NUCLEAR STRUCTURE STUDIES AT INTERMEDIATE ENERGY

FINAL REPORT

September 1992 through May 1995

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Table of Contents

I. Introduction	1
II. Final Report.	2
A. Recent work	2
B. Future plans.	3
III. Bibliography.	4
IV. Title pages, recent papers.	7

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I. INTRODUCTION

This constitutes a final report for a two-year grant ending 31 December, 1993, and an additional grant of \$15,000 for the period 1 January 1993 to 30 September 1994. At the beginning of 1993 the group consisted of the Principal Investigator (N.H.), two full-time Research Associates (A.S. and V.S.), one part-time Research Associate (M.F.) and one graduate Research Assistant (D.M.). At present only the Principal Investigator is continuing. This report covers the period from September 1992 to April 1995. During this period experiment E 352, " ^{208}Pb and ^{60}Ni (p,t) reaction at 120 MeV" was completed at the Indiana University Cyclotron Facility (IUCF). A Ph.D. has been awarded (D.M.) on the basis of this work and LAMPF (Los Alamos Meson Physics Facility) E 1201, "The ^{40}Ca , (p,2p) reaction at 800 MeV". A paper on the ^{208}Pb (p,t) experiment is being prepared for publication. In addition, five papers by members of this group, and four with other collaborators have been published since our last report (September 1992). At present we have one approved experiment (E 1201 above) in the LAMPF queue, but it is unlikely that it will ever be scheduled.

II. FINAL REPORT

A. Recent work

Our main activities since September, 1992 were:

1. Completion of final data reduction and theoretical analysis of IUCF experiment E 352, mentioned above.
2. Supervision of Ph.D. thesis (D.M.) based on LAMPF E 1201 (Part I) and IUCF E 352 (Part II). The thesis was completed and a degree awarded in January 1995.
3. Global analysis of ^{28}Si and ^{58}Ni (p,p') data at 135 (Indiana), 178 (Upsalla), 333, 500 and 800 MeV (Minnesota) on high spin stretched states. In this analysis we are studying the energy dependence of cross sections, analyzing powers, and various spin observables using the impulse approximation with various nucleon-nucleon (N-N) interactions. Among these are the free Franey-Love (FL) interaction, the effective, medium modified, Schrödinger equivalent relativistic interaction of Furnstahl and Wallace (FW), and various (ours and J. J. Kelley's) empirical effective interactions.

We are also modifying these N-N interactions along the lines suggested by G. Brown and co-workers on the modification of scalar and vector meson masses in the nuclear medium (Q.C.D. effects). Using these notions we had initial success in explaining the disagreement between (e,e') and (p,p') cross sections for the high spin unnatural parity states in ^{208}Pb (N. Hintz, A. M. Lallena and A. Sethi, Phys. Rev. C45, 1098 (1992) which was explained by the reduction of the π -meson mass in the medium. In the ^{28}Si and ^{58}Ni (p,p') cases we are looking at the excitation of natural parity states. Both the FL and FW interactions over predict cross sections with decreasing energy.

Unfortunately, if reduced meson masses are introduced the situation becomes worse. Work on this problem is continuing in 1995.

4. Five papers (see Bibliography) have been written on the analysis of proton inelastic scattering by $^{206,207,208}\text{Pb}$ at 650 MeV (our LAMPF experiment E 855) and on instrumentation for E 1201. These were:

a) A phenomenological optical potential and collective-vibrational model analysis of the elastic and inelastic data (Phys. Rev. C, to be published, 1995).

b) A model independent analysis of the elastic scattering data to obtain ground state neutron densities (PRC49, 2118 (1994)).

c) An analysis of the density differences of the Pb isotopes to obtain constraints on the nuclear compressibility--a quantity of great interest in Astrophysics. (PRC49, 2479 (1994)).

d) A microscopic analysis of $^{206,208}\text{Pb}$ Proton inelastic data using existing (^{208}Pb) and our new (^{206}Pb) RPA theoretical transition densities.

e) A paper on the instrumentation for LAMPF E 1201, "A position-sensitive proton telescope" (Nucl. Inst. and Meth. A333, 469 (1993)).

In addition, five papers have been published from collaborations with other groups (see Bibliography).

5. Work has begun on a paper covering the $^{208}\text{Pb}(p't)$ reaction at 120 MeV (IUCF experiment E 352).

B. Future plans

The main projects which we (N.H.) hope to complete in the next few years are:

1. An analysis of the ^{207}Pb (p'p') data at 650 MeV using single particle microscopic densities coupled to collective core polarization densities.
2. Completion of the global analysis of the ^{28}Si and ^{58}Ni (pp') data from $T_p = 135\text{-}800$ MeV using medium modified interactions.
3. The preparation of a paper on the $^{208}\text{Pb}(p,t)$ experiment (E 352-IUCF) based on the Ph.D. theses of D.M.
4. An analysis of unpublished proton inelastic scattering data at 650 and 860 MeV for ^{150}Gd , $^{182,186}\text{W}$ and ^{192}Os to test current Interacting Boson Models (IBM) and to determine nuclear shape parameters.

