A COMPARISON OF THE ANGULAR DECAY DISTRIBUTIONS IN THREE QUARK MODELS OF PHOTOPRODUCTION

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The constraints for angular decay distributions of resonances photoproduced in the reactions $\gamma B \to PB^*$, $\gamma B \to VB$, and $\gamma B \to VB^*$ in the "excited quark" model and the "interacting quarks" model, where quark structure is assumed only for baryons, are derived and compared with the corresponding predictions of the usual additive quark model of photoproduction including vector meson dominance and the additivity assumption. All the results of the "interacting quarks" model can be derived from the "excited quark" model and all the results of the "excited quark" model can be derived from the additive quark model.

1. *Introduction*

The purpose of this paper is to give predictions for the angular decay distributions in two quark models assuming quark structure for baryons only, and to compare these results with those obtained from the usual additive quark model of photoproduction including vector meson dominance and the additivity assumption.

We consider the decay distributions of resonances photoproduced in the reactions:

$$\gamma B \to PB^*, \tag{1}$$

$$\gamma B \to VB, \tag{2}$$

$$\gamma B \to VB^* \tag{3}$$

where γ, P, V, B and B^* denote respectively: a photon, a pseudoscalar meson, a vector meson, a $1/2^+$ baryon and a $3/2^+$ isobar.

The models we consider do not assume quark structure for mesons and for the photon. The scattering proceeds *via* direct absorption of a photon and emission of a meson by a single quark according to the graph given in Figure 1.

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The corresponding amplitude A is:

$$A = \sum_{\substack{j \neq i \\ j \neq k}} \langle P(V) q'_k | q_k \rangle \langle q'_i | \gamma q_i \rangle \langle q_j | q_j \rangle \tag{4}$$

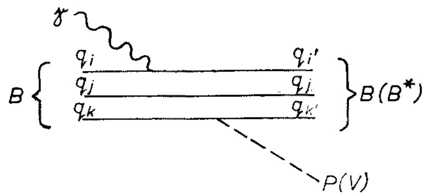

Fig. 1. The interacting quarks model

The sum in formula (4) can be split into an "off diagonal" part and a "diagonal" one:

$$A = \sum_{\substack{i \neq j \neq k \\ i \neq k}} \langle P(V) q'_i | q_i \rangle \langle q'_j | q_j \gamma \rangle \langle q_k | q_k \rangle + \sum_{\substack{i \neq j \neq k \\ i \neq k}} \langle P(V) q'_i | \gamma q_i \rangle \langle q_j | q_j \rangle \langle q_k | q_k \rangle \tag{5}$$

where the diagonal term corresponds to the graph given in Fig. 2.

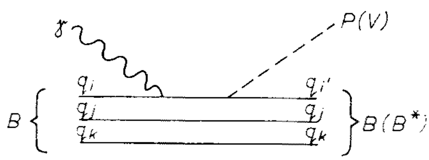

Fig. 2. The excited quark model

The model corresponding to Fig. 2 was proposed by Rubinstein, Scheck and Socolow [1] and independently by Kupsch [2]. It does not require special assumptions on the quark-quark interaction inside the baryon, so we consider it as an independent quark model.

We call the model corresponding to Fig. 1 the "interacting quarks model", and the model corresponding to Fig. 2 the "excited quark model".

Below the predictions for resonance decay distributions for both models are given.

The constraints following from these two models are compared with the results found previously for the usual additive quark model of photoproduction including vector meson dominance for the initial photon together with the additivity assumption

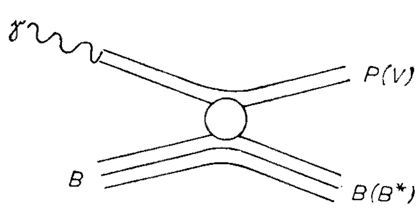

Fig. 3. The additive quark model

for hadron-hadron scattering (*cf.* Ref. [3]). Thus, the amplitudes for high-energy photoproduction are calculated as sums of the quark-quark scattering amplitudes (see Fig. 3). We call this model for shortness the additive quark model.

