EINN2017

12TH EUROPEAN RESEARCH CONFERENCE on Electromagnetic Interactions with Nucleons and Nuclei

29 OCTOBER - 04 NOVEMBER 2017

PAPHOS / CYPRUS

CONFERENCE ABSTRACTS

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Pre-conference

Sunday, October 29

(Athenaeum Ballroom)			
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09:00-10:00	Jan Bernauer	Form Factors	Pedagogical Talk (50+10)
10:00-11:00	Eliezer Piasetzky	Nuclear Matter at Short Range	Pedagogical Talk (50+10)
11:00-11:30	Coffee Break		
11:30-12:30	T. William Donnelly	Neutrino-Nucleus Interactions	Pedagogical Talk (50+10)
12:30-14:30	Lunch & Break		
14:30-14:50	Ievgen Lavrukhin	MUSE: Two Photon Exchange in Elastic e±p and µ±p Scattering	Research Talk (15+5)
14:50-15:10	Ethan Cline	Current Status of MUSE	Research Talk (15+5)
15:10-15:30	Afroditi Papadopoulou	Electrons for Neutrinos	Research Talk (15+5)
15:30-15:50	Bishoy Dongwi	The TREK/E36 experiment at J-PARC	Research Talk (15+5)
15:50-16:30	Axel Schmidt	A kick to our presentation skills	
16:30-17:00	Coffee Break		
17:00-18:30	Finding your optimal PostDoc position	Finding a great PostDoc	
19:30	Pre-conference Dinner		

Monday, October 30

(Athenaeum Ballroom)			
Time	**Speaker**	**Title**	**Format**
09:00-10:00	Justin Stevens	Experimental Hadron Spectroscopy	Pedagogical Talk (50+10)
10:00-11:00	Michael Peardon	Spectroscopy from Lattice QCD	Pedagogical Talk (50+10)
11:00-11:30	Coffee Break		
11:30-12:30	Mauro Anselmino	The Structure and Spin of the Proton	Pedagogical Talk (50+10)
12:30-14:30	Lunch & Break		
14:30-15:00	Rebecca Russell	Finding a career outside of physics	Skype Q&A
15:00-16:30	Morning Speakers, Ralf Ent (JLAB)	Academic Careers	Panel Discussion
16:30-17:00	Coffee Break		
17:00-17:20	Natalie Walford	Polarization Observables in Kaon Photoproduction Using a Polarized Frozen Spin Target in CLAS	Research Talk (15+5)
17:20-17:40	Stephen Kay	Photoproduction of the d*(2380) Dibaryon	Research Talk (15+5)
17:40-18:00	Nicolas Pierre	Monte Carlo Event Generation with Radiative QED processes in Deep-Inelastic Scattering	Research Talk (15+5)
18:00-18:20	Gregoris Spanoudes	Quasi Parton Distribution Functions: Renormalization in Dimensional Regularization	Research Talk (15+5)
18:20-18:30	Discussion and Wrap-Up		
18:30-20:00	Welcome Reception **(Amorosa Terrace)**		

Main Conference

Tuesday, October 31

Opening Session **(Athenaeum Ballroom)**			
Session chair: **Richard G. Milner**			
09:00-09:10	Welcome		
09:10-09:50	Experimental Perspectives on Electromagnetic Nuclear Physics	Rolf Ent	40’
09:50-10:30	Theoretical Perspectives on Electromagnetic Nuclear Physics	Andreas Schäfer	40’
10:30-11:00	Coffee Break		
Elastic Form Factors **(Athenaeum Ballroom)**			
Session chair: **Thomas W. Donnelly**			
11:00-11:30	Theoretical Perspective on Contributions Beyond Single-Photon Exchange in Elastic Lepton-Nucleon Scattering	Peter Blunden	30’
11:30-12:00	Experimental Perspective on Contributions Beyond Single-Photon Exchange in Elastic Lepton-Nucleon Scattering	Douglas Hasell	30’
12:00-12:30	Recent Precision Determinations of the Radii of the Proton and Light Nuclei using Atomic Physics Techniques	Julian Krauth	30’
12:30-14:30	Lunch & Break		
14:30-16:30	Parallel Workshops		
16:30-17:00	Coffee Break		
17:00-18:30	Parallel Workshops		
18:30-20:30	Poster Session with Wine & Cheese **(Asteras Restaurant)**		

Wednesday, November 01

The Origin of the Proton Spin **(Athenaeum Ballroom)**			
Session chair: **Rolf Ent**			
09:00-09:30	The Study of the Origin of Proton Spin at RHIC	Salvatore Fazio	30’
09:30-10:00	The Study of the Origin of Proton Spin at COMPASS	Fabienne Kunne	30’
10:00-10:30	New Measurements of the Weak Charge of the Proton	David Armstrong	30’
10:30-11:00	Coffee Break		
Session chair: **Susan Gardner**			
11:00-11:30	Quark Distributions from Lattice QCD	Fernanda Steffens	30’
11:30-12:00	Probing the Origin of Proton Spin using the Polarized Drell-Yan Process	Paul Reimer	30’
12:00-12:30	Overview of recent results from HAL QCD	Sinya Aoki	30’
12:30-14:30	Lunch & Break		
14:30-16:30	Parallel Workshops		
16:30-17:00	Coffee Break		
17:00-18:30	Parallel Workshops		

Thursday, November 02

Spectroscopy **(Athenaeum Ballroom)**			
Session chair: **Sinya Aoki**			
09:00-09:30	Spectroscopy with LHCb	Tadeusz Lesiak	30’
09:30-10:00	Spectroscopy at Jefferson Lab	Justin Stevens	30’
10:00-10:30	XYZ States from BESIII	Changzheng Yuan	30’
10:30-11:00	Coffee Break		
11:00-11:30	Recent Spectroscopy Results from A2/Mami	Costas Papanicolas	30’
Nuclei **(Athenaeum Ballroom)**			
Session chair: **Fabienne Kunne**			
11:30-12:00	New Insights into Nucleon-Nucleon Correlations	Axel Schmidt	30’
12:00-12:30	Understanding the Origin of Proton Spin Using Lattice QCD	Gunnar Bali	30’
12:30-14:30	Lunch & Break		
14:30-16:30	Parallel Workshops		
16:30-17:00	Coffee Break		
17:00-18:30	Oral presentations of three best posters **(Athenaeum Ballroom)**		

Friday, November 03

Beyond the Standard Model, Precision, Electroweak **(Athenaeum Ballroom)**			
Session chair: **Peter Blunden**			
09:00-09:30	Probing the Origin of Proton Spin Using Transverse Momentum Distributions	Alessandro Bacchetta	30’
09:30-10:00	Search for New Physics via the Anomolous Magnetic Moment of the Muon	Marc Vanderhaeghen	30’
10:00-10:30	Theoretical Perspective on Search for a Fifth Force via Electromagnetic Interactions	Susan Gardner	30’
10:30-11:00	Coffee Break		
Session chair: **Zein-Eddine Meziani**			
11:00-11:30	Experimental Perspective on Search for a Fifth Force via Electromagnetic Interactions	Ross Corliss	30’
11:30-12:00	Nuclear physics in Neutrino Scattering	Raúl González-Jiménez	30’
12:00-12:30	Search for New Physics with Neutrinos	James Napolitano	30’
12:30-14:30	Lunch & Break		
14:30-22:00	Half-day Excursion & Conference Dinner		

Saturday, November 04

Workshop Reports **(Athenaeum Ballroom)**			
Session chair: **Constantia Alexandrou**			
09:00-09:45	Summary I (Workshop I)	Josef Dudek	45’
09:45-10:30	Summary II (Workshop II)	Marc Vanderhaeghen	45’
10:30-11:00	Coffee Break		
Closing Session **(Athenaeum Ballroom)**			
Session chair: **Werner Vogelsang**			
11:00-11:40	New Insights into Hadron Structure	Anthony Thomas	40’
11:40-12:20	Status and Plans for the Electron-Ion Collider	Christine Aidala	40’
12:20-12:30	Closing		

Posters

1	Renormalization of nonlocal quark operators relevant to quasi-PDFs in dimensional regularization Gregoris Spanoudes
2	A Fast Approximate Method for Calculation of Coulomb Distortion in Electron Scattering by use of Partial Wave Expansions Dan Kosik
3	Model dependence in the analysis of the BRAG benchmark data Lefteris Markou
4	MUSE Trigger and Data Acquisition (TDAQ) System Ievgen Lavrukhin
5	Two-photon exchange correction to the hyperfine splitting in ordinary and muonic hydrogen Oleksandr Tomalak
6	Neutron Scalar Polarizabilities: Background Simulations for Experimental Extraction via Compton Scattering Maeve Wentland
7	Tracking Studies Using GenFit for the MUon Scattering Experiment Sara Ripley
8	First order QED corrections for the Bethe-Heitler process in the Soft photon approximation Matthias Heller
9	Neutrino Energy Reconstruction using Electron Scattering Data Afroditi Papadopoulou
10	Search for C- and CP-symmetry violating eta-meson decays at MAMI Cristina Collicott
11	Theoretical Description of the e+ e- → J/ψ π+ π- Cross Section Daniel Molnar
12	Monte Carlo Event Generation with Radiative QED processes in Deep-Inelastic Scattering Nicolas Pierre
13	Investigating the Proton Radius and Two Photon Exchange with MUSE Ethan Cline
14	Polarized Electron Source for the MOLLER Experiment Caryn Palatchi
15	Coherent pi^0 photoproduction on spin-zero nuclei Viacheslav Tsaran
16	The TREK/E36 experiment at J-PARC Dongwi Handiipondola Dongwi

Parallel Workshops

Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Tuesday, October 31

Session I Spectroscopy **(Athenaeum Ballroom)**			
14:30-16:30	Coupled-channel meson resonances from lattice QCD	Josef Dudek	25’+5’
	Spectroscopy of charmed mesons and baryons	Mike Peardon	25’+5’
	Lattice QCD investigation of the structure of the a0 (980) meson	Theo Leontiou	15’+5’
	πN p-wave resonant scattering from lattice QCD	Srijit Paul	15’+5’
	Measurement of $\pi^0\pi^{+/-}$ Photoproduction off the Deuteron with the A2 Experiment	Sebastian Lutterer	15’+5’
16:30-17:00	Coffee Break		
Session II Spectroscopy/Nuclear Physics **(Athenaeum Ballroom)**			
17:00-18:30	Helicity PDFs	Werner Vogelsang	25’+5’
	Photopion Physics at MAMI	David Hornidge	15’+5’
	Photoproduction of the d*(2380) Dibaryon	Stephen Kay	15’+5’
	Polarization Observables in Meson Photoproduction with Crystal Ball/TAPS at MAMI	Natalie Walford	15’+5’

