Twisted valence quarks and hadron interactions on the lattice

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Hadron-hadron interactions in lattice QCD can be studied, paradoxically, only at finite volumes. This is because *euclidean* correlators with two hadrons are dominated, at large euclidean times, by the state formed by the two hadrons *at rest*. The exponential decay in imaginary time is set by the sum of the two hadron masses and no scattering information can be deduced from the correlator. This observation was formalized in [1]. At finite volumes though, the hadrons are forced to interact and the energy levels depend on the their interaction. Thus, measuring the energy levels, one can deduce information about their interaction [2]. An elegant formula relating the energy levels to the phase shifts was given in [3] and we will call this approach the ``Luscher method".

One inconvenience with the Luscher method is that the phase shifts are obtained only at the discrete values of the eigenstates energies. For small boxes these values are very separated from each other. One can, of course, change the volume of the box and learn about the phase shifts at other energy values but this is, frequently, prohibitively expensive.

In applying this method to the two-nucleon system a related problem arises. The unnaturally large value of their s-wave scattering length, that is, the strength of their interaction, shifts the energy levels far away from their non-interacting values. For box sizes smaller than about 8 fm the energy levels are not in the region described by effective range theory and appear at *negative* values of the energy which, from the point of view of scattering, are unphysical [4]. The large lattice sizes needed to extract effective range parameters values make the prospect of studying nuclear interaction through lattice QCD even more distant.

In [5] it was suggested that the use of twisted boundary conditions for the quarks or, which is the same, simulations done under the presence of a constant background magnetic potential coupled to baryon number, shifts the energy levels in a calculable manner. This allows for an extra handle on the values at which the phase shifts can be determined. This method, however, requires the generation of new gauge configurations at each different value of the background field used. The purpose of this report is to point out that, under some circumstances, the same effect can be obtained by coupling only the valence quarks to the background field, which obviates the need of new gauge configurations generated with a background field. We also discuss how and when this method can be used in meson-baryon and meson-meson systems.

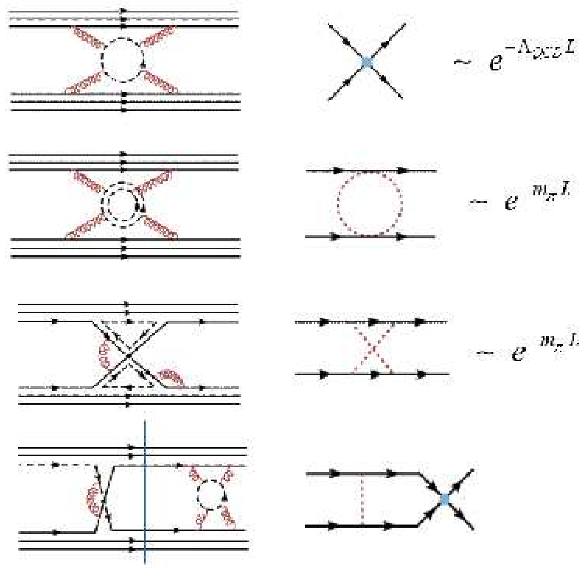

FIG. 1: QCD graphs and their low energy limit showing the exponentially reduced dependence on the sea quark boundary conditions (except for the last diagram where the nucleon can go on-shell, propagate to large distances and "feel" the effect of the boundary conditions.

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