Beam spin asymmetries in the $(ep \rightarrow e'\pi^+\pi^0 X)$ channel at CLAS12

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HUGS 2022 - **June 16, 2022**

The $ep \to e'\pi^+\pi^0(\gamma\gamma)X$ channel

In this process, a **longitudinally polarized** electron scatters inelastically off a quark within the **unpolarized** proton target. The quark fragments into a π^+, π^0, and other hadronic products X. The π^0 decays into a photon pair, which together with the π^+, form the dihadron.

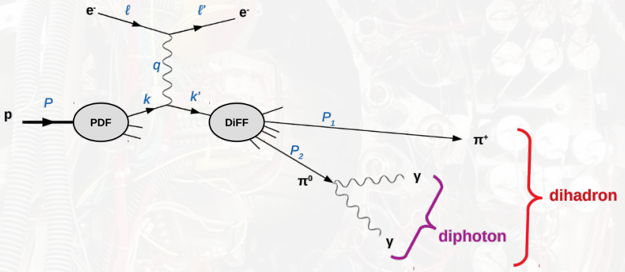


Figure: Production picture for $\pi^+\pi^0$ SIDIS dihadrons[1]. Our observables will correspond to convolutions of PDFs (parton distribution functions) and DiFFs (dihadron fragmentation functions)

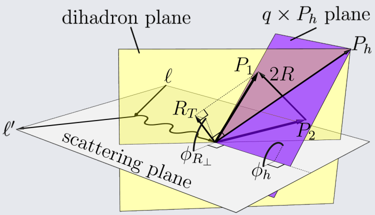
Dihadron Kinematics

The differential cross section for SIDIS dihadrons is 9-fold[2]...

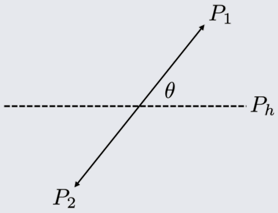
$$\frac{d\sigma}{dy\, d\psi\, dP_{h\perp}^2\, d\cos\theta\, dx\, dz_h\, dM_h\, d\phi_h\, d\phi_R}$$

...3 are integrated, 4 are binned, and 2 are fit to sinusoidal modulations

Dihadron angle definitions

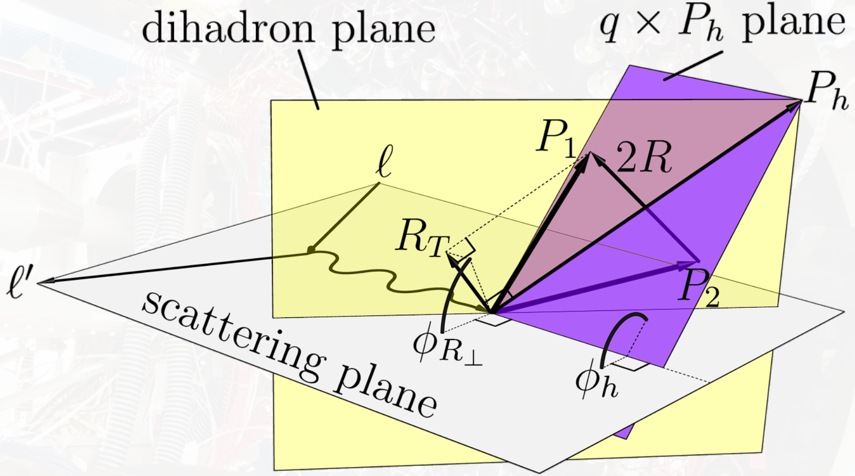


(a) Target rest-frame angular modulations (ϕ_h and ϕ_{R_T})[3]



(b) Dihadron COM frame θ

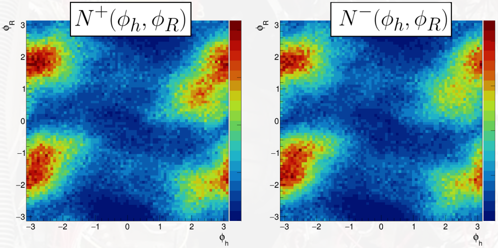
Azimuthal Modulations



Beam Spin Asymmetries

Binning our events in ϕ_h and ϕ_R, one can write...

