Impact of beam polarization at a future linear collider

Gudrid Moortgat–Pick
*Deutsches Elektronen–Synchrotron DESY, Hamburg, Germany**
(Dated: May 22, 2002)

Beam polarization at e^+e^- linear colliders will be a powerful tool for high precision analyses. In this paper we summarize the polarization-related results for Higgs and electroweak physics, QCD, Supersymmetry and alternative theories beyond the Standard Model. Most studies were made for a planned linear collider operating in the energy range $\sqrt{s} = 500 - 800$ GeV. In particular we work out the advantages of simultaneous polarization of the electron and positron beam.

I. INTRODUCTION

Physics beyond the Standard Model (SM) may well be discovered at the run II of Tevatron or at the LHC whose start is planned for 2006. However, it is well known that a linear collider (LC) will be needed for precise measurements and for the detailed exploration of possible New Physics (NP). A LC will also make possible measurements of the SM with unprecedented precision. Moreover the chiral character of the couplings can be worked out by using beam polarization. The importance of such measurements and the physics accessible with polarized electrons has been discussed for example in references [1, 2].

We will use the convention that, if the sign is explicitly given, + (−) polarization corresponds to R (L) chirality with helicity $\lambda = +\frac{1}{2}$ ($\lambda = -\frac{1}{2}$) for both electrons and positrons. In the limit of vanishing electron mass SM processes in the s–channel are initiated by electrons and positrons polarized in the same direction, i.e. $e^+_L e^-_R$ (LR) or $e^+_R e^-_L$ (RL), where the first (second) entries denote helicities of corresponding particle. This result follows from the vector nature of γ or Z couplings (helicity–conservation). In theories beyond the SM interactions also (LL) and (RR) configurations from s-channel contributions are allowed and the polarization of both beams offers a powerful tool for analyzing the coupling structure of the process as well as for enhancing rates and suppressing SM backgrounds. We assume that an electron polarization of $P_{e^-} = \pm 80\%$ (denoted by $(80, 0)$) is reachable [3] with an simultaneous positron polarization of about $P_{e^+} = \pm 40\%$ (denoted by $(80, 40)$) with no loss of intensity and about $P_{e^+} = \pm 60\%$ with 55% of beam intensity [2].

In this paper we explore the physics consequences of beam polarization, in particular when both the electron and positron beams are polarized [4]. Most studies were made for a planned linear collider operating in the energy range $\sqrt{s} = 500 - 800$ GeV. The results show that there are six principal advantages to be gained when both beams are polarized: (1) higher effective polarization $P_{eff} = (P_{e^-} - P_{e^+})/(1 - P_{e^-}P_{e^+})$, (2) suppression of background (3) enhancement of rates ($\mathcal{L}$) (4) increased sensitivity to non-standard couplings, (5) test of chiral quantum numbers of SUSY scalar particles, and (6) improved accuracy in measuring the polarization. These features will be discussed in greater detail in the following sections. In particular both for SUSY and for high precision studies in electroweak physics the polarization of both beams is crucial.

II. HIGGS PHYSICS

In order to establish experimentally the Higgs mechanism as the mechanism of electroweak symmetry breaking an accurate study of the production and decay properties of Higgs candidates is needed. The study of Higgs particles will therefore represent a central theme of the physics programme of a future LC.

Higgs production at a LC occurs mainly via WW fusion, $e^+e^- \to H\nu\bar{\nu}$, and Higgsstrahlung, $e^+e^- \to HZ$. Polarizing both beams enhances the signal and suppresses background. The scaling factors, i.e. ratios of polarized and unpolarized cross section, are given in Table I [4, 5]. Beam polarization can help to measure the HZZ and the HWW coupling separately e.g. via suppression of the WW background (and the signal of WW fusion) and enhancement of the HZ contribution with right polarized electrons and left polarized positrons. Further, variation of the relative amounts of Higgs-strahlung and WW fusion makes it possible to keep the systematics arising from the contributions to the fitted spectrum for these two processes smaller than the statistical accuracy.

Moreover beam polarization reduces considerably the error when determining the Higgs couplings. In an

*gudrid@mail.desy.de

TABLE I: Higgs production in Standard Model: Scaling factors, i.e. ratios of polarized and unpolarized cross section $\sigma^{pol}/\sigma^{unpol}$, are given in Higgs production and background processes for different polarization configurations with $|P_{e^-}| = 80\%$, $|P_{e^+}| = 60\%$ [4, 5].

