Jefferson Laboratory Theory Group

Science and Technology Review

June 25, 2003

Rocco Schiavilla

Interim Theory Group Leader

- People
- Science: Research program (broad overview)
  Selection of recent results
  Research productivity
- Support for JLab experimental program(s): current status
  future opportunities
- Mentoring postdocs and graduate students
- Summary
- Appendices: Profiles of senior staff
  N* analysis center pre-proposal
  List of publications in 02

JLab Theory Group: Senior Staff

- 4.5 full-time staff (4.5 FTE)
  - Robert Edwards *(lattice gauge theory)*
  - Franz Gross#
  - David Richards *(lattice gauge theory)*

  Distinguished Visiting Fellow: Yuri Simonov (ITEP), Oct 01-Apr 02
  Stan Brodsky (SLAC), Jan 03-Jun 03
  Barry Holstein (UMass), Jan 04-Jun 04

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

- 7 staff with joint appointments (3.5 FTE)
  - Ian Balitsky (ODU)
  - Jose Goity (Hampton)
  - Anatoly Radyushkin (ODU)
  - Winston Roberts (ODU)
  - Rocco Schiavilla (ODU)
  - Marc Vanderhaeghen (W&M)
  - Wally Van Orden (ODU)

 # 1/2 time at JLab, retired from W&M

JLab Theory Group: Junior Staff

- 3 JLab postdoctoral fellows (3 FTE)

  Deirdre Black (Ph.D. 01, Syracuse) – from Oct 01 to Sep 03
  George Fleming (Ph.D. 00, Columbia) – from Oct 02 to Sep 04
  Igor Musatov (Ph.D. 99, ODU) – from Oct 01 to Sep 03
  Mark Paris (Ph.D. 01, UIUC) – from Nov 03
  Renato Higa (Ph.D. 03, São Paulo, Brazil) - from Oct 03

- Isgur Distinguished Postdoctoral Fellow (funded by SURA and JLab)

  Evgeny Epelbaum (Ph.D. 00, Bochum) – from Oct 03

- Physics Division Research Fellow

  Wally Melnitchouk# (Ph.D. 93, Adelaide) – from Sep 02 to present

  #supported 25% by Theory Group, 75 % by Halls A, B, and C

JLab Theory Group: Associate Staff

- 4 active senior staff (100% university support)
  - Carl Carlson (W&M)
  - Chris Carone (W&M)
  - Marc Sher (W&M)
  - Peter Agbakpe (NSU)

- 4 sabbatical visitors (supported by JLab)
  - P. Blunden (Manitoba) - from Sep 02 to May 03
  - C. Carlson (W&M) - from Jul 02 (one year)
  - J. Tjon (Utrecht) - from Aug 02 (six months) and from Aug 03 (six months)
  - B. Ananthanarayan (IIS, Bangalore) – from May 03 (six months)

- 1 postdoctoral fellow (supported by external funding)
  - Vladimir Pascalutsa (W&M, Gross' DOE grant) - from Oct 03

- 5 graduate students (3 supported by JLab) + 2 LSU graduate students (starting this fall, one supported by LSU and the other by a SURA Fellowship)

The JLab Theory Group Growth at a Glance

- JLab continues to provide strong support for the 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 02-03, 2.5 new FTE:
  - 1 joint position with W&M in hadronic theory: Marc Vanderhaeghen
  - 1 permanent position in phenomenology – closely coupled to the present and future experimental programs, to be filled by end of 2003
  - Isgur Distinguished Postdoctoral Fellow: Evgeny Epelbaum
- In FY 03-04 and beyond:
  - 1 additional joint position with W&M in hadronic/nuclear theory
  - support for Diakonov's nine-month sabbatical (Apr-Dec 04)
  - Establishment of a partial-wave analysis center (see slide 22)

