Lattice QCD study of the axial charge of N(1535)

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Chiral symmetry is an approximate global symmetry in QCD, the fundamental theory of the strong interaction; this symmetry together with its spontaneous breaking has been one of the key ingredients in the low-energy hadron or nuclear physics. Due to its spontaneous breaking, up and down quarks, which have the current masses of several MeV, acquire the large constituent masses of a few hundreds MeV, and are consequently responsible for about 99% of mass of the nucleon and hence that of our world. One would thus say that chiral condensate $\langle\bar{\psi}\psi\rangle$, the order parameter of the chiral phase transition, plays an essential role in the hadron-mass generation in the light quark sector. On the other hand, chiral symmetry is restored in systems where hard external energy scales such as high-momentum transfer, temperature, baryon density and so on exist, owing to the asymptotic freedom of QCD. Then, are all hadronic modes massless in such systems? Can hadrons be massive even without non-vanishing chiral condensate?

An interesting possibility was suggested some years ago by DeTar and Kunihiro [1], who showed that nucleons can be *massive even without the help of chiral condensate* due to the possible *chirally invariant mass terms*, which give *degenerated* finite masses to the members in the chiral multiplet (a nucleon and its parity partner) even when chiral condensate is set to zero. Interestingly enough, their chiral doublet model has recently become a source of debate as a possible scenario of *observed parity doubling in excited baryons*, although their original work [1] was supposed to be applied to finite-T systems. It is thus an intriguing problem to understand the chiral structure of excited baryons in the light quark sector beyond model considerations. One of the key observables which are sensitive to the chiral structure of the baryon sector is axial charges [1].

We show the first unquenched lattice QCD results [2] of the axial charge $g_A^{N^*N^*}$ of $N^*(1535)$ in Fig. 1. One finds at a glance that they take quite small values, as $g_A^{N^*N^*} \sim \mathcal{O}(0.1)$ and that even the sign is quark-mass dependent. While the wavy behavior might come from the sensitiveness of $g_A^{N^*N^*}$ to quark masses, this behavior may indicate that $g_A^{N^*N^*}$ is rather consistent with zero.

What does the small $g_A^{N^*N^*}$ imply? Can the small $g_A^{N^*N^*}$ be accommodated in the low-energy hadron dynamics? In the chiral doublet model [1, 3], the small $g_A^{N^*N^*}$ is realized when the system is decoupled from the chiral condensate $\langle\bar{\psi}\psi\rangle$. One possible and attempting scenario might be then the chiral restoration scenario in excited hadrons [3]. If it is the case, the origin of mass of $N^*(1535)$ (or excited nucleons) is completely and essentially different from that of the positive-parity ground-state nucleon $N(940)$. While the latter is massive due to the spontaneous chiral symmetry breaking, the former acquires a large mass arising from the chirally symmetric dynamics. The mass difference between $N(940)$ and $N^*(1535)$ is only about 600 MeV and may or may not be large enough to break out from the energy region where the spontaneous chiral symmetry breaking is relevant. The success of this scenario, if correct, implies quite a nontrivial dynamics in excited hadrons.

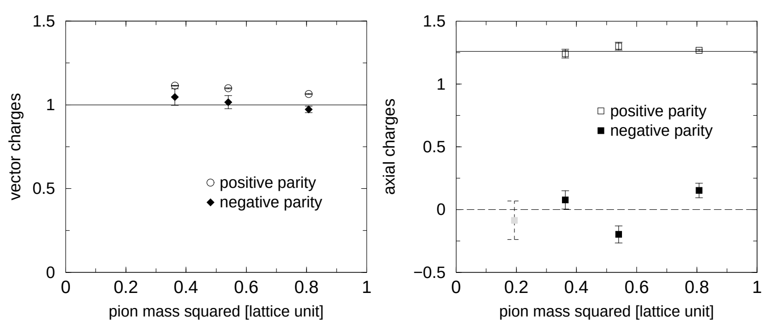

Figure 1: The renormalized vector and axial charges of the positive- and the negative-parity nucleons are plotted as the function of the squared pion mass m_π^2. **Left panel**:The results of the vector charges. The solid line is drawn at $g_V = 1$ for reference. **Right panel**:The results of the axial charges. The solid line is drawn at $g_A = 1.26$ and the dashed line is drawn at $g_A = 0$.

References

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[3] L. Y. Glozman, Phys. Rev. Lett. **99**, 191602 (2007) [arXiv:0706.3288 [hep-ph]].