“HORIZONTAL EVALUATION – NUCLEAR ISOMERS”

A. K. Jain
Department of Physics,
Indian Institute of Technology,
Roorkee, INDIA

IAEA meeting of NSDD evaluators, KFAS, Kuwait, 27-31 Jan. 2013

COLLABORATION

A.K. Jain, IIT Roorkee

Monika

Bhoomika

Filip Kondev, ANL

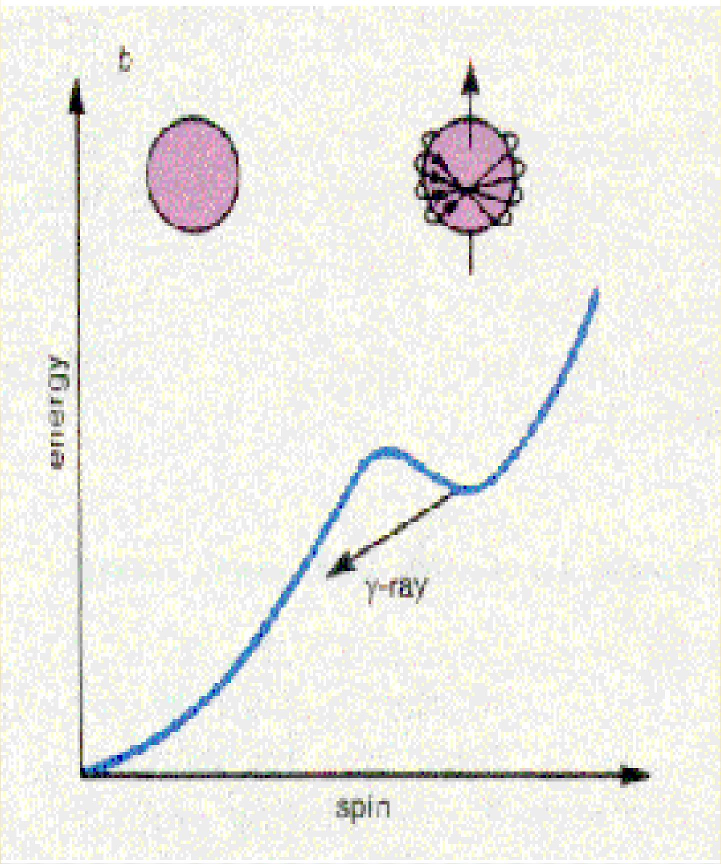
Balraj Singh, McMaster

WHAT IS A NUCLEAR ISOMER ?

- A long lived excited nuclear state
- It’s half life is much longer than a typical excited nuclear state which lives for

$10^{-16} – 10^{-18}$ seconds
- Currently adopted definition in ENSDF is 100 ns
- But we have kept track of all the levels having half-life of 1 ns or more.

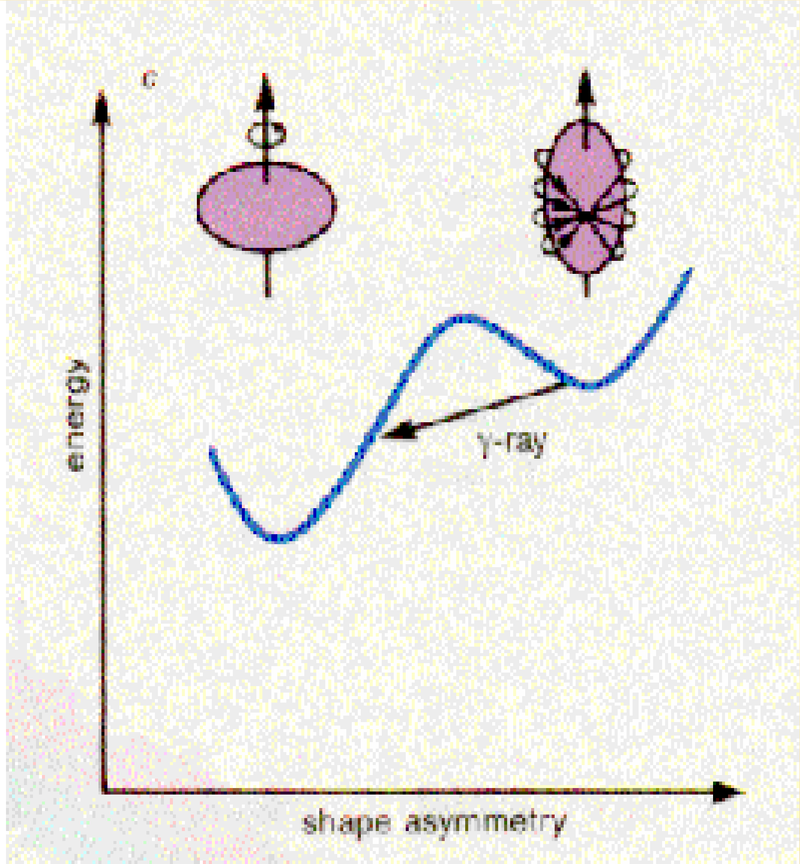
SPIN ISOMER



- It occurs due to large difficulty in meeting spin selection rules
- Ex: ^{180m}Ta which has half life of 10^{15} years

Figure :Spin isomer. *Ref. P.M. Walker and G.D. Dracoulis, Physics World Feb. (1994) p39.*

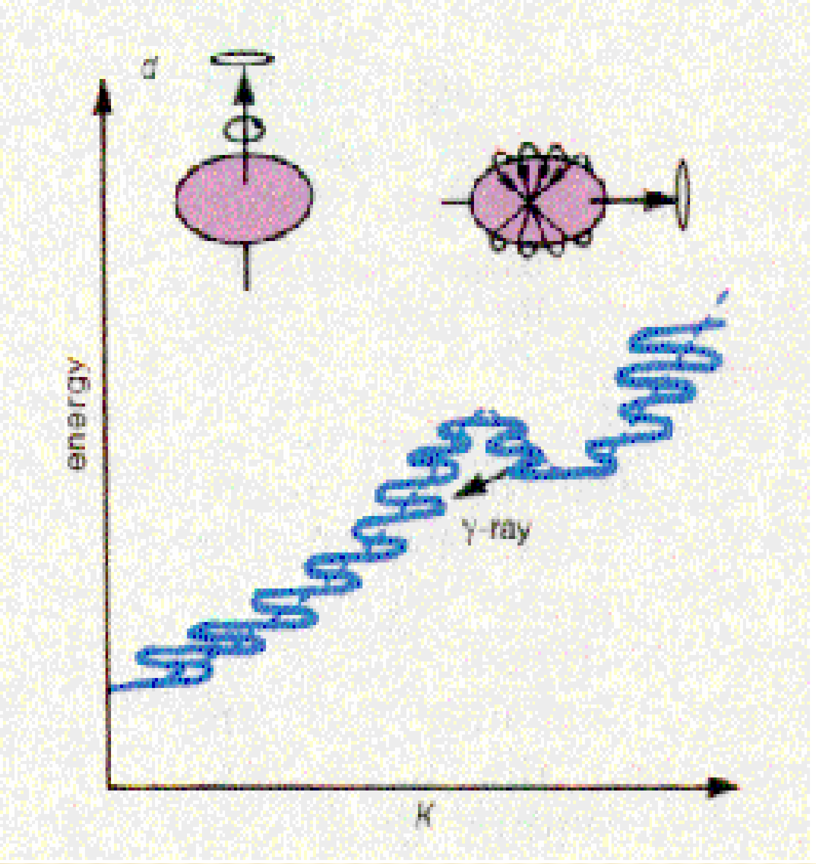
SHAPE ISOMER



- These occur when there is a secondary energy minimum at large elongation of the nucleus
- Ex: ^{72}Kr, a self conjugate nucleus (N=Z)

Figure : Shape isomer. *Ref. P.M. Walker and G.D. Dracoulis, Physics World Feb. (1994) p39.*

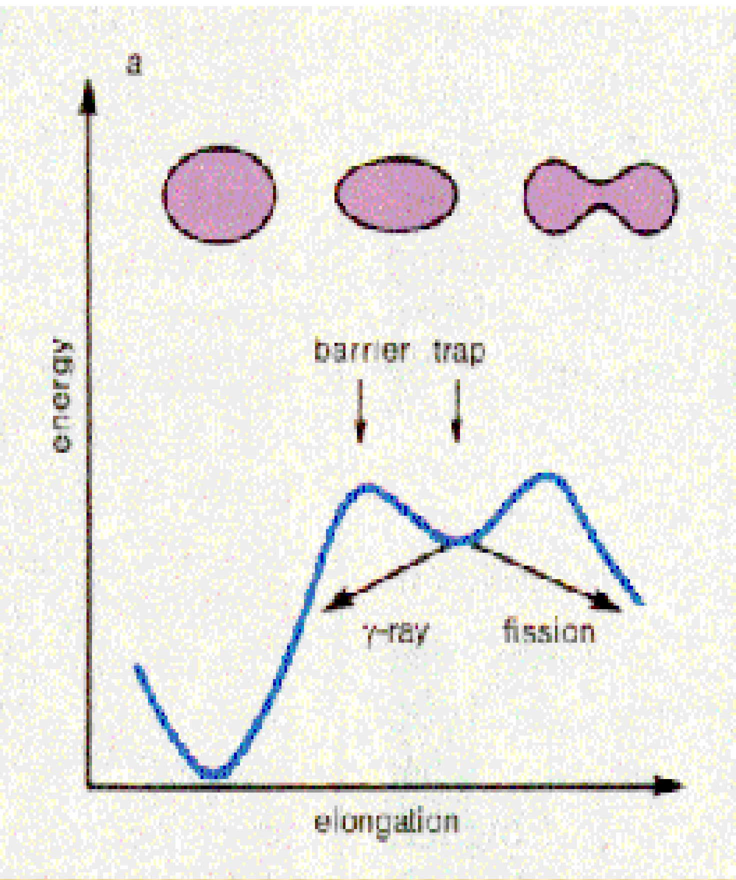
K-ISOMER



- K-isomers occur in nuclei with axially symmetric deformations when there is a secondary minimum in the potential energy surface for a certain value of K
- Ex: ^{178}Hf ; half life~ 31 years

Figure : K-isomer. *Ref. P.M. Walker and G.D. Dracoulis, Physics World Feb. (1994) p39.*

FISSION ISOMER



- It is due to trapping of nucleus in an elongated excited nuclear state.
- The time it takes for the nucleus to tunnel through fission barrier, gives rise to the long lifetime.
- Ex: ^{242}Am

Figure : Fission isomer. *Ref. P.M. Walker and G.D. Dracoulis, Physics World Feb. (1994) p39.*

ATLAS AND SYSTEMATICS OF NUCLEAR ISOMERS

- All the data extracted from the ENSDF database by using a computer code. Nubase is also being used.
- If the Isomers are defined as the excited states having half-life $\geq$ 1*ns*, the total number of isomers with confirmed half-lives – 2252
- Total number of nuclei having isomers – 1116
- Isomers with upper limit on half-lives – 606
- Isomers including all half-lives and tentative spins – 3175

