PROBLEMS IN NUCLEAR STRUCTURE

by G. Alaga

Instutute "Rudjer Bošković"
and University of Zagreb

I am pleased that this meeting of nuclear physicists is taking place in Vojvodina and I am honoured with the invitation to speak on nuclear structure. I hope in this way to contribute modestly to the success of the meeting and to pay my tribute to the development of physics in Vojvodina.

Spectroscopy, as it is well-known, is one of the oldest methods to explore the structure of the quantum systems. Atomic, molecular and solid state systems have revealed their structure through the emitted electromagentic radiations. Interaction of atomic nuclei with electromagnetic radiation has proved also extremely useful in probing the structure of atomic nuclei. Scatterings of nucleons (and nuclei) on nuclei one has discovered characteristics as in atoms (shell-structure) and those similar to molecules and solid state systems (collective effects) and their interference effects. Often one speaks of elementary and collective excitation and their interactions.

Developments of experimental techniques have enabled to discover and study in more details the isobaric analogue states, the states in nuclei far from the line of stability and higher excited states in the rotational and vibrational families.

The traditional way of nuclear spectroscopy was in analogy to the atomic and molecular spectroscopy to set up the complete decay sheme of low lying states. However, with increasing energy the number of states increases rapidly and even with improved resolution one can get information, except for some specific state, only on the average properties of those states. However, combining various techniques it is possible from these variety of states to isolate states of specific character. Specially simple structures have the yrast states of rotational and vibrational families.

Regarding the theoretical treatments of nuclear structure then follows also the experience gained to atomic, molecular and solid state systems with the adoption to nuclear case. We have the microscopic, semi-microscopic and phenomenological approaches.

The most ambicious is a microscopical approach based on the shell-model and effective two-body interactions deduced from analysis of scattering data. The other extremes are phenomenological approaches where one assumes that the shell structure averages out to well behaved functions to bulk properties of nuclei. The semi-microscopic or semi-macroscopic approaches tend to include both the shell effects and basic bulk structure of nuclei and their mutual interaction. The semi-microscopic approaches in the region of vibrational nuclei are sometimes called nuclear field theories because the vibrational particle (quasi-particle) interaction is similar to the interaction of the electron with the electromagnetic field.

The fully microscopic calculations with some restrictions could be carried out so far only for relatively simple systems with mixed success (mainly because of to many uncertainties).

It is also obvious that the phenomenological approaches will provide good descriptions in the cases that the shell structure effects averages out and will provide a fair base for a semi-microscopic description of neighbouring nuclei.

The semi classical rotations and vibrations with their characteristic interval intensity-and selection-rules applied to nuclei are expected to fall for higher excited states. The failure might be small and smooth or violent. The smooth changes we atribute to the average shell effects while the violent changes we like to atribute to the explicite appearance of the particle (quasi-particle) states on the yrast line.

The characteristic anomalies in the deformed nuclei are the effects of back banding with a marked decrease in energy and a 1/3 decrease in B(E2) values, indicating rather strong mixing of the "crossing" rotational bands. These irregularities are probably associated with the phase transitions of the second type, where many particle and states are involved.

In fig. 1. we give a possible vibration particle classification of states in even Hg nuclei. The vibrational energy $\hbar\omega$ is taken for the corresponding Pb isotopes. The proton hole and quasi neutron pair states are classified by their configuration and the total angular momentum $(j_1,j_2)J$. N is the number of vibrational quanta while Λ is their angular momentum. So the basic states are $A(j_1,j_2)J,N\Lambda;\ I>$. I is the angular momentum of the phonon particle mulriplet. Form the classification it is obvious that we have vibrational bands based on collective and cluster states. Considering the yrast line we notice states $(s^{-1}_{1/2}\ d^{-1}_{3/2})2$, $(h^{-2}_{4/2})8,10$ etc. which produce irregularities into the vibrational bands. These states we would like to call intruder states. Depending on the amount of mixing of the intruder states with neighbouring states and their relative position with respect to the state below will decide about the irregularity in energy and $B(E2)$ values on the yrast line. The 2^+ intruder state will mix the neighbouring 2^+ states and due to polarisation effect its $B(E2)$ $(2\to 0)$ value is of the order of collective $B(E2)$'s. However the decreasing in energy remains. The $(h^{-2}_{11/2})8,10$ unless degenerate with the multiplet $|(s^{-1}_{1/2}\ d^{-1}_{3/2})2,36;8>$ state will lead to the retardation of $8\to 6$ and $12\to 10$ $E(2)$ transitions in ^{198}Hg etc. Only the $B(E2)$ value of $10\to 8$ $E(2)$ transition has been measured and found comparable to the $2^+\to 0^+$ $E(2)$ transition in ^{198}Hg as expected due to plarisation effects. For the lighter Hg isotopes it decreases slightly. These irregularities due to broken pairs are associated with phase transitions of the first type. Breaking enough pairs we might get into the regions of the phase transitions of the second type.

