Nuclear data uncertainty propagation (Preliminary results)

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Contents

1 Introduction

In the framework of the NEA/subgroup-33, we have applied two methods to propagate nuclear data uncertainties to a selection of benchmarks. The methodologies were presented in a previous document [1]. Table 1 presents the benchmarks studied and the status of the calculations. The first method based on perturbation approach was applied to all benchmarks except the mcf2 and ABR system, for which we need an MCNP input. The second method, called Total Monte Carlo, requires more calculation time and only partial results are presented in the following.

Table 1
Summary table for k_{eff} calculations

Benchmark	^{239}Pu	^{240}Pu	^{241}Pu	^{235}U	^{238}U	^{56}Fe	^{52}Cr	^{58}Ni	^{23}Na	^{16}O	^{10}B
pmf1 (Jezebel-239)	/	/	/								
pmf2 (Jezebel-240)	X	X	/								
pmf6 (Flat-top)	/	/	/	/	/						
mcf1 (ZPR6-7)	/	/	/	/	/	/	/	/	/	/	
mcf2 (ZPR6-7 ^{240}Pu)	o	o	o	o	o	o	o	o	o	o	
ZPPR9	/	/	/	/	/	/	/	/	/	/	
JOYO	/	/	/	/	/	/	/	/	/	/	/
FBR	/	/	/		/	/	/	/	/	/	/
ABR	o	o	o	o	o	o	o	o	o	o	o

Legend:

X: calculations finished
/: ongoing calculations
o: calculations not started

Results are presented in two types: k_{eff} uncertainties (tables) and sensitivities for different isotopes and reactions to different benchmarks (plots). The last section presents the plost of cross sections and cross section uncertainties used in this study. The sensitivity results are independent of the covariance files, and are therefore easier to compare with results from other methods.
Sensitivities to all considered benchmarks for the above isotopes are detailed in Figs.4 to 14. In order to compare all sensitivities, Fig. 1 presents the most important reactions. From Fig. 1, a small number of reactions are important for this set of benchmarks (excluding mcf2 and ABR), as presented in the following, ordered by importance:

(1) ^{239}Pu(n,f)
(2) ^{238}U(n,γ)
(3) ^{235}U(n,f)
(4) ^{238}U(n,el)
(5) ^{238}U(n,f) and ^{239}Pu(n,γ)
(6) ^{238}U(n,inl)
(7) ^{56}Fe(n,inl)

The other reactions/isotopes are of secondary importance for this exercise. Furthermore, there is no sensitivity from thermal to $\simeq$ 100 eV (see Fig. 1). Regarding covariance files presented from Fig. 15 to 23, the uncertainties are often realistic, except in the unresolved resonance range for ^{58}Ni, ^{235}U and ^{239}Pu.

2 Conclusion

We have performed a first set of calculations presenting sensitivities to k_{eff}, cross section covariances and k_{eff} uncertainties using a perturbation method and the "Total Monte Carlo" method. These intermediate results can already be used for comparisons with other methods. In the future, updates covariances can be used to obtained adjusted k_{eff} uncertainties.

3 k_{eff} benchmark uncertainties

Table 2
Details of the comparison TMC-Perturbation method for pmf1 k_{eff} benchmarks.

	pmf1 ^{239}Pu		pmf1 ^{240}Pu		pmf1 ^{241}Pu	
	Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)	
	TMC	Perturbation	TMC	Perturbation	TMC	Perturbation
Total	940	860		130		10
MF1	440	-		-		-
(n,inl)	240	170		15		0
(n,el)	230	270		10		0
(n,γ)		140		5		1
(n,f)		780		130		10
MF4		-		-		-
MF5		-		-		-
MF6		-		-		-

Table 3
Details of the comparison TMC-Perturbation method for pmf2 k_{eff} benchmarks.

	pmf2 ^{239}Pu		pmf2 ^{240}Pu		pmf2 ^{241}Pu	
	Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)	
	TMC	Perturbation	TMC	Perturbation	TMC	Perturbation
Total	844	722	790	650		113
MF1	400	-	370	-		-
(n,inl)	170	140	70	50		10
(n,el)	250	240	30	40		16
(n,γ)	100	100	30	30		10
(n,f)	720	660	730	640		110
MF4	20	-	20	-		-
MF5	50	-	30	-		-
MF6	50	-	30	-		-

Table 4
Details of the comparison TMC-Perturbation method for pmf6 k_{eff} benchmarks.

	pmf6 ^{239}Pu		pmf6 ^{240}Pu		pmf6 ^{241}Pu		pmf6 ^{238}U	
	Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)	
	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.
Total	990	570		80		6		950
MF1	460	-		-		-		-
(n,inl)	70	20		3		0		420
(n,el)	85	80		2		0		320
(n,γ)		180		6		0		730
(n,f)		530		80		6		280
MF4		-		-		-		-
MF5		-		-		-		-
MF6		-		-		-		-
	pmf6 ^{235}U							
	Δk_{eff} (pcm)							
	TMC	Pert.						
Total		40						
MF1		-						
(n,inl)		2						
(n,el)		7						
(n,γ)		3						
(n,f)		36						
MF4								
MF5								
MF6								

Table 5
Details of the comparison TMC-Perturbation method for mcf1 k_{eff} benchmarks.

	mcf1 ^{239}Pu		mcf1 ^{240}Pu		mcf1 ^{241}Pu		mcf1 ^{238}U		mcf1 ^{235}U	
	Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)	
	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.
Total	860	530		220		30		1800		5
MF1	480	-		-		-		-		-
(n,inl)	30	16		1		0		280		0
(n,el)	15	7		0		2		60		0
(n,γ)		240		8		10		1700		2
(n,f)		530		210		30		100		5
MF4		-		-		-		-		-
MF5		-		-		-		-		-
MF6		-		-		-		-		-
	mcf1 ^{56}Fe		mcf1 ^{52}Cr		mcf1 ^{58}Ni		mcf1 ^{23}Na		mcf1 ^{16}O	
Total		85		160		6		23		40
MF1		-		-				-		-
(n,inl)		70		10		2		10		0
(n,el)		25		160		1		21		40
(n,γ)		40		20		5		1		0
(n,f)		-		-				-		-
MF4		-		-				-		-
MF5		-		-				-		-
MF6		-		-				-		-

Table 6
Details of the comparison TMC-Perturbation method for zppr9 k_{eff} benchmarks.

	zppr9 ^{239}Pu		zppr9 ^{240}Pu		zppr9 ^{241}Pu		zppr9 ^{238}U		zppr9 ^{235}U	
	Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)	
	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.
Total	680	480		115		25		1700		3
MF1	480	-		-		-		-		-
(n,inl)	<20	15		5		0		310		0
(n,el)	<20	3		1		0		320		0
(n,γ)		200		35		10		1680		2
(n,f)		440		110		25		140		2
MF4		-		-		-		-		-
MF5		-		-		-		-		-
MF6		-		-		-		-		-
	zppr9 ^{56}Fe		zppr9 ^{52}Cr		zppr9 ^{58}Ni		zppr9 ^{23}Na		zppr9 ^{16}O	
Total		70		45		10		45		85
MF1		-		-		-		-		
(n,inl)		55		5		3		25		2
(n,el)		30		40		5		35		85
(n,γ)		30		15		5		3		0
(n,f)		-		-		-		-		
MF4		-		-		-		-		
MF5		-		-		-		-		
MF6		-		-		-		-		

Table 7
Details of the comparison TMC-Perturbation method for Joyo k_{eff} benchmarks.

	Joyo ^{239}Pu		Joyo ^{240}Pu		Joyo ^{241}Pu		Joyo ^{238}U		Joyo ^{235}U			
	Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)	
	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.
Total	230	350		170		35		970		220		
MF1	280	-		-		-		-		-		
(n,inl)	15	2		2		0		70		10		
(n,el)	<30	15		2		1		85		15		
(n,γ)		170		30		10		960		125		
(n,f)		300		160		30		85		170		
MF4		-		-		-		-		-		
MF5		-		-		-		-		-		
MF6		-		-		-		-		-		

	Joyo ^{56}Fe		Joyo ^{52}Cr		Joyo ^{58}Ni		Joyo ^{23}Na		Joyo ^{16}O		Joyo ^{10}B	
Total		55		220		14		75		100		0
MF1		-		-		-		-				
(n,inl)		25		5		2		3		0		0
(n,el)		45		220		12		75		100		0
(n,γ)		20		10		10		3		0		0
(n,f)		-		-		-		-				
MF4		-		-		-		-				
MF5		-		-		-		-				
MF6		-		-		-		-				

Table 8
Details of the comparison TMC-Perturbation method for FBR k_{eff} benchmarks.

	fbr ^{239}Pu		fbr ^{240}Pu		fbr ^{241}Pu		fbr ^{238}U		fbr ^{10}B	
	Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)		Δk_{eff} (pcm)	
	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.	TMC	Pert.
Total	760	360		295		230		1400		0
MF1	420	-		-		-		-		
(n,inl)	35	10		12		12		230		0
(n,el)	15	20		2		5		25		0
(n,γ)		160		90		190		1350		0
(n,f)		320		280		130		70		
MF4		-		-		-		-		
MF5		-		-		-		-		
MF6		-		-		-		-		
	fbr ^{56}Fe		fbr ^{52}Cr		fbr ^{58}Ni		fbr ^{23}Na		fbr ^{16}O	
Total		50		30		15		35		70
MF1		-		-		-		-		
(n,inl)		40		5		5		20		0
(n,el)		10		25		10		25		70
(n,γ)		20		15		10		3		0
(n,f)		-		-		-		-		
MF4		-		-		-		-		
MF5		-		-		-		-		
MF6		-		-		-		-		

4 k_{eff} Sensitivities

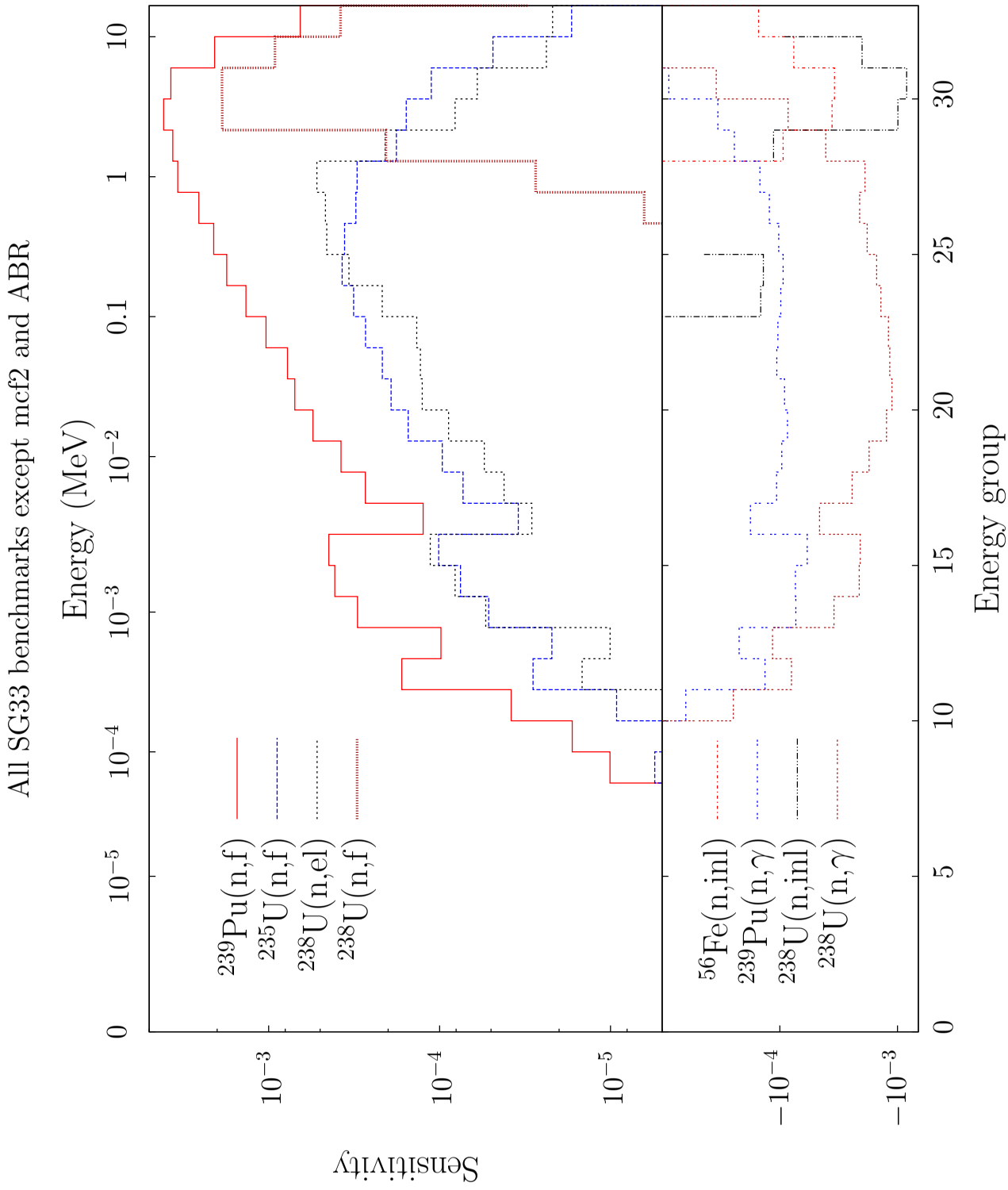

Fig. 1. Sensitivity (%/%) to 8 most important cross sections for the pmf1, pmf2, pmf6, mcf1, zppr9, joyo and fbr benchmarks.

