The Beam-Helicity Asymmetry for $\gamma p \to pK^+K^-$ and $\gamma p \to p\pi^+\pi^-$

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CLAS Collaboration

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Background

- Quantum Chromodynamics is the theory for the interactions between quarks and gluons
- QCD makes predictions on bound states composed of these particles
- Studying QCD through hadron spectroscopy
- Interested studying strange sector

Goal

We are interested in observing missing hyperon excitation predicted by Isgur and Capstick and LQCD in the > 2.0 GeV Region

$\Lambda(2000)$		*	$\Sigma(2000)$	$1/2^-$	*
$\Lambda(2020)$	$7/2^+$	*	$\mathbf{\Sigma(2030)}$	$7/2^+$	****
$\Lambda(2050)$	$3/2^-$	*	$\Sigma(2070)$	$5/2^+$	*
$\mathbf{\Lambda(2100)}$	$7/2^-$	****	$\Sigma(2080)$	$3/2^+$	**
$\mathbf{\Lambda(2110)}$	$5/2^+$	***	$\Sigma(2100)$	$7/2^-$	*
$\Lambda(2325)$	$3/2^-$	*	$\mathbf{\Sigma(2250)}$		***
$\mathbf{\Lambda(2350)}$	$9/2^+$	***	$\Sigma(2455)$		**
$\Lambda(2585)$		**	$\Sigma(2620)$		**
			$\Sigma(3000)$		*
			$\Sigma(3170)$		*

K. A. Olive *et al.*, (Particle Data Group), *Chin. Phys. C*, **38** 090001, 2014.

Goal

We are interested in observing missing hyperon excitation predicted by Isgur and Capstick and LQCD in the > 2.0 GeV Region

Λ	$1/2^-$	2015, 2095, 2160, 2195, 2235, 2280
Λ	$3/2^-$	2030, 2110, 2185, 2230, 2290
Λ	$5/2^-$	2180, 2225, 2240, 2295
Λ	$7/2^-$	2150, 2230
Σ	$1/2^-$	2110, 2155, 2165, 2205, 2260, 2275
Σ	$3/2^-$	2120, 2185, 2200, 2215, 2265, 2290
Σ	$5/2^-$	2205, 2250, 2270, 2280
Σ	$7/2^-$	2245

S. Capstick *et al.*, "Baryons in a relativized quark model with chromodynamics," *Phys. Rev. D.*, vol. 34, p. 2809, 1986.

Goal

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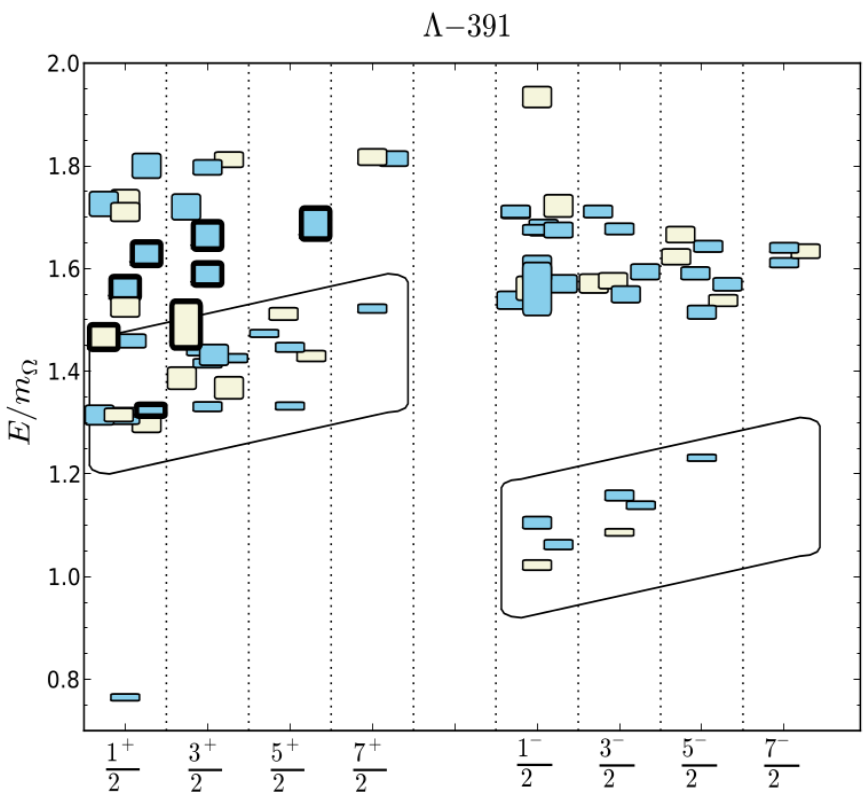
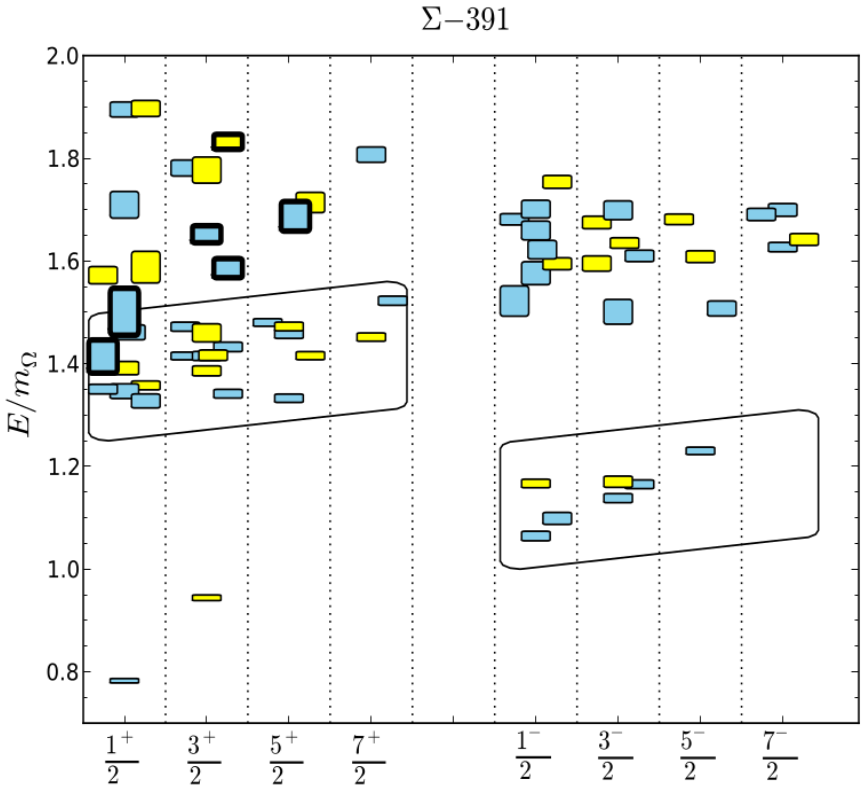




R. G. Edward *et al*, "Flavor structure of the excited baryon spectra from lattice QCD," *Phys. Rev. D*, vol. 87, p. 054506, 2013.

g12 Experiment

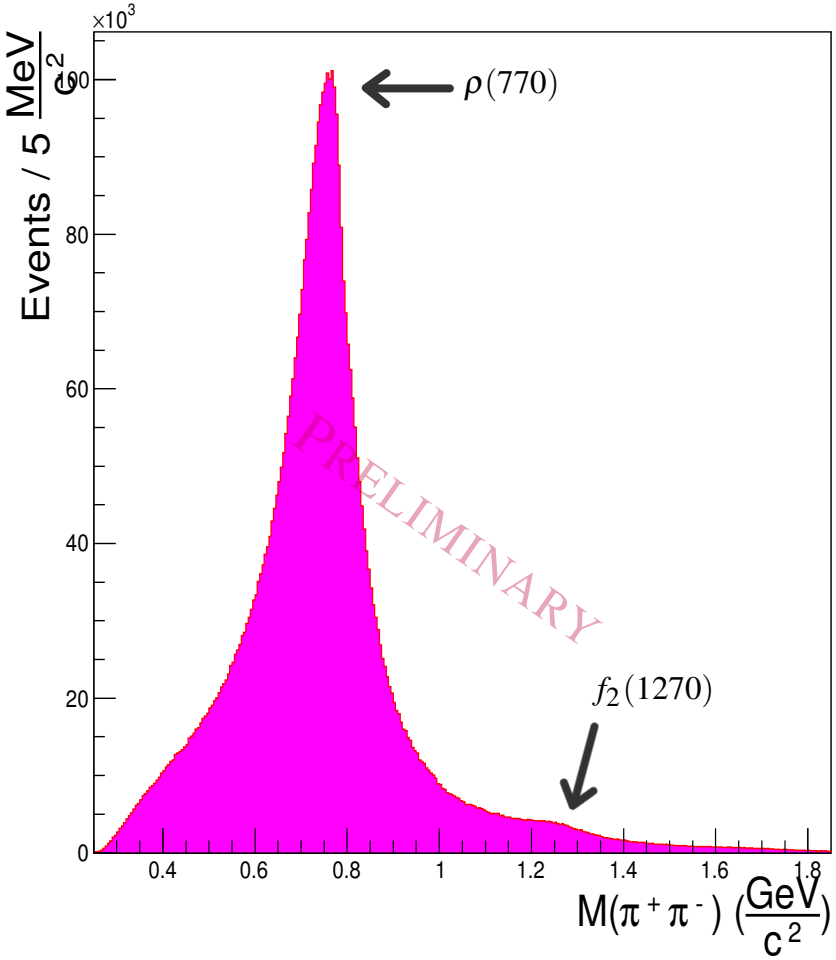
- Analysis of the reaction $\gamma p \to pK^+K^-$ and $p\pi^+\pi^-$ using data from g12 at CLAS
- The g12 experiment is a photoproduction experiment on a proton target
- Luminosity of 68 pb^{-1}
- Photon beam was circularly polarized and had an energy range between 1.1 and 5.5 GeV
- The proton target was not polarized

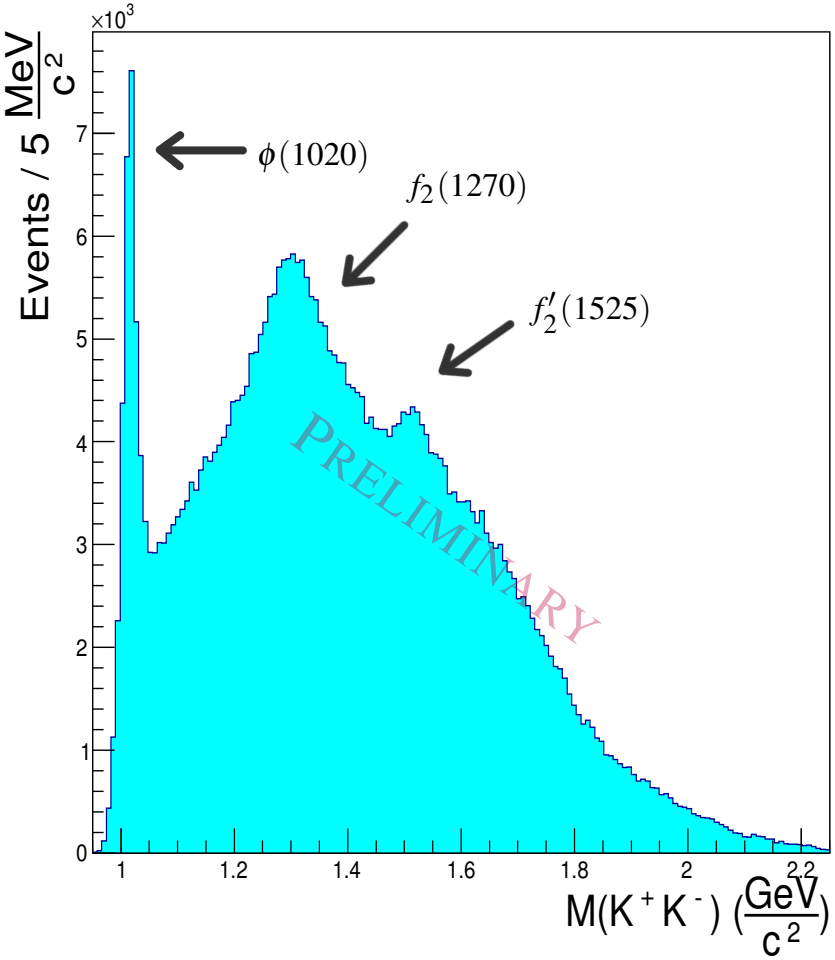
g12 Experiment

- Unprecedented statistics of strange particles in photoproduction
- Large acceptance
- All particles in final state were detected
- Maximum photon polarization of $\approx 80\%$

Mass Spectrum

$$1.1\text{GeV} < E_\gamma < 5.5\text{GeV}$$





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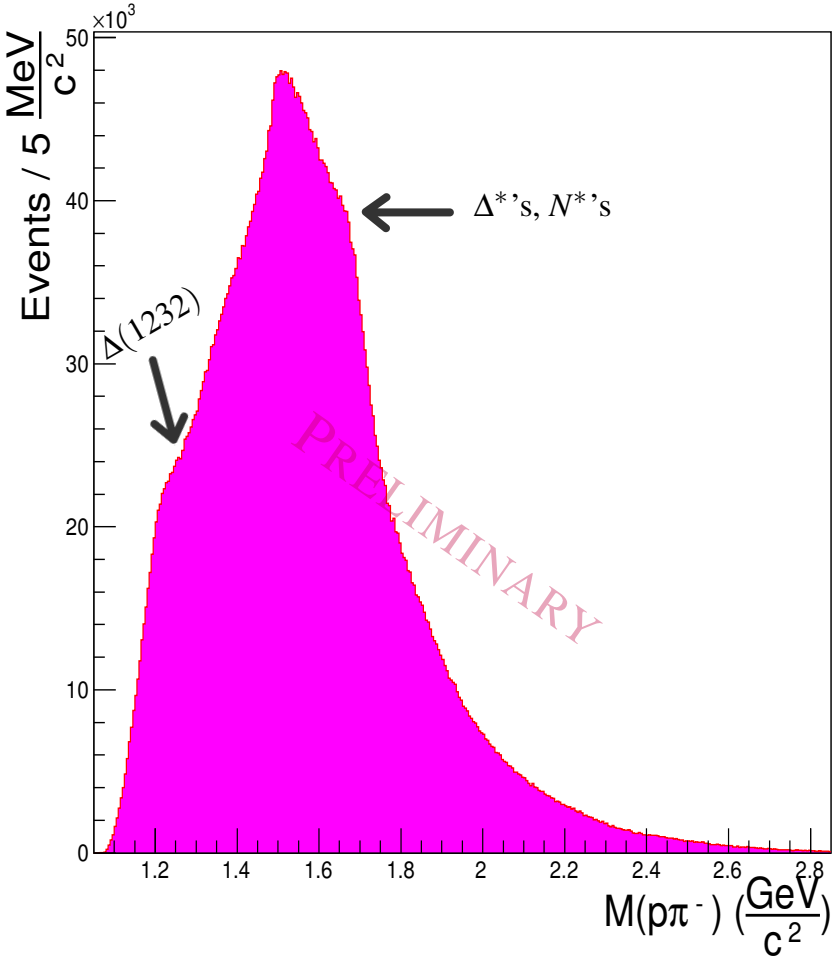

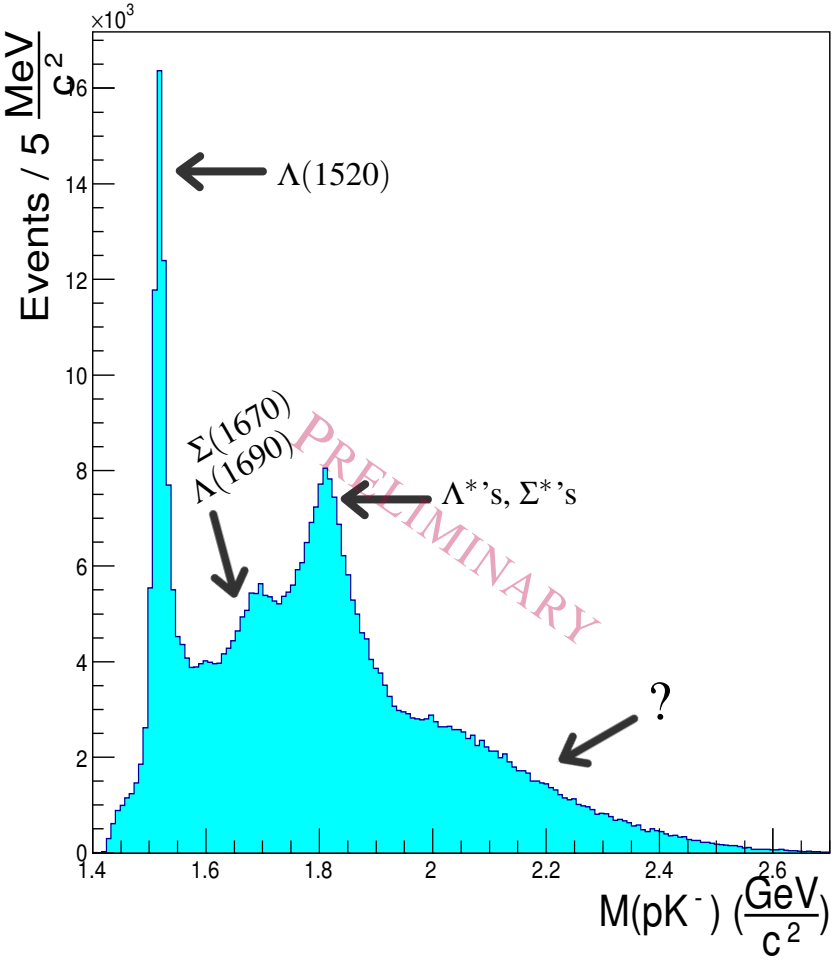

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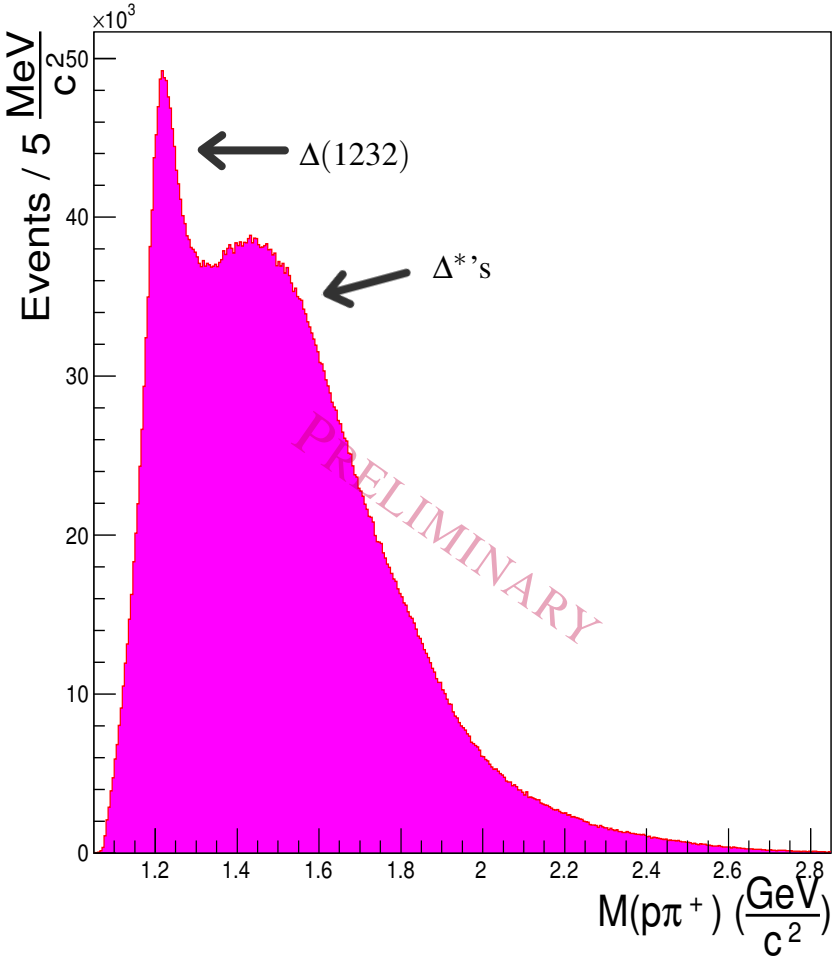
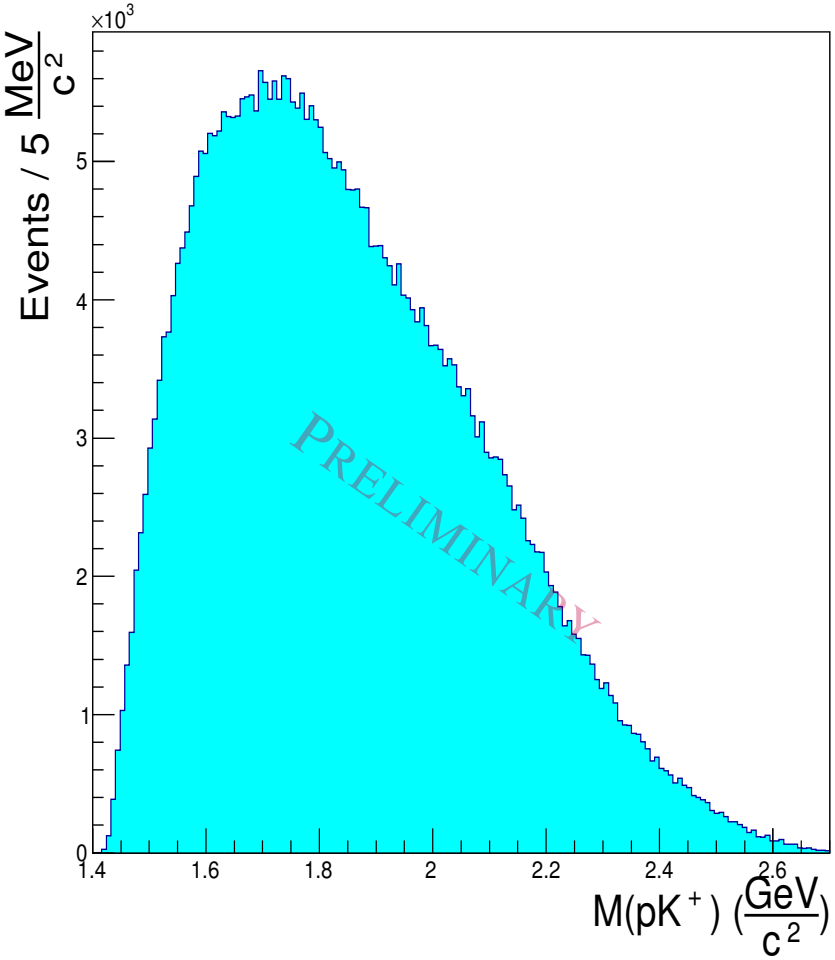
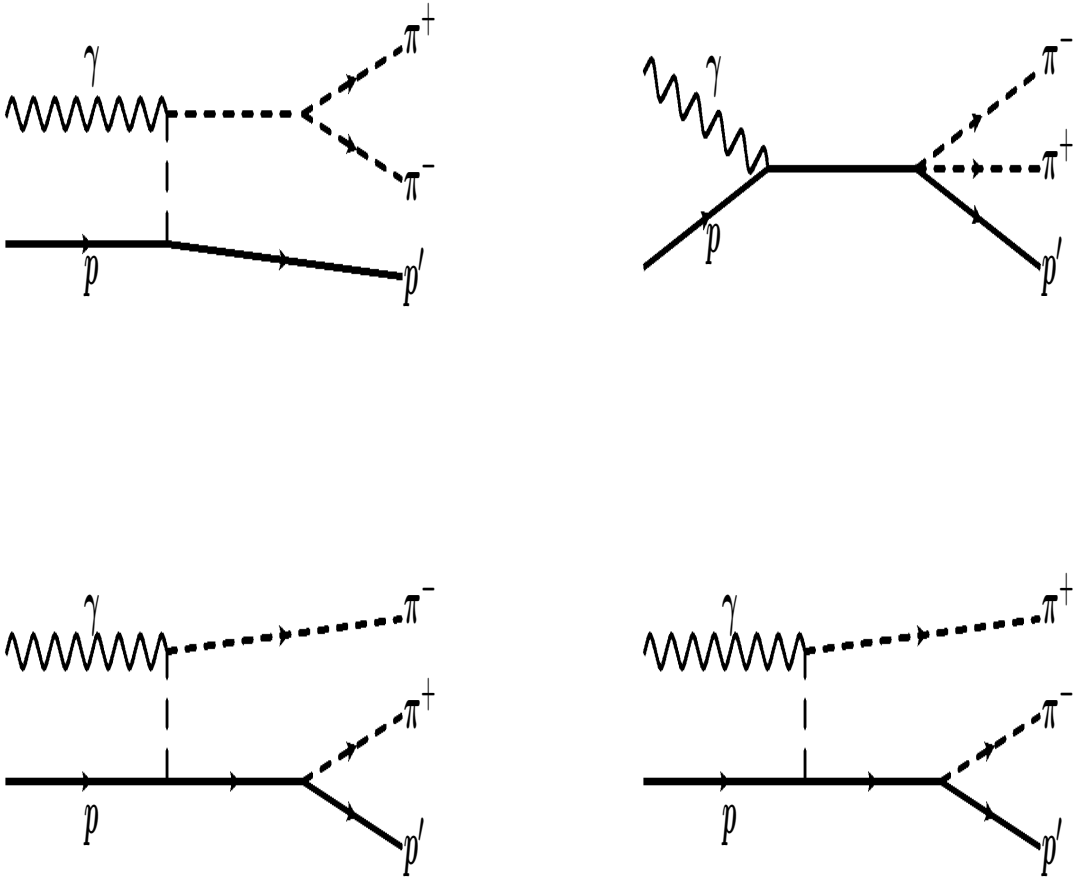




Background



W. Roberts, "Polarization observables in $\gamma N \to K\bar{K}N$," *Phys.Rev.*., C73:035215, 2006.

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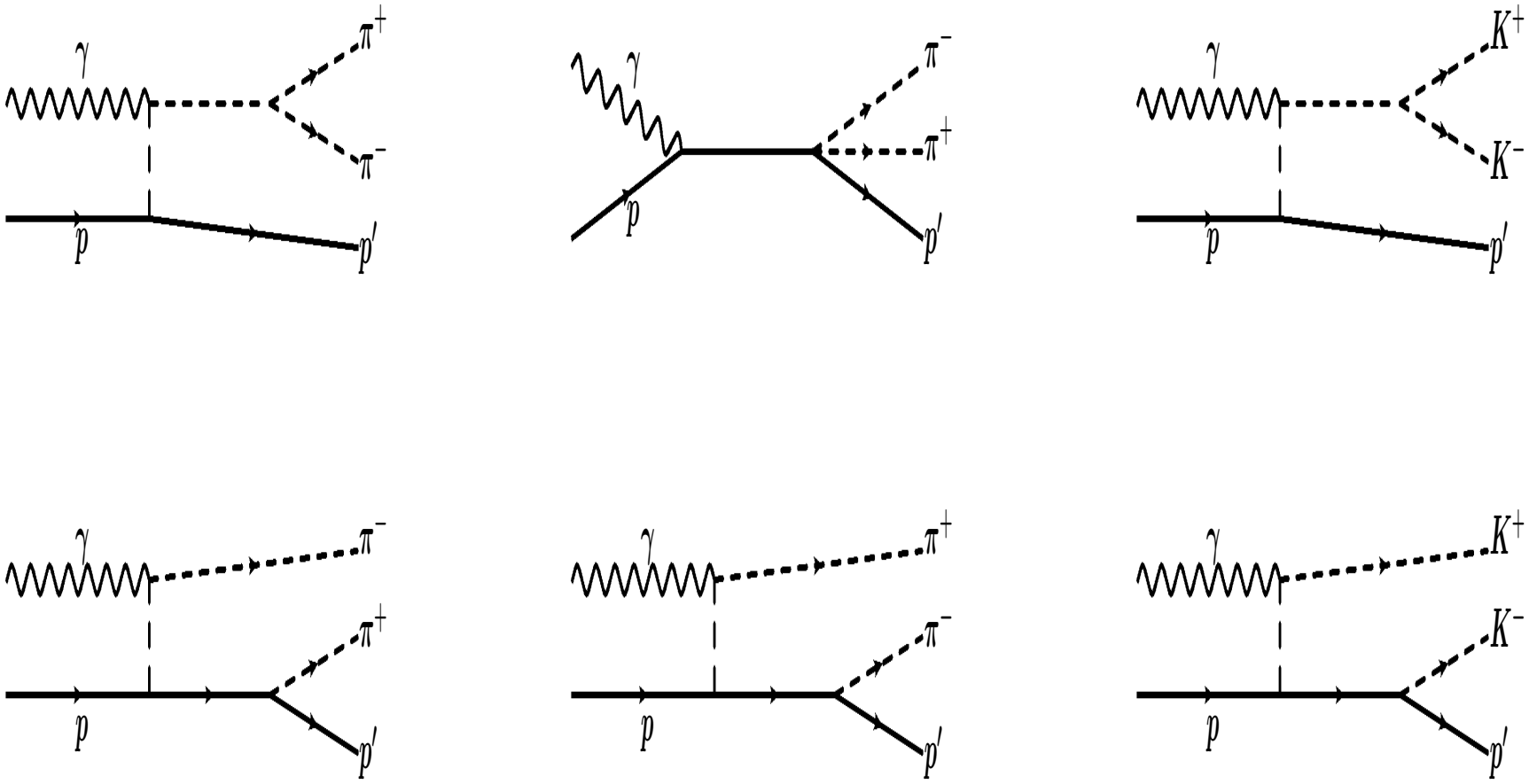


