KERNFORSCHUNGSANLAGE JÜLICH
GESELLSCHAFT MIT BESCHRÄNKTER HAFTUNG

Zentralabteilung
Brennelement- und Bestrahlungstechnologie

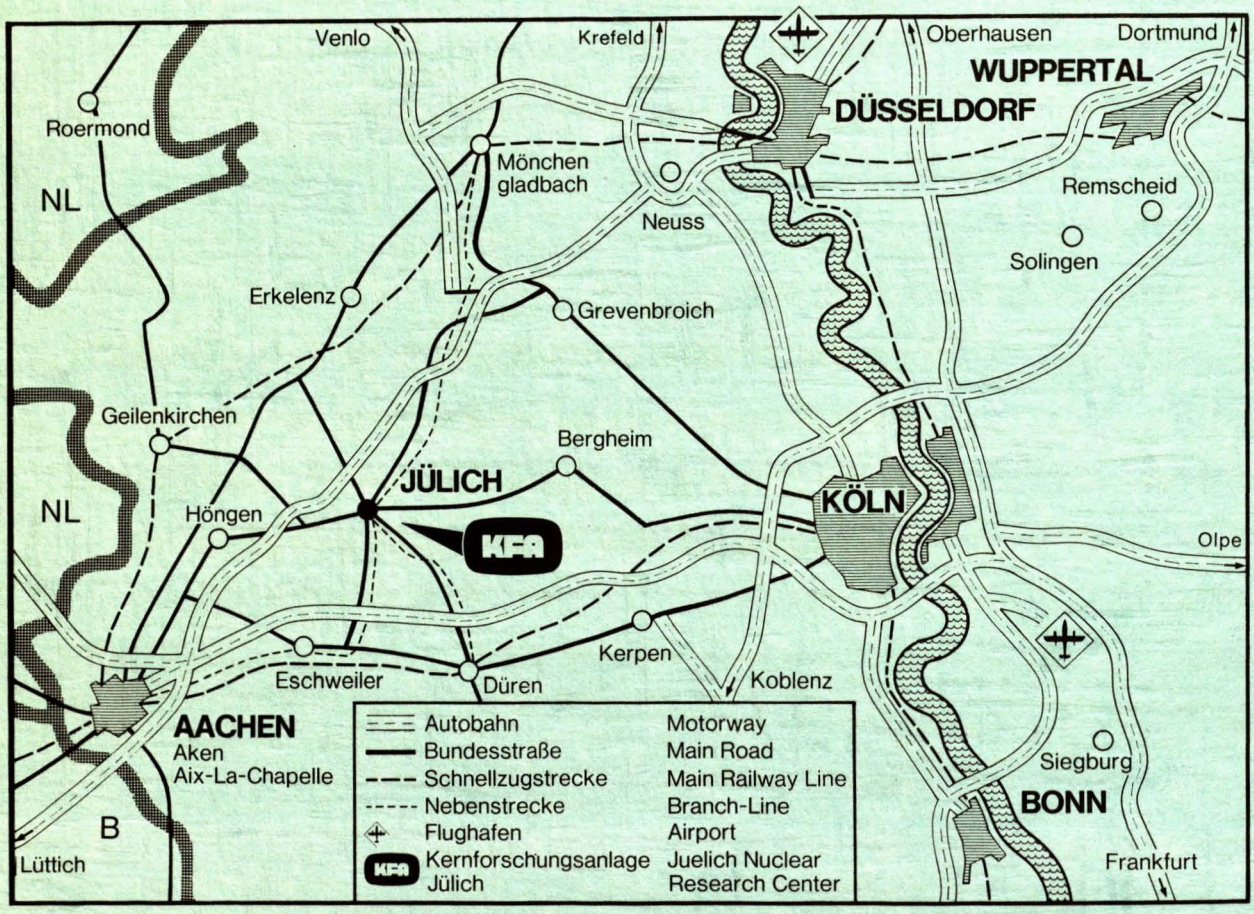
Results of the contribution to the EWGRD intercomparison of unfolding codes for neutron spectra evaluation, performed by means of the RFSP - JÜL programme

by

A. Fischer

Jül - 1279
März 1976

Als Manuskript gedruckt



Berichte der Kernforschungsanlage Jülich – Nr. 1279

Zentralabteilung Brennelement- und Bestrahlungstechnologie Jül - 1279

Im Tausch zu beziehen durch: ZENTRALBIBLIOTHEK der Kernforschungsanlage Jülich GmbH, Jülich, Bundesrepublik Deutschland

Results of the contribution to the EWGRD*) intercomparison of unfolding codes for neutron spectra evaluation, performed by means of the RFSP - JÜL programme

by

Adam Fischer**)

November 1974

*) EURATOM Working Group on Reactor Dosimetry

**) on leave from Central Research Institute for Physics
Budapest, Hungary

Editorial Note

This paper has been made during the author's IAEA fellowship in 1973/74 in the Kernforschungsanlage Jülich GmbH, Zentralabteilung Brennelement- und Bestrahlungstechnologie, Bereich Strahlenmeßtechnik, as one of two contributions from there to an intercomparison of unfolding codes for neutron spectra evaluation. This intercomparison was organized by the Sub-Group on Unfolding Codes (Chairman R. Dierckx, Ispra) of the EURATOM Working Group on Reactor Dosimetry (Chairman U. Farinelli, Rome) in 1974. The summary of all contributions and the interpretation of the results of this intercomparison has been presented under the title:

Unfolding Codes for Neutron Spectra Evaluation - Possibilities and Limitations

by R. Dierckx, EURATOM CCR, Ispra, and V. Sangiust, Politecnico di Milano, at the 1st ASTM - EURATOM Reactor Dosimetry Symposium at Petten, The Netherlands, September 1975 (Proceedings in press). A presentation of the RFSP-JÜL Programme itself - as quoted under No./1/ in the literature index of this paper - will be shortly submitted to the Kernforschungsanlage Jülich GmbH.

W. Schneider — February, 1976

Kernforschungsanlage Jülich GmbH
Zentralabteilung Brennelement- und Bestrahlungstechnologie
Leiter des Fachbereichs Strahlenmeßtechnik

Abstract

The EURATOM Working Group on Reactor Dosimetry has organzied 1974 an intercomparison of unfolding programmes. One contribution made in the Kernforschungsanlage Jülich GmbH is presented here. The calculation were made by means of the RFSP-JÜL Unfolding Programme. The spectra were unfolded using different guess spectra, different numbers of points and different interpolation formulas between the energy points. An error analysis was made using a new method to determine the energy intervals where the unfolding procedure improves the spectrum.
This work has been made during an IAEA-fellowship in the Kernforschungsanlage Jülich GmbH.

GENERAL

The Subgroup on Unfolding Codes of EWGRD has organized an intercomparison of the unfolding codes. In order to avoid large discrepancies due to different cross section sets, the same cross section set were sent to all participants.

Two activity sets were given. The first one consisted of nine detector activities. These detectors were intercalibrated in a fission spectrum and should be fitted to an accuracy of ~1 %. The second set consisted of the above mentioned nine detectors and four additional detectors, which should be fitted to an accuracy of ~4 % (See Appendix).

The report presented here describes the calculations of these spectra by the RFSP-JÜL unfolding code, performed in Jülich in 1974.

