Beam Asymmetries (Σ) for π^0, η and η' in Photoproduction at GlueX

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ON BEHALF OF THE GLUEX COLLABORATION

15TH INTERNATIONAL CONFERENCE ON MESON-NUCLEON PHYSICS AND THE STRUCTURE OF THE NUCLEON (MENU2019)

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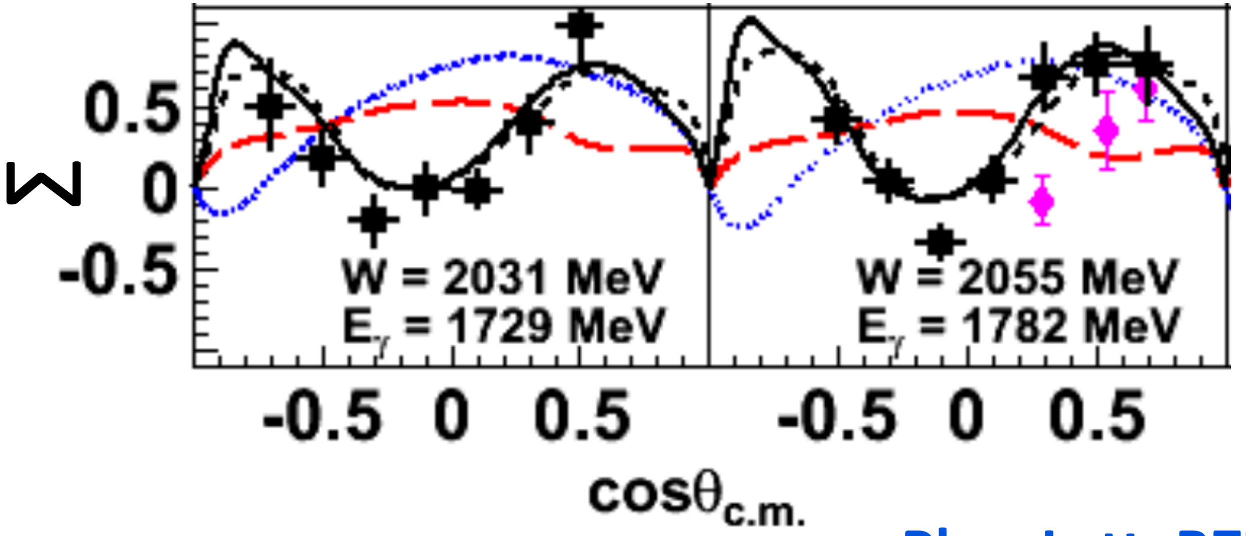
Outline

- Beam Asymmetries
- GlueX Detector
- Event Samples
- Results
- Summary

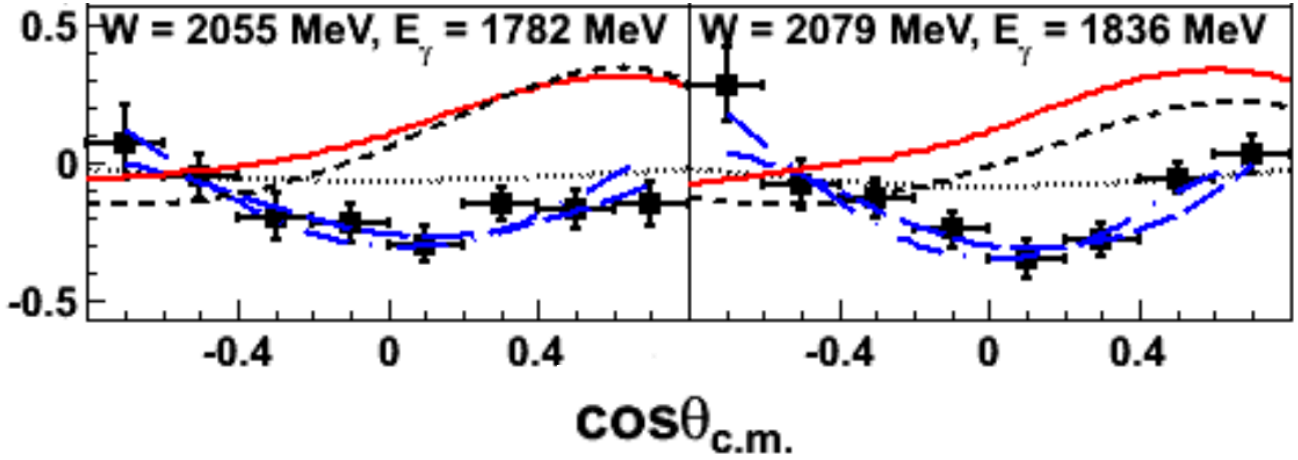
Low energy η and η' beam asymmetries

- $E_\gamma < 2$ GeV: Σ beam asymmetries provide insight to nucleon resonance.
- Measuring Σ constrains the helicity amplitudes of excited nucleon states.

