Note on energy dependence of capture cross section for individual nuclides (including 20 highest contribution nuclides and 7 nuclides with RMS (> 10%))

<Data source>

JEF-2.2: Mainly RCN and ENDF/B-V, partially JENDL-1.

Cross section adjustment based on the integral test results with the STEK experiments.

Artificial resonance parameters: Eu-155.

JENDL-3.2: JNDC original evaluation (JENDL-3.1: J. Nucl. Sci. Technol., 29, 195 (1992) and re-evaluation :1994 Gatlinburg Conf., p.809)).

Almost all evaluation for capture cross section was made with the statistical model calculation taking into consideration of level overlapping and fluctuation effects on inelastic scattering cross section, The optical model parameters in the local mass ranges were determined to reproduce systematics of total cross sections, s- and p-wave strength functions and scattering radius. Gamma-ray strength functions were determined on the basis of the differential experimental data of capture cross sections.

Cross section adjustment due to integral test was made only for Xe132, 134, Eu152 and 154 because there were no experimental data in the keV energy region.

Artificial resonance parameters for Ru101, 102, Ag107 and 109 were added to compensate missed levels.

ENDF/B-VI: ENDF/B-V and re-evaluation (mainly for resonance parameters).

BROND-2: IPPE original evaluation.

FOND-2.1: BROND-2 + others.

Ru101+ One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.7243, 0.7616, 0.7523.

Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.94±0.01 .

All evaluated data of JEF-2.2, BROND-2 and JENDL-3 agree well with the experimental data of Macklin et al.[1-3] in the energy range below 1 MeV. The data of JENDL-3.2 were modified by adopting the level scheme taken from the ENSDF.

Pd105+ One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.9490, 0.9161, 0.9594.

Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.92±0.06 .

JENDL-3.2 and JEF-2.2 agree well with the experimental data of Macklin et al.[1,3,4] JENDL-3.2 connects smoothly with the resonance cross sections but larger than the experimental data of Macklin et al. and Musgrove et al.[5] between 3 keV and 7

keV, where the other evaluated data agree with them.

Sm149-** One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 2.5437, 2.8700, 2.2990.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.88±0.06.

JENDL-3.2 adopted the new experimental data of Macklin[6]. Thus, it is systematically lower than the others which were evaluated on the basis of the older measurements in the energy range between 3 keV and 400 keV.

Tc99-* One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.6479, 0.6561, 0.5923.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.80±0.01.

Above 3 keV, JENDL-3.2, JEF-2.2 and BROND-2 are in agreement with the experimental data of Macklin et al.[7], while ENDF/B-VI runs along the averaged values of Macklin et al. and Little et al.[8] and is systematically larger than the other files below 100 keV. Below 3 keV, histogram of JENDL-3 calculated from the resolved resonance parameters is slightly lower than the others.

Cs133- One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 0.5167, 0.5184, 0.4874.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.80±0.05 .

All evaluated data of JEF-2.2, ENDF/B-VI and JENDL-3.2 agree with the experimental data of Yamamuro et al.[9] and Macklin[10], although one group cross section of JEF-2.2.2 is 6% larger than JENDL-3.2. The difference seems come from difference in the evaluated resonance parameters.

Pd107- One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 1.0700, 1.0399, 1.0520.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.94±0.01 .

All evaluated data of JEF-2.2, BROND-2, ENDF/B-VI and JENDL-3.2 agree well with the experimental data of Macklin[11] above 1.3 keV, while the cross sections of JEF-2.2 are different from those of JENDL-3.2 and ENDF/B-VI in the resolved resonance region between 50 eV and 1.3 keV.

Rh103+ One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.6832, 0.6526, 0.6774.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.96±0.00.

JENDL-3.2, JEF-2.2 and BROND-2 are in good agreement with each other and close to the experimental data of Wisshak[12] ENDF/B-VI and JENDL-3.1 are agree with the Macklin's experimental data[1-3] and larger than the former three libraries.

(Pm147)-* One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 1.5167, 1.4309, 1.2753.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.88±0.05 .

There is no experimental data of cross sections in the keV energy range. The cross sections of JENDL-3.2 was evaluated so as to smoothly continue to the cross sections calculated from the resolved resonance parameters and is 10 - 15% smaller than the other evaluated data (JEF-2.2, ENDF/B-VI and BROND-2) in the energy region below 100 keV. ENDF/B-VI shows steep reduction above 100 keV.

(Sm151)-** One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 3.3998, 2.9413, 2.1080.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.90±0.03.

There is no experimental data of cross sections in the keV energy range. JENDL-3.2 is several ten percent smaller than JEF-2.2. Below 100 keV, ENDF/B-VI and BROND-2 are in agreement with each other but different from JEF-2.2 and JENDL-3.2.

(Ru103)-** One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 1.1992, 1.2140, 0.5047.

There is no experimental data of cross sections in the keV energy range. JENDL-3.2 is factor of 2-4 smaller than JEF-2.2. ENDF/B-VI is also smaller than JEF-2.2 and crosses JENDL-3.2.

Mo97-* One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 0.3406, 0.3568, 0.3484.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.96±0.02 .

All of JENDL-3.2, JEF-2.2 and ENDF/B-VI agree with the experimental data of Musgrove et al.[13,14]

Nd145+ One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.5700, 0.5124, 0.5648.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.85±0.03 .

JENDL-3.2 and JEF-2.2 are close to the experimental data of Nakajima et al.[15], while JENDL-3.2 is slightly larger than JEF-2.2 between 60 keV and 700 keV. ENDF/B-VI and BROND-2 generally agree with the data of Musgrove et al.[5,14,16] and Bokhovko et al.[17] and are 15% or more small compared to JENDL-3.2. Above 70 keV, BROND-2 steeply decreases along the data of Bokhovko et al.

(Xe131)+* One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.2937, 0.3323, 0.3461.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=1.00±0.10 .

Although there is no experimental data of cross sections in the keV energy range, difference between the different evaluated files is considerably small. In the resolved resonance energy region below 4 keV, level missing effect is observed in ENDF/B-VI.

Eu153-* One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 2.7655, 2.9288, 2.5958.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.92±0.01 .

JENDL-3.2 agrees well with the experimental data of Macklin & Young[18] which are the lowest in the experimental data. JENDL-3.2, JEF-2.2 and ENDF/B-VI are in agreement with each other in the wide energy range, while BROND-2 is discrepant from them in the energy range between 1 keV and 20 keV.

Nd143+ One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.3550, 0.3370, 0.3589.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.90±0.01 .

JENDL-3.2, and ENDF/B-VI agree with the experimental data of Nakajima et al.[15], while JEF-2.2 is lower than these experimental data in the energy region between 5 keV and 40 keV. BROND-2 is in coincident with the JENDL-3.2 and ENDF/B-VI below 40 keV, but discrepant from them above 40 keV along the experimental data of Bokhovko et al.[17], of which energy dependence showing a steep decrease seems to be anomalous.

Ru102- One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.1581, 0.1796, 0.1642.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=1.07±0.14 .

In the energy region above 5 keV, JENDL-3.2, JEF-2.2 and ENDF/B-VI are in good agreement with the experimental data of Macklin[1-3]. BROND-2 is about 20% larger than the others. In the resolved resonance region, large difference is observed among libraries.

Ag109-* One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.7927, 0.7203, 0.6916.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.66±0.01.

Above 3 keV, JENDL-3.2, ENDF/B-VI and BROND-2 agree with the experimental data of Macklin[19], Mizumoto et al.[20], and Bokhovko et al.[17], while JEF-2.2 is considerably larger than the others above 30 keV. In the energy region between 1 keV and 2.6 keV, JENDL-3.2 was revised taking account of resonance level missing effect so that discrepancy between JENDL-3.2 and JEF-2.2 become quite small in this energy range.

Ru104+ One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.1546, 0.1658, 0.1685.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=1.06±0.14.

All libraries of JENDL-3.2, JEF-2.2, ENDF/B-VI and BROND-2 remarkably agree with each other and reproduce the average value of the experimental data of Macklin et al.[1-3] Evaluation reproduce well the fine structure due to competition with inelastic scattering at 360 keV and 900 keV.

(Cs135)+** One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 0.2445, 0.1361, 0.2284.

Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.88±0.05 .

There is no experimental data of cross sections in the keV energy range. Evaluation of JENDL-3.2 was made so as to reproduce the experimental data of thermal value and resonance integral connecting the statistical model calculation with resonance cross section due to the resonance parameter of Priesmyer[21] at 4 keV. JEF-2.2 contain the resonances belong to other isotope, but agree with JENDL-3.2 above 600 eV. ENDF/B-VI shows an artificial shape between 10 and 100 eV.

Pr141+ One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 0.1582, 0.1540, 0.1564.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.96±0.02.

JENDL-3.2, JEF-2.2 and ENDF/B-VI agree well each other and reproduce the experimental data of Stupeiga[22], Zaikin et al.[23], Taylor et al.[24,14], and Voignier et al.[25]

(Eu155)-** One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 2.8428, 2.9559, 1.3368.

Eu155 determine capture cross sections of pseudo fission products in the energy range below 1 keV. JENDL-3.1 and ENDF/B-VI were evaluated with the measured resonance parameters given by Moller et al.[26], Friesenhahn et al.[27] and Ribon[28], while JEF-2.2 seems to adopt the artificially generated ones. FOND-2 may also take them. In evaluation of JENDL-3.2, a part of parameters in JENDL-3.1 were modified so as to reproduce the new experimental data of thermal value and resonance integral reported by Sekine et al.[29] Above 100 eV where there is no experimental data, JENDL-3.2 is about factor of 2 smaller than JEF-2.2.

Pd108+* One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.1770, 0.2507, 0.2358.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=1.09±0.11.

JENDL-3.2 and BROND-2 agree with the experimental data of Macklin et al.[1-3] ENDF/B-VI is about 20% larger than them and close to the experimental data of Musgrove et al.[5] On the other hand, JEF-2.2 which runs along the experimental data of Cornelis et al.[30] is about 20% smaller than JENDL-3.2.

Xe132+** One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 0.0708, 0.0755, 0.0980.

JENDL-3.2 reproduce the experimental data of Beer et al.[31], while JEF-2.2 and ENDF/B-VI are about factor of 2 larger than JENDL-3.2 above 4 keV. Resolved resonance cross sections of JENDL-3.2 based on the measurements of Ribon[28] are larger than ENDF/B-VI and JEF-2.2 for which the effect of level missing seems appear.

Zr96-** One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.0358, 0.0590, 0.0391.
Integral test result of JENDL-3.2 with the STEK experiment: C/E=0.66±0.05, (0.97 for

capture component).

JENDL-3.2 is in general agreement with the experimental data of Wyrick & Poenitz[32] and shows the lowest in the evaluated data, but the other libraries, JEF-2.2, BROND-2 and ENDF/B-VI are not. Moreover, there are large discrepancies between the different libraries. Below 3 keV, ENDF/B-VI and JEF-2.2 took the same resonance parameters which could not reproduce the experimental data of Macklin et al.[33,34] and Lyon et al.[35]

Pd106+** One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.2027, 0.2553, 0.2772. Integral test result of JENDL-3.2 with the STEK experiment: C/E=1.17±0.09.

JENDL-3.2 runs in the intermediate between the experimental data of Macklin et al.[1-3] and Musgrove et al.[5] ENDF/B-VI is close to JENDL-3.2 except for the energy range below 10 keV. JEF-2.2 agree with the lower experimental data of Conelis et al.[30] and is systematically about 30% smaller than JENDL-3.2. BROND-2 is twisted between JENDL-3.2 and JEF-2.2.

Xe134-** One group cross sections for JEF-2.2, FOND-2.1 and JENDL-3.2: 0.0360, 0.0374, 0.0272.

JENDL-3.2 reproduces the experimental data of Beer et al.[31], but JEF-2.2 which is the same as ENDF/B-VI is about factor of 2 larger than JENDL-3.2 above 10 keV. Resolved resonance parameters of JENDL-3.2 were evaluated on the basis of the new measurements of Macklin[36].

(Zr95)+** One group cross sections for JEF-2.2, BROND-2 and JENDL-3.2: 0.0643, 0.1229, 0.1489.

Since there is no experimental data of cross sections in the keV energy range, large difference is observed between the different evaluated data files among JENDL-3.2, JEF-2.2, ENDF/B-VI and BROND-2. They are arranged in decreasing order of magnitude from ENDF/B-VI, JENDL-3.2, BROND-2 and JEF-2.2. JEF-2.2 is about factor of 2 smaller than JENDL-3.2.

Summary

Data comparison should be made for originally evaluated data. In statistics of the result of benchmark study, each data should be equally treated not to make a double count. In the present case, ideal benchmark study will be accomplished with that all participants will calculate the quantities of pseudo FP from the common evaluated FP libraries, JEF-2.2, JENDL-3.2, ENDF/B-VI and BROND-2 with their own method. Unfortunately, we did not take such a method and no person has not participate the study from ENDF/B side. I think it is not easy to make a fair conclusion to satisfy all

participants. The following is a summary of the present comparison study for capture cross sections emphasizing the reason of discrepancy between JEF-2.2 and JENDL-3.2.

In the present benchmark study, the JENDL-3.2 capture cross sections of pseudo fission product is found to be smaller than JEF-2.2 and FOND-2.1. In order to clarify the reason of the discrepancy, I compare the evaluated capture cross sections for 40 FP nuclides. It was surprised at that JENDL-3.2 data were larger than JEF-2.2 for about half number of nuclides. Further check of cross section was made for important 27 nuclides by comparing the evaluated data with the experimental data.

Large discrepancies are observed among the libraries for nuclides such as Sm-151, Ru-103 and Eu-155 whose experimental data is not available in the keV region and contribution to FBR capture rates is high. For these nuclides, JENDL-3.2 shows smaller values than JEF-2.2 and BROIND-2. It might be pointed out that this discrepancy is due to the difference of parameterization of nuclear model for such nuclides.

The selection of experimental is one of the cause to originate discrepancy between JENDL-3.2 and JEF-2.2. As shown in the figures, the JENDL-3.2 evaluation stands on later experimental data of ORNL and JAERI, which were not used for the JEF-2.2 evaluation. The later experiments show a tendency becoming smaller than older ones, for example of Ag-109 and Sm-149. New experiments have been made for important nuclides so the difference might affect to the pseudo FP cross sections. Another typical example is the resonance parameters of Eu-155 which determine cross section of the pseudo FP in the lower energy below 10 eV: JEF-2.2 adopted artificial ones to give large cross sections, but JENDL-3.2 did the experimental data.

