December 4, 2008

University of Richmond
Founded 1830

Department of Physics

Dean of the School of Arts and Sciences
University of Richmond
28 Westhampton Way
Richmond, VA 23173

Dear Dean Newcomb:

Please find enclosed my application for a full-year, enhanced-salary sabbatical leave for the 2009-2010 academic year. This document contains the six items listed under the application procedures of the instructions for applying for the enhanced-salary sabbatical leave. Page 1 of the application immediately following this cover letter lists those six items and where they can be found in the document. You should receive three letters from the external reviewers that evaluated this proposal. If you don't receive those letters soon, let me know so I can expedite the process. If you have any questions, please let me know.

Sincerely,

Dr. Gerard P. Gilfoyle
Department of Physics

University of Richmond
Virginia 23173
804-289-8252

Enhanced Sabbatical Proposal

Dr. Gerard P. Gilfoyle
Physics Department, University of Richmond

1. I am applying for a full-year, enhanced sabbatical for the 2009-2010 academic year. This year long sabbatical is contingent on funding from the University or one of the other sources listed below. If I do not receive funding, then I would prefer to be on leave during the fall, 2009 semester.

2. I will be applying to the following sources for funding the full-year sabbatical.

   (a) Jefferson Science Associates (JSA) Sabbatical Leave Support at Jefferson Lab (JLab).
   - Program funded by the Southeastern Universities Research Association (SURA) and JSA to support faculty from SURA institutions to do research at JLab.
   - I will request half of my academic year salary.
   - Application date: January 25, 2009.
   - I expect to hear about this support by mid-April, 2009.

   (b) Thomas Jefferson National Accelerator Facility
   - Program funded by JLab to support faculty doing research at JLab.
   - I will request half of my academic year salary.
   - Application date: January 25, 2009.
   - I expect to hear about this support by mid-May, 2009.

   (c) US Department of Energy (DOE)
   - Intermediate-Energy program in the DOE Office of Science supports research at JLab.
   - I requested travel support for my sabbatical.
   - Application date: December 1, 2008.
   - I expect to hear about this support by mid-April, 2009.

3. External referees.

   Dr. Richard G. Milner

   - Position - Professor of Physics and former Director, Laboratory for Nuclear Science, MIT.
   - Curriculum Vitae - Not available; see page 3 for a short biographical sketch and a listing of his publications.
   - Expertise - Experimental nuclear physicist and former director of a major US accelerator center at MIT that investigates similar physics questions to the ones studied at JLab.
   - Relationship - I have met him at conferences, but we have not worked together.

   Dr. Gerald Miller

   - Position - Professor, Department of Physics, University of Washington, Seattle.
   - Curriculum Vitae - See page 9.
   - Expertise - Theoretical physicist with expertise in intermediate energy nuclear physics like that performed at JLab; Principal investigator, 'Theoretical Nuclear Physics' Department of Energy grant DE-FG03-97ER41014.
   - Relationship - I know him professionally, but have not worked with him on any projects.

Dr. Will Brooks

- Position - Professor and Experimental Nuclear and Particle Physics Group Leader, Department of Physics, Universidad Técnica Federico Santa María, Casilla 110-V Valparaíso, Chile.
- Curriculum Vitae - See page 26.
- Expertise - Experimental physicist and former staff scientist at JLab; E5 group leader for the measurement of the neutron magnetic form factor that I am now leading.
- Relationship - He was group leader for the physics projects that I have been focused for the last few years. He is intimately aware of my contribution to the analysis of the magnetic form factor of the neutron and the structure functions of the neutron that are described in this proposal.

4. Project description - See attached document on page 37.
5. Representative grant proposals - I have included my DOE grant renewal proposal with a request for sabbatical travel funds and other items. See attached document on page 42.
6. Updated CV - See page 81.

Biographical Sketch*
Richard G. Milner

Research Interests

Professor Milner is the former Director of MIT's Laboratory for Nuclear Science (LNS), and a member of its Medium Energy Physics Group. His research is focused on studying the spin structure of strongly interacting systems. A major focus of his research effort over the last decade has been the HERMES experiment to study the spin structure of the nucleon. This work was carried out in collaboration with Prof. Robert P. Redwine. HERMES has provided important new data on the flavor decomposition of the quark spin and on the contribution of the glue, yielding a number of new, unexpected results.

One of Prof. Milner's most recent efforts was at the MIT Bates Linear Accelerator Center, where the construction of a new large detector called the "Bates Large Acceptance Spectrometer Toroid" (BLAST) was completed. This work was carried out in collaboration with Profs. Bill Bertozzi, Haiyan Gao, June Matthews, and Bob Redwine. BLAST is used with the stored polarized beam to measure spin-dependent electron scattering from polarized hydrogen, deuterium and He-3 targets. BLAST provides important information on the spin structure of light nuclei as well as on the neutron form-factors.

Career Summary

Professor Richard Milner joined the MIT faculty in 1988, where he served as Director of the Bates Linear Accelerator Center, and later as Director of MIT's Laboratory for Nuclear Science. He received his B.Sc. in 1978 and his M.Sc. in 1979 in Physics from the University College, Cork, Ireland, and his Ph.D., also in Physics, in 1984 from the California Institute of Technology, where he was was a Research Fellow from 1985 to 1988.

* From the MIT website (`http://web.mit.edu/physics/facultyandstaff/faculty/richard_milner.html`).

Publication List from the SPIRES database at Stanford

1. **"The Charge Form Factor of the Neutron at Low Momentum Transfer from the $^2\vec{\mathrm{H}}(\vec{\mathrm{e}},\mathrm{e}'\mathrm{n})\mathrm{p}$ Reaction"** , E. Geis *et al.* [BLAST Collaboration] , Phys. Rev. Lett. **101**, 042501 (2008) [arXiv:0803.3827 [nucl-ex]]

2. **"Longitudinal-transverse separations of structure functions at low Q**2 for hydrogen and deuterium"** , V. Tvaskis *et al.* , Phys. Rev. Lett. **98**, 142301 (2007) [arXiv:nucl-ex/0611023]

3. **"The beauty of the electromagnetic probe"** , R. G. Milner , Eur. Phys. J. A **28S1**, 1 (2006) , *Prepared for Symposium on 20 Years of Physics at the Mainz Microtron MAMI, Mainz, Germany, 20-22 Oct 2005*

4. **"Measurement of the proton electric to magnetic form factor ratio from $^1\vec{H}(\vec{e},e'p)$"** , C. B. Crawford *et al.* , Phys. Rev. Lett. **98**, 052301 (2007) [arXiv:nucl-ex/0609007]

5. **"Optically Pumped Polarized H, D, And 3he Gas Targets"** , T. E. Chupp, R. J. Holt and R. G. Milner , Ann. Rev. Nucl. Part. Sci. **44**, 373 (1994)

6. **"Experimental results from RHIC and plans for eRHIC"** , R. G. Milner , *Prepared for 12th International Workshop on Deep Inelastic Scattering (DIS 2004), Strbske Pleso, Slovakia, 14-18 Apr 2004*

7. **"Measurement of R = sigma(L)/sigma(T) and the separated longitudinal and transverse structure functions in the nucleon resonance region"** , Y. Liang *et al.* [Jefferson Lab Hall C E94-110 Collaboration] , arXiv:nucl-ex/0410027 , JLAB-PHY-04-45(2004)

8. **"Overview of new facilities for few body physics"** , R. G. Milner , Nucl. Phys. A **737**, 132 (2004) , *Prepared for 17th International IUPAP Conference on Few-Body Problems in Physics (FB 17), Durham, North Carolina, 5-10 Jun 2003*

9. **“The Physics Of Erhic”** , R. G. Milner , AIP Conf. Proc. **698**, 806 (2004)

10. **“Measurements of electron proton elastic cross sections for 0.4-(GeV/c)**2 ¡ Q**2 ¡ 5.5-(GeV/c)**2”** , M. E. Christy *et al.* [E94110 Collaboration] , Phys. Rev. C **70**, 015206 (2004) [arXiv:nucl-ex/0401030]

11. **“The electron-ion collider: Status and plans”** , R. G. L. Milner , AIP Conf. Proc. **675**, 988 (2003) , *Prepared for 15th International Spin Physics Symposium (SPIN 2002), Long Island, New York, 9-14 Sep 2002*

12. **“The spin structure of the nucleon”** , R. G. Milner , DESY-HERMES-97-43(1997) , *Prepared for 5th International Workshop on Deep Inelastic Scattering and QCD (DIS 97), Chicago, Illinois, 14-18 Apr 1997*

13. **“A future U.S. Electron Ion Collider”** , R. G. Milner , Nucl. Phys. A **711**, 311 (2002) , *Prepared for European Workshop on the QCD Structure of the Nucleon (QCD-N’02), Ferrara, Italy, 3-6 Apr 2002*

14. **“Hadronic physics with a polarized electron ion collider”** , J. M. Cameron, J. T. Londergan and R. G. Milner , in *Proc. of the APS/DPF/DPB Summer Study on the Future of Particle Physics (Snowmass 2001)* ed. N. Graf, , *In the Proceedings of APS / DPF / DPB Summer Study on the Future of Particle Physics (Snowmass 2001), Snowmass, Colorado, 30 Jun - 21 Jul 2001, pp M501* , SNOWMASS-2001-M501(2001) , *Prepared for APS / DPF / DPB Summer Study on the Future of Particle Physics (Snowmass 2001), Snowmass, Colorado, 30 Jun - 21 Jul 2001*

15. **“Asymmetry measurements from a polarized He-3 target”** , D. W. Higinbotham *et al.* , *Prepared for 12th International Symposium on High-energy Spin Physics (SPIN 96), Amsterdam, Netherlands, 10-14 Sep 1996*

16. **“The Hermes Experiment”** , R. G. Milner , Nucl. Phys. A **622**, 16C (1997) , *Prepared for 2nd ELFE Workshop, St. Malo, France, 23-27 Sep 1996*

17. **“New Techniques For Measuring Spin Observables Using A Polarized He-3 Internal Target And A Polarized Proton Beam”** , M. Leuschner *et al.* , *Prepared for 13th International Conference on Particles and Nuclei (PANIC 93), Perugia, Italy, 28 Jun - 2 Jul 1993*

18. **“Hadronic physics with a polarized Electron Ion Collider”** , J. M. Cameron, J. T. Londergan and R. G. Milner , AIP Conf. Proc. **588**, 1 (2001) , *Prepared for 2nd Workshop on Physics with an Electron Polarized Light Ion Collider (EPIC 2000), Cambridge, Massachusetts, 14-16 Sep 2000*

19. **“Physics with an electron polarized light-ion collider. Proceedings, 2nd Workshop, EPIC 2000, Cambridge, USA, September 14-15, 2000”** , R. G. Milner , *Prepared for 2nd Workshop on Physics with an Electron Polarized Light Ion Collider (EPIC 2000), Cambridge, Massachusetts, 14-16 Sep 2000*

20. **“Reactions Induced By Polarized Electrons On Polarized He-3 At The Mit-Bates Accelerator”** , R. G. Milner , J. Phys. Colloq. **51**, 479 (1990) , *Prepared for 7th International Conference on Polarization Phenomena in Nuclear Physics: PARIS 90, Paris, France, 9-13 Jul 1990*

21. **“Radiative corrections for (e,e-primep) reactions at GeV energies”** , R. Ent, B. W. Filippone, N. C. R. Makins, R. G. Milner, T. G. O’Neill and D. A. Wasson , Phys. Rev. C **64**, 054610 (2001)

22. **“Measurement of the high energy two-body deuteron photodisintegration differential cross-section”** , E. C. Schulte *et al.* , Phys. Rev. Lett. **87**, 102302 (2001)

23. **“Nuclear transparency from quasielastic A(e,e’p) reactions up to Q**2 = 8.1-(GeV/c)**2”** , K. Garrow *et al.* , Phys. Rev. C **66**, 044613 (2002) [arXiv:hep-ex/0109027]

24. **“The HERMES experiment”** , R. G. Milner , AIP Conf. Proc. **512**, 339 (2000) , *Prepared for 4th International Conference on Nuclear Physics at Storage Rings (STORI 99), Bloomington, Indiana, 12-16 Sep 1999*

25. **“Measurement Of The Spin Asymmetry In The Photoproduction Of Pairs Of High P(T) Hadrons At Hermes”** , R. G. Milner , *Prepared for 6th INT / Jlab Workshop on Exclusive and Semiexclusive Processes at High Momentum Transfer, Newport News, Virginia, 19-23 May 1999*

26. **“TOM: A target optical monitor of polarization and luminosity for polarized internal gas targets”** , M. L. Pitt *et al.* , *Prepared for 5th International Workshop on Polarized Beams and Polarized Gas Targets, Cologne, Germany, 6-9 Jun 1995*

27. **“Cryogenic polarized internal He-3 gas target for HERMES”** , S. F. Pate *et al.* , *Prepared for 5th International Workshop on Polarized Beams and Polarized Gas Targets, Cologne, Germany, 6-9 Jun 1995*

28. **“Temperature dependence of He-3 polarization in the HERMES internal target”** , W. Korsch *et al.* , *Prepared for 5th International Workshop on Polarized Beams and Polarized Gas Targets, Cologne, Germany, 6-9 Jun 1995*

29. **“Measurement of the spin dependent structure functions of the proton and neutron at HERA”** , R. G. Milner , AIP Conf. Proc. **223**, 305 (1991) , *Prepared for Polarized Collider Workshop, University Park, Pennsylvania, 15-17 Nov 1990*

30. **“Measurement of the neutron magnetic form factor from inclusive quasielastic scattering of polarized electrons from polarized He-3”** , H. Gao *et al.* , *In *St. Petersburg 1994, Intersections between particle and nuclear physics* 704-707*

31. **“Two body photodisintegration of the deuteron up to 2.8-GeV”** , J. E. Belz *et al.* , SLAC-REPRINT-1994-002(1994) , *Prepared for 5th Conference on the Intersections of Particle and Nuclear Physics, St. Petersburg, Florida, 31 May - 6 Jun 1994*

32. **“Nucleon form factors”** , R. G. Milner , *Prepared for 5th Conference on the Intersections of Particle and Nuclear Physics, St. Petersburg, Florida, 31 May - 6 Jun 1994*

33. **“The HERMES experiment”** , R. G. Milner , *Prepared for CERN SMC Meeting on Internal Spin Structure of the Nucleon, New Haven, CT, 5-6 Jan 1994*

34. **“Temperature dependence of He-3 polarization in aluminum storage cells”** , W. Korsch *et al.* , Nucl. Instrum. Meth. A **389**, 389 (1997)

35. **“The MIT-Bates Linear Accelerator Center”** , R. G. Milner , Nucl. Phys. News **9N2**, 4 (1999)

36. **“Electromagnetic form-factors of the nucleon from spin dependent scattering of helium-3”** , R. G. Milner , *Prepared for Baryons ’92: International Conference on the Structure of Baryons and Related Mesons, New Haven, CT, 1-4 June 1992*

37. **“Color transparency in (e,e’ p) experiments”** , R. G. Milner [NE18 Collaboration] , *Prepared for 6th Workshop on Perspectives in Nuclear Physics at Intermediate Energies, Trieste, Italy, 3-7 May 1993*

38. **“The HERMES polarized He-3 internal gas target”** , D. DeSchepper *et al.* , Nucl. Instrum. Meth. A **419**, 16 (1998)

39. **“Observation of a coherence length effect in exclusive rho0 electroproduction”** , K. Ackerstaff *et al.* [HERMES Collaboration] , Phys. Rev. Lett. **82**, 3025 (1999) [arXiv:hep-ex/9811011]

40. **“The Spin dependent momentum distributions of the neutron and proton in He-3”** , R. G. Milner *et al.* , Phys. Lett. B **379**, 67 (1996)

41. **“Measurement Of The Spin Structure Of The Nucleon At Hera”** , R. G. Milner , *Prepared for BNL Workshop on Future Directions in Particle and Nuclear PHysics at Multi-GeV Hadron Beam Facilities, Upton, NY, 4-6 Mar 1993*

42. **“Measurement of the proton spin structure function g1(p) with a pure hydrogen target”** , A. Airapetian *et al.* [HERMES Collaboration] , Phys. Lett. B **442**, 484 (1998) [arXiv:hep-ex/9807015]

43. **“The flavor asymmetry of the light quark sea from semi-inclusive deep inelastic scattering”** , K. Ackerstaff *et al.* [HERMES Collaboration] , Phys. Rev. Lett. **81**, 5519 (1998) [arXiv:hep-ex/9807013]

44. **“HERMES spectrometer”** , K. Ackerstaff *et al.* [HERMES Collaboration] , Nucl. Instrum. Meth. A **417**, 230 (1998) [arXiv:hep-ex/9806008]

45. **“Beam-induced nuclear depolarization in a gaseous polarised hydrogen target”** , K. Ackerstaff *et al.* [The HERMES Collaboration] , Phys. Rev. Lett. **82**, 1164 (1999) [arXiv:hep-ex/9806006]

46. **“Transverse longitudinal asymmetry in the quasielastic He-3 → e → e-prime) reaction”** , J. O. Hansen *et al.* , Phys. Rev. Lett. **74**, 654 (1995)

47. **“Measurement of the spin dependent asymmetry in H-3 → (e → e-prime) inelastic scattering at low-energy transfer”** , C. E. Jones *et al.* , Phys. Rev. C **52**, 1520 (1995)

48. **“Experiments with polarized electrons and polarized He-3”** , R. G. Milner , *In the Proceedings of Symposium on Future Polarization Physics at Fermilab, Batavia, Illinois, 13-14 June 1988, pp 141-164* , *Prepared for Symposium on Future Polarization Physics at Fermilab, Batavia, IL, 13-14 June 1988*

49. **“Measurement of the neutron spin structure function g1(n) with a polarized He-3 internal target”** , K. Ackerstaff *et al.* [HERMES Collaboration] , Phys. Lett. B **404**, 383 (1997) [arXiv:hep-ex/9703005]

50. **“Measurement Of The Deep Inelastic Spin Dependent Structure Functions Of The Proton And Neutron At Hera”** , D. H. Beck *et al.* , *Prepared for 3rd Conference on the Intersections between Particle and Nuclear Physics, Rockport, ME, 14-19 May 1988*

51. **“A Polarized internal He-3 target using optical pumping of metastable atoms”** , R. D. McKeown, R. G. Milner and C. E. Woodward , C88-09-12() , *Prepared for 8th International Symposium on High-energy Spin Physics, Minneapolis, MN, 12-17 Sep 1988*

52. **“An Internal polarized He-3 target for electron storage rings”** , L. H. Kramer, D. DeSchepper, R. G. Milner, S. F. Pate and T. Shin , Nucl. Instrum. Meth. A **362**, 32 (1995) , *Prepared for 17th Biennial World Conference of the International Nuclear Target Development Society (INTDS): Targets, Research Materials, and Related Topics of Hadron Physics, Bloomington, IN, 17-21 Oct 1994*

53. **“A Cryogenic storage cell for polarized internal gas targets”** , L. H. Kramer, J. F. Kelsey, R. G. Milner, P. Winn and J. McGuire , Nucl. Instrum. Meth. A **365**, 49 (1995)

54. **“Evidence For Virtual Compton Scattering From The Proton”** , J. F. J. van den Brand *et al.* , Phys. Rev. D **52**, 4868 (1995)

55. **“Measurement of the deep inelastic spin dependent structure functions of the proton and neutron at HERA”** , R. G. Milner , *In *Bonn 1990, Proceedings, High energy spin physics, vol. 1*, 411-418*

56. **“Electromagnetic physics with a polarized He-3 internal target”** , R. G. Milner , *In *Stanford 1987, Proceedings, Electronuclear physics with internal targets* 195-199*

57. **“Exclusive Electron Scattering From Deuterium At High Momentum Transfer”** , H. J. Bulten *et al.* , Phys. Rev. Lett. **74**, 4775 (1995)

58. **“Two body photodisintegration of the deuteron up to 2.8-GeV”** , J. E. Belz *et al.* , Phys. Rev. Lett. **74**, 646 (1995)

59. **“Spin dependent scattering of polarized protons from a polarized He-3 internal gas target”** , C. Bloch *et al.* , Nucl. Instrum. Meth. A **354**, 437 (1995)

60. **“Inclusive Electron Scattering From Nuclei At X Approximately = 1”** , J. Arrington *et al.* , Phys. Rev. C **53**, 2248 (1996) [arXiv:nucl-ex/9504003]

61. **“Measurement of the neutron magnetic form-factor from inclusive quasielastic scattering of polarized electrons from polarized He-3”** , H. Gao *et al.* , Phys. Rev. C **50**, 546 (1994)

62. **“Measurement of quasielastic He-3 (p, p N) scattering from polarized He-3 and the three-body ground state spin structure”** , M. A. Miller *et al.* , Phys. Rev. Lett. **74**, 502 (1995)

63. **“Inclusive electron nucleus scattering at high momentum transfer”** , D. B. Day *et al.* , Phys. Rev. C **48**, 1849 (1993)

64. **“A-dependence of nuclear transparency in quasielastic A(e,e'p) at high Q^2”** , T. G. O'Neill *et al.* , Phys. Lett. B **351**, 87 (1995) [arXiv:hep-ph/9408260]

65. **“A Laser optically pumped polarized He-3 target for storage rings”** , K. Lee, J. O. Hansen, J. F. J. van den Brand and R. G. Milner , Nucl. Instrum. Meth. A **333**, 294 (1993)

66. **“High Momentum Transfer R(T,L) Inclusive Response Functions For He-3, He-4. Slac-Ne-9 Experiment”** , Z. E. Meziani *et al.* , Phys. Rev. Lett. **69**, 41 (1992)

67. **“Measurement of spin observables using a storage ring with polarized beam and polarized internal gas target”** , K. Lee *et al.* [CE-25 Collaboration] , Phys. Rev. Lett. **70**, 738 (1993)

68. **“Nuclear structure functions at x ¿ 1”** , B. W. Filippone *et al.* , Phys. Rev. C **45**, 1582 (1992)

69. **“Experiments On Nuclei To Study Aspects Of QCD”** , R. G. Milner , *In *Lake Louise 1988, Proceedings, Quantum chromodynamics* 429-451.*

70. **“Probing The Polarized Sea By Inclusive Leptoproduction Of Hadrons”** , F. E. Close and R. G. Milner , Phys. Rev. D **44**, 3691 (1991)

71. **“Proposed measurement of the deep inelastic spin dependent structure functions of the proton and neutron at HERA”** , R. G. Milner , *In *Stanford 1989, Proceedings, Electronuclear physics with internal targets* 195-200. (see Conference Index)*

72. **“New physics with polarized He-3 targets”** , R. G. Milner , Nucl. Phys. A **508**, 599C (1990)

73. **“NUCLEAR MATTER RESPONSE FUNCTION”** , D. B. Day *et al.* , Phys. Rev. C **40**, 1011 (1989)

74. **“UPDATE ON POLARIZED HE-3 TARGET DEVELOPMENT”** , R. G. Milner, R. D. Mckeown and C. E. Woodward , *In *Newport News 1986, Proceedings, Research program at CEBAF. II.* 685-691. (see Conference Index)*

75. **“DEEP INELASTIC SCATTERING SPIN STRUCTURE FUNCTIONS”** , D. F. Geesaman, R. D. Mckeown and R. G. Milner , *In *Newport News 1986, Proceedings, Research program at CEBAF. II.* 401-405. (see Conference Index)*

76. **“MEASUREMENTS ON THE DELTA WITH A POLARIZED PROTON TARGET”** , R. G. Milner and R. D. Mckeown , *In *Newport News 1986, Proceedings, Research program at CEBAF. II.* 213-217. (see Conference Index)*

77. **“A POLARIZED HE-3 TARGET FOR NUCLEAR PHYSICS”** , R. G. Milner, R. D. Mckeown and C. E. Woodward , Nucl. Phys. A **497**, 495C (1989)

78. **“DELTA ELECTROPRODUCTION AND INELASTIC CHARGE SCATTERING FROM CARBON AND IRON”** , D. T. Baran *et al.* , Phys. Rev. Lett. **61**, 400 (1988)

79. **“MEASUREMENT OF CHARGED PION ASYMMETRIES IN SCATTERING OF POLARIZED ELECTRONS FROM POLARIZED HE-3”** , R. G. Milner and T. W. Donnelly , Phys. Rev. C **37**, 870 (1988)

80. **“INVESTIGATION OF THE INTERNAL SPIN STRUCTURE OF THE NEUTRON BY DEEP INELASTIC SCATTERING OF LONGITUDINALLY POLARIZED ELECTRONS FROM A POLARIZED HE-3 TARGET”** , R. G. Milner , *IN *PRINCETON 1984, PROCEEDINGS, POLARIZED HE-3 BEAMS AND TARGETS*, 186-193.*

81. **“Search For Fractionally Charged Particles”** , R. G. Milner, B. H. Cooper, K. H. Chang, K. Wilson, J. Labrenz and R. D. Mckeown , Phys. Rev. D **36**, 37 (1987)

82. **“Y SCALING IN ELECTRON NUCLEUS SCATTERING”** , D. B. Day *et al.* , Phys. Rev. Lett. **59**, 427 (1987)

83. **“Search For Fractional Charges In Niobium And Tungsten”** , R. G. Milner, B. H. Cooper, K. H. Chang, K. Wilson, J. Labrenz and R. D. Mckeown , Phys. Rev. Lett. **54**, 1472 (1985)

84. **“Longitudinal And Transverse Response Functions In Fe-56(E, E-Prime) At Momentum Transfer Near 1-Gev/C”** , J. P. Chen *et al.* , Phys. Rev. Lett. **66**, 1283 (1991)

CURRICULUM VITAE

Name:	Gerald Alan Miller	Office Phone:	206-543-2995
Address:	Physics Department, 351560 University of Washington Seattle, Washington 98195	Home Phone: Marital Status:	206-523-8518 Married, two children

Date and Place of birth: March 20, 1947, New York City

Education:

Bronx High School of Science	1963
City College of New York	1967
Massachusetts Institute of Technology, M.S.	1968
Massachusetts Institute of Technology, Ph.D.	1972

Employment:

University of Washington, Seattle, Washington 98195	1985 - present 1980 - 1985 1975 - 1980	Professor Associate Professor Research Assistant Professor
Jefferson Laboratory	2000-2003	Program Advisory Committee
Jefferson Laboratory	2004	Visiting Theorist
Lawrence Berkeley Laboratory	2004	Visiting Theorist
Brookhaven National Laboratory	2004	Visiting Theorist
ECT*, Trento	2003	Visiting Theorist
CSSM, Adelaide, Au.	2003	Visiting Theorist
Stanford Linear Accelerator Center	1997	Visiting Theorist
TRIUMF	1988 - 1989	Visiting Staff Member
University of Illinois	1989	Visiting Research Professor
CERN, Geneva, Switzerland	1982 - 1983	Paid Scientific Associate
Los Alamos National Laboratory	1979-1982, 1986	Prog. Advis. Comm, Visiting Staff Member
Carnegie-Mellon University Pittsburgh, PA 15213	1972 - 1975	Research Physicist

Honors and Awards:

New York Regents Scholarship, New York College Teaching Fellowship
Dean's List, Magna Cum Laude, Phi Beta Kappa, Sigma Xi
Graduate Fellowship at MIT
Fellow, American Physical Society
Fellow, American Association for the Advancement of Science

Outside Professional Positions:

Program Advisory Committee, Los Alamos National Laboratory, 1979-1982
Science Policy Advisory Committee, Los Alamos
National Laboratory, 1983-1986
Editorial Board Member, Physical Review C, 1986-1988
Program committee, DNP, American Physical Society, 1985-1987
Member, APS Task Force to review *Reviews of Modern Physics*, 1992-1993
Lead organizer, national Institute for Nuclear Theory programs, 1990-92;
1994 (workshop); 1996; 1998 (2 mini-workshops); 2001, 2004 (workshop)
National Science Foundation, Nuclear Theory panel member, 1997,2003
Physics Today, panel member for book reviews, 1997-2002
Program Advisory Committee member for Jefferson Laboratory 2000-2003
Managing Editor, International Journal Modern Physics E, 2004
USA Correspondent for Nuclear Physics News International, 2004

1. "The Role of Pairing in the Formation of Double Analogues in Heavy Nuclei," Phys. Rev. Lett. 28, 372 (1972) (with A.K. Kerman).

