POETIC 8

Sunday 18 March 2018 - Friday 23 March 2018

Other Institutes

Book of Abstracts

Contents

1

Jet Cosmology, Confinement and Fragmentation

Author: Dennis Sivers[1]

[1] *Portland Physics Institute*

Corresponding Author: densivers@sivers.com

Improvements in our understanding of confinement allows the modification of the phenomenology of jet fragmentation. Transverse-momentum dependent jet observables allow for a global description of the dynamics of QCD jets including long-range correlations associated with quantum interference.

2

NLO predictions for dijet photoproduction at the EIC

Author: Michael Klasen[None]

Corresponding Author: michael.klasen@uni-muenster.de

We present NLO predictions for dijet photoproduction cross sections at a future EIC. Similarly to inclusive jet production in DIS that we studied previously, dijet photoproduction is shown to constrain nuclear PDFs (in particular the one of the gluon) in a way that is complementary to the information from inclusive DIS. The process is also sensitive to photon PDFs, as has already been discussed elsewhere, although only at LO.

3

Introductory lecture on EIC physics (theory)

Corresponding Author: fyuan@lbl.gov

4

Introductory lecture on EIC physics (experiment)

5

(1)

Satellite workshops / 6

(1)

7

In-medium properties of B_0 and B_{s0} mesons in hot and dense strange hadronic medium.

Authors: Rahul Chhabra[1]; Arvind kumar[1]

[1] *National Institute of Technology, Jalandhar*

Corresponding Authors: rahulchhabra@ymail.com, kumara@nitj.ac.in

We investigate the effect of temperature, strangeness fraction and density of the medium on the in-medium
properties of the B_0 and B_{s0} mesons using QCD sum rules and chiral SU(3) model. We focus on the evaluation
of the in-medium masses and decay constants of above scalar B_0 and B_{s0} mesons. In-medium light quark
condensates,$\langle\bar{q}q\rangle_{\rho_B}$, strange quark condensates $\langle\bar{s}s\rangle_{\rho_B}$, and gluon condensates $\left\langle\frac{\alpha_s}{\pi}G^a{}_{\mu\nu}G^{a\mu\nu}\right\rangle_{\rho_B}$ needed in QCD sum rule calculations are evaluated using chiral SU(3) model. These results are important
in order to understand the production Υ state in heavy ion collision experiments, and the possibility on the
formation of B-N bound states. Furthermore, these results may be verified from the possible outcomes of the
future experiments like CBM and PANDA under the FAIR facility. We also compare the results of the present
investigation with the available data.

8

Inclusive photon production at NLO in e+A and p+A collisions

Author: Raju Venugopalan[1]

[1] *BNL*

Corresponding Author: rajuv@mac.com

We discuss inclusive photon production to next-to-leading order accuracy in both p+A and e+A collisions within the color glass condensate framework of high energy QCD. For hadron-hadron collisions, we will present comparisons to data in p+p and p+A collisions. For e+A data, we will outline some advantages of our framework relative to extant NLO computations in the literature.

9

New analytic solution of (linearised) Balistky-Kovchegov equation

Authors: Mariyah Siddiqah[1]; Raktim Abir[1]

[1] *Aligarh Muslim University*

Corresponding Authors: shah.siddiqah@gmail.com, raktim.ph@amu.ac.in

A typical scattering event in any collider experiments usually involve rapidly growing cascade of gluons. At high enough energy this cascade of gluons may occupy all the available final state phase space to such an extent that fusion of multiple gluons to single gluon begin to start. This could eventually develop a thermodynamical detail balance, with the usual multiple gluons produced from single gluon, which leads to the origin of gluon saturation with a characteristic momentum scale Q_s.

Balaistky-Kovchegov (BK) equation for S-matrix is the evolution equation that describe this pQCD evolution at small-x in the large N_c-limit. It describes the scattering of a dipole off a large nucleus in the high energy regime.
So far there is no exact full analytical solution to the BK equation.

In this study we have derived an exact analytical solution, for a linearised form of BK equation (linear in S-matrix), valid both within and outside the saturation region. Here we regulated the dipole integral by taking a dipole transverse-width dependent cutoff. We had also taken care of all the higher order terms which have been ignored earlier. The dipole-nucleus amplitude takes the following form,
$N = 1 - S_0 \exp\left(\frac{1+2i\nu_0}{2\chi(0,\nu_0)}\left[Li_2(-\lambda_1 x_{10}^2 Q_s^2(Y))\right]\right)$
where Li_2 is dilogarithm function and ${}_1(\ 7.22)$ is a parameter which is fixed by the definition of Q_s.

This new solution, containing a dilogarithmic function, reproduces both the Mclerran-Venugopalan initial conditions (Gaussian in scaling variable) and Levin-Tuchin solution (Gaussian in logarithm of scaling variable) in their appropriate limits. It also connects this two opposite limit smoothly with a better accuracy when compared to numerical solutions of full LO BK equation.

[1] Mariyah Siddiqah and Raktim Abir, "Solution of the linearized Balitsky-Kovchegov equation," Phys. Rev. D 95, no.7, 074035 (2017).

10

Heavy flavour production in general-mass variable flavour number scheme

Author: Hannu Paukkunen[1]

[1] *University of Jyväskylä*

Corresponding Author: hannu.paukkunen@jyu.fi

The hadroproduction of heavy-flavoured mesons has recently attracted a growing interest within the groups involved in global analysis of proton and nuclear parton distribution functions (PDFs). In particular, the D- and B-meson measurements of LHCb at forward direction are sensitive to gluon PDFs at small x and are one of the few perturbative small-x probes before the next generation DIS experiments.

