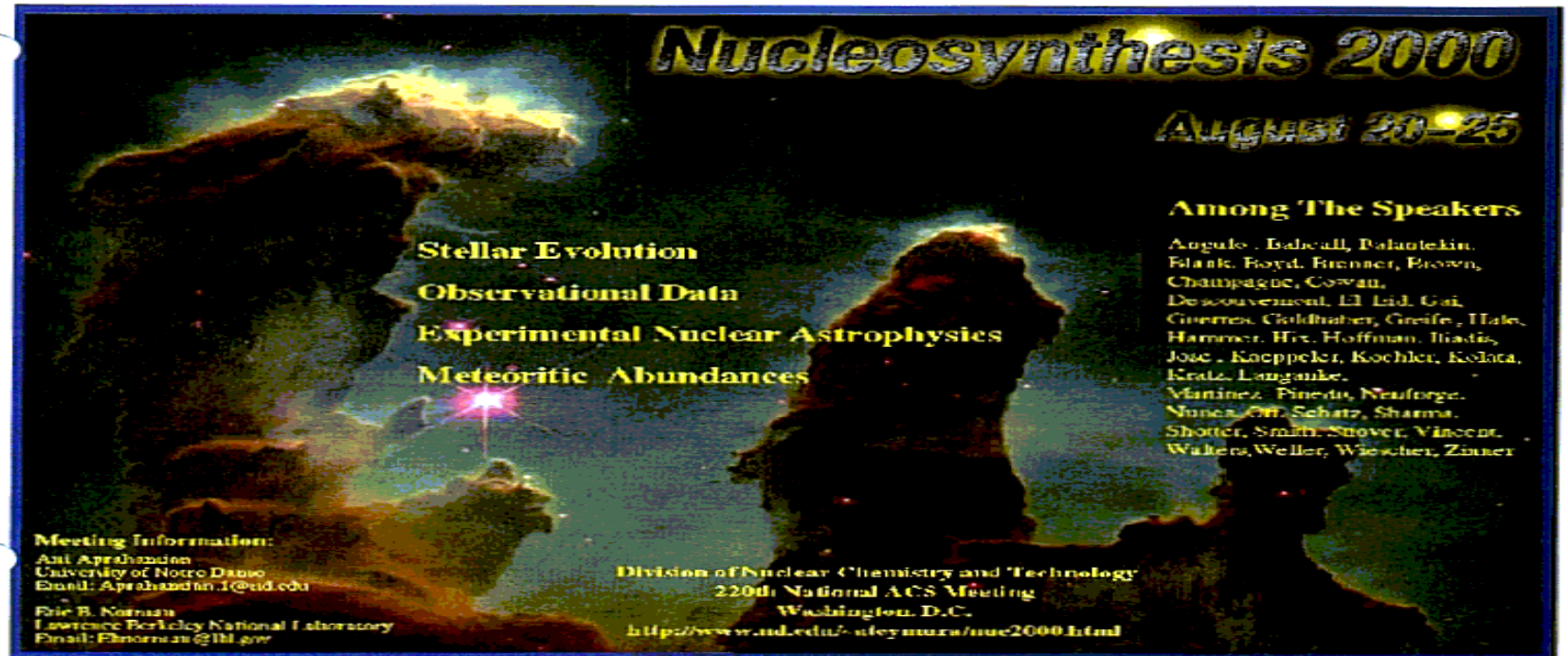
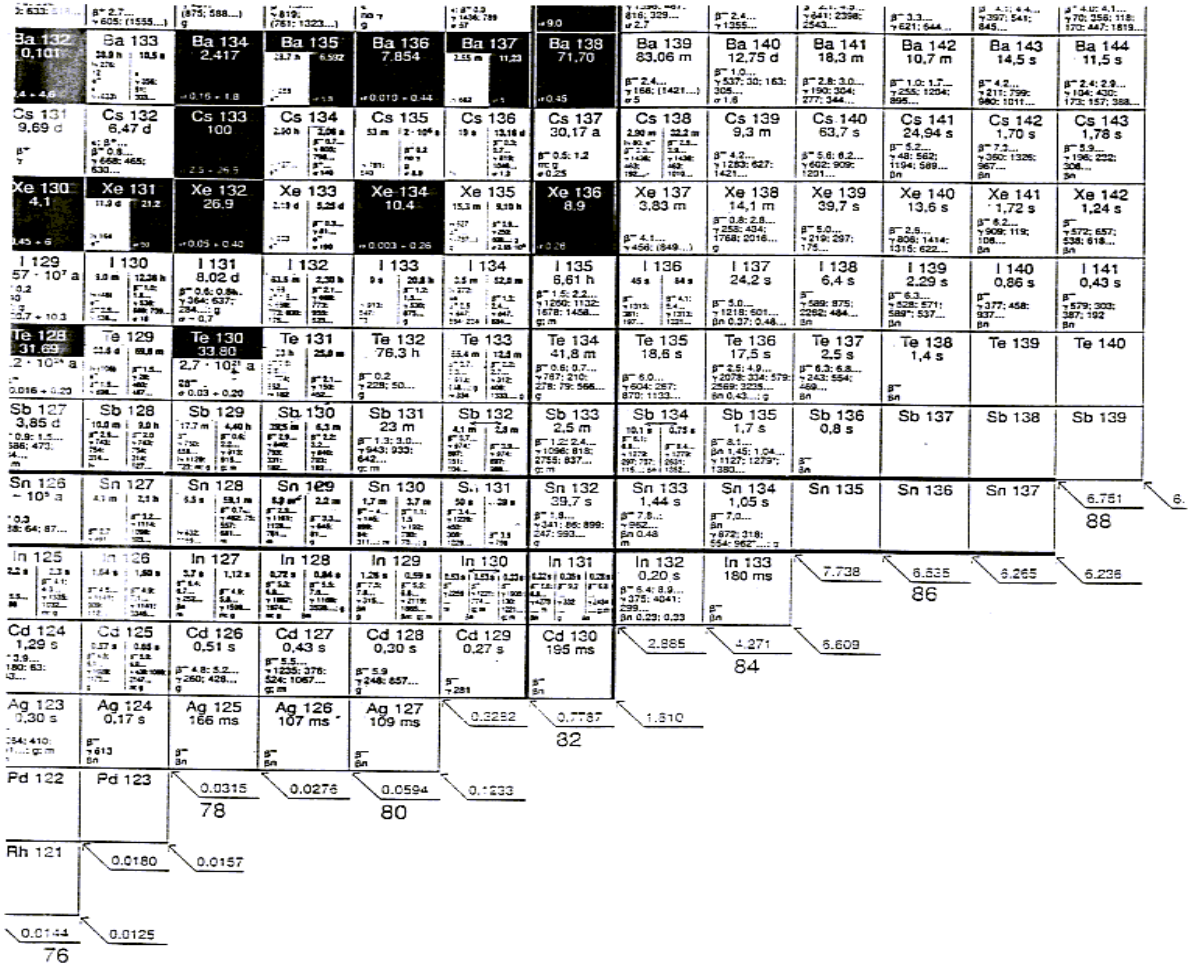


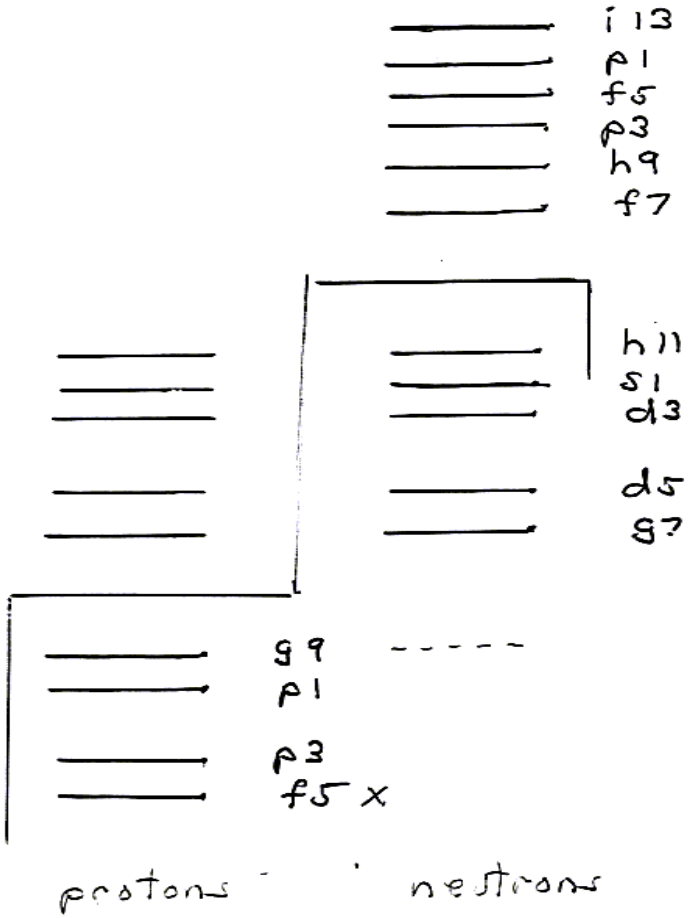
Shell model structure around ^{132}Sn

B. A. Brown

B. Alex Brown


Ba 132 0,101
Ba 133
Ba 134 2,417
Ba 135
Ba 136 7,854
Ba 137
Ba 138 71,70
Ba 139 83,06 m
Ba 140 12,75 d
Ba 141 18,3 m
Ba 142 10,7 m
Ba 143 14,5 s
Ba 144 11,5 s
Cs 131 9,69 d
Cs 132 6,47 d
Cs 133 100
Cs 134
Cs 135
Cs 136
Cs 137 30,17 a
Cs 138
Cs 139 9,3 m
Cs 140 63,7 s
Cs 141 24,94 s
Cs 142 1,70 s
Cs 143 1,78 s
Xe 130 4,1
Xe 131
Xe 132 26,9
Xe 133
Xe 134 10,4
Xe 135
Xe 136 8,9
Xe 137 3,83 m
Xe 138 14,1 m
Xe 139 39,7 s
Xe 140 13,6 s
Xe 141 1,72 s
Xe 142 1,24 s
I 129
I 130
I 131 8,02 d
I 132
I 133
I 134
I 135 6,61 h
I 136
I 137 24,2 s
I 138 6,4 s
I 139 2,29 s
I 140 0,86 s
I 141 0,43 s
Te 128 31,69
Te 129
Te 130 33,80
Te 131
Te 132 76,3 h
Te 133
Te 134 41,8 m
Te 135 18,6 s
Te 136 17,5 s
Te 137 2,5 s
Te 138 1,4 s
Te 139
Te 140
Sb 127 3,85 d
Sb 128
Sb 129
Sb 130
Sb 131 23 m
Sb 132
Sb 133 2,5 m
Sb 134
Sb 135 1,7 s
Sb 136 0,8 s
Sb 137
Sb 138
Sb 139
Sn 126
Sn 127
Sn 128
Sn 129
Sn 130
Sn 131
Sn 132 39,7 s
Sn 133 1,44 s
Sn 134 1,05 s
Sn 135
Sn 136
Sn 137
6.751
88
In 125
In 126
In 127
In 128
In 129
In 130
In 131
In 132 0,20 s
In 133 180 ms
7.738
6.535
86
6.265
6.236
Cd 124 1,29 s
Cd 125
Cd 126 0,51 s
Cd 127 0,43 s
Cd 128 0,30 s
Cd 129 0,27 s
Cd 130 195 ms
2.885
4.271
84
5.609
Ag 123 0,30 s
Ag 124 0,17 s
Ag 125 166 ms
Ag 126 107 ms
Ag 127 109 ms
0.3282
0.7787
82
1.310
Pd 122
Pd 123
0.0315
78
0.0276
0.0594
80
0.1233
Rh 121
0.0180
0.0157
0.0144
76
0.0125

