The 7th workshop on nuclear mass table with DRHBc theory

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Progress Report for nuclear region with $Z = 127, 128$

Speaker: Xiao Lu (陆晓)

Collaborators: Lu-Qi Li (李路琦), Xue-Wei Li (李雪薇), Hao Lu (陆浩), Zhan-Jiang Lian (连占江)
Yong-Jing Chen (陈永静), Ying-Xun Zhang (张英逊), Shan-Gui Zhou (周善贵)

Institute of Theoretical Physics, Chinese Academy of Sciences & Center for Theoretical Physics, China Institute of Atomic Energy

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Calculation Progress

DRHBc Calculations	Neutron (N)	$Z = 127$	$Z = 128$
Unconstrained	Odd-N	🔴	🟡
	Even-N	🟡	🔴
Constrained	Odd-N	🟡	○
	Even-N	○	🟡

🔴 Completed

🟡 In progress

○ Preparing to start

- $\boldsymbol{Z = 127}$ Odd-N: Xiao Lu (陆晓), ITP, CAS; Even-N: Xue-Wei Li (李雪薇), CIAE
- $\boldsymbol{Z = 128}$ Odd-N: Lu-Qi Li (李路琦), CIAE; Even-N: Hao Lu (陆浩), CIAE

Numerical details

- Density functional: PC-PK1
- Version: Code_DRHBc_202401
- Box size: $R_{\mathrm{box}} = 20\ \mathrm{fm}$
- Mesh size: $\Delta r = 0.1\ \mathrm{fm}$
- Energy cutoff: $E_{\mathrm{cut}} = 300\mathrm{MeV}$
- Angular momentum cutoff: $J_{\max} = 23/2\ \hbar$
- Pairing strength: $V_0 = -325\ \mathrm{MeV} \cdot \mathrm{fm}^3$
- Legendre expansion order: $\lambda_{\max} = 10$
- Initial deformation $\beta_2 = -0.4, -0.2, \dots, 0.4, 0.6$

