

Jefferson Laboratory Theory Group

Science and Technology Review

July 15, 2002

Rocco Schiavilla

Interim Theory Group Leader

- People
- Science: Research program (broad overview)
Selection of recent accomplishments
Productivity and impact
- Support for JLab (current and planned) experimental programs
- Nurturing postdocs and graduate students
- Summary
- Appendices: Profiles of senior staff
List of publications in 00-01



JLab Theory Group: Staff

- 4 full-time senior staff (4 FTE)

Robert Edwards (*lattice gauge theory*)

David Richards (*lattice gauge theory*)

Distinguished Visiting Fellow: Yuri Simonov (ITEP), Oct 01-Apr 02
Stan Brodsky (SLAC), Jan 03-Jun 03

Theory Group Leader (to be filled, R. Schiavilla acting)

- 7 senior staff with joint appointments (3.5 FTE)

Ian Balitsky (ODU)

Jose Goity (Hampton)

Franz Gross[#] (W&M)

Anatoly Radyushkin (ODU)

Winston Roberts (ODU)

Rocco Schiavilla (ODU)

Wally Van Orden (ODU)

- 3 JLab postdoctoral fellows (3 FTE)

Deirdre Black (Ph.D. 01, Syracuse) - from Oct 01 to present

Igor Musatov (Ph.D. 99, ODU) - from Oct 01 to present

Wally Melnitchouk[&] (Ph.D. 93, Adelaide) - from Aug 01 to Sep 02

George Fleming (Ph.D. 00, Columbia) - from Oct 02

retires from W&M in 02, but stays on 1/2 time at JLab

& after Sep 02, supported 25% by Theory, 75% by Halls A, B, C in FY 03



JLab Theory Group: Associate Staff

- 4 active senior staff (100% university support, 0 FTE)
 - Carl Carlson (W&M)
 - Chris Carone (W&M)
 - Marc Sher (W&M)
 - Peter Agbakpe (NSU)
- 3 sabbatical visitors (supported by JLab)
 - Peter Blunden (Manitoba) - from Sep 02 (one year)
 - Carl Carlson (W&M) - from Jul 02 (one year)
 - John Tjon (Utrecht) - from Aug 02 (six months) and from Aug 03 (six months)
- 2 postdoctoral fellows (supported by external funding)
 - Carlos Schat[#] (Hampton/Argentina-CONICET/JLab) from Sep 00
 - Bogdan Mihaila (W&M, Gross' DOE grant) from Oct 02
- 5 graduate students (3 supported by JLab) and 1 visiting graduate student (supported by external funding)

[#]At Duke after Sep 02 as a Postdoctoral Fellow



The JLab Theory Group Expansion

- JLab has followed through with a commitment to expand Theory Group
- In FY 01-02, 4 new FTE:
 - 1 Distinguished Visiting Fellow - to broaden the group's research interests and to collaborate with Theory Group members[#]
 - 2 senior staff scientists - to lead the Lattice Hadron Physics Collaboration (LHPC)
 - 1 postdoctoral fellow - to support and encourage young theorists entering the field
- In FY 03-04, 1 new FTE:
 - 2 joint positions with W&M in hadronic and nuclear theory
 - Nathan Isgur Distinguished Postdoctoral Fellow, funded by SURA (possibly a theorist)

[#] *case in point: Simonov-Gross and Simonov-Musatov collaborations; Simonov's mini-lecture series (3 lectures) and study group on the QCD correlator method (6 lectures)*



JLab Theory Group Research Activity: An Integrated Synopsis - I

- How quarks and gluons bind together to form hadrons
 - Solving QCD in the nonperturbative regime:
 - Lattice gauge theory (Edwards, Richards, Melnitchouk)
 - Field-correlator method (Simonov)
 - Solving QCD at the boundary between the perturbative and nonperturbative regimes:
 - Sum rule techniques (Balitsky, Radyushkin)
 - Hadronic form factors, quark-gluon distribution functions, and duality (Radyushkin, Balitsky, Carlson, Melnitchouk, Musatov, Edwards, Richards)
 - Understanding and modeling the mechanism of confinement and the structure and decay of hadrons:
 - Heavy-quark effective theory (Roberts, Goity)
 - Chiral dynamics and large N_c QCD (Goity, Black, Carone, Gross, Roberts)
 - Relativistic and nonrelativistic quark models (Goity, Gross, Roberts, Van Orden)