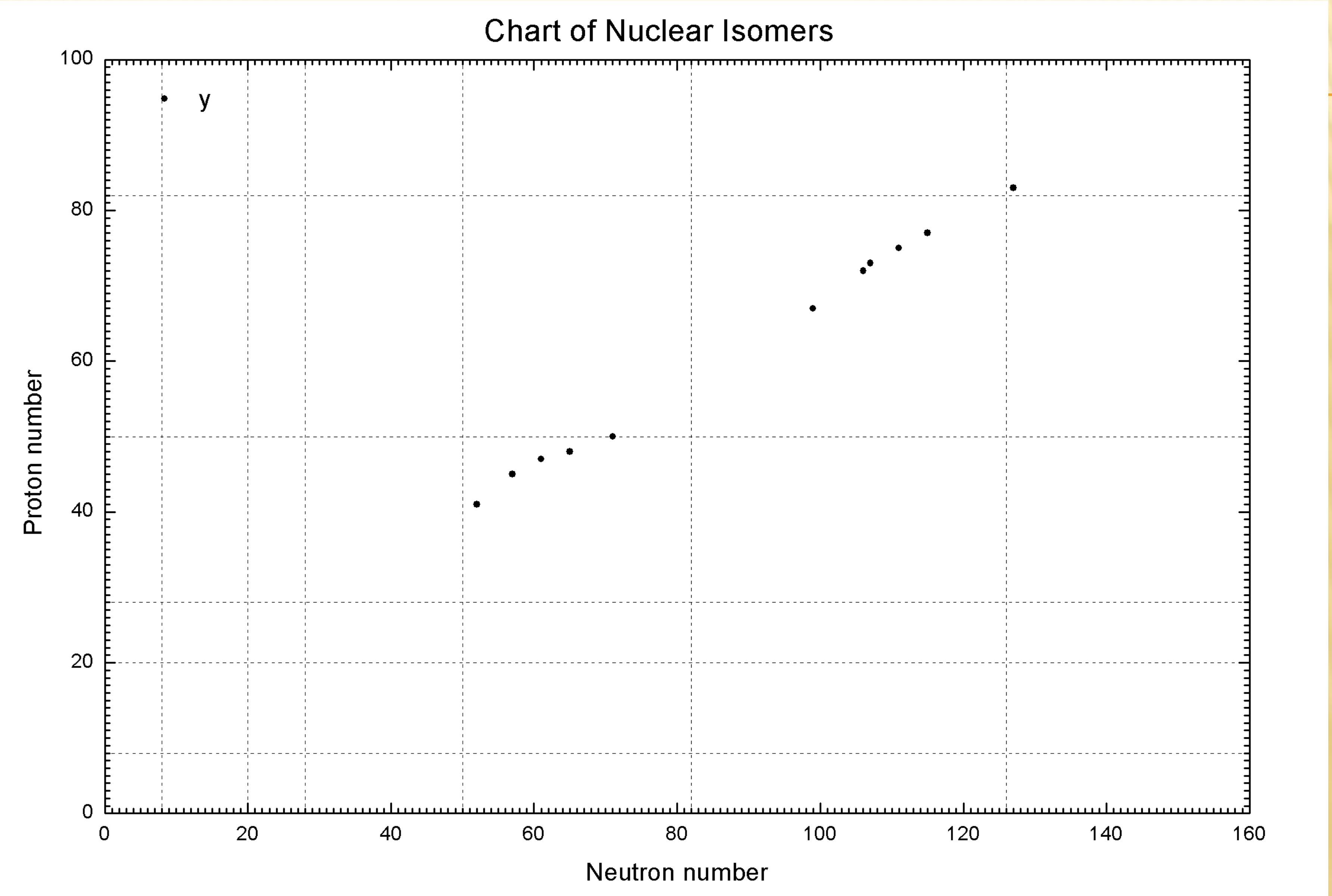


Chart of Nuclear Isomers
y
Proton number
Neutron number
0
20
40
60
80
100
120
140
160

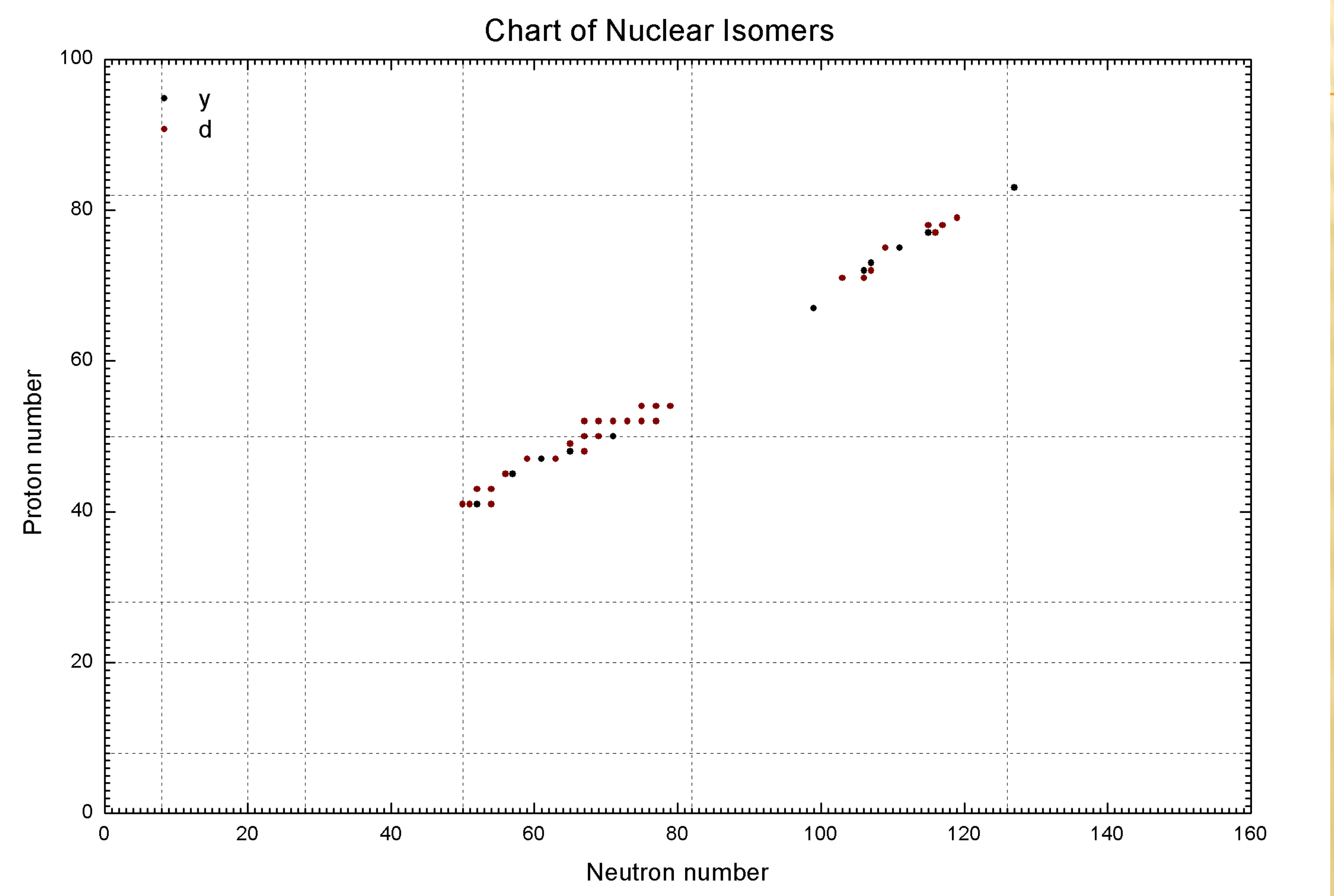


Chart of Nuclear Isomers
y
d
Proton number
Neutron number
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160

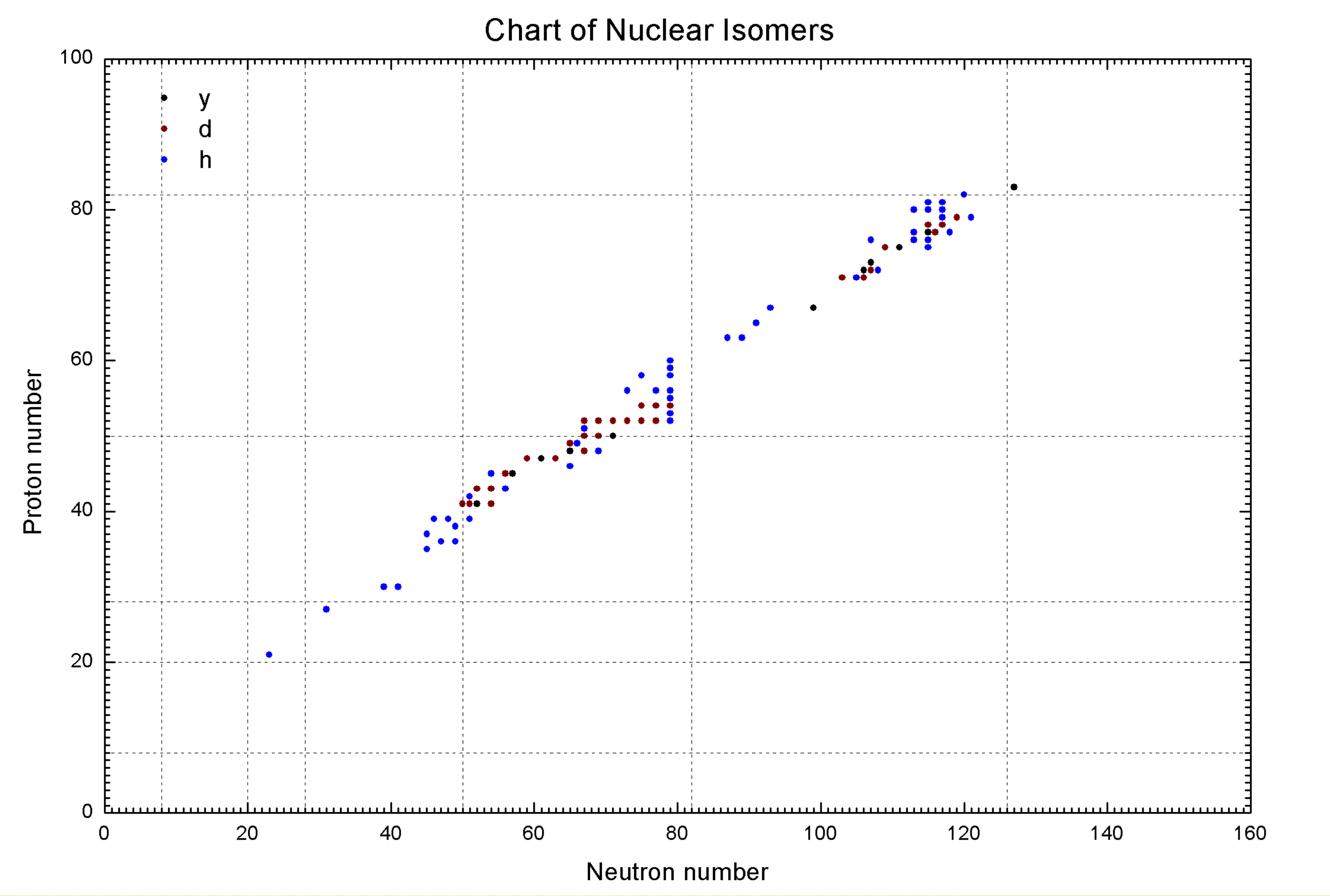


Chart of Nuclear Isomers
y
d
h
Proton number
Neutron number
0
20
40
60
80
100
120
140
160