Wednesday**, November 01**

Session I Hadron structure **(Athenaeum Ballroom)**			
14:30-16:30	Overview of exascale computing	Dirk Pleiter	25'+5'
	Hadronic contributions to the muon g-2 from lattice QCD	Hartmut Wittig	25'+5'
	The low-lying hadron masses and meson decay constants using Nf = 2 + 1 + 1 simulations with physical values of the quark masses	Simone Bacchio	15'+5'
	Nucleon Electromagnetic and Axial form factors including sea quarks contribution using lattice QCD	Kyriakos Hadjiyiannakou	15'+5'
	Using Polarized Compton Scattering to Study Proton Polarizabilities	Philippe Martel	15'+5'
16:30-17:00	Coffee Break		
Session II Nucleon Structure **(Athenaeum Ballroom)**			
17:00-18:10	Spin structure of the nucleon	Giannis Koutsou	25'+5'
	Nucleon charges at physical pion mass using twisted mass fermions	Jacob Finkenrath	15'+5'
	Progress in computing parton distribution functions at the physical pion mass from the quasi-PDF approach	Aurora Scapellato	15'+5'

Thursday**, November 02**

Session on Challenges in lattice QCD **(Athenaeum Ballroom)**			
14:30-16:30	Multi-quark studies	Marc Wagner	25'+5'
	Approaches for unstable particles	Marcus Petschlies	25'+5'
	Parton Distributions	Kostas Orginos	25'+5'
	Strangeness	Jeremy Green	25'+5'
16:30-17:00	Coffee Break		

Workshop 2: New Avenues in Lepton Scattering

Tuesday, October 31

Session I: EIC gluon and sea structure **(Ariadne Room)**			
14:30-16:30	Nucleon spatial imaging and EIC	Carlos Munoz Camacho	30'+5'
	Nucleon momentum imaging and EIC	Mauro Anselmino	30'+5'
	A polarized ^{3}He source for the EIC	Matthew Musgrave	20'+5'
	Virtual Compton Scattering on the Proton	Helene Fonvielle	20'+5'
16:30-17:00	Coffee Break		
Session II: Nuclei as a laboratory of QCD and else **(Ariadne Room)**			
17:00-18:30	Fundamental QCD at high energy at an EIC	Matthew Sievert	30'+5'
	Towards saturation: Experiments at an EIC	Thomas Ulrich	25'+5'
	The Muse experiment: A study of the proton radius puzzle with simultaneous ep and mu-p	Bill Briscoe	20'+5'

Wednesday, November 01

Session I: Nuclear & Nucleon Structure issues relevant to other fields **(Ariadne Room)**			
14:30-16:30	Hadronization/N-N correlations at an EIC	Kawtar Hafidi	30'+5'
	N-N correlations in nuclei	Meytal Duer	30'+5'
	Dispersive and model calculations of two photon exchange vs data	Oleksander Tomalak	20'+5'
	Electro-disintegration of ^{16}O as a tool for investigating $^{12}C(\alpha,\gamma)^{16}O$ reaction	Ivica Friščić	20'+5'
16:30-17:00	Coffee Break		
Session II: ERL projects and others **(Ariadne Room)**			
17:00-18:30	Overview of ERLs (Mainz, JLab, EIC…)	Sebastian Baunack	30'+5'
	LERF at JLab	Steve Benson	25'+5'
	The proton charge radius and the ProRad experiment	Mostafa Hoballah	20'+5'

Thursday, November 02

Session I: Instrumentation & Others **(Ariadne Room)**			
14:30-16:30	EIC detectors	Jose Repond	30’+5’
	Gas Electron Multipliers for high intensity applications	Michael Kohl	20’+5’
	Beam normal spin asymmetry for the ep to eDelta (1232) process	Carl Carlson	20’+5’
	Theory of two-Photon Physics	Igor Danilkin	20’+5’
	Discussion		10’
16:30-17:00	Coffee Break		

Conference Abstracts

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Pre-conference

MUSE: Two Photon Exchange in Elastic $e^{\pm}$ p and $\mu^{\pm}$ p Scattering

Ievgen Lavrukhin

Over the past decade, there were significant efforts (both theoretical and experimental) to study the two photon exchange (TPE) contribution in elastic lepton-proton scattering. There are three recent experiments (VEPP-3, CLAS and OLYMPUS), which have reported on direct measurements of TPE. All three experiments measured TPE in elastic e±p scattering at low to moderate momentum transfer (Q2 ≈ 1 ÷ 3 GeV2). The reported data indicate the presence of TPE effect. The proposed research focuses on experimental study of the TPE contribution to elastic e ±p and μ ± p scattering at a very low momentum transfer (Q2 < 0.1 GeV2). This measurement is a part of the MUon proton Scattering Experiment (MUSE). The experiment is designed to address the Proton Radius Puzzle (PRP): the discrepancy between the radius of the proton as measured with electrons, and that measured using muons. The scattering data obtained in MUSE will allow to measure TPE contribution in elastic muon-proton scattering at first time. Comparison of the TPE contribution extracted from elastic e±p and μ ±p will test lepton universality, which is related to the ”proton radius puzzle”.

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Pre-conference

Current Status of MUSE

Ethan Cline

In this talk I will discuss developments in MUSE from the most recent beam time. A brief overview of the experiment will be provided, followed by a discussion of the milestones already achieved by the experiment. Finally the goals for the remainder of the fall beam time will be presented.

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Pre-conference

Electrons for Neutrinos

Afroditi Papadopoulou

Neutrino physics is entering the age of precision measurements. A number of experiments have firmly established the occurrence of neutrino oscillations and determined the corresponding squared mass differences and mixing angles. These measurements have provided unambiguous evidence that neutrinos do have non-vanishing masses. The large θ13 mixing angle will enable future experiments to search for leptonic CP violation in appearance mode, thus addressing one of the outstanding fundamental problems of particle physics. These searches will involve high precision determinations of the oscillation parameters, which in turn require a deep understanding of neutrino interactions with the atomic nuclei comprising the detectors. In view of the achieved and planned experimental accuracies, the treatment of nuclear effects is indeed regarded as one of the main sources of systematic uncertainty. In this context, a key role is played by the availability of a wealth of electron scattering data and that will be the topic of my talk.

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Pre-conference

The TREK/E36 experiment at J-PARC

Bishoy Dongwi

The Standard Model (SM) represents our best description of the subatomic world and has been very successful in explaining how elementary particles interact under the influence of the fundamental forces. Despite its far reaching success in describing the building blocks of matter, the SM is still incomplete; falling short to explain dark matter, baryogenesis, neutrino masses and much more. The E36 experiment conducted at J-PARC in Japan aims to test lepton universality in the RK = (Ke2)/(Kμ2) ratio. In the SM, the ratio of leptonic K+ decays is highly precise with an uncertainty of 4RK/RK = 4 · 104. Any observed deviation from the SM prediction would break the universality of the lepton couplings and provide a clear indication of New Physics (NP) beyond the SM. Furthermore, the E36 detector apparatus allows sensitivity to search for light U(1) gauge bosons, which could be associated with dark matter or explain established muon-related anomalies such as the muon g 2 value, and perhaps the proton radius puzzle. A realistic simulation study is needed for these rare searches and as such verification of the Geant4/ROOT based simulation will be presented along with preliminary results.

*This work has been supported by the following DOE grants: DOE DE-SC0003884 and DE-SC0013941

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Pre-conference

Polarization Observables in Kaon Photoproduction Using a Polarized Frozen Spin Target in CLAS

Natalie Walford

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

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Pre-conference

Photoproduction of the d*(2380) Dibaryon

Stephen Kay, Mikhail Bashkanov and Daniel Watts on behalf of the A2 Collaboration

The field of multiquark states (beyond the known meson qq and baryon qqq states) has had renewed interest in recent years with findings of potential four, five and six quark states. Recent experiments by the WASA-at-COSY and HADES collaborations have observed a dibaryon (6q) resonant state, the d*(2380). Numerous measurements of this state across a range of di↵erent hadronic production channels indicate properties of M = 2380 MeV, = 70 MeV and I(Jp) = 0(3+). So far no photoproduction channels have been examined. A new measurement by the A2 collaboration at MAMI aims to observe the d*(2380) from a photoproduction reaction for the first time. A new large acceptance recoil polarimeter measures the final state spin polarisation of nucleons from the D(~,~np) deuteron photodisintegration reaction. Establishing that the d*(2380) has an electromagnetic coupling opens up opportunities to constrain its size and internal structure. First results from the analysis of the data will be presented.

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Pre-conference

Monte Carlo Event Generation with Radiative QED processes in Deep Inelastic Scattering

Nicolas Pierre

In order to apply QED corrections in the extraction of 1-photon crosssections in deep-inelastic scattering, radiation of photon have to be taken into account. In the COMPASS experiment, the production of hadrons is studied by scattering 160 GeV muons on nucleons. Radiation of photons from various ranges of kinematics, which is calculated using information from the scattered muon, thus happens. To correct for this effect, this radiation has to be taken care of in the Monte Carlo simulation used to obtain the acceptance. The DJANGOH event generator, working along with LEPTO and JETSET, is chosen as it describes well our data. The implementation into the Monte Carlo chain and the results obtained are discussed.

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Pre-conference

Quasi Parton Distribution Functions: Renormalization in Dimensional Regularization

Gregoris Spanoudes, Haralambos Panagopoulos

Quasi Parton Distribution Functions (quasi-PDFs) are nowadays widely employed in the nonperturbative study of nucleon structure in lattice QCD. The computation of these functions in large scale simulations allows the nonperturbative study of the physical PDFs from first principles. In this talk, I will present the renormalization of nonlocal quark operators involved in the definition of quasi-PDFs, in RI0 and MS renormalization schemes, using dimensional regularization. The renormalization functions of these nonlocal operators can be used to convert the corresponding lattice nonperturbative results to the MS scheme, which is the most widely used renormalization scheme for the analysis of experimental data in high-energy physics. The novel aspect of this work is the presence of nonzero quark masses in our computations, which results in mixing among these nonlocal operators in the continuum; our study is thus relevant for disentangling the observed operator mixing on the lattice.

