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Projekt Schneller Brüter

Comments on the Calculation of Reaction Rate Traverses

E. Kiefhaber

GESELLSCHAFT FÜR KERNFORSCHUNG M. B. H.

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E. Kiefhaber

Gesellschaft für Kernforschung m.b.H., Karlsruhe

Abstract

The present work is concerned with the influence of calculational methods and some changes in the nuclear data on the calculated reaction rate traverses. As an example the traverses for U235 fission and U238 capture and fission in the assembly SNEAK 3A2 are studied. Besides some sensitivity studies the adequacy of the use of a global buckling for the separated direction in one-dimensional calculations is checked by two-dimensional calculations. The influence of reflecting zones outside the blanket has been determined. We have studied the effects of applying: heterogeneity-corrected group constants, the REMØ-correction, two different types of transport cross sections and two different forms for the energy dependence of the fission spectrum. No major deficiency in the generally used calculational methods has been found so that the existing discrepancies between theory and experiment must be caused either by errors in the measurements or more probably by deficiencies in the nuclear data.

Zusammenfassung

Am Beispiel der Anordnung SNEAK 3A2 wird untersucht, welchen Einfluß die Berechnungsmethoden und einige Änderungen in den nuklearen Daten auf die berechneten Reaktionsratentraversen für U235-Spaltung und U238-Einfang und -Spaltung haben. Zunächst wurden einige Sensitivitätsuntersuchungen durchgeführt. Durch Vergleich von ein- und zweidimensionalen Diffusionsrechnungen wurde nachgewiesen, daß die Benutzung eines globalen Bucklings für die abseparierte Richtung in eindimensionalen Rechnungen gerechtfertigt ist. Der Einfluß von Reflektoren außerhalb des Blankets auf die Traversen wurde bestimmt. Außerdem wurde der Einfluß der Benutzung heterogenitätskorrigierter Gruppenkonstanten, der REMØ-Korrektur, der Art des Transportquerschnitts und der Energie-Abhängigkeit des Spaltspektrums untersucht. In den überlicherweise benützten Rechenmethoden wurden keine wesentlichen Mängel festgestellt. Daher müssen die noch bestehenden Diskrepanzen zwischen Theorie und Experiment für die Reaktionsratentraversen entweder auf Fehler in den Messungen oder, wahrscheinlicher, auf Mängel in den nuklearen Daten zurückzuführen sein.

INTRODUCTION

In the present study we will determine the influence of the calculational procedure and some changes in the nuclear data on the calculated reaction rate traverses. As an example we study the traverses for U235 fission and U238 capture and fission in the assembly SNEAK 3A2. The corresponding measurements are described in [1].

In the past it has been shown that there still exist some discrepancies between the calculated and measured reaction rate traverses (see e.g. [1], [2]) which are not yet completely understood. These discrepancies are rather large in the blanket region and less severe in the core region. But in both regions they cannot be neglected. The present study is undertaken to detect whether there are deficiencies in the usually applied methods for the calculation of the reaction rate traverses.

PELIMINARY REMARKS

Two rather trivial comments at the beginning:

1. One should make sure that the calculated fluxes have the desired accuracy, that means that convergence has been achieved and that the number of mesh points used in the calculations is sufficiently large.

2. It is important in the experiments to determine the position of the foils and the dimensions of the assembly very accurately. For example a change of the total core height by only 0.16 cm (=0.5%) leads to deviations in the reaction rates of 0.2% in the core and up to 1.4% in the blanket even if the dimensions of the zones are transformed in such a way that for this comparison it could be achieved that the boundaries of the zones do match exactly. Especially in the blanket it is essential that the position where theory and experiment are compared are in rather good agreement since otherwise rather large errors may arise because of the steep gradient of the neutron flux and the reaction rate traverses.

SENSITIVITY STUDIES

At first we will report on some sensitivity studies which were performed in order to see the influence of more or less arbitrary changes in some parameters on the calculated reaction rate traverses. As most of the usual calculations, those of this chapter are done in one-dimensional geometry using diffusion theory. The MØXTØT-set [3] is used as nuclear data basis. The parameters considered here are:

a) The boundary condition at the outside of the axial blanket.

b) The transversal buckling in the blanket for the separated space direction.

c) The removal cross section of the blanket material.

d) The transport cross section, respectively the diffusion constant of the blanket material.

e) The transport cross section, respectively the diffusion constant of the core material.

The results of the sensitivity studies are shown in figs. 1 - 5. The parameters changed for the cases 1 - 6 are listed in table 1 together with the criticality parameter k_{eff} obtained in the calculations.

From fig. 1 we see that the boundary condition $\phi = 0$ at the outer surface of the blanket has practically no influence on the reaction rate traverses in the core region. Within 0.1% they remain unchanged. At about 10 cm from the blanket surface the decrease compared to the reference case amounts to 3 - 4 %. Only within the last 5 cm the reduction is very pronounced.

The reflective boundary condition $d\phi/dz = 0$ at the blanket surface has an effect on the traverses which becomes important at even larger distances from the surface than in the previous case. In the core region too the influence is negligible (smaller than about 0.3%). But at a distance of 10 cm from the blanket surface the increase compared to the reference case amounts to about 20% for σ_c(U238) and σ_f(U235) and to about 10% for σ_f (U238) as can be seen from fig. 2.

Table 1: Parameters used for the sensitivity studies

Case	Boundary condition at the outside of the blanket	B^2_{sep} for the axial blanket *	Removal cross section in the blanket	Transport cross section in the blanket	Transport cross section in the core	k_{eff}
Reference	Usual diffusion boundary condition	$=16.949119 \cdot 10^{-4} cm^{-2}$	as usual	as usual	as usual	1.00391
1	Flux $\phi = 0$	as in the reference case	as in the reference case	as in the reference case	as in the reference case	1.00387
2	Current $\sim \frac{d\phi}{dz} = 0$	"	"	"	"	1.00407
3	as in the reference case	$9.0 \cdot 10^{-4} cm^{-2}$	"	"	"	1.00558
4	"	as in the reference case	in all groups usual value multiplied by 0.95	"	"	1.00801
5	"	"	as in the reference case	in all groups usual value multiplied by 0.95	"	1.00262
6	"	"	"	as in the reference case	in all groups usual value multiplied by 0.95	0.99193

* B^2_{sep} for the core = $16.949119 \cdot 10^{-4} cm^{-2}$ in all cases

In one-dimensional calculations one has to use most times a buckling to account for the leakage in the separated space direction. The easiest way to do this is to use an energy- and zone-independent value. This so-called global buckling is appropriate for the core region and leads to rather good criticality values. But it is questionable whether this global buckling is appropriate in the blanket- or reflector-region especially if the assembly has blanket- or reflector-regions in all space directions. For fig. 3 the buckling in the axial blanket region has been reduced compared to the value of the global buckling used in the reference case; the buckling for the core region is the same in both cases. The new blanket buckling is still independent of energy and does not vary with the position within the blanket region.

Fig. 3 shows that within the core region there is an increase of the traverses by 2 - 3%. At a distance of 10 cm from the blanket surface the increase amounts to 8 - 10%. Both changes cannot be considered as negligible because they are of the same order of magnitude as the still existing discrepancies between theory and experiment. This means that for a reliable prediction of the reaction rate traverses in the outer core region and in the blanket region some attention has to be devoted to the buckling for the separated space direction, otherwise on cannot rely on the results of one-dimensional calculations but instead has to perform two- or three-dimensional calculations.

To get an insight into the possible influence of changes in the nuclear data we reduced somewhat arbitrarily the removal- respectively the transport-cross section of the blanket composition by 5% in all energy groups.

In fig. 4 the results for the reduction of the removal cross section are shown. The increase of 6 - 7% for the traverses at the core-blanket boundary is considerable. At a distance of 10 cm from the outer blanket surface the increase amounts to about 25% compared to the reference case. Table 1 shows that there is also a remarkable increase of 0.4% in k_{eff}.

From fig. 5a we see that a reduction of the transport cross section is far less important (for the reaction rate traverses as well as for the criticality (table 1)) than a reduction of the removal cross section by the same amount for the blanket composition.

Fig. 5b shows that a 5% reduction of the transport cross section for the core composition leads to an increase of the reaction rates of about 3.5 to 4% in the outer region of the core and to an increase of about 5% in the outer blanket region.

CONCLUSIONS FROM THE SENSITIVITY STUDIES

Although a change of the removal cross section of the blanket composition by 5% seems to be unrealistically large one should have in mind that rather small changes of this cross section have a considerable influence on the reaction rate traverses. Because the blanket mainly consists of U238 a change in its removal cross section essentially means a change in the absorption cross section of U238. Therefore one has to reconsider the reaction rate traverses studied here when revised values for the absorption cross section of U238 are included in the nuclear data basis.

The remarkable changes caused by the introduction of the reflective boundary condition at the outer blanket surface illustrates the importance of the presence of reflector-material near the blanket surface. For a precise determination of reaction rate traverses within the blanket region one has to take into account the neighbouring reflecting zones. Even if only distances of more than 10 cm from the blanket surface are considered the effect of a reflector may not be negligible.

Table 2: Parameters used for the calculations with improved data and methods

Case	Group-set	Heterogeneity correction	REMØ-correction	Kind of calculation	k_{eff}	Additional comments
Reference	MØXTØT-set	no	no	Diff.	1.00391	exactly the reference case of table 1
G1	SNEAK-set	no	no	Diff.	0.98283	-
G2	MØXTØT-set	yes	no	Diff.	Δk_{het}: +0.0029	Heterogeneity correction determined with the ZERA-code
G3	MØXTØT-set	no	yes	Diff.	1.00372	-
G4	MØXTØT-set	no	no	S_6	1.0072	Transport-approximation

ONE-DIMENSIONAL CALCULATIONS WITH IMPROVED DATA AND METHODS

In this chapter we will study the influence of improved nuclear data and improved calculational methods on the reaction rate traverses. All calculations are done in one-dimensional geometry using the previously mentioned global buckling. The parameters respectively their changes are given in table 2 together with the calculated criticality parameter k_{eff}.

Influence of changes in the group-sets

In fig. 6a (case G1) the results with the recently established MØXTØT-set /‾3_7 are compared with the corresponding results obtained with the well-known SNEAK-set /‾4_7, /‾5_7. The curves are normalized at the core center. It can be seen from fig. 6 that the change in the space dependence going from the SNEAK-set to the MØXTØT-set is different for σ_c(U238) and σ_f(U235) on one hand and σ_f(U238) on the other hand. The effect for σ_f(U238) is caused by the fact that for the inelastic scattering of U238 the probability of scattering processes which degrade the neutron energy below the fission threshold of U238 is increased in the MØXTØT-set-data compared to the SNEAK-set-data. This leads to a steeper decrease of the high energy neutron flux in the outer regions of the assembly.

Fig. 6b shows that this interpretation of the results of fig. 6a is true. Here the differences are only due to the changes in the data for the inelastic scattering matrix because only these data were changed when going from the SNEAPM- to the SCTALØ-set. The corresponding criticality change of -0.001 is relatively small.

