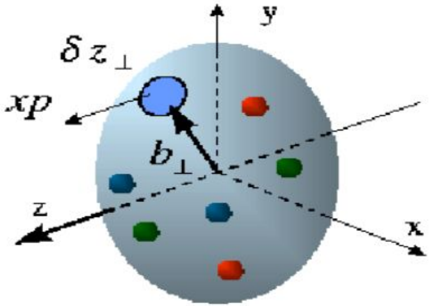
Beam Spin Asymmetries of Deeply Virtual Exclusive ρ^0 Production at CLAS12

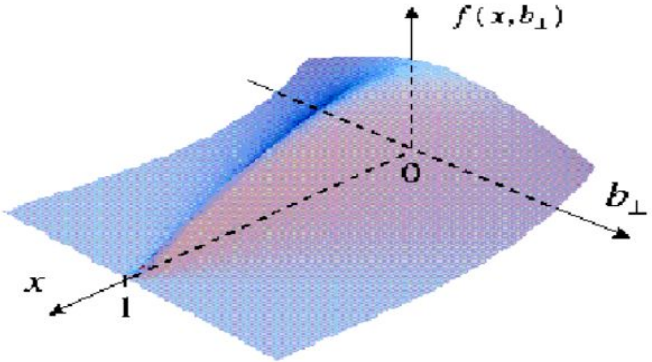
Nicholaus Trotta and Andrey Kim

University of Connecticut

University of Connecticut

Motivation





- 4 chiral-even GPDs: H, E, $\tilde{H}$, $\tilde{E}$
- 4 chiral-odd GPDs: H_T, E_T, $\tilde{H}_T$, $\tilde{E}_T$

	Meson	GPD flavor composition
$\tilde{H}$, $\tilde{E}$ / H_T, $\bar{E}_T$	π^+	$\Delta u - \Delta d$
	π^0	$2\Delta u + \Delta d$
	η	$2\Delta u - \Delta d$
H, E	ρ^0	$2u + d$
	ρ^+	$u - d$
	ω	$2u - d$

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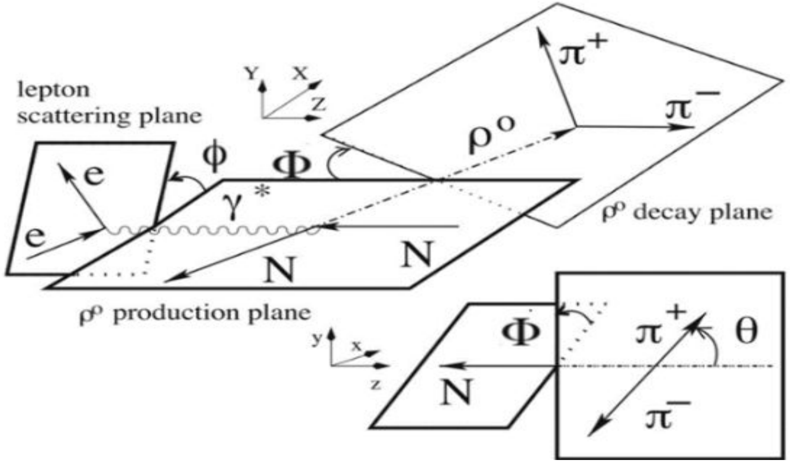


$$\frac{d^4\sigma}{dQ^2\ dx_B\ dt\ d\Phi} = \Gamma(Q^2, x_B, E)$$

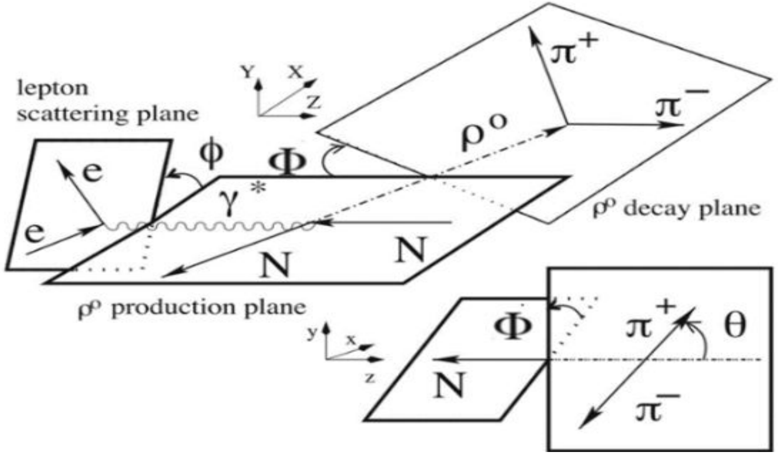
$$\frac{1}{2\pi}\left\{\frac{d\sigma_T}{dt} + \epsilon\frac{d\sigma_L}{dt}\right.$$

$$+ \epsilon\frac{d\sigma_{TT}}{dt}\cos(2\Phi) + \sqrt{2\,(\epsilon+1)}\frac{d\sigma_{LT}}{dt}\cos(\Phi)$$

$$\left. + \lambda\sqrt{2\epsilon(1-\epsilon)}\frac{d\sigma_{LT'}}{dt}\sin(\Phi)\ \right\}$$

where λ is the helicity state of the incident electron beam

Motivation



$$\frac{d^4\sigma}{dQ^2\;dx_B\;dt\;d\Phi} = \Gamma(Q^2, x_B, E)$$

$$\frac{1}{2\pi}\left\{\frac{d\sigma_T}{dt} + \epsilon\frac{d\sigma_L}{dt}\right.$$

$$\epsilon+1)\frac{d\sigma_{LT}}{dt}\cos(\Phi)$$

$$\Phi)\}$$

n beam

$$BSA = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} \propto A_{LU}^{\sin\phi}\sin\phi$$

$$A_{LU}^{\sin\phi} = \sqrt{2\epsilon(1-\epsilon)}\frac{\sigma_{LT'}^{\sin\phi}}{\sigma_0}$$

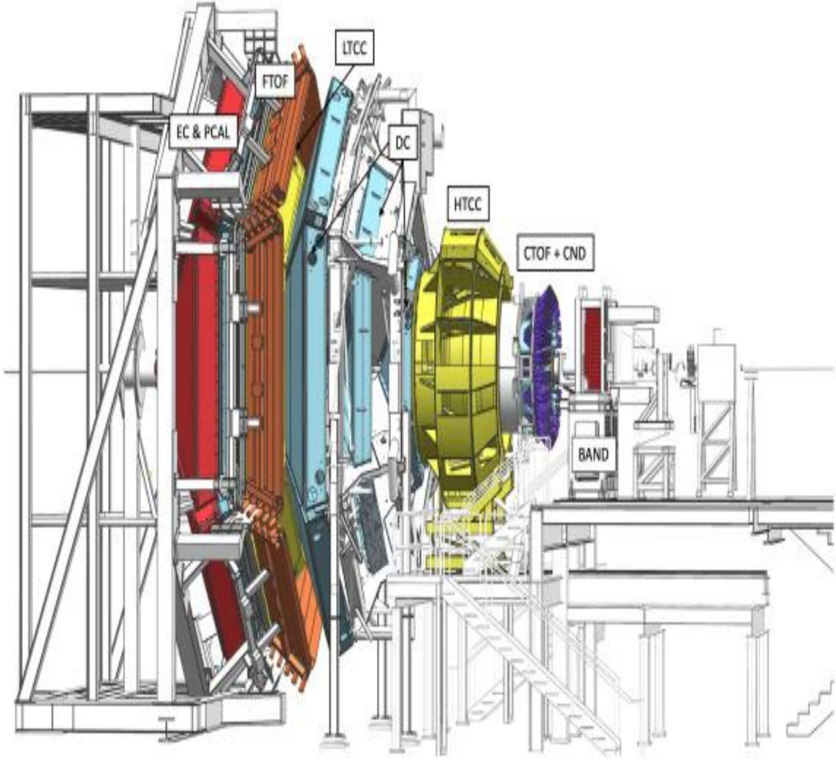
Event Selection

Data Sets:

- RGA's Fall 2018 Inbending and Outbending
- Standard RGA's particle ID
- RGA's Momentum Corrections

