FINAL REPORT

THREE YEAR PROGRESS REPORT

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on

THEORETICAL STUDIES in NUCLEAR PHYSICS

Oregon State University, Corvallis, Oregon 97331

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Contents

1 GENERAL

In 1995 the DOE grant in Nuclear Theory with Professors Rubin H. Landau and Victor A. Madsen as co-principal investigators ended. Their research was carried out in collaboration with graduate students in Corvallis, and with scientists at LLNL-Livermore, Los Alamos, TRIUMF, KFA-Julich, Hamburg University, Melbourne University, The Thinking Machine Corporation and IBM Research.

During the 1993–1994 academic year, Dr. Shashikant Phatak from the Institute of Physics, Bhubaneswar, India visited in order to collaborate with Professor Landau. This collaboration proved to be fruitful, stimulating, and effective in combining Phatak's developments of the CDM with Landau's developments in scattering and dressed bound states in momentum space. In December 1994, Landau spent a month collaborating with Dr. Phatak in India.

During the 1994–1995 academic year, Professor Manuel Paez from the University of Medellin visited with Landau to collaborate on Computational Physics projects. That visit proved to be fruitful and the two are co authors on a forthcoming book, *Projects in Computational Physical Science.*

Activities in nuclear and particle physics at Oregon State University were diverse and active. Madsen's work concentrated on the relation of reactions to the nuclear structure, and Landau's work concentrated on intermediate energy physics, few-body problems, and computational physics. The Landau group had a weekly meeting of students and visitors. There was a weekly nuclear seminar with experimental and theoretical colleagues (Krane, Madsen, Siemens, Stetz, and Welch), and a weekly departmental colloquium. We compensated for the university's geographical isolation by having a high degree of personal contact among students and faculty, excellent computer networks, and regular visits to laboratories and meetings. These visits are often by car with student accompaniment (the Nuclear Theory Institute at Seattle is 300 miles away, TRIUMF is 400 miles away).

The DOE support had permitted our group to run Unix workstations networked to other computers in the Physics Department and the University. Since 1990 we have been using IBM RISC System 6000/model 530 with console and four X–stations. The equipment was purchased and is maintained with yearly DOE funding of our group. Our activities in Computational Physics has been an excellent way for us to attract good students to our program, fits in well with the changing curricula at universities, and supports meeting some of the scientific *Grand Challenges* enunciated by the DOE.

2 DESCRIPTION of RESEARCH, LANDAU

2.1 Cloudy Bag Quark Models for the $\overline{K}$-Nucleon Interaction

We extended the cloudy, quark bag model to include P and D partial waves and associated resonances and published G. He's thesis work on this subject in Phys. Rev. C. This work solved coupled, relativistic Lippmann-Schwinger equations for the off-energy-shell T matrix for the five coupled channels $\{K^-p$, $\overline{K}^-n$, $\Sigma\pi(I=0)$, $\Sigma\pi(I=1)$, $\Lambda\pi(I=1)\}$. We examined low energy scattering and reaction data, angular distributions, branching ratios, and the strong interaction shift of kaonic hydrogen. This represents one of the most extensive fits of a quark model to data of interest to nuclear physics.

2.2 Chiral Color Dielectric Models for the πN and $\overline{K}$-N Interactions

We completed our application of the chiral color dielectric model to low- and medium-energy scattering within the coupled (πN, $\pi\Delta$) system. Dynamic baryon states in which quarks are confined by the scalar color-dielectric field were constructed in Fock space, and the spurious motion of the center of mass eliminated by constructing momentum eigenstates via a Peierls-Yoccoz projection. After deriving an effective potential, the relativistic Lippmann-Schwinger equation was solved for the T matrix and the complex energies of the T matrix's poles. The pole positions of the nucleon and delta were used to fix the few parameters of the model.

