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[Nuclear theory] Annual Progress Report

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II. Work completed since June, 1988 and Work in Progress

W. C. Haxton

Neutrino nucleosynthesis

Together with Woosley, Hartmann, and Hoffman I explored in detail the possibility that neutrino interactions with nuclei in the mantle of a collapsing star constitute an important new mechanism for nucleosynthesis. Both the nuclear physics (neutrino cross sections and spallation yields) and the stellar physics have been done with great care: the nuclear network calculations involve over 300 reactions.

The original work demonstrating that ^{19}F is a neutral current neutrino spallation product was published in *Nature*. The results of the full network calculation have been submitted to the Astrophysical Journal. Two of the most exciting results are the production of the galactic abundances of ^{7}Li and ^{11}B; the ^{7}Li result demonstrates that there is a natural galactic production mechanism that can supplement that of the big bang, thereby accounting for the Pop I abundance.

Neutrino heating in supernovae

I've also explored the importance of such inelastic neutrino reactions in transporting energy from the neutron star core to the mantle of the star. Numerical work is underway with Stephen Bruenn, one of the supernova simulators. We have established that these reactions are an important neutrino downscattering mechanism during the infall stage, leading to increased lepton number loss and a weaker shock. We are now exploring whether neutrino heating of nuclei in front of the shock wave can lessen the shock wave energy loss as it passes through the outer portions of the iron core.

An important new result is the enhanced cross sections for resonant neutrino absorption on nuclei (either through electron-neutrino or neutrino-antineutrino annihilation). Such processes could play a role in heating and in the charge-current nucleosynthesis of heavy nuclei like La.

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Parity Nonconservation

Calvin Johnson, Val Zeps, and I are involved in a major program to calculate PNC observables in nuclei near A=16. We have developed numerical techniques to evaluate PNC matrix elements in realistic single-particle bases with state-of-the-art shell model wave functions.

Mike Musolf, Ernest Henley, and I have evaluated the nuclear anapole moment, the PNC coupling of the photon induced by weak radiative corrections, for ^{133}Cs and ^{19}F. Our work demonstrates that this weak correction grows like $A^{2/3}$ and dominates the tree-level V(electron)-A(nucleus) neutral current interaction in heavy nuclei.

Double beta decay

Tony Williams and I have evaluated the contributions of the first-forbidden axial charge and vector three-current operators to two-neutrino double beta decay. The latter is of particular interest as the sum over virtual intermediate nuclear states can be done exactly by Siegert's theorem.

I have developed a powerful numerical technique for evaluating the action of 1/E-H on a state vector from the entries in the tri-diagonal Lanczos shell model matrix. This procedure should cure the primary shortcoming of existing shell model work on double beta decay, the closure assumption, while also permitting us to pertrubatively correct for various sum rule violations.

Other shell model weak interaction work

Johnson and I have completed the first full $4\hbar\omega$ calculation of ^{16}O, and are employing these wave functions to investigate the axial-charge beta decay/muon capture transition and to estimate the BGT distribution. The former is of great importance as a test of exchange currents and of the nuclear pseudoscalar coupling. The latter is of interest to ongoing and planned LAMPF (p,n) and neutrino experiments.

Test of CP Nonconservation

Andreas Schaeffer and I are estimating the atomic electric dipole moments that arise from weak hadronic or semileptonic interactions in the presence of a T-odd P-even NN interaction. We believe such T-odd P-odd observables are likely to impose the most stringent limits on T-odd P-even interactions: the suppression associated with the weak interaction is more than compensated by the exquisite precision of atomic electric dipole measurements.

Mike Musolf and I are completing a rederivation of the Schiff theorem. We believe existing treatments of penetration terms and of M2 interactions may not be correct.

Musolf and I will also study the E1 decay of the 200eV doublet in ^{229}Pa. This provides the one opportunity in nature to test the Schiff yielding in a transition moment: the photons emitted in this nuclear transition have long wavelengths on an atomic scale.

Neutrino detectors

I continue to work on the neutrino cross section for the ^{127}I detector (Homestake III) to clarify the sensitivity of this experiment to ^{8}B and ^{7}Be solar neutrinos. Adelberger and I are also discussing the feasibility of producing a ^{37}Ar neutrino calibration source by exploiting the (n,α) reaction on ^{40}Ca.

Ying, Henley and I have completed a careful estimate of the charged and neutral current neutrino cross sections for deuterium (in support of SNO). We were able to demonstrate that forbidden contributions to the cross section increase the sensitivity of the SNO detector to supernova muon and tauon neutrinos by about a factor of two.

