

INVESTIGATION OF HIGH-SPIN, PARTICLE-HOLE EXCITATIONS IN ^{208}Pb WITH INELASTIC PROTON SCATTERING AT 200 MeV

A.D. Bacher, C. Olmer, E.J. Stephenson, P. Akavoor, G.P.A. Berg, G.T. Emery,
J. Lisantti, A.K. Opper, R. Sawafta, and S.W. Wissink.
Indiana University Cyclotron Facility, Bloomington, IN 47408

The doubly-magic nucleus, ^{208}Pb , has long played an important role in linking experimental results with the theoretical descriptions of both nuclear structure and nuclear reactions. Since high-spin states with a stretched, maximum-J configuration have a unique particle-hole description in a $1\hbar\omega$ basis, comparative studies of their excitation with several probes have been an important source of information about nuclear structure, components of the effective nucleon-nucleon interaction and reaction models of inelastic scattering at intermediate energies. Nuclear structure investigations of the purity, strength and fragmentation of these states have been most fruitful when it has been possible to make comparisons between high resolution (e,e') and (p,p') measurements.

Comparative studies of stretched states in the doubly-closed-shell nucleus ^{208}Pb offer the unique possibility of observing both proton and neutron particle-hole excitations that involve different shell-model orbitals. Initial measurements with (e,e') at Bates¹ and (p,p') at IUCF^{2,3} identified levels in ^{208}Pb at 6.10, 6.43, 6.74 and 7.05 MeV with the configurations $(\nu i_{11/2}, \nu i_{13/2}^{-1}) 12^+$ (neutron), $(\nu j_{15/2}, \nu i_{13/2}^{-1}) 12^-$ (neutron), $(\nu j_{15/2}, \nu i_{13/2}^{-1}) 14^-$ (neutron) and $(\pi i_{13/2}, \pi h_{11/2}^{-1}) 12^-$ (proton), respectively. In these initial studies, the (e,e') and (p,p') strengths for the stretched 14^- (neutron) state were in good agreement with one another, while the observed strengths for the 12^- (proton) and 12^- (neutron) states disagreed by a significant amount. Subsequent measurements at IUCF⁴ with somewhat better resolution provided clear evidence that the 12^- (neutron) state is an unresolved doublet of high-spin, involving perhaps the missing 13^- (neutron) state.

These discrepancies, coupled with recent experimental developments at both Bates and IUCF, have encouraged us to undertake a new series of high-resolution measurements for comparison at the 20–30 keV level. At IUCF, the commissioning of the K600 magnetic spectrometer (≈ 20 keV at 200 MeV) and the development of intense polarized beams (>100 nA) have made it possible for us to investigate the sensitivity of spin-dependent observables (A_y and $D_{NN'}$) to the neutron and/or proton character of the nuclear excitations in ^{208}Pb .

Since the high-spin states of interest in ^{208}Pb are preferentially excited at large momentum transfer (typically 1.8 to 2 fm^{-1}), our initial measurements focussed on the angular range 28° – 52° , corresponding to a range of momentum transfer 1.5 – 3 fm^{-1} at 200 MeV. Several scheduled runs involving a coherent effort between our experimental team and a number of the IUCF support staff were required to track down instabilities in the acceleration, beam transport and beam analysis systems leading to the K600 target position. These improvements allowed us to maintain an overall resolution of ≈ 25 keV over the course of the experiment. Bill Lozowski developed new techniques in fabricating the uniform, oxygen-free ^{208}Pb targets (2 – 3 mg/cm^2) required for this work.

Two vertical-drift wire chambers in the K600 focal plane were employed to derive

the focal plane position and angle of the momentum-analyzed, inelastically-scattered protons. In the course of off-line replay of the event-recorded data, software was developed to correct for small, position-dependent aberrations in the K600 system and to sort the measurements according to scattering angle within the 4° horizontal acceptance of the spectrometer. This procedure is illustrated in Fig. 1 for the region of the spectrometer focal plane corresponding to the excitation energies of the stretched, high-spin states of interest in ^{208}Pb . The scattering angle of 44° is close to the maximum in the angular distribution for the 14^- (neutron) state.