In our study we simultaneously computed scattering amplitudes and the energies of dressed resonances (the pole positions of these amplitudes). We predicted the S- and P-wave πN phase shifts, the bare N and Δ masses, the renormalized πNN and πNΔ coupling constants, and the πNN and πNΔ vertex functions. By renormalizing the πN vertex by the pion field, the ratio of the πNΔ to πNN coupling constants was found to be closer to experiment than the SU(6) prediction. We found that the mass and width of the Δ and the mass of the nucleon are significantly affected by the closed but coupled $\pi\Delta$ channel. Since it is unusual to include this coupling, this made our calculation rather unique, as also did its simultaneous reproduction of πN scattering as well as the complex energies of the nucleon and delta.

We concluded that regardless of the size parameter used, the monopole form factors often assumed in the literature are inadequate for reproducing πN scattering, and that more realistic ones such as those from the color dielectric model are needed. We also have concluded that the radius parameter of the form factor is more than twice as large as that preferred by meson exchange potential models.

2.3 Kaon Photoproduction in the CDM

The availability of continuous, high-energy and high-intensity electron beams has revived the study of electroproduction of strange particle. The existing kaon photoproduction cross-section data are all from before 1972. Possibly as a consequence of this, the elementary $\gamma p \rightarrow K^+\Lambda$ process does not have a modern description. The basic reaction mechanism, the fundamental kaon-hyperon-nucleon coupling constant, and the proper treatment of resonant amplitudes are still controversial. Although the data can be reproduced by adjusting parameters, there are a large numbers of parameters, and the coupling constants are not consistent with those determined from hadronic processes.

In order to advance the theoretical description of elementary kaon photoproduction to a more microscopic level (from particles to quarks), we studied it in the chiral color dielectric model(CDM) as part of Mr. Lu's thesis work. In contrast to present models, the vertex functions were not phenomenological, but instead were derived from the quark wave functions of momentum-projected baryon states. We worked with a minimal-coupling color-dielectric model which included the lowest members of the meson octet and baryon octet. The quark wave functions and the effective dielectric field were obtained by solving the Euler-Lagrange equations of motion self-consistently, and then projecting onto good momentum eigenstates. The flavor SU(3) symmetry was broken only by the use of the physical hadron masses in the relevant vertices. The parameter for the shape of the dielectric self-interaction and the quark masses were taken from the study of the static properties of baryons.

In this first test of the CDM for photoproduction, we found that our simple model worked quite well near threshold and even for large momentum transfers. Apparently, the finite size of baryons arising from their quark nature decreases the large-momentum cross sections. This was in marked contrast to more phenomenological isobaric models in which a large number of resonances are introduced to reproduce the experimental energy dependence. The predictions change only slightly when quark wave functions from the cloudy bag model were used instead of the CDM ones.

2.4 $\overline{K}$ Atomic and Λ^* Hypernuclear Carbon

We have used a number of $\overline{K}N$ interaction models to construct a microscopic, momentum-space, optical potential including complete Fermi averaging, three-body dynamics, nonlocalities, and the exclusion principle. Bound states were found with $\overline{K}$ orbits internal to and external to the nucleus (Λ^* hypernuclei, and kaonic atoms).

2.5 Momentum Space Proton Scattering

We refined our momentum-space optical potential description of proton elastic and charge exchange scattering from spin $\frac{1}{2}$ nuclei. Our theory is microscopic (using our developments from the pion and kaon optical potentials), and describes the full spin structure for the interaction of two spin $\frac{1}{2}$ particles. We showed the theory to be capable of predicting all 24 spin observables — a capability which is only now being tested with the advent of polarized beam–polarized target experiments. We included the Coulomb force exactly into our spin $\frac{1}{2} \times \frac{1}{2}$ calculations (it had only been done previously for spin $0 \times \frac{1}{2}$) and have solved a long–standing challenge in the exact inclusion of singlet–triplet coupling.

