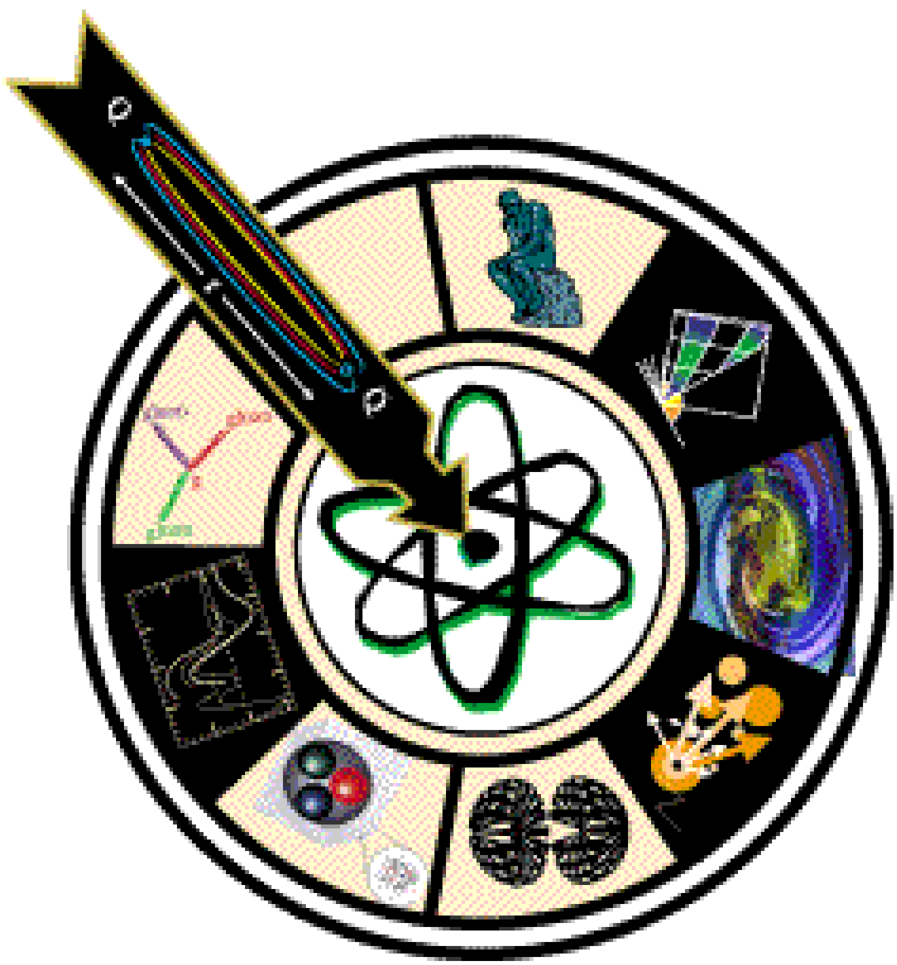
Jefferson Laboratory
Theory Group

Annual Report
April 2001



I. OVERVIEW

A. ORGANIZATION OF THIS REPORT

This report summarizes the work done the Jefferson Laboratory (JLab) Theory Group from January 1, 1999 to December 31, 2000. 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 presents a more complete summary of the research work. Publications and major talks are listed in Section III, and an Appendix lists visitors and seminars for the period covered by the report.

The JLab Theory Group interacts with many faculty, post-doctoral associates, and students, and the work done by these associates and visitors could very well be included in this report. Reluctantly, we include in this report (our first) only work by the 10 Senior Staff and the 2 Post-doctoral associates with the group in the spring of 2001, when it was prepared.

B. MEMBERS OF THE THEORY GROUP

The Jefferson Laboratory (JLab) Theory Group currently consists of 10 Senior Staff, 2 post doctoral associates, and 3 active Associate Senior Staff. The Senior Staff are listed in Table I, post doctoral associates in Table II, and the active Associate Senior Staff (i.e. those who spend several days per month with the Theory Group) in Table III.

Table I

JLab Senior Staff	
Name	half-time affiliation (if any)
Ian Balitsky	Old Dominon University
Robert Edwards	
Jose Goity	Hampton University
Franz Gross	College of William and Mary
Nathan Isgur	
Anatoly Radyushkin	Old Dominon University
David Richards	Old Dominon University
Winston Roberts	Old Dominon University
Rocco Schiavilla	Old Dominon University
J.W. (Wally) Van Orden	Old Dominon University

The JLab Theory environment is also enhanced by several post-docs and students supported by neighboring institutions. In 1999-2000, these included post-docs Gary Prezeau (Hampton), Cetin Savkli (W&M), Dirk Lehmann (Germany and Hampton), and Carlos Schat (Argentina and JLab).

Table II

JLab Post-docs	
Name	period of employment
Jun Forrest	1999-March 2000
Richard Lebed	1999-August 2000
Sabine Jeschonnek	1999-present
Wally Melnitchouk	1999-present (University relations)

Table III

JLab Associate Senior Staff (active)	
Name	home institution
Carl Carlson	College of William and Mary
Chris Caronne	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 *hadrons* refers to neutrons and protons (referred to collectively as nucleons), their excited states, and the mesons that interact with them and bind them together into nuclei. These are the nuclear bulding 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 must begin with the study of the structure of hadrons, the simplist pieces of nuclear matter we can observe in the laboratory.

At JLab these theoretical studies are carried out using a variety of tools. The simplest quark model, first developed about 30 years ago, assumed that the sea of gluons and quark-antiquark pairs could be treated as part of a static force, and proceeded to calculate the hadronic states by solving the Schrodinger equation for a static confining interaction. Current research is focused on understanding the dynamics of this confining force, and in clarifying precisely how the force arrises from Quantum Chromodynamics (QCD), the underlying theory of nuclear physics (Isgur). Models that treat the quarks relativistically are being developed (Gross and Savkli). In systems where one of the quarks is very heavy, so that is moves very slowy, an approximate theory known as Heavy Quark Effective Theory (HQEF) has been developed that works very well (Isgur, 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 led to the development of Chiral Perturbation Theory, also being studied at JLab (Goity and Roberts). At high energy the charge structure of hadrons can be calculated using QCD sum rules (Radyushkin), and the structure of the quark-antiquark sea inferred from arguments based on Chiral symmetry (Melnitchouk). Finally, in a few cases exact results for the masses of hadrons can be obtained by solving QCD on the lattice (Richards).

2. FEW NUCLEON SYSTEMS AND THE NN FORCE

The simplest nuclei consisting of a "few" nucleons (in practice 2 to 4, but sometimes as many as 7 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, and sometimes more nucleon systems can be calculated. Comparison of these results with experiment confirms the correctness of the NN force, and tells us whether of not three nucleon (NNN) or many nucleon forces are important. The goal of this work is to fully determine the nuclear forces, explain the structure and interactions of few nucleon systems, and then to explain these forces in terms of the underlying quark structure of matter and QCD.

In one of the most significant advances in recent times, the Los Alamos-Illinois-Argonne group has calculated the binding energies of the $A \leq 10$ nuclei directly from two and three nucleon forces, and JLab has played a role in this work (Schiavilla). Using wave functions and current operators consistent with these larger A studies, some electroweak interactions of few body systems of great importance for astrophysical applications have been calculated (Schiavilla). Some of these reactions cannot be measured in the laboratory, so that our only knowledge of them comes from such calculations. Relativistic and nonrelativistic models based on the exchange of mesons between nucleons have been successful in explaining deuteron form factors (Schiavilla, Gross and Van Orden) and in describing electrodisintegration of few body nuclei (Schiavilla, Gross, Jeschonneck, and Van Orden). Effective field theories (EFT) provide a systematic expansion of the interaction valid at low energies (Goity, Roberts) and work is underway to develop a relativistic EFT for the NN interaction (Goity, Prezeau, and Lehmann).

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” form 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 existance of quarks, and this method continues to be a major source of information about quark structure.

A new theoretical tool, the so-called generalized parton distributions (GPDs), has been recently developed at JLab (Radyushkin) and elsewhere. The GPDs will 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 phenomena is known as “duality”. New work at JLab is providing a better understanding of how this comes about (Isgur, Jeschonnek, Melnitchouk, and Van Orden, and Batiz and Gross).

4. EXACT SOLUTIONS OF QCD

QCD can be solved to high presicion 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 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”. Since QCD is believed to be the theoretical foundation of of nuclear physics, using lattice gauge theory to obtain exact numerical solutions remains one of the highest priorities of the Theory Group. Only a few results can be obtained on the lattice (masses of low lying states, couplings and decay amplitudes, and some moments of the DIS structure functions), but these provide guidance for the construction of the accurate models and effective theories that will provide a broader understanding.

A successful lattice gauge program requires state-of-the-art computers and sophisticated algorithms. JLab theorists are leading an effort to assemble the hardware and manpower necessary for such an effort (Richards, Edwards). A proposal to fund the Lattice Hadron Physics Collaboration has been written together with physicists at other institutions (Richards, Edwards). JLab physicists have made progress on the difficult problem of the treatment of fermions on the lattice (Edwards), and on the calculation of hadronic masses and matrix elements (Edwards, Melnitchouk, Richards).

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

II. DESCRIPTION OF CURRENT RESEARCH

IAN BALITSKY

1. DVCS at small x

Deeply virtual Compton scattering (DVCS) in the small-x region is a special case of semihard processes which can be described by the hard or BFKL pomeron. It turns out that at large momentum transfer the coupling of the BFKL pomeron to the nucleon is determined by the electric form factor of the nucleon so the DVCS amplitude in this region can be calculated without any model assumptions [1]. These results can be used for the estimates of the amplitude at experimentally accessible energies - in DESY on HERMES or at a future 20 GeV CEBAF.

2. Non-perturbative approach to renormalons in QCD

It is well known that the are two sources of the divergence of perturbative series in QCD: instantons and renormalons. For the instanton-type divergence, we have the dual interpretation: in terms of Feynman diagrams and in terms of saddle points in functional integrals. For the renormalons, only the Feynman-diagram description was known. We have found the functional-integral interpretation of renormalons and demonstrated that, unlike the instanton-type singularities, the renormalons do not correspond to a particular configuration but manifest themselves as dilatation modes in the functional space [2].

