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SEPTEMBER 1976

COMPARISON OF INTEGRAL CROSS SECTION VALUES OF SEVERAL CROSS SECTION LIBRARIES IN THE SAND-II FORMAT

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Notice

As from 1 August 1976 our name has been changed from Stichting Reactor Centrum Nederland (RCN) to Stichting Energieonderzoek Centrum Nederland (ECN), i.e. Netherlands Energy Research Foundation, ECN.

This change of title is related to the Government's resolution to broaden our aims (previously restricted to research on the release of nuclear energy) to those of a research institute concerned with the whole field of energy supply.

Accordingly the alphabetical part of the identification number of our research reports has been changed from RCN to ECN. The last report in the previous series was RCN-249. The recent series starts with ECN-1.

Abstract:

A comparison of some integral cross section values for several cross section libraries in the SAND-II format is presented. The integral cross section values are calculated with aid of the spectrum functions for a Watt fission spectrum, a 1/E spectrum and a Maxwellian spectrum. The libraries which are considered here are CCC-112B, ENDF/B-IV, DETAN74, LAPENAS and CESNEF. These 5 cross section libraries used have all the SAND-II format.

Keywords:

cross sections
integrals
comparative evaluations
data processing
data
tables
Watt fission spectrum
Boltzmann statistics
spectral functions
resonance integrals

1. INTRODUCTION

In this report a comparison is given of the cross section libraries CCC-112B, ENDF/B-IV BNL, DETAN74, LAPENAS and CESNEF.
These libraries are written in the SAND-II groups format and can be used in neutron spectrum evaluations with the SAND-II program package |1|.
For the comparison use is made of integral cross section data obtained with a fission spectrum for the fast cross section part, a thermal Maxwellian for the thermal part and a 1/E for the intermediate part of the cross section distribution. The average value and the standard deviation of the integral cross section values were determined for each reaction of the different libraries.
Especially the standard deviation of this average value may show the agreement between the different cross sections for a particular reaction, but one has to be careful because a small standard deviation can also indicate that the original data for all evaluations were identical. In some cases where it was known that exactly the same cross section was present in two libraries only one of the integral values was applied in the calculation of the average and standard deviation (e.g. CCC-112B and DETAN74).

2. ORIGIN OF THE LIBRARIES

The cross section library coded CCC-112B is part of the code package SAND-II, which was received from the Reactor Shielding Information Centre (RSIC) in Oak Ridge. The library CCC-112B is a more recent version of the library described in |1|. The ENDF/B-IV dosimetry file has been described by Magurno |2|. This file includes also a few unmodified ENDF/B-III cross section data, e.g. for the reactions $^{32}S(n,p)$, $^{54}Fe(n,p)$, $^{56}Fe(n,p)$, $^{115}In(n,n')$ and $^{58}Ni(n,p)$. The cross section data in the 620 groups as used in the SAND-II program were kindly supplied by Dr. A. Fabry from the CEN/SCK at Mol in Belgium. These data have been coded here as ENDF/B-IV BNL. At present no description of the procedure for deriving these 620 groups cross section data is available.

The cross section library DETAN-74 and the accompanying documentation were also received from Dr. A. Fabry. This file contained the cross

section data also in the SAND-II energy structure. The DETAN-74 library is partly based on the data presented by Simons and McElroy |3|, and partly equal to data in the CCC-112B library. The DETAN-74 library contains 9 new cross section sets, obtained by adjustment of cross section sets, to achieve consistent results with integral measurements. The actual source of the adjusted cross section set and other details on the adjustment procedure are not available; it was explicitly stated that the DETAN-74 file does not contain recommended values.

The microscopic cross section data, on which our LAPENAS library in 620 groups structure is based, were received from Dr. M. Vlasov of the Nuclear Data Section of the IAEA in Vienna. The data were originally obtained in the form of a copy of the tables from the work of A.A. Lapenas |4| from the Physics Institute of the Letland Academy of Science at Riga. The library comprises 22 threshold reactions. The primary cross section values for each reaction were treated as point cross section values. They were available from threshold energy to about 17.5 MeV for energy steps of 0.1 MeV. For each evaluated point cross section value also the accompanying error is supplied. In our laboratory a conversion from point values to group values was performed. This conversion consisted of a linear interpolation between the successive cross section points and the determination of the (unweighted) average cross section value for each of the 620 energy groups.

The cross section library CESNEF is based on cross section data supplied by Dr. R. Dierckx (Joint Research Centre, Ispra) as part of the data set for an international intercomparison of neutron spectrum unfolding codes. The intercomparison was proposed in February 1974 by the subgroup on unfolding techniques of the EWGRD (Euratom Working Group on Reactor Dosimetry). The original data were supplied in the form of a lineprinter output. The library comprises 13 reactions. It was assumed that the values of the lineprinter output represented group cross section values. The group cross section values in the listing comprise the energy range from the threshold energy or from 0.5 eV up to 18 MeV, and are presented in the SAND-II group structure. The origin of the non-fission threshold reactions is given by Dierckx |5|. The choice of these reactions is made on the indications of the Nuclear Data Group (CNEN, Bologna, Italy). The $^{103}Rh(n,n')^{103}Rh^{m}$ cross section is based on the work by Butler and Santry |6|.

The $^{115}In(n,n')^{115}In^{m}$, $^{47}Ti(n,p)^{47}Sc$, $^{54}Fe(n,p)^{54}Mn$ and $^{46}Ti(n,p)^{46}Sc$ reaction cross sections originate from Simons and McElroy |3|.
The $^{238}U(n,f)^{140}Ba$ cross section is obtained from the UKAEA file (DFN4010, 1970).
The cross section data for the reactions $^{58}Ni(n,p)^{58}Co$, $^{24}Mg(n,p)^{24}Na$ and $^{27}Al(n,\alpha)^{24}Na$ are based on the work by Bresesti et al. |7|.
The cross section values for the fission reactions were supplied by the Centro di Calcolo, CNEN, Bologna, Italy.

3. PLOTS AND TABLES

Tables with the 620 group cross section values and corresponding plots have been prepared for each reaction present in the libraries mentioned. These tables and plots are given in RCN reports with restricted distribution, which are available on request (ref. 8 to 12).

4. CALCULATION OF INTEGRAL CROSS SECTIONS

The integral cross sections were calculated for three theoretical neutron spectrum functions:

a) The Maxwellian spectrum function describing the distributions of thermal neutrons corresponding to a temperature of 293 K was applied to calculate the average cross section.
   This spectrum function is given by the relation:

$$\chi_m(E) = 1.5918\times10^{15}E \exp(-3.987\times10^{7}E)$$

   where E is the neutron energy expressed in MeV. No upper cut-off was used.

b) The 1/E spectrum function for the calculation of the resonance integral.
   This function is applied as follows:

$$\chi_{1/E}(E) = 1/E \text{ for } 0.55 \text{ eV} < E < 1 \text{ MeV}$$

$$\chi_{1/E}(E) = 0 \quad \text{outside this range.}$$

c) The Watt spectrum function with an average neutron energy of 2 MeV was used to calculate the average fission cross section.

The following relation holds here:

$$\chi_w(E) = 0.484 \sinh(\sqrt{2E}) \times e^{-E}$$

where E is the neutron energy in MeV, comprising the energy range between 10^{-10} MeV and 18 MeV.

The integral cross section values for each spectrum function and reaction of the different libraries was averaged. As measure of the spread in the values of the 2, 3 or 4 libraries considered the standard deviation was chosen. This measure does not imply a preference for one set or the other, as for instance may occur when the average deviation from one reference set, or the range between extreme values is considered. The chosen measure serves only as an indication of a disagreement between different sets.