2.6 Improved Inclusion of f Amplitude

Although the generalized Pauli principle forbids the nucleon–nucleon amplitude from having an f term (proportional to $\sigma_1 - \sigma_2$), a nuclear f term arises naturally in a microscopic theory for scattering from nuclei. As expected theoretically and confirmed experimentally, the $p -^{13} C\, f$ is a large amplitudes and thereby leads to the significance differences found between A_{00n0} and A_{000n} in both ^3He and ^{13}C. We reformulated the Stapp partial wave analysis of spin $\frac{1}{2} \times \frac{1}{2}$ scattering to include the coupling of the singlet and triplet channels. We modified and debugged LPOTp, and have found that some of the spin observables to be quite sensitive to this exact treatment of singlet-triplet coupling.

2.7 Coulomb plus Nuclear Scattering in Momentum Space for Coupled Angular Momentum States

The Vincent-Phatak procedure for solving the momentum-space Schrödinger equation with combined Coulomb plus short-range potentials was extended to angular momentum states coupled by an optical potential, as occurs in spin $\frac{1}{2} \times \frac{1}{2}$ scattering. We derived a generalization of the Blatt-Biedenharn phase shift parameterization for the scattering of two spin $\frac{1}{2}$ particles in which the S matrix is no longer symmetric (as occurs when there are optical potentials or complex phase shifts). The method is applied to 500 MeV polarized-proton scattering from ^{3}He. The requisite high-precision partial-wave expansions and integrations were investigated and found to be successful.

2.8 Schrödinger Optical-Potential Calculation of 500 MeV Polarized Proton Scattering from Polarized ^{13}C

We have examined how well a first order, theoretical optical potential can describe the cross sections and spin observables measured in elastic proton scattering from ^{13}C near 500 MeV. The theory includes the full spin dependences for two spin 1/2 particles, singlet-triplet mixing, nonlocalities arising from off-energy-shell behavior of the NN interaction, and Lorentz covariant, off-shell kinematics. When the resulting optical potential is used in a relativistic Schrödinger equation, multiple scattering and exchange effects are included.

2.9 Charge Symmetry Breaking in Nucleon-Trinucleon Scattering

As the last part of Mefford's thesis work, we have applied our developments in spin $\frac{1}{2} \times \frac{1}{2}$ scattering to investigate charge symmetry breaking in nucleon-trinucleon scattering. We included the Coulomb force exactly, used realistic particle and nuclear masses, and then studied the effect of charge symmetry violation at the nuclear structure level. In analogy to the work done with pions based on our theoretical analysis, we looked for deviations from 1 of the ratio of the p-^{3}H cross section to the n-^{3}He cross section, and of the ratio of the n-^{3}H cross section to the p-^{3}He cross section. We then looked at the sensitivity of the superratio formed as the ratio of these two ratio's. The calculations showed an angular region which is sensitive to charge-symmetry breaking and in which the calculations appear reliable. We also found that at large angles, extreme interference occurs and the calculations become unreliable.

2.10 Spin Observables in Elastic Proton Scattering from Polarized ^{3}He

We have collaborated in a measurement of the absolute cross section and complete sets of spin observables, A_{00ij}, in ^{3}He(p,p) elastic scattering at energies of 200 and 500 MeV. The observables depend on linear combinations of six complex scattering amplitudes for the p-^{3}He system and provide a severe test of current reaction models. The in-scattering plane observables (A_{00mm}, A_{00ll}, A_{00lm}, and A_{ooml}) are all in quantitative disagreement with both non-relativistic and semi-relativistic optical model calculations we have performed.

2.11 Deeply Bound Pionic States in Heavy Nuclei

We have investigated pion–nucleus bound states in momentum space using a microscopic optical potential with energy dependences and nonlocalities arising from elementary potential models. Our calculations confirmed the existence of deep, hybrid Coulomb–nuclear $1s$, $2s$, and $2p$ bound states. However, we found their widths to be significantly greater (20 – 300%) than reported previously for quite different potentials and their binding energies to be slightly ($\sim$ 7%) greater. Although the states remained non overlapping, our larger widths may affect experimental searches. Because the differences among models increases with binding, the model dependence appeared to arise from our inclusion of energy dependences in the optical potential, complex energy extrapolations, and our treatment of the finite-range annihilation term, the latter affecting the widths in particular. Our wave functions were similar enough to those of Toki et al. so as not to yield major changes in atomic formation rates.

