‘Calculations of Iso Spin triplet states’

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SSNET 2018

Outline

- Extended TRS calculations
- Mass differences along the N=Z line
- Calculations of T=1 rotational bands in odd-odd N=Z nuclei

Extended TRS - Model

- Deformed single particle WS potential
- Liquid drop and Strutinsky shell correction (Wigner Kirkwood)
- Developped symmetry restauration –
  particle number fluctuation via Lipking Nogami correction and gauge symmetry restauration of pairing field via double stretched QQ pairing interaction
- Minimized in deformation space
- Application to high-spin, superdeformed, shape coexistence, high-K isomers, odd-even mass differences, radii, masses, N=Z nuclei, competition of T=1 and T=0 pairing
- Collaborators: **W Satula, F Xu,** P Magierski, A Bhagwatt

HFB-LNC equations

$$\begin{pmatrix} h & \Delta - 4\lambda_2 \kappa \\ -\Delta^* + 4\lambda_2 \kappa^* & -h^* \end{pmatrix} \begin{pmatrix} U \\ V \end{pmatrix} = (\mathscr{E} + \lambda_2) \begin{pmatrix} U \\ V \end{pmatrix},$$

$$h_{\alpha\beta} = (e_\alpha - \lambda)\delta_{\alpha\beta} - \omega j^{(x)}_{\alpha\beta} + \Gamma_{\alpha\beta}, \quad \Gamma_{\alpha\beta} = \sum_{\gamma\delta} \bar{v}_{\alpha\gamma\beta\delta}\, \rho_{\delta\gamma},$$

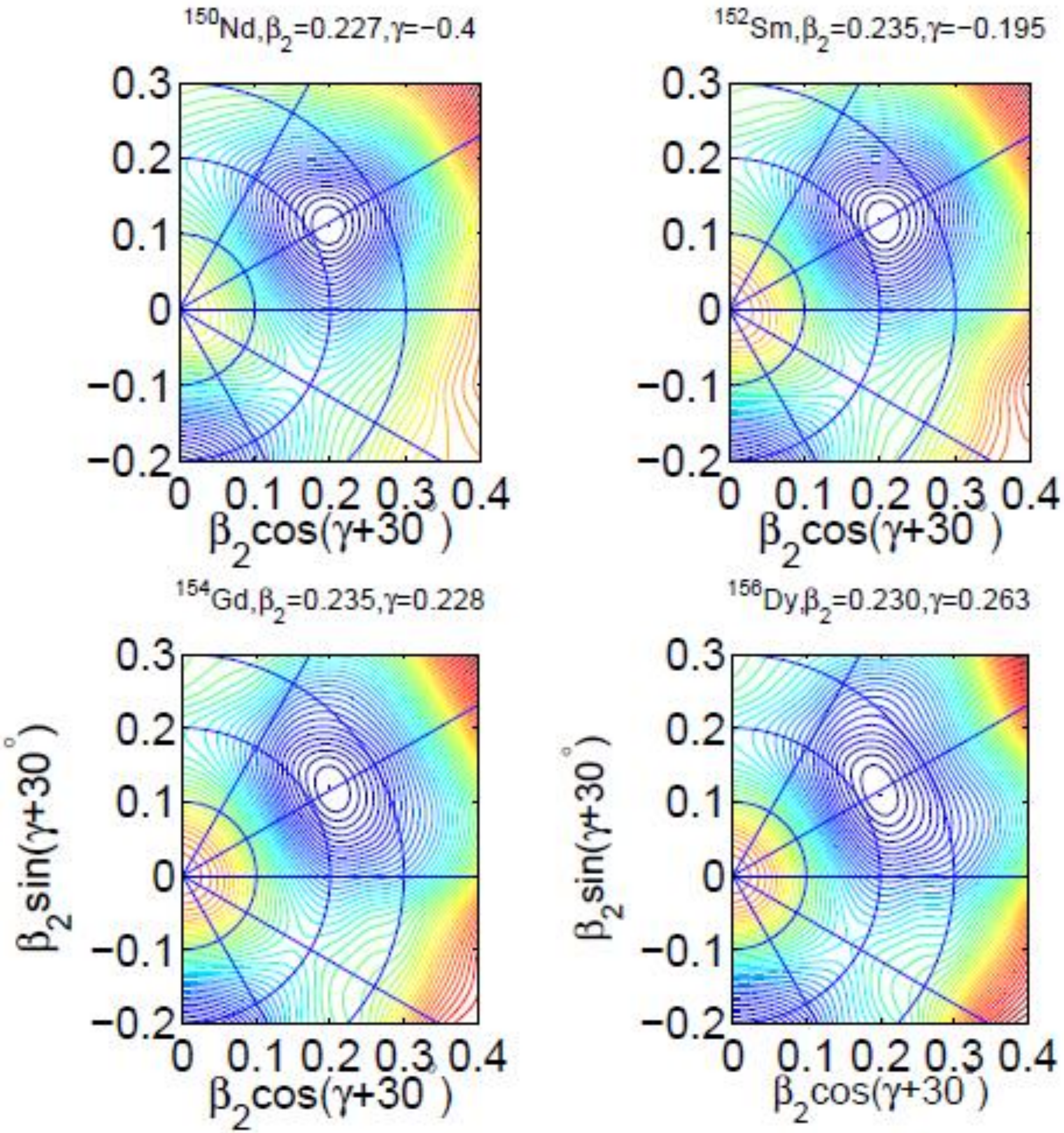
$$\Delta_{\alpha\beta} = \frac{1}{2} \sum_{\gamma\delta} \bar{v}_{\alpha\beta\gamma\delta}\, \kappa_{\gamma\delta}.$$

$$\bar{v}^{(\lambda\mu)}_{\alpha\beta\gamma\delta} = -G_{\lambda\mu}\, g^{(\lambda\mu)}_{\alpha\beta} g^{*(\lambda\mu)}_{\gamma\delta},$$

