

QCD Evolution 2024



Report of Contributions

Contribution ID: 3

Type: **not specified**

Helicity-dependent Parton Distribution Functions at NNLO: determination from DIS and SIDIS data and impact of heavy quarks

Wednesday, May 29, 2024 9:30 AM (30 minutes)

I discuss MAPPDFpol1.0, a new determination of the helicity-dependent parton distribution functions (PDFs) of the proton from a set of longitudinally polarised inclusive and semi-inclusive deep-inelastic scattering data. The determination includes, for the first time, next-to-next-to-leading order QCD corrections to both processes, and is carried out in a framework that combines a neural-network parametrisation of PDFs with a Monte Carlo representation of their uncertainties. I discuss the quality of the determination, in particular its dependence on higher-order corrections, on the choice of data set, and on theoretical constraints. I finally assess the impact of charm quark corrections in the computation of theoretical predictions, by extending the FONLL mass scheme to the case of helicity-dependent PDFs.

Author: NOCERA, Emanuele Roberto (Istituto Nazionale di Fisica Nucleare)

Presenter: NOCERA, Emanuele Roberto (Istituto Nazionale di Fisica Nucleare)

Session Classification: Wednesday

Contribution ID: 4

Type: **not specified**

Leading-Twist Flavor Singlet Quark TMDs at Small- x

Tuesday, May 28, 2024 5:00 PM (30 minutes)

We study the small- x asymptotics of the flavor singlet, leading-twist quark transverse-momentum-dependent parton distribution functions (TMDs) via the eikonal expansion of quark propagator and the gauge link, expressing the TMD operator definitions at small- x in terms of polarized dipole amplitudes, which involve an insertion of appropriate spin-dependent parton-exchange vertices into the eikonal, unpolarized Wilson line. The small- x evolution equations for polarized dipole amplitudes are constructed via the recently developed light-cone operator treatment (LCOT) method, and subsequently solved in the large- N_c , linearized, double-logarithmic approximation (DLA), for the high-rapidity asymptotic behavior of the polarized dipole amplitudes. These results yield the small- x asymptotics of all the remaining leading-twist, flavor-singlet quark TMDs.

Authors: Dr ADAMIAK, Daniel (Thomas Jefferson National Laboratory); Dr SANTIAGO, M. Gabriel (Center for Nuclear Femtography, SURA); TAWABUTR, Yossathorn (University of Jyväskylä)

Presenter: TAWABUTR, Yossathorn (University of Jyväskylä)

Session Classification: Tuesday

Contribution ID: 5

Type: **not specified**

Transverse Momentum Moments: From TMDs to collinear distributions

Monday, May 27, 2024 5:30 PM (30 minutes)

In this presentation, I explore the connection between Transverse Momentum Dependent distributions (TMDs) and collinear distributions through the introduction and analysis of Transverse Momentum Moments (TMMs). These moments are defined as weighted integrals of TMDs over their transverse momentum with a cut-off scale. I illustrate that TMMs can be understood as equivalent to collinear distributions computed within a minimal subtraction scheme, with a perturbatively calculable factor enabling their transformation to the standard $\overline{\text{MS}}$ -scheme. As a result, this framework presents promising opportunities for the simultaneous extraction of TMDs and PDFs in future research investigations. My focus will be on describing the characteristics of the zeroth, first, and second TMMs, accompanied by providing phenomenological results based on current TMD extractions.

Authors: PROKUDIN, Alexey (JLab); VLADIMIROV, Alexey; SCIMEMI, Ignazio (Universidad Complutense Madrid); DEL RIO GARCIA, Oscar (Complutense University of Madrid)

Presenter: DEL RIO GARCIA, Oscar (Complutense University of Madrid)

Session Classification: Monday

Contribution ID: 6

Type: **not specified**

Angular dependence of Drell-Yan process in the TMD factorization

Monday, May 27, 2024 5:00 PM (30 minutes)

I present the description of angular dependence of Drell-Yan process in the TMD factorization theorem. It gives access to a new details of nucleon structure, for example, it allows the separation between quark and anti-quark TMDPDFs, and is sensitive to the Boer-Mulders function. The analysis is made with the help of kinematic power corrections (KPC).

Author: VLADIMIROV, Alexey**Presenter:** VLADIMIROV, Alexey**Session Classification:** Monday

Contribution ID: 7

Type: **not specified**

String-based parametrization of nucleon GPDs at any skewness: a comparison to lattice QCD

Friday, May 31, 2024 11:30 AM (30 minutes)

We introduce a string-based parametrization for nucleon quark and gluon generalized parton distributions (GPDs) that effectively handles all skewness values. Our approach leverages conformal moments, representing them as the sum of spin- j nucleon A-form and skewness-dependent spin- j nucleon D-form factor, derived from t-channel string exchange in AdS spaces. This model-independent framework, satisfying the polynomiality condition, uses Mellin moments of empirical parton distribution functions (PDFs) to estimate these form factors. With just five Regge slope parameters, our method accurately produces various nucleon quark GPD types and symmetric nucleon gluon GPDs through Mellin-Barnes integrals. Our isovector nucleon quark GPD aligns with existing lattice data, promising to improve the empirical extraction and global analysis of nucleon GPDs in exclusive processes by avoiding the de-convolution challenge.

Author: MAMO, Kiminad (William and Mary/JLab)**Co-author:** ZAHED, Ismail (Stony Brook University)**Presenter:** MAMO, Kiminad (William and Mary/JLab)**Session Classification:** Friday

Contribution ID: 8

Type: **not specified**

Numerical implementation for twist-3 PDF evolution equations

Wednesday, May 29, 2024 10:00 AM (30 minutes)

I will present our numerical implementations for the evolution equations of twist-3 collinear parton distributions.

I will focus on the challenging aspects that this problem poses compared to the standard twist-2 case, which are mostly due to the intrinsically two-dimensional nature of the support for twist-3 distributions.

I will detail our choices for the discretization procedure, discussing different alternatives contained in the implementations.

Authors: RODINI, Simone; ROSSI, Lorenzo (Istituto Nazionale di Fisica Nucleare); VLADIMIROV, Alexey

Presenter: RODINI, Simone

Session Classification: Wednesday

Contribution ID: 9

Type: **not specified**

Complete one-loop study of exclusive J/ψ and Υ photoproduction

Monday, May 27, 2024 3:30 PM (30 minutes)

We perform the first complete one-loop study of exclusive photoproduction of vector quarkonia off a proton, including full generalised-parton-distribution (GPD) evolution. We confirm the perturbative instability of the cross section at high photon-proton-collision energies at Next-to-Leading Order (NLO) using collinear factorisation. Such an instability is known since 20 years and has been tackled by a scale-fixing criterion and the so-called Q_0 -subtraction procedure to avoid the over-subtraction of the collinear singularities. In this work, we instead resolve this problem by matching High-Energy Factorisation (HEF) in the Doubly-Logarithmic Approximation (DLA) to collinear factorisation as previously done for inclusive quarkonium production. Such a DLA is a subset of the Leading-Logarithmic Approximation (LLA) of HEF which resums higher-order QCD corrections proportional to $\alpha_s^n \ln^{n-1}(\hat{s}/M^2)$ in the Regge limit $\hat{s} \gg M^2$. This is strictly consistent with the NLO DGLAP evolution of GPDs. We use two models for the GPDs entering the calculation: the first one is taken from the PARTONS framework, which includes a full GPD evolution. The second one corresponds to an approximation valid at high energies in terms of Parton Distributions Functions (PDFs) via the Shuvaev transform, in which only PDFs are evolved. We find that the resummation cures the instability observed for the NLO calculation in CF at high energies and finally paves the way for GPD-based NLO phenomenology for exclusive quarkonium photoproduction. We then compare our results for the two GPD models and assess the reliability of the Shuvaev transform as a means to probe the small x gluon PDFs via the exclusive photoproduction of vector quarkonia.