3. Small-x physics beyond the BFKL Pomeron

In the leading logarithmic approximation (LLA), the high-energy scattering in perturbative QCD is determined by the BFKL pomeron. One of the most popular ideas how to go beyond the LLA is to reduce QCD at high energies to some sort of two-dimensional effective theory. A very promising approach is to describe the high-energy scattering in terms of the effective Wilson-line degrees of freedom [3] [56]. In this language, the effective action is determined by the amplitude of the scattering of two shock waves in QCD which is widely discussed in the literature in connection with heavy-ion collisoions.

ROBERT EDWARDS

Since the beginning of lattice gauge theory, the regularization of chiral fermions has been a severe problem. When regulating fermions on a lattice, typically, unwanted doublers with opposite chirality appear. These doublers can be lifted (given mass of the order of the cut-off) at the cost of explicitly breaking chiral symmetry. An exciting advance in QCD has been the development of a tractable method for simulations with the Overlap-Dirac operator [4]. This Dirac operator 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.

This new theoretical development has been a major focus of my research in the last few years. In starting work with these new methods Heller, Narayanan and I have used the overlap method to study for the first time in a clean method, free of systematic errors endemic to other methods, topology on gauge backgrounds [5,137,10]. The ideas of t'Hooft are well described by our results. Zero modes (would-be instantons) are well described by a power law and not exponentially distributed. The topological susceptibility scales nicely in the lattice spacing. The phenomenological prediction in the Instanton-Liquid model of the scaling of the zero-mode size distribution is not consistent with our results [5].

A surprising result found is that small fluctuations in the gauge fields can have a dramatic effect on massless fermions – possibly spoiling the usage of the Domain Wall fermion approach which must introduce a (finite) fifth dimension to realize a four dimensional chiral fermion. In a determination of the (exponential) rate in which a massless mode sets in as the fifth dimensional extent increases, I found [11] and explained in a simple model how the slow rate is related to the density of the small fluctuations in the gauge field.

An exciting application is to determine the pattern of chiral symmetry breaking in QCD. A first investigation [4,9] in quenched $SU(3)$ shows there is a finite-volume scaling region in the quark mass where chiral symmetry breaking is developing via Goldstone bosons. With the Overlap-Dirac operator, I have shown [6] for the first time, that the predictions of random matrix theory hold in various topological sectors and representations of fermions. This result ties together chiral symmetry (via chiral Lagrangians), eigenvalue spectra and topology. Chiral random matrix theory is then an *exact* finite-volume scaling prediction of QCD.

Edwards, Heller, Kiskis and Narayanan extended the study of small eigenvalues of the overlap Dirac operator to quenched gauge theories in the high-temperature, deconfined phase. They found exact zero modes indicating that gauge field configurations with non-trivial topology persist in the high temperature phase. They also found that the spectrum of the non-zero eigenvalues has two parts separated by a region in eigenvalue where the density is essentially zero. The distribution of very small non-zero eigenvalues of the overlap Dirac operator is well-described by a dilute gas of non-interacting instantons and anti-instantons and suggests the existence of a chiral condensate which was confirmed with a direct stochastic estimate [10].

During my time at Jefferson Lab, I have helped found the Lattice Hadron Physics Collaboration (LHPC) - a collaboration principally between JLab and MIT. We are proposing an ambitious program investigating hadron structure. A proposal [140] was submitted to the DOE SciDAC program (Scientific Discovery through Advanced Computing) in March of 2000 to acquire large scale computing requirements. I have been working extensively on developing the software infrastructure on the prototype system currently available.

1. Effective field theory (EFT)

One of the important open problems is the construction of an EFT for the NN system. The main difficulty encountered is due to the existence of large scattering lengths that require a formulation in which the one-pion exchange (OPE) contributions are added non-perturbatively. This posses a challenge to the standard formulation of EFT that in its standard form implements the OPE perturbatively. Some progress has been achieved towards meeting this challenge, by devising a regularization that seems to adapt well to the procedure of separating leading infrared contributions in Feynman diagrams and possibly to the procedure of resuming them. Another aim in this project is to implement Chiral Symmetry in a rigorous way. One of the important questions here is whether the EFT can be so formulated that the theoretical procedure of taking the chiral limit can be implemented.

2. Chiral perturbation theory

Chiral Perturbation Theory (ChPT) in the Baryon sector has in recent times brought deep new insights on a variety of problems. One example is the question of the deviation of the Goldberger-Treiman relation (GTR) due to the quark masses, and the problem of quantifying that deviation. In Ref. [13] we proved that the corrections to that deviation, called the discrepancy, are of next-to-next-to-leading order (NNLO). This theorem allows to predict, via the extension of the GTR to SU(3), that only the pion-nucleon couplings in the lower range of the values obtained by different analyses can be compatible with a chiral expansion.

Another interesting problem in Chiral Dynamics is the corrections introduced by the quark masses to the amplitudes of the radiative decays of the neutral pseudoscalar mesons. These decays chiefly proceed via chiral anomalies, but corrections due to chiral symmetry breaking do have important effects. In particular, and due to the possibility of measuring the π^0 lifetime to about 1.5% precision at JLab (PRIMEX collaboration), this decay is being analyzed in ChPT to NLO in full.

3. Large N QCD in baryons

QCD has only a few small expansion parameters, namely the light quark masses (leading to the possibility of formulating ChPT), and the inverse of the number of colors, leading to the 1/N expansion. The 1/N expansion has been very useful for elucidating some important qualitative features such as the OZI rule, and the valence quark structure of hadrons. The applications to the Baryon sector have been quite revealing, both in the sector of ground state Baryons as well as in the negative parity sector of excited Baryons. An analysis based on the 1/N expansion permits to perform an unbiased analysis (provided the 1/N expansion still holds for N=3!) of different aspects, such as masses and decays. The analysis carried out on the masses of the non-strange sector of the negative parity 70-plet [14] revealed that the hyperfine interaction is important, that the spin-orbit interaction is suppressed, as already noticed in the quark model, but also reveals that an effective tensor interaction with isospin exchange, in certain circles blamed on pion exchange, is also important. Currently an analysis of the whole 70-plet is being completed; this will serve as an important check of the robustness of the results obtained in the non-strange sector, and will also teach what are the important operators driving the SU(3) breaking.

FRANZ GROSS

1. Relativistic few body systems in the spectator formalism

The relativistic spectator formalism, which uses covariant equations in which $n-1$ particles in an n-body system are placed on their mass-shell, has been used successfully to describe NN scattering below 350 MeV lab energy, the deuteron form factors over the full JLab energy range, and the triton binding energy. This relativistic equation can also be used to describe mesons as a confined system of $q\bar{q}$ pairs. When relativistic equations are used to describe confined pairs, instabilitiesd can arise and the requirement that the solutions be stable places constraints on the dynamics. The stability of relativistic equations was recently studied by M. Uzzo [15].

Work on a variety of further applications of the spectator formalism are underway. In collaboration with J. Adam, S. Jeshonneck, P. Ulmer, and J. W. Van Orden an analysis of the $d(e, e'p)n$ reaction is almost complete. This work uses the relativistic plane wave impulse approximation to predict the cross section and asymmetry A_ϕ over a broad range of x and Q^2. In another work with A. Stadler, the relativistic effects in the trition binding energy are being isolated and studied, and the relativistic wave function obtained in the previous calculation is being used to study inelastic scattering from three nucleon targets.

2. Inelastic scattering and duality in 1+1 dimensions

At high energies, where one space dimension (longitudinal) sometimes plays a more important role that the others (transverse), it can be useful to study the physics in models using only 1+1 (one space and one time) dimension. Deep inelastic scattering (DIS) has been recently studied in 1+1 dimension by Z. Batiz. Recently he has shown, in some very simple cases, that the momentum and baryon conservation sum rules are equivalent, as required by covariant models which furnish only one constraint (wave function normalization) [16]. Work showing how Bloom-Gilman duality emerges from the 't Hooft model (QCD in 1+1 dimensions) is almost completed.

3. Exact solutions of field theories from the Feynman-Schwinger formalism

The Feynman-Schwinger (FS) formalism provides a convenient way to obtain exact numerical solutions of field theories. In this method the integrations over fields are replaced by path integrals over particle trajectories. Since particle trajectors lie along a line in space time, while fields occupy all of space time, the FS method, when it exists, is a considerable improvement over lattice gauge theory. So far the method has been fully developed only for scalar field theories, and techniques to extend it to Dirac fields and to QCD are being sought. When fully developed, the method can be used to obtain the exact dressed one particle masses, exact bound state energies for n-body systems, and exact n-body wave functions in Euclidean space.

So far improvements in the method have been described [17] and it has been applied to the study of confinement in scalar QED in 0+1 dimensions, where exact *analytic* solutions are available [18]. These studies show that confined particles may have physical mass poles, and that the non-existance of mass poles may be due to an inadequate approxiate solution to the field theory and not to the presence of confining forces. A major analysis of the the exact solutions of the 1, 2, and 3 body problems in scalar $\chi^2\phi$ theory, including a comparison of the exact field theoretic results with results obtained from various relativistic equations, is almost complete.

NATHAN ISGUR

While answering many questions about the quark structure of matter, the success of the pointlike constituent quark model raised many others about the relationship between the quark model and QCD, in particular questions regarding the role of gluons in the structure and dynamics of strongly interacting matter. In the quark model, gluon exchange simply provides forces between the quarks which in turn lead to a quark spectroscopy analogous to atomic spectroscopy. However, in atomic spectroscopy one has, in addition to the atoms, states in which there is just electromagnetic radiation (*i.e., light!*). The analogous "gluonic radiation" is not allowed by the confinement mechanism of QCD; in its place a new form of *quarkless* strongly interacting matter which has been dubbed "glueballs" must appear. (More important experimentally is a second form of gluonic matter in which the glue inside an ordinary piece of quark matter becomes excited.)