Besides, the cross sections of JEF-2.2 are those adjusted to the integral data of the STEK experiments. For many nuclides, the C/E values of JENDL-3.2 to the STEK experiments correlate with the cross section ratios of JENDL-3.2 to JEF-2.2. The results of integral test for JENDL-3.2 shows a trend of underestimation of reactivity worth by 5% -10% for nuclides having masses more than 130.

Accordingly, it is not strange there is systematic difference between JENDL-3.2 and JEF-2.2.

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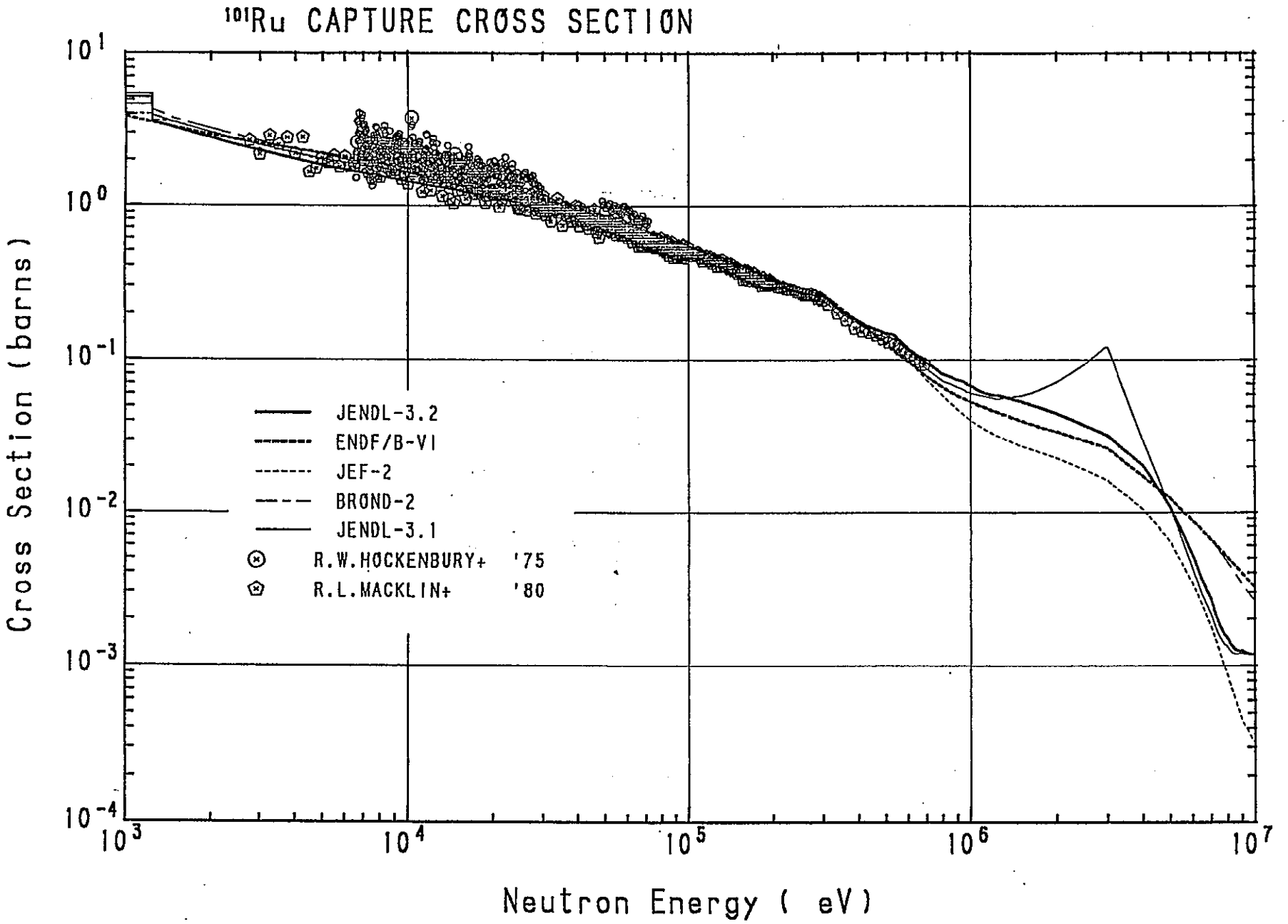

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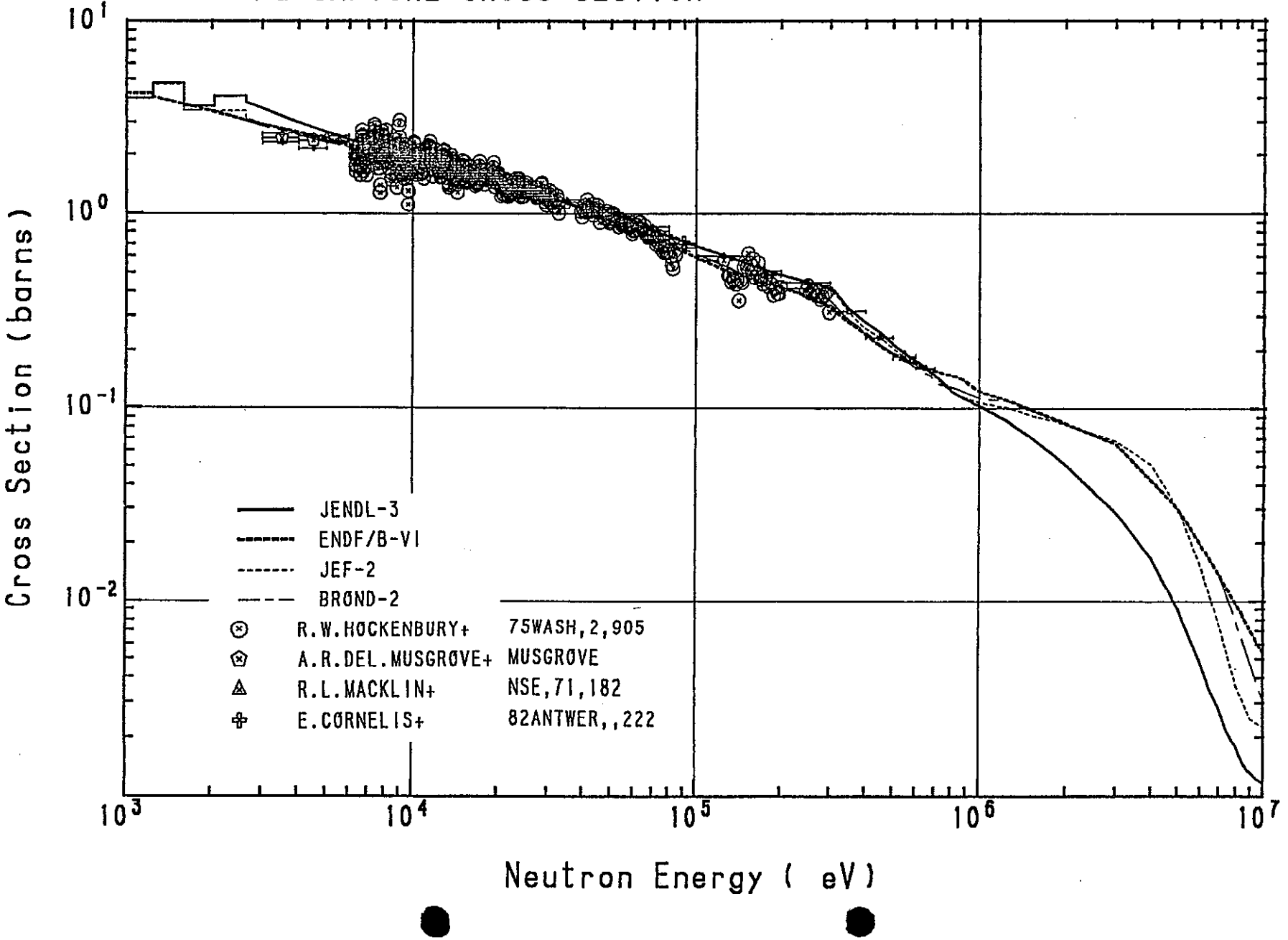
^{105}Pd CAPTURE CROSS SECTION



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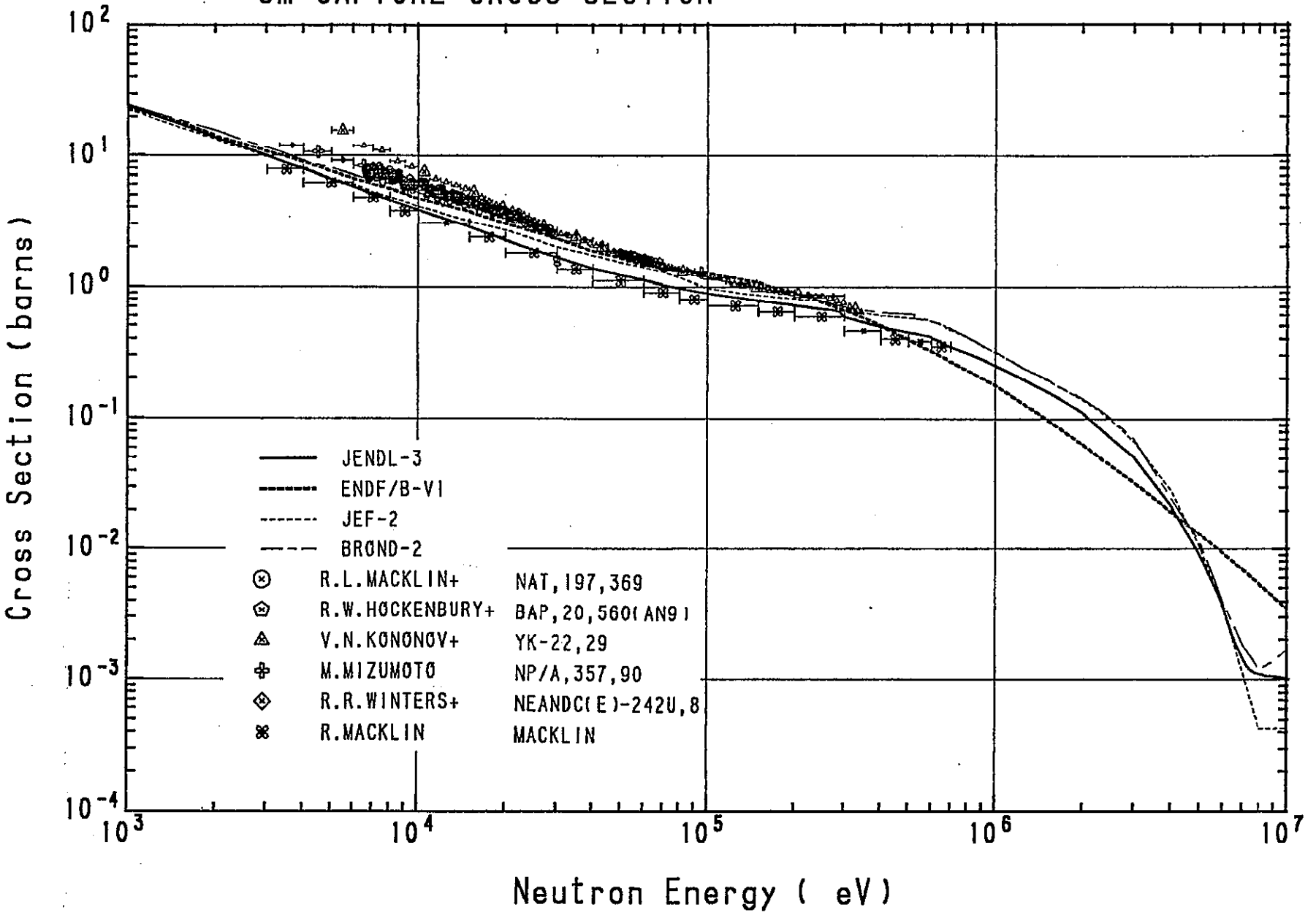

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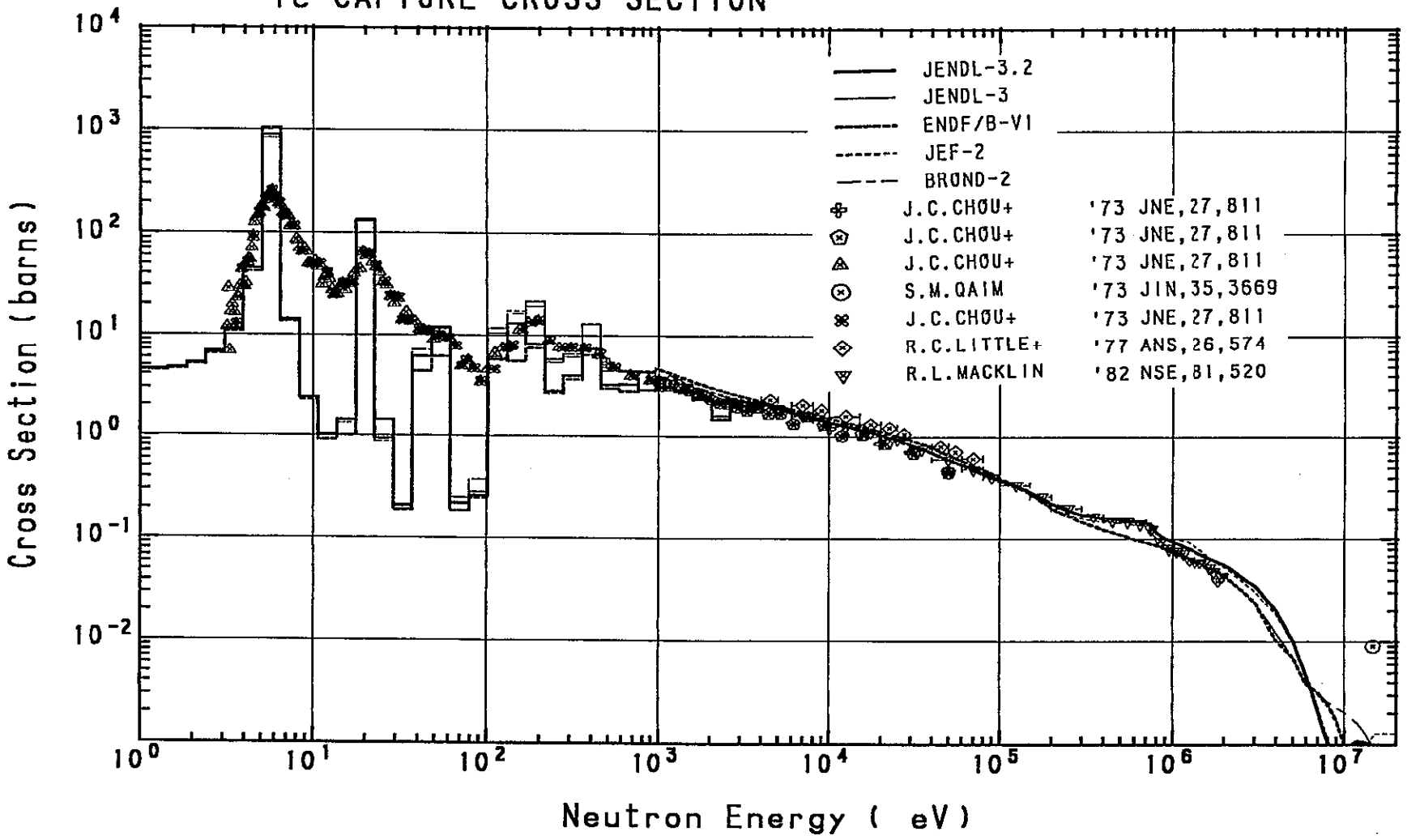
^{99}Tc CAPTURE CROSS SECTION



