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The fission process







The fission process





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- Introduction
- Experimental setup
- Data treatment
- Results: PFGS
 - characteristics
 - dependence of compound system
 - impact of excitation energy
 - angular distribution & multipolarities
- Summary
- Outlook





 For the past years: precise measurement of prompt fission γ-ray spectra (PFGS)





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- Determination of characteristics:
 - < M_{γ} >, < ϵ_{γ} >, and < $E_{\gamma,tot}$ >





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- Study of the dependence of A and Z
- Study of energy dependence
- Details about the de-excitation process of fission fragments



Experimental setup Fission fragment – γ-ray coincidences





 (Frisch-grid) ionization chamber

(fission trigger)

 LaBr₃:Ce and CeBr₃ scintillation detectors (plus BaF₂ and/or Nal:Tl/LaBr₃:Ce phoswich detectors (gamma rays)

- Coincidences
- Time-of-flight measurement

(n/ γ discrimination)



Experimental setup n/γ discrimination by time-of-flight





Due to good resolving power + excellent timing resolution of LaBr₃:Ce detectors

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Experimental setup n/γ discrimination by time-of-flight





Due to good resolving power + excellent timing resolution of $LaBr_3$:Ce detectors

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nuclear physics





Data treatment











Cf 239	Cf 240	Cf 241	Cf 242	Cf 243	Cf 244	Cf 245	Cf 246	Cf 247	Cf 248	Cf 249	Cf 250	Cf 251	Cf 252
α 7,63	α 7,59 sf	a 7,342	α 7,392; 7,358 € ?	α 7,06; 7,17	α 7,209; 7,174 g	α 7,137	α 6,750; 6,708 sf γ (42; 96) e ⁻ ; g	e α 6,296; 6,238 γ (294; 448; 418); e ⁻	α 6,258; 6,217 sf γ (43) e ⁻ ; g	α 5,812; 5,758 sf γ 388; 333; g σ 500; σt 1700	α 6,030; 5,989 sf γ (43); e σ 2000; σt < 350	α 5,679; 5,849; 6,012 γ 177; 227 σ 2900; σ ₁ 4500	α 6,118; 6,076 sf γ (43); e σ 20; σ ₁ 32
Bk 238 144 s		Bk 240 5 m		Bk 242 7 m	Bk 243 4,5 h	Bk 244 4,35 h	Bk 245 4,90 d	Bk 246 1,80 d	Bk 247 1380 a α 5,531; 5,710;	Bk 248 23,7 h > 9 a	Bk 249 320 d β 0,1; α 5,419;	Bk 250 3,217 h β 0,7; 1,8	Bk 251 55,6 m
βst		ε βsf			? α 6.575, 6.543 γ 755, 946 9	а 6,662, 6,620 у 892, 218; 922 g	γ 253, 381. e g	γ 799; 1081; 834; 1124 e ⁻	5,688 γ 84; 265 g	γ 551 ^{α?} 8 ⁻ ? 8 ⁻ ?	5,391; sf γ (327; 308) σ 700; σt - 0,1	γ 989; 1032; 1029 σι 1000	β - 0,9; 1,1 γ 178; 130; 153
	Cm 238 2,4 h	Cm 239 3 h	Cm 240	Cm 241 32,8 d	Cm 242 162,94 d	Cm 243	Cm 244	Cm 245 8500 a	Cm 246 4730 a	Cm 247 1,56 · 10 ⁷ a	Cm 248 3,40 · 10 ⁵ a	Cm 249 64,15 m	Cm 250 ~ 9700 a
	ε α 6.52	ε γ 188 9	Sf α 6,291; 6,248 st g	Sf 4 a 5,939 y 472, 431, 132 g	$ \begin{array}{c} {\rm sf} & \alpha \ 6,113; \ 6,069 \\ {\rm sf}; \ g \\ \gamma \ (44); \ e^- \\ \sigma - 20 \\ \sigma_f - 5 \end{array} $	Sf α 5.785; 5.742 ε; sf; g γ 278; 228; 210; e σ 130; σ ₁ 620	Sf α 5,805; 5,762 sf; g γ (43); e ⁺ σ 15; σ ₁ 1,1	Sf α 5,361; 5,304 sf; g γ 175; 133 σ 350; σ ₁ 2100	α 5,386; 5,343 sf; g γ (45); e σ 1,2; σ _f 0,16	α 4,870; 5,267 γ 402; 278 9 σ 60; σt 82	α 5,078; 5,035 sf; γ; e ; g σ 2,6; σ ₁ 0,36	$\begin{array}{l} \beta^{-} \ 0,9\\ \gamma \ 634; \ (560;\\ 369); \ e^{-}\\ \sigma \ \sim \ 1,6 \end{array}$	sf α ?; β ? σ - 80
Am 236 4,4 m	Am 237 73,0 m sf • 6.042 • 280; 438, 474; 909	Am 238 1,63 h sf * 5.94 7963; 919; 561; 605.	Am 239 11,9 h sf * 5.774 * 278: 228 *	Am 240 50,8 h sf • \$.378 • 988,889	Am 241 432,2 a st α 5,486; 5,443 st; γ 60; 26 σ; g σ 50 + 570; σ; 3,1	Am 242 141 a 16 h 51 r_{1}^{141} a 52,206 52,7(49) 1700 1700 1700 1210 1	Am 243 7370 a sf a 5,275; 5,233 sf; y 75; 44 o 75 + 5 o 0.074	Am 244 sf ^{26 m} ^{β⁻1,5} ^{γ(1084)} ^{g⁻1,600} ^{g⁻1,600} ^{g⁻1,600} ^{g⁻2,000} ^{g⁻2,000 ^{g⁻2,000} ^{g⁻2,000 ^{g⁻2,000} ^{g⁻2,000 ^{g⁻2,000} ^{g⁻2,000 ^{g⁻2,000} ^{g⁻2,000 ^{g⁻2,00}}	Am 245 2,05 h sf p ^{= 0,9} 7 253; (241; 296) e ⁻ : 9	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Am 247 22 m ^{β-} γ 285; 226 e ⁻		154
Pu 235 25,3 m	Pu 236 2,858 a sf α 5,768; 5,721 at: Mg 28 γ (48; 109); e ⁻ σ ₁ 160	Pu 237 45,2 d sf ^{a,5,334} ^{y,60} ^e _{vr,2300}	Pu 238 87,74 a sf s; 5;499; 5,456 s; 5; Mg γ (43; 100); e ⁻ σ 510; σ ₁ 17	Pu 239 2,411 · 10 ⁴ a sf σ,5,157; 5,144 σ,τm σ,270; σ ₁ ,752	Pu 240 6563 a sf st; (44 s ^{1,168} , 5,124 s ¹ ; (45) o ⁻ ; o o ⁻ 290; o ⁺ ₁ = 0,044	Pu 241 14,35 a sf ^{β⁻0,02; g} α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	Pu 242 3,750 · 10 ⁵ a sf α 4,901; 4,856 σ ⁺ ; γ (45) σ ⁺ ; g σ 19; σ ₁ < 0,2	Pu 243 4,956 h sf ^{β=0,6} y ⁸⁴⁹ σ < 100; σ ₁ 200	Pu 244 sf 8,00 · 10 ⁷ a a 4,589; 4,546 sf; 7 o a 1,7	$\begin{array}{c} \text{Pu 245} \\ \text{10,5 h} \\ \text{sf} \\ \begin{array}{c} \beta^{-0.9; \ 12} \\ \gamma 327; 560; \\ 308; 9 \\ \sigma 150 \end{array}$	Pu 246 10,85 d ^{β⁻ 0,2; 0,3} γ 44; 224; 180 m1	Pu 247 2,27 d	
Np 234 4,4 d «; β* γ 1559; 1528; 1602 σ1 - 900	Np 235 396,1 d e; a 5,025; 5,007 y(26; 84); e ⁻ g; a 160 + ?	Np 236 22,5 h 1,54 · 10 ⁵ a γ (642; γ 160; 6 668; γ 100; 9 668; γ 100; 9 9; 9; 2700 9; 9; 2600	Np 237 2,144 · 10 ⁶ a sf 4.790; 4.774 γ 29; 87; e ⁻ σ 180; σ ₁ 0,020	Np 238 2,117 d β ⁻ 1,2 γ 984; 1029; 1026; 924; e ⁻ g; σ ₁ 2100	$\begin{array}{c} Np \ 239 \\ 2,355 \ d \\ \beta^- \ 0,4; \ 0,7 \dots \\ \gamma \ 106; \ 278; \\ 228 \dots; \ e^-; \ g \\ \sigma \ 32 + 19; \ \sigma_1 < 1 \end{array}$	Np 240 7,22 m 65 m β=2,2, γ 555; 597, 974; e ⁻ 601; hy; g 448; g	Np 241 13,9 m ^{β⁻} 1,3 γ 175; (133) 9	$\begin{array}{c} Np & 242\\ \textbf{2,2 m} & \textbf{5,5 m}\\ \beta^-2,7 & \beta^-\\ \gamma,736; & \gamma,786;\\ 700; & 046;\\ 1473 & 159\\ 9 & 0 \end{array}$	Np 243 1,85 m ^{β⁻} _{γ 288} 9	Np 244 2,29 m β ⁻ γ 217; 681; 163; 111 9	152		
U 233 1,592 · 10 ⁵ a α 4,824; 4,783 Ne 25; γ (42; 97); e α 47; σ; 530	$\begin{array}{c} U \ 234 \\ 0,0055 \\ 2,455 \cdot 10^5 \\ a \ 4,775 \ 4,723 \ a \ c \\ mg \ 28; \ Ne; \ \gamma \ (53; \ 121,) \\ e^{-}, \sigma \ 96; \ \sigma_{1} < 0.008 \end{array}$	U 235 0,7200 26 m 7,038-10 ⁸ a 1 y (0.07) e ⁻ x 98; y 186, y 95; y 186, y 95; y 586	U 236 120 ns 2,342-10 ⁷ a 0 4,494; 4,445; 14,455; 642 81 0 ⁻ ; 0 5,1	$\begin{array}{c} U \ 237 \\ 6,75 \ d \\ \beta^{-} \ 0,2 \\ \gamma \ 60; \ 208 \\ e^{-} \\ \sigma - \ 100; \ \sigma_{1} < 0.35 \end{array}$	U 238 99,2745 270 ns. 4,468-10 ⁹ a 9,254 198. 4,498.10 ⁹ a 287.7(50.1) 27,1(50.1)	U 239 23,5 m β ⁻ 1,2; 1,3 γ 75; 44 σ 22; σ; 15	U 240 14,1 h β ⁻ 0,4 γ 44; (190) e ⁻ m		$\begin{array}{c} U \ 242 \\ 16,8 \ m \\ \end{array} \\ {}^{\beta^{-}}_{\gamma \ 68; \ 58; \ 585; \ 573 } \\ {}^{m} \end{array}$	con	npour	id syst	tems