Authors: FLETT, Christopher (IJCLab); WAGNER, Jakub (National Centre for Nuclear Research); LANSBERG, Jean-Philippe (IJCLab- Paris-Saclay U. - CNRS); NEFEDOV, Maxim (IJCLab); SZNAJDER, Paweł (NCBJ); NABEEBACCUS, Saad (IJCLab)

Presenter: LANSBERG, Jean-Philippe (IJCLab- Paris-Saclay U. - CNRS)

Session Classification: Monday

Contribution ID: 10

Type: **not specified**

Understanding the Energy Momentum Distribution with the Weizsäcker-Williams Method

Monday, May 27, 2024 10:00 AM (30 minutes)

Gravitational Form Factors (GFFs) provide an important portal for probing the energy-momentum and mass distribution of nucleons and nuclei. This work presents the study of photon and gluon momentum GFFs using the Weizsäcker-Williams method of relativistic hadrons.

First, we express the photon A-GFFs in terms of charge form factors and discuss the corresponding photon radius. Furthermore, we derive an integral relation between the gluon A-GFF and the Laplacian of the dipole scattering amplitude in the small- x framework. This relation allows us to unveil the gluon energy-momentum distribution inside hadrons through measurements at the upcoming Electron-Ion Collider.

Additionally, we generalize the analysis to study the A-GFF of nuclei and propose employing the nuclear gluon mean square radius, together with the charge distribution, to constrain the neutron distribution for large nuclei.

This work provides important insights into the energy-momentum and mass distribution of nucleons and nuclei, which are crucial for our understanding of the fundamental structure of matter and the strong interaction.

Author: XIAO, Bowen (The Chinese University of Hong Kong-(Shenzhen))

Presenter: XIAO, Bowen (The Chinese University of Hong Kong-(Shenzhen))

Session Classification: Monday

Contribution ID: 11

Type: **not specified**

Semi-inclusive deep-inelastic scattering at NNLO in QCD

Monday, May 27, 2024 12:00 PM (30 minutes)

Semi-inclusive hadron production processes in deep-inelastic lepton-nucleon scattering (SIDIS) are important probes of the fragmentation dynamics of quarks into hadrons. Moreover, longitudinally polarized SIDIS is a powerful tool for resolving the quark flavor decomposition of the proton's spin structure. In this talk, I will present the recent calculation of the full next-to-next-to-leading order (NNLO) QCD corrections to the unpolarized and longitudinally polarized SIDIS coefficient functions.

Author: STAGNITTO, Giovanni (Istituto Nazionale di Fisica Nucleare)

Presenter: STAGNITTO, Giovanni (Istituto Nazionale di Fisica Nucleare)

Session Classification: Monday

Contribution ID: 12

Type: **not specified**

SIDIS at small x: Sudakov double logs from NLO corrections

Tuesday, May 28, 2024 9:30 AM (30 minutes)

We calculate the next to leading order corrections to SIDIS at small Bjorken x using the color glass condensate formalism. We first show that all UV and soft divergences cancel. We then show that collinear divergences are absorbed into DGLAP evolution of quark-hadron fragmentation function while the rapidity divergences are absorbed into BK/JIMWLK evolution of dipoles. We finally show that imposing a kinematic constraint on the radiated gluon allows one to extract the Sudakov double log contributions in the high Q^2 limit.

Authors: JALILIAN-MARIAN, Jamal; JALILIAN-MARIAN, Jamal (Baruch College)

Presenters: JALILIAN-MARIAN, Jamal; JALILIAN-MARIAN, Jamal (Baruch College)

Session Classification: Tuesday

Contribution ID: 13

Type: **not specified**

Recent progress in the determination of GPDs and TMDs in lattice QCD

Tuesday, May 28, 2024 3:00 PM (30 minutes)

Lattice QCD simulations are nowadays being done with physical values of the light, strange and charm quark masses. These state-of-the-art gauge ensembles are enabling precision hadron structure studies. Mellin moments are extracted at the physical point providing information of the momentum fraction and angular momentum carried by quarks and gluons in hadrons. In parallel, new theoretical developments are allowing the computation of GPDs and TMDs directly in lattice QCD. Recent progress on the computation of these quantities will be presented.

Author: Prof. ALEXANDROU, Constantia (University of Cyprus & The Cyprus Institute)

Presenter: Prof. ALEXANDROU, Constantia (University of Cyprus & The Cyprus Institute)

Session Classification: Tuesday

Contribution ID: 14

Type: **not specified**

Gluon TMD modeling & proton 3D imaging

Tuesday, May 28, 2024 3:30 PM (30 minutes)

We present exploratory studies of the 3D gluon content of the proton, as a result of analyses on leading-twist transverse-momentum-dependent (TMD) gluon distribution functions, calculated in a spectator model for the parent proton. Our formalism embodies a fit-based parameterization for the spectator-mass density, suited to describe both the small- x and the moderate- x regime. Particular attention is paid to the T-odd gluon TMDs, which represent a key ingredient in the description of relevant spin asymmetries emerging when the nucleon is polarized, as the gluon Sivers effect. All these analyses are helpful to shed light on the gluon dynamics inside nucleons and nuclei, which is one of the primary goals of new-generation colliders, as the Electron-Ion Collider, the High-Luminosity LHC, and its fixed-target program.

Authors: BACCHETTA, Alessandro (Istituto Nazionale di Fisica Nucleare); Dr CELIBERTO, Francesco Giovanni (UAH Madrid); RADICI, Marco (Istituto Nazionale di Fisica Nucleare)

Presenter: Dr CELIBERTO, Francesco Giovanni (UAH Madrid)

Session Classification: Tuesday

Contribution ID: 15

Type: **not specified**

Renormalons and power corrections in pseudo- and quasi-GPDs

Monday, May 27, 2024 11:00 AM (30 minutes)

High-order behavior of the perturbative expansion for short-distance observables in QCD is intimately related to the contributions of small momenta in the corresponding Feynman diagrams and this correspondence provides one with a useful tool to investigate power-suppressed non-perturbative corrections. We use this technique to study the structure of power corrections to parton quasi- and pseudo-GPDs which are used in lattice calculations of generalized parton distributions. As the main result, we predict the functional dependence of the leading power corrections to quasi(pseudo)-GPDs on x variable for nonzero skewedness parameter ξ . The kinematic point $x = \pm\xi$ turns out to be special. We find that the nonperturbative corrections to quasi-GPDs at this point are suppressed by the first power of the hard scale only. These contributions come from soft momenta and have nothing to do with the known UV renormalon in the Wilson line. We also show that power corrections can be strongly suppressed by the normalization procedure.

Authors: BRAUN, Vladimir (University of Regensburg); KOLLER, Maria (Universitaet Regensburg); Dr SCHOENLEBER, Jakob (BNL)

Presenter: BRAUN, Vladimir (University of Regensburg)

Session Classification: Monday

Contribution ID: 16

Type: **not specified**

Transverse polarization of Λ hyperons within a jet in unpolarized hadronic collisions

Thursday, May 30, 2024 2:30 PM (30 minutes)

After recalling the latest extractions of the Λ polarizing fragmentation functions within a TMD approach from fits to e^+e^- data, I will present theoretical estimates for the spontaneous transverse polarization of Λ hyperons produced in unpolarized pp collisions inside a jet. For the latter, transverse momentum effects are included only in the fragmentation mechanism. These predictions will be then compared against preliminary STAR results.

