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DRAFT NOTES on CLIC polarization, accuracy of the polarization measurement, polarimetry upstream and downstream of the IP, and related matters

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1. Introduction

These DRAFT notes attempt to summarize what has been written, discussed and (not yet) decided in matters of beam polarization at CLIC. The aim is to trigger discussions before and during the IWLC10 workshop at CERN, hopefully leading to a conclusion concerning
(a) the accuracy required for the polarization measurements, for the 3 TeV case;
(b) the polarimeter downstream of the CLIC interaction point, for the 3 TeV case.

Other very important issues related to polarization at CLIC, such as the production and transport of the polarized beam, are not considered here.

2. CLIC baseline at 3 TeV

The baseline configuration of CLIC [1] foresees a polarized electron beam (80% polarization, longitudinal or transverse) colliding at 3 TeV c.m. energy with an un-polarized positron beam. Provisions are made to allow, at a later stage, inserting the components needed for the production and transport of polarized positrons.

Strong beam-beam effects at a 3 TeV CLIC lead to a significant disruption of the beams, the production of beamstrahlung photons and, in turn, of pairs. A particular feature at very high energy e+e- colliders is the production of a large amount of coherent pairs due to the beam-beam effects. At a 3 TeV CLIC, 3.8x108 such pairs are produced per bunch-crossing.

3. Beam-beam effects and depolarization

The small beam sizes and short bunch lengths, combined with high beam energy, lead to the on-set of significant strong-field QED effects at linear colliders. The resulting effects are simulated by codes such as GuineaPig [2] or CAIN [3]. A number of papers describe the beam-beam effects at ILC and the resulting depolarization at the IP. For CLIC at 3 TeV, for an earlier design with somewhat obsolete collision parameters, the luminosity-weighted effective depolarization was estimated to be about 7% [4]. The two main contributions are spin-flip (2.7%) and spin precession (3.5%).

More recently, for 3 TeV CLIC, a calculation using CAIN has been presented [5]. The luminosity weighted depolarization for the version CLIC_G, assuming 100% polarized e- and e+ beams, has been found to amount to **4.8% ± 1.6%**. There are two main contributions to this effect, the spin-flip part (3.4%) and the coherent pair contribution (1.3%). The error of 1.6% is almost entirely due to uncertainties in calculating the spin-flip contribution. (Note that the paper states that this work is ongoing).
A recent update of this work by the same authors gives for CLIC2010 parameters a depolarization 5.5% ± 0.1% [15]. It is unlikely that the error quoted represents the full

uncertainty in such a calculation – indeed, a comparison with GuineaPig is mentioned to give a results 10% different from the one obtained by CAIN.
Strong-field QED effects, such as the ones relevant for the beam-beam interaction at CLIC, are experimentally explored in high energy beam-on-crystal experiments. An overview can be found in [6]. These experiments generally confirm the underlying model (e.g. spin-flip), but are not accurate enough yet to reduce the uncertainties, e.g. of the depolarization at CLIC.

4. The accuracy requested for the stability and the measurement of the beam Polarization

The stability of the polarization for ILC, and the accuracy of the measurement of the polarization, have been defined as about 0.1% [7]. An estimate of the achievable accuracy for the upstream and downstream polarimeter at ILC is given as 0.25% [8], dominated by detector analyzing power uncertainty.
Lacking additional input, the value of 0.1% has been used in the list of requirements for the CLIC accelerator [9]. Given the uncertainty in the estimate of the depolarization effect for CLIC at 3 TeV, one might question this required accuracy. *Indeed, in a discussion at CERN on 31 August 2011, G. Moortgat-Pick stated that such a high accuracy was not mandatory.*

QUESTION 1:
Would it be adequate to require for CLIC at 3 TeV a polarization accuracy of "at least 1%", and, in order to leave room for all technical improvements, "as accurate as possible at the time of the experiment"?

5. The issue of a polarimeter downstream of the CLIC IP

5.1. Baseline design of the CLIC post-collision line

The present baseline design of the CLIC post-collision line originates from work by A. Ferrari et al. [10]. The design principle is illustrated in Figure 1. Due to the strong beam-beam interaction, the post-collision line must transport and dump particles from the nominal down to very small energies. The large number of coherent pairs produced implies that both same-sign charged particles (e.g. electrons) as well as opposite-sign (e.g. positrons on the electron side) must be cleanly disposed of. This is achieved by a vertical "chicane", i.e. a set of vertical deflection magnets followed by an intermediate dump, plus a second set of magnet and a long drift towards the main dump. In the latest layout of the CLIC post-collision line, the dump is at 273 m from the interaction point. [11].

5.2. Post-IP polarimeter at ILC

The design of the interaction region for ILC has been frozen, with a crossing angle of 14 mrad. The extraction line (post-collision line) design for such a scenario is described in the RDR [12] and is shown in Figure 2. The Compton interaction point (Compton IP, laser crossing particle beam) for the polarization measurement is at the centre of a vertical chicane, scattered Compton-electrons are detected in a Cerenkov detector located about 30 m downstream of the Compton IP. Details of the downstream polarimeter at the ILC are described, e.g., in [13].

