Reply to "Comment on 'Nucleon Elastic Form Factors and Local Duality' "

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Recently, we extracted [Phys. Rev. D **62**, 073008 (2000)] the proton magnetic form factor from duality-averaging purely inelastic nucleon resonance data. The point stressed by Simula is that this extraction at larger values of momentum transfer is dominated by an unconstrained kinematic region. We will show at which momentum transfers this point is relevant, and argue the need for additional precise nucleon resonance data.

In [1], we presented a newly-obtained set of precision inclusive $H(e,e')$ nucleon resonance data, spanning the four-momentum transfer squared, Q^2, range of 0.3-5.0 (GeV/c)^2. Although at disparate kinematics in both Q^2 and invariant mass squared W^2, these data appear to oscillate around one global scaling curve if presented as a function of the Nachtmann kinematic variable ξ (= $2x/(1+\sqrt{1+4M^2x^2/Q^2})$ [2], the latter including the effect of target-mass corrections to the Bjorken scaling variable x. A parameterization was given of the empirical global scaling curve to which the nucleon resonance data seem to "average". In addition, it was investigated in [3] to what extent the inclusive nucleon resonance data constrain the proton elastic magnetic form factor, assuming a concept known as parton-hadron duality. Previously, duality-based form factor extractions relied solely on deep inelastic data [4] or on older, less precise, nucleon resonance data [5].

A duality-based extraction of the proton magnetic form factor relates this elastic form factor to the integral of the inelastic structure function F_2 from pion threshold to the kinematical limit (unity for $Q > M$, with M the proton mass), multiplied by some kinematic quantities as, e.g., given in [5,3]. Thus, by definition, extraction of a higher and higher Q^2 proton magnetic form factor from duality arguments will depend on a smaller and smaller region of large ξ. Our newly-obtained nucleon resonance region data, in combination with previous SLAC data [6], constrain the empirical parameterization of the inelastic scaling curve up to $\xi = 0.86$, as rightfully mentioned by Simula [7]. As this is a parameterization of data, with a form chosen to be similar to that used in a global fit of deep inelastic data from the New Muon Collaboration (NMC) [8], it is not strange that the parametrization is not reliable beyond $\xi = 0.86$. Obviously, one has to be careful in extrapolating such empirical parameterizations beyond their region of validity.

Thus, within this approach, moments of the structure function F_2, or, equivalently, a duality-based extraction of the proton magnetic form factor, will not be trustworthy if the contribution from the region $\xi \geq 0.86$ is too large. We show in Fig. 1 the relative contribution to the Nachtmann moments of the region beyond $\xi = 0.86$ with respect to the region from pion threshold to the kinematical limit [4], for $n = 2$ (solid), 6 (dashed), and 10 (dot-dashed), given both our parameterization (thick lines) and the parameterization of Simula [7], the latter modified to better agree with constituent counting rules. At $Q^2 \approx 6$ (GeV/c)^2, ξ belonging to threshold pion production gets larger than 0.86. Above this value, the *full* integrand is given by the region beyond which our parameterization is valid.

Similarly, one can argue that if the contribution from the region beyond $\xi = 0.86$ becomes large (e.g., $> 30\%$), a duality-based extraction of the proton magnetic form factor is not reliable. As higher n moments of the F_2 structure function get weighed with additional powers of ξ^{n-2}, conclusions are more affected by the large ξ region. We have for this reason purposefully omitted the use of higher moments in [1,3].

In Fig. 2, a rectified version of the duality-based extraction of the proton magnetic form factor is given, up to a momentum transfer at which we feel confident it is reasonably constrained by precise nucleon resonance data. Fig. 2 is identical to Fig. 2 of [3], but duality-extracted data are only shown up to $Q^2 \approx 4$ (GeV/c)^2. We note that our extraction is closer to the actual data than previously thought using fits of parton distribution functions as the nucleon resonance F_2 data are, at higher ξ, definitely higher than predicted by standard CTEQ [10] or MRS [11] fits, and even slightly higher than the NMC fit [8]. This was highlighted in Fig. 2 of [1], and can similarly be witnessed from older nucleon resonance data of less precision as compared to the GRV [12] fit, as also can easily be verified in Fig. 1 of [5].