2. "Neutron Escape from Isobaric Analogue Resonances," Nucl. Phys. A212, 287 (1973).

3. "Positive Pion Production by 185 MeV Protons," Nucl. Phys. A224, 269 (1974).

4. "Angle Transformation for π-Nucleus Optical Potential," Phys. Rev. C 9, 1205 (1974) (with E. Kujawski).

5. "Effects of Nuclear Polarizability on Pion Elastic Scattering," Nucl. Phys. A223, 477 (1974).

6. "PIRK-A Computer Program to Calculate the Elastic Scattering of Pions from Nuclei," Computer Physics Communications 8, 130 (1974) (with R.A. Eisenstein).

7. "The Use of 'New' Pion Optical Potentials in the (p, π^+) and (π^+, p) Reactions," Phys. Lett. 51B, 129 (1974) (with S.C. Phatak).

8. "Angle Transformation for the Pion-Nucleus Optical Potential," Phys. Rev. C 10, 1242 (1974).

9. "Pion Charge Exchange Reactions with Nuclei," Phys. Lett. 53B, 329 (1974) (with J.E. Spencer).

10. "The (π, d) Reaction for Small Incident Pion Energies," Phys. Rev. C 11, 2001 (1975) (with R.A. Eisenstein).

11. "Implications of High Energy Pi-Nucleon Data for Elastic Pi-Nucleus Scattering," Phys. Rev. C 12, 1962 (1975) (with D.J. Ernst).

12. "The (p, π^-) Reaction and Δ^{++} Components of Nuclei," Nucl. Phys. A254, 493 (1975) (with L.S. Kisslinger).

13. "Pion Charge Exchange Reactions with Nuclei," Annals of Physics (N.Y.), 100, 562 (1976) (with J.E. Spencer).

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Education

Ph.D., September 1988, Physics, Duke University, Durham North Carolina.
M.A., June 1984, Physics. Duke University, Durham, North Carolina.
B.S., August 1981, Physics. University of Florida, Gainesville, Florida.
B.A., August 1981, Mathematics. University of Florida, Gainesville, Florida.

Employment History

January 2008 - Present	Professor Experimental Group Leader, High Energy Physics Universidad Técnica Federico Santa María
May 2005 to November 2007	Senior Staff Scientist 12 GeV Associate Project Manager for Physics Thomas Jefferson National Accelerator Facility
October 2003 to April 2005	Staff Scientist III Hall B Physicist Thomas Jefferson National Accelerator Facility
October 1995 to September 2003	Staff Scientist II Hall B Physicist Thomas Jefferson National Accelerator Facility
January 1993 to September 1995	Staff Scientist I Hall B Physicist Thomas Jefferson National Accelerator Facility
November 1990 to December 1992	*Research Associate* University of Pittsburgh

September 1988 to November 1989	*Postdoctoral Researcher* The Ohio State University

Honorary Academic Appointments

December 2005 to present	*Jefferson Lab Professor of Physics* Old Dominion University

PhD Students:

Jeffrey Lachniet, Carnegie Mellon University (Brian Quinn, University Advisor), "A high precision measurement of the neutron magnetic form factor using the CLAS detector," June 2005.

Hayk Hakobyan, Yerevan State University (Alita Danagulyan, University Advisor), "Observation of Quark Propagation Pattern in Nuclear Medium," June 2008.

Maryam Motabbed, Florida International University (Brian Raue, University Advisor), Topic will be two-photon exchange measured through electron-proton and positron-proton elastic scattering, anticipated in early 2009.

Taya Mineeva, University of Connecticut (Kyungseon Joo, University Advisor), Topic will be hadron attenuation and transverse momentum broadening for π^0 mesons in nuclear deep inelastic scattering, anticipated for summer 2011.

Research Interests

A spokesperson for five Jefferson Lab experiments:

E-94-117 "The Neutron Magnetic Form Factor from Precision Measurements of the Ratio of Quasi-elastic Electron-Neutron to Electron-Proton Scattering in Deuterium"

E-02-104 "Quark Propagation through Cold QCD Matter"

E-04-116 "Beyond the Born Approximation: A Precise Comparison of Positron-Proton and Electron-Proton Elastic Scattering in CLAS"

E-12-06-117 "Quark Propagation and Hadron Formation"

E-12-07-104 "Measurement of the Neutron Magnetic Form Factor at High Q^2 Using the Ratio Method on Deuterium"

Invited Talks

"Experimental Opportunities in High Energy Physics with ATLAS at LHC," XVI Simposio Chileno de Física, Valparaiso, Chile, November 2008.

"The Role of Kaons in Studies of Hadronization Dynamics," Workshop on CLAS Ring Imaging Cerenkov Detector, Jefferson Lab, Newport News, Virginia, August 2008

"Parton propagation and hadron formation in the space-time domain," Sixth International Conference on Perspectives in Hadronic Physics, ICTP, Trieste, Italy, May 2008

"Parton propagation and hadron formation in the space-time domain," UTFSM Seminar, Valparaiso, Chile, March 2008

“Hadron Attenuation and Medium Effects in Photoproduction: QCD in the Spacetime Domain,” Workshop on Photon-hadron Physics with the GlueX detector at Jefferson Lab, Jefferson Lab, Newport News, Virginia, March 2008.

“Parton Propagation and Hadron Formation: Present Status, Future Prospects,” Workshop on Parton Fragmentation Processes in the Vacuum and in the Medium, European Centre for Theoretical Studies in Nuclear Physics (ECT*), Trento, Italy, February 2008.

“Space-Time Properties Of Hadronization: What Physics can be Gained from a CLAS12 RICH?” CLAS 12 RICH Detector Workshop, Jefferson Lab, Newport News, Virginia, January 2008.

“Space-time Properties of Hadronization: Insights from Semi-inclusive DIS on Nuclei,” Workshop on Short-Range Structure of Nuclei at 12 GeV, Jefferson Lab, Newport News, Virginia, October 2007.

“QCD Processes in the Nucleus,” Nuclear Science Advisory Committee Long Range Plan, QCD and Hadron Physics Town Meeting, Rutgers, New Jersey, January 2007.

“Partonic Propagation Through Strongly Interacting Systems,” Workshop on High Energy Physics in the LHC Era – Valparaiso, Chile, December 2006.

“The 12 GeV Upgrade of Jefferson Lab: Physics Program and Project Status,” Workshop on High Energy Physics in the LHC Era – Valparaiso, Chile, December 2006.

“Overview of the 12 GeV Upgrade at Jefferson Lab,” 73rd Annual Meeting of the Southeastern Section of the American Physical Society, Williamsburg, Virginia, November 2006.

“QCD Confinement in Forming Systems: Measuring Characteristic Times in Hadronization Processes,” Jefferson Lab User Group Summer Workshop, Newport News, Virginia, June 2006.

“Quark Propagation, the Strong Force, and the Mystery of QCD Confinement,” Old Dominion University Physics Department Colloquium, Norfolk, Virginia, November 2005.

“Deep Inelastic Scattering Data on Nuclei with CLAS at Jefferson Lab: Present and Future,” Workshop on Parton Propagation through Strongly Interacting Matter, European Centre for Theoretical Studies in Nuclear Physics (ECT*), Trento, Italy, September 2005.

“Nucleon Form Factors – Experimental Perspectives,” Electromagnetic Interactions with Nucleons and Nuclei, Milos, Greece, September 2005.

“Space-Time Properties of Hadronization from Nuclear Deep Inelastic Scattering,” Institute of Nuclear and Particle Physics seminar, Ohio University, Athens, Ohio, March 2005.

“A Precise Determination of the Neutron Magnetic Form Factor to Higher Q^2,” Tenth International Baryons Conference, Palaiseau, France, October 2004.

“Quark Propagation and Fundamental Processes in QCD,” Jefferson Lab User Group Meeting, Newport News, Virginia, June 2004.

“Space-Time Properties of Hadronization from Nuclear Deep Inelastic Scattering,” Nuclear and Particle Physics seminar, University of Connecticut, Storrs, Connecticut, November 2003.

“Space-Time Studies of Hadronization at Jefferson Lab,” Physics Department Colloquium, University of Dortmund, Dortmund, Germany, June 2003.

“Space-Time Properties of Hadronization from Nuclear Deep Inelastic Scattering,” Second International Conference on Nuclear and Particle Physics with CEBAF at Jefferson Laboratory, Dubrovnik, Croatia, May 2003.

“The Neutron Magnetic Form Factor G_{Mn} – Status of the CLAS/E5 Measurement,” Topical Workshop on the Deuteron, Florida International University, Miami, Florida, March 2003.

“Hadronic Multi-particle Final State Measurements with CLAS at Jefferson Lab,” Second International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region, University of California, Irvine, California, December 2002.

“CLAS – A Large Acceptance Spectrometer for Intermediate Energy Electromagnetic Nuclear Physics,” 15th International Conference on Particles and Nuclei, Uppsala, Sweden, June 1999.

“First Results from CLAS,” Gordon Research Conference on Photonuclear Physics, Tilton School, Tilton, New Hampshire, July 1998.

Publications

For CLAS collaboration papers, the names of ~160 collaboration members are here omitted for brevity.

First measurement of target and double spin asymmetries for ep--> eppi0 in the nucleon resonance region above the Delta (1232), A.S. Biselli,..., W. K. Brooks, …(The CLAS Collaboration), Phys. Rev. C **78**:045204 (2008).

A double-target system for precision measurements of nuclear medium effects, H. Hakobyan, W. K. Brooks, K. Bruhwel, V. D. Burkert, T. Carstens, S. Christo, H. Egiyan, N. Gevorgyan, J. Gram, K. Hafidi, P. Hemler, D. Insley, G. Jacobs, D. Kashy, B. A. Mecking, Y. Sharabian, S. Stepanyan, D. Tilles, L. Weinstein, X. Zheng, Nucl. Instrum. Meth. A **592**:218-223 (2008)

Studies of Parton Propagation and Hadron Formation in the Space-Time Domain, W.K. Brooks, H. Hakobyan. AIP Conf. Proc. 1056:215-222 (2008).

Search for the photo-excitation of exotic mesons in the pi+ pi+ pi- system.
M. Nozar, …, W. K. Brooks, …(The CLAS Collaboration), May 2008. 6pp.
Submitted to Phys.Rev.Lett. e-Print: arXiv:0805.4438 [hep-ex]

Electro excitation of the Roper resonance for 1.7 < Q**2 < 4.5 -GeV2 in vec-ep ---> en pi+, I.G. Aznauryan, …, W. K. Brooks, ..., (The CLAS Collaboration), Phys. Rev. C **78**:045209 (2008).

Electroproduction of phi(1020) mesons at 1.4 < Q**2 < 3.8 GeV**2 measured with the CLAS spectrometer, J. P. Santoro, …, W. K. Brooks, … (The CLAS Collaboration), Phys. Rev. C **78**:025210 (2008).

Light Vector Mesons in the Nuclear Medium, M. H. Wood, …, W. K. Brooks, …(The CLAS Collaboration), Phys. Rev. C **78**:015201 (2008).

Polarized Structure Function Σ_{LT} for p(pol(e),e'K^+)Λ in the Nucleon Resonance Region, R. Nasseripour, …, W. K. Brooks, …(The CLAS Collaboration), Phys. Rev. C **77**:065208 (2008).

Ratios of N-15/C-12 and He-4/C-12 inclusive electroproduction cross sections in the nucleon resonance region, P. E. Bosted, …, W. K. Brooks, … (The CLAS Collaboration), Phys. Rev. C **78**:015202 (2008).

Deeply virtual Compton scattering beam-spin asymmetries, F. X. Girod, …, W. K. Brooks, …(The CLAS Collaboration), Phys. Rev. Lett.100:162002 (2008).

Measurement of e p --> e p pi0 beam spin asymmetries above the resonance region, R. De Masi, …, W. K. Brooks, …(The CLAS Collaboration), Phys. Rev. C **77**:042201 (2008).

"Observation of a backward peak in the $\gamma d \rightarrow \pi^{\circ} d$ cross section near the eta threshold," Y. Ilieva, …,

W. K. Brooks, … (The CLAS Collaboration), Submitted to Phys. Rev. Lett. March 2007. arXiv:nucl-ex/0703006v1.

"A Bayesian analysis of pentaquark signals from CLAS data," D. G. Ireland, …, W. K. Brooks, … (The CLAS Collaboration), Phys. Rev. Lett. **100**, 052001 (2008).

"Cross Sections and Beam Asymmetries for $ep \rightarrow en\pi^+$ in the Nucleon Resonance Region of $1.7 < Q^2 < 4.5$ GeV^2," K. Park, …, W. K. Brooks, … (The CLAS Collaboration), Phys. Rev. C**77**, 015208 (2008).

"Search for Medium Modifications of the rho meson," R. Nasseripour, …, W. K. Brooks, … (The CLAS Collaboration), Phys. Rev. Lett. **99**, 262302 (2007).

"Coherent Phi Meson Photoproduction from the Deuteron at Low Energies," T. Mibe, …, W. K. Brooks, … (The CLAS Collaboration), Phys. Rev. C **76**, 052202 (2007).

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"Cascade Production in the Reaction $\gamma p \rightarrow K^+K^+X$ and $\gamma p \rightarrow K^+K^+\pi^-X$," L. Guo, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. C **76**, 025208 (2007).

"Cross sections for the $\gamma p \rightarrow K^{*0}\Sigma^+$ Reaction at $E(\gamma) = 1.7 - 3.0$ GeV," I. Hleiqawi, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. C **75**, 042201 (2007).

"Experimental Study of Exclusive ^{2}H(e,e'p)n Reaction Mechanism at High Q^2," K.Sh. Egiyan, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. Lett. **98**, 262502 (2007).

"First Measurement of Beam-Recoil Observables C_x and C_z in Hyperon Photoproduction," R. Bradford, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. C **75**, 035205 (2007).

"Separated Structure Functions for the Exclusive Electroproduction of $K^+\Lambda$ and $K^+\Sigma^0$ Final States," P. Ambrozewicz, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. C **75**, 045203 (2007).

"Quark-Hadron Duality in Spin Structure Functions g1p and g1d," P.E. Bosted, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. C **75**, 035203 (2007).

"Search for the Θ^+ pentaquark in the reactions $\gamma p \rightarrow \bar{K}^0 K^+ n$ and $\gamma p \rightarrow \bar{K}^0 K^0 p$," R. DeVita, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. D **74**, 032001 (2006).

“Measurement of the N to Delta(1232) Transition at High Momentum Transfer by π^0 Electroproduction,” M. Ungaro,…, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. Lett. **97**, 112003 (2006).

“Measurement of the x- and Q^2-dependence of the spin asymmetry A1 of the nucleon,” K.V. Dharmawardane…, W. K. Brooks, …, (The CLAS Collaboration), Phys. Lett. B **641**, 11 (2006).

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“Search for Θ^{++} Pentaquarks in the Exclusive Reaction $\gamma p \rightarrow K^+ K^- p$,” V. Kubarovsky, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. Lett. **97**, 102001 (2006).

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“Measurement of 2- and 3-nucleon short range correlation probabilities in nuclei,” K. Egiyan, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. Lett. **96**, 082501 (2006).

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“Beam-Helicity Asymmetries in Double-Charged-Pion Photoproduction on the Proton,” S. Strauch, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. Lett. **95**, 162003 (2005).

"The deuteron structure function F2 with CLAS," M. Osipenko, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. C **73**, 045205 (2006).

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"Beam-Helicity Asymmetries in Double-Charged-Pion Photoproduction on the Proton," S. Strauch, …, W. K. Brooks, …, (The CLAS Collaboration), Phys. Rev. Lett. **95**, 162003 (2005).

"Deeply Virtual and Exclusive Electroproduction of Omega Mesons," L. Morand, …, W. K. Brooks, …, (The CLAS Collaboration). Eur. Phys. J. A **24**, 445 (2005).

"A Precise Determination of the Neutron Magnetic Form Factor to Higher Q^2," W. K. Brooks (Baryons 2004 proceedings) Nucl.Phys. A **755** (2005) 261-264.

"Radiative Decays of the Σ^0(1385) and Λ(1520) Hyperons," S. Taylor, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. C **71**, 054609, (2005).

"Exclusive Photoproduction of the Cascade (Xi) Hyperons," J. Price, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. C **71**, 058201 (2005).

"Exclusive ρ^0 Meson Electroproduction from Hydrogen at CLAS," C. Hadjidakis, …, W. K. Brooks, …, (The CLAS Collaboration). Physics Letters B **605**, 256 (2005).

"Onset of Asymptotic Scaling in Deuteron Photodisintegration," P. Rossi, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. Lett. **94**, 012301 (2005).

"Survey of $A_{LT'}$ Asymmetries in Semi-Exclusive Electron Scattering on ^{4}He and ^{12}C," D. Protopopescu, …, W. K. Brooks, …, (The CLAS Collaboration). Nucl. Phys. A **748**, 357 (2005)

"Proton Source Size Measurements in the $eA \rightarrow e'ppX$ Reaction," A. V. Stavinsky, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. Lett. **93**, 192301 (2004).

"Space-Time Properties of Hadronization from Nuclear Deep Inelastic Scattering," W. K. Brooks, Fizika B **13**, (2004) 1, 321-328.

"Complete Angular Distribution Measurements of Two-Body Deuteron Photo-disintegration between 0.5 and 3 GeV," M. Mirazita, … , W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. C **70**, 014005 (2004).

"Complete Measurement of Three-Body Photodisintegration of ^{3}He for Photon Energies between 0.35 and 1.55 GeV," S. Niccolai, …, W. K. Brooks, …, (The CLAS Collaboration).

Phys. Rev. C **70**, 065003 (2004).

"Measurement of the Polarized Structure Function $\sigma_{LT'}$ for p(e(polarized),e'π^+)n in the Delta Resonance Region," K. Joo, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. C **70,** 042201R (2004).

"Observation of an Exotic Baryon with S=+1 in Photoproduction from the Proton," V. Kubarovsky, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. Lett. **92**, 032001 (2004).

"Measurement of Beam-Spin Asymmetries for π^+ Electroproduction above the Baryon Resonance Region," H. Avakian, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. D **69** 112004 (2004).

"Hyperon Photoproduction in the Nucleon Resonance Region," J. W. C. McNabb, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. C **69**, 042201(R) (2004).

"Tensor Polarization of the phi meson Photoproduced at High t," K. McCormick, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. C **69**, 032203 (2004).

"Two-Nucleon Momentum Distributions Measured in ^{3}He(e,e'pp)n," R. Niyazov, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. Lett. **92**, 052303 (2004).

"Observation of an Exotic S = +1 Baryon in Exclusive Photoproduction from the Deuteron," S. Stepanyan, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. Lett. **91**, 252001 (2003).

"Measurement of the Spin Structure Functions in the Resonance Region for Q^2 from 0.15 to 1.6 GeV^2," R. Fatemi, …, W. K. Brooks, …,(The CLAS Collaboration). Phys. Rev. Lett. **91**, 222002 (2003).

"Measurement of Polarized Structure Function $\sigma_{LT'}$ for p(e(polarized),e'p)π^0 from Single π^0 Electroproduction in the Delta Resonance Region," K. Joo, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. C, Rapid Comm. **68**, 032201 (2003).

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“Measurement of Inclusive Spin Structure Functions of the Deuteron with CLAS,” J. Yun, …, W. K. Brooks, …, (The CLAS Collaboration). Phys Rev. C **67**, 055204 (2003).

“First Measurement of Transferred Polarization in the Exclusive e(polarized)p$\rightarrow$e'K $^+\Lambda$(polarized) Reaction,” D. Carman, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. Lett. **90**, 131804 (2003).

“A Complete Measurement of the F_2 Proton Structure Function in the Resonance Region and the Evaluation of the Moments,” M. Osipenko, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. D **67**, 092001 (2003).

“Photoproduction of the Omega Meson on the Proton at Large Momentum Transfer,” M. Battaglieri, …, W. K. Brooks, …, (The CLAS Collaboration). Phys. Rev. Lett. **90**, 022002 (2003).

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Sabbatical Proposal

Dr. Gerard P. Gilfoyle
Physics Department, University of Richmond

1 Introduction

This document is a research proposal for a full-year sabbatical at the University of Richmond. The research proposed here builds on the successful program I have developed in electro-nuclear physics at the Thomas Jefferson National Accelerator Facility (Jefferson Lab or JLab) in Newport News, VA that is externally supported by the US Department of Energy and has involved many University of Richmond undergraduates in frontier research at a world-class facility. The primary scientific instruments at Jefferson Lab are a large, one-mile-around, electron accelerator and three large particle detectors or end stations which capture and measure the debris from collisions of the electron beam with nuclear targets. The projects discussed below include an investigation into the fundamental nature of matter and an instrumentation project that are both part of the long-range plan for nuclear physics in the US [1].

The main focus of the research is two-fold. (1) The magnetic form factor of the neutron is a fundamental quantity related to the distribution of electric charges and electric currents within the atomic nucleus. To understand the interior landscape of matter we must know where the electric charge is located! The first project will complete the analysis of a large data set that uses a unique experimental technique to measure the neutron magnetic form factor in a region where there are conflicting measurements from other laboratories. This project will make an important contribution to our understanding of the nucleus and will be the subject of one or more refereed publications. (2) The highest priority in nuclear physics is the upgrade of Jefferson Lab to open new windows into the structure of matter. This undertaking will require the efforts of hundreds of physicists, engineers, and technicians over the next six years. I am the leader of one of the experiments slated to be performed in the first years of running after the upgrade is complete. In preparation for that experiment and as part of the effort to build the new particle detectors at Jefferson lab, I will be developing simulations of neutrons that are important for design and construction of the detectors and for the planning of future experiments. This last project will advance the upgrade of Jefferson and will be the subject of at least one publication, several technical reports, and will provide strong justification for future funding.

I am planning on spending the full academic year on sabbatical (2009-2010) and I am pursuing funding from the US Department of Energy, Jefferson Science Associates, and other sources. I also plan to apply for an enhanced sabbatical from the University.

2 The Quest for Quarks

Nobody has ever seen a quark. Yet, physicists have no doubt about their existence and the central role they play at the very heart of all the matter in the world around us. Figure 1 shows the current, over-simplified, picture of the structure of matter. Within the atomic nucleus lie protons and neutrons (collectively called nucleons) that are in turn composed of three smaller particles; the quarks. Other particles, the gluons, pop in and out of existence in a bubbling soup inside the nucleus and, strangely enough, create the forces that hold the quarks together. It is this force that poses one of the great challenges to our understanding of the Universe. Every other fundamental force we observe gets weaker as two particles get farther apart. This feature is what allows us to launch spacecraft to other planets and to generate electricity. The force that binds quarks or a quark and a gluon together is different. It is constant regardless of the distance between the quarks and gluons. Pull two quarks a meter apart and the force is the same as when they are 100,000 times closer. This 'confinement' means that we will never 'see' a bare quark.

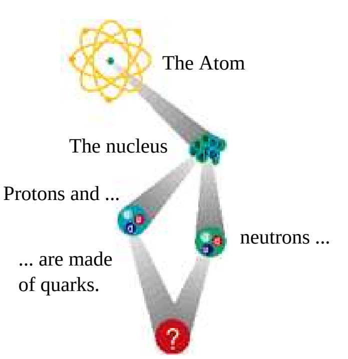

Fig 1. The structure of matter.

This is not the whole story. The best theory of the quark-quark force we have now is called quantum chromo-dynamics (QCD). QCD is built on observations made at very high energy where the environment is simpler and easier to understand, but where the conditions are different from the ones inside the nucleus. One of the main reasons for upgrading JLab is to understand the nature of confinement and how quarks combine to form protons and neutrons (the basic constituents of everyday matter). We need to map out the features of the quarks as they go about their everyday lives inside the nucleus. A vital step in this nuclear cartography is to know where the electric charges located within the nucleus and its constituents.

In this Proposal I will describe two physics projects, but first let me describe how one takes data at JLab to set the stage for the description of the research projects. The JLab accelerator produces a electron beam by pushing the electrons through the mile-long, racetrack-shaped, machine up to five times (see Figure 2). This beam is extracted and sent into one of three experimental halls. It is in the halls where the action takes place. The electron beam strikes a nuclear target and a spray of debris is produced that we detect and measure. The detector I use is called the CEBAF Large Acceptance Spectrometer or CLAS (CEBAF stands for the Continuous Electron Beam Accelerator Facility, the actual electron accelerator). This is a large (about 45 tons), \$50-million device that was built by my colleagues and me in the CLAS Collaboration. See Figure 3. The CLAS Collaboration consists of about 300 physicists from all over the world who are responsible for building, maintaining, and operating CLAS. The collision or event that I just described occurs about 2000-3000 times each second and we record a deluge of data; about 1 terabyte (1000 gigabytes) per day. One of these large data sets is the focus of the first project.

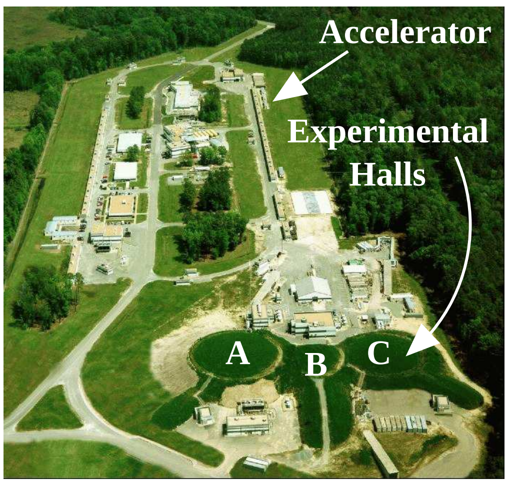

Fig 2. The accelerator at JLab.

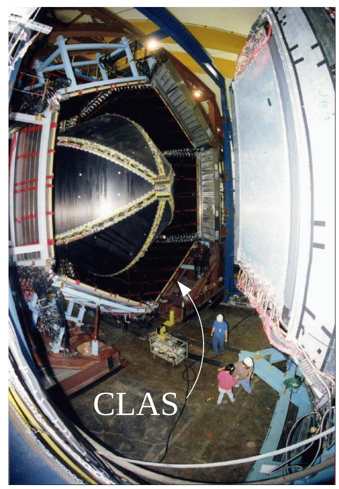

Fig 3. The CLAS detector.

