Presenter: Bland, Les (Brookhaven National Lab)
Coauthors:
Title: Prospects for Low-x Physics at RHIC
Abstract: RHIC is a versatile collider that has provided a wealth of measurements telling us about hot QCD via heavy-ion collisions, nuclear matter effects via collisions of protons or deuterons with heavy ions, and the spin structure of the proton via collisions of polarized protons. The most sophisticated experimental equipment is near midrapidity, which probes initial-state partons with momentum fraction $x \approx 2p_T/\sqrt{s}$, where $p_T$ is the transverse momentum of detected particles. Typically, $p_T$ must be large enough so that perturbative QCD is applicable. Much lower momentum fractions (down to $x 10^{-3}$) can be reached by measurements in the forward direction, defined by when the Feynman $x$ scaling variable ($x_F = 2p_z/\sqrt{s}$) is sizable. Calorimeters have been built for forward physics at RHIC. This talk will discuss options for further forward instrumentation, and the physics capabilities such new instrumentation provides.

Presenter: Boer, Daniel (University of Groningen)
Coauthors:
Title: TMDs at small $x$
Abstract: At leading twist there are eight quark and eight gluon transverse momentum distributions (TMDs), which in addition turn out to have a process dependence. This multitude of functions is much reduced when considering the small-$x$ limit, where gluons dominate and the process dependence simplifies in specific cases. This is especially relevant for the understanding of single transverse spin asymmetries which can be investigated at high energy colliders such RHIC and an EIC. This talk will review our current understanding and the experimental opportunities. The role of Wilson loop correlators will be discussed, as well as the polarization of the Color Glass Condensate and the spin-dependent odderon.

Presenter: Boglione, Mariaelena (University of Turin)
Coauthors:

Title: Probing the inner structure of nucleons: TMDs at an EIC

Abstract: I will give a brief introduction to the physics of TMDs, to their theoretical properties and phenomenological implications. I will then focus on their phenomenological extraction, with special attention to the discussion of open questions to which a future EIC could contribute, in relation to ongoing and planned activities at other facilities.

Presenter: Chu, Xiaoxuan (Brookhaven National Lab)

Coauthors:

Title: Studying photon structure at EIC

Abstract: A future Electron-Ion Collider (EIC) will deliver luminosities of $10^{33}, 10^{34} cm^{-2}s^{-1}$ for collisions of polarized electrons and protons and heavy ions over a wide range of center-of-mass energies (40 GeV to 145 GeV). One of its promising physics programs is to study the partonic structure of quasi-real photons. Measuring di-jets in photoproduction events, one can effectively access the underlying parton dynamics of the photons through the selection of the resolved photon processes. In this talk, we discuss the feasibility of tagging resolved photon processes and measuring the di-jets cross section as a function of jet transverse momentum in ranges of $x_{\gamma}^{rec}$ at an EIC. These studies show that both unpolarized and polarized parton distributions in the photon can be extracted at an EIC.

Presenter: Cooper-Sarkar, Amanda (University of Oxford)

Coauthors:

Title: Impact of potential LHeC measurements on parton distribution functions

Abstract: The potential of the LHeC, a future electron-proton collider, for precision Deep Inelastic Scattering measurements is reviewed with particular emphasis on the reduction of uncertainties on the parton distribution functions (PDFs) of the proton and on the measurement of $\alpha_s(M_Z)$. The interpretation of possible Beyond Standard Model (BSM) signals at the LHC is crucially dependent on precise knowledge of the predictions of the Standard Model (SM) and the uncertainties on PDFs and $\alpha_s(M_Z)$ are a limiting factor. The LHeC project, running in parallel with later stages of LHC running, would provide much improved precision on the PDFs as compared to the precision expected from LHC data alone.

Presenter: Cosyn, Wim (Ghent University)

Coauthors: Christian Weiss

Title: Next-generation nuclear DIS: spectator tagging with light ions at an EIC

Abstract: An Electron-Ion Collider (EIC) would enable next-generation measurements of DIS on light nuclei (deuteron, $^3$He, ...) with detection of nucleons and fragments in the forward region and measurement of their recoil momentum ("spectator tagging"). Such experiments allow one to control the nuclear configuration during the high-energy process and could be used for (a) precision measurements of neutron spin structure in electron-deuteron DIS with proton tagging, eliminating nuclear binding through on-shell extrapolation in the recoil momentum; (b) controlled measurements of the nuclear modifications of quark/gluon densities (EMC effect) in defined nuclear configurations; (c) novel studies of diffraction and nuclear shadowing at $x \ll 0.1$. Needed to describe spectator tagging
reactions with a polarized deuteron, the general structure of the cross section for SIDIS on a spin 1 target is outlined, which has additional tensor polarisation structures compared to the familiar spin 1/2 (nucleon) case. We introduce a factorized model, where deuteron structure is described using the NN light-front wave function and which accounts for relativistic spin effects. We review the physics applications of spectator tagging at an EIC, summarize the experimental and theoretical challenges, and report process simulations and physics impact studies from a dedicated R&D project.

