

Reaction mechanism and spectroscopy of superheavy nuclei

Institut Pluridisciplinaire Hubert CURIEN

Group : Du Noyau aux Etoiles

Supervisor : DORVAUX Olivier

M1 Internship defence,
ROHMER Anthony

Summary

Superheavy nuclei

Nuclei synthesis

Fusion evaporation

Detection system

Gamma spectroscopy

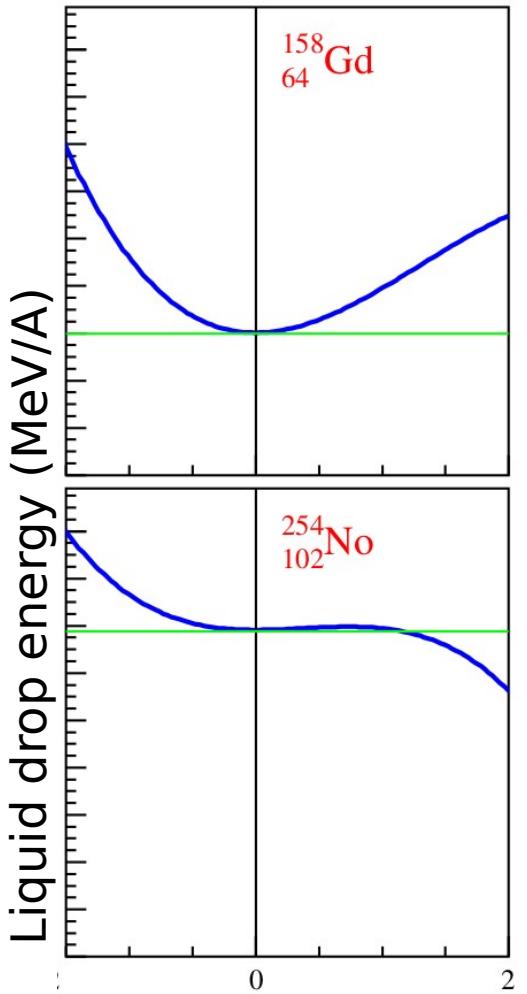
Alpha spectroscopy

Superheavy nuclei

Tableau périodique des éléments chimiques

Groupe → I A Période 1	Hydrogène 1 H 1,007975	II A 2		III A 3	Scandium 21 Sc 44,955908 (5)	IV A 4	Titanium 22 Ti 47,867 (1)	V A 5	Vanadium 23 V 50,9415 (1)	VI A 6	Chrome 24 Cr 51,9961 (6)	VII A 7	Manganèse 25 Mn 54,938044	VIII 8 9 10	Fer 26 Fe 55,845 (2)	Cobalt 27 Co 58,933194	Nickel 28 Ni 58,6934 (4)	Cuivre 29 Cu 63,546 (1)	Zinc 30 Zn 65,38 (2)	Gallium 31 Ga 69,723 (1)	Bore 32 B 10,8135	Carbone 33 C 12,0106	Azote 34 N 14,006855	Oxygène 35 O 15,99940	Fluor 36 F 18,99840316	Néon 37 Ne 20,1797 (6)	O 18
Lithium 3 Li 6,9395	Béryllium 4 Be 9,0121831	Sodium 11 Na 22,98976928	Magnésium 12 Mg 24,3055	Potassium 19 K 39,0983 (1)	Calcium 20 Ca 40,078 (4)	Rubidium 37 Rb 85,4678 (3)	Strontium 38 Sr 87,62 (1)	Césium 55 Cs 132,905452	Baryum 56 Ba 137,327 (7)	Lanthanides 57-71	Hafnium 72 Hf 178,49 (2)	Tantale 73 Ta 180,94788	Tungstène 74 W 183,84 (1)	Rhénum 75 Re 186,207 (1)	Osmium 76 Os 190,23 (3)	Iridium 77 Ir 192,217 (3)	Platine 78 Pt 195,084 (9)	Or 79 Au 196,966569	Mercurie 80 Hg 200,592 (3)	Thallium 81 Tl 204,3835	Plomb 82 Pb 207,2 (1)	Bismuth 83 Bi 208,98040	Polonium 84 Po [209]	Astate 85 At [210]	Radon 86 Rn [222]		
				Rutherfordium 104 Rf [267]	Dubrium 105 Db [268]	Seaborgium 106 Sg [269]	Bohrium 107 Bh [270]	Hassium 108 Hs [277]	Meitnerium 109 Mt [278]	Darmstadtium 110 Ds [281]	Roentgenium 111 Rg [282]	Copernicium 112 Cn [285]	Nihonium 113 Nh [286]	Flerovium 114 Fl [289]	Moscovium 115 Mc [289]	Livermorium 116 Lv [293]	Tennessee 117 Ts [294]	Organesson 118 Og [294]									
Francium 87 Fr [223]	Radium 88 Ra [226]	Actinides 89-103		Lanthane 57 La 138,90547	Cérium 58 Ce 140,116 (1)	Praséodyme 59 Pr 140,90766	Néodyme 60 Nd 144,242 (3)	Prométhium 61 Pm [145]	Samarium 62 Sm 150,36 (2)	Europium 63 Eu 151,964 (1)	Gadolinium 64 Gd 157,25 (3)	Terbium 65 Tb 158,92535	Dysprosium 66 Dy 162,500 (1)	Holmium 67 Ho 164,93033	Erbium 68 Er 167,259 (3)	Thulium 69 Tm 168,93422	Ytterbium 70 Yb 173,045	Lutécium 71 Lu 174,9668									
119 ?	120 ?			Actinium 89 Ac [227]	Thorium 90 Th 232,03577	Protactinium 91 Pa 231,03588	Uranium 92 U 238,02891	Néptunium 93 Np [237]	Plutonium 94 Pu [244]	Amerium 95 Am [243]	Curium 96 Cm [247]	Berkélium 97 Bk [247]	Californium 98 Cf [251]	Einsteinium 99 Es [252]	Fermium 100 Fm [257]	Mendéléïum 101 Md [258]	Nobelium 102 No [259]	Lawrencium 103 Lr [266]									
Métaux																											
Alcalins	Alcalino-terreux	Lanthanides	Actinides	Métaux de transition	Métaux pauvres	Métalloïdes	Autres non-métaux	Halogènes	Gaz nobles	Non classés	primordial	désintégration d'autres éléments	synthétique														

