SLAC–PUB–6316
August 1993
(E)

The $\Delta(1232)$ Resonance Transition Form Factor

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Presented at the Workshop on Exclusive
Reactions at High Momentum Transfers
Marciana Marina, Elba, Italy, June 24-26 1993.

*Work supported in part by National Science Foundation grants PHY–87–15050 (AU), PHY–89–18491 (Maryland), PHY–88–19259 (U Penn), and PHY–86–58127 (UW); by Department of Energy contracts DE–AC03–76SF00515 (SLAC), W–7405–ENG–48 (LLNL), DE–FG02–88ER40415 (U Mass), DE–AC02-ER13065 (UR) and DE–FG06–90ER40537 (UW); and by the US–Israel Binational Science Foundation.

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Abstract

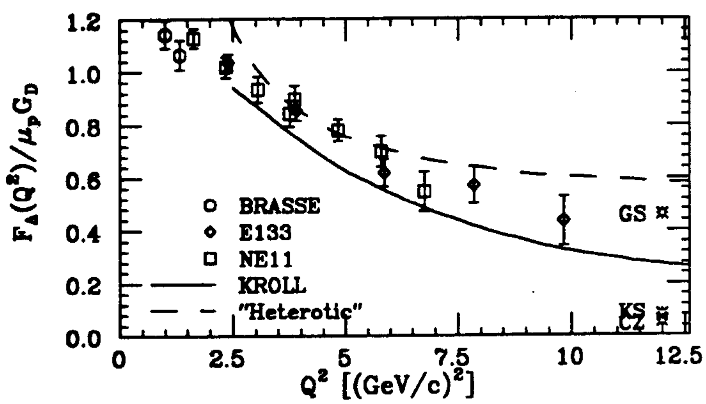
Old and new measurements of inclusive $e-p$ cross sections in the $\Delta(1232)$ resonance region have been combined, and a global data fit has been made. Using this fit to parameterize the nonresonant background, the transition form factors have been extracted out to a four-momentum transfer, Q^2, of 9.8 $(\mathrm{GeV/c})^2$. The results are systematically higher than those from a previous analysis, but agree within errors. A similar analysis has been done with $e-d$ cross sections, and σ_n/σ_p in the $\Delta(1232)$ resonance region has been extracted out to a Q^2 of 7.9 $(\mathrm{GeV/c})^2$. σ_n/σ_p for $\Delta(1232)$ production is consistent with unity, while σ_n/σ_p for the nonresonant background is constant with Q^2 at approximately 0.4.

Understanding the structure of the nucleons and their excitations is of fundamental interest. In the limit of large four-momentum transfer, leading order perturbative QCD (pQCD) is expected to be valid, but it is not clear at which Q^2 the non-leading order processes die off. The form factor analysis of Stoler[1,2] indicates that the $\Delta(1232)$ transition form factor does not exhibit the expected leading order pQCD behavior for Q^2 out to 10 $(\mathrm{GeV/c})^2$. Instead, this form factor falls off more rapidly with Q^2 than expected. Thus, there is a need for data on baryon excitation cross sections and transition form factors at large Q^2, in order to understand this effect better and also to test form factor models.

New measurements[3] have been made by SLAC experiment NE11 of inclusive electron scattering cross sections using hydrogen and deuterium targets in the region of the $\Delta(1232)$ resonance.[4] This data has been combined with low Q^2 data,[5] high Q^2 data[6] from SLAC experiment E133, and high missing mass squared, W^2, data.[7] A global fit has been made to this combined proton data. The components of the fit are separable into a nonresonant and three resonant components. The form of the fit functions for the nonresonant and $\Delta(1232)$ resonance are the same as those used by Stoler[1,2] while two higher resonances were modeled using a nonrelativistic Breit-Wigner form rather than a relativistic form for simplicity.

Using the global nonresonant fit, each individual cross section spectrum with $\Delta(1232)$ resonance data was refit to extract the transition form factor. The results of these fits are shown in Figure 1, where $G_D = (1.0 + Q^2/0.71)^{-1}$, μ_p is the proton magnetic moment, and F_Δ has been previously defined.[1,2,4] Also shown are the diquark model fit by Kroll, *et al.*,[8] the prediction from Stefanis and Bergmann[9] using their heterotic nucleon and $\Delta(1232)$ distribution amplitudes, and the asymptotic predictions (denoted by $*$) of Carlson and Poor,[10] which have been evaluated at the Q^2 shown. The Kroll curve falls below the data, but the model was tuned to agree with the previous analysis,[1,2] so this is not surprising. The heterotic curve lies above the data. Both curves are consistent with the data within errors. The major difference between this analysis and that of Stoler is the use of the global fit to the nonresonant component rather than fitting this component separately for each cross section spectrum. The effect on the extracted form factors is to shift them up by about one σ. The form factors, however, are still decreasing faster with

