The role of polarized e^+ and e^- in revealing fundamental interactions at the ILC

Polarization of both beams at the ILC would be ideal for facing both expected and unforeseen challenges in searches for new physics at the ILC: fixing the chirality of the couplings and enabling the higher precision for the polarization measurement itself as well as for polarization-dependent observables, it provides a powerful tool for studying new physics at the ILC, such as discovering new particles, analyzing signals model-independently and resolving precisely the underlying model. Techniques and engineering designs for a polarized-positron source are well advanced. Potential constraints concerning luminosity, commissioning and operating issues appear to be under control. Consideration can therefore now be given to including a polarized-positron source already in the baseline design.

The first exploration of the TeV energy scale will be made with proton–proton collisions at the Large Hadron Collider (LHC) now under construction at CERN. It is scheduled to start operation in the year 2007. Its discoveries would be complemented by the electron–positron International Linear Collider (ILC) currently being planned. It is expected that the clean signatures and in particular the precise measurements made possible by a high-luminosity linear collider at a known and tunable beam energy will bring revolutionary new insights into our understanding of the fundamental interactions of nature and the structure of matter, space and time. In the hunt for physics beyond the Standard Model (SM), only small deviations from SM predictions may be visible, and the ILC provides optimal conditions for searching for the unexpected.

The physics return from the investment in the linear collider would be maximized by providing polarized electron and positron beams. It has been recognized that beam polarization may play an important role in the ILC programme, and polarization of the electron beam is foreseen for the baseline design [1]. A high degree of at least 80% polarization is already envisaged, and new results indicate that even 90% may be achievable. A polarized electron beam will provide a valuable tool for scrutinizing the SM and diagnosing signatures of new physics.

The possibility of polarizing the positron beam is currently discussed as an upgrade option for the ILC. In [2] the physics case for the polarization of both beams has been worked out and it has been shown that the full potential of the ILC will be realized only with a polarized positron beam together with a polarized electron beam. In addition to detailed studies of the SM and properties of new particles, as well as new kinds of interactions, the polarization of both beams would also enable indirect searches with high sensitivity for new physics in a largely model-independent approach. The report also provides an overview of the current technical status of polarizing positrons. In the following a short summary is given of the results obtained.

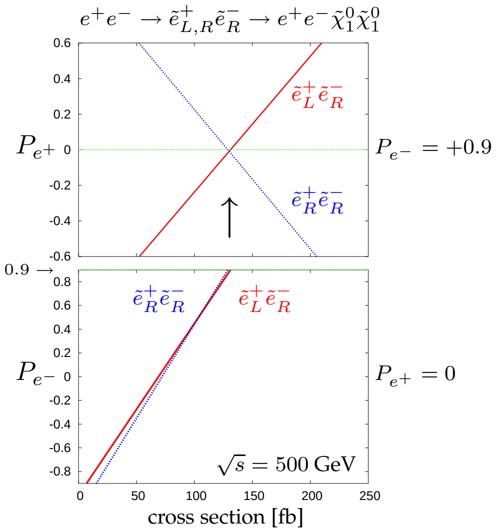
- The dominant processes in e^+e^- experiments are annihilation (s-channel) and scattering (t-channel) processes. *In t-channel processes* the helicities of the electrons and positrons can be related directly to the chirality and properties of the (new) particles produced. *In annihilation processes*, the helicities of the electron and positron are related by the spin of the particle(s) exchanged in the s-channel. Suitable combinations of the electron and positron beam polarizations may be used to enhance significantly signal rates and also to suppress efficiently unwanted background processes. These capabilities are particularly welcome in outlining searches for new physics, where in many cases only very small rates are predicted. An increased signal/background ratio combined with high luminosity provides a promising environment for discoveries even at the edge of the kinematical reach.

What physics at the ILC could only be addressed with polarized positrons and polarized electrons in direct searches?

If both beams are polarized, in t-channel processes the helicities/chiralities of the electrons and positrons can be related directly to the properties of any produced (new) particles and their interactions. The ability to adjust independently the polarizations of both beams provides unique possibilities for probing directly the properties of the produced particles. In particular, it becomes possible to access directly their quantum numbers and chiral couplings, with a minimal number of assumptions.

As an example, consider one of the best-motivated extensions of the SM, namely Supersymmetry (SUSY). This theory predicts that all new SUSY particles carry the same quantum numbers as their SM partner particles, with the exception of the spin, which differs by half a unit. A prominent sector is represented by the scalar partners of the left- and right-chiral electrons/positrons, the selectrons/spositrons $\tilde{e}^{\pm}_{L,R}$.

