中国格点 QCD 第一届年会

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线上

Book of Abstracts

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What can Lattice QCD provide for Hadron Spectroscopy

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Lattice QCD is one of the most important tool to study hadron physics. The key point by using lattice QCD results to study hadron physics is to transfer lattice QCD spectrum to the observables. The famous Luscher equation provides a powerful method to connect them. We also develop an alternative method, named as Hamiltonian Effective Field Theory (HEFT) method. In this talk we will introduce it and relevant recent researches. Once we have the link between Lattice QCD result and the observables, there are two questions, what we need from the lattice QCD and what can we learn from Lattice QCD? In this talk , I want to make some discussions.

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开幕致辞

session1 / **5**

中国格点量子色动力学的历史、现状和未来

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session1 / **6**

新一代神威超算应用支撑系统

基于最新自主软硬件技术构建的新一代神威超算系统，再一次成为高性能计算领域国之重器的重要代表，为海洋科学、航空航天、生物医药、新能源、新材料、大数据、人工智能等领域提供超强的计算能力及应用服务。报告简要介绍为应对大规模应用的挑战性问题，构建可持续发展的国产高性能计算应用生态，新一代神威超算在应用支撑体系方面做的努力和成效。

session2 / **7**

Recent results from BESIII experiment

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BESIII is an experiment running at tau-charm energy region at the Beijing Electron Positron Collider (BEPCII). Since the first data taking in 2009, BESIII has accumulated the world ' s largest data samples of D and Ds meson decays, 10 billion J/ψ and 2.7 million ψ(3686) events, and about 100 million

events with center-of-mass energy between 4 and 4.9 GeV for studies of nonstandard hadrons and the Λc. In this talk, the most recent results on the exotic charmoniumlike XYZ states, light hadron spectroscopy, the weak decays of the charmed hadrons will be reported. The measurements where lattice QCD calculations are needed will be be emphasized.

session1 / **8**

Electron Ion Collider in China (EicC)

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Lepton scattering is an established ideal tool for studying inner structure of small particles such as nucleons as well as nuclei. As a future high energy nuclear physics project, an Electron-ion collider in China (EicC) has been proposed. It will be constructed based on an upgraded heavy-ion accelerator, High Intensity heavy-ion Accelerator Facility (HIAF) which is currently under construction, together with an additional electron ring. The proposed collider will provide highly polarized electrons (with the polarization ˜80%), protons and Helium-3 (both with the polarization ˜70%), as well as unpolarized ion beams from Carbon to Uranium with viable center of mass energy from 10 to 20 GeV and the luminosity of $(2 \tilde{} 4) \times 10^{33}$ $\mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}$. The main foci of the EicC will be the precision measurements of the structure of proton in the sea quark region, including 3D tomography of nucleon which reveals the QCD dynamics; the partonic structure of nuclei and the parton interaction with the nuclear environment, in particular, the short range correlation of nucleons and the cold nuclear matter effects; the exotic states, especially those with heavy flavor quark contents. In addition, issues fundamental to understanding the origin of mass could be addressed by measurements of heavy quarkonia near-threshold production at the EicC. In order to achieve the above-mentioned physics goals, a hermetical detector system will be constructed with the cutting-edge technology. In this talk, the physics program, detector conceptual design and the project status will be reported.

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TBD

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Bridging lattice QCD to experiments using effective field theory for hadron spectroscopy

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Hadron spectroscopy on the lattice

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This is a brief review of lattice studies on hadron spectroscopy in China. The opportunities and challenges will be discussed also.

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Hadron structure in China

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I will briefly review the history and status of the lattice QCD calculation of the hadron structure in China, and discuss the present plan to reach the next milestone.

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Scientific opportunities and Computing challenges in Hot & Dense Lattice QCD

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Lattice QCD and high intensity frontiers

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面向国产超算的格点 QCD 软件系统前瞻

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Weak Decays of Charmed Baryons from LQCD

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Lattice QCD Calculation of TMD Soft Function Through Large-Momentum Effective Theory

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session4 / **18**

Distribution amplitudes from lattice QCD

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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. Also 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.

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Renormalization and extrapolation strategies for parton physics from lattice QCD

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Lattice calculation powered by factorization theory

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session4 / **21**

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.

session6 / **22**

QCD at finite temperature and density within functional renormalization group approach

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In this talk, I would like to discuss recent progress in studies of QCD at finite temperature and densities within the functional renormalization group (fRG) approaches, e.g., the QCD phase structure, QCD equation of state, baryon number fluctuations, spectral functions, real-time dynamics, etc. The relevant results are compared with those obtained from recent lattice simulations. The fRG is a nonperturbative continuum field theory, which is well suited for computation of QCD thermodynamics. Quantum, thermal and density fluctuations are encoded successively through running of the renormalization group scale in the fRG approach.

