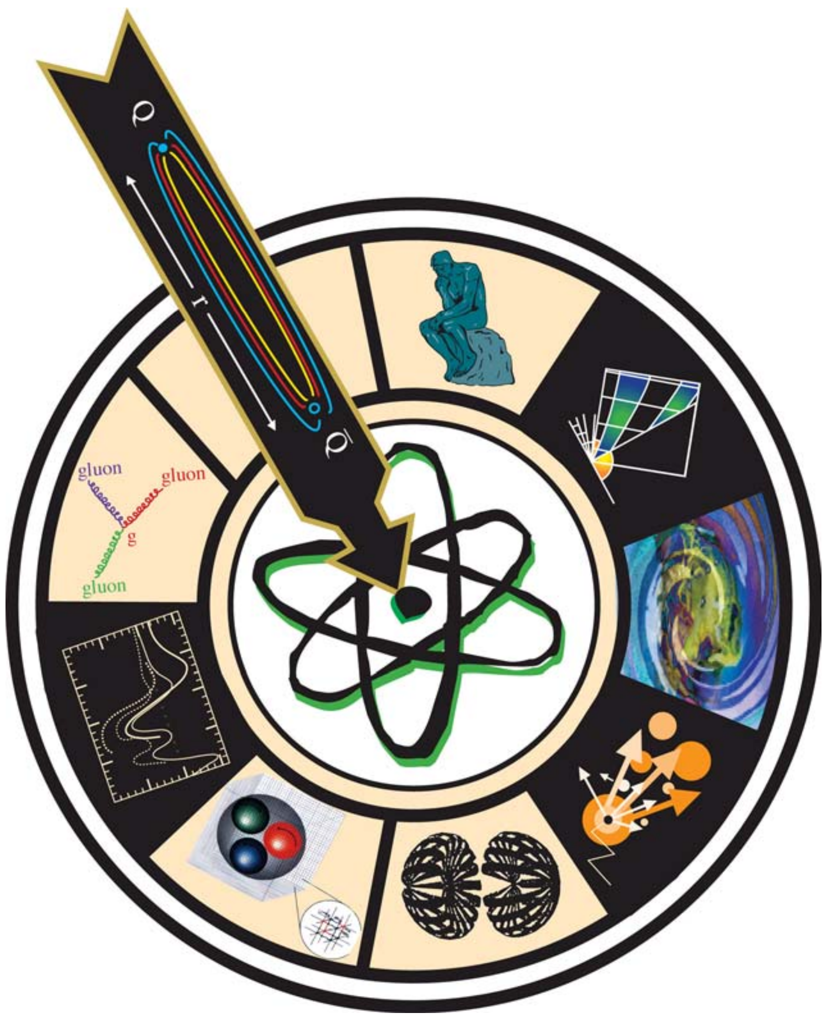
Jefferson Lab
Theory Group Annual Report
Jan. 1st – Dec. 31st, 2002



I. OVERVIEW

A. Organization of This Report

This report summarizes the work done by the Jefferson Laboratory (JLab) Theory Group from January 1, 2002 to December 31, 2002. This Overview section includes a list of staff supported by the Theory Group, and a Summary of some of the major research results. Section II describes the work of individual group members. Publications and talks are listed in Section III, and an Appendix lists visitors and seminars for the period covered by the report.

In this report we include only work done by the Senior Staff, including the Distinguished Visiting Fellow, and Postdoctoral Fellows associated with the group during the past year (2002). The JLab Theory Group interacts highly productively with many faculty, postdoctoral associates, and students, but we do not include the work of these associates and visitors in this report.

B. Members of the Theory Group

The JLab Theory Group currently consists of nine Senior Staff, three postdoctoral associates, and three active Associate Senior Staff (i.e., those who spend several days per month with the Theory Group). In the past year (2002), the Theory Group Senior Staff also included the JLab Distinguished Visiting Fellow, and the group offered support to two further postdoctoral associates. The Senior Staff are listed in Table I, the JLab Distinguished Visiting Fellow in Table II, Postdoctoral Associates in Table III, and the active Senior Staff in Table IV.

Table I

JLab Senior Staff	Half-time Affiliation (if any)
Ian Balitsky	Old Dominion University
Robert Edwards	
Jose Goity	Hampton University
Franz Gross	College of William and Mary (Retired)
Anatoly Radyushkin	Old Dominion University
David Richards	
Winston Roberts	Old Dominion University
Rocco Schiavilla	Old Dominion University
Wally Van Orden	Old Dominion University

Several students supported by neighboring institutions also strengthen the JLab Theory Group environment. In 2002, the students included Alex Babansky (ODU), Elena Kuchina (ODU), Tobias Oed (ODU), Alex Psaker (ODU) and Jorge Saez (HU).

Table II

JLab Distinguished Visiting Fellow	Period	Home Institution
Yuri Simonov	10/01-04/02	ITEP, Russia

Table III

JLab Postdocs	Period of Employment
Deirdre Black	10/01-8/03
George Fleming	10/02-9/04
Wally Melnitchouk*	08/01-8/02
Carlos Schat	10/01-8/02
Igor Musatov	10/01-9/03

*Physics Division Research Fellow (from 9/02-present)

Table IV

JLab Associate Senior Staff (Active)	Home Institution
Carl Carlson	College of William and Mary
Chris Carone	College of William and Mary
Marc Sher	College of William and Mary

C. Research Highlights

In this section highlights of the research undertaken by the JLab Theory Group are described in less technical language. The discussion is organized into four overlapping topics: *quark structure of hadrons, few-nucleon systems, deep inelastic scattering and duality,* and *solving QCD.*

1. Quark Structure of Hadrons

The word *hadron* refers to neutrons and protons (collectively as nucleons), their excited states, and the mesons that interact with them and bind them together into nuclei. These are the nuclear building blocks we observe in nature, yet they are not elementary particles. Nucleons are composed of three quarks surrounded by a sea of gluons and quark-antiquark pairs. Mesons are composed of a sea of quark-antiquark pairs and gluons. The force that binds the quarks and gluons into hadrons *confines* them, so that it is impossible to study quarks and gluons as free particles. Hence, an understanding of the structure of nuclear matter begins with the study of the structure of hadrons, the simplest pieces of nuclear matter we can observe in the laboratory.

At JLab these theoretical studies are carried out using a variety of tools. In systems where one of the quarks is very heavy, so that it moves very slowly, an approximate theory known as Heavy Quark Effective Theory (HQET) has been developed. An important application of HQET is to the weak decays of mesons containing the *b* quark; by studying the semi-leptonic decay of the *B* meson, the element V_{ub} of the CKM matrix, which describes the mixing of quark flavors under the weak interaction, can be determined, and hence constraints placed on the fundamental parameters of the Standard Model of particle physics (Roberts).

For light-quark systems, one may sometimes exploit the fact that the bare quark masses are very small. This gives rise to an approximate symmetry known as chiral symmetry, and leads to the development of Chiral Perturbation Theory, also being studied at JLab (Goity and Roberts), and of models constrained by the requirements of chiral symmetry (Black). Applications include the

study of the decay $\pi_0 \rightarrow \gamma\gamma$, relevant for the upcoming PRIMEX experiment (Goity), the strong decay of heavy mesons (Goity, Roberts), and the decays and mixing of light mesons (Black).
In the limit that the number of colors, N_c, is large, QCD greatly simplifies, and considerable insight into the structure of the strong interactions can be gleaned. This has been applied at JLAB to study the excited baryon spectrum (Goity, Schat), illustrated in Figure 1.

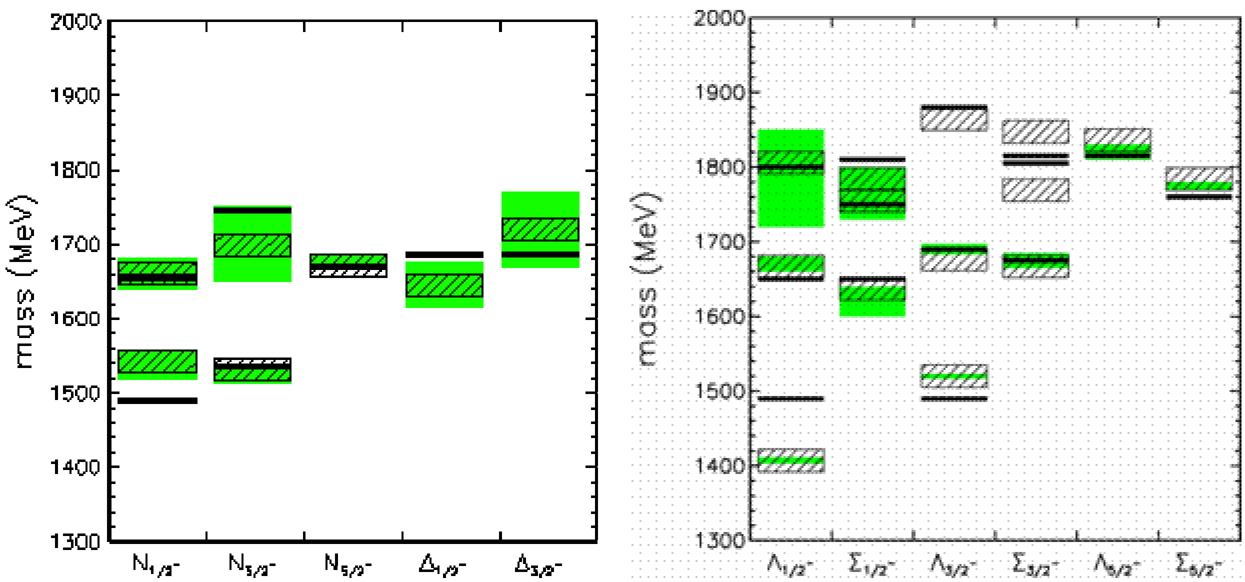


Figure 1: Masses of strangeness S=0 (left panel) and S=-1 (right panel) negative-parity excited baryons: green shaded areas correspond to experimental data, black solid lines are the Isgur-Karl QM predictions, and the hatched boxes are the 1/Nc results (Goity, Schat, and Scoccola, PRD 66, 114014 (2002)).

Finally, in a few cases exact results for the masses of hadrons, and for the quark and gluon structure, can be obtained by solving QCD on the lattice (Edwards, Fleming, Melnitchouk and Richards).

2. Few-Nucleon Systems and the NN Force

The simplest nuclei consisting of a "few" nucleons (in practice two to ten nucleons) are easiest to study both theoretically and experimentally. The force between two nucleons can be inferred from the structure of the deuteron, the only bound state of two nucleons, and the scattering of two free nucleons. Then, using the forces inferred from two-nucleon studies, the properties of three-, four-, ... ten-nucleon systems can be predicted. Comparison of these results with experiment confirms the correctness of the *NN* force, and tells us whether or not three-nucleon (*NNN*) or many-nucleon forces are important. The goal of this work is to fully determine the nuclear forces and currents, explain the structure and interactions of few nucleon systems, and then to explain these forces and currents in terms of the underlying quark structure of matter and QCD.

