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Systematic study of the de-excitation of neutron-rich nuclei produced in various fission reactions

Andreas Oberstedt

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- About ELI-NP
- Overview: the fission process
- On-going work
 - PFGS characteristics
 - dependence of compound system
 - impact of excitation energy
 - angular distribution & multipolarities
 - dependence of fragment mass
- Summary
- Outlook





Extreme Light Infrastructure – Nuclear Physics









Extreme Light Infrastructure – Nuclear Physics







Extreme Light Infrastructure – Nuclear Physics

- Nuclear physics experiments to characterize laser target interactions
- Photo-nuclear Physics
- Exotic Nuclear Physics and Astrophysics
 - complementary to other ESFRI Large Scale Physics Facilities (FAIR – Germany, SPIRAL-2 – France)
 - Applications based on high-intensity laser and very brilliant γ beams
- ELI-NP in "Nuclear Physics Long Range Plan in Europe" as a major facility

ESFRI = European Strategy Forum on Research Infrastructures





Extreme Light Infrastructure – Nuclear Physics









Characteristics:

- beam size: 1 mm at 10 m distance from collimator
- energy spread: 50 keV at E_γ=10 MeV
- linear polarization: > 95%
- time structure: micro-pulses at 16 ns distance
- photons/pulse: 10⁵
- photons/macro-pulse:
- $32 \times 10^5 \approx 3 \times 10^6$
- photons/s: 3 × 10⁸



496ns



About ELI-NP Photo-fission at ELI-NP – Physics cases



Image: Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-	ELI-BIC	ELITHGEM
(binary) fission fragments	 (γ, f) cross sections distributions (A, Z, E_{kin}, θ) dependence on E_γ 	 (γ, f) cross sections angular distributions (θ, φ) dependence on E_γ
(ternary) light charged particles	 energy and angular distributions probabilities, yields coincidences 	





Day-1 experiments on Photo-fission

From Technical Design Report (TDR):







Day-1 experiments on Photo-fission

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First, we will measure the absolute photofission cross-sections of actinide targets ... We further propose to measure the angular distribution of photofission fragments.



ELITHGEM

²³⁵U(γ, f)

- isomeric fission (complementary to ²³⁴U(n, f))
- ternary fission yields

²³²Th(γ, f) or ^{234,238}U(γ, f)

 cross section and angular distributions (higher resolution than with Bremsstrahlung)





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Day-1 experiments on Photo-fission

From Technical Design Report (TDR):

PRL 99, 042502 (2007) PHYSICAL

PHYSICAL REVIEW LETTERS

week ending 27 JULY 2007

Identification of a Shape Isomer in ²³⁵U

A. Oberstedt,^{1,*} S. Oberstedt,² M. Gawrys,³ and N. Kornilov²

¹Department of Natural Sciences, Örebro University, S-70182 Örebro, Sweden ²EC-JRC Institute for Reference Materials and Measurements, B-2440 Geel, Belgium ³Department of Fundamental Physics, Chalmers University of Technology, S-41296 Göteborg, Sweden (Received 5 April 2007; published 25 July 2007)

The shape isomer in ²³⁵U has been searched for in a neutron-induced fission experiment on ²³⁴U, which was performed at the isomer spectrometer NEPTUNE of the EC-JRC IRMM. A neutron source, with a tunable pulse frequency in the Hz to kHz range and its individually adjustable neutron pulse width in connection with an appropriate detector system turned out to be the ideal instrument to perform an isomer search, when decay half-lives above 100 μ s are expected. From the delayed fission events observed for two different NEPTUNE settings and at mean incident neutron energies $E_n = 0.95$ and 1.27 MeV the isomeric fission half-life could be determined to be $T_{1/2} = (3.6 \pm 1.8)$ ms. The corresponding cross section was determined to $\sigma_{if} = (10 \pm 8) \ \mu$ b. With these results an experimental confirmation for the existence of a superdeformed shape isomer in odd-uranium isotopes is given for the first time.

DOI: 10.1103/PhysRevLett.99.042502

PACS numbers: 21.10.Tg, 23.60.+e, 25.85.Ec, 27.90.+b

• ternary fission yields

with Bremsstrahlung)





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ELITHGEM

²³⁵U(γ, f)

- isomeric fission (complementary to ²³⁴U(n, f))
- ternary fission yields

 232 Th(γ , f) or 234,238 U(γ , f)

 cross section and angular distributions (higher resolution than with Bremsstrahlung)





Day-1 experiments on Photo-fission

From Technical Design Report (TDR):









PHYSICAL REVIEW C 96, 044301 (2017)

Correlated mass, energy, and angular distributions from bremsstrahlung-induced fission of ²³⁴U and ²³²Th in the energy region of the fission barrier

 A. Göök,^{1,*} C. Eckardt,¹ J. Enders,^{1,†} M. Freudenberger,¹ A. Oberstedt,² and S. Oberstedt³
 ¹Institut für Kernphysik, Technische Universität Darmstadt, 64289 Darmstadt, Germany
 ²Extreme Light Infrastructure—Nuclear Physics (ELI-NP)/Horia Hulubei National Institute for Physics and Nuclear Engineering (IFIN-HH), 077125 Bucharest-Magurele, Romania
 ³European Commission, DG Joint Research Centre, Directorate G—Nuclear Safety and Security, Unit G.2 Standards for Nuclear Safety, Security and Safeguards, 2440 Geel, Belgium (Received 13 March 2017; published 2 October 2017)

The bremstrahlung-induced fission of ²³⁴U and ²³²Th has been studied at the superconducting Darmstadt linear accelerator (S-DALINAC) in the excitation energy region close to the fission barrier. Fission-fragment mass and total kinetic energy (TKE) distributions from ²³⁴U were studied for the first time in this energy region. The results have been analysed in terms of fission modes, and a dominant yield of the mass-asymmetric standard-2 mode was found in both nuclei. No strong dependence of the fission-mode weights on the excitation energy of the compound nucleus was found. Correlations among mass, TKE, and angular distributions have also been investigated. A correlation in the form of an increased anisotropy for far-asymmetric masses and low TKE were found in both fissioning systems. A possible interpretation of this correlation in terms of fission modes is discussed.

DOI: 10.1103/PhysRevC.96.044301





Day-1 experiments on Photo-fission

From Technical Design Report (TDR):







Day-1 experiments on Photo-fission

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Day-1 experiments on Photo-fission

From Technical Design Report (TDR):















The fission process







The fission process



ÌFÍN-H



The fission process









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





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- Determination of characteristics:
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 - <M_{γ}>, < ϵ_{γ} >, and <E_{γ ,tot}>
- Study of the dependence of A and Z
- Study of energy dependence
- Details about the de-excitation process of fission fragments





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)





IFIN-H













IFIN-H





FIN-





FIN-ł




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





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





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



On-going work Energy dependence



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







Fit: $I_{\gamma}(\theta) = A_0 [1 + \{A_2/A_0\}P_2(\cos\theta) + \{A_4/A_0\}P_4(\cos\theta)]$ Fit result: $\{A_2/A_0\} = 0.13 \pm 0.03$



On-going work



Angular distributions and multipolarities

²⁵² Cf(sf)	Experiment (this	work)	Calculations	s (FIFRELIN ^{*)})
$ar{M}_{\gamma}$	8.28 ± 0.51		8.28	(adjusted)
\overline{M}_{γ} (L = 1)	2.31	(28 %)	3.20	(39 %)
\overline{M}_{γ} (L = 2)	5.97	(72 %)	1.45	(17 %)
${ar M}_{_\gamma}$ (experim.)			3.63	(44 %)
$\overline{\mathcal{E}}_{\gamma}$	0.79 ± 0.10	(MeV)	0.76	(MeV)
$\overline{\mathcal{E}}_{\gamma}$ (L = 1)	0.86	(MeV)	0.94	(MeV)
$\overline{\mathcal{E}}_{\gamma}$ (L = 2)	0.76	(MeV)	1.03	(MeV)
$\overline{\mathcal{E}}_{\gamma}$ (experim.)			0.50	(MeV)
$ $ $\overline{\overline{E}}_{\gamma}$	6.51 ± 0.76	(MeV)	6.30	(MeV)
$\overline{\overline{E}}_{\gamma}^{'}$ (L = 1)	1.99	(MeV)	3.00	(MeV)
\overline{E}_{γ} (L = 2)	4.52	(MeV)	1.49	(MeV)
$ar{ar{E}_{\gamma}}$ (experim.)			1.81	(MeV)

*) A. Chebboubi, priv. comm.

