NEACRP / L-289

Commission of the European Communities
and
Institut für Kernenergetik und Energiesysteme

Adjustment Results of Iron Cross Sections on the Basis of EURACOS and ASPIS Integral Measurements

(Draft Report prepared for the 28th NEACRP)

by R.D.Bächle - IKE-Stuttgart

Project Leaders: Dr. Gerfried Hehn IKE-Stuttgart
Dr. Wilhelm Matthes JRC-Ispra
Dr. Giuseppe Perlini JRC-Ispra

August 1985 IKE 6 EUR 9

Table of Contents

1 Iron Cross-Sections Adjusted to EURACOS-Fe with Global Detector Method

With the help of the modified global detector method a large number of measurements could be evaluated simultaneously in one iterative adjustment procedure /1/. For the experiment EURACOS-Fe a total number of 11 sulphur detectors as well as 330 results of proportional counters and NE 213 scintillator were used finally /2, 3/. The convergence of the adjustment method is perfect, so that the final results could be obtained after the second iteration step. For natural iron the cross-section of total inelastic scattering as well as the cross-section of elastic scattering show high sensitivity to the integral measurements. In EURLIB group structure a total number of 33 inelastic group data above the inelastic threshold of 0.8 MeV and 100 elastic group data down to thermal energy were treated as free variables for adjustment. The error covariance data of the cross-sections were taken from ENDF/B-5 /4/. The group cross-sections were processed likewise from MAT = 1326. The final results of adjustment with the global detector method to 341 integral measurements of EURACOS-Fe are presented in fig. 1.1 and fig. 1.2. The relative difference between adjusted and original data is negative, when the cross-section is reduced, and positive, if it is increased. For the inelastic cross-section we get a reduction in the total energy range above threshold. The largest effect is with -7.5 % for the small value of the cross-section near the threshold energy. For higher energies up to 8 MeV a reduction about -4% is required and above 8 MeV the correction becomes small.

The adjustment of the elastic cross-section shows the anticorrelation between elastic and inelastic cross-sections. The highest increase is about 5.5 % at 6 MeV, which corresponds to a maximum in the decrease of the inelastic cross-section. According to the sensitivity profiles and the uncertainties given for the cross-sections we get the largest changes in the MeV-region and negligably small effects in the keV-region and below that. Below the inelastic threshold of 0.8 MeV there is a small reduction of the elastic cross-section. But obviously the resonance treatment of iron cross-sections in the keV energy region is covered well. We had to apply large self-shielding factors with strong dependence on penetration depth in iron /5/. The results are in perfect agreement with integral measurements pertaining to this energy range.

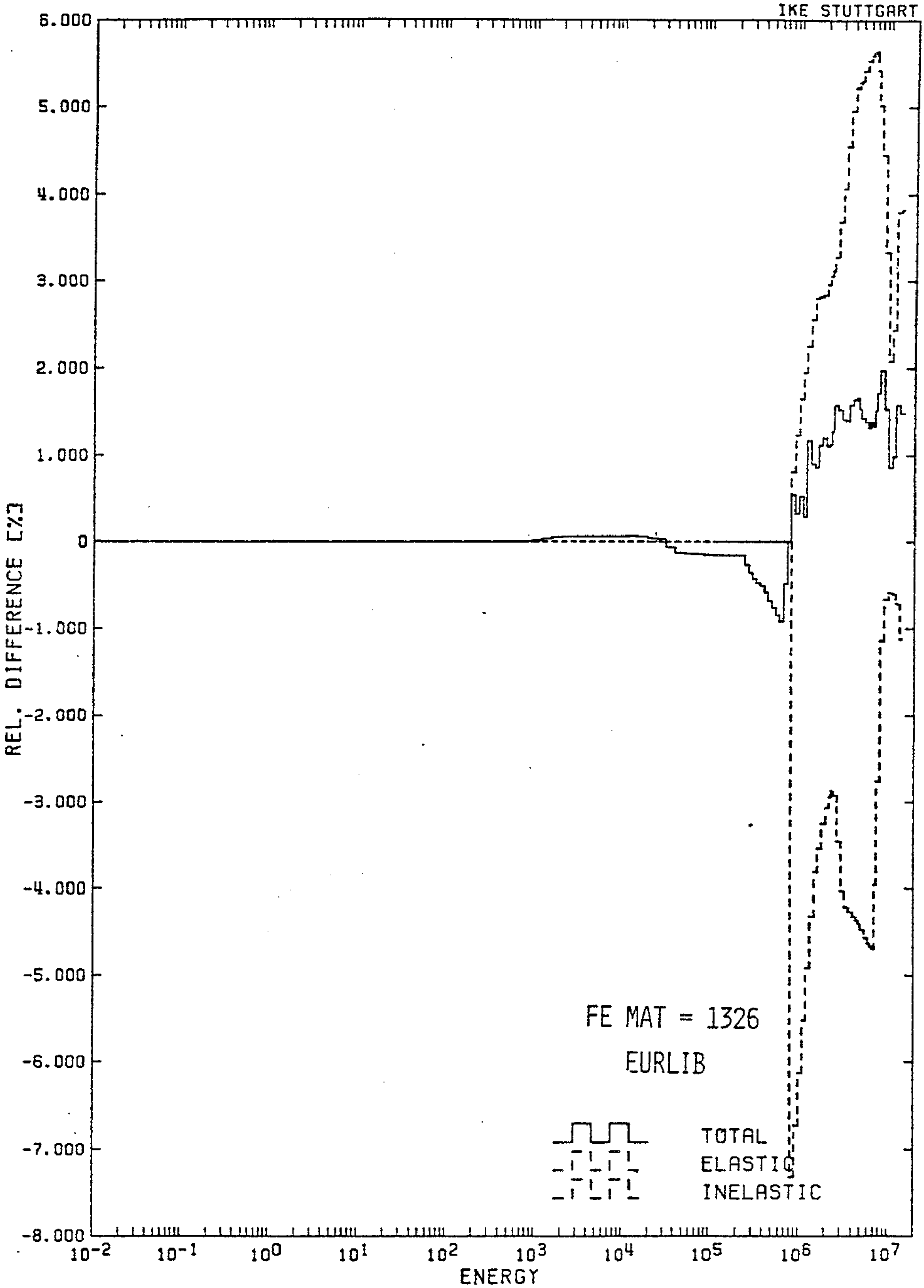

FIG. 1.1: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL CROSS-SECTIONS, GLOBAL METHOD, 2 ND ITERATION EURACOS-FE, 341 MEASUREMENTS.