^{132}Sn



- shell-model configuration mixing in a 20 orbit model space (four major shells)

- single-particle energies from experiment (many measured recently)

- CD-Bonn renormalized G matrix from Morten Hjorth-Jensen (oscillator basis)

- calculations carried out by REU* student Jeff Giansiracusa

* Research Experience for Undergraduate NSF supported program at MSU

Beta Decay of $N = 82$ Nuclei; a Test of Microscopic Shell-Model Hamiltonians

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M. Hjorth-Jensen

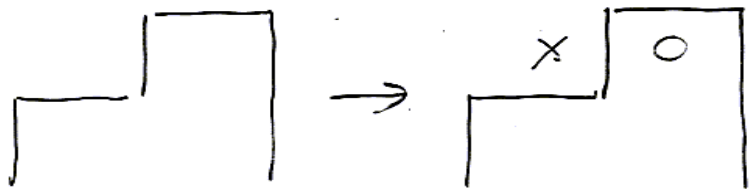
Department of Physics, University of Oslo, N-0316 Oslo, Norway

M. Sanchez-Vega*, H. Mach, B. Fogelberg and A. Lindroth

Department of Radiation Sciences, Uppsala University, S-61182 Nyköping, Sweden

Abstract

Recent advances in experimental techniques allow for the measurements of the beta decay strengths of nuclei near ^{132}Sn with considerable detail, and provide a means for stringent tests of advances microscopic models. Calculations are presented for the beta decay of ^{132}Sn and ^{133}Sb based upon a microscopic shell-model hamiltonian obtained with a renormalized G matrix. They are compared with new data for the ^{133}Sb decay and with older data for the ^{132}Sn decay. The agreement between experiment and theory is excellent over a range of four orders of magnitude in the reduced transition probability.



^{132}Sn ^{132}Sb

$^{132}Sn \rightarrow {}^{132}Sb$

11 1^+ states

low

$d5 \rightarrow d3$

$d5 \rightarrow g7$ ×
$s1 \rightarrow d3$ ×

$h11 \rightarrow h11$
$s1 \rightarrow s1$
$d3 \rightarrow d3$
$d5 \rightarrow d5$
$g7 \rightarrow g7$

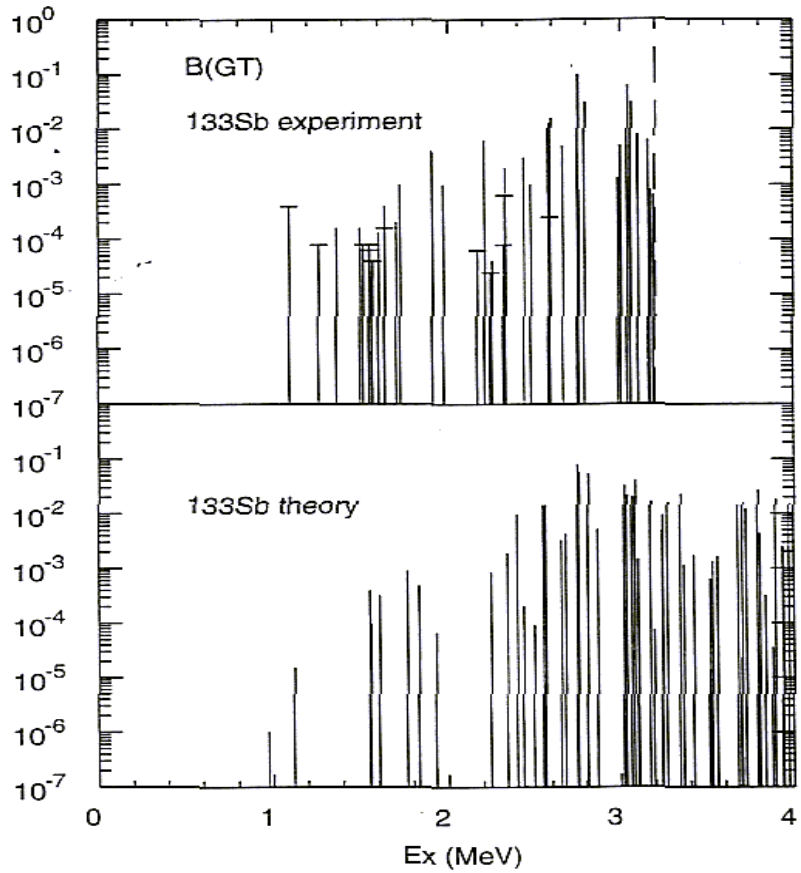
$g7 \rightarrow d5$ ×
$d3 \rightarrow s1$ ×

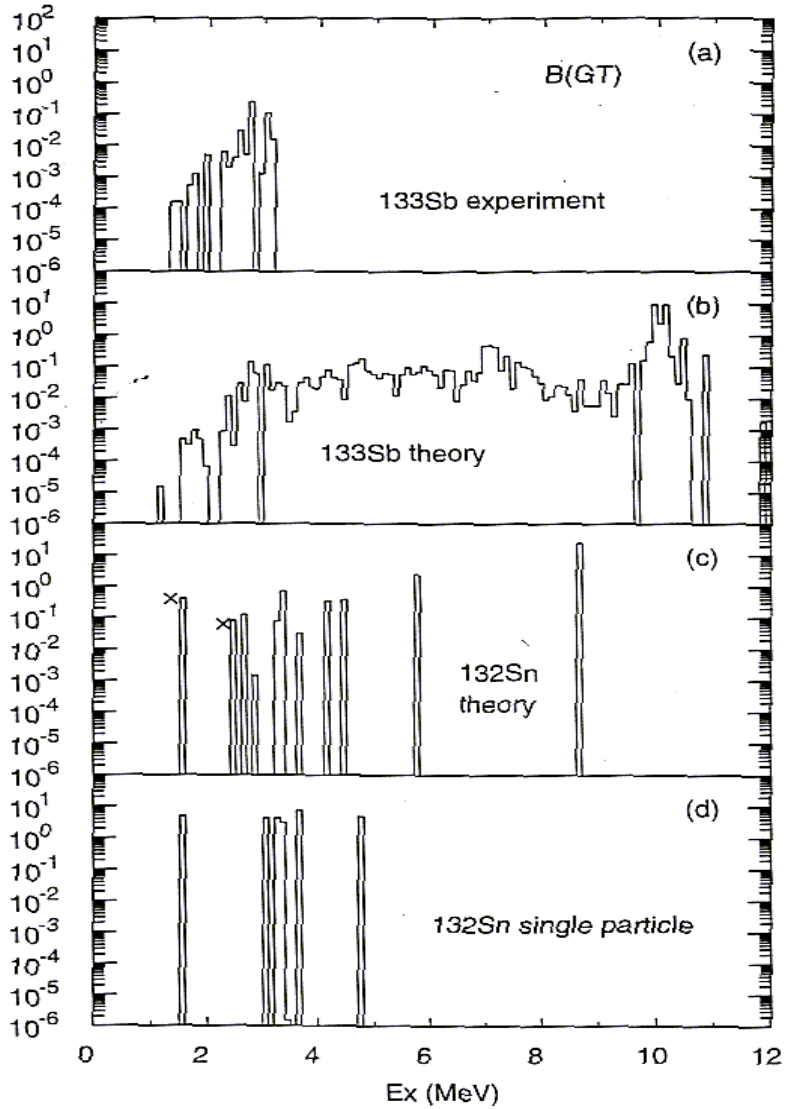
high

$d5 \rightarrow d3$

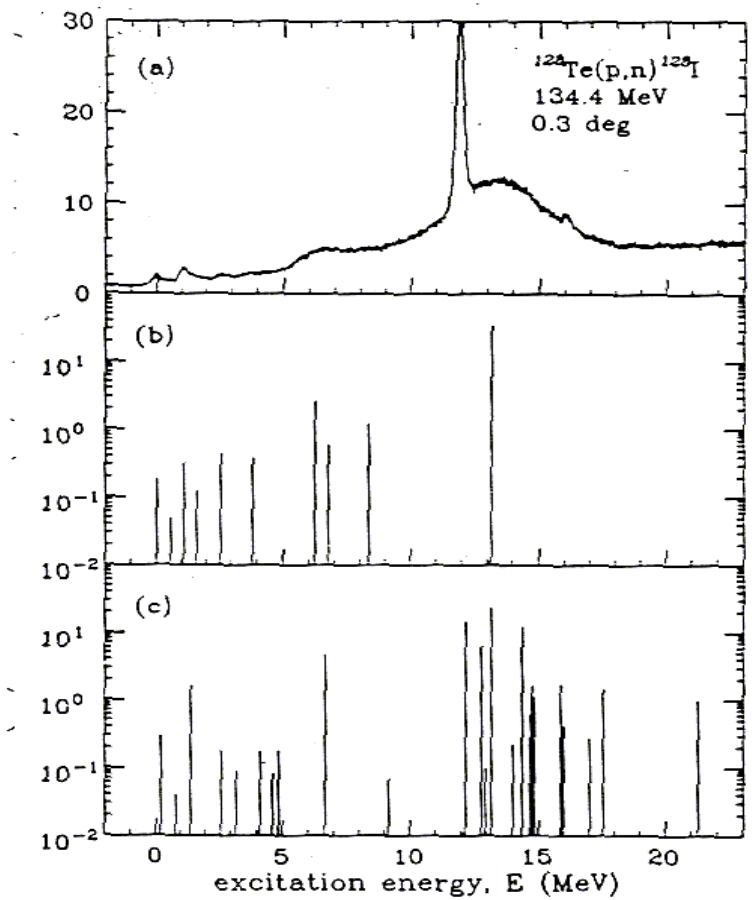
× Δl-forbidden GT

$g9 \rightarrow g7$ not included


B(GT)
133Sb experiment
133Sb theory
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0
1
2
3
4
Ex (MeV)


B(GT)
(a)
133Sb experiment
(b)
133Sb theory
(c)
132Sn
theory
(d)
132Sn single particle
Ex (MeV)

R. Madey et al PRC 39, 550 (1989)



TABLES

TABLE I. Total $B(GT)$ strength observed in beta decay.

