The wavefunctions of stable hadrons that are obtained by solving the Heisenberg problem $H_{LF}^{QCD}|\Psi>=\mathcal{M}^2|\Psi>$ have a real phase. As discussed in Ref. [11], one can distinguish "static" structure functions, the probabilistic distributions computed from the square of the light-front wavefunctions of the target hadron from the "dynamic" structure functions measured in deep inelastic lepton-hadron scattering which include the effects of rescattering associated with the Wilson line. Thus it is an important question whether the final/initial state gluonic interactions responsible for the dynamics of rescattering can be associated in a definite way with the light-front wave function eigensolutions of QCD. The resulting augmented LFWFs provide an important tool for understanding the factorization properties of dynamical hadronic phenomena including single-spin asymmetries and diffraction.

It has been shown that the light-cone gauge condition $A^+=0$ does not fix the gauge of Abelian or non-Abelian gauge fields completely [7]: one has to choose a boundary condition for the transverse component of the gauge potential at spatial infinity: $A_\perp(x^-=\pm\infty)$ [7]. The propagators of the gauge field which define the QCD Light-Front Hamiltonian in the Heisenberg problem are regulated using the principal value prescription. However, a different choice of boundary condition will lead to different properties of the light-front wave function amplitudes. In particular, if we choose a retarded ($A_\perp(x^-=-\infty)=0$) or advanced ($A_\perp(x^-=\infty)=0$) boundary condition, the resulting augmented light-front wave function will contain the necessary phase to generate the nonzero single spin asymmetry in hadronic reactions. We will demonstrate these properties, giving an explicit calculation in light-front time-ordered perturbation theory [2]. The result of our analysis provides the general structure of augmented LFWFs which is easy to apply to phenomenological applications. As an example, we will present results for the three-quark Fock state component of nucleon and the quark-antiquark component of pion at lowest non-trivial order. We can further simplify the result for the pion in terms of the distribution amplitudes. Given these light-front wave function amplitudes results, it is straightforward to calculate the pseudo-time-reversal-odd quark distributions of the nucleon and pion, by applying the overlap formalism derived in [12]. The light-cone gauge with retarded/advanced boundary condition has also been used to investigate the small-x physics [13–16], in particular, to study the evolution and factorization for nucleus-nucleus collisions [16].

The rest of this paper is organized as follows. In Sec. II, we present a general derivation of augmented LFWFs using light-front time-order perturbation theory within a lowest order