Analysis of Major Decay Channels of the η(548) and η'(958) Mesons for the GlueX Experiment

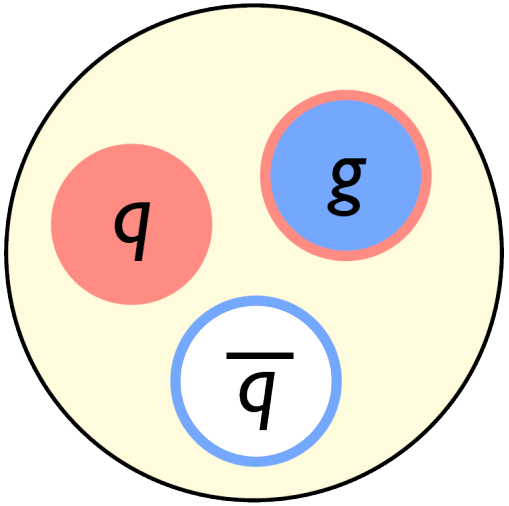
Feb. 15, 2019

Tegan Beattie, Zisis Papandreou, Justin Stevens

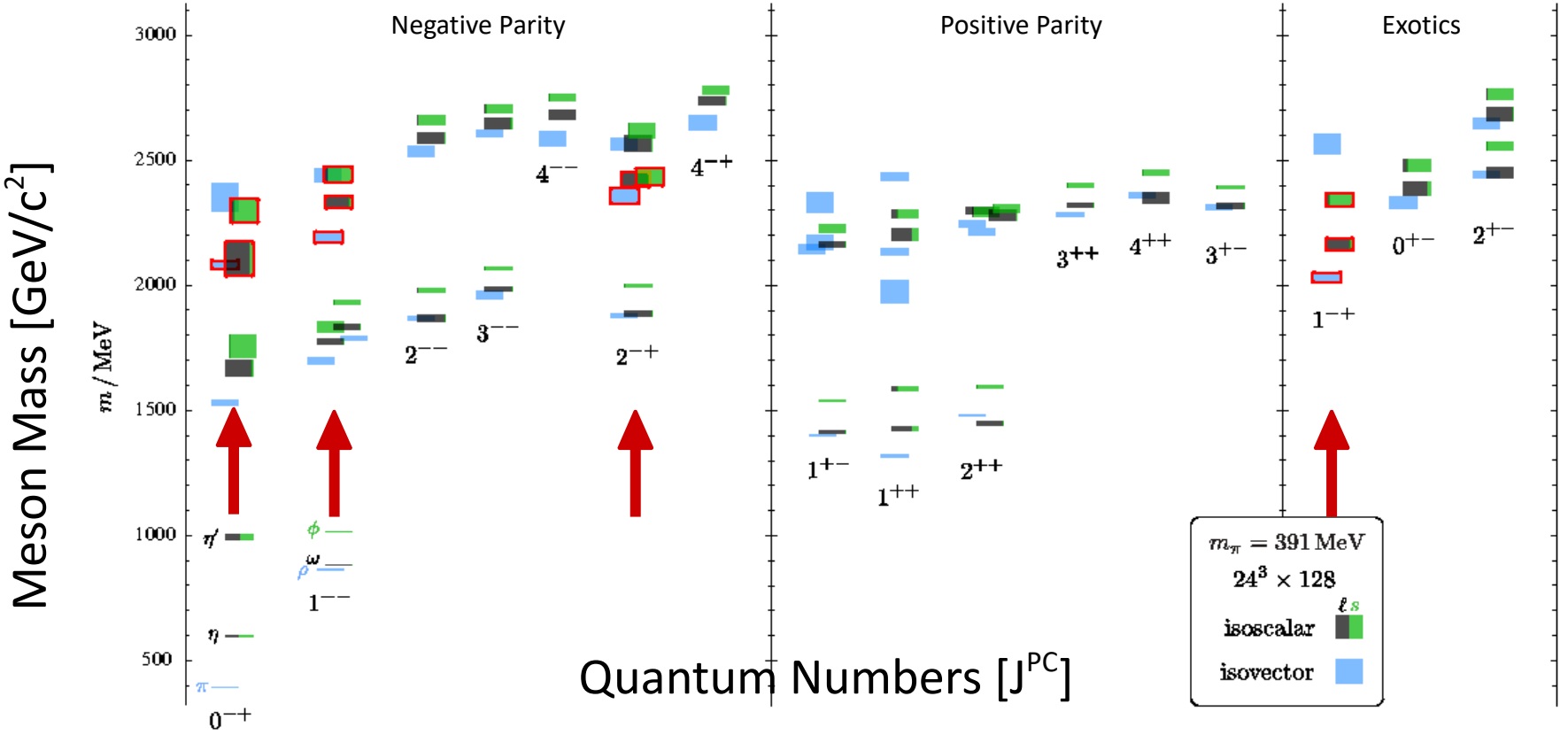
Winter Nuclear & Particle Physics Conference, Feb. 14 – 17, 2019 WNPPC *Banff, AB, Canada*

GlueX Physics

- Search for evidence of exotic J^{PC} hybrids
- Map light meson spectrum
  - Specifically, the lightest hybrid multiplet (predicted by LQCD calculations)
- Provide validation for QCD model with gluonic degrees of freedom



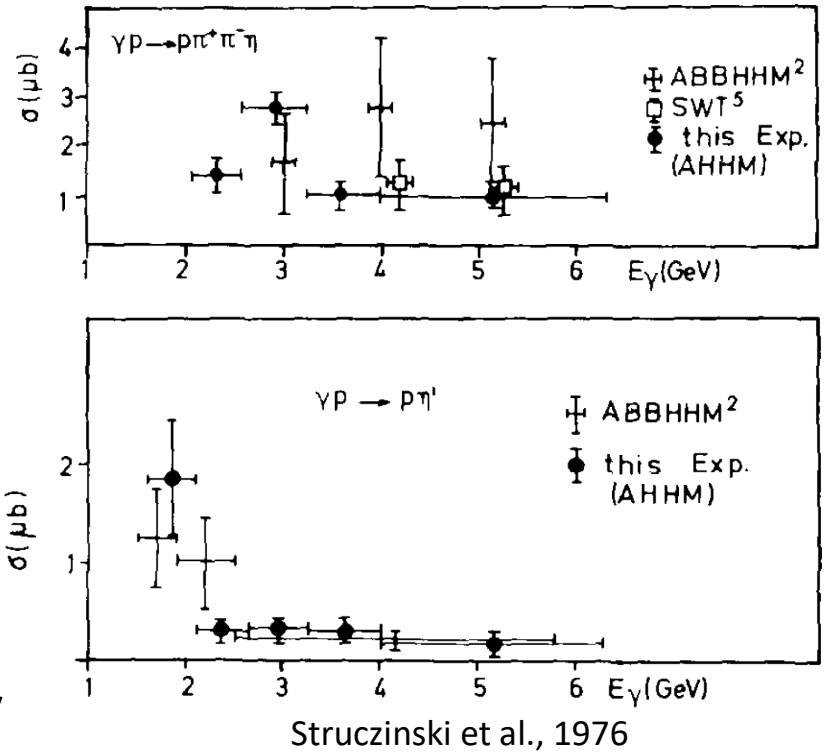
$q\bar{q}$ pair w/ contributions from an excited gluon



J.J. Dudek, R.G. Edwards, P. Guo, and C.E. Thomas, Phys. Rev. D88 094505 (2013)

Current Work

- First steps toward mapping exotics: study observables of likely decay particles
  - πη and πη' resonances high on list of possibly-accessible exotics/hybrids
  - η/η' abundantly available at GlueX
  - World η/η' photoproduction data sparse
  - Σ beam asymmetries/cross sections not yet measured at GlueX energies (9 GeV)
- Measuring η/η' observables gives input to theory



