CONSTRAINTS ON THE SPIN SYSTEM FOR TWO-BODY REACTIONS

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The quark additivity and a class of geometrical hypotheses concerning the spin dependence in two-body processes are found to be compatible and consistent with experiment only when taken in the same spin frame.

In recent papers [1] we investigated two-body processes using two basic phenomenological assumptions: the b-universality [2] and the additivity assumption. We were dealing with a class of reactions of the type

$$0^- \tfrac{1}{2}^+ \to J^P \tfrac{3}{2}^+,$$

(J^P is the spin and parity of the outgoing meson) which is especially convenient to study from the quark model point of view. The compatibility of both assumptions focused our attention on the spin reference frame in which the hypotheses should be formulated. Its choice is not a question of convention but an integral part of the assumptions. In the quark model it is recognized by the requirement that the noninteracting quarks do not change their spin projections during the scattering. (The spin flip is produced in a process by the quarks which take part in the scattering.)

The b-universality states that the helicity amplitudes in the impact parameter representation are described by a common spin independent function of c.m. energy s and impact parameter b. This conjecture implies derivative relations between the net spin flip amplitudes $T_n(s, t)$ (n is the net spin flip and t — momentum transfer)

$$T_{n'}(s, t) = a_{n'n}(s)\sqrt{-t'}^{\,n'}\left(\frac{1}{\sqrt{-t'}}\,\frac{\partial}{\partial\sqrt{-t'}}\right)^{n'-n} T_n(s, t).$$

Although the physical motivation for it is rather unclear the hypothesis was found [3] to work very well in various processes. Whereas there are hints [4] that the quark model

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should be constructed in the Gottfried–Jackson frame, there is nothing fundamental in assuming the b-universality in the helicity frame (as it has always been done). We supported the last conjecture by performing a model independent test of the b-universality in a frame different than helicity. The test showed that the Gottfried–Jackson frame is a good spin-system for the b-universality as well.

The main statement which was derived in Ref. [1] is that the hypotheses should be formulated in the same spin frame. It means that the additivity and b-universality frames coincide whatever this common spin system is (helicity, Gottfried–Jackson or others). This theorem follows from the comparison of the data with the obtained constraints on the amplitudes and density matrix elements made for $J^P = 0^-$ and 1^-. The agreement is very good in the case of two coinciding frames whereas impossible to reach when the models are formulated in two different frames. The analysis does not answer which common spin system is preferred.

In this paper we investigate the problem to what extend our previous results depend on the details of the assumed hypotheses. This concerns especially the b-universality where there does not exist any clear picture standing behind the formalism as is the case in the additive quark model. Actually various forms of the b-universality may be found in the literature [5]. This may be regarded as a warning against an excessive trust in one particular form of the hypothesis.

In the following we limit our attention to the process

$$0^-\tfrac{1}{2}^+ \to 1^-\tfrac{3}{2}^+,$$

where a comparison with the data is possible.

In attempt to enlarge the scope of hypotheses we assume only, beside the additivity, that the amplitudes with equal net spin flip $n = |\lambda_a - \lambda_b - \lambda_c + \lambda_d|$ (λ_i is the spin projection of i-th particle) behave in the same way as functions of the momentum transfer. This statement is common to all versions of the b-universality. Actually it was known and tested separately much earlier [6]. Under such conditions we are able to prove immediately two of the theorems derived in Ref. [1]. They concern the case when the additivity and b-universality frames do not coincide. (The exact form of the condition is

$$\vartheta_B - \vartheta_{B*} \neq 2k\pi, \qquad k = 0, \pm 1, \pm 2, \ldots \tag{1}$$

where $\vartheta_B(\vartheta_{B*})$ is the rotation angle of the spin projection axis of the baryon $\frac{1}{2}^+ (\frac{3}{2}^+)$ from the additivity to the b-universality frame.) The first states that all amplitudes with even/odd spin flip are the same functions of the momentum transfer. The second which has important experimental consequences puts constraints on the density matrix elements of the vector meson in the b-universality frame

$$\mathrm{Re}\, \varrho_{10} = \mathrm{const}, \qquad \varrho_{11} + \varrho_{1-1} = \mathrm{const}. \tag{2}$$

The proof is straightforward and goes by expressing the density matrix elements in terms of the quark model amplitudes and using the previous theorem. Whereas the first relation

(2) can be easily satisfied experimentally by choosing an appropriate b-universality frame the second one was checked [1] to be badly broken in several processes.

On the contrary neither of the mentioned theorems need not be valid when Eq. (1) does not occur.

Thus, although our assumptions are much weaker the main statement of Ref. [1] is still valid: The additivity and b-universality frames fulfill the relation

$$\vartheta_B - \vartheta_{B^*} = 2k\pi, \quad k = 0, \pm 1, \pm 2, \ldots$$

This includes the case of coinciding spin systems. We stress the possibility of a common spin frame as being particularly interesting in the quark model. It allows us to apply various geometrical hypotheses (containing identical behaviour of spin amplitudes with equal spin flip) to the quark scattering amplitudes directly. This could be a significant simplification in the analysis of two-body processes.

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