Andreas Oberstedt 54th ASRC International Workshop Sakura-2019, Tokai (Japan), March 25 – 27, 2019



On-going work Angular distributions and multipolarities



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On-going work Sequential emission of neutrons and γ -rays



O. Litaize et al., PRC 82, 054616 (2010)

On-going work Sequential emission of neutrons and γ-rays

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Measurement of fission fragment (pair) yields

• Due to limited mass resolution of FGIC: $\Delta A = 2 \dots 7$

Measurement of fission fragment (pair) yields

 Good agreement with previous results from Hambsch (priv. communication)

Measurement of fission fragment (pair) yields

- Creating PFGS gated on fission fragment mass (region)
- Determining their characteristics

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Average total y-ray energy per fission fragment pair

• Observe: so far data from only one LaBr₃ detector!

Average total y-ray energy per fission fragment pair

Comparison with experimental (symbols) and calculated values (lines)

Average total γ -ray energy per fission fragment pair

Comparison with experimental (symbols) and calculated values (lines)

✓ High precision PFGS measurements → reference for model calculations

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	α 7,342	α 7,392; 7,358 € ?	ε α 7,06; 7,17 g	α 7,209; 7,174 g	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; σ ₁ 1700	sf γ (43…); e σ 2000; σt < 350	6,012 γ 177; 227 σ 2900; σ ₁ 4500	sf 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	α 6,662; 6,620 γ 892; 218; 922 g	n 5,888; 6,150 γ 253; 381 e g	¢ γ 799; 1081; 834; 1124 e	α 5,531; 5,710; 5,688 γ 84; 265 g	β ⁻ 0,9 γ 551 σ ⁻ ε ⁻ ?	β 0,1; α 5,419; 5,391; sf γ (327; 308) σ 700; σt ~ 0,1	β 0,7; 1,8 γ 989; 1032; 1029 σ _f 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 9	ST α 6.291; 6,248 st 9	ST * 0.5,939 y 472, 431, 132 e ⁻ 0	ST α 6,113; 6,069 sf; g γ (44); e σ - 20 σ _f - 5	ST α 5.785; 5.742 ε; sf; g γ 278; 228; 210; e ⁺⁺ σ 130; σ ₁ 620	ST	ST 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 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	sf α ?; β ⁻ ? σ - 80
Am 236 4,4 m	Am 237 73,0 m	Am 238	Am 239	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 4 0.6,042 7 280; 438, 474; 909 9	ST * a 5,94 y 963; 919; 561; 605 9	ST α 5,774 γ 278; 226 Θ	ST а. 5,378 у 988; 889 g	ST α 5,486; 5,443 st; γ 60; 26 σ ⁻ ; g σ 50 + 570; σ _t 3,1	SI τγ (49), φ a 5,206 st; γ (49) σ 1700 σ ₁ 7000 σ ₁ 2100	ST α 5,275; 5,233 st; γ 75; 44 σ 75 + 5 σ ₁ 0,074	ST ^β ^{1,3} ^β ^{0,4} ^γ ^{7,44} ; ^φ ⁻ ; ^g ¹⁵⁴ ; ^φ ⁻ ^σ ₁ ¹⁰⁰⁰ ^σ ₁ ²²⁰⁰	51 γ 253; (241; 296) σ ; g	ST p 1,2; p 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	Pu 242 3,750 - 10 ⁵ a	Pu 243 4,956 h	Pu 244 8,00 · 10 ⁷ a	Pu 245	Pu 246 10,85 d	Pu 247 2,27 d	
sf * \$5,85 \$7 49; (756; 34) e	Sf α 5,768; 5,721 sf; Mg 28 γ (48; 109); e ⁻ σ _f 160	st α 5.334 γ 60e ⁻ α ₁ 2300	Sf α 5,499; 5,456 sf; Si; Mg γ (43; 100); e ⁻ σ 510; σ _f 17	St α 5,157; 5,144 st; γ (52) e ⁻ ; m σ 270; σ ₁ 752	ST α. 5,168; 5,124 sf; γ (45) e ; g σ 290; σ ₁ = 0,044	ST β ⁺ 0,02; g α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	ST	ST β ⁼ 0,6 γ 84; 0 σ < 100; σ ₁ 200	ST α 4,589; 4,546 sf; γ σ ⁻ 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 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 σι - 900	ε; α 5,025; 5,007 γ(26; 84); e ⁻ g; σ 160 + ?	 (; β⁻0,5,, (; β⁻; α) γ (642; γ 160; 688; e⁻ 104; e⁻ 9; σ₁ 2700 9; σ₁ 2600 	ST	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	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	β 1,3 γ 175; (133) 9	β ⁻⁺ 2,7 β ⁻⁺ γ 736; γ 786; 780; 945; 1473 159 9 9	β ⁻ γ 288 9	β^{-} $\gamma 217; 681;$ 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; σt 530	2,455 · 10 ⁵ a α 4,775; 4,723; sl Mg 28; Ne; γ (53; 121) e ⁻ ; e 96; e ₁ < 0,005	26 m γ (0,07) 26 m 7,038-10 ⁴ a α 4.398; st Ne; γ 186 σ 95; σ ₁ 550	α 4,494; 4,445; 1γ 1783; sf; γ (49; 642 sf θ ⁻ ; σ 5,1	β 0,2 γ 60; 208 θ σ ~ 100; σ ₁ < 0,35	270 ns. 4,468 · 10 ⁹ a h 2514 a 4,196 d 1879 2017 y (50 t) a 2017 y (50 t) a 2,7) e 3,10 0	β 1,2; 1,3 γ 75; 44 σ 22; σ; 15	β ⁻ 0,4 γ 44; (190) e ⁻ m		β γ 68; 58; 585; 573 m	compound systems			