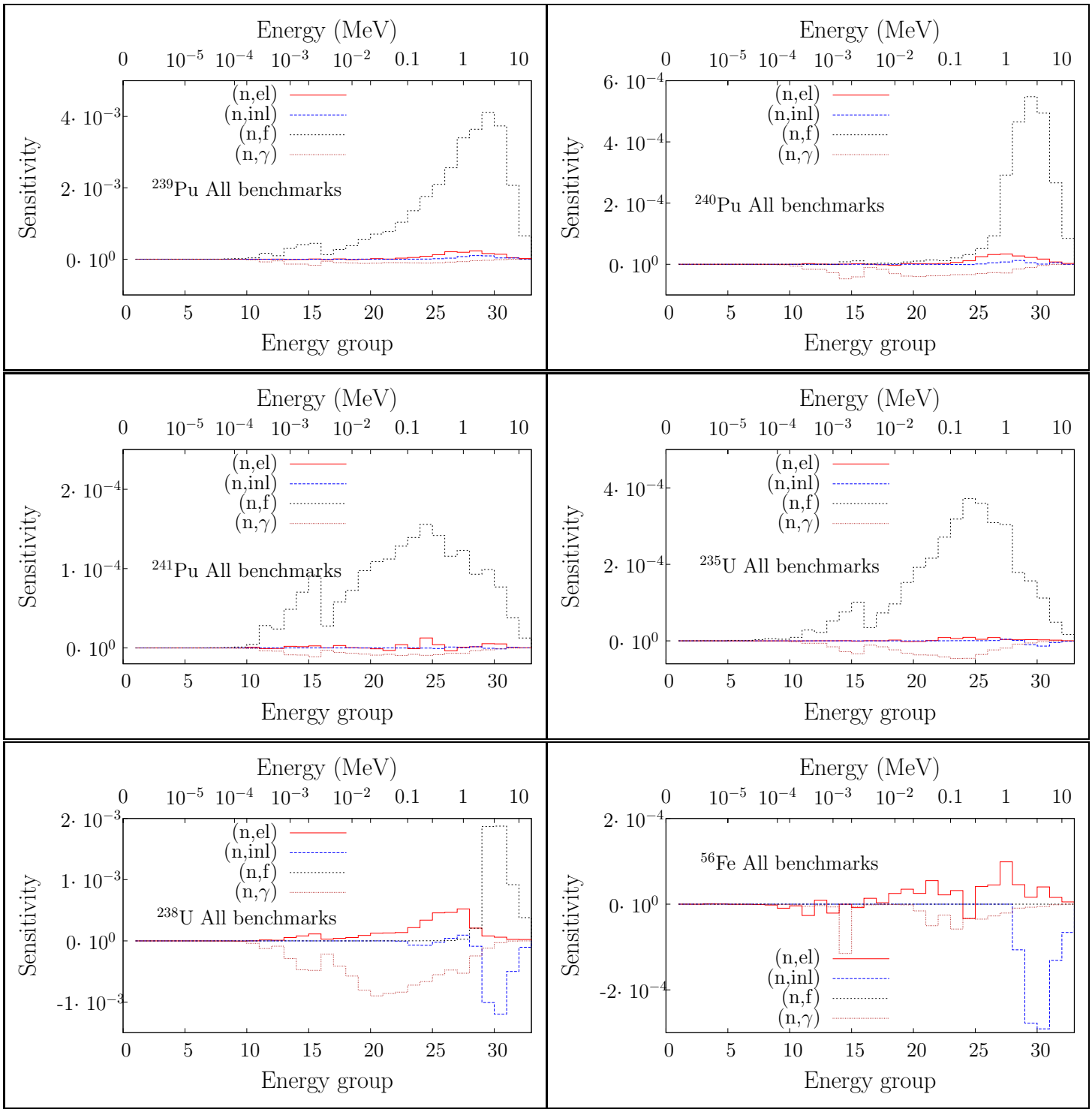

Fig. 2. Sensitivity (%/%) to ^{239,240,241}Pu, ^{235,238}U and ^{56}Fe for the pmf1, pmf2, pmf6, mcf1, zppr9, joyo and fbr benchmarks.

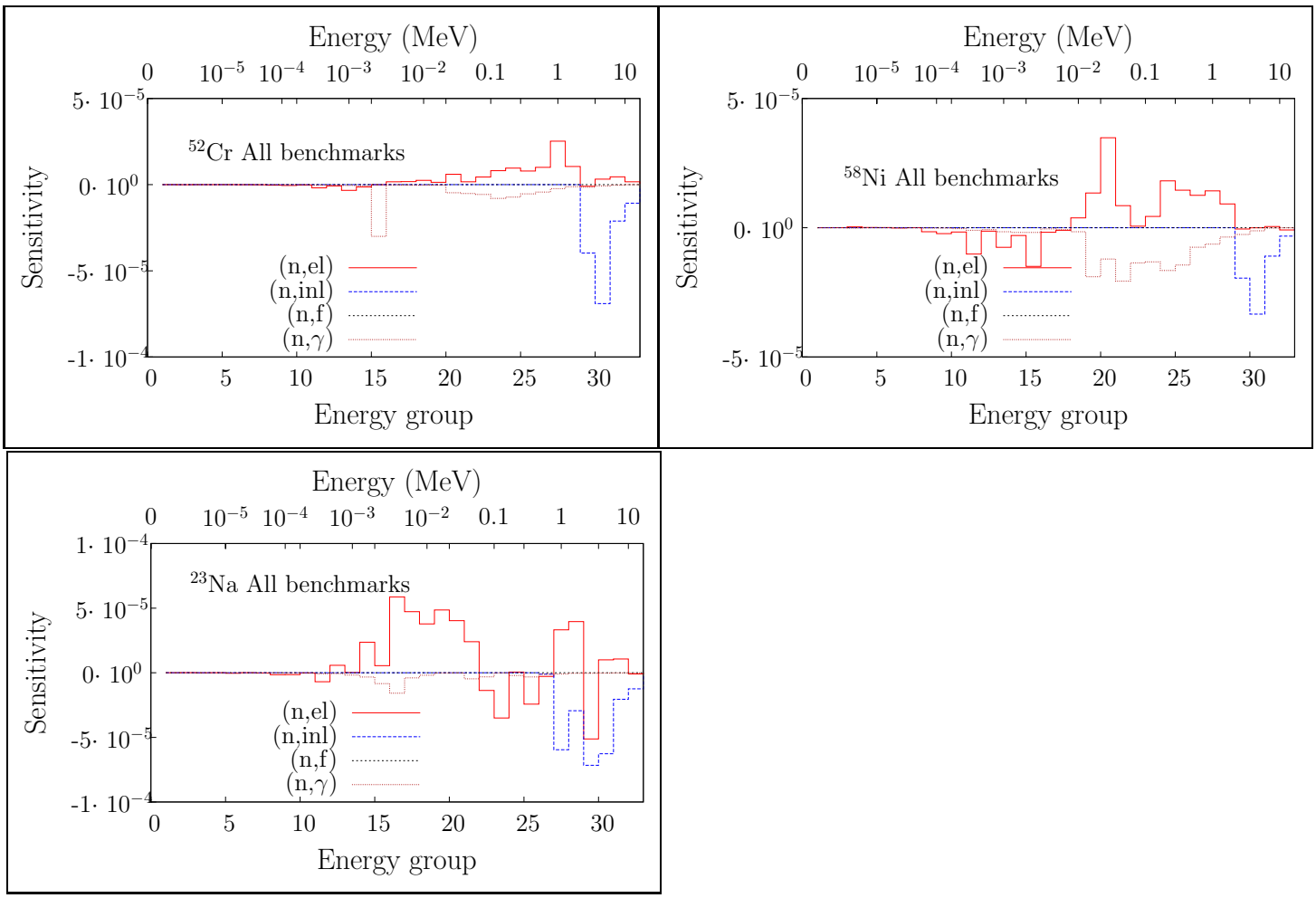

Fig. 3. Sensitivity (%/%) to ^{23}Na, ^{58}Ni and ^{52}Cr for the pmf1, pmf2, pmf6, mcf1, zppr9, joyo and fbr benchmarks.

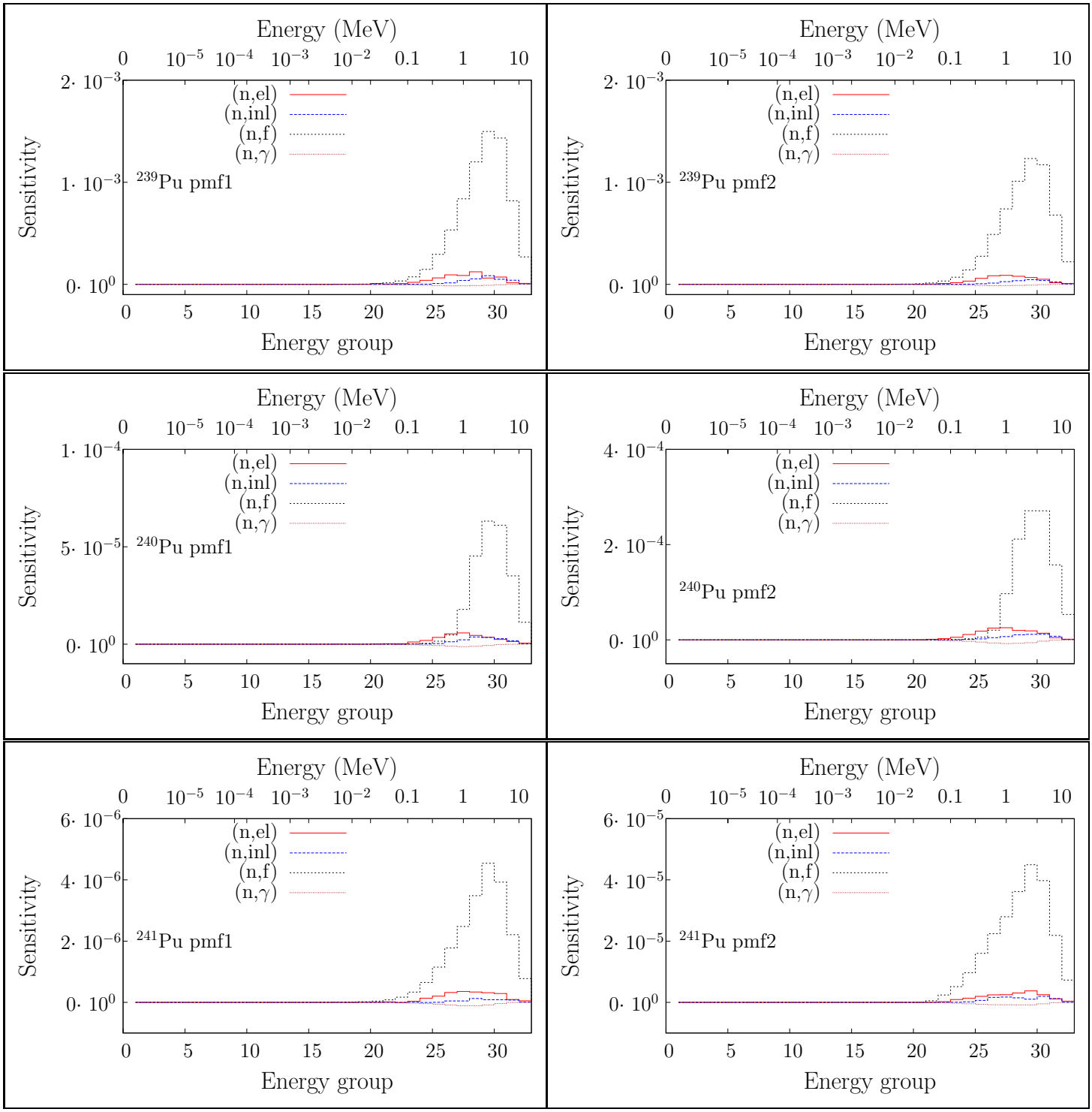

Fig. 4. Sensitivity (%/%) to ^{239,240,241}Pu for pmf1 (left) and pmf2 (right).

