Production of new particles in hadron-hadron collisions

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(Submitted April 29, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **23**, No. 11, 664–667 (5 June 1976)

The mechanism of ψ-particle production is considered within the framework of the quark-parton model. It is shown that at medium energies the valent quarks play the principle role in the ψ-meson production. The Zweig constant, which is needed for reconciliation with the experimental data on the production, turns out to be larger than the value obtained for the constant from decay data. Possible causes of this disparity are indicated.

PACS numbers: 12.40.Dd, 13.80.Kp, 14.40.−n

An investigation of the properties of the ψ mesons indicates that this resonan has most likely a hadronic character.[1] An examination of the production of th ψ particle in hadron-hadron collisions within the framework of the Drell-Yan parton model[2] leads to the conclusion that the main mechanism is the one wherein the ψ is made up of ordinary quarks. This explains the broad distribution of the ψ particle with respect to the longitudinal momentum (see Fig. 1), as observed in pp collisions at 70 GeV/c,[3] as well as the observed increase of the production cross section and the excess in the region of large $x \approx 0.6$ in meson-baryon collisions as compared with pp collisions. The mechanism whereby the ψ is produced from the sea of charmed quarks leads to a narrow distribution in the longitudinal momentum, strongly contradicting the experimental data. The resultant constant corresponding to the transition of the ordinary quarks into charmed ones is $q_z^2/4\pi \approx 8\times 10^{-4}$, which is larger by one order of magnitude than the value obtained from the ψ decay into ordinary hadrons and estimated at $q_z^2/4\pi \approx 6\times 10^{-5}$.[4]

This fact, that ψ is more strongly coupled with ordinary hadrons in production processes than in decay processes, was already noted earlier.[1]

The sea of charmed quarks in the nucleon (according to our estimates in the framework of the Drell-Yan model) turns out in this case suppressed by ≈ 20 times in comparison with the sea of ordinary quarks, and this affects substan-

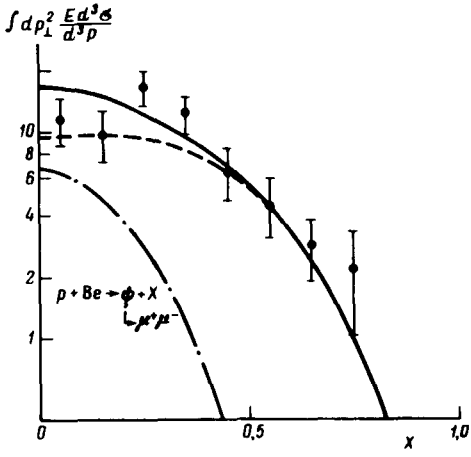

FIG. 1. Inclusive spectrum of ψ resonance in the reaction $p + Be \to \psi + X$ at 70 GeV/c. The spectrum is normalized in arbitrary units. The solid curve is the summary contribution of the ψ production from the "sea" (dash-dot line) and from the annihilation of ordinary quarks (dashed line).

ially the estimates of the cross sections for the production of the hypothetical) mesons (in the region of medium energies we have $\sigma_D/\sigma_\pi \approx 10^{-4}$). We note that vithin the framework of the indicated estimates the relative contribution of the ıssociated production of ψ with charmed particles is small at an energy ≈ 70 ;eV/c and increases with increasing energy (see Fig. 2).

The most popular explanation of the smallness of the constant for the anni-ıilation of charmed quarks into ordinary ones (the Zweig rule) in comparison vith the characteristic strong-interaction constant appears in the quark model vith color.[4] In the ψ decay, a pair of quarks in the colorless state $^3S_1$ can an-ıihilate at least into three gluons.[5] Similar arguments would lead to the same :oupling constant of ψ in production in hadron-hadron collisions. We can at-empt to connect the relatively large constant in the production with the possible ·escattering of the charmed quarks, with change of color on the "neighbors." ?hen the production could proceed via one or two gluons, and the small quantity :onnected with exchanges of the remaining gluons would not arise, owing to the :mall momentum transfer in the rescattering process. In this case the produc-ion of ψ' (3.7) is perfectly analogous to the production of ψ, and should have :lose cross-section values, whereas the observed yield ratio $\sigma_{\psi'}/\sigma_\psi$ does not :xceed 0.05 at 400 GeV/c.[6]

So small a value of the ratio $\sigma_{\psi'}/\sigma_\psi$ and the large constant in the ψ production :an then be understood by assuming that the ψ particle is produced following the lecay of one of the large-mass states whose production is not suppressed by he three-gluon mechanism. Such a state can be one of the states observed at)ESY and SLAC.[7] From the results of the SLAC experiments,[8] where they ıeasured the relative width of the cascade decay $\Gamma_{\psi' \to \gamma P_c}/\Gamma_{\psi' \to all} \approx 4\%$, and rom the results of[9], where a limitation was obtained on the intensity of the ·adiative decays of ψ' at the level $\approx 5\%$, it follows that the decay $P_c \to \psi\gamma$ is redominant for the state P_c. In this connection there is undisputed interest in earching for a peak in the $\psi\gamma$ system in hadron-hadron collisions. We note that he contribution from this mechanism should predominate in the low-energy egion. At high energies, its contribution predominates at the maximum possi-le longitudinal momenta of ψ.

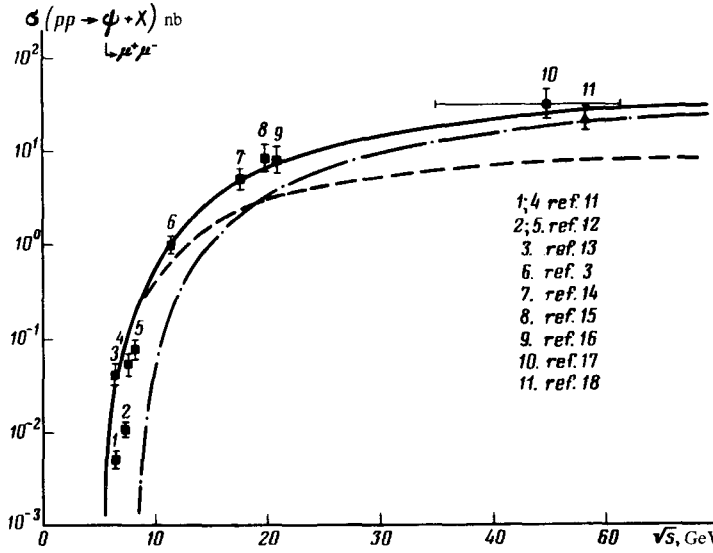

FIG. 2. Dependence of the cross section of $\psi_{\to\mu^+\mu^-}$ production in pp collisions in the Drell-Yan mechanism on the total energy. Dashed line—contribution from the annihilation of ordinary quarks; dash-dot—production from the "sea," solid curve—combined contribution. The experimental points for the pp collision were obtained from proton-nucleon data by extrapolation in accord with the $A^{2/3}$ law.

The absence of a γ quantum associated with ψ could be interpreted as a possible indication that the ψ and ψ' have different quark contents.

We note further that a similar situation obtains with the increase of the constant for the transition of strange quarks into ordinary ones, and in processes of ϕ production in pp collisions.[10] Then, within the framework of the simple $\psi \leftrightarrow \phi$ analogy, one should expect the existence of an excited state of P_λ with a transition $P \to \phi + \ldots$.

In conclusion, the authors thank S. S. Gershtein, L. G. Landsberg, M. A. Mestvirishvili, Yu. D. Prokoshkin, and L. D. Solov'ev for support and useful discussions.

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