

Light Cone 2017 (LC2017)

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Light Cone 2017 (LC2017)
Frontiers in Light Front Hadron Physics : Theory and Experiment
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Book of Abstracts

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Welcome and Opening Remarks

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New results on hard exclusive processes from Jefferson Lab

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Highlights from the CMS experiment

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Future plans of the ATLAS collaboration for the HL- LHC

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Supercomputers and new paradigms of physics

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Quarks, Gluons, and the Origin of Mass

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The Science and Opportunities at the US Electron Ion Collider

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Physics prospects of exotic and conventional bottomoniums at BELLE II

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The Belle II experiment, being constructed at the KEK laboratory in Japan, is a substantial upgrade of the Belle detector. The construction of the SuperKEKB accelerator, which is the upgrade of the KEKB accelerator, has been just completed. It aims to collect 50 times more data than the existing B-Factory samples beginning in 2018.

Belle II is uniquely positioned to study the so-called “XYZ” particles: heavy exotic hadrons consisting of more than three quarks. First discovered by Belle, the number of these particles is in the dozens now, which implies the emergence of a new category within quantum chromodynamics.

This talk will present the capabilities of Belle II to explore exotic and conventional bottomonium physics. There will be a particular focus on the physics reach of the first data, where opportunities exist to make an immediate impact in the field.

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Multiscale Methods in Quantum Field Theory

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We use a basis of Daubechies scaling functions and wavelets to make an exact multi-resolution decomposition of a quantum field theories. The representation has natural resolution and volume truncations. We discuss the use of flow equation methods to decouple scales in volume and resolution truncations of the

theory. Using the example of a free scalar field theory, where different scales are coupled by derivatives in the Hamiltonian, we show that with a natural choice of flow generator that the flow equation evolves the truncated

Hamiltonian to a unitarily equivalent truncated Hamiltonian that is block diagonal on both resolution and energy.

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Azimuthal Spin Asymmetries in SIDIS

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Azimuthal spin asymmetries provide valuable information about the three dimensional structure of proton. According to the factorization theorem, azimuthal asymmetries are related to the transverse momentum dependent (TMDs) distributions which provide information about three dimensional structure as well as spin structure of proton.

In this talk, I will present the results of azimuthal spin asymmetries in semi-inclusive deep inelastic scatterings(SIDIS) in a light front quark-diquark model of the proton. The model predictions are found to be in good agreement with COMPASS and HERMES data.

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Heavy and heavy-light mesons in the Covariant Spectator Theory

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The masses and vertex functions of heavy and heavy-light mesons, described as quark-antiquark bound states, are calculated with the Covariant Spectator Theory (CST). The CST two-body bound-state equation is similar to the Bethe-Salpeter equation, an integral equation formulated in Minkowski space with a kernel of two-particle irreducible Feynman diagrams describing the quark-antiquark interaction, except that the relative-energy loop integration is carried out by taking only the residues of the quark propagator poles into account. Cancellations between the omitted kernel pole contributions make sure that the equation has the correct limit when one quark becomes very heavy, which makes it particularly suitable to describe unequal-mass mesons. We use a kernel with an adjustable mixture of Lorentz scalar+pseudoscalar and vector linear confining interaction, together with a one-gluon-exchange kernel. I will present the results of a series of fits to the heavy and heavy-light meson spectrum, and discuss what conclusions can be drawn from it, especially about the Lorentz structure of the kernel. We also apply the Brodsky-Huang-Lepage prescription to express the CST wave functions for heavy quarkonia in terms of light-front variables. When we compare them to light-front wave functions obtained in the Hamiltonian basis light-front quantization (BLFQ) approach, we find remarkable agreement, even in excited states.

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Wilson lines and webs in higher order QCD

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Wilson lines have a number of uses in non-abelian gauge theories. A topical example in QCD is the description of radiation in the soft or collinear limit, which must often be resummed to all orders in perturbation theory. The relevant functions needed to describe this radiation involve Wilson lines, and new methods are needed to extend such calculations beyond the state of the art.

Correlators involving a pair of Wilson lines are known to exponentiate in terms of special Feynman diagrams called “webs”. I will show how this language can be extended to an arbitrary number of Wilson lines. The generalisation is highly non-trivial, and introduces novel new combinatoric structures (“web mixing matrices”) that are of interest in their own right. I will also summarise recent results obtained from applying this formalism at three-loop order, before discussing open problems and directions for future research.

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Bound state equation for the Nakanishi weight function

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The bound state Bethe-Salpeter amplitude was expressed by Nakanishi using a two-dimensional integral representation, in terms of a smooth weight function g , which carries the detailed dynamical information. A similar, but one-dimensional, integral representation can be obtained for the Light-Front wave function in terms of the same weight function g . By using the generalized Stieltjes transform, we first obtain g in terms of the Light-Front wave function in the complex plane of its arguments. Next, a new integral equation for the Nakanishi weight function g is derived for a bound state case [1]. It has the standard form $g = Ng$, where N is a two-dimensional integral operator, in contrast to previously used equation which contained the integrals in its both parts. We give the prescription for obtaining the kernel N starting with the kernel K of the Bethe-Salpeter equation. The derivation is valid for any kernel given by an irreducible Feynman amplitude.