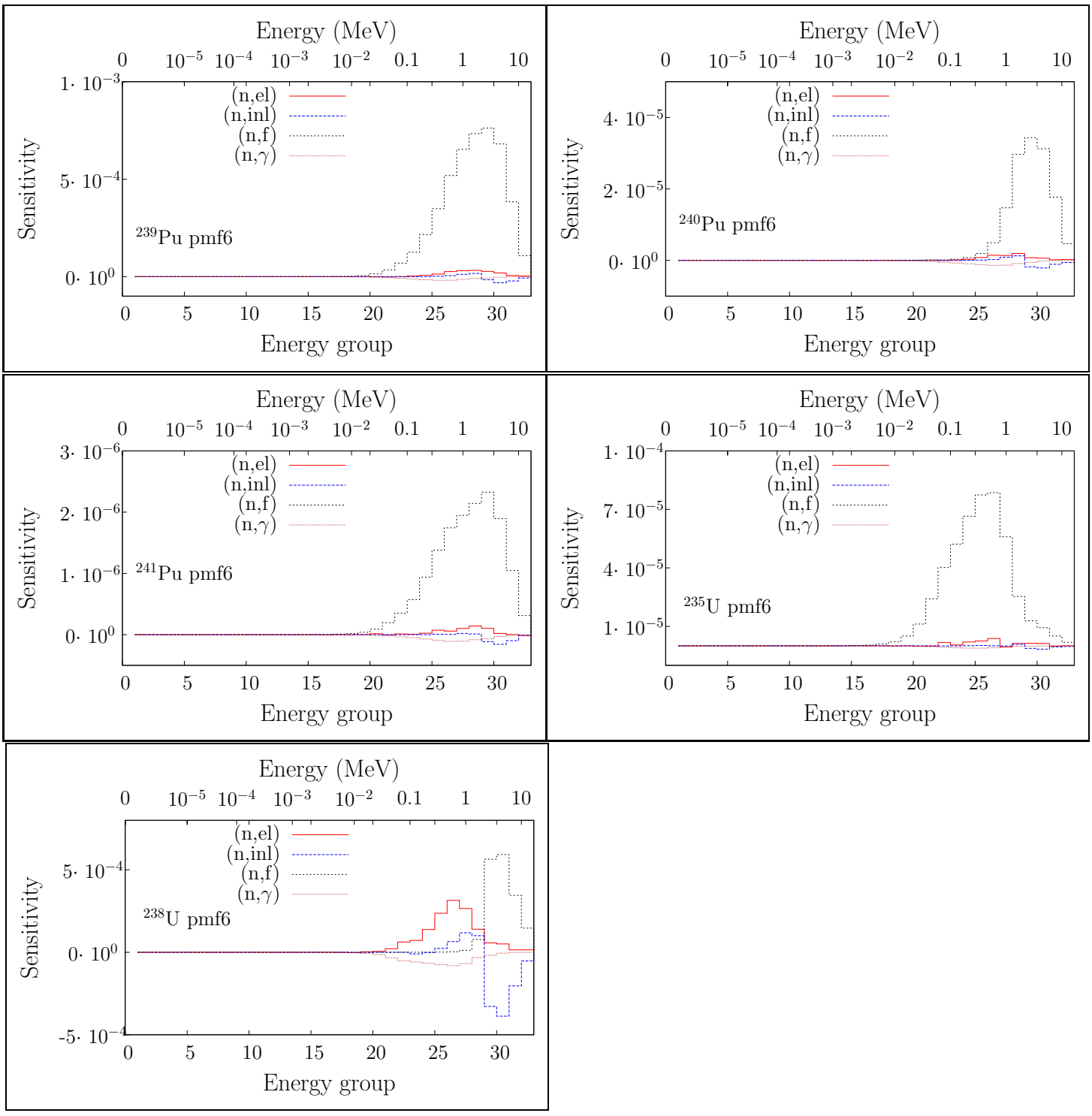

Fig. 5. Sensitivity (%/%) to ^{239,240,241}Pu and ^{235,238}U for pmf6.

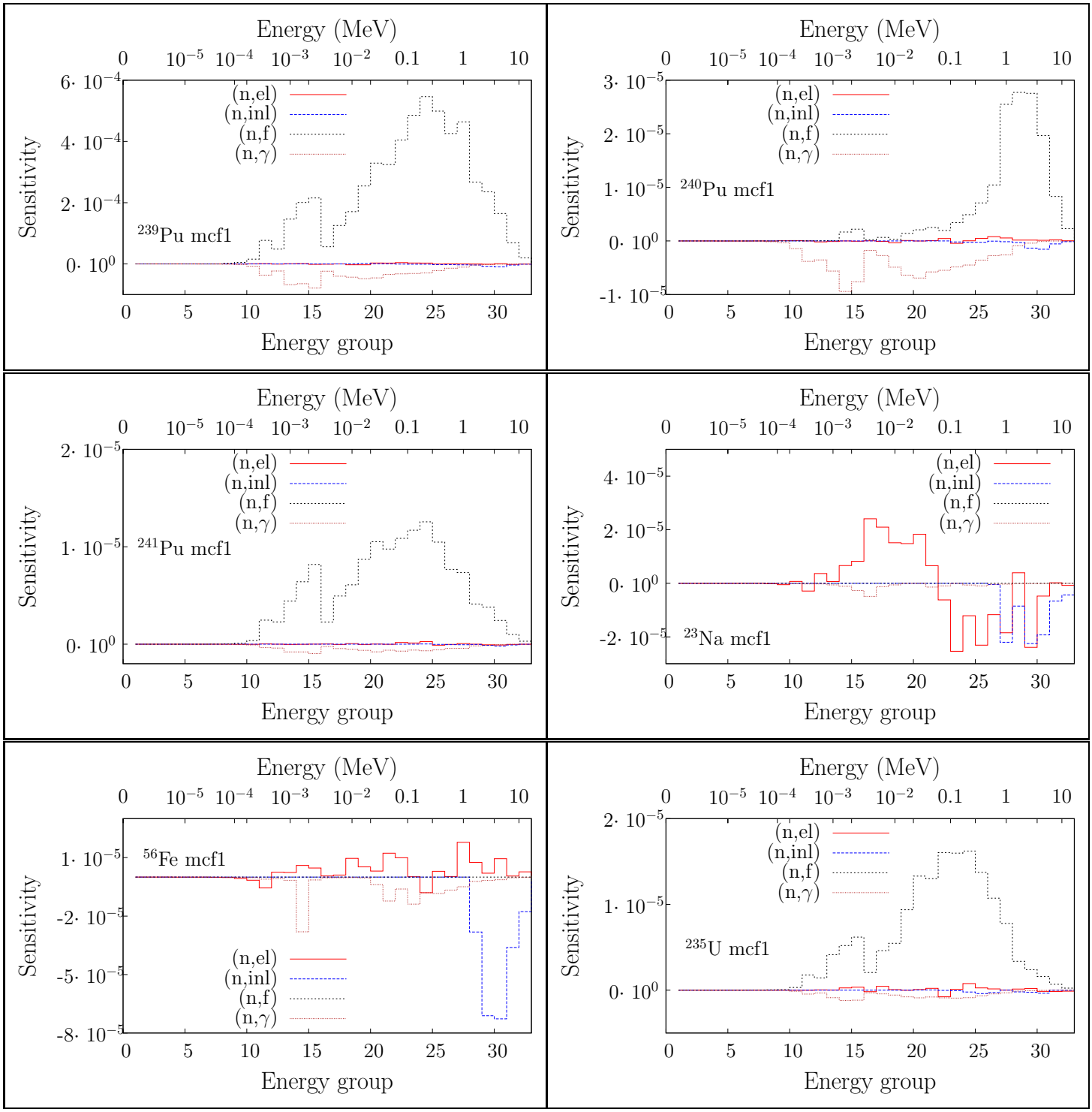

Fig. 6. Sensitivity (%/%) to ^{239,240,241}Pu, ^{23}Na, ^{235}U and ^{56}Fe for mcf1.

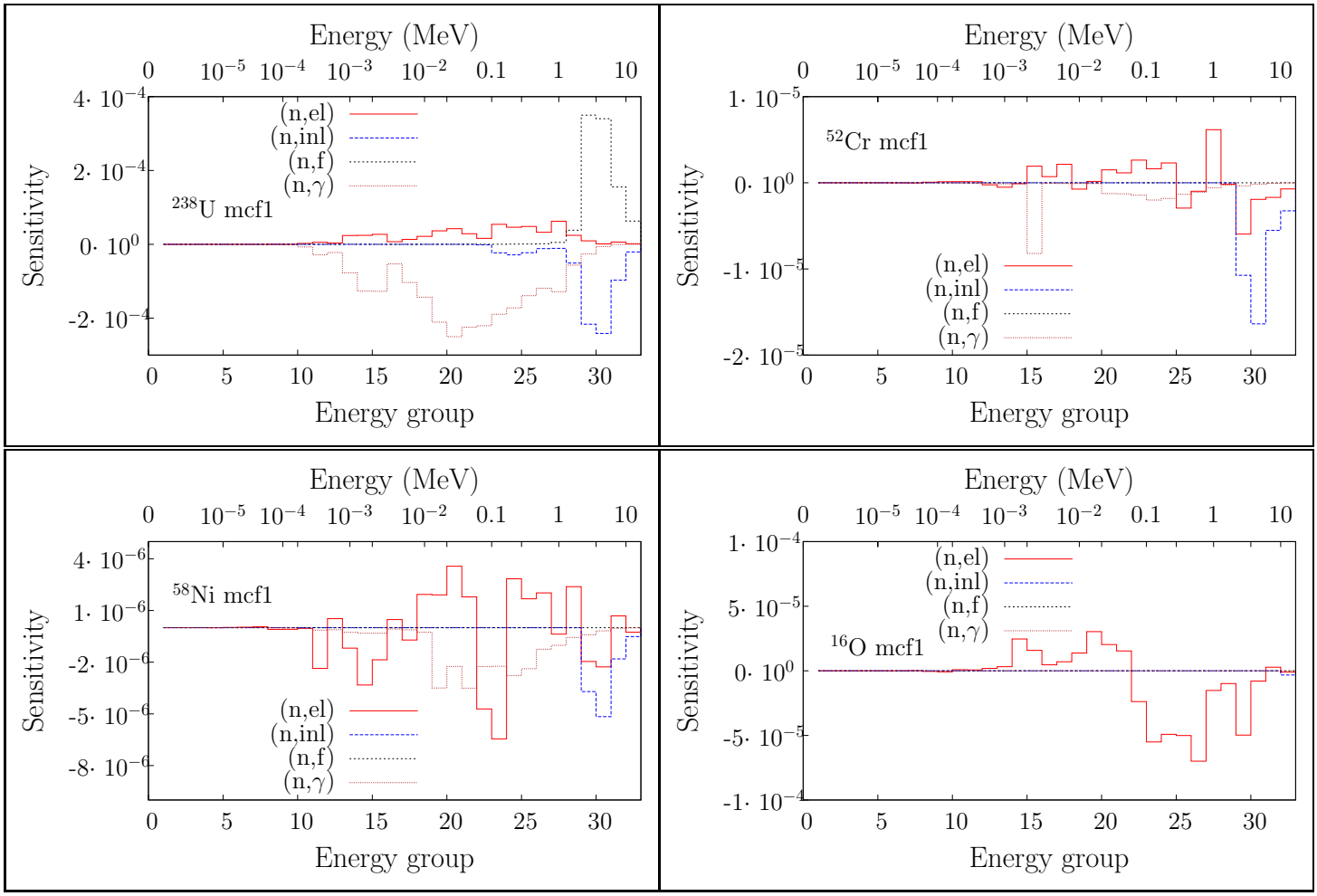

Fig. 7. Sensitivity (%/%) to ^{238}U, ^{52}Cr, ^{16}O and ^{58}Ni for mcf1.

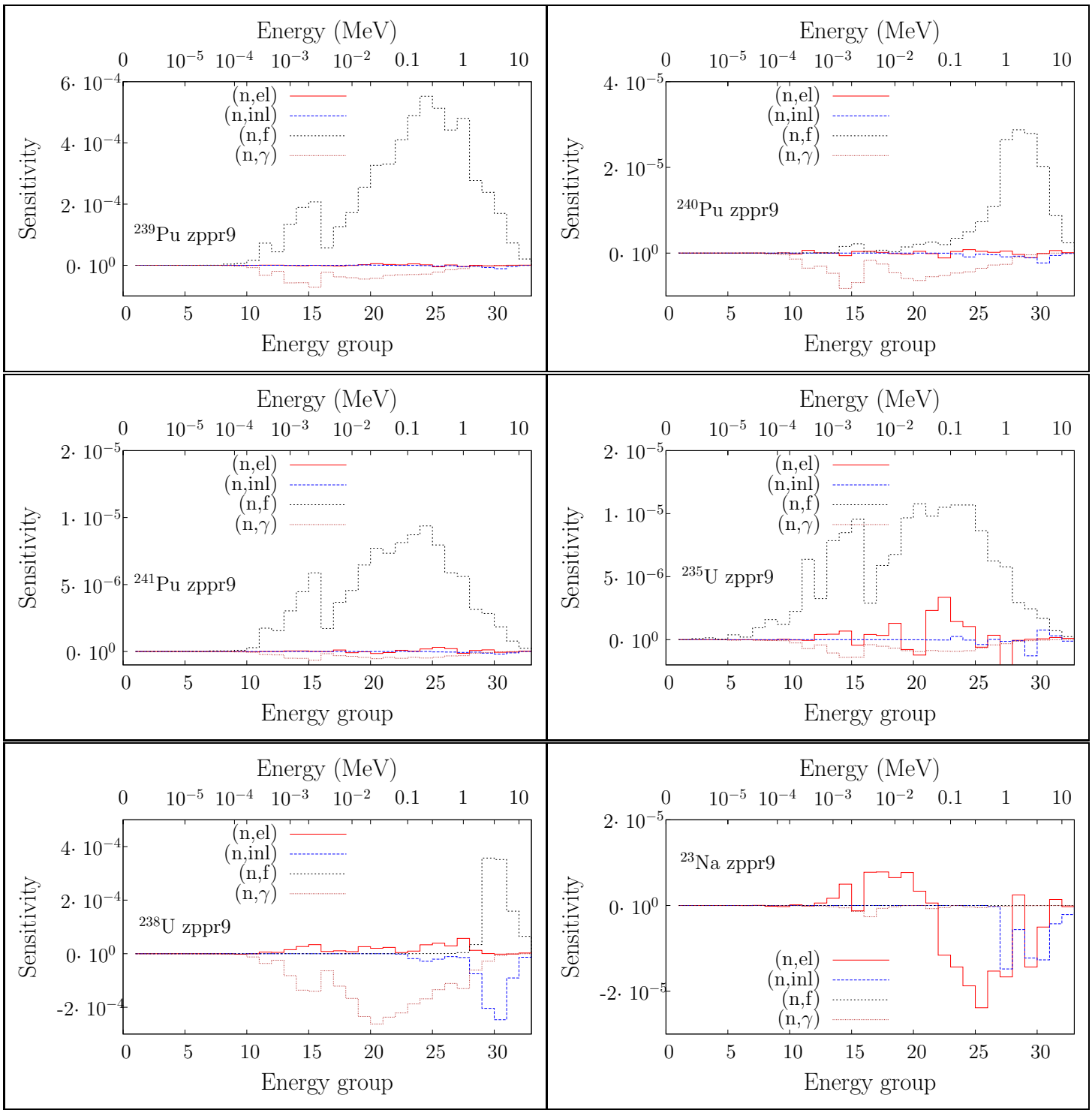

Fig. 8. Sensitivity (%/%) to ^{23}Na, ^{235,238}U, ^{239,240,241}Pu for zppr9.

