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REEVALUATION OF DECAY ENERGIES OF FISSION PRODUCT NUCLIDES IN JNDC FP DECAY DATA FILE

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Jun-ichi KATAKURA and Ryuzo NAKASIMA*

日 本 原 子 力 研 究 所
Japan Atomic Energy Research Institute

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Reevaluation of Decay Energies of Fission Product Nuclides in JNDC FP Decay Data File

Jun-ichi KATAKURA and Ryuzo NAKASIMA*

Japanese Nuclear Data Committee
Tokai Research Establishment
Japan Atomic Energy Research Establishment
Tokai-mura, Naka-gun, Ibaraki-ken

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The decay data of all experimentally identified fission product nuclides included in the JNDC FP Decay Data File are reviewed in detail, since the missing of beta-transition to unobserved highly excited states in the daughter nucleus is considered to be probable in some cases even for nuclides with small Q_β. Thus the decay energies of 127 nuclides or metastable states except for ^{88}Rb and ^{143}La revised previously are reevaluated. The results of summation calculations based on the revised JNDC FP Decay Data File modified by the present evaluation are in much better agreement with experimentally measured decay power curves than previous ones. Especially, the discrepancy remained for cooling times from a few hundreds to about 1500 seconds is removed. And the agreement is kept within about 5 % for wide range of cooling times.

Keywords: Evaluation. Decay Data, Decay Heat, Fission Product,
Summation Calculation, Average Beta Energy, Average Gamma Energy

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* Department of physics, Hosei University

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ＪＮＤＣ核分裂生成物崩壊データファイルにおける崩壊データの再評価

日本原子力研究所東海研究所シグマ研究委員会
片倉　純一・中嶋　龍三*

（１９８６年1月３１日受理）

崩壊熱評価のためにシグマ委員会で作成したＪＮＤＣ FP Decay Data File に含まれる全ての実験的に同定されている核分裂生成物の崩壊データを詳細に検討した。全部で，異性体も含む１２６核種について再評価を行った。この結果，今回の評価に基づく崩壊熱総和計算は，以前のファイルと比べ，測定値との一致がより改善された。特に，これまで，問題となっていた数百秒の冷却期間における不一致が改善され，冷却期間の広い範囲において，約５％以内の一致が得られるようになった。

東海研究所：茨城県那珂郡東海村白方字白根２の４
＊　法政大学

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1. Introduction

The decay heat estimation of fission product nuclides is very important for the safety analyses of nuclear power plants and of nuclear fuel cycle. A lot of studies in this area have been performed experimentally and theoretically to predict the decay heat accurately. The decay heat estimation by summation calculation requires the fully evaluated decay energies of fission product nuclides.

The working group on evaluation of decay heat in Japanese Nuclear Data Committee has performed the evaluation of the decay energies of fission product nuclides and has released the first version of JNDC FP Decay Data File$^{1)}$ (hereafter referred as JNDC File) in 1981, in which the average decay energies (beta- and gamma-energies) of short-lived fission product nuclies with Q_β > 5 MeV were calculated by means of gross theory of beta decay. Although the JNDC File has been successfully applied to summation calculations of decay heat, slight discrepancies with experimental decay power curves were seen for all fissioning nuclides, namely, the calculated results underestimate, for example, the gamma component of decay power for cooling times from a few hundreds to about 1500 seconds and overestimate it a little bit at longer cooling times than about 2000 seconds.

The latter discrepancy has been diminished considerably by reexamining the decay schemes of about 10 nuclides with $T_{1/2}$ > 100 seconds in 1983$^{2)}$. In this reexamination study, it has been pointed out that uncritical replacement of experimental average decay energies by the calculated ones is risky even though the Q_β-value is large, say larger than 5 MeV. The case of ^{88}Rb (Q_β = 5.309 MeV) was just the typical one. The calculated decay energies of the nuclide were adopted in the JNDC File because of it's large Q_β-value. However, the experimental decay scheme is considered to be fairly well, that is, the ratio of energy of the highest level fed by beta decay to Q_β-value is 0.914 and many excited levels in ^{88}Sr are populated in ^{88}Rb decay. So, the experimental decay energies were adopted instead of the calculated ones in this case. Actually, the apparent improvement for longer cooling times than about 2000 seconds has been achieved by replacing the originally adopted calculated decay energies of ^{88}Rb by the experimental ones. However, the discrepancy for cooling times from a few hundreds to about 1500 seconds still remains. The modifed JNDC File, in which the data of ^{88}Rb and ^{143}La were updated, will be refered as JNDC File 1.5 if necessary.

In the present paper, we reevaluate the decay energies in order to remove the discrepancy by reexamining the decay schemes of all experimentally identified fission product nuclides or metastable states included in the JNDC File. It is our standpoint here that the calculated decay energies should be adopted irrespective of the Q_β-value if experimental decay scheme is considered to be insufficient. The procedure of reexamination which is almost same as the previous one$^{2)}$, is described in Chapter 2 where reevaluated 127 nuclides or metastable states are divided into 4 groups, and the evaluated beta- and gamma-energies are listed for each group together with those of the JNDC File 1.5. In Chapter 3, the results of summation calculations based on the present evaluation are compared with experimental and the previously calculated decay power curves.

2. Examination of decay schemes

It was an essential point in our previous evaluation of decay energies[1)] that the non-negligible amount of beta intensities to unobserved highly excited levels in the daughter nucleus must be missed in most of the experimentally determined decay schemes of short-lived nuclides with large Q_β, and that it is reasonable to adopt the calculated decay energies instead of the experimental ones for nuclides with $Q_\beta > 5$ MeV. This decision of $Q_\beta > 5$ MeV, however, is rather quite arbitrary. In the present evaluation, we expect that such missing of beta branches to highly excited levels in the daughter nucleus must be probable not only for the nuclides with large Q_β but also for some of the nuclides with small Q_β, and that good experimental decay schemes may be obtained even for the nuclides with large Q_β. Thus the decay schemes of experimentally identified fission product nuclides or metastable states were reviewed again on the basis of the data taken from ENSDF (Evaluated Nuclear Structure Data File) or Nuclear Data Sheets, Table of Isotopes 7th edition and recent literatures.

In examining the decay schemes constructed using the experimental information, we suspect that the ratio of the energy of the highest level fed by beta decay (E_L) to the Q_β, i.e., E_L/Q_β and the number of levels in the daughter nucleus populated in beta decay (N_L) may provide a measure for the degree of the missed beta branches to highly excited states. The decay scheme with larger E_L/Q_β and N_L is more preferable, but it is a matter of course that the values of log•ft and the trend of level density in the daughter nucleus should also be taken into account.

The decay energies examined by this manner are divided into 4 groups and are discussed comparing with those of the JNDC File in the following.

2.1. Updating and partial modification of decay energies

By scanning the recent literatures and by reviewing the already accepted experimental decay schemes, the average beta- and gamma-energies (E_β and E_γ) of 24 nuclides or metastable states are updated or partially modified, and are listed in Table 1 together with related informations. Most of the updated data are taken from new experimental decay schemes and the other are due to the modification of Q_β-value which yields the change in the average beta energy.

2.2. Replacement of calculated decay energies by the experimental ones

The experimental decay energies of 13 nuclides or metastable states accepted in the present work are listed in Table 2 together with the calculated decay energies adopted in the JNDC File. The decay schemes of previously unidentified nuclides, ^{71}Cu and ^{165}Tb, and of 2 nuclides previously identified without decay schemes, ^{78}Zn and ^{78}Ga, have been reported after the JNDC File was released. Although these decay schemes are considered to be not so good from the values of E_L/Q_β and N_L, we accept these decay schemes rather tentatively since these nuclides do not contribute so much to decay power and the experimental gamma decay energies are larger than the calculated ones which is an opposite trend to the assumption of missing gamma rays.

The decay schemes of other 9 nuclides or metastable states in Table 2 were available already for the JNDC File but not accepted because of $Q_\beta > 5$ MeV. The decay schemes of these nuclides are considered to be fairly sufficient since the values of E_L/Q_β and N_L are relatively large. In the case of, for example ^{138}Cs, the E_L/Q_β is 0.867 and the N_L is 33, and furthermore the directly measured E_β is 1.22 MeV$^{3)}$ that seems to encourage the use of the experimental decay schemes from which E_β is derived to be

1.2474 MeV.

2.3. Replacement of experimental decay energies by the calculated ones

As the results of the present review of the decay schemes, the experimental decay energies for 46 nuclides or metastable states listed in Table 3 are replaced by the calculated ones, in which 39 nuclides or metastable states have smaller Q_β than 5 MeV. The use of experimental decay schemes for the other 7 nuclides or metastable states with $Q_\beta > 5$ MeV was rather careless mistake in the JNDC File.

In Table 3, Q_{00} is a parameter in the calculation by means of gross theory, and is interpreted as the lowest excitation energy of level in the daughter nucleus to which main beta transition is expected. However, it may be regarded as mean excitation energy when main beta transitions occur to several nearby levels with comparable intensities.

One example is the case of ^{98}Zr (Q_β = 2.239 MeV) for which the experimental information of "no gamma rays observed" was accepted previously. However, if the intensity of beta to the ground state of ^{98}Nb was 100%, the log•ft is 4.1 which seems to be rather small compared to other allowed beta transitions in this mass number region. Furthermore, more than 10 excited levels of ^{98}Nb with unassigned spins and parities have been reported up to 2 MeV in reaction experiments. Thus we adopt the calculated decay energies instead of the experimental ones assuming the possible very weak betas to some excited states in ^{98}Nb.