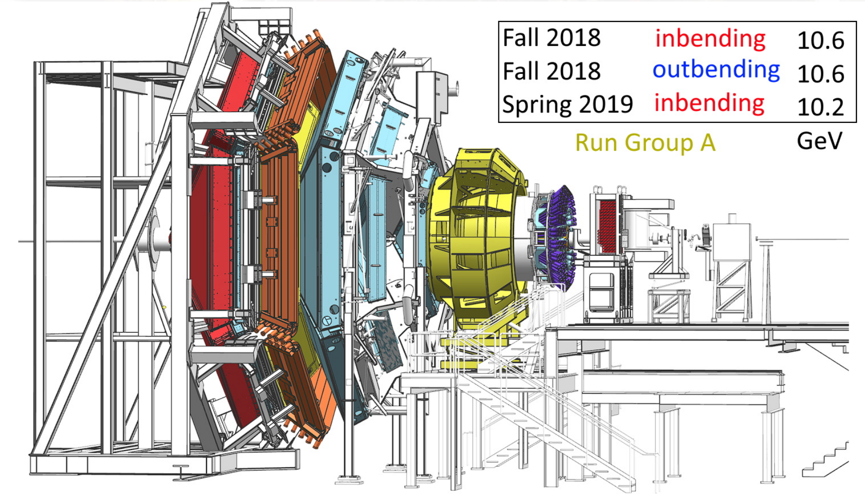
$$A_{LU} = \frac{1}{P}\frac{N^+(\phi_h,\phi_R) - N^-(\phi_h,\phi_R)}{N^+(\phi_h,\phi_R) + N^-(\phi_h,\phi_R)} = \sum_i A_{LU}^{\Psi_i}\Psi_i$$



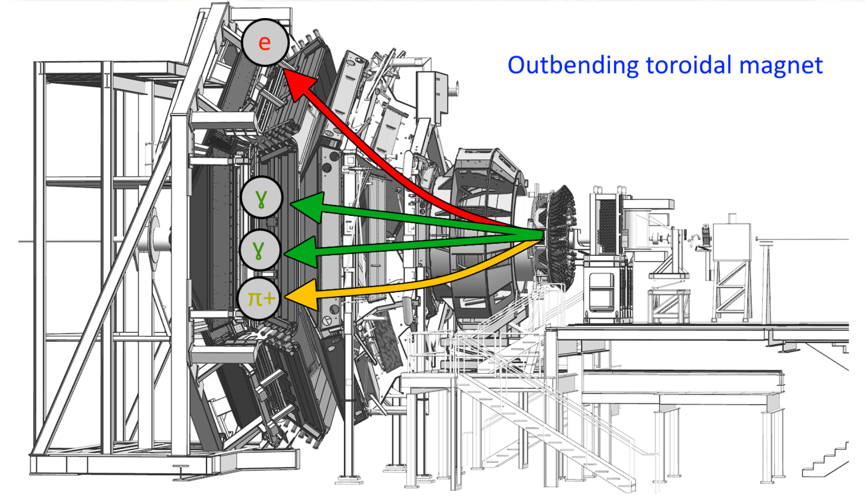
We fit these to sinusoidal modulations in (ϕ_h,ϕ_R) where the fit parameters trace back to PDFs and DiFFs...

$$\sum_i A_{LU}^{\Psi_i}\Psi_i = A_{LU}^{\sin\phi_h}\sin\phi_h + A_{LU}^{\sin(\phi_h-\phi_R)}\sin(\phi_h-\phi_R) + \ldots$$