**Presenter:** Dominguez, Fabio (*Universidade de Santiago de Compostela*)

**Coauthors:**

**Title:** Small-x evolution beyond the eikonal approximation

**Abstract:** Following the recent studies in the effects of next-to-eikonal and next-to-next-to-eikonal propagation in high-energy proton-nucleus collisions, we address the question of whether such corrections have an effect on small-x evolution. The discussion is thus centered in figuring out if the regions of phase space for which beyond-eikonal corrections would be important are part of the logarithmically enhanced regions contributing to the evolution. Taking into account considerations from NLO calculations in the CGC framework, we show explicitly that such corrections are not important at the leading logarithmic level.

**Presenter:** Dumitru, Adrian (*Dept. of Natural Sciences, Baruch College (CUNY)*)

**Coauthors:**

**Title:** Azimuthal anisotropy and the distribution of linearly polarized gluons in DIS dijet production at high energy

**Abstract:** High Pt Dijet production in ep/eA DIS at small x (high energy) involves the expectation value of a trace of four Wilson lines, i.e. the quadrupole. At leading power the isotropic part can be expressed as the conventional Weizsacker-Williams gluon distribution. On the other hand, the distribution of linearly polarized gluons determines the amplitude of the $\sim \cos(2\phi)$ anisotropy of the transverse momentum imbalance. I present numerical solutions of the JIMWLK evolution equations to discuss the behavior of these functions at small x. I will also discuss the operator that determines the next-to-leading power correction, its expectation value in a Gaussian theory (at large $N_c$), asymptotic geometric scaling, and the resulting $\sim \cos(4\phi)$ azimuthal dependence.

**Presenter:** Dupre, Raphael (*IPN Orsay*)

**Coauthors:**

**Title:** Tomographic image of the proton from DVCS data

**Abstract:** I will present our method to extract the Compton form factors of the proton based on the latest experimental Deep Virtual Compton Scattering experimental data. Then, from these results, the extraction of the three-dimensional momentum-space image and tomography of the proton. Finally, I will discuss the impact that future experiments can have to improve this picture of the nucleon.

**Presenter:** Furletova, Yulia (*Jefferson Lab*)

**Coauthors:** Christian Weiss, Sergey Furletov, Eugene Chudakov, Douglas Higinbotham, Charles
Title: Nuclear gluons probed with heavy quarks at an Electron Ion Collider

Abstract: Heavy quark production in DIS represents a direct probe of the gluon density in the target at a fixed scale. Such measurements with nuclei can address basic questions regarding the nuclear modification of gluons: gluons suppression at \( x > 0.3 \) (EMC effect) and/or gluons enhancement at \( x \approx 0.1 \) (antishadowing), as suggested by the strong shadowing observed at \( x < 0.1 \). In this talk, the status of an ongoing R&D project investigating the feasibility of direct measurements of nuclear gluons at large-\( x \) using heavy quark probes (open charm, beauty) with an Electron-Ion Collider (EIC) will be presented. The charm production rates, angle and momentum distributions, charm reconstruction, potential new methods available with EIC’s next-generation detector capabilities (pi/K identification, vertex detection), and also the uncertainties in nuclear ratio measurements and the impact on nuclear gluons will be discussed.

Presenter: Gamberg, Leonard (Penn State University-Berks)

Coauthors:

Title: Matching TMD factorization and collinear factorization

Abstract: In this talk I will review work on an improved implementation for combining transverse-momentum-dependent (TMD) factorization in semi-inclusive DIS and collinear factorization. TMD factorization is suitable for low transverse momentum physics, while collinear factorization is suitable for high transverse momenta and for a cross section integrated over transverse momentum. The result is a modified version of the standard matching prescription traditionally used in the Collins-Soper-Sterman formalism and related approaches. We briefly discuss how an EIC could help to further our study of matching between the TMD approach and collinear factorization.

Presenter: Gonzalez, Osvaldo (Old Dominion University)

Coauthors:

Title: Current fragmentation at the kinematics of the EIC

Abstract: Transverse momentum dependent functions (TMDs) are an essential component of the rich phenomenology in hadronic processes. The most recent semi-inclusive deep inelastic scattering (SIDIS) measurements have challenged our understanding of these non-perturbative functions. In this talk, I will discuss some of the complications that arise in phenomenological applications. I will pay special attention to the kinematical range of validity of the TMD formalism and discuss the need for accurate multidimensional SIDIS measurements at the energy ranges projected by the EIC.

