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## Differential Cross Sections for the Reactions $$[\gamma] p \rightarrow p [\eta] \text{ and } [\gamma] p \rightarrow p [\eta]'$$

In high-statistics differential cross sections for the reactions  $[\gamma] p \rightarrow p [\eta]$  and  $[\gamma] p \rightarrow p [\eta]'$  the CLAS at Jefferson Lab was used to measure the center-of-mass energies from near threshold up to 2.84 GeV. The eta-prime results are the most precise to date and provide the largest energy and angular coverage. The eta measurements extend the energy range of the world's large-angle results by approximately 300 MeV. These new data, in particular the  $[\eta]'$  measurements, are likely to help constrain the analyses being performed to search for new baryon resonance states.

## N\* Physics and Nonperturbative Quantum Chromodynamics

## Proceedings of the Joint ECT\*/JLAB Workshop, Trento, Italy, May 18–29, 1998

*Springer Science & Business Media* **The Workshop N\* Physics and non-perturbative QeD was held at the Eu ropean Center for Theoretical Studies and Related Areas (ECT\*) in Trento, Italy, during May 18-29, 1998. Previous**

workshops of the series on  $N^*$  Physics took place at the Florida State University (1994), at CEBAF (1995), at the Institute for Nuclear Theory in Seattle (1996) and at the George Washington University (1997). The Workshop was devoted to a summary of recent experimental and the oretical research on  $N^*$  phsyics and special emphasis was given to the infor mation that photo-and electro-production of nucleon resonances can provide on the non-perturbative regime of Quantum Chromodynamics. The idea was to stimulate discussions among experimentalists and theoreticians in order to pursue the interpretation of the huge amount of forthcoming data from several laboratories in the world. It was therefore decided to have both experimental and theoretical lectures on the main topics, like ,among the others, single and double pion production, TJ-and K-meson production, the GDH sum rule, the spin of the proton, etc. Thanks to the unusual two-week extension of the Work shop, the allotted time for the lectures was extended up to one hour in order to allow the invited lecturers to give a detailed presentation of their topics. Fi nally, various short contributions were selected to sharpen the discussion about selected items.

## Time and Place

## My Story

*William Palmer* **A Personal Memoir**

## Algebra 1 New York

## Teacher Edition

*McDougal Littell/Houghton Mifflin*

## An Introduction to Beam Physics

*Taylor & Francis* **The field of beam physics touches many areas of physics, engineering, and the sciences. In general terms, beams describe ensembles of particles with initial conditions similar enough to be treated together as a group so that the motion is a weakly nonlinear perturbation of a chosen reference particle. Particle beams are used in a variety of areas,**

## Differential Cross Section of [mml

# Math Altimg

Differential cross sections of the reaction  $[\gamma]d \rightarrow 2K + [\Sigma] - (p)$  have been measured with the CLAS detector at Jefferson Lab using incident photons with energies between 1.1 and 3.6 GeV. This is the first complete set of strangeness photoproduction data on the neutron covering a broad angular range. At energies close to threshold and up to  $E[\gamma] \sim 1.8$  GeV, the shape of the angular distribution is suggestive of the presence of s-channel production mechanisms. For  $E[\gamma] > 1.8$  GeV, a clear forward peak appears and becomes more prominent as the photon energy increases, suggesting contributions from t-channel production mechanisms. Furthermore, these data can be used to constrain future analysis of this reaction.

## Symmetries in Nuclear Structure

### An Occasion to Celebrate the 60th Birthday of Francesco Iachello - Proceedings of the Highly Specialized Seminar

*World Scientific* The Highly Specialized Seminar on "Symmetries in Nuclear Structure", held in Erice, Italy, in March 2003, celebrated the career and the remarkable achievements of Francesco Iachello, on the occasion of his 60th birthday. Since the development of the interacting boson model in the early 1970s, the ideas of Iachello have provided a variety of frameworks for understanding collective behaviour in nuclear structure, founded on the concepts of dynamical symmetries and spectrum-generating algebras. The original ideas, which were developed for the description of atomic nuclei, have now been successfully extended to cover spectroscopic behaviour in other fields, such as molecular or hadronic spectra. More recently, the suggestion by Iachello of critical point symmetries to treat nuclei in shape/phase transitional regions has opened an exciting new front for both theoreticians and experimentalists. The talks presented at the meeting covered many of the most active forefront areas of nuclear structure as well as other fields where ideas of symmetries are being explored. Topics in nuclear structure included extensive discussions on dynamical symmetries, critical point symmetries, phase transitions, statistical properties of nuclei, supersymmetry, mixed symmetry states, shears bands, pairing and clustering in nuclei, shape coexistence, exotic nuclei,