Much of my work over the period 1999 and 2000 continued to grapple with the issues raised by the success of the quark model. The bulk of this work was concerned with the valence quark model itself. These papers dealt with predictions for the $x \to 1$ spin structure functions relevant to the 12 GeV Upgrade [19], the validity of the adiabatic approximation when strong thresholds are present [20], Goldstone boson exchange competitiors to the one-gluon-exchange model [21,22], and the famous baryon spin-orbit problem [23]. Finally, the long-standing issue of whether the neutron charge radius was a dynamical distortion of the quark wavefunction or a "trivial" Foldy effect was addressed in Ref. [24]

Perhaps the most important paper on the foundations of the quark model was one dealing with the gluonic (flux tube) degree of freedom in hadrons [25]. This paper showed that the cross sections for producing hybrid mesons must be large, guaranteeing the success of the Hall D program of the 12 GeV Upgrade.

Finally, during this period, I wrote several papers on heavy quark theory. One shows that duality-violating effects are of order $1/m_Q$, contrary to naive "proofs" indicating that they are of order $1/m_Q^2$ [26]; the other deals with "missing" exclusive channels, which I argue will be found in high mass nonresonant decays [27].

SABINE JESCHONNEK

One of the most important factors in electron scattering from nuclei at high energies is the proper treatment of relativity. While it is obvious how to incorporate relativistic kinematics, relativity in the electromagnetic current operator and in nuclear dynamics needs a more sophisticated approach. Ideally, one would treat all aspects of the problem consistently in a manifestly covariant framework, e.g. using the spectator equation. In practice, this approach is limited to the deuteron, and to a somewhat simplified description of the reaction mechanism in a plane wave picture. As the experimental program carried out at Jefferson Lab includes heavier nuclei and demands a more precise description of the reaction mechanism, it is crucial to develop and test effective methods for the description of relativity under these circumstances.

In my previous work at MIT with T. W. Donnelly, we developed a fully relativistic current operator. From our calculations, we conjectured that the bulk of relativistic effects at a few GeV stems from the current operator, not from the nuclear dynamics. In this project, we explicitly checked and verified this important conjecture by comparing a manifestly covariant calculation and a calculation using the fully relativistic current operator and a nonrelativistic wave function. We found that the effects of nuclear relativistic dynamics are indeed negligible, and that the two methods give almost identical results in most kinematic regions.

In the literature, one often finds calculations of $(e, e'p)$ reactions at GeV energies using the factorization approach, especially in the context of predictions for color transparency. Factorization implies that the differential cross section can be written as the product of an off-shell electron-proton cross section and a distorted missing momentum distribution. While this factorization appears in the nonrelativistic plane wave impulse approximation, it is broken in a more realistic approach. The main source of factorization breaking is final state interactions. In my recent paper [30], sources of factorization breaking are identified and their numerical relevance is examined in the reaction ${}^2H(e, e'p)$ for various kinematic settings in the GeV regime. The results imply very clearly that factorization should not be used for precision calculations, especially as unfactorized calculations are available.

My recent work on Quark-Hadron duality with Nathan Isgur, Wally Melnitchouk, and Wally Van Orden is described below by Wally Van Orden.

WALLY MELNITCHOUK

1. Flavor asymmetry in the proton sea

The excess of $\bar{d}$ quarks over $\bar{u}$ in the proton, observed in a number of high energy experiments, is believed to arise largely from the pion cloud of the nucleon [36]. Currently there are proposals for JLab experiments to extend measurements of the $\bar{d}/\bar{u}$ ratio into previously unexplored regions of kinematics. By studying the leading nonanalytic behavior of quark distributions as a function of the quark mass, we have recently demonstrated [32] that one can predict, model-independently, the existence of a flavor asymmetry in the proton sea directly from the chiral properties of QCD. Previous analyses have needed to resort to models to account for an asymmetry. A similar mechanism also gives rise to intrinsic strange [35] (and possibly charm [34]) quarks in the nucleon, empirical evidence for which is being sought through strangeness form factor measurements by the HAPPEX (and in future G0) Collaboration at JLab.

2. Nuclear effects in the $^3He/^3H$ system

In the valence quark sector, the dynamics of spin-flavor symmetry breaking at large x are still poorly understood. The $x \to 1$ behavior of proton and neutron structure functions is particularly sensitive to the way spin-flavor symmetry is broken. In fact, QCD makes a unique prediction for this behavior, which has never been tested experimentally. Current methods of extracting neutron information from nuclear (deuteron) data suffer from sizable uncertainties beyond $x \sim 0.6$ associated with nuclear corrections [33]. A recent study [31] found that by exploiting the mirror symmetry of $A = 3$ nuclei, the simultaneous measurement of ^{3}He and ^{3}H structure functions would allow an unambiguous determination of the free neutron structure function at the $\sim$ 1–2% level. Based on this work, a proposal to measure the ^{3}He/^{3}H structure functions at a future energy upgraded CEBAF [120] formed one of the main components of the 12 GeV JLab White Paper. I played a major role in forming a collaboration of theorists and experimentalists at JLab which plans to measure and analyze structure functions, as well as form factors, of $A = 3$ nuclei.

3. Duality

My work with N. Isgur, S. Jeschonnek and J.W. Van Orden is reviewed by Wally Van Orden below. An illustration of the possible applications of local duality was also discussed in Ref. [74], where the behavior of structure functions in the limit $x \to 1$ was related to electromagnetic form factors at large Q^2, both of which will be measured at JLab. During 1999-2000 I organized a discussion group on quark-hadron duality with JLab theorists and experimentalists (from Halls A and C), which helped to clarify the interpretation of the existing JLab data, and develop ideas for future duality experiments at JLab.

4. Lattice

In the past year I have also joined the Lattice Hadron Physics Collaboration, where I have been drawn to explore the interface between lattice QCD and hadron phenomenology. In collaboration with A.W. Thomas and W. Detmold (Adelaide) and J. Negele (MIT), I have reanalyzed moments of structure functions on the lattice in order to improve the extrapolation to physical quark masses. Previous extrapolations, which assumed a linear dependence on the quark mass, overestimated the experimental values by up to 50%. The present analysis, which uses constraints from chiral perturbation theory, shows for the first time that within the current errors there is no discrepancy between the lattice data and experiment once the correct dependence on quark mass near the chiral limit is incorporated. Another problem which I am working on (in collaboration with researchers at CSSM, Adelaide) is the calculation of masses and form factors of nucleons and N^* resonances. This will provide an important complement to the experimental program in Hall B, and potentially to the exotic meson program at a future Hall D.

ANATOLY RADYUSHKIN

1. Studies in the theory of generalized parton distributions.

The structure of hadrons probed in hard scattering processes can be described in terms of various functions: hadronic form factors, parton distribution functions and distribution amplitudes. Recently, it was established that these functions can be treated as limiting cases of so-called Generalized Parton Distributions (GPDs) which provide a unified description of many inclusive and exclusive hard processes. The study of GPDs was recently included as one of the major directions of future research at higher energies at Jefferson Lab. Of particular interest for the JLab experimental program are the processes of deeply virtual Compton scattering (DVCS) and hard exclusive meson electroproduction. The GPDs accumulate information contained in nonforward matrix elements of operators built of quark and gluon fields. In my papers published in 1996-1998, I have introduced two types of nonperturbative functions parametrizing such matrix elements: double distributions (DDs) and nonforward (or skewed) distribution functions, which are particular versions of GPDs. In 1999-2000, I performed a detailed study of double distributions [37,38]. Using the relations connecting them to usual parton densities, hadronic wave functions and form factors, I developed the models for DDs which have correct spectral and symmetry properties and satisfy all necessary constraints [39,40]. These models are now widely used for making predictions for future deep exclusive scattering experiments. In particular, they were used to calculate the cross section for hard electroproduction of pions [41]. At CEBAF energies, it is important to include corrections inversely proportional to the momentum transfer ("higher twist effects"). This is a notoriously difficult problem, but in 2000, several groups (including ours) made a significant progress in studying such effects for deeply virtual Compton scattering [42].

2. Hadronic form factors.

The study of hadronic form factors provides an important information about hadronic structure. In the intermediate energy range, both soft and hard mechanisms should be included into the analysis. A detailed analysis of the interplay between soft and hard contributions was performed in [43,44]. We also studied the connection between form factors in spacelike and timelike regions. According to experimental data, the timelike form factors are factor of two larger than their spacelike counterparts. In our approach [45], this observation provides strong evidence that at present energies the hadronic form factors are dominated by the soft mechanism. The nonperturbative aspects of the soft contributions were incorporated using the method of QCD sum rules reviewed in [46].

The results of my research were reported in invited talks at several International conferences [82–85], [121–125].

DAVID RICHARDS

1. Hadron Spectrum

An important development in lattice QCD has been the construction of improved actions, enabling calculations to be performed at greatly reduced computational cost.

The non-perturbatively improved clover fermion action has no $\mathcal{O}(a)$ discretisation errors. We calculated the light hadron spectrum, the benchmark calculation of lattice QCD, within the quenched approximation using this action, and showed that the quenched spectrum agreed with the experiment at the 10% level after extrapolation to the continuum limit [49], confirming a calculation using an unimproved fermion action.

The spectrum of excited nucleons is an important component of the Jefferson Laboratory experimental program. I computed, within the quenched approximation, the masses of some low-lying negative parity baryon states, the $N^{1/2-}$ and $\Delta^{3/2-}$, using the improved fermion action [90]. A mass splitting between the negative- and positive-parity states was observed, and the mass for the parity partner of the nucleon was found to be consistent with experiment. The calculation demonstrated that the improved fermion action could indeed be employed in future calculations of the excited nucleon spectrum.

2. Weak interaction matrix elements

The experimental determination of the CKM matrix elements requires a quantitative description of the strong interaction effects masking the weak interactions of the quarks. Lattice QCD calculations provide an *ab initio* description.

We performed a calculation of the form factors near zero recoil for the semi-leptonic decay $B \to \pi l \nu$, used to determine the CKM matrix element $|V_{ub}|$, using the non-perturbatively improved fermion action in order to minimise the potentially large discretisation errors that might afflict calculations with heavy quarks [48,86]. Models of the extrapolation of the form factors to the full kinematic range were also presented. Complementing this calculation was a determination of the leptonic decay constant f_B that plays a vital role in the study of CKM quark mixing and CP violation.

