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

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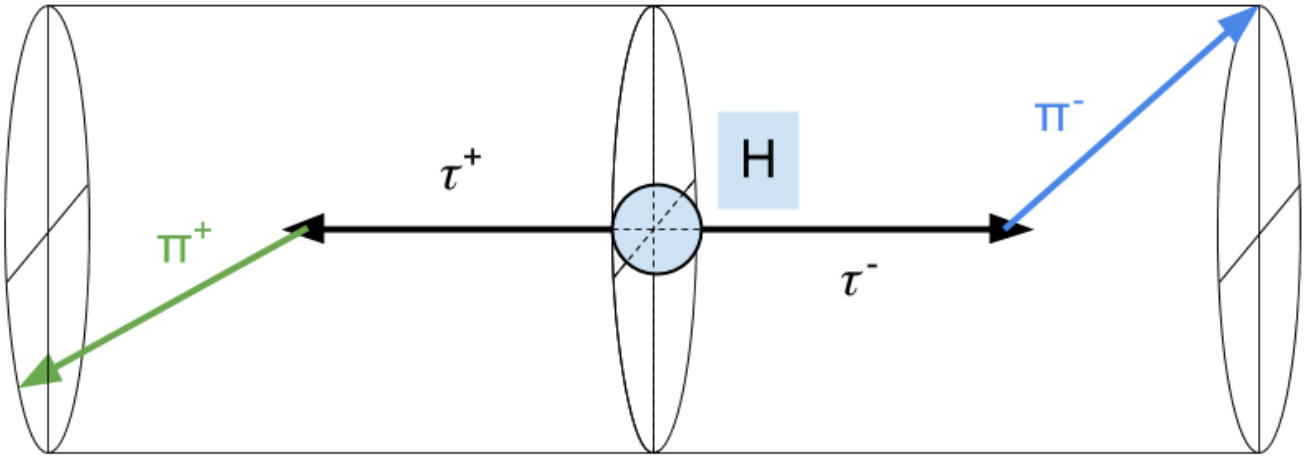
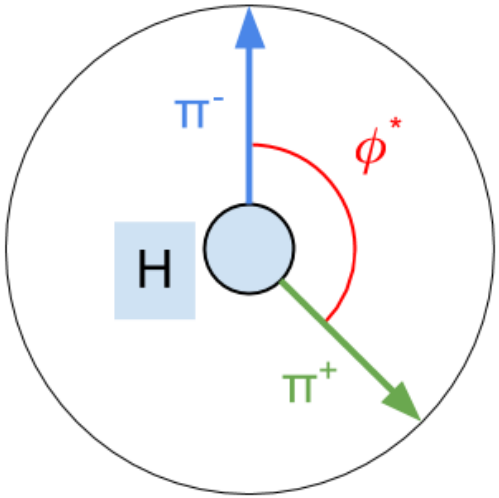
October 14, 2020

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 Tau Tagging and Decay Separation

- Strong separation of **signal** from **4f background** and tau decay separation
- Main weak point is likely limited π^0 reconstruction

Tau tagging efficiency

NN tag	Truth event type τ	bkg
τ	99.99	2.87
bkg	0.01	97.13

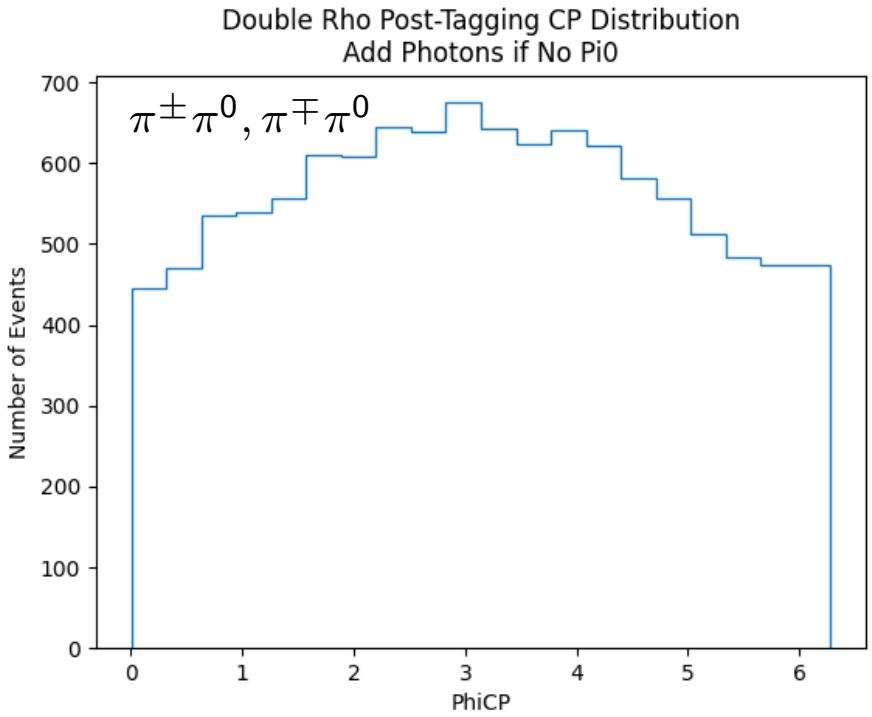
Migration among τ decay paths (%)