It has recently been shown by the ANL-UIUC-LANL collaboration that it is possible to reproduce quite well the observed low-lying energy spectra of nuclei with mass number A ≤ 10 by including *NN* and *NNN* forces. Using the resulting wave functions and electro-weak current operators constructed consistently with these forces, it has also been shown that a variety of nuclear properties, for A ≤ 7, such as elastic and inelastic electromagnetic form factors, radiative widths, β-decay and electron-capture rates, are well predicted by theory (Schiavilla). In collaboration with the Pisa group and members of the ANL-UIUC-LANL team, studies of low-energy radiative and weak capture reactions involving systems with A ≤ 7 have also been carried out based on the same realistic forces and currents (Schiavilla). Some of these processes are of considerable interest in astrophysics in relation to energy and neutrino production in main-sequence stars and primordial nucleo-synthesis.

Relativistic models based on the exchange of mesons between nucleons have also been developed and have been shown to be successful in explaining deuteron form factors (Gross, Schiavilla, Van Orden) and in describing electro-disintegration of few body nuclei (Gross, Schiavilla, Van Orden).

3. Deep Inelastic Scattering and Duality

When electrons are used to probe the structure of hadrons and few-body nuclei in their normal ground state, the energy transferred to the hadronic or nuclear target is kept to a minimum, leaving the target largely undisturbed. Alternatively, the structure of hadrons and nuclei can be studied by explicitly exciting the underlying quark degrees of freedom. This is most effectively done when both the momentum and energy transferred by the electron are large. Under these conditions, known as deep inelastic scattering (DIS), the quarks are "torn" from the initial hadronic/nuclear target, and because they cannot exist in isolation, reform into different hadrons as they leave the target. The DIS Stanford Linear Accelerator (SLAC) experiments of Friedman, Kendall and Taylor, who received the Nobel Prize in 1990, were among the first to tell us of the existence of quarks, and this method continues to be a major source of information about quark structure.

Recently, there has been great interest in DIS for the case where the partons carry only a small fraction of the nucleon longitudinal momentum, the so-called "small-x" regime. Here the density of the partons becomes very large, and the usual techniques of perturbative QCD (pQCD) can no longer be applied. However, the study of DIS at small-x provides an important bridge between the pQCD regime, and the low-energy non-perturbative sector, and hence provides insight into the pQCD/ High Density QCD/Confinement transition (Balitsky). Finally, lattice QCD enables *ab initio* calculations of the first few x moments of the parton distributions in DIS (Edwards, Melnitchouk).

A new theoretical tool, the so-called generalized parton distributions (GPDs), has been recently developed at JLab (Radyushkin) and elsewhere. The GPDs encompass both hadronic form factors and the structure functions measured in DIS, and provide an effective tool for the study of quark distributions through deeply virtual Compton scattering and deep exclusive scattering

(Balitsky, Radyushkin). This advance is one of the major new campaigns driving the JLab 12 GeV Upgrade proposal. The proton sea can also be studied in DIS (Melnitchouk).

At moderate energies excited states of hadrons appear as resonance "bumps" in DIS, and it has long been observed that the average of the cross section over these bumps reproduces the smooth result one obtains from DIS at very high energies. This phenomenon is known as "duality." New work at JLab is providing a better understanding of how this comes about (Melnitchouk, Van Orden; Gross).

4. <u>Exact Solutions of QCD</u>

QCD can be solved to high precision at very high energies, where the forces between quarks and gluons become vanishingly small (a phenomenon known as "asymptotic freedom"). However, at the moderate energies of quarks in a cool hadronic medium where the QCD forces are very strong, the theory is very difficult to solve. Only one way is known to obtain exact solutions of QCD in this region. It is a numerical method known as "lattice gauge theory" (Edwards, Fleming, Melnitchouk, Richards). Since QCD is believed to be the theoretical foundation of nuclear physics, using lattice gauge theory to obtain exact numerical solutions remains one of the highest priorities of the Theory Group.

Quantities that are computed on the lattice include the masses of low-lying states, hadronic form factors and transition form factors, and the moments of structure functions and GPDs; an example of the lattice computation of the first few moments of the nucleon flavor-non-singlet structure functions is shown in Figure 2. In addition to providing

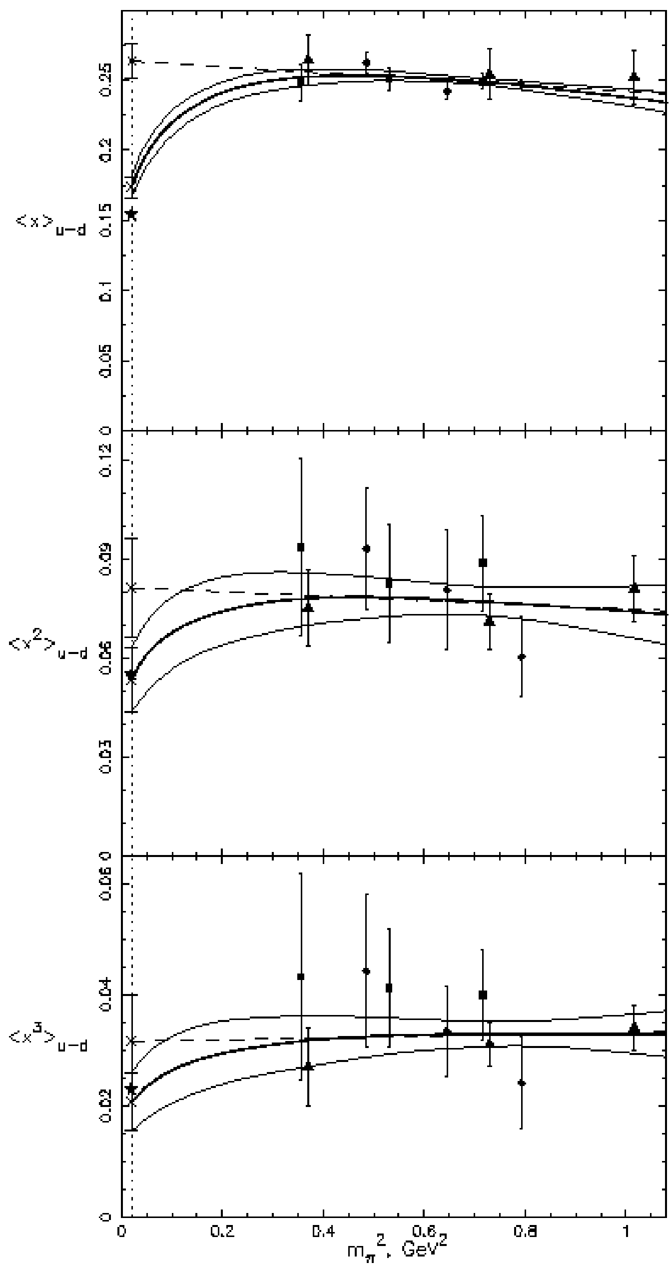


Figure 2: Moments of flavor-non-singlet nucleon structure functions. Phenomenological value is denoted by stars, lattice data by other symbols (LHPC, Edwards *et al.*, PRD66, 034506 (2002)). Solid line shows extrapolation of data to physical pion mass, using chiral form proposed by Melnitchouk *et al*. (PRL87, 172001 (2001)).

numerical values for these quantities, lattice calculations aid the testing and construction of QCD-inspired models and effective theories, which are then used to compute quantites beyond those accessible to lattice gauge calculations.

An exciting development in 2001 was the award of three years of support to Jefferson Laboratory, totaling around $2M, as part of a U.S. effort to create a *National Computational Infrastructure for Lattice QCD*, under the Department of Energy's Scientific Discovery Through Advanced Computing (SciDAC) initiative. Historically, the emphasis in lattice QCD research has been on particle physics applications, and in particular on the calculation of the weak-interaction matrix elements and investigations of the finite-temperature transition. The crucial role that lattice QCD plays in hadronic physics is now being recognized not only within the nuclear physics community, but also by the lattice community. This recognition has enabled JLab, together with colleagues at MIT, to attain an equal status with Fermilab and Brookhaven as national centers in the SciDAC program.

The goals of this project are to create a unified programming environment for the U.S. lattice community on diverse, multi-architecture machines. The five-year plan is to site three such machines, of ten teraflops/second scale, i.e., capable of 10^{13} floating-point operators per second, at each of the national centers, including JLab; the first investment in hardware at JLAB arising from the SciDAC effort was the commissioning in the Fall of 2002 of a 128-node Pentium IV Xeon cluster, with a fast Myrinet interconnection. This cluster not only serves as a test-bed for a future terascale facility, but also provides a substantial resource for lattice hadronic physics calculations. While the new facilities are enabling computations to be performed at values of the pion mass approaching the physical value, there is still a need to perform a chiral extrapolation to the physical regime, and understanding the form of that extrapolation is a crucial component of the lattice effort (Melnitchouk).

The emphasis of the current grant is on a national effort on software development to efficiently utilize the proposed terascale facilities. Here the role of the JLab Theory Group has been pivotal. Robert Edwards is a leading member of the National Software Subcommittee, and has been instrumental in the design and implementation of the QCD API (*Application Program Interface*), and the development of a C++ implementation (QDP++) conforming to the API. George Fleming and David Richards are working on the development of new codes conforming to the emerging QCD-API, and the Theory Group maintains the national lattice QCD web site (www.lqcd.org). Chip Watson, of the High-Performance Computing Group, is a PI on the national SciDAC Executive Committee.

The LQCD program is very promising, but at present it is used to compute a limited number of observables in rather simple cases. Thus, it is of critical importance to the JLab program to find alternative ways to solve QCD. Yuri Simonov, the JLab Distinguished Visiting Fellow, and his collaborators have developed a very promising method for obtaining approximate solutions to QCD. This method was studied and further developed at JLab, resulting in several new collaborations between Simonov and JLab theorists.

The technique exploits the properties of the QCD vacuum that have been extracted from lattice calculations, and allows the effective Hamiltonian for two and three quark systems to be derived directly from QCD. In the process, that part of the confining interaction that is independent of the distance (the constant term), and the spin dependence of the confining interaction, both of which are usually treated in a purely phenomenological manner, are completely given in terms of the string tension (which determines the strength of the linear part of the confining force). This allows one to understand quark and gluon confinement and the spectrum of meson and baryons largely in terms of a string tension fixed by lattice calculations. (The quark masses and the quark-gluon coupling also play a role.) The results are very promising; as good as any model calculations, but with parameters obtained entirely from QCD. The method is currently being used to study the baryon spectrum, and meson and baryon decays.

An alternative method for the exact numerical solutions of field theories is also being developed at JLab (Gross). This is known as the "Feynman-Schwinger" technique, and has not yet been applied to QCD.

