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Electroweak Physics at a Linear Collider Z-factory

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Abstract

Assuming that a linear collider like TESLA can run with polarised electron and positron beams on the Z-resonance the possibilities to measure electroweak quantities with high precision are investigated. Especially for quantities where beam polarisation is needed, namely A_{LR} and $\mathcal{A}_{\mathrm{b}}$, huge progress compared to the present precision can be expected

1 Introduction

At a next generation linear collider one should be able to polarise the electrons with the same technology as at the SLC to up to 80%. At TESLA it should also be possible to run with polarised positrons ($\mathcal{P}^+ \sim 60\%$) and high luminosity ($\mathcal{L} \sim 5 \cdot 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$) close to the peak of the Z-resonance[1]. This would allow to repeat the electroweak measurements currently performed at LEP and SLD with higher precision.

Compared to the sum of the four LEP experiments the expected gain in statistics can be around a factor of one hundred. However with the availability of beam polarisation and the good b-tagging capability at a linear collider the more relevant comparison is with SLD where the gain will be more like a factor of 2000.

The variable that is most sensitive to the effective weak mixing angle $\sin^2\theta^\ell_{\mathrm{eff}}$ is the left-right asymmetry in Z-decays if the incoming beams can be polarised. Using A_{LR}, SLD at SLAC was able to measure the weak mixing angle to a better accuracy than any single observable at LEP with less than a tenth of the luminosity [2].

Using the same scheme as the present SLD analysis, improvement, however, is limited to about a factor two due to the precision with which the electron polarisation can be measured.

If, however, also positrons can be polarised the polarisation can be measured from cross section asymmetries, so that an external measurement is only needed for polarisation differences. Such a scheme has been first proposed by A. Blondel for the case of LEP[3] where electrons and positrons could have been either polarised in one orientation or being unpolarised. In the following this scheme will be evaluated for the linear collider case.

Similar improvement as for A_{LR} can be expected for the polarised forward-backward asymmetry for b-quarks. The systematic limitations of the present measurements that would show up with the increased statistical precision can be overcome due to the good b-tagging capabilities.

The possible gain in observables, that have to do with cross section measurements and are connected to decay widths of the Z, is much weaker. These observables have already now large contributions from systematic errors due to the total luminosity measurement, the event selection and the beam energy determination and it is not clear how they can be reduced significantly.

2 General setup and assumptions

According to [1] a luminosity of $\mathcal{L} = 5 \cdot 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at the Z-pole seems realistic. Within about 70 days it is thus possible to produce $30\mathrm{fb}^{-1}$ corresponding to 10^9 hadronic Z-decays. It will be assumed that electrons and positrons can be polarised with polarisations of $\mathcal{P}^- = \pm 80\%$, $\mathcal{P}^+ = \pm 60\%$. This corresponds to an equivalent polarisation of $\frac{\mathcal{P}^+ + \mathcal{P}^-}{1+\mathcal{P}^+\mathcal{P}^-} \sim 95\%$. Also it will be assumed that the polarisation can be switched randomly from train to train.

The beam energy of both the electron and the positron beam can be measured with a spectrometer similar to the one currently being installed in LEP [4]. It should be possible that fast energy scans can be performed, so that the spectrometer can be calibrated relative to m_{Z} from LEP. With this scheme a precision of 1 MeV might be reached. It should be noted that the relevant parameter to correct the electroweak measurements is the difference $\sqrt{s} - m_Z$, so that the error on m_Z does not enter, when the spectrometer is calibrated relative to the Z-mass.

3 Lineshape parameters

The parameters that are measured at LEP in the scan around the Z-resonance are:

- the mass of the Z (m_Z)
- the width of the Z (Γ_Z)
- the hadronic peak cross section ($\sigma_0 \propto \frac{\Gamma_\ell \Gamma_{had}}{\Gamma_Z^2}$)
- the ratio of the hadronic and leptonic partial widths ($R_\ell = \frac{\Gamma_{had}}{\Gamma_\ell}$)

Since m_Z is used to calibrate the spectrometer, its precision clearly cannot be improved at TESLA. With the high statistics available at the Z running, the error on Γ_Z is equal to the error on $\sqrt{s}$, so 1 MeV is within reach.

The error on the hadronic peak cross section is dominated by uncertainties coming from the luminosity measurement, mainly from theory. It is possible that with the high luminosity available at TESLA low cross section processes like $e^+e^- \to \gamma\gamma$ can be used with smaller uncertainties, but for the moment it will be assumed that no improvement on σ_0 will be possible.