Presenter: Gupta, Rajan (Los Alamos National Lab)

Coauthors:

Title: Nucleon transverse momentum-dependent parton distributions from Lattice QCD

Abstract: We present lattice QCD calculations of transverse momentum dependent parton distribution functions (TMDs) of protons using operators with staple-shaped Wilson lines. For naively time-reversal odd observables, we study the generalized Sivers and Boer-Mulders transverse momentum shift applicable to SIDIS and DY experiments, and for T-even observables we calculate the transversity related to the tensor charge and the generalized worm-gear shift. Results obtained on two
different \( n_f = 2 + 1 \) flavor ensembles, domain-wall fermion (DWF) with lattice spacing 0.084 fm and pion mass of 297 MeV, and clover fermion with lattice spacing 0.114 fm and pion mass of 317 MeV will be compared and current level of control over systematics highlighted.

**Presenter:** Guzey, Vadim *(Petersburg Nuclear Physics Institute)*

**Coauthors:**

**Title:** Small-x collective effects in eA scattering

**Abstract:** The talk will present an overview of the small-x collective nuclear effects of shadowing and antishadowing in nuclear parton distributions (nPDFs) probed in lepton-nucleus (eA) scattering at high energies. After a review of the results of the extraction of nPDFs from the available data using global QCD fits, we will discuss predictions of the dynamical leading-twist nuclear shadowing model for small-x nPDFs. We will explain how the large nuclear gluon shadowing, which naturally emerges in this approach as a consequence of large probability of diffraction in the gluon channel measured in ep diffractive deep-inelastic scattering (DIS), is confirmed by the recent LHC data on charmonium photoproduction in nucleus-nucleus collisions at large impact parameters. We will then discuss prospects of reducing uncertainties in small-x nPDFs and establishing the dynamics of nuclear shadowing and antishadowing using various measurements of eA scattering at an Electron-Ion Collider.

**Presenter:** Gwenlan, Claire *(University of Oxford)*

**Coauthors:**

**Title:** High Q2 Physics at the LHeC and FCC-he (top, electroweak and BSM)

**Abstract:** Energy-frontier deep inelastic scattering at 1000 times higher luminosity than HERA is considered with the LHeC and further the FCC-he. These collider configurations provide unique possibilities for SM and BSM top physics, for novel electroweak precision measurements and for further BSM investigations such as for lepto-partons at the FCC-he. The high precision PDF and \( \alpha_s \) information from the LHeC will have a direct impact on the BSM search potential and interpretation of new physics at the LHC.

**Presenter:** Iancu, Edmond *(Institut de Physique Theorique de Saclay)*

**Coauthors:**

**Title:** Particle production in proton-nucleus collisions beyond leading order

**Abstract:** The cross-sections for particle production in pA can in principle be computed within perturbative QCD, using the framework of the Color Glass Condensate. However, recent efforts trying to extend such calculations beyond the leading-order (LO) approximation met with an unexpected difficulty: the next-to-leading order (NLO) prediction for the hadron multiplicity suddenly turns negative at transverse momenta of the order of a few GeV, in a range where perturbation theory was expected to be reliable. This problem triggered much interest and several studies over the last 5 years, but not satisfactory solution has emerged. In a recent publication, we have revisited the previous proposals for the CGC factorization at NLO and identified the source of the negativity problem: this is related to the subtraction method used to separate LO from NLO contributions. To overcome this difficulty, we proposed a new factorization scheme which involves no such a subtraction: the relevant, LO or NLO, perturbative contributions are included once and only once. We have thus obtained a manifestly positive expression for the cross-section for hadron multiplicities in pA. On this occasion,
we have also extended the resummation program that we recently proposed for the BK and JIMWLK evolution equations to the calculation of cross-sections. Besides its phenomenological implications, this new factorization scheme should provide a better framework for computing particle production in QCD at high energy.

**Presenter:** Klasen, Michael *(University of Münster)*
**Coauthors:**
**Title:** Nuclear PDFs from jet production at EIC
**Abstract:** We present an exploratory study of jet production at the EIC and its sensitivity to nuclear PDFs, based on NLO and aNNLO calculations with JetViP.

**Presenter:** Klein, Max *(University of Liverpool)*
**Coauthors:**
**Title:** Development of the LHeC
**Abstract:** This presentation summarises the present status and prospects for the development of the LHeC.

