3 - 14 Mass Measurement of Upper fp-shell $N=Z-2$ and $N=Z-1$ Nuclei and the Importance of Three-nucleon Force Along $N=Z$ Line*

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By using the $B\rho$-defined isochrounous mass spectrometry[1], we have measured a series of $N=Z-2$ and $N=Z-1$ nuclei far from the valley of stability, among which the masses of ^{62}Ge, ^{66}Se, and ^{70}Kr are measured for the first time. Employing our new mass data, we extend for the first time $\delta V_{\rm pn}$ for $N=Z$ nuclei up to $Z=37$, shown in Fig. 1. As can be seen, $\delta V_{\rm pn}$ for $Z>28$ even-even nuclei decreases with increasing mass number A, which seems to be in conflict with pseudo-$SU(4)$ symmetry assumption[2]. However, $\delta V_{\rm pn}$ for odd-odd nuclei increases with increasing A, which suggests the restoration of pseudo-$SU(4)$ symmetry. If pseudo-$SU(4)$ symmetry does exist, the $\delta V_{\rm pn}$ values for even-even and odd-odd nuclei should be increasing synchronously. Moreover, the mechanism of either overlaps of proton-neutron wave-functions or nuclear deformation can not cause different $\delta V_{\rm pn}(A)$ trends between odd-odd and even-even nuclei.

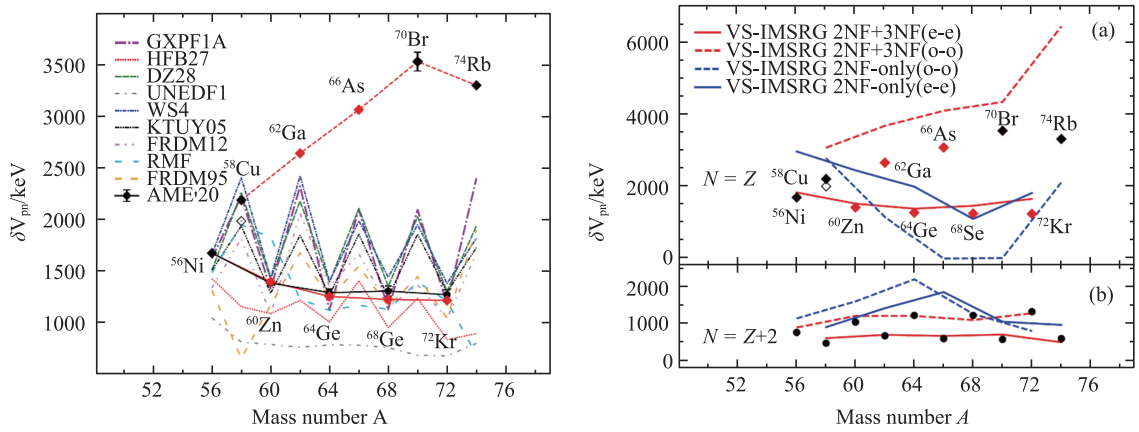

Fig. 1 (color online) The left panel: the experimental $\delta V_{\rm pn}$ for $N=Z$ nuclei beyond $A=56$ (symbols) comparing to different mass model predictions (lines). Red lines connecting symbols are to guide the eye. Red symbols indicate that one of the masses from this work is used. The open diamond marker means that $\delta V_{\rm pn}$ of ^{58}Cu is calculated using the binding energy of the $T=1$, $J^{\pi}=0^{+}$ excited state. The right panel: the experimental $\delta V_{\rm pn}$ for (a) $N=Z$ and (b) $N=Z+2$ nuclei beyond $A=56$ (symbols) comparing to the *ab initio* calculations (lines). Data uncertainties are within the size of the symbols. $\delta V_{\rm pn}$ values from *ab initio* calculations using 2NF+3NF and 2NF-only are plotted as red and blue lines (solid for even-even and dashed for odd-odd), respectively.

In order to understand the observed bifurcation of the $\delta V_{\rm pn}(A)$ trends, we have performed *ab initio* valence-space in-medium similarity re-normalization group (VS-IMSRG) calculation using a chiral interaction with two-nucleon force (2NF) at N^{3}LO and three-nucleon force (3NF) at N^{2}LO. As shown in Fig. 2, theoretical calculations can not reproduce the experimental $\delta V_{\rm pn}$ for $N=Z+2$ and $N=Z$ nuclei by using only two-nucleon force. However, our calculations with 3NF included reproduce excellently experimental $\delta V_{\rm pn}$ values for $N=Z+2$ nuclei. Calculations reproduce $\delta V_{\rm pn}$ for $N=Z$ even-even nuclei fairly well, while slightly overestimate $\delta V_{\rm pn}$ for odd-odd nuclei. More importantly, the bifurcation can be well described by VS-IMSRG with 3NF included. More discussions can be found in the upcoming publication[3].

References

[1] M. Wang, Phys. Rev. C, 106(2022)L051301.
[2] P. Van Isacker, Phys. Rev. Lett., 82(1999)2060.
[3] M. Wang, Phys. Rev. Lett., 40, 2(2023)181.

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