Nucleus	E_{max}	$B(GT)_{exp}$	$B(GT)_{th}$	$\frac{B(GT)_{th}}{B(GT)_{exp}}$
	(MeV)			
^{132}Sn	2.5	0.45	0.97	2.2
^{133}Sb	3.2	0.41	0.78	1.9
^{134}Te	1.2	0.32	0.69	2.2

$d5 \rightarrow d3 \quad B(GT)_{sp} = 9.6$

Figure Captions:

Fig. 1: $B(GT)$ vs excitation energy for the decay of ^{132}Sn and ^{133}Sb. The values are binned over 100 keV energy intervals. The theoretical values are divided by 2.0 to take into account the higher-energy renormalizations discussed in the text. The crosses in the ^{132}Sn theory spectra are the experimental values for the lowest two 1^+ states in ^{132}Sb.

Fig. 2: $B(GT)$ vs excitation energy for the decay of ^{133}Sb below 4.0 MeV showing the individual states. Experimental states with a bar on top correspond to upper limits. The theoretical values are divided by 2.0 to take into account the higher-energy renormalizations discussed in the text. The experimental data stops at the dashed line.

whats missing ?

- 2p-2h configuration mixing and Δ admixtures

  in light nuclei - sd pf shells

$$\frac{B_{th}}{B_{exp}} \approx 1.8$$

- $g_{9/2} \rightarrow g_{7/2}$

Both are at high energy and can be treated as a renormalization

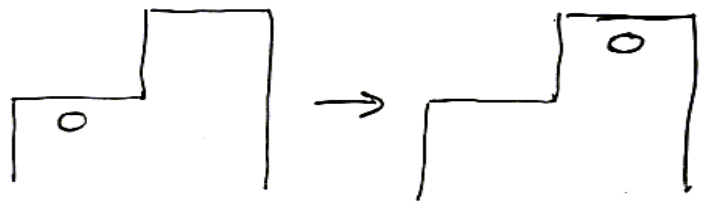
Shell Model studies of Neutron-Rich Nuclei:

^{132}Sn, Beta decay, and the r-process

By Jeff Giansiracusa

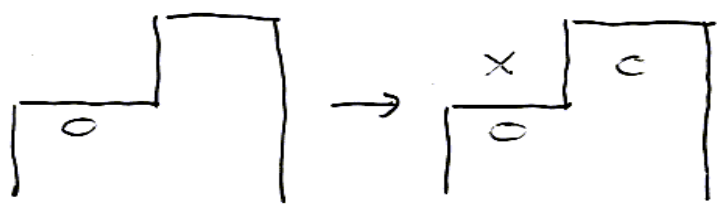
^{131}In ^{131}Sn

A



$g_{7/2} \rightarrow g_{9/2}$
(low)

B



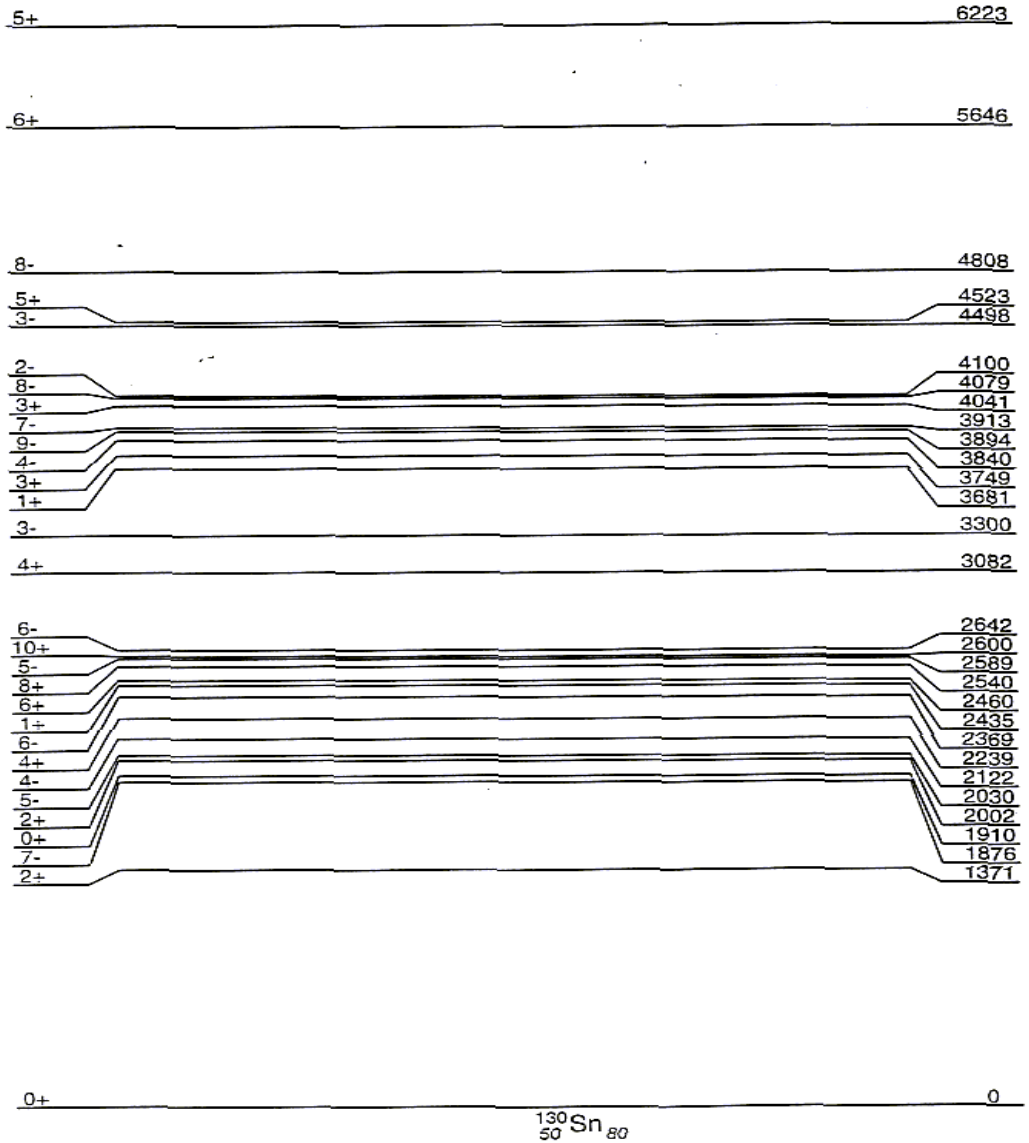
|| transitions
about 4
MeV higher

Near ^{132}Sn we can include both A and B, but for going down to ^{122}Zr we take A only

for $g_{7/2} \rightarrow g_{9/2}$ $B(GT)_{eff} \approx \frac{1}{10} B(GT)_{sp}$

7/2+	2434
5/2+	1655
1/2+	332
11/2-	242
3/2+	0

$^{131}_{50}Sn_{81}$


5+ 6223
6+ 5646
8- 4808
5+ 4523
3- 4498
2- 4100
8- 4079
3+ 4041
7- 3913
9- 3894
4- 3840
3+ 3749
1+ 3681
3- 3300
4+ 3082
6- 2642
10+ 2600
5- 2589
8+ 2540
6+ 2460
1+ 2435
6- 2369
4+ 2239
4- 2122
5- 2030
2+ 2002
0+ 1910
7- 1876
2+ 1371
0+ 0