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 χ (42: 96)	Cf 247 3,11 h • • (296; 6,238 • (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 2,388: 333 q	Cf 250 13,08 a α 6,030; 5,989 sf y (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 st χ (43): e ⁻	
α 7,63 Bk 238 144 s	sf	α 7,342 Bk 240 5 m	e?	g Bk 242 7 m sf	9 Bk 243 4,5 h sf ? o 6575 6543	g Bk 244 4,35 h st 4,6662,6620	Bk 245 4,90 d st * 5,888; 6,150 7 253; 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 84: 265	σ 500; σ ₁ 1700 Bk 248 23,7 h 9 a β ⁻ 0.9 a ⁻	a 2000; σ ₁ < 350 Bk 249 320 d β ⁻ 0,1; α 5,419; 5,391; sf 2(22; 308.)	σ 2900; σr 4500 Bk 250 3,217 h β ⁻ 0,7; 1,8 γ 989; 1032; 1029	^σ 20; σ ₁ 32 Bk 251 55,6 m β ⁻ - 0,9; 1,1	
βst	Cm 238 2,4 h	βst Cm 239 3 h	Cm 240 27 d sf	Cm 241 32,8 d sf	y /25, 946 g Cm 242 162,94 d sf a 6,113, 6,069 a', 6,113, 6,069 a', 6,113, 6,069 a', 6,113, 6,069 a', -5	9 9 Cm 243 29,1 a 5,785;5,742 c, 5,785;5,742 c, 5,785;285; 210 e ⁻ o ⁻ (2,62)	Cm 244 18,10 a sf (43.); e ⁻ (15, or 1.1	e ⁻ Cm 245 8500 a sf a 5.361; 5.304 st:g y 175; 133 y 156; or 2100	g Cm 246 4730 a α 5,386; 5,343 sf; g γ (45); e ⁻ σ 1,2; σr, 0,16	φ φ φ Cm 247 1,56 · 107 a α α 4,870; 5,267 γ 402; 278 g σ 60; σ; 82 82 82	a 700; σ ₁ = 0,1 Cm 248 3,40 · 10 ⁵ a a 5,078; 5,035 st.γ; e ⁻ ; g σ 2.6; σ 0.36	$\begin{array}{c} & \sigma_{f} 1000 \\ \hline & Cm \ 249 \\ 64,15 \ m \\ \beta^{-} \ 0,9 \\ \gamma \ 634; \ (560; \\ 369); \ e^{-} \\ \sigma \sim 1.6 \end{array}$	153 Cm 250 ~ 9700 a st α?; β ⁻ ? σ - 80	
Am 236 4,4 m	Am 237 73,0 m * 0.042 7280:438.474: 909. 9	Am 238 1,63 h sf * 5.94 963.919.561; 9	Am 239 11,9 h sf * 5.774 7 278: 226 9	Am 240 50,8 h \$ \$ \$ 988,889 9	Am 241 432,2 a sf \$\$\frac{a}{5,486;5,443}\$\$ \$\$\frac{a}{5;26}\$\$ \$\$\$\frac{a}{5;26}\$\$ \$	Am 242 141 a 5,20607.r st,7(49).e ⁻ 5,20607.r st,7(49) 9,00 0,7 e st,7(49) 0,7 e st,7(40) 0,7 e st	Am 243 7370 a sf sty.75; 5,233 st;.75; 54 or75 + 5 or10,074	Am 244 26 m 10,1 h 10,1 h 10,1 h 10,4	Am 245 2,05 h sf ^{p=0,0} ^{253;} (241;296) e ⁻ ; g	$\begin{array}{c c} Am \ 246 \\ \hline sf & \begin{array}{c} 25 \ m \\ \beta^{-} 1.2; \\ 2.2 \\ 7 \ 90; \\ 1062 \end{array} & \begin{array}{c} 39 \ m \\ \beta^{+} 779; \\ 756 \end{array}$	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 a 5,499; 5,456 ef; Si; Mg y (43; 100); e ⁻ a 510; ar 17	Pu 239 2,411 · 10 ⁴ a a 5,157; 5,144 at; 7 (52) or; m a 270; a; 752	Pu 240 6563 a sf a 5,168; 5,124 gf; y (45) e ^c ; g o 290; oft = 0.049	Pu 241 14,35 a β ⁻ 0.02; g γ (149); e ⁻ σ 370; σγ 1010		Pu 243 4,956 h sf ^{β^-0,6,} ^{γ 84,9} ^{σ < 100; σ₁ 200}	$ sf \begin{bmatrix} Pu \ 244 \\ 8,00 \cdot 10^7 a \\ a \ 4,589; \ 4,546 \\ st; \ \gamma \\ e^{-} \\ \sigma \ 1,7 \end{bmatrix} $	Pu 245 10,5 h ^{9-0,9; 1,2} ^{327; 560; ³⁰⁰⁹ ^{o 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 «; β* γ 1559; 1528; 1602 σ1 - 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 γ (642; γ 160; 6 668; φ 104; φ 668; φ 104; φ 104; φ	Np 237 2,144 · 10 ⁶ a sf	Np 238 2,117 d β ⁻ 1,2 γ 984; 1029; 1026; 924; e ⁻ g; σ ₁ 2100	$\begin{array}{c} Np \ 239 \\ 2,355 \ d \\ \beta^- \ 0.4; \ 0.7 \\ \gamma \ 106; \ 278; \\ 228; \ e^-; \ g \\ \sigma \ 32 + 19; \ \sigma_{1} < 1 \end{array}$	$\begin{array}{c c} Np & 240 \\ \hline \textbf{7,22 m} & \textbf{65 m} \\ \hline \textbf{\beta}^{-2,2,\dots} & \textbf{\beta}^{-0,9,} \\ \hline \textbf{597,\dots} & \textbf{974}; \\ e^{-} & \textbf{601}; \\ \hline \textbf{1},\dots; g & 448,\dots; g \end{array}$	Np 241 13,9 m β ⁻ 1,3 γ 175; (133) 9	$\begin{array}{c c} Np & 242\\ \hline 2,2 m & 5,5 m\\ \beta^-2,7 & \beta^-\\ 700; & 945;\\ 1473 & 159\\ 9 & 0 \end{array}$	Np 243 1,85 m ^{β⁻} _{γ 288}	$\begin{array}{c} Np \ 244 \\ 2,29 \ m \\ \beta^{-} \\ \gamma \ 217; \ 681; \\ 163; \ 111 \\ 9 \end{array}$	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 α α 4,775, 4,723; ef Mg 28, Ne; γ (53, 121) e ⁻ ; e 96; e ₁ < 0,005	U 235 0,7200 26 m 7,038-10 ⁴ a ^{4,398} ; sf Ne; y 186; o 95; or 558	U 236 120 ns 2,342-10 ⁷ a α 4,445 1y 1783; sf; γ (49; 642 st 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 m h 234 106 277 y 20, 10 277 y 20 277 y 20 2777 y 20 277 y 20 277 y 20 277 y 20 2777 y 20 2777 y 20 2777 y 20	U 239 23,5 m β ⁻ 1,2; 1,3 γ 75; 44 σ 22; σ ₁ 15	$\begin{array}{c} U \ 240 \\ 14,1 \ h \\ \beta^{-} \ 0,4 \\ \gamma \ 44; \ (190) \\ e^{-} \\ m \end{array}$		$\begin{array}{c} U \ 242 \\ 16,8 \ m \\ ^{\beta^{-}} \\ \gamma \ 68; \ 58; \ 585; \\ 573 \\ m \end{array}$	compound systems				

Previous work:

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 st	α 7,342	α 7,392; 7,358 € ?	α 7,06; 7,17 9	α 7,209; 7,174 9	α 7,137 g	α 6,750; 6,708 sf γ (42; 96) e ⁻ ; g	 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; σ ₁ 1700	α 6,030; 5,989… st 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	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	α 6.575. 6.543 γ 755; 946 9	51 4 α 6.662, 6.620 γ 892, 218, 922 9	ο 5,888, 6,150 γ 253; 381 ο 0	ε γ 799; 1081; 834; 1124 e	α 5,531; 5,710; 5,688 γ 84; 265 g	β ⁻ 0,9 × γ 551 θ ⁻ × 7	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 σ _f 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 9	ST α 6,291; 6,248 st g	ST e a 5.939 y 472, 431, 132 e g	ST α 6,113, 6,069 sf; g γ (44); e ⁻ σ - 20 σ ₁ - 5	st a 5/785, 5/792 ε; sf; g γ 278; 228; 210; e σ 130; σ ₁ 620	ST a 5,805; 5,762 af; g γ (43,); e ⁻ σ 15; σ _l 1,1	SI a 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; σt 82	α 5,078; 5,035 sf; γ; e¯; g σ 2,6; σt 0,36	β 0,9 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	Am 240	Am 241 432,2 a	Am 242	Am 243 7370 a	Am 244	Am 245 2,05 h	Am 246	Am 247 22 m		454
ε α 6,41	α 6,042 γ 280; 438; 474; 909 9	a 5,94 y 963; 919; 561; 605 g	α 5,774 γ 278; 228 σ	α 5.378. γ 988, 889 9	α 5,486, 5,443 st; γ 60; 26 e ⁻ ; g σ 50 + 570; σ ₁ 3,1	a 5,206 0,7 r st; y (49) y (42) o 1700 o ; g oy 7000 o ; 2100	α 5,275, 5,233 st; y 75; 44 σ 75 + 5 σ ₁ 0,074	• γ (1084) 898; • γ (1084) 898; • α 1600 α 154; •	β ⁺⁺ 0,9 γ 253; (241; 296) e ⁺⁻ ; g	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 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	ST α 5,499; 5,456 uf; Si; Mg γ (43; 100); e ⁻ σ 510; σ _f 17	ST α 5,157; 5,144 sf; γ (52) θ ⁻ , m σ 270; σ ₁ 752	ST α 5,168, 5,124 sf; γ (45) e ⁻ ; g σ 290; σ] = 0.049	ST β ⁼ 0.02; g α 4.896 γ (149); σ ⁼ σ 370; σ ₁ 1010	ST a 4,901; 4,856 sf; γ (45) $e^{-1}g$ σ 19; $\sigma_f < 0,2$	57 β ⁺ 0,6 γ 84; g σ < 100; σ ₁ 200	ST α 4,589; 4,546 st; γ σ ⁻ 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	Np 235 396,1 d	Np 236 22,5 h 1,54 · 10 ⁵ a	Np 237 2,144 · 10 ⁶ a	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 + ?	•: β 0,5 •: β : α γ (642; γ 160; 688); e 104; e g; σ ₁ 2700 g; σ ₁ 2600	a 4,790; 4,774 γ 29; 87; ε ⁻ σ 180; σ _f 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	p c.z., p 0.9 γ 555; γ 566; 597 974; 601; +γ; 9 448; g	β 1,3 γ 175; (133) 9	β 2,7 β γ 736; γ 786; 780; 945; 1473 159 9 9	β- γ 288 9	β γ 217; 681; 163; 111 9	152		
U 233 1,592 · 10 ⁵ a	U 234 0,0055	U 235 0,7200	U 236 120 ns 2,342-10 ⁷ a	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) e ⁻ : σ 96; σ ₁ < 0,005	26 m 7,038-10 ⁴ a α 4.398; st Νe; γ 186 e ⁻ σ 95; σ ₁ 586	α 4,494; 4,445; 542 6113) 67: σ 5,1	β 0,2 γ 60; 208 θ σ ~ 100; σ ₁ < 0,35	270 ns. 4,468-10 ⁹ a h 2514 a 4,198d 1679. 26 γ (50d σ 2.7; σ 3,100	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
0 47, 01 000	0,000,01<0,000	e e #3, aj 200	10, 0 <u>0</u> /1	0 - 100, 01 < 0,00	a constant	0 121 01 10				1			

