$r_\pi(t_2)$ corresponding to the remaining variants lie inside the region bounded by curves 1 and 2. It is interesting to note that the set $k_{(0)}$, m_ρ, $\Gamma_{(0)}$, $m_{(0)}$ (see curve 3 of Fig. 2) turns out in this case to be quite compatible, and the set $k_{(-)}$, m_ρ, $\Gamma_{(-)}$, $m_{(+)}$, as in the single-resonance approximation, yields the largest values of $r_\pi(t_2)$ (see curves 1 of Figs. 1 and 2). Consequently, if further experiments confirm the data [6] concerning the width and the height of the ρ peak, then, from this point of view, this will be a strong argument favoring the existence of a heavy ρ meson (of course, if the assumption that there are no complex zeroes of G(t) is valid.

5. For a further clarification of the situation it would be desirable to obtain more accurate data on $|G(m_\rho^2)|$ and Γ, and also additional information on G(t) at $t \sim -0.12$ GeV^2, since the results of [2], and [7], pertaining to this point are essentially different.

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VECTOR DOMINANCE AND PRODUCTION OF $\pi^\pm$ MESONS BY POLARIZED PHOTONS AT HIGH ENERGIES

N. N. Achasov and G. N. Shestakov
Mathematics Institute, Siberian Division, USSR Academy of Sciences
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The connection between pion photoproduction on nucleons and the production of vector mesons in πN collisions has been under intense investigation of late on the basis of the vector dominance model (VDM).

The VDM predictions for $\pi^\pm$-meson production by polarized photons are usually written, excluding the ωρ interference and neglecting the φ-meson contribution, in the form [1, 2]:

$$A = \frac{\sigma_\perp^+ + \sigma_\perp^- - \sigma_\parallel^+ - \sigma_\parallel^-}{\sigma_\perp^+ + \sigma_\perp^- + \sigma_\parallel^+ + \sigma_\parallel^-} = \frac{g_{\gamma\rho}^2\,\sigma_{1-1}^\rho + g_{\gamma\omega}^2\,\sigma_{1-1}^\omega}{g_{\gamma\rho}^2\,\sigma_{11}^\rho + g_{\gamma\omega}^2\,\sigma_{11}^\omega} \approx \frac{\sigma_{1-1}^\rho}{\sigma_{11}^\rho} = \frac{\rho_{1-1}^\rho}{\rho_{11}^\rho}, \qquad (1)$$

where $\sigma_\perp^\pm$ and $\sigma_\parallel^\pm$ are the differential cross section for $\pi^\pm$-meson photoproduction by photons that are polarized perpendicular and parallel to the reaction plane, respectively; $2\sigma^\pm = \sigma_\perp^\pm + \sigma_\parallel^\pm$; $\sigma_{ij}^v = \sigma_{ij}^v\sigma^v$, where σ_{ij}^v are the elements of the spin density matrix of the vector meson, σ^v is the differential cross section of the process $\pi^- p \to V^0 n$, and $g_{\gamma V}$ is the photon to vector meson transition constant.

The contribution made by the ω meson to A amounts to several per cent [3]. We shall henceforth take into account only the ρ-meson contribution and omit the index v of ρ_{ij}^v.

It was observed in [4] that relation (1) is strongly violated in the c.m.s. However, the VDM predictions formulated in the language of helicity amplitudes are not relativistically invariant and admit of an ambiguous interpretation. The right side of (1) depends on the relativistic transformations of the reference system in the reaction plane, while the left side is invariant under these transformations [5].

Using the ambiguity of the VDM predictions, Bialas and Zalewski [2] have shown that relation (1) can be satisfied in the Donohue and Hogaasen [6], in which Re $\rho_{10} = 0$ and ρ_{1-1}/ρ_{11} is maximal.

The choice of the reference frame to check the VDM predictions is very important, for it makes it possible in principle to ascertain which combinations of invariant amplitudes satisfying the Mandelstam representation are independent of the vector-meson mass [5], or if they do depend on it, in what manner.

We wish to note here the following fact: Contemporary experimental data allow us to state that for each 4-momentum transfer (t) there is a reference frame in which relation (1) is satisfied. It should not be concluded that (2) is satisfied in the Donohue-Hogaasen system.