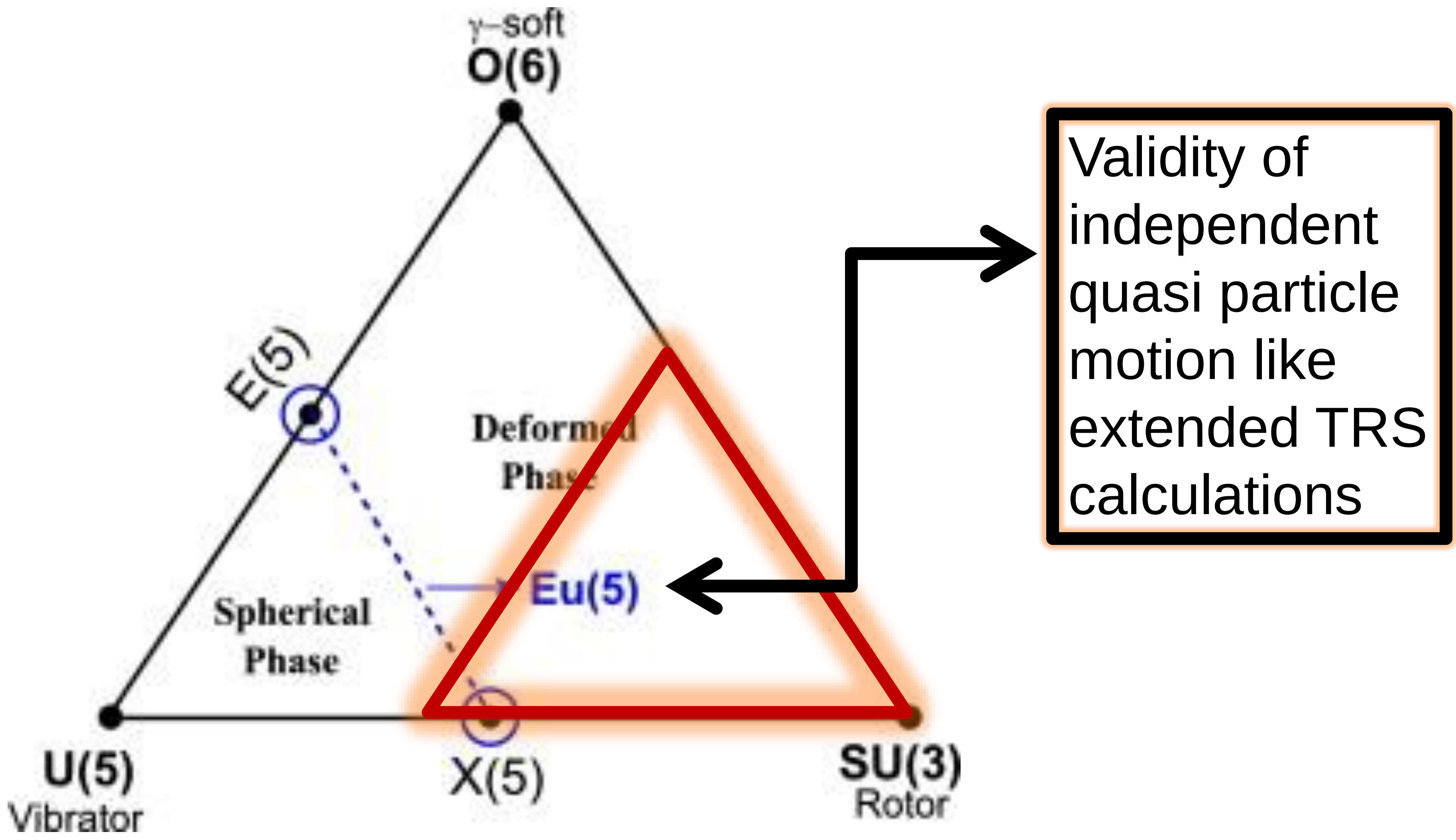
$$g^{(\lambda\mu)}_{\alpha\beta} = \begin{cases} \delta_{\alpha\bar{\beta}} & \lambda = 0, \quad \mu = 0, \\ \langle \alpha \,|\, \tilde{Q}_\mu \,|\, \bar{\beta} \rangle, & \lambda = 2, \quad \mu = 0, 1, 2. \end{cases}$$