Previous work:

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

Cf 239 ~ 39 s	Cf 240 1,06 m α 7,59	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 α 7,209; 7,174	Cf 245 43,6 m	Cf 246 35,7 h α 6,750; 6,708 sf γ (42; 96) e ⁻ : a	Cf 247 3,11 h 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 α 500; gr 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 α 2900; σt 4500	Cf 252 2,645 a α 6,118; 6,076 st γ (43); e ⁻ σ 20; σt 32	
Bk 238 144 s		Bk 240 5 m		Bk 242 7 m	Bk 243 4,5 h st ? ^a 6.575; 6.543 y 755; 946 y	Bk 244 4,35 h sf 4,662; 6,620. y 892; 218; 922 g	Bk 245 4,90 d st * 5.888; 6,150 * 253; 381 * 9	Bk 246 1,80 d ^e 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 a ⁷ y 551 a ⁷ e ⁻ a ⁷	Bk 249 320 d β ⁻ 0,1; α 5,419; 5,391; sf γ (327; 308) σ 700; σt - 0,1	Bk 250 3,217 h β 0.7; 1.8 γ 989; 1032; 1029 σ _f 1000	Bk 251 55,6 m β - 0.9; 1,1 γ 178; 130; 153	
	Cm 238 2,4 h	Ст 239 3 h	Cm 240 27 d sf g	Cm 241 32,8 d sf v 472, 431; 132 g	$\begin{array}{c c} Cm & 242 \\ 162,94 \ d \\ sf & {}_{\alpha \ 6,113, \ 6,069,} \\ {}_{\gamma \ (44,), \ 6^{-}} \\ {}_{\sigma \ -20} \\ {}_{\sigma_{1} \ -5} \end{array}$	Cm 243 29,1 a \$1 \$1 \$25,742 \$25,742 \$210e" \$130; \$5,742 \$210e" \$130; \$620	Ст 244 18,10 а sf « 5,805; 5,762 ¢ (43); e ⁻ « 16; α ₁ 1,1	Cm 245 8500 a st	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 ^g σ 60; σ ₁ 82	Cm 248 3,40 · 10 ⁵ a α 5,078; 5,035 st, γ; e ⁻ ; g σ 2,6; σt 0,36	$\begin{array}{c} Cm \ 249 \\ 64,15 \ m \\ \gamma \ 634; (560; \\ 369); \ e^- \\ \sigma \ \sim \ 1,6 \end{array}$	Cm 250 ~ 9700 a sf α ?; β ? σ - 80	
Am 236 4,4 m	Am 237 73,0 m • a 6,042 • y 280; 438; 474; • 009 • 0	Am 238 1,63 h sf * ⁴ 5,94 9 953, 919; 561; 9	Am 239 11,9 h sf * * * * * * * *	Am 240 50,8 h	Am 241 432,2 a a 5,486; 5,443 e ⁻ ; g σ 50 + 570; σ ₇ 3,1	Am 242 141 a 16 h 5 f ⁴ (49), e ⁻ 8 ⁻ 0.6, 5,20607, e 5,27(4-), 17(4-), 17(4-), 1700 e ⁻ , g 47,700 e ⁻ , g	Am 243 7370 a sf σ.5,275; 5,233 σ.75 + 5 σ; 0,074	Am 244 sf 9 1.5 (1094) 606. (1004) 606. (1005) 154 (1005) 154 (1005) 154 (1005) 154	Am 245 2,05 h β ⁻ 0,9 253: (241;296) φ ⁻ ; g	Am 246 25 m 39 m \$\begin{bmatrix} 25 m \$\begin{bmatrix} 39 m \$\begin{bmatrix} 39 m \$\begin{bmatrix} 70 m \$\b	Am 247 22 m ^{β⁻} γ 285; 226 e ⁻		154	
Pu 235 25,3 m	Pu 236 2,858 a sf a 5,768; 5,721 st: Mg 28 y (48; 109); e ⁻ o ₁ 160	Pu 237 45,2 d sf ^{a 5,334} ^{y 80} e ⁻ or 2300	Pu 238 87,74 a sf a 5.499; 5.456 af; Si; Mg y (43; 100); e ⁻ o 510; o ₁ 17	PU 239 sf 2,411 · 10 ⁴ a a 5,157; 5,144 a; y (52) o; m o 270; o ₁ 752.	Pu 240 6563 a st et, 168; 5,124 et, y (45) e ⁻¹ .0 o 290; ct = 0.040	Pu 241 14,35 a st p=0.02; g a 4,896 y (149); e ⁻ o 370; or 1010	$ sf \atop{\substack{a,750 \cdot 10^5 \ a \\ a 4,901; 4,856 \dots \\ a^{c}; \gamma (45 \dots) \\ \sigma^{c}; g}_{\sigma 19; \sigma_1 < 0,2} } $	Pu 243 4,956 h sf ^{β⁺0,6,} 784; 9 σ < 100; σ ₁ 200	Pu 244 st 8,00 + 10 ⁷ a a 4,589; 4,546 st; 7 e a 1,7	Pu 245 10,5 h sf ^{p= 0,9; 1,2} y 327; 560; 308; g o 150	Pu 246 10,85 d β ⁻ 0,2; 0,3 γ 44; 224; 180 m1	Pu 247 2,27 d β ⁻		
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; σ 160 + ?	Np 236 22,5 h 1,54 · 10 ⁵ a *, β ⁻ 0,5, *, β ⁻ , α γ (642; *, (642; γ 160; 688, !e ⁻ 104e ⁻ • 104e ⁻ 9 : 04; • 104e ⁻ 9 : 04;	Sf 4 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; 597 597 974; 601; 601; hg 448; g	Np 241 13,9 m ^{β⁻1,3} _γ 175; (133) ^g	$\begin{array}{c c} Np & 242\\ \hline 2,2 m \\ \gamma 736; \\ 700; \\ 945; \\ 1473 \\ 9 \end{array} \begin{array}{c} \beta^{-} 2,7 \\ \beta^{-} \\ \gamma 786; \\ 945; \\ 159 \\ 9 \end{array}$	Np 243 1,85 m ^{β⁻} _{γ 288}	$\begin{array}{c} Np \ 244 \\ 2,29 \ m \\ \beta^{-} \\ \gamma \ 217; \ 681; \\ 163; \ 111 \\ 9 \end{array}$	152			
U 233 1,592 · 10 ⁵ a α 4,824; 4,783 Νε 25; γ (42; 97); e σ 47; σ ₁ 530	U 234 0,0055 2,455 · 10 ³ a a 4,775 4,723; at Mg 28. Ne; 7(53:121; e ⁻ , o 96; o ₁ < 0,005	U 235 0,7200 26 m 7,038-10 ⁸ a a 4,3985 b (2,07) 0, 7,038-10 ⁸ a b (2,07) 0, 7,038-10 ⁸ a c 4,3985 b (2,07) 0, 7,038-10 ⁸ a c 4,3985 b (2,07) 0, 7,038-10 ⁸ a c 4,3985 c 95; c 7,556	U 236 120 ns 14 4783; 14 4783; 15 4783; 15 4783; 15 4783; 11 3, 11 3, 12 07; 0 5.1	U 237 6,75 d β ⁻ 0,2 γ 60; 208 e ⁻ σ - 100; σ ₁ < 0,35	U 238 99,2745 270 ns. 4,468-10 ⁹ a h 254 100 271 y 0.2 271 y 0.2 2745	U 239 23,5 m β ⁻¹ ,2; 1,3 γ 75; 44 σ 22; σ; 15	$\begin{array}{c} U \ 240 \\ 14,1 \ h \\ \beta^{-} \ 0,4 \\ \gamma \ 44; \ (190) \\ e^{-} \\ m \end{array}$		$\begin{array}{c} U \ 242 \\ 16,8 \ m \\ \gamma \ 68; \ 58; \ 585; \\ 573 \\ m \end{array}$	compound systems				

Previous work:

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	Cf 250 13,08 a α 6,030; 5,989 sf	Cf 251 898 a ^{a 5,679; 5,849;} ^{6,012}	Cf 252 2,645 a α 6,118; 6,076st
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; σ ₁ 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 238 144 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
€ βst		e βsf		à	? α 6.575; 6.543 γ 755; 946 9	е и 6.662, 6.620 у 892, 218, 922 9	n 5,888; 6,150 γ 253; 381 9 9	γ 799; 1081; 834; 1124 e	5,688 γ 84; 265 g	β ⁻ 0,9 • γ 551 θ ⁻ • 7 • 7	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	Cm 239	Cm 240	Cm 241	Cm 242	Cm 243	Cm 244	Cm 245 8500 a	Cm 246 4730 a	Cm 247	Cm 248 3.40 · 10 ⁵ a	Cm 249 64.15 m	Cm 250 ~ 9700 a
	¢ α 6.52	ε γ 188 g	sf α 6,291; 6,248 sf g	Sf 4 a 5,939 y 472, 431; 132 g	$ \begin{array}{c} \text{sf} & \alpha 6, 113; 6, 069 \\ \text{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 _f 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 ₁ 0,16	α 4,870; 5,267 γ 402; 278 9 σ 60; σ ₁ 82	α 5,078; 5,035 st; γ; e ⁻ ; g σ 2,6; σ; 0,36	$\begin{array}{c} \beta^{-} \ 0,9 \dots \\ \gamma \ 634; \ (560; \\ 369 \dots); \ e^{-} \\ \sigma \sim 1,6 \end{array}$	st α ?; β ? σ - 80
Am 236 4,4 m	Am 237 73,0 m • . • . • . • . • . • . • . • . • . • .	Am 238 1,63 h sf * 5,94 9 963; 919; 561; 9	Am 239 11,9 h sf * 5,774 * 5,774 * 278, 228. •	Am 240 50,8 h	Am 241 432,2 a sf α 5,486; 5,443 s; γ 60; 26 σ; 50 + 570; σγ 3,1	Am 242 141 a 16 h 57 (49), e ⁻ 5,2060,7, e st; (49) 17000 17000 17000 17000 171000 171000 171000 171000 171000 171000 171000 171000 17100000 17100000 171000	Am 243 7370 a sf α 5,275; 5,233 a; y 75; 44 σ 75 + 5 σ ₁ 0,074	Am 244 sf \$\begin{pmatrix} 26 m & 10,1 h & \$	Am 245 2,05 h sf ^{p=0,9} 7253: (211,296) e ⁻ ; 9	Am 246 51 0.25 m 39 m 2.2.m 0.7 7.9079, 2005, 7.9079, 154; 1002 154; 1002 756	Am 247 22 m β γ 285; 226 e		154
Pu 235 25,3 m • • 5.85 • 49(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 ^{± 5,334} ^{y 60} e ⁻ rr 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; 7 (52) o; m o 270; o; 752	Pu 240 6563 a sf α.5.168; 5.124 σ; γ (45) σ; g σ 290; τη = 0.045	Pu 241 14,35 a sf ^{a - 0,02; g} ^{a 4,896} ^{y (149); e⁻} ^{o 370; or 1010}	$\begin{array}{c} { Pu \ 242} \\ { sf} \\ { \mathfrak{sf}} \\ { $	Pu 243 4,956 h sf ^{β⁻0,6} ^{y 84; 9} _{σ < 100; σ1 200}	Pu 244 sf 8,00 - 107 a a 4,589; 4,546 st; 7 or a 1,7	Pu 245 10,5 h sf ^{7 0,9; 1,2} ^{7 327; 560; 308; 9} ^{9 150}	Pu 246 10,85 d β ⁺ 0,2; 0,3 γ 44; 224; 180	Pu 247 2,27 d β ⁻	
Np 234 4,4 d ε: β* γ 1559; 1528; 1602 σt - 900	Np 235 396,1 d e; α.5.025; 5.007 γ (26; 84); e ⁻ g; σ 160 + ?	Np 236 22,5 h 1,54 · 10 ⁵ a • β ⁻ 0,5 • β ⁻ · α γ (642; 688); e ⁻ 104; e ⁻ g; q; 2700 g; q; 2700	Np 237 2,144 - 10 ⁶ a sf a 4.790; 4.774 y 29; 87; e ⁻ o' 180; or (0,020	$\begin{array}{c} Np \ 238 \\ 2,117 \ d \\ \beta^{-} \ 1,2 \\ \gamma \ 984; \ 1029; \\ 1026; \ 924; \ e^{-} \\ g; \ \sigma; \ 2100 \end{array}$	$\begin{array}{c} Np \ 239 \\ 2,355 \ d \\ \beta^- \ 0,4; \ 0,7 \\ \gamma \ 106; \ 278; \\ 228; \ e^-; \ g \\ \sigma \ 32 + 19; \ \sigma_1 < 1 \end{array}$	Np 240 7,22 m 65 m β ⁻ 2.2 β ⁻ 0.9. γ 555; 597 g ⁻ 601: h; g 448; g	Np 241 13,9 m β ⁻ 1,3 γ 175; (133) 9	$\begin{array}{c c} Np & 242\\ \hline 2,2 m & 5,5 m\\ \beta^-2,7 & \beta^-\\ \gamma 736; & \gamma 786;\\ 780; & 945;\\ 1473 & 159\\ 9 & 9\end{array}$	Np 243 1,85 m ^{β-} ^{γ 288} 9	$\begin{array}{c} Np \ 244 \\ 2,29 \ m \\ \beta^{-} \\ \gamma \ 217; \ 681; \\ 163; \ 111 \\ 9 \end{array}$	152		
m = 900 g, a 160 + 7 g, a 2200 [g, a 2000] g 180 a 0.000 [g, a 2000] g a 180 a 0.000 [g, a 2000] g a 2100 g 32 + 19; a < 1 h = 0 g 448g g													tems
Prev	vious	work	· •	ſ		(sf), (n _{th} , f)	, (n, f	^c), (d,	pf)			

Andreas Oberstedt 54th ASRC International Workshop Sakura-2019, Tokai (Japan), March 25 – 27, 2019

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	α 7,342	α 7,392; 7,358 € ?	α 7,06; 7,17 9	α 7,209; 7,174 9	ε α 7,137 g	α 6,750; 6,708 sf γ (42; 96) e ⁻ ; g	ε 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; σι 1700	α 6,030; 5,989… sf γ (43…); e [−] σ 2000; σ ₁ < 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 _f 32					
Bk 238 144 s		Bk 240 5 m		Bk 242	Bk 243	Bk 244 4,35 h	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					
e βst		e βst		sf	Sf ? 0 6.575, 6.543. 7 755, 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	8 ^{-0,9} γ 551 θ ⁻⁷ ε 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 _f 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	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					
	€ α 6,52	ε γ 188 9	Sf a 6,291; 6,248 sf g	Sf 4 a 5,939 y 472, 431, 132 e ⁻ g	Sf a 6,113; 6,069 sf; 9 γ (44); 9 ⁻ σ - 20 σ_{f} - 5	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 g σ 60; σι 82	α 5,078; 5,035 st; 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 • 6.042 • 280; 438, 474; 909	Am 238 1,63 h sf * 5.94 7 963; 919; 561; 605.	Am 239 11,9 h sf * 5,774 * 278: 228 g	Am 240 50,8 h	Am 241 432,2 a sf a 5,486; 5,443 st; y 60; 26 c; g c; 50; 4570; c; 3,1	Am 242	Am 243 7370 a sf a:5,275; 5,233 sf; 75; 44 o:75 + 5 o:0.074	Am 244 sf p 1,5 y (1084) g 1600 g 1600 g 1600 g 26 m p - 0,4 y 744 y 744 y 744 g - 0,4 g -	Am 245 2,05 h sf ^{p=0.9} 7253: (241; 296)	Am 246 25 m 39 m 25.m 39 m 2.c., β ⁺ 2.c., 1079, 205, 799; 1062, 756, 754, 154; 154;	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 st. Mg 28 γ (48; 109); e ⁻ σ ₁ 160	Pu 237 45,2 d sf ^{a 5,334} ^{y 60} ^c ^e ^r (2300	Pu 238 87,74 a sf a 5,499; 5,456 af; Si; Mg y (43; 100); e ⁻ a 510; a; 17	Pu 239 2,411 · 10 ⁴ a sf α.5,157, 5,144 sf; γ (52) e ⁻ ; m σ 270; σ, 752	Pu 240 6563 a sf • 5.168; 5.124 g; y (45) • 7:9 • 290; e) = 0.049	Pu 241 14,35 a ^{β⁻0.02; g} ^{α 4,896} ^{γ (149); e⁻} ^{σ 370; σ 1010}	Pu 242 3,750 · 10 ⁵ a sf α 4,901; 4,856 sf; γ (45) σ ⁻ ; g σ ⁻ 19, σ ₁ < 0,2	Pu 243 4,956 h sf ^{β=0,6} ^{γ=4,,9} ^{σ < 100, σ} , 200	Pu 244 st 8,00 · 10 ⁷ a a 4,589; 4,546 st; 9 e ⁻ o 1,7	Pu 245 10,5 h sf ^{p=0,9; 1,2,} ^{y 327; 560; 308,; g} ^{s 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; 648; φ 104; φ 104 9; σ ₁ 2700 α; σ ₁ 2700	Np 237 2,144 · 10 ⁶ a sf α 4,790; 4,774 γ 29; 87 ε ⁻ σ 180; σ ₁ 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 < 1	Np 240 7,22 m 65 m β-2.2, β-0.9. γ 555; 976; 6° 601; hg 448g	Np 241 13,9 m ^{β⁻ 1,3} γ 175; (133) 9	$\begin{array}{c c} Np & 242\\ \hline 2,2 \ m & 5,5 \ m \\ \beta^-2,7 & \beta^+ \\ \gamma & 736; & \gamma & 786; \\ 700; & 945; \\ 1473 & 159 \\ 9 & 9 \end{array}$	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 \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 ⁵ a 4,775 4,723; ef Mg 28, Ne; _Y (53; 121) e [*] ; o [*] 96; o [*] _J < 0,005	U 235 0,7200 26 m 7,038-10 ⁴ a ^{4,398} ; st h ₁ (0,07) e ⁻ x 95; c ₁ 566	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 ms 4,468 - 10° n 1,254 1/26 1/27 (10, 10° 27, 100 km 27, 1100	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: $(sf), (n_{th}, f), (n, f), (d, pf)$																	