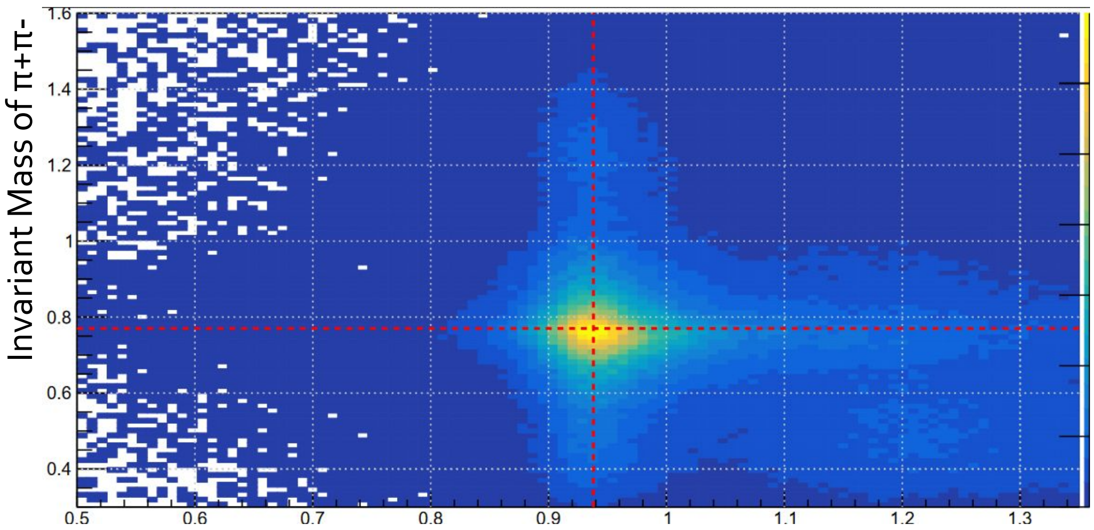
Channel:

- ep -> eρ^0p ->e$\pi^+\pi^-$(p)
  - The outgoing proton is identified by missing mass techniques
  - ρ^0 decays into $\pi^+\pi^-$
  - The electron, and pions are found using forward detector
  - DIS cuts: Q^2 > 2 GeV^2,W > 2 GeV



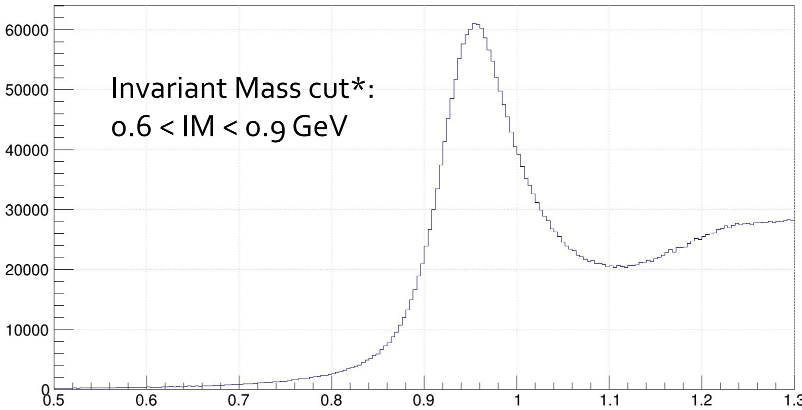
Event Selection: Exclusivity

Invariant Mass Vs Missing Mass

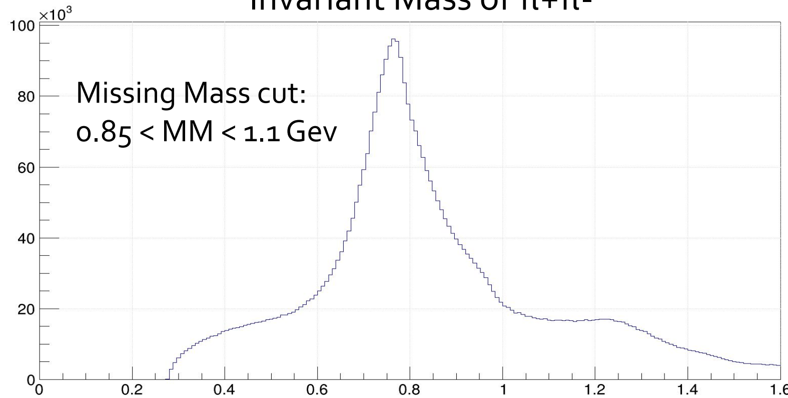


Missing Mass

Missing Mass



Invariant Mass of π+π-



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*Invariant Mass is not cut for final event selection but rather the distribution is fitted

Fitting ρ^0 example

Breit Wigner Distribution (Mesons)

$$F_x^{bw} = \frac{1}{\pi}\frac{N_x \frac{1}{2}\Gamma}{x^2 + (\frac{1}{2}\Gamma)^2}$$

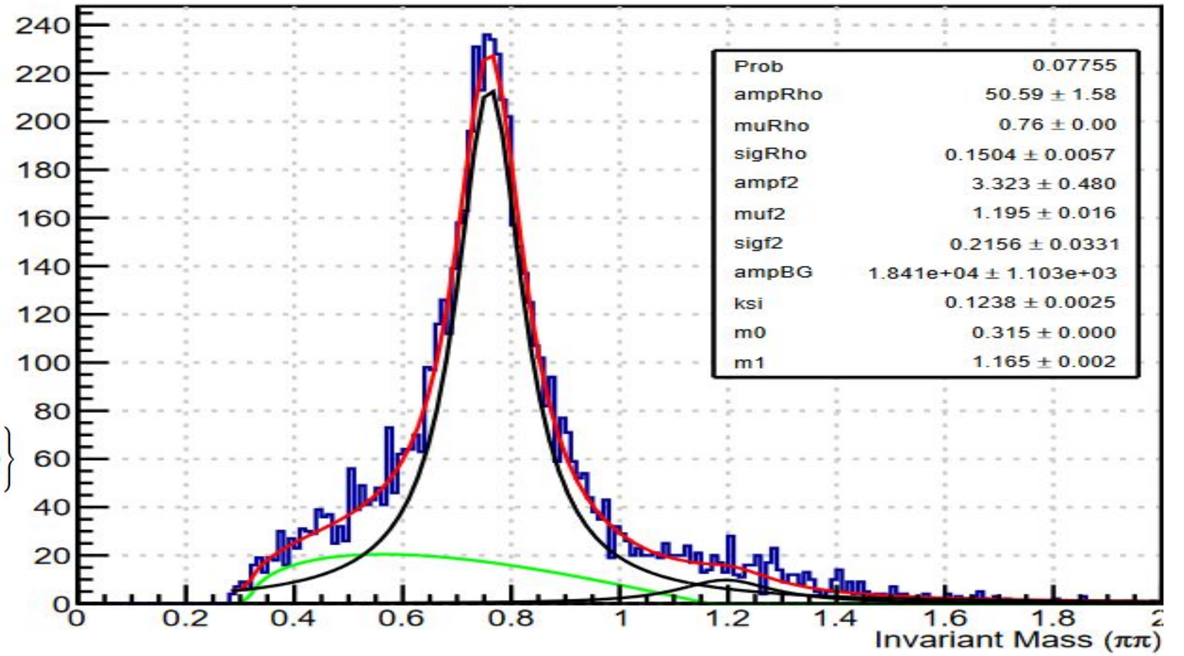
ARGUS inspired Distribution (Background)

$$F_{bg}(x) = N_{bg}\xi^3 \frac{m_1 - x}{(m_1 - m_0)^2}\sqrt{1 - \frac{(m_1 - x)^2}{(m_1 - m_0)^2}}\exp\left\{-\frac{1}{2}\xi^2\left(1 - \frac{(m_1 - x)^2}{(m_1 - m_0)^2}\right)\right\}$$