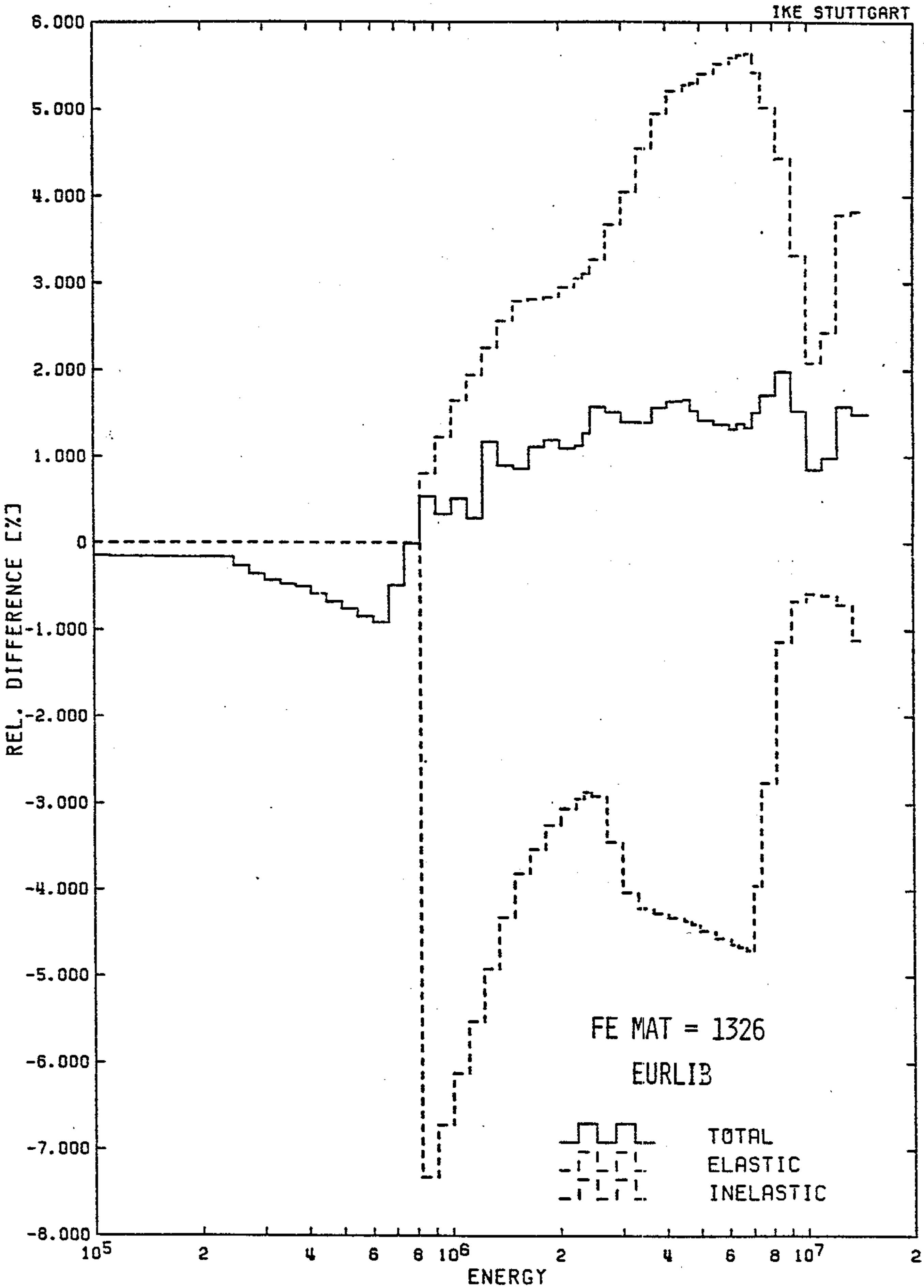

FIG. 1.2: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL CROSS-SECTIONS, GLOBAL METHOD, 2 ND ITERATION EURACOS-FE, 341 MEASUREMENTS.

9306000

2 Check of EURACOS-Fe Results by Newton Method with Singular Detectors

To check the results obtained with the global detector version of the program ADJUST-EUR the Newton version was applied to singular sulphur measurements /5/. The adjustment was performed to detectors at 38.57 cm and 79.1 cm in iron. Since the Newton version converges slower than the global detector version 8 iterations were needed. For the inelastic cross-section the convergence is shown in fig. 2.1, taking as example the cross-section values of EURLIB group number 18 (3.33 - 3.68 MeV). The final relative adjustment of the total inelastic cross-section for both sulphur detectors is given in fig. 2.2. The energy profiles as well as the absolute values agree well with the results for all detectors of fig. 1.2. It can be concluded, that in the case of EURACOS-Fe the adjustment of the iron cross-sections to the 11 sulphur detectors alone brings in principle the final results. The contribution of the 330 channels of proportional connters and NE 213 scintillator is highly consistent with the adjustment effects of 11 sulphur detectors. Otherwise the high number of measurements with proportional counters could have changed the results effectively. But this isn't the case.

This answers also to the question of correlations between different integral measurements. In our evaluation we disregarded any correlation between singular measurements. Only the total statistical and systematic error was taken into account. We can conclude from the similarity of the results of a singular sulphur detector to the final results of all detectors, that in the special evaluation of EURACOS-Fe the effect of correlation between integral measurements is negligable. On the other side the correlation between different partial cross-sections must be regarded. This holds especially for the anticorrelation between the elastic and inelastic cross-section of iron.

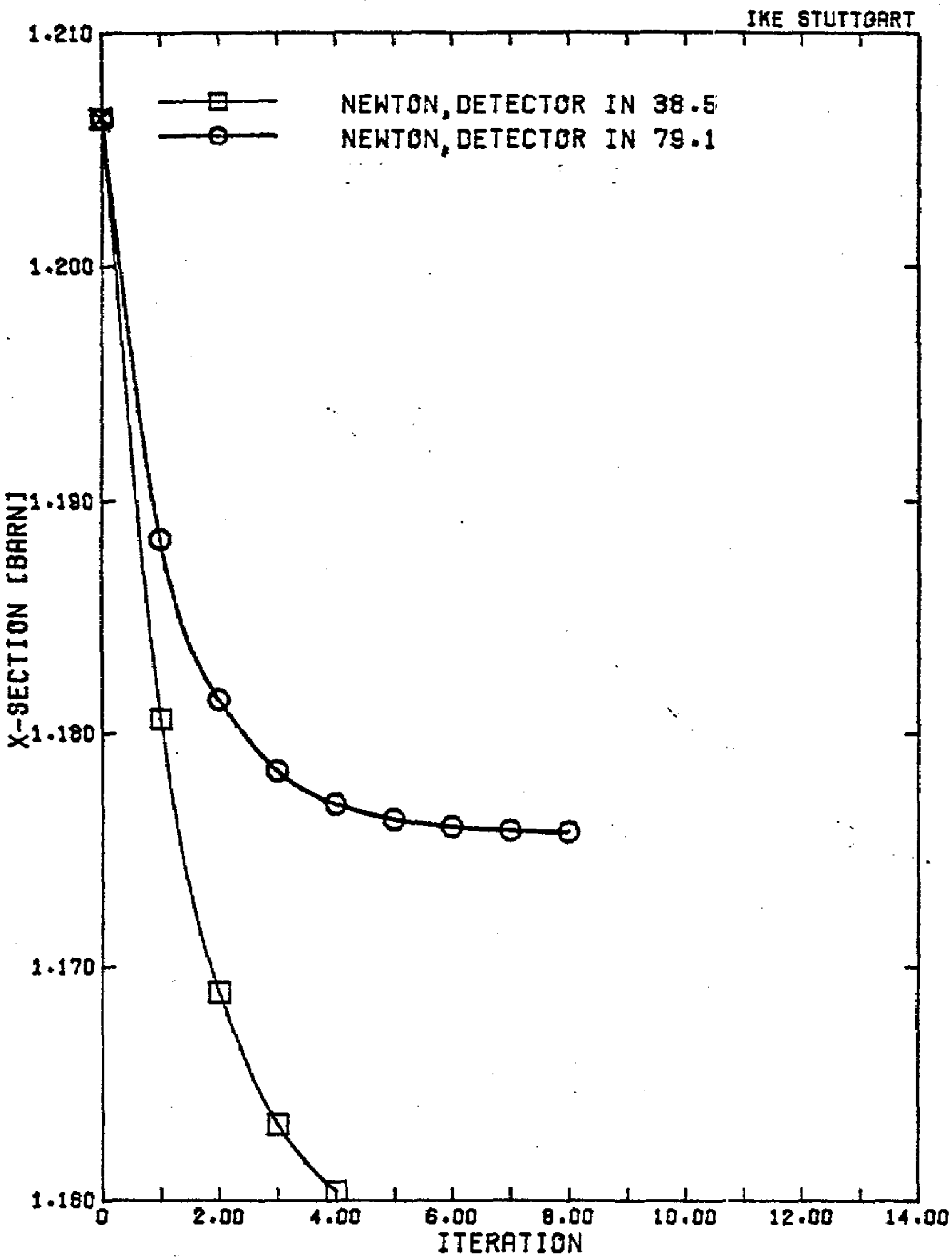

FIG. 2.1: CONVERGENCE OF THE ITERATIVE ADJUSTMENT PROCEDURE, NEWTON METHOD, REDUCTION OF THE INELASTIC IRON CROSS-SECTION OF EURLIB GROUP 18 (3.33-3.68 MEV) FOR TWO SULPHUR MEASUREMENTS AT 38.57 CM AND 79.12 CM, EURACOS-FE

