STUDIES OF EXCITED STATES IN ^{208}Pb BY INELASTIC PROTON SCATTERING AT 100 MeV

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Differential cross-section and analyzing-power data have been measured for the reaction ^{208}Pb($\vec{p}$,p')^{208}Pb at 100 MeV, covering the excitation-energy range 0-8 MeV and the angular range 7.5°-75°. A sample inelastic spectrum is shown in Fig. 1, illustrating the rich variety of transitions which are being investigated in this work. These include the low-lying collective states, natural-parity states of both collective and single-particle character, and high-spin, unnatural-parity states of "stretched" configuration. Angular distributions for the states labelled in Fig. 1 have been extracted[1], and theoretical analyses of these data are currently being pursued.

Both collective-model and microscopic DWIA analyses of the low-spin, natural-parity transitions

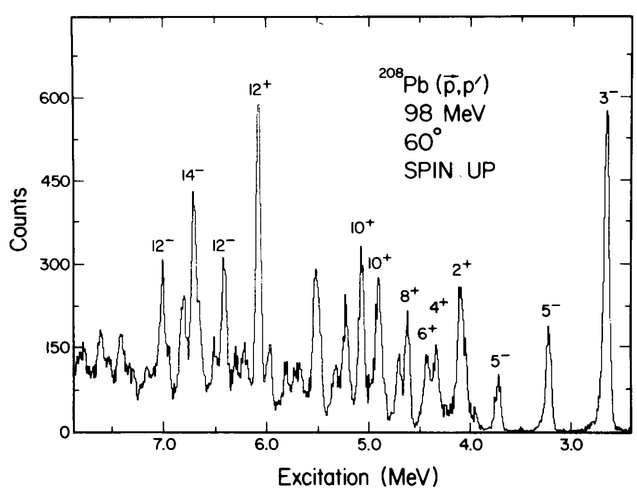

Figure 1. The inelastic proton spectrum for the scattering of 98 MeV polarized protons from ^{208}Pb.

have been carried out for these measurements at 100 MeV. The microscopic interpretation used the distorted-wave impulse approximation (DWIA)[2] with the t-matrix interaction of Love, derived from free nucleon-nucleon scattering.[3] Transition densities were taken from inelastic electron-scattering measurements.[4] Results of such calculations were in good agreement with the earlier inelastic-scattering cross-section measurements for these states in ^{208}Pb at 135 MeV.[5] However, these calculations do not provide a reasonable representation of the 100 MeV analyzing-power data. Further analyses are in progress. One possible explanation for these differences may arise from nuclear structure effects. These effects are visible as differences in the shapes of the cross-section angular distributions for the 5_1^- and 5_2^- excitations at 3.198 and 3.709 MeV, respectively, and are especially evident in the analyzing-power data shown in Fig. 2a. The transition charge densities deduced from electron scattering[4], shown in Fig. 2b, also indicate substantial differences between these two transitions. The striking differences which are apparent in the analyzing power measurements may indicate the sensitivity of such measurements to details of the nuclear wave functions, since the proton measurements are sensitive to both the proton and neutron transition densities.[6]

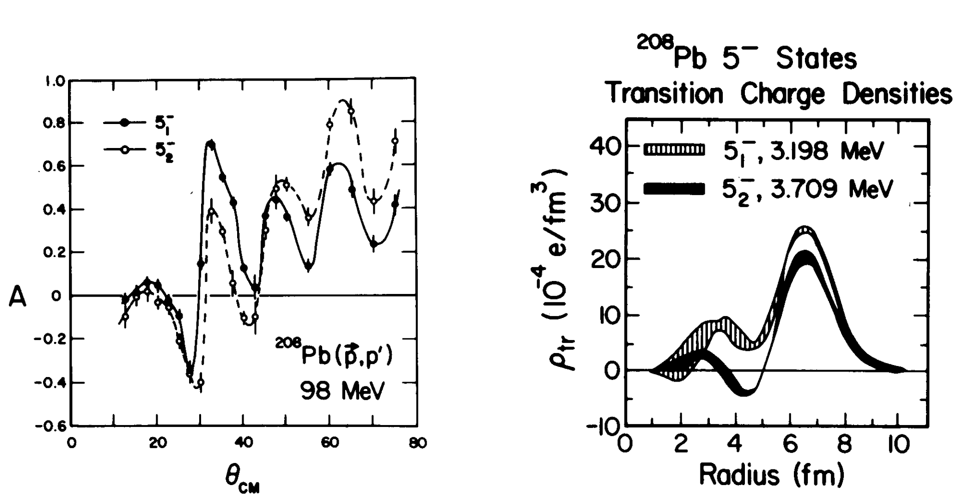

Figure 2. (a) Analyzing powers for the inelastic excitation of the two 5^- levels in ^{208}Pb. (b) Transition charge densities for the two 5^- levels in ^{208}Pb from inelastic electron scattering. (See ref. 4.)

