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DETERMINATION OF THE MESON WAVE FUNCTION USING THE CROSS SECTION OF ITS ISOLATED INCLUSIVE PRODUCTION

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DETERMINATION OF THE MESON WAVE FUNCTION USING THE CROSS SECTION OF ITS ISOLATED INCLUSIVE PRODUCTION.

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Abstract.

The inclusive meson production is considered under condition that no other hadron enters some cone around the meson momentum.The cross section involves the integral containing the meson wave function f(x) and depending on the meson momentum,that allows to reconstruct f(x).

numerically large : they contain $m_\pi/(m_u+m_d)$ /1/.For this reason,the range of validity of asymptotic calculations can be situated at rather high momenta,that complicates strongly their experimental testing.For the ρ-meson,the vector and tensor parts of the wave function are written as $1/4N\ (m_\rho \hat{e} f_V(x) + \hat{e}\hat{p} f_T(x))$ (e is the polarization vector).The leading asymptotic contribution to the form factor comes from the component f_V;for the inclusive production into an empty cone both f_V and f_T are significant.In the ρ-meson case,there are no anomalously large corrections /1/,and this is the better case concerning the range of validity.

Let's consider e^+e^--annihilation into the meson and 2 jets (Fig.1).Let ϑ be the angle between the directions of the meson and quark motion ; $\vartheta \ll 1, Q\vartheta \gg m_\rho$ .Then,in the leading logarithmic approximation the quark fragmentation will go to subsequently narrowing cones /2/,so that the angle between the direction of motion of the meson and hadrons from the jet produced will be also equal approximately to ϑ .We shall select the events of the e^+e^--annihilation into hadrons satisfying the following condition : there exists a meson with energy E and there is no other hadron (with the momentum larger then characteristic hadron momentum $\sim m_\rho$) in the cone with angle ϑ around it.Since $Q\vartheta \gg m_\rho$,the isolated meson under consideration should be produced from the colourless group of quarks and gluons.Indeed,if it belonged to a sub-jet produced by a coloured parton emitted at angle ϑ ,there would be the other hadrons with characteristic relative momenta $\lesssim m_\rho$ near it.Let $z=2E/Q$ be the jet energy fraction carried by the meson,and $z \gg m_\rho/Q, 1-z \gg m_\rho/Q$.Then,the gluon virtualness in Fig.1 is large ($\sim Q\vartheta$).

In the axial gauge,the leading contribution to the cross section comes from two diagrams in Fig.1,with opposite directions of the quark line.The π-meson (of any sign) production cross section is

$$\frac{1}{\sigma_{\mu\mu}}\frac{d\sigma^\pi}{dz} = (Q_u^2+Q_d^2)\,\frac{C_F^2}{N}\,\frac{\alpha_s^2(Q^2\vartheta^2)}{Q^2\vartheta^2}\,\frac{F^2}{z} \qquad (4)$$

where Q_u, Q_d are the quark charges,

$$F(z)=\int\frac{(1+z-zx)f(x)dx}{(1-x)(1-zx)} \qquad (5)$$

The ρ-meson(of any sign) with helicity 0 production cross section is given by the formula (4) with the substitution $F\to F_L$,where F_L is defined by the formula (5) with $f(x)\to f_V(x)$. The ρ-meson with each of helicities ±1 production cross section is given by the formula (4) with $F\to F_T$,where

$$F_T(z)= z\int\frac{f_T(x)dx}{(1-x)(1-zx)} \qquad (6)$$

With obvious variations,these formulae are valid for any pseudoscalar and vector mesons.