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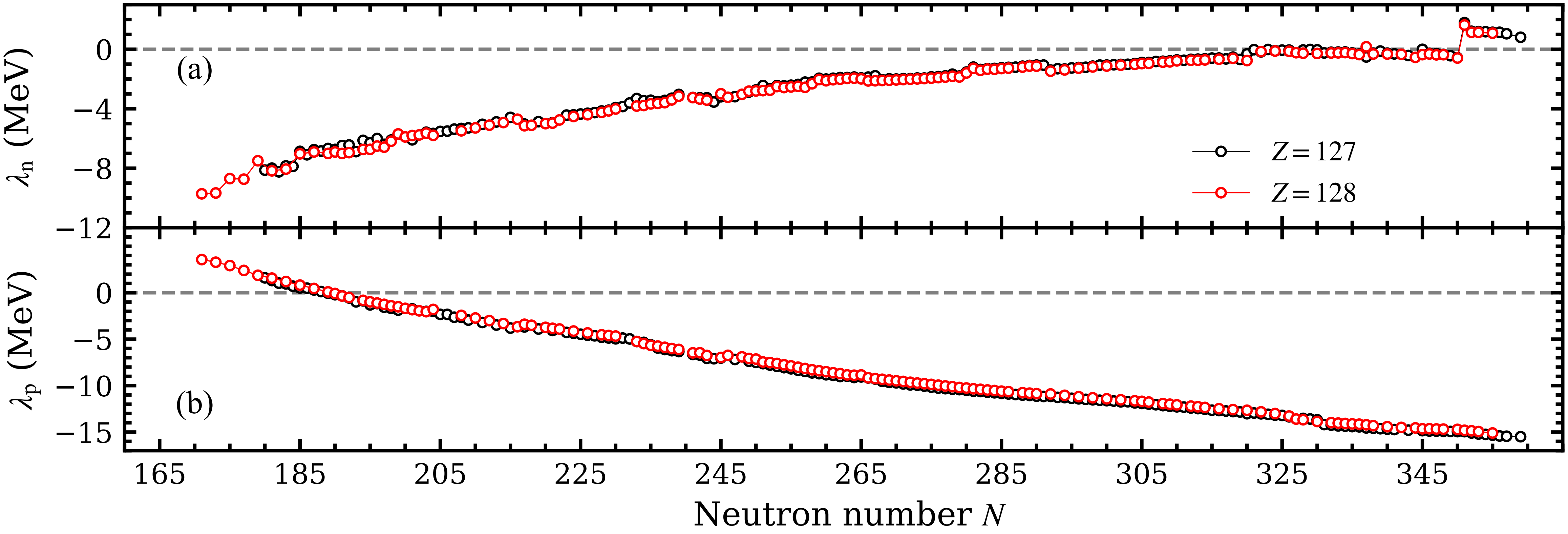
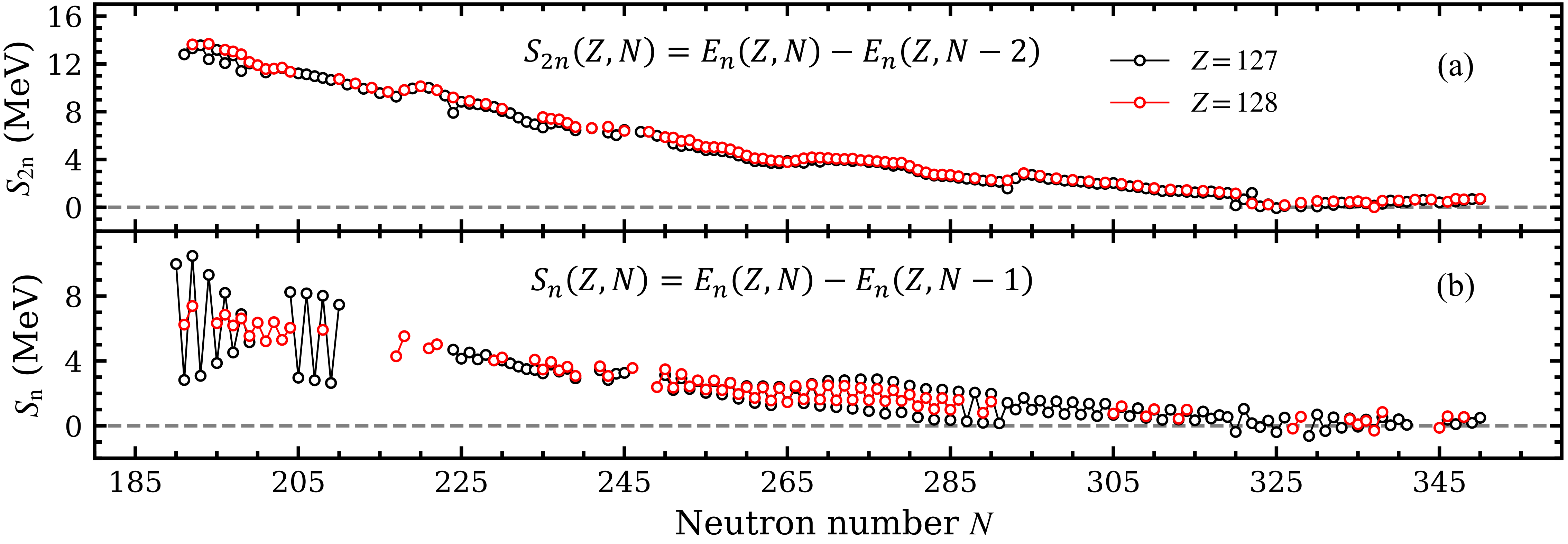
Fermi Energy



- 323 nuclei satisfy both $\lambda_n < 0$ and $\lambda_p < 0$.
- $Z = 127$: $189 \leq N \leq 350$
- $Z = 128$: $190 \leq N \leq 350$

