

Chiral Extrapolation of Generalized Parton Distribution Functions \diamond

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The concept of Generalized Parton Distributions (GPDs) was first introduced about a decade ago, generating new insights for the understanding of baryon structure in terms of the underlying quark- and gluon degrees of freedom [1].

We make use of the methods of Chiral Effective Field Theory (ChEFT) for the analysis of *moments of nucleon GPDs*, whose interpretation is much easier. *E.g.*, they can be connected to established hadron structure observables like nucleon form factors. Moments of nucleon GPDs are currently also investigated by Lattice QCD, providing simulation results at large quark masses to be extrapolated to the “real world” via ChEFT.

The first moments of nucleon GPDs can be decomposed in terms of so called generalized form factors. In Ref [2] we have calculated the generalized isovector and isoscalar form factors of the nucleon $A_{2,0}^{v,s}(t, m_\pi^2), B_{2,0}^{v,s}(t, m_\pi^2), C_{2,0}^{v,s}(t, m_\pi^2)$ up to $\mathcal{O}(p^2)$ in ChEFT, which corresponds to leading-one-loop order for these observables. The analysis is performed in the covariant framework of Baryon Chiral Perturbation Theory, making use of a variant of Infrared Regularization [3], constructed in such a way that the corresponding non-relativistic $\mathcal{O}(p^2)$ results obtained previously in Heavy Baryon ChPT are exactly reproduced.

The results reveal that up to this order the pion cloud contribution to all the six generalized form factors at finite values of the squared momentum transfer t are very small, the momentum dependence of these structures seems to be dominated by unknown short distance contributions.

Of particular interest is the forward limit case, where $A_{2,0}^v(t \rightarrow 0)$ reduces to the averaged momentum fraction $\langle x \rangle_{u-d}$. Our covariant $\mathcal{O}(p^2)$ BChPT results [2] for this isovector moment provides a smooth chiral extrapolation function between the high values at large quark-masses from Lattice QCD and the lower value known from phenomenology. The required (chiral) curvature according to this analysis does *not* originate from the chiral logarithm of the leading-non-analytic quark-mass dependence of this moment - as had been suspected in the literature for the past few years- but is due to an infinite tower of terms $(m_\pi/M_0)^n$ with well-constrained coefficients.

We have also studied the moments of axial GPDs [4], deriving the chiral expressions for the helicity dependent isovector generalized form factors $\tilde{A}_{2,0}^v(t, m_\pi^2)$ and $\tilde{B}_{2,0}^v(t, m_\pi^2)$. Again, in the limit of vanishing four-momentum transfer the form factor $\tilde{A}_{2,0}^v(t \rightarrow 0)$ is directly connected to the spin dependent analogue $\langle \Delta x \rangle_{u-d}$. Lattice data for this quantity are also available.

To $\mathcal{O}(p^2)$ in BChPT each isovector moment $(\langle x \rangle_{u-d}, \langle \Delta x \rangle_{u-d})$ depends on 3 unknown parameters: 2 couplings (corresponding to the chiral limit value of $\langle x \rangle_{u-d}$ and $\langle \Delta x \rangle_{u-d}$) and one counterterm. As the same couplings contribute in both moments, and because lattice QCD sim-

ulations have already provided data for both of them, we have performed a *combined fit* to minimize the statistical error to get the best extrapolation curves. As one can see from the figure, the results of this procedure are pretty outstanding, given that the values at the physical pion mass were not included in the fit! The chiral curvature in both observables naturally bends down to the phenomenological value for lighter quark masses, leading to a very satisfactory extrapolation curve.

We conclude that combined fits of several observables characterized by a common subset of ChEFT couplings are the winning strategy towards the precise chiral extrapolations of lattice QCD results.

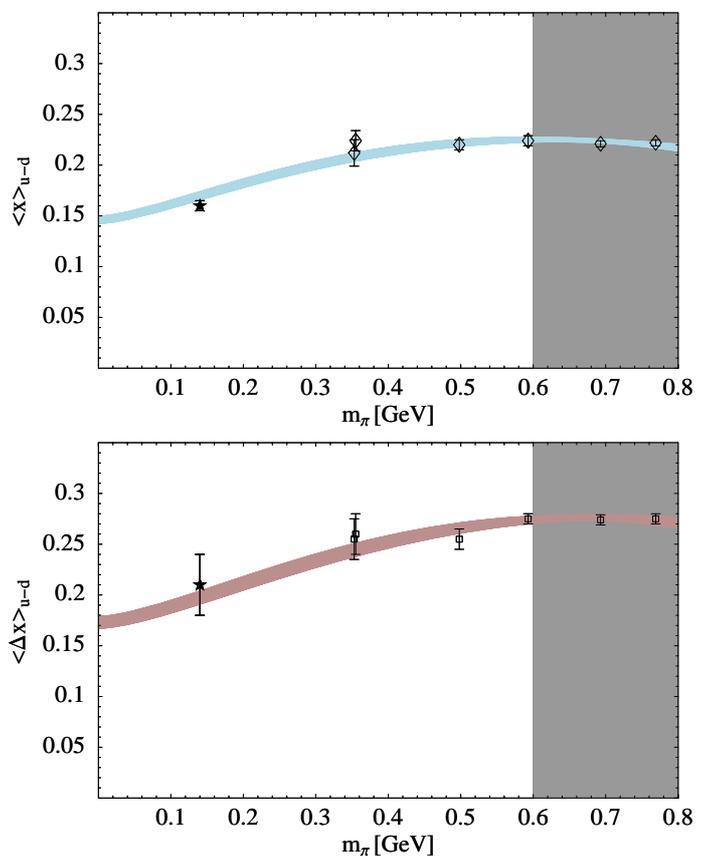


Fig. 1: Combined FIT of the $\mathcal{O}(p^2)$ results [4] to the lattice data of ref [5]. Note that the phenomenological values at physical pion mass were not included in the fit. The bands shown indicate the statistical errors.

References

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\diamond Supported in part by BMBF and EU-I3HP.