Chiral Extrapolation of g_A with Explicit $\Delta\,(1232)$ Degrees of Freedom ◇

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Lattice QCD and chiral effective field theories are important, complementary tools to deal with the non-perturbative nature of low-energy QCD and the structure of hadrons. At present there is a gap between the relatively large quark masses accessible to full-QCD lattice simulations and the small quark masses relevant for comparison with physical nucleon properties. Systematic extrapolations guided by low-energy QCD are necessary to bridge this gap. We study a way to merge Chiral Perturbation Theory, which predicts the quark mass dependence of nucleon observables, and lattice simulations, where the quark mass is a tunable parameter.

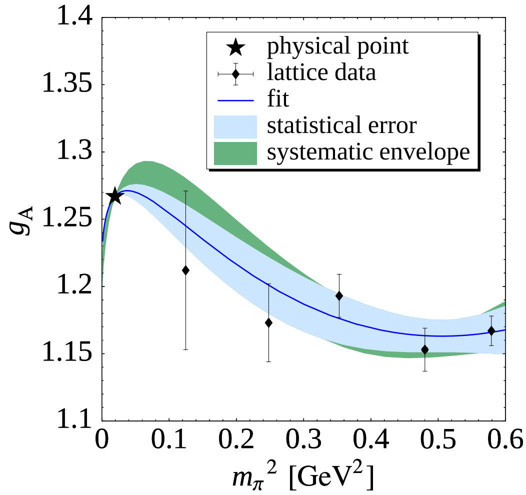
Chiral extrapolations of the axial-vector coupling constant of the nucleon g_A were the subject of our study in [1]. In this paper we compared two different two-flavor, non-relativistic chiral effective field theories at leading-one-loop level: Heavy Baryon Chiral Perturbation Theory, with pions and nucleons as active degrees of freedom, and the so-called Small Scale Expansion, which includes the $\Delta\,(1232)$ explicitly. Treating the $\Delta\,(1232)$ as an explicit degree of freedom turned out to be crucial in order to obtain a consistent extrapolation of available lattice data down to the region of small quark masses.

In ref. [2] we update and extend our previous study about the quark mass (and consequently the pion mass) dependence of g_A in the continuum and infinite volume limit. We first demonstrate that no interpolation between physical point and state-of-the-art lattice results is possible, with parameters consistent with hadron phenomenology, if we use standard chiral perturbation theory with only pions and nucleons up to next-to-leading-one-loop order. This observation holds both for the non-relativistic and infrared regularized, manifestly covariant scheme [3].

The important role played by the $\Delta\,(1232)$ in the physics behind g_A does not come as a surprise. Indeed, unlike the situation with the nucleon mass [4], the Δ-dominance of P-wave pion-nucleon scattering, or equivalently, the strong spin-isospin polarizability of the nucleon, are well-known to have a pronounced impact on matrix elements of the axial current in the nucleon ground state. The Adler-Weisberger sum rule is a prominent example illustrating this connection. In ref. [2] we outline the importance of the $\Delta\,(1232)$ in the Adler-Weisberger sum rule in a simple schematic model calculation.

We have then performed a numerical analysis of the leading-one-loop expression for $g_A(m_\pi)$ in the SSE scheme by comparing this formula with the most recent lattice results by the RBCK [5] and the LHP [6] collaborations. The figure below shows our best fit-curve to the LHPC data including the physical point (star) as a constraint. Statistical errors in the lattice data lead to an uncertainty about the interpolation curve, shown here as the inner error band. The darker "systematic band" quantifies the sensitivity to variations of the input parameters. Remarkably, all parameters in our fits turn out to be consistent with information from low-energy hadron phenomenology.

Our analysis in ref. [2] enables us to estimate systematic errors induced in the Heavy Baryon expansion by integrating out the $\Delta\,(1232)$. We find that they get out of control for pion masses larger that 300 MeV, in agreement with the conclusions of ref. [7].



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