The spectrum in Fig. 1 illustrates one of the most exciting features of inelastic proton scattering at intermediate energies, namely the selective excitation at high momentum transfer of high-spin, particle-hole states of rather pure configuration. These include the transitions at 6.74 and 7.06 MeV, which are predominantly due to the configurations $(\nu j15/2, \nu i13/2^{-1})14^-$ and $(\pi i13/2, \pi h11/2^{-1})12^-$, respectively, as well as the state near 6.43 MeV which is believed to be the 12^- member of the neutron configuration $(\nu j15/2, \nu i13/2^{-1})12^-$.

These three states have been observed in high-momentum-transfer inelastic proton[7)] and inelastic electron[8)] scattering measurements from which the spin, parity and configuration assignments have been deduced. Our initial study of these levels by the (p,p') reaction at 135 MeV, in which only differential cross sections were measured, produced an intriguing result. Whereas good agreement was found between the experimental and theoretical (DWIA) shapes of the cross- section angular distributions for all three cases, and the overall renormalization factor required to reproduce the 14^- data was similar to that required for the (e,e') analyses of this transition, the renormalization factors for (p,p') excitation of the two 12^- states are quite different from those derived in the (e,e') analyses.[9)] One possible explanation for this anomaly is that the observed two 12^- states are linear combinations of two proton and neutron particle-hole configurations. Such an explanation would require an amplitude mixing parameter of ~0.4 for the (p,p') results, which is not consistent with the analyses of the (e,e') data for these states which require very little mixing. The analyzing power data for these states at 100 MeV were expected to shed light on this puzzle since DWIA calculations indicate a sensitivity to the degree of configuration mixing.

A sample spectrum of the high-excitation-energy region of the inelastic scattering data at 100 MeV is shown in Fig. 3. The resulting cross-section and analyzing-power angular distributions for the (proton-configuration) 12^-state at 7.06 MeV are shown in Fig. 4. DWIA calculations assuming proton (solid curve labelled π) and neutron (dashed curve labelled ν) configurations for this state are also displayed. A renormalization factor, which is consistent with that obtained for this state in the

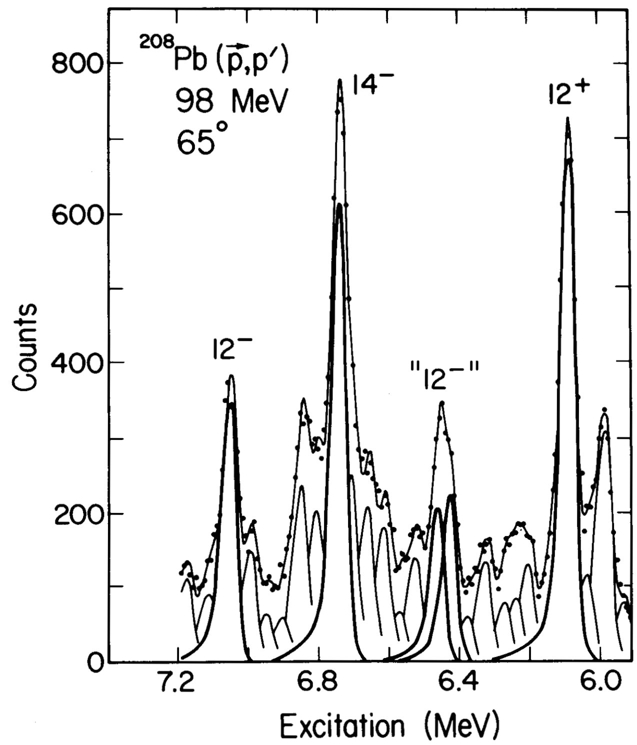

Figure 3. The inelastic proton spectrum for ^{208}Pb in the region of the high-spin states. The contribution of individual levels to the overall fitted spectrum are shown.