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Main Conference

Theoretical Perspectives on Electromagnetic Nuclear Physics

Andreas Schaefer

Various plans for future high intensity, high energy lepton nucleon colliders are presently worked out. By the time one of them will get realized theory predictions have to reach a smaller uncertainty than experiment, which is a rather tall order. This will be discussed in detail for different physics objectives of the EIC. It will be tried to identify the theory tasks which have to be met to reach this goal. Special attention will be given to the question how e+N and e+A physics can profit from each other.

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Main Conference

Theoretical Perspective on Contributions Beyond Single Photon Exchange in Elastic Lepton-Nucleon Scattering

Peter G. Blunden, Winnipeg, Manitoba

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

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Main Conference

Experimental Perspectives on Elastic Lepton-Nucleon Scattering Beyond Single Photon Exchange

Douglas Hasell

Recent, precise measurements of the proton form factor ratio, $\mu_p G^p_E/G^p_M$, determined using polarized techniques show a striking discrepancy with measurements made using the traditional, Rosenbluth separation technique. The common explanation for this discrepancy is hard, two-photon exchange (TPE) contributions. While soft, two-photon exchange is generally included in radiative corrections; hard two-photon exchange is difficult to calculate as it depends on modeling the possible intermediate nucleon states. Three recent experiments: VEPP-3, CLAS, and OLYMPUS attempted to make a direct measurement of the hard, two-photon exchange contribution. A brief overview of the discrepancy, two photon exchange, and the three experiments will be presented. The experimental results will be compared together with some theoretical and phenomenological calculations. Finally, the present understanding will be summarized and possible future efforts suggested.

Main Conference

Recent Precision Determinations of the Radii of the Proton and Light Nuclei using Atomic Physics Techniques

Julian J. Krauth, Johannes Gutenberg

In recent years the CREMA collaboration has established hydrogen-like muonic atoms as an excellent probe for nuclear structure investigations. The measurements of the Lamb shift (2S→2P) via laser spectroscopy led to precise determinations of the nuclear rms charge radii of hydrogen [1,2] and deuterium [3], improving their uncertainties by an order of magnitude. The results, however, are discrepant to the CODATA values [4] (from atomic hydrogen/deuterium spectroscopy and electron scattering) by more than five standard deviations. The reason for these discrepancies, also known as the proton radius puzzle, remains unknown. In this talk I will introduce our method and explain how we extract the charge radii from the Lamb shift measurements. Furthermore I will give insight into our recent Lamb shift measurements in muonic helium-3 and -4 ions and their impact on the proton radius puzzle.

[1] R. Pohl et al., Nature 466, 213 (2010)
[2] A. Antognini et al., Science 339, 417 (2013)
[3] R. Pohl et al., Science 353, 6300 (2016)
[4] P.J. Mohr et al., Review of Modern Physics 88, 035009 (2016)

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Main Conference

Weak boson production at RHIC

Salvatore Fazio

The three-dimensional structure of the proton in momentum space can be described via Transverse Momentum Dependent (TMDs) parton distribution functions. One of these TMDs, known as the Sivers function $f_{\perp 1T}$, describes the correlation of parton transverse momentum with the transverse spin of the nucleon. RHIC is the worlds only facility that can run polarized p+p collisions at a center-of-mass energy large enough to produce weak bosons. Accessing the Sivers function in p+p collisions through the measurement of transverse singlespin asymmetry, A_N , in weak boson production is an effective path to test the fundamental QCD prediction of its change of sign (non universality) respectively to e+p processes. Furthermore, it provides data to study the spin-flavor structure of valence and sea quarks inside the proton and to test the evolution of parton distributions. A_N has been measured at STAR in p+p collisions at $\sqrt{s}$ = 500 GeV, with a recorded integrated luminosity of 25 pb^{-1} . Within relatively large statistical uncertainties, the current data favor theoretical models that include change of sign for the Sivers function relative to observations in SIDIS measurements, if TMD evolution effects are small. STAR has just collected 350 pb^{-1} from transversely polarized p+p collisions in run 2017. This will allow us to perform a precise measurement of A_N in both weak boson and Drell-Yan production as well as other observables sensitive to the non-universality of the Sivers function via the Twist-3 formalism, e.g. A_N of direct photons. W bosons from longitudinally polarized p+p collisions provide also a unique probe for the sea quark contribution to the nucleon spin structure, through the parity-violating single-spin asymmetry, A_L. Previous measurements of A_L for W bosons by both PHENIX and STAR have provided significant constraints on the helicity distribution functions of $\bar{u}$ and $\bar{d}$ quarks. The inclusion of the run 13 dataset with a collection of 300 pb^{-1} , three times larger than the total integrated luminosity of previous years, greatly improves the statistical precision. Furthermore, the measurement of the W^+/W^- cross section ratio in unpolarized p+p collisions is sensitive to the unpolarized $\bar{u}$, and $\bar{d}$ quark distributions at large Q^2 set by the W mass. Despite the precision reached by recent extractions of the parton distribution functions (PDFs), current measurements appear to suggest different high-x behaviors of the sea quark distributions $\bar{d}/\bar{u}$. The STAR experiment hopes to shed light on this discrepancy as its data are sensitive to these distributions near the valence region at $x \leq 0.16$. Our data can possibly reach higher values of $x \sim 0.3$ by extending the analysis to more forward rapidities after including the endcap. The whole data sample of about 700 pb^{-1} collected from 2011 through 2017 can be used for this purpose.

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Main Conference

The Study of the Origin of Proton Spin at COMPASS

Fabienne Kunne

Using 160-200 GeV muon beams from CERN, the COMPASS Collaboration has performed a rich program in inclusive and semi-inclusive deep inelastic scattering off polarized nucleons. Direct measurements of the gluon helicity have been realized in the photon-gluon fusion channel. Results obtained on the longitudinal spin structure functions g1 for the proton and deuteron have been ncluded in a global NLO QCD fit of g1 world data to extract polarized parton distributions. In order to improve the knowledge of quark fragmentation functions, needed to extract polarized quark distribution functions from spin asymmetries in polarized SIDIS experiments, pion and kaon multiplicities in DIS have been measured. New results on kaon multiplicity ratio M(K-)/M(K+) for kaons produced with large fraction of virtual-photon energy will be discussed. Results on transversity and Sivers effect in SIDIS will also be shown. Finally, the ongoing and short term future physics program will be presented: this includes the first measurement of the Sivers effect in polarized Drell-Yan and studies of generalized parton distributions through exclusive muo-production of photons.

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Main Conference

Precision Measurement of the Proton's Weak Charge

David Armstrong

The QWeak collaboration has used parity-violating elastic electron-proton scattering at very low momentum transfer to precisely measure the proton's weak charge. The weak charge is cleanly predicted within the Standard Model, with minimal theoretical uncertainty. Thus, this measurement provides an avenue for a sensitive search for beyond-the-Standard Model (BSM) physics. The final results for the weak charge will be presented, as well as the extracted values of the vector weak couplings of the up and down quarks, and the weak mixing angle. We will also discuss implications for BSM physics at the multi-TeV energy scale.

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Main Conference

Recent results from the HAL QCD potential method in lattice QCD

Sinya Aoki

I first briefly explain the HAL QCD potential method to investigate hadron interactions such as nuclear force in lattice QCD. I discuss the strategy of the method, advantages and disadvantages of the potential method over the conventional finite volume method, and possible systematic errors of the method. As applications of the potential method, I present recent investigations on exotic hadrons including H-dibaryon, N-Omega and Omega-Omega bound states as well as the tetra quark candidate Zc(3900). Extensions of the potential method to rho and sigma mesons are briefly discussed.

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Main Conference

LHCb Spectroscopy: Results and Plans

Tadeusz Lesiak

The LHCb experiment is dedicated to study heavy flavor hadrons produced from pp collision at the LHC. The data collected so far comprise the world's largest sample of beauty and charm hadrons, thus enabling precision spectroscopy studies in this sector. An overview of the selected, latest LHCb on the subject is given together with the perspectives of future research. It encompasses in particular the observation of pentaquarks, the new resonances observed in $J/\psi\phi$ final state and exotic charged state Z(4430)-, as well as observation of new heavy baryons, in particular of the doubly-charmed state $\Xi cc{+}{+}$ and new Ωc resonances.

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Main Conference

Spectroscopy at Jefferson Lab

Justin Stevens

While the majority of observed mesons and baryons are successfully described by the quark model, several recent observations provide evidence for more complex configurations of quarks and gluons allowed by QCD. In particular, Lattice QCD calculations have predicted a rich spectrum of mesons containing an excited gluonic field in their wave functions. The observation of these new states, known as hybrid mesons, would provide key insight into how the gluonic degrees of freedom manifest themselves in the bound states we observe in nature. The Jefferson Lab accelerator facility was recently upgraded to a 12 GeV electron beam, providing new opportunities in spectroscopy through an upgraded CLAS detector in Hall B, and a dedicated photon beam in Hall D for the GlueX experiment. In this talk, the status of the Jefferson Lab spectroscopy program will be presented, including recent results from the GlueX experiment.

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Main Conference

XYZ States from BESIII experiment

Changzheng Yuan

The discovery of the XYZ states (also called charmoniumlike states) opened fresh vista on matter, as some of them must be particles beyond the conventional quark model. BESIII experiment in Beijing, China, discovered a charged charmoniumlike state, Zc(3900), followed by more observations on Zc(4020), X(3872), X(3823), Y(4220), and so on. In this talk, I report the most recent progress in the study of the XYZ states from the BESIII experiment.

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Main Conference

Theoretical Perspective on Searches for New Forces via Electromagnetic Interactions

Susan Gardner

The Standard Model (SM) of particle interactions cannot explain the observed dominance of dark matter over ordinary matter, of cosmic baryons over antibaryons, nor does it explain the origin of neutrino mass, be it Majorana or Dirac. It is possible that essential clues to the solutions of these puzzles can come from the identification of new forces, that do not appear within the SM, to which low-energy, high-intensity experiments can be exquisitely sensitive. I will offer an overview of the possibilities, before turning to the discussion of an experimental anomaly in 8Be nuclear transitions that may be interpreted as evidence for a new, weak force of some 12 fm in range. I will discuss its theoretical implications and note what further experimental tests can be done to probe the experimental anomaly and its interpretation. I will conclude by noting that the high-intensity electron sources necessary for such tests can be used to broader purpose, by remarking on the prospects for identifying Majorana dynamics in electronuclear physics, via the possibility of n-¯n conversion.