[1] J. Carbonell, T. Frederico, V.A. Karmanov, Phys. Lett. B, 769, 418 (2017).

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Quark mass functions and pion structure in the Covariant Spectator Theory

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We introduce a covariant approach in Minkowski space for the description of quarks and mesons that exhibits both chiral-symmetry breaking and confinement. Our quark-antiquark interaction kernel is the sum of a one-gluon exchange and a covariant generalization of the linear confining interaction. We assume a Lorentz vector structure for the one-gluon-exchange and a mixed equally-weighted scalar-pseudoscalar structure for the confining part. The kernel preserves the axial- vector Ward-Takahashi identity and our model complies with the Adler zero constraint for π - π -scattering imposed by chiral symmetry.

Using this method, we have calculated the dressed quark mass function in Minkowski space. In order to compare with Euclidean approaches, our mass function is analytically continued to the region of negative four-momenta squared, where it is fitted to the existing lattice QCD data.

As a first application the mass function is used, together with a dressed off-shell quark current that satisfies the vector Ward-Takahashi identity, in the calculation of the pion electromagnetic form factor.

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Relativistic studies of few-body systems using the Bethe-Salpeter approach

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Understanding the hadronic interactions from basic principles is one of the most important challenges in modern nuclear/particle physics.

This task is very difficult and it is therefore important to perform non-perturbative studies of few-body systems using simple models, in order to understand the response of such systems to different contributions to the interaction.

For example, ladder and cross-ladder diagrams for two-body systems, and effective three-body forces in the case of three-body systems.

Furthermore, it is well-known that in the non-relativistic treatment of three-boson systems interacting through a zero-range interaction, the binding energy is unbound from below (Thomas collapse). However, it has been shown [1,2] that in a relativistic treatment this collapse is prevented.

The Bethe-Salpeter equation provides an approach to study few-body systems in the non-perturbative regime. In this contribution we will briefly review some recent results [3,4] computed for two- and three-boson systems using the aforementioned formalism.

For the two-body system we will discuss the response to cross-ladder exchanges in the interaction kernel [3]. Regarding the three-body system having a zero-range interaction we discuss the response of to higher Fock components, and thus effective three-body forces [4]. We present results for systems where two of the particles can form a bound state and in addition for so-called Borromean systems, where no two-body bound state exists. The latter kind of systems was not treated in previous works [1,2] and therefore the true ground state is found for the first time.

[1] T. Frederico, Phys. Lett. B 282 (1992) 409

[2] J. Carbonell and V. A. Karmanov, Phys. Rev. C 67 (2003) 037001

[3] V. Gigante, J.H. Alvarenga Nogueira, E. Ydrefors, C. Gutierrez, V.A. Karmanov and T. Frederico, Phys. Rev. D 95 (2017), 056012.

[4] E. Ydrefors, J.H. Alvarenga Nogueira, V. Gigante, T. Frederico, V.A. Karmanov, Phys.Lett. B770 (2017) 131-137.

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Leading twist GPDs and spin densities in a proton

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We evaluate both chirally even and odd generalized parton distributions(GPDs) in the leading twist in a recently proposed quark-diquark model for the proton where the light-front wavefunctions are constructed from the soft-wall AdS/QCD prediction. The GPDs in transverse impact parameter space give the spin densities for different quark and proton polarizations. For longitudinally polarized proton only chiral even GPDs contribute but for transversely polarized proton both chiral even and

chiral odd GPDs contribute to the spin densities. We present a detail study of the spin densities in this model.

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Minkowski space structure of hadrons

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In this contribution I will review the recent advances in the description of light mesons, in particular the pion, as solutions of the Bethe-Salpeter equation in Minkowski space. The tool to solve the Bethe-Salpeter equation is the Nakanishi integral representation and light-front projection. Results for a “mock” pion light-front wave function based on a massive vector exchange, mimicking the self-energy of the lattice gluon, will be present. Future prospects of this research effort will be discussed.

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Charm production in interactions of antiprotons with proton and nuclei at $\bar{P}ANDA$ facility

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```
\documentclass[12pt]{article}
\usepackage{epsfig}
\setlength{\oddsidemargin}{0.0cm}
\setlength{\evensidemargin}{0.0cm}
\topmargin -1cm
\headsep -0.5cm
\textwidth 16.0cm
\textheight 25cm

\begin{document}
\begin{center}
\Large\bf Charm production in interactions of antiprotons with proton and nuclei
at  $\bar{P}ANDA$  facility
}\\
\vskip 0.1in
{\large\bf R.~Shyam1 and K.~Tsushima2}}
\\
{1 Saha Institute of Nuclear Physics, 1/AF Bidhan Nagar, Kolkata 700064, India}
\\
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}
\end{center}

\bigskip

The $\bar{P}ANDA$ experiment at the upcoming Facility for Antiproton and Ion Research (FAIR) in Heavy ion Research Lab (GSI) at Darmstadt, Germany will study interactions between antiprotons (\bar{p}) and fixed target protons (p) and nuclei (A) in the momentum range of 1.5 - 15 GeV/c. Antiproton induced reactions are a very effective tool to implant strange and charmed baryons in nuclei. $\bar{P}ANDA$ will particularly study charmed hypernuclei which are of great importance for understanding the Charm baryon-nucleon interaction. These studies are intended to address fundamental questions of QCD that lie mostly in the nonperturbative regime

