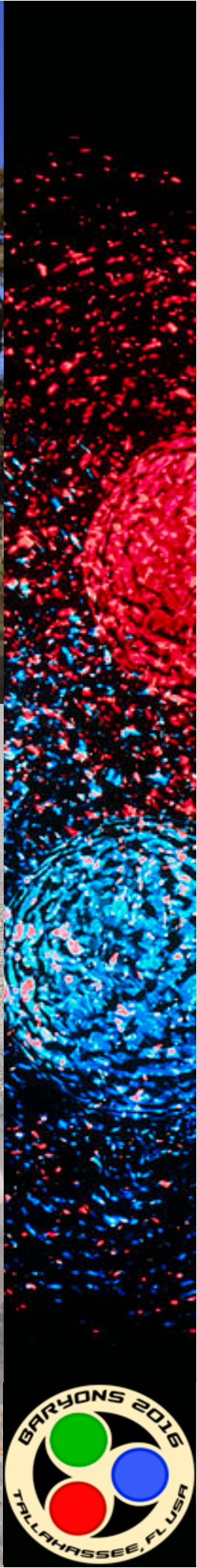
International Conference on the Structure of Baryons

BARYONS 2016

May 16-20, 2016
Florida State University
Tallahassee, USA



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1 General Information

The International Conference on the Structure of Baryons will be held May 16-20, 2016 at the Florida State University Alumni Center, 1030 W Tennessee Street. The Florida State University was officially established in 1851 and is located on the oldest continuous site of higher education in the state of Florida.

Tallahassee, best known as Floridas capital, is an intimate neo-metropolitan city where the power of state government, the academic and the artistic are complemented by subtle, old-fashioned charm. It is the perfect two- or three-day diversion for the more than 41 million annual visitors to Florida.

2 Scientific Program

The program includes contributed and invited talks highlighting the physics of baryons and related subjects in particle, nuclear, and astrophysics. The main issues to be discussed are our understanding of the structure and reactions of baryons from the fundamental theory of the strong interaction, Quantum Chromodynamics (QCD). In particular, the highly non-perturbative phenomena of quark confinement, mass generation, and spontaneous breaking of chiral symmetry will be addressed. Recent developments of new and forthcoming facilities in the world will also be showcased.

3 Accomodation

A 9-minute drive from Interstate 10, the DoubleTree Hotel is five blocks from Florida State University.

DoubleTree Downtown Tallahassee
101 South Adams Street
Tallahassee, FL 32301
Tel: 1-850-224-5000

The DoubleTree Hotel is located in the heart of Downtown Tallahassee, just blocks from the FSU Campus and adjacent to the Florida State Capital Building. The hotel is within a distance of about 1.5 miles to the conference venue. The Sunday evening reception and early registration check-in will be held at the DoubleTree Hotel.

We will provide a shuttle ride from the Florida State dormitories (Ragans Hall 2) to the Double Tree for the reception on Sunday evening. If you plan to attend, please send an email to Winston Roberts (wroberts@fsu.edu), cc to Volker Crede (crede@fsu.edu) letting us know. The shuttle will leave Ragans Hall at 5:45, and return at 7:15.

4 Information for Speakers

The Baryons 2016 venue is fully equipped. There are computers in each meeting room running Powerpoint, OpenOffice, and Acrobat PDF Reader. We request that all talks be uploaded to the Baryons 2016 Indico system the day before the scheduled talk. The use of individual laptops will not be allowed.

All speakers are strongly advised to arrive at the meeting room at least 15 minutes prior to the start of the session to confirm that the technology will work with minimum delay between speakers.

5 Registration

Early registration check-in will take place at the Double Tree Hotel on Sunday, May 15th, between 18:00-19:00. On-site registration check-in will take place on Monday, May 16th, starting at 08:00 AM in the lobby of the FSU Alumni Center. During registration check-in, the conference staff will hand out to each participant a conference bag and packet including information material, and participant badges.

Participants who have pending financial issues may settle at the registration desk during conference hours, but only via credit card. We cannot accept cash.

6 Meeting Site, Transportation and Accommodations

The Double Tree Hotel is located at 101 South Adams Street, in Tallahassee, Florida. The closest airport is Tallahassee Regional Airport (TLH) and the Double Tree Hotel provides an airport shuttle service upon prior request.

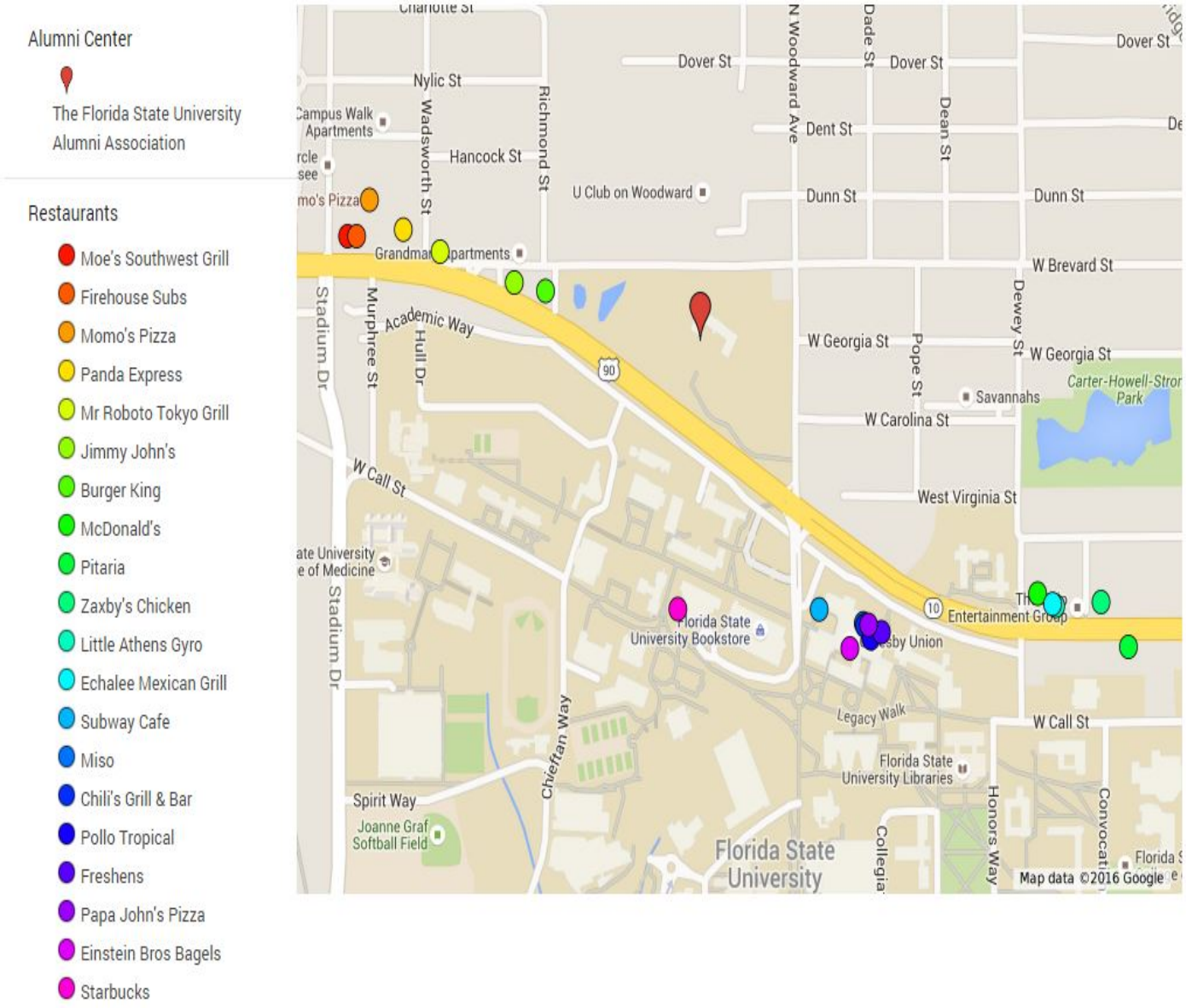
The conference venue can be easily reached from the Double Tree Hotel by public transportation. C. K. Steele Plaza – the main bus terminal – is a five minute walk from the hotel:

https://www.talgov.com/starmetro/CKSteelePlazaGateMap.aspx

The Star Metro Azalea (A) Route leaves C. K. Steele Plaza every 30 minutes from Gate 15 starting at 6:30 AM. The Canopy (C) Route leaves from Gate 3 every 35 minutes starting at 6:15 AM. The bus stop close to the Alumni Center is at the intersection of W Tennessee St and N Woodward Ave close to the Co-Cathedral of St. Thomas More. A single ride is $1.25.

Transportation from the conference site will be provided for the Wakulla Springs trip on Wednesday and to the reception/wine tasting social on Thursday. Parking is available for conference participants at the Alumni Center.

7 Some of the Restaurants near the Alumni Center



8 Wine Tasting Social

Continuing traditions, you are warmly invited to bring with you a bottle of wine from your own country. Please bring your bottle of wine to the registration check-in table on Monday or Tuesday. The conference staff will kindly store the wine for the Thursday reception/wine tasting social at the Florida State Capital Building.

9 Excursion

After lunch on Wednesday, we will board buses for an excursion to Wakulla Springs. The buses will leave from the Alumni Center at 2:00 PM and return to the Double Tree Hotel in the evening. We will enjoy a river boat ride and alligator watch on the Wakulla River. The day will end in the Wakulla Springs Lodge with a reception.

Wakulla Springs has been well known to paleontologists since approximately 1850 when the skeletal remains of a mastodon were recovered from the spring. The bottom of the spring bowl and floors of the immense underwater caverns that feed the spring are littered with the fossilized bones of giant sloth, giant armadillos, camels, and other ancient visitors. Swimming is a popular activity during the hot summer months, but with 70 degrees constant water temperature year round, Wakulla Spring's water offers visitors year round swimming enjoyment. The Springs have been the location for a number of movies, including the Creature from the Black Lagoon and some of the Tarzan movies.

The late afternoon reception will be held at the historic Wakulla Springs Lodge overlooking the spring. Wakulla Springs and Lodge is listed on the Natural Register of Historic Places and is designated as a National Natural Landmark.

Program

Monday 16th May 2016

08:00-09:00	Registration	
09:00-09:10	Welcome by the Dean of the FSU College of Arts and Sciences	Sam Huckaba
09:10-09:30	Opening Remarks	Volker Crede
09:30-10:30	**Plenary Session I (Grand Ballroom)**	
09:30	Hadronic Physics in the NSAC Long Range Plan	Donald Geesaman
10:00	Electroexcitation of Nucleon Resonances	Ralf Gothe
10:30-11:00	**Coffee Break**	
11:00-12:30	**Plenary Session II (Grand Ballroom)**	
11:00	Status and Future of PWA in Baryon Spectroscopy	Michael Doring
11:30	Baryon Spectroscopy in Photonuclear Reactions	Jan Hartmann
12:00	Baryons from the chiral Lagrangian with three light flavors	Matthias Lutz
12:30-14:00	**Lunch**	
14:00-16:10	**Parallel Sessions**	
See timetables	EM and Weak Interactions I	Cottrell Conference Room
	Hadron Spectroscopy I: Light-Flavor Baryons	Rendina Room
	Hadron Structure I	Pearl Tyner House
16:10-16:30	**Coffee Break**	
16:30-18:10	**Parallel Sessions**	
See timetables	Hadron-Hadron Interactions I	Cottrell Conference Room
	Hadron Spectroscopy II: Light-Flavor Baryons	Rendina Room
	Hadron Structure II	Pearl Tyner House

Tuesday 17th May 2016

09:00-10:30	**Plenary Session III (Grand Ballroom)**	
09:00	Spectroscopy of Strange Baryons: Future Perspectives	Albrecht Gillitzer
09:30	Photoproduction of Hyperons with Linear Polarised Photons at CLAS	Bryan McKinnon
10:00	The Spectrum and Structure of Baryon Excitations from Lattice QCD	Derek Leinweber
10:30-11:00	**Coffee Break**	
11:00-12:30	**Plenary Session IV (Grand Ballroom)**	
11:00	Proton spin structure in phase space	Cedric Lorce
11:30	Nucleon tomography in momentum space: TMDs	Haiyan Gao
12:00	Study of Nucleon's Spin and parsonic dynamics with the EIC	Abhay Deshpande
12:30-14:00	**Lunch**	
14:00-16:55	**Parallel Sessions**	
See timetables	Light-Meson Decays	Cottrell Conference Room
	Physics of Hyperons	Rendina Room
	Spin Physics and Future Opportunities at the EIC	Pearl Tyner House

Wednesday 18th May 2016

09:00-10:30	**Plenary Session V (Grand Ballroom)**	
09:00	Heavy Baryons on the Lattice	Stefan Meinel
09:30	Baryon Spectroscopy at LHCb	Patrick Spradlin
10:00	Perspectives on baryons: from the inside out	Craig Roberts
10:30-11:00	**Coffee Break**	
11:00-12:45	**Parallel Sessions**	
See timetables	Hadron Spectroscopy III	Rendina Room
	Hadron Structure III	Pearl Tyner House
	Recent Approaches to Non-Perturbative QCD I	Cottrell Conference Room
12:45-14:00	**Lunch**	
14:00	Departure to Wakulla Springs	Alumni Center

Thursday 19th May 2016

09:00-10:30	**Plenary Session VI (Grand Ballroom)**	
09:00	Spectroscopy of Exotic Baryons at LHCb	Sebastian Neubert
09:30	Exotic baryons: past and future	Jean-Marc Richard
10:00	Meson and Baryon Spectroscopy at GlueX	Eugene Chudakov
10:30-11:00	**Coffee Break**	
11:00-12:30	**Parallel Sessions**	
See timetables	Hadron Spectroscopy IV: Exotic Hadrons	Rendina Room
	Hadron Structure IV: Instrumentation	Cottrell Conference Room
	Hadron Structure V: Hadron Polarizabilities	Pearl Tyner House
12:30-14:00	**Lunch**	
14:00-15:50	**Parallel Sessions**	
See timetables	Hadron Spectroscopy V: Exotic Hadrons	Cottrell Conference Room
	Hadron Spectroscopy VI	Rendina Room
	Hadron Structure VI	Pearl Tyner House
15:50-16:10	**Coffee Break**	
16:10-17:50	**Parallel Sessions**	
See timetables	Hadron Spectroscopy VII: Heavy Flavors	Pearl Tyner House
	Hadron Spectroscopy VIII	Rendina Room
	Hadron-Hadron Interactions II: Hadron Structure	Cottrell Conference Room
18:45 - 20:30	Reception at the State Capitol	

