COMMENTS

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Dependence of the ratio of electric to magnetic $\Delta N\gamma$ couplings on the Δ^+ mass in single-pion photoproduction

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We investigate the role of the Δ^+ mass and the magnetic dipole coupling parameters in the extraction of the ratio of electric quadrupole to magnetic dipole amplitudes (EMR) in the $\Delta^+ \to p\gamma$ transition. We show that existing data on single-pion photoproduction do not allow as wide a range ($\pm 5\%$) of values for the EMR as concluded in a recent paper by Slaughter and Oneda [Phys. Rev. D **49**, 323 (1994)].

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Small electric quadrupole components in the $N \to \Delta$ transition arise from spin-dependent quark forces, and their sensitivity to models of baryon structure has made them of crucial importance and the focus of considerable attention. In a recent article, Slaughter and Oneda (SO) [1] have reported a relativistic, nonperturbative calculation of the $\Delta^+ \to p\gamma$ photon-decay helicity amplitudes, $A_{1/2}$ and $A_{3/2}$, and of the *electromagnetic ratio* (EMR) of electric quadrupole to magnetic dipole $\Delta N\gamma$ couplings, $\text{EMR} = -(G_E/G_M)_{q^2=0}$. These authors reexpressed the EMR as a function of the Δ^+ mass and the magnetic coupling, $G_M(q^2 = 0)$. They reported a large sensitivity to these parameters and asserted that "current experimental data suffice only to fix the EMR in the range $\pm 5\%$," due to the significant spread in M_{Δ^+} and $G_M(0)$ that is encountered in the literature. In their work, SO did not compute any measured physical quantities in order to constrain their calculations with existing data.

The main objective of this Comment is to contest the conclusion of SO regarding the range of values that the EMR can assume in view of existing data on single-pion photoproduction, and to clarify the role of the M_{Δ^+} and $G_M(0)$ parameters in the extraction of the EMR.

In the vicinity of an isolated resonance the scattering amplitude takes the form $f(E) = e^{i\delta}\sin\delta \approx (\Gamma/2)/(M - E - i\Gamma/2)$. The two mass parameters that can be associated with such a resonance are the energy at which the amplitude becomes purely imaginary ($\delta = \pi/2$) and the real part of the pole position in the complex-energy plane, $E = M - i\Gamma/2$. These two are identical only for a pure scattering state. For the Δ^+ excited in πN scattering, nonresonant Born terms and the inelastic branch to the γN channel significantly modify the simple Breit-Wigner form. A variety of models have been fitted to pion scattering and photoproduction data. Although these have yielded a range of *resonance energies*, the mass associated with the complex pole has remained relatively stable [2–4]. (This is to be expected since the addition of the small Born and inelastic terms can easily shift the energy where the real part of the amplitude crosses zero, but will have very little effect on the complex energy where the amplitude becomes infinite. Viewing the Δ^+ as a particle, it is the pole position that provides the best representation of its mass.) Nonetheless, the value of the *resonance energy* in a particular model is not terribly important, so long as the model is capable of providing a good representation of the data.

Another potential source of model dependence enters the extraction of the EMR through the decomposition of the pion photoproduction amplitudes into resonant and background components. This decomposition is not unique, and three prescriptions have recently been studied by Davidson, Mukhopadhyay, and Wittman (DMW) [5]. In the first, an adaptation of Olsson's work [4], the full and background parts of the $T_{(\gamma,\pi)}$ matrix are made separately unitary. The mass parameter in this description is the pole energy, M_{Δ^+}=1217 MeV in Olsson's model. In the second DMW technique, a K-matrix method, the decomposition is made in terms of K-matrix elements, and the natural mass parameter here is the energy where the P_{33} phase goes through 90°, M_{Δ^+}=1232 MeV. In the third DMW method, inspired by Noelle's work [6], the resonance+background decomposition is made in the pion phase shifts and carried through to photoproduction via unitarity. Here, the mass parameter used by DMW is M_{Δ^+}=1250 MeV.

The most $E2$-sensitive observable is the ratio of $p(\vec{\gamma},\pi^0)$ cross sections, $d\sigma_\parallel/d\sigma_\perp$, measured with the incident photon's electric vector parallel and perpendicular to the reaction plane, respectively [7]. We have varied the model parameters in the DMW code to reproduce both new data on this observable from LEGS [7,8], as well as unpolarized differential cross sections from Bonn [9]. Good fits to the data have been achieved over large ranges in angle and energy, for both (γ,π^0) and (γ,π^+) channels. (Of the two, the π^0 channel is more sensitive to the M_{Δ^+} parameter since most of the nonresonant Born terms, and in particular the nucleon pole term, do not contribute.) The magnetic couplings and the EMR values for the three DMW resonance+background decomposition methods are given in Table I, and the corresponding electric quadrupole and magnetic dipole amplitudes are shown in Fig. 1. The mass parameter and the magnetic coupling constant change with the method of parametrizing the background, but the EMR values are quite stable.

