Identical features of the semi-magic seniority isomers beyond doubly-magic cores

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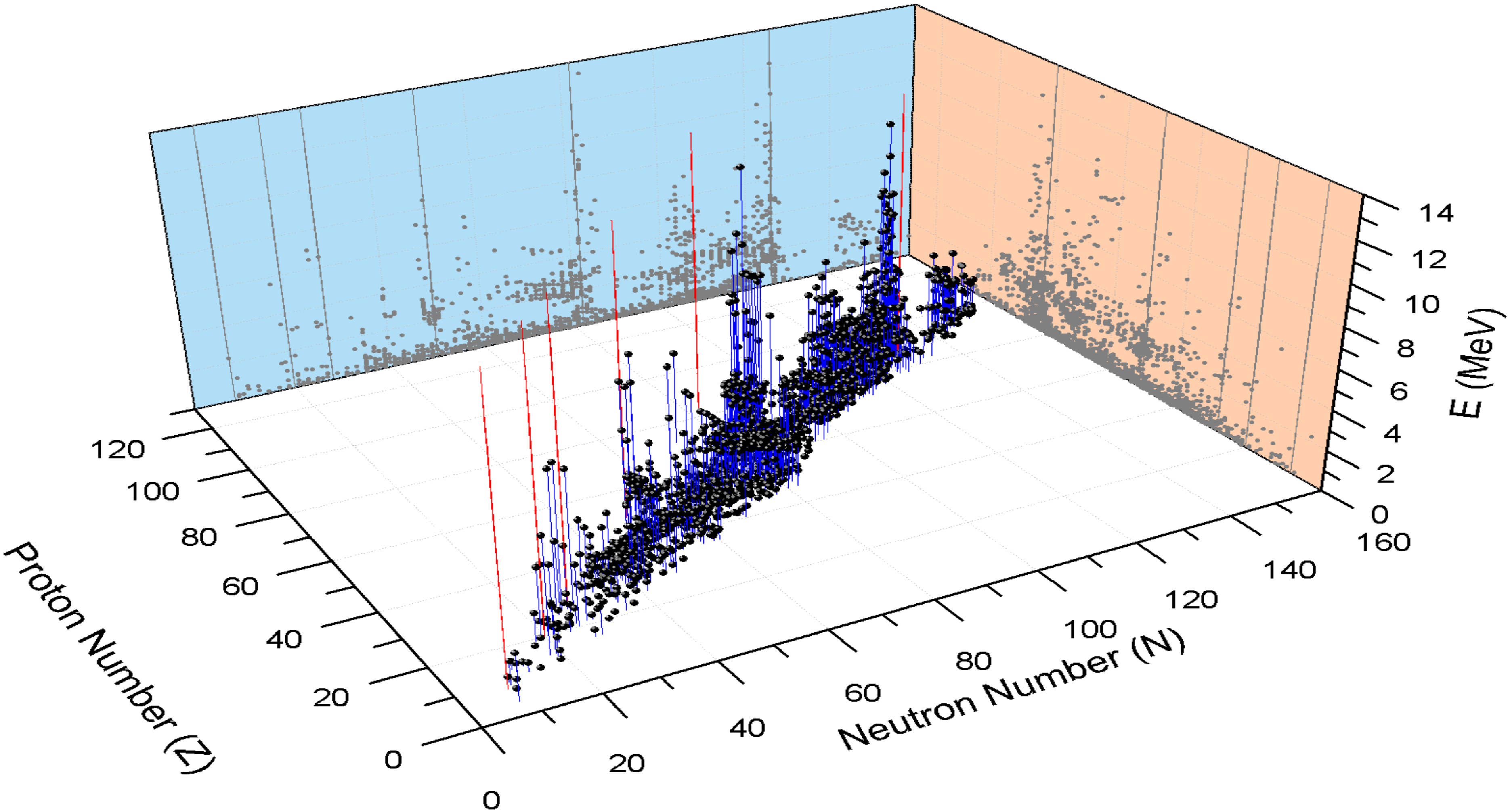
Atlas of Nuclear Isomers

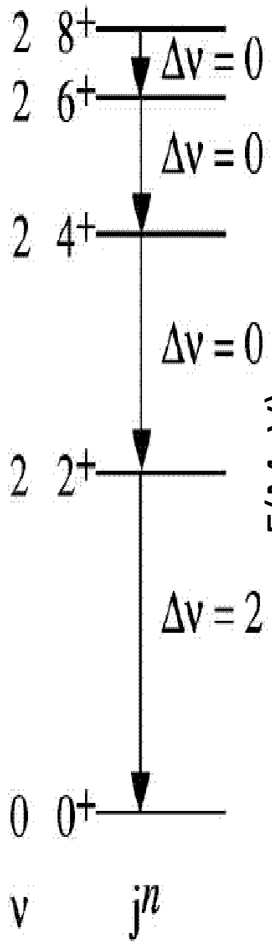
A. K. Jain, B. Maheshwari et al., Nuclear Data Sheets 128, 1 (2015)