Friday 20th May 2016

09:00-10:30	**Plenary Session VII (Ballroom)**	
09:00	Superconformal baryon-meson symmetry and light front holographic QCD	Hans Guenter Dosch
09:30	Parity Violation in Deep Inelastic Scattering at Jefferson Lab	Xiaochao Zheng
10:00	Elastic form factors and the proton radius	John Arrington
10:30-11:00	**Coffee Break**	
11:00-12:30	**Plenary Session VIII (Ballroom)**	
11:00	The $\Lambda(1405)$ and new non ordinary baryons	Eulogio Oset
11:30	The Qweak Experiment: Direct Measurement of the Proton's Weak Charge	Anna Lee
12:00	Baryon Spectroscopy and Structure - An Outlook	Volker Burkert

Parallel Sessions - Monday 16th May 2016

EM and Weak Interactions I 14:00-16:10 (Cottrell Conference Room)

14:00	Probes of CP-violation and rare decays in the heavy flavour sector at ATLAS	Soeren Prell
14:30	Λ_c decays at BESIII	Xiao Dong
14:55	Form factors and decays width of Λ_c semileptonic decay in constituent quark model	Md Mozammel Hussain
15:20	Interference effect between ϕ and $\Lambda(1520)$ production channels in the $\gamma p \to K^+K^-p$ reaction near threshold	Sun Young Ryu
15:45	b-baryon decays at LHCb - CANCELLED	Jinlin Fu

Hadron Spectroscopy I: Light-Flavor Baryons 14:00-16:10 (Rendina Room)

14:00	Polarization Observables in Vector-Meson Photoproduction off Transversely-Polarized Protons at CLAS	Priyashree Roy
14:30	Complete Experiments in pseudoscalar meson photoproduction	Yannick Wunderlich
14:55	Photoproduction of mesons off the neutron	Bernd Krusche
15:20	Polarization Observable E in π^+ Photoproduction from FROST	Steffen Strauch
15:45	Photoprodution of ω Mesons Using CLAS at Jefferson Laboratory	Zulkaida Akbar

Hadron Structure I 14:00-16:10 (Pearl Tyner House)

14:00	Two-photon exchange in proton elastic scattering	Jan Christopher Bernauer
14:30	Photon electroproduction at Jefferson Laboratory-Hall A	Maxime Defurne
14:55	Exclusive Single Pion Electroproduction off the Proton: Recent Results from CLAS	Kijun Park
15:20	Wide Angle Compton Scattering using a Compact Photon Source	Gabriel Niculescu
15:45	New results on nucleon resonance analysis of the $\gamma_v p \to \pi^+\pi^- p$ cross sections in the second and third resonance regions	Ralf Gothe

Hadron Spectroscopy II: Light-Flavor Baryons 16:30-18:10 (Rendina Room)

16:30	Photoproduction of $\pi^-\Delta^{++}$ and $\pi^+\Delta^0$ on the proton for comparing $\bar{u}u$ and $\bar{d}d$ productions at LEPS/SPring-8	Hideki Kohri
16:55	Polarization observables in double-pion photo-production with circularly polarized photons off transversely polarized protons	Lelia Net
17:20	Determination of the Spin Triplet $p\Lambda$ Scattering Length from the Reaction $\vec{p}p \to pK^+\Lambda$	Florian Hauenstein
17:45	Measurement of Polarization Observables for the recoil hyperon Λ in the reaction $\gamma p \to K^+\Lambda$ for energies up to 5.45 GeV	Shankar Adhikari

Hadron Structure II 16:30-18:10 (Pearl Tyner House)

16:30	First Rosenbluth separation on π^0 at Jefferson Laboratory-Hall A	Maxime Defurne
16:55	Studies of Strange Sea distribution functions using Kaons with CLAS12	Faitha Benmokhtar
17:20	Measurement of Proton Spin Structure Function g_2 at Low Q^2	Jie Liu
17:45	Proton Form Factor Ratio G_E/G_M from the Double Spin Asymmetry	Anusha Liyanage

Hadron-Hadron Interactions I 16:30-18:10 (Cottrell Conference Room)

16:30	Forward-backward asymmetries in the production of Λ, Ξ, and Ω baryons in proton-antiproton collisions	Bruce Hoeneisen
16:55	Baryonic forces from SU(3) chirial effective field theory	Stefen Petschauer
17:20	Baryonic b decays at LHCb - CANCELLED	Christian Voss

Parallel Sessions - Tuesday 17th May 2016

Light-Meson Decays 14:00-16:55 (Cottrell Conference Room)

14:00	An overview of light meson decays	Karol Kampf
14:30	Hadron Physics at KLOE/KLOE-2	Elena Perez Del Rio
15:00	Measuring e/m transition form factors of light mesons with the A2 setup at MAMI	Sergey Prakhov
15:30	Radiative and Hadronic Decay modes of the η-Meson with CLAS and WASA-at-COSY	Daniel Lersch
16:00	The GlueX/JEF program in Hall D at Jefferson Lab	Simon Taylor
16:30	Conversion Decays of Light Mesons	Susan Schadmand

Physics of Hyperons 14:00-16:30 (Rendina Room)

14:00	Production of hyperons and charmed baryons	Atsushi Hosaka
14:30	Toward a K_L beam in Hall D at Jefferson Lab	Simon Taylor
15:00	Ξ Baryon Spectroscopy with Kaon Beams	Megumi Naruki
15:30	Understanding the basic features of Ξ photoproduction	Kanzo Nakayama
16:00	Ξ and Ω Spectroscopy at Jefferson Lab	Lei Guo

Spin Physics and Future Opportunities at the EIC 14:00- 16:00 (Pearl Tyner House)

14:00	The Structure of the Neutron and the BoNuS Experiment	Gabriel Niculescu
14:30	Physics with polarized beams at the EIC and detector designs	Nils Feege
15:00	Recent progress on TMD study and future perspective at the EIC	Zhongbo Kang
15:30	Physics with nuclei at an electron-ion collider	Oleg Eyser

Parallel Sessions - Wednesday 18th May 2016

Hadron Spectroscopy III 11:00-12:45 (Rendina Room)

11:00	Understanding the Nucleon as a Borromean Bound-State	Jorge Segovia
11:30	Strangeness photoproduction at the BGO-OD experiment	Thomas Jude
12:55	Partial-Wave Analysis of the Reactions $\gamma p \to \eta p$, $\gamma n \to \eta n$, and $\gamma p \to K^+\Lambda$ in a Multichannel Framework	Brian Hunt
12:20	$\gamma n \to p\pi^-$ Cross Section Measurement at CLAS	Paul Mattione

Hadron Structure III 11:00-12:45 (Pearl Tyner House)

11:00	Impact of ATLAS measurements on the knowledge of the Proton structure	Gwenlan Claire
11:30	Light-cone QCD sum rules for soft contribution to exclusive Drell-Yan process $\pi^- p \to \mu^+\mu^- n$	Kazuhiro Tanaka
11:55	Measuring nucleon TMD spin-momentum correlations via Drell-Yan at Fermilab E906/E1039 SeaQuest Experiment	Kleinjan David
12:20	A Solution to the Proton Radius "Puzzle"	Blaine Norum

Recent Approaches to Non-Perturbative QCD I 11:00-12:45 (Cottrell Conference Room)

11:00	Hadron-hadron scattering and hadron spectroscopy from lattice QCD	John Bulava
11:30	Three-flavor chiral effective model with four baryonic multiplets	Miklós Zétényi
11:55	Baryon Chiral Perturbation Theory with 1/Nc expansion: masses and form factors of the baryon octet and decuplet - CANCELLED	Ishara Fernando
12:20	$\Delta(1232)$ resonance in the $\gamma p \to p\pi^0$ reaction at threshold	Astrid Hiller Blin

Parallel Sessions - Thursday 19th May 2016

Hadron Spectroscopy IV: Exotic Hadrons 11:00-12:30 (Rendina Room)

11:00	Hadron Spectroscopy with COMPASS	Johannes Bernhard
11:30	Meson Spectroscopy at CLAS	Alexander Ostrovidoc
12:00	$\Lambda(1405)$ Photoproduction at MAMI	Dominik Werthmueller

Hadron Structure IV: Instrumentation 11:00-12:30 (Cottrell Conference Room)

11:00	The international project FAIR: A status overview	Diana Nicmorus
11:30	The Charged Life of HDice at Jefferson Lab	Charles Hanretty
12:00	Tensor Polarized Deuteron at Jefferson Lab	Elena Long

Hadron Structure V: Hadron Polarizabilities 11:00-12:30 (Pearl Tyner House)

11:00	Recent results from the Crystal Ball/TAPS experiment at MAMI	Vahe Sokhoyan
11:30	Hyperon foward spin polarizability γ_0 in baryon chiral perturbation theory	Astrid Hiller Blin

Hadron Spectroscopy V: Exotic Hadrons 14:00-15:50 (Cottrell Conference Room)

14:00	Searching for the d* Dibaryons with CLAS	Paul Mattione
14:30	The Observation of the Di-Baryon in the Proton-Neutron System - Hexaquark or Molecule?	Mikhail Bashkanov
15:00	Search for the H-dibaryon in the (K^-, K^+) reaction	Jung Keun Ahn
15:25	Search for Hybrid Baryons with CLAS12 at JLAB	Lucilla Lanza

Hadron Spectroscopy VI 14:00-15:50 (Rendina Room)

14:00	Model discrimination in pseudoscalar-meson photoproduction	Jan Ryckebusch
14:30	An Update on JPAC activities	Vladyslav Pauk
15:00	Determination of T and F observables in η photoproduction on the CLAS Frozen Spin Target (FROST)	Ross Tucker
15:25	Measurement of the double polarization observables E and G at the Crystal Ball experiment at MAMI	Farah Noreen Afzal

Hadron Structure VI 14:00-15:50 (Pearl Tyner House)

14:00	Measurement of polarization transferred to a proton bound in nuclei	Eli Piasetzky
14:30	New results on spin structure functions at very low momentum transfers from JLab	Krishna Adhikari
15:00	Collins asymmetry and proton form factors at BESIII	Alaa Dbeyssi
15:25	Deeply Virtual Compton scattering with CLAS12	Angela Biselli

Hadron Spectroscopy VII: Heavy Flavors 16:10-17:50 (Pearl Tyner House)

16:10	Recent Belle Results on Charmed Baryon Spectroscopy and Decays	John Yelton
16:35	Basis Light-Front Quantization Approach to Heavy Quarkonium	Yang Li
17:00	Heavy flavour production and spectroscopy at ATLAS	Brad Abbott
17:25	XYZ exotic states at COMPASS	Johannes Bernhard

Hadron Spectroscopy VIII 16:10-17:50 (Rendina Room)

16:10	Baryon Spectroscopy at BESIII	Marco Destefanis
16:35	Resonance production and decay in pion induced collisions with HADES	Witold Przygoda
17:00	Angular distribution of exclusive dielectron production in pion-nucleon collisions	Enrico Speranza
17:25	Antibaryon Photoproduction using CLAS at Jefferson Lab	William Phelps

Hadron-Hadron Interactions II: Hadron Structure 16:10-17:50 (Cottrell Conference Room)

16:10	Superfast quarks in collider experiments and QCD evolution	Adam Freese
16:35	Measurement of the triple-differential cross section for photon + jet production at $\sqrt{s}$= 8 TeV with the CMS detector	Ajeeta Khatiwada
17:00	Inclusive cross section and double helicity asymmetry for π^0 production at midrapidity in p+p collisions at $\sqrt{s}$=510 GeV	Hari Guragain
17:25	A search for supersymmetry at CMS with two photons and missing transverse energy at $\sqrt{s} = 13$ TeV	Arka Santra

Plenary Session Abstracts

Plenary Sessions - Monday 16th May 2016

Hadronic Physics in the NSAC Long Range Plan

Geesaman, Donald

Hadronic Physics figures prominently in the 2015 Nuclear Science Advisory Committee's Long Range Plan, *Reaching for the Horizon*. In this talk I will summarize the goals we have set for ourselves and the vision we have to realize them in both hadronic physics and related areas.

Electroexcitation of Nucleon Resonances

Gothe, Ralf

Meson-photoproduction measurements and their reaction-amplitude analyses can establish more sensitively, and in some cases in an almost model-independent way, the nucleon excitations and non-resonant reaction amplitudes. However, to investigate the strong interaction from explored where meson-cloud degrees of freedom contribute substantially to the baryon structure to still unexplored distance scales where quark degrees of freedom dominate and the transition from dressed to current quarks occurs we depend on experiments that allow us to measure observables that are probing this evolving non-perturbative QCD regime over its full range. Transition form factors are uniquely suited to trace this evolution by measuring exclusive single-meson and double-pion electroproduction cross sections o the free proton. Recent eorts try to include their isospin dependence by analyzing the cross sections o the quasi-free neutron and proton in Deuterium. In the near future, these exclusive measurements will be extended to higher momentum transfers with the energy-upgraded CEBAF beam and CLAS12 to study the quark degrees of freedom, where their strong interaction is responsible for the ground and excited nucleon state formations. Recent and preliminary results will highlight the status of the analyses and of their theoretical descriptions, and an experimental and theoretical outlook will outline what shall and may be achieved in the new era of the 12-GeV upgraded transition form factor program.

This work is supported in part by the National Science Foundation under Grant PHY 1505615.

Status and Future of PWA in Baryon Spectroscopy

Doring, Michael

Light baryonic resonances are generally broad and overlap which makes their identification difficult. Furthermore, many resonances couple only weakly to the πN state that was traditionally the prime channel for spectroscopy. Photoproduction of one or more mesons provides access to new resonances predicted in QCD simulations, in particular through polarized measurements. The impact of new data from Jefferson Lab and other facilities will be discussed. Obtaining conclusive answers in baryon spectroscopy is a long-sought goal requiring improved statistical analysis techniques as the era of precision spectroscopy has begun.

Baryon Spectroscopy in Photonuclear Reactions

Hartmann, Jan

One of the remaining challenges within the standard model is to gain a good understanding of QCD in the non-perturbative regime. A key step towards this aim is baryon spectroscopy, investigating the spectrum and the properties of baryon resonances. To gain access to resonances with small πN partial width, photoproduction experiments provide essential information. Partial wave analyses need to be performed to extract the contributing resonances. Here, a complete experiment is required to unambiguously determine the contributing amplitudes. This involves the measurement of carefully chosen single and double polarization observables. In a joint endeavor by JLab, MAMI in Mainz, and ELSA in Bonn, a new generation of experiments with polarized beams, polarized proton and neutron targets, and 4π particle detection have been started in recent years. Many results of unprecedented quality were recently published by all three experiments, and included by the various partial wave analysis groups in their analyses, leading to substantial improvements, e.g. a more precise determination of resonance parameters. In this talk, an overview of recent results in non-strange reactions is given, and their impact on our understanding of the nucleon excitation spectrum is discussed.

Baryons from the chiral Lagrangian with three light flavors

Lutz, Matthias

In this talk I will review applications of the three-flavor chiral Langrangian with the baryon octet and decuplet fields. On the one hand coupled-channel approaches are known to successfully grasp some baryon resonance properties with $J^P = 1/2^-$ and $3/2^-$ quantum numbers. On the other hand the quark-mass dependence of the baryon ground-state masses with $J^P = 1/2^+$ and $3/2^+$ can be computed and compared to QCD lattice simulations. It is argued that the two issues are intimately related and reliable computations should rest on a universal parameter set. An accurate reproduction of the available QCD lattice data on the ground-state baryon masses is achieved. The number of unknown parameters is reduced significantly by sum rules that follow from QCD in the limit of a large number of colors.