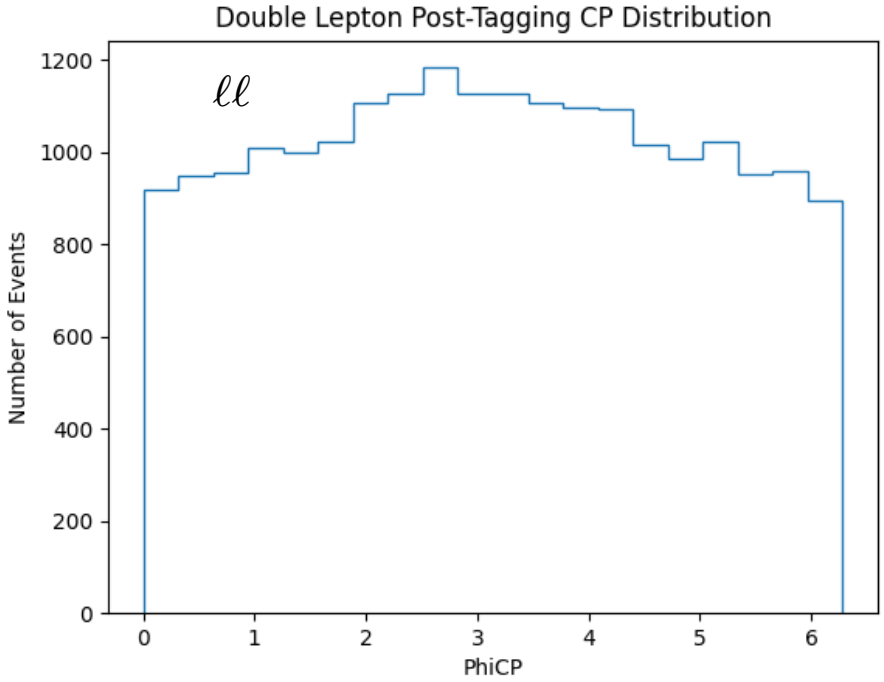
NN tag	Truth decay path $\pi^{\pm}$	$\pi^{\pm}\pi^0$	ℓ	$\pi^{\pm}2\pi^0$	$\pi^{\mp}2\pi^{\pm}$	other	bkg
$\pi^{\pm}$	**94.80**	2.75	0.06	0.22	2.08	4.02	4.27
$\pi^{\pm}\pi^0$	3.38	**92.88**	0.12	12.65	2.31	7.07	13.03
ℓ	0.92	0.83	**99.02**	0.58	2.48	6.46	44.44
$\pi^{\pm}2\pi^0$	0.02	2.05	0.01	**82.71**	0.15	8.83	4.70
$\pi^{\mp}2\pi^{\pm}$	0.42	0.47	0.25	0.32	**85.49**	10.42	8.76
other	0.47	1.03	0.53	3.53	7.48	**63.20**	24.79