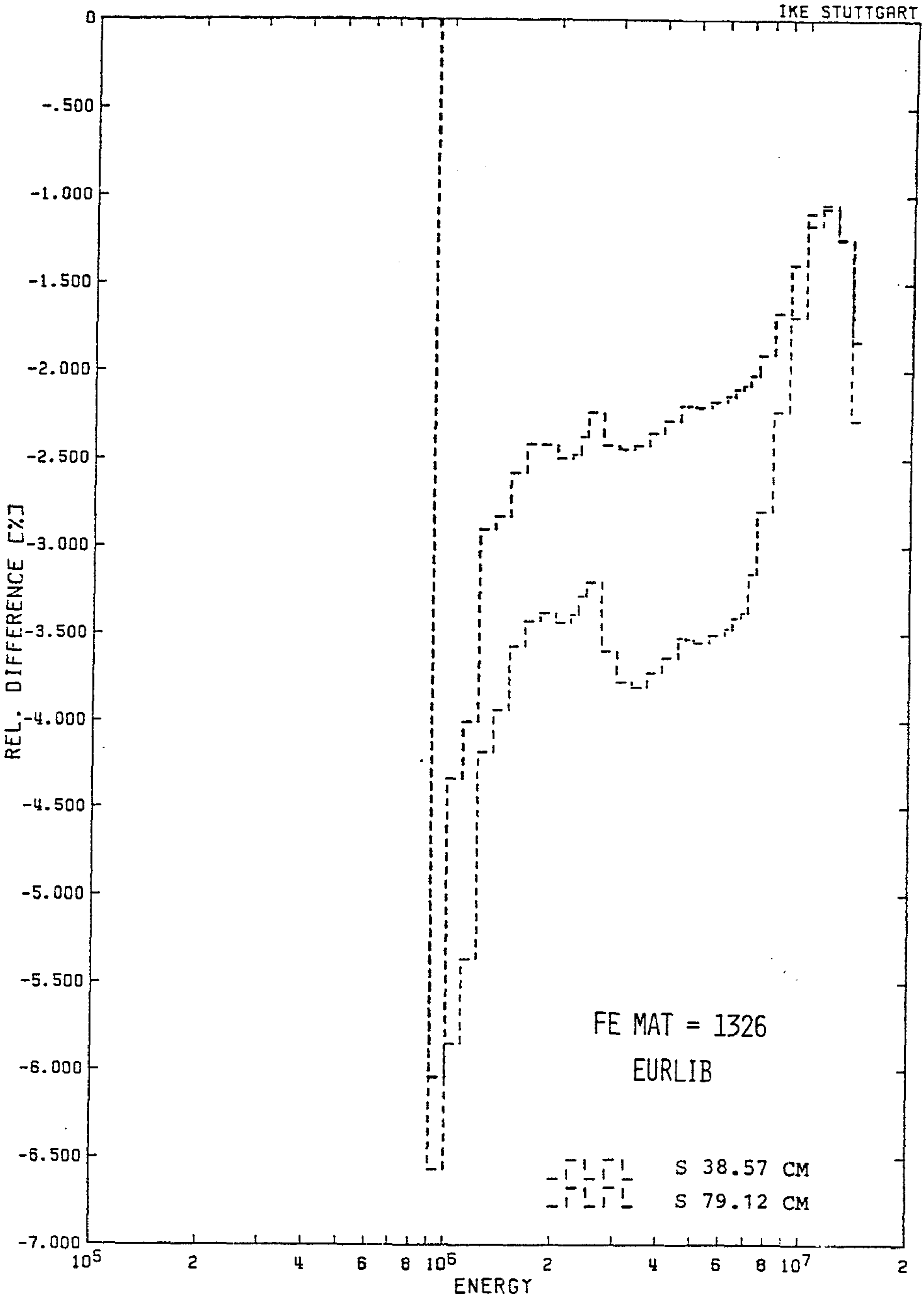

FIG. 2.2: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL INELASTIC CROSS-SECTION OF IRON FOR TWO SULPHUR MEASUREMENTS AT 38.57 CM AND 79.12 CM, NEWTON METHOD, 8TH ITERATION, EURACOS-FE.

3 Iron Cross-Sections Adjusted to ASPIS Experiment with Global Detector Method

The total number of integral measurements used for evaluating the ASPIS experiment was 501. This number include 52 foil detectors (12 S-32, 10 In-115, 16 Rh-103 and 14 Au-193) and 449 measurements of proportional counters and NE 213 scintillator /6, 7/. For adjustment the same basic iron cross-sections were applied as for EURACOS-Fe. Of course, specific group and depth dependent buckling factors as well as self shielding factors were used. The final results of adjustment to all 501 measurements of ASPIS are given in fig. 3.1 and fig. 3.2. Compared with the results obtained for EURACOS-Fe we get a good similarity in the energy profiles of the relative changes to the cross-sections. But there are two distinctive differences. For the inelastic cross-section the adjustment effect is appreciably smaller. The maximum above the inelastic threshold is reduced to -1.4 %. The same holds for the plateau up to 7 MeV, which becoms lower too. The second distinctive difference is, that the elastic cross-section remains relatively unchanged. Below the inelastic threshold at 0.8 MeV we get similar effects compared to the evaluation of EURACOS-Fe.

4 Check of ASPIS Results by Newton Method with Singular Detectors

For the adjustment obtained for all 501 measurements with the global detector method a check was made applying the Newton method to a singular sulphur detector positioned at 68.58 cm depth in iron. The result is shown in fig. 4.1. We can compare it quite well with the EURACOS-Fe results. The relative change of the inelastic cross-section is similar for both experiments in energy profile and absolute number. So we can conclude, that the results of the sulphur detectors of ASPIS would reproduce the results of EURACOS-Fe. The differences between the evaluation of both experiments are obviously due to the other detectors. Expecially the measurements with Rh-103 are responsible for differences in the final adjustment, because the measured rate of the 103 Rh(n,n')-reaction lies below that of the calculated one mostly. There is an opposite effect for the other threshold detectors applied /8/.

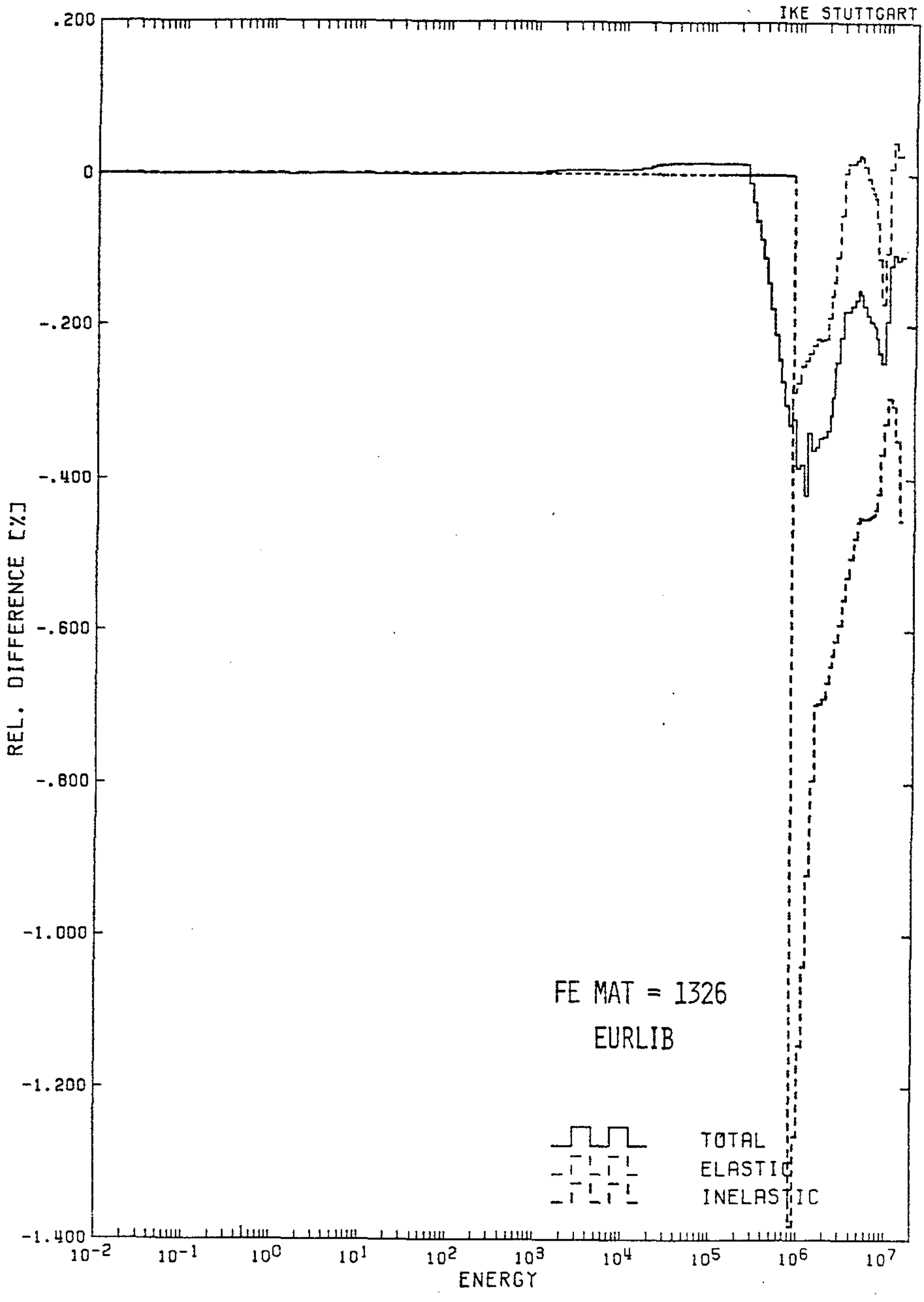

FIG. 3.1: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL CROSS-SECTIONS, GLOBAL METHOD, 2 ND ITERATION ASPIS, 501 MEASUREMENTS.

