質量数30-40,100領域の高スピン変形状態の研究

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Outline

重イオンビームを用いて行ってきた高スピン状態のこれまでの研究と今後の計画

- 質量数100領域の高スピン状態
  - ^{107}Inの高スピン状態の研究
- 質量数30－40領域の高スピン状態
  - ^{40}Caの高スピン状態
- 今後の研究計画
  - A～110領域の高スピン状態
  - A～30-40領域の高スピン状態

^{107}Inの高スピン状態

Collaborators

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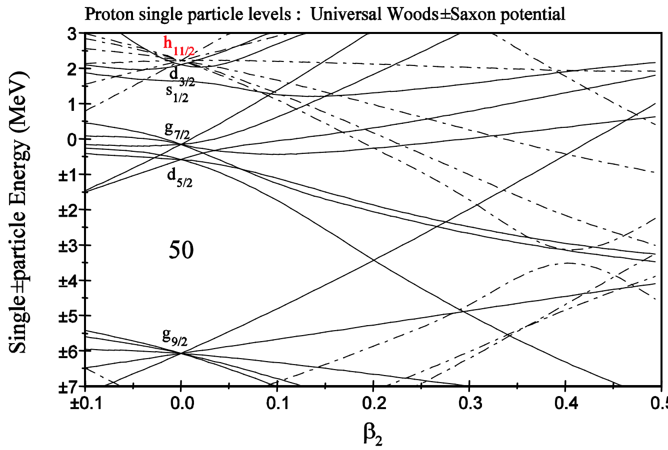
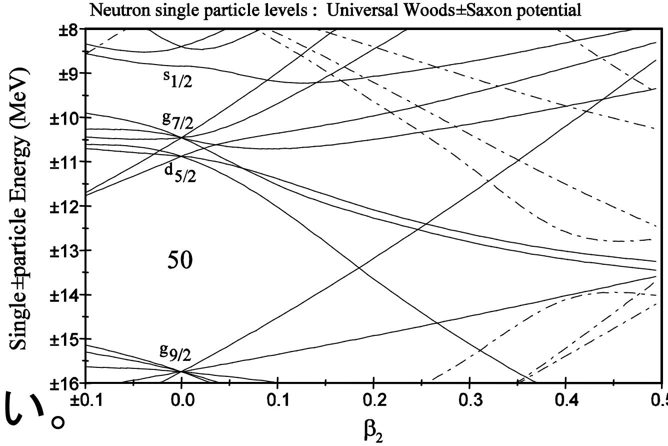
質量数～100、Z～50領域の原子核

- 基底状態近傍は単一粒子励起
- 高スピン準位
  - M1バンド $\pi g_{9/2}^{-1} \otimes \nu g_{7/2}$
  - Multi particle-hole excitation
  - Intruder バンド
    - $\pi h_{11/2}$の寄与（変形、高スピン）
    - Smooth band termination

      → ^{108}Sn, ^{109}Sb, …

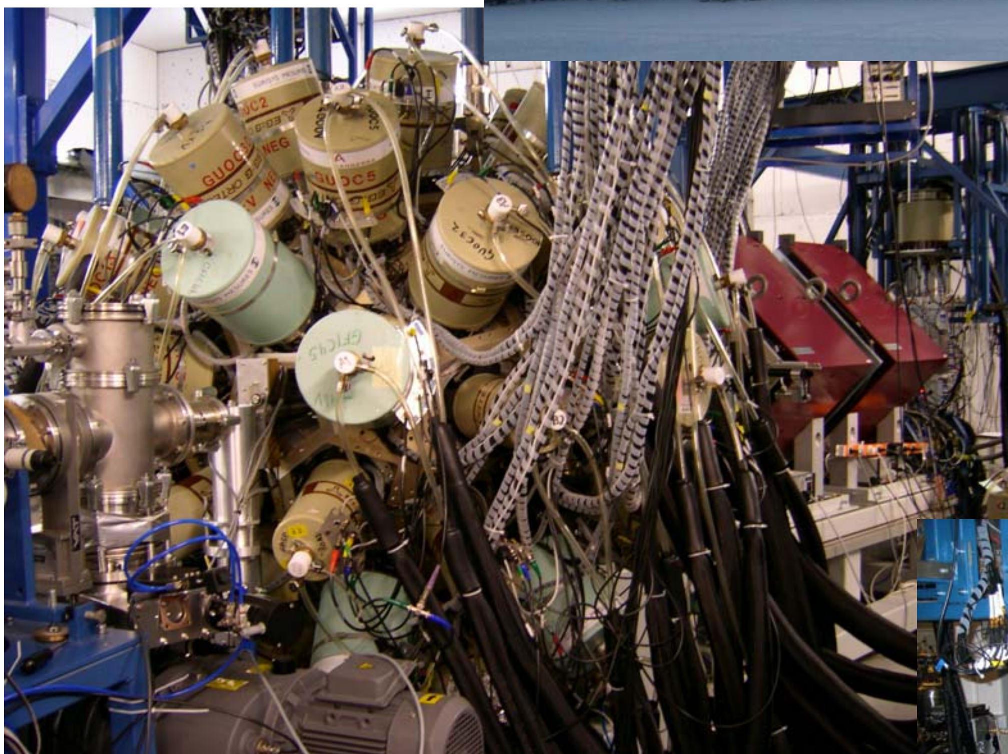




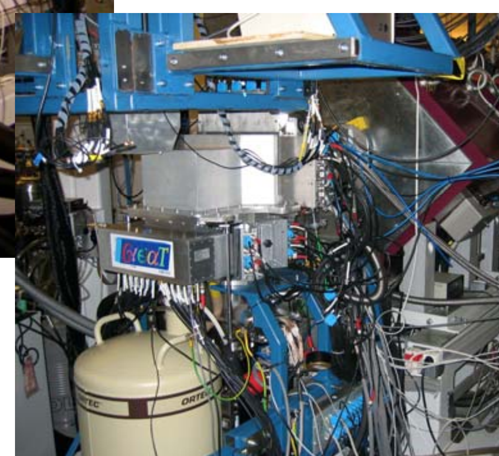
In同位体での高スピン状態はあまり良く知られていない。
Z<50核(^{107}In)で$\pi h_{11/2}$ intruder orbitalの寄与は？

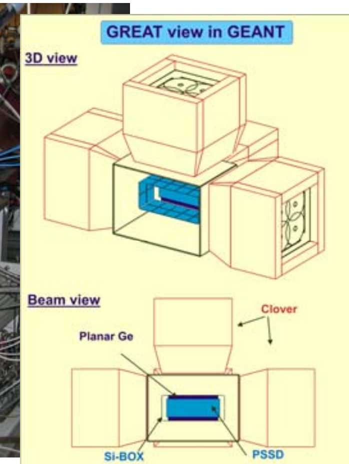
→ in-beam γ線分光による^{107}Inの高スピン状態の探索

Experimental Setup



JUROGAM
43 Ge+BGO
+ RITU
Gas filled Ion Sep.
+GREAT spectrometer

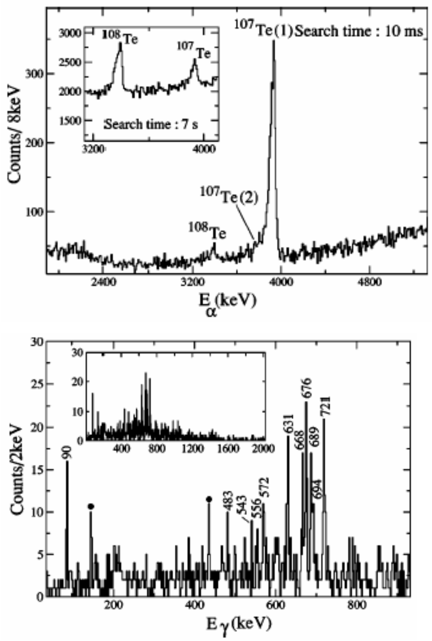




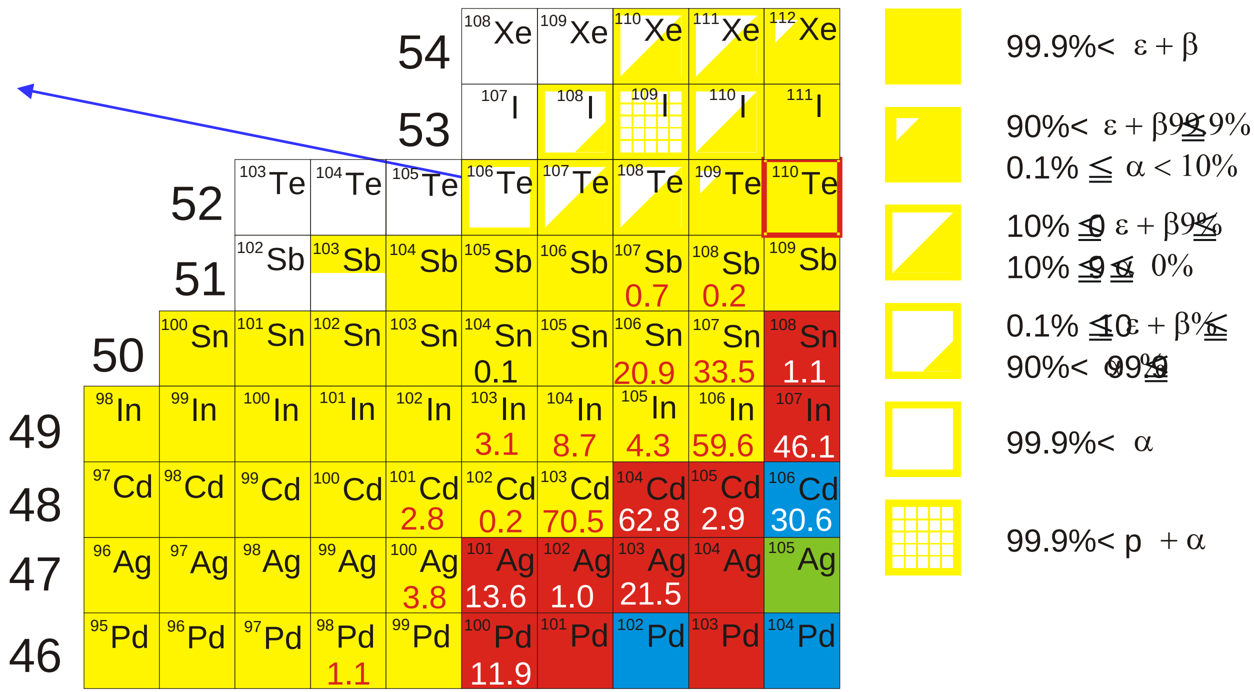
GREAT: Double sided Si strip
Si PIN photodiode array
Double sided planar Ge
Segmented Clover Ge

Study of ^{107}In (Z=49, N=58)

Reaction : ^{52}Cr(187MeV) + ^{58}Ni(580+640 μ g/cm^2)