$ \begin{array}{c} \varepsilon ; \ \beta^{+} \\ \gamma \ 1559; \ 1528; \\ 1602 \\ \sigma_{1} = 900 \end{array} $	ε; α 5,025; 5,007	•: β ⁺ 0,5 •: β ⁺ : α γ (642: γ 160;	sf a 4.790; 4.774	β 1,2 γ 984; 1029;	β ⁻ 0,4; 0,7 γ 106; 278;	β ⁻ 2,2, γ 555; γ 566; 597 974;	β-1.3	β 2,7 β γ 736; γ 786; 780; 945;	β-	β ⁻ γ 217; 681;	152		
Np 234 4,4 d	Np 235 396,1 d	Np 236	Np 237	Np 238 2,117 d	Np 239 2,355 d	Np 240	Np 241 13,9 m	Np 242	Np 243 1,85 m	Np 244 2,29 m			
Pu 235 25,3 m	Pu 236 2,858 a σ.5,768: 5,721 st; Mg 28 γ (48; 109); σ ⁻ σ ₁ 160	Pu 237 45,2 d sf s,334 r,0e ⁻ r,200	Pu 238 87,74 a sf	Pu 239 sf 2,411 · 10 ⁴ a a 5,157; 5,144 af; y (52) a 720; a, 752	Pu 240 6563 a sf a.5,168; 5,124 sf; y (45) or 200; off = 0.040	Pu 241 14,35 a sf β ^{-0,02;} g α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	Pu 242 3,750 - 10 ⁵ a α 4,901; 4,856 sf; γ (45) σ τιθ; σ ₁ < 0.2	Pu 243 4,956 h sf ^{β^{-0,6,} γ^{84,9} σ < 100, σ1 200}	Pu 244 sf \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	Pu 245 10,5 h sf ^{3^-0.9; 1,2} ^{3 327; 560; 308; 9} or 150	Pu 246 10,85 d β 0,2; 0,3 γ 44; 224; 180 m1	Pu 247 2,27 d	
Am 236 4,4 m	Am 237 73,0 m • • • 6.042 • 7280; 438, 474; 909. 9	Am 238 1,63 h sf 905.919 561: 9	Am 239 11,9 h sf * * * * * * * * * * * * * * * * *	Am 240 50,8 h \$ \$ \$ 988,889 9	Am 241 432,2 a sf st; y 60; 26 e; g s 50 + 570; g; 21	Am 242 141 a 16 h 520607.e st,7(49),e ⁻ 520607.e st,7(49)7(42) 0, ⁻ 0.0 0, ⁻	Am 243 7370 a sf a 5,275; 5,233 sf; y 75; 44 o 75 + 5 o; 0,074	Am 244 26 m 10,1 h 51 p 1,5 p 0,4 9 (1084) 996; 9 q 1600 q 200	Am 245 2,05 h sf 7253; (241; 296) e ⁻ ; g	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Am 247 22 m		154
	Cm 238 2,4 h	Ст 239 3 h	Cm 240 27 d sf	Cm 241 32,8 d 5,939 7 472, 431; 132	$\begin{array}{c c} Cm & 242 \\ \hline 162,94 \ d \\ sf_{\sigma,6,113,6,069,} \\ sf_{g} \\ \gamma (44,); e^{-} \\ \sigma - 20 \\ \sigma_{f} - 5 \end{array}$	Cm 243 29,1 a sf \$25,742 \$210e" \$210e" \$130, \$528	Cm 244 18,10 a sf g (43); e" g (5; gr 1,1	Cm 245 8500 a sf α 5,361; 5,304 3t; g γ 175; 133 σ 350; σ ₁ 2100	$\begin{array}{c} \mbox{Cm} 246 \\ 4730 \mbox{a} \\ \mbox{a} \mbox{5,386; 5,343} \\ \mbox{sf; g} \\ \mbox{γ} \mbox{(45); e^-} \\ \mbox{σ 1,2; σ_1 0,16} \end{array}$	$\begin{array}{c} Cm \ 247 \\ 1,56 \cdot 10^7 \ a \\ {}^{\alpha} \ 4,870; \ 5,267 \\ {}^{\gamma} \ 402; \ 278 \\ g \\ {}^{\sigma} \ 60; \ {}^{\sigma} \ 82 \end{array}$	Cm 248 3,40 · 10 ⁵ a ^{α 5,078;} 5,035 sf; γ; e ⁻ ; g σ 2,6; σt 0,36	$\begin{array}{c} Cm \ 249 \\ 64, 15 \ m \\ \beta^- \ 0, 9 \\ \gamma \ 634; \ (560; \\ 369); \ e^- \\ \sigma \ - \ 1, 6 \end{array}$	Cm 250 ~ 9700 a sf α ?; β ⁻ ? σ - 80
Bk 238 144 s		Bk 240 5 m		Bk 242 7 m sf	Bk 243 4,5 h (• 6,575; 6,543 7,755; 946 9	Bk 244 4,35 h • • 6.662; 6.620 • 7 892; 218; 922 9	Bk 245 4,90 d * * 5,888,6,150 * 253:381 * 9	Bk 246 1,80 d * y 799; 1081; 834; 1124 e	Bk 247 1380 a α 5,531; 5,710; 5,688 γ 84; 265 g	Bk 248 23,7 h > 9 a β ⁻ 0,9 * y 551 g ⁻ g ⁻ *	$\begin{array}{c} Bk \ 249 \\ 320 \ d \\ \beta^{-} \ 0,1; \ \alpha \ 5,419; \\ 5,391; \ sf \\ \gamma \ (327; \ 308) \\ \sigma \ 700; \ \sigma_{1} - 0,1 \end{array}$	Bk 250 3,217 h β ⁻ 0,7; 1,8 γ 989; 1032; 1029 σ ₁ 1000	Bk 251 55,6 m β ⁻ - 0,9; 1,1 γ 178; 130; 153
Cf 239 ~ 39 s	Cf 240 1,06 m α 7.59 sf	Cf 241 3,78 m	Cf 242 3,68 m ∝ 7,392; 7,358 ∢?	Cf 243 10,7 m • • • • • • • • • • • • • • • • • • •	Cf 244 19,4 m α 7,209; 7,174 g	Cf 245 43,6 m	Cf 246 35,7 h α 6,750; 6,708 sf γ (42; 96) e ⁻ ; g	Cf 247 3,11 h ^ϵ ^α 6,296; 6,238 ^γ (294; 448; 418); e ⁻	Cf 248 333,5 d α 6,258; 6,217 sf γ (43) e ⁻ ; g	Cf 249 350,6 a α 5,812; 5,758 sf γ 388; 333; g σ 500; σ ₁ 1700	Cf 250 13,08 a α 6,030; 5,989 sf γ (43); e ⁻ σ 2000; σt < 350	Cf 251 898 a α 5,679; 5,849; 6,012 γ 177; 227 σ 2900; σt 4500	Cf 252 2,645 a α 6,118; 6,076 sf γ (43); e σ 20; σt 32

Previous work:







Cf 239	Cf 240	Cf 241	Cf 242	Cf 243	Cf 244	Cf 245	Cf 246	Cf 247	Cf 248	Cf 249	Cf 250	Cf 251	Cf 252
~ 39 s	1,06 m	3,78 m	3,68 m	10,7 m	19,4 m	43,6 m	35,7 h	3,11 h	333,5 d	350,6 a	13,08 a	898 a	2,645 a
		12000		1800		A9211	α 6,750; 6,708		α 6,258; 6,217	α 5,812; 5,758	α 6,030; 5,989	α 5,679; 5,849;	α 6,118; 6,076
	α 7,59	. 1000	α 7,392; 7,358	ε α 7,06; 7,17	α 7,209; 7,174	α 7.137	sf γ (42; 96)	α 6,296; 6,238 γ (294; 448;	st γ (43)	sf γ 388; 333…; g	st γ (43…); e ⁻	6,012 γ 177; 227	st γ (43…); e
α 7,63	sf	α 7,342	e?	9	9	g	e";g	418); e ⁻	e ;g	σ 500; σι 1700	σ 2000; σt < 350	σ 2900; σ1 4500	σ 20; σ† 32
Bk 238		Bk 240		Bk 242	Bk 243	Bk 244	Bk 245	Bk 246	Bk 247	Bk 248	Bk 249	Bk 250	Bk 251
144 s		5 m		7 m	4,5 h	4,35 h	4,90 d	1,80 d	1380 a	23.7 h > 9 a	320 d	3,217 h	55,6 m
				sf	sf	sf	Sf * n 5,888; 6,150	·	α 5,531; 5,710;	8-0.9	β=0,1; α 5,419;	β=0,7; 1,8	0- 00.11
					? α 6.575, 6.543 γ 755, 946	a 6,662, 6,620 a 892, 218, 922	γ 253; 381 e	834: 1124	γ 84; 265	γ 551 β ⁻ ?	γ (327; 308)	1029	γ 178; 130;
βst		βsf		9	9	g	a a	e ⁻	g	e- e?	σ 700; σt - 0,1	of 1000	153
	Cm 238	Cm 239	Cm 240	Cm 241	Cm 242	Cm 243	Cm 244	Cm 245	Cm 246	Cm 247	Cm 248	Cm 249	Cm 250
	2,4 h	3 h	27 d	32,8 d	162,94 d	29,1 a	18,10 a	8500 a	4730 a	1,56 · 107 a	3,40 · 10 ⁵ a	64,15 m	~ 9700 a
			st	sf • a 5,939	St α 6,113; 6,069 st; g	St a 5,785; 5,742 e; st; g	ST a 5,805; 5,762	ST α 5,361; 5,304	α 5,386; 5,343	α 4,870; 5,267	- 5 078 5 035	β ⁻ 0,9	et
		γ 188	a 6,291; 6,248 sf	γ 472, 431; 132 e ⁻	γ (44); θ σ = 20	γ 278; 228; 210, e	sf; g y (43); e	st; g y 175; 133	γ (45); e	g	st; 'y; e ⁻ ; g	369); e	α?;β~?
	α 6,52	9	9	9	a1-2	σ 130; σ ₁ 620	σ 15; σι 1,1	o 350; of 2100	σ 1,2; σι 0,16	σ 60; σι 82	o 2,6; oj 0,36	σ ~ 1,6	σ ~ 80
Am 236	Am 237	Am 238	Am 239	Am 240	Am 241	Am 242	Am 243	Am 244	Am 245	Am 246	Am 247		
4,4 m	73,0 m	1,63 h	11,9 h	50,8 h	432,2 a	141 a 16 h	7370 a	26 m 10,1 h	2,05 h	25 m 39 m	22 m		
	Sf * a 6.042	Sf « a 5.94	Sf « 	st	Sf a 5,486; 5,443	St +y (49), e ⁻ 8 ⁻ 0.6, a 5,206 0.7. •	st a 5,275; 5,233	St β ⁻¹ ,5 β ^{-0,4} ε γ744;	st β 0,9	ST β 1,2; β 2,2 γ 679;	0-		154
	y 280; 438, 474; 909	γ 963; 919; 561; 605	γ 278; 228 e	α 5,378 γ 988, 889	sf; γ 60; 26 e ⁻ : g	st; y (49) y (42) o 1700 07: 0	st; y 75; 44 a 75 + 5	- γ (1084) 898; e ⁻ ; g 154; e ⁻	7 253; (241; 296)	y 1079; 205; 799; 154;	γ 285; 226		
α 6,41	g	9	0	9	<u>σ 50 + 570; σ₁ 3.1</u>	ay 7000 ay 2100	a1 0,074	oy 1600 oy 2200	e";g	1062 756	0		
Pu 235	Pu 236	Pu 237	Pu 238	Pu 239	Pu 240	Pu 241	Pu 242	Pu 243	Pu 244	Pu 245	Pu 246	Pu 247	
25,3 m	2,858 a	45,2 d	87,74 a	2,411 · 10 ⁴ a	6563 a	14,35 a	3,750 · 10 ⁵ a	4,956 h	8,00 · 10 ⁷ a	10,5 h	10,85 d	2,27 d	
sf	sf α 5.768; 5.721	sf	Sf a 5,499; 5,456	Sf a 5,157; 5,144	sf a 5,168; 5,124	st 8= 0.02; g	st a 4,901; 4,856	st	ST a 4,589; 4,546	Sf β ⁻ 0.9; 1,2	0=00.00		
a 5.85	st; Mg 28	n 5.334	st; Si; Mg y (43: 100); e ⁻	sf; γ (52) e ⁻ : m	st; γ (45) e ⁻ : α	α 4,896 γ (149); e ⁻	sf, γ (45) e ⁻ : g	β 0,6 γ 84; 0	st; y	γ 327; 560; 308; g	γ 44; 224; 180		
0	σt 160	a ₁ 2300	σ 510; σt 17	a 270; at 752	a 290; d) = 0,044	σ 370; σ ₁ 1010	σ 19; σ ₁ < 0,2	σ < 100; σ ₁ 200	a 1,7	o 150	m1	β-	
Np 234	Np 235	Np 236	Np 237	Np 238	Np 239	Np 240	Np 241	Np 242	Np 243	Np 244			
4,4 d	396,1 d	22,5 h 1.54 · 10 ⁵ a	2,144 · 10 ⁶ a	2,117 d	2,355 d	7,22 m 65 m	13,9 m	2,2 m 5,5 m	1,85 m	2,29 m			
«; β*	ε; α 5,025;	e. 8-0.5 8-10	st	β-1,2	β= 0,4; 0,7	β ⁻ 2.2, β ⁻ 0,9- γ 555; γ 566;	0= 1 2	β 2,7 β y 736: y 786:	o= *	β-	152		
γ 1559; 1528; 1602	γ(26; 84); e ⁻	γ (642; γ 160; 688); e 104; e	a 4,790; 4,774 v 29; 87; e ⁻	1026; 924; e ⁻	228; e ⁻ ; g	597 974; e 601;	γ 175; (133)	780; 945; 1473, 159,	γ 288	163; 111			
σι - 900	g; σ 160 + ?	g: at 2700 g: at 2600	σ 180; σ ₁ 0,020	g; of 2100	$\sigma 32 + 19; \sigma_1 < 1$	lγ; g 448; g	9	9 9	9	9		6	
U 233	U 234	U 235	U 236	U 237	U 238	U 239	U 240		U 242				
1,592 · 105 a	0,0055	0,7200	120 ns 2,342 - 107 a	6,75 d	99,2745	23,5 m	14,1 h		16,8 m				
α 4,824; 4,783	2,455 · 10 ⁵ a	26 m 7,038-10ª a	α 4,494; 4,445;	β-0,2	270 ns 4,468 · 10 ⁹ a	0-12:13	β-0,4		β- 	l con	าทอบท	nd svst	tems
γ (42; 97); e ⁻	α 4,775, 4,723; st Mg 28; Ne; γ (53; 121)	α 4.398; sf Iv (0,07) Ne; y 186	lγ 1783; sf; γ (49; 642 113)	e ⁻	1679. 2514. a.4,198; st 1679. 287. y (50); st	γ 75; 44	e ⁻		573				
σ 47; σι 530	e"; a 96; aj < 0,005	e ⁻ σ 95; σ ₁ 586	at 07: 05.1	σ ~ 100; σt < 0,35	a 02,7; m 3,10 %	σ 22; σι 15	m		m]			