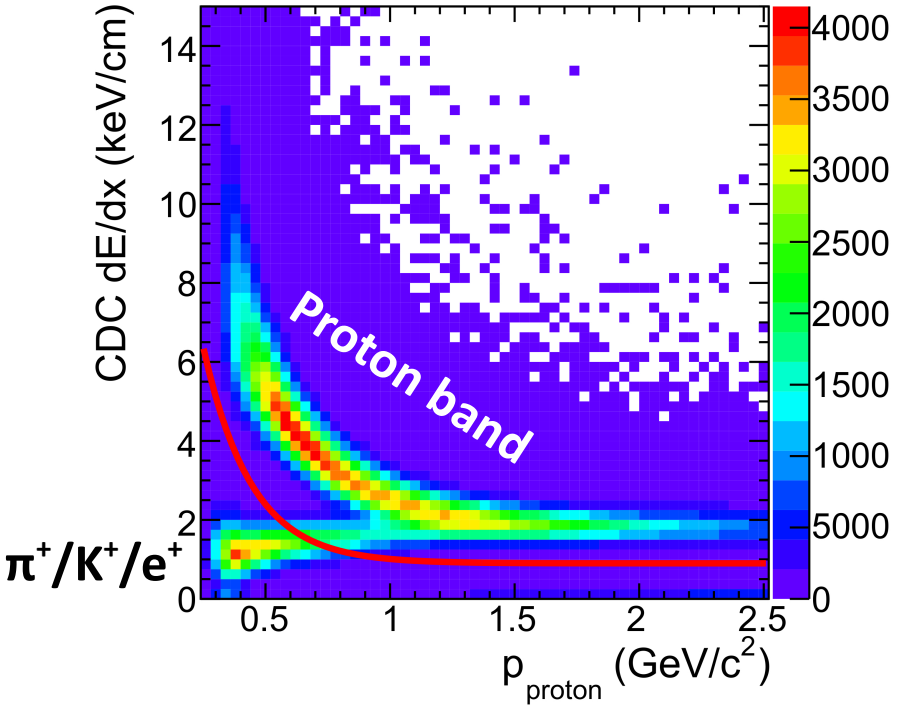
Struczinski et al., 1976

This talk: most recent results for Σ asymmetry of η' and η vs. momentum transfer (Mandelstam t)

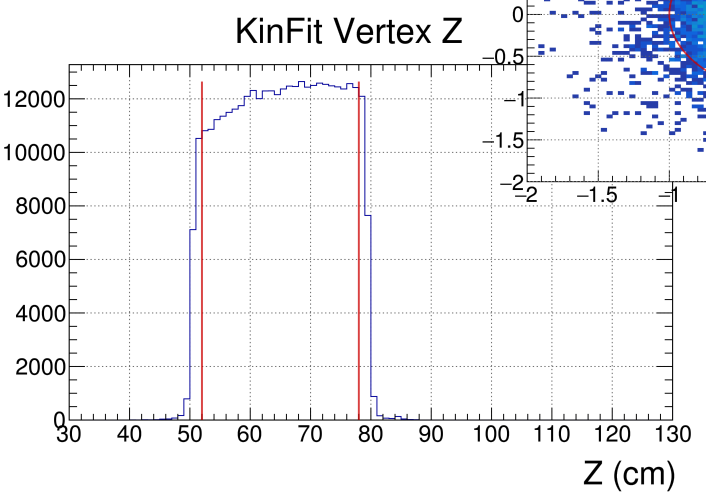
$\eta \to \pi^+ \pi^- \pi^0$, $\pi^0 \to 2\gamma$	$\eta \to 3\pi^0$, $\pi^0 \to 2\gamma$	$\eta \to 2\gamma$	$\eta' \to \pi^+ \pi^- \eta$, $\eta \to 2\gamma$
(BR ~ 22.9 %)	(BR ~ 32.7 %)	(BR ~ 39.4 %)	(BR ~ 42.9 % * 39.4 %)

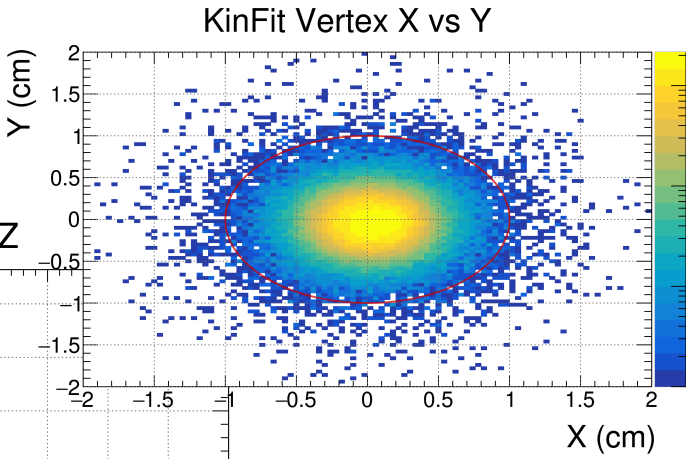
Event Selection Cuts

- Select combinations of particles which match our topology
  - 2 pos. tracks (p, π^+), 1 neg. track (π^-), 2 neutral showers (π^0 or $\eta \rightarrow 2\gamma$)
- Loose dE/dx cut for Proton/Pion separation
- Missing mass cut to select out exclusive η' production
  - Ensure invariant mass of beam + target ≈ invariant mass of candidate particle
- Kinematic fit constrains 2γ mass and tests for conservation of E and P
- Vertex cuts remove candidates with decay vertices outside target volume

