Hadron structure within the point form of relativistic quantum mechanics

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This contribution summarizes recent developments in the field of hadron form-factor calculations within constituent-quark models using the point form of relativistic quantum mechanics. The approach we are going to present is rather general and rests on a relativistic multichannel formalism which allows to describe particle production and absorption via vertex interactions that are derived from field theoretical interaction densities. Using a multichannel version of the Bakamjian-Thomas construction we calculate the invariant amplitudes for the physical processes in which the form factors are measured. Since the dynamics of γ, W, or Z^0 exchange is fully taken into account within our formulation, the corresponding 1-particle-exchange amplitudes are, as expected, a contraction of a lepton current with a hadron current times a gauge-boson propagator. Analyzing the covariant structure of the hadron current one finally obtains analytical expressions for the electroweak hadron form factors.

Such a multichannel framework has already been applied to calculate electromagnetic π [1], ρ [2], D and B-meson [3] form factors in the space-like momentum-transfer region under the assumption that quark and antiquark are bound by instantaneous forces. Surprisingly, the results were found to be equivalent with those obtained with a one-body ansatz for the current in a covariant front-form settting [4]. Weak $B \to D$ and $B \to D^*$ transition form factors (for time-like momentum transfers) have also been studied in Ref. [3]. There it has been proved that the electromagnetic and weak form factors reduce to one universal function, the Isgur-Wise function, in the heavy-quark limit $m_Q \to \infty$, confirming that heavy-quark symmetry is respected by this point-form approach. In addition a simple analytical expression for the Isgur-Wise function has been given and its agreement with corresponding front-form calculations has been verified numerically.

In the talk we want to address problems and extensions of this kind of procedure to derive currents and form factors of bound multiparticle systems. A well known problem of relativistic quantum mechanics is connected with cluster separability. In our case this, e.g., leads to spurious dependencies of the electromagnetic hadron current on the electron momenta. This resembles the spurious dependencies on the orientation of the light front that shows up in the covariant front-form approach of Carbonell et al. [4]. We will demonstrate how such spurious contributions are kept under control. Extensions concern mainly dynamical binding forces, which give rise to exchange currents and the introduction of non-valence contributions leading to quark-pair currents. An example for exchange currents will be presented in a separate contribution on pion-cloud effects in the electromagnetic nucleon form factors [5]. Here we will rather concentrate on the discussion of quark-pair currents and illustrate their role by means of a numerical study of semileptonic B decays.

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