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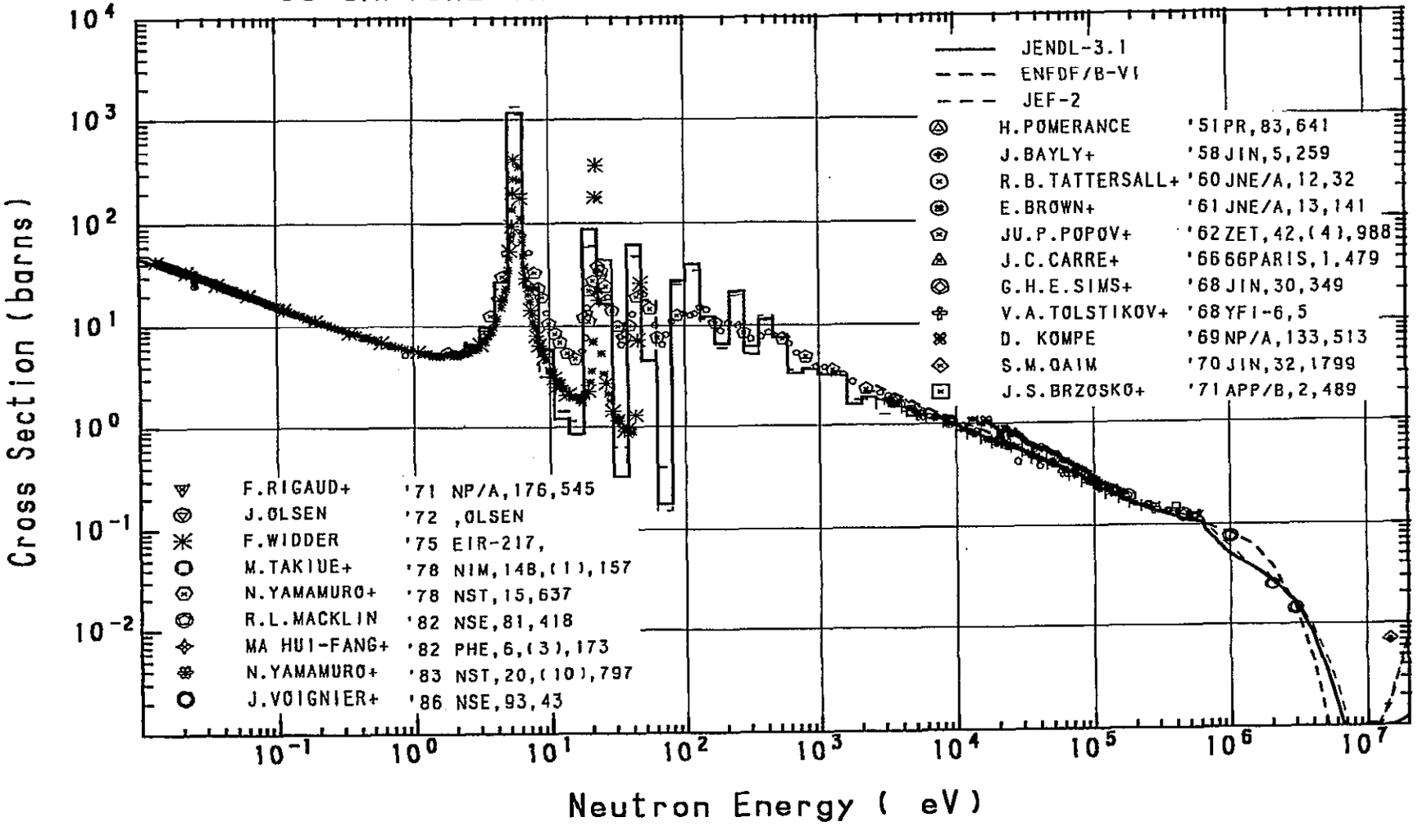

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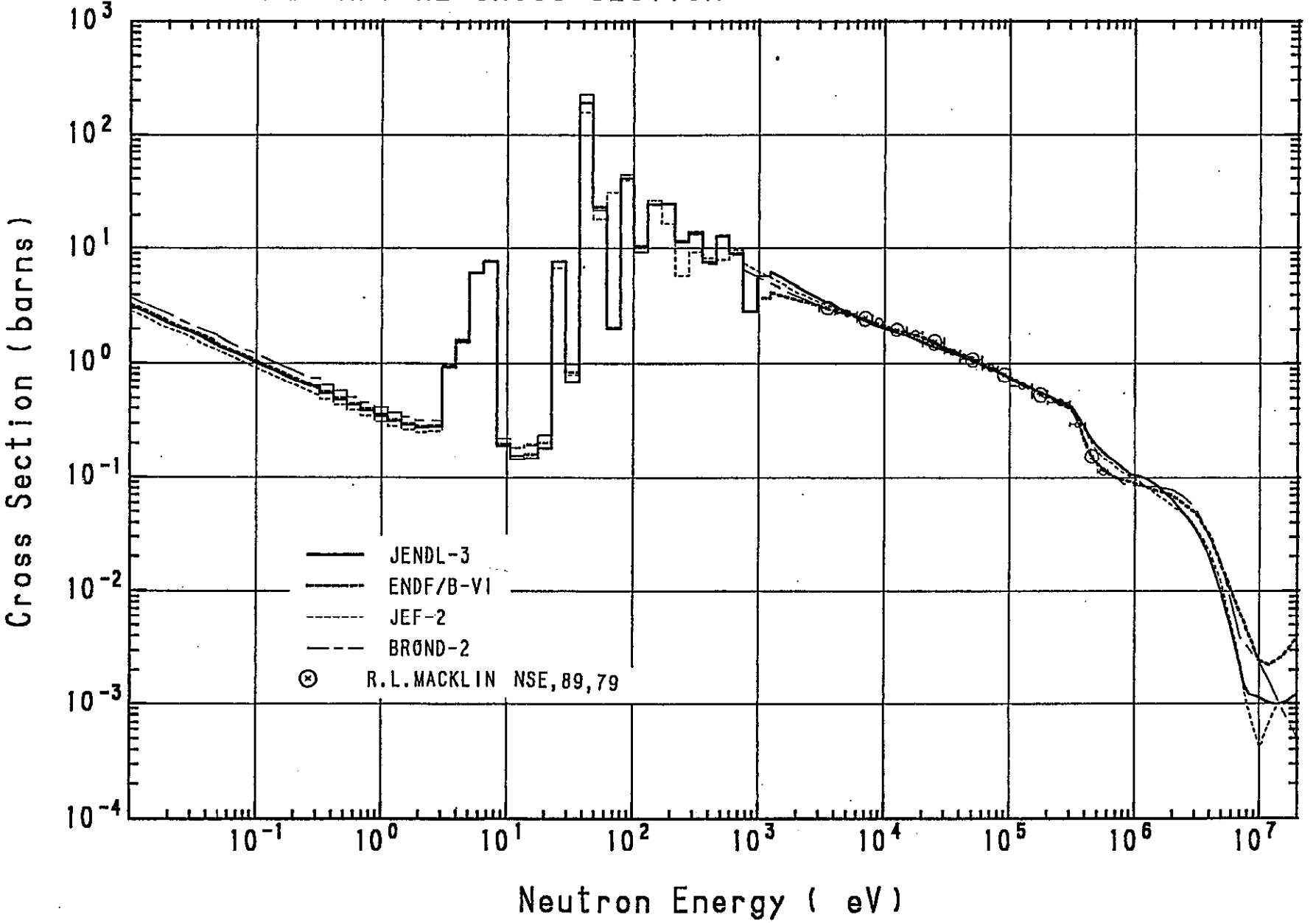

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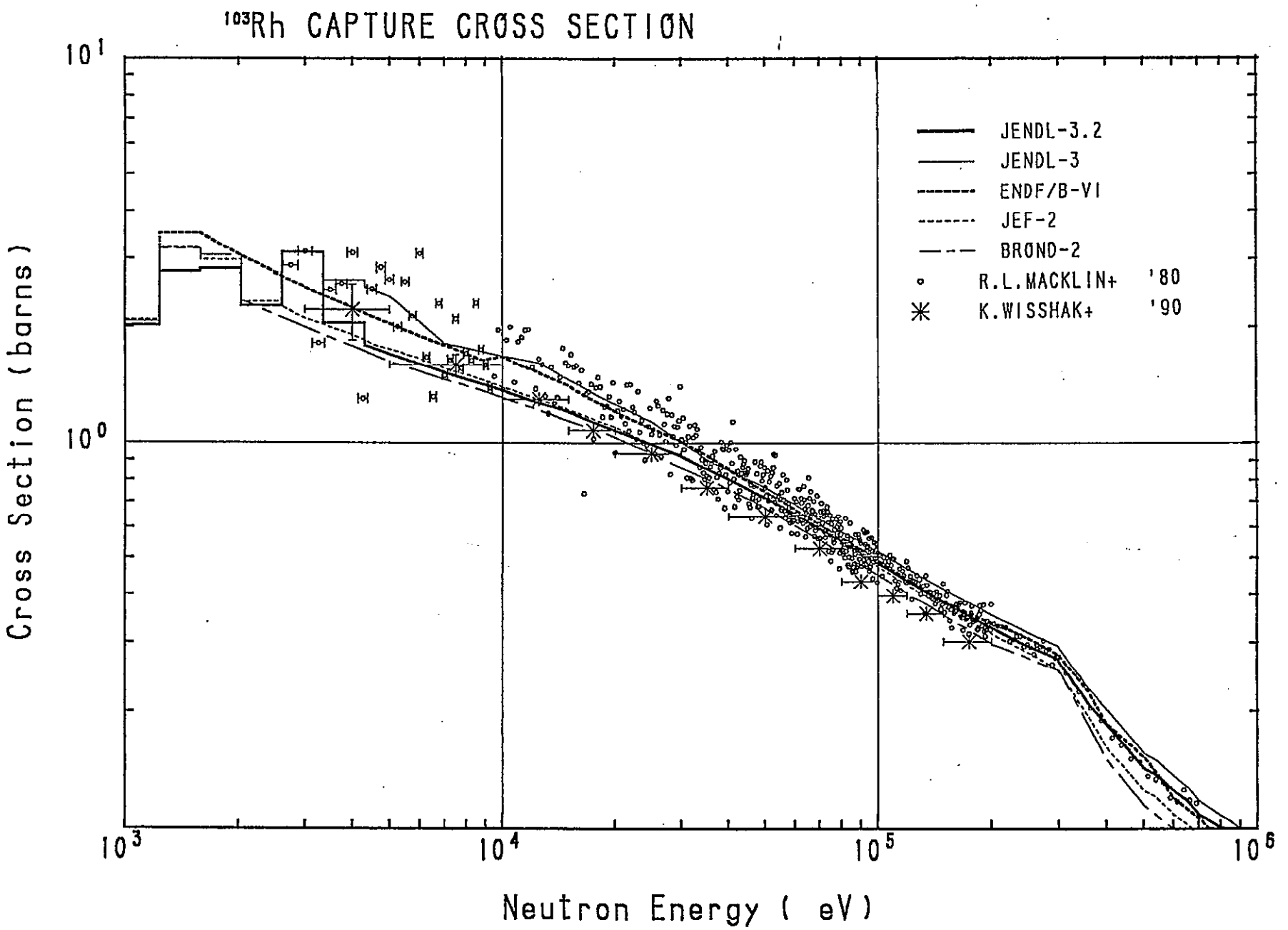
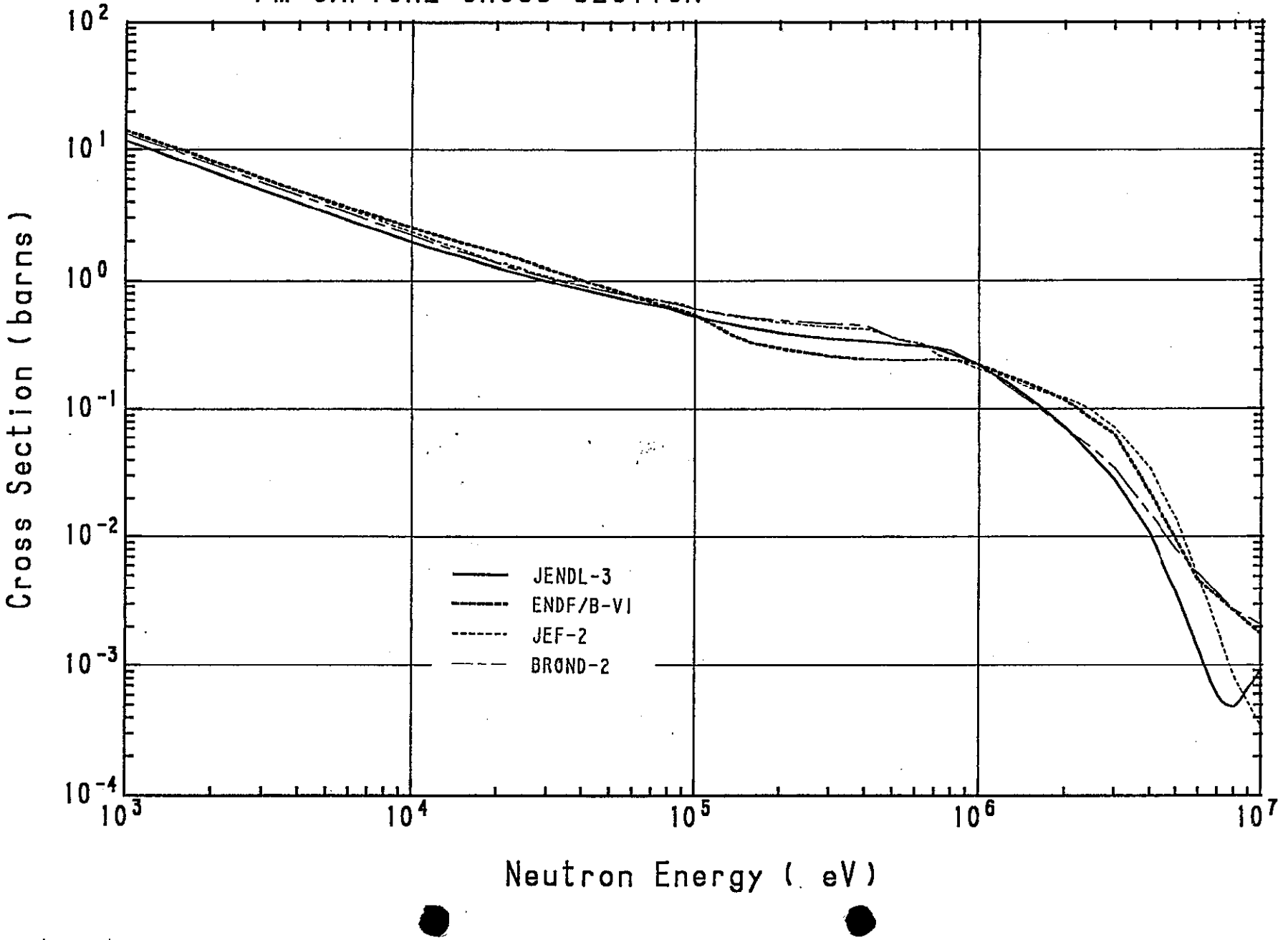