Previous work:

(sf), (n_{th}, f)





Cf 239	Cf 240	Cf 241	Cf 242	Cf 243	Cf 244	Cf 245	Cf 246	Cf 247	Cf 248	Cf 249	Cf 250	Cf 251	Cf 252
~ 39 s	1,06 m	3,78 m	3,68 m	10,7 m	19,4 m	43,6 m	35,7 h	3,11 h	333,5 d	350,6 a	13,08 a	898 a	2,645 a
		1200		1887			α 6,750; 6,708		α 6,258; 6,217	α 5,812; 5,758	α 6,030; 5,989	α 5,679; 5,849;	α 6,118; 6,076
α 7,63	α 7,59 sf	ε α 7,342	α 7,392; 7,358 € ?	α 7,06; 7,17 9	α 7,209; 7,174 9	α 7,137 g	st γ (42; 96…) e ⁻ ; g	α 6,296; 6,238 γ (294; 448; 418); e	st γ (43) e ⁻ ; g	st γ 388; 333…; g σ 500; στ 1700	st γ (43); e ⁻ σ 2000; σt < 3 50	ο 2900; στ 4500	si γ (43); e σ 20; σt 32
Bk 238		Bk 240		Bk 242	Bk 243	Bk 244	Bk 245	Bk 246 1,80 d	Bk 247 1380 a	Bk 248	Bk 249 320 d	Bk 250 3,217 h	Bk 251 55,6 m
				sf	sf	sf	sf	•	α 5,531; 5,710;	8-0.9	β= 0,1; α 5,419;	β= 0,7; 1,8	-
e βst		e βst		:	? α 6.575, 6.543 γ 755, 946 9	α 6,662, 6,620 γ 892; 218; 922 g	γ 253, 381 e g	γ 799; 1081; 834; 1124 e ⁻	5,688 γ 84; 265 g	γ 551 α? β ⁻ ? ε ⁻ ε?	5,391; st γ (327; 308) σ 700; σt ~ 0,1	γ 989; 1032; 1029 σι 1000	β ⁻ - 0,9; 1,1 γ 178; 130; 153
	Cm 238	Cm 239	Cm 240	Cm 241	Cm 242	Cm 243	Cm 244	Cm 245	Cm 246	Cm 247	Cm 248	Cm 249 64 15 m	Cm 250
	2,4 11	011	sf	sf ·	sf a 6,113, 6,069	sf a 5,785, 5,742	sf	sf	a 5,386; 5,343	α 4,870; 5,267	0,10 10 u	β= 0,9	or ou
		۴ × 188	α 6,291; 6,248	o 5.939. y 472, 431, 132	st; g	ε, sr, g γ 278; 228; 210 μ°	a 5,805, 5,762 sf; g ~ (43,): e*	a 5,361; 5,304 sf; g x 175: 133	sf; g v (45); e ⁻	γ 402; 278 g	α 5,078; 5,035 st; γ; e [−] ; g	γ 634; (560; 369); e ⁻	sf α ?; β ⁻ ?
	α 6,52	9	9	0	v1-5	σ 130; σ ₁ 620	o 15; of 1,1	σ 350; σ ₁ 2100	σ 1,2; σι 0,16	σ 60; σι 82	σ 2,6; σι 0,36	σ ~ 1,6	σ - 80
Am 236	Am 237	Am 238	Am 239	Am 240	Am 241	Am 242	Am 243	Am 244	Am 245	Am 246	Am 247		
4,4 m	73,0 m	1,63 h	11,9 h	50,8 h	432,2 a	141 a 16 h	7370 a	26 m 10,1 h	2,05 h	25 m 39 m	22 m		154
	a 6,042	a 5,94 ~ 963: 019: 561	a 5,774 y 278:228	ST	a 5,486, 5,443 af: x 60: 26	a 5,206 0.7. c	a 5,275; 5,233 st: v 75: 44	y (1084) 898:	β ⁺ 0,9 γ 253:	2.2 y 679; y 1079; 205;	β-		154
¢ 0.6.41	909	605	e	γ 988, 889 g	e g σ 50 + 570; σι 3.1	o 1700 0 g	a 75 + 5 a, 0.074	e : g 154; e g 1600 g 2200	(241; 296) e~; g	799; 154; 1062 756	γ 285; 226 e ⁻		
Pu 235	Pu 236	Pu 237	Pu 238	Pu 230	Pu 240	Pu 241	Pu 242	Pu 243	Pu 244	Pu 245	Pu 246	Pu 247	
25.3 m	2.858 a	45.2 d	87.74 a	2,411 · 10 ⁴ a	6563 a	14,35 a	3,750 · 10 ⁵ a	4,956 h	8,00 · 10 ⁷ a	10,5 h	10,85 d	2,27 d	
sf	sf a 5.768: 5.721	sf	sf a 5.499: 5.456	sf x 5.157 5.144	sf a 5.168; 5.124	sf 8= 0.02; g	sf a 4,901; 4,856	sf	sf a 4,589; 4,546	sf 8 ^{-0.9; 1.2}			
a 5,85 y 49; (756: 34)	st; Mg 28 + (48; 109); e ⁻	n 5,334 7 60 e	st; Si; Mg y (43; 100); e ⁻	st; γ (52…) o∵.m	st; γ (45) e ⁻ ; g	α 4,896 γ (149); e	sf; γ (45) e ; g	β 0,6 γ 84; g	st; y	γ 327; 560; 308; g	γ 44; 224; 180		
0	σι 160	a ₁ 2300	σ 510; στ 17	σ 270; σ ₁ 752	σ 290; σ ₁ = 0.044	σ 370; σ ₁ 1010	σ 19; σ _f < 0,2	σ < 100; σ ₁ 200	a 1,7	σ 150	m1	β-	
Np 234	Np 235	Np 236	Np 237	Np 238	Np 239	Np 240	Np 241	Np 242	Np 243	Np 244			
4,4 d	396,1 d	22,5 h 1,54 · 10 ⁵ a	2,144 · 10 ⁶ a	2,117 d	2,355 d	7,22 m 65 m	13,9 m	2,2 m 5,5 m	1,85 m	2,29 m	150		
γ 1559; 1528;	ε, α 5,025; 5,007	 ε: β⁻ 0,5 ε: β⁻ ; α γ (642; γ 160; 	a 4,790; 4,774	y 984; 1029;	γ 106; 278;	γ 555; γ 566; 597 974;	β ⁻ 1,3	γ 736; γ 786; 780: 945;	β-	γ 217; 681;	152		
1602 or - 900	γ(26; 84); e ⁻ g; σ 160 + ?	688); e ⁻ 104; e ⁻ g; g; 2700 g; g; 2600	γ 29; 87; e ⁻ σ 180; σ ₁ 0,020	1026; 924; e ⁻ g; or 2100	228; e ⁻ ; g	e 601; hy; g 448; g	γ 175; (133) g	1473 159 0 0	γ 288 g	163; 111 g			
11 233	11 234	U 235	11,236	U 237	U 238	U 239	U 240		U 242				
1,592 · 10 ⁵ a	0,0055	0,7200	120 ns 2,342-107 a	6,75 d	99,2745	23,5 m	14,1 h		16,8 m			_	
α 4,824; 4,783	2,455 · 10 ⁵ a	26 m 7,038-10 ⁸ a	α 4,494; 4,445	β- 0.2	270 ns 4,468 · 10 ⁹ a	0=10.10	β-0.4		β-	con	าทดมห	hd syst	tems
Ne 25; γ (42; 97); e	α 4,775, 4,723; st Mg 28; Ne; γ (53; 121)	α 4,398; st Hy (0,07) Ne; y 186	lγ 1783; sf; γ (49; 642 113)	γ 60; 208 e ⁻	h 2534 α 4,198st 1879	γ 75; 44	9 44; (190) e ⁻		573		pour	ia 5y5	
σ 47; σι 530	e ⁻ , σ 96; σ ₁ < 0,005	e ⁻ a 95; aj 586	et e : 0 5.1	$\sigma \sim 100; \sigma_1 < 0.35$	d 027. of 3101	σ 22; σι 15	m		m]			

Previous work:

(sf), (n_{th}, f), (n, f)





