Study of A_LR using radiative return events at ILC250

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Estimation of A_{LR} precision (1)

$$A_{LR} \equiv \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}.$$

L/R : 100% polarization

$$A_{LRobs} \equiv \frac{\sigma_{-+} - \sigma_{+-}}{\sigma_{-+} + \sigma_{+-}}$$

-/+ : Polarization at ILC

$$\sigma_{-+} = \frac{1}{4}(1+|P_-|)(1+|P_+|)\sigma_L + \frac{1}{4}(1-|P_-|)(1-|P_+|)\sigma_R$$

$$\sigma_{+-} = \frac{1}{4}(1-|P_-|)(1-|P_+|)\sigma_L + \frac{1}{4}(1+|P_-|)(1+|P_+|)\sigma_R$$

$$A_{LR} = A_{LRobs}\frac{1+|P_-||P_+|}{|P_-|+|P_+|} = A_{LRobs} \times f$$

The error of the A_{LR} can be expressed as

$$\left(\frac{\Delta A_{LR}}{A_{LR}}\right)^2 = \left(\frac{\Delta A_{LRobs}}{A_{LRobs}}\right)^2 + \left(\frac{\Delta f}{f}\right)^2$$

Estimation of A_{LR} precision (2)

Assume $\Delta|P_-|$ and $\Delta|P_+|$ are independent, then

$$\left(\frac{\Delta f}{f}\right)^2 = \left(\frac{|P_-|(1+|P_+|)(1-|P_+|)}{(|P_-|+|P_+|)(1+|P_-||P_+|)}\right)^2 \left(\frac{\Delta|P_-|}{|P_-|}\right)^2 + \left(\frac{|P_+|(1+|P_-|)(1-|P_-|)}{(|P_-|+|P_+|)(1+|P_-||P_+|)}\right)^2 \left(\frac{\Delta|P_+|}{|P_+|}\right)^2$$

As for the error of A_{LRobs}, defining

$$N_{-+} = \eta_{-+}L_{-+}\sigma_{-+} \qquad \alpha \equiv L_{-+}\eta_{-+}$$

$$N_{+-} = \eta_{+-}L_{+-}\sigma_{+-}, \qquad \beta \equiv L_{+-}\eta_{+-},$$

$$A_{LRobs} = \frac{\frac{N_{-+}}{\alpha} - \frac{N_{+-}}{\beta}}{\frac{N_{-+}}{\alpha} + \frac{N_{+-}}{\beta}},$$

N: number of events

η: selection efficiency

L: integrated luminosity

Correlated parts of the error of α and β cancel in A_{LRobs}.

-> Δα and Δβ below only refer to uncorrelated parts.

$$\left(\frac{\Delta A_{LRobs}}{A_{LRobs}}\right)^2 = \left(\frac{2\left(\frac{N_{-+}}{\alpha}\right)\left(\frac{N_{+-}}{\beta}\right)}{\left(\frac{N_{-+}}{\alpha} - \frac{N_{+-}}{\beta}\right)\left(\frac{N_{-+}}{\alpha} + \frac{N_{+-}}{\beta}\right)}\right)^2 \left(\left(\frac{\Delta\alpha}{\alpha}\right)^2 + \left(\frac{\Delta\beta}{\beta}\right)^2 + \left(\frac{\Delta N_{-+}}{N_{-+}}\right)^2 + \left(\frac{\Delta N_{+-}}{N_{+-}}\right)^2\right)$$

Estimation of A_{LR} precision (2)

Assume $\Delta|P_-|$ and $\Delta|P_+|$ are independent, then

$$\left(\frac{\Delta f}{f}\right)^2 = \left(\frac{|P_-|(1+|P_+|)(1-|P_+|)}{(|P_-|+|P_+|)(1+|P_-||P_+|)}\right)^2 \left(\frac{\Delta|P_-|}{|P_-|}\right)^2 + \left(\frac{|P_+|(1+|P_-|)(1-|P_-|)}{(|P_-|+|P_+|)(1+|P_-||P_+|)}\right)^2 \left(\frac{\Delta|P_+|}{|P_+|}\right)^2$$