In contrast to exclusive processes,we get a function rather then a number from the experiment.Solving the integral equation (5),one can reconstruct the axial wave function of the π-meson.In the ρ-meson case,it is possible to reconstruct both the vector and tensor wave functions because the polarization can be determined via the angular distribution of the $\pi\pi$-pairs.Since $f_\pi \simeq m_\pi$ and $f_\rho \sim f_\pi$, a rough dimensional estimate of the cross section is

$$\frac{\sigma^{\pi,\rho}}{\sigma_{\mu\mu}} \sim \frac{\alpha_s^2(Q^2\vartheta^2)m_\pi^2}{Q^2\vartheta^2} \qquad (7)$$

Here $Q\vartheta \gg m_\rho$ .Hence, $\sigma^{\pi,\rho}/\sigma_{\mu\mu} \ll \alpha_s^2 m_\pi^2/m_\rho^2$ .Estimates show that at a reasonable,although large,luminosity integral one can have a fairly great number of the above type events.

A similar consideration can be carried out for any mesons. Each unit of the orbital momentum projection onto the direction of motion gives additional suppression $m^2/Q^2\vartheta^2$ in the cross section.Such a suppression is known for form factors /1/.In view of this,for the mesons with the sum of quark spins S=0 : $\sigma/\sigma_{\mu\mu} \sim (m^2/Q^2\vartheta^2)^{|\lambda|+1}$,and with S=1 : $\sigma/\sigma_{\mu\mu} \sim (m^2/Q^2\vartheta^2)^{|\lambda|}$, except the case λ =0 when $\sigma/\sigma_{\mu\mu} \sim m^2/Q^2\vartheta^2$ (λ is the meson helicity).

The presented consideration is,as a matter of fact, universal and concerns the structure of any quark jet.This allows one to write the results in terms of the quark into meson fragmentation functions :

$$w_q^M(z,Q^2\vartheta^2) = \frac{C_F^2}{2N^2}\,\frac{\alpha_s^2(Q^2\vartheta^2)}{Q^2\vartheta^2}\,\frac{(F_M^q(z))^2}{z} \qquad (8)$$

where $F_M^q(z)$ is defined depending on helicity by the formula (5) or (6) via the wave function $f_M^q(x)$.Under the assumption of isotopic invariance $f_{\pi^0}^u=f_{\pi^0}^{\bar u}=-f_{\pi^0}^d=-f_{\pi^0}^{\bar d}=f_{\pi^+}^u/\sqrt{2}=f_{\pi^+}^{\bar d}/\sqrt{2}$.In the case of a gluon jet only the pseudoscalar flavour singlet mesons can be produced to the leading order in α_s (Fig.2) :

$$w_g^M(z,Q^2\vartheta^2) = \frac{1}{N^2}\,\frac{\alpha_s^2(Q^2\vartheta^2)}{Q^2\vartheta^2}\,\Big(\sum_q I_M^q\Big)^2\,\Big(\frac{z}{1-z}+\frac{1-z}{z}\Big) \qquad (9)$$

where the integral I is determined by the formula (3) and does not depend on z.In the case of light quarks,the unitary singlet η' is produced only,assuming the SU(3)-symmetry (it works quite well for pseudoscalar mesons).

There exist logarithmic corrections both of the "inclusive"/2/ and "exclusive"/1,3/ type to the process under consideration.Logarithms appear in integration over the intervals from Q^2 to $Q^2\vartheta^2$ and from $Q^2\vartheta^2$ to m^2,respectively. Therefore,if in the leading logarithmic approximation exclusive corrections are taken into account by means of an effective Q^2-dependent wave function /3/,then in the foregoing consideration one should bear in mind the wave function at the point $Q^2\vartheta^2$.Inclusive corrections become significant at so small ϑ that $\alpha_s \ln\vartheta \sim 1$,when the parton cascade succeeds in its development before meson production.In this case,

$$\frac{1}{\sigma_0}\frac{d\sigma^M}{dz} = \sum_p \int_z^1 \frac{dz'}{z'} D^p(z')\, w_p^M\Big(\frac{z}{z'},\, Q^2\vartheta^2 z'^2\Big) \qquad (10)$$

where σ_0 is the cross section of the jet production process, and $D^p(z)$ is the parton distribution function in this jet. For e^+e^--annihilation $\sigma_0 = \sigma_{\mu\mu}$,and

$$D^p(z) = 2N \sum_{q,\bar q} Q_q^2\, D_q^p(z,\, \xi(Q^2) - \xi(Q^2\vartheta^2)) \qquad (11)$$

where $D_q^p(z,\xi)$ are the parton distribution functions /2/. At not very small ϑ Eqs.(10) and (11) reproduce the result (4).