Theoretically, there are several ways to calculate the cross sections for heavy-flavoured mesons. On one hand, parton-level heavy-quark cross sections can be folded with phenomenological, scale-independent parton-to-meson fragmentation functions (FFs), or the fragmentation is adapted offline from an event generator like PYTHIA or equivalent. Alternatively, one can work fully within the framework of collinear factorization where the fragmentation is described with universal, scale-dependent FFs.

In this talk, I will concentrate on the collinear-factorization approach and describe a novel implementation of the general-mass variable flavour number scheme (GM-VFNS) which retains the mass dependence of the cross sections at low $p_{\rm T}$, but reduces to ordinary zero-mass results towards high $p_{\rm T}$. The novelty of the present implementation amounts to a proposal of how to render the cross sections finite even in the limit of very small $p_{\rm T}$ - the region that has been particularly problematic in the previous versions of GM-VFNS - and to thereby obtain a well-behaved GM-VFNS descrpition of the cross sections across all $p_{\rm T}$.

11

Coherence effects in a QCD parton cascade

Author: Víctor Vila[1]

Co-authors: Fabio Dominguez [1]; Carlos Albert Salgado Lopez [2]

[1] *Universidade de Santiago de Compostela*

[2] *Universidade de Santiago de Compostela (ES)*

Corresponding Authors: carlos.salgado@usc.es, fabio.dominguez@usc.es, victor.vila@usc.es

We study the color coherence phenomenon starting from the original quark-antiquark antenna laboratory in the presence of a medium. Measurements of jet substructure shed light on the character of the jet interactions with the dense medium formed in the collisions, which can break the intra-jet color coherence leading to interesting phenomena. Describing the decoherence of the $q\bar{q}$ pair through the survival probability, we extract some interesting interpretations in the large-N_c limit. We extrapolate previous analyzes of the antenna radiation to the case of two hard splittings inside the medium, and prove that this generalization keeps back the picture of jet quenching with effective emitters in the QCD parton cascade. With the purpose of considering a more realistic setting, we address a similar configuration in which a quark-gluon antenna with finite formation time propagates through the medium. We study the in-medium QCD branching, which is also important to understand the jet substructure in eA collisions. Finally, we discuss the role of color coherence in these configurations.

12

Black-disk asymptotics of unintegrated dipole gluon distribution

Authors: Raktim Abir[1]; Mariyah Siddiqah[1]

[1] *Aligarh Muslim University*

Corresponding Author: raktim.ph@amu.ac.in

The discovery of rapidly growing cascade of gluons and sharp non-linear rise of its distributions in DIS experiments at HERA collider provides indirect experimental evidence that proton at high energy is a hugely complex many body quantum system where gluons are the dominant degrees of freedom. By now many studies have been performed in the theoretical front to develop frameworks that extend our understanding on the structure of proton beyond just one dimensional ordinary parton distribution functions (PDFs). The attempts are mostly based on considering other (than regular PDFs) relatively closer descendants of the original, yet unknown, Wigner distribution functions which presumably contain all the information.

Transverse momentum dependent parton distributions (TMDs) or unintegrated parton distribution functions (UPDFs) are such examples that provide, in addition to longitudinal momentum fraction x of the parton, details of transverse momentum distribution and therefore contain much more detailed information on the internal structure of protons relative to the ordinary PDFs.

In this work we derive analytical results for black-disk asymptotic behavior of the unintegrated dipole gluon distribution function. By Fourier transforming asymptotic form of the S-matrix, as given by the Levin-Tuchin solution of the Balitsky-Kovchegov equation, to transverse momentum space, we derive the result in the form of a series of Bells polynomials. Interestingly, when resummation is done for the series in leading log accuracy, the results showing up striking similarity with the Sudakov form factor with role play of coupling is being done by a constant that stems from the saddle point condition along the saturation line. We also would like to discuss possible connection of unintegrated dipole gluon distribution and the Weizs\"{a}cker-Williams gluon distribution in the small-x limit.

Ref. [1] Raktim Abir, K. Banu, T. Bhattacharyya, M. Siddiqah and N. Vasim, "Black-disk asymptotics of unintegrated dipole gluon distribution," arXiv:1801.01637 [hep-ph].

13

Transverse momentum distirbutions: theory status

Author: Alexey Vladimirov[None]

Corresponding Author: vladimirov.aleksey@gmail.com

We review the theory of transverse momentum distributions (TMDs). The emphasis is made on the recent development in the perturbation theory and its influence on the predictions/extraction of TMDs.

14

NLO computations at small x for exclusive processes ; light vector meson production

Authors: Renaud Boussarie[1]; Andrey Grabovskiy[2]; Dmitry Ivanov[None]; Lech Szymanowski[3]; Samuel Wallon[None]

[1] *IFJ Krakow*

[2] *Budker Institute of Nuclear Physics (RU)*

[3] *National Centre for Nuclear Research*

Corresponding Authors: lech.szymanowski@ncbj.gov.pl, wallon@th.u-psud.fr, andrey.grabovskiy@cern.ch, d-ivanov@math.nsc.ru, renaud.boussarie@th.u-psud.fr

I will present the theoretical computation methods and several results for exclusive diffractive impact factors at NLO accuracy at small x with saturation, with an emphasis on corrections to light vector meson electroproduction on a dense target. I will discuss the practical use of our results for phenomenological predictions at an Electron-Ion Collider, as well as theoretical questions on factorization and on the linear BFKL limit.