We also looked for nuclear bound states of pions internal to the nucleus. We found only resonances and had to increase the strength of the potential at least eight-fold before bound states appeared. In the process, we discovered that at normal strength the real part of the effective local potential for a $1s$ pion in Pb had an inner attraction in addition to a strong, outer repulsive barrier. Likewise, a $2p$ pion in Ca was found to have an inner repulsion in addition to an outer attraction. It was these attractive parts which bound the pion within the nucleus as the potential strength was increased.

From a computational viewpoint we have shown that pionic atom energies can be calculated accurately in momentum space with a microscopic, nonlocal, and energy–dependent optical potential. We have done it by searching for the poles of the T matrix for the combined Coulomb plus nuclear potential in contrast to more usual eigenfunction methods.

2.12 Computational Physics

Professor Landau is one of the pioneers in the development of theoretical and computational techniques for solving quantum mechanical problems in momentum space, in particular, the solution of integral forms of the Schrödinger equation for both scattering and bound states. In recent years he has extended these techniques to include the combined Coulomb plus nuclear force problem, the solution for Gamow (resonance) states for coupled channel systems, and the computation of all spin observables for general spin $\frac{1}{2} \times \frac{1}{2}$ systems. In all cases, the use of new computational techniques has eliminated some of the more usual approximations made (usually a consequence of working in coordinate space), which in turn has led to a more microscopic understanding of the physics. Of particular interest to Landau has been the search for and the investigation of the properties of exotic atomic or nuclear states. For example, some of his discoveries of bound states in the antikaon–nucleon system supports the speculation that neutron stars may be unstable under collapse into strange matter stars. He has regularly published the major computer codes written for his research, and has applied visualization techniques to variety of problems.

Dr Landau continued to contribute to the development of Computational Physics. Landau's collaboration with Paul Fink of The Thinking Machine Corporation and Angelo Rossi of IBM Research has led to a new book, *A Scientist's and Engineer's Guide to Workstations and Supercomputers, A Unix Survival Guide*, John Wiley. By disseminating to the scientific community some of the tools which we have developed in computational nuclear physics, the community as a whole should benefit, and the contributions of nuclear physics will be better appreciated.

3 DESCRIPTION OF RESEARCH, MADSEN

3.1 Causality and Dispersion Effects in a Physical Model

Prompted by a new paper on the time dependent optical potential by Mahaux, et al, we have devised a simple model of the dynamical polarization potential in terms of a with vibrational nucleus with a sharp surface boundary. An exact energy dependent potential can be calculated leading to a time nonlocal potential, which can be also be obtained in closed form. Because of the simplicity of the model, an interpretation of the time nonlocality can be found in terms of the projectile nuclear transit time in the excited channels. (See publications sheet.)

Subsequently, it has been found that within the simple model the definition of the time dependent potential is ambiguous. Instead of using the Fourier integral of the energy dependent potential, we can use an energy integral which has a finite lower limit. However, it can be shown that these potentials are noncausal in the sense that the time nonlocal potential $V(t, t')$ can be nonzero at $t' > t$ where t is the current time and t' is the integrated time in the time nonlocal potential term of the Schrödinger equation.

Generally, this would mean that the wave function $\psi(t)$ could depend could depend on the wave function at later times $t' > t$. Likewise, in the many-body approach to the calculation of the optical potential as the self-energy operator of the time-ordered Green's function, the time dependent potential is noncausal. However, in both models it can be shown that these noncausal potentials give rise to causal wave functions because of the energy spectrum of the wave function. A paper on this subject was published in Physical Review (see publications).