Physica Scripta. Vol. T56, 159–166, 1995

N=90
isotones

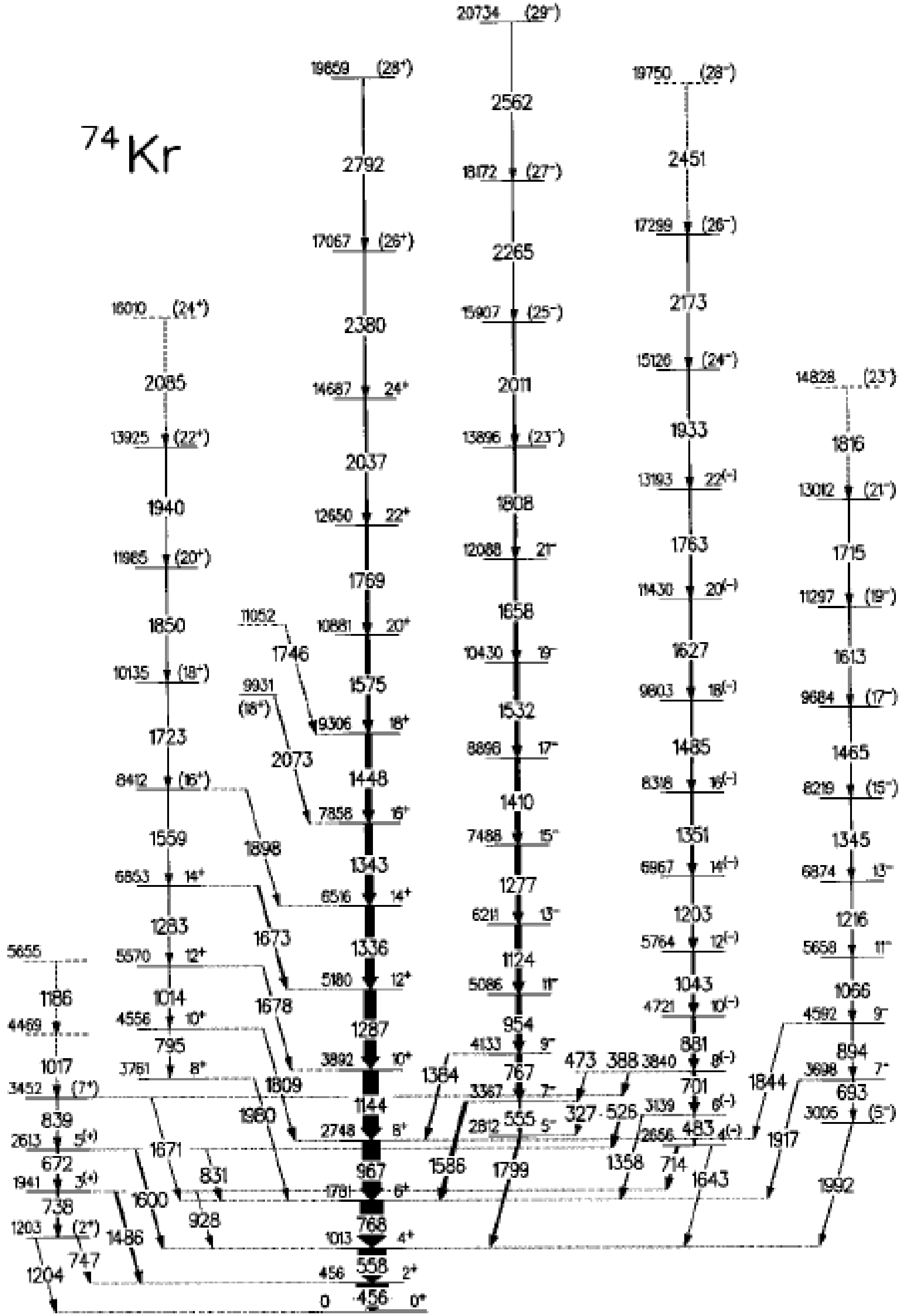


E Ganioğlu, R Wyss, P Magierski
Physical Review C 89 (1), 014311; 2014

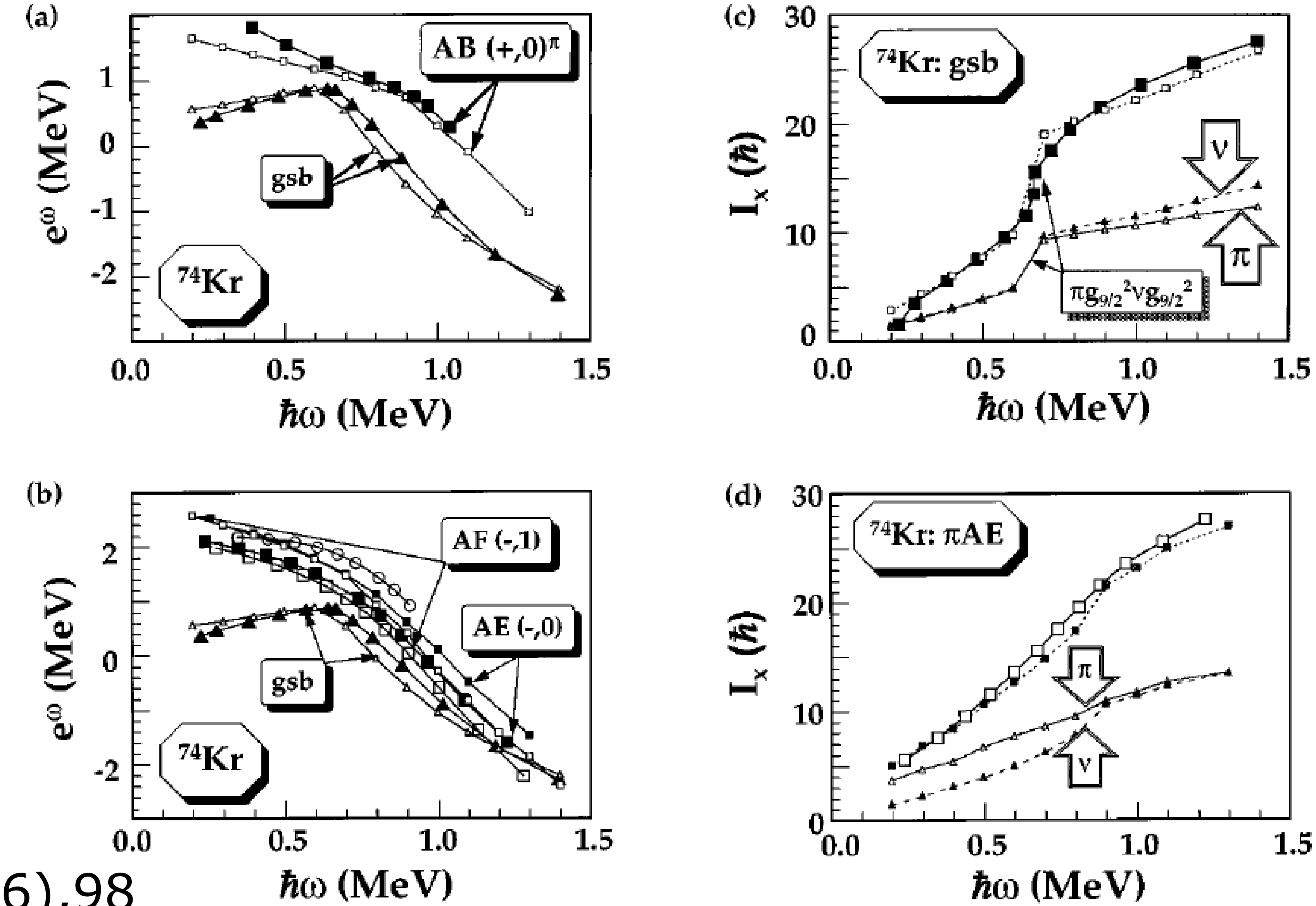


Spectrum 74Kr

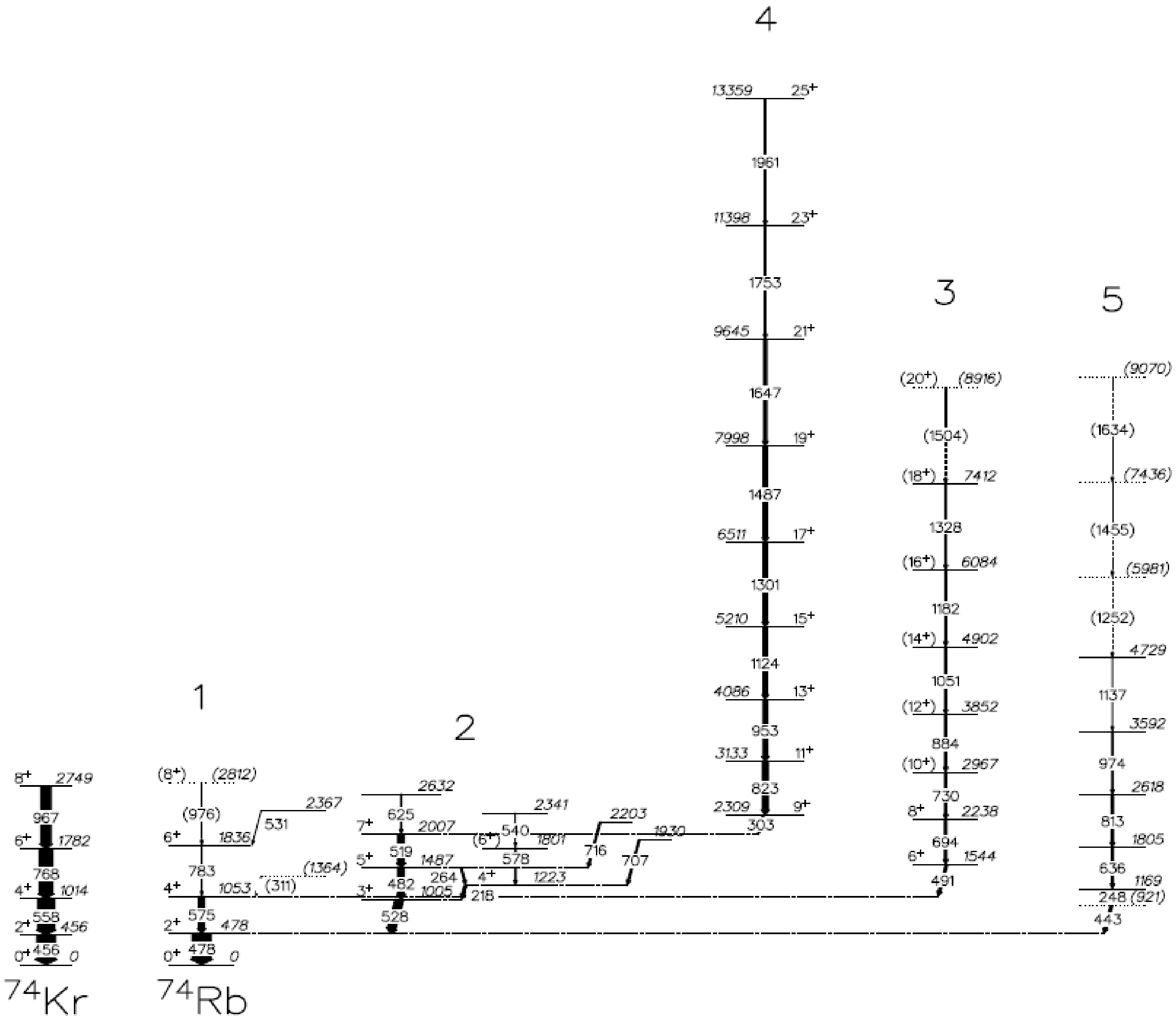
PRC 56(1996),98
D. Rudolph et.al.
'Systematics of Tz=1 nuclei in the A=80 region: high spin rotational bands in 74Kr, 78Sr and 82Zr.'



Systematics of even-even $T_z = 1$ nuclei in the $A = 80$ region: High-spin rotational bands in ^{74}Kr, ^{78}Sr, and ^{82}Zr



PRC 56(1996),98


4
13359 25+
1961
11398 23+
1753
9645 21+
1647
7998 19+
1487
6511 17+
1301
5210 15+
1124
4086 13+
953
3133 11+
823
2309 9+
303
3
(20+) (8916)
(1504)
(18+) 7412
1328
(16+) 6084
1182
(14+) 4902
1051
(12+) 3852
884
(10+) 2967
730
8+ 2238
694
6+ 1544
491
5
(9070)
(1634)
(7436)
(1455)
(5981)
(1252)
4729
1137
3592
974
2618
813
1805
636
1169
248 (921)
443
1
(8+) (2812)
(976)
6+ 1836
531
2367
783
(1364)
4+ 1053
(311)
575
2+ 478
478
0+ 0
2
2632
625
7+ 2007
519
5+ 1487
482
3+ 1005
264
528
2341
540
(6+) 1801
578
4+ 1223
218
2203
716
1930
707
8+ 2749
967
6+ 1782
768
4+ 1014
558
2+ 456
456
0+ 0
74Kr
74Rb

Iso spin and binding energies

- The ground state of all nuclei have iso spin $T=T_z=(N-Z)/2$
- Minimizing the symmetry energy ~75 $T(T+1)/A$ [MeV]
- Only exemption odd-odd N=Z nuclei
- Competition between T=0 and T=1, $T_z=0$ state
- How come?