dipole modes, and astrophysics, among others. In addition, important sessions focused on talks by European laboratory directors (or their representatives) outlining prospects for nuclear structure, and the application of symmetry ideas to molecular phenomena. Finally, a special lecture by Nobel laureate Alex Mueller, on s and d wave symmetry in superconductors, presented a unique insight into an allied field. The proceedings have been selected for coverage in: \* Index to Scientific & Technical Proceedings (ISTP / ISI Proceedings) \* Index to Scientific & Technical Proceedings (ISTP CDROM version / ISI Proceedings) \* CC Proceedings -- Engineering & Physical Sciences

## Exclusive Reactions at High Momentum Transfer

Proceedings of the International Workshop, 21-24 May 2007, Jefferson Lab, Newport News, Virginia, USA

*World Scientific* Exclusive reactions are becoming one of the major sources of information about the deep structure of nucleons and other hadrons. The 2007 International Workshop held at Jefferson Lab in Newport News, Virginia, USA - the world's leading facility performing research on nuclear, hadronic and quark-gluon structure of matter - focused on the application of a variety of exclusive reactions at high momentum transfer, utilizing unpolarized and polarized beams and targets, to obtain information about nucleon ground-state and excited-state structure at short distances. This is a subject which is central to the programs of current accelerators and especially planned future facilities. This proceedings volume contains, in concentrated form, information about the newest developments, both theoretical and experimental, in the study of hard exclusive reactions.

## The Physics of Neutrino Interactions

*Cambridge University Press* A comprehensive introduction to neutrino physics with detailed description of neutrinos and their properties.

# Cloud Computing

First International Conference,  
CloudComp 2009, Munich,  
Germany, October 19-21, 2009,  
Revised Selected Papers

*Springer* This book shows the conference proceedings of CloudComp 2009 held in Munich, Germany, in October 2009.

# Climbing the Mountain

# The Scientific Biography of Julian Schwinger

*Oxford University Press on Demand* **Julian Schwinger was one of the leading theoretical physicists of the twentieth century. His contributions are as important, and as pervasive, as those of Richard Feynman, with whom (and with Sin-itiro Tomonaga) he shared the 1965 Nobel Prize for Physics. Yet, while Feynman is universally recognized as a cultural icon, Schwinger is little known even to many within the physics community. In his youth, Julian Schwinger was a nuclear physicist, turning to classical electrodynamics after World War II. In the years after the war, he was the first to renormalize quantum electrodynamics. Subsequently, he presented the most complete formulation of quantum field theory and laid the foundations for the electroweak synthesis of Glashow, Weinberg, and Salam, and he made fundamental contributions to the theory of nuclear magnetic resonance, to many-body theory, and to quantum optics. He developed a unique approach to quantum mechanics, measurement algebra, and a general quantum action principle. His discoveries include 'Feynman's' parameters and 'Glauber's' coherent states; in later years he also developed an alternative to operator field theory which he called Source Theory, reflecting his profound phenomenological bent. His late work on the Thomas-Fermi model of atoms and on the Casimir effect continues to be an inspiration to a new generation of physicists. This biography describes the many strands of his research life, while tracing the personal life of this private and gentle genius.**

## Baryons 2002

Proceedings of the 9th International Conference on the Structure of Baryons : Jefferson Lab, Newport News, Virginia, USA, March 3-8, 2002

*World Scientific* This book deals with the latest developments in the area of three-quark systems. Emphasis is given to the discussion of new experimental results in the areas of form factors, unpolarized and polarized structure functions, and baryon structure and spectroscopy. Of particular interest are the new theoretical developments in the area of generalized parton distributions and lattice quantum chromodynamics.

