Theory of two-pion photo- and electroproduction off the nucleon

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A field-theoretical description of the photoproduction of two pions off the nucleon is presented that applies to real as well as virtual photons in the one-photon approximation. The Lorentz-covariant theory is complete at the level of all explicit three-body mechanisms of dressed interacting hadrons. The full three-body reaction dynamics of the interacting $\pi\pi N$ system is accounted for by the Faddeev-type ordering structure of the Alt-Grassberger-Sandhas equations. The formulation is valid for hadronic two-point and three-point functions dressed by arbitrary internal mechanisms — even those of the self-consistent nonlinear Dyson-Schwinger type — provided all associated electromagnetic currents are constructed to satisfy their respective (generalized) Ward-Takahashi identities. It is shown that coupling the photon to the Faddeev structure of the underlying hadronic two-pion production mechanisms results in a natural expansion of the full two-pion photoproduction current $M_{\pi\pi}^{\mu}$ in terms of multiple loops involving two-body subsystem scattering amplitudes of the $\pi\pi N$ system that preserves gauge invariance as a matter of course order by order in the number of loops. A closed-form expression is presented for the entire gauge-invariant current $M_{\pi\pi}^{\mu}$ with complete three-body dynamics. Individually gauge-invariant truncations of the full dynamics most relevant for practical applications at the no-loop, one-loop, and two-loop levels are discussed in detail. A brief descriptions is given for how to go beyond the one-photon approximation.

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