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Main Conference

Experimental Perspective on the Search for a Fifth Force via Electromagnetic Interactions

Ross Corliss

The Standard Model does not provide a complete description of the universe: cosmic motivations and anomalies in precision measurements have led to proposed standard model extensions in the form of Dark Photons or, more generically, a new force-carrier. Existing experimental searches for such particles have probed the majority of the parameter space of simple models – so far without success. With no confirmation, the earlier results remain unexplained.

I will review the anomalous measurements that motivate ongoing e↲orts, and discuss some of the atomic, nuclear, and particle physics approaches that current and upcoming experiments are employing to continue the search for a fifth force.

Main Conference

Nuclear Physics in Neutrino Scattering

Raúl González-Jiménez

Neutrino properties have been investigated for more than 80 years. It has been firmly established that neutrino oscillate and hence are massive particles. The oscillation parameters have been measured, but still one needs to determine: the neutrino-mass hierarchy, the neutrino-mass absolute scale, and whether the neutrino is a Dirac or a Majorana particle. Also, investigation of charge-parity (CP) violation in the leptonic sector of the Standard Model is of fundamental importance for the construction of cosmological models. Further development in neutrino physics requires progress in both theoretical and experimental sides. Today, huge efforts are made to achieve these goals.

Inevitably, this ambitious scientific program meets challenges that slow down the process. The underlying problem is that the energy of the incident neutrino is known only as a broad distribution. For the oscillation analyses, it is necessary to know the neutrino energy, therefore, for each event observed in the detector, the neutrino energy is reconstructed using the available experimental information and theoretical inputs. This model-dependent procedure, called neutrino-energy reconstruction, is a major source of systematic uncertainties in the determination of the neutrino properties. What complicates the reconstruction of the neutrino energy, and brings theoretical nuclear physics to the stage, is the fact that all present and future generations of neutrino-oscillation experiments use complex nuclei as target material.

We wish to present the current status of the research activities of the Ghent group, which focus on providing a consistent description of some of the reaction mechanisms playing a role in the neutrino-nucleus interaction at intermediate energies: low-energy excitations, quasielastic scattering, two-nucleon knockout processes, and pion production.

We want to stress that the investigation of the neutrino-nucleon/nucleus interaction, beyond its role in the neutrino oscillation program, is of great interest itself. It provides unique information on the weak response (axial-vector current) of nuclei and nucleons. This is essential, for instance, to disentangle the electroweak structure of the nucleon. We will show some examples of this.

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Main Conference

Search for New Physics with Neutrinos

Jim Napolitano

This talk will discuss new and forthcoming results using neutrinos to measure previously undetermined quantities and to search for new physics. Topics will include precision measurements of the mixing angle $\theta13$ using reactor antineutrinos, searches for CP violation using muon neutrino and antineutrino beams, and sterile neutrino searches based on several different techniques and experiments.

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Main Conference

Status and Plans for the Electron-Ion Collider

Christine Aidala

The Electron-Ion Collider (EIC) was endorsed in the 2015 Long-Range Plan for Nuclear Science in the U.S. as the next major facility for construction. With hadron beams ranging from protons to heavy ions, high lepton and proton polarization, center-of-mass energies from 45 to 145 GeV, and luminosities greater than 1033 cm-2 s-1, the EIC will be a powerful and versatile machine for QCD studies. Following the Long-Range Plan endorsement, the EIC User Group was officially formed in 2016, and the activities of the community have been ramping up. The latest status of the facility and its physics program will be presented.

Poster

Renormalization of nonlocal quark operators relevant to quasi-PDFs in dimensional regularization

Gregoris Spanoudes, Haralambos Panagopoulos

Quasi-Parton Distribution Functions (quasi-PDFs) are nowadays widely em-ployed in the nonperturbative study of nucleon structure on the lattice. In this work, we compute the renormalization factors of nonlocal quark operators involved in the defini-tion of quasi-quark-PDFs, in RI□ and MS renormalization schemes, using dimensional regularization. The computation is performed up to two loops using massive fermions. We use our results to evaluate the conversion factors (up to two loops) of the nonlocal operators between the above two schemes. The conversion factors can be combined with the lattice renormalization factors of nonlocal massive-quark operators defined in the RI□scheme, in order to calculate the nonperturbative renormalization of these lattice opera-tors in MS .

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Poster

A Fast Approximate Method for Calculation of Coulomb Distortion in Electron Scattering by use of Partial Wave Expansions

Dan Kosik

Butler University — I will present an approach to calculations of electron scattering reactions that include Coulomb Distortion by numerically solving for the relativistic radial wave functions for a simple nuclear charge distribution and setting the normalization and phase by comparison to a fast calculation of Bessel functions in a plane wave expansion outside of the nucleus. Calculations for a surface nuclear transition density will be discussed and its implications for calculations of cross sections for inelastic scattering.

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Poster

Model dependence in the analysis of the BRAG benchmark data

Lefteris Markou, Efstathios (Stathis) Stiliaris, Costas N. Papanicolas

The Baryon Resonance Analysis Group benchmark dataset is a set of pion photoproduction data which were independently analyzed by various groups so an assessment could be made of the inherent model dependence of pion photoproduction multipole analyses. In this work the Athens Model Independent Analysis Scheme (AMIAS) [1] is used for the analysis of the same data at the Δ(1232). The data are analyzed in a totally model independent way yielding the Probability Distribution Function and maximum uncertainty of all multipole amplitudes to which the data exhibit any sensitivity to. By imposing model restrictions to the analysis, the full solution is reduced to the model dependent results obtained by earlier analyses. It is shown that the findings of the BRAG group adequately capture the magnitude of the model error but in certain cases it is largely underestimated.

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Poster

MUSE Trigger and Data Acquisition (TDAQ) System

Ievgen Lavrukhin, Ethan Cline

A 7σ discrepancy exists between electronic and muonic measurements of the proton charge radius. This discrepancy is known as the ”proton radius puzzle”. MUSE (MUon proton Scattering Experiment) will simultaneously measure cross sections for μ±p and e±p scattering in the PSI (Paul Scherrer Institute) πM1 beam line. This will provide key missing experimental input to the puzzle: a precise measurement of muon-proton elastic scattering, with a strong systematic constraint through the simultaneous electron-proton measurement. The measurement of both charge states will allow extraction of the two-photon effect contribution for both muons and electrons.

The purpose of this work is to discuss the trigger and data acquisition system for MUSE. An overview of the progress of trigger development and the current status of the DAQ will be discussed. Planned improvement to the system that will be implemented during the fall beam time will also be presented.

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Poster

Two-photon exchange correction to the hyperfine splitting in ordinary and muonic hydrogen

Oleksandr Tomalak

The current theoretical knowledge of the two-photon exchange (TPE) correction to the hyperfine splitting (HFS) of the S energy levels in muonic hydrogen exceeds by two orders of magnitude the expected ppm accuracy level of the forthcoming ground state HFS measurements by CREMA and FAMU collaborations as well as at J-PARC. In the ordinary hydrogen, where the measurements were performed in 1970th, the TPE theory is six orders of magnitude behind the experiment. The model-independent study of the TPE contribution to HFS could provide strict constraints on the low-energy proton structure. The expansion of the proton form factors in terms of charge and magnetic radii exhibits a 70-100 ppm difference when evaluating the leading Zemach contribution to HFS in muonic hydrogen with either the charge radius from the muonic hydrogen Lamb shift or elastic electron-proton scattering. Moreover, such an expansion also reduces the corresponding theoretical error sizably. It will also be discussed how the precise 1S HFS measurements in electronic hydrogen may further reduce the proton structure uncertainty in muonic hydrogen.

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Poster

Neutron Scalar Polarizabilities: Background Simulations for Experimental Extraction via Compton Scattering

Maeve Wentland

The A2 collaboration at the institute for Nuclear Physics in Mainz Germany is working to experimentally determine nucleon polarizabilities using medium-energy Compton Scattering. While the polarizabilities of protons has been well studied the scalar polarizabilities of neutrons are largely understudied due to a number of challenges. Previous work using Deuterium targets produced results with large uncertainties.

Glasgow and Mount Allison Groups within the A2 collaboration intend to use a high-pressure, active helium-3 target to better determine these values using Compton Scattering. The experiment will be run using an incident photon range between 80-200 MeV. Helium-3 cross sections are theoretically more sensitive to scalar polarizabilities than deuteron.

In preparation for this experiment, background simulations are being carried out to help determine the expected contamination of the Compton data. This is done using simulated data that allows us to optimize the analyzing software. This information is then used to perform a sensitivity study along with theoretical differential cross section data. This sensitivity study allows us to determine the error we can expect from this experiment.

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Poster

Tracking Studies Using GenFit for the MUon Scattering Experiment

Sara Ripley

The Proton Radius Puzzle (PRP) is one of today's most recognized problems in physics. The puzzle is based on the fact that when one measures the proton charge radius via elastic electron-proton scattering or electronic hydrogen spectroscopy, the result is significantly different (over 5σ) than if one were to use muonic hydrogen spectroscopy. The MUon Scattering Experiment (MUSE) will take place with the hopes of contributing to solving the PRP. It will be carried out at the Paul Scherrer Institute in Willigen, Switzerland, and will use the πM1 beamline where the protons will be converted into a mixed species beam comprised of electrons, positrons, muons, antimuons, and charged pions. Simultaneous electron- and muon-proton scattering will then be performed allowing for the proton charge radius to be extracted from all four probes. Unlike many scattering experiments, the beam from the MUSE experiment is created at an angle and focused at the target, creating the need to reconstruct the beam line and scattered particle tracks. My project involves the GEM detectors, or Gas Electron Multipliers, which allow for a 3D reconstruction of incident beam particles. With the help of the GenFit software, I have been able to create small test cases to better understand the fitter, and I have been able to conclude that the GenFit fitter has a torque arm behavior favoring the outer GEMs, and that it presently cannot handle noise properly. I am currently working with the simulated files in order to determine the behavior of the track at the target, and will continue to work with this data to better understand the software.

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Poster

First order QED corrections for the Bethe-Heitler process in the Soft photon approximation

Matthias Heller, Oleksandr Tomalak, Marc Vanderhaeghen

High-precision calculation of electromagnetic processes become more and more important for the interpretation of scattering experiments. One example is the Bethe-Heitler process, the lepton pair photoproduction on a proton target, which can be used as a test of lepton universality. Violation of this universality could shed light on the proton radius puzzle, the discrepancy between the charge radii measurements from muonic spectroscopy and data with electrons. An upcoming experiment at MAMI (Mainz) aims to compare the cross-sections of muon and electron pair production. A precise knowledge of the electromagnetic radiative corrections is needed for these measurements. As a first step, the leading QED radiative corrections are presented in the Soft-photon approximation.