Plenary Sessions - Tuesday 17th May 2016

Spectroscopy of Strange Baryons: Future Perspectives

Gillitzer, Albrecht

Understanding the excitation pattern of baryons is a prerequisite for a deeper insight in the properties of the strong interaction in the non-perturbative regime. The baryon spectroscopy programs at various laboratories based on photo-induced reactions in the recent years was very successful in enlarging our knowledge of the nucleon and Δ excitation spectrum, after, for many years, the data base had been essentially determined by results obtained in inelastic pion-nucleon collisions. On the other hand, in the sector of strange (Λ, Σ) and multi-strange (Ξ, Ω) baryons, the last decades have not seen any substantial experimental progress. Looking at the data base of excited Ξ and Ω states, we find that very little (in case of Ξ) or almost nothing is known (in case of Ω). In a constituent quark model picture, however, according to approximate SU(3) flavor symmetry, one would expect corresponding partner states of the known N and Δ states in the Ξ spectrum (and of the Δ states in the Ω spectrum). Proving or excluding the existence of these states will be important for understanding which degrees of freedom - three-quark, quark-diquark, or meson-baryon dynamics - are relevant for the baryonic excitation pattern. The presentation will give an overview showing the current knowledge of strange baryon resonances, and discuss different approaches to access in particular Ξ and Ω excited states in current and in planned experiments.

Photoproduction of Hyperons with Linear Polarised Photons at CLAS

McKinnon, Bryan

The discrepancy between quark model predictions of nucleon excited states and those observed by experiment is further highlighted by recent Lattice QCD calculations. Searches for such missing resonances require detailed partial wave analysis, which in turn require high statistics polarisation observable measurements over a large kinematic range. As part of the N* programme with CLAS at Jefferson Lab, KY photoproduction plays an important role towards the extraction of the complete set of such observables with sufficient precision. This talk will highlight some recent CLAS measurements from experiments utilising linear polarised photon beams. Particular emphasis will be placed upon the reactions $\gamma p \to K\Lambda$ and $\gamma p \to K\Sigma$ from which the photon beam asymmetry Σ, target asymmetry T and the double polarisation observables Ox and Oz were extracted.

The Spectrum and the Structure of Baryon Excitations from Lattice QCD

Leinweber, Derek

This presentation will focus on the low-lying even- and odd-parity excitations of the nucleon and the $\Lambda(1405)$ as obtained in today's lattice QCD calculations. Commencing with a survey of the literature we'll review how results for the first even-parity nucleon excitation energy have differed by as much as 1 GeV, a rather unsatisfactory situation. Following a brief review of the methods used to isolate excitations of the nucleon in lattice QCD, and drawing on recent advances, we'll see how a consensus on the low-lying spectrum has emerged among many different lattice groups. To provide insight into the nature of these states we'll explore the wave functions and electromagnetic form factors that are available for a few of these states. Here the strange magnetic form factor of the $\Lambda(1405)$ is of particular interest, signaling an internal structure dominated by a $\bar{K}N$ molecular bound state. Having reviewed the status of lattice QCD calculations, we'll turn our attention to connecting the finite-volume results of lattice QCD to the infinite-volume results of Nature. Drawing on a simple description of the $\Lambda(1405)$ resonance, the Matrix Hamiltonian implementation of chiral effective field theory will be introduced. Consistent with the Luscher formalism for extracting phase shifts from finite volume spectra, the Hamiltonian approach can provide guidance on the manner in which physical quantities manifest themselves in the finite volume of the lattice. With this insight, we will answer the question; Have we seen the Roper in lattice QCD?

Proton spin structure in phase space

Lorce, Cedric

The internal structure of hadron can be probed in many different ways, from elastic scattering to semi-inclusive deep-inelastic scattering. Each observable reveals particular aspects of this internal structure. Relativistic phase-space distributions allow one to gather all this information in a single coherent picture, and provide a natural definition of orbital angular momentum and spin-orbit correlation. We present a short introduction to relativistic phase-space distributions and show how one can reveal the rich spin structure of the proton. As a by-product, we identified the physical meaning of all the measurable leading-twist parton distributions.

Nucleon tomography in momentum space: TMDs

Gao, Haiyan

Transverse momentum dependent parton distributions (TMDs) provide new insight about the structure of the nucleon, especially those associated with the transverse structure of the nucleon, and transverse spin. They also uncover the rich QCD dynamics, and the orbital motion and orbital angular momentum of the quarks inside the nucleon. Semi-inclusive deep-inelastic scattering (SIDIS) has proven to be an effective process to access TMDs. Such experiments have been successfully carried out at JLab during the 6-GeV era. In this talk, I will focus on the 12-GeV SoLID SIDIS program following a brief review of the 6-GeV results.

This work is supported in part by the US Department of Energy under contract number DE-FG02-03ER41231.

Study of Nucleon's spin and partonic dynamics with the Electron Ion Collider

Deshpande, Abhay

The Electron Ion Collider (EIC) was recently recommended by the US Nuclear Science Advisory Committee (NSAC) in its 2015 Long Range Planning, as the next major facility to be constructed in the US after the FRIB (the Facility for Radioactive Beams, currently under construction). The EIC will enable high-energy, high-luminosity polarized electron-polarized nucleon and unpolarized electron-nuclear collisions over a wide range in center of mass energy and nuclear species. In this talk I will focus on the potential for frontier QCD research at the EIC using its polarized beams, and elucidate how we could explore the nucleon's spin structure as well as the partonic dynamics, potentially leading to 2+1 dimensional tomographic images of the nucleon. Complementarity of the EIC with current and future facilities around the world will be discussed, while highlighting the uniqueness of EIC's abilities for this physics.

Plenary Session - Wednesday 18th May 2016

Heavy Baryons on the Lattice

Meinel, Stefan

Baryons containing charm or bottom quarks are interesting systems in QCD because their dynamics is constrained by approximate heavy-quark symmetries. Furthermore, weak decays of heavy baryons play an increasingly important role for flavor physics. I will present recent lattice QCD results for the spectrum, structure, and decays of charm and bottom baryons.

Baryon Spectroscopy at LHCb

Spradlin, Patrick

The LHCb experiment at the CERN Large Hadron Collider is collecting the world's largest sample of charm and beauty hadrons with a detector that is tailored for precision measurements of their properties. LHCb is actively exploiting its unique data set to investigate the relatively unexplored field of the physics of heavy baryons. This talk will present selected recent results from the LHCb experiment with a focus on the spectroscopy and properties of beauty baryons.

Perspectives on baryons: from the inside out

Roberts, Craig

The last three years have seen significant developments in our understanding of the internal structure of ground- and excited-state baryons and the influence this has on their interactions with electromagnetic probes. That progress has been driven by feedback between experiment and theory, and constructive interactions between diverse theoretical methods. In particular, an accumulation of evidence suggests that many features of the baryon spectrum and interactions can be explained by the existence of tight but nonpointlike diquark correlations within baryons, whose formation is driven by the same mechanism that produces both an unnaturally light pion and simultaneously a heavy constituent-quark. This presentation will provide a snapshot of contemporary theory relating to these themes.

Plenary Session - Thursday 19th May 2016

Spectroscopy of Exotic Baryons at LHCb

Neubert, Sebastian

The LHCb experiment is designed to study the decays and properties of heavy flavoured hadrons produced in the forward region from pp collisions at the CERN Large Hadron Collider. During Run1, it has recorded the worlds largest data sample of beauty and charm hadrons, enabling precise studies into the spectroscopy of such particles. The unique sample of Λ_b baryon decays has led to the discovery of a new class of exotic resonances in the $J/\psi\, p$ system. The status and latest results of the investigations into these pentaquark states will be presented.

Exotic baryons: past and future

Richard, Jean-Marc

A review of exotic baryons is presented, from the early speculations on Z-baryons in the 60s to the recent pentaquarks with hidden-charm. The phenomenological pictures are compared and commented. Some suggestions will be given for further experimental and theoretical studies.

Meson and Baryon Spectroscopy at GlueX

Chudakov, Eugene

The commissioning of the GlueX experiment in Hall D at Jefferson Lab has been completed and the the first physics run is scheduled for the Fall of 2016. The primary goal of the experiment is a search for gluonic excitation in the spectra of light mesons. Recent theoretical developments using Lattice QCD predict hybrid states, including those with exotic quantum numbers. Such states, if established, would provide a laboratory for testing QCD in the confinement regime. The experiment is using a beam of linearly polarized photons produced by the electron beam from the linear accelerator. A new, solenoid-based, hermetic detector is collecting data on meson production and decays. At the second stage of running, after 2018, the spectrometer will be equipped with an additional detector for particle identification. This will allow also to study the spectroscopy of strange baryons. For a more distant future, a possibility to build a beam of K-long mesons in the same beam line is being discussed. Such a beam would add new capabilities for doing strange-baryon spectroscopy. A description of the research program, the apparatus, and the commissioning results will be presented.

Plenary Sessions - Friday 20th May 2016

Superconformal baryon-meson symmetry and light front holographic QCD

Dosch, Hans Guenter

An effective QCD light front Hamiltonian for all light hadrons is constructed by embedding superconformal quantum mechanics into AdS space. The specific breaking of conformal symmetry inside the graded algebra determines uniquely the effective confinement potential. The generalized supercharges connect the meson and baryon light front wave functions and reproduce the characteristic features of the spectra. All light hadron masses are reproduced with an accuracy better than 10 percent.

Parity Violation in Deep Inelastic Scattering at Jefferson Lab

Zheng, Xiaochao

Sixty years after the first discovery of parity violation in electroweak interactions, parity-violating electron scattering (PVES) has become a tool not only in establishing the Standard Model of electroweak physics and studying the subatomic structure of the nucleon, but also in exploring possible new physics beyond the Standard Model. In this talk, I will present the physics of Parity Violation in Deep Inelastic Scattering (PVDIS), focusing on recent results from Jefferson Lab using the 6 GeV electron beam. I will also give a brief outlook of the PVDIS program using the 12 GeV Jefferson Lab and the Solenoid Large Intensity Device (SoLID). At the end of the talk I'd like to keep the perspective that as we progress more and more towards a thorough understanding of electroweak physics, we may also want to investigate how parity violation could affect our everyday life.

Elastic form factors and the proton radius

Arrington, John

A new generation of measurements utilizing polarization degrees of freedom in electron scattering has dramatically improved our picture of the nucleon form factors, providing clearer pictures of the short-distance structure of the proton and neutron. In more recent years, there has been renewed interest in low-Q^2 measurements which focus on the nucleons large-scale structure including the charge and magnetic radii of the proton. Differences between these results and new measurements of the atomic levels in muonic hydrogen, have given us the proton radius puzzle, which is attracted intense interest. I will give an overview of the new insight that has been gained from these measurements, present an update on recent results, and discuss future plans to further improve our detailed understanding of nucleon structure and to resolve the proton radius puzzle.

This work was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract DE-AC02-06CH11357.

The $\Lambda(1405)$ and new non ordinary baryons

Oset, Eulogio

I shall give an overview of past and recent work on the Lambda(1405) to show its "extraordinary" nature, beyond the qqq picture, and the present status. Then will show results for the Lambda$_b$ $\to$ J/psi K$^-$ p reaction comparing with LHCb data and how the complementary Lambda$_b$ $\to$ J/psi pi Sigma reaction filters isospin zero and is a good tool to provide extra information on the Lambda(1405). This issue will connect with the recent pentaquarks discovered by the LHCb collaboration and I shall elaborate on them from the theoretical point of view, making predictions for new pentaquark states of meson-baryon molecular nature.

The Qweak Experiment: Direct Measurement of the Proton's Weak Charge

Lee, Anna

The Standard Model makes a definite prediction for the neutral weak charge of the proton; any deviation from this value would be a signature of physics beyond the Standard Model. The Qweak experiment, performed over the course of 2.5 years at Jefferson Lab, will obtain a precision measurement of the weak charge by determining the magnitude of the parity-violating asymmetry in elastic scattering of the 1.1 GeV longitudinally polarized electron beam with a low momentum transfer of $Q^2 = 0.025\,(GeV/c)^2$. The experimental apparatus and technical challenges will be explained and the process of extracting the weak charge will be described. The result from a small subset of the data has been published and will be discussed. There will also be an update on the status of the current analysis of the full dataset, and descriptions of several ancillary measurements taken during the experimental run.

Baryon Spectroscopy and Structure - An Outlook

Burkert, Volker

Parallel Session Abstracts

EM and Weak Interactions I - Monday

Probes of CP-violation and rare decays in the heavy flavour sector at ATLAS

Prell, Soeren

We present the results on CP-violation searches in the Bs system, studied in the decay into J/psi phi, and the Bd system through the comparison of the decay time distributions in the flavour specific state J/psi K* and in the CP eigenstate J/psi KS, both using the Run-1 LHC dataset. We additionally present new results in the search for the rare decays of Bs and Bd into mu+mu-. Such processes involve FCNC transitions in b-hadron decays, suppressed in the standard model, and are sensitive to new physics contributions. These searches are based on the full sample of data collected by ATLAS at 7 and 8 TeV collision energy. The consistency with the SM and with other available measurements is discussed.

Λ_c decays at BESIII

Dong, Xiao

Λ_c is a charmed baryon which is interesting and can produce many chances to test the Standard Model or find new physics. The BESIII detector has accumulated 567 pb^{-1} data at the center-of-mass energy of 4.599 GeV, which is the worlds largest e^+e^- collision sample at the Λ_c pair threshold. By analyzing this data sample, we report the determinations of the absolute branching fractions of Λ_c^+ semi-leptonic decay into $\Lambda e^+\nu_e$, and 12 hadrnoic decays of pK_s, $pK^-\pi^+$, $pK_s\pi^0$, $pK_s\pi^+\pi^-$, $\Lambda\pi^+$, $\Lambda\pi^+\pi^0$, $\Lambda\pi^+\pi^+\pi^-$, $pK^-\pi^+\pi^0$, $\Sigma^0\pi^+$, $\Sigma^+\pi^0$, $\Sigma^+\pi^+\pi^-$ and $\Sigma^+\omega$. The precisions of these absolute branching fractions for these decays are improved signficantly.

Form factors and decay width of Λ_c semileptonic decay in constituent quark model

Hussain, Md Mozammel

The form factors for semileptonic decay, $\Lambda_c \to \Lambda^* l\nu_l$ has been calculated in constituent quark model. Different excited states of Λ^* has been studied. The heavy quark effective theory has been employed to compare numerical results for form factors. The decay width and branching fraction of the decay, $\Lambda_c \to \Lambda^* l\nu_l \to \Sigma\pi l\nu_l$ has been calculated for various excited states of Λ.

