

Софийски Университет
"Св. Климент Охридски"
Физически факултет
катедра Атомна физика



Структура на нисколежащи състояния в слабо деформирани и преходни изотопи на Ru

Станимир Кисьов

07.01.2016

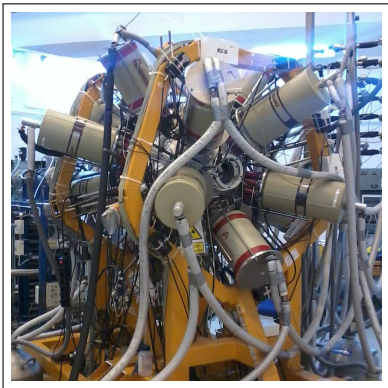
- 1 Мотивация
- 2 Експериментални детайли и резултати
- 3 Интерпретация на получените резултати

Изотопи на Ru в масовия регион $A \sim 100$

Z	100Pd 3.63 D ε: 100.00% 2.1279	101Pd 8.47 H ε: 100.00%	102Pd STABLE 1.02% 2.29299	103Pd 16.991 D ε: 100.00%	104Pd STABLE 11.14% 2.38137	105Pd STABLE 22.33%	106Pd STABLE 27.33% 2.40168	107Pd 6.5E+6 Y β-: 100.00%	108Pd STABLE 26.46% 2.41560
	99Rh 16.1 D ε: 100.00%	100Rh 20.8 H ε: 100.00%	101Rh 3.3 Y ε: 100.00%	102Rh 207.3 D ε: 78.00% β-: 22.00%	103Rh STABLE 100%	104Rh 42.3 S β-: 99.55% ε: 0.45%	105Rh 35.36 H β-: 100.00%	106Rh 30.07 S β-: 100.00%	107Rh 21.7 M β-: 100.00%
	98Ru STABLE 1.87% 2.14245	99Ru STABLE 12.76% 2.27329	100Ru STABLE 12.60% 2.27329	101Ru STABLE 17.06% 2.32886	102Ru STABLE 31.55% 2.32886	103Ru 39.247 D β-: 100.00%	104Ru STABLE 18.60% 2.4816	105Ru 4.44 H β-: 100.00%	106Ru 371.8 D β-: 100.00% 2.6463
	97Tc 4.21E+6 Y ε: 100.00%	98Tc 4.2E+6 Y β-: 100.00%	99Tc 2.111E+5 Y β-: 100.00%	100Tc 15.46 S β-: 100.00% ε: 2.65-3%	101Tc 14.02 M β-: 100.00%	102Tc 5.28 S β-: 100.00%	103Tc 54.2 S β-: 100.00%	104Tc 18.3 M β-: 100.00%	105Tc 7.6 M β-: 100.00%
	96Mo STABLE 16.67% 2.09215	97Mo STABLE 9.60% 1.91779	98Mo STABLE 24.39% 1.91779	99Mo 65.976 H β-: 100.00%	100Mo 7.3E+18 Y 9.82% 2β-: 100.00% 2.12131	101Mo 14.61 M β-: 100.00%	102Mo 11.3 M β-: 100.00% 2.50743	103Mo 67.5 S β-: 100.00%	104Mo 60 S β-: 100.00% 2.9173
54	55	56	57	58	59	60	61	N	

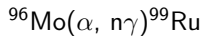
Детекторната система ROSPHERE

Смесена система от детектори от HPGe и $\text{LaBr}_3:\text{Ce}$ е използвана за измерване на кратки времена на живот на възбудени ядрени състояния (IFIN-HH, Букурещ, Румъния).