THE RFSP-JÜL CODE

The RFSP-JÜL code /1/ is a modified version of the RFSP /2/ and the well-known SPECTRA /3/ code. The mathematical side of the RFSP-JÜL code is essentially the same as that of the RFSP or the SPECTRA code. In the code the differential flux is calculated in clear numerical form in an arbitrary energy point system. The spectrum can be treated in different ways, differing only in the interpolation formula of the flux between the energy points:

1) $\Phi(E)$ is a linear function of the energy between the energy points:

$$\Phi(E) = \Phi_j \frac{E_{j+1} - E}{E_{j+1} - E_j} + \Phi_{j+1} \frac{E - E_j}{E_{j+1} - E_j} \quad \text{for} \quad E_j \leq E < E_{j+1}$$

2) $\Phi(u)$ is a linear function of the energy between the energy points:

$$E\Phi(E) = E_j\Phi_j \frac{E_{j+1} - E}{E_{j+1} - E_j} + E_{j+1}\Phi_{j+1} \frac{E - E_j}{E_{j+1} - E_j} \quad \text{for} \quad E_j < E < E_{j+1}$$

3) Ø(E) is a stepwise function of the energy:

$$\Phi(E) = \Phi_j \quad \text{for} \quad E_j \leq E < E_{j+1}$$

4) Ø(u) is a stepwise function of the energy:

$$\Phi(u) = E_j \Phi_j \; ; \quad \Phi(E) = \Phi_j \frac{E_j}{E} \quad \text{for} \quad E_j \leq E < E_{j+1}$$

The guess spectrum can be selected from the guess spectrum library or introduced as input data. The guess spectrum library contains all of the spectra of the SAND-II library /4/ in a 620-group form between 10^{-10} and 18 MeV. A special subroutine was written to transform the guess spectra to arbitrary number of energy points and to arbitrary form of the interpolation of the flux between the energy points.

CALCULATIONS AND RESULTS

In order to investigate the sensitivity of the results to the flux interpolation form and to the energy point number we calculated the spectrum for the I. detector set (9 detectors) in the following flux representations:

1) 19 energy points, Ø(E) is stepwise;
2) 72 energy points, Ø(E) is stepwise;
3) 19 energy points, Ø(u) is piecewise;
4) 72 energy points, Ø(u) is piecewise.

For all of these four cases 6 - 6 different guess spectra were used, these are shown on the Fig. 1. + 4. The 6 - 6 results are shown on the Fig. 5. + 8. In order to obtain the final results the 6 - 6 results were averaged separately for the four different flux interpolation mode and are given in tabulated form on the Tables 1 + 4. The tables contain the final result spectra, the ratio of the results and the fission spectrum as

given in the Appendix (Frye-spectrum), and the "improvement coefficient", which characterizes the unfolding effect in the different energy intervals (see the chapter "Error analysis"). The Tables contain also the ratio of the calculated and the measured activities.

For the II. detector set (13 detectors) the best guess spectrum was selected by the code from the guess spectrum library, and the unfolding was performed using this guess. The guess spectrum and the result are shown in the Fig. 9. The result is also tabulated in the Table 5. below 5.0 MeV. The result for this detector set above 5.0 MeV was equal to the result for the I. detector set, when above 5.0 MeV the same energy point system and flux interpolation ($\emptyset(u)$ linear piecewise) was used (See the Table 4.). For the II. detector set no error analysis was performed.

ERROR ANALYSIS

It is a difficult problem, to give any absolute error for the results. The more the difference between the guess spectra, the more the difference between the results is. The effectivity of the unfolding can be characterized by the ratio of the standard deviation of the guess spectra and the standard deviation of the result spectra:

$$\alpha(E) = \sqrt{\frac{\sum_{k=1}^{p}\left[\frac{\Phi_{gk}(E) - \tilde{\Phi}_g(E)}{\tilde{\Phi}_g(E)}\right]^2}{\sum_{k=1}^{p}\left[\frac{\Phi_{rk}(E) - \tilde{\Phi}_r(E)}{\tilde{\Phi}_r(E)}\right]^2}}$$

where p is the number of the different spectra (in our case p = 6);

$\emptyset_{gk}(E)$ is the k-th guess spectrum;

$\tilde{\emptyset}_g(E)$ is the averaged guess spectrum;

$\phi_{rk}(E)$ is the k-th resulted spectrum;

$\tilde{\phi}_{r}(E)$ is the averaged result spectrum.

The more the value of $\alpha(E)$, the better the unfolding in the given energy range is. Comparing for example the Fig 4. and Fig. 8. it can be seen, that the standard deviation of the results in the energy interval 1.0 - 8.5 MeV is essentially smaller than that of the guess spectra ($\alpha(E) > 1$). It means that in this interval the unfolding procedure can improve the spectrum. Below 0.5 MeV the standard deviation of the guess spectra is practically equal to that of the result ($\alpha(E) \cong 1$). The same situation can be observed above 14.0 MeV (See in the Tables). It means that in these energy intervals the unfolding procedure does not improve the spectrum, the activities does not contain information about the spectrum in this energy intervals.

CONCLUSIONS

The given spectra could be unfolded successfully by the RFSP-JÜL for different energy point systems and different flux interpolation methods. The activities for the first activity set (9 detectors) could be satisfied by the unfolded spectra for all of cases within $\sim$1 % without oscillations in the results. This is probably due to the intercalibration and the very good measurement accuracy. For the II. activity set (13 detectors) a spectrum was obtained, by which all but one (the Np237(nf)F.P.) activities could be satisfied. In this case the Np237(nf)F.P. reaction seems to contradict to the other activities. For the I. activity set an error and improvement analysis was performed. It turned out that the results of the unfolding are correct in the energy range between 1.0 and 8.5 MeV. Below and above of these values the results reflect only the guess spectra.

LITERATURE

/1/ - FISCHER A., The RFSP-JÜL programme for unfolding neutron spectra. To be published as KFA-report, Jülich.

/2/ - FISCHER A., TURI L., The RFSP programme for unfolding neutron spectra from activation data, INDC(HUN)-8/U. IAEA, May, 1972, Vienna.

/3/ - GREER, C.R., HALBLEIB, J.A., WALKER, J.V. SC-RR-67-746, 1967.

/4/ - McELROY, W.N., BERG, S., "A Computer Automated Iterative Method for Neutron Flux Spectra Determination", Vol. I.-IV., AFWL-TR-67-41 (1967).

Energy (MeV)	Flux	$\frac{\text{Flux}}{\text{Fission flux}}$	α
0.01	0.0	-	-
0.065	5.946E-1	2.440	1.11
0.40	5.819E-1	1.850	7.37
1.2	2.828E-1	1.080	3.34
2.0	1.618E-1	0.890	0.79
2.8	1.487E-1	1.290	0.92
3.6	6.039E-2	0.870	2.20
4.4	3.558E-2	0.875	6.14
5.2	2.089E-2	0.814	3.65
6.0	1.249E-2	0.968	1.27
6.8	6.380E-3	0.890	1.72
7.6	3.709E-3	0.952	3.40
8.4	1.835E-3	0.874	1.05
9.2	1.034E-3	0.923	1.54
10.0	6.358E-4	1.073	1.87
10.8	2.674E-4	1.166	1.84
12.5	6.621E-5	1.480	1.11
15.0	6.065E-6	2.102	1.01
20.0	0.0	-	-

$Rh^{103}(nn)Rh^{103m}$	0.996
$In^{115}(nn)In^{115m}$	0.988
Ti47(np)Sc47	1.006
Ni58(np)Co58	0.982
Fe54(np)Mn54	1.010
Ti46(np)Sc46	1.000
Mg24(np)Na24	0.996
Al27(nα)Na24	1.004
U238(nf)F.P.	1.014

TABLE 1. 19-point spectrum. Ø(E) is a stepwise function of the energy.