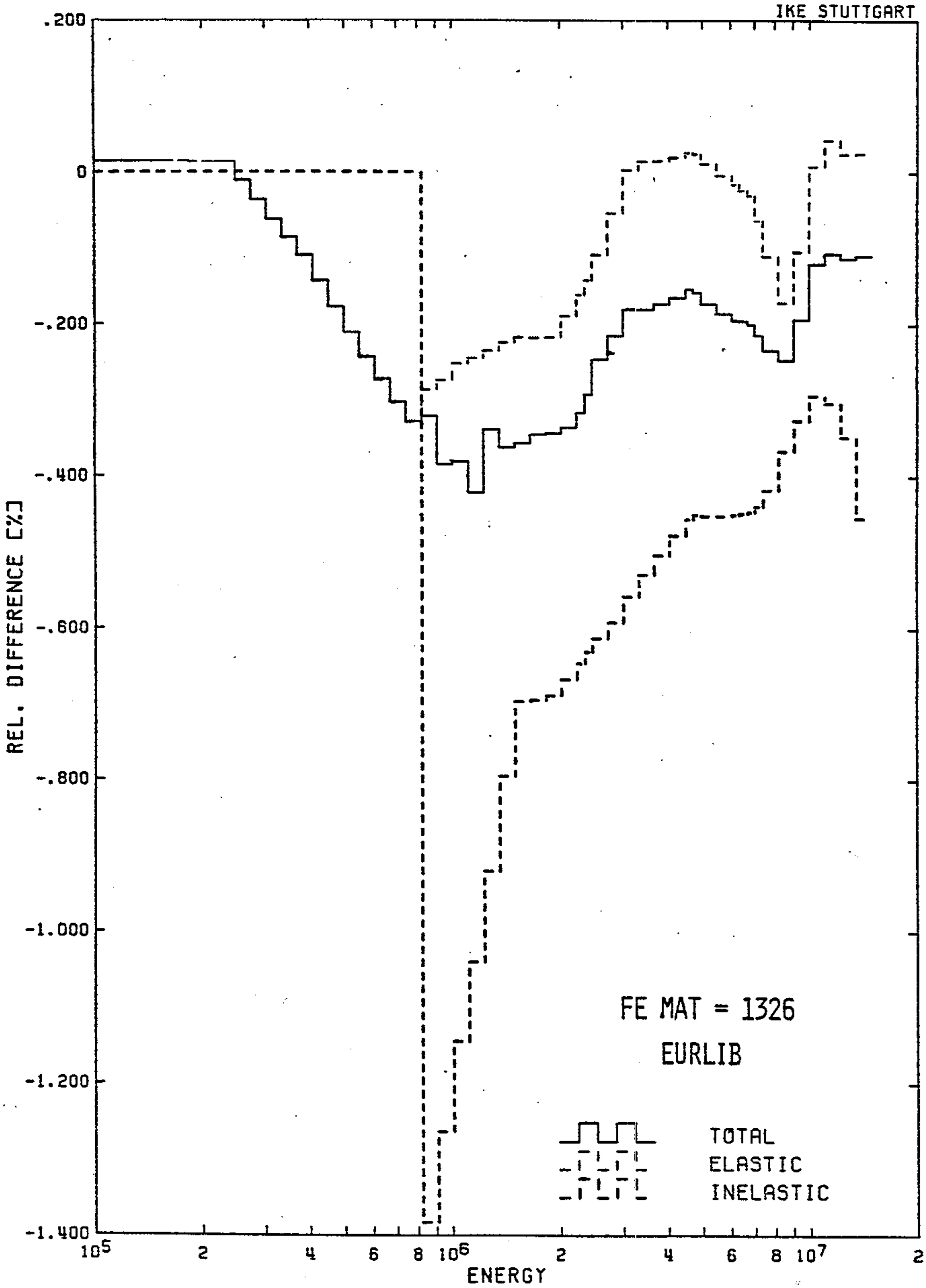

FIG. 3.2: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL CROSS-SECTIONS, GLOBAL METHOD, 2 ND ITERATION ASPIS, 501 MEASUREMENTS.

96660011

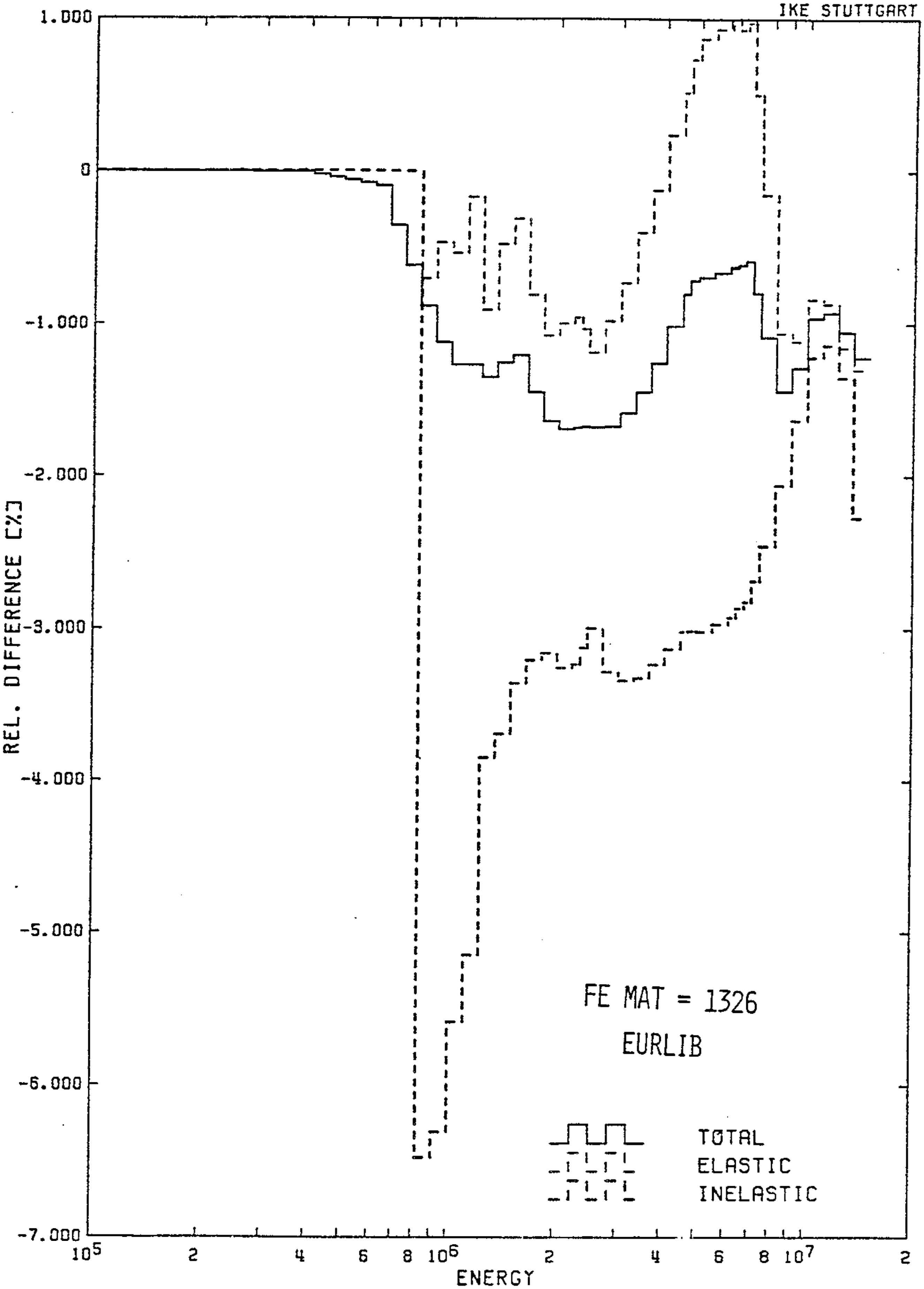

FIG. 4.1: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL CROSS-SECTIONS OF IRON FOR A SULPHUR MEASUREMENT AT 68.58 CM, NEWTON METHOD, 8TH ITERATION , ASPIS.

5 Iron Cross-Section Adjusted to Both Experiments EURACOS-Fe and ASPIS

If we take both experiments together, we have a total number of integral measurements of 341 from EURACOS-Fe and 501 from ASPIS. So the number of ASPIS measurements dominate nearly by a factor of two. We should expect a final result for cross-section adjustment, which lies in between both experiments with a preference to the ASPIS majority of measurements. This can be seen from fig. 5.1 and fig. 5.2. The inelastic cross-section has a reduction up to -2.4 % above the threshold and about -1.2 % in the plateau up to 7 MeV. The elastic cross-section shows reductions of -0.6 % between 0.8 MeV and 3 MeV and at 8 MeV.