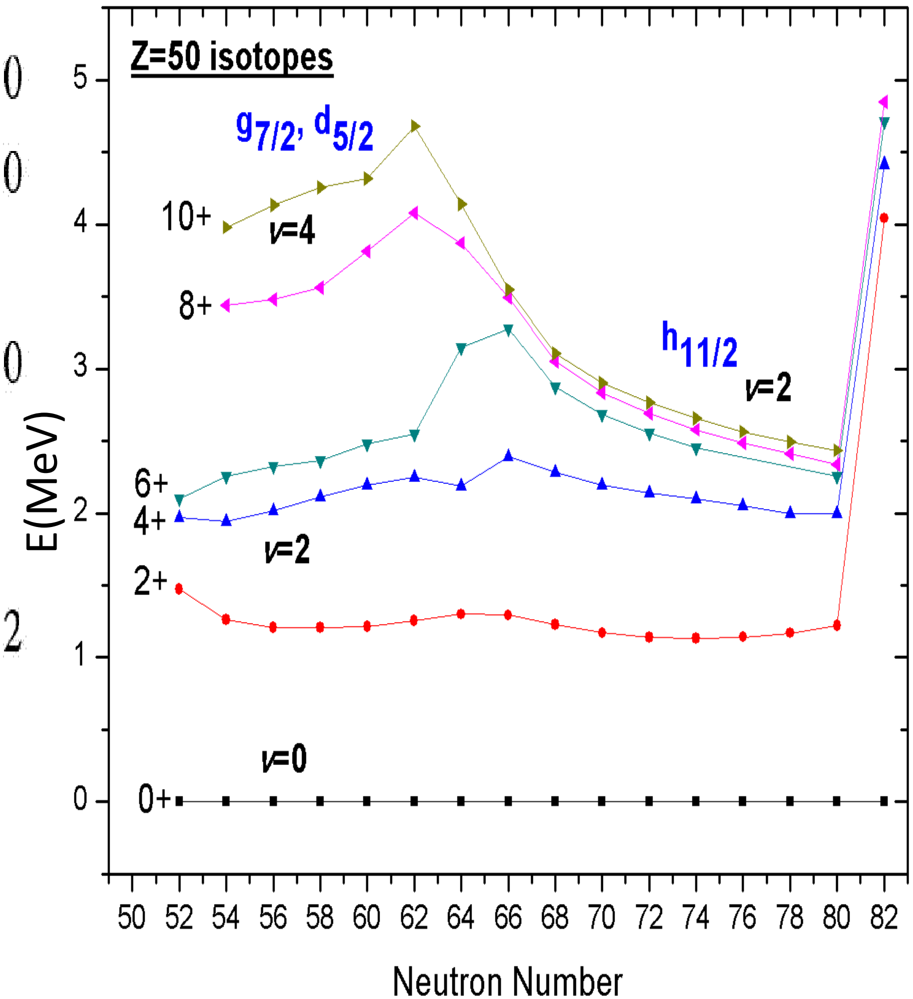


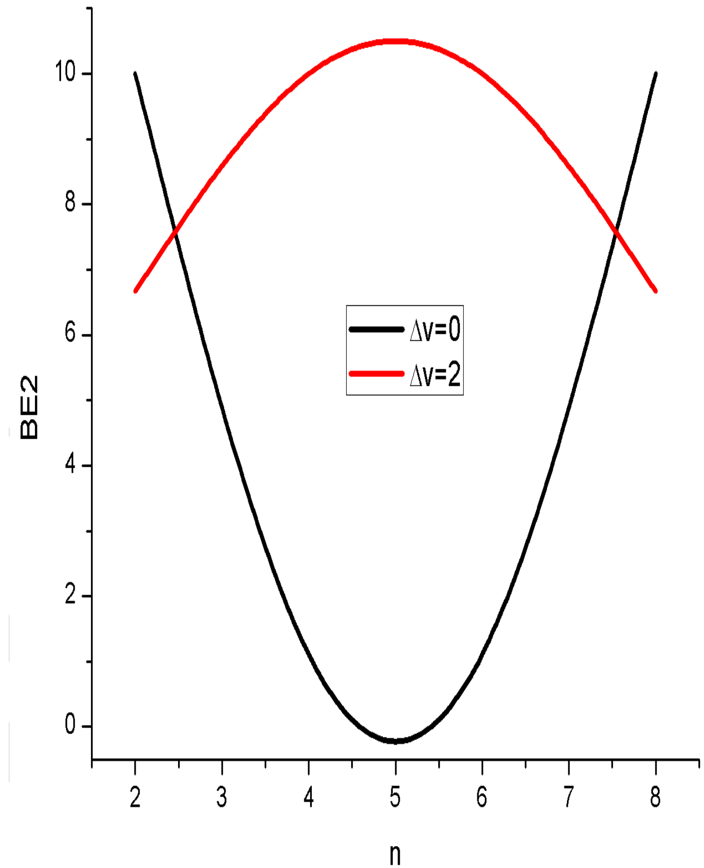
Outline

- Isomers beyond doubly magic cores: ^{132}Sn and ^{208}Pb
- The semi-magic chains:
  - Z=50 (N=84-88) and N=82 (Z=52-62)
  - Z=82 (N=128-134) and N=126 (Z=84-90)
- 6^+ isomers common in Z=50 and N=82 beyond ^{132}Sn
- 8^+ isomers common in Z=82 and N=126 beyond ^{208}Pb
- 6^+ isomers - different valence spaces in Z=50 and N=82
- 8^+ isomers - different valence spaces in Z=82 and N=126
- Still we witness identical features!
- Common factor: Seniority
- Seniority scheme and Large Scale Shell Model (LSSM) calculations for energies and B(E2) values presented