η



η'

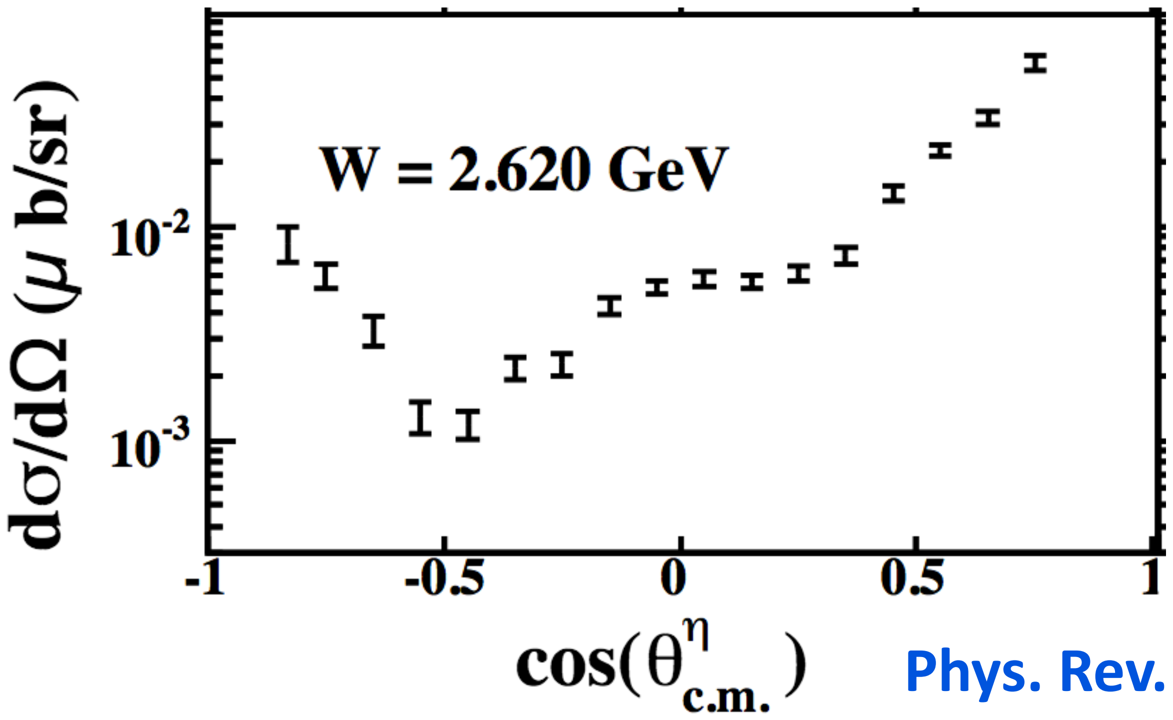


Phys.Lett. B771 (2017) 213-221

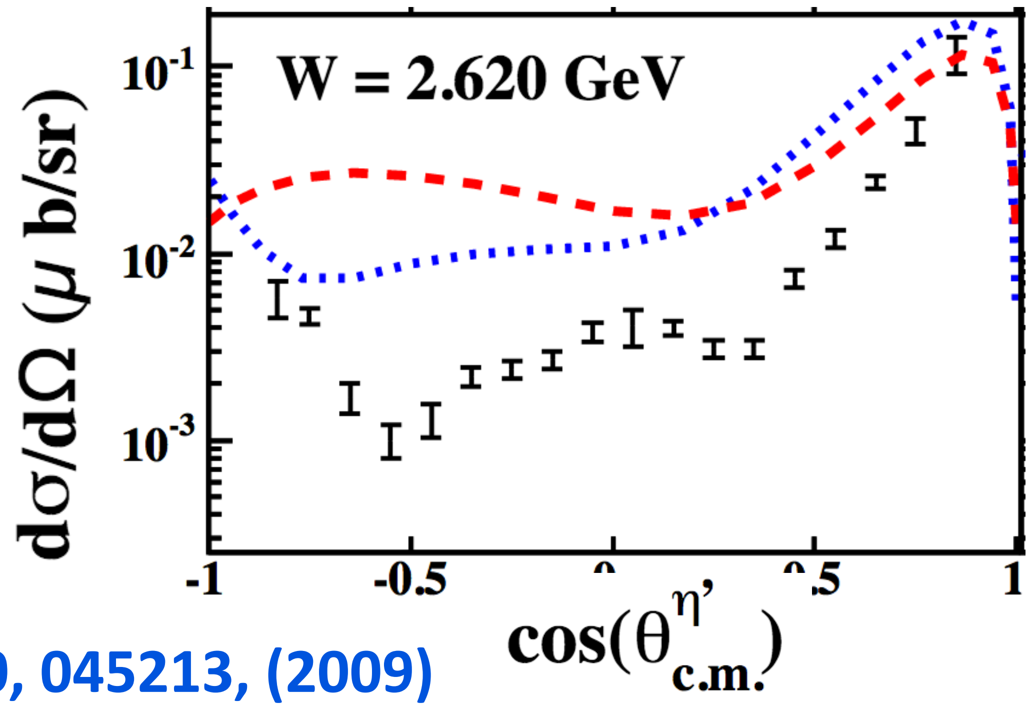
- 2/27 energy-bin measurements by CLAS