6 Conclusion of the Final Results

The final results of the cross-section adjustment can be compared with the relative standard deviation (1 σ) of the cross-sections as given in fig. 6.1. We can conclude, that all adjustment results obtained for the experiments EURACOS-Fe and ASPIS lie well within the uncertainty given for the partial cross-sections. This holds for the adjustment to singular measurements, obtained with the Newton method, as well as for the results of the global detector method, which considers a total sum of 842 integral measurements.

The largest uncertainty with 12 % is quoted for inelastic cross-section at threshold energy. Here we find in all adjustment runs for singular measurements as well as for the total sum of all available measurements, that the cross-section contained in MAT = 1326 is too high and should be reduced by -2.4 % at least according to the 842 integral measurements. For higher energies up to 7 MeV the reduction of the total inelastic cross-section should be -1.1 %, which is covered well by 5 % uncertainty quoted in fig. 6.1. That the evaluation of the inelastic iron cross-section of MAT = 1326 is relatively high, can be seen by comparing with other evaluations as shown in fig. 6.2.

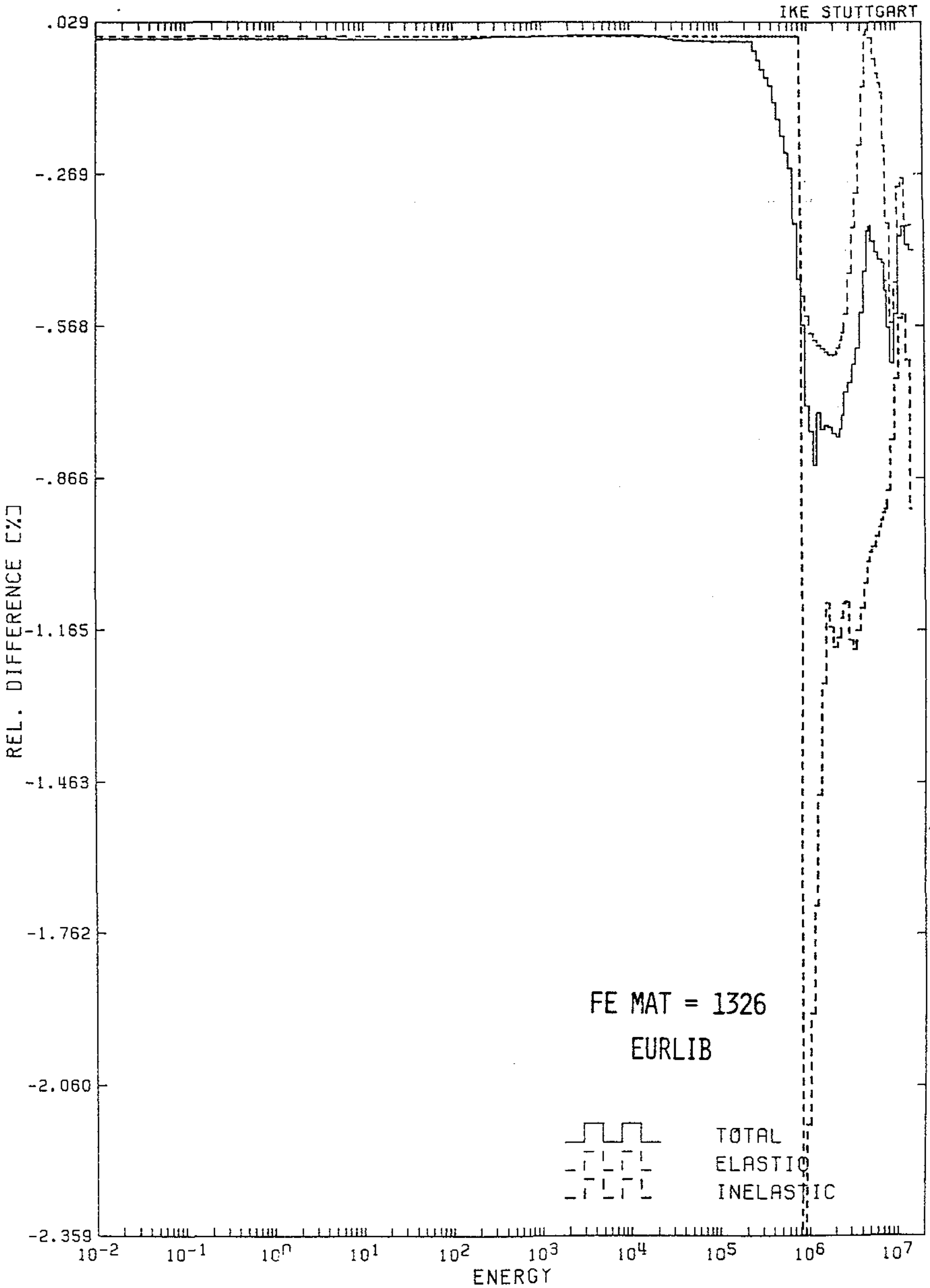

FIG. 5.1: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL CROSS-SECTIONS OF IRON FOR 341 MEASUREMENTS OF EURACOS-FE AND 501 MEASUREMENTS OF ASPIS, GLOBAL DETECTOR METHOD, 2 ND ITERATION.

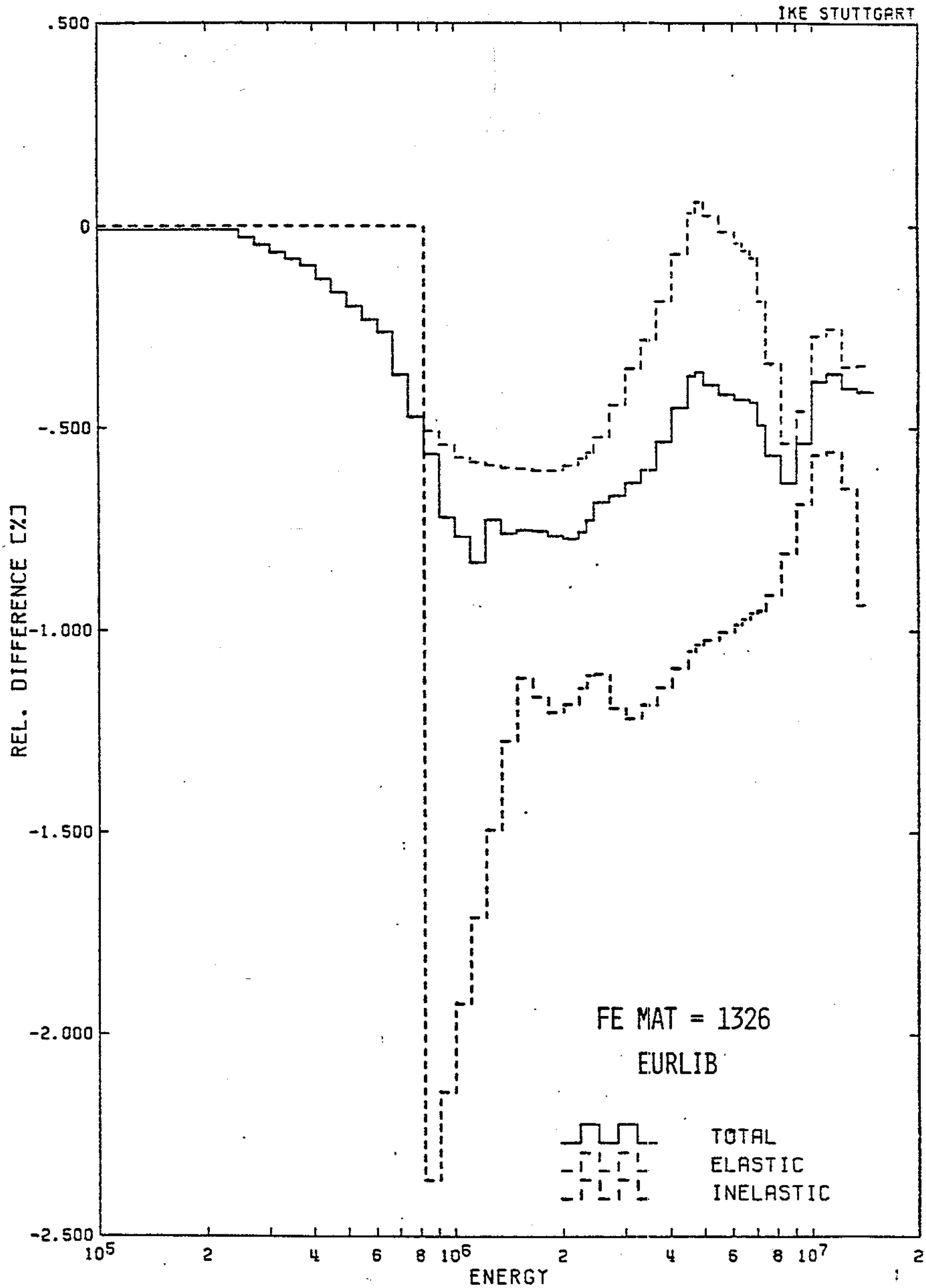

FIG. 5.2: REL. DIFFERENCE BETWEEN ADJUSTED AND ORIGINAL CROSS-SECTIONS OF IRON FOR 341 MEASURMENTS OF EURACOS-FE AND 501 MEASUREMENTS OF ASPIS, GLOBAL DETECTOR METHOD, 2 ND ITERATION.