W. Roberts, "Polarization observables in $\gamma N \to K\bar{K}N$," *Phys.Rev.*, C73:035215, 2006.

Background

- Kaon channel has less contributing diagrams
- We anticipate kaon channel to be easier to handle than pion channel

Plans

Our analysis consists of two parts:

- Beam-Helicity Asymmetry
- Partial Wave Analysis

Plans

Our analysis consists of two parts:

- **Beam-Helicity Asymmetry**
- Partial Wave Analysis

Background

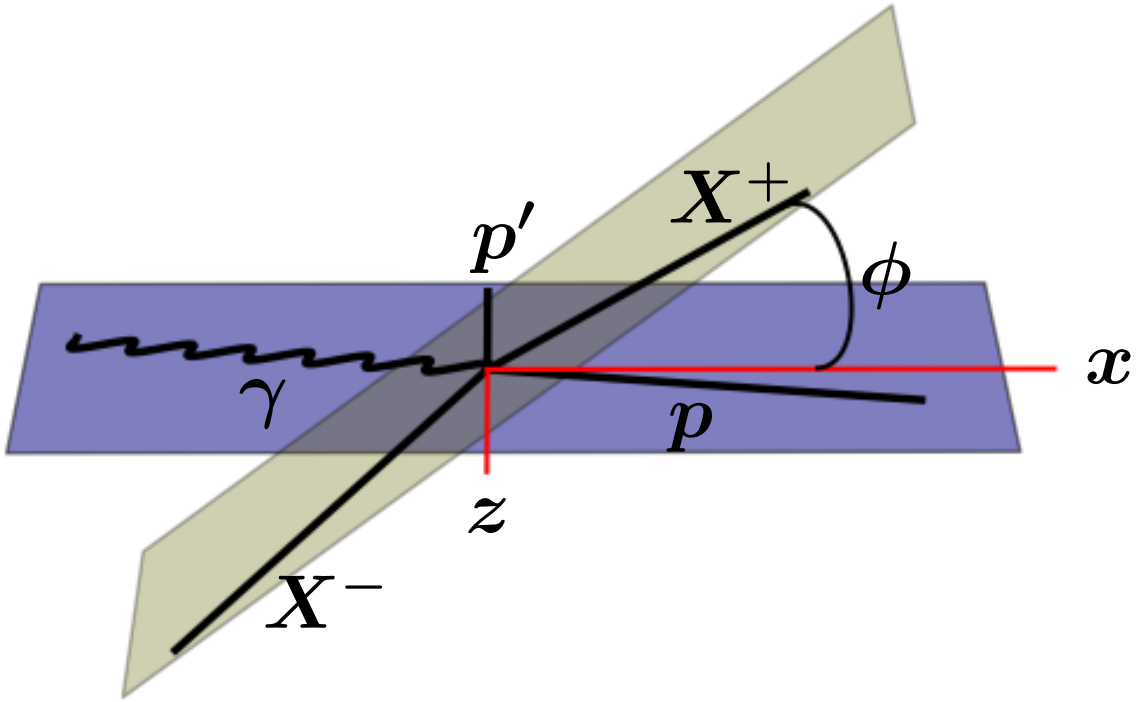
- Beam-Helicity asymmetry is a polarization observable
- Polarization observables allow probing of interfering production mechanisms
- Many theoretical models use effective Lagrangians with many parameters
- Polarization data are expected to provide constraints

Background

- The beam-helicity asymmetry is defined as

$$I^{\odot} = \frac{1}{P_\gamma} \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$

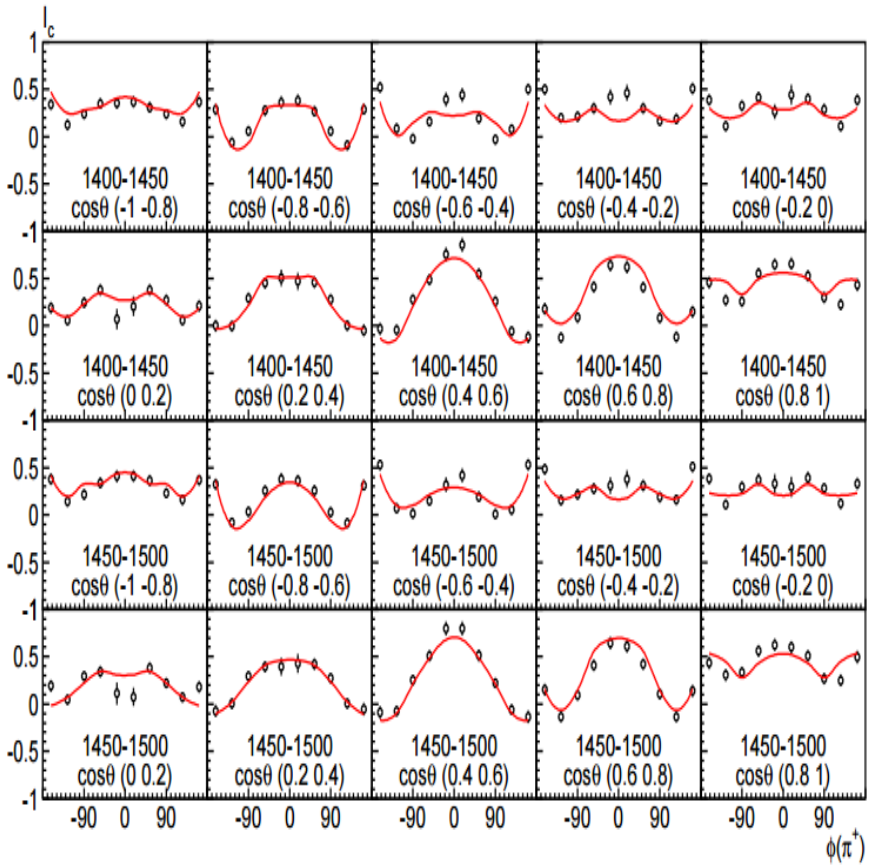
- Plane and angle definitions:

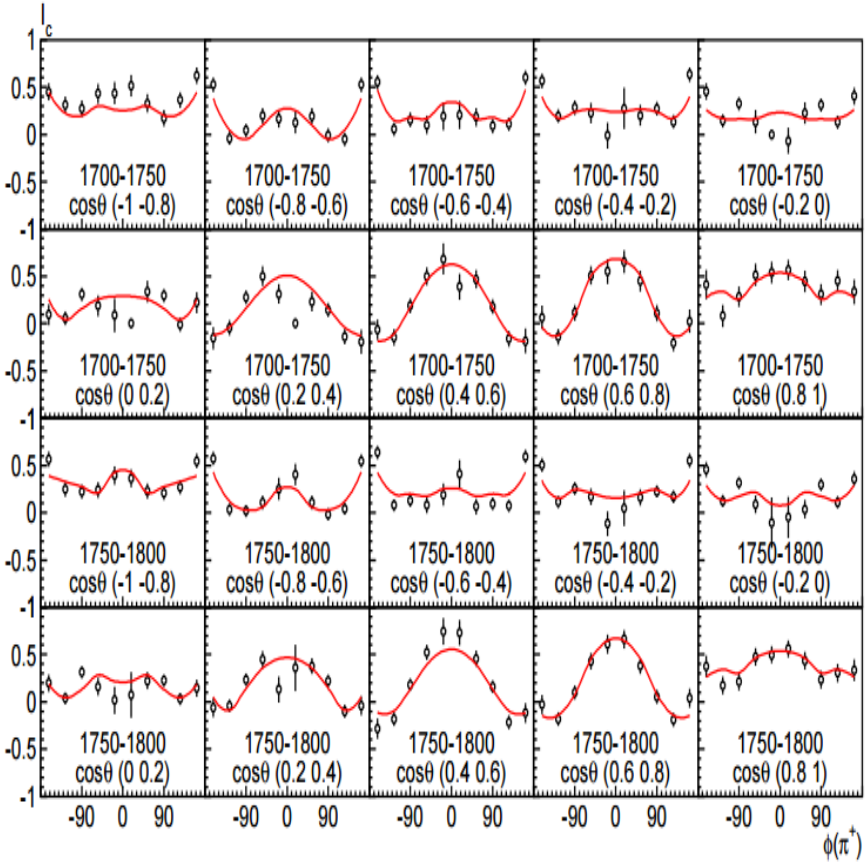


Background

- Asymmetry is difficult to model
- In the following figures, open circles are experimentally measured and red curves represent theoretical model

Background





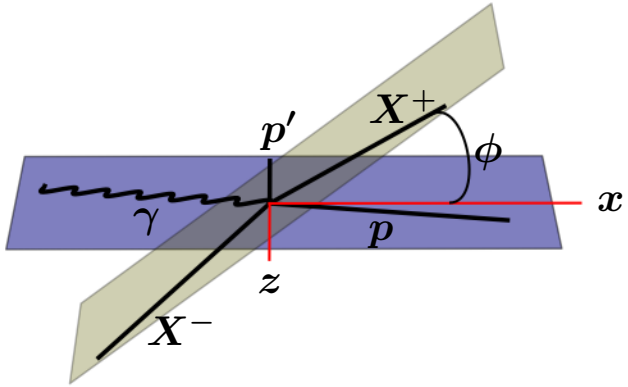
A. Sarantsev, "Properties of baryons from the Bonn-Gatchina partial wave analysis." *The 10th International Workshop on the Physics of Excited Nucleons (NSTAR2015)*. Presentation conducted from Osaka, Japan (2015, May 25). Speaker acknowledges V. Crede (FSU).

Background

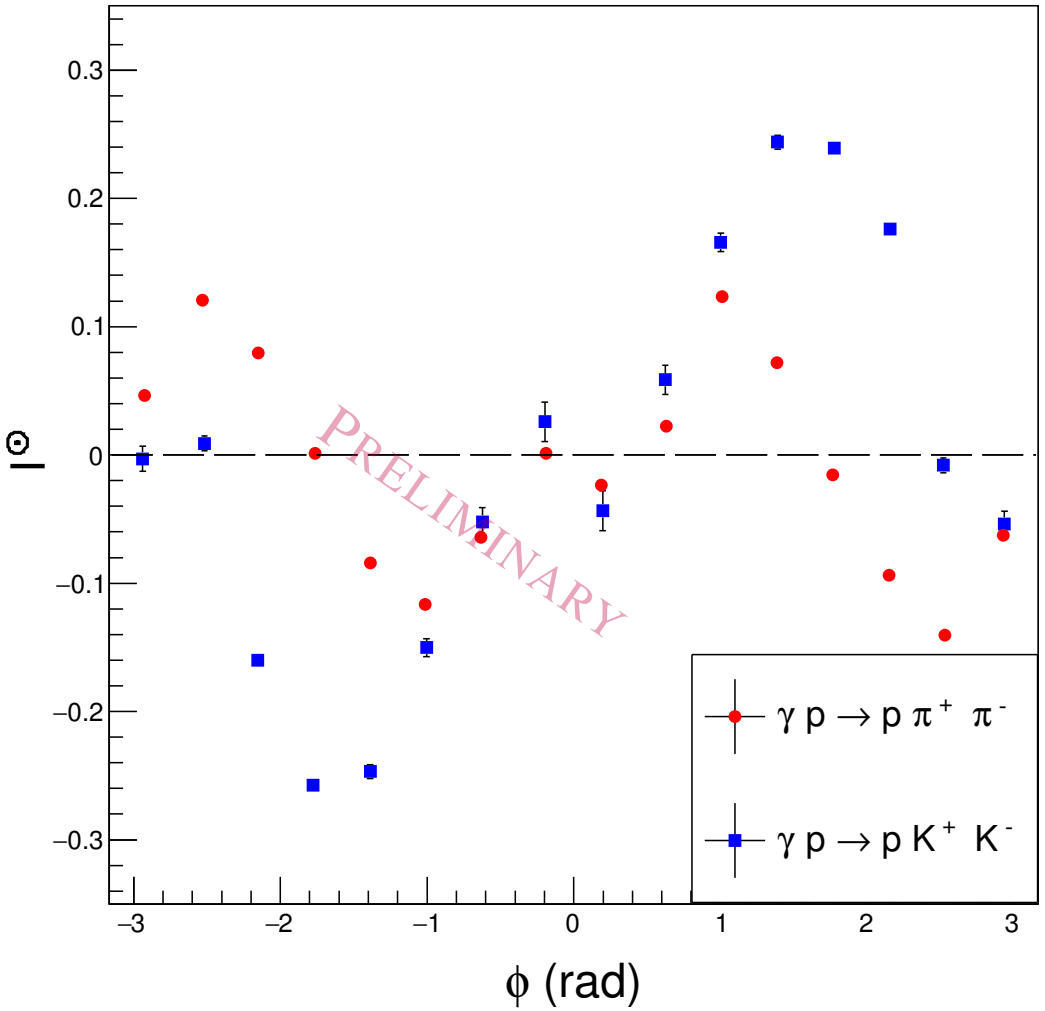
- Asymmetry is difficult to model
- Model used coupled-channel analysis and fitted to large number of partial waves

Preliminary Analysis

$$I^{\odot}(\phi) = \frac{1}{P_\gamma} \frac{\sigma^+(\phi) - \sigma^-(\phi)}{\sigma^+(\phi) + \sigma^-(\phi)}$$



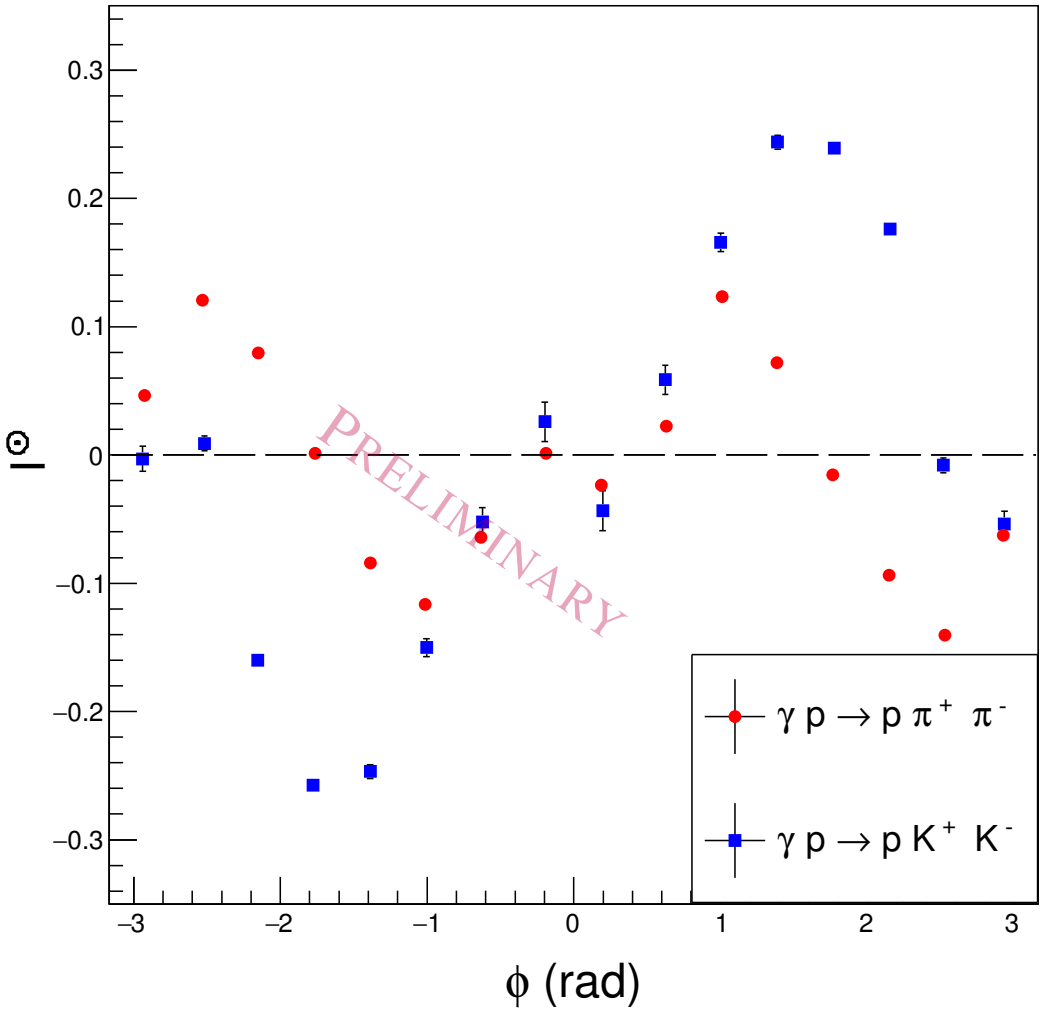
Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses



Preliminary Analysis

- First-time measurement of $I^{\odot}$ for $\gamma p \to pK^+K^-$

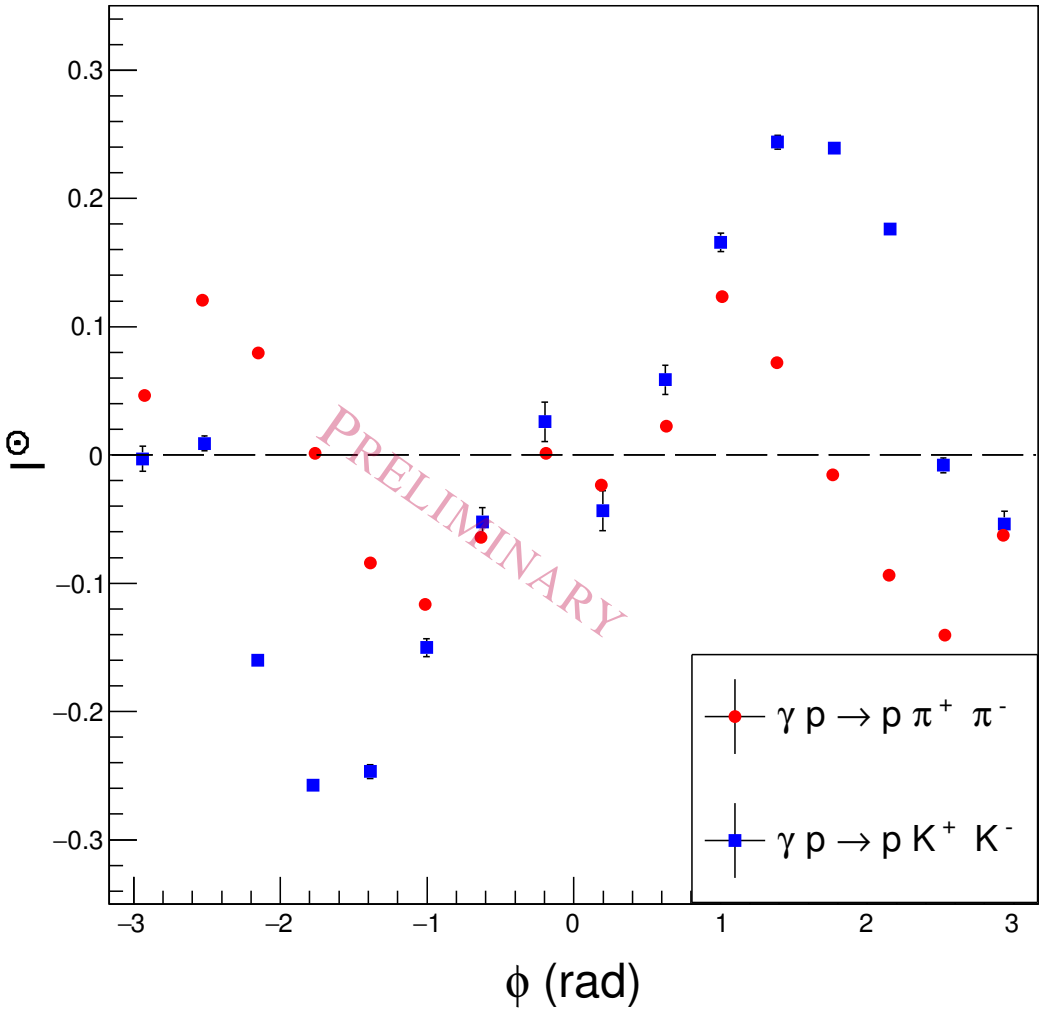
Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses



Preliminary Analysis

- First-time measurement of $I^{\odot}$ for $\gamma p \to pK^+K^-$
- Kaon asymmetry dominated by $\sin(\phi)$ term while pion's is dominated by $\sin(2\phi)$
- Kaon asymmetry overall amplitude larger than pion's

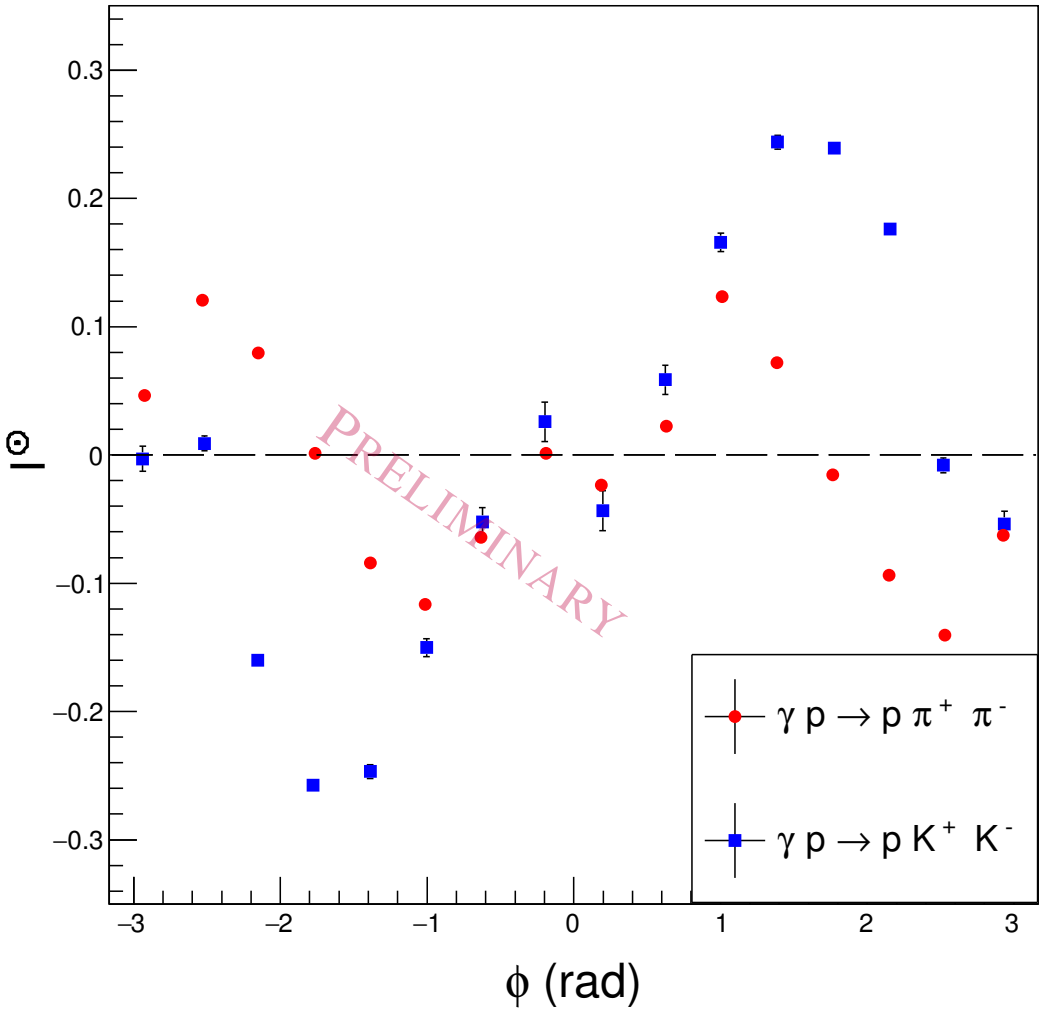
Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses



Preliminary Analysis

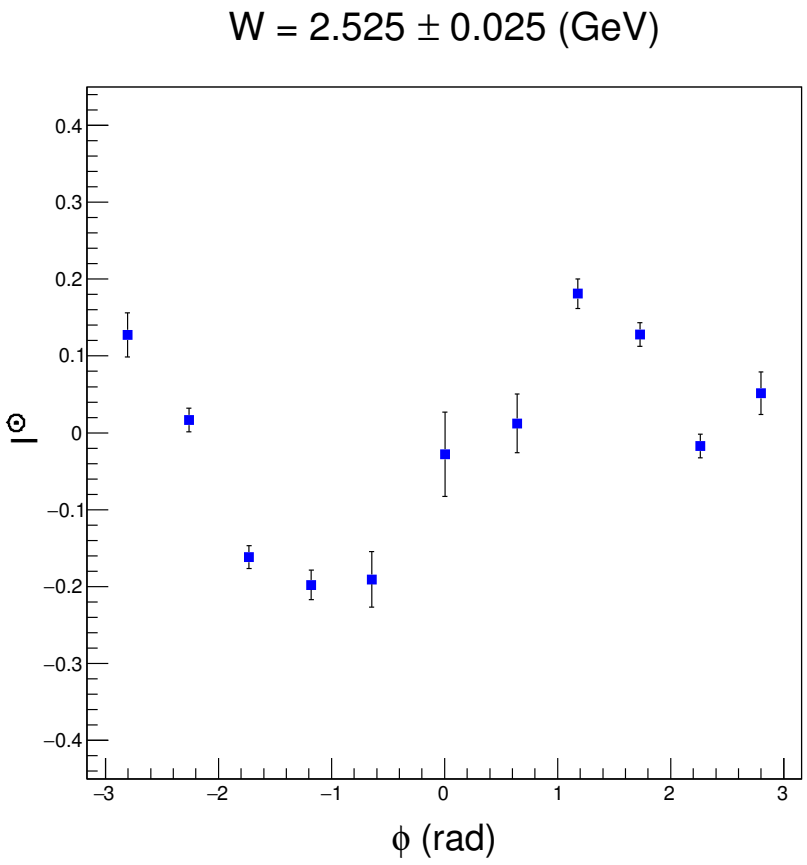
- Asymmetry is observed and is different for kaon and pion channels
- We investigate the asymmetry's sensitivities to other important kinematic variables

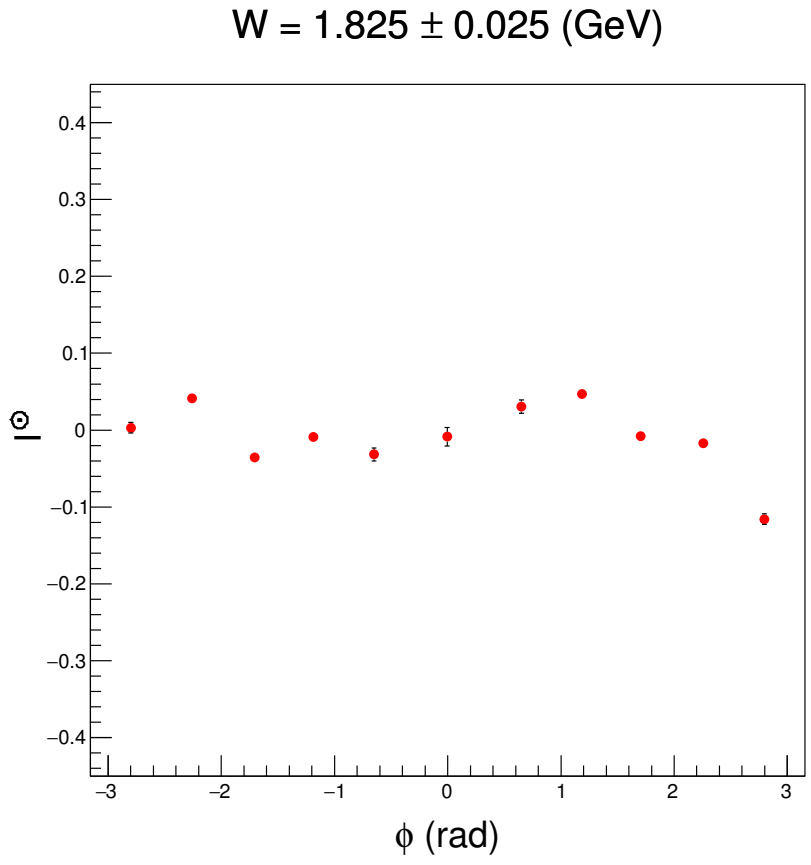
Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses



Preliminary Analysis

Approximately same excess energy over threshold





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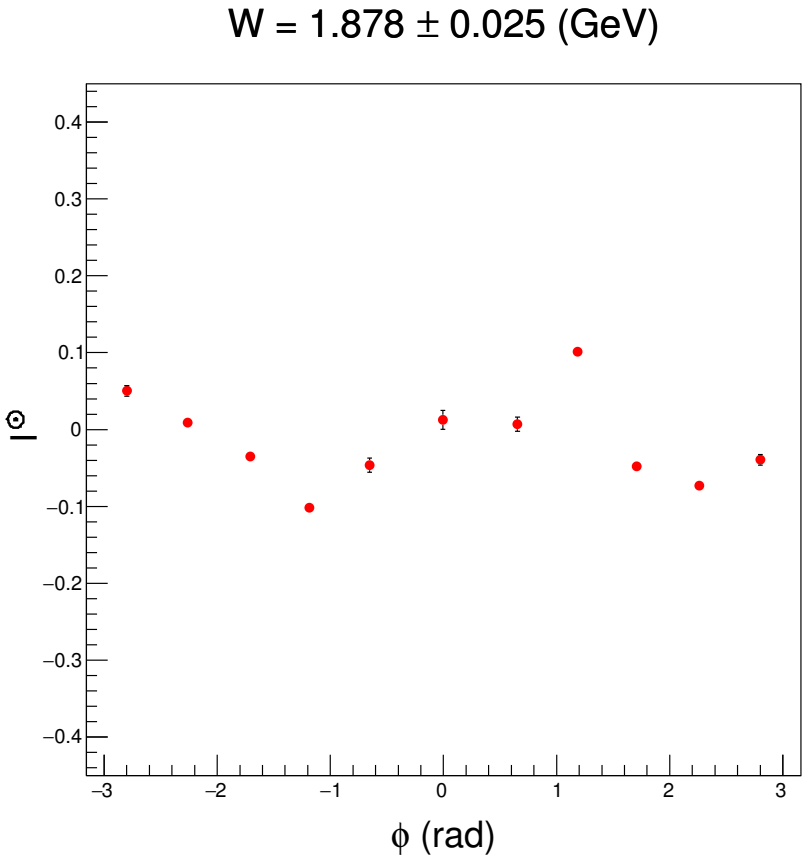
Bad Tagger Paddle



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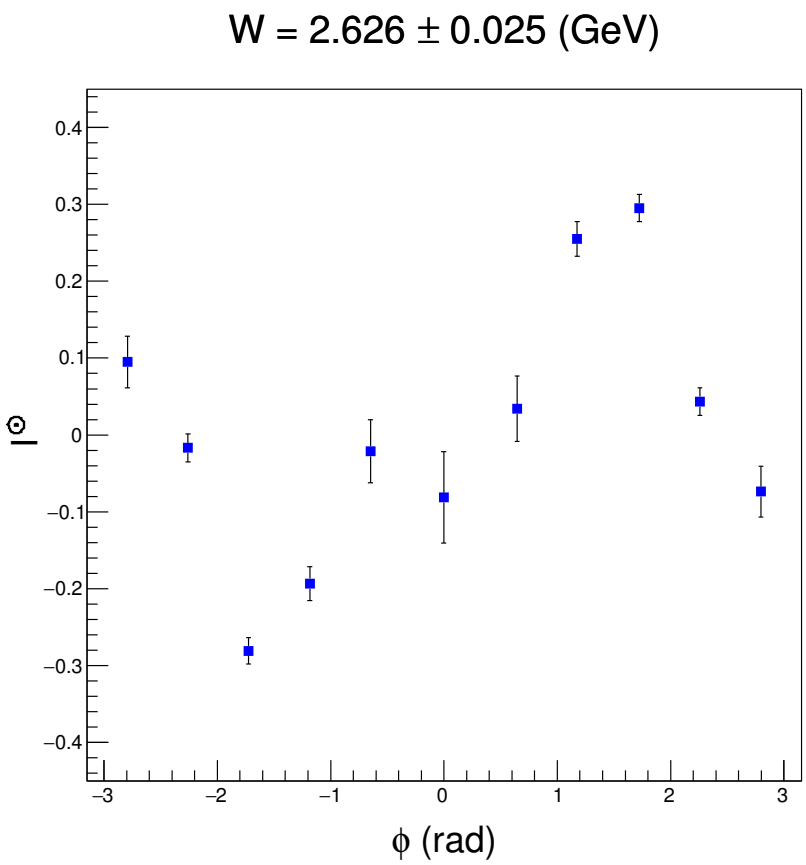

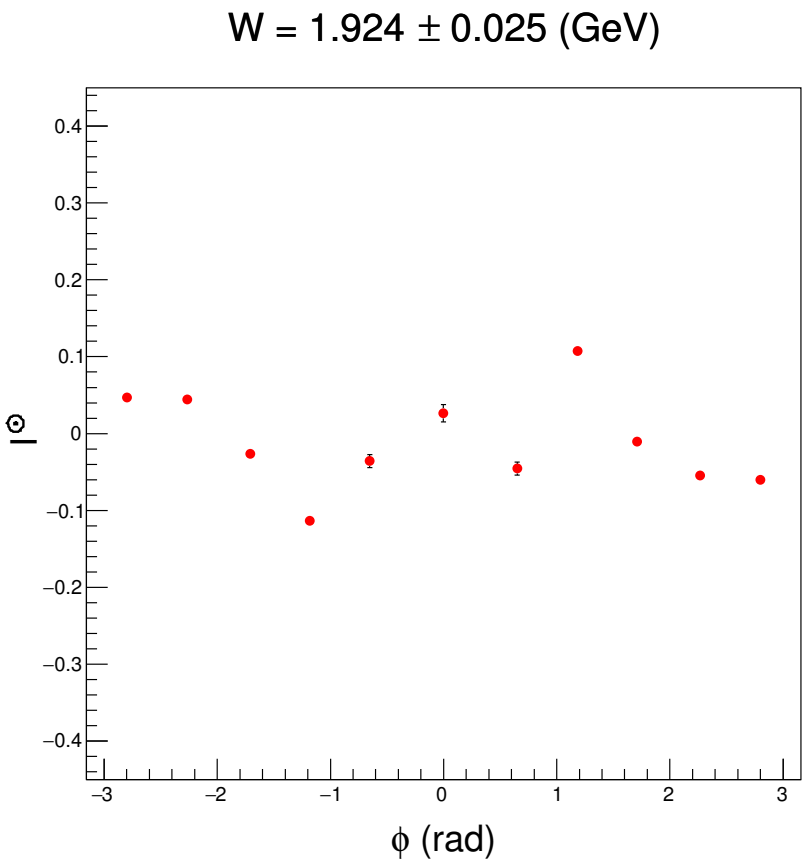

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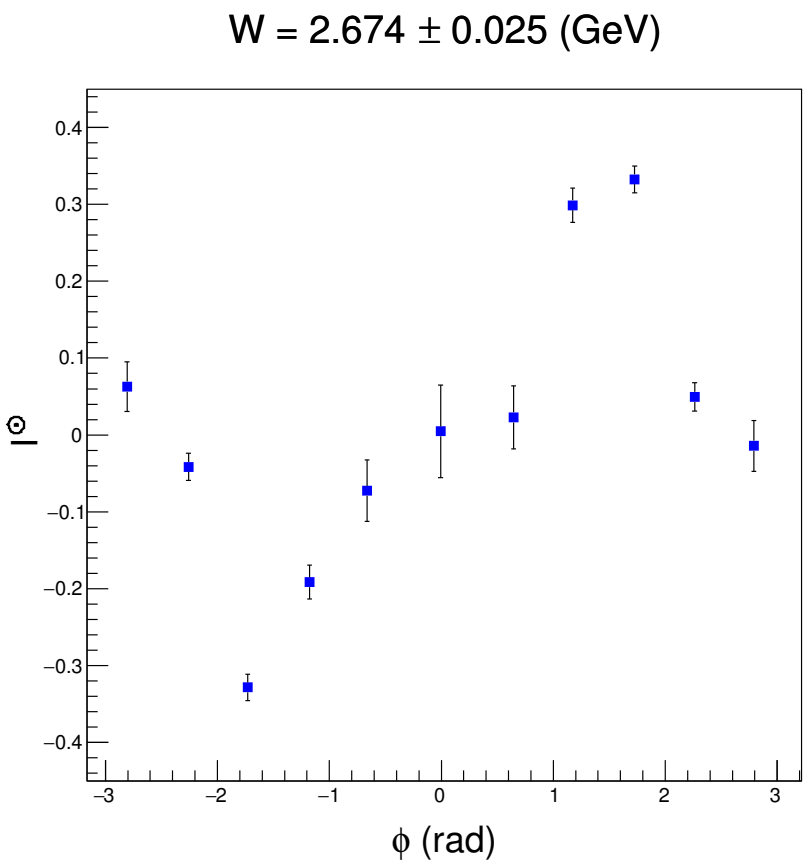

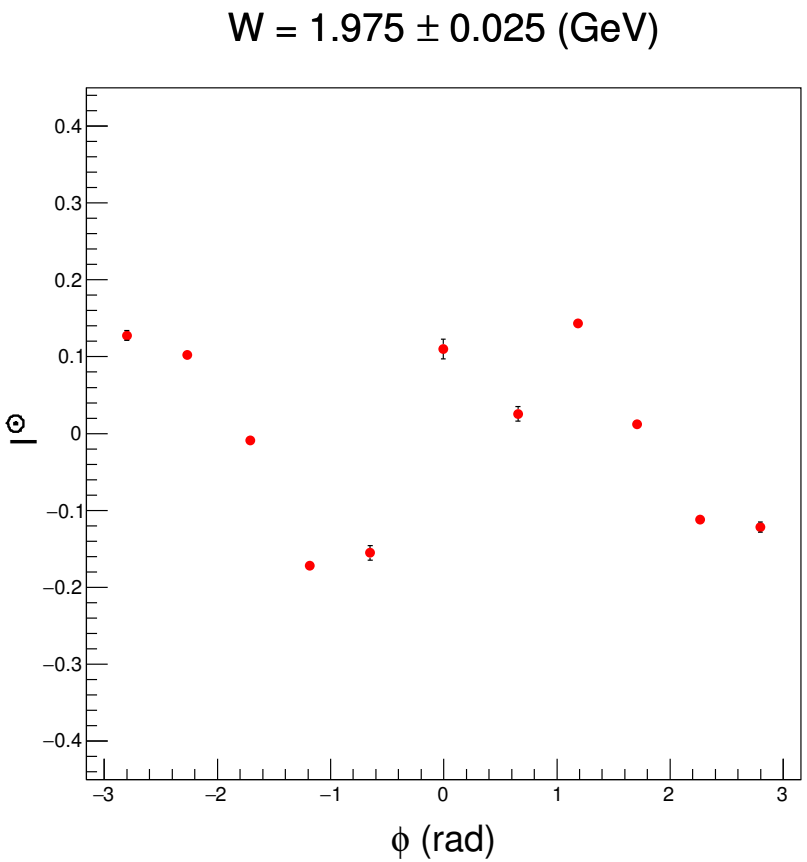

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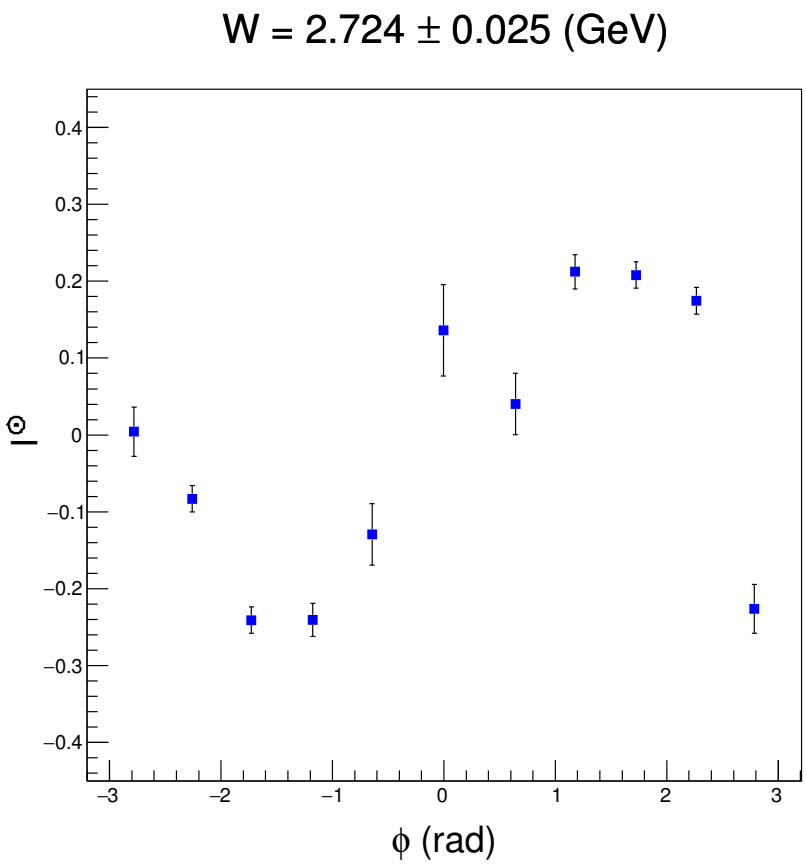

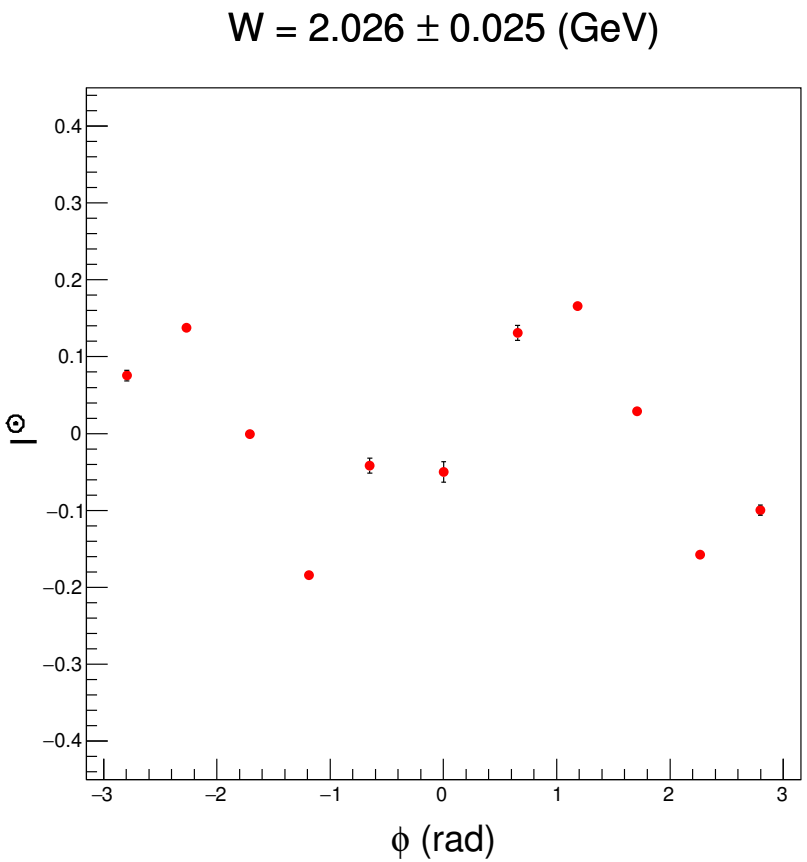

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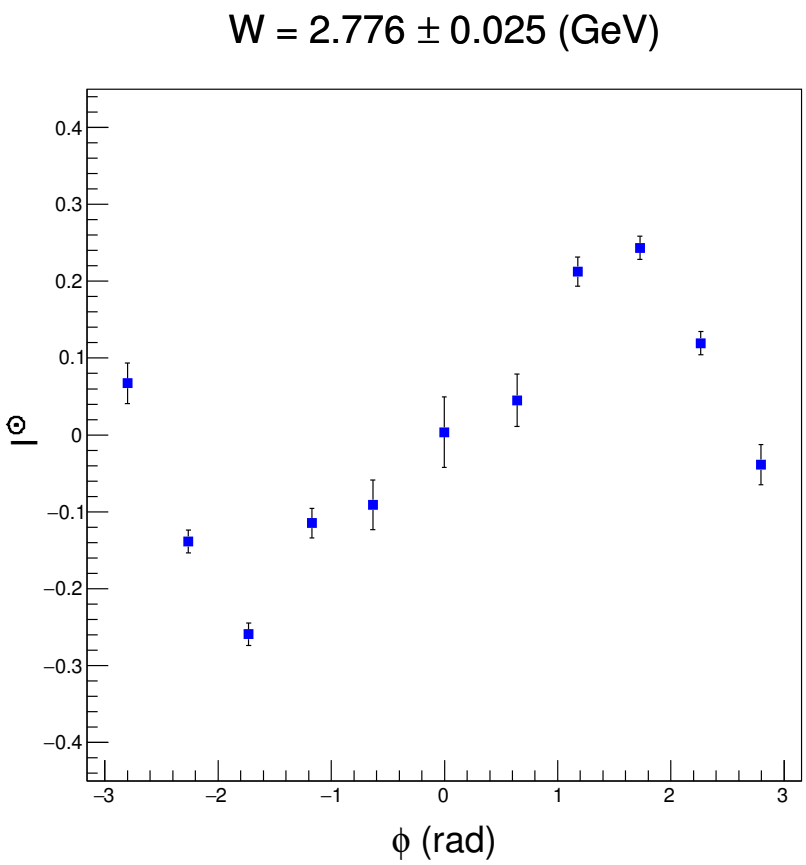

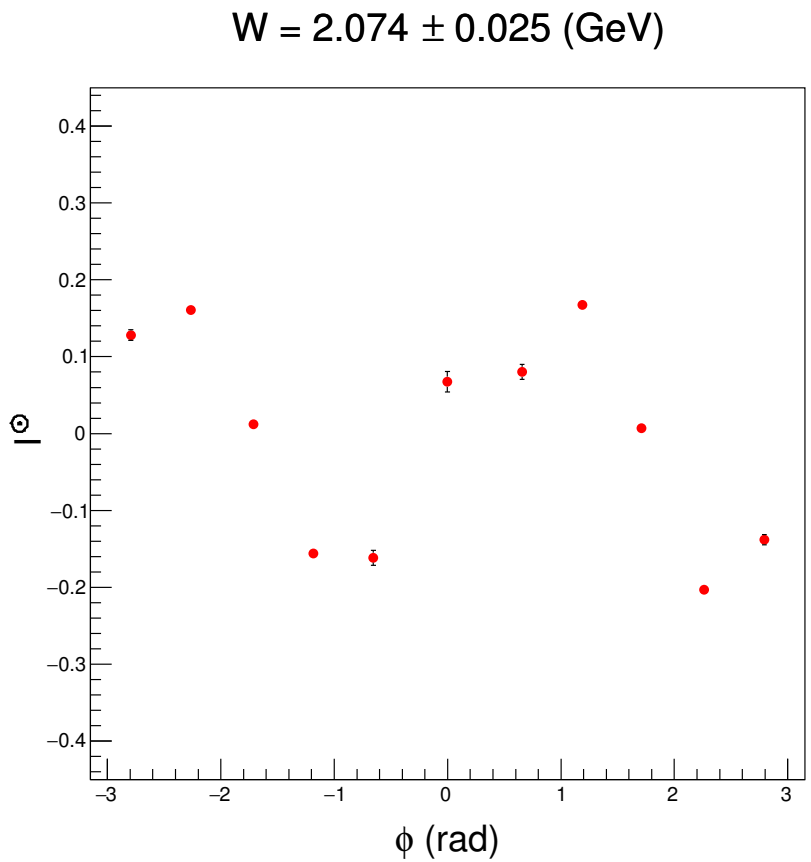

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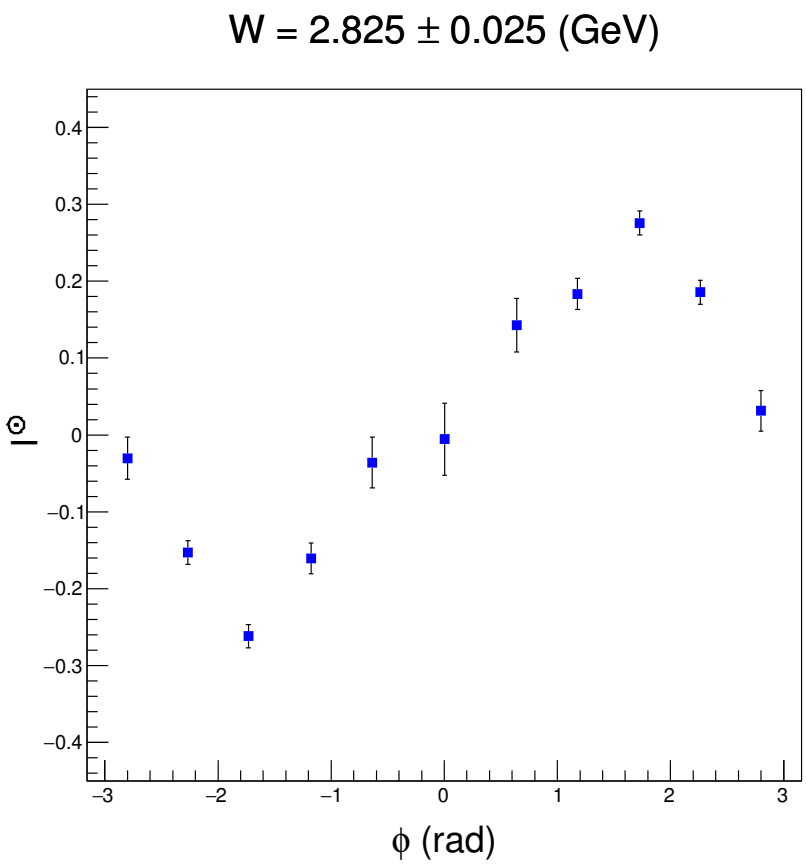

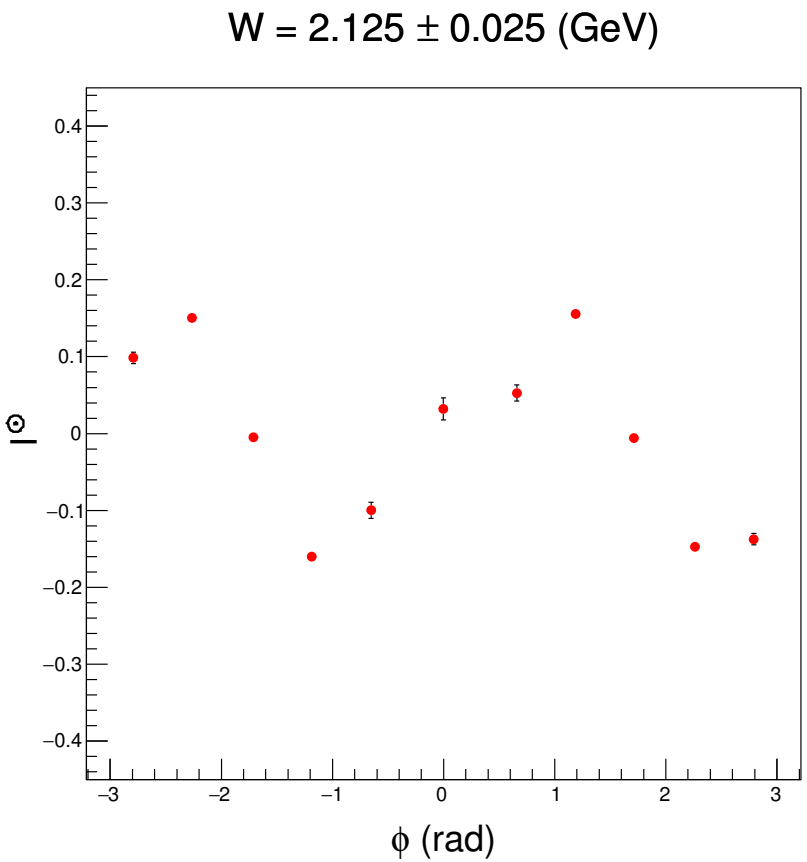

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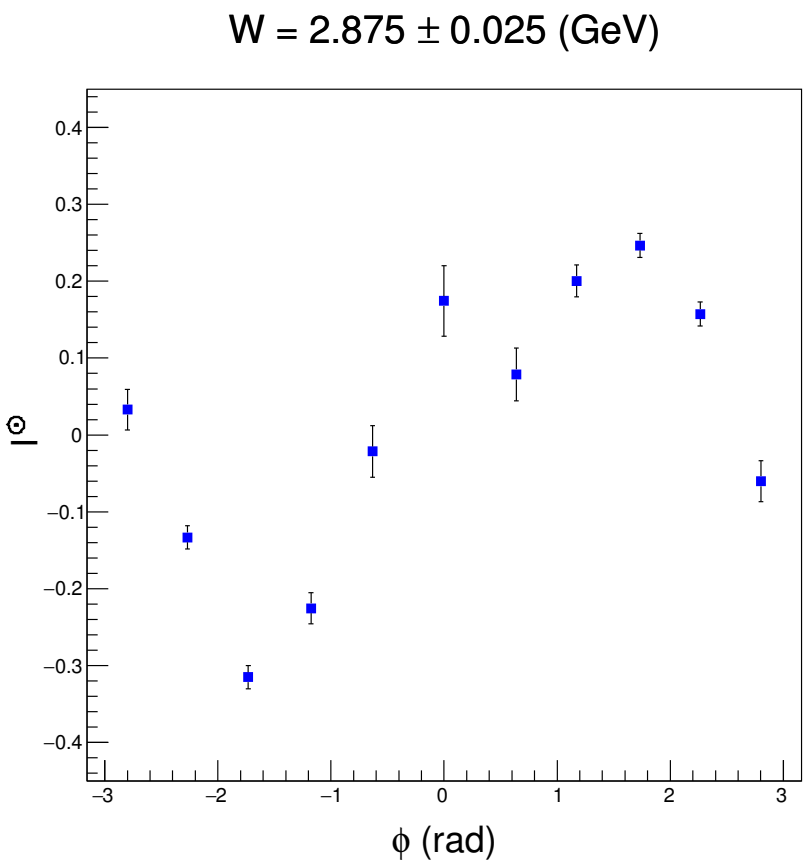

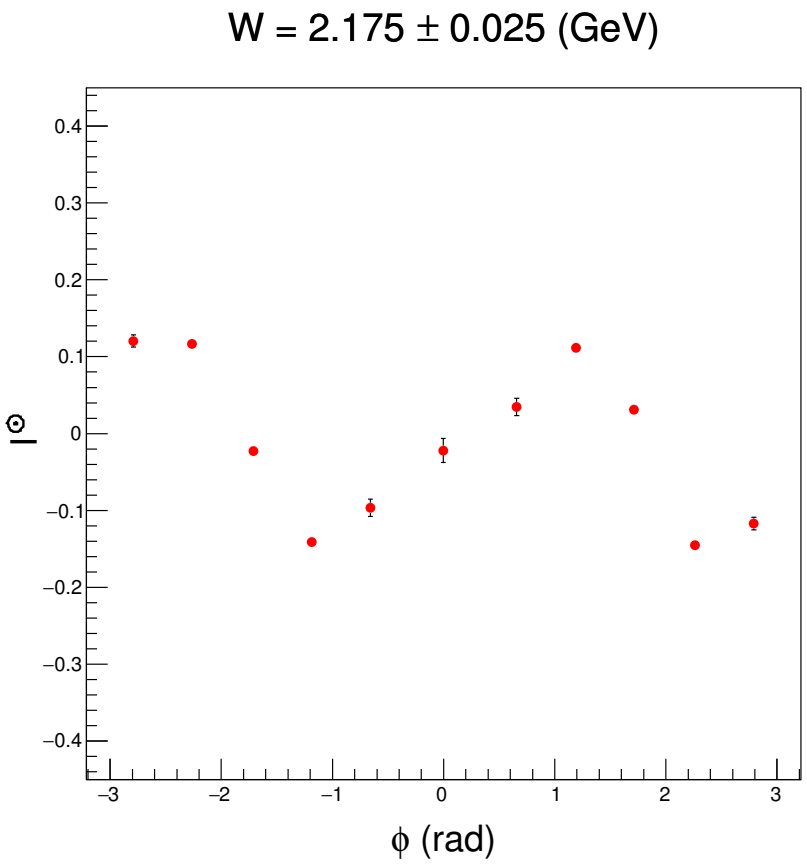

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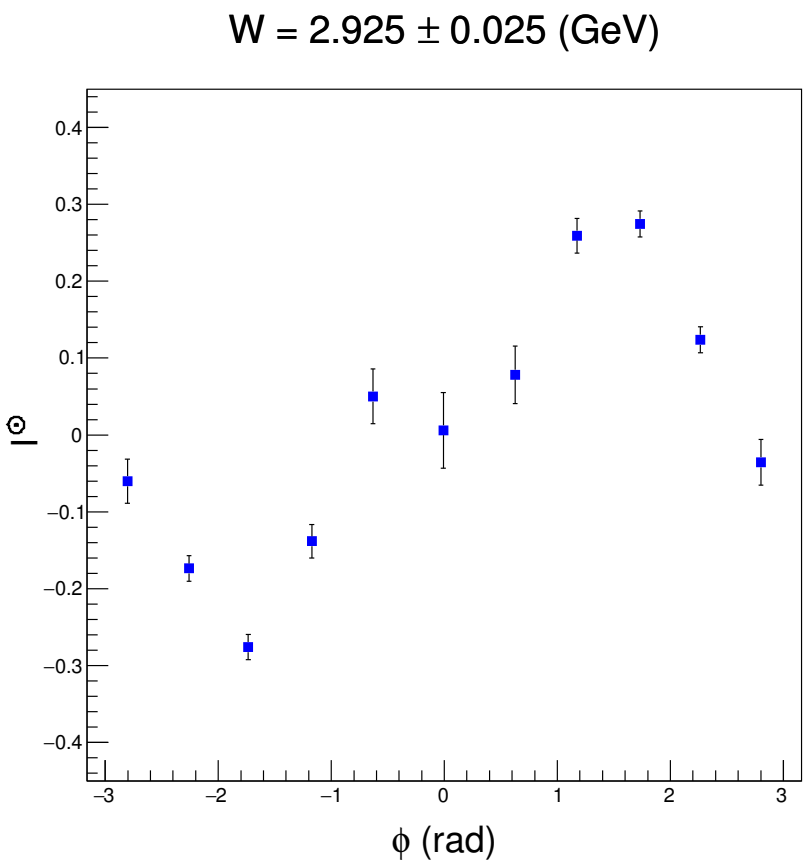