- 2/8 energy-bin measurements by CLAS

Low energy η and η' Cross-Sections

η



η'

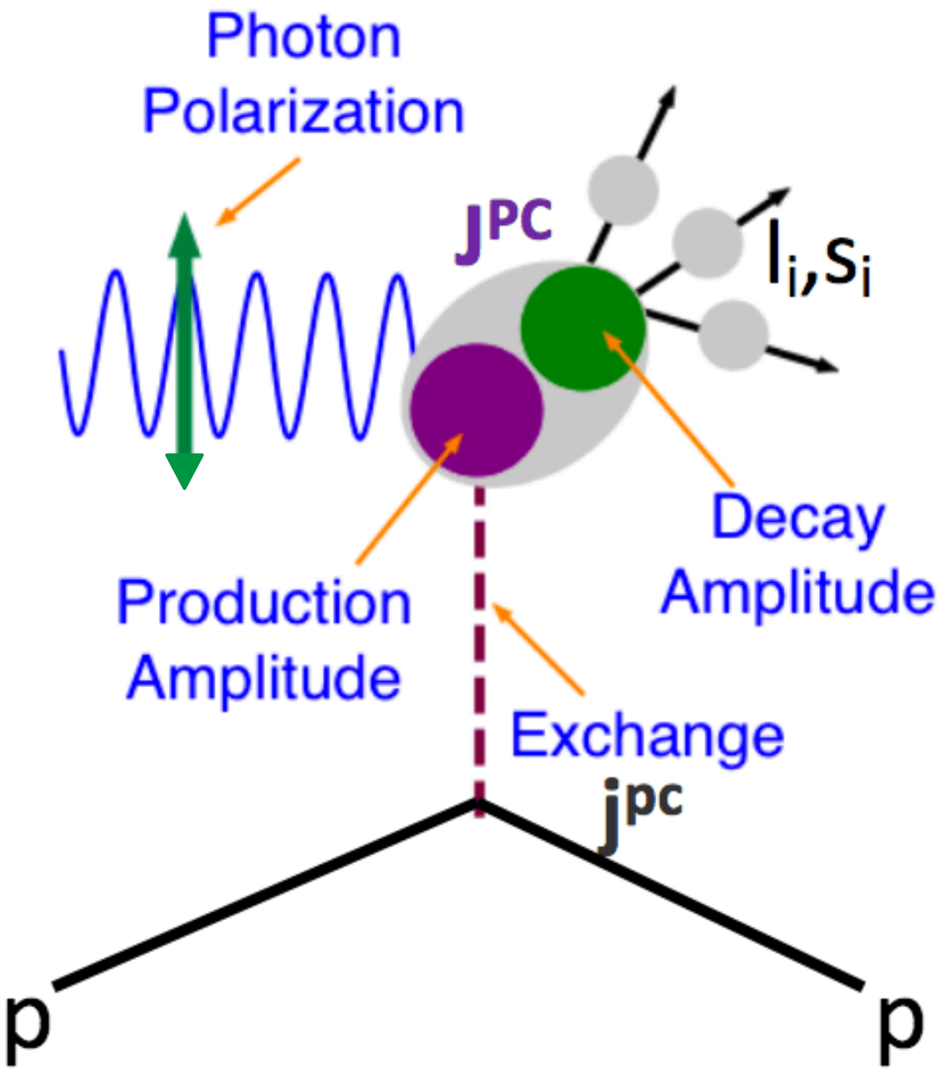


Phys. Rev. C80, 045213, (2009)