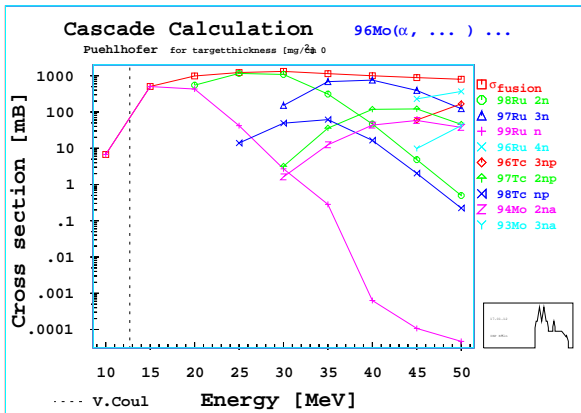
Детекторната система ROSPHERE

- 14 HPGe детектора
(добра разделителна способност по енергия)
- 11 $\text{LaBr}_3:\text{Ce}$ детектора
(добра разделителна способност по време)

Сечение за взаимодействие за $^{96}\text{Mo}(\alpha, n\gamma)^{99}\text{Ru}$ 

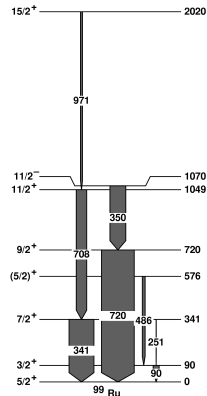
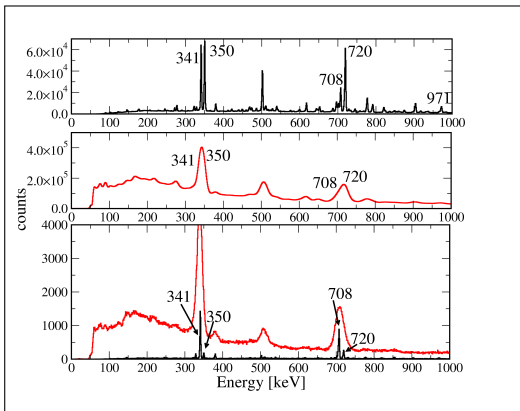
Дебелина на
мишената:
 10 mg/cm^2

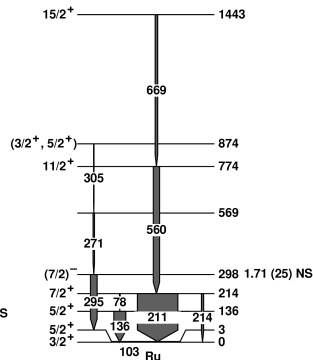
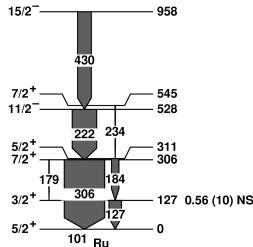
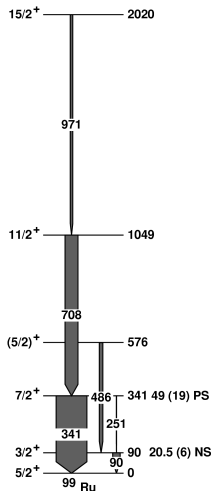
$E_{\text{beam}} = 15 \text{ MeV}$

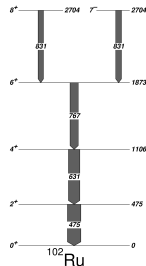
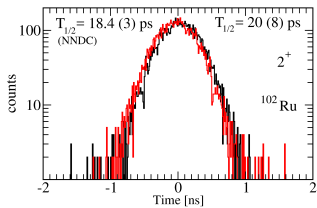
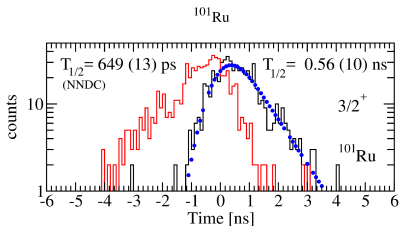
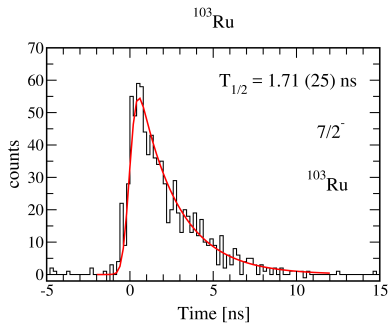
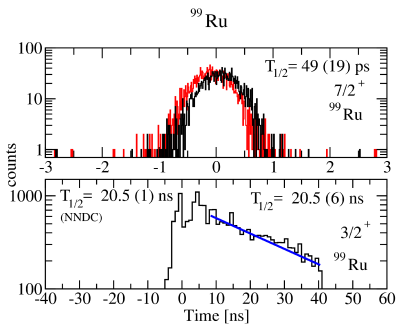