3.2 Isospin effects in nuclear vibrations

In collaboration with V.R. Brown and the experimental group at Oak Ridge, a study has been made of the systematics of neutron and proton multipole matrix elements in the isotopes of Zr. The calculations were carried out in the RPA using a harmonic oscillator basis from 1s to 8k orbitals using different strength separable interactions for neutrons and protons. Both 2_1^+ and 3_1^- multiple transition matrix elements were calculated and compared with measurements by the Oak Ridge Group coordinated by Dan Horen. Calculations of Heavy ion scattering cross sections were made using separate transition densities calculated in RPA for neutrons and protons. Good results are obtained in these calculations, except that the strengths of the calculated 3^- transitions are uniformly weak. In ^{90}Zr for which the transition density has been determined experimentally from inelastic electron scattering, the calculated transition densities are peaked at a slightly smaller radial coordinate than the experiments ones. (See publications).

3.3 Incorporation of Continuum States in TDA

In the interest of finding ways of calculating more realistic transition densities for excitation of low lying collective states in the nuclear surface region, we are trying a variational approach to including the continuum states. The latter, which supply the bulk of the "core polarization" are absolutely necessary for getting the full strength of collective transitions. In the particle-hole state, the particle is calculated in a shell model potential from the origin out to a matching point beyond the nuclear radius. These basis states individually satisfy no particular boundary conditions at the matching radius, but rather the variational wave function consisting of a linear combination of both bound and continuum radial states is constrained to match a realistic decaying exponential outside wave function. The decay constant can be chosen at will and can correspond, for example, to the experimental energy of the collective state. This procedure has been tested for one dimensional wave functions against the corresponding exact wave functions. With about 5 radial basis states, the variational wave function agrees nearly perfectly. Calculation for particle-hole states is underway.

3.4 Scattering and Charge Exchange Reactions

In collaboration with V.R. Brown and John Anderson of Livermore, we have solved the long-time problem of the reversal from the usual forward peaking of low-energy (p, n) cross sections, which occurs at some energies between 0 and 100 MeV. DWBA calculations do give this effect, but an explanation has been lacking. We have shown both by slug-model and coupled channel calculations that the effect comes about because of interference in the forward direction between neutrons produced in the volume and surface of the nucleus. A paper on this subject is in preparation.

We have also studied the analog transitions in odd nuclei, for which higher multipolarities than the usual Fermi $\Delta J = 0$ transition densities. We have shown that the contribution to the transition rate from all these $\Delta J > 0$ is proportional to $(N - A)^{-1}$ in contrast to $(N - A)^{+1}$ for $\Delta J = 0$. Thus for nuclei with a fairly high neutron excess, the effects from these higher multipoles should be fairly small. (See publications).

3.5 Partial Occupancy Of Single Particle Orbitals

The phenomenon of reduction of occupancy from nearly 100 percent for deeply bound states and partial occupancy has been explained on the basis of many- body theory by Mahaux and collaborators for closed shell nuclei. The distribution of occupancy falls slowly with increasing bound particle energy, is discontinuous at the Fermi surface, and then continues to fall off slowly with increasing energy. In the BCS type pairing model there is a rapid but continuous decrease in occupancy from essentially 100 percent to zero right near the Fermi surface. With a simple increase in the strength of the pairing interaction, such a distribution of occupancies can be obtained well above and well below the Fermi sea, but at the expense of having a very gradual change in occupancy near the Fermi energy, which would cause the shell gaps to break down. We are attempting to study the question of occupancy in open shell nucleus with a Hartree-Fock-Bogoliubov calculation in which the deeply bound orbitals, Fermi surface orbitals, and states well above the Fermi sea are all included in the transformation to quasiparticles. Most of a computer program has been written using finite range two-body forces. We speculate that components of the nuclear force with several ranges will give the required spreading out of the occupancy, while giving the realistic behavior of occupancy at the Fermi surface.