Configuration	Higgs Production		Background	
$(sgn(P_{e^-})sgn(P_{e^+}))$	$e^+e^- \to H\nu\bar{\nu}$	$e^+e^- \to HZ$	$e^+e^- \to WW$, $e^+e^- \to Z\nu\bar{\nu}$	$e^+e^- \to ZZ$
$(R0)$	0.20	0.87	0.20	0.76
$(L0)$	1.80	1.13	1.80	1.25
(RL)	0.08	1.26	0.10	1.05
(LR)	2.88	1.70	2.85	1.91

TABLE II: Determination of general Higgs couplings: Optimal errors on general $ZZ\Phi$ and $Z\gamma\Phi$ couplings for different beam polarizations [6].

	$P_{e^-} = 0 = P_{e^+}$	$P_{e^-} = 80\%$, $P_{e^+} = 0$	$P_{e^-} = 80\%$, $P_{e^+} = 60\%$
$\mathrm{Re}(b_Z)$	0.00055	0.00028	0.00023
$\mathrm{Re}(c_Z)$	0.00065	0.00014	0.00011
$\mathrm{Re}(b_\gamma)$	0.01232	0.00052	0.00036
$\mathrm{Re}(c_\gamma)$	0.00542	0.00011	0.00008
$\mathrm{Re}(\tilde{b}_Z)$	0.00104	0.00095	0.00078
$\mathrm{Re}(\tilde{b}_\gamma)$	0.00618	0.00145	0.00101
$\mathrm{Im}(\tilde{b}_Z)$	0.00521	0.00032	0.00022
$\mathrm{Im}(\tilde{b}_\gamma)$	0.00101	0.00032	0.00026

effective Lagrangian approach the general coupling between Z–, Vector– and Higgsboson can be written:

$$\mathcal{L} \ = \ (1+a_Z)\frac{g_Z m_Z}{2} H Z_\mu Z^\mu + \frac{g_Z}{m_Z} \sum_{V=Z,\gamma} \left[b_V H Z_{\mu\nu} V^{\mu\nu} + c_V (\partial_\mu H Z_\nu - \partial_\nu H Z_\mu) V^{\mu\nu} + \tilde{b}_V H Z_{\mu\nu} \tilde{V}^{\mu\nu} \right], \quad (1)$$

with $V_{\mu\nu} = \partial_\mu V_\nu - \partial_\nu V_\mu$, $\tilde{V}_{\mu\nu} = \epsilon_{\mu\nu\alpha\beta} V^{\alpha\beta}$.

Using, for example, the optimal–observable method it is possible at a LC to determine the seven complex Higgs couplings with high accuracy: the CP–even a_Z, b_Z, c_Z and b_γ, c_γ and the CP–odd $\tilde{b}_Z$ and $\tilde{b}_\gamma$. Simultaneous beam polarization considerably improves the accuracy. A study was made for $\sqrt{s} = 500$ GeV and $\mathcal{L} = 300$ fb^{-1} [6]. It shows that the $ZZ\Phi$ coupling is well constrained. However, to fix the $Z\gamma\Phi$ coupling beam polarization is essential, Table II. Simultaneous beam polarization $(\pm 80, \mp 60)$ of e^- and e^+ beams results in an further reduction of 20%–30% in the optimal errors compared to the case $(\pm 80, 0)$.

III. ELECTROWEAK PHYSICS

At TESLA [2] it is possible to test the SM with unprecedented accuracy [7]. At high $\sqrt{s}$ studies determining the triple gauge couplings [8, 9] and at low $\sqrt{s}$ an order–of–magnitude improvement in the accuracy of the determination of $\sin^2 \Theta^l_{eff}$ at $\sqrt{s} = m_Z$ may well be possible [8, 10].