Wikipedia : Periodic table (28/11/2016)



Nuclei synthesis

Neutron capture

U238 basis, and β - decay

Limited to Fermium ($Z=100$) who doesn't decay by β -

Fusion evaporation

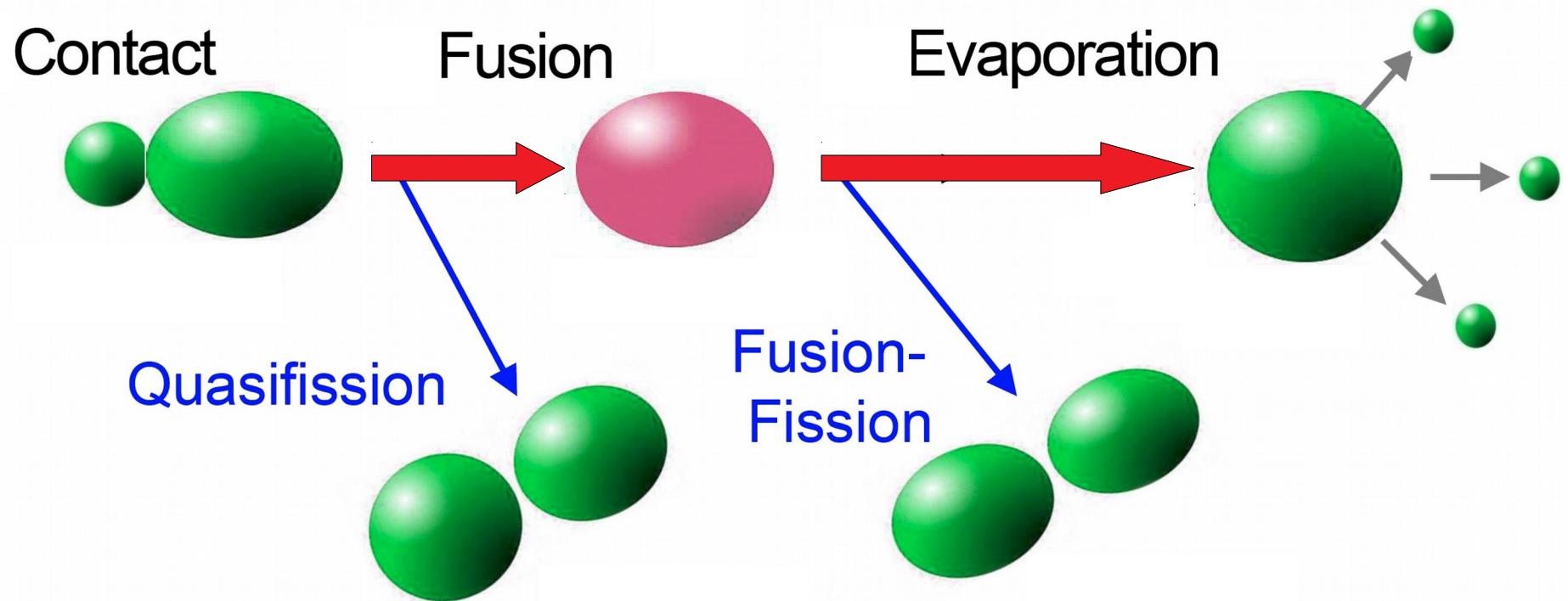
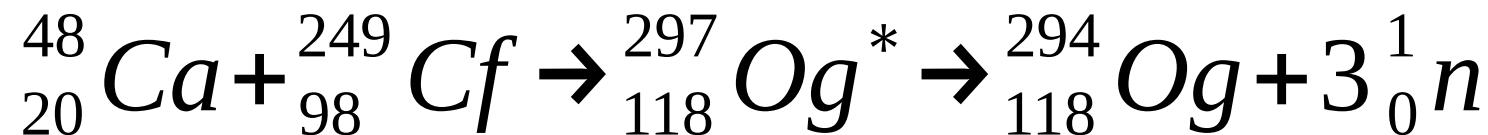
Total fusion by collision above Bass barrier