3 The Magnetic Form Factor of the Neutron

The magnetic form factor of the neutron (known symbolically at G_M^n) is a fundamental observable related to the distribution of electric charge and current within the nucleons and atomic nuclei [2]. If we are to claim we understand the nature of matter we must have a theory which describes the position of the charges and currents inside matter. Quantum chromodynamics is our best and most successful theory of how quarks and gluons interact, but at the energies of the particles inside the neutron the theory is nearly intractable. Fortunately, there is a way forward. Using computational methods on high-speed arrays of computers holds the promise of enabling us to solve QCD at nucleon energies. This technique is called 'lattice QCD' because space and time are broken down into discrete pieces and the calculations are performed on this space-time lattice which is an approximation to the nearly continuous form of Nature. Full calculations are beyond currently available computers so we make approximations and apply tests to map out the accessible regions of the lattice. As computers and our knowledge increase in power, we expect over the next decade that calculations of the neutron magnetic form factor and other, related quantities will become important tests for the success or failure of QCD in this energy regime. The magnetic form factor of the neutron is especially important because the lattice QCD calculation is, for technical reasons, simpler and 'cleaner' than others so it will be an important early benchmark to meet. It is also worth mentioning that the measurement of G_M^n is part of the long-range plan for nuclear physics in the United States [1].

The research plan for the measurement of G_M^n will now be described. The data have already been collected for the nuclear reaction $eD \rightarrow e'pn$ where the incidence electron (e) strikes a deuterium (D) target. The debris from the collision consists of the scattered electron (e'), a proton (p), and a neutron (n). The measurement was done with the CLAS detector and consist of three sets of running conditions. In two of those sets the magnet used to bend the trajectories of the electrons and protons and measure their momenta was operated in its standard mode. The analysis of those data is nearly complete and is near the end of its internal, collaboration review. The results will soon be submitted for publication [3]. They will represent a dramatic improvement in the range and precision over previous measurements. See Figure 4 which shows a commonly used form of G_M^n plotted versus the quantity Q^2 which represents the size of the kick we impart to the neutron in the collision with the electron beam. Our results are the red points and the other points represent a sample of the best measurements made from laboratories around the world [2] along with several theoretical curves [32, 5, 6, 7]. In the third set of running conditions we used the CLAS magnet in an uncommon configuration and the analysis of that data requires more work. These unanalyzed data are in a lower energy and momentum regime than the other data, but they overlap with other measurements of G_M^n made at different laboratories around the world. Notice in Figure 4, the scatter of points for Q$^2 < 1$ GeV^2. These conflicting measurements have spawned a variety of theoretical models. The experimental situation cries out for resolution and our data can help clarify the situation.

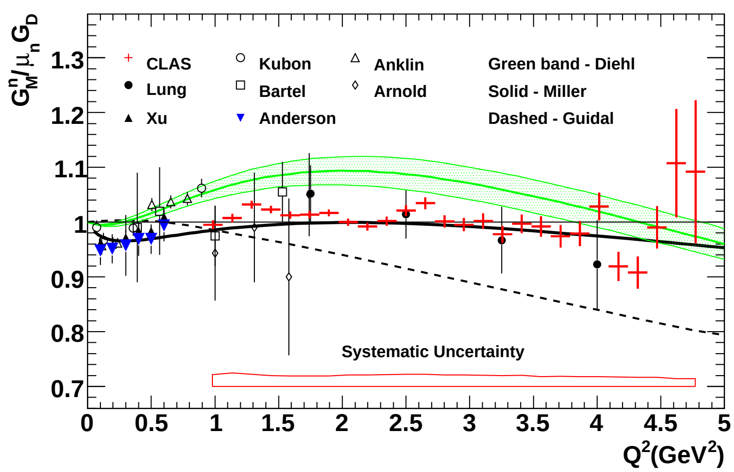

Fig 4. Our Preliminary results for G_M^n with a selection of the world's data.

The plan for attacking this problem is the following. We will extract the ratio of the production of neutrons to protons from a deuterium target to extract G_M^n as a function of Q^2. This is the same method we used successfully on the data from the other two sets of running conditions. The first step in applying this technique to our data is to calibrate the CLAS response. Some of this work has already been done, but two of the CLAS components (the large-angle calorimeters) still need to be calibrated. This will be done with data from a proton target that was exposed to the electron beam simultaneously with the deuterium target. Once the CLAS is calibrated, we then correct for a variety of effects like the detection efficiencies for protons and neutrons in CLAS and the effect of the internal motion of the neutron in the deuterium target. These corrections require a variety of methods from analysis of the calibration data to simulations of the reactions. Once the ratio of neutron to proton production is extracted and corrected, we must make careful studies of the systematic uncertainties in the measurement. For a complex detector like CLAS this process requires thoughtful analysis of the data and accurate simulations of the CLAS response to separate true physics effects from mere artifacts of the detector. When it is all done, we will publish the results.

4 Upgrading the CLAS Detector

A fundamental challenge for modern nuclear physics is to understand the structure and interactions of nucleons and nuclei in terms of QCD. Jefferson Lab's unique Continuous Electron Beam Accelerator Facility has given the United States leadership in addressing this challenge. The US Department of Energy has begun an upgrade of Jefferson Lab that will double the energy of the JLAB accelerator will enable three-dimensional imaging of the nucleon, revealing hidden aspects of its internal dynamics. It will complete our understanding of the transition between the hadronic and quark/gluon descriptions of nuclei, and test definitively the existence of exotic hadrons, long-predicted by QCD as arising from quark confinement.

To take full advantage of the new physics opportunities a new CLAS12 detector will evolve from the existing CLAS to meet the basic requirements for the study of the structure of nucleons and nuclei after the CEBAF energy upgrade to 12 GeV. See Figure 5 which shows a conceptual design of the new device. The height of the detector in the figure is about 10 meters.

There are several important questions we seek to answer. A major focus of CLAS12 will be mapping out the three-dimensional structure of the nucleon for the first time. The project is technically challenging and require the high beam currents and wide angular coverage of CLAS12. We still do not understand the source of nucleon spin. Measurements show that the quarks supply only about one-third of the total spin of the proton and our inability to understand this basic property has spawned the 'spin crisis'. Studies of the nucleon spin structure will also require high beam currents and the unique properties of CLAS12. At the higher energies, new requirements on particle identification make improvements in a wide variety of the technical properties of CLAS12 over CLAS essential for success.

In the summer of 2007, A proposal to extend the measurements of the neutron magnetic form factor to higher energy using the upgraded CEBAF and CLAS12 was approved by the JLab Program Advisory Committee. The new experiment is expected to run during the first five years of operation after the upgrade is complete. During the period of this sabbatical we will begin work on the simulation of events in the CLAS12 to further develop this proposal and others and to contribute to the design and implementation of the components of CLAS12. We are committed to development projects for the JLab 12-GeV Upgrade and will be responsible for design, prototyping, development, and testing of software for event simulation and reconstruction. The improved CLAS12 detector will have prodigious software requirements. The online data rate is expected to be 20 kHz with a 10 kByte event size and less than 15% deadtime [8]. We will collect about 1 petabyte of data each year.

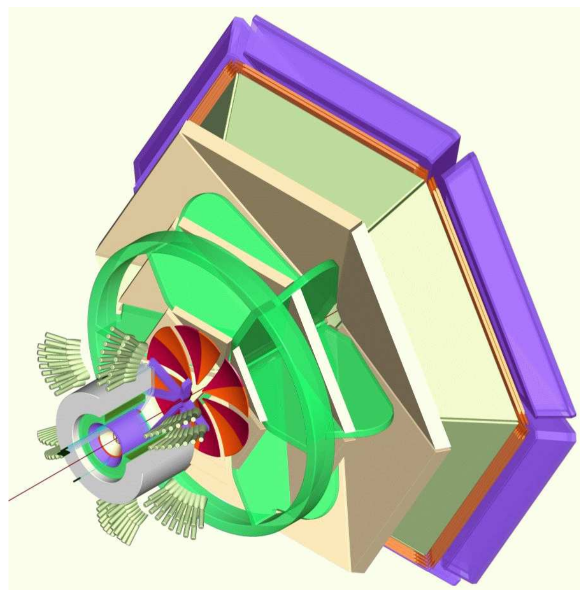

Fig 5. The CLAS12 detector.

Event simulation is an essential aspect of the design of CLAS12 and eventual precision of the detector. For many experiments, the quality of the results will be limited by systematic uncertainties instead of statistical ones. Accurate, precise calculations of the CLAS12 acceptance and response are important to keep those systematic uncertainties small. To do that we expect to generate about four times as much simulated, Monte Carlo data as CLAS12 collects. The CLAS12 simulation will produce data more slowly than the detector itself so the contribution of university groups to this effort is essential. The current CLAS detector takes data at a rate of about 3 kHz. Events can be simulated at a far slower rate; about 2-3 Hz depending on the CPU speed. We expect a similar difference with CLAS12. The same issues that arise in designing the physics experiments also arise in the design and prototyping phase of the project we are just entering. First beams are not expected until the next decade, but this work has already begun. The work described here will be the subject of JLab reports and refereed instrumentation publications.

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US Department of Energy Renewal Proposal

Medium Energy Nuclear Physics Research at the University of Richmond

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Grant Contract Number DE-FG02-96ER40980
Grant Period: June 1, 2009 - May 31, 2012

Office of Nuclear Physics: Medium Energy Nuclear Physics Program
Program Manager: Dr. Brad Tippens

Medium Energy Nuclear Physics Research at the University of Richmond

G. P. Gilfoyle
Physics Department
University of Richmond

Abstract

The nuclear physics program at the University of Richmond is focused on the structure of nucleons and the transition from the hadronic picture of matter to a quark-gluon description. We use the Thomas Jefferson National Accelerator Facility (JLab) to measure the charge and magnetization distributions of the neutron and extract components of the deuteron wave function. We propose a new program to produce strange quarks in the nucleus to study the color force via the hyperon-nucleon interaction. We will push some of these measurements to higher energy as part of the JLab 12-GeV Upgrade.

5 Project Introduction

This is a renewal application to support the University of Richmond electromagnetic nuclear physics research program at the Thomas Jefferson National Accelerator Facility (JLab). Dr. G.P. Gilfoyle is the principle investigator (PI). Our physics projects are listed in Table 1.

Title	Label
Measurement of the Neutron Magnetic Form Factor at High Q^2 Using the Ratio Method on Deuterium (Gilfoyle: spokesperson and contact person)	E12-07-104
The Neutron Magnetic Form Factor from Precision Measurements of the Ratio of Quasielastic Measurement of the Neutron Magnetic Form Factor at High Q^2 Using the Ratio Method on Electron-Neutron to Electron-Proton Scattering in Deuterium	E94-017
Out-of-Plane Measurements of the Structure Functions of the Deuteron (Gilfoyle: spokesperson)	CLAS-Approved Analysis[1]
Quark Propagation and Hadron Formation (Gilfoyle: co-spokesperson)	E12-06-117
Spectroscopic Study of Λ Hypernuclei in the Medium-Heavy Mass Region and p-Shell Region Using the $(e, e'K^+)$ Reaction (extension of E05-115)	E05-115/E08-002
Study of Light Hypernuclei by Pionic Decay at JLab	E08-012

Table 1: Summary of physics projects of the Richmond group.

We now summarize our progress in the two years since our last review (2006). We have completed the extraction of the magnetic form factor of the neutron G_M^n for two out of three data sets from the E5 running period at JLab (Section 6.1.1). We took over the completion of this project in spring 2008 after the primary researcher (Lachniet) took a job in industry and we finished the analysis to complete the internal, CLAS Collaboration technical review. The CLAS Analysis Note was approved October 1, 2008 [1].[2] We are leading the effort to publish a paper on this work. A draft has has been approved by an internal CLAS Collaboration committee and the full collaboration and submitted to Physical Review Letters [2]. We successfully defended a new proposal before the JLab Program Advisory Committee (PAC) to extend our measurements of G_M^n to higher Q^2 as part of the JLab 12-GeV Upgrade (Section 6.1.1). JLab recently received approval to begin construction on this project. The proposal E12-07-104 was approved by PAC32 in August, 2007 for running in the first five years after the 12-GeV Upgrade [3]. We have begun the analysis of the third E5 data set to

[1] The CLAS Collaboration has a procedure where Collaboration members can analyze existing data sets with official Collaboration approval. The member writes a proposal describing an analysis project, it is reviewed by an internal committee, and then defended before the full Collaboration.

[2] CLAS Collaboration rules require a separate technical paper to be reviewed by an internal committee before the process of publication begins.

extract G_M^n. We have copied the data to the Richmond computing cluster and completed initial calibrations, efficiency measurements, *etc.* (Section 6.1.1).

We have made progress in our analysis of the fifth structure function in $^2\mathrm{H}(\mathrm{e},\mathrm{e'p})\mathrm{n}$ (Section 6.1.2). This project is a CLAS Approved Analysis.[1] The reaction was simulated with the CLAS standard Monte Carlo package GSIM and we showed that our analysis algorithms are valid. We have also extracted systematic uncertainties. A new calculation by Jeschonnek and Van Orden using a fully relativistic approach in the impulse approximation described much of our data when averaged over the CLAS acceptance [4, 5].

In other contributions, we upgraded one of the CLAS online monitoring tools (online RECSIS) to the linux operating system (Section 6.1.4). Gilfoyle continues to serve as chair of the Nuclear Physics Working Group and on the CLAS Coordinating Committee (Section 6.1.5). He also served on a review panel for the CLAS12 tracking in preparation for an external review [6] and presented an overview of the CLAS12 software and the software report at a 12-GeV Upgrade workshop [7, 8]. CLAS12 is the new detector that will replace CLAS in Hall B after the 12-GeV Upgrade at JLab. He was invited to give four talks on JLab physics [9, 10, 11, 12] and his students have made four presentations in the last two years [5, 13, 14, 15].

We now summarize our Plan of Work. We have begun the analysis of the third and remaining E5 data set to extract G_M^n using the same techniques applied to other E5 data. These data could have considerable impact on the experimental situation in this Q^2 range where there are inconsistencies among different data sets and a recent, suggested observation of the pion cloud (Section 6.2.1). We will complete the analysis of the fifth structure function in quasielastic kinematics for the reaction $^2\mathrm{H}(\mathrm{e},\mathrm{e'p})\mathrm{n}$. We are generating Monte Carlo simulations now to test for acceptance effects in the two data sets where we see statistically significant results. We are analyzing the same data set as the G_M^n experiment. Once that analysis is complete we will explore other structure functions and higher energy transfer. These measurements have the potential to establish a baseline for the hadronic model at low Q^2 which will enable us to more clearly see the onset of quark-gluon degrees of freedom at higher Q^2 (Section 6.2.2). Last, we will begin work on the simulation of neutrons for the CLAS12 detector. This project is closely connected with our future physics projects and takes advantage of our past experience (Section 6.2.4).

We propose the addition to our group of a faculty researcher in hypernuclear physics. This idea is motivated by the presence at Richmond of Dr. C. Samanta who is on a three-year teaching assignment while on leave from the Saha Institute in Kolkata, India. Her position is Visiting Instructor of Physics. Dr. Samanta is an accomplished nuclear physicist with a background that bridges both theory and experiment. She is now focused on hypernuclear physics and has joined the hypernuclear collaboration at JLab under the leadership of Dr. L. Tang and will participate in an upcoming experiment in 2009 (E05-115/E08-002) and later (depending on beam schedule) E08-012. More details are in Sections 6.2.6, 6.2.7, and 7. Dr. Samanta's presence at Richmond is an opportunity for us to extend our physics reach, recruit and train more students, and enhance the physics program at JLab at comparatively little cost. We note here, this new program and our existing one are distinct. We will form one group of faculty and students, but there are no plans at this time for Dr. Samanta to join the CLAS Collaboration or for Gilfoyle to join the hypernuclear collaboration.

6 Project Description

6.1 Status of Current Projects

6.1.1 Magnetic Form Factor of the Neutron

The elastic electromagnetic form factors are the most basic observables that describe the internal structure of the proton and neutron. Their measurement is a goal of the current NSAC Long-Range Plan [16] and is Milestone HP4 in the DOE Performance Measures [17] The differential cross section for elastic electron-nucleon scattering can then be calculated in the laboratory frame as [18]

$$\frac{d\sigma}{d\Omega} = \sigma_{Mott}\left(G_E^2 + \frac{\tau}{\epsilon}G_M^2\right)\left(\frac{1}{1+\tau}\right) \tag{1}$$

where σ_{Mott} is the cross section for scattering from a point particle, G_E is the electric form factor, G_M is the magnetic form factor, $\tau = Q^2/4M^2$ where M is the nucleon mass, and $\epsilon = (1 + 2(1+\tau)\tan^2(\theta/2))^{-1}$ where θ is the electron scattering angle. There are a total of four elastic form factors (electric and magnetic ones for each nucleon).

We are part of a broad assault on the four elastic nucleon form factors at Jefferson Lab [19, 20, 21]. All four elastic form factors are needed to untangle the different quark contributions and our focus is on G_M^n. To measure G_M^n we use the ratio R of quasielastic (QE) $e-n$ to $e-p$ scattering on deuterium defined as

$$R = \frac{\frac{d\sigma}{d\Omega}(D(e,e'n))}{\frac{d\sigma}{d\Omega}(D(e,e'p))} = a(E, Q^2, \theta_{pq}^{max}, W_{max}^2)\frac{\frac{{G_E^n}^2+\tau {G_M^n}^2}{1+\tau} + 2\tau {G_M^n}^2\tan^2(\frac{\theta}{2})}{\frac{{G_E^p}^2+\tau {G_M^p}^2}{1+\tau} + 2\tau {G_M^p}^2\tan^2(\frac{\theta}{2})} \tag{2}$$

where E is the beam energy, the factor $a(E, Q^2, \theta_{pq}^{max}, W_{max}^2)$ corrects for nuclear effects and depends on cuts on θ_{pq}^{max}, the maximum angle between the nucleon direction and the three-momentum transfer $\vec{q}$, and W_{max}^2, the maximum value of the mass recoiling against the electron assuming the target was at rest. Deviations from the 'free ratio' assumption in the right-hand part of Equation 2 are parameterized by the factor $a(E, Q^2, \theta_{pq}^{max}, W_{max}^2)$ which can be calculated from deuteron models and is close to unity at large Q^2. The ratio method is less vulnerable to systematic uncertainties than previous methods [22]. The extraction of G_M^n depends on our knowledge of the other three nucleon form factors.

We have completed data collection and the analysis for a measurement of G_M^n in the range $Q^2 = 1.0 - 4.8$ GeV^2 using two out of the three sets of running conditions from the E5 running period [1, 9, 10, 22, 23]. Our results are shown in Figure 1 for two electron beam energies (2.6 GeV and 4.2 GeV) with the CLAS toroid having standard polarity (electrons inbending) along with a selection of the world's data. The reversed polarity (electrons outbending) data at 2.6 GeV are still being analyzed (see below and Section 6.2.1). The data are plotted as the ratio to $G_M^n/\mu_n G_D$ where μ_n is the neutron magnetic moment and G_D is calculated in the dipole approximation. The data are consistent with G_D for $Q^2 > 1.0$ GeV^2. A CLAS analysis note describing this work has been approved based on J.D.Lachniet's thesis (a CMU graduate student) [1].[2] The Richmond group have taken over primary responsibility for completing the work since spring 2008 after J.D.Lachniet took a position in industry. A paper has been submitted to Physical Review Letters [2]. We have taken the lead role in writing this paper and shepherding it through the review process.

We have submitted a proposal (PR12-07-104) to measure G_M^n at high Q^2 as part of the physics program for the JLab, 12-GeV Upgrade [3]. The proposal was approved by PAC32 in August, 2007. We had the primary responsibility for developing this proposal. The committee report [24] summarized the proposal in the following way:

> Proposal PR12-07-104 is a measurement of the neutron magnetic form-factor G_M^n in Hall B using a deuterium target. The method proposed is elegant and its physics essential to the program. The results of this experiment, if successful, will provide neutron data, which when combined with proton results determine the isovector form-factor, that is more readily computable on the lattice, having no disconnected quark contributions. This essential measurement will thus have the added benefit of providing a valuable test of the efficacy of lattice calculations.

[2] CLAS Collaboration rules require a separate technical paper to be reviewed by an internal committee before the process of publication begins.

This planned measurement will significantly expand the upper limit of this measurement (from Q^2 = 4.8 GeV^2 to 13.5 GeV^2), provide important constraints on generalized parton distributions, and test the validity of lattice QCD calculations. We continue to study simulations of this experiment to support the design and construction of the new, CLAS12 detector in Hall B [13, 15].

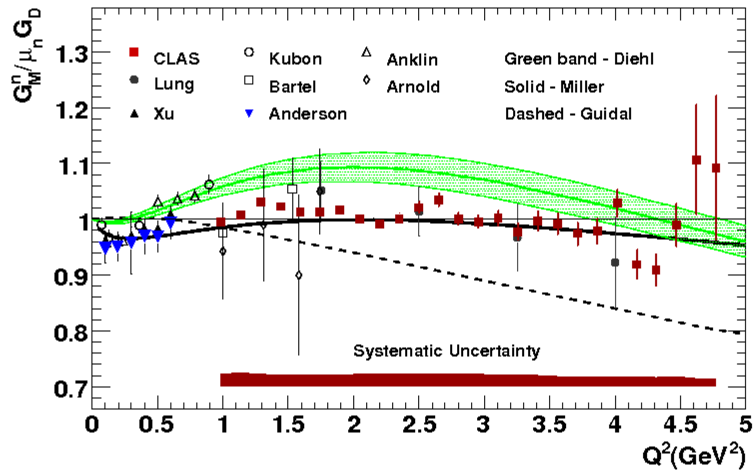

Figure 1: Selected results for $G^n_M/(\mu_n G_D)$ from the CLAS measurement are compared with a selection of previous data [25, 26, 27, 28, 29, 30, 31] and theoretical calculations [32, 33, 34, 35]

The E5 run period consists of data sets with three different sets of running conditions. Two sets at 2.6 GeV and 4.2 GeV used a standard CLAS torus magnet polarity (electrons inbending) and a third set of data was collected at 2.6 GeV with the CLAS torus polarity reversed (electrons outbending) to reach lower Q^2. These data cover the range $Q^2 \approx 0.2 - 1.0$ GeV^2 and overlap with measurements from several other laboratories and other experiments at Jefferson Lab. This region has been the focus of intense interest over the last few years because of the observation of evidence for the pion cloud [36, 37]. We are now analyzing those data. We have extracted the neutron and proton detection efficiencies, calculated the Fermi correction, and carefully matched the $e - n$ and $e - p$ solid angles to determine R. A comparison with our previous results for the 2.6-GeV, normal torus polarity results show some differences that are under investigation.

In our last renewal in 2006, we planned on developing the proposal to measure G^n_M at 12 GeV and begin the analysis of the reversed torus polarity measurements from the E5 run period. The proposal has been approved and we have made progress on the analysis. During the same time period we have taken over and completed the CLAS analysis note and lead the effort to write the paper and submit it for publication.

6.1.2 Out-of-Plane Structure Functions of the Deuteron

We are investigating the out-of-plane structure functions of the deuteron using the reaction $D(\vec{e}, e'p)n$ to establish a baseline or benchmark for the hadronic model of nuclei to meet. The data were measured with the CLAS detector in Hall B at JLab (see Section 2.2 for more details). This baseline is necessary so that we can more clearly map the transition from hadronic to quark-gluon degrees of freedom at higher Q^2. The cross section for the reaction with a polarized beam and unpolarized target can be written as

$$\frac{d\sigma^5}{d\nu d\Omega_e d\Omega_{pq}} = \sigma_L + \sigma_T + \sigma_{TT}\cos\phi_{pq} + \sigma_{LT}\cos 2\phi_{pq} + h\sigma'_{LT}\sin\phi_{pq} \tag{3}$$

where the σ_i are the different components of the cross section, $h = \pm 1$ is the helicity of the electron beam, and ϕ_{pq} is the azimuthal angle of the ejected proton relative to the 3-momentum transfer $\vec{q}$. This angle ϕ_{pq} is the angle between the plane defined by the incoming and outgoing electron 3-momenta and the plane defined by the ejected proton and neutron. See Figure 2. The ϕ_{pq}-dependent parts of Eq. 3 have not been extensively investigated in the past. They represent a model-independent measurement of a little-studied part of the deuteron cross section and probe its wave function.

In this status report we focus on our progress extracting the fifth structure function σ'_{LT} (see Eq. 3) which is the imaginary part of the LT interference. The structure functions are measured by forming asymmetries. We define the asymmetry $A_{LT'}$ as $A_{LT'} = \sigma'_{LT}/(\sigma_L + \sigma_T)$. Note this definition is slightly different from previous ones which included an additional, small contribution from σ_{TT} in the denominator of $A_{LT'}$. For our analysis, the effect of this additional term is negligible. To take full advantage of the large acceptance of the CLAS detector we form the asymmetries from the moments of the out-of-plane production. We start

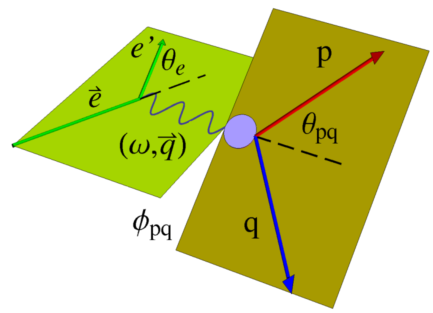

Figure 2: Kinematics of $D(\vec{e}, e'p)n$.

with the $\sin\phi_{pq}$-weighted average for different beam helicities

$$\langle \sin\phi_{pq}\rangle_{\pm} = \frac{\int_0^{2\pi} \sigma^{\pm} \sin\phi_{pq} d\phi_{pq}}{\int_0^{2\pi} \sigma^{\pm} d\phi_{pq}} = \frac{1}{N_{\pm}} \sum_{i=1}^{N_{\pm}} \sin\phi_i = \pm\frac{A'_{LT}}{2} \tag{4}$$

where the pluses and minuses refer to the beam helicity, $\sigma^{\pm}$ is the cross section in Equation 3 for different beam helicities, ϕ_i is ϕ_{pq} for an event, and $N_{\pm}$ is summed over all events of a particular beam helicity. We then subtract the two averages to obtain the asymmetry $A'_{LT} = \langle \sin\phi_{pq}\rangle_{+} - \langle \sin\phi_{pq}\rangle_{-}$. Here we report on our results for quasi-elastic kinematics.

We are analyzing the E5 data set which is the same dataset as the G_M^n measurement in Section 6.1.1. We are focused on the two, 2.6-GeV datasets with opposite torus polarities. The 4.2-GeV has inadequate statistics for our analysis. The data cover the 4-momentum transfer range $Q^2 = 0.2 - 2.0$ $(\mathrm{GeV/c})^2$. Preliminary results for A'_{LT} are shown in the left-hand panel of Figure 3 as a function of the missing momentum $\vec{p}_m = \vec{q} - \vec{p}_p$ where $\vec{p}_p$ is the measured proton momentum. In the plane-wave impulse approximation this

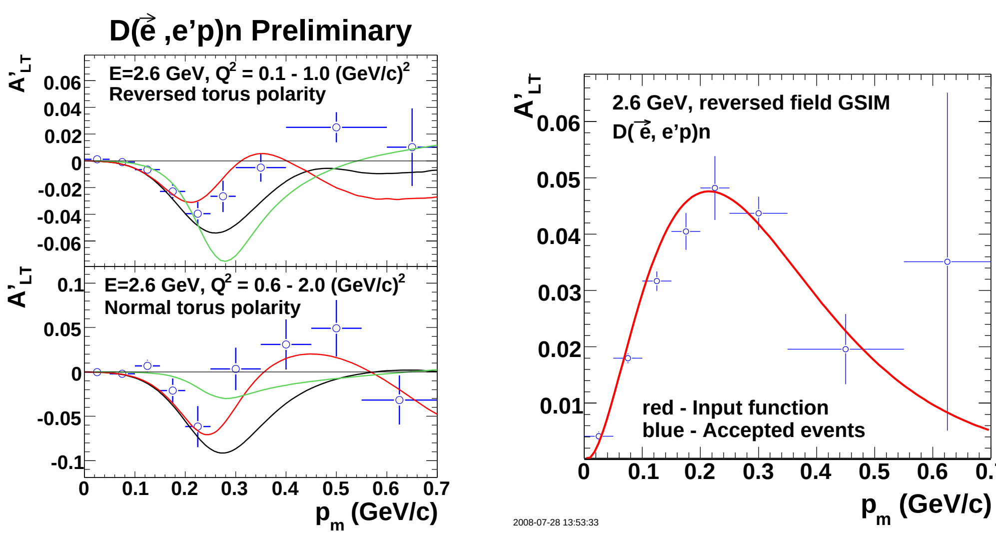

Figure 3: Preliminary results for the asymmetry A'_{LT} for the 2.6-GeV, E5 data sets (left-hand panel). Curves are discussed in the Section 6.2.2. The right-hand panel is a comparison of user inputs and simulation results for the 2.6-GeV, reversed torus polarity data.

is the opposite of the initial momentum of the proton in the deuteron. These are the first data measured for this asymmetry in this Q^2 range. We can observe small asymmetries with good precision in quasi-elastic kinematics.