**Presenter:** Kotko, Piotr *(Penn State University)*
**Coauthors:**
**Title:** Forward dijets in p-A and gamma-A collisions within the small-x improved TMD factorization
**Abstract:** The small-x improved TMD factorization is a framework which utilizes several unintegrated gluon distributions (UGDs) and accompanying off-shell gauge invariant hard factors. It is valid when the hard scale $P_T$ (given by the average $p_T$ of the jets) is much bigger than the saturation scale $Q_s$, while the third important scale, the dijet imbalance $k_T$, is arbitrary. When $k_T$ becomes of the order of $Q_s$ the framework reduces to the leading power limit of CGC, whereas when $k_T$ becomes of the order of $P_T$ it reduces to the ordinary High Energy Factorization with single UGD. We use that framework to calculate nuclear modification ratios for dijet production in p-Pb collisions and in the ultraperipheral Pb-Pb collisions at the LHC. Both processes are sensitive to different UGDs, thus being complementary. The five UGDs entering the calculation of p-Pb process can be obtained in the large $N_c$ limit from the dipole UGD and the Weizsacker-Williams (WW) UGD. The gamma-Pb process is sensitive to WW UGD directly. Since there is not much known on the WW gluons from the data, in our calculations we have used the Gaussian approximation so that all UGDs could be obtained from the dipole UGD alone. We have used the dipole UGD undergoing the nonlinear BK evolution with subleading corrections (the kinematic constraint and the DGLAP correction) and fitted to HERA data.

**Presenter:** Koutsou, Giannis *(The Cyprus Institute)*
**Coauthors:**
**Title:** Lattice QCD calculations of the quark and gluon contributions to the spin and momentum of the nucleon
**Abstract:** Recent nucleon structure results from lattice QCD will be presented, using simulations
with quark masses which reproduce physical or near-physical values of the pion mass. Emphasis will be given to observables which probe the decomposition of the nucleon spin and momentum into its quark and gluonic contributions, such as axial charges and moments of PDFs.

**Presenter:** Kovchegov, Yuri (*Ohio State University*)  
**Coauthors:** Daniel Pitonyak, Matthew Sievert  
**Title:** Helicity evolution at small $x$  
**Abstract:** We construct small-$x$ evolution equations which can be used to calculate quark and antiquark helicity TMDs and PDFs, along with the $g_1$ structure function. These evolution equations resum powers of $\alpha_s \ln^2(1/x)$ in the polarization-dependent evolution along with the powers of $\alpha_s \ln(1/x)$ in the unpolarized evolution which includes saturation effects. The equations are written in an operator form in terms of polarization-dependent Wilson line-like operators. While the equations do not close in general, they become closed and self-contained systems of non-linear equations in the large-$N_c$ and large-$N_c \& N_f$ limits.

**Presenter:** Kriesten, Brandon (*University of Virginia*)  
**Coauthors:** Simonetta Liuti, Ahba Rajan  
**Title:** Accessing quark orbital angular momentum through GTMDs  
**Abstract:** It has been a long motivated problem that the individual spin contributions of the quarks and gluons do not add up to the total spin of the proton. Two independent spin sum rules developed individually by Ji and Jaffe Manohar were proposed to provide solutions to this spin crisis by investigating the contribution of quark orbital angular momentum. The Ji definition preserves gauge invariance through a straight gauge link while the Jaffe Manohar definition uses a staple gauge link. I present a diquark model calculation of Ji and Jaffe Manohar orbital angular momentum using the GTMD $F_{14}$ simulating the difference by a single gluon exchange on one side of the diagram.

**Presenter:** Kumano, Shunzo (*KEK*)  
**Coauthors:**  
**Title:** Tensor-polarized structure functions for spin-one hadron  
**Abstract:** There are new polarized structure functions for a spin-1 hadron, and they are named $b_1$, $b_2$, $b_3$, and $b_4$. Among them, the twist-2 structure functions are $b_1$ and $b_2$, which are expressed by tensor-polarized parton distribution functions. These functions are very different from the longitudinally-polarized parton distribution functions measured by the structure function $g_1$, and they probe unpolarized-quark distributions in the tensor-polarized spin-1 hadron. The most simple and stable spin-1 target is the deuteron in deep inelastic scattering, and the structure function $b_1$ was measured by the HERMES Collaboration [1]. However, its errors are large, so that accurate measurements are planned at JLab [2] and it should be investigated by EIC. Furthermore, the Drell-Yan measurement is considered in the Fermilab E1039 experiment with the tensor-polarized deuteron target for measuring tensor-polarized antiquark distributions, and the tensor-polarization asymmetry is theoretically estimated for such an experimental proposal [3]. Since the standard convolution estimate for $b_1$ with D-state admixture is very different from the HERMES result [4], the studies of tensor-polarized structure functions could lead to a new finding in hadron physics. The future EIC project should be able to probe smaller-$x$ region than the JLab region, so that the EIC experiment...
should provide us important information in understanding the tensor structure in terms of quark and gluon degrees of freedom.

References

Presenter: Lee, Christopher (Los Alamos National Lab)
Coauthors:
Title: Precision jet physics in DIS
Abstract: Hadronic jets are treasure troves of information about the dynamics of QCD, the strong coupling, hadron structure, and new physics. In this talk I discuss advances using soft collinear effective theory (SCET) to resum perturbative predictions for jet observables in DIS to unprecedented NNNLL accuracy and rigorously identify universal nonperturbative corrections due to hadronization. These predictions make possible extractions of the strong coupling, hadronization effects, and parton distributions to the few percent level from measurements of jets in DIS using existing data from HERA or future measurements at an EIC.

