SOVIET PHYSICS JETP VOLUME 15, NUMBER 3 SEPTEMBER, 1962

Letters to the Editor

CONCERNING ONE POSSIBILITY OF DETERMINING THE MAGNETIC MOMENTS OF UNSTABLE VECTOR PARTICLES

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Submitted to JETP editor December 9, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **42**, 905-906 (March, 1962)

IT was noticed in the first articles devoted to the investigation of photoproduction of vector mesons in the Born approximation (see, for example, [1]) that the cross section for this process must have a sharp maximum for the angle $\theta = 0$, and must increase with photon energy k like k^2. It is easy to understand these properties on the basis of a simple semiclassical consideration, according to which the probability for the process is proportional to the interaction energy of the photon with the meson:

$$(ev\mathbf{A} + \mu \,\mathrm{rot}\,\mathbf{A})^2/(1 - v\cos\theta)^2; \qquad (1)^*$$

here e and μ denote the charge and magnetic moment of the meson, **A** is the vector potential of the electromagnetic field. The denominator indicates the effect of retardation. The noted rules and the extreme sensitivity of the cross section to the magnitude of the meson magnetic moment follow immediately from Eq. (1).

In previous articles, the vector meson photoproduction cross sections were obtained on the basis of perturbation theory, which is not valid for the calculation of strong interaction processes. However, the striking regularities which have been noted are entirely related to the peripheral part of the amplitude for the process, which can be calculated using perturbation theory (diagrams of the type shown in Fig. 1). Isolating the peripheral part gives the possibility of demonstrating the vector nature of certain unstable particles and of determining their anomalous magnetic moments. The purpose of the present communication is a discussion of these possibilities.

We have considered cases of photoproduction of the following unstable particles whose spin, according to hypotheses discussed in the literature, may possibly be unity: K′ particles ($K\pi$ resonance[2]) and bi-pions ($\pi\pi$ resonance[3]).

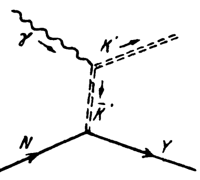

FIG. 1

The cross section for the photoproduction of K'^+ by a proton has the form

$$\frac{d\sigma}{d\Omega} = \frac{e^2 f^2}{(8\pi)^2}\frac{q}{k}\frac{F_1 g^2 + F_2 g + F_3}{E^2 (x + m^2)^2} + B. \qquad (2)$$

Here the first term is caused by a diagram of the type shown in Fig. 1, and the term B contains the central collision amplitude (the calculation of which is not possible at the present time) and the interference term, f is the K′NY interaction constant, g is the gyromagnetic ratio, q the meson momentum, k the photon momentum $x = (\mathbf{k} - \mathbf{q})^2 - (k^0 - q^0)^2$, E is the total energy in the center of mass system, m the mass of the meson, and the functions F_1, F_2, and F_3 are given by

$$\begin{aligned}
F_1 &= (E^2 - M_N^2)(E^2 - M_N^2 - m^2 - x) + \tfrac{1}{4} m^{-2} x (x + m^2)^2 \\
&+ \tfrac{1}{2} m^{-2} q^2 \sin^2\theta (E^2 - M_N^2)^2 \\
&+ \tfrac{1}{2} m^{-2} (M_Y^2 - M_N^2)(2E^2 - 2M_N^2 - m^2 - x) \\
&\times (x + m^2) + \tfrac{1}{4} m^{-4} (M_Y - M_N)^2 \\
&\times (x + m^2)^2 [x + 3m^2 + (M_N + M_Y)^2], \\
F_2 &= -m^{-2} q^2 \sin^2\theta (E^2 - M_N^2)(2E^2 - 2M_Y^2 - m^2 - x) \\
&- m^{-2} (M_Y^2 - M_N^2)(2E^2 - 2M_N^2 - m^2 - x) \\
&\times (m^2 + x + q^2 \sin^2\theta) - m^{-4} (M_Y - M_N)^2 \\
&\times (x + m^2)^2 [x + m^2 + (M_Y + M_N)^2], \\
F_3 &= 2m^{-2} q^2 \sin^2\theta [(E^2 - M_Y^2)(E^2 - M_Y^2 - m^2 - x) \\
&+ 2m^2 (x - 2M_Y M_N)] + (M_Y^2 - M_N^2) \\
&\times (E^2 - M_Y^2) \cdot 4m^{-2} q^2 \sin^2\theta + (M_Y - M_N)^2 \\
&\times \{2m^{-2} q^2 \sin^2\theta [m^2 + 2(M_Y + M_N)^2] \\
&+ m^{-4} (x + m^2)^2 [x + (M_Y + M_N)^2]\}. \qquad (3)
\end{aligned}$$

The parity of the K′ relative to Y and N was assumed to be positive. The cross section for bi-pion production reactions can be obtained from Eqs. (2) and (3) if the baryon masses in the initial and final states are assumed equal and the coupling constant, and also g and m, are replaced; furthermore, F_2 and F_3 are assumed to vanish for neutral particles.