The analysis of the asymmetry $A_{LT'}$ is far along. We have completed event selection, data corrections, and extracted systematic errors from the data. We are now studying acceptance effects using the CLAS standard simulation package GSIM. Some results for the 2.6-GeV, reversed torus polarity data are shown in the right-hand panel of Fig 3. Within the Monte Carlo uncertainties, the simulation agrees with the 'true' distribution (the red curve). We are continuing to produce these simulations to reduce the uncertainties in the calculation at high p_m seen in Fig 3 and to perform the same calculations for the 2.6-GeV, normal torus polarity data set.

We have compared our results with theoretical calculations The black curves on each plot in the left-hand panel of Fig. 3 are from Arenhövel [38] averaged over the CLAS acceptance. These calculations use the non-relativistic Schrödinger equation with relativistic corrections added along with corrections for meson exchange currents, isobar configurations, and final state interactions (FSI) [39]. Those calculations agree with the data in sign and magnitude for $p_m < 0.25$ (GeV/c), but disagree at higher missing momentum. The green curves are from Jean-Marc Laget who uses a diagrammatic approach for $Q^2 = 1.1$ GeV^2 (lower panel) and $Q^2 = 0.7$ GeV^2 (upper panel) [40]. This calculation does not reproduce the shape or Q^2 dependence of our measurement. We have a new calculation from Jeschonnek and Van Orden (JVO) shown in the red curves which is a fully relativistic calculation in the impulse approximation using the Gross equation for the deuteron ground state and the SAID parameterization of the NN scattering amplitude for FSI. The red curves in the left-hand panel of Fig.3 are averaged over the CLAS acceptance. For the high-Q^2 data set, the JVO calculation reproduces our data over the full range of missing momenta. At lower Q^2, it does well for $p_m < 0.4$ GeV, but diverges at high p_m; a sign of the increasing importance of meson-exchange currents not included in JVO. Our recent progress on this analysis was presented at the 2008 Gordon Conference on Photonuclear Reactions.

In our last renewal in 2006, we planned on completing this analysis by 2009. We still expect to meet that schedule. This work is part of a CLAS Approved Analysis[1] (see Table 1) and Gilfoyle is the spokesperson. Preliminary results have been presented at conferences [5] and a CLAS analysis note is in preparation.

6.1.3 Quark Propagation and Hadron Formation

The confinement of quarks inside hadrons is perhaps the most remarkable features of QCD and the quest to understand confinement quantitatively is an essential goal of modern nuclear physics. The subject can be investigated by striking one of the quarks with a photon and stretching out the color string tying it to its neighbors. The color string stretches until $q\bar{q}$ pairs tunnel up from the vacuum, thwarting the struck quark's attempt to escape to isolation. The real picture with full QCD is more complicated and experimental information is necessary to guide models of hadronization. Gilfoyle is a co-spokesperson on a 12-GeV experiment E12-06-117 *Quark Propagation and Hadron Formation* that lays out a program to determine the mechanisms of confinement in forming systems. We are responsible for the analysis of the π^0, η, and η' exit channels. This future experiment and E12-07-104 (the 12-GeV G_M^n measurement) have motivated our interest in the detection of neutral particles as part of the CLAS12 software development and the 12-GeV Upgrade.

6.1.4 Technical Projects

We are committed to development projects for the JLab 12-GeV Upgrade and will be responsible for design, prototyping, development, and testing of software for event simulation and reconstruction in CLAS12, the new detector in Hall B [41]. We have begun work using an early version of the CLAS12 simulation package called Sim12. We optimized and documented the procedures needed to download, install, compile, and build Sim12 [42] and optimized the configuration for faster response during run-time. We wrote plugins for different event generator output formats. After a core software program is written and distributed, any updates, critical or not, are difficult to distribute if the program is large and requires long recompilation times like Sim12. Plugins, on the other hand, can be extremely easy to implement by a user, often involving a single download into a specific directory as the only necessary step to gain or improve functionality. We developed two plugins to read in event generator results and pass them to Sim12; one using a text-based event format and the other using the LUND format [43]. The code was tested with three different Linux distributions along with initial physics testing [14]. Since then, the CLAS12 software group has developed a new program called gemc to replace Sim12. We are now getting this new package operational at Richmond [15].

We are also responsible for maintaining one of the current CLAS online monitoring tools called online RECSIS [44, 45] The CLAS collects data at a prodigious rate so it is essential that the incoming data be carefully monitored to enable early detection of any problems. We modified the CLAS standard analysis package to read the incoming datastream during an experiment and perform a full, event reconstruction on a subset of the incoming data. Histograms have been developed for monitoring purposes and these are used to generate timelines of various quantities that be observed using a web-based interface. The code has been operating reliably for years now and we modified it in fall, 2007 to use the Linux operating system when the Hall B DAQ group switched to that operating system.

6.1.5 CLAS Collaboration Service

Gilfoyle was part of the team that assessed the design of the CLAS12 drift chambers during a workshop on this topic at JLab in February, 2007 [6] in preparation for an external review of the systems. At the Hall B, 12 GeV Workshop in May, 2007 he presented the progress on the CLAS12 reconstruction and gave the report on the software portion of the workshop. He serves as chair of the Nuclear Physics Working Group and is a member of the CLAS Coordinating Committee; the primary governance committee of the CLAS Collaboration. Each physics working group in the Collaboration (there are four) is responsible for discussing, planning, and reviewing physics issues and their consequences for the CLAS instrumentation in their designated subfield [46].

6.2 Plan of Work

The research effort in nuclear physics is part of the program at the Thomas Jefferson National Accelerator Facility (JLab) in Newport News, VA. The primary goal of JLab is to unravel the quark and gluon structure of protons, neutrons, and atomic nuclei and to deepen our understanding of matter and, in particular, the confinement of quarks. In this section we describe the experimental environment and the proposed physics programs.

JLab is a unique tool for basic research in nuclear physics. The central instrument is a superconducting electron accelerator with a maximum energy of 4-6 GeV, a 100% duty cycle, and a maximum current of 200 μA. Our research is done in Hall B with the CEBAF Large Acceptance Spectrometer (CLAS) and here we propose a new program in Hall C in hypernuclear physics. CLAS is a large (45-ton), toroidal, multi-gap magnetic spectrometer with nearly full solid angle coverage (see Figure 4). A toroidal magnetic field is

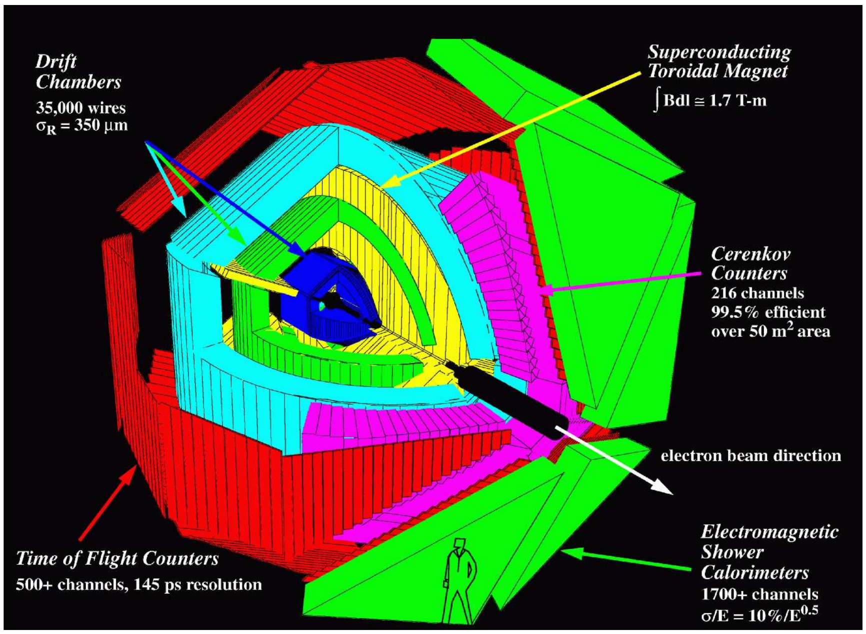

Figure 4: The CLAS detector.

generated by six iron-free superconducting coils. The particle detection system consists of drift chambers [47] to measure charged particle trajectories, Cerenkov detectors [48] to identify electrons, scintillators [49] for time-of-flight measurements, and electromagnetic calorimeters [50]. The six segments are instrumented individually to form six independent spectrometers. The Richmond group has been part of the CLAS Collaboration that built and now operates the detector since its inception.

The base equipment in Hall C consists of the moderate-resolution, 7-GeV/c High-Momentum Spectrometer and the large-acceptance Short-Orbit Spectrometer. For the hypernuclear experiments described below these detectors will be moved to make space for the High-Resolution Kaon Spectrometer (HKS) and High-Resolution Electron Spectrometer (HES) (see Figure 5). To reach very forward angles, a splitter magnet separates positive kaons, scattered electrons, and zero-degree electrons. The chicane in the figure is required so the zero-degree electrons reach the Hall C beam dump.

JLab recently received approval from DOE to begin a project to double the CEBAF energy and expand the physics reach of the laboratory. The completion of the 12-GeV CEBAF Upgrade at JLab is Recommendation 1 of the most recent Long-Range Plan of the Nuclear Science Advisory Committee [16]. To take advantage of the new physics opportunities a new detector called CLAS12 will be built in Hall B to replace the existing CLAS. We are committed to development projects for the JLab 12-GeV Upgrade and will be responsible for design, prototyping, development, and testing of software for event simulation and reconstruction.

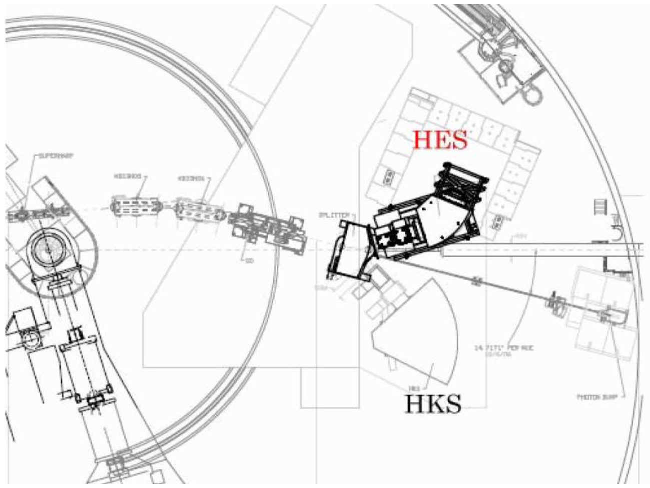

Figure 5: The HKS and HES in Hall C.

6.2.1 Magnetic Form Factor of the Neutron (*Gilfoyle*)

One of the central goals of nuclear physics now is to push our understanding of the theory of the strong interaction, Quantum Chromodynamics or QCD, into the unconquered territory of the nonperturbative region [16]. Here, the nonlinear nature of QCD dominates and defies traditional mathematical solutions; forcing us to resort to phenomenological models, effective field theories, and the daunting numerical calculations of lattice QCD. Our understanding of the structure of the proton and neutron is still clouded. One of the central questions raised in *The Frontiers of Nuclear Science* is 'What is the internal landscape of the nucleons?' [16]. The neutron magnetic form factor G_M^n is one of the fundamental quantities of nuclear physics and its evolution with Q^2 characterizes the distributions of charge and magnetization within the neutron. It is central to our understanding of nucleon structure. We are now opening a new, unprecedented tomographic view of the interior of the nucleons through the measurement of generalized parton distributions (GPDs). The elastic form factors are a limiting case related to the zeroth moment of the GPDs and provide a vital constraint to GPD models [51]. Lattice QCD calculations are now becoming feasible in the few-GeV^2 range, and over the next decade these calculations will become increasingly precise [52]. The elastic form factors here for both the proton and neutron are an important test case of the accuracy of the lattice calculations. With them, one can determine the isovector combinations of the form factors [53] which are easier to calculate on the lattice because of the lack of disconnected contributions [24]. We are part of a wide effort to measure the four elastic nucleon form factors at Jefferson Lab [19, 20, 21]. All four elastic form factors are needed to untangle the different quark contributions and our focus is on the magnetic form factor of the neutron. Our role in the G_M^n project is twofold. First, we have taken on the task of analyzing the 2.6-GeV, reversed torus polarity (electrons outbending) data from the E5 running period. The goal is to extract G_M^n using the same methods developed for the other sets of running conditions at 2.6 GeV and 4.2 GeV (both have normal torus polarity with electrons inbending). Second, we propose developing software for simulating the performance of the CLAS12 detector which will occupy Hall B after the 12-GeV Upgrade.

The current status of our understanding of G_M^n at lower Q^2 is shown in Figure 1 in Section 6.1.1 where G_M^n is scaled by the dipole form factor $G_D(Q^2) = 1/(1 + Q^2/\Delta)^2$ and $\Delta = 0.71$ GeV^2. The parameter Δ is interpreted as the square of the effective meson mass. The red points represent the recent work by Lachniet, *et al.* and our E5 group [2, 22, 23]. The blue triangles are a recent Hall A measurement at JLab by Anderson, *et al.* using the $^3\vec{\mathrm{He}}(\vec{e}, e')$ reaction in concert with theoretical calculations to extract G_M^n [26]. The remaining points are from several experiments including precise measurements of the reduced form factor by Anklin, *et al* [29] and Kubon, *et al.* [54] that use the ratio method similar in many respects (but not all) to the method we use and which is described below. We focus here on $Q^2 < 1.0$ GeV^2. Our measurement in Fig. 6.1.1 at $Q^2 = 1.0$ GeV^2 is about 6-7% below the one by Kubon *et al.* (open circle) at nearly the same Q^2. The data from Anklin *et al.* (open triangles in Fig. 6.1.1) range from 2-5% above the dipole and are a few percent above the Anderson *et al.* results where they overlap. We have preliminary results in this Q^2 range that agree with Anderson *et al.* and are about 6-7% below the results of Anklin *at al.* and Kubon *et al.*. We have data from the E5 running period that is still being analyzed that overlaps with the other measurements in this Q^2 region. In particular, for the 2.6 GeV, normal torus polarity data set discussed in Section 6.1.1 we have some data that extends down to $Q^2 \approx 0.5$ GeV^2. We also have data from the 2.6 GeV reversed torus polarity data set that goes even lower; down to $Q^2 \approx 0.2 - 0.3$ GeV^2 that is still being analyzed.

We have taken on the analysis of the existing, 2.6-GeV, reversed-torus-polarity data set from the E5 running period. These data cover the range $Q^2 = 0.2 - 2.0$ GeV^2 and overlap with our 2.6-GeV, normal-torus-polarity data set and with the results from several other groups. See Figure 1. There are disagreements between our data and some of the previous measurements and our low-Q^2 data could help sort out the experimental situation. At the same time, efforts by Friedrich and Walcher [36] to re-analyze the low-Q^2 data for all four quasielastic, nucleon form factors suggest that a structure they observe at $Q^2 \approx 0.2$ GeV^2 in all the elastic form factors is due to the presence of the pion cloud. Measurements of G_E^p and G_M^p from Bates [37], of G_E^n from Mainz [55], and of G_M^n from JLab [56], have shown structure in this Q^2 region ($\approx 0.1 - 1.0$ GeV^2). Additional theoretical work supports the observation of the pion cloud [57, 58]. There are hints of structure around $Q^2 \approx 0.38$ GeV^2 in the ratio G_e^p/G_M^p from polarization measurements in a recent Hall A experiment [59]. However, others disagree. The observation of a structure near $Q^2 \approx 0.2$ GeV^2 contradicts what is known from chiral perturbation theory and dispersion relations [60]. A recent measurement of G_E^n from Bates [61] found no evidence of a bump due to the pion cloud. Our low-Q^2 CLAS data reach down into this Q^2 range and could overlap with the bump observed in Ref [36]. We expect statistical and systematic uncertainties of about 3% each and the E5 data set has abundant overlaps and consistency checks to ensure the quality of the results. This is an excellent opportunity to improve our understanding of nucleon structure with data we already have in hand.

To this end we will use the ratio R of $e-n$ to $e-p$ scattering from a deuterium target to measure G_M^n. The technique is based on Equation 2 in Section 6.1.1 which shows that knowledge of R, nuclear correction factors $a(E, Q^2, \theta_{pq}^{max}, W_{max}^2)$, and the other elastic, nucleon form factors will enable us to extract G_M^n. To determine G_M^n we calculate the corrections $a(E, Q^2, \theta_{pq}^{max}, W_{max}^2)$ in Equation 2 with existing models [22]. The proton form factors are precisely known and the neutron's electric form factor G_E^n is typically small. By taking ratios in Equation 2 we are less sensitive to uncertainties in the luminosity, electron acceptance, electron reconstruction efficiency, trigger efficiency, the deuteron wave function, and radiative corrections. This technique does require precise knowledge of the neutron detection efficiency and careful matching of the neutron and proton acceptances. To measure the neutron detection efficiency a unique dual, hydrogen-deuterium, target cell was used in the E5 running period. We use the $ep \to e'\pi^+ n$ reaction as a source of tagged neutrons to measure the neutron efficiency simultaneously with data collection on deuterium. The neutrons are detected in two, overlapping measurements with both the electromagnetic calorimeter (EC) and the time-of-flight (TOF) system in CLAS. The TOF measurement provides a useful cross check on the EC measurement. To measure the proton detection efficiency we use elastic ep scattering on the hydrogen target to make tagged protons. Acceptance matching is done event-by-event by detecting the electron and assuming quasielastic scattering from one of the nucleons in deuterium. We then use the electron kinematics to determine if a quasielastic proton or neutron would fall in the CLAS acceptance. If so, then we search for a proton or neutron in the predicted locations. Corrections for Fermi motion of the nucleons bounds in the deuteron are calculated in simulation. To select quasielastic events we make a cut on θ_{pq} the angle between the detected nucleon and 3-momentum transfer $\vec{q}$ which effectively eliminates inelastic events for $W^2 < 1.2$ GeV^2 [2]. This method has proved successful in our previous analysis of the E5 data [2].

During the period of this proposal we will perform the analysis of the 2.6-GeV, reversed field data described above. We will be working with W.K. Brooks (JLab) the spokesperson on the original G_M^n proposal (E94-017). Dr. Brooks is now at the Universidad Técnica Federico Santa María in Chile, but spends considerable time at JLab each year. The analysis of these data and fifth-structure function data (see Section 6.1.2 and below) are from the same dataset so we can make efficient use of our time and resources.

6.2.2 Out-of-Plane Structure Functions of the Deuteron (*Gilfoyle*)

We propose to measure the out-of-plane structure functions of the deuteron in the GeV region to test the hadronic model of nuclei. The hadronic model of nuclear physics has been successful at low Q^2, but it is not well-developed in the GeV region even though we expect it to be valid there. There are few data to challenge theory. The importance of relativistic corrections (RC), final-state interactions (FSI), meson-exchange currents (MEC), and isobar configurations(IC) is our focus here. These measurements complement an effort on the theory side to clarify our understanding of the hadronic picture of the deuteron [62]. Our project is part of a larger effort to establish a baseline for the hadronic model to meet so deviations at higher Q^2 can be attributed to quark-gluon effects with greater confidence. This is an important step in answering the question posed in the most recent NSAC Long-Range Plan: 'What governs the transition from quarks and gluons to pions and nucleons?' [16]. The importance of this issue was stressed in previous JLAB PAC studies [63].

As mentioned in Section 6.1.2 we are investigating the out-of-plane structure functions of the deuteron using the reaction $D(\vec{e}, e'p)n$ with CLAS. See Eq. 3 and Fig. 2 in Section 6.1.2 for the expression for the cross section and the kinematic observables. The structure functions are an essential meeting ground between theory and experiment and the unique, nearly-4π solid angle of CLAS coupled with the high-quality, polarized beams at JLab create an inviting opportunity to study σ'_{LT}, σ_{LT}, and σ_{TT} (see Eq. 3). These structure functions depend on ϕ_{pq} and have not been extensively investigated in the past. We are making a model-independent measurement of a little-studied part of the deuteron cross section that probes its wave function. The large acceptance of CLAS gives us the capability of accessing a wide range of Q^2 and energy transfer ν.

We now discuss the present state of knowledge of these out-of-plane structure functions of the deuteron. Existing measurements of A'_{LT} are sparse. There are two measurements of $A_{LT'}$ in quasielastic kinematics at $Q^2 = 0.13$ GeV^2 [64] and 0.22 GeV^2 [65] and a single measurement at higher energy transfer ν at $Q^2 = 0.15$ GeV^2 [66]. The effect of FSI is shown in Fig. 6 from Ref. [65] where the solid curve is a calculation with FSI turned on and the dashed-dotted line shows the same calculation with FSI turned off. The same figure also shows the challenges of making these measurement with adequate statistics. Compare

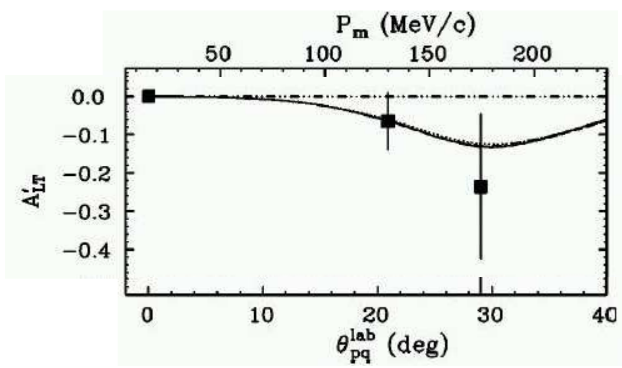

Figure 6: Measurements of A'_{LT} from Reference [65] at $Q^2 = 0.13$ (GeV/c)^2.

Fig. 6 with our preliminary measurements in Fig. 3. Measurements of A_{TT} are equally sparse. There are three quasielastic measurements [65, 67, 68] and a single one at higher ν [66]; all are for $Q^2 < 0.22$ GeV^2. Again, these measurements suffer from large uncertainties and limited coverage at large p_m which is the best region for distinguishing between competing theories. For the asymmetry A_{LT}, the situation is better. There are several measurements in quasielastic kinematics that cover the range $Q^2 = 0.013$ GeV^2 to 1.2 GeV^2. At low Q^2 nonrelativistic calculations reproduce the data [67] while at $Q^2 = 1.2$ GeV^2 relativistic calculations are preferred [69]. Between these extremes the situation is less clear; there is a significant spread in the calculations [70]. There is a single measurement at higher ν [66].

We have been working with several theory groups which we discussed in Section 6.1.2. The fifth structure function is a sensitive probe of the spin-orbit part of the NN interaction. The plot in Fig 7 shows the calculated A'_{LT} from Jeschonnek and Van Orden (JVO) [71]. With the spin-flip scattering amplitude turned off (green, dotted curve), A'_{LT} goes nearly to zero. The red, dashed curve shows a dramatic effect when the spin-orbit part is turned on in the calculation. The double-spin components (solid curve) have little effect implying the spin-orbit part of the interaction is the primary contributor.

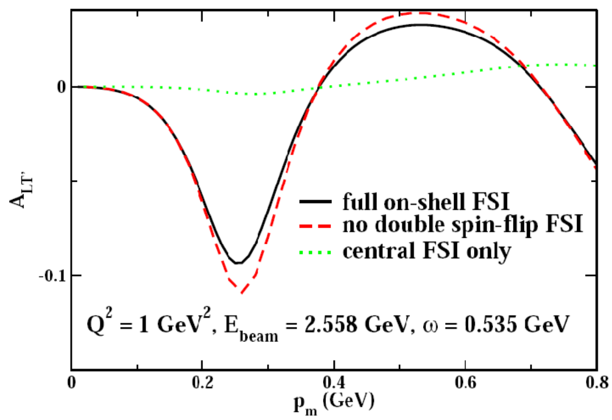

Figure 7: Effect of spin-orbit FSI forces calculated in Ref. [71].

In the period for this proposal, we will complete the analysis of the σ'_{LT} results and move on to the other two structure functions σ_{LT} and σ_{TT} in quasielastic kinematics using similar analysis methods. These other structure functions may present a greater challenge because of their sensitivity to background asymmetries created by misalignments in CLAS [72]. This project is a unique opportunity to measure the three, out-of-plane, ϕ_{pq}-dependent, structure functions in a model-independent way from a single experiment that covers a large Q^2 range under a common set of experimental conditions. Once that analysis is complete, we will investigate higher energy transfer (*i.e.*, the 'dip' region). The JVO calculations described above can also be done for higher energy transfers so there is an excellent opportunity here to cover a wide range of kinematics with a single experiment and compare it with the most modern theory. We have a chance here to untangle these different effects and establish a hadronic model baseline.

6.2.3 Quark Propagation and Hadron Formation (*Gilfoyle*)

The confinement of quarks inside hadrons is perhaps the most remarkable features of QCD and its understanding is a central challenge in nuclear physics. We will investigate the nature of confinement by studying the hadronization process across a wide range of nuclei. This will enable us to extract the quark production times (*i.e.*, the lifetime of a bare, struck quark) and the hadron formation times (*i.e.* the time for a hadron to become fully dressed with its gluon field). These physics goals are focused on one of the central questions raised by the NSAC Long-Range Plan [16] 'What governs the transition of quarks and gluons into pions and nuclei?'. A proposal (E12-06-117) for this experiment as part of the physics program for the JLab 12-GeV Upgrade was submitted and approved by the JLab PAC in the summer of 2006 [73]. Gilfoyle is a co-spokesperson on the proposal and is responsible for analysis of the π^0, η, and η' channels along with K. Joo from the University of Connecticut. During the period of this grant we will begin work on the simulation of events in the upgraded CLAS detector (CLAS12). More details can be found in Section 6.2.4.

6.2.4 CLAS12 Simulation (*Gilfoyle*)

We now discuss our plans to support the completion of the 12-GeV CEBAF Upgrade at JLab [16] mentioned in Section 6.2. Event simulation is an essential aspect of the design of CLAS12 and eventual precision of the detector. For many experiments, the quality of the results will be limited by systematic uncertainties instead of statistical ones so accurate, precise calculations of the CLAS12 acceptance and response are essential. We anticipate needing about four times as much Monte Carlo data as CLAS12 collects. The CLAS12 simulation will produce data more slowly than the detector itself by about a factor of 10^3 (a ≈ 10 Hz for the simulation versus ≈ 10 kHz in CLAS12).