JLab Theory Group Research Activity: A Synopsis - I

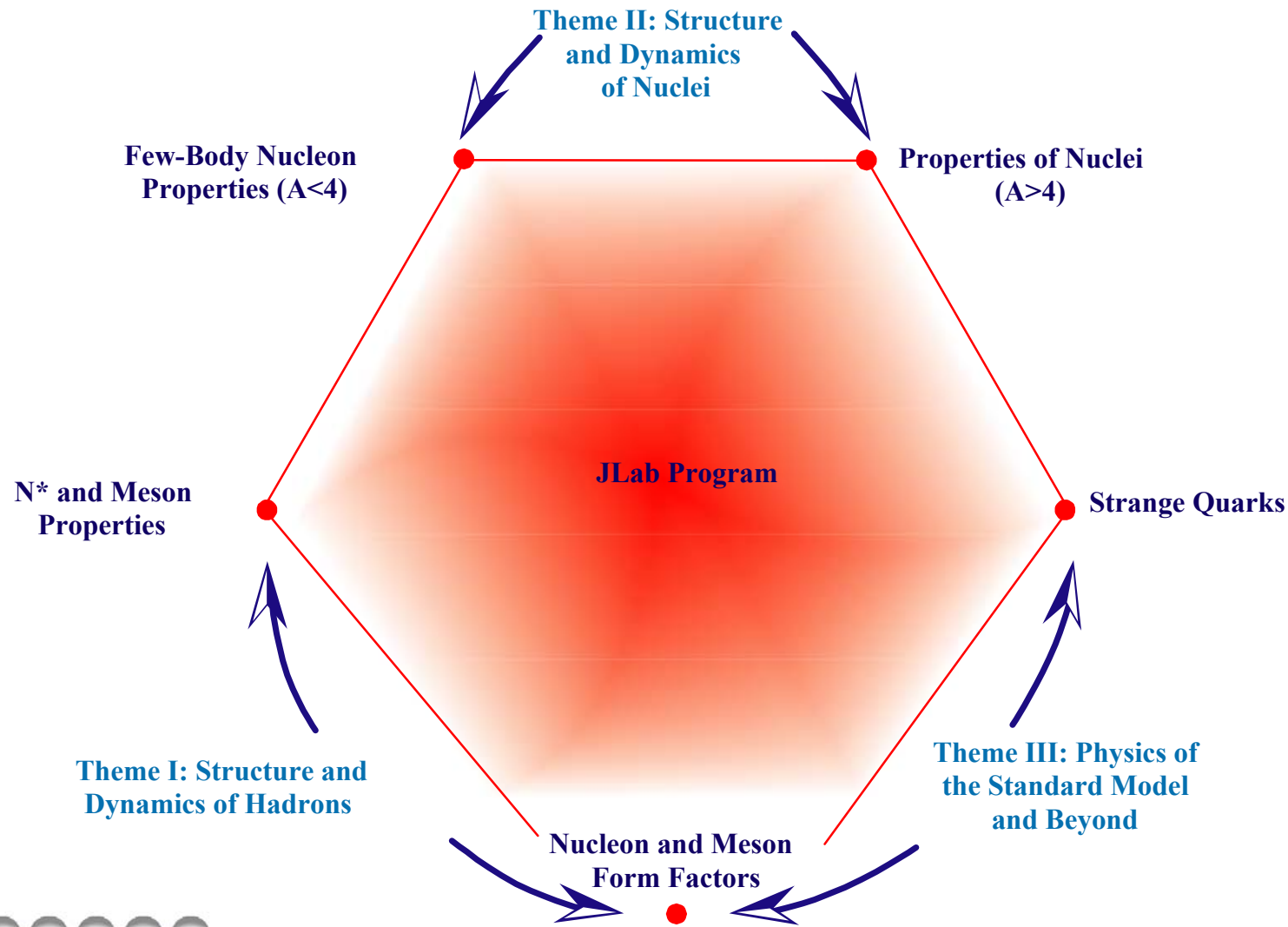
- How quarks and gluons bind together to form hadrons
  - Solving QCD in the nonperturbative regime:
    - Lattice gauge theory (Edwards, Fleming, Richards, Melnitchouk)
  - Solving QCD at the boundary between the perturbative and nonperturbative regimes:
    - Sum rule techniques (Balitsky, Radyushkin)
    - Hadronic form factors, quark-gluon distribution functions, and duality (Brodsky, Radyushkin, Vanderhaeghen, 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: A 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 (Epelbaum)
  - 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)
    - EFT studies of the structure of few-nucleon systems (Epelbaum, Gross, Schiavilla)
    - 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

