High-spin states in ^{71}As, ^{72}Se, and ^{72}Br

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Abstract. The ^{16}O + ^{58}Ni reaction was used to study yrast and non-yrast excitations in ^{71}As, ^{72}Se, and ^{72}Br. High-spin yrast and negative-parity non-yrast bands were observed in ^{72}Se. The $f_{7/2}$ proton extruder orbital was identified in ^{71}As. The odd-even staggering in the $\pi g_{9/2}\nu g_{9/2}$ decoupled band in ^{72}Br is compared with similar structures in heavier Br isotopes.

The nuclei in the A≈70 mass region exhibit a complicated interplay of single-particle and collective degrees of freedom, with spherical structures coexisting with more deformed shapes associated with the proton intruder $g_{9/2}$ orbital. Prolate, oblate, and triaxial shapes, both of collective and non-collective character, are predicted. Which shape is favored changes rapidly as a function of neutron and proton number and angular momentum, often with several shapes coexisting in the same nucleus. A highly sensitive γ-ray spectrometer and a relatively light, heavy-ion beam could extend the knowledge of both yrast and non-yrast excitations in this region of rapid shape changes and shape coexistence.

Excited states in ^{71}As, ^{72}Se, and ^{72}Br have been investigated using the ^{16}O + ^{58}Ni reaction at 59.5 MeV at ATLAS with the Gammasphere array at the target position coupled to the Fragment Mass Analyzer. This was the first experiment with this particular configuration. Gamma-gamma coincidences, as well as gamma-recoil mass coincidences, have been established. Measurements of the directional correlations (DCO) of the transitions have allowed angular momentum assignments.

The yrast band in ^{72}Se has long been understood as evidence for shape coexistence [1,2]. The yrast states at low angular momentum are weakly collective oblate states which evolve to a collective, prolate band for I>6$\hbar$. The predicted [2] positive-parity non-yrast states have to date not been observed. In the present work the negative-parity bands have been extended to 17$\hbar$. The kinematic moments of inertia, $\mathcal{J}^{(1)}$, as function of rotational frequency, $\hbar\omega$ are displayed in Fig. 1 for the positive-parity yrast band and two negative-parity bands. The negative-parity band in ^{74}Se [3] is shown for comparison. The negative-parity band-1 in ^{72}Se is built on the 3^- state which has been identified as a collective excitation in heavier Se

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isotopes [3]. The negative-parity band-2 is probably a two-quasineutron excitation involving $g_{9/2}$ and fp-shell neutrons [3].

