A study of seniority-2 configurations in $N = 126$ and 124 isotonic chains

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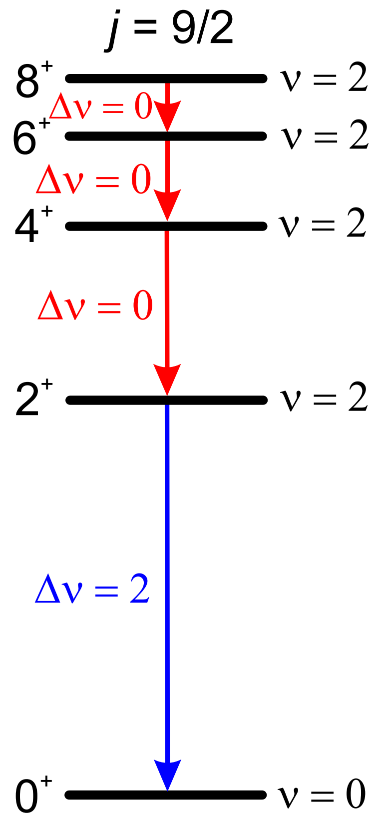
Physics case

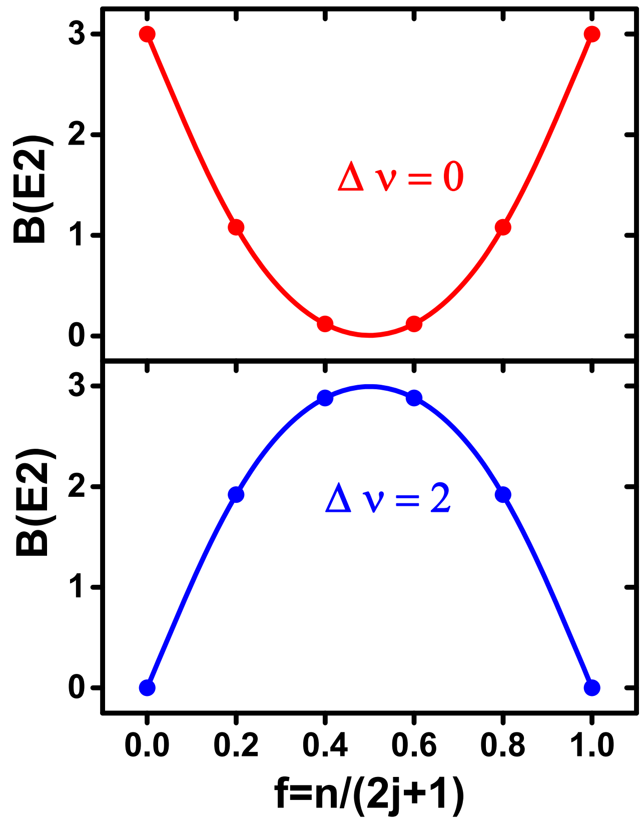
Low-energy excited states of even-even semi-magic nuclei, with more than two-particles in a single high-*j* shell, originate from angular momenta recoupling of unpaired nucleons and can be classified in multipletes that have one and the same number of unpaired nucleons - **seniority ν**

- The yrast states have seniority **ν = 2** and follow an energy pattern that is equivalent to the one for a j^2 configuration in which the energy spacing between the states decreases towards the state with maximum angular momentum.

- The absolute *E*2 transition strengths for the seniority-conserving transitions *J* → *J*-2 (*J* >4) decrease in a parabolic way with the filling of the *j*-shell and reaches a minimum at the middle of the *j*-shell.

- The absolute *E*2 transition strength for the seniority-changing transition $2^+_1(v=2) \rightarrow 0^+_1(v = 0)$ increases in a parabolic way with the filling of the *j*-shell and reaches a maximum at the middle of the j-shell.