5. RESULTS

Table 1 presents the results for the Maxwell spectrum function.
The results for the 1/E neutron spectrum are given in table 2.
The average cross section for the Watt fission spectrum function are listed in table 3.
The last 2 columns of these tables show the average value and the standard deviations in these values.
For the Maxwellian spectrum (table 1) a standard deviation higher than 5% is found for the reaction $^{238}U(n,\gamma)^{239}$.
Table 2 shows a standard deviation higher than 5% for the reactions $^{23}Na(n,\gamma)^{24}Na$, $^{58}Fe(n,\gamma)^{59}Fe$, $^{63}Cu(n,\gamma)^{64}Cu$ and $^{115}In(n,\gamma)^{116}In^{m}$.
From table 3 it follows that for most threshold reactions the standard deviation is smaller than 5%.
Exceptions are found for the reactions $^{46}Ti(n,p)^{46}Sc$, $^{47}Ti(n,p)^{47}Sc$, $^{48}Ti(n,p)^{48}Sc$, $^{55}Mn(n,2n)^{54}Mn$, $^{60}Ni(n,p)^{60}Co$, $^{63}Cu(n,2n)^{62}Cu$, $^{64}Zn(n,p)^{64}Cu$ and $^{127}I(n,2n)^{126}I$.
In figures 1...4 the cross section distributions for the reaction $^{58}Ni(n,p)^{58}Co$ are shown. Figures 5...8 show the corresponding data for the reaction $^{54}Fe(n,p)^{54}Mn$.
From these figures it is clear that important deviations between corresponding cross sections of different libraries are easily detectable. Specially in the region of the sharp increase near the threshold different shapes have been found, but also above about 13 MeV the shapes differ.

DISCUSSION

From the numerical results presented in the tables it follows that for a number of reactions the integral values show an important scatter reflecting the discrepancies in the cross section data.
This is especially the case for the 1/E and the fission neutron spectrum.
The absence of scatter and the agreement does not necessarily imply the correctness of the cross section data, but it only represents consistency of the data files considered.
The consistency may be due to the absence of new experimental data.
We did not yet try to trace the origin of important differences. Our main interest was to look for systematic differences in the data sets, which influence the integral values of importance to reactor neutron metrology.
Moreover, a tracing of discrepancies would have delayed this report since the considerations of the evaluators were not all readily available.

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ACKNOWLEDGEMENT

The authors gratefully acknowledge the assistance of L.G.A. Kramer (student from the H.T.S. Dordrecht), who performed a large part of the data treatment necessary for this work.

Table 1: Maxwellian neutron spectrum

reaction	<σ> (in b)					average <σ>	standard deviation $s_{<\sigma>}$ (in %)
	CCC-112B	ENDF/B-IV BNL	DETAN74	LAPENAS	CESNEF		
$^{6}Li(n,\alpha)^{3}H$		$8.373\times10^{}$	$8.376\times10^{}$			8.375×10^{2}	0.03
$^{10}B\ (n,\alpha)^{7}Li$		3.417×10^{3}	3.417×10^{3}			3.417×10^{3}	0.00
$^{19}F\ (n,2n)^{18}F$							
$^{23}Na(n,\gamma)^{24}Na$	4.805×10^{-1}	4.757×10^{-1}	4.805×10^{-1} *			4.781×10^{-1}	0.71
$^{24}Mg(n,p)^{24}Na$							
$^{27}Al(n,\alpha)^{24}Na$							
$^{27}Al(n,p)^{27}Mg$							
$^{28}Si(n,p)^{28}Al$							
$^{31}P\ (n,p)^{31}Si$							
$^{32}S\ (n,p)^{32}P$							
$^{34}S\ (n,\alpha)^{31}Si$							
$^{35}Cl(n,\alpha)^{32}P$							
$^{45}Sc(n,\gamma)^{46}Sc$	2.244×10^{1}	2.349×10^{1}	2.244×10^{1} *			2.297×10^{1}	3.23
$^{46}Ti(n,p)^{46}Sc$							
$^{47}Ti(n,p)^{47}Sc$							
$^{47}Ti(n,np)^{46}Sc$							
$^{48}Ti(n,p)^{48}Sc$							
$^{48}Ti(n,np)^{47}Sc$							
$^{54}Fe(n,p)^{54}Mn$							
$^{55}Mn(n,\gamma)^{56}Mn$	1.185×10^{1}		1.185×10^{1} *				
$^{55}Mn(n,2n)^{54}Mn$							
$^{56}Fe(n,p)^{56}Mn$							
$^{58}Ni(n,2n)^{57}Ni$							
$^{58}Ni(n,p)^{58}Co$							
$^{59}Co(n,\alpha)^{56}Mn$							
$^{58}Fe(n,\gamma)^{59}Fe$		1.052×10^{0}	1.063×10^{0} *			1.059×10^{0}	0.74
$^{59}Co(n,\gamma)^{60}Co$	3.288×10^{1}	3.318×10^{1}	3.288×10^{1} *			3.303×10^{1}	0.64
$^{59}Co(n,\alpha)^{56}Mn$							
$^{60}Ni(n,p)^{60}Co$							
$^{63}Cu(n,2n)^{62}Cu$							
$^{63}Cu(n,\alpha)^{60}Co$			$4.371\ 10^{-6}$ **				
$^{63}Cu(n,\gamma)^{64}Cu$	4.019×10	4.005×10^{0}	4.019×10^{0} *			4.012×10^{0}	0.25

Table 1 (continued):

reaction	$\langle\sigma\rangle$ (in b)					average $\langle\sigma\rangle$	standard deviation $s_{\langle\sigma\rangle}$ (in %)
	CCC-112B	ENDF/B-IV BNL	DETAN74	LAPENAS	CESNEF		
$^{64}Zn(n,p)^{64}Cu$							
$^{64}Zn(n,2n)^{63}Zn$							
$^{65}Cu(n,2n)^{64}Cu$							
$^{90}Zr(n,p)^{90}Y$							
$^{90}Zr(n,2n)^{89}Zr$							
$^{103}Rh(n,n')^{103}Rh^m$							
$^{109}Ag(n,\gamma)^{110}Ag^m$			3.681×10^{0}				
$^{115}In(n,n')^{115}In^m$							
$^{115}In(n,\gamma)^{116}In^m$	1.411×10^{2}	1.510×10^{2}	1.411×10^{2} *			1.461×10^{2}	4.79
$^{127}I\ (n,2n)^{126}I$							
$^{151}Eu(n,\gamma)^{152}Eu$	7.453×10^{3}						
$^{164}Dy(n,\gamma)^{165}Dy$	2.218×10^{3}						
$^{175}Lu(n,\gamma)^{176}Lu^m$	2.254×10^{1}						
$^{176}Lu(n,\gamma)^{177}Lu$	3.014×10^{3}						
$^{181}Ta(n,\gamma)^{181}Ta$			1.865×10^{1}				
$^{197}Au(n,\gamma)^{198}Au$	8.813×10^{2}	8.847×10^{2}	8.844×10^{2}			8.835×10^{2}	0.21
$^{232}Th(n,f)FP$							
$^{232}Th(n,\gamma)^{233}Th$	6.936×10^{0}	6.563×10^{0}	6.936×10^{0} *			6.750×10^{2}	3.91
$^{232}Th(n,2n)^{231}Th$							
$^{235}U\ (n,f)FP$	4.989×10^{2}	5.096×10^{2}	5.051×10^{2}		4.989×10^{2}	5.021×10^{2}	1.02
$^{237}Np(n,f)FP$	1.654×10^{-2}	1.429×10^{-2}	1.654×10^{-2} *		1.654×10^{-2}	1.579×10^{-2}	8.23
$^{238}U\ (n,f)FP$		4.104×10^{-9} ***					
$^{238}U\ (n,f)^{239}U$	2.661×10^{0}	2.411×10^{0}	2.661×10^{0} *			2.536×10^{0}	6.97
$^{239}Pu(n,f)FP$		6.969×10^{2}	6.959×10^{2}			6.855×10^{2}	2.76
$^{241}Am(n,f)FP$					2.022×10^{-7}		

*Cross section set DETAN74 = cross section set CCC-112B (only one value applied for the calculation of averag_ value and the standard deviation).