## High-precision Measurement of the Proton Elastic Form Factor Ratio [mm]

Math Alting

Here, we report a new high precision measurement of the proton elastic form factor ratio  $\mu p_{GE}/GM$  for the four-momentum transfer squared  $Q^2 = 0.3-0.7 \text{ (GeV/c)}^2$ . The measurement was performed at Jefferson Lab (JLab) in Hall A using recoil polarimetry. With the achieved  $\sim 1\%$  total uncertainty, the new data clearly show that the deviation of the ratio  $\mu p_{GE}/GM$  from unity observed in previous polarization measurements at high  $Q^2$  continues down to the lowest  $Q^2$  value of this measurement. The updated global fit that includes the new results yields in this  $Q^2$  range an electric (magnetic) form factor  $\sim 2\%$  smaller ( $\sim 1\%$  larger) than the previous global fit. We obtain new extractions of the proton electric and magnetic radii, which are  $(r_{E2})^{1/2} = 0.875 \pm 0.010 \text{ fm}$  and  $(r_{M2})^{1/2} = 0.867 \pm 0.020 \text{ fm}$ . Moreover, the charge radius is consistent with other recent extractions based on the electron-proton interaction, including the atomic hydrogen Lamb shift measurements, which suggests a missing correction in the

comparison of measurements of the proton charge radius using electron probes and the recent extraction from the muonic hydrogen Lamb shift.

## SciDAC 2007

24-28 June 2007, Boston

Massachusetts, USA

## Nuclear Science Abstracts

## Partial Wave Analysis of the Reaction $\gamma p \rightarrow p \omega$ [math Display]

We performed an event-based partial wave analysis (PWA) of the reaction  $\gamma p \rightarrow p \omega$  on a high-statistics dataset obtained using the CLAS at Jefferson Lab for center-of-mass energies from threshold up to 2.4 GeV. This analysis benefits from access to the world's first high precision spin density matrix element measurements, available to the event-based PWA through the decay distribution of  $\omega \rightarrow \pi^+ \pi^- \pi^0$ . The data confirm the dominance of the t-channel  $\pi^0$  exchange amplitude in the forward direction. The dominant resonance contributions are consistent with the previously identified states  $F_{15}(1680)$  and  $D_{13}(1700)$  near threshold, as well as the  $G_{17}(2190)$  at higher energies. Suggestive evidence for the presence of a  $J(P)=5/2^+$  state around 2 GeV, a "missing" state, has also been found. Evidence for other states is inconclusive.

## Exascale Scientific Applications

## Scalability and Performance

## Portability

*CRC Press* From the Foreword: "The authors of the chapters in this book are the pioneers who will explore the exascale frontier. The path forward will not be easy... These authors, along with their colleagues who will produce these powerful computer systems will, with dedication and determination, overcome the scalability problem, discover the new algorithms needed to achieve exascale performance for the broad range of applications that they represent, and create the new tools needed to support the development of scalable and portable science and engineering applications. Although the

focus is on exascale computers, the benefits will permeate all of science and engineering because the technologies developed for the exascale computers of tomorrow will also power the petascale servers and terascale workstations of tomorrow. These affordable computing capabilities will empower scientists and engineers everywhere." — Thom H. Dunning, Jr., Pacific Northwest National Laboratory and University of Washington, Seattle, Washington, USA "This comprehensive summary of applications targeting Exascale at the three DoE labs is a must read." — Rio Yokota, Tokyo Institute of Technology, Tokyo, Japan "Numerical simulation is now a need in many fields of science, technology, and industry. The complexity of the simulated systems coupled with the massive use of data makes HPC essential to move towards predictive simulations. Advances in computer architecture have so far permitted scientific advances, but at the cost of continually adapting algorithms and applications. The next technological breakthroughs force us to rethink the applications by taking energy consumption into account. These profound modifications require not only anticipation and sharing but also a paradigm shift in application design to ensure the sustainability of developments by guaranteeing a certain independence of the applications to the profound modifications of the architectures: it is the passage from optimal performance to the portability of performance. It is the challenge of this book to demonstrate by example the approach that one can adopt for the development of applications offering performance portability in spite of the profound changes of the computing architectures." — Christophe Calvin, CEA, Fundamental Research Division, Saclay, France "Three editors, one from each of the High Performance Computer Centers at Lawrence Berkeley, Argonne, and Oak Ridge National Laboratories, have compiled a very useful set of chapters aimed at describing software developments for the next generation exascale computers. Such a book is needed for scientists and engineers to see where the field is going and how they will be able to exploit such architectures for their own work. The book will also benefit students as it provides insights into how to develop software for such computer architectures. Overall, this book fills an important need in showing how to design and implement algorithms for exa-scale architectures which are heterogeneous and have unique memory systems. The book discusses issues with developing user codes for these architectures and how to address these issues including actual coding examples.' — Dr. David A. Dixon, Robert Ramsay Chair, The University of Alabama, Tuscaloosa, Alabama, USA

