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Presented at the Winter Workshop on
Nuclei Dynamics V, Sun Valley, ID,
February 22-26, 1988

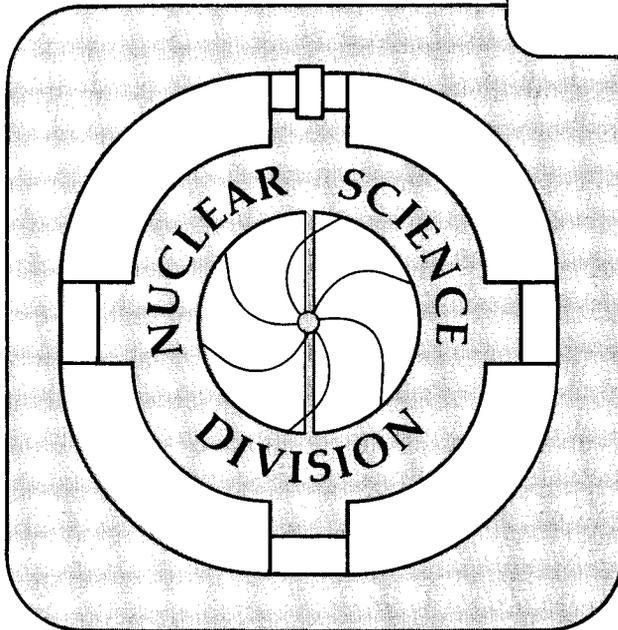
The Effective Stiffness of Nuclei Near Magic Numbers

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February 1988

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THE EFFECTIVE STIFFNESS OF NUCLEI NEAR MAGIC NUMBERS

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February 1988

In a recent study of the isotope shifts for a long sequence of Rubidium isotopes ($N = 39$ to 61) [1] we found that we were not able to explain the rapid increase in the apparent size of these nuclei around the magic number $N = 50$ [2]. Most workers in the field had assumed that the observed behavior was associated with collective zero-point motion, even though no calculations of this effect had been successful in establishing the connection [3]. In our work the one dimensional Schrödinger equation was solved for the quadrupole collective coordinate ϵ of Nilsson [4]. The potential $V(\epsilon)$ and the inertial parameters $B(\epsilon)$ were calculated microscopically and details can be found in Ref. [2].

The specific problem being addressed can be seen by first considering Fig. 1. In this figure the mean square charge radii of the ^{37}Rb isotopic sequence are plotted as filled circles connected by a solid line relative to the $N = 50$ isotope. The dot dashed line is the pure Liquid Drop Model prediction and the dashed line is the Droplet Model prediction before the effect of deformation is included. The triangular symbols correspond to adding deformation corrections from Ref. [5] to the Droplet Model according to the procedure developed in [6]. The agreement is good for well deformed nuclei far from $N = 50$, but poor in the transition region.

In Fig. 2 these results are presented in another way. Here, in the upper part of the figure, the relationships given in [2] are used to convert the observed nuclear size to an apparent deformation. Once again (as in Fig. 1) the measured values are represented by solid dots. The dashed lines are meant to guide the eye and to dramatize the sharp increase on both sides of the magic number $N = 50$. The squares represent the static predictions of Ref. [5] and the triangles those of Ref. [2]. In the lower part of the figure the deformations deduced from the measured isotope shifts are shown again and the diamond shaped symbols connected by a solid line represent the results