Special attention will be paid to the universality properties of the quark polarizing fragmentation function and, for the first time, to the role and size of its gluon counterpart.

Author: D'ALESIO, Umberto (Istituto Nazionale di Fisica Nucleare)

Co-authors: MURGIA, Francesco (Istituto Nazionale di Fisica Nucleare); GAMBERG, Leonard; ZACCCHEDDU, Marco (Jefferson Lab)

Presenter: D'ALESIO, Umberto (Istituto Nazionale di Fisica Nucleare)

Session Classification: Thursday

Contribution ID: 17

Type: **not specified**

Simultaneous Bayesian reweighting of TMDs

Friday, May 31, 2024 9:00 AM (30 minutes)

We present an extension of the Bayesian reweighting procedure to the case of multiple independent extractions of TMDs from SIDIS and e^+e^- data, namely the quark Sivers, transversity and Collins TMD functions. The reweighting is performed using A_N data measured in $p^\dagger p \rightarrow \pi X$ collisions at RHIC. The agreement with A_N data at large- x_F values, a kinematical region complementary to those explored in SIDIS measurements, is enhanced, improving the knowledge of the polarized quark TMDs in the large- x region.

Author: Dr FLORE, Carlo (Università di Torino e INFN, Sezione di Torino)

Co-authors: PROKUDIN, Alexey (JLab); MURGIA, Francesco (Istituto Nazionale di Fisica Nucleare); GONZALEZ HERNANDEZ, Jose Osvaldo (Istituto Nazionale di Fisica Nucleare); BOGLIONE, Mariaelena (Istituto Nazionale di Fisica Nucleare); D'ALESIO, Umberto (Istituto Nazionale di Fisica Nucleare)

Presenter: Dr FLORE, Carlo (Università di Torino e INFN, Sezione di Torino)

Session Classification: Friday

Contribution ID: 18

Type: **not specified**

Progress in Understanding Heavy Quark Fragmentation in the Transverse Plane

Monday, May 27, 2024 4:30 PM (30 minutes)

I discuss ongoing progress in the understanding of heavy-quark transverse momentum-dependent (TMD) fragmentation functions (FFs). These advances include their explicit next-to-leading order calculation in massive QCD and boosted Heavy-Quark Effective Theory (bHQET), exposing a rich singularity structure that is also relevant for the extension of fixed-order subtraction schemes to quasi-collinear limits, and a novel form of Collins-Soper-style evolution with respect to a dimensionless boost parameter. I further present how many independent nonperturbative bHQET functions are needed to fully characterize heavy-quark fragmentation in the transverse plane, accounting – for the first time – for arbitrary heavy hadron polarization. This analysis exposes powerful spin symmetry relations across all possible (polarized) TMD FFs for heavy quarks.

Author: MICHEL, Johannes (Nikhef/University of Amsterdam)

Presenter: MICHEL, Johannes (Nikhef/University of Amsterdam)

Session Classification: Monday

Contribution ID: 19

Type: **not specified**

Positivity constraints on parton distributions

Monday, May 27, 2024 11:30 AM (30 minutes)

I discuss the constraints that positivity of physical cross-sections impose on unpolarized and polarized collinear parton distribution functions. I explain why in a generic factorizations scheme leading-twist PDFs may turn negative beyond leading order, and show that however in the commonly used $\overline{\text{MS}}$ scheme this cannot happen in the perturbative regime. I then discuss the implications of this for phenomenology, using recent results both in the unpolarized and polarized case.

Author: FORTE, Stefano (Istituto Nazionale di Fisica Nucleare)

Presenter: FORTE, Stefano (Istituto Nazionale di Fisica Nucleare)

Session Classification: Monday

Contribution ID: 20

Type: **not specified**

Helicity and OAM at Low- x : an Exact Solution for Revised Helicity Evolution and the Small- x Asymptotics of OAM Distributions

Monday, May 27, 2024 2:30 PM (30 minutes)

We present an exact analytic solution of the revised large- N_c small- x helicity evolution equations derived recently. We find the corresponding small- x asymptotics of the flavor-singlet helicity PDFs to be

$$\begin{aligned} \Delta \Sigma(x, Q^2) &\sim \Delta G(x, Q^2) \sim \left(\frac{1}{x}\right)^{\alpha_h} \\ \end{aligned}$$

with the intercept given by an exact analytic expression which numerically evaluates to $\alpha_h \approx 3.661\sqrt{t\frac{\alpha_s}{N_c}2\pi}$. This appears to slightly disagree with the results of Bartels et al from 1996, where the intercept at large N_c is given by a different analytic expression, evaluating to $\alpha_h \approx 3.664\sqrt{t\frac{\alpha_s}{N_c}2\pi}$. We also obtain the all-order small- x and large- N_c polarized anomalous dimension $\Delta\gamma_{GG}(\omega)$ and demonstrate that it agrees with the existing finite-order results up to the three known loops.

We then turn our attention to the orbital angular momentum (OAM) distributions. We derive new small- x evolution equations needed to extract small- x asymptotics of OAM distributions. Solving these equations we obtain

$$\begin{aligned} L_{\{q + \{\bar{q}\}}(x, Q^2) &\sim L_G(x, Q^2) \sim \left(\frac{1}{x}\right)^{\alpha_h} \\ \end{aligned}$$

with the same intercept as for the helicity PDFs.

Authors: Mr MANLEY, Brandon (The Ohio State University); Mr BORDEN, Jeremy (The Ohio State University); KOVCHEGOV, Yuri (The Ohio State University); KOVCHEGOV, Yuri (The Ohio State University)

Presenters: KOVCHEGOV, Yuri (The Ohio State University); KOVCHEGOV, Yuri (The Ohio State University)

Session Classification: Monday

Contribution ID: 21

Type: **not specified**

Meson structures through collinear and transverse momentum dependent distributions

Thursday, May 30, 2024 11:30 AM (30 minutes)

Pions and kaons play an important role in QCD, as they are the pseudo-Goldstone bosons of chiral symmetry breaking while also being confined systems of quarks and gluons. Recent works on pion structures through the JAM framework introduce both Drell-Yan (DY) and leading neutron (LN) electroproduction observables to constrain parton distribution functions (PDFs) in the pion. By making use of the transverse momentum dependent (TMD) factorization, additional transverse momentum dependent DY observables led to the first simultaneous determination of both the collinear and TMD PDF in the pion. Through the knowledge of the pion PDFs, we introduce observables from the NA3 experiment which are ratios of kaon-induced DY cross sections to pion-induced DY cross sections in order to constrain kaon PDFs. We look forward to future experiments from the potential JLab 22 GeV upgrade, EIC, and COMPASS and AMBER at CERN.

