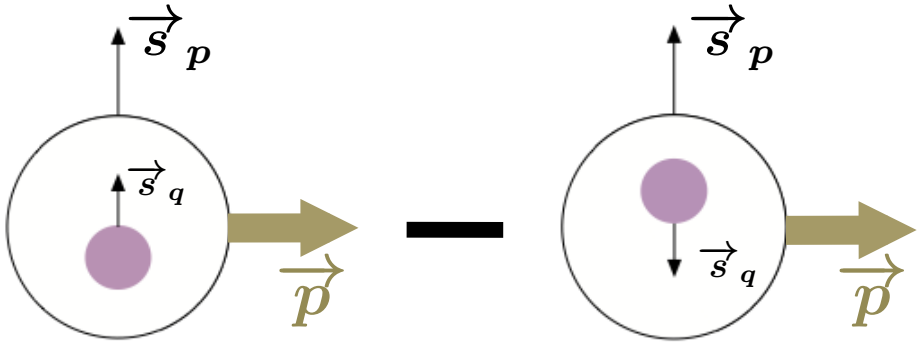
# Measuring transversity in $P^{\uparrow} + P$ Collisions with Di-Hadron Correlations at $\sqrt{S} = 200$ GeV at the STAR Experiment

KEITH LANDRY, UCLA

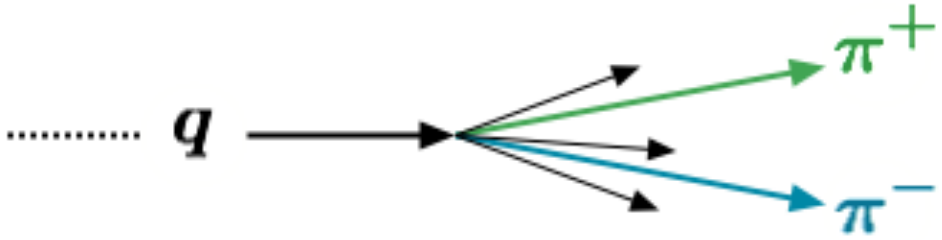
FOR THE STAR COLLABORATION


# Transversity Distribution

$h_1(x)$ 


- **Still not known all that well especially at high x**
  - **Key to understanding the proton spin structure**
- **Polarized P+P collisions at RHIC probe a unique range of X different from existing experiments ($0.1 < x < 0.35$)**
- **Needs to be paired with other chiral odd object**

# Quark Fragmentation

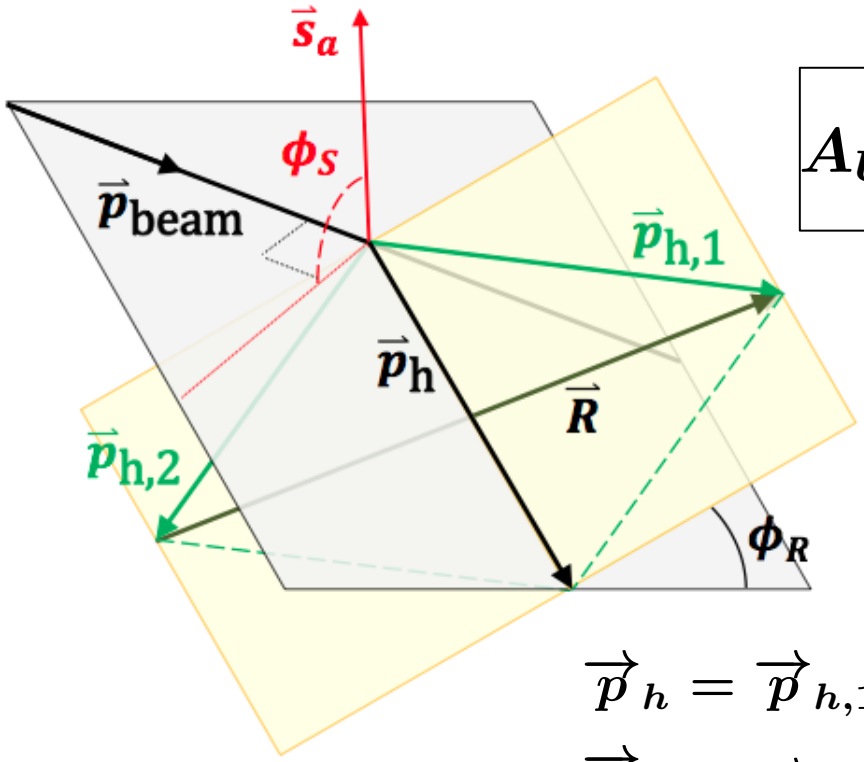



- **Interference Fragmentation Function (IFF)** $H_1^{\sphericalangle}$
- **Chiral even observable** $\propto h_1 H_1^{\sphericalangle}$
  - **Enhancement near** $\rho$ **mass (770 MeV/c²)**
  - **Partonic transverse momentum can be integrated over**

# Cross Section

$$P^{\uparrow} + P \rightarrow \pi^{+}\pi^{-} + X$$

$$d\sigma_{UT} \propto P_T^{\pi^+\pi^-} \sin(\phi_{RS}) \int dx_a dx_b f_1(x_a) h_1(x_b) \frac{d\Delta\hat{\sigma}}{d\hat{t}} H_1^{\sphericalangle}(z, M_{inv}^{\pi^+\pi^-{}^2})$$




$$A_{UT} \sin(\phi_{RS}) = \frac{1}{Pol} \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

$$\phi_{RS} = \phi_R - \phi_S$$

$\phi_R$: angle between 2 hadron plane and scattering plane

$\phi_S$: angle between spin vector and scattering plane

$$\vec{p}_h = \vec{p}_{h,1} + \vec{p}_{h,2}$$

$$\vec{R}_h = \vec{p}_{h,1} - \vec{p}_{h,2}$$

# Partial Wave Expansion

$$\sin\theta H_1^{\sphericalangle}(z,\cos\theta,M_{inv}^{\pi^+\pi^-2}) \approx H_{1,ot}^{\sphericalangle}(z,M_{inv}^{\pi^+\pi^-2})\sin\theta - H_{1,lt}^{\sphericalangle}(z,M_{inv}^{\pi^+\pi^-2})\sin\theta\cos\theta$$

P/P wave interference

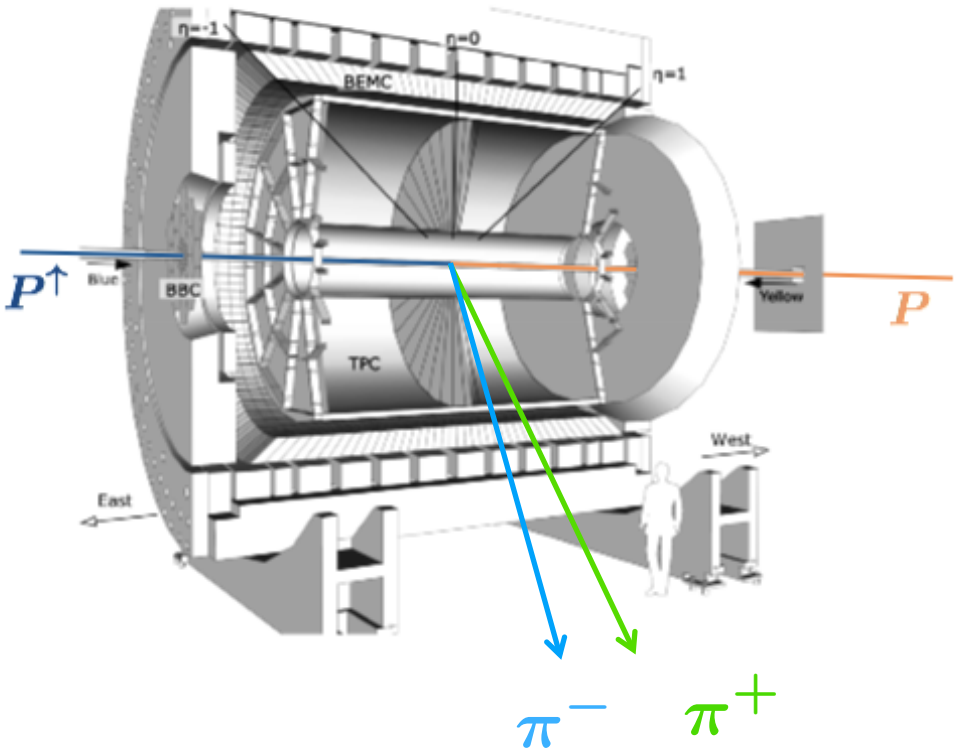
**Interference of L=1 unpolarized pair and L=1 transversely polarized pair**