3. Gauge Fixing in Lattice QCD

While most calculations in lattice QCD do not require gauge fixing, it is necessary in the calculation of the quark and gluon propagators and vertices. The improvement program therefore requires not only the construction of improved actions and operators, but also improved gauge-fixing algorithms. We introduced an improved Landau gauge fixing procedure that not only eliminated $\mathcal{O}(a^2)$ errors, but also reduced higher order discretisation errors [47,87].

4. Lattice Hadron Physics Collaboration

This collaboration represents an exciting initiative in applying lattice QCD to the solution of problems in hadronic physics. Test-bed clusters of commodity Compaq Alpha workstations, using a fast Myrinet interconnection, were installed at Jefferson Laboratory and at MIT. I ported crucial elements of the UKQCD software package to the cluster, and demonstrated that parallel jobs could be run across the whole cluster with acceptable levels of performance. This effort is already yielding physics results in the calculation of the excited nucleon spectrum.

WINSTON ROBERTS

Most 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 nonrelativistic. 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 the heavy quark effective theory grew out of work that had been done in nonrelativistic quark models of this type.

1. Heavy Quark Effective Theory

In the past, with a number of collaborators (mainly T. Mannel and Z. Ryzak), I have applied the tensor formalism of the heavy quark effective theory (HQET) to a number of processes, particularly electroweak processes.

More recently I have used the tensor formalism 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 Isgur and 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, with N. Trégourès, a graduate student (M. S. completed in the fall of 1998), I have 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.

2. Relativistic Quark Model

Inspired by HQET, I have constructed a relativistic model of heavy mesons, and applied it to the spectrum of charm and beauty mesons (with J. W. Van Orden and J. Zeng). The predictions of the model agree well with experimental measurements. The model is currently being applied to a calculation of the so-called Isgur-Wise function of HQET (with J. W. Van Orden), which is a key ingredient in the extraction of CKM matrix elements from data.

We have applied the model 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 nonrelativistic model of the mesons, with the same chiral quark model for the decays.

We are in the process of applying 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.

3. Baryon Spectroscopy

The collaboration with Simon Capstick continues, with a review article of the quark model of baryon masses and decays having just been published.

4. National Science Foundation

For the period beginning October, 1998 and ending September, 2000, I was a progrom officer in the Division of Physics at the National Science Foundation, with primary responsibility for two programs: Mathematical Physics and Nuclear Theory. My responsibilities included evaluation of unsolicited research proposals sent to the NSF and determining the level of funding, if any, appropriate for each proposal.

ROCCO SCHIAVILLA

Low-energy electroweak capture reactions involving systems with $A \leq 8$ nucleons have great astrophysical importance in relation to the energy and neutrino production in main sequence stars, in particular, the determination of the solar neutrino flux, and in relation to the abundance of primordial elements in the universe. The rates for several of these reactions cannot be measured in the energy range typical of the stellar interior. Besides their astrophysical relevance, these reactions are also very interesting from the standpoint of few-nucleon theory, since they are sensitive to ground- and scattering-state wave functions and the electroweak transition operators. In the last couple of years we have made decisive and substantial progress in the developments of accurate methods to treat these reactions.

The neutron and proton radiative captures on ^{2}H have been studied with correlated-hyperspherical-harmonics (CHH) ground- and scattering-state wave functions. A large body of *pd* capture data, including polarization observables at c.m. energies up to 2 MeV [G.J. Schmid *al.*, Phys. Rev. Lett. **76**, 3088 (1996); Wulf. *et al.*, Phys. Rev. C **61**, 021601(R) (2000); M.K. Smith and L.D. Knutson, Phys. Rev. Lett. **82**, 4591 (2000)] have become available. Detailed CHH calculations, based on the Argonne-Urbana Hamiltonian and associated currents, have been shown to describe satisfactorily all measured observables, with the exception of the differential cross section and tensor analyzing power at small angles below 100 keV. A comparison between the calculated reduced matrix elements and those extracted from fits to the observables has shown that these discrepancies are due to differences between the leading theoretical and "experimental" P-wave E1-transition strengths. It has been speculated that these differences might have implications for the nuclear interaction at very low energies. That such an analysis is now possible at all is a tribute to the great advances in both theory and experiment in this field.

Since the pioneering 1938 work by Bethe and Critchfield [Phys. Rev. **54**, 248 (1938)], a number of theorists have attempted to narrow the range of predictions for the *pp* weak capture cross section. Recently, we have shown [R. Schiavilla *et al.*, Phys. Rev. C **58**, 1263 (1998)] that, by using modern nucleon-nucleon interactions to generate the deuteron and *pp* wave functions, and tritium β-decay to constrain the nuclear axial current operator responsible for the transition, it is possible to reduce the known theoretical uncertainty to less than a %. Within the same approach, we have also studied the process ^{3}He(p,$e^+\nu_e$)^{4}He with the CHH method, including both S- and P-wave channels and all corresponding weak vector and axial-vector transitions. The calculated S-factor has been found to be $\simeq 4.5$ larger than the value adopted in the standard solar model. This new value for the *hep* S-factor and the increase in the ^{8}B neutrino spectrum, recently re-measured by Ortiz *et al.* [Phys. Rev. Lett. **85**, 2909 (2000)], appear to provide an excellent fit to the high-energy end of the most recent SuperKamiokande data set. The present, precise calculation of the *hep* S-factor and the consequent absolute prediction for the associated neutrino flux will allow much greater discrimination among proposed solar neutrino oscillation scenarios.

WALLY VAN ORDEN

1. Duality

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 in which qualitatively reproduces the features of Bloom-Gilman duality [73]. The model consists of a light 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 Bloom-Gilman duality and illuminates 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 unaccessible regions of kinematics [75](N. Isgur, S. Jeschonnek, W. Melnitchouk and J.W. Van Orden).

2. Elastic Electron-Deuteron Scattering

Over the last five years we have developed a relativistic, gauge-invariant model of elastic electron-deuteron scattering. This model is in excellent agreement with the new data for $A(Q^2)$, $B(Q^2)$ and $t_{20}(Q^2)$ obtained at Jefferson Lab. We continue to study the sensitivity of this model to nucleon electromagnetic form factors and to the $\rho\pi\gamma$ and off-shell form factors. [98,135,136] Two reviews of the deuteron related to this work are either in press or nearing completion (F. Gross and J. W. Van Orden).

III. PUBLICATIONS

A. PUBLICATIONS IN REFEREED JOURNALS (1/1/99 to 12/31/00)

[1] **I. Balitsky** and E. Kuchina, *Deeply virtual Compton scattering at small x*, *Phys. Rev.* **D62** (2000) 074004.

[2] **I. Balitsky** and A. Babansky, *Renormalons as dilatation modes in te functional space* *Phys. Rev. Lett.* **85** (2000) 4211.

[3] **I. Balitsky**, *Factorization and high-energy effective action*, *Phys. Rev.* **D60** (1999) 014020.

[4] **R. G. Edwards**, U.M Heller, R. Narayanan, *A Study of Chiral Symmetry in Quenched QCD using the Overlap-Dirac Operator*, hep-lat/9811030, Phys. Rev. D **59** (1999) 094510.

[5] **R. G. Edwards**, U.M Heller, R. Narayanan, *Approach to the Continuum Limit of the Quenched Hermitian Wilson–Dirac Operator*, hep-lat/9901015, Phys. Rev. D **60** (1999) 034502.

[6] **R. G. Edwards**, U.M Heller, J. Kiskis, R. Narayanan, *Quark Spectra, Topology, and Random Matrix Theory*, hep-th/9902117, Phys. Rev. Lett. **82**, 4188–4191 (1999).

[7] **R. G. Edwards**, U.M Heller, R. Narayanan, *Small Eigenvalues of the Staggered Dirac Operator in the Adjoint Representation and Random Matrix Theory*, hep-lat/9902021, Phys. Rev. D **60** (1999) 077502.

[8] **R. G. Edwards** and U.M Heller, *Thermodynamics with Dynamical Clover Fermions*, hep-lat/9905008, Phys. Lett. **B462** (1999) 132–136.

[9] P.H. Damgaard, **R. G. Edwards**, U.M Heller, R. Narayanan, *Universal Scaling of the Chiral Condensate in Finite-Volume Gauge Theories*, hep-lat/9907016, Phys. Rev. D **61** (2000) 094503.

[10] **R. G. Edwards**, U.M Heller, J. Kiskis, R. Narayanan, *Chiral Condensate in the Deconfined Phase of Quenched Gauge Theories*, JLAB-THY-99-33, hep-lat/9910041, Phys. Rev. D **61** (2000) 074504.

[11] C. Jung, **R. G. Edwards**, V. Gadiyak, and X.J. Xi *Residual Chiral Symmetry Breaking in Domain-Wall Fermions*, JLAB-THY-00-27, hep-lat/0007033, Phys. Rev. D **63** (2000) 054509.

[12] **J. L. Goity** and **W. Roberts**, *A Relativistic Chiral Quark Model For Pseudoscalar Emission From Heavy Mesons*, *Phys. Rev.* **D60**, 034001 (1999).

[13] **J. L. Goity**, R. Lewis, M. Schvellinger and L-Z. Zhang, *Phys. Lett.* **B 454** (1999) 115.

[14] C. Carlson, Ch. Carone, **J. L. Goity** and R. Lebed, *Phys. Rev.* **D 59** (1999) 114008.

[15] M. Uzzo and **F. Gross**, *Stability of the spectator, Dirac, and Salpeter equations for mesons*, Phys. Rev. C **59**, 1009 (1999)

[16] Z. Batiz and **F. Gross**, *Gravitational coupling to two particle bound states and momentum conservation in deep inelastic scattering*, Phys. Rev. D **61**, 114023, 2000.

[17] C. Savkli, J. Tjon, and **F. Gross**, *Feynman-Schwinger representation approach to nonperturbative physics*, Phys. Rev. C **60**, 055210 (1999).

