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LETTER TO THE EDITOR

BACKBENDING IN ^{28}Si FROM CRANKED *HFB* CALCULATION

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We report here a cranked Hartree-Fock-Bogoliubov calculation for the ground state rotational band of ^{28}Si using pairing plus quadrupole-quadrupole force as the residual interaction. The calculated energy levels agree well with a recent experiment by Kubono et al. indicating the applicability of *PPQ* force in light nuclei. A strong backbend at 10^+ appears both experimentaly and theoretically.

Investigation of backbending phenomena both experimentally and theoretically, has been a field of intensive study in nuclear physics. We have shown by theoretical calculations that rotational bands and backbending can appear in light *s-d* shell nuclei [1,3]. However experimental verification in this region is difficult because only a few members of the claimed rotational band have been identified. Recent experimental observation by Kubono et al. [2] of the 8^+ and 10^+ states of ^{28}Si has made it possible to compare theoretical results with the experiment. This has motivated us to perform a cranked *HFB* (*CHFB*) calculation described in Ref. 4 for ^{28}Si and compare the theoretical result with the experiment.

We have performed the *CHFB* calculation for ^{28}Si, in which all the nucleons are taken as active. The configuration space is chosen as the full $1s$, $1p$ and $2s$-$1d$ shells. Pairing plus quadrupole-quadrupole (*PPQ*) force of Baranger and Kumar[3] has been chosen to represent the residual interaction (Relation (15) in Ref. 4). The parameters of V_{int} are determined by performing a *CHFB* calculation for ^{20}Ne and then adjusting the parameters to get the best overall fit of the ground state rotational band[4]. Although it is not customary to use this force in *s-d* shell re-

gion, we find that it can well represent the situation in this region. The close agreement of the calculated spectrum with the experimental one shows that the validity of *PPQ* residual force extends beyond its usually accepted domain. The single particle energies are obtained from Nilsson model with zero deformation. The generalized Bogoliubov transformation is restricted to mix particles and holes of given kind and parity only. Effect of neutron-proton pairing in the Hamiltonian is taken by summing appropriate terms over both parity states of neutron and proton in the pairing and self-consistent potentials. Since the *HFB* equations are solved iteratively for each parity state of proton and neutron separately, the cross terms in the pairing potential are obtained from the solutions of the previous iteration. This will lead to the correct treatment (within restricted mixing of particles) when self-consistency is achieved.

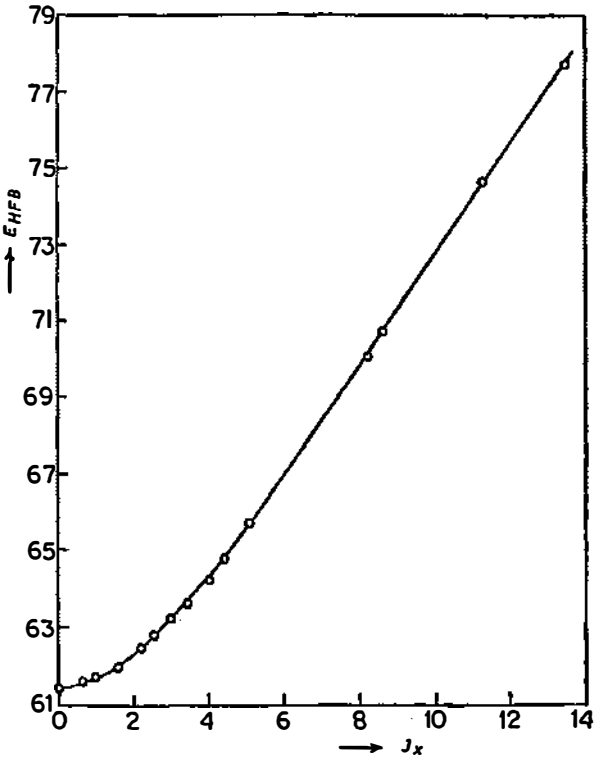

Fig. Variation of E_{HFB} with increasing angular momentum.

Fig. 1 shows the variation of E_{HFB} with the increase in angular momentum J_x. We use only one adjustable parameter, viz., the energy scale by fitting excitation energy of the 2^+ state to the experimental value. In Fig. 2 we compare the calculated spectrum with the experimental one. The fits up to 6^+ member are excellent, but the calculated 8^+ state comes out to be too low compared to the experimental value. However, it is worth mentioning here that Kubono et al.[2] admitted the possibility that the observed 8^+ may not be the lowest 8^+. If this is found to be the

case in subsequent experiments, our results would agree much better with experiment. In Fig. 3 we plotted the energy gap for proton Δ_p versus the angular frequency ω. It shows that Δ_p decreases gradually at first for small values of ω. As ω increases Δ_p falls off sharply and at a certain critical value of ω, Δ_p becomes zero.

