1 Beam polarization

1.1 Technical issues

It is expected to achieve a high longitudinal polarization degree of at least $P_{e^-} \geq 80\%$ for the electron beam at CLIC. The implementation of spin rotators is also possible in order to provide a transversely-polarized electron beam if needed for physics reasons. Upgrade possibilities to include also a polarized positron beam are available, either via an undulator radiation or via laser-Compton-Backscattering.

In order to fully exploit the polarization, it has to be possible to flip the helicity of the beams and to measure precisely the actual degree of the polarization. High precision polarimetry is mandatory. The inclusion of an upstream polarimeter with similar properties as foreseen for the ILC should be feasible. Such a Compton polarimeter would provide a polarization measurement of about $\Delta P_{e^-}/P_{e^-} \leq 0.25\%$.

For physics studies, however, the actual polarization at the interaction point is crucial. Since a rather big depolarization of about 5% due to the beam-beam interactions has been simulated for the CLIC beam-beam environment [1], the measurement of the polarization only at the upstream polarimeter will not be sufficient. Since a downstream polarimeter is not possible due to the strongly disrupted beam and the short bunches at high frequency, a control measurement of the mean beam polarization via physics processes seems to be mandatory. The opportunity to measure the polarization via physics processes as, e.g. WW production, at CLIC is under work. We assume therefore for the following that a polarization measurement of $\Delta P/P$ of about $1-2\%$ is feasible at CLIC.

1.2 Phenomenology with polarized beams

Longitudinally-polarized beams: Longitudinal polarization is defined as the ensemble of particles with definite helicity $\lambda = -\frac{1}{2}$ left– or $+\frac{1}{2}$ right-handed: $P = [\#N_R - \#N_L]/[\#N_R + \#N_L]$. Since the initial leptons can be regarded as being massless, the helicity corresponds to their chirality.

Beam polarizations of the initial particles provide access to the chirality and the interaction structure of the production processes [2]. They are important for direct as well as indirect searches for new physics. A polarized electron beam would already provide a valuable tool for stringent tests of the Standard Model and for diagnosing new physics. However, some of the interaction and precision tests are not possible with polarized electrons alone (even if we had 100% polarization).

A comprehensive overview of the physics case for the use of polarized electron and positron beams, longitudinally as well as transversely polarized, is given in [2].

- **Access to chirality:** The chiral structures of interactions in various processes can be identified independently and unambiguously. This provides the possibility of determining the quantum numbers of the interacting particles and a precise analysis of their interaction properties.

- **Access to left-right asymmetries:** Polarized beams offer the possibility of using left-right asymmetries A_{LR} as observable which is beneficial for many new physics searches, since often systematic uncertainties cancel in such asymmetries. The relative uncertainty for any A_{LR} is given by the expected polarimeter precision and can only be decreased if polarized e^+ are simultaneously available. A_{LR} is very powerful in both high precision analyses at lower energies as well as new physics searches at the energy frontier, e.g. in studies for the top couplings, in indirect searches for contact interactions and in high precision measurements at the Z-pole, see [2] and references therein.

- **Suppression of SM background processes**: With the appropriate configuration of beam polarization a more efficient control of background processes can be obtained. The higher signal-to-background ratio may be crucial for finding manifestations of particles related to new physics and determining their properties. It may also be crucial for disentangling cascade chains from heavier, almost mass degenerated particles.

  Background from WW pair production is one of the most dominant background processes in new physics searches: with $(P_{e^-}, P_{e^+}) = (+80\%, 0)$ one scales WW production by a factor 0.20.

- **Enhancement of graviton rates:** Another example for the importance of background suppression via beam polarization is the direct graviton production, $e^+e^- \to \gamma G$. The major SM background is determined by $e^+e^- \to \gamma\nu\bar{\nu}$. The contribution from $e^+e^- \to \gamma Z \to \gamma\nu\bar{\nu}$ can easily be eliminated by cutting out the E_γ region around the corresponding Z-peak, but there remains a significant, continuous distribution in E_γ from $e^+e^- \to \gamma\nu\bar{\nu}$ that has similar behaviour as the signal. Since the neutrino couples only left-handed, the background has nearly maximal polarization asymmetry and can be effectively suppressed via beam polarization: with $(P_{e^-}, P_{e^+}) = (+80\%, 0)$ one enhances $S/\sqrt{B}$ by about a factor 2.2.