[18] C. Savkli, **F. Gross**, and J. Tjon, *Confinement and the analytic structure of of the one body propagator in scalar QED*, Phys. Rev. D **62**, 116006 2000.

[19] **N. Isgur**, *Valence Quark Spin Distribution Functions*, Phys. Rev. **D59**, pp. 034013-1 to 034013-6 (1999).

[20] **N. Isgur**, *Beyond the Adiabatic Approximation: the Impact of Thresholds on the Hadronic Spectrum*, Phys. Rev. **D60**, pp. 054013-1 to 054013-7 (1999).

[21] **N. Isgur**, *Comment on 'Valence QCD: Connecting QCD to the Quark Model'*, Phys. Rev. **D61**, 118501 (2000).

[22] **N. Isgur**, *Critique of a Pion-Exchange Model for Interuark Forces*, Phys. Rev. **D62**, 054026 (2000).

[23] **N. Isgur**, *Meson-like Baryons and the Spin-Orbit Puzzle*, Phys. Rev. **D62**, 014025 (2000).

[24] **N. Isgur**, *Interpreting the Neutron's Electric Form Factor: Rest Frame Charge Distribution or Foldy Term?*, Phys. Rev. Lett. **83**, 272 (1999).

[25] **N. Isgur**, *Flux Tube Zero-Point Motion, Hadronic Charge Radii, and Hybrid Meson Production Cross Sections*, Phys. Rev. **D60**, 114016 (1999).

[26] **N. Isgur**, *Duality-Violating $1/m_Q$ Effects in Heavy Quark Decay*, Phys. Lett. **B448**, 111 (1999).

[27] **N. Isgur**, *Nonresonant Semileptonic Heavy Quark Decay*, Phys. Rev. **D60**, 074030 (1999).

[28] **S. Jeschonnek** and T.W.Donnelly, *Spin-orbit final state interaction in the framework of Glauber theory for $(e,e'p)$ reactions*, Phys. Rev. C **59**, 2676 (1999).

[29] **S. Jeschonnek** and **J. W. Van Orden**, *Origin of relativistic effects in the reaction $^2H(e,e'p)n$ at GeV energies*, Phys. Rev. C **62** (2000), 044613.

[30] **S. Jeschonnek**, *Unfactorized versus factorized calculations for $^2H(e,e'p)$ reactions at GeV energies*, JLAB-THY-00-31, Phys. Rev. C **63**, 034609 (2001).

[31] I.R. Afnan, F. Bissey, **J. Gomez**, A.T. Katramatou, **W. Melnitchouk**, G.G. Petratos and A.W. Thomas, *Neutron Structure Function and $A = 3$ Mirror Nuclei*, Phys. Lett. **B 493**, 36 (2000).

[32] A.W. Thomas, **W. Melnitchouk** and F.M. Steffens, *Dynamical Symmetry Breaking in the Sea of the Nucleon*, Phys. Rev. Lett. **85**, 2892 (2000).

[33] **W. Melnitchouk**, I.R. Afnan, F. Bissey and A.W. Thomas, *Comment on "Parton distributions, d/u, and higher twist effects at high x"*, Phys. Rev. Lett. **84**, 5455 (2000).

[34] F.M. Steffens, **W. Melnitchouk** and A.W. Thomas, *Charm in the Nucleon*, Eur. Phys. J. **C 11**, 673 (1999).

[35] **W. Melnitchouk** and M. Malheiro, *Strange Asymmetries in the Nucleon Sea*, Phys. Lett. **B 451**, 224 (1999).

[36] **W. Melnitchouk**, J. Speth and A.W. Thomas, *Dynamics of Light Antiquarks in the Proton*, Phys. Rev. **D 59**, 014033 (1999).

[37] **A.V. Radyushkin**, *Double Distributions and Evolution Equations*, Phys. Rev. **D59**, 014030 (1999).

[38] **A.V. Radyushkin**, *Symmetries and Structure of Skewed and Double Distributions*, Phys.Lett. **B449**, 81 (1999).

[39] I.V. Musatov, **A.V. Radyushkin**, *Evolution and Models for Skewed Parton Distributions*, Phys.Rev. **D61**, 074027 (2000).

[40] **A.V. Radyushkin**, *Skewed Parton Distributions*, Acta Physica Polonica, **B30**, 3647 (1999).

[41] L. Mankiewicz, G. Piller,**A.V. Radyushkin**, *Hard Exclusive Electroproduction of Pions*, Eur.Phys.J. **C10**, 307 (1999).

[42] **A.V. Radyushkin** and C. Weiss, *DVCS Amplitude with Kinematical Twist-3 Terms*, Phys.Lett. **B493**, 332 (2000).

[43] **A.V. Radyushkin**, *QCD Sum Rules and Soft-Hard Interplay for Hadronic Form Factors*, *Few Body Syst. Suppl.*, 11 (1999).

[44] A.P. Szczepaniak, **A.V. Radyushkin**, *Sudakov Suppression in the Soft Heavy to Light Meson Transition Form Factor*, Phys. Rev. **D59**, 034017 (1999).

[45] A.P. Bakulev, **A.V. Radyushkin**, N.G. Stefanis, *Form Factors and QCD in Spacelike and Timelike Region*, Phys.Rev. **D62**, 113001 (2000).

[46] **A.V. Radyushkin**, *Introduction to the QCD Sum Rule Approach*, In: *Strong Interactions at Low and Intermediate Energies*, Edited by **J. L. Goity**, World Scientific,

pp. 91-150 (2000).

[47] F.D.R Bonnet,P.O. Bowman, D.B. Leinweber, A.G. Williams, **D.G. Richards**, *Discretisation Errors in Landau Gauge on the Lattice*, Austral. J. Phys. 52, 939 (1999).

[48] K.C. Bowler, L. Del Debbio, J.M. Flynn, L. Lellouch, V. Lesk, C. Maynard, J. Nieves, **D.G. Richards** (UKQCD Collaboration), *Improved $B \to \pi l \nu$ Semi-Leptonic Form-Factors from the Lattice*, Phys. Lett. **B486**, 111 (2000).

[49] K.C. Bowler, P. Boyle, J. Garden, R.D. Kenway, **D.G. Richards**, P.A. Rowland, S.M. Ryan, H. Simma, C. Michael, H.P. Shanahan, H. Wittig (UKQCD Collaboration), *Quenched QCD with $O(a)$ Improvement. 1. The Spectrum of Light Hadrons*, Phys. Rev. **D62**, 054506 (2000).

[50] S. Capstick, T. S. H. Lee, **W. Roberts** and A. Svarc, *Evidence For The Fourth P(11) Resonance Predicted By The Constitunt Quark Model, Phys. Rev.* **C59**, 3002 (1999).

[51] N. Tregoures and **W. Roberts**, *Phenomenological Study of Strong Decays of Heavy Hadrons in Heavy Quark Effective Theory, Phys. Rev.* **D61**, 074032 (2000).

[52] S. Capstick and **W. Roberts**, *Quark Models of Baryon Masses and Decays*, Progress in Particle and Nuclear Physics **45** S241 2001.

[53] E.A. Wulf, R.S. Canon, S.J. Gaff, J.H. Kelley, R.M. Prior, E.C. Schreiber, M. Spraker, D.R. Tilley, H.R. Weller, M. Viviani, A. Kievsky, S. Rosati, and **R. Schiavilla**, *A New Photodisintegration Threshold Observable in ^3He*, Phys. Rev. C **61**, 021601(R) (2000)

[54] M. Viviani, A. Kievsky, L.E. Marcucci, S. Rosati, and **R. Schiavilla**, *Photo- and Electro-Disintegration of ^3He at Threshold and pd Radiative Capture*, Phys. Rev. C **61**, 064001 (2000)

[55] L.E. Marcucci, **R. Schiavilla**, M. Viviani, A. Kievsky, and S. Rosati, *Realistic Calculation of the hep Astrophysical Factor*, Phys. Rev. Lett. **84**, 5959 (2000)

B. PUBLICATIONS IN CONFERENCE PROCEEDINGS
(Talks given or published from 1/1/99 to 12/31/00)
Invited talks marked with an *

[56] **I. Balitsky**, *High-energy effective action from scattering of shock waves in QCD*, Proceedings of the XXIX Workshop "QCD and Multiparticle Production", ed Ina Sarcevic and Chung-I Tan, World Scientific, 2000, p. 261-269.

[57] **R.G. Edwards**, U.M Heller, R. Narayanan, *Topological Susceptibility and Zero Mode Size in Lattice QCD*, hep-lat/9810019, Proceedings of the Lattice '98 conference (Boulder, CO, 1998), Nucl. Phys. **B73** (Proc. Suppl.), 500–502, 1999.

[58] **R.G. Edwards**, U.M Heller, R. Narayanan, *Evidence for fractional topological charge in SU(2) pure Yang-Mills theory*, hep-lat/9810003, Proceedings of the Lattice '98 conference (Boulder, CO, 1998), Nucl. Phys. **B73** (Proc. Suppl.), 497–499, 1999.

[59] D. Chen, P. Chen, N. Christ, **R.G. Edwards**, G. Fleming, A. Gara, S. Hansen,C. Jung, A. Kahler, S. Kasow, A.D. Kennedy, G. Kilcup, Y.B. Luo, C. Malureanu, R. Mawhinney, J. Parsons, J. Sexton, C.Z. Sui, P. Vranas, *Status of the QCDSP Project*, hep-lat/9810004, Proceedings of the Lattice '98 conference (Boulder, CO, 1998), Nucl. Phys. **B73** (Proc. Suppl.), 898–900, 1999.

[60] **R.G. Edwards**, U.M Heller, J. Kiskis, R. Narayanan, *Topology and chiral symmetry in finite temperature QCD*, hep-lat/9908036, Proceedings of the Lattice '99 conference (Pisa, Italy, 1999), to appear in Nucl. Phys. **B** (Proc. Suppl.). Nucl. Phys. **B83** (Proc. Suppl.), 479–481, 2000.