Seniority – important signatures







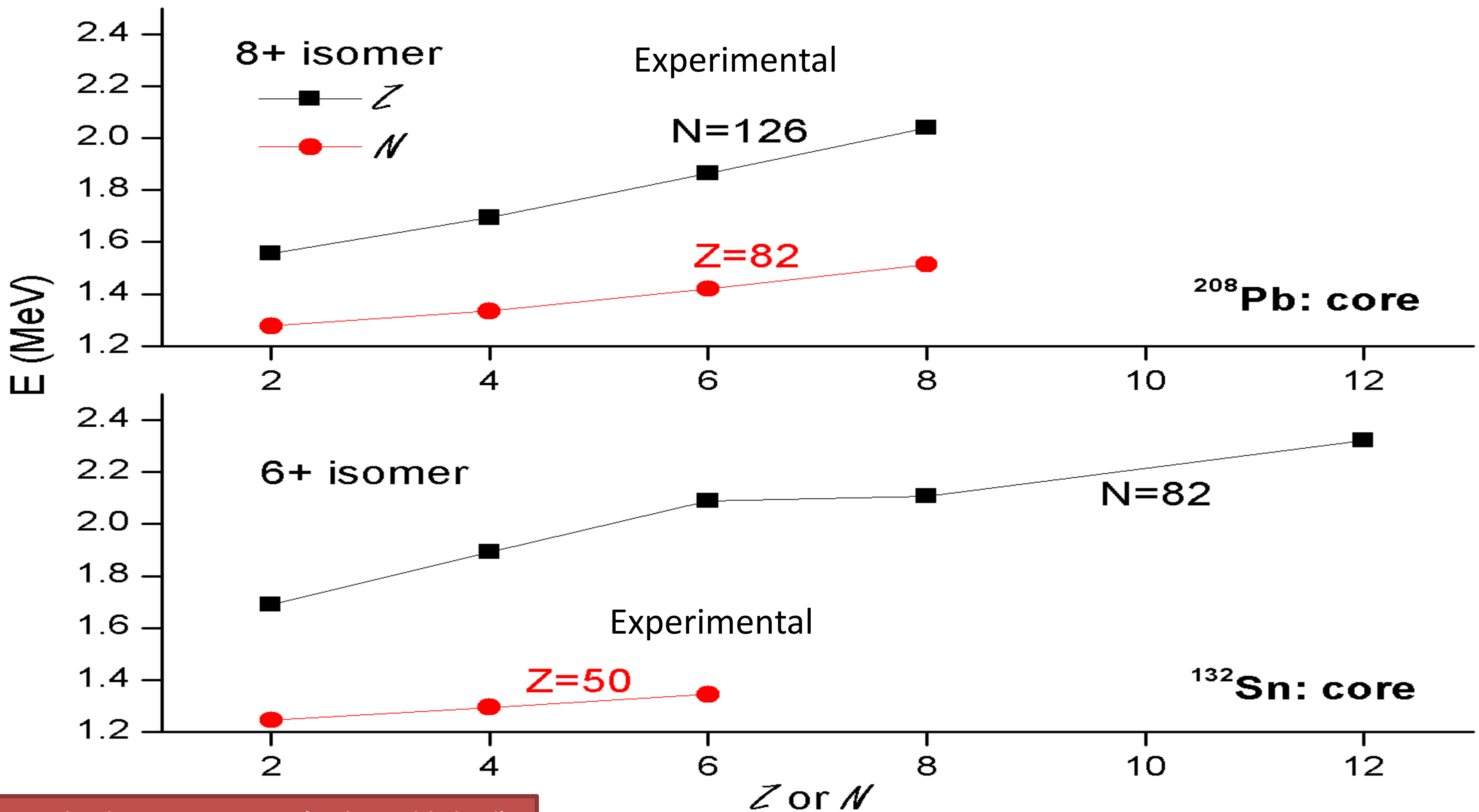
Valence spaces involved and origin of isomers

- Z=50, 6^+ isomers: Neutrons ($\mathbf{f_{7/2}}$,$p_{3/2}$,$p_{1/2}$,$h_{9/2}$,$f_{5/2}$,$i_{13/2}$)
- N=82, 6^+ isomers: Protons ($\mathbf{g_{7/2}}$,$d_{5/2}$,$h_{11/2}$,$d_{3/2}$,$s_{1/2}$)

- Z=82, 8^+ isomers: Neutrons ($\mathbf{g_{9/2}}$,$i_{11/2}$,$j_{15/2}$,$d_{5/2}$,$s_{1/2}$,$g_{7/2}$,$d_{3/2}$)
- N=126, 8^+ isomers: Protons ($\mathbf{h_{9/2}}$,$f_{7/2}$,$i_{13/2}$,$f_{5/2}$,$p_{3/2}$,$p_{1/2}$)

- These isomers have been interpreted mainly as single-j seniority isomers, arising from the highlighted orbits.
- We find that the other orbits also play an important role and a multi-j character is necessary to explain B(E2) systematic.
- Note the same set of orbits in Z=50 and N=126. However, different ordering results in isomers with different spins.

Identical features of 6+ and 8+ isomer energies



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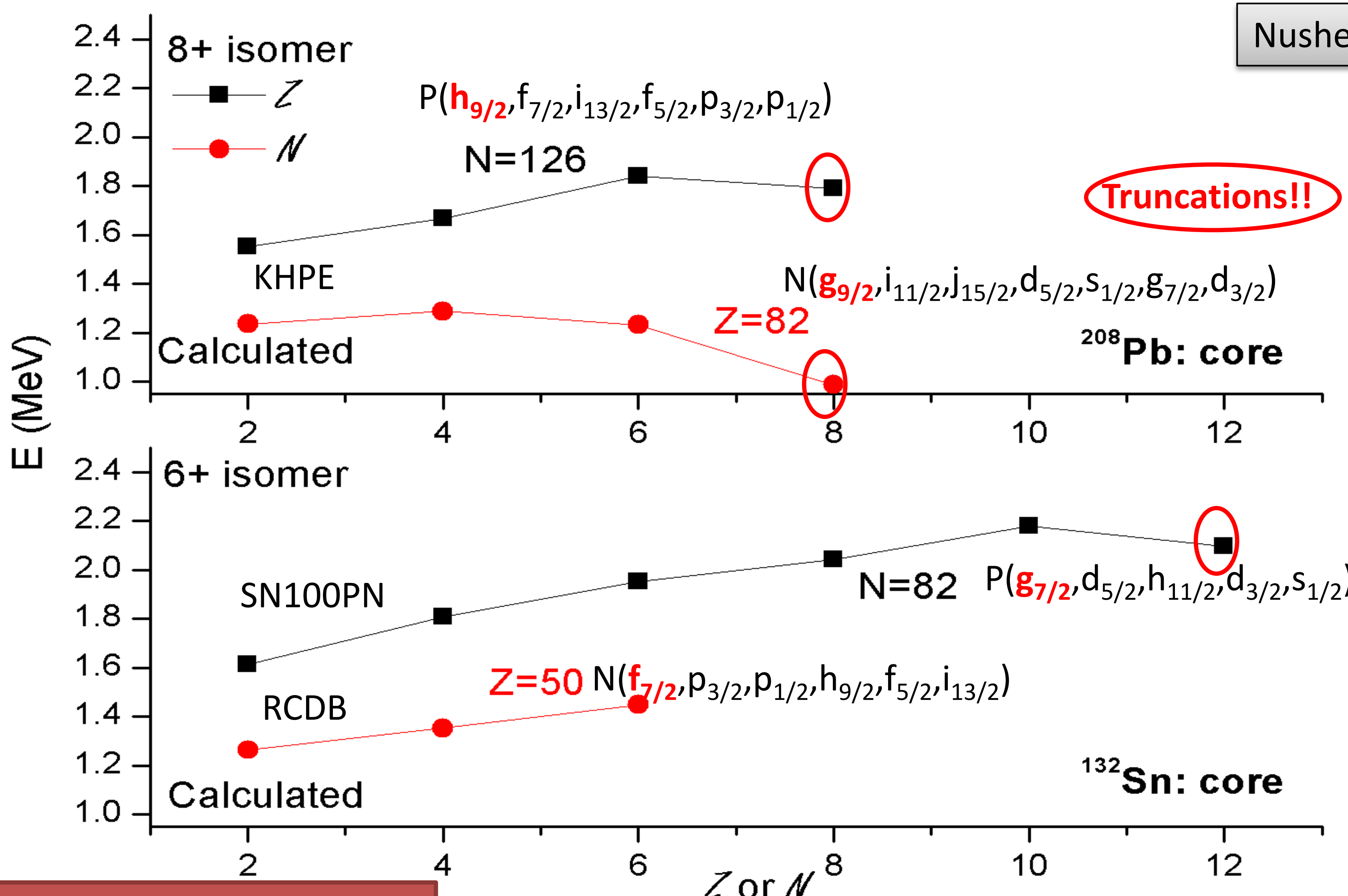
Large Scale shell model calculations