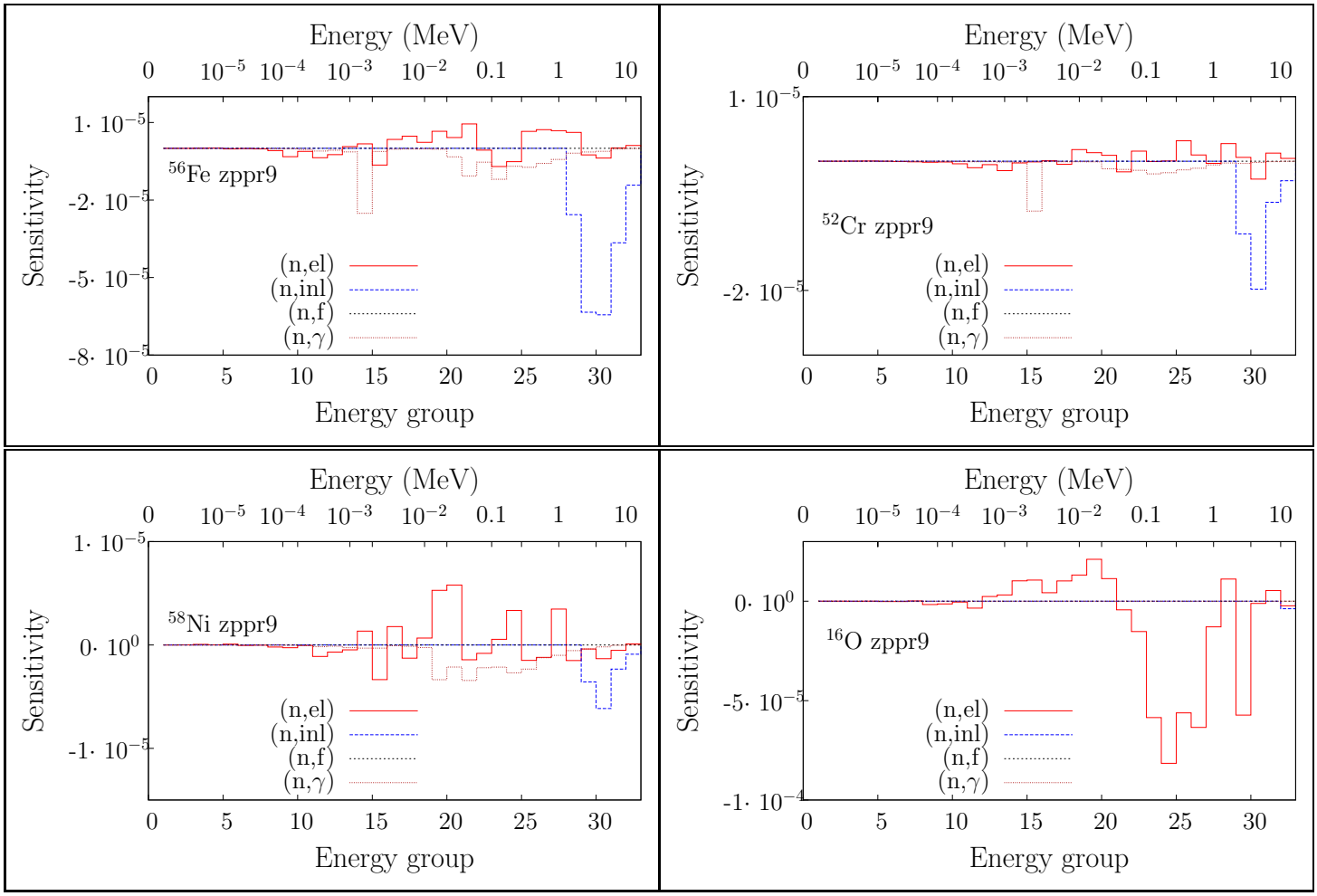

Fig. 9. Sensitivity (%/%) to ^{56}Fe, ^{52}Cr, ^{58}Ni and ^{16}O for zppr9.

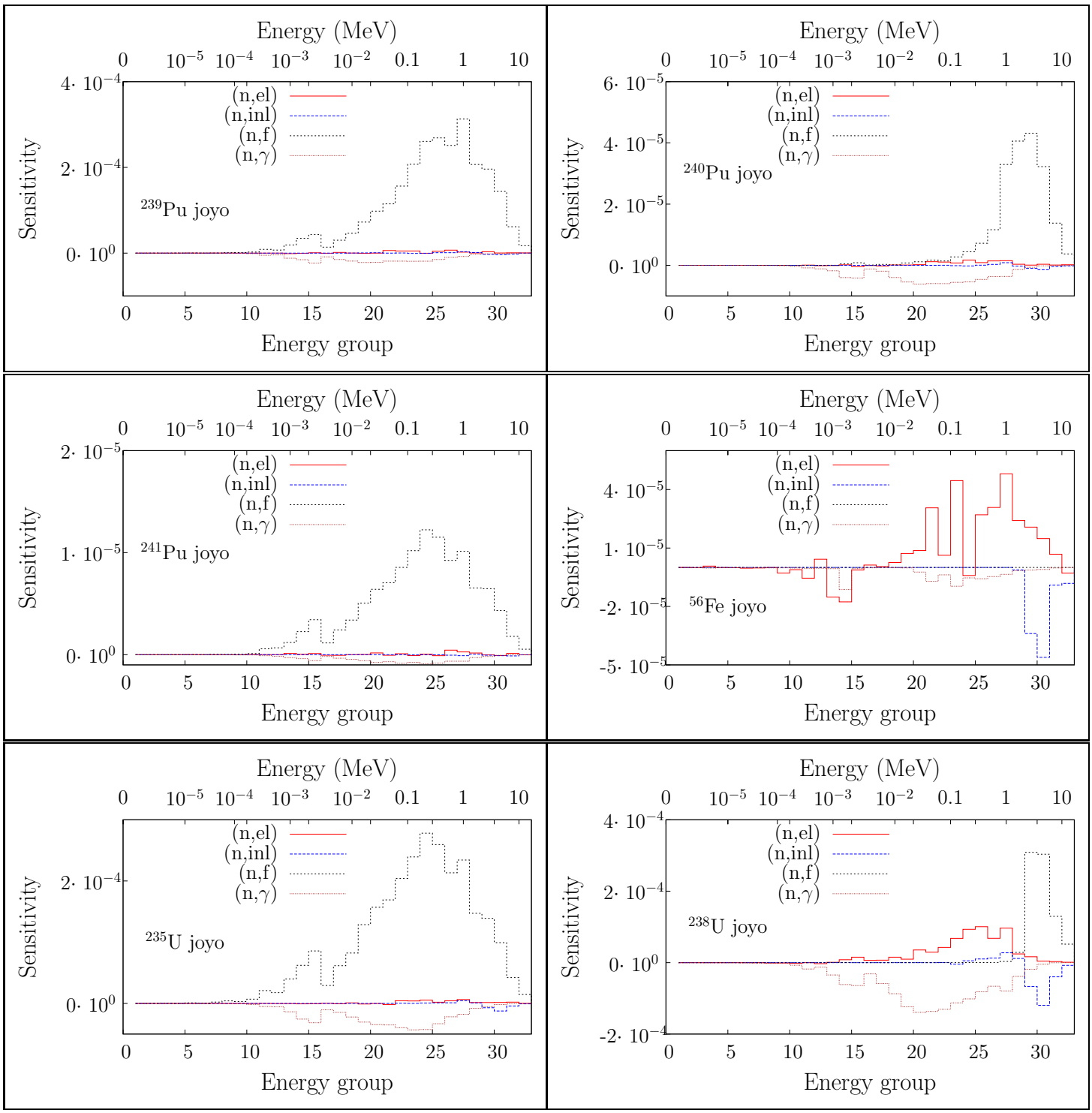

Fig. 10. Sensitivity (%/%) to ^{239,240,241}Pu, ^{56}Fe, ^{235,238} for joyo.

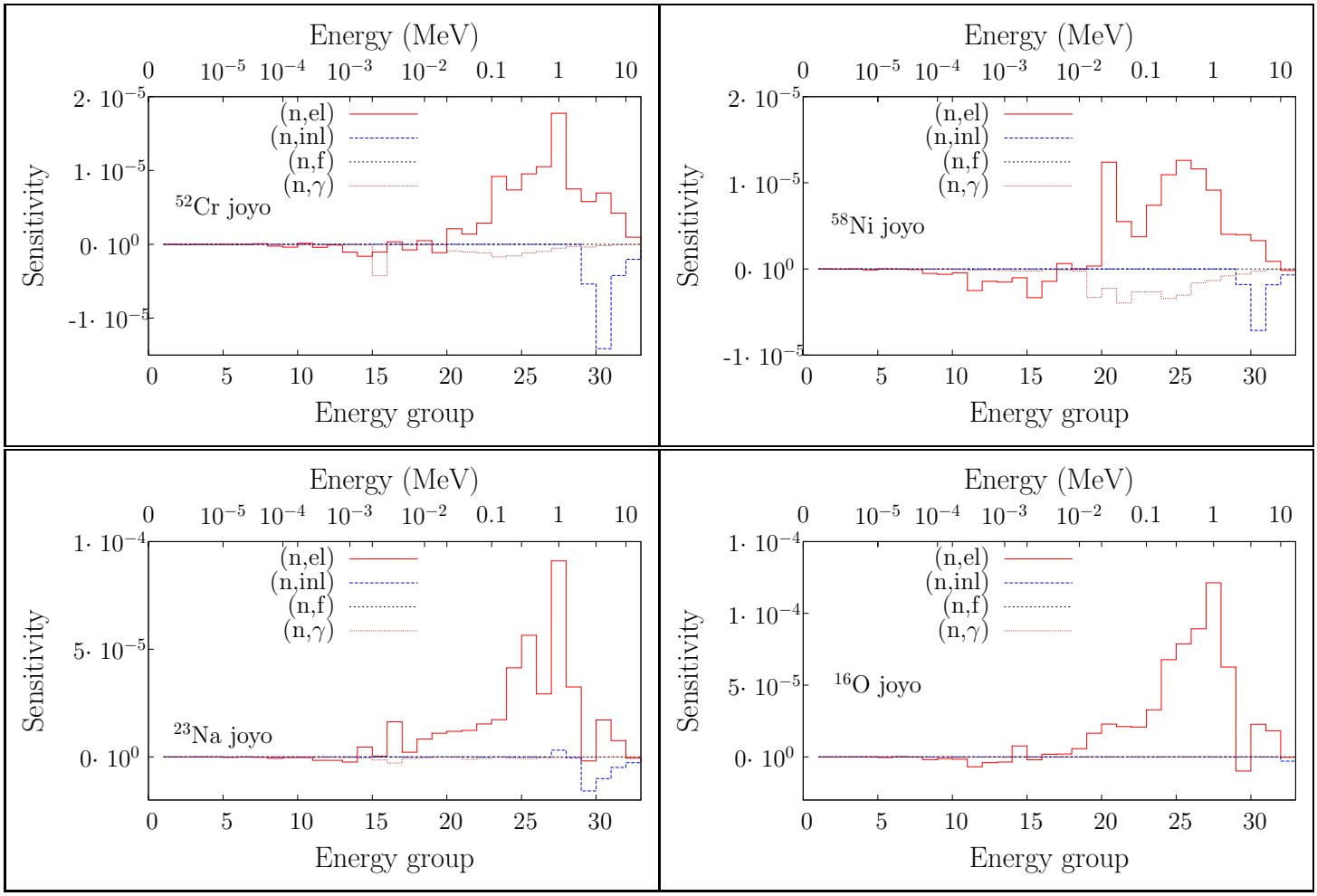

Fig. 11. Sensitivity (%/%) to ^{52}Cr, ^{58}Ni, ^{23}Na and ^{16}O for joyo.

