A New Region of Superdeformed Nuclei

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Within the framework of the nuclear harmonic–oscillator model one expects the existence of favorable shell gaps that appear regularly as a function of deformation and nucleon number. They are predicted to occur for particular magic numbers and at deformations corresponding to integer ratios of the lengths of the major–to–minor axes (e.g. for superdeformed (SD) nuclei, with a quadrupole deformation of ε_2=0.6, the ratio is 2:1). Superdeformed (SD) structures which have a major–to–minor axis ratio close to 2:1 have been found in nuclei of the A$\simeq$150 (close to ^{152}Dy) and A$\simeq$240 (close to ^{236}U) mass regions. In the A$\sim$190 region the superdeformed structures have a slightly smaller axis ratio of $\sim$ 1.7:1. Lighter mass regions near A$\sim$130, 80, and 60 have also been described as being regions of superdeformed nuclei but generally one finds these structures to have much smaller differences in the deformation from the normal–deformed states. Many of the models that explain SD nuclei predict additional minima in the potential energy surfaces at even larger deformations that correspond to prolate shapes with major–to–minor axis ratios of about 3:1. These are the long–sought–for hyperdeformed nuclei and they are generally predicted to become yrast at very high angular momentum. It is questionable whether hyperdeformed structures can survive fission since the corresponding barriers tend to be very small at these high angular momentum values. Observation of hyperdeformation would have a profound impact on our understanding of fission barriers and shape parameterizations, and provide a stringent test of theoretical models.

Recent calculations by Chasman [1, 2] using the cranked Strutinsky method and a four–dimensional shape space representing quadrupole, octupole, hexadecapole, and necking degrees of freedom, predict that a region of shape minima at deformations with 2:1 axis ratios (or larger) exist at high angular momentum in nuclei with A$\sim$110. In fact, the calculations find that many nuclei have minima in the potential energy surfaces corresponding to a variety of extended nuclear shapes. For ^{108}Cd the calculations predict a minimum in the potential energy surface corresponding to a shape with an axis ratio of $\simeq$2.3:1 which becomes yrast at I$\simeq$60$\hbar$. The very extended minimum results from the large shell corrections for both protons and neutrons at this deformation, which lies intermediate between super– and hyper– deformation. Moreover, the outer barrier to fission is calculated to be >9 MeV at I=60$\hbar$ and >6 MeV at 70$\hbar$ implying that the nucleus at this deformation is stable against fission and that it should be possible to observe the discrete gamma–ray decay of states in this minimum over a range of angular momentum.

Motivated by such considerations we have performed an experiment, at the ATLAS facility of the Argonne National Laboratory, using the Gammasphere array to search for very extended nuclear shapes with predicted deformations of $\varepsilon_2 \geq$0.6. Shown in Fig. 1 is an SD band which has been assigned to ^{108}Cd. Away from band crossings, the mass–scaled moment of inertia is very similar to that of the yrast SD band in ^{152}Dy. A Doppler Shift Attenuation measurement indicates a lower limit of the transitional quadrupole moment of $Q_t \geq$9.5 eb. These facts suggest a very extended quadrupole ellipsoidal shape of the nucleus, with a major–to–minor axis ratio $\geq$1.8. This is amongst the most deformed structures ever seen and it cannot be ruled out that the band may have a major–to–minor axis ratio >2:1 as predicted by Chasman. Moreover, calculations of very extended minima with low predicted fission barriers, as expected in the case of ^{108}Cd, present a considerable challenge to theory and such studies may point the way to firmer predictions of stable hyperdeformed nuclei accessible to experimental investigation.

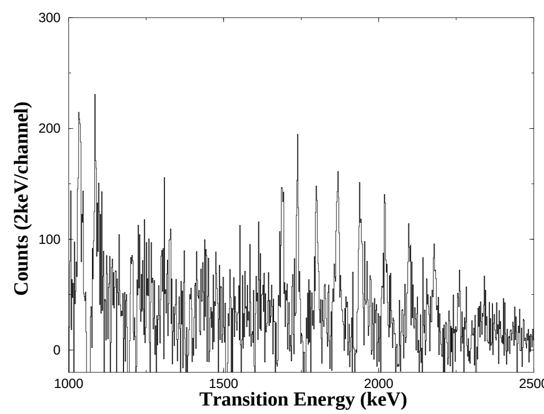

FIG. 1: Spectrum of a superdeformed band in ^{108}Cd.

REFERENCES

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