For the non-threshold reactions σ_c(U238) and σ_f(U235) the change of the inelastic scattering probabilities for U238 has little effect on the reaction rate traverses because the effect of the steeper slope of the high-energy neutron flux and the flatter slope of the low energy neutron flux in the outer regions of the assembly tend to compensate each other for the energy-integrated reaction rate traverses. The increase of the MØXTØT-set-results for σ_c(U238) and σ_f(U235) compared to the SNEAK-set-results apparent in fig. 6a is mainly caused by the reduction of the capture cross section of U238 essentially in the energy region from

5 - 800 keV. This has a rather large effect on the reaction rate traverses as has been seen in the previous chapter when the removal cross section has been reduced.

For completeness the ratios of the central reaction rates will be given in the following

$\frac{\sigma_c\text{(U235)MØXTØT-set}}{\sigma_c\text{(U235)SNEAK-set}}$	$\frac{\sigma_c\text{(U238)MØXTØT-set}}{\sigma_c\text{(U238)SNEAK-set}}$	$\frac{\sigma_f\text{(U235)MØXTØT-set}}{\sigma_f\text{(U235)SNEAK-set}}$	$\frac{\sigma_f\text{(U238)MØXTØT-set}}{\sigma_f\text{(U238)SNEAK-set}}$
1.028	0.901	1.008	0.940

Test calculations lead to the result that the reaction rate traverses are rather insensitive to a slight reduction of the U235 fission cross section. Even the inclusion of the extremely low σ_f-values of POENITZ brought about changes of less than 0.4% in the core and less than 2.8% in the blanket for the U235 fission traverse. For the U238 capture and fission traverses the differences are even smaller.

Influence of heterogeneity corrected cross sections

In fig. 7 (case G2) the influence of the heterogeneity correction on the reaction rates is shown. The results obtained with heterogeneity-corrected cross sections are compared with those obtained in a quasihomogeneous case where the thickness of the platelets has been reduced by a factor of 100. This latter case has been used as reference case and not the usually used normal homogeneous case, since it is known that the results of both do not agree completely at least for the criticality value k_{eff}. This is the reason why in table 2 only the criticality difference caused by the heterogeneity correction and not the absolute value for the criticality is given. It should be mentioned, however, that the reaction rate traverses for the quasihomogeneous and the really homogeneous case are in rather good agreement. The largest deviations are 0.4% in the core region and 0.7% in the blanket region.

The heterogeneity correction causes in the core region an increase of the traverses by about 1%. In the blanket region the traverse for σ_c(U238) is increased by about 3%, the traverse for σ_f(U235) by about 1% and the traverse for σ_f(U238) is decreased by a very small amount of less than 1%.

Influence of the REMØ-correction

The results for the case G3 of table 2 are not drawn because the changes compared to the reference case are rather small. The increase of the traverses with REMØ-corrected cross sections compared to the traverses determined in the usual way (reference case) does not exceed 0.5% in the core region and 2% in the blanket region. The values for the central reaction rates too remain nearly unchanged: for σ_c(U235), σ_f(U235), and σ_c(U238) the changes are smaller than 0.2%; σ_f(U238) is decreased by 0.6% when taking into account the REMØ-correction. This change too seems to be negligible considering the present range of uncertainty respectively the difference between theory and measurement for this quantity.

The small changes due to the REMØ-correction observed here are probably caused by the fact that the weighting spectrum used for establishing the 26-group constants is just that of the assembly SNEAK 3A2 which is considered in this study. Therefore for other assemblies the influence of the REMØ-correction on the reaction rate traverses may be much more important than it is for the present case.

Comparison of diffusion- and transport-theory-results

In fig. 8 the results for the reaction rate traverses obtained with a S_6 calculation (using the transport approximation for the scattering) and a diffusion calculation are compared. For σ_c(U238) and σ_f(U235) a decrease of about 1% is observed in the outer parts of the core and a more pronounced one (3%) in the blanket region. For σ_f(U238) the changes are more important. From the center to the core-blanket interface an increase of up to 2% is observed in the inner core region. Within the last 4 cm of the core this tendency is reversed and at the core-blanket interface there is a decrease of about 3%. At a distance of 3.5 cm from the interface a decrease of 15% can be found. Then the tendency changes once more and in the outer 10 cm of the blanket region there is an increase of about 20%.

It should be mentioned for completeness that it has been shown by comparison with S_8-calculations that the accuracy of S_6-calculations is sufficient for our present purposes. Near the core-blanket-interface where the differences are most interesting the following maximum deviations have been found between the results of S_6- and S_8-calculations: for U238 capture and U235 fission 0.03%, for U238 fission at most 0.6% but most times smaller than 0.3%.

In order to save computer time it is usual to calculate the series S_2, S_4, S_6 where the results of each step are used as initial guess for the subsequent step. By a comparison with the results of a more time consuming direct S_6-calculation it has been shown that this procedure can be applied and leads to errors which are negligible compared to the still existing discrepancies between theory and experiment.

Influence of using different types of transport cross sections

In the diffusion calculations and up to the begin of 1970 also in the S_N-calculations the current weighted transport cross sections (internal label STR) has been used. For the determination of this cross section the Russian f_t-values from the ABN-set [6] have been applied. It should be mentioned that these values have not been changed in the improved data sets as e.g. the SNEAK-set, contrary to the situation for other self-shielding factors e.g. f_γ, f_f...., which have been re-evaluated especially for the heavy isotopes in the SNEAK-set. This may lead to some inconsistency in the data sets when this type of cross section is used. The application of the flux weighted transport cross section (internal label STRTR) provides for consistency of the data in the S_N-calculations. Compared to the earlier results obtained with STR (used for example in fig. 8) the more recent results with STRTR show differences for the traverses which cannot completely be neglected as is shown in fig. 9.

A decrease of the traverses of 1.0 - 1.2% in the core region - mainly near the core-blanket interface - and of 1.3 - 2.0% in the blanket region can be observed. For the case of the stronger reflector a slight - but unimportant increase at the outer blanket boundary has been obtained. The corresponding criticality change is +0.0012 indicating that the leakage is slightly reduced.

For most energy groups the flux weighted transport cross section STRTR is somewhat larger than the current weighted transport cross section STR. This effect is more pronounced for the core composition than for the blanket composition leading to a reduced leakage out of the core and out of the whole assembly, and therefore to an increase in criticality. At the same time the core becomes less transparent for the neutrons so that the reaction rates in the outer parts of the assembly will be somewhat decreased.

From these results it is evident that the determination of the transport cross section has to be reconsidered if differences in the reaction rate traverses of less than 1% between theory and experiment have to be analysed.

The effect of the anisotropic scattering of hydrogen

The effect of the anisotropic scattering of hydrogen has been studied using for the scattering kernel the P1-approximation instead of the usual transport approximation. The flux has been determined by an S_6-calculation using the Russian ABN-set because this was the only one available for which self-consistent data for this case could be used. It has been found that its influence on the reaction rate traverses in SNEAK 3A2 can be neglected, therefore the results are not shown here. For σ_c(U238) and σ_f(U235) the differences are 0.1% in the core region and 0.2% in the blanket region. For σ_f(U238) the largest differences occur at the core-blanket interface; they amount only to 0.4%.

The change in criticality is far less than 0.1% and can therefore also be neglected.

Influence of the fission spectrum

FABRY [7] among others [8], [9] has obtained strong indications from his measurements that the U235 thermal fission spectrum has to be modified compared to the previously generally used form. We studied the influence of a different energy dependence of the fission spectrum according to FABRY's results [10] on the reaction rate traverses. The results are shown in fig. 10. With the modified data an increase of 0.7% in the core region has been obtained. In the blanket for the capture in U238 and the fission in U235 an increase of about 2% and for the fission in U238 of about 4% can be observed. Therefore one has to take into account the form of the fission spectrum if discrepancies in the reaction rate traverses of the order of 1% between theory and experiment become relevant. Using this modified fission spectrum the criticality changes by +0.0022.

RESULTS FROM TWO-DIMENSIONAL DIFFUSION CALCULATIONS

a) Comparison of one- and two-dimensional results

A comparison of 26-group results for the reaction rate traverses from one- and two-dimensional diffusion calculations for SNEAK 3A2 without any reflector shows only small deviations. For R_c(U238) and R_f(U235) in the whole core- and blanket-region the differences are smaller than 0.3%. For R_f(U238) the differences are smaller than 0.8% in the core and smaller than 1.6% in the blanket. These results indicate that in the one-dimensional calculations the use of a global buckling for both the core- and blanket-region is justified in our case.

b) Influence of the number of mesh points

For the 4 group results it has been shown for the two-dimensional calculations that a reduction of the number of mesh points by a factor of 2 in each direction (from 40 to 20 in the axial direction) leads to the following maximum deviations for the ratio of the 20 mesh points- to the 40 mesh points-results:

	Core - Region	Blanket - Region	
	maximum deviation	maximum deviation	average deviation
R_c(U238)	-1.0%	+1.9%	< 1%
R_f(U235)	-1.1%	+2.2%	< 1%
R_f(U238)	-1.2%	+4.3%	< 2%

These results show that the fission rate in U238 is most sensitive to the number of mesh points, a fact which is even more pronounced for our one-dimensional diffusion code.

c) Influence of the number of energy groups

The number of energy groups strongly influences the computer time used. This is especially important for two-dimensional calculations. Therefore one usually tries to reduce the number of energy groups used in such type of calculations. Generally the effect on the criticality is rather small if reasonable condensation procedures are used. Here we are concerned with the effect on reaction rate traverses. The few group cross sections have been obtained from 26-group cross sections for the core- and blanket-regions using the spectra of the core- and blanket-region from a spherical model calculation as weighting spectra for the condensation. The group boundaries were as follows.

For the 4-group calculation

New group	1	2	3	4
Old groups	1-6	7-9	10-13	14-26

For the 11-group calculation

New group	1	2	3	4	5	6	7	8	9	10	11
Old groups	1-3	4	5-6	7	8	9	10	11	12-13	14-15	16-26

A comparison of the 11 group results with the 26-group results for SNEAK 3A2 without any reflector is shown in fig. 11.

For R_c(U238) and R_f(U235) the differences are most times much smaller than 1% in the core- and blanket-region. For R_f(U238) the difference in the core is also smaller than 1% but in the blanket it increases up to 8%.

In fig. 12 the results of 4- and 26-group two-dimensional diffusion calculations are compared (for one-dimensional diffusion calculations similar results have been obtained). The differences are increased compared to the case with 11 groups. This effect is most pronounced in the blanket region. For R_f(U238) already in the core-region a remarkable (20%) deviation can be observed which drastically increases when going into the blanket-region. This is partially due to the fact

that only two spectra are used for the condensation, one core- and one blanket-spectrum. This does not allow to describe the transition regions appropriately. This disadvantage naturally becomes most important for threshold cross sections as is e.g. the fission in U238.
From fig. 11 and fig. 12 it can be seen that as could be expected the reaction rate traverse for the fission in U238 is most sensitive to a reduction of the number of energy groups.
The effects observed with the reduction from 26 to 11 groups can be considered as tolerable for most applications, whereas the reduction to 4 groups produces deviations in the reaction rate traverses which can be considered as tolerable only in the central core region.

d) Reaction rate traverses in SNEAK 3A2 with reflectors

Most times one calculates the reaction rate traverses in the critical assemblies only in the core- and blanket-regions. In the calculations these are the only regions which are generally taken into account because the other regions are felt to be far less important. This is correct as long as only the criticality or the reaction rates in the core and the inner part of the blanket are of interest. The reaction rates in the outer part of the blanket are influenced to a considerable amount by the presence of reflecting zones.
In the axial direction of SNEAK 3A2 the stainless steel subassembly walls can be considered as weak reflector. For the zone below the lower blanket there are in addition aluminum spacers within the subassembly walls so that this zone can be considered as a stronger reflector.
In the radial direction the aluminum walls of the empty blanket elements act as a reflecting zone. The influence of these reflecting zones has been studied by one- and two-dimensional diffusion calculations and has been taken into account for the final evaluation also in the S_N-calculations.