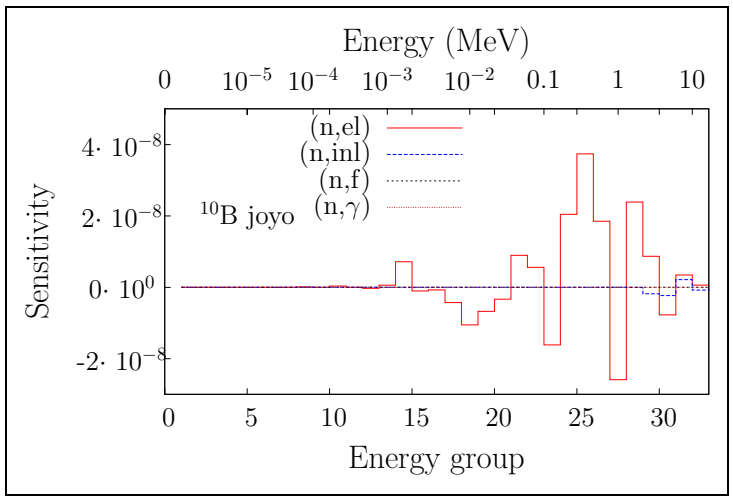

Fig. 12. Sensitivity (%/%) to ^{10}B for joyo.

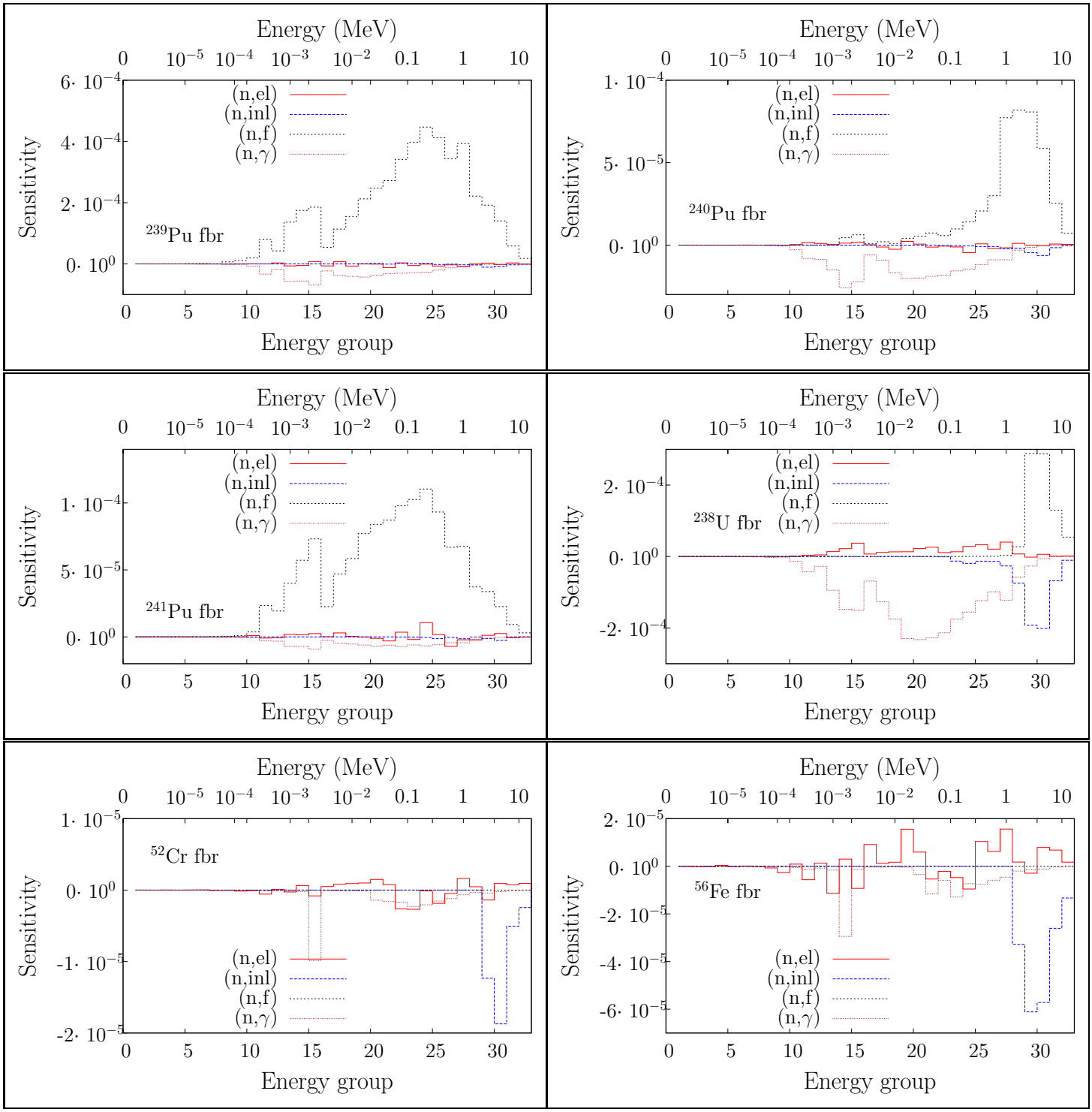

Fig. 13. Sensitivity (%/%) to ^{239,240,241}Pu, ^{238}U, ^{52}Cr and ^{56}Fe for the FBR.

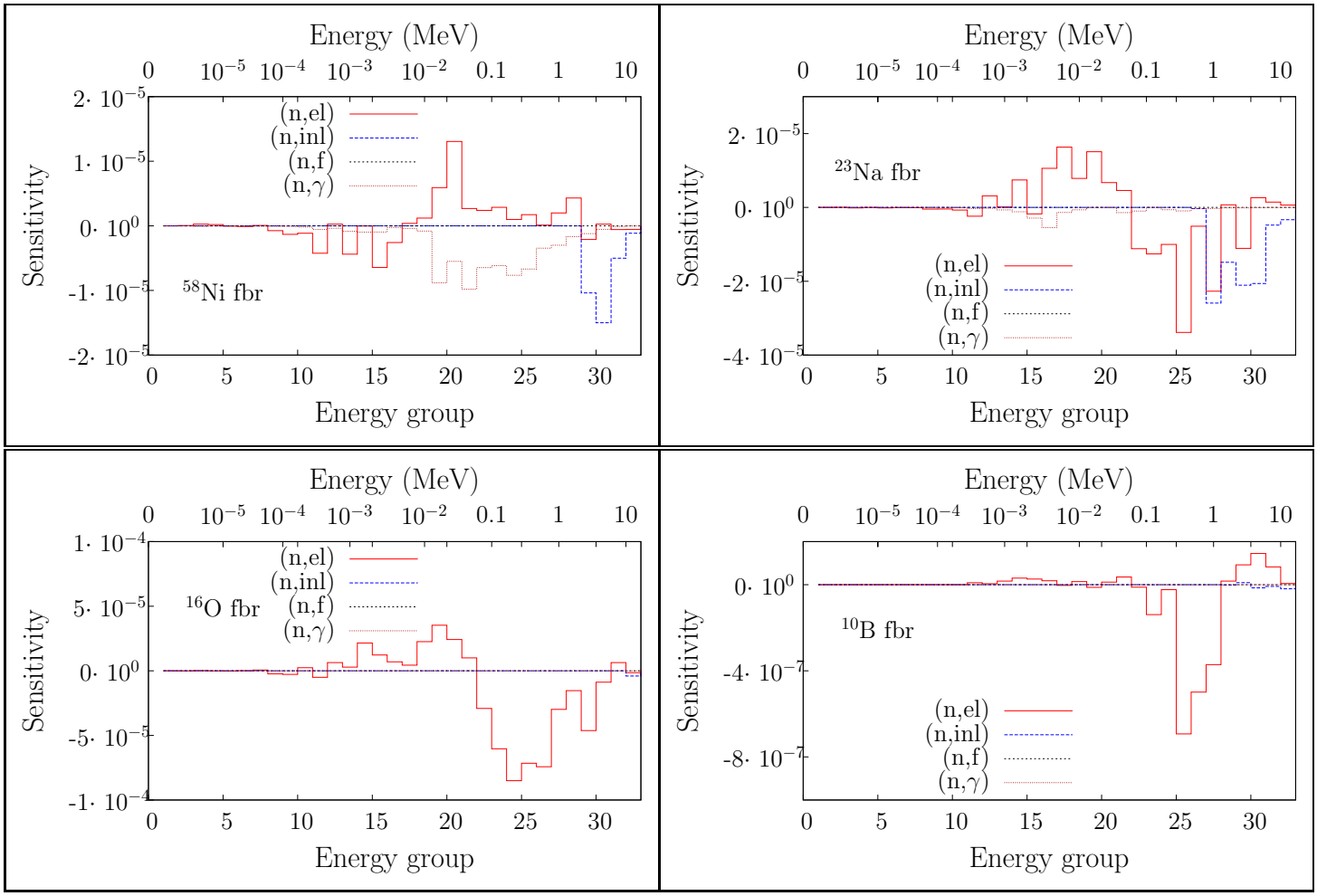

Fig. 14. Sensitivity (%/%) to ^{58}Ni, ^{23}Na, ^{10}B and ^{16}O for the FBR.

5 Cross sections and cross section uncertainties

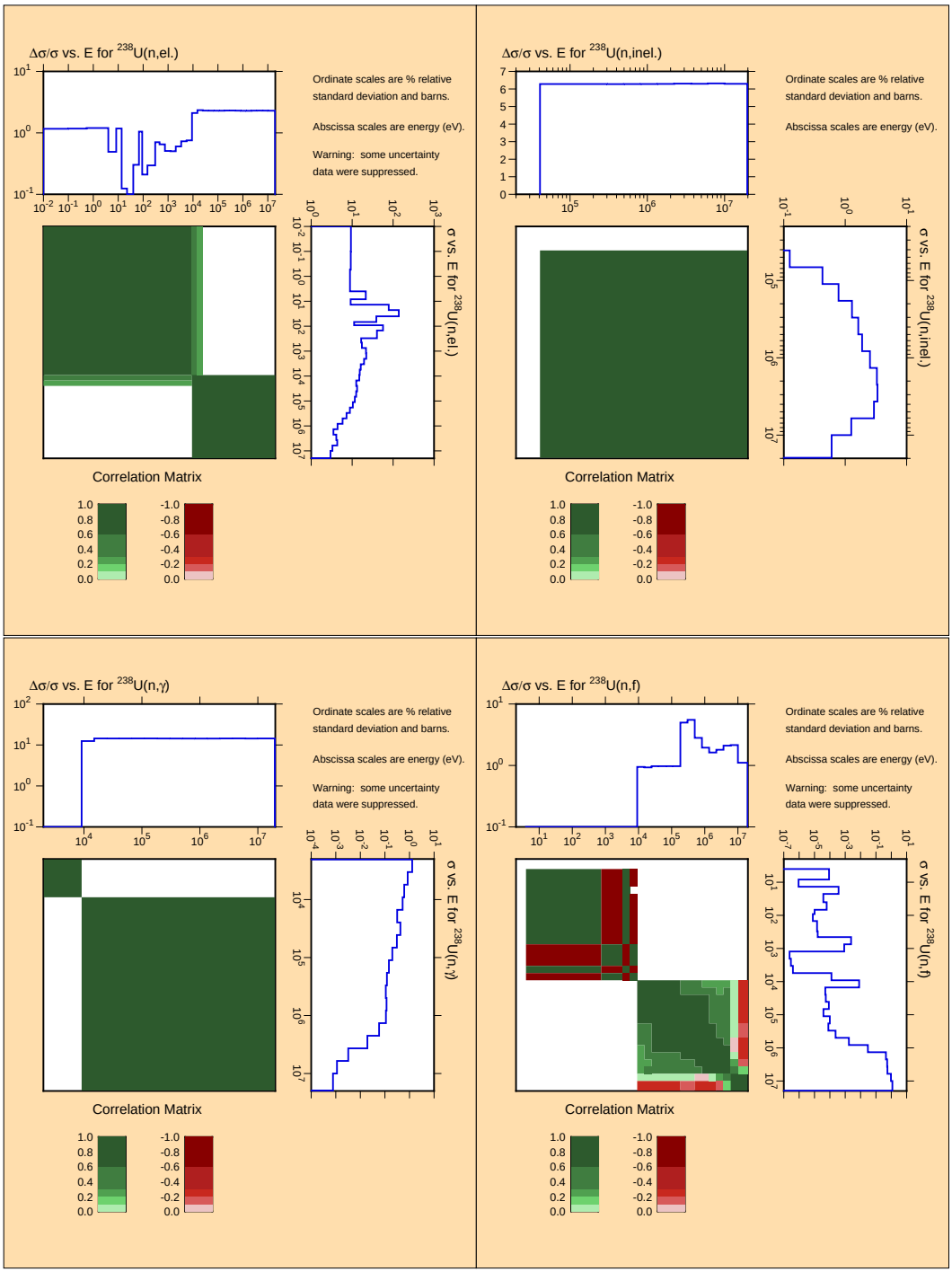

Fig. 20. Cross sections and cross section uncertainties for ^{238}U.