Energy	Flux	$\frac{\text{Flux}}{\text{F.f.}}$	α	Energy	Flux	$\frac{\text{Flux}}{\text{F.f.}}$	α
0.01	0.0	-	-	6.0	1.505E-2	0.863	2.26
0.015	3.092	33.353	1.00	6.2	1.285E-2	0.853	1.87
0.025	2.061	17.615	1.00	6.4	1.188E-2	0.913	2.04
0.040	1.247	8.483	1.00	6.6	1.063E-2	0.948	1.26
0.065	1.024	5.657	1.00	6.8	8.373E-3	0.872	1.65
0.10	7.964E-1	3.675	1.00	7.0	7.030E-3	0.876	1.24
0.15	6.309E-1	2.413	1.01	7.2	6.028E-3	0.842	1.25
0.25	5.600E-1	1.825	1.08	7.4	5.075E-3	0.825	1.03
0.4	4.822E-1	1.423	1.28	7.6	4.535E-3	0.858	1.72
0.6	5.162E-1	1.469	2.23	7.8	3.892E-3	0.852	1.79
0.8	5.213E-1	1.497	7.57	8.0	3.416E-3	0.878	2.32
1.0	4.887E-1	1.447	2.50	8.2	2.855E-3	0.856	1.66
1.2	4.516E-1	1.412	2.44	8.4	2.391E-3	0.837	1.33
1.4	3.211E-1	1.075	3.05	8.6	2.023E-3	0.828	1.19
1.6	2.548E-1	0.924	3.76	8.8	1.729E-3	0.827	1.15
1.8	2.201E-1	0.871	3.98	9.0	1.496E-3	0.837	1.20
2.0	1.981E-1	0.863	3.00	9.2	1.305E-3	0.854	1.42
2.2	1.853E-1	0.894	2.09	9.4	1.144E-3	0.876	2.00
2.4	1.720E-1	0.923	3.97	9.6	1.007E-3	0.904	2.88
2.6	1.718E-1	1.019	2.42	9.8	8.911E-4	0.938	2.46
2.8	1.639E-1	1.102	1.47	10.0	7.923E-4	0.978	1.77
3.0	1.537E-1	1.163	1.39	10.2	6.995E-4	1.013	1.52
3.2	1.159E-1	0.989	1.16	10.4	6.162E-4	1.047	1.42
3.4	8.776E-2	0.849	3.56	10.6	5.434E-4	1.084	1.36
3.6	7.709E-2	0.846	3.05	10.8	4.735E-4	1.109	1.32
3.8	6.969E-2	0.869	3.41	11.0	3.371E-4	1.043	2.13
4.0	6.070E-2	0.832	3.66	11.5	2.443E-4	1.136	1.47
4.2	5.285E-2	0.752	4.18	12.0	1.734E-4	1.212	1.26
4.4	4.606E-2	0.855	5.91	12.5	1.223E-4	1.289	1.15
4.6	4.041E-2	0.860	11.73	13.0	8.605E-5	1.370	1.09
4.8	3.565E-2	0.870	5.62	13.5	6.050E-5	1.459	1.05
5.0	3.190E-2	0.884	2.53	14.0	3.580e-5	1.579	1.05
5.2	2.766E-2	0.892	1.91	15.0	1.775E-5	1.815	1.02
5.4	2.379E-2	0.883	2.95	16.0	6.517E-6	2.177	1.00
5.6	2.037E-2	0.875	3.24	18.0	0.0	-	-
5.8	1.754E-2	0.870	2.58	20.0	0.0	-	-

$Rh103(nn)Rh103^{m}$	0.988
$In115(nn)In115^{m}$	0.994
Ti47(np)Sc47	1.005
Ni58(np)Co58	0.984
Fe54(np)Mn54	1.008
Ti46(np)Sc46	1.004
Mg24(np)Na24	0.993
Al27(nα)Na24	1.007
U238(nf)F.P.	1.015

TABLE 2. 72-point spectrum. $\phi(E)$ is a stepwise function of the energy.

Energy (Mev)	Flux	$\frac{\text{Flux}}{\text{Fission flux}}$	α
0.01	0.0	-	-
0.065	8.281E-1	3.814	1.00
0.4	5.207E-1	1.560	1.22
1.2	5.172E-1	1.586	2.33
2.0	1.739E-1	0.721	1.13
2.8	1.810e-1	1.140	1.28
3.6	8.856E-2	0.904	3.96
4.4	4.756E-2	0.817	4.35
5.2	2.825E-2	0.841	3.57
6.0	1.607E-2	0.846	3.32
6.8	9.376E-3	0.887	1.91
7.6	4.908E-3	0.849	2.38
8.4	2.577E-3	0.823	1.54
9.2	1.322E-3	0.788	1.11
10.0	7.955E-4	0.892	3.01
10.8	4.033E-4	1.005	2.00
12.5	1.331E-4	1.201	1.28
15.0	2.077E-5	1.655	1.03
20.0	0.0	-	-

Rh103(nn)Rh103^{m}	0.994
In115(nn)In115^{m}	0.995
Ti47(np)Sc47	1.006
Ni58(np)Co58	0.981
Fe54(np)Mn54	1.010
Ti46(np)Sc46	1.001
Mg24(np)Na24	0.995
Al27(nα)Na24	1.006
U238(nf)F.P.	1.011

TABLE 3. 19-point spectrum. EØ(E) is a linear piecewise function of the energy.

Energy	Flux	Flux / F.f.	α	Energy	Flux	Flux / F.f.	α
0.01	0.0	-	-	6.0	1.620E-2	0.864	2.38
0.015	3.741	45.345	1.00	6.2	1.384E-2	0.854	2.09
0.025	2.453	23.210	1.00	6.4	1.226E-2	0.876	2.98
0.040	1.503	11.300	1.00	6.6	1.155E-2	0.957	0.95
0.065	1.141	6.898	1.00	6.8	9.535E-3	0.916	1.55
0.10	8.800E-1	4.390	1.00	7.0	7.623E-3	0.850	1.38
0.15	6.880E-1	2.860	1.01	7.2	6.553E-3	0.849	1.40
0.25	5.884E-1	2.052	1.05	7.4	5.485E-3	0.826	1.06
0.4	5.095E-1	1.564	1.16	7.6	4.846E-3	0.850	1.52
0.6	4.970E-1	1.378	1.61	7.8	4.221E-3	0.862	1.96
0.8	5.383E-1	1.533	5.04	8.0	3.669E-3	0.874	2.43
1.0	5.188E-1	1.509	3.32	8.2	3.141E-3	0.872	2.20
1.2	4.904E-1	1.489	2.28	8.4	2.613E-3	0.847	1.51
1.4	3.959E-1	1.279	2.28	8.6	2.192E-3	0.830	1.23
1.6	2.800E-1	0.975	3.75	8.8	1.859E-3	0.822	1.12
1.8	2.299E-1	0.871	5.27	9.0	1.596E-3	0.829	5.10
2.0	2.025E-1	0.841	2.82	9.2	1.387E-3	0.839	1.17
2.2	1.859E-1	0.852	1.41	9.4	1.211E-3	0.858	1.44
2.4	1.749E-1	0.899	1.56	9.6	1.064E-3	0.882	2.12
2.6	1.703E-1	0.965	4.64	9.8	9.397E-4	0.913	2.89
2.8	1.720E-1	1.128	1.29	10.0	8.346E-4	0.951	2.27
3.0	1.612E-1	1.150	0.96	10.2	7.407E-4	0.999	1.74
3.2	1.404E-1	1.129	1.35	10.4	6.527E-4	1.024	1.56
3.4	1.041E-1	0.946	6.14	10.6	5.748E-4	1.058	1.47
3.6	7.850E-2	0.808	1.85	10.8	5.051E-4	1.092	1.41
3.8	7.337E-2	0.858	2.84	11.0	3.921E-4	1.059	1.87
4.0	6.495E-2	0.865	3.33	11.5	2.847E-4	1.078	1.90
4.2	5.655E-2	0.859	3.77	12.0	2.050E-4	1.167	1.40
4.4	4.913E-2	0.853	4.39	12.5	1.452E-4	1.244	1.22
4.6	4.293E-2	0.853	7.29	13.0	1.024E-4	1.325	1.13
4.8	3.777E-2	0.861	10.17	13.5	7.205E-5	1.412	1.08
5.0	3.338E-2	0.874	3.87	14.0	4.637E-5	1.510	1.07
5.2	2.950E-2	0.888	2.03	15.0	2.524E-5	1.694	1.04
5.4	2.559E-2	0.887	2.48	16.0	1.066E-5	1.981	1.02
5.6	2.193E-2	0.876	2.57	18.0	2.170E-6	2.424	1.00
5.8	1.881E-2	0.868	2.74	20.0	0.0	-	-