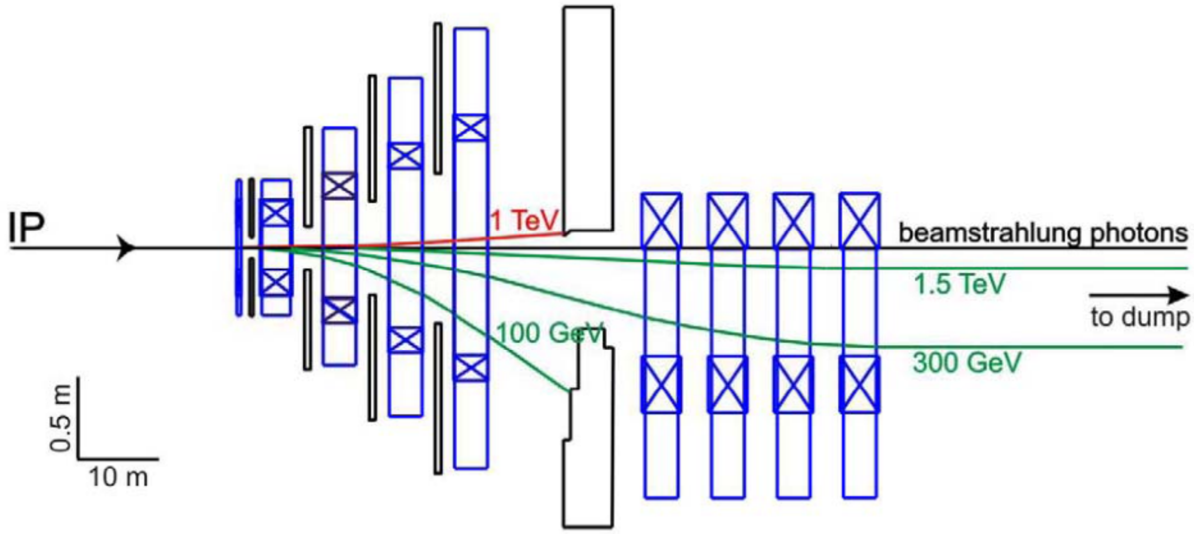

Figure 1: Schematic layout of the CLIC post-collision line, side view (for illustration, the vertical scale is enhanced by a factor 20 over the horizontal scale).

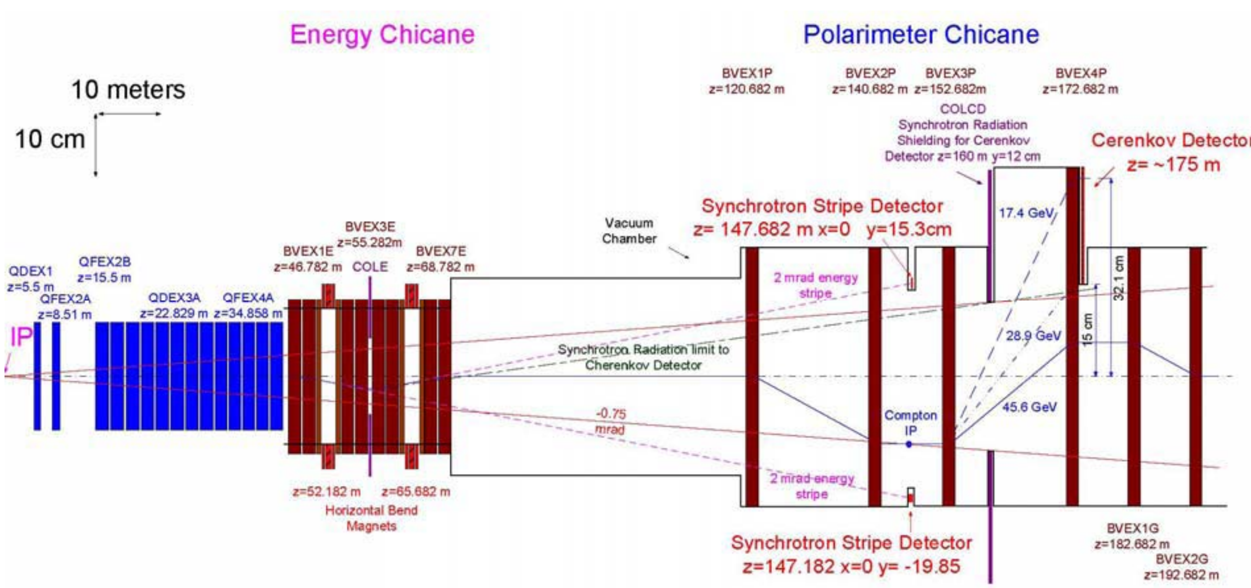

Figure 2: Post-collision line for the ILC (500 GeV), with an energy chicane followed by the polarimeter chicane, both using deflection in the vertical plane.

5.3. Options for Post-IP polarimetry at 3 TeV CLIC

The need, or at least "usefulness", of a polarimeter downstream of the 3 TeV CLIC interaction point has been pointed out repeatedly, see e.g. [14]. Similarly to the ILC, a measurement in the postcollision line while beams are **not** colliding would give increased confidence in the models of spin tracking in the BDS and final focusing system. However, for colliding beams, the difficulties to measure polarization (due to the large number of coherent pairs transported together with the spent beam) have been pointed out.

The present design of the CLIC post-collision line (see Fig. 1) leaves, a priori, one option for a polarimeter section. If the parallel section, between the end of the chicane and the beam dump, is made much longer than presently foreseen, a set of large collimators could be inserted to gradually scrape away the tail of particles with momenta of, e.g., less than 1.4 TeV. The Compton polarimeter in the remaining "pencil beam", if shown to be feasible, would therefore measure the polarization of the approx. 30% of the beam which correspond to the "1% peak" in the luminosity spectrum.
However, are these just the electrons which did not suffer from depolarization?

QUESTION 2:
Given
(a) the uncertainties in depolarization models,
(b) the difficulty to get an accurate polarization measurement in the post-collision line,
(c) the fact that the "pencil beam" in the CLIC post-collision line contains only 30% of the particles which have potentially produced interesting physics, may we conclude that the proposal for a polarimeter downstream of the CLIC IP at 3 TeV can definitively be abandoned? If not, which of the above requires further study?

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