Let us describe about one more case of ^{102}Tc (Q_β = 4.50 MeV) among many other examples. The experimental decay scheme of this nuclide accepted in the JNDC File seems to be rather insufficient since the value of E_L/Q_β is 0.408 and of N_L is 6, though reaction experiments have reported many levels up to about 3.5 MeV in ^{102}Ru which are considered to be fed by allowed beta transitions. The intensity of beta transition to the ground state of ^{102}Ru is largely scattered among the different experiments or evaluations. By examining various posibilities, the values of log•ft and the trend of level density, we adopt the calculated decay energies assuming many beta branches to highly excited states of ^{102}Ru which were not observed in beta decay but in reaction experiments.

2.4. Recalculation of decay energies

The decay energies of 44 nuclides or metastable states for which the calculated decay energies instead of the experimental ones have been adopted in the JNDC File, are recalculated by examining the available decay schemes, and are tabulated in Table 4. It is found that the experimental decay schemes of some of these nuclides or metastable states are considered to be fairly good from the values of E_L/Q_β and N_L. For the present calculations, the experimental decay schemes of such cases are suggestive to determine a parameter Q_{00} of the gross theory, together with the value of directly measured E_β 3) if available.

For example, according to the experimental decay scheme of ^{95}Sr (E_L/Q_β = 0.701, N_L = 20) which was available for the JNDC File but not accepted because of $Q_\beta > 5$ MeV, main beta transitions occur to the excited states at 0.8269 and 0.6859 MeV and possibly to the ground state of ^{95}Y. In the calculation of the JNDC File, however, strong beta transitions to the excited states at around 1.5 MeV were assumed which yields rather small E_β and large E_γ. In the present study, we assume main beta transitions to lower excited levels than in the previous calculation. Thus calculated E_β is in better agreement directly measured value of 1.92 MeV 3) than the previous one.

3. Results of summation calculations

By using the present evaluated decay energies, summation calculations of the decay power are performed with DCHAIN code$^{4)}$. The results of the summation calculations are compared with measured decay powers for burst fission of ^{235}U and ^{239}Pu by fast neutrons$^{5)}$ in Figs. 1 to 6. The ratios of the calculated values to the measured ones are shown in Figs. 7 to 12. In these figures, the calculated curves based on the original JNDC File and the JNDC File 1.5 are also shown for comparison. It is clear that the use of decay energies evaluated in the present study improves largely the agreement with the measured decay powers for wide range of cooling times for both fissioning nuclides. Especially, the gamma component of ^{239}Pu fission is improved about 10% at maximum and it's C/E ratio is kept within about 5% for every cooling times as seen Fig. 11. Although such marked improvement is achieved by the cumulative effect of the reevaluated decay energies of the present examined nuclides, it is found that in the calculation process that those of ^{102}Tc, in particular, play an important role in the present improvement. The contributions of the present examined nuclides to the decay power at 550.0 seconds after ^{239}Pu fission are shown in Table 5. At this cooling time, the discrepancy between the calculation and the measurement is most prominent for the gamma component in the previous calculations. The effect of the present evaluation for ^{102}Tc nuclide is largest in the examined nuclides. The contribution of the beta component decreases from 8.7% to 6.1% and that of the gamma component increases from 3.2% to 8.5%. The half-life of ^{102}Tc is 5.28 seconds, but that of the parent nuclide ^{102}Mo is 672.0 seconds. So, ^{102}Tc contributes to the decay power at a few hundreds seconds after a fission burst. The experimental decay scheme of this nuclide is considered to be insufficient as mentioned in Chapter II. We adopted the calculated decay energies instead of the experimental ones. The present gamma decay energy of 1.7749 MeV is about three times larger than the previously adopted value of 0.5793 MeV.

4. Conclusion

By revieweing the decay schemes of all experimentally identified nuclides or metastable states in the JNDC File, it is found that some average energies of these nuclides adopted in the JNDC File should be revised. It is clear that the adoption of the experimental or the calculated decay energies relys on the accuracy of the experimental decay scheme. Our previous criterion of the adoption of the calculated decay energies was based on the Q_β-value, that is, for the nuclides with $Q_\beta > 5$ MeV the experimental decay schemes were considered to be insufficient. So the calculated decay energies was adopted. From the present study, however, it is found that the accuracy of the decay schemes dose not always depend on the Q_β-value. Therefore, we pay an attention to the values of E_L/Q_β and N_L as a measure of the accuracy. The decay schemes with larger values of E_L/Q_β and N_L are more preferable, but it is difficult to set a difinite lower limit to them. In the present study, the experimental decay schemes with larger E_L/Q_β than at least 0.7, $E_L/Q_\beta > 0.8$ is desirable, and with fairly larger N_L are considered to be accepted. The value of N_L is examined for case by case in the present study since it depends on Q_β and level density which varies accordingly to mass number and even-odd character of the daughter nucleus.

The results of summation calculation based on the present evaluation of decay energies improve considerably those based on the original JNDC File or the JNDC File 1.5 for wide range of coolong times and agree fairly instead of the experimental ones. The present gamma decay energy of 1.7749 MeV is about three times larger than the previously adopted value of 0.5793 MeV.

4. Conclusion

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The results of summation calculation based on the present evaluation of decay energies improve considerably those based on the original JNDC File or the JNDC File 1.5 for wide range of coolong times and agree fairly well with the experimental decay powers. Especially, the disagreement remained in the previous calculations are markedly improved. In this improvement, ^{102}Tc plays an important role. We think the experimental decay scheme of the nuclide is insufficient, so we adopt the calculated decay energies of which gamma energy is about three times larger than the experimental one.

Anyway, the present evaluation leads to a quite good prediction of the decay power for wide range of cooling times. The agreement between the calculated decay power and the experimental one is kept within about 5 % and within experimental errors.

Acknowledgment

The authors are grateful to the members of the Working Group on Evaluation of Decay Heat in Japanese Nuclear Data Committee for the continuous support and encouragement to the present work.

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Table 1 Updated experimental decay energies

					Present		JNDC 1.5	
A, Z	$T_{1/2}$(sec)	Q_β(MeV)	E_L/Q_β	N_L	E_β(MeV)	E_γ(MeV)	E_β(MeV)	E_γ(MeV)
^{67}Ni	17.0	3.835	0.806	5	1.1492	1.4341	1.0213	1.4314
^{69}Cu	180.0	2.477	0.818	8	0.9354	0.2234	1.0168	0.2234
^{73}Ga	1.7549+4	1.564	0.889	10	0.4334	0.3519	0.4869	0.2008
^{79}As	492.0	2.20	0.495	7	0.8514	0.0283	0.8478	0.0193
^{82m}Br	367.8	3.1386	0.846	11	0.0755	0.0028	0.0765	0.0022
^{94}Sr	76.7	3.422	0.868	9	0.8096	1.4330	0.7980	1.4229
^{98m}Nb	3078.0	4.669	0.873	48	0.7788	2.8201	0.7783	2.7872
^{113m}Ag	72.0	2.0532	0.582	7	0.1085	0.1149	0.0949	0.0577
^{118n}In	8.5	4.40	0.585	1	0.1140	0.0716	0.1078	0.0304
^{121m}Sn	1.7356+9	0.3929	0.095	1	0.1139	0.0031	0.0372	0.0007
^{133m}Te	3324.0	3.304	0.924	39	0.3694	1.7591	0.6419	2.3316
^{133}Te	747.0	2.970	0.865	33	1.0222	1.1939	0.8052	0.9517
^{133m}I*	9.0	3.3942	---	--	0.0709	1.5633	0.0708	1.5605
^{135}I	2.358+4	2.711	0.914	26	0.3723	1.5657	0.3666	1.6451
^{141}Ba	1096.2	3.028	0.815	26	0.8207	0.8440	0.9404	0.8168
^{142}Ba	642.0	2.198	0.700	12	0.4192	1.0689	0.4374	1.0077
^{145}Ce	180.6	2.50	0.498	7	0.6384	0.8692	0.6528	0.8246
^{146}Ce	811.2	1.080	0.466	5	0.2584	0.3080	0.2758	0.3059
^{146}Pr	1444.2	4.080	0.909	33	1.2185	1.1602	1.2073	1.1493
^{147}Ce	56.4	3.20	0.373	5	1.1421	0.4775	1.2566	0.2927
^{147}Pr	798.0	2.70	0.856	19	0.7881	0.8327	0.7880	0.7171
^{152m}Pm	450.0	3.47	0.779	18	0.8437	1.4663	0.9457	1.4663
^{152}Pm	252.0	3.47	0.681	24	1.3958	0.1501	1.4037	0.1145
^{154m}Pm	162.0	4.004	0.593	11	0.8992	1.9989	1.0173	1.7002

* Only isomric transition is observed

Table 2 Adopted experimental decay energies insted of calculated ones in the JNDC FILE

					Present		JNDC 1.5	
A, Z	$T_{1/2}$(sec)	Q_β(MeV)	E_L/Q_β	N_L	E_β(MeV)	E_γ(MeV)	E_β(MeV)	E_γ(MeV)
^{68m}Cu	225.0	5.3373	0.743	10	0.2072	1.0256	0.1970	0.9560
^{71}Cu	19.5	3.812	0.623	6	1.3588	0.7121	1.3730	0.6367
^{74}Ga	486.0	5.40	0.855	34	1.0586	3.1866	1.2880	2.4010
^{78}Zn	1.47	5.60	0.635	11	1.8237	1.5222	2.2580	1.0320
^{78}Ga	5.49	8.08	0.628	20	2.5433	2.5255	2.9010	2.1610
^{87}Br	55.7	6.50	0.848	137	1.5203	3.3371	1.8130	2.4100
^{90m}Rb	258.0	6.685	0.901	30	1.3877	3.3503	1.5440	2.6660
^{90}Rb	153.0	6.578	0.915	25	1.9916	2.1641	1.5710	2.7590
^{106}Tc	36.0	6.30	0.566	20	2.1040	2.2257	1.6970	2.9330
^{137}I	24.5	5.50	0.887	107	1.7981	1.1364	1.2720	2.4600
^{138}Cs	1932.0	5.50	0.867	33	1.2474	2.3314	1.0890	2.6800
^{144}La	40.6	5.50	0.599	29	1.4665	2.0966	1.3380	2.0910
^{165}Tb	126.6	2.649	0.685	9	0.7600	0.7311	0.7917	0.5966