103Rh CAPTURE CROSS SECTION
Cross Section (barns)
Neutron Energy (eV)
JENDL-3.2
JENDL-3
ENDF/B-VI
JEF-2
BROND-2
R.L.MACKLIN+ '80
K.WISSHAK+ '90

1 - 1

^{147}Pm CAPTURE CROSS SECTION



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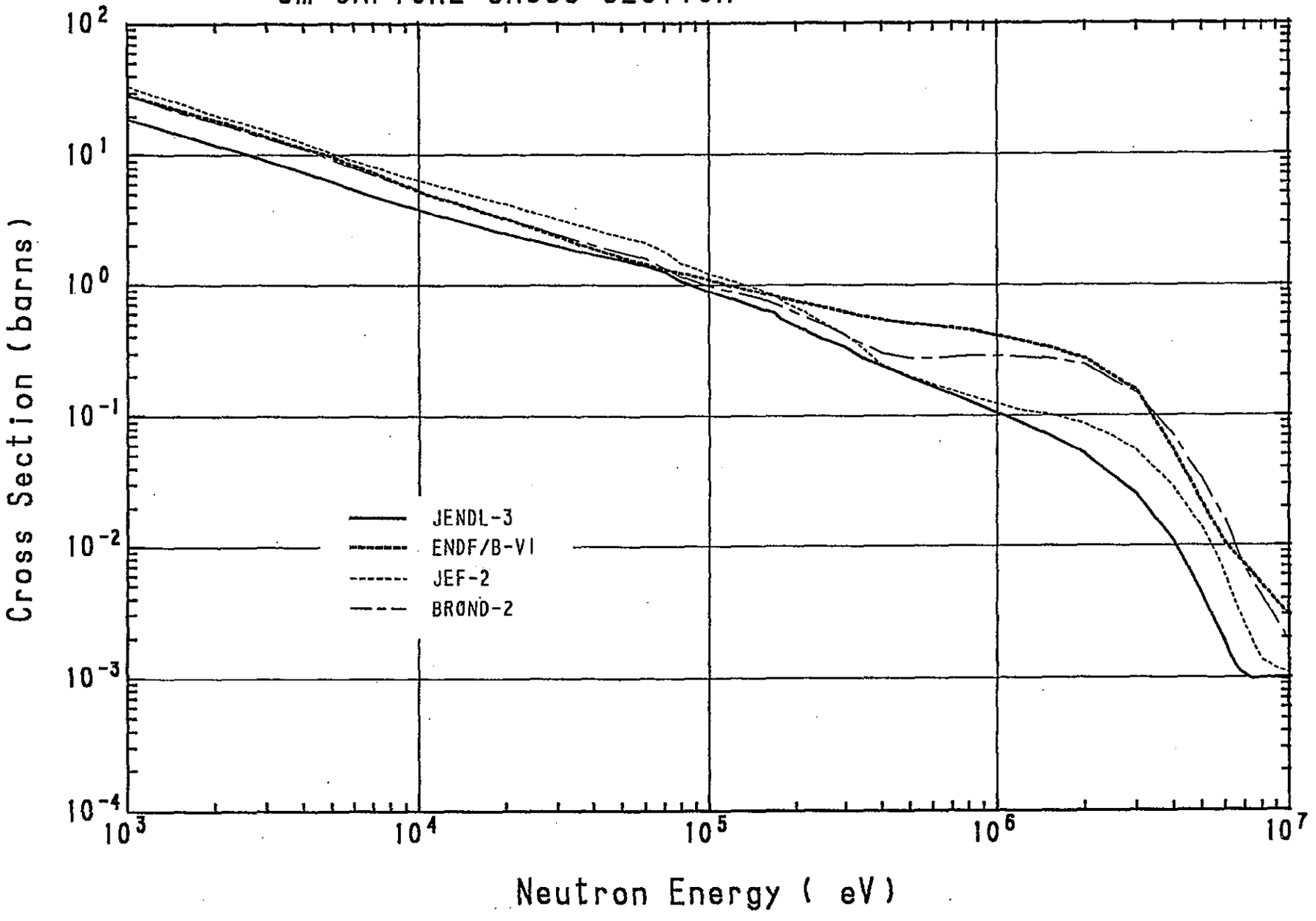
^{151}Sm CAPTURE CROSS SECTION



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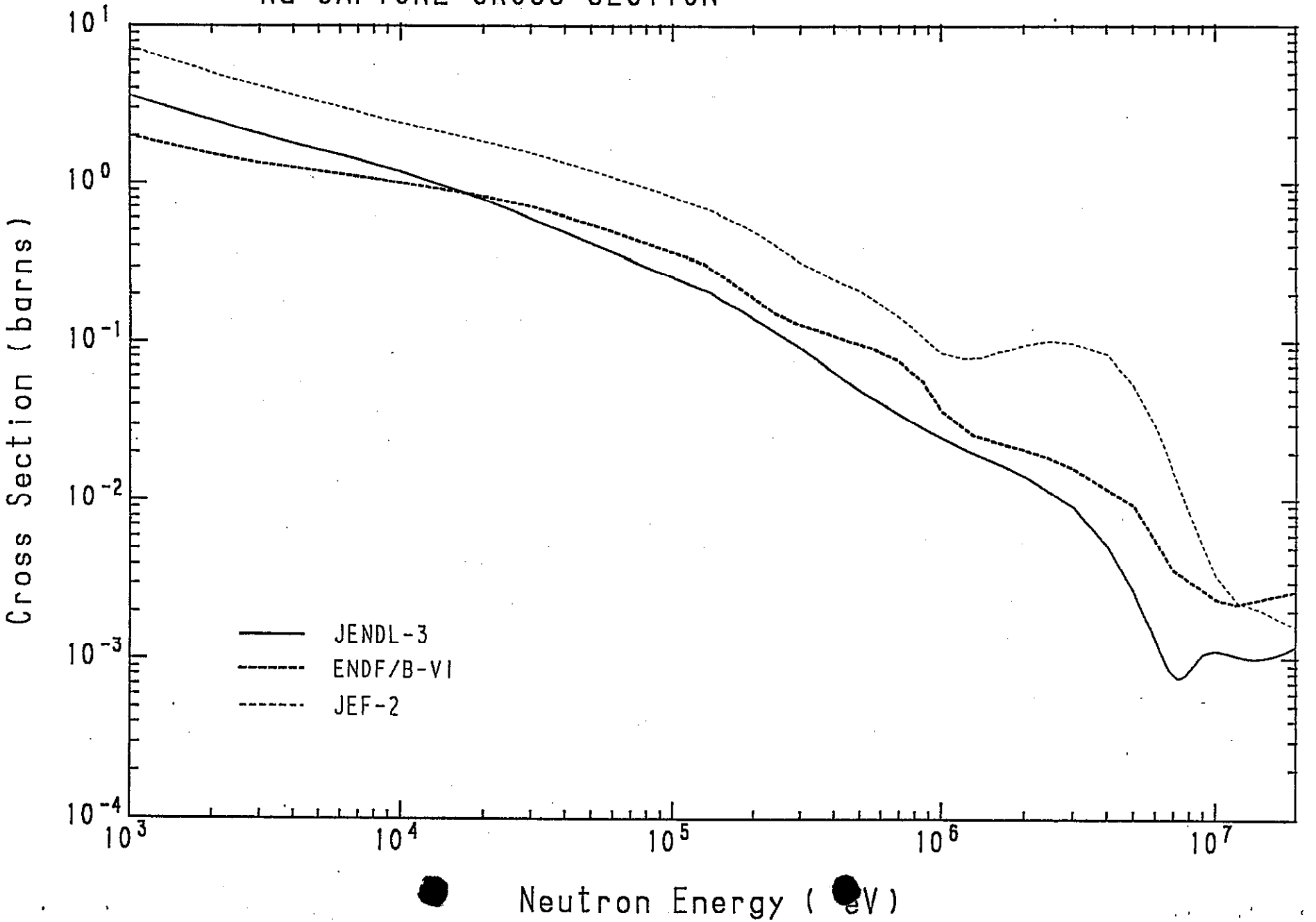