Nushell



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B(E2) values from Seniority scheme

$$B(EL) = \frac{1}{2J_i+1}\left|\left(J_f \left\| \sum_i r_i^L Y^{(L)}(\theta_{i,}\phi_i \right\| J_i \right)\right|^2$$

In single-j case, $\boxed{\Omega = \frac{1}{2}(2j+1)}$

$$\left\langle j^n v l J_f \left\| \sum_i r_i^L Y^{(L)}(\theta_{i,}\phi_i) \right\| j^n v l' J_i \right\rangle = \left(\frac{\Omega-n}{\Omega-v}\right)\left\langle j^v v l J_f \left\| \sum_i r_i^L Y^{(L)}(\theta_{i,}\phi_i) \right\| j^v v l' J_i \right\rangle$$

$$\left\langle j^n v l J_f \left\| \sum_i r_i^L Y^{(L)}(\theta_{i,}\phi_i) \right\| j^n, v\mp 2, l' J_i \right\rangle = \sqrt{\frac{(n-v+2)(2\Omega+2-n-v)}{2(2\Omega+2-2v)}}\left\langle j^v v l J_f \left\| \sum_i r_i^L Y^{(L)}(\theta_{i,}\phi_i) \right\| j^v, v\mp 2, l' J_i \right\rangle$$

It is easy to generalize these results for multi-j case with degenerate orbits by defining,

$$\tilde{j} = j \otimes j' \ldots \quad \boxed{\Omega = \frac{1}{2}\sum_j (2j+1)} \quad n = \sum_j n_j$$

$$\boxed{\begin{aligned} B(E2) &\propto \left(\frac{\Omega-n}{\Omega-v}\right)^2, \Delta v = 0 \\ B(E2) &\propto \frac{(n-v+2)(2\Omega+2-n-v)}{2(2\Omega+2-2v)}, \Delta v = 2 \end{aligned}}$$

B(E2) relations valid for single-j, and multi-j cases!!

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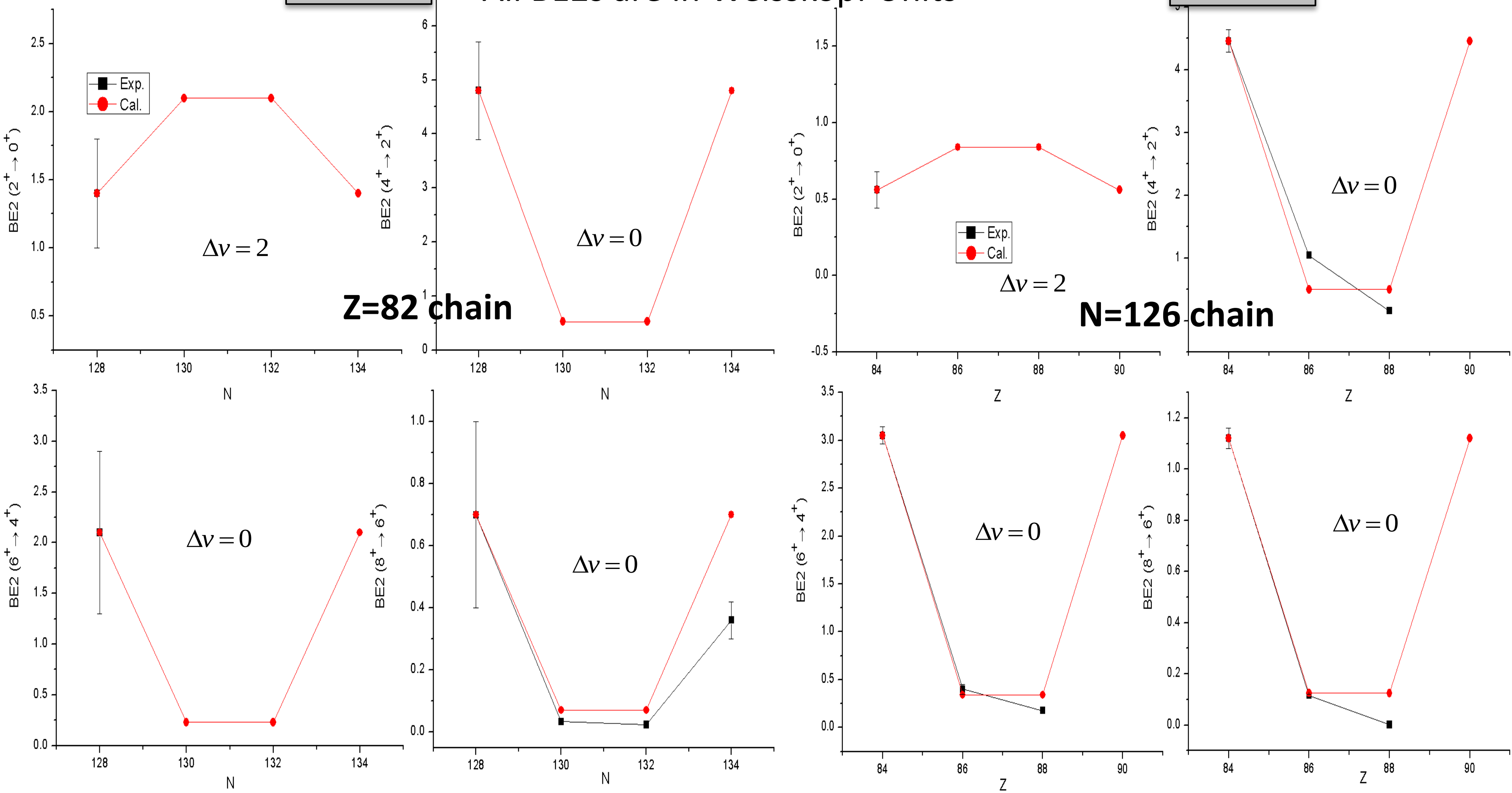
B(E2)s in Z=82 and N=126 chains – seniority