**The DETAN-74 cross section data for the $^{63}Cu(n,\alpha)^{60}Co$ reaction show subthreshold activation, corresponding to a 1/v shape.

***This values is due to subthreshold fission with sharp peaks in the keV region superimposed on a small 1/v contribution.

Table 2: The 1/E neutron spectrum

reaction	σ (in b) CCC-112B	ENDF/B-IV BNL	DETAN74	LAPENAS	CESNEF	average σ	standard deviation s_σ (in %)
$^{6}Li(n,\alpha)^{3}H$		4.002×10^{2}	4.001×10^{2}			4.002×10^{2}	0.01
$^{10}B\ (n,\alpha)^{7}Li$		1.622×10^{3}	1.622×10^{3}			1.622×10^{3}	0.00
$^{19}F\ (n,2n)^{18}F$							
$^{23}Na(n,\gamma)^{24}Na$	2.864×10^{-1}	3.315×10^{-1}	2.864×10^{-1} *			3.090×10^{-1}	10.3
$^{24}Mg(n,p)^{24}Na$							
$^{27}Al(n,\alpha)^{24}Na$							
$^{27}Al(n,p)^{27}Mg$							
$^{28}Si(n,p)^{28}Al$							
$^{31}P\ (n,p)^{31}Si$							
$^{32}S\ (n,p)^{32}P$		1.226×10^{-6}					
$^{34}S\ (n,\alpha)^{31}Si$							
$^{35}Cl(n,\alpha)^{32}P$							
$^{45}Sc(n,\gamma)^{46}Sc$	9.953×10^{1}	1.060×10^{1}	9.953×10^{0} *			1.028×10^{1}	4.45
$^{46}Ti(n,p)^{46}Sc$							
$^{47}Ti(n,p)^{47}Sc$		3.500×10^{-5}	3.669×10^{-5}		3.449×10^{-5}	3.539×10^{-5}	3.25
$^{47}Ti(n,np)^{46}Sc$							
$^{48}Ti(n,p)^{48}Sc$							
$^{48}Ti(n,np)^{47}Sc$							
$^{54}Fe(n,p)^{54}Mn$			2.039×10^{-5}	6.000×10^{-5}		4.020×10^{-5}	69.7
$^{55}Mn(n,\gamma)^{56}Mn$	1.560×10^{1}		1.560×10^{1} *				
$^{55}Mn(n,2n)^{54}Mn$							
$^{56}Fe(n,p)^{56}Mn$							
$^{58}Ni(n,2n)^{57}Ni$							
$^{58}Ni(n,p)^{58}Co$			1.163×10^{-5}	4.000×10^{-5}	4.375×10^{-5}	3.179×10^{-5}	55.3
$^{58}Fe(n,\gamma)^{59}Fe$		1.558×10^{0}	1.398×10^{0}			1.478×10^{0}	7.66
$^{59}Co(n,2n)^{58}Co$							
$^{59}Co(n,\gamma)^{60}Co$	7.254×10^{1}	7.576×10^{1}	7.254×10^{1} *			7.415×10^{1}	3.07
$^{59}Co(n,\alpha)^{56}Mn$							
$^{60}Ni(n,p)^{60}Co$							
$^{63}Cu(n,2n)^{62}Cu$							
$^{63}Cu(n,\alpha)^{60}Co$			6.169×10^{-6}				
$^{63}Cu(n,\gamma)^{64}Cu$	4.664×10^{0}	5.386×10^{0}	4.664×10^{0} *			5.025×10^{0}	10.2

Table 2 (continued):

reaction	σ (in b)					average σ	standard deviation s_σ (in %)
	CCC-112B	ENDF/B-IV BNL	DETAN74	LAPENAS	CESNEF		
$^{64}Zn(n,p)^{64}Cu$							
$^{64}Zn(n,2n)^{63}Zn$							
$^{65}Cu(n,2n)^{64}Cu$							
$^{90}Zr(n,p)^{90}Y$							
$^{90}Zr(n,2n)^{89}Zr$							
$^{103}Rh(n,n')^{103}Rh^m$				3.697×10^{-1}	4.005×10^{-1}	3.851×10^{-1}	5.66
$^{109}Ag(n,\gamma)^{110}Ag^m$			6.552×10^{1}				
$^{115}In(n,n')^{115}In^m$		1.800×10^{-2}	2.146×10^{-2}	2.022×10^{-2}	2.069×10^{-2}	2.009×10^{-2}	7.39
$^{115}In(n,\gamma)^{116}In^m$	2.842×10^{3}	3.230×10^{3}	2.842×10^{3} *			3.036×10^{3}	9.04
$^{127}I\ (n,2n)^{126}I$							
$^{151}Eu(n,\gamma)^{152}Eu$	2.365×10^{3}						
$^{164}Dy(n,\gamma)^{165}Dy$	4.192×10^{2}						
$^{175}Lu(n,\gamma)^{176}Lu^m$	1.189×10^{3}						
$^{176}Lu(n,\gamma)^{177}Lu$	1.461×10^{3}						
$^{181}Ta(n,\gamma)^{182}Ta$			7.634×10^{2}				
$^{197}Au(n,\gamma)^{198}Au$	1.616×10^{3}	1.564×10^{3}	1.600×10^{3}			1.597×10^{3}	1.95
$^{232}Th(n,f)FP$				1.827×10^{-4}	5.625×10^{-4}	3.726×10^{-4}	72.1
$^{232}Th(n,\gamma)^{233}Th$	8.021×10^{1}	8.512×10^{1}	8.021×10^{1} *			8.267×10^{1}	4.20
$^{232}Th(n,2n)^{231}Th$							
$^{235}U\ (n,f)FP$	2.870×10^{2}	2.702×10^{2}	2.702×10^{2}		2.870×10^{2}	2.786×10^{2}	3.48
$^{237}Np(n,f)FP$	9.825×10^{0}	1.214×10^{0}	9.825×10^{-1} *	9.426×10^{-1}	9.826×10^{-1}	1.030×10^{0}	12.0
$^{238}U\ (n,f)FP$		4.580×10^{-3}	3.925×10^{-3}	3.259×10^{-3}	3.358×10^{-3}	3.781×10^{-3}	16.1
$^{238}U\ (n,\gamma)^{239}U$	2.800×10^{2}	2.769×10^{2}	2.800×10^{2} *			2.785×10^{2}	0.79
$^{239}Pu(n,f)FP$		2.919×10^{2}	2.797×10^{2}			2.858×10^{2}	3.02
$^{241}Am(n,f)FP$					1.393×10^{1}		

*Cross section set DETAN74 = cross section set CCC-112B (only one value applied for the calculation of average value and the standard deviation).

