1

Extraction of DVCS form factors with uncertainties

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We discuss recent attempts to extract deeply virtual Compton scattering form factors with emphasis on their uncertainties, which turn out to be most reliably provided by method of neural networks.

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1. Introduction

Partonic structure of the nucleon, as encoded by generalized parton distributions (GPDs), is essentially non-perturbative. As such, main avenue to its determination is extraction from experimental data, mostly from measurements of deeply virtual Compton scattering (DVCS), which is a subprocess of electroproduction of real photon off nucleon. Still, more than a decade after the first such fitting attempts[1], we have only partial phenomenological knowledge of GPDs. (Recent review is available in Ref. 2.) Furthermore, although assessment of uncertainties is indispensable part of any quantitative scientific result, authors of global GPD fits usually hesitated to discuss error bands of extracted functions. It was understood that standard simple propagation of experimental uncertainties is not enough. GPD functions depend in a rather unknown manner on three kinematic variables (average and transferred parton longitudinal momentum fractions, x and ξ, and nucleon momentum transfer squared t), which makes the problem very complex from the data-analysis standpoint, and the very choice of fitting parametrization introduces unknown and possibly dominant uncertainty.

2. DVCS subtraction constant

Important role of the choice of the parametrization may be illustrated by recent attempts to determine the subtraction constant $\Delta(t)$ of DVCS dispersion relation,

$$\Re\mathfrak{e}\,\mathcal{H}(\xi,t) = \Delta(t) + \frac{1}{\pi}\text{P.V.}\int_0^1 \mathrm{d}x\left(\frac{1}{\xi-x}-\frac{1}{\xi+x}\right)\Im\mathfrak{m}\,\mathcal{H}(x,t)\,, \tag{1}$$

that is of great phenomenological interest since it is closely related to the pressure in the nucleon[3,4]. Compton form factor (CFF) $\mathcal{H}(\xi,t)$ in Eq. (1) is a convolution of GPD $H(x,\xi,t)$ with the known hard scattering amplitude and is, being dependent on two variables only, more easy extraction target. Still, $\Delta(t)$ resulting from fits to

2

CLAS DVCS data[5], came out with very different uncertainty estimation, depending on whether relatively rigid ansatz[6] for $\mathcal{H}$ was used[7] or it was parametrized by completely flexible neural networks[8], see Fig. 1.
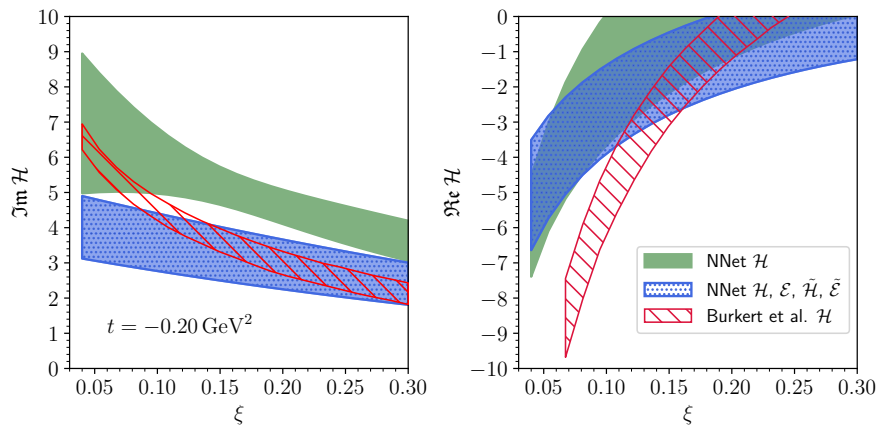

Fig. 1.   Imaginary and real part of CFF $\mathcal{H}$ resulting from fitting different parametrizations to the essentially the same data.

3. Neural network fits

In the lack of general procedure for assessment of systematic uncertainties coming from the choice of fitting ansatz, one convenient approach is using the parametrization by neural networks, which is known *not* to introduce any such systematic error. After the early proof of concept[9], first global neural network determination of CFFs was reported in Ref. 10, demonstrating the power of this approach.

Similarly, in the framework of neural net approach, we attempted to address the question of which of the four leading order CFFs, $\mathcal{H}$, $\mathcal{E}$, $\tilde{\mathcal{H}}$, and $\tilde{\mathcal{E}}$ (or, more accurately, eight sub-CFFs which are the real and imaginary parts of these four), can be reliably extracted from the given data. To this end, we used the stepwise regression method proposed in Ref. 11, where the number of sub-CFFs is gradually increased and all combinations are tried, until there is no statistically significant improvement in the description of the data. Representative subset of global DVCS data was used, with various beam and target, spin and charge asymmetries measured by HERMES[12–14], and helicity independent and dependent cross-sections measured by Hall A and CLAS JLab collaborations[5,15], where JLab data was Fourier-transformed, so that we fitted to the total of 128 harmonics.