Interference effect between ϕ and $\Lambda(1520)$ production channels in the $\gamma p \to K^+K^-p$ reaction near threshold

Ryu, Sun Young

The $\phi - \Lambda(1520)$ interference effect in the $\gamma p \to K^+K^-p$ reaction has been measured for the first time in the energy range from 1.673 to 2.173 GeV at LEPS/SPring-8. The relative phases between ϕ and $\Lambda(1520)$ production amplitudes were obtained in the kinematic region where the two resonances overlap. The measurement results support strong constructive interference when K^+K^- pairs are observed at forward angles, but destructive interference for proton emission at forward angles. Furthermore, the observed interference effect does not account for the $\sqrt{s} = 2.1$ GeV bump structure in forward differential cross sections for ϕ photoproduction. This fact suggests possible exotic structures such a hidden-strangeness pentaquark state, a new Pomeron exchange and rescattering processes via other hyperon states.

b-baryon decays at LHCb

Fu, Jinlin

The decays of b-baryons to charmless final states proceed via suppressed $b \to u$ tree and $b \to s, d$ penguin diagrams and thus are sensitive to physics beyond the Standard Model. Relevant observables to study are branching fractions, CP asymmetries triple-product asymmetries. Unexpected values of these observables have the potential to reveal New Physics. Moreover the sector is almost unexplored and peculiar to LHCb. In this work we present the latest results in the study of b-baryon decays performed by LHCb using the data sample collected during the first run of the LHC.

Hadron Spectroscopy I: Light-Flavor Baryons - Monday

Polarization Observables in Vector-Meson Photoproduction off Transversely-Polarized Protons at CLAS (On behalf of the CLAS Collaboration)

Roy, Priyashree

Studying the baryon spectrum is essential to understand the theory of the strong force, Quantum Chromodynamics (QCD), in the non-perturbative regime and to answer elementary questions such as what are the effective degrees of freedom inside baryons. Lately, photoproduction experiments have played a vital role in the understanding of the light baryon spectrum. But the spectrum is inadequately understood, particularly above 1.7 GeV c.m. energies where many resonances have been predicted by the constituent quark model as well as Lattice QCD calculations but have not yet been experimentally confirmed. It is anticipated that these resonances may predominantly couple to vector-mesons (ω, ρ, ϕ) and two-pion final states. These decay modes have been poorly explored in the past. The FROST (FROzen Spin butanol Target) experiment conducted in 2010 at Jefferson Lab using the CLAS detector, with center-of-mass energies between 1.5 and 2.3 GeV, has provided a good opportunity to study these decay modes. Here we report on preliminary results from the FROST experiment on the polarization observables for $\vec{\gamma}\vec{p} \to p\omega \to p\pi^+\pi^-(\pi^0)$ using transversely-polarized protons. Furthermore, preliminary results on the polarization observables for $\pi^+\pi^-$ photoproduction using linearly-polarized photons and transversely-polarized protons will be discussed. The latter reaction will give important information on the intermediate resonances that are involved in sequential decays to multipion final states as well as on the decay modes of the resonances to the ρ vector-meson. Many observables presented here are first-time measurements and are expected to provide further constraints to identify the contributing baryon resonances to these final states.

Complete Experiments in pseudoscalar meson photoproduction

Wunderlich, Yannick

The determination of the nucleon excitation spectrum remains one of the long standing challenges towards an understanding of non-perturbative QCD. The reaction of pseudoscalar meson photoproduction, $\gamma N \to MB$, poses an interesting field of study since it can potentially open a window to new baryon resonances, which have escaped observation in pion induced reactions. The spin structure of photoproduction results in 16 accessible polarization observables. The so-called 'Complete Experiment' problem investigates which subsets of the 16 observables are sufficient in order to determine the underlying amplitudes (e.g. 4 helicity amplitudes H_i) up to an overall phase. Chiang and Tabakin have found a mathematical solution to this problem, stating that generally 8 observables can fulfill this purpose. The Complete Experiment refers here to an investigation in each kinematic bin, energy and angle (W, θ), individually. If a truncated partial wave analysis is done with the goal of determining multipoles, the θ-distributions of the observables are utilized. In this case, less than 8 observables can already be sufficient to uniquely determine the multipoles (this is deducible from work done by Omelaenko in the 80s). The presentation will first treat the completeness problem for truncated partial wave analyses and then show preliminary results for an analysis of the process $\gamma p \to \pi^0 p$, using as input 7 polarization observables measured in the second resonance region. Supported by the Deutsche Forschungsgemeinschaft (SFB/TR16).

Photoproduction of mesons off the neutron

Krusche, Bernd

Photoproduction of mesons has recently dominated the spectroscopy of of excited nucleon states. In particular, the accessibility of single and double polarization observables has given much momentum to this field. Results from the major facilities (CLAS at Jlab, ELSA in Bonn, and MAMI in Mainz) had large impact on the partial wave analyses of many different reactions and thus on our knowledge of the nucleon excitation spectrum. The vast majority of the experiments studied photoproduction off free protons. However, results from reactions off the neutron target are also required to fix the isospin structure of the photonuclear couplings. The experimental setups at the MAMI (Mainz) and ELSA (Bonn) accelerators based on almost 4π covering electromagnetic calorimeters are particularly well suited for the study of such reactions. The detectors allow to detect and identify photons from the decay of neutral mesons, charged pions, and also recoil protons and neutrons. In contrast to experiments based on magnetic spectrometry they are thus capable to identify also reactions with purely neutral final states such as $\gamma n \to n\pi^0, n\eta, n\pi^0\pi^0, n\pi^0\eta ...$. Reactions with neutral mesons in the final state are of particular interest because non-resonant background contributions are much smaller than for charged mesons. During the last few years from both facilities results for total and differential cross sections and some results for beam-helicity asymmetries for three-body final states have been reported for the above mentioned reactions. The recently published data on the $n\pi^0$ and $n\eta$ final states demonstrate clearly the importance of measurements with neutron targets.

In case of single pion production cross section data for all other isospin channels ($p\pi^0$, $p\pi^-$, $n\pi^+$) were already available and since only three independent isospin amplitudes are involved this should be sufficient to fix the isospin structure completely. Nevertheless, different partial wave analyses predicted much different results for the $n\pi^0$ state and actually none of them agreed with the new $\gamma n \to n\pi^0$ data, which had significant impact on the isospin decomposition. The data for η production off the neutron revealed a prominent, narrow (less than 50 MeV wide) structure in the excitation function around incident photon energies of 1 GeV (statistical significance beyond any doubts), which does not exist for the proton. Many different scenarios have been discussed for it. Very recently, a second narrow structure around W=1720 MeV (which had been previously identified in Compton scattering off the proton) was identified. Currently, these measurements have reached a new level of sophistication with the measurement of double polarization observables for reactions off the quasi-free neutron. Most recent results for such observables will be reported from experiments using circularly polarized photon beams and longitudinally and transversely polarized targets. Among the results are the first split of the cross section of the $\gamma n \to n\eta$ reaction into its helicity-1/2 and 3/2 parts (clearly demonstrating that the prominent narrow structure is in helicity 1/2), helicity contributions to single and double π^0 production (all in preparation for publication) and preliminary results for the T and F asymmetries for $n\eta$, $n\pi^0$, and $n\pi^0\pi^0$ final states.

Polarization Observable E in π^+ Photoproduction from FROST

Strauch, Steffen

The spectrum of nucleon excitations is dominated by broad and overlapping resonances. Polarization observables in photoproduction reactions are key in the study of these excitations. They give indispensable constraints to partial-wave analyses and help clarify the spectrum. First results from the longitudinally-polarized frozen-spin target (FROST) program are reported. The double-polarization observable E, for the reaction $\vec{\gamma}\vec{p} \to \pi^+ n$, has been measured using a circularly-polarized tagged-photon beam, with energies from 0.35 to 2.37 GeV. The final-state pions were detected with the CEBAF Large Acceptance Spectrometer in Hall B at the Thomas Jefferson National Accelerator Facility. These polarization data agree fairly well with previous partial-wave analyses at low photon energies. Over much of the covered energy range, however, significant deviations are observed, particularly in the high-energy region where high-L multipoles contribute. The data have been included in new multipole analyses from the Bonn-Gatchina, Jlich-Bonn, and SAID groups.

Photoproduction of ω Mesons Using CLAS at Jefferson Laboratory

Akbar, Zulkaida

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. one of the vector mesons, ρ, ω, ϕ. Therefore, vector-meson studies are important to search for the so-called *missing baryon resonances*. Photoproduction of ω mesons was studied using the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab. Two observables have been measured from the reaction $\gamma p \to p\omega$: The differential cross section and the double-polarization observable E. The differential cross section measurement was performed using circularly-polarized photons produced from bremstrahlung of longitudinally-polarized electrons with energies of 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 a longitudinally-polarized frozen-spin butanol target. 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 ω mesons and also the scaling behaviour 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.

Hadron Structure I - Monday

Two-photon exchange in proton elastic scattering

Bernauer, Jan Christopher

Recent interest in the proton electromagnetic form factors is partly motivated by the discrepancy found in the determination of the electric-to-magnetic form factor ratio using different techniques. Results from scattering experiments using the Rosenbluth technique indicate that the form factor ratio is approximately constant as a function of Q^2 while experiments employing polarization show a clear, roughly linear, decline of the ratio. A possible explanation is the typically unaccounted for contribution of hard two-photon exchange to the scattering process. Theoretical calculations show large variations, many indicating an effect of the right sign and magnitude. Direct verification was sought by experiments at VEPP-3, Jefferson Lab and by the OLYMPUS collaboration at DESY. In the talk, I will discuss the OLYMPUS experiment and the current state of experimental and theoretical results.

Photon electroproduction at Jefferson Laboratory-Hall A

Defurne, Maxime

We will review the experimental program dedicated to photon electroproduction running in the Hall A of Jefferson Laboratory. First we will talk about the latest results of the E00-110 experiment running in 2004, published in Phys.Rev.C last year. Then we will present new results of photon electroproduction cross sections in the valence region ($x_{Bj} = 0.36$) at three Q^2-values (1.5, 1.75 and 2 GeV^2) from the E07-007 experiment which was running in 2010. Unlike the E00-110 experiment, each kinematical setting was run with two beam energies. It allows, for the first time, to perform a Rosenbluth separation on the photon electroproduction. These new results bring new information about the generalized parton distributions and their contributions.

Exclusive Single Pion Electroproduction off the Proton: Recent Results from CLAS

Park, Kijun

A probing the effective degrees of freedom in excited nucleon states at the varying distance scale is essential to understand the transition from the contributions of both quark core and meson-baryon cloud to the quark core dominance. Exclusive meson electroproduction off protons has been used extensively as a powerful tool. During the 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 with a broad kinematic range. In particular, several dedicated CLAS analyses using $\gamma^* p \to n\pi^+$ reaction have been utilized for the first time to explore the nucleon resonances with full range of invariant mass W from near threshold to deep inelastic scattering. As results, several low-lying nucleon resonance states have been explored including $\Delta(1232)\frac{3}{2}^+$, $N(1440)\frac{1}{2}^+$, $N(1520)\frac{3}{2}^-$, and $N(1535)\frac{1}{2}^-$ states. In addition, the recent publication showed the differential cross sections for higher W (1.6 to 2.0 GeV) and allowed to extract the $N(1675)\frac{5}{2}^-$, $N(1680)\frac{5}{2}^+$, and $N(1710)\frac{1}{2}^+$ states due to sensitivity of isospin 3/2 within the same spin-parity assignments. In this talk, I will briefly discuss these states from CLAS results and future CLAS12 N^* physics program.

Wide Angle Compton Scattering using a Compact Photon Source

Niculescu, Gabriel

Testing of the QCD-based calculations of the fundamental exclusive reactions is the subject of large interest in hadron physics. Wide Angle Compton Scattering (WACS) of photons off a polarized proton target constitutes an excellent opportunity to carry out such tests. Recently concluded data analyses based on two Jefferson Lab experiments (E99-114 and E07-002) have demonstrated the validity of the experimental technique of using untagged photon beams on a proton target, and provided high accuracy crosssection and polarization observable results (KLL) at modest values of s, u, and t. This presentation will focus on a proposal to extend these precision measurements to much larger energies. The photons will be detected by the Neutral Particle Spectrometer and the protons by the Super Bigbite Spectrometer. The experiment will use the 11 GeV JLab electron beam and a novel high intensity untagged photon source. Projected results and their impact, as well as other potential uses for the photon source developed for this experiment will be discussed.

New results on nucleon resonance analysis of the $\gamma_v p \to \pi^+\pi^- p$ cross sections in the second and third resonance regions

Gothe, Ralf

The studies of the N^* electroexcitation amplitudes, the so-called $\gamma_v pN^*$ electrocouplings, at photon virtualities $Q^2 < 5.0$ GeV^2 represent an important direction in the N^* Program with the CLAS detector at Jefferson Lab. We report new results on nine one-fold 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 1.8 GeV and at photon virtualities from 0.4 GeV^2 to 1.0 GeV^2. Due to the high statistics, the cross sections have been extracted in 0.05 GeV^2 fine Q^2-bins, which is a factor of six narrower than previously achieved [1]. Furthermore, our measurements expand the range of covered photon virtualities towards smaller values in comparison to the previous CLAS experiment [1]. These data on nine one-fold differential cross sections make it possible to establish all essential mechanisms contributing to the $\pi^+\pi^- p$ exclusive channel from their manifestations in different observables, offering a credible separation between the resonant/non-resonant contributions, which allows for a reliable extraction of the $\gamma_v pN^*$ electrocouplings as well as the N^* partial hadronic decay widths to the $\pi\Delta$ and ρp final states. We expect that the ongoing phenomenological analysis of our data within the framework of the meson-baryon reaction model JM [2,3] will improve the knowledge on $\gamma_v pN^*$ electrocouplings for states with masses above 1.6 GeV, since many of them decay preferentially to the $N\pi\pi$ final states. Resonance electrocouplings obtained from our data will offer a valuable cross-check of the resonance parameters determined from $N\pi$ electroproduction channels confronting them with the results of an independent extraction from data of another major exclusive channel. Further evidence of the existence of the new $N(1720)3/2^+$ state was recently obtained from a combined analysis of the CLAS $\pi^+\pi^- p$ photoproduction and electroproduction data [4]. The electrocouplings of the $\gamma_v pN(1720)3/2^+$ transition will be obtained from the precise electroproduction data set, which will help elucidate the internal structure of the new baryon state.

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Hadron Spectroscopy II: Light-Flavor Baryons - Monday

Photoproduction of $\pi^-\Delta^{++}$ and $\pi^+\Delta^0$ on the proton for comparing $\bar{u}u$ and $\bar{d}d$ productions at LEPS/SPring-8

Kohri, Hideki

Photoproduction reactions are dominated by isospin rules. In the case of $\pi\Delta$ photoproduction on the proton at forward π angles, the exchange of isospin=1 meson(π or ρ) 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. The cross section ratio has not been measured precisely experimentally. We present cross section ratios at E_γ=1.5-3.0 GeV for the first time. Larger ratios than 1/3 measured by our experiment at LEPS suggest that the $\bar{d}d$ productions are enhanced compared with the $\bar{u}u$ productions in the photoproduction reactions on the proton. We also present recent developments for future LEPS and LEPS2 experiments at SPring-8.