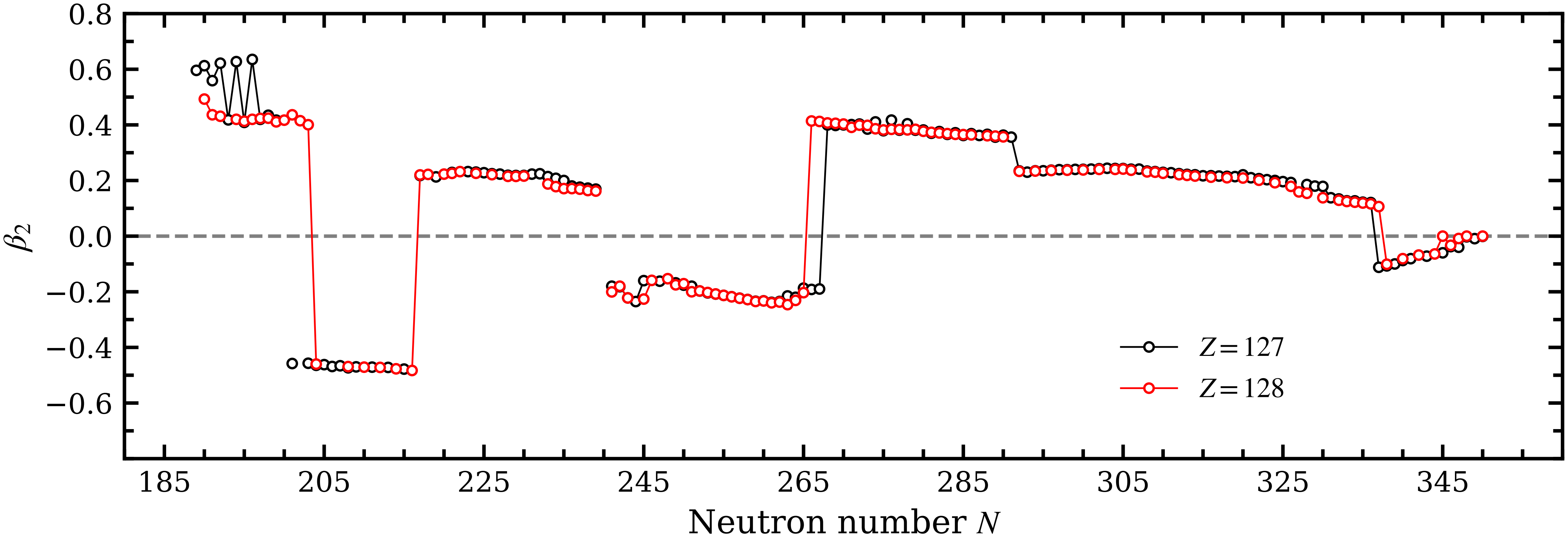
One & Two Neutron Separation Energy



- For both isotopic chains, significant odd-even staggering exists in S_n.
- In the neutron-rich region, nuclei are weakly bound against two-neutron or one-neutron emission, and even some unbound nuclei exist (≥11 nuclei).