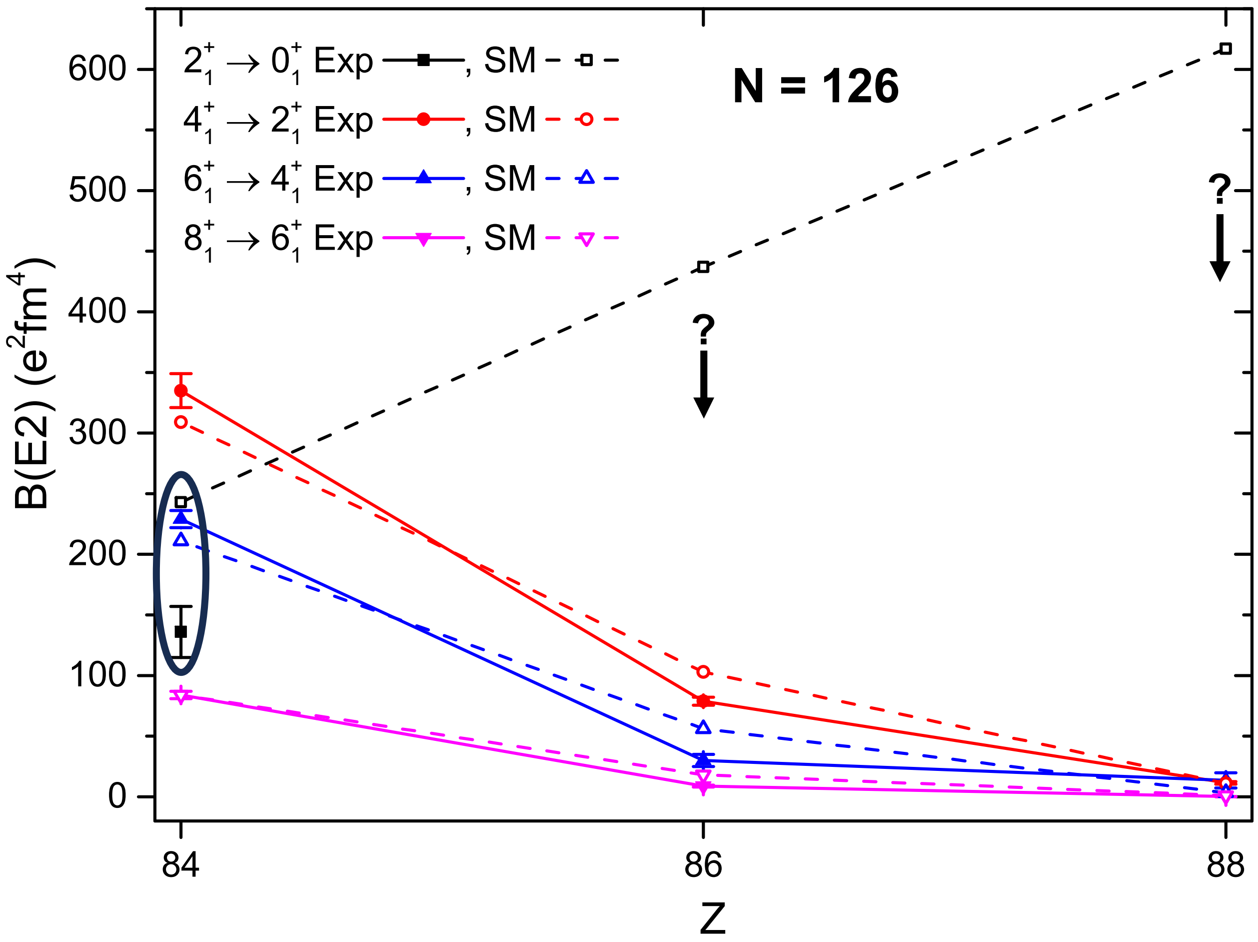




The features of the seniority scheme persist in open shell nuclei close to magic numbers in which low-energy excitations are dominated by one kind of nucleons.

N = 126 (^{210}Po – ^{212}Rn – ^{214}Ra)

Shell model: KHMY3, $0h_{9/2}$, $1f_{7/2}$, $0i_{13/2}$, $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$ for both protons and neutrons, KSHELL



Both the available experimental data (including the energy pattern of yrast states) and the shell model calculations suggest that the yrast states of ^{210}Po, ^{212}Rn and ^{214}Ra are seniority type of excitations