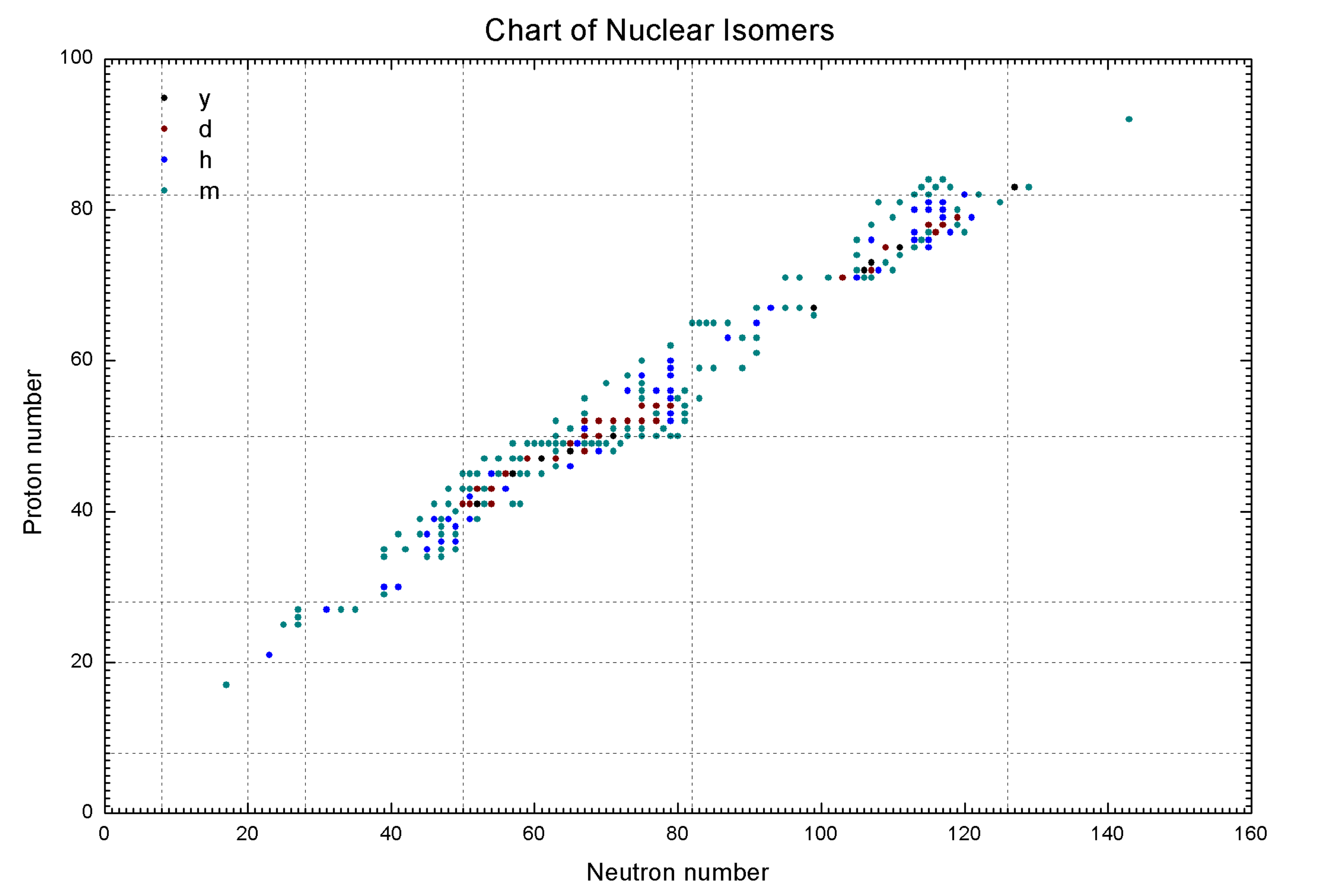


Chart of Nuclear Isomers
y
d
h
m
Proton number
Neutron number
0
20
40
60
80
100
120
140
160

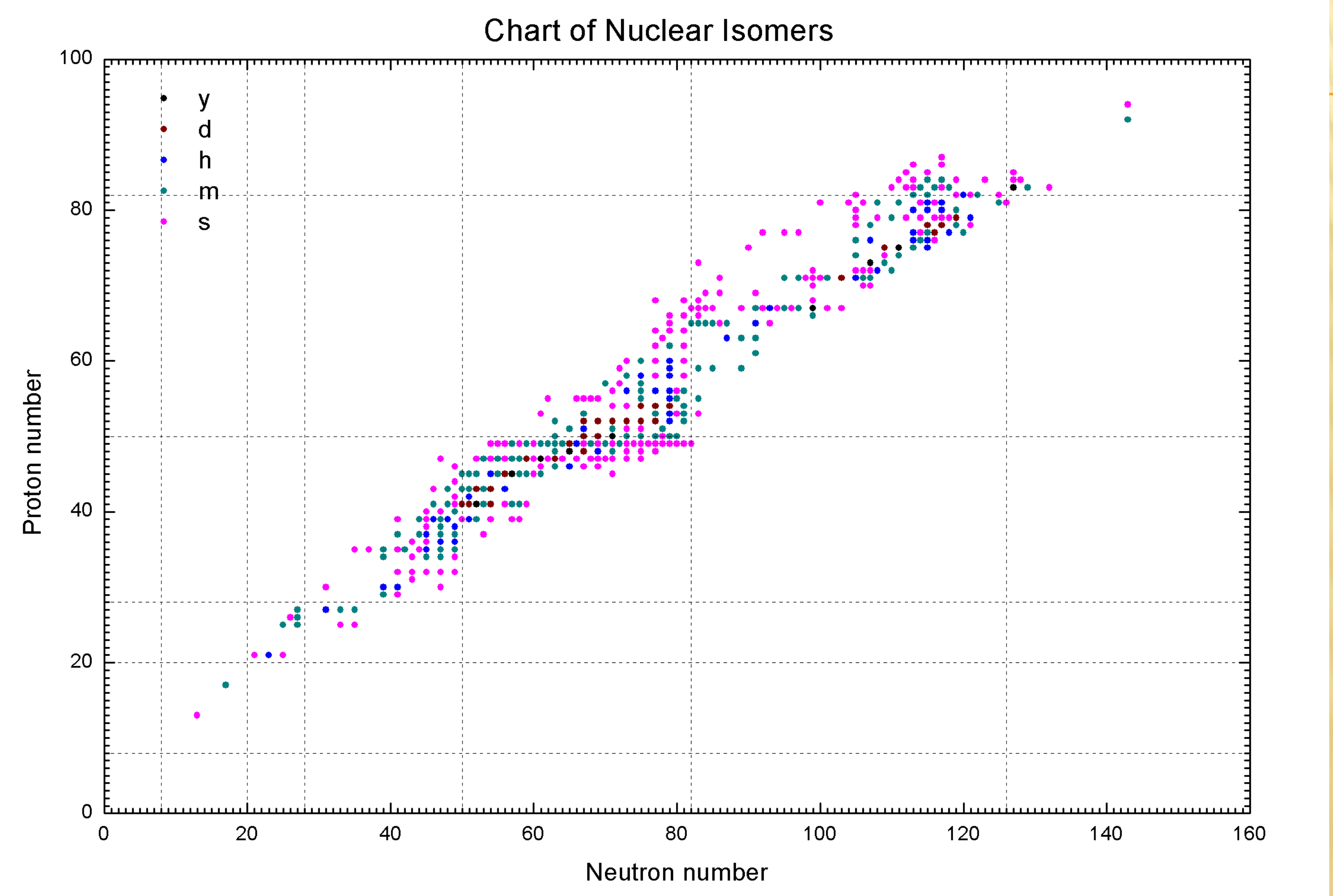


Chart of Nuclear Isomers
y
d
h
m
s
Proton number
Neutron number
0
20
40
60
80
100
120
140
160

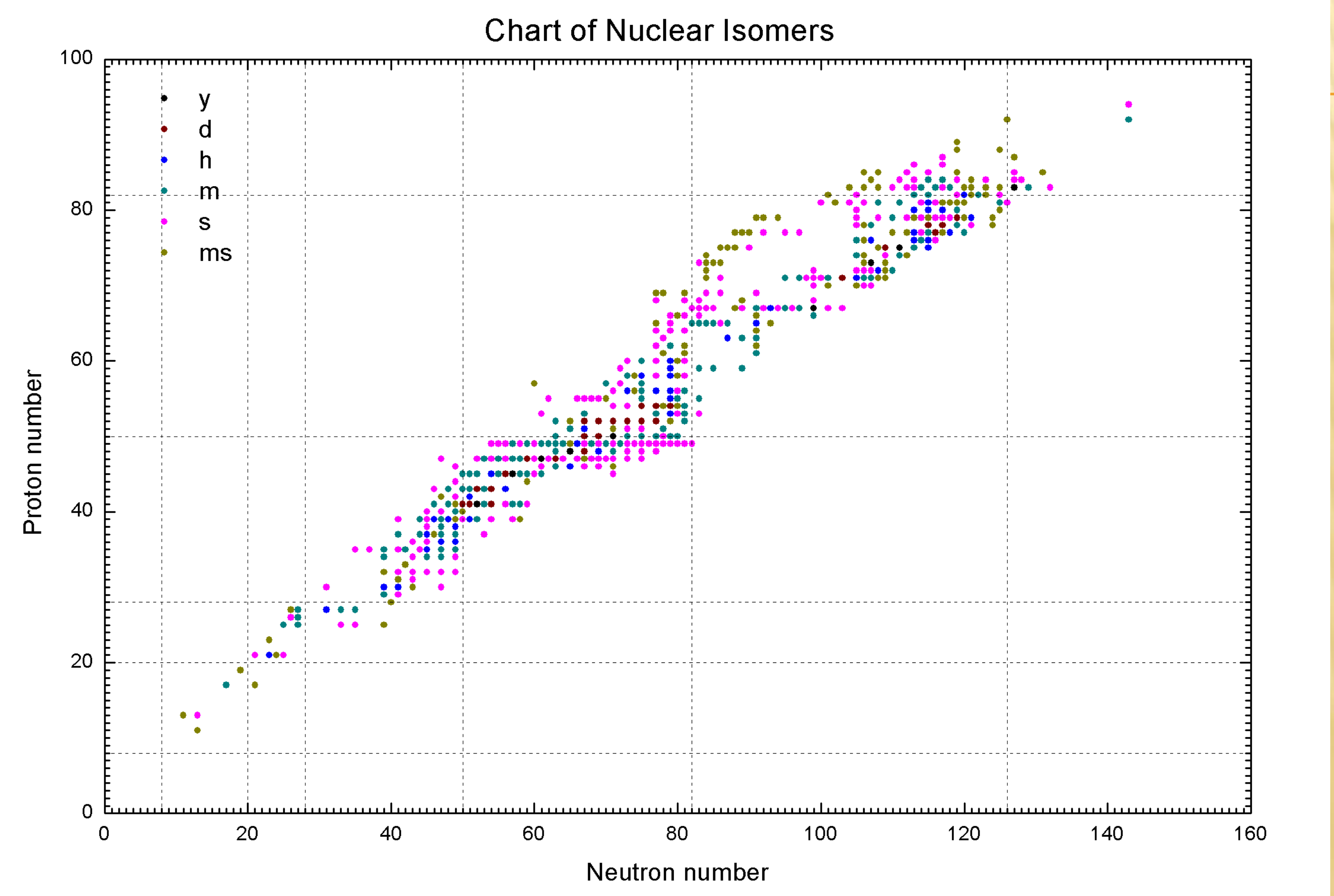


Chart of Nuclear Isomers
y
d
h
m
s
ms
Proton number
Neutron number
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160