JLab Theory Group Research Activity: A Synopsis - III

How Theory Group research matches the JLab current program



Review of Theory Group Recent Results

Brief review:

1. Lattice QCD initiative: goals and status
   - Hardware and software developments: SciDAC
   - Lattice calculation of moments of nucleon structure functions

2. Baryon structure in the large N_c limit

3. Relativistic dynamics of few-nucleon systems in the spectator (Gross) formalism

1. 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, hybrids and N* resonances, moments of structure functions and GPDs, …)
    - 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

1. Lattice QCD Initiative – Software and Hardware

- Software developments:
  - QCD-API: portable programming interface for diverse computational platforms. Development of QDP++, a C++ implementation, led by Edwards
  - Implementation of LHPC suite of physics being performed by Edwards, Fleming and Richards
- Hardware developments:
  - 128-node Pentium IV cluster connected by Myrinet commissioned in Sep 02; tackling key problems including moments of structure functions and GPDs
  - 256-node Pentium IV grid-based machine connected by GigE under order; aggregate computational capability of around 400 Gflops
  - Prototype machines for envisioned multi-Tflops facility

1. Lattice QCD Initiative – Science Component
Calculation of moments of structure functions-I

- Structure functions measure parton distribution close to light cone, and Euclidean space formulation of lattice QCD precludes direct measurement

- In the Operator Product Expansion, moments of un-polarized and polarized distribution functions

$$\langle x^n \rangle_q = \int_0^1 dx\, x^n [q(x) + (-1)^{n+1} \bar{q}(x)]$$

$$\langle x^n \rangle_{\Delta q} = \int_0^1 dx\, x^n [\Delta q(x) + (-1)^{n+1} \Delta \bar{q}(x)]$$

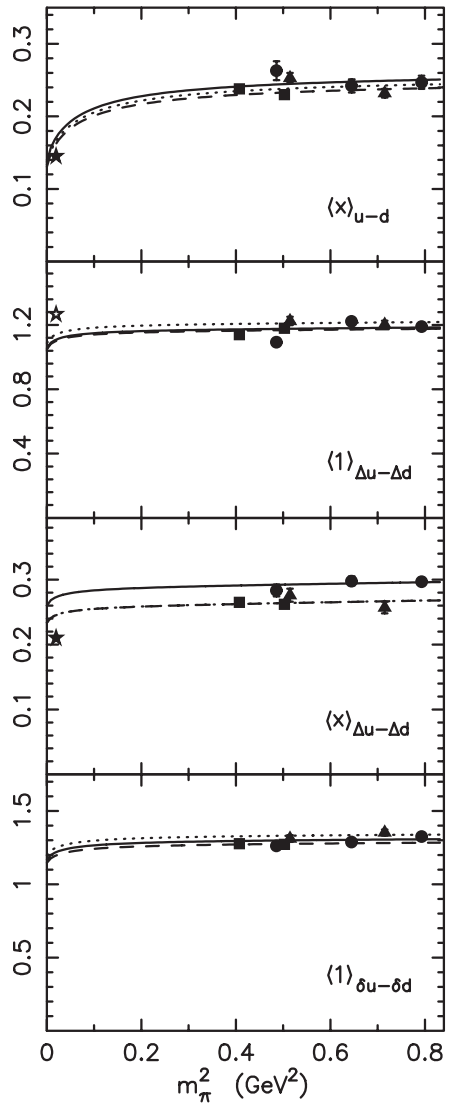
are related to matrix elements of local operators

$$\langle x^{n-1} \rangle \leftrightarrow \langle N | \overline{\psi} \gamma_{\{\mu_1} D_{\mu_2} \dots D_{\mu_n\}} \psi | N \rangle$$