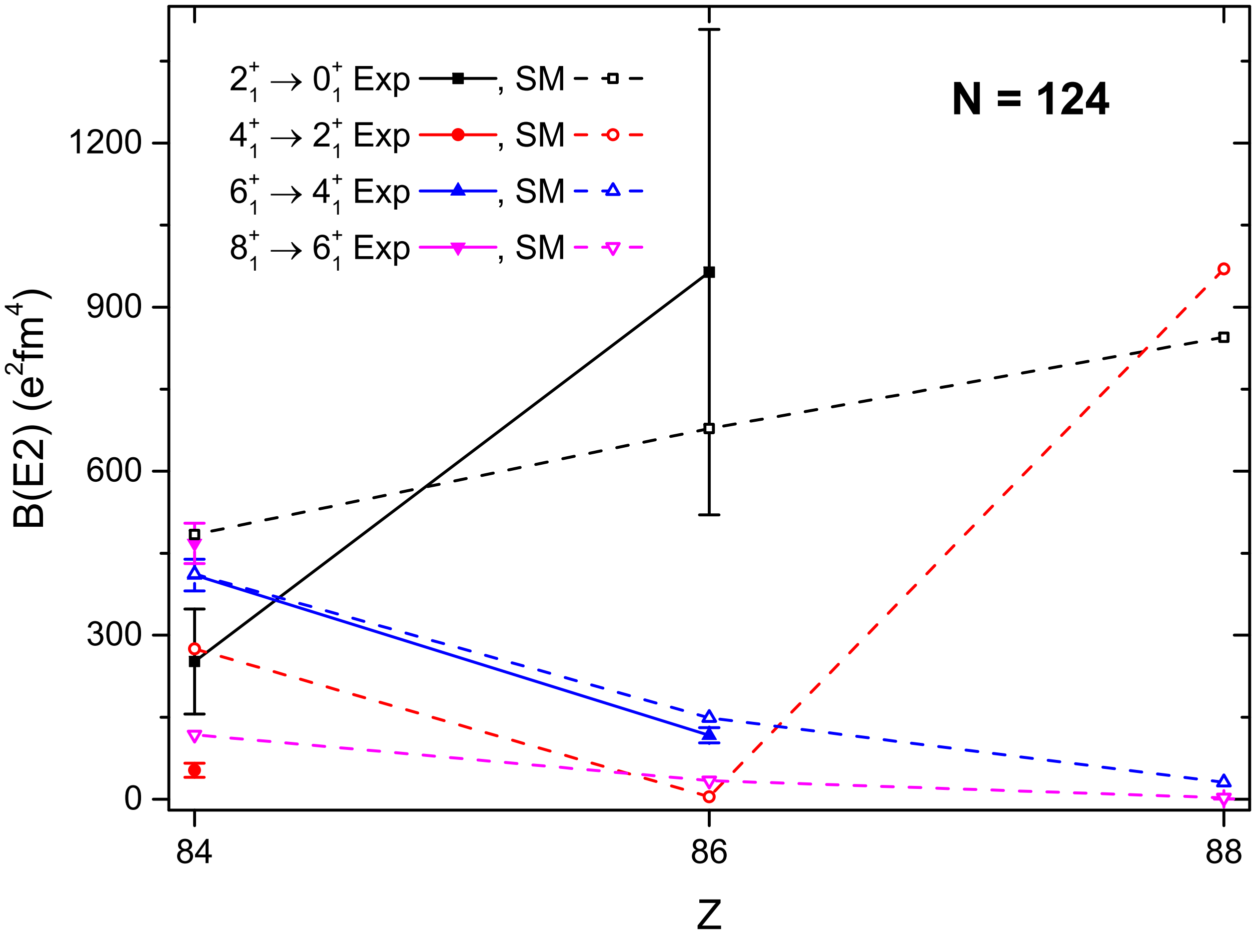
BUT

Can the shell model calculations <u>quantitatively</u> reproduce the evolution of the $B(E2;2^+_1 \rightarrow 0^+_1)$ values?

The experimental $B(E2;2^+_1 \rightarrow 0^+_1)$ values in ^{212}Rn and ^{214}Ra need to be measured!

N = 124 (^{208}Po – ^{210}Rn – ^{212}Ra)

Shell model: KHMY3, $0h_{9/2}$, $1f_{7/2}$, $0i_{13/2}$, $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$ for both protons and neutrons, KSHELL



Can we make any conclusions on the nature of yrast states in these nuclei or on the quality of the shell model calculations?

NO!

- The 6^+ and the 8^+ behave like seniority excitations.
- The calculated $B(E2;4^+_1 \to 2^+_1)$ decreases from ^{208}Po to ^{210}Rn (seniority) but then dramatically increases in ^{212}Ra (?).
- The calculated $B(E2;2^+_1 \to 0^+_1)$s increase but no quantitative comparison to experimental data is possible.

The experimental $B(E2;2^+_1 \to 0^+_1)$ values in ^{210}Rn and ^{212}Ra need to be precisely measured and reliable upper limits for the $B(E2;4^+_1 \to 2^+_1)$ needs to be determined.

RIB production from ISOLDE and experimental details

TACs comments: reduce the total transmission efficiency from 5% to 2.8% and reduced the proton current from 2 uA to 1.5 uA ⇒ a factor of 2 – 3 reduction of the beam intensity at Miniball

^{214}Ra & ^{212}Ra experiment: ThCx target

- ^{214}Ra(13 s) (^{214}Fr (5 ms) suppressed) ~3.8 p/μC + RILIS ionization scheme ⇒ 2×10^4 pps at 4.5 MeV/u at Miniball.
- ^{212}Ra (24 m) (^{212}Fr(20 m)) ~3.8 p/μC + extract ^{212}RaF ⇒ 10^4 pps at 4.5 MeV/u at Miniball.

