Global Scheme for Polarimetry

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A scheme for polarimetry at the ILC is presented. This scheme includes upstream and a downstream polarimeters as well as polarisation measurements from annihilation data.

1 Introduction

At the ILC polarisation can be measured by upstream- [1] or downstream-polarimeters [2] or from annihilation data [3]. One thus needs a concept how this different methods can be used to achieve the optimum precision.

This issue is complicated by a few things. At ILC there will be a crossing angle of around 12 mrad which maybe compensated either for the incoming or the outgoing beam by a Detector Integrated Dipole (DiD). For polarimetry it is essential that the beam in the polarimeter is parallel to the beam at the IP to avoid spin rotation from BMT precession. The dipole component of the detector solenoid and the DID thus need to be properly corrected. Polarimetry must be available from Z-running to the highest possible energy with and without positron polarisation. The aim for polarimetry is $\Delta\mathcal{P}/\mathcal{P} = 0.25\%$. This number is given by a realistic estimate of the achievable error. For physics a better value would still be useful.

If only electron polarisation is available the cross section for any process is given by $\sigma = \sigma_0(1 + \mathcal{P}_{e^-} A_{\mathrm{LR}})$. The error on A_{LR} due to polarisation is given by $\Delta A_{\mathrm{LR}}/A_{\mathrm{LR}} = \Delta\mathcal{P}_{e^-}/\mathcal{P}_{e^-}$. Since the polarisation enters only linearly the relevant quantity is the time averaged luminosity weighted polarisation value.

If also positron polarisation is available, most cross sections are given by $\sigma = \sigma_0(1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-} + (\mathcal{P}_{e^+} - \mathcal{P}_{e^-})A_{\mathrm{LR}})$. Since the observables depend on the individual polarisations as well as on the polarisation product the correlations between the two polarisations are needed. Such correlations may arise from the spacial correlation of the colliding particles inside the bunch as well as from correlated time dependences. Simulation studies indicate however, that spacial correlations are negligible. For the interesting observables an effective polarisation is needed. For example for A_{LR} one has $\mathcal{P}_{\mathrm{eff}} = \frac{\mathcal{P}_{e^+} + \mathcal{P}_{e^-}}{1 + \mathcal{P}_{e^+}\mathcal{P}_{e^-}}$. Due to favourable error propagation the error on $\mathcal{P}_{\mathrm{eff}}$ can be up to a factor of three smaller than the polarisation error.

2 Upstream polarimetry

Upstream polarimetry is described in detail in [1]. Only the polarisation before the interaction can be measured and the depolarisation in the interaction must be calculated which introduces unavoidable, however small, uncertainties. On the other hand in the clean environment upstream of the IP a high frequency laser can be used measuring every bunch.

The expected statistical error will be much less than 1%/s. A large part of the Compton spectrum can be measured resulting in a large variation of the analysing power, allowing for many internal cross checks like a measurement of the $e\gamma$ luminosity for different laser polarisations.

3 Downstream polarimetry

Downstream polarimetry is described in detail in [2]. Because of the larger background in the extraction line a large pulse power of the laser is needed allowing only for very few shots per train. A priory the polarisation of the beam after the interaction is measured. The depolarisation of the outgoing beam is about four times the one of the interacting particles. For the BMT part of the depolarisation this can however be adjusted with the right transfer matrix of the extraction line elements. For the Sokolov Ternov part this is not possible, however this part is very small in the existing designs [4]. The polarisation of the non interacting beams can be measured outside collisions.

The absolute value of the transfer matrix can be adjusted relatively easily. The sign seems to be more difficult which can be a problem if the beams don't collide exactly head-on and the spin is not perfectly aligned (see fig. 1).

The range in analysing power is also smaller than for the upstream polarimetry. It is felt, however, that the range is still large enough where it is not completely clear yet if the zero-analysing power point is needed.

The statistical error is of the order 1%/minute, permitting less cross checks than the upstream polarimeter. To improve the error on the polarisation correlations, in case positron polarimetry is available, the same bunches in the electron and positron beams should be measured.