Table 3: Watt fission neutron spectrum

reaction	(in b)					average <σ>	standard deviation s.d. (in %)
	CCC-112B	ENDF/B-IV BNL	DETAN74	LAPENAS	CESNEF		
$^{6}Li(n,\alpha)^{3}H$		4.795×10^{-1}	5.672×10^{-1}			4.734×10^{-1}	1.84
$^{10}B(n,\alpha)^{7}Li$		5.038×10^{-1}	5.605×10^{-1}			5.322×10^{-1}	7.53
$^{19}F(n,2n)^{18}F$				6.633×10^{-6}			
$^{23}Na(n,\gamma)^{24}Na$	2.686×10^{-4}	2.849×10^{-4}	2.686×10^{-4}*			2.768×10^{-4}	4.17
$^{24}Mg(n,p)^{24}Na$	1.498×10^{-4}		1.498×10^{-4}*	1.515×10^{-3}	1.446×10^{-3}	1.486×10^{-3}	2.42
$^{27}Al(n,\alpha)^{24}Na$	6.631×10^{-4}	6.843×10^{-4}	6.830×10^{-4}*	6.872×10^{-4}	6.896×10^{-4}	6.810×10^{-4}	1.79
$^{27}Al(n,p)^{27}Mg$		4.100×10^{-3}	3.837×10^{-3}	3.901×10^{-3}		3.947×10^{-3}	3.45
$^{28}Si(n,p)^{28}Al$	9.709×10^{-3}						
$^{31}P(n,p)^{31}Si$	3.301×10^{-3}		3.301×10^{-3}*				
$^{32}S(n,p)^{32}P$	6.092×10^{-2}	6.505×10^{-2}	6.091×10^{-2}*	6.304×10^{-2}		6.300×10^{-2}	3.28
$^{32}S(n,\alpha)^{29}Si$	2.234×10^{-4}						
$^{35}Cl(n,\alpha)^{32}P$	1.326×10^{-3}						
$^{45}Sc(n,\gamma)^{46}Sc$	6.241×10^{-3}	5.715×10^{-3}	6.241×10^{-3}*			5.965×10^{-3}	5.92
$^{46}Ti(n,p)^{46}Sc$	1.128×10^{-2}	9.920×10^{-3}	1.128×10^{-2}*		1.130×10^{-2}	1.083×10^{-2}	7.30
$^{47}Ti(n,p)^{47}Sc$	1.719×10^{-2}	2.174×10^{-2}	1.719×10^{-2}*		1.719×10^{-2}	1.871×10^{-2}	14.0
$^{47}Ti(n,np)^{46}Sc$		3.171×10^{-4}					
$^{48}Ti(n,p)^{48}Sc$	2.364×10^{-4}	1.695×10^{-4}	2.364×10^{-4}*			2.030×10^{-4}	23.3
$^{48}Ti(n,np)^{47}Sc$		1.820×10^{-4}					
$^{54}Fe(n,p)^{54}Mn$	7.628×10^{-2}	7.846×10^{-2}	7.627×10^{-2}*	8.358×10^{-2}	7.634×10^{-2}	7.866×10^{-2}	4.30
$^{55}Mn(n,\gamma)^{56}Mn$	3.561×10^{-3}		3.560×10^{-3}*				
$^{55}Mn(n,2n)^{54}Mn$		2.320×10^{-4}		2.003×10^{-4}		2.162×10^{-4}	10.4
$^{54}Fe(n,p)^{54}Mn$	1.086×10^{-3}	1.035×10^{-3}	1.086×10^{-3}*	1.099×10^{-3}		1.073×10^{-3}	3.15
$^{58}Ni(n,2n)^{57}Ni$	2.393×10^{-4}	2.539×10^{-4}	2.393×10^{-4}*	2.438×10^{-4}		2.456×10^{-4}	3.16
$^{58}Ni(n,p)^{58}Co$	1.022×10^{-1}	1.028×10^{-1}	1.022×10^{-1}*	1.132×10^{-1}	1.043×10^{-2}	1.056×10^{-1}	4.85
$^{58}Fe(n,\gamma)^{59}Fe$	2.864×10^{-3}	1.675×10^{-3}	2.864×10^{-3}*			2.270×10^{-3}	37.0
$^{59}Co(n,2n)^{58}Co$		1.624×10^{-4}					
$^{59}Co(n,\alpha)^{56}Co$	5.316×10^{-4}	6.381×10^{-4}	5.315×10^{-4}*			5.849×10^{-4}	12.9
$^{59}Co(n,\alpha)^{56}Mn$		1.457×10^{-4}		1.561×10^{-4}		1.509×10^{-4}	4.87
$^{60}Ni(n,p)^{60}Co$	5.302×10^{-3}	2.443×10^{-3}				3.873×10^{-3}	52.2
$^{63}Cu(n,2n)^{62}Cu$	8.46×10^{-5}		8.463×10^{-5}*	7.816×10^{-5}		8.140×10^{-5}	5.62
$^{63}Cu(n,\alpha)^{60}Co$	3.562×10^{-4}	3.471×10^{-4}	4.728×10^{-4}			3.920×10^{-4}	17.9
$^{63}Cu(n,\alpha)^{60m}Cu$	1.088×10^{-2}	1.082×10^{-2}	1.087×10^{-2}*			1.085×10^{-2}	0.39

Table 3 (continued):

reaction	$\langle\sigma\rangle$ (in b)					average $\langle\sigma\rangle$	standard deviation $s_{\langle\sigma\rangle}$ (in %)
	CCC-112B	ENDF/B-IV BNL	DETAN74	LAPENAS	CESNEF		
$^{64}Zn(n,p)^{64}Cu$	3.800×10^{-2}			4.293×10^{-2}		4.047×10^{-2}	8.62
$^{64}Zn(n,2n)^{63}Zn$				1.657×10^{-5}			
$^{65}Cu(n,2n)^{64}Cu$		2.976×10^{-4}		3.135×10^{-4}		3.056×10^{-4}	3.68
$^{90}Zr(n,p)^{90}Y$				3.566×10^{-4}			
$^{90}Zr(n,2n)^{89}Zr$	7.952×10^{-5}		7.952×10^{-5}*				
$^{103}Rh(n,n')^{103}Rh^{m}$				7.134×10^{-1}	7.221×10^{-1}	7.178×10^{-1}	0.86
$^{109}Ag(n,\gamma)^{110}Ag^{m}$			1.151×10^{-2}				
$^{115}In(n,n')^{115}In^{m}$	1.853×10^{-1}	1.704×10^{-1}	1.853×10^{-1}*	1.770×10^{-1}	1.846×10^{-1}	1.793×10^{-1}	3.93
$^{115}In(n,\gamma)^{116}In^{m}$	1.464×10^{-1}	1.350×10^{-1}	1.463×10^{-1}*			1.407×10^{-1}	5.73
^{127}I $(n,2n)^{126}I$	6.865×10^{-4}	1.149×10^{-3}	6.864×10^{-4}*			9.177×10^{-4}	35.6
$^{151}Eu(n,\gamma)^{152}Eu$	2.109×10^{-1}						
$^{164}Dy(n,\gamma)^{165}Dy$	9.893×10^{-2}						
$^{175}Lu(n,\gamma)^{176}Lu^{m}$	8.328×10^{-3}						
$^{176}Lu(n,\gamma)^{177}Lu$	1.305×10^{-1}						
$^{181}Ta(n,\gamma)^{182}Ta$			1.035×10^{-1}				
$^{197}Au(n,\gamma)^{198}Au$	8.283×10^{-2}	8.305×10^{-2}	8.555×10^{-2}			8.381×10^{-2}	1.80
$^{232}Th(n,f)FP$	7.132×10^{-2}	7.025×10^{-2}	7.131×10^{-2}*	7.156×10^{-1}	7.557×10^{-2}	7.218×10^{-2}	3.23
$^{232}Th(n,\gamma)^{233}Th$	1.018×10^{-1}	1.019×10^{-1}	1.018×10^{-1}			1.019×10^{-1}	0.07
$^{232}Th(n,2n)^{231}Th$				1.503×10^{-2}			
^{235}U $(n,f)FP$	1.230×10^{0}	1.241×10^{0}	1.241×10^{0}		1.230×10^{0}	1.233×10^{0}	0.52
$^{237}Np(n,f)FP$	1.293×10^{0}	1.337×10^{0}	1.292×10^{0} *	1.351×10^{0}	1.293×10^{0}	1.319×10^{0}	2.28
^{238}U $(n,f)FP$	2.869×10^{-1}	3.015×10^{-1}	3.004×10^{-1}	2.867×10^{-1}	3.083×10^{-1}	2.967×10^{-1}	3.25
^{238}U $(n,\gamma)^{239}U$	8.704×10^{-2}	7.429×10^{-2}	8.703×10^{-2}*			8.066×10^{-2}	11.2
$^{239}Pu(n,f)FP$	1.762×10^{0}	1.785×10^{0}	1.817×10^{0}			1.788×10^{0}	1.55
$^{241}Am(n,f)FP$					1.253×10^{0}		

*Cross section set DETAN74 = cross section set CCC-112B (only one value applied for the calculation of average value and the standard deviation).