The motivation for our group is to support our experiments that are part of the 12-GeV Upgrade in Hall B (see Table 1). Experiment E12-07-104 will measure the neutron magnetic form factor G_M^n out to $Q^2 =$

14 GeV^2 (see Sections 6.1.1 and 6.2.1). The neutron measurement will be done with both the electromagnetic calorimeters and the TOF system providing an important consistency check as in our previous measurement [1]. Fig. 8 shows a drawing of the CLAS12 detector including the electromagnetic calorimeter (EC) that will be reused from CLAS. Over most of the Q^2 range we will have excellent statistical precision so that understanding the CLAS12 response to neutrons is important for extracting G_M^n with the anticipated systematic uncertainty. Experiment E12-06-

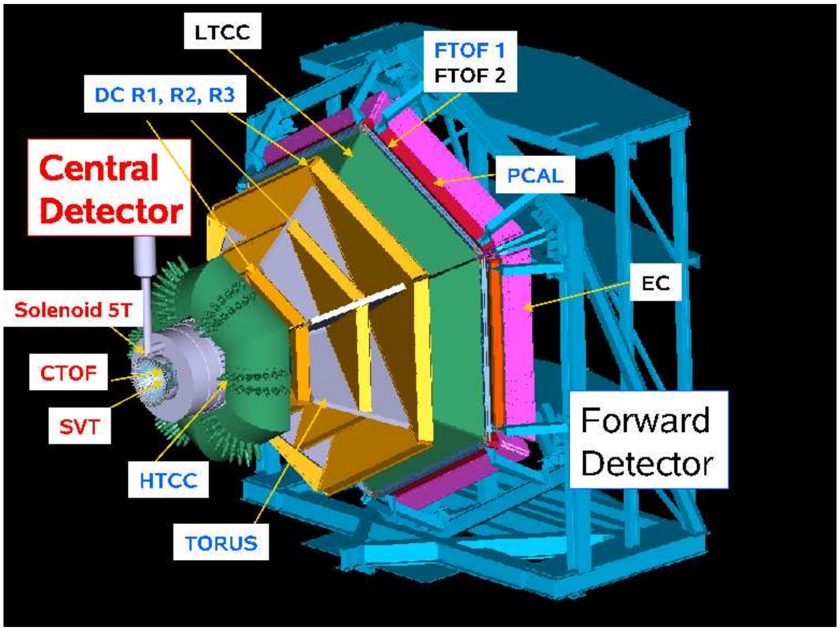

Figure 8: The CLAS12 detector in Hall B.

117 will focus on the physics of quarks moving through nuclear matter and how they evolve to fully-formed hadrons (see Sections 6.1.3 and 6.2.3). Our responsibilities are to study the electroproduction of π^0, η, and $\eta\prime$ from nuclear targets. The detection of each particle relies on resolving photons from their decay: $\pi^0 \to 2\gamma$, $\eta \to 2\gamma$, and $\eta' \to \pi^+\pi^-\eta$ where the η in the η' decay will also be detected via its 2γ decay. Detection will done in the existing EC (reused in CLAS12) augmented by a pre-shower calorimeter (PCAL) located in front (see Fig. 8). The PCAL will have higher segmentation than the EC to insure adequate spatial resolution to separate the two photons from the π^0 and η decays up to maximum momenta of 9 GeV. The Forward Detector (see Fig. 8) of CLAS12 will be able to detect all charged and neutral particles emitted in the polar angular range of 5 to 40 degrees.

We now describe the current status of the neutron simulation in CLAS12. The CLAS12 simulation package called gemc (for Geant4 Monte Carlo) is a Geant4-based simulation package with the following features: C^{++} language, object-oriented architecture, GUI interface, mysql database used for geometry, hits, magnetic field, materials, and physics output [74, 75, 76]. The TOF system has been implemented in the code, but only limited studies of its performance have been done. The EC and PCAL code has not been written. For neutron simulation one can choose a variety of physics algorithms to describe the process, but none have been tested with the CLAS12 geometry. From our experience in CLAS we know there are differences between the neutron detection efficiency measured in CLAS [2] and the same quantity derived from the current Geant3-based CLAS simulation called GSIM [77]. We are now investigating those differences in our analysis of the low Q^2 G_M^n data (see Section 6.2.1).

In order to have an adequate CLAS12 neutron simulation a number of tasks must be completed. (1) The EC and PCAL geometries have to be implemented in gemc. (2) A materials database is needed to provide the information on the composition of each component of the EC and PCAL. (3) The Geant4 algorithms for 'swimming' tracks through CLAS12 need to be tested in gemc. (4) We then construct the detector information produced by the track (digitization) and (5) test the results. To test the neutron simulation in CLAS12 we will use our experience from CLAS on the neutron detection efficiency on the

EC. If the simulation and the measured, CLAS neutron detection efficiency are consistent, then we have greater confidence in our results when we add in the PCAL. The simulation will likely be a part of the CLAS Reconstruction and Analysis Framework (ClaRA). ClaRA is an implementation of a service-oriented architecture (SOA) which grew out the older concepts of distributed computing and modular programming [78, 79]. It's goal is to provide a single framework which can be applied to the full range of physics data processing applications for the CLAS12 experiments. CLARA is currently a JLab research project under the direction of Vardan Gyurjyan and with his help we have begun using the Richmond computing cluster as a test bench for ClaRA.

For the period of this proposal we intend to begin work on the CLAS12 neutron simulation in gemc. This will involve testing the neutron simulation with the existing CLAS12 TOF system that has been implemented in gemc and installing the EC and PCAL geometry. We can then begin testing the simulation using our results from CLAS as a benchmark. We will be working with M. Ungaro at JLab who is now the lead developer for gemc. As the software matures we will make it a service in ClaRA with help from the lead developer V. Gyurjyan. We note here that Gilfoyle has long experience with CLAS software. He was one of the early developers of the primary CLAS reconstruction software (RECSIS) and developed and maintains one of the CLAS online monitoring tools (online RECSIS [44, 45]).

6.2.5 CLAS Collaboration Service (*Gilfoyle*)

During the period of this proposal we will continue to maintain the code for calculating radiative corrections for exclusive reactions on the deuteron [44, 45] and to maintain online RECSIS, one of the CLAS data-acquisition monitoring tools. This will be in addition to normal Collaboration duties. Finally, Gilfoyle is now chair of the Nuclear Physics Working Group and member of the CLAS Coordinating Committee, the main governing body of the Collaboration.

6.2.6 Hypernuclear Program (*Samanta*)

We propose here a new program to study hypernuclear at the University of Richmond. This project is motivated by the presence at Richmond of Dr. C. Samanta for the next three years on a teaching assignment from the Saha Institute in India (see Section 6.2.7). The focus of the project is to understand the little-known hyperon-nucleon (YN) interaction which could provide additional insight important for our understanding of neutron stars and the time-evolution of supernova. These topics are discussed in the NSAC Long-Range Plan [16] and DOE Milestones HP10 and NA8 [17]. To this end Dr. Samanta has joined the E05-115/E08-002 collaboration to measure the spectra and binding energies of Λ hypernuclei across a wide mass range using the $(e, e'K^+)$ reaction (see Table 1). This experiment has been rated A$^-$ by the PAC and is scheduled to run in 2009 in Hall C. It builds on a previous experiment E01-011 in 2005 by many of the same collaborators. Dr. Samanta has also joined the collaboration for a related experiment E08-012 to study hypernuclei via their pionic decay. This experiment has been rated A$^-$ by the PAC and is not yet scheduled (see Table 1).

Dr. Samanta's relevant expertise is her theoretical work on the masses and binding energies of hypernculei. The variation of the binding energy of hypernuclei with mass number A is expected to be exotic. Earlier, Dover and Gal [80] prescribed two separate mass formulae for Λ and Ξ hypernuclei by introducing several volume and symmetry terms in Bethe-Weizsäcker mass formula (BW). There after Levai *et al.*, [81] proposed a BW equation inspired by the spin-flavour SU(6) symmetry in which the pairing term of BW was replaced by the expectation value of the space-exchange or, Majorana operator and a strangeness dependent symmetry breaking term was also added. Both formulae have severe limitations described in Refs [82, 83]. None of these formulations had explicit hyperon mass consideration, they can not be used for binding energy calculation of other kind of hypernuclei.

Wigner's SU(4) symmetry arises as a result of the combined invariance in spin (I) and isospin (T). In order to incorporate the strangeness degree of isospin, SU$_T$ (2) is replaced by SU$_F$ (3) and the combined spin(I)-flavour(F) invariance gives rise to the SU(6) classification of Gursey and Radicati [84]. The SU$_F$ (3) symmetry breaks by explicit consideration of a mass dependent term in a mass formula. The SU(6) symmetry breaking is related to different strengths of the nucleon-nucleus and hyperon-nuclear interactions and has important consequences. For example, although small, the $\Sigma - \Lambda$ mass difference figures prominently in the smallness of the Λ-nuclear spin-orbit interaction [85] which is a topic of interest in the current experimental studies.

A generalized mass formula for normal nuclei and strange hypernuclei was developed by us [82, 83] in which the non-strange normal nuclei and strange hypernuclei are treated on the same footing with due consideration to SU(6) symmetry breaking. The generalization of the mass formula is pursued starting from the modified-Bethe-Weizsacker mass formula (BWM) preserving the normal nuclear matter properties. The BWM is basically the Bethe-Weizsacker mass formula extended for light nuclei [86, 87, 88, 89] which delineated several zones in nuclear chart where some new magic number appear and some known magic numbers disappear. This mass formula can explain the gross properties of binding energy versus nucleon number curves of all non- strange normal nuclei up to Z=83. This generalized mass formula will be employed to deduce the binding energies of all Λ hypernuclei in the entire nuclear chart up to $Z = 83$. The limits of stability of Λ hypernuclei [90, 91] as well as other hypernuclei will be explored in detail.

The total binding energy of a hypernucleus of total mass number A and net charge Z containing charged or neutral hyperon(s) is given by [82, 83]:

$$\begin{aligned} B(A,Z) =& 15.777A - 18.34A^{2/3} - 0.71\frac{Z(Z-1)}{A^{1/3}} - \frac{23.21(N-Z_c)^2}{(1+e^{-A/17})A} + (1-e^{-A/30})\delta + \\ & n_Y[0.0335(m_Y) - 26.7 - 48.7|S|A^{-2/3}] \end{aligned} \tag{5}$$

where $\delta = 12A^{-1/2}$ for N, Z_c even, $\delta = -12A^{-1/2}$ for N, Z_c odd, and $\delta = 0$ otherwise, n_Y = number of hyperons in a nucleus, m_Y = mass of the hyperon in MeV, S = strangeness of the hyperon and mass number $A = N + Z_c + n_Y$ is equal to the total number of baryons. N and Z_c are the number of neutrons and protons respectively while the Z in Eq. 5 is given by $Z = Z_c + n_Y q$ where q is the charge number (with proper sign) of hyperon(s) constituting the hypernucleus. For non-strange (S=0) normal nuclei, $Z_c = Z$ as n_Y =0. The choice of δ value depends on the number of neutrons and protons being odd or even in both the cases of normal and hypernuclei. For example, in case of ${}^{13}_{\Lambda}$C, $\delta = +12A^{-1/2}$ as the (N, Z_c) combination is even-even, whereas, for non-strange normal ^{13}C nucleus $\delta = 0$ as A=13(odd). The hyperon term (last term in equation 5) reflects SU(6) symmetry breaking through explicit consideration of the different masses of different hyperons. The three coefficients of the hyperon term were obtained by minimizing root mean square deviation of the theoretical hyperon separation energies from the experimental ones. The hyperon separation energy (S_Y) is defined as $S_Y = B(A,Z)_{hyper} - B(A-n_Y, Z_c)_{core}$ which is the difference between the binding energy of a hypernucleus and the binding energy of its non-strange core nucleus.

In hypernuclear production, most of the states are excited as nucleon-hole-particle states, (N^{-1},Λ). The spreading widths of these states were calculated to be less than a few 100 keV [92, 93]. This occurs because: 1) The isospin is 0 and only isoscaler particle-hole modes of the core nucleus are excited; 2) the ΛN interaction is much weaker than the nucleon-nucleon interaction; 3) the ΛN spin-spin interaction is weak and therefore the spin vector p-h excitation is suppressed; and 4) There is no exchange term. An accurate knowledge of the excited states of the Λ hypernuclei is essential for the experimental projects undertaken at JLab.

A central ΛN potential has been found on the basis of an analysis of the binding energies of 1s shell hypernuclei and Λp scattering [94]. Within the exprerimental errors, this potential makes it possible to reproduce the binding energies of three-, four-, and five-particle ground and excited states of hypernuclei and the angular and energy dependences of the cross sections for Λp scattering. Within the Λ plus core model, the potential VΛN will be matched with binding energies of heavy hypernuclei deduced by our mass formula. The excited states of the hypernuclei relevant to this experiment and other nuclei will be calculated.

During the period of this proposal Dr. Samanta will perform the following.

1. Take part in the installation, commissioning, and running of the HES and HKS (see Fig. 5) for the E05-115/E08-002 experiment. Dr. L.Tang, the collaboration leader notes that the E05-115/E08-002 collaboration has only about half the number of postdocs and graduate students as the previous, similar hypernuclear experiment E01-001 performed in 2005. Dr. Samanta's contribution will be an important addition. It is also an excellent opportunity for undergraduate involvement since much of this activity will take place in summer 2009.

2. The knock out reaction data can in principle provide valuable information on the spin-parity of the state involved if the energy sharing spectra is plotted. To achieve this goal she will start by analyzing the existing data from a previous experiment E01-011 which was performed in 2005.

3. Dr. Samanta will then carry out the same analysis for E05-115/E08-002 and later on for E08-012.

4. With existing codes Dr. Samanta will calculate the hyperon binding energy of all the possible products in the proposed reactions as well as other hypernuclei up to $Z = 83$ and study the limits of stability of charged and neutral hypernuclei in search of exotic nuclei beyond the normal drip lines. This will be important in the planning for E08-112.

5. Dr. Samanta will begin development of her calculations to include the excited states of the hypernuclei relevant to these experiments.

The leader of the hypernuclear collaboration for these experiments, Dr. L. Tang expresses his support for Dr. Samanta in a letter in Figure 9. We note here, this new program and our existing one are distinct. We will form one group of faculty and students, but there are no plans at this time for Dr. Samanta to join the CLAS Collaboration or for Gilfoyle to join the hypernuclear collaboration.

6.2.7 Faculty Researcher (*Samanta*)

As discussed in Section 6.2.6 we propose the addition of a faculty researcher to the research program in medium energy nuclear physics at the University of Richmond. The addition would provide funding for summer salary and student stipends for Dr. Chhanda Samanta. Dr. Samanta is a distinguished researcher from the Saha Institute Of Nuclear Physics in Kolkata, India who now holds a three-year teaching position as a Visiting Instructor of Physics at the University of Richmond. Her duties are to teach full-time during the academic year, but she has no teaching duties during the summer. Dr. Samanta's research career started by investigating nuclear structure using hadronic probes, but over the last three years she has focused on the effect of hyperons on the masses of nuclei. Since arriving in the US she has joined the hypernuclear collaboration at JLab led by L.Tang. The work she has done for the hypernuclear collaboration and her plan of work are described in Section 6.2.6. At Richmond, she has already started to build a group of undergraduates who would work in our research group during the summer.

The benefits of adding Dr. Samanta to our program at Richmond are twofold. (1) She will raise the physics productivity at Richmond and in the hypernuclear program at JLab. She is experienced in both experiment and theory and has a clearly defined role in the upcoming Hall C experiments described in Section 6.2.6. The group leader for the hypernuclear collaboration, Dr. L. Tang, has said she can become a 'major player' in the hypernuclear program (see letter in Fig. 9). (2) She will mentor undergraduates at Richmond so we can maintain a larger, more diverse, more robust research group. We typically support 2-4 students in the summer in our research group and that number will grow. Adding Dr. Chhanda will enable to expand the size of that group and create a more supportive and lively environment for our students to learn nuclear physics.

6.3 Education of Students: Undergraduate Research at the University of Richmond

Undergraduates are part of all stages of this physics program and the funds requested will enable us to provide an intense summer research experience for these young people. Since 1987 Gilfoyle has mentored 2-3 undergraduates doing research almost every summer with about two-thirds going on to graduate school in science and engineering at places like UC Santa Barbara, Virginia, Princeton, and Stanford. Five have received doctorates. Three from our lab are currently staff scientists at NASA-Goddard, NASA-Huntsville, and the Jet Propulsion Laboratory, one is a faculty member at Stanford, and one is a researcher at Cornell in biological physics. Among students who recently worked in our laboratory one (Burrell) is in graduate school in applied mathematics and physics at Christopher Newport University and another (Gill) is in graduate school in computer science at Columbia. Our students use modern computational techniques for simulation and to 'mine' large data sets for information using our supercomputing cluster. They take shifts at JLab, attend collaboration meetings, and present their work at local, national, and international conferences [5, 13, 14, 15]. In the last two summers four students worked in my laboratory each summer including a high school student who produced Fig. 2. They were funded by a mixture of DOE grant and University funds.

6.4 Institutional Support and Resources

6.4.1 Facilities and Support for Nuclear Physics

The nuclear physics group at the University of Richmond is supported by a computing cluster for our exclusive use. An array of student workstations is used for software development and non-CPU-intensive tasks. The system consists of 30, dual-processor machines running the Linux operating system and 3 TByte of RAID storage. Each machine has 18 GByte of disk space and 256 MByte of memory. The entire system resides on its own subnet and another machine acts as a firewall. It is in a laboratory equipped with a 5-ton, 60,000-BTU air conditioner, an upgraded electrical panel, and backup power. The support computers are located in an adjacent room; all in the Physics Department research area. It is worth noting this cluster plays two important roles. (1) It relieves pressure on the JLab computing farm. Batch jobs there can sometimes take more than a day before they are submitted. (2) The rapid turnaround on our cluster creates a compelling learning experience for our students. They get rapid feedback on their work instead of waiting for their batch jobs to be submitted on the JLab farm.

The University provides has a Linux expert on its information services staff who is responsible for keeping the CLAS software up-to-date, updating the Linux software on the cluster and in our laboratory, and general troubleshooting. The University also supports undergraduate summer stipends and student travel. We had one University-supported student in summer 2007 which allowed us to support more students in 2008. The student posters cited in Section 6.3 had travel support from the University and the American Physical Society in some cases. The University will support routine faculty travel to JLab at the level of ≈$2,500 per year per for each senior person on the grant.

6.4.2 Proximity to Jefferson Lab

Jefferson Lab is 75 miles from the University of Richmond enabling us to maintain frequent contacts with the scientific staff and users at JLab. Gilfoyle spends about 1 day each week at JLab in addition to time spent on shift, at Collaboration meetings, *etc.* The work on G_M^n was done in collaboration with W.K.Brooks, a former JLab staff scientist who is now at Universidad Técnica Federico Santa María in Chile, but spends considerable time at JLab each year. We will continue to collaborate on the work described here. The CLAS12 software is now done primarily by the CLAS12 software at JLab (M. Ungaro, D. Weygand, and V. Gyurjyan) and Gilfoyle will be collaborating with them. We also take students on shift with us and attend Collaboration meetings at little cost. The University supports routine faculty travel to JLab.

6.4.3 Sabbatical Leave

The PI (Gilfoyle) will be on sabbatical leave during the first year of this proposal (2009-2010) and will use that time to work on the project described here. He is currently pursuing funding in order to spend the full year on sabbatical.

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October 31, 2008

To Whom It May Concern,

I am strongly endorsing Professor Chhanda Samanta's application for fund support on her research at JLAB. As I understood, the application is to request addition of her into Prof. J. Gilfoyle's existing DOE grant.

Prof. Chhanda Samanta is a new full time faculty at Physics Department, Gottwald Science Center, University of Richmond. She has both experimental and theory background and has strong interest in the highly exotic Lambda-hypernuclei. She had some recent publications on the predictions of the maximum neutron number that Lambda-hypernuclei can have in comparison to strangeness nuclei. She created a formula that can calculate the drip line Lambda-hypernuclei. Because of her interest, she joined our HKS collaboration at JLAB in summer of 2008 and will participate in all our hypernuclear physics experiments in Hall C that are currently approved. I believe that her addition to the collaboration will be beneficial to our program.

The HKS program, high precision mass spectroscopy of Lambda-hypernuclei with wide mass range, has completed its second phase experiment (E01-011/HKS) and its third phase experiment E05-115 (HKS/HES) will be carried out in 2009 (from March to October). Her addition to the collaboration will definitely strengthen our collaboration with stronger U.S. participation and contributions. Her group is in Richmond, almost local to JLAB, her experimental skills will help this large scale experiment that needs five months to install and to commission all the needed equipment and beam lines and two months to run. Her theoretical background and skill will enable her to contribute on the data analysis as well.

More importantly, Prof. Chhanda Samanta can eventually become a major player in the newly created hypernuclear physics program on decay pion spectroscopy from mesonic weak decay of Lambda-hypernuclei. Technically, the goal is to reach ~100 keV energy resolution and better than 30 keV binding energy precision so that the precision of ground state and low lying states that decay significantly through weak decay will be significantly better than emulsion data. There are two major scientific goals: (1) Provide precise measurement of the ground state of light Lambda- hypernuclei to check the basic YN interaction models which were previously established relying on less precise emulsion data; and (2) search for high exotic and highly neutron rich Lambda-hypernuclei such as ${}^{6}_{\Lambda}H$ through the production of highly excited initial hypernuclear system followed by fragmentation to lighter hypernucleus then weak decay. The second goal is to study the maximum number of neutrons that are allowed for a Lambda-hypernuclei in comparison to exotic non-strange nuclei. The experiment E08-012 was conditionally approved by JLAB PAC33 with A- rating. The PAC recommended test run on the feasibility before 12 GeV upgrade shutdown. The collaboration is currently planning a parasitic run in Hall A after 2009. A general agreement was made with Hall A and currently we are studying one of the Hall A equipment, BigBite spectrometer, to confirm its capability for such test run. When BigBite study is completed, we will officially request this parasitic run to Hall A in December of 2008. The goal is to develop this new program to be carried out at the beginning

Fig 9. Letter of support from Dr. L. Tang, group leader of the hypernuclear collaboration.

of the 12 GeV period of CEBAF. Prof. Chhanda Samanta's theoretical expertise and interest in this exotic hypernuclei field will help the establishment of the program since it is new and has never been done before.

Overall, I believe that Prof. Chhanda Samanta will strengthen our U.S. experimental hypernuclear physics field and will be an important collaborator in the hypernuclear physics at JLAB. Thus, I strongly recommend her to be supported.

Sincerely,

Liguang Tang

Professor of Physics
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Fig 9 (continued). Letter of support from Dr. L. Tang, hypernuclear collaboration leader.

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4 Publications Since Last Review

Refereed Journals

The first set of publications are ones where Gilfoyle had considerable input as author or Collaboration reviewer.

1. J. Lachniet, A. Afanasev, H. Arenhvel, W.K. Brooks, G.P. Gilfoyle, S. Jeschonnek, B. Quinn, M.F. Vineyard, et al (the CLAS Collaboration), 'A Precise Measurement of the Neutron Magnetic Form Factor G_M^n in the Few-GeV^2 Region', arXiv:0811.1716v1 [nucl-ex], submitted to Physical Review Letters.

2. R. Nasseripour *et al.* (The CLAS Collaboration), 'Search for Medium Modifications of the rho meson', Phys. Rev. Lett. **99**, 262302 (2007).

3. K.Sh. Egiyan, G.A. Asryan, N.B. Dashyan, N.G. Gevorgyan, J.-M. Laget, K. Griffioen, S. Kuhn, *et al.* (The CLAS Collaboration), 'Study of Exclusive d(e,e'p)n Reaction Mechanism at High Q2', Phys. Rev. Lett. **98**, 262502 (2007).

4. R. DeVita *et al.* (The CLAS Collaboration), 'Search for the Θ^+ Pentaquark in the reactions $\gamma p \to \bar{K^0} K^+ n$ and $\gamma p \to \bar{K} 0 K^0 p$', Phys. Rev. D. **74**, 032001 (2006).

5. K. Egiyan, *et al.* (The CLAS Collaboration), 'Measurement of 2- and 3-nucleon short range correlation probabilities in nuclei', Phys. Rev. Lett. **96**, 082501 (2006).

The second set below are publications where Gilfoyle had a standard contribution in terms of CLAS service work, offering suggestions during the comment period for the Collaboration review, *etc.*

1. F.X. Girod *et al.* (The CLAS Collaboration), 'Deeply Virtual Compton Scattering Beam-Spin Asymmetries', Phys. Rev. Lett. **100**, 162002 (2008).

2. R. De Masi *et al.* (The CLAS Collaboration), 'Beam spin asymmetry in deep and exclusive ρ_0 electroproduction', Phys. Rev. C **77**, 042201 (2008).

3. D. G. Ireland *et al.* (The CLAS Collaboration), 'A Bayesian analysis of pentaquark signals from CLAS data', Phys. Rev. Lett. **100**, 052001 (2008).

4. K. Park *et al.* (The CLAS Collaboration), 'Cross Sections and Beam Asymmetries for ep→enπ^+ in the Nucleon Resonance Region of 1.7 < Q^2 < 4.5 GeV^2', Phys. Rev. C. **77**, 015208 (2008).

5. T. Mibe *et al.* (The CLAS Collaboration), 'Coherent Phi Meson Photoproduction from the Deuteron at Low Energies', Phys. Rev. C **76**, 052202 (2007).

6. M. Dugger *et al.* (The CLAS Collaboration), 'ρ_0 photoproduction on the proton for photon energies from 0.675 to 2.875 GeV', Phys. Rev. C **76**, 025211 (2007).

7. L. Guo *et al.* (The CLAS Collaboration), 'Cascade Production in the Reaction $\gamma p \to K^+ K^+ X$ and $\gamma p \to K^+ K^+ p^- X$', Phys. Rev. C **76**, 025208 (2007).

8. H. Denizli, S. Dytman, J. Mueller, *et al.* (The CLAS Collaboration), 'Q^2 Dependence of the S_{11}(1535) Photocoupling and Evidence for a P-wave resonance in eta electroproduction', Phys. Rev. C **76**, 015204 (2007).

9. I. Hleiqawi, K. Hicks, D. Carman, T. Mibe, G. Niculescu, A. Tkabladze, *et al.* (The CLAS Collaboration), 'Cross sections for the $\gamma p \to K * 0 \Sigma^+$ Reaction at E(γ) = 1.7 - 3.0 GeV', Phys. Rev. C **75**, 042201 (2007).

10. R. Bradford, R. Schumacher, *et al.* (The CLAS Collaboration), 'First Measurement of Beam-Recoil Observables C_x and C_z in Hyperon Photoproduction', Phys. Rev. C **75**, 035205 (2007).

11. P. Ambrozewicz, D.S. Carman, R. Feuerbach, M.D. Mestayer, B.A. Raue, R. Schumacher, A. Tkabladze, *et al.* (The CLAS Collaboration), 'Separated Structure Functions for the Exclusive Electroproduction of $K^+\Lambda$ and $K^+\Sigma_0$ Final States', Phys. Rev. C **75**, 045203 (2007).

12. P.E. Bosted, K.V.Dharmawardane, G.E. Dodge, T.A. Forest, S.E. Kuhn, Y. Prok, *et al.* (The CLAS Collaboration), 'Quark-Hadron Duality in Spin Structure Functions g1p and g1d', Phys. Rev. C **75**, 035203 (2007).