Single-j $g_{9/2}$

The role of same involved j=9/2 orbital
All BE2s are in Weisskopf Units

Single-j $h_{9/2}$



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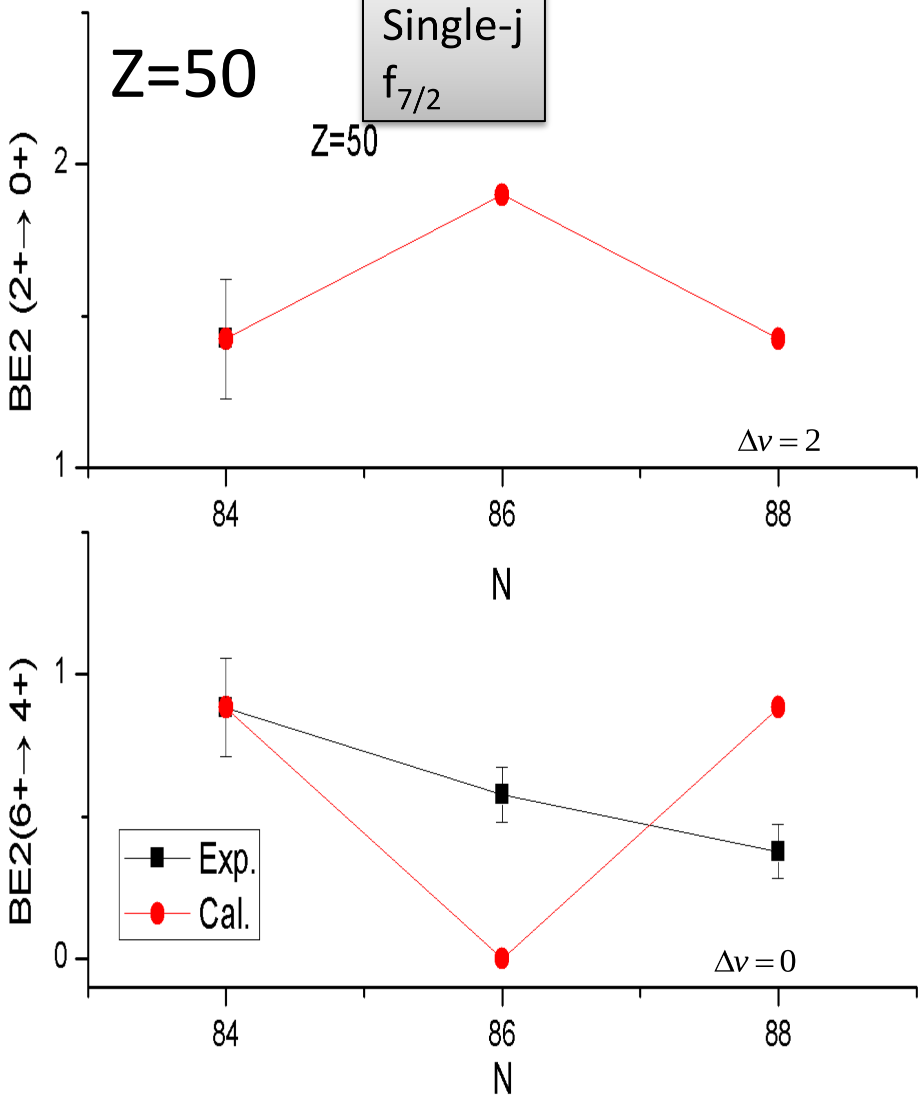
B(E2)s from seniority (single-j) and generalized seniority (multi-j)

