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Longitudinal Jet Cross Sections in Order α_s^2

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Dedicated to the memory of Kurt Symanzik

Abstract. We calculate the cross section for $e^+e^- \to 3$ jets for longitudinally polarized virtual photons up to order α_s^2 in the quark-gluon coupling.

1. Introduction

The cross sections for the production of 2, 3, and 4 jets in e^+e^- annihilation as measured at PETRA and PEP have given us useful information about the quark-gluon dynamics as described by QCD [1]. So, for example, the 3-jet cross section has been used in various ways for determining the quark-gluon coupling constant in the perturbative region [2].

Considering also the orientation of the jets with respect to the direction of the incoming beam the 3-jet cross section depends in general on three independent cross sections σ_U, σ_L, σ_T, and σ_I, where U, L, T, and I label the polarization of the ingoing virtual photon [3]. These polarization dependent cross sections which fully determine the jet angular correlations with respect to the incoming electron beam in $e^+e^- \to q\bar{q}g$ are known up to order α_s [3]. So far only the angular averaged 3-jet cross section $\sigma_{U+L} = \sigma_U + \sigma_L$ has been measured. The statistical accuracy of the e^+e^--data is not yet sufficient for determining also σ_L, σ_T, and σ_I. We expect such measurements in the near future with higher statistics data coming from PETRA and PEP. These cross sections σ_L, σ_T, and σ_I are useful to test the spin structure of the $e^+e^- \to q\bar{q}g$ matrix element, to measure the spin of the gluon or to obtain independent measurements of the quark-gluon coupling constant. For the latter it is essential to know these cross sections at least up to order α_s^2 since the coupling can uniquely be defined through renormalization only in higher order. The cross section σ_{U+L} has already been calculated up to this order [4]. These calculations have shown that it is possible to define the 3-jet cross section σ_{U+L} in such a way that it is infrared finite up to order α_s^2 [5].

In an earlier paper [6] we have calculated the virtual α_s^2 contributions to the longitudinal cross section σ_L for $e^+e^- \to q\bar{q}g$. They are infrared singular. In this paper we describe the calculation of the real α_s^2 contributions to the 3-jet cross