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

Net, Lelia

The study of multi-meson decay of baryon resonances serves as an important tool in understanding better the properties of nucleon excited states. Double pion photo-production is studied using transversely-polarized protons and circularly-polarized photons, with center-of-mass energies between 1.4 GeV and 2.3 GeV. Polarization observables $I^\odot, P_x^\odot, P_y^\odot, P_x, P_y$ are measured for the $\vec{\gamma}\vec{p} \to p\pi^+\pi^-$ reaction, using the data provided by the g9b (FROST) experiment at Jefferson Lab. Preliminary results will be reported and they will be compared with the calculations of an effective Lagrangian model. The data will help deepen our knowledge of hadronic resonance decays and possibly assist in identifying new baryon resonances.

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Determination of the Spin Triplet $p\Lambda$ Scattering Length from the Reaction $\vec{p}p \to pK^+\Lambda$

Hauenstein, Florian

The $\vec{p}p \to pK^+\Lambda$ reaction was measured with the COSY-TOF detector using a polarized proton beam of 2.7 GeV/c. From these data the $p\Lambda$ scattering length can be extracted from the final state interaction in the $p\Lambda$ invariant mass spectrum. Furthermore, it is possible to determine not only the spin averaged scattering length but also the spin triplet $p\Lambda$ scattering length utilizing the dependence of the Kaon analyzing power on the $p\Lambda$ invariant mass. The obtained spin triplet $p\Lambda$ scattering length set constraints for theoretical calculations of light hypernuclei and neutron stars. In this talk the extraction method as well as the results on the spin effective and spin triplet $p\Lambda$ scattering length and the Kaon analyzing power will be shown. The systematic errors of the extracted values will be discussed.

Measurement of Polarization Observables for the recoil hyperon Λ in the reaction $\gamma p \to \Lambda$ for energies up to 5.45 GeV.

Adhikari, Shankar

Polarization observables are important to understand the photoproduction mechanisms of intermediate baryon resonances. Photoproduction of Λ hyperon through the reaction $\gamma + P \to K^+ + \Lambda$ has been studied to measure polarization of recoil Λ, which is ultimately comes from circularly polarized photon beam. This analysis is performed on the data obtained using the CLAS detector at Jefferson lab for beam energy 1.117 - 5.45 GeV. This work concentrate on extracting transfer polarization coefficient C_x and C_z, and induced polarization P for beam energy higher than 3 GeV upto 5.45 GeV, where previous measurements are lacking. The goal of choosing beam energy higher than resonance production region is to extract t channel background that would eventually helps us to constrain the production models of the nucleon resonances.

Hadron Structure II - Monday

First Rosenbluth separation of π^0 at Jefferson Laboratory-Hall A

Defurne, Maxime

Although being a higher-twist contribution, the transverse response was assumed to be responsible of the large π^0 electroproduction cross sections measured by the Hall A and CLAS collaboration. However no Rosenbluth separation has been performed yet to verify this assumption. We will present new results of π^0 electroproduction cross sections in the valence region (x_{Bj}=0.36) at three Q^2-values (1.5, 1.75 and 2 GeV^2). Unlike the previous data sets, each kinematical setting was run with two beam energies. It allows to perform, for the first time, the separation of the longitudinal and transverse contributions.

Studies of Strange Sea distribution functions using Kaons with CLAS12

Benmokhtar, Fatiha

The understanding of the spin structure of the nucleon in terms of quarks and gluons has been the goal of intense investigations during the last decades. The techniques of inclusive and semi-inclusive polarized deep-inelastic scattering employed at CERN, SLAC, DESY, and Jefferson Lab have provided a wealth of information about the spin structure of the nucleon. The determination of strangeness is challenging and the only way of determining the strange distribution accurately from data is to include semi-inclusive information. This talk is focused on the determination of the strange sea contribution to the nucleon spin through the pseudo-scalar using semi-inclusive Kaon detection technique with CLAS12 at Jefferson Lab. The method will be explained and the expected precision of the measurements will be presented.

A Measurement of Proton Spin Structure Function g_2 at Low Q^2

Liu, Jie

Jefferson Lab has been at the forefront of a program to measure the spin-dependent structure functions over the past few decades. Measurements of these nucleon spin structure functions have been proven to be powerful tools in testing the validity of effective theories of Quantum Chromodynamics. The proton spin structure function g_1^p has been measured to very high precision over a very wide kinematic range, while the second proton spin structure function g_2^p remains largely unmeasured. The recent Jefferson Lab Hall A g_2^p experiment is an inclusive measurement of the proton g_2 structure function in the low Q^2 region ($0.02 < Q^2 < 0.2$ GeV^2). The measured data will provide an unambiguous benchmark test of Chiral Perturbation Theory (χPT) calculations by extracting the generalized longitudinal-transverse polarizability δ_{LT}, and these data will also help test the Burkhardt-Cottingham Sum Rule at low Q^2. This talk will present the details of the experiment, the analysis status and preliminary results.

Proton Form Factor Ratio G_E/G_M from the Double Spin Asymmetry

Liyanage, Anusha

Experiment E07-003 (SANE, Spin Asymmetries of the Nucleon Experiment) was carried out in Hall C at Jefferson Lab in 2009 to study the proton spin structure functions with a dynamically polarized ammonia target and longitudinally polarized electron beam. In the main experiment, scattered electrons were detected in a large acceptance non-magnetic detector array (BETA). In parallel, elastic measurements were carried out by detecting elastically scattered electrons from the polarized ammonia target in the High Momentum Spectrometer (HMS) which was on the opposite side of the beam. The elastic double spin asymmetry allows to extract the proton electric to magnetic form factor ratio G_E/G_M at $Q^2 = 2.2$ (GeV/c)^2. To reach higher Q^2 than that of the inclusive data, elastically scattered protons were detected in the HMS in coincidence with electrons detected in the BETA. The beam-target asymmetry for elastic kinematics was measured to extract G_E/G_M at $Q^2 = 5.25$ (GeV/c)^2 and $Q^2 = 6.25$ (GeV/c)^2. This alternative measurement of G_E/G_M aimed to independently verify the dramatic discrepancy at high Q^2 between the Rosenbluth and the recoil polarization transfer method. The experiment and the results will be presented in detail.

Hadron-Hadron Interactions I - Monday

Forward-backward asymmetries in the production of lambda, cascade, and omega baryons in proton-antiproton collisions

Hoeneisen, Bruce

We present measurements of the forward-backward asymmetries in the production of lambda, cascade and omega baryons in proton-antiproton collisions at sqrt(s) = 1.96 TeV recorded by the DO detector at the Fermilab Tevatron Collider. The data also confirm that the anti-lambda/lambda production ratio, measured by several experiments with various targets and a wide range of energies, is a universal function of "rapidity loss", i.e., the rapidity difference of the beam proton and the lambda.

Baryonic forces from SU(3) chiral effective field theory

Petschauer, Stefan

Results for the hyperon-nucleon interaction at next-to-leading order in chiral effective field theory are presented. These potentials include one- and two-meson exchange diagrams as well as contact terms with SU(3) symmetric low-energy constants and are found to lead to a good description of the experimental scattering data. Furthermore the properties of hyperons in nuclear matter are investigated using the chiral baryon-baryon potentials within the Brueckner-Hartree-Fock approach. We calculate the single-particle potentials of Λ and Σ hyperons in symmetric and asymmetric nuclear matter, and find good agreement with the empirical information. In particular, our calculation gives a repulsive Σ-nuclear potential and a weak Λ-nuclear spin-orbit force. Finally, we present potentials for the leading-order three-baryon interactions, which involve contact terms and irreducible one- and two-meson exchange diagrams. The pertinent low-energy constants are estimated by including decuplet baryons as explicit degrees of freedom. With these potentials one can study systematically the role of three-baryon forces, especially the ΛNN interaction, for hypernuclei and neutron star matter.

Work supported in part by DFG and NSFC (CRC110).

Baryonic b decays at LHCb

Voss, Christian

Light-Meson Decays - Tuesday

An overview of light meson decays

Kampf, Karol

The light mesons play a prominent role in hadronic processes at low energies. In my talk I will focus on theoretical calculations within Chiral Perturbation Theory and Resonance Chiral Theory. I will for example discuss the importance of the decay constant F_pi and cover all decay modes of the lightest hadron: neutral pi.

Hadron Physics at KLOE/KLOE-2

Perez Del Rio, Elena

The KLOE experiment, operating at the Phi-factory DAFNE in Frascati, has a large statistical sample, consisting of 2.5 fb^{-1} and 250 pb^{-1} on- and off- the Phi meson peak respectively. The large data sample of light meson available allows for precise measuraments on decay dynamics, transition from factors and searches of new physics. Furthermore, the KLOE2 experiment, with an improved detector, has started operation by the end of 2014 with the aim of collecting up to 5 fb^{-1} in the next year. Recent results on the KLOE data will be presented.

Measuring e/m transition form factors of light mesons with the A2 setup at MAMI

Prakhov, Sergey

Electromagnetic transition form factors (e/m TFFs) for the $\eta \to e^+e^-\gamma$ and $\omega \to \pi^0e^+e^-$ Dalitz decays have been measured in the $\gamma p \to \eta p$ and $\gamma p \to \omega p$ reactions, respectively, with the A2 tagged-photon facilities at MAMI. The results for the $\omega\pi^0$ TFF are in better agreement with phenomenological calculations compared to earlier experiments. The analyses of the $\pi^0 \to e^+e^-\gamma$ and $\eta' \to e^+e^-\gamma$ decays are in progress. New higher-statistics experiments for measuring the π^0 and $\omega\pi^0$ TFFs have been planned by the A2 Collaboration.

Radiative and Hadronic Decay modes of the η-Meson with CLAS and WASA-at-COSY

Lersch, Daniel

The radiative decay $\eta \to \pi^+\pi^-\gamma$ allows to explore the anomalous sector of QCD via the box anomaly, which is part of the Wess-Zumino-Witten Lagrangian. However, interactions between the final state pions have a considerable contribution to the decay amplitude and therefore need to be taken into account. Existing theoretical models can be tested by investigating the energy distribution of the final state photon. The amplitude of the isospin violating decay $\eta \to \pi^+\pi^-\pi^0$ is sensitive to the ratio of the light quark masses Q. This ratio is investigated via a Dalitz plot or partial wave analysis, whereas the latter one allows an explicit calculation of Q. The measurement of those η decays have been done with the CLAS detector at Jefferson Lab and with the WASA-at-COSY detector at Forschungszentrum Jülich. The η-mesons were produced at CLAS using the photoproduction reaction $\gamma p \to p\eta$, whereas hadronic reactions $pd \to {}^3\text{He}\eta$ and $pp \to pp\eta$ were used at WASA. Both experiments comprise large acceptance spectrometer with the capability to reconstruct all initial and final state particles. This talk will give an overview about the analysis status of those three data sets with respect to the decay modes $\eta \to \pi^+\pi^-\pi^0$ and $\eta \to \pi^+\pi^-\gamma$.

The GlueX/JEF program in Hall D at Jefferson Lab

Taylor, Simon

As part of the 12 GeV upgrade to CEBAF, the GlueX detector is a large acceptance spectrometer based on a solenoidal design with good coverage for both charged and neutral particles. The apparatus was designed for the flagship program to search for exotic (hybrid) mesons. The Jefferson Lab Eta Factory (JEF) program seeks to extend the physics reach of the GlueX experiment by focusing on rare decays of the η meson. In particular, the $\eta \to \pi^0\gamma\gamma$ decay allows access to the dark matter sector. A putative lepto-phobic dark boson B is predicted to manifest itself in the non-dark sector through the $B \to \pi^0\gamma$ transition. The JEF experiment will search for the B-boson in the mass range of 140-550 MeV, with sensitivity to the baryonic fine structure constant as low as 10^{-7}. The JEF search for a dark gauge boson is complementary to other accelerator-based searches for invisible decays; it is also complementary to the ongoing worldwide effort to search for a dark photon focusing mainly on signatures involving leptons. Because good photon reconstruction is essential for this challenging experiment, we plan to upgrade the inner region of the existing forward calorimeter (FCAL) in the GlueX detector with Lead Tungstate crystals, which will improve the position and energy resolution each by a factor of two relative to the lead glass blocks currently in the FCAL. The status of preparations for the JEF program will be presented.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177.

Conversion Decays of Light Mesons

Schadmand, Susan

We focus on the Dalitz decays of eta and omega mesons used for the experimental determation of electromagnetic transition form factors. The analyses are using data obtained with the WASA-at-COSY and the CLAS detectors.

Physics of Hyperons - Tuesday

Productions of hyperons and charmed baryons

Hosaka, Atsushi

We would like to discuss hadron induced hyperon and charmed baryon productions for the study of resonance structures. At sufficient high energies, we expect either forward or backward dominance corresponding to t and u channel dynamics. We discuss the production rates of these cross sections and characteristic features which are useful to extract the information of the internal structure.

Toward a K_L beam in Hall D at Jefferson Lab

Taylor, Simon

Few baryons containing strange quarks have been observed experimentally in spite of the rich spectrum of hyperons predicted by quark models. In particular, the doubly-strange Ξ states are sparse with only a few with well-established mass, width and J^P assignments and only the ground state Ω^- has firmly established quantum numbers. The field has largely stagnated for decades with some renewed interest in recent years. A K_L beam has the advantage that it contains one unit of strangeness/anti-strangeness, thereby opening up new opportunities to study hyperon production. A plan is evolving to take advantage of the existing photon beam line and experimental hall in the Hall-D complex at Jefferson Lab to deliver a beam of K_L particles onto a physics cryo-target within the GlueX detector. The recently constructed GlueX detector in Hall-D is a large acceptance spectrometer with good coverage for both charged and neutral particles that can be adapted to this purpose with a change to the size of the physics target. A preliminary conceptual design for production of a K_L beam in Hall-D and simulations of interactions of the K_L beam with a liquid hydrogen target inside the GlueX detector will be presented.

Ξ Baryon Spectroscopy with Kaon Beams

Naruki, Megumi

Properties of cascade baryons are not well determined, especially for excited states. Only the members of ground-state octet and decuplet are listed as well-established states in the PDG summary table. Our experiences and knowledge of cascades have been mainly obtained by bubble-chamber experiments performed in the '60 to '70s. The new secondary beam lines at J-PARC provides us with an opportunity to investigate cascades baryons systematically. It enable us to use beam kaons to form multi-strange systems in the mid-energy region. The future possibilities of cascade baryon spectroscopy at J-PARC will be presented.