α) Results from one-dimensional diffusion claculations

A comparison of the results for the reaction rate traverses from one-dimensional diffusion calculations is shown in fig. 13a. As reference the results for SNEAK 3A2 without any reflector have been taken. It is surprising that the addition of the weakly reflecting zone leads to a decrease of the reaction rate traverses in the outer parts of the blanket (it also leads to a very small reduction of the criticality).

For the stronger reflector an increase of the traverses in the outer parts of the blanket has been obtained as expected. The unexpected behaviour for the weak reflector could have been caused by the use of a global buckling for all zones in the one-dimensional calculations. This procedure becomes somewhat doubtful for the reflecting zones especially for the weak reflector with its rather large diffusion constant and the corresponding DB^2-term which acts as an absorption term. For the core- and blanket-regions this procedure is shown to be justified by the results discussed before.

β) Results from two-dimensional diffusion calculations

We therefore studied the influence of the reflecting zones by two-dimensional diffusion calculations too, using 26 energy groups, so that no error due to the condensation has to be considered. The results are shown in fig. 13b and fig. 13c as ratio of the traverses with reflector to those obtained without reflector. Qualitatively the results are similar to those from the one-dimensional calculations shown in fig. 13a. For the weak reflector the decrease in the outer blanket is generally less pronounced, for the stronger reflector the increase is more pronounced than in the one-dimensional case. These results clearly demonstrate, that the use of the global buckling concept is not primarily responsible for the unexpected behaviour of the traverses upon the addition of a weakly reflecting zone observed in the one-dimensional calculations. The real reason is that for such a weak reflector diffusion theory cannot be applied: the optical thickness of this weakly reflecting zone is too small so that the number of collisions within this zone becomes too small for a meaningful application of diffusion theory. This explanation has been confirmed by one-dimensional S_6-calculations which showed the expected behaviour upon addition of the weak and stronger reflector for the space-dependence of the reaction rate traverses near the outer blanket boundary as well as for the criticality.

e) Comparison of reaction rate traverses obtained from one- and two-dimensional diffusion calculations for SNEAK 3A2 with reflectors

A comparison of the results from one- and two-dimensional diffusion calculations for SNEAK 3A2 with reflectors shows that for the case of the weak reflector the differences are smaller than 2% in the whole core- and blanket region except for the outer 5 cm of the blanket. Here the two-dimensional results are up to about 15% larger than the one-dimensional results. This indicates that the concept of a global buckling may be not so well adopted for this sort of weak reflector. But these results should not be considered as conclusive because effects of mesh size or other numerical effects may also contribute to the difference mentioned above. For the case of the stronger reflector the differences between the one- and two-dimensional results are very similar to the case of the weak reflector. The increase observed within the outer 5 cm of the blanket is somewhat less pronounced, the maximum deviation being 10%. In summary one may conclude that one-dimensional calculations are sufficient if one disregards the outer 5 cm of the blanket and if an accuracy of 2% in the remaining part of the blanket and 1% in the core are considered to be sufficient.

CONCLUSIONS

The primary aim of the present work was to study whether there are deficiencies in the usually applied methods for the calculation of the reaction rate traverses. It could be shown that in the one-dimensional calculations the use of a global buckling (independent of energy and position) for the separated space direction is justified and leads to errors which are appreciably smaller than the presently existing discrepancies between theory and experiment. For the calculation of the reaction rates in the outer blanket region it is important to take into account the reflecting material which may be present in the neighbourhood of the blanket. The use of diffusion theory becomes questionable if the optical thickness of the reflecting zone is not sufficiently large.

It has been shown that for SNEAK 3A2, the assembly considered for this study, the use of REMØ-correction is only of minor importance for the determination of the reaction rate traverses. This result is probably due to the fact that the weighting spectrum used for the generation of the group constants in the SNEAK-set and MØXTØT-set has been taken from SNEAK 3A2. Therefore for other assemblies the influence of the REMØ-correction on the reaction rate traverses may be much more important.

The influence of heterogeneity-corrected group constants on the reaction rate traverses is generally of the order of 1%. The same magnitude has been observed for the difference between transport-theory and diffusion theory results except for the fission in U238 where the differences become larger. It has been found that the determination of the transport cross section (STR or STRTR) has to be considered carefully if differences in the reaction rate traverses of the order of 1% become important. The same statement applies to the energy dependence of the fission spectrum.

Some two-dimensional calculations show the adequacy of the approximations applied in the one-dimensional calculations. In addition the influence of the number of mesh points and energy groups on the reaction rate traverses has been determined for the two-dimensional diffusion calculations. The U238 fission traverse is most sensitive to both but as long as the number of mesh points and energy groups are reasonable (about 1 mean free path, and about 10 - 15 groups respectively) the accuracy is sufficient for the present purposes.

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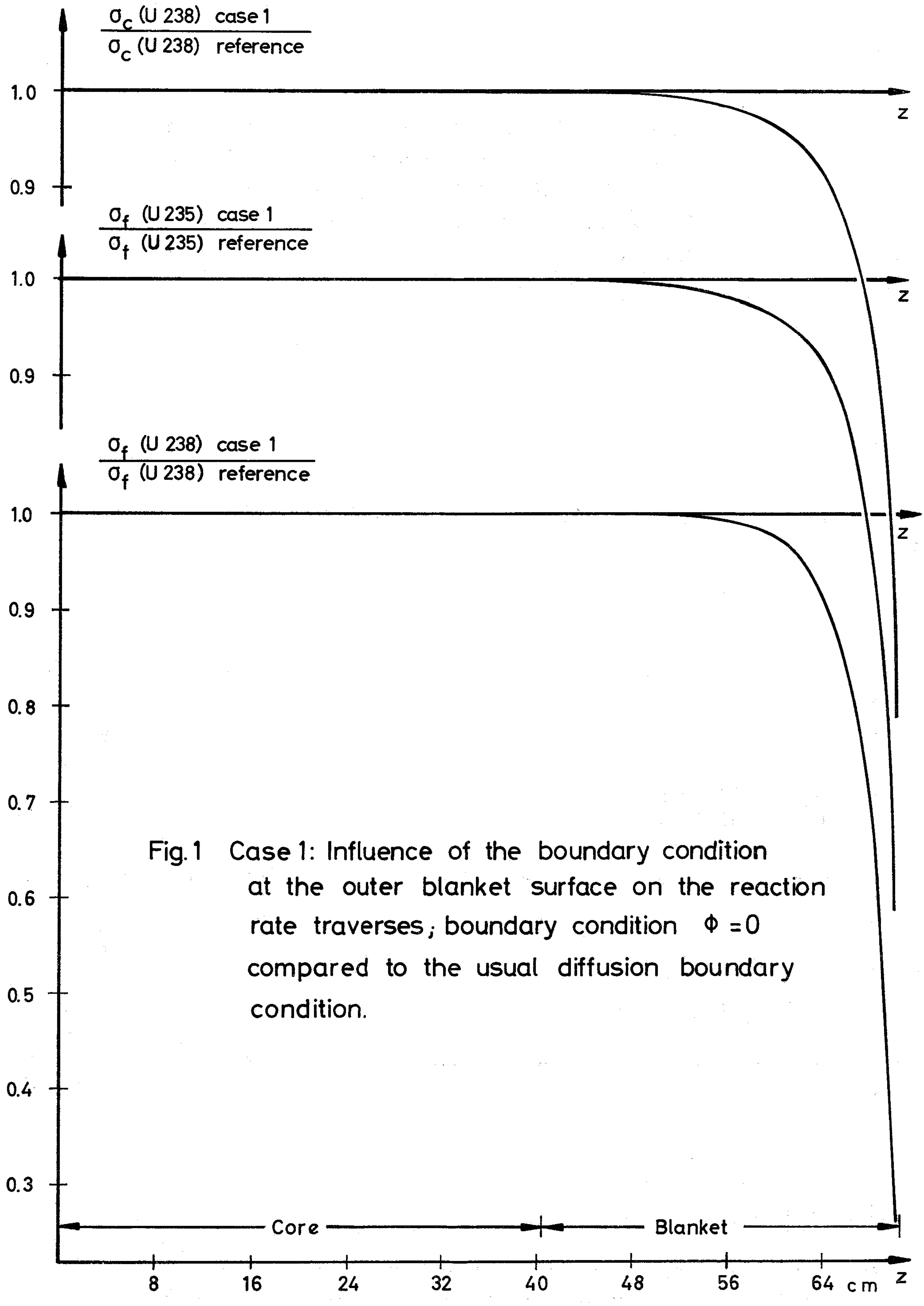
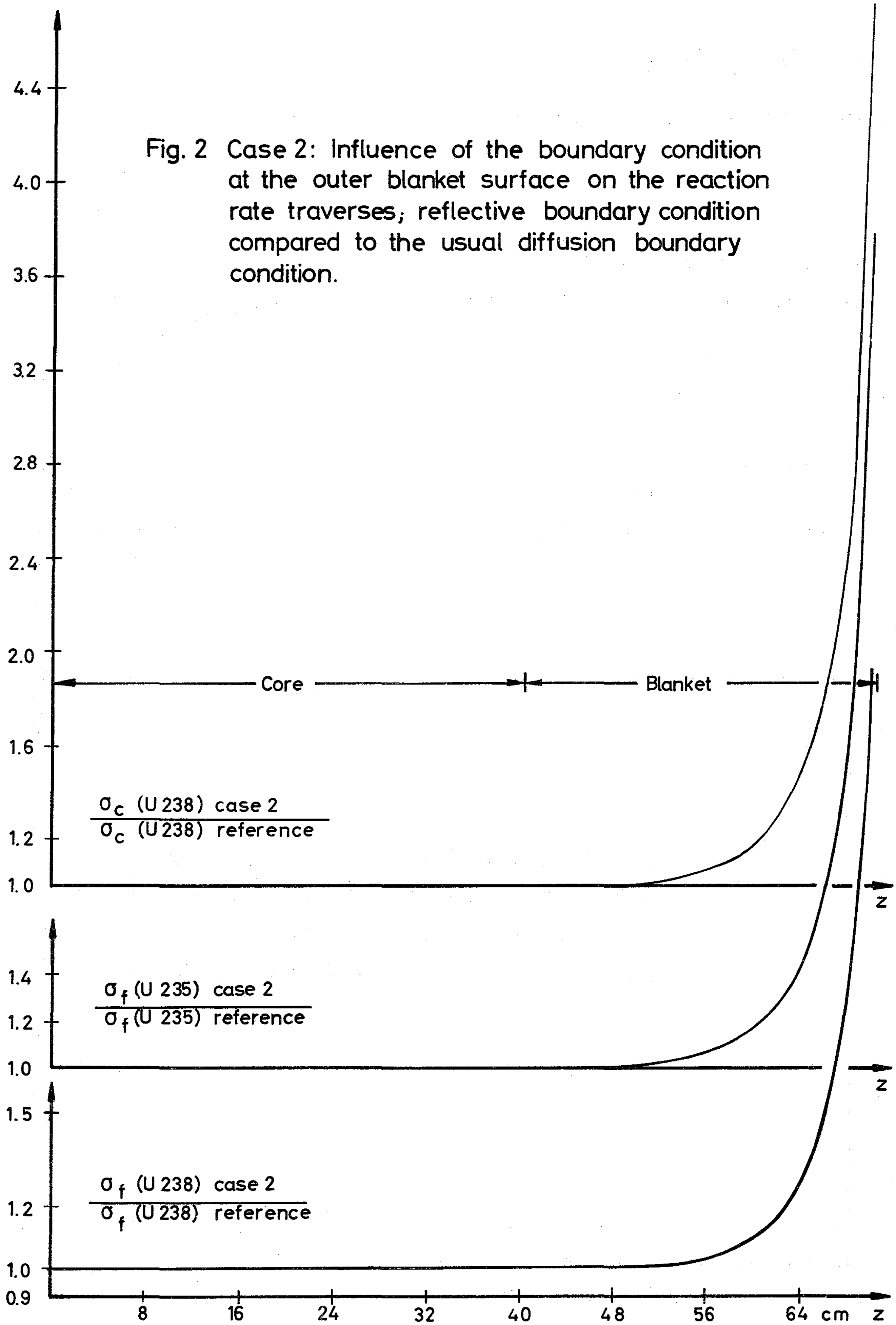