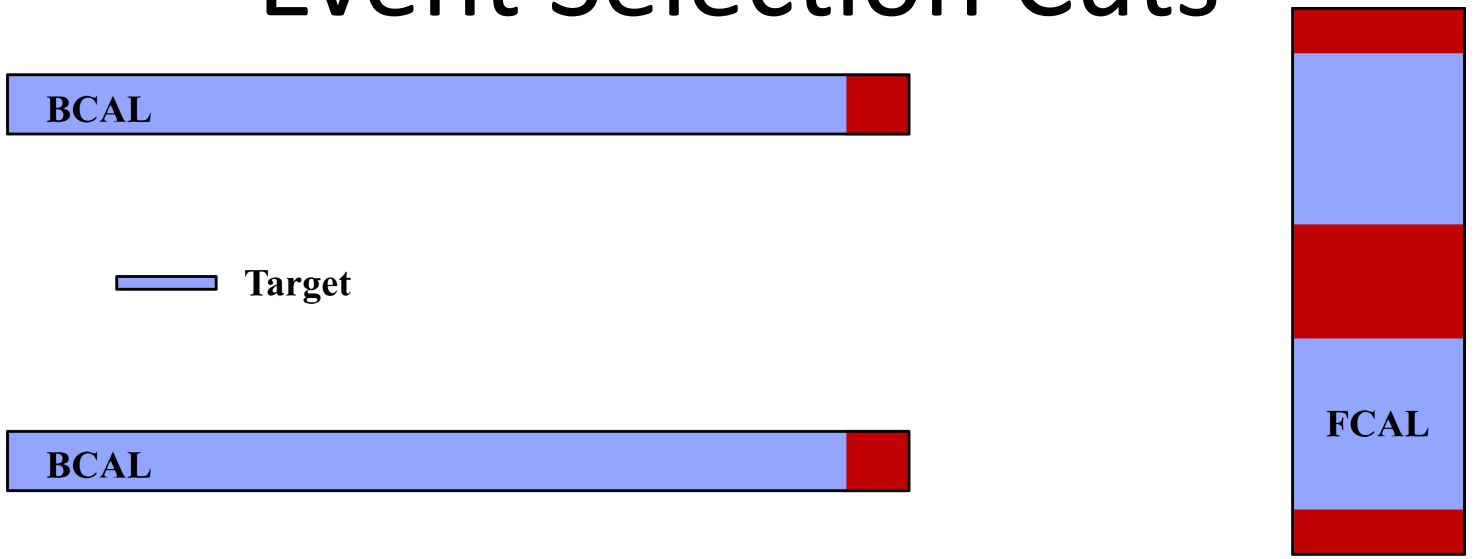


Cuts shown in RED

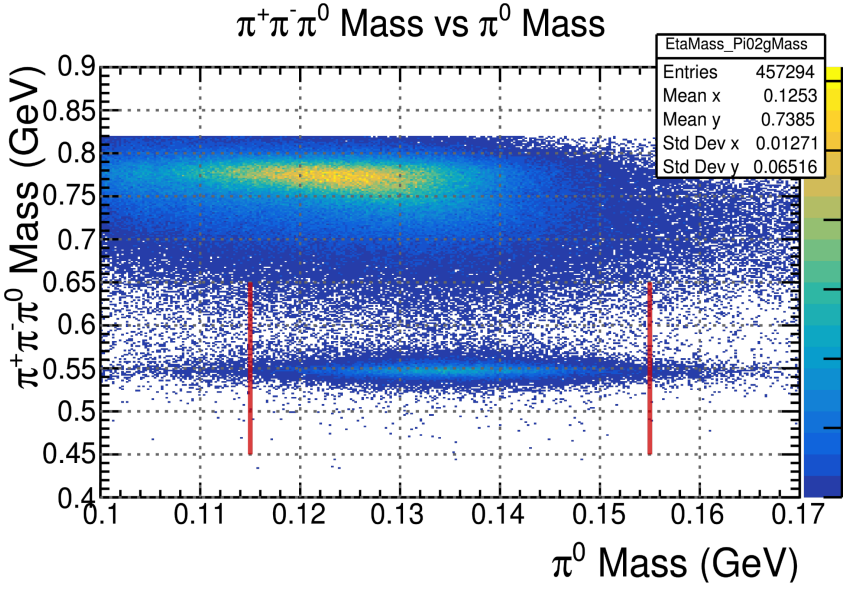


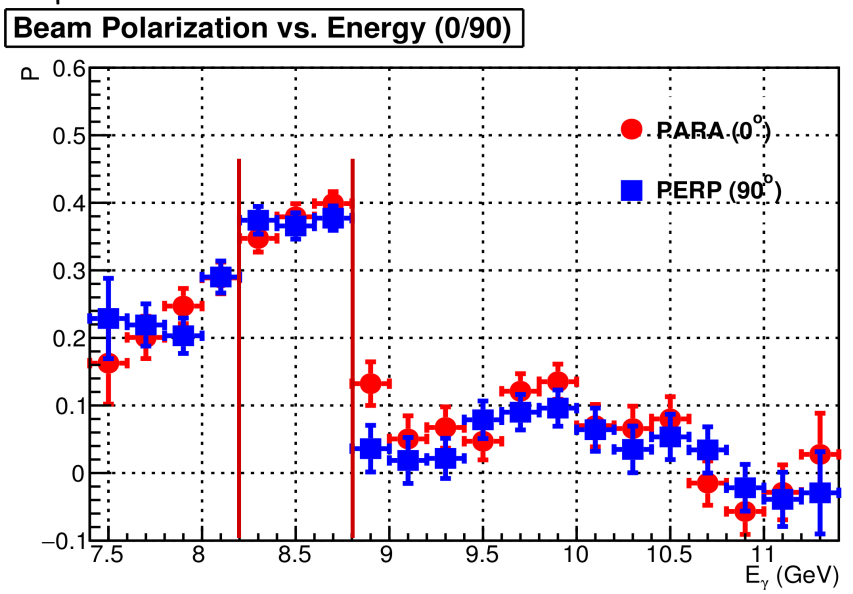


Event Selection Cuts



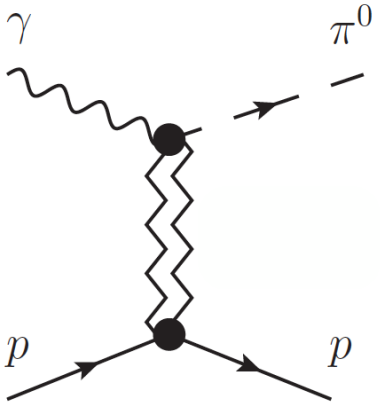
- Photon reconstruction around the beam hole and BCAL-FCAL gap less reliable
  - Fiducial cut removes combos with neutral shower close to either region
- Cut on 2γ mass to reject less-likely combos which passed kinematic fit
- Use coherent Bremsstrahlung peak data (E_γ = 8.2 – 8.8 GeV)





Beam Asymmetry

- Σ beam asymmetry: polarization observable
- Provides insight into beam-target exchange
  - Σ = 1 ⇒ natural parity exchange (ω, ρ)
- Polarized yield as a function of ϕ is proportional to PΣ



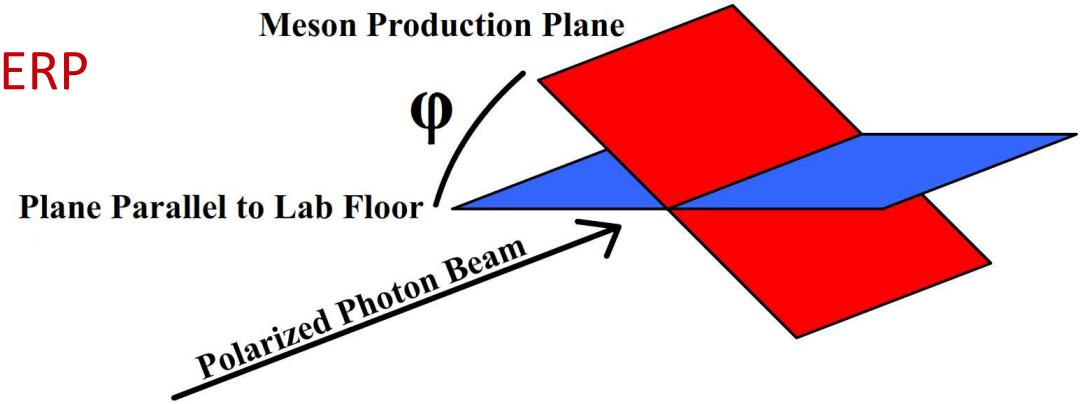
Exchange JPC

$= 1 \Rightarrow 1^{--} : \omega, \rho$

$= -1 \Rightarrow 1^{+-} : b, h$

Physics

- 2 polarization configurations: PARA, PERP
- 2 data sets: 0/90, 45/135



$$\sigma_{pol} = \sigma_{unpol} [1 - P_\gamma \Sigma \cos(2(\phi - \phi_\gamma - \phi_0))]$$

$$Y_\perp(\phi) \approx N_\perp A(\phi) [1 - P_\perp \Sigma \cos(2(\phi - \phi_0))]$$

$$Y_\parallel(\phi) \approx N_\parallel A(\phi) [1 + P_\parallel \Sigma \cos(2(\phi - \phi_0))]$$

$$\text{ASYM} = \frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma \cos(2(\phi - \phi_0))}{2 - (P_\perp - P_\parallel)\Sigma \cos(2(\phi - \phi_0))}$$

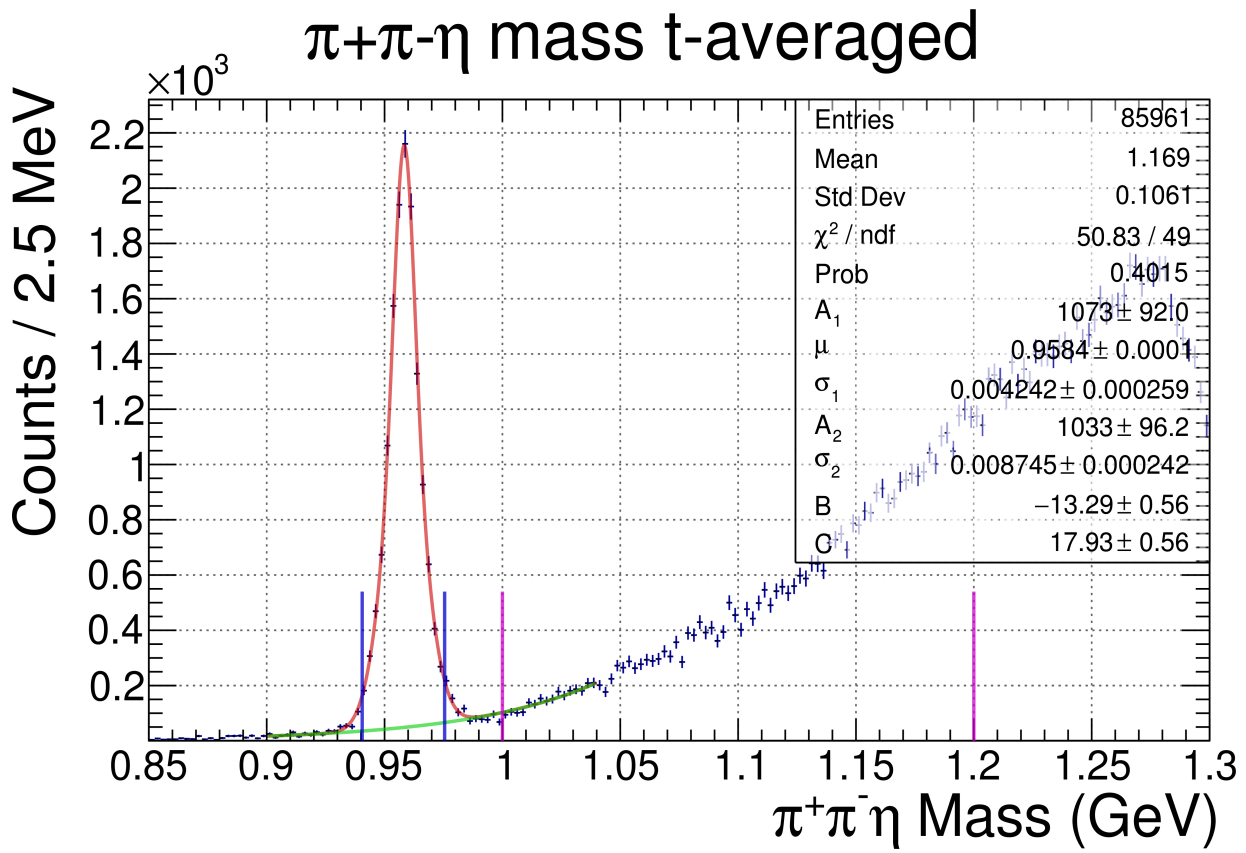
- F_R: Pair Spectrometer yields
- ϕ_0: ω asymmetry fit
- $P_\perp$ and $P_\parallel$: Triplet Polarimeter
- Σ is the only free parameter