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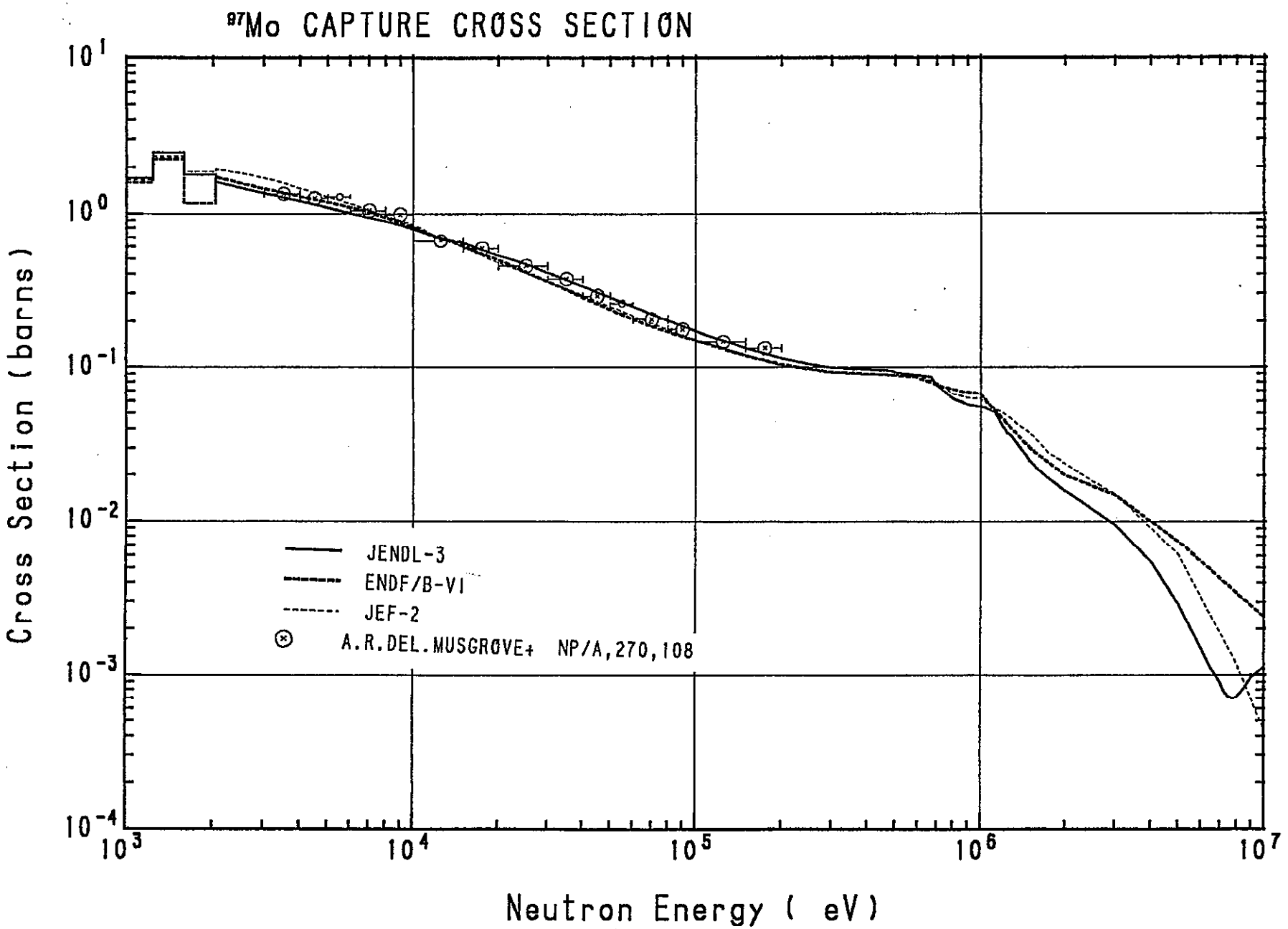
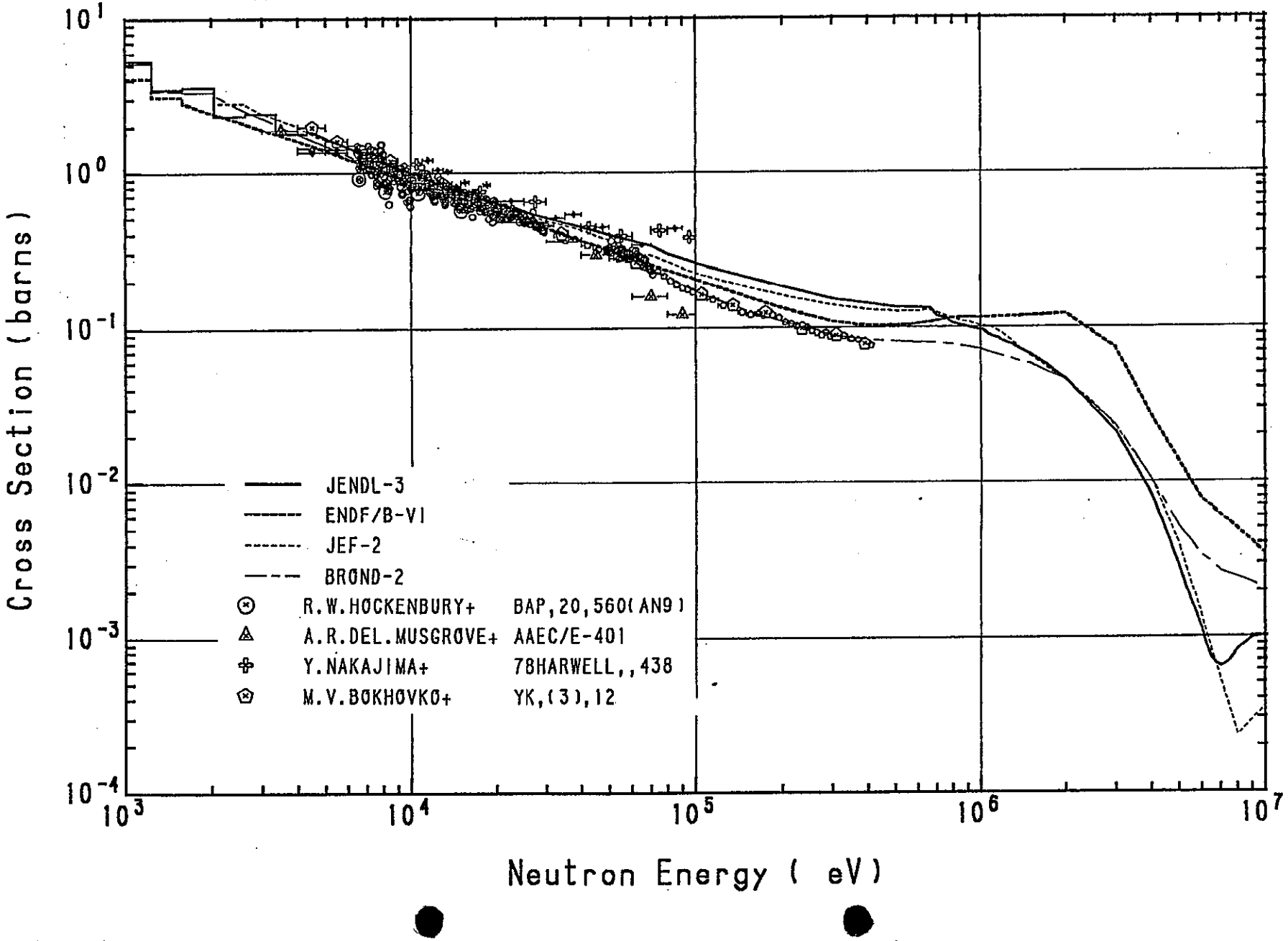
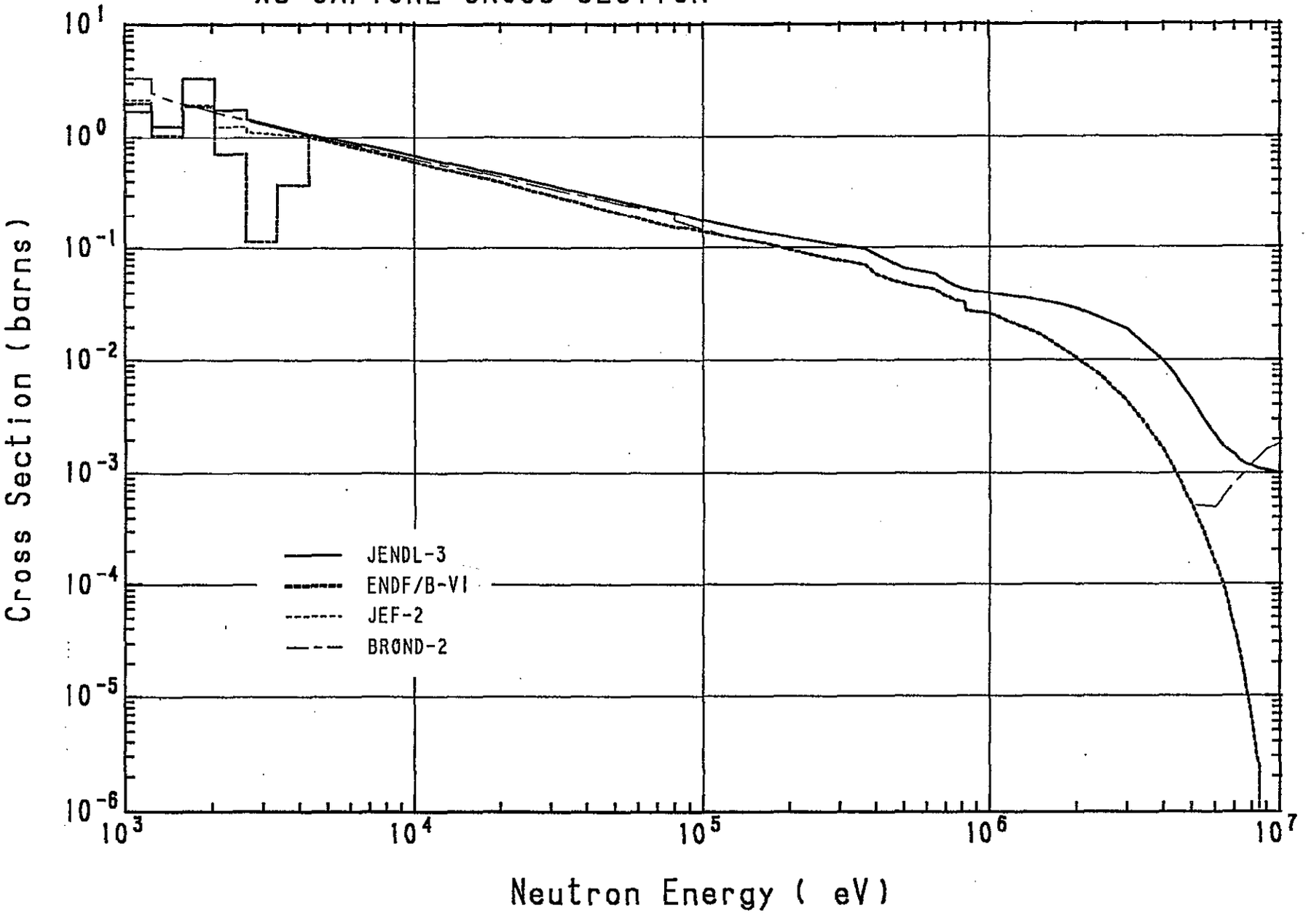


7 - 1

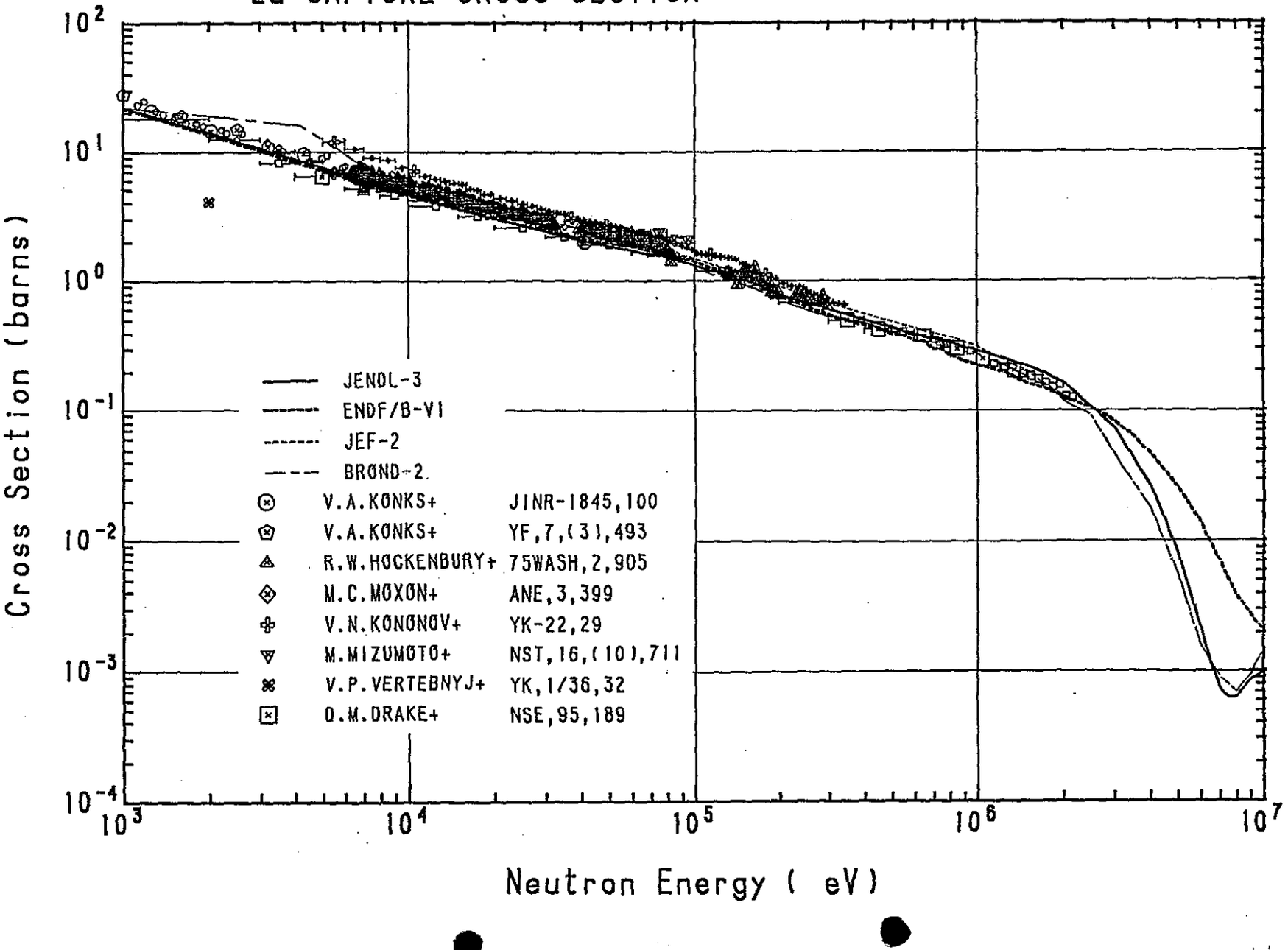

145Nd CAPTURE CROSS SECTION
Cross Section (barns)
Neutron Energy (eV)
JENDL-3
ENDF/B-VI
JEF-2
BROND-2
R.W.HOCKENBURY+ BAP,20,560(AN9)
A.R.DEL.MUSGROVE+ AAEC/E-401
Y.NAKAJIMA+ 78HARWELL,,438
M.V.BOKHOVKO+ YK,(3),12

