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Neutron Physics Calculation of Fast Reactors with Thick Stainless Steel Reflectors

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In the framework of the PSI/CEA cooperation on physics of plutonium recycling and the JEF project, calculations were performed for fast reactors with thick stainless steel reflectors.

The PSI code system has been used.

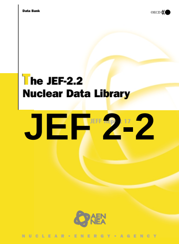
1. The required basic nuclear data systematically was generated with NJOY (Version 89.62, including a modification in RECONR to the p-wave capture in structural materials suggested by Rowlands and Eaton) and the JEF-2.2 evaluation.

   For important nuclides such as ^{56}Fe, ^{52}Cr, ^{58}Ni, ^{60}Ni, ^{23}Na, ^{235}U, ^{238}U, and ^{239}Pu, additional evaluations such as ENDF/B-VI (Rev. 2), JENDL-3.1, and BROND were considered.

2. The coupling and reformatting code MICROR was used to produce suitable pointwise and fine group data for the cell calculations (24362 points in the resonance range between 8 keV and 2eV, equally spaced in velocity, and 92 fast and epithermal groups).

3. These were performed with the spectrum cell code MICROX-2 and led to the generation of regionwise coarse group data. The standard coarse energy structure (33 groups) includes 30 fast and epithermal groups below 15 MeV, mostly equally spaced in lethargy (lethargy width is 0.5).

4. Core calculations were carried out with the diffusion- /transport-theory burnup code 2DTB, using the same meshes as suggested in the original CEA report, unless otherwise specified.



	k_{eff}	k_{eff}-Variation	^{56}Fe Evaluation	C8/F5 (E-C)/C	F8/F5 (E-C)/C	F9/F5 (E-C)/C
Exp. Error				± 0.0195	± 0.0162	± 0.0114
	1.03478	+1.71	JENDL-3.1	+0.0157	+0.0023	+0.0221
	1.01675	0	JEF-2.2	+0.0222	-0.0180	+0.0171
	1.01418	-0.19	ENDF/B-VI (Rev. 2)	+0.0231	-0.0229	+0.0158
	1.00793	-0.86	BROND	+0.0249	-0.0281	+0.0154
	1.00345	-1.30	JEF-2.1	+0.0255	-0.0309	+0.0143

Table 1: Multiplication Factor k_{eff} and Ratios of Calculated to Experimental Reaction Rate Ratios at Core Centre ((E-C)/C); Effect of the Use of Different Evaluations of ^{56}**Fe** Data Expressed for the Multiplication Factor in % of Δ k/(kk′)

Reference Calculation: k=1.01675, Obtained Using P_2S_8 Approximation, 33 Coarse Groups, and the Standard Meshing. C8= ^{238}U Captures, F8= ^{238}U Fissions, F9= ^{239}Pu Fissions, F5= ^{235}U Fissions.

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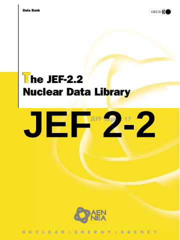


	k_{eff}	k_{eff}-Variation	Nuclide	Evaluation	C8/F5 (E-C)/C	F8/F5 (E-C)/C	F9/F5 (E-C)/C
Exp. Error					± 0.0195	± 0.0162	± 0.0114
	1.01675	0	All	JEF-2.2	+0.0222	-0.0180	+0.0171
	1.01480	-0.25	^{23}Na	ENDF/B-VI (Rev. 2)	+0.0218	-0.0247	+0.0154
	1.01675	-0.00	^{23}Na	JENDL-3.1	+0.0223	-0.0180	+0.0171
	1.01595	-0.08	^{23}Na	BROND	+0.0220	-0.0180	+0.0171
	1.01686	+0.01	^{52}Cr	ENDF/B-VI (Rev. 2)	+0.0210	-0.0147	+0.0183
	1.01663	-0.01	^{58}Ni ^{60}Ni	ENDF/B-VI (Rev. 2)	+0.0223	-0.0180	+0.0171
	1.01600	-0.07	^{235}U	ENDF/B-VI (Rev. 2)	+0.0223	-0.0186	+0.0170
	1.01583	-0.09	^{239}Pu	ENDF/B-VI (Rev. 2)	+0.0184	-0.0074	+0.0356
	1.01890	+0.21	^{238}U	ENDF/B-VI (Rev. 2)	+0.0312	-0.0416	+0.0081

Table 2: Multiplication Factor k_{eff} and Ratios of Calculated to Experimental Reaction Rate Ratios at Core Centre ((E-C)/C); Effect of the Use of Other Evaluations for Single Nuclides, Expressed for the Multiplication Factor in % of Δ k/(kk′)

Reference Calculation: k=1.01675, Obtained Using P_2S_8 Approximation, 33 Coarse Groups, and the Standard Meshing. C8= ^{238}U Captures, F8= ^{238}U Fissions, F9= ^{239}Pu Fissions, F5= ^{235}U Fissions.

	k_{eff}	k_{eff}-Variation	^{56}Fe Evaluation	C8/F5 (E-C)/C	F8/F5 (E-C)/C	F9/F5 (E-C)/C
Exp. Error				± 0.0195	± 0.0162	± 0.0114
	1.02379	+1.27	JENDL-3.1	+0.0207	-0.0113	+0.0184
	1.01068	0.	JEF-2.2	+0.0236	-0.0237	+0.0158
	1.00908	-0.16	ENDF/B-VI (Rev. 2)	+0.0241	-0.0254	+0.0154
	1.00719	-0.34	BROND-2.1	+0.0245	-0.0272	+0.0151