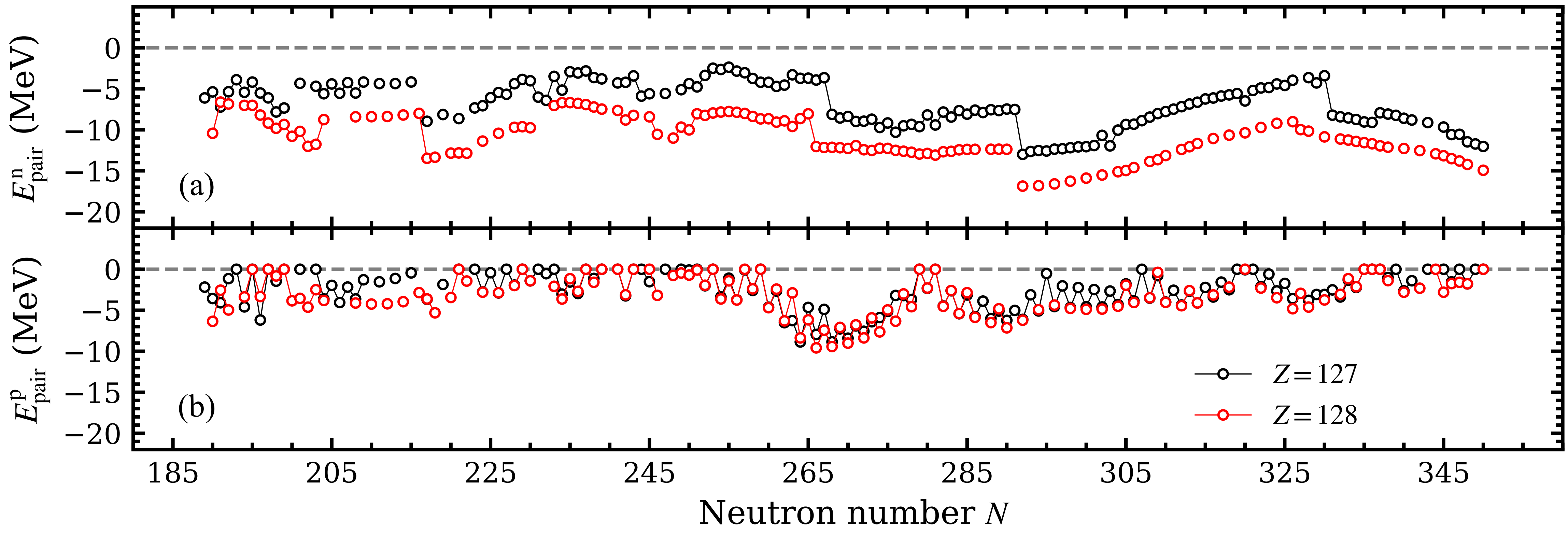
➢ Current calculation results indicate the number of bound nuclei is less than 312.

Quadrupole deformation



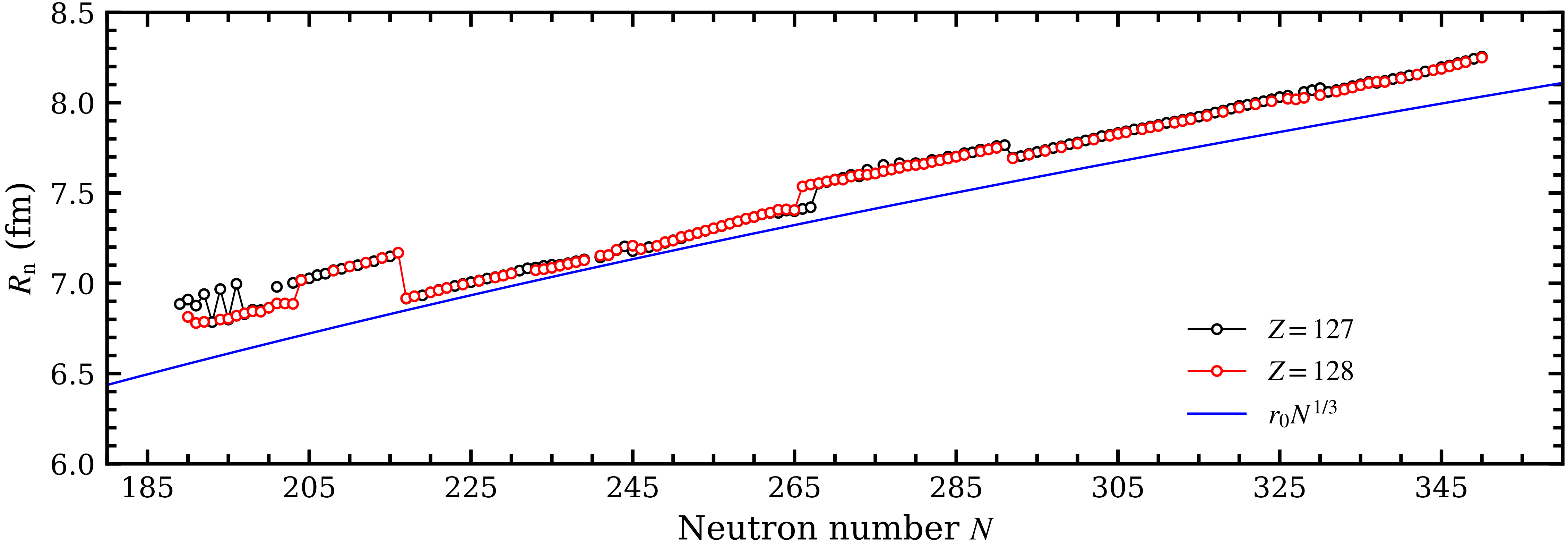
- Most nuclei exhibit prolate shapes.
- As the number of neutrons increases, the quadrupole deformation parameter gradually approaches zero.

