# Light Quarks in the Instanton Vacuum

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One of the most interesting subject in particle physics might be an investigation of structure of hadrons. In order to study the hadron structure, there had been lots of methods or schemes attempted. One has in mind, for instance, the Skyrme model, the $\sigma$ model, the NJL model, the bag model, and so on. Those models are, in some sence unfortunately, effective models, which do not have any connection with fundamental theory as a basement.

In these days one can believe that the Quantum Chromodynamics (QCD) gives a dynamics of quarks who are fundamental elements of hadrons. In QCD the keyword is *color*. Quarks are interacting via gluons, which are gauge-bosons of QCD, and those interactions are characterized by color. However, in the hadron-dynamics, for example, the nuclon interacts with meosns exchanging *flavor*. In that region the flavor is fundamental rather than color.

Light quarks, up-, down- and strange-quarks, have a good symmetry in the hadronic scale, around 1GeV. It is well known that in the light quark limit, $m \to 0$, the light quarks have the zero-energy mode through the instanton vertex, and the zero-energy mode induces an interaction between light quarks, so called 't Hooft interaction. [1] This interaction gives the excahnge of flavor, although the instanton is the classical solution of gauge-field in QCD. We investigate the hadron structures using the QCD effective theory of light quarks, where the vacuum is described as an ensemble of instantons and anti-instantons, and the light quarks interact via the vertex induced by the zero-energy mode.

We have obtained the dynamical chiral symmetry breaking of quarks and found that the procedure of the breaking symmetry does not depend on the number of quark flavor. The Karnel in the Schwinger-Dyson approach to the dynamical quark mass is, at first, different. The difference between the Karnels with different number of flavor is a number of quark loops. However those loops are, in the end, normalized by mass parameter which is fixed by so-called Gap equation. Then the expression of the dynamical quark mass is the same in any flavor group. In Figure 1 we show the mass function of $q^2$, which is common in any flavor group. We are going to extend this calculation to including a non-trivial instanton size distribution effect. The instanton size is one of the collective coordinates of the instanton. As suggested by D.I. Diakonov [2] the non-trivial instanton size distribution might be able to deal with the light quark confinement. We show the mass function with an instanton size distribution, which decreasing power in large size region is $n = -3.1$, in the single flavor system. As one can see easily the mass function is quite sensitive to the instanton size distribution.

We have just constructed the $T$-matrix of quark-quark interaction. The $T$-matrix consists with (flavor-singlet,-octet)$\otimes$(scalar,pseudoscalar) channels, corresponding to pion, $\eta$ and $\sigma$. We are going to use these channels of $T$-matrix in order to calculate, for instantce, pion-pion elastic scattering and loot at the mosonic resonances. That is in progress.

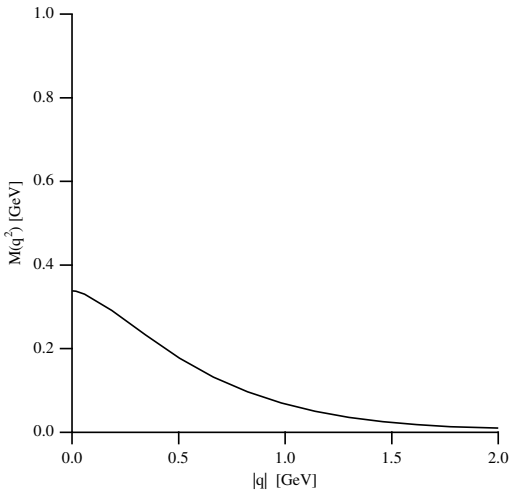


Figure 1

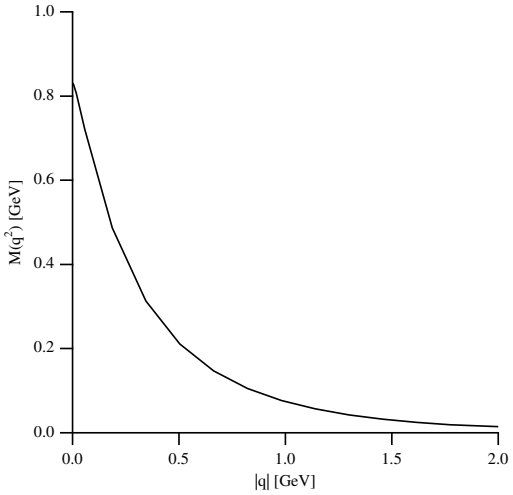


Figure 2

## References

[1] G. 't Hooft, Phys. Rev. **D14** (1976) 3432.
[2] D.I. Diakonov, *et.al.*, Nucl. Phys. **B461** (1996) 539.