Table 3: Multiplication Factor k_{eff} and Ratios of Calculated to Experimental Reaction Rate Ratios at Core Centre ((E-C)/C); Effect of the Use of Different Evaluations of ^{56}**Fe** Data in the **Radial Reflector,** Expressed for the Multiplication Factor, in % of Δ k/(kk′)

	k_{eff}	k_{eff}-Variation	^{56}Fe Evaluation	C8/F5 (E-C)/C	F8/F5 (E-C)/C	F9/F5 (E-C)/C
Exp. Error				± 0.0195	± 0.0162	± 0.0114
	1.01327	+0.25	JENDL-3.1	+0.0230	-0.0211	+0.0164
	1.01068	0.	JEF-2.2	+0.0236	-0.0237	+0.0158
	1.01022	-0.05	ENDF/B-VI (Rev. 2)	+0.0238	-0.0242	+0.0157
	1.00949	-0.12	BROND-2.1	+0.0240	-0.0250	+0.0155

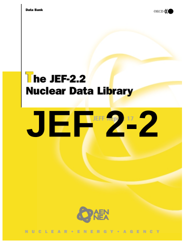
Table 4: Multiplication Factor k_{eff} and Ratios of Calculated to Experimental Reaction Rate Ratios at Core Centre ((E-C)/C); Effect of the Use of Different Evaluations of ^{56}**Fe** Data in the **Axial Reflector, Including Blankets,** Expressed for the Multiplication Factor, in % of Δ k/(kk′)

	k_{eff}	k_{eff}-Variation	^{56}Fe Evaluation	C8/F5 (E-C)/C	F8/F5 (E-C)/C	F9/F5 (E-C)/C
Exp. Error				± 0.0195	± 0.0162	± 0.0114
	1.01697	+0.61	JENDL-3.1	+0.0194	-0.0141	+0.0191
	1.01068	0.	JEF-2.2	+0.0236	-0.0237	+0.0158
	1.00995	-0.07	ENDF/B-VI (Rev. 2)	+0.0238	-0.0262	+0.0156
	1.00843	-0.22	BROND-2.1	+0.0245	-0.0272	+0.0156

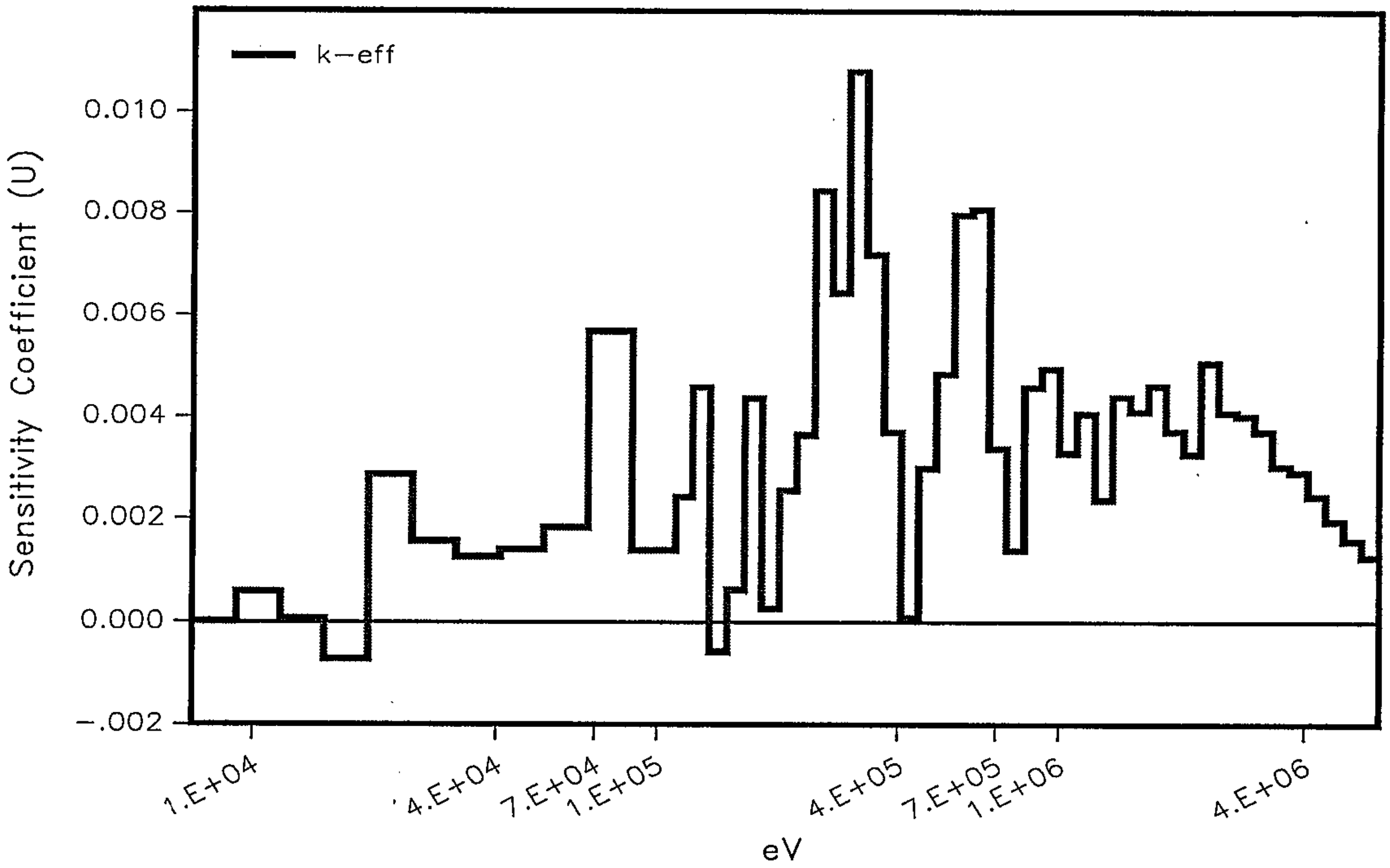
Table 5: Multiplication Factor k_{eff} and Ratios of Calculated to Experimental Reaction Rate Ratios at Core Centre ((E-C)/C); Effect of the Use of Different Evaluations of ^{56}Fe Data in the **Core**, Expressed for the Multiplication Factor, in % of Δ k/(kk′)

	k_{eff}	k_{eff}-Variation	^{56}Fe Evaluation	C8/F5 (E-C)/C	F8/F5 (E-C)/C	F9/F5 (E-C)/C
Exp. Error				± 0.0195	± 0.0162	± 0.0114
	1.01112	+0.04	JENDL-3.1	+0.0235	-0.0233	+0.0159
	1.01068	0.	JEF-2.2	+0.0236	-0.0237	+0.0158
	1.01057	-0.01	ENDF/B-VI (Rev. 2)	+0.0236	-0.0238	+0.0158
	1.01049	-0.02	BROND-2.1	+0.0236	-0.0238	+0.0158