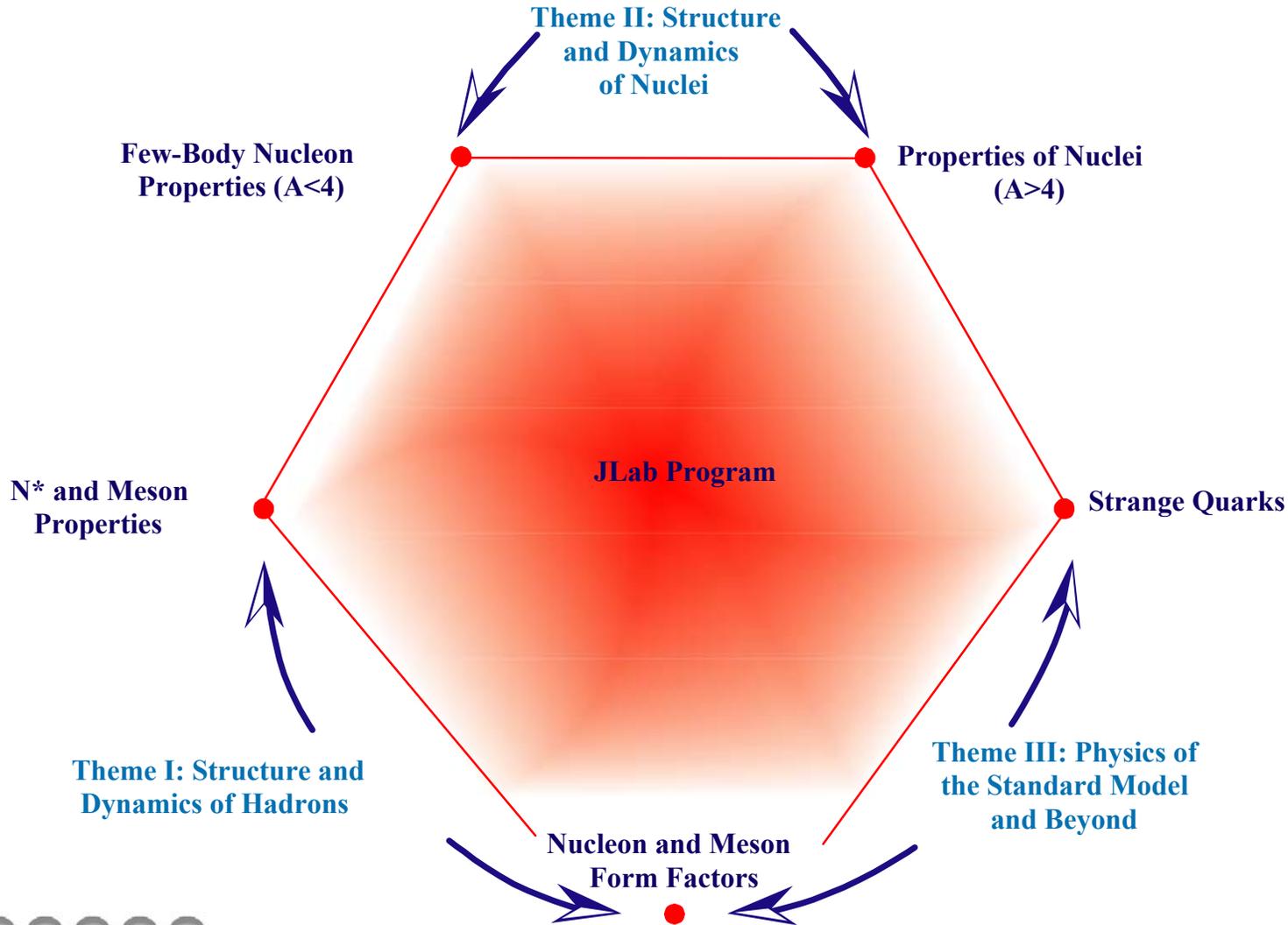
JLab Theory Group Research Activity: An Integrated Synopsis - II

- How nucleons bind together to form nuclei
 - Constructing nuclear interactions and currents
 - One-boson-exchange phenomenology and similar (Gross, Schiavilla, Van Orden)
 - Effective field theory approach (Goity)
 - Understanding quantitatively the structure and reactions of nuclei from the underlying NN (and NNN) interactions and currents
 - Relativistic approaches to nuclear dynamics (Gross, Schiavilla, Van Orden)
 - Form factors and weak transitions in few-nucleon systems (Gross, Schiavilla, Van Orden)
 - Nuclear reactions of astrophysical interest (Schiavilla)
- The standard model and beyond (Black, Carlson, Carone, Sher)
 - Constraints on lepton-flavor mixing from experiments
 - Effects of TeV-scale physics on low-energy parity violating observables
 - Signals for new light particles (e.g., gluinos) at JLab



JLab Theory Group Research Activity: An Integrated Synopsis - III

How Theory Group research matches the JLab current program



Thomas Jefferson National Accelerator Facility

Review of Theory Group Recent Accomplishments

Brief review of 3 recent results:

- Lattice Hadron Physics Collaboration (LHPC): Goals and Current Status
 - Lattice gauge calculation of resonance masses
 - Progress on the hardware and software components of LHPC
- Generalized Parton Distributions (GPD's): Application to Compton scattering on the proton
- Weak-interaction effects in few-nucleon systems



Theory Group Role in the Lattice QCD Initiative

- DOE's SciDAC program has funded a three-year (FY 02-04) National Lattice QCD Initiative at the \$6M level; JLab fund allocation is \$1.9M
- Within this broader initiative, a Lattice Hadron Physics Collaboration (LHPC; 24 theorists from 15 institutions), led by JLab-MIT, has been formed
- Three components to the lattice effort, with crucial roles in each played by **Edwards and Richards**:
 - **Science component** - To understand quantitatively hadron structure and interactions from the underlying quark-gluon dynamics (spectroscopy of glueballs and hybrids, moments of structure functions, ...)
 - Relevant for experimental program and the planned Hall D for the 12 GeV Upgrade
 - **Software component** - to create a unified programming environment for achieving high efficiency on diverse multi-teraflop hardware
 - **Hardware component** - the lattice QCD strategic plan envisions JLab as one of three national centers capable of sustaining in excess of 7 Tflops/s by 2006

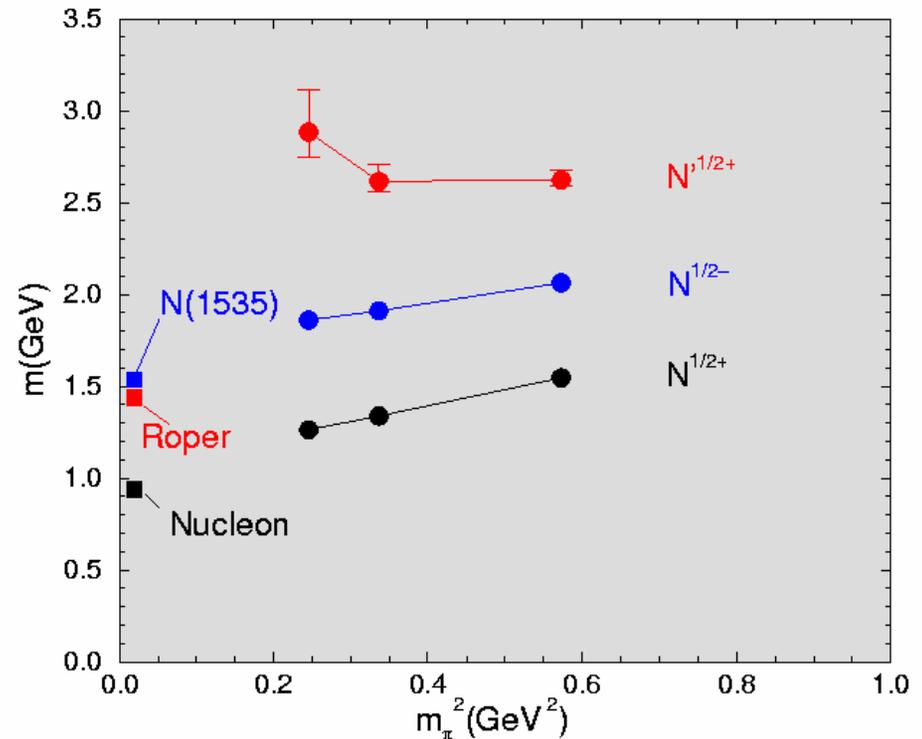


LHPC Progress I - Science Component

Lattice calculation of resonance masses[#]

- For lightest baryon masses, highly accurate quenched calculations
- Good control over systematic uncertainties associated with finite volume and finite lattice spacing
- First generation calculations of higher excited states
- Lattice calculations raising interesting challenges: nature of Roper and Lambda (1405)
- Need to extrapolate to light quark masses (pion mass) to explore chiral behavior (next slide)

J=1/2 Baryon Masses: Quenched Calculation



#Richards et al.

chiral limit



Thomas Jefferson National Accelerator Facility

LHPC Progress II - Software and Hardware Components

- Software and algorithm developments
 - **QCD-API**: portable programming interface for small and large computational platforms
 - Chiral ($m_q \rightarrow 0$) fermions on the lattice: **domain-wall construction**[#] to remove fermion flavor-doubling problem, and restore chiral symmetry
- Hardware
 - Procurement of 128 Pentium IV computing nodes and associated network is progressing; to be upgraded to 256 nodes by end of 02
 - Substantial computational resource (250 Gflops/s by end of 02) and prototype for next-generation facility