## Hidden Worlds

# Hunting for Quarks in Ordinary Matter

*Princeton University Press* **No one has ever seen a quark. Yet physicists seem to know quite a lot about the properties and behavior of these ubiquitous elementary particles. Here a top researcher introduces us to a fascinating but invisible realm that is part of our everyday life. Timothy Smith tells us what we know about quarks--and how we know it. Though the quarks that make science headlines are typically laboratory creations generated under extreme conditions, most quarks occur naturally. They reside in the protons and neutrons that make up almost all of the universe's known matter, from human DNA to distant nebulae, from books and tables to neutron stars. Smith explains what these quarks are, how they act, and why physicists believe in them sight unseen. How do quarks arrange themselves? What other combinations can nature make? How do quarks hold nuclei together? What else is happening in their hidden worlds? It turns out that these questions can be answered using a few simple principles, such as the old standby: opposites attract. With these few principles, Smith shows how quarks dance around each other and explains what physicists mean when they refer to "up" and "down" quarks and talk about a quark's color, flavor, and spin. Smith also explains how we know what we know about these oddly aloof particles, which are eternally confined inside larger particles. He explains how quark experiments are mounted and how massive accelerators, targets, and detectors work together to collect the data that scientists use to infer what quarks are up to. A nonmathematical tour of the quark world, this book is written for students, educators, and all who enjoy scientific exploration--whether they seek a taste of subnuclear physics or just wonder about nature on the smallest of scales.**

# Lattice Fermions and Structure of the Vacuum

*Springer Science & Business Media* **Among the key problems in modern field theory are the formulation of chiral group theories on the lattice and the quantitative understanding of the quark confinement mechanism. The two topics are closely related by the fact that the chiral nature of the fermions as well as the confinement force are largely topological in origin. Recent advances in this field are here reviewed by some of the world's experts.**

## Photoproduction of the

$$f_1(1285) \text{ meson}$$

## Meson

The  $f_1(1285)$  meson with mass  $1281.0 \pm 0.8$  MeV/ $c^2$  and width  $18.4 \pm 1.4$  MeV (FWHM) was measured for the first time in photoproduction from a proton target using CLAS at Jefferson Lab. Differential cross sections were obtained via the  $\eta\pi^+\pi^-$ ,  $K^+\bar{K}^0\pi^-$ , and  $K^+K^0\pi^+$  decay channels from threshold up to a center-of-mass energy of 2.8 GeV. The mass, width, and an amplitude analysis of the  $\eta\pi^+\pi^-$  final-state Dalitz distribution are consistent with the axial-vector  $J^P=1^+$   $f_1(1285)$  identity, rather than the pseudoscalar  $0^-$   $\eta(1295)$ . The production mechanism is more consistent with  $s$ -channel decay of a high-mass  $N^*$  state, and not with  $t$ -channel meson exchange. Decays to  $\eta\pi\pi$  go dominantly via the intermediate  $a_0(980)\pi$  states, with the branching ratio  $\Gamma(a_0\pi \text{ (no } \bar{K}) K) / \Gamma(a_0\pi \text{ (all)}) = 0.74 \pm 0.09$ . The branching ratios  $\Gamma(K\bar{K}\pi) / \Gamma(\eta\pi\pi) = 0.216 \pm 0.033$  and  $\Gamma(\gamma\rho^0) / \Gamma(\eta\pi\pi) = 0.047 \pm 0.018$  were also obtained. The first is in agreement with previous data for the  $f_1(1285)$ , while the latter is lower than the world average.

## Connected Newsletter

## The Extraction of $f_1(1285)$

## Math Altimg

We report on the first measurement of the differential cross section of  $\phi$ -meson photoproduction for the  $d(\gamma, pK^+K^-)n$  exclusive reaction channel. The experiment was performed using a **tagged-photon** beam and the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab. A combined analysis using data from the  $d(\gamma, pK^+K^-)n$  channel and those from a previous publication on coherent  $\phi$  production on the deuteron has been

carried out to extract the  $\phi$ -N total cross section,  $\sigma_{\phi N}$ . The extracted  $\phi$ -N total cross section favors a value above 20 mb. This value is larger than the value extracted using vector-meson dominance models for  $\phi$  photoproduction on the proton.