S/P wave interference

**Interference of L=0 unpolarized pair and L=1 transversely polarized pair**

P wave contributions come from a spin-1 resonance ( $\rho$ 770 MeV ) → expect higher asymmetry around .8 GeV

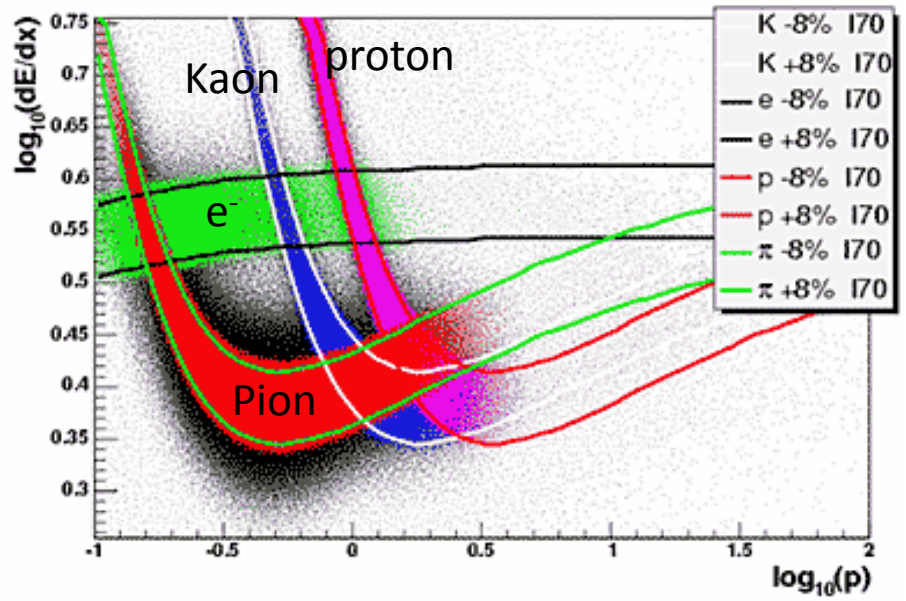
# The STAR Detector




- TPC for tracking and PID
- BEMC and BBC for triggering
- Polarization for 2012 ≈62%
- Nonzero asymmetries for 2006 200 GeV and 2011 500 GeV data

# Method

- **Find pions**




**93-95% pion**

# Method

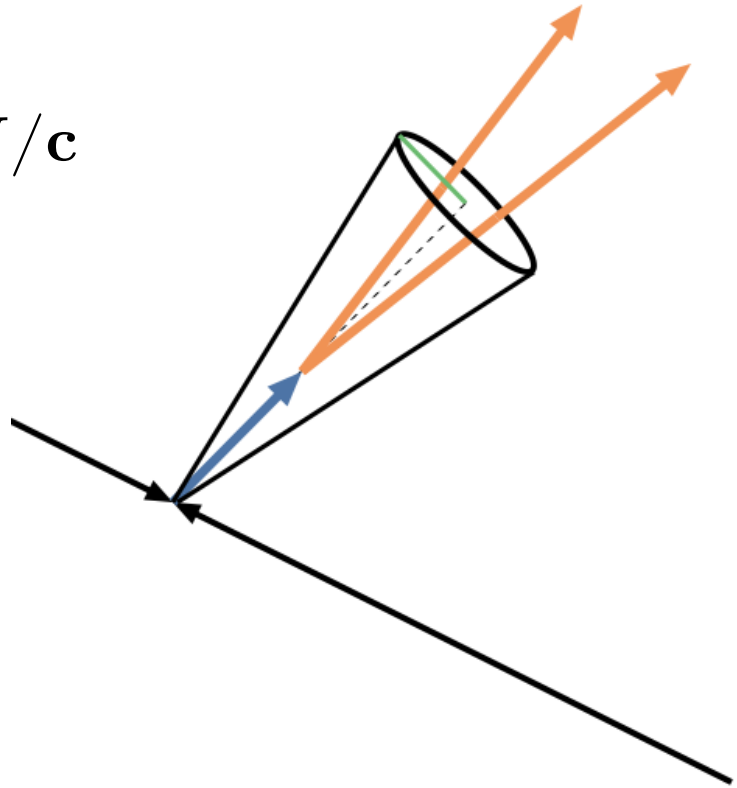
- **Find pions**
- **Combine pions into $\pi^+\pi^-$ pairs**

# Making $\pi^+\pi^-$ Pairs

- **Look at all pions in event**
- **$P_T$ of each track $> 1.5$ GeV/c**
- **good track in TPC**
- **opposite charge**
- **within a certain radius**

$$R = \sqrt{(\eta_1 - \eta_2)^2 + (\phi_1 - \phi_2)^2}$$

$$R < 0.7$$

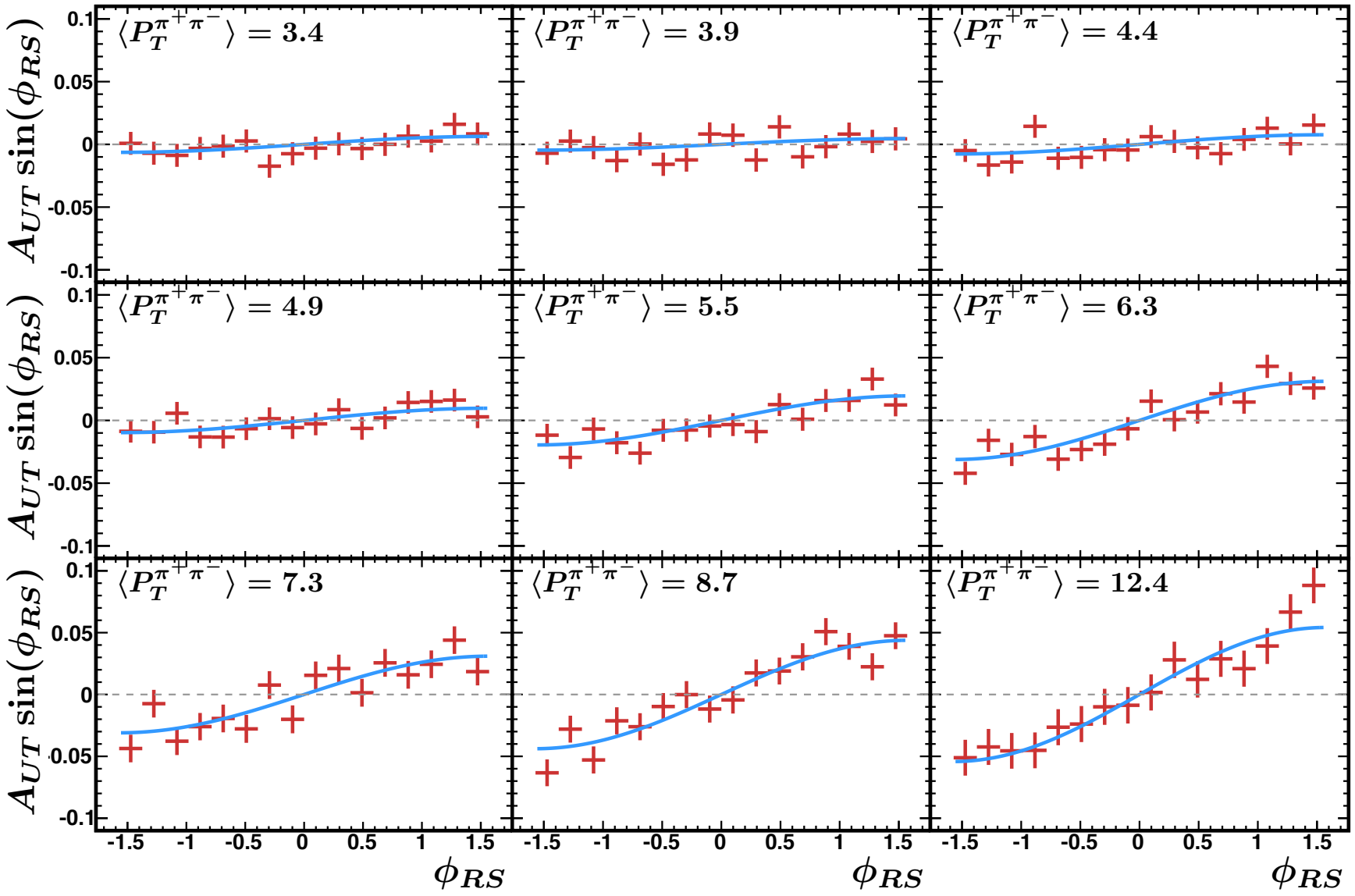


# Method

- Find pions
- Combine pions into $\pi^+\pi^-$ pairs
- **Construct asymmetry and fit with sine**