We have investigated the production of charmed baryons and mesons in the antiproton-proton interactions within a fully covariant model that is based on an effective Lagrangian approach. The charmed baryon proceeds via the t -channel D^0 and D^{*0} meson-exchange diagrams, while the charmed meson reactions are described as a sum of the t -channel Λ_c^+ , Σ_c^+ , Σ_c^{++} baryon-exchange diagrams [14,16]. The vertex constants fixed in these studies have been used to calculate the $\bar{D}D$ production in the \bar{p} -nucleus collisions that are expected to explore the properties of the charm hadrons in nuclear medium and provide information about their interactions in the nuclear environment [16]. We have also investigated the production of charm-baryon hypernucleus $^{16}_{\Lambda_c^+}\text{O}$ in the antiproton - ^{16}O collisions. We find that for antiproton beam momenta of interest to the $\bar{P}ANDA$ experiment, the 0° differential cross sections for the formation of $^{16}_{\Lambda_c^+}\text{O}$ hypernuclear states with simple particle-hole configurations, have magnitudes in the range of a few $\mu\text{b/sr}$ [17]. Thus, it is feasible to perform such experiments at the $\bar{P}ANDA$ facility even in the beginning stage of the FAIR.

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Three-dimensional structure functions have been investigated by generalized parton distributions (GPDs), transverse-momentum-dependent parton distribution (TMDs), and generalized distribution amplitudes (GDAs). The GPDs and GDAs are related with other by the s-t crossing of the Mandelstam variables, and they contain spacelike and timelike form factors of the energy-momentum tensor, so that they probe gravitational-interaction sizes of hadrons [1]. Although charge radii of the nucleons are well determined, mass radii have not been measured for any hadrons. We determine the GDAs from cross-section measurements of the hadron-pair production process $\gamma^* \gamma \rightarrow h \bar{h}$ [1]. The GDAs are expressed by a number of parameters and they are determined from pion-pair production data of KEKB. We discuss the dependence on parton-momentum fraction z in the GDAs and also the timelike form factor of the energy-momentum tensor [1]. Our studies should be valuable for probing three-dimensional structure of hadrons, especially for applications to exotic hadron candidates which cannot be used as fixed targets for GPD and TMD measurements [2]. In addition, the results should be related to the gravitational-interaction radius for the pion [1]. The GDA studies are also possible by the two-photon process into a hadron pair by ultra-peripheral collisions at LHC and RHIC. In future, there is a possibility to investigate the GPDs at J-PARC for nucleon tomography [3].

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Dynamical spin effects in the pion

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We take into account dynamical spin effects in the holographic light-front wavefunction of the pion in order to predict the pion decay constant, radius, EM form factor, Distribution Amplitude and Transition form factor. We report a remarkable improvement in the description of all data.

8

Lightfront field theory and intense laser physics

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Intense laser-matter interactions offer not only a novel experimental testing ground for fundamental physics, but also an ideal setting for exploring lightfront field theory.

I will give an overview of the application of lightfront field theory to laser-matter interactions in the relativistic and quantum regime. Topics will include non-perturbative pair production and the physical consequences of lightfront zero modes, non-perturbative methods based on superintegrable lightfront dynamics, Lorentz-invariance violating theories, and higher order processes such as electromagnetic cascades.

I will also present recent experimental results on laser-particle scattering and outline future experimental plans at the Extreme Light Infrastructure facility.

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12

Leading twist TMDs in a light-front quark-diquark model for proton

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Transverse momentum dependent parton distributions (TMDs) encode three dimensional structure as well as angular momentum information of a hadron and hence have attracted a lot of attention in recent time. We present all the twist-2 TMDs for proton in a light-front quark-diquark model (LFQDM) where the light front wave functions are modeled from AdS/QCD prediction. The relations among the TMDs are also studied. The $x - p_\perp^2$ factorization used in phenomenological extraction for TMDs is observed to hold in this model. We present the results for the quark densities and the transverse shape of the proton. The shape of the transversely polarized proton is shown to be non-spherical for nonzero transverse momentum. The scale evolution of both integrated and unintegrated TMDs are also presented. We also calculate the T-odd TMDs incorporating the final state interaction(FSI) into the wave functions. The contribution of FSI comes as a complex phase in the wave functions and produce non-vanishing T-odd TMDs. We present our model result for Sivers functions and Boer-Mulders functions.

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Transverse single spin asymmetries at large Feynman x in the STAR experiment at RHIC

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Large Transverse Single Spin Asymmetries (A_N) for forward rapidity inclusive hadron production have been observed over a wide range of center of mass energies. This large A_N has been described by phenomenological TMD models like Sivers and Collins mechanisms for initial and final state effects respectively, or by higher twist contributions in the initial and final states. It is necessary to go beyond inclusive hadron measurements of A_N to isolate the Sivers contributions, and we need to measure fragments in jets to account for the Collins contributions.

