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Detector Issues at the Photon Collider

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Presented at PLC2005, Kazimierz, Poland, September 2005

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1. Introduction

The aim of a photon collider is to study processes like $\gamma\gamma \to H \to b\bar{b}$, $\gamma\gamma \to W^+W^-$ and $\gamma\gamma \to$ SUSY [1] which needs a machine with an energy range from $\sqrt{s_{\gamma\gamma}} \sim 120\,\mathrm{GeV}$ up to the maximum possible energy. The photon collider has to be adapted to the bunch structure of the ILC, this means trains of 2800 bunches with 337 ns time between two bunches and a train repetition rate of 5 Hz. It is felt that the best laser technology for such a time structure is a laser cavity with all mirrors outside the detector. The large disruption of the electron beams in the electron-laser interaction requires a beam crossing angle larger than for the e^+e^- case. This study assumes an angle of about 35 mrad. The forward part of the $\gamma\gamma$-detector is completely driven by this crossing angle and the space needed for the laser pipes. The central part of the detector is assumed to be identical to the e^+e^- one, described in the TESLA TDR[2]. The assumed beam parameters are summarised in table 1 and the tracking system of the detector is shown in figure 1.

2. Constraints from the Lasersystem

A possible laser cavity for the photon collider is described in detail in [4]. A sketch of the system is shown in the left plot of figure 2. All mirrors are outside the detector and only the space for the pipes has to be left in the forward region. The beam crossing angle is assumed to be in the horizontal plane. To minimise the dead space the laser pipes should then lie in the

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	e^+e^- [3]	$\gamma\gamma$ [1]
$N/10^{10}$	2	2
σ_z [mm]	0.3	0.3
pulses/train	2820	2820
Repetition rate [Hz]	5	5
$\gamma\epsilon_{x/y}/10^{-6}$ [m·rad]	10./0.03	2.5/0.03
$\beta_{x/y}$ [mm] at IP	15/0.4	1.5/0.3
$\sigma_{x/y}$ [nm]	553/5	88/4.3
$\mathcal{L}(z > 0.8 z_m)$ [$10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$]	3.4	1.1

Table 1. Beam parameters for ILC [3] and the $\gamma\gamma$ collider [1].

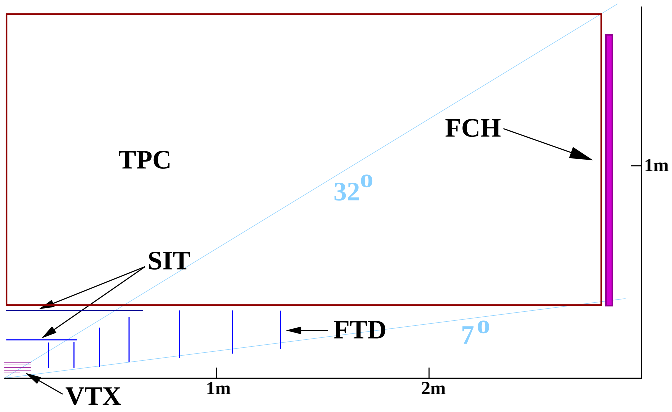

Fig. 1. Tracking system of the TESLA TDR detector

vertical plane. The right plot of figure 2 shows the cross section of the detector at the calorimeter surface. The laser pipes have an opening angle of 38 mrad and a stay-clear from the z-axis of 17 mrad is needed. These conditions require a beam-laser crossing angle of 55 mrad and an outer edge of the laser beampipe of 93 mrad.

3. Detector and Backgrounds

The background in the detector is driven by the large disruption angle and the angle between the outgoing beam and the B-field. The left plot of figure 3 shows the energy distribution on the detector surface per bunch crossing. Due to the large deposited energy there is a large potential for backscattering from the detector exit into the sensitive detectors. This background needs to be shielded by a thick tungsten mask that surrounds the laser pipes. The mask is shown in figure 4. It consist of two parts. The