Fig. 1 Case 1: Influence of the boundary condition at the outer blanket surface on the reaction rate traverses; boundary condition $\Phi = 0$ compared to the usual diffusion boundary condition.

Fig. 2 Case 2: Influence of the boundary condition at the outer blanket surface on the reaction rate traverses; reflective boundary condition compared to the usual diffusion boundary condition.



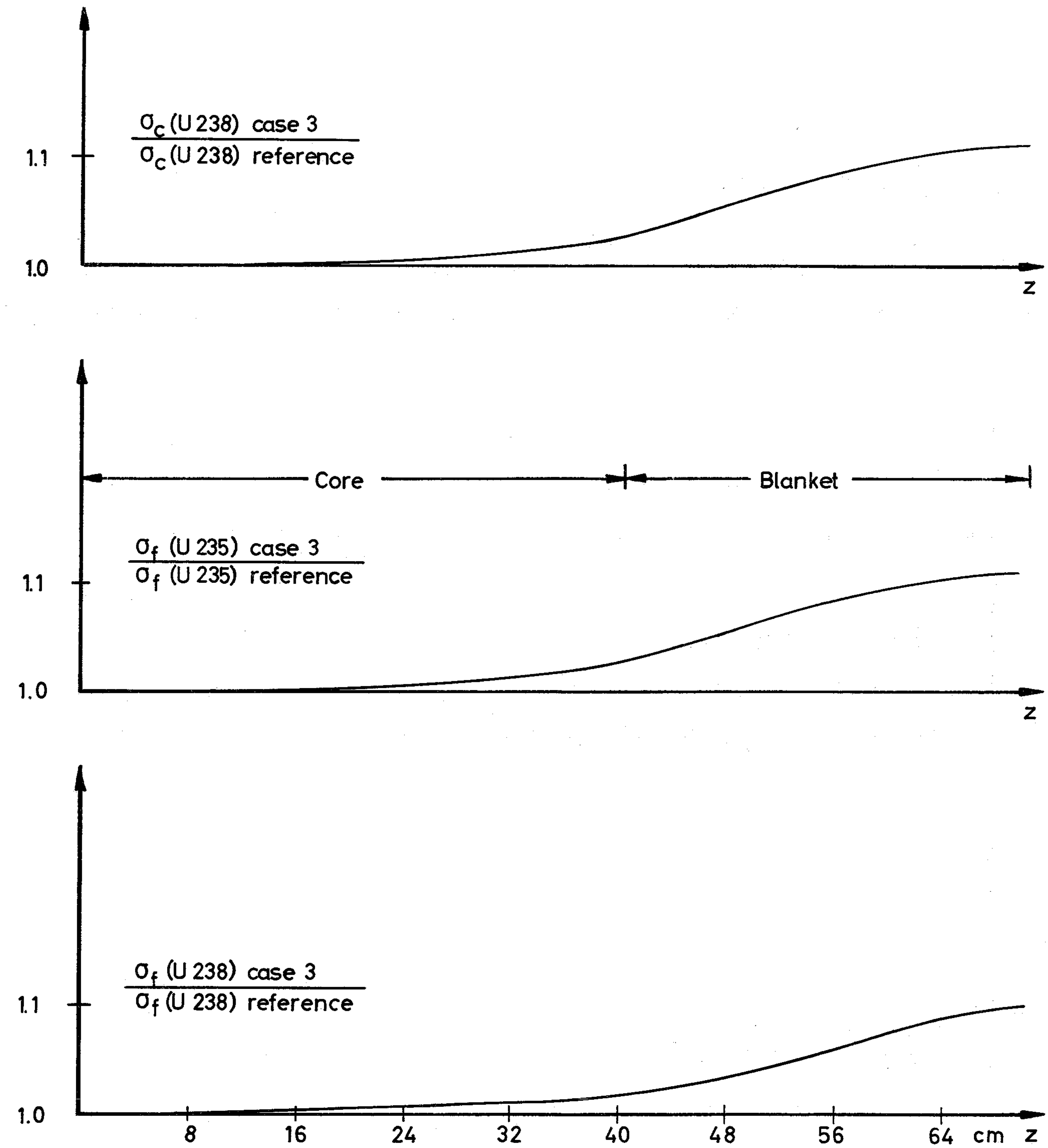


Fig. 3 Case 3: Influence of $B^2_{sep.}$ in the blanket region on the reaction rate traverses; $B^2_{sep} = 9.0 \cdot 10^{-4} cm^{-2}$ for case 3, $B^2_{sep} = 16.949119 \cdot 10^{-4} cm^{-2}$ for the reference case.

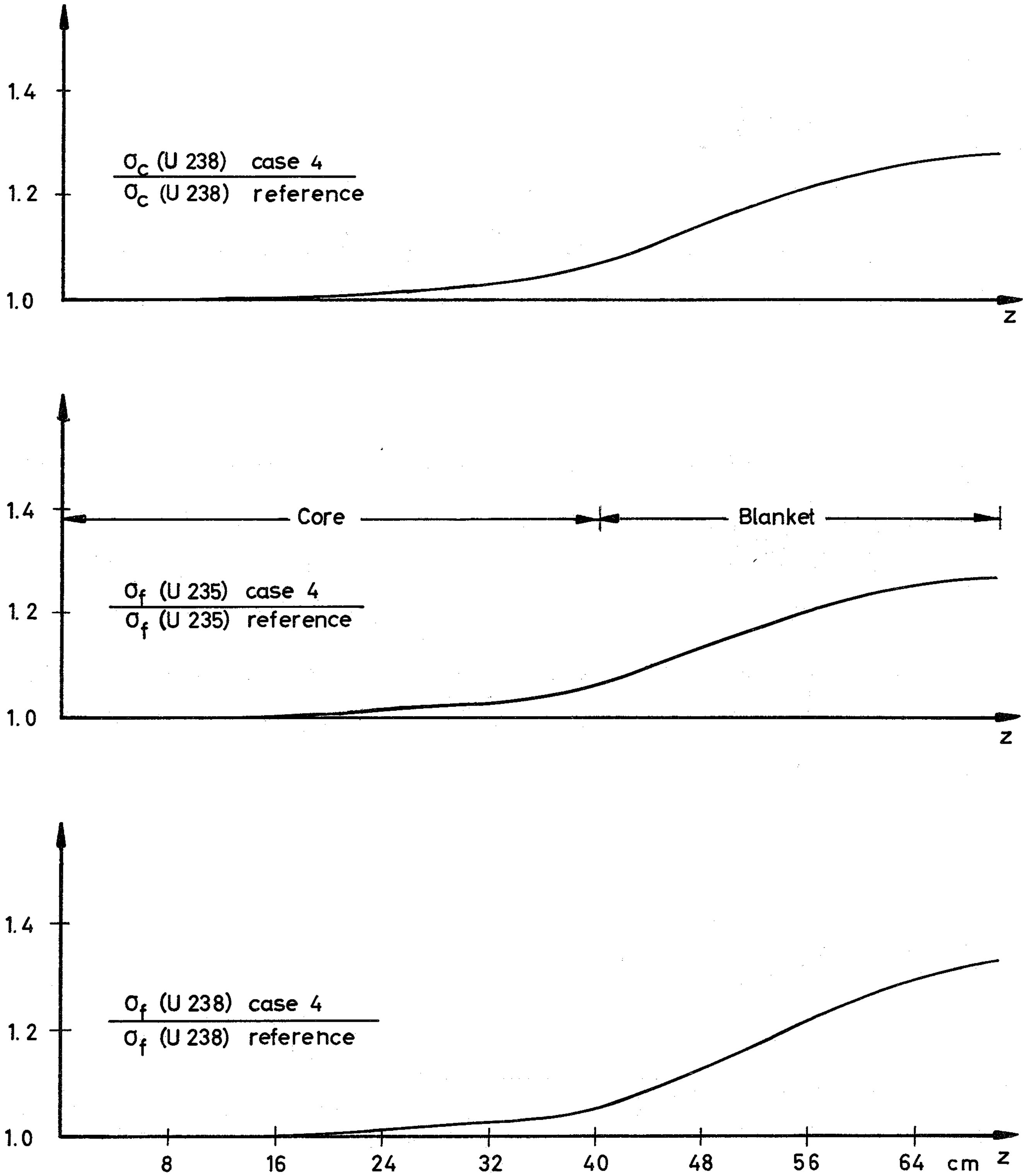


Fig. 4 Case 4: Influence of a 5% reduction of Σ_{rem} for the blanket-composition on the reaction rate traverses.

