LaMET 2021 Online

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Zoom

Book of Abstracts

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Session I / 1

Distribution amplitudes of K* and φ from lattice QCD with large momentum effective theory

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We present the first lattice QCD calculation of the distribution amplitudes of longitudinally and transversely polarized vector mesons K∗ and φ using large momentum effective theory. We use the clover fermion action on three ensembles with 2+1+1 flavors of highly improved staggered quarks (HISQ) action, generated by MILC collaboration, at physical pion mass and {0.06, 0.09, 0.12} fm lattice spacings, and choose three different hadron momenta Pz = {1.29,1.72,2.15} GeV. The resulting lattice matrix elements are nonperturbatively renormalized in a hybrid scheme proposed recently. An extrapolation to the continuum and infinite momentum limit is carried out. We find that while the longitudinal distribution amplitudes tend to be close to the asymptotic form, the transverse ones deviate rather significantly from the asymptotic form. Our final results provide crucial ab initio theory inputs for analyzing pertinent exclusive processes.

Session I / 2

Light-Front Wave Functions From LaMET

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Light-front wave functions play a fundamental role in the light-front quantization approach to QCD and hadron structure. However, a naive implementation of the light-front quantization suffers from various subtleties including the well-known zero-mode problem such as the associated rapidity divergences as well as breaking of spatial rotational symmetry. In the talk, I will show that the light-front quantization should be viewed as an effective theory in which small k^+ modes have been effectively "integrated out", with an infinite number of renormalization constants. Instead of solving light-front quantized field theories directly, we make the large momentum expansion of the equal-time Euclidean correlation functions in instant quantization as an effective way to systematically calculate light-front correlations, including the light-front wave function amplitudes. This large-momentum effective theory accomplishes an effective light-front quantization through lattice QCD calculations. We demonstrate our approach using an example of a pseudo-scalar meson wave function.

Session I / 3

Topics in LaMET

Author: Jiunn-Wei Chen[None]

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I would like to talk about some unrelated topics in LaMET, including the renormalon effect, applying Chiral Perturbation Theory to quasi-PDFs, and the matching kernels for the hybrid renormalization and self-renormalization.

Session II / 4

Disentangling Long and Short Distances in Momentum-Space TMDs

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The extraction of nonperturbative TMD physics is made challenging by prescriptions that shield the Landau pole, which entangle long- and short-distance contributions in momentum space. The use of different prescriptions then makes the comparison of fit results for underlying nonperturbative contributions meaningless on their own. We propose a model-independent method to restrict momentum-space observables to the perturbative domain. This method is based on a set of integral functionals that act linearly on terms in the conventional position-space operator product expansion (OPE). Artifacts from the truncation of the integral can be systematically pushed to higher powers in $\Lambda_{\rm QCD}/k_T$. We demonstrate that this method can be used to compute the cumulative integral of TMDPDFs over k_T in terms of collinear PDFs, accounting for both radiative corrections and evolution effects. This gives a systematic way of correcting the naive picture where the TMDPDF integrates to a collinear PDF, and we find that for the unpolarized distribution the corrections are a percent-level effect. We also show that, when supplemented with experimental data and improved perturbative inputs, these functionals will enable model-independent limits to be put on the nonperturbative OPE contributions in the Collins-Soper kernel and intrinsic TMD distributions.

Session I / 5

Collins-Soper kernel from transverse momentum-dependent wave functions in LaMET

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In this work we present the transversity $b_\perp$-dependence Collins-Soper kernel extracted from pion transverse momentum dependent wave functions in the framework of large momentum effective theory from lattice QCD. We use clover fermion action with $2+1+1$ flavors of highly improved staggered quarks (HISQ), generated by MILC Collaboration. A single ensemble is used, with lattice spacing $a = 0.12$fm and volume as $L^3 \times T = 48^3 \times 64$. The results are presented based on pion mass $M_\pi = 670$MeV, and three hadron momenta as $P^z = 2\pi/L \times \{8, 10, 12\} = \{1.72, 2.15, 2.58\}$GeV. The result of Collins-Soper kernel is determined of joint fit through momentum pairs.