GigaZ: Beam polarization of both e^- and e^+ at GigaZ would make possible the most sensitive test of the SM ever made by significantly reducing the polarization error when using the Blondel Scheme [11] coupled with Compton polarimetry. In the SM the left–right asymmetry A_{LR} in the process $e^+e^- \to Z \to \ell^+\ell^-$ depends only on the effective leptonic mixing. Applying the Blondel Scheme means that A_{LR} is directly expressed by the cross sections for the production of Z's with longitudinally polarized beams:

$$A_{LR} = \sqrt{\frac{(\sigma^{RR} + \sigma^{RL} - \sigma^{LR} - \sigma^{LL})(-\sigma^{RR} + \sigma^{RL} - \sigma^{LR} + \sigma^{LL})}{(\sigma^{RR} + \sigma^{RL} + \sigma^{LR} + \sigma^{LL})(-\sigma^{RR} + \sigma^{RL} + \sigma^{LR} - \sigma^{LL})}}. \quad (2)$$

In this case measurement of the cross sections for all spin combinations (RR), (RL), (LR), (LL) can be used to determine the effective polarization and it is not necessary to know the beam polarization with extreme accuracy. Fig. 1 shows the statistical error on A_{LR} as a function of the positron polarization for $P_{e^-} = 80\%$. Already with about 20% positron polarization the goal of $\delta \sin^2 \theta_{eff} \sim 10^{-5}$ can be reached. The Blondel scheme also requires some luminosity for the less favoured combinations (LL) and (RR). However only about 10% of running time will be needed for these combinations to reach the desired accuracy for these high precision measurements. The Blondel Scheme has the additional advantage that the polarization measured in this way is the luminosity-weighted value at the interaction point, rather than the value at the location of the polarimeter.

High $\sqrt{s}$: The production $e^+e^- \to W^+W^-$ occurs in lowest order via γ–, Z– and ν_e–exchange. In order to test the SM with high precision one can carefully study triple gauge boson couplings. These couplings can be determined by measuring the angular distribution and polarization of the $W^{\pm}$'s. Simultaneously fitting of all couplings results in a strong correlation between the $\gamma-$ and $Z-$couplings whereas polarized beams are well suited to separate these couplings. TESLA with its high luminosity is a very promising device to measure these couplings with high precision: At $\sqrt{s} = 500$ GeV and with $|P_{e^-}| = 80\%$ statistical errors of O(10^{-4}) can be reached. Moreover, using simultaneous beam polarization $(80, 60)$ the errors can be further reduced by up to a factor 1.8 compared to the case with $(80, 0)$. [9]. An further advantage of using polarized e^- and e^+ beams is that one could gain about a factor two in running time by using the optimal beam configuration [8].

IV. QCD PHYSICS

Strong–interaction measurements at a future LC will form an important component of the physics programme. We restrict ourselves in this section to the study of polarization effects as a tool for determining a) the top couplings and b) polarized γ structure functions.

Production of tops and FCN couplings: High precision measurements of the properties and the interaction of top quarks will be an essential part of the LC research program since the top as heaviest known elementary particle probably plays a key role in pinning down the origin of electroweak symmetry breaking. In [12] polarization effects were studied at the top threshold. The main background comes from $e^+e^- \to W^+W^-$. The scaling factors for suppressing this background are shown in Table I. The gain in using simultaneously polarized e^- and e^+ beams (80,60) is given by the higher effective polarization of $P_{eff} = 0.946$ compared to the case for only polarized electrons so that the top vector couplings v_t can be measured up to 1% with $\mathcal{L} = 300$ fb^{-1}. The advantage of using polarized e^- and e^+ beams has also been studied for deriving limits on top flavour changing neutral couplings (FCN) from single top production and its FCN decays [13]. With e^- and e^+ polarization (80, 45), limits are improved by about a factor 2.5 compared to unpolarized beams, wheras in each case the positron polarization improves the limits obtained with only electron polarization by 30%–40%. These improvements correspond to an increase in rate of a factor of 6–7.

Polarized structure functions (PSF) *of photons:* For the LC $\gamma\gamma$, γe^- and e^-e^- modes are conceivable, and these could be used to study polarized structure functions of photons. For TESLA these options are discussed as a possible upgrade, but it is already possible to get information about PSF even in the normal e^+e^- mode if one uses highly polarized e^+ and e^- beams in the process $e^+e^- \to \gamma\gamma + e^+e^- \to \text{Di-jets} + e^+e^-$ [14]. Since depolarization tends to be large at the $e\gamma$ vertex one needs highly polarized e^- and e^+ beams to get first experimental hints on polarized PSF.

V. ALTERNATIVE THEORIES

Search for additional gauge bosons Z', W' and for contact interactions: Beam polarization is a helpful tool to enlarge the discovery reach of Z', W' due to higher effective polarization and correspondingly a higher luminosity for specific channels, but the predicted effects are strongly model dependent. With $(80, 60)$ the discovery reach is increased by 10%–20% compared to the case when $(80, 0)$ [15]. Beam polarization is also important to distinguish between different models of contact interactions. Simulation studies are given in [15]. Using $(80, 40)$ instead of only $(80, 0)$ could enlarge the discovery reach for the scale Λ of contact interactions in $e^+e^- \to b\bar{b}$ by up to 40% for RR or RL interactions.