2. *The constraints on the decay distributions in the excited quark model and in the interacting quarks model*

Here we give the constraints on the angular decay distributions of photoproduced resonances in the excited quark model and in the interacting quarks model, when the photon interacts directly with each individual quark from the target.

The results are presented in terms of the transversity statistical tensors [4].

The excited quark model and the interacting quarks model give only predictions equivalent to class (a) relations according to the classification given by Białas and Zalewski [5]. The constraints following from these models coincide with those obtained from the additive quark model. The results are presented in Tables I–III.

TABLE I

Comparison of the angular decay distributions in three quark models for the process $\gamma B \to PB^*$

$\gamma B \to BP^*$

	Class	Additive quark model, Ref. [6a]	Excited quark model	Interacting quarks model
$\gamma\perp$:	(a)	$T_2^2 = 0$	yes	no
		$T_0^2 = -\frac{1}{2}$	yes	no
$\gamma^{\parallel}$:	(a)	$T_0^2 = \frac{1}{4}$	yes	no
	(c)	$\mathrm{Re}\ T_2^2 = -\frac{\sqrt{6}}{8}$	no	no
		$\mathrm{Im}\ T_2^2 = 0$	no	no

TABLE II

Comparison of the angular decay distributions in three quark models for the process $\gamma B \to VB$

$\gamma B \to VB$

	Class	Additive quark model, Ref. [6b]	Excited quark model	Interacting quarks model
$\gamma\perp$:	(c)	$\mathrm{Im}\ T_2^2 = 0$	no	no
$\gamma^{\parallel}$:	(a′)	$\mathrm{Re}\ T_2^2 = \frac{\sqrt{6}}{2} T_0^2$	no	no

TABLE III

Comparison of the angular decay distributions in three quark models for the process $\gamma B \to VB^*$

$\gamma^{\perp} B \to VB^*$				$\gamma^{\parallel} B \to VB^*$				$\gamma^{u} B \to VB^*$			
Class	Additive quark model Ref. [6b]	Excited quark model	Interacting quarks model	Class	Additive quark model Ref. [6b]	Excited quark model	Interacting quarks model	Class	Additive quark model Ref. [6b]	Excited quark model	Interacting quarks model
(a)	$T^{20}_{00} = \sqrt{2}\, T^{02}_{00}$	yes	no	(a)	$T^{22}_{20} = -T^{20}_{20}$	yes	yes	(a′)	$T^{20}_{00} = \frac{2}{\sqrt{6}} \operatorname{Re} T^{20}_{20}$	no	no
	$T^{22}_{20} = \frac{1}{2} T^{20}_{20}$	yes	no		$T^{22}_{02} = -\sqrt{2}\, T^{02}_{02}$	yes	yes				
	$T^{22}_{02} = \frac{1}{\sqrt{2}} T^{02}_{00}$	yes	no		$T^{22}_{22} = 0$	yes	yes		$T^{22}_{00} = \frac{2}{\sqrt{6}} \operatorname{Re} T^{22}_{20}$	no	no
					$T^{22}_{2-2} = 0$	yes	yes				
	$T^{22}_{00} = \frac{1}{2\sqrt{6}} - \frac{1}{\sqrt{2}} T^{02}_{00}$	yes	no		$T^{22}_{00} = -\frac{1}{2\sqrt{6}}$	yes	no		$T^{22}_{22} + (T^{22}_{2-2})^* = \sqrt{6}\, T^{22}_{02}$	no	no
									$T^{22}_{11} = (T^{22}_{1-1})^*$	no	no
(b)	$T^{20}_{20} = -\sqrt{2}\, T^{02}_{02}$	no	no		$\sqrt{2}\, T^{02}_{00} + T^{20}_{00} = -\frac{1}{2\sqrt{6}}$	yes	no				
	$T^{22}_{20} = -T^{22}_{02}$	no	no								
	$\operatorname{Im} T^{22}_{2-2} = 0$	no	no	†	$T^{22}_{00} + T^{20}_{00} + \sqrt{2}\, T^{02}_{00} = -\frac{1}{\sqrt{6}}$	yes	yes				
	$\operatorname{Re} T^{22}_{1-1} = 0$	no	no								
(c)	$\operatorname{Im} T^{20}_{20} = \operatorname{Im} T^{02}_{02} = 0$	no	no								
	$\operatorname{Im} T^{22}_{22} = \operatorname{Im} T^{22}_{20} = 0$	no	no	(c)	$\operatorname{Im} T^{02}_{02} = \operatorname{Im} T^{22}_{02} = 0$	no	no				
	$\operatorname{Im} T^{22}_{02} = 0$	no	no		$T^{22}_{11} = T^{22}_{1-1}$	no	no				
	$\operatorname{Re} T^{22}_{11} = 0$	no	no								
	$T^{22}_{00} - T^{22}_{22} - T^{22}_{2-2} = \frac{1}{\sqrt{6}}$	no	no		$T^{02}_{00} + \sqrt{2}\, T^{20}_{00} + \sqrt{6}\, T^{02}_{02} = 0$	no	no				

