DOE/ DOE/ER/40427--14-P92

DE92 015349

Nuclear Theory Progress Report

April 1991 - April 1992

Nuclear Theory Group

Department of Physics, FM-15

University of Washington, Seattle, Washington 98195

Nuclear Theory Group, University of Washington

II. Progress Report, April 1991 - April 1992

Wick Haxton

Most of my recent work continues to focus on nuclear and particle astrophysics, symmetry tests in nuclei and atoms, and many-body physics.

1. Nuclear Astrophysics

Zhang and I completed work on the effects of turbulence or density fluctuations on matter-enhanced solar neutrino reactions. We obtained an analytic result that very accurately reproduces and explains the dramatic regeneration effects found numerically by several authors. I am now exploring, in the MSW mechanism, whether the flavor-dependence of the index of refraction can destroy phase coherence by spreading the neutrino wave packet in very dense matter. A review on the solar neutrino problem is being completed, including a careful analysis of the combined constraints from various experiments. Ying, Henley, and I also recently completed an improved calculation of cross sections for SNO.

Kar Lee and I are extending our analysis of red giant cooling by nuclear axion emission. Our original paper was the first to exploit metallicity in particle astrophysics. We have now examined a claim that SN1987A events in the Kamioka II detector tightly constrain axions in the "Turner Window", and found that the claim was exaggerated.

Wei Lin and I are working through several interesting ideas that might lead to a more robust core-collapse supernova mechanism. Two issues involve the star's entropy during the infall stage. Conventional β decay is frequently modeled as a heating process, yet work I performed with Bruenn clearly demonstrates it refrigerates. Similarly, neutral current β decay (neutrino pair production) cools the star, and this process leads to no loss of lepton number. Both mechanisms help maintain a lower entropy during collapse, and thus lead to a more robust core bounce. In the late stage we are examining new heating mechanisms, including $\nu\bar{\nu} \rightarrow$ plasmon and neutral current inelastic reactions off correlated nucleons. (The interesting effects for the latter involve the second-order polarization insertion.)

2. Symmetry Tests

I recently demonstrated that, in theories motivated by the 17 keV neutrino where the usual Majorana neutrino mass in $\beta\beta$ decay vanishes, a direct proportionality between 0ν and 2ν decay rate results. The proportionality measures a new quantity $< m_i^3 >$ that involves a weighted sum over the cubes of the Majorana mass eigenstates. This result eliminates one proposed class of theories that could incorporate a 17 keV neutrino.

I am extending the Haxton-Zhang analysis of neutrino oscillations to the neutral kaon system. While there is no K-$\bar{K}$ analog of the MSW mechanism, one can drive kaon oscillations by appropriate density variations in a regenerator. This opens up some amusing experimental possibilities, including a strong energy dependence in the $K_L \rightarrow K_S$ regeneration amplitude.

Henley, Musolf, and I are completing work on nuclear anapole moments, extending our earlier treatment of pion loops and exchanges to include vector mesons. The intent is to treat all the nuclear polarization and exchange current diagrams that would arise from the standard $\pi + \omega + \rho$ Hamiltonian used in parity violation studies in nuclei. We intend to establish quantitative relationships between the hyperfine dependence of atomic parity violation and the hadronic weak interaction.

Several projects related to atomic and nuclear electric dipole moments are in progress. Antje Hoering and I are studying edms induced by a T-odd P-even nuclear interaction combined with Z_0 exchange between atomic electrons and the nucleus. Mike Musolf and I are completing a careful analysis of the contributions of penetration terms, relativistic corrections, and the higher order T-odd M2 nuclear moment to atomic edms. Kar Lee and I are evaluating the nuclear quantities (polarization sums, one-body couplings, and exchange currents) that will govern the edm of ^{201}Hg, where the best measurements have been made.

3. Many-body Physics

The fractional quantum Hall effect can be studied in a tractable Hilbert space by mapping this planar problem onto a sphere, with the perpendicular magnetic field provided by a monopole at the sphere's center. The problem of the residual electron-electron interaction then is seen to be similar to the shell model, where the fractional fillings of the first Landau level correspond to various partial occupations of a single shell, where the J of the shell is related to the number of monopole quanta. Joe Ginocchio and I have been able to rewrite the standard Laughlin wave function for the FQHE in an elegant way in this geometry, and to prove that this wave function is a state of maximum seniority in the limit $J \rightarrow \infty$. We have also made progress in generalizing Laughlin's wave function for fractional fillings $1/m$, $m \neq$ integer.

In the work on edms and on double beta decay, a variation of the Lanczos algorithm is being used to calculate fully interacting shell model Green's Functions exactly. The double beta decay work involves a collaboration with Engel and Vogel.

E. M. Henley

1. Parity Nonconservation and the Standard Model

(a) The Anapole Moment

Mike Musolf, Wick Haxton, and I have almost completed the inclusion of the rho- and omega-meson exchanges to the anapole moment.

2. Time Reversal Invariance

(a) Beta Decay Tests

There is an ongoing experiment at the Nuclear Physics Laboratory to test time reversal in positron- and electron-decays of mass 8 nuclei. Since the final state of the decay consists of two alpha particles, questions arise as to the role of the hadronic final state scattering effects. S. Ying, a student I am supervising, and I have examined this time reversal test in detail. We have also looked at the effects of the final state electromagnetic corrections due to the electron-nuclear interaction. Mr. Ying defended his thesis recently, and the work is essentially completed.

(b) Enhanced Beta Decay Tests

By choosing a first forbidden beta decay, it is possible to enhance the sensitivity to time-reversal odd nuclear forces. I.B. Khriplovich and I have examined such tests in some detail and have concluded that the best examples are those in which mixing occurs in the initial state. If the admixed state is close in energy and of the opposite parity, the sensitivity and experimental practicality are both improved. This work is being written up for publication.

3. Aspects of the Quark-Gluon to Nucleon-Meson Transition: Quarks in Nuclei

(a) The NN System

Since the annihilation of a proton and antiproton only occurs when the two particles overlap appreciably, this system should be a good laboratory to examine the quark-gluon to meson-baryon transition. Mary Alberg, Larry Wilets, Dale Kunz, and I are continuing to examine the combination of the ^3P_O and $^3S_1$ models for exclusive annihilation channels. We have concentrated on strange baryonic final states because the decays of these baryons test the spin degrees of freedom in the process. We have almost completed our examination of the $\Lambda\bar{\Lambda}$ final states; it is for this reaction that the best data is available. Angular distributions, spin correlations, and polarizations have been examined. We have begun to examine the $\Lambda\bar{\Sigma}$ and $\Sigma\bar{\Lambda}$ final states.