- **Enhancement of SUSY rates:** The LHC has a large discovery potential to detect coloured supersymmetric (SUSY) particles up to 2.5 TeV. Therefore the main task of the future LC will be to discover the non-coloured SUSY particles and to really establish the SUSY relations, i.e. to probe and determine experimentally all model parameters and assumptions, as e.g. couplings and quantum numbers.

  Since often the rates in SUSY electroweak processes can be very small polarized e^+ may be essential to enhance the rates. As an example, we take the CLIC benchmark scenario 'Model I' and study the neutralino/chargino production. In Table 1 we list only those pairs that result in cross sections for unpolarized beams that are larger than 1 fb. The polarization of the beams is crucial for enhancing the rates and to provide more observables to enable unravelling the parameters.

$\sqrt{s}$/TeV	$(P(e^-), P(e^+))$	$\tilde{\chi}_1^+\tilde{\chi}_1^-$	$\tilde{\chi}_2^+\tilde{\chi}_2^-$	$\tilde{\chi}_1^0\tilde{\chi}_2^0$	$\tilde{\chi}_2^0\tilde{\chi}_2^0$	$\tilde{\chi}_3^0\tilde{\chi}_4^0$
3.0	unpolarized	10.7	11.6	2.6	4.0	4.8
	$(-80\%, 0)$	19.3	18.0	4.8	7.1	5.6
	$(+80\%, 0)$	2.2	5.2	< 1	< 1	4.0
	$(-80\%, +60\%)$	30.9	28.4	7.6	11.4	8.5
	$(-80\%, -60\%)$	7.7	7.6	1.9	2.9	2.7
	$(+80\%, -60\%)$	< 1	6.0	< 1	< 1	5.7
	$(+80\%, +60\%)$	3.4	4.4	< 1	1.3	2.3

Table 1: The production cross section of $e^+e^- \to \tilde{\chi}_i\tilde{\chi}_j$ pairs in scenario 'Model I' that result in > 1 fb are listed. All other pairs, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{\mp}$, $\tilde{\chi}_1^0\tilde{\chi}_{3,4}^0$, $\tilde{\chi}_2^0\tilde{\chi}_{3,4}^0$, $\tilde{\chi}_3^0\tilde{\chi}_3^0$, $\tilde{\chi}_4^0\tilde{\chi}_4^0$, lead to smaller cross sections < 1 fb. Beam polarization is essential to enhance the rates.

Transversely-polarized beams: The availability of simultaneously polarized beams offers also the option to exploit effects from transversely polarized beams.

- **General remarks:** In order to exploit the effects of transversely polarized beams, the polarization of both beams is required, otherwise all effects at leading order from transverse polarization vanish for $m_e \to 0$ (suppression by $m_e/\sqrt{s}$), since it enters only bilinear in the cross sections and related expressions. Spin rotators after the damping ring will allow the spins of the beams to be set to any arbitrary orientation by the time they reach the interaction region (for details see [2] and references therein).

- **Access to CP-violating phenomena, ED models, TGC:** Transversely polarized beams open up new possibilities to explore, e.g. CP-violation phenomena in SUSY, to distinguish between different models of extra dimension models (ED), and to provide unique access to specific triple-gauge couplings (TGC).

References

[1] I.R. Bailey *et al.*, *In the Proceedings of 11th European Particle Accelerator Conference (EPAC 08), Magazzini del Cotone, Genoa, Italy, 23-27 Jun 2008, pp MOPP024.*

[2] G. Moortgat-Pick et al., *Phys. Rep.***460** *(2008), 131 (Preprint hep-ph/0507011).*