R_ℓ also receives substantial contributions from systematic uncertainties due to the leptonic and hadronic event selection. The uncertainties from the leptonic event selection, especially for muons, are mainly of statistical nature. So it can be assumed that they scale with the luminosity. The uncertainty on the hadronic event selection will be assumed to stay at the best value reached at LEP (0.05%) [2]. A more careful study on this subject is in progress [5].

The interesting physics parameters that can be derived from the lineshape parameters are

- the mass of the Z (m_Z)
- the strong coupling constant at the Z-mass ($\alpha_s(m_Z^2)$)
- the radiative correction parameter normalising the strength of the Z-couplings to the fermions ($\Delta\rho$)
- the number of light neutrino species (N_ν)

The possible improvements in these parameters are summarised in table 1. It can be seen that an interesting gain can be obtained for $\alpha_s(m_Z^2)$ and $\Delta\rho$. N_ν is completely determined by σ_0 so that no change is expected, if the luminosity determination cannot be improved.

	LEP [2]	TESLA
m_Z	91.1867 ± 0.0021 GeV	± 0.0021 GeV
$\alpha_s(m_Z^2)$	0.1212 ± 0.0034	± 0.0016
$\Delta\rho$	$(0.42 \pm 0.12) \cdot 10^{-2}$	$\pm 0.05 \cdot 10^{-2}$
N_ν	2.994 ± 0.0011	± 0.0011

Table 1: Possible improvement in the physics quantities derived from the Z-line shape with a high luminosity Z-running at TESLA. For α_s and $\Delta\rho$ $N_\nu = 3$ is assumed.

4 Measurement of R_{b}

The fraction of $\mathrm{b\overline{b}}$ events within the hadronic event sample $R_{\mathrm{b}} = \sigma_{\mathrm{b\overline{b}}}/\sigma_{\mathrm{had}}$ is closely related to the ratio of partial widths $R_{\mathrm{b}}^0 = \Gamma_{\mathrm{b\overline{b}}}/\Gamma_{\mathrm{had}}$ ($R_{\mathrm{b}}^0 = R_{\mathrm{b}} + 0.0002$). R_{b}^0 plays a special role within the electroweak quantities, since in the ratio of widths basically all corrections from the electroweak propagator and from QCD effects cancel, so that R_{b}^0 only measures corrections to the Zbb vertex. At LEP R_{b}^0 is limited by systematic errors, mainly from three sources:

1. background from $\mathrm{c\overline{c}}$ event. This error arises mainly from physics uncertainties in charm production and decay;

2. background from light quark events containing a gluon splitting $g \rightarrow \mathrm{b\overline{b}}$. This background is to a large extent irreducible and the error is due to the uncertainty in the frequency of the gluon splitting process;

3. hemisphere correlations from hard gluon radiation. Hard gluons emitted at large angle take energy from both hemispheres. Since the b-tagging efficiency is a function of the energy of the decaying B-hadron this leads to a correlation between the hemispheres.

The LEP analysis with the smallest error at present from DELPHI [6] has about equal statistical and systematic uncertainties. The DELPHI analysis works with an efficiency of 30% and a purity of 98%. At TESLA a purity of 99.3% at the same efficiency seems feasible [7], reducing the statistical error by a factor 20. At the same time the charm background is reduced by a factor four. Even if no new understanding of the charm background is gained until then, the systematics from this source will be reduced accordingly.

The gluon splitting into $\mathrm{c\overline{c}}$ and $\mathrm{b\overline{b}}$ pairs is measured at LEP. With the large statistics and the high quality b-tag there is no doubt that this can be measured much more accurate at TESLA.

The impact parameter resolution at TESLA is about a factor 10 better than at LEP and the losses of $\mathrm{b\overline{b}}$ events are mainly due to the invariant mass cut. Since the invariant mass is a Lorenz invariant quantity the energy dependence of the b-tag should be much reduced, so that also for the QCD hemisphere correlations a reduction of a factor four to five is realistic.

In summary a total error of $\Delta R_{\mathrm{b}} = 0.00014$ can be expected which is an improvement of a factor five compared to the present LEP average [2].

5 Measurement of A_{LR}

5.1 The Blondel scheme for the linear collider

In general the cross section $\mathrm{e}^+\mathrm{e}^- \to \mathrm{Z} \to \mathrm{f\bar{f}}$ for polarised beams can be written as

$$\sigma = \sigma_u \left[1 - \mathcal{P}^+\mathcal{P}^- + A_{\mathrm{LR}}(\mathcal{P}^+ - \mathcal{P}^-)\right], \tag{1}$$

where $\mathcal{P}^+$ and $\mathcal{P}^-$ are the longitudinal polarisations of the positrons and electrons measured in the direction of the particle's velocity. σ_u is the unpolarised cross section and A_{LR} the left-right asymmetry.

