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A Future Linear Collider with Polarised Beams Searches for New Physics[1]

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Abstract

There exists a world–wide consensus for a future e^+e^- Linear Collider in the energy range between $\sqrt{s} = 500 - 1000$ GeV as the next large facility in HEP. The Linear Collider has a large physics potential for the discovery of new physics beyond the Standard Model and for precision studies of the Standard Model itself. It is well suited to complement and extend the physics program of the LHC. The use of polarised beams at a Linear Collider will be one of the powerful tools. In this paper some highlights of searches for physics beyond the Standard Model at a future Linear Collider with polarised e^- and e^+ beams are summarised.

1 Beam Polarisation at a Linear Collider

The next future large facility in high energy physics will most probably be a Linear Collider (LC) in the energy range between LEP and O(1 TeV). The existing world–wide proposals are designed with high luminosity of about $\mathcal{L} = 3.4 \cdot 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at $\sqrt{s} = 500$ GeV and $\mathcal{L} = 5.8 \cdot 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at $\sqrt{s} = 800$ GeV, see e.g. [1]. A LC will not only be well suited to complement [2] but also to extend the physics program of the Hadron Colliders, the Tevatron and the future Large Hadron Collider (LHC).

A LC has a large potential for the discovery of new particles and is – due to its clear signatures – very well suited for the precise analysis of new

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physics (NP) as well as of the Standard Model (SM) [1]. Providing precision studies in this energy range, in particular in the electro–weak sector, even small traces of physics beyond the SM might be found, even if high scale particles of a NP might not be directly produced at the LHC or the first phase of a LC. For these studies the GigaZ option of the LC, i.e. running with very high luminosity at the Z and the WW threshold, is decisive.

An important tool of a LC is the use of polarised beams. In the following we will summarise some highlights of searches and analyses of new physics with the help of polarised beams [1, 3, 4].

Already in the base line design it is foreseen to use electron beams polarised to around 80% via a strained photocathode technology [1] similar to those at the SLC where in the last year of running 1994/95 $P_{e^-} = (77.34\pm0.61)\%$ ([3] and references therein) was reached. In order to generate also polarised positrons the use of a helical undulator is favoured producing polarised photons which generate via pair production positrons with a designed polarisation degree of about 40% (with full intensity of the e^+ beam) up to 60% (with probably about 55% intensity) [5]. There already exists a world–wide collaboration supporting the activities to get a prototype for a polarised positron source at the 50 GeV Final Focus Test Beam at SLAC [6].

It is foreseen to measure the polarisation with Compton polarimetry and it is assumed that one could reach even an accuracy better than $\Delta(P_{e^\pm}) < 0.5\%$ [7]. The simultaneous use of M$\not{o}$ller polarimetry will also be studied [8]. However, the reachable accuracy with Compton and M$\not{o}$ller polarimetry will not be sufficient for the high precision tests at GigaZ. For this purpose one uses an alternative Blondel Scheme [9], see next section, where one expresses the polarisation via polarised cross sections. There one can avoid absolute measurements of polarisation and use polarimetry only for relative measurements.

After a short introduction into the physics of beam polarisation we begin our summary with high precision studies of the SM as a motivation for new physics searches.

1.1 Introductory remarks

Within the Standard Model (SM) only V, A couplings happen in the s–channel (γ, Z exchange) and therefore the configurations LR ($P_{e^-} < 0$, $P_{e^+} > 0$) and RL ($P_{e^-} > 0$, $P_{e^+} < 0$) are possible for the e^-e^+ helicities. That means that once the e^- polarisation is chosen also the e^+ helicity is fixed by the interaction. For these processes an additional simultane-

	RL	LR	RR	LL	P_{eff}	$\mathcal{L}_{eff}/\mathcal{L}$
$P_{e^-}=0$, $P_{e^+}=0$	0.25	0.25	0.25	0.25	0.	0.5
$P_{e^-}=-1$, $P_{e^+}=0$	0	0.5	0	0.5	-1	0.5
$P_{e^-}=-0.8$, $P_{e^+}=0$	0.05	0.45	0.05	0.45	-0.8	0.5
$P_{e^-}=-0.8$, $P_{e^+}=+0.6$	0.02	0.72	0.08	0.18	-0.95	0.74