I am also pursuing a speculative idea for a geochemical integration of the ^{8}B solar neutrino flux over the past one billion years. If such a measurement is possible, one would obtain a quantitative test of standard solar model predictions of the changing core opacity. (The ^{8}B neutrino luminosity doubling time is about 0.9 billion years.)

Destruction of ^{7}Li in the big bang

Adelberger and I are excited about the possibility that the reaction $^{7}\mathbf{Be}(n,\alpha)\alpha$ could contribute to the destruction of ^{7}Be (the parent of ^{7}Li) in the big bang. R-matrix calculations of the cross section are being carried out. The principal shortcomings of nonstandard cosmologies in which the universe is closed by baryons are the overproduction of ^{7}Li and resulting fission-cycled r-process production of heavy nuclei.

Neutrino oscillations

John Bahcall and I have just completed a paper in which a Monte-Carlo treatment of solar model undertainties was combined with an analytic treatment of matter-enhanced neutrino oscillations. The goal was to determine the possible implications of future experiments given the inherent theoretical uncertainties in neutrino fluxes.

Flavor violation

Dean Wampler and I are completing work on the conversion of bound muons to electrons in the nuclear field. Our special emphasis is on interactions where the nucleus is left in an excited state. Our goal is to determine whether limits on the excited state transitions impose significant new constraints on the parameters governing muon number violation.

E. M. Henley

The focus of my work continues to be symmetries and the connection between quark-gluon and nucleon-meson degrees of freedom.

Parity Nonconservation:

Michael Musolf, Wick Haxton and I have developed a nucleon-meson calculation of the anapole moment of the nucleon and of nuclei. We find that nuclear effects dominate, particularly the effects of parity mixing in the ground state of nuclei. Suggestions for measuring the anapole moment have been made and the work has been submitted for publication. Further work on inelastic scattering and off-mass shell effects remains to be carried out.

Time Reversal Invariance:

In connection with invited talks, I had to review the status of time reversal invariance; this has led to a renewed interest in attempts to unify the treatment of tests that have already been carried out. I am also examining time reversal symmetry in the beta decays of ^{8}Li and ^{8}B.

Chiral Symmetry:

The Nambu-Jona-Lasinio model of chiral symmetry and its breaking is, in my view, a very useful one for mimicking part of the consequences of non-perturbative QCD. Together with G. Krein, I have investigated the effects of the up and down quark mass differences on nucleon and mirror nuclei, as well as on electron scattering and static magnetic moments. The effects and their dependence on nuclear density are revealing and help to explain the Nolen-Schiffer anomaly and other nuclear problems not easily understood in terms of standard nuclear theory. Part of this work has been submitted for publication and another part is being prepared for publication.

The $N\bar{N}$ System:

The annihilation of antinucleons on nucleons occurs when the two particles overlap, so that this phenomenon is likely to involve quark degrees of freedom, even at low energies. We (Mary Alberg, Larry Wilets, and I) have advanced the idea that one should not discuss the superiority of the so-called $^{3}P_{0}$ over the $^{3}S_{1}$ model, but that both of these models should be used together, as they represent difference aspects of QCD. This idea is being tested in the theoretical analysis of $p\bar{p} \rightarrow \Lambda\bar{\Lambda}$, where polarizations can be measured. We intend to extend this work to other strange baryons.

Use of the Light Cone for Exclusive Reactions:

The light cone frame, or light cone algebra, has been and is being used to analyze features of exclusive reactions. My student, S. Ying, has analyzed the nucleon form factor for momentum transfers of the order of 3-4 GeV with a diquark model for the nucleon, suggested by the QCD sum rule and moments of the distribution function. This work is being submitted for publication. Another student, A. Szczepaniak, has also examined the spin content of the nucleon with a light-cone wavefunction. Together with A. Szczepaniak and W-Y.P. Hwang, I am examining the decay of the B meson to two pions by means of light cone algebra. Preliminary results give a very small decay rate for this branch.

Photo- and Neutrino- Disintegration of the Deuteron:

Together With G.A. Miller and S. Ying, I concluded the work on the photodisintegration of the deuteron, with emphasis on the forward cross section. This work has been published. An extension of this work, with W. Haxton and S. Ying, has been carried out to the charged and neutral current neutrino induced disintegration. We extended previous work by including retarded (forbidden) matrix elements. This work has been submitted for publication.