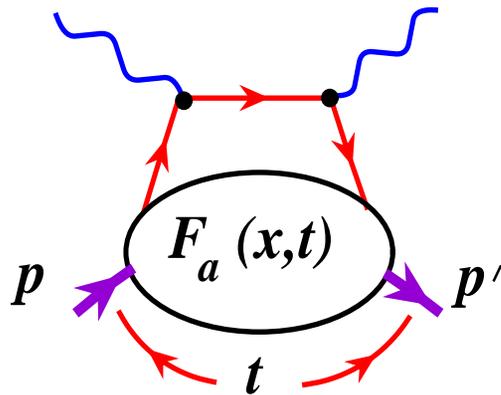
[#]Edwards and Heller



Thomas Jefferson National Accelerator Facility

GPDs and Wide Angle Compton Scattering on the Proton - I

- Generalized Parton Distributions (GPDs) model nonperturbative quark-gluon dynamics and lead to predictions for deeply exclusive scattering (DES) processes
- DES measurements of GPDs drive one of the campaigns in the 12 GeV upgrade program
- Compton scattering process described by "handbag" mechanism[#]:



$$\sum_a e_a^2 \int_0^1 F_a(x, t) \frac{dx}{x}$$

- GPD $F_a(x, t)$ parameterizes "soft" physics

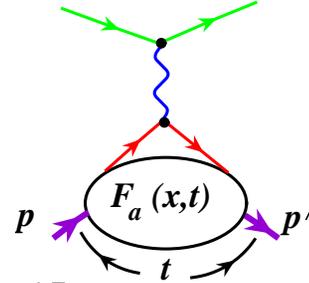
[#] *Kroll and Radyushkin*

GPDs and Wide Angle Compton Scattering on the Proton - II

Modeling $F_a(x,t)$:

i) $F_a(x,t) \rightarrow f_a(x)$ as $t \rightarrow 0$, $f_a(x)$ DIS parton distribution function; GPD formalism provides unified description of DIS and DES processes

ii) Consider e-p elastic scattering

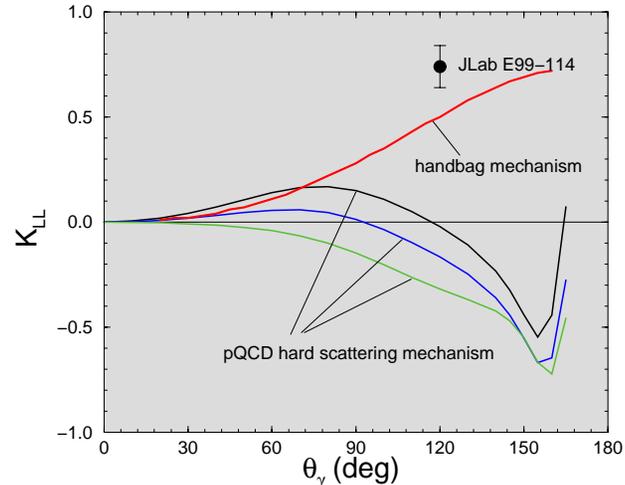
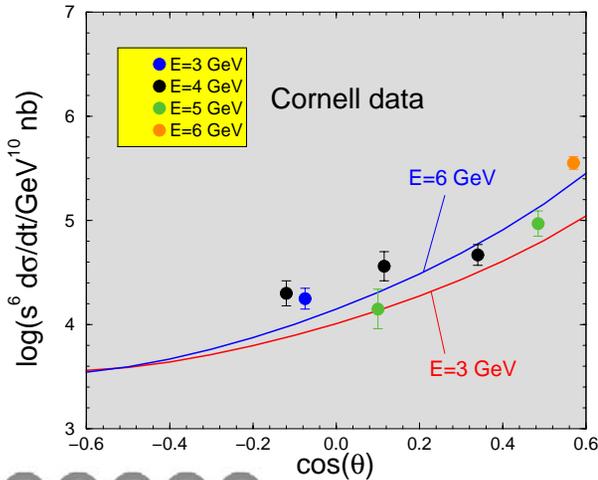


$$F_1(t) = \sum_a e_a \int_0^1 F_a(x,t) dx$$

i) + ii) $\rightarrow F_a(x,t) = f_a(x) \exp\left[t / (2x\lambda^2)\right]$ with λ from fitting proton $F_1(t)$

