Shape transition and coexistence in Te isotopes studied with the quadrupole collective Hamiltonian based on a relativistic energy density functional

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Motivation

From collective perspectives, nuclear structure gradually, or abruptly increases its collectivity towards the mid-shell region, resulting in various deformation. Especially near the major shell closure, distinct intrinsic shapes can mix within a finite nucleus under the influence of intruder states, which is corresponding to 2p-2h excitation. This peculiar phenomenon is called shape coexistence.

In the case of Cd (Z=48) and Sn (Z=50) isotopes, experiments have shown the significant role of intruder states built on the 0_2^+ state. Thus, it is of much interest to study whether the phenomenon persists to Te (Z=52) within universal and full-configurational self-consistent mean-field framework based on energy density functional theory.

Framework

Ground-state properties and collective potential can be calculated with SCMF framework which employs the relativistic Hartree-Bogoliubov method.

We mainly employed DD-PC1 interaction for p-h channel[58], which cause nuclear deformation.

For p-p channel, paring part of finite-range Gogny force with separate modification has been chosen[60].

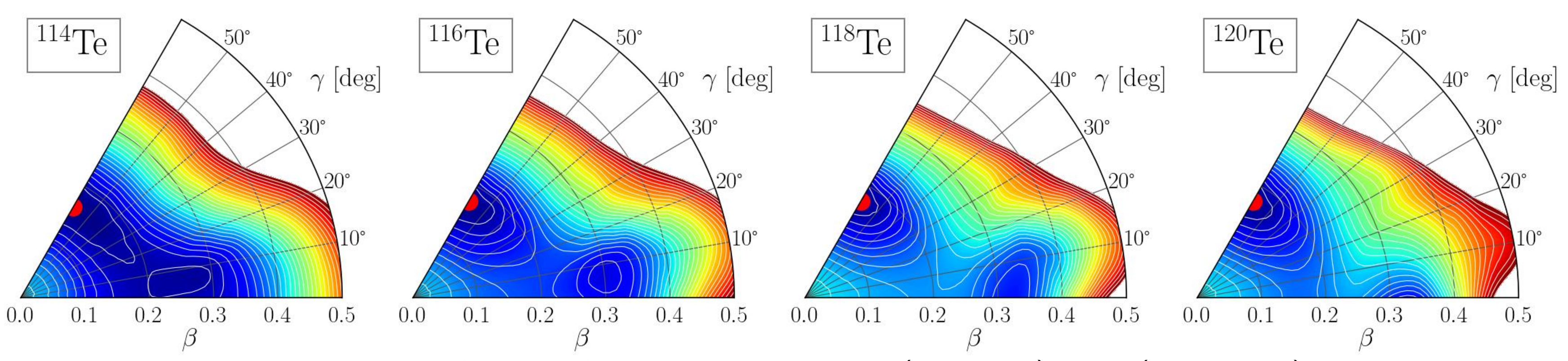
Excited-state properties can be obtained through diagonalization of quadrupole collective Hamiltonian:

$$\hat{H}_{\text{coll}} = \hat{T}_{\text{vib}} + \hat{T}_{\text{rot}} + V_{\text{coll}}$$

*The moment of inertia involved in kinetic parts are evaluated using Inglis-Belyaev (IB) formula[63, 64], and the mass parameters are approximated by cranking formula.