SO have suggested that the uncertainty in M_{Δ^+} is at least 30 MeV. In order to investigate the explicit sensitivity of the EMR value to such variations, we have arbitrarily changed the mass parameter by $\pm$15 MeV and have refitted the other model parameters to the data. The resulting predictions for the K-matrix resonance+background decomposition method are shown in Fig. 2, together with polarization data from LEGS and cross section data from Bonn—dashed curve, $\delta M_{\Delta^+} = -15$ MeV, and dashed-dotted curve, $\delta M_{\Delta^+} = +15$ MeV. [For both of these cases the corresponding values for the magnetic coupling and the EMR are $G_M(0)$=2.8, and EMR=−2.8%.] It is not possible to obtain anything approaching a reasonable fit to the data. (If only the Δ^+ mass is changed, with no attempt to optimize the other model parameters, the predictions for both $d\sigma_\parallel/d\sigma_\perp$ and $d\sigma/d\Omega$ are even worse.) Very similar results are obtained with either the Olsson or the Noelle decompositions. The large shifts from the solid curves in Fig. 2 are essentially

TABLE I. The Δ^+ masses, magnetic couplings, and the EMR values for the three DMW [5] resonance+background decomposition methods.

Method	M_{Δ^+} (MeV)	$G_M(0)$	EMR (%)
Olsson	1217	2.74	−2.6
K matrix	1232	3.03	−2.7
Noelle	1250	3.48	−2.8

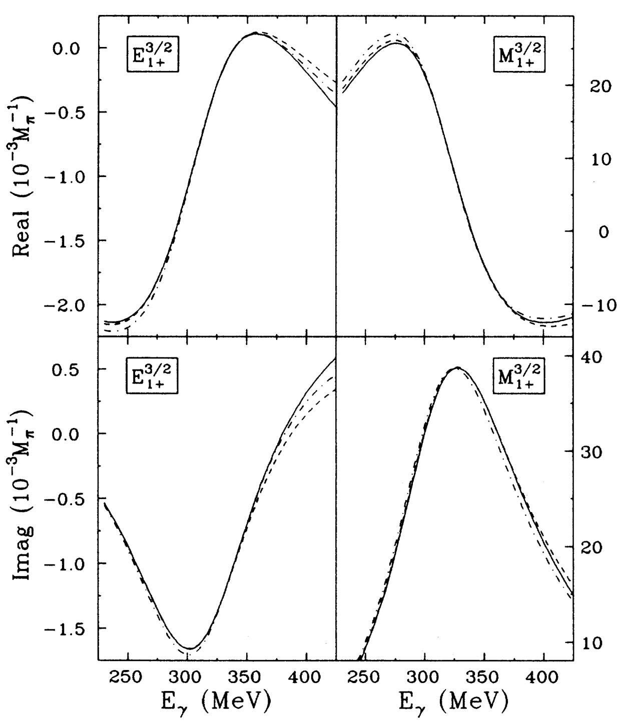

FIG. 1. Real and imaginary parts of the electric quadrupole ($E^{3/2}_{1+}$) and magnetic dipole ($M^{3/2}_{1+}$) amplitudes for the three DMW [5] resonance+background decomposition methods in units of $m_{\pi^+}^{-1}$. The solid, dashed, and dot-dashed curves are from the Olsson, the K-matrix, and the Noelle prescriptions, respectively.

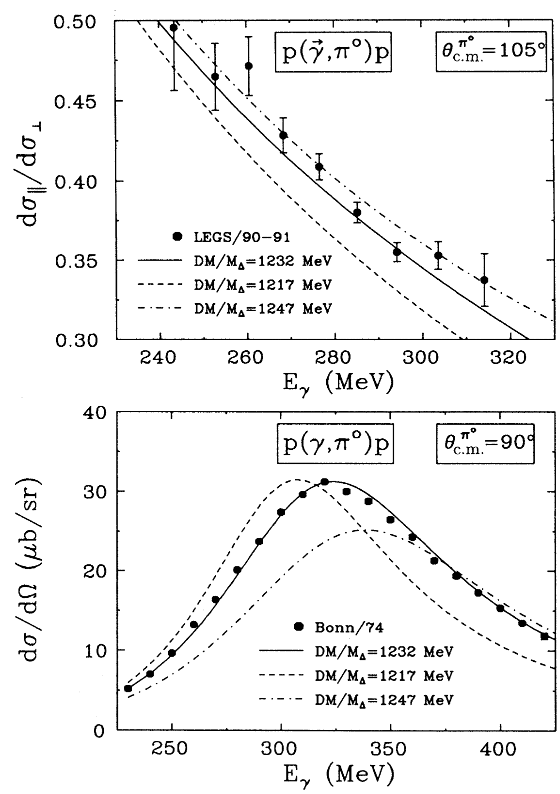

FIG. 2. The ratio of $p(\vec{\gamma},\pi^0)$ cross sections, $d\sigma_\parallel/d\sigma_\perp$, at $\theta^{\pi^0}_{c.m.}$=105° from LEGS [7] and the unpolarized differential cross sections, $d\sigma/d\Omega$, at $\theta^{\pi^0}_{c.m.}$=90° from Bonn [9] are shown, together with predictions using the K-matrix method of DMW [5]. The solid, dashed, and dot-dashed curves are obtained using δM_{Δ^+} = 0 MeV, −15 MeV, and +15 MeV, respectively.

due to the fact that the mass parameter was fitted to πN scattering and the requirement of unitarity removes any freedom of adjustment in the photoproduction channel.

The accuracy of existing data on single-pion photoproduction on the nucleon does not allow as wide a range of values ($\pm 5\%$) for the EMR as concluded by Slaughter and Oneda. There have been recent changes in the best estimate for the EMR [10,8], and there will continue to be improvements as more data become available. But these changes reflect the effects of new high-precision data on $E2$-sensitive observables, *not* on uncertainties in the magnetic dipole coupling or in the Δ^+ mass.

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