$Rh103(nn)Rh103^{m}$	0.992
$In115(nn)In115^{m}$	0.994
Ti47(np)Sc47	1.006
Ni58(np)Co58	0.984
Fe54(np)Mn54	1.009
Ti46(np)Sc46	1.001
Mg24(np)Na24	0.993
Al27(nα)Na24	1.006
U238(nf)F.P.	1.013

TABLE 4. 72-point spectrum. EØ(E) linear piecewise function of the energy

Energy	Flux	Energy	Flux
4.0E-7	0.0	6.5E-2	9.815
6.5E-7	1.334E+5	1.0E-1	6.852
1.0E-6	8.809E+4	0.15	4.716
1.5E-6	5.329E+4	0.25	3.132
2.5E-6	3.120E+4	0.40	1.367
4.0E-6	1.932E+4	0.6	5.049E-1
6.5E-6	1.267E+4	0.8	3.810E-1
1.0E-5	8.443E+3	1.0	3.597E-1
1.5E-5	5.341E+3	1.2	4.495E-1
2.5E-5	3.333E+3	1.4	3.952E-1
4.0e-5	2.042E+3	1.6	2.730E-1
6.5E-5	1.235E+3	1.8	2.319E-1
1.0E-4	7.786E+2	2.0	2.144E-1
1.5E-4	5.019E+2	2.2	1.899E-1
2.5E-4	3.119E+2	2.4	1.653E-1
4.0E-4	1.949E+2	2.6	1.625E-1
6.0E-4	1.305E+2	2.8	1.782E-1
8.0E-4	9.585E+1	3.0	1.714E-1
1.0E-3	7.160E+1	3.2	1.537E-1
1.5E-3	6.104E+1	3.4	1.053E-1
2.5E-3	5.525E+1	3.6	6.929E-2
4.0E-3	2.786E+1	3.8	7.015E-2
6.0E-3	2.208E+1	4.0	6.494E-2
8.0E-3	2.343E+1	4.2	5.741E-2
1.0E-2	2.837E+1	4.4	5.004E-2
1.5E-2	2.437E+1	4.6	4.328E-2
2.5E-2	1.583E+1	4.8	3.789E-2
4.0E-2	1.256E+1	5.0	3.366E-2

$Rh103(nn)Rh103^{m}$	0.997
$In115(nn)In115^{m}$	0.983
Ti47(np)Sc47	1.011
Ni58(np)Co58	0.992
Fe54(np)Mn54	1.011
Ti46(np)Sc46	1.001
Mg24(np)Na24	0.997
Al27(nα)Na24	1.006
U238(nf)F.P.	1.016
U235(nf)F.P.	0.981
Am241(nf)F.P.	0.990
Np237(nf)F.P.	1.125
Th232(nf)F.P.	0.987

TABLE 5. The resulted spectrum for the 13-detector set and the corresponding calculated/measured activity ratios (EØ(E) is linear piecewise; above 5 MeV see Table 4.)

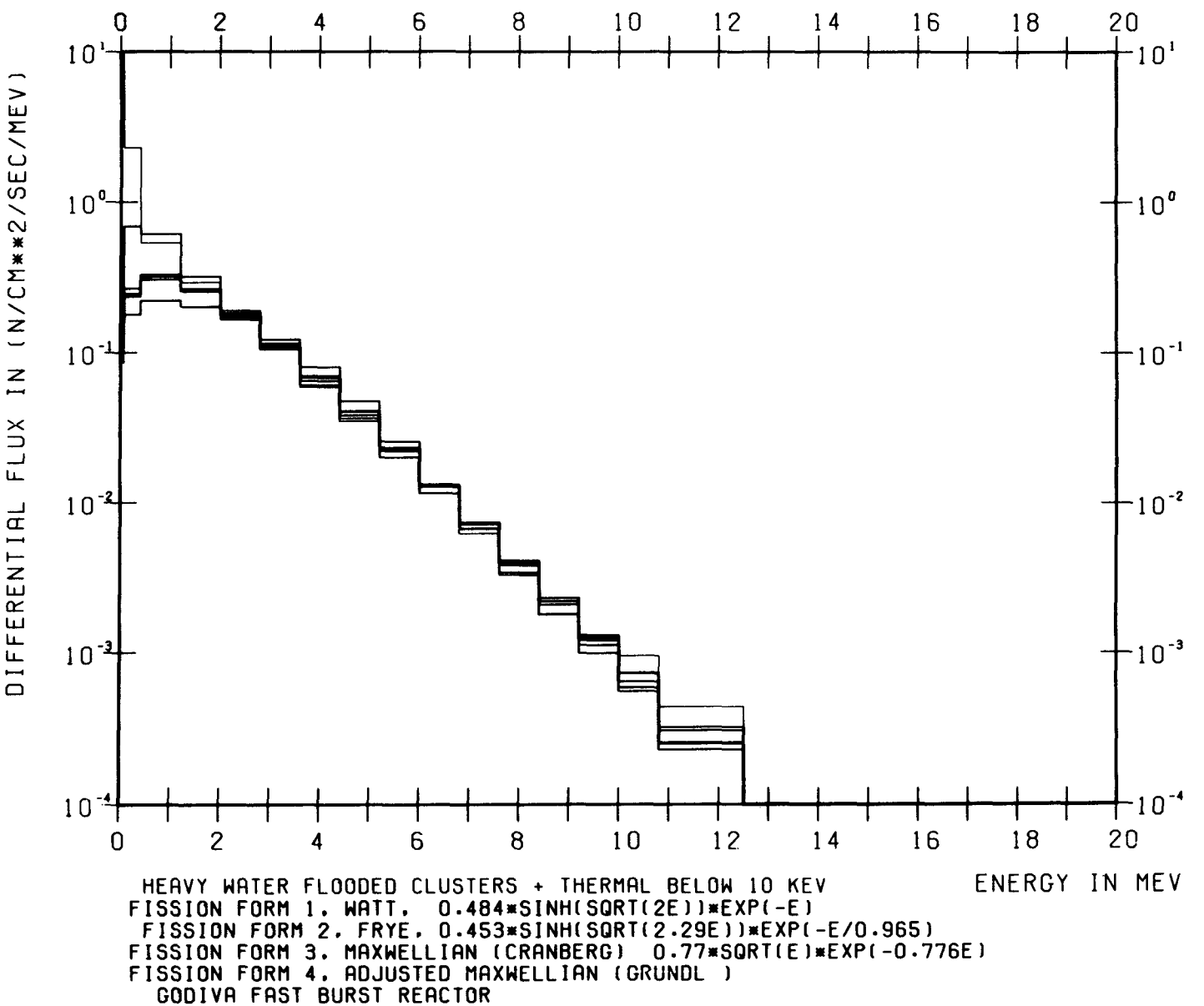


Fig. 1. The guess spectra in 19-point stepwise form.