(b) Strangeness in Nucleons

The EMC measurements of the nucleon structure function together with earlier measurements of the σ-term in pion-nucleon scattering have led to the conclusion that the strangness matrix elements of a nucleon might be large. Although there are numerous papers that attempt to show how this puzzling result can be understood without a large strangeness "content", there are only a few papers that suggest how to actually measure the strangeness matrix elements. G. Krein, A.G. Williams, S. Pollock, and I have examined and suggested various ways of measuring these matrix elements. They include elastic scattering of electrons and neutrinos from light isospin zero nuclei, and ϕ production. This work was completed and has been published.

In addition, we examined in detail electro-ϕ production from protons as a method of measuring the vector strangeness matrix element in the proton. Both magnitude and angular distributions (or t and Q^2 dependences) of the cross section were calculated. It is found that the magnitude is likely to be about the same as that due to vector meson dominance. A difference shows up in the angular (or t-) dependence, but it will not be trivial for experimentalist to see this effect. It is likely that polarization studies will be required and we intend to examine these next. The work without polarization was completed and has been accepted for publication.

We also examined neutrino and antineutrino scattering from deuterium in detail. Here, the ratio of the difference between these cross sections to their sums is a direct measure of the strangeness axial matrix element of the nucleon. This ratio can be large, even approaching unity, for quite small values of the strangeness axial matrix elements. We included an examination of the best momentum transfer(s). The work has been concluded and submitted for publication.

Lastly Werner Koepf, Steve Pollock, and I calculated the vector and axial-vector strangeness matrix elements to be expected in a simple (naive) model where, not only the pion, but all eight Goldstone pseudoscalar bosons couple to quarks. We have used a point nucleon, a chiral bag and a constituent quark model to estimate the matrix elements. This calculation is being completed and being written up for publication.

4. Superallowed Beta Decays

The lifetime of superallowed beta decays have been measured to very high precision; they have been calculated to similar precision with the inclusion of radiative, overlap, and other corrections. There is a puzzling Z-dependent remaining discrepancy between experiment and theory which prevents the extraction of the Weinberg angle, tests of CVC and of unitarity of the Kobayashi-Maskawa matrix. Together with Wick Haxton and Wei Lin, I am examining this problem, particularly the overlap and Coulomb corrections. We are incorporating the most important Coulomb corrections into the extended shell model from the beginning. This requires a fair amount of work, which is still going on.

5. QCD Sum Rules

(a) The axial vector nucleon coupling constants, g_A.

W-Y.P. Hwang, Leonard Kisslinger, and I have used QCD sum rules to determine both the isovector and isoscalar axial-vector coupling constants. We find that the standard parameters give a value of 1.26 for the isovector g_A if diagrams up to dimension eight are included consistently. We also find that this coupling becomes 1.0 when chiral symmetry is restored. The value of the isoscalar coupling was also computed as well as its change when chiral symmetry is restored. This work has been submitted for publication.

(b) Other investigations

We have begun to examine sum rules for calculating the induced pseudoscalar coupling constant and the weak parity-violating meson-nucleon couplings.

Together with J. Pasupathy, I have begun to examine the changes of nucleon properties in the nuclear medium. We have begun with the mass and expect to proceed to g_A.

G. A. Miller

My principal interest is in employing the vast array of nuclear properties and reactions to study Quantum Chromodynamics (QCD). This requires examinations of low and high momentum transfer properties. Processes involving fundamental symmetries can provide relevant information about how QCD is manifest in nuclei, and are often of high intrinsic interest. I summarize the recent progress.

I. High Energy Probes of QCD and Nuclear Properties

Much of the recent work is concerned with color transparency effects. This is the vanishing of initial and final state interactions in high momentum transfer (Q^2) nuclear reactions in which the resolution is good enough to ensure that no extra pions are created in the fundamental hadronic two-body reaction. Examples are the $(e, e'p)$, (p, pp) and $(e, e'\Delta)$ reactions. Experiments at SLAC (NE-18) and BNL searching for color transparency are underway. The origins of this unusual phenomenon are based on three main points: (a) small objects are produced in high Q^2 exclusive processes, (b) the interactions of such small color singlet objects are suppressed due to the effects of cancellation of gluonic emission (c) if the small object remains small for long enough it can escape the nucleus without further interactions.

1. B.K. Jennings (TRIUMF) and I continue to examine color transparency. The salient feature of our approach is the use of a hadronic basis to describe wave packets formed in high Q^2 processes. We used this approach to analyze the earlier BNL color transparency (p, pp) experiment. In a recent Physics Letter we studied approaches in which the (p, pp) amplitude is described as a coherent sum of perturbative and non-perturbative terms. The previously proposed non-perturbative amplitudes are the Landshoff term of Ralston and Pire and the $(c\bar{c})$ threshold enhancements of Brodsky and deTeramond. Including either of these effects improves the agreement between theory and the present experiment. In addition, the Landshoff term causes a huge enhancement at higher energies.

Our most recent efforts involve using data for the (pp, pX) reaction as constraints on the interaction between the ejected wave packet and target nucleons.

2. Recent work with T.-S. H. Lee (ANL) concerns predictions relevant for exploring color transparency in $(p, 2p)$ nuclear reactions. These have often been made using simplified treatments of nuclear dynamics. We examine the extent to which the earlier predictions are valid by carrying out calculations using an improved treatment of the proton scattering wave functions, nucleon Fermi motion and the effects of long and short range nuclear correlations. Our calculations verify the universal expectation that conventional mechanisms yield an almost energy-independent transparency. Including the effects of short range correlations increases the computed ^{12}C transparency by about 30 percent. A paper is in press at Phys. Rev. C.

3. L. Frankfurt (MSU) M. Strikman (PSU) and I have completed a detailed study of the underlying assumptions about color transparency. A new method is invoked to study

whether a small wavepacket or point-like configuration (PLC) is actually formed in a high Q^2 process. We find that a PLC is formed in many non-relativistic and relativistic quark models, as well as the Skyrmion model. The requirement for PLC formation is that quark-quark correlations be important. In contrast, mean field models or those in which the Feynman (1972, lecture 29) mechanism is dominant have no PLC. We review the evidence that the nuclear interactions of a PLC should be suppressed. The nuclear time development of the PLC is studied and a new exactly solvable model is introduced. We find that measuring color transparency effects provides promising new methods to investigate nucleon and nuclear structure in the domain of non-perturbative QCD, construct a theory of superdense nuclear matter, and disentangle the physics of heavy ion collisions. The simplest versions of popular hadronic models show that interesting phenomena may exist for momentum transfers as low as about 1 GeV/c^2.

4. An "Introduction to Color Transparency" has been prepared for publication in a volume containing the lectures of the first INT summer school, "N^*'s and Nucleon Structure". I serve as the editor of this book.

5. I am making further studies of the nuclear time development of the wavepacket with a student, W. Greenberg. We have made a careful study of the multiple-scattering series required to compute the effects of wavepacket-nucleus interactions. We confirm the accuracy of some earlier approximate treatments, and examine the amount of transparency obtained if the initial wavepacket is not of zero extent.