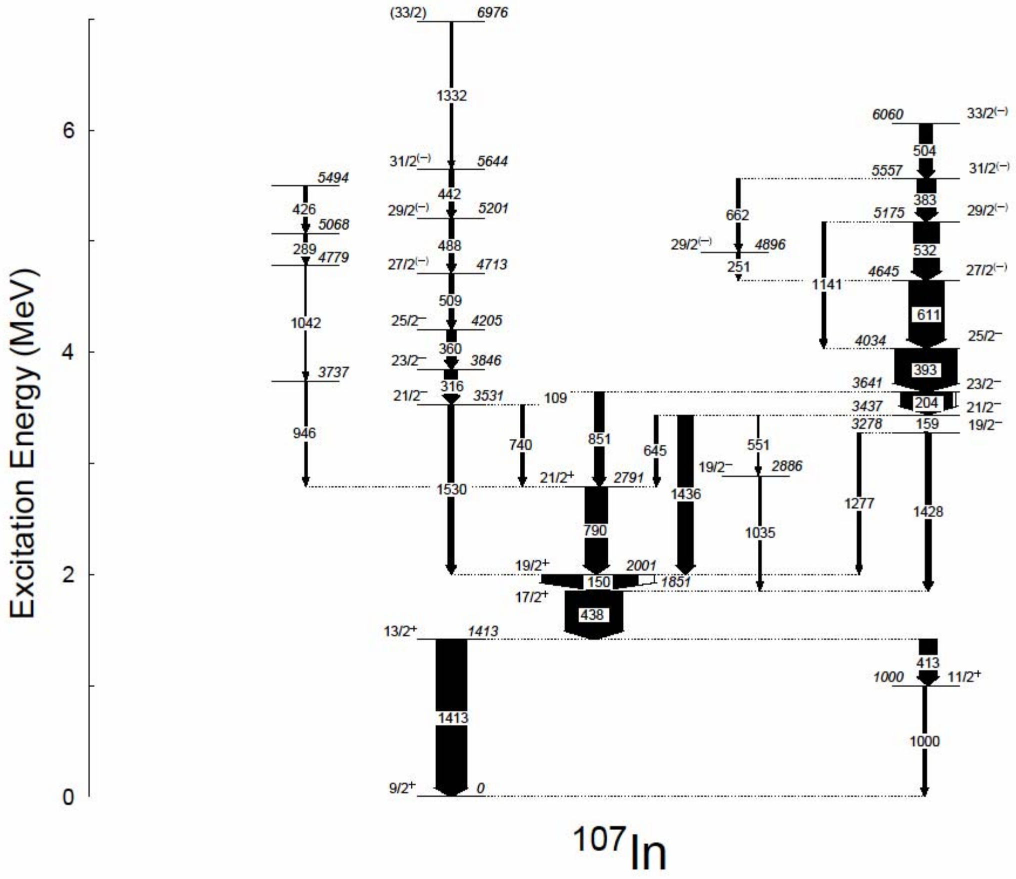


B. Hadinia et al.
PRC70, 064314(2004)



^{58}Ni(^{52}Cr, 3p)^{107}In

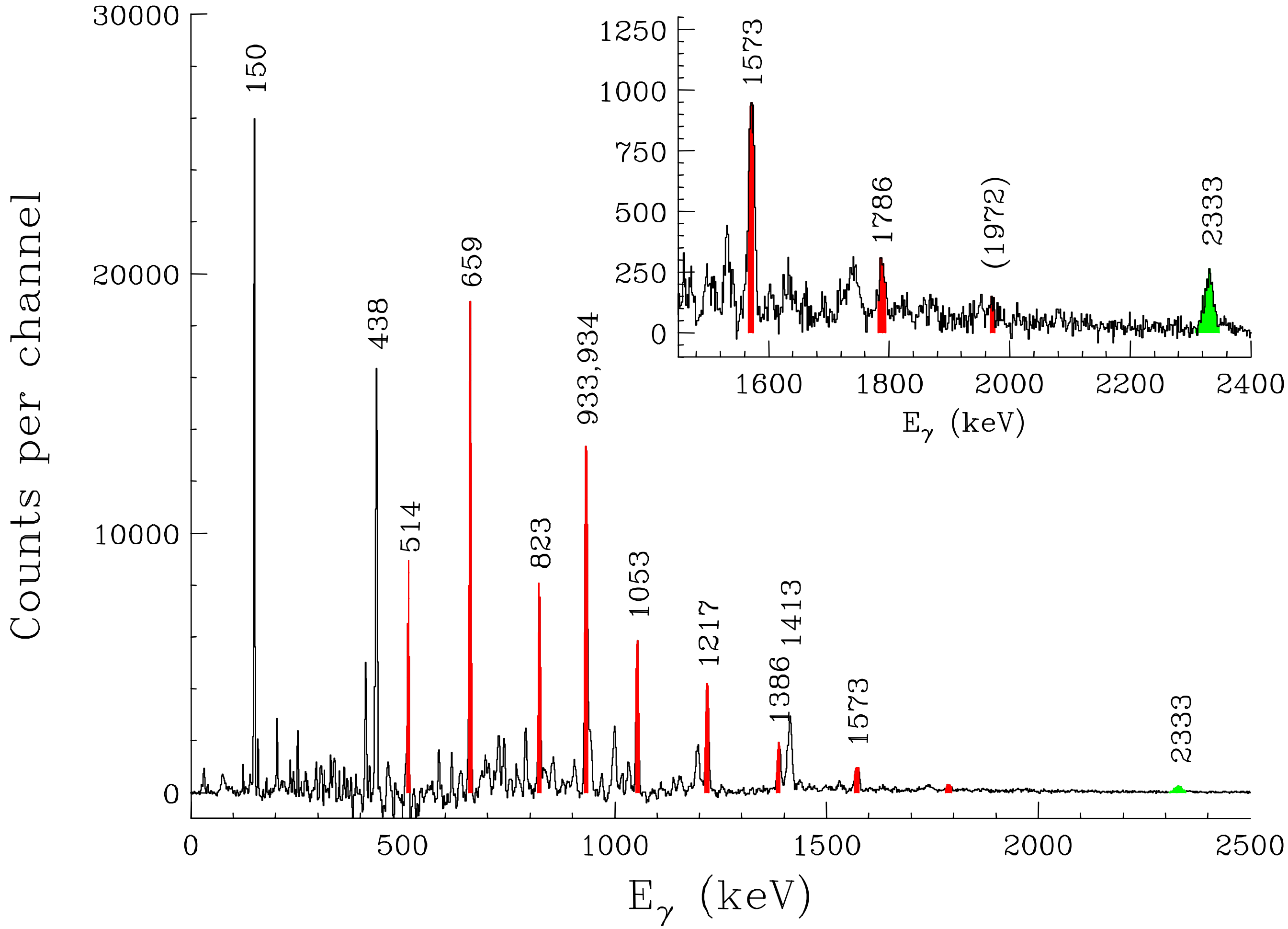
^{107}In level scheme

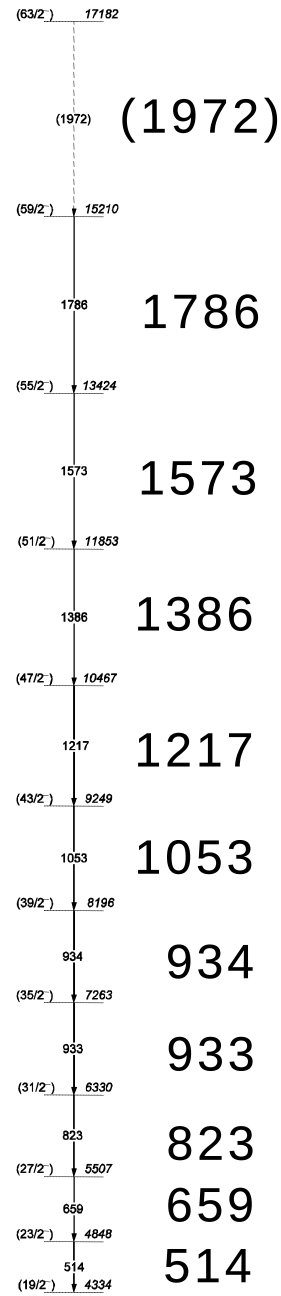


S.K. Tandel et al.
PRC58, 3738 (1998)

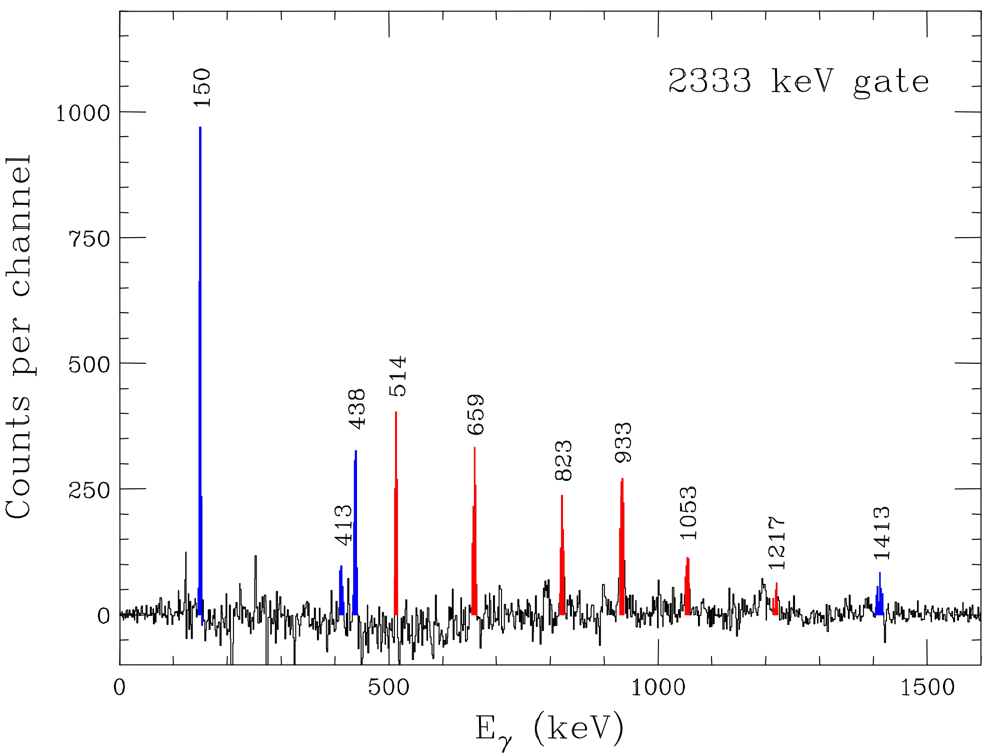
A rotational band in ^{107}In

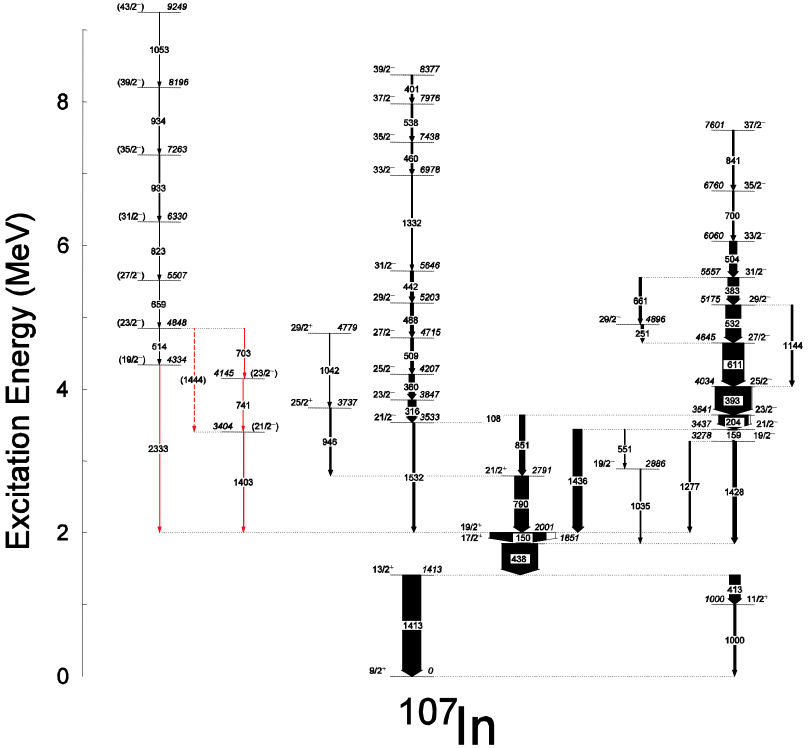
Sum of 514,823,1053,1386,1573,1786 keV gate