13. M. Battaglieri, R. De Vita, V. Kubarovsky, *et al.* (The CLAS Collaboration), 'Search for $\Theta^+(1540)$ pentaquark in high statistics measurement of $\gamma p \to \bar{K}^0 K^+ n$ at CLAS', Physical Review Letters **96**, 042001 (2006).

14. K.V. Dharmawardane, P. Bosted, S.E. Kuhn, Y. Prok, *et al.* (The CLAS Collaboration), ' Measurement of the x- and Q^2-dependence of the spin asymmetry A1 of the nucleon', Phys. Lett. B **641**, 11 (2006).

15. S. Chen, H. Avakian, V. Burkert, P. Eugenio, *et al.* (The CLAS Collaboration), 'Measurement of Deeply Virtual Compton Scattering with a Polarized Proton Target', Phys. Rev. Lett. **97**, 072002 (2006).

16. S. Niccolai, M. Mirazita, P. Rossi, *et al.* (The CLAS Collaboration), 'Search for the Θ^+ pentaquark in the $\gamma d \to \Lambda n K^+$ reaction measured with CLAS', Phys. Rev. Lett. **97**, 032001 (2006).

17. B. McKinnon, K. Hicks, *et al.* (The CLAS Collaboration), 'Search for the Θ^+ pentaquark in the reaction $\gamma d \to p K^- K^+ n$', Phys. Rev. Lett. **96**, 212001 (2006).

18. H. Egiyan, V. Burkert, *et al.* (The CLAS Collaboration), 'Single π^+ electroproduction on the proton in the first and second resonance regions at 0.25 $\mathrm{GeV}^2 < Q^2 <$ 0.65 GeV^2 using CLAS', Phys. Rev. C **73**, 025204 (2006).

19. R. Bradford, R. Schumacher, *et al.* (The CLAS Collaboration), 'Differential cross sections for $\gamma + p \to K^+ + Y$ for Λ and Σ_0 hyperons', Phys. Rev. C **73**, 035202 (2006).

20. M. Dugger, B. Ritchie, *et al.* (The CLAS Collaboration), 'Eta-prime photoproduction on the proton for photon energies from 1.527 to 2.227 GeV', Phys. Rev. Lett. **96**, 062001 (2006).

Technical Reports

1. J.D. Lachniet, W.K. Brooks, G.P. Gilfoyle, B. Quinn, and M.F. Vineyard. 'A high precision measurement of the neutron magnetic form factor using the CLAS detector', CLAS Analysis Note 2008-103, Jefferson Lab, 2008.

2. G.P.Gilfoyle, 'CLAS12 Event Reconstruction Overview', presented at the Hall B, 12 GeV Upgrade Workshop, May 14-15, 2007, Jefferson Lab.

3. G.P.Gilfoyle, 'Software Report', presented at the Hall B, 12 GeV Upgrade Workshop, May 14-15, 2007, Jefferson Lab.

4. G.P.Gilfoyle and V.Mokeev, 'Baryon Form Factors', update of the CLAS Conceptual Design Report, `http://www.jlab.org/Hall-B/clas12/Physics/Baryon/Baryon.pdf`, March, 2007, last accessed April 28, 2008.

5. L.B.Weinstein, G.P.Gilfoyle, F.J.Klein, 'Charged Particle Tracking in CLAS12', report of the internal CLAS Collaboration review committee, Feb., 2007.

Proceedings (denotes undergraduate co-author)*

1. G.P. Gilfoyle, *et al.*, (the CLAS Collaboration), 'Review of QCD Processes in Nuclear matter at Jefferson Lab', XVI International Workshop on Deep-Inelastic Scattering and Related Subjects, April 7-12, 2008, London, to be published in the DIS2008 proceedings.

2. G.P.Gilfoyle, 'Hunting for quarks', presented at the Conference Experience for Undergraduates, Division of Nuclear Physics meeting, Fall, 2008, Newport News, VA.

3. G.P. Gilfoyle, *et al.*, (the CLAS Collaboration), 'Measuring form Factors and Structure Functions with CLAS', Proceedings of the Third High-Energy Physics International Conference (HEP-MAD07), SLAC eConf C0709107, 2008.

4. G.P. Gilfoyle, *et al.*, (the CLAS Collaboration), 'A Precise Measurement of the Neutron Magnetic Form Factor G_M^n in the Few-GeV^2 Region', Exclusive Reactions at High Momentum Transfer, World Scientific, 2008.

5. M.Jordan* and G.P.Gilfoyle, 'Analysis of Out-of-Plane Measurements of the Fifth Structure Function of the Deuteron', Bull. Am. Phys. Soc., Fall DNP Meeting, DF.00009 (2208).

6. M.Moog* and G.P.Gilfoyle, 'Study of Inelastic Background for Quasielastic Scattering from Deuterium at 11 GeV', Bull. Am. Phys. Soc., Fall DNP Meeting, DF.00068 (2008).

7. G.P.Gilfoyle, 'Measuring the Fifth Structure Function in $D(\vec{e}, e'p)n$', poster presented at the Gordon Conference on Photonuclear Reactions, Tilton, NH, August 12, 2008.

8. K.Dirgachev* and G.P.Gilfoyle, 'CLAS 12 Simulation Analysis and Optimization', Bull. Am. Phys. Soc., Fall DNP Meeting, DA.00019 (2007).

9. E.F. Bunn, C.W. Beausang, M. Fetea, G. Gilfoyle, O. Lipan, M. Trawick, J. Mable, and J. Wimbush, 'The Richmond Physics Olympics', American Association of Physics Teachers meeting, Greensboro, NC, August, 2007.

5 Principal Collaborators

I have worked with many members of the CLAS Collaboration over the years. A listing of the full collaboration is available at the following website.

`http://www.jlab.org/Hall-B/general/phonebook.html`

The list below includes members of the Collaboration that I have worked with closely over the last four years and others outside the Collaboration.

Mac Mestayer	William Brooks	Bernhard Mecking
Lawrence Weinstein	Michael Vineyard	Andrei Afanasev
David Jenkins	Jeffrey Lachniet	Latifa Elouadrhiri
Sabine Jeschonnek	J.W. Van Orden	Hartmuth Arenhövel
John Arrington	Mark Ito	Eliot Wolin
Arne Freyberger	Kawtar Hafidi	Brian Quinn

The remaining members of the CLAS Collaboration are listed below.

A. Klimenko	S.E. Kuhn	P.E. Bosted	K.V. Dharmawardane
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H. Avakian	H. Bagdasaryan	N. Baillie	J.P. Ball
N.A. Baltzell	S. Barrow	V. Batourine	M. Battaglieri
K. Beard	I. Bedlinskiy	M. Bektasoglu	M. Bellis
N. Benmouna	A.S. Biselli	B.E. Bonner	S. Bouchigny
S. Boiarinov	R. Bradford	D. Branford	S. Buhltmann
V.D. Burkert	C. Butuceanu	J.R. Calarco	S.L. Careccia
D.S. Carman	B. Carnahan	A. Cazes	S. Chen
P.L. Cole	P. Collins	P. Coltharp	P. Corvisiero
D. Crabb	H. Crannell	V. Crede	J.P. Cummings
R. De Masi	R. DeVita	E. De Sanctis	P.V. Degtyarenko
H. Denizli	L. Dennis	A. Deur	C. Djalali
J. Donnelly	D. Doughty	P. Dragovitsch	M. Dugger
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T. Mibe	K. Mikhailov	R. Minehart	M. Mirazita
R. Miskimen	V. Mokeev	L. Morand	S.A. Morrow
M. Moteabbed	G.S. Mutchler	P. Nadel-Turonski	J. Napolitano
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J. Shaw	N.V. Shvedunov	A.V. Skabelin	E.S. Smith
L.C. Smith	D.I. Sober	A. Stavinsky	S.S. Stepanyan
B.E. Stokes	P. Stoler	S. Strauch	R. Suleiman
M. Taiuti	S. Taylor	D.J. Tedeschi	U. Thoma
R. Thompson	A. Tkabladze	S. Tkachenko	L. Todor
C. Tur	M. Ungaro	A.V. Vlassov	D.P. Weygand
M. Williams	M.H. Wood	A. Yegneswaran	J. Yun
L. Zana	J. Zhang	B. Zhao	Z. Zhao

The members of the hypernuclear collaboration are listed below.

A. Margaryan	Yerevan Physics Institute, Armenia	L. Tang	Hampton University, USA
O. Hashimoto	Tohoku Univbersity, Japan	J. Reinhold	Florida International University, USA
Ed. Hungerford	University of Houston, USA	M. Furic	University of Zagreb, Croatia
F. Garibaldi	Istituto Nazionale di Fisica Nucleare, Italy	S.N. Nakamura	Tohoku Univbersity, Japan

6 Biographical Sketch: Dr. Gerard P. Gilfoyle

Degrees

Ph.D., University of Pennsylvania, 1985 - 'Resonant Structure in $^{13}C(^{13}C,^{4}He)^{22}Ne$', H.T. Fortune, adviser.

A.B., cum laude, Franklin and Marshall College, 1979.

Experience

2008-present - Clarence E. Denoon Professor of Science, University of Richmond.

2004-present - Professor of Physics, University of Richmond.

2002-2003 - Scientific Consultant, Jefferson Laboratory.

1999-2000 - American Association for the Advancement of Science Defense Policy Fellow.

1994-1995 - Scientific Consultant, Jefferson Laboratory.

1993-2004 - Associate Professor of Physics, University of Richmond.

Summer, 1988 - Visiting Research Professor, University of Pennsylvania.

1987-1993 - Assistant Professor, University of Richmond.

1985-1987 - Postdoctoral Research Fellow, SUNY at Stony Brook.

1979-1985 - Research Assistant, University of Pennsylvania.

Research and Teaching Grants

1990-present - US Department of Energy ($1,361,000).

2002-2003 - SURA Sabbatical Support ($10,000).

2002-2003 - Jefferson Laboratory Sabbatical Support ($28,335).

2001-2002 - National Science Foundation ($175,000).

1999-2000 - American Association for the Advancement of Science ($48,000).

1995-1997 - National Science Foundation($14,986).

1994-1995 - CEBAF Sabbatical Support ($24,200)

1992-1995 - National Science Foundation ($49,813).

1989-1991 - Research Corporation($26,000).

1987-2007 - University of Richmond Research Grants($13,082).

Selected Service

2006 - present - Chair, Nuclear Physics Working Group, CLAS Collaboration.

2006 - present - CLAS Coordinating Committee.

2005 - Reviewer, National Science Foundation (Nuclear Physics).

2003 - present - Southeastern Universities Research Association Trustee.

2002 - present - Reviewer, CLAS Collaboration.

2002 - Reviewer, Civilian Research and Development Foundation.

2002 - 2003 - American Physical Society Task Force on Countering Terrorism.

2000 - 2006 - Chair, Department of Physics.

2000 - Reviewer, US Department of Defense.

1999 - Reviewer, Department of Energy EPSCoR Program.

1996 - Chair, review panel, National Science Foundation, Instrumentation and Laboratory Improvement Program.

Honors

2004 - Who's Who Among America's Teachers.

2003 - University of Richmond Distinguished Educator Award.

Phi Beta Kappa, 1978.

Selected Listing of Refereed Publications

1. K.Sh. Egiyan, G.A. Asryan, N.B. Dashyan, N.G. Gevorgyan, J.-M. Laget, K. Griffioen, S. Kuhn, *et al.* (The CLAS Collaboration), 'Study of Exclusive d(e,e'p)n Reaction Mechanism at High Q2', Phys. Rev. Lett. **98**, 262502 (2007).

2. M. Battaglieri, R. De Vita, V. Kubarovsky, *et al.*, (The CLAS Collaboration), 'Search for $\theta^+(1540)$ pentaquark in high statistics measurement of $\gamma p \to \overline{K}_0 K^+ n$ at CLAS', Physical Review Letters 96, 042001 (2006).

3. D. Protopopescu, *et al.*, (The CLAS Collaboration), 'Survey of A'_{LT} asymmetries in semi-exclusive electron scattering on ^{4}He and ^{12}C', Nuclear Physics, A748, 357 (2005).

4. K. Joo, *et al.*, (The CLAS Collaboration), 'Measurement of Polarized Structure Function σ'_{LT}) for $p(\vec{e}, e'p)\pi^0$ from single π^0 electroproduction in the Delta resonance region', Physical Review C, Rapid Communications, **68**, 032201 (2003).

5. B. Mecking, *et al.*, (The CLAS Collaboration), 'The CEBAF Large Acceptance Spectrometer', Nucl. Instr. and Meth., **503**/3, 513 (2003).

6. G.P.Gilfoyle and J.A.Parmentola, 'Using Nuclear Materials to Prevent Nuclear Proliferation', Science and Global Security **9**, 81 (2001).

7. G.P.Gilfoyle, 'A New Teaching Approach to Quantum Mechanical Tunneling', Comp. Phys. Comm., **121-122**, 573 (1999).

8. G.P.Gilfoyle, M.S.Gordon, R.L.McGrath, G.Auger, J.M.Alexander, D.G.Kovar, M.F. Vineyard, C.Beck, D.J. Henderson, P.A.DeYoung, D.Kortering, 'Heavy Residue Production in the 215 MeV ^{16}O+^{27}Al Reaction', Phys. Rev., **C46**, 265(1992).

Selected Presentations

1. "Measuring the Fifth Structure Function in $D(\vec{e}, e'p)n$", poster presented at the Gordon Conference on Photonuclear Reactions, Tilton, New Hampshire, August 10-15, 2008.

2. "Review of QCD Processes in Nuclear Matter at Jefferson Lab", presented at the XVI Workshop on Deep Inelastic Scattering and Related Subjects", London, England, April 8, 2008.

3. "A High-Precision Measurement of G_M^n with CLAS", Workshop on Exclusive Reactions at High Momentum Transfer, Newport News, VA, May 22, 2007.

4. 'Measurements of the Fifth Structure Function of the Deuteron', CLAS Collaboration Meeting, March 3, 2006.

5. 'Out-of-Plane Measurements of the Structure Functions of the Deuteron', plenary session of the CLAS Collaboration Meeting, November 13, 2003.

6. 'Maintenance and Upgrading of the Richmond Physics Supercomputing Cluster', V.Davda and G.P.Gilfoyle, Program and Abstracts for the Fall 2003 Meeting of the Division of Nuclear Physics of the American Physical Society, Tucson, AZ, Oct 30 - Nov 1, 2003.

7. 'Using Nuclear Materials to Prevent Nuclear Proliferation', colloquium presented at Thomas Jefferson National Accelerator Facility, Norfolk, VA, March 7, 2001.

7 Biographical Sketch: Dr. Chhanda Samanta

Degrees Ph.D., University of Maryland, 1981 -'A study of proton and alpha induced quasifree knockout reactions', N.S. Chant and Prof. P. G. Roos, advisors .
M.Sc., August 1971, University of Calcutta, INDIA.
B.Sc., August 1969, University of Calcutta, INDIA.

Experience 2007-present - Visiting Lecturer,University of Richmond .
2007-present - Sr. Professor H, Saha Institute Of Nuclear Physics
2003-2006 - Professor G, Saha Institute Of Nuclear Physics
1996-2003 - Professor F, Saha Institute Of Nuclear Physics
2006-present - Affiliate Professor, Homi Bhabha National Institute, BARC, Mumbai
2000-2008 - Affiliate Professor, Virginia Commonwealth University, Richmond,VA
1995-1996 - C.O.E - Professor, RCNP, Osaka University, JAPAN
1991-1996 - Associate Professor, Saha Institute of Nuclear Physics, INDIA
1986-1991 - Reader, Saha Institute of Nuclear Physics, INDIA
1986 - Visiting Scientist, University of Maryland, College Park, MD
1985 - Visiting Scientist, Institut für Kernphysik, Karlsruhe, GERMANY
1983-1986 - Lecturer, Saha Institute of Nuclear Physics, INDIA
1982-1983 - Postdoctoral Fellow, Saha Institute of Nuclear Physics, INDIA
1978-1981 - Research Assistant, University of Maryland, College Park, MD
1976-1981 - Research Assistant, Goddard Space Flight Centre, Greenbelt, MD
1975-1976 - Teaching Assistant, University of Maryland, College Park, MD
1973-1974 - Teaching Assistant, University of Utah, Salt Lake City, Utah

Honors 1998 - Yamada Science Foundation award, Japan
1995 - Center Of Excellence Professor Award, Ministry of Education, Science, Sports and Culture (MONBUSHO), Japan
2003 - Affiliate Professor, Virginia Commonwealth University, Richmond, Va.

Refereed Publications

1. D.N. Basu, P. Roy Chowdhury and C. Samanta 'Nuclear equation of state at high baryonic density and compact star constraints', Nuclear Physics A811 (2008) 140.
2. C. Samanta, P. Roy Chowdhury and D. N. Basu 'Lambda hyperonic effect on the normal driplines', Jour. Phys. G **35** (2008) 065101.
3. P. Roy Chowdhury, C. Samanta and D. N. Basu, 'Search for long lived heaviest nuclei beyond the valley of stability', Phys. Rev. C **77**, 044603 (2008).
4. P. Roy Chowdhury, C. Samanta and D. N. Basu 'Nuclear lifetimes for alpha radioactivity of elements with 100¡Z¡130' Nuclear Data and Atomic Data Tables (available online from March 2008).
5. C. Samanta , P. Roy Chowdhury, and D. N. Basu, 'Predictions of Alpha Decay Half lives of Heavy and Superheavy Elements', Nucl. Phys. A **789**, 142 (2007)
6. P. Roy Chowdhury, C. Samanta and D. N. Basu 'Alpha Decay chains from element 113', Phys. Rev. C **75**, 047306 (2007).
7. D. N. Basu, P. Roy Chowdhury, and C. Samanta 'Equation of state for isospin asymmetric nuclear matter using Lane potential' Acta Physica Polonia **37** (2006) 2869.
8. S. Adhikari, C. Basu, C. Samanta, S. S. Brahmachari, B. P. Das, and P. Basu 'Performance of an axial gas ionization detector' IEEE Transactions on Nuclear Sciences, **53** (2006) 2270.

9. C. Samanta, P. Roy Chowdhury and D. N. Basu ‘Generalized mass formula for non-strange and hyper nuclei with SU(6) symmetry breaking’, Jour. Phys. G: Nucl. Part. Phys.**32**, (2006) 363, nucl-th/0504085.

10. P. Roy Chowdhury, C. Samanta and D. N. Basu, ‘Alpha decay half-lives of new superheavy element’, Phys. Rev. C **73** (2006) 014612, nucl-th/0507054.

11. R. Kanungo, et al.,‘Observation of a two-proton halo in Ne-17’, Euro. Phys. Jour A **25** (2005) 327-330 Suppl. 1

12. D. N. Basu, P. Roy Chowdhury, and C. Samanta, ‘Folding model analysis of proton radioactivity of spherical proton emitters ’, Phys. Rev. C **72** (2005) 051601 (R).

13. P. Roy Chowdhury, C. Samanta, D. N. Basu ,‘Modified Bethe-Weizscker mass formula with isotonic shift and new drip lines ’ , Mod. Phys. Lett. **A21** (2005)1605.

14. C. Samanta, ‘Mass formula from normal to hypernuclei’ (Invited Talk) Proceedings of the Carpathian Summer School of Physics 2005 (Exotic Nuclei and Nuclear/Particle Astrophysics), Mamaia-Constanta, Romania 13 - 24 June 2005 ed. by S. Stoica, L. Trache, and R. E. Tribble, World Scientific, Singapore, p. 29.

15. C. Samanta, P. Roy Chowdhury and D. N. Basu (Invited Talk) ‘Modified Bethe-Weizscker mass formula with isotonic shift, new driplines and hypernuclei’, AIP Conference Proceedings **802**, 142 (2005).

16. S.Adhikari, C.Samanta, C.Basu, B.J.Roy, S.Ray, A.Srivastava, K.Ramachandran, V. Tripathi, K.Mahata, V.Jha, P.Sukla, S.Rathi, M.Biswas, P.Roychowdhury, A.Chatterjee, and S.Kailas, ‘Reaction mechanisms with loosely bound nuclei ^{7}Li + ^{6}Li at forward angles in the incident energy region 14-20 MeV’, Phys. Rev. C **74** (2006) 024602.

17. R. Kanungo, M. Chiba, N. Iwasa, S. Nishimura, A. Ozawa, C. Samanta, T. Suda, T. Suzuki, Y. Yamaguchi, T. Zheng and, I. Tanihata ”Experimental evidence of core modification in near drip-line nucleus 23O”, Phys. Rev. Lett. **88** (2002) 142502.

18. C.Samanta, N.S.Chant, P.G.Roos, A.Nadasen and A.A.Cowley, ‘^{16}O(α,αp) and ^{40}Ca(α,αp) reactions at 139.2 MeV incident energy ’, Phys. Rev.C **35** (1987) 333.

19. C.Samanta, N.S.Chant, P.G.Roos, A.Nadasen, J.Wesick and A.A.Cowley, ‘Tests of the factorized distorted-wave impulse approximation for (p, 2p) reaction’, Phys. Rev.C **34** (1986) 1610.

20. C.Samanta, N.S.Chant, P.G.Roos, A.Nadasen and A.A.Cowley, ‘Discrepancy between proton and alpha induced cluster knockout reactions on ^{16}O”, Phys. Rev C **26** (1982) 1379.

8 Student Tracking Information

The University of Richmond is a primarily undergraduate institution and the Physics Department has no graduate students.

9 Discussion of Budget

9.1 Budget Justification

YEAR 1

A.1 Senior personnel's summer salaries are 2/9's of their academic year salaries or $13,500 whichever is smallest.

B.3 Two undergraduate students per senior personnel for 10 summer weeks. This rate is the same as the University stipends. Includes 8.5% for fringe benefits.

D.1 Domestic travel:

1. $1000 - Round trip mileage charge for students to take shifts at JLab and attend Collaboration meetings. Based on 12-16 shifts per year and three Collaboration meetings of about 3 days/meeting. It is 150 miles round trip from the University of Richmond to JLab, at $0.42 per mile. Note: routine faculty travel of this sort is covered by the University.
2. $1000 - Lodging at the JLab residence facility ($55/night) during shifts for faculty and students and Collaboration meetings based on 12-16 shifts/yr and three Collaboration meetings of about 3 days/meeting.
3. $2000 - Additional travel expenses for invited talks. Over the last two years Gilfoyle and Samanta have been invited to give eight talks. There are some University funds for this travel, but they are limited and we have made heavy use of them in the last two years.
4. $7000 - Expenses for staying at the JLab residence facility for 32 weeks during a one-year sabbatical in 2009-2010. Based on four nights per week in the residence facility and one round trip from Richmond to JLab each week. We have subtracted the University's contribution of support for 'routine' travel which consists of covering one round trip per week plus travel for shifts and CLAS Collaboration meetings.

   Total = $11,000

F.1 - $1,500 - Computer parts and repair (*e.g.*, office supplies, *etc* for our computing cluster and associated laboratory at Richmond and an office we have at JLab.

H.1 - Indirect costs: 52% of wages, salaries, and fringe benefits.

YEAR 2

A.1 Senior personnel's summer salaries are 2/9's of their academic year salaries or $13,500 whichever is smallest.

B.3 Two undergraduate students per senior personnel for 10 summer weeks. This rate is the same as the University stipends. Includes 8.5% for fringe benefits.

D.1 Domestic travel:

1. $1000 - Round trip mileage charge for students to take shifts at JLab and attend Collaboration meetings. Based on 12-16 shifts per year and three Collaboration meetings of about 3 days/meeting. It is 150 miles round trip from the University of Richmond to JLab, at $0.42 per mile. Note: routine faculty travel of this sort is covered by the University.
2. $1000 - Lodging at the JLab residence facility ($55/night) during shifts for faculty and students and Collaboration meetings based on 12-16 shifts/yr and three Collaboration meetings of about 3 days/meeting.

3. \$2000 - Additional travel expenses for invited talks. Over the last two years Gilfoyle and Samanta have been invited to give eight talks. There are some University funds for this travel, but they are limited and we have made heavy use of them in the last two years.

   Total = \$4,000

F.1 - \$1,500 - Computer parts and repair (*e.g.*, office supplies, *etc* for our computing cluster and associated laboratory at Richmond and an office we have at JLab.

H.1 - Indirect costs: 52% of wages, salaries, and fringe benefits.

YEAR 3

A.1 Senior personnel's summer salaries are 2/9's of their academic year salaries or \$13,500 whichever is smallest.

B.4 Two undergraduate students per senior personnel for 10 summer weeks. This rate is the same as the University stipends. Includes 8.5% for fringe benefits.

D.1 Domestic travel:

1. \$1000 - Round trip mileage charge for students to take shifts at JLab and attend Collaboration meetings. Based on 12-16 shifts per year and three Collaboration meetings of about 3 days/meeting. It is 150 miles round trip from the University of Richmond to JLab, at \$0.42 per mile. Note: routine faculty travel of this sort is covered by the University.
2. \$1000 - Lodging at the JLab residence facility (\$55/night) during shifts for faculty and students and Collaboration meetings based on 12-16 shifts/yr and three Collaboration meetings of about 3 days/meeting.
3. \$2000 - Additional travel expenses for invited talks. Over the last two years Gilfoyle and Samanta have been invited to give eight talks. There are some University funds for this travel, but they are limited and we have made heavy use of them in the last two years.

   Total = \$4,000

F.1 - \$1,500 - Computer parts and repair (*e.g.*, office supplies, *etc* for our computing cluster and associated laboratory at Richmond and an office we have at JLab.

H.1 - Indirect costs: 52% of wages, salaries, and fringe benefits.

9.2 Current and Pending Support

We have no pending proposals at this time.

9.3 Anticipated Carryover

By the end of this proposal period we expect to have less than $1000 remaining.

Curriculum vitae
Gerard P. Gilfoyle

Degrees

Ph.D., University of Pennsylvania, 1985 - 'Resonant Structure in $^{13}C(^{13}C,^{4}He)^{22}Ne$',H.T. Fortune, advisor.
A.B., cum laude, Franklin and Marshall College, 1979.

Experience

2008-present - Clarence E. Denoon Professor of Science.
2004-present - Professor of Physics, University of Richmond.
2002-2003 - Scientific Consultant, Jefferson Laboratory.
1999-2000 - Defense Policy Fellow, American Association for the Advancement of Science.
1994-1995 - Scientific Consultant, Jefferson Laboratory.
1993-present - Associate Professor of Physics, University of Richmond.
Summer, 1988 - Visiting Research Professor, University of Pennsylvania.
1987-1993 - Assistant Professor, University of Richmond.
1985-1987 - Postdoctoral Research Fellow, SUNY at Stony Brook.
1979-1985 - Research Assistant, University of Pennsylvania.

Research and Teaching Grants

2007-2009 - Department of Energy (\$60,000).
2005-2007 - Department of Energy (\$55,000).
2002-2003 - SURA Sabbatical Support (\$10,000).
2002-2003 - Jefferson Laboratory Sabbatical Support (\$28,335).
2002-2005 - Department of Energy (\$225,000).
2001-2002 - National Science Foundation (\$175,000).
1999-2002 - Department of Energy (\$222,000).
1996-1999 - Department of Energy (\$300,000).
1995-1997 - National Science Foundation (teaching, \$14,986).
1994-1995 - CEBAF Sabbatical Support (\$24,200)
1993-1996 - Department of Energy (\$284,000).
1992-1995 - National Science Foundation (teaching, \$49,813).
1990-1993 - Department of Energy (\$287,000).
1989-1991 - Research Corporation(\$26,000).
1987-2007 - University of Richmond Research Grants(\$17,477).

