# NSTAR 2017

*The 11th International Workshop on the Physics of Excited Nucleons*

August 20 – 23, 2017

at the University of South Carolina, Columbia, SC

Organizers:
R. Gothe (Chair), Y. Ilieva, V. Mokeev, E. Santopinto, and S. Strauch

# List of Speakers

1. **Adhikari, Shankar**, "Measurement of polarization observables for Lambda in the reaction $\gamma p \rightarrow K^{+}\Lambda$", Parallel Session A3 (DMSB 124) on Tuesday, August 22, 2017, 17:10.

2. **Akbar, Zulkaida** , "Photoproduction of $\omega$ Mesons using CLAS at Jefferson Laboratory ", Parallel Session A3 (DMSB 124) on Tuesday, August 22, 2017, 16:30.

3. **Angelini, Giovanni**, "CLAS12 RICH: New hybrid geometry for strangeness studies.", Parallel Session B5 (DMSB 125) on Wednesday, August 23, 2017, 11:40.

4. **Bashir, Adnan**, "Structure of the Orbital Excited N* from SDE", Parallel Session B4 (DMSB 125) on Wednesday, August 23, 2017, 08:30.

5. **Bernauer, Jan**, "Two-Photon-Exchange: Future experimental prospects", Parallel Session C3 (DMSB 126) on Tuesday, August 22, 2017, 16:50.

6. **Blunden, Peter**, "Overview of recent theoretical work on two-photon exchange", Parallel Session C3 (DMSB 126) on Tuesday, August 22, 2017, 16:00.

7. **Briceno, Raul**, "Resonance properties via lattice QCD", Parallel Session B1 (DMSB 125) on Sunday, August 20, 2017, 13:30.

8. **Brodsky, Stanley J.**, "Supersymmetric features of hadron physics and other novel properties of QCD from Light-Front Holography and Superconformal Quantum Mechanics ", General Session P5 (DMSB 123) on Tuesday, August 22, 2017, 10:00.

9. **Buchmann, Alfons**, "Electromagnetic multipole moments of baryons", Parallel Session D3 (DMSB 122) on Tuesday, August 22, 2017, 17:10.

10. **Bulava, John**, "Hadron scattering amplitudes from lattice QCD with controlled errors", Parallel Session B1 (DMSB 125) on Sunday, August 20, 2017, 14:00.

11. **Burkert, Volker**, "A Light Front Relativistic Quark Model with Running Quark Mass", Parallel Session D3 (DMSB 122) on Tuesday, August 22, 2017, 16:30.

    **Burkert, Volker**, "N* Experiments and their Impact on Strong QCD Physics", General Session P1 (DMSB 123) on Sunday, August 20, 2017, 09:00.

12. **Cao, Tongtong**, "Determination of the Polarization Observables $C_x$, $C_z$, and $P_y$ for the Quasi-Free Mechanism in the reaction $\overrightarrow{\gamma} d \rightarrow K^{+} \overrightarrow{\Lambda} n$", Parallel Session A4 (DMSB 124) on Wednesday, August 23, 2017, 10:00.

13. **Carman, Daniel**, "CLAS N* Excitation Results from Pion and Kaon Electroproduction", General Session P7 (DMSB 123) on Wednesday, August 23, 2017, 15:30.

14. **Cole, Philip**, "Bridging Time-Like and Space-Like N* Form Factors", Parallel Session C5 (DMSB 126) on Wednesday, August 23, 2017, 10:50.

15. **Crede, Volker**, "Understanding the Spectrum of Excited Nucleons using CLAS at Jefferson Lab", General Session P5 (DMSB 123) on Tuesday, August 22, 2017, 09:00.

16. **D'Angelo, Annalisa**, "Hybrid Baryon Search at CLAS12", General Session P4 (DMSB 123) on Monday, August 21, 2017, 12:00.

17. **Davoudi, Zohreh**, "Beyond nucleon properties from lattice QCD", Parallel Session B2 (DMSB 125) on Tuesday, August 22, 2017, 14:30.

18. **Deur, Alexandre**, "The QCD running coupling at all scales and the connection between the proton mass and $\Lambda_{\overline{MS}}$", Parallel Session B4 (DMSB 125) on Wednesday, August 23, 2017, 09:40.

19. **Doering, Michael**, "Developments of the Julich-Bonn Dynamical Coupled-Channel Analysis", General Session P5 (DMSB 123) on Tuesday, August 22, 2017, 08:30.

20. **Eichmann, Gernot**, "Baryon structure and reaction mechanisms from Dyson-Schwinger equations", General Session P4 (DMSB 123) on Monday, August 21, 2017, 11:30.

21. **Elouadrhiri, Latifa**, "Confinement in N* and DIS Physics", Parallel Session C1 (DMSB 126) on Sunday, August 20, 2017, 13:30.

22. **Fedotov, Gleb**, "New results on $\gamma_v p \rightarrow p'\pi^+\pi^-$ cross sections in the resonance region with CLAS", Parallel Session A5 (DMSB 124) on Wednesday, August 23, 2017, 12:20.

23. **Fersch, Robert**, "Measurements of the Nucleon Spin-Structure Functions in and above the Resonance Region from the Hall-B EG1 experiment at Jefferson Laboratory", Parallel Session A1 (DMSB 124) on Sunday, August 20, 2017, 14:20.

24. **García-Tecocoatzi, Hugo**, "Baryon masses and strangeness suppression in the Unquenched Quark model", Parallel Session D3 (DMSB 122) on Tuesday, August 22, 2017, 16:50.

25. **Girod, Francois-Xavier**, "Unraveling confinement forces with DVCS", Parallel Session C1 (DMSB 126) on Sunday, August 20, 2017, 14:00.

26. **Gleason, Colin**, "Determination of the Hyperon Induced Polarization and Polarization–Transfer Coefficients for Quasi-Free Hyperon Photoproduction off the Bound Neutron", Parallel Session A2 (DMSB 124) on Tuesday, August 22, 2017, 14:50.

27. **Grames, Joseph**, "Polarized Positron Beam R&D at Jefferson Lab", Parallel Session C3 (DMSB 126) on Tuesday, August 22, 2017, 17:10.

28. **Hagelstein, Franziska**, "The Role of the $\Delta(1232)$-Resonance in the (Muonic) Hydrogen Spectrum", Parallel Session C4 (DMSB 126) on Wednesday, August 23, 2017, 09:20.

29. **Hansen, Maxwell**, "Total decay and transition rates from LQCD", Parallel Session B1 (DMSB 125) on Sunday, August 20, 2017, 14:20.

30. **Hiller Blin, Astrid**, "Relating CP-violating decays to the neutron EDM", Parallel Session B3 (DMSB 125) on Tuesday, August 22, 2017, 17:10.

    **Hiller Blin, Astrid**, "Peripheral transverse densities of the baryon octet from ChPT and dispersion analysis", Parallel Session C1 (DMSB 126) on Sunday, August 20, 2017, 14:20.

    **Hiller Blin, Astrid**, "Studying the Pc(4450) resonance in J/psi photoproduction off protons", Parallel Session D2 (DMSB 122) on Tuesday, August 22, 2017, 14:50.

31. **Hollis, Gary**, "Fermi-unsmearing: A Monte Carlo method to correct for Fermi-motion of a target nucleon.", Parallel Session A4 (DMSB 124) on Wednesday, August 23, 2017, 09:40.

32. **Huang, Fei**, "Nucleon resonances in γp→K∗+Λ", Parallel Session B3 (DMSB 125) on Tuesday, August 22, 2017, 17:30.

33. **Ireland, Dave**, "Evaluating Polarization Data", Parallel Session B5 (DMSB 125) on Wednesday, August 23, 2017, 11:20.

34. **Jiang, Hao**, "Polarization Observables $T$ and $F$ in the $p(\gamma, \pi^0)p$ Reaction", Parallel Session A3 (DMSB 124) on Tuesday, August 22, 2017, 17:50.

35. **Jones, Mark**, "Virtual Compton Scattering measurements in Hall C at JLab", Parallel Session C4 (DMSB 126) on Wednesday, August 23, 2017, 10:00.

36. **Jung, Ju-Hyun**, "Constituent-quark model with pionic contributions: electromagnetic $N \to \Delta$ transition", Parallel Session D3 (DMSB 122) on Tuesday, August 22, 2017, 17:30.

37. **Kamano, Hiroyuki**, "Electromagnetic N* Transition Form Factors in the ANL-Osaka Dynamical Coupled-Channels Approach", General Session P3 (DMSB 123) on Monday, August 21, 2017, 10:00.

38. **Kohl, Michael**, "Experimental Advances in Two-Photon Contributions to Lepton-Proton Scattering", Parallel Session C2 (DMSB 126) on Tuesday, August 22, 2017, 14:00.

39. **Kohri, Hideki**, "Photoproduction of $\pi^-\Delta^{++}$, $\pi^+\Delta^0$, and $\pi^+ n$ on the proton at $E_\gamma = 1.5 - 3.0$ GeV at LEPS/SPring-8", Parallel Session B3 (DMSB 125) on Tuesday, August 22, 2017, 16:50.

40. **Koshchii, Oleksandr**, "Lepton mass effects in two-photon exchange theory", Parallel Session C2 (DMSB 126) on Tuesday, August 22, 2017, 14:50.

41. **Koutsou, Giannis**, "Nucleon and Delta structure results from lattice QCD", Parallel Session C4 (DMSB 126) on Wednesday, August 23, 2017, 09:00.

42. **Lebed, Richard**, "Constituent Counting Rules and Exotic Hadrons", Parallel Session D2 (DMSB 122) on Tuesday, August 22, 2017, 15:10.

43. **Leskovec, Luka**, "A lattice QCD study of pion-nucleon scattering in the Roper channel", Parallel Session B2 (DMSB 125) on Tuesday, August 22, 2017, 14:50.

44. **Leupold, Stefan**, "Hyperon-photon physics", Parallel Session C5 (DMSB 126) on Wednesday, August 23, 2017, 11:40.

45. **Lu, Haiyun**, "Beam-Target Asymmetry for $\gamma n(p) \to \pi^- p(p)$ in $N^*$ Resonance Region", Parallel Session A2 (DMSB 124) on Tuesday, August 22, 2017, 15:10.

46. **Mai, Maxim**, "Status of the Lambda(1405)", General Session P3 (DMSB 123) on Monday, August 21, 2017, 09:00.

47. **Markov, Nikolay**, "Exclusive $\pi^0$ electroproduction in the resonance region.", Parallel Session A5 (DMSB 124) on Wednesday, August 23, 2017, 11:20.

48. **Mathieu, Vincent**, "Analyticity Constraints for the Baryon Spectrum", Parallel Session D2 (DMSB 122) on Tuesday, August 22, 2017, 14:00.

49. **Mattione, Paul**, "$\gamma n \to p\pi^-$ Cross Section Measurement at CLAS", Parallel Session A2 (DMSB 124) on Tuesday, August 22, 2017, 14:00.

50. **McKeown, Bob**, "Future Facilities and QCD Physics", General Session P2 (DMSB 123) on Sunday, August 20, 2017, 11:30.

51. **Melnitchouk, Wally**, "Duality between resonances and parton physics", Parallel Session A1 (DMSB 124) on Sunday, August 20, 2017, 13:30.

52. **Mokeev, Victor**, "Nucleon Resonance Structure from Exclusive Meson Electroproduction with CLAS", General Session P2 (DMSB 123) on Sunday, August 20, 2017, 11:00.

53. **Myhrer, Fred**, "Lepton bremsstrahlung at low energies", Parallel Session C3 (DMSB 126) on Tuesday, August 22, 2017, 17:30.

54. **Nakamura, Satoshi**, "Photo- and Electroexcitation of Bound Neutrons and Protons", Parallel Session B3 (DMSB 125) on Tuesday, August 22, 2017, 16:00.

55. **Net, Lelia**, "Polarization observables in double charged pion photo-production with circularly polarized photons off transversely polarized protons", Parallel Session A3 (DMSB 124) on Tuesday, August 22, 2017, 17:30.

56. **Niculescu, Ioana** , "Quark Hadron Duality in Unpolarized Structure Functions", Parallel Session A1 (DMSB 124) on Sunday, August 20, 2017, 14:00.

57. **Nys, Jannes**, "Finite-Energy Sum Rules in Eta Photoproduction off the Nucleon", Parallel Session D2 (DMSB 122) on Tuesday, August 22, 2017, 14:30.

58. **Oset, Eulogio**, "Chiral Unitary and New Developments in the Baryon Sector", General Session P6 (DMSB 123) on Tuesday, August 22, 2017, 11:00.

59. **Paolone, Michael**, "The VCS-$\Delta$ experiment at MAMI", Parallel Session C4 (DMSB 126) on Wednesday, August 23, 2017, 09:40.

60. **Park, Kijun**, "Extracting Resonance Parameters from Exclusive Electroproduction off Protons at CLAS", Parallel Session A5 (DMSB 124) on Wednesday, August 23, 2017, 10:50.

61. **Pasyuk, Eugene**, "Advances in N* spectroscopy from Exclusive Photoproduction at CLAS", Parallel Session A3 (DMSB 124) on Tuesday, August 22, 2017, 16:00.

62. **Phelps, Evan**, "Response Functions from Exclusive Measurements of $\omega$ Meson Electroproduction off the Proton", Parallel Session A5 (DMSB 124) on Wednesday, August 23, 2017, 11:40.

63. **Pisarski, Robert**, "When are mesons eigenstates of SU(3) versus that of flavor?", Parallel Session C1 (DMSB 126) on Sunday, August 20, 2017, 14:40.

64. **Ramalho, Gilberto**, "N* Form Factors based on a Covariant Quark Model", Parallel Session D3 (DMSB 122) on Tuesday, August 22, 2017, 16:00.

65. **Ramstein, Béatrice**, "Studying time-like electromagnetic baryonic transitions with HADES in $\pi$-N reactions", Parallel Session C5 (DMSB 126) on Wednesday, August 23, 2017, 11:20.

    **Ramstein, Béatrice**, "Time-Like Baryon Transitions in Hadroproduction", General Session P7 (DMSB 123) on Wednesday, August 23, 2017, 15:00.

66. **Roberts, Craig**, "N* Structure: A Window on Strong QCD", General Session P1 (DMSB 123) on Sunday, August 20, 2017, 09:30.

67. **Rodríguez-Quintero, José**, "A process-independent QCD effective charge: a main ingredient for a further computation of nucleon-to-resonances transitions", Parallel Session B4 (DMSB 125) on Wednesday, August 23, 2017, 09:00.

68. **Ryckebusch, Jan**, "Resonance Parameters from Strangeness Photo- and Electroproduction", General Session P7 (DMSB 123) on Wednesday, August 23, 2017, 14:00.

69. **Sadasivan, Daniel**, "Disentanglement of Electromagnetic Baryon Properties", Parallel Session B4 (DMSB 125) on Wednesday, August 23, 2017, 10:00.

70. **Sandorfi, Andrew**, "Spin Asymmetries and Helicity Amplitudes from Pion Production from Polarized Neutrons at Jefferson Lab", General Session P3 (DMSB 123) on Monday, August 21, 2017, 08:30.

71. **Santopinto, Elena**, "N* Structure from Constituent Quark Models", General Session P8 (DMSB 123) on Wednesday, August 23, 2017, 17:00.

72. **Sato, Toru**, "Quark-hadron duality in parity-violating electroweak reactions", Parallel Session A1 (DMSB 124) on Sunday, August 20, 2017, 14:40.

    **Sato, Toru**, "Exclusive Meson Electroproduction off Bound Nucleons", General Session P8 (DMSB 123) on Wednesday, August 23, 2017, 16:30.

73. **Schmieden, Hartmut**, "First Results from the BGO-OD Experiment at ELSA", Parallel Session C5 (DMSB 126) on Wednesday, August 23, 2017, 12:20.

74. **Segovia, Jorge**, "Valence-quark structure in nucleon resonances from DSEs", General Session P6 (DMSB 123) on Tuesday, August 22, 2017, 12:00.

75. **Shah, Zalak**, "Mass spectra of singly beauty $\Omega_b^-$ baryon", Parallel Session D3 (DMSB 122) on Tuesday, August 22, 2017, 17:50.

76. **Shanahan, Phiala**, "Gluon structure of hadrons", Parallel Session B1 (DMSB 125) on Sunday, August 20, 2017, 14:40.

77. **Skorodumina, Iuliia**, "Investigation of Exclusive $\pi^+\pi^-$ Electroproduction off the Bound Proton in Deuterium in the Resonance Region with CLAS", Parallel Session A4 (DMSB 124) on Wednesday, August 23, 2017, 09:20.

78. **Sokhoyan, Vahe**, "N* Photoexcitation Results from Mainz", General Session P5 (DMSB 123) on Tuesday, August 22, 2017, 09:30.