Тройни съвпадения в $^{96}\text{Mo}(\alpha, n\gamma)^{99}\text{Ru}$

Прилагането на енергетично условие с детекторите от HPGe намалява броя събития в детекторите от $\text{LaBr}_3:\text{Ce}$, но намалява съществено фоновото ниво.



Нисколежащи състояния в $^{99,101,103}\text{Ru}$ 



Модел на твърд триаксиален ротор плюс частица

$$\kappa_4 = 0.070$$

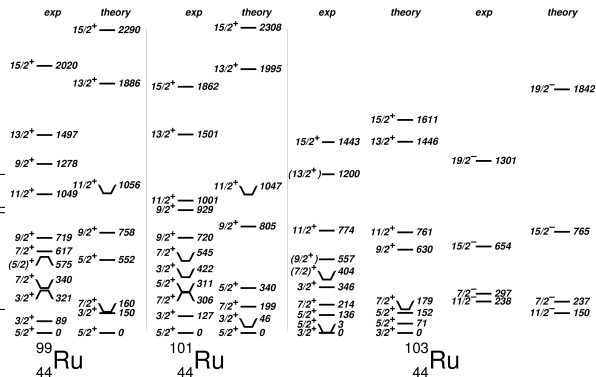
$$\mu_4 = 0.39$$

$$\kappa_5 = 0.062$$

$$\mu_5 = 0.43$$

nucleus	ϵ_2	γ
^{99}Ru	+0.149	28.0
^{101}Ru	+0.187	26.0
^{103}Ru	+0.230	26.0

$$\epsilon_4 = -0.04$$



Модел на твърд триаксиален ротор плюс частица

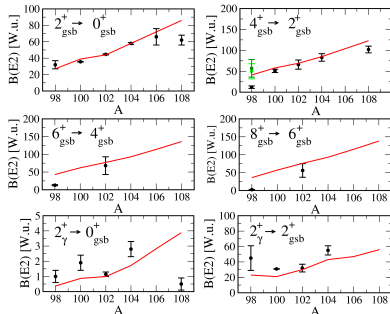
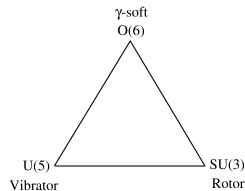
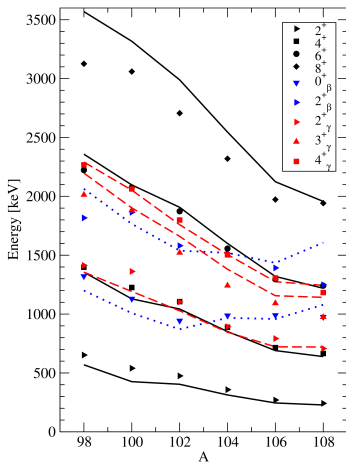
J_i^π	E_γ^{exp} (keV)	$B(M1)^{exp}$ (W.u.)	$B(M1)^{th}$ (W.u.)	$B(E2)^{exp}$ (W.u.)	$B(E2)^{th}$ (W.u.)	μ^{exp} μ_N	μ^{th} μ_N	Q^{exp} (b)	Q^{th} (eb)
$^{99}_{44}\text{Ru}$									
$5/2^+$	0					-0.641 (5)	-0.954	0.079 (4)	-0.008
$3/2^+$	0					-0.284 (6)	0.001	0.231 (13)	0.123
$3/2^+$	90	0.00018 (7)	0.024	50.1 (18)	22.4				
$7/2^+$	341	0.011 (5)	0.0008	0.036 (23)	0.12				
	251			3.0 (12)	2.4				
$^{101}_{44}\text{Ru}$									
$5/2^+$	0					-0.719 (6)	-0.801	0.46 (2)	0.109
$3/2^+$	0					-0.210 (5)	-0.272		
$3/2^+$	127	0.016 (3)	0.008	20 (5)	0.03				
$7/2^+$	306	0.014 (5)	0.002	1.3 (13)	0.02				
	179			13 (5)	22.5				
$^{103}_{44}\text{Ru}$									
$3/2^+$	0					0.200 (7)	0.415	0.62 (2)	0.491
$7/2^+$	214			46 (19)	13				
	211	0.048 (20)	0.007						
	78	0.017 (8)	0.002						