15

Leading and Higher Twist Contributions to Proton Angular Momentum

Authors: Simonetta Liuti[1]; Abha Rajan[1]; Michael Engelhardt[None]

[1] *University of Virginia*

Corresponding Authors: engel@nmsu.edu, ar5xc@virginia.edu, sl4y@virginia.edu

I will present an analysis of the parton transverse momentum, k_T, substructure of the generalized Wandzura Wilczek relations involving twist three Generalized Parton Distributions. Out of 16 possible Equation of Motion relations that can be written in the T-even sector, I will focus on three helicity configurations that can be detected analyzing specific spin asymmetries: two correspond to longitudinal proton polarization and are associated with quark orbital angular momentum and spin-orbit correlations; the third, obtained for transverse proton polarization, is a generalization of

the relation obeyed by the g2 structure function. An additional relation connecting the off-forward extension of the Sivers function to an off-forward Qiu-Sterman term will also be discussed.

16

Gluon TMDs from quarkonium pair production at the LHC

Author: Marc Schlegel[1]

Co-authors: Jean-Philippe Lansberg [2]; Cristian Pisano [3]; Florent Scarpa [4]

[1] *New Mexico State University*

[2] *IPN Orsay, Paris Sud U. / IN2P3-CNRS*

[3] *University of Pavia*

[4] *IPN Orsay - Paris-Sud U. - CNRS/IN2P3*

Corresponding Authors: cristian.pisano@unipv.it, scarpaflorent@ipno.in2p3.fr, lansberg@in2p3.fr, marc.schlegel@uni-tuebingen.de

The feasibility of extracting information on gluon Transverse-Momentum Dependent (TMD) parton distributions, in particular the distribution of linearly polarized gluons, is discussed for the production of quarkonium pairs in proton collisions. Evidences are presented that azimuthal modulations of the cross section, caused by linearly polarized gluons, may be larger for a quarkonium pair in the final state, compared to other final states. Numerical estimates for the azimuthal modulations are presented as well.

17

Geometry tagging with heavy ions at the EIC

Author: Pawel Nadel-Turonski[1]

Co-authors: Mark Baker [2]; Vasiliy Morozov [3]; Alberto Accardi [4]; William King Brooks [5]; Raphael Dupre [6]; Kawtar Hafidi [7]; Charles Hyde [8]; Kijun Park [8]; Tobias Toll ; Liang Zheng [9]; Caleb Fogler ; Mathieu Ehrhart [6]; Stukes James ; Guohui Wei [3]; Amy Sy [3]

[1] *Stony Brook University*

[2] *University of Surrey*

[3] *Jefferson Lab*

[4] *Hampton U. and Jefferson Lab*

[5] *Federico Santa Maria Technical University (CL)*

[6] *IPN Orsay*

[7] *Argonne National Lab*

[8] *Old Dominion University*

[9] *China University of Geosciences*

Corresponding Authors: liangzhphy@gmail.com, ehrhart@jlab.org, jstukes@jlab.org, kawtar@anl.gov, dupre@ipno.in2p3.fr, gwei@jlab.org, ttoll@bnl.gov, morozov@jlab.org, amysy@jlab.org, accardi@jlab.org, cfogl002@odu.edu, turonski@jlab.org, m.baker@surrey.ac.uk, parkkj@jlab.org, chyde@odu.edu, brooksw@jlab.org

The Electron-Ion Collider (EIC) will provide the first opportunity to study electron-nucleus (eA) scattering at high energies. For heavy ions, key measurements include QCD at high gluon densities and the onset of saturation, mapping of the transverse spatial gluon distribution through coherent diffraction, and parton/hadron propagation in cold nuclear matter. All these measurements greatly benefit from, or in the case of coherent diffraction critically rely on, an excellent capability to detect the

outgoing nuclear fragments (geometry tagging). Knowing the path length traversed inside the nucleus allows a better understanding of parton propagation, and being able to select central collisions at low-x gives a significant boost to the nuclear thickness (and effective gluon density) beyond the average value for a heavy nucleus. It has also been shown that for coherent diffraction, a sufficient suppression of the large incoherent background can be achieved if, in addition to emitted nucleons and light ions, also the residual nucleus can be detected (including A-1 nuclei). This talk will present the physics opportunities and detection requirements for geometry tagging in eA at an EIC, and discuss some specific results from a project on this topic funded through JLab LDRD.

18

Next-to-Leading Order QCD Corrections to Inclusive Heavy-Flavor Production in Polarized Deep-Inelastic Scattering

Authors: Felix Hekhorn[1]; Marco Stratmann[2]

[1] *Universität Tübingen*

[2] *University of Tübingen*

Corresponding Authors: marco.stratmann@uni-tuebingen.de, felix.hekhorn@uni-tuebingen.de

We provide a first calculation of the complete next-to-leading order QCD corrections for heavy flavor contributions to the inclusive structure function g_1 in longitudinally polarized deep-inelastic scattering. The results are derived with largely analytical methods and retain the full dependence on the heavy quark's mass. We discuss all relevant technical details of the calculation and present numerical results for the heavy quark scaling functions. We perform important crosschecks to verify our results in the known limit of photoproduction and for the unpolarized electroproduction of heavy quarks. We also compare our calculations to the available, partial results in the polarized case, in particular, in the limit of asymptotically large photon virtualities. First steps towards phenomenological applications are taken by providing some estimates for inclusive charm production in polarized deep-inelastic scattering at a future electron-ion collider and studying their sensitivity to the polarized gluon distribution. The residual dependence of heavy quark electroproduction on unphysical factorization and renormalization scales and on the heavy quark mass is investigated.

