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Color Transparency in $(e, e'p)$ and the Electroproduction of N^* Resonances

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A hadronic picture of color transparency is discussed for the $(e, e'p)$ reaction. It is argued that such a picture leads naturally to constraints on the 4-momentum transfer Q necessary for the onset of novel behavior in the measured $A^{\rm eff}/A$ of quasielastic knockout at small missing momenta. It is also suggested that the measurement of N^* production at quasifree $(e, e'p)$ kinematics is useful in disentangling the state of the struck ejectile at the point of the initial hard process from the diffractive excitation it suffers as it passes through the nuclear medium.

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The hypothesis of color transparency suggests that at high Q^2 the final-state interactions of a proton in certain exclusive processes should become arbitrarily weak. In the following, the quasielastic $(e, e'p)$ reaction will be considered in the exclusive limit where the missing energy provided to the nuclear target is much less than the pion mass. The notion, due to Brodsky and Mueller [1, 2], is that the detection of a proton, in $(e, e'p)$ for example, at large Q^2 implies that it originated from a color-singlet qqq Fock component of small transverse spatial size and, hence, that the $A^{\rm eff}/A$ (N.B. $A^{\rm eff}/A$ is defined as the ratio of the nuclear to proton cross sections, such that $A^{\rm eff}/A = \sigma_A/A\sigma_p$.) associated with such a reaction would tend to one for increasingly large Q^2. However, this simple quark picture, motivated by perturbative QCD, makes no prediction as to what momentum transfers are necessary to observe this phenomenon. It shall be argued that the consideration of a hadronic picture of color transparency, in constrast, offers some constraint.

In a hadronic picture [3, 4], it is supposed that the hard process produces a superposition of N^* states of narrow transverse spatial size for sufficiently large Q^2. Each of the produced hadronic states will interact with the nuclear medium with its usual cross-section, yet the superposition of states will interact weakly – in a way commensurate with its small transverse size [5, 6] – if non-diagonal transitions, *i.e.*, $N \leftrightarrow N^*(1440)$ etc., are allowed, as then the strong interactions of each of the states in the superposition may cancel. Such non-diagonal transitions are not included in a Glauber treatment of the final-state interactions and are known as Gribov corrections [7]. They were originally discussed in the context of elastic hadron-deuterium scattering [7]. For sufficiently large beam energies, the incoming hadron may be diffractively excited to a state h^* upon interaction with a nucleon (without changing the nuclear state); the diffractively excited h^* may then convert back to

a ground state hadron in its interaction with the subsequent nucleon, ultimately reducing the total hadron-deuterium cross section at high energies. The importance of this phenomenona in producing a quantitative understanding of the total neutron-deuterium cross sections has been discussed by Murthy *et al* [8]. (For a general review of the role of Gribov corrections in modifying the total hadron-nucleus cross section at high energies, see Ref. [9].) This picture suggests, then, that the ejectile in the $(e, e'p)$ reaction may also suffer diffractive excitation in its interactions with the nuclear medium; consequently, the measured A^{eff}/A may be distinct from that predicted from Glauber theory, even if the ejectile is not produced in a state of small transverse spatial size. This effect has been documented in model calculations of color transparency in diffractive charmonium photoproduction [10, 11]. The experimental goal, then, is not only to measure the evolution of A^{eff}/A with Q^2, but also to disentangle the modification of the struck ejectile as a result of the hard process from its diffractive excitation as it passes through the nuclear medium. To this end, it is suggested that $(e, e'N^*)$ production should be studied in the same experimental set-up as the $(e, e'p)$ reaction. It is expected from model studies of charmonium that the behavior of A^{eff}/A for N^* production will be quite sensitive to the wavefunction of the ejectile produced in the hard process [10, 11].

Here the kinematical constraints on the diffractive excitation of the knocked-out proton in its interactions with the medium and on N^* production as a result of the initial hard process will be discussed. These constraints are necessary, rather than sufficient, in nature. The impact of these constraints on the proposed measurements of color transparency in $(e, e'p)$ are examined, and, as a consequence, it is suggested that a Q^2 in excess of 10 GeV^2 is required in order to observe a non-trivial effect.