Presenter: Liu, Keh-Fei (University of Kentucky)
Coauthors:
Title: PDF from hadronic tensor on the Lattice and connected sea evolution
Abstract: A path-integral formulation of the hadronic tensor is reviewed where the connected and disconnected sea parsons are separated. I shall discuss how they can be calculated on the lattice and identified from experiments. I will also discuss how the evolution equations can be extended to accommodate both the connected and disconnected sea partons.

Presenter: Lyonnet, Florian (SMU)
Coauthors:
Title: Vector boson production in pPb and PbPb collisions at the LHC and its impact on ncteqfit PDFs
Abstract: We provide a comprehensive comparison of $W^\pm/Z$ vector boson production data in PPb and PbPb collisions at the LHC with predictions obtained using the nCTETQ fit PDFs. We identify the measurements which have the largest potential impact on the PDFs, and estimate the effect of including these data using a Monte Carlo reweighting method. We find this data set can provide information about both the nuclear corrections and the heavy flavor (strange quark) PDF components. As for the proton, the parton flavor determination/separation is dependent on nuclear corrections (from heavy target DIS, for example), this information can also help improve the proton PDFs.

Presenter: Majumder, Abhijit (Wayne State University)
Coauthors:
Title: Jet quenching and the relation between $\hat{q}$ and the TMDPDF
Abstract: We take a closer look at the single particle nuclear modification factor ($R_{AA}$) and azimuthal anisotropy ($v_2$) of leading hadrons at high transverse momentum ($p_T$) at both RHIC and LHC collision energies. We focus on the established reduction in the interaction measure $\hat{q}/T^3$ between RHIC and LHC, as discovered by the JET collaboration. The centrality dependence of the $R_{AA}$ and $v_2$ at both these collision energies strongly suggests that the reduction is not caused by a temperature dependence in the ratio of $\hat{q}/T^3$ but rather by an energy dependence of $\hat{q}$. We study this dependence by introducing an $x$-dependence in the distribution function that is integrated to obtain $\hat{q}$. We conjecture on possible forms of a scale dependence by relating $\hat{q}$ to an object similar to a transverse momentum dependent parton distribution function (TMDPDF). The ensuing operator product is then related to quantities that may be estimated in lattice QCD.

Presenter: Miller, Gerald (University of Washington)
Coauthors:
Title: eA collective effects at an EIC
Abstract: Recent exciting developments that connect lepton-nucleus deep-inelastic scattering with $(e,e')$ quasielastic scattering at large values of Bjorken $x$ are reviewed. The surprise is that the interesting nuclear dependence of each reaction has the same common origin, which is related to close encounters between two nucleons. Implications for an EIC are discussed.

Presenter: Mueller, Berndt (Duke University and Brookhaven National Lab)
Coauthors:
Title: A future electron-ion collider at BNL
Abstract: The existing AGS-RHIC accelerator complex at BNL can be cost-effectively transformed into a polarized electron-ion collider (eRHIC) by the addition of an electron accelerator. In my talk I will survey the current status of eRHIC design, including options for the electron accelerator, our ongoing eRHIC accelerator and detector R&D efforts, and the science program that can be enabled by this facility.

Presenter: Nocera, Emanuele (University of Oxford)
Coauthors:
Title: Unpolarized and helicity PDFs at an EIC
Abstract: I review the current progress in the determination of the collinear unpolarized and polarized parton distribution functions (PDFs) of the proton. I summarize the methodology used to extract PDFs from experimental data, and the way in which different physical processes can be used to constrain different PDFs. I outline our present knowledge of PDFs, and the limitations entailed for an accurate determination of the proton’s substructure in terms of parton dynamics. I delineate how the program at a future Electron Ion Collider should allow us to successfully address some of these open issues.
Presenter: Olness, Fredrick (SMU)
Coauthors:
Title: The xFitter Project: an open source QCD fit framework
Abstract: xFitter is an open-source package that provides a framework for the determination of the parton distribution functions (PDFs) for many different kinds of analyses in Quantum Chromodynamics (QCD). It encodes results from a wide range of experimental measurements, and these are complemented with a variety of theoretical options for calculating PDF-dependent cross section predictions. While primarily based on the approach of collinear factorisation, xFitter also provides facilities for fits of dipole models and transverse-momentum dependent PDFs. The package can be used to study the impact of new precision measurements on the PDFs.

Presenter: Orginos, Kostas (William and Mary / Jefferson Lab)
Coauthors:
Title: Lattice QCD calculations of GPDs
Abstract: Lattice QCD offers the possibility of computing Generalized Parton Distributions (GPDs) from first principles. In order to achieve this several technical obstacles resulting from the formulation of QCD on a Euclidean lattice, have to be overcome. In this talk I review recent lattice QCD calculations of GPDs. In addition I will discuss what the future of such calculations is and explore the potential impact that Lattice QCD may have to the future electron ion collider experimental program.