79. **Sparveris, Nikos**, "N to $\Delta$ transition: recent results and prospects", Parallel Session C4 (DMSB 126) on Wednesday, August 23, 2017, 08:30.

80. **Strakovsky, Igor**, "Exclusive Meson Photoproduction off Bound Nucleons", Parallel Session B5 (DMSB 125) on Wednesday, August 23, 2017, 10:50.

81. **Strauch, Steffen**, "Baryons in Medium", General Session P8 (DMSB 123) on Wednesday, August 23, 2017, 17:30.

82. **Svarc, Alfred**, "From Experimental Data to Pole Parameters in a Model Independent Way (Angular Dependent Phase Rotations and L+P method)", General Session P3 (DMSB 123) on Monday, August 21, 2017, 09:30.

83. **Tandy, Peter**, "Aspects of Nucleon Parton Structure from a DSE Implementation of QCD", Parallel Session B4 (DMSB 125) on Wednesday, August 23, 2017, 09:20.

84. **Thiel, Annika**, "N* Photoexcitation Results from Bonn", General Session P4 (DMSB 123) on Monday, August 21, 2017, 11:00.

85. **Tian, Ye**, "Exclusive $\pi^-$ Electroproduction off the Neutron in Deuterium in the Resonance Region", Parallel Session A4 (DMSB 124) on Wednesday, August 23, 2017, 08:30.

86. **Tiator, Lothar**, "The MAID Legacy and Future", General Session P1 (DMSB 123) on Sunday, August 20, 2017, 10:00.

87. **Tomalak, Oleksandr**, "Two-photon exchange correction in elastic lepton-proton scattering. Dispersive and model calculations", Parallel Session C2 (DMSB 126) on Tuesday, August 22, 2017, 15:10.

88. **Tomasi-Gustafsson, Egle**, "Two-photon exchange: myth and history", Parallel Session C3 (DMSB 126) on Tuesday, August 22, 2017, 16:30.

89. **Trivedi, Arjun**, "Measurement of New Observables from the $\pi^+\pi^- p$ Electroproduction off the Proton", Parallel Session A5 (DMSB 124) on Wednesday, August 23, 2017, 12:00.

90. **Walford, Natalie**, "Polarization Observables in Meson Photoproduction with the Crystal Ball/TAPS at MAMI", Parallel Session A2 (DMSB 124) on Tuesday, August 22, 2017, 14:30.

    **Walford, Natalie**, "Polarization Observables in $\gamma p \to K^+ + \Lambda$ and $K^+ + \Sigma^0$ Using Circularly Polarized Photons on a Polarized Frozen Spin Target", Parallel Session A3 (DMSB 124) on Tuesday, August 22, 2017, 16:50.

    **Walford, Natalie**, "Photoproduction of $\pi^0\pi^\pm$ Pairs off Nucleons", Parallel Session B5 (DMSB 125) on Wednesday, August 23, 2017, 12:00.

91. **Wilson, David**, "An $a_0$ resonance from lattice QCD", Parallel Session B2 (DMSB 125) on Tuesday, August 22, 2017, 14:00.

92. **Wu, Jiajun**, "Nucleon Excited States from Lattice QCD and Hamiltonian Effective Field Theory", General Session P7 (DMSB 123) on Wednesday, August 23, 2017, 14:30.

93. **Xie, Ju-Jun**, "Nucleon N(2120) resonance in $\phi p$ and $K\Lambda(1520)$ photon production", Parallel Session B3 (DMSB 125) on Tuesday, August 22, 2017, 16:30.

94. **Yurov, Mikhail**, "Two-photon exchange contribution to elastic electron-proton scattering", Parallel Session C2 (DMSB 126) on Tuesday, August 22, 2017, 14:30.

95. **Zhang, Jixie**, "Exclusive $\pi^-$ electroproduction from the neutron in the resonance region", Parallel Session A4 (DMSB 124) on Wednesday, August 23, 2017, 09:00.

96. **Zou, Bing-Song**, "N* Production from $e^+e^-$ Annihilation", General Session P6 (DMSB 123) on Tuesday, August 22, 2017, 11:30.

97. **Zétényi, Miklós**, "Polarization and dilepton anisotropy in pion-nucleon collisions", Parallel Session C5 (DMSB 126) on Wednesday, August 23, 2017, 12:00.

# Program

## Saturday, August 19, 2017

### Registration

Time: Saturday, August 19, 2017, 18:00 – 19:30
Room: Sonoco Pavilion

### Opening Reception

Time: Saturday, August 19, 2017, 18:00 – 20:00
Room: Sonoco Pavilion

## Sunday, August 20, 2017

### Registration

Time: Sunday, August 20, 2017, 07:30 – 09:00
Room: Lobby near DMSB 123

### Opening / Welcome / Introduction

Time: Sunday, August 20, 2017, 08:30 – 09:00
Room: DMSB 123

### General Session P1

Time: Sunday, August 20, 2017, 09:00 – 10:30
Room: DMSB 123
Chair: Steffen Strauch

**N* Experiments and their Impact on Strong QCD Physics**

Volker Burkert, Jefferson Laboratory

09:00
DMSB 123

Strong QCD is our theoretical tool to come to a full understanding of the physics of confinement, dynamical mass creation, and the breaking of chiral symmetry. With the right experimental and theoretical tools, the study of the structure of the nucleon and its energy spectrum can provide a tremendous amount of knowledge of the degrees of freedom underlying the excitation of nucleons. Nathan Isgur, in his last public talk at the NSTAR 2000 conference at Jefferson Lab, entitled "Why N*'s are important?", gave three answers: (1) "Nucleons are the stuff of which our world is made. As such they must be at the center of any discussion of why the world we actually experience has the character it does". (2) "Nucleons are the

simplest system in which the quintessentially non-abelian character of QCD is manifest." (3) "Baryons, while relatively simple, are sufficiently complex to reveal physics hidden from us in the mesons." In the opening talk of this conference I will emphasize the importance of precision measurements of many different final meson states, and of a broad variety of polarization observables that will lead us to a more complete knowledge of the energy spectrum of nucleons. Further progress on the development of theoretical tools related to the spectrum and structure of excited nucleons is essential to come closer to a meaningful comparison of experiment and theory in this domain of confinement. In presenting selected results from the past decade. I hope to illustrate progress that has been made both in experiment and in our understanding of the importance of the N* programs, and well of its vitality. I am confident the N* program continues worldwide and especially at the Jefferson Lab accelerator with higher energies and new instrumentation.

[1] Nathan Isgur, in "Excited Nucleons and Hadronic Structure", World Scientific Publishing, 2001, e-print: nucl-th/0007008.

### N* Structure: A Window on Strong QCD

Craig Roberts, Argonne National Laboratory

09:30
DMSB 123

One of the greatest challenges within the Standard Model is to discover the source of visible mass. Indeed, this is the focus of one of the Millennium Problems posed in 2000 by the Clay Mathematics Institute. The answer is hidden within quantum chromodynamics, the relativistic quantum field theory believed to describe nuclear physics; and it is quite likely that revealing the origin of mass will also explain the nature of confinement. In addressing these issues, this presentation will sketch key insights drawn using modern methods to solve the continuum bound-state problem and how they have been informed by modern experiments on nucleon-to-resonance transition form factors.

### The MAID Legacy and Future

Lothar Tiator, Johannes Gutenberg University Mainz

10:00
DMSB 123

MAID was introduced in 1998 as a unitary isobar model for pion photo- and electroproduction on nucleons. It quickly developed into a project that included EtaMAID and KaonMAID for $\eta$ and $K$ photo-and electroproduction and in addition a dynamical model DMT, that gives the most reliable predictions for pion photo- and electroproduction in the threshold region up to the $\Delta(1232)$.

MAID was constructed in a way to minimize the free parameters, which are mainly for electromagnetic resonance production of only well established 4-star $N$ and $\Delta$ resonances with hadronic parameters taken from PDG. This is probably part of the success, that it did not overfit all available data structures, but used only the substantial degrees of freedom. Up to now it can still provide reliable predictions for new polarization observables.

MAID has also been used for partial wave analysis, providing single-energy multipoles for photoproduction and single-$Q^2$ transition form factors for up to 10 $N$ and $\Delta$ resonances in the region $0 \leq Q^2 \leq 5\,\mathrm{GeV}^2$. The latest update for $e, e'\pi$ is MAID2007 and the latest extensions are Two-Pion-MAID in 2007 and ChiralMAID in 2012.

Currently, we are updating EtaMAID, analyzing high precision differential cross sections from MAMI and single spin and double beam-target polarization observables from MAMI, ELSA and JLab. Results with new and updated $\eta N$ and $\eta' N$ branching ratios will be presented. An update for pion photo- and electroproduction is also planned.

## Break (Coffee / Refreshments)

Time: Sunday, August 20, 2017, 10:30 – 11:00
Room: Sonoco Pavilion

## General Session P2

Time: Sunday, August 20, 2017, 11:00 – 12:00
Room: DMSB 123
Chair: Ralf Gothe

### Nucleon Resonance Structure from Exclusive Meson Electroproduction with CLAS

Victor Mokeev, Jefferson Lab

11:00
DMSB 123

The CLAS detector at Jefferson Lab has provided the dominant part of the available worldwide data on exclusive meson electroproduction off protons in the nucleon resonance ($N^*$) region. A large body of data on differential cross sections, as well as single- and double-polarization asymmetries have been obtained at invariant masses of the final state hadrons $W < 2.0$ GeV and photon virtualities $Q^2 < 5.0$ GeV$^2$. The current status and prospects for the extraction of the $\gamma_v pN^*$ electrocouplings from these data will be presented. The CLAS data on $N\pi$, $N\eta$, and $p\pi^+\pi^-$ electroproduction has provided $\gamma_v pN^*$ electrocouplings for most $N^*$ states in the mass range up to 1.8 GeV. In the near term future, the electrocouplings of most $N^*$ states in the mass range up to 2.0 GeV will be obtained at $Q^2 < 5.0$ GeV$^2$. In this regard, the new results on "missing" baryon states recently available from the combined studies of the CLAS $p\pi^+\pi^-$ photo- and electroproduction data will be discussed.
Physics analyses of the CLAS results on $\gamma_v pN^*$ electrocouplings have revealed the $N^*$ structure as a complex interplay between the inner core of three dressed quarks and an external meson-baryon cloud. The Dyson-Schwinger Equations of QCD have conclusively demonstrated the capability to explore the momentum dependence of the dynamical quark mass (mass function) from the CLAS data on the $\gamma_v pN^*$ electrocouplings of resonances of different quantum numbers. The $\gamma_v pN^*$ electrocoupling studies that will be extracted for $Q^2 < 12$ GeV$^2$ in the upcoming experiments with CLAS12 will allow us to explore the dressed quark mass function in the transition from the confinement to the pQCD regimes of the strong interaction, which will allow us to address the challenging problems on the nature of $> 98\%$ of hadron mass and the mechanisms for quark-gluon confinement.
Studies of high-lying ($M > 2.0$ GeV) resonance electrocouplings will also shed light on the existence of new states of baryon matter, the so-called hybrid baryons. The prospects for these studies will be discussed.

### Future Facilities and QCD Physics

Bob McKeown

11:30
DMSB 123

## Lunch Break

Time: Sunday, August 20, 2017, 12:00 – 13:30

## Parallel Session A1

Time: Sunday, August 20, 2017, 13:30 – 15:00
Room: DMSB 124
Chair: Gernot Eichmann

**Duality between resonances and parton physics**

Wally Melnitchouk, Jefferson Lab — 13:30 DMSB 124

An overview will be given of recent progress in understanding the duality between the physics of nucleon resonances and the partonic structure of hadrons.

**Quark Hadron Duality in Unpolarized Structure Functions**

Ioana Niculescu, James Madison University — 14:00 DMSB 124

Quark hadron duality establishes an intriguing connection between medium and high energy physics by identifying in certain cases dual descriptions of observables either in terms of explicit quark degrees of freedom or as averages over hadronic variables. Duality has been extensively studied in inclusive electron scattering experiments Jefferson Lab. The present talk is an overview of these results for unpolarized structure functions for proton, neutron, and nuclei.

**Measurements of the Nucleon Spin-Structure Functions in and above the Resonance Region from the Hall-B EG1 experiment at Jefferson Laboratory**

Robert Fersch, Christopher Newport University — 14:20 DMSB 124

In the EG1 experiment in Hall-B at Jefferson Lab (2000-2001), polarized electrons with energies of 1.6, 2.5, 4.2 and 5.7 GeV were scattered from proton and deuteron targets ($NH_3$ and $ND_3$ dynamically polarized along the beam direction) and detected with CLAS. Virtual photon asymmetries $A_1$ and $A_2$ and nucleon spin structure functions $g_1$ and $g_2$ were measured over a wide kinematic range ($0.05$ GeV$^2 < Q^2 < 5$ GeV$^2$ and $1.08$ GeV $< W < 3$ GeV). These (now available) data are able to constrain parametrization of world data in the resonance region, offer a better understanding of quark-hadron duality, and provide more precise values of higher-twist matrix elements in the framework of the Operator Product Expansion.

**Quark-hadron duality in parity-violating electroweak reactions**

Toru Sato, Osaka University — 14:40 DMSB 124

## Parallel Session B1

Time: Sunday, August 20, 2017, 13:30 – 15:00
Room: DMSB 125

Chair: David Wilson

**Resonance properties via lattice QCD**

Raul Briceno, JLab/ODU

13:30
DMSB 125

Lattice QCD is a powerful, model-independent tool for the determination of hadronic properties directly from QCD. In recent years there has been significant progress in our ability to extract increasingly complicated quantities using this approach. In particular, we are finally at a stage where elastic and inelastic hadronic amplitudes are being extracted. Also, we have seen the first photo-/electro-production calculations. These calculations have been made possible by a series of technological and formal achievements, some of which I will discuss. The techniques are universal and have been used and tested for a large variety of channels, resonant as well as non-resonant. I will review some of the more recent numerical results pertaining to the study of resonant reactions and discuss the information we are able to extract about resonances on the lattice. I will also give an outlook for where the field is heading.

**Hadron scattering amplitudes from lattice QCD with controlled errors**

John Bulava, U. of Southern Denmark and CP3-Origins

14:00
DMSB 125

Given the impressive improvements in statistical precision that have been achieved in recent lattice QCD calculations of hadron scattering amplitudes, it is now important to address systematic errors due to the lattice spacing, finite volume, and reduced symmetry. As a first illustration, results for the isovector p-wave elastic pion-pion scattering amplitude as well as the isovector timelike pion form factor are presented. Finally, an outlook for meson-baryon scattering amplitudes is discussed.

**Total decay and transition rates from LQCD**

Maxwell Hansen, Helmholtz Institute Mainz

14:20
DMSB 125

I discuss a new technique for extracting decay and transition rates into final states with any number of hadrons. The approach is only sensitive to total rates, in which all out-states are summed. For processes involving external currents, differential rates with respect to the current $q^2$ may also be extracted. Our method requires solving the inverse problem of extracting a spectral function from a correlator and also necessitates a smoothing procedure to give a well-defined infinite-volume limit. Both of these steps are accomplished by the Backus-Gilbert method and, as we show with a numerical example, reasonable precision can be expected in cases with multiple open decay channels. Potential applications include nucleon structure functions and the onset of the deep inelastic scattering regime.

**Gluon structure of hadrons**

Phiala Shanahan, College of William and Mary

14:40
DMSB 125

I will discuss recent progress in lattice QCD determinations of the gluonic structure of hadrons and nuclei

## Parallel Session C1

Time: Sunday, August 20, 2017, 13:30 – 15:00
Room: DMSB 126
Chair: Volker Burkert

### Confinement in N* and DIS Physics

Latifa Elouadrhiri, Jefferson Lab

13:30
DMSB 126

A fundamental challenge of modern nuclear physics is to understand the structure of the building blocks of nuclear matter, protons and neutrons, the origin of baryon masses and the confinement of quarks and gluons. Electron scattering is a superb experimental tool to study the internal structure of nucleons at differing distance scales, as the resolving power of the probe can be varied revealing the nucleon internal structure, and providing insight into the quark and gluon dynamics and the forces confining them in the nucleon. The Generalized Parton Distributions (GPDs) provide the theoretical framework to interpret the experimental data. The CLAS12 detector is scheduled for completion in the fall of 2017. Employing continuous wave electron beams of up to 12 GeV energy, will enable the user community from around the world to perform precise exclusive experiments in a large kinematical regime to effectively engage in nuclear imaging and obtaining insight into the forces that confine quarks and gluons in the nucleon. I will review the landscape of both theory and experiments, and describe the new equipment with focus on the approved science program for the CLAS12 detector, which will provide the capabilities needed for a challenging experimental program for Nucleon and Nucleon excitation.