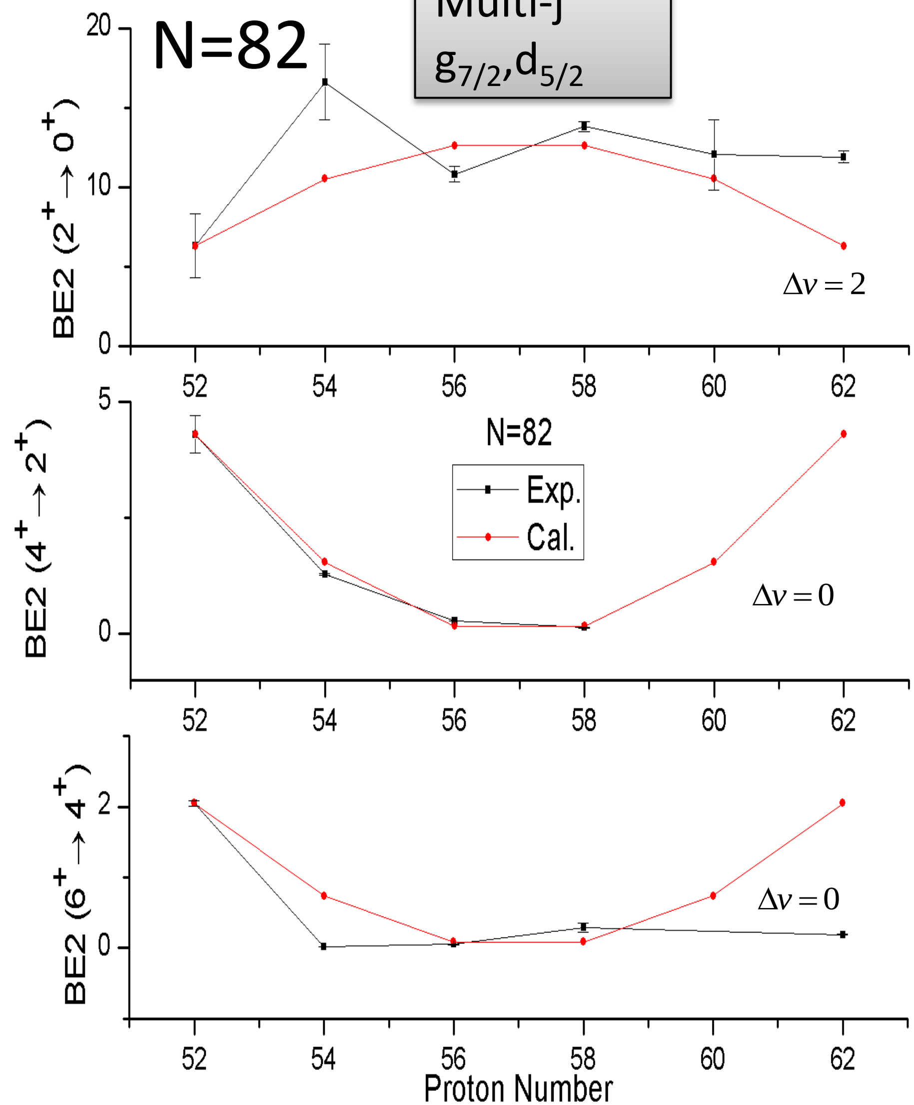
Z=50

Single-j
$f_{7/2}$



N=82

Multi-j
$g_{7/2}$,$d_{5/2}$



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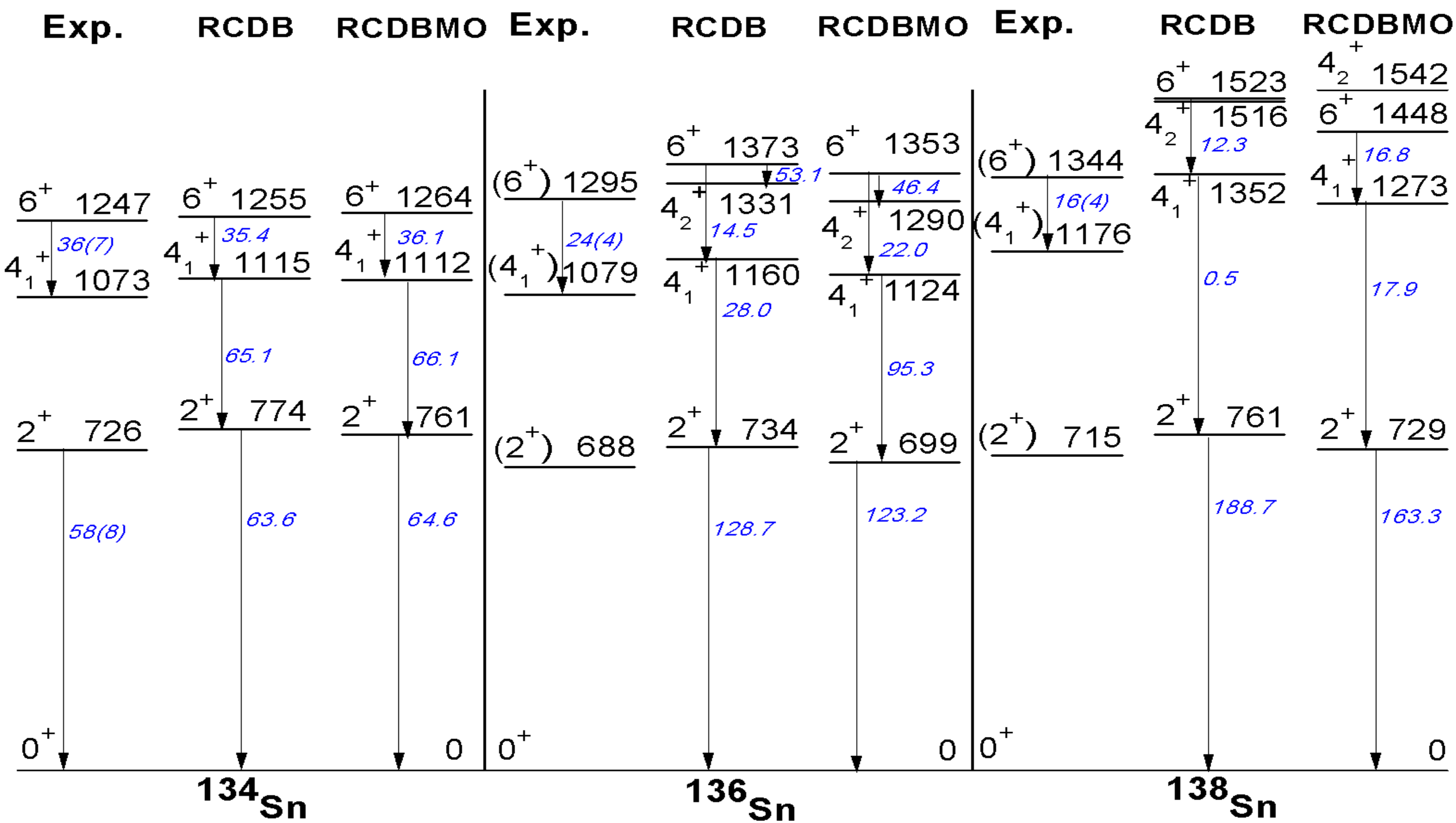
All BE2s are in Weisskopf Units