Understanding the basic features of Ξ photoproduction

Nakayama, Kanzo

The photoproduction of cascade baryons off nucleons is discussed. It is a part of our theoretical effort in connection to the cascade baryon spectroscopy program at the Thomas Jefferson National Accelerator Facility (JLab). Specifically, the reaction $\gamma N \to KK\Xi$ is investigated, in conjunction with the $\bar{K}$-induced reaction $\bar{K} + N \to K\Xi$, within a relativistic hadron exchange model of strong interactions. The latter reaction is planned to be studied at J-PARC; it can also be studied at JLab if the secondary K_L beam becomes available. The basic features of these reactions and their manifestations in some of the observables will be discussed.

Ξ and Ω Spectroscopy at Jefferson Lab

Guo, Lei

Compared to the tremendous experimental progress made in the nucleon resonances, the advances in cascade and Omega spectroscopy have been scarce. The large amount of photoproduction data that have been collected in the past decade by the CLAS collaboration, and the next generation of experiments to be performed at the upgraded facilities at Jefferson Lab, will make it possible to investigate the photoproduction mechanisms of these baryon states with multiple strange quarks with unprecedented statistics in terms of both cross section and polarization measurements. It could also be possible to discover the missing S=-2 and S=-3 states as expected by various quark model predictions and Lattice QCD calculations. The incoming Very Strange Experiment at CLAS12 using the Forward Tagger, and the cascade spectroscopy program at GlueX will be discussed.

Spin Physics and Future Opportunities at the EIC - Tuesday

The Structure of the Neutron And the BoNuS Experiment

Niculescu, Gabriel

Since the late 60s inclusive electron-nucleon scattering has proven a rich source of information on the internal structure of nucleons and nuclei. While both electron-proton and electron-neutron interactions are equally important, as they provide access to different linear combinations of the underlying quark distributions, the latter type of studies have been hindered by the lack of a neutron target. The existing neutron results have been obtained by subtracting suitably smeared proton data from deuteron/light nuclei distributions, which are prone to uncertainties due to nuclear binding effects. The Jefferson Lab BONuS experiment addresses this problem using a detector capable of detecting spectator protons stemming from e+d interaction down to 70 MeV/c. F2 structure function results (and moments thereof) obtained during the 6 GeV era of Jefferson Lab using this technique will be presented. Progress on follow-on experiment BoNuS12, identified as one of the top priority experiments in the 12 GeV era, will also be discussed, as well.

Physics with polarized beams at the EIC and detector designs

Feege, Nils

The Electron Ion Collider (EIC, arXiv:1212.1701.v3) will allow for precision measurements of the partonic and spin structure of nucleons and the partonic structure of nuclear matter using high energy, high luminosity electron-proton and electron-ion collisions, respectively. The electron, proton, and light ion beams at the EIC will be polarized. Together with recent advances in theoretical frameworks achieved for transverse momentum dependent parton distributions (TMDs) and generalized parton distributions (GPDs), these measurements promise to yield multi-dimensional maps of the momentum and spatial distribution of partons inside hadrons. Furthermore, the EIC will provide new insights into how quarks and gluons give rise to overall nucleon properties like spin. Well designed experiments integrated into the interaction region are the key to unlock this physics potential. In this talk, I will present the physics addressed with polarized beams at the EIC and detector concepts currently being evaluated for this facility.

Recent progress on TMD study and future perspective at the EIC

Kang, Zhongbo

Transverse momentum dependent (TMD) parton distribution and fragmentation functions are novel theoretical concept, which provide information on the parton's intrinsic transverse motion, and thus present a path to three-dimensional nucleon tomography. In this talk, I will first review recent theoretical advances in TMD study. In particular, we discuss the current efforts and status in determining the TMD parton distributions and fragmentation functions from semi-inclusive deep inelastic scattering, e+e-, as well as p+p collisions. We then outline the future perspective at the future electron ion collider (EIC).

Physics with nuclei at an electron-ion collider

Eyser, Oleg

Experiments in the past decades have revealed an unexpected richness of nature as described by quarks and gluons in QCD. Nucleons exhibit a complex substructure that remains challenging for theory and requires precision measurements that disentangle the dynamics and contributions from different degrees of freedom, including spin and orbital angular momentum. At the same time, nucleons that are bound inside nuclei reveal a collective behaviour that under extreme conditions leads to its own QCD substructure. Observations of a quark gluon plasma at the highest temperatures and densities in heavy ion collisions, where the relevant degrees of freedom are quarks and gluons, have lead to studies of condensed matter of the strong force and the self interaction of gluons. Similarly, high energy deep inelastic scattering has pointed towards a dominance of gluons towards low partonic monenta in the nucleon, where it is expected that the gluon density has to reach a non-linear region and saturate in order to not violate unitarity. This so called color glass condensate is supposed to be universal and well within the reach of an electron-ion collider, where the nucleus serves as an amplifier for the gluon density. The short range structure of nuclei can be analyzed over a wide range of partonic momenta and momentum transfer for a variety of light and heavy ion species.

Hadron Spectroscopy III - Wednesday

Understanding the Nucleon as a Borromean Bound-State

Segovia, Jorge

We explain how the emergent phenomenon of dynamical chiral symmetry breaking ensures that Poincar covariant analyses of the three valence-quark scattering problem in continuum quantum field theory yield a picture of the nucleon as a Borromean bound-state, in which binding arises primarily through the sum of two separate contributions. One involves aspects of the non-Abelian character of QCD that are expressed in the strong running coupling and generate tight, dynamical color-antitriplet quark-quark correlations in the scalar-isoscalar and pseudovector-isotriplet channels. This attraction is magnified by quark exchange associated with diquark breakup and reformation, which is required in order to ensure that each valence-quark participates in all diquark correlations to the complete extent allowed by its quantum numbers. Combining these effects, we arrive at a properly antisymmetrised Faddeev wave function for the nucleon and calculate, e.g., the flavor-separated versions of the Dirac and Pauli form factors and conclude that available data and planned experiments are capable of validating the proposed picture.

Strangeness photoproduction at the BGO-OD experiment

Jude, Thomas

The BGO-OD experiment at the ELSA accelerator facility uses an energy tagged bremstrahlung photon beam to investigate the excitation structure of the nucleon. The setup consists of a highly segmented BGO calorimeter surrounding the target, with a particle tracking magnetic spectrometer at forward angles. Compared to constituent quark models (CQMs), models including psuedoscalar meson-baryon interactions have had improved success in describing baryon excitation spectra. Vector-meson baryon interactions have also been predicted to dynamically generate states, which may have been observed in photoproduction reactions. BGO-OD is ideal for investigating low momentum transfer processes due to the acceptance and high momentum resolution at forward angles. This enables the investigation of degrees of freedom not derived from CQMs, and in particular, strangeness photoproduction where t-channel exchange mechanisms play a important role. The ability of the BGO-OD to reconstruct final states of mixed charge also renders the experiment ideal for the investigation of higher lying hyperon states, for example $\Lambda(1405)$. With the first major data taking periods for BGO-OD complete, an extensive programme for the investigation of associated strangeness photoproduction has begun. This includes final states with charged and neutral kaons, for the investigation of ground level and excited hyperons. Data has also been taken with a deuterium target for the investigation of neutral channels such as $K^0\Lambda$ and $K^0\Sigma^0$. The current status of analysis and perspectives will be presented.

Supported by DFG (SFB/TR-16).

Partial-Wave Analysis of the Reactions $\gamma p \to \eta p$, $\gamma n \to \eta n$, and $\gamma p \to K^+\Lambda$ in a Multichannel Framework

Hunt, Brian

The goal of our research is to determine the properties of nucleon resonances using a multichannel partial-wave analysis. Currently, many predicted resonances have not been found, while the properties of several known resonances are relatively uncertain. This is changing with the recent experimental emphasis on photoproduction reactions. High-quality data for a number of spin observables is helping us solve the question of the missing resonances, and is allowing us to obtain nearly model-independent solutions for these reactions. This work focuses on analyzing the world database for the photoproduction reactions $\gamma p \to \eta p$, $\gamma n \to \eta n$, and $\gamma p \to K^+\Lambda$ by model-independent single-energy fits. Our single-energy amplitudes are then included in the multichannel energy-dependent fits, which are used to determine resonance parameters. We will present preliminary results for our single-energy solutions, the corresponding energy-dependent solution, and some resonance parameters.

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

Mattione, Paul

Measuring the spectrum of N^* resonances will provide valuable information on the degrees of freedom within the nucleon, shedding light on whether there is a significant contribution from a correlated quark-pair, or diquark, in the nucleon. To extract these states, measurements of both γp and γn cross sections are necessary to disentangle the isospin components of the photoproduction amplitudes. The γn world data set is much smaller than that for γp, and the N^* amplitudes on the neutron have very large uncertainties due to low statistics. A preliminary 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 performing a model-dependent correction for final-state interactions in the target deuteron. These data are a factor of 2.5x more than the world data set for this channel, providing much needed statistics to improve the amplitude extraction for coupling to the N^* resonances.

Hadron Structure III - Wednesday

Impact of ATLAS measurements on the knowledge of the Proton structure

Claire, Gwenian

Several measurements performed by the ATLAS collaboration can be used to constrain the proton structure. Measurements of the W+c production and the inclusive W and Z differential cross sections are found to constrain the poorly known strange-quark density at low x. Similarly, the ratio of W+/W- production is found to constrain the valence quarks at low x. New results will be presented using W,Z production at 13 TeV. New precise measurements of Drell-Yan cross section measurements performed above the Z peak region have a different sensitivity to parton flavour, parton momentum fraction x and scale Q compared to measurements on the Z peak. A large impact is found on the photon content of the proton as well as high x quarks. Measurements of the inclusive jet and photon cross sections are standard candles and constrain the medium and high x gluon densities. New precise measurements of inclusive photon and jet cross sections at 8 TeV are presented and compared to various PDF predictions.

Light-cone QCD sum rules for soft contribution to exclusive Drell-Yan process $\pi^- p \to \mu^- n$

Tanaka, Kazuhiro

Exclusive Drell-Yan process, $\pi^- p \to \mu^+ \mu^- n$, may be measured using the high-intensity pion beams at J-PARC, and its QCD description is complementary to that for the deeply virtual meson production, $\gamma^* p \to \pi N$, at e.g., JLAB. The leading hard exclusive amplitude for exclusive Drell-Yan process was obtained by E.R. Berger, M. Diehl, and B. Pire [Phys. Lett. B 523 (2001) 265] in terms of the partonic subprocess convoluted with the relevant nonperturbative functions, the nucleon generalized parton distributions (GPDs) and the pion distribution amplitudes, and, recently, subleading amplitudes, suppressed by the inverse powers of the dilepton mass Q, have also been calculated by S. V. Goloskokov and P. Kroll [Phys.Lett. B748 (2015) 323]. However, those predictions based on the QCD factorization approach still seem to have large uncertainties that originate from the treatment of the pion pole contribution arising in the relevant GPDs in the ERBL region, the parton transverse momentum to regularize the endpoint singularities, the so-called soft-overlap mechanism, etc. These effects related to soft contribution important at J-PARC kinematics are not directly accessible in the usual framework for QCD factorization of the hard exclusive amplitudes. We study the exclusive Drell-Yan process constructing the light-cone QCD sum rules for the corresponding exclusive amplitudes, which allow us to estimate the relevant soft contributions making use of dispersion relations and quark-hadron duality.

Measuring nucleon TMD spin-momentum correlations via Drell-Yan at Fermilab E906/E1039 SeaQuest Experiment

David, Kleinjan

The Drell-Yan process is an ideal probe to measure the naive T-odd Boer-Mulders and Sivers transverse momentum dependent parton distribution functions (TMDs), both of which describe spin-momentum correlations in the nucleon. Previous experimental results of cos(2) modulations in dilepton azimuthal distributions suggest significant non-pertubative effects, including a non-zero Boer-Mulders TMD. The Boer-Mulders TMD has been confirmed non-zero by semi-inclusive deep-inelastic scattering experiments. Presently, E906/SeaQuest experiment at Fermilab can measure Drell-Yan produced from a 120 GeV unpolarized proton beam directed on unpolarized nucleon targets. The cos(2) modulations will be measured to greater precision and at higher-x than previous experiments, deepening our understanding of the role the (anti)quark Boer-Mulders TMD plays the structure of the nucleon. In the future, the E1039/Seaquest experiment will introduce the beam onto a transversely polarized nucleon target. The transverse single spin asymmetry of Drell-Yan production will directly measure the sign and magnitude of sea quark Sivers TMD, which may probe the role sea quark OAM plays in the spin of the nucleon. Much remains to be learned about sea quarks in the nucleon. Measurement of spin-momentum correlations probes parton dynamics, providing insight beyond static quantities and shedding further light on the dynamical origins of the nucleon sea.

A Solution to the Proton Radius "Puzzle"

Norum, Blaine

The reported large discrepancy between the proton charge radius measured using the muonic atom Lamb shift [0.84087(39) fm] and that extracted from elastic electron scattering measurements [0.879(8) fm] has generated a great deal of interest. To examine possible origins of this discrepancy we reanalyzed the published electron scattering data from Saskatchewan (1974), Mainz (1980), and Mainz (2014) using standard statistical methods. We found that these data are actually in very good statistical agreement with the muonic atom results. While strictly speaking not germane to the extraction of the charge radius, we also found that a simple dipole function with its single parameter fixed to the muonic atom value of the proton radius reproduces GE_p within $\approx 1\%$ up to momentum transfers of $q^2 = 30\ fm^{-2}$.

Recent Approaches to Non-Perturbative QCD I - Wednesday

Three-Flavor chiral effective model with four baryonic multiplets

Zétényi, Miklós

We present a version of the so-called extended linear sigma model that contains four multiplets of spin-1/2 baryons. Two of these multiplets transform in a mirror way under chiral transformations, which allows for chirally invariant mass terms. The model is constructed in the case of three quark flavors and then reduced to the two-flavor case. In this way, four nucleonic states are obtained which mix to produce the nucleon and the three nucleon resonances, N(1440), N(1535), and N(1650). We determine the parameters of the nucleonic part of the Lagrangian from a fit to masses and decay properties of these states. We study the limit of vanishing quark condensate and identify the chiral partners.

Baryon Chiral Perturbation Theory with 1/Nc expansion: masses and form factors of the baryon octet and decuplet

Fernando, Ishara

Work in progress on calculating masses, and vector and axial-vector current form factors for the low lying octet and decuplet baryons is presented. The framework used is heavy baryon ChPT supplemented with the constraints imposed by consistency with a $1/N_c$ power counting. The calculations are carried out in the power counting scheme where both $M_{\pi,K,\eta}$ and $1/N_c$ are considered to be quantities of O(ξ). In that scheme, the mentioned observables are evaluated to include sub-leading terms suppressed up to O(ξ^3). The improvement of the expansion resulting from implementing the consistency with the $1/N_c$ power counting is discussed. Possible applications to recent results obtained in lattice QCD will be discussed.