The hadronic picture discussed here relies on the notion that the hadronic basis is dual to the quark-parton one. Support certainly exists for such an equivalence. For

example, Bloom and Gilman have observed that the resonance form factors observed at low Q^2 can be averaged over a finite range in x so that the deep inelastic – large Q^2 – structure functions are recovered [12]. Nevertheless, the duality invoked here must still be regarded as an assumption, albeit a reasonable one.

II. CONSTRAINTS ON N* PRODUCTION

The kinematical constraints on diffractive excitation of the struck ejectile and on N^* production in the initial hard process shall be examined in turn. To derive a constraint on diffractive excitation [13], consider the process

$$N + A \rightarrow N^* + A \,, \tag{1}$$

where N is an initial hadron and A is a nucleus at rest. Energy-momentum conservation requires that the 4-momentum transfer $\tilde{q}$ to the nucleus must satisfy

$$\frac{(p_N - \tilde{q}) \cdot (p_A + \tilde{q})}{E_N} + \frac{(M_{N^*}^2 - M_N^2)}{2E_N} = M_A \,, \tag{2}$$

where $p_N = (E_N, \vec{p}_N)$, $\tilde{q} = (\nu, \vec{q})$ $[\tilde{q}^2 = -Q^2]$, and $p_A = (M_A, 0)$. Assuming the energy transfer ν and the 3-momentum transfer transverse to $\vec{p}_N$ are zero, this can be inverted to yield

$$q_L = \frac{p_N}{2} - \frac{p_N}{2}\sqrt{1 - \frac{2(M_{N^*}^2 - M_N^2)}{p_N^2}} \,, \tag{3}$$

where q_L is the magnitude of the longitudinal 3-momentum transfer. Evidently, p_N^2 must exceed $2(M_{N^*}^2 - M_N^2)$ for the above expression to be meaningful. For very large nucleon momenta, Eq. 3 becomes

$$q_L \approx \frac{(M_{N^*}^2 - M_N^2)}{2p_N} \,, \tag{4}$$

so that the longitudinal momentum transfer associated with physical N^* production becomes arbitrarily small as the projectile momentum increases. The assumptions of

zero ν and q_T means that the expression for q_L given in Eq. 3 is the 4-momentum difference between a physical diffractively produced N^* and the initial nucleon. It is also the 4-momentum difference between a physical diffractively produced N^* and a virtual N^* produced with the momentum of the initial nucleon. It is the production and propagation of the latter which gives rise to the quantum-mechanical interference effects in the final-state interactions necessary for color transparency. The magnitude of q_L can be used as an estimate of the "lifetime" of the virtual N^*. In order to have an impact on the final-state interactions, such a N^* must necessarily live long enough in order to interact with another nucleon in its path. Thus, q_L must certainly be small enough that

$$q_L << M_\pi \,, \tag{5}$$

where the typical nucleon-nucleon separation is given by the range of the one-pion exchange force. This constraint on q_L can be readily translated into an expression for the formation length. Defining the formation length l_f as $1/q_L$ [9], one has, then, the constraint that $l_f >> 1/M_\pi$, or, roughly, that $l_f >> 1.4$ fm. In this context, l_f is the lifetime of the diffractively excited N^*. It should be emphasized that the constraint represented by Eqs. 3 and 5 is a necessary one. Even if the struck ejectile were produced in a state of small transverse spatial size at low Q^2, Eq. 5 must be satisfied in order for such an ejectile to interact "weakly".

Now the constraint on N^* production at the initial vertex shall be examined. The role of N^* resonances in the hard process determine whether or not the initial amplitude may be of small transverse size. It is, then, an independent constraint from that of Eq. 5. For the purposes of argument, the $(e, e'p)$ reaction at the top of the proton's quasielastic peak is considered. To derive a constraint, it is necessary to compute the momentum difference between a physical N^* resonance and a proton, assuming that

the N and N^* emerge in a parallel direction. That momentum mismatch can then be used to estimate the lifetime of the N^* produced in the hard process. For the purposes of color transparency, the final state N^* must be *identical* to the knocked-out proton. The momentum difference, then, of a *physical* N^* and the knocked-out proton defines the extent to which a N^* participating in the coherent superposition of states is off its mass-shell. As a practical estimate of the Q^2 necessary for a particular N^* to be produced and propagate so as to have a finite effect on the final-state interactions, it shall be required that

$$\frac{\hbar c}{|p_{N^*} - p_N|} >> 1.4 \text{ fm} \,, \tag{6}$$

so that the off-shell N^* has the possibility of rescattering to an out-going nucleon state upon interaction with a subsequent nucleon along its path. Once again, the range of the one-pion exchange force has been taken as a typical estimate of the nucleon-nucleon separation.