Investigate the generalised pairing hamiltonian

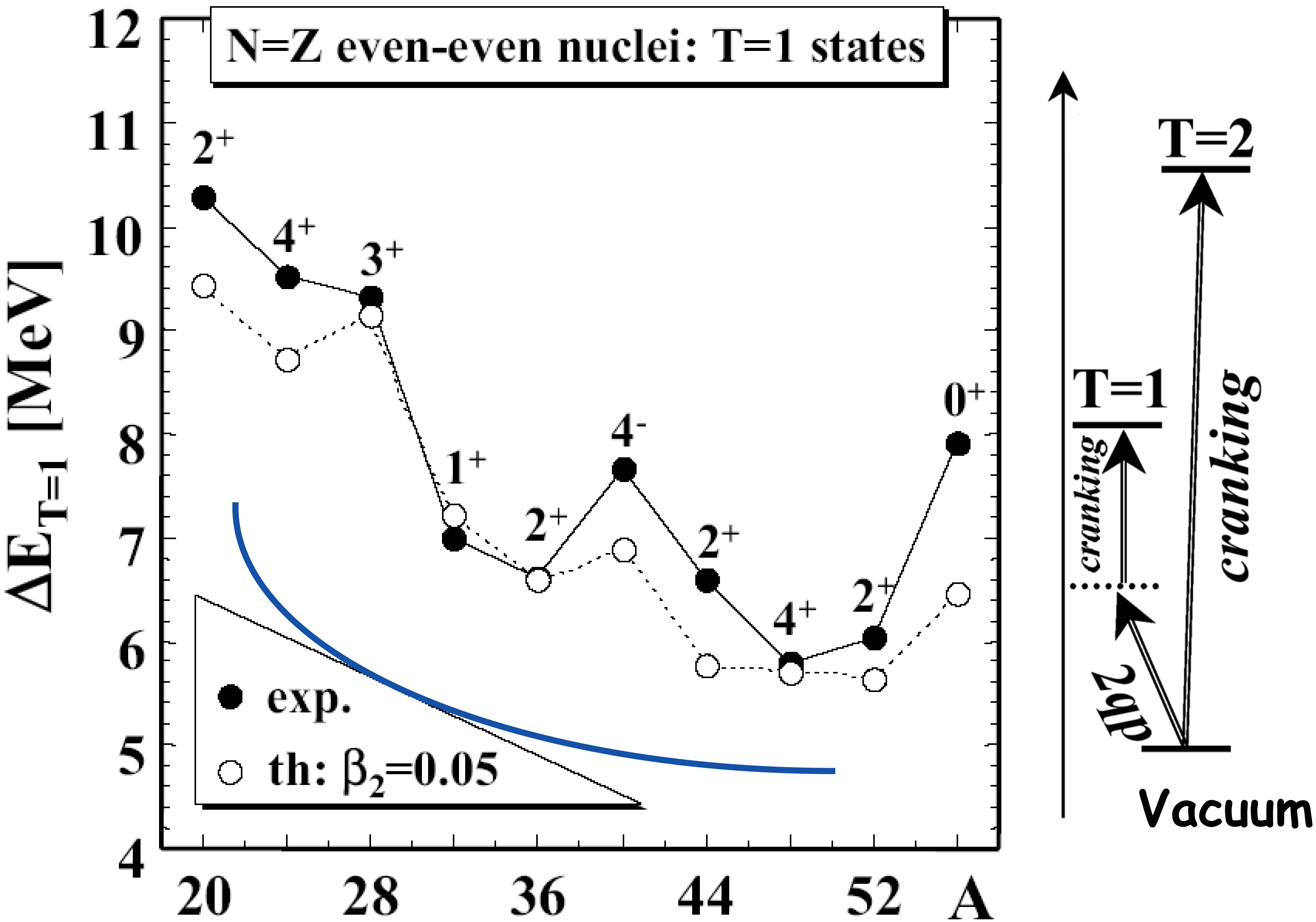
$$\hat{H}^{\omega_\tau} = \hat{h}_{sp} - G_{t=1}\hat{\boldsymbol{P}}_1^\dagger \hat{\boldsymbol{P}}_1 - G_{t=0}\hat{\boldsymbol{P}}_0^\dagger \hat{\boldsymbol{P}}_0 - \vec{\boldsymbol{\omega}}_\tau \vec{\hat{\boldsymbol{t}}},$$

$$\hat{\boldsymbol{P}}_{1\pm1}^\dagger = \sum_{i>0} \hat{a}_{in(p)}^\dagger \hat{a}_{\bar{i}n(p)}^\dagger \qquad \hat{\boldsymbol{P}}_{10}^\dagger = \frac{1}{\sqrt{2}} \sum_{i>0} (\hat{a}_{in}^\dagger \hat{a}_{\bar{i}p}^\dagger + \hat{a}_{ip}^\dagger \hat{a}_{\bar{i}n}^\dagger),$$

$$\boldsymbol{P}_0^\dagger = \frac{1}{\sqrt{2}} \sum_{i>0} (a_{in}^\dagger a_{\bar{i}p}^\dagger - a_{ip}^\dagger a_{\bar{i}n}^\dagger).$$

Employ approximate number projection via L.N.

$$\hat{\mathcal{H}}^\omega = \hat{H}^\omega - \sum_\tau \lambda_\tau^{(1)} \Delta \hat{N}_\tau - \sum_{\tau\tau'} \lambda_{\tau\tau'}^{(2)} \Delta \hat{N}_\tau \Delta \hat{N}_{\tau'}$$



Delta E~75 T(T+1)/A

PRL 87 (2001) 25504, W Satula & R Wyss

Massdifference in the presence of T=0 pairing

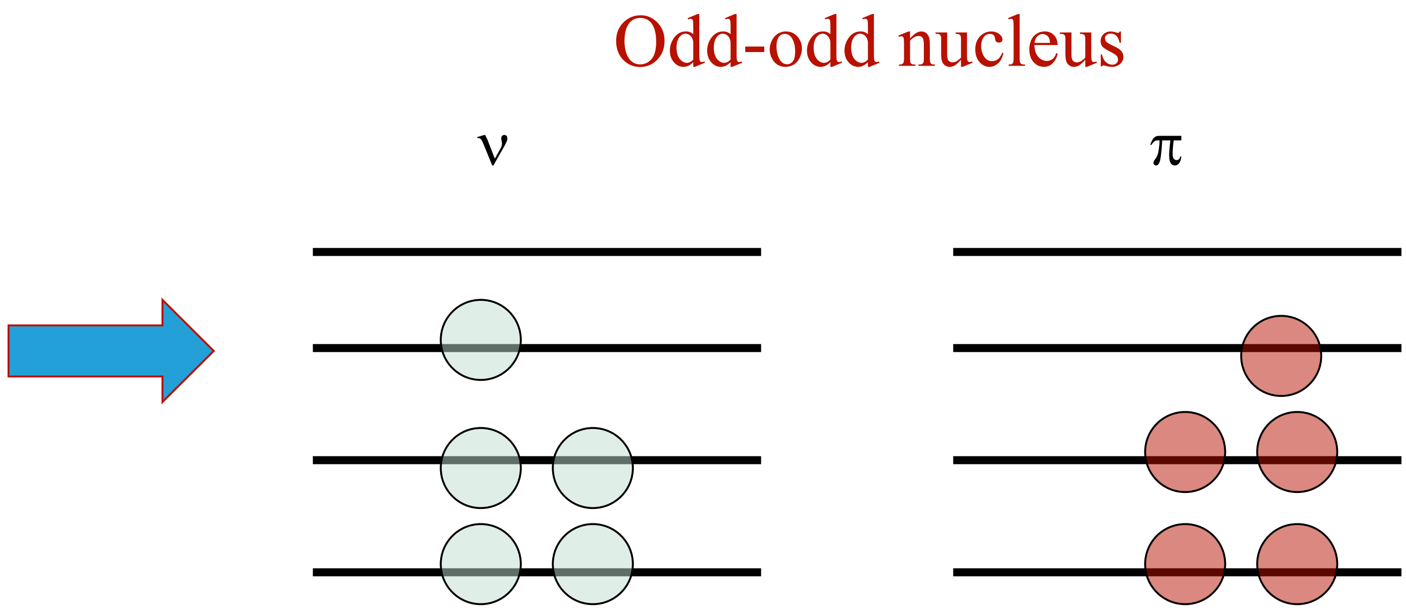
- T=0 states in o-o nuclei carry angular momentum
- Cannot be described by the BCS-vacuum of e-e nuclei (time even)
- Correspond to 2qp excitations