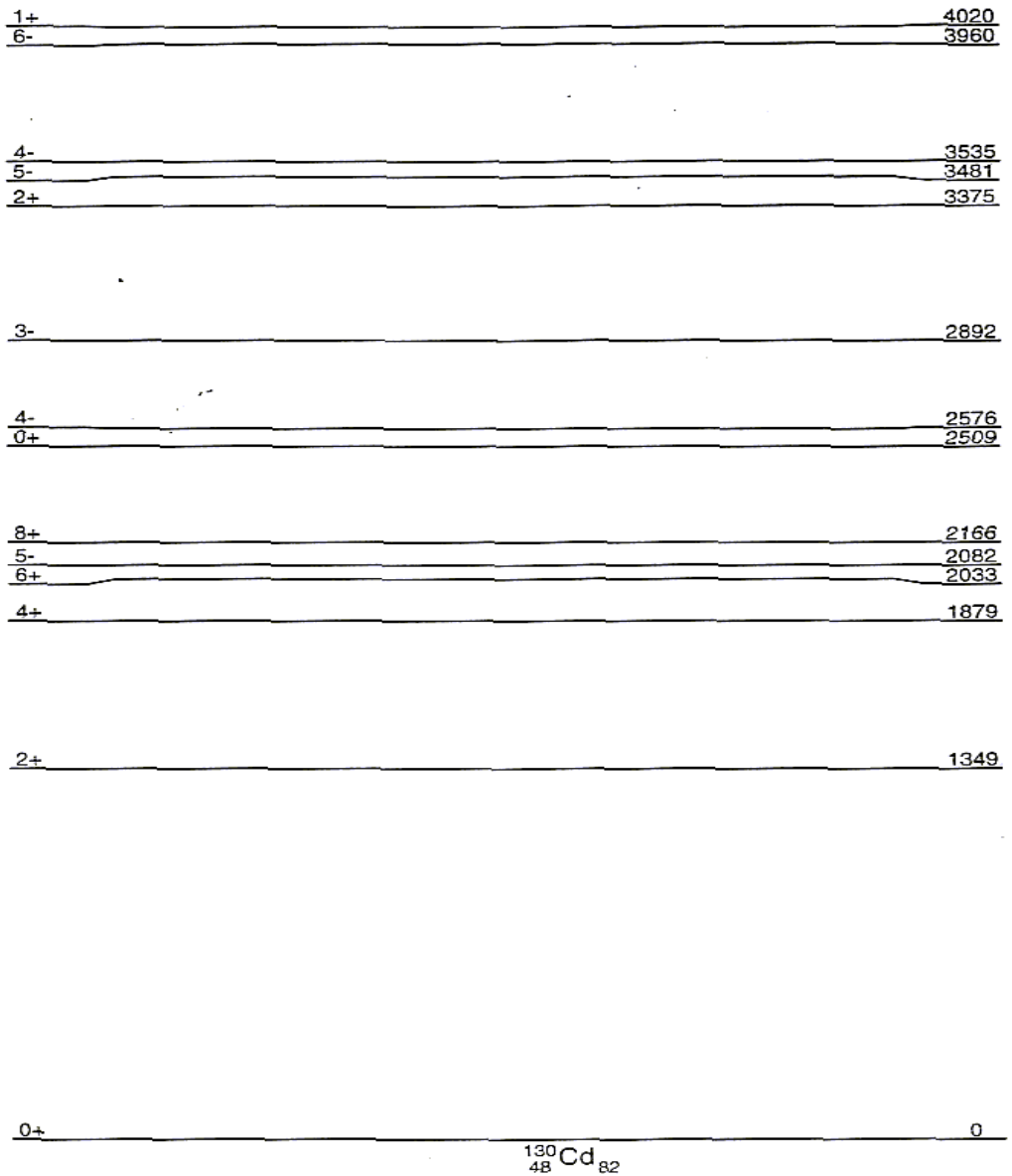
$^{130}_{50}Sn_{80}$

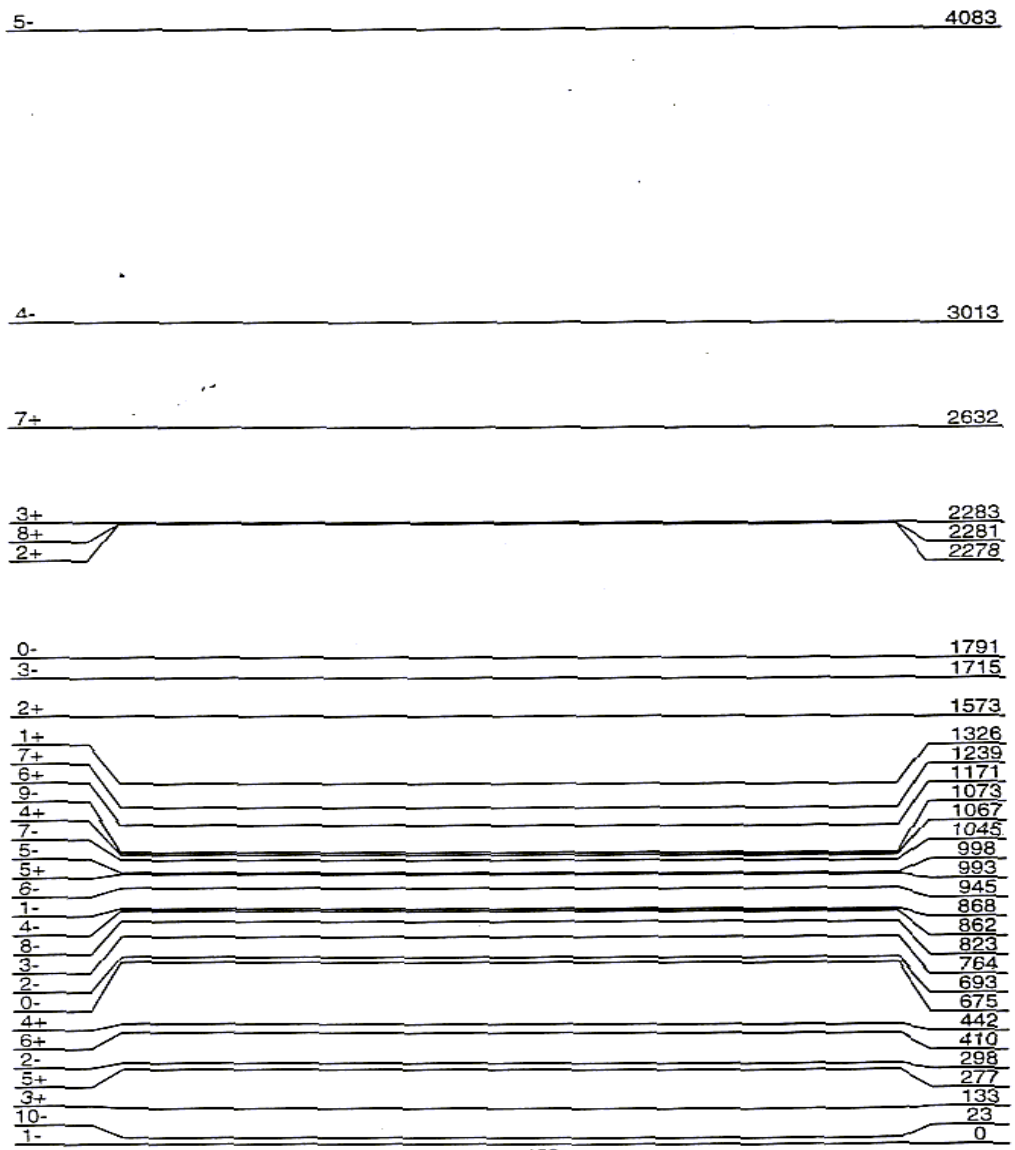
3/2- 1483

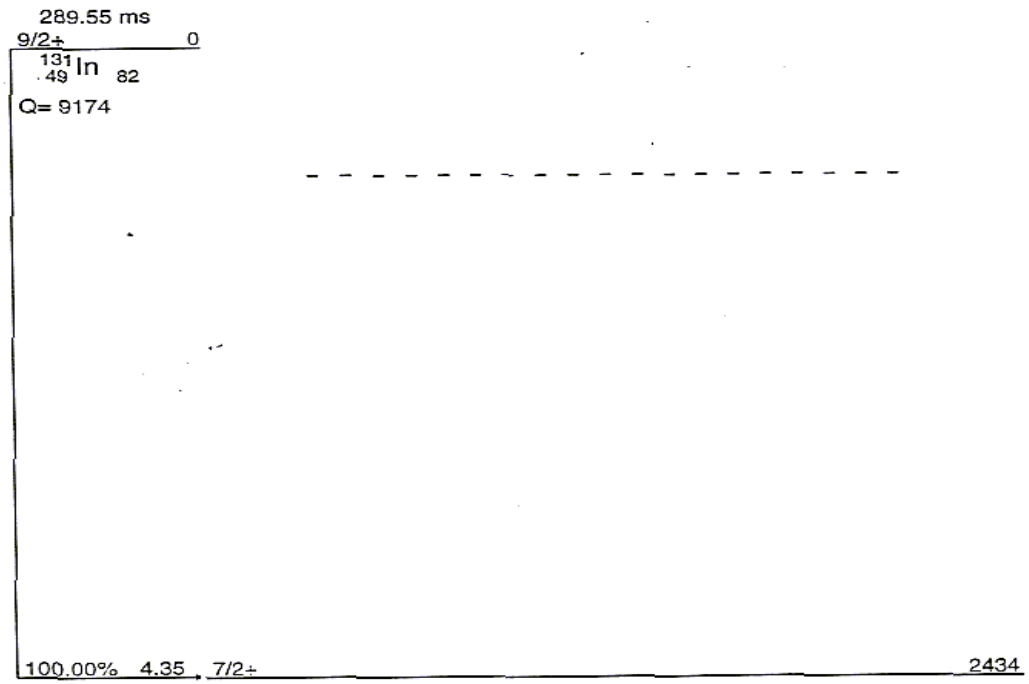
1/2- 363

9/2+ 0

$^{131}_{49}In_{82}$


1+ 4020
6- 3960
4- 3535
5- 3481
2+ 3375
3- 2892
4- 2576
0+ 2509
8+ 2166
5- 2082
6+ 2033
4+ 1879
2+ 1349
0+ 0
$^{130}_{48}Cd_{82}$


5-
4083
4-
3013
7+
2632
3+
8+
2+
2283
2281
2278
0-
3-
1791
1715
2+
1573
1+
7+
6+
9-
4+
7-
5-
5+
6-
1-
4-
8-
3-
2-
0-
4+
6+
2-
5+
3+
10-
1-
1326
1239
1171
1073
1067
1045
998
993
945
868
862
823
764
693
675
442
410
298
277
133
23
0
130
49
In
81