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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 st	α 7,342	α 7,392; 7,358 € ?	ε α 7,06; 7,17 9	α 7,209; 7,174 9	α 7,137 g	α 6,750; 6,708 sf γ (42; 96) e ⁻ ; g	 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; σ ₁ 1700	α 6,030; 5,989 st 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 _f 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	α 6.662, 6.620 γ 892, 218, 922 g	α 5,888, 6,150 γ 253, 381 α α	¢ γ 799; 1081; 834; 1124 e	α 5,531, 5,710, 5,688 γ 84; 265 g	β ⁻ 0,9 × γ 551 θ ⁻ * 7	β 0,1; α 5,419; 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 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 9	α 6,291; 6,248 st g	α 5.939 γ 472, 431; 132 9 9	sf; g γ (44); σ ⁻ σ - 20 σ _f - 5	e; sf; g γ 278; 228; 210; e σ 130; σ _f 620	α 5,805; 5,762 sf; g γ (43,); e α 15; α _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	β 0,9 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	Am 240	Am 241 432,2 a	Am 242	Am 243 7370 a	Am 244	Am 245 2,05 h	Am 246	Am 247 22 m		151
ε α 6.41	ST a 6,042 y 280; 438; 474; 909 g	а 5.94 у 963; 919; 561; 605 9	α 5,774 γ 278, 228 Θ	α 5,378. γ 988, 889 g	S1 α 5,486, 5,443 st, γ 60; 26 e ⁻ ; g σ 50 + 570; σ ₁ 3.1	a 5,206 st; γ(49) σ 1700 σγ7000 σγ2100	51 α 5,275; 5,233 sf; γ 75; 44 α 75 + 5 α; 0.074	• γ(1084) 898; • γ(1084) 898; • α1 1600 σ1 2200	β ^{**} 0,9 γ 253; (241; 296) e ^{**} ; g	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	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	S1 α 5,768; 5,721 st; Mg 28 γ (48; 109); e ⁻ σ _t 160	α 5.334 γ 60	SI α 5,499; 5,456 uf; Si; Mg γ (43; 100); e ⁻ σ 510; σ _f 17	51 α 5,157; 5,144 sf; γ (52) e ⁻ ; m σ 270; σ _t 752	51 α 5,168; 5,124 st; γ (45) $0^{-}; g$ σ 290; σ] = 0,044	51 β ⁻ 0.02; g α 4.896 γ (149); e ⁻ σ 370; σ ₁ 1010	51 α 4,901; 4,856 sf; γ (45) σ ; g σ 19; $\sigma_{1} < 0,2$	β 0,6 γ 84; 9 σ < 100; σ ₁ 200	SI α 4,589; 4,546 sf; γ θ ⁻ α 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 2,144 · 10 ⁶ a	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⁻, α γ (642; γ 160; 688); ε⁻ 104; ε⁻ 9; σ₁ 2700 9; σ₁ 2600 	ST	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	β 2.2, β 0.9 γ 555; γ 566; 597 974; 601; Pr; 9 448; 9	β 1,3 γ 175; (133) g	β ⁻ 2,7 γ 736; γ 786; 780; 945; 1473 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	26 m 7,038-10 ⁴ a α 4.398; sl ŀγ (0,07) e ⁻ σ 95; σ ₁ 586	α 4,494; 4,445; iγ 1783; sf; γ (49; 642 sf 0 ⁻ ; σ 5,1	β 0,2 γ 60; 208 σ σ - 100; σ ₁ < 0,35	270 ns. 4,468-10 ⁹ a 57 2534, a 4,198; d 1679 281; 7 (50; d w 2,7; et 3.101	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	vious	work				(sf), (n _{th} , f)	, (n, 1	⁻), (d,	pf)			
Rece	ent e	xperi	ment	: (<u> </u>	(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	Cf 247 3,11 h	Cf 248 333,5 d α 6,258; 6,217	Cf 249 350,6 a a 5,812; 5,758	Cf 250 13,08 a	Cf 251 898 a	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 € ?	α 7,06; 7,17 g	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; σ ₁ < 3 50	γ 177; 227 σ 2900; σ ₁ 4500	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 sf (* 6.575. 6.543 y 755. 946 y	Bk 244 4,35 h st v 6.662, 6.620 v 892, 216, 922, g	Bk 245 4,90 d sf * * * * * * * *	Bk 246 1,80 d ^e y 799; 1081; 834; 1124 e	Bk 247 1380 a α 5,531; 5,710; 5,688 γ 84; 265 9	Bk 248 23.7 h > 9 a β ⁻ 0.9 * y 551 \$ 7 g ⁻ 7 *	Bk 249 320 d β ⁻ 0,1; α 5,419; 5,391; sf γ (327; 308) σ 700; σt - 0,1	Bk 250 3,217 h β 0,7; 1,8 γ 989; 1032; 1029 σ; 1000	$\begin{array}{c} Bk \ 251 \\ 55,6 \ m \\ \end{array} \\ \begin{array}{c} \beta^{-} \sim 0,9; \ 1,1 \\ \gamma \ 178; \ 130; \\ 153 \end{array}$
	Cm 238 2,4 h	Ст 239 3 h	Cm 240 27 d sf • 6.291; 6.248 §f 9	Cm 241 32,8 d sf • 5,939 • 7472,431; 132 • 9	$\begin{array}{c} \mbox{Cm 242} \\ \mbox{162,94 d} \\ \mbox{sf} & \alpha 6,113, 6,069 \\ \mbox{sf}, g \\ & \gamma (44), e^{-} \\ \sigma - 20 \\ \sigma_{f} - 5 \end{array}$	Cm 243 29,1 a sf α 5.785, 5.742 κ; st; g γ 278, 228; 210; e ⁻ σ 130, σ ₁ 620	Cm 244 18,10 a sf (a 5,805; 5,762 sf; g (43,); e ⁻ (15; o ₁ , 1, 1	Cm 245 8500 a sf a 5.361: 5.304 sf: g y 175: 133 o 350: or 2100	Cm 246 4730 a α 5,386; 5,343 sf; g γ (45); e ⁻ σ 1,2; σ _f 0,16	Cm 247 1,56 · 10 ⁷ a α 4,870; 5,267 γ 402; 278 ^g σ 60; σ ₁ 82	Cm 248 3,40 · 10 ⁵ a α 5,078; 5,035 st, γ; e ⁻ ; g σ 2,6; σt 0,36	$\begin{array}{c} Cm \ 249 \\ 64,15 \ m \\ \gamma \ 634; (560; \\ 369); \ e^- \\ \sigma \ -1,6 \end{array}$	Cm 250 ~ 9700 a sf α ?; β ⁻ ? σ - 80
Am 236 4,4 m	Am 237 73,0 m sf v a 6.042 v 280: 438: 474: 909 g	Am 238 1,63 h sf * 5,94 y 963; 919; 561; 005 9	Am 239 11,9 h sf • 5,774. • 7 276,228. • 9	Am 240 50,8 h sf (\$ 5.378 7 988,889 9	Am 241 432,2 a sf a 5,486; 5,443 sî, y 60; 26 e^; g o 50 + 570; or 3,1	Am 242 141 a 16 h γ(49), e ⁻ 0. ⁽² 0.6, σ 5,206 0/24) σ 1700 9 ⁽² (49) σ 1700 9 ⁽² (49) σ 1700 9 ⁽² (49)) σ 1700 9 ⁽² (49)) σ 1200 9 ⁽² (49))	Am 243 7370 a sf g: 5,276; 5,233 g: 7, 75; 44 g: 7, 51 + 5 g: 0,074	Am 244 56 m (0-1,5) (10,1 h (0-1,4) (10,4) (1	Am 245 2,05 h sf β ^{+ 0,9} γ253: (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 sf, 5,768; 5,721 sf, Mg 28 y (48; 109); e ⁻ o ₁ 160	Pu 237 45,2 d sf ^{x 5,334} ^{y 60} e ⁻ _{rr} 2300	Pu 238 87,74 a sf σ 5,499; 5,456 σt, Si, Mg γ (43; 100); σ ⁻ σ 510; σ ₁ 17	Pu 239 2,411 · 10 ⁴ a (, 5,157; 5,144 e ⁽ ; m o 270; o ₁ 752	Pu 240 6563 a sf a 5,168; 5,124 e ⁽¹⁾ e ⁽²⁾ c	Pu 241 14,35 a sf ^{(a,4,896} ⁽¹⁴⁹⁾ ; e ⁻ ^{(370. or 1010}	$\begin{array}{c c} Pu & 242 \\ \hline 3,750 \cdot 10^5 a \\ \hline α 4,901; 4,856 \\ $s!; γ (45) \\ σ; g \\ σ 19; $a_1 < 0.2$ \\ \end{array}$	Pu 243 4,956 h sf ^{\$^0.8} ^{3⁸9} ^{\$^0.8}	$\begin{array}{c} Pu \; 244 \\ \text{8,00} \cdot 10^7 \text{ a} \\ \text{sf} \\ \frac{\alpha \; 4,589; \; 4,546}{\text{sf}; \; \gamma} \\ \frac{\text{sf}; \; \gamma}{\sigma} \\ \frac{\sigma}{\sigma} \; 1,7} \end{array}$	$ sf_{\substack{\beta^{=} 0.9; \ 1.2 \\ 306; \ 9 \\ \sigma \ 150}} Pu \ 245 \\ \beta^{=} 0.9; \ 1.2 \\ \beta^{=} 0.9; \ 1.2 \\ 306; \ 9 \\ \sigma \ 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 ε; β ⁺ γ 1559; 1528; 1602 σ ₁ - 900	$\begin{array}{c} Np \ 235\\ 396,1 \ d\\ \epsilon; \ \alpha \ 5,025;\\ 5,007,\\ \gamma \ (26; 84,); \ e^{-}\\ g; \ \sigma \ 160 + ? \end{array}$	Np 236 22,5 h 1,54 · 10 ⁵ a < β ⁻ 0,5 < β ⁻ , α × (642) × 160, 688) < 104	Np 237 2,144 + 10 ⁶ a sf α 4.790; 4.774 γ 29; 87; ε ⁻ σ 180; σ ₁ 0.020	Np 238 2,117 d β ⁻ 1,2 γ 984; 1029; 1026; 924; e ⁻ g: σr 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; 974; e ⁻ 974; e ⁻ 601; h ; g 448; g	Np 241 13,9 m ^{β⁻1,3} _γ 175; (133) 9	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Np 243 1,85 m ^{β⁻_{γ 288} 9}	$\begin{array}{c} \text{Np 244} \\ 2,29 \text{ m} \\ \beta^{-} \\ \gamma 217; 681; \\ 163; 111 \\ 9 \end{array}$	152		