Search for large extra dimensions: In the direct search for extra dimensions, $e^+e^- \to \gamma G$, beam polarization enlarges the discovery reach for the scale M_D [16], and is a crucial tool for suppressing the dominant background $e^+e^- \to \nu\bar{\nu}\gamma$ [17]. In the case of two extra dimensions the reach is enlarged by 16% with simultaneous beam polarization $(80, 60)$ compared to the case with only electron polarization. Furthermore the background can be significantly reduced, the ratio $\frac{S}{\sqrt{B}}$ is improved by a factor 2.2 for $(80, 0)$ and by a factor 5 for $(80, 60)$. This corresponds to an increase in rate by a factor 5 compared to when only electrons are polarized, and a factor 25 when both beams are polarized.

VI. SUSY PHYSICS

Polarization effects play a crucial role in discovering SUSY and in the determination of supersymmetric model parameters. Simultaneous polarization of both beams could lead to an additional increase of the scaling factor up to an factor 1.6 for realistic positron polarizations compared to the case of only polarized electrons, depending on the process and on the scenario [4]. This enhancement can not be expressed by the effective polarization, because these rates depend explicitly on the polarization of both beams. In the following, however, we do not focus on these statistical effects of beam polarization but on the determination of the underlying SUSY model. In SUSY models all coupling structures consistent with Lorentz invariance should be considered. Therefore it is possible to get appreciable event rates for polarization configurations that are unfavorable for SM processes.

All numerical values quoted below, if not otherwise stated, are given for the LC–reference scenario for low $\tan\beta$ with the SUSY parameters $M_2 = 152$ GeV, $\mu = 316$ GeV, $\tan\beta = 3$ and $m_0 = 100$ GeV [18].

Stop Sector: In [19] the feasibility of determining the stop mixing angle in the process $e^+e^- \to \tilde{t}_1\tilde{t}_1$ at TESLA has been investigated. The study was made at $\sqrt{s} = 500$ GeV, $\mathcal{L} = 2\times 500$ fb^{-1} and polarization $(80, 60)$ for the parameters $m_{\tilde{t}_1} = 180$ GeV, $\cos\Theta_{\tilde{t}_1} = 0.57$. The resulting errors are $\delta(m_{\tilde{t}_1}) = 1.1$ GeV and $\delta(\cos\Theta_{\tilde{t}_1}) = 0.01$. If only polarized electrons were used then these errors would increase by about 20%.

Slepton sector: Beam polarization is a useful tool to improve the accuracy of the end–point method for determining the selectron masses [20]. Furthermore with beam polarization the association between the chiral fermions and their scalar SUSY partners can be established: $e^-_{L,R} \stackrel{Susy}{\to} \tilde{e}^-_{L,R}$, $e^+_{L,R} \stackrel{Susy}{\to} \tilde{e}^+_{R,L}$. The production of sleptons $e^+e^- \to \tilde{e}_L\tilde{e}_L$, $e^+e^- \to \tilde{e}_R\tilde{e}_R$ proceeds via γ and Z exchange in the direct channel and $\tilde{\chi}^0_i$ exchange in the crossed channels and with the intial configurations $e^-_L e^+_R$ and $e^-_R e^+_L$. The mixed production $\tilde{e}_L\tilde{e}_R$ is only possible via the crossed channels and with the extraordinary beam configurations: $e^+_L e^-_L \to \tilde{e}^-_L\tilde{e}^+_R$ and $e^+_R e^-_R \to \tilde{e}^-_R\tilde{e}^+_L$, and allows to test the association between chiral leptons with the weak quantum numbers R, L and their scalar partners [21]. For this test the polarization of both beams is indispensable since the suppression of the s–channel is not possible with only polarized electrons.

We show polarized cross sections including ISR and beamstrahlung for the different selectron pair production at $\sqrt{s} = 450$ GeV. For $P(e^-) = -80\%$ and variable $P(e^+)$ one sees from Fig. 2a that for $P(e^+) < 40\%$ the significantly highest rates are those for the pair $\tilde{e}^-_L\tilde{e}^+_R$, at least two times larger than for all other pairs. This clear distinction between the different production channels is only possible for energies close to the threshold since for higher energies the effects are covered by kinematical reasons.