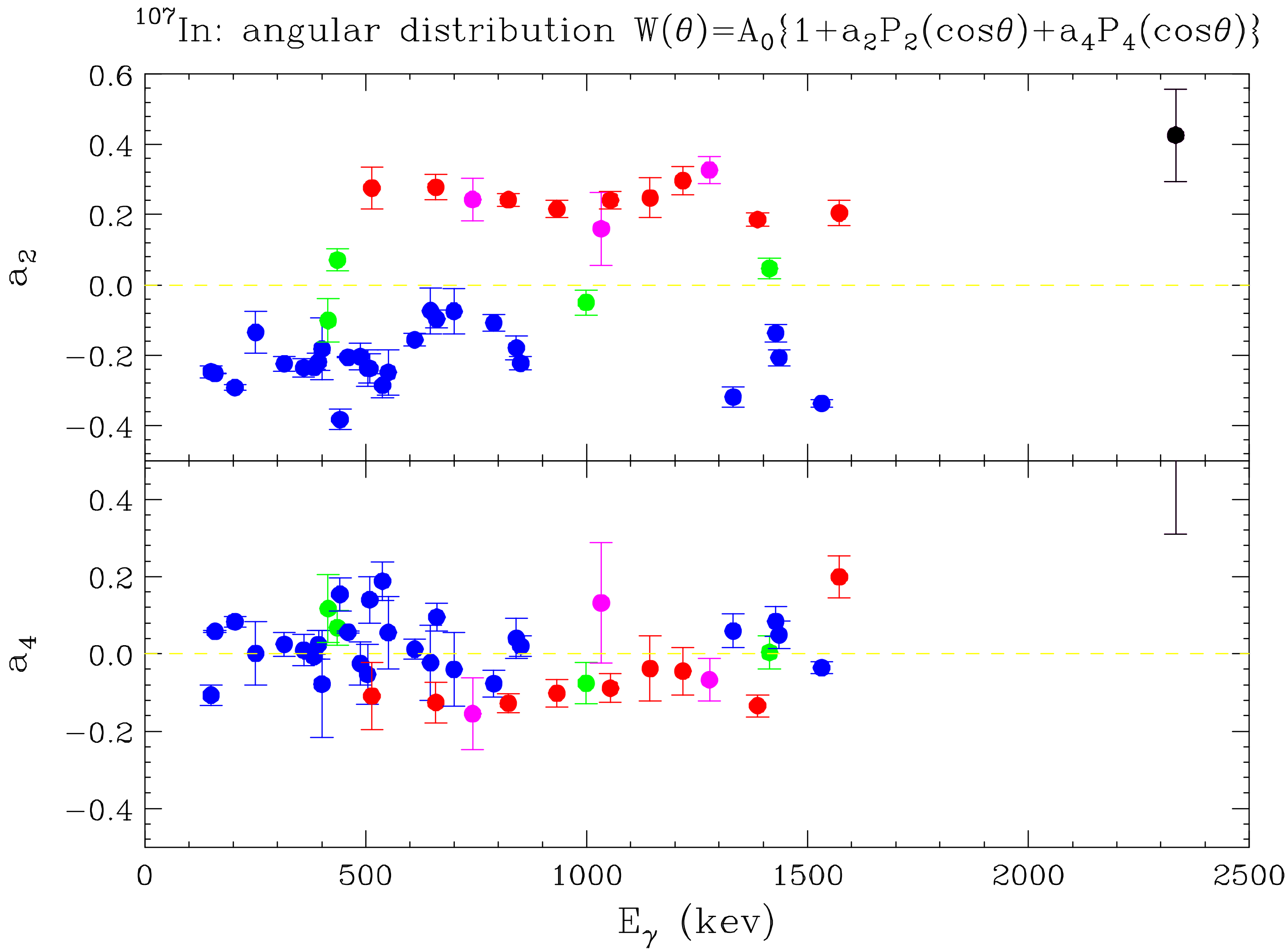


Linking transitions





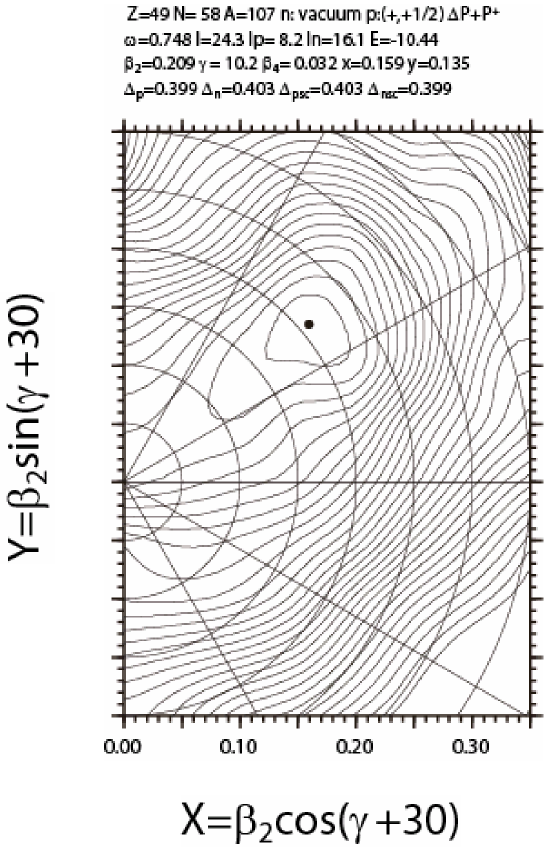
角度分布



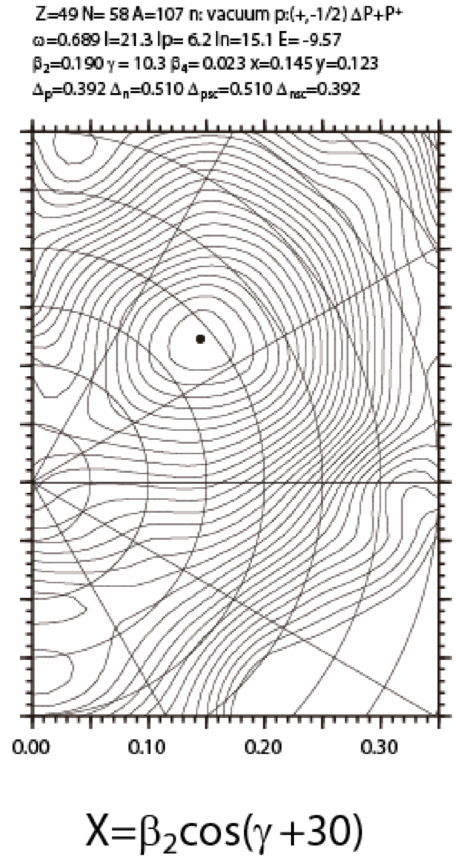
^{107}In: angular distribution $W(\theta)=A_0\{1+a_2P_2(\cos\theta)+a_4P_4(\cos\theta)\}$
0.6
0.4
0.2
0.0
−0.2
−0.4
a_2
0.4
0.2
0.0
−0.2
−0.4
a_4
0
500
1000
1500
2000
2500
E_γ (kev)

Total Routhian Surface Calculation

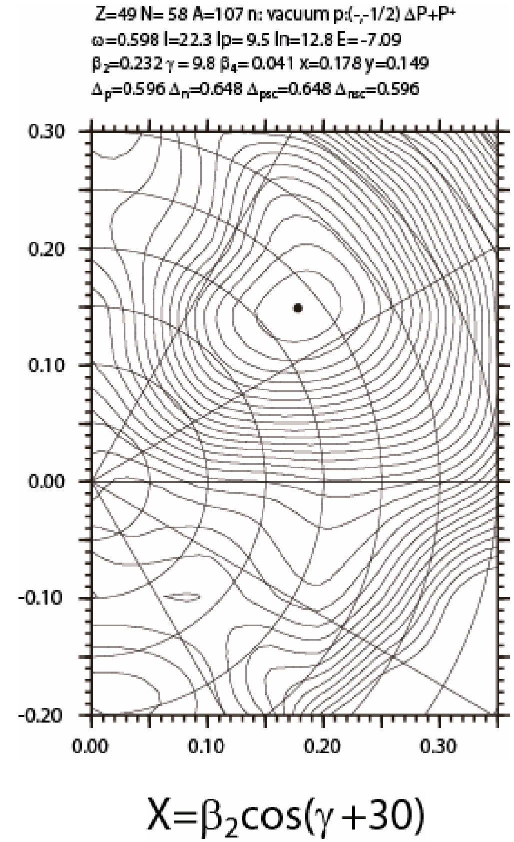
A conf. (+,+1/2)



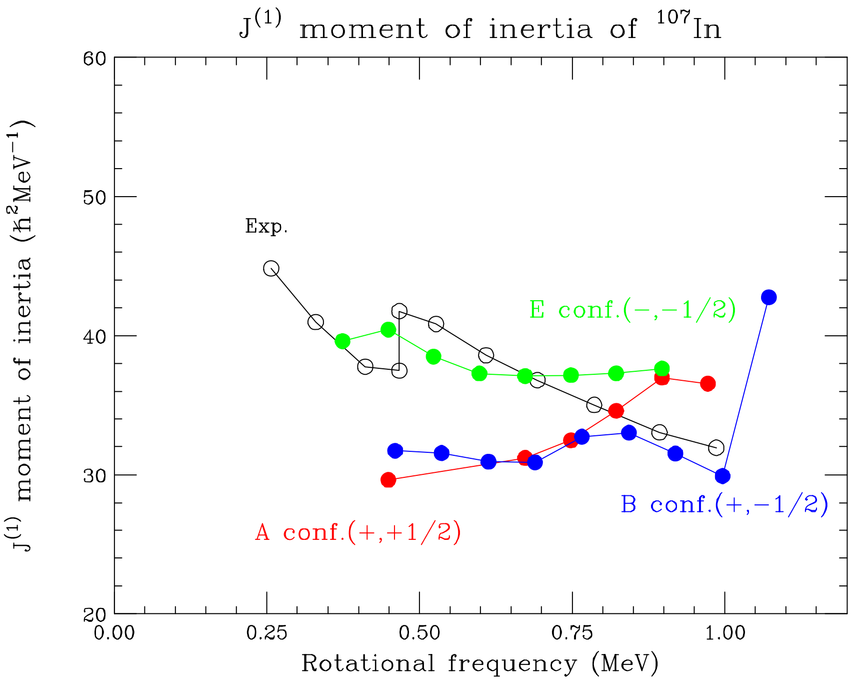
B conf.(+,-1/2)

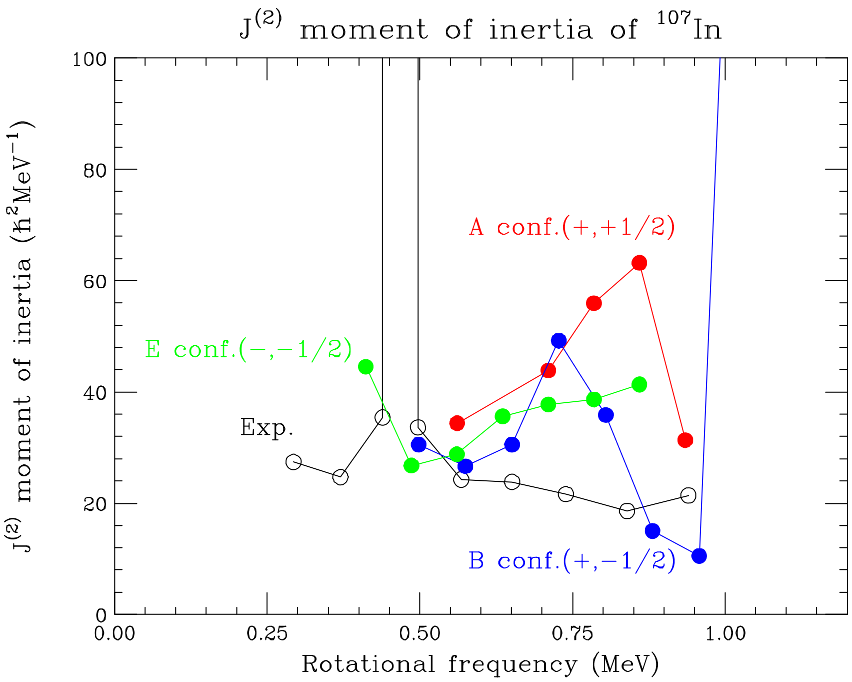


E conf.(-,-1/2)



$J^{(1)}$,$J^{(2)}$ moment of inertia Exp. and TRS calc.