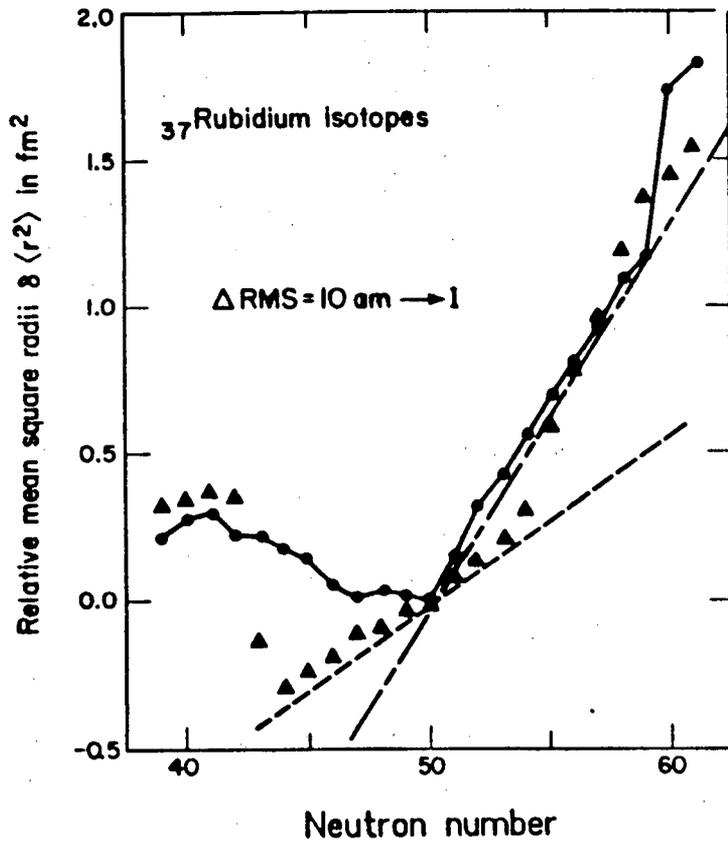


Fig. 1: The relative mean-square charge radii of a series of rubidium isotopes is plotted relative to the value at $N = 50$. The dashed line represents the Droplet Model prediction without the inclusion of deformation effects.

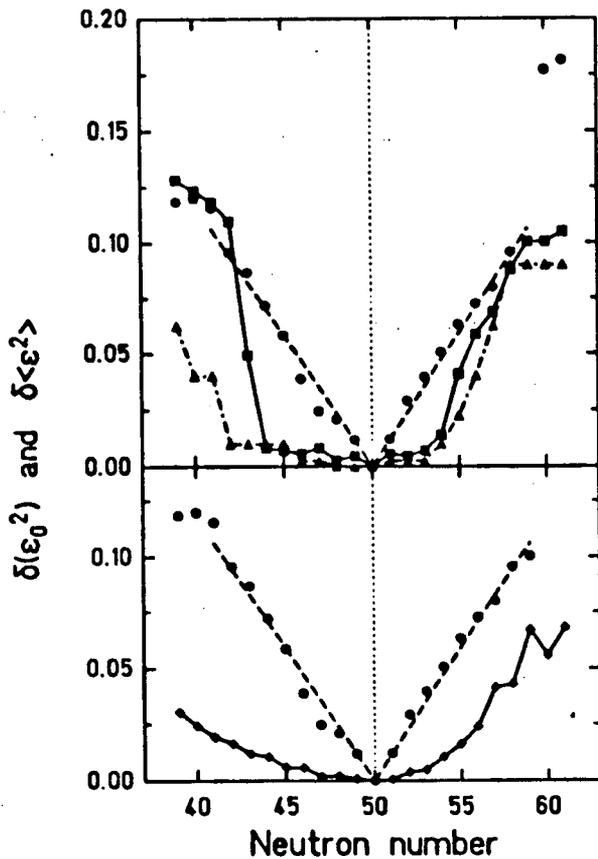


Fig. 2: Various values of the change in the mean-square deformation $\delta(\epsilon_0^2)$ or $\delta\langle\epsilon^2\rangle$ that have been calculated or inferred from measurement are plotted against the neutron number. The round filled points are deduced from the measured values shown in Fig. 1. The dashed line is meant to guide the eye and it represents the measured behaviour of the transition nuclei that is the major concern of this paper.

of the zero-point motion calculations described in Ref. [2]. The agreement near $N = 50$ has not improved much and the agreement for well deformed nuclei beyond the transition region is not as good as it was before. These results were found to be insensitive to the size of the inertial parameters.

In Fig. 3 examples are given of three of the calculations on which Fig. 2 is based. These show the potential above and the resulting probability distribution below. The vertical bars connected by a line indicate the "width" of the distribution.