As for the error of A_{LRobs}, defining

$$N_{-+} = \eta_{-+} L_{-+} \sigma_{-+} \qquad \alpha \equiv L_{-+}\eta_{-+}$$

$$N_{+-} = \eta_{+-} L_{+-} \sigma_{+-}, \qquad \beta \equiv L_{+-}\eta_{+-},$$

$$A_{LRobs} = \frac{\frac{N_{-+}}{\alpha} - \frac{N_{+-}}{\beta}}{\frac{N_{-+}}{\alpha} + \frac{N_{+-}}{\beta}},$$

N: number of events

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$\Delta A_{LRobs} = 6.81 \times 10^{-8} \times \Delta$correlated

Correlated parts of the error of α and β cancel in A_{LRobs}.

-> Δα and Δβ below only refer to uncorrelated parts.

$$\left(\frac{\Delta A_{LRobs}}{A_{LRobs}}\right)^2 = \left(\frac{2\left(\frac{N_{-+}}{\alpha}\right)\left(\frac{N_{+-}}{\beta}\right)}{\left(\frac{N_{-+}}{\alpha} - \frac{N_{+-}}{\beta}\right)\left(\frac{N_{-+}}{\alpha} + \frac{N_{+-}}{\beta}\right)}\right)^2 \left(\left(\frac{\Delta\alpha}{\alpha}\right)^2 + \left(\frac{\Delta\beta}{\beta}\right)^2 + \left(\frac{\Delta N_{-+}}{N_{-+}}\right)^2 + \left(\frac{\Delta N_{+-}}{N_{+-}}\right)^2\right)$$

Results

If errors of η, L, and polarization are negligible,

$A_{LR} = 0.22815 \pm 0.00017$

If we add polarization error $\Delta f/f = 0.001$,

Absolute error of $A_{LR} = 0.00021$

If $\Delta\alpha/\alpha = \Delta\beta/\beta$ (uncorrelated) = **0.00006 (i.e. 0.006%)**,

Absolute error = 0.000218 (cf. Abs. error at SLC = 0.00219)

In order to achieve 10 times better precision than SLC, we need to keep the uncorrelated part of the error on product of efficiency and luminosity below 0.006%.

Cut Table

Number of events with (P_e-, P_e+) = (-0.8, +0.3) polarization

Process	Signal	4f_sw_sl	4f_sze_sl	4f_sznu_sl	4f_ww	4f_zz	Background Total
Expected	3.25017e+07	5.4719e+06	1.18316e+06	243096	9.89268e+06	455954	1.72468e+07
Cut 1	3.10963e+07	5.10134e+06	534339	241228	9.64957e+06	432962	1.59594e+07
Cut 2	2.44416e+07	566437	25287.2	140890	2.40774e+06	75801.6	3.21616e+06
Cut 3	2.44199e+07	61265.7	23784.1	18126.3	362353	60237.6	525767
Cut 4	2.44198e+07	61190	23730.7	18022.4	362353	60061.6	525358

Efficiency = 0.75134 ±0.00028 (0.037%) **B/S= 0.02151 for (-0.8, +0.3)**

Binomial error

Increasing samples
-> can concatenate the nTuple??

Number of events with (P_e-, P_e+) = (+0.8, -0.3) polarization

Process	Signal	4f_sw_sl	4f_sze_sl	4f_sznu_sl	4f_ww	4f_zz	Background Total
Expected	2.15581e+07	434154	1.08253e+06	83384	682874	272178	2.55512e+06
Cut 1	2.06154e+07	399858	455053	82533.5	666727	257213	1.86138e+06
Cut 2	1.62129e+07	66637.4	24657.1	54821.6	173510	50281.4	369907
Cut 3	1.61991e+07	11216.1	23192.1	7382.85	23112.3	41545.2	106448
Cut 4	1.6199e+07	11189.3	23132	7314.02	23112	41358.8	106106

Efficiency = 0.75141 ±0.00026 **B/S= 0.00655 for (+0.8, -0.3)**

Future Plan

- Presentation at Snowmass EF04 tonight.
- Refine the draft of thesis.
- Include the all backgrounds.