Kinematical

$$J^{(1)} = \left[\frac{2}{\hbar^2} \frac{dE(I)}{d(I^2)} \right]^{-1} = \hbar \frac{I}{\omega}$$

Dynamical

$$J^{(2)} = \left[\frac{1}{\hbar^2} \frac{d^2E(I)}{dI^2} \right]^{-1} = \hbar \frac{dI}{d\omega}$$

^{40}Caの高スピン状態

Collaborators

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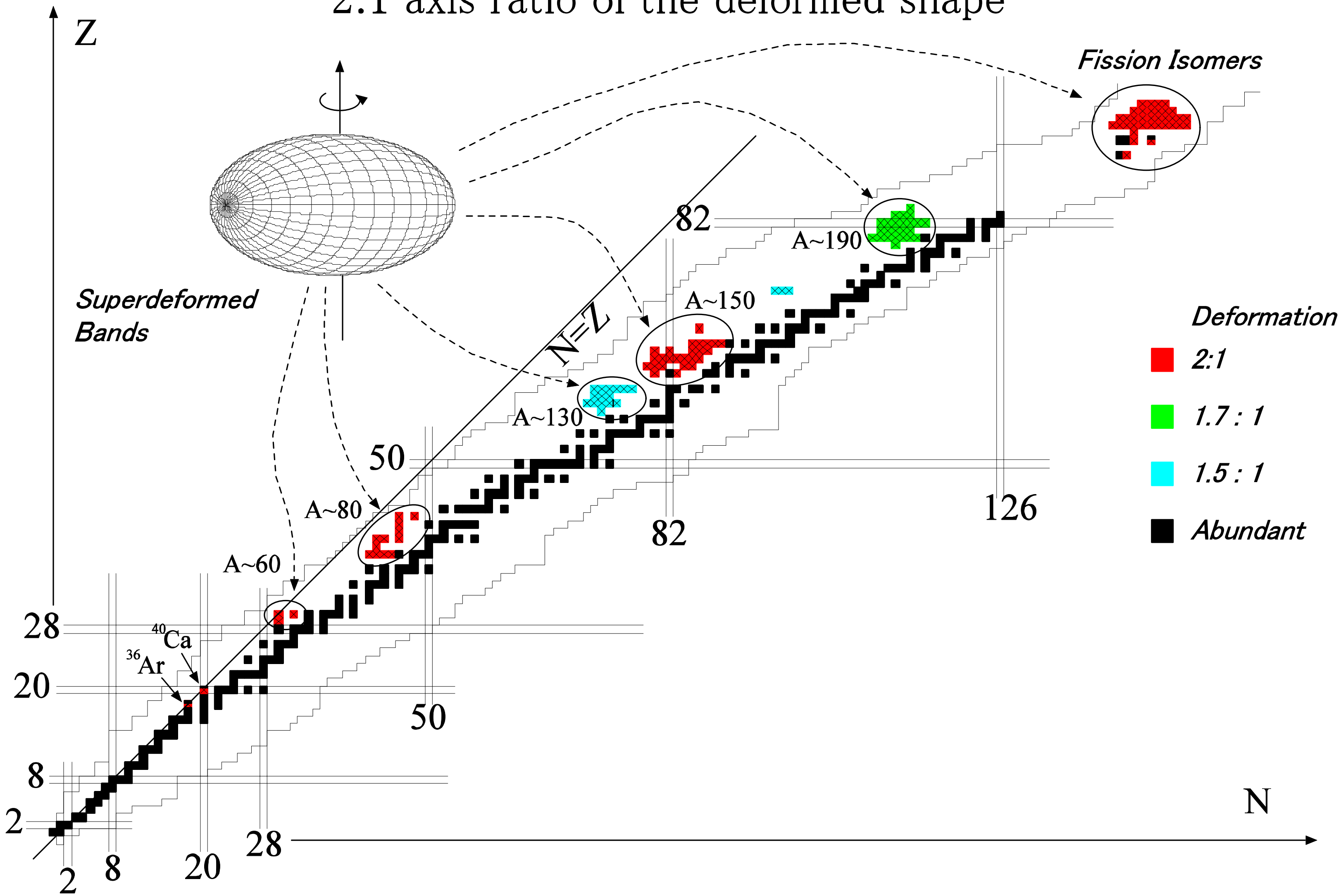
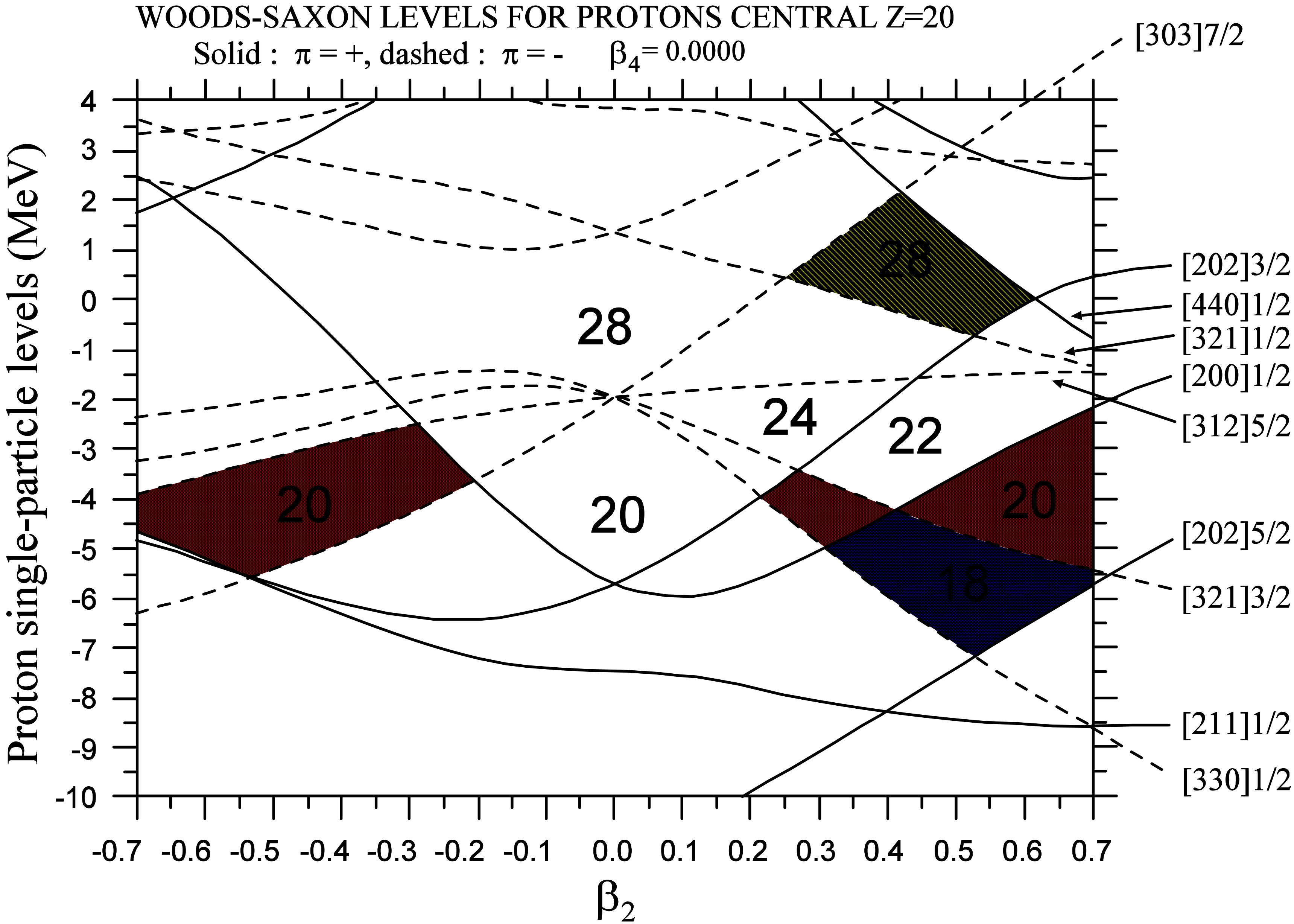
Superdeformation

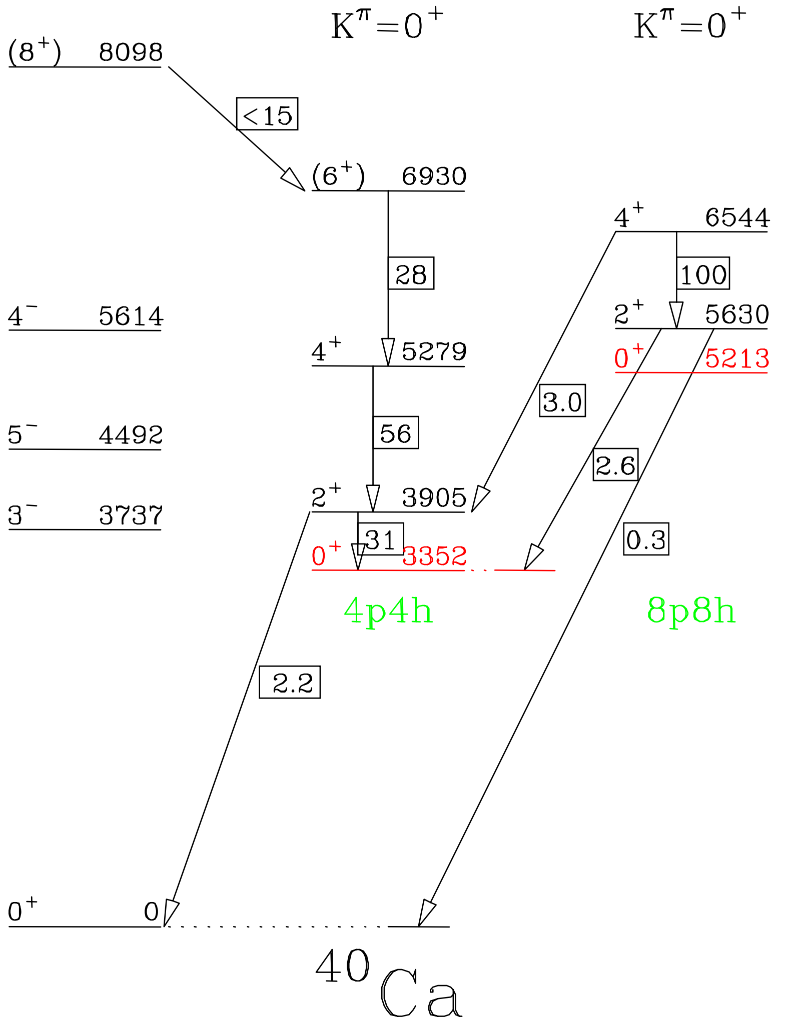
2:1 axis ratio of the deformed shape



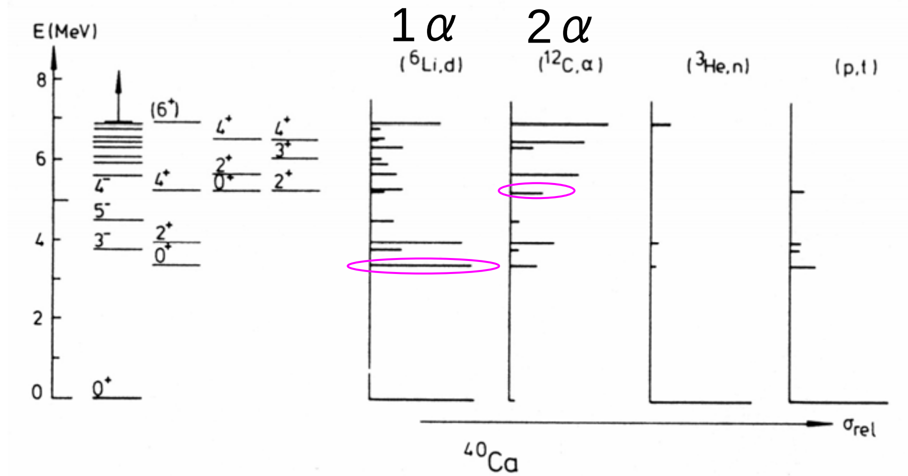


WOODS-SAXON LEVELS FOR PROTONS CENTRAL Z=20
Solid : π = +, dashed : π = -   β4= 0.0000
Proton single-particle levels (MeV)
β2
28
28
24
22
20
20
20
18
[303]7/2
[202]3/2
[440]1/2
[321]1/2
[200]1/2
[312]5/2
[202]5/2
[321]3/2
[211]1/2
[330]1/2

High-spin states in ^{40}Ca



J.L. Wood et al, Phys. Rep. 215 (1992)101



Percentage of wave-functions in ^{40}Ca

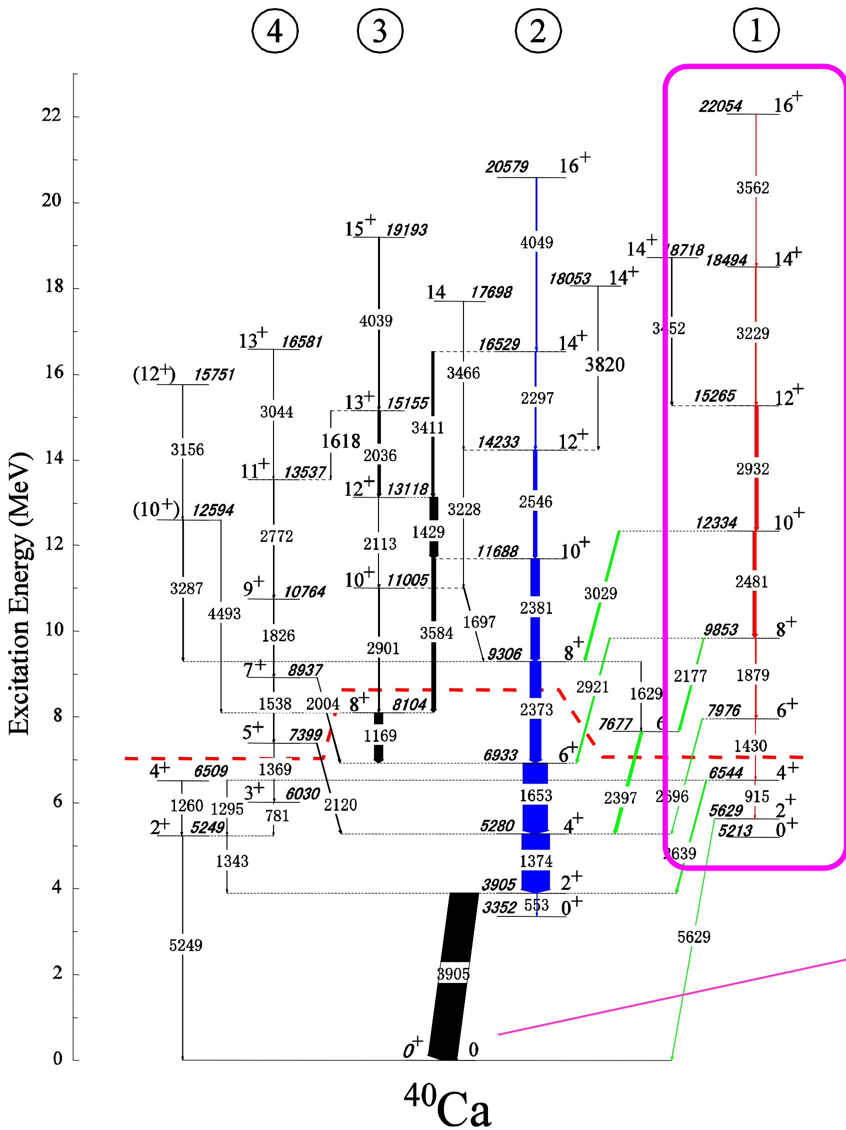
W.J.Gerace and A.M.Green, NPA123, 241 (1969).

