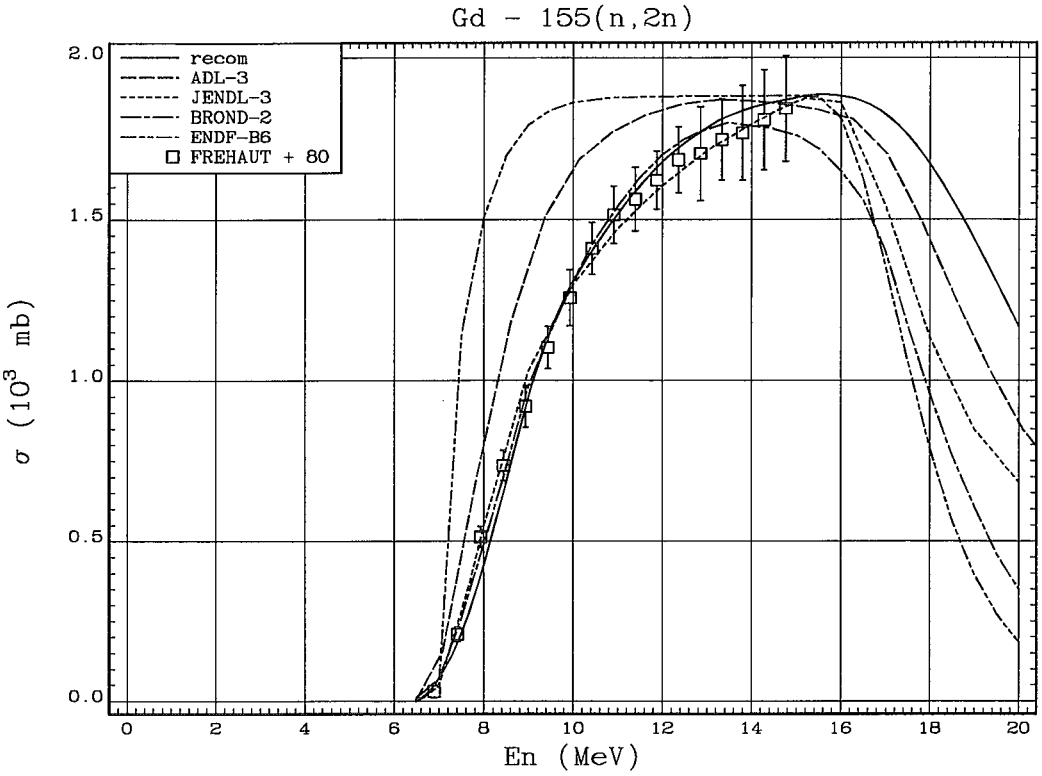

Fig.293. ^{155}Gd(n,2n)^{154}Gd reaction cross section.

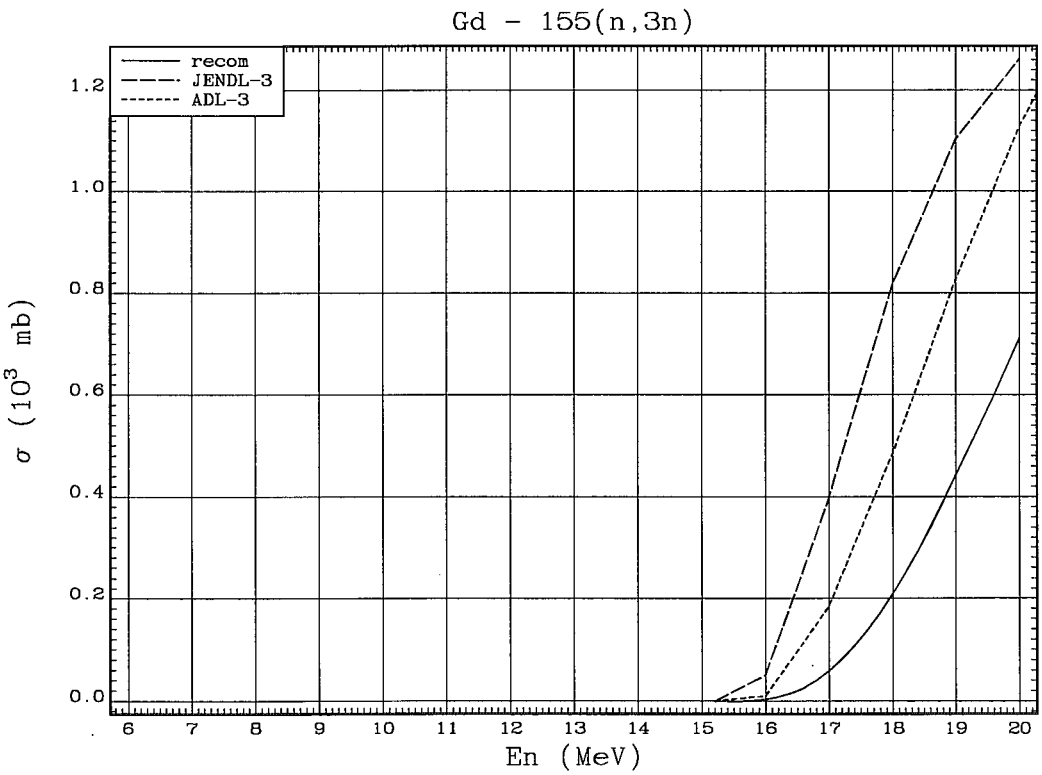

Fig.294. ^{155}Gd(n,3n)^{153}Gd reaction cross section.

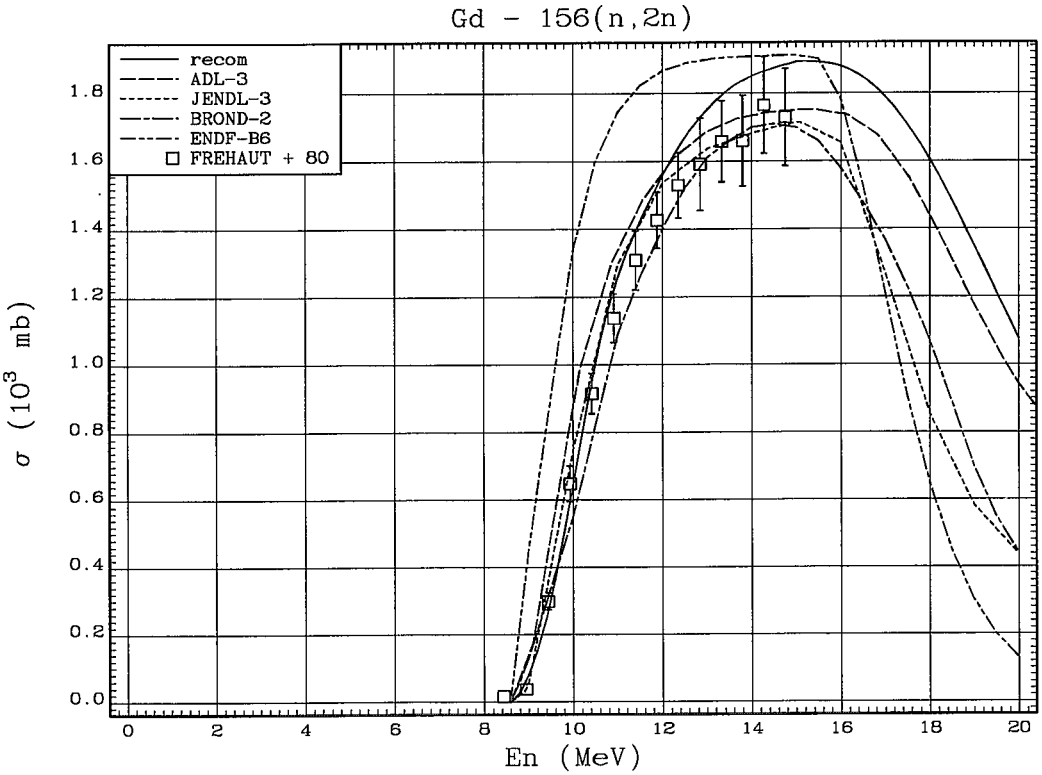

Fig.295. ^{156}Gd(n,2n)^{155}Gd reaction cross section.

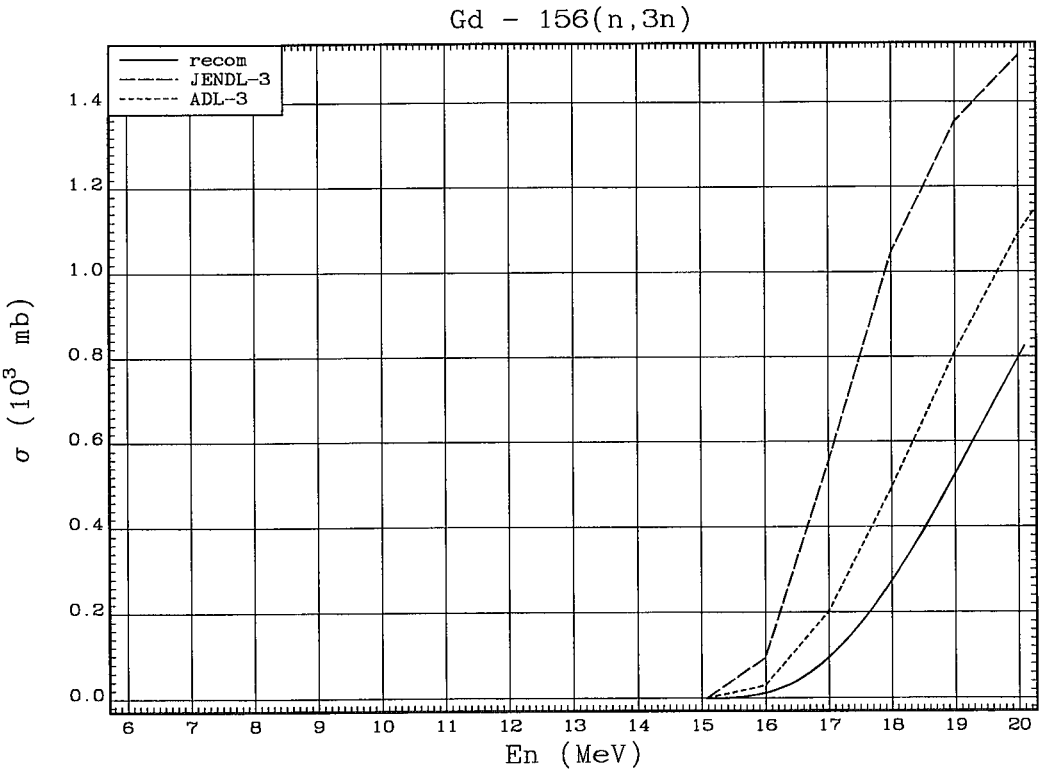

Fig.296. ^{156}Gd(n,3n)^{154}Gd reaction cross section.