Cf 239 ~ 39 s	Cf 240 1,06 m	Cf 241 3,78 m	Cf 242 3,68 m	Cf 243 10,7 m	Cf 244 19,4 m	Cf 245 43,6 m	Cf 246 35,7 h α 6,750; 6,708	Cf 247 3,11 h	Cf 248 333,5 d α 6,258; 6,217	Cf 249 350,6 a α 5,812; 5,758 sf	Cf 250 13,08 a α 6,030; 5,989 sf	Cf 251 898 a α 5,679; 5,849; 6,012	Cf 252 2,645 a α 6,118; 6,076
α 7,63	α 7,59 sf	α 7,342	α 7,392; 7,358 € ?	α 7,06; 7,17 9	α 7,209; 7,174 g	α 7,137 g	γ (42; 96…) e [–] ; g	γ (294; 448; 418); e	γ (43) e ⁻ ; g	γ 388; 333; g σ 500; σι 1700	γ (43…); e σ 2000; σt < 3 50	γ 177; 227 σ 2900; σ ₁ 4500	γ (43); e σ 20; σ ₁ 32
Bk 238		Bk 240		Bk 242	Bk 243	Bk 244	Bk 245	Bk 246	Bk 247 1380 a	Bk 248	Bk 249 320 d	Bk 250 3.217 h	Bk 251
βsf		βst		sf	Sf ? α 6.575. 6.543 γ 755. 946 9	Sf	Sf * 0.5888; 0,150 y 253; 381 g	ε γ 799; 1081; 834; 1124 e	α 5,531; 5,710; 5,688 γ 84; 265 g	β ⁻ 0.9 • γ 551 α ⁻ • • • • • 7	$\begin{array}{l} \beta^{-} \ 0,1; \ \alpha \ 5,419; \\ 5,391; \ sf \\ \gamma \ (327; \ 308) \\ \sigma \ 700; \ \sigma_1 \ - \ 0,1 \end{array}$	β 0,7; 1,8 γ 989; 1032; 1029 σ ₁ 1000	β - 0,9; 1,1 γ 178; 130; 153
	Cm 238	Cm 239	Cm 240	Cm 241	Cm 242	Cm 243	Cm 244	Cm 245	Cm 246 4730 a	Cm 247	Cm 248	Cm 249 64.15 m	Cm 250 ~ 9700 a
	ε α 6.52	ε γ 188 g	Sf a 6,291; 6,248 sf g	Sf (0.5,939 y 472, 431, 132 0		Sf α 5.785; 5,742 ε; sf; g γ 278; 228; 210; e σ 130; σ ₁ 620	Sf α 5,805; 5,762 sf; g γ (43); e ⁻ σ 15; σ _f 1,1	Sf α 5,361; 5,304 st; g γ 175; 133 σ 350; σ ₁ 2100	$\begin{array}{c} \alpha \ 5,386; \ 5,343\\ sf; \ g\\ \gamma \ (45); \ e^-\\ \sigma \ 1,2; \ \sigma_1 \ 0,16 \end{array}$	α 4,870; 5,267 γ 402; 278 9 σ 60; σt 82	α 5,078; 5,035 st; γ; e ⁻ ; g σ 2,6; σ ₁ 0,36	$\begin{array}{c} \beta^{-} \ 0,9\\ \gamma \ 634; \ (560;\\ 369); \ e^{-}\\ \sigma \sim 1,6 \end{array}$	st α ?; β ? σ - 80
Am 236 4,4 m	Am 237 73,0 m sf • 6.042 • 280; 438; 474; 009 g	Am 238 1,63 h sf * 5.94 * 963; 919; 561; 9	Am 239 11,9 h sf 4 5,774 7 278: 228 9	Am 240 50,8 h	Am 241 432,2 a sf α 5,486; 5,443 sf; γ 60; 26 σ 50 + 570; σf 3,1	Am 242 141 a 16 h sf 14(49).e ⁻ B ⁻ 0.6 s 5,200 0.7, e st,7(49) 7(42) o 1700 e ⁻ ;g o ⁻ ;g o ⁻ ;g o ⁻ ;g	Am 243 7370 a sf a.5,275; 5,233 sf; y 75; 44 o 75 + 5 o (0,074	Am 244 sf ^{26 m} β ^{-1,5} γ(1084) ^{g-1000} ^{g-1000} ^{g-200} ^{g-2200}	Am 245 2,05 h sf ^{β=0.9} 7253: (241; 296) •••9	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Am 247 22 m ^{β⁻} γ 285; 226 e ⁻		154
Pu 235 25,3 m 5,85 9 40; (756; 34)	Pu 236 2,858 a sf σ.5.768; 5.721 sf: Mg 28 γ(48; 109); e ⁻ σ ₁ 160	Pu 237 45,2 d sf	Pu 238 87,74 a sf ^{α 5,499; 5,456} #; Si; Mg γ(43; 100); e ⁻ σ 510; σ ₁ 17	Pu 239 2,411 · 10 ⁴ a sf α,5,157; 5,144 σ; m σ 270; σ ₁ 752	Pu 240 6563 a sf (c,5,168; 5,124) (c); (c); (c); (c); (c); (c); (c); (c)	Pu 241 14,35 a sf ^{β=0.02; g} ^{α 4,896} γ (149); e ⁻ σ 370; σγ 1010	$\begin{array}{c} {Pu \ 242} \\ {sf} \\ \overbrace{{}_{\sigma 4,901; \ 4,856}^{\sigma 7,9} \sigma ^{\circ 7,9} \sigma ^{$	Pu 243 4,956 h sf ^{β=0,6} γ ⁸⁴⁹ σ<100; σ ₁ 200	Pu 244 sf 8,00 · 10 ⁷ a a 4,589; 4,546 sf; 7 o ⁻ o ⁻ o ⁻ , o ⁻ , o ⁻ ,		Pu 246 10,85 d ^{β⁻ 0,2; 0,3} γ 44; 224; 180 m1	Pu 247 2,27 d	
Np 234 4,4 d ϵ; β* γ 1559; 1528; 1602 σ1 - 900	Np 235 396,1 d ε; α 5,025; 5,007 γ(26; 84); e ⁻ g; σ160 + ?	Np 236 22,5 h 1,54 · 10 ⁵ a • (β ⁻ 0,5 • γ (642; 688); e ⁻ γ (60; 048); e ⁻ 0 (9, -γ 260) 04, -γ 2600	Np 237 2,144 · 10 ⁶ a sf α 4,790; 4,774 γ 29; 87 e ⁻ σ 180; σ _f 0,020	Np 238 2,117 d β ⁻ 1.2 γ 984; 1029; 1026; 924; e ⁻ g; σ ₁ 2100	$\begin{array}{c} Np \ 239 \\ 2,355 \ d \\ \beta^- \ 0,4; \ 0,7 \\ \gamma \ 106; \ 278; \\ 228; \ e^-; \ g \\ \sigma \ 32 + 19; \ \sigma_1 < 1 \end{array}$	Np 240 7,22 m 65 m β=2,2, β=0,9. γ 555; 597 φ= 601; ή 948	Np 241 13,9 m β ⁻ 1,3 γ 175; (133) 9	Np 242 2,2 m 5,5 m β ⁻² ,7 β ⁻ γ 736; γ 786; 780; 945; 1473 159 9 9	Np 243 1,85 m ^{β⁻} _{γ 288}	Np 244 2,29 m β ⁻ γ 217; 681; 163; 111 9	152		
U 233 1,592 \cdot 10 ⁵ a α 4,824; 4,783 Ne 25; γ (42; 97); e ⁻ σ 47; σ 530	U 234 0,0055 2,455 · 10 ³ a « 4,775; 4,723; et Mg 28; Ne; ₁ (53; 121) « ⁺ ; « 96: ₀₁ < 0.005	U 235 0,7200 26 m 7,038-10 ⁸ a a 4,398st Ne; y 186 e ⁻ o 95. at 566	U 236 120 ns 2,342-10 ⁷ a α 4,494; 4,445; 51; γ (49; 113) 61 0 ⁻ ; σ 5,1	$\begin{array}{c} U \ 237 \\ 6,75 \ d \\ \beta^{-} \ 0,2 \\ \gamma \ 60; \ 208 \\ e^{-} \\ \sigma \ - \ 100; \ \sigma_{1} < 0.35 \end{array}$	U 238 99,2745 270 m 102 102 270 m 4,468-10 ⁹ a 4,108d 270 m 270 m 270 m 270 m 270 m 270 m	U 239 23,5 m ^{β⁻} 1,2; 1,3 _γ 75; 44 _σ 22; σ ₁ 15	$\begin{array}{c} U \ 240 \\ 14,1 \ h \\ \beta^- \ 0,4 \\ \gamma \ 44; \ (190) \\ e^- \\ m \end{array}$		$\begin{array}{c} U \ 242 \\ 16,8 \ m \\ \beta^{-} \\ \gamma \ 68; \ 58; \ 585; \\ 573 \\ m \end{array}$	con	npour	nd syst	tems

Previous work:

(sf), (n_{th}, f), (n, f), (d, pf)