The STAR forward electromagnetic calorimeter, Forward Meson Spectrometer (FMS), measures π^0 and η mesons at high x_F (0.2-0.6) where A_N is known to be large. With the addition of pre-shower and post-shower detectors in 2015-2017, FMS is capable of detecting direct photons and Drell-Yan (DY) pairs and, hence, capable of testing the predicted change in sign of A_N in DY and direct photons compared to semi-inclusive DIS. Observation of large A_N for isolated π^0 is still a puzzle. In this context, we take advantage of the large acceptance of FMS to reconstruct electromagnetic jets. We will show A_N for electromagnetic jets and neutral pions and Collins measurements for π^0 's in jets from $p \uparrow + p \uparrow$ collisions at $\sqrt{s} = 500$ GeV.

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The Schwinger model: operator solutions and a genuine light-front treatment

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We present a review of a few operator solutions of the Schwinger model found in the past along with a new solution obtained within the light-front field theory. In the former results, a few subtle points, related to the residual gauge invariance in the covariant gauge and to the choice of field variables, are identified and an improvement is suggested. Then a summary of the previous light-front attempts is given pointing out certain limitations of that scheme. In the second half of our contribution, we focus on the Schwinger model, formulated in terms of light front (LF) variables and restricted to the covariant (Feynman) gauge. A simple operator solution of the two components of the corresponding Dirac equation is found in terms of the free massless LF fermion field and the LF gauge field. The recently proposed quantization of two-dimensional massless LF fields proved very useful in constructing this operator solution. Axial anomaly is obtained as a consequence of the point-splitting regularization of the fermion current. The Schwinger mechanism and chiral symmetry is studied. Finally, possibilities to derive non-trivial vacuum structure in the LF Schwinger model, based on the residual large gauge transformations, are analyzed.

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Transverse degrees of freedom in QCD: momenta, spins and more

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Light-front quantized quark and gluon states (partons) play a dominant role in high energy scattering processes. The initial state in these processes is a mixed ensemble of partons, while any produced pure partonic state appears as a mixed ensemble in the 3D world of the detector. The transition from collinear hard physics to the 3D structure including partonic transverse momenta is related to confinement and might hint at a more fundamental link between color and spatial degrees of freedom.

Wilson loops, including Wilson lines along light-like directions such as used in the studies of transverse momentum dependent distribution functions (TMDs) might play a role here, establishing a direct link between transverse spatial degrees of freedom and gluonic degrees of freedom. They lead to many peculiarities among them single spin asymmetries in the physics of TMDs but they also unify and simplify our picture for gluons in the low- x domain.

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Nonperturbative Renormalization Approach to Hamiltonian Light-Front Field Theory

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In this talk I will report our recent progress on nonperturbative renormalization scheme in Hamiltonian light-front theory. Our study is based on Basis Light-front Quantization (BLFQ), a nonperturbative method in Hamiltonian formalism and with Fock-sector truncation. So far our study has been focusing on the physical electron system (in $|e\rangle+|e\gamma\rangle$) and the positronium system (in $|e+e\rangle+|e+e\gamma\rangle$). For the physical electron system we adopt the sector-dependent renormalization scheme together with wavefunction rescaling. I will show that the obtained observables such as the form factors and the parton distributions agree with those from perturbation theory. In the positronium system, we extend the sector-dependent renormalization scheme to a basis state-dependent scheme and evaluate the needed counterterms from a series of parallel single electron systems with truncation parameters matched to those in the positronium system. We will compare the resulting mass spectrum and the associated wavefunctions with those from an earlier calculation based on an effective interaction restricted to the leading Fock sector.

33

End Point Model of Exclusive Processes

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The end point model is based on the assumption that exclusive hadronic processes at large momentum transfer get dominant contribution from the kinematic region corresponding to Feynman x approximately equal to one. The reaction proceeds by hard scattering of only one of the quarks while the remaining quarks act as soft spectators. The process involves non-perturbative physics and we are required to model the hadron wave function. However we can extract the x -dependence of the wave function from the form factor data. This x -dependence correctly predicts the observed scaling laws of exclusive processes both at large (fixed) center of mass scattering angle as well as fixed center of mass energy (s). The formalism applies at laboratory energies and also leads to the observed scaling behaviour of F_2/F_1 . The scaling laws do not depend on the detailed modelling of the hadron wave function. The formalism can also be used to make detailed prediction of the magnitude of the cross sections. However these depend on the hadron wave function model as well as the soft spectator quark kernel. We present a detailed calculation of Compton scattering within this framework.

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Resonances in coupled channel scattering from lattice QCD

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Most of the hadrons in nature are not stable under the strong interaction and appear as resonances in the scattering of lighter hadrons. Therefore, the study of resonances (often in coupled-channel scattering) lets us understand the workings of QCD in its low-energy non-perturbative region. This is a challenging field and there have been many advancements in this area using lattice QCD over the last few years. I will discuss how from explicit lattice calculation we can extract properties of these resonances - such as mass, width, decay constant and form factors and will show some recent results.

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Sivers TMD within SCET

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We study the TMDs in SIDIS process within the framework of Soft-collinear effective field theory (SCET). We calculate the factorized spin dependent cross-section for SIDIS and formulate the matrix elements corresponding to the TMDs. We focus on the Sivers TMD resulting when the target is transversely polarized with unpolarized quarks. The matching coefficients at tree and one loop level are calculated.

2

Kaon in the nuclear medium

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Using the light-front kaon wave function based on a Bethe-Salpeter amplitude model for the quark-meson interaction, we study the electromagnetic form factors, decay constants and charge radii of the kaon in nuclear medium within the framework of light-front field theory. The kaon model we adopt is well constrained by previous studies to explain the kaon properties in vacuum.