Service

2007-present - Richmond Science Scholars Committee.
2006-present - CLAS Coordinating Committee (manages 300-member CLAS Collaboration at Jefferson Lab).
2006-present - Chair, Nuclear Physics Working Group of the CLAS Collaboration.
2005-present - Reviewer for SURA Graduates Fellowship.
2005-2006 - Reviewer for AAAS Defense Policy Fellowship.
2003-present - Southeastern Universities Research Association Trustee.
2002-present - Reviewer, CLAS Collaboration.
2002 - Reviewer, Civilian Research and Development Foundation.
2002-2003 - American Physical Society Task Force on Countering Terrorism.
2000-2006 - Chair, Department of Physics.

Service 2000-2006 - University Science Review Committee.
1993-1999, 2001 - Ethyl and Oldham Scholarship Committees
2000 - Reviewer, US Department of Defense.
1999 - Reviewer, Department of Energy EPSCoR Program.
1997-99 - Science Initiative Research Committee.
1997 - Chair, Jefferson Laboratory CLAS Collaboration nominating committee.
1996 - Chair, review panel, National Science Foundation, ILI Program.
1996-1998 - Managed the Physics Department's high school outreach program.

Honors 2004 Who's Who Among America's Teachers.
2003 University of Richmond Distinguished Educator Award.
Sigma Chi Educator of the Month Award, March, 1990.
Academic All-American in football, 1979.
Phi Beta Kappa, 1978.

Courses Taught

Introductory physics with Calculus 1-2	Quantum mechanics 1-2
Algebra-based introductory physics 1-2	Classical mechanics
Liberal arts physics 1-2	Statistical mechanics
Intermediate laboratory	Computational methods in physics
Senior Seminar	Junior Seminar

Selected Listing of Refereed Publications

1. D. G. Ireland et al. (The CLAS Collaboration), 'A Bayesian analysis of pentaquark signals from CLAS data', Phys. Rev. Lett. **100**, 052001 (2008).

2. M. Battaglieri, R. De Vita, V. Kubarovsky, et al. (The CLAS Collaboration), 'Search for $\theta^+(1540)$ pentaquark in high statistics measurement of $\gamma p \to \overline{K}_0 K^+ n$ at CLAS', Physical Review Letters 96, 042001 (2006).

3. P. Rossi, et al. (The CLAS Collaboration), 'Onset of asymptotic scaling in deuteron photodisintegration', Physical Review Letters, 94 012301 (2005).

4. D. Protopopescu, et al. (The CLAS Collaboration), 'Survey of A'_{LT} asymmetries in semi-exclusive electron scattering on ^{4}He and ^{12}C', Nuclear Physics, A748, 357 (2005).

5. S. Stepanyan, *et al.* (The CLAS Collaboration), 'Observation of an Exotic $S = +1$ Baryon in Exclusive Photoproduction from the Deuteron', Physical Review Letters **91**, 252001 (2003).

6. K. Joo, *et al.* (The CLAS Collaboration), 'Measurement of Polarized Structure Function σ'_{LT}) for $p(\vec{e}, e'p)\pi^0$ from single π^0 electroproduction in the Delta resonance region', Physical Review C, Rapid Communications, **68**, 032201 (2003).

7. B. Mecking, *et al.*, (The CLAS Collaboration), 'The CEBAF Large Acceptance Spectrometer', Nucl. Instr. and Meth., **503**/3, 513 (2003).

8. G.P.Gilfoyle and J.A.Parmentola, 'Using Nuclear Materials to Prevent Nuclear Proliferation', Science and Global Security **9**, 81 (2001).

9. G.P.Gilfoyle, 'A New Teaching Approach to Quantum Mechanical Tunneling', Comp. Phys. Comm., **121-122**, 573 (1999).

10. G.P.Gilfoyle, M.S.Gordon, R.L.McGrath, G.Auger, J.M.Alexander, D.G.Kovar, M.F. Vineyard, C.Beck, D.J. Henderson, P.A.DeYoung, D.Kortering, 'Heavy Residue Production in the 215 MeV $^{16}O+^{27}Al$ Reaction', Phys. Rev., **C46**, 265(1992).

Selected Presentations

1. "Measuring the Fifth Structure Function in $D(\vec{e}, e'p)n$", poster presented at the Gordon Conference on Photonuclear Reactions, Tilton, New Hampshire, August 10-15, 2008.

2. "Review of QCD Processes in Nuclear Matter at Jefferson Lab", presented at the XVI Workshop on Deep Inelastic Scattering and Related Subjects", London, England, April 8, 2008.

3. "Hunting For Faculty Jobs", Panel on academic careers at the headquarters of the American Association for the Advancement of Science, December 6, 2007.

4. "Measuring Form Factors and Structure Functions with CLAS", HEPMAD07, Antananarivo, Madagascar, September 11, 2007.

5. "Measurement of the Neutron Magnetic Form Factor at High Q^2 Using the Ratio Method on Deuterium", presented to JLab Program Advisory Committee, August 7, 2007.

6. "A High-Precision Measurement of G_M^n with CLAS", Workshop on Exclusive Reactions at High Momentum Transfer, Newport News, VA, May 22, 2007.

7. "Out-of-Plane Measurements of the Fifth Structure Function of the Deuteron", G.P. Gilfoyle, (the CLAS Collaboration), Bull. Am. Phys. Soc., Fall DNP Meeting, DF.00010(2006).

8. 'Picking Winners: Emerging Technologies for Countering Terrorism', colloquium presented at Virginia Commonwealth University, Richmond, Virginia, April 22, 2005.

9. "Out-of-Plane Measurements of the Structure Functions of the Deuteron", plenary session of the CLAS Collaboration Meeting, November 13, 2003.

10. "Maintenance and Upgrading of the Richmond Physics Supercomputing Cluster", V.Davda and G.P.Gilfoyle, Program and Abstracts for the Fall 2003 Meeting of the Division of Nuclear Physics of the American Physical Society, Tucson, AZ, Oct 30 - Nov 1, 2003.

11. "Putting the Genie Back in the Bottle: Nuclear Non-proliferation in the New Millenium", Funsten Series Lecture presented at the Science Museum of Virginia, January 29, 2003.

12. "A New Teaching Approach to Quantum Mechanical Tunneling", Presented at the Conference on Computational Physics 1998, September 2-5, 1998, Granada, Spain.

Refereed Publications

1. F.X. Girod et al. (The CLAS Collaboration), 'Deeply Virtual Compton Scattering Beam-Spin Asymmetries', Phys. Rev. Lett. **100**, 162002 (2008).

2. R. De Masi et al. (The CLAS Collaboration), 'Beam spin asymmetry in deep and exclusive rho0 electroproduction', Phys. Rev. C **77**, 042201 (2008).

3. D. G. Ireland et al. (The CLAS Collaboration), 'A Bayesian analysis of pentaquark signals from CLAS data', Phys. Rev. Lett. **100**, 052001 (2008).

4. K. Park et al. (The CLAS Collaboration), 'Cross Sections and Beam Asymmetries for ep$\rightarrow$enpi$^+$ in the Nucleon Resonance Region of $1.7 < Q^2 < 4.5$ GeV^2', Phys. Rev. C. **77**, 015208 (2008).

5. R. Nasseripour et al. (The CLAS Collaboration), 'Search for Medium Modifications of the rho meson', Phys. Rev. Lett. **99**, 262302 (2007).

6. T. Mibe et al. (The CLAS Collaboration), 'Coherent Phi Meson Photoproduction from the Deuteron at Low Energies', Phys. Rev. C **76**, 052202 (2007).

7. M. Dugger et al. (The CLAS Collaboration), 'rho0 photoproduction on the proton for photon energies from 0.675 to 2.875 GeV', Phys. Rev. C **76**, 025211 (2007).

8. L. Guo et al. (The CLAS Collaboration), 'Cascade Production in the Reaction gp$\rightarrow$K+K+X and gp$\rightarrow$K+K+p-X', Phys. Rev. C **76**, 025208 (2007).

9. H. Denizli, S. Dytman, J. Mueller, *et al.* (The CLAS Collaboration), 'Q2 Dependence of the S11(1535) Photocoupling and Evidence for a P-wave resonance in eta electroproduction', Phys. Rev. C **76**, 015204 (2007).

10. I. Hleiqawi, K. Hicks, D. Carman, T. Mibe, G. Niculescu, A. Tkabladze, *et al.* (The CLAS Collaboration), 'Cross sections for the gamma p $\rightarrow$ K*0 Sigma+ Reaction at E(gamma) = 1.7 - 3.0 GeV', Phys. Rev. C **75**, 042201 (2007).

11. K.Sh. Egiyan, G.A. Asryan, N.B. Dashyan, N.G. Gevorgyan, J.-M. Laget, K. Griffioen, S. Kuhn, *et al.* (The CLAS Collaboration), 'Study of Exclusive d(e,e'p)n Reaction Mechanism at High Q2', Phys. Rev. Lett. **98**, 262502 (2007).

12. R. Bradford, R. Schumacher, et al. (The CLAS Collaboration), 'First Measurement of Beam-Recoil Observables Cx and Cz in Hyperon Photoproduction', Phys. Rev. C 75, 035205 (2007).

13. P. Ambrozewicz, D.S. Carman, R. Feuerbach, M.D. Mestayer, B.A. Raue, R. Schumacher, A. Tkabladze, et al. (The CLAS Collaboration), 'Separated Structure Functions for the Exclusive Electroproduction of K+Lambda and K+Sigma0 Final States', Phys. Rev. C 75, 045203 (2007).

14. P.E. Bosted, K.V.Dharmawardane, G.E. Dodge, T.A. Forest, S.E. Kuhn, Y. Prok, et al. (The CLAS Collaboration), 'Quark-Hadron Duality in Spin Structure Functions g1p and g1d', Phys. Rev. C 75, 035203 (2007).

15. M. Battaglieri, R. De Vita, V. Kubarovsky, et al. (The CLAS Collaboration), 'Search for Theta+(1540) pentaquark in high statistics measurement of gamma p → anti-K0 K+ n at CLAS', Physical Review Letters 96, 042001 (2006).

16. K.V. Dharmawardane, P. Bosted, S.E. Kuhn, Y. Prok, et al. (The CLAS Collaboration), ' Measurement of the x- and Q2-dependence of the spin asymmetry A1 of the nucleon', Phys. Lett. B 641, 11 (2006).

17. S. Chen, H. Avakian, V. Burkert, P. Eugenio, et al. (The CLAS Collaboration), 'Measurement of Deeply Virtual Compton Scattering with a Polarized Proton Target', Phys. Rev. Lett. 97, 072002 (2006).

18. S. Niccolai, M. Mirazita, P. Rossi, et al. (The CLAS Collaboration), 'Search for the Theta+ pentaquark in the $\gamma d \to \Lambda n K^+$ reaction measured with CLAS', Phys. Rev. Lett. 97, 032001 (2006).

19. B. McKinnon, K. Hicks, et al. (The CLAS Collaboration), 'Search for the Theta+ pentaquark in the reaction gamma d → p K- K+ n', Phys. Rev. Lett. 96, 212001 (2006).

20. H. Egiyan, V. Burkert, et al. (The CLAS Collaboration), 'Single pi+ electroproduction on the proton in the first and second resonance regions at 0.25 GeV2 ¡ Q2 ¡ 0.65 GeV2 using CLAS', Phys. Rev. C 73, 025204 (2006).

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Other Publications

E.F.Bunn, M.S.Fetea, G.P.Gilfoyle, H.Nebel, P.D.Rubin, and M.F.Vineyard, 'Investigative Physics - Student Guide', inquiry-based laboratory manual for general physics, 2008 and ongoing.

G.P. Gilfoyle, *et al.*, (the CLAS Collaboration), "Measuring form Factors and Structure Functions with CLAS", Proceedings of the Third High-Energy Physics International Conference (HEP-MAD07), SLAC eConf C0709107, 2008.

G.P. Gilfoyle, *et al.*, (the CLAS Collaboration), "A Precise Measurement of the Neutron Magnetic Form Factor G_M^n in the Few-GeV^2 Region", Exclusive Reactions at High Momentum Transfer, World Scientific, 2008.

G.P.Gilfoyle, 'Swarm Intelligence', APS News, January, 2003, published by the American Physical Society.

G.P.Gilfoyle, 'Are you coming back?', Faculty accounts of AAAS Fellowship experiences, http://fellowships.aaas.org/experiences/facexp1.shtml, [Accessed 1 Jan 2003].

G.P.Gilfoyle, 'Nuclear Terrorism', Richmond Alumni Magazine, **64**, No. 2, 29, (2002).

G.P.Gilfoyle, P.D.Rubin, and M.F.Vineyard, 'Investigative Physics - Student Guide', inquiry-based laboratory manual for general physics with calculus, 1995.

Invited Talks and Panels

1. "Discussion of the Startup of the Large Hadron Collider", interview on 'Jack and Jen in the Morning Show', Station MIX 103.7, Richmond, VA, Sep 9, 2008.

2. "Discussion of Ballistic Missile Defense in Europe and Iranian Missile Tests", interview by Jimmy Barrett, Station 1140 WRVA, Richmond, VA, AM News Radio, July 15, 2008.

3. "Update on the analysis of the G_M^n measurement using the ratio method in CLAS", presented in the plenary session of the CLAS Collaboration meeting May 29, 2008.

4. "Review of QCD Processes in Nuclear Matter at Jefferson Lab", presented at the XVI Workshop on Deep Inelastic Scattering and Related Subjects", London, England, April 8, 2008.

5. "Hunting For Faculty Jobs", Panel on academic careers at the headquarters of the American Association for the Advancement of Science, December 6, 2007.

6. "Science and Security in an Age of Terrorism", talk presented to the Brandermill/Midlothian/Wood Lake Lion's Club, University of Richmond, November 8, 2007.

7. "Hunting for Quarks", Conference Experience for Undergraduates (CEU) Nuclear Physics Seminar, Fall, 2007 meeting of the Division of Nuclear Physics of the APS, October 13, 2007.

8. "Nuclear Physics at the University of Richmond", American School of Antananarivo, Antananarivo, Madagascar, September 13, 2007.

9. "Measuring Form Factors and Structure Functions with CLAS", HEPMAD07, Antananarivo, Madagascar, September 11, 2007.

10. "Measurement of the Neutron Magnetic Form Factor at High Q2 Using the Ratio Method on Deuterium", presented to JLab PAC32, August 7, 2007.

11. "A High-Precision Measurement of G_M^n with CLAS", Workshop on Exclusive Reactions at High Momentum Transfer, Newport News, VA, May 22, 2007.

12. "Science and Security in an Age of Terrorism", presented to the 5400 Club, Richmond, VA, January 15, 2007.

13. 'Picking Winners: Emerging Technologies for Countering Terrorism', colloquium presented to the Physics Department at Virginia Commonwealth University, April 22, 2005.

14. ‘Picking Winners: Emerging Technologies for Countering Terrorism’, colloquium presented to the Physics Department at Idaho State University, October 5, 2004.

15. ‘Picking Winners: Emerging Technologies for Countering Terrorism’, joint Math/Physics seminar at the University of Richmond, September 22, 2004.

16. ‘Hunting for Quarks’, University of Richmond Interdisciplinary Science Seminar Series, September 22, 2004.

17. ”Science and Security in an Age of Terrorism”, colloquium presented at Union College, Schenectady, NY, October 15, 2003

18. ”Nuclear Security and Terrorism in the New Millennium”, seminar presented at Union College, Schenectady, NY, October 15, 2003

19. ”New Technologies for Countering Terrorism”, seminar presented at the University of Richmond, Richmond, VA, October 20, 2003.

20. ”Structure Functions of the Deuteron”, seminar presented at the University of Richmond, Richmond, VA, September 29, 2003.

21. ‘Nuclear Non-Proliferation in an Age of Terrorism’, colloquium presented at James Madison University, Harrisonburg Virginia, February 14, 2003.

22. ‘Science and Security in an Age of Terrorism’, Funsten Series Lecture presented at the Science Museum of Virginia, February 5, 2003.

23. ‘Putting the Genie Back in the Bottle: Nuclear Non-proliferation in the New Millennium’, Funsten Series Lecture presented at the Science Museum of Virginia, January 29, 2003.

24. ‘Activities for Countering Terrorism at IEEE and DTRA’, presented to the American Physical Society Task Force on Countering Terrorism, American Center for Physics, College Park, MD, May 3, 2002.

25. ‘Loose Nukes: Fissile Material Security in Russia’, colloquium presented at the Institute for Nuclear and Particle Physics, Ohio University, Athens, OH, April 3, 2002.

26. ‘Loose Nukes: Fissile Material Security in Russia’, Lunchtime Forum presented at the University of Richmond, April 1, 2002.

27. ‘Loose Nukes: Fissile Material Security in Russia’, colloquium presented at the College of William and Mary, March 22, 2002.

28. ‘Loose Nukes: Fissile Material Security in Russia’, talk presented to the West Richmond Rotary Club, Richmond, VA, Feb. 27, 2002.

29. “9/11: A Call for Change”, member of a panel discussion on the 9/11 attacks, University of Richmond Town Meeting, Richmond, VA, October 10, 2001.

30. ‘The September 11 Attacks’, interviewed by local TV station (Channel 12) to discuss the September 11 attacks, Sep 11, 2001.

31. ‘Science in the Public Interest: The AAAS Science and Engineering Fellowships’, Conference on Science for the Public Good, Virginia Commonwealth University, Richmond, VA, June 1, 2001.

32. ‘Using Nuclear Materials to Prevent Nuclear Proliferation’, colloquium presented at Thomas Jefferson National Accelerator Facility, Newport News, VA, March 7, 2001.

33. ‘The Dale Earnhardt Crash’, interviewed by local TV station (Channel 6) to discuss the physics behind Dale Earnhardt’s fatal crash in the Daytona 500, Feb. 22, 2001.

34. ‘Using Nuclear Materials to Prevent Nuclear Proliferation’, colloquium presented at Old Dominion University, Norfolk, VA, Nov. 3, 2000.

35. ‘Using Nuclear Materials to Prevent Nuclear Proliferation’, seminar presented at the University of Richmond, September 19, 2000.

36. ‘Using Nuclear Materials to Prevent Nuclear Proliferation’, invited talk presented to the Unconventional Nuclear Warfare Defense Task Force of the Defense Science Board, Arlington, VA, June 8, 2000.

37. ‘New Tools and Opportunities for Preventing Nuclear Use and Proliferation’, invited talk presented to Dr. Hans Mark, Director of Defense Research and Development, the Pentagon, May 12, 2000.

38. ‘New Tools and Opportunities for Preventing Nuclear Use and Proliferation’, invited talk presented to the Nuclear Materials Council, US Department of Energy Headquarters, Washington, DC, April 26, 2000.

39. ‘New Tools and Opportunities for Preventing Nuclear Use and Proliferation’, invited talk presented to the Advanced Concepts Group, Sandia National Laboratory, Albuquerque, NM, April 12, 2000.

40. ‘Preventing Nuclear Proliferation with Intrinsic Tags’, invited talk presented to the Program on Science, Technology, and Society, MIT, Cambridge, MA, January 26, 2000.

41. ‘Deterring and Detecting Nuclear Smuggling’, Presented at the Plutonium Shape Working Meeting, December 13, 1999, Sterling, Virginia.

42. ‘Undergraduate Research in the Natural Sciences at the University of Richmond’, talk presented at the University of Richmond Board of Trustees dinner, September 30, 1999.

43. ‘A New Teaching Approach to Quantum Mechanical Tunneling’, Presented at the Conference on Computational Physics 1998, September 2-5, 1998, Granada, Spain.

44. ‘The EPR Paradox’, presented to the University of Richmond Physics Department, March 6, 1997.

45. ‘The Nature and Structure of Matter’, Presented at the Virginia Science Museum, January 22, 1995.

46. ‘The Limits to Nuclear Fusion of the $^{16}O+^{27}Al$ System’, presented to the Department of Physics, Virginia Commonwealth University, November 15, 1990.

47. 'The Limits to Nuclear Fusion of the $^{16}O+^{27}Al$ System', presented to the Department of Physics, George Washington University, April, 1990.

48. 'Incomplete Fusion Reactions in the $^{16}O+^{27}Al$ System', presented to the Department of Physics, University of Richmond, February 7, 1987.

49. 'Incomplete Fusion Reactions in the $^{16}O+^{27}Al$ System', presented to the Department of Physics, Yale University, January 21, 1987.

50. 'Incomplete Fusion Reactions in the $^{16}O+^{27}Al$ System', presented to the Department of Physics, Rutgers University, October 5, 1986.

51. 'Quasimolecular States in the $^{13}C+^{12}C$ System', presented to the Department of Physics, University of Pennsylvania, September 14, 1985.

52. 'Quasimolecular States in the $^{13}C+^{12}C$ System', presented to the Department of Physics, SUNY at Stony Brook, April 25, 1985.

53. 'Quasimolecular States in the $^{13}C+^{12}C$ System', presented to the Department of Physics, Franklin and Marshall College, March 11, 1985.

Abstracts of Presentations at National and International Meetings

1. K.Dirgachev and G.P.Gilfoyle, 'CLAS 12 Simulation Analysis and Optimization', Bull. Am. Phys. Soc., Fall DNP Meeting, DA.00019 (2007).

2. K.Greenholt and G.P.Gilfoyle, 'Fiducial Cuts on CLAS for the E5 Data Set', Bull. Am. Phys. Soc., Fall DNP Meeting, FR.0006(2005).

3. R.Burrell and G.P.Gilfoyle, 'Momentum Corrections for the E5 Data Set', Bull. Am. Phys. Soc., Fall DNP Meeting, FR.00068(2005).

4. K.Greenholt and G.P.Gilfoyle, 'Generating Fiducial Cuts for CLAS E5', Bull. Am. Phys. Soc., April Meeting, S.06(2005).

5. R.Burrell and G.P.Gilfoyle, 'Momentum Corrections for the CLAS E5 Data Set', Bull. Am. Phys. Soc., April Meeting, S.07(2005).

6. V.Davda* and G.P.Gilfoyle, 'Maintenance and Upgrading of the Richmond Physics Supercomputing Cluster', poster presented at the Conference Experience for Undergraduates at the Fall 2003 Meeting of the Division of Nuclear Physics of the American Physical Society, Tucson, AZ, Oct 30 - Nov 1, 2003.

7. A. Rayner*, and G.P.Gilfoyle, 'Pion Identification in CLAS', Program and Abstracts of the Conference of the International Association of Physics Students, Odense, Denmark, August 14, 2003.

8. A. Rayner*, A.Mackenzie*, and G.P.Gilfoyle, 'Pion Identification in CLAS', Program and Abstracts of the Seventeenth National Conference on Undergraduate Research, University of Utah, UT, March 13-15, 2003.

9. F. Chinchilla*, M.S. Fetea, G.P. Gilfoyle, and M.F. Vineyard, 'From Quarks to Nucleons', 14th Summer School on Understanding the Structure of Hadrons, Prague, Czech Republic, July 9-13, 2001.

10. M. F. Vineyard, G. P. Gilfoyle, and P.D.Rubin, 'Laboratory-Based Introductory Physics at the University of Richmond', talk presented at the American Association of Physics Teachers Chesapeake Section meeting, Baltimore, MD, April, 2001.

11. F. Chinchilla*, M. F. Vineyard, and G. P. Gilfoyle, 'Development and Maintenance of a Linux Computing Cluster', poster presented at the Conference Experience for Undergraduates at the Fall 2000 Meeting of the Division of Nuclear Physics of the American Physical Society, Williamsburg, VA, Oct. 4-7, 2000.

12. G.P.Gilfoyle and J.A.Parmentola, 'Using Nuclear Materials to Prevent Nuclear Proliferation', talk presented to the 41st Meeting of the Institute for Nuclear Materials Management, July 16-20, 2000, New Orleans, LA.

13. D.Vermette* and G.P.Gilfoyle, 'Elastic Peak Monitoring for the CLAS', talk presented to the XIV International Conference for Physics Students, August 20, 1999, Helsinki, Finland.

14. S.Levy*, G.P.Gilfoyle, and M.Mestayer, 'Drift Velocity Calibration for the CLAS Drift Chamber System', Bull. Am. Phys. Soc., **41**, 950 (1996).

15. S.Levy*, G.P.Gilfoyle, and M.Mestayer, 'Drift Velocity Calibration for the CLAS Drift Chamber System', Conference Program and Abstracts of the Eighth National Conference on Undergraduate Research, University of North Carolina at Asheville, April 14-16, 1996.

16. A.L.Caraley, K.T.Brinkman, B.J.Fineman, N.Gan, R.L.McGrath, M.Sharan, J.Velkovska, B.B.Back, D.J. Blumenthal, C.N. Davids, B.G. Glagola, P.A. DeYoung, P. Decowski, and G.P. Gilfoyle, 'Enhanced Residue Cross Sections in the $^{58}\mathrm{Ni} + ^{112}\mathrm{Sn}$ System', Bull. Am. Phys. Soc. **40**, 935(1995).

17. H.Funsten and G.P.Gilfoyle, 'Calculation of the Pseudoscalar Decay Angular Distribution for a Scalar+Vector Meson in Electroproduction', Bull. Am. Phys. Soc. **39**, 1416(1994).

18. G.P.Gilfoyle, A.S. Snyder*, M. Nimchek*, C.A. Cardounel*, S. Sigworth*, C. Smith*, J. Rollinson*, M. McGehee*, R. Zurmuhle, H.T.Fortune, M. McKenzie, M. Simpson*, and J. Arrison, 'Statistical Analysis of the $^{12}\mathrm{C} + ^{13}\mathrm{C}$ Nuclear Reaction', Bull. Am. Phys. Soc. **39**, 1431(1994).

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20. M.T.Nimchek*, A.S.Snyder*, and G.P.Gilfoyle, 'Statistical Analysis of the $^{12}\mathrm{C} + ^{13}\mathrm{C}$ System', Conference Program and Abstracts of the Eighth National Conference on Undergraduate Research, Western Michigan University, April 14-16, 1994.

21. R.G.Ohl*, M.F.Vineyard, S.E.Atencio*, C.Cardounel,* G.P.Gilfoyle, A.S.Snyder*, B.G.Glagola, D.J.Henderson, J.F.Mateja, A.W.Wuosmaa, and F.W.Prosser, 'Incomplete Fusion in ^{28}Si and ^{24}Mg Nuclei', Conference Program and Abstracts of the Eighth National Conference on Undergraduate Research, Western Michigan University, April 14-16, 1994, VIII-181.

22. P.A. DeYoung, C.J. Gelderloos, J. Sarafa, M.S. Gordon, G.P. Gilfoyle, R.L. McGrath, J.M. Alexander, 'Correlation Measurements of Light Charged Particles at 20^o from 140 MeV ^{16}O+^{27}Al and ^{18}O+^{27}Al Reactions', Bull. Am. Phys. Soc. **38**, 1828(1993).

23. A.S.Snyder*, C.A.Cardounel*, S.Sigworth*, C.Smith*, and G.P.Gilfoyle, 'The Search for Nuclear Molecules in the $^{12}C +^{13} C$ System', Abstract Book of the National Conference on Undergraduate Research, **708**(1992).

24. J.H.Rollinson*, M.F.Vineyard, S.E.Atencio*, J.F.Crum*, G.P.Gilfoyle, R.G.Ohl*, R.S.Trotter*, D.G.Kovar, B.G.Glagola, D.J.Henderson, J.F.Mateja, C.F.McGuire, and F.W.Prosser, 'Light Particles Produced in Central Collisions Between ^{40}Ca and ^{12}C Nuclei', Abstract Book of the National Conference on Undergraduate Research, **709**(1992).