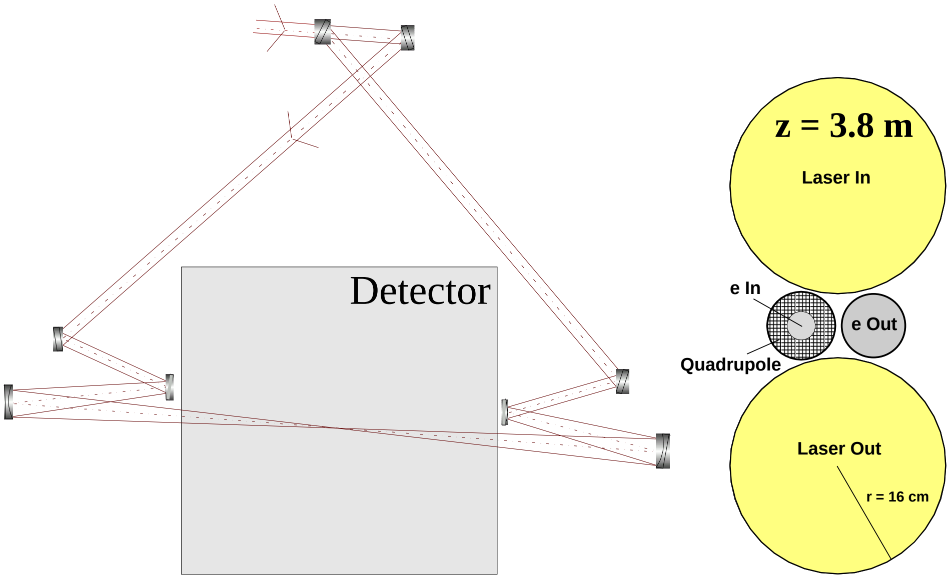

Fig. 2. Left: Principle setup of the laser cavity. Right: Laser- and beampipes at the detector exit.

outer, conical part starts at $z = 23\,\mathrm{cm}$ and shields the full detector apart from the innermost layer of the microvertex detector. It surrounds directly the laser pipes. This mask is, however, not sufficient to protect the TPC against photons. Not to increase the dead region of the detector further a second mask is added inside the outer mask. Since the background is not symmetric in the azimuthal plane the space occupied by the laser pipes can be left free. This mask can only start at $z = 1\,\mathrm{m}$ in order not to be hit by too many electrons and positrons from the interaction point. With this masking system the photon background in the TPC is on the same level as in $\mathrm{e^+e^-}$ running [2]. The background in the vertex detector for $\gamma\gamma$ and $\mathrm{e^+e^-}$ is shown in the right plot of figure 3. The background from direct hits from the interaction point is significantly smaller than in $\mathrm{e^+e^-}$ because the PLC runs in $\mathrm{e^-e^-}$ mode where the two bunches repel each other ("anti pinch effect") contrary to the $\mathrm{e^+e^-}$ mode where they attract each other ("pinch effect"). In the inner layer there is a significant amount of backscattering which cannot be masked, however the level still stays below the one in $\mathrm{e^+e^-}$.

With this masking scheme the detector stays dead below a polar angle of 7.5°. However some tagging calorimeters between the mask and the in- and outgoing beampipes, that could be used for photon structure-function measurements should still be possible. In the $\mathrm{e}\gamma$ mode also the space used by one of the laser pipes could be used for such a device.

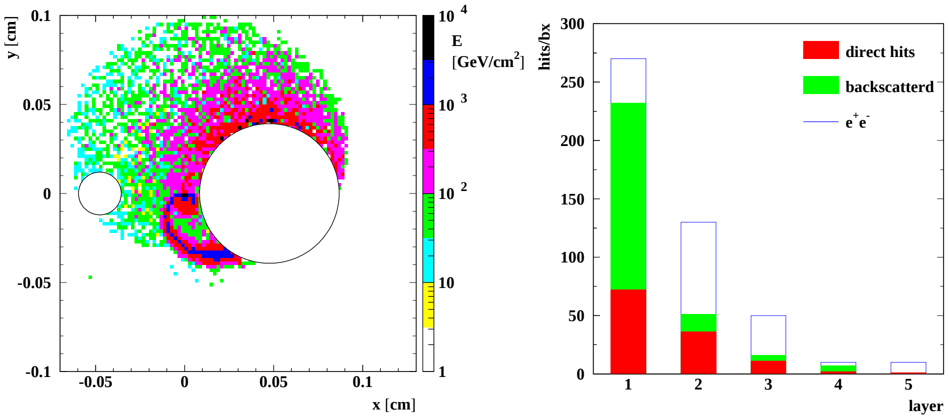

Fig. 3. Left: Energy deposited on the detector surface per bunch crossing. Right: Hits per bunch crossing in the microvertex detector.

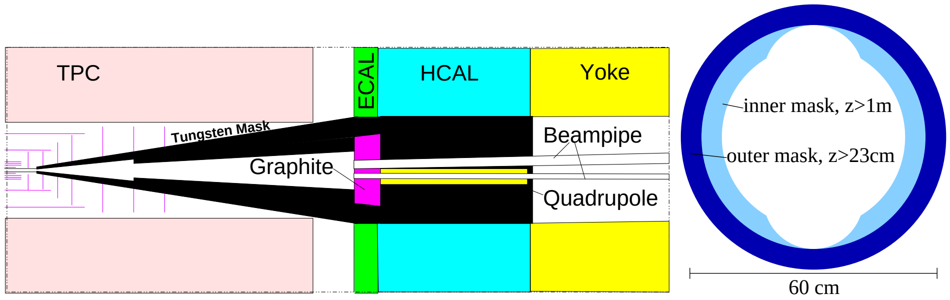

Fig. 4. Mask of the $\gamma\gamma$ detector. Left: x-z projection, right: x-y projection

4. Low Energy $q\bar{q}$−Background

Because of the large luminosity and high cross section of $\gamma\gamma \to q\bar{q}$ at low $\sqrt{s}$ one to two pileup events will be overlaid in each bunch crossing depending on the running scenario [5]. Roughly half of the charged tracks originating from these events can be tagged by the vertex detector due to the separation of the vertices in the z-direction (see fig. 5 left). The tracks from the pileup events are forward peaked (see fig. 5 right), so that they can be largely rejected if the physics channel of interest is concentrated in the central region of the detector, like the production of Higgs bosons.