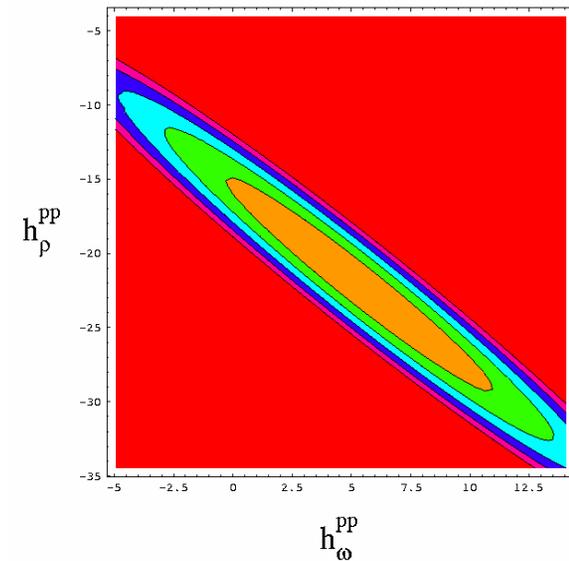
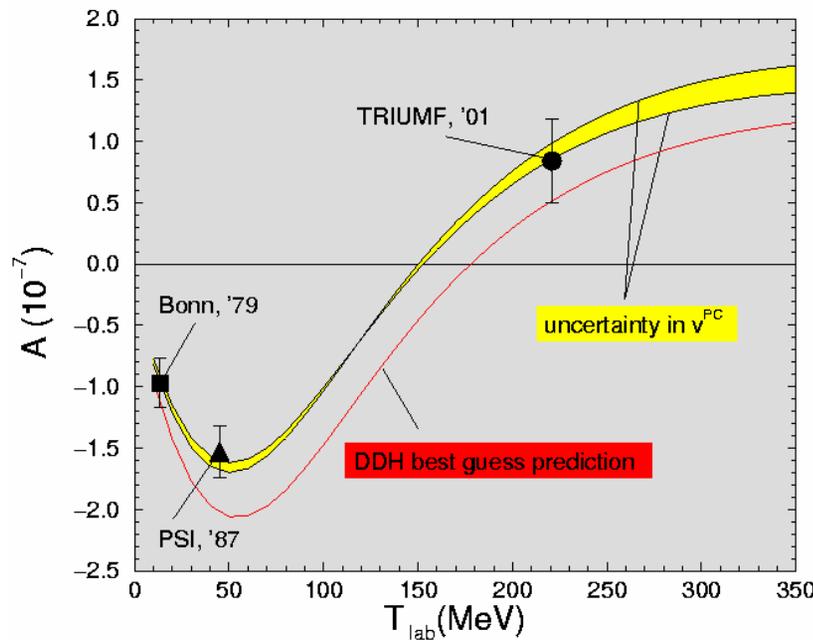
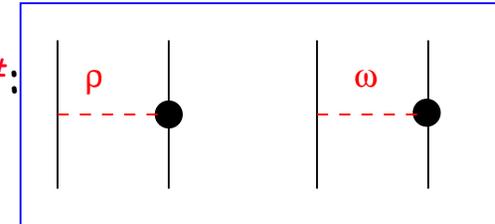
Compton Scattering

Polarization Transfer in Compton Scattering



Weak-Interaction Effects in Few-Nucleon Systems - I

- Weak interactions induce (tiny !) parity-violating (PV) components in the NN potential
- Recent work on pp elastic scattering, np radiative capture and deuteron electrodisintegration
- PV effects - longitudinal asymmetry in pp elastic scattering[#]:



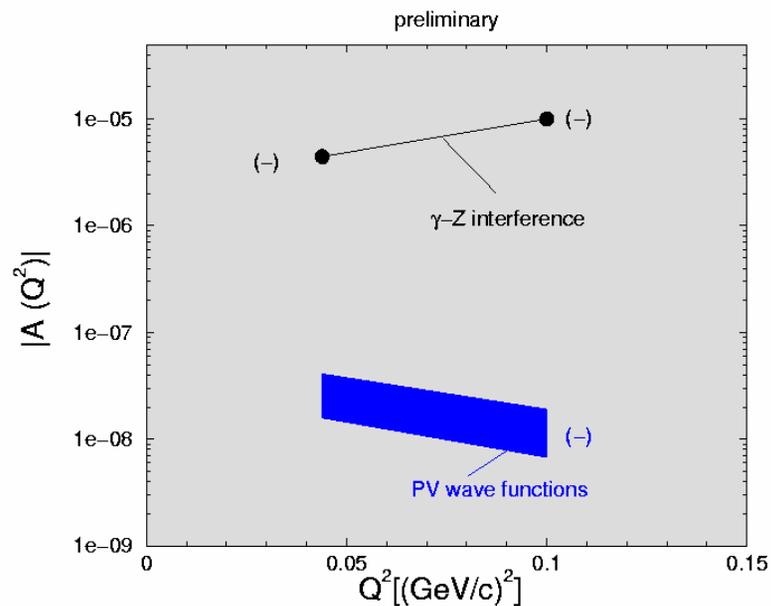
[#] Carlson, Schiavilla, Brown, and Gibson