Table 3 Calculated decay energies insted of experimental ones adopted in the JNDC File

			Present			JNDC 1.5			
A, Z	$T_{1/2}$(sec)	Q_β (MeV)	Q_{00}	E_β (MeV)	E_γ (MeV)	E_L/Q_β	N_L	E_β (MeV)	E_γ (MeV)
^{73}Zn	23.5	4.70	1.0	1.5436	1.1709	0.299	2	1.8772	0.4691
^{74}Zn	95.0	2.350	0.8	0.5777	0.8597	0.106	3	0.8985	0.1416
^{79}Ge	42.0	4.15	0.0	1.7316	0.2298	0.232	4	1.7443	0.2057
^{96}Y	6.0	7.015	0.2	2.6565	1.2056	0.227	2	3.4228	0.0
^{96m}Y	10.0	7.015	3.8	1.3270	3.9096	0.625	2	1.1236	4.0310
^{98}Zr	30.7	2.239	0.0	0.8367	0.1647	0.0	1	0.9075	0.0
^{98}Nb	2.86	4.585	0.0	1.9964	0.0991	0.569	8	2.0049	0.0797
^{99}Zr	2.1	4.460	1.0	1.4090	1.1841	0.228	3	1.4629	0.8227
^{99}Nb	15.0	3.624	0.5	1.2746	0.6217	0.649	1	1.5175	0.1676
^{100m}Y	0.55	9.342	0.0	3.2900	2.2530	0.036	2	4.2390	0.0060
^{100}Y	0.735	9.342	1.0	2.9420	2.9890	0.159	5	3.9286	0.6659
^{100}Zr	7.1	3.360	0.5	1.1141	0.6982	0.725	7	1.2770	0.3766
^{100m}Nb	3.1	6.229	1.5	1.6960	2.3614	0.408	5	1.7556	2.2065
^{100}Nb	1.5	6.229	1.0	1.9485	1.8464	0.283	4	2.2782	1.3486
^{102}Mo	672.0	1.04	0.0	0.3506	0.0473	0.346	3	0.3613	0.0185
^{102}Tc	5.28	4.50	1.5	1.1536	1.7749	0.408	6	1.9523	0.5793
^{102m}Tc	261.0	4.52	2.5	0.6487	2.8481	0.607	7	0.8552	2.4299
^{103}Tc	54.2	2.35	0.5	0.7040	0.5527	0.453	15	0.8489	0.2371
^{105}Tc	468.0	3.40	0.5	1.1692	0.6116	0.707	25	1.2442	0.4741
^{107}Ru	252.0	3.15	0.5	1.0561	0.5962	0.410	6	1.2116	0.2408
^{108m}Rh	360.0	4.50	2.5	0.6345	2.8541	0.629	4	0.7893	2.2721
^{108}Rh	16.8	4.50	1.0	1.3904	1.2493	0.234	4	1.8128	0.3378
^{109}Ru	34.5	4.093	0.8	1.3283	0.9712	0.111	2	1.5157	0.4181
^{109}Rh	80.0	2.496	0.3	0.8517	0.3743	0.527	8	0.8787	0.2995
^{113}Pd	90.0	3.241	0.5	1.0900	0.6102	0.0	1	1.4456	0.0
^{114}Pd	144.0	1.392	0.0	0.4825	0.0849	0.0	1	0.5198	0.0
^{115m}Ag	18.0	3.183	0.8	0.9330	0.8815	0.329	5	1.0773	0.5725
^{118}Cd	3018.0	0.743	0.0	0.2345	0.0299	0.0	1	0.2447	0.0
^{119m}In	1080.0	2.6483	0.0	0.9777	0.1297	0.472	7	1.0384	0.0217

Table 3 (Continued)

			Present			JNDC 1.5			
A, Z	$T_{1/2}$(sec)	Q_β(MeV)	Q_{00}	E_β(MeV)	E_γ(MeV)	E_L/Q_β	N_L	E_β(MeV)	E_γ(MeV)
^{119}In	126.0	2.337	0.8	0.5637	0.8375	0.337	2	0.6023	0.7669
^{120}Cd	57.8	1.720	0.0	0.6072	0.1275	0.0	1	0.6596	0.0
^{121}In	30.0	3.360	1.0	0.9233	1.0735	0.276	2	0.9852	0.9264
^{127m}Sn	247.8	3.105	0.8	0.8903	0.8865	0.504	3	1.0285	0.6316
^{130m}Sn	102.0	3.947	0.8	1.2086	1.0521	0.275	4	1.4742	0.8883
^{130}Sn	222.0	2.0	1.0	0.3376	1.0264	0.521	2	0.4109	0.9801
^{131}Sn	39.0	4.620	0.8	1.4644	1.1937	0.173	1	1.6379	0.7982
^{132m}Sb	252.0	5.60	2.5	1.1113	2.9074	0.585	5	1.3083	2.5726
^{140}Xe	13.6	4.06	1.3	1.0581	1.4675	0.573	25	1.2308	1.1491
^{143}Ba	14.5	4.3	0.5	1.4582	0.8568	0.546	17	1.7020	0.3329
^{148}Pr	138.0	4.897	1.3	1.1504	2.0940	0.611	11	1.6530	1.1648
^{149}Pr	138.0	3.0	0.5	0.9526	0.6161	0.191	12	1.1372	0.1798
^{153}Pm	324.0	1.797	0.1	0.6072	0.1722	0.563	11	0.6638	0.0521
^{157}Sm	480.0	2.60	0.3	0.8626	0.4016	0.325	5	0.9049	0.3072
^{159}Eu	1122.0	2.630	0.3	0.8729	0.4052	0.578	15	0.9759	0.2643
^{160}Eu	41.0	4.40	0.8	1.1696	1.5389	0.628	6	1.4565	0.7605
^{162}Gd	540.0	1.40	0.5	0.2862	0.5370	0.315	1	0.3377	0.4260

Table 4 Recalculated decay energies

				Present		JNDC 1.5	
A, Z	$T_{1/2}$(sec)	Q_β(MeV)	Q_{00}	E_β(MeV)	E_γ(MeV)	E_β(MeV)	E_γ(MeV)
^{70m}Cu	46.0	6.310	2.3	1.4492	2.9819	1.6500	2.1670
^{75}Zn	10.2	5.725	1.5	1.7331	1.8100	2.1430	0.8703
^{76}Ga	27.6	6.774	2.0	1.7459	2.8317	1.7460	2.4960
^{80}As	15.2	5.70	0.5	2.1993	0.8271	2.4790	0.2590
^{81}Ge	10.1	6.198	0.3	2.4426	0.8407	2.1260	0.8810
^{82m}As	14.0	7.40	2.5	1.8179	3.3033	1.9540	2.7630
^{82}As	19.1	7.40	0.2	2.9171	1.0849	1.9900	2.9540
^{83}As	13.3	5.460	1.5	1.6367	1.7346	2.0000	0.9930
^{88}Br	16.3	8.60	2.5	2.3364	3.4469	2.4540	3.2100
^{91}Kr	8.57	6.20	1.5	1.8714	1.9897	2.0550	1.6170
^{93}Rb	5.93	7.36	1.3	2.4053	2.0631	2.1470	2.6750
^{94}Rb	2.80	9.50	2.3	2.7162	3.5747	2.9940	3.6550
^{95}Sr	25.1	6.093	0.8	2.1317	1.3476	1.5930	2.4420
^{97m}Y	1.19	7.338	2.0	2.0760	2.6795	2.6830	1.4720
^{97}Y	3.72	6.670	0.8	2.3548	1.4679	2.4720	1.2310
^{104}Tc	1092.0	5.40	1.5	1.4031	2.1305	1.2440	2.6780
^{105}Mo	36.7	5.40	1.0	1.7411	1.4361	1.2900	2.3650
^{107}Tc	21.0	4.20	1.3	1.1682	1.4147	1.6820	0.9858
^{110m}Rh	28.5	5.405	2.0	1.1446	2.6654	2.2370	0.7770
^{110}Rh	3.0	5.40	0.5	1.9101	1.0811	2.2020	0.4860
^{111}Rh	11.0	3.50	0.8	1.0774	0.8982	1.4590	1.0670
^{115}Pd	37.4	4.414	1.0	1.3453	1.2512	1.4350	1.0670
^{132}Sb	168.0	5.60	2.0	1.1968	2.7279	1.1970	2.7280
^{136m}I	44.8	7.0	2.0	1.7596	2.9420	1.7600	2.9420
^{136}I	85.1	7.0	2.5	1.6996	3.0665	1.7600	2.9420
^{138m}Cs	174.0	5.58	2.3	0.2832	0.7066	0.2800	0.7340
^{139}Xe	40.8	4.88	0.5	1.6654	1.0149	1.0020	2.2390
^{140}Cs	65.5	6.045	1.3	1.5577	2.3981	1.4290	2.7910
^{141}Cs	24.9	4.98	1.0	1.5043	1.4450	1.2760	2.1350
^{144}Ba	11.5	3.06	0.8	0.8326	0.9476	0.9463	0.7050

Table 4 (Continued)