Cf 239 ~ 39 s	Cf 240 1,06 m	Cf 241 3,78 m	Cf 242 3,68 m α 7.392; 7.358	Cf 243 10,7 m	Cf 244 19,4 m	Cf 245 43,6 m	Cf 246 35,7 h α 6,750; 6,708 sf γ (42; 96)	Cf 247 3,11 h a 6,296; 6,238 y (294; 448;	Cf 248 333,5 d α 6,258; 6,217 sf γ (43)	Cf 249 350,6 a α 5,812; 5,758 sf γ 388; 333; g	Cf 250 13,08 a α 6,030; 5,989 sf γ (43); e ⁻	Cf 251 898 a α 5,679; 5,849; 6,012 γ 177; 227	Cf 252 2,645 a α 6,118; 6,076 sf γ (43); e ⁻		
Bk 238 144 s	51	а 7,342 Вк 240 5 m	er	Bk 242 7 m sf	Bk 243 4,5 h 4,5 h • 6.575. 6.543. 755. 946.	Bk 244 4,35 h sf • 6.662, 6.620 • 992; 218; 922	Bk 245 4,90 d sf * 5.888.6,150 * 7253,381 *	Bk 246 1,80 d 7799; 1081; 834; 1124	Bk 247 1380 a α 5,531; 5,710; 5,688 γ 84; 265 g	Bk 248 23.7 h > 9 a β ⁻ 0.9 ³ γ551 ³ γ ⁻ ⁷ σ ⁻ 7	$\begin{array}{c} Bk \ 249 \\ 320 \ d \\ \beta^{-} 0.1; \alpha 5.419; \\ 5,391; \ sf \\ \gamma (327; 308) \\ \sigma \ 700; \ \sigma_{1} - 0.1 \end{array}$	Bk 250 3,217 h β ⁻ 0,7; 1,8 γ 989; 1032; 1029 φ; 1000	$\begin{array}{c} Bk \ 251 \\ 55,6 \ m \\ \beta^ 0.9; \ 1,1 \\ \gamma \ 178; \ 130; \\ 153 \end{array}$		
	Cm 238 2,4 h	Cm 239 3 h	Cm 240 27 d sf	Cm 241 32,8 d \$5,939 7 472; 431; 132 9	Cm 242 162,94 d sf a 6,113, 6,069 sf, g y (44); e ⁻ g - 20 v ₁ - 5	Cm 243 29,1 a sf α 5,785; 5,742 ε; sf; g γ 278; 228; 210e ^a σ 130; σ ₁ 620	Cm 244 18,10 a sf s; g y (43); e ⁻ o 15; or 1.1	Cm 245 8500 a st a 5.381; 5.304 st: g y 175; 133 y 350; y 2100	Cm 246 4730 a α 5,386; 5,343 sf; g γ (45); e σ 1,2; σ ₁ 0,16	Cm 247 1,56 · 10 ⁷ a α 4,870; 5,267 γ 402; 278 9 σ 60; σ ₁ 82	Cm 248 3,40 · 10 ⁵ a ^{α 5,078; 5,035} st; γ; e ⁻ ; g σ 2,6; σ 0,36	$\begin{array}{c} Cm \ 249 \\ 64,15 \ m \\ {}^{\beta^- 0,9}_{\gamma \ 634; \ (560; \\ 369); \ e^- \\ \sigma \ \sim \ 1,6 \end{array}$	Cm 250 ~ 9700 a sf α ?; β ⁻ ? σ - 80		
Am 236 4,4 m	Am 237 73,0 m	Am 238 1,63 h sf 963: 919: 561: 05. 9	Am 239 11,9 h • 5,774 • 7 276: 226 • 9	Am 240 50,8 h	Am 241 432,2 a st c 5,486; 5,443 st; y 60; 26 c 7:9 c 50 + 570; cy 3,1	Am 242 141 a 16 h 51 4(49), e ⁻ 5,2000,7,8 st,7(49) 1700 4,7,9 a,7009 a,2100	Am 243 7370 a sf a.5.275; 5.233 sf; y.75; 44 a.75; +5 ar, 0.074	Am 244 sf 26 m 10,1 h β ^{-1,5} γ(1084) 898; σ1600 154;σ ⁻ σ2200	Am 245 2,05 h sf β ^{- 0,0} γ253 (241;296) θ ⁻ ;9	Am 246 25 m 39 m 39 m 39 m 39 m 37 39 m 39 m 30 m 	Am 247 22 m ^{β⁻} γ 285; 226 e ⁻		154		
Pu 235 25,3 m	Pu 236 2,858 a sf α 5,768; 5,721 sf, Mg 28 γ (48; 109); e ⁻ σ ₁ 160	Pu 237 45,2 d	Pu 238 87,74 a sf sf, 5,499; 5,456 sf; Si; Mg y (43; 100); e ⁻ o 510; o ₁ 17	Pu 239 2,411 · 10 ⁴ a sf σ.5,157; 5,144 st, γ (52) φ.7m σ.270; σ ₁ ,752	Pu 240 6563 a sf α.5.168: 5.124 sf; γ (45) α ⁻ 20 α ⁻ 20, σ) = 0.049	Pu 241 14,35 a sf β ^{-0,02;} g α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	Pu 242 3,750 · 10 ⁵ a st γ (45) σ 19, σ ₁ < 0,2	Pu 243 4,956 h sf ^{β^{-0,6} γ^{84;9} σ^{(100, σ}, 200}	Pu 244 sf 8,00 · 10 ⁷ a a 4,589; 4,546 sf; 7 o ⁻ o ⁻ o ⁻ ,7	Pu 245 10,5 h sf ^{β⁻0.9; 1,2} ^{γ 327; 560; 308; 9} o 150	Pu 246 10,85 d β ⁼ 0,2; 0,3 γ 44; 224; 180	Pu 247 2,27 d			
Np 234 4,4 d «; β ⁺ γ 1559; 1528; 1602 σ1 - 900	Np 235 396,1 d ε; α 5,025; 5,007 γ(26; 84); e g; σ160 + ?	Np 236 22,5 h 1.54 · 10 ⁵ a γ 642; γ 160; 668; φ 104; φ - 104; φ - 104; φ - 104; φ -	Np 237 2,144 · 10 ⁶ a a 4,790; 4,774 γ 29; 87 e ⁻ σ 180; σ ₁ 0,020	Np 238 2,117 d β ⁻ 1,2 γ 984; 1029; 1026; 924; e ⁻ g; σ ₁ 2100	$\begin{array}{c} Np \ 239 \\ 2,355 \ d \\ \beta^- \ 0,4; \ 0,7 \dots \\ \gamma \ 106; \ 278; \\ 228 \dots; \ e^-; \ g \\ \sigma \ 32 + 19; \ \sigma_1 < 1 \end{array}$	Np 240 7,22 m 65 m β-2.2 β-0.9. γ 555; 597 6° 601; h 944	Np 241 13,9 m ^{β⁻ 1,3} _γ 175; (133) 9	Np 242 2,2 m 5,5 m β ⁻² ,7 β ⁻ γ 736; γ 786; 780; 945; 1473 159 9 9	Np 243 1,85 m ^{β⁻} _{γ 288}	Np 244 2,29 m β ⁻ γ 217; 681; 163; 111 9	152				
U 233 1,592 · 10 ⁵ a α 4,824; 4,783 Ne 25; γ (42; 97); e σ 47; σ ₁ 530	U 234 0,0055 2,455 · 10 ⁵ a 4,775 4,723; st Mg 28, Ne; _Y (53; 121) e ⁻ ; o ⁻ 96; o _f < 0,005	U 235 0,7200 26 m 7,038-10 ⁴ a hy (0.07) e ⁻ x, 186, y 95; cy 566	U 236 120 ns 2,342-10 ⁷ a α 4,494; 4,445; 642 at 0 ⁻ ; σ 5,1	$\begin{array}{c} U \ 237 \\ 6,75 \ d \\ \beta^{-} \ 0,2 \\ \gamma \ 60; \ 208 \\ e^{-} \\ \sigma \sim 100; \ \sigma_1 < 0,35 \end{array}$	U 238 99,2745 270 ns. 4,468-10 ⁹ n 19254 1936 1937 1938 1939 1939 1939 1939 1939 1939 1939	U 239 23,5 m β ⁻ 1.2; 1,3 γ 75; 44 σ 22; σ; 15	U 240 14,1 h ^{β⁻0,4} ^{γ 44;} (190) ^{e⁻} m		U 242 16,8 m ^{β⁻} γ 68; 58; 585; 573 m	compound systems					
Prev	Previous work: $(sf), (n_{th}, f), (n, f), (d, pf)$														





Cf 239 ~ 39 s	Cf 240 1,06 m	Cf 241 3,78 m	Cf 242 3,68 m	Cf 243 10,7 m	Cf 244 19,4 m	Cf 245 43,6 m	Cf 246 35,7 h α 6,750; 6,708	Cf 247 3,11 h	Cf 248 333,5 d a 6,258; 6,217	Cf 249 350,6 a ^{a, 5,812; 5,758}	Cf 250 13,08 a α 6,030; 5,989	Cf 251 898 a a 5,679; 5,849;	Cf 252 2,645 a a 6,118; 6,076
α 7.63	α 7,59 sf	ε α 7.342	α 7,392; 7,358 ε ?	α 7,06; 7,17 g	α 7,209; 7,174 g	α 7,137	sτ γ (42; 96…) e ⁻ ; g	α 6,296; 6,238 γ (294; 448; 418); e ⁻	si γ (43) e ⁻ ; g	γ 388; 333…; g σ 500; σι 1700	si γ (43…); e ⁻ σ 2000; σ ₁ < 350	γ 177; 227 σ 2900; σ ₁ 4500	γ (43); e σ 20; σ _f 32
Bk 238 144 s		Bk 240 5 m		Bk 242 7 m	Bk 243 4,5 h	Bk 244 4,35 h	Bk 245 4,90 d	Bk 246 1,80 d	Bk 247 1380 a	Bk 248 23.7 h > 9 a	Bk 249 320 d	Bk 250 3,217 h	Bk 251 55,6 m
ßst		e βst		:	? α 6.575, 6.543 γ 755, 946 9	¢ α 6,662; 6,620 γ 892; 218; 922 g	n 5,888; 6,150	γ 799; 1081; 834; 1124 e	5,688 γ 84; 265 g	α? γ 551 α? φ ⁻ ε?	5,391; sf γ (327; 308) σ 700; σ ₁ ~ 0,1	γ 989; 1032; 1029 στ 1000	β ~ 0,9; 1,1 γ 178; 130; 153
	Cm 238 2,4 h	Cm 239 3 h	Cm 240 27 d	Cm 241 32,8 d	Cm 242 162,94 d	Cm 243 29,1 a	Cm 244 18,10 a	Cm 245 8500 a	Cm 246 4730 a	Cm 247 1,56 · 10 ⁷ a	Cm 248 3,40 · 10 ⁵ a	Cm 249 64,15 m	Cm 250 ~ 9700 a
	ε α 6,52	е у 188 g	α 6,291; 6,248 st g	a 5,939 y 472, 431; 132 e g	sf; 9 γ (44); σ ⁻ σ - 20 σ _f - 5	ε; sf; g γ 278; 228; 210; e σ 130; σ ₁ 620	α 5,805; 5,762 st; g γ (43); e ⁻ σ 15; σ _f 1,1	α 5,361; 5,304 st; g γ 175; 133 σ 350; σ ₁ 2100	α 5,386, 5,343 sf; g γ (45); e σ 1,2; σ _f 0,16	α 4,870, 5,267 γ 402; 278 g σ 60; σι 82	α 5,078; 5,035… st; γ; e ; g σ 2,6; σ ₁ 0,36	γ 634; (560; 369); e ⁻ σ ~ 1,6	sf α ?; β ? σ - 80
Am 236 4,4 m	Am 237 73,0 m	Am 238	Am 239 11,9 h	Am 240 50,8 h	Am 241 432,2 a	Am 242	Am 243 7370 a	Am 244	Am 245 2,05 h	Am 246	Am 247 22 m		
ε α 6,41	ST • a 6,042 y 280; 438, 474; 909 g	ST * a 5,94 y 963; 919; 561; 605 9	ST *	ST	ST α 5,486; 5,443 st; γ 60; 26 e ⁻ ; g σ 50 + 570; σ ₁ 3,1	ST γ ₁ (49), e 6 0.0 a 5,206 0,7 • st γ (49) γ (42) σ 1700 e ; g σ ₁ 7000 σ ₁ 2100	ST α 5,275; 5,233 sf; y 75; 44 σ 75 + 5 σ ₁ 0.074	SI ^{β 1,2} ^{β 0,4} γ 744, γ (1084) 898; e ⁻ ; g 154; e ⁻ α ₁ 1600 α ₁ 2200	ST β ⁺⁻ 0,9 γ 253; (241; 296) e ⁻ ; g	ST p 1,4; p 2,2 y 679; y 1079; 205; 799; 154; 1062 756	β γ 285; 226 e		154
Pu 235	Pu 236 2,858 a	Pu 237 45,2 d	Pu 238 87,74 a	Pu 239 2,411 · 10 ⁴ a	Pu 240 6563 a	Pu 241 14,35 a	Pu 242 3,750 · 10 ⁵ a	Pu 243 4,956 h	Pu 244 8,00 · 10 ⁷ a	Pu 245 10,5 h	Pu 246 10,85 d	Pu 247 2,27 d	
ST α 5,85 γ 49; (756; 34) e ⁻	ST α 5,768; 5,721 st; Mg 28 γ (48; 109); e ⁻ σ _f 160	sτ n 5.334 γ 60 θ σ _f 2300	ST α 5,499; 5,456 st; Si; Mg γ (43; 100); e ⁻ σ 510; σ ₁ 17	SI α 5,157; 5,144 sf; γ (52) θ ⁻ ; m σ 270; σ ₁ 752	SI a 5,168; 5,124 st; $\gamma (45)$ $0^{-}; g$ $\sigma 290; \sigma - 0.044$	ST β ⁼ 0,02; g α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	S1 α 4,901; 4,858 sf; γ (45) $\Theta^{-}; g$ σ 19; $\sigma_{1} < 0.2$	β 0,6 γ 84; g σ < 100; σ ₁ 200	SI a 4,589; 4,546 st; γ e ⁻ a 1,7	β 0.9; 1,2 γ 327; 560; 308; g σ 150	β 0,2; 0,3 γ 44; 224; 180 m ₁	β-	
Np 234 4,4 d	Np 235 396,1 d	Np 236 22,5 h 1,54 · 10 ⁵ a	Np 237	Np 238 2,117 d	Np 239 2,355 d	Np 240 7,22 m 65 m	Np 241 13,9 m	Np 242 2,2 m 5,5 m	Np 243 1,85 m	Np 244 2,29 m			
 ε; β* γ 1559; 1528; 1602 σ1 - 900 	ε; α 5,025; 5,007 γ(26; 84); e ⁻ g; σ 160 + ?	 ε: β⁻ 0,5 ε: β⁻ 0,5 ε: β⁻ 160; 688); ε⁻ 104; ε⁻ 9: σ₁ 2700 9: σ₁ 2600 	α 4,790; 4,774 γ 29; 87; ε ⁻ σ 180; σ ₁ 0,020	β ⁻ 1,2 γ 984; 1029; 1026; 924; e ⁻ g; σ; 2100	β 0,4; 0,7 γ 106; 278; 228; e ⁻ ; g σ 32 + 19; σ ₁ < 1	p c.s., r p 0.9 γ 555; γ 566; 597 974; 601; hγ; g 448; g	β 1,3 γ 175; (133) g	β ^{-2,7} β ⁻ γ 736; γ 786; 780; 945; 1473 159 0 0	β ⁻ γ 288 g	β ⁻ γ 217; 681; 163; 111 9	152		
U 233 1,592 · 10 ⁵ a	U 234 0,0055	U 235 0,7200	U 236	U 237 6,75 d	U 238 99,2745	U 239 23,5 m	U 240 14,1 h		U 242 16,8 m				
α 4,824; 4,783 Ne 25; γ (42; 97); e σ 47; σ ₁ 530	2,455 · 10 ⁵ a α 4,775; 4,723; sl Mg 28; Ne; γ (53; 121) σ ⁻ ; σ 96; σ ₁ < 0,005	26 m ^α 4.398; st Ne; γ 186 e ⁻ σ 95; σ ₁ 586	α 4,494; 4,445; iγ 1783; sf; γ (49; 642 sf e ⁻⁷ ; σ 5,1	β 0,2 γ 60; 208 e σ ~ 100; σ ₁ < 0,35	270 ns. 4,468-10 ⁹ a h; 2534 a 4,198; sl 1679 26/1; y (50) a a 27,1 y 310	β 1,2; 1,3 γ 75; 44 σ 22; σι 15	β ⁻ 0,4 γ 44; (190) e ⁻ m		β γ 68; 58; 585; 573 m	con	npour	id syst	tems
Dress													
Prev	Previous work: $(sf), (n_{th}, f), (n, f), (d, pf)$												
Rece	Recent experiments: (sf)												





