Recent Developments of PEPSI and SPHINX

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Abstract

Recent developments of the two MC-generators SPHINX and PEPSI are discussed. In SPHINX the process of polarized photo production was included to simulate the potential of a polarized HERA to measure the photon structure function. In PEPSI the CC polarized cross sections on tree level have been added together with the electroweak corrections to simulate their effect on CC signals proposed for a polarized HERA.

1 Introduction

The PEPSI and SPHINX programs are Monte Carlo event generators for longitudinally polarized deep inelastic lepton-nucleon scattering (DIS) and longitudinally polarized high energy hadron-hadron collisions, respectively. They both use probabilistic methods to generate events with unit weight. The generation process can be split up into three parts. At first, the kinetic variables of the partonic reaction are determined according to the complete cross section yielding a two parton initial state and a two, three or four parton final state. The 'partons' include quarks, leptons and gauge bosons here. The next stage consists of an iterative generation of initial and final state showers. Finally, the parton cascades fragment into hadrons which may further decay. Until now, polarization is only taken into account by the partonic cross section and the initial state shower. A polarized treatment of the final state shower is in principle straight forward for longitudinal polarization, whereas to our knowledge no model of polarized fragmentation exists so far.

In the following we report recent developments concerning SPHINX and PEPSI. For further information please refer to [1] and the WWW pages
`http://th.physik.uni-frankfurt.de/~martin/sphinx.html` and
`http://th.physik.uni-frankfurt.de/~maul/pepsi.html`.

2 SPHINX

High energy scattering of a (quasi-)real photon on a hadron is very similar to hadron-hadron collisions. The hadronic component of the photon is described by unpolarized and polarized photonic parton distribution functions much in the same fashion as for hadrons. To leading order in the strong coupling constant one can thus clearly distinguish between a direct cross section and a resolved cross section. In the first case, the photon couples completely to a parton of the hadron, in the second case it fluctuates into quarks (and possibly further into gluons) right

before the hard interaction with the hadron occurs. To next-to-leading order this distinction breaks down, but a new pragmatic definition can be found [2].

The unpolarized parton distributions of the photon have already been explored at HERA during the last years and a resolved component of the total cross section was established. Polarized photo production experiments have not been conducted yet and therefore it is "unknown territory". We sought to develop a tool for experimentalists which enables them to study the feasibility of such experiments.

PYTHIA 5.6 [3], the basis of the SPHINX program, already includes unpolarized photo production which made an extension of SPHINX to longitudinally polarized photo production quite simple. In principle, only the leading order polarized direct cross sections $f_i\gamma \to f_i\gamma$, $f_i\gamma \to f_i g$ and $g\gamma \to q\bar{q}$ had to be added and the polarized parton distribution functions of the photon had to be included. In the following we want to discuss some points of interest:

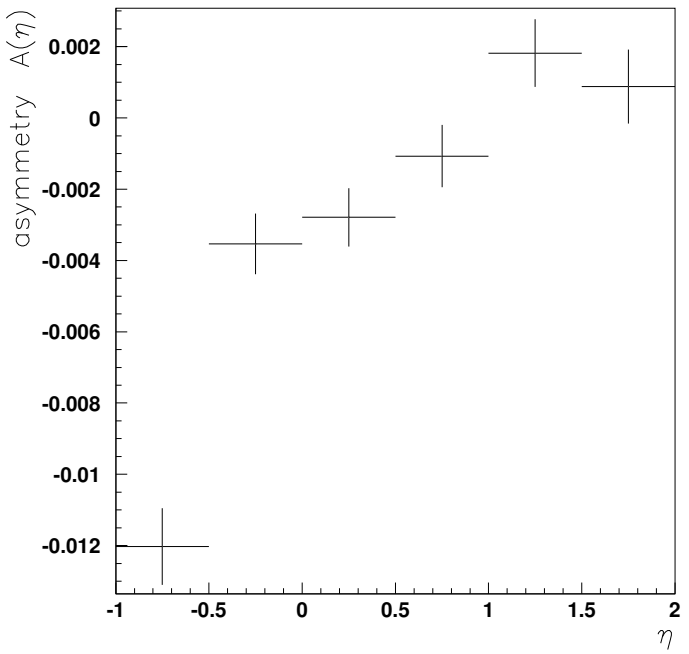

Figure 1: Inclusive jet asymmetry for photo production at the HERA polarized collider. *The error bars are not the expected experimental (statistical) error bars but the error bars of the Monte Carlo due to the limited number of simulated events.*

- The polarized parton distributions of the photon are completely unknown. We included the minimally and maximally saturated ansätze by Glück and Vogelsang [4]. These can be used to determine the sensitivity of the asymmetries to the polarized parton distributions of the photon.