Table 1: Fraction of colliding particles ($\mathcal{L}_{eff}/\mathcal{L}$) and the effective polarisation (P_{eff}) for different beam polarisation configurations, which are characteristic for γ, Z exchange in the s–channel [10].

ous positron polarisation leads to an enhancement (or suppression) of the fraction of colliding particles, which is expressed by the effective luminosity

$$\mathcal{L}_{eff}/\mathcal{L} := \frac{1}{2}(1 - P_{e^-}P_{e^+}) \tag{1}$$

and of the effective polarisation

$$P_{eff} := (P_{e^-} - P_{e^+})/(1 - P_{e^-}P_{e^+}). \tag{2}$$

In Table 1 we list $\mathcal{L}_{eff}$ and P_{eff} for some characteristic values of P_{e^-} and P_{e^+}. One can see that for unpolarised e^+ even a complete polarisation of the e^- beam does not increase the fraction of colliding particles. However, with simultaneously polarised positrons this fraction will be enhanced.

It is well–known that with suitably polarised beams one can suppress processes, e.g. the dominant SM processes $e^+e^- \to W^+W^-$, ZZ. Some scaling factors $\sigma^{pol}/\sigma^{unpol}$ for these processes are given in Table 2.

What is even more interesting, beyond the SM there are possible coupling structures in the s-channel, where the configurations LL and RR could lead to strong signals. Simultaneous polarisation of both beams would lead therefore to fast and easy diagnostics and we will give one example.

These 'rules' are not generally valid for t–channel exchanges since in that case the helicity of the incoming e^- is coupled to the outgoing particle at the vertex and not to the incoming e^+. This can easily be seen when studying the well–known Bhabha scattering. The LR and RL coupling characteristics occur in the s– and t–channel. However, also the LL coupling is allowed in the t–channel and the cross section can be enhanced in this configuration,

$(P_{e^-} = \mp 80\%,\, P_{e^+} = 0, \pm 60\%)$	$e^+e^- \to W^+W^-$	$e^+e^- \to ZZ$
$(+0)$	0.2	0.76
(-0)	1.8	1.25
$(+-)$	0.1	1.05
$(-+)$	2.85	1.91

Table 2: Scaling factors $\sigma^{pol}/\sigma^{unpol}$ for the SM processes $e^+e^- \to W^+W^-$ and $e^+e^- \to ZZ$ for different configurations of beam polarisation [3].

see Table 5. Another example, where the advantage of both beams polarised is obvious, is single W production since with e^- polarisation only the W^- production can be suppressed. For the corresponding W^+ production the polarisation of e^+ is needed.

2 Electroweak high precision analyses of the SM

Electroweak precision tests with an unprecedented accuracy – at high energies as well as at the Z resonance and the WW threshold – would allow one to see hints for new physics, even if new particles are not directly produced. In the following section we list some examples for these high precision measurements at a LC, e.g. the measurement of triple gauge couplings. After that we will have a look at the additional prospects of GigaZ which is planned as an upgrade.

2.1 Anomalous couplings in $e^+e^- \to W^+W^-$

In order to test the SM with high precision one can study triple gauge boson couplings, which are generally parametrised in an effective Lagrangian e.g. by the C–, P–conserving couplings g_1^V, κ_V, λ_V with $V = \gamma, Z$. In the SM at tree level the couplings have to be $g_1^V = 1 = \kappa_V$, while λ_V are identical to zero.

These couplings can be determined by measuring the angular distribution and polarisation of the $W^\pm$'s. Fitting simultaneously all couplings results in a strong correlation between the $\gamma-$ and $Z-$couplings. It turns out that the polarisation of the beams is very powerful for separating these couplings: e.g. the polarisation of $P_{e^-} = \pm 80\%$ (together with $P_{e^+} = \mp 60\%$) improves the sensitivity up to a factor 1.8 (2.5), see Table 3 [11, 1].