At $\vartheta \sim 1$ the cross section is no longer universal and depends strongly on a specific process.In the e^+e^--annihilation case,the contribution to the cross section comes from the diagrams of the type in Fig.1,from the diagrams in which the gluon is emitted from enother part of the quark line,and also from the diagrams with the emission of two gluons.The calculation for the latter case is more cumbersome. Nevertheless,the angle $\vartheta \sim 1$ can be suited to diminish the requirements for the energy of initial particles and to increase the cross section at a given $Q\vartheta$.Analisis of such a case will be presented elsewhere.

Thus,in order to determine the wave function of light mesons,some rare events of the e^+e^--annihilation into hadrons should be selected at an energy when the jets are clearly observed.Since it is necessary to construct the z-distribution the number of events should be sufficiently large.If one takes $Q\vartheta \sim 3m_\rho$ and Q=10 Gev,then,according to the estimate (7), $\sigma^{\pi,\rho} \lesssim 2\cdot 10^{-38}$ sm^2.

References.

1.V.L.Chernyak.Proceedings of the 15th Leningrad Winter School on Elementary Particle Physics (1980).

2.Yu.L.Dokshitzer a.o.Phys.Reports 58,269 (1980).

3.S.J.Brodsky.SLAC-PUB-2447 (1979),

G.P.Lepage,S.J.Brodsky.Phys.Letters 87B,359 (1979).