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Poster

Neutrino Energy Reconstruction using Electron Scattering Data

Afroditi Papadopoulou

Neutrino physics is entering the age of precision measurements. A number of experiments have firmly established the occurrence of neutrino oscillations and determined the corresponding squared mass differences and mixing angles. These measurements have provided unambiguous evidence that neutrinos do have non-vanishing masses. The large θ13 mixing angle will enable future experiments to search for leptonic CP violation in appearance mode, thus addressing one of the outstanding fundamental problems of particle physics. These searches will involve high precision determinations of the oscillation parameters, which in turn require a deep understanding of neutrino interactions with the atomic nuclei comprising the detectors. In view of the achieved and planned experimental accuracies, the treatment of nuclear effects is indeed regarded as one of the main sources of systematic uncertainty. In this context, a key role is played by the availability of a wealth of electron scattering data and that will be the topic of my poster.

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Poster

Search for C- and CP-symmetry violating eta-meson decays at MAMI

Cristina Collicott, Sergey Prakhov

Charge conjugation (C), parity (P), and time reversal (T) are three basic symme-tries. These symmetries can also be combined to form additional symmetries (ex, CP - or CP T -symmetry). While these symmetries were once thought to be absolute, experiments dating back to the 1950s began to reveal interactions which violated these symmetries. Most notable from these experiments were the P -symmetry violating β-decay of 60Co to 60Ni [Wu/Lee/Yang, 1957], and the CP -symmetry violating decays of neutral kaon-mesons [Christenson, 1964].

These early discoveries motivated extensions to the Standard Model in the form of a third generation of quarks (extending the total number of quarks to six). The inclusion of complex phases in the Yukawa couplings, which describe the couplings of the Higgs scalar to quarks, results in a single CP violating parameter within the Standard Model. This is known as the Kobayashi-Maskawa mechanism and allows the Standard Model a method to account for CP violation through the three-generation quark mixing. While this is thought to be the dominant source of CP violation, evidence from astrophysics (specifically the matter/anti-matter asymmetry) suggests additional sources of CP violation not yet accounted for within the Standard Model.

We present here a search for C- and CP -symmetry violating decay modes of the eta (η) meson. The experimental challenge of such a search is predominantly the accumulated ex-perimental statistics necessary to probe these forbidden decay modes. The largest statistics of η decays in the world, based on 6.2× 107 η mesons produced in the γp → ηp reaction, was accumulated by the A2 Collaboration at the Mainz Microtron, MAMI. This allows further improvement of the existing upper limits for the branching ratios of several forbidden decays of the η meson. We present a new upper limit for the C-symmetry violating decay modes, η → 3γ and η → π0γ, and for the CP -symmetry violating decay mode, η → 4π0.

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Poster

Theoretical Description of the e+ e- → J/ψ π+ π- Cross Section

Daniel Molnar, Igor Danilkin, Marc Vanderhaeghen

In this work, we aim to provide a physical description of the recent BESIII data on the e+e− → J/ψ π+π− scattering. Exotic mesons are created in this reaction, which sequentially decay into pions and charmonium. In the ψπ invariant mass distribution, one can observe two peaks, which correspond to the exotic meson Zc(3900) and its kinematic reflection. Its shape can be parameterized as an S-wave Breit-Wigner and a background, which comes from the final state interactions of two pions. The latter we implement using unitarity and analyticity constraints. In result, a simultaneous description of ψπ and ππ invariant mass distributions is achieved.

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Poster

Monte Carlo Event Generation with Radiative QED processes in Deep-Inelastic Scattering

Nicolas Pierre

In order to apply QED corrections in the extraction of 1-photon cross-sections in deep-inelastic scattering, radiation of photon have to be taken into account. In the COMPASS experiment, the production of hadrons is studied by scattering 160 GeV muons on nucleons. Radiation of photons from various ranges of kinematics, which is calculated using information from the scattered muon, thus happens. To correct for this effect, this radiation has to be taken care of in the Monte Carlo simulation used to obtain the acceptance.

The DJANGOH event generator, working along with LEPTO and JETSET, is chosen as it describes well our data. The implementation into the Monte Carlo chain and the results obtained are discussed.

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Poster

Investigating the Proton Radius and Two Photon Exchange with MUSE

Ethan Cline, Ievgen Lavrukhin

In an effort to understand the Proton Radius Puzzle, the MUon proton Scattering Experiment (MUSE) is attempting to simultaneously measure e± p and μ±p elastic cross sections. MUSE aims to shed light on the puzzle, and investigate the Two Photon Exchange (TPE). With access to a Q2 range of 0.002 GeV2 to 0.08 GeV2, MUSE has unprecedented potential to measure the TPE. In this work we will demonstrate the precision of MUSE and its ability to extract a precise proton charge radius, as well as the sensitivity of MUSE to TPE and the kinematic region accessible to the experiment.

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Poster

Polarized Electron Source for the MOLLER Experiment

Caryn Palatchi, Kent Paschke

The MOLLER experiment at Jefferson Laboratory will be part of a new generation of ultra high precision electroweak experiments. It will measure the Moller (electron-electron scattering) parity-violating asymmetry, providing an unprecedented precision on the electroweak mixing angle. To achieve such small uncertainties, innovative techniques in the electron source are required to switch the beam helicity more quickly than previously achievable. The key technology is the Pockels cell in the laser optics of the polarized electron source. RTP crystals, which do not suffer from piezo-electric ringing at low frequency, have been demonstrated to achieve almost an order of magnitude faster transition times than commonly used KD*P crystal cells. This poster will detail the design modifications made to the RTP cell in order to achieve beam quality which is comparable to traditional KD*P controlled accelerator beams. The specific challenges for this use of the RTP system, including laser and crystal constraints, will be discussed.

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Poster

Coherent pi^0 photoproduction on spin-zero nuclei

Viacheslav Tsaran, Marc Vanderhaeghen

The method of coherent π0 photoproduction (γ+Ag.s. → π0+Ag.s., where Ag.s. is a nucleus in its ground state) provides an efficient tool to study nucleon distribution and the neutron skin of various nuclei. We investigate the case of nuclei with zero spin and isospin from theoretical point of view in the framework of a distorted wave impulse approximation in the momentum space. For the pion-nucleus final-state interaction we employ a phenomenological pion-nucleus optical potential which involves analysis of pion-pion elastic scattering as a solution of the Lippmann-Schwinger integral equation. As a first application, we show results for the 12C nucleus, for which the harmonic oscillator shell model is used to develop the second-order optical potential.

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Poster

The TREK/E36 experiment at J-PARC

Dongwi Handiipondola Dongwi, Michael Kohl, Tongtong Cao

The Standard Model (SM) represents our best description of the subatomic world and has been very successful in explaining how elementary particles interact under the influence of the fundamental forces. Despite its far reaching success in describing the building blocks of matter, the SM is still incomplete; falling short to explain dark matter, baryogenesis, neutrino masses and much more. The E36 experiment conducted at J-PARC in Japan aims to test lepton universality in the RK = Γ(Ke2)/Γ(Kμ2) ratio. In the SM, the ratio of leptonic K+ decays is highly precise with an uncertainty of □RK/RK = 4 · 10−4. Any observed deviation from the SM prediction would break the universality of the lepton couplings and provide a clear indication of New Physics (NP) beyond the SM. Furthermore, the E36 detector apparatus allows sensitivity to search for light U(1) gauge bosons, which could be associated with dark matter or explain established muon-related anomalies such as the muon g − 2 value, and perhaps the proton radius puzzle. This poster presentation will showcase both the Geant4 and real TREK/E36 geometry, results from the Geant4/ROOT monte carlo verification study using data, as well as preliminary results.

*This work has been supported by the following DOE grants: DOE DE-SC0003884 and DE-SC0013941

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Coupled-channel meson resonances from lattice QCD

Jozef Dudek

I will present recent results from the Hadron Spectrum Collaboration in which coupled-channel meson resonances are determined using lattice QCD. After a brief overview of the technique used to calculate scattering amplitudes taking advantage of the finite-volume of the lattice, I will illustrate the method using examples in the scalar, vector and tensor sectors. I will discuss how results potential inform our understanding of light meson spectroscopy.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Spectroscopy of charmed mesons and baryons

Michael Peardon

A review of recent lattice calculations of the spectrum and scattering prop-erties of hadrons containing charm quarks will be presented. Future prospects for these studies and open questions will be reviewed.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Lattice QCD investigation of the structure of the a_0 (980) meson

Theodoros Leontiou, Constantia Alexandrou, Joshua Berlin, Mattia Dalla Brida, Jacob Finkenrath, Marc Wagner

Lattice QCD investigation of the light scalar meson spectrum using two- and four-quark inter-polating fields reveals a $q\bar{q}$-like candidate for the a0 (980) meson. The analysis is performed using AMIAS, a novel statistical method based on the sampling of all possible solutions allowed by the spectral decomposition of the hadron correlation functions, as well as applying the standard varia-tional approach (Figure 1). We include the computation of diagrams with closed quark loops and show that these contributions are important for physically meaningful results.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

pi N p-wave resonant scattering from lattice QCD

Srijit Paul, Constantia Alexandrou, Giannis Koutsou, Luka Leskovec, Marcus Petschlies, John Negele, Stefan Meinel, Georgo Silvi

This talk focuses on the study of πN scattering in P -wave and I = 3/2, where the Δ resonance resides. We use Nf = 2 + 1 flavors of tree- level improved Wilson-clover quarks corresponding to a pion mass of ∼ 250 MeV with lattice sizes 2.8 and 3.7 fm. A combination of stochastic, forward and sequential propagators has been implemented to construct correlation matrices from qqq and Nπ interpolating fields and the low-lying energy spectrum is determined using the variational analysis. We will discuss the intricacies of the system studied and present preliminary phase shifts from the L¨uscher analysis.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Measurement of $\pi^0\pi^{+/-}$ Photoproduction off the Deuteron with the A2 Experiment