error $[10^{-4}]$:	Δg_Z^1	$\Delta\kappa_\gamma$	λ_γ	$\Delta\kappa_Z$	λ_Z
unpolarised beams					
$\sqrt{s} = 500$ GeV	38.1	4.8	12.1	8.7	11.5
$\sqrt{s} = 800$ GeV	39.0	2.6	5.2	4.9	5.1
only electron beam polarised, $\lvert P_{e^-}\rvert = 80\%$					
$\sqrt{s} = 500$ GeV	24.8	4.1	8.2	5.0	8.9
$\sqrt{s} = 800$ GeV	21.9	2.2	5.0	2.9	4.7
both beams polarised, $\lvert P_{e^-}\rvert = 80\%$, $\lvert P_{e^+}\rvert = 60\%$					
$\sqrt{s} = 500$ GeV	15.5	3.3	5.9	3.2	6.7
$\sqrt{s} = 800$ GeV	12.6	1.9	3.3	1.9	3.0

Table 3: Sensitivity for anomalous triple gauge couplings in $e^+e^- \to W^+W^-$ with different configurations of beam polarisation [1].

2.2 Transversely polarised beams in $e^+e^- \to W^+W^-$

Another promising possibility to study the origin of electroweak symmetry breaking is the use of transversely polarised e^+e^- beams which projects out $W_L^+W_L^-$ [12]. The asymmetry with respect to the azimuthal angle of this process, $dA_T/d\cos\theta = \int d^2\sigma/(d\cos\theta d\cos\Phi)\cos 2\Phi d\Phi$, focusses on the LL mode. The corresponding asymmetry is even pronounced at high energies,far above the WW threshold, and still reaches there of about 10%. The advantage of this observable is that at high energies this asymmetry peaks at larger polar angles away from the beam direction where the analysis might be difficult. One has to note, however, that for the use of transverse beams the polarisation of both beams is needed. The effect does not occur if only one beam is polarised since the cross section is given by:

$$\sigma \;=\; (1 - P^L_{e^-}P^L_{e^+})\sigma_{unp} + (P^L_{e^-} - P^L_{e^+})\sigma^L_{pol} + P^T_{e^-}P^T_{e^+}\sigma^T_{pol}. \tag{3}$$

2.3 GigaZ

At the GigaZ option resonance production $e^+e^- \to Z \to f\bar{f}$ is studied and the effective electroweak leptonic mixing angle can be measured via the left–right asymmetry

$$A_{LR} = \frac{2(1 - 4\sin^2\Theta^\ell_{eff})}{1 + (1 - 4\sin^2\Theta^\ell_{eff})^2} \tag{4}$$

of this process. Since one gets only a gain in analysis power if the error due to the polarisation measurement $\Delta A_{LR}(pol)$ is smaller than the statistical error

$\Delta A_{LR}(stat)$ one has to know $P_{e^\pm}$ extremely accurately, even $\Delta P_{e^\pm} < 0.5\%$ would not be sufficient. Therefore one uses an alternative Blondel Scheme [11, 1] and expresses A_{LR} via polarised rates:

$$A_{LR} = \sqrt{\frac{(\sigma^{++} + \sigma^{+-} - \sigma^{-+} - \sigma^{--})(-\sigma^{++} + \sigma^{+-} - \sigma^{-+} + \sigma^{--})}{(\sigma^{++} + \sigma^{+-} + \sigma^{-+} + \sigma^{--})(-\sigma^{++} + \sigma^{+-} + \sigma^{-+} - \sigma^{--})}} \quad (5)$$

With this method, polarimetry has to be used only for calibration and one can reach a spectacular accuracy for the electroweak observables, see Table 4 [1]. The polarisation of the positron beam is absolutely needed but already a polarisation of about $P_{e^+} = |40\%|$ would be sufficient, see Fig. 1a, to measure these observables with an unprecedented accuracy.