At an e^-e^- collider slepton production occurs via t–channel exchange. It is only possible to verify the association between $e^-_{L,R}$ and $\tilde{e}^-_{L,R}$.

Chargino sector: In the MSSM the chargino production depends on the fundamental parameters M_2, μ, $\tan\beta$, $m_{\tilde{\nu}_e}$. For completely longitudinally polarized beams and assuming that the masses of the exchanged sneutrinos $m_{\tilde{\nu}_e}$ are known, it has been shown [22] that these parameters can be determined quite well. Furthermore a method has been shown to constrain $m_{\tilde{\nu}_e}$ indirectly even if the direct production of $m_{\tilde{\nu}_e}$ is beyond the kinematical reach [23], since the forward–backward–asymmetry of the decay electron in $e^+e^- \to \tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^-_1 \to \tilde{\chi}^0_1 e^-\bar{\nu}$, is very sensitive to $m_{\tilde{\nu}_e}$. With additional positron beam polarization one gets further increase in the rates by a factor of about 1.6, so that the statistical error in ΔA_{FB} is reduced by 20%.

In single chargino production, $e^+e^- \to \tilde{e}\tilde{\chi}^-\nu_e$, $e^+e^- \to \tilde{e}\tilde{\chi}^+\bar{\nu}_e$ [3] the preferred beam polarization configurations are (RR) and (LL), which are disfavoured in the SM. Since one expects small event rates positron polarization could play a major role in the measurement and analysis of this process.

Neutralino sector: As in the cases studied before, beam polarization is crucial for a comprehensive determination of the fundamental parameters, and in particular of M_1 [24]. Furthermore neutralino production in lowest order occurs via Z, $\tilde{e}_L$ and $\tilde{e}_R$ exchange and is sensitive to the chiral couplings and the masses of $\tilde{e}_L$, $\tilde{e}_R$. Therefore the ordering of magnitude of the cross sections for different polarization configurations depends significantly on the character of the neutralinos [23].

A linear collider with polarized beams offers even the possibility to verify very accurately the fundamental SUSY assumption that the Yukawa couplings, $g_{\tilde{W}}$ and $g_{\tilde{B}}$ are indentical to the SU(2) and U(1) gauge couplings g and g'. Varying the left–handed and right–handed Yukawa couplings leads to a significant change in the corresponding left–handed and right–handed production cross sections. Combining the measurements of the polarized cross sections σ_R with $(+90, -60)$ and σ_L with $(-90, +60)$ for the process $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$, the Yukawa couplings $g_{\tilde{W}}$ and $g_{\tilde{B}}$ can be determined to quite a high precision as demonstrated in Fig. 2b. The 1σ statistical errors have been derived for an integrated luminosity of $\int \mathcal{L}\, dt = 100$ and 500 fb^{-1} and for $P(e^-) = \pm 90\%$, $P(e^+) = \mp 60\%$.

Analogues to the chargino case and the indirect constraining of the sneutrino mass it is possible to constrain the selectron masses indirectly via the analysis of forward–backward asymmetries of neutralino decay leptons [23]. Since neutralinos are Majorana fermions the neutralino production is exactly forward–backward symmetric if CP is conserved. However, due to spin correlations between production and decay, non vanishing asymmetries

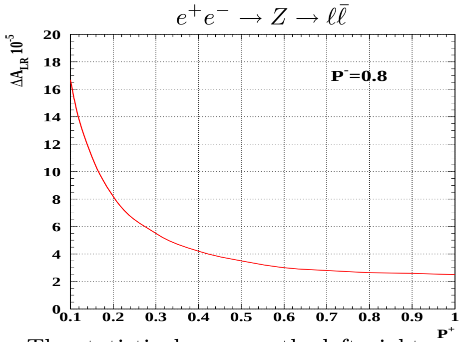

FIG. 1: Test of Electroweak Theory: The statistical error on the left–right asymmetry A_{LR} of $e^+e^- \to Z \to \ell\bar{\ell}$ at GigaZ as a function of the positron polarization $P(e^+)$ for fixed electron polarization $P_{e^-} = \pm 80\%$ [8].