Multinucleon transfert

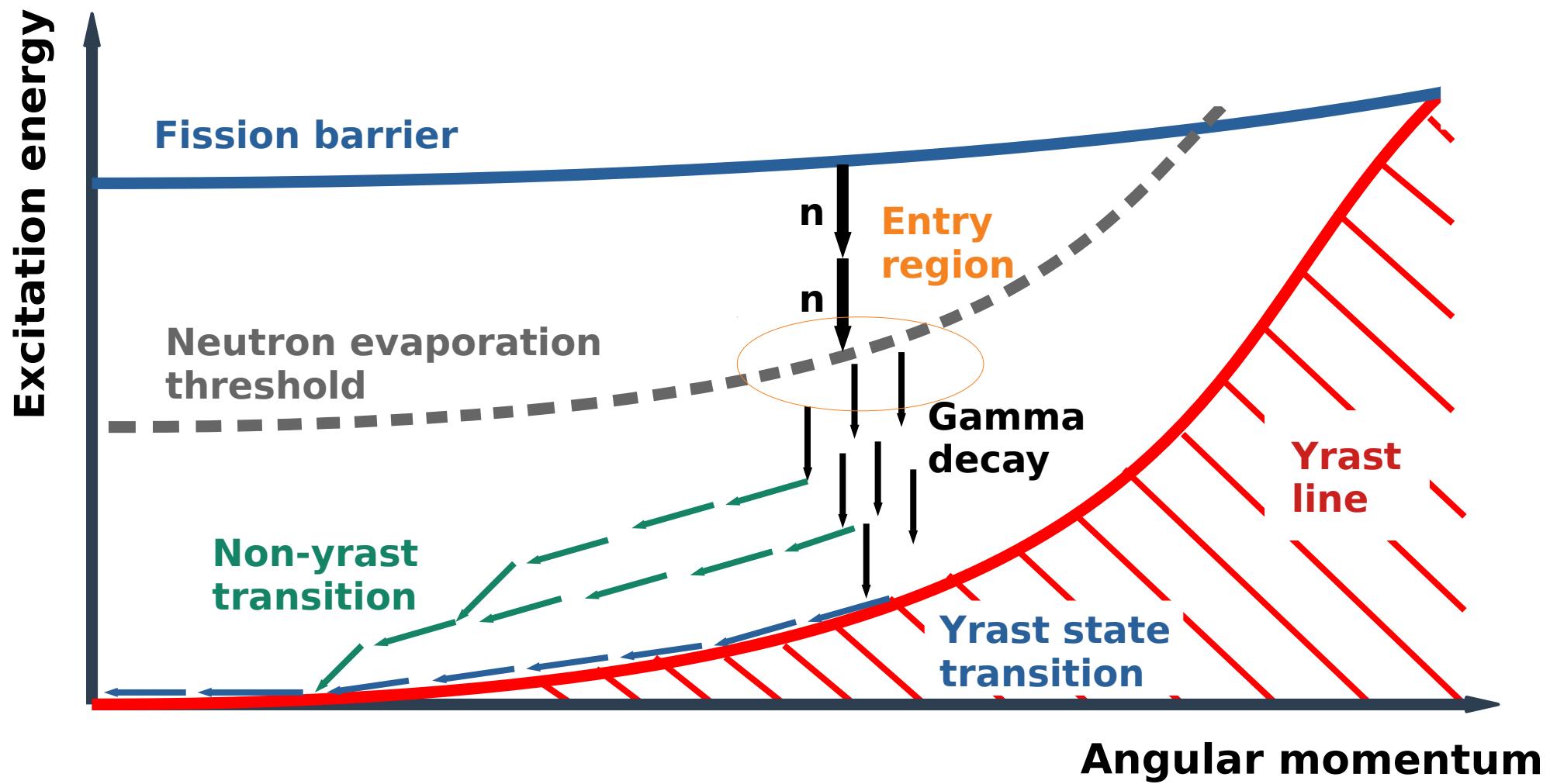
Collision below Bass barrier

Low cross section, difficulty to separate reaction products

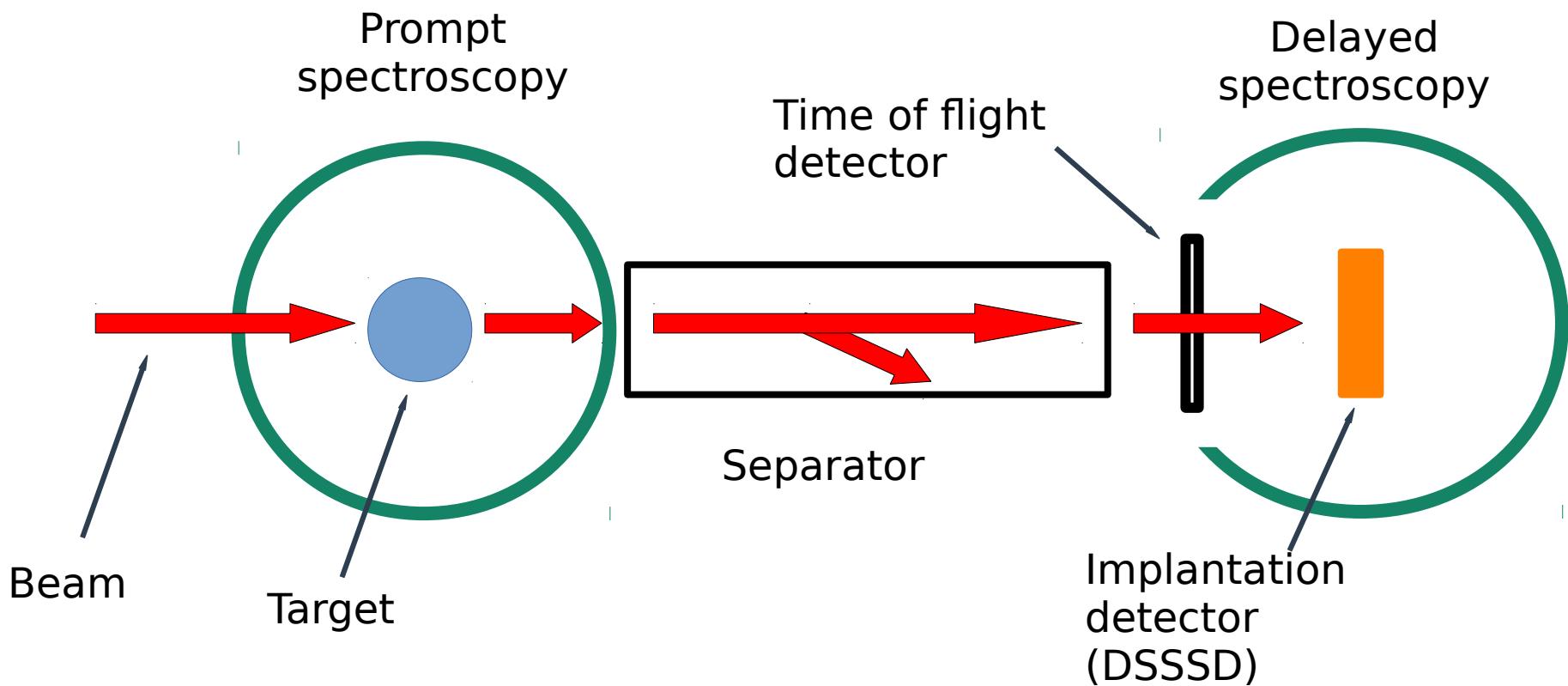
Fusion evaporation



Fusion evaporation