Total Distribution

$$F(M_{\pi\pi}) = N_\rho F_\rho^{bw} + N_{f2}F_{f2}^{bw} + N_{bg}F_{bg}$$

Invariant Mass of π+π-

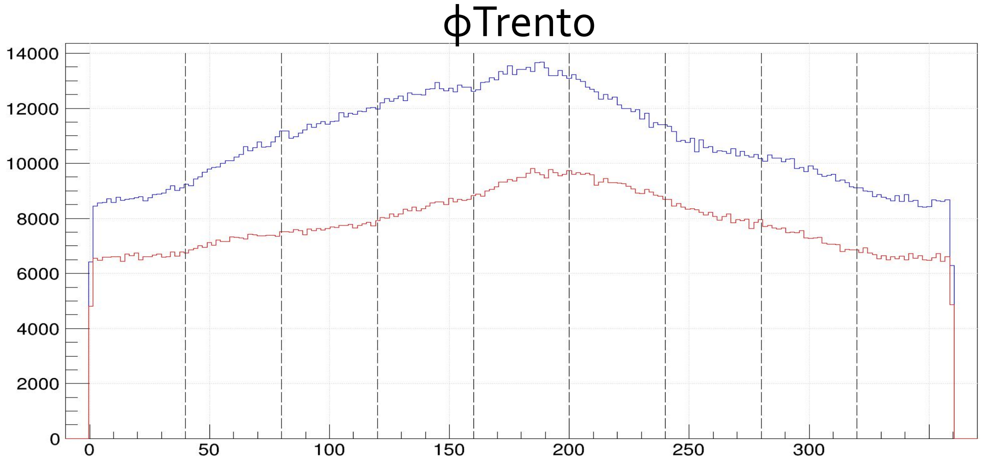


1D Bins in -t

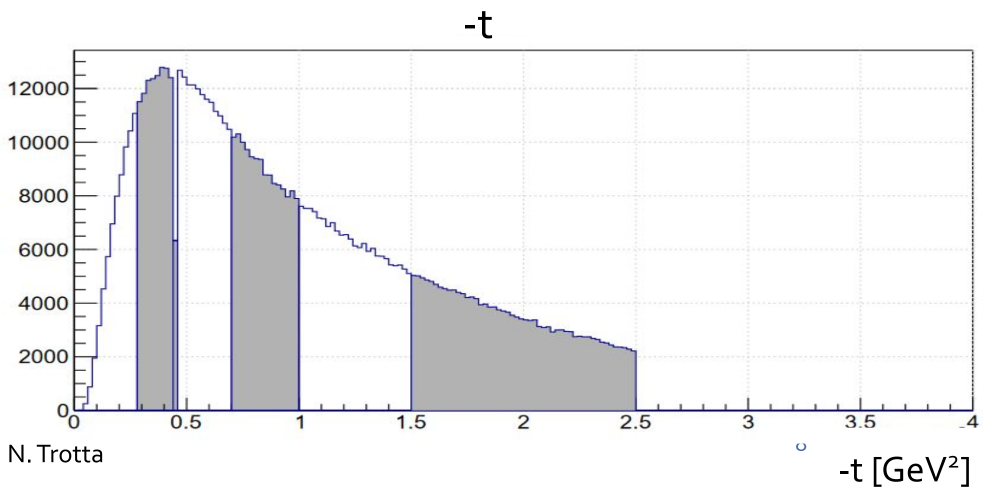
- 6 bins in -t
- 9 equidistance bins in ϕ
- Events were divided into either positive or negative helicity
- 108 invariant mass were fitted
- This was done independently for both inbending and outbending
- $N^{+}_{\rho o}$ and $N^{-}_{\rho o}$ are the amplitude of ρ^{o} fits in positive and negative helicity bins

$$BSA = \frac{1}{P_b}\frac{N_i^+ - N_i^-}{N_i^+ + N_i^-}$$

P_b is the average beam polarization



Negative helicity in red and positive helicity in blue



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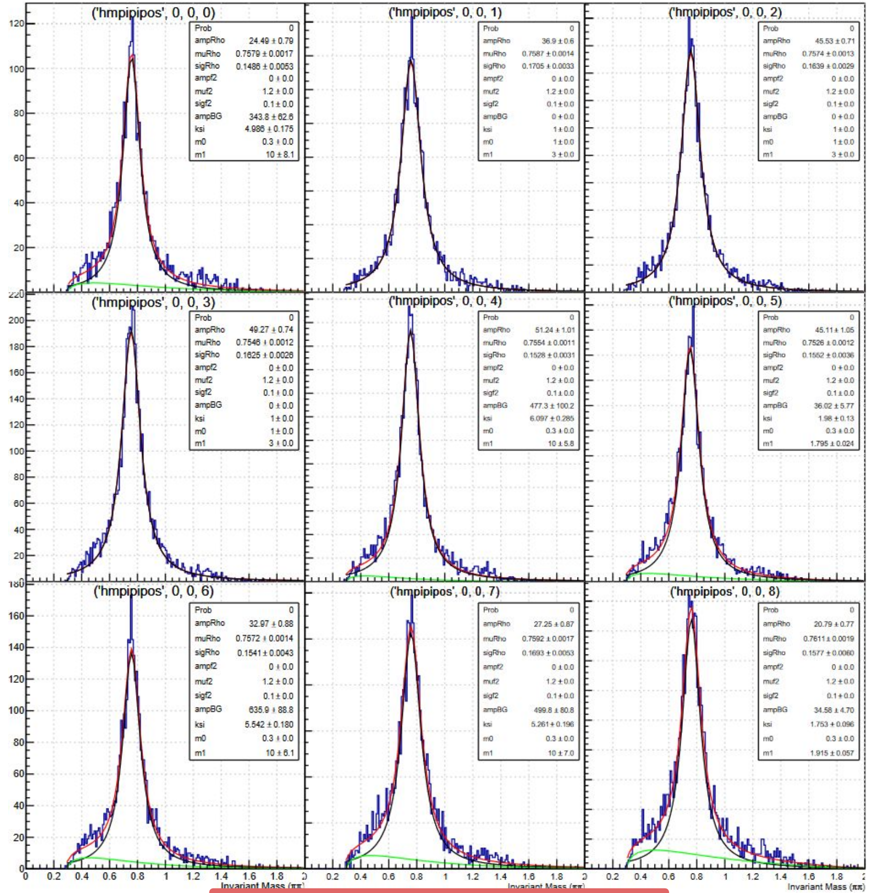
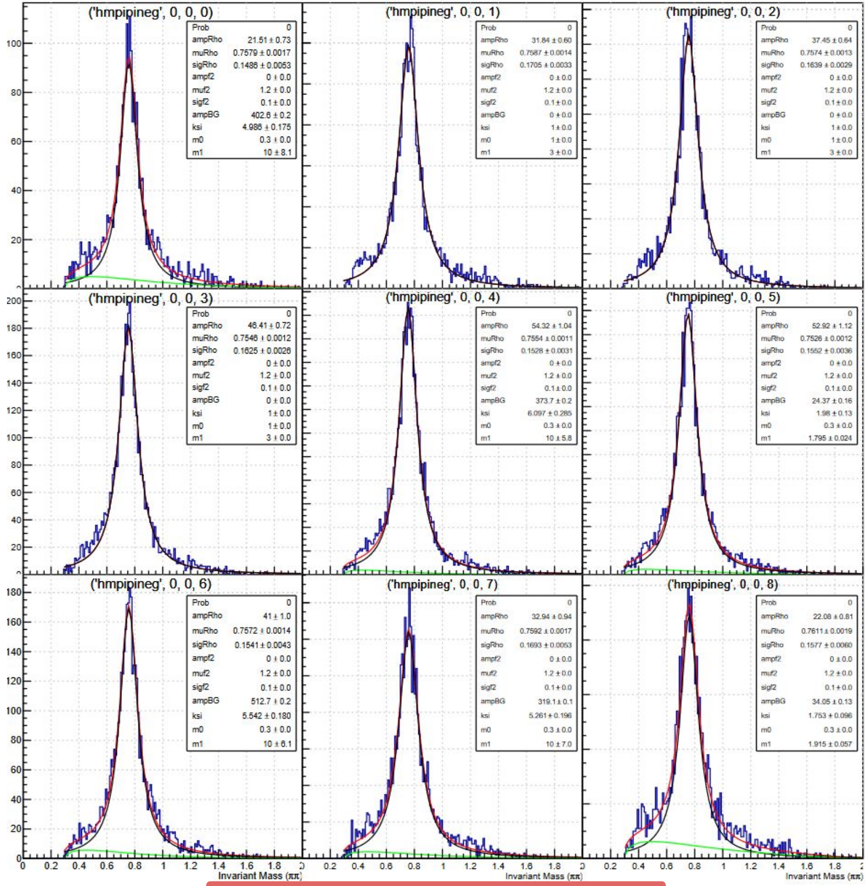
1D Bins in -t: Invariant Mass Fits (-t bin 1)