## Measurement of "pretzelosity"

### Asymmetry of Charged Pion

### Production in Semi-inclusive Deep Inelastic Scattering on a Polarized

### Mathvariant

An experiment to measure single-spin asymmetries in semi-inclusive production of charged pions in deep-inelastic scattering on a transversely polarized  $^3\text{He}$  target was performed at Jefferson Lab in the kinematic region of 0.16

## Photoproduction of

### $\omega$

### Mesons Off Nuclei and Impact of

### Polarization on the Meson-nucleon Interaction

We consider photoproduction of  $\omega$  mesons off complex nuclei to study interactions of transversely and longitudinally polarized vector mesons with nucleons. Whereas the total cross section for interactions of the transversely polarized vector mesons with nucleons  $\sigma_T = \sigma(V_T N)$  can be obtained from coherent photoproduction, measurements of vector meson photoproduction in the incoherent region provide a unique opportunity to extract the not-yet-measured total cross section for longitudinally polarized mesons  $\sigma_L = \sigma(V_L N)$ . The predictions for the latter strongly depend on the theoretical approaches. This work is stimulated by the construction of the new experiment GlueX at Jefferson Lab, designed to study the photoproduction of mesons in a large beam

energy range up to 12 GeV.

## Educational Programs that Work

### NSTAR 2002

Proceedings of the Workshop on  
the Physics of Excited Nucleons :  
9-12 October 2002, Pittsburgh,  
Pennnsylvania [sic], USA

*World Scientific* This book covers recent advances in the physics of nucleon resonances, including new experimental results from laboratories in the USA, Europe, and Asia, and new developments in effective field theories, quark models, and lattice gauge theory.

### Exclusive Processes at High Momentum Transfer

May 15-18, 2002, Jefferson Lab,  
Newport News, Virginia

*World Scientific* This book focuses on the physics of exclusive processes at high momentum transfer and their description in terms of generalized parton distributions, perturbative QCD, and relativistic quark models. It covers recent developments in the field, both theoretical and experimental. Contents: Perspectives on Exclusive Processes in QCD (S J Brodsky); High- $t$  Meson Photo- and Electroproduction: A Window on Partonic Structure of Hadrons (J-M Laget); Nucleon Hologram with Exclusive Leptoproduction (A Belitsky & D Muller); QCD Factorization for the Pion Diffractive Dissociation into Two Jets (D Yu Ivanov); GPDs, Form Factors and Compton Scattering (P Kroll); Real Compton Scattering from the Proton (A Nathan); Resonance Exchange Contributions to Wide-Angle Compton Scattering: The D-Term (T Oppermann); Proton-Antiproton Annihilation into Two Photons at Large  $s$  (C Weiss); Quark-Hadron Duality Studies at Jefferson Lab; An Overview of New and Exisiting Results (C Keppel); Novel Hard Semiexclusive Processes and Color Singlet Clusters in Hadrons (M Strikman et al.); and other

papers. Readership: Theoretical and experimental researchers in nuclear and elementary particle physics.

## Advances in Nuclear Physics

### Volume 27

*Springer Science & Business Media* This volume contains two major articles, one providing a historical retrospective of one of the great triumphs of nuclear physics in the twentieth century and the other providing a didactic introduction to one of the quantitative tools for understanding strong interactions in the twenty-first century. The article by Igal Talmi on “Fifty Years of the Shell Model - the Quest for the Effective Interaction”, pertains to a model that has dominated nuclear physics since its infancy and that developed with astonishing results over the next five decades. Talmi is uniquely positioned to trace the history of the Shell Model. He was active in developing the ideas at the shell model’s inception, he has been central in most of the subsequent initiatives which expanded, clarified and applied the shell model and he has remained active in the field to the present time. Wisely, he has chosen to restrict his review to the dominating issue: the choice of the effective interactions among valence nucleons that determine the properties of low lying nuclear energy levels. The treatment of the subject is both bold and novel for our series. The ideas pertaining to the effective interaction for the shell model are elucidated in a historical sequence.