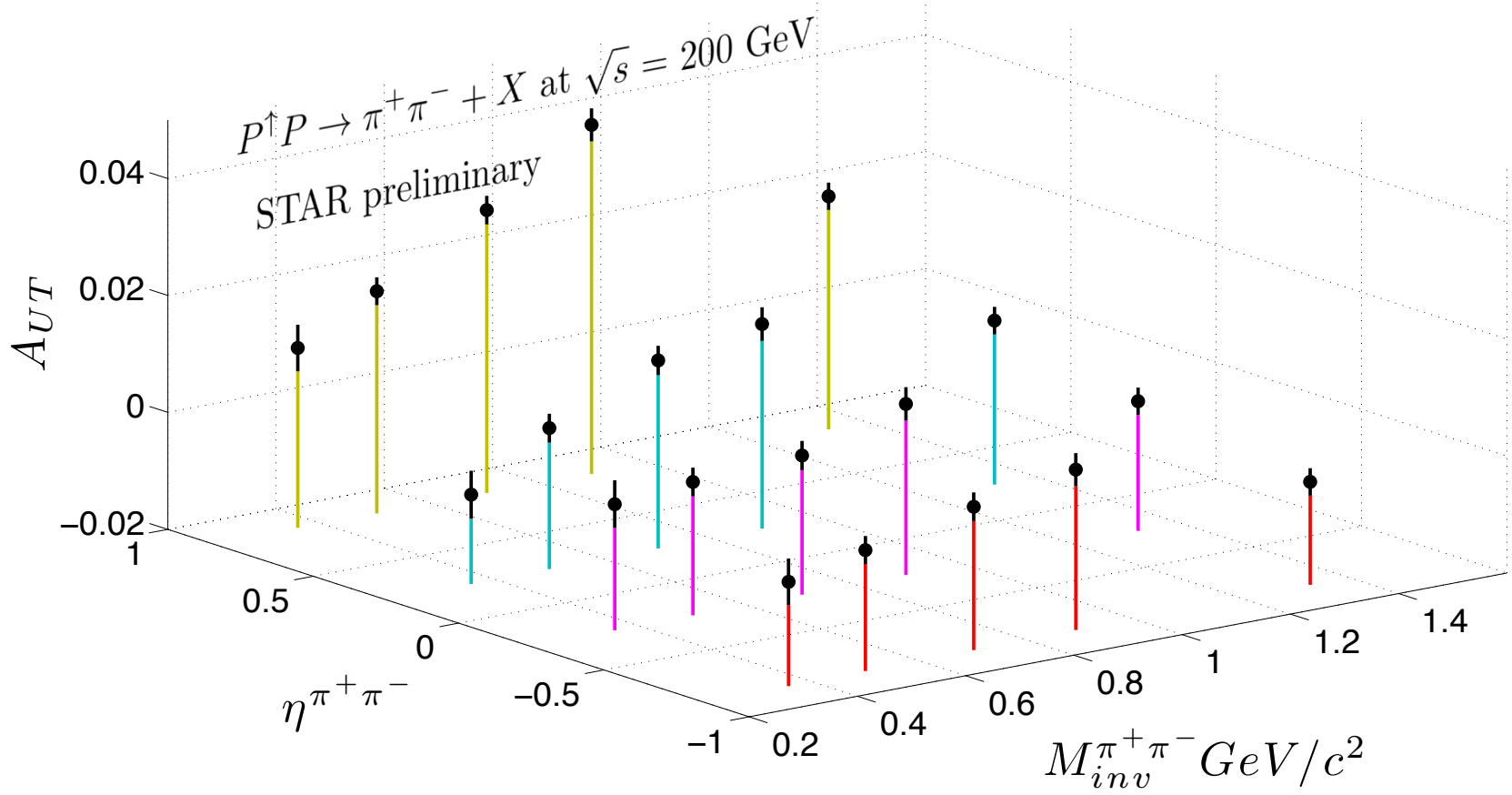
$$A_{UT}\sin(\phi_{RS}) = \frac{1}{Pol}\frac{\sqrt{N^{\uparrow}_{\phi_{RS}} N^{\downarrow}_{\phi_{RS}+\pi}} - \sqrt{N^{\uparrow}_{\phi_{RS}+\pi} N^{\downarrow}_{\phi_{RS}}}}{\sqrt{N^{\uparrow}_{\phi_{RS}} N^{\downarrow}_{\phi_{RS}+\pi}} + \sqrt{N^{\uparrow}_{\phi_{RS}+\pi} N^{\downarrow}_{\phi_{RS}}}}$$

# Selected Sine Fits



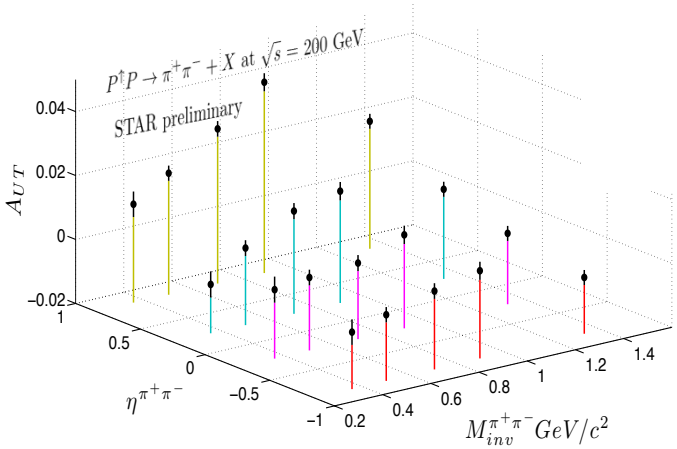
# Results

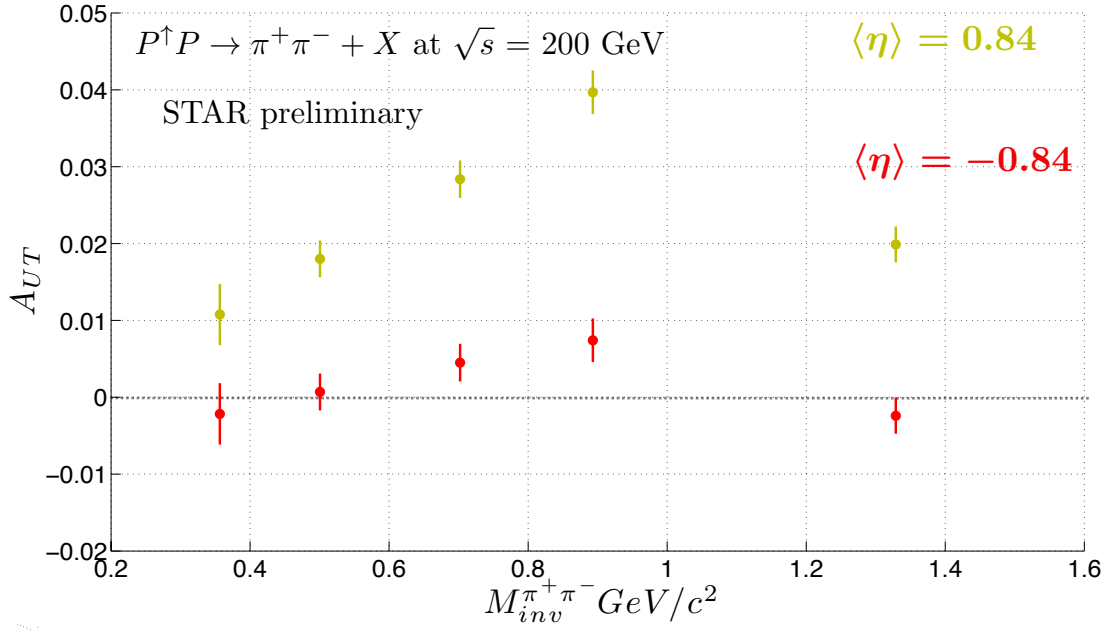
# Asymmetry as function of $M_{inv}^{\pi^+\pi^-}, \eta^{\pi^+\pi^-}$