II. DESCRIPTION OF CURRENT RESEARCH

Ian Balitsky

In 2002, work continued on the deep inelastic scattering (DIS) from nucleon and nuclei at small x. The DIS is a unique experiment, which allows us to take "snapshots" of the constituents inside a hadron or nucleus at different moments of time with different resolutions. At low x, we probe the high-density domain of QCD where the constituents are small, but their density is so large that the packing factor for partons is large and, therefore, we cannot use ordinary pQCD methods. This high-density regime of QCD may serve as a bridge between the well-studied domain of pQCD and the "real" non-perturbative QCD regime governed by physics of confinement. It turns out that the small-x behavior of structure functions in the high-density regime is governed by the nonlinear evolution for the Wilson-line operators suggested in my paper several years ago. This nonlinear equation (sometimes referred to as the Balitsky-Kovchegov equation) was re-obtained since then by a number of different approaches and now it is a basis for the modern study of the DIS in QCD in the high-density regime. As usual, the region of the validity of this equation has to be determined by the magnitude of the next-to-leading (NLO) corrections. There are two types of the NLO corrections: due to the high density of partons and due to the running coupling constant. In collaboration with A. Belitsky (University of Maryland) we have found the NLO corrections to the nonlinear equation responsible for the high-density effects. This is the first part of an ongoing project aimed at the calculation of the total set of the small-x evolution equations in the next-to-leading order. When accomplished, this NLO result will give us an opportunity to separate the running coupling constant effects versus the effects due to the high density of partons providing a valuable insight into the pQCD/HighDensityQCD/Confinement transition.

Deirdre Black

The scalar mesons are currently the subject of considerable interest since, although they play an important role in low energy strong processes, their properties are not well understood. There are too many states to fit into a conventional $\mathrm{SU}(3)\, q\bar{q}$ multiplet and several states - the controversial σ and κ mesons as well as the $a_0(980)$ and $f_0(980)$ - are lighter than constituent quark model expectations. Previously I was involved in developing a nonlinear chiral Lagrangian description of low energy meson scattering and decay in which the scalar, as well as the vector, mesons are included explicitly. Recently, I have extended this approach to include radiative processes and also begun to study ways of treating final state interactions in scalar meson production processes.

Rare radiative decays of the φ meson (to $\pi\pi\gamma$ and $\pi\eta\gamma$) have been measured for the first time recently at Novosibirsk, at Jefferson Lab, and by the KLOE collaboration working at the φ factory at Frascati. The search for these decay modes was motivated by the suggestion that a measurement of the branching fractions could distinguish between conventional and exotic explanations of the $a_0(980)$ and $f_0(980)$ states, specifically between $q\overline{q}$, $qq\overline{q}\overline{q}$ and $K\overline{K}$ molecule scenarios. It is proving difficult to use the experimental three-body decay measurements to extract information about the scalar resonances in a model-independent way. In collaboration with Harada and Schechter, I have developed a new approach to studying radiative decays involving light scalar mesons, in which all the strong and electromagnetic interactions are treated in a chiral framework. We found that, although it has the nice feature of respecting chiral symmetry and making many predictions, our model, at tree-level, seems too simple to describe the radiative φ decays. In this context we also studied isospin-violating $a_0 - f_0$ mixing and realized that this interesting phenomenon, contrary to certain suggestions, cannot resolve the difficulty of explaining the radiative φ decay data. We have now calculated kaon loop corrections to our original amplitudes and have also found that chiral invariance determines some features of the shape of the radiative decay spectrum. While we can now fit the radiative φ data in isolation, we are still working on doing a global fit including the strong processes that we studied previously.

With Abdel-Rahim, Fariborz and Schechter, I have also studied the isospin-violating strong decay $\eta \rightarrow 3\pi$. This is a rather interesting process. On the one hand, it has historically been surprisingly difficult to describe using the simplest chiral treatments, while on the other, it is potentially a sensitive probe of the up-down quark mass difference. In the early 1980s, Gasser and Leutwyler extended the original Current Algebra result to next-to-leading order in Chiral Perturbation Theory, and other authors subsequently investigated the effects of final state interactions and violations of Dashen's Theorem, all of which bring theory into closer agreement with experiment, although the shape of the Dalitz plot is still not fully understood. We have explored the effect of explicitly including scalar mesons, taking into account higher order symmetry breaking, and found that at tree level the scalar contributions also improve the theoretical prediction for the $\eta \rightarrow 3\pi$ rate. Our result is still smaller than the experimental value. We intend to analyze final state interactions for this process in more detail and to study the related process $\eta' \rightarrow 3\pi$. The latter is also interesting since the effect of $a_0 - f_0$ mixing, which will soon be measured experimentally at COSI in Germany, is likely to be more important.

In parallel with nonlinear chiral Lagrangian descriptions, I have, with Schechter et al., also studied meson-meson scattering using SU(3) Linear Sigma models. There we found that the scalar mesons emerge with properties consistent with our previous work. In this case the mass of the scalar mesons is shifted from a "bare" value to a "physical" value by the effects of unitarization. With Abdel-Rahim, Fariborz, Nasri and Schechter, I applied the analogue of our analysis of low-energy $\pi\pi$ scattering to the case of a strongly-coupled Higgs sector in the electroweak theory. Specifically, we studied two Higgs production processes, WW fusion and gluon-gluon fusion, which for the case of a Heavy Higgs, require unitarization. We used K-matrix unitarization of WW scattering and found, similarly to other authors, that the position of the Higgs peak changes relative to the tree-level mass. We also suggested a new way of treating the gluon-fusion Higgs production process, based on an analogy with σ "production" and decay to two pions. This leads to a rather different di-gauge boson spectrum to that obtained by other methods of unitarization such as adding a Breit-Wigner width term to the Higgs propagator.

We are currently also studying a K-matrix unitarized nonlinear sigma model, and comparing with $\pi\pi$ scattering data. We are also thinking of ways in which the K-matrix-related model for σ production discussed above can be applied to the radiative φ decays and η,η' decays discussed previously. We hope that this may eventually be applied to the D decays $D \to 3\pi, \pi\pi K$, which have been analyzed recently by the E791 and FOCUS collaborations working at Fermilab. Dalitz plot analyses of these decays have provided important evidence for the σ and κ states.

Finally, motivated by recent indications of large $\mu-\tau$ neutrino mixing, with Han, He and Sher, I considered the bounds on related $\mu-\tau$ flavor violation in the charged lepton sector. Using an effective operator approach where the scale of new physics associated with charged lepton flavor violation is encoded in a certain class dimension-six four-fermion effective operators, we systematically analyzed existing experimental bounds the scale of new physics. Most of the bounds come from rare τ and B decays. We also discussed operators which are either weakly constrained or not yet subject to any experimental bounds. This, together with other studies of lepton flavor violation (for example $\mu-e$ mixing), complements what we learn from neutrino oscillations and will help in eventually achieving an understanding of lepton flavor dynamics.

Robert Edwards

An exciting advance in lattice QCD has been the solution of the problem of regulating chiral fermions. The method developed – the Overlap/Domain Wall Method – allows for the first time, the realization of exact chiral symmetry on the lattice free of doublers and any other approximations. There are exact zero modes related to topology and non-zero modes responsible for chiral symmetry breaking. In the Domain Wall approach, a flavor fifth dimension is introduced that if infinite in extent, once integrated out a four-dimensional Dirac operator with exact chiral symmetry is induced.

This new theoretical development has been a major focus of my research in the last few years. I have investigated how symmetry-breaking effects are manifested in the Domain Wall approach with a finite fifth-dimensional extent [Phys. Rev. D63, 054509 (2001)] and how these chiral symmetry-breaking effects are related to an induced four-dimensional kernel of the Dirac operator. In work with Heller [Phys. Rev. D63, 094505 (2001)], I showed how the Domain Wall operator can be made to have exact chiral symmetry even with finite fifth-dimensional extent. Many important properties of the Dirac operator were clarified. These new chiral fermions

methods are now being used in calculations of fundamental quantities in QCD, such as the pion form factor, with the computations employing pion masses down to 300 MeV. First results for Generalized Parton Distributions for the proton are also appearing.
Edwards has also been extensively involved in the U.S. SciDAC program. One part of this effort has been the development of the software and hardware infrastructure for these new lattice QCD calculations. The current calculations at JLab have used this new software, *QDP++* and *Chroma*. The calculations are using the new lattice 128-node Pentium 4 Myrinet cluster. A new 256-node three-dimensional Gigabit Ethernet mesh system is in final commissioning. The second part of the GPD calculations will be carried out on this new system.

George Fleming

I completed my work, in collaboration with Greg Kilcup and Dan Nelson of Ohio State University, on computing the ratio of the up-quark mass to the down-quark mass in lattice QCD with three light dynamical fermions. This important work essentially rules out a massless up quark as the explanation for the observed lack of CP violation in the strong interaction [Phys.Rev.Lett.**90**:021601, 2003].

Jose Goity

Large N_c QCD in Baryons

The most difficult domain in QCD is the resonance domain. While at high energy the usage of perturbative QCD, and at very low energies the usage of Chiral Perturbation Theory allow for rigorous (i.e. model independent) description of the various phenomena, in the resonance region there seems to be a lack of a consistent expansion scheme. There is, however, one parameter that can be used to expand any observable or green function in QCD, namely the inverse of the number of colors $1/N_c$. This and the light quark masses are indeed the only available expansion parameters in the resonance region. The validity of the $1/N_c$ expansion for the real world with $N_c = 3$ is an open problem where important inroads have been made. The expansion has shown success in the meson sector, for instance by giving the only rigorous explanation for OZI suppression, and in recent applications, in combination with Chiral Perturbation Theory. Since it is an expansion that applies at all energy scales, it is clear that there is plenty of opportunity to understand its range of validity.

Perhaps the most interesting application is that to the resonance region, as it is the only QCD parameter that we can use to formulate a rigorous framework. In particular the baryon sector presents a very interesting scenario for this application of the $1/N_c$ expansion. Building on previous foundational work on ground state baryons by Dashen, Manohar and coworkers, and on excited baryons by JLG and collaborators, the study of masses and decays has been carried out for negative and positive parity excited baryons, in some cases including the strange sector as well. The framework established represents the only rigorous QCD effective theory in the resonance domain. Many insights have been gained that will be further improved with the richer database on N^* and on other excited baryons that will result from JLab. Two projects were completed in collaboration with C. Schat and N. Scoccola on the masses of the 70-plet and the

56-plet. Currently, a broad analysis of the decays on non-strange members of the 70-plet is being completed.

Chiral Perturbation Theory

Work has been carried out in two different projects, namely, 1) the study of the π^0 decay rate into two-photons to next to leading order, and 2) the study of isospin breaking in the πN couplings.

1. The $\pi^0 \to \gamma\gamma$ decay is currently of direct importance to Jefferson Lab where it will be measured to a new level of precision by the PRIMEX experiment scheduled to run in 2004. In collaboration with A. Bernstein, J. Donoghue and B. Holstein, an analysis of the decay to NLO in Chiral Perturbation Theory combined with the $1/N_c$ expansion. The analysis showed that there is a correction that increases the rate calculated when isospin breaking is ignored and no NLO corrections are included. The dominant correction is driven by the isospin breaking effects stemming from $m_u \neq m_d$ that give an admixture of the pure U(3) states associated with the η and the η' into the physical π^0. This admixture is such that it produces an enhancement of about 4% in the rate. This effect is a definite theoretical prediction that can be tested by the PRIMEX experiment where the expected error will be in the range of 1.5%. The PRIMEX will therefore be able to test the anomaly as well as the corrections induced by quark masses.

2. An extensive analysis of isospin breaking in the nucleon sector has been undertaken in collaboration with J. Saez, a graduate student at Hampton University. Of special interest is the study of isospin breaking in the π-N couplings. First results were obtained on isospin breaking in the Goldberger-Treiman relation, and currently a full-fledged analysis is under way.