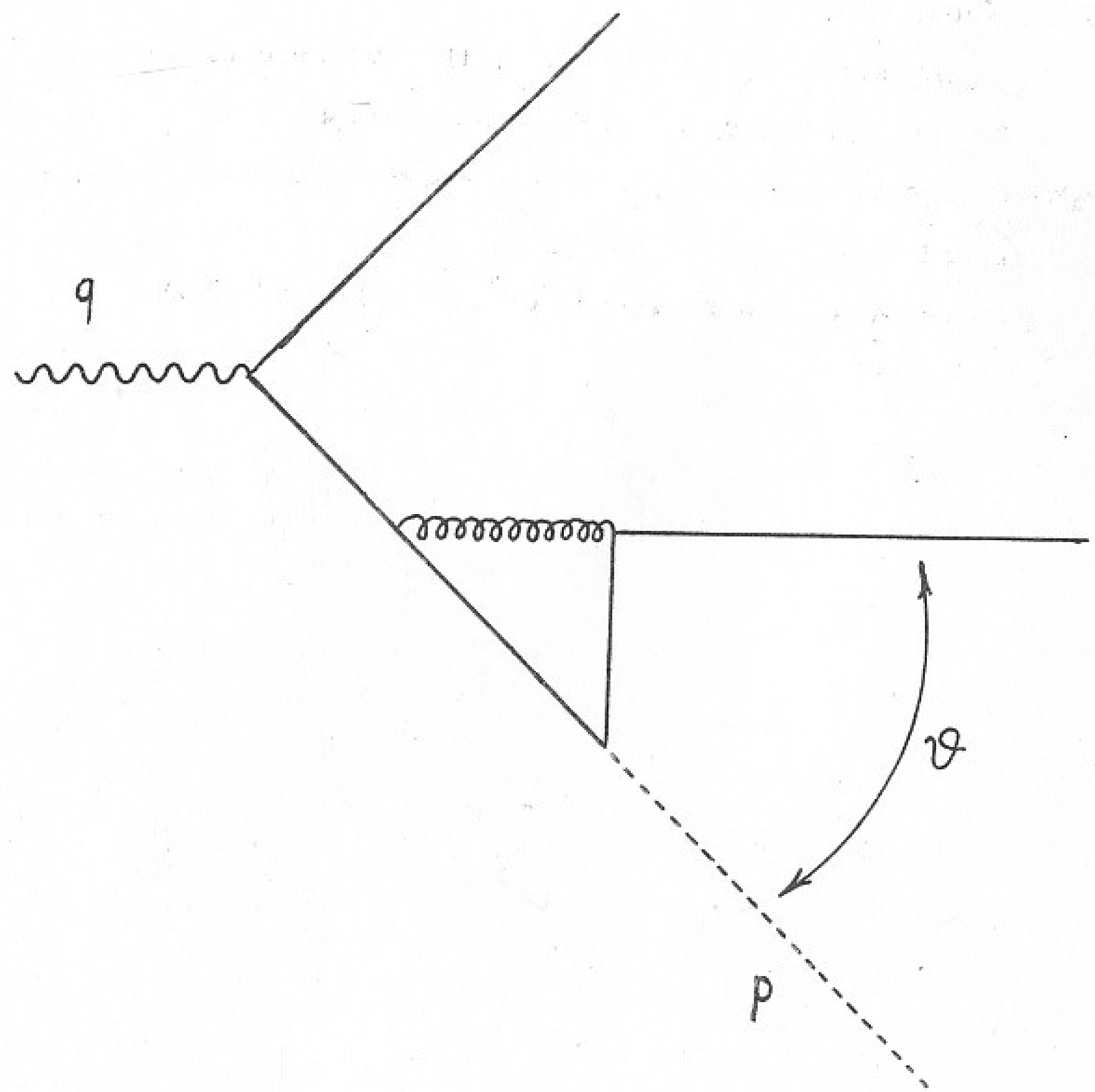

Fig.1

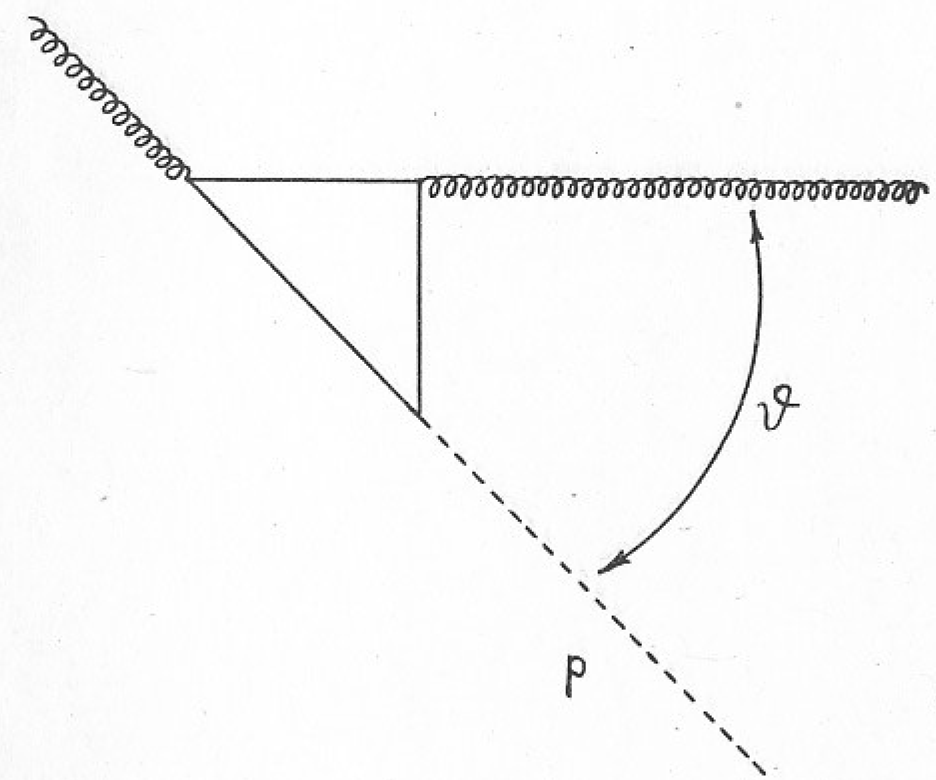

Fig.2

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