# Asymmetry as function of $M_{inv}^{\pi^+\pi^-}, \eta^{\pi^+\pi^-}$

**$\eta <$ expected to show minimal asymmetry. From unpolarized beam.**



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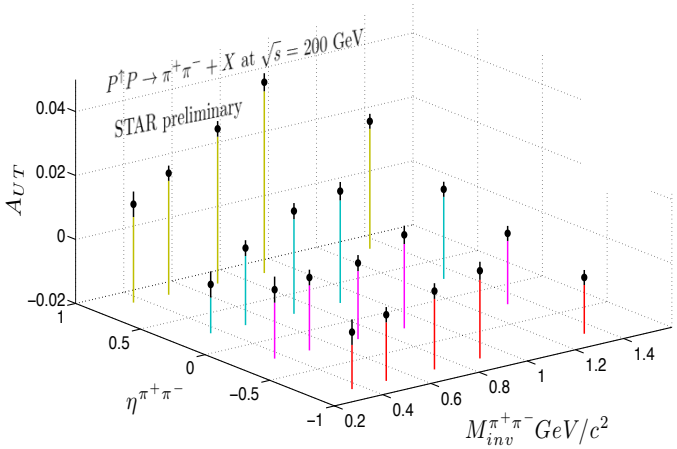
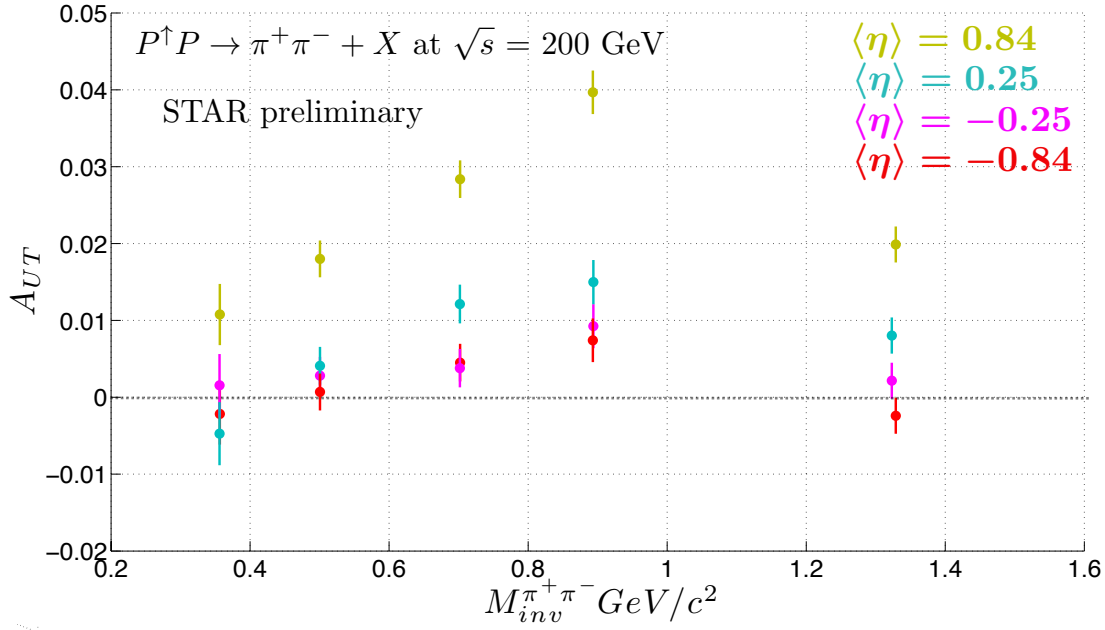
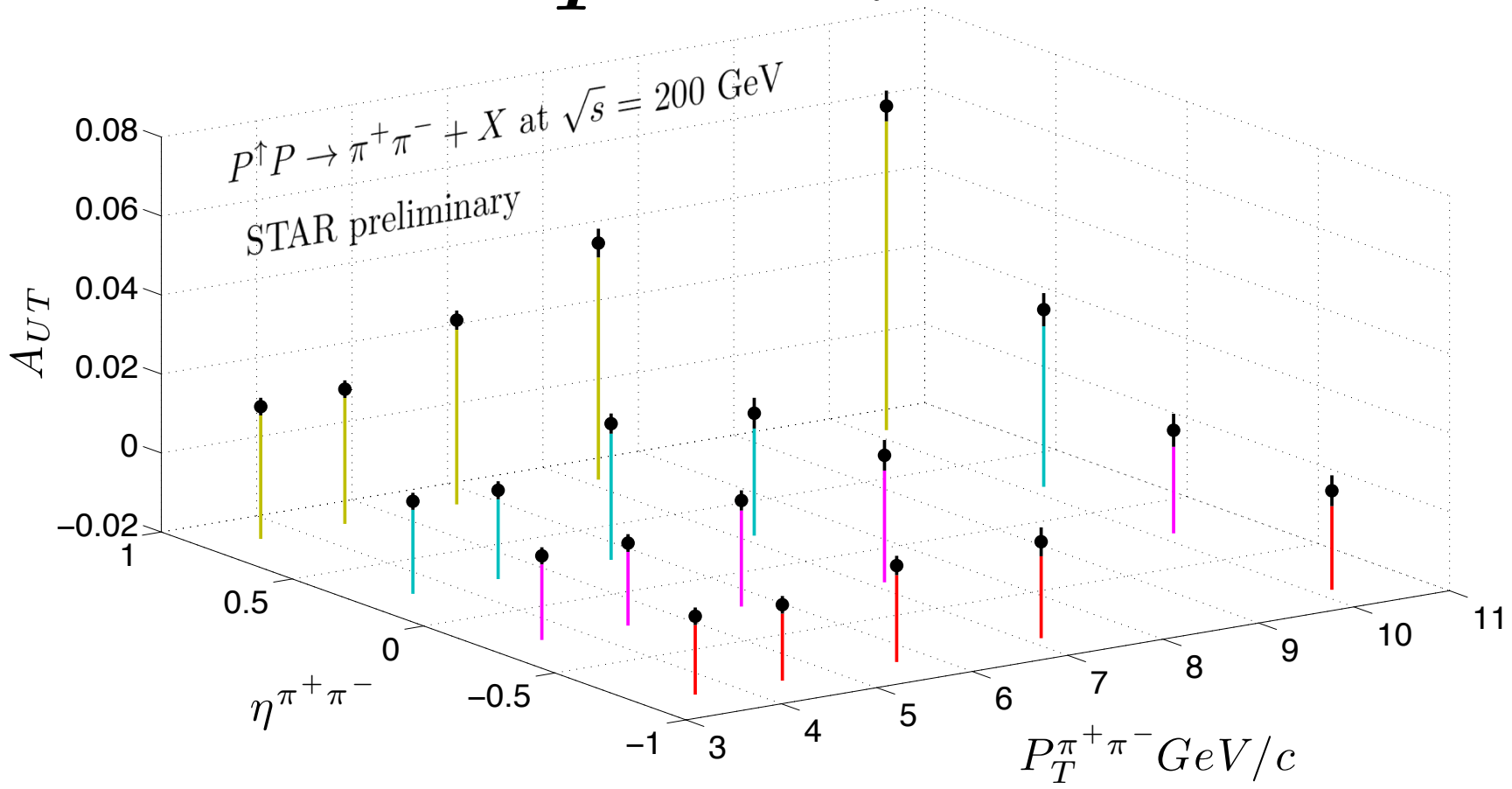