With the assumption of an absolute electron/positron polarisation of $\mathcal{P}^- = 80\%$ and $\mathcal{P}^+ = 60\%$ and the possible polarisation states $\pm\mathcal{P}^-$ and $\pm\mathcal{P}^+$ four statistically independent measurements are possible:

$$\begin{aligned}
\sigma_{++} &= \sigma_u \left[1 - \mathcal{P}^+\mathcal{P}^- + A_{\mathrm{LR}}(\ \ \mathcal{P}^+ - \mathcal{P}^-)\right] \\
\sigma_{-+} &= \sigma_u \left[1 + \mathcal{P}^+\mathcal{P}^- + A_{\mathrm{LR}}(-\mathcal{P}^+ - \mathcal{P}^-)\right] \\
\sigma_{+-} &= \sigma_u \left[1 + \mathcal{P}^+\mathcal{P}^- + A_{\mathrm{LR}}(\ \ \mathcal{P}^+ + \mathcal{P}^-)\right] \\
\sigma_{--} &= \sigma_u \left[1 - \mathcal{P}^+\mathcal{P}^- + A_{\mathrm{LR}}(-\mathcal{P}^+ + \mathcal{P}^-)\right]
\end{aligned}$$

where in $\sigma_{\pm\pm}$ the first sign denotes the positron- and the second one the electron polarisation.

The left-right asymmetry is then given by

$$A_{\mathrm{LR}} = \sqrt{\frac{(\sigma_{++} + \sigma_{-+} - \sigma_{+-} - \sigma_{--})(-\sigma_{++} + \sigma_{-+} - \sigma_{+-} + \sigma_{--})}{(\sigma_{++} + \sigma_{-+} + \sigma_{+-} + \sigma_{--})(-\sigma_{++} + \sigma_{-+} + \sigma_{+-} - \sigma_{--})}}$$

without a need for polarisation measurements.

The statistical error is given as usual by

$$\Delta A_{\mathrm{LR}}{}^2 = \sum_{i=\pm, j=\pm} \left(\frac{\partial A_{\mathrm{LR}}}{\partial \sigma_{ij}} \Delta\sigma_{ij}\right)^2$$

where the derivatives are given by

$$\begin{aligned}
\frac{\partial A_{\mathrm{LR}}}{\partial \sigma_{++}} &= \frac{1}{8\sigma_u \mathcal{P}^+\mathcal{P}^-}\left[-\mathcal{P}^+ + \mathcal{P}^- - (\mathcal{P}^+\mathcal{P}^- - 1)A_{\mathrm{LR}}\right] \\
\frac{\partial A_{\mathrm{LR}}}{\partial \sigma_{-+}} &= \frac{1}{8\sigma_u \mathcal{P}^+\mathcal{P}^-}\left[-\mathcal{P}^+ - \mathcal{P}^- - (\mathcal{P}^+\mathcal{P}^- + 1)A_{\mathrm{LR}}\right] \\
\frac{\partial A_{\mathrm{LR}}}{\partial \sigma_{+-}} &= \frac{1}{8\sigma_u \mathcal{P}^+\mathcal{P}^-}\left[\ \ \mathcal{P}^+ + \mathcal{P}^- - (\mathcal{P}^+\mathcal{P}^- + 1)A_{\mathrm{LR}}\right] \\
\frac{\partial A_{\mathrm{LR}}}{\partial \sigma_{--}} &= \frac{1}{8\sigma_u \mathcal{P}^+\mathcal{P}^-}\left[\ \ \mathcal{P}^+ - \mathcal{P}^- - (\mathcal{P}^+\mathcal{P}^- - 1)A_{\mathrm{LR}}\right]
\end{aligned}$$

Ignoring the terms proportional to A_{LR} the derivatives for the large cross sections σ_{+-} and σ_{-+} are proportional to $\mathcal{P}^+ + \mathcal{P}^-$, whereas the ones at the small cross sections σ_{++} and σ_{--} are proportional to $|\mathcal{P}^+ - \mathcal{P}^-|$. In addition, for equal luminosity, the absolute errors on the large cross sections are larger than on the small ones, so that the optimal distribution of luminosities is around

$$\frac{\mathcal{L}_{+-}+\mathcal{L}_{-+}}{\mathcal{L}} = \sqrt{\frac{(1-\mathcal{P}^+\mathcal{P}^-)(\mathcal{P}^- - \mathcal{P}^+)^2}{(1+\mathcal{P}^+\mathcal{P}^-)(\mathcal{P}^- + \mathcal{P}^+)^2 + (1-\mathcal{P}^+\mathcal{P}^-)(\mathcal{P}^- - \mathcal{P}^+)^2}} \tag{2}$$