A, Z	$T_{1/2}$(sec)	Q_β(MeV)	Q_{00}	Present E_β(MeV)	 E_γ(MeV)	JNDC 1.5 E_β(MeV)	 E_γ(MeV)
^{145}La	29.2	4.2	1.3	1.0929	1.5250	1.4520	0.8021
^{152m}Pm	900.0	3.47	1.5	0.6608	1.7332	1.0540	0.9648
^{153}Nd	32.0	3.40	0.5	1.1110	0.6723	0.9685	0.6232
^{154}Nd	40.0	2.230	0.5	0.6072	0.6076	0.5170	0.5846
^{158}Sm	330.6	1.718	0.5	0.4084	0.5549	0.4077	0.5547
^{159}Sm	10.1	3.462	0.8	1.0002	0.9650	1.1270	0.6892
^{161}Eu	24.8	3.519	0.8	1.0059	1.0062	1.1320	0.7815
^{163}Gd	68.0	3.157	0.8	0.8592	0.9613	0.9852	0.6846
^{166}Tb	56.4	4.0	1.5	0.7479	2.0498	0.9471	1.6111
^{167}Tb	30.7	3.566	0.8	1.0140	1.0273	1.1400	0.7513
^{168}Dy	132.0	1.491	0.5	0.3187	0.5429	0.3176	0.5427
^{169}Dy	38.2	2.852	0.5	0.8661	0.6322	0.3653	0.6319
^{170}Dy	20.4	2.360	0.5	0.6479	0.6290	0.6463	0.6285
^{172}Ho	35.6	4.036	1.5	0.7571	2.0579	0.9442	1.6450

Table 5 Contribution of examined nuclides to decay power at 700.0 seconds after ^{239}Pu fission by fast neutron

	Beta component (%)		Gamma component (%)		Total (%)	
A, Z	Present	JNDC 1.5	Present	JNDC 1.5	Present	JNDC 1.5
^{102}Tc	6.1	8.7	8.5	3.2	7.3	5.9
^{104}Tc	5.8	5.7	7.9	8.3	6.9	7.0
^{105}Tc	6.0	5.9	2.8	3.0	4.3	4.4
^{133}Te	2.5	2.4	2.6	2.8	2.6	2.6
^{141}Ba	2.6	2.6	2.4	2.6	2.5	2.6
^{142}Ba	1.5	1.5	3.4	3.6	2.5	2.6
^{108}Rh	2.6	2.5	2.1	2.2	2.3	2.3
^{107}Ru	2.9	2.9	1.5	1.6	2.2	2.2
^{138}Cs	1.5	1.4	2.5	3.1	2.0	2.2
^{90}Rb	1.9	1.9	1.9	2.0	1.9	1.9
^{148}Pr	1.1	1.1	1.8	1.9	1.5	1.5
^{132m}Sb	0.8	0.8	2.0	2.1	1.4	1.5
^{147}Pr	1.3	1.2	1.2	1.0	1.3	1.1
^{132}Sb	0.8	0.8	1.6	1.7	1.2	1.2

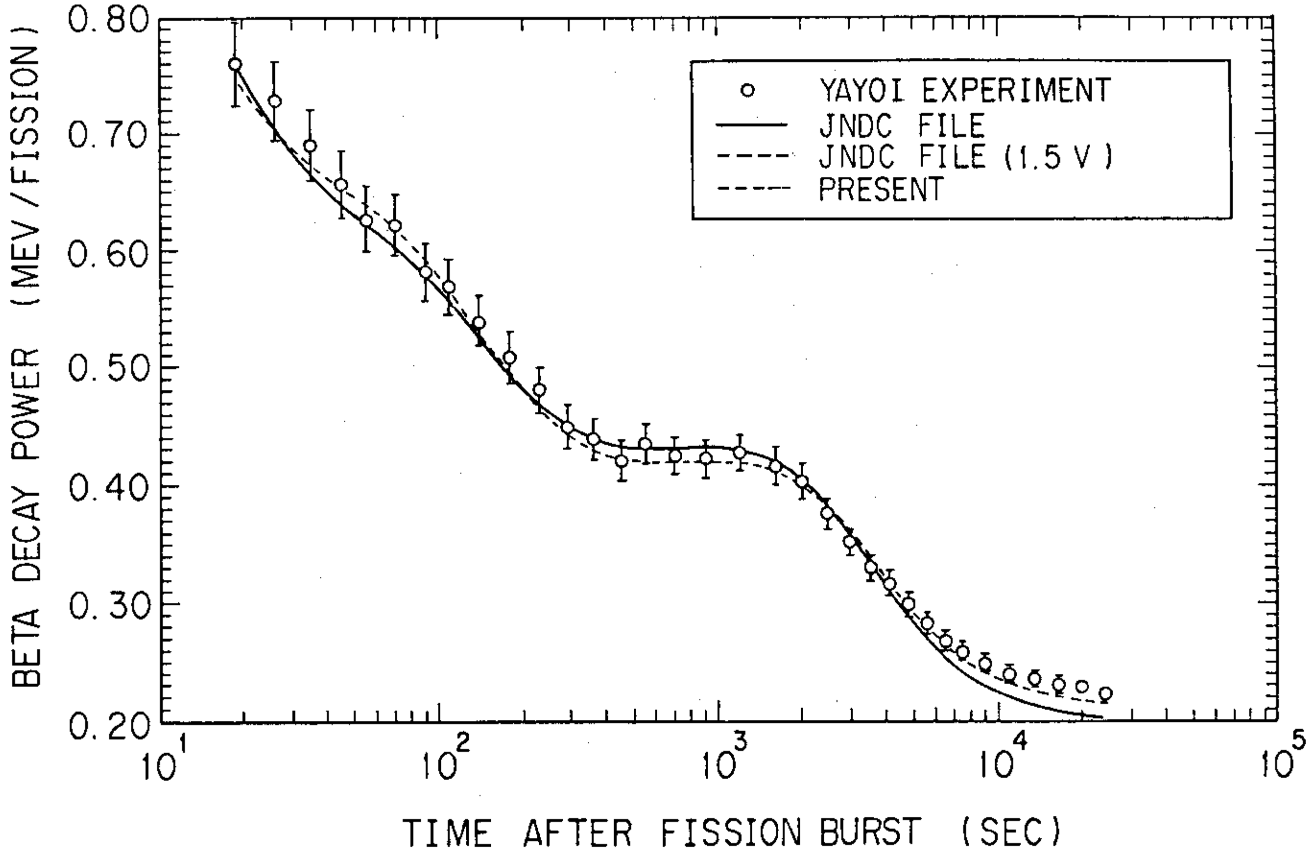

Fig. 1 Beta component of decay power after ^{235}U fissions by fast neutrons.

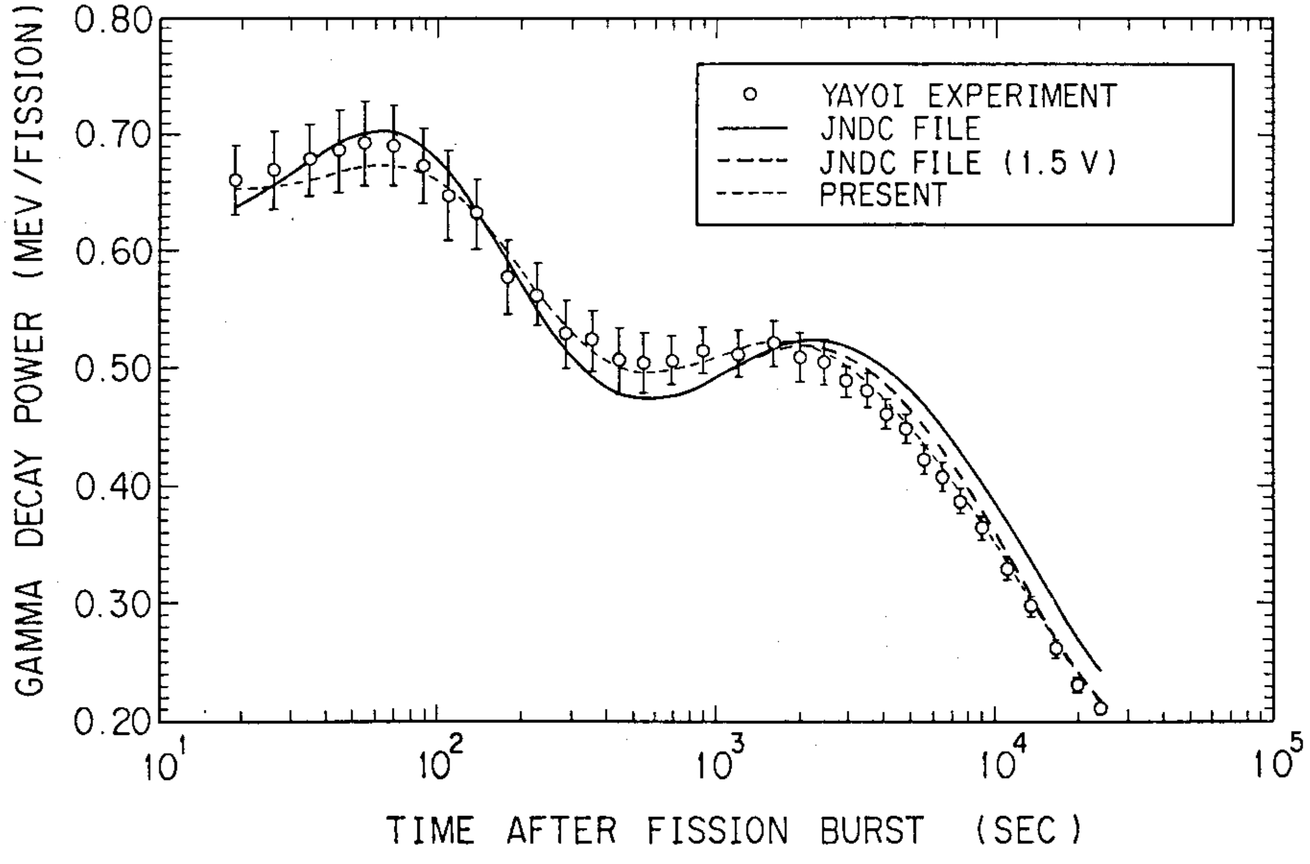

Fig. 2 Gamma component of decay power after ^{235}U fissions by fast neutrons.