Cf 239 ~ 39 s	Cf 240 1,06 m	Cf 241 3,78 m	Cf 242 3,68 m	Cf 243 10,7 m	Cf 244 19,4 m	Cf 245 43,6 m	Cf 246 35,7 h α 6,750; 6,708 sf γ (42; 96)	Cf 247 3,11 h a 6,296; 6,238 y (294; 448;	Cf 248 333,5 d α 6,258; 6,217 sf γ (43)	Cf 249 350,6 a α 5,812; 5,758 sf γ 388: 333; q	Cf 250 13,08 a α 6,030; 5,989 sf γ (43,); e ⁻	Cf 251 898 a	Cf 252 2,645 a α 6,118; 6,076 st γ (43); e ⁻
α 7,63 Bk 238 144 s	s	α 7,342 Bk 240 5 m	e?	g Bk 242 7 m	9 Bk 243 4,5 h 51 (***********************************	g Bk 244 4,35 h sf * 6.662, 6.620 * 882 218 922	e g Bk 245 4,90 d st • 5,888; 6,150 • 253; 381	418); e Bk 246 1,80 d ^e y 799; 1081; 834; 1124.	e ⁻ :g Bk 247 1380 a α 5,531; 5,710; 5,688 γ 84; 265	σ 500; σן 1700 Bk 248 23,7 h φ 0,9 φ 551 φ 7	<u>σ 2000; σt < 350</u> Bk 249 320 d β ⁻ 0,1; α 5,419; 5,391; sf γ (327; 308)	$\begin{array}{c} \sigma & 2900; \ \sigma_1 \ 4500 \\ \hline \\ Bk \ 250 \\ 3,217 \ h \\ \beta^{-} \ 0,7; \ 1,8 \\ \gamma \ 989; \ 1032; \\ 1029 \end{array}$	σ 20; σ ₁ 32 Bk 251 55,6 m β - 0.9; 1,1 γ 178; 130;
βst	Cm 238 2,4 h	βst Cm 239 3 h [¢] γ 188	Cm 240 27 d sf g	g Cm 241 32,8 d 5,939. 1472,431,132.	$\begin{array}{c} g \\ \hline \\ Cm 242 \\ 162,94 d \\ sf & a 6,113,6,069 \\ sf, g \\ \gamma (44,); e^{-} \\ \sigma - 20 \\ \sigma_{\gamma} - 5 \end{array}$	0 Cm 243 29,1 a sf a.5.785,5.742 c.sf.g y 276,228. 210, e o 130, or, 620	g Cm 244 18,10 a sf a 5,805; 5,762 sf; g y (43); e ⁻ a 15; cg 1,1	e Cm 245 8500 a sf a 5.381; 5.304 st.g y 175; 133 y 350; ay 2100	g <u>Cm 246</u> 4730 a ^{α 5,386; 5,343 sf; g γ (45); e⁻ σ 1,2; σ₁ 0,16}	Cm 247 1,56 · 107 a α 4,870; 5,267 γ 402; 278 g σ 60; σ; 82	σ 700; σt = 0,1 Cm 248 3,40 · 10 ⁵ a α 5,078; 5,035 sf, γ; e ⁻ ; g σ 2,6; σt 0,36	$\begin{array}{c} \sigma_{1} \ 1000 \\ \hline $	153 Cm 250 ~ 9700 a sf α ?; β ⁻ ? σ - 80
Am 236 4,4 m	Am 237 73,0 m • 6.042 • 720: 436. 474: 909. 9	Am 238 1,63 h st 4 9963;919;561; 9	Am 239 11,9 h sf 4 0.5.774 1,278.226 9	Am 240 50,8 h sf	Am 241 432,2 a sf a 5,486; 5,443 sf; y 60; 26 e;; g a 50,4 570; g; 3,1	Am 242 141 a 51 Hy (49), e ⁻ a 5,206 a 7,700 a 7,700 a 7,700 a 7,200 a 7	Am 243 7370 a sf \$\$275,5233 \$\$75,544 \$75+5 \$\$0,0074	Am 244 26 m 10,1 h 26 m 4 7 1,5 4 7 (1084) 90; 15490 15490 15490 15490 15490 10,1 h 10,1 h	Am 245 2,05 h sf β ^{- 0,9} ²⁵³ ; (241;296) e ⁻ ; g	Am 246 51 25 m 39 m (b ^{-1,2;} 2.2 799; 1079; 1082 56	Am 247 22 m ^{β⁻} γ 285; 226 e ⁻		154
Pu 235 25,3 m	Pu 236 2,858 a sf σ 5.768; 5.721 σ; 160 γ (48; 100); σ ⁻ σ; 160	Pu 237 45,2 d sf # 5.334 y 60e r, 2300	Pu 238 87,74 a sf st, 5,499; 5,456 st, 51, Mg γ (43; 100); e ⁻ σ 510; σ ₁ 17	Pu 239 2,411 - 10 ⁴ a sf s ¹ ; ₇ (52) o ⁻ m o 270; o ₁ 752	Pu 240 6563 a sf α.5,168; 5,124 σ; γ (45) σ; 290; τη = 0,044	Pu 241 14,35 a sf ^{a - 0,02; g} ^{a 4,896} ^{y (149); e⁻} ^{o 370; or 1010}	$\frac{Pu \ 242}{3,750 \cdot 10^5 \text{ a}}$	Pu 243 4,956 h sf ^{5 849} _{0 < 100; 01} 200	PU 244 st 8,00 · 107 a st; γ o ⁻ o 1,7	Pu 245 10,5 h sf ^{7 327; 560; 3089} ^{9 150}	Pu 246 10,85 d ^{β⁻ 0,2; 0,3} γ 44; 224; 180 m1	Pu 247 2,27 d	
Np 234 4,4 d ε: β* γ 1559; 1528; 1602 σ ₁ = 900	Np 235 396,1 d e; a 5,025; 5,007 y(26; 84); e ⁻ g; a 160 + ?	Np 236 22,5 h 1,54 · 10 ⁵ a • (642; 688); e ⁻ 104; e ⁻ g: σ ₁ 2700 g: σ ₁ 2700	Np 237 2,144 - 10 ⁶ a sf a 4.790; 4.774 y 29; 67; e ⁻ o 180; ar (0,020	Np 238 2,117 d β ⁻ 1,2 γ 984; 1029; 1026; 924; e ⁻ g; σ ₁ 2100	$\begin{array}{c} Np \ 239 \\ 2,355 \ d \\ \beta^- \ 0,4; \ 0,7 \\ \gamma \ 106; \ 278; \\ 228; \ e^-; \ g \\ \sigma \ 32 + 19; \ \sigma_1 < 1 \end{array}$	Np 240 7,22 m 65 m β ⁻ 2.2, β ⁻ 0.9. γ 555; 597 g ⁻ 601; hig 448ig	Np 241 13,9 m β ⁻ 1,3 γ 175; (133) 9	$\begin{array}{c} Np & 242 \\ \textbf{2,2 m} & \textbf{5,5 m} \\ \beta^- 2,7 & \beta^- \\ \gamma^7 36; & \gamma^7 86; \\ 780; & 945; \\ 1473 & 159 \\ 9 & 9 \end{array}$	Np 243 1,85 m ^{β⁻} ^{γ 288} 9	Np 244 2,29 m ^{β⁻} γ217; 681; 163; 111 9	152		
m = 900 g, m 180 + ? g, m 2800 g, m 2800 g, m 2100 g, m 2100 g 32 + 19, m < 1 y - g 444 - g g<												tems	
Pre	Previous work: (sf), (n _{th} , f), (n, f), (d, pf)												
Rece	Recent experiments: (sf), (n _{th} , f)												