Signal vs 4f Background

Preliminary Post-Tagging CP Distributions

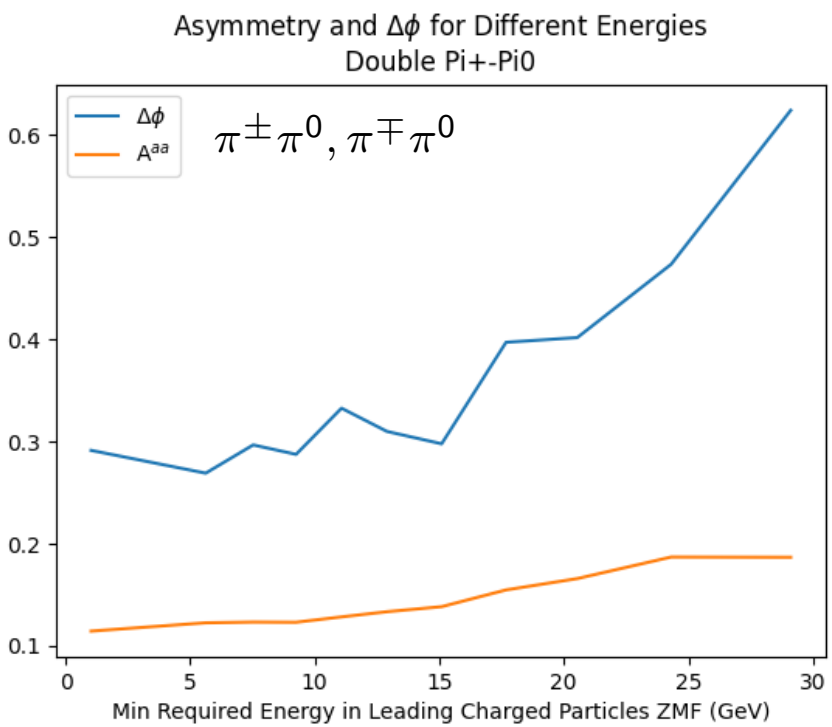
- Plotting all events' calculated CP values based on **decay label given by NN**
- For decay paths with **neutral pions**, poor π^0 reconstruction required using **unpaired photons** to make enough events be usable
  - $\pi^{\pm}$: require leading $\pi^{\pm}$ with non-zero PCA
  - ℓ: require leading ℓ with non-zero PCA
  - $\pi^{\pm}2\pi^{\pm}$: require three charged pions, one of different charge
  - $\pi^{\pm}\pi^0$: require leading $\pi^{\pm}$ and 1 π^0 or γ
  - $\pi^{\pm}2\pi^0$: require leading $\pi^{\pm}$ and 1 π^0 or γ

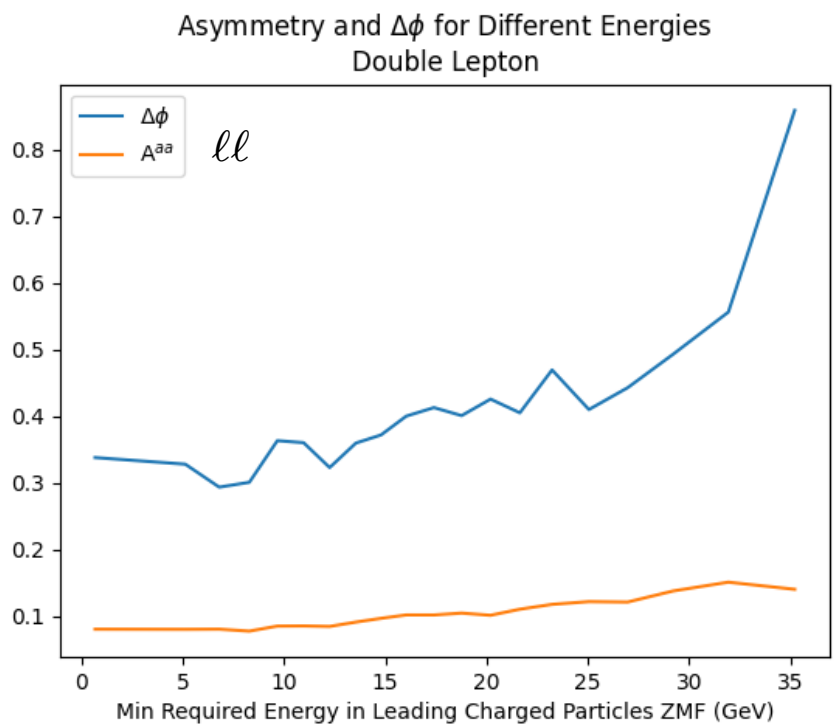




Asymmetry Weighting of Post-Tagged Distributions

- Improved asymmetry for higher-energy events holds for post-tagging CP distributions, making energy-binned weighting worthwhile
- To improve mixing angle measurements, must **fit many decay paths simultaneously**
- Technique from the literature: separate out decay paths and require all to agree on fitted phase. (Putting distributions together doesn't improve results enough.)





Next Steps

- **Adding more background data**: either scale background and signal to proper cross section or sample from uniform CP distribution for background
- **Simultaneously fit** all decay paths to estimate CP analysis precision
- Full SiD reconstruction, full tau reconstruction