The elastic cross-section of natural iron is measured more precisely than the inelastic. In the keV energy region an error of 1 % is quoted in fig. 6.1. In accordance to this the lowest changes of the adjusted cross-sections are found for this energy region in fig. 5.1. In the same energy region large self-shielding factors had been applied to both experiments separately /1, 8/. Since the adjustment is performed on the basis of macroscopic group cross-sections, we get a perfect check of the self-shielding factors, too. We can conclude, that the newest evaluated cross-sections of iron are in agreement with measurements of deep penetration experiments. The adjustments lie well within the 1 σ-uncertainties. Compared with published results a good progress has been achieved /9/.

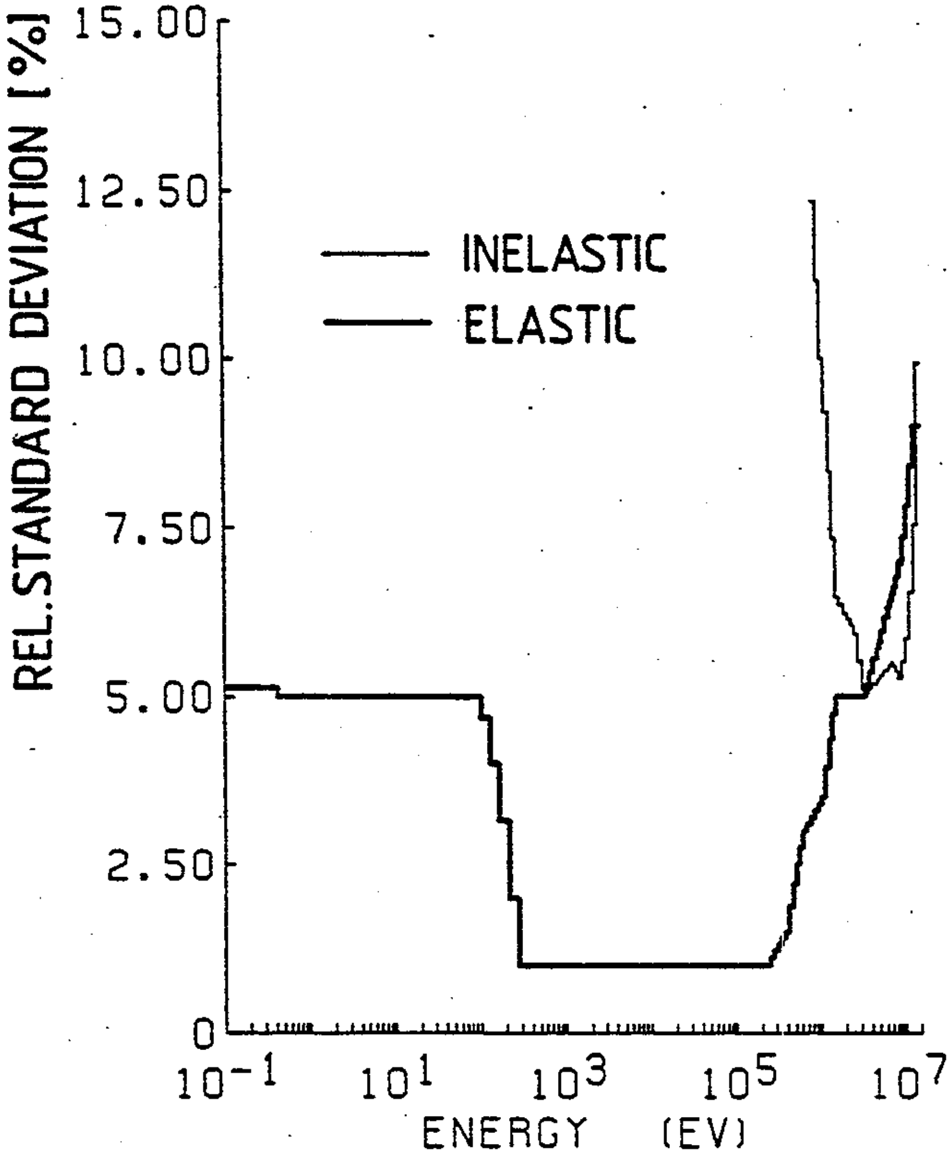

FIG. 6.1: RELATIVE STANDARD DEVIATION OF THE IRON INELASTIC AND ELASTIC SCATTERING CROSS-SECTION IN EURLIB GROUP STRUCTURE FROM ENDF/B-5 /4/.

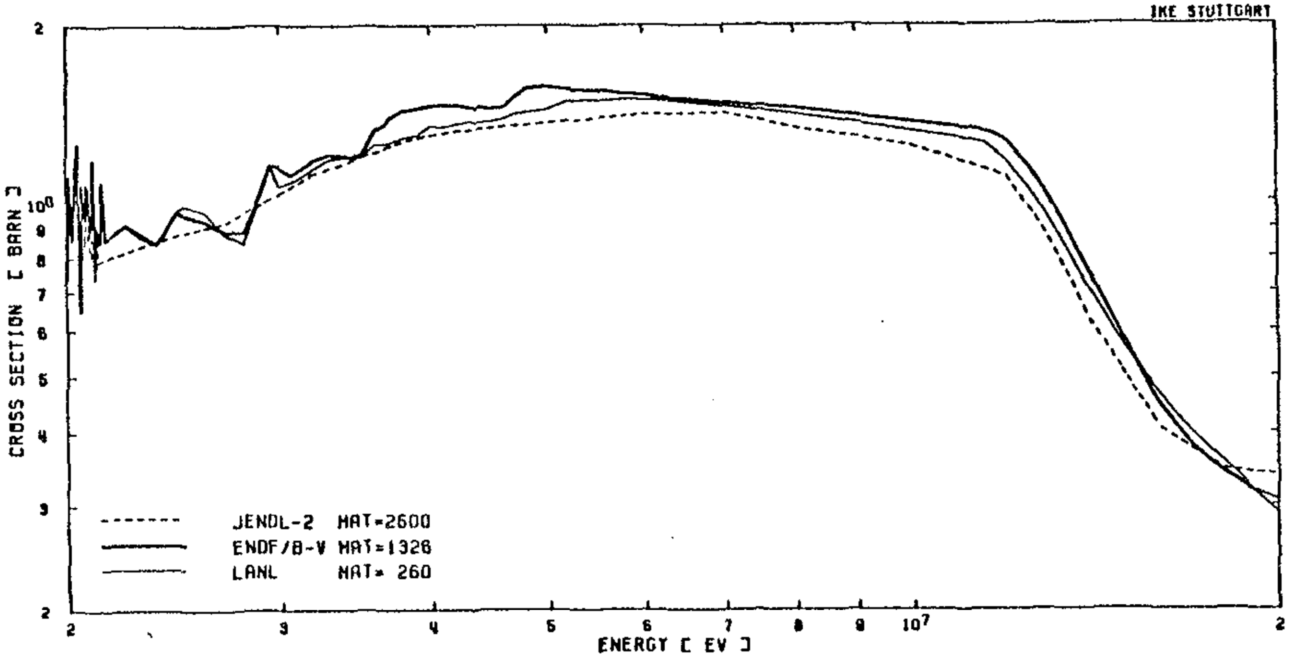

FIG. 6.2: INELASTIC SCATTERING CROSS SECTION OF IRON FROM THREE DIFFERENT EVALUATIONS.