- The current experimental setup at DESY is such, that electrons and hadrons collide and react via the exchange of a virtual photon. The program therefore allows not only to generate photon-hadron events at fixed energies but also electron-hadron collisions at fixed

energies. This is done by calculating parton distributions of the electron via a convolution of the polarized Weizsäcker-Williams spectrum with the parton distributions of the photon.

- The leading order cross sections for the production of QCD jets with high transverse momentum and the production of direct photons are implemented.

- Double spin asymmetries for photo production are expected to be of the order of one percent and below. Consequently, one needs at least 10^6 *events per bin* to achieve decent accuracy and program runs become somewhat lengthy. This is illustrated by Figure 1 which shows the inclusive jet asymmetry for photo production at polarized HERA using the maximally saturated set of polarized photon distribution function from [4]. We chose the same kinematic cuts as the authors of [5] and the showering routines were switched on. $16 \cdot 10^6$ events were simulated yielding a total execution time of approximately 3 days on a Pentium 200 personal computer.

3 PEPSI

The possibility of measurements of CC events by missing momentum in deep inelastic scattering is one of the most interesting perspectives of a polarized HERA. For this purpose on twist-2 level within the framework of the naive parton model the polarized contribution to CC events together with the $\mathcal{O}(\alpha_{\rm em})$ electroweak corrections is now included into the MC-generator PEPSI. Unpolarized CC events are already contained in the LEPTO code [6], which forms the basis of PEPSI, and the polarized extension can be provided on twist-2 level by a simple substitution of the parton distributions. For W^- exchange:

$$\begin{aligned} U(x,Q^2) &\longrightarrow U(x,Q^2) + \lambda\Delta U(x,Q^2) \\ \bar{U}(x,Q^2) &\longrightarrow 0 \\ D(x,Q^2) &\longrightarrow 0 \\ \bar{D}(x,Q^2) &\longrightarrow \bar{D}(x,Q^2) - \lambda\Delta\bar{D}(x,Q^2) \quad . \end{aligned} \tag{1}$$

And for W^+ exchange:

$$\begin{aligned} U(x,Q^2) &\longrightarrow 0 \\ \bar{U}(x,Q^2) &\longrightarrow \bar{U}(x,Q^2) - \lambda\Delta\bar{U}(x,Q^2) \\ D(x,Q^2) &\longrightarrow D(x,Q^2) + \lambda\Delta D(x,Q^2) \\ \bar{D}(x,Q^2) &\longrightarrow 0 \quad . \end{aligned} \tag{2}$$

U denotes the u-like flavor of each generation, D the corresponding d-like flavor of each generation and $\bar{U}, \bar{D}$ are the corresponding anti particles. λ is the sign of the relative polarization configuration of the two beams, i.e., $\lambda = 1$ for anti parallel and $\lambda = -1$ for parallel spin configuration. x is the usual Bjorken x and Q^2 the virtuality of the exchanged W boson. The very important feature of the CC events is that the polarization of the quarks can be expressed by their helicity. Consequently, for the electroweak corrections on the twist-2 level we can use the corresponding unpolarized but helicity dependent formula [7], and include those electroweak corrections again by a substitution of the parton distributions:

$$q(x,Q^2) \longrightarrow \sum_{b=0,l,i,q} c_b \rho_C^2(P) \left[\frac{1+P}{2} R_b + \frac{1-P}{2} \bar{R}_b \right] \quad , \tag{3}$$