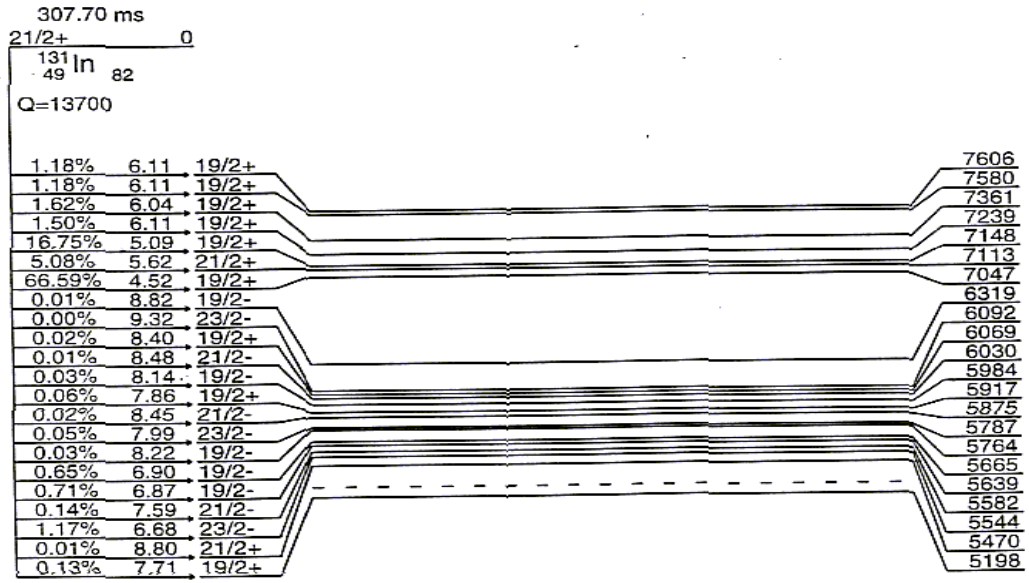


3/2+ 0

individual branches < 0.80% not shown
0.00% of total branching not shown

$^{131}_{50}Sn_{81}$

Pn = 0.00%
Sn = 5280

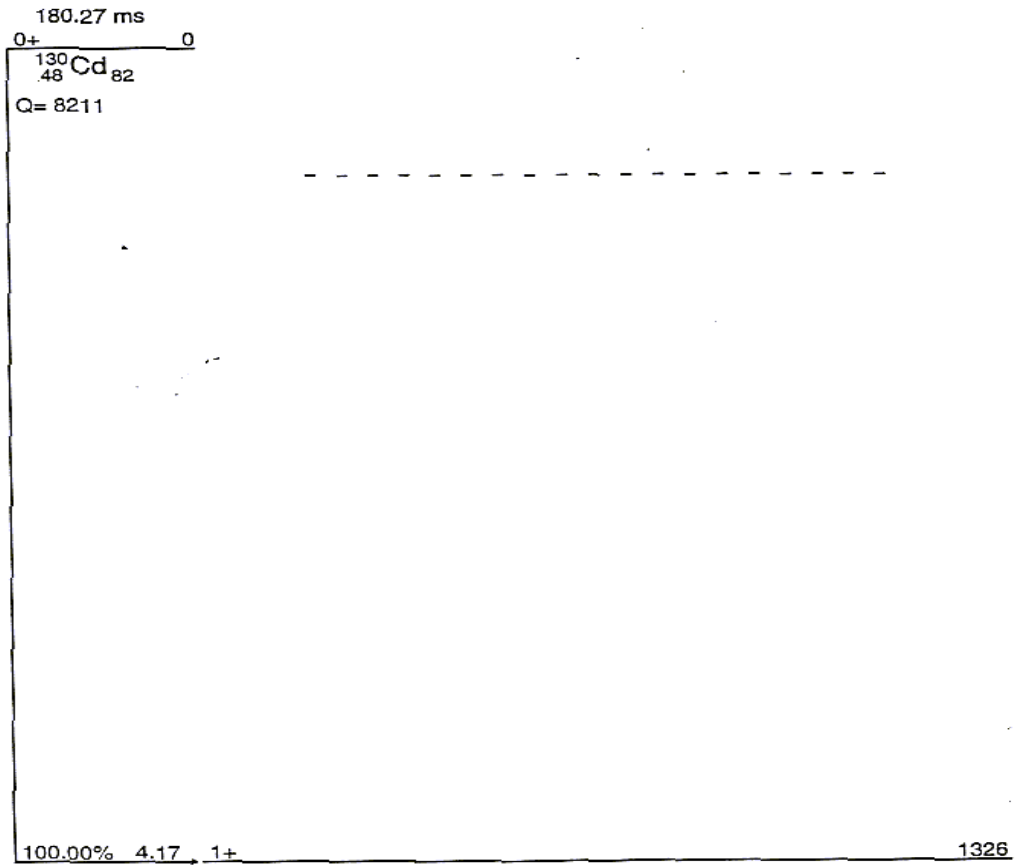


3/2+ 0

individual branches < 0.80% not shown
3.06% of total branching not shown

$^{131}_{50}Sn_{81}$

Pn = 99.87%
Sn = 5280

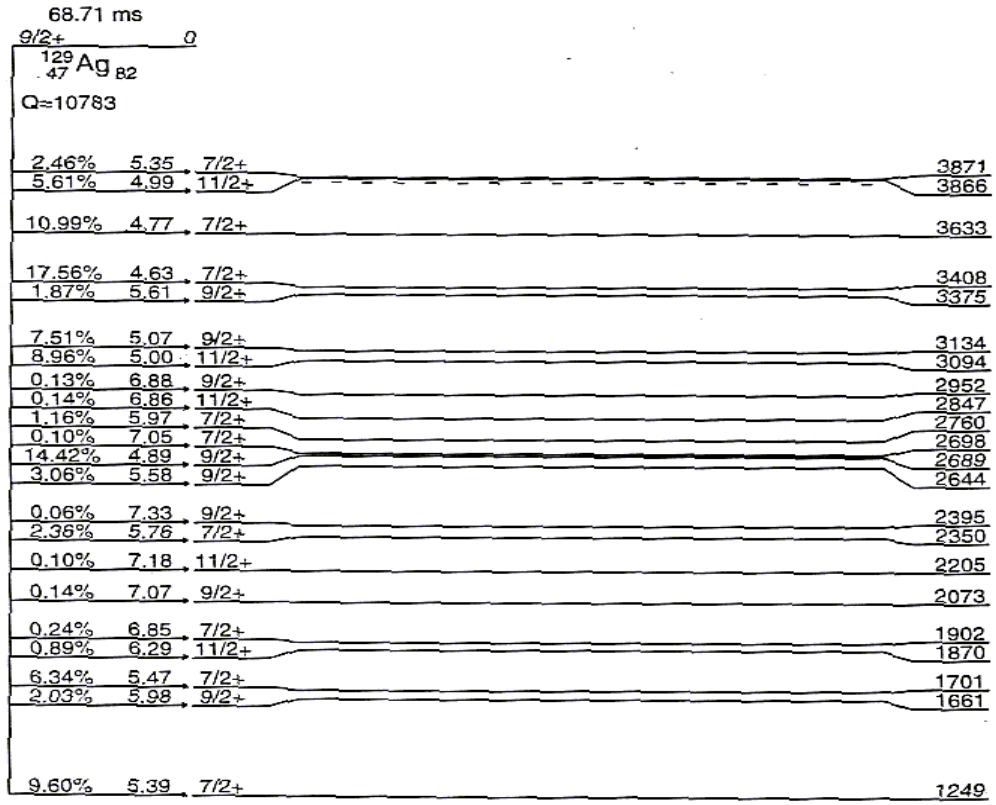


1- 0

individual branches < 0.80% not shown
0.00% of total branching not shown

$^{130}_{49}In_{81}$

Pn = 0.00%
Sn = 5020

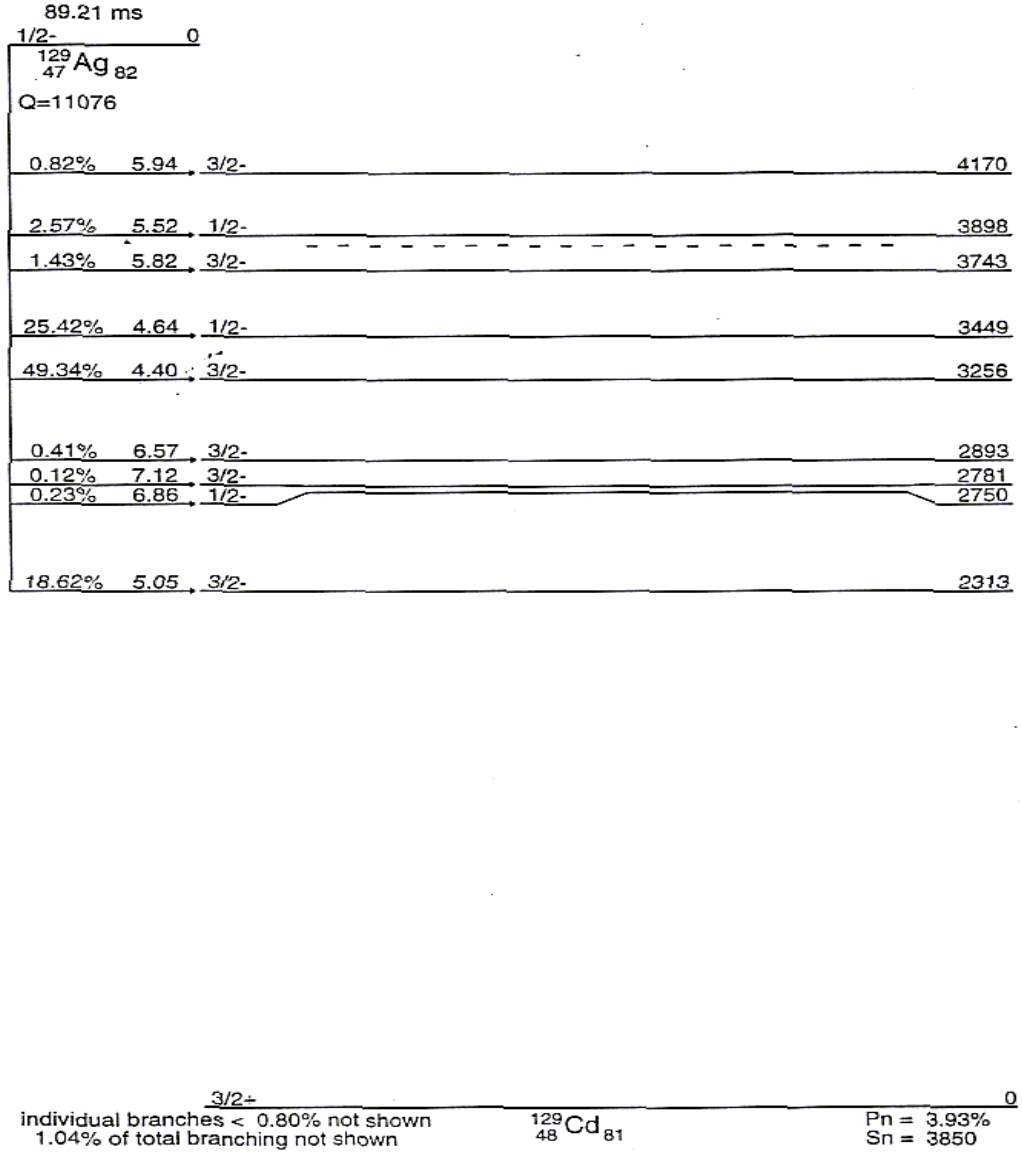


3/2+ 0

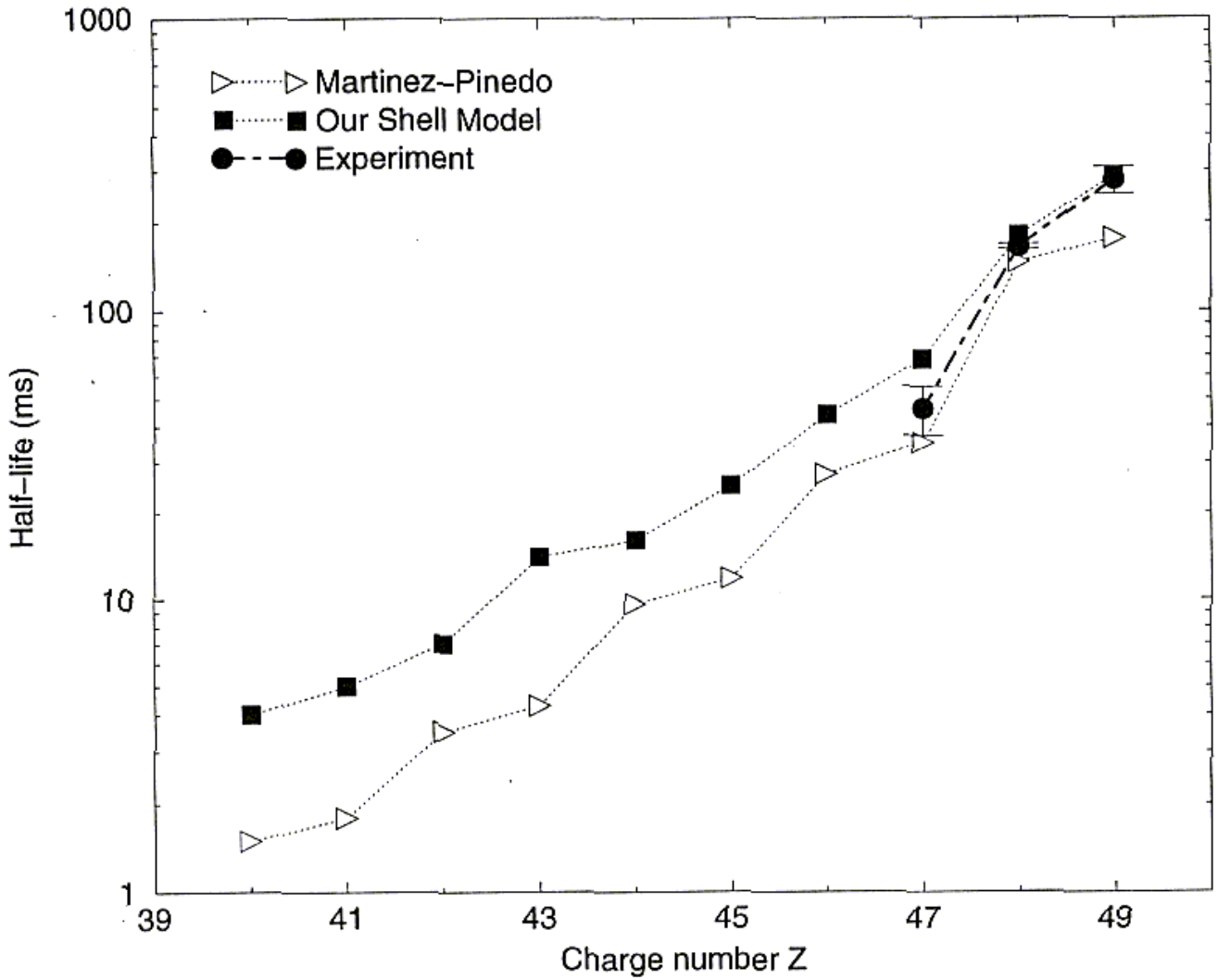
individual branches < 0.80% not shown
4.27% of total branching not shown

$^{129}_{48}Cd_{81}$

Pn = 10.29%
Sn = 3850


89.21 ms
1/2- 0
$^{129}_{47}Ag_{82}$
Q=11076
0.82% 5.94 3/2- 4170
2.57% 5.52 1/2- 3898
1.43% 5.82 3/2- 3743
25.42% 4.64 1/2- 3449
49.34% 4.40 3/2- 3256
0.41% 6.57 3/2- 2893
0.12% 7.12 3/2- 2781
0.23% 6.86 1/2- 2750
18.62% 5.05 3/2- 2313
3/2+ 0