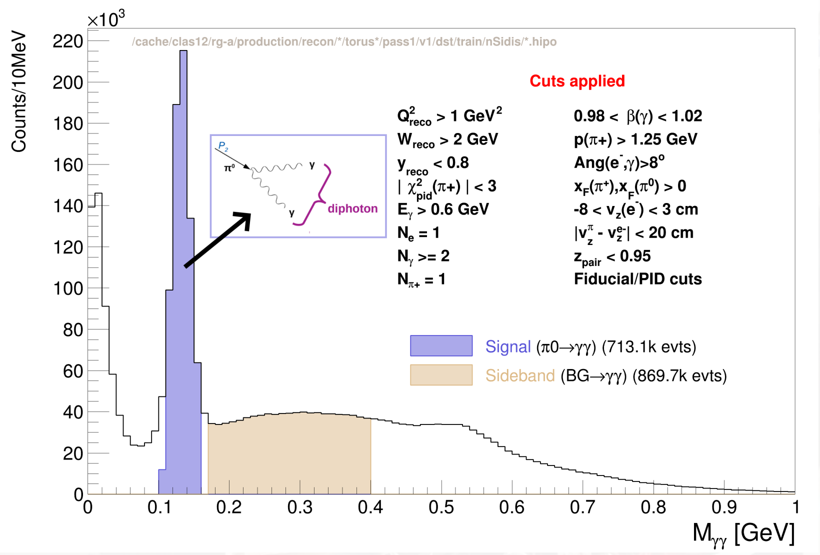
CLAS12 Detector Apparatus

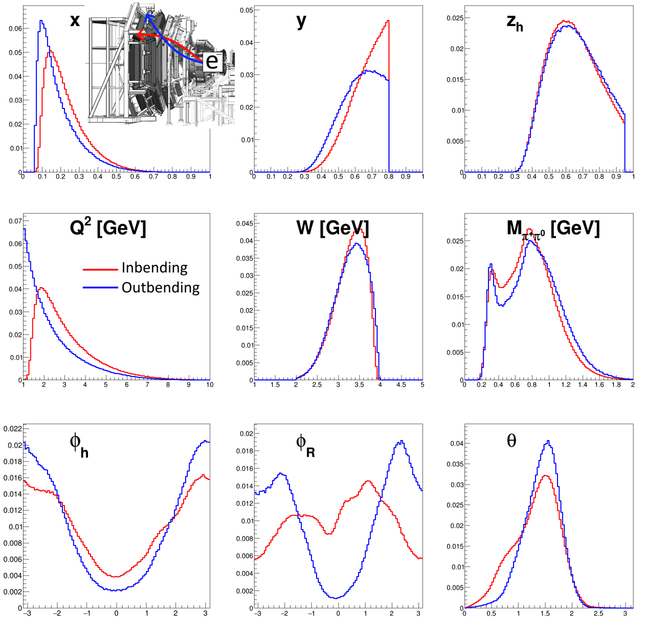


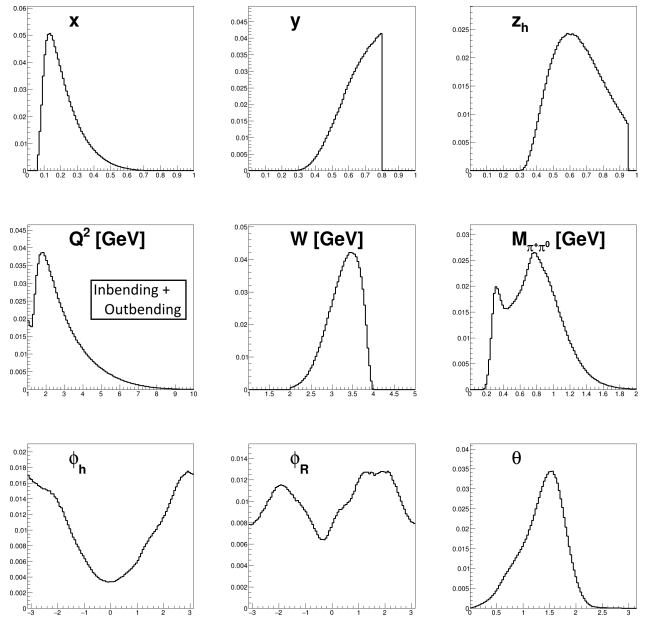
Cartoon of inclusive event



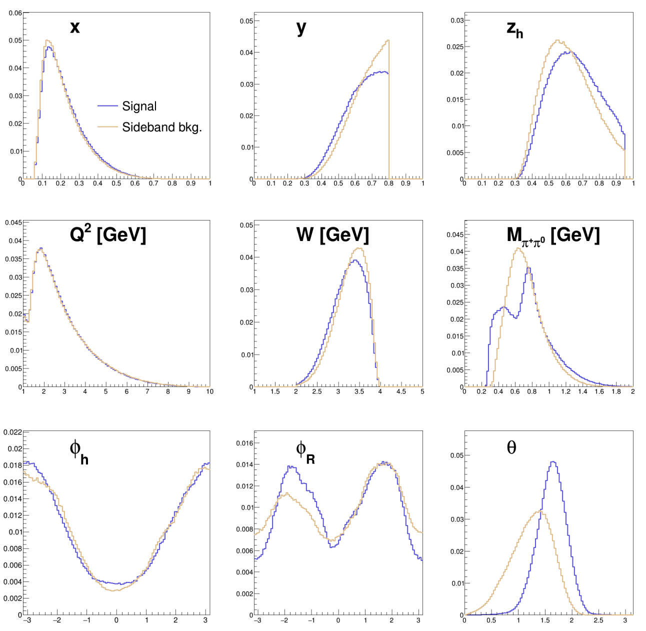
Diphoton Mass Reconstruction




x
e
y
z_h
Q^2 [GeV]
Inbending
Outbending
W [GeV]
$M_{\pi^+\pi^0}$ [GeV]
ϕ_h
ϕ_R
θ



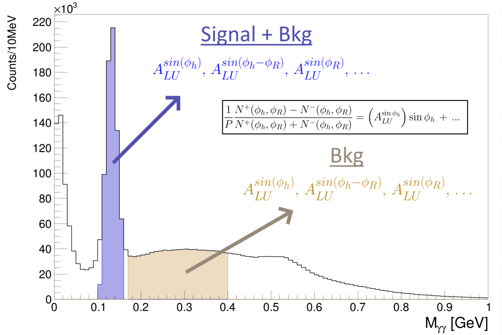
x
y
z_h
Q^2 [GeV]
W [GeV]
$M_{\pi^+\pi^0}$ [GeV]
Inbending +