Other features with respect to momentum transfer are not explicitly taken into account in Eq. (2) and the formulas derived from it. We carried out

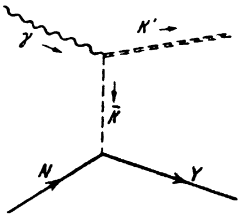

FIG. 2

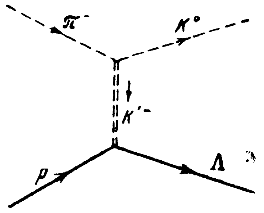

FIG. 3

a special investigation of the contribution due to a diagram of the type shown in Fig. 2, when not a vector but a pseudoscalar particle (respectively a K or π meson) is present in the intermediate state. The contribution of this diagram proved to be considerably less than the contribution explicitly isolated in Eq. (2) for the same unfavorable values of the coupling constants.† The coupling constant f was estimated from experimental data on the reaction $\pi^- + p \rightarrow \Lambda + K^0$ under the assumption that the diagram shown in Fig. 3 is responsible for this reaction. The coupling constant $f_{K'K\pi}$ was estimated on the basis of data concerning the width of the $K\pi$ resonance. A magnitude ~ 2 was obtained as the result for f^2. For this value of f^2 with k = 4BeV, $\theta = 0$ and the anomalous part of the magnetic moment equal to zero, the first term in Eq. (2) amounts to 10^{-31} cm^2/sr. For $\theta = 30°$ this term decreases by a factor of two. It is possible to use the standard method of separating out the pole part, which was developed (see, for example, [4]) for the analysis of nucleon-nucleon scattering data, for a determination of the product f^2g^2 from experimental data; the quantity B depends slightly on θ.

Thus, a measurement of unstable particle photoproduction cross sections in the region of small angles seems extremely desirable to us.

The authors express their gratitude to Professor M. A. Markov for his interest in the work.

*rot = curl.

†It is also necessary to note that the amplitude corresponding to this diagram does not interfere with the principal pole diagram.

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Translated by H. H. Nickle
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RADIATION OF MOLECULES UNDER RESONANT CONDITIONS

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Submitted to JETP editor December 30, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **42**, 907-908 (March, 1962)

We report briefly the results of an investigation of the effects of radiation in the coherent field of a beam of molecules in a mixed energy state. A two-quantum system in a mixed state is described by the function

$$\psi = a\psi_1 + b\psi_2,$$

with $|a|^2 + |b|^2 = 1$. When a molecule beam in such a state enters a cavity tuned to the transition frequency $h\nu_{12} = E_1 - E_2$, it will continue to radiate [1,3] in spite of the fact that the number of molecules in upper and lower energy levels is the same. In the ordinary case the expression for $|a(t)|^2$ can be represented in the form [4]

$$|a(t)|^2 = \frac{(\mu E/h)^2 \sin^2\{\pi t\,[(\nu-\nu_0)^2 + (\mu E/h)^2]^{1/2}\}}{(\nu-\nu_0)^2 + (\mu E/h)^2},$$

where μ is the dipole moment and E is the intensity of the resonant field of frequency ν, close to the frequency of the molecular transition $\nu_0 = \nu_{12}$.

A mixed quantum state can be obtained in an ammonia molecule beam at the output of the cavity of an ordinary maser. It is customary to assume that when saturation is reached in the output beam, i.e., when the population of both levels is the same and $N_2 - N_1 = 0$, the beam becomes inactive and can radiate spontaneously only incoherent oscillations. In the papers cited it was shown that when a molecule beam enters the second cavity, the molecules emit electromagnetic radiation at the frequency of the first cavity, regardless of the tuning of the second cavity. This phenomenon was called a "molecular bell" or "preliminary induction." [3,4]

To investigate the properties of such radiation, we constructed a maser comprising a NH_3-beam spectroscope with three cascaded cavities, the first of which was in the ordinary maser mode. The frequency ν_2 of the radiation in the second cavity was quite monochromatic (as in an ordinary maser) and coincides with the radiation frequency in the first cavity accurate to better than 10^{-12}.

The radiation power in the second and third cavities was investigated as a function of the settings of the first and second cavities, of the voltage on the sorting system, and of the pressure of