Taking $\mathcal{P}^- = 80\%$ and $\mathcal{P}^+ = 60\%$ the optimum is around 0.1, which means that only very little luminosity is needed for the small cross sections, so that only few Zs are lost. Figure 1 shows the statistical error on $A_{\rm LR}$ for these polarisation values as a function of the luminosity spent on the small cross sections using $A_{\rm LR} = 0.15$. Since the minimum is very shallow no complicated optimisation procedure will be needed.

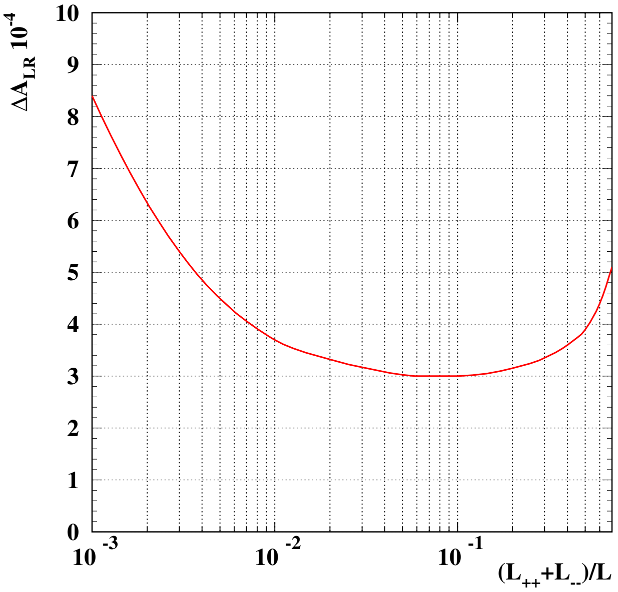

Figure 1: Statistical error on $A_{\rm LR}$ as a function of the luminosity spent on the small cross sections.

With 10^9 registered Zs which corresponds to roughly 70 days of running at a luminosity of $5 \cdot 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ an error of $\Delta A_{\rm LR} = 3.0 \cdot 10^{-5}$ can be reached. Figure 2 shows the statistical error as a function of the positron polarisation. For high values of $\mathcal{P}^+$ the error is nearly constant, so that not much can be gained increasing $\mathcal{P}^+$ much above 60%.

Although no absolute polarisation measurements are needed in this scheme some relative measurements are still required. Especially the difference between the absolute values of the positive and negative polarisations has a significant impact on the determination of $A_{\rm LR}$. This will be treated in detail in section 5.1.1.

Other possible systematic errors should be well under control:

- The change of $A_{\rm LR}$ with the centre of mass energy close to the peak of the Z-resonance is about $2 \cdot 10^{-2}/\,\mathrm{GeV}$, the beam energy needs thus to be controlled to about 1 MeV

- Non-resonant backgrounds need to be kept below 10^{-4} which seems no problem extrapolating the LEP experience.

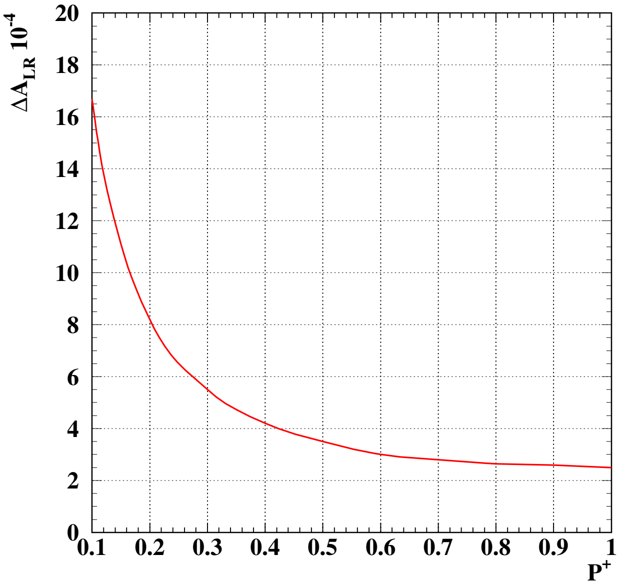

Figure 2: Statistical error on A_{LR} as a function of the positron polarisation.