4 PUBLICATIONS and PRESENTATION (Three Years), RUBIN H LANDAU

4.1 Books

1. *Quantum Mechanics II, Second Edition*, Rubin H. Landau, John Wiley, New York, 1996 (2nd printing).
2. *Computational Physical Science, A Project Approach*, Rubin H. Landau and Manuel. J. Paez, John Wiley, New York, to be published 1997.

4.2 Refereed Publications

1. *Exotic Gamow States of Atoms, Nuclei, and Particles*, R.H. Landau, Computational Quantum Physics, Vanderbilt University, Nashville, AIP Conf. Procds. **260**, 83 (1992).
2. *Visualizations in few body physics*, R. H. Landau, T. Mefford, G. He, and P. Fink, Computers in Physics. **7**, 296 (1993).
3. *Cloudy Bag Model for the S-D Wave $\overline{K}N$ System*, G.He and R. H. Landau, Phys. Rev. C, **48**, 3047 (1993).
4. *Deep Pionic Bound States in a Nonlocal Optical Potential*, D. Lu and R.H. Landau, Phys. Rev. C, **49**, 878, (1994).
5. *Schrödinger Optical Potential Calculation of 500 MeV Polarized Proton Scattering from ^{13}C*, T. Mefford, R. Landau, L. Berge, and K. Amos, Phys. Rev. C, **50**, 1648, (1994).
6. *Coulomb plus Nuclear Scattering in Momentum Space for Coupled Angular-Momentum States*, D. Lu, T. Mefford, G. Song, and R.H. Landau, Phys. Rev. C, **50**, 3037, (1994).
7. *Chiral Color Dielectric Model for S and P Wave Scattering in the Coupled $(\pi N, \pi\Delta)$ System*, D. Lu, S.C. Phatak, and R.H. Landau, *The π N Newsletter*, (ISSN 0942-4148), **10**, 209, (1995).
8. *Pion-Nucleon Scattering and the πNN Coupling Constant in the Chiral Color Dielectric Model*, D. Lu, S.C. Phatak, and R.H. Landau, Phys. Rev. C, **51**, 2207 (1995).
9. *Kaon Photoproduction in the Chiral Color Dielectric Model*, D. Lu and R.H. Landau, Phys. Rev. C, **52**, 1662 (1995).
10. *Charge Symmetry Breaking in 500 MeV Nucleon–Trinucleon Scattering*, D. Mefford and R.H. Landau, Phys. Rev. C, **52** 1212 (1995).
11. *Elastic Scattering of Polarized Protons from Polarized ^3He*, O. Häusser, B. Larson, W.P. Alford, C. Chan, P.P.J. Delheij, R.S. Henderson, K.P. Jackson, R.H. Landau, T. Mefford, C.A. Miller, A. Rahav, L. Ray, A. Trudel, and M.C. Vetterli, Phys. Lett. **B343**, 36 (1995).
12. *Spin Observables in Elastic Proton Scattering from Polarized ^3He*, E.J. Brash, O. Häusser, W.J. Cummings, M. Bahrami, P.P.J. Delheij, R.S. Henderson, M.C. Vetterli, D.M. Whittal, B. Larson, R.H. Landau, T. Mefford, and L. Ray, Phys. Rev. C, **52**, 807 (1995).
13. *Computation in Modern Physics, a Book Review*, R.H. Landau, IEEE Computational Sci. and Engr. **2**, 84 (1995).
14. *Applications of the Chiral Color Dielectric Model to Low Energy Meson-Baryon Interactions*, D. Lu, S.C. Phatak, and R.H. Landau, Nucl. Phys. **A585**, 381 (1995).
15. *A Cloudy Bag Model for the S-D Wave $\bar{K}N$ System*, G. He, and R. H. Landau, Nucl. Phys. **A585**, 379 (1995).

16. *Computational Physics at Oregon State University*, R. H. Landau, Procds. Supercomputing'95, ACM, IEEE, 167 (1995).