Presenter: Page, Brian (Brookhaven National Lab)
Coauthors:
Title: Experimental aspects of jet physics in ep collisions
Abstract: Jets have been an important observable in high-energy physics for over four decades, and a steady advance of experimental technique and theoretical understanding has turned them into precision tools for investigating QCD. A precise understanding of QCD is the overarching goal of the proposed Electron-Ion Collider (EIC), so it is natural to ask what role jet observables can play in the EIC physics program. This talk will discuss various experimental aspects of jet production from ep collisions at an EIC, including production rates, particle content and typical energy ranges. Several analysis examples, which demonstrate the utility of jet observables at an EIC, will also be discussed.

Presenter: Petriello, Frank (Northwestern University)
Coauthors:
Title: Inclusive jet production in electron-nucleon collisions
Abstract: We discuss the $O(\alpha^2\alpha_s^2)$ perturbative corrections to inclusive jet production in electron-nucleon collisions. This process is of interest to the physics program of a future Electron Ion Collider (EIC). It is also a useful benchmark to determine the impact of and need for precision calculations at the EIC. Our calculation allows for a completely differential description of the final state and is implemented in a flexible Monte Carlo program. The higher-order corrections have a non-trivial dependence on the jet kinematics and arise from an intricate interplay between all contributing partonic channels.
Presenter: Pisano, Cristian (University of Pavia and INFN Pavia)
Coauthors:
Title: Transverse momentum dependent gluon distributions at the EIC
Abstract: Asymmetries in heavy quark pair and dijet production in electron-proton collisions allow studies of gluon transverse momentum dependent distributions (TMDs), in close analogy to studies of quark TMDs in semi-inclusive DIS. We consider both unpolarized and transversely polarized protons and calculate the maximal asymmetries allowed. In addition, we consider the small-x limit and expectations from a McLerran-Venugopalan model for unpolarized and linearly polarized gluons and from a perturbative, large transverse momentum calculation for the T-odd gluon TMDs. Comparison to related observables at RHIC and LHC is expected to provide valuable information about the process dependence of the gluon TMDs. In particular this will offer the possibility of a sign change test of the gluon Sivers TMD and two other T-odd gluon TMDs.

Presenter: Pitonyak, Daniel (Penn State University-Berks)
Coauthors:
Title: Twist-3 spin observables and multi-parton correlations in electron-proton collisions at an EIC
Abstract: We review twist-3 spin observables in electron-proton collisions, with particular emphasis on their relevance for an Electron-Ion Collider. We focus on transverse single-spin asymmetries and discuss how electron-proton collisions can give us insight into the analogous observables in proton-proton collisions. We also show how twist-3 observables give us direct access to multi-parton correlations in hadrons.

Presenter: Prokudin, Alexei (Penn State University-Berks)
Coauthors:
Title: What do we know about transversity distribution of the nucleon?
Abstract: In my talk I will present status and progress of extractions of transversity distribution of the nucleon from Semi Inclusive Deep Inelastic Scattering and e+e- data using Collins asymmetries and dihadron asymmetries. I will discuss the impact of Electron Ion Collider data and data from other facilities such as Jefferson Lab 12 GeV and RHIC on the extraction of transversity and tensor charge.

Presenter: Rajan, Abha (University of Virginia)
Coauthors: Simonetta Liuti
Title: Partonic orbital angular momentum and Lorentz invariance relations
Abstract: We show that Generalized Transverse Momentum Distributions (GTMDs) and twist three Generalized Parton Distributions (GPDs) can be connected through Lorentz Invariant Relations (LIRs). In particular, the GTMDs $F_{14}$, or the correlation of an unpolarized quark in a longitudinally polarized proton, is known to describe the quarks Orbital Angular Momentum (OAM). In a separate approach, the twist three GPD $\tilde{E}_{2T}$ was also be shown to connect to OAM. We show that these two definitions are connected by a LIR. The twist three GPD, $\tilde{E}_{2T}$, through an implicit quark gluon interaction reproduces the effects of intrinsic transverse momentum in the GTMDs. We find similar relations for other GTMDs and GPDs. For example, the GTMD $G_{11}$ which describes quark spin orbit correlations in the proton can be connected to another twist three GPD, $E'_{2T}$. 
Presenter: Ringer, Felix (Los Alamos National Lab)

Coauthors: Zhongbo Kang, Ivan Vitev

Title: The jet fragmentation function in $pp$ and $ep$ collisions

Abstract: We consider the jet fragmentation function which describes the longitudinal momentum distribution of hadrons inside a reconstructed jet. In the past years, this jet substructure observable has been measured with high precision by the experimental collaborations at the LHC. In addition, studying the jet fragmentation function can provide valuable insights into the QCD dynamics relevant at an electron ion collider (EIC). We review the definition of semi-inclusive jet functions within Soft Collinear Effective Theory (SCET) and their application to semi-inclusive jet cross sections. The semi-inclusive jet functions satisfy renormalization group (RG) equations which take the form of standard timelike DGLAP evolution equations, analogous to collinear fragmentation functions. By solving these RG equations, the resummation of potentially large single logarithms ($\alpha_s \ln R$) can be achieved. We present numerical results at NLO+NLL$_R$ accuracy for both $pp$ and $ep$ collisions.