Session I / 6

Updated Result on Nucleon Transversity Parton Distribution Function from Lattice QCD

Author: Fei Yao[None]

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In this talk, I present some updated results on nucleon transversity parton distribution function (PDF) from lattice QCD using large-momentum effective theory. The calculation is done with three lattice spacings, 0.086, 0.064 and 0.049 fm. The bare matrix elements are nonperturbatively renormalized in a recently proposed hybrid scheme. Also a continuum extrapolation is performed. Our results show agreement with recent global analyses within errors.

Session I / 7

Pion and kaon distribution amplitudes and SU(3) flavor breaking effect from lattice QCD

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We present the state-of-the-art lattice QCD calculation of the light-cone distribution amplitudes (DAs) of pion and kaon using large-momentum effective theory. The calculation is done at three lattice spacings $a \approx \{0.06, 0.09, 0.12\}$˜fm and physical pion and kaon masses, with the meson momenta $P_z = \{1.29, 1.72, 2.15\}$ GeV. The result is non-perturbatively renormalized in a recently proposed hybrid scheme, and extrapolated to the continuum as well as the infinite momentum limit. We find {a significant deviation of the pion and kaon DAs from the asymptotic form, and make a prediction for the $SU(3)$ flavor breaking effect in the kaon DA.

Session II / 8

One-loop structure of parton distribution for the gluon condensate and ”zero modes”

Authors: Anatoly Radyushkin[None]; Shuai Zhao[1]

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We present the results for the one-loop corrections to the “gluon condensate” twist-4 PDF F(x), in particular, we give expression for the gg-part of its evolution kernel. To enforce strict compliance with the gauge invariance requirements, we have used on-shell states for external gluons and have obtained identical results both in Feynman and light-cone gauges. No “zero mode” terms were found for $F(x)$. However, a $q^2\delta(x)$ term was found for the $\xi = 0$ GPD $F(x, q^2)$ at nonzero momentum transfer q. These results do not agree with the original attempt of one-loop calculations of $F(x)$ for gluon states, which sets alarm warning for calculations and the lattice renormalization procedures that use matrix elements with virtual external gluons.

Session II / 9

The continuum and leading twist limits of pseudo-PDFs

Authors: Anatoly Radyushkin[None]; Joseph Karpie[None]; Kostas Orginos[1]; Savvas Zafeiropoulos[2]

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The continuum limit is a fundamental step when using a lattice regulator and necessary for any high precision calculation using lattice QCD. The matrix elements used in determining a PDF have two dimensionful parameters, compared to the 0 or 1 of most lattice calculations, which significantly complicates the continuum limit extrapolation. In this presentation, I will describe a method which will allow for a continuum limit extrapolation from any ensemble without having to fix any of the parameters. It also can be extended to other systematic errors such as removing higher twist effects. I will demonstrate this method on a set of ensembles with $m_\pi = 440$ MeV and lattice spacings $a = 0.048, 0.065$, and 0.075 fm.

Session II / 10

Gluon Parton Distribution of the Pion and Nucleon from Lattice QCD

Authors: Huey-Wen Lin[None]; Zhouyou Fan[None]

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We present the x-dependent nucleon and pion gluon distribution from lattice QCD using the pseudo-PDF approach, on lattice ensembles with $2 + 1 + 1$ flavors of highly improved staggered quarks (HISQ), generated by MILC Collaboration. We use clover fermions for the valence action and momentum smearing to achieve pion boost momentum up to 2.56˜GeV on three lattice spacings $a \approx 0.9, 0.12$ and 0.15˜fm and three pion masses $M_\pi \approx 220$, 310 and 690˜MeV.
We compare our pion and preliminary nucleon gluon results with the determination by global fits.

Session II / 11

Approaching Continuum limits of Strange Parton Distribution Functions in Lattice QCD

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We present preliminary lattice QCD calculations of the unpolarized and polarized distributions of the strange quark using the LaMET method. We use three $N_f = 2+1+1$ HISQ ensembles generated by MILC collaboration at lattice spacings $a \approx 0.09, 0.12$ and 0.15 fm, and clover valence fermions with two valence pion masses: 310 and 690 MeV. We use momentum-smeared sources to improve the signal up to nucleon boost momentum $P_z = 2.15$ GeV, and determine nonperturbative renormalization factors in RI/MOM scheme. We compare our results with the matrix elements obtained from matching the PDFs from CT18NNLO and NNPDF3.1NNLO global fits.