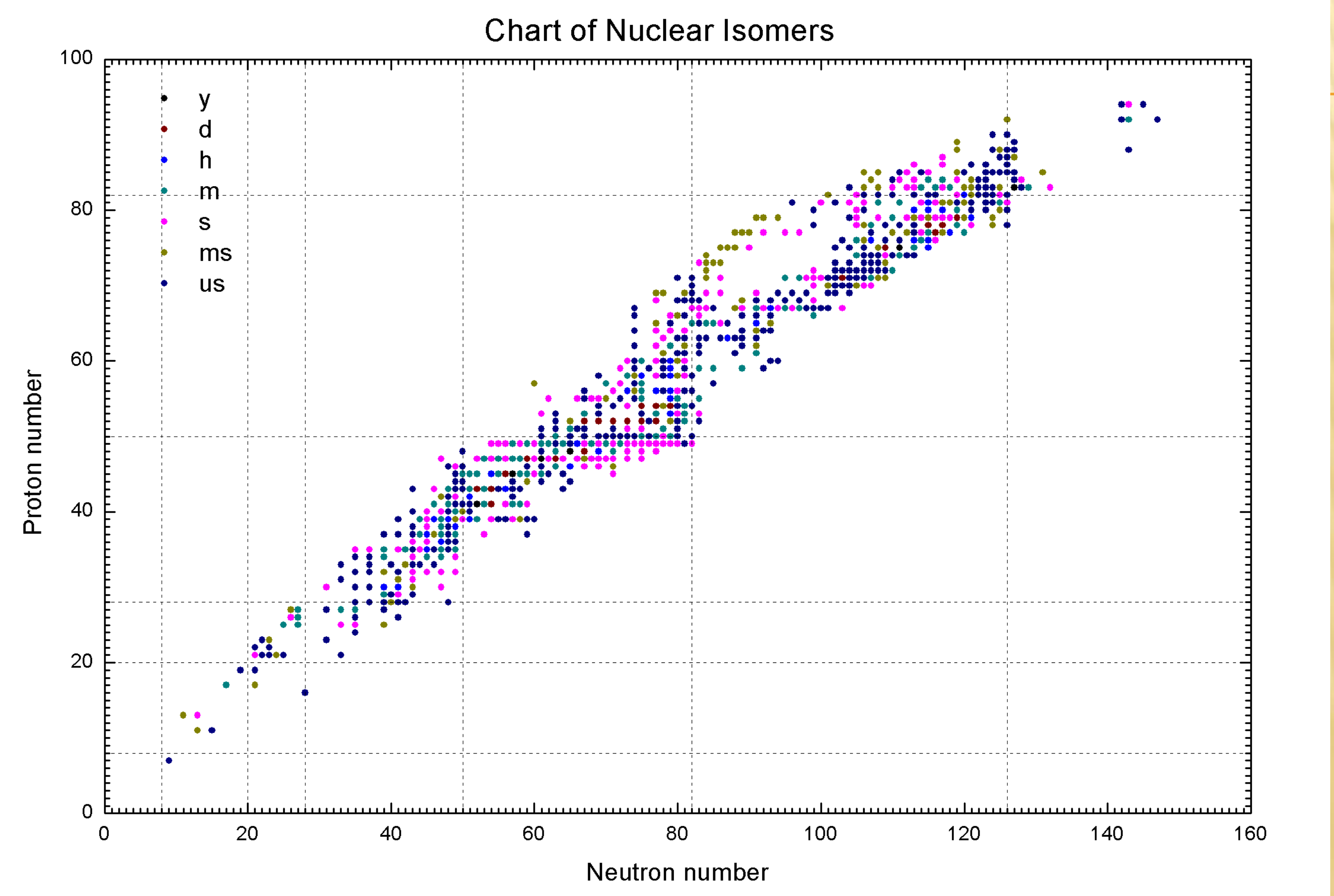


Chart of Nuclear Isomers
y
d
h
m
s
ms
us
Proton number
Neutron number
0
20
40
60
80
100
120
140
160

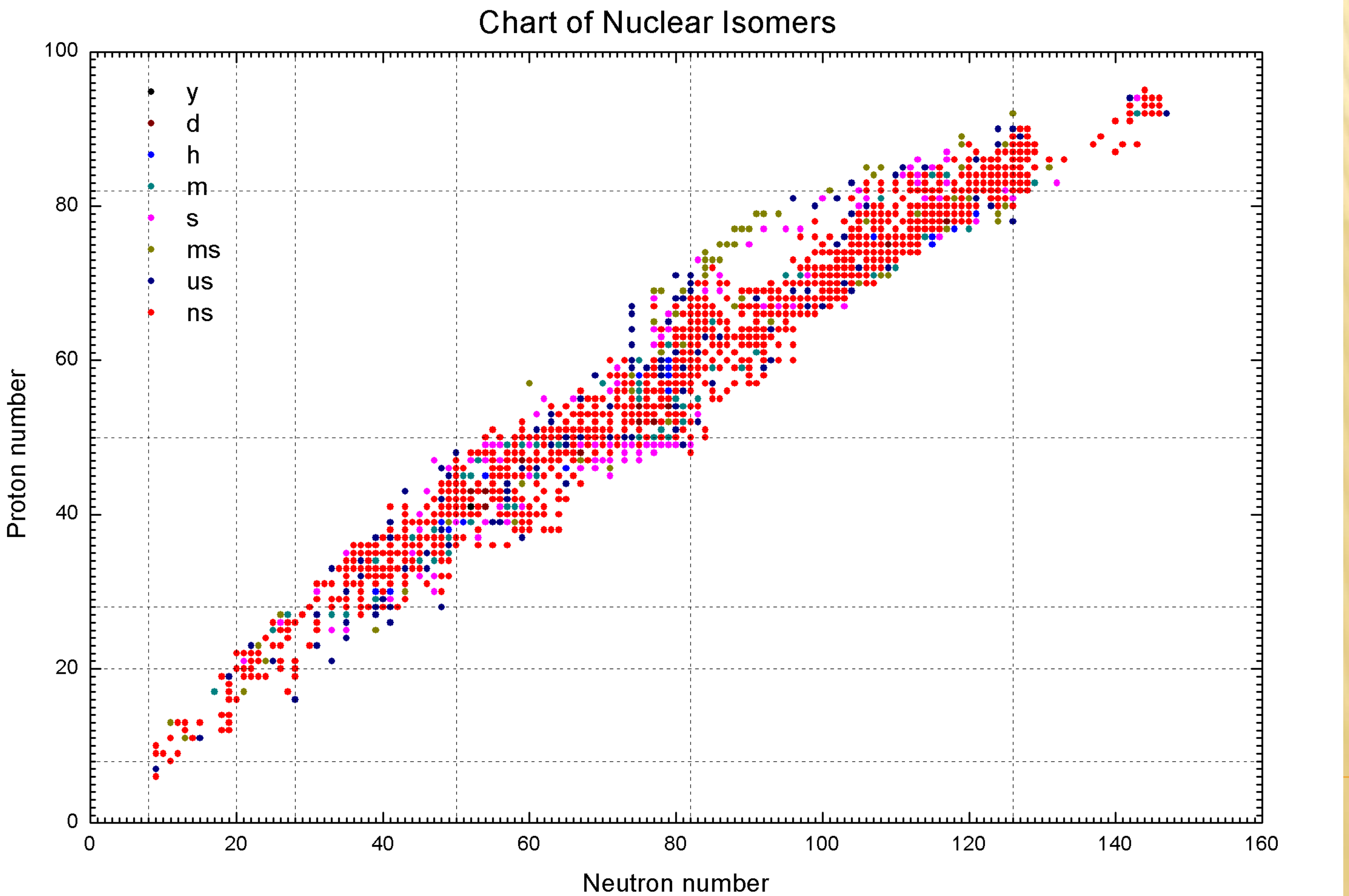


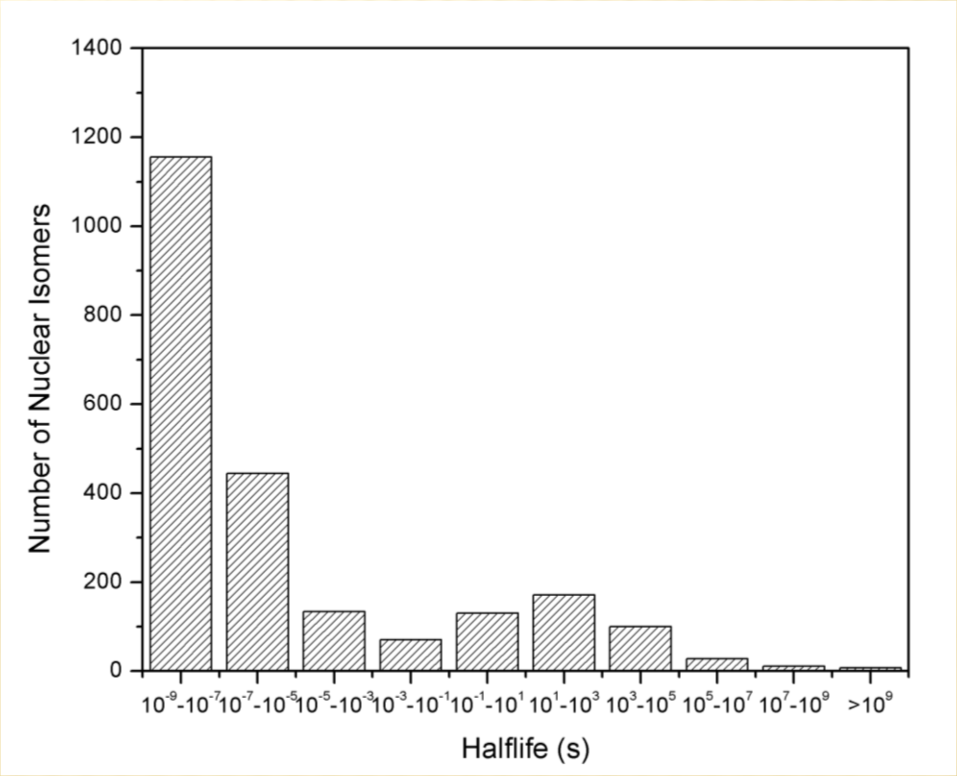
Chart of Nuclear Isomers
y
d
h
m
s
ms
us
ns
Proton number
Neutron number
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160

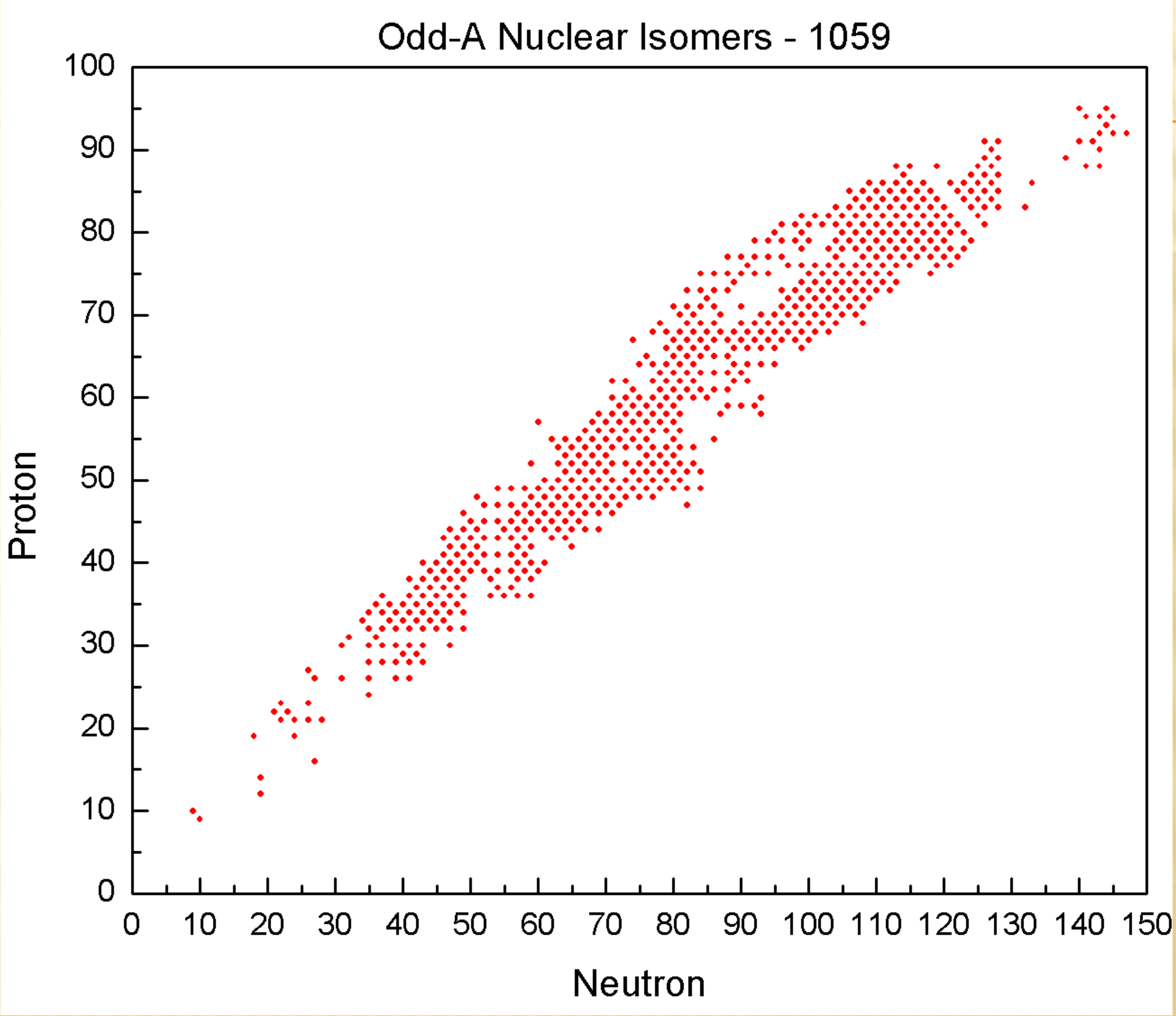
NUCLEI HAVING ISOMERS WITH :