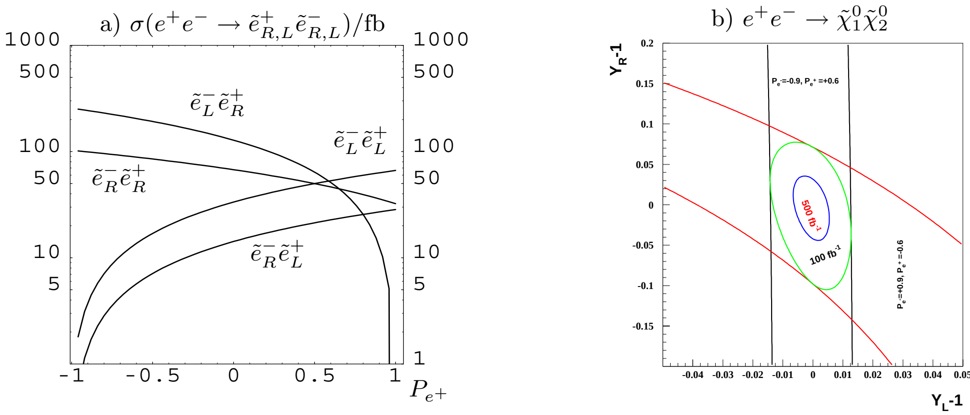

FIG. 2: a) Production cross sections as a function of P_{e^+} for $\sqrt{s} = 450$ GeV, $P_{e^-} = -0.8$, $m_{\tilde{e}_R} = 137.7$ GeV, $m_{\tilde{e}_L} = 179.3$ GeV, $M_2 = 156$ GeV, $\mu = 316$ GeV and $\tan\beta = 3.$, $\mu = 316$ GeV and $\tan\beta = 3$. ISR corrections and beam strahlung are included [21]; b) Contours of the cross sections $\sigma_L\{12\}$ and $\sigma_R\{12\}$ in the plane of the Yukawa couplings $g_{\tilde{W}}$ and $g_{\tilde{B}}$ normalized to the SU(2) and U(1) gauge couplings g and g' $\{Y_L = g_{\tilde{W}}/g,\ Y_R = g_{\tilde{B}}/g'\}$ for the set RP1 at the e^+e^- c.m. energy of 500 GeV; the contours correspond to the integrated luminosities 100 and 500 fb^{-1} and the longitudinal polarization of electron and positron beams of 90% and 60%, respectively.

A_{FB} of the decay electron can occur [25]. Beam polarization enlarges these asymmetries by about a factor 3 if both beams are simultaneously polarized. With (85,60), e.g., in the reactions $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$, $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 e^+e^-$ the asymmetry is about 4% in the case of only polarized electrons but up to 13% if both beams are polarized, Fig. 3a. Since these asymmetries are very sensitive to the mass of the exchanged selectrons it is possible to constrain the slepton masses indirectly.

The MSSM contains four neutralinos. One additional Higgs singlet yields the (M+1)SSM with 5 neutralinos. Superstring–inspired E_6–models with additional neutral gauge bosons or Higgs singlets have a spectrum of six or more neutralinos. In certain regions of the parameter space, where the lightest neutralino is singlino–like, the same mass spectra of the light neutralinos are possible in the MSSM, (M+1)MSSM and E_6. Since beam polarization is sensitive to the different couplings, it is a powerful tool for distinguishing between these models [26].

R–parity violating SUSY: In R–parity violating SUSY, processes can occur which prefer the extraordinary (LL) or (RR) polarization configurations. An interesting example is $e^+e^- \to \tilde{\nu} \to e^+e^-$, Fig. 3b. The main background to this process is Bhabha scattering. Polarizing both electrons and positrons can strongly enhance the signal. A study [27] was made for $m_{\tilde{\nu}} = 650$ GeV, $\Gamma_{\tilde{\nu}} = 1$ GeV, with an angle cut of $45^0 \leq \Theta \leq 135^0$ and a lepton–number violating coupling $\lambda_{131} = 0.05$ in the R–parity violating Langrangian $\mathcal{L}_{\not R} \sim \sum_{i,j,k} \lambda_{ijk} L_i L_j E_k$. Here $L_{i,j}$ denotes the left–handed lepton and squark superfield and E_k the corresponding right–handed field [27]. The cross section $\sigma(e^+e^- \to e^+e^-)$ including $\sigma(e^+e^- \to \tilde{\nu} \to e^+e^-)$ gives i) 7.17 pb (including Bhabha–background of 4.50 pb) for the unpolarized case, ii) 7.32 pb (including Bhabha–background of 4.63 pb) for $P_{e^-} = -80\%$ and iii) 8.66 pb (including Bhabha–background of 4.69 pb) for $P_{e^-} = -80\%$, $P_{e^+} = -60\%$. This means that the electron polarization enhances the signal only slightly by about 2%, whereas the simultaneous polarization of both beams with $(-80, -60)$ produces a further increase by about 20%. This configuration of beam polarizations, which strongly suppresses pure SM processes, allows one to perform fast diagnostics for this R–parity violating process. For example the process $e^+e^- \to Z'$ could lead to a similar resonance peak, but with different polarization dependence. In the latter case only the 'normal' configurations LR and RL play a role and its rates will be strongly suppressed by LL.