Detection system



Gamma spectroscopy

R ~ 1 : closed shell nucleus

$$R = \frac{E(4^+)}{E(2^+)}$$

Nuclear pairing lowing 0+ state and bring the others

R = 2 : purely vibrational nucleus

The nuclei oscillate between different forms

R = 10/3 : purely rotationnal even-even nucleus

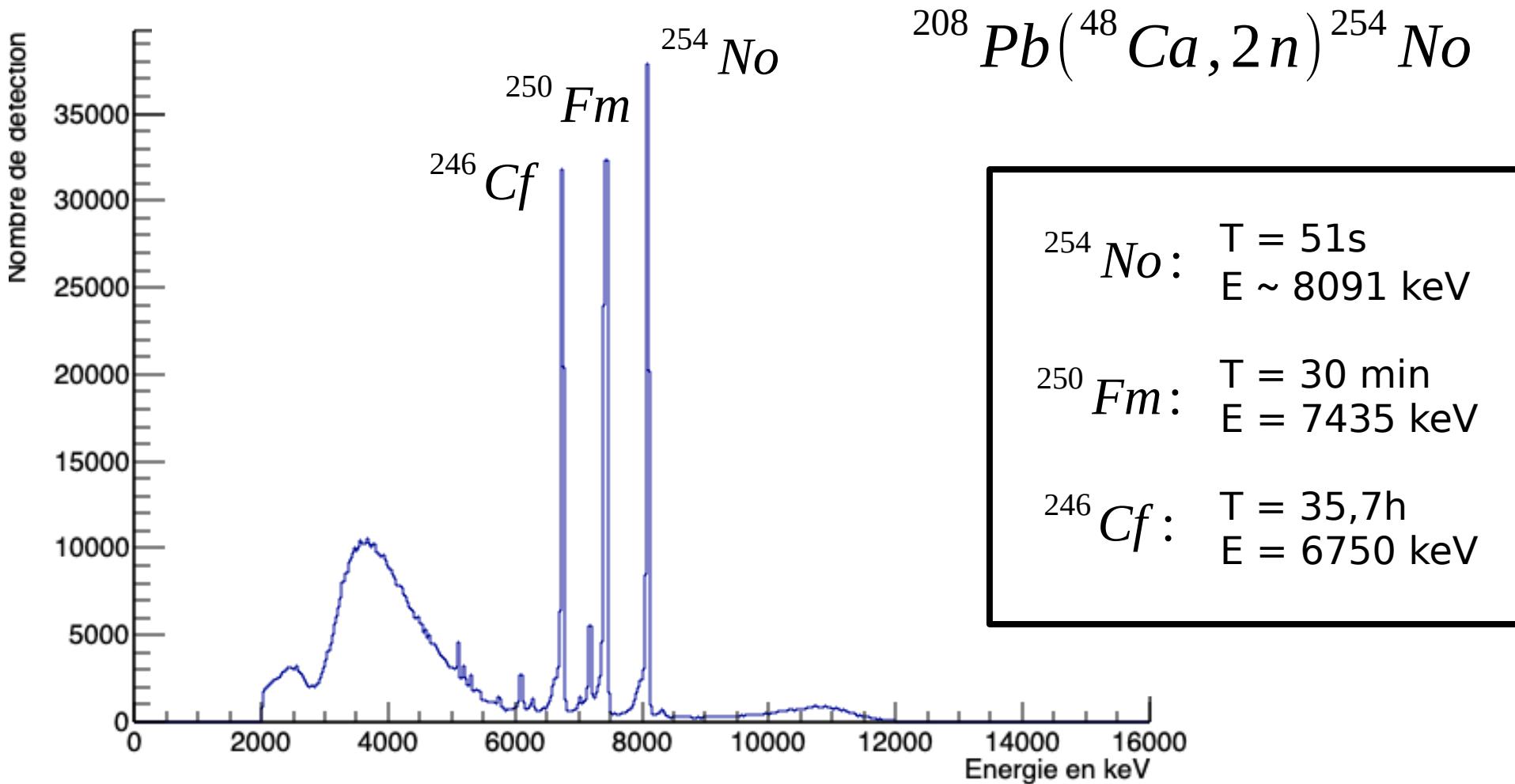
$$E_{rot} = \frac{\hbar^2}{2\zeta} (j(j+1))$$

j : azimuthal quantum number

ζ : inertial momentum

Ref : Noyaux et particules, modèles et symétries (Luc Valentin)