Sebastian Lutterer

In low energy QCD, there are two points of interest for studying the photopro-duction of pion pairs off (quasi-) free nucleons. On the one hand, it serves to investigate the excitation spectrum of the free nucleon, in particular for excited states which decay predominantly via cascades of intermediate excited states to the ground state. In order to get the full picture for both isospins, both the proton and the neutron need to be considered. While the study of the free proton is possible in fixed-target experiments, the same cannot be said for the short-lived free neutron. Thus, using deuterium, both nucleon channels can be explored quasi-free with one participant and one spectator. On the other hand, quasi-free production of pion pairs off heavier nuclei also figures prominently in the study of the in-medium properties of nucleon resonances. Double me-son production channels make the largest contribution to the second resonance bump of the nucleon which disappears for photoproduction off nucleons bound in nuclei. The special interest in the mixed charged channels π0π± is related to the contribution of the ρ-meson. This decay is forbidden for the π0π0 final state due to isospin conservation. The coupling to a ρ could induce substantial in-medium effects when the ρ spectral function itself is modified in the medium. In the present work production of π0π± pairs off liquid deuterium is analysed using data taken at MAMI with the A2 experiment as a starting point for a detailed investigation of this channel for nuclear targets. Data for a 4He target have also already been taken.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Photopion Physics at MAMI

David Hornidge

Recent measurements and future plans for photopion experiments with the CB-TAPS detector system in the A2 hall at the Mainzer Microtron will be presented. First, a measurement with linearly polarized photons and an unpolarized liquid-hydrogen target will be discussed. The beam asymmetry along with differential cross sections provide the most stringent test to date of the predictions of Chiral Perturbation Theory and its energy region of convergence1 . Second, a more recent measurement was performed using both circularly polarized photons and a transversely polarized butanol frozen-spin target to extract the polarization-dependent differential cross section associated with the target asymmetry2. Results from both measurements have been used for a model independent determination of S- and P -wave multipoles in the π0 threshold region, which includes for the first time a direct determination of the imaginary part of the E0+ multipole. Finally, plans for a novel π0 photoproduction measurement on 3He to obtain the elusive E0+ multipole for the neutron channel will be introduced.

References

1. D. Hornidge et al., Phys. Rev. Lett. 111, 062004 (2013).
2. S. Schumann et al., Phys. Lett. B 750, 252 (2015).

Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Photoproduction of the d*(2380) Dibaryon

Stephen Kay, Mikhail Bashkanov, Daniel Watts

The field of multiquark states (beyond the known meson qq and baryon qqq states) has had renewed interest in recent years with findings of potential four, five and six quark states. Recent experiments by the WASA-at-COSY and HADES collaborations have ob-served a dibaryon (6q) resonant state, the d*(2380). Numerous measurements of this state across a range of different hadronic production channels indicate properties of M = 2380 MeV, Γ = 70 MeV and I(J^p) = 0(3+). So far no photoproduction channels have been examined.

A new measurement by the A2 collaboration at MAMI aims to observe the d*(2380) from a hotoproduction reaction for the first time. A new large acceptance recoil po-larimeter measures the final state spin olarisation of nucleons from the D(□γ,□hp) deuteron photodisintegration reaction. Establishing that the d*(2380) has an electromagnetic cou-pling opens up opportunities to constrain its size and internal structure. First results from the analysis of the data will be presented.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

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

Natalie Walford

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

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Hadronic contributions to the muon g-2 from lattice QCD

Hartmut Wittig

I present results and strategies for the determination of the hadronic contributions to the muon anomalous magnetic moment. Results for the hadronic vacuum polarisation contribution will be discussed focussing on controlling systematic errors arising from finite-volume effects, quark-disconnected diagrams and the deep infrared region of the vector correlator. Several strategies for computing the hadronic light-by-light scattering contribution will be discussed, including the analytic determination of the QED kernel, as well as the determination of the transition form factor for the process $\pi0 \rightarrow \gamma * \gamma *$.

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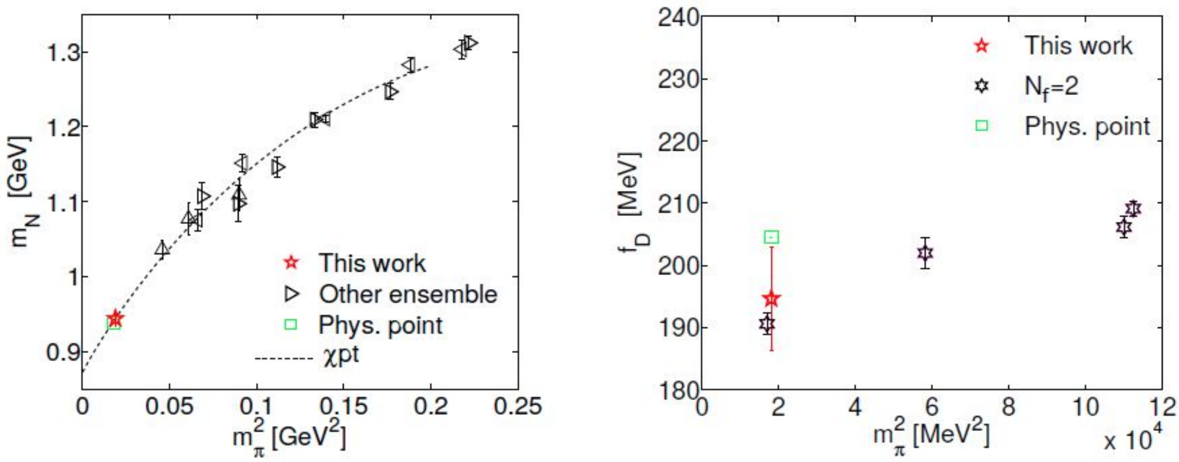
Workshop 1: Spectroscopy and Hadron structure from lattice QCD

The low-lying hadron masses and meson decay constants using Nf = 2 + 1 + 1 simulations with physical values of the quark masses

Simone Bacchio, Constantia Alexandrou, Panayiotis Charalambous, Martha Constantinou, Jacob Finkenrath, Kyriakos Hadjiyiannakou

We present recent results on the mass of the low-lying mesons and baryons as well as on the meson decay constants using a new ensemble simulated at the physical values of the light, strange and charm quark masses. As depicted in Fig. 1, the nucleon mass using the new ensemble agrees with the experimental value. In the figure we also include our previous nucleon mass results using Nf = 2 + 1 + 1 simulations. We also show results on the D-meson decay constant for several pion masses. In particular, we assess unquenching effects due to the presence of strange and charm quarks in the sea by comparing to our previous Nf = 2 results using the same action. As depicted in Fig. 1, the D-meson decay constant computed using Nf = 2 and Nf = 2 + 1 + 1 ensembles are in agreement although the results for Nf = 2 + 1 + 1 are still preliminary. In the presentation we will also discuss our results on the renormalized quark masses computed in the MS scheme and compare with previous results.

Figure 1



Left: The nucleon mass versus the pion mass squared using Nf = 2+1+1 twisted mass fermion ensembles. Black trangles show our lattice results for heavier than physical masses of the pion. The red star is the result presented in this work. The green square is the physical value. The dashed line is the expected behavior predicted by chiral perturbation theory.

Right: Comparison of D-meson decay constant computed on Nf = 2 and Nf = 2 + 1 + 1 ensembles at different pion mass. Black stars show our results for Nf = 2 simulations. The red star is the preliminary result for this work. The green square is the physical value.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Nucleon Electromagnetic and Axial form factors including sea quarks contribution using lattice QCD

Kyriakos Hadjiyiannakou, Constantia Alexandrou, Martha Constantinou, Karl Jansen, Christos Kallidonis, Giannis Koutsou, Alejandro Vaquero Aviles-Casco

We present lattice QCD results for the nucleon Electromagnetic and Axial form factors using twisted mass clover improved fermions tuned to reproduce the physical value of the pion mass. Up, down, strange and charm quark contributions will be presented. Sea quark contributions have been evaluated using Graphics Cards to reach high statistics. Excited state effects have thoroughly been studied to extract the contribution of the ground state. The form factors have been fitted using model dependent and model independent expressions. Representative results for the Electromagnetic and axial form factors are shown in Figs. 1 and 2.

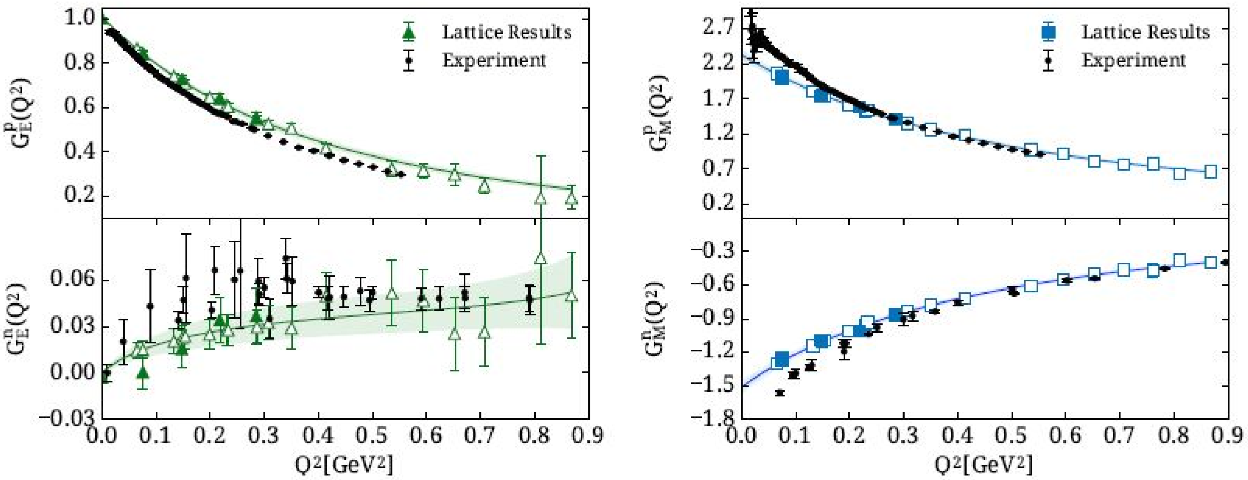

FIG. 1: Proton and neutron electric (left) and magnetic (right) form factors.