$\begin{array}{c} U \; 233 \\ 1,592 \cdot 10^5 \; a \\ \alpha \; 4,824; \; 4,783 \\ Ne \; 25; \\ \gamma \; (42; 97); \; e^- \\ \sigma \; 47; \; \sigma_1 \; 530 \end{array}$	U 234 0,0055 2,455 · 10 ³ a « 4,775, 4,725; sf Mg 28; Ne: _Y (53; 121) « ^c : o 96; o ₁ < 0.005	U 235 0,7200 26 m ¹ / ₄ (0,07) ¹ / ₂ (0,07) ² / ₂ (1,0) ² / ₂ (1,0) (1,0) ² / ₂ (1,0) ²	U 236 120 ns 2,342-10 ⁷ a 4,494; 4,445; 542 51 (49; 113) 67; 0 5,1	U 237 6,75 d β ⁻ 0,2 γ 60; 208 e ⁻ σ - 100; σ ₁ < 0,35	U 238 99,2745 270 m 4,468-10° 0 1/2514 4,468-10° 0 201,100 0 201,100 0 201,100 0	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	con	npour	nd syst	tems
Prev	/ious	work		C		(sf), (n _{th} , f)	, (n, 1	f), (d,	pf)			
Rece	ent e	xperi	ment	: (<u> </u>	(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 9	α 7,209; 7,174 9	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; σ ₁ 1700	sf γ (43…); e σ 2000; σt < 3 50	6,012 γ 177; 227 σ 2900; σι 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 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
βst		e βsf		51	? α 6.575, 6.543 γ 755, 946 9	ві « 6.662, 6.620 у 892, 218, 922 g	n 5,888, 0,150 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 θ ⁻ × 7	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 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	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 9	ST α 6,291; 6,248 st g	ST • a 5,939 y 472, 431; 132 e ⁻ 9	SI $a = 6,113; 6,069$ sf; g $\gamma (44); e^{-1}$ $\sigma = 20$ $\sigma_{f} = 5$	ST α 5,785, 5,742 ε; sf; g γ 278; 228; 210; e ^π σ 130; σ ₁ 620	ST α 5,805; 5,762 sf; g γ (43,); e α 15; α _f 1,1	ST a 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 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	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 α 5,378. γ 988; 889 9	ST α 5,486; 5,443 sf; γ 60; 26 e ⁻ ; g σ 50 + 570; σ ₁ 3,1	SI τη (49), e 6 0.0 a 5,206 st; γ (49) γ (42) σ 1700 e ⁷ , g σ ₁ 7000 σ ₁ 2100	ST α 5,275; 5,233 sf; γ 75; 44 α 75 + 5 α; 0.074	SI ^{β 1,2} ^{β 0,4} γ 744; γ (1084) 898; σ ⁻ ; g 154; σ ⁻ σ ₁ 1600 σ ₁ 2200	ST β ⁺⁻ 0,9 γ 253; (241; 296) σ ⁺ ; 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 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	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 * a 5,85 y 49; (756; 34) e	ST α 5,768; 5,721 sf; Mg 28 γ (48; 109); e ⁻ σ _f 160	st α 5.334 γ 60e ⁻ σ ₁ 2300	ST α 5,499; 5,456 st; Si; Mg γ (43; 100); σ ⁻ 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 st; γ (45) e ⁻ ; g σ 290; σ) = 0,044	ST β ⁻ 0.02; g α 4.896 γ (149); e ⁻ σ 370; σ _f 1010	SI α 4,901; 4,856 sf; γ (45) e ⁻ ; g σ 19; σ ₁ < 0,2	ST β ⁺ 0,6 γ 84; g σ < 100; σt 200	ST α 4,589; 4,546 st; γ σ ⁻ 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 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 σι - 900 	e; α 5,025; 5,007 γ(26; 84); e ⁻ g; σ 160 + ?	 ε; β⁻0,5 ε; β⁻; α γ (642; γ 160; 688); e⁻ 104; e⁻ α; α; 2700 α; α; 2600 	ST α 4,790; 4,774 γ 29; 87; e ⁻ σ 180; σ _f 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	β ⁻² .2,β ^{-0,9} . γ 555; γ 566; 597974; e ⁻ 601; hy; g 448; g	β 1,3 γ 175; (133) g	β 2,7 γ 736; γ 786; 780; 945; 1473 0 0	β ⁻ γ 288 g	β γ 217; 681; 163; 111	152		
U 233 1,592 · 10 ⁵ a	U 234 0,0055	U 235 0,7200	U 236 120 ns 2,342 · 10 ⁷ a	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	$2,455 \cdot 10^{5}$ a 4,775, 4,723; st Mg 28; Ne; γ (53; 121) e^{-} , e^{-} 6; $e_{\gamma} < 0,005$	26 m 7,038-10 ⁴ a 4,398; st Νe; γ 186 σ ⁻ σ ⁻	α 4,494; 4,445; 4,445; iγ 1783; sf; γ (49; 642 113) 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 2534 e 4,198 al 1879 287 y 50 a d v 2.7; e(3,10	β 1,2; 1,3 γ 75; 44 σ 22; σι 15	$\beta^{-} 0.4$ $\gamma 44; (190)$ e^{-} m		β γ 68; 58; 585; 573 m	con	npour	nd syst	tems
Pre	vious	work		C		(sf), (n _{th} , f)	, (n, f	⁼), (d,	pf)			
Rece	ent e	xperi	ment	: (<u> </u>	(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	α 7,342	α 7,392; 7,358 € ?	ε α 7,06; 7,17 g	α 7,209; 7,174 9	α 7,137 g	α 6,750; 6,708 sf γ (42; 96) e ; g	ε 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; σ ₁ 1700	α 6,030; 5,989 sf γ (43); e ⁻ σ 2000; σ ₁ < 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	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
βst		e βsf		51 0	? α 6.575; 6.543 γ 755; 946 9	6.662, 6.620 γ 892, 218, 922 g	n 5,888; 0,150 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 × 551 σ ⁻ * 7	β ⁻ 0,1; α 5,419; 5,391; sf γ (327; 308) σ 700; σt - 0,1	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	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	ε γ 188 g	α 6,291; 6,248 sf g	a 5.939 y 472, 431, 132 e 0	sf; g γ (44); e ⁻ σ - 20 σ _f - 5	ε; sf; g γ 278; 228; 210; e σ 130; σ _f 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, 5,287 γ 402; 278 g σ 60; σt 82	α 5,078; 5,035 sf; 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	Am 240	Am 241 432,2 a	Am 242	Am 243 7370 a	Am 244	Am 245 2,05 h	Am 246	Am 247 22 m		154
ε α 6,41	α 6,042 γ 280; 438; 474; 909 9	a 5,94	α 5,774 γ 278; 226 e g	α 5,378 γ 988, 889 g	α 5,486; 5,443 sf; γ 60; 26 e ⁻ ; g σ 50 + 570; σ ₁ 3,1	a 5,206 st; γ (49) σ 1700 σ; g σ 7700 σ; 2	α 5,275; 5,233 st; γ 75; 44 σ 75 + 5 α; 0,074	• γ (1084) 898; • ; g σ; 1600 σ; 2200	β 0,9 γ 253; (241; 296) e ⁻ ; g	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	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	
* α 5,85 γ 49; (756; 34) e	α 5,768; 5,721 st; Mg 28 γ (48; 109); e ⁻ σ _t 160	α 5.334 γ 60 e ⁻ α _f 2300	α 5,499; 5,456 uf; Si; Mg γ (43; 100); e ⁻ σ 510; σ _f 17	α 5,157; 5,144 st; γ (52) e ⁻ ; m σ 270; σ ₁ 752	α 5,168; 5,124 st; γ (45) e ; g σ 290; dγ = 0,044	β ⁻ 0,02; g α 4,896 γ (149); e ⁻ σ 370; σ ₁ 1010	$\begin{array}{c} \alpha \ 4,901; \ 4,856\\ \text{sf}; \ \gamma \ (45)\\ \theta^{-}; \ g\\ \sigma \ 19; \ \sigma_{1} < 0.2 \end{array}$	β 0,6 γ 84; g σ < 100; σ ₁ 200	α 4,589, 4,546 sf; γ e σ 1,7	β 0.9; 1,2 γ 327; 560; 308; g σ 150	$\begin{array}{c} \beta^{+} \ 0,2; \ 0,3 \\ \gamma \ 44; \ 224; \ 180 \\ m_1 \end{array}$	β-	
Np 234 4,4 d	Np 235 396,1 d	Np 236 22,5 h 1,54 · 10 ⁵ a	Np 237 2,144 · 10 ⁶ a	Np 238 2,117 d	Np 239 2,355 d	Np 240 7,22 m 65 m 8 ⁻²² 8 ⁻⁰⁹	Np 241 13,9 m	Np 242 2,2 m 5,5 m	Np 243 1,85 m	Np 244 2,29 m	150		
 ε; β* γ 1559; 1528; 1602 σ₁ - 900 	e; α 5,025; 5,007 γ(26; 84); e ⁻ g; σ160 + ?	 ε; β⁻¹0,5, ε; β⁻¹; α γ (642; γ 160; 688; e⁻¹ 104; e⁻¹ g; σ₁ 2700 g; σ₁ 2600 	a 4,790; 4,774 γ 29; 87; e ⁻ σ 180; σ _f 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	γ 555; γ 566; 597 974; e 601; łγ; g 448; g	β 1,3 γ 175; (133) g	γ 736; γ 786; 780; 945; 1473 159 9 9 9	β ⁻ γ 288 9	ρ γ 217; 681; 163; 111 g	152		
U 233 1,592 · 10 ⁵ a	U 234 0,0055	U 235 0,7200	U 236 120 ns 2,342 - 10 ⁷ a	U 237 6,75 d	U 238 99,2745	U 239 23,5 m	U 240 14,1 h		U 242 16,8 m				h a .aa a
α 4,824; 4,783 Ne 25; γ (42; 97); e σ 47; σ ₁ 530	α 4,775, 4,723; sl Mg 28; Ne; γ (53; 121) e , σ 96; σ ₁ < 0,005	25 m 7,038-10 α 4.398; sf Ι _γ (0.07) Νε; γ 186 e ⁻ σ 95; σ ₁ 586	iγ 1783; 4,445; 642 113) at 0 ⁻ ; σ 5,1	β 0,2 γ 60; 208 e σ ~ 100; σ ₁ < 0,35	270 ns 4,468 10° a h 2514 a 4,198 a 4 1979 2011 y 50 4 a a 2011 y 50 4 a a 2,7 ey 3,10	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	ia syst	tems
Prev	/ious	work	:	C		(sf), (n _{th} , f)	, (n, f	^F), (d,	pf)			
Rece	ent e	xperi	ment	: (<u> </u>	(sf), (n _{th} , f)						
Арр	roved	d pro	posal	s: [(n, f)							