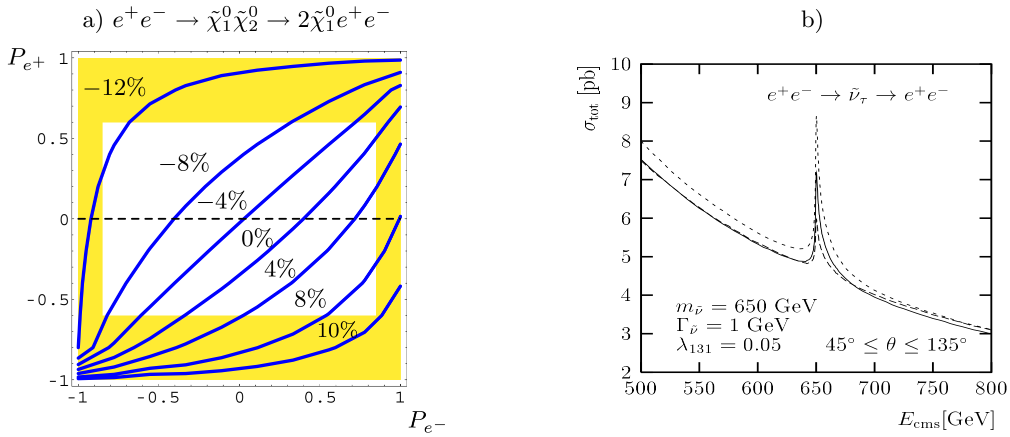

FIG. 3: *a) Contour lines of the forward–backward asymmetry of the decay electron A_{FB}/% of $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$, $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 e^+e^-$ at $\sqrt{s} = (m_{\tilde{\chi}^0_1} + m_{\tilde{\chi}^0_2}) + 30$ GeV in the reference scenario as a function of a) P_{e^-} and P_{e^+} for fixed $m_{\tilde{e}_L} = 176$ GeV, $m_{\tilde{e}_R} = 132$ GeV; b) Sneutrino production in R–parity violating model: Resonance production of $e^+e^- \to \tilde{\nu}$ interfering with Bhabha scattering for different configurations of beam polarization: unpolarized case (solid), $P_{e^-} = -80\%$ and $P_{e^+} = +60\%$ (hatched), $P_{e^-} = -80\%$ and $P_{e^+} = -60\%$ (dotted) [27].*

VII. CONCLUSION

The clean initial state of e^+e^- collisions in a linear collider is ideally suited for the search for new physics, and the determination of both Standard Model and New Physics couplings with high precision. Polarization effects will play a crucial role in these processes. We have shown that simultaneous polarization of both beams can significantly expand the accessible physics opportunities. A recurring theme in this paper is that the simultaneous polarization of both electrons and positrons can be used to determine quantum numbers of new particles, increase rates, suppress background, raise the effective polarization, reduce the error in determining the effective polarization, distinguish between competing interaction mechanisms, and expand the range of measurable experimental observables. These virtues help to provide us with unique new insights into Higgs, Electroweak, QCD, Alternative Theories and SUSY. In particular it allows to enlight the structure of the underlying model.

The author would like to thank H. Steiner for collaboration on various issues of the work presented here, and M. Battaglia for many helpful discussions. GMP was partially supported by the DPF/Snowmass Travel Fellowship from the Division of Particles and Fields of the American Physical Society, and of the Snowmass 2001 Organizing Committee.

