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SOME THOUGHTS ON e^+e^- COLLISIONS IN CLIC

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Abstract

Linear e^+e^- colliders have the potential to also be used to realise e^-e^- collisions. Some preliminary thoughts about the realisation of this at CLIC are presented. Luminosity and some background estimates are also given.

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SOME THOUGHTS ON e^-e^- COLLISIONS IN CLIC

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1 Introduction

While e^-e^- collisions are considered an interesting option also in CLIC (compact linear collider ¹), not much effort was taken to investigate this further. This is partly due to limited resources, but mainly due to the belief that an e^+e^- collider would easily fulfill the requirements for an e^-e^- machine. Generally we consider using the same beam parameters for the e^-e^- case as for e^+e^- . This will first of all ensure that the requirements can actually be met by the machine. In addition, some thought has gone into the choice of parameters. They are aimed to maintain a delicate balance of difficulty in all sub-systems. Table 1 shows some of the fundamental parameters of CLIC.

That solving the problems of the e^+e^- machine solves those of the e^-e^- machine as well is quite obvious for most of the components, like the injectors, the damping rings, the main linacs and most of the beam delivery systems. While it is clear that solutions must have been found because an electron beam is necessary in both machines, it is also clear that the solution for the electron beam is simpler or at least never more difficult than that for the positron beam. E.g. the production of electrons is less demanding than the production of positrons. The problems of cooling the beams in the damping ring and accelerating them in the main linac are not more difficult for electrons than for positrons. The main considerations in these parts of the machine are whether it is necessary to switch the polarity of power supplies to adapt for the different sign of charge or not. These considerations will however only play a role when a real technical design is made and potential additional cost has to be taken into account. However this cost should be relatively small. In addition, it is very likely that this cost already arises if one wants to obtain the possibility of gamma-gamma collisions in CLIC.

In the interaction region, it is not quite so clear that the problems arising from e^-e^- collisions will have been solved automatically by solving them for the e^+e^- operation. The main reason is that in the latter case the two beams attract each other while in the former case they repel each other. Since the luminosity is enhanced by beam-beam forces in the e^+e^- collisions it is reduced by the same forces in the case of e^-e^- .

2 Luminosity

The beams are focused to very small spot sizes during the collision. They therefore create strong electro-magnetic fields which for e^-e^- collisions defocus the other

Figure 1. The relative luminosity spectrum for the e^+e^- and the e^-e^- case. The bins have a width of $0.5\%E_{cm}$

bunch, reducing the luminosity. In addition, the particles trajectories are bent leading to the emission of beamstrahlung. With some probability, colliding particles therefore have lost some energy; this leads to the creation of a luminosity spectrum.

Usually not the total luminosity is of interest but only the fraction above a certain centre-of-mass energy. This fraction varies depending on the precise type of measurements planned. As a figure-of-merit the luminosity $\mathcal{L}_1$ can be used; it is the amount which has $E_{cm} \geq 0.99 \times E_{cm,0}$. The beam-beam interaction has been simulated with GUINEA-PIG ². Figure 1 shows the relative luminosity spectra for e^+e^- and e^-e^- collisions and Fig. 2 contains the absolute spectra. As can be seen the relative spectrum is better for e^-e^- while the absolute luminosity in the peak

Table 1. Basic parameters of CLIC for e^+e^- collisions at $E_{cm} = 3$ TeV.

Parameter	symbol	value
luminosity in the peak [$\text{cm}^{-2}\text{s}^{-1}$]	$\mathcal{L}_1$	3×10^{34}
pulses per second	f_{rep}	100 Hz
bunches per pulse	n_b	154
bunch distance	Δt	0.67 ns
bunch charge	N	4×10^9
hor. beam size at IP	σ_x	43 nm
vert. beam size at IP	σ_y	1 nm
bunch length at IP	σ_z	$35 \mu\text{m}$
norm. hor. emittance before BDS	ϵ_x	$0.68 \mu\text{m}$
norm. vert. emittance before BDS	ϵ_y	10 nm

Figure 2. The absolute luminosity spectrum for the e^+e^- and the e^-e^- case.

Table 2. The background level in the e^+e^- and the e^-e^- machine. All background numbers are per bunch crossing; only hadronic events with a centre-of-mass energy above 5 GeV are considered.

Luminosity	$\mathcal{L}$	$[10^{34} \text{ cm}^{-2} \text{ s}^{-1}]$	10.0	2.5
Av. Energy loss	ΔE	[%]	31	27
γ p. Beamparticle	n_γ		2.3	2.0
No of coh. pairs	n_{coh}	$[10^6]$	690	490
Their total Energy	E_{coh}	$[10^6 \text{ TeV}]$	440	320
No of hadr. events	n_{had}		4.05	1.05
No of incoh pairs	n_{pair}	$[10^3]$	230	75

$\mathcal{L}_1$ is larger by a factor 2.5 for e^+e^- . In principle it should therefore be possible to reduce the horizontal spot size for the e^-e^- machine somewhat. This would degrade the spectrum but increase the absolute luminosity in the peak. However, it does currently not seem very likely that a smaller transverse beam size can be achieved, reference ³ gives some detail for e^+e^- .

An important problem that needs to be studied is the reduction of the luminosity that results from offsets between the two beams at the interaction point. In the case of e^+e^- the attracting force between the beams allows to have significant luminosity even for offsets of a few times the RMS beam sizes. In the e^-e^- machine this will not be the case, which may lead to tighter tolerances for transverse jitters in all parts of the machine.

Figure 3. Angular distribution of the spent beam and the coherent pairs produced in the collision.

3 Background

Several different background sources exist at the interaction point of a linear collider. For an e^-e^- collider, the ones which are induced by the machine should be comparable to the e^+e^- case. During the beam-beam interaction important sources of background are the creation of electron-positron pairs in the field of the oncoming bunch, the so-called coherent pair creation. Also the production of hadrons in two-photon collisions may be significant. Simulation results are shown in table 2. The number of beamstrahlung photons and their energy changes slightly compared to the e^+e^- case. Also for the coherent pair production the changes are not enormous. The rate of hadronic background events is strongly reduced. The main reason is that the former two processes depend on the fields while the latter also depends on the luminosity.

The angular distribution of the spent beams is of some concern; particles at large angle can be lost in the extraction line which transports the spent beams to the beam dumps. As shown in Fig. 3, all the simulated 50000 beam particles have an angle of less than 6 mrad. The same is true for the coherent pairs produced in the collision. The exit hole in the detector ensures that all particles with angles of less than 10 mrad leave the detector without any interaction in the e^+e^- mode. This should also be sufficient for e^-e^- operation.

4 Conclusion

In CLIC it will be possible to have not only e^+e^- collisions but also e^-e^- collisions. The beam parameters used in these modes may not be very different. The lumi-

osity in the e^-e^- mode will be smaller than in e^+e^- by a factor 4. The spectrum however will be better. In the peak of the luminosity spectrum the difference between e^+e^- and e^-e^- will be about a factor 2.5 only. The background conditions in the e^-e^- mode are expected to be better than with e^+e^- collisions. Further study is clearly required.

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References

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