### Unraveling confinement forces with DVCS

Francois-Xavier Girod, JLab

14:00
DMSB 126

The shear forces and pressure confining partons in the Nucleon are encoded in the space-space components of the Energy-Momentum Tensor (EMT). The matrix elements of the EMT are accessible *via* the second Mellin moment of the chiral even Generalized Parton Distributions (GPDs) in Hard Exclusive Scattering. We present a model dependent investigation of parton confinement using Deeply Virtual Compton Scattering (DVCS) on Hydrogen $\gamma^* p \to \gamma p$. We make use of simple approximations to allow a dispersion analysis of the unpolarized and beam-polarized cross-sections, extracted from existing and projected data at the CEBAF Large Acceptance Spectrometer in Hall B at Jefferson Lab. The confinement forces are derived from the subtraction constant (D-term) in the dispersion analysis. The validity of those approximations ultimately will be controlled from the knowledge accumulated with the full 12 GeV program at Jefferson Lab.

### Peripheral transverse densities of the baryon octet from ChPT and dispersion analysis

Astrid Hiller Blin, Universidad de Valencia

14:20
DMSB 126

Transverse densities describe the distribution of charge and current in hadrons at fixed light-front time and enable a spatial representation of hadrons as relativistic systems. We report about a recent calculation of the transverse densities of the spin-1/2 flavor-octet baryons at peripheral distances b of the order of $1/M_p i$, using methods of relativistic chiral perturbation theory (ChPT) and dispersion analysis

[arXiv:1703.04534]. The densities are represented as dispersive integrals over the imaginary parts of the form factors in the timelike region (spectral functions). The isovector spectral functions on the two-pion cut $t > 4M_p i^2$ are calculated using relativistic ChPT including octet and decuplet baryons. The ChPT calculations are extended into the rho meson mass region using an N/D method that incorporates the pion electromagnetic form factor data. The isoscalar spectral functions are modeled by vector meson poles. We compute the peripheral charge and magnetization densities in the octet baryon states, estimate the uncertainties, and determine the quark flavor decomposition. The approach can be extended to baryon form factors of other operators and the moments of generalized parton distributions.

**When are mesons eigenstates of SU(3) versus that of flavor?**

Robert Pisarski, Brookhaven National Laboratory

14:40
DMSB 126

It is well known that the eta' meson is mainly a SU(3) flavor singlet, while the phi meson is mainly s-bar s. We give an elementary but general explanation of this using chiral symmetry, introducing the concept of hetero- and homochiral states, such as the eta' and phi, respectively. We predict that an excited phi, and associated states, are heterochiral, so that the excited phi is not mainly s-bar s, but is close to a singlet in SU(3) flavor. We categorize spin-two mesons, which include both types.

## 'Star Wars Musiclipse' Concert, South Carolina Philharmonic

Time: Sunday, August 20, 2017, 15:30 – 17:30
Room: Koger Center for the Arts

# Monday, August 21, 2017

## Registration

Time: Monday, August 21, 2017, 07:30 – 09:00
Room: Lobby near DMSB 123

## General Session P3

Time: Monday, August 21, 2017, 08:30 – 10:30
Room: DMSB 123
Chair: Lothar Tiator

**Spin Asymmetries and Helicity Amplitudes from Pion Production from Polarized Neutrons at Jefferson Lab**

Andrew Sandorfi, Jefferson Lab

08:30
DMSB 123

The spectrum and photocouplings to excited $N*$ states provide benchmark tests for models of nucleon structure. These require a determination of photoproduction amplitudes and are extracted through detailed

partial-wave analyses (PWA), which must be fit to many different polarization observables to mitigate ambiguities. Since the electromagnetic interaction is not isospin invariant, the $N^*$ photocouplings for neutron and proton targets are different. While considerable data has been accumulated in photoproduction reactions with protons, comparatively little information is available from neutron targets, and there is almost no spin-dependent neutron data. As a result, the photocouplings to states excited from neutrons are poorly determined. To address such issues, the Jlab E06-101 (*g14)* experiment was performed during 2011-2012 using the CLAS detector in Hall B with circularly and linearly polarized photons incident on longitudinally polarized Deuterons in frozen-spin targets of solid Hydrogen-Deuteride (HD). Measurements of the beam-target helicity asymmetry ($E$) in the $\gamma + n(p) \to \pi^- + p(p)$ reaction, spanning the nucleon resonance region from invariant mass $W$= 1500 to 2300 MeV, have recently been reported [1]. These will be compared to PWA predictions, along with their extracted photocouplings. Other observables are under study and preliminary results will be presented.
[1] D. Ho *et al.*, Phys. Rev. Lett. **118**, 242002 (2017).

**Status of the Lambda(1405)**

Maxim Mai, George Washington University

09:00
DMSB 123

Antikaon-nucleon scattering is an important testing ground for our understanding of QCD in the low and intermediate energy regime. Recent high precision data on the energy shift and width of the Kaonic-hydrogen as well as the lineshape measurements in the pi-Sigma photoproduction experiment at CLAS have sparked new interest in this interaction channel.
In my talk, I will review the current theoretical progress and how modern experimental data can be used to reduce the uncertainty of results thereof.

**From Experimental Data to Pole Parameters in a Model Independent Way (Angular Dependent Phase Rotations and L+P method)**

Alfred Svarc, Rudjer Boskovic Instite

09:30
DMSB 123

It is well known that unconstrained single-energy partial wave analysis (USEPWA) gives many equivalent discontinuous solutions, so a constraint to some theoretical model must be used to ensure the uniqueness. It can be shown that it is a direct consequence of not specifying the angle-dependent part of continuum ambiguity phase which mixes multipoles, and by choosing this phase we restore the uniqueness of USEPWA, and obtain the solution in a model independent way [1]. Up to now, there was no reliable way to extract pole parameters from so obtained SE partial waves, but a new and simple single-channel method (Laurent + Pietarinen expansion) applicable for continuous and discrete data has been recently developed [2-5]. It is based on applying the Laurent decomposition of partial wave amplitude, and expanding the non-resonant background into a power series of a conformal-mapping, quickly converging power series obtaining the simplest analytic function with well-defined partial wave analytic properties which fits the input. The method is particularly useful to analyse partial wave data obtained directly from experiment because it works with minimal theoretical bias since it avoids constructing and solving elaborate theoretical models, and fitting the final parameters to the input, what is the standard procedure now. The generalization of this method to multi- channel case is also developed and presented. Tests are performed on Bonn-Gatchina P11 πN partial wave amplitudes taken from BG2011-2 solution [6] by comparing our results with exact results obtained by analytic continuation [7]. As a demonstration this method is applied to GWU-SAID [8] E1+ and M1+ multipoles. Unifying both methods in succession, one constructs

a model independent procedure to extract pole parameters directly from experimental data without referring to any theoretical model. We give preliminary results for USEPWA of kaon photoproduction on the world collection of real data. References: [1] A. Svarc, https://indico.cern.ch/event/591374/contributions/2477135/ , PWA9/ATHOS4: The International Workshop on Partial Wave Analyses and Advanced Tools for Hadron Spectroscopy, Bad Honnef near Bonn (Germany) from March 13 to 17, 2017. [2] A. Svarc, M. Hadzimehmedovic, H. Osmanovic, J. Stahov, L. Tiator, and R. L. Workman, Phys, Rev. C88, 035206 (2013). [3] A. Svarc, M. Hadzimehmedovic, R. Omerovic, H. Osmanovic, and J. Stahov, Phys, Rev. C89, 0452205 (2014). [4] A. Svarc, M. Hadzimehmedovic, H. Osmanovic, J. Stahov, L. Tiator, and R. L. Workman, Phys, Rev. C89, 65208 (2014). [5] A. Svarc, M. Hadzimehmedovic, H. Osmanovic, J. Stahov,, and R. L. Workman, arXiv:1405.6474 [nucl-th], Phys. Rev. C. in press [6] `http://pwa.hiskp.uni-bonn.de/BG2014_02_ampl.php` [7] E. Gutz, et al, Eur. Phys. J. A (2014) 50: 74 [8] `http://gwdac.phys.gwu.edu/analysis/pr_analysis.html`

**Electromagnetic N* Transition Form Factors in the ANL-Osaka Dynamical Coupled-Channels Approach**

Hiroyuki Kamano, KEK

10:00
DMSB 123

The electromagnetic transition form factors of nucleon resonances (N*) have been being extensively studied because those are expected to be the key to quantitatively disentangling the N* substructures and their scale dependence in a close relation with experiments.
In this talk, I overview our recent efforts to extract electromagnetic N* transition form factors through a comprehensive analysis of the data for meson electroproduction reactions off the proton target within the ANL-Osaka dynamical coupled-channels approach. Here preliminary results for the extracted form factors associated with low-lying N* resonances will also be presented, with an emphasis on the complex-valued nature of the transition form factors defined by resonance poles.

## Break (Coffee / Refreshments)

Time: Monday, August 21, 2017, 10:30 – 11:00
Room: Sonoco Pavilion

## General Session P4

Time: Monday, August 21, 2017, 11:00 – 12:30
Room: DMSB 123
Chair: Jan Ryckebusch

**N* Photoexcitation Results from Bonn**

Annika Thiel, HISKP, University of Bonn

11:00
DMSB 123

The dynamics of the quarks and gluons inside the nucleon are a long-standing question in hadron physics. To shed more light on this topic, the excitation spectrum of the nucleons needs to be measured and compared to theoretical models like constituent quark models or lattice QCD calculations. Until now, several predicted resonances have not been found by experiments, which is the well-known missing resonances problem. The excitation spectrum of the nucleon consists of several strongly overlapping resonances,

which makes it difficult to disentangle and identify them. To determine their exact contributions, a solution of the partial wave analysis has to be found. For a complete experiment, which leads to an unambiguous solution, at least 8 well-chosen single and double polarization observables are needed. With the CBELSA/TAPS experiment, the measurement of several single and double polarization parameters in different reactions is possible by using a circularly or linearly polarized photon beam on a longitudinally or transversally polarized butanol target. The CBELSA/TAPS setup provides a nearly $4\pi$ angular coverage and a high detection efficiency for neutral states, which gives an ideal condition for the study of final states comprising neutral mesons. In this talk results of different polarization observables for single and double meson photoproduction will be presented. Additionally, the impact of the polarization data will be shown and an outlook on the further perspectives will be given. Supported by the DFG (SFB/TR16).

**Baryon structure and reaction mechanisms from Dyson-Schwinger equations**

Gernot Eichmann, IST Lisboa

11:30
DMSB 123

I will review results for the light baryon spectrum obtained from solving QCD's three-body Faddeev equation as well as its quark-diquark simplification. Both approaches yield similar results, which underlines the role of diquark correlations within baryons. The resulting baryons carry a rich structure with relativistically induced orbital angular momentum that would be forbidden in the non-relativistic quark model. I will further discuss recent progress on the spectrum of strange baryons, nucleon transition form factors, and a microscopic approach to meson electroproduction.

**Hybrid Baryon Search at CLAS12**

Annalisa D'Angelo, University and INFN Rome Tor Vergata

12:00
DMSB 123

A program has been approved at JLAB to search for new excited baryon states in the mass range from 1.8 GeV to 3 GeV with CLAS12. For the first time the behavior of resonance electrocouplings over the full spectrum of excited proton states will be studied at very low photon virtualities, approaching the photon point. The experiment will measure $K\Lambda$, $K\Sigma 0$ and $\pi+\pi-$ p exclusive final states using longitudinally polarized electron beams of 6.6 GeV and 8.8 GeV, to cover the range of invariant masses up to 3 GeV. By studying the Q2 evolution of electroexcitation amplitudes it will be possible to distinguish between regular N* states and possible additional hybrid baryon states, with the glue as an extra constituent component beyond the three constituent quarks.

## Lunch Break

Time: Monday, August 21, 2017, 12:30 – 13:30

## Total Solar Eclipse - Reception

## Group Photo

## Total Solar Eclipse - Main Event, 2 min 30 sec in Columbia - 14:43

Time: Monday, August 21, 2017, 13:30 – 16:30
Room: DMSB Rooftop

## "Laying the God Particle to Rest"; Public Lecture by Craig Roberts

Time: Monday, August 21, 2017, 17:30 – 19:00
Room: DMSB 101

# Tuesday, August 22, 2017

## General Session P5

Time: Tuesday, August 22, 2017, 08:30 – 10:30
Room: DMSB 123
Chair: Annalisa D'Angelo

### Developments of the Julich-Bonn Dynamical Coupled-Channel Analysis

Michael Doering, George Washington University

08:30
DMSB 123

Results for baryon spectroscopy by the Julich-Bonn collaboration and other groups will be reviewed. Highlights contain common efforts of different phenomenology groups and the impact of recent high-precision data from ELSA, JLab, MAMI, and other facilities. Questions will be addressed of how to proceed to reach conclusive answers in baryon spectroscopy and how phenomenology can be connected to theory in a meaningful way. Formal S-matrix constraints and statistical aspects for the determination of the scattering amplitude and resonance content will be discussed.

### Understanding the Spectrum of Excited Nucleons using CLAS at Jefferson Lab

Volker Crede, Florida State University

09:00
DMSB 123

Baryons are complex systems of confined quarks and gluons and exhibit the characteristic spectra of excited states. These states are sensitive to the details of quark confinement, which is only poorly understood with quantum chromodynamics (QCD), the fundamental theory of the strong interaction. To gain insight into this complex dynamics, the nucleon excitation spectrum has been studied for many years. The key question remains what are the relevant degrees of freedom for the resonance physics of QCD. Are the so-called constituent quarks the most efficient way to describe reaction amplitudes and the excitation spectrum of QCD with light quarks? To what extent are diquark correlations, gluonic modes or hadronic degrees of freedom important in this physics? On the experimental side, high-energy electrons and photons are a remarkably clean probe of hadronic matter. Significant progress has been achieved with the recent high-statistics polarization data from Jefferson Lab using the CEBAF Large Acceptance Spectrometer (CLAS) and combining polarized tagged-photon beams with polarized targets. Such experiments are important steps toward so-called complete experiments that will allow us to unambiguously determine the scattering amplitudes in the underlying reactions and to identify nucleon resonance contributions in amplitude analyses. In this presentation, I will discuss recent results from the experimental N* program at Jefferson Lab.

**N* Photoexcitation Results from Mainz**

Vahe Sokhoyan, University of Mainz, Institute for Nuclear Physics

09:30
DMSB 123

The A2 Collaboration performs a manifold research program using real photons in the Crystal Ball/TAPS experiment at the MAMI accelerator facility in Mainz. The experiments are carried out with high-intensity unpolarized, linearly or circularly polarized photon beams, and unpolarized or polarized targets. The Crystal Ball/TAPS setup provides almost complete coverage in solid angle and is well suited for the detection of multi-particle final states. In order to probe the internal structure of the nucleon, the spectrum of baryon resonances is studied via measurements of unpolarized cross-sections and various polarization observables in single and double meson photoproduction. Furthermore, experiments with light and heavy nuclear targets are carried out to study the production of mesons off neutrons and to investigate modifications of baryons in the nuclear medium. In this talk, recent results, the current status, and future plans for new experiments at MAMI will be presented.

**Supersymmetric features of hadron physics and other novel properties of QCD from Light-Front Holography and Superconformal Quantum Mechanics**

Stanley J. Brodsky, SLAC National Accelerator Laboratory, Stanford University

10:00
DMSB 123

A primary question in hadron physics is how the mass scale for hadrons emerges from the QCD Lagrangian, even in the limit of zero quark mass. I will present a new approach to color confinement and the emergence of the QCD mass scale, based on ''light-front holography'', a formalism which relates the bound-state amplitudes in the fifth dimension of AdS space to the boost-invariant light-front wavefunctions describing the structure of hadrons in physical space-time. The result is a nonperturbative, relativistic light-front quantum mechanical wave equation which incorporates color confinement and predicts the spectroscopic and dynamical features of hadron physics, including a massless pion for zero quark mass, form factors, structure functions, as well as linear Regge trajectories with identical slopes in the radial quantum number n and orbital angular momentum L for both mesons and baryons. One can extend the analysis using superconformal algebra where the hadronic eigensolutions form 2 X 2 supersymmetric representations of the conformal group. The resulting light-front bound-state equations predict striking similarities between the meson, baryon, and tetraquark spectra. The mass scale underlying the masses of the light-quark hadrons also determines the mass scale $\Lambda$s which controls the evolution of the perturbative QCD coupling. The predicted hadronic light-front wavefunctions lead to a new understanding of the conversion of quarks and gluons to hadrons and jet hadronization at the amplitude level.
I will also discuss (1) a new mechanism for Higgs production at high longitudinal momentum at the LHC, and (2) applications of the Principle of Maximum Conformality (PMC), which sets the renormalization scale of perturbative QCD predictions for LHC reactions at every order unambiguously. The PMC predictions are independent of the choice of renormalization scheme and eliminate the n! renormalon divergence.