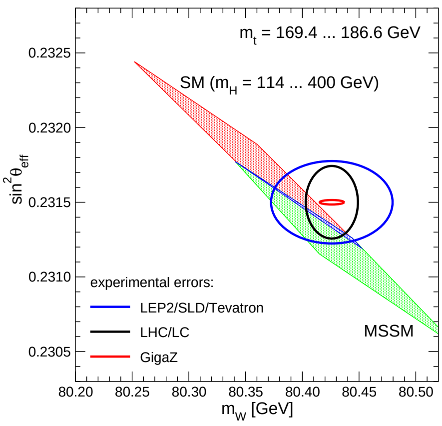
To probe their quantum numbers one has to separate experimentally the pairs $\tilde{e}^{+}_{L}\tilde{e}^{-}_{R}$ produced only by a t-channel process from the pairs $\tilde{e}^{+}_{R}\tilde{e}^{-}_{R}$ produced by an s-channel process. In quite a number of scenarios even a highly polarized electron beam will not be sufficient to separate such pairs, because both are produced with almost identical cross sections and have the same decays. With polarized positrons in adition to polarized electrons, the conjugate pairs have different cross sections, and the $\tilde{e}^{+}_{L}$ and $\tilde{e}^{-}_{R}$ can be distinguished by charge separation. As seen from this example, polarized positrons may be essential when probing properties of new physics.



• In a number of cases the direct reach for new physics mass scales may not be sufficient at future experiments. It is therefore important to have suitable tools for tracking indirect signals for physics beyond the SM and for studying the relative novel interactions. Extensions of the SM might manifest themselves only in tiny deviations, therefore it will be important to provide very sensitive tools for high-precision measurements.

Which hints for deviations from the SM could only be revealed with both e^- and e^+ beams polarized at the ILC?

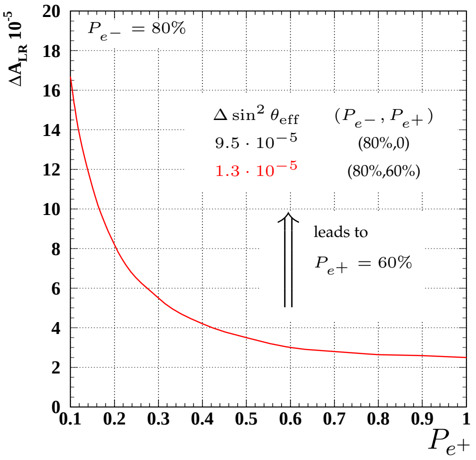
Among the most powerful searches for small traces of new physics are the high-precision tests of the SM. Having both beams polarized will make it possible to perform tests of the electroweak sector with unprecedented precision, at the Z pole, at the WW threshold and at higher energies. In the GigaZ option the ILC runs at the Z-boson resonance, obtaining about 10^9 Z events in 50–100 days of running. Both beams must be polarized in order to achieve the desired precision.



As pioneered by the SLD experiment at the SLC, the weak mixing angle $\sin^2\theta_{\rm eff}$ can be measured accurately by the left-right asymmetry. In the GigaZ option such a precision can be improved by an order of magnitude. This will have far-reaching implications for consistency tests of the electroweak theory and the Higgs sector and can point to scales beyond the ones kinematical accessible. For example, the resulting bounds on the mass of the Higgs boson in the SM improves also by about one order of magnitude, and the allowed parameter range for a specific SUSY mass parameter, $m_{1/2}$, is reduced by about a factor five.

To perform such high precision tests it is required to know the polarization at the per mille-level, which is not possible with conventional polarimetry alone, but may be achieved if both beams are polarized by applying the Blondel scheme originally proposed for LEP. In the SM, the left–right asymmetry $A_{\rm LR}$ can be written in terms of $\sin^2\theta_{\rm eff}$, and an extremely precise measurement of $A_{\rm LR}$ is required to meet the desired precision on $\sin^2\theta_{\rm eff}$.

The statistical power of the data sample can be exploited fully only when the error due to the polarization uncertainty is smaller than that from statistics, $\Delta A_{\rm LR}({\rm pol}) < \Delta A_{\rm LR}({\rm stat})$. For 10^8–10^9 Zs, this occurs when $\Delta P_{\rm eff} < 0.1\%$. In this limit $\Delta\sin^2\theta_{\rm eff} \sim 10^{-5}$, which is an order of magnitude smaller than the present value for this uncertainty. The polarization of both beams is required to reach the desired precision in the Blondel scheme. A polarization degree of $P_{e^+} \sim 60\%$ is sufficient, assuming $\Delta P_{e^-}/P_{e^-} = \Delta P_{e^+}/P_{e^+} = 0.5\%$.