$$\Psi^{o-o}_{T=0} = \alpha^{+}_{1n}\alpha^{+}_{1p}|VAC_{BCS}>$$

$$|VAC_{BCS}> = \prod_{i>0}(u_i + v_{i1}c^{+}_{ip}c^{+}_{\bar{i}p} + v^{*}_{i2}c^{+}_{ip}c^{+}_{\bar{i}n})$$

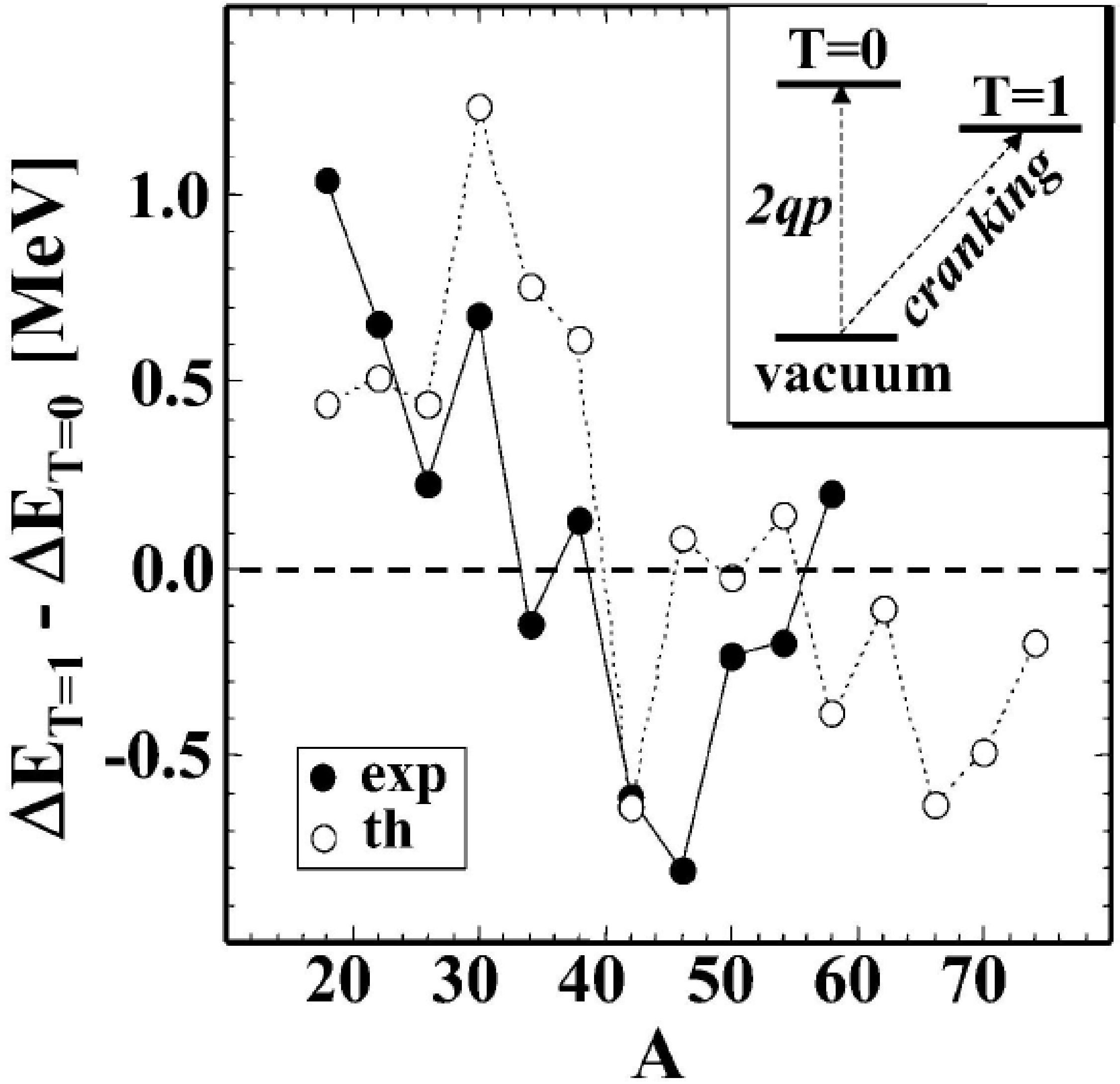
$$(u_i + v_{i1}c^{+}_{in}c^{+}_{\bar{i}n} + v_{i2}c^{+}_{in}c^{+}_{\bar{i}p})$$

Mass difference in odd-odd N=Z nuclei – Problem for T=0 scenario?



odd-odd T=0 nucleus has always a given spin (odd spin) and parity (even).
This level is blocked for pairing correlations, irrespectively we deal with T=0 or T=1 pairing. The symmetry of the wavefunction of e-e nuclei is different from that of o-o