4 Polarimetry from annihilation data

Without positron polarisation the cross section is $\sigma = \sigma_0(1 + \mathcal{P}_{e^-} A_{\mathrm{LR}})$. Two measurements are possible in this case with three unknowns so that no model independent measurement of the polarisation is possible. However for W-pair production the forward peak is completely dominated by neutrino t-channel exchange involving only the well known Weν coupling at low t without a significant contribution from the triple gauge boson couplings (see fig. 2). With 500 fb^{-1} of data this allows a determination of the polarisation on the 0.1% level together with the triple gauge couplings [3].

With positron polarisation four measurements are possible with four unknowns. so that the polarisation can be determined in a model independent way using W- or fermion pair production. However in this case a significant part of the luminosity has to be spent on the J=0 states which are of little interest for most analyses. If no physics motivation exists to run at these states the model independent determination of the polarisations can thus be a rather expensive measurement. If this measurement is done using 500 fb^{-1} both polarisations can be measured on the 0.1% level. Due to the anticorrelation between the two values the effective polarisation even is known to 0.02% [3].

If the polarisation is measured from data polarimeters are still needed for some corrections like time-correlations between the two polarisations or a polarisation difference between the left- and the right-handed states. These effects are larger than for a pure polarisation

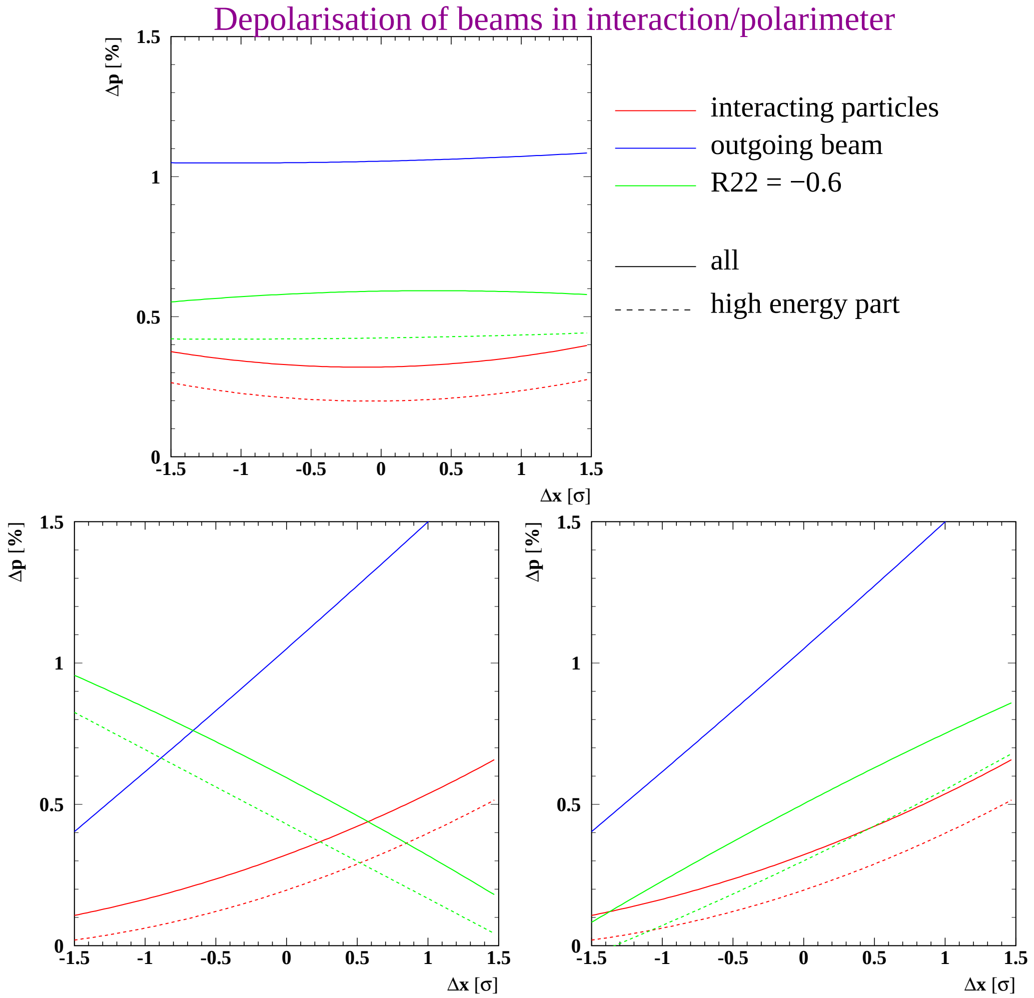

Figure 1: Depolarisation of the beams in the interaction and in the polarimeter as a function of horizontal offset of the beams. In the upper plot it is assumed that the spin is perfectly aligned to the beam direction while in the lower plots a misalignment of 50 mrad is assumed. In the upper and lower left plot a transfer matrix element of -0.6, in the lower right plot +0.6 is assumed.

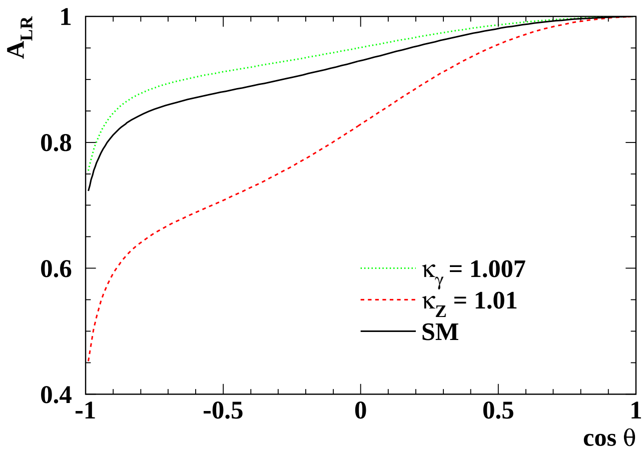

Figure 2: Left-right asymmetry for W-pair production as a function of the production angle for the SM and with anomalous triple gauge couplings.

measurement. Also a large integrated luminosity is needed for a polarisation measurement with data, so that polarimeters are also needed for example for an energy scan.