Franz Gross

Review of Electromagnetic Structure of the Deuteron

A major review was written in collaboration with Ron Gilman [J.Phys.G28, R37 (2002)]. The review focused on the recent JLab experimental measurements of the deuteron electromagnetic structure functions A, B and T_{20} extracted from high-energy elastic *ed* scattering, and the cross sections and asymmetries extracted from high-energy deuteron photodisintegration. The theoretical calculations reviewed ranged from non-relativistic and relativistic models using the traditional meson and baryon degrees of freedom, to effective field theories, to models based on the underlying quark and gluon degrees of freedom of QCD, including non-perturbative quark cluster models and perturbative QCD. The review discussed why elastic *ed* scattering and photodisintegration seem to require very different theoretical approaches, even though they are closely related experimentally. This review has also been summarized in some invited talks, including one at the 2002 Elba Workshop on Electron-Nucleus Scattering.

The Role of Interaction Vertices in Bound State Calculations

In recent studies of the one and two-body Greens' function for scalar interactions it was shown that crossed ladder and "crossed rainbow" (for the one-body case) exchanges play a crucial role in non-perturbative dynamics. In this letter [Phys.Lett.B531, 161 (2002)] exact analytical and numerical results were used to show that the contribution of vertex dressings to the two-body bound state mass for scalar QED are cancelled by the self-energy and wave function normalization. This proves that the mass of a two-body bound state as given by the full theory can, in a very good approximation, be obtained by summing only ladder and crossed ladder diagrams using a bare vertex and a constant dressed mass. The implications of the remarkable cancellation between rainbow and crossed rainbow diagrams, that is a feature of one-body calculations, are also examined.

Covariant Description of Inelastic Electron-Deuteron Scattering

In collaboration with several JLab theorists, a discussion of the covariant theory of deuteron electro-disintegration, *d(e,e'p)n*, using the covariant spectator theory and the transversity formalism, was presented [Phys.Rev.C66, 044003 (2002)]. This paper, expected to be the first of a series, reviews the relativistic kinematics, and obtains simple theoretical formulae for the unpolarized cross section in the relativistic impulse approximation (RIA). Numerical predictions for the scattering in the high Q^2 region obtained from the RIA and five other approximations were discussed. It was shown that measurements of the unpolarized coincidence cross section and the asymmetry A_ϕ, to an accuracy that will distinguish between different theoretical models, is feasible over most of the wide kinematic range accessible at Jefferson Lab.

Wally Melnitchouk

Quark-Hadron Duality

Quark-hadron duality addresses perhaps the core issue in strong interaction physics, namely, the nature of the transition from quark to hadron degrees of freedom. The classic manifestation of quark-hadron duality in inclusive electron--nucleon scattering ("Bloom-Gilman duality") has been studied in detail through a series of high-precision experiments at Jefferson Lab, both in unpolarized and polarized structure functions. In order to uncover the dynamical origin of the observed equivalence of the scaling and resonance-averaged structure functions, I have carried out a study of duality (in collaboration with F. E. Close) in the nonrelativistic quark model with various scenarios of hyperfine symmetry breaking. This work established consistency relations, which can rule out certain forms of symmetry breaking mechanisms, and confirm others as compatible with duality.

When applied to the specific case of elastic scattering, local duality can also be used to relate elastic form factors with structure functions near $x \approx 1$. While earlier work focused on the free nucleon case, similar relations can also be derived for bound nucleons. In particular, recent data from ^{4}He(e,e'p) experiments at Jefferson Lab, which obtained limits on the nuclear medium dependence of the nucleon form factors, have been used to constrain the medium modification of the inclusive structure function at large x. This has enabled constraints to be placed on models of the nuclear EMC effect in which a sizable fraction of the effect is attributed to the modification of the internal quark structure of the nucleon in medium.

Chiral Symmetry and Lattice QCD

The spontaneously broken chiral symmetry of QCD plays a fundamental role in nuclear physics. Its importance is particularly evident in the extrapolation of lattice data from large quark masses, where most simulations are currently performed, to the physical (chiral) regime. In on-going work with A. W. Thomas and W. Detmold, I have analyzed moments of unpolarized and polarized nonsinglet quark distributions, taking into account general constraints imposed by the chiral symmetry of QCD. The inclusion of the (model-independent) leading non-analytic behavior of the moments arising from Goldstone boson loops leads to an excellent description of both the lattice data and the experimental values of the moments. For the polarized distributions, the role of the Δ baryon is particularly important in understanding the chiral corrections to g_A.

Future work will in addition examine the chiral corrections to the moments of pion structure function, for which fewer lattice data presently exist.

Nuclear Effects in Few-Nucleon Systems

The extraction of the free neutron structure function from nuclear data requires accurate knowledge of nuclear effects. On-going work on the g_1 and g_2 structure functions of ^{3}He and deuterium, as well as their moments, is quantifying the nuclear corrections in different kinematical regimes. In particular, finite-Q^2 effects are being evaluated which are of importance in the "transition" region of intermediate Q^2, and in the region dominated by resonances, where much of the Jefferson Lab data are collected.

Igor Musatov

Generalized Parton Distributions (GPDs) are a subject of intensive research, both theoretical and experimental, and a significant part of the JLab research program. Recently, there was significant progress in the theoretical understanding of GPDs in the specific kinematics of vanishing four-momentum transfer.

To establish the relationship between theoretical models for GPDs and experimental observables within currently accessible kinematical regions, one needs to extend the theoretical description of the physical amplitudes to incorporate the momentum transfer dependence. Particularly, the parameterization of the DVCS and hadron annihilation amplitudes beyond the leading twist is required to restore gauge invariance in the case of not-very-small momentum transfers [Musatov and Radyushkin, in progress].

A practical way to build t-dependent GPDs is to relate the GPDs to known physical observables (structure functions and form factors) along with QCD-inspired models of hadron structure. It was found that light cone wave functions with power-law momentum behavior may be used to derive realistic GPDs [Mukherjee, Musatov, Pauli, Radyushkin, to be published].

An important task is to provide experimentalists an effective algorithm, which will allow the evaluation of observables for DVCS using different theoretical models for GPDs as an input [Kuchina and Musatov, in progress]. The work is being done in cooperation with JLab experimental groups.

Anatoly Radyushkin

Generalized Parton Distributions and Form Factors

The Compton scattering in its various versions provides a unique tool for studying hadronic structure. In situations where one can use factorization for separation of hard (perturbative) and soft (non-perturbative) contributions, the non-perturbative part is described by generalized parton distributions (GPDs). The completed and ongoing research includes the construction of models for GPDs in the pion case and also in the experimentally more important nucleon case, including the helicity-flip distributions. The models include, in a self-consistent way, the dependence of GPDs on all variables: momentum fraction *x*, skewedness ξ and momentum transfer *t*. This is achieved by incorporating the double distribution formalism. The models for GPDs also provide predictions for form factors.

Time-Like Processes

The generalized parton distributions can be also used in "time-like" processes such as $p\bar{p} \to \gamma\gamma$, related by crossing to Compton scattering. Other examples are the inverse processes $\gamma\gamma \to p\bar{p}, \pi\pi$ and $\gamma^*\gamma \to p\bar{p}, \pi\pi$. In the latter case, we study both the case of large and small invariant masses of the $\gamma^*\gamma$ system. Our approach is based on the double distribution formalism, and one direction of study is its connection with an alternative approach based on two-meson and two-nucleon distribution amplitudes.

Hard Meson Electroproduction

The physics of generalized parton distributions can be also studied in the processes of the electro-production of vector and pseudo-scalar mesons. The ongoing research is based on the extension of existing perturbative QCD calculations of the relevant cross sections with the aim of studying the feasibility of extracting the generalized parton distributions from the hard meson electro-production experiments at Jefferson Lab energies.

David Richards

David Richards continued his study of the spectrum of baryon resonances within lattice QCD. An important accomplishment was the determination of the mass of the first radial excitation of the nucleon, the so-called Roper resonance, within full QCD. Earlier computations within the quenched approximation had revealed an ordering of the masses of the nucleon (N), its parity partner $N^{1/2-}$ and the Roper resonance N' in accord with quark-model expectations $m_N < m_{N_{1/2-}} < m_{N'}$, and in contradiction to the experimentally observed ordering $m_N < m_{N'} < m_{N^{1/2-}}$. The study revealed that the ordering observed in the quenched approximation persisted to full QCD, albeit for hadrons composed of quarks with masses around that of the strange quark.

An important development towards the end of the year was the inauguration of a 128-node Pentiun IV Xeon cluster, capable of sustaining of 100 Gflop/sec and representing a revolution in the computational resources available to the Lattice Hadron Physics Collaboration. Considerable effort was devoted to the development of the application software to enable lattice QCD codes to run efficiently on the cluster, using the QDP++ programming interface whose development is being driven by Robert Edwards. The first physics project is the computation of the form factor of the pion, particularly timely because of the upcoming Hall C experimental measurement. Future projects will address the excited baryon and nucleon spectrum, and the determination of the nucleon structure functions, form factors and GPD's. The considerable computational resources provided by this and future clusters are the essential elements in attaining the light quark masses that we know are crucial to faithfully describing QCD.

Winston Roberts

All of my research focuses on aspects of hadron spectroscopy using two somewhat different approaches. One of these is the effective Lagrangian approach, such as the heavy quark effective theory (HQET). The other is the use of specific constituent quark models, both relativistic and non-relativistic. Although such models are, for the most part, not rigorously derived from QCD, they are nevertheless very useful in helping us to understand and integrate a wide range of data in hadron phenomenology. As an example of the possible impact of such models, note that HQET grew out of work that had been done in non-relativistic quark models of this type.

Heavy Quark Effective Theory

Recently I have used the tensor formalism of HQET to examine the strong decays of heavy hadrons in a manner that allows treatment of decays involving light daughter hadrons other than pions. The formalism reproduces the results of the spin-counting arguments of the late Nathan Isgur and his collaborator Mark Wise, but this formulation, in principle, could allow study of the $1/m$ corrections to ratios of decay rates. As there are not much data on the strong decays of charm and beauty hadrons, I have, along with N. Trégourès, a graduate student (M. S. completed in the fall of 1998), applied this formalism to hadrons with strangeness to see if we can understand the global features of these decays within this framework. We have found that treating the strange quark as a heavy one leads to surprisingly good results in most cases. This formalism is now being applied to the decays of heavy baryons. However, since data in this sector are even scarcer than in the meson sector, the predictions of HQET will be compared with those of a quark model.

My most recent work in this area focused on the extraction of V_{ub} from the semi-leptonic decays of B mesons. Using HQET as it applies to the transitions between heavy mesons and light ones, a number of measurements were found that could be used to extract this important element of the CKM matrix; in particular, that the ratio of differences of differential helicity decay rates, measured in the semi-leptonic decays of B mesons to ρ mesons and D mesons to ρ mesons, denoted

$$\left(d\Gamma_{+}^{B} / dq^{2} - d\Gamma_{-}^{B} / dq^{2}\right) / \left(d\Gamma_{+}^{D} / dq^{2} - d\Gamma_{-}^{D} / dq^{2}\right),$$

was independent of any form factors, in leading order. This may turn out to play a significant role in the extraction of V_{ub}.