A related work with Strikman and Frankfurt was to show that high energy nuclear quasielastic reactions provide decisive tests of nuclear binding/pion models of the EMC effect. Such models are often used to analyze high Q^2 quasi-elastic and deep inelastic (e, e') reactions. We demonstrate that, in those models the presence of non-nucleonic components in the wave function cause the scattering from forward and backward moving target protons to be significantly different. The sensitivity of current (e, $e'p$) and (p, pp) color transparency experiments is sufficient to observe these differences. The work was published in Phys. Rev. Letters.

The nuclear Drell-Yan experiment at Fermilab put significant constraints on nuclear pionic distributions. I showed that these constraints rule out significant effects of $K - \pi$ interactions in K-nuclear elastic scattering. A note was submitted to Comments on Phys. Rev. Lett.

II. Relativistic Wave Functions and Light Front Techniques

Almost all interesting nuclear experiments involve relativistic kinematics. Properly invariant wave functions are needed. T. Frederico (CTA, Brasil) and I have been trying to develop light front techniques using pion phenomenology as an example. We examine the pion decay constant f_π, radius r_π and deep-inelastic scattering structure function. The technique is to use quark diagrams and project the bound state wave function on the null plane. We find that the resulting formulae are the same as the Hamiltonian front form scheme of Coester and co-workers. Components other than $q\bar{q}$ are necessary to reproduce the observables. The work on f_π and r_π is in press at Phys. Rev. D. The structure function calculations are in preparation for publication.

III. Charge Symmetry Breaking

Charge symmetry, CS, is the invariance of the strong interaction under the interchange of up and down quarks. We call this property the light flavor symmetry of QCD. The QCD quark based definition of CS allows one to account for all cases of charge symmetry breaking CSB, implying that CSB in nuclear and particle physics is due to the idfference between the down and up quark masses δm and the non-equality of their electromagntic interactions. The large body of data that support this conclusion was reviewed, and a value of δm (at a scale of 1 $(\mathrm{GeV/c})^2$) extracted. This work with Nefkens and Slaus has just been published in Comments on Nuclear and Particle Physics.

I continue to work on CSB with student Yan Zhang. We are studying the off-mass-shell dependence of $\rho^0\omega$ mixing. This is response to a claim by Thomas and Goldman and a student that such a dependence completely suppresses the nuclear effects of $\rho^0\omega$ mixing.

Lawrence Wilets

$\overline{p}$-p to $\overline{\Lambda}$-Λ and $\overline{\Lambda}$-Σ Collisions, with Mary Alberg, E. M. Henley and D. A. Kunz (Colorado). Analysis of experimental data in terms of model using both vector and scalar interactions has yielded the best fits to date. An important feature in the fit is adjustment of the $\overline{\Lambda}$-Λ (for example) potential beyond the predictions of simple SU(3) models. Several papers and conference proceedings have resulted.

A Chirally Invariant Chromo-dielectric Soliton Model was proposed in a paper by G. Fai, R. Perry and myself. Two subsequent papers by G. Krein, A. Williams, P. Tang and myself have been published. In these we demonstrated confinement and also exhibited the emergence of the pion as a Nambu-Goldstone boson. The general problem of massless quarks in a dielectric bag is being pursued by Ping Tang for his doctoral dissertation. This involves constructing the Dirac propagator for a non-local potential. Other applications (see below) have emerged.

The N-N Interaction and Six-quark Structure in the Chromodielectric Soliton Model, with W. Koepf and Fl. Stancu (Liége). This is a logical extension of our solitons model studies here. One important application planned is to utilize the six-quark wave functions so obtained in conjunction with two body correlation functions already available in order to determine the quark structure of nuclear matter.

Dynamics of Chromodielectric Flux Tubes, with John Winchester, M. Watrous and B. Balantekin (Wisconsin). This is a study of flux tube dynamics such as may be encountered in relativistic heavy ion collisions. Oscillations and break-up are being calculated in the chromo-dielectric model.

Isotopic Effects in Atomic Parity Nonconservation Experiments, with S. Pollock and E. N. Fortson. There have been suggestions to measure atomic parity nonconservation (PNC) along an isotopic chain, taking ratios of observables in order to cancel complicated atomic structure effects. This yields information on the weak mixing angle, $\sin^2\theta_W$, and depends upon nuclear structure effects, such as the neutron rms radius. A precision measurement of $\sin^2\theta_W$ in this regime could make a significant contribution to tests of the Standard Model at the level of one loop radiative corrections. To examine the sensitivity to nuclear structure, we consider the case of Pb isotopes using various recent relativistic and non-relativistic nuclear model calculations. Contributions from nucleon internal weak structure are included, but found to be fairly negligible. The spread in predicted neutron structure among present models may preclude a determination of $\sin^2\theta_W$ at the $<1\%$ level. On the other hand, atomic PNC experiments could provide a unique method to measure neutron distributions in heavy nuclei.

A Transport Theory of Relativistic Heavy Ion Collisions with Chiral Symmetry, with Wein-Min Zhang. A transport theory is developed from the quark level for describing chiral symmetry and the dynamics of meson production in high energy heavy-ion collisions. We treat the strong interaction effectively by the Nambu-Jona-Lasinio (NJL) model. The generalized Boltzmann equations of the kinetic theory for constituent quarks and mesons are derived by using the closed time-path Green's function (CTPGF) technique and loop expansion approach. Chiral symmetry, energy spectrum, dissipation and density distributions of constituent quarks and mesons can then be discussed self-consistently in non-equilibrium dynamical processes. In particular, the formulation of exploring chiral symmetry and the process of dynamical meson production as collective $q\bar{q}$ excitations in heavy-ion collisions is presented. A paper on the topic has been accepted for publication in Physical Review C.

Quantum Molecular Dynamics, with W. Beck. The terminology has been applied by others to the model introduced here to describe many-body collisions (and structure) by classical equations of motion with momentum-dependent interactions to simulate the Pauli and Heisenberg principles. Comparisons with H. Feldmeier's gaussian wave packet formulation have been made. Calculations on atomic systems are in progress. W. Lynch of Michigan state has proposed a collaboration to calculate the intermediate weight and intermediate energy systems being investigated experimentally there. Collaborations have been established with the Los Alamos plasma physics group (J. Cahn) applying the method to atomic and plasma problems.

The H_2 Molecule as a Plasma, with M. Alberg, J. Cahn (LANL) and Lee Collins (LANL). Fusion rates for hydrogen isotopes of hydrogen in a plasma requires the screening of the isotopes. This is being calculated in the Hartree-Fock approximation using Green's function techniques and spheroidal coordinates. Both cold and finite temperature plasmas are being considered.

Nuclear Physics, a chapter in *The Encyclopedia of Physical Science and Technology.* This is a revision of the chapter previously published, and was prepared in collaboration with P. Siemens (Oregon State).

