Fast or slow positron spin flipping

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Outline

ILC Baseline Design → positron polarization >30%

Advantages of e+ polarization:

- Enhancement / suppression of processes
- Precision physics
- Higher sensitivity to new physics phenomena
- …

→ Use it for physics

- Required precision for measurements
- Slow positron helicity reversal
- Fast positron helicity reversal
- Summary

Proposals for fast flipping → see next talk by Ken

Minimal Machine: Running Strategy

Physics between 200 GeV and 500 GeV
Luminosity: Year 1-4: L_{int} = 500 fb^{-1}
Energy stability and precision below 0.1%
Electron polarization > 80%

(e- helicity reversal randomly train by train)

ee→HZ	at 350 GeV (mH≈120 GeV)	few 10^4
ee→ tt	at 350 GeV	10^5
ee → qq (μμ)	at 500 GeV	$5 \cdot 10^5$ ($1 \cdot 10^5$)
ee → WW	at 500 GeV	10^6

➔ High statistical precision at per-mille level !!

Uncertainties:

$$\Delta\sigma \propto \frac{1}{\sqrt{N}} \oplus \frac{\Delta L}{L} \oplus \frac{\Delta E}{E} \oplus \frac{\Delta P}{P}$$

→ O(10^{-3})

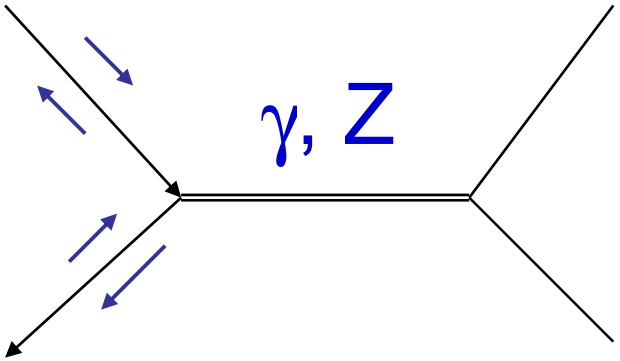
Polarimeter: $\delta P_{e-}/P_{e-} = \delta P_{e+}/P_{e+} = 0.25\%$ **(see ILC-NOTE-2008-047)**

Precision processes:

e+e- → ff, tt

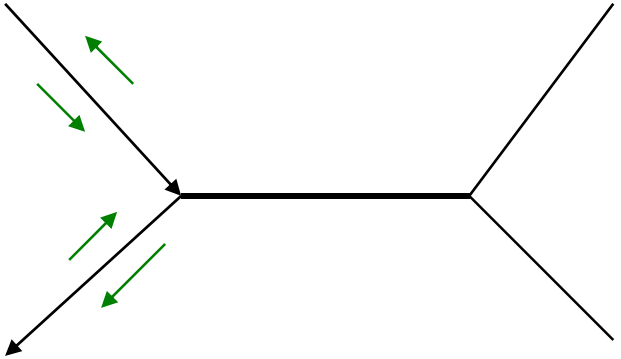
e+e- → W+W-

J=1



but not

J=0



s-channel cross sections with pol beams

Can perform independent measurements

$$\sigma_{++} = \tfrac{1}{4}\sigma_u\left[1 + P_{e^+}P_{e-} + A_{LR}\left(+P_{e^+} + P_{e-}\right)\right]$$
$$\sigma_{--} = \tfrac{1}{4}\sigma_u\left[1 + P_{e^+}P_{e-} + A_{LR}\left(-P_{e^+} - P_{e-}\right)\right]$$

=0 (SM) if both beams 100% polarized

$$\sigma_{-+} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(-P_{e^+} + P_{e-}\right)\right]$$
$$\sigma_{+-} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(+P_{e^+} - P_{e-}\right)\right]$$

Standard Model
s-channel

- and determine simultaneously Pe-,Pe+, A_{LR}, σ_u
- or use + - and - + pairing and polarization measurements:

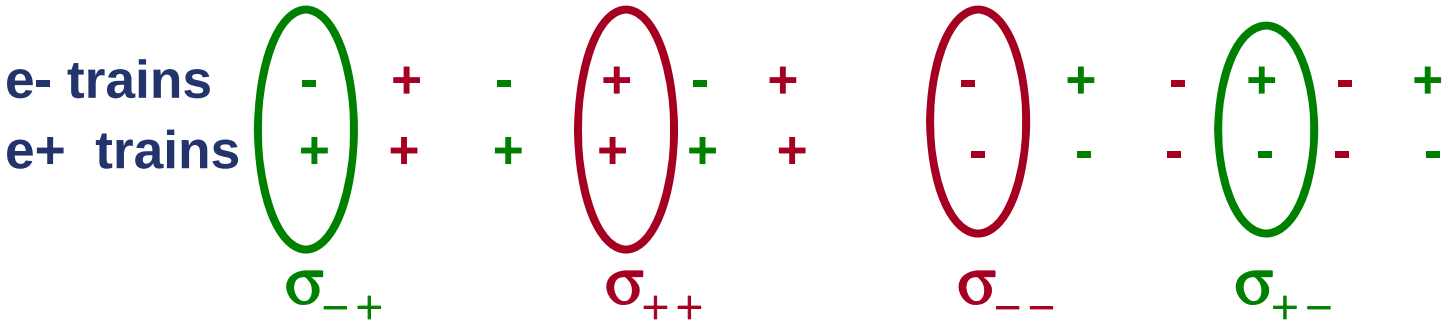
$$\sigma_u = \frac{1}{2}\frac{\sigma_{+-} + \sigma_{-+}}{1 + |P_{e-}P_{e+}|}$$

$$A_{LR} = \frac{\sigma_{-+} - \sigma_{+-}}{\sigma_{-+} + \sigma_{+-}} \cdot \frac{1 - P_{e^-}P_{e^+}}{-P_{e^-} + P_{e^+}}$$