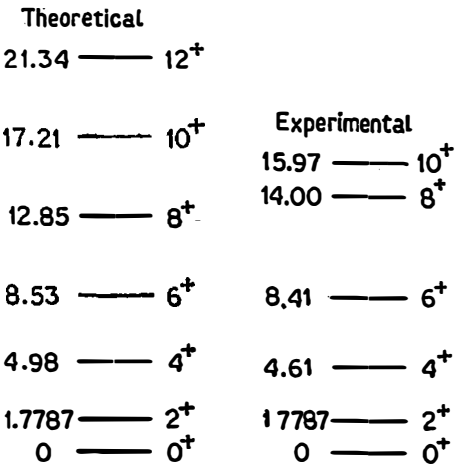

Fig. 2. Comparison of calculated energy level of the G. S. rotational band with experiment.

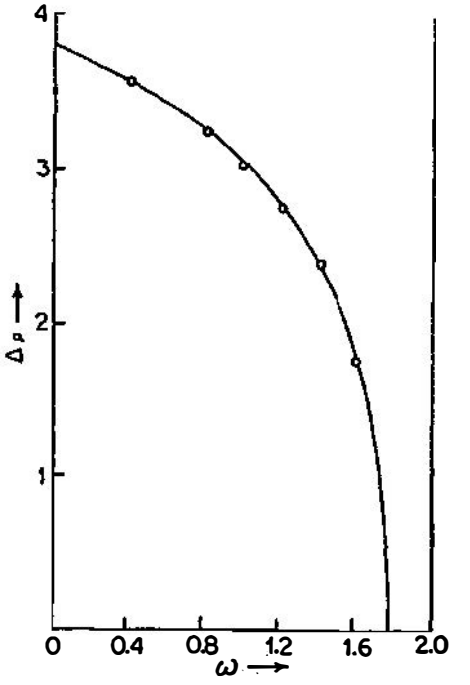

Fig. 3. Change of energy gap for proton (Δ_p) with angular frequency.

It is to be noted here that in this case $\Delta_p \approx \Delta_n$ (energy gap for neutron) since the number of proton and neutron are equal. In Fig. 4, we plot $2\mathcal{I}/\hbar^2$ against $(\hbar\omega)^2$, in which the experimental points have been calculated from Ref. 4 using Eqs. (13) and (14). The experimental result shows a strong backbend at $I = 10^+$. Because of the above mentioned ambiguity regarding the 8^+ state, the magnitude of backbend may be less, if a lower 8^+ is later identified as the member of the ground state band. Our calculation also reproduces a backbend at $I = 10^+$.

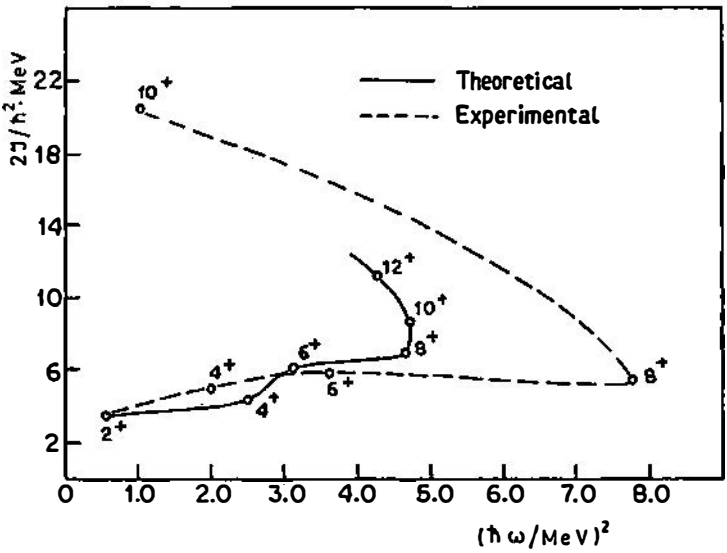

Fig. 4. Plot of moment of inertia against square of angular velocity for ^{28}Si.

We may finally sum up our observation as:

1. *PPQ* force with neutron-proton pairing may be used as the residual interaction in the *s-d* shell region.

2. *HFB* calculation in this region reasonably reproduces observed backbending.

In view of the uncertainity about the 8^+ state and our calculation, it seems that a proper identification of the 8^+ member of the ground state band is very important.

References

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REDUCIRANI *HFB* RAČUN MOMENATA USTRAJNOSTI STANJA VISOKOG SPINA U ^{28}Si

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Metodom Hartree-Fock-Bogoljubova uz uvjet na moment količine gibanja i broj čestica računati su momenti ustrajnosti za stanja visokog spina u ^{28}Si. U ostatno međudjelovanje uključena je sila sparivanja i kvadrupol-kvadrupol sila. Izračunato znatno smanjivanje iznosa momenta ustrajnosti za nivo 10^+ slaže se s eksperimentima.