Authors: PROKUDIN, Alexey (JLab); JI, Chueng (NCSU); PITONYAK, Daniel (Lebanon Valley College); MOFFAT, Eric (Penn State Berks / Argonne National Lab); GAMBERG, Leonard; SATO, Nobuo (Jefferson Lab); BARRY, Patrick (Argonne National Lab); MELNITCHOUK, Wally (Jefferson Lab)

Presenter: BARRY, Patrick (Argonne National Lab)

Session Classification: Thursday

Contribution ID: 22

Type: **not specified**

Double-Spin Asymmetries in Polarized p+p Collisions and kT Factorization at Small x

Wednesday, May 29, 2024 5:00 PM (30 minutes)

Double spin asymmetries for particle and jet productions in longitudinally polarized proton-proton collisions have been the flagship measurements at RHIC to study proton's spin content originating from gluons. Conventional theoretical framework used to extract gluons' helicity distribution relies on the collinear factorization framework which is applicable primarily when there exists a large external momentum. In this talk, I will discuss a transverse momentum dependent framework developed to be applicable at small x and derived a formula for the double-spin asymmetry of gluon productions at the central rapidity region of p+p collisions. The formula is projectile and target symmetric. Expressed in a kT factorized form, the formula involves a convolution of the gluon helicity TMDs and twist-3 helicity-flip TMDs originating from both the projectile and the target. It is further argued that small x evolution can be effectively included by evolving these TMDs in the double logarithmic approximation.

Author: LI, Ming (The Ohio State University)**Co-author:** KOVCHEGOV, Yuri (The Ohio State University)**Presenter:** LI, Ming (The Ohio State University)**Session Classification:** Wednesday

Contribution ID: 23

Type: **not specified**

Exclusive and semi-inclusive diffractive processes in the shockwave approach

Tuesday, May 28, 2024 5:30 PM (30 minutes)

The center-of-mass energies available at modern accelerators, such as the Large Hadron Collider (LHC), and at forthcoming generation accelerators, such as the Electron-Ion Collider (EIC), offer us a unique opportunity to investigate hadronic matter under the most extreme conditions ever reached. In particular, they allow access to the so-called \textit{Regge-Gribov} (or \textit{semi-hard}) limit of QCD, characterized by the scale hierarchy $s \gg \{Q^2\} \gg \Lambda_{\text{QCD}}^2$, where \sqrt{s} is the center-of-mass energy, $\{Q\}$ a set of hard scales characterizing the process and Λ_{QCD} is the QCD mass scale. This kinematic limit is the stage where some of the most intriguing phenomena of strong interactions manifest themselves, such as the formation of a state of gluonic matter that is known under the name of \textit{color glass condensate} (CGC). This state is characterized by a high-density of particles possessing a color charge (color condensate), by a slow evolution compared to the natural time of the interaction and by a disordered field distribution (properties assimilable to those of a glass). The quest for the saturation regime constitutes one of the pillars of the EIC physics program and a stimulating opportunity for the LHC experiments. In order to reveal saturation, highly accurate theoretical predictions are therefore unavoidable

In this talk, I will present the full next-to-leading order results for the cross-sections of diffractive single- or double hadron photo- or electroproduction with large p_T , on a nucleon or a nucleus and a pioneering calculation of the exclusive diffractive production of a transversely polarized light-meson in $\gamma^{(*)} p$ collision, obtained in a framework mixing the higher-twist formalism of exclusive processes with the Balitsky shockwave effective theory of small- x physics.

Authors: GRABOVSKY, Andrey (Novosibirsk State U and Budker INP); SZYMANOWSKI, Lech (Ecole Polytechnique, CphT/SINS Warsaw); FUCILLA, Michael; BOUSSARIE, Renaud (Brookhaven National Lab); WALLON, Samuel (LPT Orsay)

Presenter: FUCILLA, Michael

Session Classification: Tuesday

Contribution ID: 24

Type: **not specified**

Factorization of ep diffraction

Friday, May 31, 2024 10:00 AM (30 minutes)

Diffractive processes are events with large rapidity gaps, which typically comprise a double-digit percent of events at colliders and are important for small- x physics. We present a comprehensive factorization of ep diffraction, using effective field theory. We show that there are four nontrivial unpolarized diffractive structure functions at leading power, including the conventional F_2^D and F_L^D , as well as two large less-studied structures. We compare and contrast the factorization with traditional choices for global fits, including Collins' hard-scattering formula with diffractive PDFs (dPDFs) and the Ingelman-Schlein model. We provide model-independent perturbative predictions for ratios of structure functions, for both coherent and incoherent diffraction. For the incoherent case, these predictions hold regardless of how many color channels contribute, and hence can be tested experimentally, even if it is difficult to isolate pure color-singlet exchange.

Author: SCHINDLER, Stella**Co-authors:** STEWART, Iain (MIT); LEE, Kyle (MIT)**Presenter:** SCHINDLER, Stella**Session Classification:** Friday

Contribution ID: 25

Type: **not specified**

Transverse Single-Spin Asymmetries and the Universal Nature of Transversity PDFs and Nucleon Tensor Charges

Thursday, May 30, 2024 3:00 PM (30 minutes)

I will report on recent QCD global analyses of transverse single-spin asymmetries involving two different approaches: transverse momentum dependent (TMD)/collinear twist-3 (CT3) observables involving single-hadron FFs, and twist-2 collinear observables involving dihadron fragmentation functions (DiFFs). A byproduct of these studies is the extraction of the transversity PDFs and calculation of the nucleon tensor charges. I will discuss new developments in the theory and phenomenology of DiFFs in determining the transversity PDFs and examine their compatibility with the TMD/CT3 approach as well as lattice QCD computations of the nucleon tensor charges.

Authors: PITONYAK, Daniel (Lebanon Valley College); PITONYAK, Daniel (Lebanon Valley College)

Co-authors: COCUZZA, Christopher (Jefferson Lab); METZ, Andreas (Department of Physics, Temple University, Philadelphia); PROKUDIN, Alexey (JLab); SATO, Nobuo (Jefferson Lab); SEIDL, Ralf (RIKEN)

Presenters: PITONYAK, Daniel (Lebanon Valley College); PITONYAK, Daniel (Lebanon Valley College)

Session Classification: Thursday

Contribution ID: 26

Type: **not specified**

The axial current and its divergence

Wednesday, May 29, 2024 11:00 AM (30 minutes)

It is well known that the axial current exhibits the so-called chiral anomaly. The role of this anomaly in the context of the spin sum rule of the nucleon has been intensely discussed soon after the experimental discovery of the spin crisis in the late 1980s. While this field was largely dormant over the last decades, recent work has revived interest in this area. We will discuss perturbative calculations that can shed new light on the role of the axial anomaly in the helicity PDFs and GPDs.

Author: METZ, Andreas (Department of Physics, Temple University, Philadelphia)

Co-authors: Dr FREESE, Adam (Jefferson Lab); PASQUINI, Barbara (Istituto Nazionale di Fisica Nucleare); LORCE, Cedric (Ecole polytechnique, Paris-Saclay U.); Mr CASTELLI, Jorge Ignacio (Temple University); RODINI, Simone

Presenter: METZ, Andreas (Department of Physics, Temple University, Philadelphia)

Session Classification: Wednesday

Contribution ID: 27

Type: **not specified**

$1/Q^2$ power corrections to TMD factorization for Drell-Yan hadronic tensor

Tuesday, May 28, 2024 10:00 AM (30 minutes)

I present the full list of $\frac{1}{Q^2}$ power corrections to unpolarized Drell-Yan hadronic tensor for electromagnetic (EM) current at large N_c and demonstrate EM gauge invariance at this level.

Author: BALITSKY, Ian**Presenter:** BALITSKY, Ian**Session Classification:** Tuesday

Contribution ID: 28

Type: **not specified**

pT resummation in Drell Yan and determination of the W mass at hadron colliders

Monday, May 27, 2024 3:00 PM (30 minutes)

I describe recent developments in Drell Yan transverse-momentum resummation, and their implications on the definition of a new observable for W-boson mass extraction from charge-current Drell Yan data.