## Break (Coffee / Refreshments)

Time: Tuesday, August 22, 2017, 10:30 – 11:00
Room: Sonoco Pavilion

## General Session P6

Time: Tuesday, August 22, 2017, 11:00 – 12:30

Room: DMSB 123
Chair: Alfred Svarc

**Chiral Unitary and New Developments in the Baryon Sector**

Eulogio Oset, Universidad de Valencia

11:00
DMSB 123

I shall report on recent developments combining chiral dynamics of meson baryon interaction and the generation of some resonances, together with mechanisms that develop a triangle singularity and are responsible for further stabilizing the resonances, the explanation of some particular decay modes, or the explanation of some experimental peaks. Examples of them are the explanation of the $\pi N^*(1535)$ contribution in the $\gamma p \to p\pi^0\eta$ reaction, the peak observed in the $\gamma p \to K^+\Lambda(1405)$ reaction around 2110 MeV, the $\pi N^*(1535)$ and $f_0(500)N$ decay modes of the $N^*(1875)$ and the $\pi\Delta$ decay of the $N^*(1700)$.

**N* Production from $e^+e^-$ Annihilation**

Bing-Song Zou, Institute of Theoretical Physics, CAS

11:30
DMSB 123

Up to now, the N* production from $e^+e^-$ annihilations has been studied only around charmonium region. Charmonium decays to N*'s are analogous to (time-like) EM form factors in that the charm quark annihilation provides a nearly pointlike ($ggg$) current. Complementary to other sources, such as $eN$, $KN$ and $\pi^-N$ reactions, this new source for N* spectroscopy has a few advantages, such as an isospin filter and a low spin filter. The experimental results on N* from $e^+e^-$ annihilations and their phenomenological implications are reviewed. Possible new sources on N* production from $e^+e^-$ annihilations are discussed.

**Valence-quark structure in nucleon resonances from DSEs**

Jorge Segovia, Technische Universität München

12:00
DMSB 123

Nonperturbative quantum chromodynamics poses significant challenges. Primary amongst them is a need to chart the behaviour of QCD's running coupling and masses into the domain of infrared momenta. Contemporary theory is incapable of solving this problem alone but a collaboration with experiment holds a promise for progress. This effort can benefit substantially by exposing the structure of nucleon excited states and measuring the associated transition form factors at large momentum transfers. Large momenta are needed in order to pierce the meson-cloud that, often to a significant extent, screens the dressed-quark core of all baryons; and it is via the $Q^2$-evolution of form factors that one gains access to the running of QCD's coupling and masses from the infrared into the ultraviolet.
We present a unified QCD-based description of elastic and transition form factors involving the nucleon and its resonances. We compare predictions made using a framework built upon a Faddeev equation kernel and interaction vertices that possess QCD-like momentum dependence with results obtained using a confining, symmetry-preserving treatment of a vector $\otimes$ vector contact-interaction in a widely-used leading-order (rainbow-ladder) truncation of QCD's Dyson-Schwinger equations. This comparison explains that the contact-interaction framework produces hard form factors, curtails some quark orbital angular momentum correlations within a baryon, and suppresses two-loop diagrams in the elastic and transition electromagnetic currents. Such defects are rectified in our QCD-based approach and, by contrasting the results obtained for the same observables in both theoretical schemes, shows those objects which are most sensitive to the momentum dependence of elementary quantities in QCD.

## Lunch Break

Time: Tuesday, August 22, 2017, 12:30 – 14:00

## IAC Meeting

Time: Tuesday, August 22, 2017, 12:30 – 14:00
Room: Sonoco Pavilion

## Parallel Session A2

Time: Tuesday, August 22, 2017, 14:00 – 15:30
Room: DMSB 124
Chair: Volker Crede

### $\gamma n \to p\pi^-$ Cross Section Measurement at CLAS

Paul Mattione, Jefferson Science Associates

14:00
DMSB 124

Measuring the spectrum of $N^*$ resonances will provide valuable information on the degrees of freedom within the nucleon, shedding light on whether there are significant contributions from correlated quark-pairs, or diquarks. To extract these states, measurements of both $\gamma p$ and $\gamma n$ cross sections are necessary to disentangle the isospin components of the photoproduction amplitudes.
A measurement of the $\gamma n \to p\pi^-$ differential cross section will be shown using data from the Jefferson Lab CLAS g13 experiment. These results were determined by first measuring the cross section for $\gamma d \to p\pi^-(p)$, and then by performing a correction for final-state interactions in the target deuteron. From these data, the first-ever determination of the excited neutron multipoles for the $N(1440)1/2^+$, $N(1535)1/2^-$, $N(1650)1/2^-$, $N(1720)3/2^+$ resonances will be shown. These cross section data are a factor of 2.5x more than the world data set for this channel, providing important constraints needed to advance coupled-channel analysis fits that are sorely lacking $\gamma n$ data.

### Polarization Observables in Meson Photoproduction with the Crystal Ball/TAPS at MAMI

Natalie Walford, University of Basel

14:30
DMSB 124

A comparison of experimentally observed excited nucleon states to model predictions or lattice QCD calculations is made, large differences arise, specifically concerning the number of excited states. In order to fully understand the strong interaction in the non-perturbative region, the excitation spectrum of nucleons is an important tool to use. The electromagnetic coupling of photons to protons is different than that of neutrons in certain states. Several experimental facilities have dedicated programs to measure polarization observables in different photoproduction reactions including the Crystal Ball/TAPS setup at the MAMI accelerator in Mainz, Germany. A complete partial wave analysis (PWA) can assist in yielding more information about any reaction with polarization observables playing a crucial role. Spin observables are essential in disentangling the contributing resonant and non-resonant amplitudes, whereas cross-section data alone is not sufficient for separating resonances. Preliminary results of polarization observables ($E$, $T$, and $F$) of $\eta$, single, and double $\pi$ production will be shown with comparison to predictions of recent multipole analyses. These results will allow for significantly increasing the world database on these reactions.

### Determination of the Hyperon Induced Polarization and Polarization–Transfer Coefficients for Quasi-Free Hyperon Photoproduction off the Bound Neutron

Colin Gleason, University of South Carolina

14:50
DMSB 124

Many excited states ($N^*$) predicted by quark models, but not observed in $\pi N$ channels, are expected to couple strongly to kaon–hyperon (KY) channels. While in the last decade data has been published for KY photoproduction off the proton, data off the neutron are scarce. In this talk we will show preliminary results for $P$, $C_x$, and $C_z$ for the reaction $\gamma d \rightarrow K^0\Lambda(p)$ for $E_\gamma$ between 0.9–2.6 GeV and $\cos\theta^{CM}_{K^0}$ between -0.9–1. The data was collected in experiment E06-103 (g13) with the CLAS detector at Thomas Jefferson National Accelerator Facility using a circularly polarized photon beam and an unpolarized LD2 target. We will discuss the effect of neutron binding on the observables and the comparison of our results with theoretical predictions. Our study is part of a larger effort by the g13 group to provide cross–sections and polarization observables for meson photoproduction off the neutron and is expected to have a large impact on the $N^*$ research.

### Beam-Target Asymmetry for $\gamma n(p) \rightarrow \pi^- p(p)$ in $N^*$ Resonance Region

Haiyun Lu, University of Iowa

15:10
DMSB 124

The excited-state spectrum of the nucleon is a complicated overlap of many resonances that must be disentangled through multipole analyses of reaction amplitudes. Meson photoproduction, which has been a fruitful probe of N* structure, requires data on many different polarization observables to constrain its four complex amplitudes. While considerable data has been accumulated with proton targets, comparatively little information is available from neutron targets. Recently, the first beam-target helicity asymmetries with circular beam polarization in the $\gamma n(p) \rightarrow \pi^- p(p)$ reaction have been reported in Physical Review letters 118, 242002 (2017). This talk presents a parallel analysis from the same experiment of the beam-target double-polarization observable "G" with linearly polarized beam for the same reaction. Linearly polarized photons and longitudinally polarized deuterons in a solid hydrogen deuteride (HD) target were used with the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab (JLab). Data are combined to extract the beam ($\Sigma$) and beam-target (G) asymmetries. Preliminary results for the $\Sigma$ observables are consistent with measurements from the g11 experiment at JLab and theoretical model predictions. The energy and angular dependence of $G$ will be reported, together with comparisons to predictions from existing partial wave analyses.

## Parallel Session B2

Time: Tuesday, August 22, 2017, 14:00 – 15:10
Room: DMSB 125
Chair: Raul Briceno

### An $a_0$ resonance from lattice QCD

David Wilson, Trinity College Dublin

14:00
DMSB 125

I will discuss a recent coupled-channel scattering calculation in a0 quantum numbers by the Hadron Spectrum Collaboration. Utilising the variational method with large bases of operators, including those that resemble q-qbar and meson-meson like constructions, many energy levels can be extracted. These spectra are then used with the coupled-channel extensions of Lüscher's finite volume formalism, to determine

the infinite volume coupled-channel scattering amplitudes. The resonance poles of these amplitudes are then studied.

**Beyond nucleon properties from lattice QCD**

Zohreh Davoudi, University of Maryland - College Park

14:30
DMSB 125

Over the past decade , first-principles lattice QCD calculations of the spectral and structure properties in the single-nucleon sector have been extended to the multi-nucleon sector, with rapid progress in computational technologies and theoretical understanding. This talk reviews some of the recent progress in this front. Among the results that will be briefly presented are the hadronic interactions, and nuclear matrix elements for nuclear reactions and nuclear structure. The challenges in moving towards lattice QCD calculations of light nuclear systems at lighter quark masses will be discussed, along with the impact of the precision results in this area on the theoretical and experimental program in nuclear and particle physics.

**A lattice QCD study of pion-nucleon scattering in the Roper channel**

Luka Leskovec, University of Arizona

14:50
DMSB 125

We present a lattice QCD study of the puzzling positive-parity nucleon channel, where the Roper resonance $N^*(1440)$ resides in experiment. The study is based on an ensemble of gauge configurations with $N_f = 2 + 1$ Wilson-clover fermions with a corresponding pion mass of $156$ MeV and lattice size $L = 2.9$fm. We use several $qqq$ interpolating fields combined with $N\pi$ and $N\sigma$ two-hadron operators in calculating the energy spectrum in the rest frame. Combining experimental data with the Luescher formalism implies an additional energy level in the spectrum near the Roper mass $m_R = 1.43$GeV for our lattice. We do not observe any such additional energy level, which implies that $N\pi$ elastic scattering alone does not render a low-lying Roper resonance. The current status indicates that the $N^*(1440)$ might arise as dynamically generated resonance from coupling to other channels, most notably the $N\pi\pi$.

## Parallel Session C2

Time: Tuesday, August 22, 2017, 14:00 – 15:30
Room: DMSB 126
Chair: Douglas Hasell

**Experimental Advances in Two-Photon Contributions to Lepton-Proton Scattering**

Michael Kohl, Hampton University

14:00
DMSB 126

The famous discrepancy between measurements of the proton electric-to-magnetic form factor ratio with polarized and unpolarized methods has generated significant interest both experimentally and theoretically. The widely preferred explanation of the discrepancy has been hard two-photon exchange, which had been a neglected piece of the radiative corrections. A variety of experiments have been conceived and carried out to probe the effects of hard two-photon exchange on various observables, and to quantify the effect itself which can only be calculated with prior knowledge of hadronic structure. I will introduce the subject of two-photon exchange with an overview of the experimental status.
This work has been supported by NSF and DOE.

### Two-photon exchange contribution to elastic electron-proton scattering

Mikhail Yurov, University of Virginia

14:30
DMSB 126

Two experimental techniques, Rosenbluth separation and recoil polarization transfer, used to extract proton's electromagnetic form factors ratio $\frac{G_E}{G_M}$ yield markedly different results. Modern theoretical calculations suggest that two-photon exchange (TPE) might be responsible for the observed discrepancy and that it is $\varepsilon$ dependent.
Jefferson Lab Experiment E05-017 was designed to measure the TPE contribution over a wide range of $\varepsilon$ and $Q^2$. In contrast with the conventional Rosenbluth method, E05-017 detected the elastically scattered proton rather than the electron. This approach returns a much more precise extraction of the form factor ratios. While comparisons of $e^+p$ and $e^-p$ scattering have been used to constrain TPE at low $Q^2$, our measurements provide additional information on the $\varepsilon$ dependence at low $Q^2$, and can constrain the size of TPE at much larger $Q^2$ values.
After a brief description of the experimental goals and techniques, the current status of the analysis will be presented. Preliminary results will be shown.

### Lepton mass effects in two-photon exchange theory

Oleksandr Koshchii, The George Washington University

14:50
DMSB 126

The future MUSE [1] experiment, which is devised to solve the "Proton Radius Puzzle", is going to directly measure two-photon exchange (TPE) effects by studying the asymmetries in elastic $e^{\pm}$ and $\mu^{\pm}$ scattering. Kinematic conditions of this experiment do not permit us to employ a widely used ultrarelativistic ($m_l \to 0$) approximation in calculation of muonic TPE in MUSE. This means that the standard soft-photon (model-independent) TPE estimations have to be revised to include the mass of the lepton in final expressions. In addition, helicity-flip transitions, which are proportional to the mass of the lepton and that are usually neglected in scattering of ultrarelativistic electrons, needs to be taken into account, as well. These transitions describe dynamic properties of the proton and they will make a difference in comparison of electron vs muon scattering in MUSE. In our talk, we will present our model-independent charge asymmetry predictions for scattering of unpolarized and massive leptons on proton targets, estimated based on the soft-photon approximation calculation [2]. In addition, we will discuss our recent results on calculation of the major helicity-flip contribution that is represented by a scalar $\sigma$ meson exchange in the $t$-channel [3].
[1] R. Gilman, E. J. Downie, G. Ron, et al. (MUSE), arXiv:1303.2160 [2] O. Koshchii, A. Afanasev, arXiv:1705.00338 [3] O. Koshchii, A. Afanasev, Phys. Rev. D 94, 116007 (2016)

### Two-photon exchange correction in elastic lepton-proton scattering. Dispersive and model calculations

Oleksandr Tomalak, JGU Mainz

15:10
DMSB 126

In view of the proton form-factor problem and proton radius puzzle, the two-photon exchange (TPE) corrections require a model-independent investigation as the largest source of the hadronic uncertainty in modern experiments. I present the dispersion relation approach based on unitarity and analyticity to evaluate the TPE in the elastic electron-proton scattering. The leading elastic and first inelastic $\pi N$ intermediate state contributions are accounted for in the region of small momentum transfer $Q^2 \lesssim 1\,\mathrm{GeV}^2$ based entirely on data input. The novel methods of the analytical continuation allowed to exploit the MAMI form factor data and the MAID parameterization for the pion electroproduction amplitudes as an

input in the calculation. The results are compared to the recent CLAS, VEPP-3 and OLYMPUS data as well as the full TPE correction in the near-forward approximation, which is based on the Christy and Bosted unpolarized structure functions fit. Additionally, predictions are given for a forthcoming muon-proton scattering experiment (MUSE) within the hadronic model.

## Parallel Session D2

Time: Tuesday, August 22, 2017, 14:00 – 15:30
Room: DMSB 122
Chair: Toru Sato

### Analyticity Constraints for the Baryon Spectrum

Vincent Mathieu, Jefferson Lab

14:00
DMSB 122

There are several experiments in Europe (COMPASS, LHCb), USA (CLAS, GlueX) and Asia (BES, Belle) devoted to hadron spectroscopy. In this talk, their goals and prospects are presented with a special emphasis on the discovery of new 'exotic' resonances. There are indeed indications from these experiments about resonances (hybrid mesons, glueballs, tetraquarks, etc) beyond the quark model classification. However a close collaboration between theorists and experimentalists is necessary to draw robust conclusions about their existence.
To this end the Joint Physics Analysis Center (JPAC) was set up between Jefferson Lab and Indiana University. Its goal is to provide the theoretical framework, based on the principles of the S-Matrix theory, for the analysis of hadron spectroscopy experiments data. Our main results concern baryons (the N*, Delta, Lambda and Sigma baryon resonances), light mesons (eta, omega and phi) decays and heavy meson ("XYZ states") spectroscopy. With the advent of the GlueX detector at the Jefferson Lab, we also working on the photoproduction of mesons (pion, eta, rho and omega). In this talk, I will present the main results of the JPAC concerning some of the various projects mentioned above.
In particular, I will focus on the analyticity constraints on amplitude construction, their implementation on baryon analysis.
To facilitate the interactions with the community a interactive webpage, where the models can be dowloaded and simulated, was recently created: http://www.indiana.edu/ jpac/index.html <http://www.indiana.edu/ jpac/index.html> In the talk, I will also present and show the main features of this website.