Table 6: Multiplication Factor k_{eff} and Ratios of Calculated to Experimental Reaction Rate Ratios at Core Centre ((E-C)/C); Effect of the Use of Different Evaluations of ^{56}Fe Data in the **Shield**, Expressed for the Multiplication Factor, in % of Δ k/(kk′)



Influence of the Reflector Fe56 Elastic Cross Section



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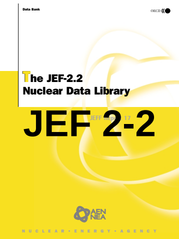

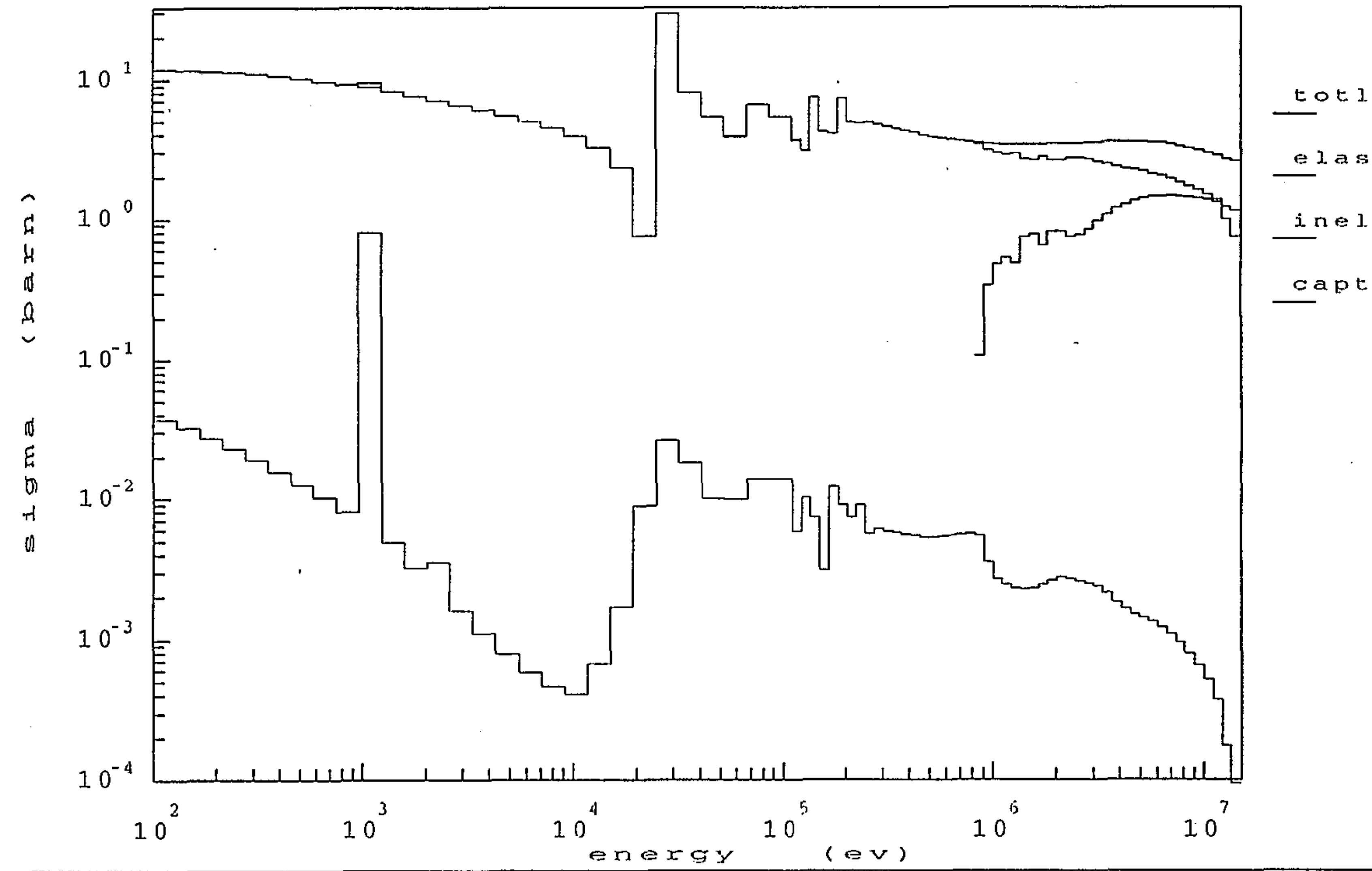

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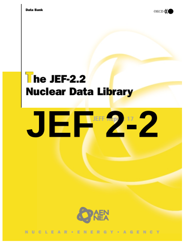