Strangeness in Nucleons:

Together with G.A. Miller, G. Krein, and A. Williams, I am investigating methods of testing the degree of strangeness content of the nucleon. To this end, we have suggested neutrino reactions in which a ϕ, K^{+}, or K^{-} are produced and are calculating the expected rates for these reactions.

Electron-Electron Correlations and the Dissolution Problem:

Yang Pang, Larry Wilets and I are investigating improved methods for circumventing the negative energy "dissolution problem" that plagues relativistic calculations of atomic problems in the presence of electron-electron correlations (or other two-body problems). Particular applications of interest to us include parity and time reversal studies. We are concentrating on the use of a local effective one-body potential and a Green's function approach to circumvent the problem.

Subatomic Physics:

I continue to struggle with the completion of the proposed revision and hope to complete it during the coming year.

G. A. Miller

During the past year I have tried to learn how and why Quantum Chromodynamics (QCD) is manifest (or not manifest) in nuclei. This has led to work in diverse areas: probing nuclear properties with high energy beams; deriving nuclear properties from the strong coupling limit of QCD; using symmetry tests; and obtaining a new relativistic field theory of nuclear matter which maintains chiral symmetry. The paragraphs below are meant to provide a brief summary of newer aspects of my research. Further details and information regarding continuations of older projects may be found in the list of publications.

High Energy Probes of Nuclear Properties:

In this work the assumed underlying quark-gluon aspects of nuclei are sought. Very often a careful conventional hadronic calculation must be carried out to define the standard nuclear model expectations.

Birse, Bickerstaff and I suggested the use of the nuclear Drell-Yan process (Production of $\mu^+ + \mu^-$ pairs in proton-nucleus collisions) to distinguish different theories of lepton-nucleus deep inelastic scattering (the first EMC effect). A Fermilab experiment led by LAMPF physicists, was recently performed. H. Jung and I have made new calculations assuming nucleon and pionic constituents of nuclei. The new feature is to include an improved treatment of relativistic aspects of the nucleon Fermi motion. This leads to reasonable agreement with the preliminary data. However, the data for low target x do not exhibit the expected shadowing behavior. This, a puzzle for all treatments, remains to be understood.

The nuclear Drell-Yan and deep inelastic scattering processes are concerned with determining how the nuclear environment influences the structure function of a nucleon. To address this problem it is necessary to understand the structure function of a free nucleon. Thus a project with C. Benesh (a 1988 University of Washington Ph.D.) to compute the structure function of a free nucleon was carried out. The goal was to relate low-energy models of confinement with high-energy data. The use of good quark wave functions, extraction of twist-2 terms, and QCD evolution led to a reasonable reproduction of the experimentally observed valence quark distributions. We also computed the spin-dependent structure function g_1, with results in accord with the new experimental findings on the spin of the proton. The key point is that the momentum transfer (Q^2) dependence of the gluonic triangle anomaly allows the proton spin to be carried by valence quarks at low Q^2 and by polarized sea at large values of Q^2.

Strong Coupling Approximation to QCD and Low Energy Nuclear Properties:

Does QCD reproduce the qualitative features of the meson-baryon dynamics that underlie ordinary nuclear physics? Presumably, the existence of nuclei is related to long-distance, non-perturbative, large coupling constant features of QCD. Thus I use the strong-coupling limit of QCD (SCQCD). At large distances or low values of the momentum transfer the coupling constant is large. Thus SCQCD is based on low-order perturbation expansions in inverse powers of the coupling constant. The essential new feature is that the principle of local gauge invariance requires the inclusion of the gluonic degrees of freedom. These are described by lines of color electric flux and are important. In computing hadronic matrix elements gluonic overlaps are included as factors multiplying the usual quark matrix elements. A consequence of this approach is that quark exchange terms, in which quarks are exchanged between hadrons without interactions, are multiplied by a gluonic overlap that vanishes. Thus, in nuclei the Pauli principle is obeyed at the hadronic level. This feature is important in understanding the origin of the shell model.

Other aspects of this study involve dynamics. I have found that the gluonic effects of flux tube rearrangement, computed in low orders of the strong coupling expansion, provide negligible contributions to interactions. This result has been verified by several authors. A more significant mechanism in SCQCD is the breaking of electric flux lines. The requirements of local gauge invariance allow this to happen only if a quark-antiquark pair is emitted or absorbed. This leads to meson emission from baryons, which is the basis of conventional approaches to nuclear dynamics. Meson-nucleon and meson-delta coupling constants have been computed, with results in qualitative agreement with experiment. The net result of all of this is that SCQCD seems to reproduce the salient features of the meson-baryon picture of low momentum transfer nuclear physics.