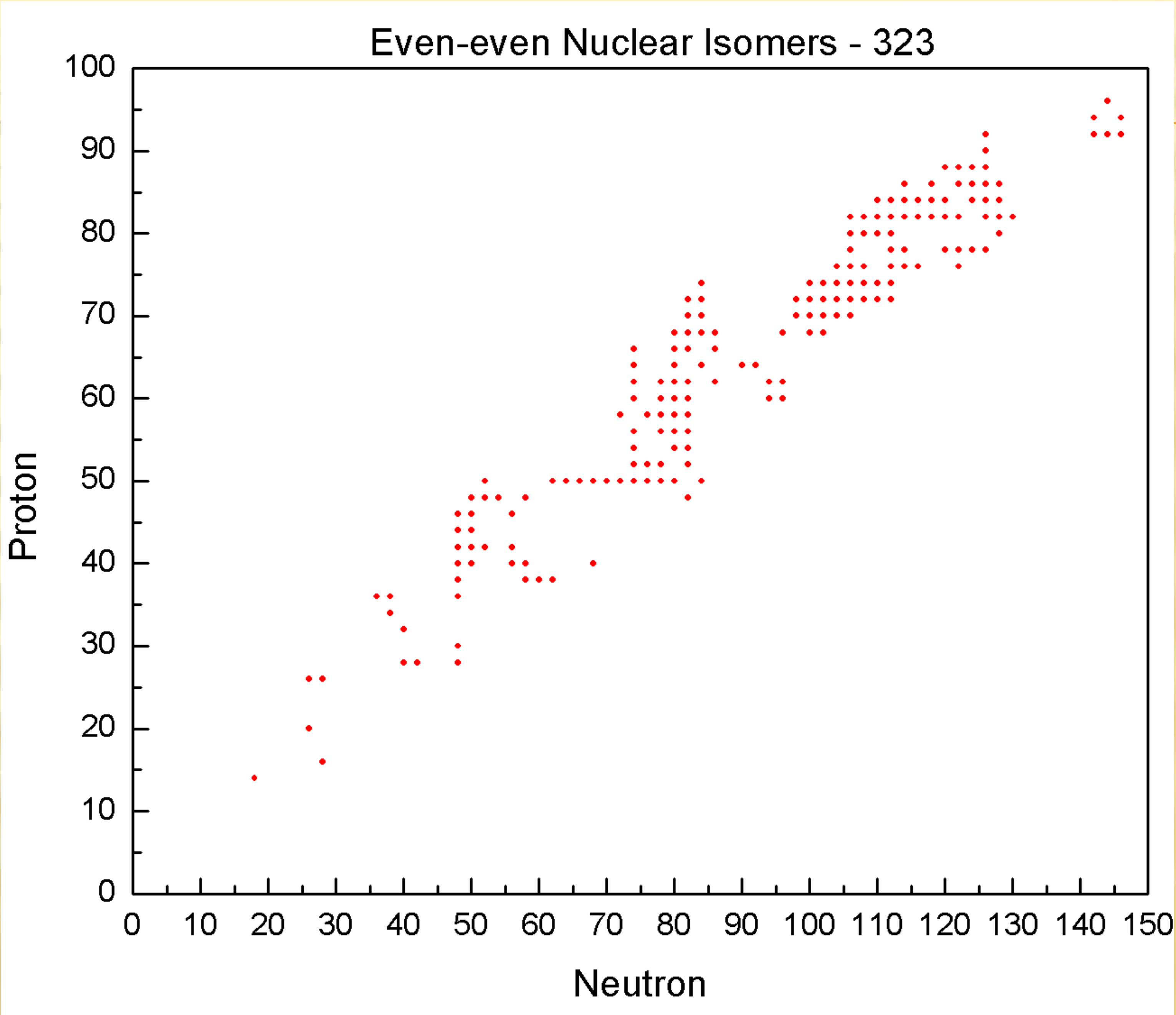
- $\tau \geq 1ns = 1116$
- $\tau \geq 5ns = 1010$
- $\tau \geq 100ns = 815$
- $\tau \geq 1\mu s = 674$
- $\tau \geq 1ms = 479$
- $\tau \geq 1s = 371$
- $\tau \geq 1m = 220$
- $\tau \geq 1h = 89$
- $\tau \geq 1d = 40$
- $\tau \geq 1y = 11$

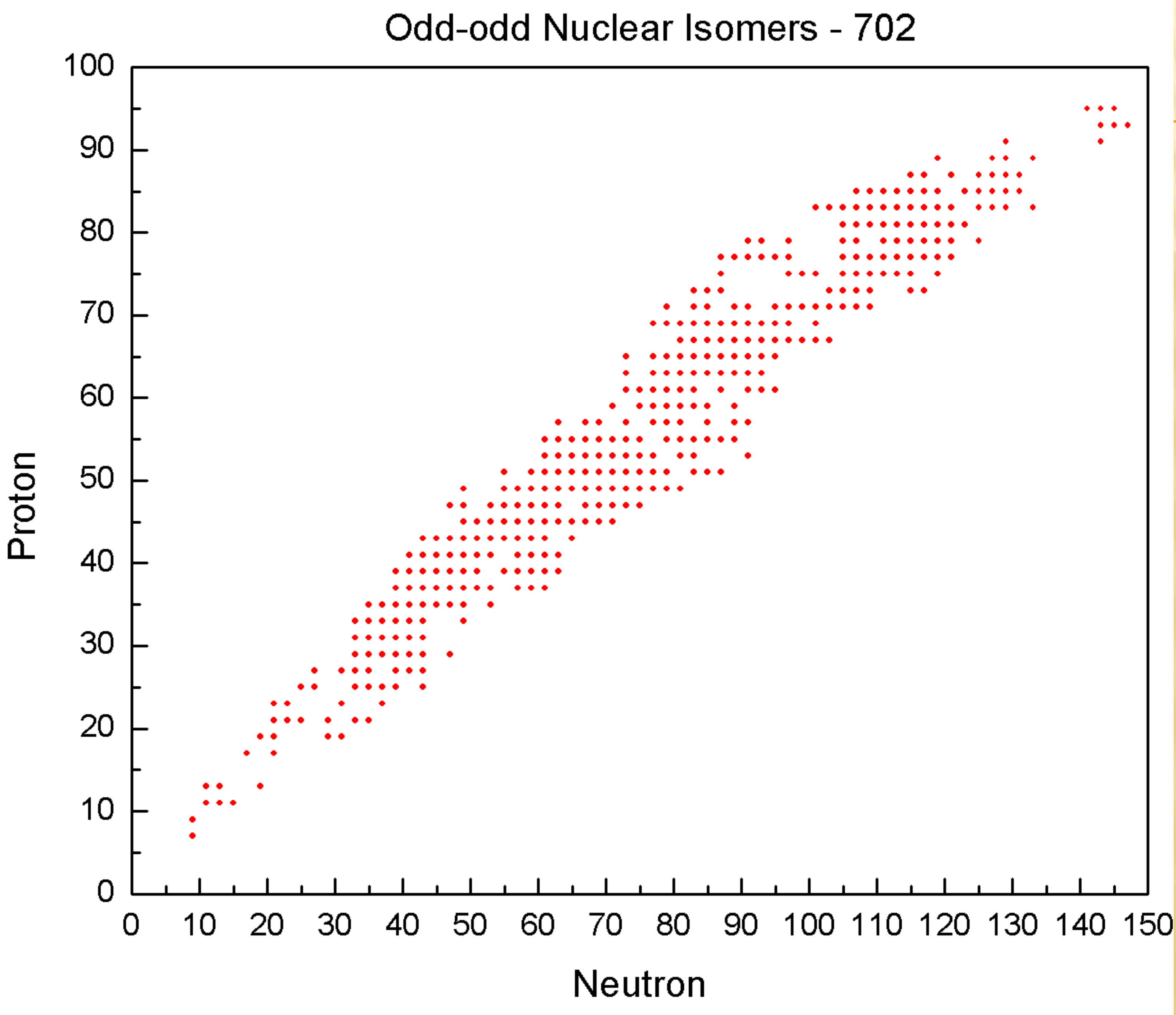
STATISTICS OF HALF-LIVES

- Maximum number of Isomers are observed at time scale of $10^{-9} – 10^{-7}$
- Number falls considerably with increasing half-lives
- Dip can be seen at half-lives of the order of 1*ms* to 0.1*s*
- Otherwise, half-lives are decaying almost exponentially.




Odd-A Nuclear Isomers - 1059
Proton
Neutron
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150


Even-even Nuclear Isomers - 323
Proton
Neutron
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150


Odd-odd Nuclear Isomers - 702
Proton
Neutron
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

70-80 mass region

$^{A}_{Z}X_{N}$	E(KeV)	I^{π}	$T_{1/2}$	λ	References
$^{70}_{27}Co_{43}$	0+X ( )	(3+)	0.50(18)s		2000Mu10 2003Sa40 2000Mu10
$^{70}_{28}Ni_{42}$	2860 (2)	(8+)	0.232 (1)us	(E2)	1999Le68 2003GrZZ 1998Gr14 2003GrZZ
$^{70}_{29}Cu_{41}$	101.1 (3)	(3-)	33(2)s	(M3)	2002We03 2000Ko14 2001StZZ 2004Va07 2002We03 1975Re09 1971Ta03 2004Va07
$^{70}_{29}Cu_{41}$	242.6 (5)	1+	6.6(2)s		2002We03 2000Ko14 2001StZZ 2004Va07 1975Re09 1971Ta03 2004Va07
$^{70}_{31}Ga_{39}$	879.1 (1)	4-	22.7 (5)ns	E2(+M3)	1975Hu06 1997Is13
$^{70}_{33}As_{37}$	32.008 (23)	2+	96 (3)us	E2	
$^{70}_{35}Br_{35}$	2292.3(8)	9+	2.2(2)s		1981Vo04
$^{71}_{28}Ni_{43}$	499 ( )	(1/2-)	2.3(3)s		2009St07 2009St07
$^{71}_{29}Cu_{42}$	2755.7(6)	(19/2-)	0.271 (14)us	[E2]	1998Gr14 1998Is11
$^{71}_{30}Zn_{41}$	157.7 (13)	9/2+	3.96(5)h	[M4]	1989He05 1992Be51 1989He05 1989Ra17 1989He05 2003Ho02 2003Ho02 1989He05 1964So01 1961Th04 1958Le26 1967Vi08
$^{71}_{32}Ge_{39}$	174.943 (9)	5/2-	79 (2)ns	E2	1973HaVW 1968Mo12
$^{71}_{32}Ge_{39}$	198.354 (14)	9/2+	20.41 (18)ms	M2	1970Be29 1975Ri03 1976Br41 1973RiZI 1980Jo11 1976Ga33 1974Bu14 1971Mu14 1971Go21 1970Ru08 1969Ru10 1966Me02

180 mass region

$^{A}_{Z}X_N$	E(KeV)	I^π	$T_{1/2}$	λ	References
$^{180}_{71}Lu_{109}$	624.0(5)	(9-)	1 (GE)ms	E1	2001Wh01
$^{180}_{72}Hf_{108}$	1141.50(5)	8-	5.47(4)h	E1 M2+E3	2001Al23 1951Bu50 1963Ra14 1985Ke02 1992Ke04 1992Ke04 1989Ra17 1971Ko29 1976Kr11 1989Ra17 1973Ka31
$^{180}_{72}Hf_{108}$	1374.15(4)	(4-)	0.57 (2)us		1990GrZS
$^{180}_{72}Hf_{108}$	2425.8(10)	(10+)	15 (5)us		
$^{180}_{72}Hf_{108}$	2486.3(9)	12+	10 (1)us	E1 M2 E3	2000Wh04
$^{180}_{72}Hf_{108}$	2538.3(12)	(14+)	10 (GT)us	E2	
$^{180}_{72}Hf_{108}$	3599.3(18)	(18-)	90 (10)us	M2	
$^{180}_{73}Ta_{107}$	77.1 (8)	9-	1.2E+15(GT)y		2002We01 1985Wa02 1981Co17 1981Co17 1980Sh06 1983Wa01 1981Co17 1980Bu09 1983Wa01 1985Cu03 1981No09 1955Eb14 1958Ba51 1958Eb09 1958Mi90 1967Sa05 1977Ar11 1994Wa34 1980Bu09 1989Ra17 1994Wa34
$^{180}_{73}Ta_{107}$	107.85(4)	0-	19.2 (7)ns	E1	1998Dr07 1999Sa59
$^{180}_{73}Ta_{107}$	177.65(3)	8+	70.0 (14)ns	E1+M2	1998Dr07 1999Sa59
$^{180}_{73}Ta_{107}$	356.68(6)	7+	42 (3)ns	M1	1998Dr07 1999Sa59
$^{180}_{73}Ta_{107}$	463.24(6)	7-	31.2 (19)ns	E1+M2	1998Dr07 1999Sa59