• Direct searches for physics beyond the SM, e.g., for supersymmetry or large extra dimensions, will be a major research field in the physics programme at the ILC. Precise understanding of the interaction structure and the underlying model is required, entailing the determination of the –often numerous– free parameters of the new theory with sufficiently high accuracy. As one example, the minimal supersymmetric extension of the

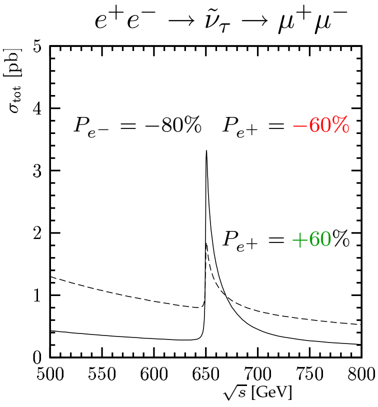
Standard Model (MSSM) has 105 new parameters if not imposing specific model assumptions and mass unifications. The polarization of both beams would be crucial for facing the challenge of constraining or determining them.

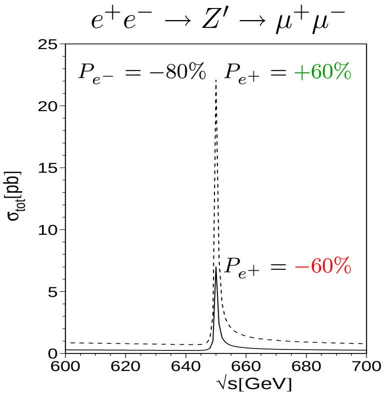
How can polarized positrons disentangle new physics?

Polarized positrons provide more observables, and lead to much higher precision for the polarization-dependent observables. Some properties of new particles, such as spin and chiral quantum numbers and their interactions, can be probed directly. Furthermore, control of background processes becomes more efficient. The higher signal-to-background ratio may be crucial for finding manifestations of particles related to new physics and determining their properties, in particular also at the edge of the kinematical reach of the machine.

The polarization of both beams allows one to probe directly not only the chiral quantum numbers as shown in the first figure above, but also the spins of particles produced as resonances.

A prominent example in an R-parity violating SUSY model is the production of a spin-0 particle, the scalar neutrino, with $\mu^+\mu^-$ in the final state. Since the sneutrino couples only to left-handed $e^\pm$, the peak is strongest for the LL polarization configuration, a signature that would point directly to the presence of a spin-0 resonance (left figure).





The SM background is strongly suppressed and one gets a $S/B \sim 11$ for $(P_{e^-}, P_{e^+}) = (-80\%, -60\%)$, whereas for $(P_{e^-}, P_{e^+}) = (-80\%, 0\%)$ the ratio is only $S/B \sim 4$. Conversely, in the case of a spin-1 resonance, e.g. the Z' particle in the SSM model (right figure), the corresponding resonance peak would be strongest for the LR configuration, with a similar polarization dependence as the SM background. This simple example shows how one can disentangle the form of interaction if both beams can be polarized.

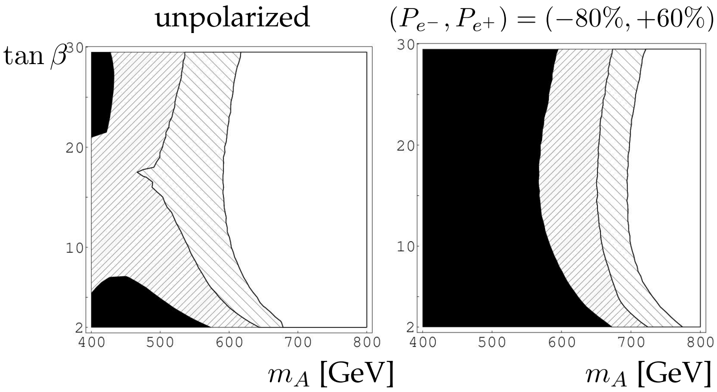
• The increases in signal event rates for optimal choices of the e^- and e^+ beam polarizations may even be indispensable, in some cases, for the observation of marginal signals of new physics, e.g., in heavy non-SM Higgs production. Such searches would complement the parameter space accessible in heavy Higgs searches at the LHC.

How could positron beam polarization, P_{e^+}, be helpful in Higgs searches at the ILC?

For light Higgs searches in the SM, P_{e^+} leads to a better separation of the two major production processes, Higgs-strahlung and WW fusion, which is improved by a factor 4 with $(P_{e^-}, P_{e^+}) = (\pm 80\%, \mp 60\%)$ compared to having $P_{e^-} = \pm 80\%$ only, and a factor 2 can be gained in the suppression of the WW background. In Higgs searches in SUSY, over large parts of the whole parameter space with $m_H \approx m_A \gg m_Z$, the coupling of the heavy Higgs boson to two gauge bosons is suppressed and only the pair-production channel $e^+e^- \to HA$ contributes at full strength. However, this channel is limited by kinematics to the region $m_H < \sqrt{s}/2$. In this case, one could only search for the rare single Higgs production processes, which can be considerably enhanced by positron polarization.