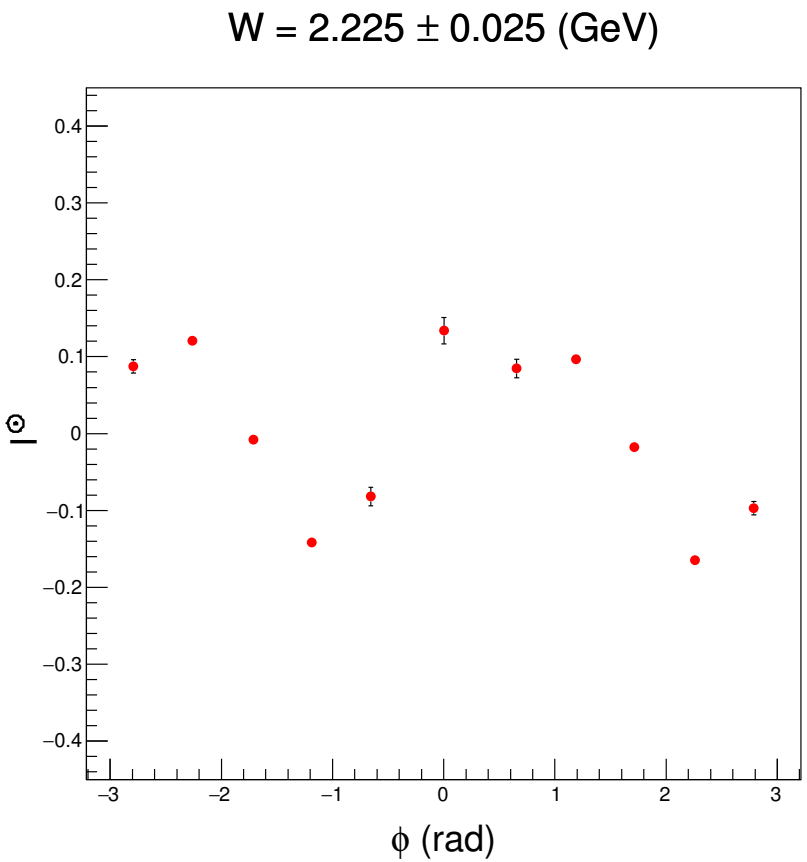

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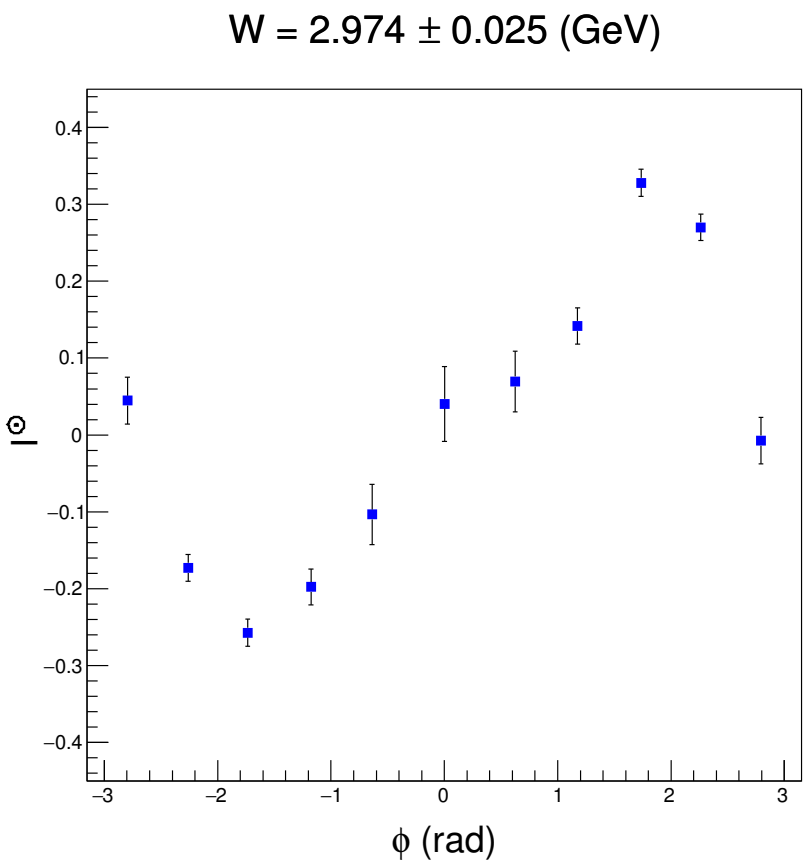

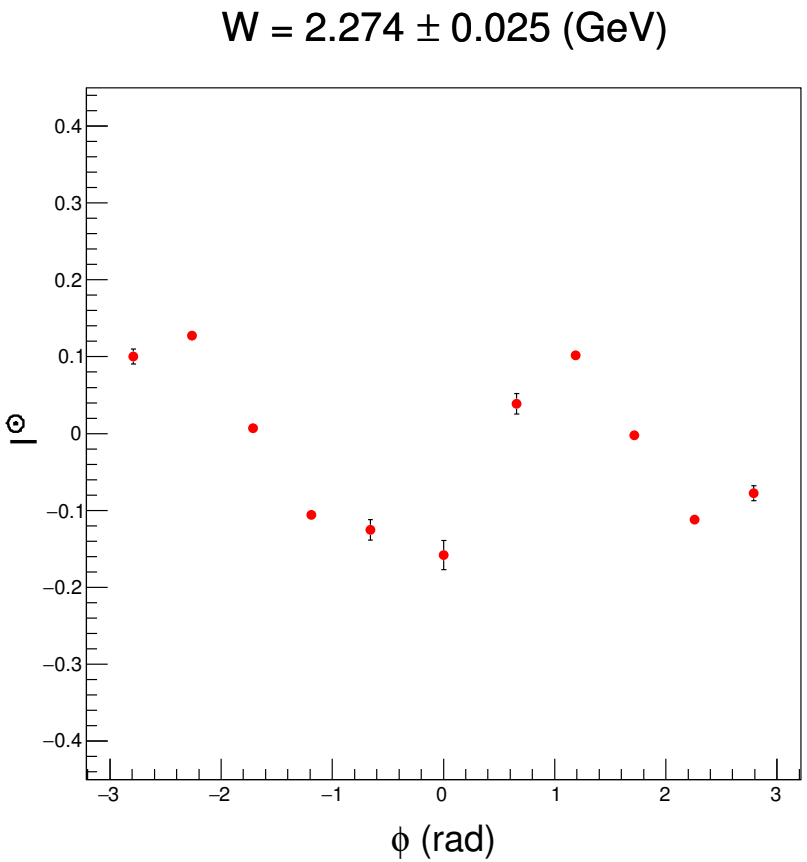

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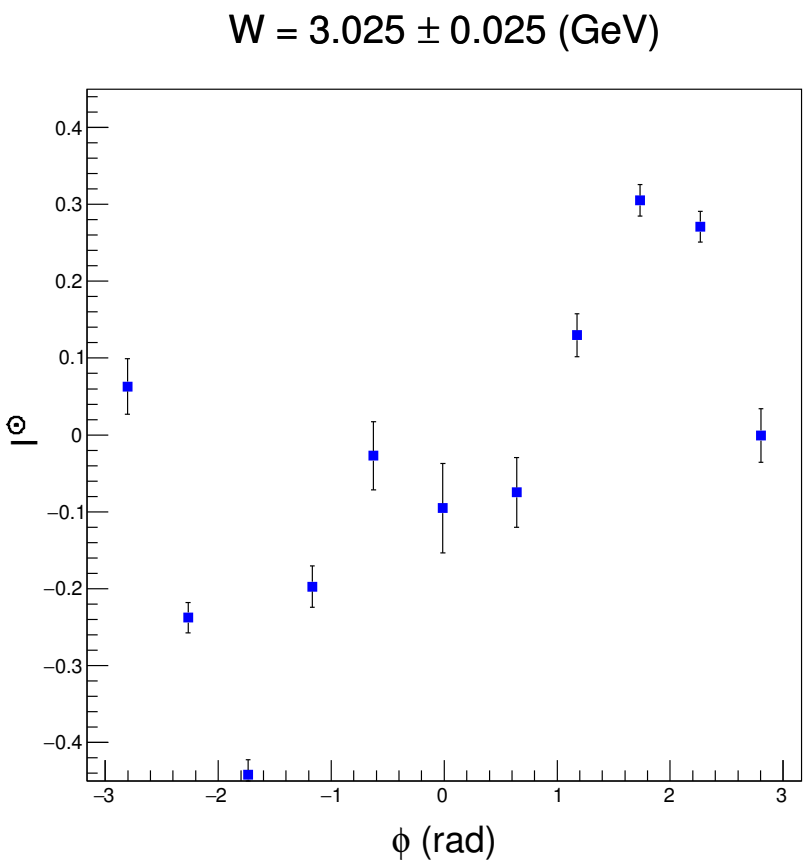

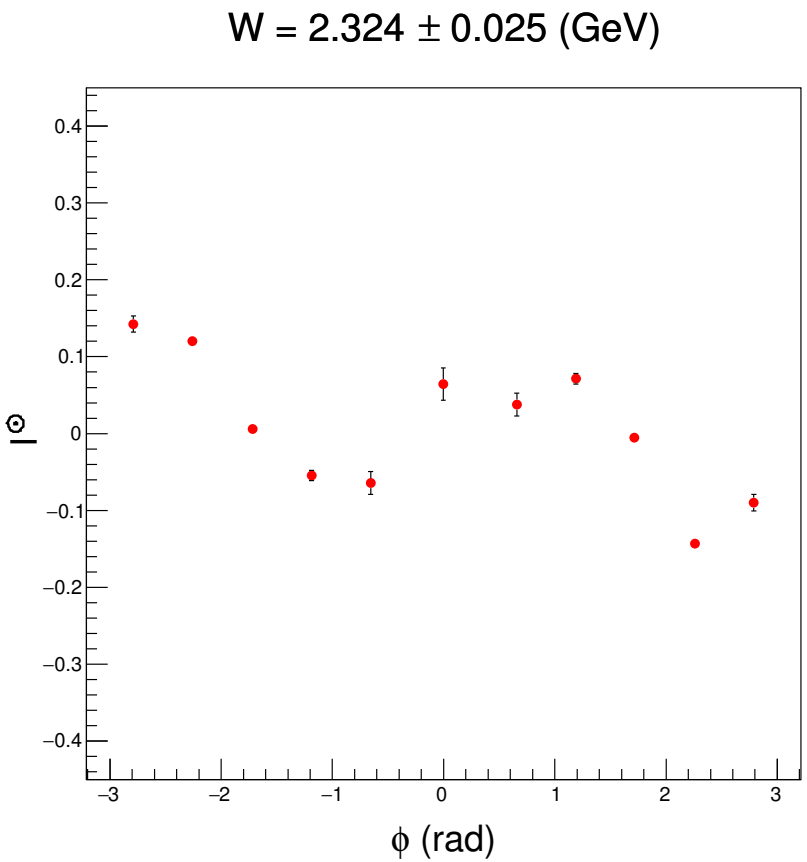

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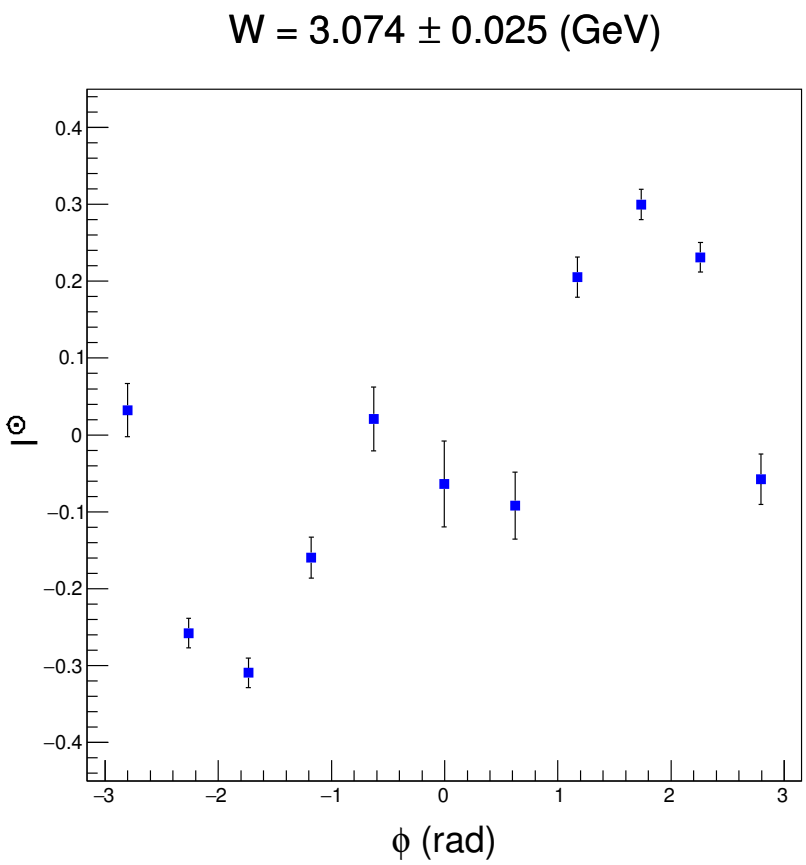

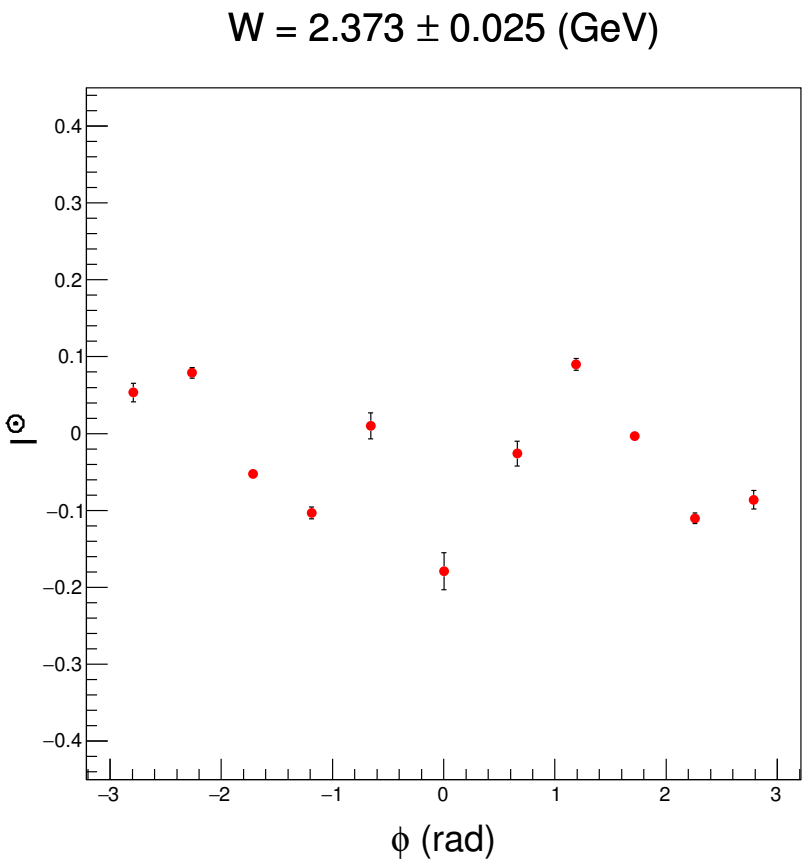

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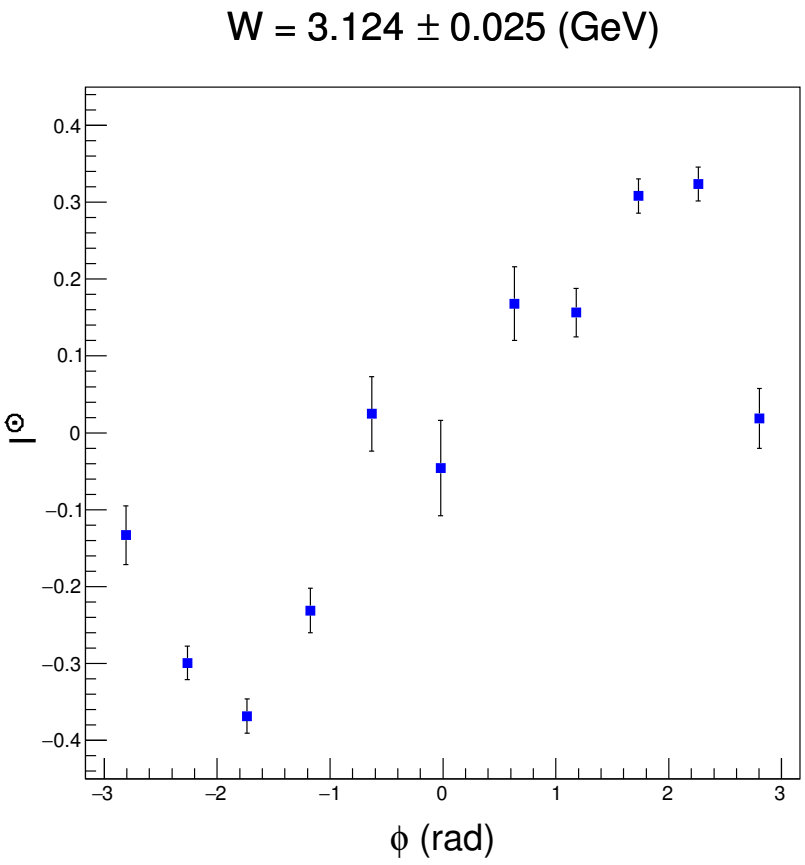

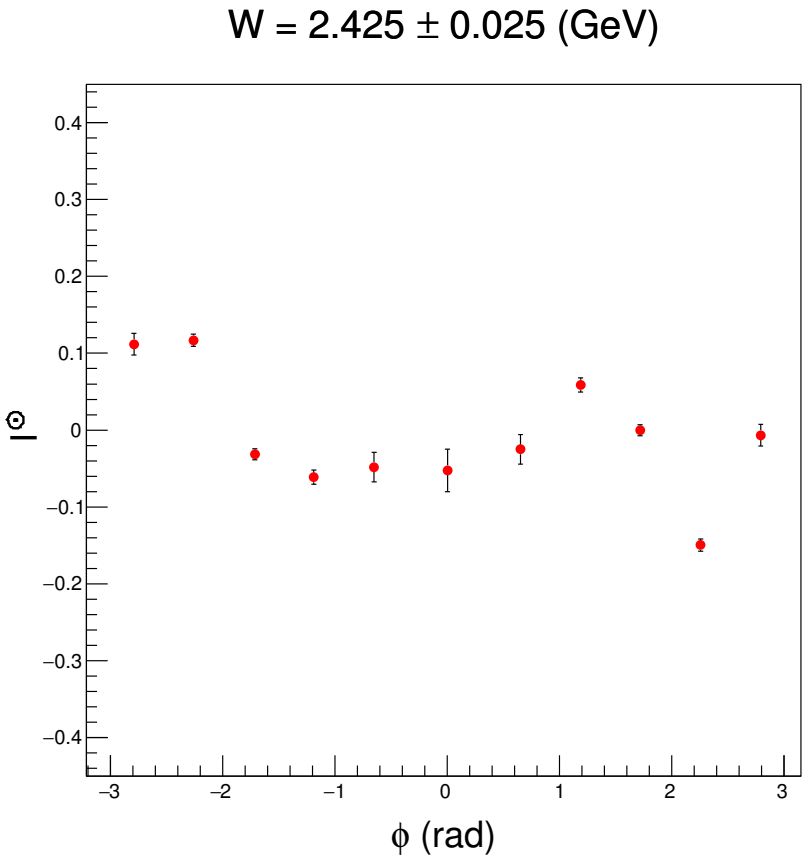

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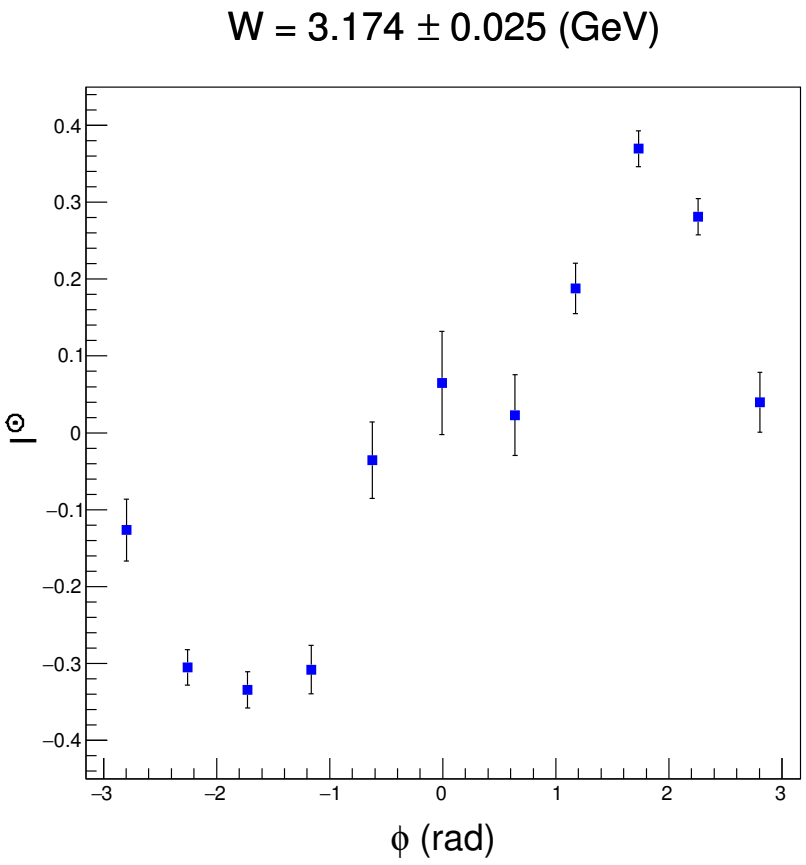

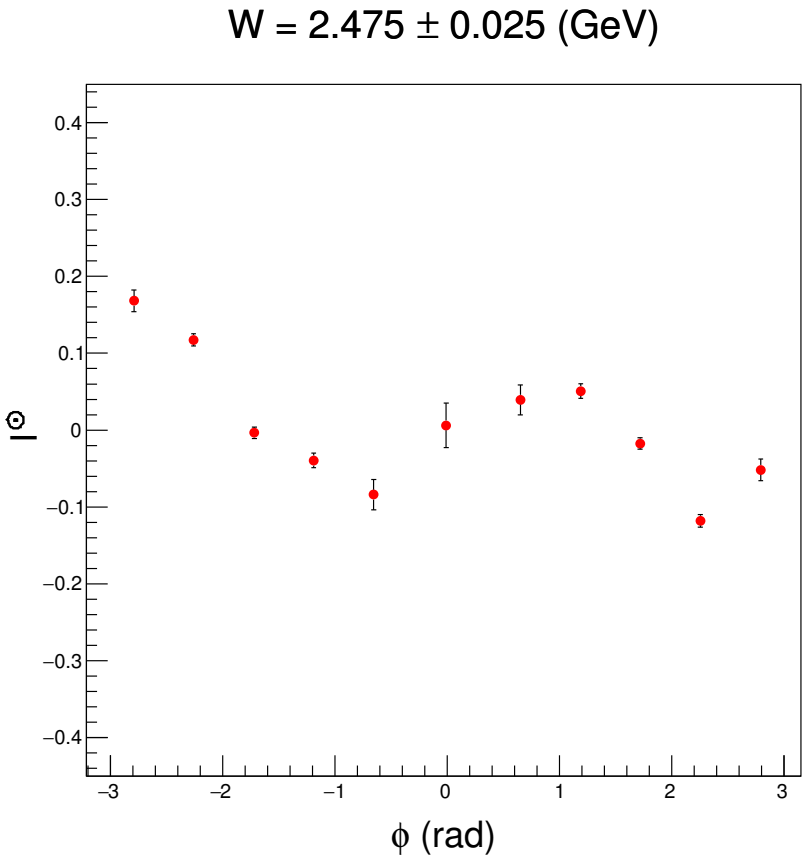

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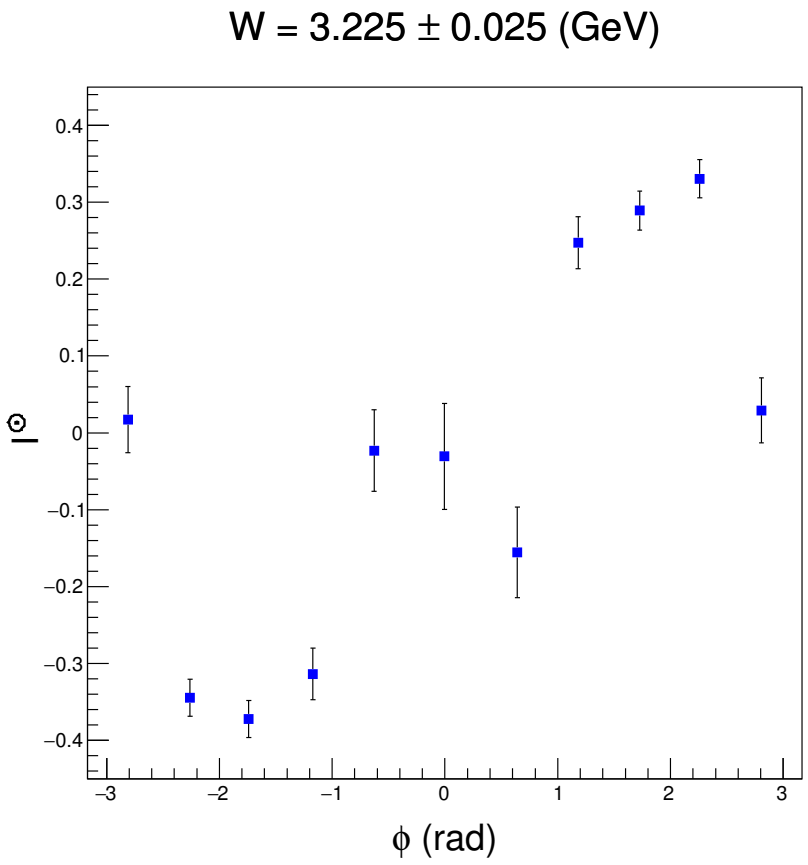

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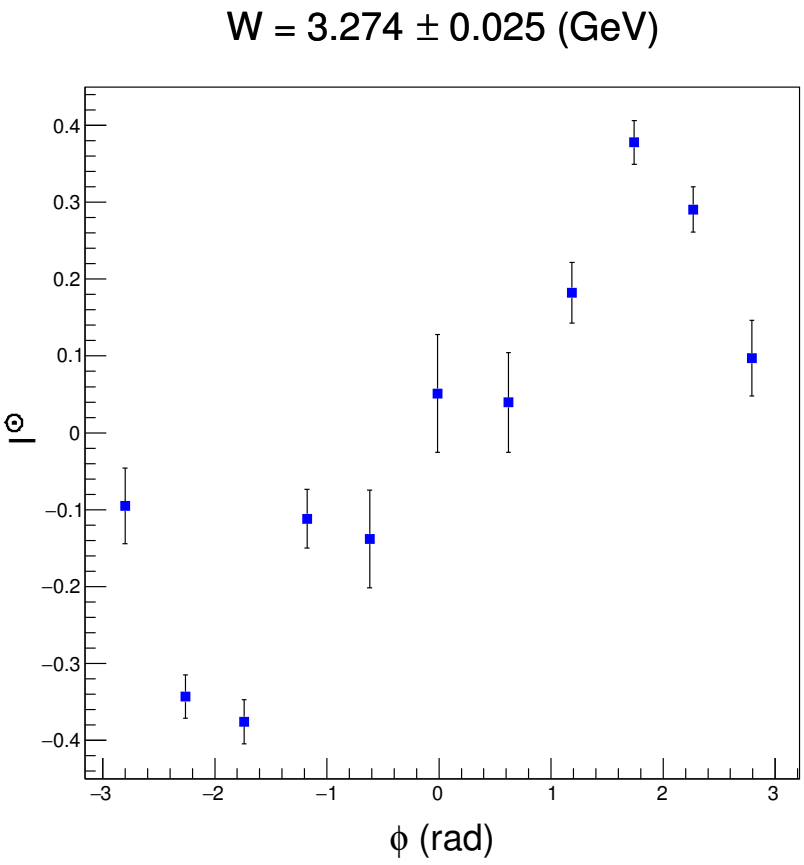

