BACKGROUND AT THE INTERACTION POINT FROM THE CLIC POST-COLLISION LINE*

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Abstract

The 1.5 TeV electron/positron CLIC beams, with a total power of 14 MW per beam, are disrupted at the interaction point (IP) due to the very strong beam-beam effect. The resulting spent beam products are transported to suitable dumps by the post-collision beam line, which generates beam losses and causes the production of secondary cascades towards the interaction region. In this paper the electromagnetic backgrounds at the IP are presented, which were calculated using biasing Monte Carlo techniques. Also, a first estimate is made of neutron backshine from the main beam dump.

CLIC POST-COLLISION LINE

The 1.5 TeV beams at CLIC are collided with nanometre beam sizes, leading to huge beam-beam effects, including much disruption in the main beam and production of beamstrahlung photons, coherent and incoherent pairs. The extraction line [1] [2] is designed for minimal losses, but losses occur in the carbon magnet protection absorbers, intermediate dump and main dump. Both absorbers and dumps have the potential to generate backscattered photons and neutrons which can trigger false hits in the detector, and can damage, for example, detector silicon.

LOCATIONS OF PARTICLE LOSS

From the IP, the spent beam passes through 27.5 m of drift space before encountering five vertically bending magnets to provide separation between electrons/positrons of opposite charge and beamstrahlung photons. To protect these magnets, carbon-based protection absorbers scrape the beam. Total losses in the window-frame magnets are less than 100 W/m.

Intermediate Dump

At 67 m from the IP, the beams are directed onto the intermediate dump. For the purpose of simulations, the dump is assumed to consist of a carbon-based absorber with water-cooled aluminium plates and an iron jacket. The asymmetric aperture is designed such that all coherently produced electons/positrons of the opposite charge to the main beam will be absorbed, as indicated in Figure 1. The minimum vertical half-aperture is 5 cm for the upper aperture and 49 cm for the lower aperture, centred on the beamstrahlung photon axis. Beamstrahlung photons pass through the intermediate dump aperture, as well as electrons/positrons of the same charge as the main beam and possessing at least 14% of the nominal beam energy. Electrons/positrons below this energy threshold are lost in the lower half of the intermediate dump, which is necessary to avoid losses in the following C-type magnets.

Main Dump

Electrons/positrons and photons that pass through the aperture of the intermediate dump are directed through four vertically bending C-type magnets, designed to reduce the derivative of the dispersion to zero for the charged beam. At this point, both the electrons/positrons and beamstrahlung photons are transported in parallel towards the main dump at 273 m from the IP. The main dump is a water-based dump, similar in design to that of the ILC [3].

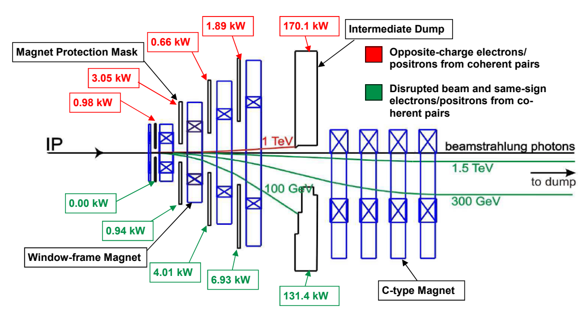

Figure 1: Schematic layout of the CLIC post-collision line showing the power losses at the magnet absorbers and intermediate dump.

PHOTON BACKGROUND CONTRIBUTION

Particles lost in the magnet protection absorbers and intermediate dump interact predominantly with the carbon of the absorber. Typically, interactions of electrons/positrons with carbon results in electromagnetic cascade showering, an iterative process of Bremsstrahlung and pair-production. At lower energy, Compton scattering and multiple deflections dominate. This permits large deflection angles, where

* The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project EuCARD, grant agreement no.227579

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some of the photons will be directed to the IP, contributing to background. The two sets of vertically bending magnets form a chicane, intended to minimise the available line-of-sight to the IP.

