GPD from Timelike Compton Scattering: $\chi^2_{kin}-$ Studies

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Motivation

- **Generalized Parton Distributions (GPDs)** provide 3D imaging of the nucleon, unifying Parton distributions and form factors(FF).
- **Timelike Compton Scattering (TCS)** is a process sensitive to GPDs via interference with Bethe-Heitler (BH)[1].
- Offers unique access to the *real part* of Compton Form Factors (CFFs).

Experimental Setup

- TCS description: $\gamma p \rightarrow \gamma^* p' \rightarrow e^+e^-p'$
- Real photon beam produced via bremsstrahlung off 11.5 GeV electron beam in HallD Jlab.
- γ interact with the proton target and the product are detected by the GlueX Detector
- Excellent vertex and momentum resolution allows precise invariant mass reconstruction.

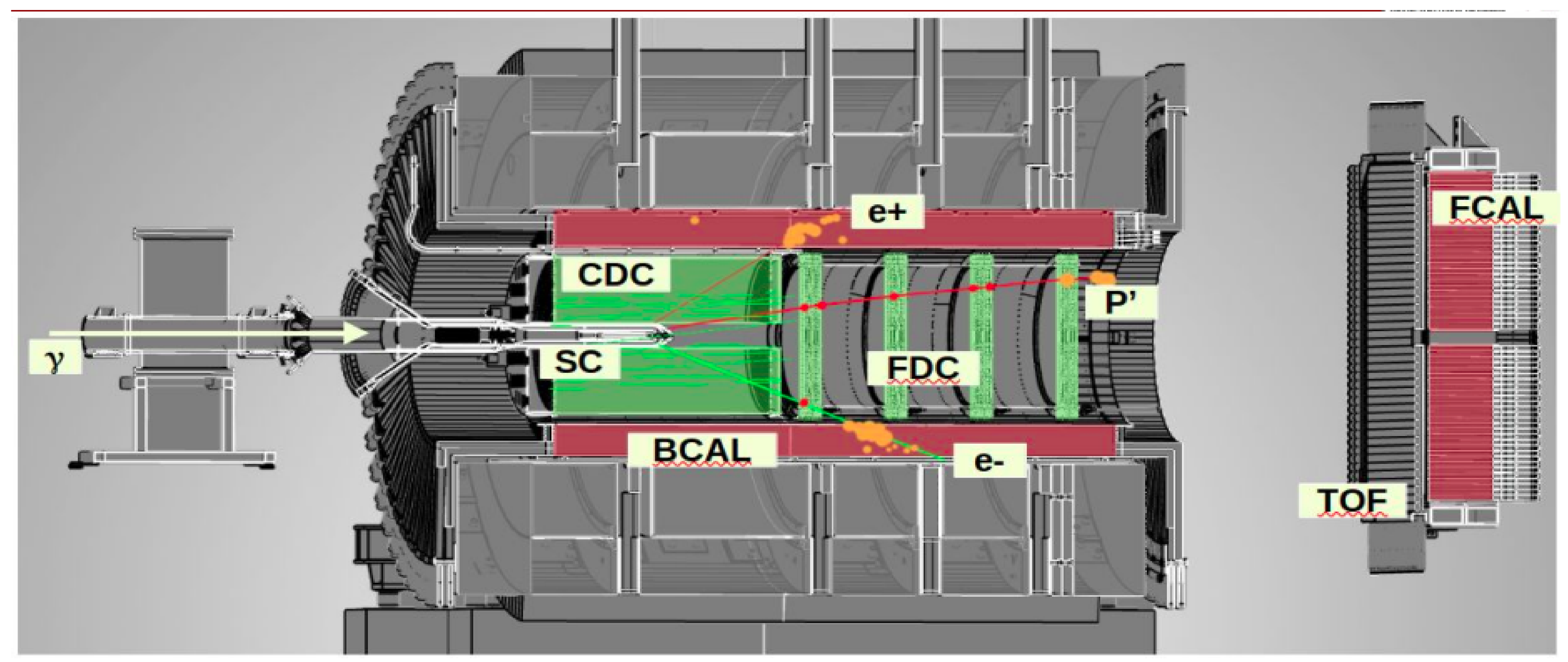

Figure 1. Gluex Detector Schematic.