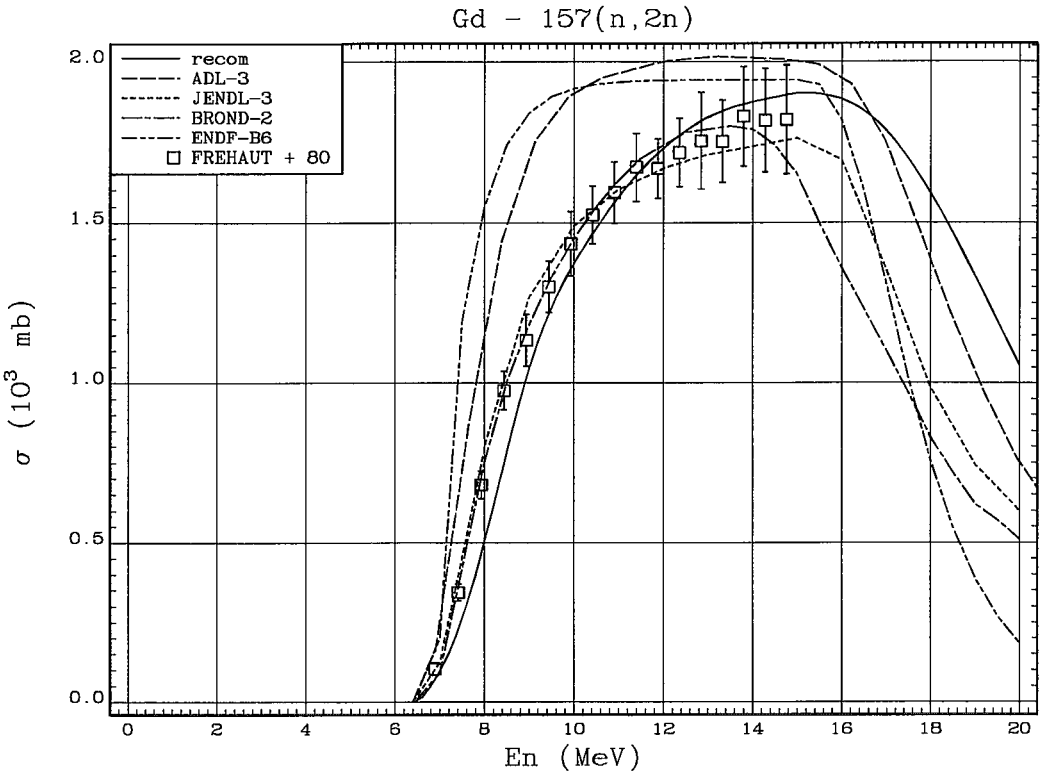

Fig.297. ^{157}Gd(n,2n)^{156}Gd reaction cross section.

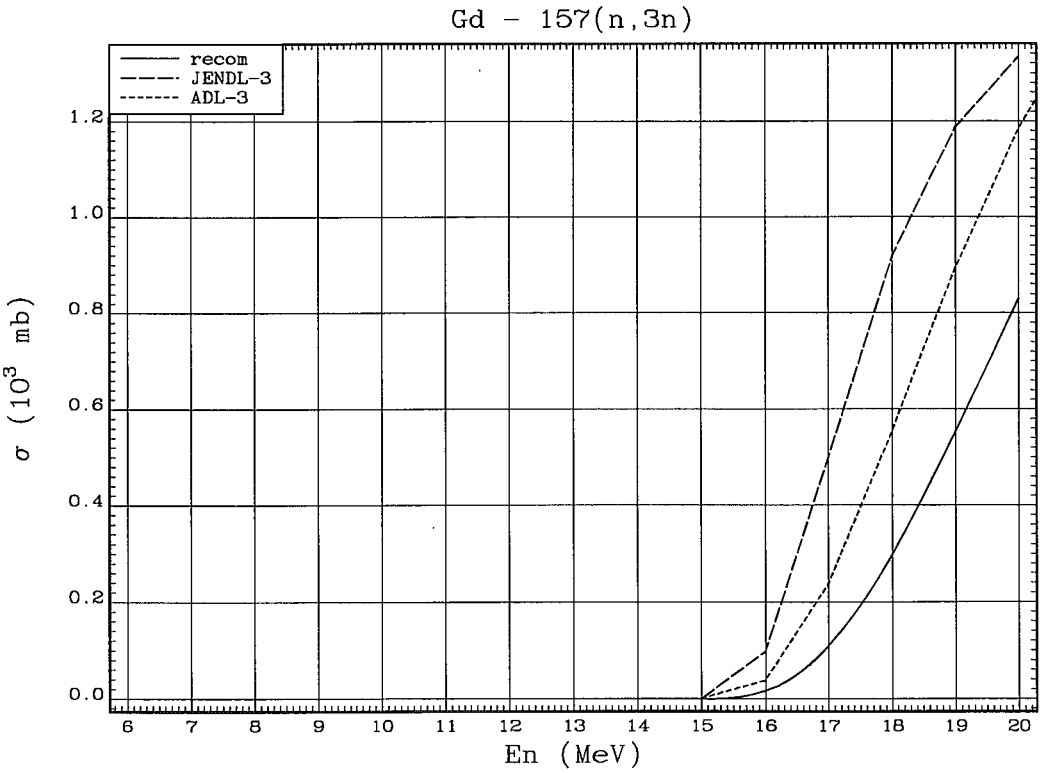

Fig.298. ^{157}Gd(n,3n)^{155}Gd reaction cross section.

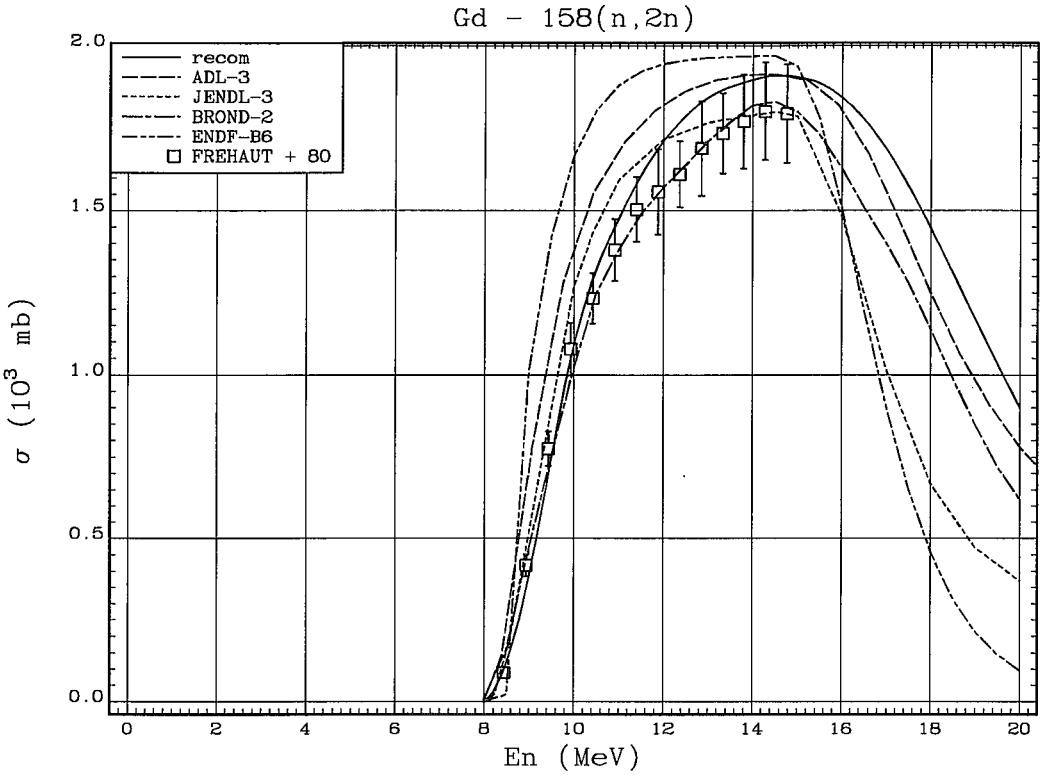

Fig.299. ^{158}Gd(n,2n)^{157}Gd reaction cross section.

