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Detector issues for a photon collider

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Abstract. The photon collider is an option at the ILC. In this note detector issues are discussed that are relevant for the change from the e^+e^- mode of the ILC to the $\gamma\gamma$ mode.

Keywords. International linear collider; photon collider.

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1. Introduction

It has been proposed to collide a high power laser beam with the linear collider electron beams to create high energy photon beams which then collide in the IP [1]. The photon collider has been adapted as an option in the ILC program [2], which means that its possible construction should be enabled in the ILC design while a final decision to build it will only be taken, when it is supported by the findings of LHC and e^+e^- running of the ILC.

The physics case for the $\gamma\gamma$ collider has been studied in some detail [3,4]. The strongest point is certainly Higgs physics. For a light Higgs the $H\gamma\gamma$ coupling can be measured to 2%. This coupling is sensitive to Higgs couplings to heavy charged particles and its measurement is unique for a $\gamma\gamma$ collider. However if deviations are found, the new physics lies probably below 1 TeV and can be seen directly after the energy upgrade.

Heavy SUSY Higgses are produced pairwise in e^+e^- running limiting the discovery range to $\sqrt{s}/2$. In $\gamma\gamma$ they are produced singly in the s-channel, so that they can be discovered up to $0.8\sqrt{s}_{ee}$ [5]. Since for medium $\tan\beta$ also the LHC cannot see heavy SUSY Higgses the photon collider has a unique discovery window for them. In theory the $\gamma\gamma$ collider also has a good sensitivity to the CP properties of these states [6]. However, this still needs to be verified in an experimental study.

Also the production cross-sections for charged superpartners of SM particles are large. However, the backgrounds are large as well. Since the production cross-sections can be reliably calculated in QED the events can be used for the precision measurements of decay properties. It has been shown that the decay properties improve the reconstruction of SUSY breaking parameters. However, no comparative study reconstructing specific decay modes exists in e^+e^-.

2. Detector and machine issues

The disruption angle of the outgoing electron beam is around 15 mrad. The crossing angle thus has to be about 10 mrad larger than the minimum possible large crossing angle in e^+e^-. Since such a large crossing angle certainly will not be accepted by the e^+e^- community, the crossing angle will have to be changed for $\gamma\gamma$ running.

Since photons cannot be deflected, the beam dump has to have a straight line of sight to the interaction point so that neutrons from the dump can fly back into the detector the same way. $\mathcal{O}(10^{12})$ neutrons/cm^2/a are expected for a water dump, which starts to be worrying. In the e^+e^- case the neutron problem is solved automatically if the same dump is used with a different crossing angle. The entrance window into the dump should not be a problem for $\gamma\gamma$. However, the energy density in the core of the photon beam is too high for a water dump. Preliminary studies show, that this problem might be solved by an argon tank in front of the water [7].

The direct e^+e^- pair background coming from the IP is smaller in $\gamma\gamma$ than in e^+e^- since $\gamma\gamma$ will run with two e^- beams which repel each other. However, because of the large disruption and crossing angle there is a potentially large background from backscattering at the detector exit. A masking system has been designed to suppress this background [4] (see figure 1) so that the final background is similar to the e^+e^- case.

At small angles the space in the $\gamma\gamma$ detector is taken by the laser pipes and the masking system. However, everything can be fit in a cone with 7° half opening angle which is about the angle where the tracking in the detector concepts start. It should be possible to use the central parts of the e^+e^- detectors also for $\gamma\gamma$ and replace only the inner region.

A potential problem for the photon collider is the beam–beam feedback. Because of the interplay of the crossing angle and the detector solenoid the charge centre gets shifted where the shift depends on the $e\gamma$ conversion efficiency and the beam–beam interactions. For the luminosity studied in [3] the beam–beam deflection is a step function [8] (see figure 2). In this case scanning techniques can be used. However, it has to be shown that this is still true for the luminosities discussed recently [9]. In addition the BPMs need to have a very large aperture because of the large disruption angle.

Switching the ILC from the e^+e^--mode to the $\gamma\gamma$-mode is a major enterprise. In the common IP the detector and the beam delivery system have to be moved to the new crossing angle. The low angle region of the detector has to be changed and the laser system has to be installed or removed. The post IP diagnostics has to be

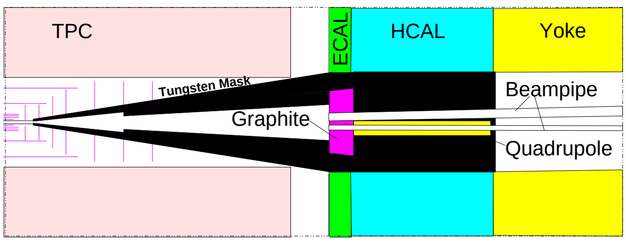

Figure 1. The masking system of a $\gamma\gamma$ detector (x–z projection).

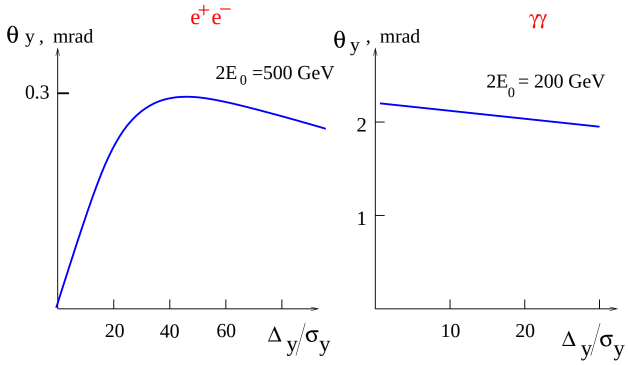

Figure 2. Beam–beam deflection for e^+e^- and $\gamma\gamma$.

removed or installed and the full extraction line has to be replaced. For the change to $\gamma\gamma$ also the laser has to be commissioned without beam. All these probably need a total time of one to two years. During most of this time the second IP, if existent, could continue to take data.

In the full LINAC the positron arm has to be changed to electrons, the polarisation has to be retuned to the new crossing angle and the laser has to be commissioned with the beam.

With only one IP it is probably unrealistic to change back and forth between the two modes. In this case a second IP should be installed at least for $\gamma\gamma$ running or in the worst case $\gamma\gamma$ running can be done after completion of the e^+e^- program.

For the common interaction region the transverse size of the hall and the tunnel has to be large enough to allow for the change in crossing angle. The hall has to be long enough for additional laser pipes and a laser hall above the detector is needed. The laser hall can possibly be situated above the ground level.

3. Discussion points

Not to preclude the photon collider already from the beginning some precautions have to be taken in the design. The strongest constraints come from the different crossing angle, the extraction line instrumentation and the beam dump. One has to study what needs to be foreseen already from the start to make the construction of the $\gamma\gamma$ collider possible later and what time it needs to change between the two modes. The detector seems less of a concern, but its compatibility with the $\gamma\gamma$ mode should be verified.

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