Symmetry Tests:

A. Charge Symmetry Breaking (CSB):

I have maintained my interest in this subject which was the central aspect of my Ph.D. thesis. Studies of CSB in the neutron-proton system with Henley and Cheung stimulated a TRIUMF experiment. Thus the first observation of CSB in a system without the Coulomb force was made. An experiment is in progress at the Indiana Cyclotron facility. Currently I am working on an extensive review for Physics Reports with Slaus (Zagreb) and Nefkens (UCLA). We study the hypothesis that all observed CSB from mesonic systems to heavy nuclei can be explained in terms of quark mass differences and electromagnetic interactions between quarks.

B. Parity Violation in Proton-Proton Scattering:

D. Driscoll, a graduate student, and I are making a careful investigation. The ultimate goal of such studies is to determine the weak parity violating interactions in the presence of strong forces. Several aspects are necessary to do this. First, we develop a new distorted wave treatment which minimizes the sensitivity to the unknown off-shell nucleon-nucleon T-matrix. In this framework the computed parity violating asymmetries are essentially independent of the strong interaction potential. Then the parity violating nucleon-nucleon potential is computed without making the usual non-relativistic approximations. This is important at energies greater than about 500 MeV. We ae also studying the effects of parity violation in inelastic channels. We believe this necessary to understand the LAMPF data at 800 MeV.

C. CP Violation

This work (with M.J. Iqbal at TRIUMF) was stimulated by the December, 1988 TRIUMF workshop on rare decays and CP violation. A new technique is developed to calculate CP violating (CPV) observables directly from the hadronic CPV measured in the neutral kaon system. (The recentl CERN measurements of the parameter ϵ' makes this possible.) The idea is to employ hadronic matrix elements for the strong and weak interactions so that the calculation is strongly constrained by experimental measurements. We first study the neutron electric dipole moment. In addition, CPV meson-nucleon coupling constants can also be determined. The nuclear consequences of the CPV pion-nucleon coupling constant G_{CPV} seem very small. However the CPV coupling constant for the decay of the lambda to pion and nucleon is about six orders of magnitude larger than G_{CPV}. Thus CPV may be observable in the decays of hyperons. (See also Donoghue *et al.*, Phys. Rev. D 34, 833 (1986)).

Pions in Relativistic Theories of Nuclei:

Understanding the saturation properties of normal nuclear matter has been one of the most challenging problems in theoretical physics. Recently, successful treatments of nuclear matter have been obtained from relativistic quantum field theories. However, pionic effects are not important in the commonly used mean field or Hartree-Fock approximation to such theories. This is surprising since pions mediate the nucleon-nucleon interaction at all but the shortest range. There are many other reasons for thinking pions to be important. Furthermore, chiral symmetry is an important approximate symmetry of strongly interacting systems which requires pionic degrees of freedom.

In our work (with Hong Jung, a graduate student, and F. Beck, Darmstadt) we aim to obtain a relativistic chiral treatment of nuclear matter studying the pion ring series. This is because the attractive nature of the pion-nucleon interaction can lead to pionic enhancement and the pion ring series is the proper partial summation for this collectivity. The dynamics is obtained with Weinberg's pseudovector representation of the linear σ model with vector ω mesons and δ isobars also included.

To obtain a result that maintains chiral symmetry and achieves nuclear matter saturation it is necessary to include terms beyond the mean field approximation. This is to include the ring series. The resulting treatment incorporates the physics of the original Walecka model, partial conservation of the axial vector current, and delta contributions. Our treatment respects chiral symmetry in the limit of massless pions.

The numerical results are that the binding energy density and incompressibility of normal nuclear matter are reproduced. The pion-ring series including nucleons and delta isobars provides the necessary attraction and its density dependence. The effects of the scalar field are not significant.

Our results are different than the findings of other relativistic approaches. It is therefore interesting to seek experimental tests to distinguish the various ideas. One consequence of our approach is the existence of a pion condensate for values of the Fermi momentum greater than about 2.4 fm^1. Another challenge is to understand the optical potential. The effects of vacuum polarization (VP) are absent in our approach. Discovery of a phenomenon uniquely explained by VP terms would rule out the present approach.

The successful reproduction of the experimental values of the saturation properties indicates that studies of relativistic pion dynamics are worthwhile.