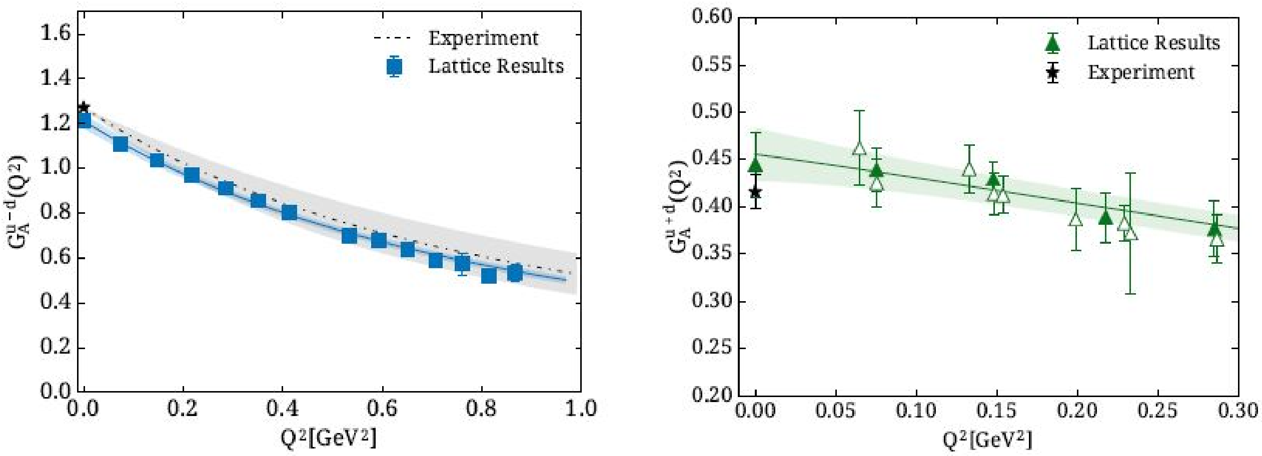

FIG. 2: Isovector (left) and isoscalar (right) nucleon axial form factors.

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Using Polarized Compton Scattering to Study Proton Polarizabilities

Philippe Martel, Mount Allison

The most fundamental properties of a proton are its mass and electric charge which, along with its anomalous magnetic moment, describe its interaction with an electromagnetic wave. However, this assumes the proton is a point-like particle, and higher order terms are therefore necessary to incorporate the internal structure of the pro-ton. The next terms that appear in the effective Hamiltonian are the scalar and vector, or spin, polarizabilities, the latter of which have not been fully experimentally determined. Three Compton scattering ob-servables, which exhibit dependence on these parameters, have been measured at the Mainz Microtron (MAMI) in a program to extract these polarizabilities. This program made use of the A2 tagged photon beam, various proton targets, and the nearly 4π detection capability of the Crystal Ball and TAPS detectors. The three observables mea-sured were the beam asymmetry Σ3, with a linearly polarized beam on an unpolarized LH2 target, and two double-polarization asymmetries Σ2x and Σ2z, both with a circularly polarized beam on either a trans-versely or longitudinally polarized frozen-spin butanol target, respec-tively. All three experiments have been performed, with the analyses essentially finalized and in various states of publication. Additionally, initial data has been taken to study the scalar polarizabilities, and the first run with an active polarized target was performed with the goal of extending the kinematic range of these observables to lower energies. This talk will discuss these measurements, as well as various fitting studies that are being performed with the data in hand, and plans for future measurements.

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Spin structure of the nucleon

Giannis Koutsou

I will review recent progress in nucleon structure calculations on the lattice, focusing on the nucleon spin and momentum decomposition. Details of recent results obtained from simulations with physical or near-physical quark mass values will be presented, including challenges in obtaining a reliable signal for the required disconnected contributions and in suppressing excited states.

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Nucleon charges at physical pion mass using nf=2 twisted mass fermions

Jacob Finkenrath, Constantia Alexandrou, Giannis Koutsou, Kyriakos Hadjiyiannakou, Martha Constantinou, Colin Lauer, Simone Bacchio

We will present recent results on the nucleon charges, baryons and mesons in the light and strange quark sector. By using the European Twisted Mass Collabo-ration nf = 2 clover-twisted mass ensembles at physical light quark masses the computed quantities are unbiased from the usual mass-extrapolation. Tuned twisted mass fermions are free from linear lattice artifact and adding a finite Sheikholeslami-Wohlert term suppressed highly the unphysical flavor breaking effects for lattice spacings below a < 0.1 fm. Additionally by increasing the physical box size from (5.4 fm)4 to (7.1 fm)4 at constant physics we can study finite volume effects and can control lattice systematics in a sufficient way.

Preliminary examples of the results are shown in fig.. Here we plotted the pion mass dependence on the average light quark mass (left side) and the proton mass (middle) and the axial charge (right) in dependence on the lattice extent in one direction at physical quark masses. The red horizontal lines correspond to the experimental values. As depicted the finite size effects are under control while the axial charge deviates also for larger lattice sizes from the experimental value. In this contribution we will discuss this systematics and shed light on possible ways to further minimize these effects.

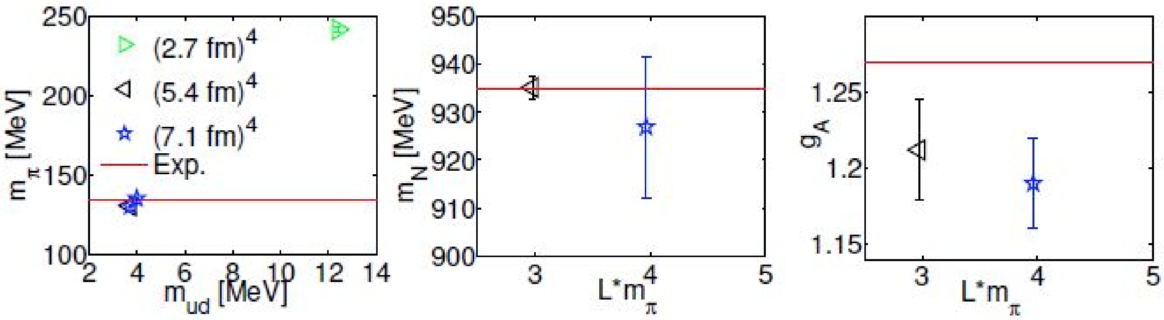

Figure 1: The figure shows some of the physical results determined from the nf = 2 twisted clover ensembles: **Left**: The pion mass mπ dependence on the light average quark mass mud is shown. **Middle**: The nucleon mass mN depen-dence on the lattice extent is shown. **Right**: The axial charge gA dependence on the lattice extent is shown.

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Progress in computing parton distribution functions at the physical pion mass from the quasi-PDF approach

Aurora Scapellato, Constantia Alexandrou, Martha Constantinou, Karl Jansen, Krzysztof Cichy, Fernanda Steffens, Kyriakos Hadjiyiannakou, Giannis Koutsou, Simone Bacchio

Parton distribution functions (PDFs) describe the inner dynamics of partons inside a hadron, by giving information on the momentum distribution of partons. Extracting PDFs has been a long standing goal in lattice gauge theory, since they are given in terms of non-local light cone correlations in Minkowski space-time and light-like distances are not accessible on Euclidean lattice. In 2013 the quasi-PDF approach has been proposed, providing up to now promising results for parton distributions at non-physical pion masses. We present the latest results of our effort in computing the iso-vector combination for the unpolarized, helicity and transversity quasi-distributions within the proton, obtained with Nf = 2 twisted mass clover-improved fermions at the physical pion mass and discuss their renormalization and matching to the physical PDFs.

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Multi-quark studies

Marc Wagner

Studying multi-quark systems with lattice QCD is very challenging. I discuss several typical problems in the context of tetraquark studies, including the large noise-to-signal ratio, technical aspects of the computation of diagrams and problems associated with the presence of lighter multi-particle states.

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Matrix elements of unstable states: The radiative transition pi pi to pi gamma in lattice QCD

Marcus Petschlies, Constantia Alexandrou, Stefan Meinel, Luka Leskovec, John W. Negele, Srijit Paul, Andrew Pochinsky, Sergey Syritsyn, Gumaro Rendon

The ab-initio, non-perturbative calculation of transition matrix elements with unstable final hadron states has recently become a field of intensive study in lattice QCD. It combines several key concepts of lattice field theory, such as L¨uscher's finite volume method for scattering phase shifts and the Brice˜no - Hansen - Walker-Loud formalism for mapping finite- to infinite-volume matrix elements. At the example of our ongoing lattice calculation of the radiative process $\pi\gamma \to (\rho \to)\ \pi\pi$ I discuss the steps on the way to extract an infinite-volume $1 \to 2$ transition matrix element from lattice simulation data.

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Direct Computation of Parton Distribution Functions using lattice QCD

Kostas Orginos

For many years it was thought that in Euclidean space only moments of parton distribution func-tions (PDFs) can be defined and thus Lattice QCD computations for parton distribution functions were of limited value. Novel ideas introduced recently have removed these limitations and thus non-perturbative computations of parton distribution functions from QCD are now available. In this talk I am presenting the basic ideas that allow for the definition of PDFs in Euclidean space and present recent numerical results. Furthermore, I am discussing the future of such computations and the potential impact to phenomenology.

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Workshop 1: Spectroscopy and Hadron structure from lattice QCD

Strangeness

Jeremy Green

The presence of strange quarks in the nucleon is a nontrivial prediction of QCD. It has been challenging, however, to measure in experiments, or to compute using lattice QCD. The latter is because strange quarks appear only in disconnected diagrams, which must be estimated stochastically. The current status of these calculations will be reviewed. There has been a considerable amount of progress over the last few years: we are now able to obtain a clear picture of the contri-bution from strange quarks to the distributions of charge, magnetization, and spin in the nucleon, among other observables.

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Nucleon momentum imaging and EIC

Mauro Anselmino

Despite the fact that nucleons form the almost totality of the visible matter in the Universe, they are still mysterious composite objects. The Transverse Momentum Dependent Partonic Distributions (TMD-PDFs) and Fragmentation Functions (TMD-FFs) should reveal new properties of the 3-dimensional momentum structure of nucleons and of the quark hadronization process. Many experimental data are now available, much progress has been made in their phenomenological interpretation, future facilities and experiments are being planned. A short summary of the situation is presented.

Workshop 2: New Avenues in Lepton Scattering

A Polarized 3He++ Ion Source for an EIC

Matthew Musgrave, Richard Milner, James Maxwell, Anatoli Zelenski, Ed Beebe, Grigor Atoian, Alexander Pikin, John Ritter, Sergey Kondrashev, Deepak Raparia

The capability of accelerating a polarized 3He ion beam in RHIC would provide an effective polarized neutron beam for the study of new high-energy QCD studies of nucleon structure. This development would be particularly beneficial for the future plans of an Electron Ion Collider, which could use a polarized 3He ion beam to probe the spin structure of the neutron. The proposed polarized 3He ion source is based on the Electron Beam Ion Source (EBIS) currently in operation at Brookhaven National Laboratory (BNL). 3He gas would be polarized within the 5 T field of the EBIS solenoid via Metastability Exchange Optical Pumping (MEOP) and then pulsed into the EBIS vacuum and drift tube system where the 3He will be ionized by the 10 Amp electron beam. The goal of the polarized 3He ion source is to achieve 2.5 x 1011 3He++/pulse at 70% polarization. An upgrade of the EBIS is currently underway at BNL in two phases. Phase one will increase the ion production capability by lengthening the trap volume and allow gas injection into the ionization region. Phase two will enable polarized 3He ion production. The source is being developed through collaboration between BNL and MIT.