Relativistic Quark Model

We have applied a model of heavy mesons to strong decays of heavy mesons using a chiral quark model to describe the decays (with J. L. Goity). Our results show that relativistic effects are quite large, as some of the results obtained here are very different from those obtained using a non-relativistic model of the mesons, with the same chiral quark model for the decays.

We have also applied this relativistic model of the mesons to their electromagnetic decays. For mesons like the D^*, the electromagnetic decay width is comparable to the strong one, because of the very limited phase space for strong decays. In the case of some excited mesons like D_s^{**} and B_s^{**}, the electromagnetic decays are expected to be dominant, as the only kinematically-allowed strong decays are both OZI and isospin violating.

Hadron Spectroscopy

In addition to the projects described above, I am also working on quark models for the semi-leptonic decays of baryons (and mesons), as well as a description of meson photo-production and electro-production processes using a phenomenological Lagrangian approach.

Carlos Schat

The study of QCD in the limit of a large number of colors, N_c, has proved a powerful tool in understanding general aspects of the structure of mesons. In particular, it provides a rigorous explanation of the OZI rule suppressing the decay of initial-state quarks, and a justification of the applicability of the quenched approximation in lattice QCD. In general the expansion in 1/N seems to be well behaved in the meson sector. The extent to which it works in that case is an important question, though the quenched spectrum in lattice QCD is correct at around the 10% level.

The application of the 1/N expansion in the baryon sector is extremely interesting and has as in the meson sector good potential for explaining features observed in the spectrum and decay amplitudes of baryons. The expansion can provide insight into the importance of the various interactions between the constituent quarks as it has been realized in various works mentioned next. In collaboration with J. Goity and N. Scoccola, the masses of the 70-plet and 56-plet nucleon resonances were investigated. Fits to the experimentally observed resonance data revealed that the spin-orbit effects are small, while the breaking of spin-flavor symmetry is dominated by the hyperfine interactions. Furthermore, fits to the model are able to accommodate the Λ(1405) resonance interpreted as a three quark state rather than a baryon-meson resonance. Further work with D. Pirjol on the assignments of states in the different SU(3) multiplets of the

70-plet was pursued, clarifying the relevance of different effective interactions for the possible different assignments. These results further strengthen the observation that consistency with phenomenology demands a small spin-orbit interaction.

Rocco Schiavilla

In the last few years, a "Standard Nuclear Physics Model" (SNPM) has been emerging, in which nuclei are viewed as assemblies of individual nucleons interacting among themselves via two- and three-body potentials, and with external electro-weak probes via currents consisting of one- and many-body components [for a recent review of the SNPM, see Rev.Mod.Phys.**70**, 743 (1998)]. How these effective potentials and currents arise from the underlying quark and gluon degrees of freedoms, the ultimate building blocks of nuclear matter, is still an open question.

The deceptively simple picture put forward in the SNPM, however, has been shown to provide a quantitatively accurate description of nuclear structure and dynamics over a wide range of energy, from the few keV of astrophysical relevance to the MeV regime of nuclear spectra to the tens to hundreds of MeV measured in nuclear response experiments. In the nuclear astrophysics realm, the SNPM has led to accurate predictions for the cross sections of the $pp \rightarrow d\ e^+\nu_e$, $pd \rightarrow {}^3\mathrm{He}\gamma$ and $p\,{}^3\mathrm{He} \rightarrow {}^4\mathrm{He}e^+\nu_e$ processes occurring in the *pp* chain, whose network of reactions, converting hydrogen into helium, constitute the principal source of energy and neutrinos in the Sun.

In the few MeV energy region relevant for nuclear structure, the SNPM has successfully predicted the observed energy spectra of low-lying states of nuclei with mass numbers in the range A=2-10 [the Argonne-Los Alamos-Urbana group, Phys. Rev. C**62**, 014001 (2000)], the measured rates of radiative and weak transitions between some of these states, and lastly, the experimentally known elastic and inelastic electromagnetic form factors of nuclei with A=2-6 up to momentum transfers of $\simeq$ 1 GeV/c.

Finally, in the hundreds of MeV energy regime, the SNPM has produced a quantitative understanding of the electromagnetic response of light nuclei, in particular of the role played by correlations and many-body currents in the distribution of longitudinal and transverse strength in the quasi-elastic region and beyond.

My research interests deal, in general terms, with the development and application of the SNPM and of methods, in particular, quantum Monte Carlo techniques, for its practical implementation. Recently, I have been interested in:

- Parity-violating defects, due to hadronic weak interaction, on the properties of few-nucleon systems, such as the photon asymmetry in $n^\rightarrow p$ radiative capture at thermal energies and the longitudinal asymmetry in deuteron electro-disintegration at quasi-elastic kinematics [Phys. Rev. C**67**, 032501 (2003)].
- Weak transitions, in particular, β-decays and electron- and muon-captures in A=3-7 nuclei [Phys. Rev. C**65**, 054302 (2002)].
- Quasi-elastic (*e,e'*) response from light nuclei [Phys. Rev. C**65**, 024002 (2002) and Phys. Lett. B553, 191 (2003)].

Yuri Simonov

The main research activity is the development of the non-perturbative QCD based on the method of field correlators, which has a universal character.

The topics include:

- chiral symmetry breaking in the confining vacuum;
- structure of hadrons (mesons, baryons, hybrids, and glueballs);
- non-perturbative theory of scattering and structure functions;
- perturbation theory in the non-perturbative confining background.

Wally Van Orden

One of the more intriguing experimental results to come from Jefferson Lab has been the verification of Bloom-Gilman duality, in which the inclusive structure function at low W (where W is the mass of the hadronic final state) is found to follow a global scaling curve, which describes high W data, to which the resonance structure function averages. The equivalence of the averaged resonance and scaling structure functions was also found to hold for each resonance region, so that the resonance-scaling duality appears to exist locally as well as globally. To help understand the physics of duality, we have constructed a simple quantum-mechanical model, which qualitatively reproduces the features of Bloom-Gilman duality. The model consists of a light scalar quark bound to an infinitely heavy quark by a relativistic harmonic oscillator potential. The excitation spectrum of this system consists of an infinite number of infinitely narrow resonances. We find that this simple system reproduces the qualitative features of the Bloom-Gilman duality and illustrates the minimal physical conditions for this phenomenon to occur. An additional finding of this study is that the usual separation of deep inelastic scattering into a "resonance region" at low W and a "scaling region" at high W is totally spurious, and that resonances are an integral part of the scaling structure functions. This has important practical consequences for global analyses of parton distributions, and could open the way to an enormously rich program at Jefferson Lab extending structure functions into previously inaccessible regions of kinematics. The original model contained only scalar particles including a "scalar photon" probe. We have now extended the model [Phys. Rev. D65, 094038 (2002)] to include a vector photon and have shown that the model satisfies the appropriate sum rules and that the scaling and duality of the simpler model are retained. Work on an extension of this approach to a Dirac constituent quark in linear scalar potential with a color Coulomb interaction is nearing completion.

III. PUBLICATIONS AND TALKS

A. <u>Publications in Refereed Journals</u>

[1] **I. I. Balitsky** and A. V. Belitsky, *Nonlinear Evolution in High Density QCD*, Nucl. Phys. B629, 290-322 (2002)

[2] **D. Black**, T. Han, H.-J. He, M. Sher, *Tau-mu Flavor Violation as a Probe of the Scale of New Physics*, Phys. Rev. D66:053002 (2002).

[3] **D. Black**, M. Harada, J. Schechter, *Vector Meson Dominance Model for Radiative Decays Involving Light Scalar Mesons*, Phys. Rev. Lett. Server: Phys. Rev. Lett. 88, 181603 (2002), Print Issue of 6, May 2002.

[4] Abdel-Rehim, **D. Black**, A. H. Fariborz, J. Schechter, *Effects of Light Scalar Mesons in eta -> 3pi decay*, Phys. Rev. D67:054001 (2003).

[5] D. Dolgov, R. Brower, S. Capitani, P. Dreher, J.W. Negele, A. Pochinsky, D.B. Renner, N. Eicker, Th. Lippert, K. Schilling, **R. G. Edwards**, U.M. Heller, *Moments of Nucleon Light Cone Quark Distributions Calculated in Full Lattice QCD*, Phys. Rev. D66:034506 (2002).

[6] **J. L. Goity**, A. M. Bernstein, J. F. Donoghue, B. R. Holstein, *The Decay pi0 -> gamma gamma to Next to Leading Order in Chiral Perturbation Theory*, Phys. Rev. D66:076014 (2002).

[7] **J. L. Goity**, **C.L. Schat**, N.N. Scoccola, *Negative Parity 70-plet Baryon Masses in the 1/N(c) Expansion*, Phys. Rev. D66:114014 (2002).

[8] **J. L. Goity**, *The Decay PIO --> Gamma Gamma to Next to Leading Order in Chiral Perturbation Theory*, Phys. Rev. D66:076014 (2002).

[9] **C. L. Schat**, **J. L. Goity**, N. N. Scoccola, *Masses of the 70-Baryons in Large N(C) QCD*, Phys. Rev. Lett. 88:102002 (2002).

[10] R. Gilman and **F. Gross,** *Electromagnetic Structure of the Deuteron*, J. Phys. G: Nucl. Part. Phys. 28, R37-R116 (2002).

[11] J. Adam, Jr., **F. Gross**, S. Jeschonnek, P. Ulmer, **J. W. Van Orden**, *Covariant Description of Inelastic Electron-Deuteron Scattering: Predictions of the Relativistic Impulse Approximation*, Phys. Rev. C66:044003 (2002).

[12] C. Savkli, **F. Gross** and J. Tjon, *The Role of Interaction Vertices in Bound State Calculations*, Phys. Lett. B531:161-166 (2002).

[13] Horvath, S.J. Dong, T. Draper, **N. Isgur**, F.X. Lee, K.F. Liu, J. McCune, H.B. Thacker, J.B. Zhang, *Local Chirality of Low-Lying Dirac Eigenmodes and the Instanton Liquid Model*, Phys. Rev. D66:034501 (2002).

[14] **W. Melnitchouk**, K. Tsushima and A. W. Thomas, *Quark-Hadron Duality and the Nuclear EMC Effect*, Eur. Phys. J. A14 (2002) 105.

[15] W. Detmold, **W. Melnitchouk**, A.W. Thomas, *Moments of Isovector Quark Distributions From Lattice QCD*, Phys. Rev. D66:054501 (2002).

[16] J.M. Zanotti, S. Bilson-Thompson, F.D.R. Bonnet, P. Coddington, D.B. Leinweber, A.G. Williams, J. Zhang, **W. Melnitchouk**, F.X. Lee, *Hadron Masses From Novel Fat Link Fermion Actions*, Phys. Rev. D 65:074507 (2002).

[17] **A. Radyushkin**, *Generalized Parton Distributions*, Workshop on Electron-Nucleus Scattering VII, Elba International Physics Center, Italy, June 24-28, 2002, European Journal of Physics C (to appear).

[18] **A. Radyushkin**, *Hadron Structure: the Fundamental Physics to Access via GPDs*, European Workshop on the QCD Structure of the Nucleon QCD-N'02, April 3-6, 2002, Ferrara, Italy, Nucl. Phys A711, pp. 99c-108c (2002).

[19] C. Schulte, **A. Radyushkin**, et al., *High Energy Angular Distribution Measurements of the Exclusive Deuteron Photodisintegration*, Phys.Rev.C66:042201, 2002.