## Exclusive & Semi-exclusive Processes At High Momentum Transfer

*World Scientific* Electrocardiology has witnessed a century of development since the introduction of Einthoven's Galvanometer. With rapid progress in the scientific, technological and clinical aspects of the field of electrocardiology in recent years, electrocardiology now covers a wide range of topics from molecules as the electrical origin of the heart to diagnostic and therapeutic applications for cardiovascular diseases. This volume presents the latest information and developments in the field, from basic science to clinical electrocardiology. A wide range of topics are covered, including molecular biology, genetics, channelopathy, atrial fibrillation, catheter ablation, modeling of cardiac electrical activity, cardiac mapping, as well as diagnosis, treatment and prevention of cardiac disease and arrhythmic disorders. Contributors to the volume include leading experts in the field such as PJ Schwartz, C Antzelevitch, Y Rudy,

HJGM Vrijin, DG Escande, AAM Wilde, DA Kass, J Jalife and A d'Avila. The book is an essential source of reference for cardiologists and electrocardiologists.

## GDH 2004

*World Scientific* This volume presents an overview of the many new and exciting results, both theoretical and experimental, in the area of spin structure functions and sum rules at low to moderate photon virtuality  $Q^2$ . It includes contributions from many leading scientists in the field worldwide. The volume covers the following topics: • recent results on the Gerasimov-Drell-Hearn (GDH) sum rule with real photons and its extensions to virtual photons • inclusive spin structure functions at low to moderate  $Q^2$  and their moments • exclusive measurements of nucleon spin structure in the resonance region • spin polarizabilities and Compton scattering • chiral perturbation theory and other low-energy limits of QCD • lattice QCD, duality, and phenomenological models • nuclear effects and the GDH sum rule in nuclei • experimental techniques (polarized targets and beams) • future plans and projects Contents: What are These Sum Rules Good For? (X Ji) Structure of the Nucleon: Spin Observables (U Meissner) Experimental Verification of the GDH Sum Rule (K Helbing) Status of the GDH Experiment on the Deuteron at MAMI (O Jahn) Study of the Polarized Structure Functions of the Neutron at Low  $Q^2$  Using Polarized  $^3\text{He}$  (S Choi) The First Moment of  $g_1$  Measured with the CLAS Detector (G Dodge) Quark Hadron Duality Tests on Polarized Structure Functions Using CLAS (T Forest) Proton Spin Structure at High Parton Densities (B Badelek) Nucleon Spin Structure and Its Connections to Various Sum Rules (J Soffer) Spin Asymmetries for Exclusive and Semi-Exclusive Reactions with CLAS (A Biselli) Helicity Dependence of the  $N\pi(\pi)$  Processes on the Proton: New Results from Mainz (P Pedroni) Strangeness Photoproduction and the GDH Experiments at LEPs (Y Ohashi) What We are Learning about the Quark Structure of Hadrons from Lattice QCD (J Negele) Higher Twists in Spin Structure Functions from a "Constituent Quark" Point of View (A Sidorrov & C Weiss) Polarized Structure Functions and the GDH Integral from Lattice QCD (G Schierholz) Spin Asymmetry and GDH Sum Rule for Real and Virtual Photons for the Deuteron (H Arenhövel et al.) The Generalized GDH Sum for  $^3\text{He}$  (K Slifer) A Study of the Final State Effects in the Electro-disintegration of a Polarized Helium-3 Target (G Salmè et al.) and other papers Readership: Graduate students and researchers in nuclear, high energy and particle physics. Keywords: Sum Rule; Nucleon Spin Structure Functions; Real Photons; Electron Scattering; Polarized Beams; Polarized Targets Key Features: Features contributions from renowned experts in the field, including Xiangdong Ji, Ulf Meissner and John Negele Presents a comprehensive overview of the field Includes up-to-date research results from many international laboratories and pedagogical overview talks

## Applied Science

Transactions and Year Book ...

Focus on Educational Success

Abstracts of Exemplary Programs

Puppy Dog Pals: Adopt-a-palooza

*Disney Electronic Content* **Read along with Disney! When Bob tells the pups they're going to help out at the local pet adoption event, Adopt-a-palooza, Bingo and Rolly can't wait to go. But when an energetic little puppy runs away, Bingo and Rolly make it their mission to bring him back....and then help him find the perfect pet owner to call his own!**

## Direct Observation of Quark-hadron Duality in the Free Neutron

$F_2$  Structure Function

Using data from the recent BONuS experiment at Jefferson Lab, which utilized a novel spectator tagging technique to extract the inclusive electron-free neutron scattering cross section, we obtain the first direct observation of quark-hadron duality in the neutron  $F_2$  structure function. The data are used to reconstruct the lowest few ( $N=2, 4$  and  $6$ ) moments of  $F_2$  in the three prominent nucleon resonance regions, as well as the moments integrated over the entire resonance region. Comparison with moments computed from global parametrizations of parton distribution functions suggest that quark-hadron duality holds locally for the neutron in the second and third resonance regions down to  $Q^2 \sim 1 \text{ GeV}^2$ , with violations possibly up to 20% observed in the first resonance region.