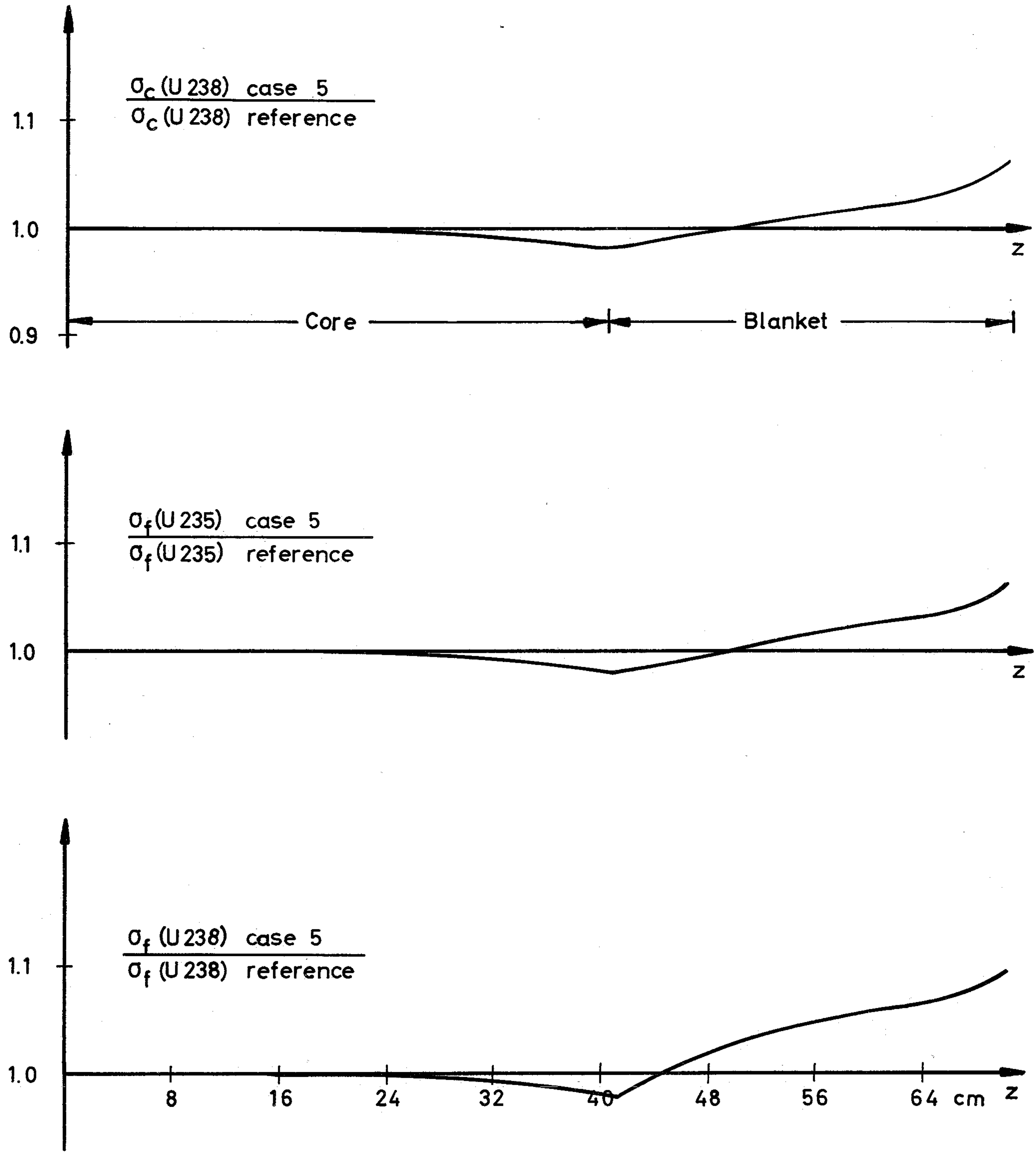


Fig. 5a Case 5: Influence of a 5% reduction of the transport cross section Σ_{tr} for the blanket composition on the reaction rate traverses.

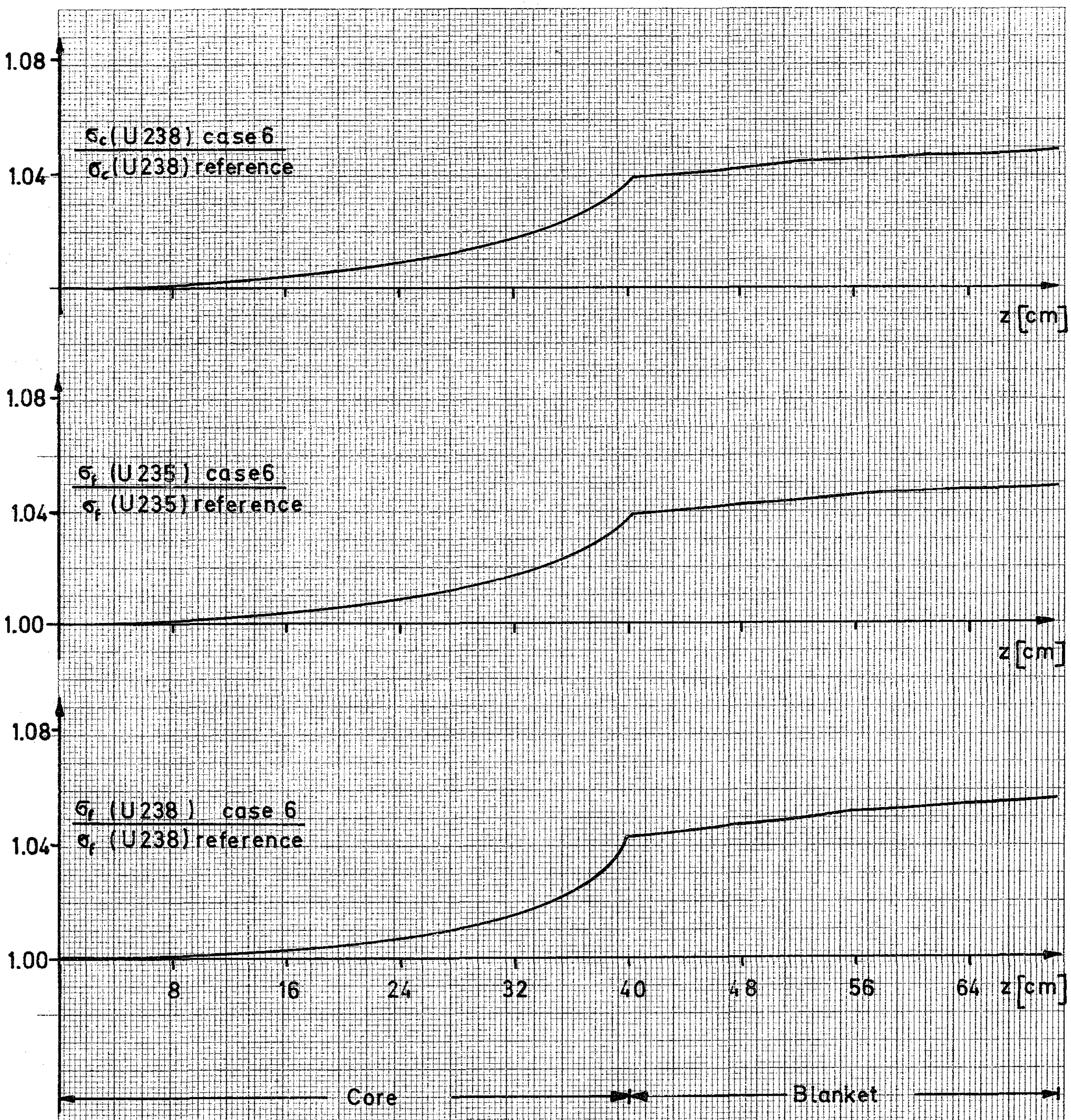


Fig. 5b Case 6: Influence of a 5% reduction of the transport cross section $\sum_{tr}$ for the core composition on the reaction rate traverses

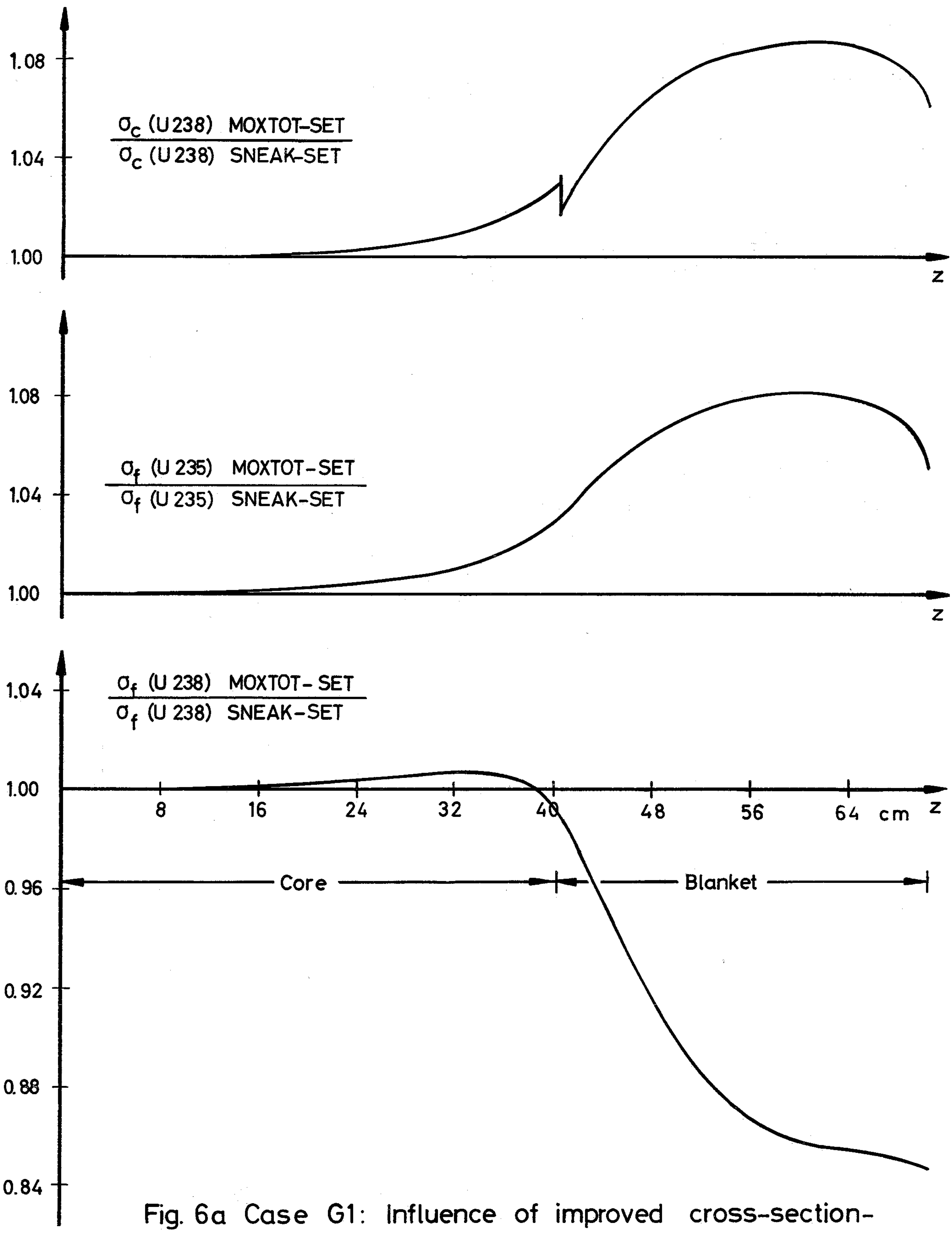


Fig. 6a Case G1: Influence of improved cross-section-set-data on the reaction rate traverses.