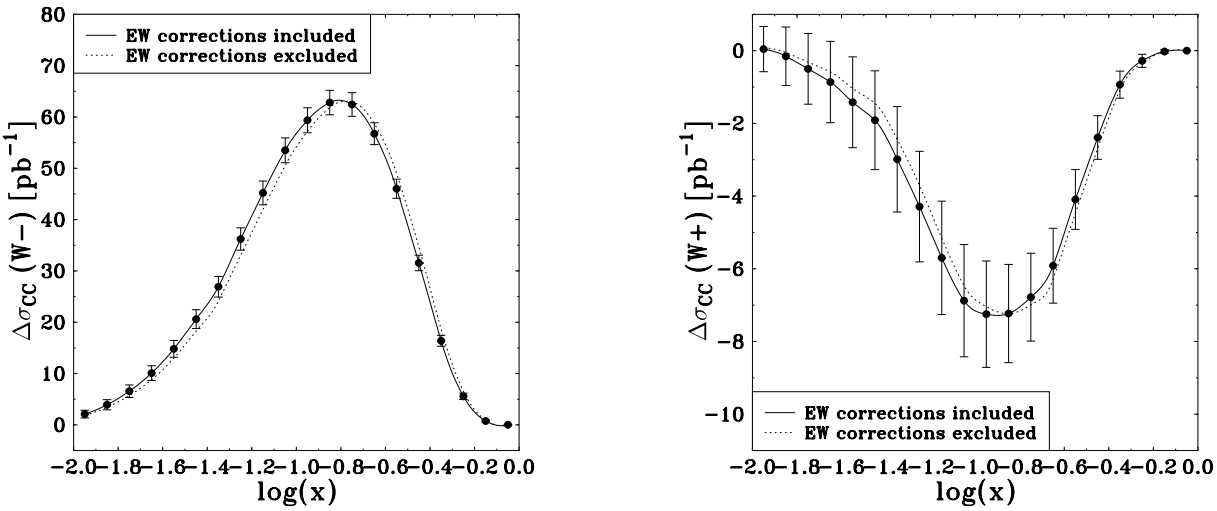

Figure 2: Spin dependent cross section $\Delta\sigma_{CC} := \sigma_{CC}^{\lambda=1} - \sigma_{CC}^{\lambda=-1}$ in the case of W^- exchange (left) and W^+ exchange (right). Solid line: including electroweak corrections and dotted line: without them. The error bars correspond to 25 pb^{-1} per relative polarization and 100 % beam polarization. This corresponds to 200 pb^{-1} altogether and 70 % beam polarization for the electron and proton beam.

with $P = P_l P_q, P_l, P_q = \{+1; -1\}$ for particles and anti particles, and $c_b = \{1, Q_l^2, Q_l Q_q, Q_q^2\}, b = \{0, l, i, q\}$ being the charge factor. q denotes the quark flavor and l the incoming lepton. The genuine electroweak corrections are included in the form factor ρ_C while the functions R_b contain the one photon bremsstrahlung originating from the quark leg (q), from the lepton leg (l) and from the interference of both (i). (0) denotes the tree contribution. The functions R_b are in general convolutions of the parton distributions, to be more precise

$$\begin{aligned}
R_0 &= q(x,Q^2) \\
\bar{R}_0 &= (1-y)^2 q(x,Q^2) \\
R_b &= \frac{\alpha_{\rm em}}{\pi}\left\{S_b q(x,Q^2) + \int_1^{1/x} dz \left[T_b \frac{r_b q(zx,Q^2) - q(x,Q^2)}{z-1} + U_b \frac{1}{z} q(zx,Q^2)\right]\right\} \\
\bar{R}_b &= \frac{\alpha_{\rm em}}{\pi}\left\{\bar{S}_b q(x,Q^2) + \int_1^{1/x} dz \left[\bar{T}_b \frac{\bar{r}_b q(zx,Q^2) - q(x,Q^2)}{z-1} + \bar{U}_b \frac{1}{z} q(zx,Q^2)\right]\right\} \quad . \qquad (4)
\end{aligned}$$

The exact definition of the functions U_b, T_b, S_b, r_b and $\bar{U}_b, \bar{T}_b, \bar{S}_b, \bar{r}_b$ is to be found in [8]. These formulae are available in FORTRAN in the program HECTOR [9], and we took them partially from this code. From the four contributions the single photon bremsstrahlung radiation from the lepton leg ($b = l$) is dominant, while the others give only minor corrections.

In Fig. 2 the electroweak (EW) corrections are shown for the spin dependent charged current cross sections for W^- and W^+ exchange. The parton distributions used are from the polar-

ized/unpolarized package GRSV LO STD described in [10]. In the kinematic range used here, i.e., $0.01 < x, y < 0.89$, $600 < Q^2$. The electroweak corrections are rather small. Only in the case of 1000 pb $^{-1}$ there might be a chance in the W^- case that the error bars could become smaller than the effect due to the electroweak corrections.

4 Conclusions

The new upgrade of the program SPHINX including polarized photo production allows the simulation of various models for the photon structure. The upgrade on PEPSI allows the analyses of polarized CC processes at a polarized HERA including electroweak corrections. The effect of the latter on the spin dependent part of the cross section is rather small in the kinematic range covered by the polarized HERA.

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