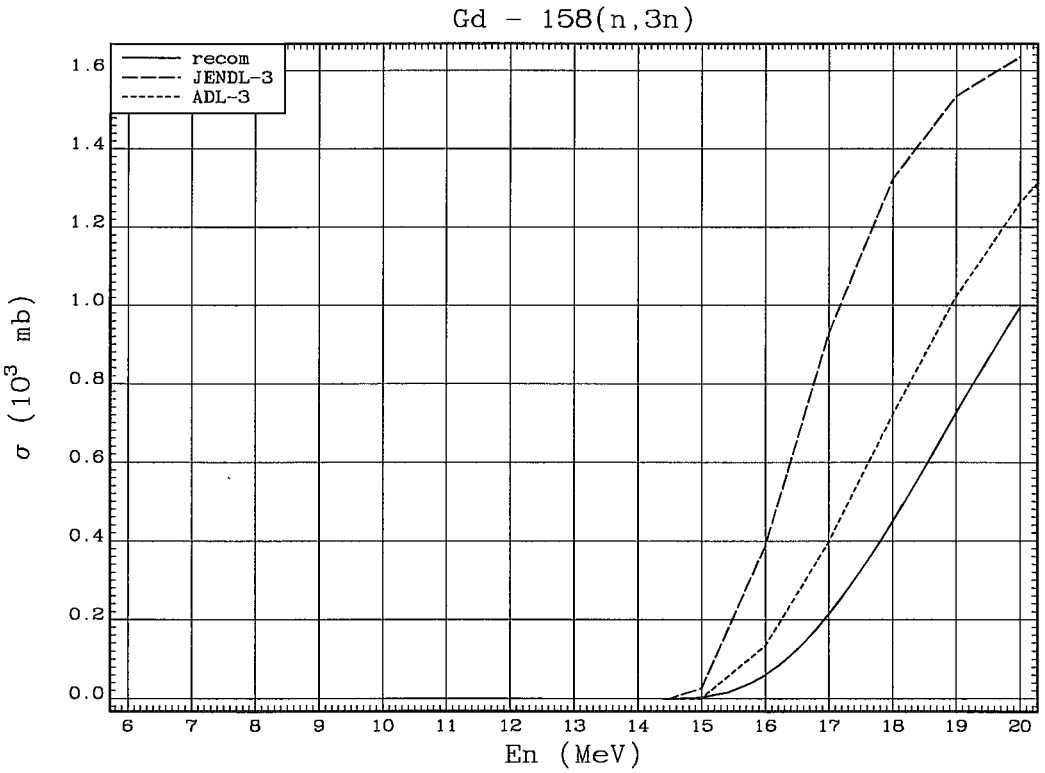

Fig.300. ^{158}Gd(n,3n)^{156}Gd reaction cross section.

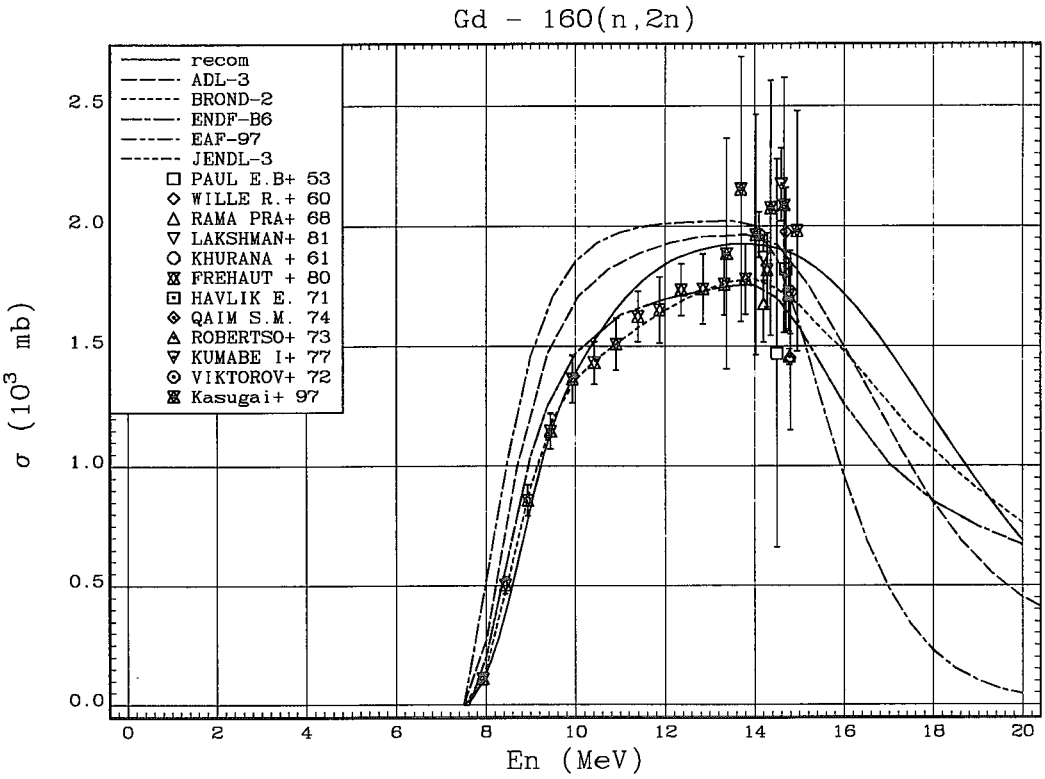

Fig.301. ^{160}Gd(n,2n)^{159}Gd reaction cross section.

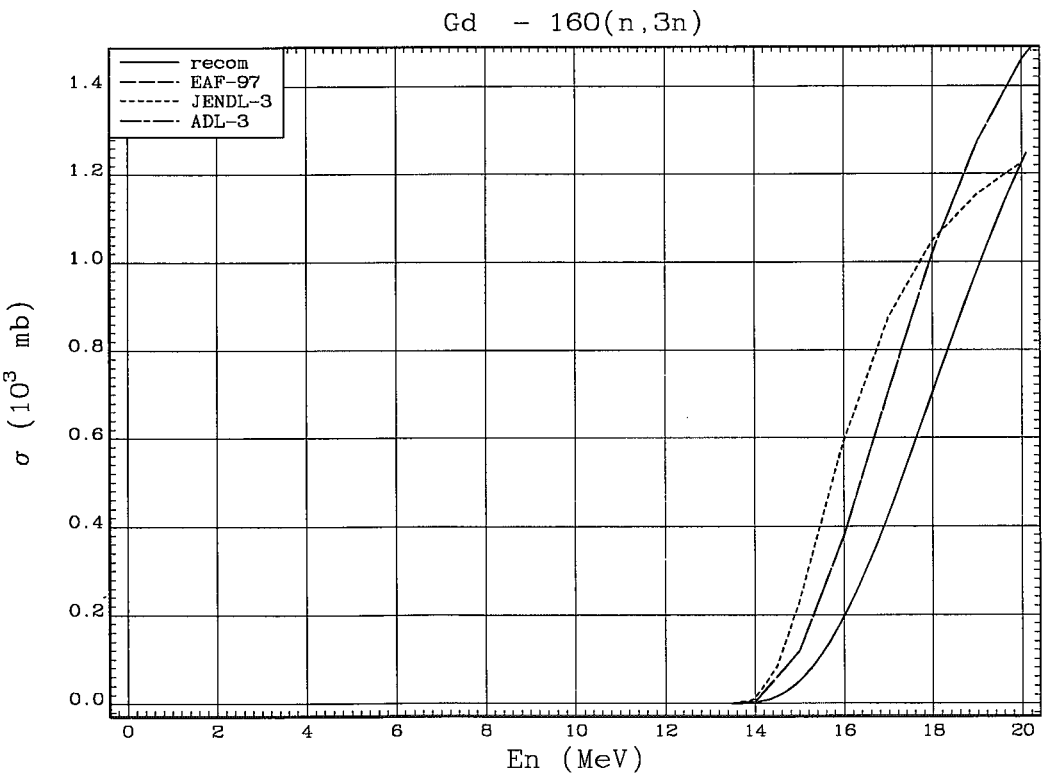

Fig.302. ^{160}Gd(n,3n)^{158}Gd reaction cross section.

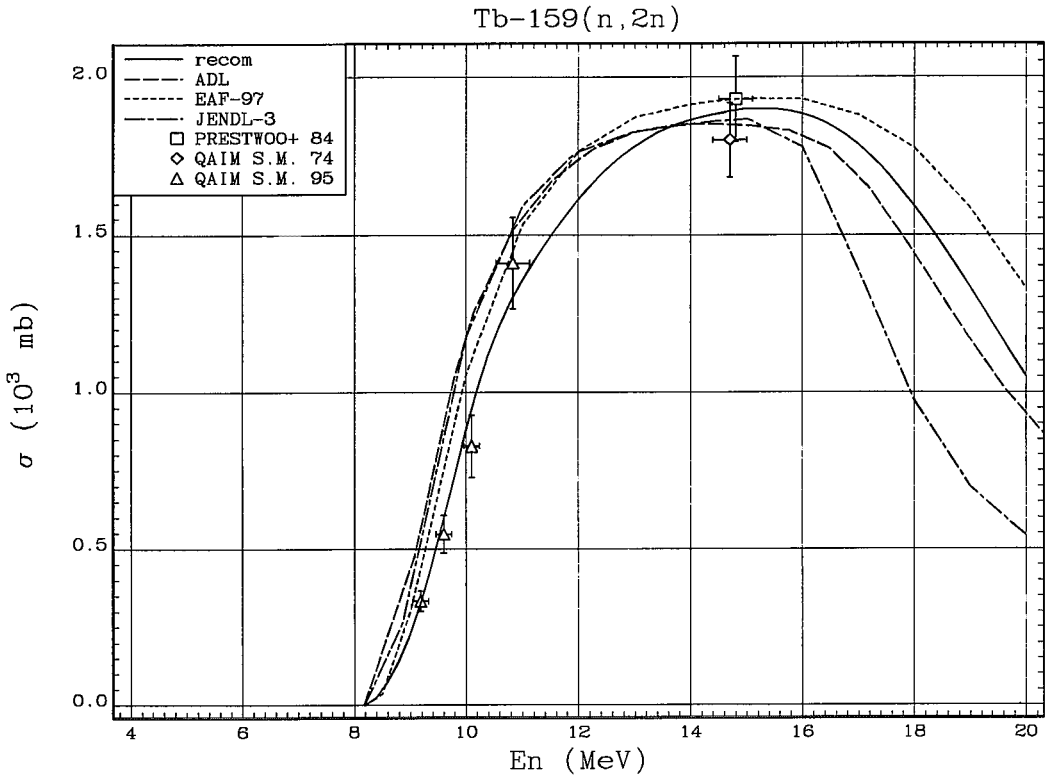

Fig.303. ^{159}Tb(n,2n)^{158}Tb reaction cross section.