220-235 mass region

${}^{A}_{Z}X_N$	E(KeV)	I^π	$T_{1/2}$	λ	References
${}^{220}_{91}Pa_{129}$	0.0+X ( )		0.78 (16)us		1987FaZS 1987MiZO 1973Ta30
${}^{222}_{89}Ac_{133}$	0.0+X ( )		63(3)s		1972Es03 1972Es03 1972Es03 1973Mo07 1982Bo04 1972Es03 1972Es03 1972Es03
${}^{227}_{89}Ac_{138}$	27.37(1)	3/2+	38.3 (3)ns	E1	1985Is03 1972Ga39 1963Su10 1961Br32 1969La04 1965PoZZ
${}^{229}_{88}Ra_{141}$	142.67 (6)	1/2+	17.23 (12)ns	(E2) E2	
${}^{231}_{88}Ra_{143}$	66.21(9)	(1/2+)	53 (AP)us	E2	2001Fr05
${}^{231}_{91}Pa_{140}$	84.2148(13)	5/2+	45.1 (13)ns	E1 E1	
${}^{233}_{90}Th_{143}$	1.85E3 (25)		50 (+50-4)ns		1994Ob02 1994Ob02 1994Ob02
${}^{233}_{91}Pa_{142}$	86.468 (9)	5/2+	35.7 (10)ns	E1 E1	
${}^{234}_{91}Pa_{143}$	73.92+X ( )	(0-)	1.159(11)m		2004WoZZ 1951Ba83 1956On07 1963Bj02 1969SaZR 1969DeZX 1963Bj02
${}^{234}_{92}U_{142}$	1421.257 (17)	6-	33.5 (20)us	(M1+E2) [E1] M1+E2 E1 M1+E2 [M1+E2] [E1] E2 [M2] M1+E2 [E1] [M2]	
${}^{235}_{92}U_{143}$	0.0765 (4)	1/2+	26(AP)m	E3	1966Ma20 1968Ne04 1974Ne09 1971Ar48 1972Ne12 1979Iz02 1993Ko32 1989Ko52 1992Vs01 1992Vo05 1992Bo26
${}^{235}_{94}Pu_{141}$	3.0E+3 (2)		25 (5)ns		1969Me11 1970Bu02 1972Ga42 1978SoZP
${}^{235}_{95}Am_{140}$	0.0+X ( )		9.9(5)m		

FOCUS ON THE ACTINIDES AND BEYOND

- Interesting region due to many reasons
- Not much data – easier to handle
- Still not understood very well

FISSION ISOMERS ($T_{1/2}$ >100 NS)

S.N.	A	X	β_2	Excitation energy (keV)	Half-life	G.S. Half-life	J (spin and parity)	decay mode
	Odd-odd							
1	234	Pa	0.2150	79	1.159 m	6.70 h	(0^-)	β^- =100 %; IT=0.16;SF=e-10
2	238	Np	0.2150	2300#	112 ns	2.117 d		SF~100%; IT?
3	238	Am	0.2150	2500#	35 μs	98 m		SF~100%; IT?
4	240	Am	0.2230	3000	940 μs	50.8 h		SF~100%; IT?
5	242	Am	0.2240	48.6	141 y	16.02 h	5^-	IT~100%;α=0.45;SF~4.7e-9
6	242	Am	0.2240	2200	14 ms	16.02 h	$(2^+,3^-)$	SF~100%; IT?;α ?
7	242	Bk	0.2240	200#	600 ns	7 m		SF~100%; IT?
8	244	Am	0.2240	200#	900 μs	10.1 h		SF~100%; IT?
9	244	Am	0.2240	200#	6.5 μs	10.1 h		SF~100%; IT?
10	244	Bk	0.2340	500#	820 ns	4.35 h		SF~100%; IT?
11	246	Am	0.2350	2000#	73 μs	39 m		SF~100%; IT?
12	246	Md	0.2340	60	4.4 s	0.9 s		β^+>77;β^+SF>10;α 23
13	256	Es	0.2270	0#	7.6 h	25.4 m	(8^+)	β^-~100;β^-SF=0.002
14	256	Md	0.2370	160#	77 m	77 m	(1^-)	β^+=?;α=9.2;SF 3
15	258	Md	0.2270	0#	52 m	51.5 d	1^-#	e=?;SF 20;β^- 10#;α 1.2
16	262	Bh	0.2390	220	9.5 ms	22 ms		α=?;SF<10
	Even-even							
17	236	U	0.2150	2750	120 ns	2.342E7 y	(0^+)	IT=87;SF=13;α=10
18	238	U	0.2150	2557.9	280 ns	4.468E9 y	0^+	IT=?;SF=2.6;α=0.5
19	242	Cm	0.2240	2800	180 ns	162.8 d		SF ?; IT?
20	244	Cm	0.2340	1100#	>500 ns	18.1 y		SF~100%; IT?
21	250	No	0.2350	1050#	51 μs	4.2 μs	(6^+)	SF~100%;IT ?;α ?
22	254	No	0.2460	1295	264.9 ms	51 s	(8^-)	IT>80;SF=0.020;α=0.01
23	254	No	0.2460	3220#	183.8 μs	51 s	(16^+)	IT=100;SF 0.012
24	262	Rf	0.2290	600#	47 ms	2.3 s	high	SF=100
	Even-odd							
25	237	Pu	0.2150	2900	1.1 μs	45.64 d		SF=?
26	239	Pu	0.2230	3100	7.5 μs	24110 y	$(5/2^+)$	SF~100%; IT?
27	241	Pu	0.2240	2200	21 μs	14.325 y		SF=100%
28	253	Rf	0.2360	200#	52 μs	48 μs	$(1/2)^{(-\#)}$	SF=?;α=5#
29	257	Rf	0.2380	73	4.3 s	4.7 s	$(11/2^-)$	α~100;SF=0.7#;β^+ ?
30	261	Rf	0.2280	70#	81 s	1.9 s	$(9/2^+)$#	α=?;β+<15;SF<10
31	263	Hs	0.2390	320	760 μs	0.74 ms	low#	α=?;SF?

32	265	Sg	0.2290	70#	16 s	16.2 s	$(3/2^+)$#	α>65;SF?
33	277	Hs	0.1450	100#	130 s	11 ms		SF=100
	Odd-even							
34	239	Am	0.2150	2500	163 ns	11.9 h	$(7/2^+)$	SF~100%; IT?
35	241	Am	0.2230	2200	1.2 μs	432.6 y		SF=100%
36	243	Am	0.2240	2300	5.5 μs	7370 y		SF~100%; IT?
37	245	Am	0.2340	2400#	640 ns	2.05 h		SF~100%; IT?
38	245	Md	0.2240	100#	900 μs	0.90 ms	$1/2^-$#	SF=?;α ?
39	247	Md	0.2350	260	250 ms	1.2 s	$(1/2^-)$	α=79;SF=21
40	253	Lr	0.2360	30#	1.32 s	0.57 s	$(1/2^-)$	α=90;SF=8;β^+=1#
41	257	Db	0.2470	140#	670 ms	1.82 s	$(1/2^-)$	α>87;SF<13;β^+=1#
42	261	Bh	0.2390		12.8 ms	11.8 ms	$(5/2^-)$	α=95;SF<5

- Total no. of fission isomers with half-life greater than 100 NS = 42

FISSION ISOMERS (1NS<T$_{1/2}$<100NS)

A	X	β_2	Excitation energy (keV)	Half-life	G.S. half-life	J (spin and parity)	decay mode
Even-Even							
234	Pu	0.2160	4170	3 ns	8.8 h		IT ?; SF< 100%
236	Pu	0.2150	4000	34 ns	2.858 y		SF<100%
238	Pu	0.2150	~2400	0.6 ns	87.7 y		SF<100%
238	Pu	0.2150	~3500	6 ns	87.7 y		SF<100%
240	Cm	0.2240	3000	55 ns	27 d		SF~100%
240	Pu	0.2230	X	3.7 ns	6561 y	(0^+)	SF>0
242	Pu	0.2240	~2000	3.5 ns	3.75E5 y		SF<100%
242	Pu	0.2240	~2000+Y	28 ns	3.75E5 y		SF<100%
246	Cf	0.2340	2500	45 ns	35.7 h		SF<100%
Even-Odd							
233	Th	0.2150	1850	50 ns	21.83 m		IT~100%, (SF)
235	Pu	0.2150	3000	25 ns	25.3 m		SF<100%
237	Pu	0.2150	2600	97 ns	45.64 d		SF>0
241	Pu	0.2240	2200+X	32 ns	14.325 y		SF=100%
243	Pu	0.2240	1700	45 ns	4.956 h		SF=100%
243	Cm	0.2340	1900	42 ns	29.1 y		SF<100%
245	Pu	0.2350	2000	90 ns	10.5 h		SF<100%
241	Cm	0.2230	2300	15.3 ns	32.8 d		SF=100%
245	Cm	0.2340	2100	13.2 ns	8423 y		SF<100%
Odd-Even							
237	Np	0.2150	2800	45 ns	2.144E6 y		SF<100%
237	Am	0.2150	2400	5 ns	73.6 m		SF>0
242	Bk	0.2240	0+X	9.5 ns	7 m		SF<100%
243	Bk	0.2340	~2200	5 ns	4.5 h		SF<100%
245	Bk	0.2340	~1560	2 ns	4.95 d		SF=100%

- Total no. of fission isomers with half-life greater than 100 NS = 42; in which
  - Odd-odd =16
  - Even-even =8
  - Even-odd =9
  - Odd-even =9
- Total no. of fission isomers with half-life in the range of 1 NS to 100 NS =23; in which
  - Odd-odd=0
  - Even-even=9
  - Even-odd=9
  - Odd-even=5
- Total fission isomers = 42+23 = 65