To begin, then, consider the invariant mass of the struck ejectile: $W \equiv (E_k + \nu, \vec{k} + \vec{q})$, where the initial nucleon in the nucleus has momentum $\vec{k}$ and energy $E_k = \sqrt{M_N^2 + k^2}$. (Nuclear binding corrections will be neglected throughout this paper, as they are inessential to the development of a constraint in Q^2.) Applying the kinematic condition at the top of the quasielastic peak, $2M_N\nu = Q^2$ (N.B. $Q^2 \equiv q^2 - \nu^2$), one has

$$W^2 = M_N^2 + 2\nu(E_k - M_N) - 2\vec{k}\cdot\vec{q} \,. \tag{7}$$

If the final particle is a proton, then Eq. 7 implies that $\vec{k} = 0$. However, if $W^2 \neq M_N^2$, then $\vec{k}$ is finite. Choosing "head-on" kinematics so that $\vec{k}\cdot\vec{q} = -kq$ implies that k must satisfy

$$k = \frac{(M_{N^*}^2 - M_N^2)}{2q} + \frac{(\sqrt{M_N^2 + k^2} - M_N)}{\sqrt{1 + \frac{2m_N}{\nu}}} \,. \tag{8}$$

As q increases, the required k decreases to zero, so that arbitrarily large mass N^*'s can be produced in the $Q^2 \to \infty$ limit. (For finite Q^2, Eq. 8 also serves as a constraint: only those N^*'s whose production requires $k < k_F \sim .26$ GeV/c may be considered [14]. Numerically, however, this constraint is no more restrictive than Eq. 6.) The desired momentum difference can now be straightforwardly calculated. Exploiting energy-momentum conservation, along with Eq. 8, yields that the energy of the produced N^* must satisfy

$$2\epsilon_f E_{N^*} = 2\epsilon_f E_k + 2\nu M_N + 2\vec{k}_i \cdot \vec{k}_f - 2k_f^2 \,, \tag{9}$$

where the initial electron has energy ϵ_i and momentum $\vec{k}_i$, and the final electron has energy $\epsilon_f \equiv \epsilon_i - \nu$ and momentum $\vec{k}_f \equiv \vec{k}_i - \vec{q}$. Neglecting the mass of the electron and applying the quasielastic condition $Q^2 = 2M_N\nu$ gives, finally,

$$E_{N^*} = \sqrt{M_N^2 + k^2} + \frac{Q^2}{2M_N} \,. \tag{10}$$

If the knocked-out particle were a proton, then its energy would be given by Eq. 10 with $k = 0$. Consequently, the momentum difference of a N^* and a proton at quasifree kinematics is

$$p_{N^*} - p_N = \chi \left(\sqrt{\left(1 + \frac{\sqrt{M_N^2 + k^2} - M_N}{\chi}\right)^2 - \frac{M_{N^*}^2}{\chi^2}} - \sqrt{1 - \frac{M_N^2}{\chi^2}} \right) \,, \tag{11}$$

with $\chi \equiv M_N + Q^2/2M_N$ and k given by Eq. 8. For very large Q^2, this reduces to merely

$$p_{N^*} - p_N \approx -\frac{2M_N(M_{N^*}^2 - M_N^2)}{Q^2} \,, \tag{12}$$

so that the momenta can become arbitrarily close as Q^2 increases. For finite Q^2, it is possible to estimate the extent to which virtual N^* production will affect the final-state interactions, through the use of Eq. 6.

The constraints for N^* production and propagation derived above can now be discussed in the context of the existing experimental proposals which search for color transparency in the quasielastic $(e, e'p)$ process.

