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SUMMARY OF WEEKLY RESEARCH PROGRESS MEETING OF MAY 22, 1952

Sergey Shewchuck

June 2, 1952

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Berkeley, California

SUMMARY OF WEEKLY RESEARCH PROGRESS MEETING OF MAY 22, 1952

by Sergey Shewchuck

I. An Excitation Function for the Reaction $p + p \longrightarrow \pi^+ + d$. A. Schulz.

The experiment discussed in this talk has been summarized in an abstract report UCRL-1703, entitled "The Excitation Function for π^+ Mesons Produced in p - p Collisions" by A. G. Schulz, D. Hamlin, M. J. Jakobson and J. Merritt. It is reproduced as follows:

"The relative cross sections at one angle for the reaction $p + p \longrightarrow \pi^+ + d$ have been measured using the external proton beam of the Berkeley synchro-cyclotron. The π^+ mesons produced at $0^\circ \pm 5^\circ$ to the beam direction are magnetically separated from the proton beam and detected by scintillation counters using a delayed coincidence between the π^+ and its μ^+ decay. A polyethylene-carbon difference is used to obtain the hydrogen contribution. In order to obtain protons of various energies below 340 Mev, lead absorbers are placed in the proton beam immediately ahead of the polyethylene and carbon targets. The π^+ contribution from the lead absorbers is automatically subtracted with the carbon contribution.

At each proton energy the π^+ energy spectrum is scanned in the region of the characteristic peak attributed to the reaction given above and the relative $d\sigma/d\Omega$ is obtained by integrating over meson energy. The data obtained thus far agrees with an $E^{3/2}$ curve, where E is the meson kinetic energy in the center mass system. The data joins smoothly with the data for higher proton energies as obtained from the inverse experiment and detailed balancing."

II. First Excited States of Even-Even Nuclei. J. Rasmussen.

Extensive work with β decay schemes in recent years has determined many energies and a few spin and parity assignments for low-lying nuclear levels. The nuclear shell model has been quite successful in the correlation of spin and parity assignments of ground and excited states of nuclei with odd mass number, but

it has seldom been applied to interpreting spectra of the even-even nuclei.

In Figure 1, there are plotted the energies of first excited states of even-even nuclei against the mass number. One notes the maxima in energy at the closed shell "magic number" nuclei. The smooth trend with A, especially in the region of large A, is quite striking. The energy tends to level off at 40 Kev for high mass numbers, as recently indicated by Asaro and Perlman.[1] Another regularity in these excited states in the empirical rule of Sunyar and Goldhaber[2] that the first excited state usually has spin 2 and even parity.

A simple calculation of rotational energy levels of a spherical drop of nuclear mass and dimensions yields energies in the neighborhood of a few kev for the heaviest nuclei. Teller and Wheeler[3] have discussed at length the operation of exchange effects in elevating rotational levels. The lower dashed line in Figure 1, represents the simple rigid rotator J = 2 level. It is designated by $E_{min,\ J = 2}$ and computed by the equation:

$$E_J = \frac{J\ (J + 1)}{2} \quad .54\ A^{-5/3}\ \text{Mev.}$$

The upper dashed line is the estimated limiting energy below which rotational levels will be absent, given by Rosenfeld[4] as $E_{lim} \approx 40/A$ Mev. Teller and Wheeler[3] estimate the limit somewhat lower than Rosenfeld.

None of the experimental points lie below the dashed line corresponding to the simple J = 2 rotational level. Too, the experimental curve generally lies above the E_{lim} value except in the regions near A = 170 and the heaviest nuclei. Since the estimates of the E_{lim} are only approximate, it is indeed tempting to identify the $I = 2^+$ first excited states with the J = 2 rotational level. Then, the observed sharp energy maxima at closed shells and the broad minima in between might be explained qualitatively as follows: The closed shell nuclear configurations

have a high degree of rotational symmetry, which elevates the rotational energy levels to very high values. As one proceeds away from the closed shell nuclei, the symmetries tend rapidly to be "washed out" by the extra nucleons or holes and the rotational levels tend to descend toward the values that would be obtained in the totally random liquid drop. The effect is particularly striking about the doubly closed shell nucleus Pb^{208}.