[61] P.H. Damgaard, **R.G. Edwards**, U.M Heller, R. Narayanan, *Finite-Volume Scaling of the Quenched Chiral Condensate*, hep-lat/9909009, Proceedings of the Lattice '99

conference (Pisa, Italy, 1999), Nucl. Phys. **B83** (Proc. Suppl.), 434–436, 2000.

[62] **R.G. Edwards**, U.M Heller, R. Narayanan, *Overlap Dirac Operator, Eigenvalues and Random Matrix Theory*, hep-lat/9909024, Proceedings of the Lattice '99 conference (Pisa, Italy, 1999), Nucl. Phys. **B83** (Proc. Suppl.), 446–448, 2000.

[63] **R.G. Edwards**, U.M Heller, J. Kiskis, R. Narayanan, *Topology and Chiral Symmetry in QCD with Overlap Fermions*, JLAB-THY-99-41, hep-lat/9912042, Proceedings for NATO Advanced Research Workshop *Lattice Fermions and Structure of the Vacuum*, Dubna, Russia, Oct 1999.

[64] A. Bode, **R.G. Edwards**, U.M Heller, R. Narayanan, *First Experiences with HMC for Dynamical Overlap Fermions*, JLAB-THY-99-40, hep-lat/9912043, Proceedings for NATO Advanced Research Workshop *Lattice Fermions and Structure of the Vacuum*, Dubna, Russia, Oct 1999.

[65] * **R.G. Edwards**, U.M Heller, R. Narayanan, *The Overlap-Dirac Operator: Topology and Chiral Symmetry Breaking* JLAB-THY-00-01, hep-lat/0001013, Proceedings for Chiral '99, Taipei, Taiwan, Sep. 13-18, 1999, Chin. J. Phys. 38, 594–604, 2000.

[66] S. Capstick, *et al.*, *Key Issues In Hadronic Physics*, hep-ph/0012238, Presented at APS Division of Nuclear Physics Town Meeting on Electromagnetic and Hadronic Physics, Newport News, Virginia, 1-4 Dec 2000.

[67] * **F. Gross** [panel and discussion leader], D. Drechsel, J. Friar, V. Pandharipande, and I. Sick, *Conference discussion of the nuclear few-body problem: questions and issues*, Presented to the XVIIth European conference on few-body problems in physics, 11 - 16 September 2000, Evora, Portugal. (To be published in the proceedings).

[68] * **N. Isgur**, *The Quark Structure of Matter*, in proceedings of 25^{th} *INS International Symposium*, published by INS (1999).

[69] * **N. Isgur**, *Spectroscopy: An Introduction and Overview*, in proceedings of "Baryons '98", published U. Bonn (1999).

[70] * **N. Isgur**, *Strangeness in the Nucleon*, in proceedings of *PAVI 98*, published World Scientific (1999).

[71] * **N. Isgur**, *Why N^*'s Are Important*, to appear in Proceedings of the N^* '98 Workshop, JLAB-THY-00-20, nucl-th/0007008 (2000).

[72] **S. Jeschonnek** and T. W. Donnelly, *The fifth response function and spin-orbit final state interaction in the framework of Glauber theory for $(e,e'p)$ reactions*, Progress in Particle and Nuclear Physics, **44**, 59 (2000).

[73] **S. Jeschonnek**, *Quark-Hadron Duality*, Lectures at the HUGS Summerschool, Jefferson Lab, Newport News, USA, 6/9/00 (to be published).

[74] **W. Melnitchouk**, *Local Quark-Hadron Duality in Structure Functions*, International Conference of Quark Nuclear Physics, Adelaide, Australia, Nucl. Phys. **A680**, 52c (2001) [held in 2000].

[75] * **W. Melnitchouk**, *Quark-Hadron Duality in Electron Scattering*, To appear in Proceedings of the 2nd Workshop on Physics with an Electron Polarized Light Ion Collider, Cambridge, Massachusetts, Sep. 2000.

[76] **W. Melnitchouk**, *Asymmetric Quarks in the Proton*, Symmetries in Subatomic Physics, 3rd International Symposium, Adelaide, Australia (AIP Conference Proceedings, Melville, NY 2000).

[77] **W. Melnitchouk**, *Flavor Decomposition of the Nucleon*, Workshop On Exclusive And Semi-exclusive Processes at High Momentum Transfer, Newport News, Virginia (World Scientific, 2000).

[78] * **W. Melnitchouk**, *QCD and the Structure of the Nucleon in Electron Scattering*, To appear in Proceedings of the 14th Annual HUGS Summer School (HUGS 99), Newport

News, Virginia, June 1999.

[79] J. Haidenbauer, **W. Melnitchouk** and J. Speth, *Meson-Exchange Model for the Hyperon–Nucleon Interaction*, 15th International Conference On Particle And Nuclei (PANIC 99), Uppsala, Sweden, Nucl. Phys. **A663**, 549 (2000).

[80] * **W. Melnitchouk**, *Flavor Asymmetry in the Proton and Semi-Inclusive Processes*, Physics with a High Luminosity Polarized Electron Ion Collider, Bloomington, Indiana (World Scientific, 2000).

[81] **W. Melnitchouk**, *Quark Asymmetries in the Proton*, Future Directions in Quark Nuclear Physics, Adelaide, Australia (World Scientific, 1999).

[82] **A.V. Radyushkin**, *Skewed Parton Distributions*, Nucl.Phys. **A666**, 225 (2000).

[83] **A.V. Radyushkin**, *Generalized Parton Distributions*, Nucl. Phys.B (Proc. Suppl.) **90**, 113 (2000).

[84] **A.V. Radyushkin**, *Deeply virtual hadron production*, Talk at International workshop NSTAR2000, Jefferson Lab, Newport News, February 2000 (to be published in Proceedings).

[85] **A.V. Radyushkin**, *QCD calculations of form factors*, Talk at International workshop "Chiral Dynamics 2000", Jefferson Lab, Newport News, July 17-20, 2000 (to be published in Proceedings).

[86] K.C. Bowler, C.M. Maynard, L. Lellouch, J. Nieves, **D.G. Richards**, L. Del Debbio, J.M. Flynn, V.I. Lesk (UKQCD Collaboration), *An Investigation of the Soft Pion Relation in Quenched Lattice QCD*, Nucl. Phys. (Proc. Suppl.) 83, 313 (2000).

[87] F.D.R. Bonnet, P.O. Bowman, D.B. Leinweber, **D.G. Richards**, A.G. Williams, *Improved Landau Gauge Fixing and Discretisation Errors*, Nucl. Phys. (Proc. Suppl.) 83, 905 (2000).

[88] * **D.G. Richards**, *Lattice Gauge Theory: QCD from Quarks to Hadrons*, Lectures given at 14th. Annual HUGS at CEBAF, Newport News, Virginia, 1-18 June 1999.

[89] **D.G. Richards**, *Review of NN Interaction from Lattice QCD*, to be published in 3rd. Workshop on Chiral Dynamics - Chiral Dynamics 2000: Theory and Experiment, Newport News, Virginia, 17-22 July, 2000.

[90] **D.G. Richards** (UKQCD and LHPC Collaboration), *N^* Spectrum using an $\mathcal{O}(a)$-improved Fermion Action*, to be published in Proceedings of Lattice 2000, Bangalore, India, 17-22 Aug., 2000.

[91] O. Benhar, A. Fabrocini, and **R. Schiavilla**, eds., *Electron-Nucleus Scattering*, ETS Editrice, Pisa, 1999

[92] * M. Viviani, **R. Schiavilla**, and A. Kievsky, *Electrodisintegration of ^{3}He at Threshold* in *Electron-Nucleus Scattering*, O. Benhar, A. Fabrocini, and R. Schiavilla, eds., ETS Editrice, 1999

[93] * S. Rosati, A. Kievsky, M. Viviani, L.E. Marcucci, and **R. Schiavilla**, *Hyperspherical-Harmonics Methods for Few-Nucleon Systems* in *Perspectives in Hadron Physics*, S. Boffi, C. Ciofi degli Atti, and M. Giannini, eds., World Scientific, Singapore, 2000

[94] * **R. Schiavilla**, *Electro-Weak Reactions for Astrophysics* in *Few-Body Problems in Physics*, S.N. Yang, ed., Nucl. Phys. A in press

[95] * **R. Schiavilla**, *Interactions, Currents, and the Structure of Few-Nucleon Systems* in *Bologna 2000–Structure of the Nucleus at the Dawn of the Century*, G. Bonsignori, ed., World Scientific, Singapore, in press

[96] * **R. Schiavilla**, *Electromagnetic Structure of Few-Nucleon Systems* in *Few-Body Problems in Physics*, A. Stadler, A. Arriaga, A. Fonseca, and T. Pena, G. Rupp, eds., Nucl. Phys. A in press

[97] * **R. Schiavilla**, *The hep Astrophysical Factor* in *Neutrino Oscillations and their*

Origin–NOON2000, Y.Suzuki, K.Kaneyuki and M.Miura, eds., World Scientific in press
[98] ****J. W. Van Orden**, *MEC and relativistic effects in the deuteron*, Bates 25th Anniversary Symposium, Massachusetts Institute of Technology, November 3, 1999. **published** in *Bates 25: Celebrating 25 Years of Beam to Experiment*, AIP Conference Proceedings **520**, 130 (2000).

