THE CURRENT STATUS OF CONSTITUENT QUARKS IN RESONANCE PHOTO AND ELECTROPRODUCTION

F E Close

CERN

First of all, why is $\gamma N \to N^*$ interesting? From $\pi N \to \pi N$ we know that there is a rich resonant structure at low energies and if we replace the incident π by a photon then we obtain several bonuses, a) the photon has spin 1 and so we can study the spin dependence of resonant excitation, b) it has mixed I=0, 1 so both proton and neutron targets give interesting structure, c) it has U=0, d) we can vary the photon mass by performing electroproduction, e) as a consequence of d) we are at the gateway to the deep inelastic region and from the phenomenological similarities between the resonance and deep inelastic data we may hope to gain some insights into the dynamics of deep inelastic scattering.

Not only is the photon interesting in its own right but as a consequence of a), b), c) it is especially useful for testing symmetry schemes like SU(6), quark models etc. A nice example of this is given by Lipkin. When you photoexcite p or n then the first thing seen above the threshold is the huge $\Delta^{+,o}(1236)$ resonance. If one instead fired a high intensity Σ^- into the Coulomb field of a nucleus (Primakoff excitation) no analogous Σ^{-*} would be seen if $U_\gamma=0$ since $U_{\Sigma^-} = \frac{1}{2}$ while $U_{\Sigma^{-*}} = \frac{3}{2}$.

Photoproduction data for excitation of $D_{13}(1520)$

To illustrate the current status of quark models and approaches based on the Melosh transformation I shall concentrate on the $D_{13}(1520)$, this being the resonance whose couplings are the best determined (apart from the familiar $\Delta(1236)$). We shall consider a real photon with $J_z=+1$ interacting with a nucleon with $J_z=\pm\frac{1}{2}$ to form the resonant state in either $J_z=+\frac{1}{2}$ or $+\frac{3}{2}$ described by helicity amplitudes A,B respectively. Then for neutron and proton targets typical results of phenomenological analyses are given in the table[1]

	A^P	B^P	A^N	B^N
MO	−26±15	194±31	−85±14	−124±13
KMOR	−19±8	169±12	−77±5	−120±10
MW	−6±6	165±11	−66±10	−118±13
DLR	3±14	183±14	−81±21	−155±22

Although the absolute magnitudes vary among the analyses several common features emerge,

(i) $A^P \lesssim o,\ A^N < o$

(ii) $|B^P, B^N| > |A^P, A^N$

(iii) $B^P > -B^N$ (except possibly for DLR)

Furthermore $A^P:A^N:B^P:B^N$ is roughly the same for each analysis, i.e. although the analyses differ in the absolute size of the resonance they agree on the relative importance of the various couplings.

Comparison with Models

In a constituent quark basis the SU(6) assignments of the nucleon and D_{13} are known. In order to compute the algebraic properites of the photoexcitation matrix elements $A^{P,N}$ $B^{P,N}$ for $(D_{13}|J_{(+)}{}^{e.m.}|\ N)$ it is necessary first to have a hypothesis for the transformation properties of $J_{(+)}{}^{e.m}$ in constituent space. If we suppose that the current acts only on a single quark or, equivalently, that it belongs to an {SU(3), $\underset{\sim}{8}$} part of a $\underset{\sim}{35}$ then the most general form for $J_{(+)}^{e.m}$ is (2)

$$J_{(+)}^{em} \sim E\{\underset{\sim}{35};W=o,W_z=o;\ \Delta\ell_z=+1$$
$$+M\{\underset{\sim}{35};W=1,W_z=1;\ \Delta\ell_z=o\}$$
$$+C\{\underset{\sim}{35};W=1\ W_z=o;\Delta\ell_z=+1\}$$
$$+D\{\underset{\sim}{35},W=1\ W_z=-1;\Delta\ell_z=+2\}$$

This general structure is obtained in Melosh transformation based approaches(3) and also in explicit quark models(4), though in the majority of cases these latter models have restricted their attention to E and M alone(+).

Given this general structure we have three unknowns, E,M,C (the D does not contribute to the D_{13} excitation since this latter has L=1) and so with four amplitudes $A^{P,N}$, $B^{P,N}$ we can obtain one relation independent of E,M,C and depending only upon the group transformation properties of $J^{e.m.}$ and the states. This reads(3)

$$A^N+\frac{1}{3}A^P = \frac{1}{\sqrt{3}}(B^N+\frac{1}{3}B^P) \qquad (1)$$

and is seen to be in good agreement with the data

If we now define $R=C/_E$ then we find two relations

$$B^N = -\frac{1+R/3}{1+R}B^P \qquad (2)$$

$$A^N+\frac{1}{3}A^P = -\frac{2}{3\sqrt{3}}\frac{B^P}{1+R} \qquad (3)$$

and elimination of R between these would recover the single relation eq. 1

If R=1 we find the CRAP relations*(5) of the ^3P_o model while for R=o one obtains the CLOG relations(6) common to <u>any</u> explicit quark model with C=o

From relation (2), which involves only the biggest couplings of this prominent resonance, it seems that R≠o (except maybe DLR and possible uncertainties in nuclear physics for neutron data extraction?) One can't rule out R=1 but, if we were cavalier and ignored error bars we would conclude $\frac{1}{2} \lesssim R \lesssim \frac{2}{3}$.