III. IMPACT ON PROPOSED EXPERIMENTS

Tables I and II show the kinematics for the NE18 experiment at SLAC [15] and for the proposed follow-up experiment [16], as well as the quantities $\delta p_{N^*} \equiv p_{N^*} - p_N$ (Eq. 11) and $q_L^{N^*}$ (Eq. 3) defined in the previous section for a selection of the low-lying N^* resonances. One anticipates that several N^* states must be allowed to participate in order to generate a large change in the final-state interactions. In the light of the constraints posed by Eqs. 5 ($q_L << M_\pi$) and 6 ($\hbar c/\delta p_{N^*} >> 1.4$ fm), it is possible to evaluate the efficacy of these experiments in testing the color transparency hypothesis. Note that the $N(1710)$ has been included, in addition to the two most low-lying N^* resonances, as it is believed to be the second radial excitation of the nucleon. In general, the coherent mixing of the *radial* excitations may cause the largest alteration of the final-state interactions, as the wavefunctions of the successively radially excited nucleonic states are rather different.

As can be seen, even with the *weak* constraints $q_L^{N^*} < M_\pi$ and $\hbar c/\delta p_{N^*} > 1.4$ fm, that the role of the $N(1440)$ and $N(1710)$ is negligible for the kinematics of the NE18 experiment. Indeed, the $\Delta(1232)$ may play some role only at their highest Q^2 values. The production of the $\Delta(1232)$ resonance is interpreted in the non-relativistic quark model as a "spin-flip" transition. The $\Delta(1232)$'s radial wavefunction differs slightly from that of nucleon's due to D-state admixtures from color hyperfine forces, but this is a rather small effect [17]. Consequently, it would seem that the evolution in A^{eff}/A with Q^2 in the NE18 experiment due to color transparency effects should be essentially negligible. This conclusion can also be drawn for the kinematics of the Hall

C experiment proposed at CEBAF [18]. However, the situation looks much brighter for the NE18 follow-up experiment proposed at SLAC [16], as shown in Table II, as then the $N(1440)$ may participate coherently both in the hard process and in the final-state interactions. It must be emphasized, however, that Eqs. 5 and 6 are necessary, rather than sufficient, constraints. The actual magnitude of the effect of color transparency on $A^{\rm eff}/A$ for a particular Q^2 must be calculated in the context of a dynamical model. In this regard, perhaps even higher Q^2 values than those of the NE18 follow-up experiment will be required to see a significant effect.

IV. DISCUSSION

In this paper, it has been argued that "color transparency" in the quasielastic knock-out of protons in the $(e,e'p)$ reaction at small missing momenta can be envisaged as due to the production and propagation of a coherent superposition of N^* resonances [3]. In this regard, the constraints on N^* production and propagation – from kinematical considerations alone (Eqs. 5 and 6) – have been derived and applied to the conditions of the proposed color transparency experiments. The conclusion is that the change in $A^{\rm eff}/A$ with Q^2 due to color transparency effects both in the NE18 experiment at SLAC and in the experiments proposed at CEBAF is probably negligible. However, the situation for the follow-up NE18 experiment looks much better, and it is urged that experiments be performed at Q^2 still higher than those proposed.

The NE18 and CEBAF proposals were constructed as a result of early theoretical estimates of the color transparency phenomenon, which, in fact, indicated that $A^{\rm eff}/A$ could change by as much as 25% by a Q^2 of 7 $(\mathrm{GeV/c})^2$ [19,20]. This is obviously at odds with the conclusions of this work, and it is interesting to discuss why these early calculations estimate a much larger effect. The calculation of Farrar *et al.*[19,20] uses a semi-classical expression to estimate the final-state interactions of an expanding

point-like object in the nuclear medium. They assume that the initial object at the point of the hard process is of size $\sim 1/Q^2$ for *all* Q^2 and assume that the final-state interactions of such an object can be modelled using the Glauber formula, presuming that the initial object undergoes a classical, monotonic expansion. Both assumptions are suspect (indeed, such a treatment of the final-state interactions is not supported by quantum-mechanical considerations[9–11, 21]), and both would seem to overestimate the transparency effect. However, the quantum mechanical calculation of Jennings and Miller [4] – the only such published as yet for the $(e,e'p)$ reaction – also reports large effects in the $Q^2 < 10(\mathrm{GeV/c})^2$ regime – comparable to those of Farrar *et al.*. However, given their uncontrolled approximation to the multiple scattering problem (see their Eq. 38), it is difficult to see how their results can be robust. There may be an additional difficulty in predicting the onset of transparency with Q^2. That is, the treatment of the nucleus itself is quite crude in all existing calculations of transparency [4, 10, 11, 19, 20], so that the possible break-up of the nucleus upon diffractive excitation is not explicitly treated. Rather, the nucleus is modeled as a passive object with a given density distribution. This simplication could certainly allow "sub-threshold" diffractive excitation, and, consequently, enhanced effects at low Q^2.