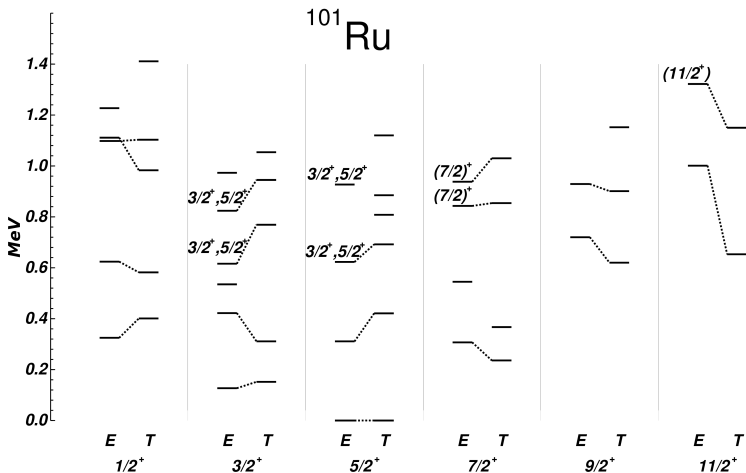
J_i^π	E_γ^{exp} (keV)	$B(E1)^{exp}$ (W.u.)	$B(E1)^{th}$ (W.u.)
$^{103}_{44}\text{Ru}$			
$7/2^-$	294	7.0×10^{-6} (11)	0.22×10^{-6} (11)

Пресмятания с IBM-1 за четно-четните Ru ядра

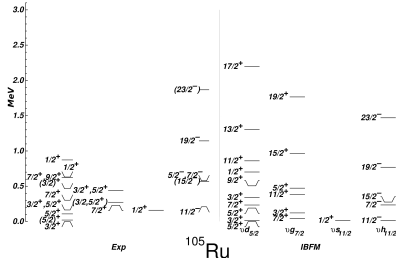
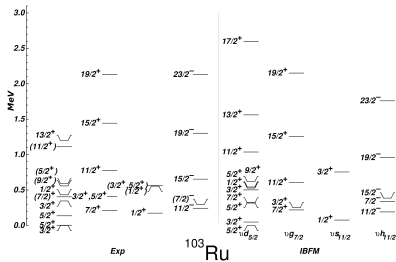
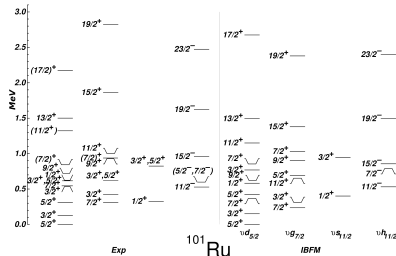
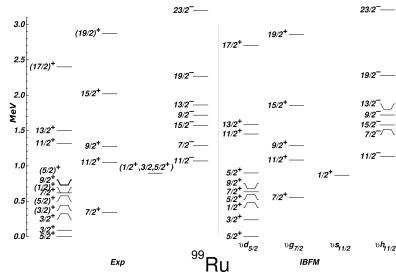
Разширен Q формализъм