Alpha spectroscopy



Conclusion

Find island of stability

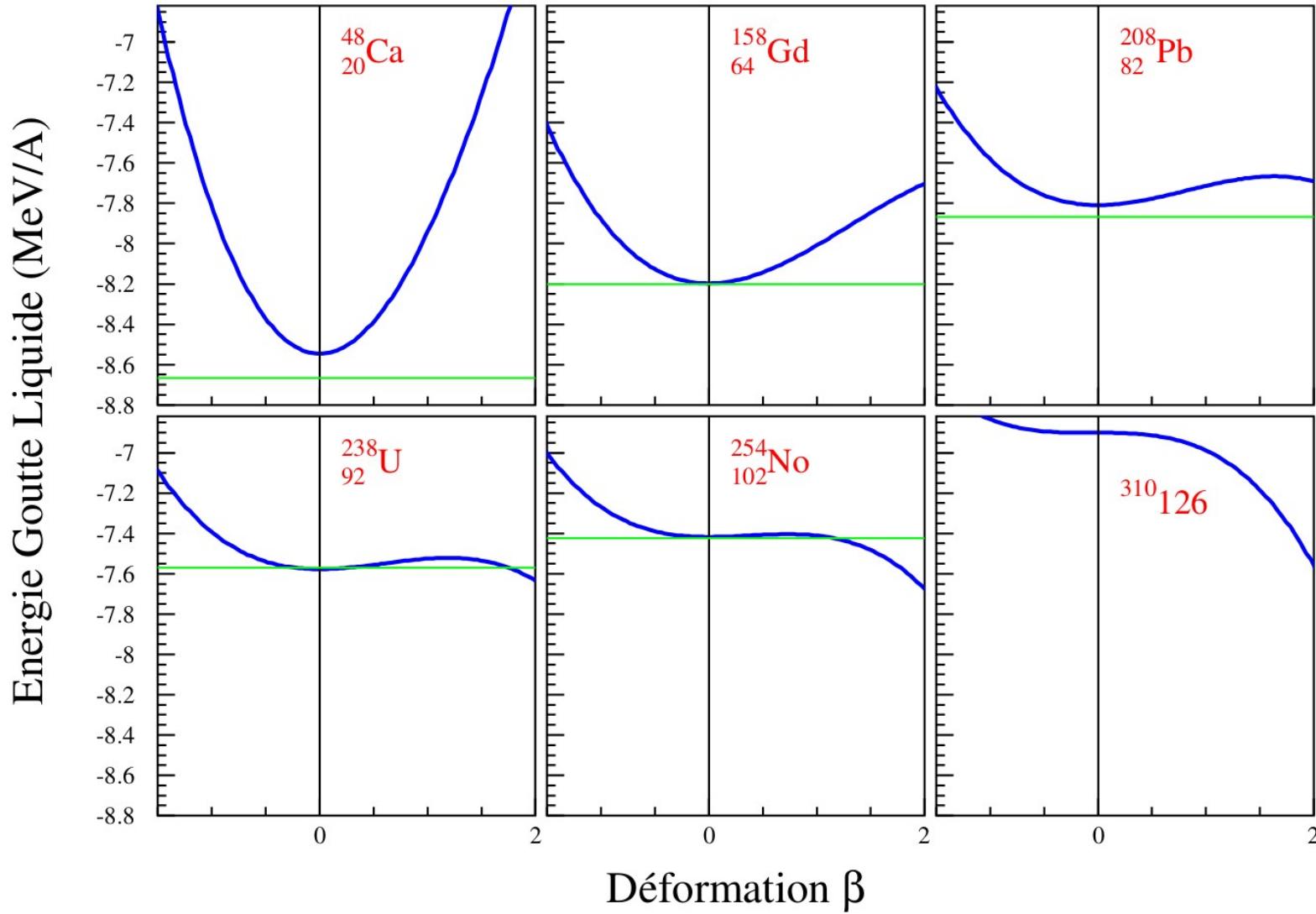
Study the nuclear structure

Constrain the models

Study of strong interaction

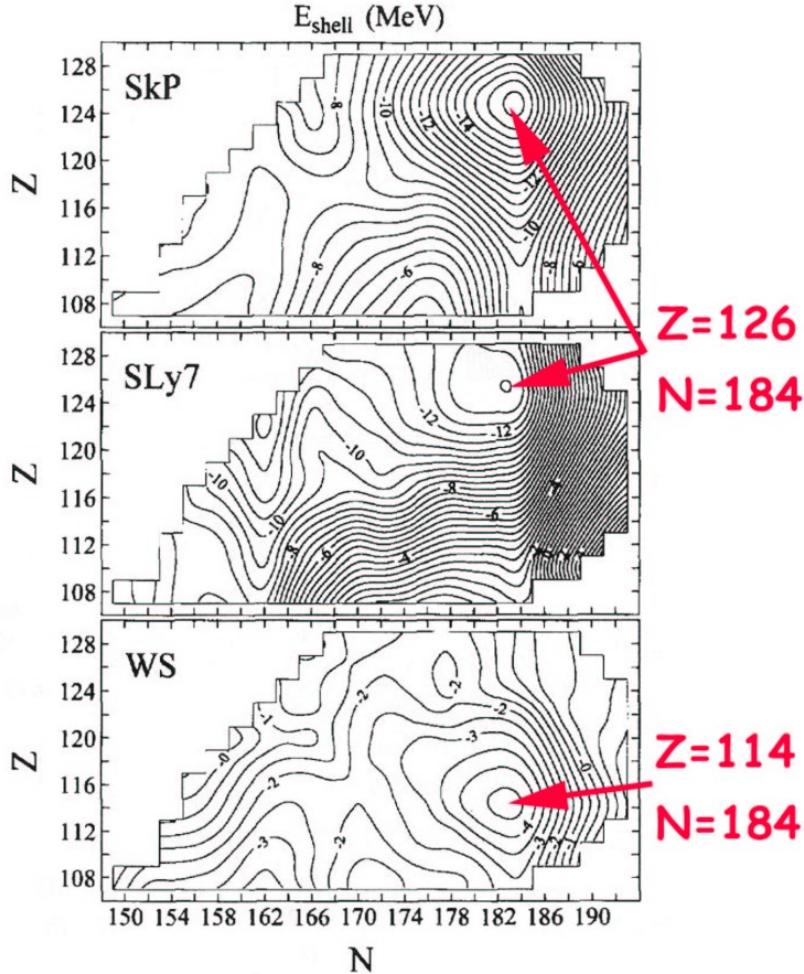
Chemical property

Liquid drop model

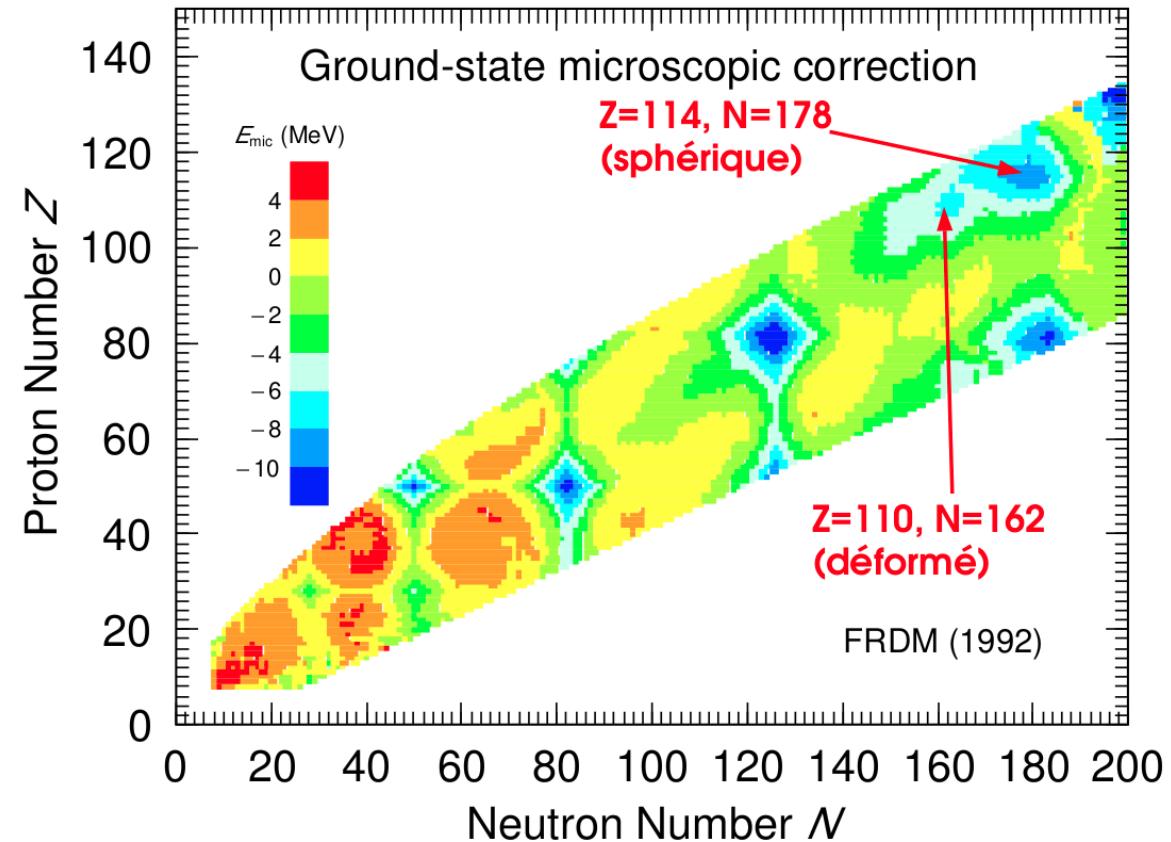