Cf 239 ~ 39 s	Cf 240 1,06 m	Cf 241 3,78 m	Cf 242 3,68 m	Cf 243 10,7 m	Cf 244 19,4 m	Cf 245 43,6 m	Cf 246 35,7 h α 6,750; 6,708 sf	Cf 247 3,11 h	Cf 248 333,5 d α 6,258; 6,217	Cf 249 350,6 a α 5,812; 5,758	Cf 250 13,08 a α 6,030; 5,989 sf	Cf 251 898 a α 5,679; 5,849; 6,012	Cf 252 2,645 a α 6,118; 6,076 st
α 7,63 Bk 238 144 s	α 7,59 sf	α 7,342 Bk 240 5 m	α 7,392; 7,358 € ?	Bk 242 7 m	Bk 243	Bk 244 4,35 h	γ (42; 96) e ⁻ ; g Bk 245 4,90 d	γ (294; 448; 418); e ⁻ Bk 246 1,80 d	γ (43) e ^{-;} g Bk 247 1380 a	γ 388; 333; g σ 500; στ 1700 Bk 248 23,7 h > 9 a	γ (43); e ⁻ σ 2000; σt < 350 Bk 249 320 d	γ 177; 227 σ 2900; στ 4500 Bk 250 3,217 h	γ (43); e σ 20; σ ₁ 32 Bk 251 55,6 m
βst		e βst		sf	Sf ? α 6.575, 6.543 γ 755, 946 9	Sf	Sf + α 5.888, 6,150 γ 253; 381 σ ⁺ g	ε γ 799; 1081; 834; 1124 e	α 5,531; 5,710; 5,688 γ 84; 265 g	β ⁻ 0,9 • • • • • • •	$\begin{array}{l} \beta^{-} \ 0,1; \ \alpha \ 5,419; \\ 5,391; \ sf \\ \gamma \ (327; \ 308) \\ \sigma \ 700; \ \sigma_1 \sim 0,1 \end{array}$	β 0,7; 1,8 γ 989; 1032; 1029 σ ₁ 1000	β - 0,9; 1,1 γ 178; 130; 153
	Cm 238 2,4 h	Cm 239 3 h	Cm 240 27 d	Cm 241 32,8 d	Cm 242 162,94 d sf a,6,113; 6,069	Cm 243 29,1 a sf • 5,785; 5,742	Cm 244 18,10 a	Cm 245 8500 a	Cm 246 4730 a a 5,386; 5,343	Cm 247 1,56 · 10 ⁷ a g 4.870; 5.267	Cm 248 3,40 · 10 ⁵ a	Cm 249 64,15 m	Cm 250 ~ 9700 a
	ε α 6,52	ε γ 188 g	α 6,291; 6,248 st g	a 5,939 y 472, 431, 132 e g	st; 9 γ (44); σ ⁻ σ - 20 σ ₁ - 5	ε; sf; g γ 278; 228; 210; e σ 130; σ ₁ 620	α 5,805; 5,762 sf; g γ (43); e σ 15; σ _f 1,1	α 5,361; 5,304 sf; g γ 175; 133 σ 350; σ ₁ 2100	sf; g γ (45); e σ 1,2; σ _f 0,16	γ 402; 278 9 σ 60; σι 82	α 5,078; 5,035 st; γ; e ; g σ 2,6; σ ₁ 0,36	γ 634; (560; 369); e σ ~ 1,6	sf α ?; β ? σ - 80
Am 236 4,4 m	Am 237 73,0 m sf • 6.042 • 280: 438: 474: 909	Am 238 1,63 h sf * 5.94 * 963; 919; 561; 605 9	Am 239 11,9 h sf * 5.774 * 278: 228 9	Am 240 50,8 h	Am 241 432,2 a sf a 5,486; 5,443 sf; y 60; 26 c; 50 c; 50 c; 570; cr, 3,1	Am 242	Am 243 7370 a sf a 5,275; 5,233 sf; y 75; 44 o 75 + 5 g, 0.074	Am 244 sf ^{26 m} 10,1 h φ ^{-1,5} φ ^{-0,4} γ(1084) 808; φ ⁻¹ 1600 φ ₁ 2200 φ ₁ 1600	Am 245 2,05 h sf ^{p=0.9} 253: (241; 296) •:9	Am 246 sf ^{25 m} 39 m ^{25 π} 39 m ^{25 π} 39 m ³⁷ 39 m ³⁷ 205 ⁷⁹⁰ ; 154; 154; 154;	Am 247 22 m ^{β-} γ 285; 226		154
Pu 235 25,3 m	Pu 236 2,858 a	Pu 237 45,2 d	Pu 238 87,74 a	Pu 239 2,411 · 10 ⁴ a	Pu 240 6563 a	Pu 241 14,35 a	Pu 242 3,750 · 10 ⁵ a	Pu 243 4,956 h	Pu 244 8,00 · 10 ⁷ a	Pu 245 10,5 h	Pu 246 10,85 d	Pu 247 2,27 d	
Sf	Sf α 5,768; 5,721 st; Mg 28 γ (48; 109); e ⁻ σ _f 160	st π 5.334 γ 60 θ σ _f 2300	Sf α 5,499; 5,456 st; Si; Mg γ (43; 100); e ⁻ σ 510; σ ₁ 17	ST α 5,157; 5,144 sf; γ (52) e ⁻ ; m σ 270; σ ₁ 752	ST α 5,168; 5,124 sf; γ (45) e ⁻ ; g σ 290; d] = 0,048	ST β ⁻ 0,02; g α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	ST α 4,901; 4,856 sf; γ (45) e ⁻ ; g σ 19, σ ₁ < 0,2	51 β ⁼ 0,6 γ 84; g σ < 100; σ ₁ 200	ST α 4,589; 4,546 st; γ θ ⁻ α 1,7	ST β ⁺ 0.9; 1.2 γ 327; 560; 308; g σ 150	β 0,2; 0,3 γ 44; 224; 180 m ₁	β-	
Np 234 4,4 d ε; β ⁺ γ 1559; 1528; 1602 σ ₁ -900	Np 235 396,1 d ε; α 5,025; 5,007 γ (26; 84); e g; σ 160 + ?	Np 236 22,5 h 1,54 · 10 ⁵ a • (6 ²); 6 ³ (6 ³); 6 ³ • (6 ⁴); 6 ³ (6 ⁴); 6 ³ (7, 6 ²); 7 ¹ (6 ³); 6 ³ (7, 6 ³); 6 ³); 6 ³); 7 ³	Np 237 sf a 4.790; 4.774 y 29; 67; 6 o 180. or 0,020	Np 238 2,117 d β ⁻ 1,2 γ 984; 1029; 1026; 924; e ⁻ g; σ ₁ 2100	Np 239 2,355 d β ⁻ 0,4; 0,7 γ 106; 278; 228; e ⁻ ; g σ 32 + 19; σ] < 1	Np 240 7,22 m 65 m β ⁻ 2.2, β ⁻ 0.9. γ 555; 597 974; 601; hi.g 448i.g	Np 241 13,9 m ^{β⁻ 1,3} γ 175; (133) 9	$\begin{array}{c c} & Np & 242 \\ \hline \textbf{2,2 m} &, & \textbf{5,5 m} \\ \beta^{-2,7,} & \beta^{-} \\ \gamma & 736; & \gamma & 786; \\ 780; & \textbf{445}; \\ 1473, & 159, \\ 9 & 9 \end{array}$	Np 243 1,85 m	Np 244 2,29 m β ⁻ γ 217; 681; 163; 111 9	152		
U 233 1,592 · 10 ⁵ a α.4,824; 4,783 Ne 25; γ (42; 97); e σ 47; σ ₁ 530	U 234 0,0055 2,455 · 10 ⁵ a ^a 4,775,4723; st Mg 28; Ne; γ (53; 121) e ⁻ ; o 96; o ₁ < 0.005	U 235 0,7200 26 m 7,038-10 ⁴ a 4,398; st ht (0.07) r 956 s; st 556	U 236 120 ns 2,342-10 ⁷ a a 4,494; 4,445; 642 tf 07: a 5,1	$\begin{array}{c} U \ 237 \\ 6,75 \ d \\ \beta^{-} \ 0,2 \\ \gamma \ 60; \ 208 \\ e^{-} \\ \sigma - 100; \ \sigma_1 < 0,35 \end{array}$	U 238 99,2745 270 ms 4,468 - 10° m h 234 10° m 277 ms 4,468 - 10° m	U 239 23,5 m β ⁻ 1,2; 1,3 γ 75; 44 σ 22; σ ₁ 15	U 240 14,1 h β ⁻ 0,4 γ 44; (190) e ⁻ m		U 242 16,8 m ^{β⁻} γ 68; 58; 585; 573 m	con	npour	nd syst	tems
Prev	Previous work: (sf), (n _{th} , f), (n, f), (d, pf)												
Rece	Recent experiments: (sf), (n _{th} , f)												





Cf 239 ~ 39 s	Cf 240 1,06 m	Cf 241 3,78 m	Cf 242 3,68 m	Cf 243 10,7 m	Cf 244 19,4 m	Cf 245 43,6 m	Cf 246 35,7 h	Cf 247 3,11 h	Cf 248 333,5 d	Cf 249 350,6 a	Cf 250 13,08 a	Cf 251 898 a	Cf 252 2,645 a
α 7,63	α 7,59 sf	ε α 7,342	α 7,392; 7,358 ε ?	α 7,06; 7,17 g	α 7,209; 7,174 g	ε α 7,137 g	sf γ (42; 96) e ⁻ ; g	α 6,296; 6,238 γ (294; 448; 418); e	sf γ (43) e ⁻ ; g	sf γ 388; 333…; g σ 500; σι 1700	sf γ (43…); e ⁻ σ 2000; σ ₁ < 350	6,012 γ 177; 227 σ 2900; σ ₁ 4500	st γ (43); e σ 20; σ ₁ 32
Bk 238 144 s		Bk 240 5 m		Bk 242	Bk 243 4,5 h	Bk 244 4,35 h	Bk 245	Bk 246 1,80 d	Bk 247 1380 a	Bk 248 23.7 h > 9 a	Bk 249 320 d	Bk 250 3,217 h	Bk 251 55,6 m
¢ βst		e βst		51 0	? α 6.575, 6.543 γ 755, 946 9	6.662, 6.620 γ 892, 218, 922 9	n 5,888, 6,150 γ 253, 381 σ	ε γ 799; 1081; 834; 1124 e	α 5,531; 5,710; 5,688 γ 84; 265 g	β ⁻ 0,9 γ 551 σ ⁻ (?) (?)	β ⁻ 0,1; α 5,419; 5,391; sf γ (327; 308) σ 700; σ ₁ ~ 0,1	β ⁻ 0,7; 1,8 γ 989; 1032; 1029 σι 1000	β ⁺⁻ - 0,9; 1,1 γ 178; 130; 153
	Cm 238 2,4 h	Cm 239 3 h	Cm 240 27 d	Cm 241 32,8 d	Cm 242 162,94 d	Cm 243 29,1 a	Cm 244 18,10 a	Cm 245 8500 a	Cm 246 4730 a	Cm 247 1,56 · 10 ⁷ a	Cm 248 3,40 · 10 ⁵ a	Cm 249 64,15 m	Cm 250 ~ 9700 a
	ε α 6,52	е у 188 g	α 6,291; 6,248 st 9	st * a 5.939 y 472, 431, 132 e ⁻ g	st a 6,113,6,000 af; g γ (44); e ⁻ σ - 20 σ _f - 5	s; a 5,76, 5,742 ε; st; g γ 278; 228; 210; e σ 130; σ ₁ 620	α 5,805; 5,762 sf; g γ (43); e ⁻ σ 15; σ _f 1,1	α 5,361; 5,304 st g γ 175; 133 σ 350; σ ₁ 2100	α 5,386; 5,343 sf; g γ (45); e ⁻ σ 1,2; σ _f 0,16	α 4,870; 5,267 γ 402; 278 g σ 60; σ ₁ 82	α 5.078; 5,035… sf; γ; e ; g σ 2,6; σ ₁ 0,36	β 0,9 γ 634; (560; 369); e σ ~ 1,6	st α ?; β ? σ - 80
Am 236 4,4 m	Am 237 73,0 m	Am 238	Am 239 11,9 h	Am 240 50,8 h	Am 241 432,2 a	Am 242	Am 243 7370 a	Am 244	Am 245 2,05 h	Am 246	Am 247 22 m		
ε α 6,41	ST * a 6,042 y 280; 438; 474; 909 g	Sf * a 5,94 y 963; 919; 561; 605 9	Sf «	ST * α 5,378 γ 988, 889 9	ST α 5,486; 5,443 st; γ 60; 26 e ⁻ ; g σ 50 + 570; σ ₁ 3.1	ST ¹ γ (49), e ⁻ β 0.6 α 5,206 0.7 γ st, γ (49) γ (42) σ 1700 e ⁻ ; g σ ₁ 7000 σ ₁ 2100	sf α 5,275; 5,233 sf; γ 75; 44 σ 75 + 5 σ; 0.074	SI μ ^{-1,5} μ ^{-0,4} • γ (1084) 898; σ ⁻ , g 154; σ ⁻ σ ₁ 1000 σ ₁ 2200	ST β ⁺ 0,9 γ 253; (241; 296) e ⁻ ; g	ST p ⁻¹ ,2; p ⁻ 2,2 y 679; y 1079; 205; 799; 154; 1062 756	β γ 285; 226 e		154
Pu 235 25,3 m	Pu 236 2,858 a	Pu 237 45,2 d	Pu 238 87,74 a	Pu 239	Pu 240 6563 a	Pu 241 14,35 a	Pu 242 3,750 · 10 ⁵ a	Pu 243 4,956 h	Pu 244 8,00 · 10 ⁷ a	Pu 245 10,5 h	Pu 246 10,85 d	Pu 247 2,27 d	
st x a 5,85 y 49; (756; 34) e ⁻	ST α 5,768; 5,721 st; Mg 28 γ (48; 109); e ⁻ σ ₁ 160	st π 5.334 γ 60e ⁻ π _f 2300	ST α 5,499; 5,456 ut; Si; Mg γ (43; 100); e ⁻ σ 510; σ _t 17	ST α 5,157; 5,144 sf; γ (52) e ⁻ ; m σ 270; σ ₁ 752	ST α 5,168; 5,124 sf; γ (45) 0 ; g σ 290; σ ₁ = 0,044	ST β ⁻ 0,02; g α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	SI α 4,901; 4,856 sf, γ (45) θ ⁻ ; g σ 19; σ _f < 0,2	5Γ β ⁺ 0,6 γ 84; 9 σ < 100; σ ₁ 200	SI α 4,589; 4,546 sf; γ e σ 1,7	ST β ⁺⁺ 0.9; 1.2 γ 327; 560; 308; g σ 150	β 0,2; 0,3 γ 44; 224; 180	β-	
Np 234 4,4 d	Np 235 396,1 d	Np 236 22,5 h 1,54-10 ⁵ a	Np 237	Np 238 2,117 d	Np 239 2,355 d	Np 240 7,22 m 65 m	Np 241 13,9 m	Np 242 2,2 m 5,5 m	Np 243 1,85 m	Np 244 2,29 m			
ε; β ⁺ γ 1559; 1528; 1602 σι - 900	e; α 5,025; 5,007 γ(26; 84); e ⁻ g; σ 160 + ?	 ε; β⁻ 0,5 ε; β⁻ 1, α γ (642; γ 160; 688); e⁻ 104; e⁻ 9; σ₁ 2700 9; σ₁ 2600 	SI α 4,790; 4,774 γ 29; 87; e ⁻ σ 180; σ ₁ 0,020	β 1,2 γ 984; 1029; 1026; 924; e g; σ ₁ 2100	β 0,4; 0,7 γ 106; 278; 228; e ⁻ ; g σ 32 + 19; σ ₁ < 1	β 2.2, β 0.9. γ 555; γ 566; 597 974; e ⁻ 601; hγ; g 448; g	β 1,3 γ 175; (133) g	β ⁻ 2,7 β ⁻ γ 736; γ 786; 780; 945; 1473 159 0 0	β ⁻ γ 288 g	β ⁻ γ 217; 681; 163; 111 9	152		
U 233 1,592 · 10 ⁵ a	U 234 0,0055	U 235 0,7200	U 236	U 237 6,75 d	U 238 99,2745	U 239 23,5 m	U 240 14,1 h		U 242 16,8 m				
α 4,824; 4,783 Ne 25; γ (42; 97); e σ 47; σ ₁ 530	2,455 · 10 ⁵ a α 4,775; 4,723; el Mg 28; Ne; γ (53; 121) e ⁻ ; σ 96; σ ₁ < 0,005	25 m	α 4,494; 4,445; iγ 1783; sf; γ (49; 642 113) st e ⁻ ; σ 5,1	β 0,2 γ 60; 208 e σ ~ 100; σ ₁ < 0,35	270 ns. 4,468-10 ⁹ a h; 2514 a 4,198; d 1579 2517; γ (50,4); e a 277; γ (50,4); e a 2,7; γ (3,10)	β 1,2; 1,3 γ 75; 44 σ 22; σ ₁ 15	β 0,4 γ 44; (190) e m		β γ 68; 58; 585; 573 m	con	npour	id syst	tems
Prev	Previous work: (sf), (n _{th} , f), (n, f), (d, pf)												
Rece	Recent experiments: [] (n _{th} , f)												
Арр	rove	d pro	posal	s: (]	(n, f)							