C. UNPUBLISHED INVITED TALKS GIVEN AT MAJOR CONFERENCES (1/1/99 to 12/31/00)

[99] **I. Balitsky**, *Factorization and high-energy effective action*, Workshop "Hard Parton Physics in High-Energy Nuclear Collisions " (BNL)-
[100] **I. Balitsky**, *Effective action for high-energy scattering in QCD*, Workshop on electron-nucleus collisions (BNL) -
[101] **I. Balitsky**, *Factorization and high-energy effective actionin QCD*, International Workshop "BH-70" (Paris, France)-
[102] **I. Balitsky**, *Deeply virtual Compton scattering at small x*, Workshop "eRHIC summer meeting at BNL" -
[103] **R. G. Edwards**, *Topology and Chiral Symmetry Breaking in Lattice QCD*, Talk given at the Aspen Center for Physics, Dirac Spectrum and Topology Workshop, May. 1999.
[104] **R. G. Edwards**, *The Overlap-Dirac Operator: Topology and Chiral Symmetry Breaking*, Invited talk given at Chiral '99, Taipei, Taiwan, Sep. 1999.
[105] **R. G. Edwards**, *Light Quark Physics on the Lattice*, Invited talk given at the Workshop on the Low-Energy Electroweak Sea-quark Structure of the Nucleon, Storrs, Conn., Nov. 1999.
[106] **R. G. Edwards**, *Chiral Symmetry on the Lattice: Recent Progress*, Invited talk given at the UKQCD Workshop, Edinburgh, Scotland, Sep. 2000.
[107] **R. G. Edwards**, *Lattice Hadron Physics Collaboration*, Invited talk given at the UKQCD Workshop, Edinburgh, Scotland, Sep. 2000.
[108] **R. G. Edwards**, *SZIN and the Art of Software Maintenance*, Invited talk given at the UKQCD Workshop, Edinburgh, Scotland, Sep. 2000.
[109] **R. G. Edwards**, *Realization of 4D Chiral Fermions*, Invited talk given at the Workshop on a New Computing Venue for Lattice Gauge Theory Calculations, Brookhaven National Lab, Oct. 2000.
[110] **J. L. Goity**, *The Goldberger-Treiman discrepancy in SU(3)*, in Workshop on Chiral Dynamics, Bad Honneff, Germany (1999).
[111] **J. L. Goity**, *Tests of Chiral Symmetry with a photon beam*, in Hall-D Workshop, Rensselaer, (1999)
[112] **J. L. Goity**, *The Goldberger-Treiman discrepancy and the value of* $g_{\pi NN}$, in Chiral Dynamics: Theory and Experiment III, (2000)
[113] **J. L. Goity**, *Chiral Perturbation Theory*, Lectures at the Indian Summer School *Understanding the Structure of Hadrons*, Prague, Czech Rep., (2000).
[114] **F. Gross** *Theory and Application of the Relativistic Spectator Theory*, Presented to the Symposium On Current Topics In The Field Of Light Nuclei Cracow, Poland, June 24, 1999
[115] **F. Gross** *Workshop Summary* Presented to the Symposium On Current Topics In The Field Of Light Nuclei Cracow, Poland, June 24, 1999
[116] **F. Gross** *Relativistic treatment of few-nucleon systems: parables, paradigms, and paralysis* Presented to the ECT* Workshop on The Nuclear Interaction: Modern Developments Trento Italy, June 30, 1999.

[117] **F. Gross** *Studies of Simple Nuclei at Jefferson Laboratory*, Third Latin American Workshop On Nuclear And Heavy Ion Physics San Andres Islands, Colombia, September 14 1999.

[118] **F. Gross** *Relativistic boosts, interaction currents, and three body forces*, Workshop on the Nuclear Standard Model: Ieri, Oggi, Domani; A Celebration for Vijay Pandharipande's Sixtieth Birthday, Elba International Physics Center, Elba, Italy, June 26-30, 2000.

[119] **F. Gross** *The Spectator Equation*, ETC* Workshop on Relativistic Dynamics and Few-Hadron Systems Trento, Italy, November 6 - 17, 2000.

[120] G.G. Petratos, I.R. Afnan, F. Bissey, J. Gomez, A.T. Katramatou, **W. Melnitchouk** and A.W. Thomas, *Measurement of the* F_2^n/F_2^p *and* d/u *Ratios in Deep-Inelastic Scattering off* ^3H *and* ^3He, Presented at the Workshop on Nucleon Structure in the High-x Region (HiX2000), held at Temple University, Philadelphia (April 2000).

[121] **A.V. Radyushkin**, *Skewed Parton Distributions*, Invited talk at JLab-KFZ-Jülich workshop, Jülich (Germany), June 1999.

[122] **A.V. Radyushkin**, *Form Factor* $\gamma^*\gamma \to \pi^0$ *in Perturbative QCD and QCD sum rules*, Invited talk at the International Workshop on Light-Cone Wave Functions, Regensburg, Germany, August 1999.

[123] **A.V. Radyushkin**, *Summary talk of the Workshop on Light-Cone Wave Functions*, Regensburg, Germany, August 1999.

[124] **A.V. Radyushkin**, *Puzzle of Local Duality*, Invited Talk at Workshop on Deep Inelastic Scattering at Low-Q^2, MIT, Cambridge, Mass. September 1999.

[125] **A.V. Radyushkin**, *Generalized Parton Distributions*, Talk at International Workshop "QCDNET 2000", Paris, France, September 14, 2000.

[126] **R. Schiavilla**, *Proton Weak Captures on Proton and* ^3He, presented at the workshop *Nuclear Reactions in Stars and in the Laboratory*, European Center for Theoretical Studies in Nuclear Physics and Related Areas, Trento, Italy, February 1999

[127] **R. Schiavilla**, *Modern Potentials and the Electromagnetic Structure of the Deuteron*, presented at the workshop *Quantum Monte Carlo Methods*, University of Illinois at Urbana-Champaign, Urbana, Illinois, May 1999

[128] **R. Schiavilla**, *Interactions, Currents and the Electromagnetic Structure of the Deuteron at the Order* $(v/c)^2$, presented at the symposium *Current Topics in the Field of Light Nuclei*, Jagellonian University, Cracow, Poland, June 1999

[129] **R. Schiavilla**, *Electromagnetic Structure of the Deuteron*, presented at the workshop *The Nuclear Interaction: Modern Developments*, European Center for Theoretical Studies in Nuclear Physics and Related Areas, Trento, Italy, July 1999

[130] **R. Schiavilla**, *Electromagnetic Structure of the Trinucleons: a Theorist's Perspective*, presented at the workshop *Experiments with Tritium at Jlab*, Jefferson Lab, September 1999

[131] **R. Schiavilla**, *Electromagnetic Structure of Light Nuclei*, presented at the workshop *Nucleon-Nucleon Correlations in Nuclei and Quark Correlations in the Proton*, Santorini, Greece, October 1999

[132] **R. Schiavilla**, *Electroweak Interactions for Astrophysics*, presented at the Fall meeting of the Division of Nuclear Physics of the American Physical Society, Asilomar, Pacific Grove, California, October 1999

[133] **R. Schiavilla**, *Exchange Current Effects in Nuclei*, presented at the *Few-Nucleon Working Group–Chiral Dynamics 2000*, Jefferson Lab, Newport News, Virginia, July 2000

[134] **R. Schiavilla**, *Ab Initio Microscopic Calculations of Capture Reactions*, presented at the mini-symposium *Nuclear Structure Applications*, Fall meeting of the Division of Nuclear Physics of the American Physical Society, Williamsburgh, Virginia, October 2000
[135] **J. W. Van Orden**,*The deuteron in the light of the new data from Jefferson Lab*, Jefferson Lab Users Group Meeting, June 24, 1999.
[136] **J. W. Van Orden**, *Deuteron Calculations with the Gross Equation*, International Workshop on Relativistic dynamics and few-hadron systems, ECT*, Trento, Italy, November 17, 2000

D. REVIEWS, EDITORSHIPS. AND MAJOR PROPOSALS (1999 and 2000)

[137] **R. G. Edwards**, U.M Heller, R. Narayanan, *Chiral Fermions on the Lattice*, FSU-SCRI-98-24, hep-lat/9905028, Parallel Computing **25**, 1395 (1999).
[138] *Strong Interactions at Low and Intermediate Energies*, **J. L. Goity** Editor. World Scientific (2000).
[139] *Hadronic Structure*, **J. L. Goity** Editor. World Scientific (2000).
[140] The Lattice Hadron Physics Collaboration, *Nuclear Theory with Lattice QCD: A Proposal to use Lattice QCD to Understand the Structure and Interactions of Hadrons*, submitted to the U.S. Dept. of Energy, March 2000.

APPENDICES

A. WORKSHOPS FUNDED JOINTLY WITH INT

May 19-22, 1999	Exclusive and Semi-Exclusive Processes at High Momentum Transfer
July 17-22, 2000	Chiral Dynamics 2000: Theory and Experiment

B. LONG TERM VISITORS IN 1999 – 2000

Wally Melnitchouk	Adelaide University	9/1/99-1/01
Steve Wallace	University of Maryland	8/99-8/00
Chris Michael	University of Liverpool	10/9-12/18/00
David Ernst	Vanderbilt Univesity	9/1/00-8/01
Inna Aznauryan	Yerevan Physics Institute	5/1-10/1/99
		2/13-8/13/00
Carlos Schat	Argentina (CONICET)	9/00-9/02