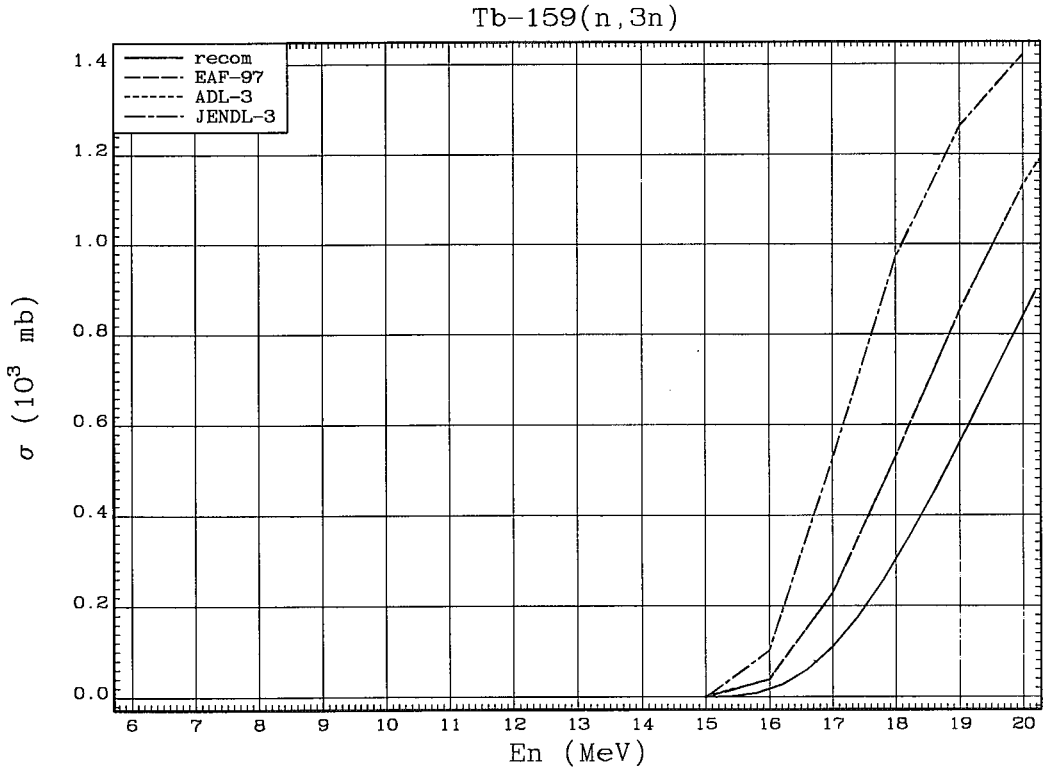

Fig.304. ^{159}Tb(n,3n)^{157}Tb reaction cross section.

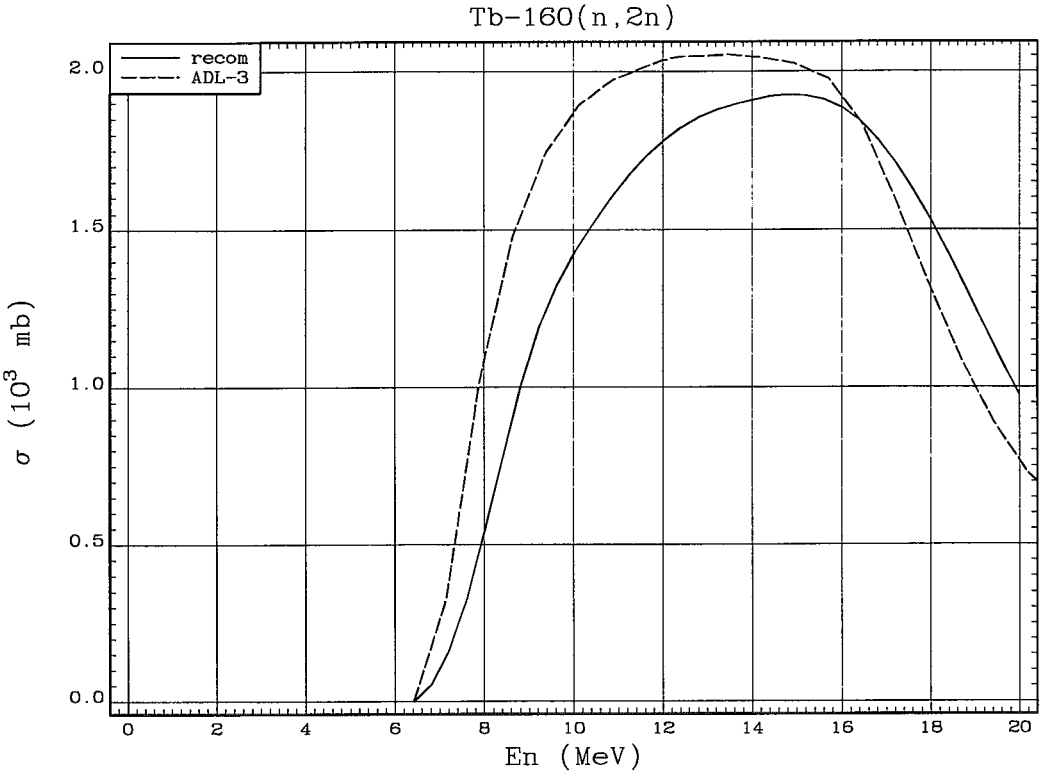

Fig.305. ^{160}Tb(n,2n)^{159}Tb reaction cross section.

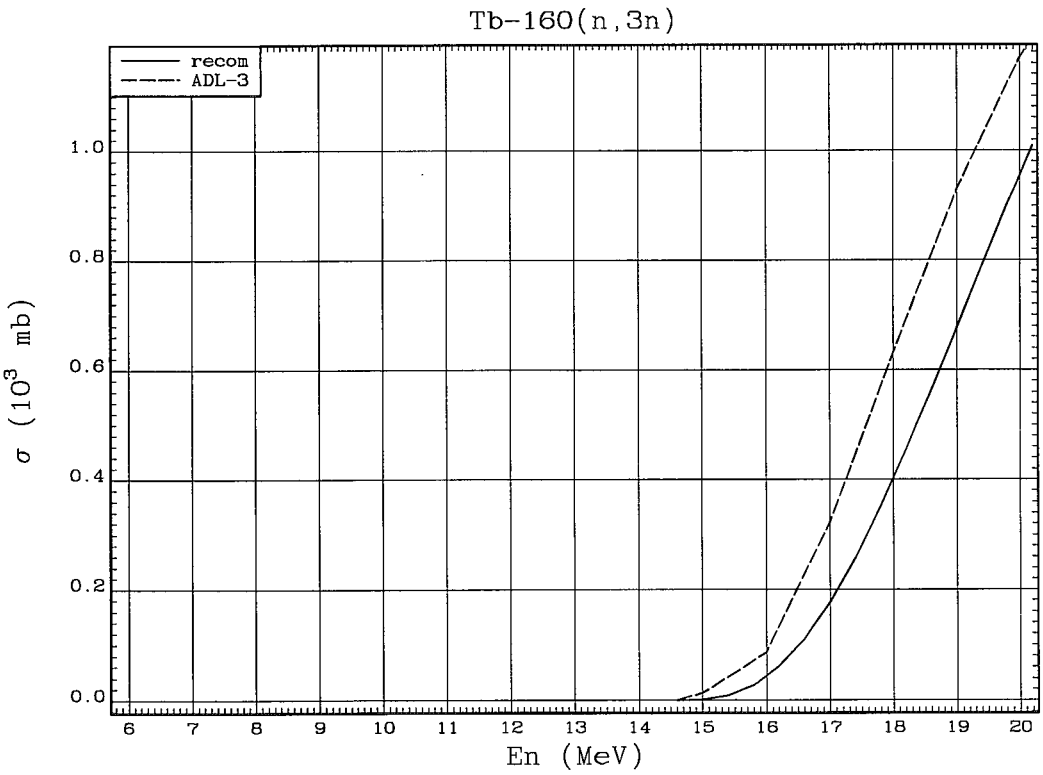

Fig.306. ^{160}Tb(n,3n)^{158}Tb reaction cross section.