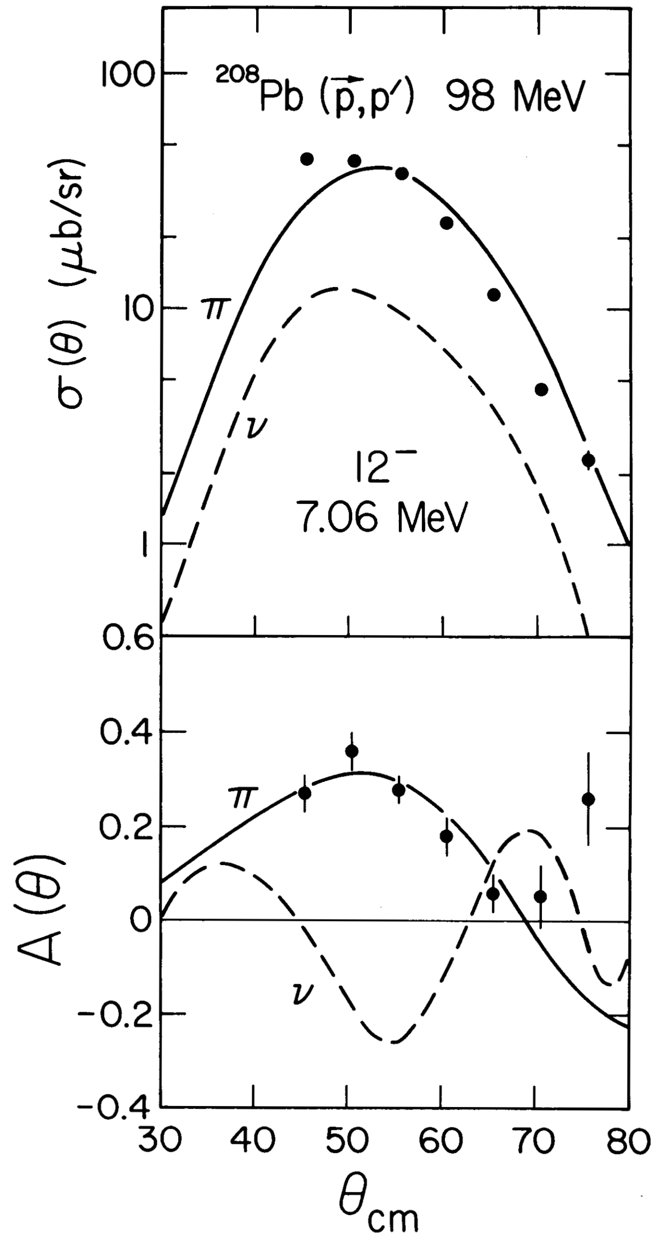

Figure 4. Cross section and analyzing power measurements for the 12⁻ "stretched"-configuration proton state at 7.06 MeV in ^{208}Pb.

earlier (p,p') measurements at 135 MeV, has been applied to the predicted cross sections shown here. The results indicate that the (p,p') measurements at the two energies are in good agreement. Further evidence for the predominantly proton nature of this state comes from a comparison of the predicted and experimental analyzing powers. The sensitivity of the analyzing power measurements to the basic configuration of the state is clearly established and offers some new hope for understanding the character of these high-spin states.[6)]

The measurements at 100 MeV were performed with an energy resolution of ~50 keV, somewhat better than was available at 135 MeV. These new measurements reveal that the peak near 6.43 MeV consists of a doublet which was unresolved in the (p,p') measurements at 135 MeV. Peak-fitting analyses have indicated that the separation of the members of the doublet appears to be about 30 keV. (The results of the peak-fitting procedure are shown in Fig. 3.) The two members both appear to be of high spin, to peak at a momentum transfer similar to that observed for the proton 12^-state at 7.06 MeV, and to be excited with nearly equal cross sections. The existence of several other high-spin states with the same particle-hole structure is expected in this region of excitation, but this is the first observation reported. The determination that the 6.43 MeV level is a closely-spaced doublet will have important implications on the decuced mixing parameter for the 12^- configurations. However, preliminary indications are that the existence of the doublet will not alter the mixing parameter enough to bring the (p,p') and (e,e') results into agreement.

It is clear that further experimental information with better resolution will be required to understand the nature of these high-spin states in ^{208}Pb. Preliminary tests of recent modifications to the QDDM detector system indicate that such high-resolution studies may now be possible. The usual QDDM detector system (helix position detector immediately followed by two ΔE,E scintillators) was modified by the installation of an additional helix detector, separated by approximately 20 cm from the front detector and preceding the two scintillators. The resulting system provides two position signals for each scattering event and thus the horizontal angle of each particle entering the front helix can be calculated. Tests of this double-helix detector system have been carried out at 180 MeV for (p,p') reactions on ^{28}Si. Results indicate that the position-dependent energy resolution commonly encountered with the usual QDDM detector system can be significantly reduced by corrections utilizing the additional horizontal angle measurement. Relatively good energy resolution was obtained over the entire position spectrum (~60 keV at 180 MeV, rather than >90 keV for no correction) and a significantly lower background level was observed in these preliminary experiments. Following additional tests of this system at lower incident energies (~100 MeV), it is anticipated that the improved energy resolution and reduced background levels will have great impact on many facets of the present (p,p') research effort.

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