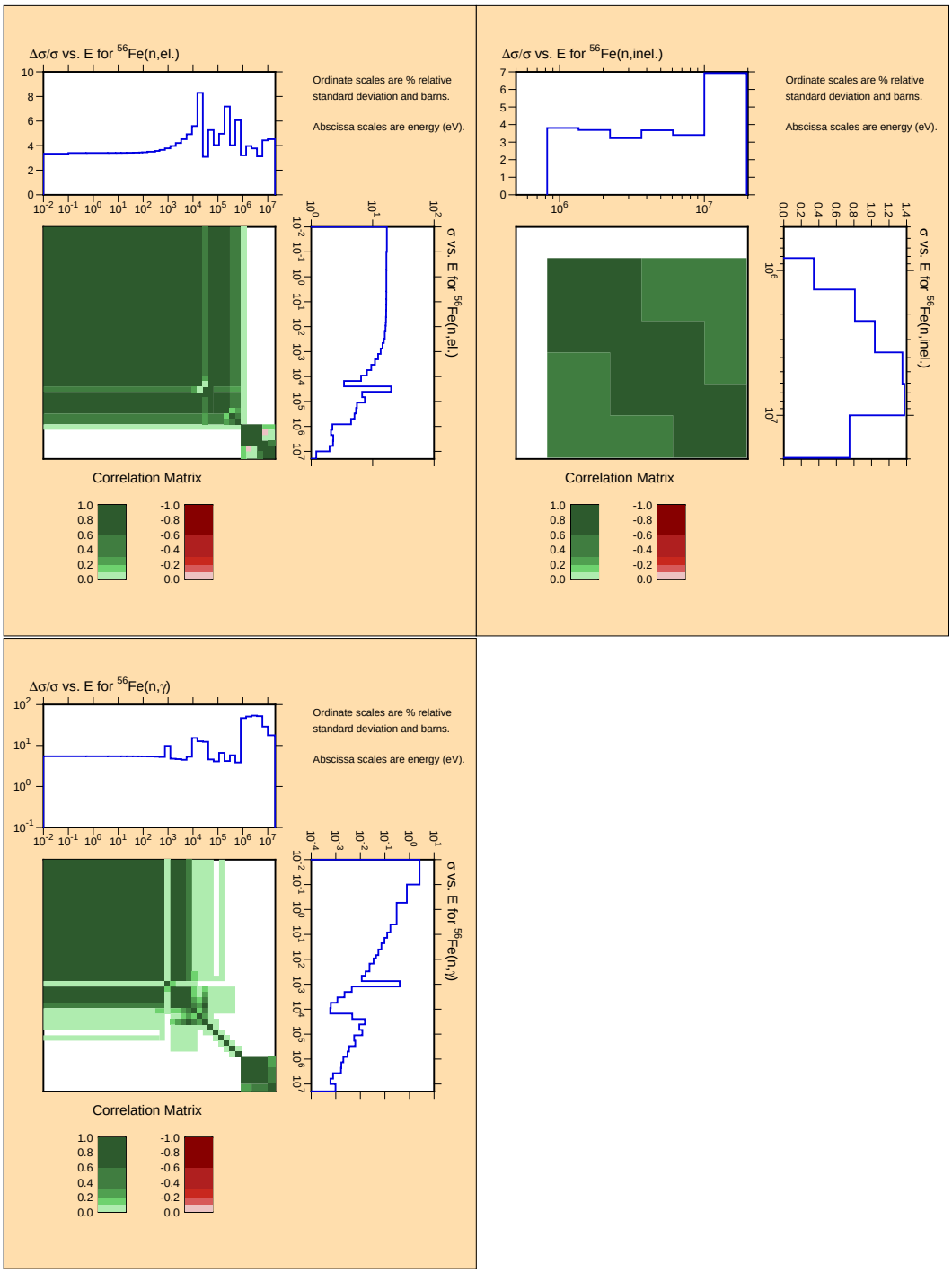

Fig. 15. Cross sections and cross section uncertainties for ^{56}Fe.

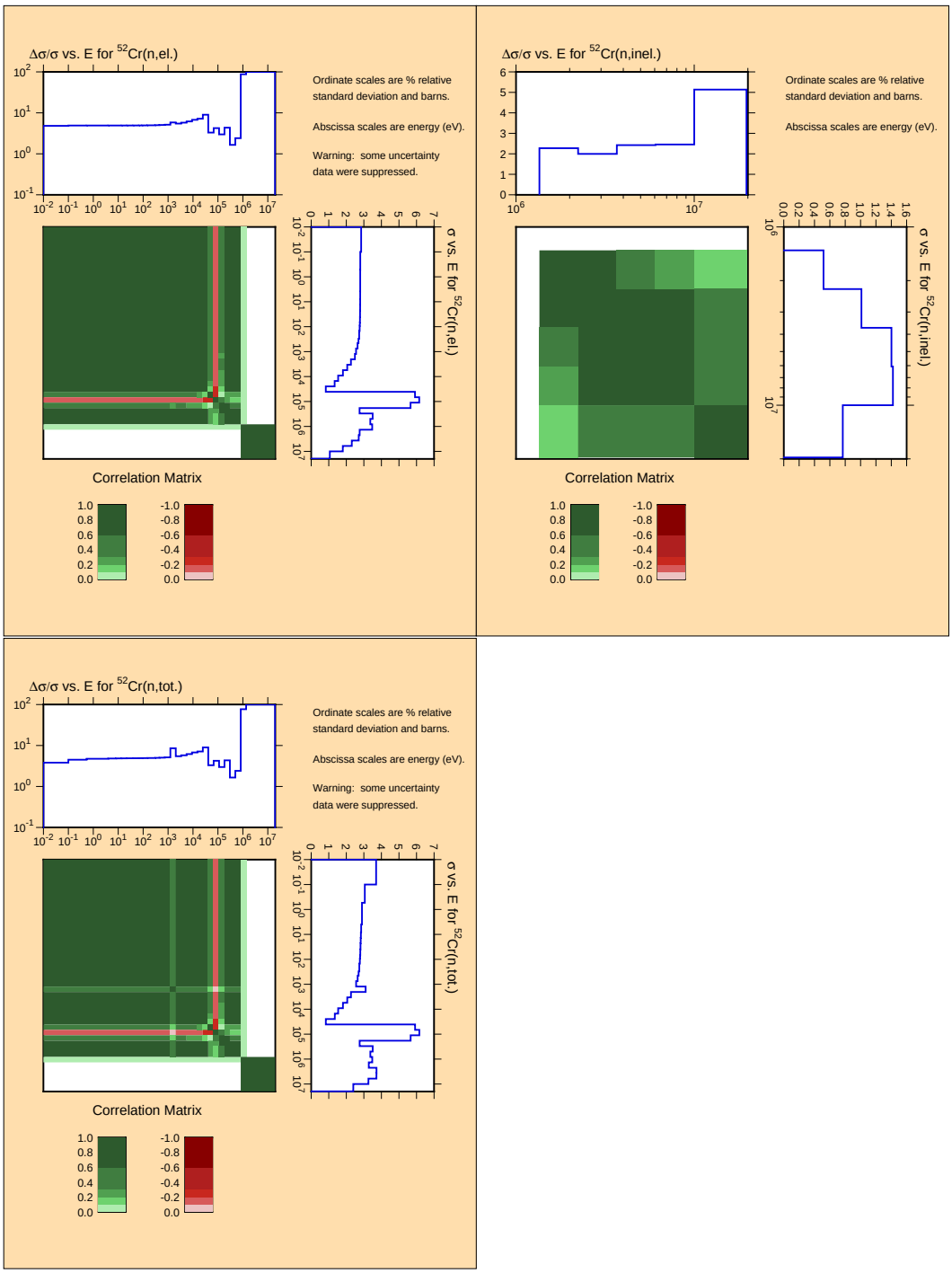

Fig. 16. Cross sections and cross section uncertainties for ^{52}Cr.

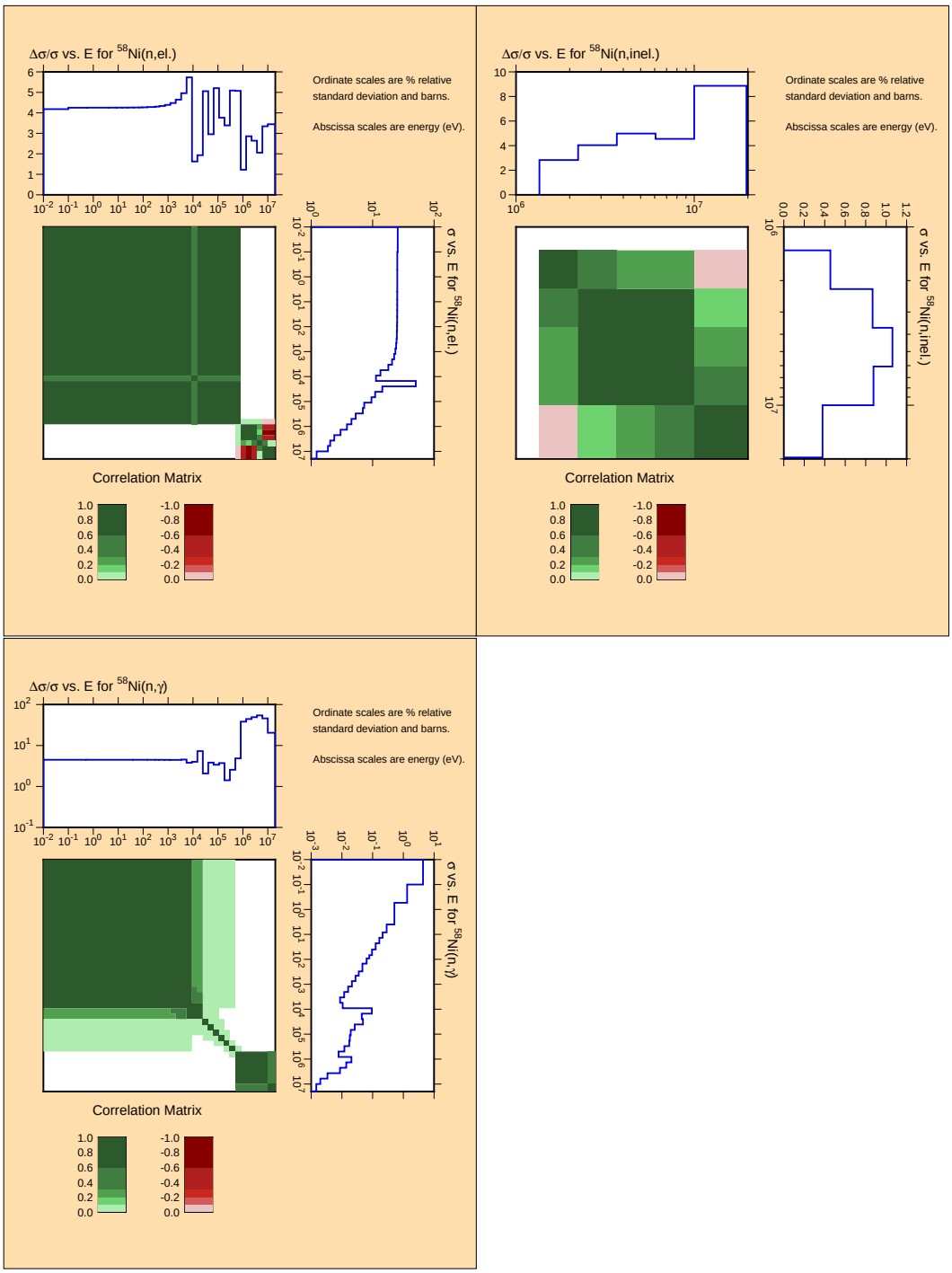

Fig. 17. Cross sections and cross section uncertainties for ^{58}Ni.