Single production of a heavy Higgs boson via $e^+e^- \to \nu\bar{\nu}H$ can extend significantly the kinematical reach of the ILC. However, in such cases, a very low cross section of about ≤ 0.05 fb is expected, and both a high integrated luminosity as well as enhancement of the cross section via beam polarization are needed.

In a large region of the m_A-$\tan\beta$ parameter space the cross section for the rare process $e^+e^- \to \nu\bar{\nu}H$ is $\sigma > 0.05$ fb (black), > 0.02 fb (right dashed) and > 0.01 fb (left dashed) at $\sqrt{s} = 1000$ GeV. The polarization of the positron beam leads to a further enhancement of the signal by a factor 1.6 and of the ratio $S/\sqrt{B}$ by about 1.4 compared to the case with only $P_{e^-} = 80\%$.



Another example of new physics where background suppression is important is the search for direct signatures of massive Kaluza-Klein spin-2 gravitons. A manifestation of direct graviton production, envisaged in formulations of gravity with extra compactified spatial dimensions, is a relatively soft photon and missing energy. The major background process is $\gamma\nu\bar{\nu}$ production. Since the neutrino coupling is only left-handed, the background has a nearly maximal polarization asymmetry and, consequently, polarized electron and positron beams are extremely effective in suppressing the $\gamma\nu\bar{\nu}$ effects. Compared with the case of only polarized electrons, the background process can be suppressed by a factor of about 2 whereas the signal will be enhanced by a factor of about 1.5.

In general, such enhancements of cross sections and the ratio S/B may be particularly important just at the edge of the kinematical reach of the machine. The extension of the kinematic reach provided by polarized positrons may be crucial, and motivate possible future energy upgrades.

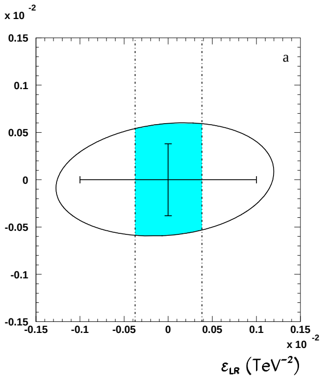
• Some new physics scales, such as those characterizing gravity in models with extra dimensions or the compositeness scale of quarks and leptons, could be too large to be directly accessible at the energies of present as well as future accelerators. Therefore it will also be important at the ILC to devise indirect search strategies for new physics, with high sensitivity and large model-independence. Indeed, the ILC has a large discovery potential for indirect searches beyond the kinematical limit. Effective interactions represent a general framework for the low-energy parametrization of the effects of non-standard dynamics due to exchanges between SM particles of very heavy states with masses beyond the available accelerator energy. This is the case of the four-fermion contact interactions (CI) inspired by compositeness but applicable much more generally, and of the mass scales characterizing models of gravity in large extra dimensions. Manifestations of such new interactions can be probed through deviations of cross sections from the SM predictions, and indirect bounds on the new energy scales and coupling constants can thereby be derived.

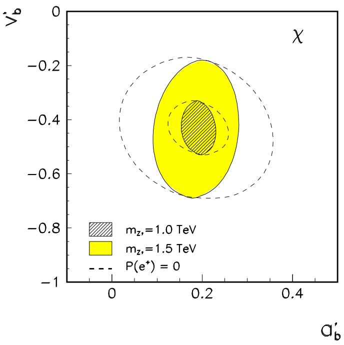
Does P_{e^+} help to derive model-independent results in indirect searches beyond the kinematical limit?

Longitudinal polarization of both beams is decisive for deriving model-independent bounds on the different possible couplings. With both beams polarized, the error in $\Delta P/P$ is reduced, the accuracy of the A_{LR} measurement is considerably enhanced and more observables can be defined, which enables one to disentangle and constrain the different couplings in a model-independent approach.

In order to optimize the sensitivities for model distinctions in searches for any kind of new physics, high-precision measurements of masses, cross sections and asymmetries are required. Positron polarization significantly improves the precision of polarization-dependent observables. The left-right asymmetry, which can be crucial for distinguishing different models, is often limited by systematic uncertainties. These can be reduced significantly when both beams are polarized, e.g., already with a polarization degree of $P_{e^+} = 60\%$, the relative error of A_{LR} is reduced by more than a factor 3.