Mean-field results

Mean-field energy surfaces

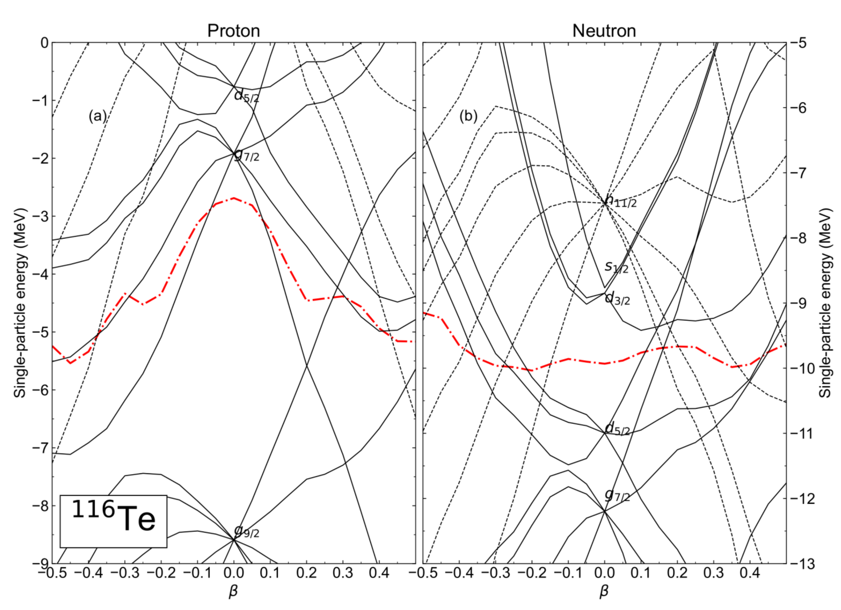


The presence of local minima on $(\beta, \gamma) = (0.3, 7)$ hints the intruder low-lying 0^+ state.

Single particle energies

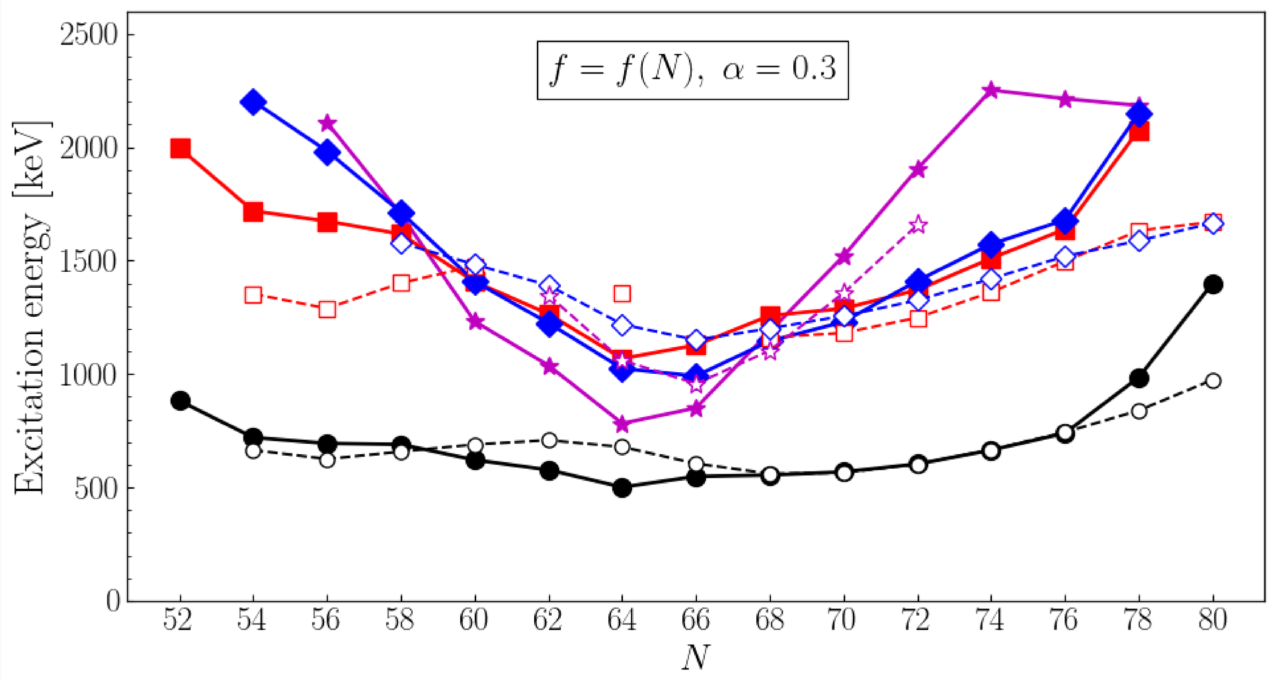
In proton/neutron energies, the density around ε_F at β =-0.2/0.3 is relatively low.