Literature

/1/ Bächle, R.-D.; Hehn, G.; Pfister, G.; Mattes, M.; Matthes, W.:
EURLIB Data Adjustment to Integral Experiments.
5. Progress Report: Modified Global Detector Method and Adjustment of Cross-Sections Using Measurements of the EURACOS Experiment. IKE 6 EUR 5, 1983

/2/ Perlini, G.; Gonano, G.:
The Iron Benchmark Experiment at EURACOS II.
5. Int. Triga User's Conf., Portoroz, 1978

/3/ Perlini, G.; Gonano, G.:
The EURACOS Deep Penetration Iron Benchmark Experiment.
NEA-Specialist Meeting on Shielding Benchmarks, Paris, 1984

/4/ Muir, D.; La Bauve, R.:
COVFILS, a 30 Group Covariance Library Based on ENDF/B-5.
LA-8733-MS, 1981

/5/ Bächle, R.-D.; Hehn, G.; Mattes, M.:
EURLIB Data Adjustment to Integral Experiments.
3. Progress Report: Work on the Program ADJUST-EUR.
IKE 6 EUR 3, 1982

/6/ Carter, M.D.; McCracken, A.K.; Packwood, A.:
The Winfrith Iron Benchmark Experiment.
NEACRP-A-498, 1982

/7/ Butler, J.; Carter, M.D.; McCracken, A.K.; Packwood, A.:
Results and Calculational Model of the Winfrith Iron Benchmark Experiment.
NEACRP-A-629, 1983

/8/ Hehn, G.; Bächle, R.-D.; Pfister, G.; Mattes, M.; Matthes, W.:
Adjustment of Neutron Multigroup Cross-Sections with Error Covariance Matrices to Deep Penetration Integral Experiment.
Nucl. Data for Science and Technology, Antwerpen, 1982

/9/ Hall, M.C.G.:
Cross-Section Adjustment with Monte Carlo Sensitivities: Application to the Winfrith Iron Benchmark.
NSE 81, 3, 1982

THE INTERNATIONAL INTERCOMPARISON OF CODES FOR RADIATION ASSESSMENT OF TRANSPORTATION PACKAGES

1 At the meeting held in Paris on 25/26 May 1987 it was decided that problems 5 and 6 of NEACRP-L-290 should be extended to include the sources of Cobalt-60 produced in the end-fittings of the fuel elements by thermal neutron activation. The posulated distributions of thermal neutron flux in the top and bottom fittings are respectively given in the attached Figs 1 and 2, and are also summarised in Tables 1 and 2. The Cobalt-59 content of material 1.4541 of which the end-fittings are constructed is assumed to be 0.1% by weight. In addition it is assumed that the expansion spaces contain 8.0×10^{-4} gm/cc Co^{59} in the void to repressent the presence of springs.

2 Previously at the meeting of June/July 1986 the following modifications to the specification of the problems were agreed:-

Problem 2a	The moderating material would extend over the height of the cavity (not the flask).
Problem 4	Use the geometry of problem 1a for the flask, ie the flask is of cast iron with no fins and no neutron shielding material. Problem 4 thus concentrates on examining the effects of the detailed representation of the source region without any complexities due to the geometry of the flask.
Problems 5 and 6	The calculation of K_{eff} for the flask would be sufficient to give the multiplication of neutron sources. (The alternative would be to perform a fixed source calculation and follow the neutrons through as many generations as necessary). The emphasis was placed on the comparisons of the predicted sources of fission product gamma-rays and neutrons from the actinides. The calculation of their subsequent penetration through the flask walls was considered to be of less importance as this would have been examined in the earlier problems (but see section 4 below).

3 At the meeting of May 1987 further modifications were made to problems 5 and 6 for those participants who wished to

perform calculations for a flask containing the predicted sources.

a There would be no basket

b The flask would be dry

c The active lengths of the five fuel elements would be smeared to fill the cavity over that length.

d The expansion spaces, plugs and end-fittings of the fuel elements would be smeared to fill the cavity over their respective lengths ie separate smears for each of the nine regions of figure IV/1 of NEACRP-L-290.

e The flask for these problems would be that of problem 1a.

4 The calculation of the source strengths for problems 5 and 6 should be carried out for various burn-ups to cover the range given in Table A6 for the axial distributions. This will enable the predictions of the various codes to be compared at a number of burn-ups which will demonstrate in paticular any effects due to the use of different cross-section libraries for the actinides. For the shielding calculation the source should be given the appropriate axial variation where possible and the axial distribution of the external dose-rates calculated. This would demonstrate any differences resulting from the use of uniform source strengths in problem 1a and indicate to what extent it is necessary to include the axial variation of the source in such calculations.

5 For completeness the corrigendum to NEARCP-L-290 which was issued by the NEA Data Bank in 1986 is also attached.

A F AVERY

Radiation Physics and Shielding Group
AEE Winfrith

November 1987

CORRIGENDUM TO NEACRP-L-290

Intercomparison of codes for the shielding assessment of transportation packages.

Corrected specifications

1. Nature of source

To the second part of Tables I/1,2; II/1,2; III/1,2; IV/1,2 labeled "Source description", the following line must be added:

source characteristic volume distributed fixed source

2. Flux density dimension

In Fig. I/2,3,4; II/4; III/4; IV/4; V/2; VI/2 replace the abszissa labeled with
ø [1/s·MeV]
by
ø [1/(s·cm²·MeV)]

3. Polyethylene and Epoxy cast resin composition (p.62)

In Table A7: "Composition of Materials used" replace the five lines

polyethylene	0.91	C	14.4
		H	85.6
epoxi cast resin	1.4	C	0.95
		H	0.09
		O	0.21

by:

polyethylene	0.91	C	85.6
		H	14.4
epoxi cast resin	1.25	C	76.3
		H	6.7
		O	17.0

4. Averaging specification (p 12)

Replace in Table I/4 the line
"surface averaged [1] dose rates (μSv/h)"
by
"maximum dose rates (μSv/h)"
and omit the subscript at the bottom of the page

TABLE 1

THERMAL NEUTRON FLUX AT THE TOP OF THE FUEL ELEMENT

Distance above the active fuel (cm)	Thermal Neutron Flux ($n/cm^2.s$)
0	1.89,13
2.5	2.09,13
5.0	1.62,13
7.5	1.60,13
10.0	1.35,13
12.5	1.08,13
15.0	9.58,12
17.5	8.73,12
20.0	6.47,12
22.5	4.64,12
25.0	3.67,12
27.5	3.16,12
30.0	2.53,12
32.5	1.91,12
35.0	1.50,12
37.5	1.14,12
40.0	6.61,11
42.5	3.33,11
45.0	2.44,11
47.5	1.72,11
50.0	1.35,11
51.8	1.32,11

NOTE: 1.89,13 = 1.89×10^{13}

TABLE 2

THERMAL NEUTRON FLUX AT THE BOTTOM OF THE FUEL ELEMENT

Distance below the active fuel (cm)	Thermal Neutron Flux ($n.s^{-1}cm^{-2}$)
0	2.22,13
2.5	4.10,13
5.0	5.45,13
7.5	5.30,13
10.0	4.49,13
12.5	3.60,13
15.0	3.18,13
17.5	2.90,13
20.0	2.15,13
22.5	1.54,13
25.0	1.22,13
27.5	1.05,13
30.0	8.40,12
32.5	6.35,12
35.0	4.98,12
37.5	3.80,12
40.0	2.39,12
42.5	1.40,12
45.0	1.14,12
47.5	8.80,11
50.0	6.20,11
52.5	5.07,11
55.0	4.60,11
57.5	3.95,11
60.0	3.68,11
60.8	3.46,11