L. Wilets

Current and Recently Completed Research

Chirally-invariant Chromodielectric Soliton Model

Recently, G. Fai, R. Perry and I proposed a chirally invariant version of the Friedberg-Lee soliton model, where quarks are coupled only to the gluonic field, not to the scalar σ-field. Along with P. Tang, G. Krein and A. Williams, we have demonstrated, in the local approximation, how confinement is effected and how the pion emerges as a Nambu-Goldstone boson. Work is continuing (as Tang's thesis) to solve the problem with its full nonlocality and to construct the pion explicitly.

Six-quark Systems for N-N Processes

In a series of papers, Fl. Stancu (University of Liège) and I have presented the classification and construction of six-quark systems appropriate for N-N scattering and bound state systems. The scheme is based on orthogonal parity (molecular) eigenstates, as distinct from the popular cluster states, which omit certain important configurations. The algebra is actually easier using these orthogonal functions rather than the non-orthogonal cluster model functions. We have performed calculations of the short range (actually, spherical) interaction energy for both current and constituent quark models and find a dramatic lowering of the energy relative to the separated 3-quart clusters. This calls into serious question previous calculations, which generally neglect these configurations. The neglected configurations are actually constructed from the same spatial functions as the ones used in common cluster models. We supply the algebra for practitioners in the field in order to facilitate the inclusion of these states in their work.

The Gluon Propagator in Medium

P. Tang and I are preparing a paper on the gluon propagator in inhomogeneous dielectric media, in various gauges. Errors in previous works on the subject are being corrected.

Many-bag Systems: Wigner-Seitz Method

In previous papers, M. Birse, J.J. Rehr, J. Achtzehnter, W. Scheid and I proposed a preliminary "crystalline" approximation for many-bag systems. This was then further approximated by the Wigner-Seitz cell method which is actually more realistic (i.e. less unrealistic). An important problem is the filling of the Block bands. This problem is not serious in solid state physics because there the residual two-body interactions are weak. In QCD they are strong and are responsible for color confinement and (for example) N-Δ splitting. M. Birse (Manchester), Fl. Stancu (Liége) and I have embarked on a renewed program to study intra-band configuration mixing using the chromo-dielectric model and the numerical methods developed (item 2 above) for 6-quark systems. The goal is to extract nucleon form factors as a function of density, as well as to study the hadron-plasma phase transition.

Atomic Structure and Symmetry Violation

Atomic symmetry violation experiments by the Fortson group at the University of Washington and elsewhere now demand more precise atomic calculations in order to interpret the results. I have a continuing interest in such calculations. Working in the context of soliton bags, M. Li, R. Perry and I developed very accurate techniques for constructing Dirac propagators in external, one-body (local) potentials; from this can be constructed projection operators. In collaboration with E.M. Henley and me, Y. Pang is in the process of producing a program to construct Dirac propagators and projection operators for local and non-local potential operations, such as relativistic Hartree-Fock potentials. Although this has not been done before, it is generally recognized as an excellent way of handling the "continuum dissolution" problem. A perturbation theory built on RHF states should converge more rapidly than one built on plane waves, especially for heavy atoms. Techniques developed earlier (with E.M. Henley) should now be very appropriate for correlation calculations. Pang and I expect to work closely with Dr. Martensson-Pendrill, an eminent atomic theorist from Goteborg, during her Fulbright fellowship term here.

Semi-classical Atomic and Nuclear collisions

W. Beck, a part-time doctoral student of mine, has been continuing a study of atomic and nuclear collisions. The work is based on a model introduced earlier, which simulates the Pauli and Heisenberg principles by a momentum-dependent potential. An essential feature of the potential is the length-momentum scaling in order to reproduce the Fermi sea for non-interacting particles. (The Randrup form, proposed subsequently, does not have this scaling.)

Cold Fusion Limits, and Related Real Physics

M. Alberg (Seattle University), J.J. Rehr, J. Mustre de Leon and I have placed realistic limits on cold fusion, which are well beyond the range of reported experiments. A screened potential for charged particles in an electron gas was used for the *d-d* or *p-d* potential and the *d* or *p* interaction with the crystal was calculated using a spherical average of the Matteiss muffin-tin approximation. Inclusion of higher angular modes would only further decrease the calculated rate. Thus an overly optimistic estimate of the *p-d* rate in the small tetrahedral site yields 10^{-49}/sec, far below the "experimental" report of $10^{-(19-23)}$/sec.