[1] SLAC–Report 485, submitted to Snowmass 96.
[2] J. A. Aguilar-Saavedra *et al.*, EFCA/DESY LC Physics Working Group, [hep-ph/0106315].
[3] Ch. Baltay, ECFA/DESY LC–workshop, Obernai, October 1999.
[4] G. Moortgat-Pick and H. Steiner, Eur. Phys. J. direct **C 6** (2001), 1. [hep-ph/0106155] and references therein.
[5] K. Desch, ECFA/DESY LC–workshop, Obernai, October 1999.
[6] K. Hagiwara, S. Ishihara, J. Karnoshita, B.A. Kniehl, Eur. Phys. J. C14 (2000) 457.
[7] J. Erler, S. Heinemeyer, K. Mönig, G. Moortgat-Pick, P. Rowson, E. Torrence, G. Weiglein, G.W. Wilson, *Positron polarization and low energy running at a Linear Collider*, contribution to this workshop.
[8] R. Hawkings and K. Mönig, EPJ*direct* C 8 (1999) 1.
[9] K. Mönig, LC–PHSM–2000–059; W. Menges, LC–PHSM–2001–022.
[10] S. Heinemeyer, Th. Mannel, G. Weiglein, hep-ph/9909538, LC Workshop, Sitges 1999; J. Erler, S. Heinemeyer, W. Hollik, G. Weiglein, P.M. Zerwas, Phys. Lett. **B486** (2000) 125; S. Heinemeyer, G. Weiglein, hep-ph/0012364, LCWS 2000, Chicago, Ocober 2000.
[11] A. Blondel, Phys. Lett. **B202** (1988) 145.
[12] J.H. Kühn, LC–TH–2001-04.
[13] J.A. Aguilar-Saavedra, hep-ph/0012305.
[14] M. Stratmann, Nucl. Phys. Proc. Suppl. 82 (2000) 400; private communication with M. Stratmann and A. Vogt.
[15] A. Leike, S. Riemann, Z. Phys.C75 (1997) 341; S. Riemann, Proceedings of the 1996 DPF / DPB Summer Study on New Directions for High-energy Physics, hep-ph/9610513; R. Casalbuoni, S. De Curtis, D. Dominici, R. Gatto,

S. Riemann, LC-TH-2000-006, hep-ph/0001215; S. Riemann, Proceedings of 4th International Workshop on Linear Colliders (LCWS 99), Sitges, Barcelona, Spain; S. Riemann, LC-TH-2001-007.
[16] A. Vest, LC–TH–2000–058.
[17] G. Wilson, ECFA/DESY LC–workshop, Padua, May 2000.
[18] S. Ambrosanio, G.A. Blair, P.M. Zerwas, EFCA/DESY LC–workshop, 1998.
[19] A. Bartl, H. Eberl, S. Kraml, W. Majerotto, W. Porod, EPJdirect C6 (2000) 1, LC–TH–2000–031.
[20] M. Dima, J. Barron, A. Johnson, L. Hamilton, U. Nauenberg, M. Route, D. Staszak, M. Stolte, T. Tara, *Mass Determination Method for* $\tilde{e}^{\pm}_{L,R}$ *above Production Threshold*, contrbution to this workshop.
[21] C. Blöchinger, H. Fraas, G. Moortgat–Pick, W. Porod, in preparation.
[22] S.Y. Choi, A. Djouadi, M. Gouchait, J. Kalinowski, H.S. Song, P.M. Zerwas, Eur. Phys. J. C14 (2000) 535, LC–TH–2000-016.
[23] G. Moortgat–Pick, A. Bartl, H. Fraas, W. Majerotto, Eur. Phys. J. C18 (2000) 379, hep-ph/0007222; LC-TH-2000-033, hep-ph/0004181; LC-TH-2000-032, hep-ph/0002253; G. Moortgat-Pick, H. Fraas, Acta Phys. Polon. B30 (1999) 1999 .
[24] S.Y. Choi, J. Kalinowski, G. Moortgat-Pick, P.M. Zerwas, Eur. Phys. J. **C** 010815, hep-ph/0108117.
[25] G. Moortgat-Pick, H. Fraas, Phys. Rev. **D 59** (1999) 015016, hep-ph/9708481;
[26] G. Moortgat–Pick, F. Franke, S. Hesselbach, H. Fraas, Proceedings of the LC–Workshop, Sitges 1999; S. Hesselbach, F. Franke, H. Fraas, LC–TH–2000–025, hep-ph/0003272.
[27] M. Heyssler, R. Rückl, H. Spiesberger, Proceedings of the LC–Workshop, Sitges 1999; private communication with H. Spiesberger.