NOTE: 2.22,13 = 2.22×10^{13}

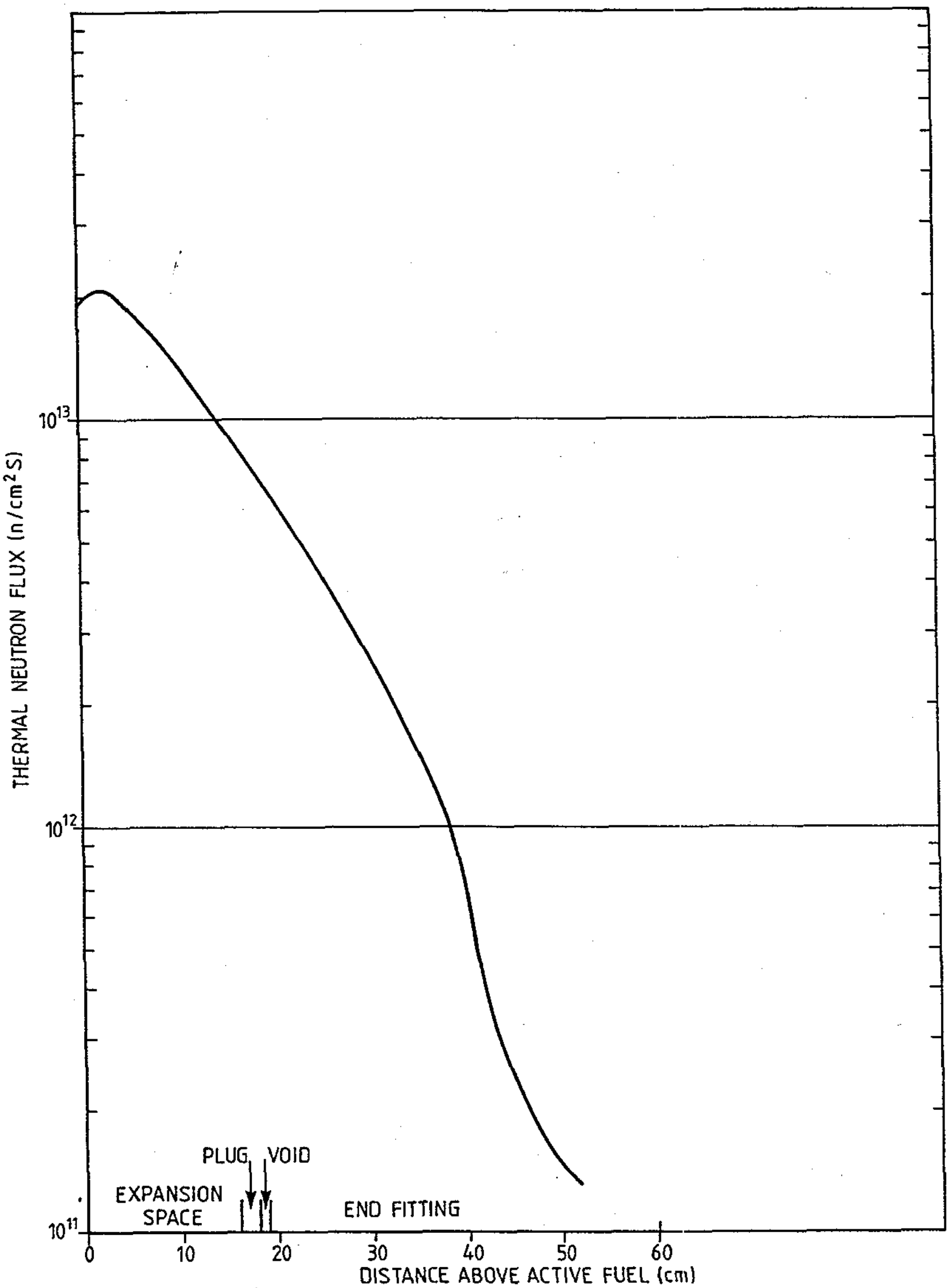

FIG.1 THERMAL NEUTRON FLUX AT THE TOP OF THE FUEL ELEMENT

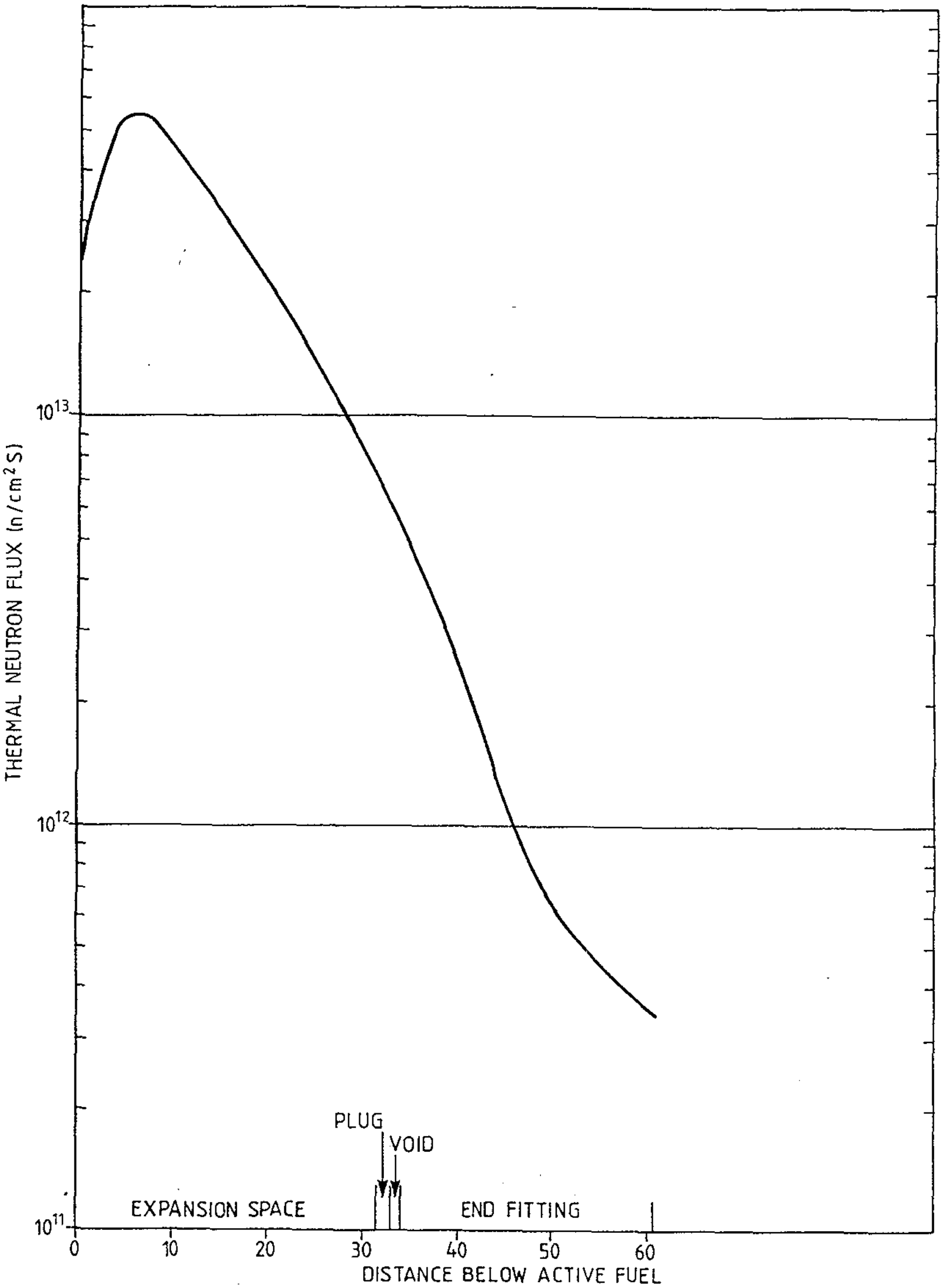

FIG. 2 THERMAL NEUTRON FLUX AT THE BOTTOM OF THE FUEL ELEMENT

DISTRIBUTION:
(To Participants at 1987 meeting)

Belgium

Mr A Renard
Belgunucleaire
25 rue de Champ de Mars
Bruxelles
Belgium

Finland

Dr F Wasastjerna
Nuclear Engineering Laboratory
Technical Research Centre of Finland
POB 169
SF-00181 Helsinki 18

France

Mr C Diup
CEN Saclay
DRE/SERMA/LEP
F-91191 Gif/Yvette Cedex
France

Mr L Bourdet
CEN Saclay
DRE/SERMA/LEP
F-91191 Gif/Yvette Cedex
France

R F Germany

A U Gewehr
Gesellschaft fur Reaktorsicherheit
Forschunsgelaende
D-8046 Garching

Italy

Dr Giafranco Gualdrini
ENEA-T13/FICS
CRE "E Clementel"
Via Mazzini 2
I-40139 Bologna
Italy

Mr Sergio Mancioppi
ENEA/DISP-ARA-RAM
Via Vitaliano Brancati 48
I-00144 Roma
Italy

Japan

Mr Shun-ichi Tanaka
Department Reactor Engineering
JAERI
Tokai-Mura
Naka-gun
IBARAKI-KEN 319-11

Sweden

Mr D Mennerdahl
E Mennerdahl Systems
Pl 457
5-186 00 Vallentuna
Sweden

Switzerland

Dr J F Jaeger
Eidgenoessisches Institut fuer Reaktorforschung
CH-5303 Wuerenlingen

United Kingdom

Mr A F Avery
Atomic Energy Establishment
Winfrith
Dorchester
Dorset
GB
DT2 8DH

United States

Mr R M Westfall
Oak Ridge National Laboratory
PO Box X
Oak Ridge, TN 37831

Mr C V Parks
Nuclear Engineering Application Department
Martin Marietta Energy Systems Inc
PO Box X
Oak Ridge, TN 37831

NEA Secretariat

Mr E Sartori
NEA Data Bank
91191 Gif-sur-Yvete CEDEX
France