- To measure the luminosity differences between the different polarisation states a LEP-type luminometer measuring small angle Bhabha scattering is required. However also here only relative measurements need to be done.
- Beamstrahlung, with the amount expected for the high luminosity Z-running [8], modifies A_{LR} by $\Delta A_{\mathrm{LR}} = 9 \cdot 10^{-4}$. It thus needs to be known to a few percent precision.

5.1.1 Measurement of the polarisation difference

In the scheme proposed here a possible difference of the absolute values of the positive and the negative polarisation can be measured only with polarimetry. It will thus be assumed that a Compton polarimeter of the same type as the one operated at SLD [9] is installed in the electron and the positron beam.

In this type of polarimeter the beam is scattered by a highly polarised laser beam where the sign of the laser polarisation is chosen at random and the asymmetry of the scattered electrons is analysed by a detector (Cherencov in the case of SLD). The possibility to vary the laser polarisation enables one to measure the two electron (positron) polarisation states independently. An additional effect that can disturb the polarisation measurement, is a possible asymmetry of the laser currents, dependent on the polarisation. This can be overcome if, as at SLD, the detector consists of different channels with different analysing power.

Due to the simultaneous application of the Blondel scheme, the analysing powers of the different detector channels need not to be known a priori but can be obtained from data. The laser polarisation can be measured very precisely. It enters only proportional to the small polarisation difference, so that its error is totally negligible. Assuming analysing powers of 0.4 and 0 for the two detector channels the error on $A_{\rm LR}$ becomes

$$\Delta A_{\rm LR} \;=\; \Delta A^{(0)}_{\rm LR}\sqrt{1+8/x}$$

where $\Delta A^{(0)}_{\rm LR}$ is the error on $A_{\rm LR}$ without the contribution from the polarimeter and x is the ratio of Compton events in each polarimeter channel to the number of Z events. $x \sim 10$, which seems no problem given the SLD experience, would thus increase the statistical error to $\Delta A_{\rm LR} \;=\; 4\cdot 10^{-5}\cdot\sqrt{\frac{10^9}{N_Z}}$.

5.1.2 Alternative measurement of the polarisation difference

If, in addition to the positive and negative polarisation, also unpolarised beams are used, nine different polarisation combinations are possible. In this scheme the polarisation of the positive and negative states can be measured separately from data. The statistical error for this case increases to $\Delta A_{\rm LR} \;=\; 7\cdot 10^{-5}\cdot\sqrt{\frac{10^9}{N_Z}}$. However the residual polarisation of the unpolarised beam must be known to better than 10^{-4} to get the systematic uncertainty from this source below the statistical error.

5.2 Interpretation of $A_{\rm LR}$

Given all the errors explained above, $\Delta A_{\rm LR} \;=\; 10^{-4}$ seems a realistic estimate for the final precision on $A_{\rm LR}$. This corresponds to an error of 0.000013 in $\sin^2\theta^\ell_{\rm eff}$. At the Born level α, $G_{\rm F}$ and $m_{\rm Z}$ enter in the definition of $\sin^2\theta$ where all give an uncertainty on the prediction of at least one order of magnitude better than the experimental precision of the measurement.

At the considered level of accuracy, however, one has to consider effects of radiative corrections, which is actually the main interest to do the measurement. At this level all parameters of the Standard Model enter into the prediction.

The by far largest correction comes from the running of the fine structure constant to the Z mass. Using only measurements of the hadronic cross section at low energies a value of $\alpha_{QED}(m_{\rm Z}^2) = 1/(128.896\pm 0.090)$ has been obtained [10], which translates into an error on $\sin^2\theta^\ell_{\rm eff}$ of 0.00023. Imposing QCD for energies above 1.7 GeV the error could recently be reduced by about a factor of four [11, 12, 13], but even this completely dominates over the experimental error. If the hadronic cross section can measured to 1% for energies up to around 3.6 GeV the error can be reduced by a total factor of nine. If it is known to 1% up to the Υ the total reduction is a factor 14 [13]. This would correspond to $\Delta\sin^2\theta^\ell_{\rm eff} = 0.000017$.

A top mass error of 1 GeV would contribute an uncertainty of 0.000032 to the $\sin^2\theta^\ell_{\rm eff}$ prediction. At TESLA it should be possible to measure $m_{\rm t}$ to 120 MeV, so that the top contribution to $\Delta\sin^2\theta^\ell_{\rm eff}$ will be negligible.

A 5% variation in the Higgs mass changes $\sin^2\theta^\ell_{\rm eff}$ by 0.000025. If the Higgs is found at the time the $A_{\rm LR}$ measurement will be done, its mass can be measured on the 200 MeV level, so that it also does not contribute to the error. If it is not found, the measurement of $\sin^2\theta^\ell_{\rm eff}$ can be used to predict the Higgs mass on the $\sim 5\%$.