The above mentioned observables are evaluated for the + component of the electromagnetic current, J_+ , in the Breit frame.

In order to consistently incorporate the constituent up and strange quarks of the kaon immersed in symmetric nuclear matter, we use the Quark-Meson Coupling model, which has been widely applied to various hadronic and nuclear phenomena in a nuclear medium with success.

We predict the in-medium modifications of the kaon electromagnetic form factor, charge radius and weak decay constant in symmetric nuclear matter. Study also the sensitivity of the electromagnetic form factors and charge radius to the model's parameters; namely, the quark masses, μ , m_s , and the regulator mass, m_R . It is found that after a fine tuning of the regulator mass, i.e. $m_R = 0.6$ GeV, the model is suitable to fit the available experimental data within the theoretical uncertainties of kaon in medium

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Higher moments on strangeness fluctuation using finite volume PNJL model

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The strongly interacting matter is supposed to have a rich phase structure at finite temperature and density. While our Universe at present epoch contains a significant fraction of color singlet hadrons, color non-singlet states especially quarks and gluons may have been prevalent in the few microseconds after the Big bang. One of the fundamental goals of the heavy ion collision experiments is to map the QCD phase diagram and to locate the critical end point where the first order phase transition from hadronic state to quark gluon plasma (QGP) phase become continuous. This results in long range correlation and fluctuation at all length scales. The correlation length and the magnitude of the fluctuations of the conserved quantities diverge at the critical point. Since the higher non Gaussian moments such as kurtosis, skewness are much more sensitive to the correlation length, they can provide much better handle in location of CEP. Here we have investigated the 2+1 flavor Polyakov loop extended Nambu—Jona-Lasinio (PNJL) model to study the strangeness susceptibilities which are related to the moments of net-Kaon distributions. We have considered the finite volume system as the location of CEP strongly depends on the finite size of the system. We have studied the kurtosis and skewness which are the ratio of the fourth order to second order and third order to second order susceptibilities. Kurtosis and skewness have been calculated as a function of collision centrality from 7.7, 11.5, 19.6, 27, 39, 62.4 to 200 GeV in Au+Au collision. Our result has been compared with the hadron resonance gas model. Near the critical region the skewness and kurtosis for the strangeness susceptibility show large values and deviate from being constant. We have also studied the higher moments of baryon-strange (BS), baryon-charge (BQ) and charge-strange (QS) correlations with the collision centrality for better understanding of the critical region.

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Z_N symmetry and Confinement-Deconfinement transition in $SU(N)$ +Higgs theory.

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We study Z_N symmetry in $SU(N)$ +Higgs theories. The Z_N symmetry can act only on the gauge fields, the action is not invariant. This leads to explicit breaking of Z_N symmetry. However, we find that the strength of the explicit breaking depends on the parameters of the theory, vanishing in parts of the symmetric phase. According to conventional expectations the symmetry is

restored only in the pure gauge limit. We argue that the symmetry restoration is due to enhancement of the phase space in the continuum limit i.e. when the temporal lattice sites are larger.

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Jet-like azimuthal correlations in p+p and p+A collisions at forward rapidity with STAR

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At very low Bjorken x , parton densities in a nucleon/nucleus reach a point where the gluons are expected to transit to a saturation regime. The saturation scale (Q_s) is defined as the inverse of typical transverse inter-partonic distance and can be expressed as $Q_s \sim (A/x)^{1/3}$. So far no clear experimental observation of the onset of gluon saturation has been made. Observables at forward rapidity at STAR probe gluons at very small x ($.001 < x < .005$) in heavy nuclei where parton saturation is expected. Previous results on di-pion azimuthal correlations in d+Au collisions in STAR showed hints of saturation. The azimuthal correlations of jets produced in hard scatterings are expected to be modified due to multiple gluon scatterings in proton-nuclei collisions. Scanning these correlations as a function of rapidity and the transverse momentum has the potential to yield critical insight into gluon saturation.

During the 2015 RHIC run, STAR recorded data in p+p, p+Al and p+Au collisions at $\sqrt{s} = 200$ GeV, with central calorimeters and the Forward Meson Spectrometer (FMS), which covers a wide acceptance of 2.5 to 4.0 in pseudorapidity over the full azimuth. Jets are reconstructed from these data using electromagnetic energy deposits from the calorimeter depositions using the anti- k_T clustering algorithms. The status of azimuthal jet-like correlations for the data in this unique acceptance will be presented.

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Electron Wigner distributions from light front wave functions

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We study the Wigner distributions for a physical electron, which reveal the multidimensional images of the electron. The physical electron is considered as a composite system of a bare electron and photon. The Wigner distributions for an unpolarized, longitudinally polarized and transversely polarized electron are presented in transverse momentum plane as well as in impact parameter plane. We also evaluate all the leading twist generalized transverse momentum distributions (GTMDs) for electron.

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Transverse momentum distributions in spin-1 diquark model

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In the present work, we have studied the transverse momentum distributions (TMDs) in spin-one diquark model. We have used the overlap representation of light-front wave functions (LFWFs) where the spin-1/2 relativistic composite system consists of spin-1/2 fermion and spin-1 vector boson. The results have been obtained for T-even TMDs ($h_{\{1\}}$ and $h_{\{1T\}}^{\perp}$) in transverse momentum plane for fixed value of longitudinal momentum fraction x .