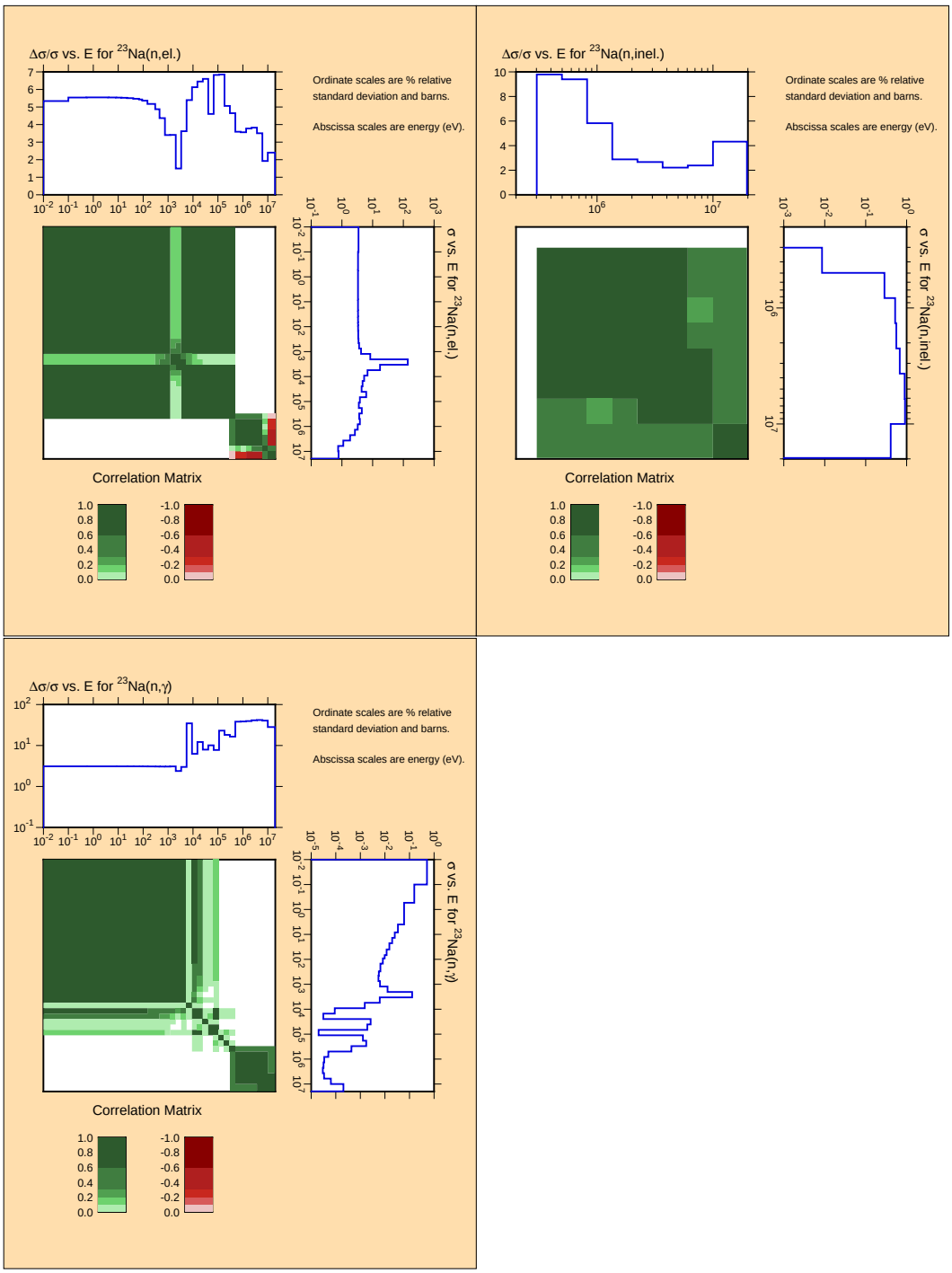

Fig. 18. Cross sections and cross section uncertainties for ^{23}Na.

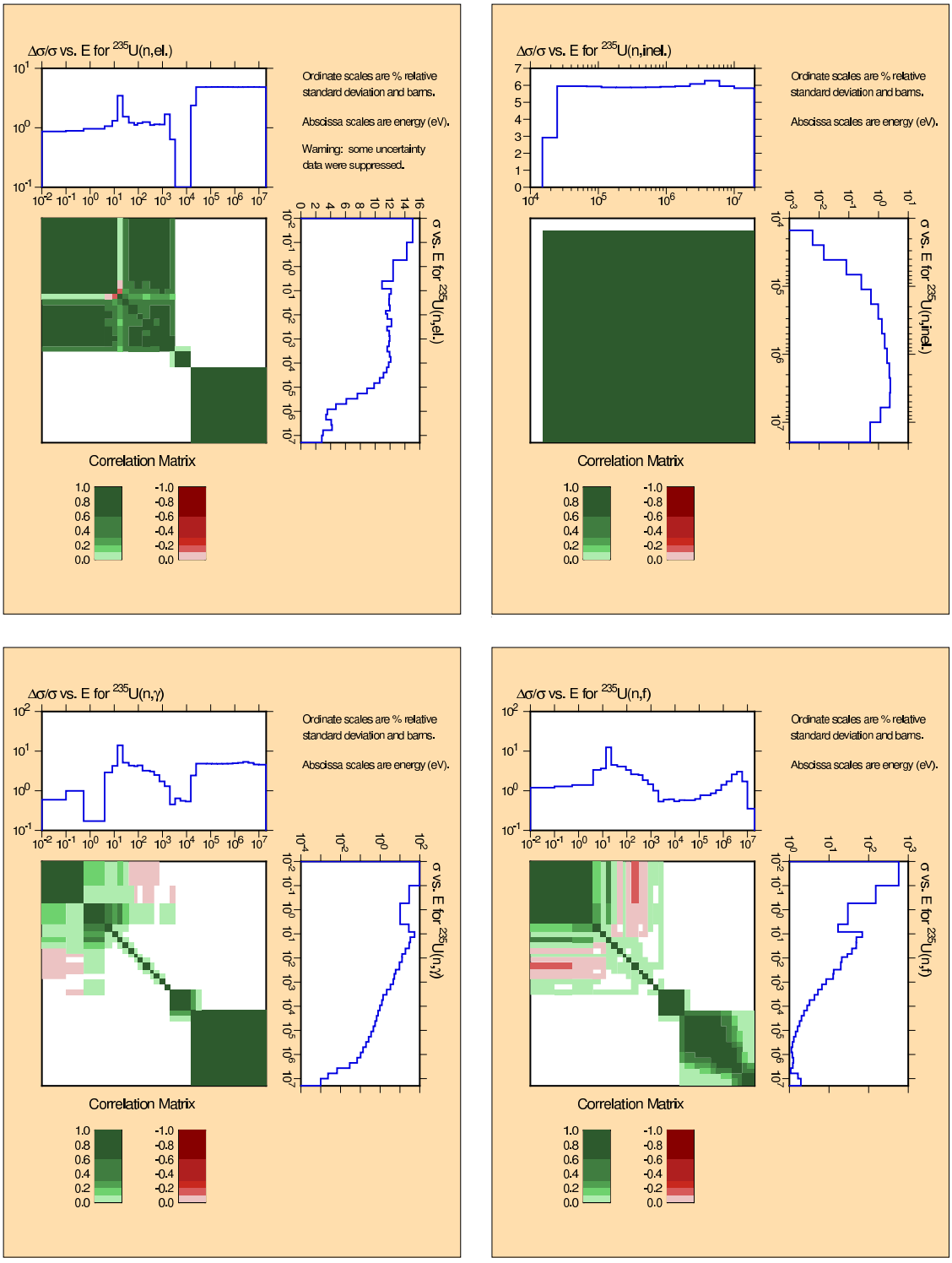

Fig. 19. Cross sections and cross section uncertainties for ^{235}U.

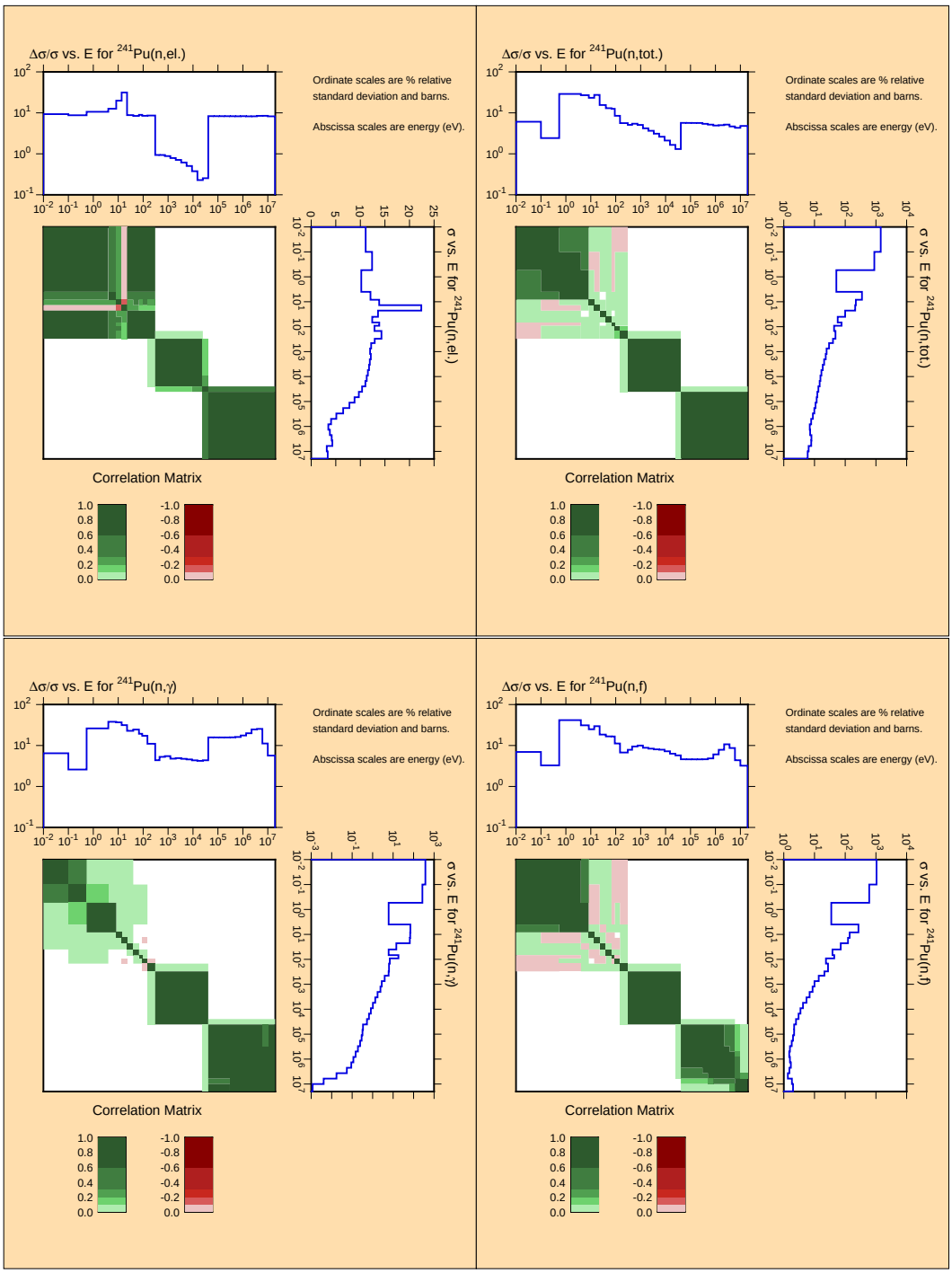

Fig. 21. Cross sections and cross section uncertainties for ^{241}Pu.

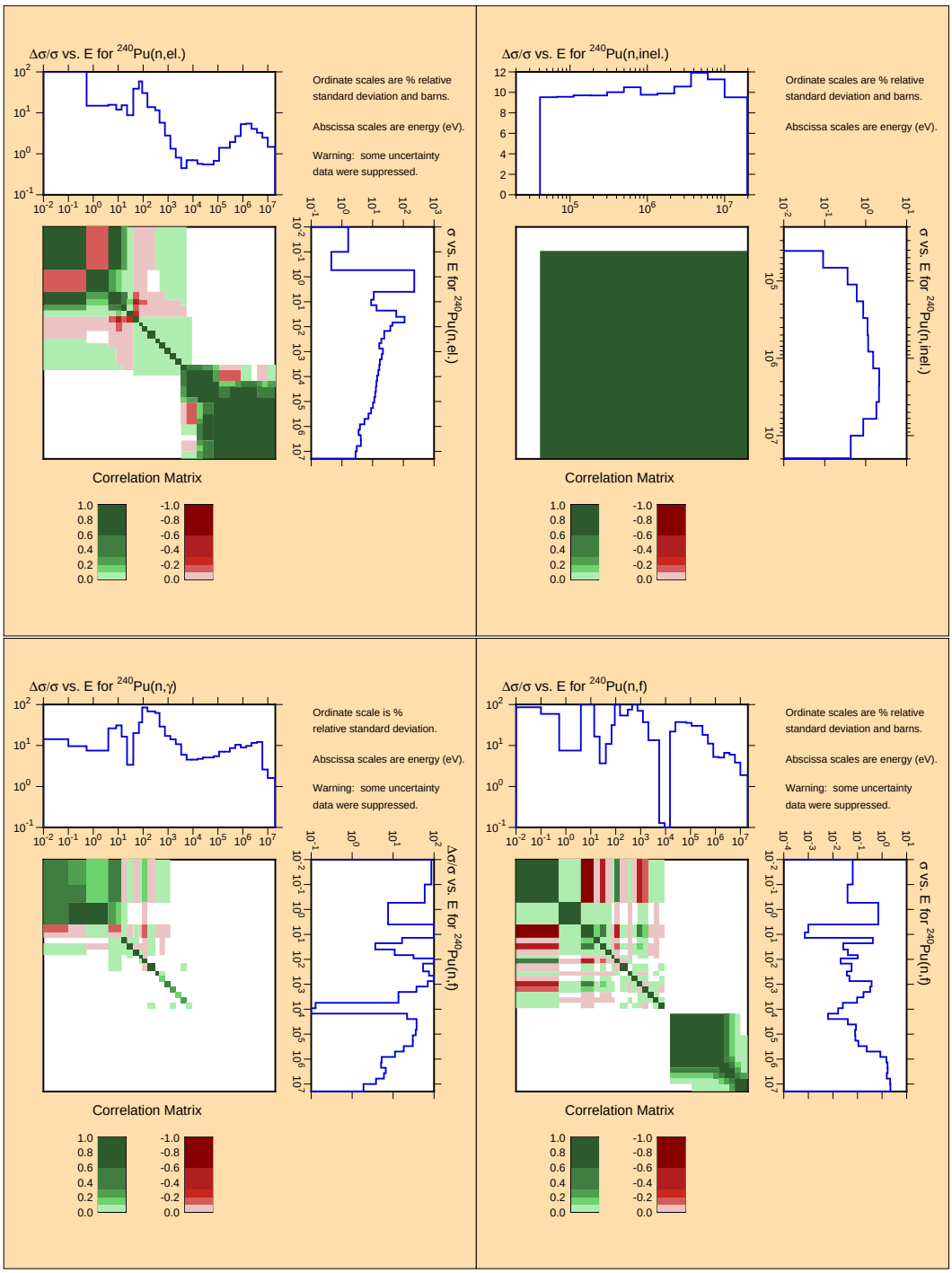

Fig. 22. Cross sections and cross section uncertainties for ^{240}Pu.