Mass difference between T=1 and T=0 state in N=Z odd-odd nuclei

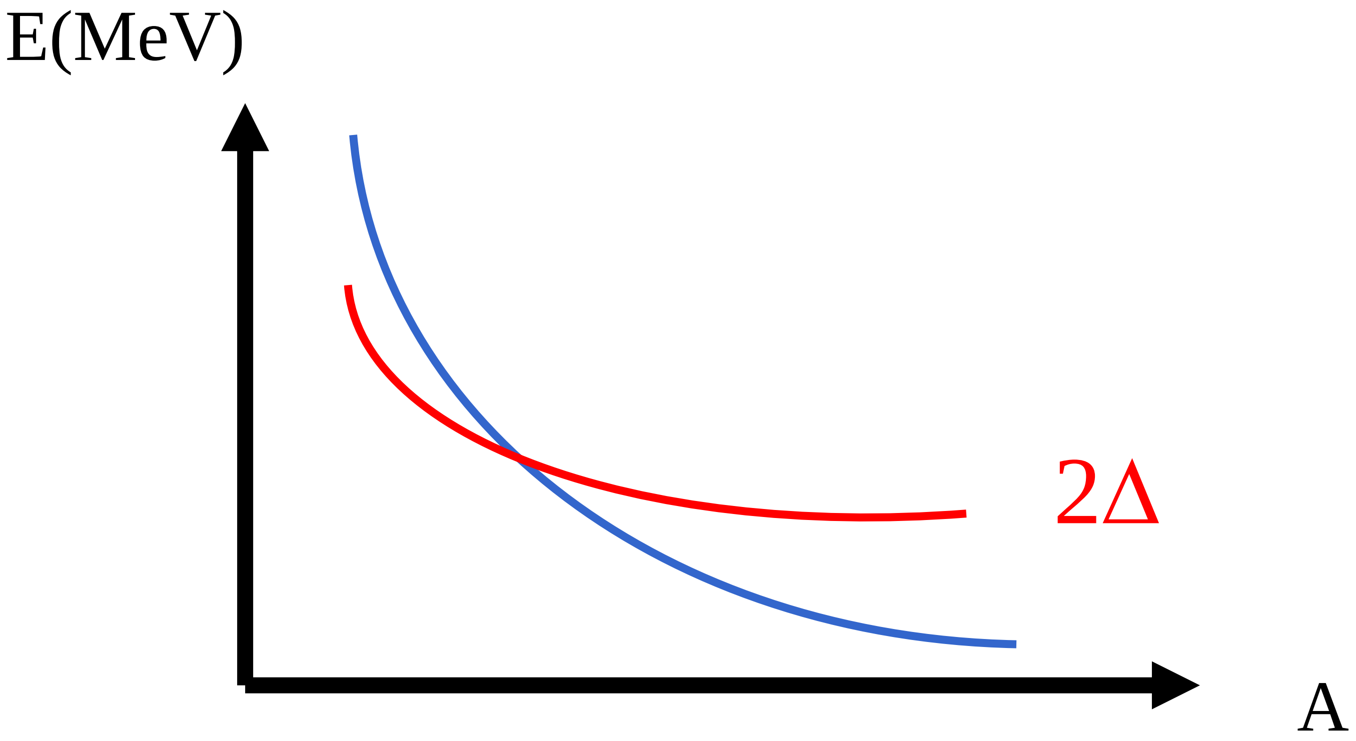


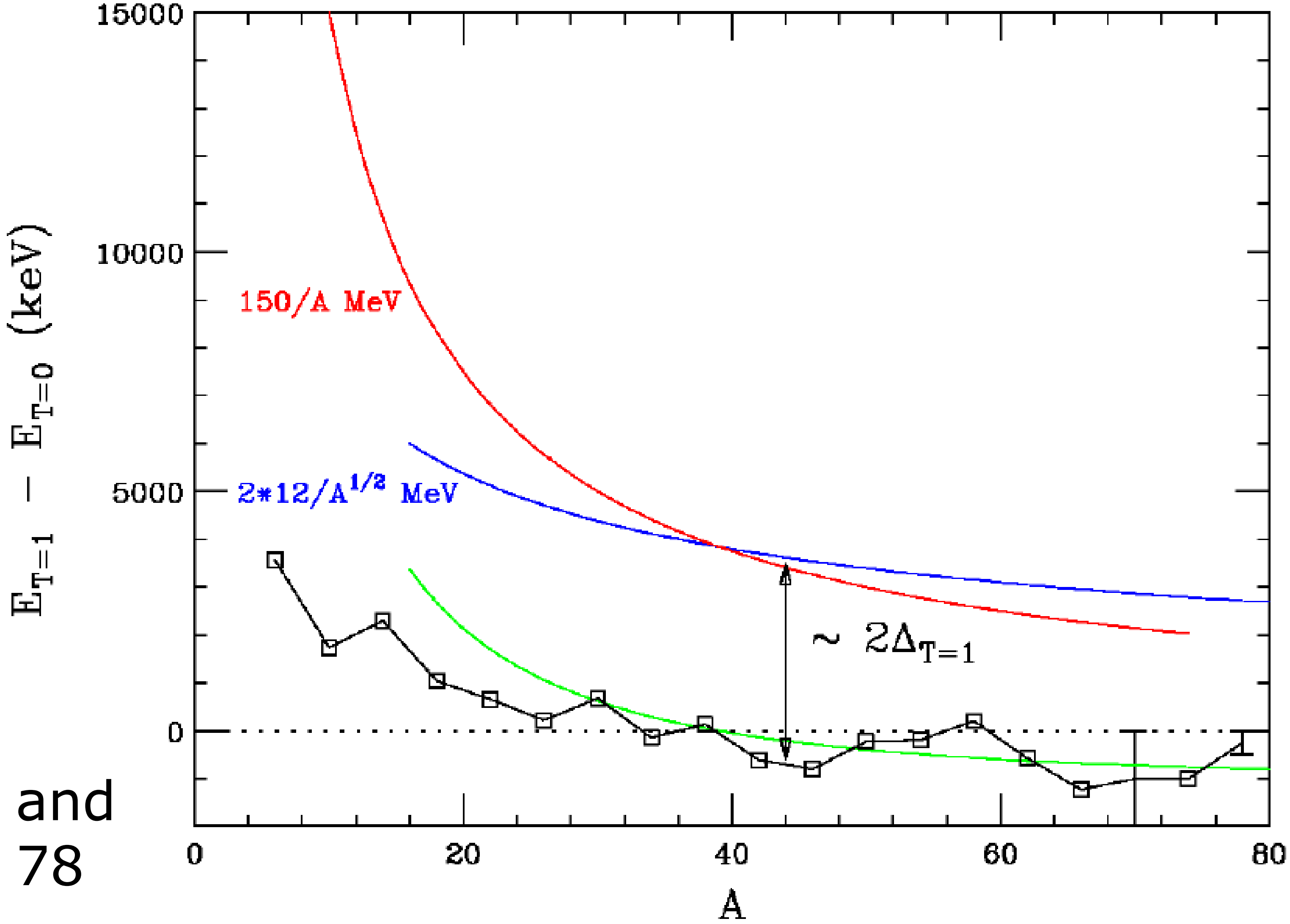
PRL 87 (2001) 25504, W Satula & R Wyss

Competition between 2qp excitation and symmetry energy in o-o nuclei

T=0 states in o-o nuclei are 2qp excitations ~1/sqrt(A)