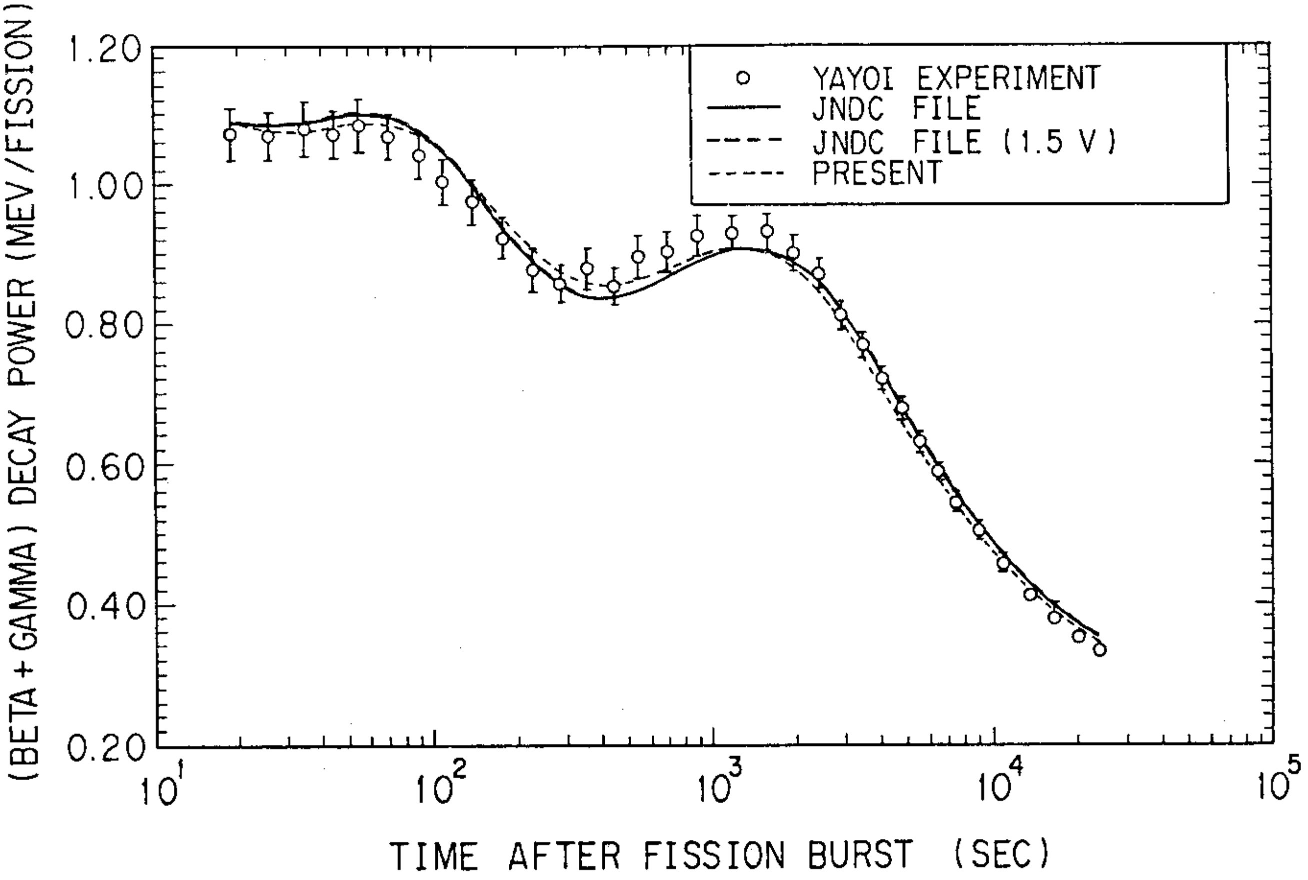

Fig. 3 Total decay power after ^{235}U fissions by fast neutrons.

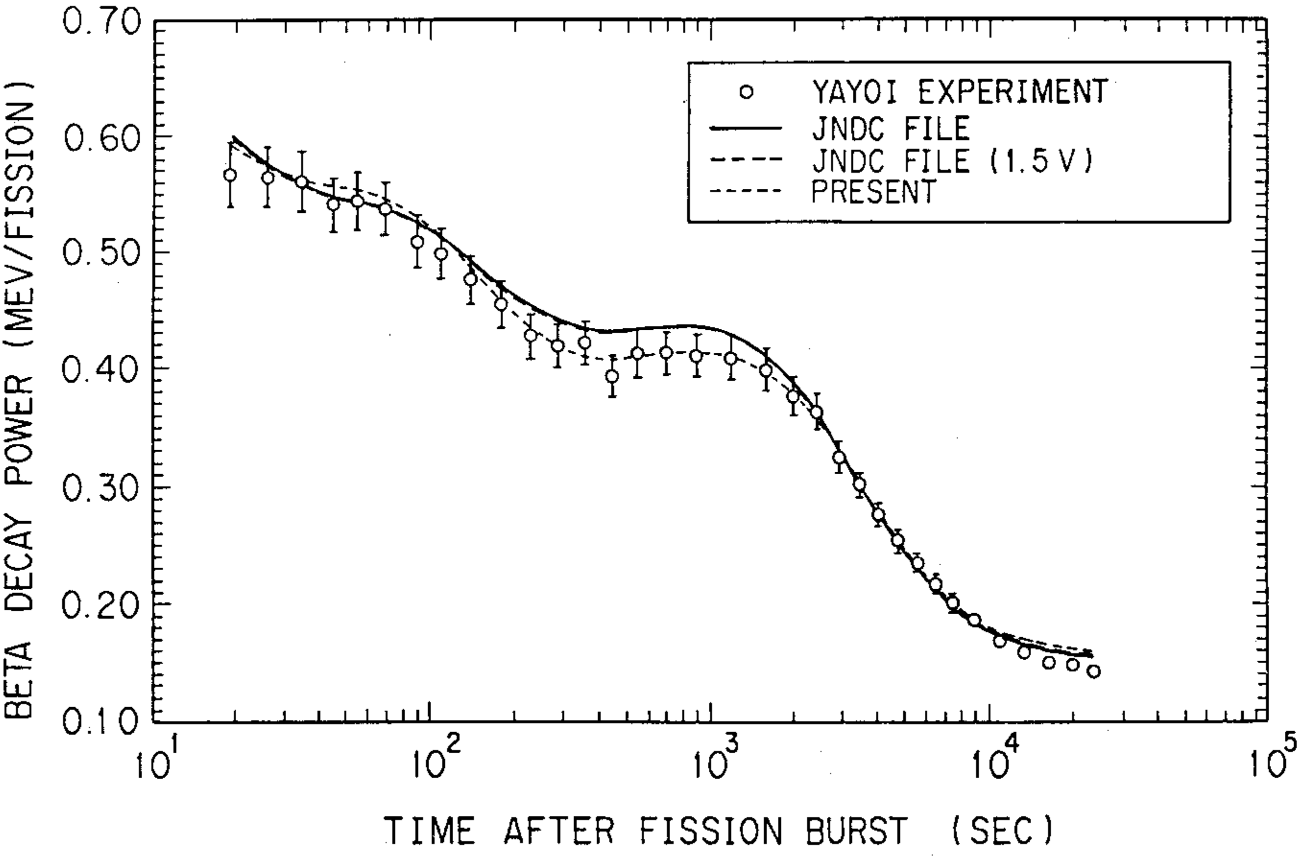

Fig. 4 Beta component of decay power after ^{239}Pu fissions by fast neutrons.