Author: Mr TORRIELLI, Paolo (Università di Torino e INFN)

Presenter: Mr TORRIELLI, Paolo (Università di Torino e INFN)

Session Classification: Monday

Contribution ID: 29

Type: **not specified**

Breakdown of collinear factorisation in exclusive $\pi^0\gamma$ photoproduction due to Glauber pinch

Tuesday, May 28, 2024 4:30 PM (30 minutes)

In this talk, I will discuss our work in 2311.09146, regarding the breakdown of collinear factorisation in the exclusive photoproduction of a $\pi^0\gamma$ pair. Such a process is sensitive to both quark and gluon GPD channels. In the latter case, the amplitude fails to factorise, due to the presence of a Glauber pinch, which has the same power counting as the collinear pinch. The Glauber pinch that occurs here is peculiar, since the mechanism that produces it involves two loop integrals. This is corroborated by an explicit calculation of the gluon GPD channel to $\pi^0\gamma$ pair photoproduction, which leads to a divergent amplitude already at leading twist-2 and at leading order in α_s . Such collinear factorisation breaking effects also occur in similar processes, such as the crossed channel of $\pi^0 N \rightarrow \gamma\gamma N$ scattering for the same reason. On the other hand, it should be stressed that for processes where the gluon GPD channel is forbidden, which correspond to the case where the outgoing meson is a charged pion or a rho meson, collinear factorisation works without any issues.

Authors: SCHOENLEBER, Jakob (BNL); SZYMANOWSKI, Lech (Ecole Polytechnique, CphT/SINS Warsaw); NABEEBACCUS, Saad (IJCLab); WALLON, Samuel (LPT Orsay)

Presenter: NABEEBACCUS, Saad (IJCLab)

Session Classification: Tuesday

Contribution ID: 30

Type: **not specified**

TMD factorization: Bridging large x and small x

Tuesday, May 28, 2024 11:00 AM (30 minutes)

QCD factorization takes on different forms in the large- x and the small- x regimes. In the large- x motivated collinear factorization, one gets the DGLAP evolution equation, whereas, in the small- x motivated rapidity factorization, the BFKL equation is the major player. To unify different regimes, a new TMD factorization based on the background field method is proposed, which not only reduces to CSS and DGLAP in the large- x limit and BFKL in the small- x limit, but also defines a general evolution away from these regimes. Such a factorization has the potential to significantly advance our comprehension of high-energy processes and the three-dimensional structure of hadrons.

Authors: Dr TARASOV, Andrey (North Carolina State University); TIWARI, Shaswat (North Carolina State University); MUKHERJEE, Swagato (Assistant Physicist); Dr SKOKOV, Vladimir (North Carolina State University)

Presenter: TIWARI, Shaswat (North Carolina State University)

Session Classification: Tuesday

Contribution ID: 31

Type: **not specified**

Phenomenology of GPDs with lattice QCD and experimental data

Thursday, May 30, 2024 9:30 AM (30 minutes)

I will present the limits and complementarity of GPD phenomenology using simultaneously lattice QCD, experimental data and theoretical models. I will point out how none of the three can convey a satisfactory picture alone as of now, but explore collectively complementary information. I will stress the crucial role of evolution in the uncertainties on the lattice, the modeling of GPDs at small x and in the deconvolution problem from experimental data.

Author: DUTRIEUX, Herve (William & Mary)**Presenter:** DUTRIEUX, Herve (William & Mary)**Session Classification:** Thursday

Contribution ID: 32

Type: **not specified**

State-of-the-art of observables for Generalized TMDs

Thursday, May 30, 2024 10:00 AM (30 minutes)

In this presentation, we provide an overview of Generalized Transverse Momentum Dependent Distributions (GTMDs) of hadrons, recognized as the most comprehensive two-parton correlation functions. We discuss recent advancements in this field, emphasizing the state-of-the-art observables for these quantities and their significant implications for the field of spin physics.

Author: BHATTACHARYA, Shohini (Los Alamos National Laboratory)

Presenter: BHATTACHARYA, Shohini (Los Alamos National Laboratory)

Session Classification: Thursday

Contribution ID: 33

Type: **not specified**

Towards the transverse SSA for $ep \rightarrow hX$ at NLO and its connection to $ep \rightarrow \gamma X$

Wednesday, May 29, 2024 3:30 PM (30 minutes)

We present a calculation of the single-spin asymmetry (SSA) for the single-inclusive production of hadrons in collisions of transversely polarized protons and unpolarized electrons, $ep \uparrow \rightarrow hX$. We compute this transverse spin observable within the collinear twist-3 factorization approach in perturbative QCD to next-to-leading order (NLO) accuracy. Several production channels contribute at NLO and this talk will focus especially on the $qg \rightarrow g$ channel featuring quark-gluon-quark correlations inside the proton and the fragmentation of a gluon to the observed hadron. This channel is closely related to the similar process $ep \uparrow \rightarrow \gamma X$ and we show how its transverse SSA can be obtained from the $qg \rightarrow g$ channel. Finally we show some numerical estimates for $ep \uparrow \rightarrow \gamma X$ at a future Electron-Ion Collider (EIC)

Authors: REIN, Daniel (Universität Tübingen); SCHLEGEL, Marc (University of Tuebingen); VOGELSANG, Werner (Univ. Tuebingen)

Presenter: REIN, Daniel (Universität Tübingen)

Session Classification: Wednesday

Contribution ID: 35

Type: **not specified**

Nuclear effects on transverse momentum dependent Drell Yan production in pA

Thursday, May 30, 2024 4:30 PM (30 minutes)

The Drell-Yan process is essential for the determination of the collinear and transverse momentum dependent (TMD) parton distribution function. For a nuclear target, in addition to the non-perturbative parton structure that is intrinsically different from that of a free nucleon, there are dynamical nuclear matter effects that modify the TMD cross section in proton-nucleus (pA) collisions. Perturbatively, they arise from forward scatterings between proton-collinear partons and the nuclear medium before the hard process. We study explicitly the opacity-one nuclear corrections to the TMD Drell-Yan cross section up to next-to-leading order. We find that the associated collinear and rapidity divergences lead to i) an in-medium renormalization group equation that encodes parton energy loss, and ii) a Balitsky-Fadin-Kuraev-Lipatov evolution equation for the forward scattering cross-section. I will discuss the connection of this work to earlier studies and phenomenological applications.

Authors: KE, Weiyao (Central China Normal University); Dr VITEV, Ivan (Los Alamos National Laboratory)

Presenter: KE, Weiyao (Central China Normal University)

Session Classification: Thursday

Contribution ID: 36

Type: **not specified**

A semi-analytical x -space solution for parton evolution

Thursday, May 30, 2024 5:30 PM (30 minutes)

I will present a novel semi-analytical method for parton evolution. The talk is based on work done with co-authors Oliver Schüle and Fabian Wunder, the corresponding preprint is [arXiv:2404.18667](#).

The presented method is based on constructing a family of analytic functions spanning x -space which is closed under the considered evolution equation. Using these functions as a basis, the original integro-differential evolution equation transforms into a system of coupled ordinary differential equations, which can be solved numerically by restriction to a suitably chosen finite subsystem. The evolved distributions are obtained as analytic functions in x with numerically obtained coefficients, providing insight into the analytic behavior of the evolved parton distributions.

As a proof-of-principle, we applied our method to the leading order non-singlet and singlet DGLAP equation. Comparing our results to traditional Mellin-space methods, we found good agreement. The method has been implemented in the code POMPOM in `Mathematica` as well as in `Python`.