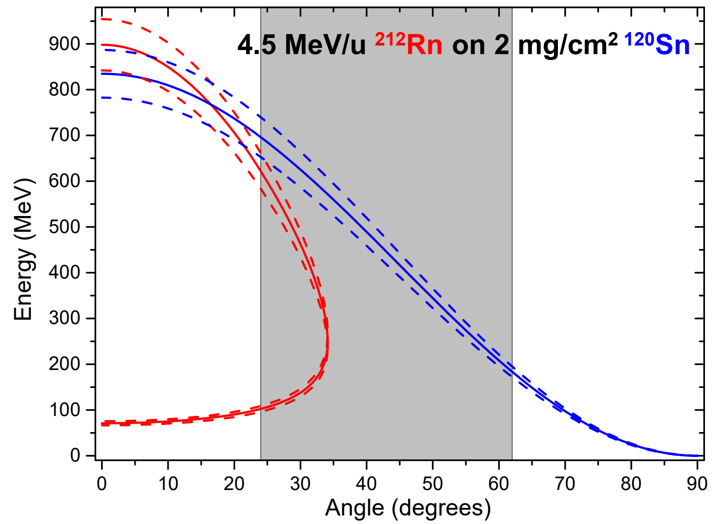
TACs comments: the beams are possible, switching from ^{214}Ra to ^{212}Ra is possible (1 shift).

^{212}Rn & ^{210}Rn experiment: UCx or ThCx target + cold plasma ion source VD7

TACs comments: the beams have been delivered to Miniball before with intensitity of 10^7 – 10^6 pps ⇒ we have assumed 5×10^5 pps at 4.5 MeV/u.

Experimental set-up – Miniball + DSSD

- Target 2 mg/cm^2 ^{120}Sn.
- Reaction – safe Coulomb excitation.
- Beam energy 4.5 MeV/u.
- DSSD at 20 mm behind the target ⇒ useful angular coverage 27° - 62°.



Count rate estimates

^{214}Ra case: physics goal – measure the $B(E2;\, 2^+ \rightarrow 0^+)$ value
Beam intensity – 2×10^4 pps
$E_\gamma(2^+ \rightarrow 0^+)$ = 1382 keV
$B(E2;\, 2^+ \rightarrow 0^+)$ = 308 e^2fm^4 (a half of the SM value)

γs/shift	γs/2day
35	210 (7%)

^{212}Ra case: physics goal – measure the $B(E2;\, 2^+ \rightarrow 0^+)$ value and estimate ($B(E2)$ < X) the $B(E2;\, 4^+ \rightarrow 2^+)$
Beam intensity – 10^4 pps
$E_\gamma(2^+ \rightarrow 0^+)$ = 629 keV
$B(E2;\, 2^+ \rightarrow 0^+)$ = 422 e^2fm^4 (a half of the SM value)
$E_\gamma(4^+ \rightarrow 0^+)$ = 825 keV
$B(E2;\, 4^+ \rightarrow 2^+)$ = 485 e^2fm^4 (a half of the SM value)

	γs/shift	γs/day	γs/3 days
$2^+ \rightarrow 0^+$	235	705 (4%)	2115(2%)
$4^+ \rightarrow 2^+$	4	12(30%)	36(17%)

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^{210}Rn case: physics goal – measure the $B(E2;\, 2^+ \rightarrow 0^+)$ value and estimate ($B(E2)$ < X) the $B(E2;\, 4^+ \rightarrow 2^+)$
Beam intensity – 5×10^5 pps
$E_\gamma(2^+ \rightarrow 0^+)$ = 644 keV
$B(E2;\, 2^+ \rightarrow 0^+)$ = 520 e^2fm^4 (lower experimental limit)
$E_\gamma(4^+ \rightarrow 0^+)$ = 818 keV
$B(E2;\, 4^+ \rightarrow 2^+)$ = 5 e^2fm^4 (the SM value)

	γs/shift	γs/day	γs/4 days
$2^+ \rightarrow 0^+$	15120(0.8%)		
$4^+ \rightarrow 2^+$	3	9	36(17%)

Beam intensity 1.6×10^5 pps 12

Beam-time request

Run 1 (^{214}Ra & ^{212}Ra)

- 1 shift for tunning ^{214}Ra beam (RILIS).
- 6 shifts for data taking, ^{214}Ra.
- 1 shift for switching to ^{212}RaF (TAC).
- 1 shift for tunning ^{212}Ra.
- 9 shifts for data taking, ^{212}Ra.

In total: 18 shifts

Run 2 (^{210}Rn)

- 1 shift for tunning ^{210}Rn.
- 12 shifts for data taking, ^{210}Rn.

In total: 13 shifts