To visualise the improvement, figure 3 shows the fit χ^2 as a function of the Higgs mass for the present electroweak precision data [2] and for the TESLA expectation.

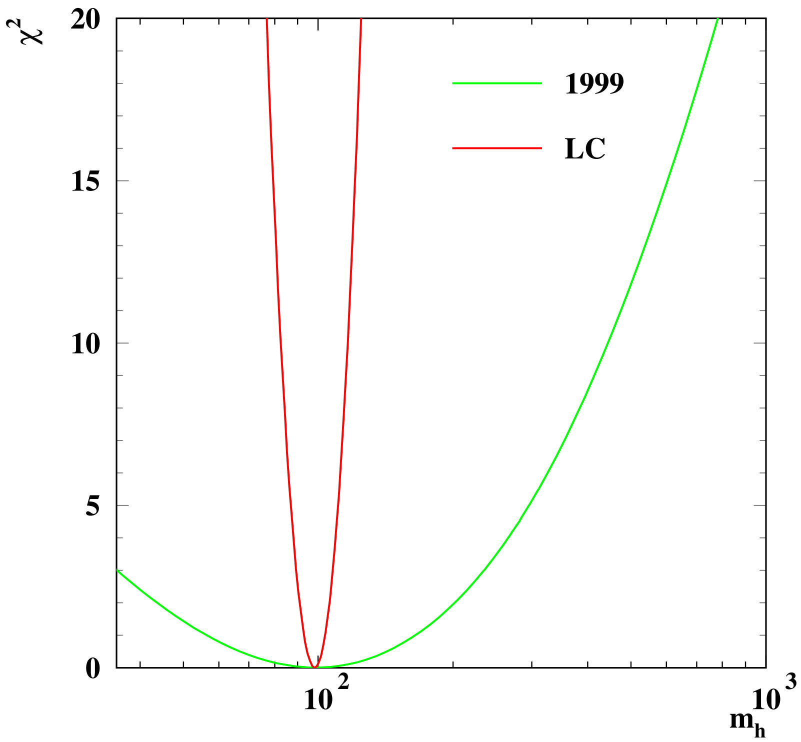

Figure 3: $\Delta\chi^2$ as a function of the Higgs mass for the electroweak precision data now and after the LC-Z-factory running

6 Measurement of $\mathcal{A}_{\rm b}$

At LEP the forward backward asymmetry for a quark q measures the product of the coupling parameters for the initial state electron and the final state quark:

$$
\begin{aligned}
A^q_{FB} &= \frac{\sigma^{(q)}_F - \sigma^{(q)}_B}{\sigma^{(q)}_T} \\
&= \frac{3}{4}\mathcal{A}_{\rm e}\mathcal{A}_{\rm q}
\end{aligned}
$$

If polarised beams are available the left-right-forward-backward asymmetry is sensitive to the final state coupling only:

$$
\begin{aligned}
A^q_{FB,LR} &= \frac{\sigma^{(q)}_{L,F} - \sigma^{(q)}_{L,B} - \sigma^{(q)}_{R,F} + \sigma^{(q)}_{R,B}}{\sigma^{(q)}_L + \sigma^{(q)}_R} \\
&= \frac{3}{4}\mathcal{P}\mathcal{A}_{\rm q}
\end{aligned}
$$

Statistically this quantity is a a factor $\mathcal{P}/\mathcal{A}_{\rm e} \sim 6$ more sensitive to $\mathcal{A}_{\rm q}$ than A^q_{FB}. However most systematic errors are proportional to the asymmetry, so that no gain is obtained there.

At LEP two methods are used to measure A_{FB}^{b}, high p_t leptons and a jetcharge measurement combined with a lifetime b-tag. With the better b-tagging possibilities at a linear collider additional methods like vertex-charge techniques are possible at SLD [14], however in the following only the extrapolation of the LEP methods will be discussed.

For the lepton-measurement the ALEPH analysis [15] ($A_{\mathrm{FB}}^{b} = 0.1008 \pm 0.0043(stat) \pm 0.0028(syst)$) is taken as a reference.

The statistical error with the assumed number of events will be $\Delta\mathcal{A}_{\mathrm{b}} = 4 \cdot 10^{-4}$. With this projected uncertainty the ALEPH analysis would be completely dominated by the systematics from light end especially charm quarks. However with the excellent b-tagging possibilities a b-tag with 85% efficiency and a charm rejection of a factor 50 will be possible [7] reducing the systematic error from this source to the same size as the statistical error.