Outbending
ϕ_h
ϕ_R
θ


x
Signal
Sideband bkg.
y
z_h
Q^2 [GeV]
W [GeV]
$M_{\pi^+\pi^0}$ [GeV]
ϕ_h
ϕ_R
θ

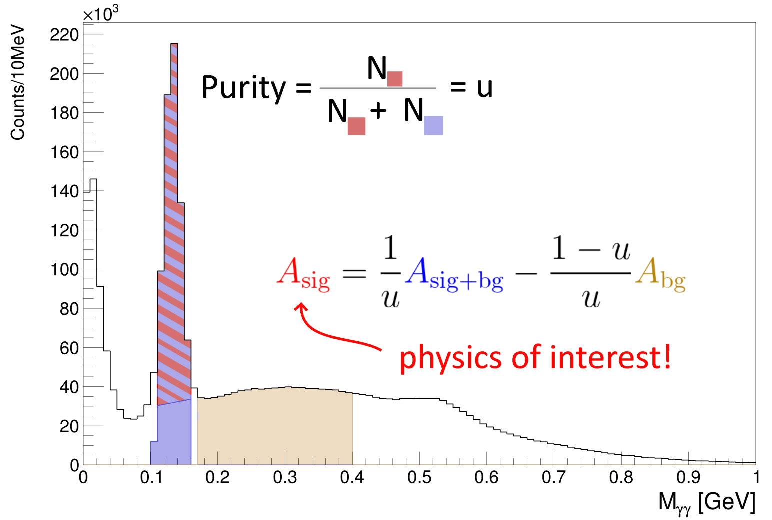
Sideband Method (Motivation)

The problem with $\pi^+\pi^0$ asymmetries

The $\pi^+\pi^0 \to \pi^+\gamma\gamma$ Gaussian signal sits atop a non-negligible background. While the $\pi^+\pi^0$ kinematics has beam asymmetries $A_{LU}^{f(\phi_h,\phi_R)}$, the background can (**and does**) have asymmetries too.