For example, in Bhabha scattering the four-fermion CIs are parametrized by three couplings (ϵ_{RR}, ϵ_{LR}, ϵ_{LL}). The t-channel contributions depend only on $\epsilon_{\mathrm{LR}} = \epsilon_{\mathrm{RL}}$, whereas the s-channel contribution depends only on the pairs (ϵ_{RR}, ϵ_{LR}), (ϵ_{LR}, ϵ_{LL}). In order to derive model-independent bounds, it is necessary to have both beams polarized. Tight bounds up to $5 \cdot 10^{-4}$ TeV^{-2} at 95% CL can be derived. It has been assumed that no deviations from the SM are measured within the experimental uncertainty in the observables, i.e. the combinations of polarized cross sections σ_{++}, σ_{+-} and σ_{-+}.





Extra neutral gauge bosons Z' can be probed by their virtual effects on cross sections and asymmetries. For energies below a Z' resonance, measurements of fermion-pair production are sensitive only to the ratio of Z' couplings and Z' mass. As an example, beam polarizations $(P_{e^-}, P_{e^+}) = (80\%, 60\%)$ would improve the measurement of the $b\bar{b}$ couplings of the Z' without knowledge of the Z' mass by about a factor 1.5, compared to $P_{e^-} = 80\%$ only. The crucial point is the fact that the systematic errors can be significantly reduced when both beams are polarized.

• With both beams polarized, another powerful tool would be available at the ILC, namely the use of transversely-polarized beams.

What can be done with transversely-polarized beams at the ILC?

Transversely-polarized beams enhance the physics potential significantly in SM physics as well as in different new physics models. New CP-sensitive observables can be constructed in general, and azimuthal asymmetries can be exploited. These new observables are important e.g. in SUSY searches for the resolution of new CP-violating phenomena. Moreover these new asymmetries are sensitive to new kinds of interactions, e.g., spin-2 graviton exchanges in specific extra-dimensional models. However, both beams have to be polarized, otherwise all effects at the leading order from transverse polarization vanish for $m_e \to 0$ (suppression by $m_e/\sqrt{s}$).

As an example, consider a powerful method for testing the electroweak gauge group in the SM: the gauge-boson self-interactions can be parametrized in the most general way with 14 parameters of the triple gauge couplings (TGC), e.g. g_1^{R}, κ^{L}, λ^{R}, g_5^{R}. Transversely-polarized beams provide the unique access to one specific TGC. Longitudinally-polarized e^- and e^+ beams are sufficient for most TGCs, but an exception is the specific coupling $\tilde{h}_+$, which is a linear combination of imaginary parts of TGC's, $\tilde{h}_+ = \mathrm{Im}(g_1^{\mathrm{R}} + \kappa^{\mathrm{L}})/\sqrt{2}$.

For determining the TGCs, one gains about a factor 1.8 with both beams longitudinally polarized, compared with having only polarized electrons. However, as seen in the Table, $\tilde{h}_+$ is only accessible with transversely-polarized beams.

1-σ statistiscal reach on TGCs in units of 10^{-3}

$\sqrt{s} = 500$ GeV	$\tilde{h}_-$	$\tilde{h}_+$	Im λ^{R}	Im g_5^{R}
No polarization	11	—	3.1	17
$\lvert P_{e^-}\rvert = 80\%$	4.5	—	1.4	4.3
$\lvert P_{e^\pm}\rvert = (80\%, 60\%)$	2.5	—	0.75	2.3
$\lvert P_{e^\pm}^{\mathrm{T}}\rvert = (80\%, 60\%)$	3.7	3.2	0.98	4.4

• Having both beams transversely polarized is particularly interesting in the search for novel sources of CP violation in new physics models. The measured baryon asymmetry of the Universe cannot be explained by the small amount of CP violation present in the SM. Scenarios for new physics predict numerous additional sources of CP violation. However, there are tight experimental bounds on CP-violating parameters beyond the SM. The use of transversely-polarized beams enables the construction of sensitive, new CP-odd observables using products of particle momenta or azimuthal asymmetries. They enlarge the number of observables available to constrain the new physics parameters. In

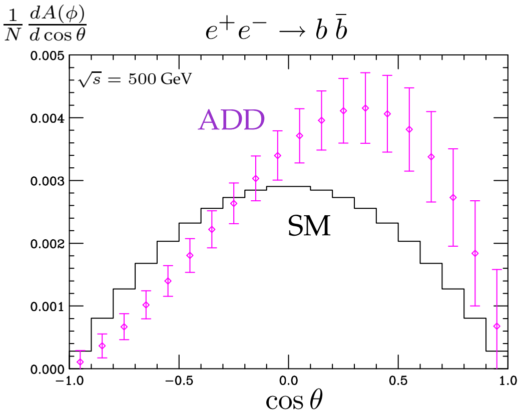
SUSY, for example, many of the 105 free parameters are possible CP-violating phases, see [2] for detailed examples.