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Study of Twist-2 GTMDs in scalar-diquark model

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We investigate the Generalized Transverse-Momentum Dependent Distributions (GTMDs) describing the parton structure of hadrons using the light-front scalar-diquark model. In particular, we study the twist-2 GTMDs for scalar (γ^+) diquark and the corresponding Wigner distributions for the unpolarized, longitudinally unpolarized and transversely unpolarized proton. The relation of F_{14} GTMD with orbital angular momentum is also studied.

38

Supersymmetric Properties of Hadron Physics from Light-Front Holography and Superconformal Algebra and other Advances in Light-Front QCD

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A remarkable feature of QCD is that the mass scale which controls color confinement and hadron mass scales does not appear explicitly in the QCD Lagrangian. However, de Alfaro, Fubini, and Furlan have shown that a mass scale κ can appear in the equations of motion without affecting the conformal invariance of the action if one adds a term to the Hamiltonian proportional to the dilatation operator or the special conformal operator. Applying the same procedure to the light-front Hamiltonian leads to a unique confinement potential $\kappa^4 \zeta^2$ for mesons, where ζ is the LF radial variable conjugate to the invariant mass. The same result, including spin terms, is obtained using light-front holography, the duality between the front form and five-dimensional anti-de Sitter space, if one modifies

the action by the dilaton in the fifth dimension z of AdS_5 . One obtains relativistic, Poincaré invariant, light-front quantum mechanical, bound-state wave equations which incorporate quark and gluon confinement and successfully predict many observed spectroscopic and dynamical features of hadron physics, such as form factors and linear Regge trajectories with identical slope in both the radial quantum number and the internal orbital angular momentum. Generalizing this procedure using superconformal algebra, leads to a unified Regge spectroscopy of meson, baryon, and tetraquarks, including remarkable supersymmetric relations between the masses of mesons and baryons of the same parity. One also predicts observables such as hadron structure functions, transverse momentum distributions, and the distribution amplitudes defined from the hadronic light-front wavefunctions. The pion is massless for zero quark mass, consistent with chiral invariance. The analytic behavior of the QCD coupling controlling quark and gluon interactions at large and small distances is also determined. The mass scale κ underlying confinement and hadron masses can be connected to the mass parameter Λ in the QCD running coupling $\alpha_s(Q^2)$ by matching the nonperturbative dynamics to the perturbative QCD regime. The result is an effective coupling defined at all momenta and the determination of a momentum scale which sets the interface between perturbative and nonperturbative hadron dynamics. Applications to jet hadronization at the amplitude level will also be discussed.

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Sivers and $\cos(2\phi)$ asymmetries in J/ψ production in SIDIS process

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Gluon Sivers function (GSF) and Boer-Mulders function (BMF) have been receiving lot of interest both theoretically and experimentally, as they provide the information about the spin nature of the hadron. GSF describes the distribution of unpolarized gluons inside the transversely polarized proton. Gluon version BMF represents the density of linearly polarized gluons inside an unpolarized hadron. However, the information about these functions is not apprehended yet. GSF and BMFs can be extracted by measuring Sivers and $\cos(2\phi)$ asymmetries in ep and pp collision. In order to advance in understanding about these obscure functions, we estimate Sivers and $\cos(2\phi)$ asymmetries in J/ψ production in semi-inclusive deep inelastic (SIDIS) process employing TMD factorization framework. NRQCD based color octet model is adopted for calculation J/ψ production rate. J/ψ production in SIDIS process directly probes the GSF and BMFs. The estimated Sivers asymmetry is negative and is in considerable agreement with COMPASS data at $z = 1$. $\cos(2\phi)$ asymmetry is estimated as a function of p_T and Bjorken variable (x_B).

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SUSY searches at CMS

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Supersymmetry (SUSY) is the most popular model for new physics as it is able to address some of the fundamental drawbacks of the standard model (SM) of particle physics. Among them are the 'hierarchy problem' that deals with a huge gap in the strength of gravitational and electroweak interactions, and absence of suitable candidate for dark matter. For each SM particle, SUSY introduces a partner that differs in spin by half. Since its inception the CMS experiment at the LHC is actively pursuing for these supersymmetric partners. The talk reviews recent results on CMS searches for SUSY signature, based on the pp collision data recorded at 13 TeV, the highest energy ever achieved in the laboratory.

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Transverse Single Spin Asymmetry in J/ψ production

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Transverse Single Spin Asymmetries (TSSAs) in J/ψ production in scattering of low virtuality electrons/unpolarised proton target have been proposed as promising tools to explore the Gluon Sivers Function (GSF). We estimate TSSA in electroproduction of J/ψ for JLab, HERMES, COMPASS, and e-RHIC energies and in hadroproduction of J/ψ for RHIC energies. We present estimates of TSSAs in J/ψ production within generalised parton model (GPM) using recent parametrizations of Gluon Sivers Function and compare results obtained using color singlet model (CSM) and color evaporation model (CEM) of quarkonium production.