19

Transverse dynamics of quarks in the proton - from Ji to Jaffe-Manohar orbital angular momentum

Author: Michael Engelhardt[None]

Corresponding Author: engel@nmsu.edu

Quark orbital angular momentum (OAM) in the nucleon can be evaluated directly by employing a Wigner function embodying the simultaneous distribution of parton transverse position and momentum. This distribution can be accessed via a generalization of the nucleon matrix elements of quark bilocal operators which have been used previously in the lattice evaluation of transverse momentum dependent parton distributions (TMDs). By supplementing these matrix elements with a nonzero momentum transfer, mixed transverse position and momentum information is generated. In the quark bilocal operators, a gauge connection between the quarks must be specified; a staple-shaped gauge link path, as used in TMD calculations, yields Jaffe-Manohar OAM, whereas a straight path yields Ji OAM. A lattice calculation at a pion mass of 518 MeV is presented which demonstrates that the difference between Ji and Jaffe-Manohar OAM can be clearly resolved. The obtained

Ji OAM is confronted with traditional evaluations utilizing Ji's sum rule. Jaffe-Manohar OAM is enhanced in magnitude compared to Ji OAM.

20

Things to be learned from HERA

Author: Iris Abt[1]

[1] *MPI*

Corresponding Author: isa@mpp.mpg.de

HERA was running with four experiments. The collaborations focused on different physics questions; ZEUS and H1 were both multipurpose experiments for ep DIS. The HERA inclusive DIS data alone cover a phase-space allowing the extraction of PDFs. More information/PDFs can be extracted by adding heavy flavor and jet data. It is discussed what was learned about the proton, what polarised beams can do for you, what challenges the combination of data brings and how data should be published.

21

Wigner and Husimi distributions for nucleon tomography

Author: Yoshitaka Hatta[1]

[1] *Kyoto U*

Corresponding Author: hatta@yukawa.kyoto-u.ac.jp

The Wigner and Husimi distributions have been proposed as phase space distributions of partons inside the nucleon. I discuss various aspects of these distribution including their experimental measurement, model calculations, applications to spin physics.

22

Photoproduction and ultra-peripheral collisions with Pythia 8

Author: Ilkka Helenius[1]

Co-author: Torbjorn Sjostrand

[1] *Tübingen University*

Corresponding Authors: torbjorn@thep.lu.se, ilkka.helenius@uni-tuebingen.de

Photoproduction in electron-proton collisions were extensively studied at HERA for several observables. In these processes a quasi-real photon from the lepton interacts with the proton. Due to the small virtuality, the photons may also fluctuate into a hadronic state so that constituting partons act as initiators of the hard process. The partonic structure of these resolved photons can be described with DGLAP-evolved PDFs obtained through a global analysis and gives rise also to multipartonic interactions. Similar interactions can happen also in ultra-relativistic heavy-ion collisions if the colliding ions passes each other with a large impact parameter so that no strong interaction can happen. However, the ultra-relativistic ions produce photons which may still interact with the other nucleus.

These interactions are referred to as ultra-peripheral collisions and provide an unique opportunity to study photon-nucleus interactions at the LHC. In this talk, I will present our recent Pythia 8 implementation for photoproduction and how the flux of photons form nuclei is obtained applying equivalent photon approximation. In particular, I will show results for dijet photoproduction at HERA and in ultra-peripheral Pb+Pb collisions at the LHC and discuss about theoretical uncertainties related to multiparton interactions and photon PDFs. As an application, the potential of the ultra-peripheral collisions to further constrain the nuclear PDFs is studied.

23

Linearly polarized gluons and axial charge fluctuations in the Glasma

Author: Tuomas Lappi[1]

[1] *University of Jyvaskyla*

Corresponding Author: tuomas.v.v.lappi@jyu.fi

We calculate energy deposition and axial charge production from color flux tubes at early times in a heavy-ion collision. Based on analytic expressions for the space-time dependent fluctuations of the axial charge and energy density distributions in terms of the unpolarized and linearly polarized gluon distributions of the nuclei, we develop a phenomenological model for the initial state, which can be used as an input to anomalous hydrodynamic simulations. Besides fluctuations of the axial charge density, we also calculate fluctuations of the energy density and discuss how our results can be used to consistently include fluctuations of the energy density on sub-nucleonic scale into simple initial state models, such as for example the MC-Glauber model.

[1] T. Lappi, S. Schlichting, arXiv:1708.08625 [hep-ph]

24

Exclusive vector meson production off nuclei

Author: Heikki Mäntysaari[1]

Co-authors: Bjoern Schenke [2]; Raju Venugopalan [3]

[1] *University of Jyväskylä*

[2] *Brookhaven National Lab*

[3] *Brookhaven National Laboratory*

Corresponding Authors: bschenke@quark.phy.bnl.gov, rajuv@mac.com, heikki.mantysaari@jyu.fi

Thanks to A^{1/3} enhancement on the saturation scale in a heavy nucleus compared to that of the proton, nonlinearities are enhanced in nuclei compared to proton. This makes nuclear DIS an ideal laboratory to study the small-x structure of the nucleus. Probably the most powerful process for this is exclusive vector meson production, which at leading order is proportional to the squared gluon density. Exclusive J/Psi and rho production is thus especially sensitive to the non-linear small-x structure of the nuclei.