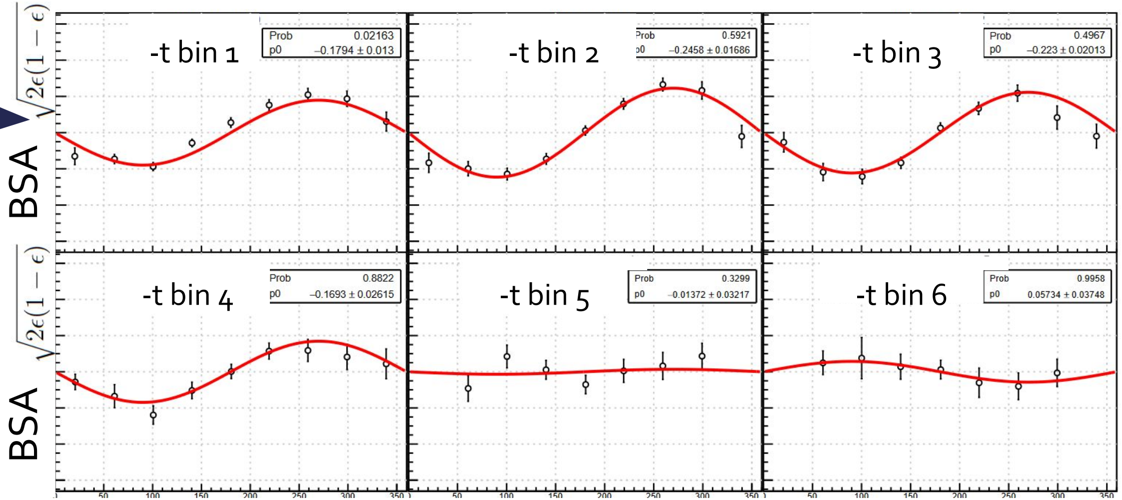
Positive Helicity



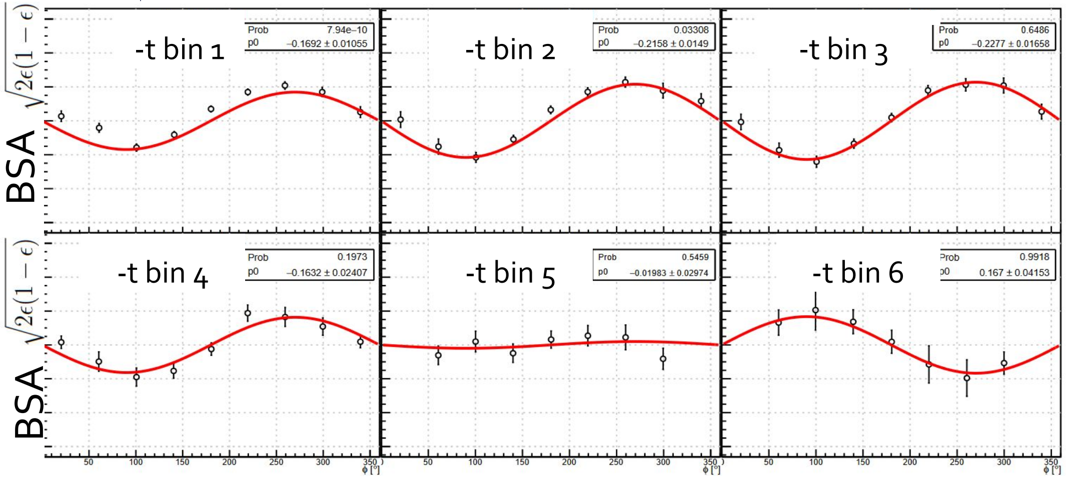
Negative Helicity

1D Bins in -t: BSA

Inbending



Outbending



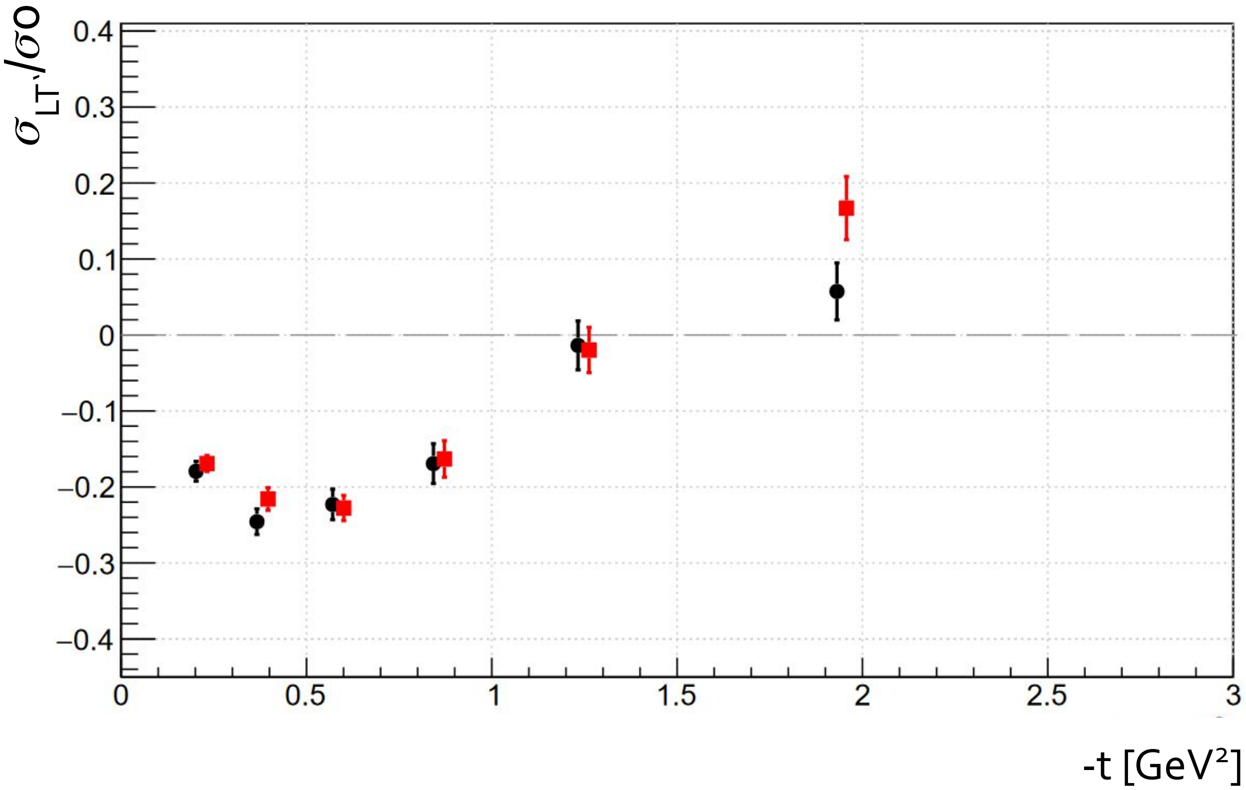
$$BSA = \frac{1}{P_b}\frac{N_i^+ - N_i^-}{N_i^+ + N_i^-}$$

$$BSA = A_{LU}\sin\phi$$

1D Bins in -t: $\sigma_{LT`}/\sigma_0$ for both inbending and outbending

$$BSA = A_{LU} \sin\phi$$

$$A_{LU}^{\sin\phi} = \sqrt{2\epsilon(1-\epsilon)} \frac{\sigma_{LT'}^{\sin\phi}}{\sigma_0}$$