Method

Side-Band Asymmetry Correction

- Percentage of background events under η or η' peak is not negligible!
  - If background has different Σ asymmetry, our measured peak Σ is diluted

- To correct for this, measure Σ_{SB} and f, the dilution factor
  - Σ_{SB} is the asymmetry for events in a mass side-band (purple bars below)
  - f = B / (S + B) is found from a mass spectrum fit (double Gaussian + exponential)

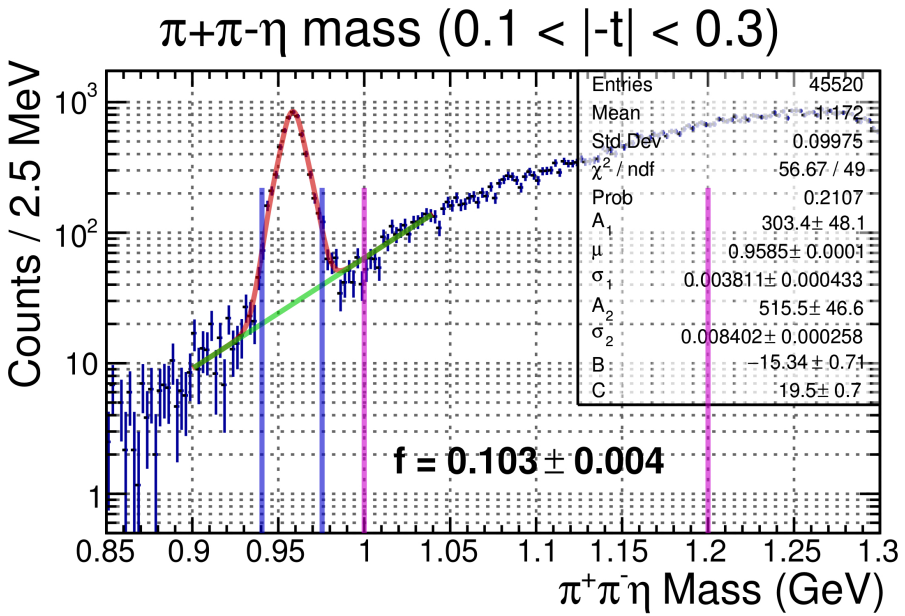


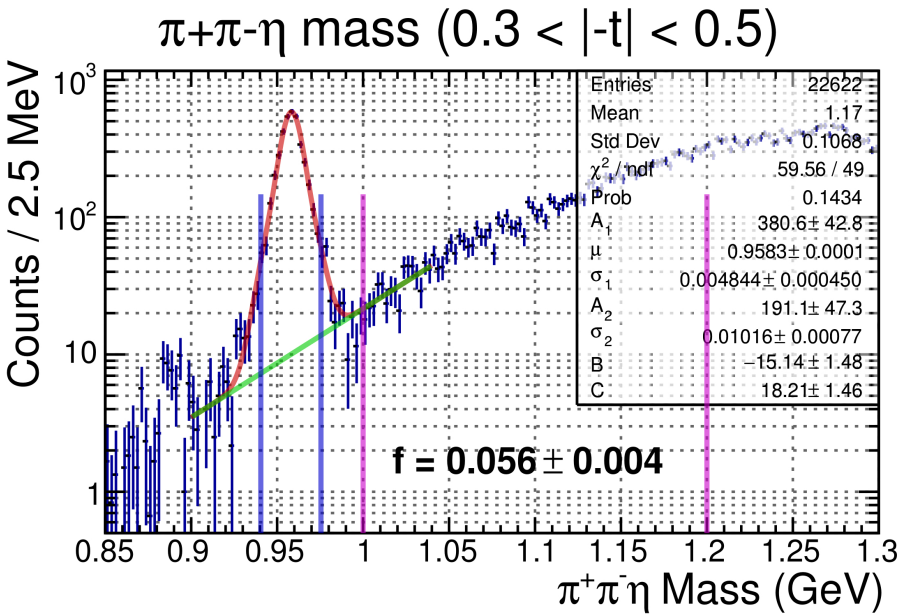
Then,

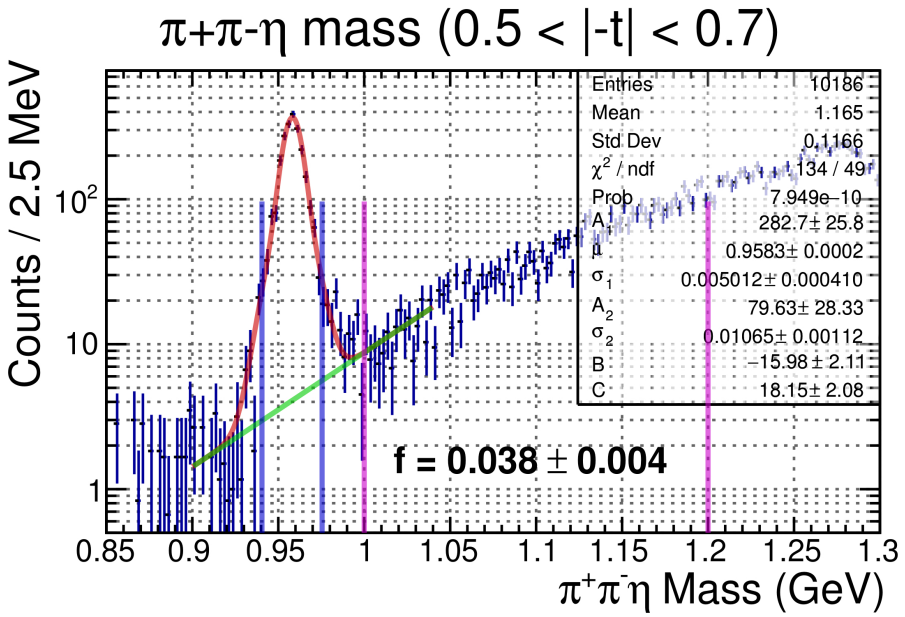
$$\Sigma_{COR} = \frac{\Sigma - f\,\Sigma_{SB}}{1 - f}$$

