Covariant Electroweak Structure of Light and Strange Baryons

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We have investigated the electromagnetic and axial form factors of all light and strange baryon ground states within the relativistic constituent-quark model. The electromagnetic and axial current operators have been constructed along the spectator model in point-form relativistic dynamics. We have obtained covariant predictions for the electroweak form factors, for momentum transfers up to $Q^2 = 4$ GeV^2, as well as the electric radii, magnetic moments, and axial charges. The theoretical results in general agree very well with the existing phenomenological data. In cases, where no experimental information is yet available, the results are compatible with data from lattice quantum chromodynamics. While our results for the nucleon have already been published in the literature, we show here only the electromagnetic and axial form factors of the Δ. Corresponding results for the strange baryons are due to be published elsewhere.

1 Theory and Framework

Electromagnetic and weak form factors are decisive observables reflecting the finite extension of hadrons. There has been a long-lasting debate about which degrees of freedom govern the structure of baryons at low and intermediate momentum transfers. With the advent of new and more precise experimental data these questions might soon be settled. In addition, lattice-QCD results have by now become more and more helpful for the understanding of various model results.

We have carried out a full program of investigating the electroweak structures of baryons in the framework of the relativistic constituent-quark model (RCQM). Starting out from a relativistically invariant mass operator, yielding a correct description of baryon spectroscopy, we have proceeded to calculate the electromagnetic and axial form factors of all baryon ground states in the point-form approach. The latter has the big advantage of yielding covariant predictions for the observables, i.e. the matrix elements of the current operators sandwiched between the mass-operator eigenstates. In particular, the form factors cannot only be made to fulfill all symmetries of the Poincaré group but also to observe time

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reversal invariance and current conservation, even if a spectator-model construction is employed [1, 2]; in these references, like in the ones given in the next paragraph, one can also find a thorough description of our theoretical framework, while all details of the calculations are contained in ref. [3].

Regarding the nucleon all the relativistic predictions specifically by the RCQM based on Goldstone-boson exchange (GBE) [4, 5] have already been published in the literature. Refs. [6–8] contain the electromagnetic form factors of both the proton and the neutron, together with their electric radii and magnetic moments, as well as the nucleon axial form factors and the nucleon axial charge. Electric radii and magnetic moments of all baryon ground states are published in ref. [9], while in refs. [10, 11] the predictions of the axial charges have been reported for all baryon ground states and also their excitations up to a resonance energy of $E \sim 2$ GeV. In some of these references as well as in refs. [2, 12] comparisons to analogous predictions by the one-gluon-exchange (OGE) RCQM [13] have also been given.

Due to space limitations in this contribution, we have chosen to exemplify our results by considering only the Δ. The corresponding results for all the other strange baryon ground states are in the course of being published in forthcoming papers.

2 Results

Fig. 1 contains the covariant predictions of the GBE [4] and OGE [13] RCQMs for the electromagnetic form factors of the Δ's. Except for the the magnetic moments of the Δ^+ and Δ^{++}, for which experimental data exist (shown in Fig. 1 by the solid triangle and solid square, respectively), we can compare our results only to available lattice-QCD data [14]. From this, obviously, the RCQM predictions are found to be quite reasonable, where in particular the experimentally measured magnetic moments are reproduced within their uncertainties. Contrary to the case of the nucleon [2, 12], also no decisive differences are seen between the GBE and OGE RCQM results for the Δ electromagnetic form factors.

In Fig. 2 we show the covariant RCQM predictions for the Δ axial form factor $G_A^\Delta(Q^2)$. Our definition of this observable is given in ref. [11], where also the values of the Δ axial charges, g_A^Δ=-4.47 and g_A^Δ=-4.30 for the GBE and OGE RCQMs, respectively, were published. All of these results are again found in good agreement with most recent lattice-QCD results [17,18], and in addition the values for the axial charges are nicely compatible with results from chiral perturbation theory [19].

The overall behaviour of our RCQM results for all the other strange baryons turns out to be very similar to what is shown here for the Δ's and has been seen before for the nucleon. Whenever experimental data exist (beyond the nucleon specifically for the electric radii and magnetic moments) the theoretical predictions, especially of the GBE RCQM, are well compatible with them. In other cases, when lattice-QCD results are available, we usually find reasonable agreement too.

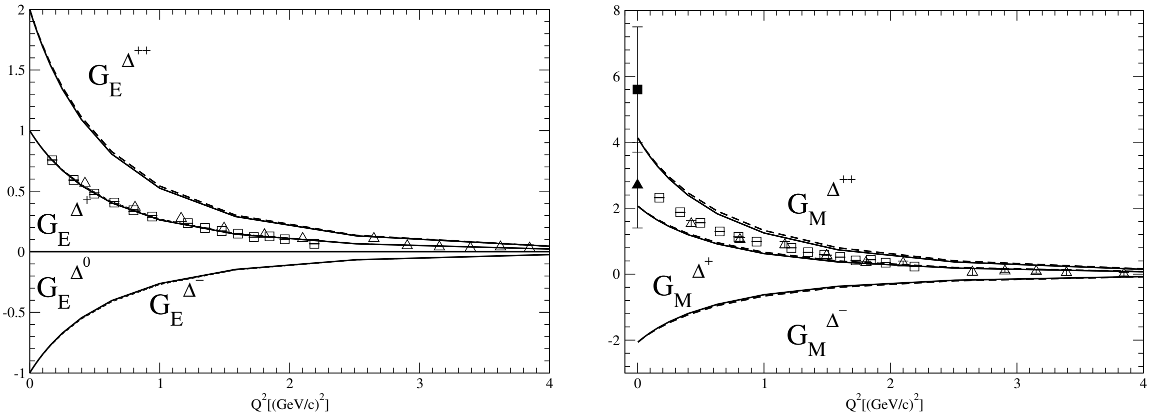

Figure 1: Electric (left panel) and magnetic (right panel) form factors of the Δ's as predicted by the GBE (solid lines) and OGE (dashed lines) RCQMs in comparison to lattice-QCD results for the Δ^+ from ref. [14] (open triangles and open squares) and experimental values for magnetic moments of the Δ^+ (solid triangle) and Δ^{++} (solid square) from refs. [15] and [16], respectively.

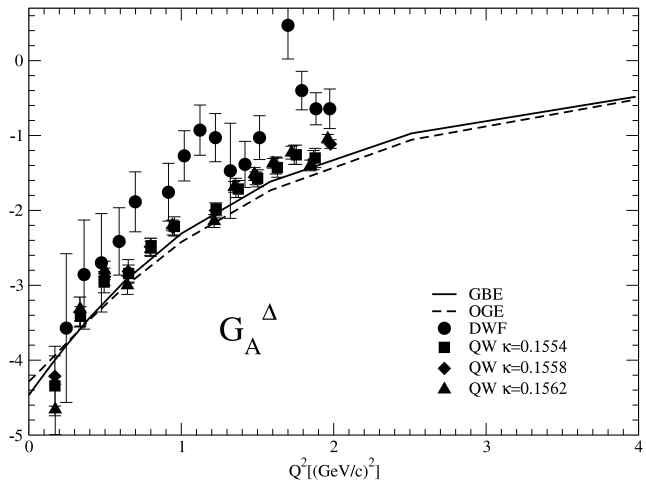

Figure 2: Δ axial form factor G_A^Δ as predicted by the GBE (solid lines) and OGE (dashed lines) RCQMs in comparison to lattice-QCD results from refs. [17,18].

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