individual branches < 0.80% not shown
1.04% of total branching not shown
$^{129}_{48}Cd_{81}$
Pn = 3.93%
Sn = 3850

Z / N	77	78	79	80	81	82	83	84	
50						^{132}Sn			Sn
49	930 ms	1100 ms	579 ms	548 ms	467 ms	290 ms	207 ms	162 ms	In
48		811 ms	373 ms	362 ms	229 ms	180 ms	104 ms	88 ms	Cd
47				*121 ms*	*258 ms*	*68 ms*	*63 ms*		Ag
46					64 ms	44 ms	124 ms		Pd
45					72 ms	25 ms	30 ms		Rh
44					24 ms	16 ms			Ru
43						*14 ms*			Tc
42						7 ms			Mo
41						7 ms			Nb
40						4 ms			Zr


Martinez-Pinedo
Our Shell Model
Experiment
1000
100
10
1
Half-life (ms)
39
41
43
45
47
49
Charge number Z

For $N \geq 83$ first-forbidden beta (FF) is more important

we follow the work of Warburton with some approximations

- rank 0 $\vec{\sigma} \cdot \vec{p}$ strength calibrated to
  $^{133}Sn \rightarrow {}^{133}Sb$
  $7/2^- \quad 7/2^+$

- rank 1 $\vec{r}$ and $\vec{r} \times \vec{\sigma}$

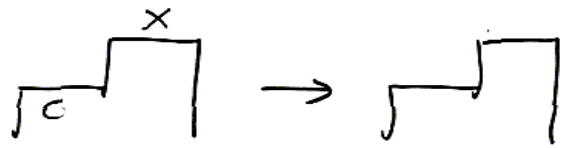
  linear combination an approximation to Warburton's exact form