25. M.F.Vineyard, S.E. Atencio*, G.P. Gilfoyle, R.G. Ohl*, J. Rollinson*, R.S. Trotter*, D.G. Kovar, B.G. Glagola, D.J. Henderson, J.F. Mateja, C.F. McGuire, R. Clark, D. Olive, and F.W.Prosser, 'Proton and alpha-Particle Correlations with Heavy Residues in the ^{40}Ca+^{12}C Reaction at E(^{40}Ca)=450 MeV', Bull. Amer. Phys. Soc. **36**, 1270(1991).

26. J.D.Hewitt, F.W.Hersman, M.D.Mestayer, S.Christo, C.Cuevas, B.Kross, D.Tilles, S.Zhou, W.Vulcan, R.A.Miskimen, K.Wang, R.Hicks, K.Lee, S.Churchwell, M.F.Vineyard, G.P.Gilfoyle, S.A.Dytman, C.Tam, and H.Baghei, 'Helium Dominated Argon-Ethane Mixtures for Drift Chambers in High Magnetic Fields, Bull. Am. Phys. Soc. **35**, (1990).

27. R.A.Kryger, J.J.Kolata, P.A.DeYoung, C.Copi, J.Sarafa, D.G.Kovar, G.P.Gilfoyle, and S.Sigworth*, 'N-LCP Two Particle Correlation Functions Measured from the $^{16}O +^{27} Al$ Reaction at E(^{16}O) = 215 MeV', Bull. Amer. Phys. Soc. **35**, 948(1990).

28. P. A. DeYoung, C. Gelderloos, D. Kortering, J. Sarafa, K. Zienert, R. L. McGrath, J. M. Alexander, G. P. Gilfoyle, M. Gordon, D. Kovar, C. Beck, M. F. Vineyard, 'Light particle - Light Particle correlations for $^{16}O +^{27} Al$ Reactions Below 14 MeV/u', Bull. Amer. Phys. Soc. **33**, 928 (1988).

29. G. P. Gilfoyle, R. L. McGrath, J. M. Alexander, M. Gordon, D. Kovar, G. Auger, C. Beck, M. F. Vineyard, 'Simulations of ^{16}O-induced Reactions on ^{27}Al at 215 MeV', Bull. Amer. Phys. Soc. **33**, 978 (1988).

30. G. P. Gilfoyle, F. L. McGrath, J. M Alexander, M. Gordon, D. Kovar, G. Auger, C. Beck, M. F. Vineyard, 'Velocity Spectra of ^{16}O-induced Reactions on ^{27}Al at 215 MeV', Bull. Amer. Phys. Soc. **32**, Addendum (1987).

31. G. P. Gilfoyle, M. S. Gordon, J. M. Alexander, R. L. McGrath, P. A. DeYoung, D. G. Kovar, M. F. Vineyard, and C. Beck, '^{16}O-induced reactions on ^{27}Al at 215 MeV', Bull. Amer. Phys. Soc. **32**, 1206 (1986).

32. P. A. DeYoung, D. Bui, K. Kortering, K. Kossen, G. P. Gilfoyle, M. S. Gordon, D. G. Kovar, R. L. McGrath, J. M. Alexander, M. Vineyard, and C. Beck, 'Light- particle emission from the $^{16}O +^{27}$ Al system at 13.5 MeV/u', Bull. Amer. Phys. Soc. **32**, 1206 (1986).

33. M. S. Gordon, G. P. Gilfoyle, J. M. Alexander, R. L. McGrath, P. A. DeYoung, G. Auger, X. Lu, and D. M. deCastro-Rizzo, 'Small momentum correlations from the $^{16}O +^{27}$ Al reaction', Bull. Amer. Phys. Soc. **32**, 1207 (1986).

34. D M. DeCastro-Rizzo, G. P. Gilfoyle, M. S. Gordon, J. M. Alexander, R. L. McGrath, X. Lu, and L. Vaz, 'Large angle light-particle light-particle correlation measurements', Bull. Amer. Phys. Soc. **31**, 784 (1986).

35. G. P. Gilfoyle, and H. T. Fortune, 'Systematics of the $^{13}C(^{13}C, \alpha)^{22}Ne$ reaction', Bull. Amer. Phys. Soc. **31**, 784 (1986).

36. J. W. Sweet, G. P. Gilfoyle, H. T. Fortune, K. S. Dhuga, M. A. Carchidi, M. Burlein, M. Dwyer, and R. Gilman, 'Resonance in $^{12}C(^{18}O, \alpha)^{26}Mg$', Bull. Amer. Phys. Soc. **31**, 732 (1985).

37. G. P. Gilfoyle, and H. T. Fortune, 'Statistical Analysis of $^{13}C(^{13}C, \alpha)^{22}Ne$', Bull. Amer. Phys. Soc. **30**, 707 (1985).

38. J. L. Cavuto, G. P. Gilfoyle, and H. T. Fortune, 'Statistical model calculations for $^{13}C(^{13}C,)^{22}Ne$', Bull. Amer. Phys. Soc. **31**, 708 (1985).

39. J. Richards*, G. P. Gilfoyle, and H. T. Fortune, 'Partial wave decomposition of $^{13}C(^{13}C, \alpha)^{22}Ne$ near the Coulomb barrier', Bull. Amer. Phys. Soc. **31**, 707 (1985).

40. M. G. Burlein, G. P. Gilfoyle, H. T. Fortune, K. S. Dhuga, M. A. Carchidi, M. Dwyer, J. W. Sweet, and R. Gilman, 'Direct and compound components of the $^{27}Al(^{6}Li, \alpha)^{29}Si$ reaction at 32 MeV', Bull. Amer. Phys. Soc. **31**, 725 (1985).

41. M. Burlein, M. Carchidi, H. T. Fortune, G. P. Gilfoyle, J. Gorres, R. Gilman, P. Kutt, S. Saini, J. W. Sweet, R. T. Kouzes, and R. Sherr, 'The $^{70}Zn(p, t)^{68}Zn$ reaction at $E_p = 35$MeV and coexistence in the zinc isotopes', Bull. Amer. Phys. Soc. **30**, 726 (1985).

42. G. P. Gilfoyle, R. Gilman, K. S. Dhuga, M. A. Carchidi, J. W. Sweet, and H. T. Fortune, 'Partial wave decomposition of$^{13}C(^{13}C, \alpha)^{22}Ne$', Bull. Amer. Phys. Soc. **29**, 626 (1984).

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44. L. C. Bland, H. T. Fortune, R. Gilman, G. S. Stephans, G. P. Gilfoyle, C. L. Morris, S. J. Seestrom-Morris, S. J. Greene, P. A. Seidl, R. R. Kiziah, C. F. Moore, 'Spinflip dipole resonance excitation', Bull. Amer. Phys. Soc. **28**, 705 (1983).

45. G. P. Gilfoyle, H. T. Fortune, L. C. Bland, G. S. Stephans, K. S. Dhuga, M. A. Carchidi, J. W. Sweet, A. H. Wuosmaa, and R. Gilman, 'Resonances in $^{13}C(^{13}C, \alpha)^{22}Ne$', Bull. Amer. Phys. Soc. **28**, 715 (1983).

46. K. S. Dhuga, L. C. Bland, G. P. Gilfoyle, H. T. Fortune, M. A. Carchidi, G. S. Stephans, and J. W. Sweet, 'The ^{25}Mg$(\alpha, \mathrm{d})^{27}$Al reaction at E$(\alpha) = 25$ MeV', Bull. Amer. Phys. Soc. **28**, 715 (1983).

47. H. T. Fortune, G. P. Gilfoyle, K. S. Dhuga, M. A. Carchidi, J. W. Sweet, A. Wuosmaa, and R. Gilman, 'More resonances in ^{12}C$(^{12}\mathrm{C}, \alpha)^{20}$Ne', Bull. Amer. Phys. Soc. **28**, 993 (1983).

48. J. W. Sweet, G. P. Gilfoyle, H. T. Fortune, L. C. Bland, G. S. Stephans, K. S. Dhuga, M. A. Carchidi, P. Kutt, R. Gilman, and R. W. Zurmuhle, 'Resonances in the $^{12}\mathrm{C}+^{18}\mathrm{O}$ system from the ^{12}C$(^{18}\mathrm{O}, \alpha)^{26}$Mg reaction', Bull. Amer. Phys. Soc. **27**, 699 (1982).

49. L. C. Bland, G. P. Gilfoyle, H. T. Fortune, G. S. Stephans, K. S. Dhuga, M. A. Carchidi, J. W. Sweet, R. W. Zurmuhle, and R. Gilman, '^{12}C$(^{12}\mathrm{C}, \alpha)^{20}$Ne angular correlation measurements', Bull. Amer. Phys. Soc. **27**, 715 (1982).

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Jefferson Laboratory Technical Reports

1. L.B.Weinstein, G.P.Gilfoyle, F.J.Klein, "Charged Particle Tracking in CLAS12", report of the internal CLAS Collaboration review committee, Feb., 2007.

2. G.P.Gilfoyle and V.Mokeev, "Baryon Form Factors", update of the CLAS Conceptual Design Report, `http://www.jlab.org/Hall-B/clas12/Physics/Baryon/Baryon.pdf`, March, 2007, last accessed April 28, 2008.

3. G.P.Gilfoyle and A.Afanasev, "Radiative Corrections for Deuteron Electrodisintegration", CLAS-Note 2005-022.

4. G.P.Gilfoyle, M.Ito, and E.J.Wolin, "Online RECSIS", CLAS-Note 98-017.

5. M.Mestayer and G.P.Gilfoyle, "Effects of Discrete Ionization in the CLAS Drift Chambers", CLAS-Note 96-008.

6. G.P.Gilfoyle, S.Levy, and M.Mestayer, "Spatial Resolution of the Nose Cone Prototype Drift Chamber", CLAS-Note 96-009.

7. G.P.Gilfoyle, M.V.Kossov, E.Burtin, M.D.Mestayer, and L.Y.Murphy, "Drift Velocity Calibration of the CLAS Drift Chambers", CLAS-Note 95-022.

8. R.W.Major, M.F.Vineyard, and G.P.Gilfoyle, "Effects of absorbed X-ray dose on resistivity and Young's modulus of a conducting elastomer", CLAS-Note 91-011.

Jefferson Laboratory Talks and Presentations

1. “Nuclear Physics Working Group Report”, plenary session, CLAS Collaboration Meeting, May 31, 2008.

2. “Nuclear Physics Working Group Report”, plenary session, CLAS Collaboration Meeting, Nov 2, 2007.

3. “Nuclear Physics Working Group Report”, plenary session, CLAS Collaboration Meeting, June 14, 2007.

4. “Measurement of the Neutron Magnetic Form Factor at High Q2 Using the Ratio Method on Deuterium”, plenary session, CLAS Collaboration meeting June 12, 2007.

5. Software Report”, plenary session, Hall-B, 12-GeV Upgrade Workshop, May 15, 2007.

6. ”CLAS12 Reconstruction Overview”, Hall-B, 12-GeV Upgrade Workshop, May 14, 2007.

7. ”Nuclear Physics Working Group Report ”, plenary session, CLAS Collaboration Meeting, November 4, 2006.

8. ‘Measurements of the Fifth Structure Function of the Deuteron’, CLAS Collaboration Meeting, March 3, 2006.

9. ‘Nuclear Physics Working Group report’, presented at the plenary session of the CLAS Collaboration meeting June 18, 2005.

10. ‘Progress Report on the $d(\vec{e}, e'p)n$ reaction for the E5 run period’, presented at the Nuclear Physics Working Group meeting during the CLAS Collaboration meeting June 17, 2005.

11. ‘Progress Report on Out-of-Plane Measurements of the Structure Functions of the Deuteron’, presented at the Nuclear Physics Working Group meeting during the CLAS Collaboration meeting Feb 25, 2005.

12. ”Radiative Corrections for E5”, CLAS Collaboration Meeting, June 20, 2004.

13. ”Out-of-Plane Measurements of the Structure Functions of the Deuteron”, plenary session of the CLAS Collaboration Meeting, November 13, 2003.

14. ‘Out-of-Plane Measurements of the Structure Functions of the Deuteron’, CLAS Collaboration Meeting, July 26, 2003.

15. ‘Out-of-Plane Measurements of the Structure Functions of the Deuteron’, CLAS Collaboration Meeting, February 28, 2003.

16. ‘E5 Status Report’, Plenary Session of the CLAS Collaboration Meeting, October 19, 2002.

17. ‘RECSIS Online Progress’, Plenary session of the CLAS Collaboration Meeting, January, 1999.

18. ‘RECSIS Online Progress’, Talk presented at the CLAS Collaboration Meeting, January, 1998.

19. ‘Tracking Progress’, CLAS Collaboration Meeting, September, 1997.

20. ‘Online Monitoring with RECSIS ’, CLAS Collaboration Meeting, September, 1997.

21. ‘RECSIS Online’, CLAS Software Working Group Meeting, August, 1997.

22. ’Recent Drift Chamber Software Developments’, CLAS Collaboration Meeting, January, 1997.

23. ‘CLAS Drift Chamber Calibration Software’, presented to the Software Working Group and to the Drift Chamber Working Group, CLAS Collaboration Meeting, July 17-20, 1996.

24. ‘Laser Calibration of the CLAS Drift Chambers’, CLAS Collaboration Meeting, November, 1995.

25. ‘Drift Chamber Analysis’, CLAS Collaboration Meeting, November, 1995.

26. ‘Effects of Discrete Ionization in the Nose Cone Prototype’, CLAS Collaboration Meeting, June, 1995.

27. ‘Data Definitions for the Drift Chambers’, CLAS Collaboration Meeting, June, 1995.

28. ’Recent Drift Chamber Developments and Prospects’, CLAS Collaboration Meeting, November, 1994.

29. ’Recent Drift Chamber Developments and Prospects’, CLAS Software Working Group Meeting, October, 1994.

30. ‘Spin 0 Decay Angular Distribution for Interfering Mesons in Electroproduction’, CLAS Collaboration Meeting, July, 1994.

31. ’Recent Drift Chamber Developments and Prospects’, CLAS Software Working Group Meeting, July, 1994.

32. ‘Electroproduction of the $f_0(980)$ Scalar Meson’, CLAS Collaboration Meeting, March, 1994.

33. ’Recent Drift Chamber Developments and Prospects’, CLAS Software Working Group Meeting, March, 1994.

Projects Managed for the US Department of Defense (dates show completion).

1. ‘Net Assessment of the Comprehensive Test Ban Treaty (CTBT)’ - Fall, 2000.

2. ‘Assessing Preventive Threat Reduction’ - Summer, 2000.

3. ‘The Future of Cooperative Threat Reduction’ - Summer, 2000.

4. ‘Development of a postdoctoral fellowship program at the Advanced Systems and Concepts Office (ASCO) of the Defense Threat Reduction Agency (DTRA)’, summer, 2000.

5. ‘Science and Technology Review of the Defense Threat Reduction Agency’, Dulles, VA, April 5 and June 28-30, 2000.

6. ‘A Nuclear Planning and Modeling Tool’, spring 2001.

7. ‘Development of Multi-Polar Exchange Models of Nuclear Conflict’, Summer 2001.

Independent Undergraduate Research Projects Directed[3]

- * - *indicates projects that were presented at national or international meetings.*
- ** - *indicates projects that also received travel funds to attend those meetings from the American Physical Society.*

1. 'Precision of the G_M^n Measurement at high Q^2', Mark Moog, summer, 2008.**
2. 'GEMC Installation', Justin Nguyen, summer, 2008.
3. 'Systematic Uncertainties in A'_{LT} for $D(\vec{e}, e'p)n$', Matt Jordan, summer, 2008.**
4. 'Averaging Theoretical Predictions for $D(\vec{e}, e'p)n$', Matt Jordan, spring and summer, 2008.
5. 'Investigating Asymmetries in the $D(e, e')n$ Reaction', Kuri Gill, senior thesis in Physics, January, 2008.
6. 'CLAS 12 Simulation Analysis and Optimization', Kirill Dergachev, summer, 2007 and spring, 2008.**
7. 'Simulations of CLAS for the $\cos(2\phi_{pq})$ analysis', Kuri Gill, summer and fall, 2007.**
8. 'Scientific Advice to the House: Who Has the Congressional Ear?', Kristen Greenholt, senior thesis in Political Science with Dr. D. Palazzolo and Dr. P.Smallwood, April, 2007.
9. 'Extracting the Fifth Structure Function and Hadronic Fiducial Cuts for the CLAS E5 Data Run at Jefferson Laboratory', Kristen Greenholt, senior thesis in Physics, winner of the Taylor award for best Senior Seminar, April, 2007.
10. 'Extracting the Fifth Structure Function and Hadronic Fiducial Cuts for the CLAS E5 Data Run', Kristen Greenholt, summer 2006.**
11. 'CLAS Simulations for the E5 Data Set', Rusty Burrell, senior thesis in Physics, April, 2007 and summer 2006.**
12. 'Extracting the Fifth Structure Function and Electron Fiducial Cuts for the CLAS E5 Data Run', Kristen Greenholt, summer, 2004.**
13. 'Momentum Corrections for the E5 Dataset', R.Burrell, summer, 2004 and summer 2005.**
14. 'Maintenance and Upgrading of the Richmond Physics Supercomputing Cluster', V.Davda*, summer, 2003.**
15. 'Pion Identification in CLAS', Arthur Rayner, 2002-2003.*
16. 'The Angular Distribution of the $f_0(980)$', Alasdair Mackenzie, 2002.
17. 'From Quarks to Nucleons', F. Chinchilla, summer, 2001.*

[3]The projects listed in this section were performed during summer fellowships or as independent, academic-year investigations or both.

18. ‘Analysis of Electron Scattering Data From the CLAS’, Adam Weaver, 2001.
19. ‘Development and Maintenance of a Linux Computing Cluster’, F. Chinchilla, summer, 2000.*
20. ‘Update of the Investigative Physics Laboratory Manual for Physics 132’, Ryan Hall, 2000.
21. ‘Elastic Peak Monitoring for the CLAS’, David Vermette, 2000.*
22. ‘Development of Efficient Reconstruction Algorithms for Particle Tracks at Jefferson Labs’, David Vermette, 1998-1999.*
23. ‘Determining the Maximum Drift Time of the CLAS’, Danielle Clement, 1998.
24. ‘Simulation of $f_0(980)$ Production in the CLAS’, Hong-Ying Lan, 1997-1998.
25. ‘Spatial Resolution of the Nose Cone Prototype Drift Chamber’, Steven Levy, 1996.*
26. ‘Tests of Drift Velocity Algorithm Speeds’, Yaw Opoku, 1996.
27. ‘A Graphical User Interface for the CLAS Drift Chamber Calibration Software’, Hong-Ying Lan, 1996.
28. ‘Drift Velocity Calibration for the CLAS Drift Chamber System’, Steven Levy, 1995-1996.
29. ‘Statistical Analysis of the $^{12}\mathrm{C} +^{13} \mathrm{C}$ System’, M.Nimchek, summer, 1994.*
30. ‘Search for Resonances in the $^{12}\mathrm{C}(^{13}\mathrm{C},\alpha)^{21}\mathrm{Ne}$ Reaction’, A.S.Snyder, 1991-1993.*
31. ‘Light Particles Produced in Central Collisions Between $^{40}\mathrm{Ca}$ and $^{12}\mathrm{C}$ Nuclei’, J.H.Rollinson, summer 1991.*
32. ‘A Computer Simulation of a Nuclear Fusion Reaction for Evaporation Residues’, Craig Gosdin, 1990.
33. ‘Measuring Cross Sections From the $^{12}\mathrm{C}(^{13}\mathrm{C},\alpha)^{21}\mathrm{Ne}$ Reaction’, C.Cardounel, 1990-1991.
34. ‘Analysis of the $^{12}\mathrm{C}$+$^{13}\mathrm{C}$ Potential Energy’, A.S.Snyder, 1990.
35. ‘Analysis of the $^{12}\mathrm{C}$+$^{13}\mathrm{C}$ Reaction’, S.Sigworth, 1989.
36. ‘A Computer Simulation of a Nuclear Fusion Reaction for Evaporation Residues’, Craig Gosdin, 1988.
37. ‘Analysis of the $^{12}\mathrm{C}(^{13}\mathrm{C},\alpha)^{21}\mathrm{Ne}$ Reaction’, M.Simpson, 1988.
38. ‘Analysis of the $^{13}\mathrm{C}(^{13}\mathrm{C},\alpha)^{21}\mathrm{Ne}$ Reaction’, J.Richards, 1984.

Presentations at the University of Richmond Student Symposium

1. ‘CLAS 12 Simulation Analysis and Optimization’, K.Dirgachev and G.P.Gilfoyle, Spring 2008.
2. “Hadronic Fiducial Cuts on CLAS for the E5 Data Set”, K.Greenholt and G.P.Gilfoyle, Spring 2007.
3. ‘CLAS Simulations for $D(\vec{e},e'p)n$’, R.Burrell, K. Gill, and G.P.Gilfoyle, Spring 2007.
4. ‘Fiducial Cuts on CLAS for the E5 Data Set’, K.Greenholt and G.P.Gilfoyle, Spring 2006.

5. ‘Momentum Corrections for the E5 Data Set’, R.Burrell and G.P.Gilfoyle, Spring, 2006.
6. ‘Generating Fiducial Cuts for CLAS E5’, K.Greenholt and G.P.Gilfoyle, Spring, 2005.
7. ‘Momentum Corrections for the CLAS E5 Data Set’, R.Burrell and G.P.Gilfoyle, Spring, 2005.
8. ‘Maintenance and Upgrading of the Richmond Physics Supercomputing Cluster’, V.Davda* and G.P.Gilfoyle, Spring, 2004.
9. ‘Measuring the Boltzman constant with the Millikan oil drop apparatus’, Gary Larson and G.P.Gilfoyle, Spring, 2004.
10. ‘Measuring interatomic distances with X-rays’, Benjamin Crider and G.P.Gilfoyle, Spring, 2004.
11. ‘Studying transmission of microwaves’, Trin Chavalittumrong and G.P.Gilfoyle, Spring, 2004.
12. ‘Dynamical chaos in a double pendulum’, Timothy Lambie-Hanson and G.P.Gilfoyle, Spring, 2004.
13. ‘Testing Models of Air Friction’, Daniel Katz and G.P.Gilfoyle, Spring, 2004.
14. ‘Pion Identification in CLAS’, A. Rayner, A.Mackenzie, and G.P.Gilfoyle, Spring 2003.
15. ‘Analysis of Electron Scattering Data From the CLAS’, A.Weaver, and G.P.Gilfoyle, Spring 2002.
16. ‘Development and Maintenance of a Linux Computing Cluster’, Francisco Chinchilla, M.F.Vineyard, and G.P.Gilfoyle, Spring 2001.
17. ‘Development of Efficient Reconstruction Algorithms for Particle Tracks at Jefferson Labs’, D. Vermette, and G.P.Gilfoyle, Spring 1998.
18. ‘Determining the Maximum Drift Time of the CLAS’, D. Clement, and G.P.Gilfoyle, Spring 1998.
19. ‘Drift Velocity Calibration for the CLAS Drift Chamber System’, S.Levy, and G.P.Gilfoyle, and M.Mestayer, Spring 1996.
20. ‘Environmental Effects on the CLAS drift Chambers’, S.Levy and G.P.Gilfoyle, Spring, 1995.
21. ‘Statistical Analysis of the ^{12}C(^{13}C$, \alpha)^{21}$Ne Reaction’, M.Nimchek, A.S.Snyder, and G.P.Gilfoyle, Spring 1994.
22. ‘Search for Nuclear Molecules in the $^{12}C +^{13} C$ System’, A.S.Snyder, C.A.Cardounel, S.Sigworth, C.Smith, and G.P.Gilfoyle, Spring 1991.
23. ‘Analysis of Data for the Search for Nuclear Molecules in the $^{12}C +^{13} C$ System’, C.A.Cardounel, A.S.Snyder, S.Sigworth, C.Smith, and G.P.Gilfoyle, Spring 1991.
24. ‘Protons and alpha-particles Produced in Central Collisions Between ^{40}Ca and ^{12}C Nuclei’, J.H.Rollinson, M.F.Vineyard, S.E.Atencio, J.Crum, G.P.Gilfoyle, R.G.Ohl, Spring, 1991.
25. ‘Analysis of the ^{12}C(^{13}C$, \alpha)^{21}$Ne Reaction’, S.K.Sigworth and G.P.Gilfoyle, Spring, 1989.
26. ‘Calibrations of Sodium Iodide Detectors in ^{16}O-Induced Reactions’, G.Turner and G.P.Gilfoyle, Spring, 1988.

Remaining University and Professional Service (see pages 81-82 for highlights)

1. 2007-present - Member of the Environmental Awareness Group.
2. 2006-present - Organized Physics outreach program called Deconstruction Night.
3. 2006-present - Physics webpage manager.
4. 2004-present - Faculty advisor to the Richmond Physics Olympics.
5. 2005 - Wrote and developed the Physics assessment plan.
6. 2005 - Chair of mid-course review for Dr. Ted Bunn.
7. 2004 - Member of the local organizing committee for PN12, the Physics of Nuclei at 12 GeV held at Newport News, VA, Nov 1-5, 2004.
8. 2004-2005 - Chair of Physics faculty search committee (two tenure-track appointments, one laboratory director, and one adminstrative assistant).
9. 2004 - Dual-degree engineering adviser.
10. 2004 - Chair of mid-course review for Dr. Mirela Fetea.
11. 2003-2004 - Chair of Physics faculty search committee (one laboratory director).
12. 2002-2003 - Chair of Physics faculty search committee (one adjunct faculty appointment).
13. 2002-present - Reviewer, CLAS Collaboration.
14. 2004 - Chair of promotion review for Dr. Michael Vineyard.
15. 2001-2002 - Chair of Physics faculty search committee (one tenure-track appointment).
16. 2001 - Managed Physics Department review by Research Corporation.
17. 2000-present - University Science Review Committee.
18. 2000-present - Represented Physics at Prospective Student Open House and Majors' Fair.
19. 2000-2003 - Served on the Academic Computing Committee.
20. 2000-2002 - Academic Computing Committee.
21. 2000 - Organized the 'Take-Your-Children-To-Work Day at the Advanced Systems and Concepts Office (ASCO) of the Defense Threat Reduction Agency (DTRA)', May 17, 2000.
22. 1999, 2001-2002 - Physics Department's high school outreach program.
23. 1999, 2001-2002 - University Marshall.
24. 1997 - Chair, Jefferson Laboratory CLAS Collaboration nominating committee.

25. 1998-1999 - Chair, Science Initiative curriculum sub-committee.
26. 1997-99 - Science Initiative Research Committee.
27. 1996-1998 - University Technology Fellow.
28. 1995-1999 - Oldham Merit Scholarship Committee.
29. 1995-1997 - Undergraduate Research Committee.
30. 1995 - Organizer for CLAS Collaboration Meeting, June, 1995.
31. 1992-1994 - Science Center Computing Committee.
32. 1995-1995 - Network Committee.
33. 1993-1994, 2001 - Ethyl and Albemarle Merit Science Scholarship Committee.
34. 1993-1996 - Honors Committee.
35. 1993-1994 - Dean of Arts and Sciences ad hoc Committee on Evaluations.
36. 1992-1994 - Faculty Research Committee.
37. 1991-present - Undeclared Student Advisor (except during leave).
38. 1988-1989 - Chair, Task Force on the Future of Academic Computing.
39. 1988-1991 - Chair, Academic Computing.