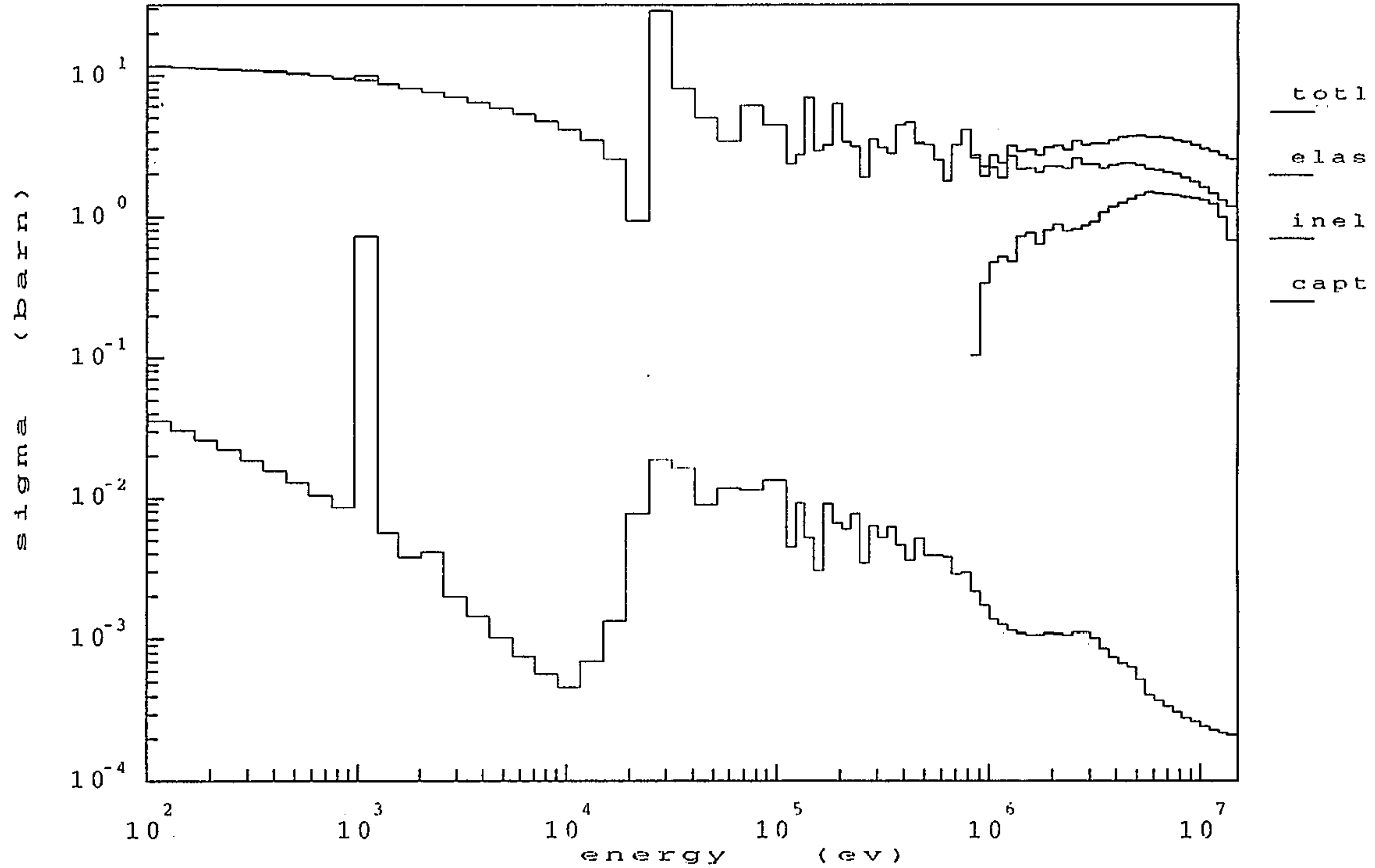

Paul Scherrer Institut PSI LWR-Physik	Cross Sections of Fe-56 (JEF2.2)	NJOY 7. 9.94

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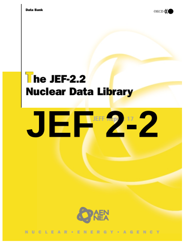
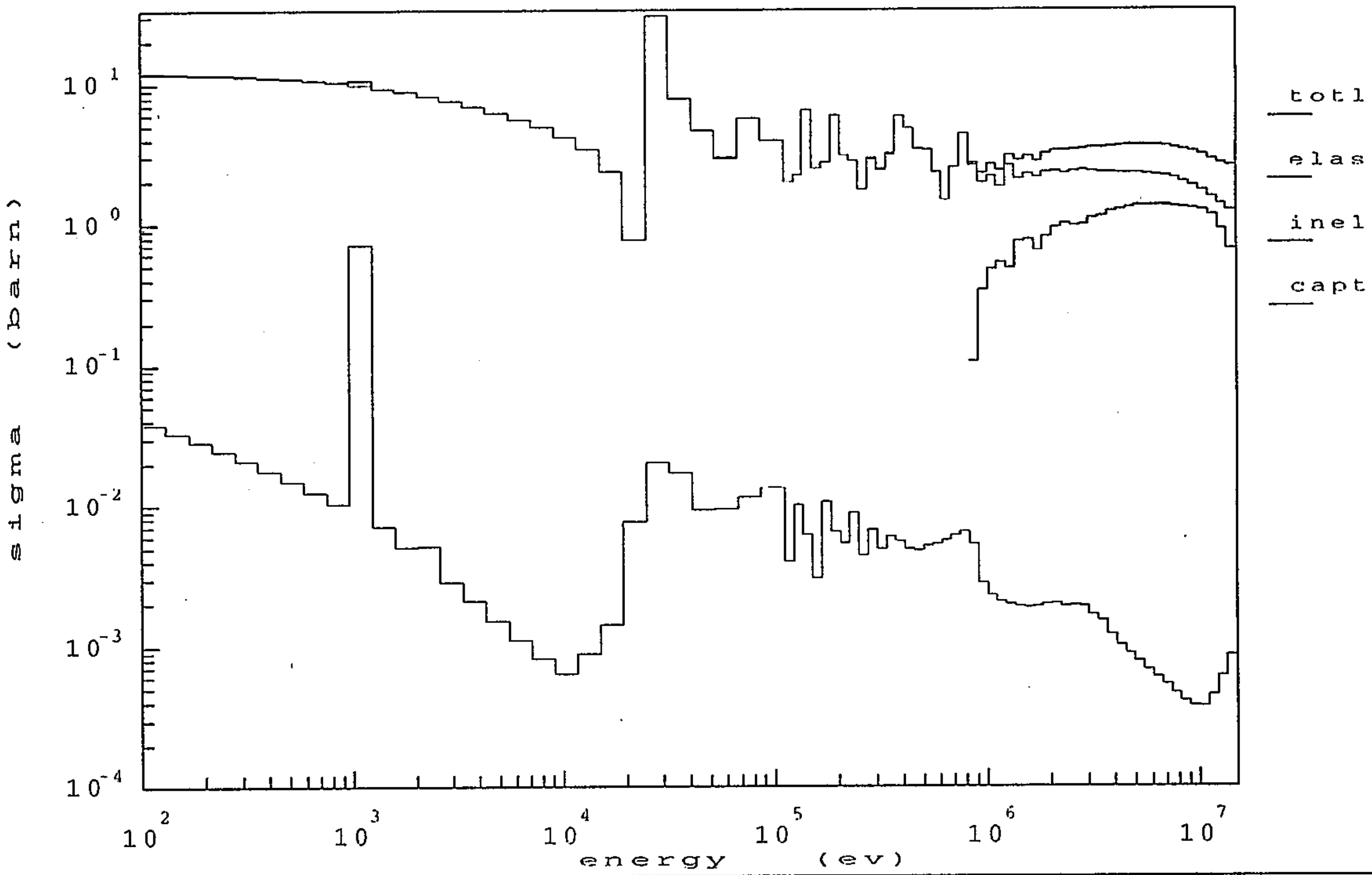