$$H = \varepsilon \hat{n}_d - \kappa Q^2 - \kappa' L^2$$



IBFM-1 пресмятания за енергетичните нива в ^{101}Ru 

Интерпретация на получените резултати



Спектроскопични фактори за (d,p) реакции

Ядро	E_{lev}^{\dagger} [keV]	ℓ	$J^{\pi\dagger}$	$C^2 S'_{exp}$	$C^2 S'_{th}$	Ядро	E_{lev}^{\dagger} [keV]	ℓ	$J^{\pi\dagger}$	$C^2 S'_{exp}$	$C^2 S'_{th}$
⁹⁹ Ru	0.0		5/2 ⁺		3.14	¹⁰³ Ru	0.0	2	3/2 ⁺	1.44	0.010
⁹⁹ Ru	89.6		3/2 ⁺		0.008	¹⁰³ Ru	2.8	2	5/2 ⁺	1.35	2.20
⁹⁹ Ru	340.9		7/2 ⁺		2.97	¹⁰³ Ru	136.1	2	5/2 ⁺	0.012	0.13
⁹⁹ Ru	575.8		(5/2) ⁺		0.03	¹⁰³ Ru	174.3	0	1/2 ⁺	0.75	1.15
⁹⁹ Ru	618.1		(1/2 ⁺)		0.85	¹⁰³ Ru	213.6	4	7/2 ⁺	1.80	3.70
⁹⁹ Ru	734.1		(5/2) ⁺		0.005	¹⁰³ Ru	238.2	5	11/2 ⁻	3.2	7.08
⁹⁹ Ru	1069.9		11/2 ⁻		8.86	¹⁰³ Ru	346.4	2	3/2 ⁺	0.06	0.005
						¹⁰³ Ru	404.2		7/2 ⁺		0.006
						¹⁰³ Ru	432.1	0	1/2 ⁺	0.027	0.048
¹⁰¹ Ru	0.0	2	5/2 ⁺	2.10	2.10	¹⁰⁵ Ru	0.0	2	3/2 ⁺	0.009	0.13
¹⁰¹ Ru	127.2	2	3/2 ⁺	0.067	0.014	¹⁰⁵ Ru	20.6	2	(5/2) ⁺	1.54	1.75
¹⁰¹ Ru	306.9	4	7/2 ⁺	5.3	4.13	¹⁰⁵ Ru	107.9	2	5/2 ⁺	0.07	0.31
¹⁰¹ Ru	311.4		5/2 ⁺		0.07	¹⁰⁵ Ru	159.5	0	1/2 ⁺	0.74	0.96
¹⁰¹ Ru	325.2	0	1/2 ⁺	0.96	1.13	¹⁰⁵ Ru	208.6	5	11/2 ⁻	2.7	6.19
¹⁰¹ Ru	422.2	2	3/2 ⁺	0.15	0.66	¹⁰⁵ Ru	229.5	4	7/2 ⁺	0.75	3.45
¹⁰¹ Ru	527.6	5	11/2 ⁻	5.82	7.69	¹⁰⁵ Ru	301.7	4	7/2 ⁺	0.24	0.03
¹⁰¹ Ru	545.1		7/2 ⁺		0.003	¹⁰⁵ Ru	631.3	0	1/2 ⁺	0.06	0.08
¹⁰¹ Ru	616.3		3/2 ⁺ , 5/2 ⁺		0.002						
¹⁰¹ Ru	623.6	0	1/2 ⁺	0.063	0.021						
¹⁰¹ Ru	824	2	3/2 ⁺ , 5/2 ⁺	0.40	0.31						
¹⁰¹ Ru	1098	0	1/2 ⁺	0.028	0.10						
¹⁰¹ Ru	1111	0	1/2 ⁺	0.17	0.28						