In order to further investigate the differences displayed in Fig. 2 we converted the calculated width of the wave function $\langle \epsilon^2 \rangle$ to an effective stiffness for the potential K_{eff} using the simple relationship $\langle \epsilon^2 \rangle = (2BK)^{-1/2}$, and a typical value ($B = 35 \text{ MeV}^{-1}$) for the inertial parameter. These values are shown as the dots connected by a solid line in Fig. 4. The nuclei near the magic number $N = 50$ are seen to be stiffer than the Liquid Drop Model prediction ($K \sim 86 \text{ MeV}$) and the nuclei further away seem to be softer. Strictly speaking the very low values of K_{eff} far from $N = 50$ correspond to potentials that have developed secondary minima (as can be seen in Fig. 3) rather than actual lower K values. The dashed line in Fig. 4 represents the behavior of K_{eff} that would be required in order to correctly reproduce the values of $\langle \epsilon^2 \rangle$ along the dashed line in Fig. 2. The transition away from $N = 50$ is extremely abrupt, far in excess of any change that could be expected in the microscopic calculation of potential energy surfaces.

At this point in our study of these measurements it seems impossible to resolve the differences between the measured and calculated values. A wider survey is planned of similar isotopic sequences and perhaps a study of isotonic sequences around $Z=50$.

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This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

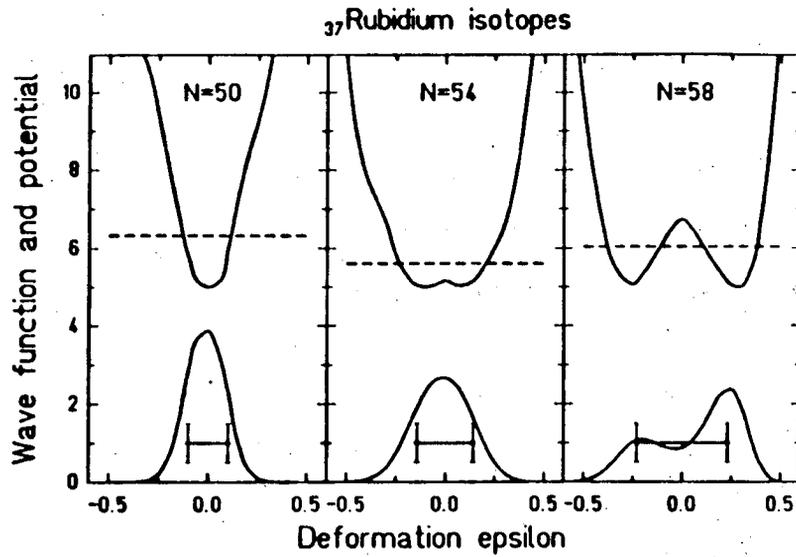


Fig. 3: Three examples of the potentials used in the zero-point motion calculations are shown. The horizontal dashed line represents the value of the energy and the probability distribution is shown at the bottom. The bars connected with a horizontal line are located at $\pm \langle \epsilon^2 \rangle^{1/2}$.

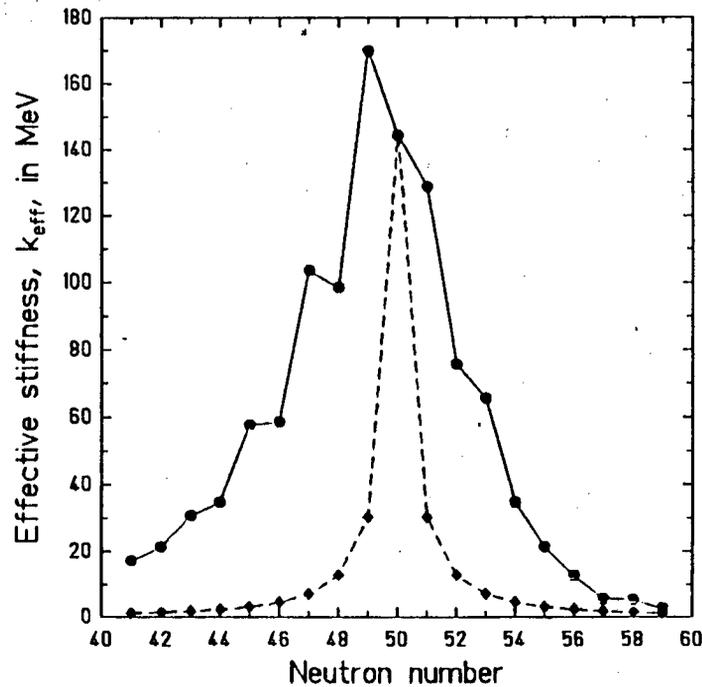


Fig. 4: The effective stiffness K_{eff} of a sequence of $_{37}\text{Rb}$ isotopes is plotted against the neutron number.

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