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Polarized Photon Structure at e^+e^- Colliders

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Abstract

A set of experiments at high energy e^+e^- colliders is proposed which provides a distinctive determination of the polarized parton distributions of the longitudinally polarized photon.

The polarized parton distribution $\Delta f^\gamma = (\Delta q^\gamma, \Delta G^\gamma)$ of the longitudinally polarized photon are presently unmeasured. Two extreme estimates based on VMD considerations were presented in [1]. The first, maximally saturated, extreme estimate was characterized by

$$\Delta f^\gamma(x, \mu^2) \approx f^\gamma(x, \mu^2) \quad (1)$$

with $f^\gamma(x, \mu^2)$ taken from [2] while the second, minimally saturated, extreme estimate was distinguished by

$$\Delta f^\gamma(x, \mu^2) = 0 \quad (2)$$

with $\mu^2 = 0.25 \text{ GeV}^2$ for both sets which were evolved to $Q^2 > \mu^2$ according to the appropriate leading order (LO) renormalization group equations¹. In the following we discuss some experiments at e^+e^- colliders which are sensitive to Δf^γ , i.e. which clearly distinguish between the two extreme sets of polarized parton distributions [1] mentioned above.

The preparation of polarized photon beams at a circular collider like LEP200 affords a polarization of the $e^\pm$ beams which then provides, via Bremsstrahlung, a photon polarization

$$P^\gamma(y) = \frac{1 - (1 - y)^2}{1 + (1 + y)^2} \quad (3)$$

with y being the fractional energy of the radiated photon. For $y^\pm \approx 0.7$, for example, one obtains $P^\gamma(y^+) P^\gamma(y^-) \approx 0.7$ and $\sqrt{s_{\gamma\gamma}} \approx 140 \text{ GeV}$ at LEP200. Higher degrees of polarization and energies may be achieved at forthcoming linear colliders combined with backscattered laser induced photons [3]. Our results will refer, for definiteness, to fully polarized photon beams at $\sqrt{s_{\gamma\gamma}} = 140 \text{ GeV}$ but will be presented in a scaled form which is almost energy independent.

A distinction of the differently saturated $\Delta G^\gamma(x, Q^2)$ is provided by essentially gluon induced processes such as $G^\gamma\gamma \rightarrow c\bar{c}$ or $f^\gamma\gamma \rightarrow jet + X$ in singly resolved processes which could be experimentally distinguishable by tagging on single spectator jet events. The

¹Parametrizations of both sets are obtainable in a FORTRAN – code upon request via the e – mail address UPH409@UNIDOZR.HRZ.UNI-DORTMUND.DE.

results of the calculations are presented in Figs. 1,2 in terms of

$$A^j(x_F, x_T^{min}) = \frac{d\Delta\sigma^{\gamma\gamma_r \rightarrow j+X}(x_F^j, x_T^j > x_T^{min})}{d\sigma^{\gamma\gamma_r \rightarrow j+X}(x_F^j, x_T^j > x_T^{min})} \quad (4)$$

with γ_r denoting the resolved photon, $j = (\text{jet}, c\bar{c})$, $x_F^j = p_{\parallel}^j/p_{\parallel, max}^j \approx 2p_{\parallel}^j/\sqrt{s_{\gamma\gamma}}$, where x_F is defined with respect to the direction of the resolved photon, $x_T^j = 2p_T^{jet}/\sqrt{s_{\gamma\gamma}}$ or $2p_T^c/\sqrt{s_{\gamma\gamma}}$. The subprocess cross sections involved in eq.(4) are well known [4, 5]. The scales adopted for the parton distributions were taken to be $p_{T, min}^{jet}$ and $2m_c$ respectively.

A distinction of the differently saturated $\Delta q^\gamma(x, Q^2)$ is best achieved via the measurement of the polarized structure function $g_1^\gamma(x, Q^2)$ which in LO has the following dominant contribution from $\Delta q^\gamma(x, Q^2) = \Delta \bar{q}^\gamma(x, Q^2)$ with $q = (u, d, s)$

$$g_1^{\gamma, q}(x, Q^2) = \sum_{q=u, d, s} e_q^2 \Delta q^\gamma(x, Q^2) \quad (5)$$

The result presented in Fig. 3 includes the massive charm contribution, i.e.

$$g_1^\gamma(x, Q^2) = g_1^{\gamma, q}(x, Q^2) + g_1^{\gamma, c}(x, Q^2) \quad (6)$$

with

$$g_1^{\gamma, c} = g_1^{\gamma^* \gamma \rightarrow c\bar{c}}(x, Q^2) + g_1^{\gamma^* G \rightarrow c\bar{c}}(x, Q^2) \quad (7)$$

calculated with the help of the appropriate subprocess cross sections for [6] $\Delta\sigma(\gamma^*\gamma \rightarrow c\bar{c})$ and the closely related $\Delta\sigma(\gamma^*G \rightarrow c\bar{c})$, assuming $m_c = 1.5 \text{ GeV}$ for the charm quark mass. Note that the results for g_1^γ/α are dominated by the u - quark contribution due to its larger charge factor.

The feasibility of a distinctive determination of the polarized parton distributions of the longitudinally polarized photon is clearly indicated by a combined analysis of the proposed measurements.

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Figure Captions

Fig. 1 Predictions for the singly resolved charm production asymmetry $-A^{c\bar{c}}(x_F, x_T^{min})$ with $x_T^{min} = 0.05$ as defined in eq.(4) for the two differently saturated Δf^γ . The full (dashed) line corresponds to the maximally (minimally) saturated set. The scale in the parton distributions and α_s was taken to be $2m_c$ with $m_c = 1.5 \text{ GeV}$.

Fig. 2 Same as in Fig. 1, but for the asymmetry $A^{jet}(x_F, x_T^{min})$ for singly resolved jet production. The scale was taken to be $p_{T,min}^{jet}$.

Fig. 3 Prediction for the polarized photon structure function g_1^γ/α at $Q^2 = 10 \text{ GeV}^2$, calculated according to eqs. (5)–(7). The results for the two sets are distinguished as in Figs. 1,2.

FIG. 1

FIG. 2

FIG. 3