54th ASRC International Workshop Sakura-2019, Tokai (Japan), March 25 – 27, 2019 Andreas Oberstedt

Summary

- ✓ High precision PFGS measurements → reference for model calculations
- 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 (in progress)
- Preliminary results : PFGS dependence of fragment mass
- ✓ Data analysis of recent experiments in progress, e.g. ²³³U (n_{th}, f) PFGS

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

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

→ Photo-fission at ELI-NP !

ELI-NP and further photo-fission physics goals

ELIADE

8 Ge clover detectors

ELIGANT

$\begin{array}{c} 30 \ LaBr_3 \ or \ CeBr_3 \\ 20 \ ^7Li \ glass \ det. \\ 30 \ liquid \ scintillators \end{array}$

Outlook

ELI-NP and further photo-fission physics goals New position-sensitive twin FGIC (TU Darmstadt)

ELIADE

8 Ge clover detectors

(courtesy M. Peck)

ELIGANT

30 LaBr₃ or CeBr₃ 20 ⁷Li glass det. 30 liquid scintillators


Outlook



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

 measurement of fission fragments, γ rays and neutrons
 correlations I
 - o correlations !







- New results from recent measurements
- Study of PFGS characteristics depending on fission fragment mass (continued)
- New experiments are approved and scheduled
- Study of entrance channel effects
 - (n,f) vs. (d,pf)
 - (p,p'f) vs. (γ,f)
 - etc.
 - \rightarrow Photo-fission at ELI-NP !
 - → Particle-induced fission elsewhere !





Particle-induced fission studies

Outlook

VESPA++ @ JRC Geel





OSCAR @ OCL



8 LaBr₃ detectors
7 liquid scintillators
+ pos. sensit. FGIC

 $30 \text{ LaBr}_3 \text{ detectors} + \text{TPC}$



The collaborators



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PhD students





ありがとうございました!