† данни от NNDC

Експериментални и IBFM-1 пресметнати вероятности за преход

Ядро	E_{level} [keV]	J_i^π	E_γ [keV]	J_f^π	$B(M1)_{exp}$ [W.u.]	$B(E2)_{exp}$ [W.u.]	$B(M1)_{IBFM}$ [W.u.]	$B(E2)_{IBFM}$ [W.u.]
⁹⁹ Ru	89.57	3/2 ⁺	89.50	5/2 ⁺	0.000175 (4)	50.1 (10)	0.000169	31.0
⁹⁹ Ru	340.90	7/2 ⁺	340.81	5/2 ⁺	0.011 (5)	0.036 (23)	0.001	11
			251.0	3/2 ⁺		3.0 (12)		2
⁹⁹ Ru	575.83	(5/2) ⁺	486.19	3/2 ⁺	0.11 (3)	0.18 +53-18	0.57	3.78
			575.75	5/2 ⁺	0.035 (10)	11 (5)	0.001	23
⁹⁹ Ru	617.89	7/2 ₂ ⁺	528.36	3/2 ⁺		120 (7)		3
			617.89	5/2 ⁺	0.09 (6)	23 (18)	0.002	15
⁹⁹ Ru	719.87	9/2 ⁺	379.07	7/2 ⁺	0.0045 (8)	3 +4-3	0.052	6.9
			719.81	5/2 ⁺		46 (6)		26
⁹⁹ Ru	1048.50	11/2 ⁺	328.57	9/2 ⁺	0.011 (7)	2.9 (17)	0.0004	0.1
			707.56	7/2 ⁺		23 (13)		19
⁹⁹ Ru	1497.06	13/2 ⁺	777.25	9/2 ⁺		110 (6)		38
⁹⁹ Ru	2020.29	15/2 ⁺	971.95	11/2 ⁺		61 (25)		40
⁹⁹ Ru	3094.45	(19/2) ⁺	1074.14	15/2 ⁺		35 +14-29		40
¹⁰¹ Ru	127.229	3/2 ⁺	127.226	5/2 ⁺	0.01598 (11)	19.9 (24)	0.052	31.4
¹⁰¹ Ru	306.858	7/2 ⁺	179.636	3/2 ⁺		13 (4)		2
			306.857	5/2 ⁺	0.014 (4)	1.4 +15-4	0.001	0.8
¹⁰¹ Ru	720.02	9/2 ⁺	720.02	5/2 ⁺		40 (10)		31
¹⁰¹ Ru	1500.9	13/2 ⁺	780.9	9/2 ⁺		120 (4)		48
¹⁰¹ Ru	1862.4	15/2 ⁺	861.2	11/2 ⁺		<25		57

S. Kisyov^{1,2}, S. Lalkovski^{1,3}, D. Ivanova¹, N. Mărginean², D. Bucurescu²,
R. F. Casten⁴, Gh. Căta-Danil², I. Căta-Danil², D. Deleanu², N. Florea²,
D. Ghiță², T. Glodariu², P. Van Isacker⁵, J. Jolie⁶, R. Lica², R. Mărginean²,
C. Mihai², A. Negret², C. Nița², A. Olacel², S. Pascu², P. Petkov^{2,7}, T. Sava²,
E. Stefanova⁷, R. Suvaila², S. Toma², O. Yordanov⁷, N.V. Zamfir²,

¹*Faculty of Physics, University of Sofia " St. Kliment Ohridski" , Sofia, Bulgaria*

²*Horia Hulubei National Institute for Physics and Nuclear Engineering IFIN-HH,
Magurele, Romania*

³*Department of Physics, University of Surrey, Guildford, Surrey GU2 7XH, United
Kingdom*

⁴*Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut
06520, USA*

⁵*GANIL,CEA/DSM-CNRS/IN2P3, BP 55027, F-14076 Caen Cedex 5, France*

⁶*Institut für Kernphysik, University of Cologne, Cologne, Germany*

⁷*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Science,
Sofia, Bulgaria*