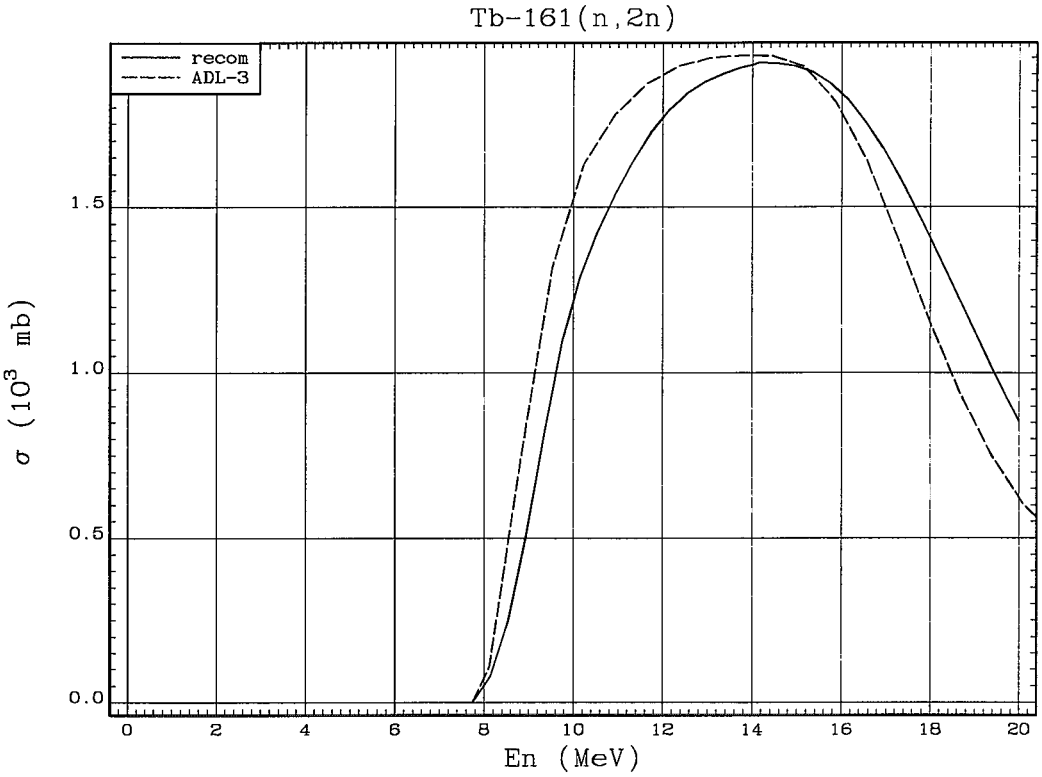

Fig.307. ^{161}Tb(n,2n)^{160}Tb reaction cross section.

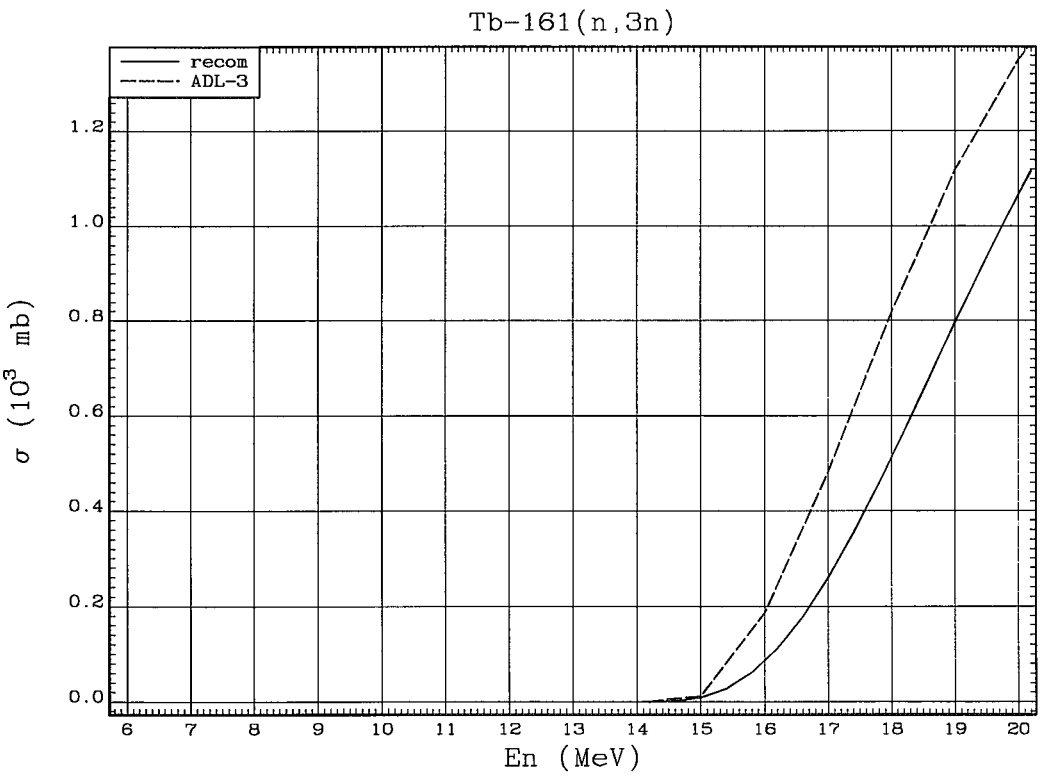

Fig.308. ^{161}Tb(n,3n)^{159}Tb reaction cross section.

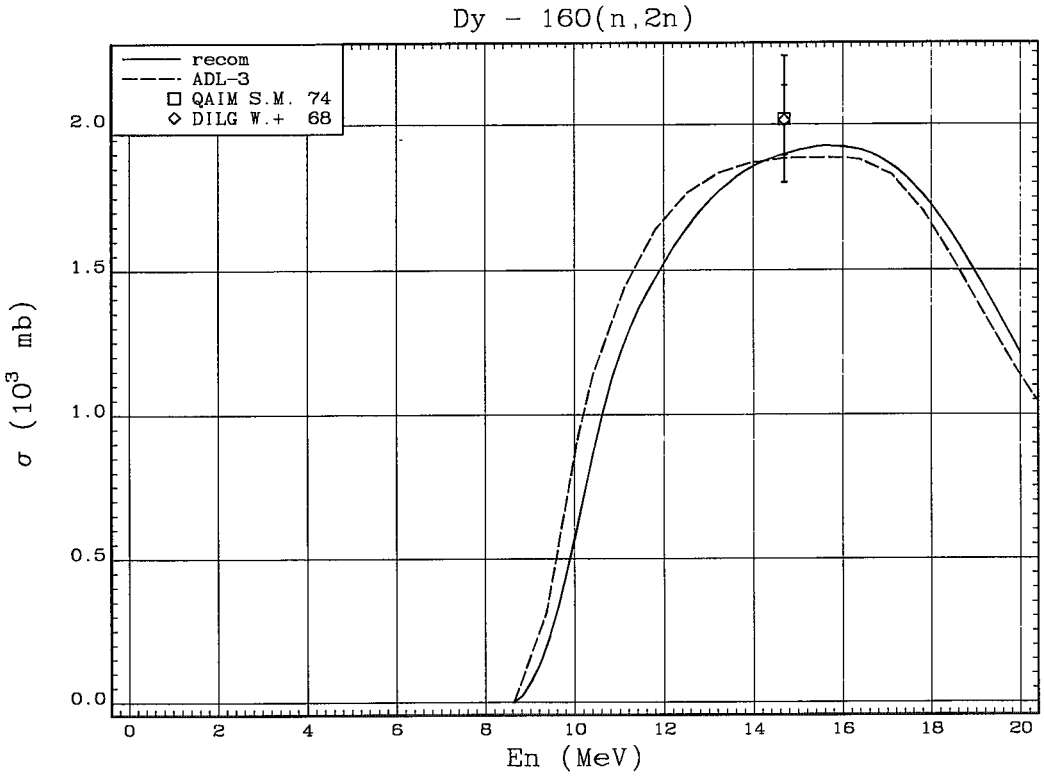

Fig.309. ^{160}Dy(n,2n)^{159}Dy reaction cross section.

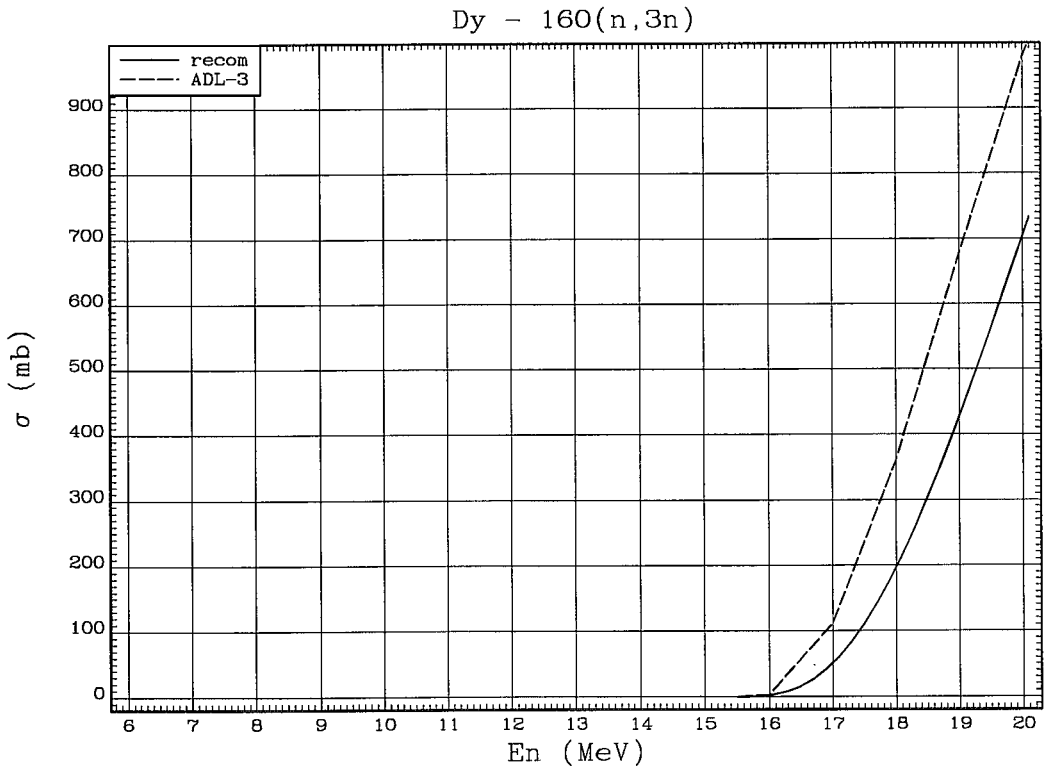

Fig.310. ^{160}Dy(n,3n)^{158}Dy reaction cross section.