Paul Scherrer Institut PSI LWR-Physik	Cross Section of Fe-56 (BROND)	NJOY 7. 9.94

Main Points

- Large uncertainties primarily in the **elastic scattering** cross sections of ^{56}Fe above 10 keV (see Figures) cause various spectral effects, leeding to k_{eff} differences primarily due to modified core-blanket/reflector interactions.

- The larger is the ^{56}Fe elastic scattering cross section, the larger are the computed neutron flux in the core and power density, and the smaller the computed reflector and blanket fluxes: More neutrons leak from the blankets and reflector into the core, resulting in a smaller leakage from the core (see Figure).

  From high to low are the ^{56}Fe elastic scattering cross sections from JENDL-3.1, JEF-2.2, ENDF/B-VI (Rev. 2), BROND, and JEF-2.1 (see Figures).

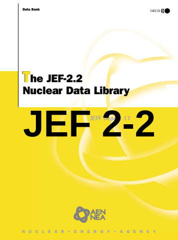
- The larger is the Fe elastic cross section, the smaller is the computed ratio F8/F5 (F5 increases, F8, a threshold reaction at about 400 keV, is less sensitive to the elastic scattering cross section of Fe above 10 keV).

- The larger is the Fe elastic cross section, the smaller is the computed ratio F9/F5 (the ^{235}U fission cross section is larger than the ^{239}Pu fission cross section between 10 and 100 keV).

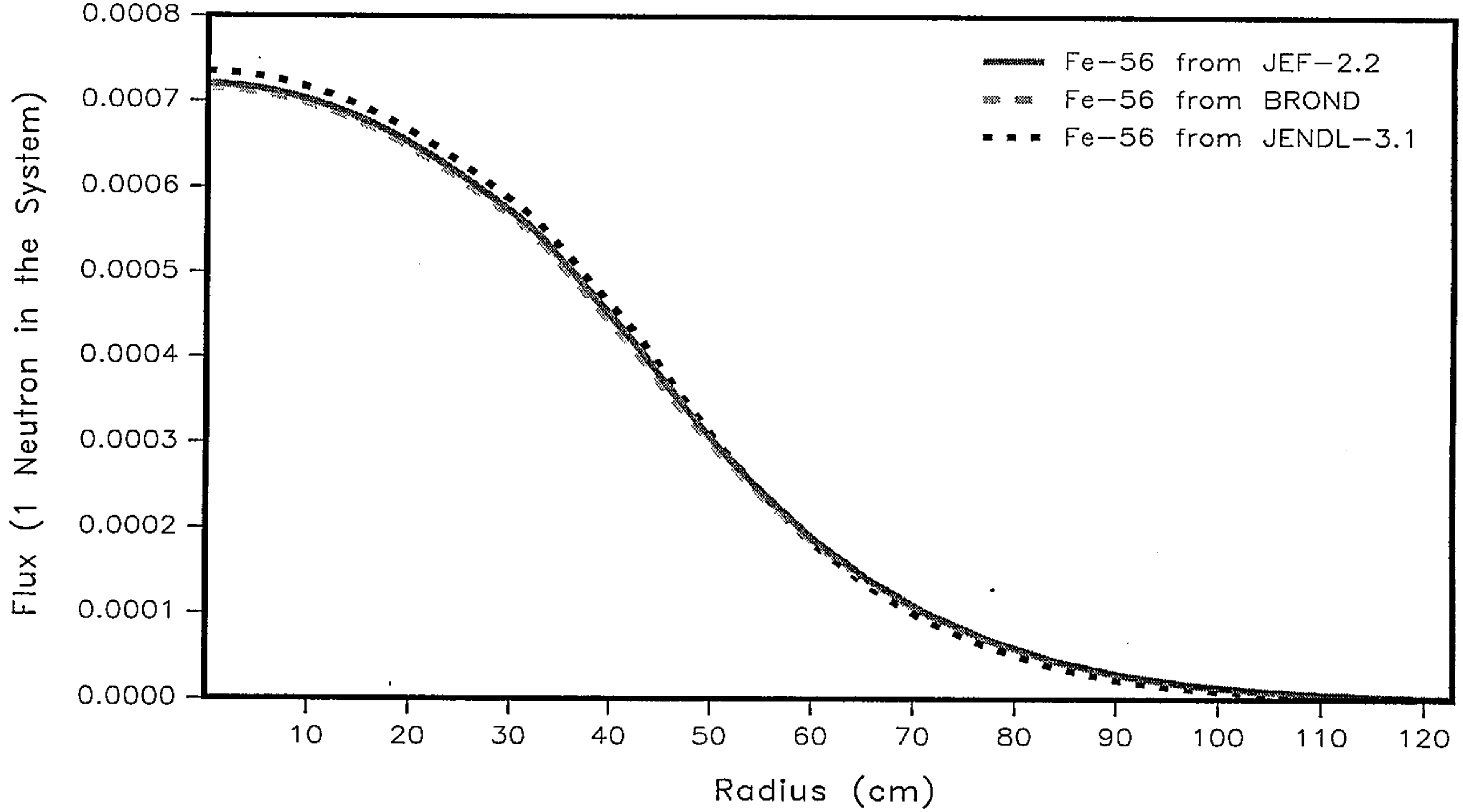
- The larger is the Fe elastic cross section, the larger is the computed ratio C8/F5 (C8, in the energy range of interest, is more sensitive to the elastic scattering cross section of Fe than F5 does).