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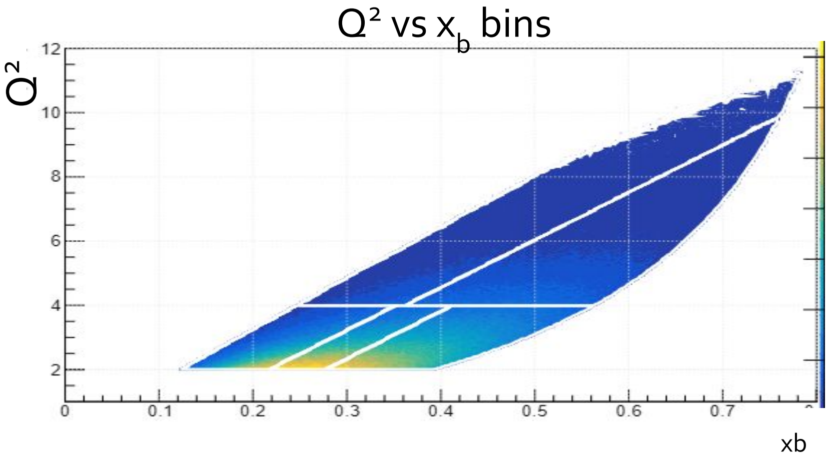
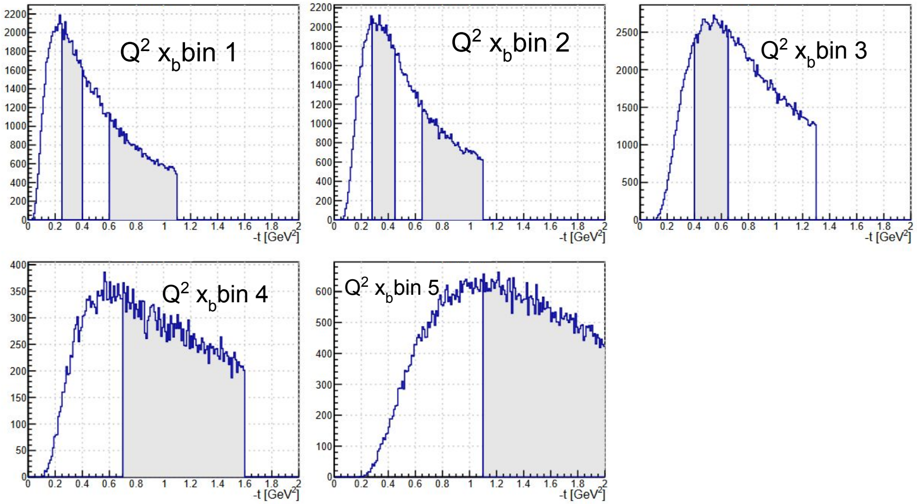
3D Bins in Q^2,x_b, and -t

- 5 bins in Q^2 and x_b
  - Further divided into -t bins
  - 9 equidistance bins in ϕ
  - Events were divided into either positive or negative helicity
  - 135 invariant mass were fitted for both inbending and outbending
- $N^+_{\rho o}$ and $N^-_{\rho o}$ are the amplitude of ρ^o fits in positive and negative helicity bins

$$BSA = \frac{1}{P_b}\frac{N_i^+ - N_i^-}{N_i^+ + N_i^-}$$





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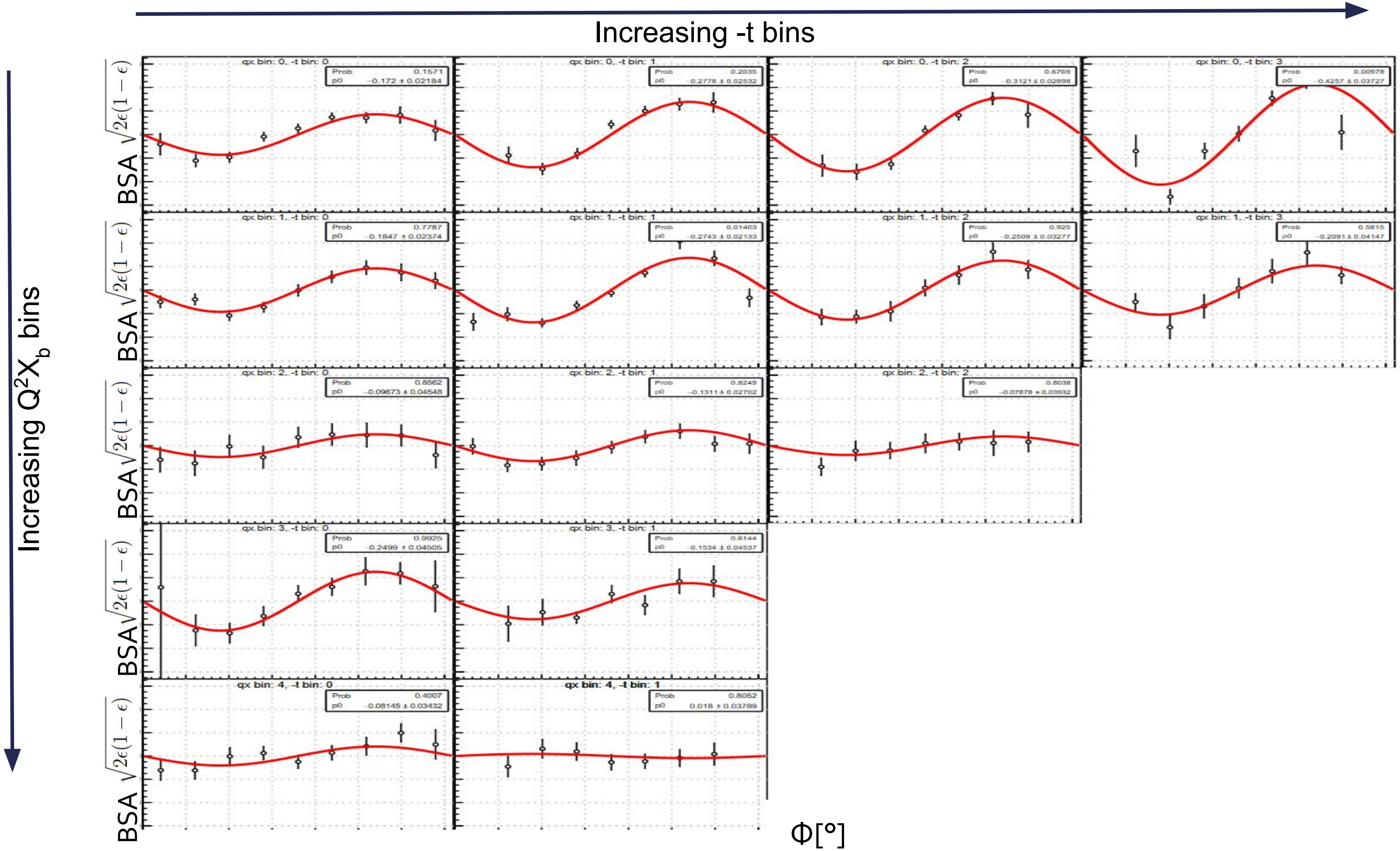
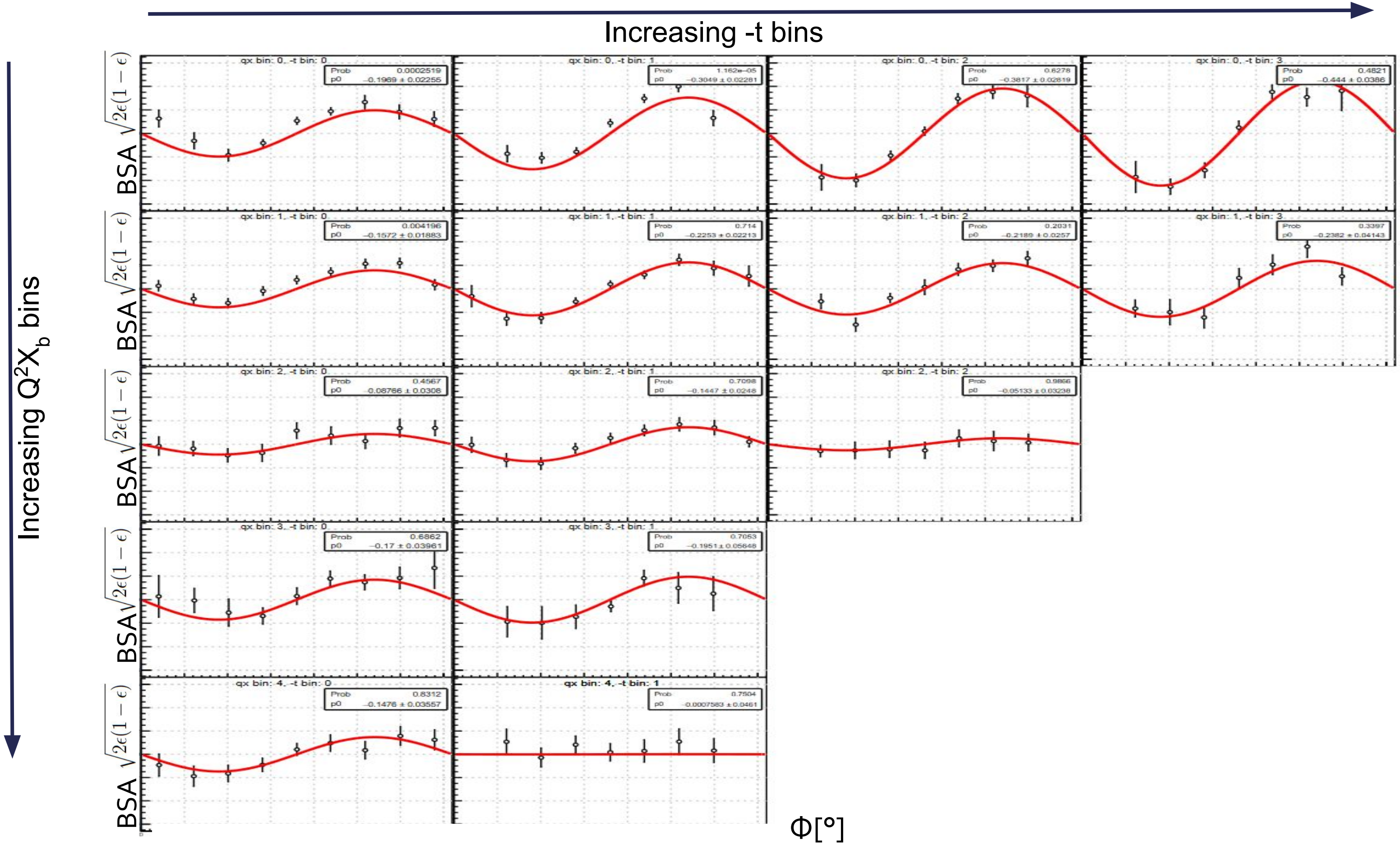
3D Bins: BSA Inbending

