Mainz Measurement of the $E2/M1$ Ratio in the N-Δ Transition

Beck *et al.* [1] have recently reported precise measurements of differential cross sections and polarized photon asymmetries on the reaction $\vec{\gamma} p \rightarrow p\pi^0$, using tagged photons in the energy region 270 to 420 MeV, thus spanning the $\Delta(1232)$ resonance. This augments the data from the Brookhaven LEGS facility [2].

Let us emphasize from the outset that the $E2/M1$ ratio in the N-Δ transition *is not directly measured* by Beck *et al.,* despite the title of their paper. This is an *inferred* quantity requiring theoretical modeling of the data. Here, we take issue with some points of the analysis reported by Beck *et al.* We show that our $E2/M1$ ratio, $R_{\rm EM}$, extracted from the data of Beck *et al.* [1] is *substantially* different from what is obtained in Ref. [1]: while Beck *et al.* obtain this ratio to be $-(2.5 \pm 0.2 \pm 0.2)\%$, we get $-(3.19 \pm 0.24)\%$. This difference is mostly due to the inaccuracy introduced by the use of approximations in identifying $R = C_\parallel/12A_\parallel$ with $R_{\rm EM}$, in Eqs. (7) and (8) of Ref. [1]. We also emphasize that the systematic error of $\pm 0.2\%$ for $R_{\rm EM}$ estimated by Beck *et al.*, due to "...limited angular efficiency for detecting the recoil proton...and from ignoring the isospin $1/2$ contributions," *does not* include the error made by them in ignoring the E_{1+} multipole in $A_\parallel$.

We start with the coefficients characterizing the differential cross section, assuming dominance of s and p waves,

$$A_\parallel = |E_{0+}|^2 + |3E_{1+} - M_{1+} + M_{1-}|^2, \qquad (1)$$

$$B_\parallel = 2\,{\rm Re}[E_{0+}(3E_{1+} + M_{1+} - M_{1-})^*], \qquad (2)$$

$$C_\parallel = 12\,{\rm Re}[E_{1+}(M_{1+} - M_{1-})^*], \qquad (3)$$

correcting an error in Eq. (4) of Ref. [1]. Key to the analysis of Beck *et al.* is identifying R with $R_{\rm EM}$. This is imprecise for the following reasons. First, this requires neglecting M_{1-}, E_{0+}, and the isospin $1/2$ components of M_{1+} and E_{1+} in Eqs. (1)–(3), and in addition neglecting E_{1+} in Eq. (1) altogether. Second, equality of R and $R_{\rm EM}$ is not a good approximation even at the K-matrix pole as implicitly assumed in Ref. [1]. It gets far worse away from this pole. Finally, contrary to the assertions of Ref. [1], ${\rm Re}(M_{1+} - M_{1-})$ is *not* zero and ${\rm Im}\,M_{1+}$, ${\rm Im}\,M_{1-}$ are *not* purely isospin $3/2$, even at the K-matrix pole. These effects need to be estimated in a model, as done by us below. We realize that some of these approximations are unavoidable for Beck *et al.* in order to extract $R_{\rm EM}$ from the data, in absence of a model. The best they can do is not to neglect E_{1+} in Eq. (1), as we show below.

We use our effective Lagrangian approach [3] to analyze the Mainz data set without making any of the above approximations, and retaining partial waves beyond s and p. We get at the K-matrix pole, 338.4 ± 0.5 MeV, $M1 = 282.5 \pm 1.3$, $E2 = -9.00 \pm 0.66$, both in units of 10^{-3} GeV$^{-1/2}$, and $R_{\rm EM} = -(3.19 \pm 0.24)\%$; at 340 MeV, we get $R_{\rm EM} = -(3.09 \pm 0.24)\%$. The value of R at 340 MeV is $-(2.69 \pm 0.17)\%$, consistent with the result of Ref. [1]. The difference between R and $R_{\rm EM}$, given here, is mainly due to the isospin $3/2$ piece of the E_{1+} in Eq. (1), neglected by Beck *et al.* This can be verified by using *their* value of R and correcting for the isospin $3/2$ piece of the E_{1+} amplitude. This gives $R_{\rm EM} \approx -(2.9 \pm 0.23)\%$, in agreement with our value.

Workman has reached a similar conclusion about the importance of E_{1+} in $A_\parallel$ [4], but concludes, based on the overall agreement of previous VPI multipole solutions with the new Mainz data, that $R_{\rm EM} = -(1.5 \pm 0.5)\%$. Although the VPI multipoles give a good *overall* fit to the new Mainz data, they consistently overpredict the crucial photon asymmetry data at 340 MeV. As a measure of this, using the s and p wave multipoles from the VPI W500 solution, we find at 340 MeV, $R = -1.2\%$, which is substantially smaller in magnitude than both our result and the Mainz result. Thus, for $R_{\rm EM}$ at 340 MeV, of interest to hadron theory, we recommend our number to the reader.

A comparison between the LEGS [2] and the Mainz [1] published data indicates no significant discrepancy between $R_{\rm EM}$ inferred from the former database [5] and the present Mainz result presented here.

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