Session II / 12

Polarized gluon pseudodistributions at short distances

Authors: Anatoly Radyushkin[None]; Ian Balitsky[1]; Wayne Morris[None]

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We present the results that are necessary in the ongoing lattice calculations of the polarized gluon parton distribution functions within the pseudo-PDF approach. We give a classification of possible two-gluon correlator functions and identify those that contain the invariant amplitude determining the polarized gluon PDF in the light-cone $z^2 \to 0$ limit. One-loop calculations have been performed in the coordinate representation and in an explicitly gauge-invariant form. We introduce the reduced Ioffe-time distribution (ITD), which requires a special construction in this case, and obtain the matching relation between the reduced ITD and its light-cone analog that is necessary for conversion of lattice data into the light-cone PDF.

Session I / 13

Review on Linear Divergence

Author: Yushan Su[1]

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Large-momentum effective theory provides a way to extract the parton physics from lattice data based on first-principle calculation. In applying large-momentum effective theory, renormalization of
the Euclidean correlators in lattice regularization is a challenge due to
linear divergences in the self-energy of Wilson lines. We will give a review on different renormalization methods to deal with linear divergences, including RI/MOM and ratio scheme. In these renormalization methods, people divide the bare hadron matrix element by another matrix element. Then we will talk about the self-renormalization method proposed recently, including a detailed numerical test on the linear divergence factors in the previous methods. Our test shows that the linear divergence can be eliminated in the ratio scheme. Moreover, we find a large non-perturbative effect in the RI/MOM and
ratio scheme, suggesting favor of the hybrid renormalization procedure proposed recently. Finally, we will talk about the hybrid renormalization method.

Session I / 14

Renormalize quasi TMD-PDF on lattice

Co-author: Yi-Bo Yang [1]

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Non-local operator has linear divergence on lattice. RI/MOM scheme cannot eliminate the linear divergence in quasi-PDF operator, especially for the clover valence quark. Using RI/MOM scheme will undermine the credibility of our results.
We try to use the square root of Wilson loop to renormalize bare matrix element of TMD-PDF. When calculating TMD-PDF in the rest frame, we found renormalized matrix elements on different lattice spacings are separated, especially for the finer lattice. But if we change the scale from fm to a(lattice spacing), the curves of different lattice spacings are consistent, which indicates that the linear divergence has been eliminated and only the log(z/a) and log(b/a) are left. In fact, perturbation

theory tells us that Wilson loop is not able to cancel out all the log divergences, even in the one-loop level.
We are trying to remove those log divergences and renormalize quasi TMD-PDF.

Session I / 15

The transversity parton distribution function of the nucleon using the pseudo-distribution approach

Authors: HadStruc Collaboration[None]; Nikhil Karthik[None]

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I will present some recent results from the HadStruc collaboration on the extraction of transversity PDF of the proton by using fits to NLO leading-twist OPE. I will explain how the systematic errors are taken care of, and then present the x-dependence of the transversity PDF and its comparison with recent JAM global fit results.

Session II / 16

Gluon distributions of the nucleon from lattice QCD

Author: Raza Sufian[None]

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We present lattice QCD calculation of unpolarized and polarized gluon Ioffe-time distributions using the pseudo-PDFs approach. We construct the nucleon interpolation fields using the distillation technique and smear the gauge fields using gradient flow. We calculate flow time-independent reduced Ioffe-time pseudo-distribution and from that, determine the unpolarized gluon PDF in the $\overline{\mathrm{MS}}$ scheme at $\mu = 2$ GeV. We also present progress towards determining gluon helicity distribution from lattice QCD calculation.

Session I / 17

Valence parton distribution of pion from lattice QCD at physical point

Authors: Andrew Hanlon[1]; Luchang Jin[None]; Peter Petreczky[2]; Swagato Mukherjee[1]; Xiang Gao[3]; Nikhil Karthik[None]; Philipp Scior[2]; Sergey Syritsyn[4]; Yong Zhao[1]

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We present the first lattice calculation of pion valence parton distribution using matching formula at NNLO level. We use the Wilson-Clover fermion on three 2+1 flavor HISQ ensembles of lattice spacings a = 0.04, 0.06 and 0.076 fm, with two pion mass including the physical one. Two unitary

Domain-Wall calculations at physical point are also presented. This allows us to control the continuum limit, quark mass effects as well as the chiral symmetry. Our analysis use ratio-based schemes to renormalize the equal-time bilocal quark-bilinear matrix elements. We extract first few moments model independently and reconstruct the x-dependent PDF.

