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Review

Parton fragmentation functions

A. Metz^a, A. Vossen^{b,*}

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ABSTRACT

The field of fragmentation functions of light quarks and gluons is reviewed. In addition to integrated fragmentation functions, attention is paid to the dependence of fragmentation functions on transverse momenta and on polarization degrees of freedom. Higher-twist and di-hadron fragmentation functions are considered as well. Moreover, the review covers both theoretical and experimental developments in hadron production in electron–positron annihilation, deep-inelastic lepton–nucleon scattering, and proton–proton collisions.

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E-mail address: agvossen@gmail.com (A. Vossen).

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^a Department of Physics, Temple University, Philadelphia, PA 19122, United States

^b Center for Exploration of Energy and Matter, Indiana University, Bloomington, IN 47408, United States

Corresponding author.

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1. Introduction

Quantum chromodynamics (QCD) is the generally accepted fundamental theory of the strong interaction. Thanks to the asymptotic freedom of QCD [1,2] many high-energy scattering processes can be analyzed using perturbation theory. In most cases such analyses are in the form of factorization theorems, which separate the perturbatively calculable part of the cross section from the non-perturbative part [3]. If specific particles are identified in the final state, parton fragmentation functions (FFs) appear frequently as non-perturbative ingredient of QCD factorization formulas. (In the older literature the term parton decay functions instead of FFs was often used.) Generally, FFs describe how the color-carrying quarks and gluons transform into color-neutral particles such as hadrons or photons.

The concept of FFs was already used shortly after the parton model [4–6] had been introduced [7]. This was in the pre-QCD era, at a time when key characteristic features of the partons, like their interactions, were heavily under debate. Early on FFs were considered as counterpart of parton distribution functions (PDFs). While PDFs were understood as probability densities for finding partons, with a given momentum, inside color-neutral particles, FFs were understood as probability densities for finding color-neutral particles inside partons [7,6].

FFs are intimately connected with another type of non-perturbative objects, the so-called (time-like) cut-vertices [8,9]. More precisely, cut-vertices correspond to certain moments of FFs [10]. They were introduced in order to obtain a formulation of processes with identified hadrons that is similar to, for instance, Wilson's operator product expansion [11]. Nowadays FFs are more frequently used than cut-vertices.

The best studied FF is what we denote by $D_1^{h/i}(z)$ in this paper. It describes the fragmentation of an unpolarized parton of type i into an unpolarized hadron of type h, where the hadron carries the fraction z of the parton momentum. Here one has in mind the longitudinal momentum of the hadron, that is, the component of the momentum along the direction of motion of the parton. Therefore, $D_1^{h/i}(z)$ is often called a collinear FF or also an integrated FF, since the transverse momentum of the hadron \vec{P}_{hT} relative to the parton is integrated over. To be now more specific about the meaning of this function we note

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