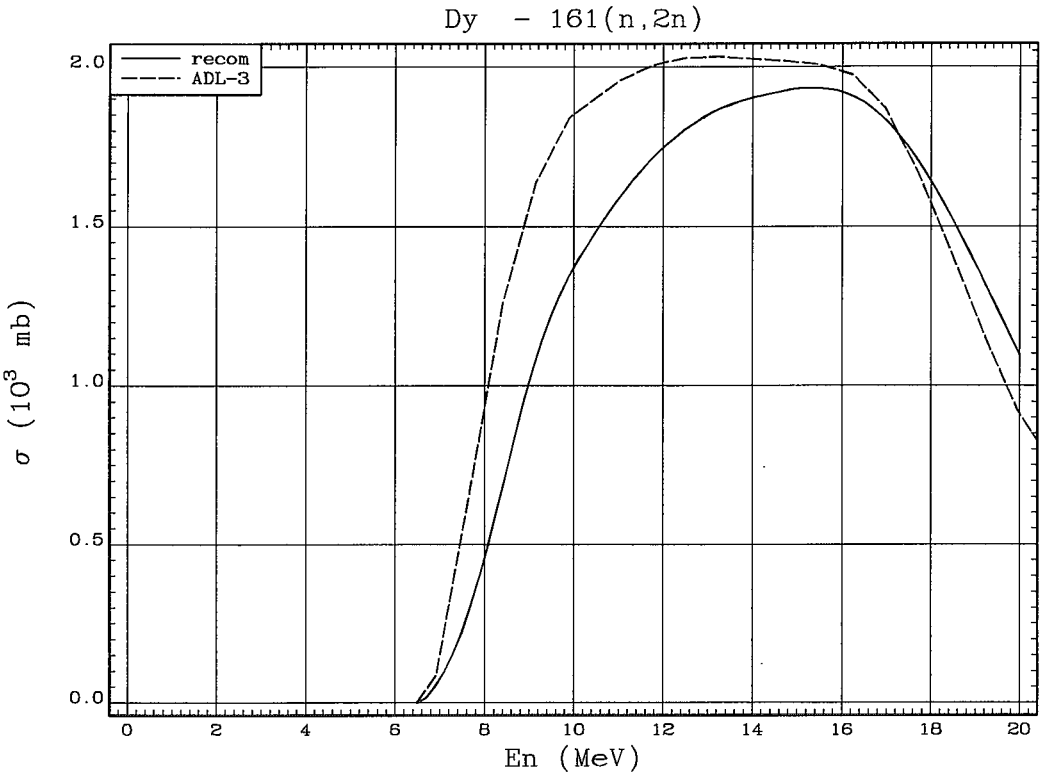

Fig.311. ^{161}Dy(n,2n)^{160}Dy reaction cross section.

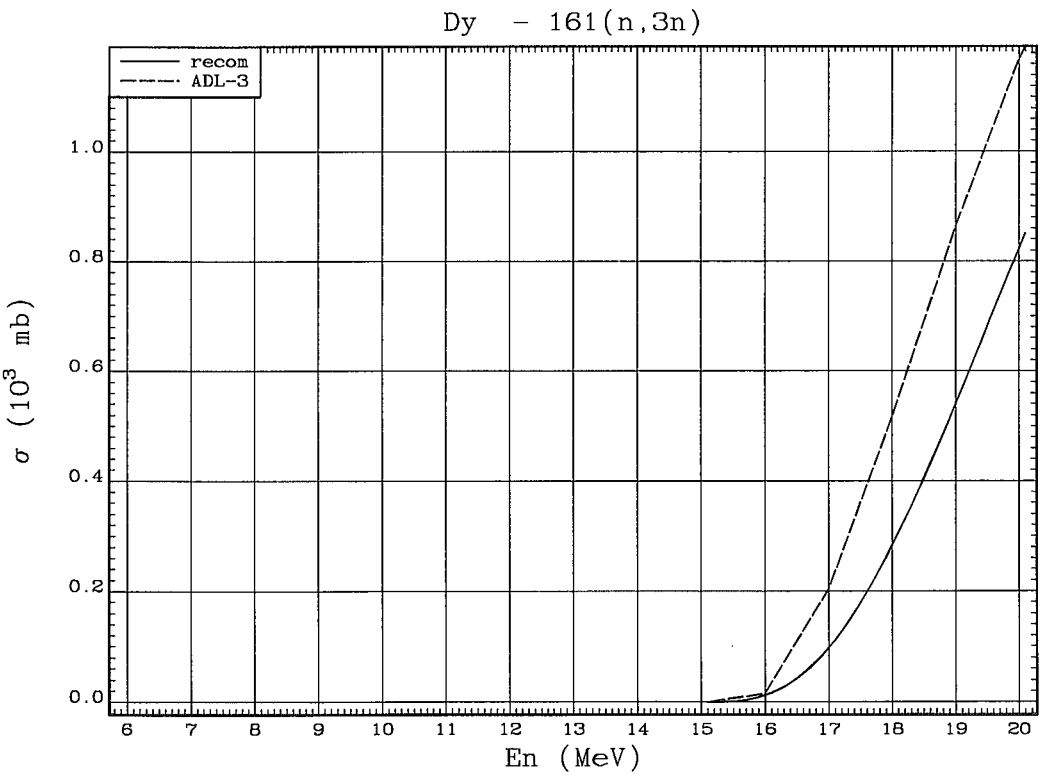

Fig.312. ^{161}Dy(n,3n)^{159}Dy reaction cross section.

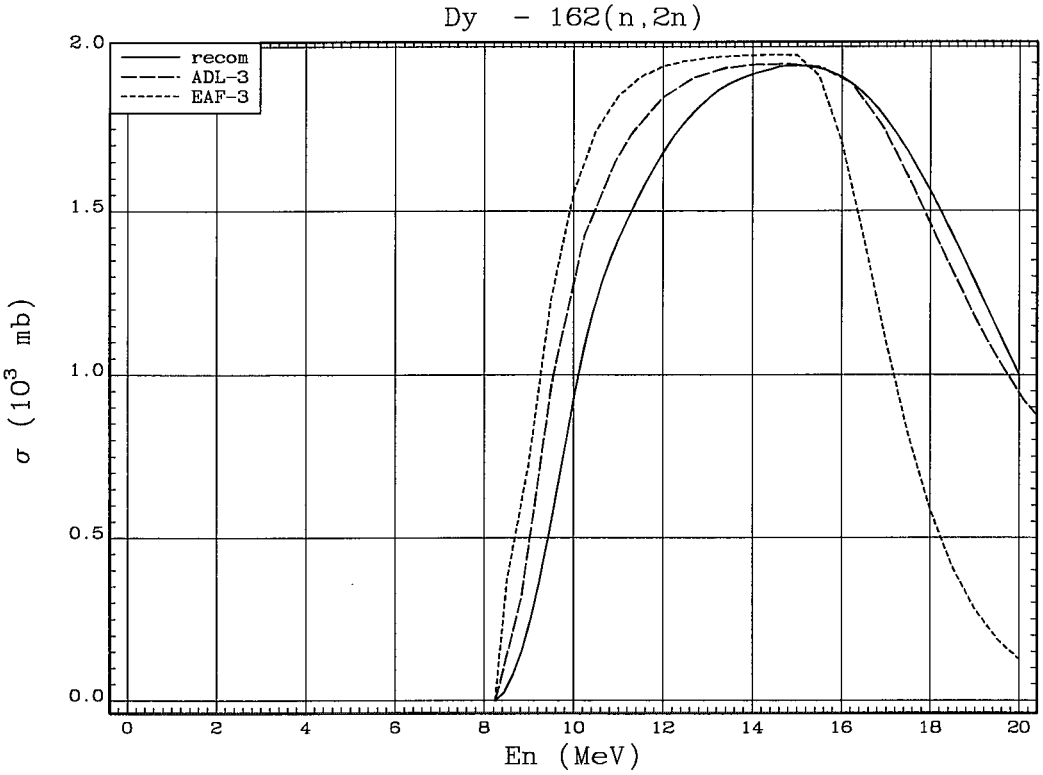

Fig.313. ^{162}Dy(n,2n)^{161}Dy reaction cross section.