- 1/64 Energy-bin measurement by CLAS
- 1/64 Energy-bin measurement by CLAS

- GlueX is not sensitive to the nucleon resonance physics.
- t-channel component of the model extends from low energy up to the GlueX energy.
- Gluex Σ and cross-section measurements could constrain models extending to low energy.

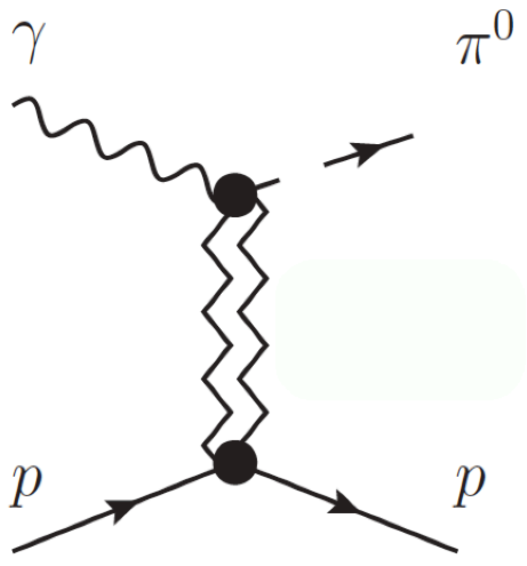
Beam Asymmetry Motivation



- First step of mapping out a hybrid exotic meson spectrum: measuring observables
- Understanding the t-channel exchange J^{PC} for meson photoproduction → filtering possible J^{PC} for hybrid photoproduction
  - Lightest multiplet of exotic mesons with $J^{PC} = 1^{-+}$ involves the same Regge exchanges that appear in $\boldsymbol{\pi^0, \eta, \eta'}$

Beam Asymmetry Motivation

- Σ provides insight into the production mechanism for pseudoscalar mesons.
- GlueX asymmetry measurements will offer new constraints to Regge models.
- Only measurement of Σ for γp → ηp at $E_\gamma > 3$ GeV was made by GlueX.
- No measurement of Σ for γp → η’p at $E_\gamma > 3$ GeV has been made.