Non-perturbative Renormalization and Ghost States in a Relativistic Field Theory, with R.D. Puff. G. Krein (São Paulo) and C. Nemes (Bela Horizonte). Ghosts plague all relativistic field theories; here we consider a local relativistic theory of mesons and nucleons with point coupling (no cut-off). The locations and residues of these complex poles are studied for various levels of approximation.

Suzhou Huang

1. The Role of Anomalous Singularity in Hadronic Form Factors (with Wei Lin).

By assuming chiral-symmetry breaking as the dominant dynamics in the light-hadron structure, we study the electromagnetic (EM) form factor of light hadrons in the Nambu-Jona-Lasinio (NJL) type of models in the large-N limit from a dispersion relation point of view. In addition to the expected pole from the vector-meson dominance, we identify the anomalous singularity, occurring to loosely bound states of the constituent quarks, as the other "pole" that alters the form factor from a monopole-like form to a dipole one. This mechanism is explicitly demonstrated in a two-dimensional version of the NJL type models, the Gross-Neveu model, in which all the interested quantities are calculated analytically and detailed comparison with two-dimensional QCD is made. The two-dimensional analysis is then argued to be qualitatively similar to the realistic four-dimensional case. The relevance of the dipole-generating mechanism to the phenomenology of the rho and the nucleons is indicated by quantitative estimates of the anomalous thresholds in their form factors.

2. Current-current Correlations in the QCD Vacuum (with Ming Chu, Jeff Grandy and John Negele).

Two-point current correlation functions in the QCD vacuum provide rich information in understanding the structure of hadrons. On the one hand these correlations can be related to the experimental data through dispersion relations; on the other hand they can be calculated theoretically either through lattice gauge simulations or through various hadron models. We are now undertaking a large scale simulation in the quenched approximation and measuring these correlation functions on the lattice. In the mesonic channels our numerical results are qualitatively consistent with the available experimental data. Baryonic current-current correlations, which are so far not known experimentally, will be measured soon.

3. Manifestation of Anomaly and Condensate on the Light-cone (with Wei Lin).

The canonical quantization procedure *a la* Dirac and Bergman for the constrained systems was carried out for fermions on a light-cone lattice (for x^- only). The advantage for using a lattice is that it not only regulates both infrared and ultraviolet singularities, it also makes the number of constraints countable and therefore avoids the ambiguity in the Dirac-Bergmann procedure. It is found that the fermion propagator violates the covariance if the naive definition of the time ordering is used. However, this violation can be cured by a T^* ordering. Once this problem is fixed the canonical quantization procedure becomes equivalent to the Feynman rules from the instantaneous quantization. By first integrating out the k^- component in the loop integrals we recover the expressions of the equal-x^+ Feynman rules of the light-cone quantization for both anomaly and condensate, at least up to one loop level. Though the renormalization subtractions are altered somewhat in the k^- integration process, the final physical results are nevertheless unchanged from that of the conventional covariant integration. It was found that the ultraviolet regularizations automatically regularized the infrared singularities in k^+ in the cases we considered. A direct solution of the constraint equation which gives rise to the fermion condensate is now being pursued.

4. Nucleon Solution of the Faddeev Equation in Nambu-Jona-Lasinio Model (with John Tjon).

Given the phenomenological success of the Nambu-Jona-Lasinio model in describing the meson physics in the low energy limit, it is tempting to find the fully relativistically structured nucleon solution in the same model under the same approximation employed in the mesonic sector. To achieve this goal we need to solve a relativistic Faddeev equation, which is seemingly formidable. The crucial observation in simplifying the task is that the two-body T-matrix in the diquark channel has a factorizable form. The factorizability of the two-body T-matrix can reduce the three-body Faddeev equation to a tractable two-body Bethe-Salpeter equation without assuming the existence of the diquark bound state. At the moment all the analytic derivations have been finished and we are in a position to solve the reduced two-body Bethe-Salpeter equation numerically.

5. Curvature Effect and Stability of the Hadronic and Plasma Bubbles (with Jean Potvin).

It has been shown that surface tension between the hadronic and plasma phases is finite when the interface is flat or has very small curvatures. However, when the bubble radius is not too much larger than a typical hadron size the effects of the curvature may not be negligible. The stability of the hadronic droplet in a plasma medium and the plasma droplet in a hadronic medium are not necessarily reflected by the finiteness of the surface tension with a flat interface. We are currently doing the simulations of quenched SU(3) QCD for the cases of finite bubble radius. We used lattices up to $20 \times 20 \times 20 \times 2$. Even for a radius as big as 8 lattice spacings no clear signals were detected in the limit when the external temperature gradient, which forces the formation of the bubble, was switched off adiabatically. This in turn indicates that hadronic and plasma droplets with a radius of several fermi cannot spontaneously exist. We will use a larger lattice in the future and see where the curvature effect becomes negligible. In addition, we would also like to find out the relative stability between the two kinds of bubbles.

Jerry Cooperstein

1. Supernova Explosions: Hydrodynamical Simulations

A new hydrodynamical simulation program has been developed. Its numerical procedure is fully implicit, with respect to both the hydrodynamics and radiative transport, and as such the calculation can follow the entire Type II Supernova process from the development of the initial instability in the massive stellar progenitor, through the ensuing catastrophic implosion and explosion phases, using continuous and self-consistent physical ingredients throughout. In addition, this code will be used to study the birth of neutron stars and calculate detailed neutrino specta of all types as might be detected terrestrially.

In the past year, fully general relativistic dynamics have been incorporated and major improvements have been made in a number of the physics ingredients (detailed below), especially as regards the equation of state and methods of radiative transport.

A burning network has been developed and will soon be introduced into the simulations, to calculate the self-consistent nucleosynthetic yields produced in the supernova, including the r-process elements.

So far the calculation has been carried out for about 400 milliseconds after the bounce of the supernova core in both the case of "direct" explosions and "delayed" ones, each calculation taking several hours of Cray 2 CPU time on the National Energy Research Supercomputor Center at Livermore National Laboratory. Further improvements in the equation of state must be implemented to go to later times.

2. Equation of State of Dense Matter

The compressible liquid drop model equation of state used in earlier calculations has been extended to cover very neutron rich matter, and spliced smoothly with neutron matter, through a new parameterization of the symmetry energy. Phase transitions of either first or second order have been included, for densities greater than nuclear matter density, and numerical simulations have been carried out in this regime. The general effect of phase transitions has been to soften the equation of state. A paper describing this work has been submitted to Nuclear Physics A.

3. Neutrino proceses in Dense Matter: Radiative Transport

A new method of calculating radiative transport in regions of high velocity flows has been developed, together with Ed Baron of the University of Oklahoma, and is being published in the Astrophysical Journal. This new method of "flux-limiting" works when material velocities are close to the speed of light, in the supernova case up to about one third the limiting value. Significant differences are found with the zero velocity methods that have generally been used in the supernova problem, and may have important consequences for the supernova mechanism.

