DETERMINATION OF THE K*-MESON SPIN

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A possible method for the determination of the spin of the K*-particle is analyzed, on the basis of the production of (K, $\bar{K}$*) or ($\bar{K}$, K*) pairs in colliding electron-positron beams.

AFTER the discovery of the K*-meson [1,2] with a mass of 885 MeV and isospin T = 1/2, several methods for the determination of its spin have been proposed [3-5]. Since vector mesons with strangeness S = ± 1 and isospin 1/2 have been predicted on the basis of the hypothesis of unitary symmetry [6], the determination of the spin of the K* is of special interest. In this note we consider a method for determining the spin of the K* (if its value is zero or one), on the basis of a study of the production of ($\bar{K}$, K*) or (K, $\bar{K}$*) pairs in colliding electron-positron beams, of the kind for which the possible experiments have been widely discussed in recent times [7,8].

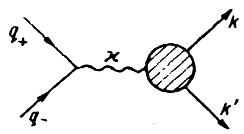
The matrix element for the process

$$e^+ + e^- \to \bar{K} + K^*(K + \bar{K}^*) \tag{1}$$

has the following expression in the one-photon approximation (cf. figure):

$$S(k, k'; q_+, q_-) = -(2\pi)^4\, i\delta(q_+ + q_- - k - k')\,(m_e^2/E_+E_-)^{1/2} \times ie\bar{v}(q_+)\gamma_\mu u(q_-)\varkappa^{-2}\langle kk'|j_\mu(0)|0\rangle. \tag{2}$$

Here k and k′ are the 4-momenta of K($\bar{K}$) and K*($\bar{K}$*), respectively, q_+ and q_- are the 4-momenta of the positron and electron respectively, $\kappa = q_+ + q_-$ is the total 4-momentum, and j_μ is the current-density operator of the strongly interacting particles in the Heisenberg picture.



The relative parity of K and K* is $P = -(-1)^s$, where s is the spin of the K* meson (parity conservation in the process K* → K + π). Therefore the matrix element of the current in Eq. (2) is an axial vector, independently of the spin of the K*.

If the spin of the K* is zero we have only two vectors at our disposal (the momenta k and k′) out of which it is impossible to construct an axial vector. Therefore the matrix element of the current vanishes and the production of a spinless K* is forbidden for the process (1) in the one-photon approximation. For spin 1 there is also the polarization vector e of the K* meson in addition to the two momentum vectors. The process (1) is allowed and the matrix element of the current can be written in the form

$$\langle kk'|j_\mu(0)|0\rangle = (2k_0 2k_0')^{-1/2}\, ia(\varkappa^2)\,\varepsilon_{\mu\nu\rho\sigma}e_\nu k_\rho k'_\sigma, \tag{3}$$

where the formfactor $a(\kappa^2)$ is determined by the strong interactions. It is easy to see that this expression automatically satisfies the condition

$$(k + k')_\mu \langle kk'|j_\mu(0)|0\rangle = 0, \tag{4}$$

implied by current conservation. As a consequence of the transformation properties of the current operator under charge conjugation the final state is odd with respect to C and has the form

$$K\bar{K}^* - \bar{K}K^*. \tag{5}$$

Therefore the cross sections for the production of (K^+, K^{*-}) and (K^- K^{*+}) pairs are equal. In the case of production of neutral K mesons the K_1^0(K_2^0) will appear together with the K_2^0(K_1^0) from the decay of the K^{*0}. From Eqs. (2) and (3) we obtain the following expression for the cross section

$$d\sigma = \frac{\alpha}{64}|a(\varkappa^2)|^2(1 + \cos^2\theta)\frac{|\mathbf{k}|^3}{E^3}\sin\theta\, d\theta, \tag{6}$$

where $E = E_+ = E_-$, θ is the angle between the momenta q_- and **k** and

$$|\mathbf{k}| = [16E^4 - 8(M^2 + M'^2)E^2 + (M'^2 - M^2)^2]^{1/2}/4E,$$

where M and M′ are the masses of the K and K* respectively.

The probability of the decay K* → K + γ is

$$\frac{1}{\tau} = \frac{1}{96\pi}\left(\frac{M'^2 - M^2}{M'}\right)^3 |a(0)|^2. \tag{7}$$

Combining (6) and (7) we obtain the expression for the total cross section

$$\sigma = 4\pi\alpha \frac{M'^3}{(M'^2 - M^2)^3} \frac{1}{\tau} \left| \frac{a(\varkappa^2)}{a(0)} \right|^2 \frac{|\mathbf{k}|^3}{E^3}. \quad (8)$$

In order to get an estimate, suppose the width of the radiative decay of the K* to be 1% of the width of the principal decay mode into a K and pion (16 Mev); then

$$\sigma = 2{,}5 \cdot 10^{-32} \left| \frac{a(\varkappa^2)}{a(0)} \right|^2 \frac{|\mathbf{k}|^3}{E^3} \text{ cm}^2.$$

Therefore a peak in the spectrum of K-mesons (charged or neutral—the result is the same), with position and width corresponding to the production of a pair of K*-K, will indicate that the spin of the K* is one.

In conclusion we note that the considered method is based on the one-photon approximation. For energies above the threshold of reaction (1) the interference of the matrix element (2) with the matrix element of two-photon exchange can become important. This is, however, irrelevant for our main conclusion, since for the case of spin 0 there can be no interference and the hindrance in the production of K* is lifted only in the order α^4. In the case of spin 1 radiative corrections may modify the form of the angular distribution (6). If, however, both the K and the $\overline{\text{K}}$ are observed at a fixed angle, the interference disappears [7] and in this case the angular distribution (6) holds true up to terms of order α^3.

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Note added in proof (December 10, 1962). Recent experimental indications have appeared[9] in favor of spin 1 for the K*.

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