Figure 1. $\Delta(1232)$ transition form factors scaled by $\mu_p G_d$ extracted from fits to cross section data at each Q^2 point. Error bars are statistical only. Also shown are the diquark model fit by Kroll *et al.*[8], the heterotic prediction from Stefanis and Bergmann[9], and the asymptotic predictions (denoted by $*$) by Carlson and Poor[10], which have been evaluated at the Q^2 shown.

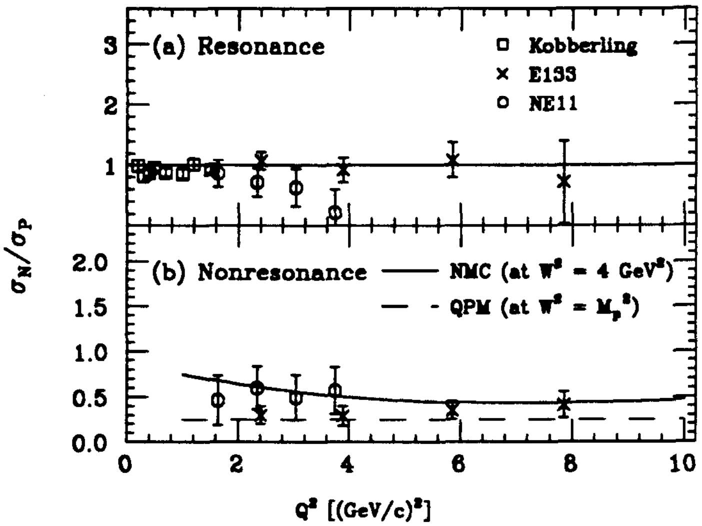


Q^2 than expected from leading order pQCD. The upward shift of the data points brings them in closer agreement with the heterotic prediction.

Using the results from the proton global fit, the deuterium data was analyzed in order to extract information on σ_n/σ_p as a function of Q^2 for the resonant and nonresonant components separately. The shape of the quasielastic peak was modeled with a non-relativistic Plane Wave Impulse Approximation (PWIA) calculation[11] using the Paris[12] deuteron wavefunction. The effects due to meson-exchange currents (MEC) were modeled using a parameterization[13] based on calculations by Laget[14] at $Q^2 = 1.75$ (GeV/c)^2. The proton resonant and nonresonant components from the proton global fit were separately Fermi smeared using the light cone smearing formalism of Sargsyan, Frankfurt, and Strikman[15] Off-mass-shell corrections[16] were applied to the input on-mass-shell model structure functions in the smearing process. The result was smeared proton resonant and nonresonant cross sections which were fit to the deuterium data along with the quasielastic and MEC components. The fit coefficients yield information on the σ_n/σ_p ratios for the smeared components in the region of the $\Delta(1232)$ resonance as shown in Figure 2. The resonant σ_n/σ_p ratios were consistent with unity for all values of Q^2 as expected from isospin invariance. The nonresonant σ_n/σ_p ratios were roughly constant with Q^2 at a value of around 0.4. The top curve in (b) corresponds to the NMC deep inelastic model[18] evaluated at a fixed missing mass squared, $W^2 = 4.0$ GeV^2. The bottom curve is the Quark Parton Model (QPM) prediction at x = 1 ($W^2 = M_p^2$). Within errors the results are consistent with both curves.

In summary, new results on the $\Delta(1232)$ transition form factors from the combined SLAC NE11 and E133 cross sections show a small systematic upward shift from a previous analysis[1,2] However, these results still fall faster with Q^2 than expected from leading order pQCD. Ratios of σ_n/σ_p have been extracted from deuterium cross sections using a model dependent method. The results for the $\Delta(1232)$ are consistent with unity as expected from isospin invariance, and the results for the nonresonant background are approximately 0.4 which is consistent with deep inelastic results. More details of this analysis and a model dependent study will soon be published[4]

Figure 2. σ_n/σ_p for the resonant and nonresonant cross section components in the region of the $\Delta(1232)$ resonance. The errors are statistical only. Previous data at low Q^2 from Köbberling[17] is also shown. Plot (b) also contains two curves. One is the NMC deep inelastic model evaluated at $W^2 = 4$ GeV^2, and the other is the Quark Parton Model prediction at x=1 ($W^2 = M_p^2$).



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