[20] M. Gockeler, R. Horsley, D. Pleiter, P.E.L. Rakow, G. Schierholz, C. M. Maynard, **D. G. Richards**, *Negative-Parity Baryon Masses Using an O(a)-Improved Fermion Action*, Phys. Lett. B532, 63 (2002).

[21] **W. Roberts**, *Rho Polarization and 'Model Independent' Extraction of |V((ub)|/|V(cd)| From D --> Rho L Nu and B --> Rho L Nu,* Phy. Rev. Letters, April 2002.

[22] **W. Roberts**, *On the Monopole Model of Form Factors for Heavy Meson Decays*, Phy. Rev. C., April 2002.

[23] J. Carlson, J. Jourdan, **R. Schiavilla** and I. Sick, *Longitudinal and Transverse Quasi-Elastic Response Functions of Light Nuclei,* Phys. Rev. C65:024002 (2002).

[24] J. Carlson, **R. Schiavilla**, V. R. Brown and B. F. Gibson, *Parity-Violating Interaction Effects: The Longitudinal Asymmetry in pp Elastic Scattering*, Phys. Rev. C65:035502 (2002).

[25] L.E. Marcucci, S. Rosati, **R. Schiavilla**, A. Kievsky and M. Viviani, *Theoretical Study of the* ^{3}He(μ^-,ν_μ)^{3}H *Capture*, Phys.Rev.C66:054003 (2002).

[26] **R. Schiavilla** and R.B. Wiringa, *Weak Transitions in A=6 and A= 7 Nuclei*, Phys. Rev. C65:054302 (2002).

[27] **R. Schiavilla** and V.R. Pandharipande, *Elastic e-d Scattering Data and the Deuteron Wave Function*, Phys. Rev. C65:064009 (2002).

[28] **Yu A. Simonov**, *Chiral Lagrangian with Confinement From the QCD Lagrangian*, Phys. Rev. D65:094018 (2002).

[29] **Yu A. Simonov**, *The Feynman-Schwinger (World Line) Representation in Perturbative QCD*, in the Michael Marinov Memorial Volume, "Multiple Facets of Quantization and Supersymmetry," M. Olshanetsky and A. Vainshtein, eds. (World Scientific), 369-388.

[30] **Yu A. Simonov**, *Spin-Dependent Forces of Quarks in Baryon*, Phys. Rev. D65:116004 (2002).

[31] **Yu. A. Simonov**, J. A. Tjon, *The Feynman-Schwinger Representation in QCD*, Annals of Physics, Vol. 300, 54-87 (2002).

[32] **Yu. A. Simonov**, J. A. Tjon, *Baryon Magnetic Moments in the Effective Quark Lagrangian Approach*, Phys. Rev. D65:094013 (2002).

[33] A.M. Badalian, B.L.G. Bakker, **Yu. A. Simonov**, *Light Meson Radial Regge Trajectories*, Phys. Rev. D66:034026 (2002).

[34] V. I. Shevchenko, **Yu. A. Simonov**, *Interaction of Wilson Loops in the Confining Vacuum*, Phys. Rev. D66:056012 (2002).

[35] S. Jeschonnek and **J. W. Van Orden**, *Quark Hadron Duality in a Relativistic Confining Model*, Phys. Rev. D65:094038 (2002).

B. Publications in Conference Proceedings

[36] I. Balitsky, *Renormalons as Dilatation Modes in the Functional Space*, in Minneapolis 2002, Continuous Advances in QCD, May 2002, 177-185.

[37] **D. Black**, *Radiative Decays Involving Light Scalar Mesons*, Proceedings of Quark Confinement and the Hadron Spectrum V, Gargnano, Italy, Sept. 2002, N. Brambilla (ed.), World Scientific.

[38] **D. Black**, *Vector-Meson-Dominance Model for Radiative Decays Involving Light Scalar Mesons*, Proceedings of QCD 2002, Montpellier, France Nucl. Phys. B (Proc. Suppl.) 121 (2003) 95-98.

[39] Dreher, P., et al. (SESAM and LHPC Collaborations), *Continuum Extrapolation of Moments of Nucleon Quark Distributions in Full QCD*, Proc. of Lattice 2002, MIT,

Cambridge, MA, June 24-29, 2002, Elsevier, R. Edwards, J. Negele and D. Richards (eds.), 392-394 (Nucl. Phys. B (Proc. Suppl.) 119 (2003), 392-394).

[40] **R. G. Edwards** and U. M. Heller, *Probing the QCD Vacuum with Overlap Fermions*, Workshop on Lattice Hadron Physics, Cairns, Australia, July 2001, Nucl. Phys. B (Proc. Suppl.) 109A (2002) 124-128.

[41] **R. G. Edwards**, *Baryon Spectroscopy on the Lattice*, Proc. of Baryons 2002, Newport News, VA, Mar. 2002 (World Scientific), 2003, 43-52.

[42] **R. G. Edwards,** U. Heller, **D. Richards,** *Spectroscopy Using the Anisotropic Clover Action*, in Baryons 2002, Proc. of Lattice 2002, MIT, Cambridge, MA, June 24-29, 2002, Elsevier, R. Edwards, J. Negele and D. Richards (eds.), 305-307 (Nucl. Phys. B (Proc. Suppl.) 119 (2003), 305-307).

[43] Pochinsky, W. Akers, R. Brower, J. Chen, P. Dreher**, R. Edwards**, S. Gottlieb, D. Holmgren, P. Mackenzie, J. Negele, **D. Richards**, J. Simone and W. Watson, *Large Scale Commodity Clusters for Lattice QCD*, Proc. of Lattice 2002, MIT, Cambridge, MA, June 2002, Nucl. Phys. Proc. Suppl. 119, 2003, 1044-1046.

[44] **G. Fleming**, D. R. Nelson and G. W. Kilcup, *Gasser-Leutwyler Coefficients: A Progress Report*, in Lattice 2002, Proc. of the XXth International Symposium on Lattice Field Theory, MIT, Cambridge, MA, June 2002, North Holland, 2002. Nuclear Physics B (Proc. Suppl.) 119 (2003), pp. 245-247.

[45] T. Bhattacharya, **G. T. Fleming,** G. W. Kilcup, R. Gupta, W. Lee and S. Sharpe, *Progress Report on the Staggered e'/e Project***,** Proc. of the XXth International Symposium on Lattice Field Theory, MIT, Cambridge, MA, June 2002, North Holland, 2002. Nuclear Physics B (Proc. Suppl.) 119 (2003), pp. 428-430.

[46] **G. Fleming**, G. W. Kilcup and D. R. Nelson, *Gasser-Leutwyler Coefficients From Partially Quenched Lattice QCD*, in PANIC 2002, Proc. of the 16th International Conference on Particles and Nuclei, Osaka, Japan, Sept. 30-Oct. 4, 2002, H. Toki, K. Imai and T. Kishimoto (eds.), Elsevier Science, 2003, 883c-886c.

[47] **J. L. Goity,** $\pi^0 \rightarrow \gamma\gamma$ *to NLO in ChPT*, Baryons 2002, Proc. Of the Ninth International Conference on the Structure of Baryons, Newport News, VA, Mar. 3-8, 2002, C. Carlson and B. A. Mecking (eds.), World Scientific, 2003, 611-614.

[48] **F. Gross**, *Electromagnetic Structure of the Deuteron: Review of Recent Theoretical and Experimental Results*, Proc. of the 7th Workshop on Electron Nucleus Scattering VII, Elba International Physics Center, Elba, Italy, June 2002.

[49] **F. Gross**, *Relativistic Theory of Few Body Systems*, in Proceedings of the Workshop on Nuclear Dynamics: From Quarks to Nuclei, held in honor of Peter Sauer, IST, Lisbon, Portugal, Oct. 31-Nov. 2, 2002. Few Body Systems Suppl.

[50] D. Leinweber, J. N. Hedditch, **W. Melnitchouk**, A.W. Thomas, A. G. Williams, R. D. Young, J. M. Zanotti, J.B. Zhang, *FLIC Fermions and Hadron Phenomenology*, International Conference on Quark Nuclear Physics (QNP '02), June 2002, Juelich, Germany, European Journal of Physics A, Nov. 2002.

[51] W. Detmold, **W. Melnitchouk**, A.W. Thomas, *Moments of Isovector Quark Distributions in Lattice QCD*, International Conference on Quark Nuclear Physics (QNP '02), June 2002, Juelich, Germany.

[52] W. Detmold, A. W. Thomas, **W. Melnitchouk**, *Chiral Behavior of Quark Distributions From Lattice QCD*, Ninth International Symposium on Meson-Nucleon Physics and the Structure of the Nucleon, PiN Newsletter 16, 2002, pp. 331-333.

[53] **W. Melnitchouk**, *Quark Hadron Duality: Resonance and the Onset of Scaling*, ICTP Third International Conference on Perspectives in Hadronic Physics, Trieste, Italy, May 2001, Nucl. Phys. A699 (2002) 278.
[54] **W. Melnitchouk**, A.W. Thomas, *Deep Inelastic Scattering From Light Nuclei*, Workshop on Testing QCD Through Spin Observables in Nuclear Targets, UVA, Charlottesville, VA, April 2002, World Scientific (2002).
[55] **W. Melnitchouk**, S. Bilson-Thompson, F.D.R. Bonnet, P.D. Coddington, D. B. Leinweber, A.G. Williams, J. M. Zanotti, J. B. Zhang, F. X. Lee, *Baryon Resonance From a Novel Fat Link Fermion Action*, Workshop on Lattice Hadron Physics, Cairns, Australia, July 2001, Nucl. Phys. B (Proc. Suppl.) 109A (2002) 96-100.
[56] **W. Melnitchouk**, J. N. Hedditch, D. B. Leinweber, A. G. Williams, J. Zanoti, J. B. Zhang, *Excited Baryons From the FLIC Fermion Action*, Lattice 2002, MIT, June 2002, 293-295 (Nucl. Phys. B (Proc. Suppl.) 119 (2003), 293-295).
[57] A.W. Thomas, W. Detmold, W. **Melnitchouk**, *Progress in the Calculation of Parton Distributions in QCD*, ICTP Third International Conference on Perspectives in Hadronic Physics, Trieste, Italy, May 2001, Nucl. Phys. A699 (2002) 26.
[58] A. W. Thomas, **W. Melnitchouk**, F. M. Steffens, *Flavor Asymmetry of the Nucleon Sea: Unambiguous Role of Goldstone Bosons*, Proc. 7th Conference on Intersections Between Particle and Nuclear Physics, Quebec City, Quebec, Canada, May 2000, AIP Conf. Proc. 549 (2002), pp. 463-466.
[59] J. M. Zanotti, S. Bilson-Thompson, F. D. R. Bonnet, P. D. Coddington, D.B. Leinweber, A.G. Williams, J. B. Zhang, **W. Melnitchouk**, F. X. Lee, *Novel Fat Link Fermion Actions, Workshop on Lattice Hadron Physics*, Cairns, Australia, July 2001, Nucl. Phys. B (Proc. Suppl.) 109A (2002) 101-105.
[60] A. Mukherjee, I.V. Musatov, H.C. Pauli, **A.V. Radyushin,** *Power-Law Wave Functions and Generalized Parton Distributions for Pion*, Proc. of the Workshop on Spontaneously Broken Chiral Symmetry and Hard QCD Phenomena, Physikzentrum Bad Honnef, Germany, July 2002.
[61] **A. Radyushkin**, *Generalized Parton Distribution*, International Workshop on Spontaneously Broken Chiral Symmetry and Hard QCD Phenomena, Bad Honnef, Germany, July 2002.
[62] **A. Radyushkin**, *Hadron Structure: The Fundamental Physics to Access via GPDs*, European Workshop on the QCD Structure of the Nucleon QCD-N'02, April 2002, Ferrara, Italy, Nucl. Phys A711, pp. 99c-108c (2002).
[63] **A. Radyushkin**, *Generalized Parton Distributions*, Workshop on Electron-Nucleus Scattering VII, Elba International Physics Center, Italy, June 2002, European Journal of Physics C (to appear).
[64] **D. G. Richards**, M. Gockeler, P. E. L. Rakow, D. Pleiter, G. Schierholz, R. Horsley, C. M. Maynard, *Lattice Calculation of Baryon Masses Using Clover Fermion Action*, Proc. of Baryons 2002, Newport News, VA, Mar. 2002, World Scientific, 627-630.
[65] **D.G. Richards**, *Excited N* Spectrum and Lattice QCD*, Meeting of the Division of Particles and Fields (DPF), Williamsburg, VA, May 2002.
[66] **D. G. Richards**, *Threshold Resonances – A Lattice Perspective*, Proc. NSTAR 2002, Pittsburgh, PA, Oct. 2002, World Scientific (to appear).
[67] M. Viviani, L. E. Marcucci, A. Kievsky, S. Rosati and **R. Schiavilla**, *Electromagnetic and Weak Transitions in Light Nuclei*, Proc. VII Conference on Electron-Nucleus

