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TITLE GLOBAL NUCLEAR-STRUCTURE CALCULATIONS

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GLOBAL NUCLEAR-STRUCTURE CALCULATIONS

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Theoretical studies based on the single-particle model and its various extensions, such as the macroscopic-microscopic method and RPA treatments of additional residual interactions, have over the last 40 years been enormously successful in providing a quantitative theoretical interpretation of a large number of different low-energy nuclear-structure properties. In the early 1950's the nuclear magic numbers were explained in terms of a simple, spherical single-particle model with a spin-orbit interaction with an adjustable spin-orbit strength. In 1955 Nilsson extended the model to a deformed single-particle well, and this model was very successful in interpreting a vast amount of experimental low-energy spectroscopic data.

The single-particle model serves as a starting point in the macroscopic-microscopic method for calculating the nuclear potential energy as a function of shape. In this approach, the macroscopic energy is calculated for the shape of interest, and single-particle levels are calculated for a well of this shape and used to determine a microscopic correction by use of Strutinsky's method. The total potential energy is then obtained as the sum of the macroscopic term plus the microscopic correction. By calculating the potential energy for a large number of shapes one may determine nuclear ground-state masses and shapes, fission-barrier heights, and fission-isomeric states. At this conference we will also hear about how the model has been applied to studies of high-spin phenomena.

The single-particle model also serves as a starting point for calculating various transition-rate nuclear matrix elements. One example of this type is Gamow-Teller β-strength functions. Since the transition amplitude is sensitive to small perturbations from residual interactions, it is necessary to add residual pairing and Gamow-Teller interactions to the basic single-particle model to obtain reasonable agreement with data.

The goal of such theoretical studies is to understand the experimentally established properties of nuclei in terms of a simple underlying physical picture. It is particularly important to understand whether deviations between the model and data are due to poorly determined model parameters, or alternatively if a refinement of the model or even a completely new model is required. Usually a model can be characterized as pro-

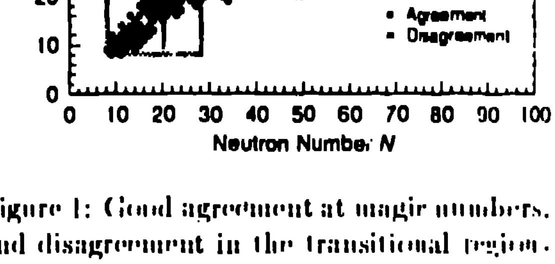

Figure 1: Good agreement at magic numbers, and disagreement in the transitional region, $N = 56$ and $N = 86$. Spherical levels are used if $|\epsilon_2| < 0.15$.

viding a simple underlying physical picture only if it has relatively few parameters. Although few-parameter models often exhibit larger deviations between calculated results and data than do multi-parameter models, these deviations are often open to interpretations that yield new physical insight. These deviations may, for example, be due to a known approximation in the model or reveal a previously unknown phenomenon. As an example, we mention a mass calculation that showed unusually large deviations between calculated and measured ground-state masses in the vicinity of ^{222}Ra. These deviations were shown to be due to the neglect of octupole shape degrees of freedom. Their occurrence stimulated a revival of the study of octupole shape degrees of freedom in this region.

The model used here represents a unified macroscopic-microscopic approach with about 10 parameters in the macroscopic part and 10 in the single-particle model, not counting such previously well determined parameters as the proton and neutron mass, Planck's constant, and the speed of light. Our aim here is to show some remarkable strengths and some weaknesses of these single-particle-based models by applying them globally to calculations of such diverse properties as ground-state masses, deformations, spins and pairing effects, β-decay, fission-barrier structure, and spontaneous-fission half-lives. Some examples of results obtained are shown in figs. 1–4. Our analysis in the full conference contribution will point to a direction for the nineties for these types of models.

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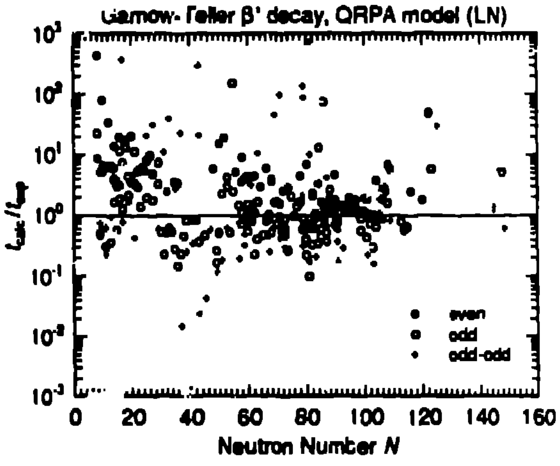

Figure 3: Comparison of experimental half-lives for EC and β^+ decay with QRPA calculations in the Lipkin-Nogami pairing model.

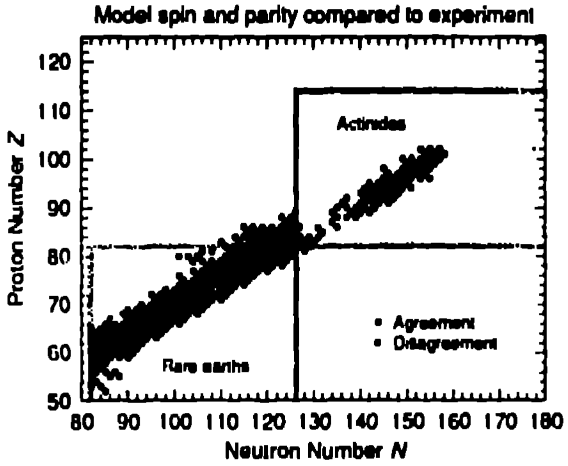

Figure 2: Good agreement in deformed and spherical regions.

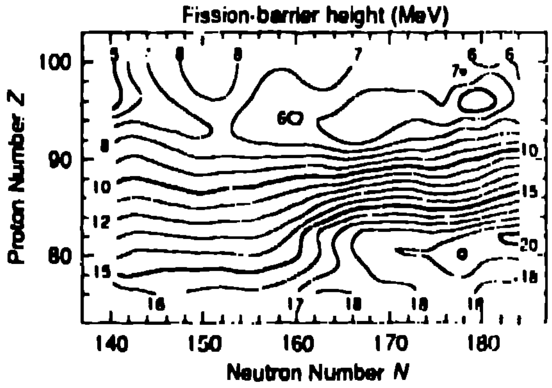

Figure 4: Calculated fission-barrier heights for heavy nuclei.