As an example of the potential of the $sin^2\theta_{eff}$ measurement at GigaZ, Fig. 1b [13] compares the present experimental accuracy on $sin^2\theta_{eff}$ and M_W from LEP/SLD/Tevatron and the prospective accuracy from the LHC and from a LC without GigaZ option with the predictions of the SM and the MSSM. With GigaZ a very sensitive test of the theory will be possible.

a) b)

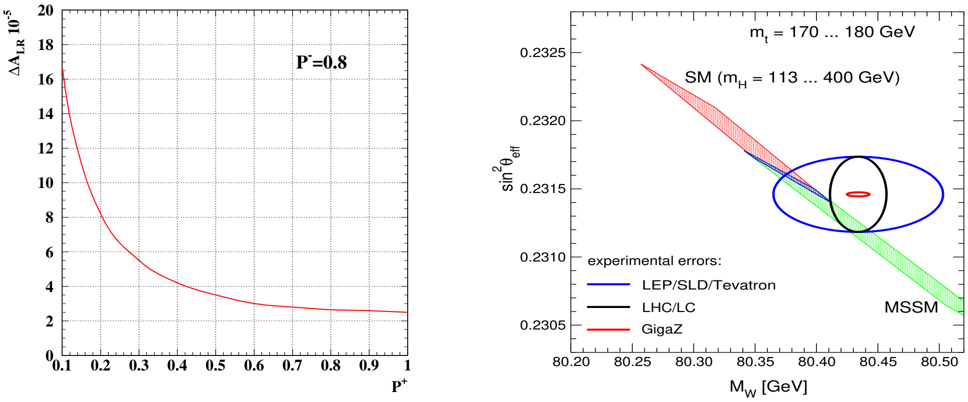

Figure 1: a) Test of Electroweak Theory: The statistical error on the left–right asymmetry A_{LR} of $e^+e^- \to Z \to \ell\bar{\ell}$ at GigaZ as a function of the positron polarisation P_{e^+} for fixed electron polarisation $P_{e^-} = \pm 80\%$ [11]; b) The theoretical prediction for the relation between $\sin^2\theta eff$ and M_W in the SM is compared to the experimental accuracies at LEP 2/Tevatron (Run IIA), LHC/LC and GigaZ [13]. The Higgs boson mass is taken in the intermediate range.

It should also be mentioned that with the help of polarised beams a LC could be sensitive to electroweak dipole form factors. They have been analysed

	LEP2/Tev.	Tev./LHC	LC	LC+GigaZ/WW
ΔM_W	34 MeV	15 MeV	10 MeV	7 MeV
$\Delta \sin^2\theta_{eff}/10^{-5}$	17	14-20	–	1.3
Δm_t	5 GeV	1-2 GeV	0.1 GeV	0.1 GeV
Δm_h	–	0.2 GeV	0.05 GeV	0.05 GeV

Table 4: Sensitivity to electroweak observables at different colliders in comparison [13].

in [14] with regard to CP violation of the τ lepton and via CP–odd triple product correlations. Sensitivity bounds for the real and imaginary parts of these form factors have been set up to $O(10^{-19})$ ecm.

In the same context one should not forget that also for the analysis of heavy gauge bosons, as e.g. for the Z', and for contact interactions the use of polarised beams is very important and also sensitivity can be enhanced significantly [3, 15].

3 Beyond the Standard Model

3.1 Supersymmetry

Supersymmetry is widely regarded as one of the best motivated extensions of the SM. However, since the SM particles and their SUSY partners are not mass degenerate, SUSY has to be broken, which leads even for its minimal version, the Minimal Supersymmetric Standard Model (MSSM), to 105 free new parameters. In specific scenarios of SUSY breaking one can end up with only a few parameters: 5 in mSUGRA, 4 in AMSB and 5 in GMSB. However, one should note that one of the most favoured motivation for SUSY – the unification of the gauge couplings – is consistent within the general MSSM independently of the large number of new parameters.

In order to exactly pin down the structure of the underlying model it is therefore unavoidable to extract the parameters without assuming a particular symmetry breaking scheme. Since the LC with its extremely clear signatures provides a measurement of the particle masses of $O(100)$ MeV, of the rates and branching ratios at the % level, the LC is well suited for revealing the underlying structure of the model. Different procedures have been worked out to determine the general MSSM parameters and to test fundamental SUSY assumptions, as e.g. the equality of quantum numbers or couplings of the particles and their SUSY partners in a model–independent way as possible. It turns out that the use of polarised beams plays a decisive role in this context.