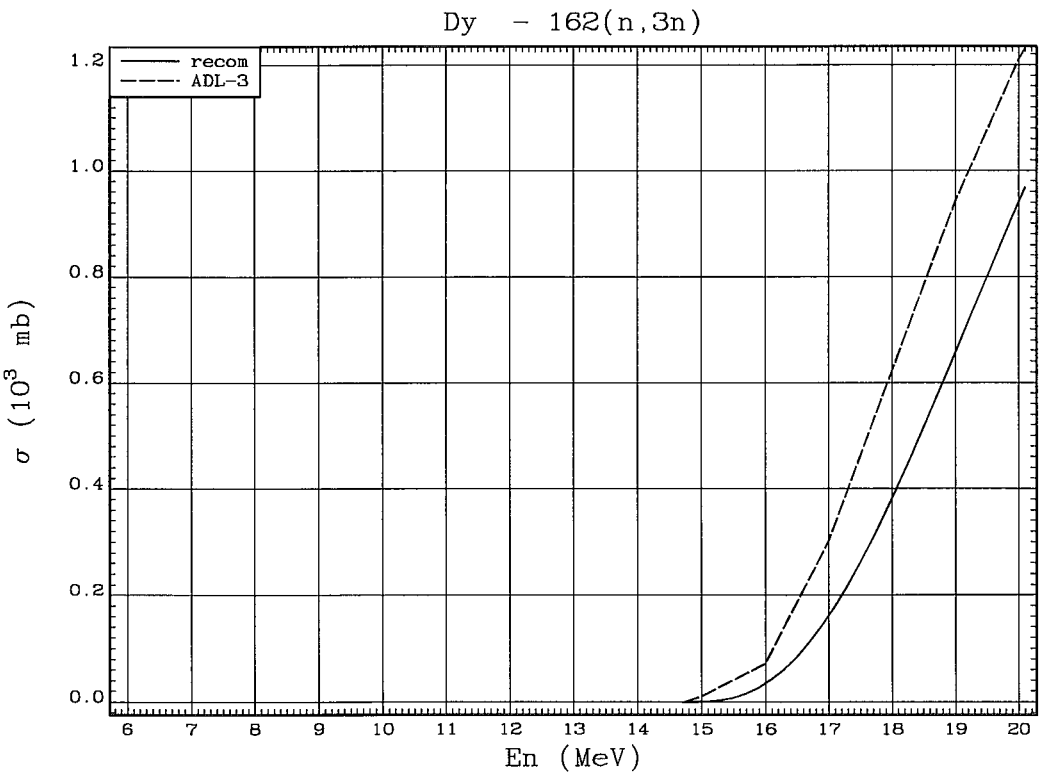

Fig.314. ^{162}Dy(n,3n)^{160}Dy reaction cross section.

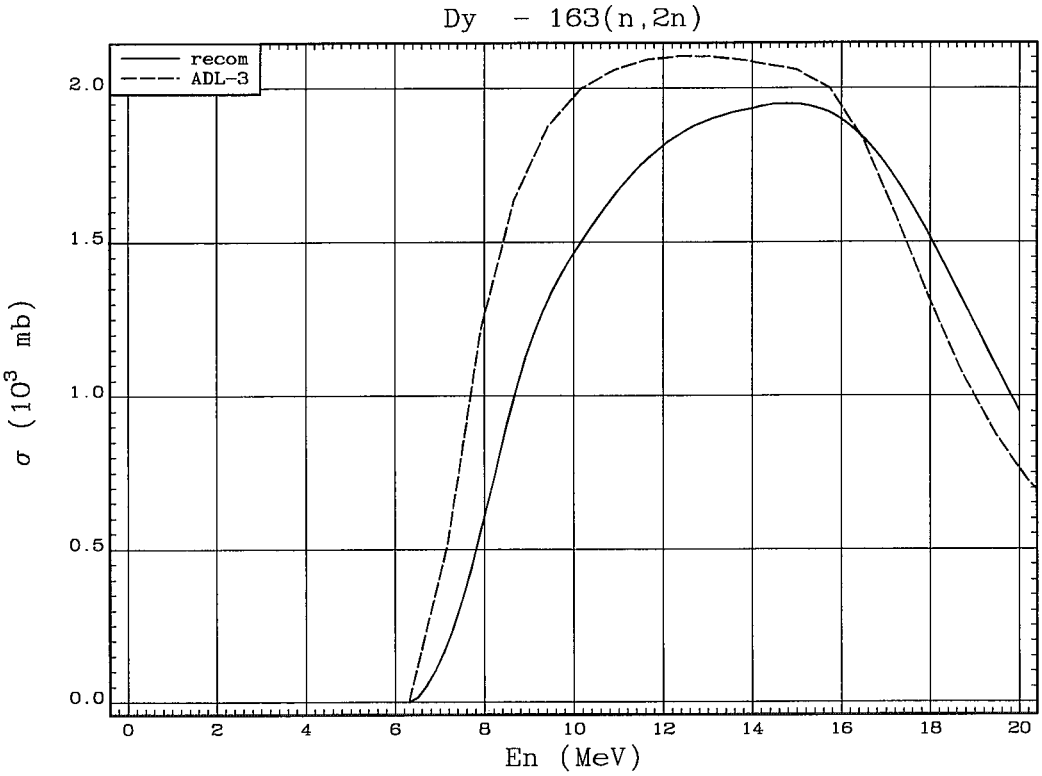

Fig.315. ^{163}Dy(n,2n)^{162}Dy reaction cross section.

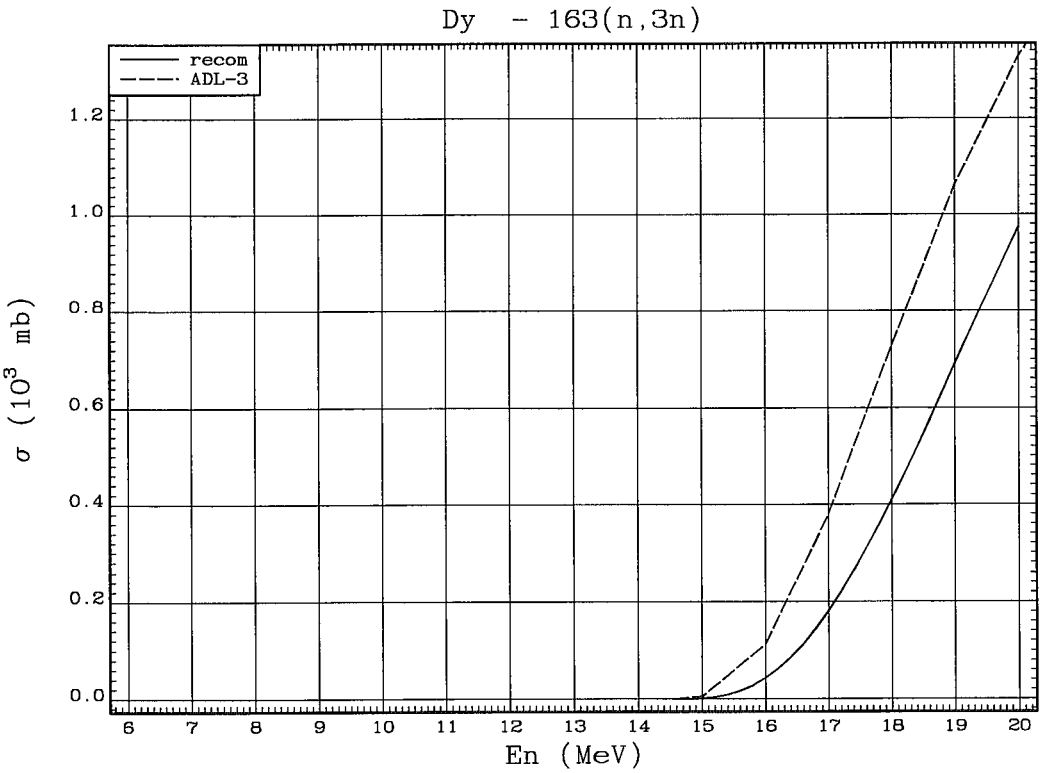

Fig.316. ^{163}Dy(n,3n)^{161}Dy reaction cross section.

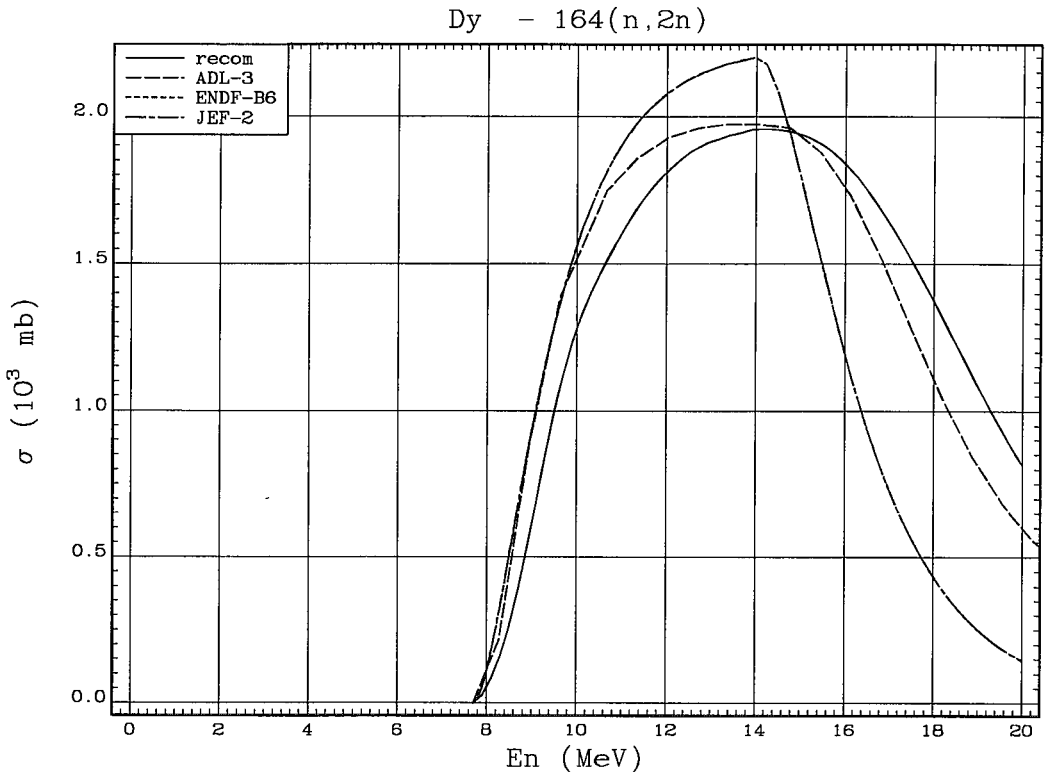

Fig.317. ^{164}Dy(n,2n)^{163}Dy reaction cross section.