- Moments can be computed on Euclidean lattices

1. Lattice QCD Initiative – Science Component
Calculation of moments of structure functions-II

- Importance of correctly including effect of pion cloud at light pion masses shown by Melnitchouk et al.; simulations should be performed near physical u- and d-quark masses, where this effect can emerge
- Domain-wall formulation of lattice fermions preserves analogue of chiral symmetry, while maintaining flavor identification
- Flavor-non-singlet momentum fraction carried by quarks of mass around that of s-quark shown to be compatible with experiment, Edwards et al.
- Large computational resources demands of domain-wall fermions being satisfied by 128-node and upcoming 256-node clusters
- Physics benefits from collaboration within SciDAC: calculations of DFs and GPDs using configurations generated by the MILC collaboration



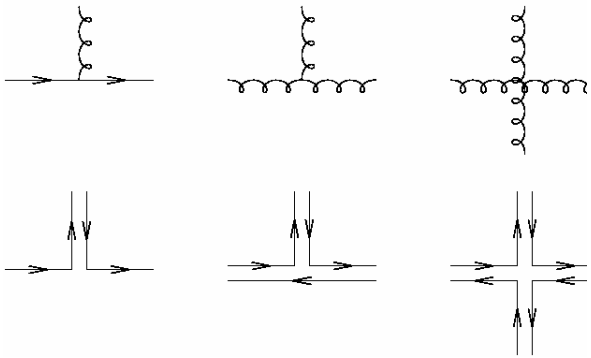
Moments of flavor non-singlet nucleon structure functions. Different symbols denote different lattice spacings, star denotes experimental value

2. Baryon Structure in the Large N_c Limit – I

- The large N_c limit attempts to create a framework for non-perturbative QCD in which systematic expansions for observables can be performed

- The infinite number of Feynman diagrams for a given process are organized into distinct classes based on the power of N_c arising in each, according to:

i)



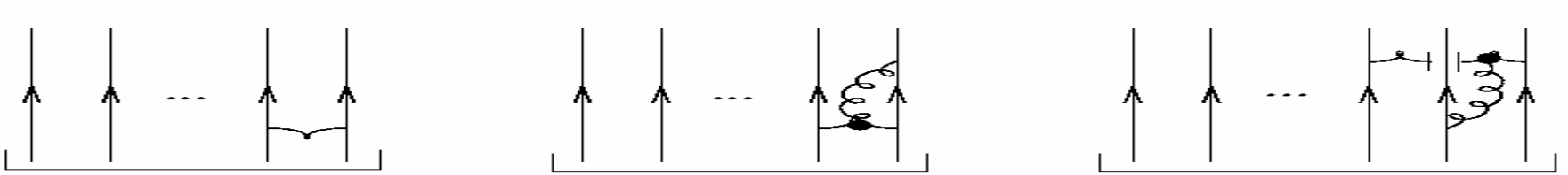
ii) α_S scales as $1/N_c$

iii) factors of N_c from color loops

- Baryons are made up of N_c quarks:

$$\frac{1}{\sqrt{N_c!}}\epsilon_{\alpha_1\alpha_2\ldots\alpha_{N_c}}\, q_{\alpha_1}(1)q_{\alpha_2}(2)\ldots q_{\alpha_{N_c}}(N_c), \quad \alpha_i \text{ is a color index}$$

- Baryon masses are ~ $(N_c)^1$, while their radii are ~ $(N_c)^0$; for example:

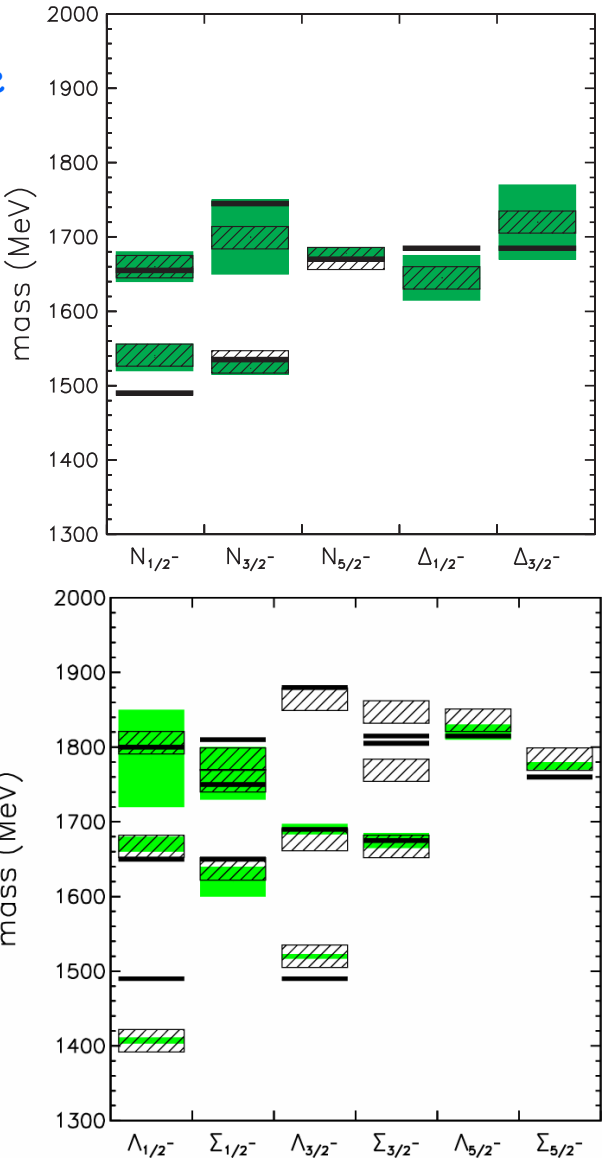


2. Baryon Structure in the Large N_c Limit – II

- Baryon observables are expressed as linear combinations of operators O_i acting on the quark spin-flavor d.o.f., for example

$$M = \sum_i c_i O_i$$

- Each operator O_i has a well defined $1/N_c$ power behavior from
  - i) counting the minimum number of gluons necessary for such an operator to appear in an interaction
  - ii) combinatoric powers of N_c if the N_c quarks contribute coherently to the operator's matrix element
- Some comments:
  - i) $\Lambda(1405)$ is the lightest N* despite containing a s-quark, since the hyperfine operator does not contribute to flavor-singlet states, but pushes all the others up by 200-300 MeV
  - ii) good fit to N(1535)-N(1650) and N(1520)-N(1700) splittings follows from flavor-dependent operators
  - iii) the spin-orbit coupling is not large, but nevertheless explains the $\Lambda(1520)$-$\Lambda(1405)$ splitting



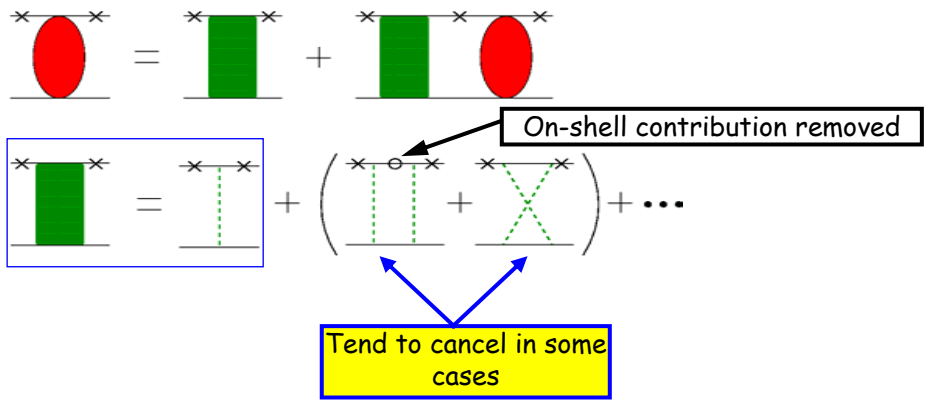
Masses of strangeness S=0 (upper panel) and S=-1 (lower panel) negative-parity excited baryons: green shaded areas correspond to experimental data, black solid lines are the Isgur-Karl QM predictions, and the hatched boxes are the $1/N_c$ results#