TCS and BH Interference [2]

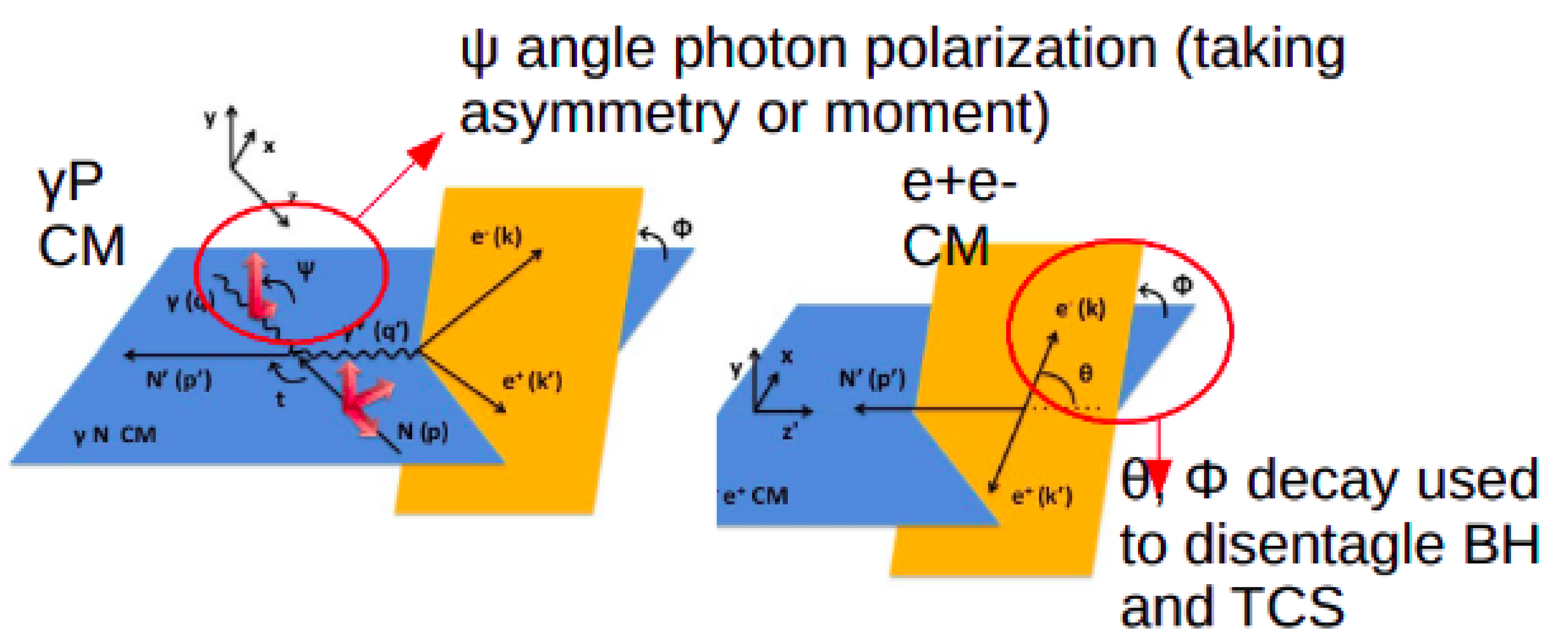

Figure 2. Frame of reference for studying TCS and BH.

The Analysis Goal is to extract Compton Form Factors from asymmetries. The interference term $\propto$ Re($\mathcal{H}$) and can be isolated via angular asymmetries.

This enable model-independent constraint of $H(x,\xi,t)$ at skewness $\xi = \frac{Q'^2}{2s-Q'^2}$, parton momentum fraction x and momentum transfer t.

A step towards that goal is to study the χ^2 dependence of some of the TCS/BH event selection kinematic terms.