T=1states have larger symmetry energy ~ 1/A



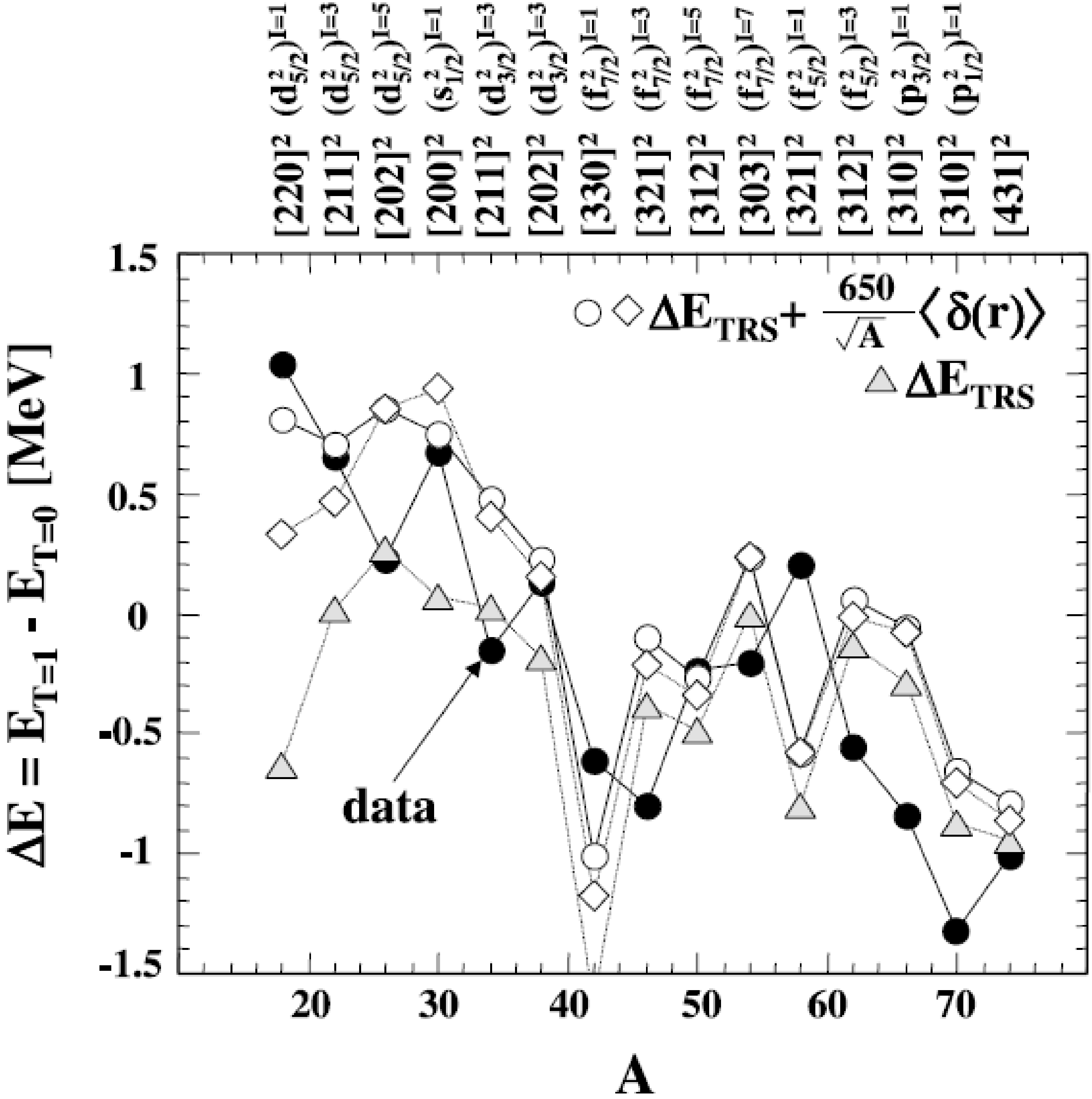


Prog in Nuclear and Particle Physics 78 (2014)24

Overview of neutron–proton pairing

S. Frauendorf[a], A.O. Macchiavelli[b,*]

S. Glowacz, W. Satula R. A. Wyss; 'Cranking in iso space'; Eur. Phys. J. A19 33-44 (2004)



- **Mass differences do not disproof existence of T=0 pairing**

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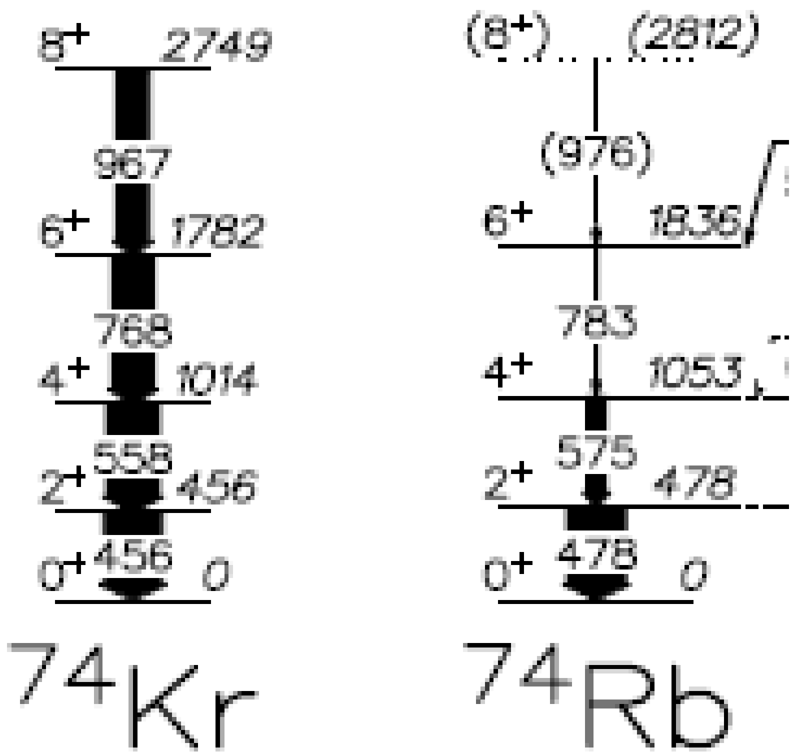
Rotational T=1 states in odd-odd N=Z nuclei

Isobaric Triplet: 74Kr – 74Rb – 74Sr

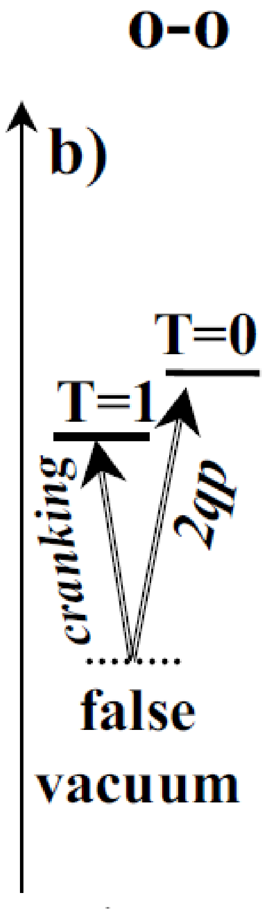


T=1, Tz=1; T=1, Tz=0

S.M. Fischer et al

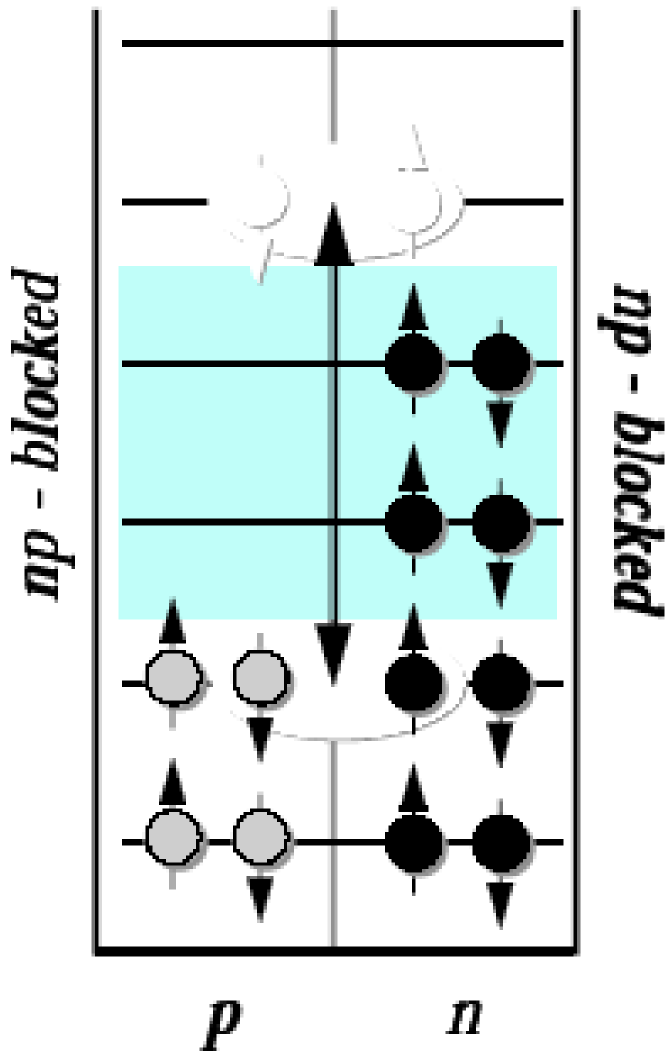
PHYSICAL REVIEW C 74, 054304 (2006)