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Study the QCD Phase Structure via RHIC Beam Energy Scan

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session6 / **24**

Quarkonia and heavy quark diffusion in the hot gluonic medium

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In this talk I will report our recent lattice calculations on the heavy quark diffusion in the hot medium. The calculations are carried out in the quenched approximation on large, fine, isotropic lattices. The quark masses cover physical charm quark mass, physical bottom quark mass and infinite heavy quark mass.

session6 / **25**

Fluctuations of conserved charges in strong magnetic fields

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We present results on the second-order fluctuations of and correlations among net baryon number, electric charge, and strangeness in (2+1)-flavor lattice QCD in the presence of a background magnetic field. We extended our previous simulations with pion mass m_π =220 MeV [1] to physical pion mass $m_\pi = 140$ MeV. Simulations are performed on $32^3 \times 8$ lattices using the highly improved staggered fermions with different values of lattice spacing corresponding to temperatures ranging from 144 MeV to 166 MeV. The magnetic field strength eB is simulated with 9 different values up to $\sim 40 m_\pi^2$ at each temperature. We discuss the temperature and eB dependences of the second-order fluctuations of and correlations among net baryon number, electric charge, and strangeness. We find that these fluctuations and correlations are substantially affected by the magnetic field at $eB \sim 15 m_\pi^2$, which is around the strength produced in the initial stage of non-central heavy-ion collisions at the LHC

energy. We propose that these fluctuations and correlations could be useful for probing the existence of a magnetic field in heavy-ion collision experiments.

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Chiral properties of (2+1)-flavor QCD in strong magnetic fields at zero temperature

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We have performed (2+1)-flavor QCD lattice simulations using the Highly Improved Staggered Quarks (HISQ) action on $N_\sigma = 32$ and $N_\tau = 96$ lattices. In our lattice simulations the strange quark mass is fixed to its physical quark mass $m_s^{\rm phy}$ and light quark mass is set to $m_s^{\rm phy}/10$ which corresponds to $M_\pi \approx 220$ MeV at zero temperature. We have studied the masses and magnetic polarizabilities of light and strange pseudo-scalar mesons, chiral condensates, decay constants of neutral pion and neutral kaon in the presence of background magnetic fields with eB ranging up to around 3.35 GeV^2 ($\sim 70\ M_\pi^2$) in the vacuum. We find that the masses of neutral pseudo-scalar mesons monotonously decrease and then saturate at a nonzero value as the magnetic field strength grows, while there exists a non-monotonous behavior of charged pion and kaon masses as magnetic field grows. We observe a qB scaling of the up and down quark flavor components of neutral pion mass, neutral pion decay constant as well as the quark chiral condensates in the magnetic field strength window (0.05GeV^2, 3.35 GeV^2). We show that the correction to the Gell-Mann-Oakes-Renner relation involving neutral pion is less than 6\%, and the correction for the relation involving neutral kaon is less than 30\% as eB up to 3.35 GeV^2. The validity of 2-flavor GMOR suggests that neutral pion is still the Goldstone boson, the mass reduction of neutral pion explains the reduction of the critical temperature of chiral symmetry breaking. And we further find that the reconciliation of magnetic catalysis and reduction of pion mass intrinsically lies in the Ward identity. This talk is based on Phys.Rev.D 104 (2021) 1, 014505.

session4 / **27**

Correlated Dirac Eigenvalues and Axial Anomaly in Chiral Symmetric QCD

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In this talk I will present the novel relations between the quark mass derivatives $[\partial^n \rho(\lambda, m_l)/\partial m_l^n]$ of the Dirac eigenvalue spectrum and the $(n+1)$-point correlations among the eigenvalues. Using these relations we present lattice QCD results for $\partial^n \rho(\lambda, m_l)/\partial m_l^n$ ($n = 1, 2, 3$) for m_l corresponding to pion masses $m_\pi = 160 - 55$ MeV, and at a temperature of about 1.6 times the chiral phase transition temperature. Calculations were carried out using (2+1) flavors of highly improved staggered quarks with the physical value of strange quark mass, three lattice spacings $a = 0.12, 0.08, 0.06$˜fm. We find that $\rho(\lambda \to 0, m_l)$ develops a peaked structure. This peaked structure arises due to non-Poisson correlations within the infrared part of the Dirac eigenvalue spectrum, becomes sharper as $a \to 0$, and its amplitude is proportional to m_l^2. We demonstrate that this $\rho(\lambda \to 0, m_l)$ is responsible for the manifestations of axial anomaly in two-point correlation functions of light scalar and pseudoscalar mesons. After continuum and chiral extrapolations we find that axial anomaly remains manifested in two-point correlation functions of scalar and pseudoscalar mesons in the chiral limit. This talk is based on PRL 126 (2021) 082001.

