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COUPLED CHANNEL CALCULATION OF INELASTIC SCATTERING BASED ON A MICROSCOPIC NUCLEAR DESCRIPTION

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ABSTRACT

The detailed shell model wave functions for  $^{60}\text{Ni}$  are tested by comparing the predicted cross-sections for 17.8 MeV protons exciting a number of levels, with experiment. It is concluded that the collective 2+ state is moderately well represented but not the non-coherent levels, which present a much greater challenge to the structure theory.

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Until recently the only available description of nuclear states possessing collective properties was a macroscopic one. This description forgoes a derivation of the detailed nucleon correlations resulting from the action of the forces between nucleons, in favor of the assumption of collective vibrational or rotational motion which can be described in terms of several macroscopic parameters. Recent developments in the theory of nuclear structure have been aimed at describing the nucleonic substructure of this collective motion, especially in the vibrational regions. There is considerable evidence, based mainly on energy level systematics, that these more fundamental descriptions contain a certain element of truth. But the energy levels are the easiest nuclear property to calculate (because the Hamiltonian is stationary at its eigenstates). A more rigorous test of the theory must be based on transition rates, both gamma decay and inelastic excitation, and on two-nucleon transfer reactions. This paper and experimental work in progress<sup>1)</sup> form part of a program directed toward that end.

In recent work we have formulated the problem of using microscopic descriptions of nuclear structure to calculate inelastic cross sections for alpha particles and nucleons<sup>2-6)</sup>. In this note we report the solution of the coupled equations for scattering of protons on  $^{60}\text{Ni}$  using the microscopic description of the nucleus given by Arvieu et al.<sup>7)</sup>. The method of calculating the scalar and

vector form factors connecting each excited state to the ground was described in our earlier publication, where cross sections were calculated in the distorted wave Born approximation<sup>3)</sup>. For the coupled channel calculation we need also the form factors interconnecting excited states. These can also be obtained in the convenient closed form described in the earlier work. The equations we solve describe the coupled system of proton and nucleus in any one of its lowest six states: the ground state, collective 2+, and excited 0+, two non-collective 2+ and a 4+ state.

The only parameters of the calculation are those of the optical potential and the direct interaction between the scattered proton and the nucleons of the nucleus. The optic parameters were chosen to be those obtained from an uncoupled treatment of the elastic scattering<sup>8)</sup>.

As to the parameters of the direct interaction, if the vacuum interaction can be used as a guide, then in the present case the spin-dependent part is negligible. Since the range of the force can be regarded as essentially known (say 1.85F) that leaves one parameter, the well depth of the spin-independent part<sup>9)</sup>. For the calculation shown here this parameter had the value -50 MeV.

The results of the calculation for 17.8 MeV protons are compared with experiment<sup>1)</sup> in the figure. One can remark that the microscopic description of the collective 2+ state yields a cross section in moderate agreement with experiment. The other levels are reproduced to better than an order of magnitude as to cross section, but the details of the angular distributions, except for the  $2_2$ , are not in agreement with the data. Also shown in the figure (by dashed lines) are the cross-sections predicted by the macroscopic vibrational model using  $\beta_2 = 0.25$ . The higher 0,2,4 triplet are treated as two phonon states. The differential cross section for the collective 2+ state agrees very well with

experiment, a well known property of this model. That the microscopic model does not do as well for this state at forward angles reflects only the trivial deficiency that single-particle wave functions of a harmonic oscillator potential were used rather than of a finite potential well.

We would like to interpret these cross section calculations as a test of the nuclear structure since we believe that all the important elements of the reaction have been properly handled. In that case the conclusion is that the collective  $2+$  state is adequately represented aside from the qualification discussed in our earlier work<sup>9)</sup>. The microscopic description of the non-coherent  $2+$  states and the excited  $0+$  state is not so good. In fact it is easily understood that coherent states are more easily described than non-coherent states where the final result depends delicately on the cancellations between the elementary single-particle excitations<sup>10)</sup>. The  $4+$  level which is coherent is fairly well represented by the microscopic description given by Arvieu et al.