We would like to use this opportunity to emphasize the need for additional, high-precision, inclusive nucleon resonance data at higher Q^2 (and thus higher ξ) than presented in [1]. Simula [7] constructs pseudo-data representing the average strength in the nucleon resonance region using an old SLAC parameterization [13]. We first note that only a paucity of $H(e,e')$ nucleon resonance data exists for $Q^2 > 8$ (GeV/c)^2. Furthermore, questions have been raised regarding the treatment of radiative corrections and normalizations concerning the existing high-Q^2 SLAC data obtained in the 1970's, e.g., radiative correction procedures did not have access to reasonable models and muon, tau, and quark loops were not included [14]. The latter questions should be especially prominent in the nucleon resonance region. Lastly, as most of this existing data is obtained at rather large electron scattering angles, one needs to make a guess on the longitudinal/transverse character of this data.

It is of great importance to expand the high-precision nucleon resonance data set, including a verification of its longitudinal/transverse character, to values of $\xi \geq 0.8$. This would allow for a quantitative verification of duality between various nucleon resonance regions and deep inelastic regions, similar as has been done for $\xi \leq 0.8$ in [1]. In addition, if duality is quantitatively confirmed, this would allow for a precise verification of our knowledge of large-x parton distribution functions.

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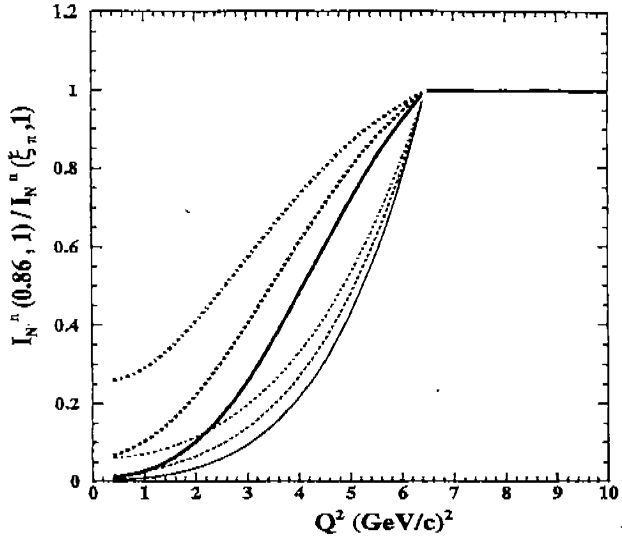

FIG. 1. The relative contribution to the Nachtmann moments of the region above $\xi = 0.86$ with respect to the total integral from pion threshold to the kinematical limit constraining the proton magnetic form factor extraction. Thick lines are for the parameterization given by [3], thin lines are for the parameterization given by [7], for $n = 2$ (solid), $n = 6$ (dashed), and $n = 10$ (dot-dashed), respectively. At $Q^2 \approx 6$ (GeV/c)^2, ξ for pion threshold becomes larger than 0.86.

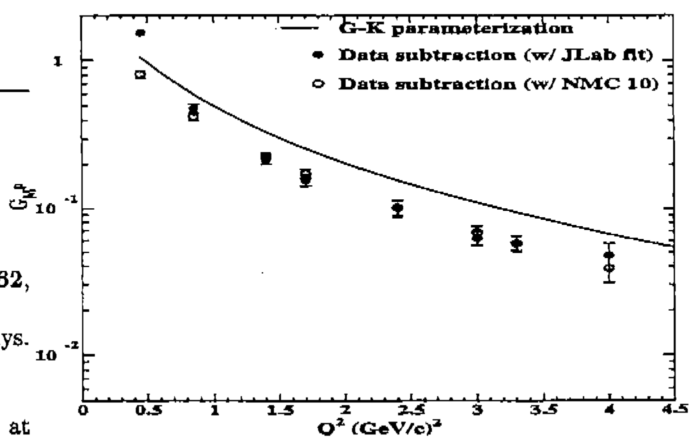

FIG. 2. The proton magnetic form factor extracted from the inelastic data using duality assumptions as described in the text. The extracted data are compared to the model curve of [9], which agrees well with the global data set in this range of Q^2. A similar extraction of the proton magnetic form factor at higher Q^2 requires precise inelastic data at higher Q^2 than presently available.

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