### Finite-Energy Sum Rules in Eta Photoproduction off the Nucleon

Jannes Nys, Ghent University

14:30
DMSB 122

Pseudoscalar-meson photoproduction on the nucleon is of current interest for hadron reaction studies. At low energies it provides information about the nucleon spectrum, while at high energies it reveals details of the residual hadron interactions due to cross-channel particle (Reggeon) exchanges. These two regimes are analytically connected, a feature that can be used to relate properties of resonances in the direct channel to Reggeons in the cross channels. In practice this can be accomplished through dispersion relations and finite-energy sum rules (FESR) [1].
At high energies (Elab>4 GeV), only the unpolarized differential cross section has been measured, providing little constraints on theoretical models. Forthcoming data from the GlueX experiment at Jefferson Lab are expected to improve the situation.

Even though photons couple to both isospin I=0,1 states, there are some notable differences between high energy photoproduction of the η (I=0) and the π0 (I=1). In contrast to the η, the π0 differential cross section has a dip in the momentum transfer range, $-t\sim0.5-0.6$ GeV2. The dip in π0 photoproduction is expected to be associated with zeros in the residues of the dominant ρ/ω Regge exchanges [2,3]. It is an open question, what mechanisms are responsible for filling in the dip in eta photoproduction. It is often assumed that large unnatural contributions come into play. Finite-energy sum rules can provide clues here by relating the t-dependence of Regge amplitudes to that of the low-energy amplitude, usually described in terms of a finite number of partial waves. Early attempts could not resolve this issue due to the low quality of the data and the large uncertainties in the parametrization of the partial waves. Nowadays, however, there are several models that have been developed for the resonance region of η photoproduction allowing for a more precise FESR analysis.
The largest uncertainty in η photoproduction stems from the unnatural parity Regge exchanges. These contributions can be isolated through photon beam asymmetry measurement. Such measurement will soon be published by the GlueX collaboration. The experiment uses linearly polarized photons with energy $E_{lab}\gamma\sim9$ GeV and it has simultaneously measured η and π0 production. Those data will reduce the systematic uncertainties and provide a better constraint on Regge amplitudes.
We have analyzed $\gamma N\rightarrow\eta N$ within a FESR framework [4]. Using these sum rules, one is able to obtain the t-dependence of the high-energy Regge residues using low-energy models. We found that a residue nonsense-wrong signature zero (NWSZ) seems to be lacking in the t-channel helicity flip amplitude of the ρ residue. Including this in our model results in a mechanism where the dip in η photoproduction is filled up with natural contributions, rather than genuinely assumed unnatural b exchange [5]. The upcoming GlueX results will be able to either confirm or refute this explanation: photon beam asymmetry close to $\Sigma=+1$ within the range $-t\approx0.5-0.6$ GeV2 indicate that the absence of a dip in eta photoproduction should indeed be attributed to natural exchanges.
[1] V. Mathieu, I. V. Danilkin, C. Fernández-Ramírez, M. R. Pennington, D. Schott, A. P. Szczepaniak, and G. Fox, Phys. Rev. D92, 074004 (2015). [2] V. Mathieu, G. Fox, and A. P. Szczepaniak, Phys. Rev. D92, 074013 (2015). [3] V. Mathieu et al., In preparation. [4] J. Nys, V. Mathieu, C. Fernández-Ramírez, A. N. Hiller Blin, A. Jackura, M. Mikhasenko, A. Pilloni, A. P. Szczepaniak, G. Fox, and J. Ryckebusch (JPAC), (2016), arXiv:1611.04658 [hep-ph]. [5] F. D. Gault and A. D. Martin, Nucl. Phys. B32, 429 (1971).

**Studying the Pc(4450) resonance in J/psi photoproduction off protons**

Astrid Hiller Blin, University of Mainz

14:50
DMSB 122

The LHCb has reported the observation of a resonancelike structure, the Pc(4450), in the J/psi p spectrum. In our work, we discuss the feasibility of detecting this structure in J/psi photoproduction, e.g. in the measurement that has recently been approved for the CLAS12 experiment at JLab.
We take into account the experimental resolution effects, and perform a global fit to world J/psi photoproduction data, predicting that it will be possible to observe a sizable cross section close to the J/psi production threshold. We present a first estimate of the upper limit for the branching ratio of the Pc(4450) into the J/psi p channel, and we study the angular distributions of the differential cross sections. This will shed light on the nature and couplings of the Pc(4450) structure in the future photoproduction experiments.

### Constituent Counting Rules and Exotic Hadrons

Richard Lebed, Arizona State University

15:10
DMSB 122

The constituent counting rules, i.e., the scaling behavior of amplitudes (in terms of the number of fundamental constituents) for exclusive processes when high energy scales are present, have been known for decades, and have been borne out in a number of experiments. Such scaling would be sensitive, in particular, to possible exotic multiquark content. Here we examine how one may use the rules to test for pentaquarks in electroproduction, or for tetraquarks in $e^+e^-$ annihilation. An interesting new type of scaling (separate Mandelstam s and t behavior) arises in the forward scattering direction. The correct scaling arises naturally in AdS/QCD, in which the amplitudes can be computed explicitly.

## Break (Coffee / Refreshments)

Time: Tuesday, August 22, 2017, 15:30 – 16:00
Room: Sonoco Pavilion

## Parallel Session A3

Time: Tuesday, August 22, 2017, 16:00 – 18:10
Room: DMSB 124
Chair: Andrew Sandorfi

### Advances in N* spectroscopy from Exclusive Photoproduction at CLAS

Eugene Pasyuk, Jefferson Lab

16:00
DMSB 124

This year marks 70th anniversary of the discovery of pion. Just two years later the first pion photoproduction experiment was carried out. Another three years passed and the first nucleon resonance was observed in pion nucleon scattering. That was the beginning of the nucleon resonance era. The latest edition of the Review of the Particle Physics lists 60 non-strange baryons. But there are still more states predicted than observed. Until late 90's of the 20th century most of the data on the nucleon resonances came from pion nucleon scattering. Over the last two decades the focus was shifted to the photoproduction experiments. CEBAF Large Acceptance Spectrometer, CLAS, is one of the major contributors to this field. An overview of the results of the photoproduction experiments with CLAS will be presented.

### Photoproduction of $\omega$ Mesons using CLAS at Jefferson Laboratory

Zulkaida Akbar, The Florida State University

16:30
DMSB 124

The spectrum and properties of the excited states of baryons reveal the dynamics and degrees of freedom of the interaction within them. Higher-lying excited states are generally predicted to have strong couplings to a heavier meson, e.g. to one of the vector mesons, $\rho, \omega, \phi$. Therefore, vector-meson studies are important to search for the so-called *missing baryon resonances*. Photoproduction of $\omega$ mesons was studied using the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab. Two observables have been measured from the reaction $\gamma p \rightarrow p\omega$: The differential cross section and the double-polarization observable E. The observables were measured using the decay mode $\omega \rightarrow \pi^+\pi^-\pi^0$. The differential cross section measurement was performed using circularly-polarized photons produced from

bremsstrahlung of longitudinally-polarized electrons with the tagged photon energies up to 5.7 GeV, incident on an unpolarized liquid hydrogen target. The double-polarization observable E was measured using circularly-polarized photons for an energy range up to 2.4 GeV and the longitudinally-polarized Frozen-Spin Butanol Target (FROST). The differential cross section as well as the polarization observable allow us to find N$*$ resonances decaying to $p\omega$ through multi-channel Partial Wave Analysis (PWA) that has been developed for the $\omega$ channel. The observables also provide a probe to test theoretical models on the production mechanism of $\omega$ mesons and also the scaling behavior of the cross section. We found that the $\gamma p \to p\omega$ differential cross section at higher energies exhibits a scaling behavior as predicted by pQCD.

**Polarization Observables in $\gamma p \to K^+ + \Lambda$ and $K^+ + \Sigma^0$ Using Circularly Polarized Photons on a Polarized Frozen Spin Target**

Natalie Walford, The Catholic University of America

16:50
DMSB 124

The search for undiscovered excited states of the nucleon continues to be a focus of experiments at the Thomas Jefferson National Accelerator Facility (JLab). A large effort was done using the CEBAF Large Acceptance Spectrometer (CLAS) detector to provide the database, which will allow nearly model-independent partial wave analyses (PWA) to be carried out in the search for such states. Polarization observables play a crucial role in the effort, as they are essential in disentangling the contributing resonant and non-resonant amplitudes. Recent coupled-channel analyses have found strong sensitivity of the $K^+ + \Lambda$ channel to several higher mass nucleon resonances. In 2008 and 2010, double-polarization data were taken at JLab using circularly and linearly polarized tagged photons incident on a longitudinally and transversely polarized frozen spin butanol target (FROST), operated at the temperature of 30 mK. The reaction products were detected in CLAS. This work is based on the analysis of FROST data and the extraction of the $E$, $L_x$, $L_z$, $T$, $F$ , $T_x$, and $T_z$ asymmetries of the K + $\Lambda$ and K + $\Sigma$0 final states and their comparison to predictions of recent multipole analyses. There are very few published measurements of the $T$ asymmetry and none for the $E$, $L_x$, $L_z$, $F$, $T_x$, and $T_z$ asymmetries for the K + $\Lambda$ final state. The K + $\Sigma$0 final state has no published measurements for these asymmetries. This work is the first of its kind and will significantly broaden the world database for these reactions.

**Measurement of polarization observables for Lambda in the reaction $\gamma p \to K^+\Lambda$**

Shankar Adhikari, Florida International University

17:10
DMSB 124

Spin observables are important to understand the production mechanisms of hyperons, as well as the contribution of intermediate baryon resonances. Lambda polarizations have been studied extensively in the recent decades using the reaction $\gamma p \to K^+\Lambda$. This talk presents the measurement of transferred polarization coefficients $C_x$ and $C_z$, and the induced polarization P, using a new set of high statistics data, obtained using the CEBAF Large Acceptance Spectrometer (CLAS) detector at the Jefferson lab. The photon beam energy range is 1.117 to 5.45 GeV. These results ($C_x$, $C_z$ and $P$) are extracted simultaneously using Maximum Likelihood Method. The measurements for $C_x$ and $C_z$ represents nearly one order of magnitude increase in statistics. These results also extended the kinematic range for $W > 2.46$ GeV, important for understanding the non-resonant contributions.

**Polarization observables in double charged pion photo-production with circularly polarized photons off transversely polarized protons**

Lelia Net, University of South Carolina

17:30
DMSB 124

The study of excited states of the nucleon facilitates the understanding of the nucleon structure and its underlying symmetry and couplings. A main goal of the $N^*$ program at the Thomas Jefferson National Accelerator Facility is to investigate the excitation and decays of the baryon resonances and assist in identifying the "missing" nucleon resonances that are predicted by theoretical models. One way to study the nucleon resonances is by extracting polarization observables, which provide more information than the unpolarized cross-section studies, e.g. access to the transition amplitudes of the reaction. Double-pion photoproduction is the dominating process at high energies, having the largest cross-section, and thus it plays an important role in probing the nucleon resonance spectrum. The CLAS g9b (FROST) experiment at Thomas Jefferson National Accelerator Facility provided double-pion photoproduction data using transversely polarized protons and circularly polarized photons, with energies up to 3.0 GeV. Beam- and target-polarization asymmetries were measured and the polarization observables $I^{\odot}$, $P_x^{\odot}$, $P_y^{\odot}$, $P_x, P_y$ were extracted for the $\gamma p \rightarrow p\pi^+\pi^-$ reaction. The results are reported and compared with the calculations of an effective Lagrangian model. The data will help deepen the current knowledge of hadronic resonance decays and possibly assist in identifying new baryon resonances via PWA (Partial Wave Analysis) and in this way will contribute to a more comprehensive understanding of the strong interaction.

**Polarization Observables $T$ and $F$ in the $p(\gamma, \pi^0)p$ Reaction**

Hao Jiang, University of South Carolina

17:50
DMSB 124

The theory that describes the interaction of quarks is Quantum Chromodynamics (QCD), but how quarks are bound inside a nucleon is not yet well understood. Pion photoproduction experiments reveal important information about the nucleon excited states and the dynamics of the quarks within it and thus provide a useful tool to study QCD. Detailed information about this reaction can be obtained in experiments that utilize polarized photon beams and polarized targets.
Pion photoproduction in the $\gamma p \rightarrow \pi^0 p$ reaction has been measured in the FROST experiment at the Thomas Jefferson National Accelerator Facility. In this experiment circularly polarized photons with electron-beam energies up to 3.082 GeV impinged on a transversely polarized frozen-spin target. Final-state protons were detected in the CEBAF Large Acceptance Spectrometer. Results of the polarization observables $T$ and $F$ have been extracted. The data generally agree with predictions of present partial wave analyses, but also show marked differences. The data will constrain further partial wave analyses and improve the extraction of proton resonance properties. This work is supported in parts by NSF PHY-1505615.

## Parallel Session B3

Time: Tuesday, August 22, 2017, 16:00 – 17:50
Room: DMSB 125
Chair: Bingsong Zou

**Photo- and Electroexcitation of Bound Neutrons and Protons**

Satoshi Nakamura, Universidade Cruzeiro do Sul

16:00
DMSB 125

Data for photon- and electron-induced meson productions off the deuteron are primary source to assess transition form factors that excite the neutron to resonances. However, extracting the transition form factors from the data is not trivial due to nuclear effects such as the Fermi motion and final state interactions (FSI). In this talk, we develop a model for pion photoproductions on the deuteron taking account of these nuclear effects. We study how much the FSI change unpolarized and polarized cross sections for the pion photoproductions off the deuteron. Then we also examine if kinematical cuts used in an experimental analysis can remove the FSI effects. Finally we extract elementary (un)polarized differential cross sections of the nucleon from the photon-deuteron cross sections, and examine how the FSI could distort the extracted elementary cross sections.

### Nucleon N(2120) resonance in $\phi p$ and $K\Lambda(1520)$ photon production

Ju-Jun Xie, Institute of modern physics, Chinese academy of sciences

16:30
DMSB 125

We have studied the N(2120) resonance in the $\gamma p \to K^+\Lambda(1520)$ and $\gamma p \to \phi p$ reactions within the resonance model and the effective Lagrangian approach. It is shown that when the contributions from the $N(2120)$ resonance is considered, the current experimental measurement could be well reproduced. In addition, we also demonstrate that the angular distributions provide direct information of these reactions, which could be useful for the investigation of the $N(2120)$ resonance and may be tested by future experiments.

### Photoproduction of $\pi^-\Delta^{++}$, $\pi^+\Delta^0$, and $\pi^+n$ on the proton at $E_\gamma = 1.5{-}3.0$ GeV at LEPS/SPring-8

Hideki Kohri, RCNP, Osaka University

16:50
DMSB 125

We carry out photoproduction experiments using linearly polarized photon beams with energies of 1.5-3.0 GeV at LEPS/SPring-8. Photoproduction reactions are dominated by isospin rules. In the case of the $\pi\Delta$ photoproduction at forward $\pi$ angles, the exchange of isospin=1 ($\pi$ or $\rho$) in the $t$-channel is the most dominant reaction mechanism, which is considered to give a cross section ratio $\sigma(\pi^+\Delta^0)/\sigma(\pi^-\Delta^{++})$ of 1/3. Our preliminary experimental ratios are close to 1/3 at very small pi angles and are larger than 1/3 at larger angles. Larger cross section ratios suggest the $dd$ productions are enhanced compared with the $uu$ productions. The $\pi^+n$ photoproduction, which is caused by the dd productions, is compared with the $\pi\Delta$ photoproduction. These comparisons are important to study N* or $\Delta$* resonances. We are developing a polarized HD target and a large acceptance LEPS2 spectrometer for the near future experiments. Present status of the developments is reported.

### Relating CP-violating decays to the neutron EDM

Astrid Hiller Blin, University of Mainz

17:10
DMSB 125

We use the present upper bound on the neutron electric dipole moment to give an estimate for the upper limit of the CP-violating couplings of the eta(') to the nucleon. Using this result, we derive constraints on the CP-violating two-pion decays of the eta(') mesons. Our results (PRD95 (2017), 036022; arXiv:1612.02276 [hep-ph]) are relevant for the running and planned GlueX and LHCb measurements of rare meson decays.

### Nucleon resonances in γp→K∗+Λ

Fei Huang, University of Chinese Academy of Sciences

17:30
DMSB 125

The high-precision cross-section data for the reaction γp→K∗+Λ reported by the CLAS Collaboration at the Thomas Jefferson National Accelerator Facility have been analyzed based on an effective Lagrangian approach in the tree-level approximation. Apart from the t-channel K, κ, K∗ exchanges, the s-channel nucleon (N) exchange, the u-channel Λ, Σ, Σ∗(1385) exchanges, and the generalized contact term, the contributions from the near-threshold nucleon resonances in the s-channel are also taken into account in constructing the reaction amplitude. It is found that, to achieve a satisfactory description of the differential cross section data, at least two nucleon resonances should be included. By including the N(2060)5/2− resonance, which is responsible for the shape of the angular distribution near the K∗Λ threshold, and one of the N(2000)5/2+, N(2040)3/2+, N(2100)1/2+, N(2120)3/2− and N(2190)7/2− resonances, one can describe the cross-section data quite well, with the fitted resonance masses and widths compatible with those advocated by the Particle Data Group. The resulted predictions of the beam, target, and recoil asymmetries are found to be quite different from various fits, indicating the necessity of the spin observable data for γp→K∗+Λ to further pin down the resonance contents and associated parameters in this reaction.

