Polarization Measurement from ILC Collision Data

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Outline

Consider Angular Information by Using differential Cross Section

Outlook: Studying the final state $q\bar{q}l\nu$

Reminder: The Unified Approach

χ^2-Minimization of the polarized cross sections:

- Combining all suitable processes
- Considering all statistical and systematical uncertainties
- Using a full covariance Matrix (Ξ)

$$\chi^2 = \sum_{\text{process}} \left(\vec{\sigma}_{\text{data}} - \vec{\sigma}_{\text{theory}}\right)^T \Xi^{-1} \left(\vec{\sigma}_{\text{data}} - \vec{\sigma}_{\text{theory}}\right)$$

$$\vec{\sigma} := \begin{pmatrix} \sigma_{-+} & \sigma_{+-} & \sigma_{--} & \sigma_{++} \end{pmatrix}^T$$

$$\Xi := \Xi_N + \Xi_B + \Xi_\varepsilon + \Xi_\mathcal{L};$$

$$\left(\Xi_\varepsilon\right)_{ij} = \text{corr}\left(\vec{\sigma}_i^\varepsilon,\ \vec{\sigma}_j^\varepsilon\right) \frac{\partial \vec{\sigma}_i}{\partial \varepsilon_i} \frac{\partial \vec{\sigma}_j}{\partial \varepsilon_j} \Delta\varepsilon_i \Delta\varepsilon_j$$

Compensation non-perfect helicity reversal: Using 4 independent parameters

$$\underbrace{P^-_{e^-} = -80\%,}_{\text{"left"-handed } e^-\text{-beam}} \quad \underbrace{P^+_{e^-} = 80\%,}_{\text{"right"-handed } e^-\text{-beam}} \quad \underbrace{P^-_{e^+} = -30\%,}_{\text{"left"-handed } e^+\text{-beam}} \quad \underbrace{P^+_{e^+} = 30\%,}_{\text{"right"-handed } e^+\text{-beam}}$$

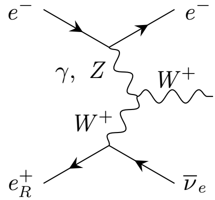
Consider Angular Information by Using differential Cross Section

Outlook: Studying the final state $q\bar{q}l\nu$

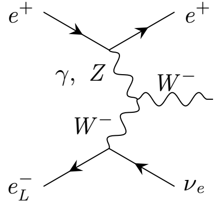
Consideration of the Addition Information from the Angular Distribution

- Total cross section
  - Rely on theoretical calculation
  - ⇒ Susceptible to BSM effects
- Differential cross section
  - Additional usage of the production-angle information
  - ⇒ Increase of the robustness against BSM effects
- Starting with Single W Process
  - Angular distribution has a large dependence on the chirality
  - Separated in W^+ and W^- production
  - ⇒ Sensitive to individual beam polarization
    - W^+: only sensitive to P_{e^+}
    - W^-: only sensitive to P_{e^-}
- Further processes can easily be included

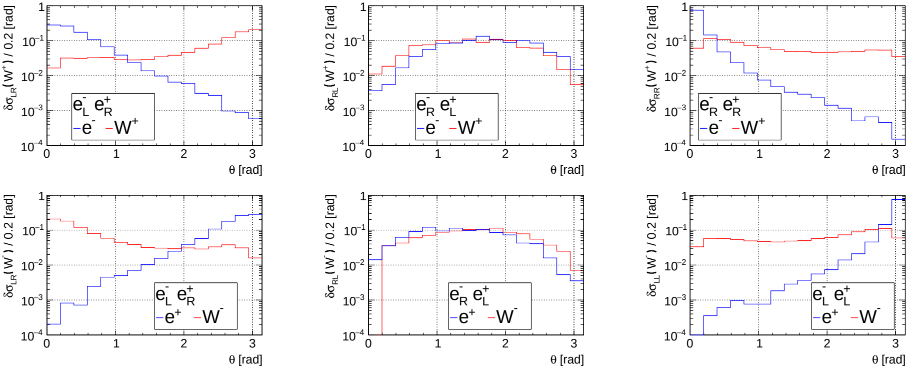
$e^- e^+ \longrightarrow W^+ e^- \bar{\nu}_e$



$e^- e^+ \longrightarrow W^- e^+ \nu_e$



Single $W^{\pm}$: Polar Production Angle Distribution



- Single differential cross section: $\partial\sigma/\partial\theta$
  - Two independent angles: $\theta_e,\ \theta_W$
  - For now start with $\theta_e \rightarrow e^{\pm}$ also needed for separation between $W^{\pm}$
- $\partial\sigma/\partial\theta$ will be calculated via $\Delta\sigma_i/\Delta\theta_i$ ("cross section for the i-th bin in θ")

Defining Differential Cross Sections

Measured cross section:

$$\overbrace{\frac{\partial\sigma}{\partial\theta}}^{\text{differential cross section}} \longrightarrow \overbrace{\delta_i\sigma_{\text{data}}}^{\text{cross section per } i\text{th bin}} := \frac{\delta_i D - \delta_i \mathfrak{B}}{\delta_i\varepsilon \cdot \mathcal{L}}$$

