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Revealing fundamental interactions: the rôle of polarized positrons and electrons at the Linear Collider*

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Abstract

The proposed International Linear Collider (ILC) is well-suited for discovering physics beyond the Standard Model and for precisely unraveling the structure of the underlying physics. The physics return would be maximized by providing polarized beams. This report shows the paramount role of polarized beams and summarizes the benefits obtained from polarizing the positron beam, as well as the electron. The physics case for this option is illustrated explicitly by analyzing reference reactions in different physics scenarios. The results show that positron polarization, combined with the clean experimental environment provided by a Linear Collider, would allow one to improve dramatically the potentials of searches for new particles and the identification of their dynamics, which could open the road to resolve open problems of the Standard Model. The report also presents an overview of possible designs for polarizing both beams, as well as for measuring the polarization.

Chapter 7

Concluding Remarks

Strong theoretical arguments and perhaps some experimental evidence indicate that the Standard Model of elementary particles is not the final theory of everything, and a variety of possible extensions have been proposed. Many of these envisage new building blocks and new interactions near the Fermi scale, and perhaps at higher mass scales. The choice among such scenarios, and hence the direction of new physics beyond the Standard Model, is of paramount importance. As the first machine to probe directly the TeV scale, the LHC will surely provide new discoveries and valuable information in this regard. However, it is generally agreed that the clean and precise environment of e^+e^- collisions at the ILC is ideally suited to the search for new physics and for determining precisely the underlying structure of the new interactions, whatever direction the LHC results may favour.

As we have demonstrated here, polarized beams will be very powerful tools to help reach these goals. The physics examples presented here have shown that having both beams polarized simultaneously will provide high flexibility and a very efficient means for the disentanglement of non-standard effects in various new physics scenarios, and their positive identification, as well as having the capacity to observe surprises in precision tests of the Standard Model. Having two polarized beams available is crucial for determining the properties and the quantum numbers of new particles, and to test fundamental model assumptions, as we have shown in the specific example of supersymmetry.

The larger number of observables accessible with two polarized beams provide better tools for revealing the structure of the underlying physics and determining new physics parameters in model-independent analyses. New signals may become accessible by maximizing the analyzing power using suitable beam polarizations combined with high luminosity. In many cases, as we have shown, double beam polarization enables better statistics to be obtained and the dominant systematical errors in indirect searches to be reduced. This can give access to physics scales that may be far beyond the direct kinematical reach of accelerators.

To fully exploit high-precision tests of the Standard Model at GigaZ, both beams must be polarized. To make full use of the extremely high statistics, the beam polarizations must be known with high precision, which cannot be provided by conventional polarimetry methods. However, the required precision can be achieved in the Blondel scheme, where both electron and positron polarizations are needed.

Further, with both beams polarized, one has the possibility to exploit transversely polarized beams for physics studies. This option provides new and efficient observables for the detection of possible sources of CP violation. Additionally, it becomes easier to observe the effects of massive gravitons and to distinguish between different models with extra spatial dimensions, far below the threshold for the spin-2 excitations. One can test specific triple-gauge-boson couplings which are not accessible otherwise. The power to identify new physics with polarized beams would represent a step forward of the utmost importance for our understanding of fundamental interactions.

An overview of the physics benefits coming from positron polarization has been given in this report, also in comparison with the case of only polarized electrons. An overview of the machine design for polarized beams at the ILC has also been given. SLAC experiments established that reliable high-energy electron beams with a polarization of 85-90% can be provided for an LC. The standard source for polarized electrons is a DC gun with a strained superlattice photocathode. To obtain polarized positrons at an LC, two methods are discussed:
a) Circularly polarized photons from a helical undulator can be used to generate longitudinally polarized positrons in a target via $e^{\pm}$ pair production; design and R&D towards developing such a source are well advanced.
b) Circularly polarized photons can also be obtained by backscattering of laser light off the electron beam.
A demonstration experiment, E166 at SLAC, for an undulator-based polarized positron source is now being prepared and will run in 2005. Prototypes of both superconducting and permanent magnets for helical undulators with lengths of 10 or 20 periods length are already under construction at Daresbury Laboratory. Meanwhile, the concept of the laser-based positron source is being tested in an experiment at KEK.

As already emphasised precise physics analyses at an LC require accurate beam polarization measurements. The primary polarimetry measurement at the ILC will be performed with a Compton polarimeter, with an expected accuracy $\Delta P_{e^-}/P_{e^-} = 0.25\%$. The polarimeters can be located upstream or downstream of the Interaction Point (IP), and it would be desirable to implement polarimeters at both locations. A downstream polarimeter may require a large crossing angle at the IP. Therefore, polarimetry is one of the main issues entering into the decision on the crossing angle(s) for the interaction region(s).

Since polarimeters measure either the polarization of the incoming beam before it has been depolarized by the beam-beam interaction, or that of the outgoing beam after depolarization in the interaction region, it is desirable to measure the polarization directly from the data via processes with precisely known polarization structures, such as WW production. Alternatively, in the GigaZ option, one may apply the Blondel scheme, for which polarized positrons are needed. Methods for measuring the polarization using annihilation data involve physics assumptions that have to be considered in the framework of the model in which the data are analysed. The data-driven methods therefore cannot replace completely the polarimeters but provide an independent and complementary measurement. The data methods offer the possibility to reach a precision even better than the polarimeters, if the underlying physics is well understood.

In summary, it has been demonstrated that having simultaneously polarized e^- and e^+ beams is a very efficient tool for direct as well as indirect searches for new physics. This option provides ideal preparation even for unexpected new physics. Polarized positrons are necessary for several specific physics issues, and enrich the physics potential considerably. Techniques and engineering design for a polarized positron source are becoming well advanced. Consideration can therefore be given to including a polarized positron source in the ILC baseline design.