# Asymmetry as function of $P_T^{\pi^+\pi^-}, \eta^{\pi^+\pi^-}$



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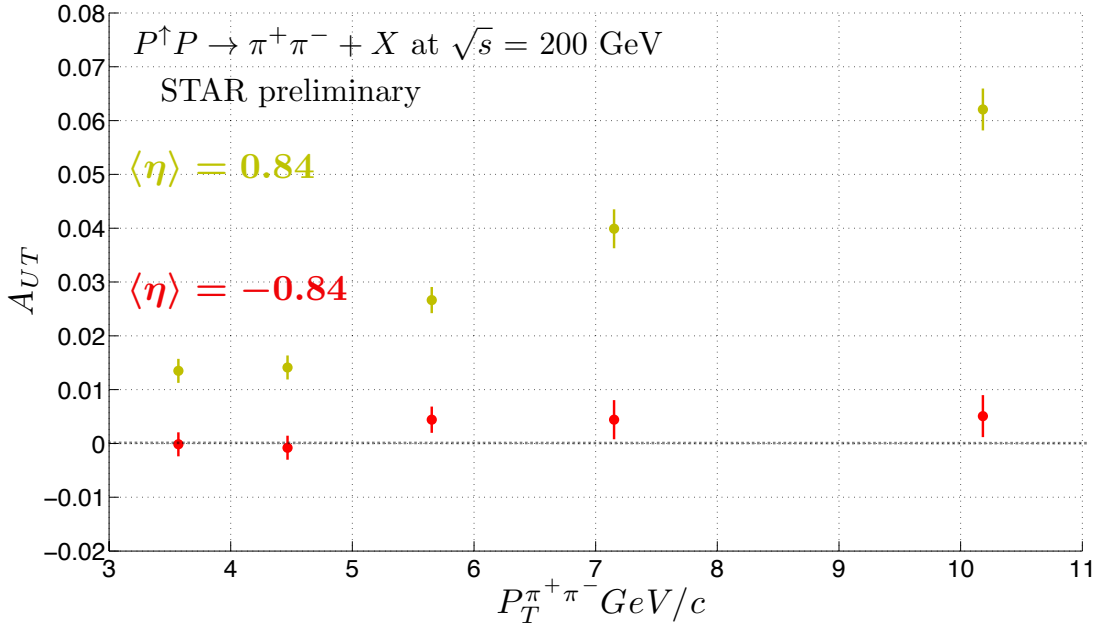


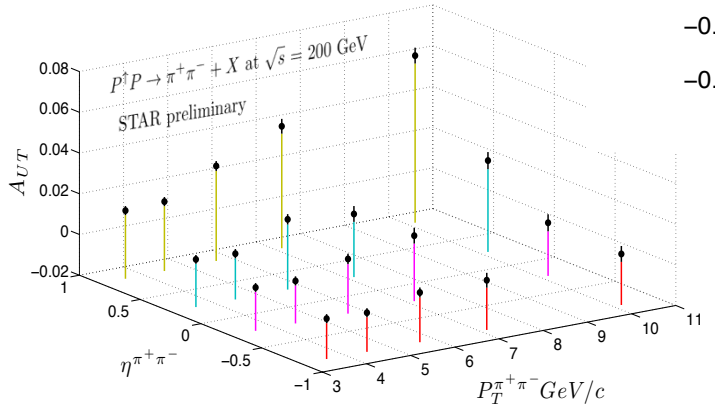

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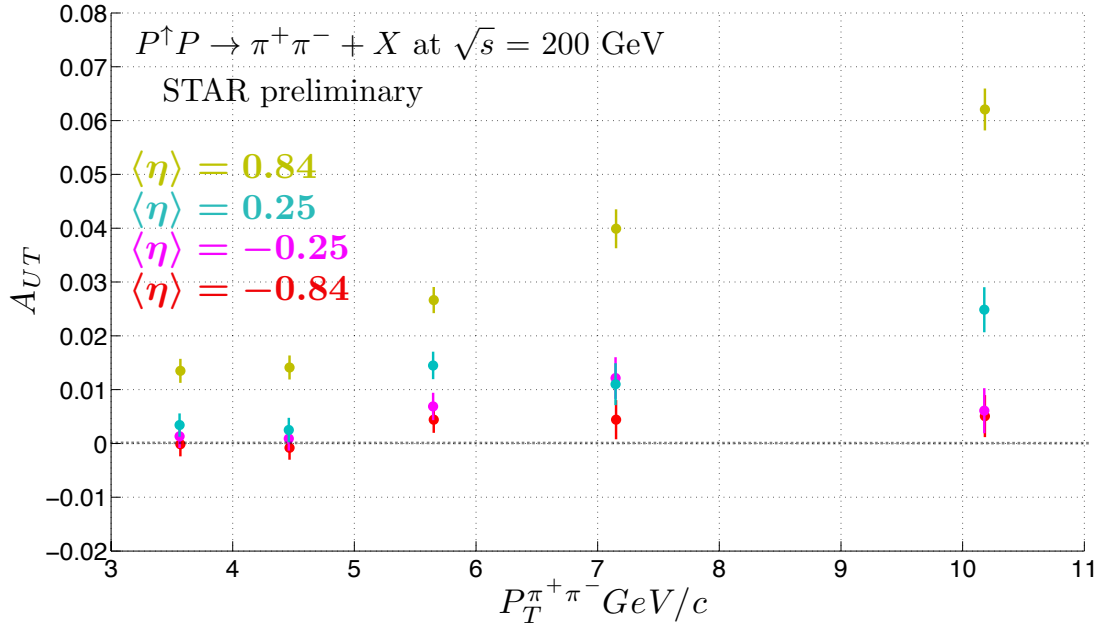
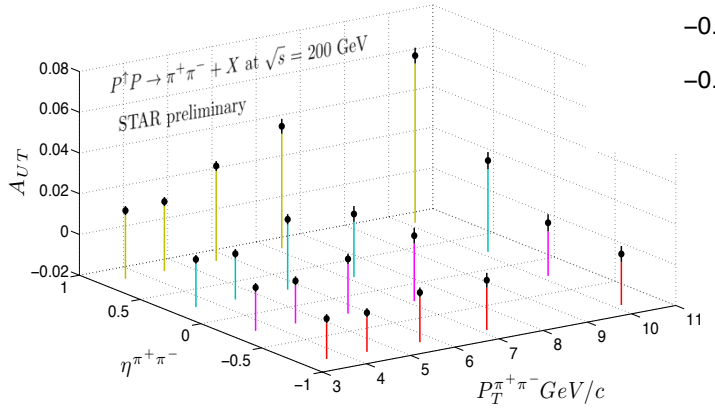
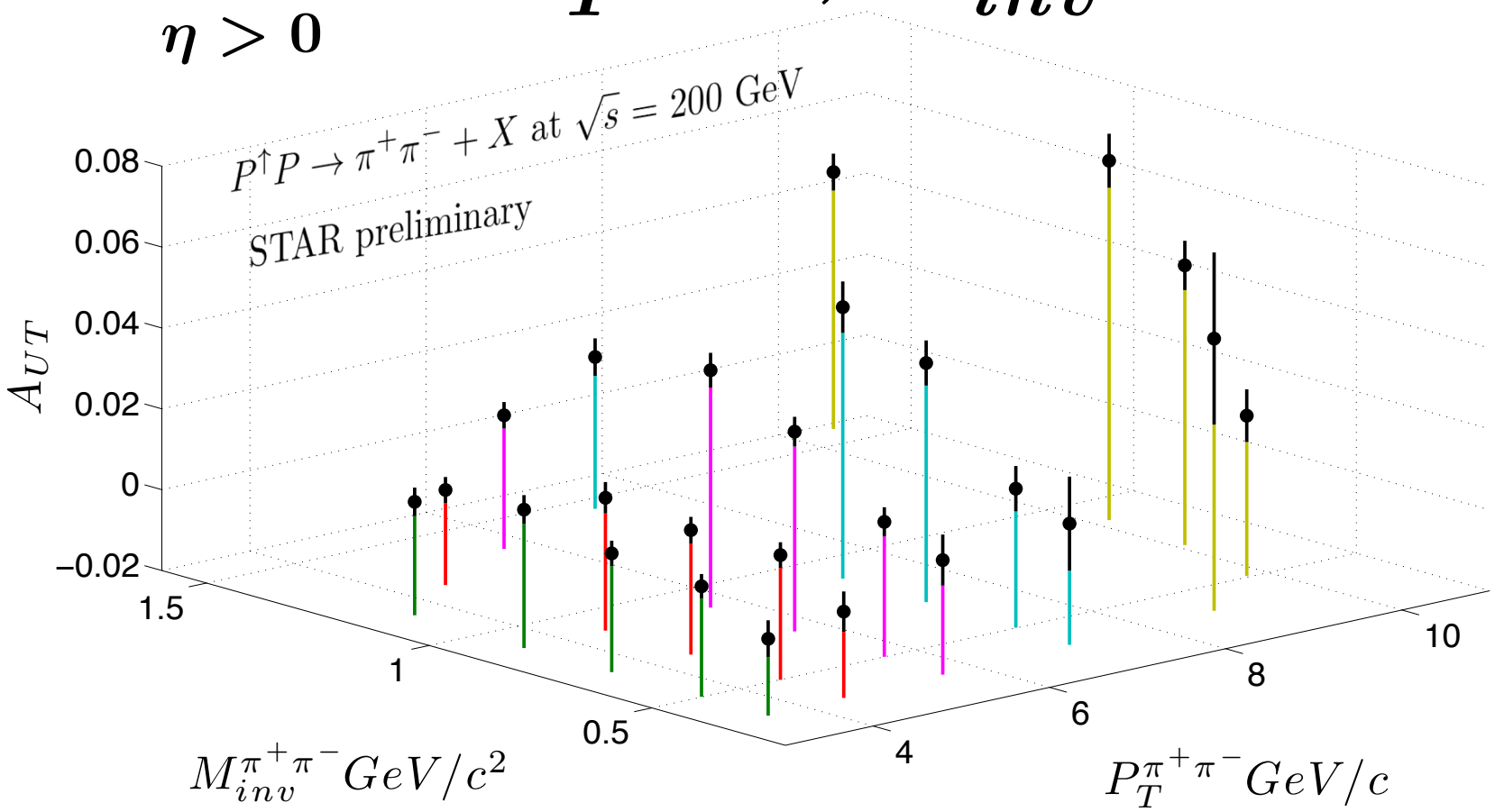