Weak-Interaction Effects in Few-Nucleon Systems - II

PV effects - deuteron electrodisintegration in quasielastic kinematics[#]

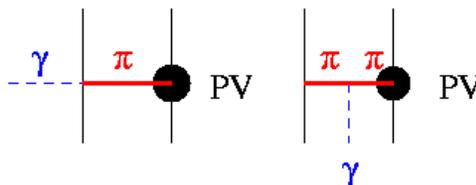
$$A = \frac{\left[\begin{array}{c} |f, PC\rangle \\ \gamma \\ |d, PC\rangle \end{array} \right]^* \left[\begin{array}{c} |f, PC\rangle \\ Z \\ |d, PC\rangle \\ + \\ \gamma \\ PV \end{array} \right]}{\left| \begin{array}{c} \gamma \\ |d, PC\rangle \end{array} \right|^2} + C.C.$$

Asymmetries at Quasi-Elastic Peak



γ -induced asymmetry due to:

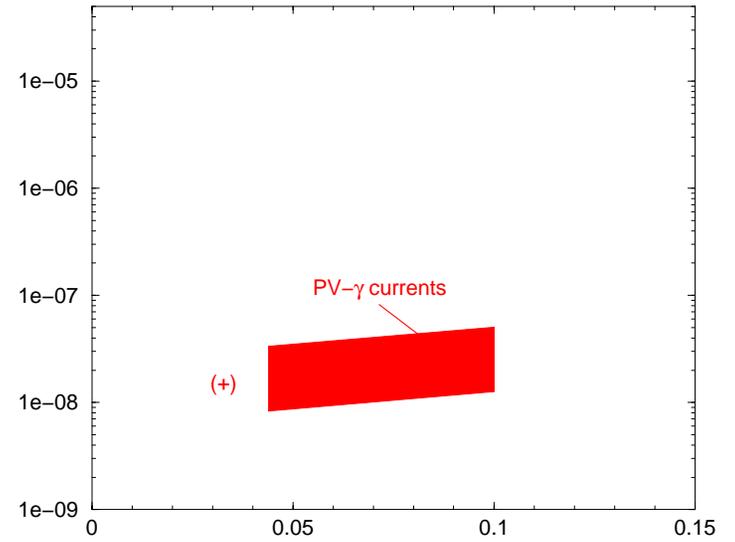
- PV components in w.f.'s
- PV components in EM current



[#] Carlson and Schiavilla



Thomas Jefferson National Accelerator Facility



Research Productivity and Impact

(Senior Staff and Postdoctoral Fellows Only)

- Publications listed in the 2001 Annual Report:
 - 24 publications in refereed journals and 2 (commissioned) review articles
 - 28 publications in conference proceedings (most invited)
 - 24 unpublished invited talks at major conferences/workshops
 - 21 seminars/colloquia at universities and labs around the world
- Active program of seminars, workshops, short- and long-term visitors (listed in the 2001 Annual Report)



JLab Theory Group: Support for the Experimental Program at JLab

- Strong theoretical support for the current experimental program(s) at JLab - from proposal to publication !
- Strong theoretical support for the 12 GeV upgrade proposal
 - Generalized Parton Distributions (GPDs) co-developed by Radyushkin
 - Study of hybrid hadrons proposed by the late Nathan Isgur
- Few-Body Initiative and Excited-Hadron Discussion Group[#] - joint theoretical/experimental seminars/informal meetings on few-body and hadron physics
- Mini-lecture Series - 3 lectures for experimentalists and graduate students on a topic relevant to the experimental program:
 - I. Aznauryan - Electro-production of pions (in support of the N* Program) (Aug 01)
 - J.-M. Laget - High energy meson photo-production and GPDs (Oct 01)
 - Yu. Simonov - The QCD vacuum and its imprint on normal and hybrid hadrons (Nov 01)
 - O. Benhar - Scaling in DIS and proton response (Mar 02)
 - Planned in 02/03: J. Tjon, C. Carlson and S. Brodsky
- Input to TAC and PAC on theory behind JLab experimental proposals

