QCD in Two Photon Physics at Future Linear Colliders

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Abstract. Prospects for QCD studies in two-photon interactions at a future linear e^+e^- and $\gamma\gamma$ collider are discussed.

INTRODUCTION

Traditionally e^+e^- colliders provide a wealth of two-photon data. The photons are produced via bremsstrahlung [1] from the electron and/or positron beam, which leads to a soft energy spectrum for the photons. A photon collider [2] converts the electron beams of a linear e^+e^- collider into high energy photon beams via Compton laser backscattering. A plethora of QCD physics topics in two-photon interactions can be addressed with a linear e^+e^- collider or photon collider.

I TOTAL CROSS SECTION

The total $\gamma\gamma$ cross-section is not understood from first principles. Fig. 1 shows photon-photon cross-section data compared with phenomenological models [3]. All models predict a rise of the cross-section with the collision energy, $\sqrt{s}_{\gamma\gamma}$, but the predictions for high photon-photon energies show dramatic differences.

To distinguish between the models the cross-sections need to be determined to a precision of better than 10% [3], difficult to achieve in the e^+e^- collider mode, since the variable $\sqrt{s}_{\gamma\gamma}$ needs to be reconstructed from the visible hadronic final state. However, for a photon collider the photon beam energy can be tuned with a spread of less than 10%, such that measurements of $\sigma_{\gamma\gamma}^{tot}$ can be made at a number of different energy values in the range $50 < \sqrt{s}_{\gamma\gamma} < 400$ GeV with a precision in the range of 5% to 10%. The largest uncertainty is the diffractive contribution to the cross-section. The slope of the rise of the cross-section can be determined much more accurately. Fitting data to the Regge inspired form s^ϵ in the high energy region, one can determine ϵ with a precision of $\Delta\epsilon = 0.02$. The models show a variation between $\epsilon = 0.08$ and $\epsilon = 0.26$

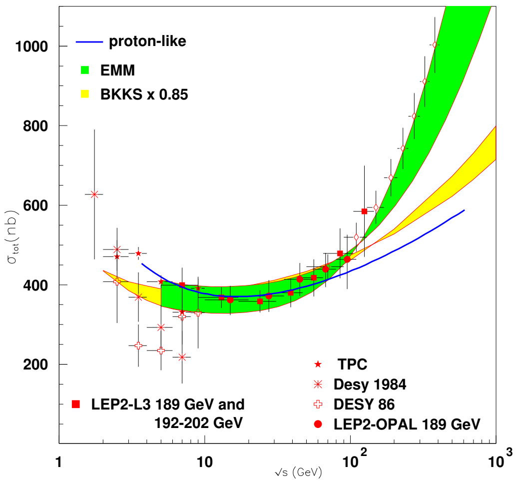

FIGURE 1. The total $\gamma\gamma$ cross-section as function of the collision energy, compared with model calculations (see [3]).

II PHOTON STRUCTURE

The classical way to study the structure function of the photon, F_2^γ, is via deep inelastic electron-photon scattering (DIS), i.e. two-photon interactions with one quasi-real (virtuality $Q^2 \sim 0$) and one virtual ($Q^2 >$ few GeV^2) photon.

To measure F_2^γ it is important to detect (tag) the scattered electron which has emitted the virtual photon. Background studies suggest that these electrons can be detected down to 25 mrad and down to 50 GeV. For $e\gamma$ collisions at a photon collider the systematic error can be controlled to about 5%. Fig. 2 shows the results [5], with statistical and (5%) systematical error, for 20 fb^{-1} photon collider luminosity. Measurements can be made in the region $5.6 \cdot 10^{-5} < x < 0.56$ and $10 < Q^2 < 8 \cdot 10^4$ GeV^2. For the e$^+$e$^-$ collider mode the hadronic final state needs to be measured accurately in order to reconstruct x. This limits x_{min} to around 10^{-3}, but does enable measurements in the high x ($0.1 < x < 0.8$) and high Q^2 ($Q^2 > 100$ GeV^2) range, for detailed F_2^γ QCD evolution tests [6]. At very high Q^2 values ($Q^2 \sim 10000$ GeV^2) also Z and W exchange will become important [7], and the up and down type quark content of the photon can be determined separately.

DIS $e\gamma$ scattering constrains the gluon distribution only weakly via QCD evolution. Direct information on the gluon in the photon can however be obtained from measurements of jet and charm production [8] at an e$^+$e$^-$ and photon collider. Values of x_γ down to a few times 10^{-3} can be reached [8,9], a region where predicted gluon distributions typically differ by a factor of two or more.

A linear collider also provides circularly polarised photon beams, offering a unique opportunity to study the polarised parton distributions of the photon, for which no experimental data are available to date. These can be obtained from inclusive