## Parallel Session C3

Time: Tuesday, August 22, 2017, 16:00 – 17:50
Room: DMSB 126
Chair: Douglas Hasell

### Overview of recent theoretical work on two-photon exchange

Peter Blunden, University of Manitoba

16:00
DMSB 126

In this talk I will given an overview of recent progress in theoretical calculations of two-photon exchange (TPE) effects in elastic electron-proton scattering. This will include a survey of existing models and theoretical frameworks. TPE effects are relevant for extractions of proton form factors at high $Q^2$, and of the proton radius at low $Q^2$. Recent experiments to directly measure hard TPE effects by comparing positron and electron scattering are being presented in an earlier session, and I will discuss the findings from a theoretical perspective.

### Two-photon exchange: myth and history

Egle Tomasi-Gustafsson, CEA,IRFU, and Université Paris-Saclay

16:30
DMSB 126

After recalling the arguments for possible excess of two-photon contribution over alpha-counting, model independent statements about the consequences on the observables will be given. The relevant experimental data are discussed: (polarized and unpolarized) electron and positron elastic scattering on the proton, as well as annihilation data. Finally a recent reanalysis of the Rosenbluth data in terms of form factor ratio will be presented.

### Two-Photon-Exchange: Future experimental prospects

Jan Bernauer, MIT

16:50
DMSB 126

Contemporary experiments show a non-zero, but small two-photon-exchange contribution to elastic proton scattering. Unfortunately, this result does not resolve the discrepancy between form factor ratio extractions based on unpolarized and polarized techniques, as a substantially bigger effect is required. However, with a positron beam of higher energy e.g. at Jefferson Lab or DESY, a new generation of experiments can probe directly the kinematic region where the discrepancy is large. In my talk, I will discuss some possible scenarios and expected figure-of-merits for such experiments.

### Polarized Positron Beam R&D at Jefferson Lab

Joseph Grames, Jefferson Lab

17:10
DMSB 126

The Polarized Electrons for Polarized Positrons (PEPPo) experiment at the injector of the Continuous Electron Beam Accelerator Facility demonstrated for the first time the efficient transfer of polarization from electrons to positrons via a two-step process: polarized bremsstrahlung radiation is induced by a polarized electron beam in a high-Z target; and then the polarized bremsstrahlung produces polarized positrons via the pair-production process in the same target. Positron polarization up to 82% was measured for an initial electron beam momentum of 8.19 MeV/c, limited only by the electron beam polarization. We will present the results of the PEPPo experiment, and then comment on the challenges and prospects for providing useful polarized positron beams at the 12 GeV Upgrade of CEBAF.

### Lepton bremsstrahlung at low energies

Fred Myhrer, University of South Carolina

17:30
DMSB 126

We will show that at the low energies at PSI the muon proton bremsstrahlung spectrum is no longer peaked in the directions of the traveling muon. The "peaking approximation" is still very good for electron proton bremsstrahlung.

## Parallel Session D3

Time: Tuesday, August 22, 2017, 16:00 – 18:10
Room: DMSB 122
Chair: Elena Santopinto

### N* Form Factors based on a Covariant Quark Model

Gilberto Ramalho, LFTC, Universidade Cruzeiro do Sul

16:00
DMSB 122

We discuss the results from the covariant spectator quark model for some of the well known nucleon resonances (N*). The form factors and helicity amplitudes are compared with the available data, particularly with the recent Jefferson Lab data at low and high square momentum transfer ($Q^2$). The role of the valence quarks and the meson cloud excitations in the different reactions is discussed. We present also some predictions for N* form factors at large $Q^2$.

### A Light Front Relativistic Quark Model with Running Quark Mass

Volker Burkert, Jefferson Laboratory

16:30
DMSB 122

I will report on the LF RQM development reported in the Ref. [1] – [6] by the authors. The work is based on prior research by I. G. Aznauryan and others. In the talk we discuss the model ingredients and the determination of the open parameters in fits to the nucleon electromagnetic form factors. We then confront the predictions of the model to transition form factors of the Δ(1232)3/2+ as well as several excited nucleon states, e.g. the Roper N(1440)1/2+, N(1520)3/2-, N(1535)1/2-. We will also discuss the special case of N(1675)5/2-, which reveals the nearly pure meson-baryon contributions to the electromagnetic transition to this state from a proton target, although the resonance corresponds to a strong 3-quark state, as it is revealed in the case of the photo-excitations from a neutron target.
References: [1] Phys.Rev. C95 (2017) 0652. [2] e-print: arXiv:1603.06692 [hep-ph]. [3] Phys.Rev. C92 (2015), 035211. [4] Phys.Rev. C92 (2015), 015203 . [5] Phys.Rev. C85 (2012), 055202 . [6] Prog.Part.Nucl.Phys. 67 (2012) 1-54.

### Baryon masses and strangeness suppression in the Unquenched Quark model

Hugo García-Tecocoatzi, INFN sezione di Genova

16:50
DMSB 122

In this contribution, we briefly analyze the formalism of the unquenched quark model (UQM) and its application to calculate the mass shifts of ground-state octet and decuplet baryons due to the coupling to the meson-baryon continuum. We also describe the electro-production of Baryon- Meson states from proton in the framework of the UQM. Finally, we discuss the strangeness suppression factor within the UQM, and the theoretical results are in good agreement with the values extracted from CERN and JLab experiments.

### Electromagnetic multipole moments of baryons

Alfons Buchmann, Institute for Theoretical Physics, University of Tuebingen

17:10
DMSB 122

Electromagnetic multipole moments provide important information concerning the charge and magnetization distributions in baryons. In particular, quadrupole and octupole moments reveal interesting details about their structure, which have not been fully explored.
We calculate the charge quadrupole and magnetic octupole moments of baryons using a group theoretical approach based on broken SU(6) spin-flavor symmetry. The latter is an approximate symmetry of the QCD Lagrangian that becomes exact in the limit of large number of colors $N_C$. The spin-flavor formalism includes in addition to the usual one-quark currents, two- and three-quark terms in the electromagnetic current operator. The two- and three-quark operators provide an effective description of quark-antiquark and gluon degrees of freedom in baryons, which are essential for a consistent description of baryon structure [1].
We obtain relations between the transition multipole moments to excited states and the electromagnetic properties of the baryon ground states. Our results are compared to experimental quadrupole and octupole transition moments, which are extracted from electromagnetic transition amplitudes to excited baryon states as measured at various electron accelerator facilities [2].
Finally, using various baryon models, we interpret our theoretical results in terms of deviations of the baryon charge and current distributions from spherical symmetry [1].
References [1] A. J. Buchmann, J. A. Hester, R. F. Lebed, Phys. Rev. D 66, 056002 (2002); A. J. Buchmann, R. F. Lebed, Phys. Rev. D 67, 016002 (2003); A. J. Buchmann and E. M. Henley, Phys. Rev.

C 63, 015202 (2001); Phys. Rev. D **65**, 073017 (2002); Eur. Phys. J. A 35, 267 (2008); Phys. Rev. D **83**, 096011 (2011); Few-Body Syst. 55, 749 (2014).
[2] D. Drechsel, S. S. Kamalov, and L. Tiator, Eur. Phys. J. A 34, 69 (2007), http://www.kph.uni-mainz.de/MAID/; L. Tiator, D. Drechsel, S. S. Kamalov, M. Vanderhaeghen, Eur. Phys. J. ST 198, 141 (2011); I. G. Aznauryan and V. D. Burkert, Prog. Part. Nucl. Phys. 67, 1 (2012); C. Patrignani et al. (Particle Data Group), Chinese Physics C 40, 100001 (2016).

### Constituent-quark model with pionic contributions: electromagnetic $N \to \Delta$ transition

Ju-Hyun Jung, Universität Graz

17:30
DMSB 122

We are interested in calculating pion-cloud contributions to the electromagnetic $N \to \Delta$ transition form factors. Starting point is an SU(6) spin-flavor symmetric constituent-quark model with instantaneous confinement that is augmented by dynamical pions which couple directly to the quarks. This system is treated in a relativistically invariant way within the framework of point-form quantum mechanics using a multichannel formulation. In order to calculate pion-cloud effects one needs strong $\pi N\Delta$ and $\pi - \Delta\Delta$ couplings and form factors as well as electromagnetic $N$, $\Delta$ and $N \to \Delta$ form factors for the bare baryons (i.e. $N$ and $\Delta$ without pionic contributions). In our model we have only four parameters, the constituent-quark mass, the pion-quark coupling, the mass of the bare $N$ and $\Delta$ (which is the same due to SU(6) symmetry) and a range parameter for the three-quark wave function of the $N$ and the $\Delta$. Results for the strong $\pi NN$, $piN\Delta$ and $\pi\Delta\Delta$ couplings and form factors compare surprisingly well with phenomenological fits of those quantities in purely hadronic models. Up till now we have calculated the electromagnetic form factors of the bare nucleon and the $N \to \Delta$ transition with this microscopic model. Already without pion cloud these quantities compare reasonably well with the data. Although we consider only S-wave for $N$ and $\Delta$ and have not taken account pion-cloud effects or a D-wave contribution in the $\Delta$ up till now, we obtain non-zero ratios $R_{EM} = \frac{E2}{M1}$ and $R_{EM} = \frac{C2}{M1}$. Having collected the necessary ingredients, it remains to be seen to which extend the electromagnetic $N \to \Delta$ transition is affected by the pion cloud.

### Mass spectra of singly beauty $\Omega_b^-$ baryon

Zalak Shah, Sardar Vallabhbhai National Institute of Technology

17:50
DMSB 122

The mass spectra of singly bottom baryon $\Omega_b^-$ is determined using the Hypercentral Constituent Quark Model [1]. The confinement potential is assumed in the hyper central co-ordinates as hyper coulomb plus power potential. The ground state $m_{\Omega_b^-}$= 6048.8 $\pm$ 3.2 MeV with $J^P = \frac{1}{2}^+$ is found experimentally till now [2]. Our calculated mass spectra for $\Omega_b^-$ is obtained by varying potential index $\nu$ value from 0.5 to 2.0 for ground and radial excited states while orbital excited states are determined at $\nu$=1.0. Lattice QCD results and other recent theoretical predicted masses are close to our obtained results [3,4,5]. Using these mass spectra we plotted Regge trajectories in (n, $M^2$) and (J, $M^2$) planes. The trajectories are useful to determine unknown $J^P$ values of particular states.
[1] Z. Shah, K. Thakkar, A. K. Rai and P. C. Vinodkumar, Eur. Phys. J A **52**, 313 (2016); Chin. Phys. C **40**, 123102 (2016). [2] C. Patrignani et. al., Chin. Phys. C **40**, 100001 (2016). [3] Z. S. Brown, W. Detmold, S. Meinel, and K. Orginos, Phys. Rev. D **90**, 094507 (2014). [4] S. S. Agaev, K. Azizi, and H. Sundu, arXiv:1703.07091v1 [hep-ph] (2017). [5] K-W Wei, B. Chen, N Liu, Q. Q. Wang and X-H Guo arXiv:1609.02512v1 [hep-ph] (2016).

## Conference Dinner, Top of Carolina

Time: Tuesday, August 22, 2017, 19:00 – 21:00
Room: Capstone Building

# Wednesday, August 23, 2017

## Parallel Session A4

Time: Wednesday, August 23, 2017, 08:30 – 10:20
Room: DMSB 124
Chair: Dan Carman

### Exclusive $\pi^-$ Electroproduction off the Neutron in Deuterium in the Resonance Region

Ye Tian, Syracuse University

08:30
DMSB 124

We report the analysis of extracting the exclusive $\gamma^* n(p) \rightarrow p\pi^-(p)$ reaction cross section from deuterium data. The existing $\gamma^* n \rightarrow p\pi^-$ event generator is modified to include the spectator (proton) information based on the CD-Bonn potential to simulate the real data process. With this method, the exclusive quasi-free process is isolated successfully as demonstrated by the comparison of the spectator momentum distribution of the simulation with the missing momentum distribution of the data, and the kinematical final-state-interaction contribution factor $R_{FSI}$ is extracted directly from the data according to the ratio between the exclusive quasi-free and full cross sections. The results of this analysis are new the exclusive and quasi-free cross sections off neutrons bound in deuterium. Furthermore, the corresponding example structure functions are extracted from those cross sections as well. The experiment was done in Hall B at the Thomas Jefferson National Laboratory (JLab) by using the CEBAF Large Acceptance Spectrometer (CLAS) detector, the "e1e" run data off a liquid deuterium target will provide these final results with a kinematic coverage for the hadronic invariant mass ($W$) up to $1.825$ GeV and in the momentum transfer ($Q^2$) range of $0.4 - 1.0$ GeV/c$^2$.

### Exclusive $\pi^-$ electroproduction from the neutron in the resonance region

Jixie Zhang, University of Virgina

09:00
DMSB 124

Pion production from the nucleon is a well-known technique for investigating the resonance. However, data on the neutron are relative scarce when comparing to the proton. In Hall B at Jefferson Lab we have studied the differential cross sections for exclusive $\pi^-$ electro-production from the neutron in the reaction of e+d $\rightarrow$ e$'$+$\pi^-$+p+p$_r$ over a broad kinematics range in the BONuS experiment (*Barely off-shell Nuclear Structure*), where p$_r$ denotes the recoil proton. The experiment was performed using a radial time projection chamber (RTPC) and the CEBAF Large Acceptance Spectrometer (CLAS). The RTPC detector was specially built to detect low energy recoil protons with momenta of 70-250 MeV/c. The differential cross sections for D$(e, e'\pi^- p)$p have been extracted, with the proton detected either by CLAS or by the RTPC. The structure functions $\sigma_{\rm T} + \varepsilon\sigma_{\rm L}$, $\sigma_{\rm LT}$ and $\sigma_{\rm TT}$ were determined and will be presented in comparison with MAID and SAID models.

### Investigation of Exclusive $\pi^+\pi^-$ Electroproduction off the Bound Proton in Deuterium in the Resonance Region with CLAS

Iuliia Skorodumina, University of South Carolina

09:20
DMSB 124

During the last years, experiments of meson electroproduction on the deuteron target have been inducing more and more scientific interest, as they give access to the exclusive reactions off neutrons and allow to judge the influence of the nuclear medium on the reaction processes. Beside that, these experiments offer a great opportunity to study the initial and final state interactions for different exclusive channels as well as the effects of the Fermi motion of nucleons. Being the lightest and most weakly bound nucleus, the deuteron is the best target to start these efforts.
The main purpose of the research I am currently carrying out is to provide new information on exclusive charged double pion electroproduction off the proton bound in deuteron via the analysis of CLAS experimental data. The research aims to provide for the first time a set of integrated and one-fold differential cross sections of this exclusive channel in the quasi-free regime. The extracted cross sections will be compared with the corresponding cross sections of the same reaction off the free proton, which have been recently extracted from the same run period (that included both a hydrogen and deuterium target run in the same experimental configuration) [G. Fedotov *et al.*, Analysis report on the $ep \rightarrow e'p'\pi^+\pi^-$ reaction in the CLAS detector with a 2.039 GeV beam for 0.4 GeV2 $< Q^2 <$ 1.0 GeV$^2$ and 1.3 GeV $< W <$ 1.825 GeV. CLAS-ANALYSIS-NOTE-2017-101]. The direct comparison of these two sets of cross sections obtained under the almost identical conditions will hence provide the experimentally best possible opportunity to investigate the differences and alterations that occur in the exclusive reaction off bound proton in comparison with that off the free proton. This comparison will also allow us to understand the influence of Fermi motion and final state interactions on the cross sections better.
In the talk I am going to introduce the preliminary integrated and differential cross sections of the $\gamma_v p(n) \rightarrow p'(n')\pi^+\pi^-$ reaction and their comparison with the corresponding cross-sections off the free proton. Beside that, some details of the data analysis as well as some specific issues intrinsic for the deuteron target experiment will be presented.

### Fermi-unsmearing: A Monte Carlo method to correct for Fermi-motion of a target nucleon.

Gary Hollis, University of South Carolina

09:40
DMSB 124

For many reasons, especially the measurement of cross sections off the neutron, scattering experiments may use bound nucleons as targets. However, the bound nucleon's momentum is not negligible, and the nucleon is said to have Fermi-motion. For quasi-free scattering, when all final state particles besides the spectator(s) are measured, the initial momentum can be inferred and the cross section can be extracted. However, whenever it is impractical to reconstruct the initial momentum of the target nucleon, the current approach is to ignore the motion of the target nucleon and hence to accept a distortion in the cross section known as Fermi-smearing. This talk discusses the development of a Monte Carlo method that removes this distortion effect, resulting in a realistic W-dependence of the cross section.