Steven Bass

Renormalization Effects in QCD

Since arriving in Seattle, I have continued my work on renormalization effects in QCD (in particular field theory anomalies) and their role in the parton model. This work is being carried out in collaboration with Dr. N.N. Nikolaev of the L.D. Landau Institute (Moscow) and Universita di Torino (Italy). It continues the physics exchange between the Landau Institute and the University of Washington, which began when Dr. Nikolaev visited the INT in the summer of 1991.

It is well known that the axial vector current, which is constructed in any gauge invariant renormalization scheme, does not satisfy the canonical Ward identities. This effect is the axial anomaly. The anomaly is relevant to our understanding of the EMC Spin Effect (EMC = European Muon Collaboration).

Using a polarized muon beam and a polarized target, EMC measured the spin dependent (deep inelastic) proton structure function $g_1^P(x)$. In the old (pre QCD) parton model of Feynman the first moment of $g_1^P(x)$ determines the fraction of the proton's helicity which is carried by its quarks. Hence, there was great surprise in the high energy physics community when this quantity came out to be zero. A detailed QCD analysis has shown that $g_1(x)$ does not measure quark helicity content after all. This result follows from the strong U(1) axial anomaly in QCD. The anomaly is a renormalization effect which arises in any interacting gauge theory. As Veneziano has stressed, the EMC Spin Effect should be interpreted as a violation of Zweig's Rule which is catalyzed by the anomaly. If our nuclear models are to provide a gauge invariant description of spin dependent processes at the quark level, then they need to be modified to include the axial anomaly.

In the work of previous authors, the EMC Spin Effect has been discussed as a first moment problem. I have recently shown that the axial anomaly is relevant to each of the moments of $g_1(x)$ and not just the first moment. This result implies that the axial anomaly is manifest over a complete range of x in the EMC data. It is not seen only at small x ($x < 0.05$). The latter would follow from a naive application of factorization in the partons' transverse momentum squared k_T^2. Factorization of mass singularities is a necessary but not sufficient condition to define the parton model in spin dependent QCD. We also need to consider the locality of the photon parton interaction.

Wei Lin

1. Weak Interaction Physics.

A) Superallowed β Decays:

Experimentalists have measured the decay lifetime of eight 0^+ nuclei to a very high precision. This provides the best available value for the Fermi coupling constant and the best test for conserved vector current, after making some theoretical corrections. One major correction is the nuclear mismatch caused by isospin-symmetry-breaking forces between the nucleons. Of special interest is the Z-dependence of this correction. Previous calculations by the MSU and Chalk River groups yield disagreeing results and neither approach could address separately a smooth Z-dependence and a shell-fluctuation part.

Ernest Henley, Wick Haxton and I have re-formulated the problem to overcome that. And the two contributions to the nuclear mismatch, *i.e.*, the radial overlap and the isospin mixing, can be calculated in a consistent way.

B) Neutrino Neutral Current Absorption/Emission in Supernovae:

Wick Haxton and I are investigating the effects of energy deposit on matter from neutrinos via neutral current interactions. Neutrino elastic scattering from nucleons is bound to have significant contribution to the heating in the "hot bubble" in delayed-shock explosion supernovae when the Fermi-Dirac distribution is used for the neutrinos.

Plasmon decay is one of the important cooling mechanisms for stars at the late stage of the evolution. Preliminary kinematic calculations indicate plasmon excitation and decay might be important for various stages of the supernova explosion. We have done the relativistic calculation of the photon polarization insertion at finite temperature and density, including the vacuum polarization effect, which has not been investigated in previous calculations of the plasmon emissivity of $\nu\bar{\nu}$ pairs.

2. Microscopic Nuclear Structure

Extensive numerical codes have been developed to calculate from the free space NN strong and Coulomb interactions the isospin-symmetry-breaking nuclear G-matrix elements, which will eventually lead to the shell-model effective interaction. One of the applications will be for the problem described in 1.A. When the Coulomb force is turned off, we reproduce the result of Kuo *et al.*

3. Hadron Structure in Chiral Symmetric Quark Models.

Suzhou Huang and I studied the role of anomalous singularities in hadronic structure. A resulting paper was submitted to Nucl. Phys. **B**. See Suzhou's report.

4. Anomaly and Condensates in Null-Plane Quantization.

Suzhou Huang and I are studying the subject. See Suzhou's report.

III. Publications since April, 1991

Published

1. M.A. Alberg, E.M. Henley, L. Wilets, and P.D. Kunz, "Scalar and Vector Contributions to $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ and $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$ + c.c.," AIP Conference Proceedings 243, *Intersections between Particle and Nuclear Physics* (AIP, NY, 1992), p. 345.
2. O. Benhar, A. Fabrocini, S. Fantoni, G.A. Miller, V.R. Pandharipande, and I. Sick, "Scattering of GeV Electrons by Nuclear Matter," Phys. Rev. C44, 2328 (1991).
3. R.C. Brower , nd Suzhou Huang, "Dynamical Universality for Z_2 and Z_3 Lattice Gauge Theories at Finite Temperature," Phys. Rev. D44, 3911 (1991).
4. S.W. Bruenn and W.C. Haxton, "Neutrino-Nucleus Interactions in Core Collapse Supernovae," Ap. J. 376, 678 (1991).
5. A.E.L. Dieperink and G.A. Miller, "Nucleon Binding Corrections to Lepton-Nucleus Deep Inelastic Scattering: Use of a Realistic Spectral Frunction," Phys. Rev. C44, 866 (1991).
6. L. Frankfurt, G.A. Miller, and M. Strikman, "High Energy Nuclear Quasielastic Reactions: Decisive Tests of Nuclear Binding/Pion Models of the EMC Effect," Phys. Rev. Lett. 68, 17 (1992).
7. H. Frauenfelder and E.M. Henley, *Subatomic Physics*, 2nd Ed., Prentice-Hall, Englewood Cliffs, NJ, 1991.
8. T. Frederico, E.M. Henley, and G.A. Miller, "Parity Violation in Elastic Electron-deuteron Scattering: Light-front Dynamics," Nucl. Phys. A533, 617 (1991).
9. D.H. Hartmann, W.C. Haxton, R.D. Hoffman, and S.E. Woosley, "Neutrino-induced Nucleosynthesis in Core-Collapse Supernovae," Nucl. Phys. A527, 663c (1991).
10. W.C. Haxton and W-M. Zhang, "Solar Weak Currents, Neutrino Oscillations, and Time Variations," Phys. Rev. D43, 2484 (1991).
11. W.C. Haxton and K.Y. Lee, "Red Giant Evolution, Metallicity, and New Bounds on Hadronic Axions," Phys. Rev. Lett. 66, 2557 (1991).
12. W.C. Haxton, "Double Beta Decay Mass Constraints on 17 keV Neutrinos," Phys. Rev. Lett. 67, 2431 (1991).
13. W.C. Haxton, "Long-term Neutrino Flux Integrations," in *Trends in Astroparticle Physics*, ed. D. Cline and R. Peccei (World Scientific, Singapore, 1992), p. 369.
14. W.C. Haxton, "Solar and Supernova Neutrino Interactions," in *Trends in Astroparticle Physics*, ed. D. Cline and R. Peccei (World Scientific, Singapore, 1992), p. 483.
15. W.C. Haxton, "A 17 keV Neutrino?", in *Physics News 1991* (AIP, New York).
16. W.C. Haxton, "The Neutrino Process and Neutrino R-Process," in *Unstable Nuclei in Astrophysics*, ed. S. Kubono and T. Kajino (World Scientific, 1992), p. 263.
17. E.M. Henley, G. Krein. S.J. Pollock, and A.G. Williams, "Measuring Strangeness Matrix Elements of the Nucleon," Phys. Lett. B269, 31 (1991).