Cranking calculations for the T=1 band in 74Rb

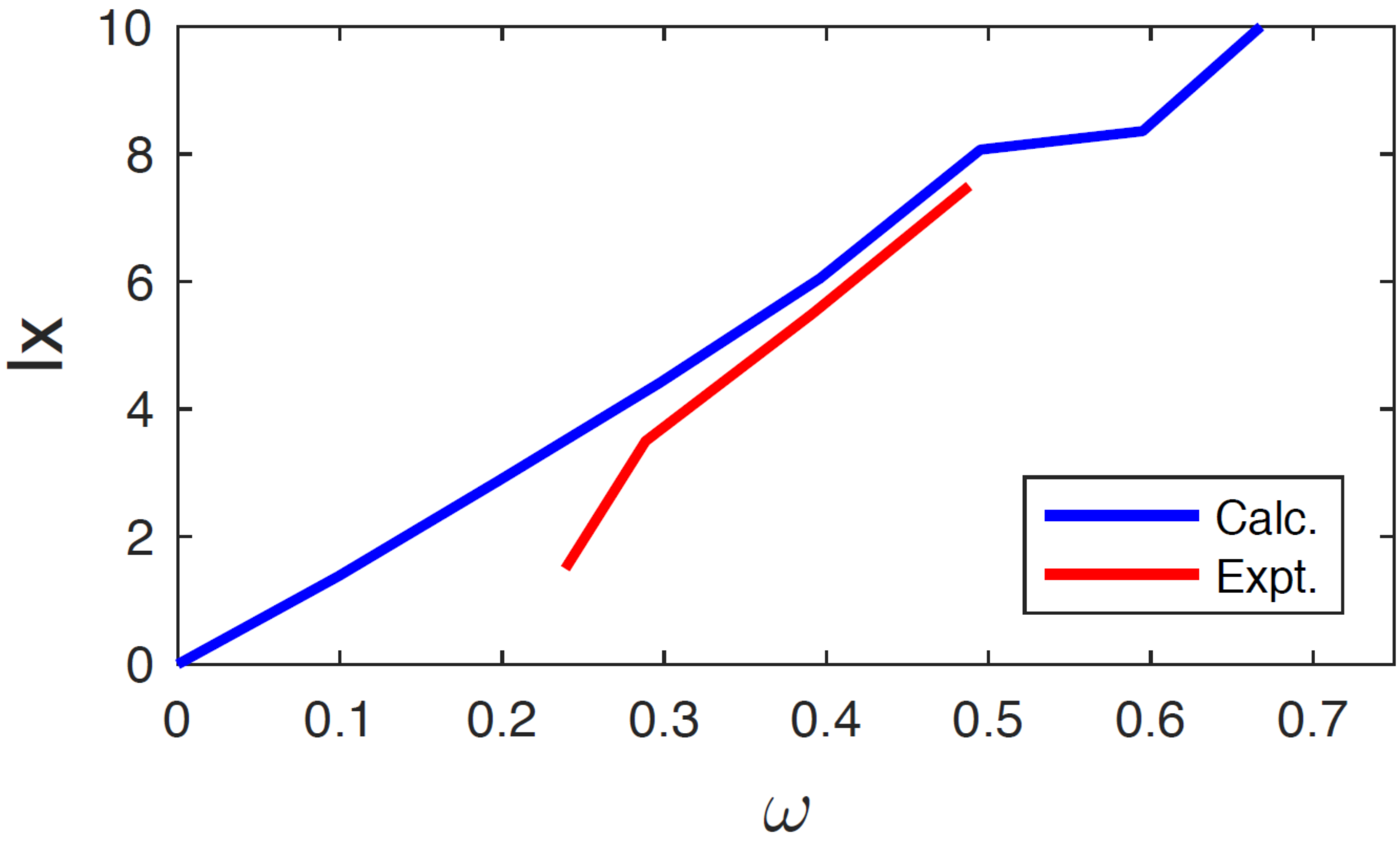


- Starting from the ’false’ vacuum with <N>=37 and <Z>=37
- Keep only iso vector nn and pp pairing – due to isobaric symmetry of T=1 triplet state of 74Sr, 74Rb and 74 Kr
- Iso spin Tx spontanously aligned due to T=1 iso vector pairing

Generalised blocking effect:
T=0 pairng correlations present only in N~Z nuclei



74Rb, T=1, Theory vs Experiment



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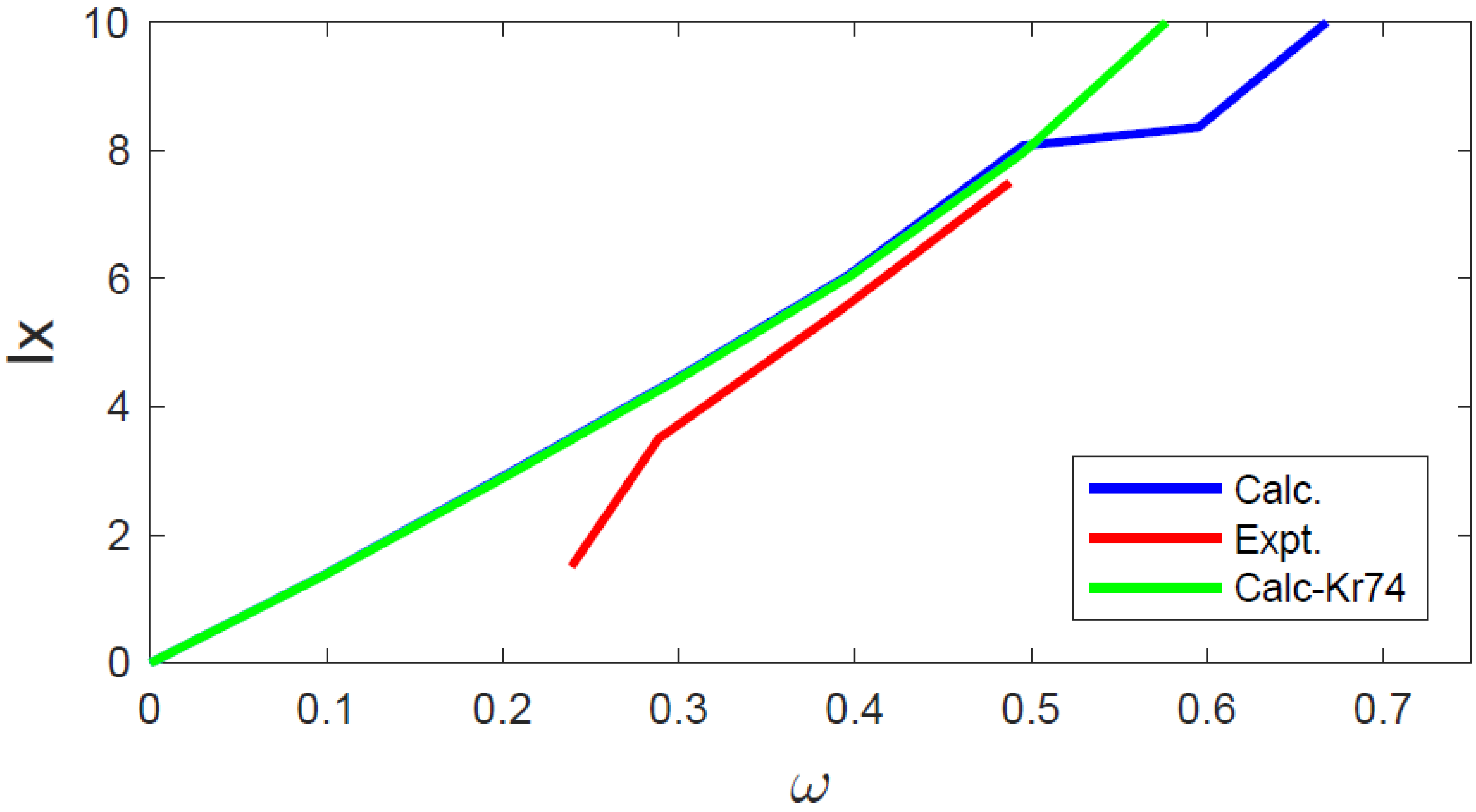
74Kr, 74Rb calculations and experiment



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Conclusions

- T=0 pairing correlations still subject of debate
- Cranking calculations of ’false vacuum’ state of odd-odd N=Z nuclei nicely accounts to the date
- Result of symmetry breaking of T=1 iso vector pairing field

Thank you for your attention