State	E(exp)	0p-0h	2p-2h	4p-4h	6p-6h	8p-8h
0_1^+	0	82.81	16.81	1.0	0.04	0.0
0_2^+	3.35	2.89	2.25	68.89	20.25	6.76
0_3^+	5.21	1.0	2.25	16.81	12.25	67.24

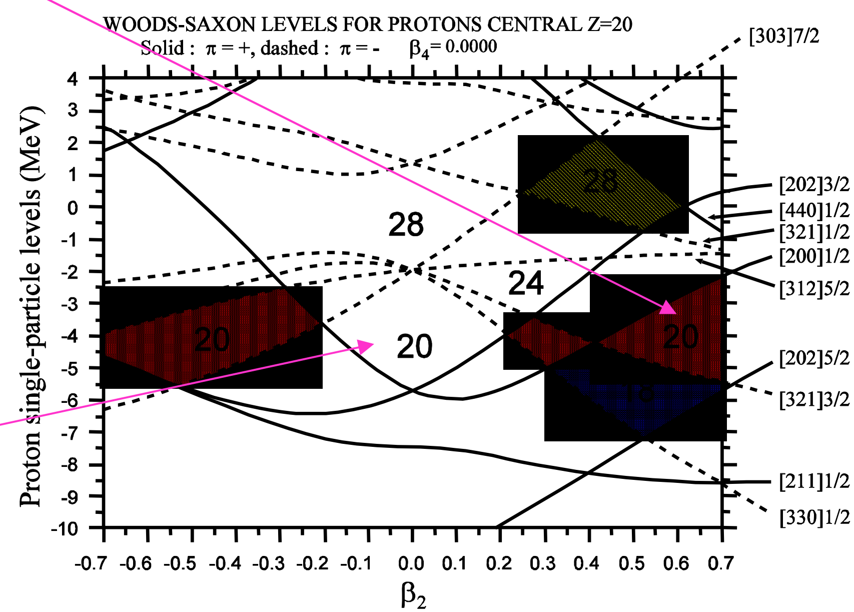
Shell Model by M.Sakakura, A.Arima, T.Sebe, PL61B, 335(1976).

State	E(exp)	0p-0h	2p-2h	4p-4h	6p-6h	8p-8h
0_1^+	0	46.46	35.04	14.48	3.56	0.46
0_2^+	3.35	25.71	2.24	34.17	29.93	7.95
0_3^+	5.21	15.07	20.49	48.69	12.27	3.49

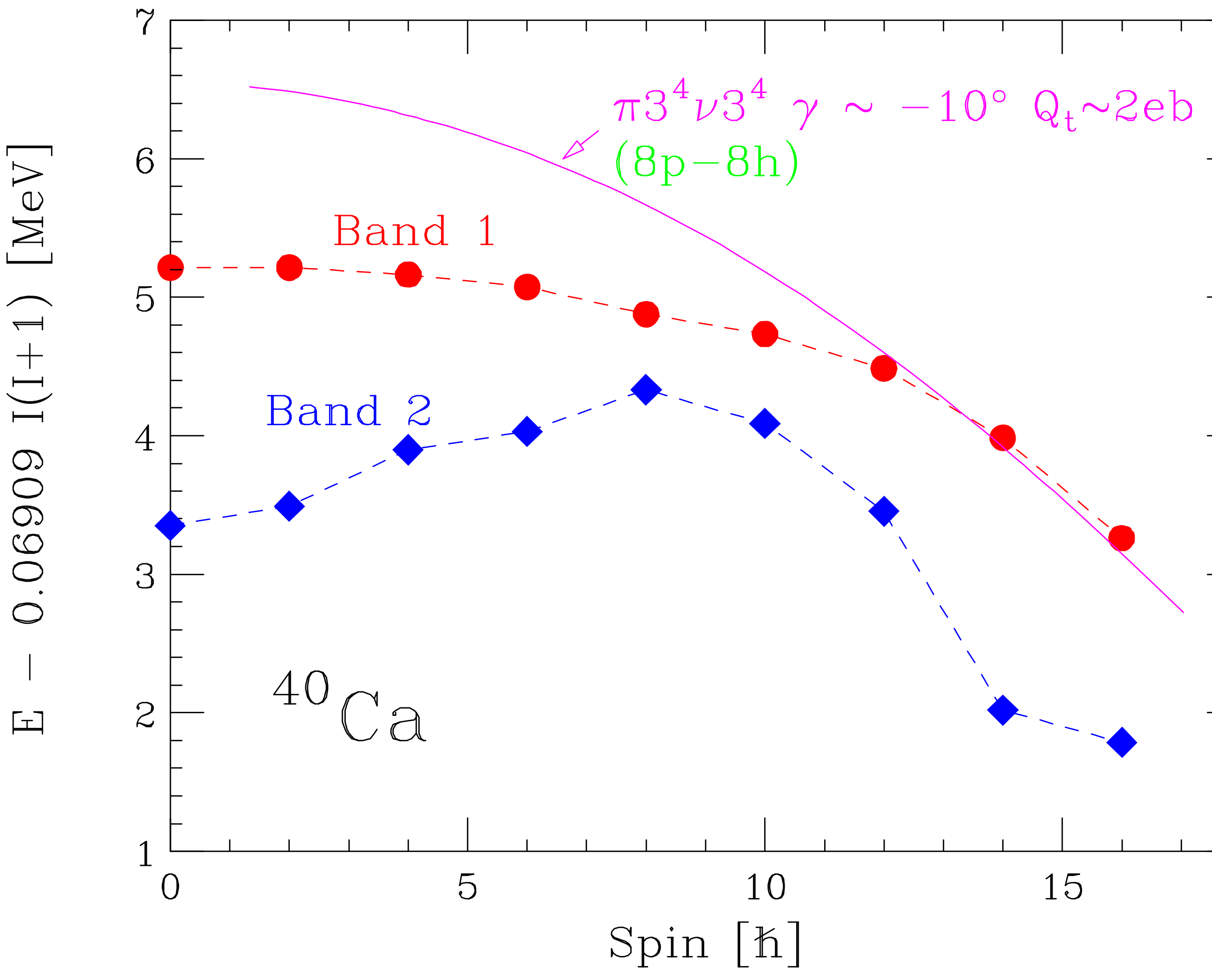
SD band in ^{40}Ca



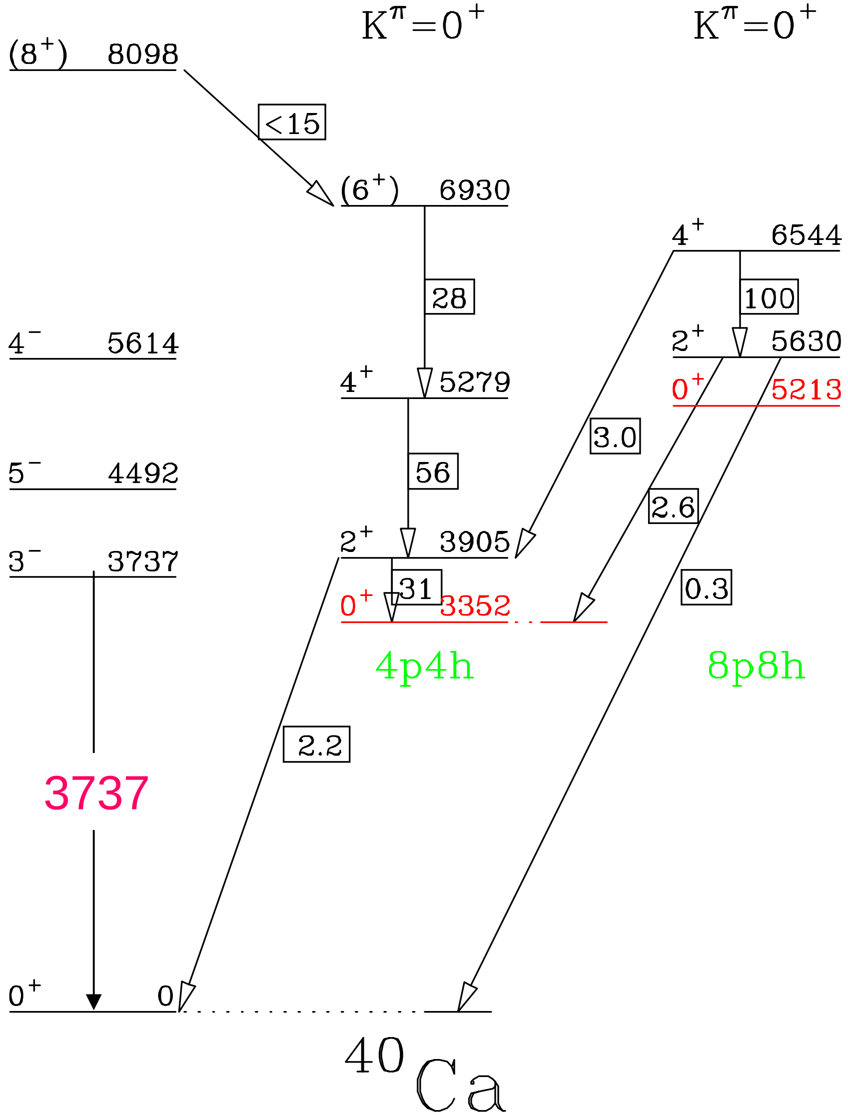
^{20}Ne + ^{28}Si → 2α + ^{40}Ca
ATLAS accelerator at ANL
Beam: ^{20}Ne 84MeV (80MeV after Ta foil)
Target: 0.45 mg/cm^2 ^{28}Si on 1mg/cm^2 Ta
Gammasphere (101Ge)
+ Microball (95 CsI(Tl))
ε (p)=60%, ε (α)=47%