[#] *W. Melnitchouk played pivotal role*



Thomas Jefferson National Accelerator Facility

JLab Theory Group: Nurturing Postdocs and Graduate Students

- Good environment for postdocs and students, strengthened by the strong visitor and seminar programs, mini-lecture series, ...
- People who have completed their postdocs in the last three years:
 - J. Forest → "two-body problem", stay at home mom at present
 - S. Jeschonnek → Asst. Prof. (tenure-track), Ohio State University at Lima
 - R. Lebed → Asst. Prof. (tenure-track), Arizona State University
 - W. Melnitchouk → Physics Division Research Fellow at JLab
- Nine Ph.D.'s in the last four years (five of them in academic positions):
 - D. Krioukov, ODU 98 → Software company
 - M. Uzzo, W&M 98 → Research Scientist-Harvard Smithsonian Center for Astrophysics
 - L. Zhang, Hampton 98 → Oracle Corporation
 - I. Grigentch, ODU 99 → Software company
 - I. Musatov, ODU 99 → Postdoctoral Fellow, JLab Theory Group
 - P. Agbakpe, Hampton 00 → Asst. Prof. (tenure-track), Norfolk State University
 - L. Marcucci, ODU 00 → Researcher (tenure-track), University of Pisa, Italy
 - A. Rakotovao, ODU 00 → Back to Madagascar ?
 - Z. Batiz, W&M 01 → Postdoctoral Fellow, CFIF-Lisbon, Portugal
- Five students currently working towards their Ph.D.'s



JLab Theory Group: Summary

- Theory Group carries out a broad program of research in nuclear and hadronic physics with a number of different "tools"
 - Three themes: structure and dynamics of hadrons (1) and nuclei (2), and physics of the Standard Model and beyond (3)
 - Recent "tool" addition: lattice gauge theory
 - Best gauge of scientific quality is the research carried out so far[#]
- Theory Group actively supports the present and planned experimental program at JLab
 - Few-Body and Excited-Hadron Initiatives, and mini-lecture series
 - Its broad research program beneficial to other labs as well
- Theory Group provides a nurturing environment for postdocs and graduate students in both experiment and theory
 - Seminars, mini-lecture series, study groups
 - Strong program of short- and long-term visitors
- JLab provides strong support for theory (see slide 4).

[#] *see Appendices with senior staff profiles and publication list in 00-01*



Appendix: Profiles of Senior Staff-1

Ian Balitsky

- Ph.D., St. Petersburg, 1981
- Researcher, St. Petersburg Nuclear Physics Institute, 1980-1989
Senior Researcher, St. Petersburg Nuclear Physics Institute, 1989-1992
Postdoctoral Fellow, Penn State University, 1992-1995
Research Scientist, MIT, 1995-1996
Senior Staff/Assoc. Prof., JLab/ODU, 1996-present
- Author of 60 publications
- Research Highlights:
 - BFKL pomeron ($B \rightarrow$ Balitsky)
 - Sum rules for static hadronic properties
 - Nonlocal operator product expansion and light-cone sum rules
 - Valley method for instanton interactions
 - Spin structure of the proton
 - Small- x evolution in high density QCD



Appendix: Profiles of Senior Staff-2

Robert Edwards

- Ph.D., New York University, 1989
- Postdoctoral Research Scientist, SCRI-FSU, 1989-1992
Assistant Research Scientist, SCRI, 1992-1997
Associate Research Scientist, SCRI, 1997-1999
Senior Staff, JLab, 1999-present
- Honors: Gordon Bell Prize for Price Performance SC98 for the QCDSF Supercomputer, 1998
- Author of over 50 publications
- Research Highlights:
 - Spectroscopy studies in lattice QCD
 - Hadronic structure in lattice QCD
 - Chiral fermion development and studies in chiral symmetry breaking in gauge theories
 - Hardware and software development



Appendix: Profiles of Senior Staff-3

Jose` Goity

- Ph.D., University of Munich, 1985
- Postdoctoral Fellow at:
 - Max Planck Institute, 1984-1985
 - CNRS-Institute of Theoretical Physics, Marseilles, 1985-1986
 - Bern University, 1986-1988
 - Paul Scherrer Institute, 1988-1991
 - CEBAF, 1991-1993
- Senior Staff/Asst. Prof., JLab/Hampton, 1993-1998
- Senior Staff/Asst. Prof., JLab/Hampton, 1998-present
- Author of 50 publications
- Research Highlights:
 - Chiral perturbation theory with heavy quark symmetry
 - Chiral perturbation theory for light baryons
 - Strangeness in exchange currents using effective Lagrangians
 - Large N_c limit



Appendix: Profiles of Senior Staff-4

Franz Gross

- Ph.D., Princeton University, 1963
- Instructor-Research Associate, 1963-1966
- Asst. Prof., Cornell University, 1966-1969
- Assc. Prof., Cornell University, 1969-1970
- Assc. Prof., W&M, 1970-1976
- Prof., W&M, 1976-1986
- Senior Staff/Prof., JLab/W&M, 1985-present
- Honors: Sporn Award, Fullbright Fellow, Woodrow Wilson Fellow, Fellow of the American Physical Society
- Author of 122 publications and 1 book
- Research Highlights:
 - Relativistic theory of few body systems
 - Relativistic boson-exchange model of nuclear forces
 - Elastic and inelastic e-d scattering
 - Covariant calculations of three body bound states
 - Quark models for mesons
 - Exact solutions of field theories using the Feynman-Schwinger technique