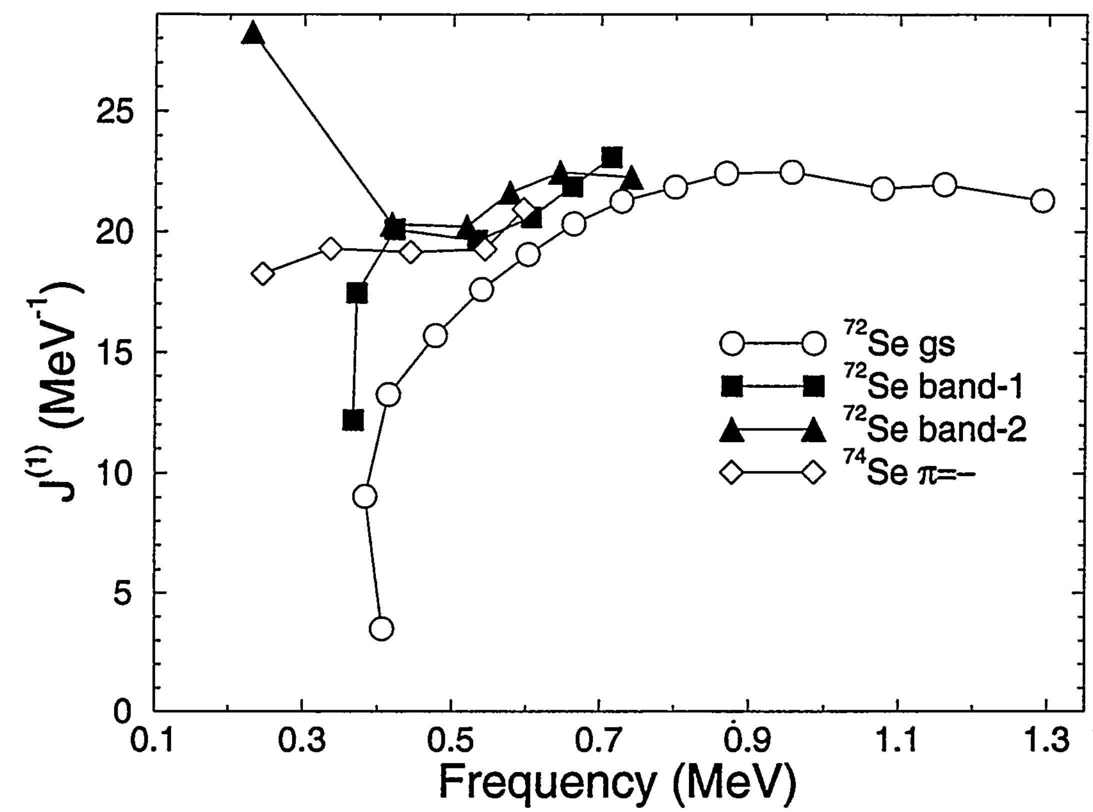

Fig. 1: $\mathcal{J}^{(1)}$ *vs.* $\hbar\omega$ for yrast and negative-parity bands in ^{72}Se and the negative-parity band in ^{74}Se.

The positive-parity yrast structure in ^{71}As is based on the $\pi g_{9/2}$ configuration which is low-lying for large prolate deformations. Total Routhian Surface (TRS) calculations [4] predict this band to be γ-soft at low rotational frequencies, becoming more rigid, but highly triaxial, at higher frequencies. In the present work the negative-parity yrast band has been extended to $(37/2)^-$ and a new negative-parity ΔI=1 band identified, as shown in Fig. 2. This new negative-parity band has the characteristics expected for the $7/2^-[303]$ extruder orbital from the $\pi f_{7/2}$ shell, which is expected to be near the Fermi surface for the large, $\beta > 0.3$, deformations which are known to characterize ^{71}As. The experimental B(M1)/B(E2) ratios for this band, which vary between 4 and 6 $\mu_N^2/(eb)^2$, are in good agreement with theoretical values of this ratio expected for the proton $f_{7/2}$ extruder orbital. This is the first identification of this orbital in this mass region and further supports arguments for large prolate deformations in ^{71}As.