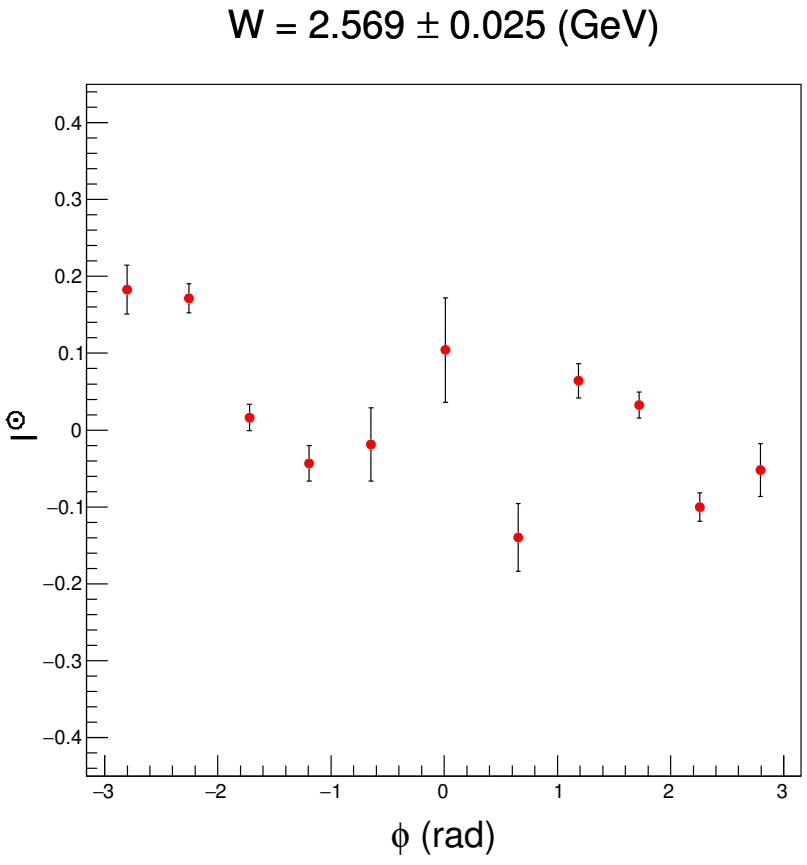

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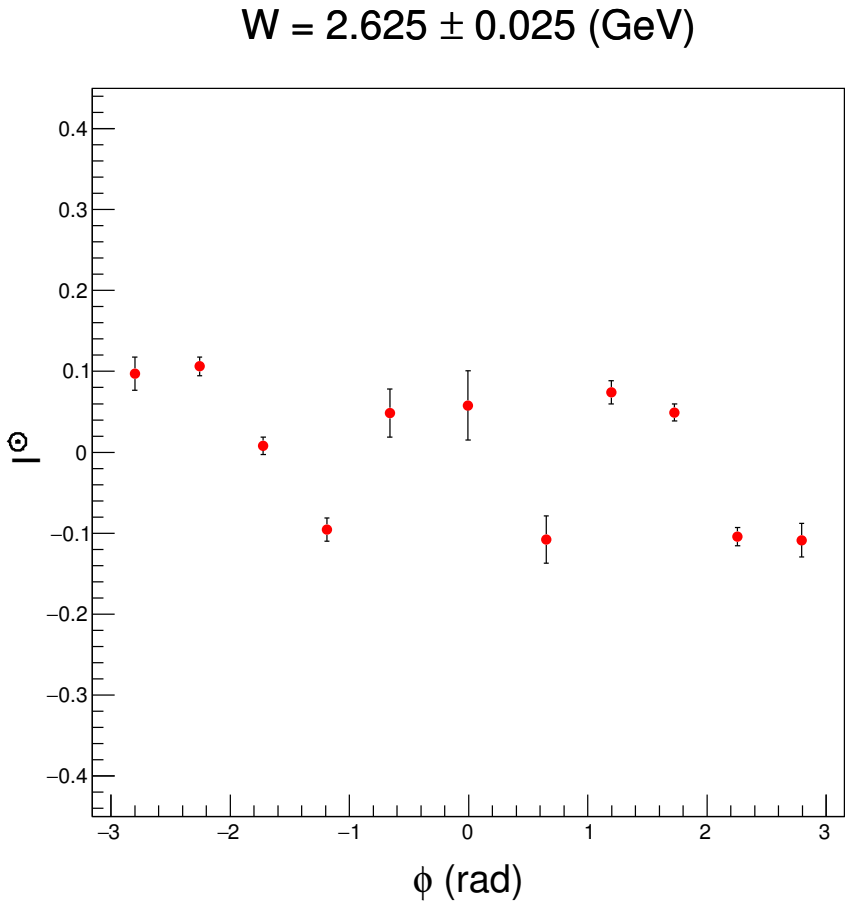
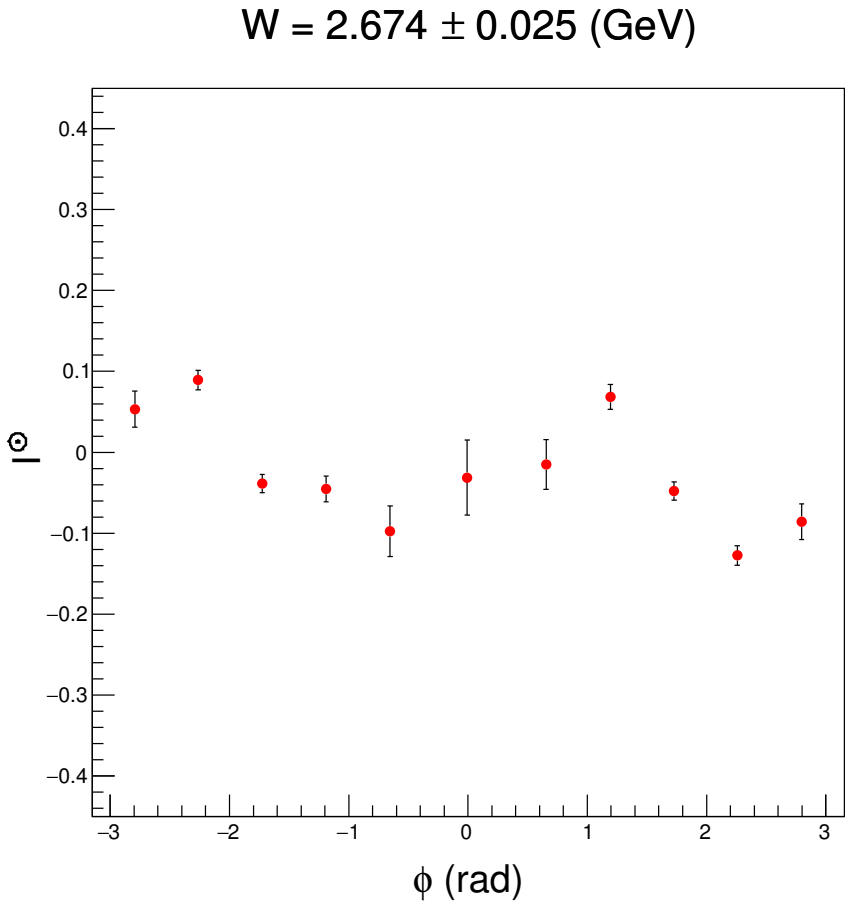


Preliminary Analysis



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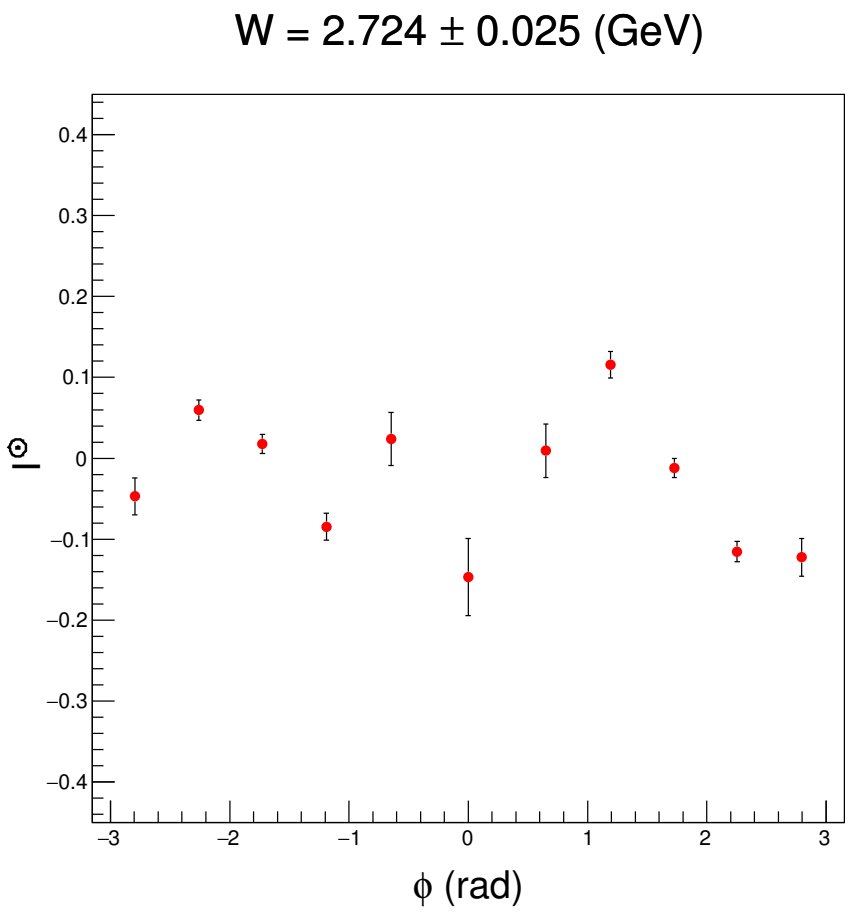

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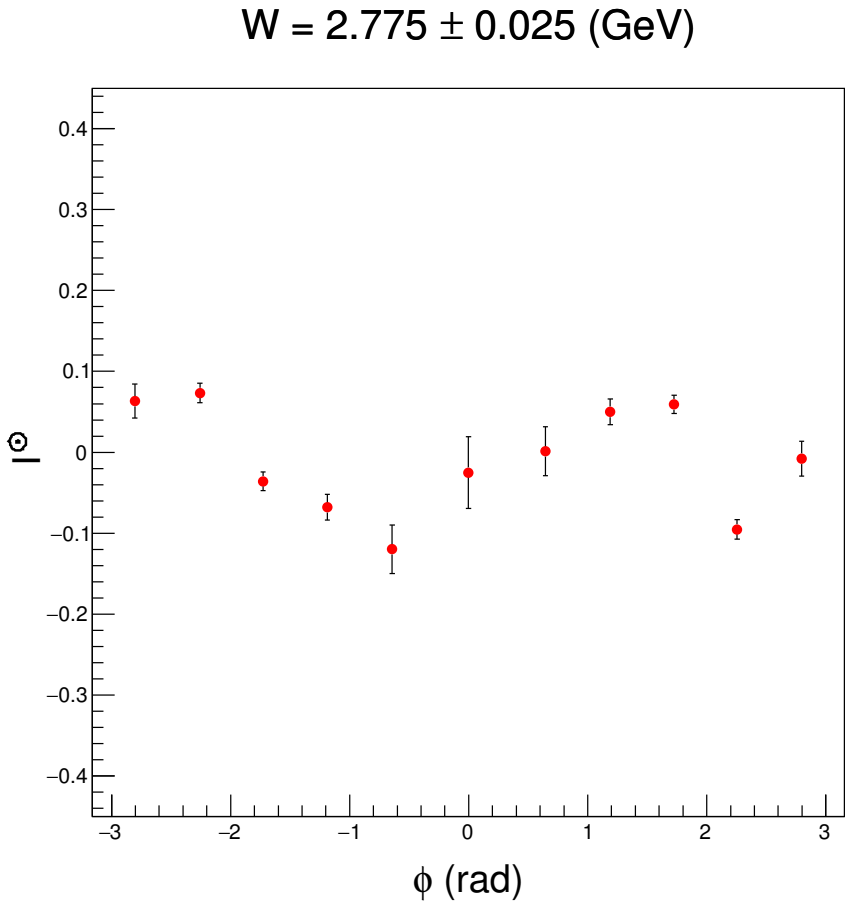

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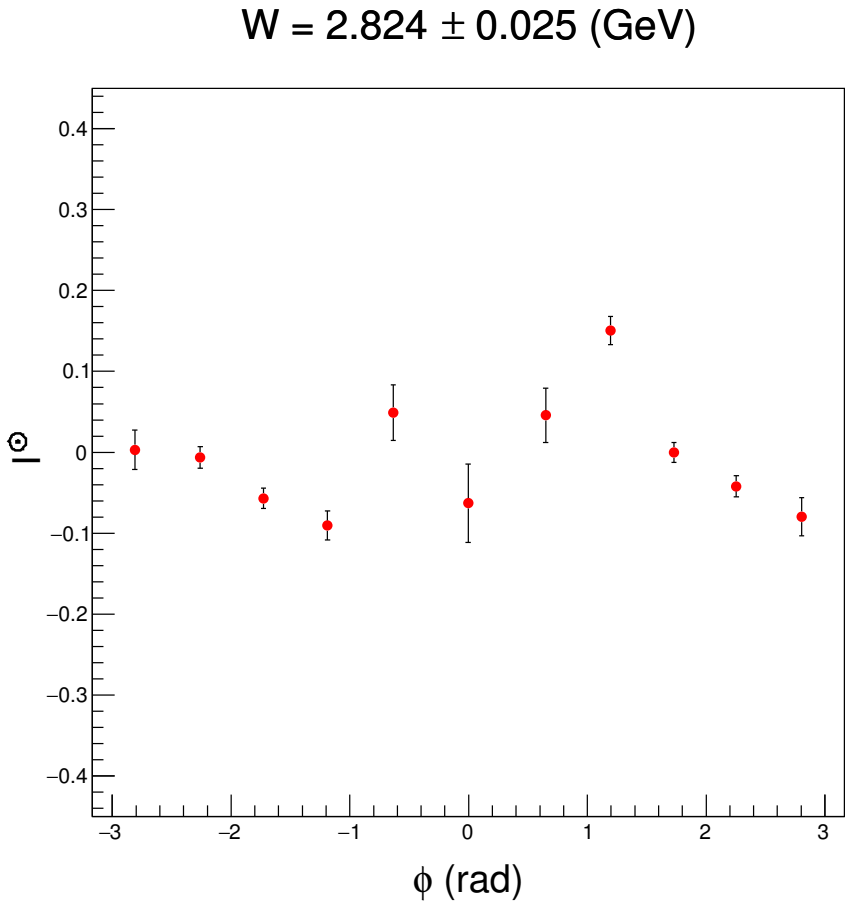

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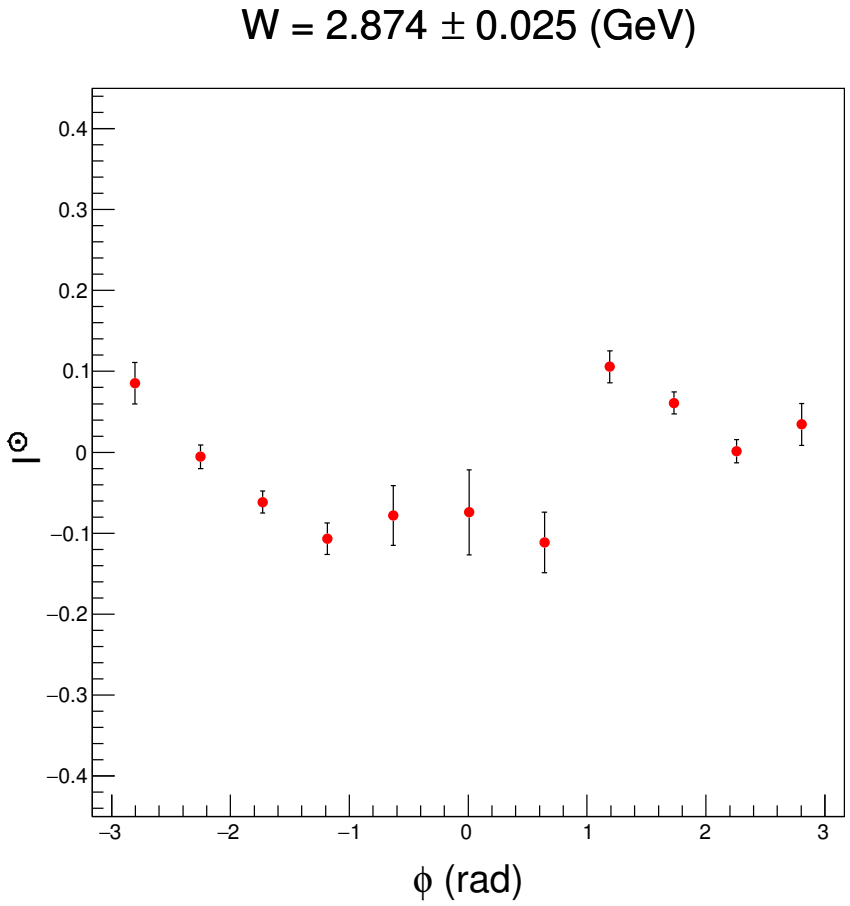

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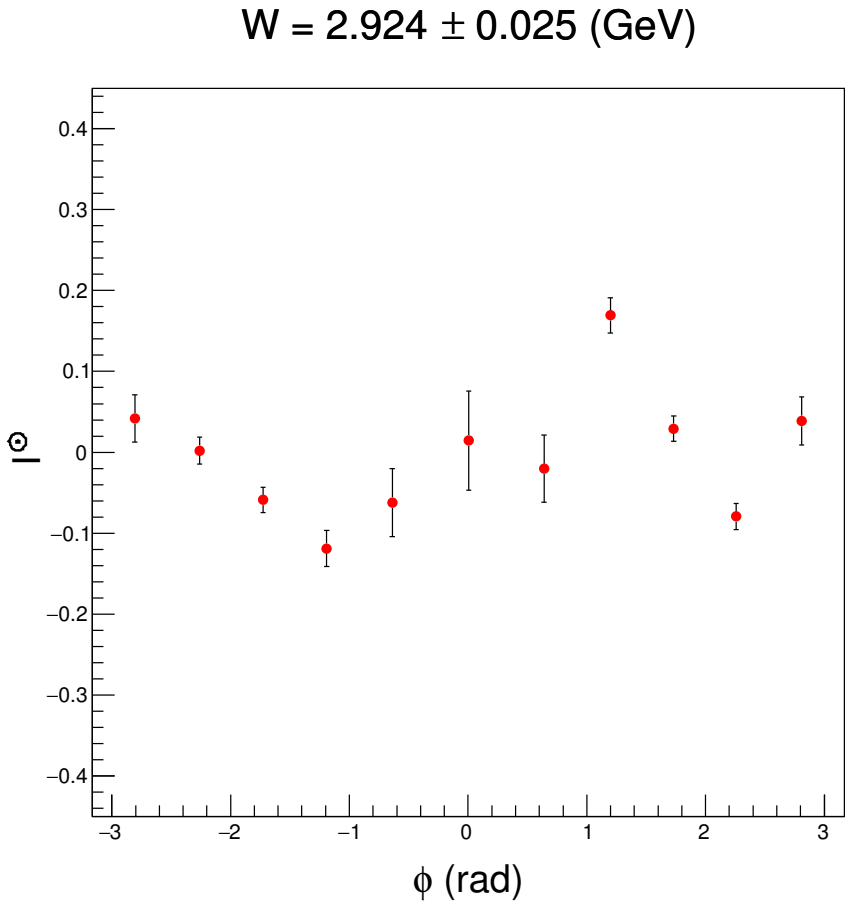

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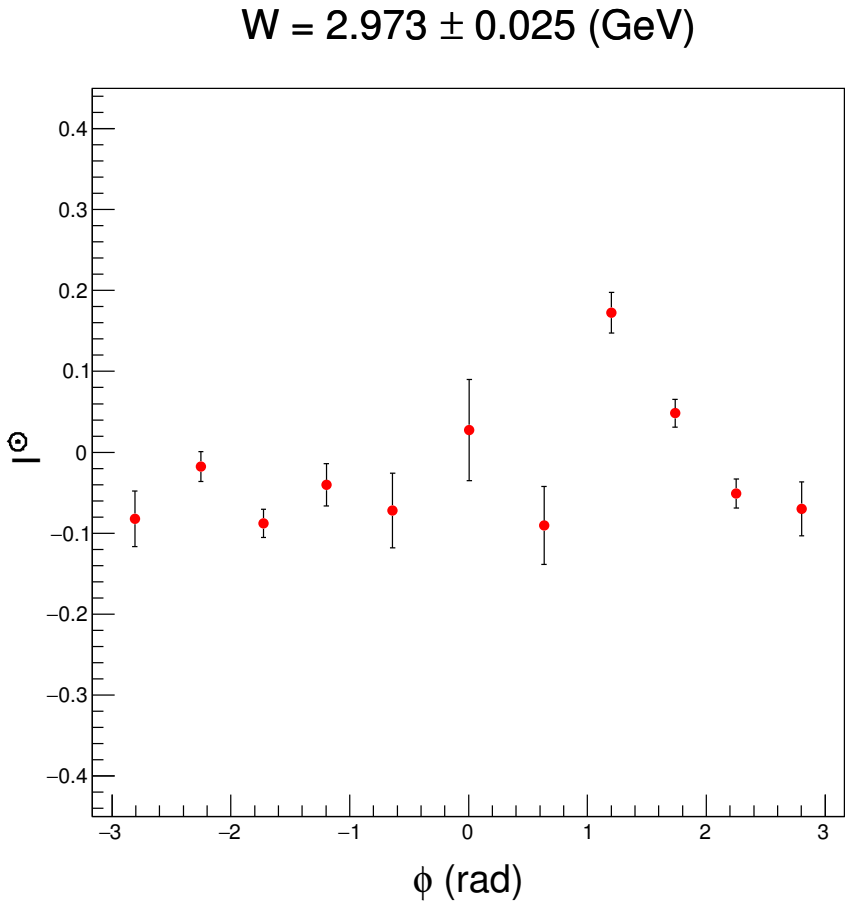


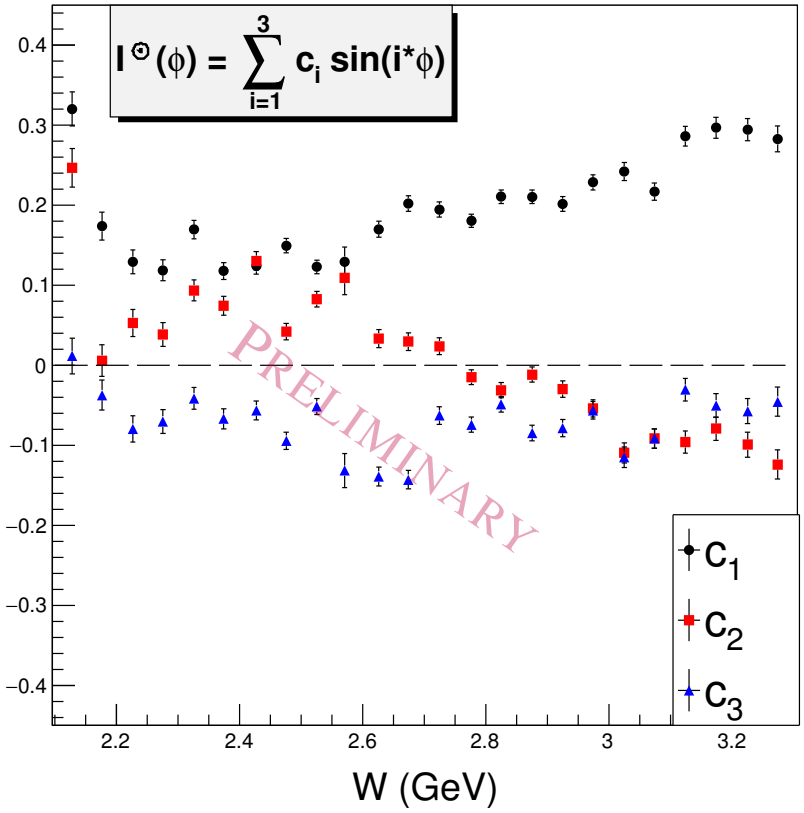
Preliminary Analysis

Replay

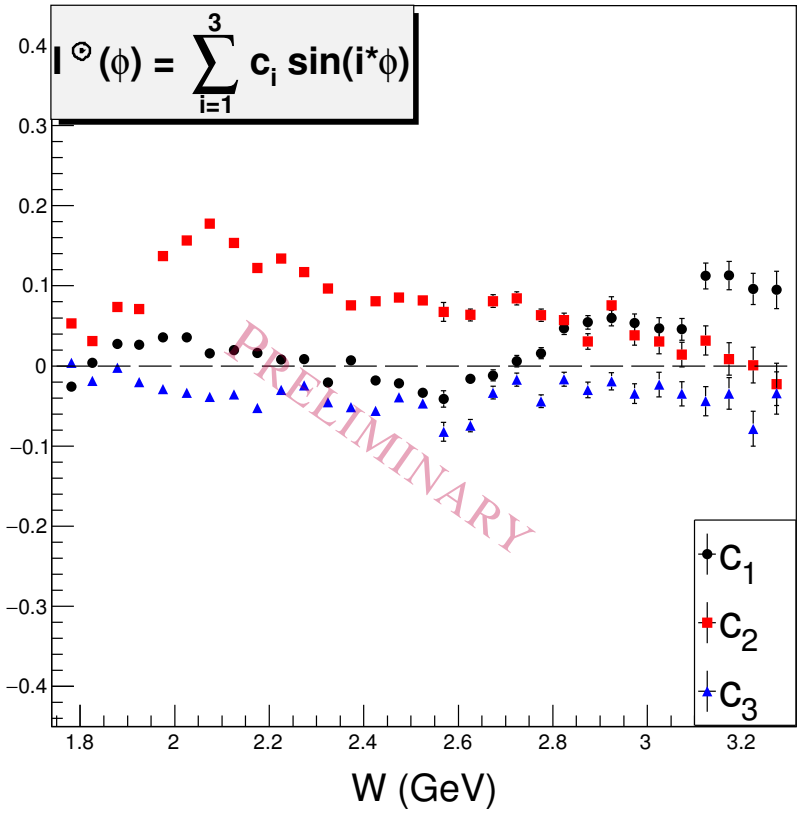
All Plots Side-by-Side

Preliminary Analysis

$\gamma p \to pK^+K^-$



$\gamma p \to p\pi^+\pi^-$



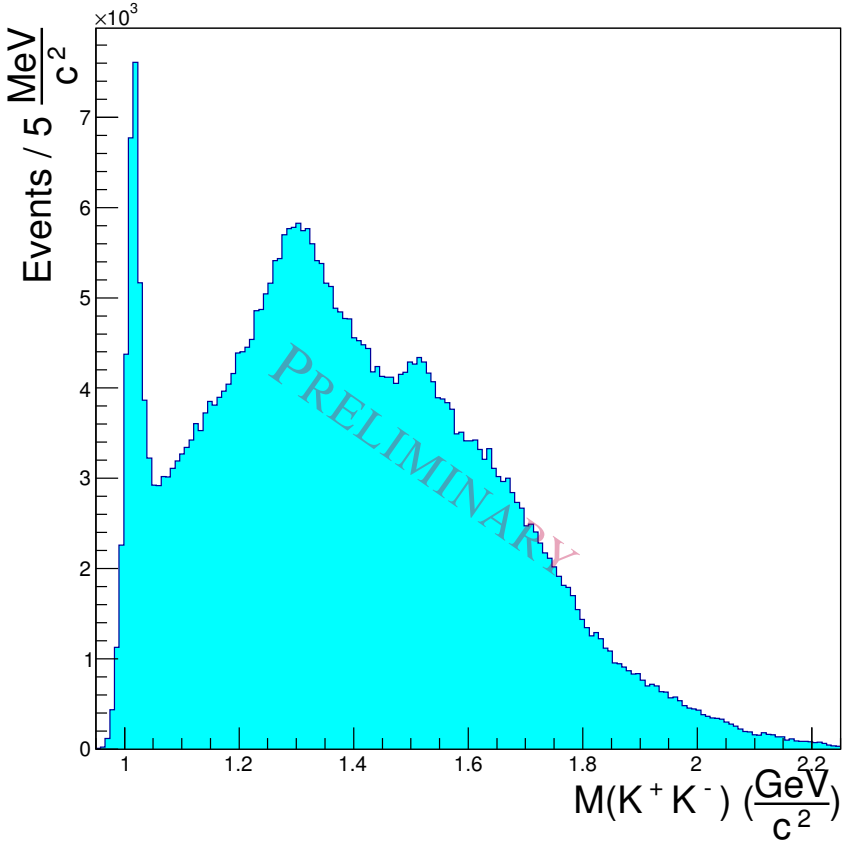
Preliminary Analysis

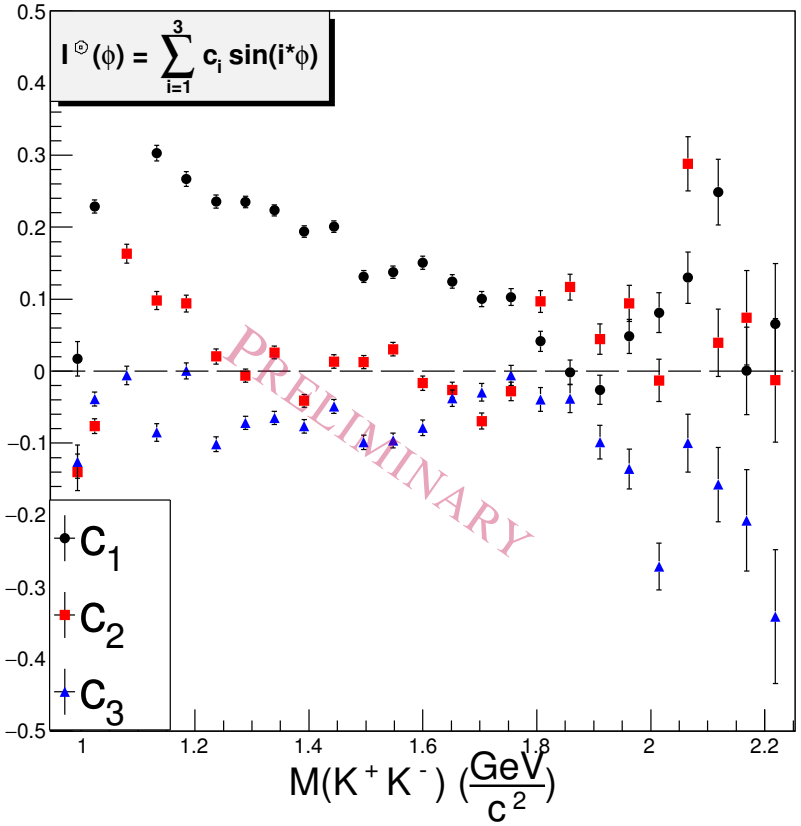
- Fourier analysis shows clearer picture
- Pion asymmetry is mostly $\sin(2\phi)$ dominated
- Kaon asymmetry is $\sin(\phi)$ dominated
- Sensitive to w