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Virtual Compton Scattering on the Proton: New measurements of Generalized Polarizabilities at MAMI

Helene Fonvieille

An experiment has been performed recently at MAMI by the A1 Collaboration in order to obtain new information about the generalized polarizabilities (GPs) of the proton. The structure functions PLL − PT T /ǫ and PLT , as well as the electric and magnetic GPs, have been determined at three new values of Q2: 0.1, 0.2 and 0.45 GeV2. The preliminary results of the experiment will be presented.

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The MUSE Experiment: A Study of the "Proton Radius Puzzle" with simultaneous e-p and mu-p Elastic Scattering

William Briscoe

The controversy over the significant difference between the determination of proton radius using high-precision muonic hydrogen techniques and from electronic scattering and atomic measurements is called the "Proton Radius Puzzle" (PRP). The resolution of the puzzle remains unclear and appears to require new experimental results. The MUSE Collaboration will perform an experiment at the Paul Scherrer Institut (PSI) to make simultaneous measurements of muon-proton and electron-proton elastic scattering in an attempt to resolve the PRP.

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Workshop 2: New Avenues in Lepton Scattering

Dispersive and model calculations of two-photon exchange versus data

Oleksandr Tomalak

In view of the proton form-factor problem and proton radius puzzle, the two-photon exchange (TPE) corrections require a model-independent investigation as the largest source of the hadronic uncertainty in modern experiments. I present the dispersion relation approach, which is based on unitarity and analyticity, to evaluate the TPE in the elastic electron-proton scattering. The leading elastic and first inelastic pion-nucleon intermediate state contributions are accounted for in the region of small momentum transfer below 1 GeV2 entirely from the data input. The novel methods of the analytical continuation allowed to exploit the MAMI form factor fits and the MAID parameterization for the pion electroproduction amplitudes as an input in the calculation. The results are compared to the recent CLAS, VEPP-3 and OLYMPUS data as well as the full TPE correction in the near-forward approximation, which is based on the Christy and Bosted unpolarized structure functions fit. Additionally, predictions are given for a forthcoming muon-proton scattering experiment (MUSE) within the hadronic model and near-forward approximation.

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Electro-disintegration of ^{16}O as a tool for investigating the astrophysical $^{12}C(\alpha, \gamma)^{16}O$ reaction

Ivica Friščić

The relative abundance of 12C and 16O isotopes in massive stars (red giants) plays an important role in further nucleosynthesis and the consequent end of those star's lives. Understanding this abundance requires knowing the 12C(a, g)16O interaction cross section, but due to the Coulomb barrier, the cross section at stellar energies (~ 300 keV) is extremely small (~10–17 b), making direct reaction measurement impossible. Measurements of this have been made at higher energies and then extrapolated to stellar energies. Unfortunately, this extrapolation is a major contribution to the uncertainty.

As an alternative, the inverse reaction, the electro-disintegration of 16O, has a larger cross section than the direct 12C(a, g)16O reaction at the same energy. Compared to photo-disintegration, its cross section formula is more complicated, but since it is mediated by the exchange of virtual photons, transferred 3-momentum is independent of the transferred energy and can be large enough to detect the produced a particle in coincidence with the scattered electron.

We discuss what kind of experimental set-up is needed to perform such experiment, as well as what valuable information can be extracted from the measured data.

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Workshop 2: New Avenues in Lepton Scattering

Low-Energy Accelerators for High Precision Measurements

Sebastian Baunack

Energy Recovering Linacs (ERL) are a new type of electron accelerators which provide high beam currents at moderate electron energies in the range of a few hundred MeV. Experiments at such facilities can reach high luminosities using thin targets which allows for measurements with unprecedented precision. The acceletors can also operate in the so called external-beam-mode and deliver the electron beam to experiments with thick targets in order to reach very high luminosites.

The new experiments cover topics like nucleon form factors, nucleon polarizibil-ities, searches for particles in the dark sector and a high precision determination of the weak mixing angle. The talk will focus on the new acclerator MESA at Mainz which will be constructed within the next few years.

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Workshop 2: New Avenues in Lepton Scattering

Low Energy Nuclear Physics Experiments at Jefferson Lab

Stephen Benson

Jefferson Lab houses a state-of-the-art 12 GeV accelerator (CEBAF) that may be used to probe nuclear structure. Not all of the experiments at Jefferson Lab are carried out at the GeV scale though. Experiments in the CEBAF injector and in the Low Energy Recirculation Facility (LERF) are capable of doing experiments at low center of mass energy with very high intensities. I will go over some examples of experiments that have been either carried out or have been proposed using these low energy electron sources. The LERF contains an Energy Recovery Linac (ERL) that allows some novel experiments due to the combination of low energy, high current, and thick targets. An example of this, an experiment looking for dark matter candidates, will be described in some detail.

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Workshop 2: New Avenues in Lepton Scattering

The proton charge radius and the ProRad experiment

Mostafa Hoballah, Eric VOUTIER, Ronald Kunne, Dominique Marchand, Jacques Van De Wiele

The proton, a primary building block of the visible universe, was long ago shown to be a non-point like particle with intricate internal structure. The charge radius of the proton characterises its inside charge distribution. After decades of measurements, this radius – as extracted from world data electron scattering and atomic spectroscopy experiments - converged to the 0.87510(610) fm CODATA 2014 value. Novel muon spectroscopy techniques recently turned upside down this certainty providing the terrifically accurate 0.84184(67) fm measurement, about 5 standard deviations with respect to the electron CODATA. The absence of a consensus on the understanding of this discrepancy calls for new experiments breaking accuracy and momentum transfer frontiers and testing possible New Physics (NP) scenarios.

The ProRad (Proton Radius) experiment at the PRAE (Platform for Research and Applications with Electrons) multidisciplinary facility in Orsay, intends to measure the electric form factor of the proton with sub-percent accuracy in the never-explored momentum transfer range 10-5-10-4 (GeV/c2)2. The experiment consists in measuring the cross section for the elastic scattering of 30-70 MeV/c electrons off protons in the 6°-16° angular range. Accuracy in all respects is the key challenge for this experiment, starting with the well-defined and established PRAE electron beam. An energy compression system intends to reduce the beam momentum dispersion down to 5.10-4, and a spectrometer measures the beam energy with a 5.10-4 accuracy. The interaction region consists of a 250 µm beam spot size colliding with a boundary-free self-replenishing laminar liquid hydrogen jet. The detector setup is built from 28 elementary cells made of a scintillating fibres position detector and a BGO crystal. The principle of operation of the essential elements of the ProRad experiment will be discussed.

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EIC Detectors

Jose Repond

The planned Electron-Ion Collider (EIC) will collide (polarized) electrons and (polarized) protons or nuclei at high luminosity. To fully exploit the physics potential of this unique facility state-of-the-art detectors are required. My talk will review the particular challenges being faced and the various detector concepts being developed to address these.

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Workshop 2: New Avenues in Lepton Scattering

Gas Electron Multipliers for high-intensity applications

Michael Kohl

Two Gas Electron Multiplier (GEM) telescopes, each consisting of three 10x10 cm2 triple-GEM chambers were built, tested and operated by the Hampton University group. The GEMs are read out with APV-25 frontend cards and FPGA based digitizing electronics developed by INFN Rome. The telescopes were initially used for the luminosity monitoring system at the OLYMPUS experiment at DESY in Hamburg, Germany, via elastic forward-angle lepton-proton scattering with positron and electron beams at 2 GeV. The GEM elements have been recycled to serve in another two applications: Three GEM elements are used to track beam particles in the Muon Scattering Experiment (MUSE) at Paul Scherrer Institute (PSI) in Switzerland. A set of four elements has been configured as a prototype tracker for phase-1A of the DarkLight experiment at the Low-Energy Recirculator Facility (LERF) at Jefferson Lab in Newport News, USA, in a first test run in summer 2016. The Hampton group is constructing the DarkLight phase-1C lepton trackers. Further efforts are ongoing to optimize the data acquisition performance for high-rate GEM operations at MUSE and DarkLight. An overview of the GEM detector related activities will be given.

This work has been supported by the U.S. National Science Foundation and Department of Energy.

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Beam normal spin asymmetry for the e p to e Delta(1232) process

Carl Carlson

We calculate the single spin asymmetry for the ep → eΔ(1232) process, for an electron beam polarized normal to the scattering plane. Such single spin asymmetries vanish in the one-photon exchange approximation, and are directly proportional to the absorptive part of a two-photon exchange amplitude. As the intermediate state in such two-photon exchange process is on its mass shell, the asymmetry allows one to access for the first time the on-shell Δ → Δ as well as N∗ → Δ electromagnetic transitions. We present the general formalism to describe the ep → eΔ beam normal spin asymmetry, and provide a numerical estimate of its value using the nucleon, Δ(1232), S11(1535), and D13(1520) intermediate states. We compare our results with the first data from the Qweak@JLab experiment and give predictions for the A4@MAMI experiment.

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Workshop 2: New Avenues in Lepton Scattering

Theory of Two-Photon Physics

Igor Danilkin, Marc Vanderhaeghen

In my talk, I will present our recent dispersive analysis of the $\gamma\gamma* \to \pi\pi$ processes from the threshold up to the f2(1280) region in the $\pi\pi$ invariant mass. These amplitudes serve as important input to constrain the hadronic piece of light-by-light scattering contribution to (g-2) and support the current experimental program at BESIII. As well, I will present an application of the light-by-light scattering sum rules to the $\gamma\gamma*$-production of mesons in light of the new data by the Belle Collaboration on the transition form factors.

[1] I. Danilkin and M. Vanderhaeghen, “Light-by-light scattering sum rules in light of new data,” Phys. Rev. D 95 (2017) no.1, 014019 [arXiv:1611.04646 [hep-ph]].

[2] I. Danilkin and M. Vanderhaeghen, “Dispersive analysis of the $\gamma\gamma* \to \pi+\pi-$, $\pi0\pi0$ processes,” (in preparation)