^{131}Xe CAPTURE CROSS SECTION



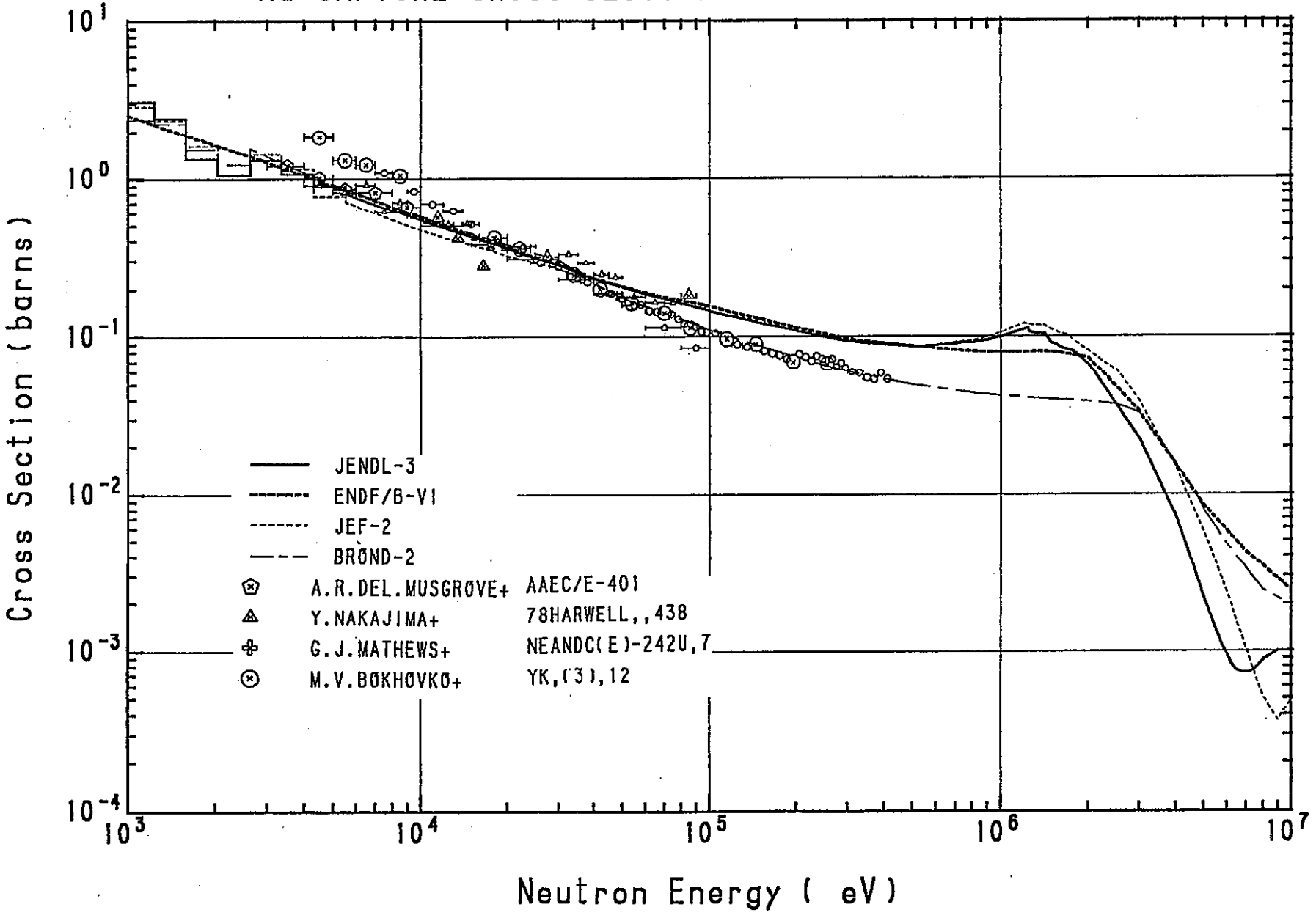
5 - 1

^{153}Eu CAPTURE CROSS SECTION



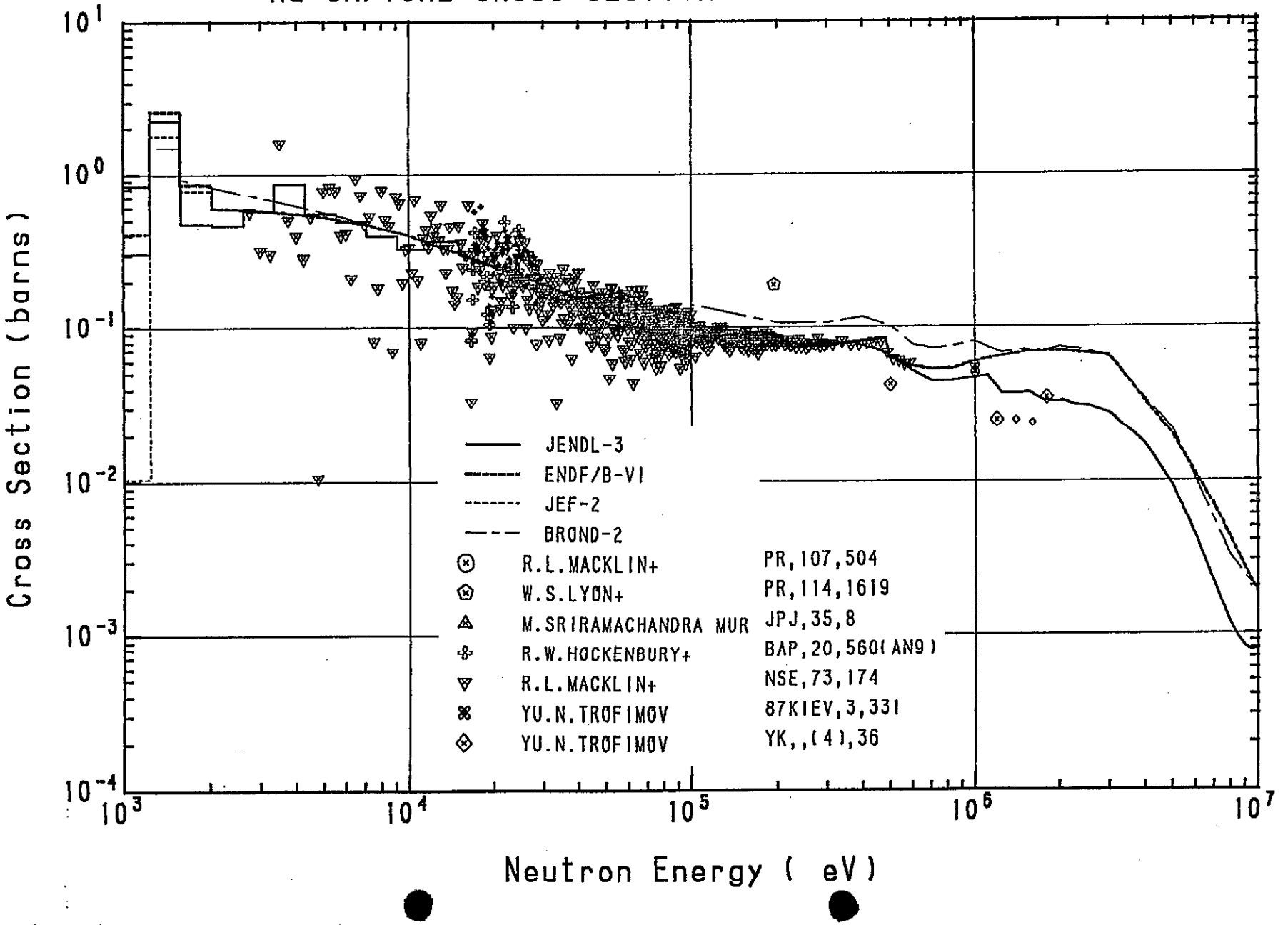
3 - 1

^{143}Nd CAPTURE CROSS SECTION

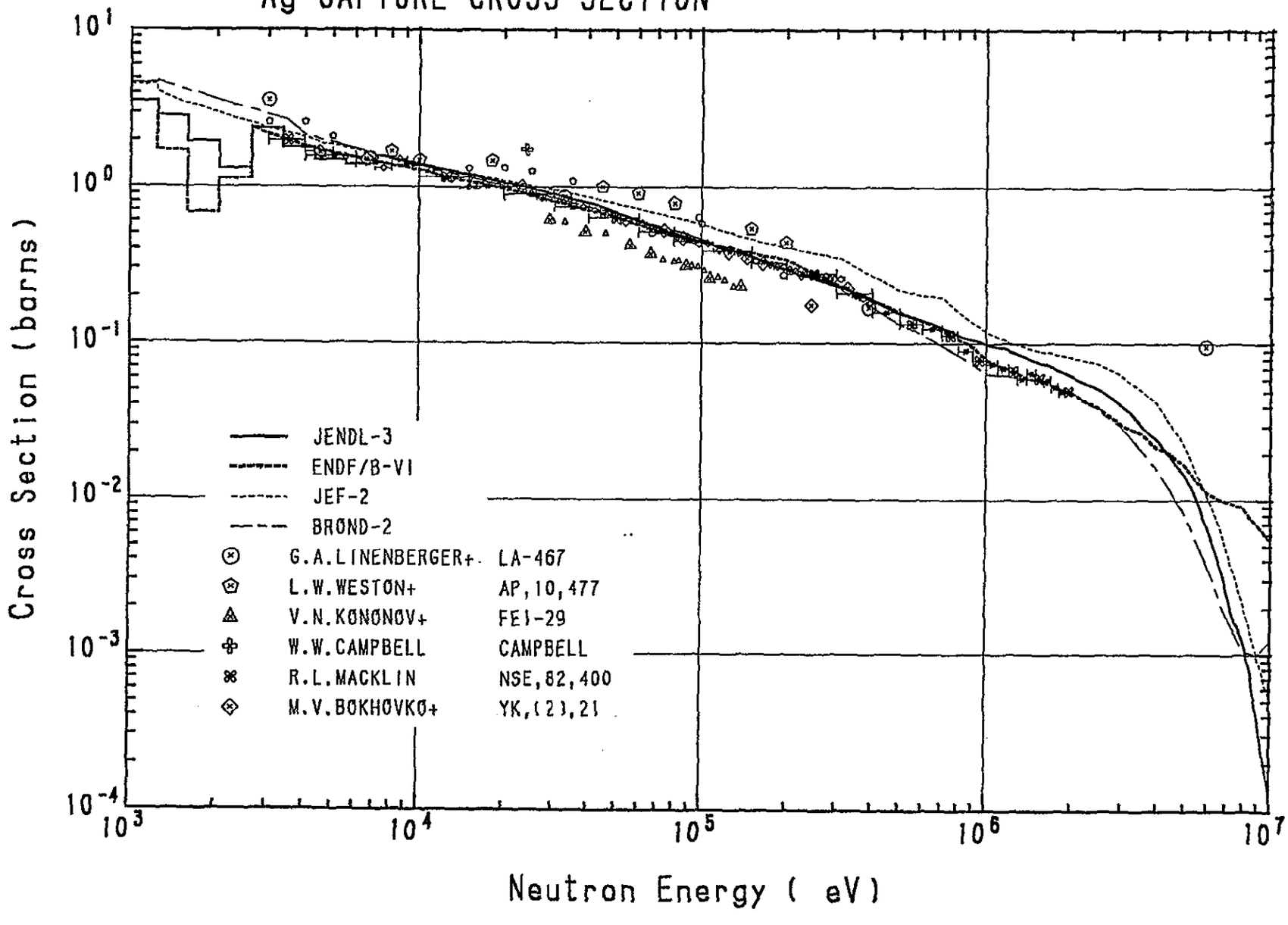


11 - 1

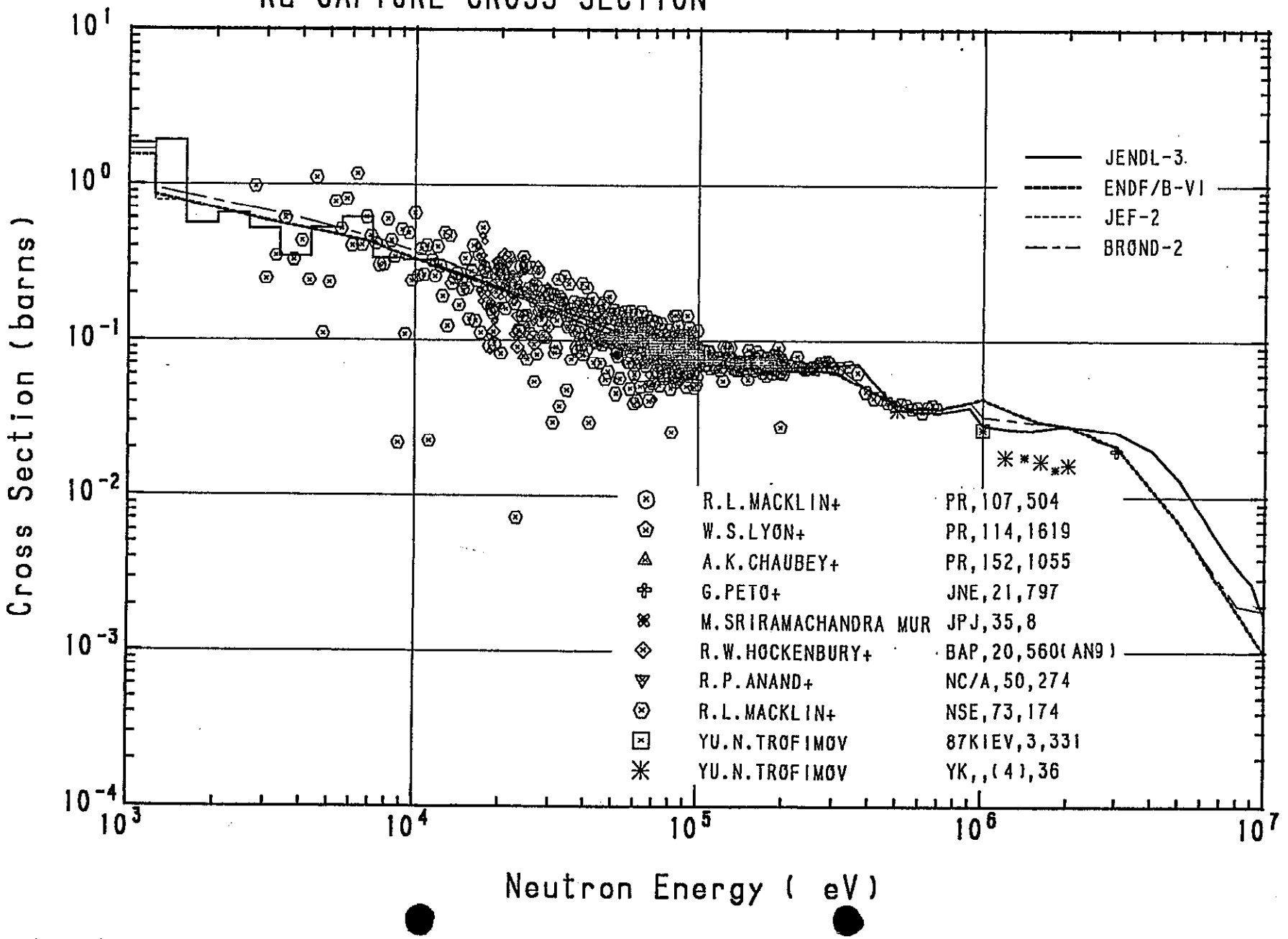
^{102}Ru CAPTURE CROSS SECTION



3 - 1

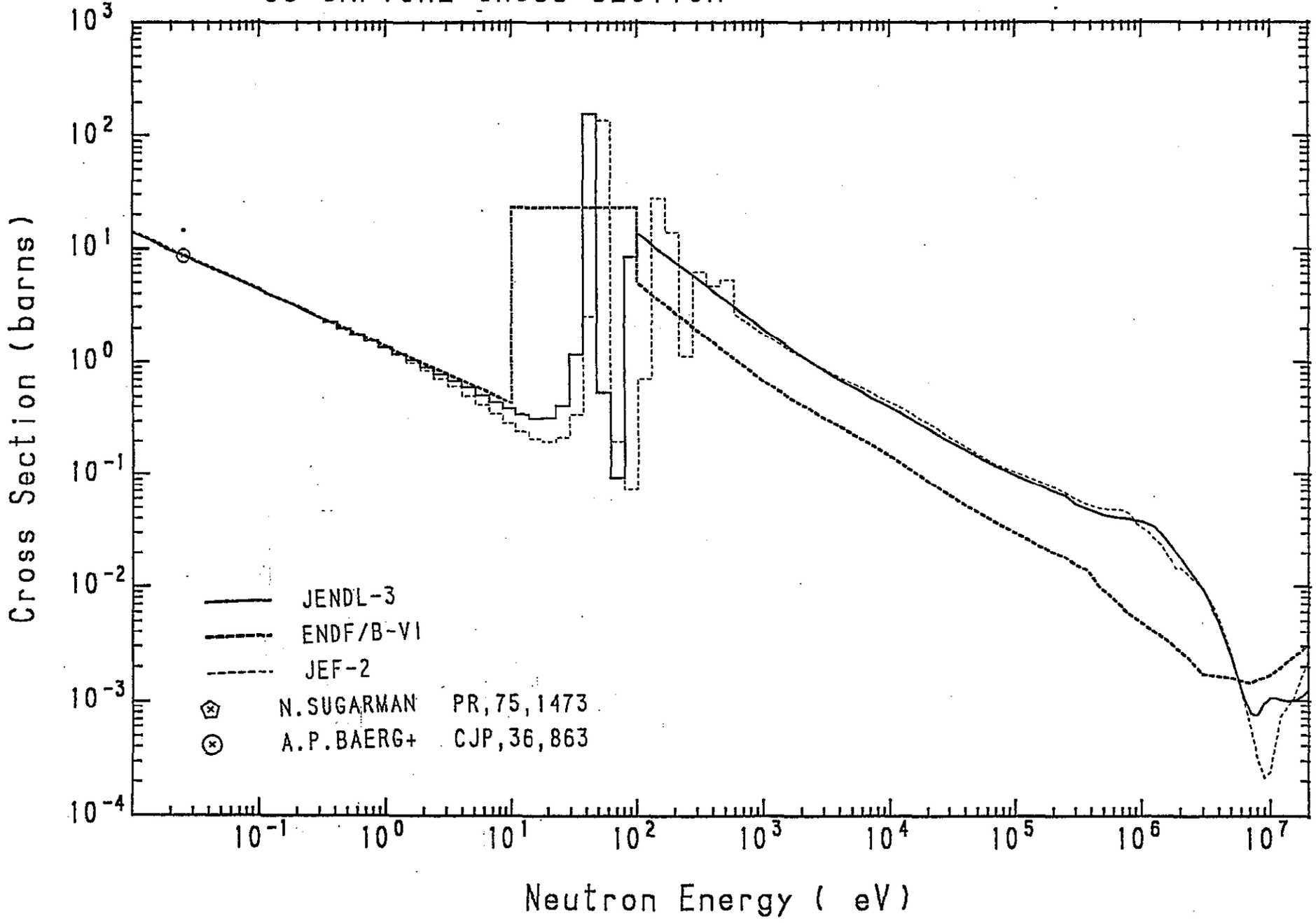

109Ag CAPTURE CROSS SECTION
Cross Section (barns)
Neutron Energy (eV)
JENDL-3
ENDF/B-VI
JEF-2
BROND-2
G.A.LINENBERGER+ LA-467
L.W.WESTON+ AP,10,477
V.N.KONONOV+ FEI-29
W.W.CAMPBELL CAMPBELL
R.L.MACKLIN NSE,82,400
M.V.BOKHOVKO+ YK,(2),21