18. E.M. Henley, "Parity - An Overview and Status Report," Chinese J. Phys. 30, 1 (1992).

19. E.M. Henley, Solutions Manual to *Subatomic Physics*, Prentice-Hall, Englewood Cliffs, NJ, 1991.

20. E.M. Henley, "Guest Comment: The Teaching of Physics", Am. J. Phys. 60, 107 (1992).

21. H. Henning, P.U. Sauer and W. Theis, "Comment on Trinucleon Electromagnetic Form Factors," Nucl. Phys. A537, 367 (1992).

22. B.K. Jennings and G.A. Miller, "The Energy Dependence of Color Transparency," Phys. Rev. D44, 692 (1991).

23. B.K. Jennings and G.A. Miller, "Color Transparency and Non-perturbative Contributions to High Energy (p,pp) Reactions," Phys. Lett. B274, 442 (1992).

24. H. Jung and G.A. Miller, "Nucleon Self-energy in Relativistic Nuclear Matter with Pion Ring Series," Phys. Rev. C43, 1958 (1991).

25. J. Kunz, P.J. Mulders, and G.A. Miller, "Charge Distributions of Hyperons," Phys. Lett. B255, 11 (1991).

26. G.A. Miller and P.U. Sauer, "Total Cross Section for $p + p \rightarrow p + p + \pi^0$ near Threshold," Phys. Rev. C44, R1725 (1991).

27. G.A. Miller, "Color Transparency," SLAC Workshop on *High Energy Electroproduction and Spin Physics*, February 1992, p. 364.

28. B.M.K. Nefkens, G.A. Miller and I. Slaus, "Charge-Symmetry of the Strong Interaction is the Light-Flavor Symmetry of QCD," Comm. Nucl. & Part. Phys. 20, 221 (1991).

29. A. Stadler, W. Glöckle, and P.U. Sauer, "Faddeev Equations with Three-Nucleon Force in Momentum Space," Phys. Rev. C44, 2319 (1991).

30. L. Wilets and W. Beck, "Fermi Molecular Dynamics," in *Advances in Nuclear Dynamics*, eds. W. Bauer and J. Kapusta (World Scientific, Singapore, 1991), p. 185.

31. A.G. Williams, G. Krein, and C.D. Roberts, "Modelling the Quark Propagator," Annals of Physics 210, 464 (1991).

Accepted for Publication

1. S. Bass, "Partons and the EMC Spin Effect," Zeitschrift für Physik C.

2. A. Bulla and P.U. Sauer, "Inclusion of πNN Vertex into Δ-Isobar Dynamics," Few-Body Systems.

3. M-C. Chu and S. Huang, "The Relevance of Dilute Instanton Ensemble to Light Hadrons," Phys. Rev. D.

4. T. Frederico and G.A. Miller, "Null-plane Phenomenology for the Pion Decay Constant and Radius," Phys. Rev. D.

5. D. Hartmann, W.C. Haxton, G. Mathews, T.A. Weaver, and S.E. Woosley, "Neutrino Induced light Element Synthesis," in *Nuclei in the Cosmos, Baden/Vienna*, ed. H. Oberhummer (MPI Munich, 1990.

6. W.C. Haxton, "Solar Neutrinos: Theoretical Status," Proceedings *Current Topics in Astrofundamental Physics*, Erice, Italy, September 1991 (World Scientific).

7. W.C. Haxton, "Solar Neutrinos: Theory vs. Experiment," Proceedings *TAUP '91*, Toledo, Spain, September 1991 (Elsevier Science Publishers).

8. E.M. Henley, T. Frederico, S.J. Pollock, S. Ying, G. Krein, and A.G. Williams, "Some Measurements for Determining Strangeness Matrix Elements in the Nucleon," Proc. XIIIth European Conference on *Few-Body Problems in Physics*, Elba, Italy, September 1991.

9. E.M. Henley, W-Y.P. Hwang, and L.S. Kisslinger, "The Axial Coupling Constants and Chiral Symmetry Restoration," Phys. Rev. D.

10. E.M. Henley, W-Y.P. Hwang, and L. Kisslinger, "Nucleon Axial Coupling Constants and QCD Sum Rules," Proc. Symposium on *Contemporary Physics*, Philadelphia, October 1991.

11. E.M. Henley, "Symmetry Tests in Hadronic Systems," Proc. Few Body XIII, Intl. Conf. on *Few Body Problems in Physics*, Adelaide, Australia, January 1992.

12. E.M. Henley, G. Krein, and A.G. Williams, "Phi Production as a Measure of the Strangeness Content of the Nucleon," Phys. Lett. B.

13. T-S.H. Lee and G.A. Miller, "Color Transparency and High Energy (p,2p) Nuclear Reactions, Phys. Rev. D.

14. G.A. Miller and B.K. Jennings, "Color Transparency: Enchantment and Effort," Proc. 5th International Meeting on *Perspectives in Nuclear Theory at Intermediate Energies*, Trieste, 1991.

15. G.A. Miller, "Nucleon Models of Deep Inelastic Scattering," Proc. Riken Winter Seminar on *Quarks and Gluons in Nucleons and Nuclei*, Japan, January 1992.

16. G.A. Miller, "Introduction to Color Transparency," in *N*'s and Nucleon Structure*, ed. G.A. Miller (World Scientific, Singapore, 1992).

17. M.T. Peña, H. Garcilazo, U. Oelfke, and P.U. Sauer, "Effect of the NΔ Interaction on Observables of the πNN and γNN Systems," Phys. Rev. C (May 1992).

18. I. Slaus, B.M.K. Nefkens, and G.A. Miller, "Quark Mass Difference and the Origin of Charge Symmetry Breaking," Denton workshop on Accelerator Physics, November, 1990.

19. L. Wilets and P. Siemens, "Nuclear Physics," 2nd Edition, Encyclopedia of Physical Science and Technology, Academic Press.

20. L. Wilets, "Relativistic projection and Boost of Solitons," Proc. Intl. Workshop on *Relativistic Aspects of Nuclear Physics*, Rio de Janeiro, August 1991.