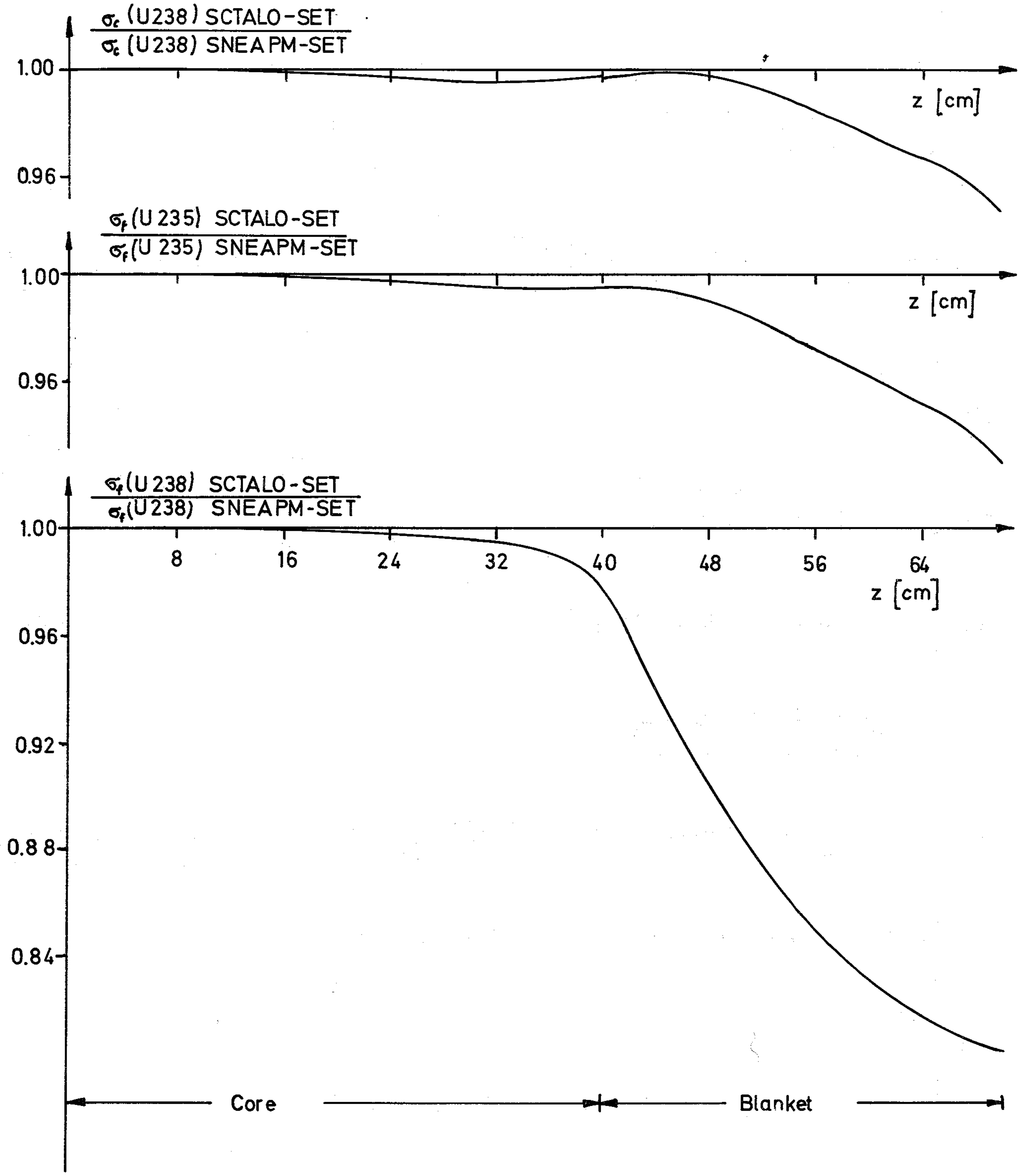


Fig. 6b Influence of changes in the inelastic scattering probabilities on the reaction rate traverses in SNEAK-3A2

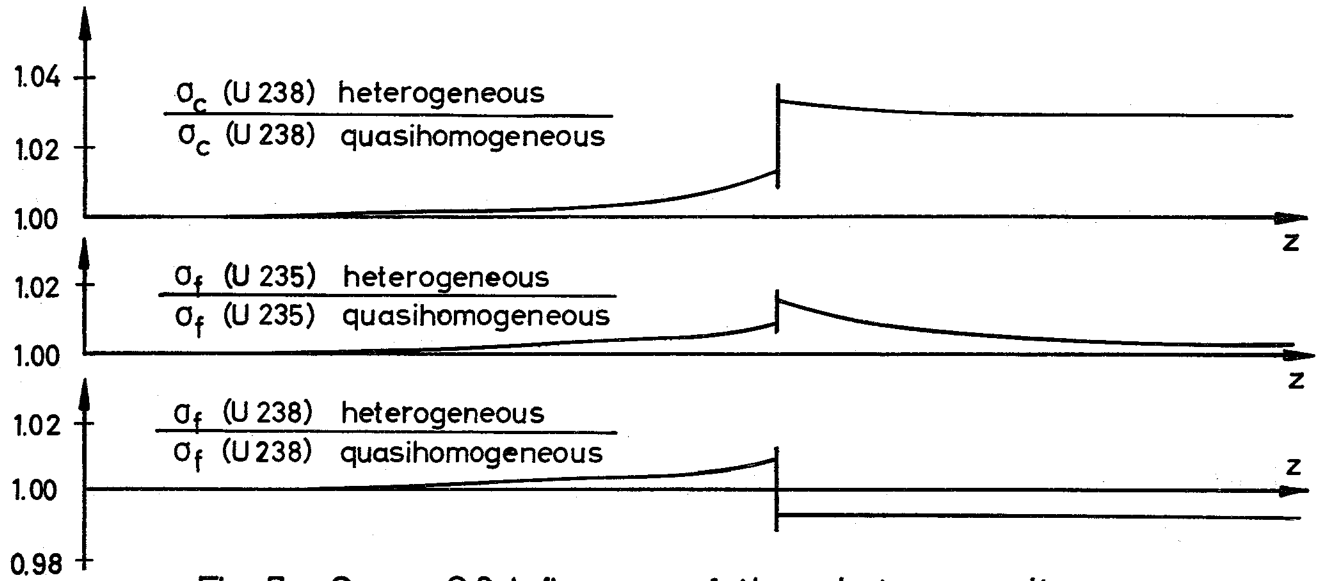


Fig. 7 Case: G2 Influence of the heterogeneity-effect on the reaction rate traverses.

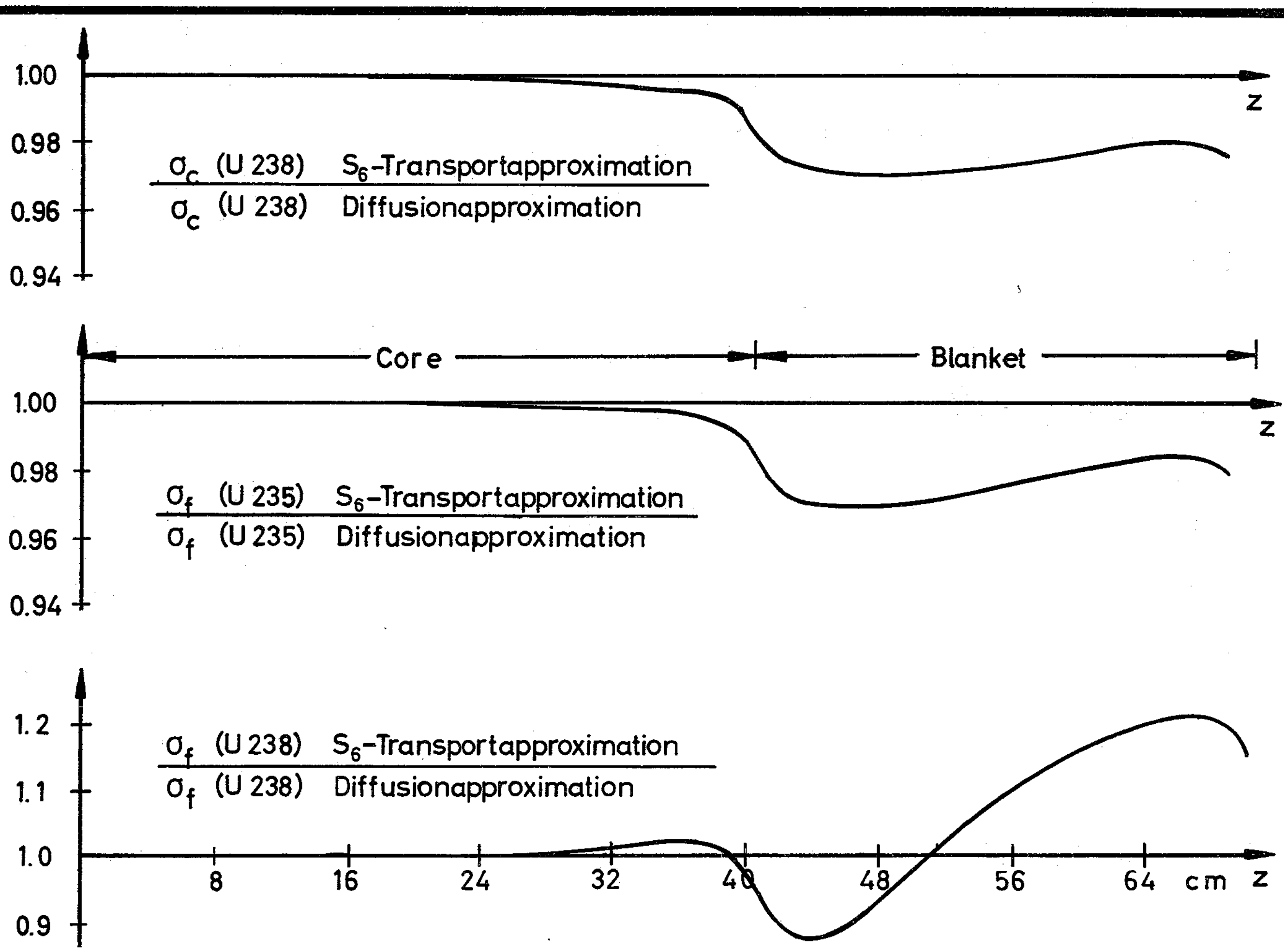


Fig. 8 Case: G4 Comparison of reaction rate traverses obtained by S_6-transport calculation to those obtained by diffusion calculation (MOXTOT-SET).