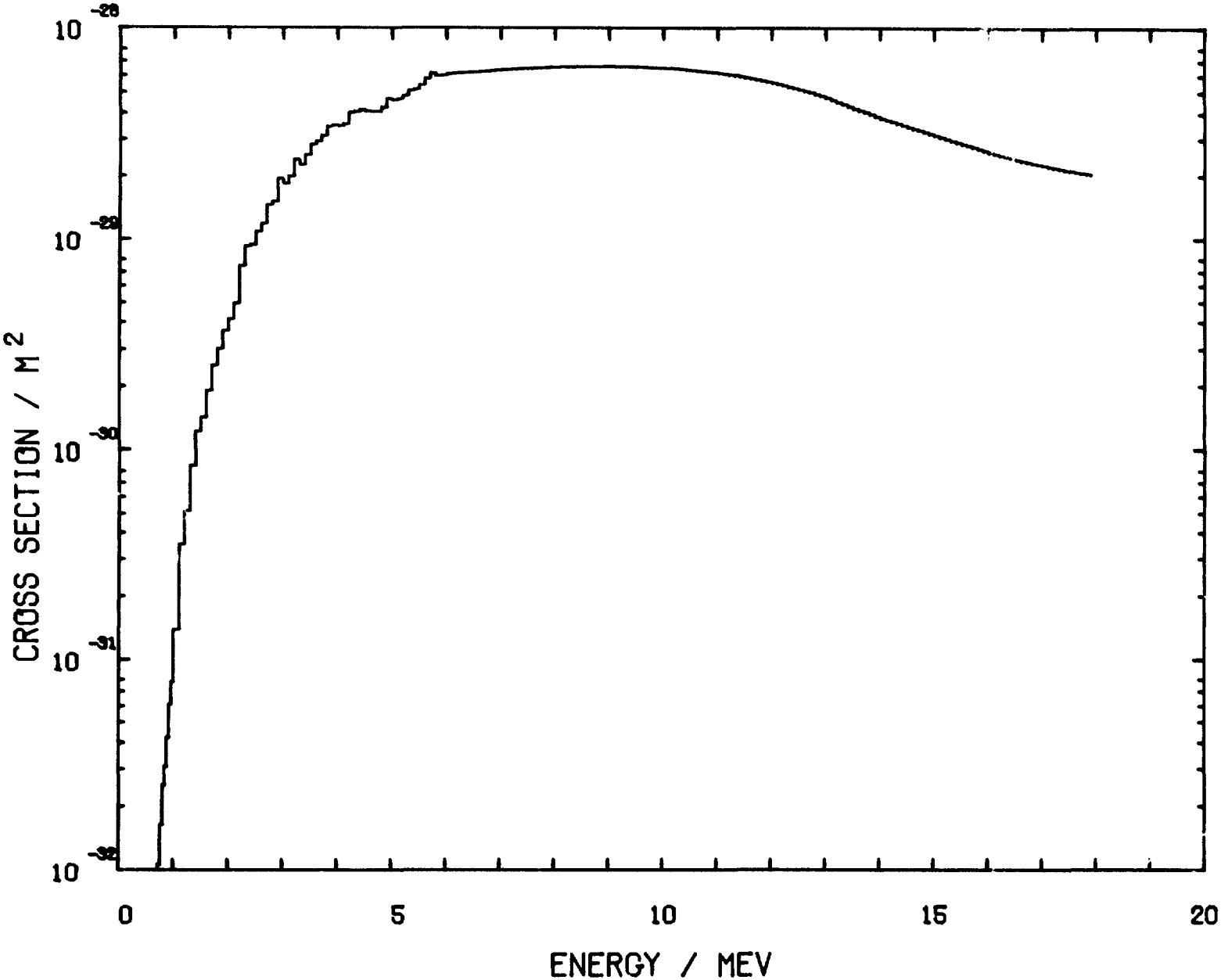

Fig. 1 Cross section curve for the reaction ^{58}Ni (n,p) ^{58}Co (from ENDF/B–IV BNL).

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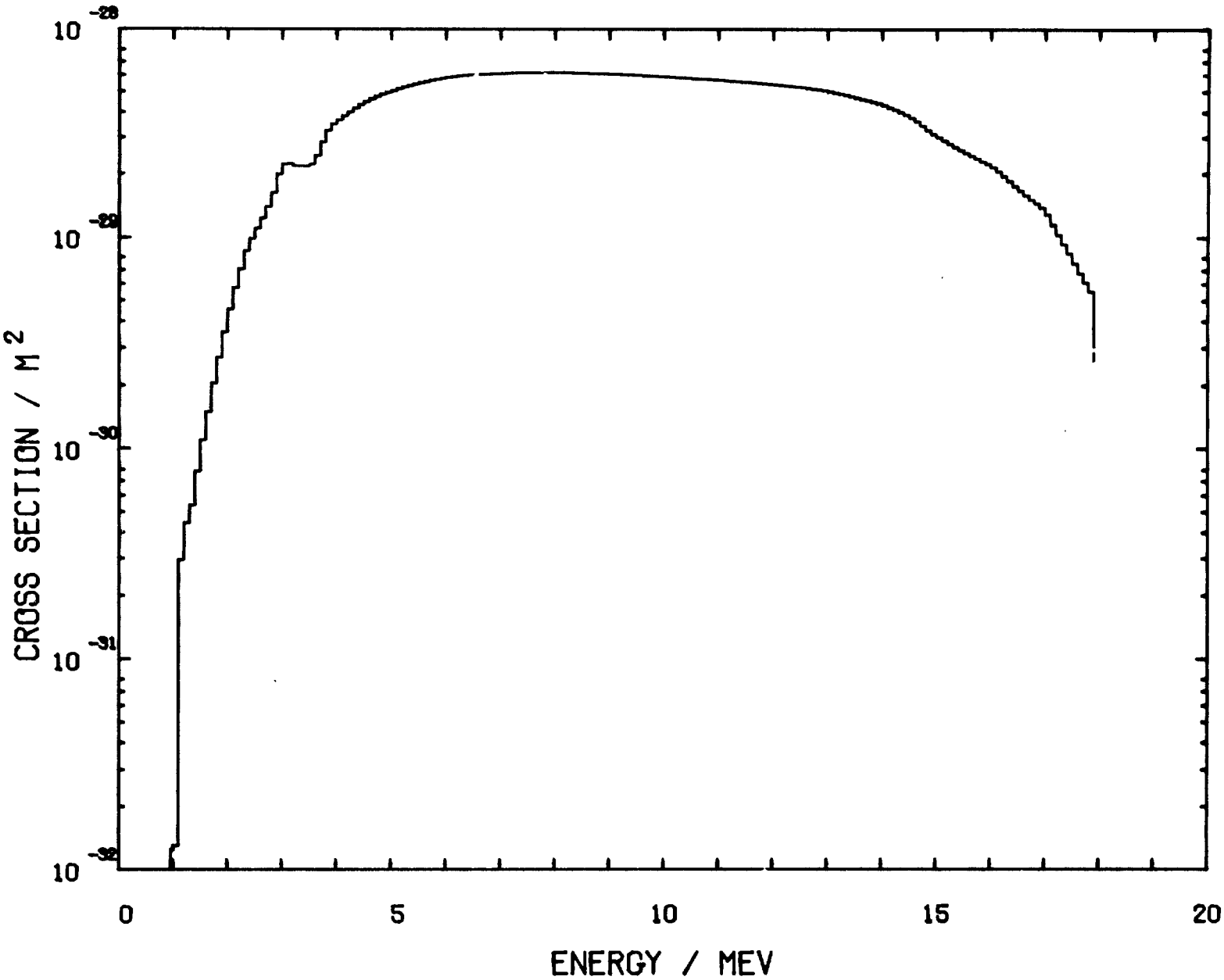


Fig. 2 Cross section curve for the reaction $^{58}Ni\ (n,p)^{58}Co$ (from DETAN 74).