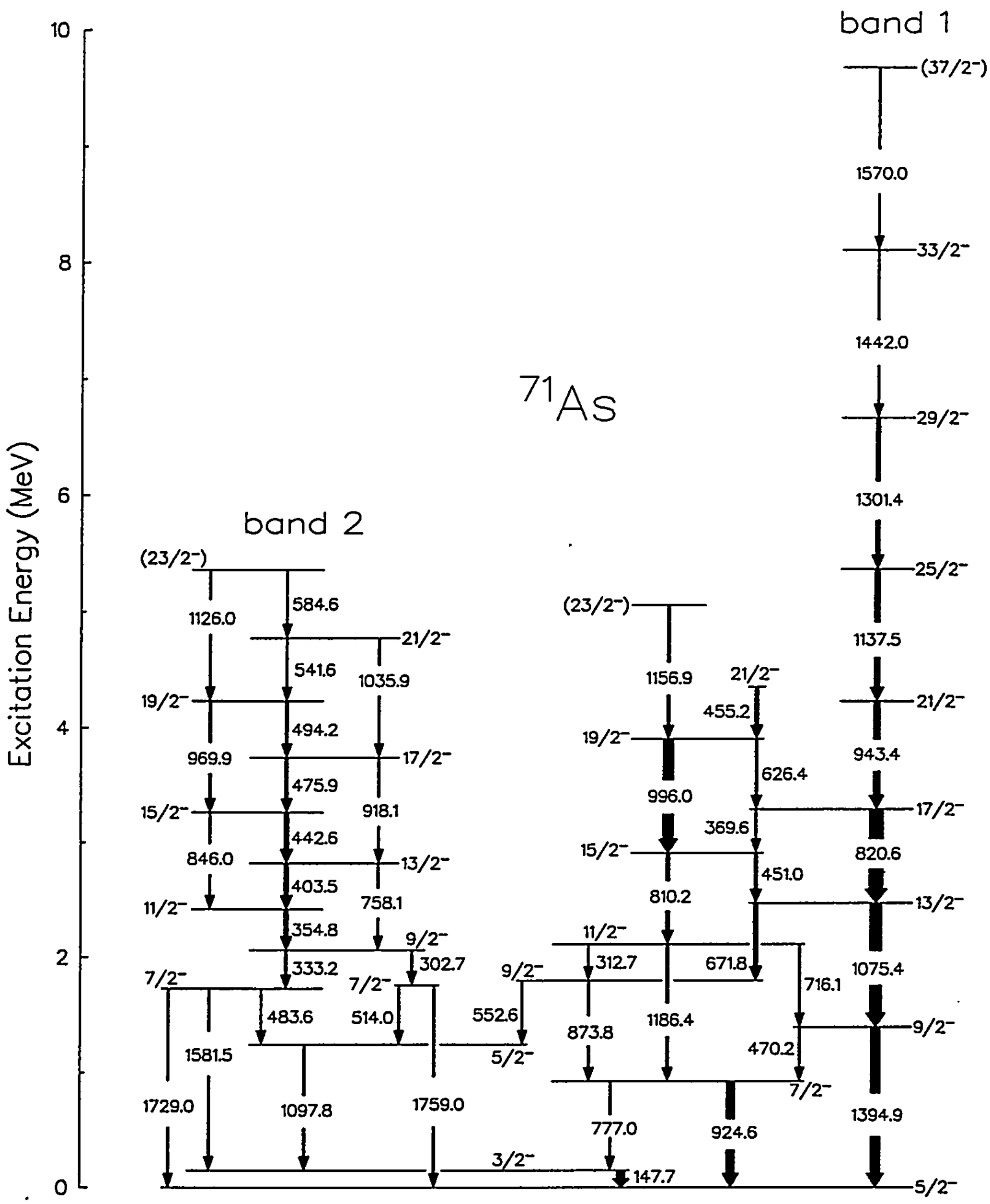

Fig. 2: Partial level scheme of ^{71}As highlighting negative-parity excitations.

The low-spin members of the positive-parity yrast band in ^{72}Br had been previously established [5,6]. The ground-state 3^+ assignment can be understood as the coupling of both the proton and neutron in the low-Ω $g_{9/2}$ orbitals, $3/2^+[431]$. In the present work both signature partners are observed and extended to (18^+), for α=0, and (21^+), for α=+1.

Signature inversion at low spin for the positive-parity bands in the heavier Br isotopes has been observed and interpreted as a change in the sign of the triaxial deformation as a function of rotational frequency [7-9]. In Fig. 3 the signature splittings, the energy differences of the states with I and I-1 divided by twice the spin, for the positive-parity bands in ^{72,74,76}Br are compared. In ^{72}Br no signature inversion at low rotational frequency is observed. This suggests that the $\gamma < 0$, collective deformation persists to low frequency in ^{72}Br, with low-Ω $g_{9/2}$ neutrons *and* protons. This is in contrast to the heavier isotopes, with higher-Ω $g_{9/2}$ neutrons, where non-collective shapes are important at the lowest frequencies [8,9].

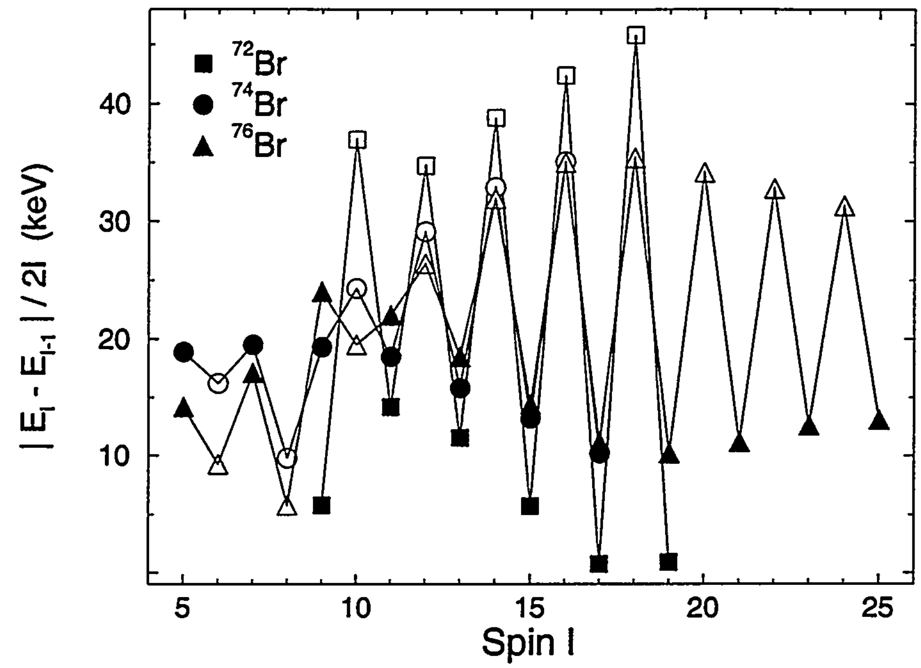

Fig. 3: Signature splitting for positive-parity bands in ^{72,74,76}Br. Open symbols are α=0; closed symbols are α=+1.

In summary, both yrast and non-yrast structures have been observed in several A≈72 nuclei up to high angular momenta. Large deformations, β >0.3, are necessary to reproduce the observed band structures, as well as non-axial shapes, which are more rigid in ^{72}Br with N=37.

This work supported in part by U.S. National Science Foundation and Department of Energy.

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