17. *Computer Scientists Should Not Teach Computational Science*, R. H. Landau, IEEE Computational Sci. and Engr., Summer (1996).

18. Approximately 25 web tutorials contributed to Northwest Alliance for Computational Science Project (NACSE) and Undergraduate Computational Science and Engineering (UCES); see http://www.physics.orst.edu/~r

4.3 Invited Conference Talks

1. *Visualizations while Computing Particle Scattering & Exotic Bound States*, American Physical Society, Washington, D.C., April 1992.

2. *Visualizations while Computing Particle Scattering & Exotic Bound States*, Amer. Phys. Soc., Washington, D.C., April 1992.

3. *Bound States, Resonances, and Poles in Low Energy Antikaon Interactions*, Amer. Phys. Soc., Washington, D.C., April 1993 (organizer of session).

4. *Quark Models of the Low-Energy $\overline{K}N$ and πN Interactions*, R.H. Landau, Department of Atomic Energy Symposium on Nuclear Physics, Bhubaneswar, India, December 1994, **37A**, 144 (1995).

5. *UCES Award Talk: Computational Physics Course & Laboratory Development*, http://model.ams.ameslab.gov/awar 1995.

6. Panel Member, *Assessment of Publications in Computational Science and Engineering*, R. H. Landau, Supercomputing'95, San Diego, December 1995.

7. *Revealing Singularities in πN and $\overline{K}N$ Interactions*; Chairman of Session on New Techniques; R. H. Landau, Mesons'96 International Conference, Krakow, Poland, May 1996.

4.4 Conference Participation

1. *Optical Potential Calculation of 500 MeV Polarized Proton Scattering from ^{13}C*, T. Mefford, R. H. Landau, L. Berge, and K. Amos, Washington, DC, April 1992, BAPS **37** 901 (1992).

2. *Computation of Kbar-N S, P & D Wave Interactions in the Cloudy Bag Model*, G. He and R. H. Landau, Santa Fe, BAPS **37**, 1274 (1992).

3. *Microscopic Optical Potential model of Spin $\frac{1}{2} \times \frac{1}{2}$ Scattering*, T. Mefford and R.H. Landau, Asilomar, BAPS **38**, 1834 (1993)

4. *Deep Pionic Bound States in Momentum Space*, D. Lu and R.H. Landau, Asilomar, BAPS **38**, 1835 (1993).

5. *A Cloudy Bag Model for the S–D Wave $\bar{K}N$ System.* R.H. Landau and G. He, Asilomar, BAPS **38**, 1824 (1993).

6. *A Graduate and Undergraduate Course in Computational Physics*, R.H. Landau, National Conference on Academic Programs in Computational Science and Engineering Education, Albuquerque, (1994).

7. *Pion–Nucleon Scattering in Chiral Color Dielectric Model*, S.C. Phatak, D. Lu, and R.H. Landau, 5^{th} Conf. on Intersections of Nuc. & Part. Phys, St. Petersburgh, June, 1994.

8. *Computational Physics at Oregon State University*, R. H. Landau, Procds. Supercomputing'95, San Diego, December 1995.

9. *UCES Awards Conference*, Washington, DC, August 1995.

10. Department of Atomic Energy Symposium on Nuclear Physics, Bhubaneswar, India, December 1994.

11. *Revealing Singularities in πN and $\overline{K}N$ Interactions*; Chairman of Session on New Techniques; R. H. Landau, Mesons'96 International Conference, Krakow, Poland (1996).

4.5 Invited Seminars

1. National Institute for Nuclear Theory, Seattle, *A Review of The Low Energy Antikaon–Nucleon Interaction*, July, 1992.

2. Department of Physics, University of Nevada, Reno, *Gamow States of Atoms, Nuclei, and Particles in Momentum Space*, April 1993.