Authors: WUNDER, Fabian (Eberhard Karls Universität Tübingen); HAUG, Juliane (Universität Tübingen); Mr SCHÜLE, Oliver (Universität Tübingen)

Presenter: HAUG, Juliane (Universität Tübingen)

Session Classification: Thursday

Contribution ID: 37

Type: **not specified**

Perturbative T -odd asymmetries in the Drell-Yan process revisited

Thursday, May 30, 2024 5:00 PM (30 minutes)

I will present a calculation of perturbative T -odd contributions to the lepton angular distribution in the Drell-Yan process. The talk is based on work done with Valery Lyubovitskij, Werner Vogelsang, and Alexey Zhevlakov; the corresponding pre-print is available under [arXiv:2403.18741](#).

Using collinear factorization, we worked at the first order in QCD perturbation theory where these contributions appear, $\mathcal{O}(\alpha_s^2)$, and address both W^\pm and γ/Z^0 boson exchange. A major focus of our calculation is on the regime where the boson's transverse momentum Q_T is much smaller than its mass Q . We carefully expanded our results up to next-to-next-to-leading power in Q_T/Q . Our calculation provides a benchmark for studies of T -odd contributions that employ transverse-momentum dependent parton distribution functions. In the neutral-current case we compare our results for the T -odd structure functions to available ATLAS data.

Authors: ZHEVLAKOV, Alexey; WUNDER, Fabian (Eberhard Karls Universität Tübingen); LYUBOVITSKIJ, Valery (Tuebingen University); VOGELSANG, Werner (Univ. Tuebingen)

Presenter: WUNDER, Fabian (Eberhard Karls Universität Tübingen)

Session Classification: Thursday

Contribution ID: 39

Type: **not specified**

Description of Collins asymmetries in e^+e^- annihilation with a Monte Carlo event generator

Thursday, May 30, 2024 3:30 PM (30 minutes)

The string+3P0 model of hadronization has been recently applied to the fragmentation of a string stretched between a quark-antiquark pair with correlated spin states. The pair is assumed to be created in e^+e^- annihilation via the exchange of a virtual photon. To perform simulations of e^+e^- events, the model has been implemented in the Pythia Monte Carlo event generator by extending the StringSpinner package.

Using StringSpinner, we have performed simulations of e^+e^- events at the center of mass energy of 10.6 GeV. The obtained results for the Collins asymmetries for back-to-back hadrons as well as their comparison with data from the Belle and BaBar collaborations are discussed.

Author: KERBIZI, Albi (Istituto Nazionale di Fisica Nucleare)

Presenter: KERBIZI, Albi (Istituto Nazionale di Fisica Nucleare)

Session Classification: Thursday

Contribution ID: 40

Type: **not specified**

Factorization for J/psi lepton production at small transverse momentum

Wednesday, May 29, 2024 12:00 PM (30 minutes)

When quarkonium is produced in the low-transverse momentum region, the contribution of soft and ultra-soft radiation between the heavy-quark pair becomes relevant. At this region, non-relativistic QCD (NRQCD) breaks down and we need to promote the long-distance matrix elements to the TMD shape functions (TMDShFs) in the NRQCD factorization procedure. In this talk, I discuss the cross section factorization for the J/ψ lepton production in terms of these TMDShFs at small transverse momentum.

I then discuss our results of the TMDShFs at next-to-leading order in the QCD coupling constant, the renormalization group evolution for the TMDShFs and the matching onto the collinear functions at high transverse momentum.

Author: F. ROMERA, Samuel (University of the Basque Country)

Co-authors: ECHEVARRIA, Miguel (University of the Basque Country UPV/EHU); TAEELS, Pieter (University of Antwerp)

Presenter: F. ROMERA, Samuel (University of the Basque Country)

Session Classification: Wednesday

Contribution ID: 41

Type: **not specified**

Recent developments in transverse momentum-dependent parton densities and corresponding parton showers based on parton branching model

The Parton Branching (PB) method outlines the evolution of transverse momentum-dependent (TMD) parton distributions across various kinematic regions, ranging from small to large transverse momenta k_T . In the small region, the PB method is highly sensitive to both the intrinsic motion of partons (intrinsic k_T) and the resummation of soft gluons, as described by the PB TMD evolution equations. The PB method is employed to investigate the role of soft (non-perturbative) gluon emissions in TMD, along with integrated collinear parton densities. Notably, soft gluons make a significant contribution to collinear parton densities. Within the PB framework, the Sudakov form factor is divided into perturbative and non-perturbative components. Analytical calculation of the non-perturbative part is feasible under specific conditions. The inclusion of soft (non-perturbative) gluons in parton density evolution is crucial for effectively canceling divergent terms.

It is suggested that the non-perturbative part of the Sudakov form factor has its correspondence in TMD parton distributions. In the PB approach, this non-perturbative Sudakov form factor is constrained through fits of inclusive, collinear parton densities. A detailed examination of the PB TMD methodology at next-to-leading order (NLO) in Drell-Yan (DY) production for low transverse momenta is presented. The extraction of intrinsic k_T is showcased, demonstrating minimal dependence on DY mass and center-of-mass energy. This contrasts with tuned standard Monte Carlo event generators, which typically exhibit a strong increase in intrinsic Gauss width with center-of-mass energy.

Author: TAHERI MONFARED, Sara (DESY)

Presenter: TAHERI MONFARED, Sara (DESY)

Session Classification: Thursday

Contribution ID: 42

Type: **not specified**

Spin asymmetries for C -even quarkonium production as a probe of gluon distributions

Wednesday, May 29, 2024 3:00 PM (30 minutes)

Within the framework of transverse momentum dependent factorization in combination with non-relativistic QCD, we study charmonium and bottomonium production in hadronic collisions. We focus on quarkonium states with even charge conjugation, for which the color-singlet production mechanism is expected to be dominant in the small transverse momentum region, $q_T^2 \ll 4M_{c,b}^2$. It is shown that the distributions of linearly polarized gluons inside unpolarized, longitudinally and transversely polarized protons contribute to the cross sections for scalar and pseudoscalar quarkonia in a very distinctive, parity-dependent way, whereas their effects on higher angular momentum states are strongly suppressed. We present analytical expressions for single and double spin asymmetries, which would allow for the direct extraction of the gluon transverse momentum dependent distributions, mirroring the phenomenological studies of the Drell-Yan processes aimed at the extraction of their quark counterparts. By adopting Gaussian models for the gluon TMDs, which fulfill without saturating everywhere their positivity bounds, we provide numerical predictions for the transverse single-spin asymmetries. These observables could be measured at LHCSpin, the fixed target experiment planned at the LHC.

Author: PISANO, Cristian (Istituto Nazionale di Fisica Nucleare)

Co-authors: MAXIA, Luca (University of Groningen); KATO, Nanako (Istituto Nazionale di Fisica Nucleare)

Presenter: PISANO, Cristian (Istituto Nazionale di Fisica Nucleare)

Session Classification: Wednesday

Contribution ID: 43

Type: **not specified**

Wilson loop correlators

Friday, May 31, 2024 12:00 PM (30 minutes)

Particular gluon transverse momentum dependent distributions (TMDs and GTMDs) become Wilson loop correlators in the limit of small x . In this talk I will discuss the consequences of this and what happens under evolution.