We show that gluon saturation gives rise to a strong modification of the scaling in both the nuclear mass number A and the virtuality Q2 of the vector meson production cross-section in exclusive deep-inelastic scattering off nuclei. As reported in [1], we show that in the future Electron-Ion Collider the kinematical lever arm in Q^2 is expected to be enough to observer the qualitative transition from the saturated to the dilute region.

Before EIC, exclusive processes off nuclei in the photoproduction region can be studied in ultraperipheral heavy ion collisions (UPCs). We show that depending on the momentum transfer -t of the process, the incoherent cross section is sensitive to either fluctuations of the nucleon positions from the Woods Saxon distribution (small -t), or to the fluctuations of the proton/neutron substructure (larger -t). Including the nucleon substructure is found to be necessary for a good description of the recent ALICE UPC data [2].

[1] H. Mäntysaari, R. Venugopalan, arXiv:1712.02508
[2] H. Mäntysaari, B. Schenke, Phys.Lett. B772 (2017) 681-686, arXiv:1705.03177

25

Entanglement Entropy in High Energy Collisions

Author: Michael Lublinsky[1]

[1] *Ben-Gurion University of the Negev (IL)*

Corresponding Author: michael.lublinsky@cern.ch

I will first discuss entanglement entropy of
soft gluons in a light cone wave function of a fast moving projectile hadron and
then entropy production in collisions with target nucleus.

26

Gluon EMC effect and exotic glue in nuclei from lattice QCD

Author: Phiala Shanahan[1]

[1] *Massachusetts Institute of Technology*

Corresponding Author: pshana@mit.edu

I will describe the status of lattice QCD studies of gluon structure quantities in nucleons and nuclei. I will focus in particular on the prospects for controlled determinations of key effects such as a gluon analogue of the EMC effect, and exotic glue in nuclei, ahead of the planned EIC.

27

Entanglement in an expanding QCD string

Author: Stefan Floerchinger[1]

Co-authors: Jürgen Berges [1]; Raju Venugopalan [2]

[1] *Heidelberg University*

[2] *Brookhaven National Laboratory*

Corresponding Authors: rajuv@mac.com, stefan.floerchinger@cern.ch, j.berges@thphys.uni-heidelberg.de

We develop a novel real-time approach to computing the entanglement between spatial regions for Gaussian states in quantum field theory. The entanglement entropy is characterized in terms of

local correlation functions on space-like Cauchy hypersurfaces. The framework is applied to explore an expanding light cone geometry in the particular case of the Schwinger model for quantum electrodynamics in 1+1 space-time dimensions. We observe that the entanglement entropy becomes extensive in rapidity at early times and that the corresponding local reduced density matrix is a thermal density matrix for excitations around a coherent field with a time dependent temperature. Since the Schwinger model successfully describes many features of multiparticle production in electron-positron collisions, our results provide an attractive explanation in this framework for the apparent thermal nature of multiparticle production even in the absence of significant final state scattering.

28

Possibilities for nPDFs at an EIC

Author: Maria Zurita[1]

Co-authors: elke-caroline Aschenauer [2]; Hannu Paukkunen [3]; Salvatore Fazio ; Matthew Lamont [2]

[1] *Brookhaven National Laboratory*

[2] *BNL*

[3] *University of Jyväskylä*

Corresponding Authors: macl@bnl.gov, hannu.paukkunen@jyu.fi, mzurita@bnl.gov, sfazio@bnl.gov, elke@bnl.gov

Our knowledge of nuclear Parton Distribution Functions is currently limited by the restricted kinematic space covered in fixed target $e + A$ experiments and $p(d) + A$ collisions. In this talk I will present an impact study of the possibilities offered by an Electron-Ion Collider for the improvement of the understanding of collinear factorized nuclear PDFs.

29

Photon jet angular correlations in p+A collisions at central rapidities

Authors: Sanjin Benic[None]; Adrian Dumitru[1]

[1] *Baruch College (City University of New York)*

Corresponding Authors: adrian.dumitru@baruch.cuny.edu, sanjinb@phy.hr

We report on a recent computation [1] of the semi-inclusive photon-jet angular correlations in high energy $p+A$ collisions at the next-to-leading order (NLO) in the Color Glass Condensate framework. The NLO result considers the $p+A \to q\bar{q}\gamma$ channel appropriate at central rapidities. We focus on the nearly back-to-back photon-jet configurations and find the leading-order $p + A \to q\gamma$ contribution to be suppressed relative to the NLO. Integrating over the quark phase space at NLO we obtain an analytic expression for the $p+A \to q\gamma + X$ cross section and identify the corresponding transverse momentum gluon distributions. We find explicit expressions for the angular harmonics $\langle \cos n\phi \rangle$ with ϕ as the angle between the net and the average photon-jet transverse momentum and provide numerical estimates on their transverse momentum dependence and sensitivity to the saturation scale.

[1] S. Benic, A. Dumitru, Phys.Rev. D97 (2018) no.1, 014012.

30

Operator Product Expansion in Wilson lines with sub-eikonal spin corrections

Author: Giovanni Antonio Chirilli[1]

[1] *University of Regensburg*

Corresponding Author: giovanni.chirilli@gmail.com

Abstract:

Low-x evolution of spin-dependent TMDs and spin g_1 structure function are relevant for the future Electron Ion Collider.
Recently, the spin-low-x evolution was obtained in the saturation formalism. Unfortunately, it does not agree with previous result obtained by calculation of perturbative diagrams in the leading log approximation so an independent study on this subject becomes necessary. To this end, I will discuss the Operator Product Expansion in terms of Wilson lines with sub-eikonal corrections, and study the low-x evolution of the spin-dependent TMDs and spin g_1 structure function. To extend the low-x evolution of TMD at NLO level, it is important to study the conformal properties of the relevant operators. As a starting point, I will consider the conformal invariance of the low-x evolution of gluon TMD in the Sudakov regime.