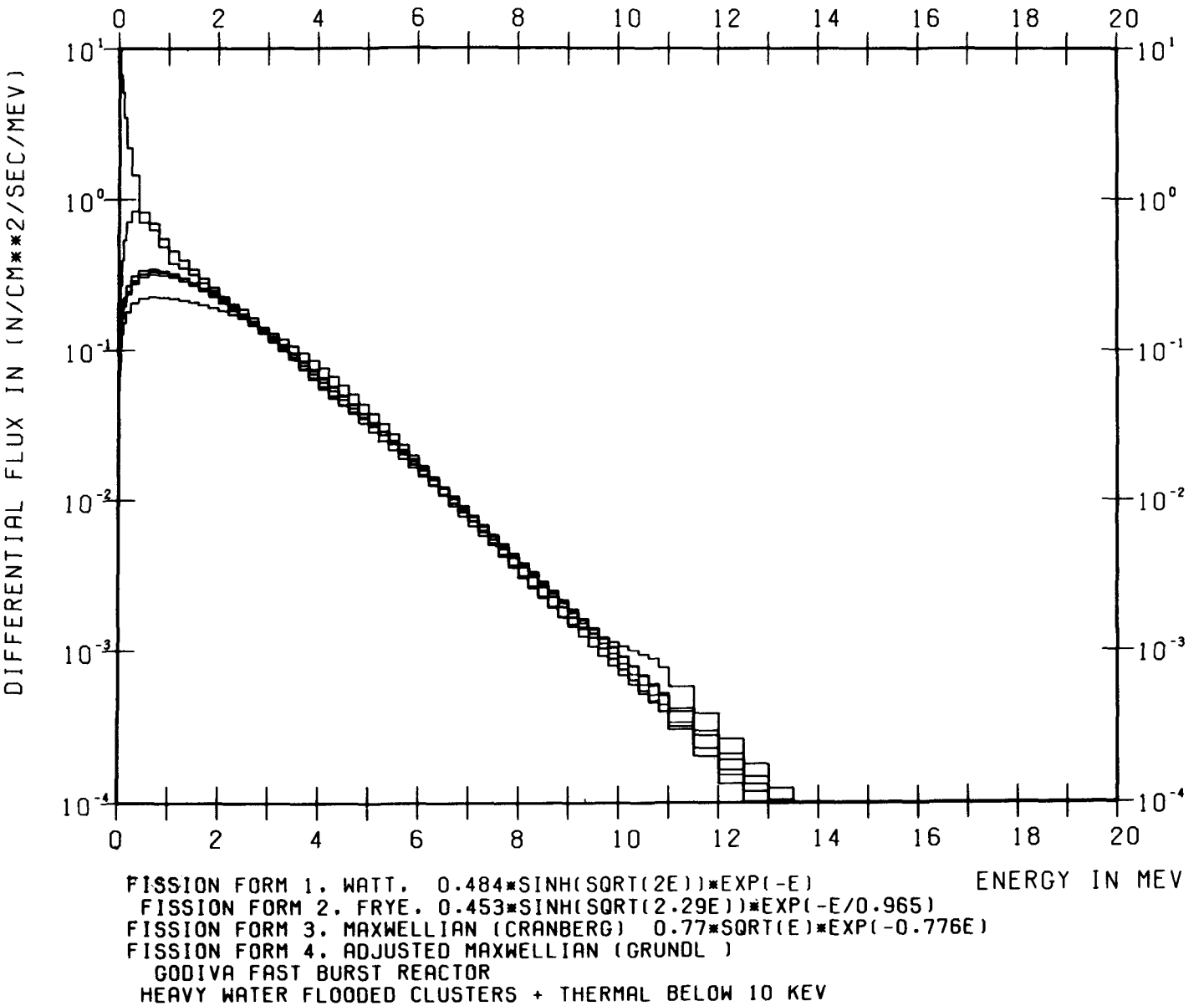


Fig. 2. The guess spectra in 72-point stepwise form.

