The Nucleon-to-Delta(1232) Transition Form Factors in Chiral Perturbation Theory ◇

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Utilizing the methods of chiral effective field theory we present an analysis of the electromagnetic transition of a nucleon to the Delta(1232) resonance in the framework of the non-relativistic "small scale expansion" (SSE) [1] to leading-one-loop order (order ϵ^3). We discuss the momentum dependence of the three complex valued form factors parametrizing this transition, associated with a magnetic dipole, an electric quadrupole and a coulomb quadrupole transition. The diagrams contributing to the transition at the pertinent order are given in figure 3. Updating the findings of [2] we observe important short range contributions to the radius of the quadrupole transition multipoles. Figures 1 an 3 give an overview of our results which are discussed in detail in reference [3]. Furthermore this reference gives an analysis of the quark mass dependence of the form factors, where exciting structures are found (e.g. turning points and a divergence in the chiral limit for the Coulomb form factor)

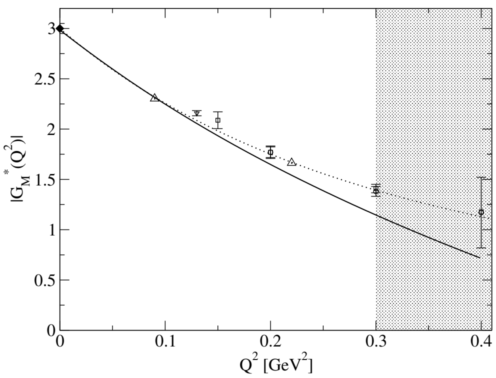

Fig. 1: The $\mathcal{O}(\epsilon^3)$ result for the momentum transfer dependence of the absolute value of the magnetic dipole form factor (solid line). The experimental data (measured in pion-electroproduction on the resonance) up to $Q^2 = 0.2$ GeV^2 are used to extract the three unknown coupling constants of the ChPT calculation which parametrize short distance physics. The dashed line shows the result of the phenomenological parametrization $\left|\mathcal{G}_M(Q^2)\right| = \frac{3}{\left(1+\frac{Q^2}{0.71\,\mathrm{GeV}^2}\right)^2}\exp\left(-0.21\frac{Q^2}{\mathrm{GeV}^2}\right)$. The grey shaded band indicates the area where a low energy expansion like the one applied here may not be trusted anymore.

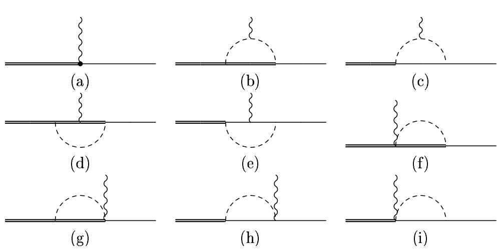

Fig. 2: Diagrams contributing to the nucleon (solid lines) to Delta(1232) (double lines) transition at order ϵ^3. The dashes lines denote pions, the wiggly line the incoming virtual photon.

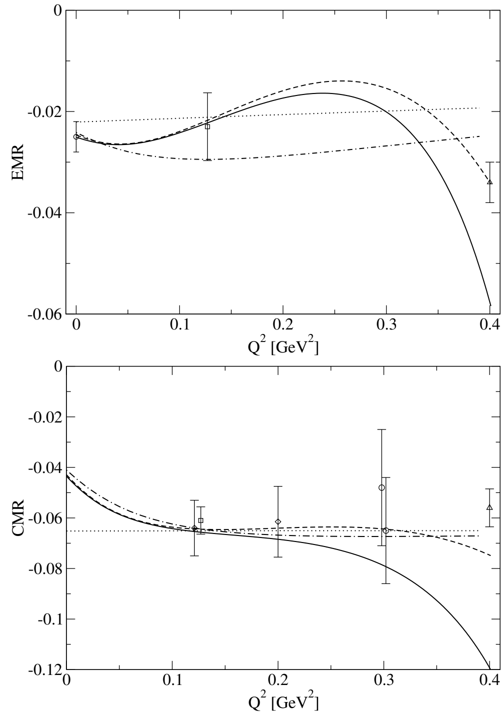

Fig. 3: Upper plot: The result for the ratio of electric quadrupole to magnetic dipole form factor (EMR). The solid line shows the $\mathcal{O}(\epsilon^3)$ SSE result, the dashed line represents our result for $\mathcal{G}_E(Q^2)$ normalized to the phenomenological dipole moment given above. The deviation between both curves indicates the size of the errors due to unknown higher order effects. The dotted and dashed dotted curves represent the results of popular models (MAID and DMT) and demonstrate that we find new and exciting structures in this form factor generated by the pion cloud surrounding the nucleon. Ongoing experiments will show the significance of these structures. Note that only the experimental result at $Q^2 = 0$ is included in our fit; the momentum transfer dependence is a prediction.
Lower plot: The result for the ratio of coulomb quadrupole to magnetic dipole form factor (CMR). The curves are the same as in the plot above. Note that none of the existing experimental data is used as input knowledge, our curve is a pure prediction. The references for the models and experiments can be found in [3].

In conclusion we find that ChPT provides a very satisfying description of the momentum transfer dependence of all three transition form factors. Furthermore, previously unknown new structures in the quadrupole transitions are predicted and can hopefully soon be confirmed by experiments.

References

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