† Obtained by combining the two previous relations

For comparison we list all results obtained from the usual additive quark of photoproduction (*cf.* Ref. [6]) and indicate by "yes" those which also follow from the excited quark model and those which follow from the interacting quarks model. The absence of predictions is marked by "no". Symbols $\gamma^{\perp}$ and $\gamma^{\parallel}$ mean polarization of the initial photon normal and parallel to the scattering plane while γ^{u} means an unpolarized photon. Symbols (a), (a′), (b) and (c) indicate the relations belonging to the classes (a), (a′), (b) and (c), respectively. We recall that the relations of classes (a) and (a′) are derived from the additivity assumption for quark-quark amplitudes only (relations of class (a′) exist only for the photoproduction of vector mesons and have no covariant properties in contrast to the regular class (a) relations [6b]); the relations of classes (b) and (c) need additional assumptions about the quark-quark amplitudes.

3. The comparison of the predictions on the decay distributions following from the different quark models of photoproduction

In the additive quark model we have the following predictions on the angular decay distributions (*cf.* Ref. [6]): for the process (1) the relations of classes (a) and (c), for the process (2) the relations of classes (a′) and (c) and for the process (3) the relations of classes (a), (a′), (b) and (c) in the classification given in the Refs [5–6]. In the additive quark model all linear relations between the single and joint statistical tensors for the resonances photoproduced by linearly polarized photons are derived in the cases when photons are polarized perpendicular and parallel to the scattering plane; the consideration of the other kind of linear polarization of the initial photon gives no new predictions.

The excited quark model reproduces all the relations of class (a) obtained from the additive quark model.

The interacting quarks model gives only a few of the class (a) predictions of the excited quark model.

The additive quark model predictions on the decay distributions were compared with experimental data [7], [6a] for the processes (1) and (2). All relations are satisfied by the existing data[1]. The data for double resonance production processes (3) are not yet available.

4. Conclusions

The number of predictions on the angular decay distributions following from the excited quark model and the interacting quarks model, described in the Figs 2 and 1, is much smaller than the number of relations following from the quark model of photoproduction including the assumption of vector meson dominance and the additivity

[1] The additive quark model relation for the process (2) induced by unpolarized photons (see Table II) reads as $\varrho_{1-1} = 0$ in the frame with quantization axis in the reaction plane. The data from Ref. [8] suggest that this relation is satisfied in the helicity frame.

assumption. All constraints of the excited quark model and the interacting quarks model are also given by the additive quark model.

The additive quark model predictions were checked for the single statistical tensors for the following processes: $\gamma p \to \pi^- \Delta^{++}$, $\gamma p \to \varrho^0 p$ and $\gamma p \to \omega^0 p$ and all predictions are confirmed by the data (relation of class (a′) in the helicity frame while relations of class (c) in the Donohue-Høgaasen frame [9]). There are no experimental data for the joint statistical tensors. In this way we have no good reason to discard the relations of classes (a′), (c) and (b).

Thus we see that from the three compared quark models of photoproduction, the additive quark model gives more constraints on the decay distributions of the photoproduced resonances than the excited quark model, next the excited quark model gives more constraints than the interacting quarks model.

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