#Goity, Schat, and Scoccola, PRD 66, 114014 (2002)

3. Relativistic Dynamics of Few-Nucleon Systems in the Spectator (Gross) formalism – I

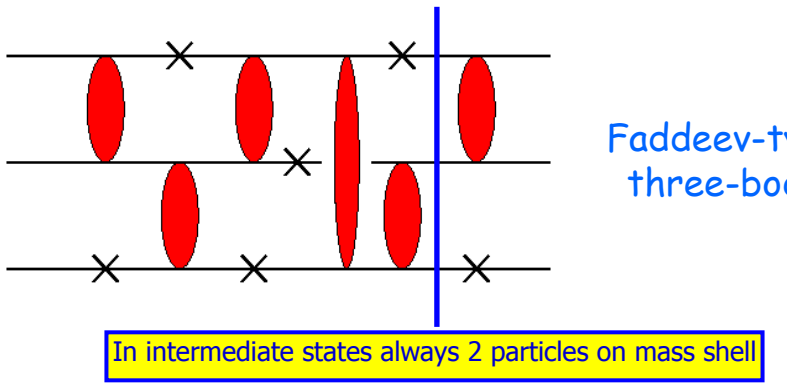
- The spectator formalism[#] provides a consistent framework for including relativity in the dynamics of few-nucleon systems:

i) Gross ladder approximation



OBE model with pseudo-scalar (π,η), scalar (σ,δ), and vector (ρ,ω) mesons, including off-shell couplings, constrained to fit NN data (see next slide)

ii)



Faddeev-type integral equation for three-body scattering amplitude

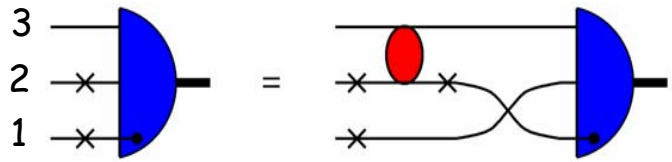
[#] *F. Gross, PR 186, 1448 (1969); PRD 10, 223 (1974); PRC 26, 2203 (1982)*

3. Relativistic Dynamics of Few-Nucleon Systems in the Spectator (Gross) formalism – II

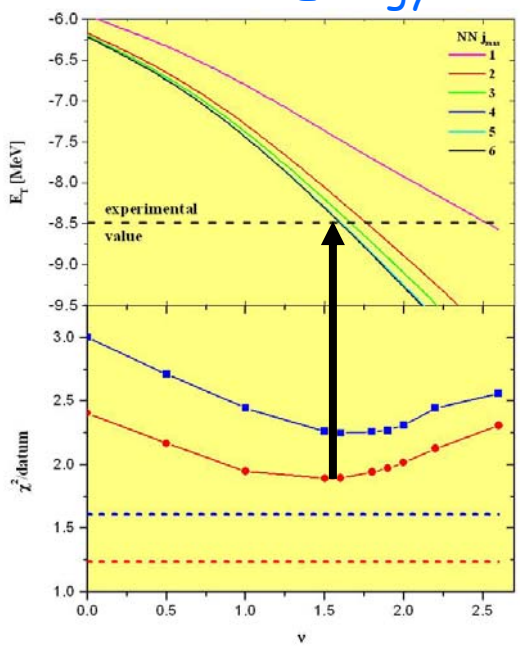
- Bound state energy is a pole in the scattering amplitude below threshold:

$$M = -\frac{\Gamma\overline{\Gamma}}{M_t^2 - P^2} + R$$

- Vertex function Γ satisfies a homogeneous integral equation:



Triton Energy#



closest to experimental binding energy

best NN fit

- OBE theory with off-shell couplings ~ OBE theory without off-shell couplings + many-body interactions