6^+ seniority isomers beyond ^{132}Sn

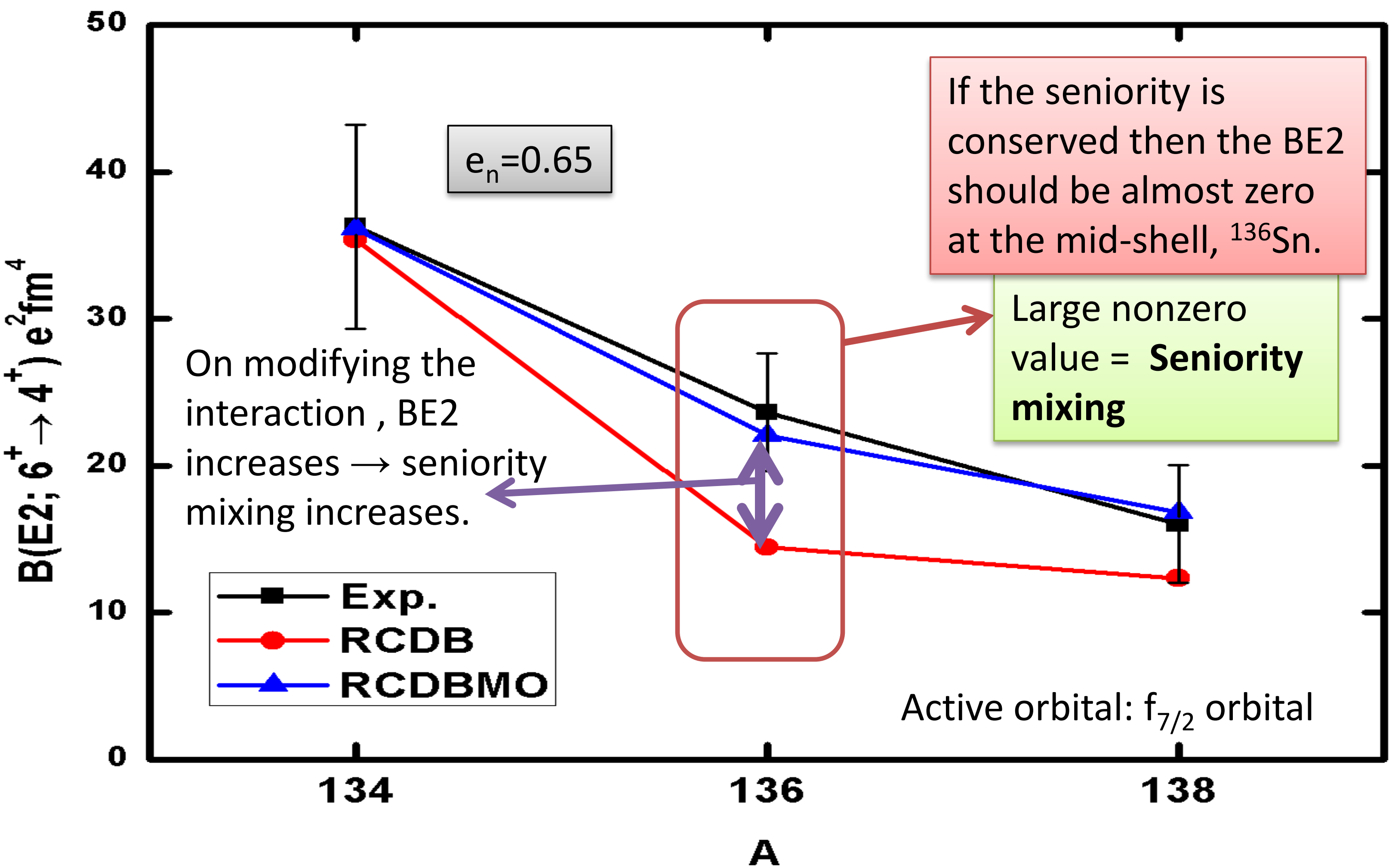
B. Maheshwari, A. K. Jain and P. C. Srivastava, Phys. Rev. C **91**, 024321 (2015)



Exp. Data: Simpson *et al.* Phys. Rev. Lett. 113, 132502 (2014), and references therein.

A small change in TBME & seniority mixing

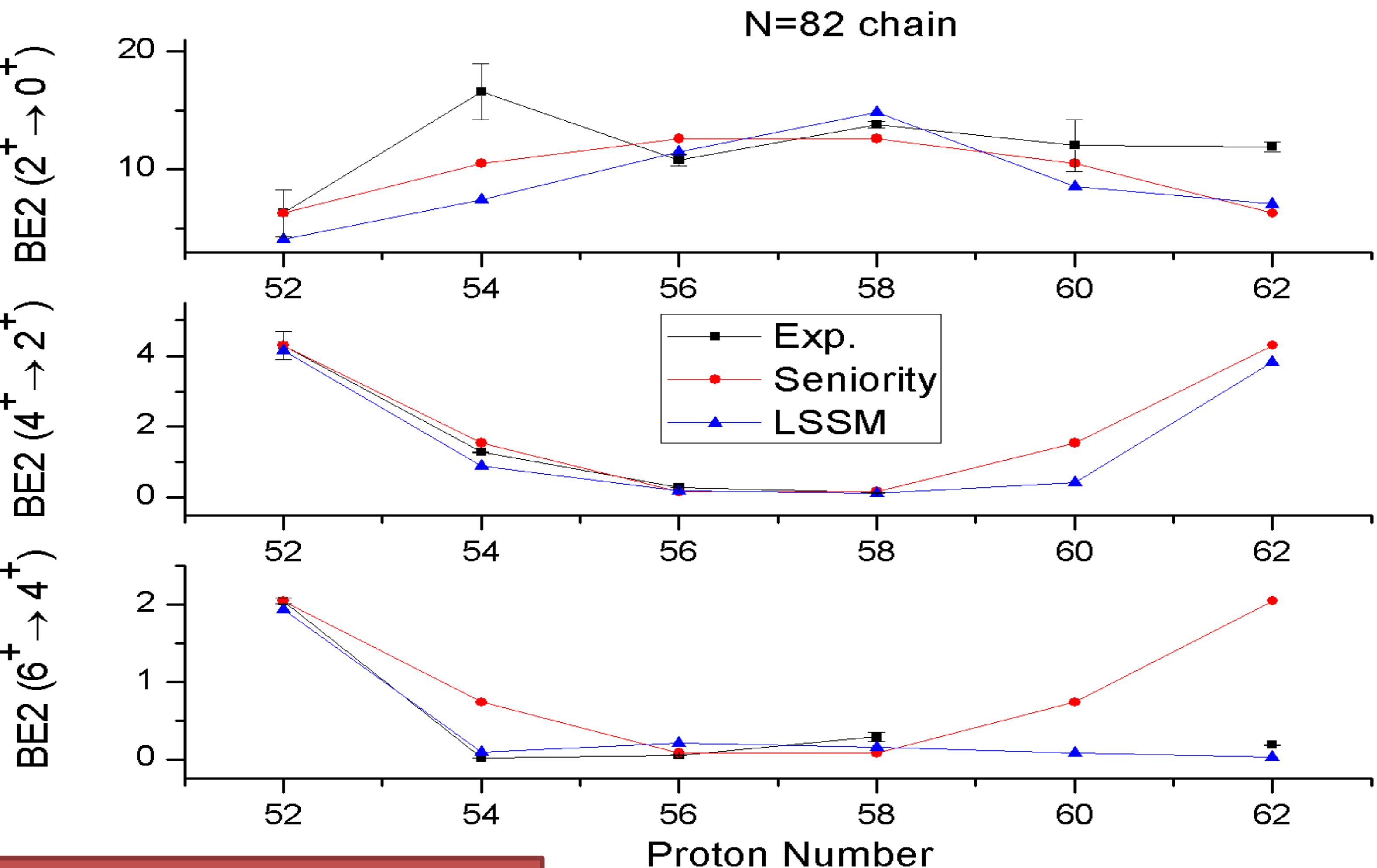
B. Maheshwari, A. K. Jain and P. C. Srivastava, Phys. Rev. C **91**, 024321 (2015)