21. S. Ying, W.C. Haxton, and E.M. Henley, "Charged and Neutral Current Solar Neutrino Cross Sections for Heavy-Water Cerenkov Detectors," Phys. Rev. C.

22. S. Ying, "Patterns of Spontaneous Chiral Symmetry Breaking," Phys. Lett. B.

23. W-M. Zhang and L. Wilets, "A Transport Theory of Relativistic Heavy-Ion Collisions with Chiral Symmetry," Phys. Rev. C.
24. W-M. Zhang, Da Hsuan Feng, and Jian-Min Yuan, "Quantum-Classical Correspondence and Quantum Chaos," in *Directions in Chaos*, Vol. 4, eds. B.L. Hu, D.H. Feng, and J-M. Yuan (World Scientific, 1992), to be published.

Submitted for Publication

1. R. Brower, S. Huang, J. Potvin and C. Rebbi, "The Surface Tension of Nucleating Hadrons through the Free Energy of an Isolated Quark," Phys. Rev. D.
2. R. Brower, S. Huang, J. Potvin, C. Rebbi, and J. Ross, "A Numerical Study of Perfect Wetting in Quenched QCD," Phys. Rev. D.
3. J. Cooperstein, "Supernovae, the Equation of State, and Phase Transitions," Nuclear Physics A.
4. J. Cooperstein, "Flux Limited diffusion in Hydrodynamics," The Astrophysical Journal.
5. L. Frankfurt, G.A. Miller, and M. Strikman, "Color Transparency Phenomena and Nuclear Physics," Comm. Nucl. & Part. Phys.
6. T. Frederico, E.M. Henley, S.J. Pollock, and S. Ying, "Neutrino and Antineutrino-deuteron Elastic Scattering and the Axial Isoscalar Nucleon Current," Phys. Rev. C.
7. E.M. Henley and I.B. Khriplovich, "First Forbidden β-Decays as a Probe of T-Odd Nuclear Forces," Phys. Lett. B.
8. S. Huang and W. Lin, "The Role of Anomalous Singularity in Hadronic Form Factors," Nucl. Phys. B.
9. G.A. Miller, "Comment on 'Pion Contribution to K^+-Nucleus Scattering," Phys. Rev. Lett.
10. S.J. Pollock, E.N. Fortson, and L. Wilets, "Atomic Parity Nonconservation: Electroweak Parameters and Nuclear Structure,"
11. U. Ritschel, L. Wilets, J.J. Rehr, and M. Grabiak, "Nonlocal Dielectric Functions in Classical Electrostatics and QCD," J. Phys. G.
12. A. Stadler and P.U. Sauer, "Effect of the Three-Nucleon Force on the Three-Nucleon Ground State: Reducible and Irreducible Contributions," Phys. Rev. C.
13. M.I. Strikman, L.L. Frankfurt, and T. Frederico, " 'Good' Component Approach in Light-Cone Quantum Mechanics of the Deuteron Form-Factors," Phys. Rev. C.
14. Wei-Min Zhang, Da Hsuan Feng, and Lay Nam Chang, "Quenched quantum Mechanics," submitted to Phys. Rev. Lett.

In Preparation

1. W.R. Greenberg and E.L. Lomon, "The $\Lambda N - \Sigma N$ Interaction with Isobar coupling," for Phys. Rev. D.

2. W.C. Haxton and K. Lee, "Constraints on Hadronic Axions," for Phys. Rev. D.

3. W. Koepf, S. Pollock, and E.M. Henley, "Strangeness Matrix Elements in the Nucleon," for Phys. Rev. D.

4. G.A. Miller and W.R. Greenberg, "A Closer Look at Color Transparency," for Phys. Rev. D.

5. G.A. Miller and T. Frederico, "Deep Inelastic Structure Function of the Pion in the Null-plane Phenomenology," for Phys. Rev. D.

6. G.A. Miller, M. Strikman, L. Frankfurt, and W. Greenberg, "Exactly Solvable Model for Color Transparency Effects," for Phys. Lett. B.

7. G.A. Miller, M. Strikman, and L. Frankfurt, "PLC Formation in High Momentum Transfer Semi-exclusive Nuclear Reactions," for Phys. Lett. B.

IV. Invited Talks since April, 1991

W.C. Haxton

1. "Weak Interactions and Astrophysics," 10 lectures, Tokyo Metropolitan University, June 1991
2. "The Neutrino process and Neutrino r-process," Workshop on *Unstable Nuclei in Astrophysics*, Tokyo, Japan, June 1991
3. "Neutrinos: Theory," American Chemical Society Meeting, New York, August 1991
4. "Solar and Supernova Neutrinos," School on Astrofundamental Physics, Erice (Sicily), August 1991
5. "Theory Overview: Solar Neutrinos," Workshop on *Theoretical Aspects of Underground Physics*, Toledo, Spain, September 1991
6. "Oscillations of Solar Neutrinos," colloquium, University of California, San Diego, October 1991
7. "Red Giant Evolution, Metallicity, and New Constraints on Axions," APS meeting, Michigan State University, October, 1991
8. "Constraints on T-Violating, P-Conserving NN Forces," APS Meeting, Michigan State University, October 1991
9. "Solar Neutrinos," AAPT meeting, Michigan State University, October 1991
10. "Neutrino Physics in Supernovae," University Lecture, University of Wisconsin, November, 1991
11. "Oscillations of Solar Neutrinos," colloquium, University of British Columbia, December 1991
12. "Neutrino Physics of Core-Collapse Supernovae," colloquium, Physics Division, Argonne National Laboratory, February 1992
13. "The Neutrino from Hell and Related Stories," University of California, Santa Cruz, February, 1992, Iowa State University, April 1992
14. "Neutrino Oscillations and the Solar Neutrino Problem," colloquium, Iowa State University, April 1992
15. "Double Beta Decay," colloquium, Washington University, April 1992

E. M. Henley

1. "Measuring the Strangeness Content of the Nucleon," Arizona State University, May 1991; National Taiwan University, May 1991.
2. "Status of Parity and Time Reversal Invariance," Arizona State University, May 1991

3. "Parity Noninvariance and the Standard Model," Tsing-Hua University, Taiwan, May 1991
4. "Measuring Strangeness Matrix Elements in the Nucleon," 13th European Conference on Few Body Problems, Italy, September 1991
5. "Parity Nonconservation," National Chen Kung University, Taiwan, September 1991
6. "Status of Time Reversal Invariance," National Taiwan University, October 1991
7. "Charge Symmetry Breaking and Chirality," Academia Sinica, Taiwan, October 1991
8. "Nucleon Axial Coupling Constants and QCD Sum Rules," Contemporary Physics Symposium, Philadelphia, PA, October 1991
9. Short talks on "Nucleon Axial Coupling Constants and QCD Sum Rules" and on "Introduction to Symmetries," 13th International Conference on Few-body Problems in Physics, Adelaide, Australia, January 1991