3.1.1 Stop mixing angle in $e^+e^- \to \tilde{t}_1\tilde{t}_1$

As demonstrated in [1] the mass and the mixing angle of $\tilde{t}_1$ can be extracted with high precision via the study of polarised cross sections for light stop production. At a high luminosity LC, $\mathcal{L} = 2 \times 500$ fb, and with $P_{e^-} = 80\%$ and $P_{e^+} = 60\%$ an accuracy of $\delta(m_{\tilde{t}_1}) \approx 0.8$ GeV and $\delta(\cos\theta_{\tilde{t}}) \approx 0.008$ could be reached, see Fig. 2 [16]. Similar studies have been done for the $\tilde{\tau}$ sector [17].

3.1.2 Quantum numbers in $e^+e^- \to \tilde{e}^+_{L,R}\tilde{e}^-_{L,R}$

SUSY transformations associate chiral leptons to their scalar SUSY partners: $e^-_{L,R} \leftrightarrow \tilde{e}^-_{L,R}$ and the antiparticles $e^+_{L,R} \leftrightarrow \tilde{e}^+_{R,L}$. In order to prove this association between scalar particles and chiral quantum numbers the use of polarised beams is necessary [3, 18]. The selectron production process occurs via γ and Z exchange in the s–channel and via $\tilde{\chi}^0_i$ exchange in the t–channel. As already mentioned in the general introduction one has a direct link between chiralities of the SM particle and its scalar partner only in the t–channel. Therefore one has to project out the t–channel exchange in order to test the association of chiral quantum numbers to the scalar SUSY partners.

With e.g. completely polarised $e^-_L e^+_L$ only the pair $\tilde{e}^-_L\tilde{e}^+_R$ contributes and the selectrons can be identified via their charge. In our example we have chosen $m_{\tilde{e}_L} = 200$ GeV, $m_{\tilde{e}_R} = 190$ GeV, so that the kinematical decay characteristics are the same for both pairs, $\tilde{e}^-_L\tilde{e}^+_R$ and $\tilde{e}^-_L\tilde{e}^+_L$. For unpolarised e^+ and $P_{e^-} = -80\%$ the production cross section of both pairs are nearly the same. This will essentially not be changed even if $P_{e^-} = -100\%$ were available. However, even if only partially polarised beams of maximal $P_{e^-} = -80\%$ and $P_{e^+} = -60\%$ were available it could be sufficient to probe this association, since in this case the pair $\tilde{e}^-_L\tilde{e}^+_R$ dominates by more of a factor of 3 in our example, Fig. 2b [6]. This example shows that a polarised e^+ beam is really necessary.

3.1.3 Gaugino/higgsino sector

The SUSY partners of the charged and neutral gauge bosons are the charginos $\tilde{\chi}^\pm_{1,2}$ and neutralinos $\tilde{\chi}^0_{1,\ldots,4}$. Strategies have been worked out to determine

a) b)