Author: BOER, Daniel (University of Groningen)

Presenter: BOER, Daniel (University of Groningen)

Session Classification: Friday

Contribution ID: 44

Type: **not specified**

The perturbative tail of the TMD shape function in SIDIS

Wednesday, May 29, 2024 2:30 PM (30 minutes)

Quarkonia are very “handy” objects for the spin-physics community because they can be used to fill up the lack of information on gluon transverse momentum dependent distributions (TMDs) at energies Q

less than 100 GeV. In particular, among the different kinds of quarkonia, the J/ψ is definitely the one that attracts the most attention. Nonetheless, its theoretical description is still under debate. Only recently, it has been understood that a correct factorization at small- q_T requires the introduction of novel quantities: the so-called TMD shape functions, which include smearing effects. Within the non-relativistic QCD approach, they can be thought of as a TMD extension of the long-distance matrix elements that are valid at high- q_T (collinear description). Although the TMD shape functions have been initially introduced for hadronic processes, recently their perturbative tails in semi-inclusive deep-inelastic scattering have been determined via a matching procedure. In this talk I will present such derivation, also including subleading (but non-negligible) terms. I will then discuss the implications of the result, and in particular the presence of a process-induced dependence that spoils the TMD shape function universality. The phenomenological studies presented in this talk could be performed at the future Electron-Ion Collider.

Author: MAXIA, Luca (University of Groningen)

Co-authors: PISANO, Cristian (Istituto Nazionale di Fisica Nucleare); BOER, Daniel (University of Groningen)

Presenter: MAXIA, Luca (University of Groningen)

Session Classification: Wednesday

Contribution ID: 45

Type: **not specified**

Updates on gluon helicity pdf from JAM

Wednesday, May 29, 2024 11:30 AM (30 minutes)

Recently, new results on the extraction of gluon helicity PDFs have been presented. These new results provide a comprehensive global analysis involving double spin asymmetries from high-energy polarized jet data, large- x polarized DIS, and recent calculations from LQCD. In this talk, I will provide a summary of the recent findings.

Author: SATO, Nobuo (Jefferson Lab)**Presenter:** SATO, Nobuo (Jefferson Lab)**Session Classification:** Wednesday

Contribution ID: 46

Type: **not specified**

High-Energy Behavior of pseudo- and quasi-PDFs: Implications for Lattice Calculations

Tuesday, May 28, 2024 9:00 AM (30 minutes)

Pseudo and quasi-PDFs are key tools to compute parton distribution functions (PDFs) directly on the lattice.

However, using the lattice to make these calculations has its challenges. To get the Bjorken- x dependence from the bi-local operator, one needs to know the behavior of these operators for large values of the momentum hadronic target.

Lattice calculation, on the other hand, can provide values only for finite values of this parameter. I will describe the method to obtain such behavior by resumming the necessary logarithms, thereby providing a way to enhance the accuracy and reliability of lattice-derived PDFs.

Author: CHIRILLI, Giovanni Antonio (University of Salento)

Presenter: CHIRILLI, Giovanni Antonio (University of Salento)

Session Classification: Tuesday

Contribution ID: 47

Type: **not specified**

New insights on DIS factorization at threshold

Friday, May 31, 2024 9:30 AM (30 minutes)

Deep Inelastic Scattering at large Bjorken x provides an interesting and unique framework to test modern factorization techniques. Although this topic has been widely discussed in the past within the context of effective theories, a consistent treatment in full QCD still faces issues regarding the treatment of rapidity divergences, subtractions, and the role played by soft radiation. In this talk, I will present a factorization theorem for DIS in the threshold region valid in full QCD addressing in detail the subtleties involved in the separation of the various contributions. I will also point out strong analogies and similarities between Transverse Momentum Dependent (TMD) factorization, offering a new appealing perspective that might open the path for a global study of hadronization effects involving different observables.

Author: SIMONELLI, Andrea**Co-authors:** ACCARDI, Alberto (Hampton U. and Jefferson Lab); SIGNORI, Andrea (Istituto Nazionale di Fisica Nucleare); COSTA, Caroline (Jefferson Lab); CERUTTI, Matteo (Istituto Nazionale di Fisica Nucleare)**Presenter:** SIMONELLI, Andrea**Session Classification:** Friday

Contribution ID: 48

Type: **not specified**

A study of TMD evolution effect on $\cos 2\phi$ azimuthal asymmetry in a back-to-back J/ψ -jet production at the EIC

Wednesday, May 29, 2024 4:30 PM (30 minutes)

A back-to-back semi-inclusive $J/\psi + jet$ production is a promising process to study gluon transverse momentum distribution (TMDs) at the future electron-ion collider (EIC). A back-to-back configuration allows a higher transverse momentum for J/ψ . We present an extension of a previous work where we studied $\cos 2\phi$ azimuthal asymmetry within the TMD factorization framework. We present the effect of TMD evolution on the asymmetry in two approaches that differ in the parameterization of the perturbative tails of the TMDs and the non-perturbative factors. We found that the asymmetry increases with the total outgoing transverse momentum, however, it decreases with the transverse momentum of J/ψ or the jet. We investigated the uncertainty coming from the parameterizations of the non-perturbative Sudakov factors in the larger b_T region, which we found to be sensitive to the contributions from the non-perturbative region, influencing the asymmetry significantly.

Authors: PAWAR, AMOL (Indian Institute of technology Bombay); MUKHERJEE, Asmita (Physics Department, IIT Bombay); SIDDIQAH, Mariyah (University of Kashmir); KISHORE, Raj (University of Basque Country); SANGEM, Rajesh (Istituto Nazionale di Fisica Nucleare)

Presenter: KISHORE, Raj (University of Basque Country)

Session Classification: Wednesday

Contribution ID: 49

Type: **not specified**

New insights on flavor dependence in TMD extractions from global fits

Thursday, May 30, 2024 11:00 AM (30 minutes)

In this talk, we present the latest results by the MAP Collaboration about the extraction of unpolarized quark Transverse-Momentum-Dependent Distributions (TMD PDFs) and Fragmentation Functions (TMD FFs) from global fits of Drell-Yan and Semi-Inclusive Deep-Inelastic Scattering (SIDIS) data sets. In particular, we discuss the impact of the introduction of flavour dependence in the nonperturbative models. We obtain significant deviations of the shape of the extracted TMDs among different quarks, suggesting that the 3D momentum distribution of quarks inside the proton depends on the flavour.

Author: CERUTTI, Matteo (Hampton University and Jefferson Lab)

Co-authors: BACCHETTA, Alessandro (Istituto Nazionale di Fisica Nucleare); SIGNORI, Andrea (Istituto Nazionale di Fisica Nucleare); BISSOLOTTI, Chiara (UChicago Argonne, Argonne National Laboratory); DELCARRO, Filippo (Istituto Nazionale di Fisica Nucleare); BOZZI, Giuseppe (University of Cagliari and INFN, Cagliari); ROSSI, Lorenzo (Istituto Nazionale di Fisica Nucleare); RADICI, Marco (Istituto Nazionale di Fisica Nucleare); Dr BERTONE, Valerio (CEA Paris-Sclay)

Presenter: CERUTTI, Matteo (Hampton University and Jefferson Lab)

Session Classification: Thursday

Contribution ID: 50

Type: **not specified**

Energy-Energy Correlation in the back-to-back region at N3LL+NNLO in QCD

Tuesday, May 28, 2024 11:30 AM (30 minutes)

We consider the Energy-Energy Correlation function in electron-positron annihilation to hadrons. We concentrate on the back-to-back region, performing all-order resummation of the logarithmically enhanced contributions in QCD perturbation theory, up to next-to-next-to-next-to-leading logarithmic (N3LL) accuracy. Away from the back-to-back region, we consistently combine resummed predictions with the known fixed-order results up to next-to-next-to-leading order (NNLO). We present an illustrative comparison with LEP data and a model for inclusion of NP QCD effects.