Preliminary Analysis

- Can make asymmetry measurements binning with respect to different kinematic variables

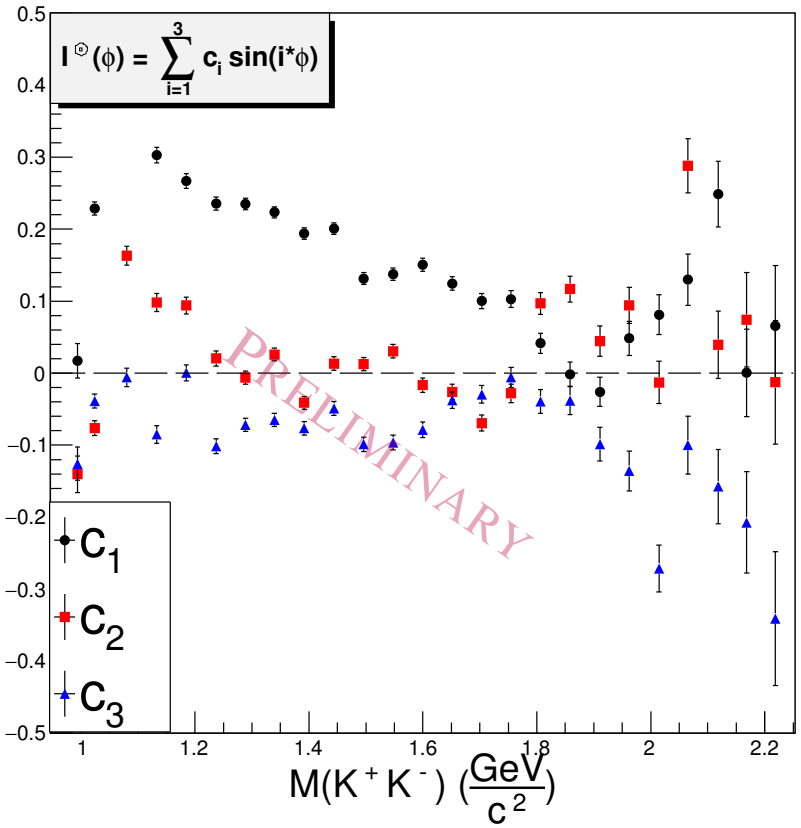
Preliminary Analysis



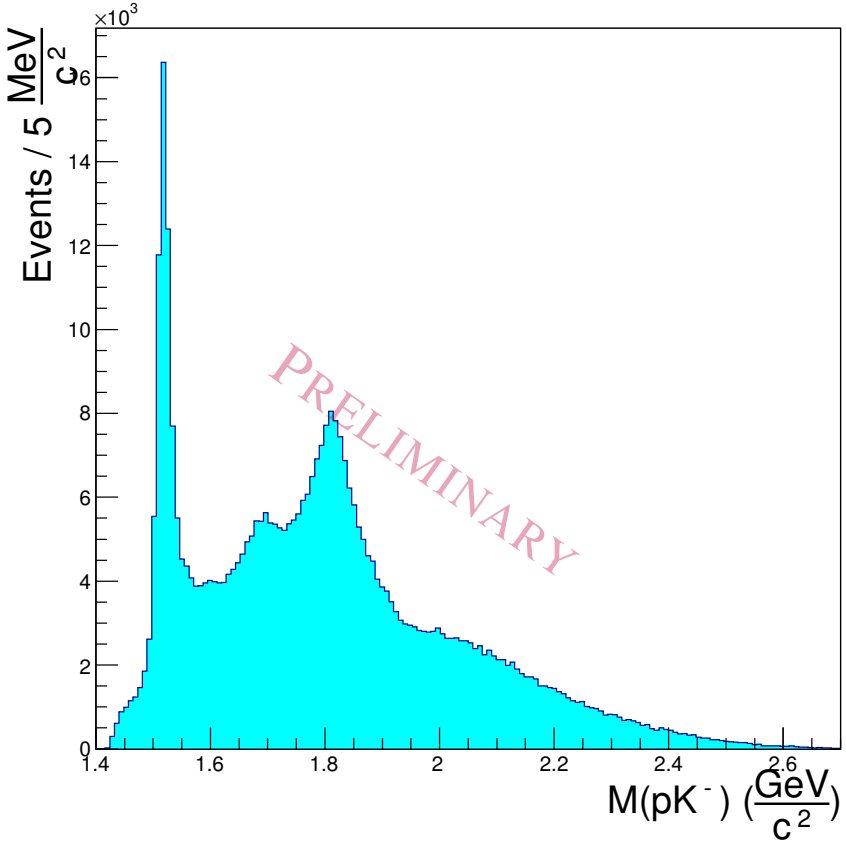


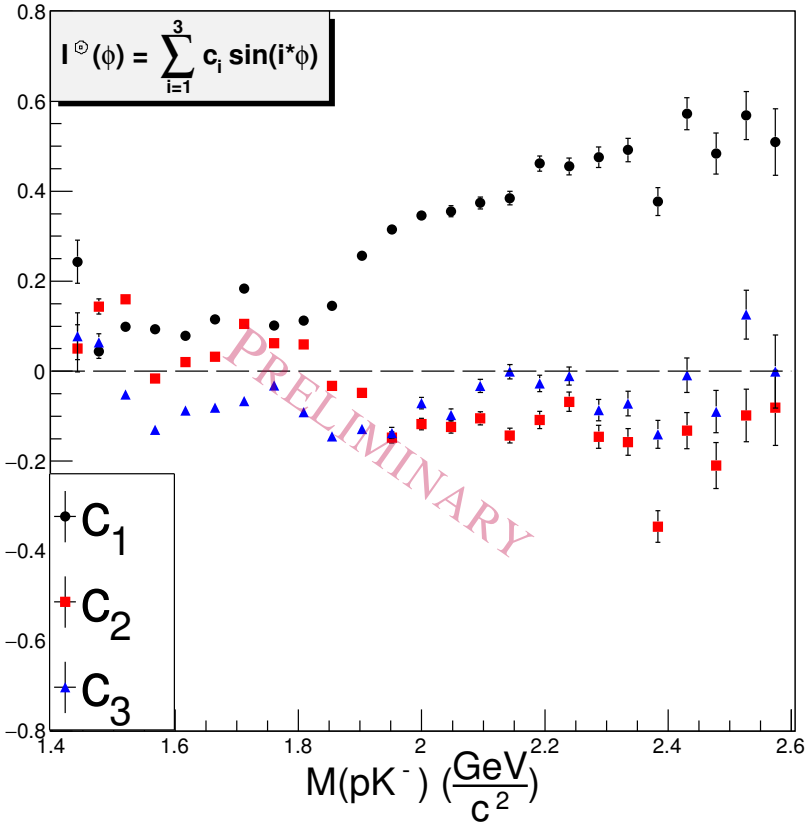
Preliminary Analysis

- Overall asymmetry amplitude decreases as invariant mass increases



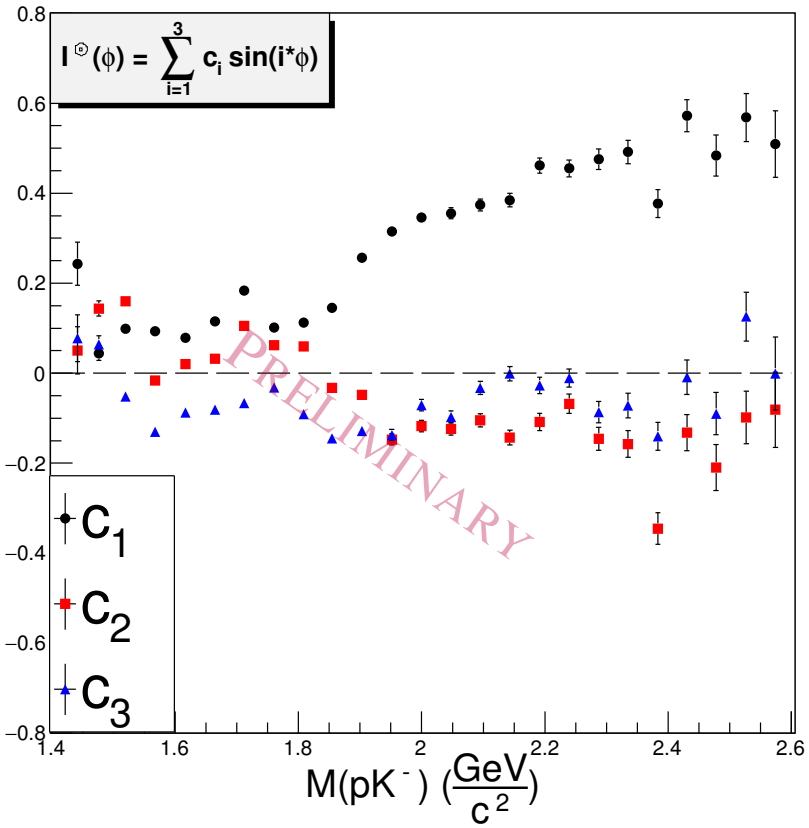
Preliminary Analysis





Preliminary Analysis

- Overall amplitude increases as invariant mass increases
- Amplitude greater than 0.5 at masses greater than 2.2 GeV



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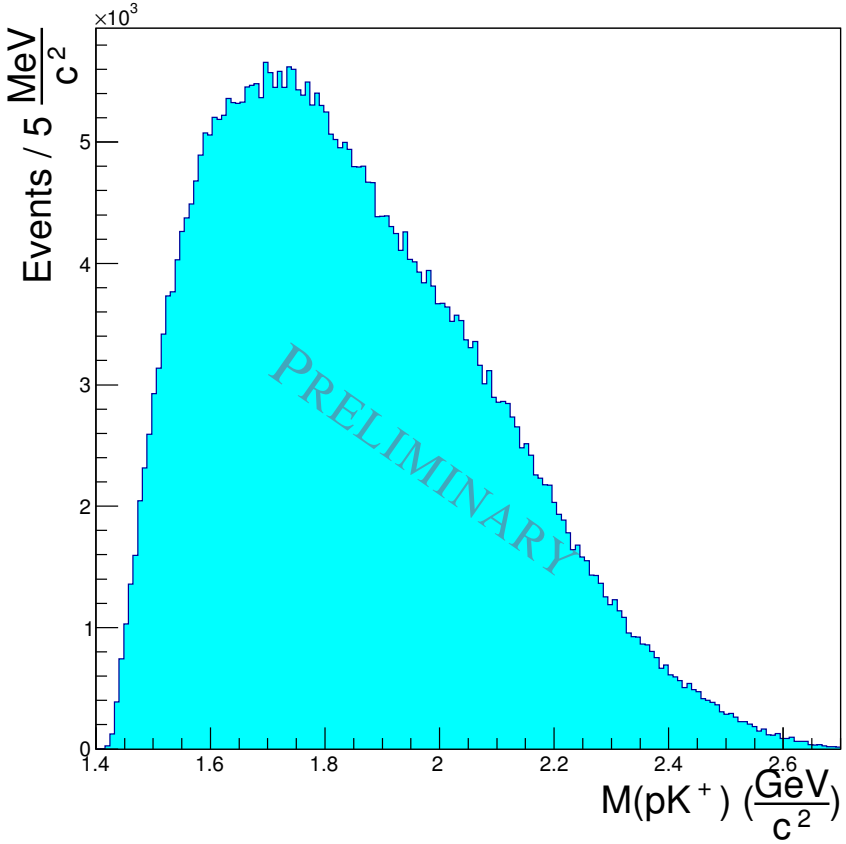
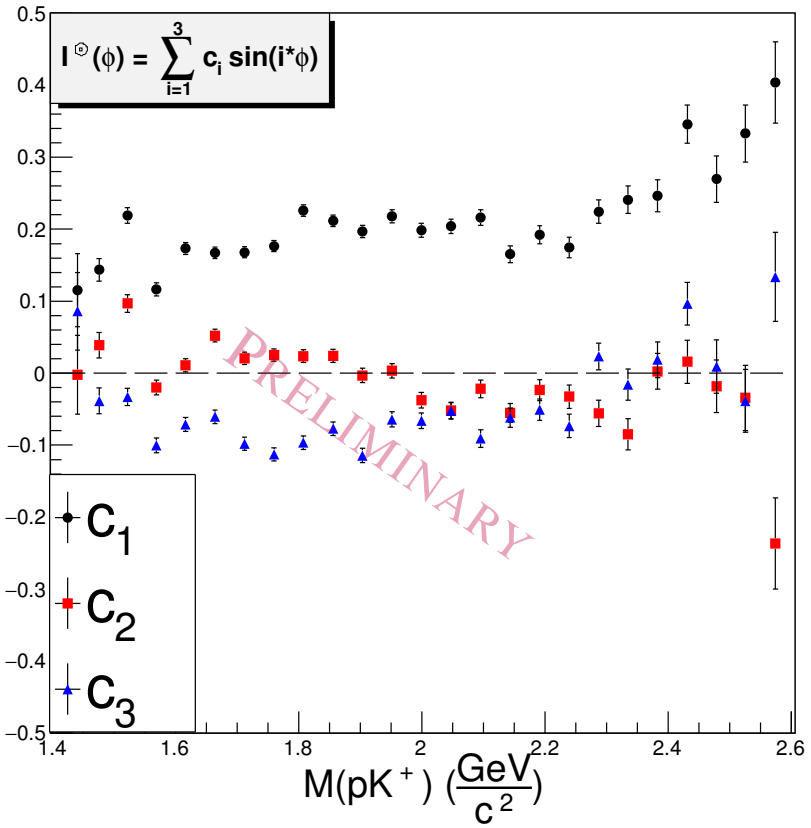
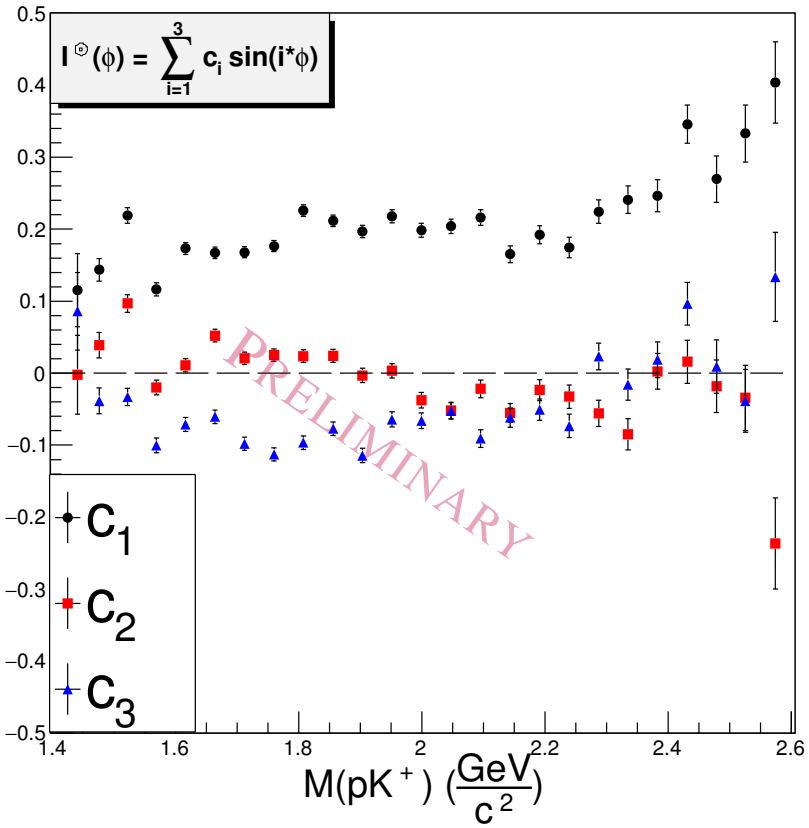


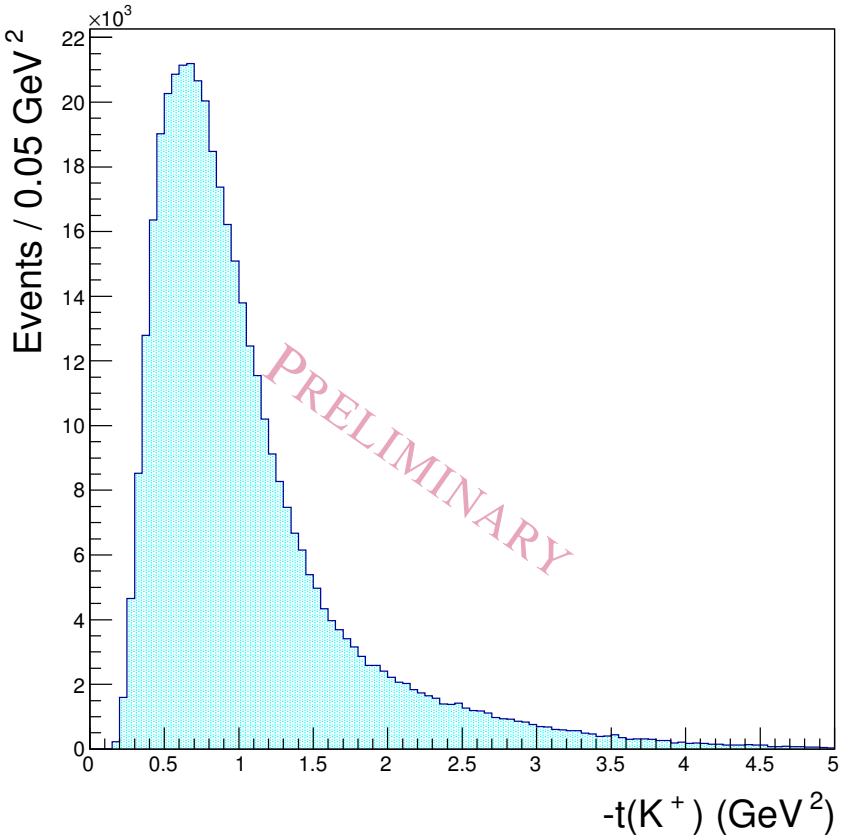


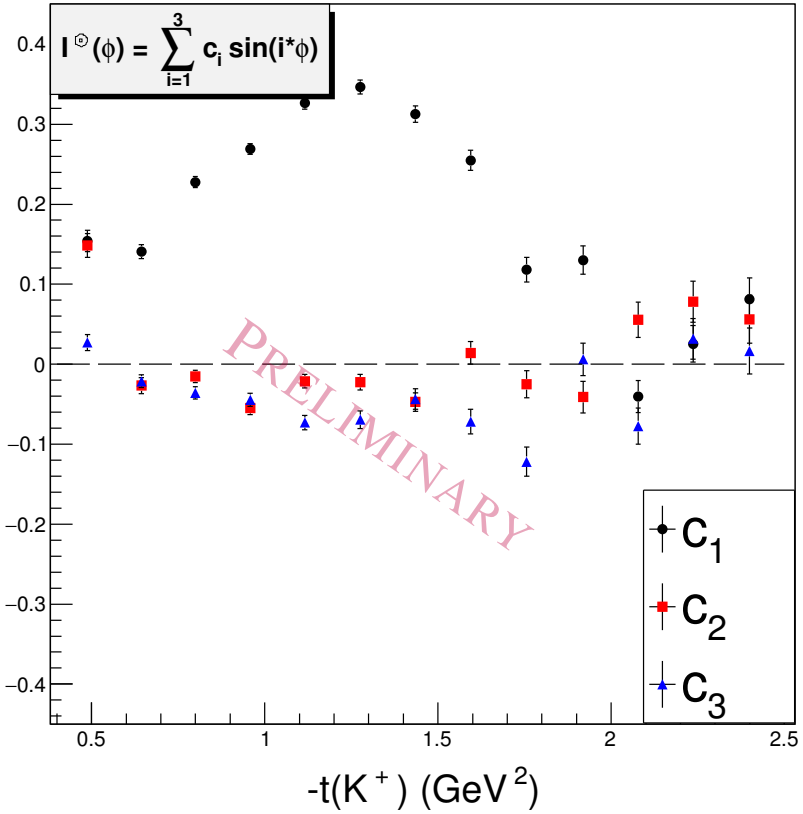
Preliminary Analysis

- Overall, approximately constant asymmetry



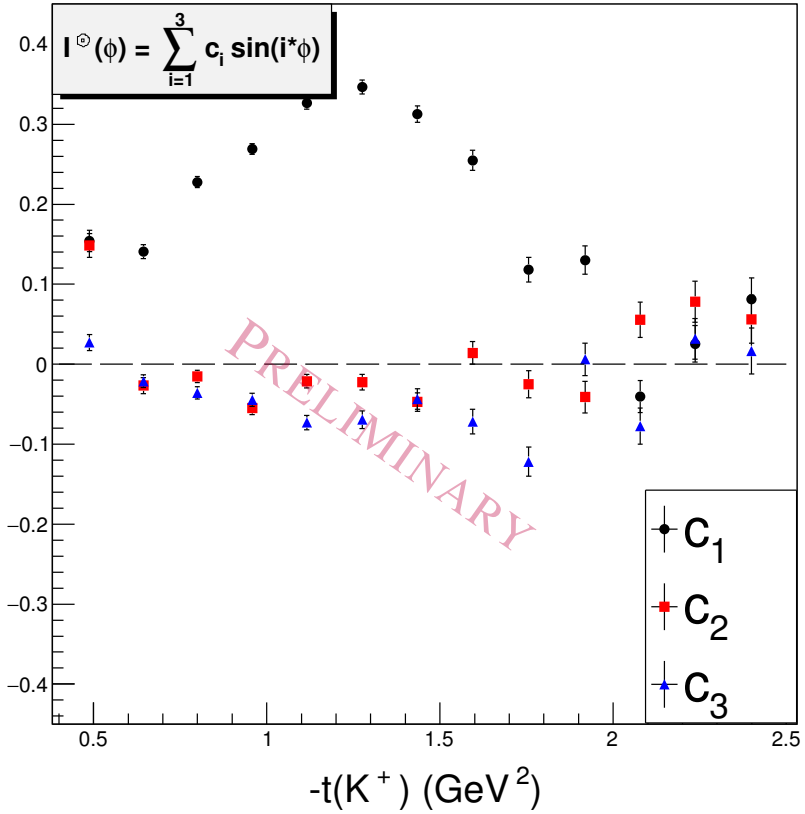
Preliminary Analysis



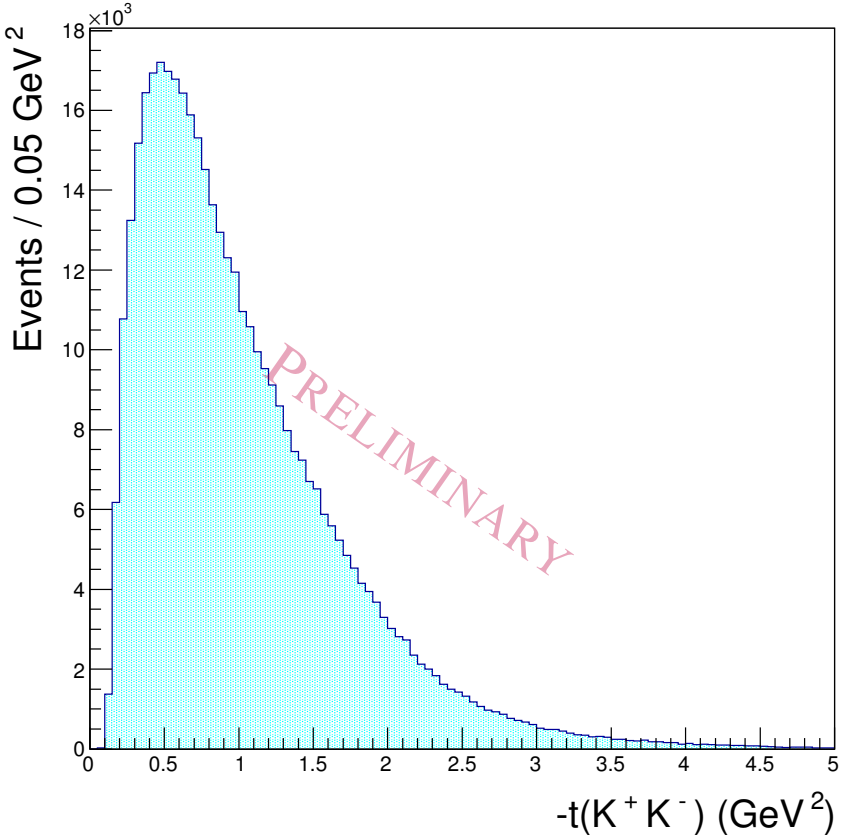


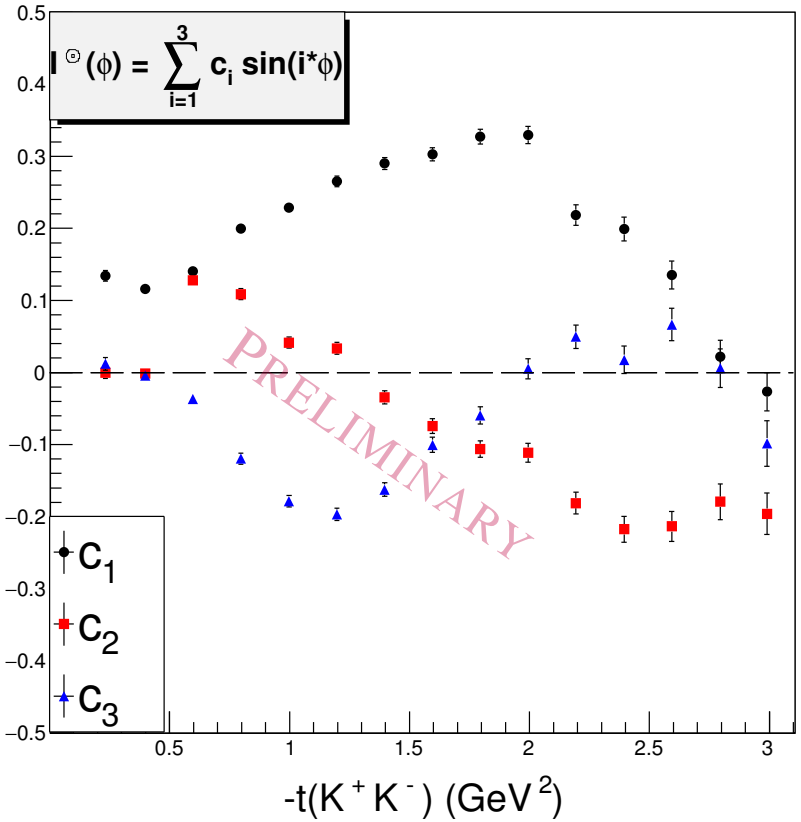
Preliminary Analysis

- Smooth dependence on t
- Amplitude achieves maximum at $-t \approx 1.25\text{GeV}^2$



