Consistent Effective Description of Nucleonic Resonances in an Unitary Relativistic Field-Theoretic Way (Abstract) [1] [2] [3]

F. Kleefeld

Inst. f. Theor. Physics III, University of Erlangen-Nürnberg, 91058 Erlangen, Germany,
kleefeld@theorie3.physik.uni-erlangen.de,
http://theorie3.physik.uni-erlangen.de/people/kleefeld.html

Abstract. Nowadays there is a lot of evidence that strong interaction (SI) physics at high energies is described by the fundamental non–abelian local gauge theory called Quantum-Chromo Dynamics (QCD). The physical Fock-state vectors are observed to be colour-singlets consisting of (anti-)quarks (Q, $\bar{Q}$) und gluons (g), e.g. $|\,Q\bar{Q}>$, $|\,QQQ>$, $|\,\bar{Q}\bar{Q}\bar{Q}>$, $|\,Q\bar{Q}Q\bar{Q}>$, $|\,QQQQQQ>$, $|\,gg>$, $|\,ggg>$, $|\,Q\bar{Q}gg>$, ... At intermediate and low energies however the theory of SI is based on effective non-local non-renormalizable Lagrangian densities (like in Chiral Pert. Theory (χPT)), which are determined by the dynamics of effective degrees of freedom like (anti-)nucleons $N, \bar{N}$ (N =proton, neutron), (anti-)mesons ϕ (ϕ=π, η, ρ, ...) and eventually exotic states etc.. The Fock-state vectors of such theories are e.g. $|\,N>$, $|\,\bar{N}>$, $|\,\phi>$, $|\,NN>$, $|\,N\bar{N}>$, $|\,N\phi>$, $|\,NN\phi>$, $|\,\phi\phi>$, $|\,\phi\phi\phi>$, ... The connection between QCD and the effective field theories (EFT) of SI is established by a "bosonisation" procedure which is a change from the renormalizable local action of QCD to the non-renomalizable non-local actions of the EFTs; for the state vectors this procedure is equivalent to a change of basis between the infinite dimensional Fock-state basis of QCD to the infinite dimensional Fock-state basis of the EFTs. What do I mean with non-renormalizable? The action of such theories contains infinitely many counter-terms to get the theory finite. Why can we handle - these days - non-renormalizable field-theories? The non-locality of EFTs allows in momentum space low-momentum expansions as seen in χPT. To handle nucleonic degrees of freedom in such EFTs one has to introduce vertex-functions commonly called formfactors (containing cutoffs) which are non-local functions generating the dynamics of an infinity of interaction diagrams in an EFT. These diagrams then can be removed from the action of a non-renormalizable EFT. This procedure ends up in an action with a finite number of interaction terms ("tree-level") with a lot of physics hidden in the functional behaviour of the vertex functions. Furthermore low and intermediate energy physics successfully is described by the use of resonance propagators, i.e. they are treated like "degrees of freedoms", which are seen in the experiment and behave like particles with complex mass which is usually not compatible with the idea of unitarity.

In analogy to the role of vertex-fuctions in non-renormalizable theories and with respect to the infinite dimension of the effective Fock-state basis I present a "toy-model" in which fermionic and bosonic resonances are considered to be "particles", i.e. they consistently are described by (anti-)commuting effective field-operators (containing dynamics of infinitely many quark-gluon or meson-nucleon diagrams) which are comfortably treated by Wick's Theorem in a covariant framework and obey unitarity. Non-trivial implications to couplings of non-local interactions are shown.

[1] Abstract of a talk given at XIV. Int. Sem. on High Energy Probl., 17.-22.8.1998, Dubna
[2] Our Institutes Preprint-No. FAU-TP3-98/11
[3] For more information see also: nucl-th/9806060