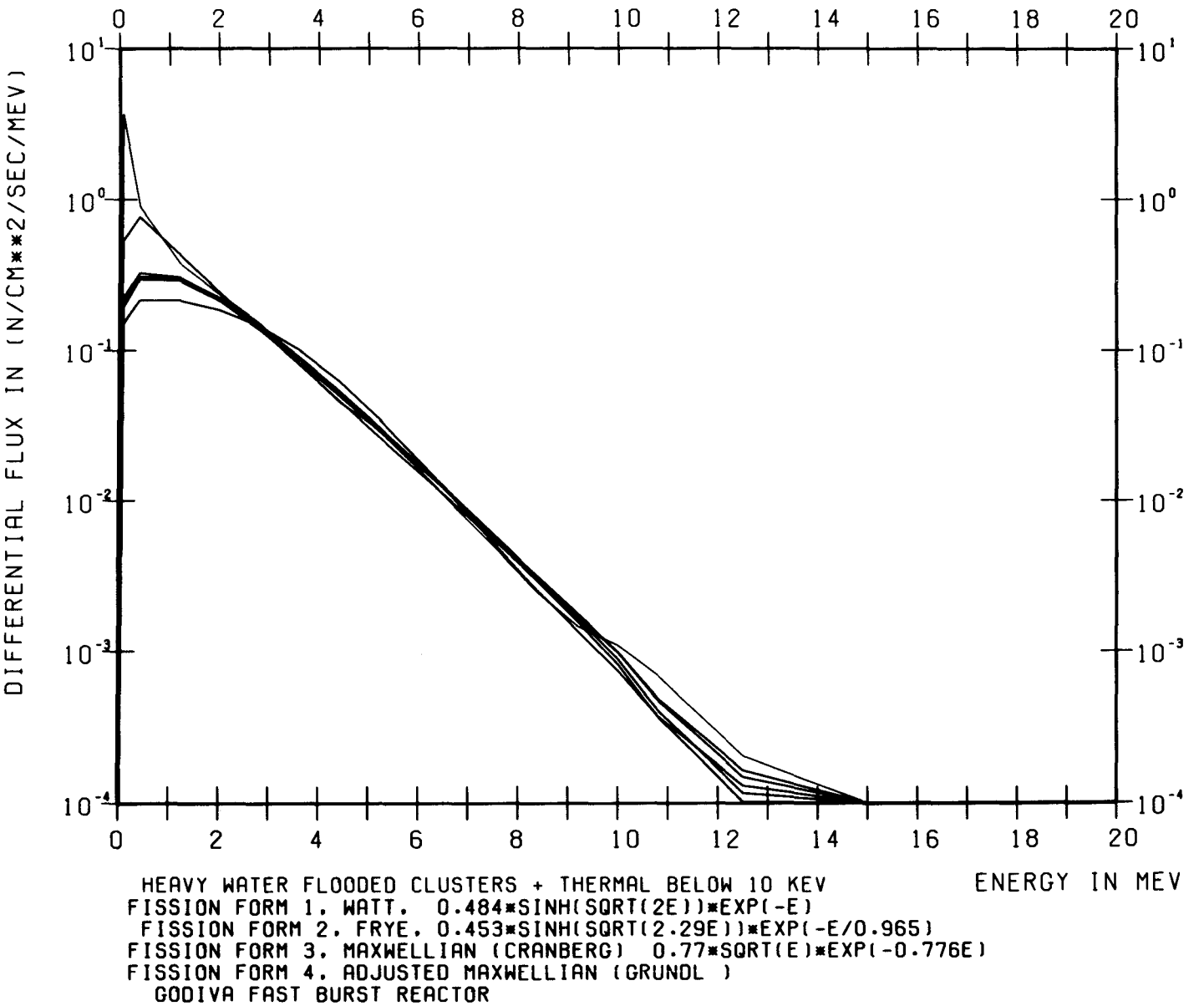


Fig. 3. The guess spectra in 19-point linear piecewise form

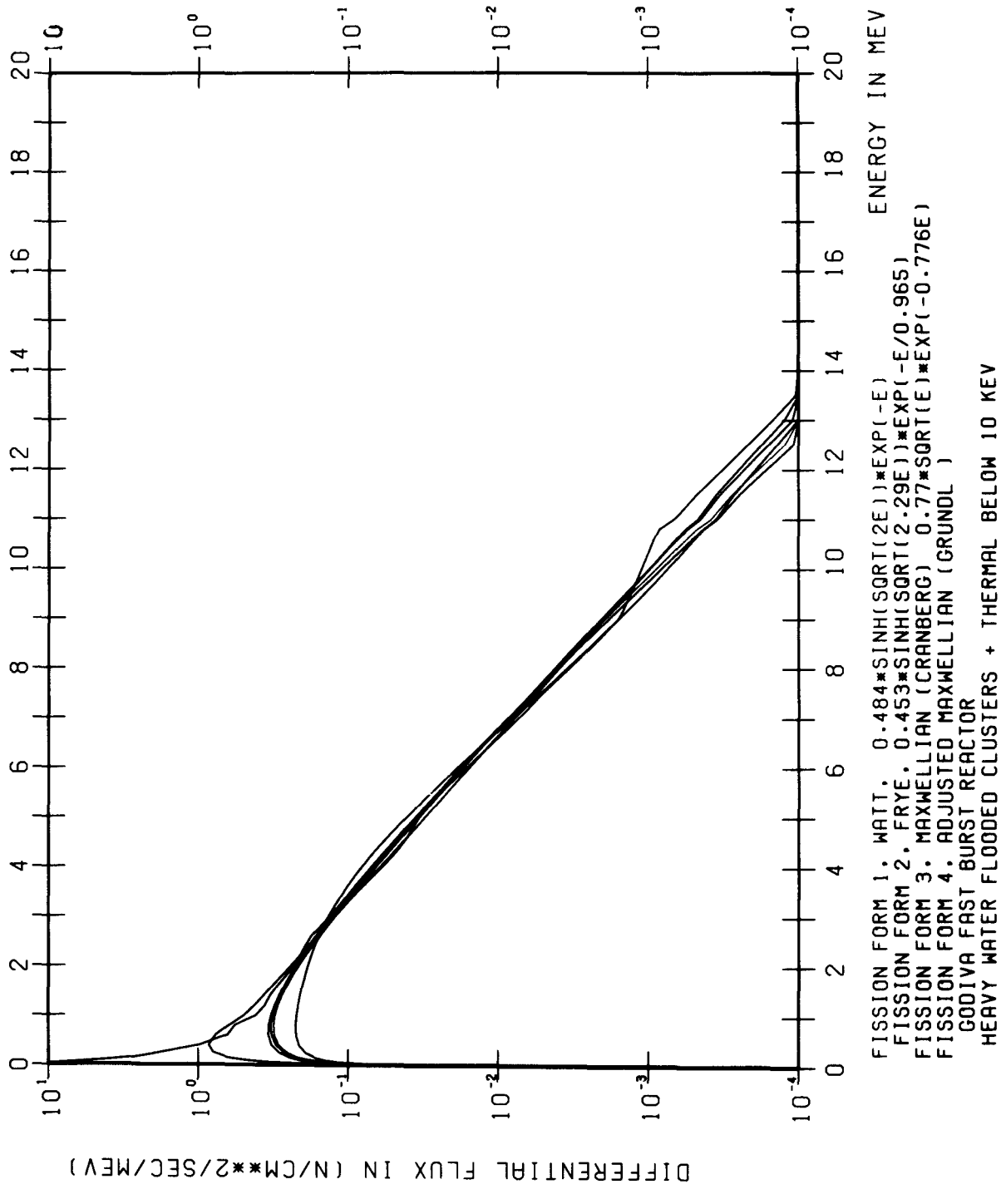


Fig. 4. The guess spectra in 72-point linear piecewise form.

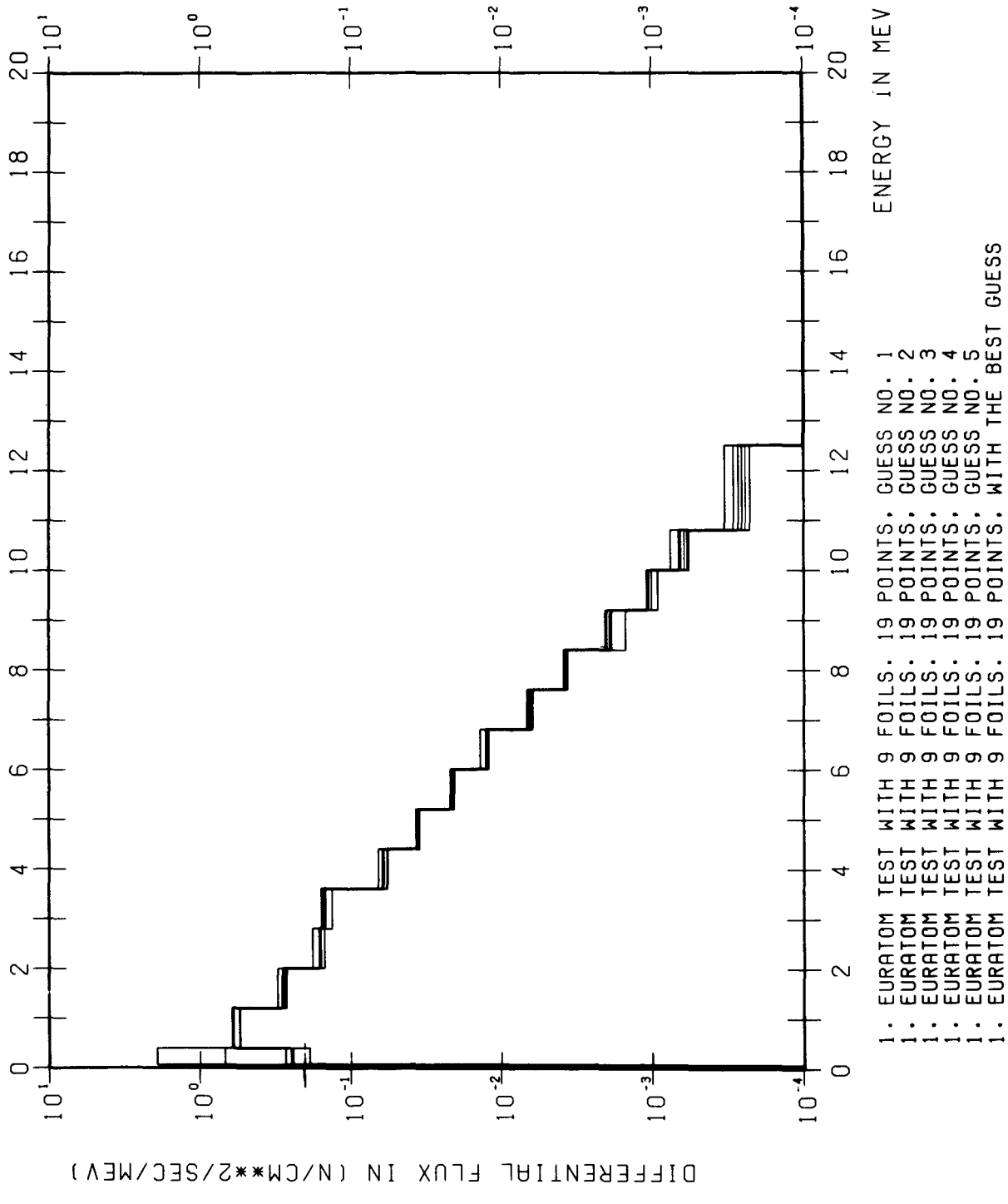


Fig. 5. The result spectra for the guess spectra in the Fig 1.

