Chiral Extrapolations in Covariant BChPT ◇

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We explore the possibilities of chiral extrapolations using the covariant formulation of chiral effective field theories (EFTs) with baryons. In particular, we study the convergence of the chiral expansion for the examples of the nucleon mass, the anomalous magnetic moment and the isovector Dirac radius of the nucleon. In the calculation of these quantities at next to leading one loop level, i.e. order p^4, we rely on a modified scheme of infrared regularization (IR), which will be discussed in-depth in a forthcoming publication [1].

Calculating an observable in EFT, one has a freedom of choice which part of the *analytic* pieces of the result is considered to arise from loop dynamics and which one corresponds to local operators. Taking advantage of this freedom, the IR-scheme [2] was introduced to overcome the long-known problem of power-counting violations in the $\overline{\text{MS}}$-scheme of covariant BChPT. Compared to standard $\overline{\text{MS}}$-results, IR absorbs an infinite sum of terms analytic in the quark mass into low energy constants (LECs). Therefore problems[1] can arise due to the fact, that in EFT at a certain order only a finite number of LECs is included. Here [1] we propose to only consider those analytic terms as part of short distance physics, which can be absorbed into LECs present at the order of the calculation. After this modification the expanded results still reproduce the HBChPT findings at the order of the calculation.

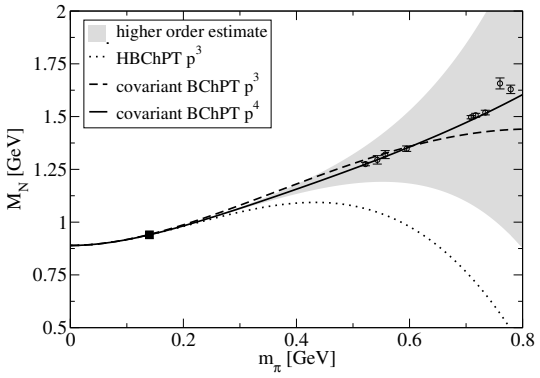

Fig. 1: The quark-mass dependence of the nucleon mass in ChPT. Lattice data from [3].

We apply this proposal to the following observables: the quark mass dependence of the nucleon mass, the anomalous magnetic moment and the isovector Dirac radius of the nucleon. In modified IR these quantities do have the following properties:

1. A successful chiral extrapolation of currently available lattice data to the physical point can be performed with values for the EFT couplings which are consistent with known information from scattering theory. Figs. 1 - 3 show fits of three, two and one parameters respectively to lattice data and the physical point.
2. We do see a clear convergence pattern of the results when going from p^3 to p^4.
3. Fits not including the physical points only lead to marginal changes of the best-fit curves. The shown lattice data and our ChPT calculations together are able to give correct predictions for the physical values of all three observables with small error bars.
4. Comparing the results of the covariant calculations to those of non-relativistic HBChPT, we conclude, that a covariant calculation is crucial in order to describe the quark mass dependencies beyond the physical point.
5. Finally, we estimate higher order effects by adding a typical next order structure and vary its strength within natural size. The impact of these effects is indicated by the gray shaded bands in Figs. 1 - 3.

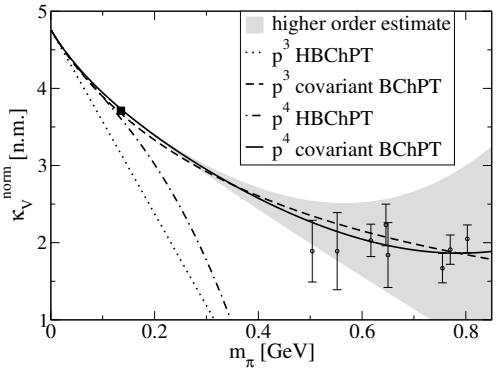

Fig. 2: The quark-mass dependence of the isovector anomalous magnetic moment of the nucleon in ChPT. Lattice data from [4].

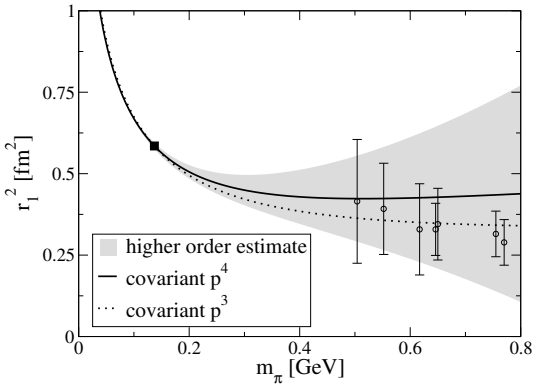

Fig. 3: The quark-mass dependence of the radius of the isovector Dirac form factor of the nucleon. Lattice data from [4].

References

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[3] QCDSF-UKQCD Collaboration (A. Ali Khan *et al.*), Nucl. Phys. **B689** (2004) 175-194
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[1] For example the unexpanded results can display a non-physical scale dependence or show incorrect thresholds and singularities.