Events spectrum

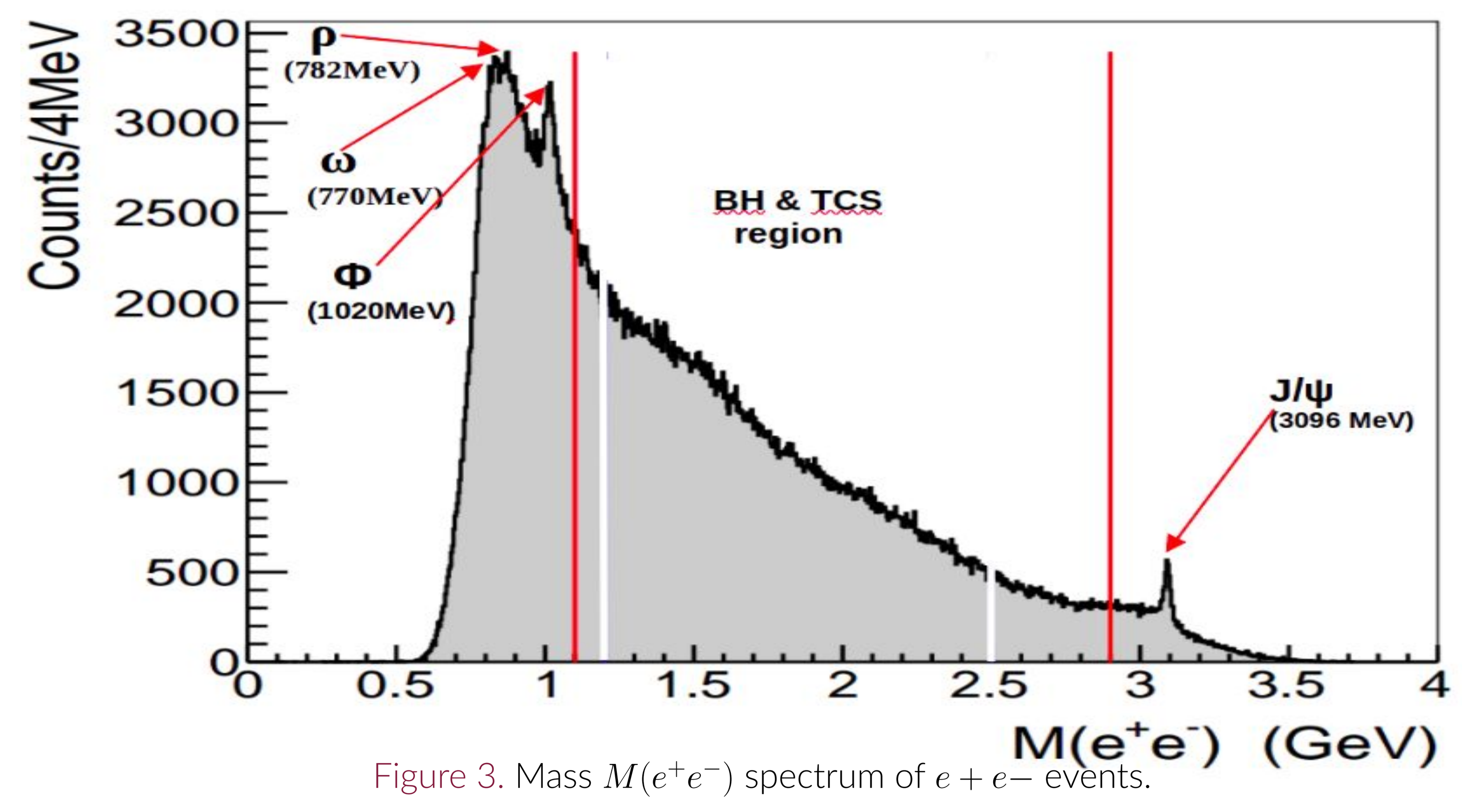

Figure 3. Mass $M(e^+e^-)$ spectrum of $e+e-$ events.

BH & TCS region: $\mathbf{1.2 \leq M(e^+e^-) \leq 2.5}$ GeV Lies away from many meson resonances.

χ^2_{kin} dependence of Event Selection Variables

Cuts Applied: the cuts variables are ideally zero for Exclusive events.

$$M^2_{miss} = (P^\mu_\gamma + p^\mu_p - p^\mu_{\gamma^*} - p^\mu_{p'})^2,\ \ |M^2_{miss}| \leq 0.04GeV^2$$

$$\Delta P_\perp = \vec{P}_{p'\perp} - \vec{P}_{\gamma^*\perp},\ \ |\Delta P_\perp| \leq 0.05GeV$$

$$\Delta\Phi = \Phi_{\vec{P}_{p'}} - \Phi_{\vec{P}_{\gamma^*}},\ \ |\Delta\Phi| \leq 0.15rad$$

$$P^{imb}_T = |\vec{P}_{\perp\gamma^*} + \vec{P}_{\perp p'}|,\ \ P^{imb}_T \leq 0.125GeV/c$$

