Furthermore, the radiative decays of the neutral states X(5568)^0 and X(5616)^0 are investigated. The partial width of the X(5568)$^0 \to B_s^{*0}\gamma$ is estimated to be

$$\Gamma(\mathrm{X}(5568)^0 \to \mathrm{B}_s^{*0}\gamma) = 2.7 \sim 4.7\,\mathrm{keV}, \tag{1}$$

The widths of the radiative decay processes for X(5616) are estimated to be

$$\begin{aligned} \Gamma(\mathrm{X}(5616)^0 \to \mathrm{B}_s^{0}\gamma) &= 100 \sim 173\ \mathrm{keV}, \quad (2)\\ \Gamma(\mathrm{X}(5616)^0 \to \mathrm{B}_s^{*0}\gamma) &= 3 \sim 10\ \mathrm{keV}. \quad (3) \end{aligned}$$

We propose to study these states by radiative decay experimentally, which would help us to further understand the observed structure in the $B_s\pi$ invariant mass spectrum by the D0 Collaboration.

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1 - 8 Analysis of the Hidden Bottom Decays of Z_b(10610) and Z_b(10650) via Final State Interaction

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In 2011, the Belle Collaboration reported two new bottomonium-like states, $Z_b^\pm(10610)$ and $Z_b^\pm(10650)$ in the invariant mass spectrum of $\Upsilon(mS)\pi (m=1,2,3)$ and $h_b(nP)\pi (n=1,2)$ of the dipion decays of $\Upsilon(5S)$(Z_b and Z_b' refer to $Z_b(10610)$ and $Z_b(10650)$, respectively.)[1]. The quantum numbers of these bottomonium-like states were determined to be $J^P=1^+$ due to the analysis of charged pion angular distribution. From the observed channels of the Z_b and Z_b', one can find these two bottomonium-like states could not be conventional bottomonia and contain at least four constitute quarks.

Being the candidates of exotic states, the Z_b and Z_b have attracted the interest of theorists. Since the masses of Z_b and Z_b' are close to the $B\bar{B}^*$ and $B^*\bar{B}^*$ thresholds, respectively. It is naturally to consider these two states as the molecules of the $B\bar{B}^*$ and $B^*\bar{B}^*$, respectively. On the other hand, the tetraquark interpretation can not be excluded. The calculation of the spectrum under both the assumptions of hadronic molecules and tetraquark states were carried out in different works[2,3]. Also, the decay information can provide more information of the inner structure of the Z_b and Z_b'. For the transitions between the lower heavy quarkonium, the glue emission and hadronization is one of the most important mechanisms, which could be dealt by using the QCD Multipole-Expansion[4]. However, the investigations on the decays of the higher heavy quarkonium indicate that the final-states interactions play dominant roles in understanding the decay behaviors of the higher heavy quarkonium [5]. Furthermore, the Z_b' states contain at least four constitute quarks, the transitions between the Z_b' states and the bottomonium could occur va quark rearrangement. Such kind of quark rearrangements could phenomenologically be described in hadronic level, which is the same as the final state interactions in methodology.

Along this way, we apply the final state interaction mechanism to study the hidden bottom decays of the Z_b/Z_b'[6]. Our results point out that the final-state interaction plays important roles in interpretation of the branching ratios of the hidden bottom decays of the Z' states. Besides the observed channels of the Z_b/Z_b', the $\eta_b(nS)\rho$, $(n=1,2)$ modes can provide us more information on these two bottomonium-like states. We predict their branching ratios

$$\begin{aligned} \mathcal{B}(Z_b \to \eta_b(1S)\rho) &= (0.88 \sim 5.23)\%,\\ \mathcal{B}(Z_b \to \eta_b(2S)\rho) &= (0.11 \sim 0.43)\%,\\ \mathcal{B}(Z_b' \to \eta_b(1S)\rho) &= (0.49 \sim 8.34)\times 10^{-4},\\ \mathcal{B}(Z_b' \to \eta_b(2S)\rho) &= (0.10 \sim 1.16)\times 10^{-4}, \quad (1) \end{aligned}$$

where the branching ratio of $Z_b \to \eta_b(1S)\rho$ could reach up to 5.23%, which is of the same order of $\mathcal{B}(Z_b \to \Upsilon(2S)\pi)$.