We stated the belief that the important elements of the reaction have been properly handled. Still there are several points which, though believed to be minor, should be kept in mind. Contributions from nucleon exchange of the projectile with one from the nucleus are neglected. One can understand qualitatively that these contributions should be small compared to the direct. Secondly, the spin-orbit term in the optical potential has been omitted. At the moderately low energy of these calculations this is not a serious deficiency. Unlike the exchange scattering, it can be easily incorporated into the calculation.



## REFERENCES AND FOOTNOTES

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7. R. Arvieu, E. Salusti and M. Veneroni, Phys. Letters 2 (1963) 142
8. F. G. Perey, Phys. Rev. 131 (1963) 745. The surface absorption potential given in Table 1 was used except that the spin-orbit part was neglected.
9. See section 3.2 of ref. 3 for a discussion of the direct interaction and its relation to a truncated nuclear structure calculation
10. See fig. 4 of ref. 3 where it can be seen that a small change in the amplitude of any of the single-particle transitions contributing to the  $O+$  could drastically change its form factor. This sensitivity is typical of non-coherent states.

FIGURE CAPTION

Fig. 1. Coupled channel calculation of inelastic scattering of 17.8 MeV protons on  $^{60}\text{Ni}$  are compared with experiment. The solid lines are based on a microscopic description of the nucleus while the dashed lines are based on the macroscopic vibrational model.

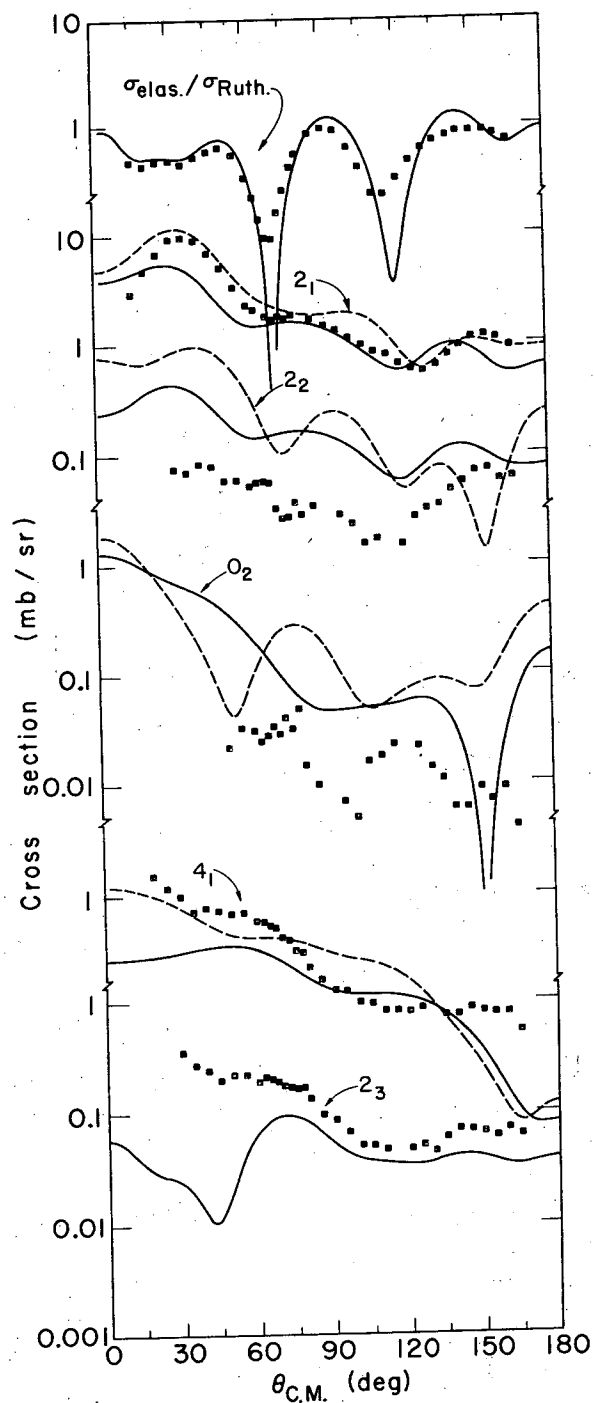


Fig. 1

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