Session II / 18

Towards High-Precision Nucleon Parton Distributions via Distillation

Authors: Colin Egerer[1]; Robert Edwards[None]; Christos Kallidonis[2]; Kostas Orginos[3]; Anatoly Radyushkin[None]; David Richards[1]; Eloy Romero[1]; Savvas Zafeiropoulos[4]

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We apply the Distillation spatial smearing program to the extraction of the
unpolarized isovector valence PDF of the nucleon using the pseudo-distribution formalism. The improved volume sampling and control of excited-states afforded by distillation leads to a dramatically improved determination of the requisite Ioffe-time Pseudo-distribution (pITD).
The valence PDF is extracted by analyzing both the matched Ioffe-time Distribution (ITD), as well as a direct matching of the pITD to the PDF. The latter method of extraction is facilitated by a novel expansion of the pITD in a set of Jacobi polynomials using the NLO coordinate space matching kernel. Generalizing this expansion, we are able to introduce nuisance parameters to quantify and remove higher-twist and discretization effects present in the pITD signal - the most notable among these being a short-distance tension of the pITD with the expected DGLAP evolution of the unpolarized pseudo-PDF. Observance and correction of this discrepancy underscores the utility of distillation in such structure studies. Prospects for other collinear distributions is also discussed.

Session I / 19

Lattice QCD Determination of the Bjorken-x Dependence of PDFs at Next-to-next-to-leading Order

Authors: Xiang Gao[1]; Andrew Hanlon[1]; Nikhil Karthik[2]; Swagato Mukherjee[1]; Peter Petreczky[3]; Philipp Scior[3]; Sergey Syritsyn[4]; Yong Zhao[None]

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In this talk, we present a direct calculation of the x-dependence of pion valence PDF with the large-momentum effective theory approach. In this calculation we adopt the most up-to-date theoretical developments on the systematic corrections, which include the hybrid renormalization scheme that rigorously renormalizes the lattice matrix elements at both short and long distances, as well as the two-loop matching kernel that allows for direct calculation of the x-dependence of the PDF

without any model assumption. Therefore, we are able to make predictions for the PDF at $x \in [x_{\min}, x_{\max}]$ where the systematic uncertainties are under control, which is a firm step towards precision-controlled calculation.

Session II / 20

First Lattice QCD Study of Proton Twist-3 GPDs

Authors: Andreas Metz[1]; Jack Dodson[None]; Aurora Scapellato[1]; Fernanda Steffens [2]; Krzystof Cichy[3]; Martha Constantinou[1]; Shohini Bhattacharya[1]

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Calculating the x-dependence of PDFs and GPDs from lattice QCD has become feasible in the last few years due to novel approaches. In the work presented, we employ the quasi-distributions method, which relies on matrix elements of non-local operators, matched to the light-cone distributions using Large Momentum Effective Theory (LaMET). We focus on results for the first-ever lattice QCD calculation of twist-3 GPDs. The calculation is performed using one ensemble of two degenerate light, a strange and a charm quark (Nf =2+1+1) of maximally twisted mass fermions with a clover term leading to a pion mass of 260 MeV.

Session II / 21

x-dependence of transversity GPDs on the lattice

Authors: Aurora Scapellato[None]; Constantia Alexandrou[None]; Fernanda Steffens [1]; Karl Jansen[2]; Krzystof Cichy[3]; Kyriakos Hadjiyiannakou[4]; Martha Constantinou[5]

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In this talk we present results for isovector transversity generalized parton distributions (GPDs) of the proton obtained within lattice QCD. We employ the quasi-distribution formalism, which relies on computations of nonlocal matrix elements of boosted hadron states. Large momentum effective theory (LaMET) is then used to match quasi- to light-cone GPDs.
Results are obtained on an $N_f = 2+1+1$ ensemble of maximally twisted mass fermions, with pion mass $M_\pi = 260$ MeV and lattice spacing $a \simeq 0.093$ fm. The proton is boosted up to 1.67 GeV. Using this setup we disentangle the four transversity GPDs that exist for the proton (H_T, E_T, $\tilde{H}_T$, $\tilde{E}_T$) and extract the x-dependence of the GPDs at zero and nonzero skewness.