OTHER ISOMERS IN ACTINIDES AND BEYOND

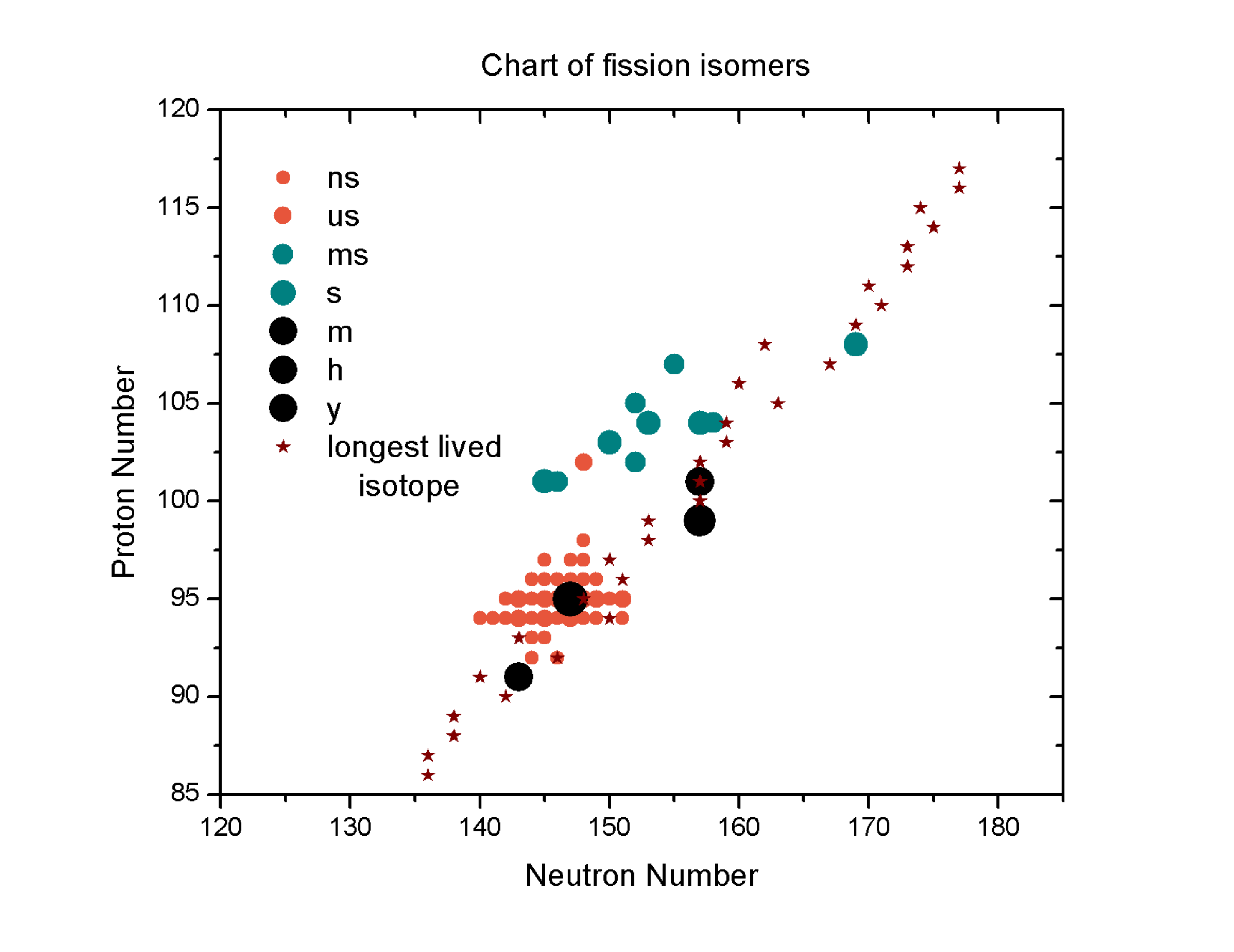
A	X	β_2	Excitation energy (keV)	Half-life	G.S. Half-life	J (spin and parity)	decay mode
Even-even							
214	Th	-0.052	2181	1.24 μs	87 ms	8^+#	IT=100
216	Th	0.008	2043	134 μs	26 ms	(8^+)	IT ?;α=2.8
216	Th	0.008	2646.8	580 ns	26 ms	(11^-)	IT=100
216	Th	0.008	3681.4	740 ns	26 ms	(14^+)	IT=100
234	U	0.215	1421.257	33.5 μs	2.455E5 y	6^-	IT=100
236	Pu	0.215	1185.45	1.2 μs	2.858 y	5^-	IT=100
240	Pu	0.223	1308.74	165 ns	6561 y	(5^-)	IT=100
244	Cm	0.234	1040.188	34 ms	18.1 y	6^+	IT=100
250	Fm	0.235	1199.2	1.92 s	30 m	(8^-)	IT>80;α 20; β^+ ?;...
252	No	0.236	1254.5	109 ms	2.47 s	(8^-)	IT=100
256	Rf	0.247	1120#	25 μs	6.4 ms		IT=100; SF ?
256	Rf	0.247	1400#	17 μs	6.4 ms		IT=100; SF ?
256	Rf	0.247	2400#	27 μs	6.4 ms		IT=100; SF ?
262	Sg	0.229	860	330 ms	6.9 ms		α=100
266	Hs	0.230	1100	280 ms	2.3 ms	(9^-)#	α=?
270	Ds	0.221	1390	10 ms	0.10 ms	$(10)^{(-\#)}$	α=?;IT=?
Odd-Odd							
216	Ac	-0.018	420#	300 ns	440 μs		IT=100
218	Ac	0.029	530#	103 ns	1.08 μs	(11^+)	IT=100
222	Ac	0.129	200#	1.05 m	5 s	high	α=?;IT<10;β^+=1.4
236	Np	0.215	60	22.5 h	153E3 y	1	ε=50;β^-=50
236	Am	0.215	50#	2.9 m	3.6 m	(1^-)	β^+=?;α=?
240	Np	0.223	18	7.22 m	61.9 m	(1^+)	β^-~100; IT=0.12
242	Np	0.224	0#	5.5 m	2.2 m	6^+#	β^-=100
244	Am	0.224	88.6	26 m	10.1 h	1^+	β^-~100; ε=0.0361
246	Am	0.235	30#	25 m	39 m	$2^{(-)}$	β^-~100; IT=0.02
248	Bk	0.235	30#	23.7 h	>9 y	$1^{(-)}$	β-=70;ε=30;α=0.001#
250	Bk	0.235	35.59	29 μs	3.212 h	4^+	IT=100
250	Bk	0.235	84.1	213 μs	3.212 h	7^+	IT ?
250	Es	0.244	200#	2.22 h	8.6 h	$1^{(-)}$	β^+~100;α ?
254	Es	0.226	84.2	39.3 h	275.7 d	2^+	β^-=98;IT 3;α=0.32;...
254	Md	0.237	50#	28 m	28 m	3^-#	β^+~100;α ?

258	Db	0.238	60#	1.9 s	4.2 s		β^+~100; IT ?
266	Mt	0.230	1140	6 ms	1.7 ms		α=100
276	Mt	0.202	140	10 s	0.72 s		α=100
Odd-Even							
215	Ac	0.000	1796	185 ns	0.17 s	$21/2^-$	IT=100
215	Ac	0.000	2490	335 ns	0.17 s	$(29/2^+)$	IT=100
217	Ac	0.008	2012	740 ns	69 ns	$(29/2)^+$	IT=95.7;α=4.3
217	Pa	0.000	1860	1.08 ms	3.6 ms	$29/2^+$#	α=73;IT?
229	Pa	0.190	11.6	420 ns	1.50 d	$3/2^-$	IT=100
237	Np	0.215	945.2	710 ns	2.144E6 y	(11/2,13/2)	IT=100
245	Es	0.234	283	290 ns	1.1 m	$(7/2^-)$	IT=100
249	Bk	0.235	8.777	300 μs	330 d	$(3/2^-)$	IT=100
249	Md	0.235	100#	1.9 s	21.7 s	$(1/2^-)$	α=100
251	Bk	0.235	35.5	58 μs	55.6 m	$7/2^+$#	IT=100
251	Md	0.236	55		4.3 m	$(1/2^-)$	IT ?
255	Lr	0.246	39	2.54 s	31.1 s	$(7/2^-)$	α=100
255	Lr	0.246	1463	1.63 ms	31.1 s	$(25/2^+)$	IT=100; α 0.15
Even-Odd							
215	Th	-0.018	1421.3	770 ns	1.2 s	$9/2^+$#	IT=100
217	Th	-0.018	673.8	141 ns	0.241 ms	$(15/2^-)$	IT=100
229	Th	0.190	0.0076	>1 m	7932 y	$3/2^+$#	IT ?;α ?
235	U	0.215	0.0765	26 m	7.04E8 y	$1/2^+$	IT=100
237	U	0.215	274	155 ns	6.75 d	$(7/2)^-$	IT=100
237	Pu	0.215	145.543	180 ms	45.64 d	$1/2^+$	IT=100
239	U	0.223	20#	>250 ns	23.45 m	$(5/2^+)$	β^-=100
239	U	0.223	133.799	780 ns	23.45 m	$1/2^+$	IT=100
239	Pu	0.223	391.584	193 ns	24110 y	$7/2^-$	IT=100
241	Pu	0.224	161.6852	880 ns	14.325 y	$1/2^+$	IT=100
243	Pu	0.224	383.6	330 ns	4.956 h	$(1/2^+)$	IT=100
243	Cm	0.234	87.4	1.08 μs	29.1 y	$1/2^+$	IT=100
243	Cm	0.234	96		29.1 y	$(7/2^+)$	IT=100
245	Pu	0.235	264.5	330 ns	10.5 h	$(5/2^+)$	IT=100
245	Cm	0.234	355.92	640 ns	8423 y	$1/2^+$	IT=100
247	Cm	0.235	227.38	26.3 μs	1.56E7 y	$5/2^+$	IT=100
247	Cm	0.235	404.9	100.6 ns	1.56E7 y	$1/2^+$	IT=100

247	Fm	0.234	49	5.1 s	31 s	(1/2$^+$)	α~100;IT ?
249	Cf	0.235	144.98	45 μs	351 y	5/2$^+$	IT=100
251	Cf	0.236	370.47	1.3 μs	898 y	11/2$^-$	IT=100
251	Fm	0.245	200.09	21.1 μs	5.30 h	(5/2$^+$)	IT=100
251	No	0.236	106	1.02 s	0.80 s	(1/2$^+$)	α=100
251	No	0.236	1750	2 μs	0.80 s		IT ?
253	Fm	0.236	351	560 ns	3 d	(11/2$^-$)	IT=100
253	No	0.236	167.34	30.3 μs	1.62 m	(5/2$^+$)	α=?
253	No	0.236	1200	706 μs	1.62 m	>21/2	IT ?
255	Rf	0.246	-85	1 s	2.3 s	5/2$^+$#	α=100
257	Rf	0.238	1155	134.9 μs	4.7 s	(21/2$^+$)	IT=100
261	Sg	0.238	100#	9.3 μs	0.23 s	(11/2$^-$)	IT=100
263	Sg	0.229	51	420 ms	1 s	(3/2$^+$)#	α=?;IT?
265	Hs	0.230	229	360 μs	1.9 ms	(9/2$^+$)#	α=100;IT?
267	Hs	0.230	39	990 μs	52 ms		α=?;IT?
271	Ds	0.221	68	1.7 ms	*1.63 ms/90 ms	(9/2$^+$)#	α=100
273	Ds	0.222	198	120 ms	0.17 ms	(3/2$^+$)#	α=100
281	Ds	0.108	230#	0.9 s	20 s		α=100
285	Cn	0.089	560#	15 s	30 s		α=100
289	Fl	-0.052	960#	1.1 s	*0.97 s/2.2 s		α=100
293	Lv	-0.070	930#	80 ms	53 ms		α=100

- Total no. of other isomers (except fission isomers) in actinides and beyond = 85 (odd-odd=18, even-even=16, even-odd=38, odd-even=13)
- Total no. of fission isomers = 65 (odd-odd=16, even-even=17, even-odd=18, odd-even=14)
- Total no. of isomers in actinides and beyond = 85+65 = 150 (odd-odd=34, even-even=33, even-odd=56, odd-even=27)

CHART OF FISSION ISOMERS



FISSION ISOMERS HAVING HALF-LIFE MORE THAN THEIR GROUND STATE HALF-LIFE

Nuclei	Isomeric state half-life	Ground state half-life
242Am	141 y	16.02 h
246Md	4.4 s	0.9 s
250No	51 us	4.2 us
253Lr	1.32 s	0.57 s
256Es	7.6 h	25.4 m
261Rf	81 s	1.9 s
277Hs	130 s	11 ms

Longest lived fission isomeric state is in 242Am with half-life of 141 y

FISSION ISOMERS WITH $T_{1/2}$(I.S.)>$T_{1/2}$(G.S.)