Paramétrisation : Myers - Swiatecki NPA 81 (1966)

Island of stability



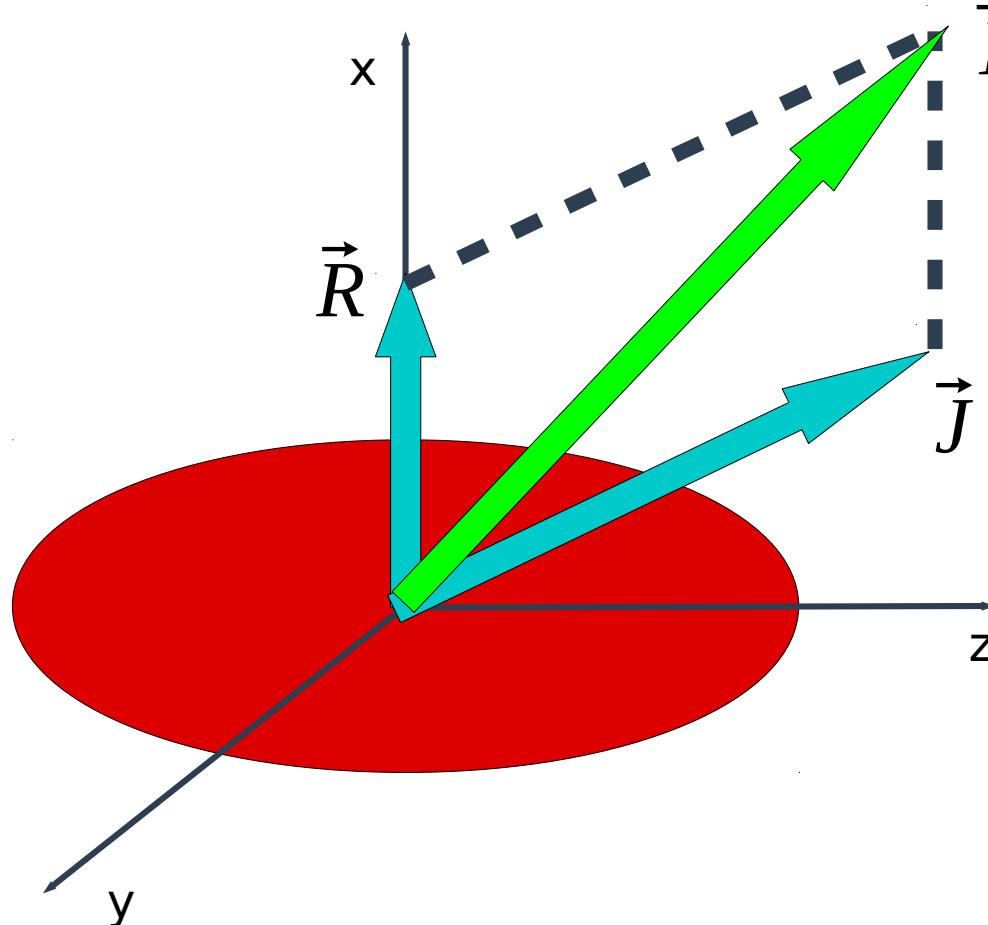
S. Cwiok et al. Nucl. Phys.
A611 (1996) 246.



P.Möller et al. At. Data. Nucl. Data
Tables 59 (1995) 185.

Collective rotation

Ref : Noyaux et particules, modèles et symétries (Luc Valentin)



\vec{R} Rotational angular momentum

\vec{J} Individual angular momentum

\vec{I} Total angular momentum

ζ Moment of inertia

$$K = \vec{I} \cdot \vec{z}$$

$$E_{rot} = \frac{\hbar^2}{2\zeta} (j(j+1) - K) + \frac{\hbar^2 K}{2\zeta_z}$$

Even-even nucleus $J^\pi = 0^+ \Leftrightarrow K = 0$