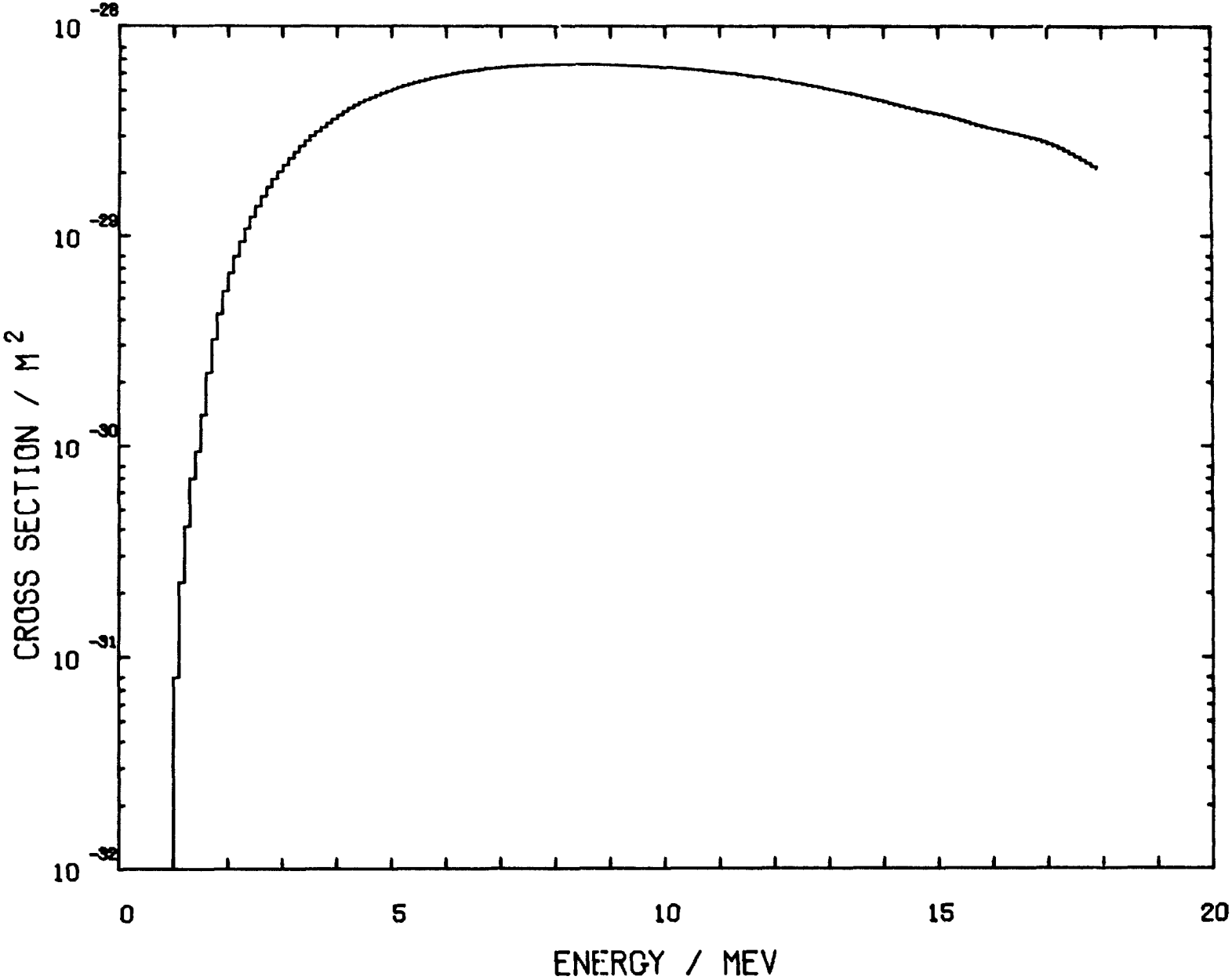


Fig. 3 Cross section curve for the reaction ^{58}Ni (n,p) ^{58}Co (from LAPENAS).

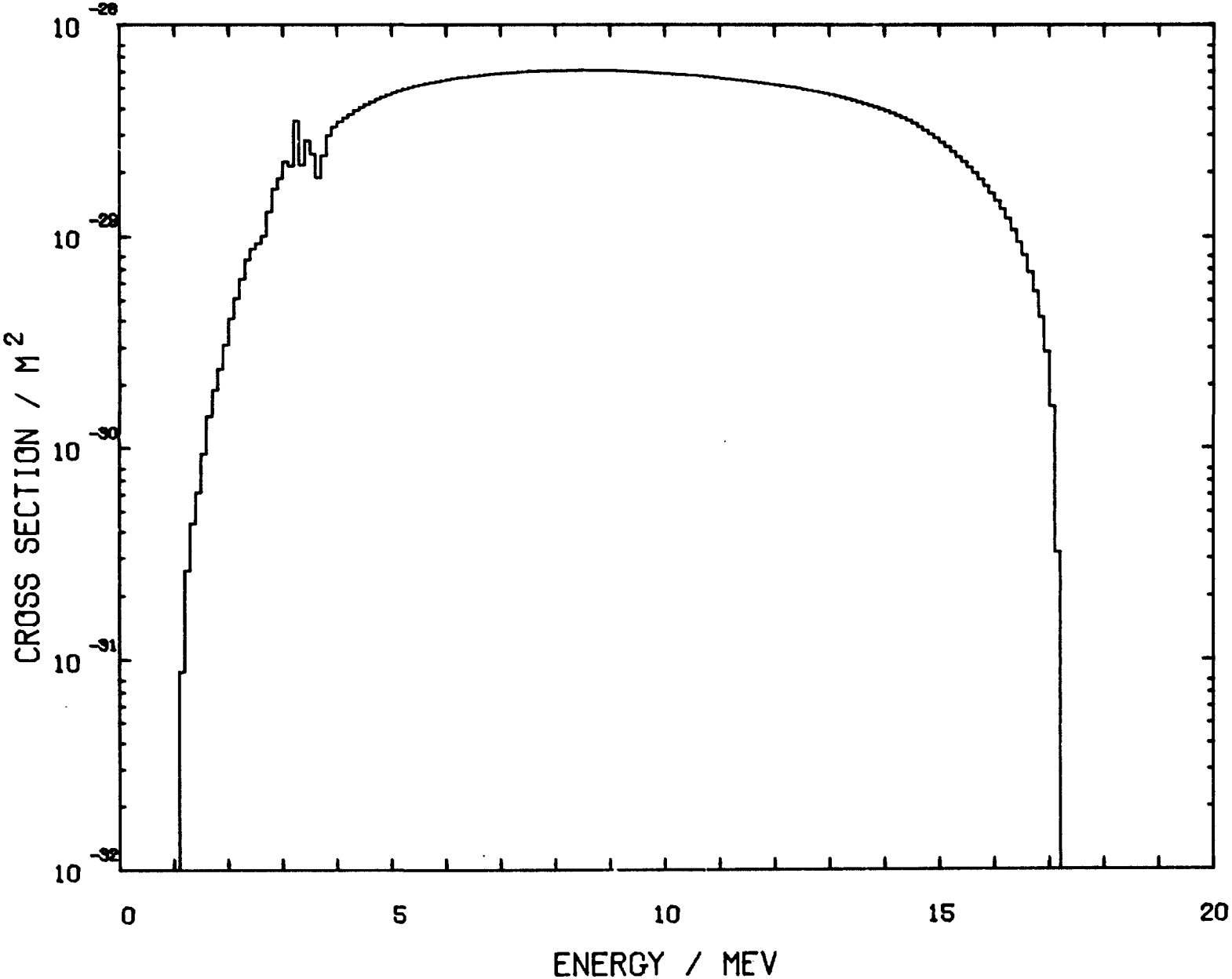
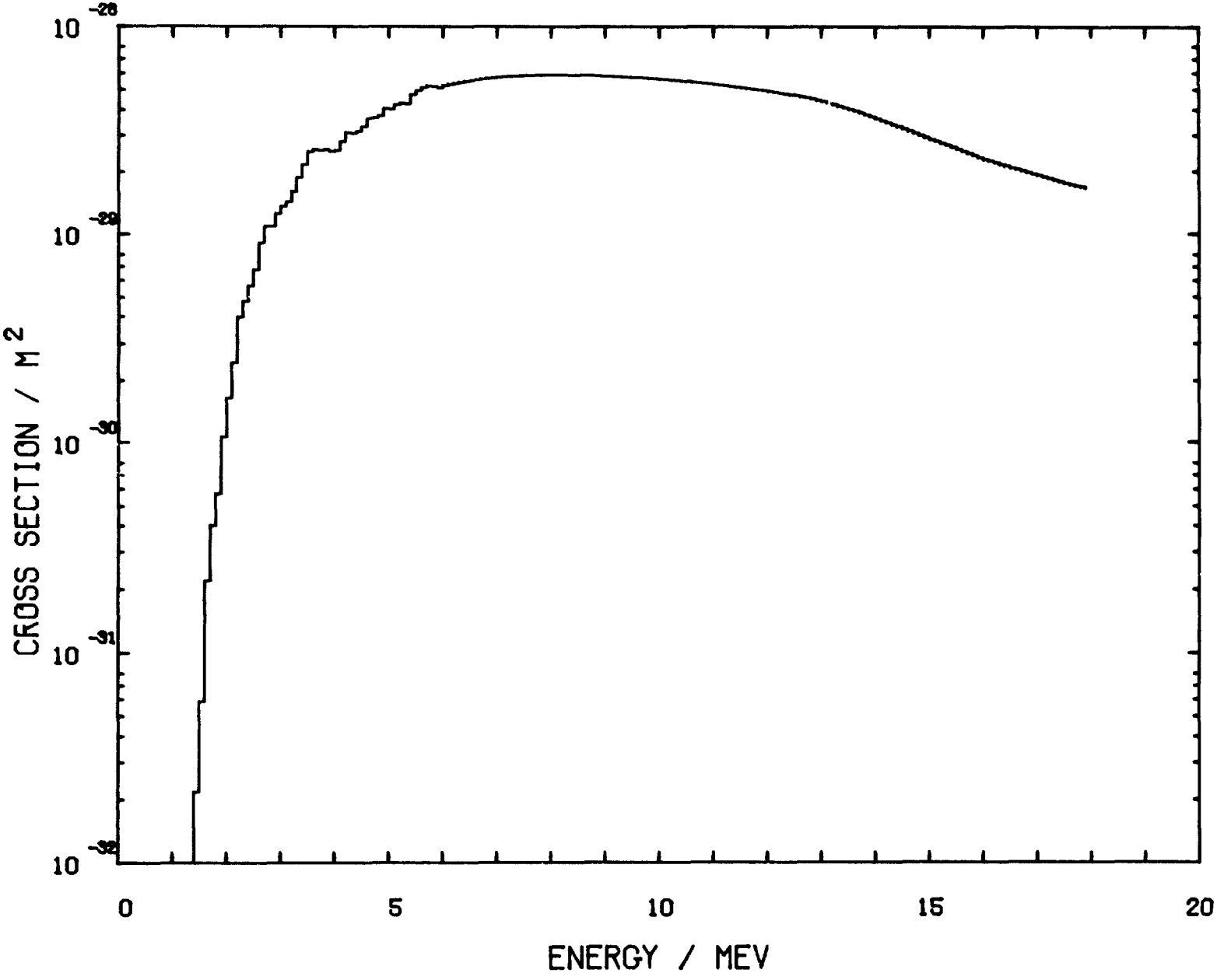