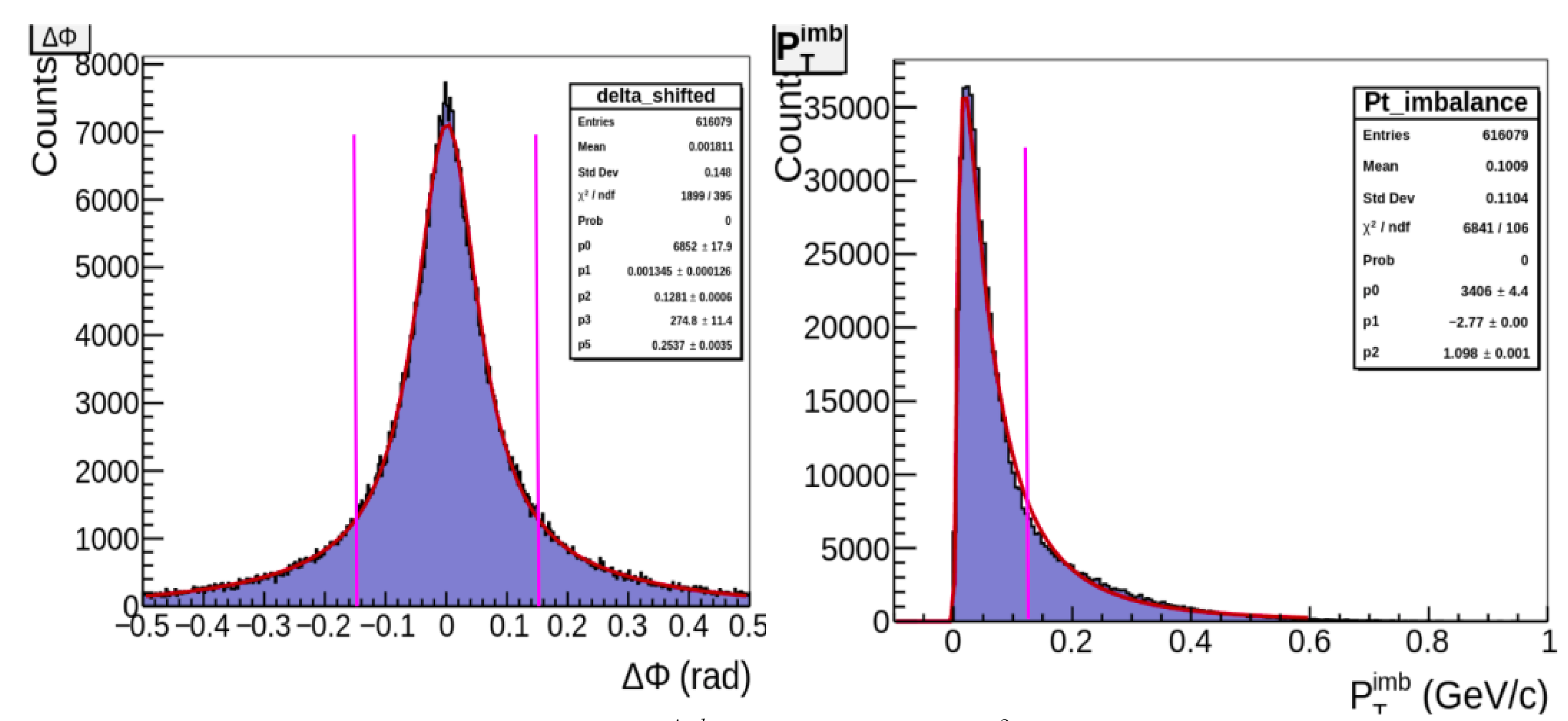

Figure 4. $\Delta\Phi$ & P^{imb}_T counts for a given χ^2_{kin} cut value

Fitting function for Exclusive Events Selection Kinematic Variable

$$f(x) = \underbrace{A_L \cdot \frac{(\Gamma/2)^2}{(x-\mu)^2 + (\Gamma/2)^2}}_{\text{Lorentzian core}} + \underbrace{A_G \cdot \exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma_G}\right)^2\right)}_{\text{Gaussian tails}}$$

$$f(x) = \frac{1}{x\,\sigma_{\ln}\sqrt{2\pi}} \exp\left(-\frac{(\ln x - \mu_{\ln})^2}{2\sigma^2_{\ln}}\right)$$

Where: x: the variable ($\Delta P_\perp, \Delta P^{imb}_T, \Delta\Phi, \& M^2_{miss}$).
$A_L \equiv P[0]$: Amplitude of the Lorentzian core, μ: shared mean,
$\Gamma \equiv P[2]$: FWHM of the Lorentzian,
$A_G \equiv P[5]$: Amplitude of the Gaussian tail & σ_G: width of the Gaussian. $\mu_{\ln}$: mean of $\ln x$ & $\sigma_{\ln}$: standard deviation of $\ln x$