- Therefore: The larger the Fe elastic cross section, the larger the computed k_{eff}, even though C8/F5 becomes larger !!

- The use of the BROND evaluation of ^{56}Fe gives globally the best agreement with experiment (although there are "still" various compensating effects among the different reaction rates).



Central Flux Traverses in PECORE



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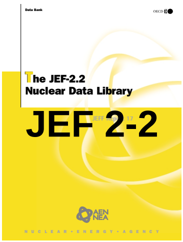
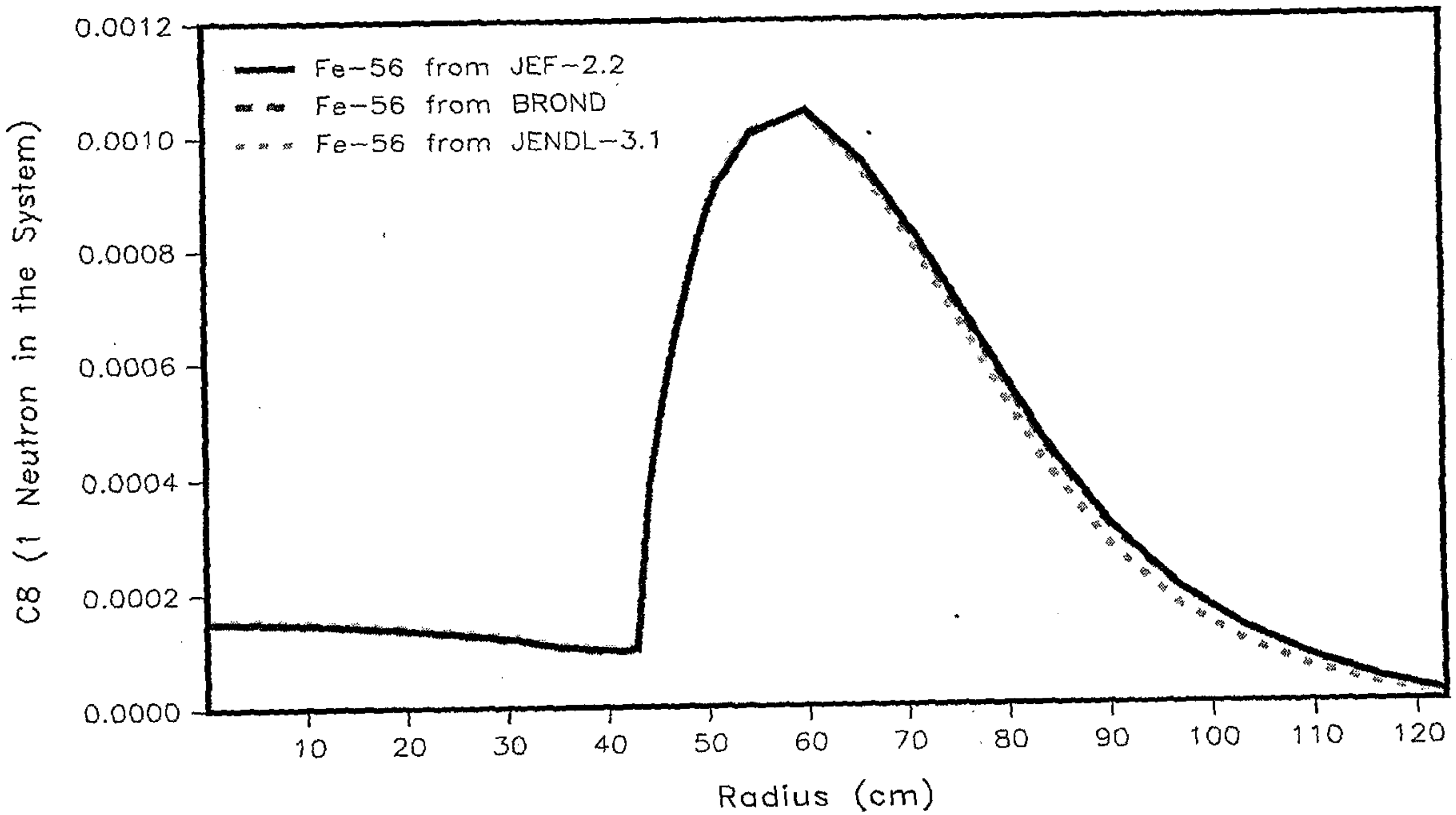