# Asymmetry as function of $P_T^{\pi^+\pi^-}, M_{inv}^{\pi^+\pi^-}$

$\eta > 0$



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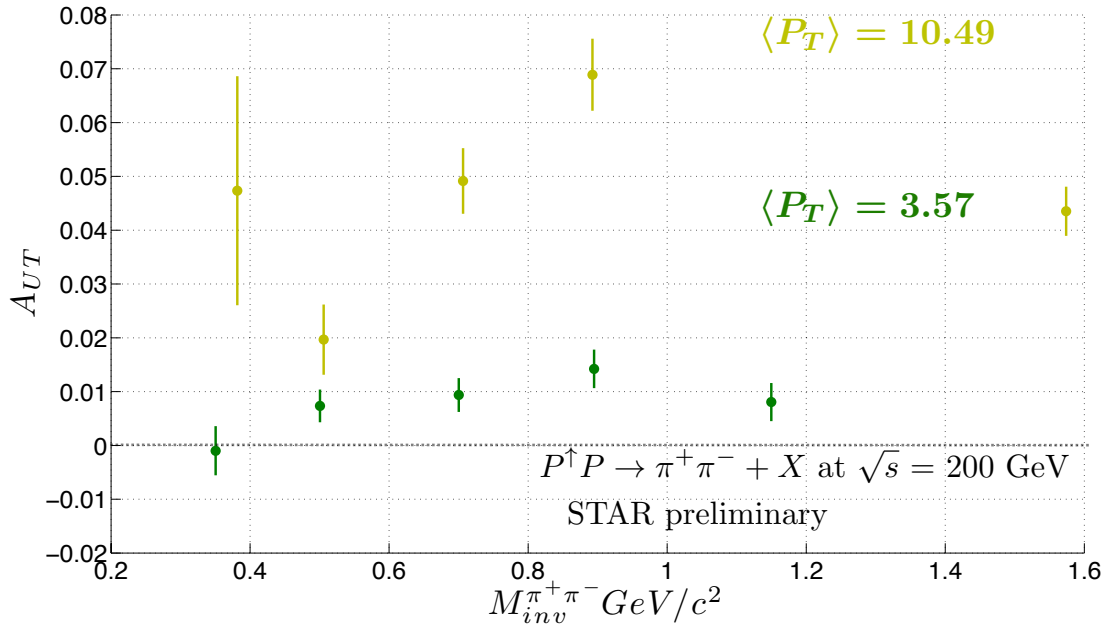


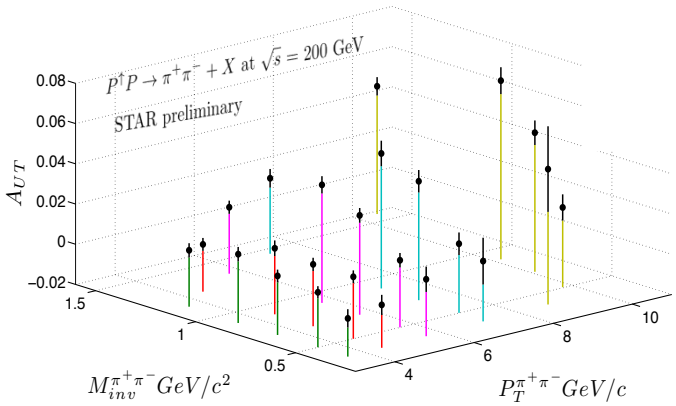

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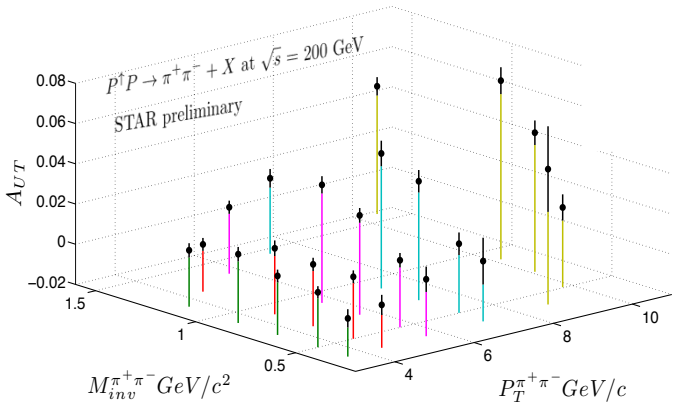
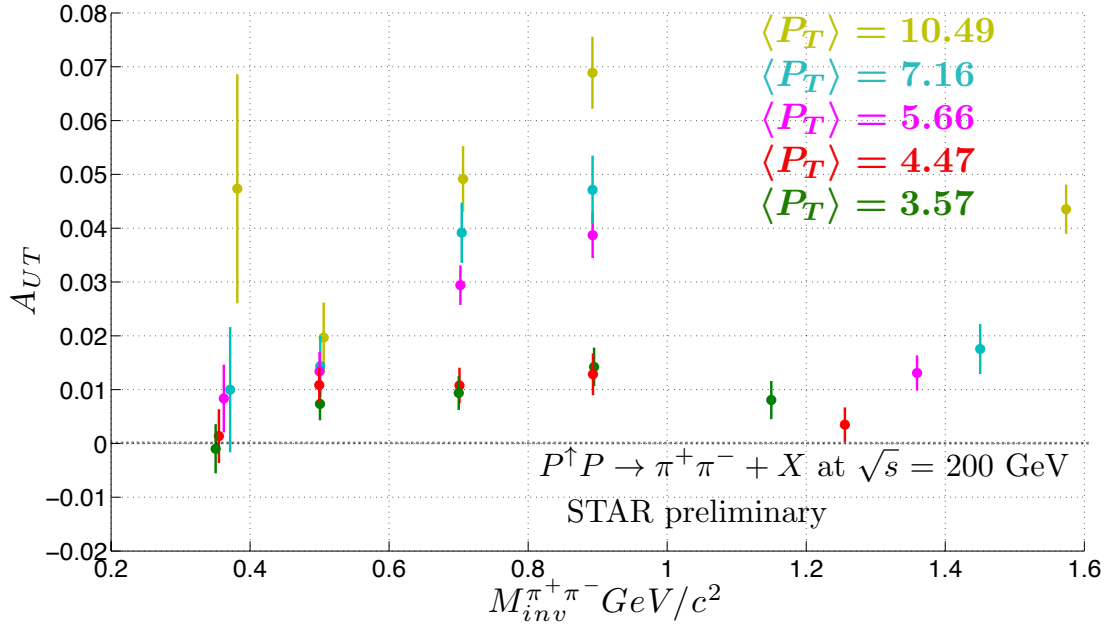
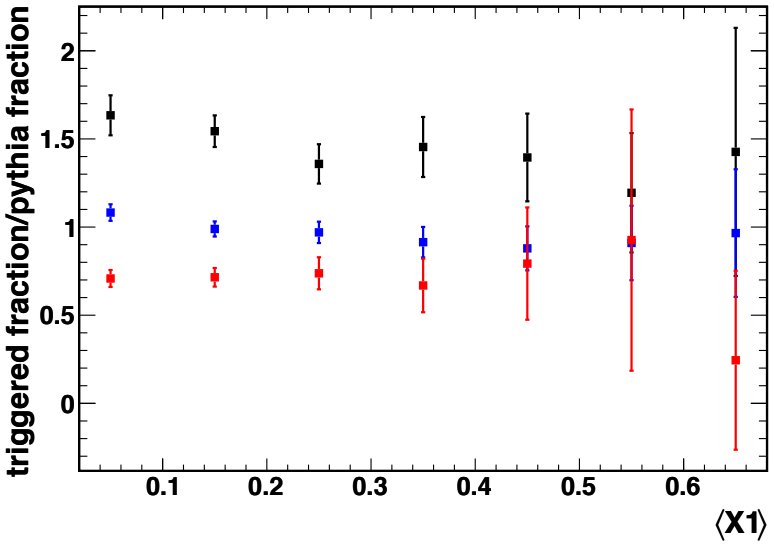