Our investigations suggest interesting physics problems which have been left unsolved before. For example, two point charges in a degenerate electron gas using (a) Thomas-Fermi or (b) Hartree-Fock. Even the full, non-linear single charge Thomas-Fermi calculations have not been uncovered in the literature, but we have now calculated the problem and find that it reduces the screened potential (increases screening) by 17% from the usually quoted linear result. (This is like charge renormalization.) We have the tools to tackle the two-center problem for both T-F and H-F.

Calculation of N-$\bar{N} \to \Lambda\bar{\Lambda}$:

A collaboration with M. Alberg (Seattle University), E.M. Henley and D. Kunz (University of Colorado) on $N\bar{N}$ rare processes is discussed in Henley's report.

Book

I have completed a book entitled "Nontopological Solitons", and it has been published by World Scientific (Singapore, 1989).

Other Research Activities Involving Research Faculty

A.G. Williams, G. Krein, and C.D. Roberts*

Quark Propagator in an Ansatz Approach to QCD.

We study dynamical symmetry breaking in an ansatz approach to quantum chromodynamics without imposing the frequently used approximation $\alpha(-(p-k)^2) \simeq \alpha_s(-p_>^2)$ where $p_>^2 \equiv \max(p^2, k^2)$ for the running coupling constant in the quark Schwinger-Dyson equationWe present detailed numerical results and compare these with results obtained when using this approximation. We see in this context that a gluon propagator which has the form $1/k^4$ in the infrared is too singular and must be regulated. The implications and prospects for confinement are discussed. We find good results for various physical quantities of interest including f_π, $< \bar{q}q >$, and Λ_{QCD} as in earlier treatments which used this approximation. This work has been submitted for publication in Nucl. Phys. B.

* University of Melbourne

G. Krein, P. Tang and A.G. Williams

Dynamical Chiral Symmetry Breaking in Quantum Chromodynamics with Confinement and Asymptotic Freedom.

We calculate the quark self-energy from dynamical chiral symmetry breaking in quantum chromo-dynamics using an ansatz for the proper quark-gluon vertex and the dressed gluon propagator which is consistent with the Slavnov-Taylor identities in the quark sector. In this way much of the symmetry information of quantum chromodynamics is retained, including, for example, chiral symmetry. Both confinement and asymptotic freedom are included in the gluon propagator. We find that it is straightforward to obtain good results for the pion decay constant f_π, the quark condensate $< \bar{q}q >$, and the scale parameter of quantum chromodynamics Λ_{QCD}. This work was published in Phys. Lett. B215, 145 (1988).

G. Krein and A.G. Williams

Covariant Model of Chiral Symmetry Breaking in QCD. Breaking.

Dynamical chiral symmetry breaking is studied in QCD using an ansatz for the dressed gluon propagator and the quark-gluon vertex which is consistent with the Slavnov-Taylor identities in the quark sector, and with confinement and asymptotic freedom. We obtain solutions for the Schwinger-Dyson equation for the quark self-energy over twenty orders of magnitude when we have exact chiral symmetry and when explicit chiral symmetry breaking bare-masses are included. We compare these results and examine the consequences for some important physical quantities. Submitted for publication in Physical Review C.

G. Krein, A. Szczepaniak and A.G. Williams

The Pion Form Factor.

We are calculating the pion electromagnetic form factor using a quark propagator obtained in a previous study[1] of dynamical chiral symmetry breaking in QCD. The effects of confinement and asymptotic freedom are analyzed.

[1] A.G. Williams, G. Krein and C.D. Roberts, submitted to Nucl. Phys. B.

III. Publications since June, 1988

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35. Fl. Stancu and L. Wilets, "The Important Configurations in Six Quark N-N States," Phys. Rev. C 38, 1145 (1988).

36. K.D. Wampler and L. Wilets, "On the Numerical Solution of the Hill-Wheeler Equation," Computers in Physics 2, 53 (1988).

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38. A.G. Williams and L.R. Dodd, "Chiral Nontopological Solitons with Perturbative Quantum Pions," Phys. Rev. D 37, 1971 (1988).

39. A.G. Williams, "Charge-Symmetry Breaking in the Nucleon-Nucleon System," in *High Energy Spin Physics*, ed. K.J. Heller (AIP No. 187, 1989), p. 572.

40. S.E. Woosley and W.C. Haxton, "Supernova Neutrinos, Neutral Currents, and the Origin of Fluorine," Nature 334, 45 (1988).