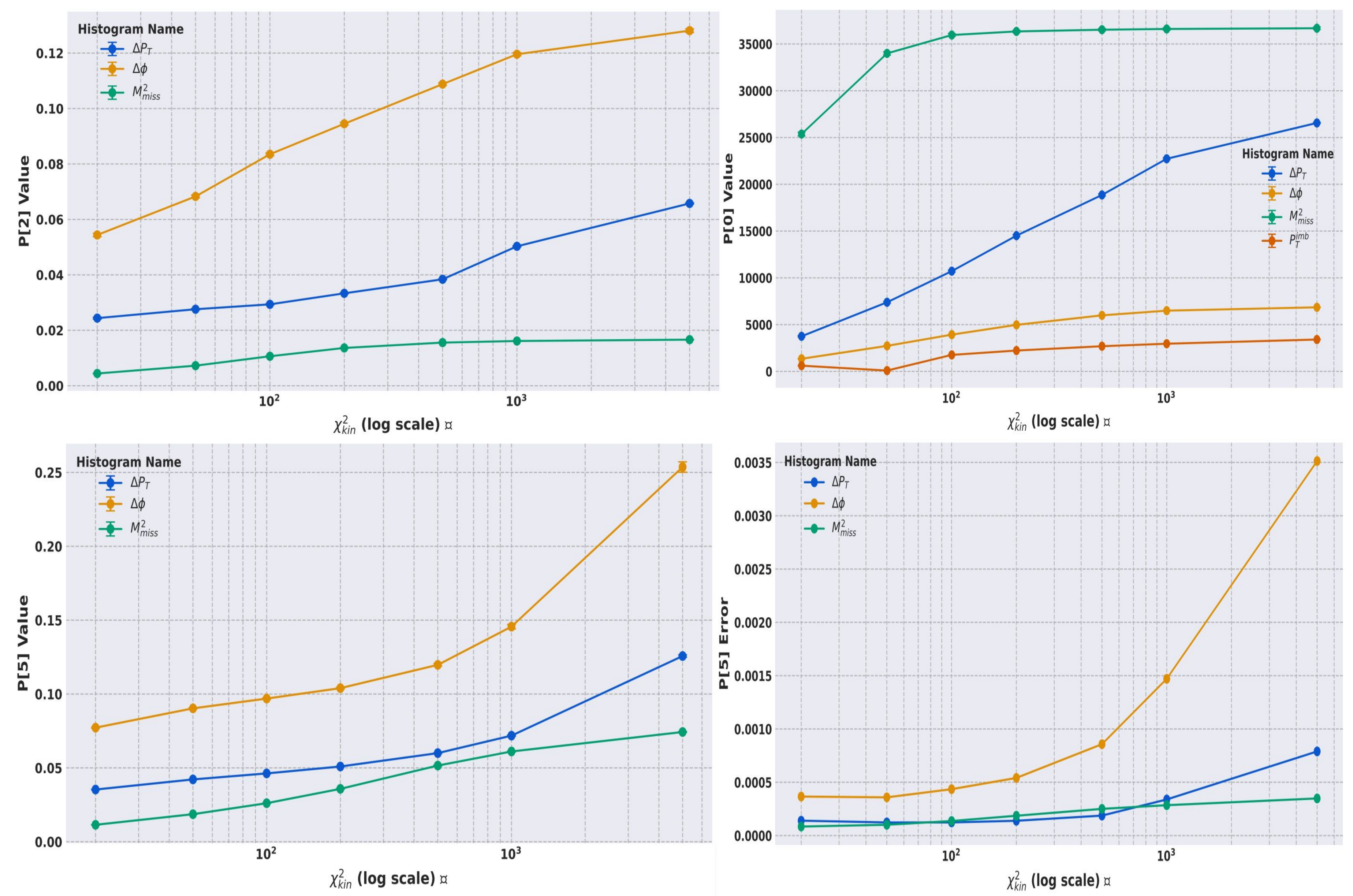

Figure 5. $\Delta P_T, \Delta P^{imb}_T, \Delta\Phi, \& M^2_{miss}$ dependence on χ^2_{kin}

- The above plots shows that the four variables have dependence on χ^2_{kin}
- It indicates that the optimum cut for the χ^2_{kin} should be 100.0 since the M^2_{miss} amplitude began to drop after that value.
- At χ^2_{kin} below 100.0, the rate of change of width of the variables decrease & stabilize.

Outlook

- Impliment the new χ^2_{kin} cut for optimum event selections.
- Remove regions with very high BH events that suppress TCS events.
- Continue background suppression studies.

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References

[1] P Chatagnon, S Niccolai, S Stepanyan, MJ Amaryan, G Angelini, WR Armstrong, H Atac, C Ayerbe Gayoso, NA Baltzell, L Barion, et al. First measurement of timelike compton scattering. *Physical review letters*, 127(26):262501, 2021.

[2] M Boër, M Guidal, and M Vanderhaeghen. Timelike compton scattering off the proton and generalized parton distributions. *The European Physical Journal A*, 51(8):103, 2015.