  strength calibrated to
  $^{132}In \rightarrow {}^{132}Sn$

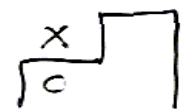
- rank 2 ignored

^{132}In ^{132}Sn

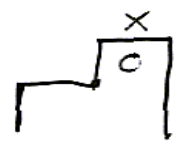
7^-



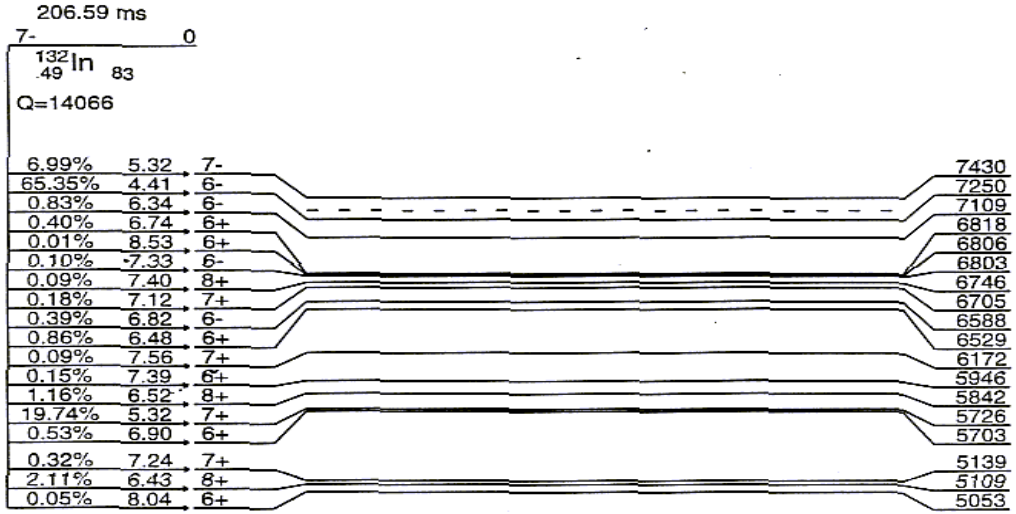
0^+



mainly FF



mainly $5_{7/2} \rightarrow 5_{9/2}$



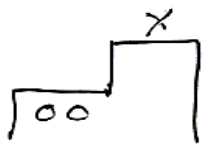
0+ 0

individual branches < 0.80% not shown
0.65% of total branching not shown

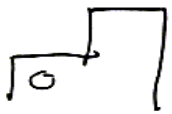
$^{132}_{50}Sn_{82}$

Pn = 7.33%
Sn = 7330

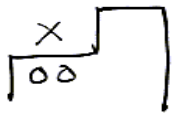
^{131}Cd



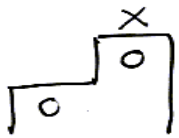
^{131}In



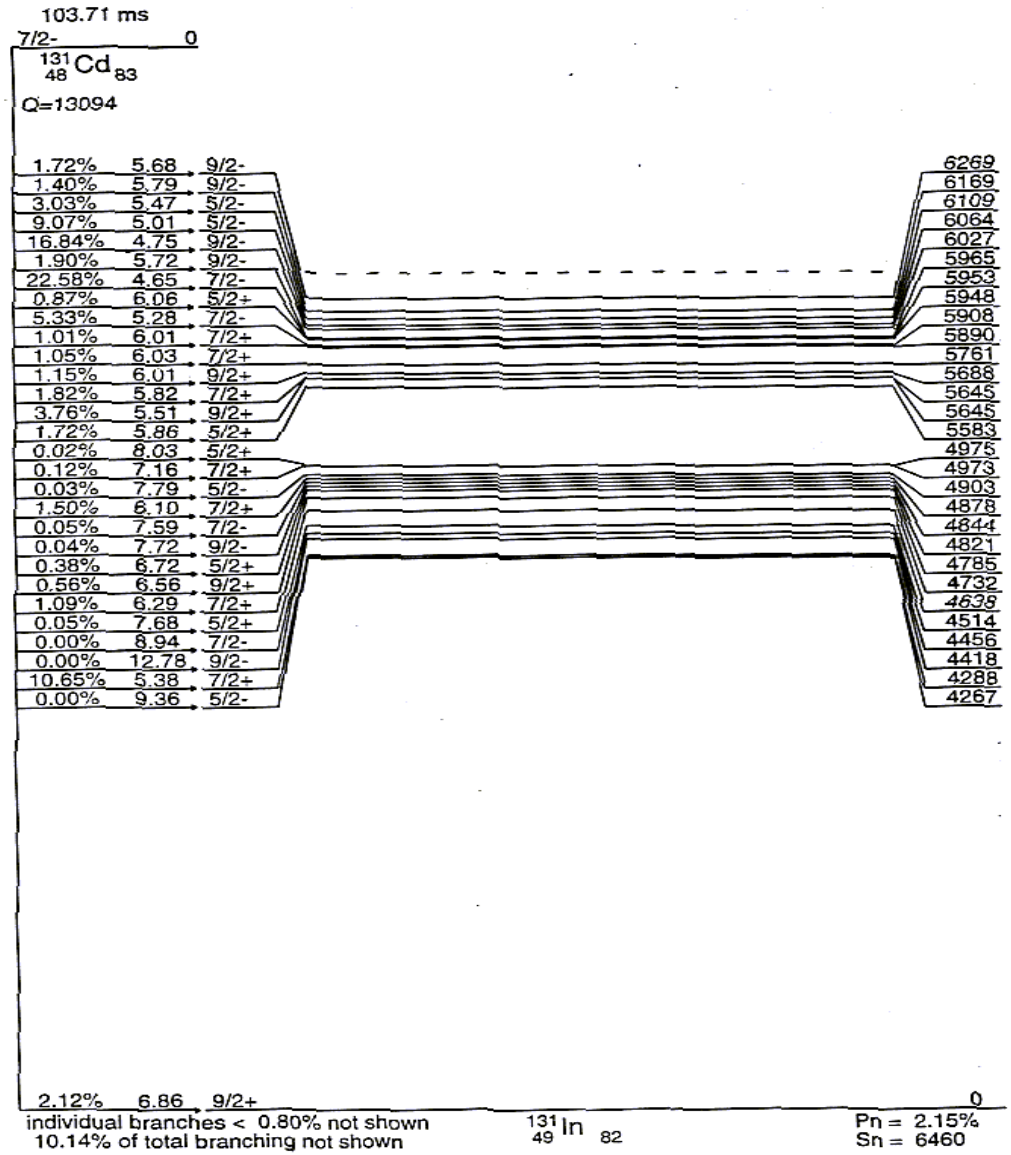
weak FF



mainly FF



mainly
$g_{7/2} \rightarrow g_{9/2}$

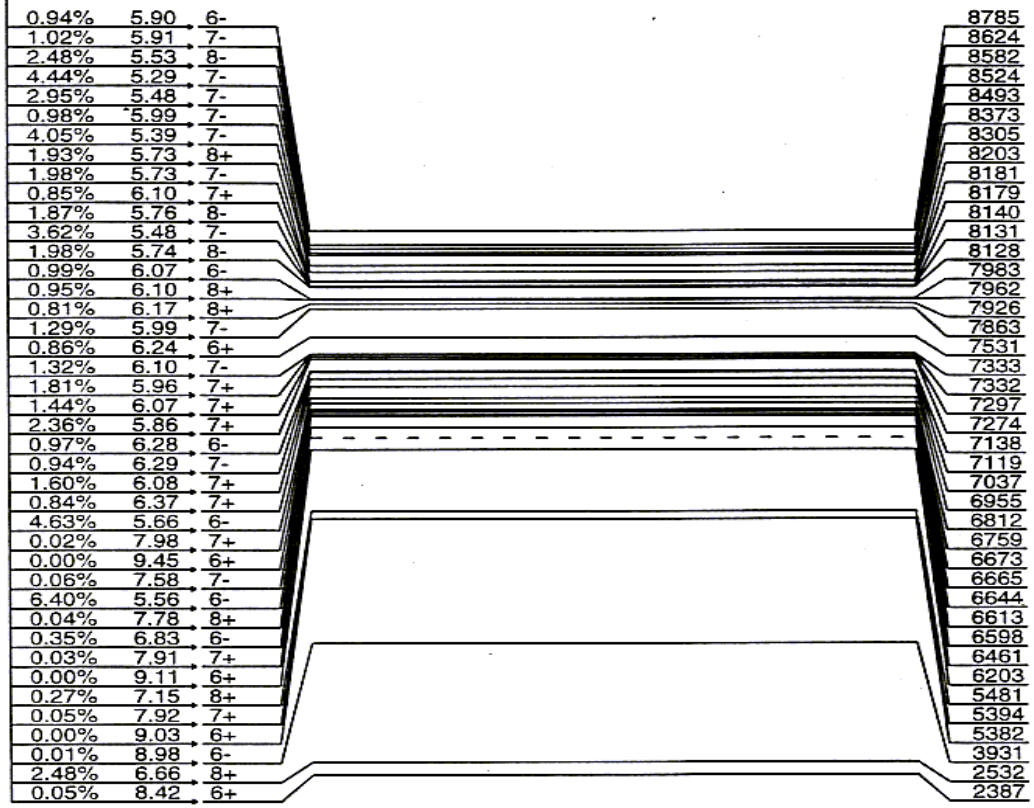

103.71 ms
7/2- 0
131 48 Cd 83
Q=13094
1.72% 5.68 9/2-
1.40% 5.79 9/2-
3.03% 5.47 5/2-
9.07% 5.01 5/2-
16.84% 4.75 9/2-
1.90% 5.72 9/2-
22.58% 4.65 7/2-
0.87% 6.06 5/2+
5.33% 5.28 7/2-
1.01% 6.01 7/2+
1.05% 6.03 7/2+
1.15% 6.01 9/2+
1.82% 5.82 7/2+
3.76% 5.51 9/2+
1.72% 5.86 5/2+
0.02% 8.03 5/2+
0.12% 7.16 7/2+
0.03% 7.79 5/2-
1.50% 6.10 7/2+
0.05% 7.59 7/2-
0.04% 7.72 9/2-
0.38% 6.72 5/2+
0.56% 6.56 9/2+
1.09% 6.29 7/2+
0.05% 7.68 5/2+
0.00% 8.94 7/2-
0.00% 12.78 9/2-
10.65% 5.38 7/2+
0.00% 9.36 5/2-
6269
6169
6109
6064
6027
5965
5953
5948
5908
5890
5761
5688
5645
5645
5583
4975
4973
4903
4878
4844
4821
4785
4732
4635
4514
4456
4418
4288
4267
2.12% 6.86 9/2+
0
individual branches < 0.80% not shown
10.14% of total branching not shown
131 49 In 82
Pn = 2.15%
Sn = 6460

62.66 ms

7- 0

$^{130}_{47}Ag_{83}$

Q=16329



0+ 0

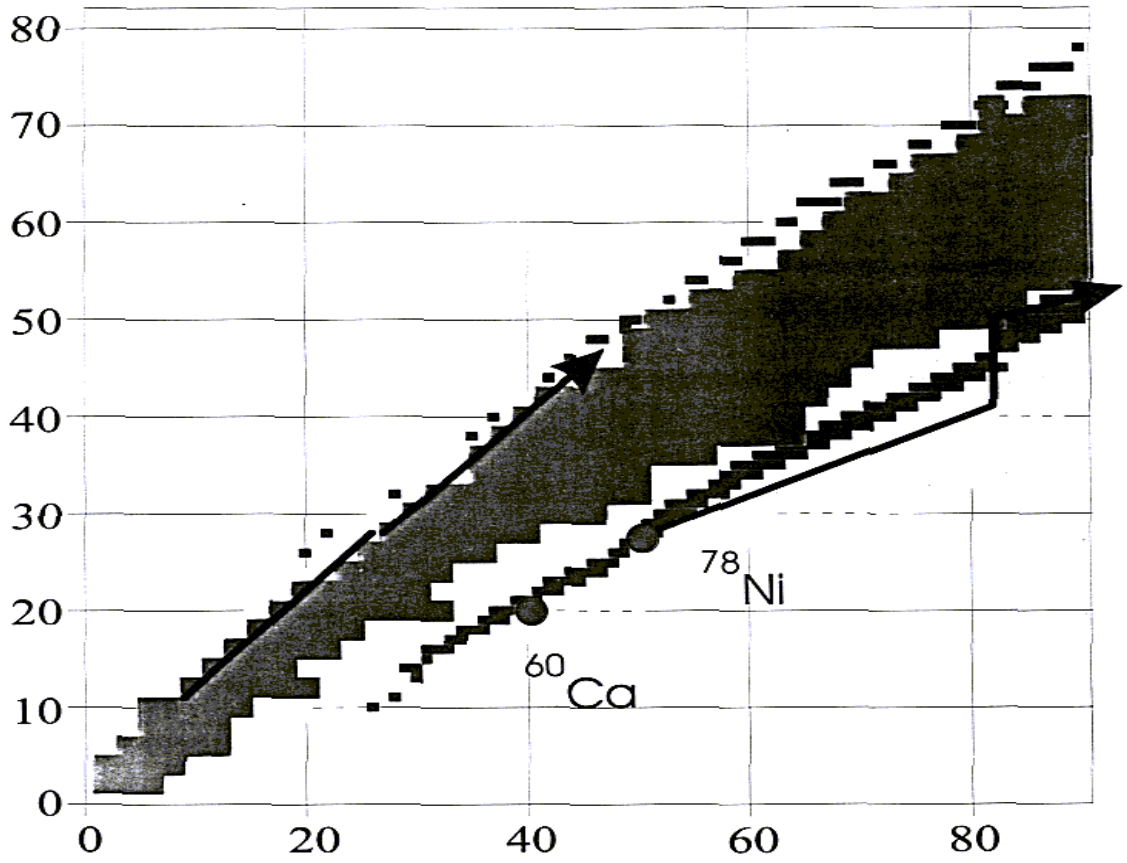
individual branches < 0.80% not shown
40.34% of total branching not shown

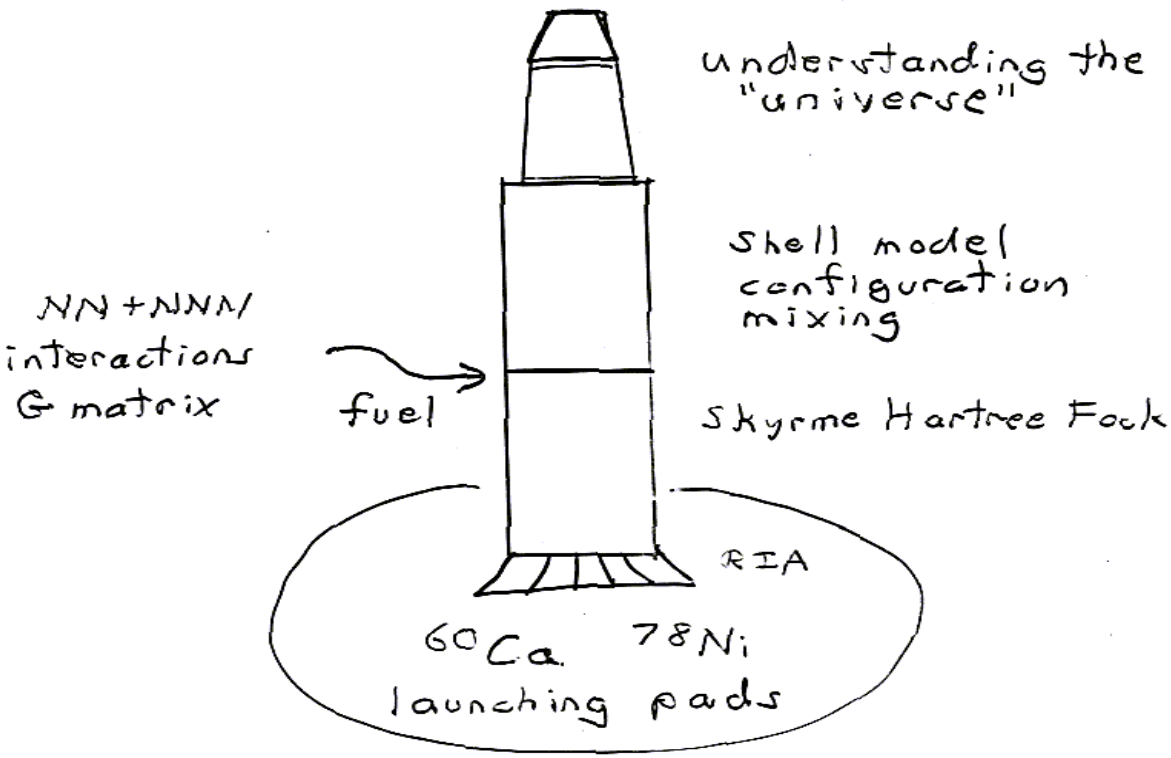
$^{130}_{48}Cd_{82}$

Pn = 97.13%
Sn = 6340

Single Particle Energies in Magic Nuclei

- the basic input to shell model configuration mixing
- relies heavily on experiment