$P_{eff} > P_{e+}, P_{e-}$

Slow helicity reversal

e+ helicity flip less frequent than e- helicity reversal



- Half of measurements spent to 'inefficient' helicity pairing σ_{--} and σ_{++}
- Have to combine σ_{+-} and σ_{-+} measured in different runs with different luminosities

➔ Large systematic uncertainties due to

- **luminosity variations**
- **polarization variations**
- **variations of detector efficiencies**
- **…**

Slow helicity reversal

Have a 'quadratic' term;

$$\sigma_{++} = \tfrac{1}{4}\sigma_u\left[1+P_{e^+}P_{e-}+A_{LR}\left(+P_{e^+}+P_{e-}\right)\right]$$
$$\sigma_{--} = \tfrac{1}{4}\sigma_u\left[1+P_{e^+}P_{e-}+A_{LR}\left(-P_{e^+}-P_{e-}\right)\right]$$
$$\sigma_{-+} = \tfrac{1}{4}\sigma_u\left[1-P_{e^+}P_{e-}+A_{LR}\left(-P_{e^+}+P_{e-}\right)\right]$$
$$\sigma_{+-} = \tfrac{1}{4}\sigma_u\left[1-P_{e^+}P_{e-}+A_{LR}\left(+P_{e^+}-P_{e-}\right)\right]$$

- term $P_{e-} \bullet P_{e+}$ ⇔ need to understand correlations !
- systematic errors have to be known and small

➔ Need long-term stability at the level of (few) 10^{-3}

Fast helicity reversal

- Left-Right Asymmetry is a 'robust' quantity, most systematic effects cancel if
  - **equal luminosities delivered to + and – helicities**
  - **equal polarization for + and – helicities**

  Both realized at SLC due to fast random helicity flip

$$A_{LR} = \frac{\sigma_- - \sigma_+}{\sigma_- + \sigma_+} \cdot \frac{1}{P_{e^-}} \cong \frac{N_- - N_+}{N_- + N_+} \cdot \frac{1}{P_{e^-}}$$

- ILC:

$$A_{LR} \cong \frac{N_{-+} - N_{+-}}{N_{-+} + N_{+-}} \cdot \frac{1 + P_{e^-} P_{e^+}}{P_{e^-} + P_{e^+}}$$

$$\sigma = \frac{N}{\varepsilon \cdot L}$$

Fast flipping: s-channel ALR with pol e+ beams

Measurements with equal + - and - + pairing only (no - - , no ++)

$$\sigma_{-+} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(-P_{e^+} + P_{e-}\right)\right]$$
$$\sigma_{+-} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(+P_{e^+} - P_{e-}\right)\right]$$

Left-Right asymmetry

$$A_{LR} \cong \frac{N_{-+} - N_{+-}}{N_{-+} + N_{+-}} \cdot \frac{1 - P_{e^-}P_{e^+}}{-P_{e^-} + P_{e^+}}$$

P_{eff}

Error propagation

➔ $$\frac{\Delta P_{eff}}{P_{eff}} \cong F\,\frac{\Delta P_e}{P_e}$$

(80%,30%): F= 0.5
(80%,60%): F=0.25

Fast flipping: s-channel cross sections with pol e+ beams

Measurements with equal + - and - + pairing only (no - - , no ++)

$$\sigma_{-+} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(-P_{e^+} + P_{e-}\right)\right]$$
$$\sigma_{+-} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(+P_{e^+} - P_{e-}\right)\right]$$

$P_{e+,} = 0$

$$\sigma_u = \frac{1}{2}\frac{\left(N_+ + N_-\right)}{L}$$

$P_{e+,} > 0$:

$$\sigma_u = \frac{1}{2}\cdot\frac{N_{+-} + N_{-+}}{L\cdot\left(1+|P_{e-}P_{e+}|\right)}$$

enhancement ~$(1+P_{e-}P_{e+})$

→ (80%, 30%): ~25% gain in eff lumi
but add. uncertainty $\delta\sigma_u$ ~0.07%

→ (80%, 60%): ~50% gain in eff lumi
but add. uncertainty $\delta\sigma_u$~0.11%

Z pole running

- GigaZ as not highest priority in ILC schedule
- Is important for checks of
  - **electroweak symmetry breaking ($\sin^2\theta_W$)**
  - **Understanding of LHC results ?**
- Z pole running with calibration data ?!

  Studies are under way
- Need all four combinations $\sigma_{+-/-+}$ $\sigma_{\pm\pm}$ to determine simultaneously A_{LR} and effective polarization with reasonable precision
  - **Polarimeters needed for time-dependent precise relative polarization monitoring**

Summary

- With **fast helicity reversal**
  - **substantially smaller systematic uncertainties**
  - **'in phase' with electrons → increase of lumi (>25%)**
  - **smaller polarization error**
  - **→ High precision and best flexibility for new physics**
- Large syst. uncertainties with **slow helicity reversal** could reduce physics output substantially
  - **Realistic stability (Lumi, Pol) in ILC ?**
- GigaZ: does not work with slow helicity flipping
- Destroying the e+ polarization ?
  - **Needs some effort to do that (damping time not sufficient)**
  - **Zero e+ polarization has to be verified**
    - can be measured with absolute error of 0.13% (J. List)
    - → Additional uncertainty for observables

Conclusion: Keep the e+ pol and perform fast spin flip

To be considered: e+ polarization with 250 GeV undulator