Central C8 Traverses in PECORE



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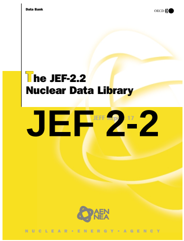
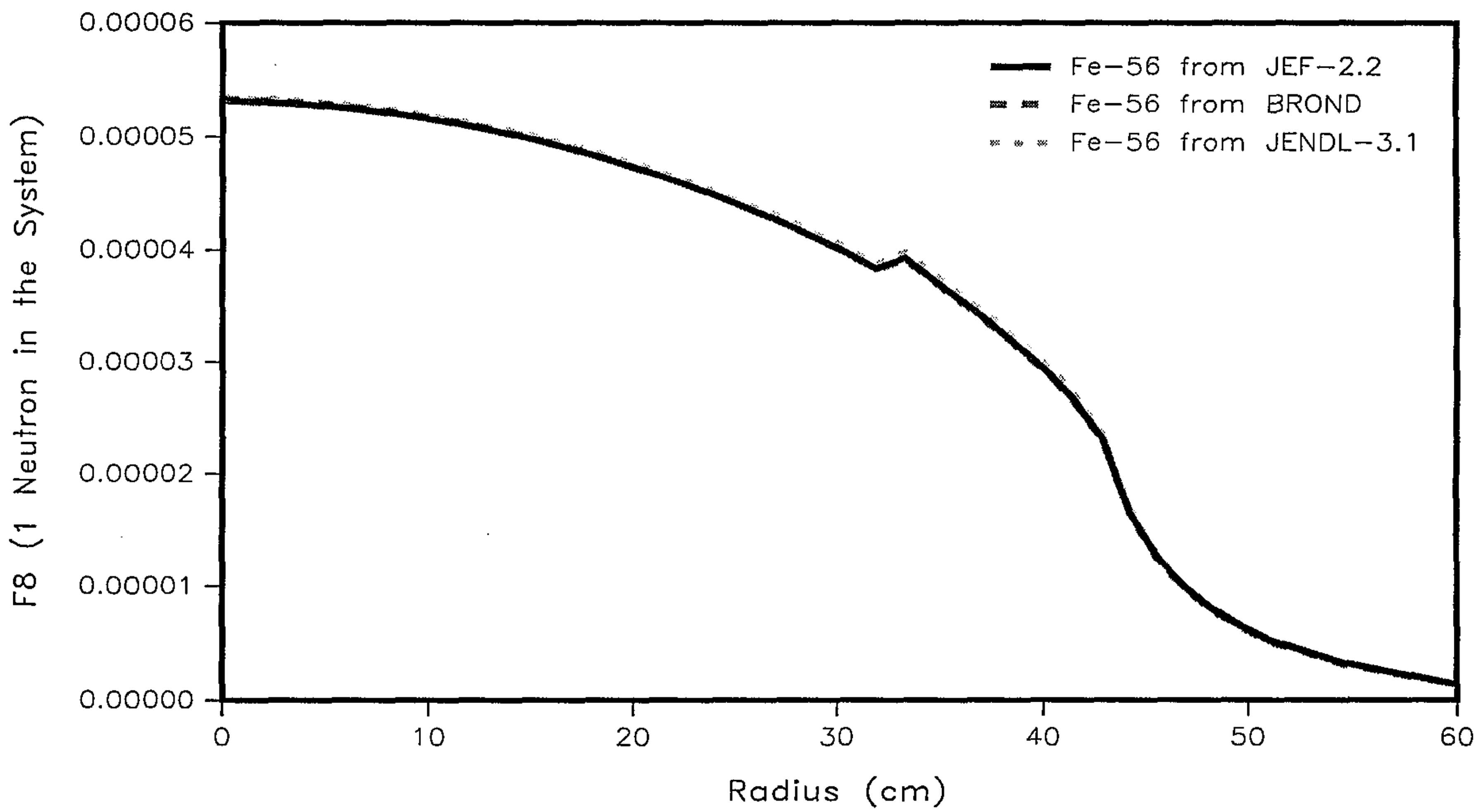