$B\overline{B}$-mixing introduces a correction to the measured asymmetry ($A_{\mathrm{FB}}^{meas} = A_{\mathrm{FB}}(1-2\chi)$) so that it has to be measured from double lepton events. This introduces an additional statistical error of $\Delta\mathcal{A}_{\mathrm{b}} = 9 \cdot 10^{-4}$. If the mixing analysis is done with the same lepton selection as the asymmetry analysis all uncertainties due to the sample composition of the $\mathrm{b\overline{b}}$ events cancel. Thus a total error of $\Delta\mathcal{A}_{\mathrm{b}} = 11 \cdot 10^{-4}$ from the lepton analysis will be possible.

For the jetcharge method the recent DELPHI analysis [16] ($A_{\mathrm{FB}}^{b} = 0.0982 \pm 0.0047(stat) \pm 0.0016(syst)$) will be extrapolated.

The statistical error is expected to become $\Delta\mathcal{A}_{\mathrm{b}} = 5 \cdot 10^{-4}$. With the same efficiency for the b-tag as in the DELPHI analysis (75%) the purity will be 99% instead of 92% [7] leading to a systematic error from light quark backgrounds of $\Delta\mathcal{A}_{\mathrm{b}} = 1 \cdot 10^{-3}$. Some further optimisation in the efficiency purity working point is clearly possible.

Another source of uncertainty is hemisphere correlations. With a cut on the thrust of the events (see fig 4 [17]) the correlation can be brought down to the 10^{-3} level, so that even taking the full correlation as systematic uncertainty a total error of $\Delta\mathcal{A}_{\mathrm{b}} = 14 \cdot 10^{-4}$ from the jetcharge analysis is possible.

Combining the two analysis a total error of $\Delta\mathcal{A}_{\mathrm{b}} = 1 \cdot 10^{-3}$ seems realistic. As can be seen from figure 5 this is an improvement of similar size as for $\mathcal{A}_{\mathrm{e}}$.

7 Conclusions

With 10^9 Zs at a polarised linear collider huge improvements in the coupling parameters $\mathcal{A}_{\mathrm{e}}$, $\mathcal{A}_{\mathrm{b}}$ will be possible. $\mathcal{A}_{\mathrm{b}}$ can be measured to a precision on 10^{-3} and $\mathcal{A}_{\mathrm{e}}$ to a precision of 10^{-4} corresponding to an error in $\sin^2\theta_{\mathrm{eff}}^{\ell}$ of 0.000013. However, to make this measurement useful, the hadronic cross section below the Υ needs to measured to about 1% precision in order to calculate the running of the fine structure constant up to the Z mass.

If the Higgs is found until then a stringent test of the Standard Model will be possible, if not it's mass can be predicted with a 5% precision. Also in models like the MSSM some interesting predictions are possible [18].

Due to systematic limitations the improvement in the knowledge of the parameters connected with the Z partial widths will be much worse. For R_{b} a factor five could be obtained, while for $\alpha_s(m_{\mathrm{Z}}^2)$ and $\Delta\rho$ only a factor two is possible.

In summary, with relatively little investment in time and money a large improvement in the electroweak precision observables can be achieved. Since Z-running will be necessary anyway for detector calibration the additional investment is even less. The Z-factory