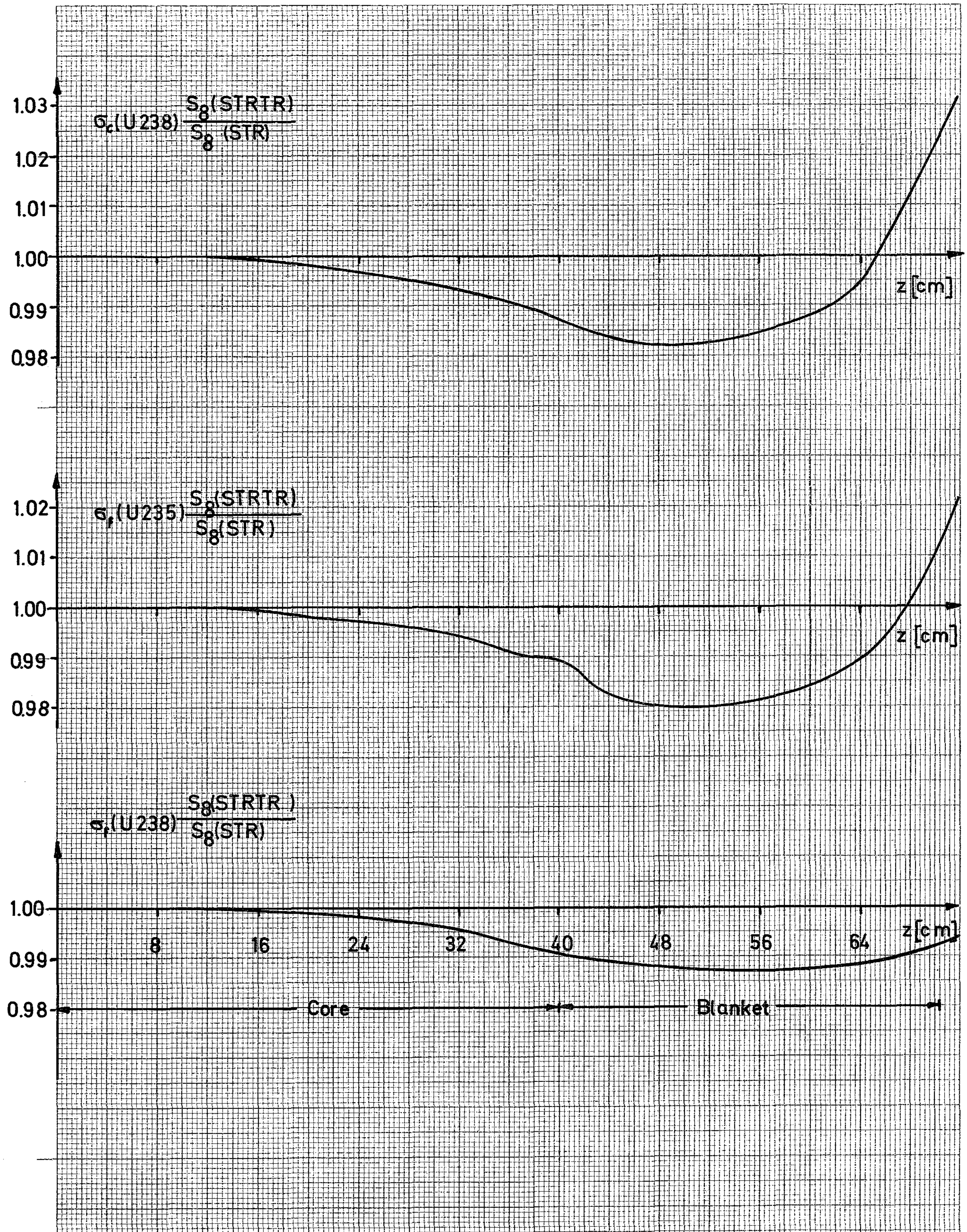


Fig. 9 The influence of using different types of transport cross section in S_N-calculations on the reaction rate traverses in SNEAK-3A2

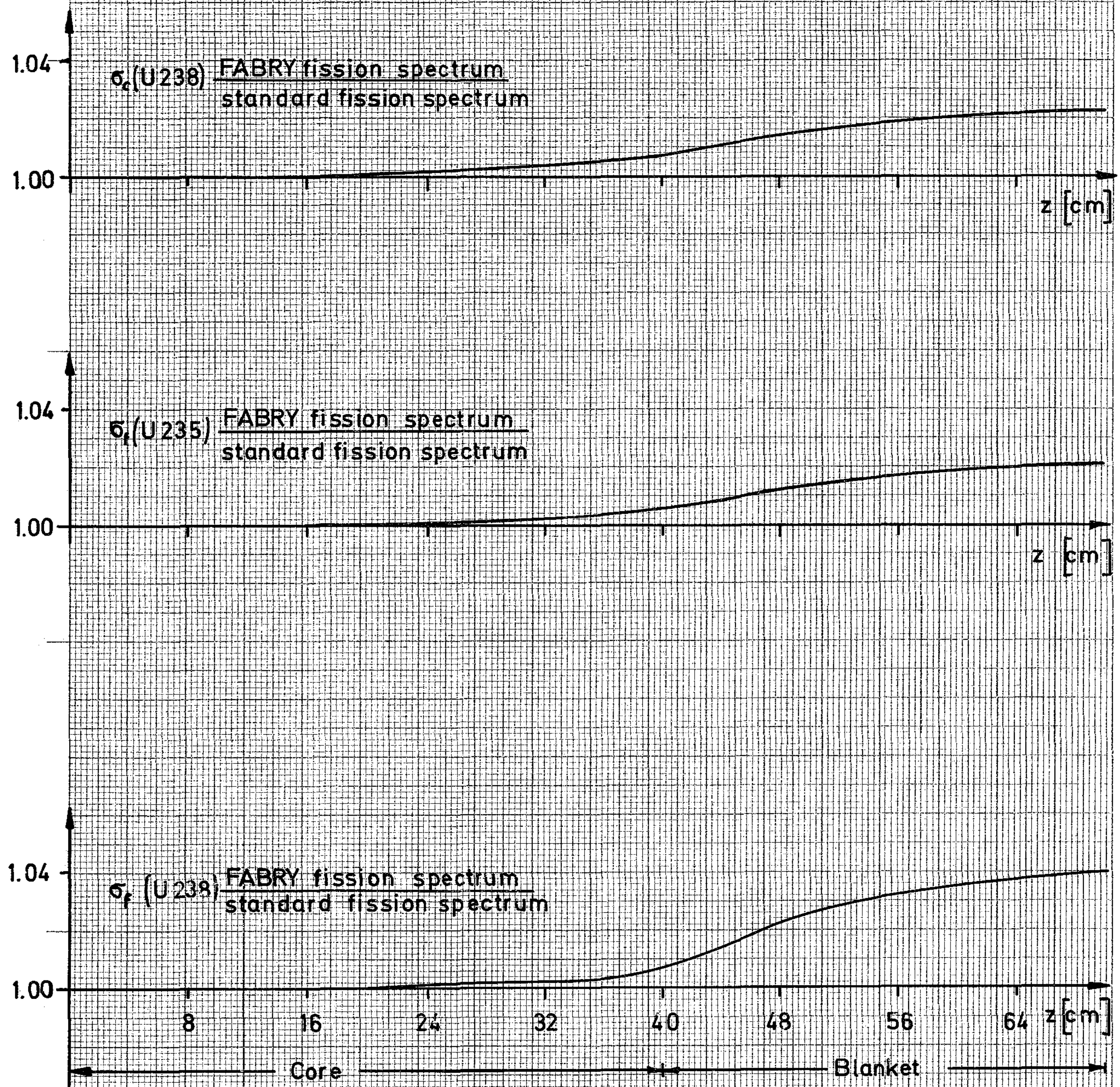


Fig.10 Influence of FABRY's fission spectrum on the reaction rate traverses in SNEAK-3A2

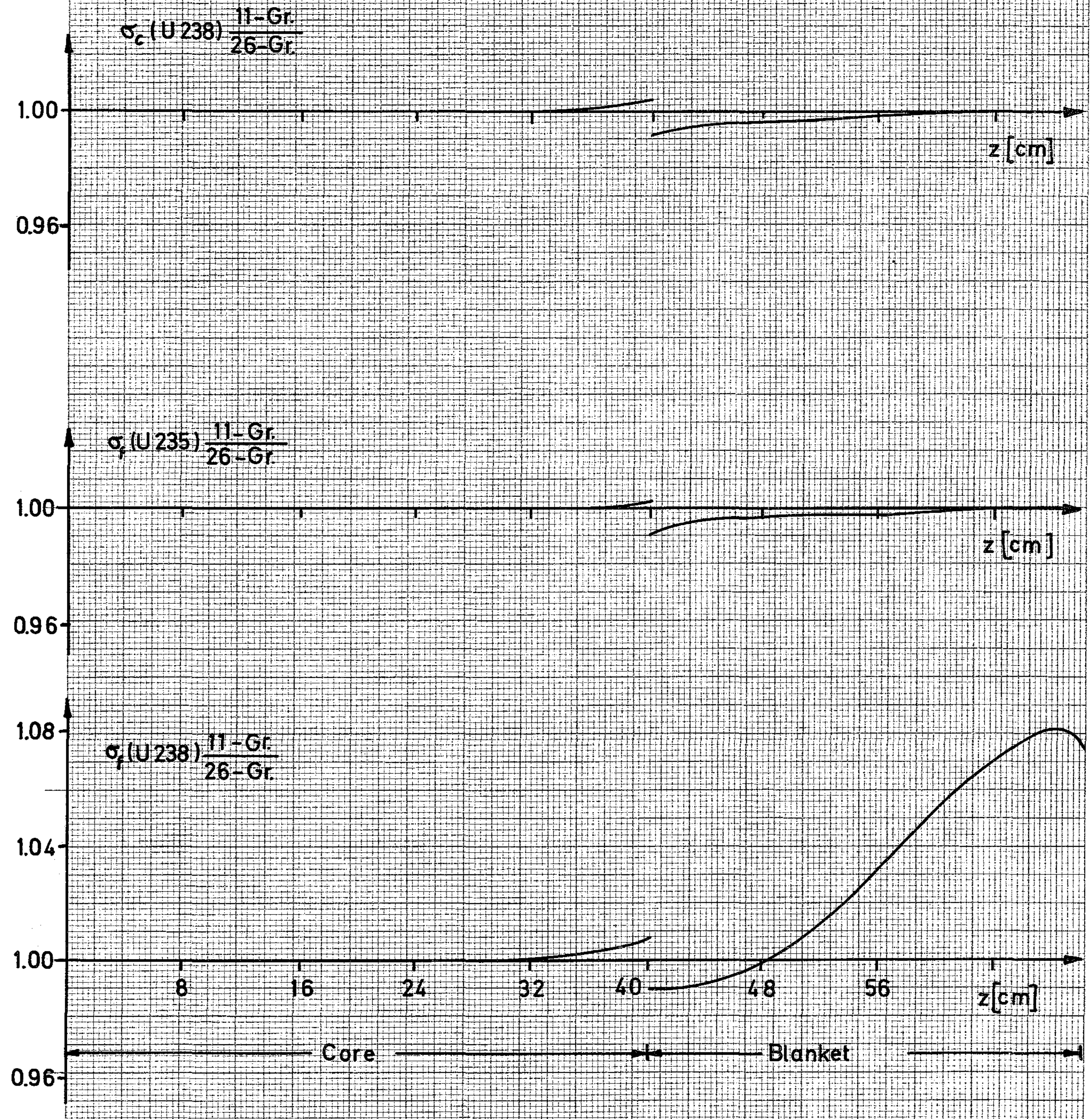


Fig. 11 : Comparison of reaction rate traverses for SNEAK-3A2 using 11 and 26 energy groups for twodimensional diffusion calculations