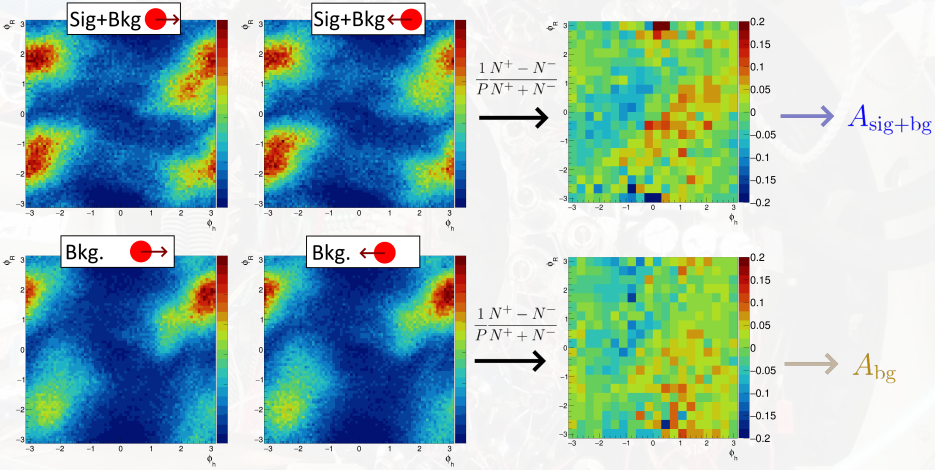


Removing background via sideband



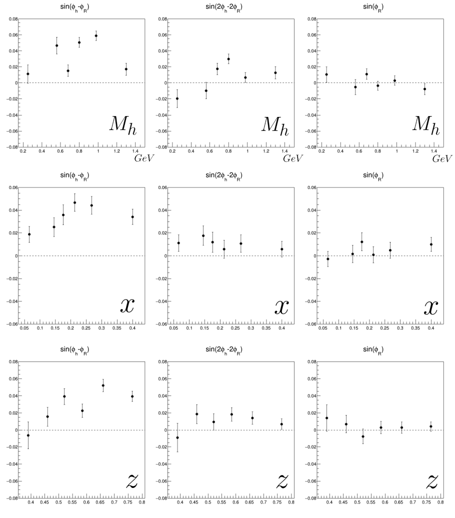
$$A_{\mathrm{sig}} = \frac{1}{u} A_{\mathrm{sig+bg}} - \frac{1-u}{u} A_{\mathrm{bg}}$$

Signal vs. Sideband Modulations



Preliminary A_{LU} results

$\pi^+\pi^0$ asymmetries @ CLAS12



- Statistically significant asymmetries seen for various modulations in both M_h, x, and z binnings
- $A_{LU}^{sin(2\phi_h - 2\phi_R)}$ sign change near ρ^+ mass matches result from $\pi^+\pi^-$ asymmetry studies[3]
- Future work → reduce bkg, implement alternate bkg. subtraction methods (sWeights, COWs), partial wave analysis

List of References

[1] C. Dilks. "Beam Spin Asymmetries of $\pi^+\pi^0$ dihadrons from SIDIS at CLAS12". In: (2021).

[2] S. Gliske, A. Bacchetta, and M. Radici. "Production of two hadrons in semi-inclusive deep inelastic scattering". In: *Physical Review D* 90.11 (Dec. 2014). DOI: 10.1103/physrevd.90.114027. URL: https://doi.org/10.1103%5C%2Fphysrevd.90.114027.

[3] T. Hayward. "Dihadron beam spin asymmetries on an unpolarized hydrogen target with CLAS12". In: (2021). URL: https://www.jlab.org/Hall-B/general/thesis/THayward_thesis.pdf.

List of References

[4] M. Mirazita, H. Avakian, and Courtoy. "Beam Spin Asymmetry in Semi-Inclusive Electroproduction of Hadron Pairs". In: *Physical Review Letters* 126.6 (Feb. 2021). ISSN: 1079-7114. DOI: 10.1103/physrevlett.126.062002. URL: http://dx.doi.org/10.1103/PhysRevLett.126.062002.

Extraction example

- In principle, one performs a binned (or un-binned) fit to...

$$A_{LU} = \frac{1}{P}\frac{N^+(\phi_h,\phi_R) - N^-(\phi_h,\phi_R)}{N^+(\phi_h,\phi_R) + N^-(\phi_h,\phi_R)} = \sum_i A_{LU}^{\Psi_i}\Psi_i$$

- One finds that the $\sin\phi_R$ fit coefficient has the following form [4]

$$A_{LU}^{\sin\phi_R} = \sqrt{2\epsilon(1-\epsilon)}\frac{F_{LU}^{\sin\phi_R}}{F_{UU,T} + \epsilon F_{UU,L}}$$

$$F_{LU}^{\sin\phi_R} \propto \left(\frac{M_p}{m_{\pi^+\pi^0}} x\, e^q(x) H_1^{\sphericalangle q}(z, \cos\theta, m_{\pi^+\pi^0}) + \frac{1}{z} f_1^q(x)\tilde{G}^{\sphericalangle q}(z, \cos\theta, m_{\pi^+\pi^0})\right)$$

Summary

Using BELLE and unpolarized beam+target data we extract new physics