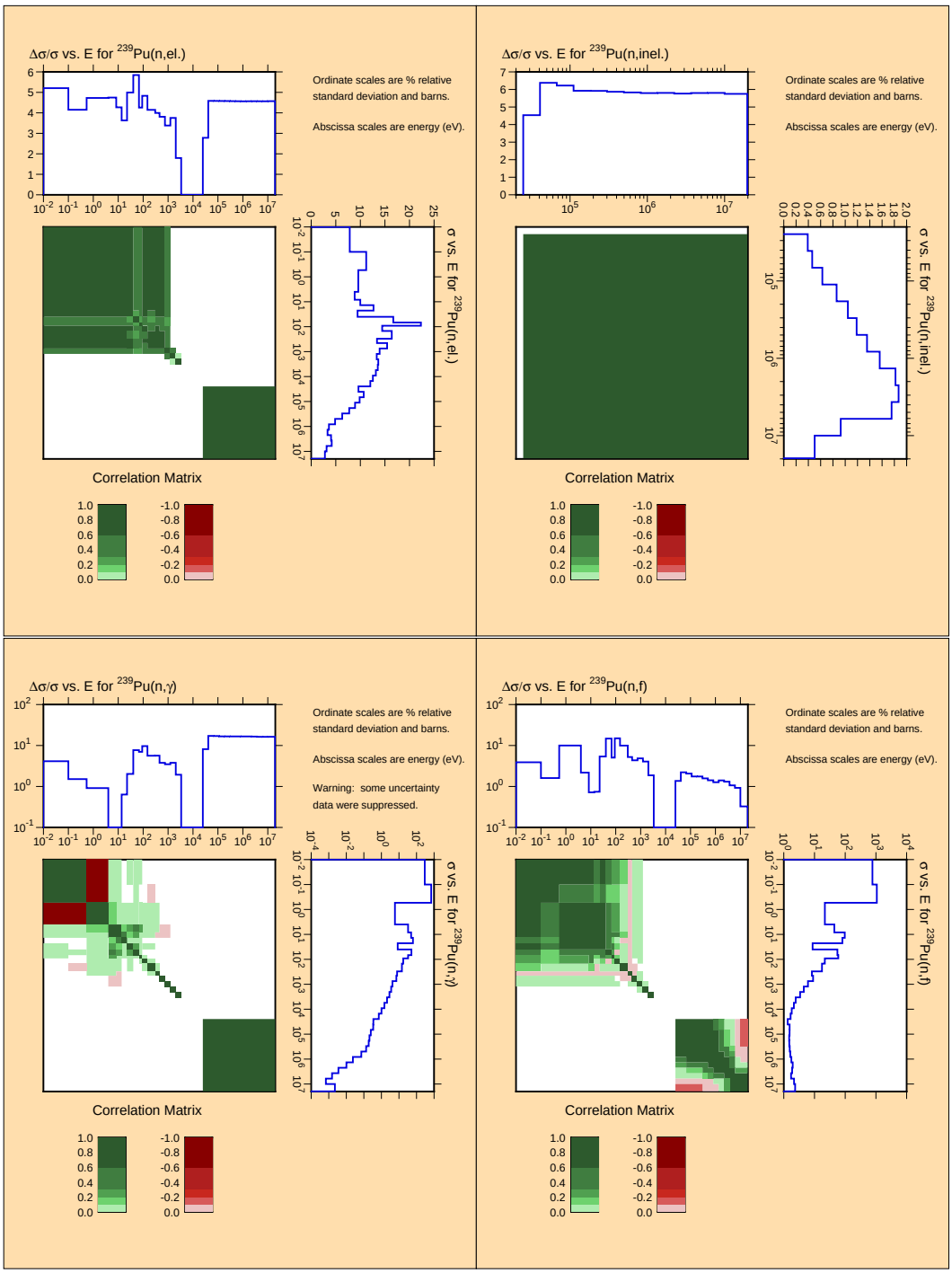

Fig. 23. Cross sections and cross section uncertainties for ^{239}Pu.

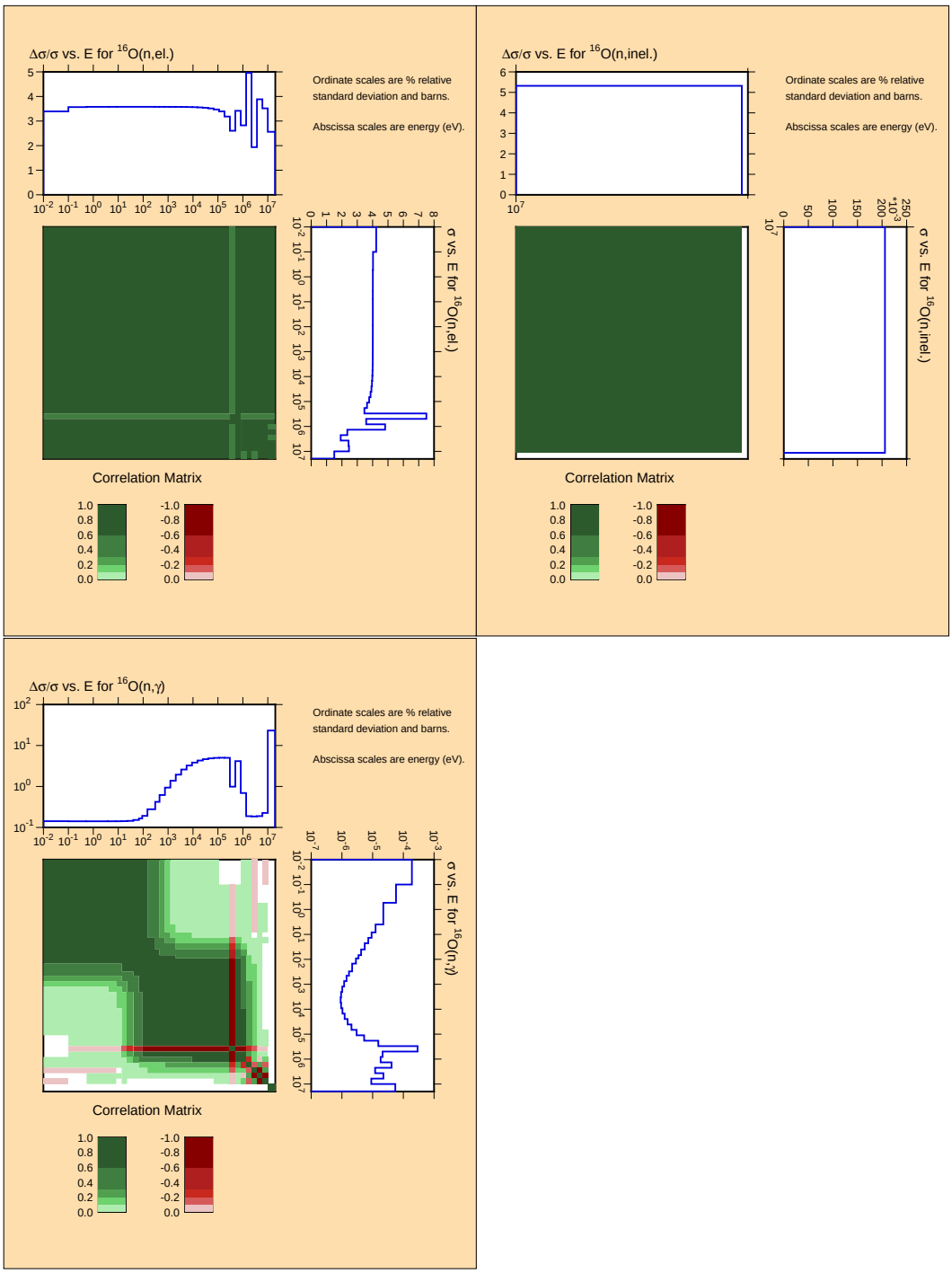

Fig. 24. Cross sections and cross section uncertainties for ^{16}O.

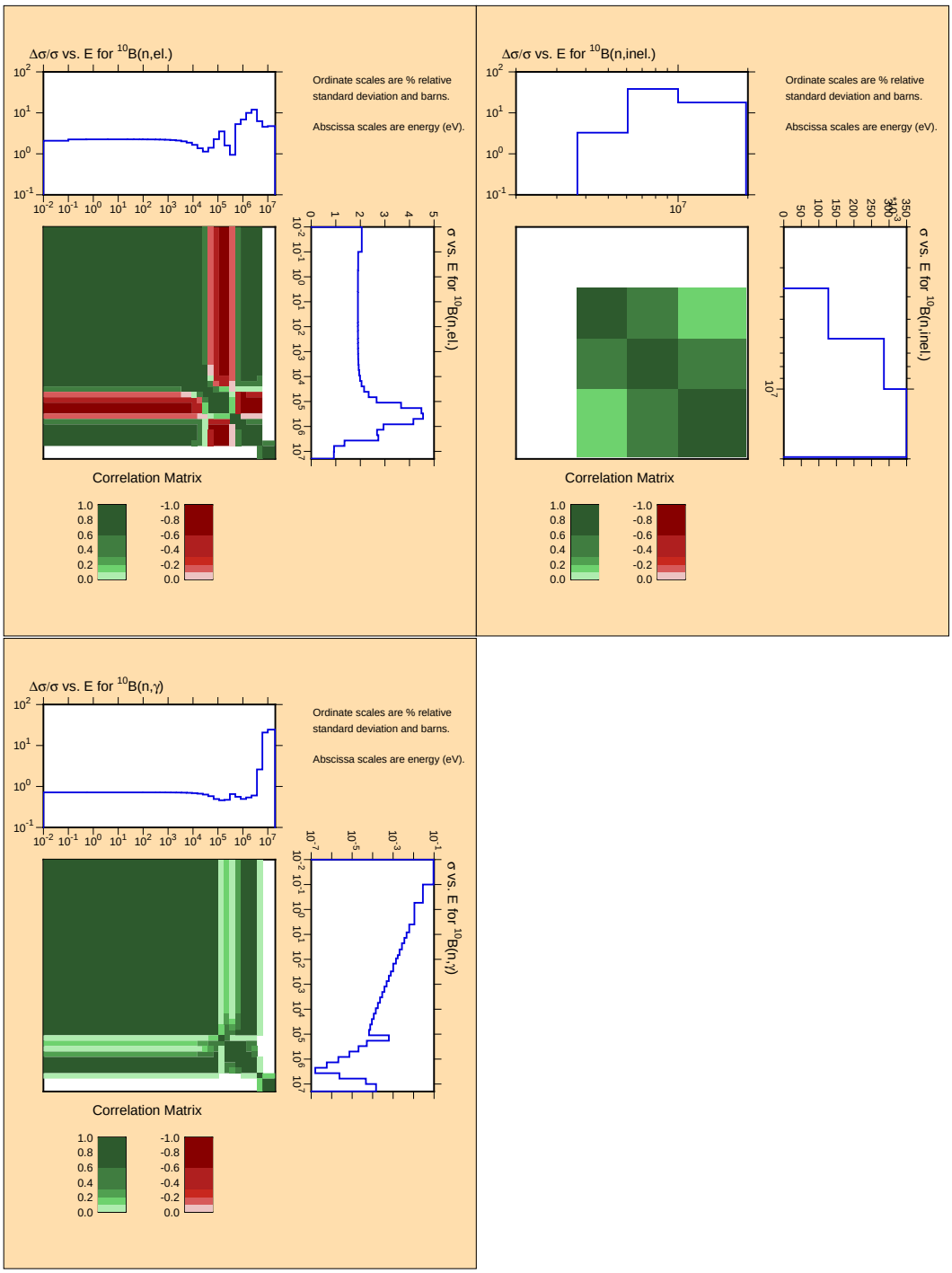

Fig. 25. Cross sections and cross section uncertainties for ^{10}B.

References

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