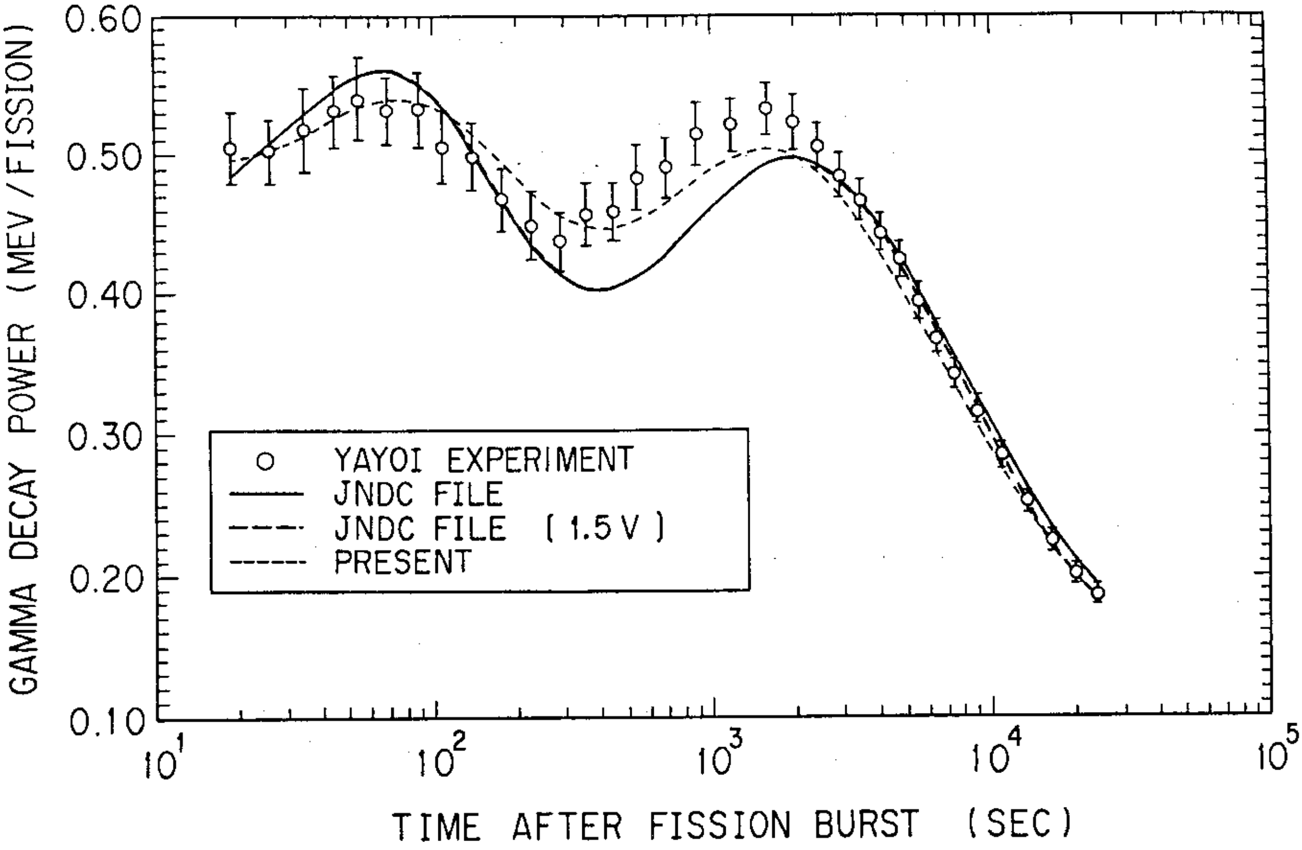

Fig. 5 Gamma component of decay power after ^{239}Pu fissions by fast neutrons

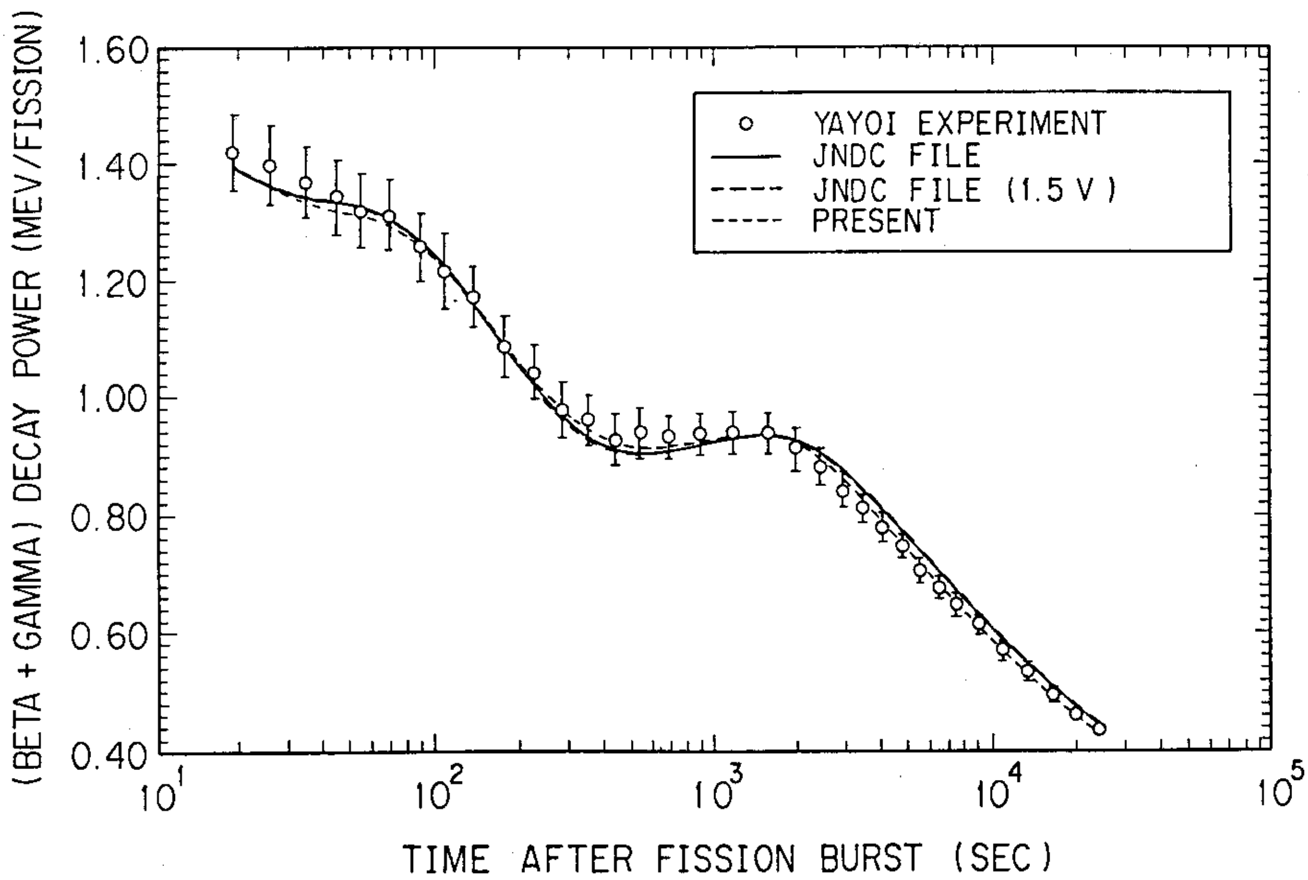

Fig. 6 Total decay power after ^{239}Pu fissions by fast neutrons.

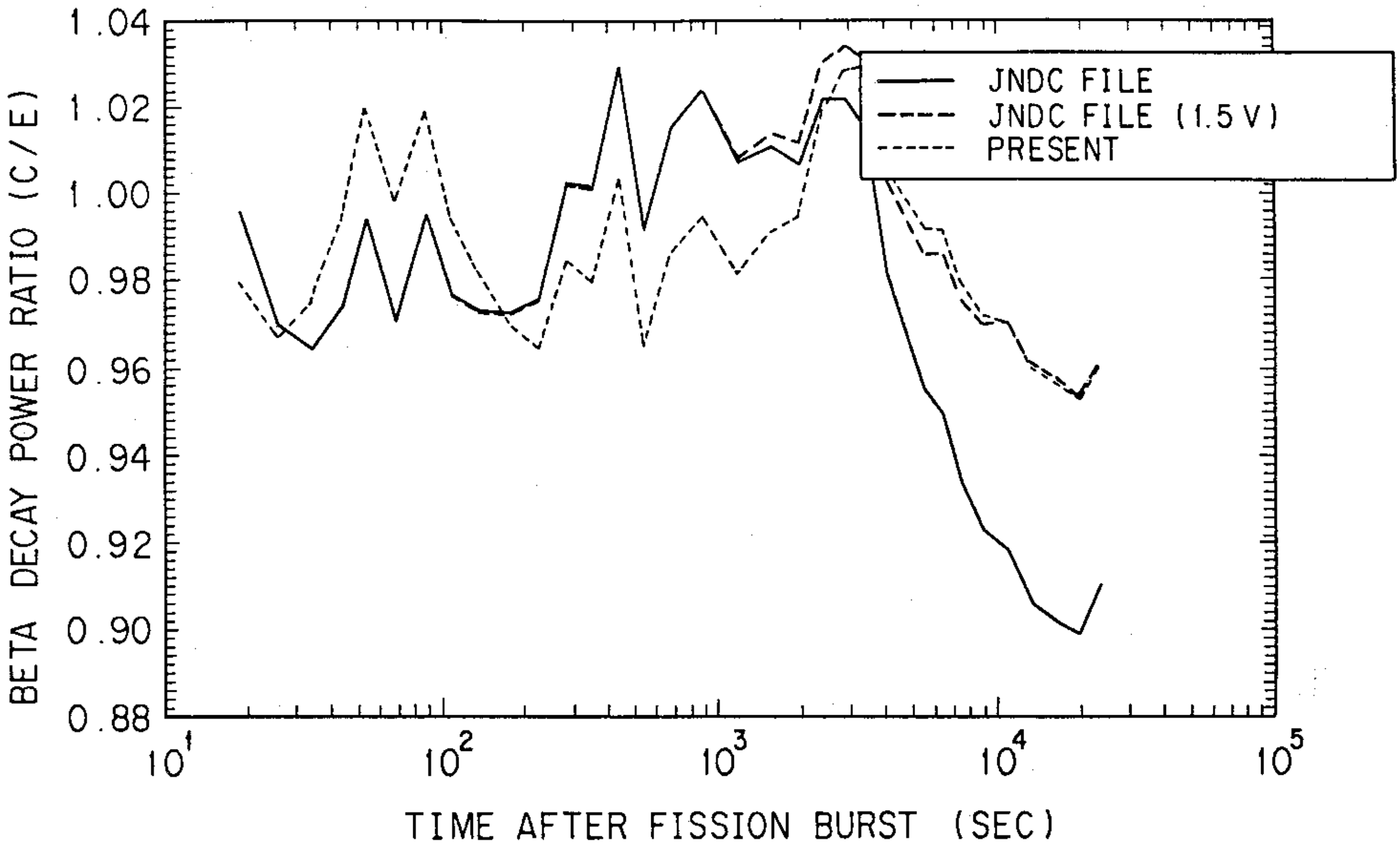

Fig. 7 Ratio of calculated valueus to measured values for beta component of decay power after ^{235}U fissions by fast neutrons.