Although we have no financial support for this program we have, provided by the University, an abundance of supercomputer time, office and secretarial facilities, and the part-time (voluntary) assistance of Michael Franey on computer and nuclear reaction problems.

In the following sections we include a final Bibliography and copies of recent papers, or their title pages.

Finally we wish to give thanks to the AEC, ERDA and DOE for their continuous and generous support for the program at the John H. Williams Laboratory of Nuclear Physics since the late 40's.

III. BIBLIOGRAPHY (AUGUST 1992 TO PRESENT)

Minnesota authors are underlined. An asterisk (*) indicates paper written by Minnesota authors.

A. Published Papers

1. Pion production at small angles, J. Langenbruener,

M.B. Bararkat, E.V. Hungerford III, C.T. Pillai, N. Tanaka, H.A. Thiessen, L.J. Rybarcyk, K.W. Jones, B.D. Barlow, J.B. McClelland, D.C. Dressman, S.C. Piltch, D.M.

Mihailidis, J.B. Donahue, C.L. Morris and R.D. Werbeck, Nucl. Inst. and Meth. (1992 or 1993).

*2. A positron-sensitive proton telescope, D. Mihailidis, N.M. Hintz, A. Sethi, M.K. Jones, L. Rybarcyk, K. Koch, and C.L. Morris, Nucl. Inst. and Meth. A333, 469 (1993).

3. Spin-Longitudinal and Spin-Transverse Response of ^{40}Ca to 500 MeV Protons at Low Momentum Transfer, A. Green, W. Unkelbach, F.T. Baker, D. Beatty, L. Bimbot, X.Y. Chen, V.R. Cupps, C. Djalali, G. Edwards, R.W. Ferguson, C. Glashausser, K.W. Jones, M.K. Jones, G. Kumbartzki, A. Sethi, B. Storm and J. Wambach, Phys. Rev. Lett. 70, 734 (1993).

4. Separation of $\Delta S=0$ and $\Delta S=1$ in the response of ^{12}C to 318 MeV protons, F.T. Baker, D. Beatty, L. Bimbot, V. Cupps, C. Djalali, R.W. Ferguson, C. Glashausser, G. Graw, A. Green, K. Jones, M. Morlet, S.K. Nanda, A. Sethi, B.H. Storm, W. Unkelbach, and A. Willis, Phys. Rev. C 48, 1106 (1993).

5. Spin correlation measurements for $\vec{p} + \vec{p}$ elastic scattering 497.5 MeV, G.W. Hoffmann, M.L. Barlett, W. Kielhorn, G. Pauletta, M. Purcell, R. Ray, J.F. Amann, J.J. Jarmer, K.W. Jones, S. Penttilä, N. Tanaka, G. Burleson, J. Faucett, M. Gilani, G. Kyle, L. Stevens, A.M. Mack, D. Mihailidis, T. Averett, J. Comfort, J. Görden, and J. Tinsley, Phys. Rev. C49, 630 (1994).

*6. Extraction of neutron densisite from elastic proton scattering by $^{206,207,208}\text{Pb}$ at 650 MeV, V.E. Starodubsky and N.M. Hintz, Phys. Rev. C49, 2118 (1994).

*7. Constraints on the nuclear compressibility from analysis of the breathing mode and density differences of lead isotopes, V.E. Starodubsky and N.M. Hintz, Phys. Rev. C49, 2479 (1994).

8. Energy dependence of the $^{12}\text{C} (p,p') ^{12}\text{C}$ reaction from 200 to 800 MeV, K.W. Jones, C. Glashausser, R. de Swiniarski, F.T. Baker, T.A. Carey, J.R. Comfort, W. Cornelius, J.L. Escudié, M. Grazzaly, A. Green, M. Haji-Saeid, N. Hintz, G. Igo, J.B. McClelland, J.M. Moss, S. Nanda, and C.A. Whitten, Phys. Rev. C50, 1982 (1994).

B. In Press

*1. Proton scattering by $^{206,207,208}\text{Pb}$ at 650 MeV: Phenomenological analysis, A.M. Mack, Norton M. Hintz, D. Cook, M.A. Franey, J. Amann, M. Barlett, G.W. Hoffmann, G. Pauletta, D. Ciskowski and M. Purcell, Phys. Rev. C (June or July 1995).

*2. Test of Hartree-Fock-RPA neutron and proton transition densities for $^{206,208}\text{Pb}(p,p')$ at 660 MeV, V.E. Starodubsky and Norton Hintz, Journal of Physics G (June or July 1995).

C. Contributed Papers

*1. High Spin States in the (p,t) Reaction, D.N. Mihailidis, N.M. Hintz, A. Sethi, E.J. Stephenson, A. Bacher, J. Liu, X.L. Zhang, S. Wells, IUCF Scientific and Technical Report (1992).

*2. High Spin States in ^{206}Pb with the (p,t) reaction, D.N. Mihailidis, N.M. Hintz, A. Sethi, E.J. Stephenson, A. Acher, J. Liu, X.L. Zhang, and S. Wells, DNP meeting of the APS, Oct. 1993.

D. Degrees awarded

"Nucleon Knockout and Nucleon Transfer Reactions at Intermediate Energies, Dimitris Mihailidis, Ph.D. University of Minnesota, Jan. 1995.