However for physics channels that are also peaked in the forward region, like the production of W-bosons [6], the pileup events are a severe problem. Fig. 6 shows the W-mass spectrum from the $e\gamma \to We\nu$ analysis with and without pileup tracks [6]. After pileup rejection the spectrum gets significantly broadened and the resolution on the decay angles gets worse. In addition the pileup contributes roughly 15 hits per layer in the microvertex detector. This dominates over the hits from beam beam interactions in the outer three layers

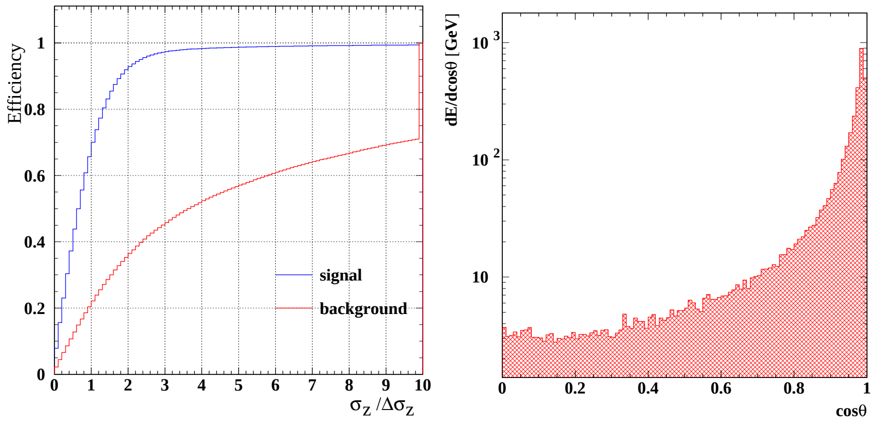

Fig. 5. Left: Track tagging efficiency for a cut on the normalised z-impact parameter for signal and pileup tracks. Right: Polar angle distribution for pileup tracks.

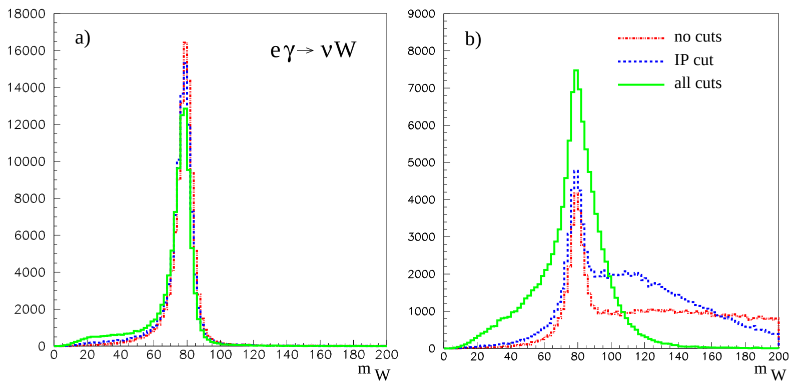

Fig. 6. Reconstructed W-mass at the different levels of pileup rejection without (a) and with (b) overlaid pileup events in the $e\gamma \to W\nu$ analysis.

5. The Beam Dump

Since photons cannot be deflected there has to be a direct line of sight from the interaction point to the beam dump. The standard ILC design contains a water dump at a distance of about 100 m from the detector.

Such a dump has been simulated with Geant4 [7] using the physics list QGSP_HP and a cross section bias of 100. Cross checks have been done with LHEP_GN, QGSP_GN, and a cross section bias of one and consistent results have been found. For a neutron kinetic energy of $E_n > 15\,\mathrm{keV}$ about 3.5 neutrons/bx/cm^2 have been found with this setup from the γ-beam only corresponding to $5 \cdot 10^{11}$ neutrons/cm^2/year. If the electron beam will be dumped in the same beam dump this number has to be doubled. Such a neutron flux will be a problem for a CCD vertex detector. Some ideas how to reduce the neutron flux exist [8], but there is no detailed design yet.

6. Conclusions

The forward region of a $\gamma\gamma$ detector will be heavily affected by the space occupied by the beam and laser pipes and by a masking system suppressing backgrounds. The region below 7.5° will be dead, possibly apart from some tagging detectors for two-photon physics. In the rest of the detector, however, the environment will be similar to the e^+e^- case so that the same detector can be used for both running modes.

A possible problem is the neutron flux from the dump. If a non radiation hard technology should be used for the vertex detector a simple water dump is probably not possible.

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