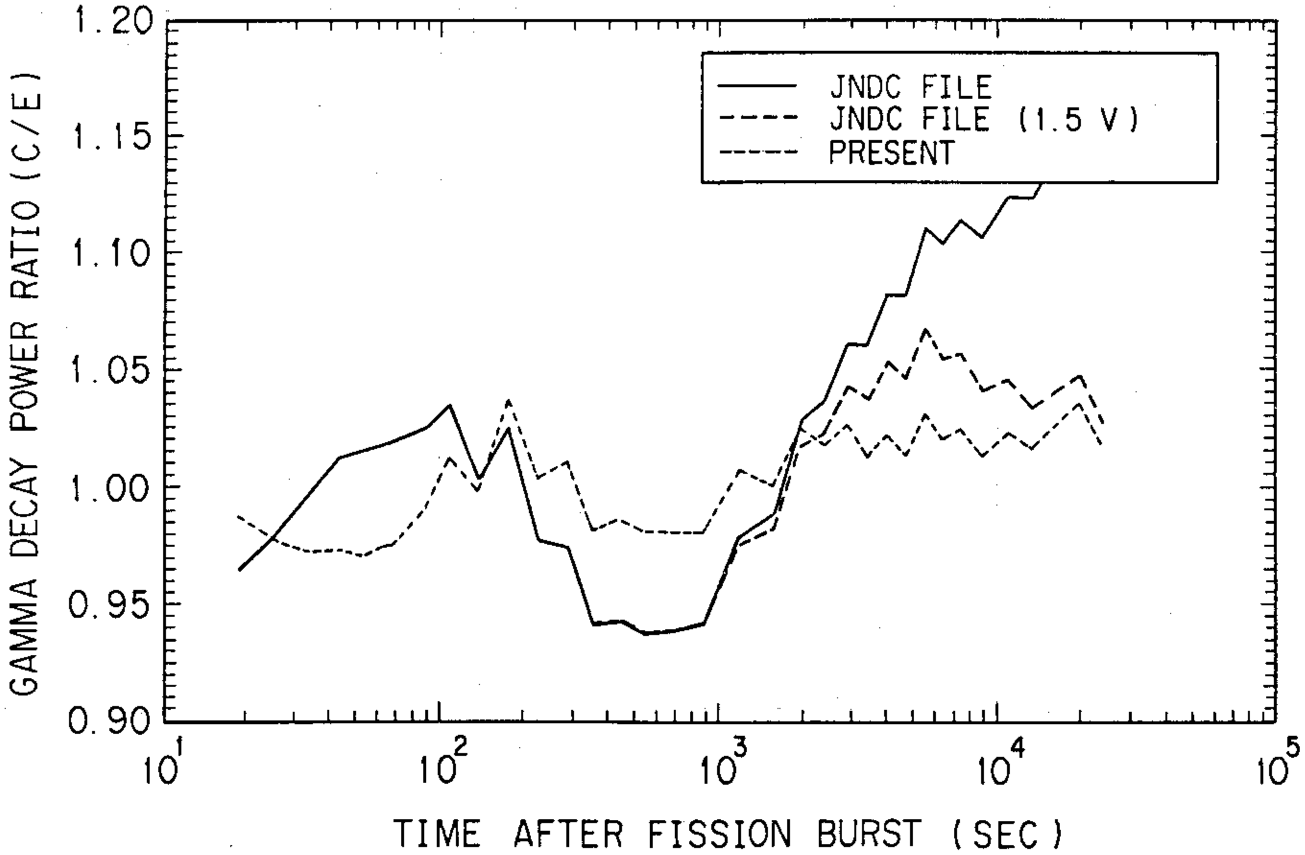

Fig. 8 Ratio of calculated values to measured values for gamma component of decay power after ^{235}U fissions by fast neutrons.

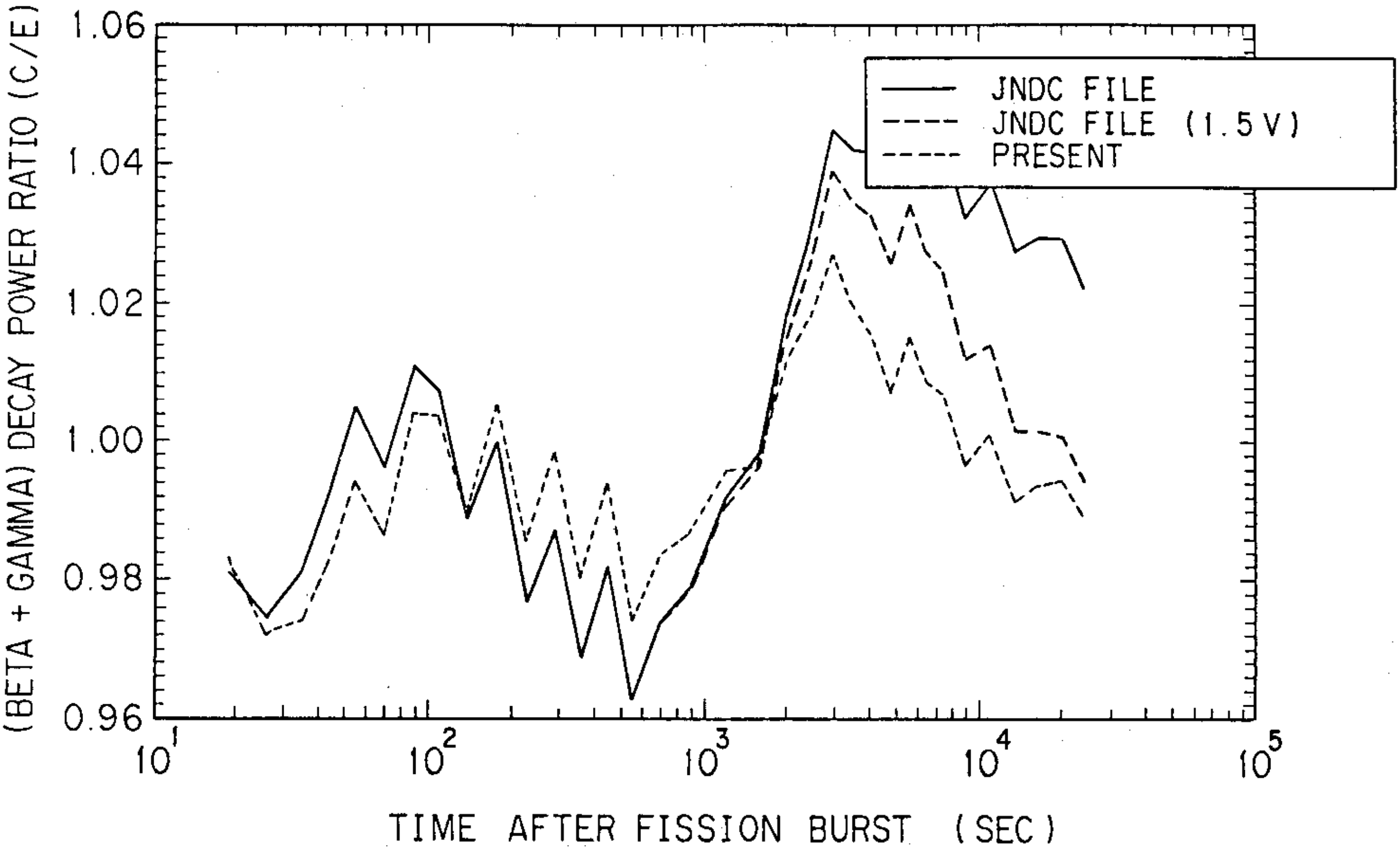

Fig. 9 Ratio of calculated values to measured values for total decay power after ^{235}U fissions by fast neutrons.