Fig. 4 Cross section curve for the reaction ^{58}Ni (n,p) ^{58}Co (from CLSNEF).



RMG 4519 Fig. 5 Cross section curve for the reaction $^{54}Fe(n,p)\ ^{54}Mn$ (from ENDF/B–IV BNL).

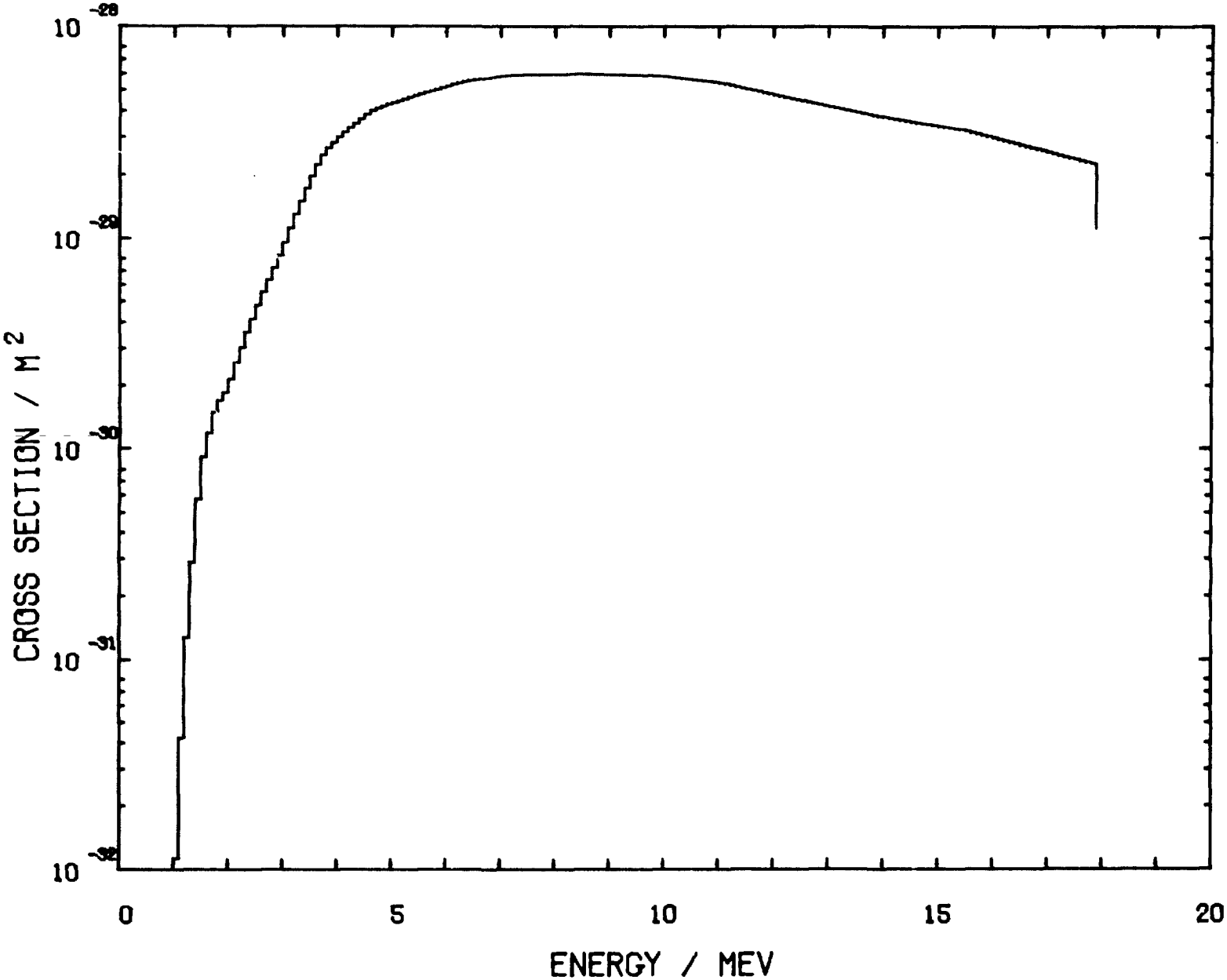


Fig. 6 Cross section curve for the reaction $^{54}Fe(n,p)\ ^{54}Mn$ (from DETAN 74).