### Determination of the Polarization Observables $C_x$, $C_z$, and $P_y$ for the Quasi-Free Mechanism in the reaction $\overrightarrow{\gamma}d \rightarrow K^+\overrightarrow{\Lambda}n$

Tongtong Cao, Hampton University

10:00
DMSB 124

Besides the reaction $\overrightarrow{\gamma}p \rightarrow K^+\overrightarrow{\Lambda}$, the Quasi-Free (QF) mechanism in the reaction $\overrightarrow{\gamma}d \rightarrow K^+\overrightarrow{\Lambda}n$

provides an alternative means to study photoproduction of strangeness off the proton leading to the $K^+\Lambda$ state. In this work, we determine the polarization transfers, $C_x$ and $C_z$, from circularly polarized photons to the $\Lambda$, and the hyperon recoil polarization, $P_y$, for the QF mechanism in the reaction $\overrightarrow{\gamma} d \to K^+ \overrightarrow{\Lambda} n$ for $E_\gamma$ between 0.9−2.6 GeV and $cos\theta_{KCM}$ between -1−1. The observables are obtained from data taken with the CLAS detector at the Thomas Jefferson National Accelerator Facility during the E06−103 (g13) experiment. The extracted observables are compared to published CLAS results on the reaction $\overrightarrow{\gamma} p \to K^+ \overrightarrow{\Lambda}$. In the talk, effects of the Fermi momentum of the bound proton on the extracted observables will be discussed. This work is funded in part by the U.S. NSF under grant PHY-125782.

## Parallel Session B4

Time: Wednesday, August 23, 2017, 08:30 – 10:20
Room: DMSB 125
Chair: Craig Roberts

### Structure of the Orbital Excited N* from SDE

Adnan Bashir, University of Michoacan

08:30
DMSB 125

I present advances towards the calculation of the $N \to N*(1535)$ Transition Form Factor through Schwinger-Dyson equations.

### A process-independent QCD effective charge: a main ingredient for a further computation of nucleon-to-resonances transitions

José Rodríguez-Quintero, University of Huelva & CAFPE (U. Granada)

09:00
DMSB 125

We have recently unified two widely different approaches to understanding the infrared behaviour of quantum chromodynamics (QCD), one essentially phenomenological, based on data, and the other computational, realised via quantum field equations in the continuum theory. Using the latter, we explained and calculated a process-independent running-coupling for QCD, a new type of effective charge that is an analogue of the Gell-Mann–Low effective charge in quantum electrodynamics. This process-independent charge will necessarily be a noteworthy piece of information for the effort to derive the nucleon-to-resonances transitions and, reversely, the measurements of these transitions will be crucial for the practical validation of that charge.

### Aspects of Nucleon Parton Structure from a DSE Implementation of QCD

Peter Tandy, Kent State University

09:20
DMSB 125

The parton structure of the nucleon is investigated in an approach based upon QCD's Dyson-Schwinger equations. The method accommodates a variety of QCD's dynamical outcomes including: the running mass of quark propagators and formation of non-pointlike di-quark correlations. The method can produce a large number of moments, and thus complements lattice-QCD which is presently reliable for about 3 moments only. All needed elements, including the nucleon wave function solution from a covariant Faddeev equation, are encoded in spectral-type representations in the Nakanishi style to facilitate Feynman

integral procedures and allow insight into key underlying mechanisms. Results will be presented for spin-independent PDFs arising from a truncation to allow only scalar di-quark correlations. initial explorations of axial-vector di-quark correlations and extension to TMDs may be discussed if results are available.

**The QCD running coupling at all scales and the connection between the proton mass and $\Lambda_{\overline{MS}}$**

Alexandre Deur, Jefferson Lab

09:40
DMSB 125

The running coupling $\alpha_s(Q^2)$ sets the strength of QCD as a function of the momentum transfer $Q$. Knowing the $Q^2$-dependence of $\alpha_s$ is necessary to describe hadronic interactions at both large and short distances. At short distances, the $Q^2$-dependence is specified by perturbative QCD and its renormalization group equation. It is well known, with the 5-loops calculations now available. Since QCD is nearly conformal at small distances, the strength of the $Q^2$-dependence is set by a non-perturbative parameter, usually $\Lambda_{QCD}$. In this talk, we will show the prediction of holographic-QCD for $\alpha_s$ at low $Q^2$, and compare it to experimental data and to other non-perturbative calculations. Matching the high and low $Q^2$ regimes of $\alpha_s(Q^2)$ allows us to relate $\Lambda_{QCD}$ to the holographic-QCD confinement parameter $\kappa$, thereby establishing an explicit relation between the physics of confinement and the dynamical interactions of quarks and gluons at short distances. This provides an analytic connection between hadronic masses and $\Lambda_{QCD}$.

**Disentanglement of Electromagnetic Baryon Properties**

Daniel Sadasivan, George Washington University

10:00
DMSB 125

Through recent advances in experimental techniques, the precise extraction of the spectrum of baryonic resonances and their properties becomes possible. Helicity couplings at the resonance pole are fundamental parameters describing the electromagnetic properties of resonances and enabling the comparison of theoretical models with data. We have extracted them from experiments carried out at Jefferson Lab and other facilities using a multipole analysis within the Julich-Bonn framework. Special attention has been paid to the uncertainties and correlations of helicity couplings. Using the world data on the reaction $\gamma p \rightarrow \eta p$, we have calculated, for the first time, the covariance matrix. Our results are useful in several ways. They quantify uncertainties but also correlations of helicity couplings. Second, they can tell us quantitatively how useful a given polarization measurement is. Third, they can tell us how the measurement of a new observable would constrain and disentangle the resonance properties which could be helpful in the design of new experiments. Finally, on the subject of the *missing resonance problem*, model selection techniques and statistical tests allow us to quantify the significance of whether a resonance exists.

## Parallel Session C4

Time: Wednesday, August 23, 2017, 08:30 – 10:20
Room: DMSB 126
Chair: Eulogio Oset

### N to Δ transition: recent results and prospects

Nikos Sparveris, Temple University

08:30
DMSB 126

The study of the N to Δ transition has been the subject of an intense scientific interest for more than two decades. The pion electroproduction and VCS channels of the transition provide access to the N to Δ transition amplitudes and offer a path for the exploration of the dynamics associated with the presence of non-spherical angular momentum amplitudes in hadrons. At the same time the VCS channel provides access to another set of fundamental properties of the nucleon, the Generalized Polarizabilities. Recent results from JLab and MAMI will be presented and future prospects will be discussed.

### Nucleon and Delta structure results from lattice QCD

Giannis Koutsou, The Cyprus Institute

09:00
DMSB 126

Recent nucleon structure results will be presented from lattice QCD simulations at physical or near physical quark mass. We will also present results on the electromagnetic and axial delta and nucleon to delta transition, as well as an outlook on the study of resonances on the lattice.

### The Role of the $\Delta(1232)$-Resonance in the (Muonic) Hydrogen Spectrum

Franziska Hagelstein, JGU Mainz

09:20
DMSB 126

The electromagnetic excitation of the $\Delta(1232)$ plays an appreciable role in the Lamb shift and hyperfine structure of muonic hydrogen. Its effect appears at the order $\alpha^5$, together with other proton-polarizability contributions, and therefore is subleading with respect to the proton charge radius contribution which is of order $\alpha^4$, see e.g. [1]. We use the large-$N_c$ relations for the nucleon-to-delta transition form factors [2] to compute the $\Delta(1232)$ contribution. We show that the hyperfine splitting is dominated by the magnetic $N \to \Delta$ transition and present a simple formula, involving the nucleon Pauli form factor, setting a lower bound on the absolute effect of the $\Delta$-resonance. The planned PSI measurement of the ground-state hyperfine splitting in muonic hydrogen will require at least a factor 10 improvement in precision of the theory predictions of proton polarizability contributions [3].
[1] F. Hagelstein, et al., Prog. Part. Nucl. Phys. 88 (2016) 29-97. [2] V. Pascalutsa and M. Vanderhaeghen, Phys. Rev. D 76 (2007) 111501. [3] R. Pohl, et al., physics.atom-ph/1609.03440.

### The VCS-Δ experiment at MAMI

Michael Paolone, Temple University

09:40
DMSB 126

High precision measurements of the Virtual Compton Scattering reaction at the first nucleon resonance have been performed at the MAMI Microtron at Mainz. The experiment focuses on the study of the electric Generalized Polarizability of the proton and on the first extraction of the Coulomb quadrupole transition amplitude through the photon excitation channel. In this talk details of the experiment, the status of the data analysis, and preliminary results will be presented.

**Virtual Compton Scattering measurements in Hall C at JLab**

Mark Jones, Jefferson Lab

10:00
DMSB 126

The Generalized Polarizabilities, GPs, are fundamental quantities of the nucleon and as such they are extremely valuable for a deeper and more complete understanding of the nucleon structure. The GPs can be accessed experimentally through measurements of the Virtual Compton Scattering reaction. They can be seen as Fourier transforms of local polarization densities (electric, magnetic, and spin) and therefore are a probe of the nucleon dynamics, allowing us, e.g., to study the role of the pion cloud and quark core contributions to the nucleon GPs at various length scales.
A new experiment in Hall C at JLab will explore the proton GPs with an unprecedented high precision. The unique capabilities of the experimental setup, namely the high resolution of the spectrometers combined with the ability to place the spectrometers in very small angles, will provide high precision measurements of the VCS reaction in a kinematic region where the GPs are changing rapidly and exhibit a puzzling dependence with $Q^2$. The upcoming measurements will explore the mechanisms responsible for the non-trivial $Q^2$ dependence of the electric GP and will significantly improve the knowledge of the magnetic GP.

## Break (Coffee / Refreshments)

Time: Wednesday, August 23, 2017, 10:20 – 10:50
Room: Sonoco Pavilion

## Parallel Session A5

Time: Wednesday, August 23, 2017, 10:50 – 12:40
Room: DMSB 124
Chair: Victor Mokeev

**Extracting Resonance Parameters from Exclusive Electroproduction off Protons at CLAS**

Kijun Park, Jefferson Lab

10:50
DMSB 124

The measurement of the excited nucleon states play a crucial role for the insight of the structure of the nucleon. Such a $N^*$ spectrum contains the direct information of the underlying degree of freedom of the nucleon. In particular, the exclusive meson electroproduction off protons is a powerful tool to probe the effective degrees of freedom in excited nucleon states at the varying distance scale where the transition from the contributions of both quark-core and meson-baryon cloud to the quark-core dominance. During the past decade, the CLAS collaboration has executed a broad experimental program to study the excited states of the proton using polarized electron beam and both polarized and unpolarized proton targets. The measurements covered a broad kinematic range in the invariant mass $W$ and photon virtuality $Q^2$ with nearly full coverage in polar and azimuthal angles in the hadronic CM system. As results, several nucleon resonance states in particular from near pion threshold to $W < 2$ GeV have been explored. These include the axial form factors, $\Delta(1232)\frac{3}{2}^+$, $N(1440)\frac{1}{2}^+$, $N(1520)\frac{3}{2}^-$, $N(1535)\frac{1}{2}^-$ as well as the $N(1675)\frac{5}{2}^-$, $N(1680)\frac{5}{2}^+$, and $N(1710)\frac{1}{2}^+$ states. I will briefly discuss these resonance states as well as DIS results from the single charged pion electroproduction data at CLAS.

**Exclusive $\pi^0$ electroproduction in the resonance region.**

Nikolay Markov, University of Connecticut

11:20
DMSB 124

The exclusive electroproduction process $ep \to e'p'\pi^0$ was measured in the range of the photon virtuality $Q^2 = 0.4-1.0$ GeV$^2$, and the invariant mass range of the $p\pi^0$ system of $W = 1.1-1.8$ GeV. For the first time, these kinematics are covered in exclusive $\pi^0$ electroproduction off the protons with nearly complete angular coverage in the $p\pi^0$ center of mass system with extremely high statistics. Cross section and beam spin asymmetry were measured and structure functions $\sigma_T + \epsilon\sigma_L$, $\sigma_{TT}$, $\sigma_{LT}$ and $\sigma'_{LT}$were extracted via the fitting the $\phi^*$ dependance. Comparison between the experimental results on exclusive structure functions $\sigma_T + \epsilon\sigma_L$, $\sigma_{TT}$, $\sigma_{LT}$ and evaluations within the JLAB/YerPHY unitary model revealed the data sensitivity to the variations of the electroexcitation amplitudes for the nucleon resonances $N(1650)1/2^-$, $N(1685)5/2^+$, and $\Delta(1700)3/2^-$. Combined studies of $\pi^+n$ and $\pi^0p$ electroproduction off protons data from CLAS at W >1.6 GeV will provide the first results on the high lying N* and $\Delta$* electrocouplings at $Q^2 < 1.0\ GeV^2$ for all excited nucleons with substantial decays to the $N\pi$ final states. These new experimental data will extend the insight into the complex interplay between inner quark core and outer meson-baryon cloud in the structure of nucleon resonances with masses above 1.6 GeV.

**Response Functions from Exclusive Measurements of $\omega$ Meson Electroproduction off the Proton**

Evan Phelps, University of South Carolina

11:40
DMSB 124

A central goal of hadronic physics is to understand the structure of hadrons in terms of Quantum Chromodynamic's (QCD's) current quarks and gluons and to connect the observable properties of hadrons to the dynamical content of QCD. This endeavor entails knowledge of the baryon spectrum, the proton form factor, and transition form factors. Photoproduction experiments are excellent probes of the excited baryon spectrum, and electroproduction experiments additionally afford access to the proton and transition form factors. Among electroproduction channels, $\omega$ electroproduction provides a discriminating probe of the high-lying resonance region due to the meson's high mass, narrow decay width, and isoscalar nature that restricts it to isospin-$1/2$ resonance couplings. Using data collected by Jefferson Lab's CLAS detector during run periods E1F and E16, with beam energies close to 6 GeV, exclusive $\omega$ electroproduction off the proton was studied via the three-pion decay channel, $ep \to e\omega p \to e\pi^+\pi^-\pi^0 p$. Differential cross sections were measured for $W = [1.72, 2.60)$ GeV, $Q^2 = [1.85, 5.15)$ GeV$^2$, and over the full solid-angular range. Response functions $R_T + \epsilon_L R_L$, $R_{TT}$, and $R_{TL}$ were extracted in order to be utilized in the extraction of resonance parameters within single-channel or dynamical coupled channel analyses. Results, conclusions, and prospects will be reported.

**Measurement of New Observables from the $\pi^+\pi^-p$ Electroproduction off the Proton**

Arjun Trivedi, University of South Carolina

12:00
DMSB 124

A key objective of the N* program is to measure the resonance transition form factors that contain information needed to explore the distance-dependence description of the interaction of a probe with the nucleon resulting in its excitation to one of its various resonance states. These resonance transition form factors are sensitive to the underlying degrees of freedom of the nucleon and their dynamics while being confined within the nucleon, and therefore serve to understand the emergent complexity of the Universe at the most fundamental level. Experimental observables from single- and double-charged electroproduction channels serve as dominant sources for the extraction of these form factors in the two dimensional landscape spanned by the variables $Q^2$ and $W$, which map out the space-time scale of the degrees of

freedom and their dynamics during the interaction as well as the range of possible excitations of the nucleon, respectively. For the first time, in hitherto unexplored regions of $Q^2$ and $W$, observables in the double-charged channel that are sensitive to the polarization of the virtual photon are measured using the $\pi^+\pi^- p$ reaction channel. I will present preliminary measurements for these new observables for $2\ GeV^2 < Q^2 < 5\ GeV^2$ and $1.400\ GeV < W < 2.125\ GeV$ using data collected at the experimental facility of Jefferson Laboratory, preceded by an introduction to these observables and the relevant details of the experimental analysis.