3 - 1

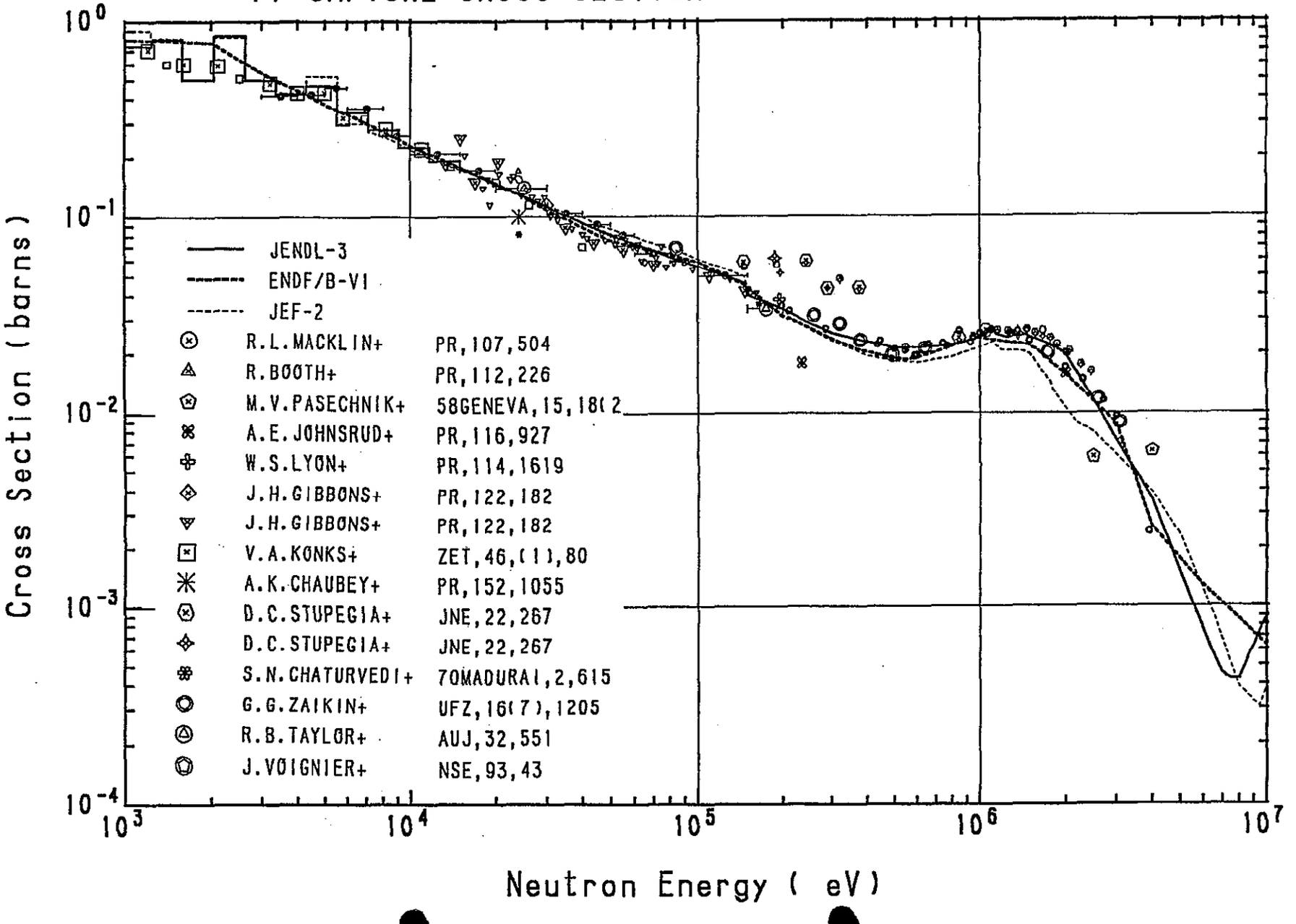

104Ru CAPTURE CROSS SECTION
Cross Section (barns)
Neutron Energy (eV)
JENDL-3
ENDF/B-VI
JEF-2
BROND-2
R.L.MACKLIN+ PR,107,504
W.S.LYON+ PR,114,1619
A.K.CHAUBEY+ PR,152,1055
G.PETO+ JNE,21,797
M.SRIRAMACHANDRA MUR JPJ,35,8
R.W.HOCKENBURY+ BAP,20,560(AN9)
R.P.ANAND+ NC/A,50,274
R.L.MACKLIN+ NSE,73,174
YU.N.TROFIMOV 87KIEV,3,331
YU.N.TROFIMOV YK,,(4),36