- Within manifestly covariant spectator theory:
  - i) consistent treatment of 2N and 3N systems
  - ii) realistic NN potentials available
  - iii) electromagnetic currents for three-nucleon systems derived&

#Stadler and Gross, PRL **78**, 26 (1997)

&Gross, Van Orden and collaborators, to be published

Research Productivity
(Senior and Junior Staff, and Postdoctoral Fellows Only)

- Publications and invited talks in 2002:
  - 32 publications in refereed journals
  - 33 publications in conference proceedings (most invited)
  - 25 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 2002 Annual Report)

Articulating the JLab Physics Program to the Community at Large: Role of Theory Group

- Published and/or commissioned review articles in last few years:

  Structure and Dynamics of Few-Nucleon Systems, Rev. Mod. Phys. **70**, 743 (1998)
  Quark Models of Baryon Masses and Decays, Prog. Part. Nucl. **45**, 241 (2001)
  The Deuteron: Structure and Form Factors, Adv. Nucl. Phys. **26**, 293 (2001)
  Generalized Parton Distributions, Handbook of QCD (World Scientific, 2001), ch. 19
  High-Energy QCD and Wilson Lines , Handbook of QCD (World Scientific, 2001), ch. 22
  Electromagnetic Structure of the Deuteron, J. Phys. *G* **28**, R37 (2002)
  Quark-Hadron Duality in Electron Scattering, to appear in Phys. Rep. (2003)
  Nuclear Effects in Deep Inelastic Scattering at High x, to appear in J. Phys. *G* (2004)
  Elastic Electron Scattering from Few-Body Systems, to appear in Ann. Rev. Nucl. Part. Sc. (2004)

- Membership in IACs and LOCs of major international conferences and workshops (02-03 selection): Baryon 2002, DPF2002, Lattice 2002, Nstar 2002, Exclusive Processes at High Momentum Transfer, Elba-VII, Few-Body XVII, INT Program on GPDs

- (Co-)Editorships of proceedings, books, etc. (01-03 selection): Chiral Dynamics:Theory and Experiment (World Scientific, 2001), Lepton Scattering, Hadrons and QCD (World Scientific, 2001), Lattice Hadron Physics (Nucl. Phys. Proc. Suppl. 109A, 2002), Electron-Nucleus Scattering VII (EPJ A, 2003)

- "Community" service: Roberts, NSAC member; Schiavilla, Chair Elect of APS Few-Body Topical Group

JLab Theory Group: Support for the Experimental Program at JLab - I

- Strong theoretical support for the current experimental program(s) at JLab (see following slide) – from proposal to publication !
- Strong theoretical support for the 12 GeV upgrade proposal:
  generalized parton distributions, study of hybrid hadrons, few-body program, Primex, …
- Excited-Hadron and Radiative-Corrections Discussion Groups# – joint theoretical/experimental seminars/informal meetings on hadron physics and on the treatment of radiative corrections in electron scattering
  # W. Melnitchouk played pivotal role
- Mini-lecture Series – 3 lectures for experimentalists and graduate students on a topic relevant to the experimental program:
  - J. Tjon – Relativistic hadron dynamics (Nov 02)
  - P. Blunden – Radiative corrections in electro-weak processes (Jan 03)
  - S. Brodsky – QCD phenomenology and light-front wave functions (Feb 03)
  - S. Reddy – Novel phases at high density and their role in the structure and evolution of of neutron stars (Apr 03)
  - Planned in Jul 03: C. Carlson on single-spin asymmetries
- Input to TAC and PAC on theory behind JLab experimental proposals

JLab Theory Group: Support for the Experimental Program at JLab - II

- Out of over 90 publications in the last three years, about 2/3 are directly related to specific experiments and/or aspects of the experimental program

- Leading role in organization of workshops and study groups, recent examples:

  workshops on Electron-Nucleus Scattering VII (2002) and Gluonic Excitations at JLab (2003), and the INT program on GPDs and Hard Exclusive Processes (2003)

  study group on radiative corrections led to a very productive interaction between experimentalists and theorists (contribution of box and crossed-box diagrams on Rosenbluth separation …)