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Lattice calculation of the muon g-2

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Lattice calculation of the K_L and K_S mass difference for physical quark masses

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The two neutral kaon states in nature, the K_L (long-lived) and K_S (short-lived) mesons, are the two time-evolution eigenstates of the $K^0 - \overline{K^0}$ mixing system. The prediction of their mass difference Δm_K based on the standard model is an important goal of lattice QCD. In this talk, I will present the preliminary results from a calculation performed on an ensemble of $64^3 \times 128$ gauge configurations with inverse lattice spacing of 2.36 GeV and physical quark masses. While the statistical error approaches a relatively small size of 9\%, several sources of systematic errors may have more significant effects. In this talk I will also address studies performed on smaller lattices to estimate the systematic errors in our result.

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格点场论研究早期宇宙对称性破缺

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session7 / **31**

Charmonia Decays on the Lattice

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The charmonia decays present an ideal laboratory for testing the interplay between perturbative and nonperturbative QCD. In this talk, I focus on the all-photon decay and radiative decay of charmoina. Adopting a new method proposed recently, we perform the systematic lattice calculations on ηc/χc0→2γ and J/ψ→γηc. By using three Nf=2 twisted mass gauge ensembles with different lattice spacings, we obtain the final decay width for these processes. In the end, more interesting charmonia decays are looked forward.

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Charm meson decay constants from lattice QCD

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K->lnul'+l'-衰变宽度的格点计算

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lattice ensemble generation with clover action

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Quantum Computing Platform for High Energy Physics

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session8 / **36**

Lattice QCD gauge configuration generation at near physical point

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The solve of Dirac equation for light quarks in lattice QCD suffered from the critical mass slowing down problem, which can be solved by the recently developed multigrid method. In this talk, I will discuss the techniques and algorithms in lattice QCD gauge configuration generation, and combine the HMC and multigrid algorithm to speed up the gauge configuration generation at near physical point.

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Machine learning spectral functions in lattice QCD

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We study the inverse problem of reconstructing spectral functions from Euclidean correlators via machine learning. We propose a novel neutral network, sVAE, which is based the variational autoencoder (VAE) and can be naturally applied to study the inverse problem. The prominent feature of the sVAE is that a Shannon-Jaynes entropy term having the ground truth values of spectral functions as prior information is included in the loss function to be minimized. We train the network with general spectral functions produced from a Gaussian mixture model. As a test, we use four different types of correlators generated from physically motivated spectral functions made of one resonance peak, a continuum term and perturbative spectral function obtained using non-relativistic QCD. From the mock data test we find that the sVAE in most cases is comparable to the maximum entrop method (MEM) in the quality of reconstructing spectral functions and even outperforms the MEM in the reconstruction of spectral function from pNQRCD. By applying to temporal correlators in the pseudoscalar channel obtained in the quenched lattice QCD at 0.75 T_c on $128^3 \times 96$ lattices and

$1.5\ T_c$ on $128^3 \times 48$ lattices, we find that the resonance peak of η_c extracted from both the sVAE and MEM has a substantial dependence on the number of points in the temporal direction (N_τ) adopted in the lattice simulation and N_τ larger than 48 is neeeded to resolve the fate of η_c at $1.5\ T_c$.

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Lattice realization of ξ gauge

We perform a lattice implement of ξ gauge, a more general covariant gauge. We will present the performance of our lattice realization in ξ gauge and primary results of gluon propagators and dynamical overlap quark propagators with $\xi \in [0, 0.2]$. We calculate several renormalization constants under ξ gauge configurations and discuss the gauge invariance under the MS-bar scheme through RI/MOM scheme (perturbative region). We hope this implement provides a new choice to check gauge dependency in numerical calculation.

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Propagator generation with Chroma+QUDA for various fermion actions

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We will present how to calculate propagators on Chroma with overlap and HISQ (highly improved staggered quark) valence quark, which are not fully supported on Chroma before. For overlap, we setup the fermion action based on polynomials of hwilson action, create overlap dslash on QUDA, migrate Arnoldi algorithm from gwu-code to solve the eigensystem for deflation, and migrate multishift algorithm to calculate propagators with different mass. For HISQ, we write an interface between Chroma and QUDA to put the inversion on GPU and accelerate the calculation. The multigrid algorithm is also used for the HISQ inversion.