2 - 1

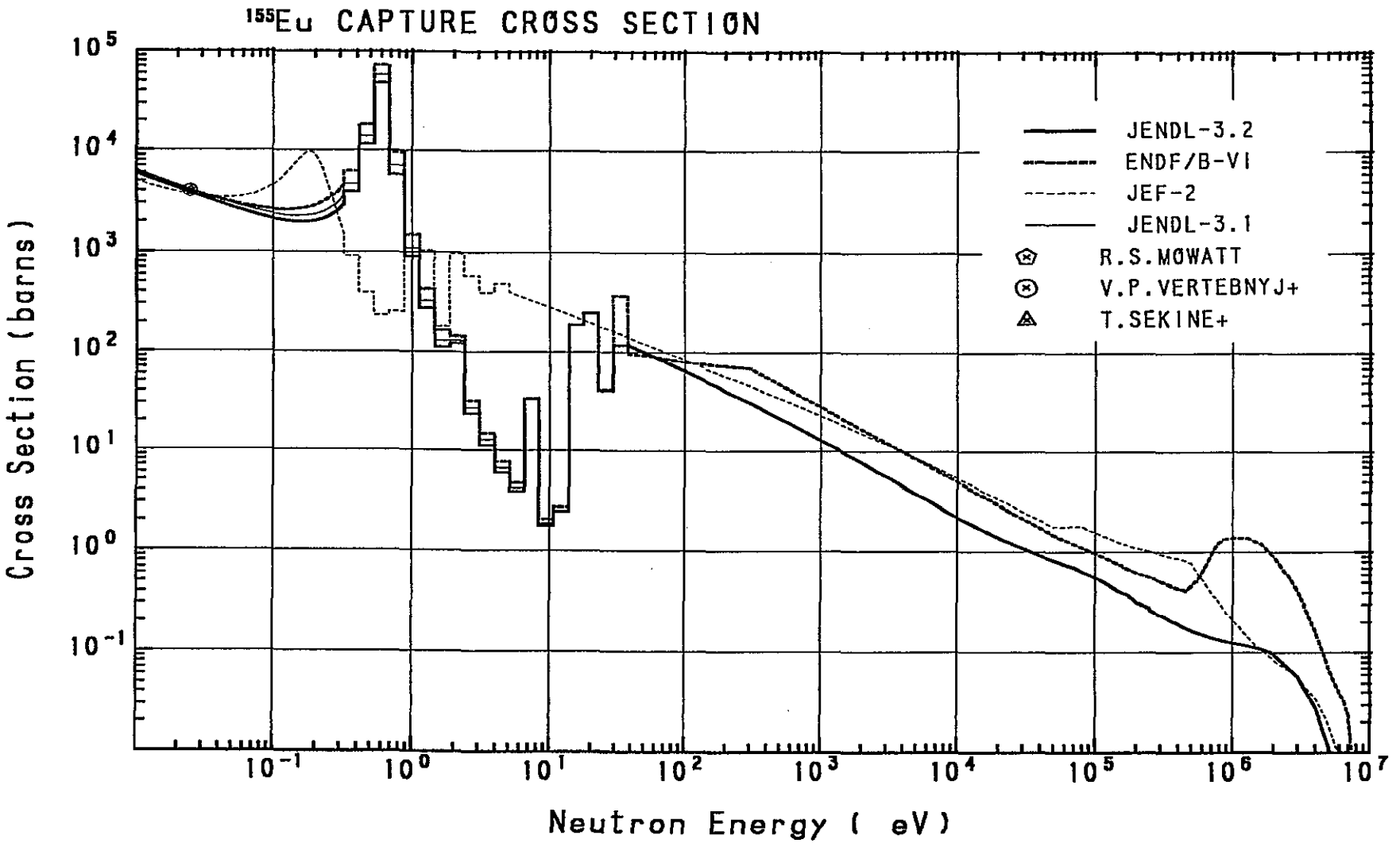
^{135}Cs CAPTURE CROSS SECTION



^{141}Pr CAPTURE CROSS SECTION

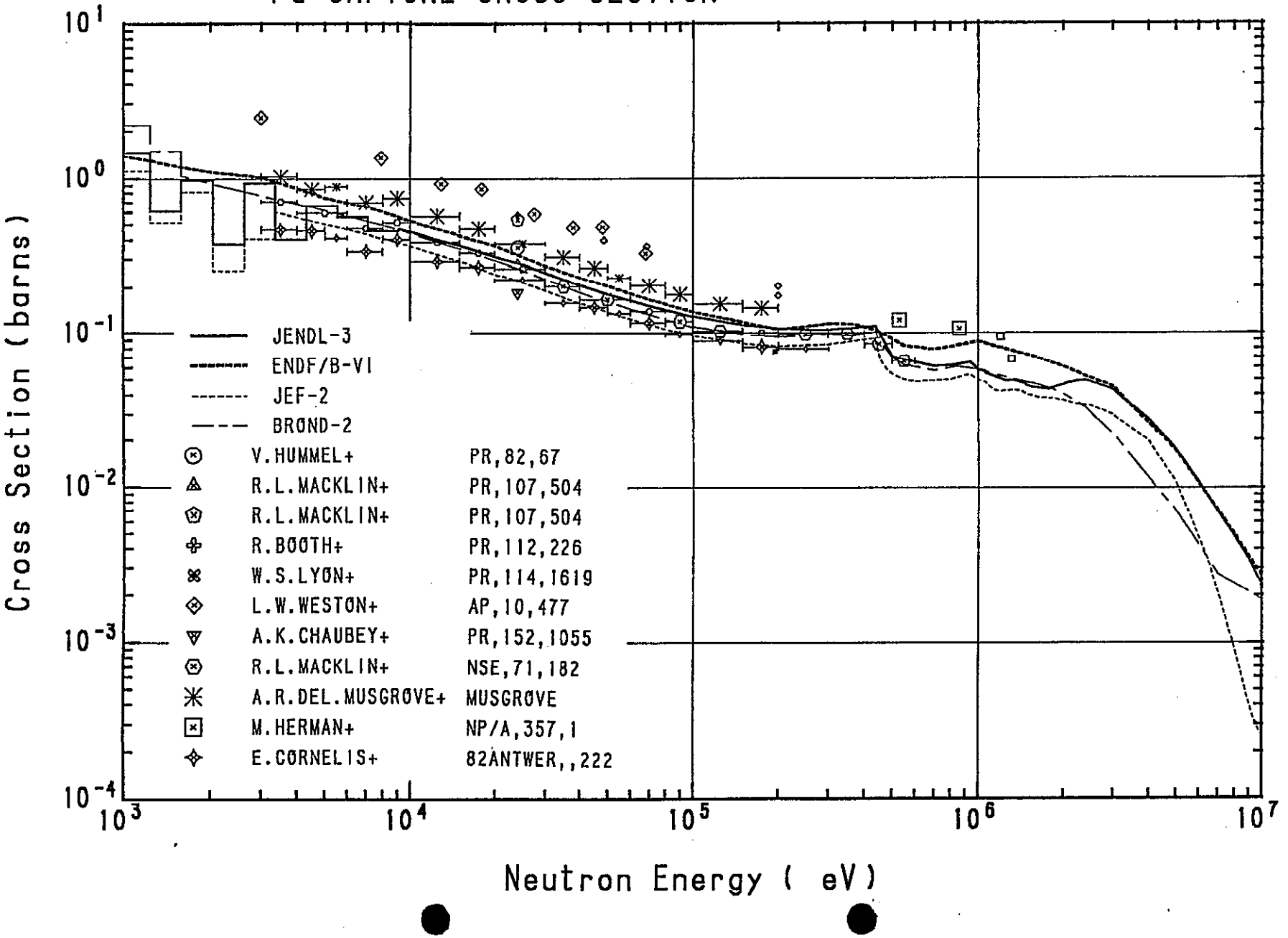


3 - 1

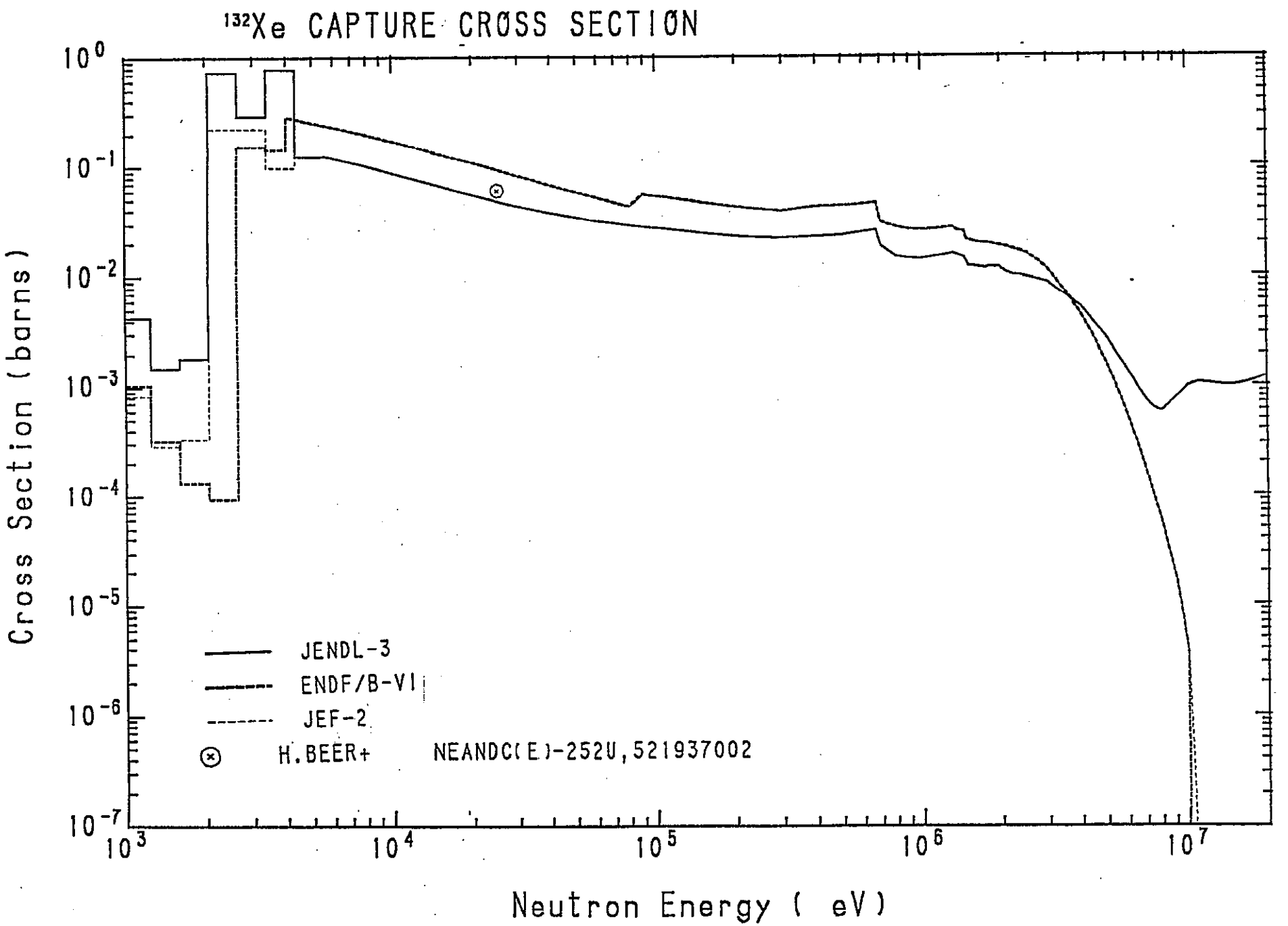

155Eu CAPTURE CROSS SECTION
Cross Section (barns)
Neutron Energy (eV)
JENDL-3.2
ENDF/B-VI
JEF-2
JENDL-3.1
R.S.MOWATT
V.P.VERTEBNYJ+
T.SEKINE+

11 - 1

^{108}Pd CAPTURE CROSS SECTION



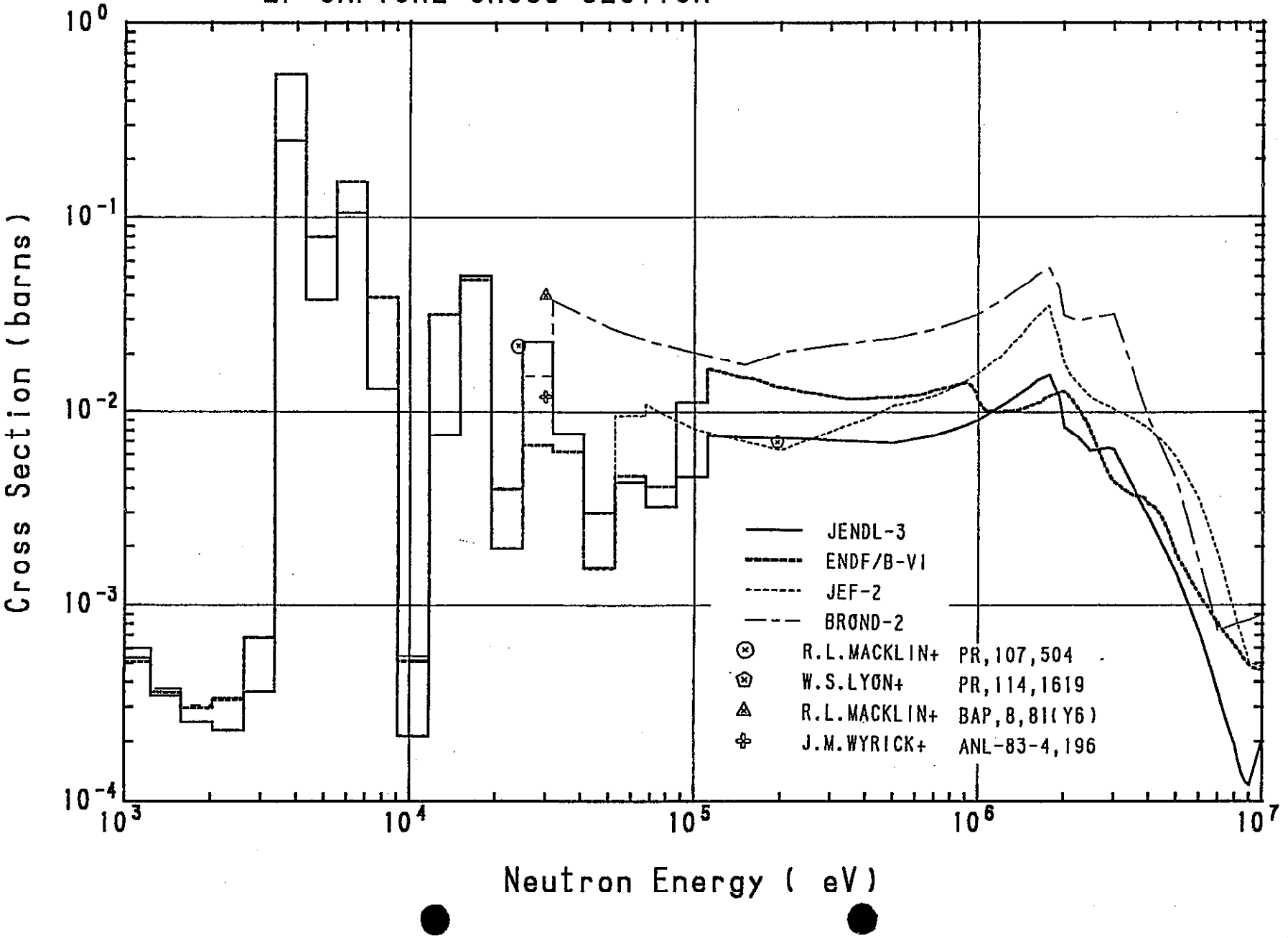
1 - 1


132Xe CAPTURE CROSS SECTION
Cross Section (barns)
Neutron Energy (eV)
JENDL-3
ENDF/B-VI
JEF-2
H.BEER+
NEANDC(E)-252U,521937002

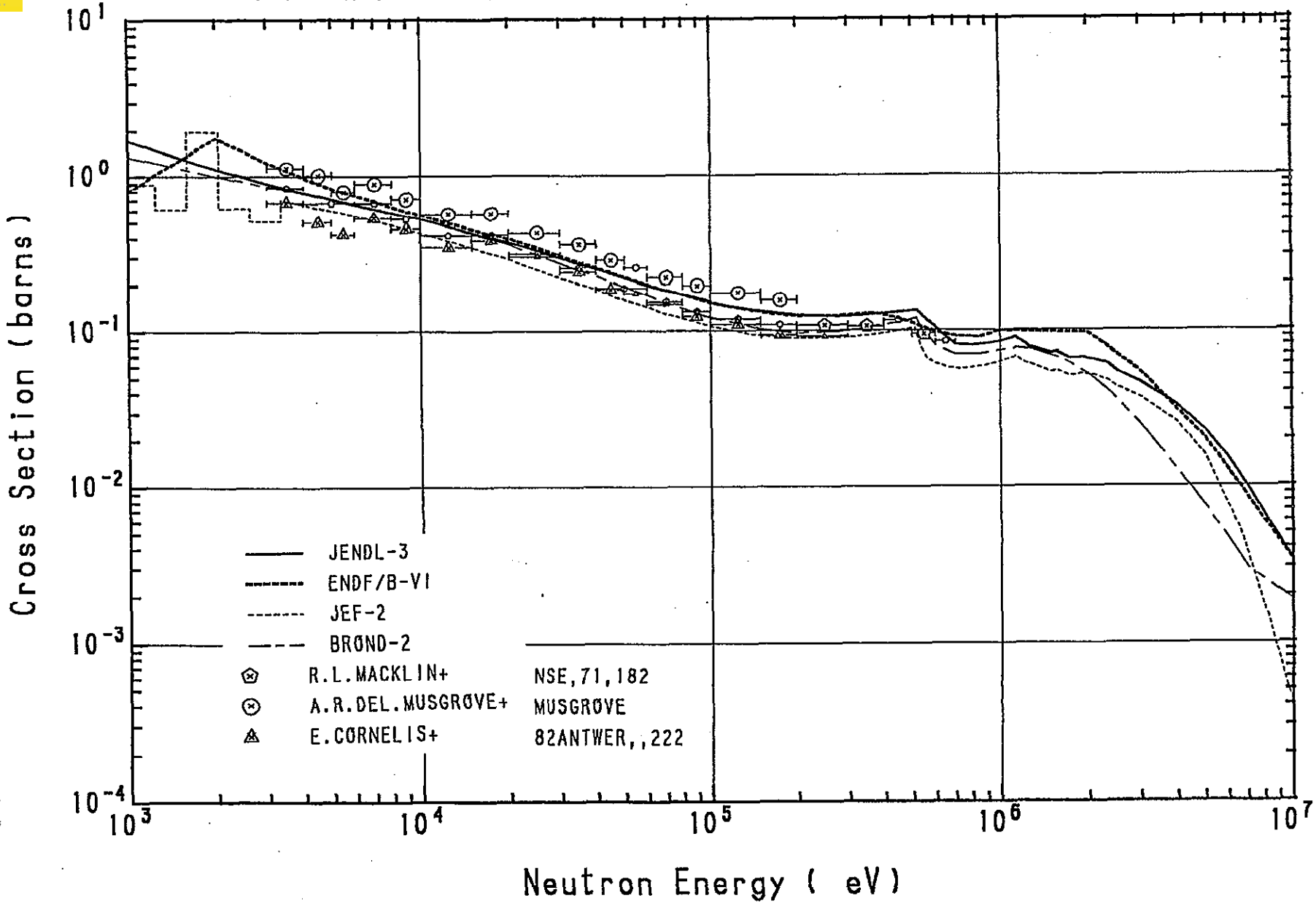
1507003?

13 - 1

^{96}Zr CAPTURE CROSS SECTION

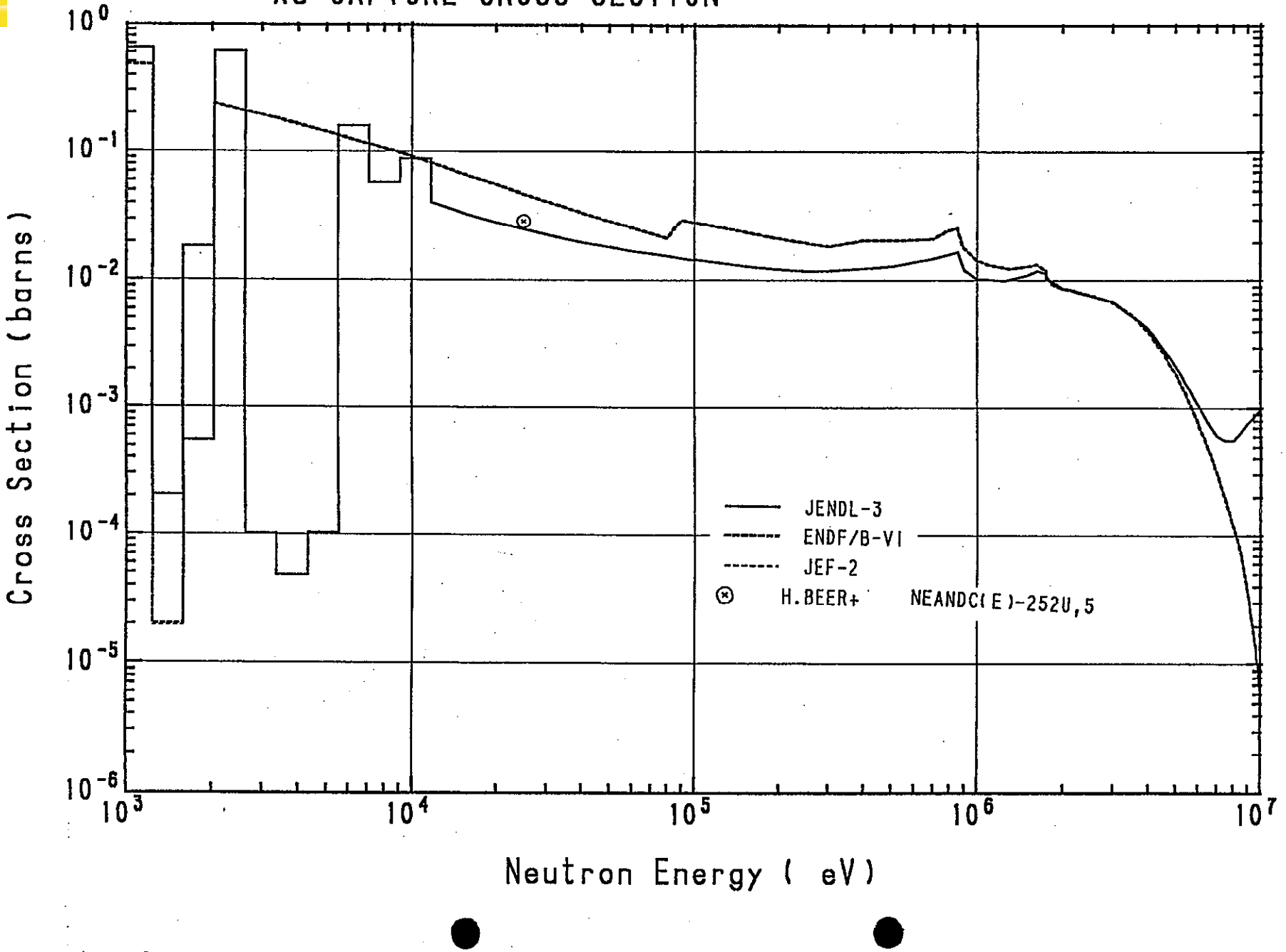


7 - 1



15 - 1

^{134}Xe CAPTURE CROSS SECTION



11 - 1

^{95}Zr CAPTURE CROSS SECTION