$\delta_i D$	Number of signal events	of the ith bin
$\delta_i \mathfrak{B}$	Number of expected background events	of the ith bin
$\delta_i \varepsilon$	Selection efficiency	of the ith bin
$\mathcal{L}$	Integrated luminosity	

Theoretical cross section:

$$\begin{aligned}\delta_i\sigma_{\pm\pm} = &\frac{\left(1\pm\left|P^{\pm}_{e-}\right|\right)}{2}\frac{\left(1\pm\left|P^{\pm}_{e+}\right|\right)}{2}\delta_i\sigma_{RR} + \frac{\left(1\mp\left|P^{\pm}_{e-}\right|\right)}{2}\frac{\left(1\mp\left|P^{\pm}_{e+}\right|\right)}{2}\delta_i\sigma_{LL}\\ + &\frac{\left(1\pm\left|P^{\pm}_{e-}\right|\right)}{2}\frac{\left(1\mp\left|P^{\pm}_{e+}\right|\right)}{2}\delta_i\sigma_{RL} + \frac{\left(1\mp\left|P^{\pm}_{e-}\right|\right)}{2}\frac{\left(1\pm\left|P^{\pm}_{e+}\right|\right)}{2}\delta_i\sigma_{LR}\end{aligned}$$

$$\delta_i\sigma_{\text{theory}} := f\left(\theta_i\right) \cdot \sigma_{\text{theory}}$$

$f\left(\theta_i\right)$ is directly obtained from the angular distributions

Implementing Differential Cross Sections in the χ^2 Minimization

Replacing: $\sigma \longrightarrow \delta_k\sigma$ + Sum over all bins

$$\chi^2 = \sum_{\text{process}} \sum_{\theta_k} \left(\delta_k\vec{\sigma}_{\text{data}} - \delta_k\vec{\sigma}_{\text{theory}}\right)^T \left(\delta_k\Xi\right)^{-1} \left(\delta_k\vec{\sigma}_{\text{data}} - \delta_k\vec{\sigma}_{\text{theory}}\right)$$

$$\delta_k\vec{\sigma} := \begin{pmatrix} \delta_k\sigma_{-+} & \delta_k\sigma_{+-} & \delta_k\sigma_{--} & \delta_k\sigma_{++} \end{pmatrix}^T$$

$$\delta_k\Xi := \delta_k\Xi_N + \delta_k\Xi_{\mathfrak{B}} + \delta_k\Xi_{\varepsilon} + \delta_k\Xi_{\mathcal{L}};$$

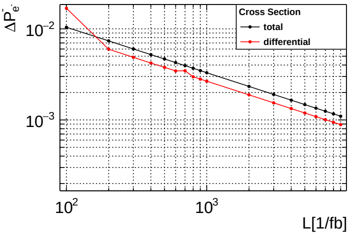
$$\left(\delta_k\Xi_{\varepsilon}\right)_{ij} = \text{corr}\left(\vec{\sigma}_i^{\varepsilon},\ \vec{\sigma}_j^{\varepsilon}\right) \frac{\partial\left(\delta_k\vec{\sigma}_i\right)}{\partial\left(\delta_k\varepsilon_i\right)} \frac{\partial\left(\delta_k\vec{\sigma}_j\right)}{\partial\left(\delta_k\varepsilon_j\right)} \Delta\left(\delta_k\varepsilon_i\right) \Delta\left(\delta_k\varepsilon_j\right)$$

Remarks:

- Due to correlations, the binning in θ has to be equal for all cross sections
- It can differ between processes and decay-channels
- Range and number of bins of θ can be changed externally for each process

First Toy Monte Carlo: Preliminary Results

500 GeV Single $W^{\pm}$ only



Using the following configuration:

- Using 16 equal bins in a θ range of $[0, \ \pi]$
- Signal determination bin-by-bin:
  $\langle \delta_k D \rangle = \delta_k \sigma_{\text{theory}} \cdot \delta_k \varepsilon \cdot \mathcal{L} + \delta_k \mathfrak{B}$
- For the start:
  Statistical error only + no background
- Using H-20 integrated luminosity sharing due to energy

- Differential cross section have a higher statistic uncertainty:
  - Expectation of $\delta_k D$ can be for some bins $\mathcal{O}(1)$
  - Some zero diagonal entries of the covariance matrix $\rightarrow$ not invertible

  $\Rightarrow$ Dropping χ^2-terms with $\delta_k D = 0$
- Ongoing work:
  - Calculating the angular distribution of further processes
  - The only "issue" is a proper definition of the individual production angle

Consider Angular Information by Using differential Cross Section

Outlook: Studying the final state $q\bar{q}l\nu$

Studying the final state $q\bar{q}l\nu$ (Outlook)

- Studying the final state $q\bar{q}l\nu$:
  - Using a full simulation
  - At $E_{\mathrm{CMS}} = 250$ GeV due to the staging scenario

- Precise measurement of the W-mass

  $\rightarrow$ provides additionally a realistic estimation on the selection efficiency and background values for the polarization measurement

- (Optional) Measurement of Triple Gauge Couplings (TGC)