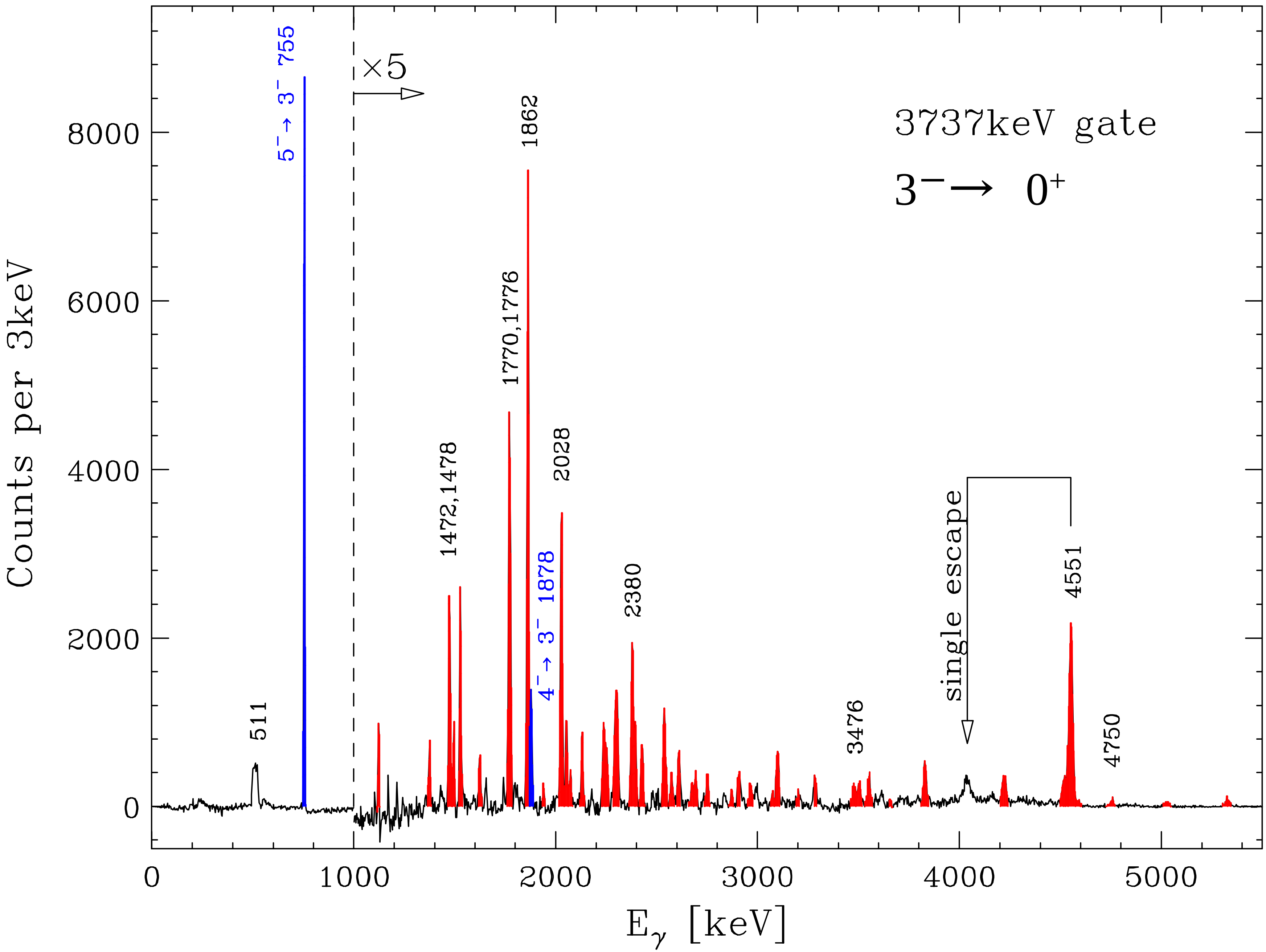
Cranked Relativistic Mean-Field Calculation



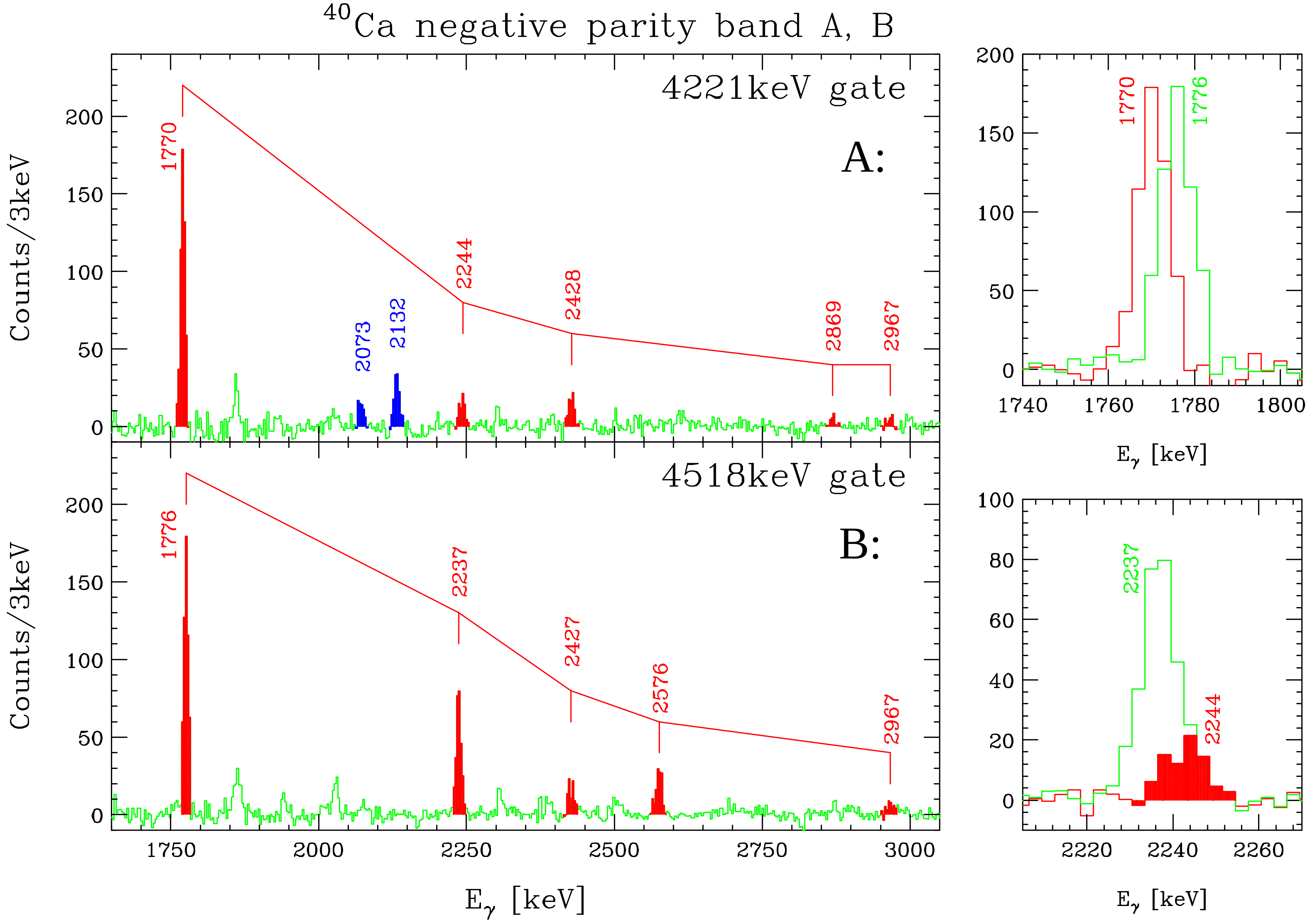
known excited states of ^{40}Ca



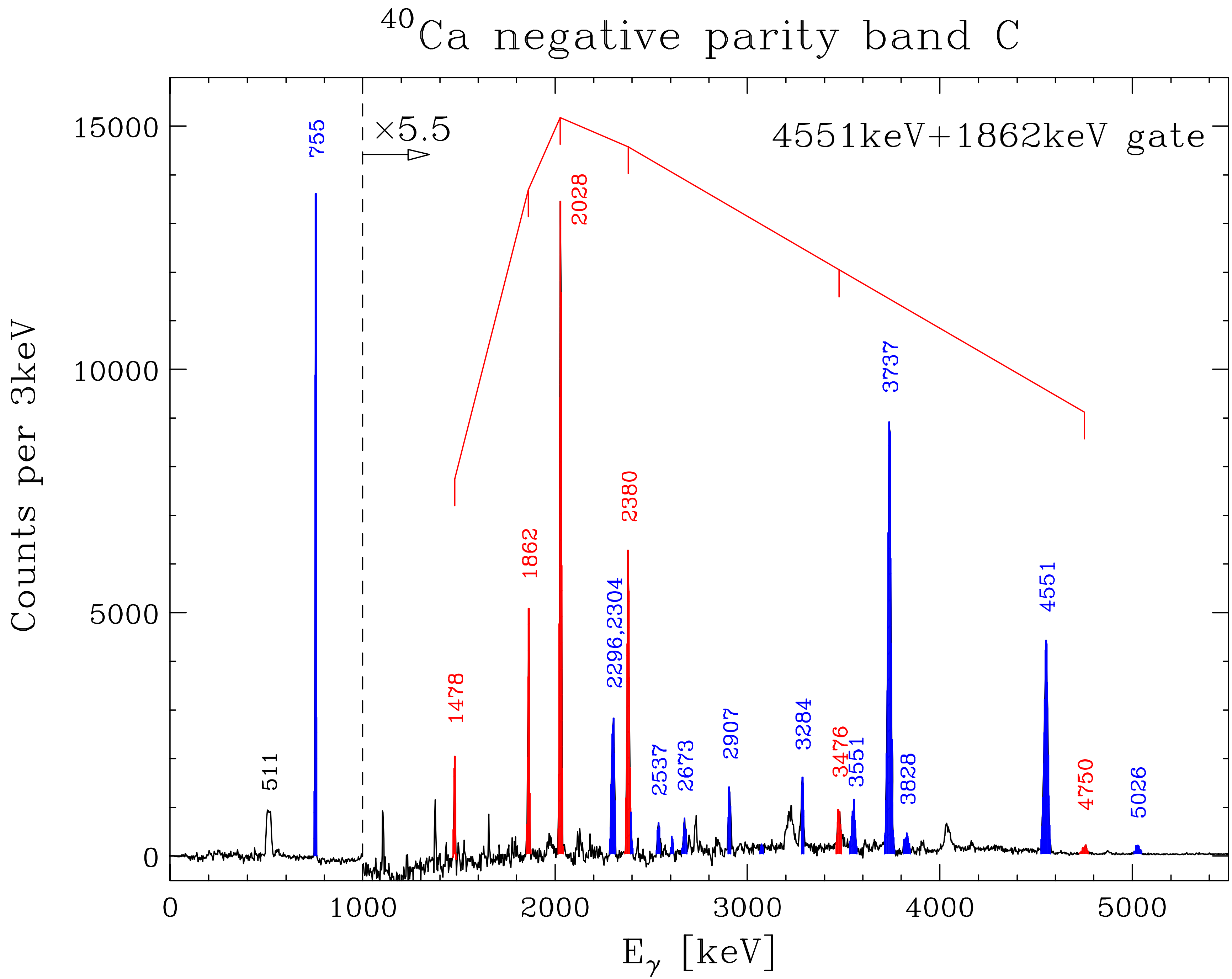
J.L.Wood et al., Phy.Rep.215(1992)101



3737keV gate
3⁻→ 0⁺
×5
5⁻ → 3⁻ 755
1862
1770,1776
1472,1478
2028
4⁻ → 3⁻ 1878
2380
511
3476
single escape
4551
4750
Counts per 3keV
Eγ [keV]
0
2000
4000
6000
8000
0
1000
2000
3000
4000
5000



^{40}Ca negative parity band A, B
4221keV gate
A:
1770
2073
2132
2244
2428
2869
2967
4518keV gate
B:
1776
2237
2427
2576
2967
Counts/3keV
Counts/3keV
E_γ [keV]
1770
1776
E_γ [keV]
2237
2244
E_γ [keV]



^{40}Ca negative parity band C
4551keV+1862keV gate
×5.5
Counts per 3keV
E_γ [keV]
15000
10000
5000
0
1000
2000
3000
4000
5000
511
755
1478
1862
2028
2296,2304
2380
2537
2673
2907
3284
3476
3551
3737
3828
4551
4750
5026

Cranked Relativistic Mean Field Calculation (preliminary results)

- Negative parity band :

$\rightarrow$ odd number of particle in $f_{7/2}$ orbital

- Signature $\alpha = 0$ band (A, B)