## Resources in Education

# Rosenbluth Separation of the $\pi^0$ Electroproduction Cross-Section

We present deeply virtual  $\pi^0$  electroproduction cross-section measurements at  $x_B=0.36$  and three different  $Q^2$ -values ranging from 1.5 to 2  $\text{GeV}^2$ , obtained from experiment E07-007 that ran in the Hall A at Jefferson Lab. The Rosenbluth technique was used to separate the longitudinal and transverse responses. Results demonstrate that the cross section is dominated by its transverse component, and thus is far from the asymptotic limit predicted by perturbative Quantum Chromodynamics. An indication of a non-zero longitudinal contribution is provided by the interference term  $\sigma_{LT}$  also measured. Results are compared with several models based on the leading twist approach of Generalized Parton Distributions (GPDs). In particular, a fair agreement is obtained with models where the scattering amplitude is described by a convolution of chiral-odd (transversity) GPDs of the nucleon with the twist-3 pion distribution amplitude. Therefore, neutral pion electroproduction may offer the exciting possibility of accessing transversity GPDs through experiment.

# Spectroscopy of $^9\text{Be}(e, e'K^+)^9\text{Li}$

**Background:** In the absence of accurate data on the free two-body hyperon-nucleon interaction, the spectra of hypernuclei can provide information on the details of the effective hyperon-nucleon interaction.

**Purpose:** To obtain a high-resolution spectrum for the  $^9\text{Be}(e, e'K^+)^9\text{Li}$  reaction. **Method:** Electroproduction of the hypernucleus  $^9\text{Li}$  has been studied for the first time with sub-MeV energy resolution in Hall A at Jefferson Lab on a  $^9\text{Be}$  target. In order to increase the counting rate and to provide unambiguous kaon identification, two superconducting septum magnets and a Ring Imaging Cherenkov detector (RICH) were added to the Hall A standard equipment. **Results:** The cross section to low-lying states of  $^9\text{Li}$  is concentrated within 3 MeV of the ground state and can be fitted with four peaks. The positions of the doublets agree with theory while a disagreement could exist with respect to the relative strengths of the peaks in the doublets. A  $\Lambda$  separation energy,  $B[\Lambda]$ , of  $8.36 \pm 0.08$  (stat.)  $\pm 0.08$  (syst.) MeV was measured, in agreement with an earlier experiment.

# Differential Cross Sections and Recoil Polarizations for the Reaction

## [math Display

Here, high-statistics measurements of differential cross sections and recoil polarizations for the reaction  $\gamma p \rightarrow K^+ \Sigma^0$  have been obtained using the CLAS detector at Jefferson Lab. We cover center-of-mass energies ( $\sqrt{s}$ ) from 1.69 to 2.84 GeV, with an extensive coverage in the  $K^+$  production angle. Independent measurements were made using the  $K^+ p \pi^-$  ( $\gamma$ ) and  $K^+ p (\pi^- , \gamma)$  final-state topologies, and were found to exhibit good agreement. Our differential cross sections show good agreement with earlier CLAS, SAPHIR and LEPS results, while offering better statistical precision and a 300-MeV increase in  $\sqrt{s}$  coverage. Above  $\sqrt{s} \approx 2.5$  GeV,  $t$ - and  $u$ -channel Regge scaling behavior can be seen at forward- and backward-angles, respectively. Our recoil polarization ( $P_\Sigma$ ) measurements represent a substantial increase in kinematic coverage and enhanced precision over previous world data. At forward angles we find that  $P_\Sigma$  is of the same magnitude but opposite sign as  $P_\Lambda$ , in agreement with the static SU(6) quark model prediction of  $P_\Sigma \approx -P_\Lambda$ . This expectation is violated in some mid- and backward-angle kinematic regimes, where  $P_\Sigma$  and  $P_\Lambda$  are of similar magnitudes but also have the same signs. In conjunction with several other meson photoproduction results recently published by CLAS, the present data will help constrain the partial wave analyses being performed to search for missing baryon resonances.

## Crime Lab Chemistry

### Teacher's Guide

*Gems* Crime lab chemistry (grades 4-8) - teacher's guide :BG06903.