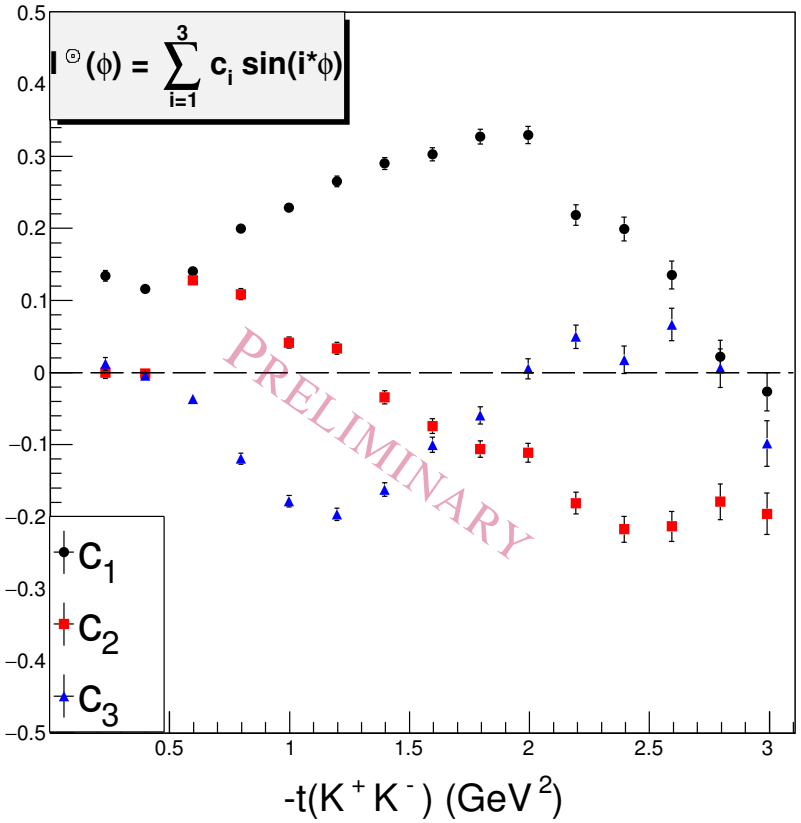
Preliminary Analysis





Preliminary Analysis

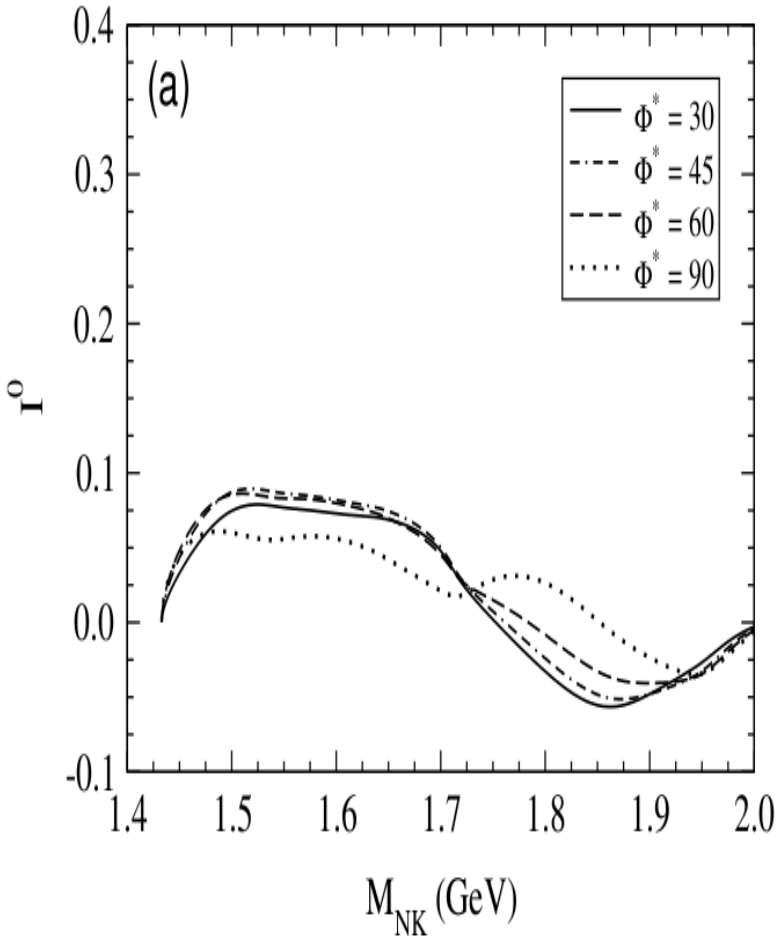
- Also shows interesting features

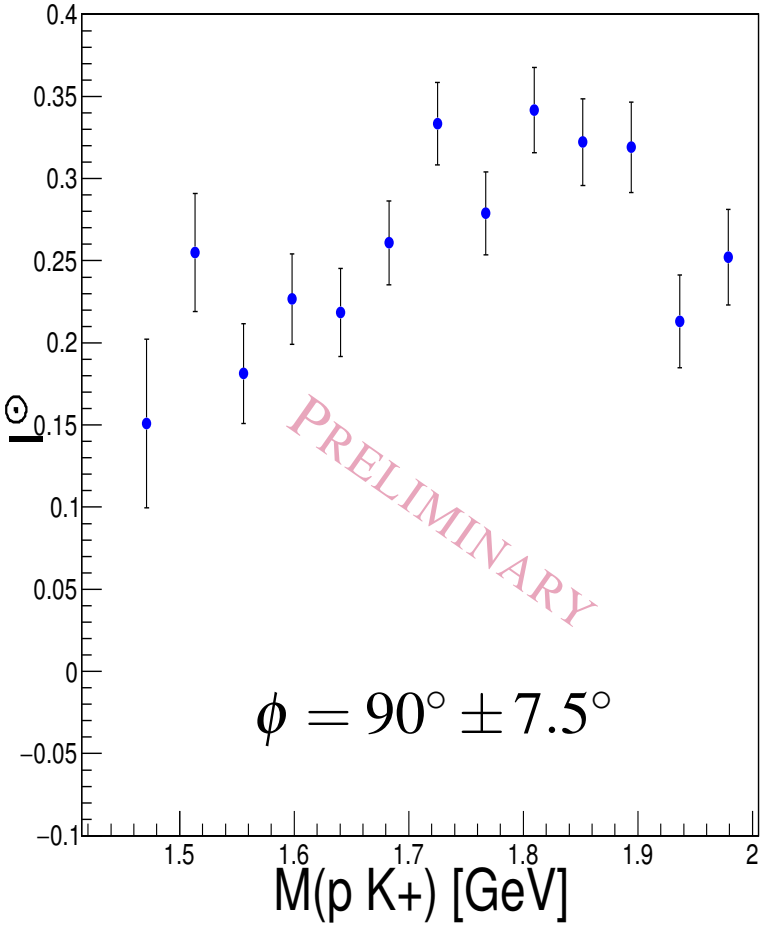


Preliminary Analysis

- Can make asymmetry measurements binning with respect to different kinematic variables
- Can compare to theory

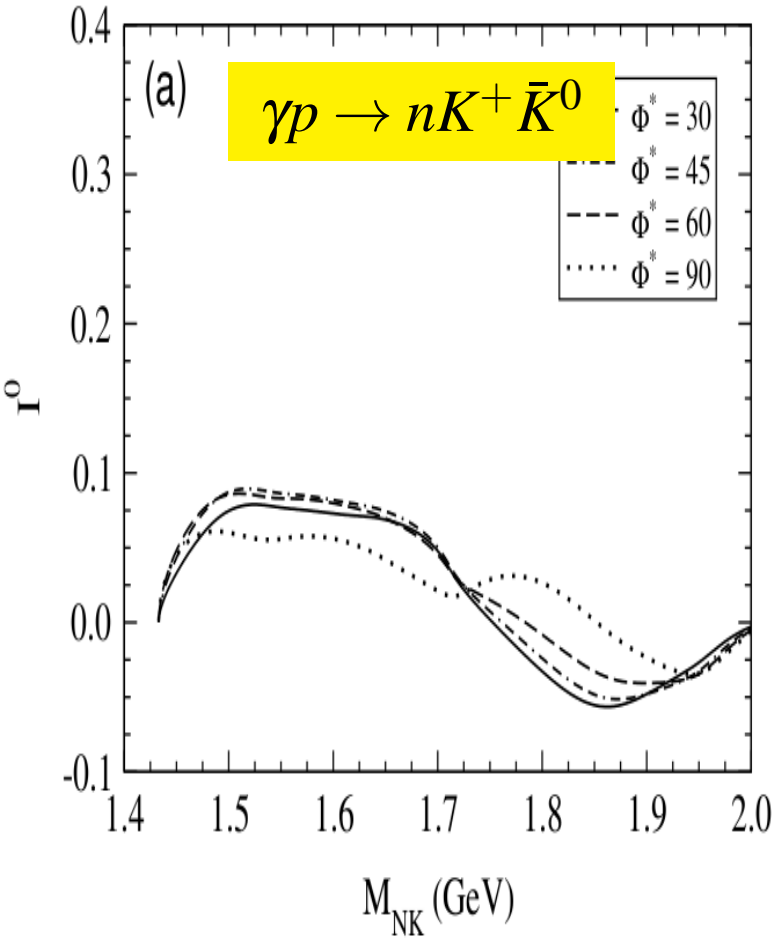
Preliminary Analysis

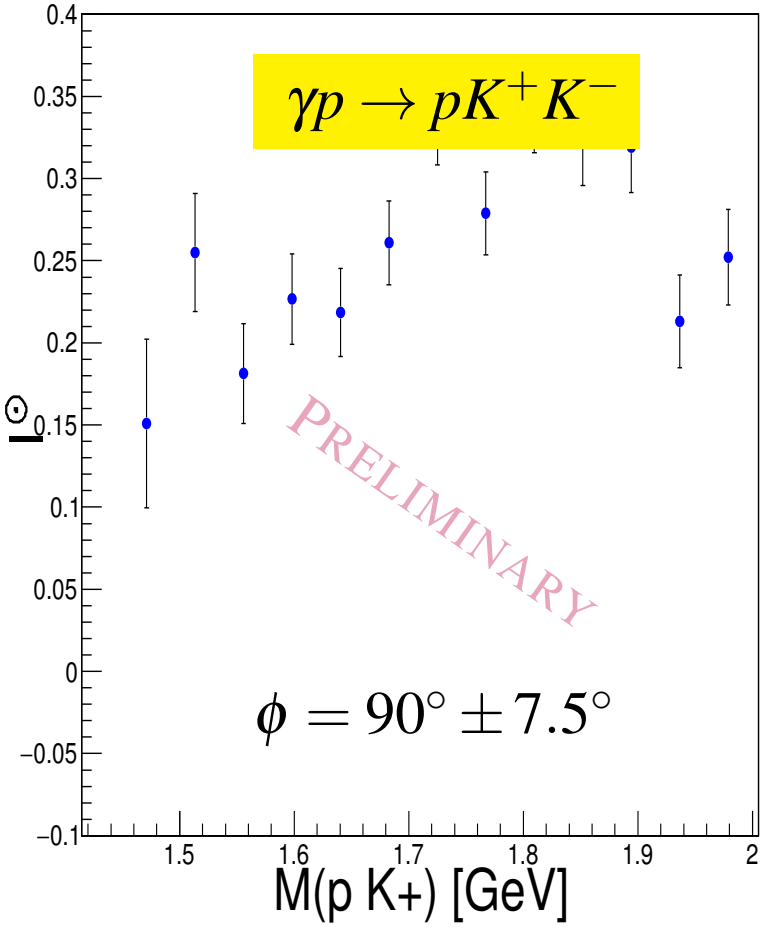




W. Roberts, "Polarization observables in $\gamma N \to K\bar{K}N$," *Phys.Rev.*, C73:035215, 2006.

Preliminary Analysis





W. Roberts, "Polarization observables in $\gamma N \to K\bar{K}N$," *Phys.Rev.*, C73:035215, 2006.

Preliminary Analysis

- Can make asymmetry measurements binning with respect to different kinematic variables
- Can compare to theory
- $\gamma p \to p\pi^+\pi^-$ asymmetry is sensitive to center-of-mass energy
- $\gamma p \to pK^+K^-$ asymmetry overall amplitude is much larger
- Invariant mass appears to affect asymmetries significantly
- Plane definition appears to affect frequency

Preliminary Analysis

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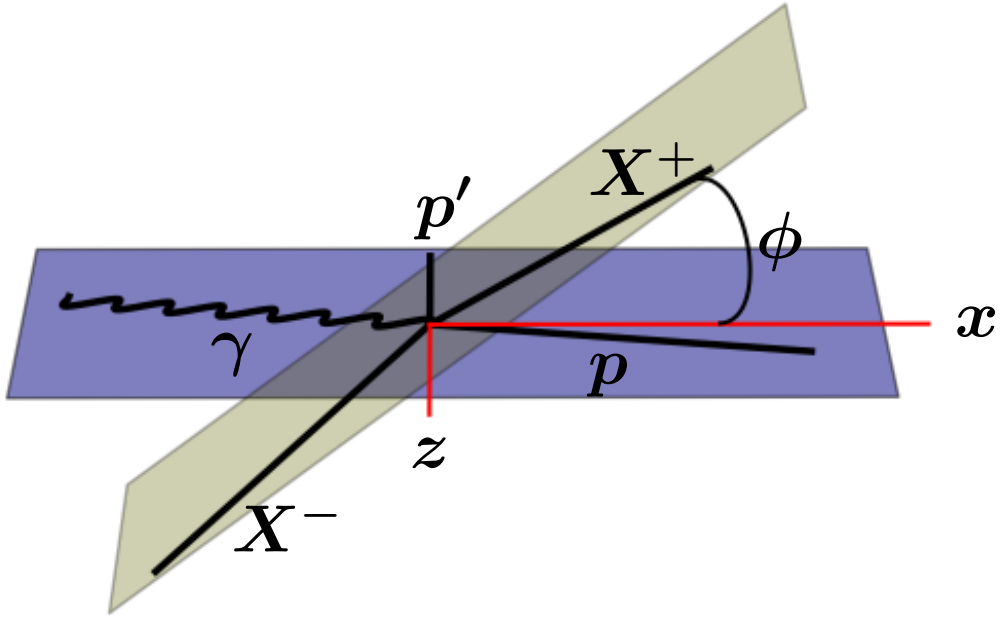
- $\gamma p \to pK^+K^-$ asymmetry overall amplitude is much larger
- Invariant mass appears to affect asymmetries significantly
- **Plane definition appears to affect frequency**

Preliminary Analysis

$$I^{\odot}(\phi) = \frac{1}{P_\gamma} \frac{\sigma^+(\phi) - \sigma^-(\phi)}{\sigma^+(\phi) + \sigma^-(\phi)}$$



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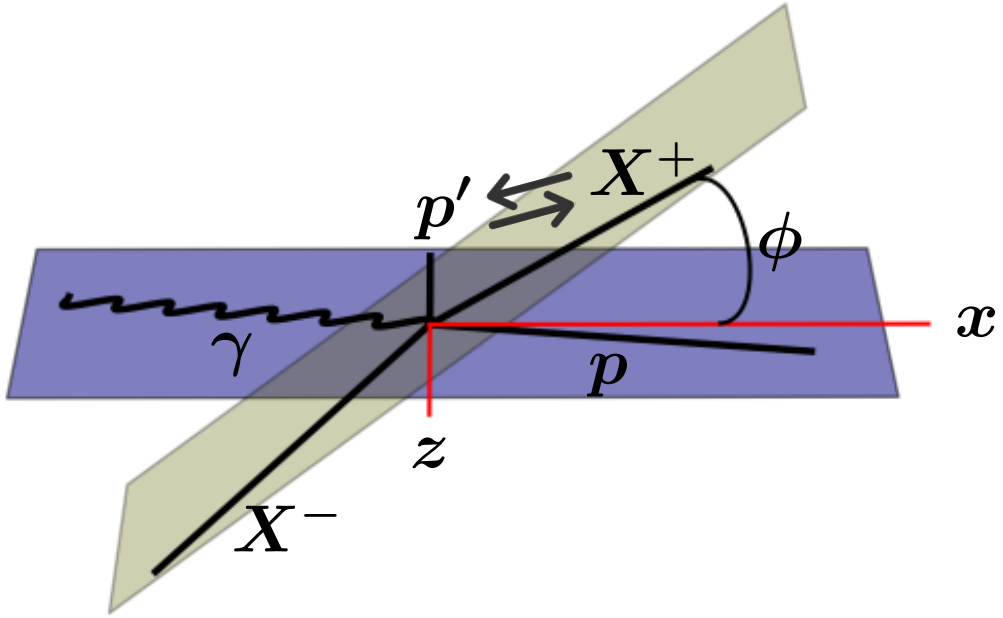

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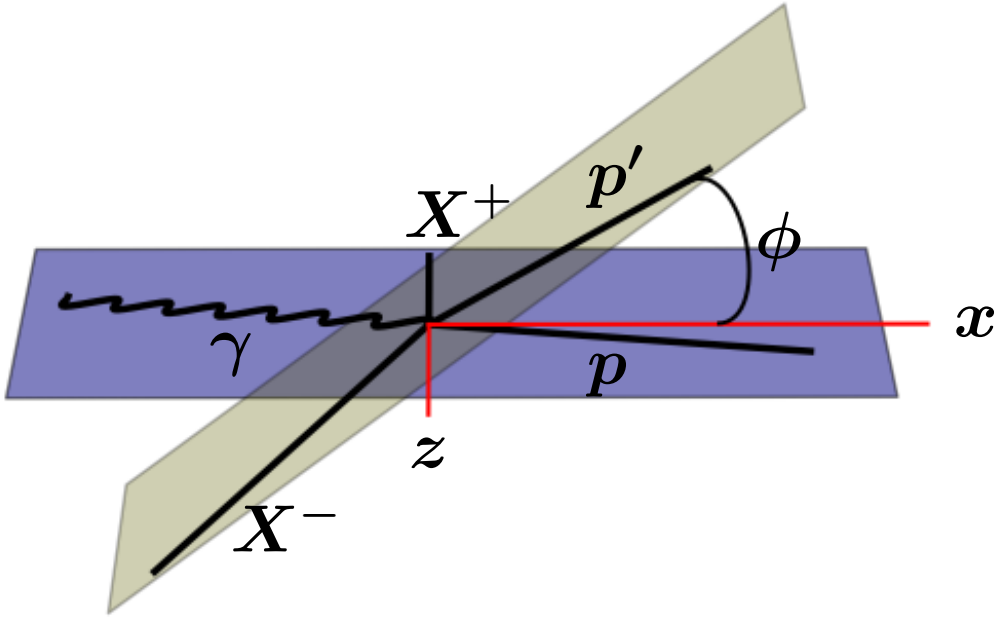

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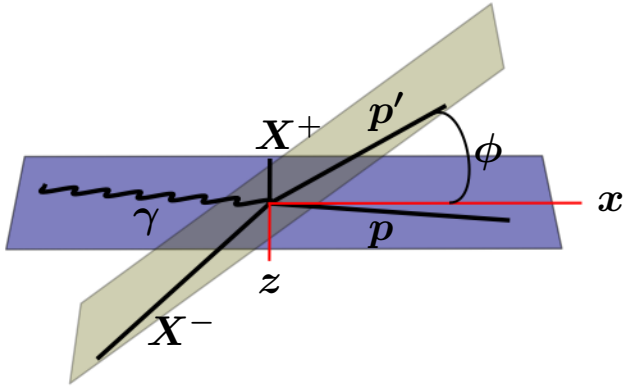
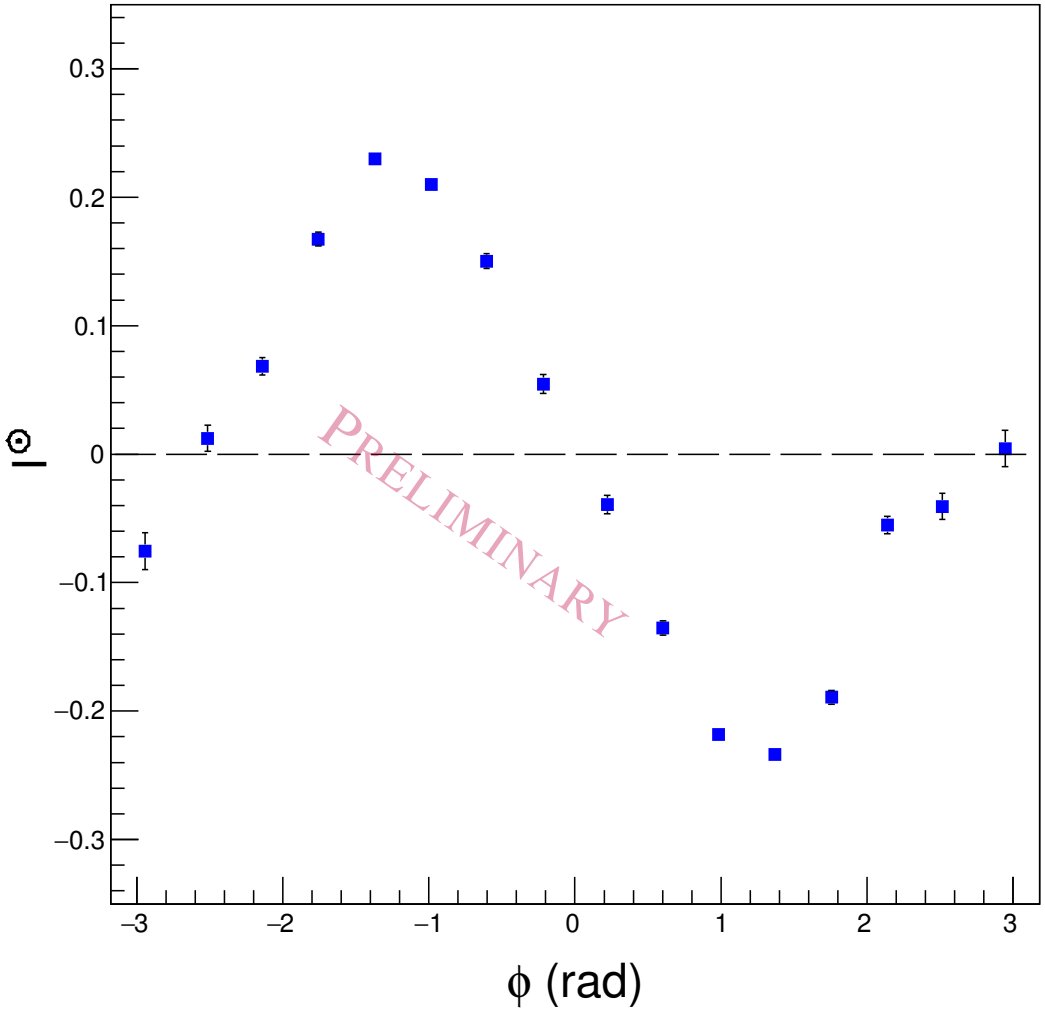


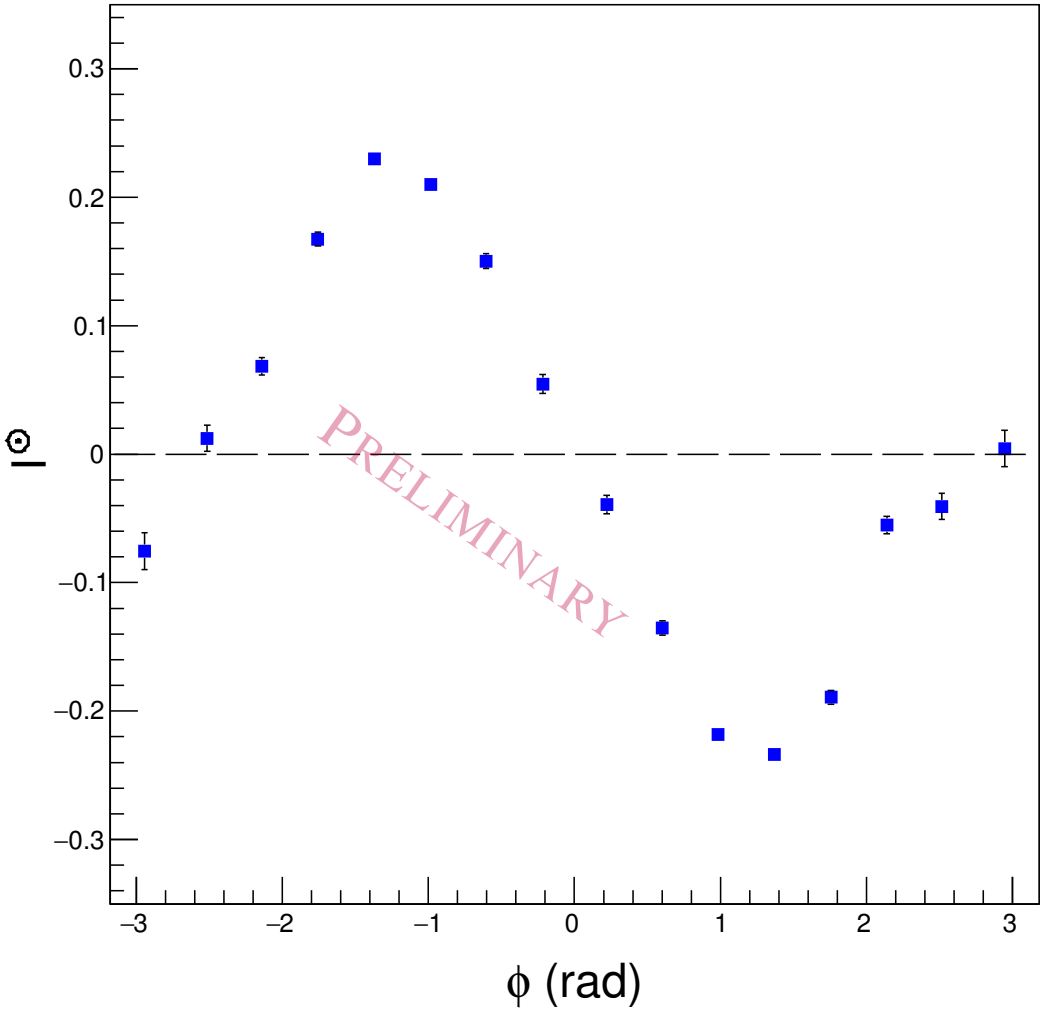
Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses



Preliminary Analysis

Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses

- $\sin(\phi)$ dominated



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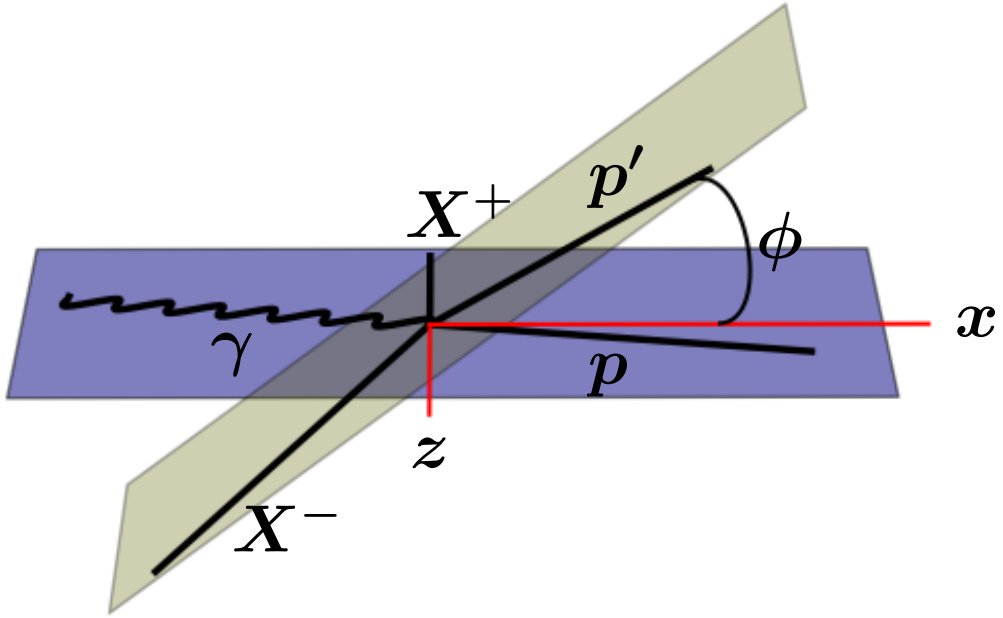

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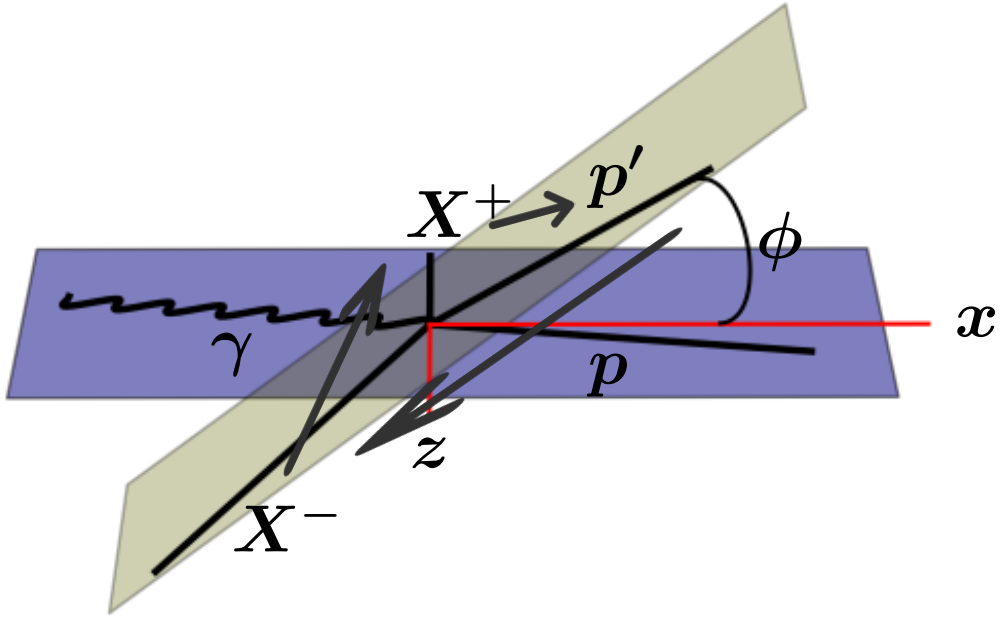