Appendix: Profiles of Senior Staff-5

Anatoly Radyushkin

- Ph.D., Moscow State University, 1978
- Junior Scientist, JINR-Dubna, 1978-1983
Senior Scientist, JINR-Dubna, 1983-1988
Leading Scientist, JINR-Dubna, 1988-1992
Senior Staff/Prof., JLab/ODU, 1992-present
- Honors: Two Annual Awards at JINR-Dubna, Fellow of the American Physical Society, ODU Eminent Scholar, Alexander von Humboldt Award
- Author of 132 publications
- Research Highlights:
 - Factorization for hard inclusive processes and elastic form factors in QCD
 - QCD sum rules for form factors
 - Wilson loop/renormalization group approach to infrared behavior of QCD
 - Nonlocal condensate formalism in QCD sum rules
 - Deeply virtual exclusive processes in QCD and generalized parton distribution functions



Appendix: Profiles of Senior Staff-6

David Richards

- Ph.D., University of Cambridge, 1984
- Postdoctoral Fellow:
 - Southampton University, U.K., 1984-1986
 - Argonne National Laboratory, 1986-1988
 - University of Edinburgh, Scotland, 1988-1993
- PPARC Advanced Fellow, University of Edinburgh, Scotland, 1993-1999
- Senior Staff/Visiting Assc. Prof., JLab/ODU, 1999-2001
- Senior Staff, JLab, 2001-present
- Author of 59 publications
- Research Highlights:
 - Energy-energy correlations in QCD
 - Two-gluon exchange models of the pomeron and diffractive scattering
 - Spectroscopy of excited baryons from lattice QCD
 - Lattice QCD calculations of weak-interaction matrix elements and quark distribution amplitudes
 - Nucleon-nucleon interaction in lattice QCD



Appendix: Profiles of Senior Staff-7

Winston Roberts

- Ph.D., University of Guelph, 1988
- Visiting Researcher, Institut des Sciences Nucleaires, Grenoble, France, 1988-1989
- Postdoctoral Fellow, Harvard University, 1989-1991
- Senior Staff/Asst. Prof., JLab/ODU, 1991-1997
- Senior Staff/Asst. Prof., JLab/ODU, 1997-present
- NSF Program Manager for "Mathematical Physics" and "Nuclear Theory," 1998-2000
- Honors: Canada NSERC Postdoctoral Fellowship, NSF National Young Investigator Award (1994-1999)
- Author of 44 publications
- Research Highlights:
 - Expansion in $1/m_Q$ in heavy quark effective theory
 - Application of heavy quark symmetry to charm beta decay
 - Baryon resonances in the $3P_0$ decay model and the search for missing resonances



Appendix: Profiles of Senior Staff-8

Rocco Schiavilla

- Ph.D., University of Illinois at Urbana-Champaign, 1987
- Postdoctoral Fellow at:
 - DPHN/HE Saclay, 1987-1988
 - CEBAF, 1988-1990
 - Argonne National Laboratory, 1990-1992
 - Staff Scientist, INFN-Lecce, 1992-1993
 - Senior Staff/Asst. Prof., JLab/ODU, 1993-1999
 - Senior Staff/Assoc. Prof., JLab/ODU, 1999-2002
 - Senior Staff/Prof., JLab/ODU, 2002-present
- Honors: Enrico Fermi Scholar, Argonne Nat. Lab., 1990-1992
- Author of 78 publications
- Research Highlights:
 - Nuclear interactions and currents
 - Electro-weak structure and response of light nuclei
 - Weak and radiative capture reactions of astrophysical interest
 - Hamiltonian approach to relativistic dynamics
 - Exact quantum Monte Carlo methods for nuclei



Appendix: Profiles of Senior Staff-9

Wally Van Orden

- Ph.D., Stanford University, 1978
- Postdoctoral Fellow, University of Maryland, 1978-1981
Asst. Prof., University of Maryland, 1981-1987
Staff Scientist, CEBAF, 1987-1990
Senior Staff/Asst. Prof., JLab/ODU, 1990-1998
Senior Staff/Prof., JLab/ODU, 1998-present
- Author of 46 publications
- Research Highlights:
 - Relativistic models for elastic and quasi-elastic scattering from light nuclei
 - Covariant model for nucleon-nucleon scattering and application to elastic and quasi-elastic scattering
 - Relativistic constituent quark model of heavy mesons
 - Relativistic three-body systems