Session II / 22

Global QCD Analysis of Pion Parton Distributions Including Lattice QCD Data

Authors: Chris Monahan[1]; Colin Egerer[2]; Patrick Barry[None]; David Richards[2]; Jianwei Qiu[2]; Joseph Karpie[None]; Kostas Orginos[3]; Raza Sufian[None]; Savvas Zafeiropoulos[4]; Wally Melnitchouk[2]; nobuo sato[5]

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For the first time, we perform a fit of pion parton distribution functions (PDFs) to reduced pseudo Ioffe time distributions and current-current correlator "good lattice cross sections" generated from lattice QCD simultaneously with experimental data. We make use of the factorization formulas convoluting the matching coefficients with the valence quark distribution to fit to real components of the lattice QCD data. We discuss the impacts of each of the lattice QCD datasets on the central values and uncertainties of the various JAM PDF sets, as well as quantify the systematic effects associated with the lattice.

Session II / 23

QCD factorization for twist-3 quasi and pseudo-distributions

Authors: Vladimir Braun[None]; Yao Ji[None]; Alexey Vladimirov[1]

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In this talk, I will discuss our recent studies of the twist-3 nucleon parton distribution functions suitable for lattice simulations. The corresponding factorized expressions are derived in terms of the twist-two and twist-three collinear distributions to one-loop accuracy. We present the one-loop matching coefficient functions both in position space, as the factorization theorem for Ioffe-time distributions, and in momentum space, for quasi- and pseudo-distributions.

Session II / 24

Lattice Calculation of the Second Moment of the Pion Light-Cone Distribution Amplitude

Authors: Anthony Grebe[None]; David Lin[1]; Issaku Kanamori[2]; Robert Perry[None]; Santanu Mondal[3]; William Detmold[4]; Yong Zhao[5]

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The pion light-cone distribution amplitude (LCDA) carries information about the momentum distribution of its quarks, which is an important input to various experiments. We present a proof-of-concept lattice calculation of the second Mellin moment of the pion LCDA as the first numerical implementation of the heavy-quark operator product expansion (HOPE) method. The resulting value for the second Mellin moment, determined in quenched QCD at a pion mass of $m_\pi = 550$ MeV at a factorization scale of 2 GeV, is $\langle \xi^2 \rangle = 0.210 \pm 0.013$ (stat.) ± 0.034 (sys.). This result is compatible with those from previous determinations of this quantity.

Session II / 25

Investigation of the fourth moment of the pion light-cone distribution amplitude

Authors: Anthony Grebe[1]; William Detmold[1]; C.-J. David Lin[2]; Issaku Kanamori[3]; Robert Perry[2]; Santanu Mondal[4]; Yong Zhao[5]

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The light-cone distribution amplitude (LCDA) is a key object of interest in a range of high-energy, exclusive processes in QCD. In this talk, we describe the application of the heavy quark operator product expansion (HOPE) method to a preliminary study of the fourth Mellin moment of the pion LCDA. This constitutes the first study of the fourth moment from lattice QCD. We present an exploratory investigation at a pion mass of 560 MeV in the quenched approximation.

Session I / 26

Lattice QCD calculation of the Collins-Soper kernel from quasi TMDPDFs

Authors: Michael Wagman[None]; Phiala Shanahan[None]; Yong Zhao[None]

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I will present a LQCD calculation of the nonperturbative Collins-Soper kernel, which describes the rapidity evolution of quark transverse-momentum-dependent parton distribution functions. The kernel is extracted at transverse momentum scales in the range 400 MeV < qT < 1.7 GeV in a calculation with dynamical fermions and quark masses corresponding to a larger-than-physical pion mass of 538 MeV. It is found that different approaches to extract the Collins-Soper kernel from the same underlying lattice QCD matrix elements yield significantly different results and uncertainty estimates, revealing that power corrections, such as those associated with higher-twist effects, and perturbative matching between quasi and light-cone beam functions, cannot be neglected.