5 Global scheme for polarimetry

Some processes at the ILC can have up to 10^6 events. For electron polarisation only a polarimetry error of 0.25% thus may still be the limiting error. Since this error seems to be on the edge of the possibilities all possible cross checks and redundancies are needed. Upstream polarimetry gives the cleanest measurement with the highest time granularity and most internal granularity. Downstream polarimetry gives access to the depolarisation in collision and having two independent polarimeters allows a cross calibration of the two. Even if additional information can be obtained from annihilation data it is important to have both polarimeters installed. In stable running the upstream device will give the main input for variations and correlations while the downstream polarimeter measures the depolarisation in the collision which also may be fluctuating. It can be hoped that the absolute calibration can be obtained from annihilation data.

Not to be sensitive to time dependent variations in the beam energy, the detector efficiency etc. it is also important to flip the polarisation fast. For electrons it seems no problem to flip the polarisation train by train. The fast flipping is even more important if positron polarisation is available because of the $(1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-})$ term in the cross section. A cheap scheme exists to flip also the positron polarisation train by train [5]. It is difficult to quantify at the moment how much the error would increase if the fast flipping scheme is not available but it is definitely an advantage to avoid possible error sources in the design.

6 Conclusions

Polarimetry is an essential ingredient for data analysis at the ILC and it can well be the limiting systematic uncertainty for some measurements. One thus should make every effort to get the error down. Only a combination of the three different schemes can give us the cross checks and redundancy to reach this goal.

The price for the polarimeter is not only negligible compared to the total cost of the ILC but also cheap compared to the cost for running the machine. A cost optimisation, assuming a constant error for some of the high statistics observables would also favour an investment into an optimal polarimetry setup.

References

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