$$BSA = A_{LU} \sin\phi$$

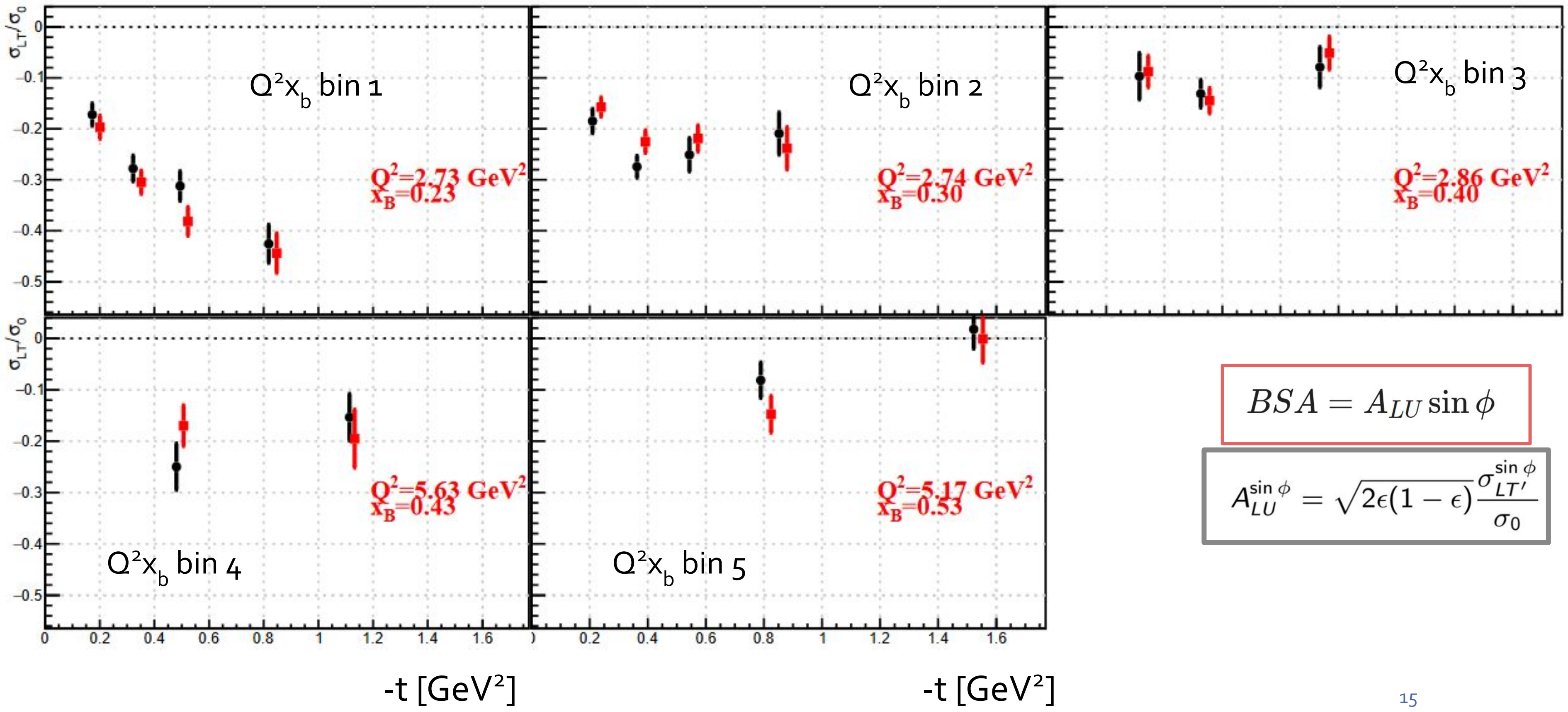


3D Bins: BSA Outbending

$$BSA = A_{LU} \sin\phi$$



3D Bins: $\sigma_{LT'}/\sigma_0$ for both inbending and outbending



$$BSA = A_{LU} \sin\phi$$

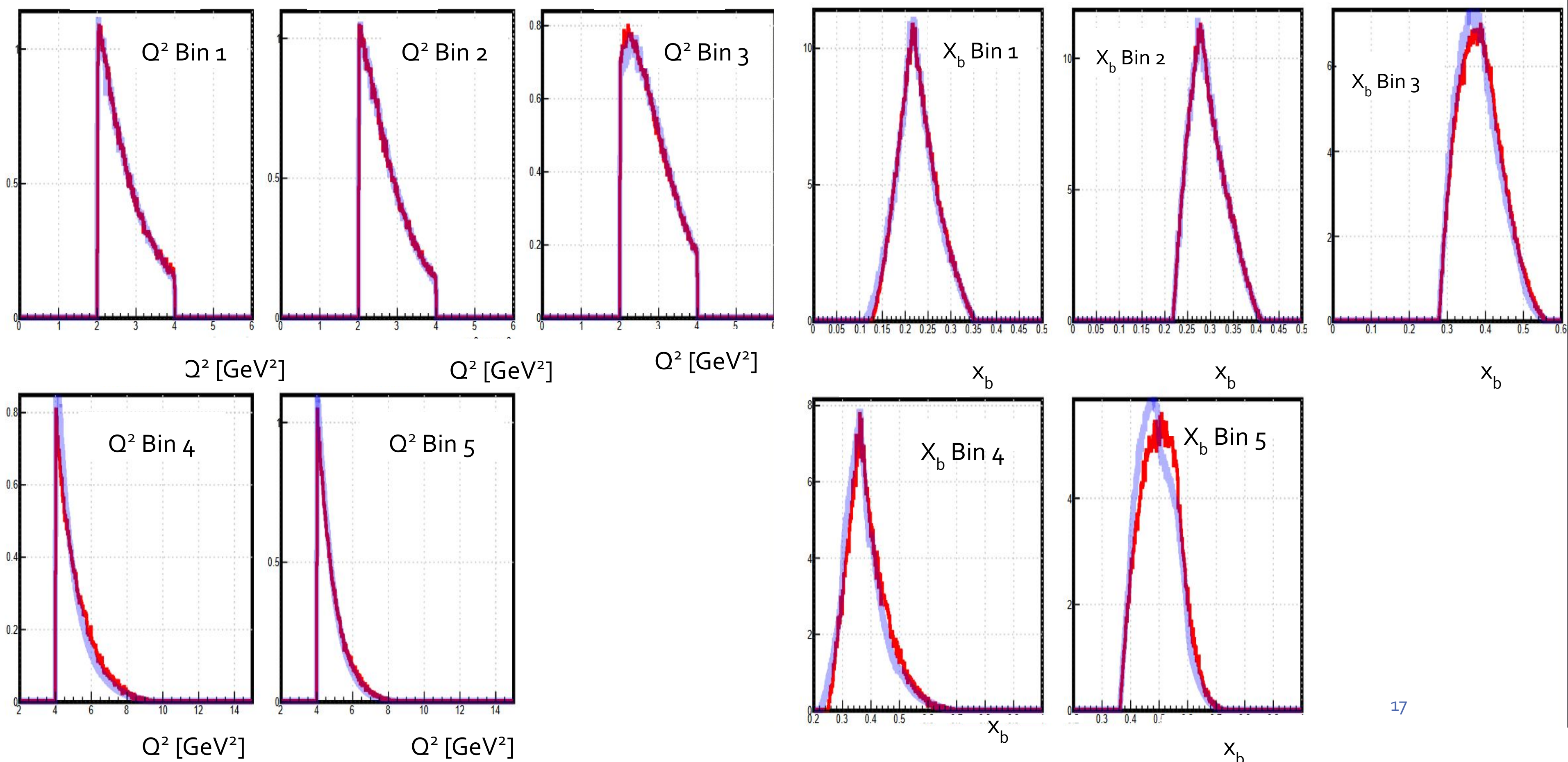
$$A_{LU}^{\sin\phi} = \sqrt{2\epsilon(1-\epsilon)}\frac{\sigma_{LT'}^{\sin\phi}}{\sigma_0}$$

Dashed line = 0.0

Monte Carlo Simulation

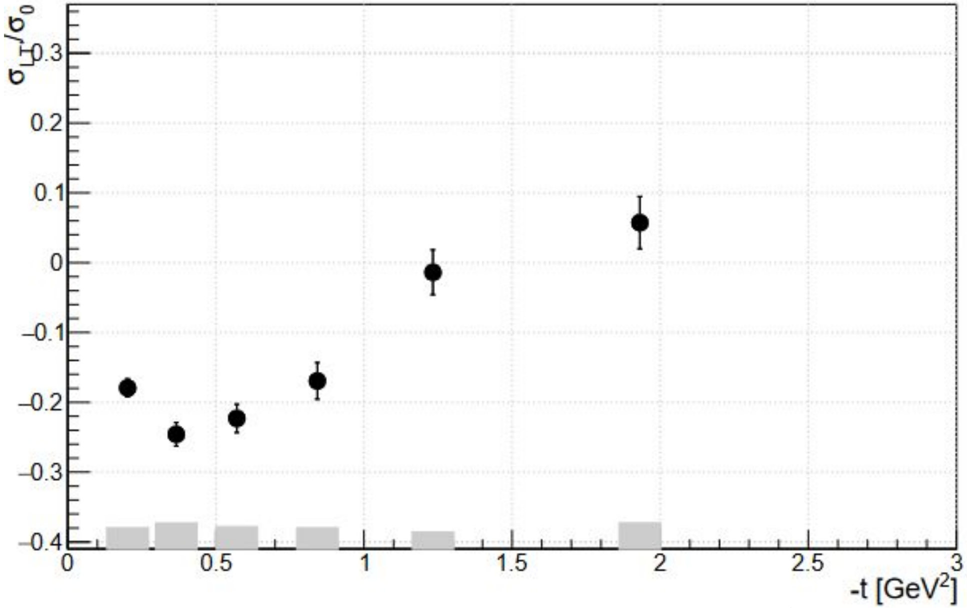
- Generator
  - A phase space generator was created to simulate the reaction $ep \rightarrow ep\rho^0 \rightarrow ep\pi^+\pi^-$