Author: FERRERA, Giancarlo (University of Milan and INFN, Milan)

Presenter: FERRERA, Giancarlo (University of Milan and INFN, Milan)

Session Classification: Tuesday

Contribution ID: 51

Type: **not specified**

A first implementation of the HSO approach to TMD phenomenology

Thursday, May 30, 2024 12:00 PM (30 minutes)

We present a first practical implementation of a recently proposed hadron structure oriented (HSO) approach to TMD phenomenology applied to Drell-Yan like processes, including lepton pair production at moderate Q^2 and Z^0 boson production. We emphasize the HSO's preservation of a basic TMD parton-model-like framework even while accounting for full TMD factorization and evolution. We argue that moderate Q measurements should be given greater weight than high Q measurements in extractions of nonperturbative transverse momentum dependence.

Authors: SIMONELLI, Andrea; ASLAN, Fatma (JLab/UConn); GONZALEZ HERNANDEZ, Jose Osvaldo (Istituto Nazionale di Fisica Nucleare); BOGLIONE, Mariaelena (Istituto Nazionale di Fisica Nucleare); Mr ROGERS, Ted (Old Dominion University / Jefferson Lab); RAINALDI, Tommaso (Old Dominion University)

Presenter: GONZALEZ HERNANDEZ, Jose Osvaldo (Istituto Nazionale di Fisica Nucleare)

Session Classification: Thursday

Contribution ID: 52

Type: **not specified**

Parton pseudo-Distributions and their evolution

Tuesday, May 28, 2024 12:00 PM (30 minutes)

The calculation of parton distributions of the nucleon is a requisite for understanding hadronic cross sections in terms of quarks and gluons. Over the last decade many calculations from first principles lattice QCD have begun through matrix elements which can be factorized similarly to cross sections. In this talk, I will highlight our calculations using the pseudo-PDF approach and its relation to the standard PDF. In this framework, lattice data can be combined with experimental data to obtain higher quality PDFs than either individually. Furthermore we can study the scale dependence to non-perturbatively learn the evolution of the parton pseudo-distributions.

Author: KARPIE, Joseph (Jefferson Lab)**Presenter:** KARPIE, Joseph (Jefferson Lab)**Session Classification:** Tuesday

Contribution ID: 53

Type: **not specified**

Explore Nucleon Tomography Through Correlation Measurements

Tuesday, May 28, 2024 2:30 PM (30 minutes)

Correlation measurements in DIS and pp collisions provide unique opportunity to explore nucleon structure, including TMDs, GPDs, and more recently Wigner distributions. In this talk, I will review some of recent studies, which can be explored at the current and future facilities, such as JLab 12 GeV, EIC and LHC.

Author: YUAN, Feng (Lawrence Berkeley Lab)

Presenter: YUAN, Feng (Lawrence Berkeley Lab)

Session Classification: Tuesday

Contribution ID: 55

Type: **not specified**

Nuclear-modified TMD PDFs and FFs

Wednesday, May 29, 2024 9:00 AM (30 minutes)

For more than 50 years, bound nucleons have been known to undergo non-trivial modifications due to the presence of the cold nuclear medium. During this time, experimental measurements at collider facilities have focused on exploring how the one-dimensional structure of nucleons is modified, with global QCD analyses proving extremely successful in extracting these distributions. More recently, we have extended this methodology to describe the three-dimensional structure of bound nucleons and used experimental data from Jefferson Lab to constrain the nuclear-modified TMD fragmentation functions. Our methodology incorporates the global set of experimental data from both Drell-Yan production and Semi-Inclusive Deep Inelastic Scattering. Through a comprehensive global extraction of these distributions, we demonstrate the effectiveness of this extension by strongly describing the entire global dataset. Additionally, I will discuss the use of lepton-jet correlations and transverse EECs as a precision probe of the structure of bound nucleons and efforts to extend this framework within a GLV formalism.

Author: TERRY, John (LANL)**Presenter:** TERRY, John (LANL)**Session Classification:** Wednesday

Contribution ID: 56

Type: **not specified**

One-loop evolution of twist-2 generalized parton distributions

Thursday, May 30, 2024 9:00 AM (30 minutes)

In this talk, I will revisit the evolution of generalised parton distributions (GPDs) at leading order in the strong coupling constant α_s for all of the twist-2 quark and gluon operators. I will present a rederivation of the one-loop evolution kernels, expressing them in a form suitable for implementation, and check analytically that some basic properties, such as DGLAP/ERBL limits and polynomiality conservation, are fulfilled. I will also present a number of numerical results obtained with a public implementation of the evolution in the library APFEL++ and available within the PARTONS framework.

Author: Dr BERTONE, Valerio (CEA Paris-Sclay)

Presenter: Dr BERTONE, Valerio (CEA Paris-Sclay)

Session Classification: Thursday

Contribution ID: 58

Type: **not specified**

Lattice QCD for TMD Physics: Nonperturbative Collins-Soper Kernel

Monday, May 27, 2024 9:30 AM (30 minutes)

Progresses related to lattice QCD calculations of the rapidity anomalous dimension of quark transverse-momentum-dependent distributions, i.e., the Collins-Soper (CS) kernel, will be presented. Methodological and numerical advances over the last year will be reviewed. Results from the state-of-the-art lattice QCD calculations will be presented and compared with the those from the phenomenological parametrizations of experimental data.

Author: MUKHERJEE, Swagato (Assistant Physicist)

Presenter: MUKHERJEE, Swagato (Assistant Physicist)

Session Classification: Monday

Contribution ID: 60

Type: **not specified**

First Results on Deeply Virtual Exclusive Experiments from the EXCLAIM collaboration

Friday, May 31, 2024 11:00 AM (30 minutes)

Understanding the 3D quark-gluon structure of nucleons is entering an era of precision, which is furthered by the 12 GeV upgrade at Jefferson Lab and the upcoming EIC. I will give an overview of the work done by the EXCLUSives via Artificial Intelligence and Machine learning (Exclaim) collaboration, an interdisciplinary effort by ML experts, nuclear theorists and experimentalists centered around building physics informed deep-learning architectures, which utilize new experimental data and first-principle lattice QCD calculations in order to access the 3D structure of matter. Our approach offers a benchmarking framework for studying various Deeply Virtual Exclusive Scattering processes and extracting Compton Form Factors and Generalized Parton Distributions.

Author: MARIJA ČUIĆ, Marija**Presenter:** MARIJA ČUIĆ, Marija**Session Classification:** Friday

Contribution ID: 61

Type: **not specified**

Parton shower algorithm based on the small- x evolution equation

Wednesday, May 29, 2024 5:30 PM (30 minutes)

We develop a novel parton shower algorithm based on the Gribov-Levin-Ryskin (GLR) evolution equation incorporating the gluon fusion effect to simulate the small- x gluon cascade. The formulations of both forward and backward evolution for the GLR equation are presented in our work, and the results from the Monte Carlo implementation of the GLR equation are in complete agreement with its numerical solutions. It provides a vital tool to describe fully exclusive hadronic final states in collisions at the future electron-ion collider. This work thus paves the way for developing an event generator that embodies the saturation effect.

Authors: ZHOU, Jian (Shandong University); SHI, Yu

Co-author: WEI, Shuyi (Shandong University)

Presenter: SHI, Yu

Session Classification: Wednesday

Contribution ID: **62**

Type: **not specified**

Social dinner

Wednesday, May 29, 2024 8:00 PM (2 hours)

Bardelli restaurant:

<https://maps.app.goo.gl/rwzbeBYRTj6cs11a9>