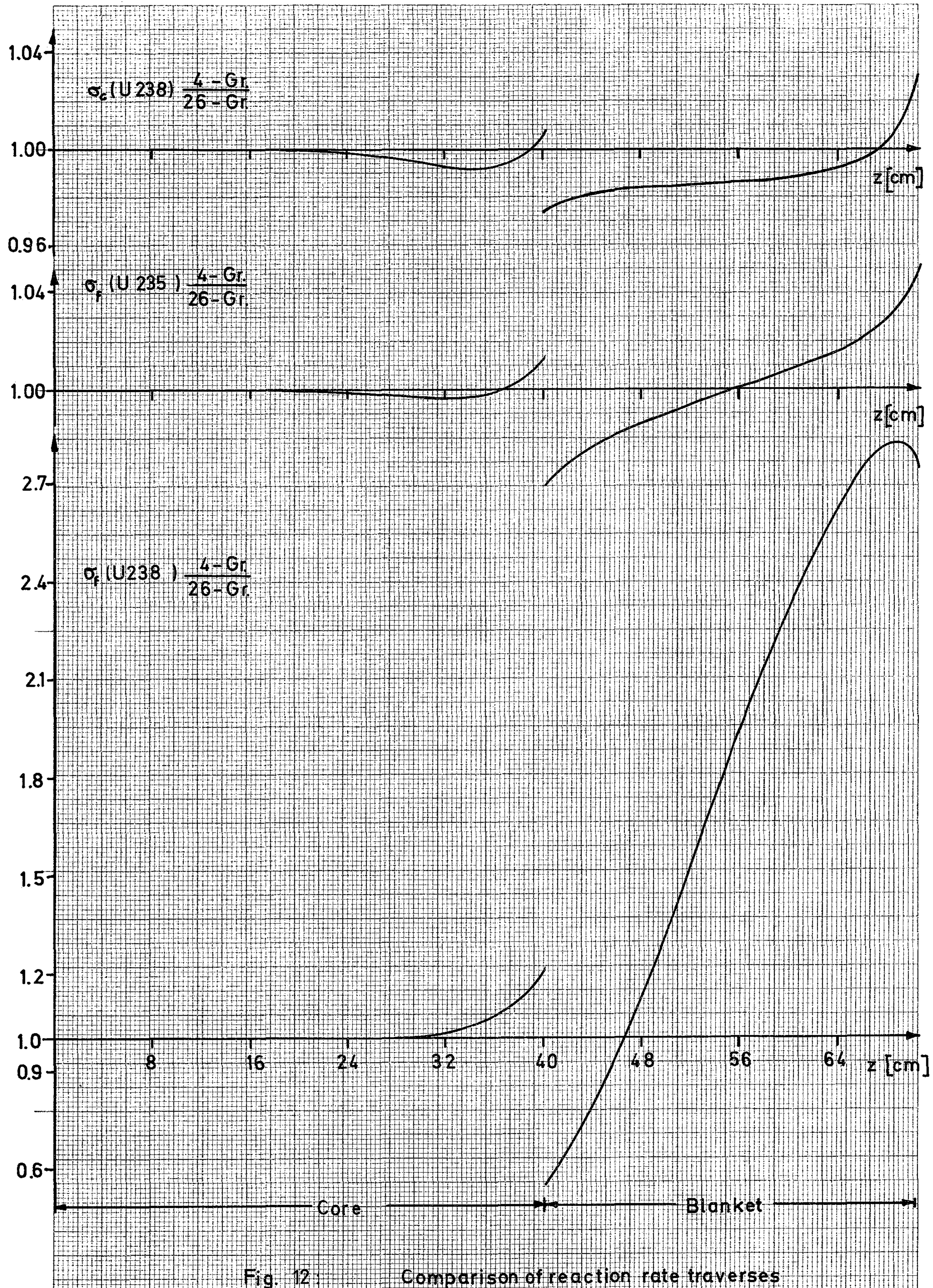


Fig. 12 : Comparison of reaction rate traverses for SNEAK-3A2 using 4 and 26 energy groups for twodimensional diffusion calculations

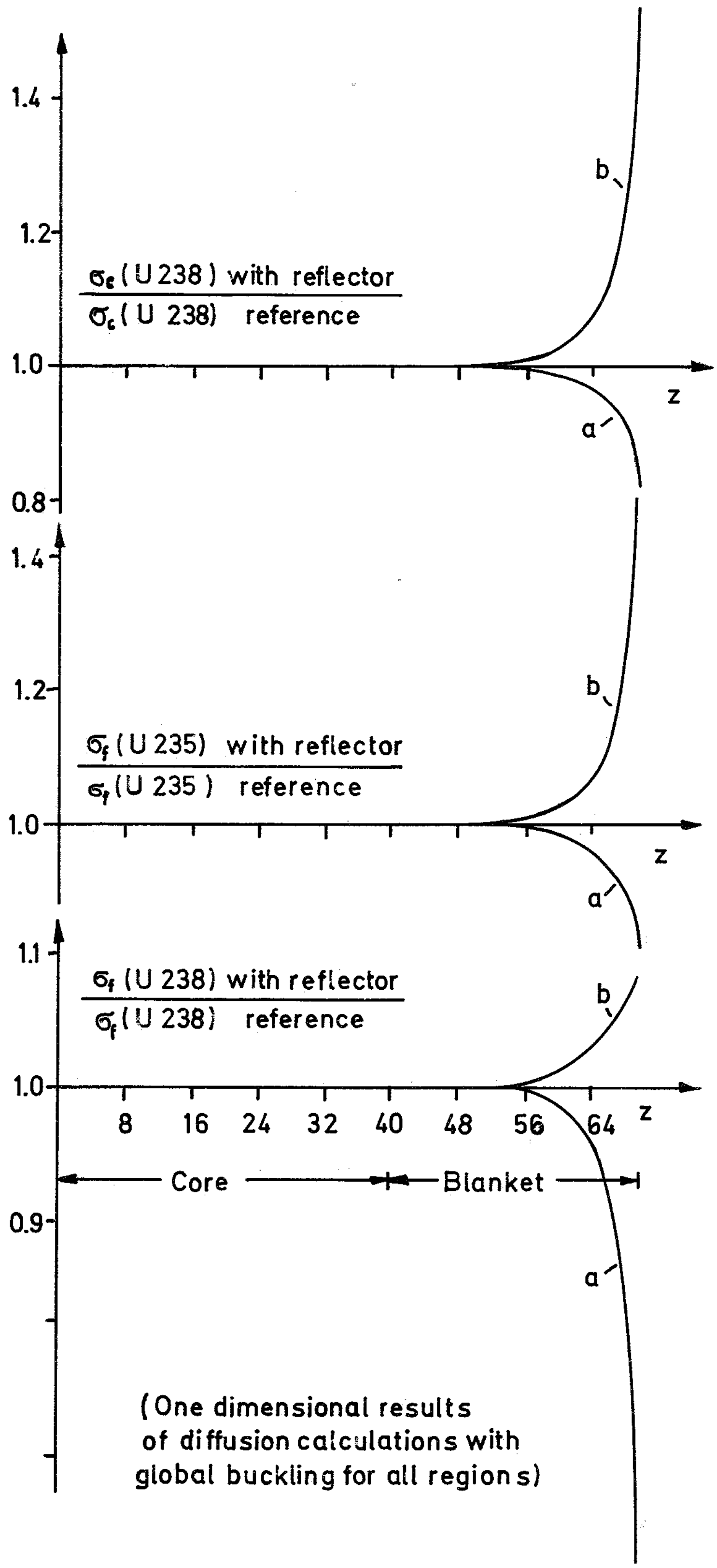


Fig. 13 A : Influence of reflectors on the reaction rate traverses

Curve a : weak reflector

Curve b: stronger reflector

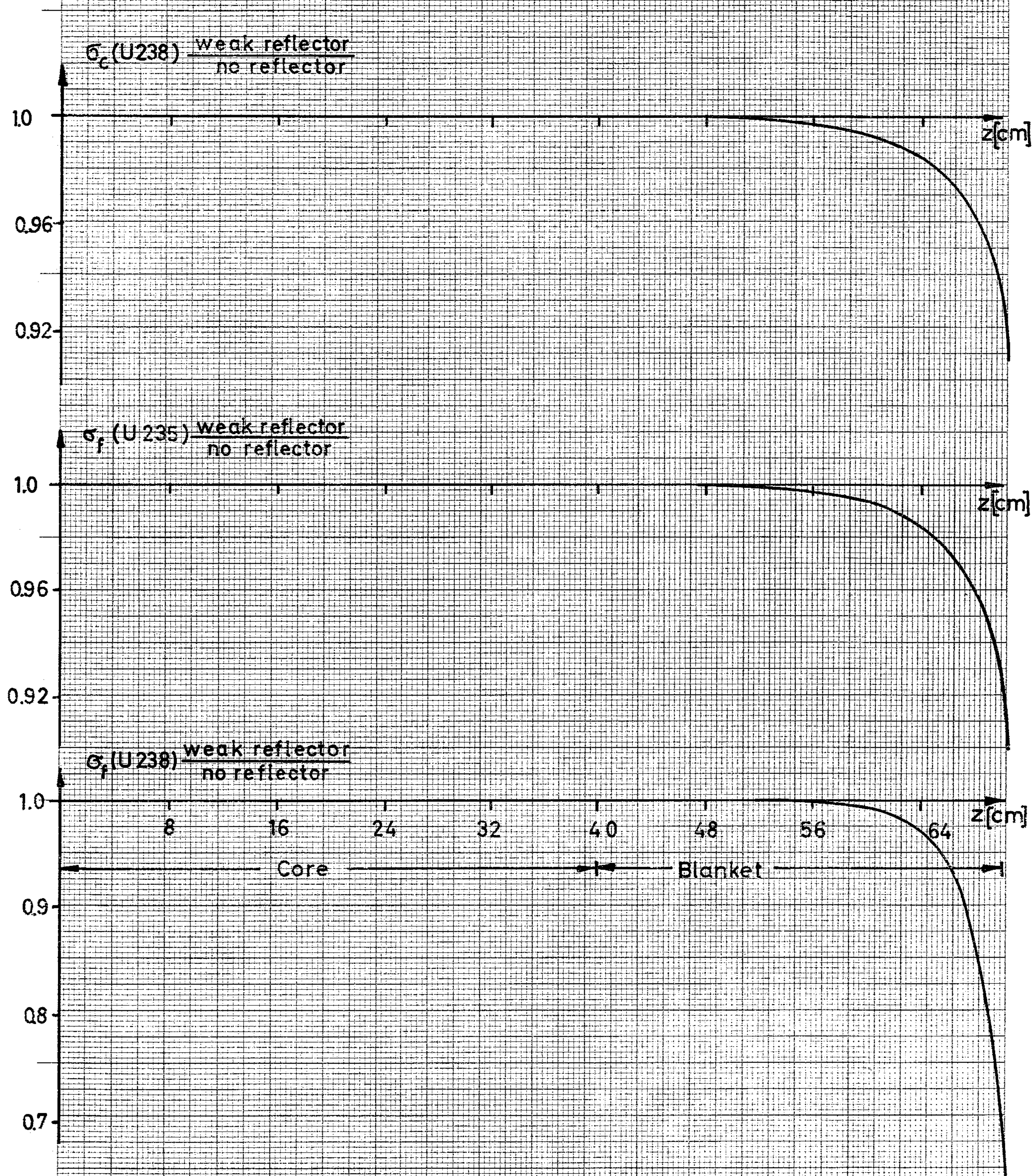


Fig. 13 B: Two dimensional results of diffusion calculations for the influence of a weak reflector on the reaction rate traverses

Fig. 13 C : Two dimensional results of diffusion calculations for the influence of a stronger reflector on the reaction rate traverses