- A significant portion of Theory Group resources are devoted to support long-term visiting theorists working in projects very closely coupled to experiments and/or experimental programs, a few recent examples:

  Laget [2 months, (e,e'p) on few-body nuclei], Aznauryan [2 months, N*], Bonnet [6 months, pion form factor lattice calculation], Stadler and Pena [6 weeks, electro-disintegration of ^{3}He in the spectator- equation formalism], Close [2 months, hybrid mesons], …

Expanding Theory Group Support of JLab Experimental Program: the N* Analysis Center - I

A proposal for the establishment of an N* analysis center at JLab[#]

- **Role:** to develop, maintain, and update the theoretical and computational tools necessary to carry-out analysis of the large body of data associated with the N* program

- **Scientific relevance:** to identify N* resonances and map-out their electromagnetic couplings, thus providing: i) comparison with results from LQCD calculations, ii) constraints on and insights into the modeling of baryons, in particular in connection with the "missing resonance" problem

- **Critical theoretical issues:**
  - i) background-resonance separation
  - ii) incorporation of multi-particle final states
  - iii) importance of analyticity

[#]see pre-proposal in appendix

Expanding Theory Group Support of JLab Experimental Program: the N* Analysis Center - II

Proposed structure:

- senior theorist with a broad knowledge of hadronic and electromagnetic interactions, reaction theory, and the methods used in phenomenological analysis
- mid-level staff position and several term/visiting positions for theorists and experimentalists to advance the program and to interface with outside groups
- Establishment of a Scientific Advisory Board, consisting of the new permanent senior theorist, two representatives of the in-house N* groups, and two representatives of the N* community
- Total budget ~ $ 460k per year (+overhead)

JLab Theory Group Other Needs

- One-two additional postdoc position(s) (the current number is three):

  i) junior/senior staff ratio will be 3/11 in FY04 (projected to be 3/12 in FY05 or FY06, when the new JLab/W&M position is expected to be filled)

  ii) the group, given its size and breadth of research interests, could (and should) support more postdoctoral fellows

- Additional funds for supporting long-term visitors:

  i) the present operating budget of Theory Group is insufficient to maintain the long-term visitor program at current levels#

#case in point: Dmitri Diakonov, for whom Hall B and Physics Division will provide 75% of the required nine-month support in FY04

JLab Theory Group: Mentoring 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 four 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 five 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 (+two in fall) 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 programs at JLab
  - Excited-Hadron Initiative and Radiative Corrections Study Group, and 5 mini-lecture series
  - Its broad research program beneficial to other labs as well
  - Future opportunities: the N* Analysis Center
- Theory Group provides a mentoring 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 Appendices with senior staff profiles and publication list in 02

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 Instute, 1989-1992
  Postdoctoral Fellow, Penn State University, 1992-1995
  Research Scientist, MIT, 1995-1996
  Senior Staff/Assc. Prof., JLab/ODU, 1996-present
- Author of 60 publications
- Research Highlights:
  - BFKL pomeron (B → 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 QCDSP 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/Assc. Prof., JLab/Hampton, 1998-2002
  Senior Staff/ Prof., JLab/Hampton, 2002-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, 1985-2002
  Senior Staff/Emeritus Prof., JLab/W&M, 2002-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: Three Annual Awards at JINR-Dubna, Fellow of the American Physical Society, ODU Eminent Scholar, ODU Annual Faculty Research Award, 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/Assc. 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 3P0 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/Assc. Prof., JLab/ODU, 1999-2002
  Senior Staff/Prof., JLab/ODU, 2002-present
- Honors: Enrico Fermi Scholar, Argonne Nat. Lab., 1990-1992, Fellow of the American Physical Society
- Author of 87 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/Assc. Prof., JLab/ODU, 1990-1998
  Senior Staff/Prof., JLab/ODU, 1998-present
- Honors: ODU Eminent Scholar
- 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 ed scattering
  - Relativistic constituent quark model of heavy mesons
  - Relativistic three-body systems