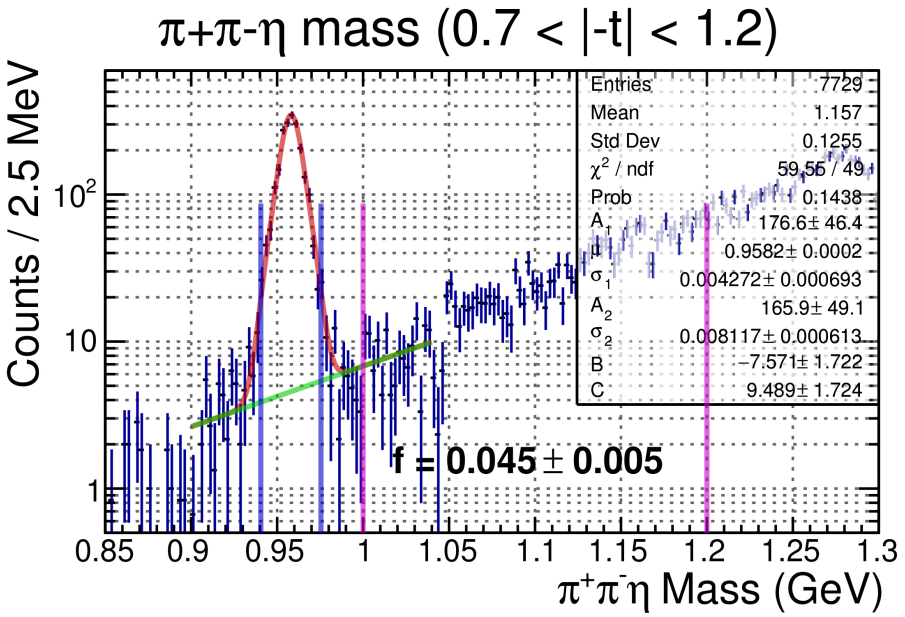
$\eta' \longrightarrow \pi+ \pi- \eta$

Mass Plots



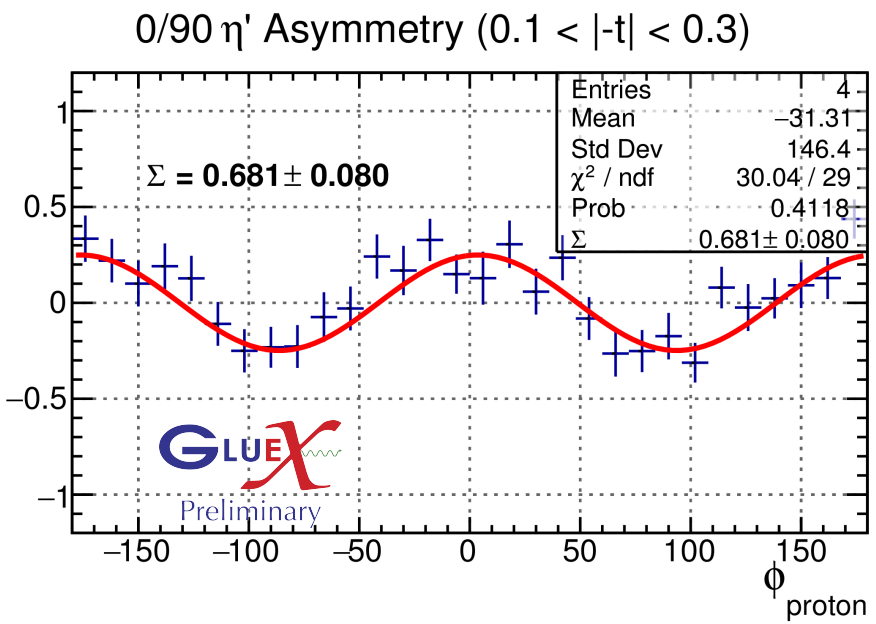


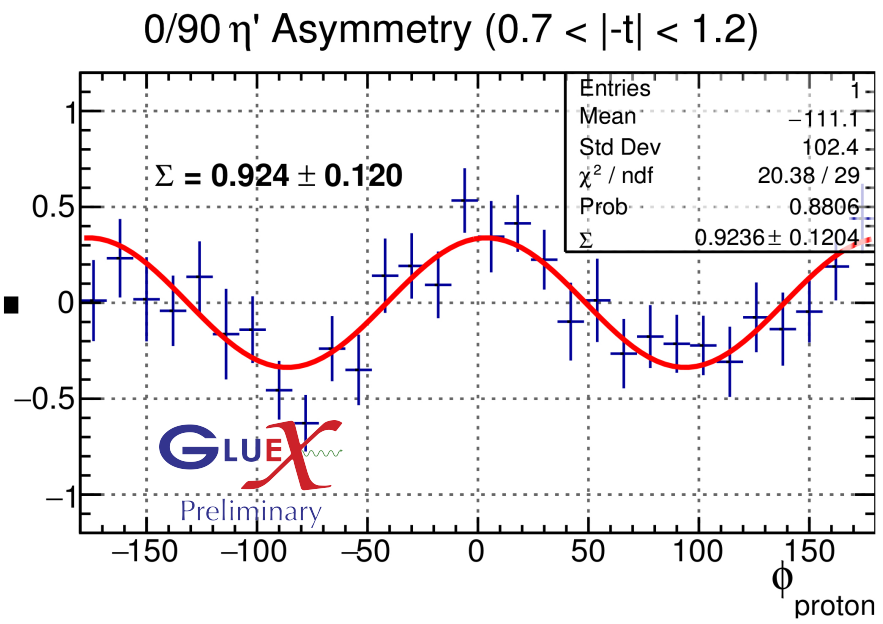


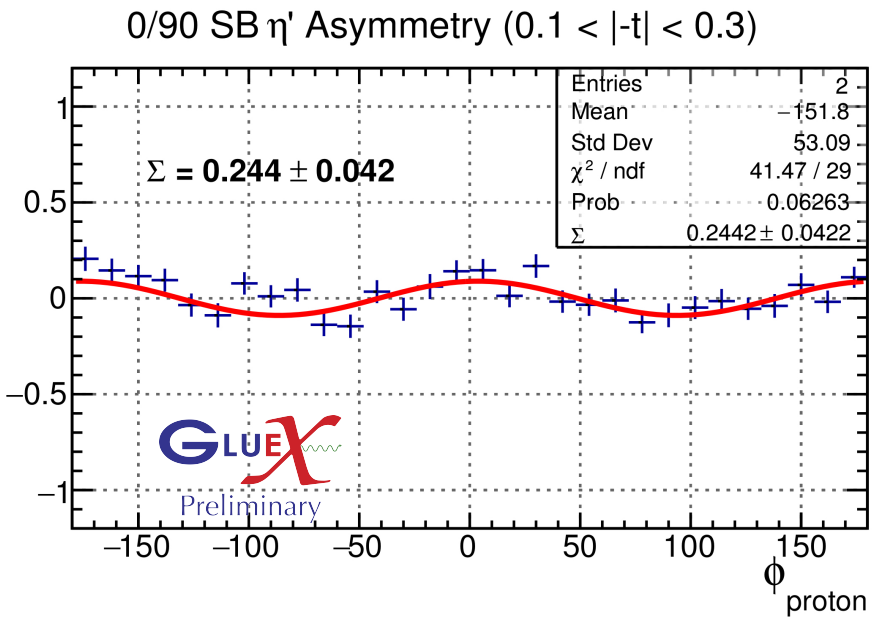


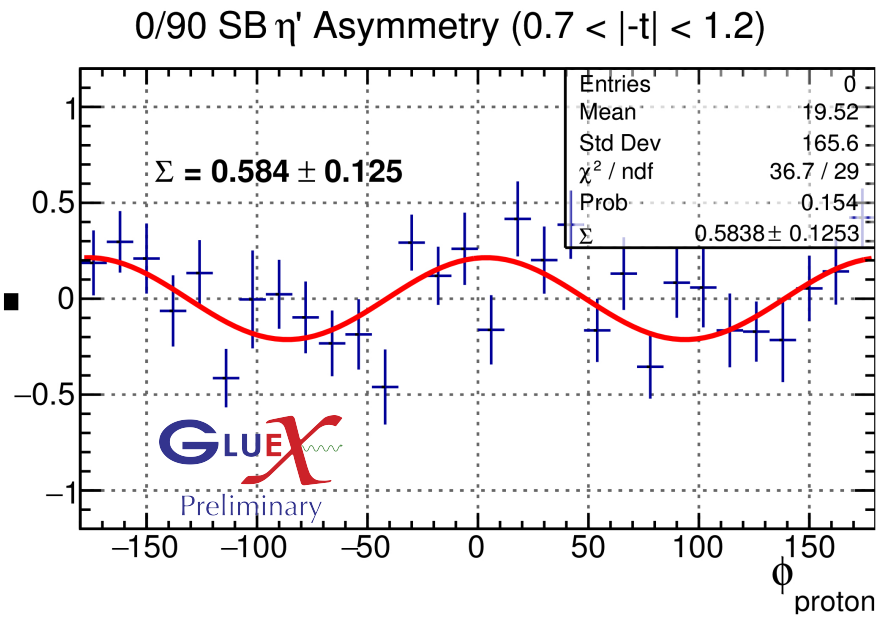