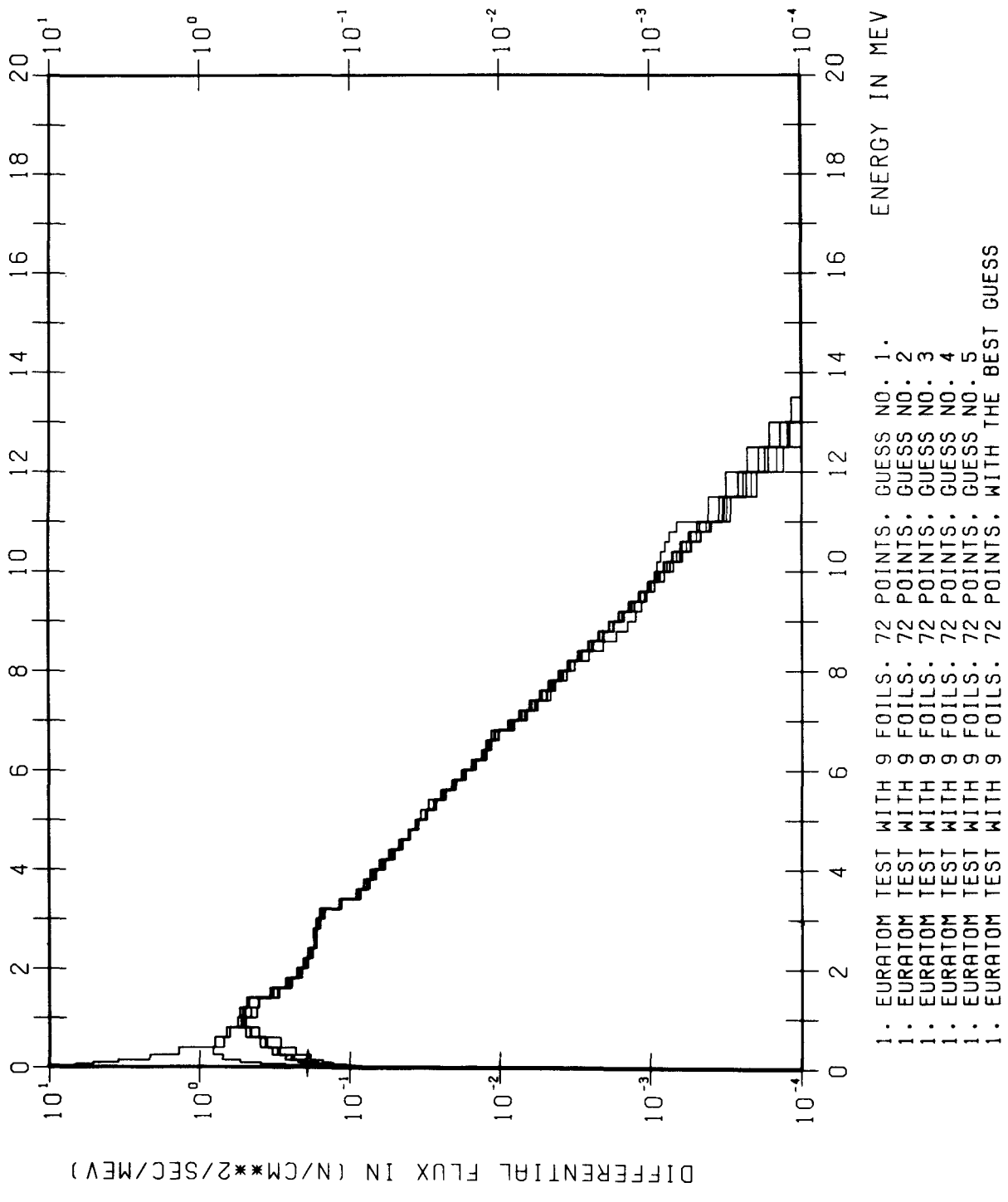


Fig. 6. The result spectra for the guess spectra in the Fig. 2.

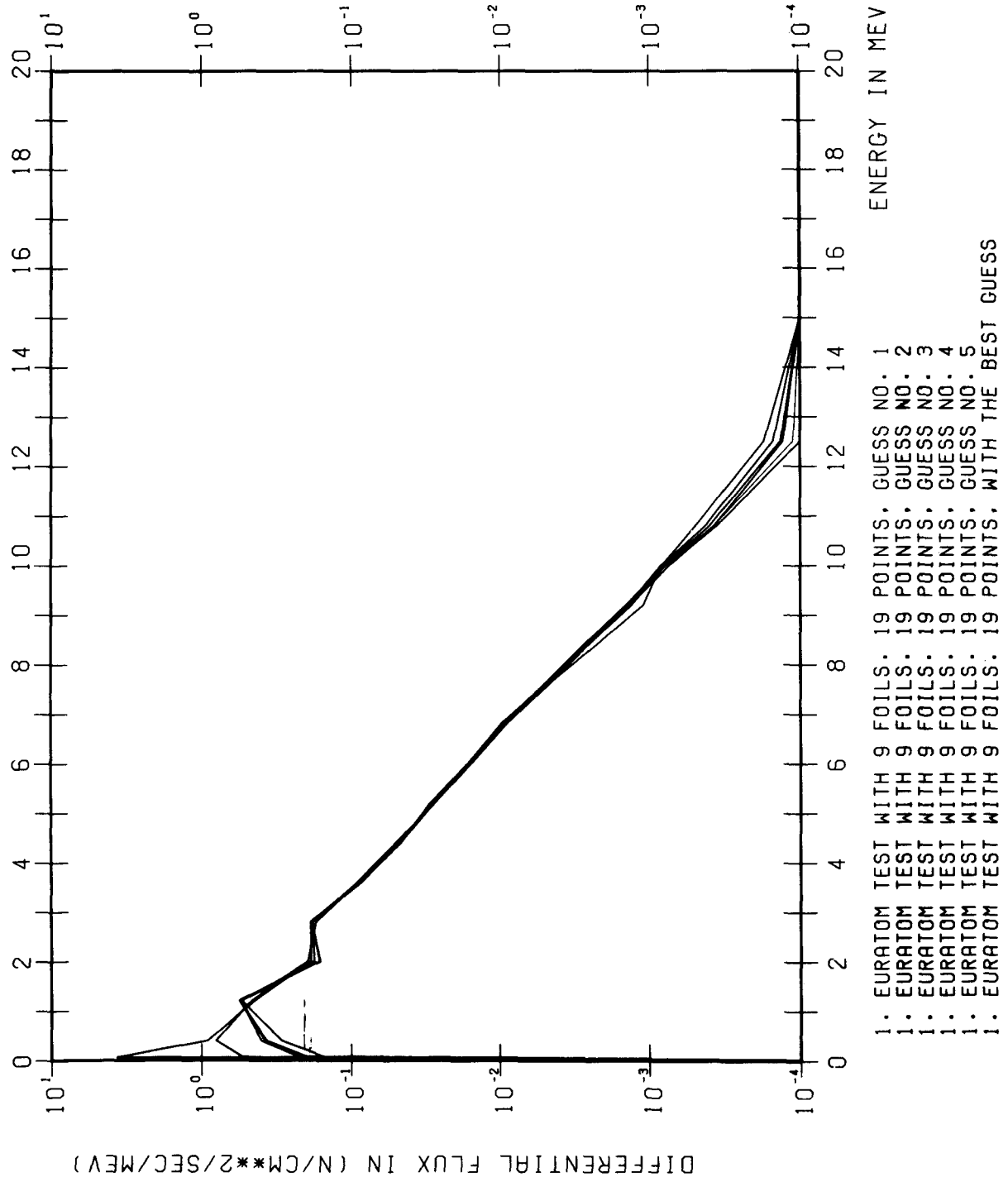


Fig. 7. The result spectra for the guess spectra in the Fig. 3.