31

The quark and gluon structure of the proton in the high-precision LHC era

Author: Juan Rojo[1]

[1] *VU Amsterdam and Nikhef*

Corresponding Author: j.rojo@vu.nl

The determination of the quark and gluon structure of the proton is a central component of the precision phenomenology program at the Large Hadron Collider (LHC) as well of future hadron-hadron and lepton-hadron colliders. In this talk I review recent progress in the determination of the quark and gluon structure of the proton, with emphasis on the impact of new processes in the global PDF fit, such as top quark differential distributions and the transverse monument of Z bosons, and discuss some of their implications for the current and upcoming LHC runs and well as for future colliders. I will also discuss a number of related aspects of the global QCD analysis including the photon content of the proton, the need for small-x resummation in HERA data, the connection with lattice QCD calculations, and a recent precision determination of the strong coupling constant.

32

Quark / Antiquark Correlations in Heavy-Light Ion Collisions

Author: Douglas Wertepny[1]

Co-authors: Matthew Sievert [2]; Mauricio Martinez Guerrero [3]

[1] *Universidade de Santiago de Compostela*

[2] *Los Alamos National Laboratory*

[3] *North Caroline State University*

Corresponding Authors: mmarti11@ncsu.edu, sievertmd@gmail.com, dwertepny@gmail.com

The correlation length associated with color-charge fluctuations, known as the inverse saturation momentum, plays a fundamental role in the initial conditions of heavy-ion collisions. With state-of-the-art hydrodynamic codes tailored for the finite-baryon-density physics of the Beam Energy Scan, it is interesting to study the analogous role of correlations between quarks and antiquarks. While recent work has studied the quantum statistical effects of Bose enhancement for gluons and Pauli blocking for quarks, we will present here new results on the quark / quark, quark / antiquark, and antiquark / antiquark correlation functions in asymmetric "heavy-light"ion collisions. The correlation function is dominated by qualitatively different mechanisms at different length scales, and quantum entanglement between two sets of quark / antiquark pairs leads to highly nontrivial correlations. The results of this work can be used to construct initial state models for heavy-ion collisions which incorporate nontrivial spatial fluctuations of quarks and antiquarks.

33

Nucleon structure from lattice QCD

Author: Giannis Koutsou[1]

[1] *The Cyprus Institute*

Corresponding Author: g.koutsou@cyi.ac.cy

I will review recent progress in nucleon structure calculations on the lattice, focusing on results obtained from simulations with physical or near-physical quark mass values. In particular, results on moments of generalized parton distributions and the axial, scalar, and tensor charges will be presented. I will also discuss the implications of these results on the decomposition of the nucleon spin and its momentum.

34

TMD results from RHIC: Perspectives from a hadron collider and insights for a future EIC

Author: Renee Fatemi[1]

[1] *University of Kentucky*

Corresponding Author: renee.fatemi@uky.edu

During the last decade a robust TMD program has blossomed at RHIC. A variety of observables, including $W^{\pm}/Z$ and hadron+jet reconstruction, are sensitive to TMD parton distribution and fragmentation functions. This talk will review existing results, outline plans for continued studies in proton-proton collisions and discuss the implications for a future EIC.

35

Nucleon TMDs from Lattice QCD

Author: Rajan Gupta[1]

[1] *Los Alamos National Lab*

Corresponding Author: rajangupta53@gmail.com

Nucleon TMDs from Lattice QCD

We summarize the calculation of the SIvers, Boer-Mulders, generalized transversity and worm-gear shifts using two ensembles of gauge configurations with different discretization of the fermion Dirac actions. We discuss factorization and renormalization of the operators and present estimates of lattice discretization artifacts. For these TMD observables, we find that the results are consistent between the two ensembles at sufficiently large separation of the quark fields within the operator, whereas deviations are observed in the local limit and in the case of a straight link gauge connection, which is relevant to the studies of parton distribution functions. Lastly, we provide a connection between the lattice data and phenomenological estimates extracted from experimental data.

36

QCD mechanisms for accessing the nucleon GPDs with the exclusive pion-induced Drell-Yan process $\pi^- p \to \ell^+ \ell^- n$

Author: Kazuhiro Tanaka[None]

Corresponding Author: kztanaka@juntendo.ac.jp

The nucleon generalized parton distributions (GPDs) are accessed by deeply virtual Compton scattering and deeply virtual meson production with lepton beam. A complementary probe with hadron beam is the exclusive pion-induced Drell-Yan process, $\pi^- p \to \ell^+ \ell^- n$, allowing us to access the GPDs at large timelike virtuality [1]. Recent calculations on this process in terms of QCD factorization as the partonic subprocess convoluted with the nucleon GPDs and the pion distribution amplitudes [2,3] have demonstrated the feasibility of its measurement via a spectrometer at the High Momentum Beamline being constructed at J-PARC [3]. At the same time, however, the possibilities of the corrections due to "soft mechanisms"beyond the QCD factorization framework are pointed out [2,4]: those mechanisms could be caused by the treatment of the pion pole contribution arising in the relevant GPDs in the ERBL region, the parton transverse momentum to regularize the end-point singularities, the so-called soft-overlap mechanism, etc. We discuss a new estimate of the soft mechanisms, which allows us to express the corresponding soft exclusive amplitude in terms of the relevant GPDs, making use of dispersion relations and quark-hadron duality. As a result, we show [4] that, at the J-PARC kinematics, the soft mechanisms could give the several times larger cross sections than the corresponding cross sections calculated by the QCD factorization. We also discuss the possible roles of the similar soft mechanisms in the complementary space-like process, i.e., the deeply virtual pion production in the lepton-proton scattering.