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Viscous effects on Heavy Quark Radiative Energy Loss in a QCD Medium

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Jet quenching provides tomographic information of the evolution of the QCD matter formed in the ultra-relativistic heavy ion collisions. Perturbative QCD calculation for the jet quenching requires the informations of both elastic and inelastic scatterings. We study the heavy quark radiative

energy loss in a dynamically screened expanding QCD medium by incorporating the off-equilibrium distribution function in the kinematics. Viscous effects on the inelastic energy loss are explicitly incorporated via viscous corrections to the bosonic and fermionic thermal distribution functions. The non-ideal effect to the many-body interactions are also included through the Hard Thermal Loop technique. The jet energy loss is studied within relativistic viscous hydrodynamic evolution of matter. In the boost invariant longitudinal expansion of the medium, the specific flow direction gives rise to an anisotropy in the QCD plasma. We explore the directional dependence of the radiative energy loss in the expanding viscous QCD plasma. The results have direct implications on the D meson spectra as well as on the nuclear modification factor.

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Ratios of vector and pseudoscalar B meson decay constants in the light cone quark model

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We study the decay constants of pseudoscalar and vector B meson in the framework of light cone quark model (LCQM). We apply the variational method to the relativistic Hamiltonian with the Gaussian-type trial wave function to obtain the values of β (scale parameter). Then with the help of known values of constituent quark masses, we obtain the numerical results for the decay constants f_P and f_V , respectively. We compare our results with the other calculations and the existing experimental results.

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Predictions for Diffractive phi meson production using an AdS/QCD Light front wavefunction

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We predict the rate of diffractive phi meson electro-production using the Impact-parameter dependent Color Glass Condensate dipole model. We use an anti de -Sitter/quantum chromodynamics holographic light front wavefunction. Our predictions are compared to the available HERA data.

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Gluon Wigner distribution in the dressed quark model for different polarization

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We study the Wigner distribution of gluon in light-front dressed quark model using the overlap of light front wave functions (LFWFs). In a dressed quark model, instead of a proton state, we assume the target state as a composite spin 1/2 state of quark dressed with a gluon. This state allows us to calculate the gluon Wigner distribution analytically in term of LFWFs using Hamiltonian perturbation theory. We present our result for different polarization configurations of the gluon in the dressed quark state. At the leading twist, one obtains 16 gluon Wigner distributions. However, we obtain 9 independent gluon Wigner distributions that can be studied. We use an improved numerical technique to remove the cutoff dependence of the Fourier transformed integral over Δ_{\perp} .

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TSSA in low-virtuality leptonproduction of open charm as a probe of the gluon Sivvers function

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We propose the low-virtuality leptonproduction of open charm, $p^{\uparrow}l \rightarrow D^0 + X$, treated here in a generalized parton model framework, as a probe of the gluon Sivvers function

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Higgs boson physics at CMS

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Latest results from the CMS experiment on studies of Higgs boson production are presented. Searches involving 125 GeV Higgs boson using various Standard Model production and decay modes have been performed using proton proton collisions from data accumulated during the LHC Run II with center of mass energy of 13 TeV. Similar dataset have also been used to place constraints on physics beyond the Standard Model involving extended Higgs sectors.

Heavy quarkonium production using improved holographic wave-functions

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Lightfront field theory and intense laser physics

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Hadron Spectra, Scattering Properties and Decays from Basis Light Front Quantization

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Recent developments using Basis Light Front Quantization (BLFQ) [1-3] will be summarized and applications to meson and baryon systems will be presented. We will present results for spectroscopy, form factors, distribution amplitudes and decays. Starting from the heavy quarkonia systems, charmonia and bottomonia, we proceed towards lighter mesons and then to baryons. The Hamiltonian eigenvalue problem is addressed within a holographic basis and with the adoption of (a) a longitudinal confining interaction; (b) finite quark masses, and (c) the one-gluon exchange interaction with running coupling. Comparisons with Lattice QCD and Dyson-Schwinger results, where available, will be presented. Prospects for applications to more complex multi-quark and multi-gluon systems will be outlined. We will also present an update on applications of the time-dependent BLFQ (tBLFQ) approach to non-perturbative scattering [4].

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Soft - collinear effects in threshold and joint resummation

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Perturbative expressions for many QCD observables measured at colliders are plagued by large logarithmic corrections which arise after cancellation of real and virtual contributions. These large logarithmic corrections, which arise either at small Q_T or at partonic threshold can be organized and brought under control through all order resummation. Joint resummation formalism allows simultaneous resummation of threshold and recoil effects.

We consider the effect of the leading soft-collinear terms of the form $i \sum_j^{2j-1} d_{ij} \frac{\ln^j N}{N}$ and estimate the impact of leading soft-collinear effects on joint resummed calculations for prompt photon production.

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Searches for Exotics at CMS

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I will discuss the results of searches for various new physics phenomena in the pp collisions at 13 TeV delivered by LHC and collected with the CMS detector in last couple of years. These searches cover a broad spectrum of beyond standard model physics models. In many cases, these results are the most stringent limits on these new phenomena.

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Highlights from the CMS experiment

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During the LHC Run 2, the CMS experiment has so far recorded ~50 /fb of proton-proton collision data at sqrt(s)=13 TeV. With such a large volume of data-set at an unprecedented energy, CMS has updated most of its new physics searches while the precision on various SM measurements has substantially improved. This presentation would feature most recent results on Higgs boson, Top quark, flavor physics, Heavy Ion, and new physics searches.