Presenter: Ryan, Sinead (Trinity College Dublin)

Coauthors:

Title: The $X,Y,Z$ states from Lattice QCD: progress and prospects

Abstract: Lattice calculations of hadron spectroscopy are discussed, with a particular focus on the $X,Y,Z$ states in charmonium. Recent progress that has enabled determinations of scattering parameters, including in a coupled-channel analysis, is briefly described. The prospects for an application of these ideas to the $X,Y,Z$ states and the challenges that entails is included.

Presenter: Sato, Nobuo (Jefferson Lab)

Coauthors:

Title: Towards universal fit of PDFs, spin dependent PDFs (SPDF) and fragmentation functions (FF)

Abstract: We present a new global QCD analysis of spin-dependent PDFs (SPDF) and fragmentation functions (FF) performed by the JAM (Jefferson Lab Angular Momentum) Collaboration which includes all available data on inclusive spin structure functions from CERN, SLAC, DESY and JLab and all semi-inclusive hadron production data from electron-positron annihilation experiments including the most resent measurements from Belle and BaBar.

Presenter: Schäfer, Andreas (Regensburg University)

Coauthors:

Title: GPDs on and off the lattice

Abstract: The QCD group in Regensburg is working on a variety of GPD related questions. I will present some of them, trying to avoid overlap with other speakers on GPD topics. Two topics which will be covered are: (1) Exclusive heavy quarkonia production in proton-proton collisions including resummation of beyond NLO contributions to the heavy quarkonia photoproduction cross-sections. and, (2) Recent Lattice QCD results for moments of GPDs by RQCD.
Presenter: Schenke, Björn (Brookhaven National Lab)
Coauthors: Heikki Mantysaari
Title: Evidence of strong proton shape fluctuations from incoherent diffraction
Abstract: We show within the saturation framework that measurements of exclusive diffractive vector meson production in electron-proton scattering at HERA provide evidence for strong geometric fluctuations of the proton. In comparison, the effect of saturation scale and color charge fluctuations is weak. This knowledge will allow detailed future measurements of the incoherent cross section at e.g. an electron ion collider to tightly constrain the fluctuating geometry of the proton as a function of the parton momentum fraction x. We discuss how this information is highly relevant for the understanding of proton-heavy ion collisions at RHIC and LHC.

Presenter: Schlichting, Sören (University of Washington)
Coauthors:
Title: Azimuthal correlations in p+p/A collisions and their relation to proton structure
Abstract: Experimental results on long range azimuthal correlations in p+p and p+A collisions have triggered an exciting debate on the origin of the observed ridge structure. At present competing theoretical explanations exist, attributing the observed correlations either to initial state effects, reflecting multi-parton correlations in the hadronic wave, or to final state effects, reflecting the collective response to the initial state geometry. In this talk I will provide a brief overview of the current theoretical status and discuss how, in both scenarios, the correlations observed in p+p/A collisions relate to fundamental aspects of proton structure.

Presenter: Sievert, Matthew (Los Alamos National Lab)
Coauthors: Yuri Kovchegov, Daniel Pitonyak
Title: Small-x asymptotics of the quark helicity distribution
Abstract: We present the solution of the small-x evolution equations for the quark helicity distribution. Because of the complexity of the equations, we employ an iterative numerical solution, obtaining the power-law behavior of the quark helicity distribution at small x. We discuss the phenomenological implications of this solution, particularly for the proton spin budget. We also note a disagreement with previous results in the literature, and we discuss possible origins of this discrepancy.

Presenter: Steffens, Fernanda (DESY-Zeuthen)
Coauthors:
Title: Direct calculation of PDFs in Lattice QCD
Abstract: Parton distributions are usually defined as light-cone correlations in the nucleon. Until recently, however, it was not possible to calculate the distributions in lattice QCD because, unlike spatial correlations, one cannot simulate light-cone correlations in a Euclidian lattice. In 2013, Ji proposed a way to circumvent this restriction, through the use of quark quasi-distributions which are defined as purely spatial correlations. Although they are not the physical distributions, the quark quasi-distributions are related to the quark distributions through a perturbative calculation. Within this procedure, a direct calculation of the distributions in lattice QCD became a possibility, and we present here a high statistics analysis of the x-dependence of the bare unpolarized, helicity
and transversity iso-vector parton distribution functions (PDFs) from lattice calculations employing (maximally) twisted mass fermions. The x-dependence of the calculated PDFs resembles those of the phenomenological parameterizations, a feature that makes this approach promising despite the lack of a full renormalization program for them.