In addition, the radiative transitions of the neutral Z_b/Z_b' to $\eta_b(nS)$, $(n=1,2)$ are also considered

$$\begin{aligned}\mathcal{B}(Z_b\to\eta_b(1S)\gamma) &= (0.43\sim 2.71)\times 10^{-5},\\ \mathcal{B}(Z_b\to\eta_b(2S)\gamma) &= (0.34\sim 1.47)\times 10^{-4},\\ \mathcal{B}(Z_b'\to\eta_b(1S)\gamma) &= (0.78\sim 13.0)\times 10^{-6},\\ \mathcal{B}(Z_b'\to\eta_b(2S)\gamma) &= (0.38\sim 4.26)\times 10^{-5},\end{aligned} \quad (2)$$

which is of order of $10^{-6}\sim 10^{-4}$. With the running of the Belle II in the near future, the predicted branching ratios of $Z_b^{(\prime)}\to\eta_b(mS)\rho/\gamma$, $(m=1,2)$ could be further tested.

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1 - 9 Light-front Approach to Hadron Structure

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Although Quantum chromodynamics (QCD) has been accepted as the fundamental theory for strong interaction, it remains a curious fact and a longstanding puzzle that strong interaction exhibits distinct pictures at different energy regimes: at high energy the particles behave as bound states consisting of quarks and gluons (partons) interacting through the fundamental QCD interactions, whereas at low energy protons and neutrons (nucleons) become the relevant degrees of freedom and they interact via the effective nucleon-nucleon interactions. Understanding the connection between these different pictures will significantly enhance our understanding of strong interaction and answer many fundamental questions such as the origin of the mass and spin of hadrons, the mechanism for confinement of quarks and gluons. The key to these connections lies in the structure of hadrons on the parton level. The major challenge here is that the hadron structure is mostly determined by the nonperturbative domain of QCD. Although enormous progress has been made in understanding QCD in the perturbative domain, in the nonperturbative domain our knowledge is still rather limited. Recently new tools have been continually developed which probe the nonperturbative structure of QCD, for example, hard diffractive reactions, semi-inclusive deep inelastic scattering (SIDIS) and deep virtual Compton scattering (DVCS). The Electron Ion Colliders (EICs) will be the most effective facility for realizing these processes and measuring the pertinent observables characterizing the structure of hadrons. The proposed EIC facilities include eRHIC at the BNL, JLEIC at JLab in USA, LHeC at CERN in Europe and the future EicC in China.

In order to efficiently utilize the experimental facility and interpret data, one needs to develop theoretical approaches linking the QCD theory with experimental data. In view of the recent developments on both the experimental and the theory sides, we propose to explore the hadron structure from the first-principle approach based on light-front quantization[1], which provides an alternative nonperturbative tool to lattice formalism and a direct way to calculate the QCD observables. One of the main advantages of light-front quantization is that by adopting Hamiltonian formalism it provides access to the wavefunction of bound states, which encodes the complete information of hadron structure.

Based on light-front quantization, the Basis Light-front Quantization (BLFQ)[2] has been developed over the last ten years as a numerical nonperturbative approach to quantum field theory. This method combines the advantages of light-front dynamics with modern developments in *ab initio* nuclear structure calculations. The diagonalization of the light-front Hamiltonian in a Fock-space basis yields the mass eigenstates of the system, along with wavefunctions which can then be applied to determine spin structures, electromagnetic form factors and generalized parton distributions (GPDs) of hadrons and other observables. The ultimate goal of BLFQ is to study hadron structure from first-principles of QCD. So far, BLFQ has been successfully applied in QED system such as the physical electron[3] and the strong coupling positronium[4]. Recently, this formalism has been applied to the heavy quarkonium system to investigate the spectroscopy and decay constants which are are comparable to experimental measurements. However, most of the current applications of BLFQ are restricted to the leading Fock sector and