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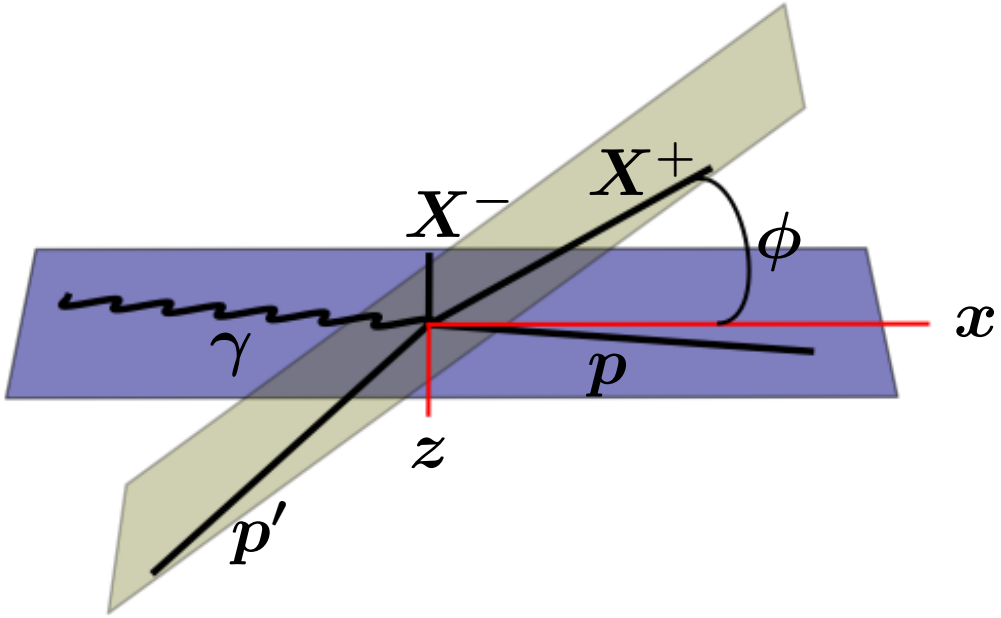

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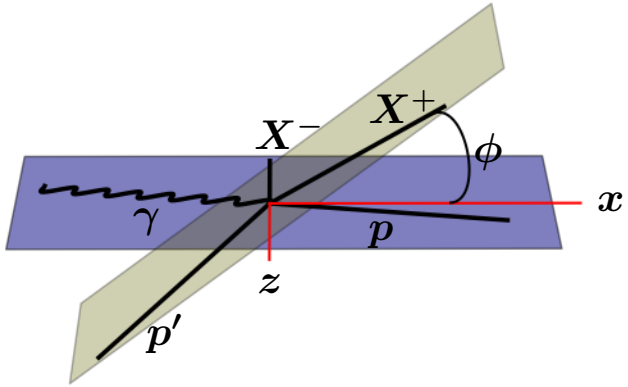
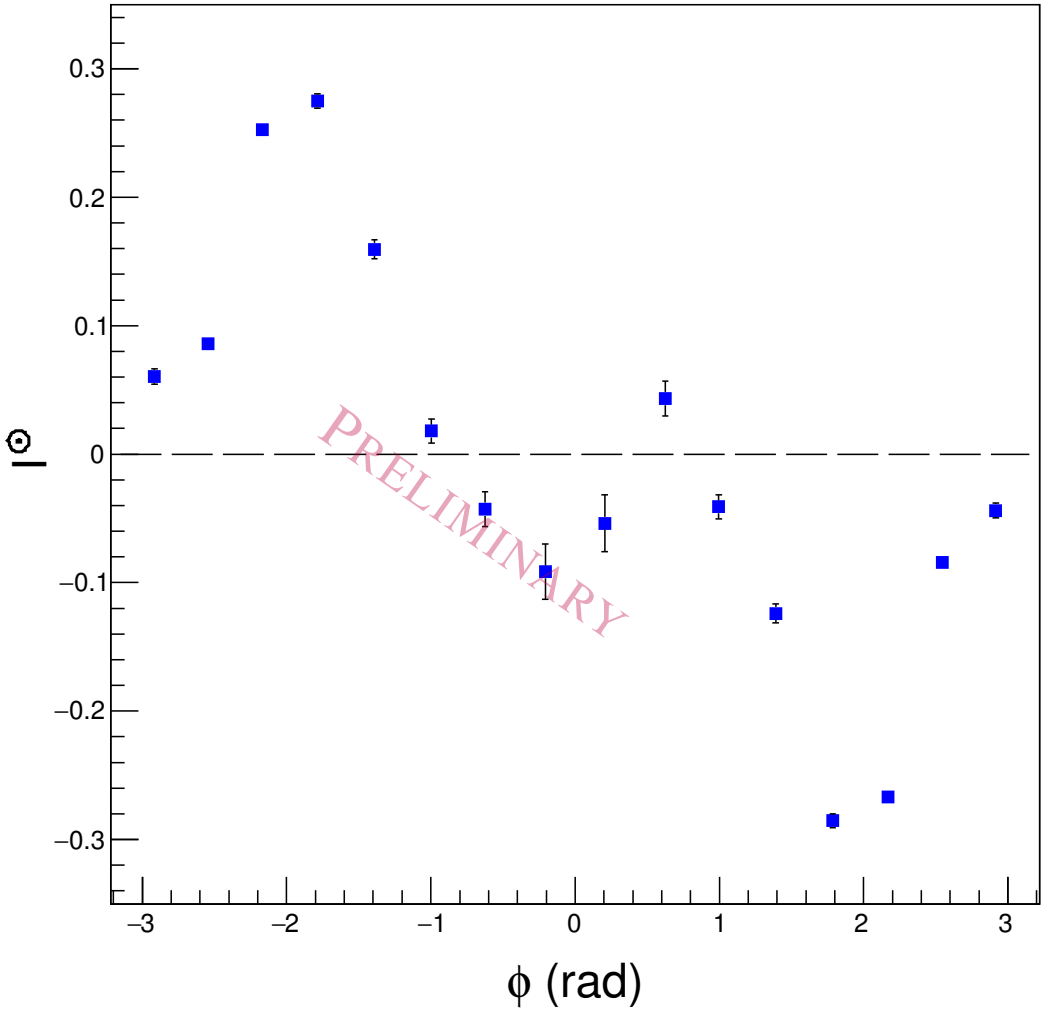


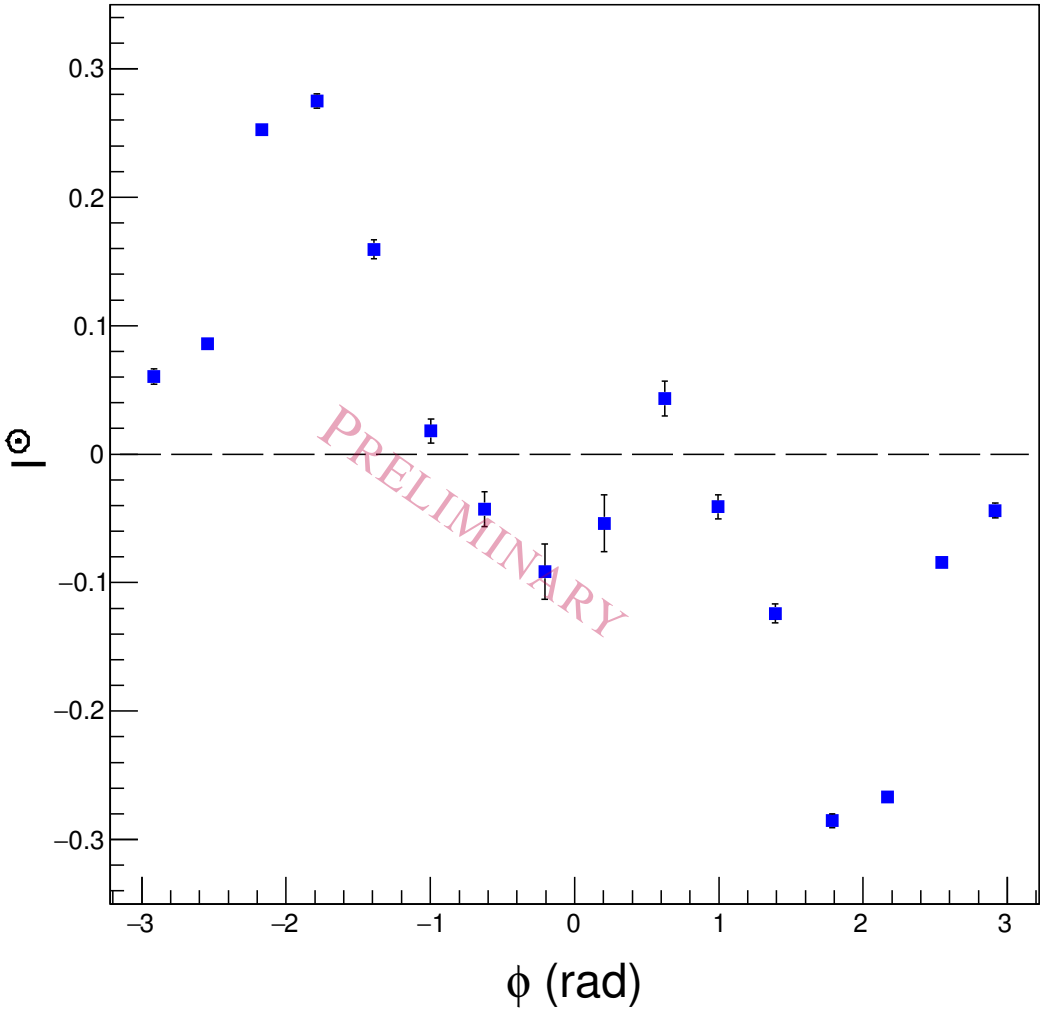
Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses



Preliminary Analysis

Integrated over E_γ, $\cos(\theta_{\mathrm{cm}})$, invariant masses

- Dominated by $\sin(\phi)$ term but $\sin(2\phi)$ contributes as well



Conclusions

- Searching for missing hyperon excitations
- First-time measurement of the beam-helicity asymmetry for $\gamma p \to pK^+K^-$
- Beam-helicity asymmetry is a polarization observable sensitive to many important kinematic variables and is flavor-dependent
- Theoretical models are currently limited
- Current measurements are expected to provide constraints
- Still searching for a deeper understanding of the physics behind this puzzling observable

Acknowledgements

Dr. Lei Guo
Dr. Brian Raue
Dr. Jason Bono

g12 Group
CLAS Collaboration
Thomas Jefferson Accelerator Facility

Thank you!
Questions?

Introduction

Goal

g12

Mass Spectrum

Beam-Helicity Asymmetry

Pion Asymmetry Animation

Kaon Asymmetry Animation

Slew of Variables

Meson-Meson Configuration $I^{\odot}$ Comparison

Neutral-Baryon Configuration $I^{\odot}$ Comparison

Positive-Baryon Configuration $I^{\odot}$ Comparison

Conclusions

References

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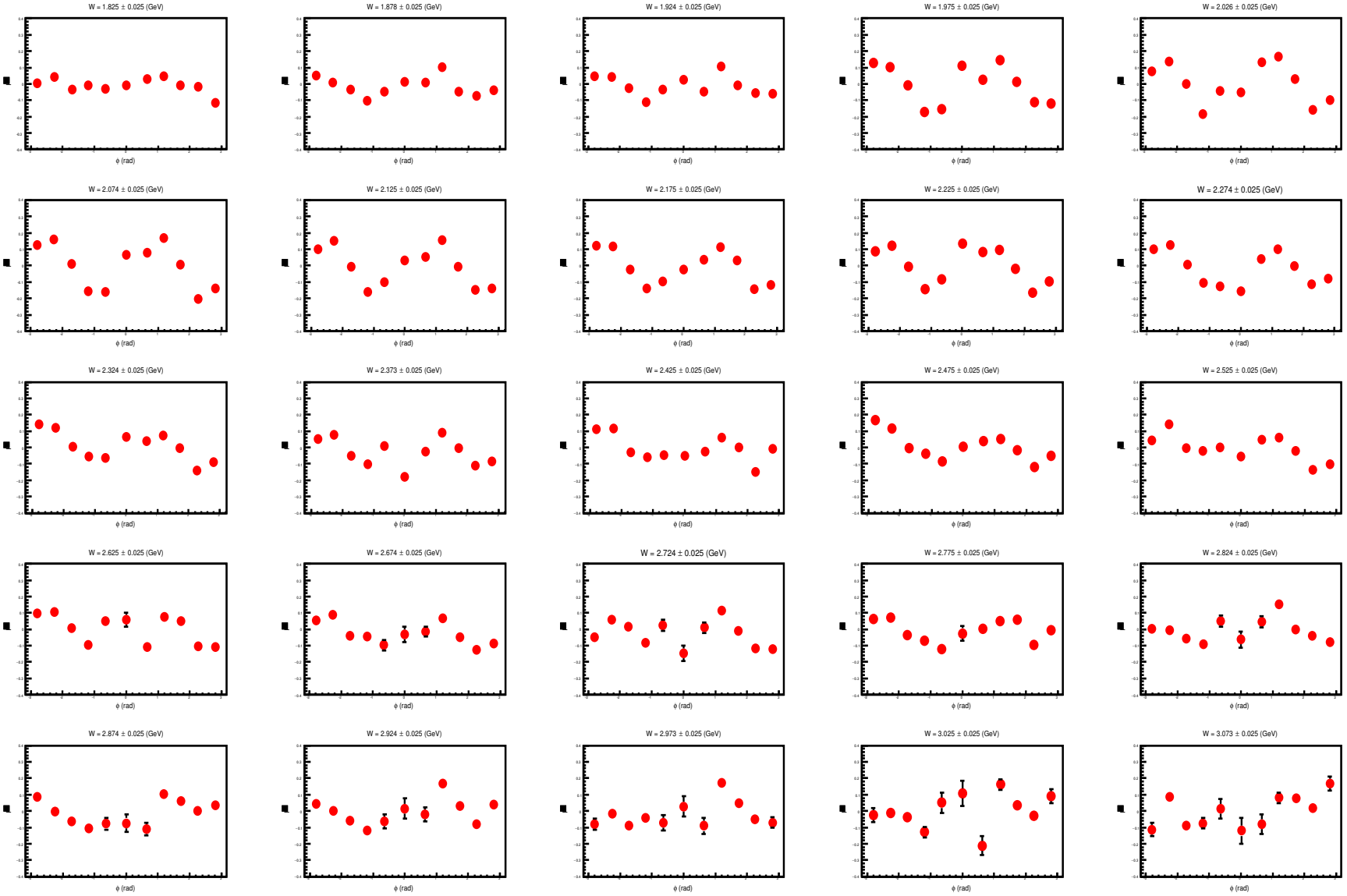
Beam-Helicity Asymmetry

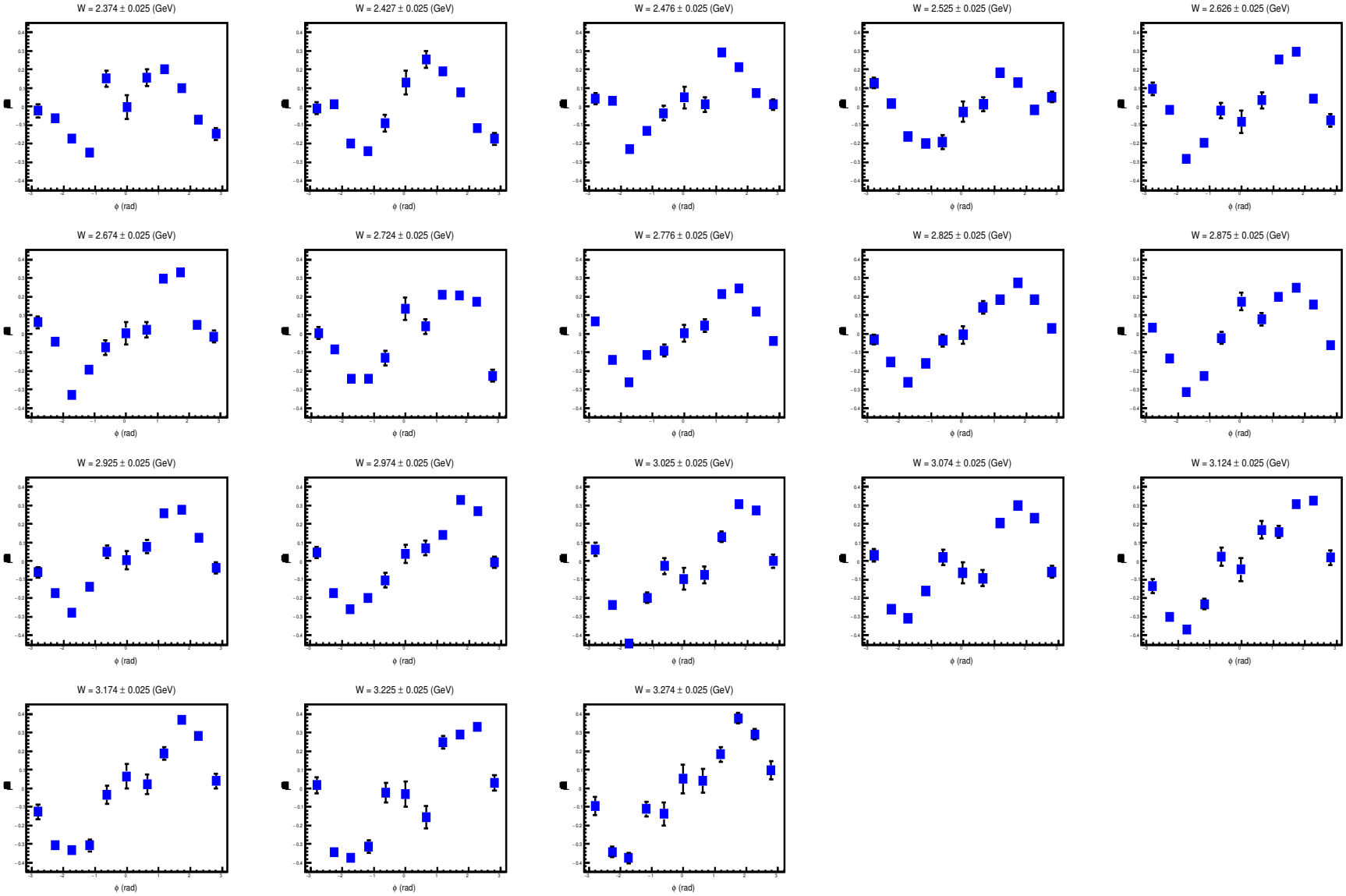
Preliminary Analysis



Preliminary Analysis

Back

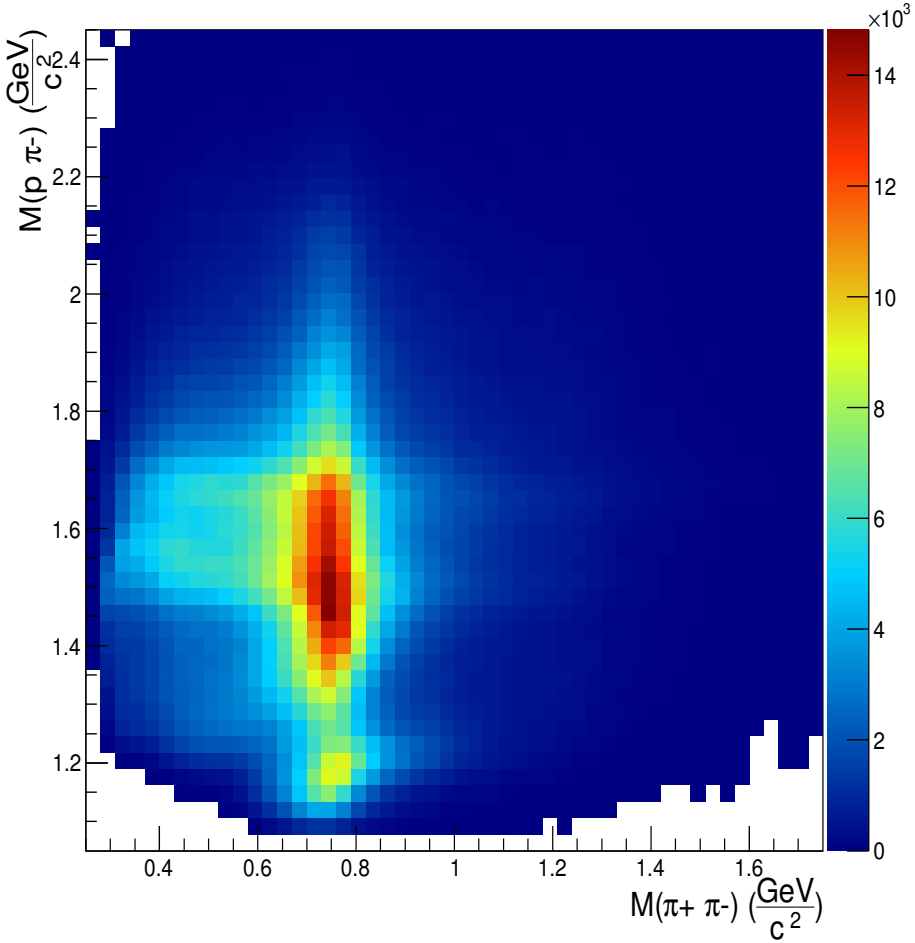
Preliminary Analysis

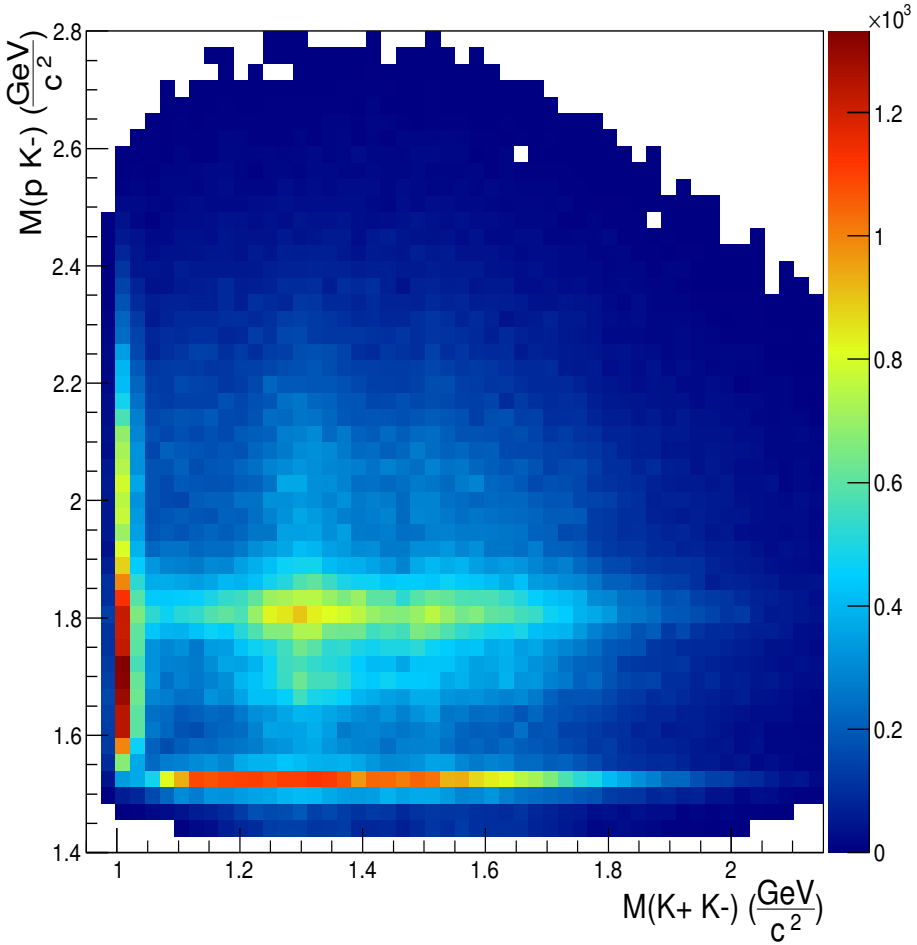


Preliminary Analysis

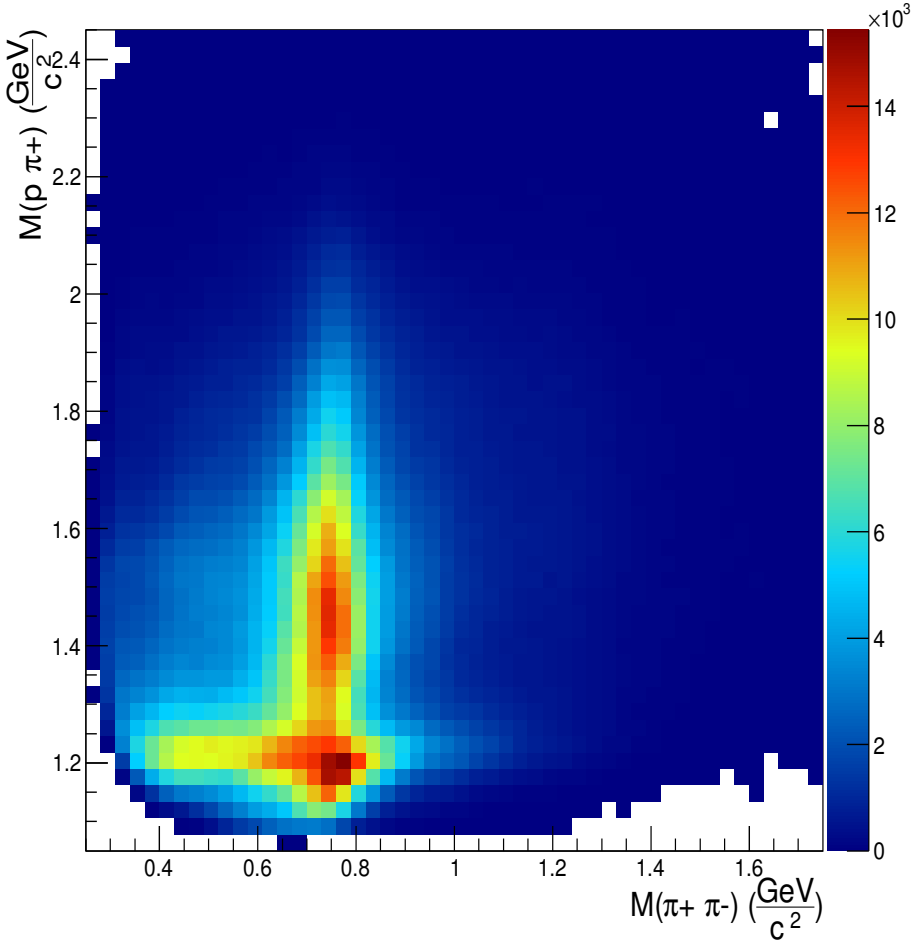
Back

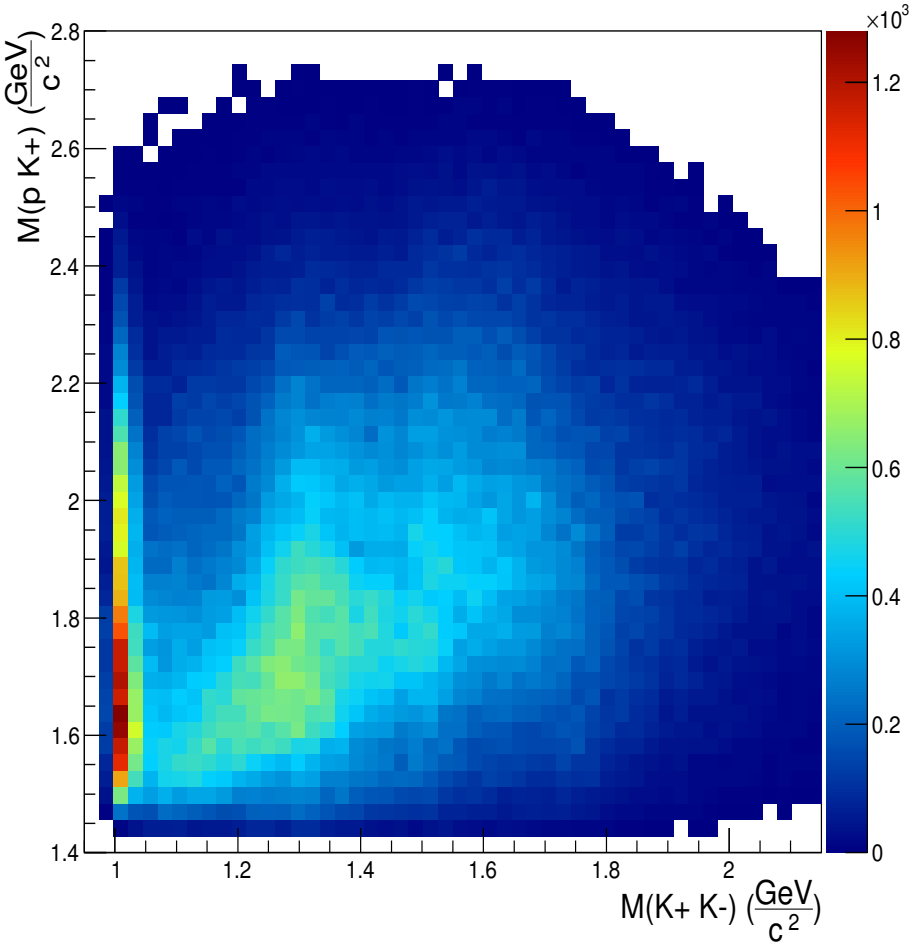
Scatter Plots





Scatter Plots





Scatter Plots