41. S. Ying, E.M. Henley, and G.A. Miller, "Deuteron Photodisintegration," Phys. Rev. C 38, 1584 (1988).

Accepted for Publication

1. J.N. Bahcall and W.C. Haxton, "Matter-Enhanced Neutrino Oscillations in the Standard Solar Model," Phys. Rev. D.

2. W.C. Haxton, "Fundamental Aspects of Nuclear Physics," Symposium for A. Bromley, Yale Nuclear Structure Laboratory, August 1987.

4. W.C. Haxton, "Neutrino Astrophysics and the Shell Model," to appear in the Proceedings of the Symposium on the 40th Anniversary of the Shell Model (1989).

5. E.M. Henley, "Electron Scattering and Weak Interactions," Proc. Workshop on *Hadronic Physics in the 1990's with Multi-GeV Electrons*, Seillac, France, June 1988.

6. E.M. Henley, "Status of Time Reversal Invariance," Proc. International Symposium on *Weak and Electromagnetic Interactions in Nuclei (WEIN '89)*, Montreal, May 1989.

7. E.M. Henley and G. Krein, "Chiral Symmetry Restoration and Quadi-elastic Electron-Nucleon Scattering," Proc. International Symposium on *Weak and Electromagnetic Interactions in Nuclei (WEIN '89)*, Montreal, May 1989.

8. E.M. Henley, "Space-Time Symmetries in Nuclei," Proc. XXIII Yamada Conference on *Weak Processes and Nuclear Structure*, Osaka, Japan, June 1989.

9. M. Li, L. Wilets, and R.J. Perry, "Numerical Methods in Calculating Boson and Fermion Loop Corrections," J. Computational Physics.

10. G.A. Miller, "Strong Coupling QCD and the Nucleus," Proc. Workshop on *Hadronic Physics in the 1990's with Multi-GeV Electrons*, Seillac, France, June 1988.

11. G.A. Miller, "Nuclear Wave Functions in Deep Inelastic Scattering and Drell-Yan Processes," LAMPF Workshop on *Nuclear and Particle Physics on the Light Cone*, Los Alamos National Laboratory, July 1988.

12. G.A. Miller, "The b_1 Structure Function and Nuclear Pions," Proc. SLAC Workshop on *Electron Scattering Using Internal Targets*, January 1989.

13. S. Ying, W. Haxton, and E. Henley, "Neutrino Disintegration of Deuterium," Proc. International Symposium on *Weak and Electromagnetic Interactions in Nuclei (WEIN '89)*, Montreal, May 1988.

Submitted for Publication

1. M.N. Butler and G.A. Miller, "The Q^2 Dependence of the EMC Effect," Phys. Rev. C.
2. D.E. Driscoll and G.A. Miller, "Relativistic and Strong Distortion Effects in Proton-Proton Parity Violation," Phys. Rev. C.
3. W.C. Haxton, E.M. Henley, and M. Musolf, "The Nucleon and Nuclear Anapole Moments," Phys. Rev. Lett.
4. H. Jung and G.A. Miller, "Pionic Contributions to Deep Inelastic Structure Functions," Phys. Lett. B.
5. G. Krein and A.G. Williams, "Covariant Model of Chiral Symmetry Breaking in QCD," Phys. Rev. C.
6. G. Krein, P. Tang, L. Wilets, and A.G. Williams, "The Chromodielectric Model: Confinement, Chiral Symmetry Breaking, and the Pion," Phys. Rev. C.
7. Fl. Stancu and L. Wilets, "Six-quark States in the MIT Bag," Phys. Rev. C.
8. K.D. Wampler, "The Object-oriented Programming Paradigm (OOPP) and FORTRAN Programs," Computers in Physics.
9. A.G. Williams, G. Krein, and C.D. Roberts, "Quark Propagator in an Ansatz Approach to QCD," Nucl. Phys. B.
10. S. Ying, W. Haxton, and E. Henley, "Neutral and Charged-Current Disintegration of Deuterium by Solar and Supernova Neutrinos," Phys. Rev. D.
11. S. Ying, "Diquark, QCD Sum Rule and Nucleon Form Factor," Phys. Rev. D.