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Spin-1 and Perturbative QCD

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The annihilation or production process $e^+ + e^- \rightarrow \rho^+ + \rho^-$ is studied with respect to the universal perturbative QCD (pQCD) predictions. Sub-leading contributions are considered together with the universal leading pQCD amplitudes such that the matrix elements of the ρ -meson electromagnetic current satisfy the constraint from the light-front angular condition. The data from the BaBar collaboration for the time-like ρ -meson form factors at $\sqrt{s} = 10.58$ GeV puts a stringent test to the onset of asymptotic pQCD behaviour. The $e^+ + e^- \rightarrow \rho^+ + \rho^-$ cross-section for s between 60 GeV² and 160 GeV² is predicted where the sub-leading contributions are still considerable.

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Interpolating Quantum Electrodynamics

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The instant form and the front form of relativistic dynamics proposed by Dirac in 1949 can be linked by introducing an interpolating angle. Entwining the fermion propagator interpolation with our previous works of the interpolating helicity spinors[1] and the electromagnetic gauge field interpolation[2], we now complete the interpolation between these two forms of quantum electrodynamics (QED). We exemplify the characteristic difference of the fermion propagator between the instant form dynamics (IFD) and the front form dynamics, or the light-front dynamics (LFD), presenting the whole landscape of both the Compton scattering amplitudes and the two-photon production amplitudes in the pair annihilation of fermion and anti-fermion process which show the frame dependence as well as the interpolating angle dependence.

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Selected Results from ALICE Experiment at LHC

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Properties of nuclear matter at large densities have been investigated by colliding nuclei at progressively increasing energies over the last three decades. The features of strongly interacting matter have been studied systematically in collisions of a wide range of interacting-system sizes. The ALICE experiment at CERN continues to record data in pp collisions and in Pb-Pb collisions at the highest energies achieved in the Large Hadron Collider. The evolution of strongly interacting matter is probed by studying the production of a wide spectrum of hadrons and nuclei and by studying correlations in their production. The effect of system size is investigated by a systematic study of discerning features through their dependence on the measured final state hadron multiplicities. Selected results from pp, p-Pb and Pb-Pb collisions at different centre of mass energies will be presented.

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Study of Boson Stars and Boson Shells

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In this talk I would present some fascinating new results obtained in the gravity theory in general relativity.

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Instant-Form versus Light-Front Quantization of Some Field Theories

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In this talk, I will consider the instant-form and light-front quantization of some field theory models and demonstrate the advantages of the light-front quantization over the instant-form quantization.

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Searches for boosted top quarks at LHC

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Many beyond-Standard-Model (BSM) theories predict massive new particles. The detection of such massive particles at the Large Hadron Collider (LHC) is very challenging. Heavy mass of these particles ensures their dominant decay to top quarks. The top quarks coming from such massive particles are heavily boosted. Thus, the search for boosted tops allows the detection for these particles. We have studied the phenomenology of massive first Kaluza Klein (KK) mode for the Higgs boson and the gluon decaying to top quarks in two classes of bulk Randall Sundrum model. We show that such resonances are within the present reach of LHC.

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Charged compact boson stars in a theory of mass-less scalar field

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In this work we propose to present some new results obtained in a study of the phase diagram of charged compact boson stars in a theory involving a massless complex scalar field with a conical potential coupled to a U(1) gauge field and gravity. In particular, we present the new bifurcation points obtained in the phase diagram of this theory. The theory is seen to contain rich physics in a particular domain of the phase diagram.

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Wormholes In A Theory Of Complex Scalar Phantom Field

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We study the wormholes in a theory involving massive complex scalar phantom field coupled to gravity. We consider a specific model defined by a certain action and a particular metric tensor and appropriate boundary conditions which provide us the desired wormhole solution. We construct the mathematical formalism for our model and obtain the Einstein equation and the matter field equations and discuss the physics of wormholes expected to result from our model.

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The Belle II Experiment

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The Belle II experiment at the asymmetric e^+e^- SuperKEKB collider is a major upgrade of the Belle experiment, which ran at the KEKB collider at the KEK laboratory in Japan. The design luminosity of SuperKEKB is $8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$, 40 times higher than that of KEKB. The expected integrated luminosity of Belle II is 50 ab^{-1} , 50 times higher than that of Belle. The experiment will focus on discoveries of new physics beyond the Standard Model, via high precision measurements of heavy flavor decays and searches for rare signal events. The upgrade to the SuperKEKB collider has been completed and testing of the collider is going on. The detector, electronics, software, and computing systems are all being substantially upgraded. In this talk we present the status of SuperKEKB and Belle II detector construction. The expected sensitivity to new physics of the Belle II data set will be also discussed.

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Equivalence of One Loop expressions in Covariant and Light-Front QED

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We revisit the proof of equivalence of one loop expressions for fermion self-energy and vertex correction in light-front time-ordered perturbation theory (LFTOPT) and Covariant QED at the Feynman diagram level emphasizing the importance of the three-term photon propagator in light-front gauge. We generalize the proof of equivalence for one loop vertex correction diagram which was presented earlier by us only for the $+$ component of Λ^μ .