Study of A_LR using radiative return events at ILC250

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Estimation of A_{LR} precision (1)²

$$\begin{split} A_{LR} &\equiv \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}. & L/R : 100\% \text{ polarization} \\ A_{LRobs} &\equiv \frac{\sigma_{-+} - \sigma_{+-}}{\sigma_{-+} + \sigma_{+-}} & -/+: \text{Polarization at ILC} \\ \sigma_{-+} &= \frac{1}{4}(1 + |P_-|)(1 + |P_+|)\sigma_L + \frac{1}{4}(1 - |P_-|)(1 - |P_+|)\sigma_R \\ \sigma_{+-} &= \frac{1}{4}(1 - |P_-|)(1 - |P_+|)\sigma_L + \frac{1}{4}(1 + |P_-|)(1 + |P_+|)\sigma_R \\ A_{LR} &= A_{LRobs} \frac{1 + |P_-||P_+|}{|P_-| + |P_+|} = A_{LRobs} \times f. \end{split}$$

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 ALR precision (2)³

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 $N_{-+} = \eta_{-+}L_{-+}\sigma_{-+}$ $\alpha \equiv L_{-+}\eta_{-+}$ $N_{+-} = \eta_{+-}L_{+-}\sigma_{+-}$, $\beta \equiv L_{+-}\eta_{+-}$, $A_{LRobs} = \frac{\frac{N_{-+}}{\alpha} - \frac{N_{+-}}{\beta}}{\frac{N_{-+}}{\alpha} + \frac{N_{+-}}{\beta}}$, N: number of events

- η : selection efficiency
- L: integrated luminosity

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

-> $\Delta \alpha$ and $\Delta \beta$ 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)⁴

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

As for the error of A_{LRobs} , defining $N_{-+} = \eta_{-+}L_{-+}\sigma_{-+}$ $\alpha \equiv L_{-+}\eta_{-+}$ $N_{+-} = \eta_{+-}L_{+-}\sigma_{+-}, \quad \beta \equiv L_{+-}\eta_{+-},$ $A_{LRobs} = \frac{\frac{N_{-+}}{\alpha} - \frac{N_{+-}}{\beta}}{\frac{N_{-+}}{\alpha} + \frac{N_{+-}}{\beta}},$ $A_{LRobs} = \frac{A_{LRobs}}{\frac{N_{-+}}{\alpha} + \frac{N_{+-}}{\beta}},$

- N: number of events
- η : selection efficiency
- L: integrated luminosity

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

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

-> $\Delta \alpha$ and $\Delta \beta$ 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 $\eta,$ 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_s	$1 4 f_ww$	$4f_zz$	Background Total
Expected	3.25017e + 07	5.4719e+06	1.18316e+0	6 243096	9.89268e+06	455954	1.72468e + 07
Cut 1	3.10963e+07	5.10134e + 06	5534339	241228	$9.64957e{+}06$	432962	$1.59594 \mathrm{e}{+07}$
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
fficiency	y = 0.751	34 ±0.00 Binomi	028 (0.0	37%) Increa	B/S= sing sam	0.021 bles	51 for (-0.8, +
fficiency	y = 0.751 .	34 ±0.00 Binomi	028 (0.0 al error	37%) Increa	B/S= sing sam -> can co	0.021 bles ncater	51 for (-0.8, +
fficiency	y = 0.751	34 ±0.00 Binomi s with (P.	028 (0.0 al error e-, P _e +) =	37%) Increa (+0.8, -(B/S= sing sam -> can co 0.3) polari	0.021 ples ncater zation	51 for (-0.8, +
fficiency Number Process	y = 0.751 r of event s Signal	34 ±0.00 Binomi s with (Pa 4f_sw_sl	028 (0.0 al error $e^{-}, P_e^{+}) =$ 4f_sze_sl	37%) Increa (+0.8, -(4f_sznu_sl	B/S= sing sam -> can co 0.3) polari 4f_ww 4f_zz	0.021 ples ncater zation Backg	51 for (-0.8, +
fficiency Number Process Expect	y = 0.751 r of event s Signal ed 2.15581e+	34 ±0.00 Binomi s with (Pa 4f_sw_sl -07 434154	028 (0.0 al error $e^{-}, P_e^{+}) =$ $4f_{sze_{sl}}$ 1.08253e+06	37%) Increa (+0.8, -(4f_sznu_sl 4	B/S= ising sam -> can co 0.3) polari 4f_ww 4f_zz 682874 27217	0.021 ples ncater zation Backg 8 2.5551	51 for (-0.8, + nate the nTup round Total
fficiency Number Process Expect Cut 1	y = 0.751 r of event s Signal ed 2.15581e+ 2.06154e+	34 ±0.00 Binomi s with (Pa 4f_sw_sl 4 -07 434154 -07 399858	028 (0.0 al error $e^{-}, P_e^{+}) =$ 4f_sze_sl 1.08253e+06 455053	37%) Increa (+0.8, -(4f_sznu_sl 4 83384 (82533.5 (B/S = asing samp -> can co 0.3) polari 4f_ww 4f_zz 682874 27217 6666727 25721	0.021 ples ncater zation Backg 8 2.5551 3 1.8613	51 for (-0.8, + nate the nTup round Total 2e+06 88e+06
fficiency Number Process Expect Cut 1 Cut 2	y = 0.751 r of event s Signal ded 2.15581e+ 2.06154e+ 1.62129e+	34 ±0.00 Binomi S with (Pa 4f_sw_sl -07 434154 -07 399858 -07 66637.4	028 (0.0 al error $e^{-}, P_e^{+}) =$ 4f_sze_sl 1.08253e+06 455053 24657.1	37%) Increa (+0.8, -(4f_sznu_sl 4 83384 82533.5 54821.6	B/S= asing samp -> can co 0.3) polari 4f_ww 4f_zz 682874 27217 666727 25721 173510 50281	0.021 ples ncater zation Backg 8 2.5551 3 1.8613 .4 36990	51 for (-0.8, + nate the nTup round Total 2e+06 38e+06 7

Cut 4 1.6199e+07 11189.3 23132 7314.02 23112 41358.8 106106

Efficiency = 0.75141 \pm 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.