This talk is based on my publication [3] in collaboration with several theorists and experimentalists, and on my recent new results [4].

References:
[1] E.R. Berger, M. Diehl, and B. Pire, Phys. Lett. B523 (2001) 265.
[2] S. V. Goloskokov and P. Kroll, Phys.Lett. B748 (2015) 323.
[3] T. Sawada, W. C. Chang, S. Kumano, J. C. Peng, S. Sawada and K. Tanaka, Phys. Rev. D 93, 114034 (2016) [arXiv:1605.00364 [nucl-ex]].
[4] K. Tanaka, arXiv:1709.01063 [hep-ph]] and in preparation.

37

GPD phenomenology and its challenges

Author: Kresimir Kumericki[1]

[1] *University of Zagreb*

Corresponding Author: kkumer@phy.hr

After a brief reminder about the role of GPDs in the description of hadron structure, I will review what is known about these functions after a decade and a half of experiments and fits to the data, with emphasis on deeply virtual Compton scattering. I will show results of global fits, both in the traditional and in the neural network approach. I will also discuss main challenges for phenomenology in the light of recent and forthcoming experiments.

38

Quark-gluon correlations in the twist-3 TMD $e(x, \mathbf{k}_\perp)$ using light-front wave functions.

Author: Simone Rodini[1]

Co-author: Barbara Pasquini [1]

[1] *University of Pavia*

Corresponding Authors: pasquini@pv.infn.it, simone.rodini01@universitadipavia.it

Higher-twist transverse-momentum dependent parton distributions (TMDs) go beyond the parton model description of a proton as they describe correlations between quarks and gluons. Higher-twist TMDs, however, turn out to be very elusive objects, as they are difficult to extract from experimental data. Twist-3 distributions can be decomposed as a sum of different contributions. In general, these contributions are separated into two different types: lower-twist (i.e. twist-2) contributions and pure twist-3 contributions. Most of the phenomenological parametrizations and models rely on the so called Wandzura-Wilczeck (WW) approximation, that set to zero the pure twist-3 contributions. The WW approximation, however, remove the richness of the twist-3 distributions. I will show how the quark-gluon correlations (pure twist-3 contributions) entering the chiral-odd distribution $e(x, \mathbf{k}_\perp)$ can be calculated by using the formalism of light-front wave functions (LFWFs).
The parametrization of the LFWFs is chosen by the comparison with the distribution amplitudes of the proton. The parameters of the LFWFs are fitted on the MMHT2014 parametrization for the valence-quark and gluon contributions to the unpolarized parton distribution $f_1(x)$. With these fit parameters, I will show predictions of the pure twist-3 part of $e(x, \mathbf{k}_\perp)$, and I will compare the results for $e(x)$ to a recent extraction, obtained from the analysis of preliminary data of the beam asymmetry for di-hadron semi-inclusive deep inelastic scattering at CLAS 6 GeV.

39

Unequal Rapidity Correlators in the Dilute Limit of JIMWLK

Authors: Tuomas Lappi[1]; Andrecia Ramnath[1]

[1] *University of Jyvaskyla*

Corresponding Authors: anramnat@student.jyu.fi, tuomas.v.v.lappi@jyu.fi

Within the Colour Glass Condensate effective field theory, the JIMWLK equation can also be used to describe the energy evolution of long-range rapidity correlations in nuclear collisions. The projectile interaction with the target classical field is described by Wilson lines. It is useful for numerical implementations to study JIMWLK evolution as a stochastic process. A Langevin equation then governs the evolution of the Wilson lines. I will present a diagrammatic interpretation of the long range rapidity correlators in the Langevin picture. By evolving the classical field in the direct and complex conjugate amplitudes, we have studied the cross section for two-gluon production. In the dilute limit, the rapidity correlations from the Langevin framework map to the transverse momentum correlations that appear in BFKL evolution. This link will give some insight into the interpretation of BFKL evolution as a stochastic process.

40

Deep inelastic scattering in the dipole picture at next-to-leading order

Author: Henri Hänninen[1]

[1] *University of Jyväskylä*

Corresponding Author: hejohann@student.jyu.fi

We study quantitatively [1] the importance of the recently derived NLO corrections [2,3,4] to the DIS structure functions at small x in the dipole formalism. We show that these corrections can be significant and depend on the factorization scheme used to resum large logarithms of energy into renormalization group evolution with the BK equation. This feature is similar to what has recently been observed for single inclusive forward hadron production [5,6]. Using a factorization scheme consistent with the one recently proposed for the single inclusive cross section, we show that it is possible to obtain meaningful results for the DIS cross sections. We also discuss ongoing work to combine these NLO DIS structure functions in the improved factorization scheme with the resummed/NLO BK evolution equation in order to do consistent NLO accuracy comparisons with HERA data.