They can be related to the oblate/prolate global/local minimum in PES, respectively.



Spectroscopic results

Excited energy spectrum



Successfully reproduces the parabolic behavior.

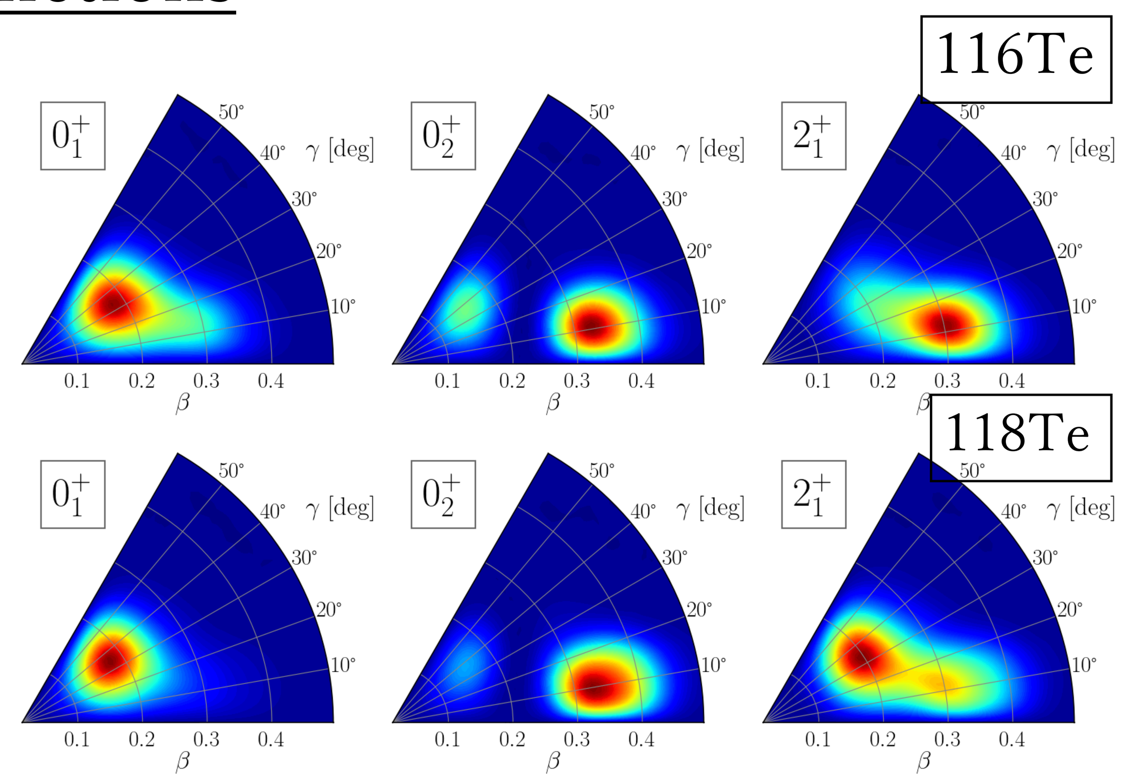
The lower estimation of 0_2^+ state can indicate the overestimation of shape-mixing.

FIG. 3. low-lying energy spectrum for the Te isotopic chain. Paring strength is now a function of N [62], and moment of inertia are increased by 30% to supplement the empirical discrepancy of IB formula.

Collective wave functions

For both nuclei, we can clearly associate the prolate- or oblate-side states with mean-field PES minima.

Presumably 2_1^+ of 116Te is constructed on prolate intruder configuration.



