$H \to \tau^+\tau^-$ CP Violation Analysis for SiD

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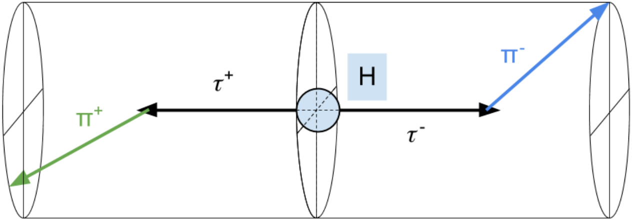
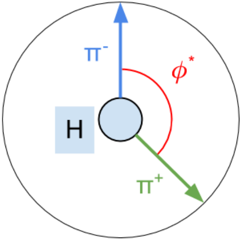
Tau-Based Analysis of Higgs CP Violation

- General methodology: extract **polarimeter vector** from analyzing tau decay; find **azimuthal angle** between τ^+ and τ^- polarimeter vectors
- Polarimeter vectors vary with tau decay; $\tau^\pm \to \pi^\pm \nu_\tau$ (below) and $\tau^\pm \to \pi^\pm \pi^0 \nu_\tau$ are the simplest to analyze, but using **higher-multiplicity decays** would allow for **more events** to be used



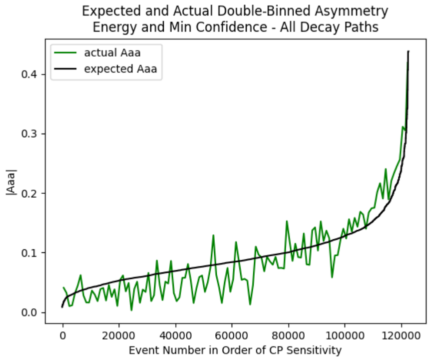


$$\vec{n}_- \equiv \frac{\vec{q}_{\pi^-} \times \vec{q}_{\tau^-}}{|\vec{q}_{\pi^-} \times \vec{q}_{\tau^-}|} \qquad \vec{n}_+ \equiv \frac{\vec{q}_{\pi^+} \times \vec{q}_{\tau^-}}{|\vec{q}_{\pi^+} \times \vec{q}_{\tau^-}|}$$

$$\cos(\phi^*) \equiv \vec{n}_- \cdot \vec{n}_+$$

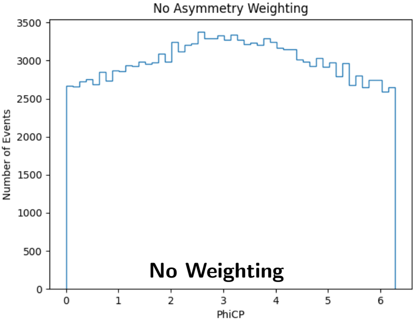
Review of Double-Binned Expected Asymmetry

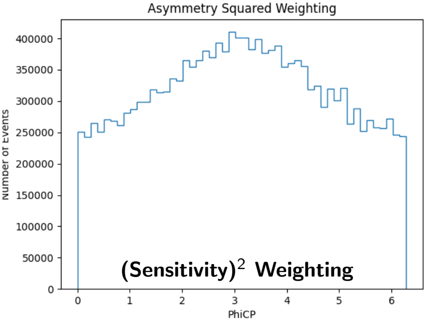
- Events binned separately by **leading charged particle energy and NN prediction confidence** for each decay path
- Asymmetry calculated based on cosine fit to groups of **400 events** for each binning process, each event assigned **expected asymmetry (A^{aa})** equal to **average** of fitted asymmetries
- Asymmetries calculated from groups of 1000 events **binned based on expected asymmetry** roughly agreed with expected asymmetry distribution
- Asymmetry distributions **skewed toward high asymmetry values**



Preliminary Mixing Angle Precision Estimation Methods

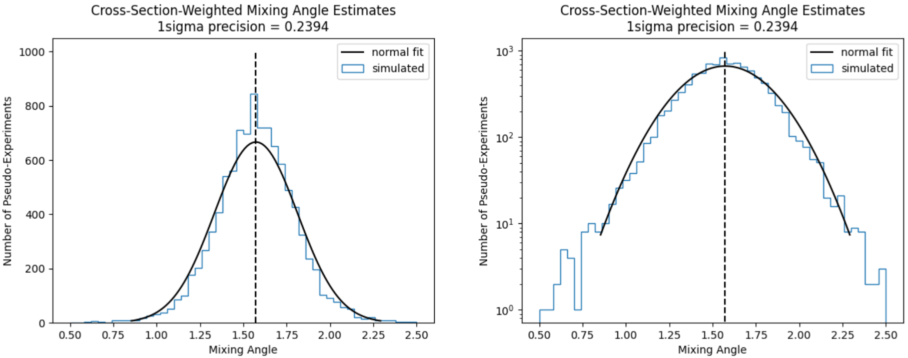
- Based on ILD's method, I used **randomized cross-section-weighted samples** from the full 190k signal events used for testing
  - As with ILD, background events were simulated as having a flat ϕ_{CP} distribution
  - 892 signal events, 2355000 4f bkg events for $1ab^{-1}$ of eLpR data
- Each ϕ_{CP} value was weighted by the **square of the corresponding CP sensitivity**
- The expected asymmetry was calculated from the entire 190k signal events and simulated background; this asymmetry was enforced for mixing angle estimation
- **Mixing angle** was calculated for each cross-section-weighted sample





Preliminary Mixing Angle Precision

- With eLpR polarization, $Z \to e^+e^-, \mu^+\mu^-$, and considering only signal and 4f background, a preliminary mixing angle precision of **239.4 mrad** is obtained
- This is about three times worse than ILD's result, but the two results really are **not very comparable** yet (including $Z \to qq$ events and eRpL polarization should dramatically improve SiD's result as it did for ILD)
- Additionally, my simulations here assume that the asymmetries for background events follow the same distributions as signal events; this is the worst case scenario and **can be improved upon**



Next Steps

- Use more background event files to approximate **background event asymmetry distributions** and avoid worst-case-scenario asymmetry assumptions
- Use both polarizations and inclusive background samples to make results **more comparable** to ILD's
- Implement $Z \to qq$ cutflow to increase number of usable signal events
- Improve method for **calculating expected asymmetry** from energy-based asymmetry and confidence-based asymmetry
- Develop a more sophisticated **sensitivity-based weighting system**: $|Aaa|^2$ works nicely but is somewhat arbitrary