Relativistic Quark Model of Mesons with Current Quark Masses

L. D. Soloviev

Institute for High Energy Physics, 142284, Protvino, Russia

We consider a relativistic quantum model of mesons in which current quarks and antiquarks confined in a meson are described by the Dirac equations and the gluon field contribution at large distances is approximated by the Nambu–Goto straight-line quantum string. The current quark masses and the string tension are the main parameters of the model. Additional parameters are phenomenological constants which approximate nonstring short-range quark-antiquark interactions not growing with the meson spin.

The model describes the masses of all the mesons from pion to Υ lying on the leading Regge trajectories (i.e. the lowest radial excitations in terms of the potential quark models; the higher radial excitatios, or the daughter trajectories, correspond to the string oscillations). The quantized string in the model accounts for two mechanisms of the potential quark models: confining potential and constituent quark masses. The comparison of the measured meson masses with the model predictions allows one to determine the current quark masses (in MeV) to be $m_s = 3D224 \pm 7,\ \ m_c = 3D1440 \pm 10$ and $m_b = 3D4715 \pm 20$. The universal string tension is found to be $0.176 \pm 0.002\ GeV^2$. The chiral SU_3 model makes it possible to estimate from here the u- and d-quark masses to be $m_u = 3D6.2 \pm 0.2\ MeV$ and $m_d = 3D11.1 \pm 0.4\ MeV$.

The Regge trajectories for the light-quark mesons beginnig at spin 1 are practically linear. The corresponding trajectories for the heavy-light-quark mesons are not linear but can be reprisented by approximate straight lines for spins less than 6 by replacing the argument m^2 by $(m - m_h)^2$ where m_h is the heavy-meson mass. The effective slopes of these straight line are bigger than for the light-quark mesons and are growing with m_h. The trajectories for heavy quarkonia are essentially nonlinear. The Regge trajectories beginning at spin 0 are always nonlinear in the region of low spins.

The model predicts many masses of high-spin mesons. In some cases the masses of unknown low-spin mesons can also be predicted by an extrapolation in quark masses of the phenomenological parameters of the model. In this way the model predicts the mass of $\eta_b(1S)(0^{-+})$ to be 9500 ± 30 MeV (bigger than the mass of Υ; a potential quark model predicts 9400 MeV). The mass of $B_c(0^-)$ is predicted to be 6400 ± 30 MeV (to be compared with the potential quark model prediction 6270 MeV) and a new $K^*(1^-)$ meson with mass 1900 MeV is predicted.

The relativistic wave functions of composit mesons obtained within the model allow one to analyse the spin structure of polarized mesons. The average spin projections of the u- and $\bar{d}$-quarks within the ρ^+ devided by the same projection of the total spin of the meson are found to be 0.22 and 0.23, respectively. These numbers are twice as small as the nonrelativistic quark model predictions 0.5. At the same time they are slightly different from 0.17 for zero quark masses, so one can hope that future polarization experiments will be able to estimate the light-quark current masses from experiment. The corresponding numbers for the u- and $\bar{s}$-quarks within the K^{*+} are 0.22 and 0.42 which shows an 80% violation of the flaviour SU_3 for the spin structure within a relativistic model. The meson spin structure results suggest a new approach to understanding the nucleon spin structure obtained from polarized deep inelastic lepton-nucleon scattering.

References

[1] The full text of this report is to be published in
L. D. Soloviev. Yadernaya Fizika, March 1999.

[2] Details of this approach can be found in
L. D. Soloviev. Proceedings of the 10th Int. Conf. "Problems of Quantum Field Theory", Alushta,1996, page 75 (JINR E-2-96-369, Dubna, 1996); IHEP reports 96-97, 97-81, 98-29, Protvino; Phys.Rev. D **58**, 035005, 1998; Teoreticheskaya i Matematicheskaya Fizika, **116**, No 2, 225-247, 1998.