**Presenter:** Sumbera, Michal *(Nuclear Physics Institute ASCR)*  
**Coauthors:** Roman Pasechnik, Victor Goncalves, Jan Nemchik  
**Title:** Color dipole approach to Drell-Yan and heavy quarkonia production at RHIC and LHC  
**Abstract:** We review the recent progress in color dipole description of the Drell-Yan ($\gamma$ and $Z_0$) dilepton and heavy quarkonium spectra in pp and pA collisions at RHIC and LHC energies. Different phenomenological models based on the saturation physics are used to constrain QCD dynamics. We also study azimuthal correlations between mid-rapidity dilepton pairs (from Drell-Yan process or quarkonia decay) and central or forward high-$p_T$ pions which promise to be even more restrictive for saturation models. Predictions for the rapidity and transverse momentum distributions of dileptons and pions are presented.

**Presenter:** Tarasov, Andrey *(Brookhaven National Lab)*  
**Coauthors:**  
**Title:** Rapidity factorization and EIC  
**Abstract:** Rapidity factorization is a theoretical approach which allows us to study high-energy scattering reactions in a wide range of kinematic variables. This is especially important for the future Electron Ion Collider (EIC) which will give access to values that can not be reached with present fixed-target experiments. I will present an overview of the method and show how it can be used in study of particle production at EIC.

**Presenter:** Vitev, Ivan *(Los Alamos National Lab)*  
**Coauthors:**  
**Title:** Opportunities with jet physics in eA collisions  
**Abstract:** The past five years have seen tremendous interest in the use of jets in reactions in large nuclei to both advance many-body QCD at the high-energy frontier and to constrain the transport properties of novel phases of nuclear matter. Current facilities use jets to explore the properties of the quark-gluon plasma created at RHIC and LHC. A future EIC will leverage new opportunities to utilize jets as probes of strong gluon field dynamics. In this talk I will discuss the complementarity of semi-inclusive DIS measurements, jet cross sections and jet substructure in eA collisions.

**Presenter:** Wu, Bin *(Ohio State University)*  
**Coauthors:** Alfred Mueller, Bo-Wen Xiao, Feng Yuan  
**Title:** Medium induced transverse momentum broadening in hard processes  
**Abstract:** I shall talk about our recent work (arXiv:1608.07339) on the transverse momentum broadening of high-energy partons in deep inelastic scattering on a large nucleus. We find that one can factorize the vacuum radiation contribution and medium related $p_T$ broadening effects into the Su-
dakov factor and medium dependent distributions, respectively. Our results show that on a future
electron-ion collider (EIC) one may systematically study the interplay between hard vacuum gluon
radiation and nuclear matter induced radiation as a function of photon virtuality. Our derivations can
also be generalized to other hard processes, such as dijet productions, which can be used as a probe
to measure the medium $p_T$ broadening effects in heavy ion collisions when Sudakov effects are not
overwhelming.

Presenter: Zhang, Chen (School of Physics, Peking University)
Coauthors:
Title: Opportunities for Higgs physics at future lepton-nucleon colliders
Abstract: Future lepton-nucleon colliders such as the LHeC and FCC-he have promising potential
in improving our knowledge of the Higgs boson. In this talk, I will emphasize the LHeC sensitivity to
bottom and charm Yukawa couplings and recent progress of the LHeC exotic Higgs decay studies.

Presenter: Zhao, Yuxiang (Stony Brook University)
Coauthors: Abhay Deshpande, Krishna Kumar, Jin Huang, Seamus Riordan, Marco Stratmann
Title: Electroweak and BSM physics at an EIC
Abstract: We discuss measurements of parity violating asymmetries in the DIS region at an EIC with
high luminosity. With $\gamma Z$ interference in the electroweak processes, the parity violating asymmetries
are associated with a new series of structure functions, $F_1^{\gamma Z}$, $F_3^{\gamma Z}$, $g_1^{\gamma Z}$, $g_5^{\gamma Z}$, which provide unique,
yet unmeasured, combinations of unpolarized/polarized parton distribution functions. We will present
the projections of these structure functions from electron-proton collisions at a future EIC with differ-
ent beam energy configurations considering QED, QCD radiative corrections as well as corrections of
detector smearing. We will also present the weak mixing angle $\sin^2(\theta_W)$ study at a much higher $Q^2$
range than fixed target measurements using electron-deuteron collisions at an EIC. In addition, the
searches for e-tau charged lepton flavor violation at an EIC will be discussed in the talk.