**New results on $\gamma_v p \to p'\pi^+\pi^-$ cross sections in the resonance region with CLAS**

Gleb Fedotov, Ohio University

12:20
DMSB 124

The new results on the integral and single-differential cross sections of the $\pi^+\pi^-$ electroproduction off protons measured in the invariant mass range of the final hadron system $W$ from 1.3 GeV to 1.825 GeV and at photon virtualities $Q^2$ from 0.4 GeV$^2$ to 1.0 GeV$^2$ will be reported. These measurements have expanded the range of covered photon virtualities towards smaller values in comparison with the previous CLAS experiments and allowed to extract the cross sections in 0.05-GeV$^2$-fine Q$^2$-bins, which is a factor of six narrower than previously achieved [M. Ripani et al. CLAS Collaboration, Phys. Rev. Lett. 91, 022002 (2003).].
The extracted cross sections were compared with the prediction of recently developed TWOPEG [Iu. Skorodumina et al. arXiv:1703.08081 (2017)] event generator which is based on JM model [V.I.Mokeev, V.D.Burkert et al, Phys. Rev. C93, 025206 (2016)] fit to the previously available data and a good agreement was revealed. The resonant contribution to the cross section was estimated with the direct use of the phenomenological reaction model (JM) and was found to be significant.
The studies of the N* electroexcitation amplitudes, also known as electrocouplings, at various photon virtualities represent an important part of the scientific program with the CLAS and CLAS12 detectors at Jefferson Lab. It is expected that the future detailed analysis of the extracted cross sections within JM model will improve the knowledge on $\gamma_v p$N* electrocouplings for exited states with masses above 1.6 GeV, since many of them decay preferentially to the N$\pi\pi$ final state. For low-laying resonances this analysis will offer a valuable cross-check of the obtained resonance parameters via their comparison with the independent results from N$\pi$ exclusive channel.

## Parallel Session B5

Time: Wednesday, August 23, 2017, 10:50 – 12:20
Room: DMSB 125
Chair: Eugene Pasyuk

**Exclusive Meson Photoproduction off Bound Nucleons**

Igor Strakovsky, The George Washington University

10:50
DMSB 125

An overview of the GW SAID group effort to analyze pion photoproduction on the neutron-target will be given. The disentangling of the isoscalar and isovector EM couplings of N$*$ and $\Delta*$ resonances does require compatible data on both proton and neutron targets. The final-state interactions play a critical role in the state-of-the-art analysis in extraction of the $\gamma$n $\to$ $\pi$N data from the deuteron target experiments. Then resonance couplings determined by the SAID PWA technique are compared to previous findings.

The neutron program is an important component of the current JLab, MAMI-C, SPring-8, ELSA, and ELPH studies.

**Evaluating Polarization Data**

Dave Ireland, University of Glasgow

11:20
DMSB 125

There is a large amount of polarization observable data that has been collected in recent years, from a variety of channels and from different experiments. If this data is going to prove ultimately useful in the study of $N^\star$ resonances, and other physics topics, it is imperative that it be consistent, to avoid pathologies in the fitting of models. Taking an example of $K\Lambda$ photoproduction, a method will be demonstrated that ensures data representing a set of different observables, which could have been extracted independently from different experiments, are guaranteed to be self-consistent.

**CLAS12 RICH: New hybrid geometry for strangeness studies.**

Giovanni Angelini, The George Washington University

11:40
DMSB 125

The JLAB CLAS12 detector will provide a world-leading facility for the study of electron-nucleon scattering. The experiment will accumulate data with unprecedented statistical accuracy, thanks to its 12 GeV polarized electron beam and its luminosity, the availability of unpolarized as well as polarized hydrogen and nuclear target, and its wide kinematic coverage. The CLAS12 physics program is very broad and includes studies on the meson spectroscopy with quasi-real photoproduction in a large variety of final states. The particle identification will be complemented by a Ring Imaging Cherenkov Detector (RICH), that will provide separation of kaons from protons and pions in the momentum range between 3-8 GeV/c allowing the study of double and triple strange baryons. In this talk, we will focus on the new technologies developed for the RICH, especially on the complex mirror system, that thanks to a hybrid geometry allow reducing the photo-detection area. The expected performance of the detector will be presented as well.

**Photoproduction of $\pi^0\pi^\pm$ Pairs off Nucleons**

Natalie Walford, University Basel

12:00
DMSB 125

Photoproduction of meson pairs off (quasi-) free nucleons is important to investigate the excitation spectrum of the nucleon for low energy QCD, in particular for excited states which decay predominantly via intermediate excited states to the ground state. Quasi-free production of such pairs off heavier nuclei also figures prominently in the study of the in-medium properties of nucleon resonances. Double meson production channels make the largest contribution to the second resonance bump of the nucleon, which disappears for photoproduction off nucleons bound in nuclei. The special interest in the mixed charged channels $\pi^0\pi^\pm$ is related to the contribution of the $\rho$-meson. This decay is forbidden for the $\pi^0\pi^0$ final state due to isospin conservation. The coupling to a $\rho$ could induce substantial in-medium effects when the $\rho$ spectral function itself is modified in the medium. In the present work, production of $\pi^0\pi^\pm$ pairs off liquid deuterium and liquid hydrogen was analysed using data taken at MAMI with the A2 experiment as a starting point for a detailed investigation of this channel for nuclear targets.

## Parallel Session C5

Time: Wednesday, August 23, 2017, 10:50 – 12:40
Room: DMSB 126
Chair: Reinhard Beck

### Bridging Time-Like and Space-Like N* Form Factors

Philip Cole, Lamar University

10:50
DMSB 126

The study of electromagnetic transitions opens a window into the very nature of the strong interaction. And, indeed, such a study of how a ground-state nucleon transitions to an excited state, over a broad range of q2, will provide keen insight into the evolution of how dynamically-generated masses emerge from the asymptotically-free, nearly massless quarks of perturbative QCD as well as provide information on the ancillary effects from the meson-baryon cloud. The space-like (q2<0) region has been explored more intensively, particularly at JLab, but efforts have also begun in studying the time-like (q2>0) region at GSI. We are living in exciting times whereby near-future prospects exist in extracting high-quality data in both the space-like and time-like regimes (JLab12 and FAIR, for example). The recent ECT* workshop, entitled space-like and time-like electromagnetic baryonic transitions, brought together several disparate communities of experimentalists and theorists. The goal and purpose of this workshop was to make the very first steps towards a much needed consistent description spanning the two kinematical regimes in q2. The discussions included photoproduction measurements (ELSA, JLab, LEPS, and MAMI), wherein the q2=0 point anchors the connection between space-like and time-like regions and meson-beam data (GSI, FAIR, and J-PARC) and amply complements the requisite information for baryon spectroscopy. This talk will present the outcomes from this ECT* workshop and will set the stage for the dedicated NSTAR 2017 parallel session entitled baryon structure through meson electroproduction, transition form factors, and time-like form factors.

### Studying time-like electromagnetic baryonic transitions with HADES in $\pi$-N reactions

Béatrice Ramstein, Institut de Physique Nucléaire d'Orsay

11:20
DMSB 126

A dedicated programme to study electromagnetic baryonic transitions in the time-like region has started using the pion beam [1] and the HADES (High Acceptance Di-Electron Spectrometer) set-up [2] at GSI. Combined measurements of hadronic and dielectron final states have been performed for the first time in $\pi$-N reactions, using polyethylene and carbon targets. Differential cross-sections of the exclusive channels with two pions in the final state ($\pi^-\pi^+n$, $\pi^0\pi^-p$) were obtained in the second resonance region with an unprecedented statistics. These new data were included in the partial wave analysis (PWA) of the Bonn-Gatchina group [3] together with the world data from pion and photon beam facilities. The obtained solution provides the excitation function of the two-pion production in photo- and pion- induced reactions around the pole of the N(1520)$D_{13}$ resonance and of its decomposition into the different resonant, non-resonant and $\rho$ contributions.
Results for the exclusive $ne^+e^-$ production will be compared to various model calculations. In addition, the extraction of the $\rho$ contribution in the two-pion production channels are used to investigate the validity of the Vector Dominance Model for baryon transitions. The angular distributions of the leptons, which contain additional information on the electromagnetic structure of the different transitions, will also be discussed.

The prospects for future experiments where the third resonance region will be investigated will also be presented.
[1] P. Salabura, J. Stroth, L. Fabbietti (HADES), Nucl. Phys. News 25 (2015) 22. [2] G. Agakishiev et al. (HADES), Eur. Phys. J. A 41 (2009) 243. [3] A.V. Anisovich, E. Klempt, A.V. Sarantsev, U. Thoma, Eur. Phys. J. A 24 (2005) 111.

**Hyperon-photon physics**

Stefan Leupold, Uppsala University

11:40
DMSB 126

In the last decades a lot of progress has been made in the understanding of the electromagnetic form factors of the nucleons and transition form factors of the nucleon to baryonic resonances. This information can be complemented and deeper examined by determining the corresponding quantities for hyperons. Dalitz decays of hyperons into lighter hyperons and a lepton pair provide access to low-energy transition form factors. On the theory side one can use dispersion theory to relate these form factors to the pion vector form factor and pion-hyperon scattering amplitudes. The latter can be addressed with chiral perturbation theory including decuplet states [1]. In my talk I will report on these ongoing theory developments.
[1] C. Granados, S. Leupold and E. Perotti, The electromagnetic Sigma-to-Lambda hyperon transition form factors at low energies, Eur. Phys. J. A 53, 117 (2017).

**Polarization and dilepton anisotropy in pion-nucleon collisions**

Miklós Zétényi, Wigner RCP, Budapest

12:00
DMSB 126

We study hadronic polarization and the related anisotropy of the dilepton angular distribution for the reaction $\pi N \to N e^+ e^-$. We employ consistent effective interactions for baryon resonances up to spin-5/2 to compute their contribution to the anisotropy coefficient. We show that the spin and parity of the intermediate baryon resonance is reflected in the angular dependence of the anisotropy coefficient. We present results for the anisotropy coefficient including the N(1520) and N(1440) resonances, which are essential at the collision energy of the recent data obtained by the HADES collaboration on this reaction. We conclude that the anisotropy coefficient provides useful constraints for unravelling the resonance contributions to this process.

**First Results from the BGO-OD Experiment at ELSA**

Hartmut Schmieden, Physics Institute (PI), University of Bonn

12:20
DMSB 126

BGO-OD is a new experiment at the University of Bonn‘s ELSA accelerator facility. It consists of a highly segmented BGO calorimeter at central angles combined with an Open Dipole magnetic spectrometer in forward directions. The setup is ideal for meson photoproduction at low momentum transfers, in particular in KY photoproduction. It allows to investigate threshold effects and the role of (vector-) meson – baryon interactions. Data taking has started and first preliminary results will be shown.

## Lunch Break

Time: Wednesday, August 23, 2017, 12:40 – 14:00

## General Session P7

Time: Wednesday, August 23, 2017, 14:00 – 16:00
Room: DMSB 123
Chair: Fred Myhrer

### Resonance Parameters from Strangeness Photo- and Electroproduction

Jan Ryckebusch, Ghent University

14:00
DMSB 123

We lay out a framework that can be used to obtain estimates of the possible impact of (combinations) of polarization measurements in strangeness photoproduction from the nucleon. To this end, we introduce a geometrical measure to quantify the distance between models for strangeness photoproduction in amplitude space. Experimental observables, with finite accuracy, map to probability distributions in amplitude space, and the characteristic width scale of such distributions needs to be smaller than the distance between models if the observable data are going to be useful. We therefore also introduce a method for evaluating probability distributions in amplitude space that arise as a result of one or more measurements, and show how one can use this to determine what further polarization measurements are going to be necessary to be able to discriminate among models.

### Nucleon Excited States from Lattice QCD and Hamiltonian Effective Field Theory

Jiajun Wu, University of Adelaide

14:30
DMSB 123

An approach for relating the nucleon excited states extracted from lattice QCD and the nucleon resonances of experimental data has been developed using the Hamiltonian effective field theory (HEFT) method. By formulating HEFT in the finite volume of the lattice, the eigenstates of the Hamiltonian model can be related to the energy eigenstates observed in Lattice simulations. By taking the infinite-volume limit of HEFT, information from the lattice is linked to experiment. The approach opens a new window for the study of experimentally-observed resonances from the first principles of lattice QCD calculations. With the Hamiltonian approach, one not only describes the spectra of lattice-QCD eigenstates through the eigenvalues of the finite-volume Hamiltonian matrix, but one also learns the composition of the lattice-QCD eigenstates via the eigenvectors of the Hamiltonian matrix. One learns the composition of the states in terms of the meson-baryon basis states considered in formulating the effective field theory. One also learns the composition of the resonances observed in Nature. In this presentation, I will focus on recent breakthroughs in our understanding of the structure of the N*(1535), N*(1440) and Lambda(1405) resonances using this method.

### Time-Like Baryon Transitions in Hadroproduction

Béatrice Ramstein, Institut de Physique Nucléaire d'Orsay

15:00
DMSB 123

Originally designed to study medium effects in $e^+e^-$ production in heavy-ion reactions in the SIS-18 energy range (1-3 GeV/nucleon), the High Acceptance Di-Electron Spectrometer (HADES) [1] installed at GSI is a versatile detector. Its excellent particle identification capabilities allowed for a systematic investigation of dielectron, strange particles and pion production in proton, deuteron or heavy-ion induced

reactions on proton or nucleus. The obtained dilepton spectra measured at various beam energies show important contributions from baryon resonance decays ($R \rightarrow Ne^+e^-$) and a strong influence of the intermediate vector mesons ($\rho/\omega/\phi$) in the corresponding time-like electromagnetic form factors.
In order to directly access such transitions, HADES has started a dedicated pion-nucleon programme [2]. For the first time, combined measurements of hadronic and dielectron final states have been performed in $\pi$-N reactions in the second resonance region, using polyethylene and carbon targets. While providing new determinations of the baryon-meson couplings, the results allow to investigate the validity of the Vector Dominance Model for baryon transitions and the helicity structure of the time like electromagnetic baryon transitions, paving the way for more precise future measurements.
The results of the HADES collaboration obtained with proton and pion beams will be presented, as well as prospects for HADES measurements at SIS-18 in the near future and later at SIS-100 (FAIR).
[1] G. Agakishiev et al. (HADES), Eur. Phys. J. A 41 (2009) 243. [2] P. Salabura, J. Stroth, L. Fabbietti (HADES), Nucl. Phys. News 25 (2015) 22.

**CLAS N* Excitation Results from Pion and Kaon Electroproduction**

Daniel Carman, JLab

15:30
DMSB 123

The study of the structure of excited nucleon $N^*$ states employing the electroproduction of exclusive reactions is an important avenue for exploring the nature of the non-perturbative strong interaction. The electrocouplings of $N^*$ states in the mass range below $W$=1.8 GeV have been determined from analyses of CLAS $\pi N$, $\eta N$, and $\pi\pi N$ data at four momentum transfers $Q^2$ up to 5 GeV$^2$. This work has made it clear that consistent results from independent analyses of several exclusive channels with different couplings and non-resonant backgrounds but the same $N^*$ electro-excitation amplitudes, is essential to have confidence in the extracted results. In terms of hadronic couplings, many high-lying $N^*$ states preferentially decay through the $\pi\pi N$ channel instead of $\pi N$. Therefore, data from the $KY$ channels already measured with CLAS will be crucial to provide an independent analysis to compare the extracted electrocouplings for the high-lying $N^*$ states against those determined from the $\pi N$ and $\pi\pi N$ channels. These comparisons await the develop of suitable $KY$ reaction models. Starting later this year, a program to study the structure of $N^*$ states in various exclusive electroproduction channels using the new CLAS12 spectrometer will get underway. These studies will probe the structure of these states in the mass range up to $W$=3 GeV and $Q^2$ up to 12 GeV$^2$, thus providing a means to access $N^*$ structure information spanning a broad regime encompassing both low and high energy degrees of freedom.

## Break (Coffee / Refreshments)

Time: Wednesday, August 23, 2017, 16:00 – 16:30
Room: Sonoco Pavilion

## General Session P8

Time: Wednesday, August 23, 2017, 16:30 – 18:00
Room: DMSB 123
Chair: Yordanka Ilieva

**Exclusive Meson Electroproduction off Bound Nucleons**

Toru Sato, Osaka University

16:30
DMSB 123

Excited nucleon states are characterized by the poles and residues of the meson production amplitudes. In this talk we briefly discuss the the ANL-Osaka dynamical coupled channel (DCC) approach to analyze meson production reactions and the resonance parameters extracted from the amplitudes within the DCC model.
The isospin structure of those resonance parameters will clarify the structure of resonances together with possible non-trivial effects of meson production mechanism. We then discuss the electroweak pion production reactions on deuteron and possible effect of final state interaction when extracting neutron amplitudes.

**N* Structure from Constituent Quark Models**

Elena Santopinto, INFN Genova

17:00
DMSB 123

A review of quark model theoretical results on electromagnetic transition form factors of the N* resonances will be presented and discussed in comparison with the experimental data

**Baryons in Medium**

Steffen Strauch, University of South Carolina

17:30
DMSB 123

Many QCD-based models predict changes of the nucleon wave functions in the nuclear medium, including observable changes in the nucleon structure functions and electromagnetic form factors. While these in-medium form factors are not observable, they provide a natural explanation of a variety of experimental results. I will review some of these findings and discuss upcoming experiments.

**Concluding Remarks — NSTAR 2019 will be held in Bonn**

Time: Wednesday, August 23, 2017, 18:00 – 18:30
Room: DMSB 123