experimentally [44].

## 6. SUMMARY AND PERSPECTIVES

In conclusion, we have presented a novel approach to the dynamics of parton-hadron conversion and confinement, based on an effective QCD field theory and a kinetic multi-particle description in real time and complete phase space. Our formulation provides an extension of the well-understood perturbative QCD parton evolution to account for the full space-time history traced from parton cascade development, via cluster formation and decay, all the way to the production of final hadrons. The essential points in our approach may be summarized as follows.

**(i)** We have constructed a scale-dependent Lagrangian that incorporates *both* parton and hadron degrees of freedom. It is manifestly gauge- and Lorentz-invariant, and consistent with the scale and chiral symmetry properties of QCD. The introduction of the scale $L(r)$ determines locally which are the relevant degrees of freedom around a given space-time point $r$.

**(ii)** The formulation recovers QCD with its symmetry properties at short space-time distances, and merges into an effective low-energy description of hadronic degrees of freedom at large distances. In between the two regimes it interpolates as determined by the scale-($L$-)changing dynamics, and results in a transformation from partonic to hadronic degrees of freedom.

**(iii)** The dynamics is described by a set of coupled kinetic equations that derive from the field equations of motion, and yield a real-time description in both position and momentum space, constrained by the uncertainty principle.

As a test application, we have considered the prototype reaction $e^+e^- \to hadrons$ where the fragmentation of parton jets and their hadronization serves as a generic process that can also be imagined as an integral part of more complex reactions. We investigated in detail the specifics of the time evolution of parton shower, cluster formation and hadron production in phase space, which extends the usual QCD evolution techniques that are limited to momentum space and integrated over time. The consistency with experimental data was tested, and we found good agreement with measured hadron spectra. A prospective method