

The lay-out of the photon collider at the international linear collider

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Abstract. One of the interaction regions at the linear colliders should be compatible both with e^+e^- and $\gamma\gamma, \gamma e$ modes of operation. In this paper, the differences in requirements and possible design solutions are discussed.

Keywords. Photon collider; linear collider; gamma gamma; photon photon; photon electron; Compton scattering.

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The photon collider ($\gamma\gamma, \gamma e$) is being considered as an ‘option’ in the international linear collider (ILC) project [1–3], while e^+e^- collisions are ‘baseline’. In reality, this means that at the beginning of its operation, the ILC will run in the e^+e^- mode, and then one of the interaction regions (IPs) and the detector will be upgraded for operation in the $\gamma\gamma, \gamma e$ mode. The photon collider has many specific features that strongly influence the baseline ILC configuration and the parameters of practically all of its subsystems. They should be included into the baseline design from the very beginning – otherwise, the upgrade will be very costly or even impossible at all.

Here, we discuss only the requirements related to the ILC lay-out. They are the following:

- For the removal of disrupted beams, the crab-crossing angle at one of the interaction regions should be about 25 mrad [2,3]
- The very wide disrupted beams should be transported to the beam dumps with acceptable losses. The beam dump should be able to withstand absorption of a very narrow photon beam after Compton scattering.

Both of these requirements are mandatory for the photon collider. They do not contradict the e^+e^- mode of operation, which can run at the same IP without any modification to the IP (only the forward part of the detector has to be modified). However, such conditions are not optimum for e^+e^- .

For e^+e^- collisions, two IPs are currently being considered, one with a small crossing angle (2 mrad), and the other with a large crossing angle (14 or 20 mrad). While this paper was in preparation, the beam-delivery group suggested 14 mrad

at both IPs. In $\gamma\gamma$ collisions, the outgoing beams are strongly disrupted, and for their removal a larger crossing angle is needed. The minimum crossing angle is the sum of the disruption angle and the angular size of the final quad. Detailed considerations show that the minimum crossing angle required for $\gamma\gamma$ collisions is about 25 mrad [2,3].

There are also differences in the requirements for the extraction lines and beam dumps due to the very different beam properties. In the e^+e^- case, after collision the beams remain quite monochromatic and there is a possibility to measure their properties (the energy spectrum and polarization). Such an extraction line should be quite long and equipped with many magnetic elements and diagnostics.

At the photon collider, the situation is different:

- The disrupted beams at a photon collider consist of an equal mixture of electrons and photons (and some admixture of positrons).
- Low-energy particles in the disrupted beams have a large angular spread and need exit pipes of a large diameter.
- Following the Compton scattering, the photon beam is very narrow, with a power of about 10 MW. It cannot be dumped directly at a solid or liquid material.

There exists an idea of a beam dump for the photon collider, as well as some simulations [3,4]. In short, it is a long tube, the first 100 m of which is vacuum, followed by a 150 m long gas converter ended by the water beam dump. The diameter of the tube at the beam dump is about 1.5 m. In addition, there are fast sweeping magnet for electrons. Due to the large beam width, no detailed diagnostics is possible, only beam profile measurements may be possible.

At present, the ILC beam delivery group has the following suggestion [5]. The extraction lines and the beam dump for e^+e^- and $\gamma\gamma$ are very different. Their replacements (transition to $\gamma\gamma$ and back after the energy upgrade) will be problematic due to induced radioactivity. It therefore makes sense to have different crossing angles and separate extraction lines and beam dumps for e^+e^- and $\gamma\gamma$. For the transition from e^+e^- to $\gamma\gamma$, one has to move the detector about 700 m of the upstream beam line (figure 1). The displacement of the detector is equal to 1.8 m and 4.2 m for the increase of the crab-crossing angle from 20 to 25 mrad and from 14 to 25 mrad, respectively. The photon collider needs an additional 250 m of tunnels for the beam dump. This is quite a lot of work.

My first reaction to the above suggestion was quite negative: too expensive, needs a lot of extra work, and is time-consuming. An alternative suggestion may be the following: the same crossing angle, the same beam dump and no detector displacement. What are the disadvantages? In this case, the designs of the extraction line and the beam dump are dictated by $\gamma\gamma$, and so no precision diagnostic in the extraction line for e^+e^- is possible. But is it really necessary? Indeed, without such a special extraction line we can measure the energy and polarization before collisions, many characteristics during the beam collision (the acolinearity angles, distributions of the secondary e^+e^- pairs, the beam deflection angles); we can measure the angular distributions and the charged and neutral contents in the disrupted beams. All these allow the reconstruction of the dynamics of beam collisions, with proper corrections in the simulation. For example, the depolarization during the

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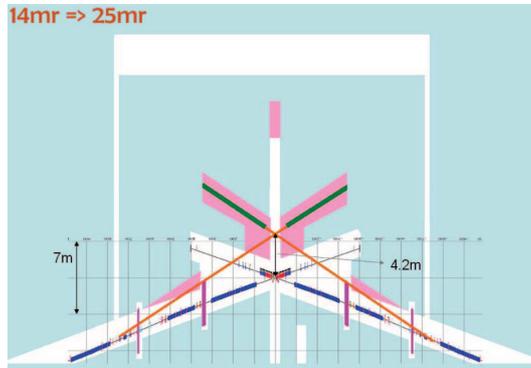


Figure 1. The upgrade path from e^+e^- to $\gamma\gamma$ (14 mrad to 25 mrad).

collision is rather small and knowledge of beam sizes with a 10–20% accuracy is sufficient for introducing theoretical corrections. Direct measurement of the polarization after the collision does not exclude the necessity of such a correction, it is just one additional cross-check, but there are many other cross-checks besides the polarization. In addition, the requirement for the instrumented extraction line for e^+e^- restricts the accessible set of beam parameters and correspondingly the luminosity. One cannot use it for the case of large beamstrahlung losses. It will not work, for example, in the CLIC environment or at the photon collider. In other words, such diagnostic of outgoing beams is useful but not absolutely necessary at linear colliders.

Although the alternative suggestion looks possible and can save money, labor and time, it influences the e^+e^- plans too much. The diagnostics of the outgoing beams will be less precise and it can affect the quality of some physics results. Attempts to reach a consensus would create a tension between e^+e^- and $\gamma\gamma$ communities.

So, in the end I agree with 14 mrad crossing angles at both IPs at the start of the ILC. The upgrade to 25 mrad adds only a fraction of the cost and engineering work, but decouples e^+e^- and $\gamma\gamma$, which is very important. The moving of the detector (perhaps only 3 or so times ever) is not a problem. Hopefully, the shift of the upstream beamlines (700 m) is not a big problem as well, especially if beamline elements are installed on long movable platforms. The upgrade to 25 mrad should be included to the ILC baseline design.

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