[200]1/2 $\alpha = -1/2 \rightarrow$ [321]3/2 $\alpha = -1/2$: conf.1

[200]1/2 $\alpha = +1/2 \rightarrow$ [321]3/2 $\alpha = +1/2$: conf.2

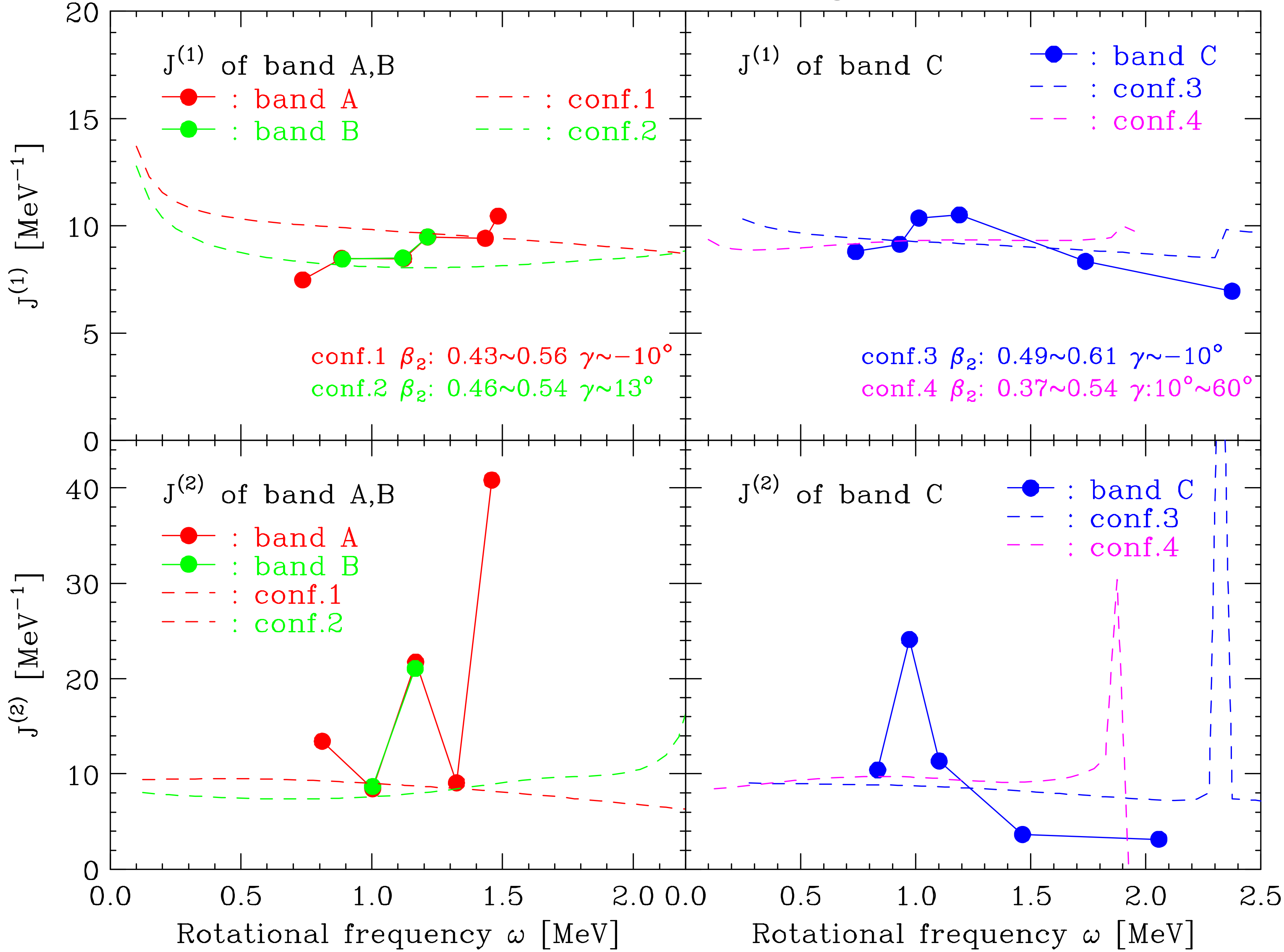
- Signature $\alpha = 1$ band (C)

[200]1/2 $\alpha = -1/2 \rightarrow$ [321]3/2 $\alpha = +1/2$: conf. 3

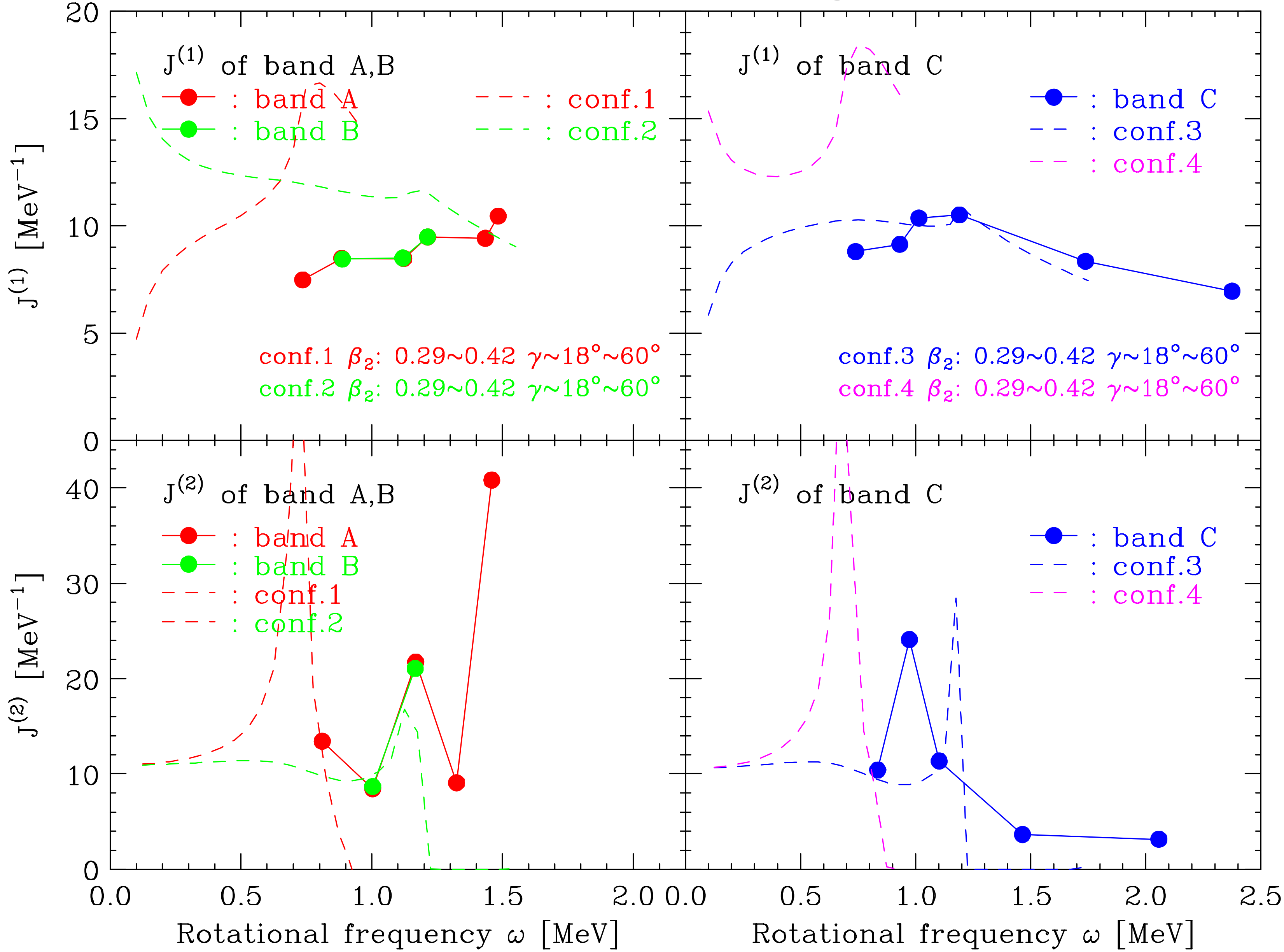
[200]1/2 $\alpha = +1/2 \rightarrow$ [321]3/2 $\alpha = -1/2$: conf. 4

- $\pi\, 3^3\, \upsilon\, 3^2,\ \pi\, 3^3\, \upsilon\, 3^4$

CRMF: $\pi 3^3 \upsilon 3^4$ configuration



CRMF: $\pi\, 3^3\, \upsilon\, 3^2$ configuration



- Level scheme of ^{40}Ca is extended to 17^- at 23.5MeV
- Three negative parity bands in ^{40}Ca
- Angular distribution → Spin assignments
- Residual Doppler shift analysis

→ Qt(band A) = 0.90 ± 0.17eb, $\beta_2 = 0.32 \pm 0.06$

Qt(band C) = 0.53 ± 0.13eb, $\beta_2 = 0.20 \pm 0.05$

- Cranked Relativistic Mean Field calculation in progress
- $\pi 3^3 \nu 3^2$, $\pi 3^3 \nu 3^4$ configurations

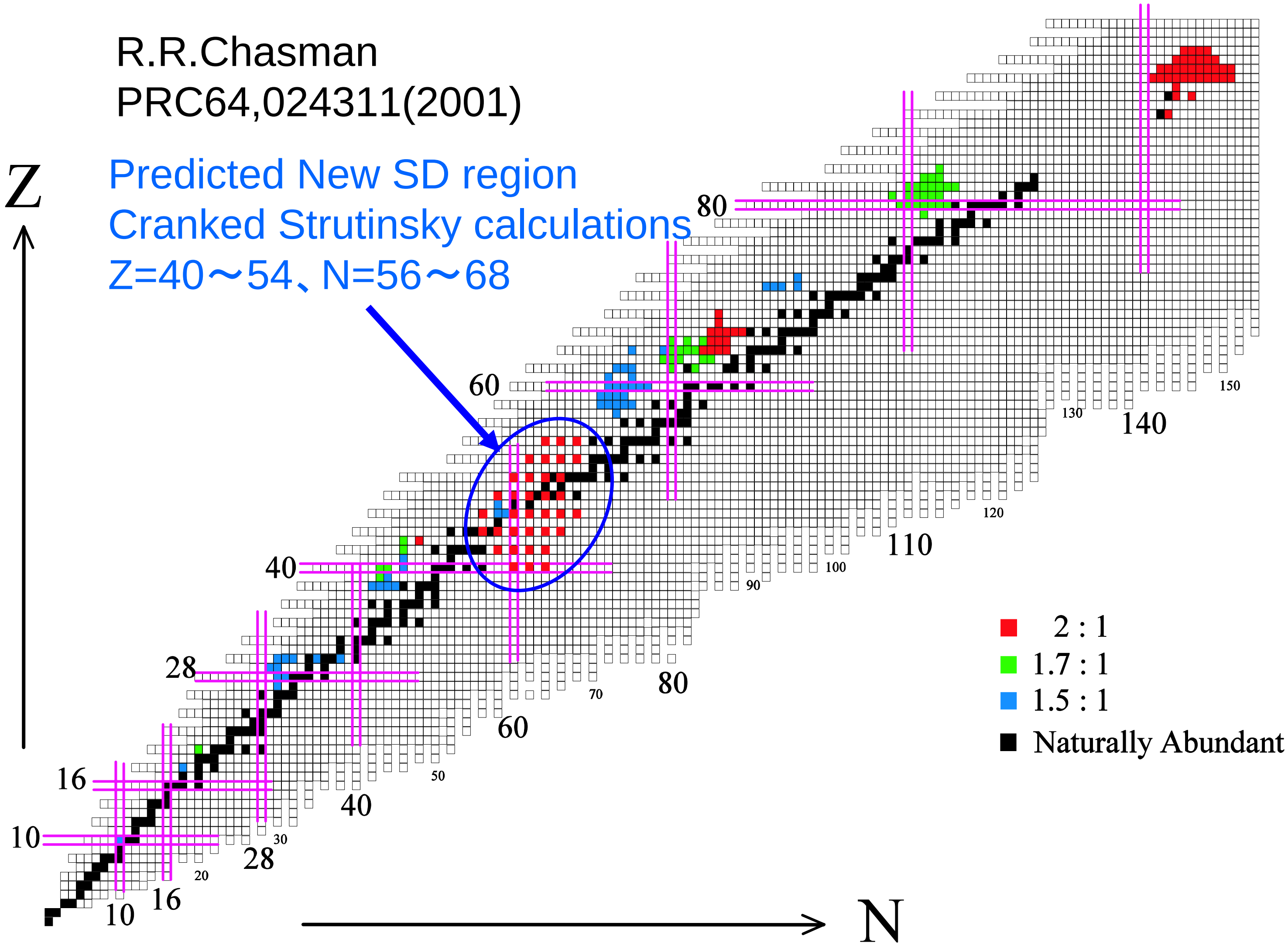
今後の研究計画

- A～110領域の高スピン状態
  - 高スピンの極限
  - 変形の極限
- A～30-40領域の高スピン状態
  - 未開拓のSD領域

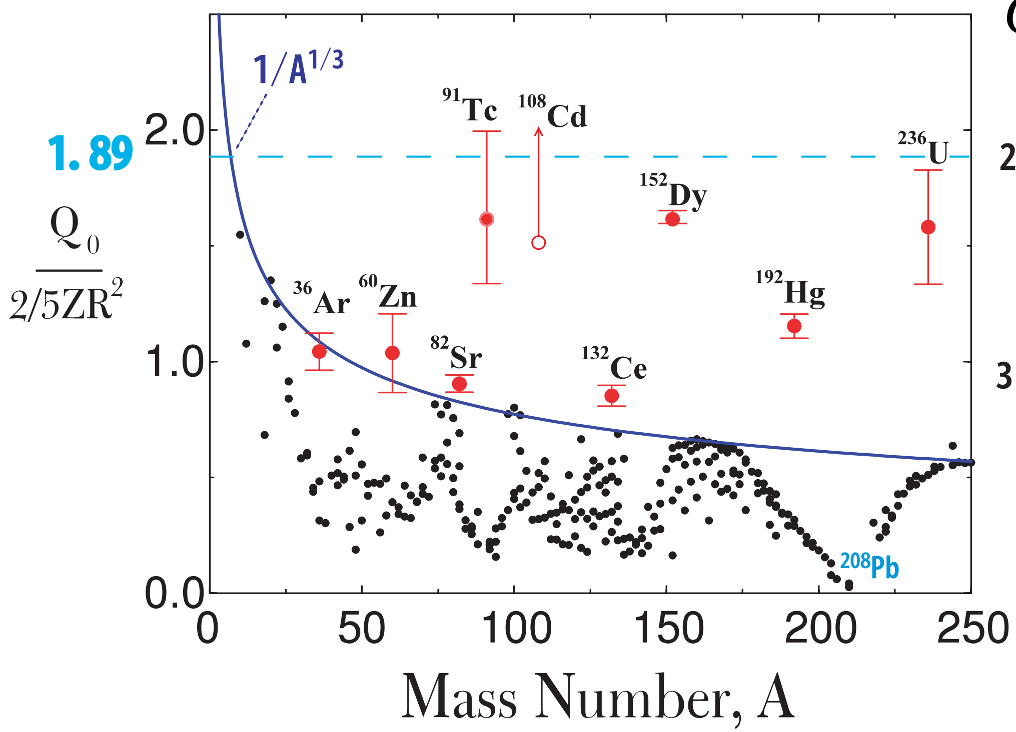
A～110領域の高スピン状態の研究

R.R.Chasman
PRC64,024311(2001)