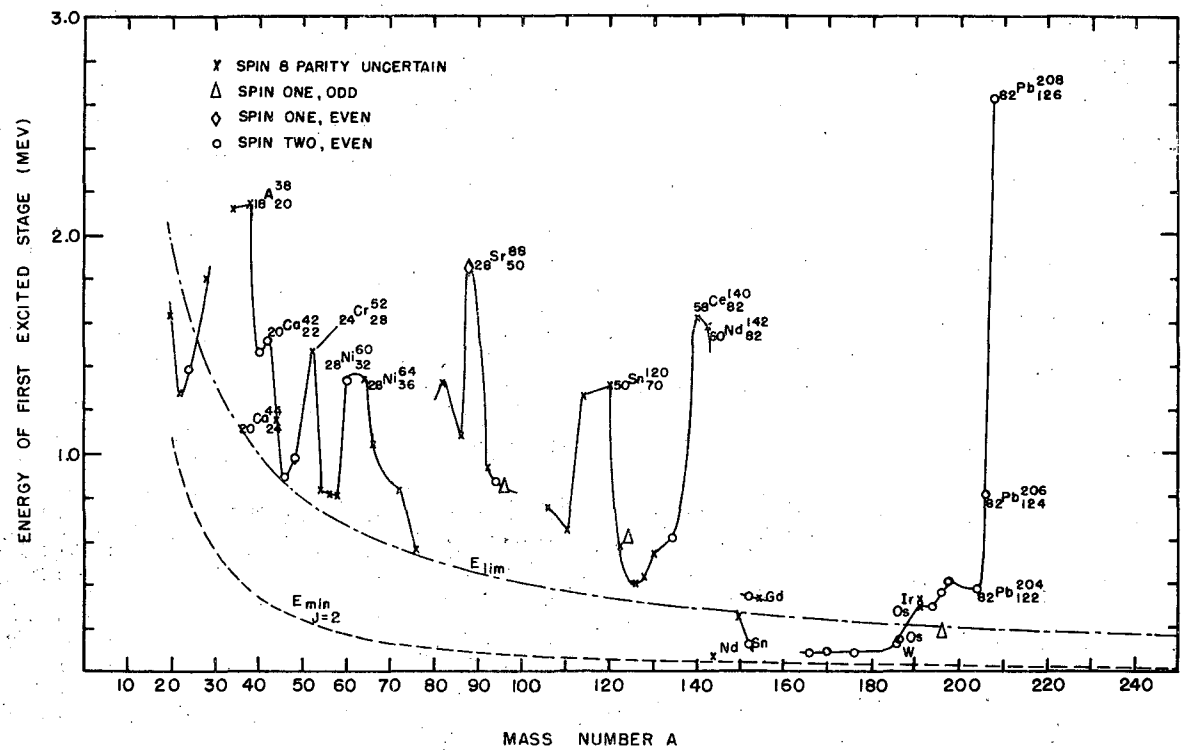
One significant feature of the liquid drop model that would diminish rotational symmetry, and consequently lower the rotational energy levels, is the zero point vibration. The lowest possible mode of vibration is of second order (n=2). Since two-fold rotational symmetry is unaffected by the important n=2 mode of vibration the exchange effects of Teller and Wheeler[3] would be expected to affect the nuclear rotational levels by raising the odd levels far above the even. One thus may account for the empirical rule that the first excited states of even-even nuclei are usually spin two, even parity.

If the liquid drop interpretation of the low-lying levels in even-even nuclei is valid and if the principal factor diminishing the rotational symmetry is the zero point vibration, then there follow consequences affecting the theories of fission and alpha decay. Since zero point vibration would be at a minimum for nuclei at or near closed shell configurations, such nuclei evidently show the greatest resistance to deformation from the spherical shape, e.g. Pb^{208}. This is reasonable in that for particles in a spherical box (infinite potential walls) the total energy of a system of particles in closed shells will increase with with any distortion at constant volume from the spherical shape. The variation in resistance to spheroidal distortion might be represented in the liquid drop model as a varying surface tension reaching maxima at closed shell configurations. Fission predictions based on liquid

drop, however, have varied from experiment; but the theory modification does not seem too serious in the heavy nuclei region. Future data on the energies of the first excited states of even-even nuclei for $A > 238$ may help decide whether the explanation of the fission threshold behavior by an increasing surface tension is reasonable. Alpha decay rates should likewise be affected by the variation in amplitude of the zero point vibration. That is, alpha decay rates should be lower near closed shell configurations, since the effective nuclear radius will be smaller there.

Possible consequences of the two-model theory of nuclear levels may be considered. The single particle wave function theory has been quite successful in interpreting nuclear levels of odd nucleon nuclei. Yet there seems to be good evidence for interpreting many low-lying levels of even-even nuclei in terms of rotational levels of a liquid drop, perturbed by the Teller-Wheeler exchange effects.

1. F. Asaro and I. Perlman, to be published in Phys. Rev.
2. M. Goldhaber and A. W. Sunyar, Phys. Rev. 83, 906 (1951)
3. E. Teller and J. A. Wheeler, Phys. Rev. 53, 778 (1938)
4. L. Rosenfeld. Nuclear Forces, Interscience Publishers, New York: 1949. P 279.



ENERGIES OF FIRST EXCITED STATES OF EVEN-EVEN NUCLEI

(MAGIC NUMBER NUCLEI WRITTEN IN)

Figure 1