  - A breit wigner was used to simulate ρ^0
  - μ (mean value) = 0.755 GeV, Γ (full width half mass) = 0.146 GeV
- The generated data was passed through GEMC to be reconstructed
- Weights were created to match the reconstructed MC to the reconstructed data

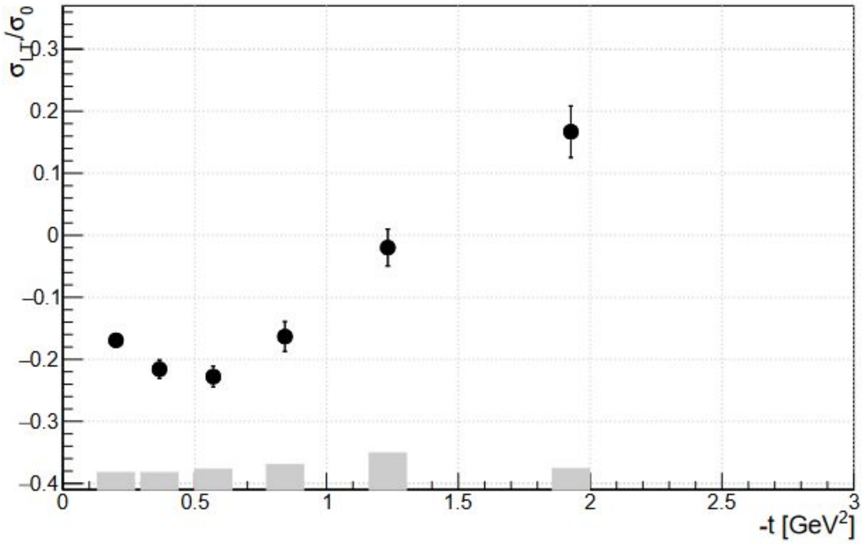
Simulation: MC Reconstructed vc Data Reconstructed



Systematic Uncertainty

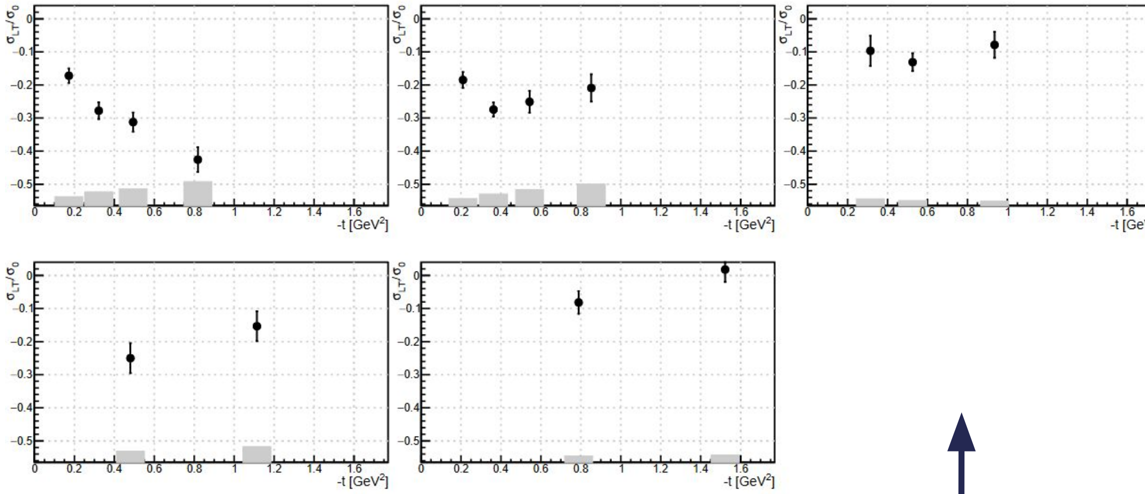
- 1D binning {-t}
- Gray bands show the total systematic uncertainties