Scattering, O. Benhar, A. Fabrocini, S. Fantoni and R. Schiavilla (eds.), Eur. Phys. J. 2002 (in press).

[68] L. E. Marcucci, M. Viviani, A. Kievsky, S. Rosati and **R. Schiavilla**, *Three Nucleon Electroweak Capture Reactions*, in Proc. of the Workshop on Nuclear Dynamics: From Quarks to Nuclei, held in honor of Peter Sauer, IST, Lisbon, Portugal, Oct. Nov. 2002. Few Body Systems Suppl.

[69] **W. Van Orden**, S. Jeschonnek, *Energy-Weighted Sum Rules, y-Scaling and Duality*, invited talk, Conference on Electron-Nucleus Scattering VII, Elba International Physics Center, Elba, Italy, June 2002.

C. Unpublished Invited Talks Given at Conferences and Workshops

[70] **I. Balitsky**, *Small-x Evolution in the High Density QCD*, International Conference on Theoretical Physics, UNESCO, Paris, France, July 2002.

[71] **I. Balitsky**, *Small-x Evolution of Wilson Lines*, International Workshop on Low-x Physics, Antwerpen, Belgium, Sept. 2002.

[72] **I. Balitsky**, *Small-x Evolution in the High Density QCD*, International Workshop on Coherent Effects at RHIC and LHC: Initial Conditions and Hard Probes, Trento, Italy, Oct. 2002.

[73] **D. Black**, *Vector-Meson-Dominance Model for Radiative Decays Involving Light Scalar Mesons*, APS Meeting of Division of Particles and Fields, Williamsburg, VA, June 2002.

[74] **R. G. Edwards**, *The Lattice Initiative at Jefferson Lab*, Jefferson Lab Users Group Meeting, June 2002.

[75] **R. G. Edwards**, *Calculation of Nucleon Electromagnetic Form-Factors, Parton-Distribution Moments, and Leading Light-Cone Wavefunctions*, LHPC Workshop, Sept. 2002.

[76] **R. G. Edwards**, *The QIO Interface*, SciDAC Software Subcommittee Workshop, Fermilab, Feb. 2002.

[77] **R. G. Edwards**, *SciDAC Software*, SciDAC Lattice Hall-Hands Meeting, Fermilab, Feb. 2002.

[78] **R. G. Edwards**, *Tutorial on the QDP++ Data Parallel Programming Interface*, SciDAC Software Workshop, Fermilab, Feb. 2002.

[79] **G. Fleming**, *Gasser-Leutwyler Coefficients From Partially Quenched QCD*, PANIC 02 Conference, Osaka, Japan, Sept.-Oct. 2002.

[80] **W. Melnitchouk**, *Semi-Inclusive Reactions*, Jefferson Lab Annual Users Group Meeting, Jefferson Lab, June 2002.

[81] **W. Melnitchouk**, *Spin and Flavor Structure of the Nucleon: A Theoretical Review*, Gordon Conference on Photonuclear Reactions, Tilton, NH, Aug. 2002.

[82] **W. Melnitchouk**, *Quark Hadron Duality in Structure Functions – The Resonance-Scaling Transition*, Workshop on the Structure of the Nucleon, ECT, Trento, Italy, Sept. 2002.

[83] **W. Melnitchouk**, *Nucleon Structure Functions: The Resonance-Scaling Transition*, Fall Meeting of the APS Division of Nuclear Physics, Michigan State University, East Lansing, Oct. 2002.

[84] A. Freund, **A. Radyushkin**, A. Schafer, C. Weiss, *Exclusive Annihilation pp{bar}-Gamma Gamma in a Generalized Parton Picture*, Workshop on Testing QCD Through Spin Observables in Nuclear Targets, University of Virginia, Charlottesville, April 2002.

[85] **A.V. Radyushkin**, *Proton-Antiproton Annihilation Into Two Photons in QCD*, International Workshop on Physics with Antiprotons at GSI, Darmstadt, Germany, June 2002.

[86] **D. G. Richards**, *Excited Spectroscopy From Lattice QCD*, Workshop on the Structure of the Nucleon, ECT, Trento, Italy, Sept. 2002.

[87] **C. L. Schat**, *Orbitally Excited Baryon Spectroscopy in the 1/Nc Expansion,* INT Workshop on the Phenomenology of Large N(C) QCD, Arizona State University, Tempe, Jan. 2002.

[88] **R. Schiavilla**, *Weak Interaction Effects in Light Nuclei*, Workshop on Modern Nuclear and Sub-nuclear Physics and JLab Experiments, Univ. of Georgia, Athens, Sept. 2002.

[89] **R. Schiavilla**, *Weak Interaction Effects in Few-Nucleon Systems*, Workshop on Future Few-Nucleon Low Energy Experimental Physics, Trento, Italy, Dec. 2002.

[90] **Y. Simonov**, *Nonperturbative QCD*, INT Workshop on the Phenomenology of Large N(C) QCD, Arizona State University, Tempe, Jan. 2002.

[91] S. Jeschonnek and **W. Van Orden**, *Quark-Hadron Duality*, in "Baryons 2002," Proceedings of the Ninth International Conference on the Structure of Baryons, Jefferson Lab, Newport News, VA, Mar. 3-8, 2002, C. Carlson and B. A. Mecking (eds.), World Scientific, 2003, 222-233.

D. Seminars and Colloquia

[92] **I. Balitsky**, *Small-x Evolution in the High Density QCD*, CERN, Geneva, Switzerland, June 2002.

[93] **I. Balitsky**, *Nonlinear Evolution in High Density QCD*, Saclay Physics Institute, Paris, France, July 2002.

[94] **I. Balitsky,** *Small-x Evolution in the High Density QCD*, International Conference on Theoretical Physics, Paris, France, July 2002.

[95] **I. Balitsky**, *Small-x Evolution of Wilson Lines*, International Workshop on Low-x Physics, Antwerpen, Belgium, Sept. 2002.

[96] **D. Black**, *Chiral Lagrangian Treatments of the Light Scalar Mesons*, Trinity College, Dublin, Ireland, Dec. 2002.

[97] **D. Black**, *A Nonet of Light Scalar Mesons: Implications for Radiative Decays*: a) GSI, Darmstadt; b) University of Tubingen; c) Technical University of Munich; and d) Julich Research Center, Germany, Dec. 2002.

[98] **D. Black**, *Introduction to Chiral Symmetry and Effective Lagrangians for QCD*, Hampton University Graduate Studies Program, Jefferson Lab., Hampton, VA, June 2003.

[99] **R. G. Edwards**, Lattice Hadron Physics Collaboration Software Meeting, MIT, Cambridge, MA, Mar. 2002.

[100] **J. Goity**, Caltech, Pasadena, CA, May 2002.

[101] **F. Gross**, *Calculations of Bound States and Self-Energies From Field Theory*, George Washington University, Washington, D.C., April 2002.

[102] **F. Gross**, *Calculations of Bound States and Self-Energies From Field Theory*, Center for Nuclear Physics, University of Lisbon, Portugal, June 2002.

[103] **W. Melnitchouk**, *Quark-Hadron Duality in Electron-Hadron Scattering*, University of Adelaide, Australia, Dec. 2002.

[104] **A. Radyushkin**, *Generalized Parton Distribution*, Duke University, Durham, NC, Oct. 2002.

[105] **D. G. Richards**, *Lattice QCD and eScience*, University of Edinburgh, England, Sept. 2002.

[106] **D. G. Richards**, *Baryon Spectroscopy and Lattice QCD*, Ohio State University, Athens, Feb. 2002.

[107] **D. G. Richards**, *Excited N* Spectrum and Lattice QCD*, Meeting of the Division of Particles and Fields (DPF), Williamsburg, VA, May 2002.

[108] **W. Roberts**, *Phenomenological Lagrangian Description of Two-Pion Photo-production: A Work- in-Progress*, GLC Group Meeting, Jefferson Lab, Dec. 2002.

[109] **R. Schiavilla**, *Weak Interaction Effects in Few-Body Systems*, CalTech, Pasadena, CA, Jan. 2002.

[110] **R. Schiavilla**, *Low-Energy Capture Reactions*, University of Pittsburgh, Feb. 2002.

[111] **R. Schiavilla**, *Low-Energy Capture Reactions*, University of Kentucky, Lexington, Mar. 2002.

[112] **R. Schiavilla**, Ohio University, Athens, May 2002.

[113] **R. Schiavilla**, *Hadronic Weak Interaction Effects in Few Nucleon Systems*, University of Lecce, Italy, Dec. 2002.

[114] **R. Schiavilla**, *Parity-Violating Effects in Few-Nucleon Systems*, Old Dominion University, Nov. 2002.

E. <u>Reviews, Editorships and Major Proposals (2002)</u>

[115] **R. G. Edwards**, DOE-NP Outstanding Junior Investigator Award Review Panel, Germantown, MD, Mar. 2002.

[116] **R. G. Edwards**, JLab Institutional Plan Review, Aug. 2002.

[117] **F. Gross**, SURA Board of Trustees Meeting, Nashville, TN, April 2002.

[118] **F. Gross**, Member of Panel, Review of Bonn Physics Group (review grant applications to the DFG), Bonn, Germany, Sept. 2002.

[119] A. C. Kalloniatis, D. B. Leinweber, **W. Melnitchouk** and A. G. Williams (eds.), Lattice Hadron Physics, Proc. of Workshop held in Cairns, Australia, July 2001, published in Nucl. Phys. Proc. Suppl. 109A (2002) 1-230, Elsevier Science B.V., Amsterdam, 2002.