# Trigger Bias




$f_i f_j \rightarrow f_i f_j \quad gg \rightarrow gg$

$f_i g \rightarrow f_i g \quad gg \rightarrow f_k \bar{f}_k$

- JP1 and JP2 triggers are more sensitive to quark jets
- Trigger has ≈50% more quark-quark events
- 33% increase in observed asymmetries over particle level asymmetries

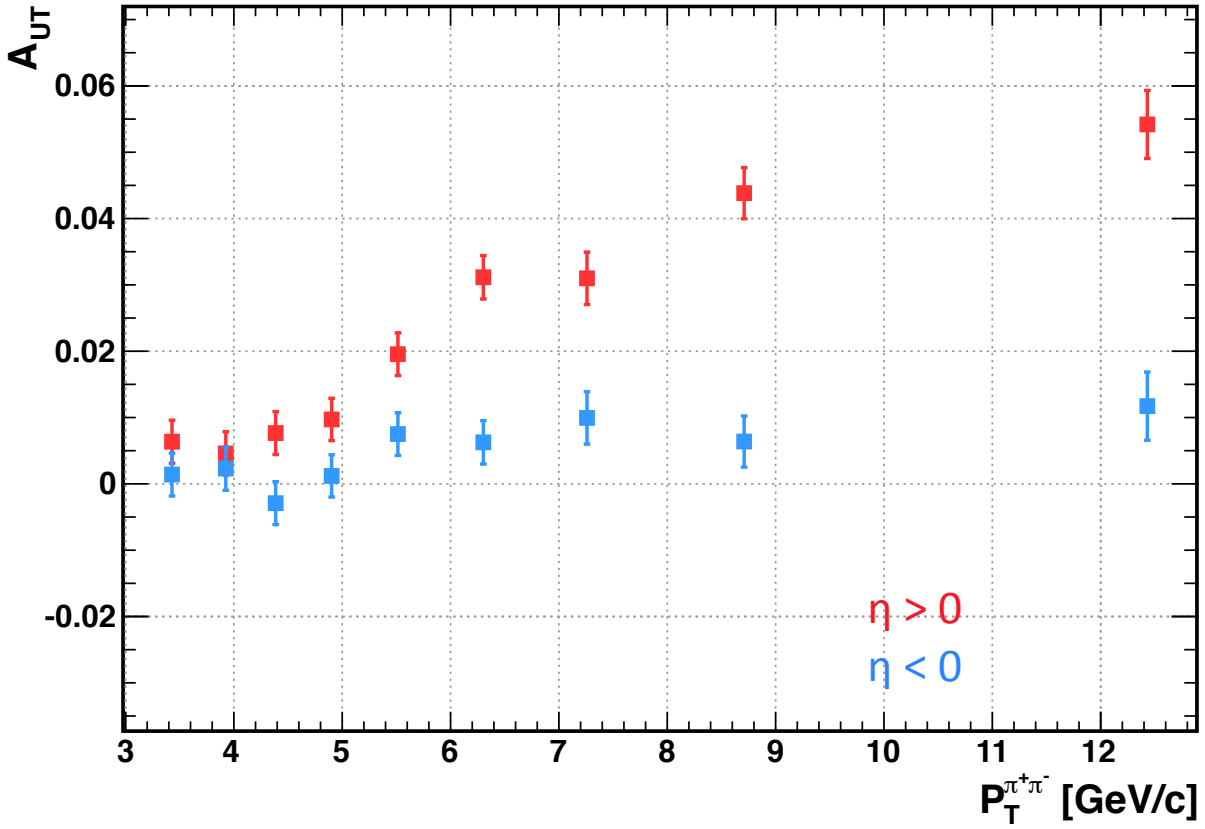
# Summary

- **Preliminary results show a high asymmetry at high $\eta^{\pi^+\pi^-}$ and $P_T^{\pi^+\pi^-}$**
- **Enhancement to asymmetry is seen around $\rho$ mass**
- **Results in conjunction with SIDIS data can be used to extract transversity**
- **Tests the universality of transversity**
- **Paper with 2006 data: arXiv:1504.00415**
- **Nonzero asymmetries for Collins fragmentation function also**