Pairing Energy



- The odd-even staggering has been observed in $E^{\mathrm{n}}_{\mathrm{pair}}$, which is caused by the unpaired particle.
- The sudden changes in $E^{\mathrm{n}}_{\mathrm{pair}}$ are related to the changes in deformation.
- $E^{\mathrm{p}}_{\mathrm{pair}}$ is close to zero or even vanish.

Neutron rms radii

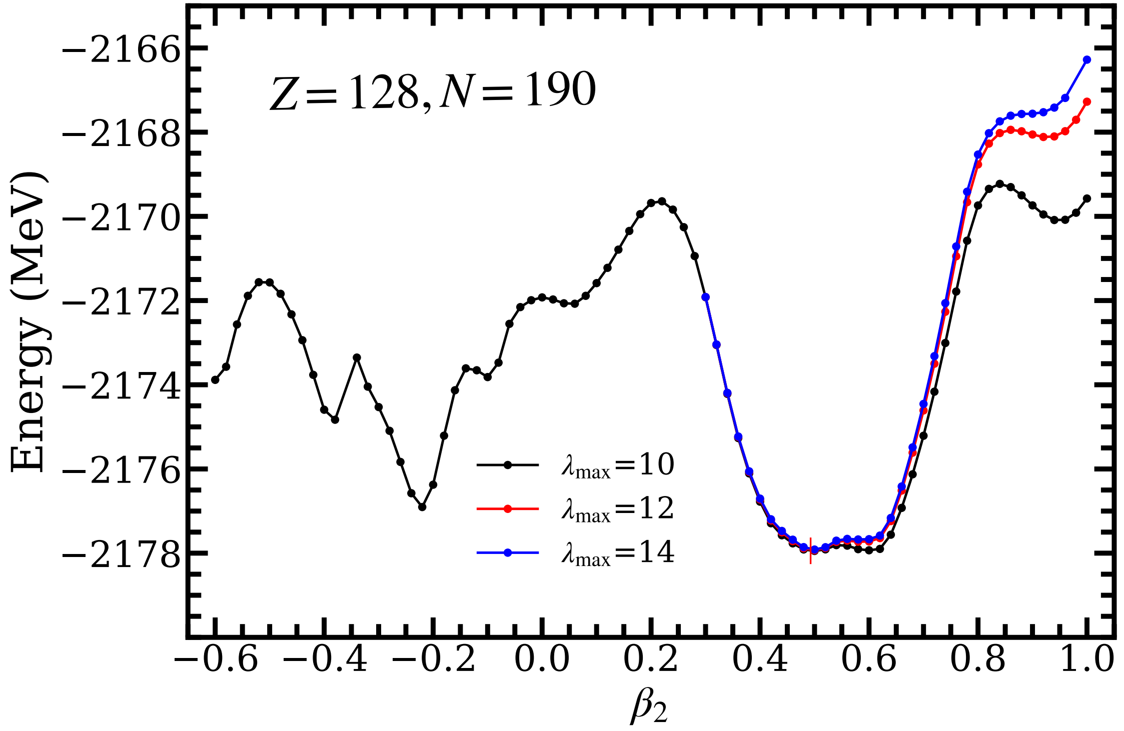


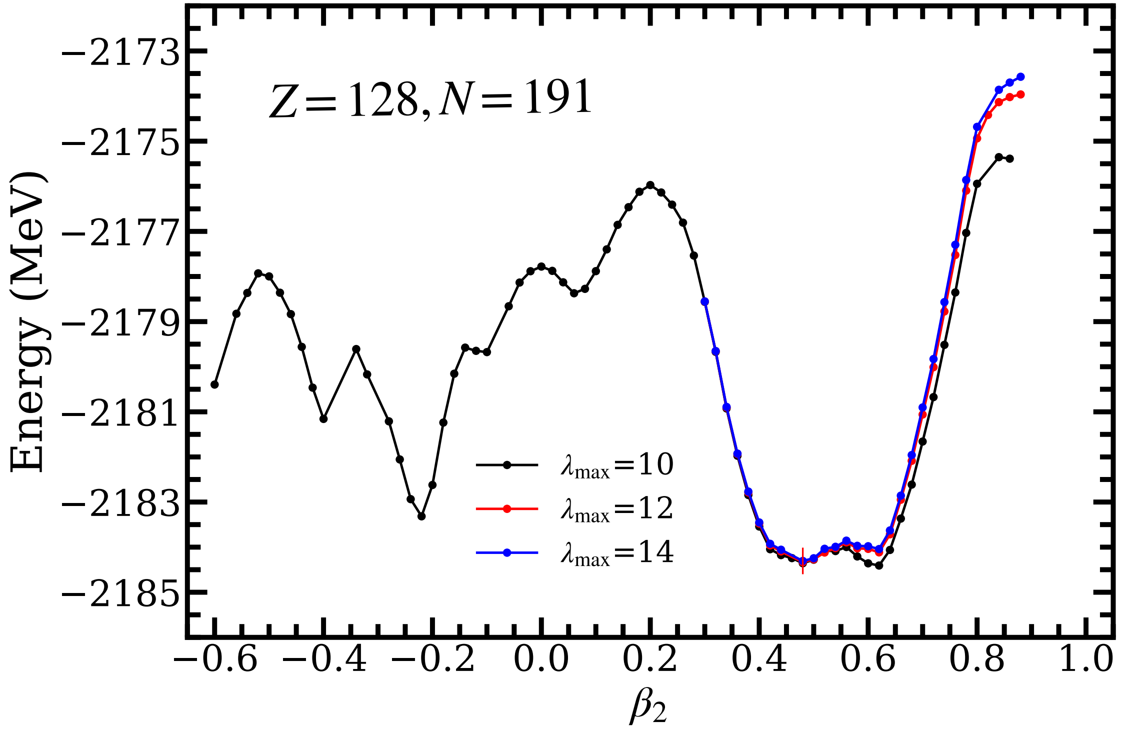
$r_0 = 1.140$ fm [1]

- The systematic trend of the neutron radii can be roughly described by the empirical formula.
- The sudden changes in R_n are related to the changes in deformation.

[1] P. Guo, X. Cao, et al., At. Data Nucl. Data Tables 158, 101661 (2024).

Potential energy curve





- For neutron-deficient atomic nuclei, the Legendre expansion truncations up to 12 may be necessary to obtain the stable results.

Summary

Summary

- Unconstrained DRHBc calculations for $Z = 127$ and $Z = 128$ isotopic chains are almost completed.
- Almost 312 bound nuclei are predicted.
- The Legendre expansion truncations with $\lambda_{\max} = 10$ may not be sufficient to obtain the ground sate of neutron-deficient atomic nuclei; conducting higher truncation is suggested to test the convergence.

Next step

- Perform constrained calculations to construct potential energy curves, in order to further check the results.

Thank you for your attention!

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