Unfortunately, then, no complete calculation of the $(e,e'p)$ reaction at the Q^2 considered here has yet been performed. However, estimates of the struck ejectile size with Q^2 come from examining the Q^2 fall-off of simple models for the qqq Fock component of the proton form factor [22], and these suggest that the struck ejectile will maintain its conventional hadronic size for Q^2 up to $Q^2 \sim 10 - 30(\mathrm{GeV/c})^2$. It should be emphasized, however, that even if the struck ejectile does not attain a small transverse spatial size at finite Q^2, the final-state interactions of a struck ejectile may still be modified from those of the traditional Glauber theory by Gribov corrections

[10, 11].

To the end of disentangling the modification of the struck ejectile in the hard process with Q^2 from the diffractive excitation the proton may suffer in its passage through the nucleus, it is suggested that study be made of the A-dependence of the electroproduction of the N^* resonances – $\Delta(1232)$, $N(1440)$ (if possible!), etc. – with Q^2. (Note that $A^{\rm eff}/A$ for N^* production can be formally defined as the ratio of the nuclear to proton production cross sections; that is, $A^{\rm eff}/A = \sigma_{A\to N^*(A-1)}/A\sigma_{p\to N^*}$. However, what is important is the A-dependence, that is, the coefficient α in the parameterization $A^{\rm eff}/A \propto A^{\alpha}$.) It is to be emphasized that these measurements should be performed at quasifree *proton* kinematics. Thus, it is suggested that these $(e, e'N^*)$ measurements be performed in concert with a measurement of $(e, e'p)$. Why is this useful? Model calculations of the diffractive photoproduction of charmonium excited states indicate that the $A^{\rm eff}/A$ associated with these states are very sensitive to the form of the wavefunction of the initial produced state [10, 11]. For example, suppose the momentum transfer were sufficient for diffractive excitation to occur (Eq. 5), but that the initial wavefunction of the struck ejectile had essentially been unmodified by the hard process. Then, it would be natural to imagine that the final-state interactions could produce more of a particular N^* than had existed in the initial state, so that the $A^{\rm eff}/A$ for that N^* could exceed one! On the other hand, if one were able to form an initial state of "point-like" transverse size at *very* large Q^2, and the momentum of the ejectile were sufficient for it to escape the nucleus without expansion, then the $A^{\rm eff}/A$ of the proton and its "sister" states would be comparable and close to 1. This would occur even though the nucleon excited states are generally of a larger spatial size than the nucleon and, thus, possess – in isolation – a larger total cross section in nuclear matter. Consequently, the measurement of the $(e, e'N^*)$ reaction in the kinematics discussed can offer much insight into the physics of the

hard process and subsequent final-state interactions at large Q^2.

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REFERENCES

* Present address.

[1] S. J. Brodsky, in *Proceedings of the Thirteenth International Symposium on Multiparticle Dynamics*, W. Kittel, W. Metzger, and A. Stergiou, eds. (World Scientific, Singapore, 1982), p. 963.

[2] A. Mueller, in *Proceedings of the Seventeenth Rencontre de Moriond, Moriond, 1982*, J. Tran Tranh, ed. (Editions Frontieres, Gif-sur-Yvette, France, 1982), p. 13.

[3] B. K. Jennings and G. A. Miller, Phys. Lett. **B236**, 209 (1990).

[4] B. K. Jennings and G. A. Miller, Phys. Rev. **D44**, 692 (1991).

[5] Al. B. Zamolodchikov, B. Z. Kopeliovich, and L. I. Lapidus, JETP Lett. **33**, 595 (1981).

[6] G. Bertsch, S. J. Brodsky, A. S. Goldhaber, and J. G. Gunion, Phys. Rev. Lett. **47**, 297 (1981).

[7] V. N. Gribov, Sov. Phys. JETP **29**, 483 (1969).

[8] P. V. R. Murthy *et al.*, Nucl. Phys. **B92**, 269 (1975).

