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Angular dependences in inclusive two-hadron production at BELLE

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Abstract

A collection of results is presented relevant for the analysis of azimuthal asymmetries in inclusive two-hadron production at BELLE. The aim of this overview is to provide theoretical ingredients necessary to extract the Collins effect fragmentation function. The latter arises within the Collins–Soper factorization formalism, which describes both the transverse momentum and Q^2 dependence of the cross section and its angular dependences at low and moderate transverse momentum. Since the Collins effect is not the only source of angular dependences, a discussion of various other effects is included. This concerns higher twist contributions, photon–Z-boson interference effects, radiative corrections, beam polarization and weak decays. Furthermore, different frames, transverse momentum weighting and ratios of asymmetries are discussed. These issues are all of relevance for the unambiguous measurement of the Collins effect.

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1. Introduction

The BELLE experiment at KEK in Japan measures with very high luminosity the process of electron–positron annihilation in collisions of 8.0 GeV electrons and 3.5 GeV positrons. The center of mass energy is selected to be on-resonance of the $\Upsilon(4S)$ meson, which has a mass of 10.5800 ± 0.0035 GeV and which decays more than 96% of the time into $B\bar{B}$ meson pairs. The main aim of the measurements of B and $\bar{B}$ decays is to study CP violation. Besides this goal,

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there are other interesting studies that can be performed at BELLE[1] and for which also the off-resonance data are useful (which in the case of BELLE are taken 60 MeV below resonance). The acquisition of off-resonance data is mostly used for background studies, but is also of interest for physics studies that are not b-quark specific. This overview discusses such a case, namely the study of azimuthal asymmetries in the inclusive production of two almost back-to-back hadrons, $e^+e^- \to h_1h_2X$. There are several effects that can cause such asymmetries and one would like to disentangle them in order to isolate perturbative from nonperturbative effects. In the latter type of effects quark spin is expected to play a nontrivial role via the so-called Collins effect [1]. By measuring azimuthal asymmetries it may be possible to obtain trustworthy quantitative knowledge on this type of effect, for instance from the BELLE data. Recently, the first results from BELLE were published [2] and the purpose of this overview is to discuss the theoretical aspects of such type of study.

The Collins effect was first discussed in the context of semi-inclusive deep inelastic scattering (SIDIS) of leptons off transversely polarized protons, as a means to access transversity [1]. Transversity [3] describes the extent to which quarks are transversely polarized inside a proton that is polarized transversely to the probing particle, which in the case of SIDIS is a virtual photon. The Collins effect describes the angular asymmetry in the distribution of hadrons produced from a transversely polarized fragmenting quark. Via this effect the transverse polarization of the struck proton results in an asymmetric distribution of final state hadrons. If sufficiently large, the Collins effect would thus allow for a measurement of transversity and subsequently of the tensor charge, the fundamental charge that can only be measured through transversity.

The first nonzero Collins effect asymmetry in polarized SIDIS has been observed by the HERMES experiment [4] (using a deuteron target the COMPASS experiment obtained a result consistent with zero [5], presumably due to cancellations between proton and neutron contributions). The HERMES result indicates that both transversity and the Collins effect are nonzero. For an extraction of transversity from those SIDIS data a separate measurement of the Collins effect fragmentation function needs to be performed. This can best be done in the process $e^+e^- \to h_1h_2X$ [6] and motivates the BELLE efforts concerning the measurement of this process. Some earlier attempt to use LEP1 data has been undertaken [7], but without study of systematic effects and still remains preliminary. Moreover, as will be discussed, it is likely that the Collins effect asymmetry in $e^+e^- \to h_1h_2X$ has a powerlike fall-off behavior with energy, which would favor an extraction at BELLE over LEP1.

We will study various effects that could lead to azimuthal asymmetries in the process of interest, $e^+e^- \to h_1h_2X$, which besides the Collins effect, include electroweak γ–Z interference effects, beam polarization effects and radiative corrections. In order to arrive at an unambiguous interpretation of the data the magnitude and scale dependence of the various effects need to be estimated, of course to the extent to which that is possible from first principles. The effects will not be treated simultaneously; combinations of effects will only be considered when the analysis requires it. As a rule we will ignore effects that are expected to be smaller than a permille, such as Z–Z contributions or beam polarization in combination with γ–Z interference. From the possible contributions considered the higher-twist effects are the least known, but unfortunately not necessarily below the percent level at BELLE. In cases where no reliable estimate can be given, such as for twist-4 effects ($\mathcal{O}(\Lambda^2/Q^2)$), additional observables or checks may need to be

[1] We have chosen to focus on BELLE, but the observables to be discussed can of course also be studied at other e^+e^- colliders.