Similar classification can be made and discussion carried out for *Pt, Cd, Pd, Au, Ag,* etc. nuclei having 1,2,... etc. particles of holes coupled to the vibrator. This represents an alternative much more operative formulation to the nuclear field theory.

Some progress with moderate success have been made recently in this field mainly due to the available new data.

It is obvious that one should probably along these lines expect further progress in nuclear structure calculations and fix the parameters which should serve as a guide with the regard to the microscopic calculations.

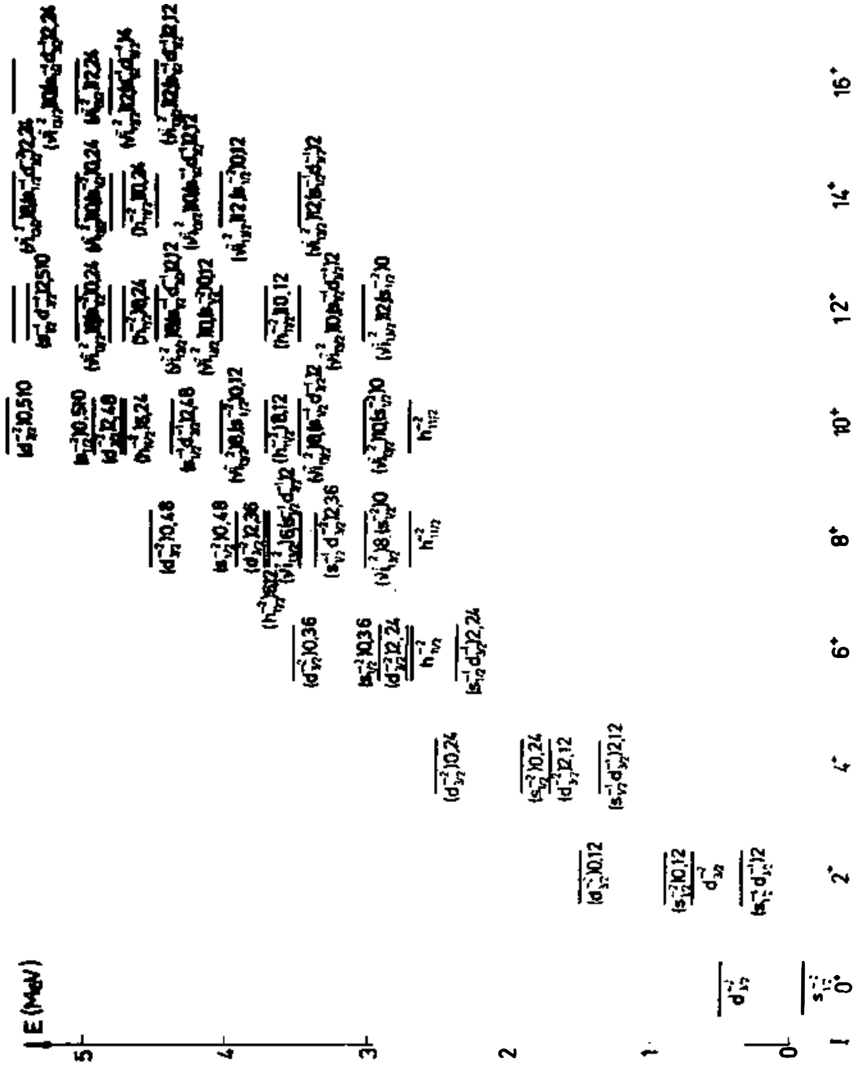

Fig. 1.