Results, displayed on Figs. 2 and 3, show that from the present data only $\mathfrak{Im}\,\mathcal{H}$, $\mathfrak{Im}\,\tilde{\mathcal{H}}$, and $\mathfrak{Re}\,\mathcal{E}$ can be reliably extracted, with maybe some ambiguous hints of $\mathfrak{Re}\,\mathcal{H}$ or $\mathfrak{Im}\,\mathcal{E}$. This is similar to the conclusions of Ref. 11, which used method of local fits (which is also resistant to the problem of choice of the ansatz function).
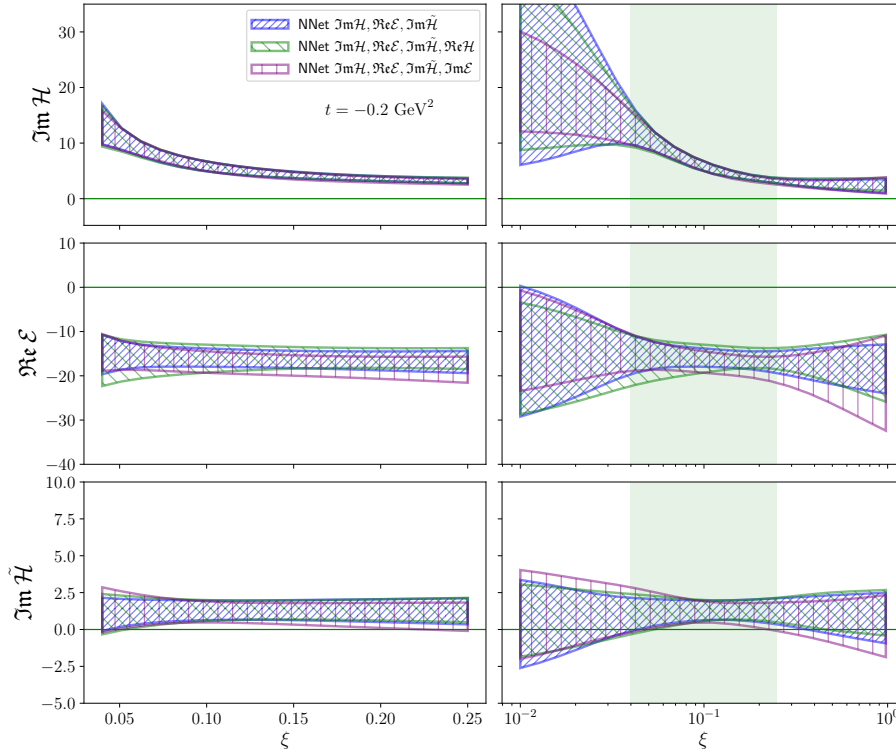
Fig. 2.   Neural network extraction of dominant CFFs from DVCS data. Results for various sets of CFFs are consistent in the data region (left) and also when extrapolated outside of the data region (right). Dispersion relation constraints were *not* used.

4. Conclusion

How to reliably determine uncertainties of GPD or CFF functions extracted by fitting of ansatz function is an important open question for this area of research. At the moment, the best confidence is provided by the method of neural networks.

Acknowledgments

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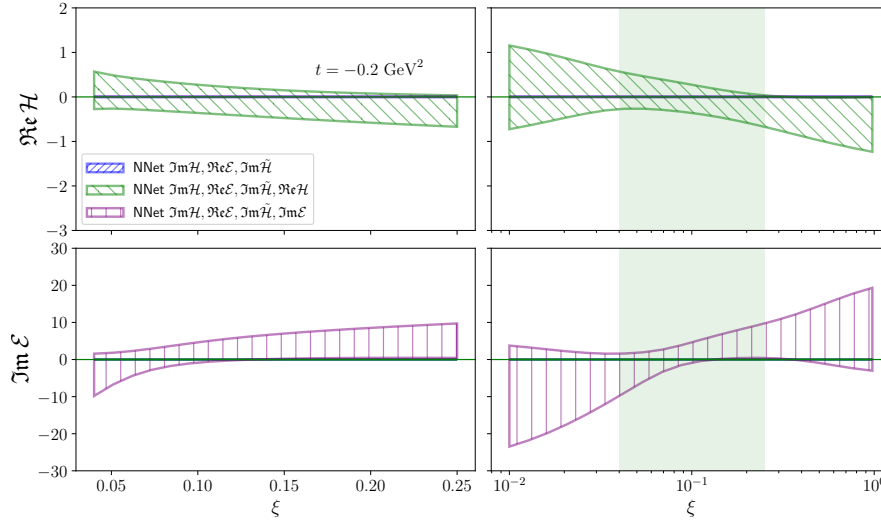
4

Fig. 3.   Extracted $\mathfrak{Re}\,\mathcal{H}$ or $\mathfrak{Im}\,\mathcal{E}$ are mostly consistent with zero, but their addition to the model improves description of the data from $\chi^2/\text{npts} = 103.1/128$ to $97.4/128$ or $96.4/128$, respectively.

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