Are transversely-polarized beams also useful for indirect searches at the ILC?

Transversely-polarized beams are sensitive to non-standard interactions which are not of the current-current type, such as those mediated by spin-2 gravitons or (pseudo)scalar exchanges, even in indirect searches. Sensitivities to a high mass scale of, e.g., an extra-dimensional model, up to ≥ 3 TeV are achievable, and models can be distinguished. Success in identifying new physics even in indirect searches using polarized e^- and e^+ beams would represent a big step forward for our understanding of fundamental interactions.

One representative example is the distinction between extra dimensions in the models of Randall-Sundrum (RS) and Arkani-Hamed, Dimopoulos, Dvali (ADD).

With transversely-polarized beams a new asymmetry in $\sin 2\phi$ can be constructed, which is sensitive to the cut-off independent imaginary parts of the amplitude originating from the exchange of the (almost) continuous spectrum of ADD gravitons. Below the graviton resonance poles no imaginary parts emerge in the RS model, if one neglects the (small) widths with respect to the masses. The new asymmetry therefore vanishes for both the SM and the RS scenario, so that a non-zero value unambiguously signals the ADD graviton exchange. Such a model distinction is achievable up to ≥ 3 TeV.



• Summarizing, the polarization of both beams enhances strongly the physics potential of the ILC in general: the polarization of both beams reveals uniquely the chirality of the couplings and provides a higher precision in measuring the polarization itself and polarization-dependent observables. It is therefore important for high-precision tests of the Standard Model as well as for detecting and revealing of any kind of new physics. The availability of more independent observables, the potential to polarize and tune the beams independently, the improved accuracy in measuring the observables as well as the exploitation of even transversely-polarized beams are all powerful tools for direct as well as indirect searches.

How to generate (polarized) positrons at the ILC?

Several possibilities as positron source are under discussion:
a) a conventional, non-polarized source,
b) a helical undulator-based polarized source,
c) a laser-based polarized source.

A common requirement for all kinds of positrons sources for the ILC is a very high intensity far beyond the positron source at the SLC which is the positron source with the highest intensity operated up to now.

Are polarized positrons already technically feasible?

For the undulator-based polarized positron source an experimental proof-of-principle test is currently running. Prototypes for the specific helical-undulator ILC design are already under construction. For this source, an electron beam with an energy of $E_{\mathrm{beam}} \geq 150$ *GeV will be needed, and the undulator length will be about* 200 *m.*

The proof-of-principle experiment for the undulator-based polarized-positron source is the project E-166, currently running at SLAC. It uses the 50 GeV Final Focus Test Beam (FFTB) to generate, via a 1 m long helical undulator, polarized photons which are then converted at a thin target into polarized positrons. The polarization of the photons as well as the positrons will then be analyzed and compared with simulations. Since the photon spectrum, the chosen target material and the thickness are similar to those foreseen for the possible ILC design, polarized positrons are produced with the same polarization characteristics as expected at the ILC.
Helical undulator prototypes for a specific ILC design are currently being developed at the Daresbury and Rutherford Laboratories, U.K. Two designs are being discussed: the first device uses superconducting magnets and the second one a Halbach undulator with permanent magnets. The decision between both technologies is foreseen for this year.

Another scheme proposed for polarizing positrons is to use a multi-laser device; the details for such a laser-based scheme are still to be defined, but the feasibility is being tested in an experiment at KEK. A general decision concerning the choice of the positron source, unpolarized or polarized, is expected this year. The other possibilities will continue to be discussed as options.

Polarized positrons already at the beginning of ILC operation?

The polarization of both beams prepares the ILC better for the unexpected. Since the chirality of couplings can uniquely be determined the use of polarized positrons together with polarized electrons provides direct access to all kinds of possible interactions and allows a specific analysis of the interaction structure of generic unforeseen signals of new physics.

A polarized e^+ source seems feasible from day one without compromising reliability of the collider. A delayed implementation of the polarized e^+ option would thus cause additional downtime.

Questions concerning the luminosity and commissioning aspects of including a polarized source are under study. It is expected that one could avoid any major loss in integrated luminosity when using a polarized-positron source. In order to avoid critical impact on commissioning and operation, a low-intensity "keep-alive" beam has been proposed to monitor the linac. Ongoing reliability studies, comparing an undulator-based polarized-positron source with the conventional non-polarized source indicate that both kinds of sources are practically on an equal footing if a conventional keep-alive positron source is added to the undulator design, see [3].