[120] **A. Radyushkin** (co-editor), Exclusive Processes at High Momentum Transfer, Proc. of the workshop held at Jefferson Laboratory, Newport News, VA, May 2002, World Scientific Publishing, Dec. 2002.

[121] **D. G. Richards, R. G. Edwards** and J. Negele (eds.), Proc. of 20th International Symposium on Lattice Field Theory, Cambridge, MA, June 2002, Nucl. Phys. B (Proc. Suppl) 119 (2003).

[122] O. Benhar, A. Fabrocini and **R. Schiavilla** (eds.), Electron-Nucleus Scattering, Eur. Phys. J. 2002 (in press).

F. Workshops and Conference Organization

[123] **R. Edwards**, Member of Local Organizing Committee, The XX International Symposium on Lattice Field Theory (LATTICE 2002), MIT, Cambridge, MA, June 2002.

[124] **J. Goity**, Member of the Organizing Committee, INT Workshop on the Phenomenology of Large N(c) QCD, Arizona State University, Tempe, Jan. 2002.

[125] **W. Melnitchouk**, Session Organizer, Testing QCD Through Spin Observables in Nuclear Targets, University of Virginia, Charlottesville, April 2002.

[126] **A. Radyushkin**, Organizer, Workshop on Exclusive Processes at High Momentum Transfer, Jefferson Laboratory, May 2002.

[127] **D. G. Richards**, Organizer and Member of the Local Organizing Committee, BARYONS 2002, Mar. 2002, Jefferson Lab., Newport News, VA.

[128] **D. G. Richards**, Member of the Local Organizing Committee, The XX International Symposium on Lattice Field Theory (LATTICE 2002), MIT, Cambridge, MA, June 2002.

[129] **D. G. Richards**, Member of the International Advisory Committee, N*2000 Conference, Pittsburgh, PA, Oct. 7-12, 2002.

[130] **W. Roberts**, Co-organizer, Workshop on Modern Nuclear and Sub-nuclear Physics and JLab Experiments, Univ. of Georgia, Athens, Sept. 2002.

[131] **R. Schiavilla**, Co-organizer, Electron-Nucleus Scattering VII, Elba International Physics Center, Elba, Italy, June 2002

APPENDIX

A. Workshops Funded Jointly with INT

INT Workshop on the Phenomenology of Large N(c) QCD, Arizona State University, Tempe, AZ, Jan. 2002.

B. Long Term Visitors in 2002

Christian Weiss	University of Regensburg	11/16/01-2/4/02
Renato Higa	University of Sao Paulo, Brazil	2/2-7/26/02
Inna Aznauryan	Yerevan Physics Institute	4/15-8/10/02
Pervez Hoodbhoy	Quaid-e-Azam Univ., Pakistan	6/23-8/12/02

C. Short Term Visitors in 2002

Jiri Adam	Inst. Nuclear Physics, Czech Republic	1/4-1/25/02
George Strobel	Univ. of Georgia	1/14/02
John Tjon	Utrecht	1/20-2/9/02
Ben Baker	Vrije University	1/26-2/1/02
Boris Gelman	Univ. of Maryland	1/29-1/30/02
Valeria Gadiyak	Univ. of Maryland	2/1-2/4/02

Jiri Adam	Inst. Nucl. Physics, Czech Republic	2/3-2/26/02
Bogdan Mihaila	Argonne National Laboratory	2/5-2/6/02
Igor Shovkovy	Univ. of Minnesota	2/10-2/12/02
Shi-Lin Zhu	California Institute of Technology	2/12-2/14/02
Tony Thomas	Adelaide	2/23-2/27/02
Hank Thacker	Univ. of Virginia	2/25/02
Jean-Marc Laget	SACLAY	2/26-3/2/02
Omar Benhar	INFN, Italy	3/4-3/23/02
Hans Pirner	Univ. of Heidelberg	3/25-3/31/02
Norbert Ligterink	Univ. of Heidelberg	3/30-4/2/02
Herbert Weigel	MIT	4/13-4/16/02
John Tjon	Utrecht	4/14-4/18/02
Misak M. Sargsian	Florida International University	4/28-5/3/02
Thomas Steele	Univ. of Saskatchewan	5/4-5/8/02
Avraham Rinat	Weizmann Institute	5/7-5/10/02
Jean-Marc Laget	SACLAY	5/12-5/18/02
Dae Sung Hwang	Stanford University	5/13/02
Peter Kroll	University of Wuppertal	5/18-5/23/02
Daniel Pirjol	Univ. of California at San Diego	5/18-5/23/02
Tetsuro Mizutani	VPI&SU	5/20-5/24/02
Jean-Marc Laget	Saclay	5/29-6/14/02
Martin Mojzis	Comenius Univ., Slovakia	6/2-6/8/02
Gregg Franklin	Carnegie Mellon University	6/3-6/6/02
Andrei Belitsky	University of Maryland	6/3-6/7/02
Antonio Pineda	University of Barcelona	6/4-6/9/02
Eulogio Oset	Univ. of Valencia, Spain	6/5-6/8/02
Steve Mintz	Florida International University	6/5-6/12/02
Sabine Jeschonnek	Ohio State	6/9-6/29/02
Waseem Kamleh	Adelaide	6/15-6/20/02
Patricia Rankin	Univ. of Colorado	6/16-6/19/02
James Zanotti	Adelaide	6/29-7/2/02
Stewart V. Wright	Univ. of Liverpool	6/30-7/5/02
Manoel R. Robilotta	Univ. of Sao Paulo, Brazil	7/13-7/20/02
Tony Williams	Adelaide	7/24-7/28/02
Alfons Buchmann	Tuebingen	8/25-29/02
Omar Benhar	INFN, Italy	9/17-9/24/02
Nikolay Ya. Ivanov	Yerevan Physics Institute	9/18-10/5/02
Bogdan Mihaila	Argonne National Laboratory	9/23-9/27/02
Johannes Weda	Utrecht	9/28-10/4/02
Jean-Marc Laget	SACLAY	10/6-10/19/02
Bin Liu	University of Tennessee	10/12-10/15/02
Vladimir Pascalutsa	Ohio University	10/16-10/17/02
Sabine Jeschonnek	Ohio State	10/26-11/5/02
Gautam Rupak	Lawrence-Berkeley Laboratory	10/27-10/29/02
Norberto N. Scoccola	Comm. Nacional de Energia Atomica	11/4/11/10/02
Robert B. Wiringa	Argonne National Laboratory	11/10-11/17/02

Christian Weiss	Regensburg University	11/16-11/24/02
Larry McLerran	Brookhaven National Laboratory	11/30-12/3/02

D. Theory Seminars in 2002

G. Strobel, University of Georgia, 1/14/02
Baryon Magnetic Moments and Spin Dependent Quark Forces

B. A. Gelman, University of Maryland, 1/30/02
What Can We Learn About the Nucleon-Nucleon Interaction From Large N_c *QCD?*

V. Gadiyak, University of Maryland, 2/4/02
A Lattice Study of the Magnetic Moment and the Spin Structure of the Nucleon

B. Mihaila, Argonne National Laboratory, 2/6/02
Coupled-Cluster Calculations for p-Shell Nuclei

I. Shovkovy, University of Minnesota, 2/11/02
Cold Dense Quark Matter

S.-L. Zhu, California Institute of Technology, 2/13/02
Parity Violation as a Probe of Hadron Dynamics

H. B. Thacker, University of Virginia, Charlottesville, 2/25/02
Using the Dirac Operator as a Probe of Topological Charge in QCD

H. Asatrian, Yerevan Physics Institute, 3/18/02
Two-Loop Corrections to $B \rightarrow X_s \ell^+ \ell^-$ *in the Standard Model*

H. J. Pirner, University of Heidelberg, 3/27/02
Critical Correlations of Wilson Lines in SU(3) and the High Energy $\gamma^* p$ *Cross Section*

N. Ligterink, University of Heidelberg, 4/1/02
Modern Resonance Theory: The rho Meson and the Pionic Continuum

H. Weigel, University of Tuebingen, 4/15/02
Chiral Quark Models and Nucleon Structure Functions

T. Barnes, ORNL and University of Tennessee, 4/22/02
Desperately Seeking Strangeness: Strange Mesons at JLab

M. M. Sargsian, Florida International University, 4/29/02
Generalized Eikonal Approximation in High Energy Electro-disintegration Reactions on Nuclei

T. Steele, University of Saskatchewan, 5/6/02

Scalar Gluonium: A Gaussian Sum-Rules Analysis

D. S. Hwang, SLAC, Stanford, CA/Sejong University, 5/13/02
Studies of Polarization Transfer, Generalized Parton Distributions, and Single-Spin Asymmetries in Light-Cone Field Theory

P. Kroll, University of Wuppertal, 5/20/02
Wide-Angle Compton Scattering

M. Mojzis, University of Bratislava, 6/3/02
How Strange is the Nucleon?

A. Pineda, University of Barcelona, 6/5/02
Effective Field Theories for Heavy Quarkonium

S. L. Mintz, Florida International University, 6/7/02
Weak Lambda Production Near Threshold in Electron-Proton Scattering

W. Kamleh, University of Adelaide, 6/19/02
Accelerated Overlap Fermions

J. Zanotti, University of Adelaide, 7/1/02
Baryon Resonance Spectroscopy From A Novel Improved Fermion Action

A. G. Williams, Adelaide University, 7/25/02
Understanding QCD: Lattice QCD, Gauge-Fixing and the Transition to the Perturbative QCD Regime

A. Buchmann, University of Tuebingen, 8/26/02
Quadrupole Moments of Baryons

N. Y. Ivanov,Yerevan Physics Institute, 9/23/02
Single Spin Asymmetry in Heavy Quark Photo-production (and Decay) as a Test of pQCD

B. Liu,University of Tennessee, 10/14/02
Two-Body Dirac Equations for Nucleon-Nucleon Scattering

V. Pascalutsa, Ohio University, 10/17/02
EFT of Higher Spin N Resonances and Nucleon Compton Scattering*

G. Rupak, Lawrence-Berkeley Laboratory, 10/28/02
ChPT for the Discrete Lattice

S. L. Yakovlev, Saint Petersburg State University, 10/30/02
Coulomb Fourier Transformation of the Three-Body Hamiltonian with a Repulsive Coulomb Interaction in One Particle Pair

F. Bonnet, University of Regina, 11/4/02
The Quark Propagator in Landau Gauge

R. B. Wiringa, Argonne National Laboratory, 11/11/02
Nuclear Forces and the Destiny of the Universe

C. Weiss, Regensburg University, 11/18/02
Compton Scattering in the Crossed Channel: Exclusive Annihilation $p\bar{p} \rightarrow \gamma\gamma$

L. McLerran, Brookhaven National Laboratory, 12/2/02
The Color Glass Condensate

E. Theory Mini-Lecture Series in 2002

J.-M. Laget, Commissariat A L'Energie Atomique, Oct. 22, 24, 29, 2002
Meson Photo-production: A Window on the Quark-Gluon Structure of the Hadronic Matte

J. Tjon, University of Utrech, Nov. 11, 13, 15, 2002
Relativistic Hadron Dynamics