[1] B. Ducloué, H. Hänninen, T. Lappi, Y. Zhu, Phys.Rev. D96 (2017) no.9, 094017
[2] G. Beuf, Phys.Rev. D94 (2016) no.5, 054016
[3] G. Beuf, Phys.Rev. D96 (2017) no.7, 074033
[4] H. Hänninen, T. Lappi, R. Paatelainen, arXiv:1711.08207 [hep-ph]
[5] E. Iancu, A.H. Mueller, D.N. Triantafyllopoulos, JHEP 1612 (2016) 041
[6] B. Ducloué, T. Lappi, Y. Zhu, Phys.Rev. D95 (2017) no.11, 114007

41

Drell-Yan lepton angular distributions

Author: Werner Vogelsang[None]

Corresponding Author: werner.vogelsang@uni-tuebingen.de

We discuss various aspects of azimuthal asymmetries in the Drell-Yan process, focusing on the role of perturbative-QCD calculations. We address both the fixed-target and the collider regime. Furthermore, we present pQCD predictions for the Drell-Yan cross section averaged over the azimuthal angle, where we discuss the role of QCD threshold resummation.

42

Second moment of the pion distribution amplitude from Lattice QCD

Author: Piotr Korcyl[1]

[1] *Jagiellonian University & Regensburg University*

Corresponding Author: piotr.korcyl@uj.edu.pl

We report on the status of a current project by the RQCD lattice QCD group aimed at non-perturbatively estimating the second moment of the pion distribution amplitude. Our investigation is carried out using Nf=2+1 dynamical non-perturbatively order a improved Wilson fermions on lattices of different volumes and pion masses down to 220 MeV. We employ momentum smearing in order to

decrease the contamination of excited states and increase statistical precision. Preliminary attempts of a combined chiral and continuum extrapolation will be discussed.

44

NLO corrections for DIS structure functions in the dipole factorization

Author: Guillaume Beuf[None]

Corresponding Author: guillaume.beuf@gmail.com

In the regime of low Bjorken x, Deep Inelastic Scattering (DIS) is better described within the dipole factorization formalism, which allows to take into account the nonlinear effects of gluon saturation as well as the resummation of the high-energy leading logarithms (LL).

So far, phenomenological studies have been performed successfully at LO in the dipole factorization, with high-energy LL resummation, in the context of DIS at HERA and pp, pA and AA collisions at the LHC and RHIC. However, in order to reach a decent precision for the theory, NLO corrections should be included, as well as high-energy NLL resummations. This is important not only to fully benefit from the precision of HERA and LHC data, but also in prevision of a future electron-ion collider.

In this talk, I will present a full calculation of the (fixed order) NLO corrections to DIS structure functions on a dense target in the dipole factorization picture. By contrast to earlier studies, both the quark-antiquark-gluon and quark-antiquark Fock state contributions to the NLO corrections are explicitly calculated.

45

Diffraction studies for future colliders

Corresponding Author: krzysztof.golecbiernat@gmail.com

46

Diffraction, ultra-peripheral collisions, low x physics at the LHC and connection to EIC

Corresponding Author: p.braun-munzinger@gsi.de

47

Probing gluon TMDs in heavy-quark pair production at an EIC

Corresponding Author: cristian.pisano@ca.infn.it

48

PDFs from pp and ep at the LHC

49

Parton distribution functions from large momentum effective theory

Corresponding Author: zhangjianhui@gmail.com

50

Pseudo Parton Distributions an the Lattice

Corresponding Author: jmkarpie@email.wm.edu

51

Gluons and sea quarks in the proton at low scales

Corresponding Author: markus.diehl@desy.de

We study the evolution of parton densities in the proton to very low scales. Starting with Mellin moments obtained from global PDF fits, we find that the current knowledge of PDFs exludes scenarios in which the gluon or the antiquark distributions in the proton vanish (or are very small) at some low scale, at least when perturbative evolution is used.

52

nPDFs at LHeC

Corresponding Author: hannu.paukkunen@jyu.fi

Satellite workshops / 53

Future ep/eA experiments

Corresponding Author: m.wing@ucl.ac.uk

Satellite workshops / 54

General Purpose Event Generators: Overview and Status

Corresponding Author: eif.lonnblad@thep.lu.se

Satellite workshops / 55

TMDs from parton branching and parton showers in MC event generators

Corresponding Author: hannes.jung@desy.de

Satellite workshops / 56

Workshop goals

Satellite workshops / 57

DIPSY and Angantyr: Towards eA exclusive final states

Corresponding Author: bierlich@thep.lu.se

Satellite workshops / 58

BeAGLE: Benchmark eA Generator for LEptoproduction

Corresponding Author: baker@rcf.rhic.bnl.gov

Satellite workshops / 59

Herwig 7

Corresponding Author: stefan.gieseke@kit.edu

Satellite workshops / 60

ep in Pythia 8

Corresponding Author: ilkka.helenius@uni-tuebingen.de

Satellite workshops / 61

Radiative Corrections

Corresponding Author: andrea.bressan@cern.ch

Satellite workshops / **62**

Data preservation

Corresponding Author: andrii.verbytskyi@mpp.mpg.de

Satellite workshops / **63**

Discussion: General MCEG

Satellite workshops / **64**

Sartre: A Generator for Diffractive Physics in ep and eA

Corresponding Author: thomas.ullrich@bnl.gov

Satellite workshops / **65**

Lessons from MCEG at small-x for p+p/A, A+A : sampling nuclei for EIC

Corresponding Author: prithwish2005@gmail.com

Satellite workshops / **66**

Discussion: eA

Satellite workshops / **67**

arTeMiDe

Corresponding Author: vladimirov.aleksey@gmail.com