3. Variable Energy Cyclotron Centre, Calcutta, India, *The $\overline{K}$-Nucleon Interaction*, December 1994.

4. Variable Energy Cyclotron Centre, Calcutta, India, *The Role of Physics in Computational Science*, December 1994.

5. Institute of Physics, Bhubaneswar, India, *The $\overline{K}$-Nucleon and πN Interactions at Low Energies*, December 1994.

6. Institute of Physics, Bhubaneswar, India, *The Role of Physics in Computational Science*, December 1994.

7. Institute of Research, University of Warsaw, Poland, *Computers, Physics, Education, and All That*, May 1995.

8. Institute of Research, University of Warsaw, Poland, *The Interaction of Antikaons with Nucleons and Nuclei*, May 1995.

4.6 External Thesis Examiner

1. *A Model for the Short Range Nuclear Force*, Melinda Swift, The University of Adelaide, South Australia, 1993.

2. *Study of Baryonic Properties in Chiral Color Dielectric Model*, Sarira Sahu, Institute of Physics, Bhubaneswar, India, 1994.

3. *Probing the $\Lambda - \Lambda$ Interaction: Studies of $^6He_\Lambda - \Lambda$ and the Reaction $\xi + d \rightarrow \Lambda + \Lambda + n$*, Steven Car, The Flinders University of South Australia, 1996.

5 PUBLICATIONS (Three Years), VICTOR A. MADSEN

1. *Theoretical Treatment of Analog (p,n) Cross Sections for Odd Nuclei: Application to measuremnets of* ^{105}Pd *at 26 MeV* V.A. Madsen et al., Phys. Rev C**47** 2077, (1993)

2. *Different Effects of Valence Neutrons on the Isospin Character of Transitions to the First* 2^+ *and* 3^- *States of* $^{90,92,94,96}Zr$ D.J. Horen et al., Phys. Lett. **B 296** 18 (1992)

3. *Systematics of Isospin Character of Transitions to the* 2^+ *and* 3^- *States in* $^{90,92,94.96}Zr$ D.J. Horen et al. Phys. Rev. C**47**, 629 (1993)

4. *Mean Fields: Explicit dispersive and retardation properties of the dynamical polarization potential within a simple model* V.A. Madsen et al. Phys. Rev. **C48**, 1221 (1993).

5. *Causality with noncausal optical potentials* V.A. Madsen, and K.I. Goldman, Phys. Rev. C**51**,2011, (1995)

6. *Low lying Gamow-Teller states in* ^{92}Nb S.M. Grimes, et al, accepted for publication in Phys. Rev. C.

   Why the simple nuclear Ramsauer model works S.M. Grimes, J.D. Anderson, and V.A. Madsen, to be submitted for publication.

7. *Inversion of the forward angle quasielastic (p,n) cross section: A means of detecting rapid changes in the forward scattering amplitude* V.A. Madsen el al. submitted to Phys. Rev. C.

6 GRADUATE STUDENTS DIRECTED, LANDAU

GRADUATE STUDENTS DIRECTED, LAST FIVE YEARS

Name	Degree	Year	Thesis Title	Present Position
Jeffrey Schnick	PhD	1988	Potential Model Investigation Low-Energy $\overline{K}N$ Interaction & $\overline{K}$-Nucleus Bound States	Assoc. Prof. of Physics St. Anselm Coll., Manchester, NH
Paul Fink	MS	1989	New Computational Methods for $\overline{K}$-Nucleus Bound States	Sci. Applications Specl. Thinking Machine Corp. Minn. Supercomput. Centr.
Guanliang He	PhD	1992	Cloudy Quark Bag Model S, P, and D Wave Interactions for Coupled Channel $\overline{K}N$ System	Trading Programmer Quant. Financial Trading Conshohocken, PA
Timothy Mefford	PhD	1995	Proton Scattering from Spin $\frac{1}{2}$ Nuclei	Tektronics Corp,
Dinghui Lu	PhD	1995	Color Dielectric Quark Model for πN and $\overline{K}N$ Interaction	Research Associate, Adelaide

We have not been supported for any research associates.