If we also define μ=M/E we would find for A^P

$$A^P = \frac{E}{6\sqrt{2}}\{\ 1-2\mu-R\ \} \qquad (4)$$

and since $A^P \simeq o$ then we find, roughly, that

$$E:M:C \simeq 4:1:2. \qquad (5)$$

This crude calculation agrees with the computerised fit to the full <u>70</u> plet of resonances by the authors of ref (7) who find

$$E:M:C \simeq 3.85:\ 1\ :\ 1.97$$

These authors would therefore conclude that quark models are inadequate unless a spin-orbit (C) term is included.

Now, in dynamical models in principle one has C≠o if one does not make the traditional assumption that the quark mass is heavy (and most of the model fits suggest that some effective mass of ∿300 MeV is appropriate, so the neglect of C then seems rather odd), nor neglect internal momenta of the quarks in the nucleon.
In particular the work of Bowler should be mentioned in this regard where C≠o in his harmonic oscillator quark model calculations. However, there is a catch: if C≠o then dynamical models necessarily require <u>non-additive</u> interactions on general grounds and the possibility that this is also necessary in the general algebraic approach is discussed by Osborn in these proceedings. In particular these would correspond to non <u>35</u> interactions of the photon.

(+) In the earliest days even M alone.

(*) This acronym for Colglazier Rosner and Petersen is due to Jon Rosner.

Sum Rules

In photoproduction (Q^2=o) the Drell-Hearn-Gerasimov sum rule

$$\frac{2\pi^2\alpha}{M^2} \quad \kappa^2 = \int \frac{d\nu}{\nu} \left[\sigma^{\gamma p}_{\frac{3}{2}}(\nu) - \sigma^{\gamma p}_{\frac{1}{2}}(\nu)\right]$$

clearly requires that

$$\sigma_{\frac{3}{2}} > \sigma_{\frac{1}{2}}$$

for a substantial range of ν (in particular small ν where the dominant weighting of the integrand occurs). Karliner used the MO analysis and found nice saturation of this sum rule by the low energy resonances. It was noted in ref (2) that the 70 plet of states contribute to the sum rule with the right sign if M^2 < EC. This is indeed the case empirically as we saw above and in turn is responsible for Karliner's rapid saturation of the DHG sum rule.

At large spacelike Q^2 there is a sum rule of Bjorken (plus a small assumption[8])

$$\int G_1^{\gamma p}(x)\,dx = \frac{1}{3}\left|\frac{g_A}{g_V}\right|$$

where $G_1(x) \sim \sigma_{\frac{1}{2}} - \sigma_{\frac{3}{2}}$; $x=Q^2/2M\nu$ and so here it seems $\sigma_{\frac{1}{2}} > \sigma_{\frac{3}{2}}$ i.e. the opposite behaviour to that in photoproduction. This requires M^2 > EC at large Q^2. Is this change in spin structure already apparent in the electroproduction data in the resonance region? This will be discussed by Dr. Foster.

Conclusions

The priorities in fitting models to data in the resonance region seem to me to be as follows. First, do the general algebraic properties (e.g. 1-3) work? If the answer is no then no explicit model built within the algebraic framework will work. If the answer is yes then one should go further and try to constrain the dynamical properties (SHO potentials etc.). Places where explicit models have some advantages might be in their ability to take some account of SU(6) breaking effects by relating various N* within a super-multiplet. Also if non 35 interactions are necessary one whould motivate them by an explicit model since to write down the most general interaction would be impossible. Perhaps one should take the quark model, find what are the most important non 35 terms and then discuss the algebraic properties of these terms.

However, we first have to decide whether the general algebraic structure within 35 is adequate and one more place where this should be pursued is in $\pi N \to N\rho$ for which the general structure is contained in ref.2 but for which, to date, only explicit models have been used.[9]

APOLOGY AND REFERENCES

Due to limitations of space I must omit many references which can be found in Ref. 2.

1. See D Lyth, these proceedings.
2. F Close, H Osborn, A Thomson, CERN-TH-1818 (1974).
3. A Hey, J Weyers, Phys. Lett. 48B(1971) 69, F Gilman, I Karliner, Phys. Lett. 46B(1973) 426. (These latter authors have C=0)
4. See ref. 2
5. E Colglazier, J Rosner, Nucl. Phys. B27(1971) 349 W Peterson, J Rosner, Phys. Rev. D7(1973) 747
6. F Close, F Gilman, Phys. Lett. (1972)
7. R Cashmore, A Hey, P Litchfield, CERN- (1974)
8. J Ellis, R Jaffe, SLAC-PUB-1288 (1973)
9. S Meshkov, A Rosenfeld, these proceedings.

DISCUSSION

MORPURGO I differ from your definition of 'quark model calculations'; in these calculations we have several degrees of freedom with the wave functions on the outside and the current operators on the inside. In my opinion the discrepancy between the several ways of looking at things lies in what is written for the current. The Melosh people write it by beginning with a Dirac current and performing a Melosh transformation on it; the 'quark model calculations' are more general: