Photon collider at TESLA: parameters and interaction region issues

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Abstract.
Photon colliders ($\gamma\gamma$, γe) are based on backward Compton scattering of laser light off the high energy electrons of linear colliders. Recent study has shown that the $\gamma\gamma$ luminosity in the high energy peak can reach 0.3–0.5 $L_{\mathrm{e^+e^-}}$. Typical cross sections of interesting processes in $\gamma\gamma$ collisions are higher than those in $\mathrm{e^+e^-}$collisions by about one order of magnitude, so the number of events in $\gamma\gamma$ collisions will be more than that in $\mathrm{e^+e^-}$ collisions. In this paper possible parameters of a photon collider at TESLA and a laser scheme are briefly discussed.

I INTRODUCTION

The unique feature of the e^+e^- Linear Colliders (LC) with the energy from hundreds GeV to several TeV is the possibility to construct on its basis a Photon Linear Collider (PLC) using the process of the Compton backscattering of laser light off the high energy electrons [1].

The maximum c.m.s. energy in $\gamma\gamma$ collisions reaches about 0.8 (0.9 in γe collisions) of that in $\mathrm{e^+e^-}$ collisions. Typical luminosity distribution [2,3] in $\gamma\gamma$ collisions has a high energy peak and some low energy part. The peak has the width at half of maximum about 15%, photons here can have high degree of circular polarization. This region is the most valuable for experimentation. Comparing event rates in $\gamma\gamma$ and $\mathrm{e^+e^-}$ collisions we will use the value of $\gamma\gamma$ luminosity in this peak.

In this talk I briefly discuss physics, possible parameters of the photon collider at TESLA and a lasers–optics scheme. For more details and references see my recent paper [3].

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II PHYSICS

Physics in e^+e^- and $\gamma\gamma$, γe collisions is quite similar because the same particles can be produced. However, reactions are different and can give complementary information. Some phenomena can best be studied at photon colliders due to better accuracy (larger cross-sections) or larger accessible masses (a single resonance (in $\gamma\gamma$ and γe) or a pair of light and heavy particles (in γe). A short list of processes for the physics program of the photon collider is presented in Table 1 [4].

TABLE 1. Gold-plated processes at photon colliders

$\gamma\gamma \to h^0 \to b\bar{b}$	$\mathcal{SM}$ Higgs, $m_{h^0} < 160$ GeV or $\mathcal{MSSM}$ Higgs, $m_{h^0} < 130$ GeV
$\gamma\gamma \to h^0 \to WW^*$	$\mathcal{SM}$ Higgs, 140 GeV$< m_{h^0} < 190$ GeV
$\gamma\gamma \to h^0 \to ZZ$	$\mathcal{SM}$ Higgs, 180 GeV$< m_{h^0} < 350$ GeV
$\gamma\gamma \to H, A \to b\bar{b}$	single production of $\mathcal{MSSM}$ heavy Higgs states, for large $\tan\beta$
$\gamma\gamma \to \tilde{f}\bar{\tilde{f}},\ \tilde{\chi}_i^+\tilde{\chi}_i^-,\ H^+H^-$	large cross sections, possible observations of FCNC
$\gamma\gamma \to S$	$\tilde{t}\bar{\tilde{t}}$ stoponium in the S-wave
$e^-\gamma \to \tilde{e}^-\tilde{\chi}_1^0$	$m_{\tilde{e}^-} < 0.9\sqrt{s_{e^+e^-}} - m_{\tilde{\chi}_1^0}$
$\gamma\gamma \to W^+W^-$	anomalous W interactions, extra dimensions
$\gamma e^- \to W^-\nu_e$	anomalous W couplings
$\gamma\gamma \to WWWW, WWZZ$	strong WW scattering, quartic anomalous W, Z couplings
$\gamma\gamma \to t\bar{t}$	anomalous top quark interactions
$\gamma e^- \to \bar{t}b\nu_e$	anomalous Wtb coupling
$e^-\gamma \to e^-X$	spin independent and spin dependent photon structure functions
$e^-\gamma \to \nu_e X$	flavour decomposition of the quark distributions in the photon
$\gamma g \to q\bar{q},\ c\bar{c}$	gluon distribution in the photon
$\gamma\gamma \to J/\psi J/\psi$	QCD Pomeron

III POSSIBLE LUMINOSITIES OF $\gamma\gamma$,γe COLLISIONS AT TESLA

As it is well known in e^+e^- collisions the luminosity is restricted by beamstrahlung and beam instabilities. In $\gamma\gamma$ collisions these effects are absent, therefore one can use beams with much smaller cross section. At present TESLA beam parameters the $\gamma\gamma$ luminosity is determined only by the attainable geometric L_{ee} luminosity.

Recently it was found that horizontal emittance at TESLA damping ring can be reduced by a factor of 4 in comparison with the previous design. The resulting parameters of the photon collider at TESLA for 2E=500 GeV and H(130) are presented in Table 2 [3].

Figures for the luminosity distribution in $\gamma\gamma$ and γe collisions can be found elsewhere [3].

TABLE 2. Parameters of the $\gamma\gamma$ collider based on TESLA. Left column for 2E=500 GeV, next two columns for Higgs with M=130 GeV, two options: $x = 1.8, \lambda = 1.06$ μm and $x = 4.6 \lambda = 0.32$ μm.

	2E=500 $x = 4.6$	2E=200 $x = 1.8$	2E=158 $x = 4.6$
$N/10^{10}$	2	2	2
σ_z, mm	0.3	0.3	0.3
$f_{rep} \times n_b$, kHz	14.1	14.1	14.1
$\gamma\epsilon_{x/y}/10^{-6}$,m·rad	2.5/0.03	2.5/0.03	2.5/0.03
$\beta_{x/y}$,mm at IP	1.5/0.3	1.5/0.3	1.5/0.3
$\sigma_{x/y}$,nm	88/4.3	140/6.8	160/7.6
L_{ee}(geom), 10^{33}	120	48	38
$L_{\gamma\gamma}(z > 0.8 z_{m,\gamma\gamma}), 10^{33}$	11.5	3.5	3.6
$L_{\gamma \mathrm{e}}(z > 0.8 z_{m,\gamma \mathrm{e}}), 10^{33}$	9.7	3.1	2.7

For these luminosities the rate of production of the SM Higgs boson with M_H=130(160) GeV in $\gamma\gamma$ collisions is 0.9(3) of that in e^+e^- collisions at 2E = 500 GeV (both reactions, ZH and H$\nu\nu$) [3].

Comparing the $\gamma\gamma$ luminosity with the e^+e^- luminosity ($L_{e^+e^-} = 3 \times 10^{34}$ cm^{-2}s^{-1} for $2E = 500$ GeV) we see that for the same energy $L_{\gamma\gamma}(z > 0.8 z_m) \sim 0.4 L_{e^+e^-}$. Having beams with smaller emittances one can get higher $\gamma\gamma$ luminosity, while e^+e^- luminosity is restricted by beam collision effects.

Typical cross sections of interesting processes in $\gamma\gamma$ collisions are higher than those in e^+e^-collisions by about one order of magnitude [2–4], so the number of events in $\gamma\gamma$ collisions will be more than that in e^+e^- collisions. For example, the cross section for production of H^+H^- pairs in collisions of polarized photons is higher than that in e^+e^- collisions by a factor of 20 (not far from the threshold); this means 8 times higher production rate for the luminosities given above.

IV LASERS, OPTICS

A key element of photon colliders is a powerful laser system which is used for e$\to \gamma$ conversion. Lasers with the required flash energies (several J) and pulse duration $\sim$ 1 ps already exist. The main problem is the high repetition rate, about 10–15 kHz, with a pulse structure repeating the time structure of the electron bunches. The most attractive and reliable solution at this moment is an "optical storage ring" (fig.1), with a diode pump laser injector. This approach can be considered as a base-line solution for the TESLA photon collider [3].

The laser pulses are send to the interaction region where they are trapped in an optical storage ring. Each bunch makes about 6 round trips (12 collisions with the

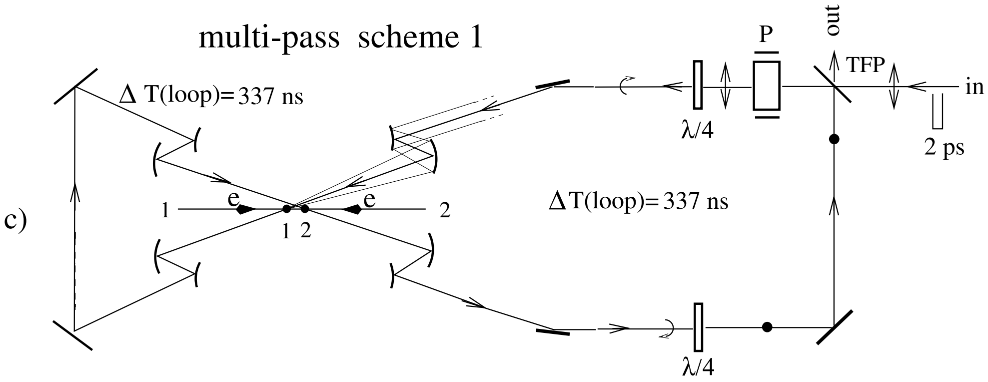

FIGURE 1. Optical storage ring for $e \to \gamma$ conversions. P is a Pockels cell, TFP is a thin film polarizer, thick dots and double arrows show the direction of polarization.

electron beams) and then is deleted from the ring. All these tricks can be done by switching one Pockels cell (2 round trips are possible without Pockels cell).

A laser system required for a such optical storage ring can consist of about 8 lasers of 1.5 kW average power each. Due to the high average power and reliability the lasers should be based on diode pumping. This technology is developed very actively for a inertial fusion. Present cost of diodes for such laser system is about 25 M$ and it is expected that their cost will be further decreased several times. Such system can be done now: all technologies exist.

V CONCLUSION

The luminosity in $\gamma\gamma$ collisions (in the high energy peak) can reach about 40% of e^+e^- luminosity. Since cross sections in $\gamma\gamma$ collisions are typically higher by one order of magnitude than those in e^+e^- collisions and because of access to higher masses for some particles, the photon collider now has very serious physics motivation. There is good scheme for the laser system, which, it seems, can be build now.

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