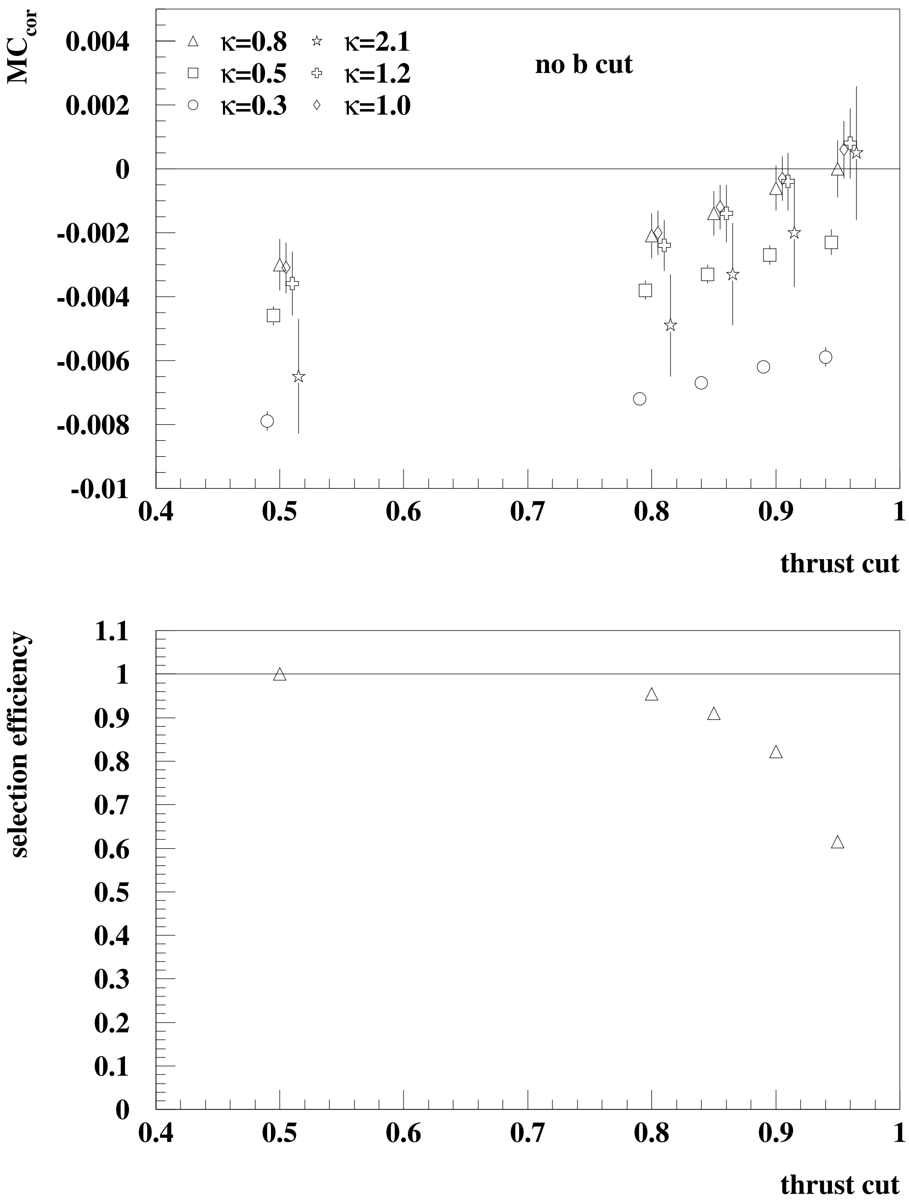

Figure 4: Hemisphere correlation for the $A_{\rm FB}^{b}$ jetcharge analysis as a function of the thrust cut

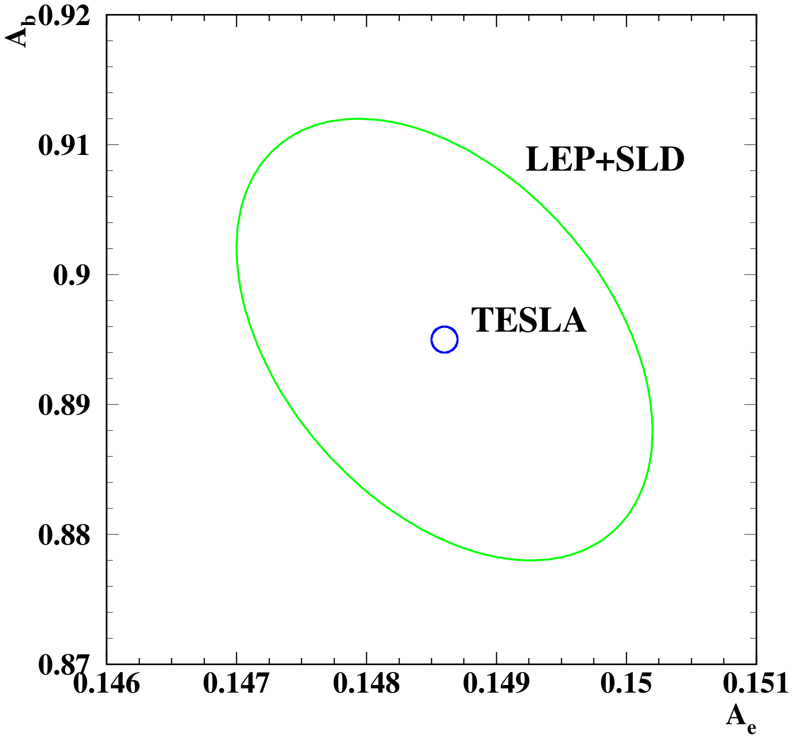

Figure 5: $\mathcal{A}_\mathrm{b}$ vs $\mathcal{A}_\mathrm{e}$ for LEP/SLD compared to the expectation from the TESLA Z-factory running

option is thus a nice supplement to the already rich linear collider program.

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