SIMULATION TOOLS

For the simulations, the Monte Carlo code GEANT4 [4] was used, with collision data generated using GUINEA-PIG [5]. In the photon study, GEANT4 was interfaced via BDSIM [6]. In order to reduce simulation time, a leading particle biasing method was implemented for the pair-production process [7][8]. In terms of the simulation model, the extraction line components were generated using the Mokka geometry description language. Kinetic energy cuts were set at 10 keV for photons, neutrons and charged particles to ensure that low-energy information was captured.

PHOTON BACKGROUND RESULTS

The photon background as a result of the first magnet and its protection absorber were discussed in [9]. The results presented here are the integrated photon contribution from the five window-frame magnets, their absorbers and the intermediate dump. Since there are negligible losses in the C-type back-bending magnets, these have not been simulated. The photon background from the main dump (at 273 m from the IP) is expected to be low, and will be modeled in future studies.

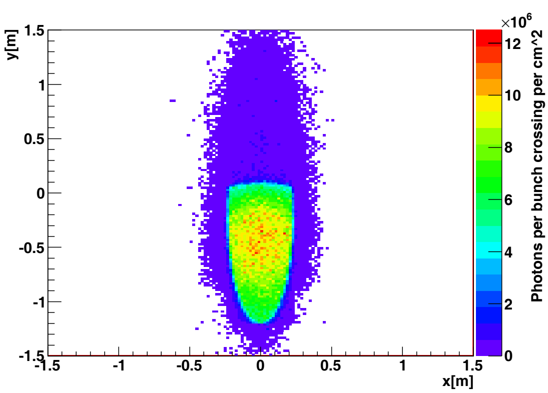

Figure 2: Photons backscattered from the intermediate dump (observed at the upstream end of the dump, 67 m from the IP). The area or higher photon density corresponds to the asymmetric aperture in the dump.

The sharp discontinuity of photon density in Figure 2 demonstrates the shielding effect of the intermediate dump aperture limitation against backscattered photons in this region. Despite the dump body being the source of the photons, a low photon density is observed in this region. The high density of photons in the aperture reinforces the reasoning for having a magnetic chicane. By positioning magnets between the dump and the IP, the line-of-sight is limited by these offset apertures, leading to a reduction in IP background due to photons.

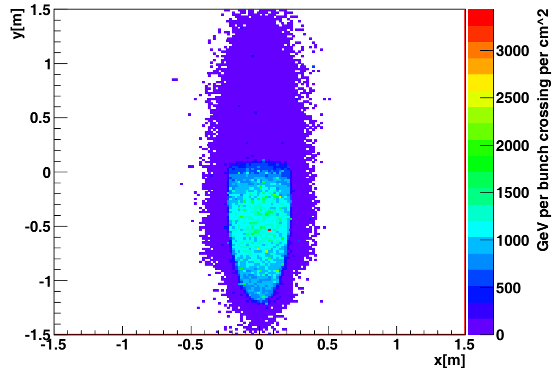

Figure 3: Energy flow of photons (details see Figure 2).

Figure 3 shows an area with a low energy density in the region outside of the beam pipe aperture. In the aperture region, the density of photons increases towards the centre, whereas the energy flow appears to be reasonably constant across this region. This suggests that photons in the centre of the aperture are likely to have less energy per photon than those at the extremity of the aperture. This is of particular importance since the line-of-sight to the IP is centred on the axis of the plot, and this appears to be a low energy density region at ≈20% maximum intensity.

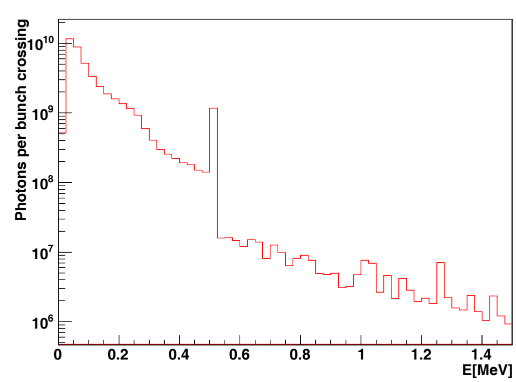

Figure 4: Energy distribution of backscattered photons (as Figure 2, observed at 67 m from the IP).