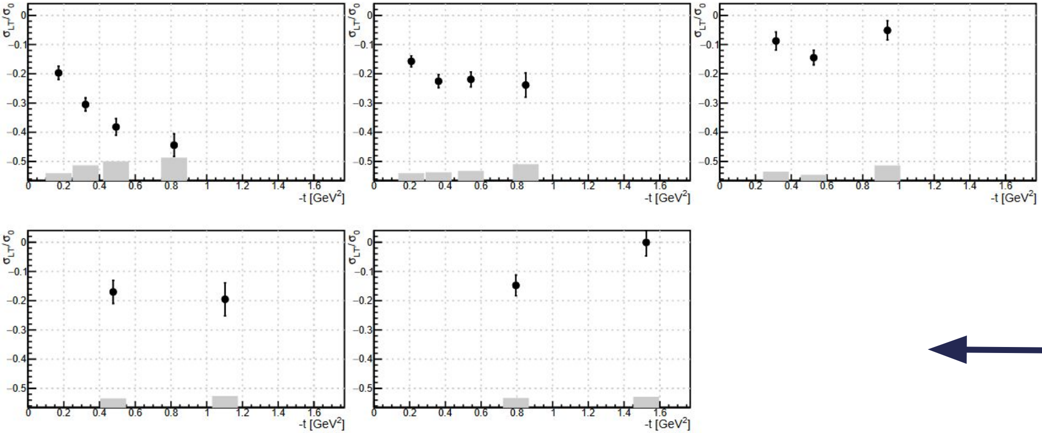


Systematic Uncertainty

- 3D binning $\{Q^2, x_b, -t\}$
- Gray bands show the total systematic uncertainties



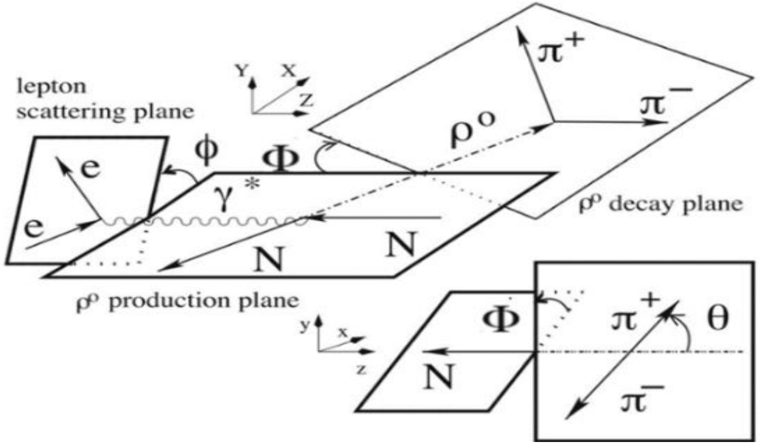
Inbending



Outbending

Outlook and Conclusion

- Our results found that Chiral Odd GPDs play a significant role in vector meson production
- Results are significant in $-t<1$ GeV^2 (the region with dominant GPDs contributions)
- Spin density matrix elements (SDMEs)



Thank You!

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Backup

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Maximum Likelihood Estimation Method (MLM)

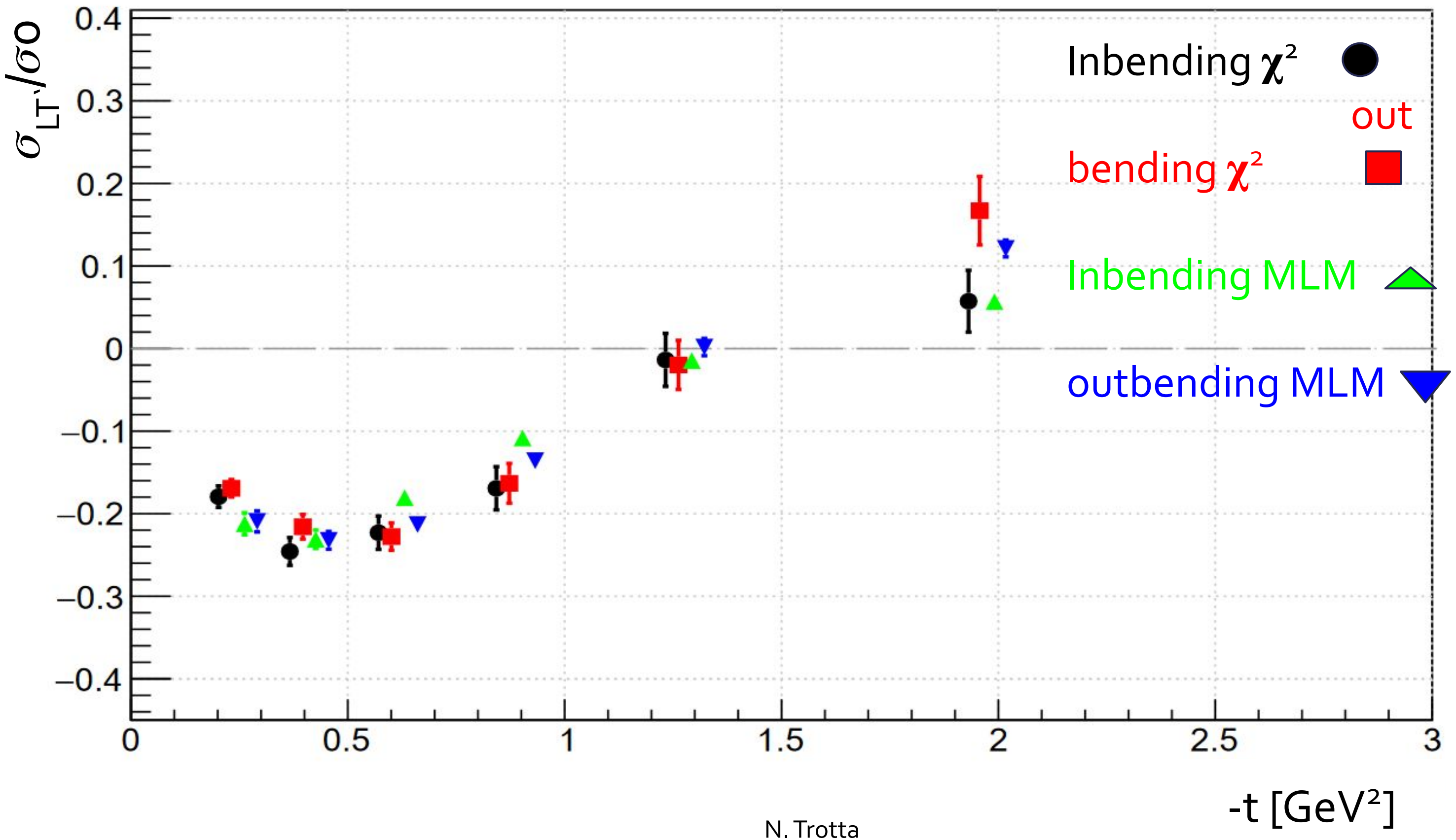
- Can be used to to extract the modulations as an alternative method to the background subtraction
  - Allows for extraction of the modulations without binning in the azimuthal angle, ϕ
  - No assumptions are made about the distributions of the parameters
- Using the following yield for polarized beam and unpolarized target

$$dN(\vec{\theta}, \vec{x}, h_b, h_t) = L\eta(\vec{x})\sigma_{UU}(\vec{x})(1 + A_{UU}((\vec{\theta})\vec{x}) + A_{LU}((\vec{\theta})\vec{x}))$$

- Need to find the minimum of the negative log of the likelihood function
  - Assuming that net polarization is zero, then the unpolarized terms can be summed over a monte carlo

$$-log(L(\vec{\theta})) = N_{data}log(\sum_{i}^{N_{MC}} 1 + A_{UU}^{cos\phi}cos(\phi) + A_{UU}^{cos2\phi}cos(2\phi)) - \sum_{i}^{N_{data}} log(1 + A_{UU}^{cos\phi}cos(\phi) + A_{UU}^{cos2\phi}cos(2\phi) + A_{LU}^{sin\phi}sin(\phi))$$

1D Bins: MLM vs χ^2



3D Bins: MLM vs χ^2

Dashed line = 0.0