Central F8 Traverses in PECORE



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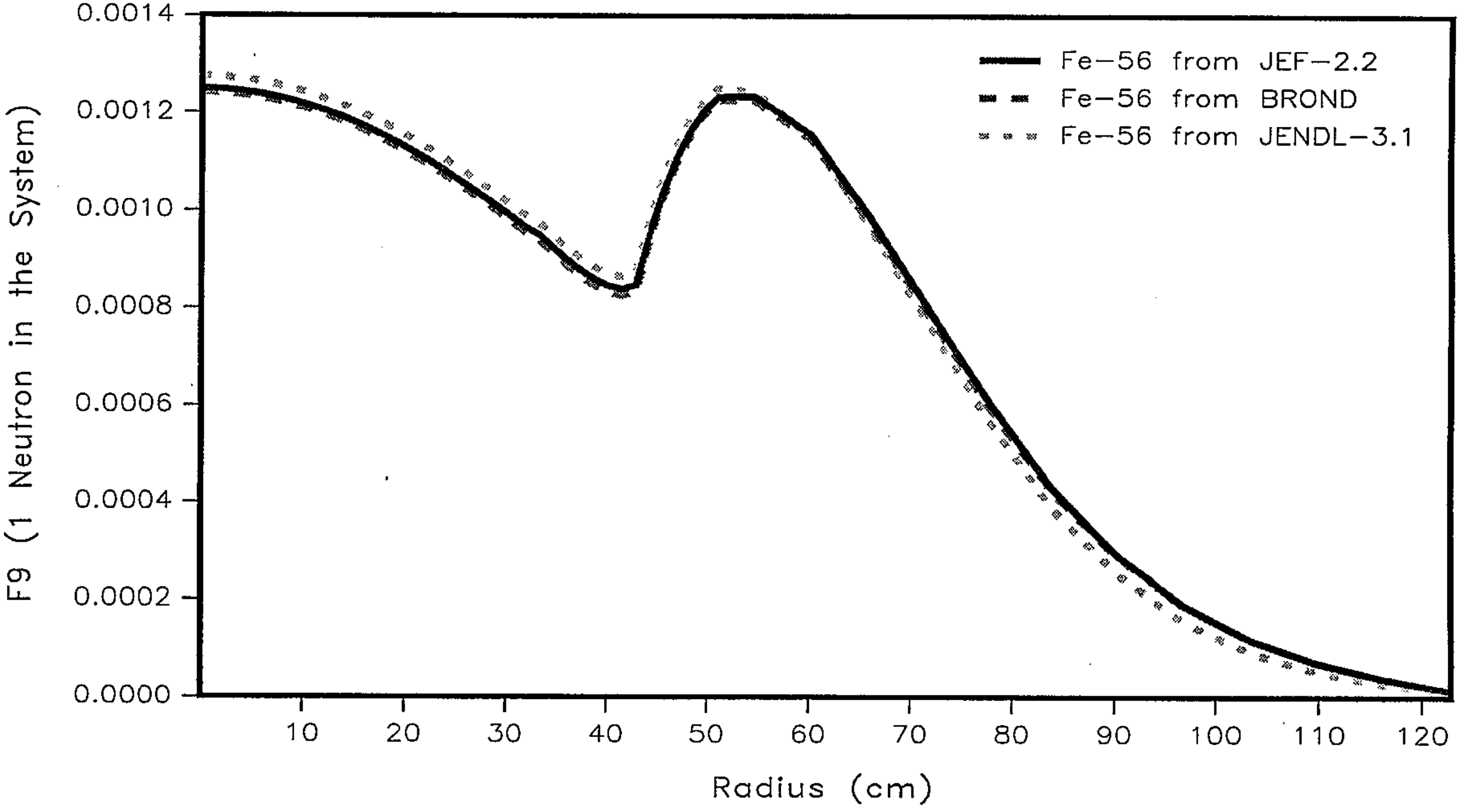
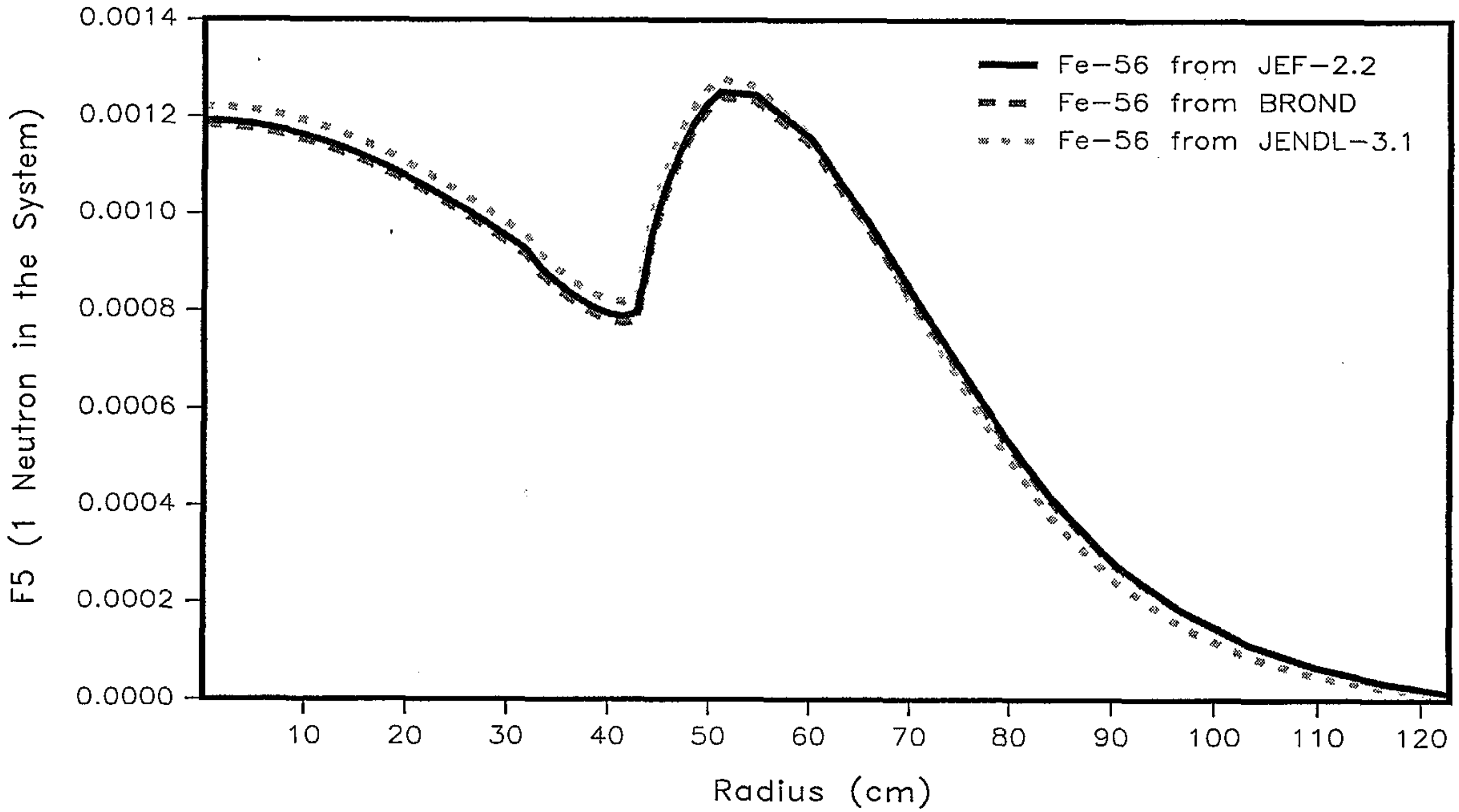
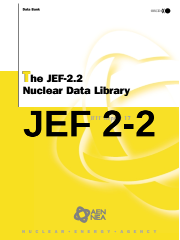
Central F9 Traverses in PECORE



Central F5 Traverses in PECORE





Central Radial Power Distributions in PECORE