[9] N. N. Nikolaev, Sov. Phys. Usp. **134**, 369 (1981).

[10] S. Gardner, preprint CEBAF-PR-02-002, submitted to Phys. Rev. C.

[11] B. Z. Kopeliovich and B. G. Zakharov, Phys. Rev. **D44**, 3466 (1991).

[12] E. Bloom and F. Gilman, Phys. Rev. **D4**, 2901 (1971).

[13] M. L. Good and W. D. Walker, Phys. Rev. **120**, 1857 (1960).

[14] S. Fantoni and V. R. Pandharipande, Nucl. Phys. **A427**, 473 (1984).

[15] R. McKeown, R. Milner, *et al.*, NPAS NE18 proposal.

[16] R. Ent, B. Filippone, W. Lorenzon, R. Milner, *et al.*, NPAS E145 proposal, May, 1992.

[17] N. Isgur, G. Karl, and R. Koniuk, Phys. Rev. **D 25**, 2394 (1982) and references therein.

[18] R. Milner *et al.*, CEBAF-PR-89-010.

[19] G. R. Farrar, H. Liu, L. L. Frankfurt, and M. I. Strikman, Phys. Rev. Lett. **61**, 686 (1988).

[20] L. L. Frankfurt, M. I. Strikman, M. B. Zhalov, Nucl. Phys. **A515**, 599 (1990).

[21] B. Z. Kopeliovich, Sov. J. Part. Nucl. **21**, 49 (1990).

[22] N. N. Nikolaev, KFZ Jülich preprint, IKP-KFA-2 (1992).

TABLES

TABLE I. Longitudinal momentum transfer $q_L^{N^*}$ (Eq. 3) and $\delta p_{N^*} \equiv p_{N^*} - p_N$ (Eq. 11) in GeV/c for the $\Delta(1232)$, $N(1440)$, and $N(1710)$ resonances for the NE18 experiment.

Q^2 (GeV/c)^2	ε_i (GeV)	ε_f (GeV)	p_N (GeV/c)		δp_{N^*} (GeV/c)	$q_L^{N^*}$ (GeV/c)
7.0	5.1	1.4	4.6	$\Delta(1232)$	-0.074	0.071
				$N(1440)$	-0.14	0.13
				$N(1710)$	-0.26	0.24
5.0	4.1	1.4	3.5	$\Delta(1232)$	-0.099	0.094
				$N(1440)$	-0.19	0.18
				$N(1710)$	-0.36	0.32
3.0	3.0	1.4	2.4	$\Delta(1232)$	-0.15	0.14
				$N(1440)$	-0.31	0.29
				$N(1710)$	-0.60	0.57
1.0	1.9	1.4	1.1	$\Delta(1232)$	-0.42	0.52

TABLE II. Longitudinal momentum transfer $q_L^{N^*}$ (Eq. 3) and $\delta p_{N^*} \equiv p_{N^*} - p_N$ (Eq. 11) in GeV/c for the $\Delta(1232)$, $N(1440)$, and $N(1710)$ resonances for the NE18 follow-up experiment. Both $q_L^{N^*}$ and the magnitude $|\delta p_{N^*}|$ are reported in column 6 as, for these kinematics, the difference between these quantities is negligible to the precision quoted. The final column gives $|\delta p_{N^*}|$ in fermis.

Q^2 (GeV/c)^2	ε_i (GeV)	ε_f (GeV)	p_N (GeV/c)		$\lvert\delta p_{N^*}\rvert$ & $q_L^{N^*}$ (GeV/c)	$\lvert\delta p_{N^*}\rvert$ (fm)
15.0	21.0	13.0	8.9	$\Delta(1232)$	0.036	5.5
				$N(1440)$	0.068	2.9
				$N(1710)$	0.12	1.7
12.0	18.3	11.9	7.3	$\Delta(1232)$	0.044	4.5
				$N(1440)$	0.083	2.4
				$N(1710)$	0.14	1.4
9.0	15.4	10.6	5.7	$\Delta(1232)$	0.057	3.5
				$N(1440)$	0.11	1.8
				$N(1710)$	0.19	1.1
6.0	12.1	8.9	4.0	$\Delta(1232)$	0.081	2.4
				$N(1440)$	0.15	1.3
				$N(1710)$	0.27	0.72