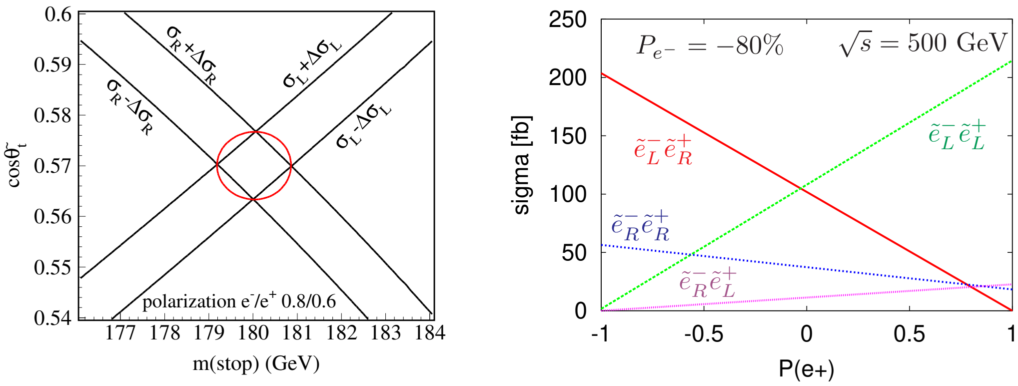

Figure 2: a) Determination of $\theta_{\tilde{t}}$ and $m_{\tilde{t}_1}$ via contour lines for the left and right polarised cross sections in the process $e^+e^- \to \tilde{t}_1\tilde{t}_1$; b) Test of selectron quantum numbers in $e^+e^- \to \tilde{e}^+_{L,R}\tilde{e}^-_{L,R}$ with fixed electron polarisation $P_{e^-} = -80\%$ and variable positron polarisation P_{e^+}. For $P_{e^+} = 0$ both pairs $\tilde{e}^-_L\tilde{e}^+_R$ and $\tilde{e}^-_L\tilde{e}^+_L$ have nearly the same cross sections, however, for $P_{e^+} = -60\%$ the pair $\tilde{e}^-_L\tilde{e}^+_R$ dominates by more than a factor 3 [6].

the mixing angles via polarised rates in $e^+e^- \to \tilde{\chi}^\pm_i\tilde{\chi}^\mp_j$ and $e^+e^- \to \tilde{\chi}^0_i\tilde{\chi}^0_j$ and to derive the underlying MSSM parameters ([19] and references therein). If only the lightest particles $\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^0_1\tilde{\chi}^0_2$ were accessible, it would be sufficient for determining the fundamental MSSM parameters M_1, Φ_{M_1}, M_2 and μ, Φ_μ, i.e. the U(1), the SU(2), and the higgsino mass parameters with their CP–violating phases. The ratio of the two Higgs vev's $\tan\beta = v_2/v_1$ can only be derived if $\tan\beta$ is not too large ([19] and references therein). In Fig. 3a, it is demonstrated, how to fix $|M_1|$ and Φ_{M_1} with polarised cross sections $\sigma(e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2)$ and the light masses $m_{\tilde{\chi}^0_1}$, $m_{\tilde{\chi}^0_2}$. The beam polarisation is needed in order to resolve ambiguities and to improve the statistics. Once the parameters are determined one can efficiently test whether the gauge couplings g_{Bee} and g_{Wee} are identical to the Yukawa couplings $g_{\tilde{B}e\tilde{e}}$ and $g_{\tilde{W}e\tilde{e}}$, respectively, by studying the polarised cross sections as a function of the ratios $g_{Bee}/g_{\tilde{B}e\tilde{e}}$ and $g_{Wee}/g_{\tilde{W}e\tilde{e}}$ and comparing it with experimental expectations [19], see Fig. 3b.

3.1.4 The case of high $\tan\beta$: τ polarisation

A crucial parameter is $\tan\beta$, but high values of $\tan\beta$ will be very difficult to determine with high precision. In case of $\tan\beta > 10$ the chargino and

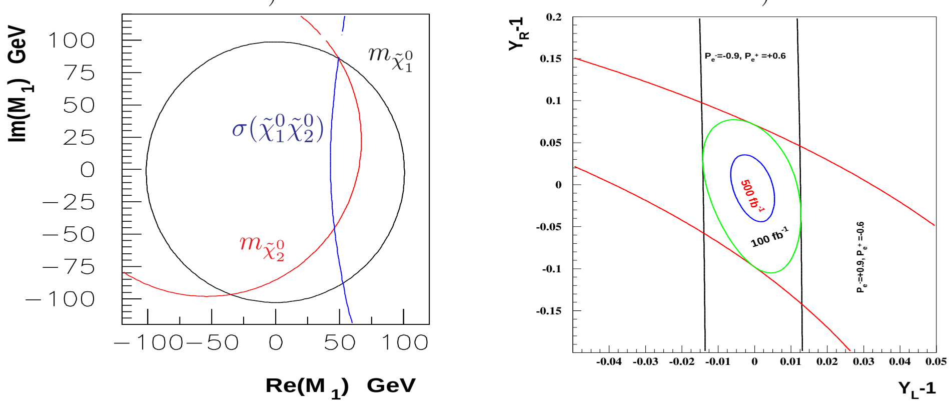

Figure 3: a) Contours of two neutralino masses (1,2) and one neutralino production cross section $\sigma(e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2)$ in the $Re(M_1)$, $Im(M_1)$ plane; b) Contours of the cross sections $\sigma(e^+_R e^-_L \to \tilde{\chi}^0_1\tilde{\chi}^0_2)$ and $\sigma(e^+_L e^-_R \to \tilde{\chi}^0_1\tilde{\chi}^0_2)$ in the plane of the Yukawa couplings $g_{\tilde{W}}$ and $g_{\tilde{B}}$ normalised to the SU(2) and U(1) gauge couplings g and g' $\{Y_L = g_{\tilde{W}}/g,\, Y_R = g_{\tilde{B}}/g'\}$ [19].