Results: PFGS High precision γ-ray measurements



Excellent agreement between our experimental results and those from advanced model calculations *)

- *) full Hauser-Feshbach Monte Carlo simulations by
 - D. Regnier et al. (code: FIFRELIN, CEA Cadarache)
 - P. Talou et al. (code: CGMF, LANL)





Results: PFGS High precision γ-ray measurements





Results: PFGS



High precision γ -ray measurements







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High precision γ -ray measurements







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Systematics of PFGS average total energy per fission



According to Nifenecker (1972) and Valentine (2001), revised 2017: A. Oberstedt et al., PRC 96, 034612
Systematics of PFGS average total energy per fission



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Systematics of PFGS average total energy per fission



According to Nifenecker (1972) and Valentine (2001), revised 2017: A. Oberstedt et al., PRC 96, 034612

Systematics of PFGS average total energy per fission



Allows interpolation to unmeasured fissioning systems, here ${}^{238}U(n_{th},f)$: A. Oberstedt et al., PRC 96, 034612



Results: energy dependence Average total energy per fission



From thermal to fast neutron-induced fission



- Tudora: Point-by-Point model
- Litaize et al.: FIFRELIN code, Nucl. Data Sheets 118, 216 (2014)
- CEA DAM/DIF & LICORNE: preliminary experimental results







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Correlations between fission fragments and γ -rays



Results: angular distribution Prompt fission γ-ray multipolarities



Fit: W(θ) = A₀ [1 + {A₂/A₀}P₂(cos θ) + {A₄/A₀}P₄(cos θ)]

ÌFÍN-ÀH



Results: angular distribution Prompt fission γ-ray multipolarities





Fit result: $\{A_2/A_0\} = 0.13 \pm 0.03$



Results: angular distribution Theory







Results: angular distribution Prompt fission γ-ray multipolarities



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Results: angular distribution Comparison with previous measurements *)



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Results: angular distribution Comparison with previous measurements *)



*) Hoffman, Phys. Rev. 133 (1964)

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Results: PFGS



Angular distributions for 500 keV energy bins





Results: PFGS



Angular distributions for 500 keV energy bins



\rightarrow consider energy range E_v = 0.1 – 1.5 MeV



Results: angular distribution Comparison with previous measurements



ÌFÍN-HÌ



Results: angular distribution Comparison with previous measurements



For $E_v = 0.1 - 1.5$ MeV : \rightarrow differences !

*) Kopach et al., Phys. Rev. Lett. 82 (1999)

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Results: PFGS



Angular distributions for 500 keV energy bins



- \rightarrow again: fit of Legendre polynomials
- \rightarrow decomposition of multipolarities L = 1 and 2



Results: PFGS Decomposition of multipolarities



- → multipolarity-dependent spectra
- → multipolarity-dependent PFGS characteristics

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Results: PFGS Comparison with FIFRELIN calculations *)



Good agreement between integral spectra!

FIN-ł



Results: PFGS Comparison with FIFRELIN calculations *)



Good agreement between integral spectra! But FIFRELIN also provides multipolarity-dependent PFGS.



Results: PFGS Comparison with FIFRELIN calculations *)



From our observations: unassigned transitions \rightarrow L = 2, L = 2 + unassigned \rightarrow L = 2'.



Results: angular distribution Comparison with FIFRELIN calculations *)



²⁵² Cf(sf)	Experiment (this work)		Calculations (FIFRELIN)	
$ar{M}_\gamma$	8.28 ± 0.51		8.28	(adjusted)
\overline{M}_{γ} (L = 1)	2.40	(29 %)	3.20	(39 %)
${ar M}_\gamma$ (L = 2')	5.88	(71 %)	5.08	(61 %)
${ar M}_{_{\gamma}}$ (unassign.)				
$\overline{\mathcal{E}}_{\gamma}$	0.81 ± 0.10	(MeV)	0.76	(MeV)
$\overline{\mathcal{E}}_{\gamma}$ (L = 1)	0.88	(MeV)	0.94	(MeV)
$\overline{\mathcal{E}}_{\gamma}$ (L = 2')	0.79	(MeV)	0.65	(MeV)
$\overline{\mathcal{E}}_{\gamma}$ (unassign.)				
$ $ $\overline{\overline{E}}_{\gamma}$	6.75 ± 0.76	(MeV)	6.30	(MeV)
$\overline{\overline{E}}_{\gamma}^{'}$ (L = 1)	2.11	(MeV)	3.00	(MeV)
$\overline{E}_{\gamma}^{'}$ (L = 2')	4.64	(MeV)	3.30	(MeV)
$ec{ar{E}_{_{\gamma}}}$ (unassign.)				

*) A. Chebboubi, priv. comm.

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 + High precision PFGS measurements → reference for model calculations – e.g.: ²⁵²Cf(sf)







Sequential emission of neutrons and γ -rays









Sequential emission of neutrons and γ -rays







- + High precision PFGS measurements → reference for model calculations – e.g.: ²⁵²Cf(sf)
- Revised systematics for spontaneous and thermal neutron-induced fission
- Predictions of PFGS characteristics for fast neutroninduced fission -> rather good agreement
- Measured γ-ray angular distribution from ²⁵²Cf(sf) → dominant E2 character, in good agreement with previous observations + FIFRELIN calculations
- Preliminary results : <M_{γ,L=1}> ≈ 2.4 and <M_{γ,L=2}> ≈ 5.9, as
 well as <E_{γ,tot(L=1)}> ≈ 2.1 MeV and <E_{γ,tot(L=2)}> ≈ 4.6 MeV





Sequential emission of neutrons and γ -rays







Sequential emission of neutrons and γ -rays







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- + Average spin of fission fragments : $\Delta J \approx 14 \hbar$







Sequential emission of neutrons and γ -rays







But:

- Discrepancies compared to Kopach et al., PRL 88 (1999)
- From angular distribution :

 $<S_n> = 2 \times <E_{\gamma,tot(L=1)}> \approx 4.2$ MeV, while weighted with fission fragment distribution : $<S_n> \approx 5.9$ MeV !

(fission fragment distributions from GEF, $S_n(Z,A)$ according to Vogt et al., PLB 517 (2001))

- High energy quadrupole γ rays (of several MeV) observed, whose origin cannot be explained with rotational states
- To be continued ...







- New results from recent measurements
- New experiments are approved and scheduled
- Study of PFGS characteristics depending on fission fragment mass
- Study of entrance channel effects
 - (n,f) vs. (d,pf)
 - (p,p'f) vs. (γ,f)
 - etc.







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 - etc.
- New instruments (talk by S. Oberstedt)
- And last but not least:
 - → Photo-fission at ELI-NP !







ELI-NP and further photo-fission physics goals

ELIADE



8 CLOVER Ge detectors + 4 large-volume $LaBr_3$ detectors (3" x 3")

ELIGANT



17 $LaBr_3 + 17 CeBr_3$ detectors (3" x 3") and 33 liquid + 29 ⁶Li glass scintillation detectors


Outlook II



ELI-NP and further photo-fission physics goals

New position-sensitive twin FGIC (TU Darmstadt)

ELIADE





(courtesy M. Peck)

+ ELIGANT



8 CLOVER Ge detectors + 4 large-volume $LaBr_3$ detectors (3" x 3")

17 $LaBr_3 + 17 CeBr_3$ detectors (3" x 3") and 33 liquid + 29 ⁶Li glass scintillation detectors



Outlook II



ELI-NP and further photo-fission physics goals

New position-sensitive twin FGIC (TU Darmstadt)

ELIADE





(courtesy M. Peck)



- Study of the fission fragment de-excitation process
 o measurement of fission fragments, γ rays and neutrons
 - \circ correlations !

Andreas Oberstedt

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The collaborators



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Thank you!