$\Delta(1232)$ in the $\gamma p \to o\pi^0$ reaction at threshold

Hiller Blin, Astrid

We calculate the neutral pion photoproduction on the proton near threshold in covariant baryon chiral perturbation theory, including the $\Delta(1232)$ resonance as an explicit degree of freedom, up to chiral order $p^{7/2}$ in the delta counting. We compare our results with recent low-energy data from the Mainz Microtron for angular distributions and photon asymmetries. The convergence of the chiral series of the covariant approach is found to improve substantially with the inclusion of the $\Delta(1232)$ resonance.

Hadron Spectroscopy IV: Exotic Hadrons - Thursday

Hadron Spectroscopy with COMPASS

Bernhard, Johannes

The COMPASS experiment at CERN aims to contribute to the understanding of the structure and the dynamics of hadrons. With its large acceptance over a wide kinematic range for both charged and neutral particles, COMPASS is well suited for a detailed study of final states produced in inelastic interactions of hadrons or polarized muons with target nucleons. We present an overview of current activities in hadron spectroscopy of light mesons at a beam momentum of 190 GeV/c with an emphasis on the + final state for which COMPASS recorded the worlds largest data sample. This allows us to measure the properties of known resonances with unprecedented precision and opens the door for new discoveries such as the recently observed axial-vector meson a1(1420). Additionally, the findings are crosschecked with the analysis of the 00 channel and found to be well compatible. Furthermore, amplitudes of the + subsystems are extracted from data as a function of the 3 mass. Other studies in COMPASS include Primakoff reactions on nuclear targets, central production of pions and kaons, as well as diffractive production of final states with and .

Meson Spectroscopy at CLAS

Ostrovidov, Alexander

$\Lambda(1405)$ Photoproduction at MAMI

Werthmueller, Dominik

Despite being classified as a 4-star state by the PDG the nature of the $\Lambda(1405)$ is still not well understood. The picture of a p-wave excitation of the uds ground state within the classic quark model fails at describing its low mass. Alternative models involving exotic structures, such as pentaquarks or hybrids, have been proposed but it is becoming widely accepted that the $\Lambda(1405)$ emerges as a dynamically generated resonance from the antikaon-nucleon interaction. Since the early calculations of Dalitz and Tuan new insights have been gained, especially using unitary chiral perturbation theory frameworks, which for example, found evidence for a two-pole structure of the $\Lambda(1405)$. On the experimental side, the recent high quality data obtained from photoproduction measurements at the CLAS experiment set new standards for future experiments, which are still required to ensure progress in understanding the $\Lambda(1405)$. The high quality and intensity electron beam at the MAMI accelerator facility in Mainz is used by the A2 collaboration to produce a real photon beam via the tagged bremsstrahlung technique. Using an electron beam energy of 1.6 GeV allows the photoproduction of the $\Lambda(1405)$ near threshold from a proton target in the reaction $\gamma p \to K^+\Lambda(1405)$. The excellent photon detection capabilities of the electromagnetic calorimeters Crystal Ball and TAPS will enable a precise measurement of the $\Sigma^0\pi^0$ final state. In addition, the A2 setup would be ideally suited for the very challenging measurements of the radiative decays of the $\Lambda(1405)$, which have never been directly measured before but can provide crucial information about the internal structure of the state. A report on the status of the data analysis and planned activities will be presented.

Hadron Structure IV: Instrumentation - Thursday

The international project FAIR: A status overview

Nicmorus, Diana

The new international accelerator facility FAIR under construction in Darmstadt aims at studying matter at atomic, nuclear and hadronic levels. I will review several important aspects towards the realization of the Facility for Antiproton and Ion Research, and discuss recent developments. I will present the focus of the experimental programmes - hadron physics, nuclear structure and compressed nuclear matter physics, plasma and atomic physics, as well as related applications.

The Charged Life of HDice at Jefferson Lab

Hanretty, Charles

Polarized targets, especially of the frozen-spin variety, are highly valuable tools in the study of nucleon structure and the interaction mechanisms of its constituents. One such target, HDice, is a next generation target system operated at Jefferson Lab in Newport News, VA. This unique target is a quantum crystal of molecular HD in its solid phase. Both H and D can be polarized in true frozen-spin states, and spin can be transferred between H and D to optimize conditions for specific fixed-target experiments. Recently, the target has been used for the E06-101 N* run in Hall B (CLAS-6) using photon beams, with in-beam polarization lifetimes of years. Its potential for use with electron beams in CLAS-12 would open a window to a plethora of experiments; three A-rated experiments with transversely polarized HD have already been approved and designated as high-impact for Hall B. However, new polarization loss-mechanisms become active with charged-particle beams. Since the energy deposition in HD is nearly independent of the electron beam energy, polarization lifetimes can be studied with MeV-scale beams. A new 10 MeV accelerator is under construction at JLab and will be used to optimize the performance of the HDice target system with electrons. The principles of this complex target system, the aforementioned eHD test program, as well as HDices future use with CLAS-12 will be discussed.

Tensor Polarized Deuteron at Jefferson Lab

Long, Elena

With the development of a new solid DNP spin-1 tensor-polarized target, interest has been growing to explore physics that can be extracted using such a target. In the DIS region, HERMES data measured the b1 structure function at a surprising large, negative value that cannot be explained using conventional models but only with novel physics such as 6-quark hidden color effects. A new experiment at JLab will confirm the HERMES data as well as map out the region of zero-crossing. Additionally, in the quasi-elastic region, tensor polarization experiments can be used to better understand the deuteron's S/D wavefunction ratio, probe the tensor force that's expected to be the source of short range correlations, and provide a crucial test of relativistic light-cone and virtual-nucleon models. A second experiment at JLab will probe this quasi-elastic tensor structure of the deuteron. An overview of this emerging tensor program will be discussed.

Hadron Structure V: Hadron Polarizabilities - Thursday

Recent Results from the Crystal Ball/TAPS experiment at MAMI

Sokhoyan, Vahe

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 take advantage of high-intensity unpolarized, linearly or circularly polarized photon beams, and unpolarized or polarized targets. The detector setup provides almost complete coverage in solid angle and is well suited for the detection of multi-particle final states. The long-term research programs performed with the Crystal Ball/TAPS experiment are diverse. 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. The program aiming to determine the scalar and spin polarizabilities of the nucleons with high precision is performed with the Compton scattering experiments. Studying the properties and decays of light mesons also represents an important part of the effort of the collaboration. Furthermore, experiments with light and heavy nuclear targets are carried out to search for the modifications of hadrons in the nuclear medium, using a novel experimental technique. The upcoming upgrade of the tagging system of the Crystal Ball/TAPS experiment will allow us to perform new measurements with unprecedentedly high precision. In this talk, recent results, the current status, and future plans for new high-precision experiments at MAMI will be presented.

Hyperon forward spin polarizability γ_0 in baryon chiral perturbation theory

Hiller Blin, Astrid

We present the calculation of the hyperon forward spin polarizability γ_0 using manifestly Lorentz-covariant baryon chiral perturbation theory including the intermediate contribution of the spin-3/2 states. As at the considered order the extraction of γ_0 is a pure prediction of chiral perturbation theory, the obtained values are a good test for this theory. After including explicitly the decuplet states, our SU(2) results have a very good agreement with the experimental data and we extend our framework to SU(3) to give predictions for the hyperons γ_0 values. Prominent are the Σ^- and Ξ^- baryons as their photon transition to the decuplet is forbidden in SU(3) symmetry and therefore they are not sensitive to the explicit inclusion of the decuplet in the theory.

Hadron Spectroscopy V: Exotic Hadrons - Thursday

Searching for d* Dibaryons with CLAS

Mattione, Paul

Over the past several decades, a number of groups have reported evidence of dibaryons, bound states of two baryons. However, only one unambiguous dibaryon state is known to exist: the deuteron, which has a binding energy of only 2.2 MeV. Recently, the WASA-at-COSY collaboration has reported evidence for a d*(2380) bound state in pNd. Studying dibaryon resonances is important for understanding the properties of the strong force in nuclear systems. A study of the dd-+ reaction is shown using data from the Jefferson Lab CLAS g13 experiment. Strong, resonance-like d structures are seen in Dalitz plots of this system, indicating potential N bound states. Preliminary fits of this data to Breit-Wigner line-shapes will be shown. However, in the long-run, an amplitude analysis of this data needs to be performed to study the interference between these potential N bound states, the , and other potential backgrounds. With over 3 million events and a detected dibaryon in the final state, these CLAS data are a promising place to search for dibaryon resonances.

The observation of a Di-Baryon in the Proton-Neutron System - Hexaquark or Molecule?

Bashkanov, Mikhail

Several new findings in the four and five quark systems reheat the interest in the field of multiquark states (beyond trivial $q\bar{q}$ and qqq). A lot of progress is made in the $6q$ sector on both the baryonium and di-baryon sides. A resonance like structure observed in double-pionic fusion to deuteron, at $M = 2.38$ GeV with $\Gamma = 70$ MeV and $I(J^P) = 0(3^+)$ has been consistently observed in a wealth of reaction channels, supporting the existence of a resonant dibaryon state - the $d^*(2380)$. These studies include measurement of all the principle decay channels in pd and dp collisions in the quasi-free mode by the WASA-at-COSY and HADES collaborations. Recently the d^* has been observed in two-body reactions, which are amenable to simpler interpretation through partial wave analysis. The pn decay channel was measured by use of polarized deuterons on a proton target in inverse kinematics. These new np analyzing power data exhibit a pronounced resonance effect in their energy dependence. The SAID partial-wave analysis with inclusion of these data reveals a pole in the complex plane of the ${}^3D_3$ partial wave at (238010)MeV$-i$(405)MeV in accordance with the $d^*(2380)$ resonance hypothesis. The internal structure of the $d^*(2380)$ is largely unknown. It can contain various hidden color $6q$ configurations and $\Delta\Delta$ molecular structures with angular momentum L=0,2,4,6. A large set of already available experimental data constrains the internal structure of the $d^*(2380)$ dibaryon. Future plans to improve our understanding of the d^* will be presented as well as the exciting possibilities for investigation of SU(3) multiplet companions and mirror partners of the d^*.

Search for the H-dibaryon in the (K^-, K^+) reaction

Ahn, Jung Keun

A recent claim from the LHCb collaboration on the observation of two hidden-charm pentaquark states revives hopes for experimental discoveries of other multiquark baryonic states such as the H-dibaryon with a 6-quark ($uuddss$) configuration. Recent theoretical predictions for the mass of H-dibaryon pointing to the mass region near $\Lambda\Lambda$ threshold also encourage experimental searches. A dedicated experiment (J-PARC E42) has been proposed to search for the H-dibaryon in the bound and unbound mass regions near $\Lambda\Lambda$ threshold. The experiment is designed to measure production of $\Lambda p\pi^-$, $\Lambda\Lambda$ and $\Xi^- p$ systems in the $^{12}C(K^-, K^+)$ reaction with a 1-MeV mass resolution. A new large-acceptance spectrometer (Hyperon Spectrometer) is now under construction, consisting of a superconducting dipole magnet and a time projection chamber. The current status of the J-PARC E42 experiment will be presented. On the other hand, the H-dibaryon can be produced through $\Xi^- p$ fusion in the elementary $K^-(pp) \to K^+\Xi^- p \to K^+ H$ reaction from ^{12}C. Therefore, a fraction of di-proton pairs in relative S-wave state in ^{12}C is very interesting. A preliminary idea on the di-proton measurement via the (p,p'^2He) reaction will also be discussed.

Search for Hybrid Baryons with CLAS12 at JLAB

Lanza, Lucilla

Hybrid baryons are hypothetical three-quark states with dominant gluonic admixtures. Their existence is allowed by QCD, and lattice QCD calculations now predict several baryon states with dominant gluonic admixture to the wave function, and with the lowest mass hybrids approximately 1.3 GeV above the nucleon ground state of 0.94 GeV, i.e. in the range W = 2.2-2.3 GeV. An experimental program is under development to analize the mass range up to 3.5 GeV with the CLAS12 setup in HallB at Jefferson Laboratories exploiting the process e+p $\rightarrow$ e'+ K^++ Λ. Electron beams with energies of 6.6, 8.8, and 11 GeV impinging upon a liquid hydrogen target in the CLAS12 center may be employed. Scattered electrons may be detected in an angle range of 2.5 to 4.5 in the Forward Tagger(FT) and for angles greater than 6 in the CLAS12 Forward Detector. FT allows to probe the crucial Q^2 range where hybrid baryons may be identified due to the fast dropping of their $A_{1/2}(Q^2)$ electro-coupling and to the suppression of $S_{1/2}(Q^2)$. The Gent Regge plus Resonance model has been used to include a realistic hybrid resonance contribution at the amplitude level to determine the sensitivity of the CLAS12 apparatus to a hybrid baryon signature.

Hadron Spectroscopy VI - Thursday

Model discrimination in pseudoscalar-meson photoproduction

Ryckebusch, Jan

We lay out a framework that can be used to obtain estimates of the possible impact of (combinations) of polarization measurements in pseudoscalar-meson photoproduction from the nucleon. To this end, we introduce a geometrical measure to quantify the distance between models for pseudoscalar-meson 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.

An update on JPAC activities

Pauk, Vladiszlav

The Joint Physics Analysis Center (JPAC) between Indiana University and Jefferson Lab is a theory group aimed for developing analysis tools for hadron spectroscopy. In this talk Ill summarize recent activities of JPAC in hadron structure and spectroscopy. First, I'll present a new method of experimental analysis of the proton electric form factor. The suggested approach is aimed for adding a missing puzzle in the proton radius problem. In particular, we propose to measure the proton form factor in the photo production of lepton pairs on a proton target. The comparison of the production rates for the electron versus muon pairs gives a direct access for testing the lepton universality and comparison of the proton radius extraction from the electron versus muon scattering type experiments. Furthermore, Ill summarize recent JPAC efforts on hyperon spectrum and hidden charm pentaquark searches.

Determination of T and F observables in η photoproduction on the CLAS Frozen Spin Target (FROST)

Tucker, Ross

Polarization observables are an important tool for understanding and clarifying baryon resonance spectra. In 2010, experiments were conducted at Jefferson Lab using a polarized photon beam incident on a polarized frozen spin target (FROST). We present preliminary data of the T and F asymmetries for η photoproduction from the proton, along with comparisons to theoretical predictions. The data used in the present analysis were taken during the second running period of FROST using the CLAS detector at Jefferson Lab, with transversely-polarized protons in a butanol target or circularly-polarized incident tagged photons with energies between 0.62 and 2.93 GeV.

Work at Arizona State University is supported by the U.S. National Science Foundation award PHY-1306737.

Measurement of the double polarization observables E and G at the Crystal Ball experiment at MAMI

Afzal, Farah Noreen

For a better understanding of the nucleon excitation spectra and hence QCD at the non-perturbative regime, meson photoproduction reactions are studied at facilities like MAMI in Mainz where the Crystal Ball experiment is located. To be able to describe the photoproduction processes, polarization observables need to be measured in addition to the unpolarized cross section. The A2 collaboration has measured the double polarization observables E and G for the first time simultaneously using a longitudinally polarized electron beam together with a diamond radiator resulting in an elliptically polarized photon beam. Additionally a longitudinally polarized butanol target was utilized. Preliminary results for the photoproduction reaction $\vec{\gamma}\vec{p} \to p\pi^0$ will be presented in this talk.