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TBD

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Lattice QCD study of multi-quark states

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session3 / **45**

What can Lattice QCD provide for Hadron Spectroscopy

Corresponding Author: wujiajun@ucas.ac.cn

Lattice QCD is one of the most important tool to study hadron physics. The key point by using lattice QCD results to study hadron physics is to transfer lattice QCD spectrum to the observables. The famous Luscher equation provides a powerful method to connect them. We also develop an alternative method, named as Hamiltonian Effective Field Theory (HEFT) method. In this talk we will introduce it and relevant recent researches. Once we have the link between Lattice QCD result and the observables, there are two questions, what we need from the lattice QCD and what can we learn from Lattice QCD? In this talk , I want to make some discussions.

session3 / **46**

The study of pseudoscalar glueball on Lattice QCD

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session3 / **47**

Finite-volume and finite-tempetature effects in chiral effective field theory

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session3 / **48**

Most charming dibaryon

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A pair of triply charmed baryons, $_{ccccc}$, is studied as an ideal dibaryon system by $(2+1)$-flavor lattice QCD with nearly physical light-quark masses and the relativistic heavy quark action with the physical charm quark mass. The spatial baryon-baryon correlation is related to their scattering parameters on the basis of the HAL QCD method. The $_{cccccc}$ in the $^1S_0$ channel taking into account the Coulomb repulsion with the charge form factor of $_{ccc}$ leads to the scattering length $a_0^C \simeq -19$ fm and the effctive range $r_{\rm eff}^C \simeq 0.45$ fm. The ratio $r_{\rm eff}^C/a_0^C \simeq$–0.024, whose magnitude is considerably smaller than that of the dineutron (-0.149), indicates that $_{cccccc}$ is located in the unitary regime.

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Possibility of Glueball at Physical Point

We perform an exploratory study of glueballs on two RBC/UKQCD gauge ensembles with the $N_f = 2+1$ physical quark masses at two lattice spacings. The statistical uncertainties of the glueball correlation functions are considerably reduced through the cluster decomposition error reduction (CDER) method. The Bethe-Salpeter wave functions are obtained for the scalar, tensor and pseudoscalar glueballs by using the spatially extended glueball operators defined through the gauge potential $A_\mu(x)$ in the Coulomb gauge. These wave functions show similar features of non-relativistic two-gluon systems, and then are used to optimize the signals of the related correlation functions at the early time region and the ground state masses can be extracted precisely thereafter. By the assumptions that the glueball operators defined in terms gauge potentials couple almost exclusively to pure glueball states, the obtained masses are interpreted to be those of the ground state pure gauge glueballs. Our result shows the \red{possibility} of glueball states in the presence of dynamical quarks, even though many systematic uncertainties have not yet be well tackled with.

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Recent progress in the construction of covariant chiral nuclear forces

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session4 / **51**

Valence parton distribution of pion from lattice QCD at physical point

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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.

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Proton momentum and angular momentum decompositions with overlap fermions

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DSEs meet LQCD: foundations of EHM

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The contribution of QCD trace anomaly to hadron mass

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We present the first Lattice QCD calculation of the quark and gluon trace anomaly contributions to the hadron masses, using the overlap fermion on the 2+1 flavor dynamical Domain wall quark ensemble. The result shows that the gluon trace anomaly contributes to most of the nucleon mass, and the contribution in the pion state is smaller than that in others.

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Flavor contents of the vacuum from the Dirac spectrum of overlap fermions

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session7 / **56**

Lattice QCD calculation of the two-photon exchange contribution to the muonic-hydrogen Lamb shift

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The measurement of muonic-hydrogen spectroscopy provides the most precise determination of the proton charge radius, where the two-photon exchange contribution plays an important role in the understanding of μH spectroscopy. We will report a lattice QCD calculation of the two-photon exchange contribution by constructing the proton four-point correlation function.

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Recent development in lattice effective field theory

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Nuclear reactions in harmonic-oscillator traps

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开幕致辞

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Transverse Momentum Dependent PDF Calculation

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session1 / **65**

Challenges in computing partons on lattice

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EIC in China will primarily probe parton physics in a high-energy
proton or nucleus. However, computing partons on lattice
is a difficult task and may take years to get high precisions.
In this talk, I will consider a number of key factors
which one must control to get reliable calculations, which
include renormalization of linear divergences, taking continuum limit, creating large momentum states, and perturbative matching to higher-orders. Some progress
in these areas will be discussed.

session3 / 66

Lorentz invariant 3-body quantization condition in Lattice QCD

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The three-particle quantization condition on the lattice is written down in a manifestly relativistic-invariant form by using a generalization of the non-relativistic effective field theory (NREFT) approach. A partial diagonalization of the quantization condition into the various irreducible representations of the (little groups of the) octahedral group has been carried out both in the center-of-mass frame and in moving frames. Furthermore, producing synthetic data in a toy model, the relativistic invariance is explicitly demonstrated for the three-body bound state spectrum.