$\eta' \longrightarrow \pi+ \pi- \eta$

0/90 Asymmetry Plots



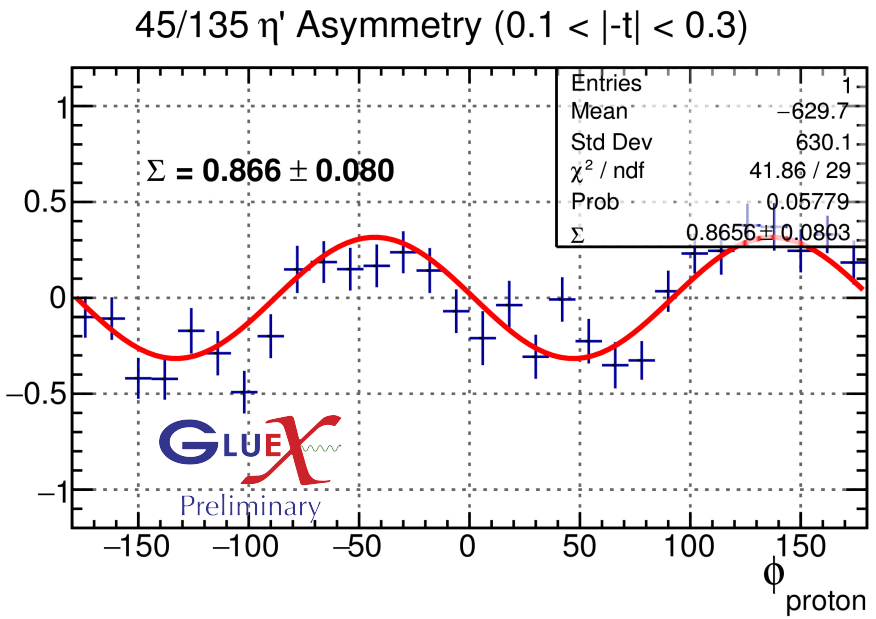


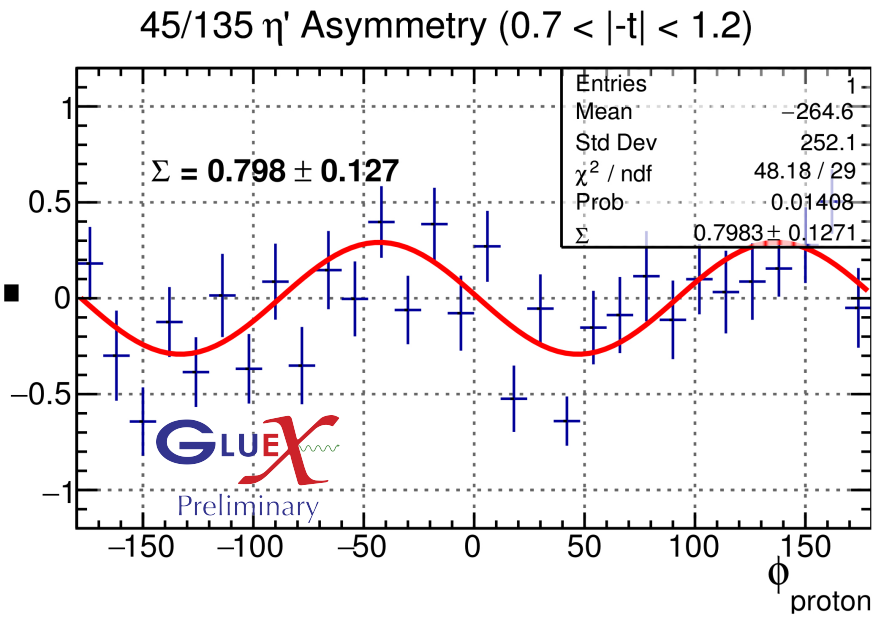


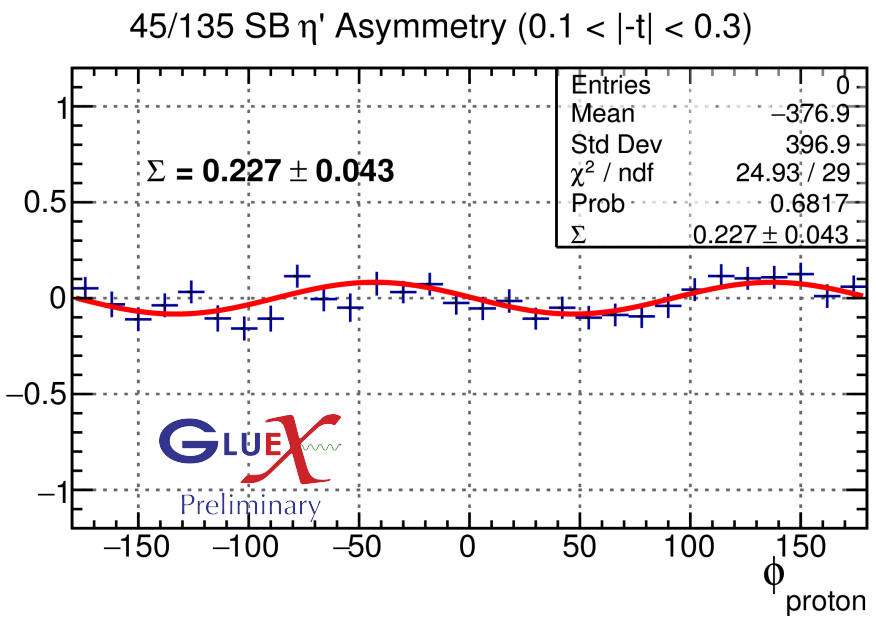


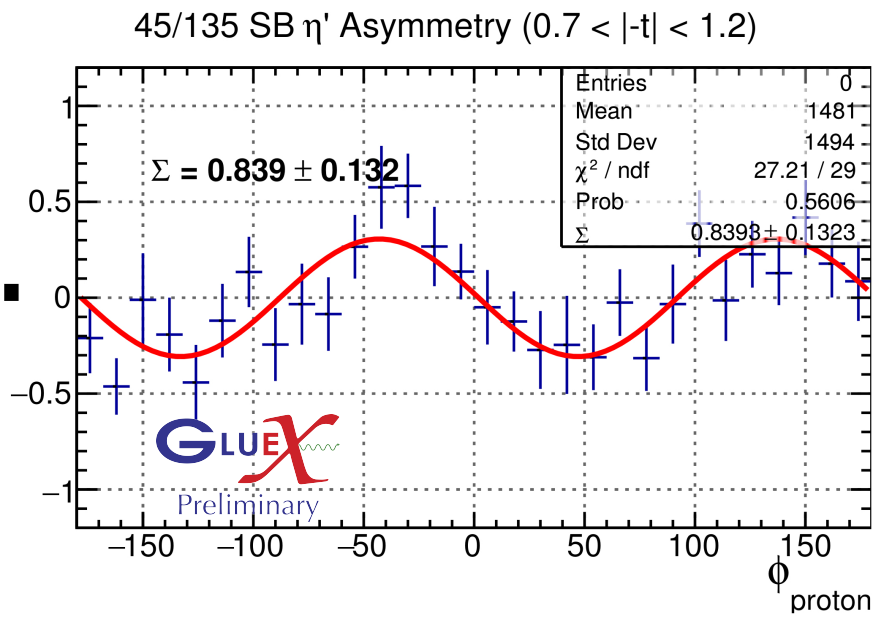
$\eta' \longrightarrow \pi+ \pi- \eta$