Hadron Structure VI - Thursday

Measurement of polarization transferred to a proton bound in nuclei

Piasetzky, Eli

Possible differences between free and bound protons may be observed in the ratio of polarization-transfer components. We report the measurement of this ratio on deuteron at low and high missing momenta. Observed increasing deviation of the measured ratio from that of a free protonas a function of the virtuality, similar to that observed in 4He, indicates that the effect in nuclei is due to the virtuality of the knock-out proton and not due to the average nuclear density. The measured differences from calculations assuming free-proton form factors (about 10%), may indicate in-medium modifications. Preliminary data on proton removed from carbon will also be presented.

New results on spin structure functions at very low momentum transfers from Jefferson Lab

Adhikari, Krishna

Several experiments in Jefferson Lab have collected a large amount of data on the spin structure of nucleons using polarized electron beam directed on various polarized targets (NH_3 and ND_3, ^3He). In these double polarization experiments, either the double spin asymmetries $A_{||}$ and A or the polarized cross section differences $\Delta\sigma_{||}$ and $\Delta\sigma$ are measured with high precision over a wide kinematic range, with 0.02 GeV$^2 < Q^2 <$ 5.0 GeV^2 and 1.08 GeV$< W <$ 3.0 GeV and from these measurements, the spin structure functions and their moments are extracted. These data help us shed more light on the nucleon spin structure in the region of quark-confinement as well as in the transition region between hadronic and partonic degrees of freedom. With these data, it is possible to put constraints on quark-hadron duality, test pQCD predictions for the quark polarization at large x, and test various predictions for moments of structure functions from sum rules and QCD based effective theories such as Chiral Perturbation Theory (PT) as well as from phenomenological models. Additionally, these data make it possible to perform more precise calculations of higher-twist matrix elements in the framework of the Operator Product Expansion. At very low momentum transfers ($Q^2 \to 0$), the first moment (Γ_1) of structure function g_1 is constrained by the GDH sum rule and its PT extensions, which makes measurements of g_1 in this region uniquely interesting. In this talk, I will present new results on spin structure functions from various experiments at Jefferson Lab with an emphasis on low Q^2 measurements. In particular, I will present new results from the EG4 experiment with CLAS, which measured the double polarized cross section difference on NH_3 and ND_3 (with both electron beam and targets longitudinally polarized) down to $Q^2 = 0.02$ GeV^2.

Collins asymmetry and proton form factors at BESIII

Dbeyssi, Alaa

We report on the measurement of the $e^+e \to \bar{p}p$ cross section using the data collected by the BESIII detector at 12 c.m. energies in the range between 2.23 to 3.67 GeV. The proton electromagnetic form factor in the time-like region is measured. BESIII also collected data from the Λ_c-pair mass threshold to 4.6 GeV. Based on this data set, the Λ_c form factor can be studied for the first time. In addition, based on 65/pb data collected at 3.65 GeV, we explore Double Collins asymmetries by looking at the two back-to-back charged pions, which has similar energy coverage with the SIDIS experiments. The results of the first measurement of Collins asymmetry at low Q will be reported.

Deeply Virtual Compton scattering with CLAS12

Biselli, Angela

The Generalized Parton Distributions (GPDs) have emerged as a universal tool to describe hadrons in terms of their elementary constituents, the quarks and the gluons. Deeply Virtual Compton Scattering (DVCS) on a proton or neutron (N), $eN \to e'N'\gamma$, is one of the simplest processes that can be described in terms of GPDs. The amplitudes of DVCS and Bethe-Heitler, process where a photon is emitted by the incident or scattered electron, can be accessed via cross section measurements or exploiting their interference which give rise to spin asymmetries. Spin asymmetries, cross sections and cross-section differences can be connected to different combinations of the four leading order GPDs ($H, E, \tilde{H}, \tilde{E}$) for the two quark flavors depending on the observable and the type of target. This talk focuses on recent CLAS results and gives an overview of the upcoming experimental program on DVCS in Hall B at 12 GeV. Several experiments have been proposed to extend and improve the current measurements on polarized and unpolarized proton and as well as new measurements on neutron target. This program, once completed, will bring us a step closer to fully reveal the 3D quark structure of the nucleon.

Hadron Spectroscopy VII: Heavy Flavors - Thursday

Recent Belle Results on Charmed Baryon Spectroscopy and Decays

Yelton, John

Electron-Positron annihilations in the Upsilon resonance region have for many years proved a wonderful source of charmed baryon data. In this talk I review recent results on charmed baryons using data from the Belle experiment, which has collected the world's largest dataset in this energy range.

Basis Light-Front Quantization Approach to Heavy Quarkonium

Li, Yang

We present the properties of heavy quarkonium obtained within the Basis Light-Front Quantization approach [1]. An effective Hamiltonian is developed based on the Light-Front Holographic QCD plus the one-gluon exchange interaction. The produced mass spectra of charmonium and bottomonium agree with experiments to within a root mean square (r.m.s.) deviation of 40 MeV in the masses of the known states below open flavor thresholds. The resulting light-front wavefunctions grant access to hadronic observables relevant for experiments. We evaluate the decay constants, the form factors and the r.m.s. radii, and compare with experiments and other established approaches. We discuss our progress for evaluating additional observables including the generalized parton distributions (GPDs) of quarkonium (cf. [2]). We also apply the light-front wavefunctions to diffractive vector meson production in Deep Inelastic Scattering (DIS). Our predictions for these observables can be tested at current and forthcoming experimental facilities, e.g., LHC, RHIC and EIC. We will also discuss the prospect of extending the Basis Light-Front Quantization approach to the baryon sector.

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Heavy flavour production and spectroscopy at ATLAS

Abbott, Brad

ATLAS has a wide programme to study the production properties of conventional and exotic quarkonium, beauty, and charm bound states. This presentation will cover the latest results on J/psi, psi2s and Upsilon production at 7, 8, and 13 TeV, D meson production with Run-1 data, and B+ production at 13 TeV. The latest results in the ATLAS programme of heavy hadron production and spectroscopy are also presented, including studies of B_c and Lambda$_b$ decays, and measurement of b-quark fragmentation functions.

XYZ exotic states at COMPASS

Bernhard, Johannes

The COMPASS experiment at CERN contributes to the understanding of the structure and the dynamics of hadrons. With large acceptance over a wide kinematic range for both charged and neutral particles, COMPASS is well suited for detailed studies of inelastic reactions of hadrons or muons with target nucleons with a focus on the extraction of hadron resonance parameters. We present an overview of current activities in the search for XYZ exotic states with muon-beam induced photo-production at beam energies from 160 GeV to 200 GeV. As a first result, an upper limit for the exclusive production of the charged $Z_c(3900)$ was established as well as an upper limit for the partial width of its decay $Z_c(3900) \rightarrow J/\Psi\pi^{\pm}$. In addition, we will explore future possibilities within the COMPASS-II program, such as a study of neutral $Z_c(3900)$ production in the $J/\Psi\pi^0$ channel as well as a study of X(3872) production in the $J/\Psi\pi^+\pi^-\pi^{\pm}$ channel.

Hadron Spectroscopy VIII - Thursday

Baryon spectroscopy at BESIII

Destefanis, Marco

The BESIII experiment, hosted at the IHEP of Beijing, has collected the world largest data sample in the charmonium energy region. One of the most important physics goals of BESIII is the investigation of the QCD prediction. QCD can be accessed in a unique way by means of hadron spectroscopy. Charmonium decays provide an excellent scenario for studying nucleons, hyperons and their excited states, such as the N*, * , * and * resonances, as well as threshold production. The most recent results for baryon spectroscopy from BESIII will be discussed.

Resonance production and decay in pion induced collisions with HADES

Przygoda, Witold

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A major goal of the High Acceptance Di-Electron experiment (HADES) [1] at GSI is to study the electromagnetic properties of hadronic matter in the 1-3.5 GeV/nucleon incident energy range. The present interpretation of dilepton spectra measured in heavy-ion reactions at various energies is based on hadronic models, which predict in-medium modifications of the ρ meson spectral function due to its coupling to resonance-hole states [2]. In the energy range of the HADES experiments, the ρ meson is mainly produced in primary NN or secondary πN collisions, which opens the possibility to constrain the interpretation of medium effects by measuring dielectron emission in elementary reactions and better understand the relation between the couplings of the baryonic resonances to the ρ meson and the electromagnetic structure of the corresponding baryonic transitions. Recently, HADES collected data in $\pi^- - N$ reactions at four different pion beam momenta (0.656, 0.69, 0.748 and 0.8 GeV/c) [3]. In this measurement two targets (polyethylene and carbon) were used with the aim to subtract events from scattering on carbon and identify pure contribution from scattering on protons. Exclusive channels with one pion ($\pi^- p$), two pions ($n\pi^+\pi^-$ and $p\pi^-\pi^0$) and dileptons (ne^+e^-) in the final state were identified. The normalization was done based on the elastic scattering ($\pi^- p$) channel with the cross sections taken from the SAID database [4]. Results for exclusive channels with two pions in the final state have been included in a combined partial wave analysis (PWA) of the Bonn-Gatchina group [5]. The obtained solution provides the excitation function of two-pion production around the pole of the $N(1520)D_{13}$ resonance with the decomposition into contributing channels, in particular coupling to the intermediate ρ meson. The ρ spectral distribution obtained from the partial wave analysis is used to compute the respective contribution to the exclusive ne^+e^- channel, assuming strict Vector Meson Dominance. The results of this analysis will be presented.

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Angular distribution of exclusive dielectron production in pion-nucleon collisions

Speranza, Enrico

A study of the angular distribution of the dilepton produced in the reaction $\pi N \to N e^+ e^-$ is presented [1]. Effective interactions describing only the physical degrees of freedom for baryon resonances up to spin-5/2 are employed to compute the spin-anisotropy coefficient for isolated intermediate baryon resonances. It is shown that a given spin-parity state of the intermediate resonance exhibits a characteristic angular dependence of the spin-anisotropy coefficient. Furthermore, the spin-anisotropy coefficient resulting from the interference between resonances with different spin and parity is presented. Our results show that the spin-anisotropy coefficient can help disentangle the resonance contributions to the process [2]. Moreover, it is argued that the study of polarization observables can provide information on the production process and equilibration mechanism in heavy-ion collisions.

[1] E. Speranza, M. Zetenyi, and B. Friman (to be published)

[2] W. Przygoda (HADES Collaboration), talk presented at The 10th International Workshop on the Physics of Excited Nucleons, NSTAR2015, 25-28 May 2015, Osaka

Antibaryon Photoproduction using CLAS at Jefferson Lab

Phelps, Williams

There is little known about the baryon-antibaryon photoproduction mechanism. Three reactions, $\gamma p \to pp\bar{p}$, $\gamma p \to pp\bar{n}\pi^-$, and $\gamma p \to pn\bar{p}\pi^+$ have been investigated for the photon energy range of 4.4-5.45 GeV. The data were from the g12 experiment taken with the CLAS detector using a liquid hydrogen target in Hall B at Thomas Jefferson National Accelerator Facility. This experiment had high statistics, with an integrated luminosity of 68 pb^{-1}. General features of the data and preliminary cross sections for the $p\bar{p}$ system will be discussed.

Hadron-Hadron Interactions II: Hadron Structure - Thursday

Superfast quarks in collider experiments and QCD evolution

Freese, Adam

Quantum chromodynamics has been extremely successful in describing many high-energy experiments with the use of universal parton distribution functions. PDFs of the free proton are well-constrained by experimental data, but nuclear PDFs require further elaboration. One of the unique aspects of nuclear QCD is the possibility of superfast partons with Bjorken $x > 1$, which are indicative of short range correlations between bound nucleons. We present investigations of superfast quarks at energy scales relevant to both the LHC and EIC that take into account not only the latest phenomenology of nuclear SRCs, but also parton-level modifications of nucleons within the nuclear medium. An account will additionally be given for QCD evolution of superfast quarks, with corrections due to finite target mass and higher-twist effects.

Measurement of the triple-differential cross section for photon + jet production at $\sqrt{s} = 8$ TeV with the CMS detector

Khatiwada, Ajeeta

We measure the triple differential cross section for photon plus jet as a function of photon transverse momentum (p_T^γ), photon pseudorapidity (η^γ), and jet pseudorapidity (η^{jet}). The production of photons in association with jets can be used to understand gluon distribution functions as well as to test perturbative Quantum Chromodynamics (QCD). The measurement is made using data collected by the Compact Muon Solenoid detector in proton-proton collisions at the center-of-mass energy of 8TeV. For each bin, a signal fraction is extracted by fitting a Multivariate Analysis distribution of single photon triggered data candidates with Monte Carlo signal template and data-driven background template. The background template is obtained by optimizing the data sideband region to reduce bias and systematics. The final value of triple differential cross sections at various kinematic regions are compared to theoretical predictions at leading and next-to-leading order.

Inclusive cross section and double-helicity asymmetry for π^0 production at midrapidity in p+p collisions at $\sqrt{s} = 510$ GeV

Guragain, Hari

One of the major objectives of the RHIC spin program at BNL is the measurement of the gluon helicity contribution, ΔG, to the proton spin via measuring the double longitudinal spin asymmetry (A_{LL}) in various channels. In PHENIX (Pioneering High Energy Nuclear Interaction eXperiment) the A_{LL} in π^0, η, J/ψ etc. are measured in wide rapidity range. In this talk, A_{LL} in π^0 production in central rapidity and J/ψ production in forward rapidity will be discussed. The π^0 is reconstructed through its diphoton decay channel within the rapidity range of $|\eta| < 0.35$ and azimuthal angle of $180\,^\circ$. Similarly, J/ψ is reconstructed via dimuon decay channel within the rapidity range of $1.2 < |\eta| < 2.2$. Results for A_{LL} in π^0 and J/ψ production from the data collected in the year 2013 at center of mass energy ($\sqrt{s}$) = 510 GeV will be presented. Also, their impact on ΔG constraint will be discussed. In year 2013, the total integrated luminosity was 150 pb^{-1} which is almost ten times the total luminosity recorded in the year 2009 at $\sqrt{s} = 200$ GeV. Due to increase in the center of mass energy and integrated luminosity, the new measurements cover the Bjorken x range down to 0.01 for π^0 and 0.002 for J/ψ.

A search for supersymmetry at CMS with two photons and missing transverse energy at $\sqrt{s} = 13$ TeV

Santra, Arka

The missing transverse energy, potentially a sign of new physics, is a measure of the imbalance in the observed energy of an event. The Standard Model background prediction for the missing transverse energy in the two photon final state was determined using a data-driven technique, where different components of the background were estimated from different side- bands to the candidate two photon sample. This background was compared with the observed missing transverse energy distribution produced in proton- proton collisions, collected by the CMS Experiment at the CERN LHC at $\sqrt{s} = 13$ TeV. The results were then interpreted using simplified supersymmetry models.