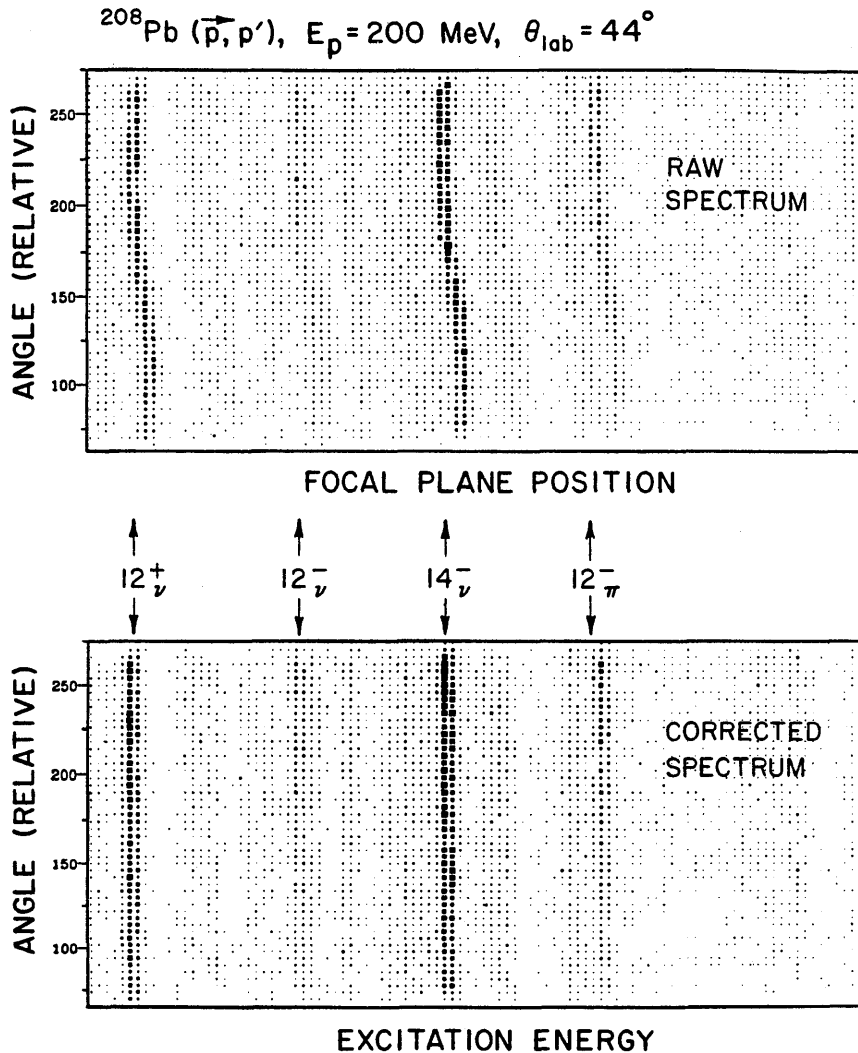


Figure 1. The high-spin state region of excitation in ^{208}Pb at a scattering angle of 44° . At the top, an uncorrected spectrum of focal-plane position versus angle illustrates the small (expected) aberrations in the magnetic analysis system. At the bottom, the corrected spectrum transformed to excitation energy versus scattering angle illustrates the removal of aberrations.

Figure 2 shows the aberration-corrected results for the same region of excitation, but at a scattering angle of 36° where the four states are more equally excited. In the projected spectrum (at the bottom of Fig. 2), the high-spin states are the most dominant feature of the excitation energy region between 6 and 7 MeV. At the level of an overall resolution of 25 keV, the 12^+ (neutron), 14^- (neutron) and 12^- (proton) states appear as single states, well-resolved from nearby, weaker states of lower multipolarity. The 12^- (neutron) state, near an excitation energy of 6.43 MeV, appears in this work to be resolved from several nearby levels that are not as strongly excited.