45/135 Asymmetry Plots



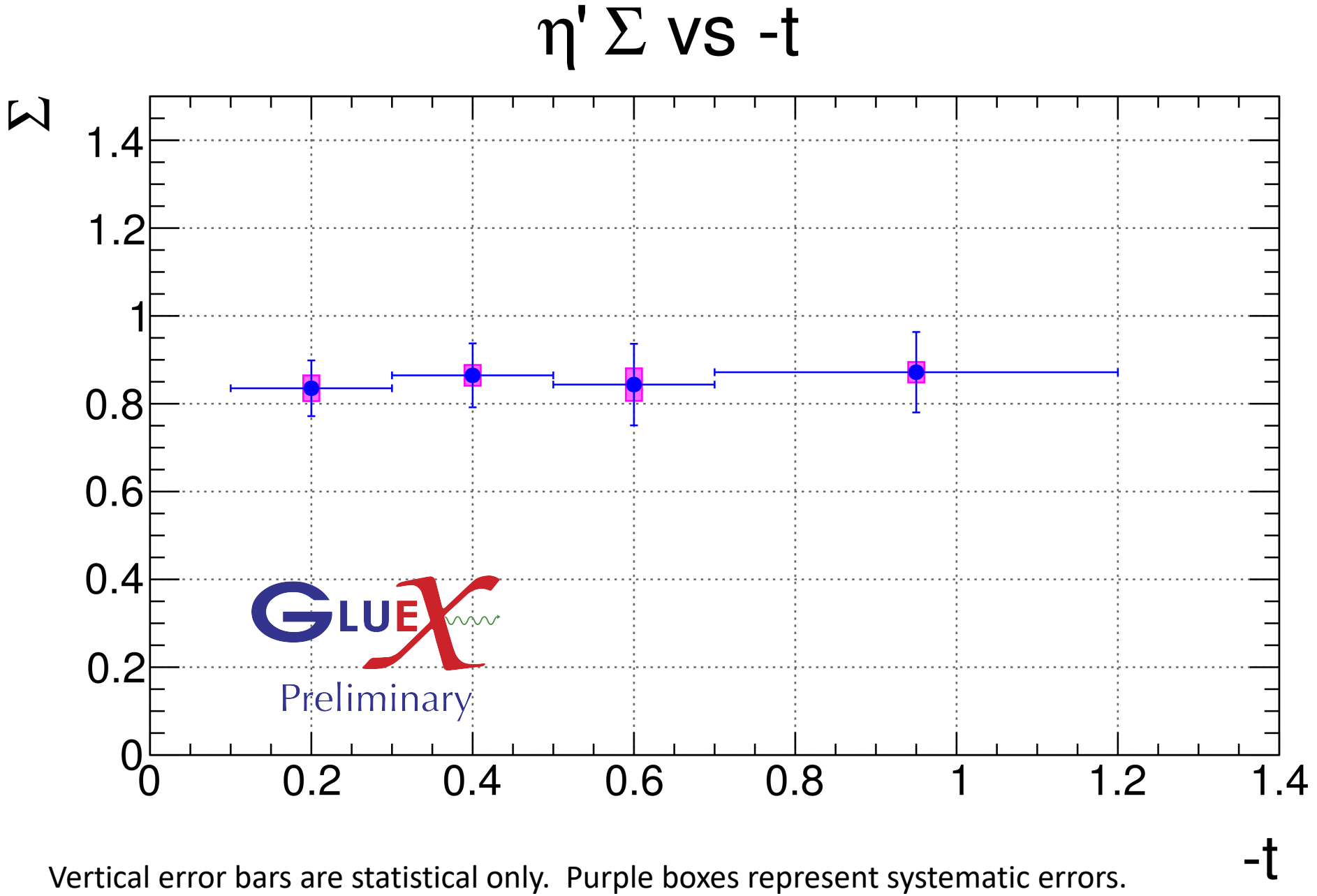






$\eta' \longrightarrow \pi+ \pi- \eta$

Corrected Asymmetry vs. -t



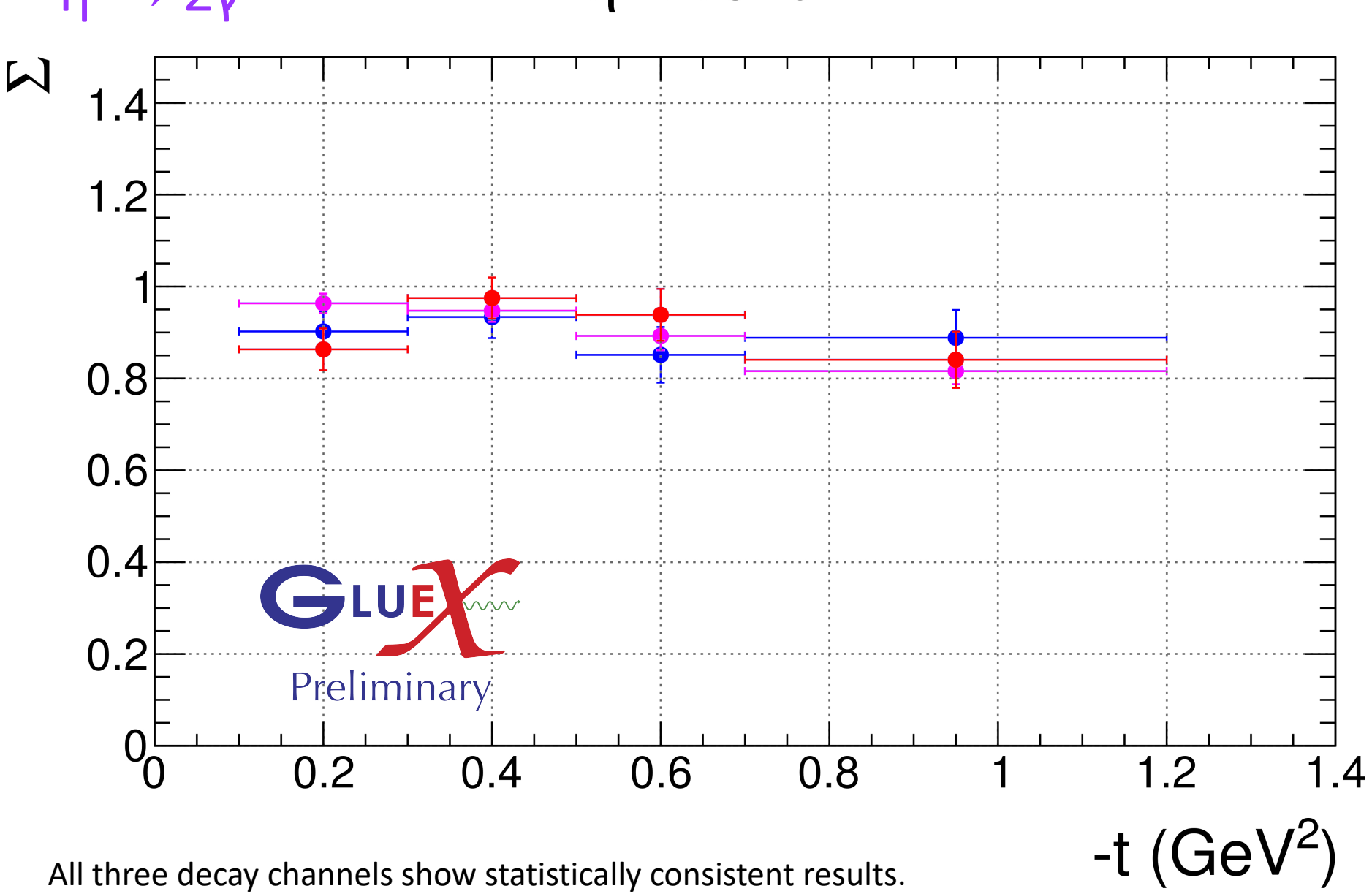
Vertical error bars are statistical only. Purple boxes represent systematic errors.

