DOUBLE LOGARITHMIC ASYMPTOTICS OF QUARK AMPLITUDES WITH FLAVOUR EXCHANGE

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Quark scattering and annihilation processes appear as subprocesses in hadronic reactions with particles produced at large transverse momenta or in two-body scattering with large momentum transfer.
In this contribution we represent results /1/ on the quark scattering and annihilation amplitudes in the Regge region

$$s \simeq -u \gg |t| \qquad \text{or} \qquad s \simeq -t \gg |u| \; . \tag{1}$$

We consider amplitudes with two quarks or quark and antiquark in the exchange channel, so that flavour quantum numbers can be exchanged. The amplitudes with only gluons in the exchange channel and the related questions of the vacuum singularity and the gluon Reggeization have been investigated earlier /2/.
We calculate the perturbative contributions to these amplitudes in the double logarithmic approximation. The perturbative contributions arise from the integration region in the loop momenta k, where its transverse components $k_\perp$ with respect

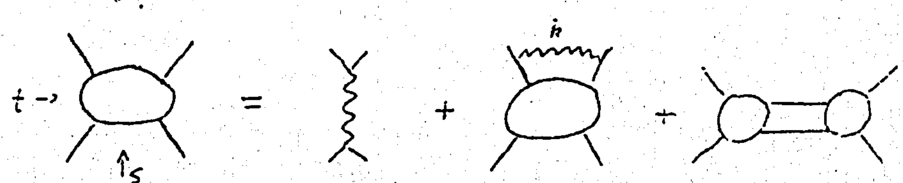
to the external momenta p_1, p_2 are restricted by the condition

$$k_\perp^2 > \mu^2 . \qquad (2)$$

At the momentum scale μ^2 the coupling is still small. In the region below μ^2 non-perturbative contributions become essential.

In the calculations we use a method based on dispersion relations and gauge invariance. It has essential advantages compared to the conventional approach /3/, which is based on Bethe-Salpeter equations. In our approach it is not necessary to consider off-mass shell amplitudes and we do not need to analyze complicated higher order graphs. We deal with only gauge invariant sets of graphs.

The main point in our approach consists in isolating the softest virtual particle with the lowest transverse momentum in the graph. It turns out that the integration over the momenta of the remaining virtual particles can be expressed in terms of on-mass shell amplitudes. The physical idea, the separation of interactions at different scales, is similar to the renormalization group. An essential ingredient of the method is Gribov's bremsstrahlung theorem /4/. On the basis of this method we obtain equations for the perturbative contributions to the considered quark amplitudes. The equations can be written in terms of graphs as follows.



(3)

The first term on the right-hand side represents the Born contribution. The second and the third terms are the contributions of the softest virtual particles, if this softest particle is a gluon or a quark. The blobs on the right-hand side

are the same amplitude as in the left-hand side with the cut-off μ replaced by the transverse momentum of the soft particle $|k_\perp|$, $|k_\perp| > \mu$.
In terms of partial waves the equations have a simple form. They are ordinary differential equations of Riccatti type and in the case of the colour singlet channel they are just algebraic equations. We obtain simultaneously the equations for both signatures. For example for the colour singlet channel we have

$$f_0^+(\omega) = \frac{(N^2-1)}{2N}\frac{g^2}{\omega} + \frac{1}{8\pi^2}\frac{1}{\omega}\left(f_0^+(\omega)\right)^2$$

$$f_0^-(\omega) = \frac{(N^2-1)}{2N}\frac{g^2}{\omega} - \frac{N^2-1}{N}\frac{g^2}{4\pi^2}\frac{1}{\omega^2}f_8^+(\omega) + \frac{1}{8\pi^2}\frac{1}{\omega}\left(f_0^-(\omega)\right)^2 \qquad (4a)$$

and for the positive signature colour octett channel we have

$$f_8^+(\omega) = -\frac{g^2}{2N\omega} + \frac{Ng^2}{8\pi^2}\frac{1}{\omega}\frac{d}{d\omega}f_8^+(\omega) + \frac{1}{8\pi^2}\frac{1}{\omega}\left(f_8^+(\omega)\right)^2 \qquad (4b)$$

The resulting equations allow to analyze the singularity structure in the ω plane generated by the perturbative contributions. It turns out that in all channels the negative signature amplitude has singularities to the right of the right-most singularities of the corresponding positive signature amplitude.

The singularities of the colour singlet quark amplitudes can be interpreted directly as singularities of the hadronic amplitudes with meson quantum number exchange. One has to keep in mind that the double logarithmic amplitude is only a part of the full amplitude. Non-perturbative contributions leading to meson Regge trajectories have to be included.
The most important perturbative singularities in the colour singlet channel lie in the right half-plane. They are fixed square root singularities whereas the particle Regge poles move to the left with increasing t . Thus there is a kinematical region, where the perturbative singularities become important at high energies.

References:

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