Predicted New SD region
Cranked Strutinsky calculations
Z=40～54、N=56～68



Limit of deformation



$$Q_0 = \frac{2}{5} Z R^2 \frac{x^2 - 1}{x^{2/3}} \times 10^{-2} eb$$

x : major-to-minor axis ratio

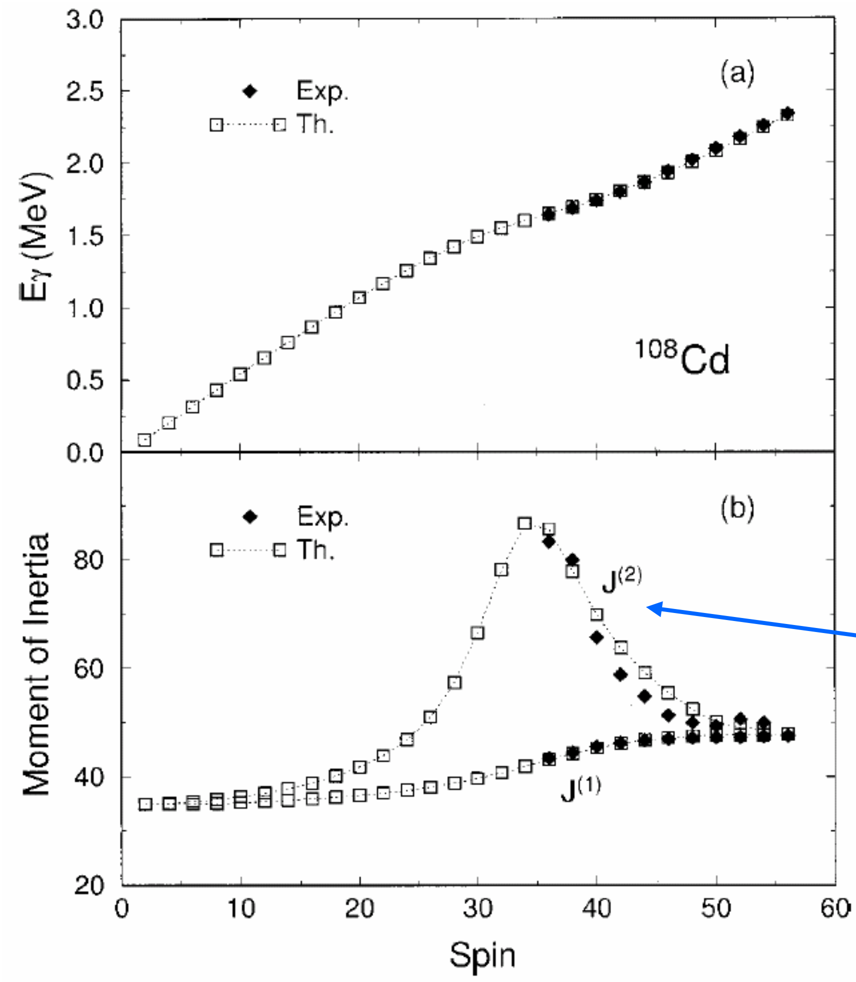
x = 2 ⟶ 2:1deformation

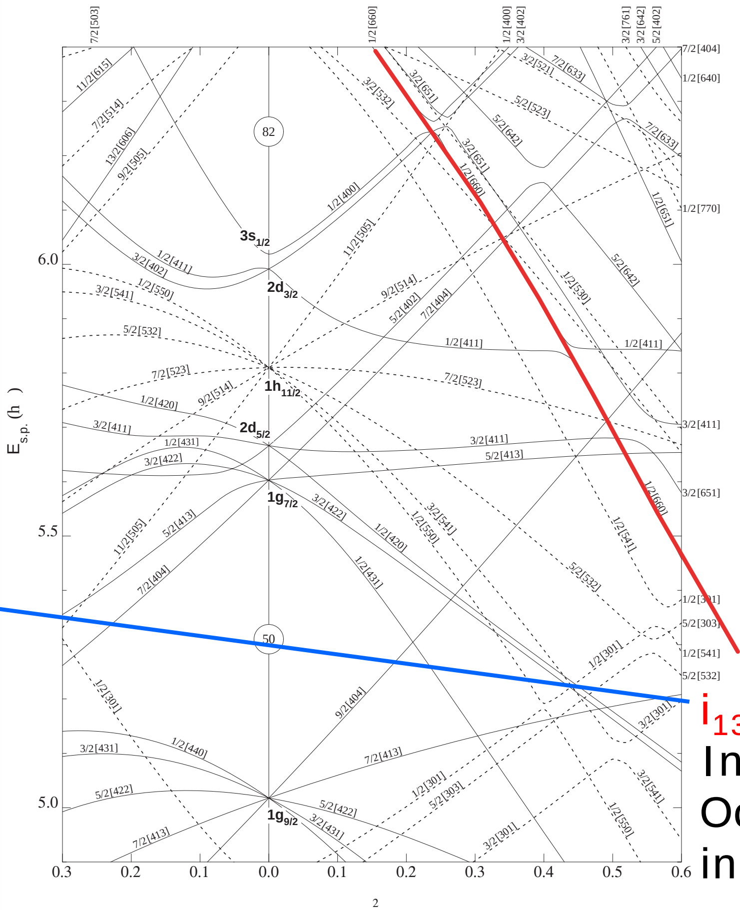
$$\frac{Q_0}{2/5 Z R^2} = 1.89$$

$R = 1.2A^{1/3}$ fm

R.M.Clark et al., Phys. Rev. Lett. 87, 202502 (2001)

$i_{13/2}$ intruder orbital





$i_{13/2}$ proton Intruder Occupied in ^{108}Cd

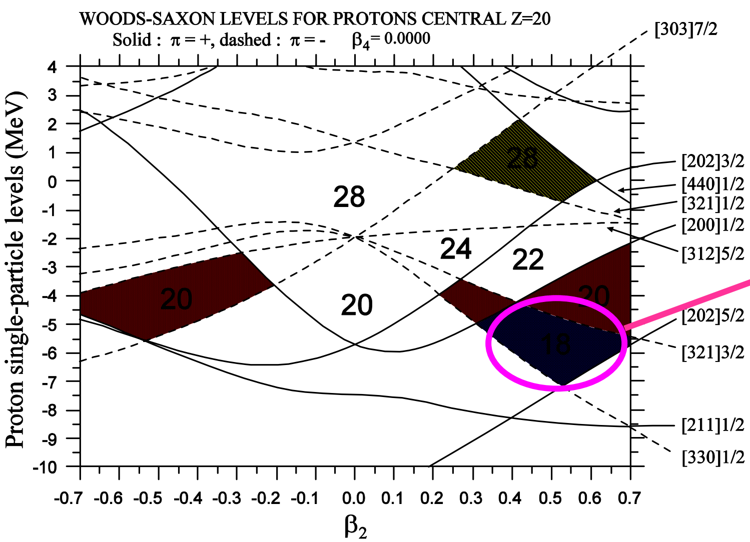
C-T. Lee et al., PRC 65, 041301 (2002)

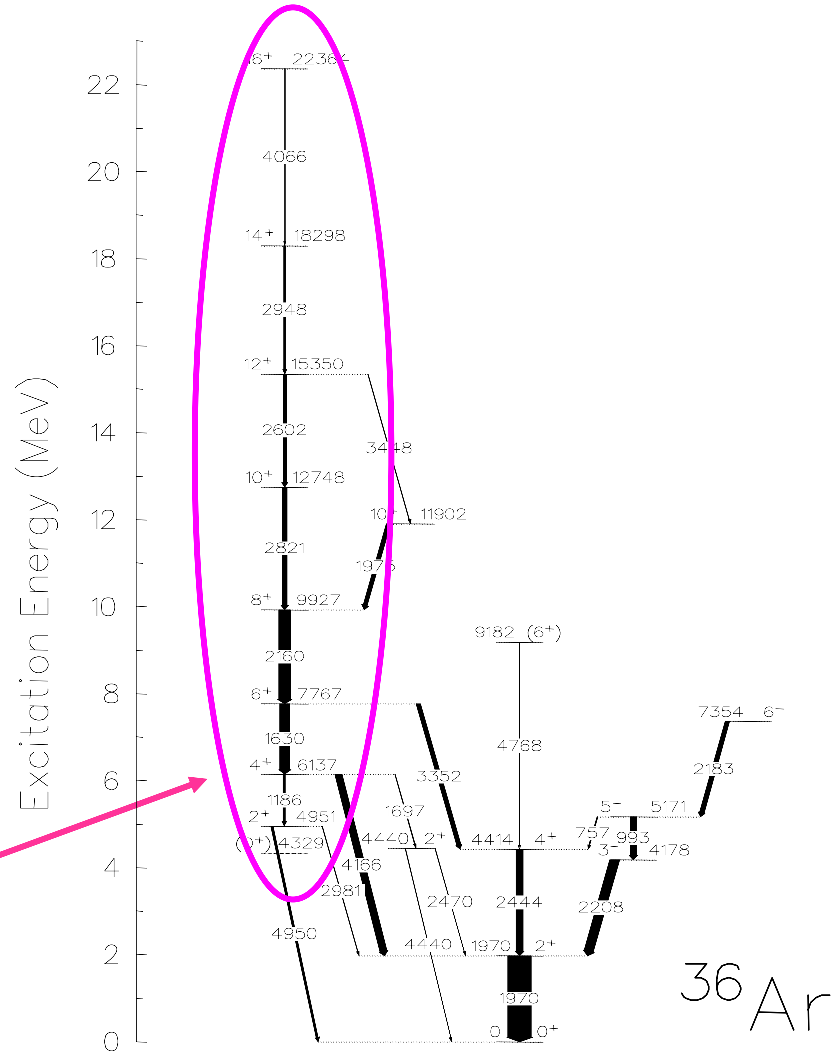
A～110の高スピン原子核の生成

- ^{100}Ru: $^{96}Zr(^{13}C, \alpha 5n)$
- ^{106}Pd: $^{96}Zr(^{13}C, 3n)$, $^{96}Zr(^{18}O, \alpha 4n)$
- ^{110}Cd: $^{96}Zr(^{22}Ne, \alpha 4n)$
- ^{114}Sn: $^{100}Mo(^{22}Ne, \alpha 4n)$
- ^{118}Te: $^{100}Mo(^{22}Ne, 4n)$
- ^{122}Xe: $^{110}Pd(^{18}O, 6n)$

A～40領域の超変形状態の探索

- ^{40}Ca　I　>　16ħ
  - Backbending around 20ħ?
- ^{36}S (Z=16, N=20), ^{32}S(Z=N=16)
- ^{40}Ar (Z=18, N=22)
  - ^{36}Ar (Z=18, N=18)
- Ri beamを用いた高スピン分光
  - ^{50}Ti(Z=22,N=28), ^{48}Ca(Z=20,N=28)





C.E. Svensson et al., PRL85,2693 (2000)