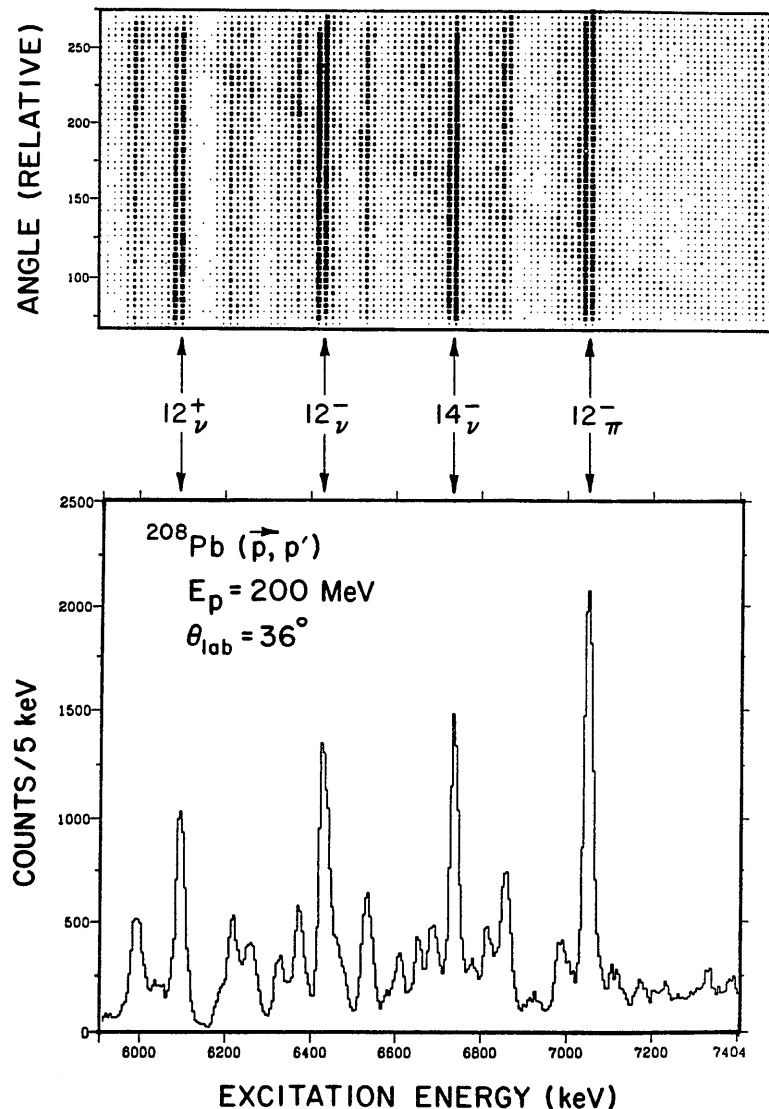


Figure 2. The high-spin state region in ^{208}Pb at a scattering angle of 36° . At the top, the corrected two-dimensional plot of excitation energy versus scattering angle is shown. The faint diagonal line represents elastic scattering from the thin carbon backing ($\approx 5 \mu\text{g}/\text{cm}^2$). At the bottom, the projected spectrum shows the high-spin states described in the text.

Figure 3 shows the inelastic proton spectrum, again at a scattering angle of 36° , for a range of excitation energies from the first-excited, 3^- state at 2.615 MeV up to about 7.5 MeV. Several of the more prominent states have been labeled by previously determined⁵ values of spin and parity. A more complete analysis, including both cross-section and analyzing-power angular distributions for all of the states in this energy range, is in progress. In a recent run, measurements have been extended forward in angle to about 8° in order to provide additional information for the identification of lower-spin states in the spectrum.