neutralino sector is insensitive to this parameter. In the Higgs sector the case $\tan\beta > 10$ will lead to uncertainties of about $\Delta(\tan\beta) > 10\%$ (for rather low $m_A \leq 200$ GeV [20]). However, in many scenarios one could determine $\tan\beta$ from another sector whose particles are relatively light: the $\tilde{\tau}$ sector [17].

The polarisation of τ's from $\tilde{\tau}_i \to \tau\tilde{\chi}^0_j$ is sensitive to $\tan\beta$ [21] and the τ polarisation can be rather accurately measured at a LC via e.g. the τ decays $\tau \to \pi\nu$ and $\tau \to \rho\nu$, see Fig. 4a [17]. It has been shown that in case of a sufficient higgsino admixture in the $\tilde{\chi}^0_j$ it is possible to determine high $\tan\beta$ (and in principle also A_τ), without any assumptions on the SUSY breaking mechanism: after determining the $\tilde{\tau}$ mixing angle via polarised rates, preferable in the configuration σ_{RL} due to WW background suppression, one can determine $\tan\beta$ from the τ polarisation, see Fig.4b. For high $\tan\beta \geq 20$ one can reach an accuracy of about 10%.

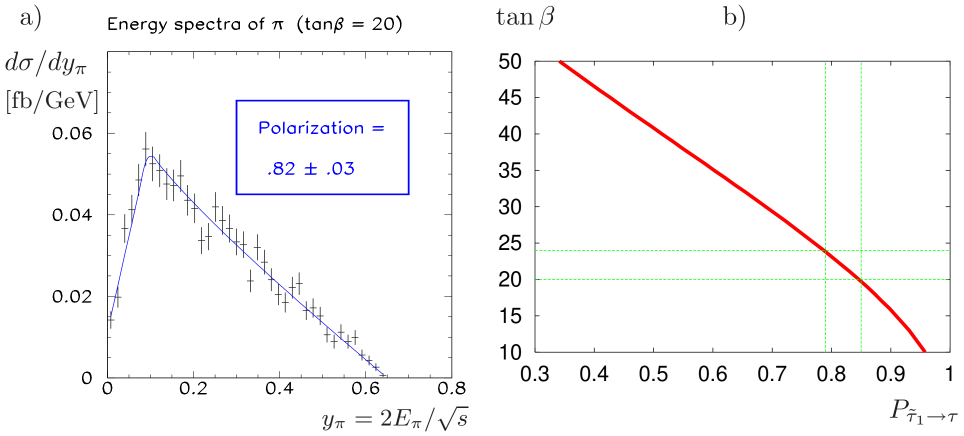

Figure 4: a) Determining the τ polarisation $P_{\tilde{\tau}_1\to\tau}$ from the pion energy distribution in the decay $\tilde{\tau}_1 \to \tau\tilde{\chi}^0_1 \to \nu_\tau \pi \tilde{\chi}^0_1$ leads to b) an accurate determination of high $\tan\beta = 20 \pm 2$ [17].

3.1.5 Extended SUSY models

In case of R–parity violating SUSY non–standard couplings could occur which produce a scalar particle in the s–channel: $e^+e^- \to \tilde{\nu} \to e^+e^-$. The process gives at the resonance a significant signal over the background. Since $\tilde{\nu}$ focus out both left–handed e^- and e^+ –the LL configuration– it can be easily analysed and identified by the use of beam polarisation ([22, 3]): here only polarised e^- do not enhance the signal in practice. However, simultaneously polarised beams enhance the signal considerably, see Table 5.

One could also extend the MSSM without changing the gauge group, by introducing an additional Higgs singlet, leading to (M+1)SSM with one additional neutralino. Since the mass spectra of the four light neutralinos could be similar to those in the MSSM in some parts of the (M+1)SSM/MSSM parameter space, a distinction between these models might be difficult via spectra and rates alone. However, polarisation effects might then indicate the different coupling structure in the (M+1)SSM [23] and help disentangling the models, Fig. 5.