80
70
60
50
40
30
20
10
0
0
20
40
60
80
78Ni
60Ca

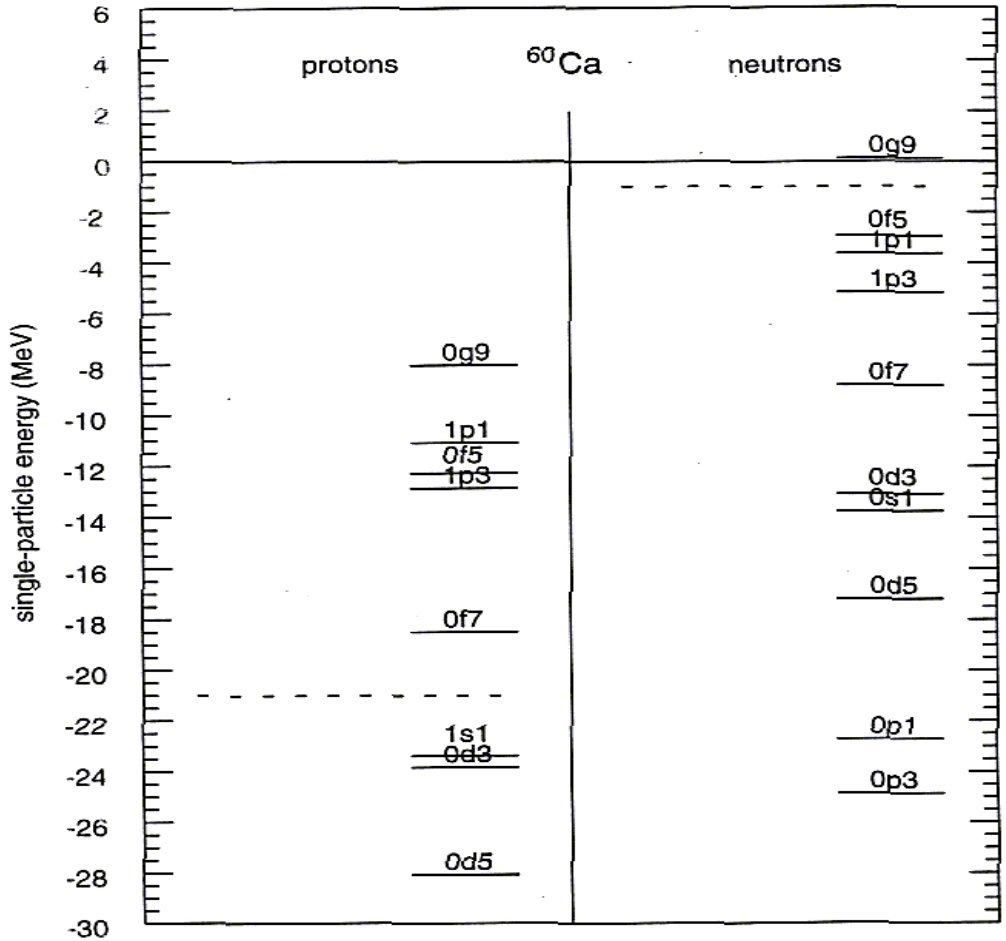

understanding the "universe"
Shell model configuration mixing
NN + NNN interactions G matrix
fuel
Skyrme Hartree Fock
RIA
60Ca 78Ni
launching pads

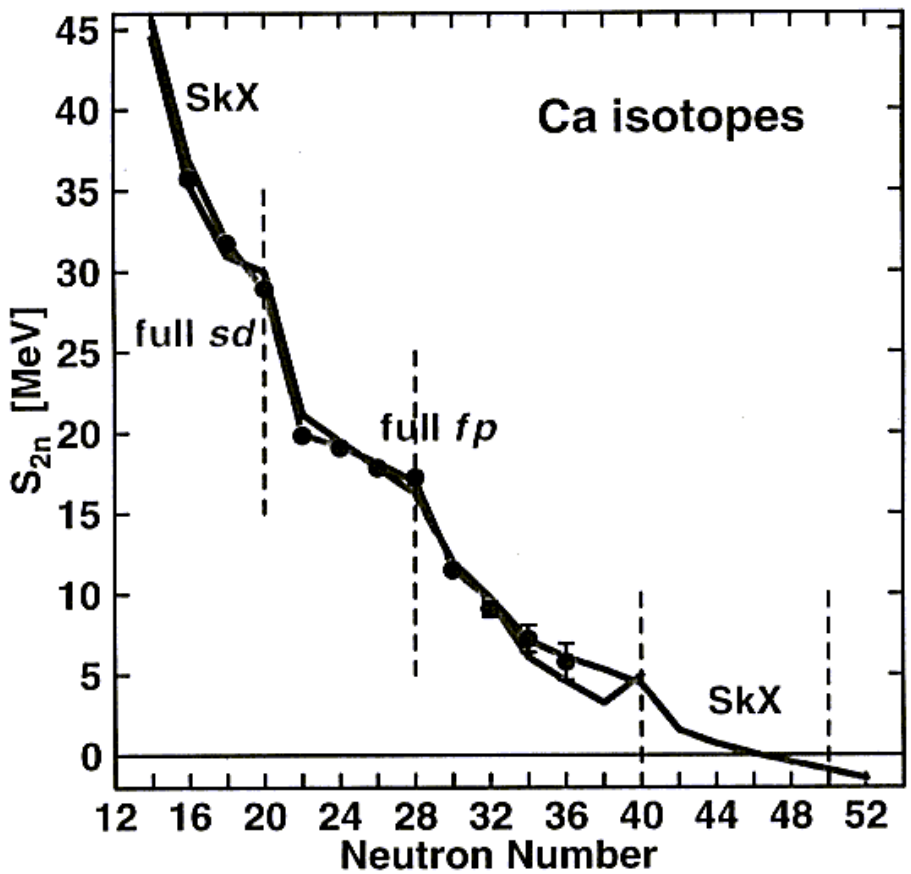
Current "best" prediction for ^{60}Ca

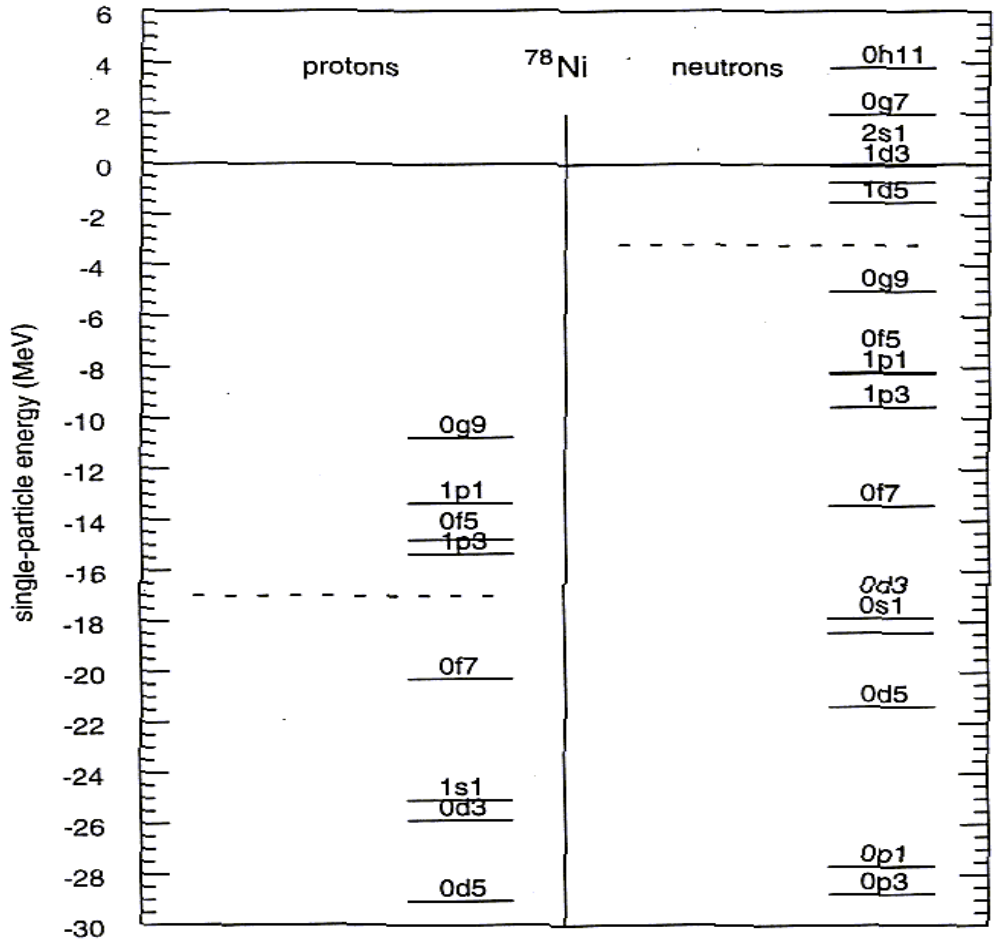
Skyrme Hartree-Fock

- global (all nuclei)
- diverse (BE, radii ---)
- minimal number of parameters ~ 8
- example of a density functional theory (Kohn-Sham for atomic physics)

SkX parameters determined partly by known single-particle energies


protons
60Ca
neutrons
single-particle energy (MeV)
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0g9
1p1
0f5
1p3
0f7
1s1
0d3
0d5
0g9
0f5
1p1
1p3
0f7
0d3
0s1
0d5
0p1
0p3


Ca isotopes
SkX
full sd
full fp
SkX
S_{2n} [MeV]
Neutron Number
45
40
35
30
25
20
15
10
5
0
12
16
20
24
28
32
36
40
44
48
52


single-particle energy (MeV)
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
protons
^{78}Ni
neutrons
0g9
1p1
0f5
1p3
0f7
1s1
0d3
0d5
0h11
0g7
2s1
1d3
1d5
0g9
0f5
1p1
1p3
0f7
0d3
0s1
0d5
0p1
0p3