A more detailed comparison with recent (e,e') measurements⁶ at Bates is underway. We intend to use these relatively pure neutron and proton particle-hole excitations in ^{208}Pb as a test of the impulse approximation model (DWIA) for proton inelastic scattering at 200 MeV. It appears that the predicted sensitivity of the analyzing power to the neutron and/or proton character of the nuclear excitation is born out by the present work. A more pronounced sensitivity is predicted for $D_{NN'}$. The first measurements of spin transfer coefficients for these high-spin states in ^{208}Pb will be performed later this year using the newly commissioned K600 focal plane polarimeter.

1. J. Lichtenstadt et al., Phys. Rev. Lett. **44**, 858 (1980).
2. G.S. Adams et al., Phys. Lett. **91B**, 23 (1980).

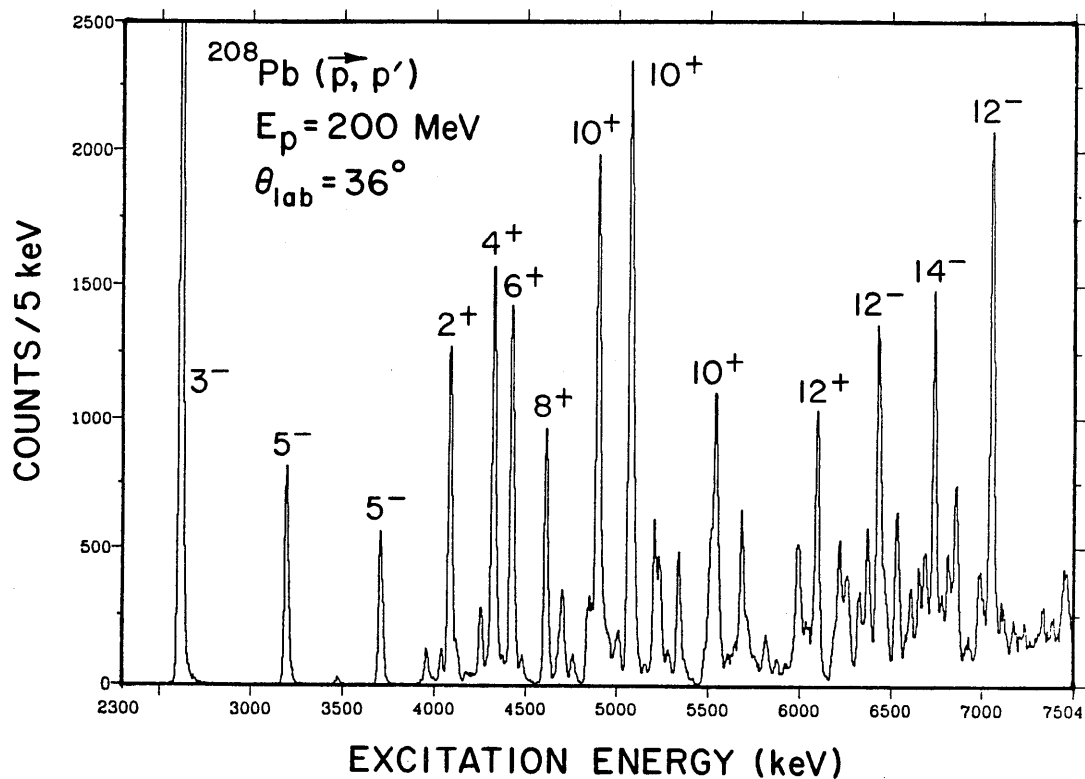


Figure 3. Inelastic scattering proton spectrum from ^{208}Pb at a scattering angle of 36° .

3. A.D. Bacher et al., Phys. Lett. **97B**, 58 (1980).
4. A.D. Bacher in Polarization Phenomena in Nuclear Physics – 1980 (AIP Conf. Proc. No. 69) p. 220.
5. M.J. Martin, Nuclear Data Sheets **47**, 797 (1986).
6. J.P. Connelly, private communication.