IV. Invited Talks since June, 1988

W. C. Haxton

1. "Summary Talk: Spin and Symmetries," International Conference on *High Energy Spin Physics*, Minneapolis, September, 1988.
2. "The Origin of ^{19}F and other Supernova Stories," Princeton University. November, 1988.
3. "Neutrino Physics in Collapsing Stars," University of Virginia, December. 1988.
4. "The Origin of ^{19}F and other Supernova Stories," Michigan State University, January, 1989.
5. "The Origin of ^{19}F and other Supernova Stores," TRIUMF, February, 1989.
6. "Neutrino Reheating and Nucleosynthesis in Supernovae," UCLA Workshop on the Next Supernova, February, 1989.
7. "Nuclear Physics of Supernovae," colloquium, Oregon State University, February, 1989.
8. "Nuclear Physics of Supernovae," colloquium, University of Oregon, February, 1989.
9. "Particle Properties, New Particles, and Anomalous Phenomena," provocateur's talk, Town Meeting on *Electroweak Interactions and Astrophysics*, Santa Fe, April, 1989.

10. "Double Beta Decay," Lawrence Berkeley Laboratory, May, 1989.
11. "Neutrino-induced Nucleosynthesis in Supernovae," Department of Physics, University of California, Berkeley, May, 1989.
12. "The Nuclear Physics of Stars," K1200 Inauguration, Michigan State University, May, 1989.
13. "Neutrino Astrophysics and the Shell Model," Argonne Symposium on the 40th Anniversary of the Shell Model, May, 1989.
14. "Parity Violation in the NN Interaction," TRIUMF Symposium on *Spin and Symmetries*, June, 1989.

E. M. Henley

1. "Electron Scattering and Weak Interactions," at the First European Workshop on *Hadronic Physics in the 1990's with Multi-GeV Electrons*, Seillac, France, June 27-July 2, 1988.
2. "Status of Parity Nonconservation and Time Reversal Invariance," University of Vienna, June 24, 1988 and Giessen University, W. Germany, July 6, 1988.
3. "Electron Scattering and Weak Interactions," Argonne National Laboratory, March 10, 1989.
4. "An Axial electromagnetic Current - The Anapole Moment," American Physical Society, May 1-4, 1989.
5. "Status of time Reversal Invariance," International Symposium on *Weak and Electromagnetic Interactions in Nuclei*, Montreal, May 15-19, 1989.
6. "Space-Time Symmetries in Nuclei," XXIII Yamada Conference on *Weak Processes and Nuclear Structure*, Osaka, Japan, June 1989.

G. A. Miller

1. "Strong Coupling QCD and Nuclear Physics," European Workshop on *Hadronic Physics in the 1990's with Multi-GeV Electrons*, Seillac, France, July 1988.
2. "Nuclear Wave Functions in Deep Inelastic Scattering and Drell-Yan Production Processes," *Nuclear and Particle Physics on the Light Cone*, Los Alamos, July 1988.
3. "Lepton-Nucleus Deep Inelastic Scattering," TRIUMF, September 1988.
4. "Studying the Nuclear Sea with the Drell-Yan Process," TRIUMF, October 1988.
5. "The b_1 Structure Function and Nuclear Pions," 1989 SLAC Workshop on Electron Scattering, January 1989.
6. "Nuclear Color Transparency," TRIUMF, February 1989.
7. "A New Look at CP Violation," University of Illinois, April 1989, Carnegie-Mellon University, April 1989, Indiana University Cyclotron Facility, May 1989.
8. "Relativistic Pion Ring Series for Nuclear Matter," Baltimore APS Meeting, May 1989.
9. "Drell-Yan Nuclear Physics," University of Alberta, June 1989.

L. Wilets

"Various topics relating to soliton and Chromodielectric models:"

1. Jilin University, PRC, August 24, 1988.

2. Beijing Institute of Modern Physics, PRC, 12 one-hour lectures, August 29-September 3, 1988.
3. Institute of Atomic Energy, Beijing, PRC, September 12, 1988.
4. The Ohio State University, November 14, 1988.
5. University of Frankfurt, January 12, 1989.
6. University of Maryland, April 28, 1989.

"Is the Nucleon a Dirac Particle?"

7. Jilin University, PRC, August 25, 1988.
8. Kent State University, November 11, 1988.
9. Workshop on Heavy Ions, Hirschegg, Austria, January 17, 1989.
10. Workshop on Relativistic Heavy Ion Collisions, Budapest, June 12, 1989.

"Six quark Basis States for N-N Processes"

11. Jilin University, PRC, August 26, 1988.

A. G. Williams

1. "Charge Symmetry Breaking in the Nucleon-Nucleon System," 8th International Symposium on High Energy Spin Physics, Minneapolis, September 12-17, 1988.