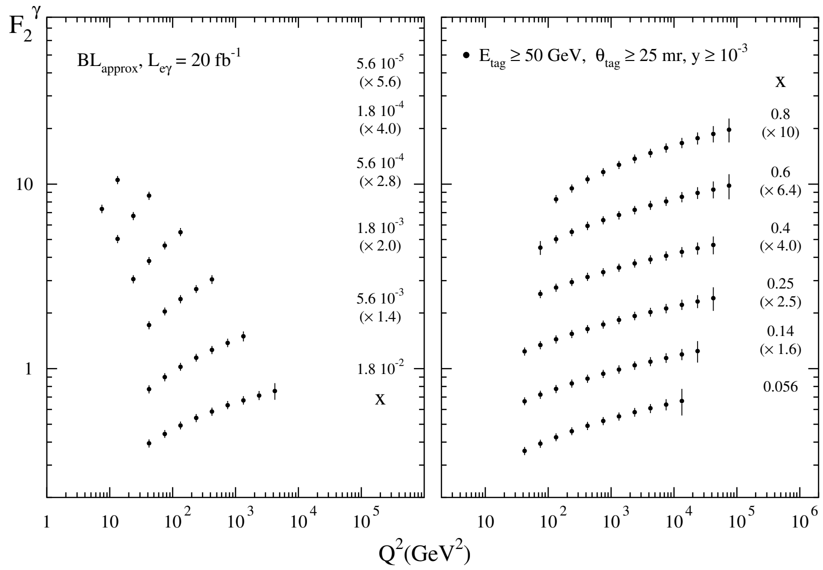

FIGURE 2. The kinematic coverage of the measurement of F_2^γ for the backscattered $e\gamma$ mode at a 500 GeV linear collider.

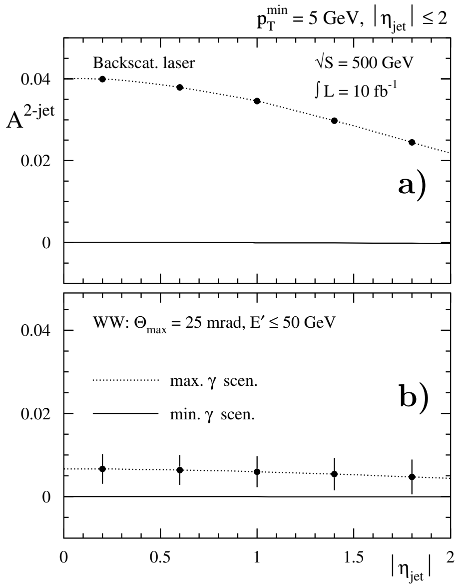

FIGURE 3. di-jet spin asymmetry for events with $x_\gamma < 0.8$, $p_T^{jet} = 5$ GeV and $|\eta_{jet}| < 2$ for collisions at an $e\gamma$ collider (a) and $\gamma\gamma$ (b) collisions at an e$^+$e$^-$ collider. Predictions are shown for two different assumptions for the polarized parton distributions of the photon. Only statistical errors are shown.

polarised deep inelastic $e\gamma$ measurements and from jet measurements [10,11] in polarised $\gamma\gamma$ scattering. Fig. 3 shows the asymmetry measured for dijet events, for the e^+e^- and photon collider modes separately. Already with very modest luminosity significant measurements of the polarised parton distributions become accessible at a linear collider. The extraction of the polarised structure function $g_1(x, Q^2)$ can however be best done at the $e\gamma$ mode of a photon collider.

III TESTING OF BFKL DYNAMICS

The most promising measurement for observing the effect of the large logarithms is the total $\gamma^*\gamma^*$ cross-section. The events are measured by tagging both scattered electrons. At a 500 GeV e^+e^- collider about 3000 events are expected per year (200 fb^{-1}) and a factor of 3 less in the absence of BFKL effects in the data [12]. Tagging electrons down to as low angles as possible (e.g. 25 mrad) is however needed.

Closely related is vector meson production, e.g $\gamma\gamma \to J/\psi J/\psi$ or (at large t) $\gamma\gamma \to \rho\rho$. J/ψ's can be detected via their decay into leptons, and separated from the background through a peak in the invariant mass. Approximately 100 fully reconstructed 4-muon events are expected for 200 fb^{-1} of luminosity for a 500 GeV e^+e^- collider [13].

Further processes include $e\gamma$ scattering with associated jet production [14], g_1 at small x [11], and $e^+e^- \to e^+e^-\gamma X$ and $\gamma\gamma \to \gamma X$ [15]. In all, the study of all these processes will provide new fundamental insight in small x QCD physics.

REFERENCES

1. C. F. Weizsäcker, Z. Phys. **88** (1934) 612; E.J. Williams, Phys. Rev. **45** (1934)729.
2. I.F.Ginzburg, G.L.Kotkin, V.G.Serbo and V.I.Telnov, Nucl. Instr. and Meth. **205** (1983) 47; I.F.Ginzburg, G.L.Kotkin, S.L.Panfil, V.G.Serbo and V.I.Telnov, Nucl. Instr. and Meth. **219** (1984) 5; V.I.Telnov, Nucl. Instr. and Meth. **A294** (1990) 72.
3. R. M. Godbole and G. Pancheri, hep-ph/0010104.
4. R. M. Godbole, G. Pancheri and A. De Roeck, LC-TH note in preparation.
5. A. Vogt, Nucl. Phys. Proc. Suppl. **82** (2000) 394;
   A. De Roeck, A. Vogt, LC-TH note in preparation.
6. R. Nisius, Phys. Rep. **332** (2000) 165.
7. A. Gehrmann-De Ridder et al., Phys. Lett. **B469** (1999) 259.
8. P. Jankovski, M. Krawczyk, and A. De Roeck, LC-TH-2000-034, hep-ph/0002169.
9. T. Wengler, A. De Roeck, Workshop on Photon Colliders, DESY, June 2000.
10. M. Stratmann, Nucl. Phys. Proc. Suppl. **82** (2000) 400.
11. J. Kwiecinski and B. Ziaja, hep-ph/0006292.
12. J. Kwiecinski, L. Motyka, Phys. Lett. **B462** (1999) 203.
13. J. Kwiencinski, L.Motyka, A. De Roeck, LC-TH-2000-012, hep-ph/0001180.
14. G. Contreras and A. De Roeck, LC-TH note in preparation.
15. N. Evanson and J. Forshaw, LC-TH-2000-010, hep-ph/9912487.