C. SHORT TERM VISITORS IN 1999 – 2000

Wally Melnitchouk	University of Adelaide	1/17-2/1/99
Veljko Dmitrasinovic	University of South Carolina	1/19-1/21
John Tjon	University of Utrecht	2/9-2/20
Alfons Buchmann	University of Tubingen	2/15-2/28
Fabrizio Gabbiani	Duke University	2/21-2/23
Nikolai Uraltsev	University of Notre Dame	2/28-3/8
Emil Truhlik	Czech Academy of Science	3/1-3/31
Daniel Phillips	University of Washington	3/14-3/16
Robert Edwards	Florida State University	3/28-3/30
Inna Aznauryan	Yerevan Physics Institute	5/1-10/1
William Donnelly	Center for Theoretical Physics M.I.T.	5/5-5/10
Ted Barnes	Oak Ridge National Lab	6/13-6/15
Nicolaj Merenkov	Kharkov Institute of Physics	6/16-8/31
Norberto Scoccola	Physics Dept-CNEA-Argentina	6/21-7/1
Jean-Marc Laget	University of Saclay	7/9-9/7
David Ernst	Vanderbilt University	7/13-7/23
Frank Close	CERN	7/14-7/16
John Tjon	University of Utrecht	8/4-8/28
Robert Edwards	Florida State University	8/23-8/29
Hans-Christian Pauli	MPI Kernphysik Heidelberg	9/22-9/25
Omar Benhar	INFN Sezione Roma 1	9/27-10/3
Dieter Drechsel	Johannes Gutenberg-Universitaet Mainz	9/30-10/30
Alexey Petrov	Johns Hopkins University	10/10-10/15
Manuel Malheiro	Universidade Federal Fluminense Brazil	10/17-10/23
Jiri Adam	Institute of Nuclear Physics, Czech Republic	11/08-11/28
Jose Udias	Universidad Complutense de' Madrid	11/11-11/12
Michele Viviani	INFN Sezione di Pisa	11/23-11/30
Alejandro Kievsky	Duke University	11/25-11/27
Urs Heller	Florida State University	11/28-12/02
Andrew Pochinsky	Massachusetts Institute of Technology	11/28-12/03
Ted Barnes	Los Alamos National Lab	12/01-12/14
Daniel Phillips	University of Washington	12/06-12/22
Wayne Polyzou	University of Iowa	12/11-12/14
Robert Wiringa	Argonne National Lab	12/12-12/19
Philip Page	Los Alamos National Lab	01/09-01/16/00
Keh-Fei Liu	University of Kentucky	02/09-02/10
Teresa Pena	University de Lisboa	02/13-02/26
Alfred Stadler	University de Lisboa	02/13-02/26
Joe Carlson	Los Alamos National Lab	02/18-02/24
Vladimer Braun	Regensburg University	03/06-03/20
Carlos Ordonez	University of Houston	03/07-03/12
Dan-Olof Riska	University of Helsinki	03/22-03/26
Stefano Capitani	Massachusetts Institute of Technology	03/25-03/31
Jerrold Franklin	Temple University	04/01-04/04
Guiseppina Orlandini	University of Trento	05/02-05/05
Andrei Belitsky	ITP, State Univ. of New York at Stony Brook	05/21-05/27
John Tjon	University of Utrecht	06/02-07/01
Jean-Marc Laget	SACLAY	06/19-07/02

C. SHORT TERM VISITORS IN 1999 – 2000 (cont'd)

Fernando Steffens	University of Sao Paulo	07/10-07/20
Giovanni Salme	INFN-Sezione Roma 1	07/13-07/20
Joe Carlson	Los Alamos National Lab	07/13-07/21
Leonid Glozman	GRAZ University	07/26-07/30
John Negele	Massachusetts Institute of Technology	07/24-07/28
Anthony Williams	University of Adelaide	08/06-08/08
Reinhard Alkofer	University of Tuebingen	08/27-08/29
Dieter Dreschel	University Mainz, Germany	09/26-10/14
Jochen Heisenberg	University of New Hampshire	10/22-10/24
Noam Shoresh	University of Washington	10/28-10/30
Noberto Scoccola	Physics Dept-CNEA-Argentina	11/20-12/02
Jiri Adam	Institute of Nuclear Physics, Prague	11/27-12/18

D. THEORY SEMINARS IN 1999 – 2000

Veljko Dmitrasinovic, University of South Carolina, 1/20/99
Scalar Mesons and Axial Baryon Number Nonconservation.

Fabrizio Gabbiani, Duke University, 2/22/99
Rare Kaon Decays in Chiral Perturbation Theory

Alfons Buchmann, University of Tubingen, 2/23/99
The $N \to \Delta$ Quadrupole Transition and the Deformation of the Nucleon

Gunther Piller, SLAC,
Exclusive Electroproduction of Mesons from Nucleons

Daniel Phillips, University of Washington, 3/15/99
Probing the Effectiveness: Effective Field Theory Calculations of Electron-Deuteron and Photon-Deuteron Scattering

Ivan Horvath, University of Virginia, 3/19/99
Chiral Symmetry, Dynamical Fermions and Lattice QCD

Robert G. Edwards, Florida State University, 3/29/99
Improved Actions in Lattice QCD

Nikolai Uraltsev, University of Notre Dame
Heavy Quarks in QCD: When Nonperturbative QCD Can Become Tractable, 4/12/99
The Heavy Quark Expansion in Dynamics, 4/19/99
Challenges in the Heavy Quark Expansion: Local Duality and It's Violations, 4/26/99

T. W. Donnelly, Center for Theoretical Physics M.I.T., 5/10/99
Scaling and Superscaling Violations

D. THEORY SEMINARS IN 1999 – 2000 (cont'd)

Ted Barnes, Theor. Physics ORNL and U. Tenn., 6/14/99
BB Intermeson Potentials: The Simplest Problem in Nuclear Physics

Norberto Scoccola, Physics Dept - CNEA- Argentina, 6/28/99
Hyperon Properties in the Skyrme Model

Steve Mintz, Florida International University, 7/12/99
The Reaction $e^- + p \longrightarrow \Lambda + \nu$ *and the*
Contributions of the Individual Form Factors to the Differential Cross Section

Frank Close, CERN, 7/16/99
Glueballs and the Pomeron: A Central Mystery

David Ernst, Vanderbilt University, 7/20/99
Mesons-Nucleus Scattering: Are the Properties of the Nucleon Modified by the Nuclear Medium?

Inna Aznauryan, Yerevan Physics Institute, 7/21/99
The Correspondence Between Dispersion Relations, Dynamical Models
and Effective Lagrangians in the Photo-and -Electroproduction

Michael Ramsey-Musolf, University of Connecticut
Electric Dipole Moments, and the Mass Scale of New T-odd, P-even Interactions, 7/22/99
Strange Quark Form Factors: Theoretical Status, 8/4/99

Robert Edwards, Florida State University, 8/24/99
Chiral Fermions Via the Overlap and Domain Wall Formulations

Elena Gubankova, North Carolina State University, 8/30/99
Flow Equations for Solving QCD Bound State Problem

Hans-Christian Pauli, MPI Kernphysik Heidelberg, 9/22/99
On the Effective $q\bar{q}$*-Interaction in Mesons Obtained From Front Form QCD*

Omar Benhar, INFN Sezione Roma 1, 9/29/99
The Imprint of the Equation of State on the Axial W-Modes of Oscillating Neutron Stars

Manuel Malheiro, Universidade Federal Fluminense, 10/18/99
Compton Scattering on the Deuteron in Baryon Chiral Perturbation Theory

Urs Heller, SCRI, Florida Statae University, 11/29/99
Some Results from Lattice QCD Simulations

Martin Olsson, University of Wisconsin, Madison, 12/8/99
QCD Strings and Scalar Confinement

Wayne Polyzou, University of Iowa, 12/13/99
The Point-Form Impulse Approximation-Applications to Elastic Electron-Deuteron Scattering

Philip Page, Los Alamos National Laboratory, 1/10/00
Exact Symmetry of Large N_c QCD

Keh-Fei Liu, University of Kentucky, 2/9/00
Parton Degrees of Freedom From Path-Integral Formalism

Vladimir Braun, University of Regensburg
Baryon Wave Functions in QCD and Integrable Models, 3/9/00
Light Cone Sum Rules for Exclusive Processes in the General GeV Region, 3/13/00

Stephen Wallace, University of Maryland, 3/20/00
Transition from Hadronic to Partonic Interactions for a Composite Spin-1/2 Model of a Nucleon

Stefano Capitani, MIT, 3/27/00
Lattice Renormalization and Calculation of Nucleon Form Factors

Michael Ramsey-Musolf, University of Connecticut, 3/29/00
Electrons, New Physics, and the Future of Parity Violation

Jerrold Franklin, Temple University, 4/3/00
Magnetic Moments

Philip Page, Los Alamos National Laboratory, 5/2/00
Relativistic Symmetry Suppresses Quark Spin-Orbit Splitting and (Field) Symmetrization Selection Rules

Giuseppina Orlandini, University of Trento, 5/3/00
Role of NNN Force in 3-Body Photodisintegration

Simonetta Liuti, University of Virginia, 5/15/00
From Partons to Constituent Quarks

Andrei Belitsky, ITP, State Univ of New York, 5/22/00
Asymmetries in DVCS and Skewed Parton Distributions

Jean Marc Laget, SACLAY, 6/26/00
Hard and Semi-Hard Processes

Derek Leinweber, CSSM University of Adelaide, 7/6/00
Constituent Quarks, Chiral Symmetry and the Strange-Quark Contribution to the Nucleon Magnetic Moment

Fernando Steffens, University of Sao Paulo, 7/12/00
The Pauli Principle in the Proton Sea

Giovanni Salme', INFN-Sezione Roma I, 7/14/00
Poincaré Convariant Current Operator and Elastic Electron-Deuteron Scattering in the Front-form Hamiltonian Dynamics

D. THEORY SEMINARS IN 1999 – 2000 (cont'd)

Eulogio Oset, University of Valencia, 7/31/00
Chiral Unitary Approach to Kbar N and Kbar Nucleus Interaction:
Application to K^- Atoms, Scalar Mesons in a Nuclear Medium and Phi Decay in Nuclei

Anthony Williams, University of Adelaide, 8/7/00
Calculations of gluon and Quark Propagators - What can be Learnt?

Reinhard Alkofer, University of Tuebingen, 8/28/00
What the Infrared Behavior of QCD Green's Functions Can Tell Us About the Confinement Mechanism(s) in Convariant Gauges

Stefan Schramm, University of Frankfurt, 10/23/00
Semiclassical QCD on the Lattice

Jochen Heisenberg, University of New Hampshire, 10/23/00
Tackling the Many Body Problem of the Nucleus:
"Exact" Solutions to the Schroedinger Equation

Noam Shoresh, University of Washington, 10/30/00
Physical Results from Unphysical Simulations

George Fleming, Ohio State University, 11/13/00
Applications of Dynamical Domain Wall Fermions

Dick Furnstahl, Ohio State University, 12/11/00
Effective Field Theory for Many-Body Systems

E. THEORY MINI-LECTURE SERIES IN 1999 – 2000

Wally Melnitchouk, FZ-Juelich, 1/25-1/29/99
Quark asymmetries in the nucleon

David Richards, ODU/JLAB, 5/3-5/7/99
Lattice Gauge Theory-QCD from Quarks to Hadrons

Dieter Drechsel, Johannes Gutenberg-Universitatet, 10/4-10/8/99
The Spin Structure of the Nucleon in the Resonance Region

John W. Negele, Massachusettes Institute of Technology, 7/24-7/28/00
Insight into the Role of Instantons from Lattice QCD