$\eta \rightarrow \pi^+ \pi^- \pi^0$

$\eta \rightarrow 3\pi^0$

$\eta \rightarrow 2\gamma$

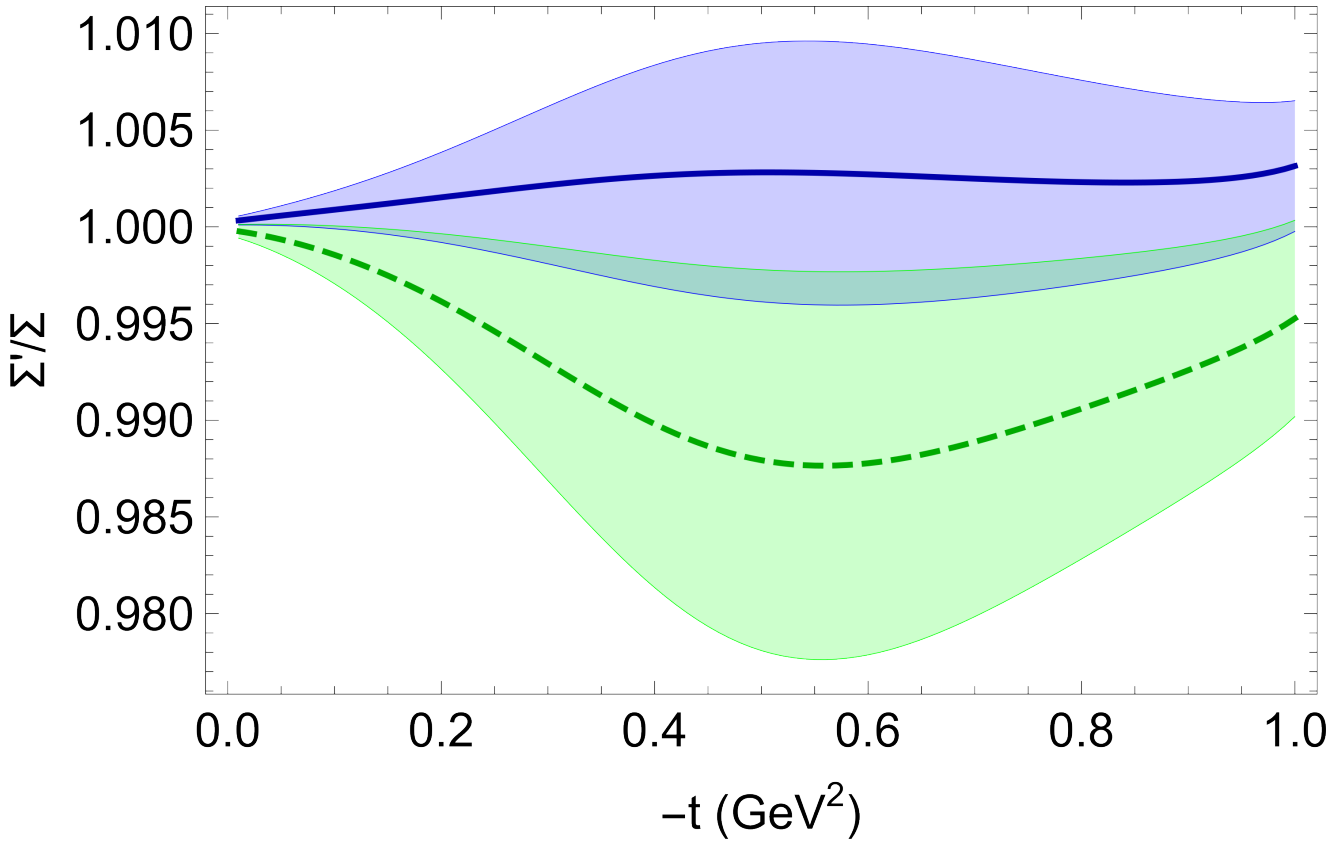
Corrected Asymmetry vs. -t



All three decay channels show statistically consistent results.

JPAC Predictions for $\Sigma_{\eta'}/\Sigma_{\eta}$

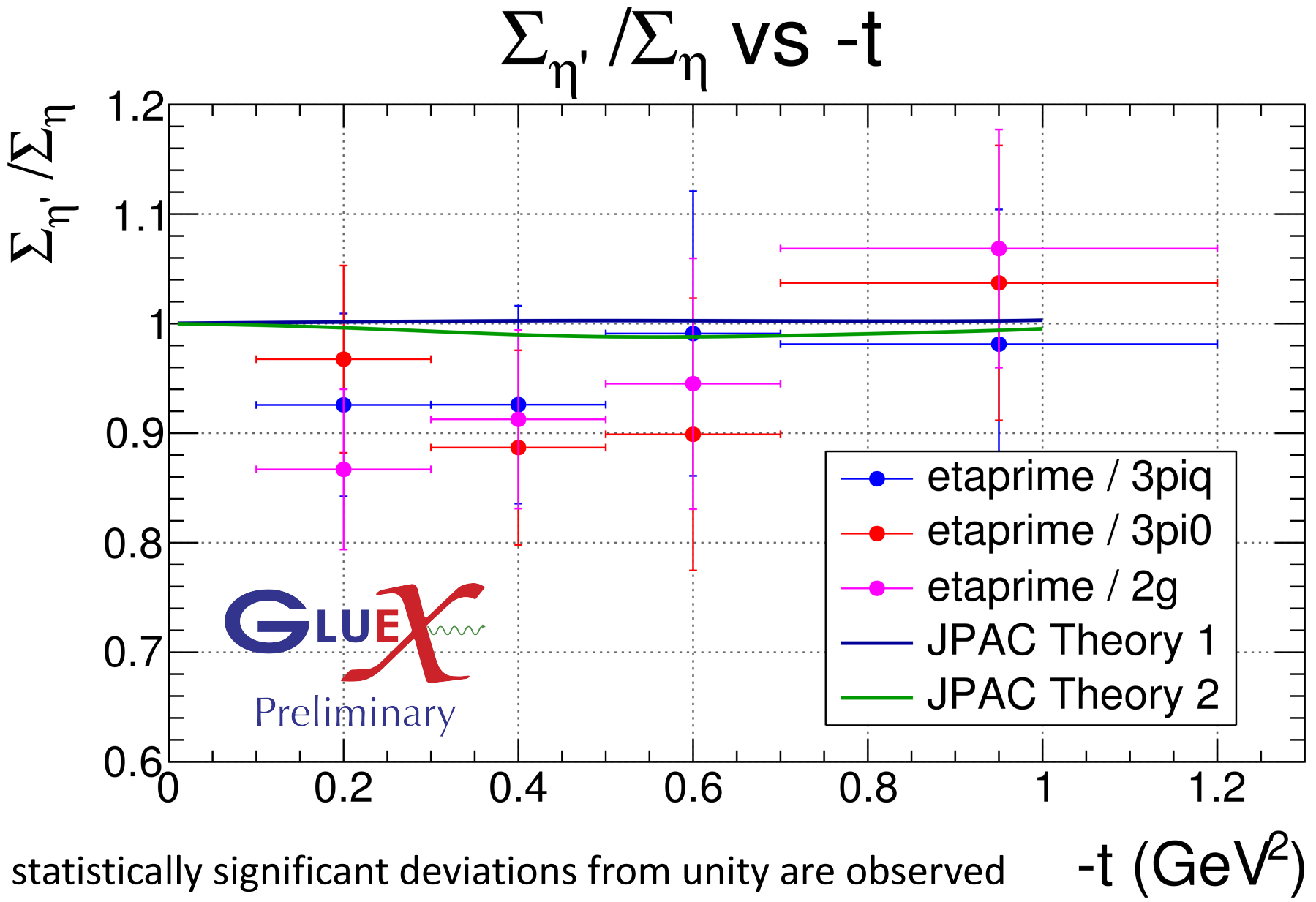
- η' beam-target exchanges dominated by ρ, ω, b, and h mesons
- Assuming no contribution from hidden strangeness exchange of ϕ and h' mesons implies that the Σ asymmetry of the η' and η will be equal
- JPAC predictions for two model assumptions for $\Sigma_{\eta'}/\Sigma_{\eta}$ allowing ϕ exchange:



- Significant deviation from 1 may imply non-negligible ϕ/h' contributions or more complicated interactions between the proton and produced meson

Mathieu, V. et. Al (JPAC), Phyiscs Letters B, 2017, ISSN 0370-2693, https://doi.org/10.1016/j.physletb.2017.09.081.

η' / η Beam Asymmetry Ratio



No statistically significant deviations from unity are observed
(Largest deviation is ≈ 1.5 σ)

Summary and Outlook

- We are able to measure beam asymmetries vs. t for the
  - η, in three decay channels
  - η', never before measured at high beam energies

- Both asymmetries are highly positive
  - Mostly natural parity exchange

- Ratio of asymmetries consistent with JPAC theory predictions

- Analysis will be continued with new 2018 data when available

- Future:
  - Acceptance studies
  - Cross sections
  - Partial wave analysis (eventually)