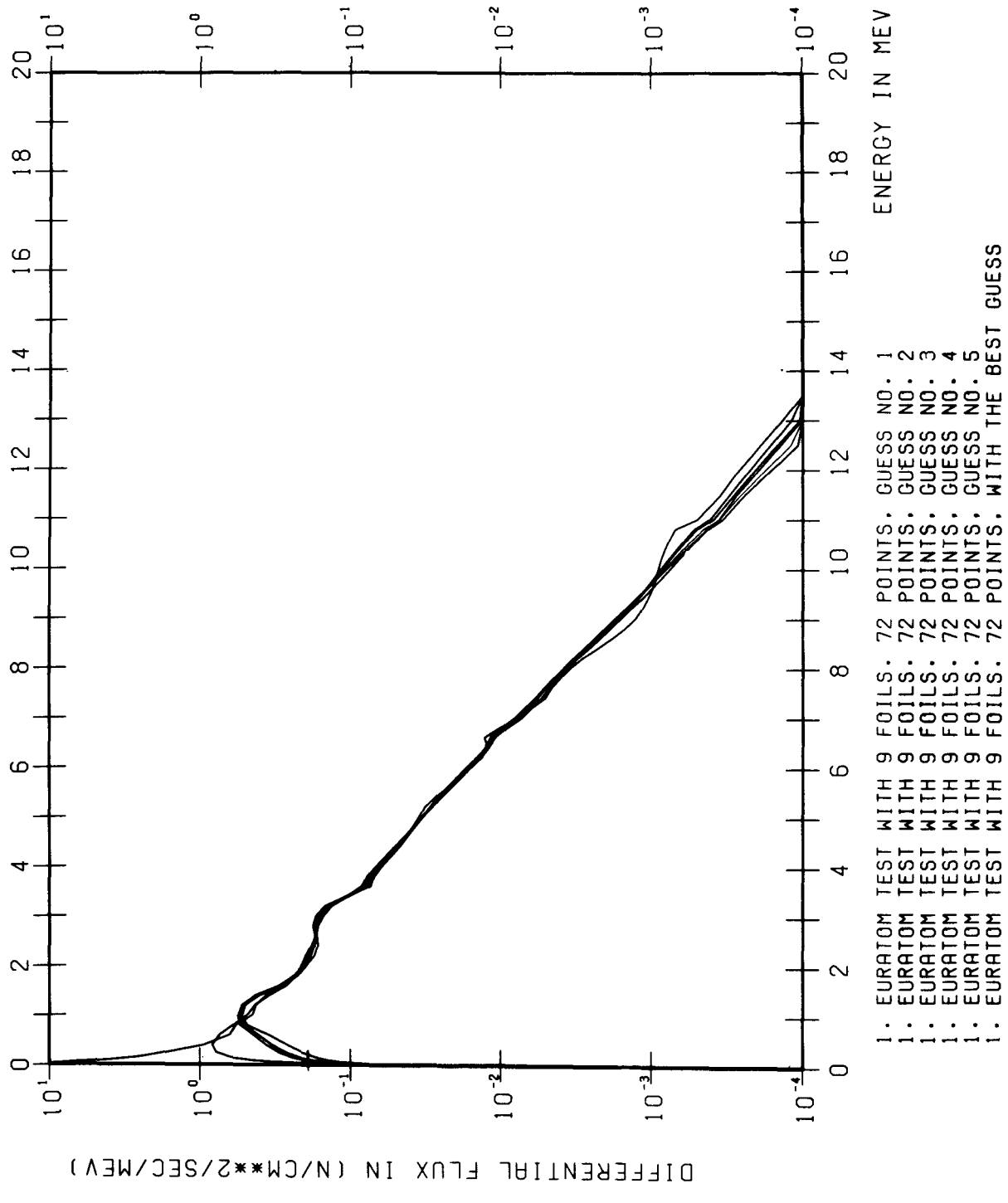


Fig. 8. The result spectra for the guess spectra in the Fig. 4.

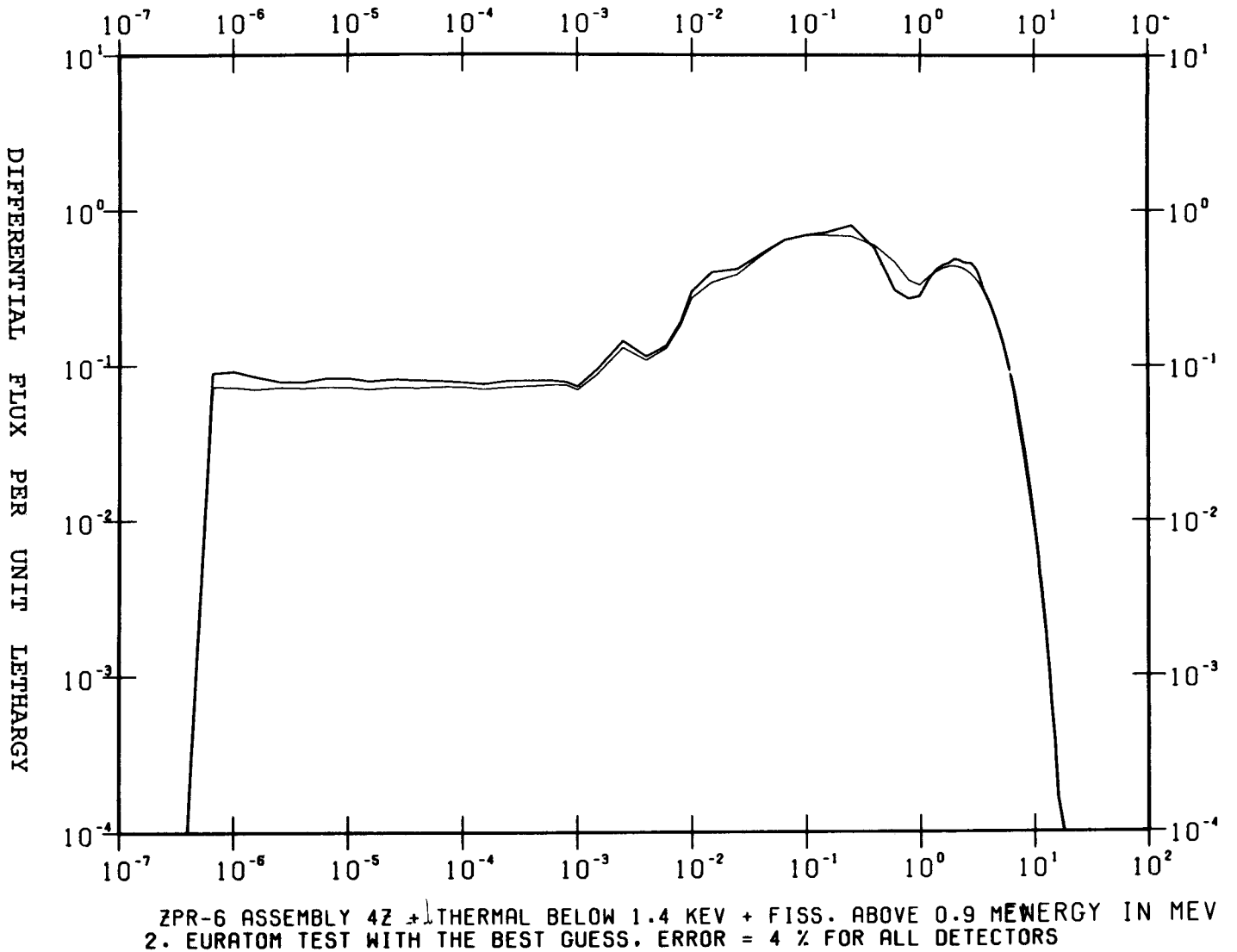


Fig. 9. The result spectrum for the 13-detector set.

APPENDIX

Inviting paper to the intercomparison

An intercomparison of unfolding or evaluation codes is undertaken by the subgroup on unfolding codes of the EWGRD. It is decided to let calculate two problems by different users using same or different codes, utilizing same input activation data and same cross-section files.

All activation and fission rates were obtained from irradiation in the core center of the reactor L 54 of CESNEF, Politecnico di Milano, under 1 mm cover.

The cross-section files are already sent to the participants either as listing either written on a tape.

The fission spectrum is assumed as :

$$\phi_F = 0.4527 \; e^{-E/0.965} \; \sinh\sqrt{2.29\ E}$$

following data are given :

problem 1

nine threshold reaction covering the range 0.5 MeV - 11 MeV intercalibrated in a well known reference fast spectrum. For this reason errors in the cross-section play a minor role; activities may be fitted at 1% (one percent).

activities

Rh^{103}	0.780663	
In^{115A}	0.183712	
Ti^{47}	0.15946	10^{-1}
Ni^{58}	0.97884	10^{-1}
Fe^{54}	0.67752	10^{-1}
Ti^{46}	0.98207	10^{-2}
Mg^{24}	0.12318	10^{-2}
Al^{27}	0.58135	10^{-3}
U^{238}	0.28813	

./.

problem 2

13 detectors (9 from problem 1 and 4 measured absolutely) activities may be fitted to ±4% (four percent)

range	:	1 ev - 11 MeV	
detectors	:	1 to 9 : see above	
further	:	U^{235} :	$0.29041 \quad 10^{2}$
		Am^{241} :	$0.27310 \quad 10^{1}$
		Np^{237} :	$0.13127 \quad 10^{1}$
		Th^{232} :	$0.72556 \quad 10^{-1}$

It is asked :

1. the deviations of the measured from the calculated activities in the obtained spectrum
2. the spectrum itself
3. the deviations from the fission spectrum