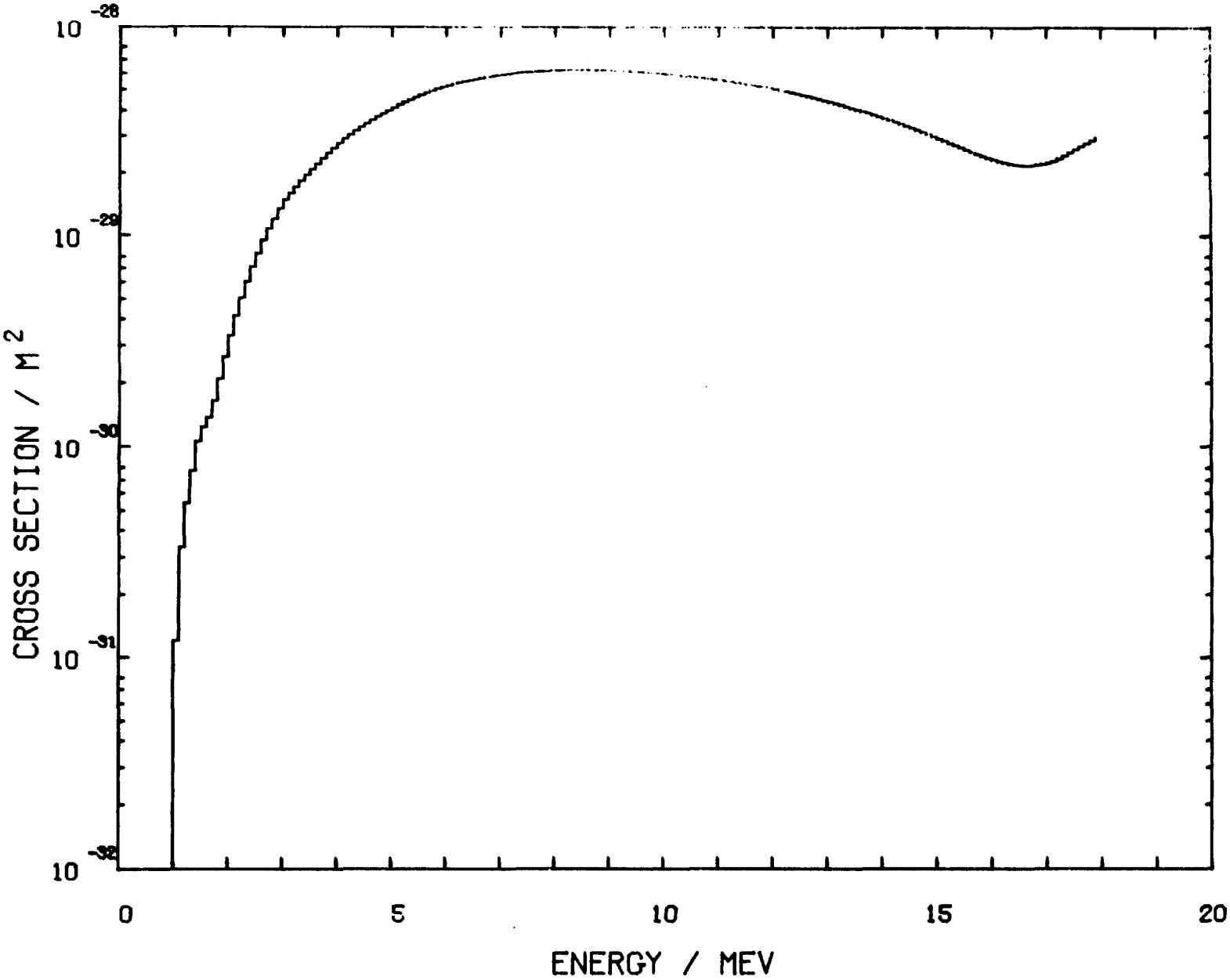


Fig. 7 Cross section curve for the reaction $^{54}Fe(n,p)\ ^{54}Mn$ (from LAPENAS).

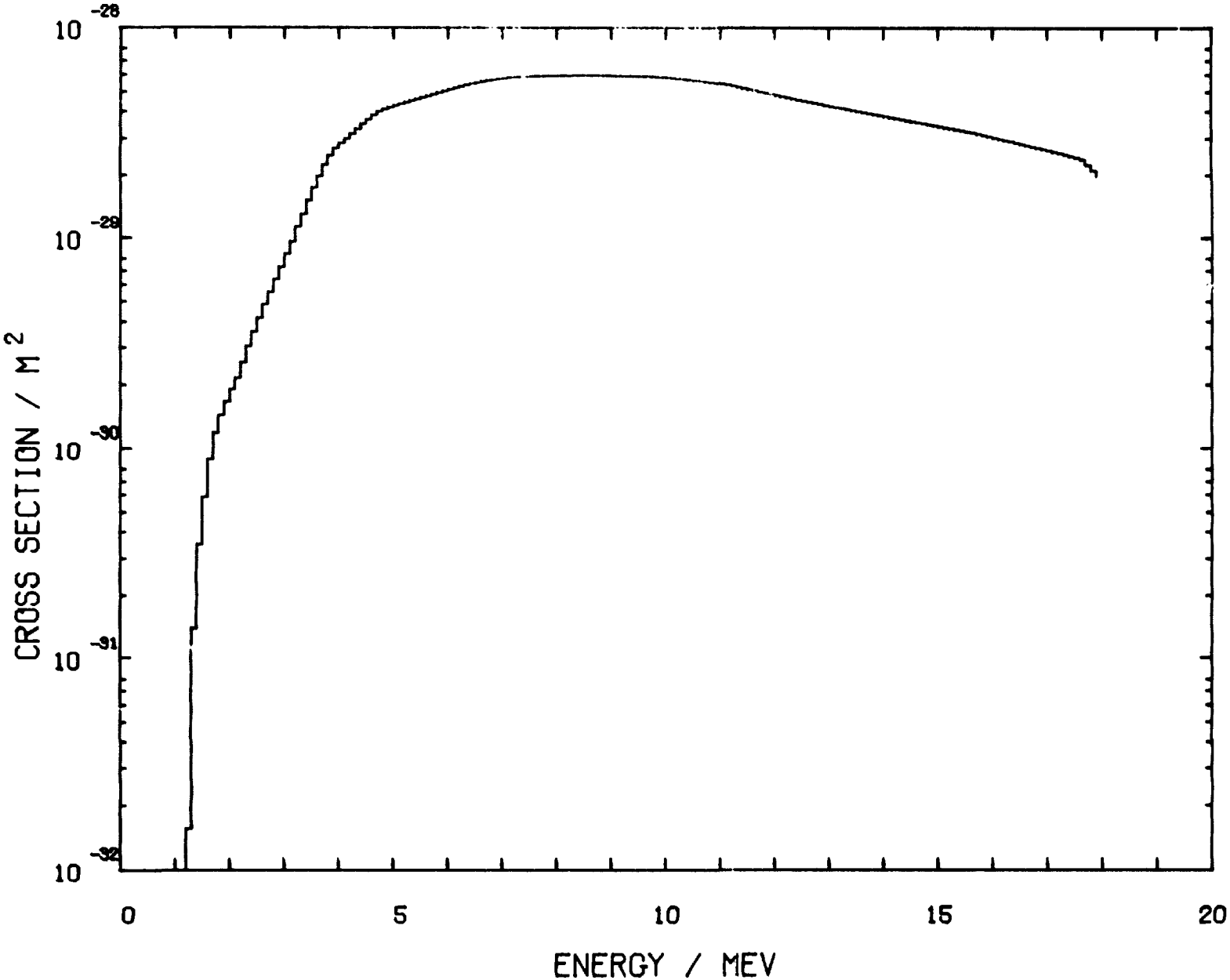


Fig. 8 Cross section curve for the reaction $^{54}Fe(n,p)\ ^{54}Mn$ (from CESNEF).