In Figure 4, the photon energy distribution shows the annihilation peak at 511 keV, with the peak number of photons in the 10-50 keV region. The previous study [9] revealed that these very low energy photons are attenuated by the shielding effect of the magnets, leaving a characteristic Compton scattering peak at 200 keV.

Figure 5 shows the transverse symmetry of the intermediate dump, with the peak appearing at x' = 0. The vertical distribution shows an asymmetry, caused by the aperture asymmetry. Photons with positive vertical angles are largely attenuated by the shielding effect of the dump

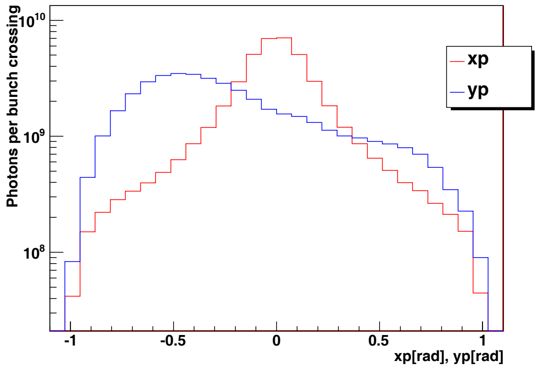

Figure 5: Angular distribution of backscattered photons (as Figure 2, observed at 67 m from the IP).

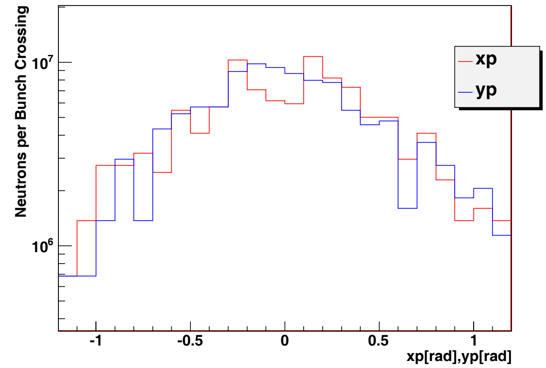

Figure 6: Horizontal and vertical angular distribution of backscattered neutrons, obtained from GEANT4 simulations at the upstream (entrance) end of the CLIC main beam dump.

aperture restriction. The backscattered photon flux passing through the front face of the intermediate dump, towards the IP is calculated as $6.71 \pm 0.01 \times 10^5$ photons cm^{-2} per bunch crossing.

Photons at the IP

By angular extrapolation of the distribution of the backscattered photons detected at the entrance of the first magnet (at 27.5 m from the IP), the flux including the shielding effect of the magnets and absorbers is estimated. The flux through a 2 m x 2 m plane at 0.0 m is calculated as 8.4 ± 2.8 photons cm^{-2} per bunch crossing, with an average energy of 162 ± 4 keV. In the previous study, the first magnet and absorber system contributed a flux of 0.73 ± 0.05 photons cm^{-2} per bunch crossing, suggesting that approximately 7.7 ± 2.6 photons cm^{-2} per bunch crossing is contributed by the subsequent absorbers and the intermediate dump. By comparison, if the upstream magnets and absorbers were not present, the background flux from the entrance of the intermediate dump would be 530 ± 20 photons cm^{-2} per bunch crossing.

NEUTRON BACKGROUND

Neutrons will be produced wherever particles are lost, but predominantly by the high-power beam in the main beam dump. Simulations of neutron production and backscattering from the main dump in direction of the IP have started. Preliminary results for the number of neutrons per bunch crossing, produced by colliding 1.5 TeV electron beams, are shown in Figure 6. In preparation of backtracking these neutrons and estimating the flux at the IP, biasing techniques are being introduced in the simulations. The full post-collision line model, as used for the work on photons, will eventually be inserted in the code for neutrons, with the aim to obtain a realistic picture of the number of neutrons reaching the CLIC detector.

SUMMARY

The results of this study find the intermediate dump to be a significant contributer to IP background. Due to the total loss of the opposite-charge electrons/positrons, the losses on the intermediate dump are an order of magnitude larger than the magnet protection absorbers, and thus more photons are produced. This study demonstrates the effectiveness of the magnetic chicane in background photon reduction, providing ≈98% attenuation of the number of photons. Simulations for the neutron background from the post-collision line are under way.

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