	$\sigma(e^+e^- \to e^+e^-)$ with $\sigma(e^+e^- \to \tilde{\nu} \to e^+e^-)$	Bhabha–background
unpolarised	7.17 pb	4.50 pb
$P_{e^-} = -80\%$	7.32 pb	4.63 pb
$P_{e^-} = -80\%$, $P_{e^+} = -60\%$	8.66 pb	4.69 pb
$P_{e^-} = -80\%$, $P_{e^+} = +60\%$	5.97 pb	4.58 pb

Table 5: Sneutrino production in R–parity violating SUSY: Cross sections of $e^+e^- \to \tilde{\nu} \to e^+e^-$ for unpolarised and polarised beams. Assuming $m_{\tilde{\nu}} = 650$ GeV, $\Gamma_{\tilde{\nu}} = 1$ GeV, an polar angle cut of $45^0 \leq \theta \leq 135^0$ and the R–parity violating coupling $\lambda_{131} = 0.05$ [22].

3.2 Large extra dimensions

Another approach to physics beyond the SM, which could also solve the hierachy problem, is offered by the idea of large extra dimensions. At a LC the process $e^+e^- \to \gamma G$ is promising and it has been worked out that with running at two different $\sqrt{s}$ one can determine the number of extra dimensions [1, 24]. The use of properly polarised beams enlarges on one hand the sensitivity to the new scale M_D and suppresses the main background $e^+e^- \to \nu\nu\gamma$ significantly. The ratio $S/\sqrt{B}$ is enhanced by a factor of about 2.1 (4.4) if $P_{e^-} = +80\%$ (and $P_{e^+} = -60\%$) is used.

4 Summary

A Linear Collider in the TeV range with its clean initial state of e^+e^- collisions is ideally suited for the search for new physics, for the determination of both Standard Model and non-standard couplings with high precision and for revealing the structure of the underlying model. The use of polarised beams plays a decisive role. Simultaneous polarisation of both beams can significantly expand the accessible physics opportunities compared to the case of e^- polarisation only[4]. The use of simultaneously polarised e^- and e^+ beams has several advantages for: determining quantum numbers of new particles, providing higher sensitivity to non–standard couplings, increasing rates and background suppression, raising the effective luminosity and expanding the range of measurable observables e.g. with the help of trans-

[4]For updates see POWER group (Polarisation at Work in Energetic Reactions) http://www.ippp.dur.ac.uk/~gudrid/power/

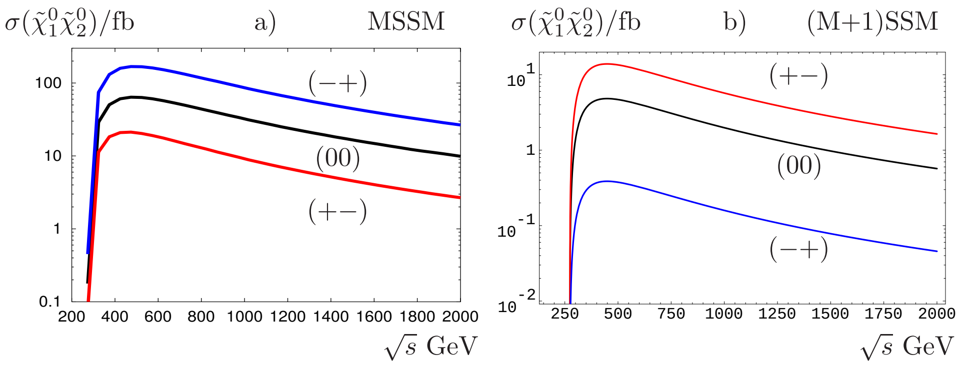

Figure 5: Cross sections for the process $\sigma(e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2)$ with polarised beams ($P_{e^-} = \pm 80\%, P_{e^+} = \mp 60\%$) for an example in a) the MSSM and in b) the (M+1)SSM, where the mass spectra of the light neutralinos are similar [23].

versely polarised beams.

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