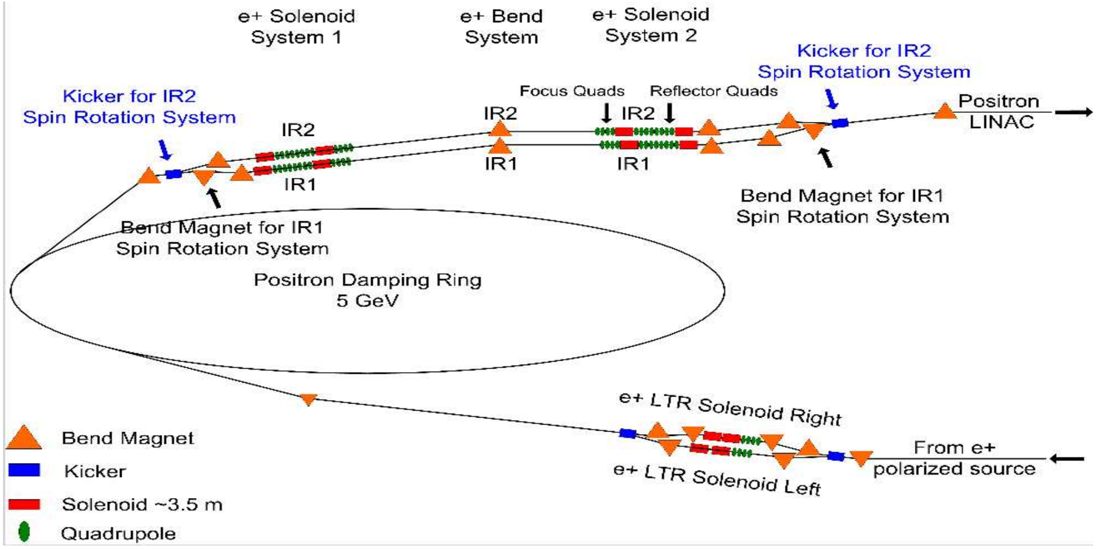
How precise could one measure the polarization at the ILC? Which further spin manipulations may be needed?

The experience from the SLD experiment leads to an expected precision at the ILC of about $\Delta P_{e^-}/P_{e^-} \sim \Delta P_{e^+}/P_{e^+} \leq 0.25\%$ *with a Compton polarimeter. To get even higher precision,* $\Delta P/P < 0.1\%$*, one must use the Blondel scheme for polarization measurement. This scheme requires polarized positrons and the capability to switch the polarizations of both beams independently. In order to keep systematics under control, fast switching is desired.*

For both polarized electrons and positrons, the polarization measurement will be done with Compton polarimetry. Depending on the final choice of a beam head-on design or a crossing-angle design, the polarimeter could be installed upstream and/or downstream.

Pulse-to-pulse switching of the positron polarization can be accomplished by utilizing slow kicker magnets. A pair of dipoles is turned on between pulse-trains to deflect the beam through solenoids to rotate the spin to the opposite helicity. With such a system, the change of positron polarization can happen between pulse-trains, which is fast enough to keep any systematics well under control.

To provide transversely-polarized beams, one just has to change the spin rotator settings —consisting of two solenoids and a bend-rotation system, while minimizing the emittance dilution— just after the damping system. Such a device will allow one to set the spins at any arbitrary orientations by the time they reach the interaction region (IR). Details can be found in [2] and references therein.



• In the report [2] many examples from the Standard Model as well as from numerous models beyond the Standard Model have shown in detail that simultaneously polarized e^- and e^+ beams will provide a very efficient tool for direct as well as indirect searches for new physics.

What are the conclusions?

Polarized positrons are essential for resolving several specific physics issues, and enrich the physics potential considerably. They would serve as a superior experimental tool to face the (expected and unforeseen) challenges of possible new physics, as well as making possible the precise study of the underlying model.

In the cases of representative examples, the qualitative and quantitative improvement factors obtainable if both beams are polarized have been derived, assuming in most cases $(|P_{e^-}|, |P_{e^+}|) = (80\%, 60\%)$, as compared to the case of only polarized electrons $((|P_{e^-}|, |P_{e^+}|) = (80\%, 0))$: see also the summary table. The results show that the polarization of both beams

- is required to probe directly specific new physics properties, including particle quantum numbers,
- enables one to detect even very small traces of new physics, for example in Higgs searches, supersymmetry and models of gravity in extra dimensions,
- offers model-independent searches and differentiates between models in indirect searches,
- provides sensitive new observables in searches for new sources of CP violation,
- allows to perform tests of the SM with an unprecedented precision,
- enables one to control SM as well as background processes, for example from new physics itself,
- leads to higher statistics, better control of systematics and much higher precision in polarization-dependent observables such as left-right asymmetries.