G. A. Miller

1. "The Energy Dependence of Color Transparency," University of Regensburg, June 1991
2. "Color Transparency: Enchantment and Effort," 5th Intl. Meeting on *Perspectives in Nuclear Physics*, Trieste, Italy, May 1991
3. "Nuclear Physics Applications of Light Cone Quantum Mechanics," Intl. workshop on *Light Cone Hamiltonian Methods*, Heidelberg, June 1991
4. "Seeing color Transparency with a Hadronic Basis," Gordon Conference, July 1991
5. "Introduction to Color Transparency, a 4-lecture series," Institute for Nuclear Theory, July 1991
6. "Nucleon Models of Deep Inelastic Scattering," 2-lecture series, First Riken Winter School, Yuzawa, Japan, January 1992
7. "Does a PLC really exist?", SLAC Workshop, January 1992
8. "Changing Hopes into Realities in Color Transparency," Pennsylvania State Workshop on *High Energy probes of QCD and Nuclei*, March 1992
9. "Nuclear Physics Applications," SMU Light-cone Quantization Conference, May 1992

L. Wilets

1. "The Chromodielectric Model of Quark Clusters in Nuclei," *Clusters in Hadrons and Nuclei*, Tübingen, July 1991
2. "Relativistic Projection and Boost of Solitons," Intl. Workshop on *Relativistic Aspects of Nuclear Physics*, Rio de Janeiro, August 1991
3. "The Cold Fusion Saga," The Brazilian Division of Nuclear Physics, Lindoya, September 1991
4. "The Chromodielectric Soliton Model," Institute of Theoretical Physics, São Paulo, September 1991
5. "The Nucleon as a Composite," University of São Paulo, September 1991; Institute for Advanced Study, São Paulo, September 1991
6. "Nuclear Structure Effects in Atomic Parity Nonconservation," colloquium, University of Florida, October 1991
7. "e^+-e^- Pairs in Heavy Ion Collisions," University of Florida, October, 1991

S. Bass

1. "Axial Anomalies and the Higher Moments of $g_1^P(x)$," FEWBODY XIII, Adelaide, Australia, January, 1992

V. Investigations Planned

W.C. Haxton

In nuclear astrophysics:

• With MingXing Luo I am evaluating the Compton production of (very low energy) muon and tauon solar neutrinos.

• Jerry Cooperstein and I will likely collaborate on a calculation of the Dirac mass limit from the SN1987A cooling rate.

• I would like to extend the Haxton-Lee red giant analysis to AGB stars, where the higher core temperatures might allow us to completely close the "Turner Window" due to the more favorable Boltzman factors.

In symmetry tests:

• I would like to explore recent chiral Lagrangian results on the effect of s-quark nucleonic components on hadronic weak interaction operators (M. Savage, et al.). No realistic evaluation of the matrix elements of the new operators has yet been made.

• There are indications, from a recent analysis of the beta decay of ^{37}Ca, that forward-angle (p,n) reactions underestimate the Gamow-Teller strength in the region of the giant resonance. This result is important because of claims that g_A is renormalized in nuclei. I have a conjecture that may explain this discrepancy.

Many-body physics:

• I intend to explore variations of the Lanczos algorithm where state vectors are truncated in order to control the size of the Hilbert space. The hope is to find an approximate but useful algorithm for very large basis shell model calculations.

E.M. Henley

1. The Standard Model and Symmetries

a) I intend to complete the work on the anapole moment together with Wick Haxton and Michael Musolf. I may extend this work to inelastic scattering.

b) In addition, together with Wick Haxton and Wei Lin, I hope to conclude the investigation of the superallowed beta decays.

2. Quarks in Nucleons and Nuclei

a) Work on the $N\bar{N}$ system will continue to include decays to $\Lambda\bar{\Sigma}$, $\Sigma\bar{\Lambda}$, $\Sigma\bar{\Sigma}$.

b) The work on phi production as a means to measure the strangeness vector matrix element in the nucleon, will be expanded to include polarization. This study should allow one to more clearly distinguish between vector dominance and the presence of strangeness in the nucleon.

c) I have become interested in studying the off-mass shell electromagnetic interaction of nucleons. I have ideas about how to proceed with this investigation and how to test the theoretical framework.

d) I intend to continue to investigate the application of QCD sum rules. In addition to studying the induced pseudoscalar coupling and the weak meson-nucleon couplings, I would like to examine what happens when SU(3) is broken by adding a strange quark mass. These investigations can be carried out both for free nucleons and nucleons in nuclear matter, Thus, I first want to complete the investigations undertaken with J. Pasupathy on the changes that occur in nuclei or nuclear matter.

G.A. Miller

I. I will continue to study color transparency.

1. I plan to extend and publish the study of the use of data for the (pp, pX) reaction to constrain the interaction between the ejected wave packet and target nucleons.

2. I intend to generalize the work on the origin of the PLC and present it as a letter.

3. The exactly soluble model will be applied to a three-dimensional reaction and submitted for publication.

4. I plan to study how color transparency effects suppress nuclear spin-orbit interactions.

5. I expect that the multiple-scattering work with W. Greenberg will be written up and submitted.

6. Greenberg and I may investigate nuclear photoproduction of charmonium as another search for color transparency.

7. Strikman, Frankfurt and I will study momentum transfer (Q^2) dependence of the plan-nucleus final state interactions (FSI) in the $(e, e'\pi)$ reaction. The purpose is to see how or if the FSI disappear with increasing Q^2.

II. The work on relativistic wave functions and light front techniques will continue. The first job is to complete our model study of the pionic deep inelastic scattering structure function.

III. The study of the off-mass-shell dependence of ρ^0-ω mixing will continue towards publication.

Possible new investigations involve the application of a promising new treatment of low energy QCD, chiral perturbation theory, to nuclear properties. I intend to study the broader implications of the recent nuclear Drell-Yan experiment at Fermilab.

L. Wilets

Work will continue on modelling QCD with the chromodielectric soliton model, with application to a microscopic description of the pion and its coupling to hadrons (with P. Tang); flux tube dynamics (with M. Watrous and B. Balantekin; N-N collisions and the quark structure of nuclei (with W. Koepf and Fl. Stancu).

Quantum Fermi molecular dynamics will be pursued for both atomic and nuclear systems (with W. Beck). A collaboration with W. Lynch of MSU is being launched to describe experimental data obtained there, and with J. Cohen and coworkers at LANL.

Analysis of $\overline{N}$-N to rare processes will be continued in collaboration with M. Alberg, E.M. Henley and P.D. Kunz.

M. Alberg and I are returning to antiprotonic atoms.

Molecular-plasma physics calculations at zero and finite temperatures will be pursued with M. Alberg, and J. Cohen and L. Collins (LANL).

DATE
FILMED
7/15/92