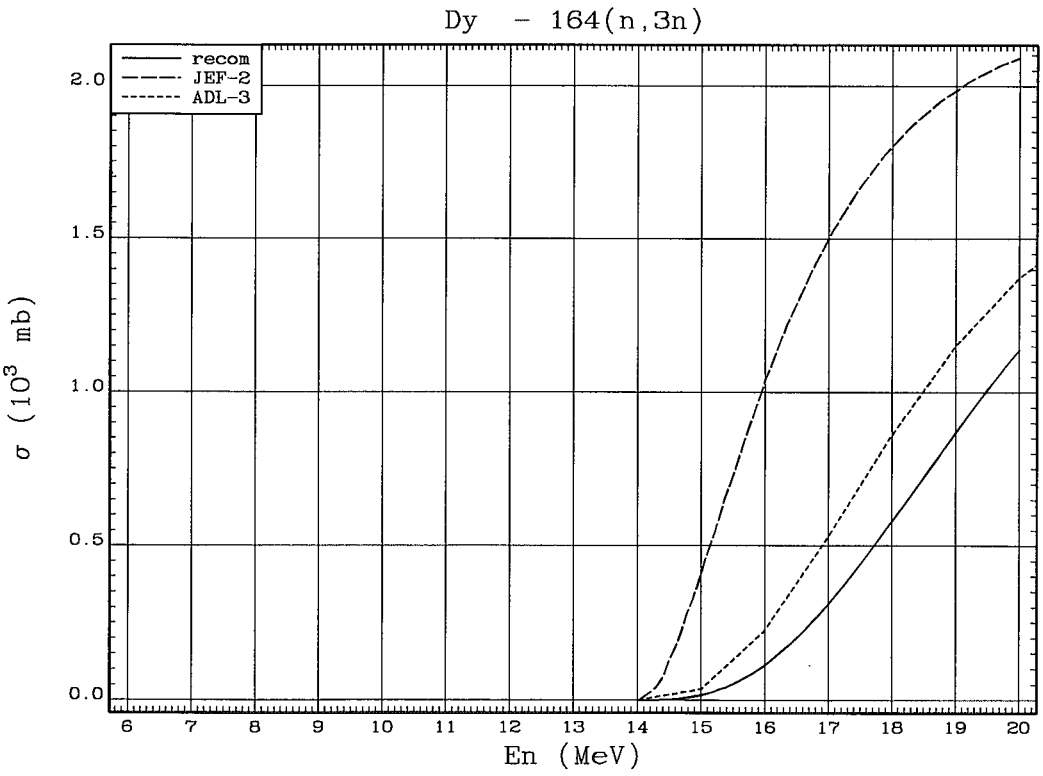

Fig.318. ^{164}Dy(n,3n)^{162}Dy reaction cross section.

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国際単位系 (SI) と換算表

表 1　SI 基本単位および補助単位

量	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd
平面角	ラジアン	rad
立体角	ステラジアン	sr

表 2　SI と併用される単位

名称	記号
分，時，日	min, h, d
度，分，秒	°, ′, ″
リットル	l, L
トン	t
電子ボルト	eV
原子質量単位	u

$1\ \mathrm{eV} = 1.60218 \times 10^{-19}\ \mathrm{J}$

$1\ \mathrm{u} = 1.66054 \times 10^{-27}\ \mathrm{kg}$

表 5　SI 接頭語

倍数	接頭語	記号
10^{18}	エクサ	E
10^{15}	ペタ	P
10^{12}	テラ	T
10^{9}	ギガ	G
10^{6}	メガ	M
10^{3}	キロ	k
10^{2}	ヘクト	h
10^{1}	デカ	da
10^{-1}	デシ	d
10^{-2}	センチ	c
10^{-3}	ミリ	m
10^{-6}	マイクロ	μ
10^{-9}	ナノ	n
10^{-12}	ピコ	p
10^{-15}	フェムト	f
10^{-18}	アト	a

表 3　固有の名称をもつ SI 組立単位

量	名称	記号	他の SI 単位による表現
周波数	ヘルツ	Hz	s^{-1}
力	ニュートン	N	$m \cdot kg/s^2$
圧力，応力	パスカル	Pa	N/m^2
エネルギー，仕事，熱量	ジュール	J	$N \cdot m$
工率，放射束	ワット	W	J/s
電気量，電荷	クーロン	C	$A \cdot s$
電位，電圧，起電力	ボルト	V	W/A
静電容量	ファラド	F	C/V
電気抵抗	オーム	Ω	V/A
コンダクタンス	ジーメンス	S	A/V
磁束	ウェーバ	Wb	$V \cdot s$
磁束密度	テスラ	T	Wb/m^2
インダクタンス	ヘンリー	H	Wb/A
セルシウス温度	セルシウス度	℃	
光束	ルーメン	lm	$cd \cdot sr$
照度	ルクス	lx	lm/m^2
放射能	ベクレル	Bq	s^{-1}
吸収線量	グレイ	Gy	J/kg
線量当量	シーベルト	Sv	J/kg

表 4　SI と共に暫定的に維持される単位

名称	記号
オングストローム	Å
バーン	b
バール	bar
ガル	Gal
キュリー	Ci
レントゲン	R
ラド	rad
レム	rem

$1\ \text{Å} = 0.1\ \mathrm{nm} = 10^{-10}\ \mathrm{m}$

$1\ \mathrm{b} = 100\ \mathrm{fm}^2 = 10^{-28}\ \mathrm{m}^2$

$1\ \mathrm{bar} = 0.1\ \mathrm{MPa} = 10^5\ \mathrm{Pa}$

$1\ \mathrm{Gal} = 1\ \mathrm{cm/s}^2 = 10^{-2}\ \mathrm{m/s}^2$

$1\ \mathrm{Ci} = 3.7 \times 10^{10}\ \mathrm{Bq}$

$1\ \mathrm{R} = 2.58 \times 10^{-4}\ \mathrm{C/kg}$

$1\ \mathrm{rad} = 1\ \mathrm{cGy} = 10^{-2}\ \mathrm{Gy}$

$1\ \mathrm{rem} = 1\ \mathrm{cSv} = 10^{-2}\ \mathrm{Sv}$

（注）

1. 表 1 ― 5 は「国際単位系」第 5 版，国際度量衡局 1985 年刊行による。ただし，1 eV および 1 u の値は CODATA の 1986 年推奨値によった。
2. 表 4 には海里，ノット，アール，ヘクタールも含まれているが日常の単位なのでここでは省略した。
3. bar は，JIS では流体の圧力を表わす場合に限り表 2 のカテゴリーに分類されている。
4. EC 閣僚理事会指令では bar，barn および「血圧の単位」mmHg を表 2 のカテゴリーに入れている。

換　算　表

力	N(=10^5dyn)	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

粘　度　$1\ \mathrm{Pa \cdot s (N \cdot s/m^2)} = 10\ \mathrm{P}$（ポアズ）$(\mathrm{g/(cm \cdot s)})$

動粘度　$1\ \mathrm{m^2/s} = 10^4\ \mathrm{St}$（ストークス）$(\mathrm{cm^2/s})$

圧力	MPa(=10 bar)	kgf/cm²	atm	mmHg(Torr)	lbf/in²(psi)
	1	10.1972	9.86923	7.50062×10^3	145.038
	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	1.33322×10^{-4}	1.35951×10^{-3}	1.31579×10^{-3}	1	1.93368×10^{-2}
	6.89476×10^{-3}	7.03070×10^{-2}	6.80460×10^{-2}	51.7149	1

エネルギー・仕事・熱量	J(=10^7 erg)	kgf・m	kW・h	cal（計量法）	Btu	ft・lbf	eV
	1	0.101972	2.77778×10^{-7}	0.238889	9.47813×10^{-4}	0.737562	6.24150×10^{18}
	9.80665	1	2.72407×10^{-6}	2.34270	9.29487×10^{-3}	7.23301	6.12082×10^{19}
	3.6×10^6	3.67098×10^5	1	8.59999×10^5	3412.13	2.65522×10^6	2.24694×10^{25}
	4.18605	0.426858	1.16279×10^{-6}	1	3.96759×10^{-3}	3.08747	2.61272×10^{19}
	1055.06	107.586	2.93072×10^{-4}	252.042	1	778.172	6.58515×10^{21}
	1.35582	0.138255	3.76616×10^{-7}	0.323890	1.28506×10^{-3}	1	8.46233×10^{18}
	1.60218×10^{-19}	1.63377×10^{-20}	4.45050×10^{-26}	3.82743×10^{-20}	1.51857×10^{-22}	1.18171×10^{-19}	1

1 cal = 4.18605 J（計量法）
= 4.184 J　（熱化学）
= 4.1855 J　（15 °C）
= 4.1868 J（国際蒸気表）

仕事率　1 PS（仏馬力）
= 75 kgf・m/s
= 735.499 W

放射能	Bq	Ci
	1	2.70270×10^{-11}
	3.7×10^{10}	1

吸収線量	Gy	rad
	1	100
	0.01	1

照射線量	C/kg	R
	1	3876
	2.58×10^{-4}	1

線量当量	Sv	rem
	1	100
	0.01	1

（86 年 12 月 26 日現在）