Indeed, when the ρ-meson spin-matrix elements measured experimentally in the Gottfried-Jackson system [7], which are subject to large errors, are recalculated to the Donahue-Hogaasen system, the central question is the correct allowance for the errors [6]. To get around this difficulty, we use Regge models for the ρ-meson production; these describe well the experimental data and predict accurately the maximum value of A, which equals unity. The experimental data on ρ-production in a broad range of energies are well described by models with exchange of π, ω, A_2 and π, π_c, ω, A_2 Regge-poles [8, 9]. We shall use these models and the obtained result will be true for both. It is easy to verify that the maximum and minimum value of ρ_{1-1}/ρ_{11} is reached in two systems in which Re $\rho_{10} = 0$. These systems are rotated through $\pi/2$ relative to each other in the reaction plane. Here

$$\max A = (\beta - \alpha)/(\beta + \alpha), \qquad \min A = (\beta - \gamma)/(\beta + \gamma),$$

where

$$\beta = \rho_{11} + \rho_{1-1}, \quad \alpha = \frac{1}{2}(1 - \beta - \delta), \quad \gamma = \frac{1}{2}(1 - \beta + \delta), \tag{2}$$

$$\delta = [(\rho_{00} - \rho_{11} + \rho_{1-1})^2 + 8(\mathrm{Re}\rho_{10})^2]^{1/2}, \qquad \alpha + \beta + \gamma = 1;$$

$$\alpha,\ \beta,\ \gamma \geqslant 0 \ [6].$$

In the expressions for α, β, and γ, use is made of the ρ-meson spin density matrix in the Gottfried-Jackson system. In the aforementioned Regge pole models for the $\pi N \to \rho N$ reaction with one pole of unnatural parity, referred to above, the following relation exists between the ρ_{ij} in the Gottfried-Jackson system [10]:

$$\rho_{00}(\rho_{11} - \rho_{1-1}) = 2(\mathrm{Re}\rho_{10})^2, \tag{3}$$

Then $\alpha = 0$ and

$$\max A = 1, \quad \min A = 2\beta - 1 = 2(\rho_{11} + \rho_{1-1}) - 1. \tag{4}$$

Experiments on ρ^0 production [8] indicate that min $A \leq 0$ when $0.02 \leq |t|.(c/\mathrm{GeV})^2 \leq 0.4$. Thus, the contemporary experimental data for A from the ρ^0-production can be reconciled with the data from the photoproduction for each value of $|t|$ in the indicated interval by transforming the reference frame in the reaction plane.

In a quite recent paper [11] Harari and Horovitz conclude, on the basis of a theoretical and experimental analysis of the photoproduction and of the results of [2] for max A (max A ≤ 0.5) from ρ-production, that the VDM predictions for A should be violated when $|t| = \mu^2$ (μ is the pion mass). They predict for photoproduction $A \approx 1$ at $|t| = \mu^2$. However, as shown by us, A = 1 does not contradict the data on ρ-meson production.

We note that if we assume the ρ, B Regge-pole model for the ω-production, then the conclusion for max A remains unchanged when account is taken of the ω-meson contribution.

It must be borne in mind, of course, that relation (3) is satisfied in the models under consideration already at not too small $|t|$. However, with increasing laboratory energy, (3) is satisfied for ever decreasing $|t|$. In practice, expressions satisfying (3) are obtained for ρ_{ij} already at 3 GeV, starting with $|t| \approx \mu^2$.

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NEW POSSIBILITY OF EXPLAINING THE COMPLEX FORM OF THE ENERGY SPECTRUM OF ULTRAHIGH ENERGY PRIMARY COSMIC RAYS

G. V. Kulikov, Yu. A. Fomin, and G. B. Khristiansen
Nuclear Physics Research Institute of the Moscow State University
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It can now be regarded as finally established that at energies $E \sim (2 - 4) \times 10^{15}$ eV the exponent of the energy spectrum of primary cosmic radiation increases from a value $\gamma = 1.6 - 1.7$ at $E < 10^{15}$ eV to a value $\gamma = 2.3 - 2.4$ at $E > 10^{16}$ eV [1 - 7]. Numerous experimental data indicate also that this exponent subsequently decreases back to $\gamma = 1.6 - 1.7$ at $E \gtrsim 10^{17} - 10^{18}$ eV [7 - 12]. Until recently, this result was considered in a natural fashion within the framework of the diffusion picture of cosmic-ray propagation in our galaxy, and the superposition of cosmic rays of galactic and metagalactic origin [7, 13, 14]. It became clear of late, however, that during the course of the interaction between the 3°K relict radiation and the cosmic rays the energy of the latter decreases, and a sharp cutoff of the energy spectrum sets in starting with an energy $\sim 3 \times 10^{19}$ eV [15, 16]; this apparently contradicts the available preliminary experimental data [17]. According to [18] there can exist in the universe also infrared radiation with temperature 8°K, leading to an earlier cutoff of the energy spectrum (at $\sim 10^{19}$ eV) and to a still greater discrepancy with experiment. It is therefore time to examine other possible models for the origin of ultrahigh-energy cosmic rays, such that the cosmic-ray propagation time from the source to the earth is much shorter