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Processes of heavy quark pair (lepton pair) and two gluon (two photon) production in the high energy quark (electron) proton peripheral collisions

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Abstract

We considered the three jet production processes in the region of the incident lepton, photon, quark or gluon fragmentation. The fourth jet is created by the recoil proton. The kinematics of jet production is discussed in jets production in the fragmentation region. The non-trivial relation between the momenta of the recoil proton and the polar angle of its emission was derived.

Based on this formalism the differential cross sections of QCD processes $gp \to (ggg)p$; $qp \to (q\bar{Q}Q)p$; $gp \to (gQ\bar{Q})p$ were obtained, including the distribution on transverse momentum component of jets fragments. It was shown that the role of the contribution of "non-Abelian" nature may become dominant in a particular kinematics of the final particles. The kinematics, in which the initial particle changes the direction of movement to the opposite one, was considered in the case of heavy quark–antiquark pair production.

Different distributions, including spectral, azimuthal and polar angle distribution on the fragments of jets can be arranged using our results. We present besides the behavior of the ratio of non-Abelian contribution to the cross section to the total contribution. We show that it dominates for large values of the transverse momenta of jets component (gluons or quarks). Some historical introduction to the cross-sections of peripheral processes, including 2γ creation mechanism production, including the result Brodsky–Kinoshita–Terazawa, is given.

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1. Introduction

It is known [1] that the differential cross sections of small angle elastic (and inelastic) scattering processes do not fall with increasing the center of the mass total energy $\sqrt{s}$, $s = 4E^2$. The reason for this is the contribution to the cross section from the photon exchange between charged particles. Similar phenomena take place as well in the strong interaction sector, where gluons take place instead of a photon.

The simplest processes of this kind are the scattering of a charged particle in the external field of nuclei and the elastic scattering of one sort of charged particles on the other one. The total cross sections of these processes do not exist due to contributions of large impact parameters, which correspond to small scattering angles. The momentum of the virtual photon in the scattering channel (t channel) tends to the mass shell. So the virtual photon in the t channel becomes a real one. In the case of inelastic processes $a + b \to a + b + X$, with the set of particles x belonging to one of the directions in the center of mass a or b, the cross sections are finite [2–9]. Besides, the square of 4-momentum of a virtual photon is negative and restricted from below by the magnitude of some quantity of the created set of particles, invariant mass square of (ax), (bx). The finiteness of the transfer momentum module caused the so-called Weizsacker–Williams (WW) enhancement [7]. Namely, the region of small momentum transfer is realized in the appearance of a large logarithmic factor $L = \ln(s^2/(m_1^2 m_2^2))$. For modern colliders this factor is of an order of 20. It often turns out that the consideration is restricted to the WW approximation. This means the accuracy of the order $1 + O\frac{1}{L}$. The cross sections of inelastic peripheral processes are as usually large.

The background caused by the events of the large-angle kinematics of produced particles determines the accuracy of peripheral cross sections

$$1 + O\left(\frac{\alpha}{\pi}, \frac{m^2}{s}\right). \tag{1}$$

So the total accuracy of theoretical estimates is better than 5%.

The cross sections of interaction of photons with the target will also not fall with energy when taking into account the contributions of higher orders of perturbation theory (PT).

The main attention in our paper is paid to the double gluon emission and production of the pair of heavy quarks with subsequent jet production, in the fragmentation region of the incident particle.

Our paper is organized as follows.

First, we give an estimation of the magnitudes of the cross sections of several processes in high energy $ep \to (eab)p$, $qp \to (qab)p$ collisions in the fragmentation region of a projectile e, q. In Section 2, we give a short historical introduction to the study of the processes of lepton pair production in high energy lepton–lepton, ion–ion collisions. In Section 3, the method of description of high energy processes based on the Sudakov parametrization of the four momenta of the problem is developed. The differential cross sections are expressed in terms of physically measurable energy fractions and the transverse component of the final particles. In Section 4, the simplest QCD processes with 2 jet production are presented. In Section 5, we consider the process of heavy quark–anti-quark pair production in collisions of projectile with the color-less target. In Section 6, the QED process of double bremsstrahlung is studied. In Section 7, a similar QCD process of emission of two gluons is considered. In Section 8, the specific details of jet production on a fixed target are considered.