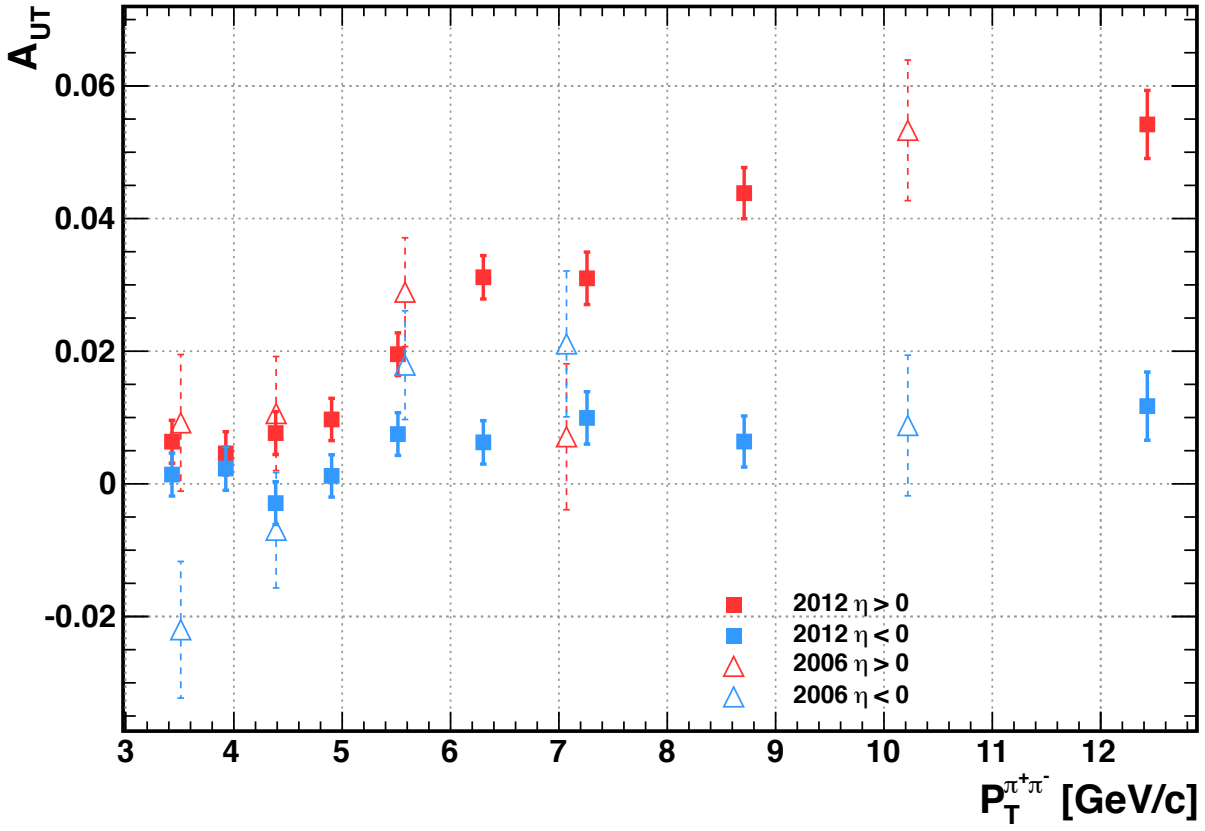
# Thank You

# 1D binning

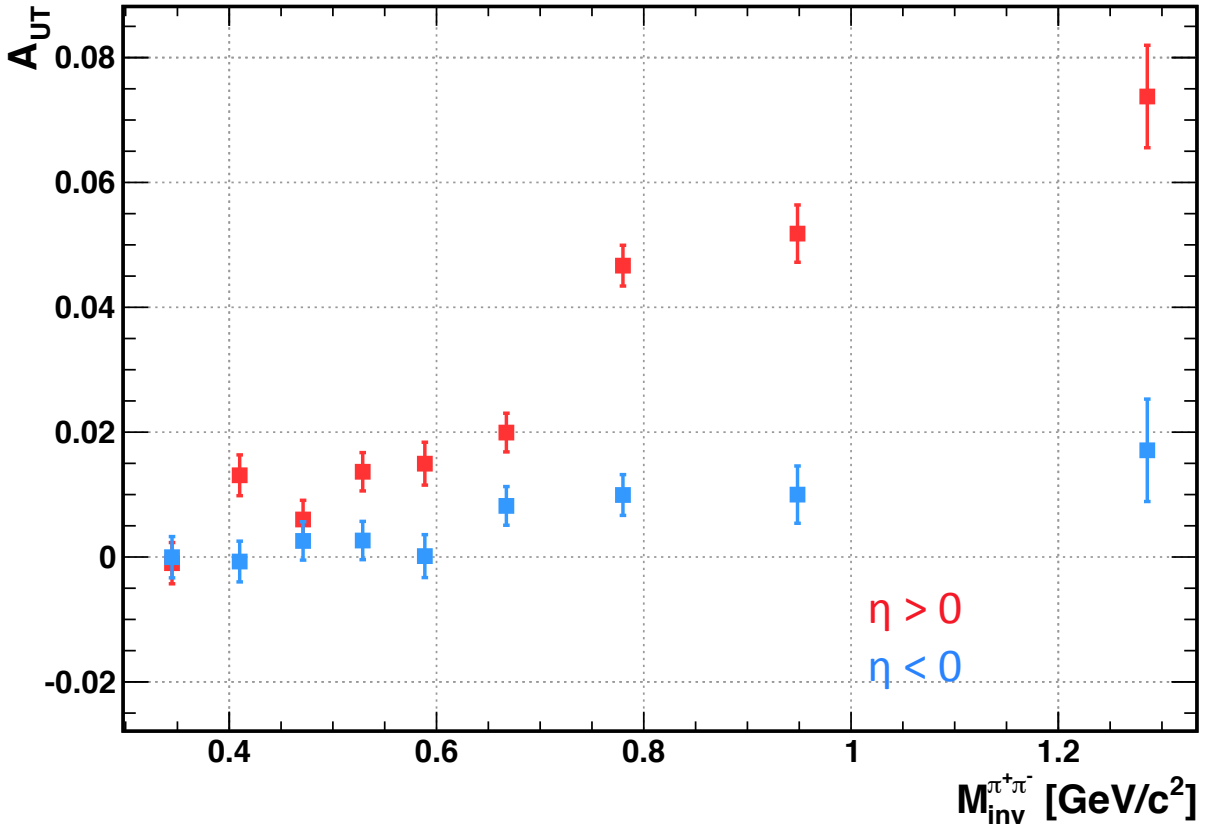
# Asymmetry Vs Pt



# Asymmetry vs pt



# Asymmetry Vs Mass



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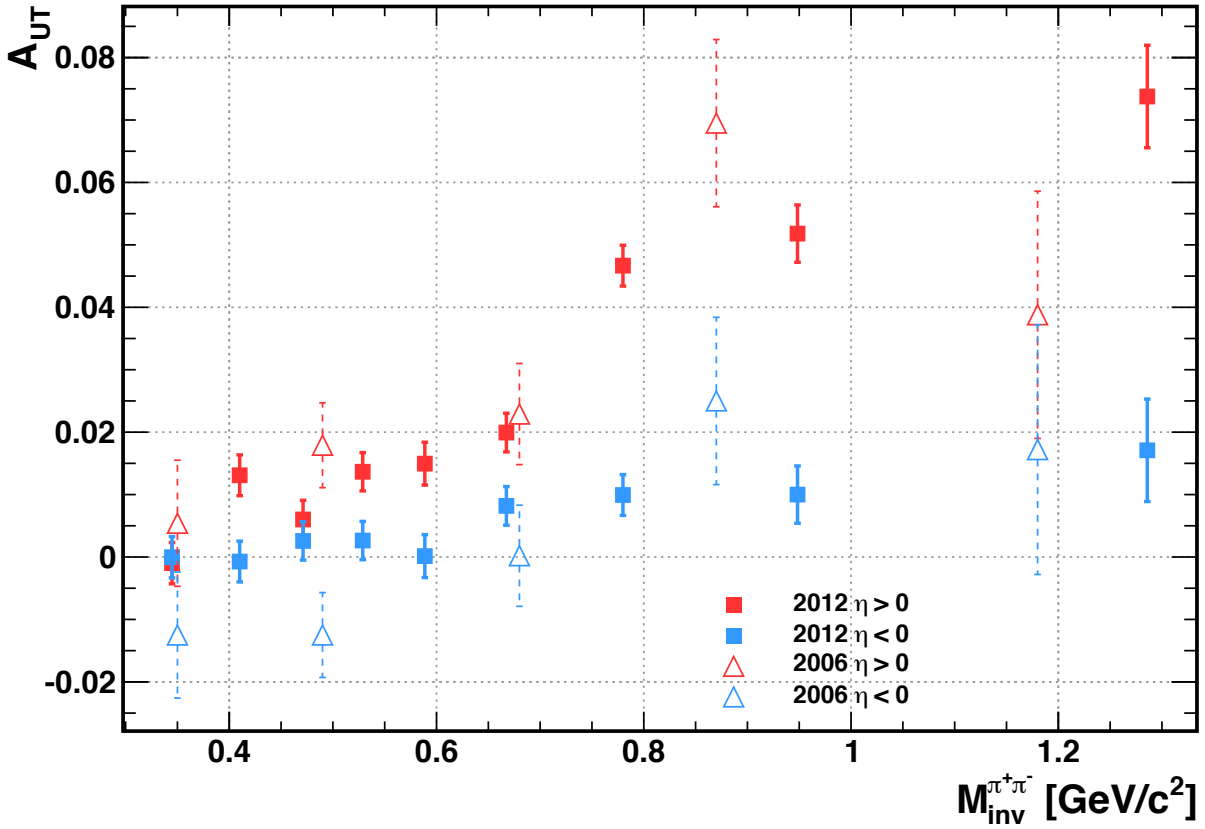

# Asymmetry Vs Eta