RCDBMO: modified RCDB by reducing the diagonal and non-diagonal $\upsilon f_{7/2}^{2}$ TBME by 25 keV.

BE2s in the N=82: comparison with LSSM

e_p=1.5



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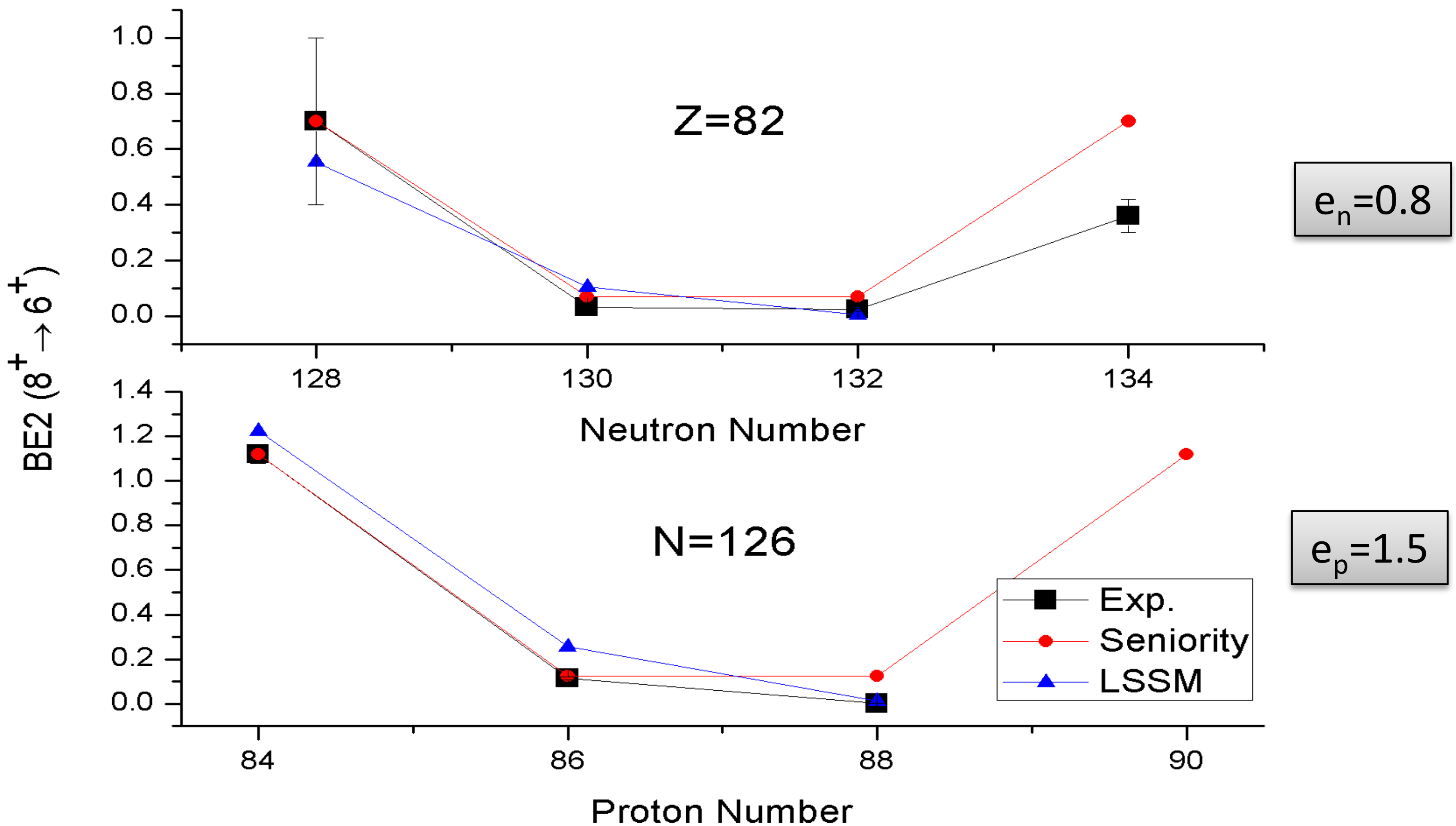
All BE2s are in Weisskopf Units

BE2s of the 8^+ isomers in the Z=82 and N=126 – comparison with LSSM



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All BE2s are in Weisskopf Units

Brief

- Atlas of nuclear isomers lists about 2469 isomers with a half-life $\geq$ 10 ns.
- Seniority isomers due to E2 transitions in various semi-magic chains have been studied.
- Their identical features have been understood on the basis of seniority.
- This simple scheme gives one a chance to explore the neutron-rich nuclei, as well as study their similarities and differences with the neutron-deficient ones.
- Possibility to explore the nuclear extremes.
- Large Scale shell model calculations help to validate these results.
- The inclusion of seniority mixing via a small change in TBME in n-rich Sn isomers is required.
- May help predict unknown B(E2)s and also unknown isomers.

Thank you !