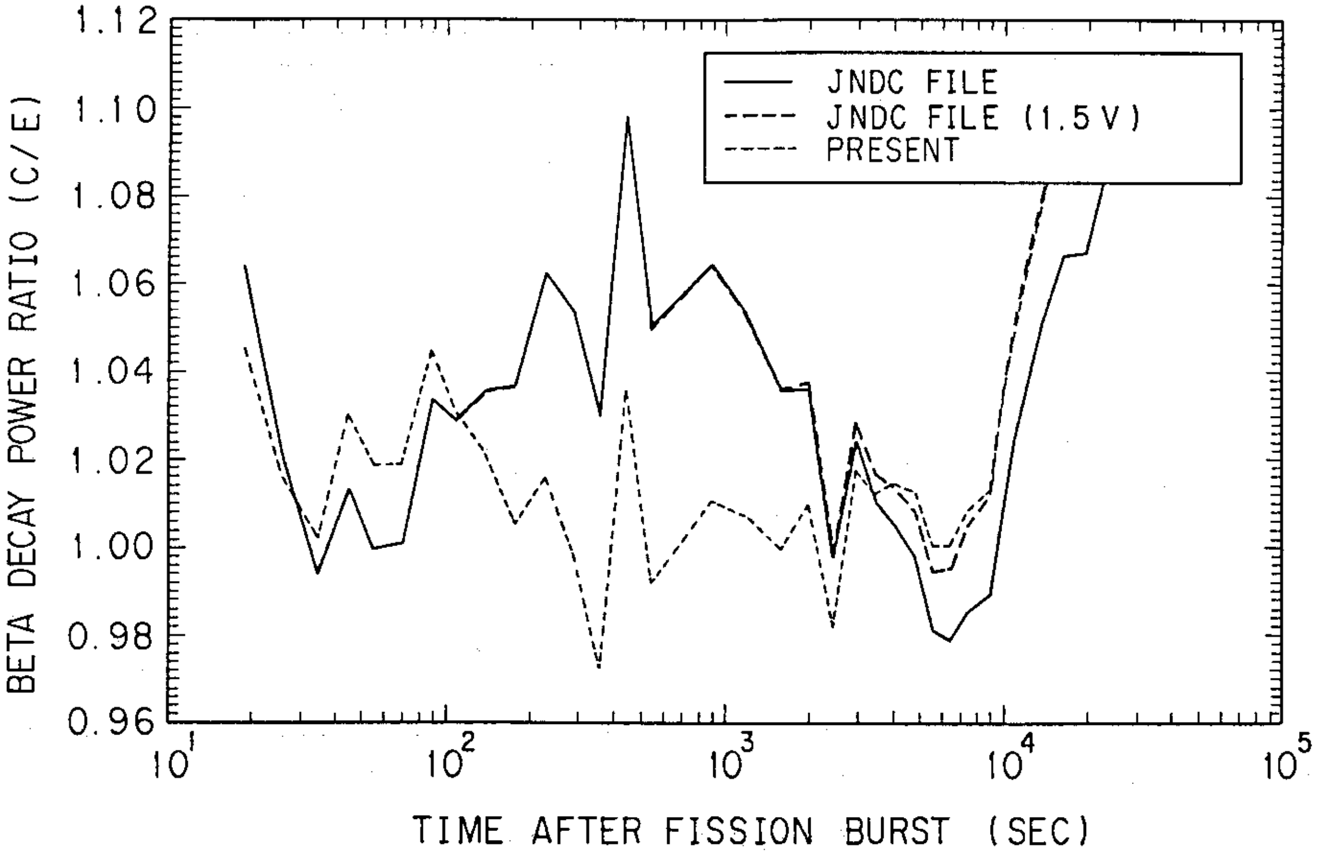

Fig. 10 Ratio of calculated values to measured values for beta component of decay power after ^{239}Pu fissions by fast neutrons.

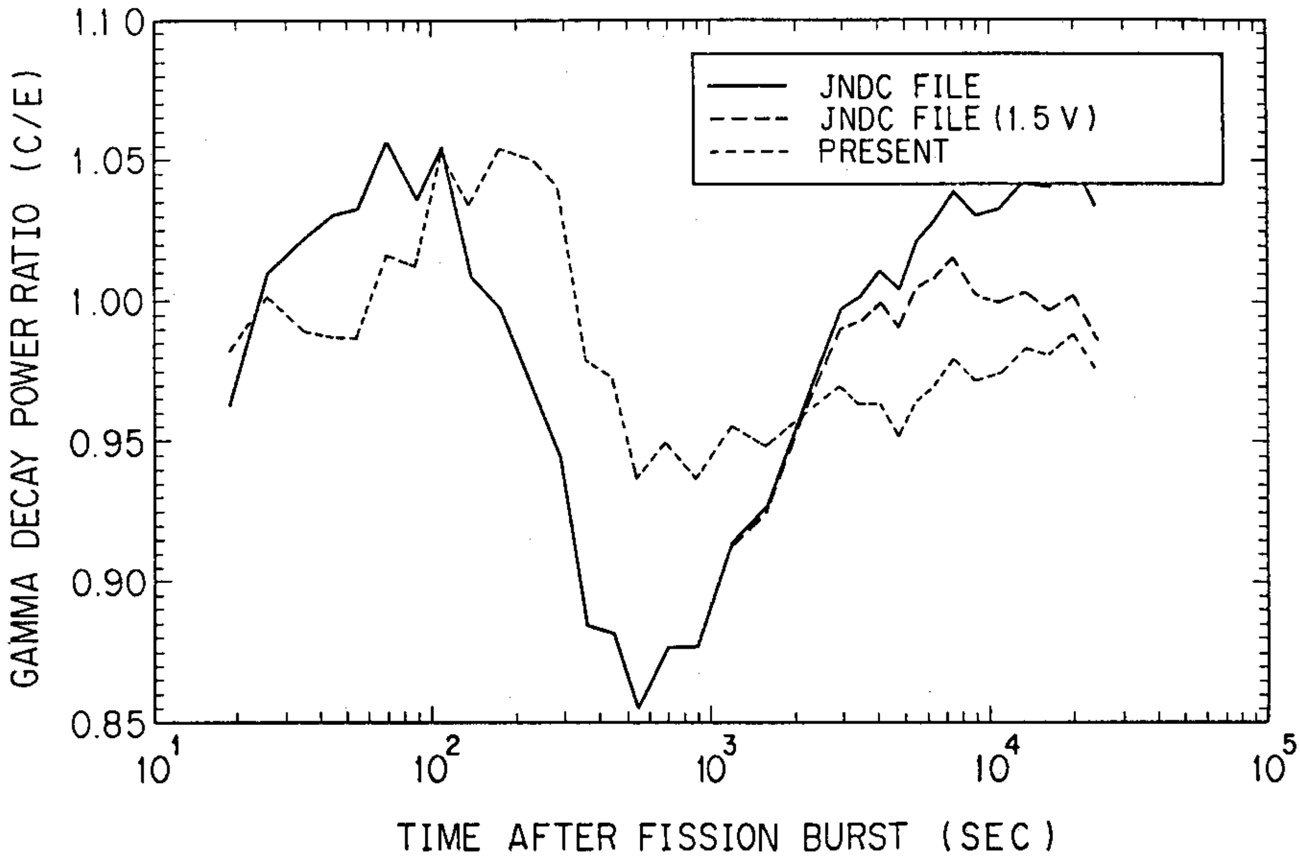

Fig. 11 Ratio of calculated values to measured values for gamma component of decay power after ^{239}Pu fissions by fast neutrons.

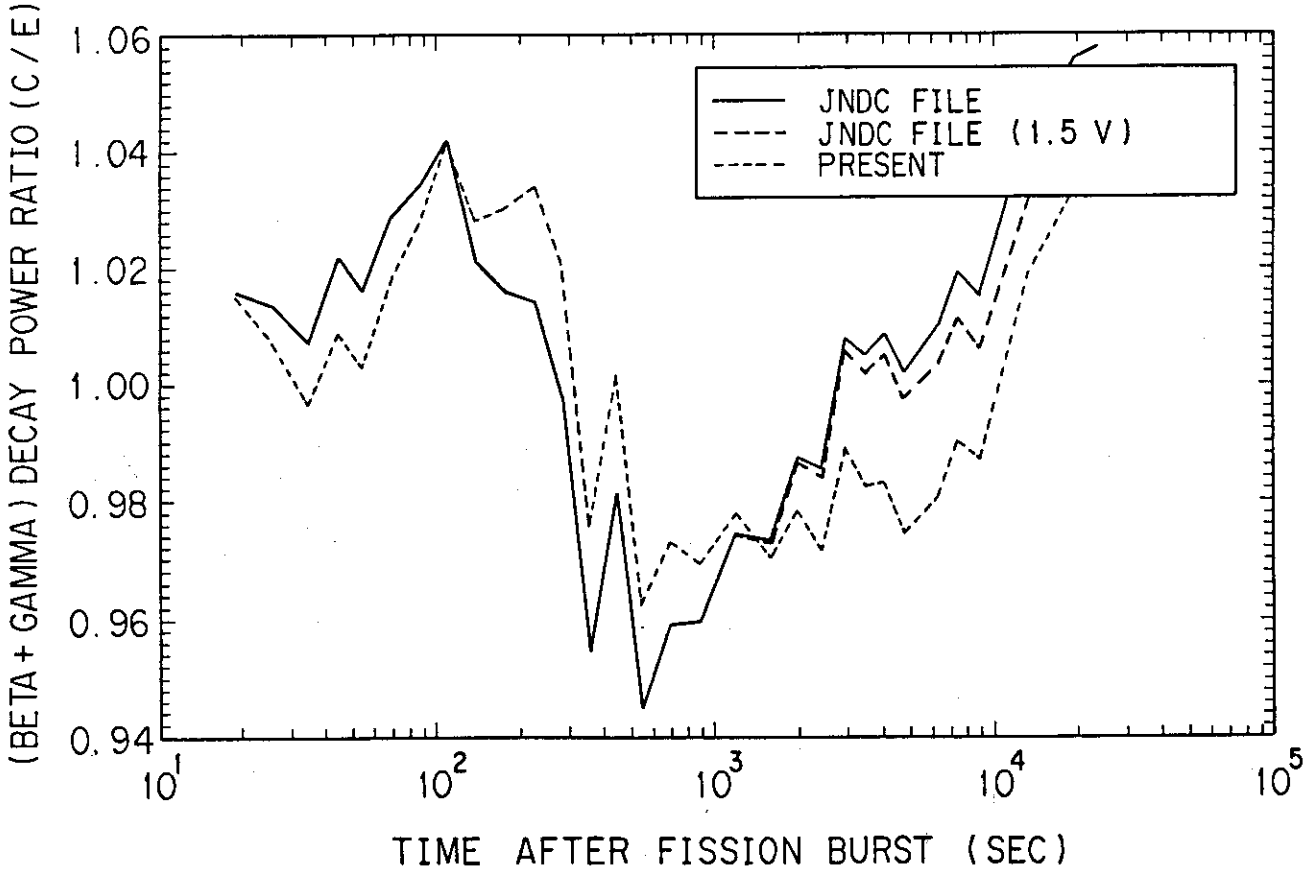

Fig. 12 Ratio of calculated values to measured values for total decay power after ^{239}Pu fissions by fast neutrons.