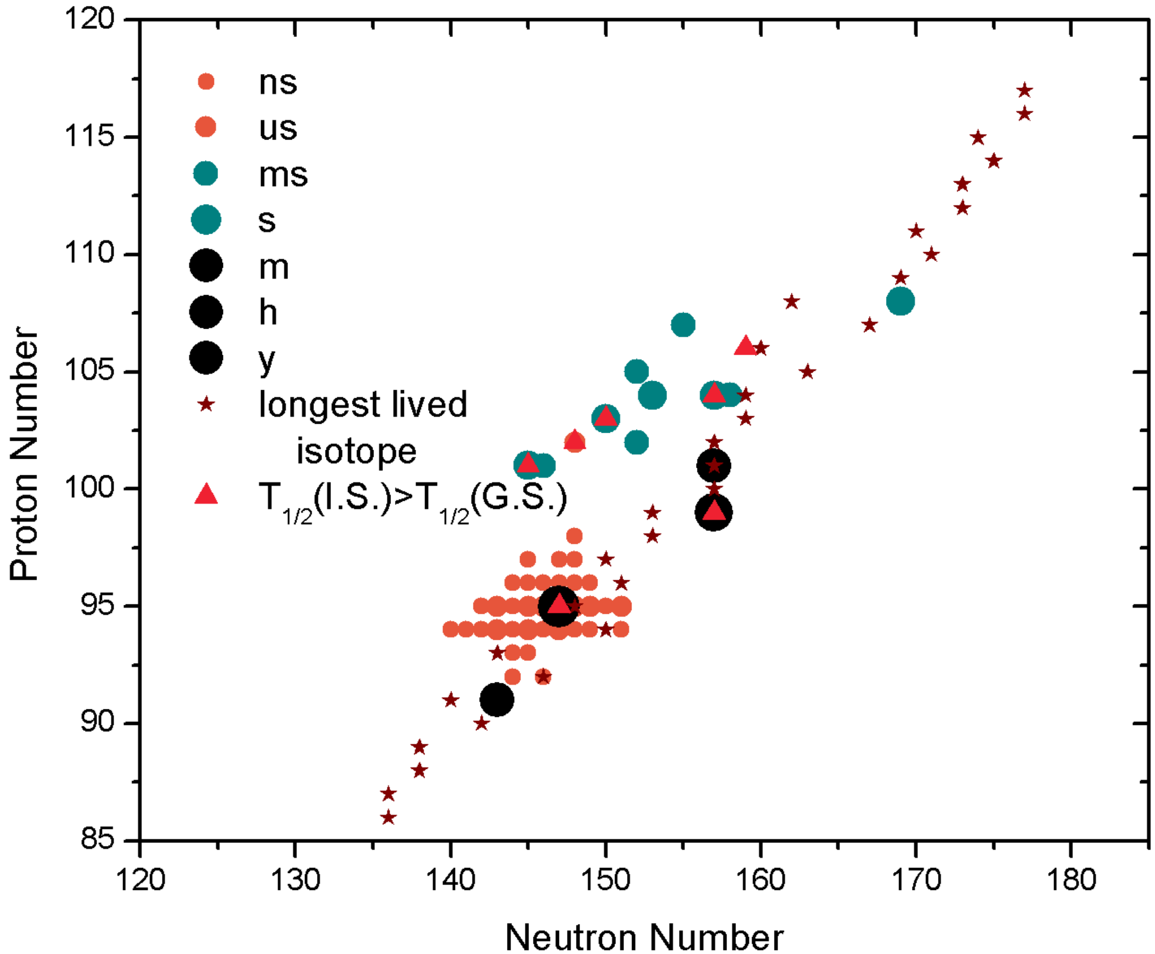
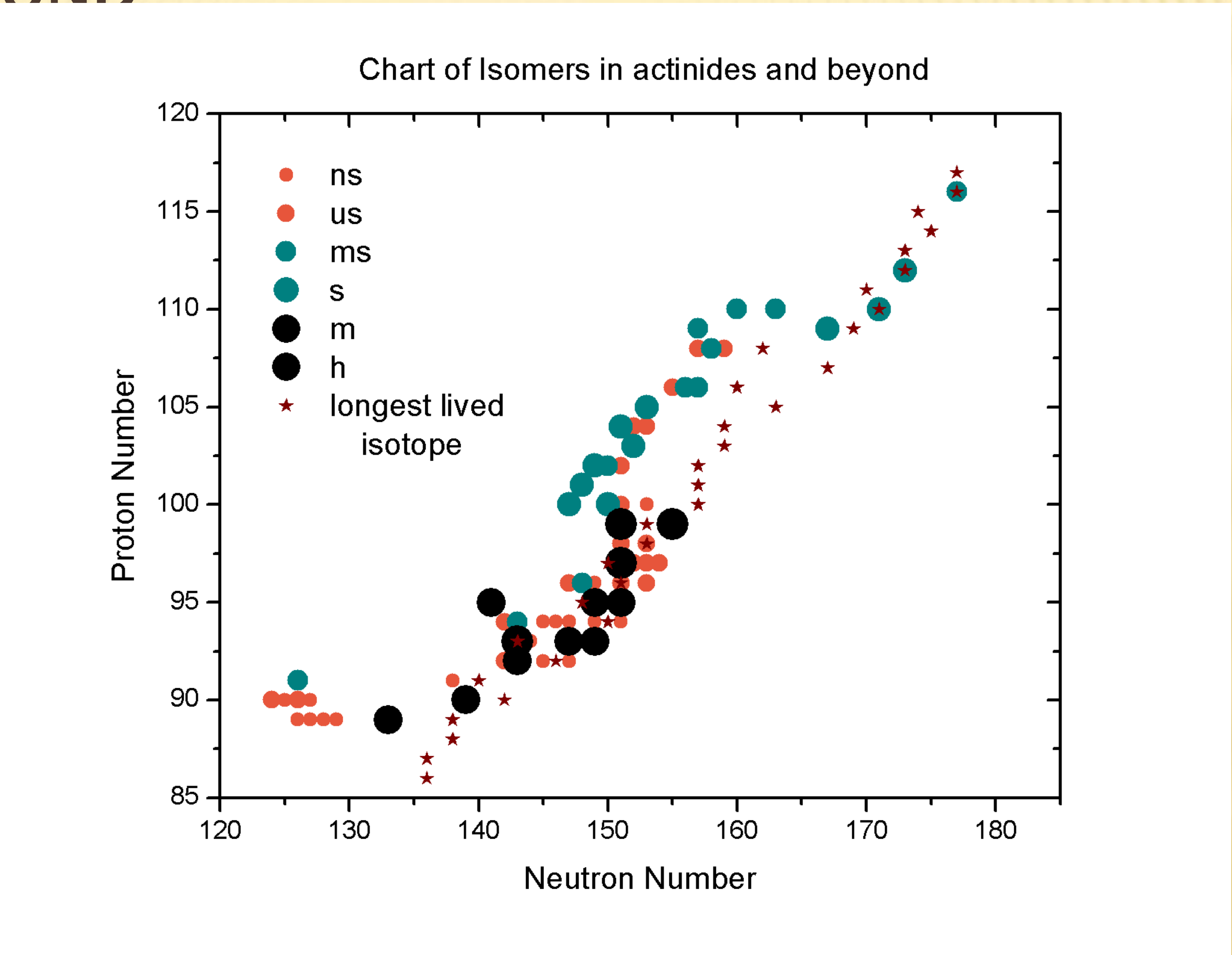
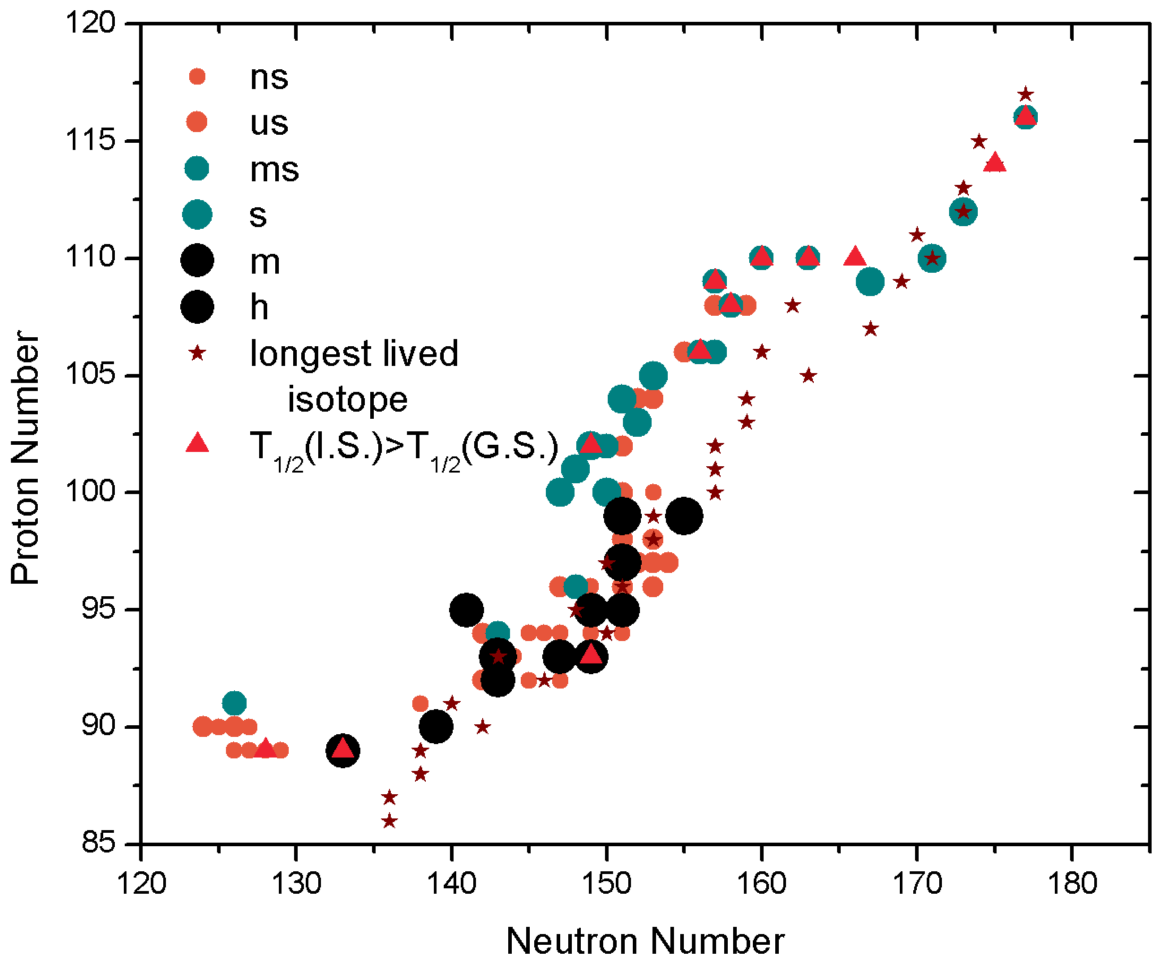


CHART OF NORMAL ISOMERS IN ACTINIDES AND BEYOND



NORMAL ISOMERS WITH $T_{1/2}$(I.S.)>$T_{1/2}$(G.S.)



OTHER ISOMERS HAVING HALF-LIFE MORE THAN THEIR GROUND STATE

Nuclei	Isomeric state half-life	Ground state half-life
217Ac	740 ns	69 ns
222Ac	1.05 m	5 s
242Np	5.5 m	2.2 m
251No	1.02 s	0.80 s
262Sg	330 ms	6.9 ms
266Hs	280 ms	2.3 ms
266Mt	6 ms	1.7 ms
270Ds	10 ms	0.10 ms
273Ds	120 ms	0.17 ms
276Mt	10 s	0.72 s
289Fl	1.1 s	0.97s
293Lv	80 ms	53 ms

CONFIGURATION ASSIGNMENT

Nucleus	Spin and parity	ENSDF	Our assignment
242Am(Z=95,N=147)	5^-	p5/2[523],n5/2[622]	p5/2[523],n5/2[622]
256Es(Z=99,N=157)	(8^+)	p7/2[633],n9/2[615]	p7/2[633],n11/2[615]
256Md(Z=101,N=155)	(1^-)	p7/2[514],n7/2[613]	p9/2[514],n7/2[613]

- 256Es should have spin and parity of 9^+ due to its odd neutron in 11/2[615] on the basis of Nilsson scheme.

- 256Md should have proton configuration as p9/2[514] to follow the tentative spin and parity assignment.

SOME INCONSISTENCIES

- 245Md, 253Rf, 254Md, 256Md, 261Bh, 263Hs,265Sg, 271 Ds,289Fl, 293Lv are some cases which are having the isomeric states with a given half-life according to NUBASE-12 but ENSDF does not support these.

STRUCTURE AND SPECTROSCOPY IN THE SECOND WELL

- Fission isomers are also SD states but at low spins, unlike SD bands seen at high spins.
- Their study, experimentally and theoretically, will lead to new structure information at very large deformation.
-

Thank you…..