One should keep in mind that the examples given here by no means exhaust the whole phenomenology of polarized electron and positron beams. Studies are still ongoing and further ideas for the exploitation of both beams polarized are emerging.

References

[1] ICFA, *Parameters for the Linear Collider*, see webpage:
www.interactions.org/linearcollider/documents/index.htm.

[2] G. Moortgat-Pick et al., *The role of polarized positrons and electrons in revealing fundamental interactions at the Linear Collider* , CERN-PH-TH/2005-036, hep-ph/0507011, to be submitted to Physics Reports.

[3] Studies by T. Himel; Talks by E. Elsen, N. Phinney at the 'Workshop on Positron Sources for the International Linear Collider', Daresbury Laboratory, April 2005, see webpage:
www.astec.ac.uk/id_mag/ID-Mag_Helical_ILC_Positron_Production_Workshop.htm.
E. Elsen, T. Himel, S. Schätzel, 2005 ALCPG&ILC Snowmass Workshop, Colorado, August 2005.

Case	Effects	Gain& Requirement
SM:		
top threshold	Electroweak coupling measurement	factor 3
$t\bar{q}$	Limits for FCN top couplings improved	factor 1.8
CPV in $t\bar{t}$	Azimuthal CP-odd asymmetries give access to S- and T-currents up to 10 TeV	$P^{\mathrm{T}}_{e^-} P^{\mathrm{T}}_{e^+}$ required
W^+W^-	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$	up to a factor 2
	TGC: error reduction of $\Delta\kappa_\gamma$, $\Delta\lambda_\gamma$, $\Delta\kappa_Z$, $\Delta\lambda_Z$	factor 1.8
	Specific TGC $\tilde{h}_+ = \mathrm{Im}(g_1^{\mathrm{R}} + \kappa^{\mathrm{R}})/\sqrt{2}$	$P^{\mathrm{T}}_{e^-} P^{\mathrm{T}}_{e^+}$ required
CPV in γZ	Anomalous TGC $\gamma\gamma Z$, γZZ	$P^{\mathrm{T}}_{e^-} P^{\mathrm{T}}_{e^+}$ required
HZ	Separation: $HZ \leftrightarrow H\bar{\nu}\nu$	factor 4 with RL
	Suppression of $B = W^+\ell^-\nu$	factor 1.7
$t\bar{t}H$	Top Yukawa coupling measurement at $\sqrt{s} = 500$ GeV	factor 2.5
SUSY:		
$\tilde{e}^+\tilde{e}^-$	Test of quantum numbers L, R and measurement of $e^\pm$ Yukawa couplings	P_{e^+} required
$\tilde{\mu}\tilde{\mu}$	Enhancement of S/B, $B = WW$ $\Rightarrow m_{\tilde{\mu}_{\mathrm{L,R}}}$ in the continuum	factor 5-7
HA, $m_A > 500$ GeV	Access to difficult parameter space	factor 1.6
$\tilde{\chi}^+\tilde{\chi}^-$, $\tilde{\chi}^0\tilde{\chi}^0$	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$ Separation between SUSY models, 'model-independent' parameter determination	factor 2–3
CPV in $\tilde{\chi}^0_i\tilde{\chi}^0_j$	Direct CP-odd observables	$P^{\mathrm{T}}_{e^-} P^{\mathrm{T}}_{e^+}$ required
RPV in $\tilde{\nu}_\tau \to \ell^+\ell^-$	Enhancement of S/B, $S/\sqrt{B}$ Test of spin quantum number	factor 10 with LL
ED:		
$G\gamma$	Enhancement of S/B, $B = \gamma\nu\bar{\nu}$,	factor 3
$e^+e^- \to f\bar{f}$	Distinction between ADD and RS models	$P^{\mathrm{T}}_{e^-} P^{\mathrm{T}}_{e^+}$ required
Z′:		
$e^+e^- \to f\bar{f}$	Measurement of Z' couplings	factor 1.5
CI:		
$e^+e- \to q\bar{q}$	Model independent bounds	P_{e^+} required
Precision measurements of the Standard Model at GigaZ:		
Z-pole	Improvement of $\Delta\sin^2\theta_W$	$\sim$ factor 10
	Improvement of Higgs bounds	$\sim$ factor 10
	Constraints on CMSSM parameter space	factor 5
CPV in $Z \to b\bar{b}$	Enhancement of sensitivity	factor 3

Some of the physics examples given in the report [2]. The case of having both beams polarized is compared with the case of using only polarized electrons; in most cases $(|P_{e^-}|, |P_{e^+}|) = (80\%, 60\%)$ is compared to $(|P_{e^-}|, |P_{e^+}|) = (80\%, 0\%)$, details see corresponding section in [2]; B (S) denotes background (signal); CPV (RPV) means CP (R-parity) violation.