Electric transition ratios

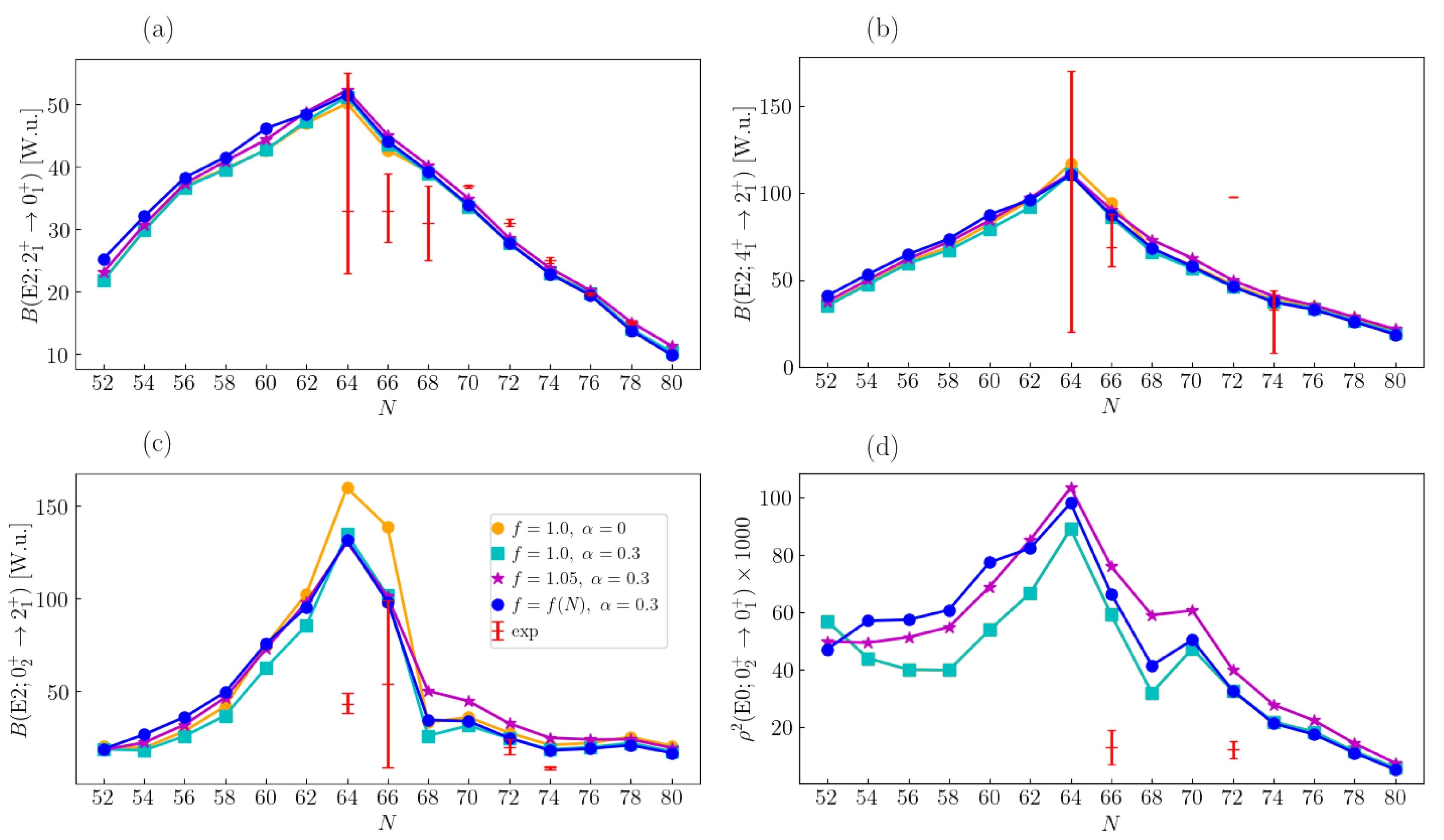


FIG. 5. (a) $B(E2; 2_1^+ \to 0_1^+)$, (b) $B(E2; 4_1^+ \to 2_1^+)$, (c) $B(E2; 0_2^+ \to 2_1^+)$ (d) $\rho^2(E0; 0_2^+ \to 0_1^+)$ values for Te isotopic chain.

Interband transition ratios, indicators of shape mixing and evolution of collectivity, are generally large near the mid-shell nuclei.

Summary

- By analyzing the intrinsic shape evolution and spectroscopic observables, we predict the occurrence of shape coexistence around neutron mid-shell region (116-118Te) theoretically.
- The lower estimation of 0_2^+ state opens a further challenge to our framework, possibly stems from the overestimation of the effect of shape mixing.