Exchange J^{PC}

$$1^{--} : \omega, \rho$$
$$1^{+-} : b, h$$

$$\Sigma = \frac{|\omega + \rho|^2 - |h + b|^2}{|\omega + \rho|^2 + |h + b|^2}$$

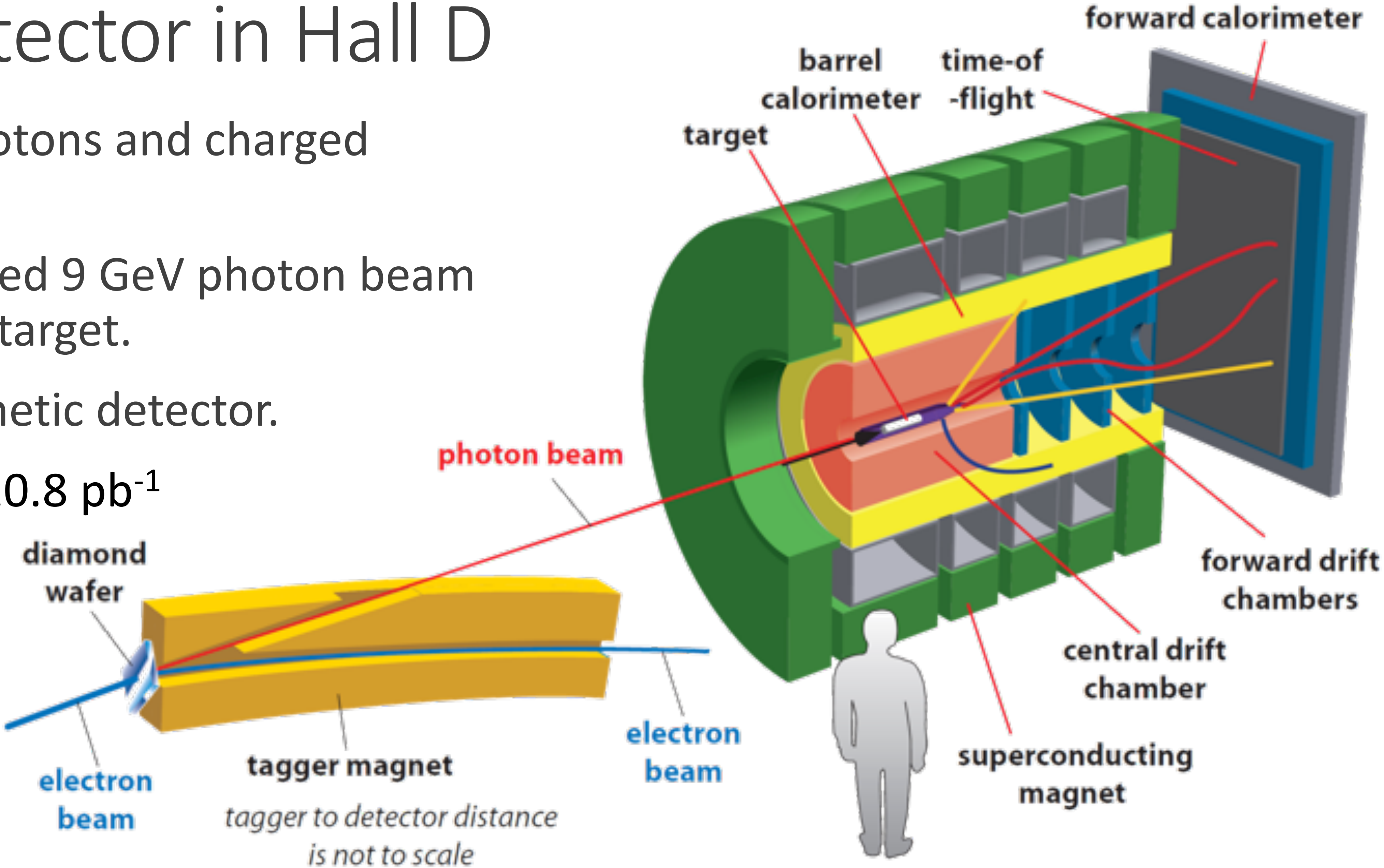
(True for π^0)

Mathieu et al. PRD 92, 074013 (2015)

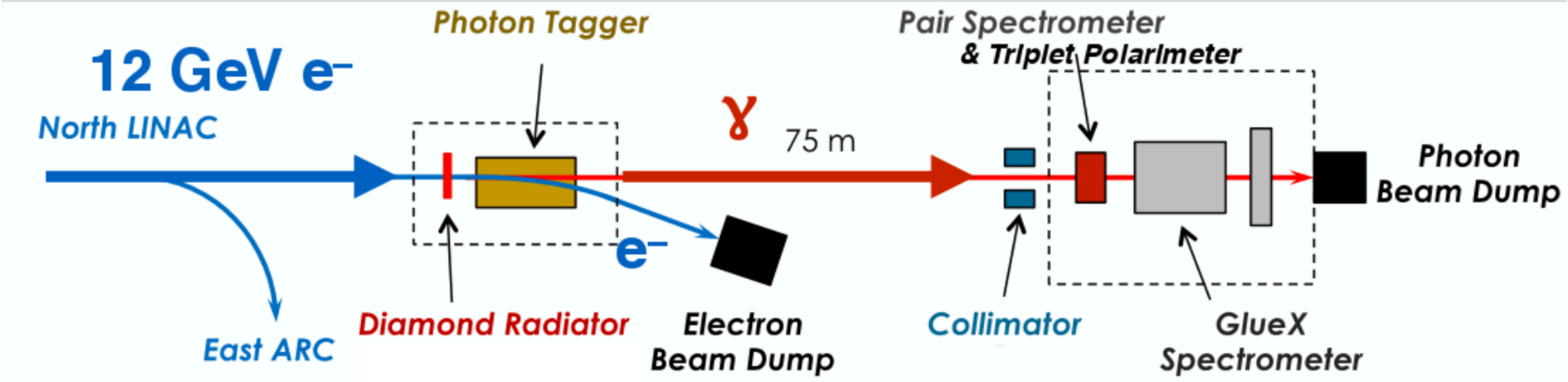
- Σ = 1, exchange dominated by vector mesons
- Σ = -1, exchange dominated by axial-vector mesons

GlueX Detector in Hall D

- Sensitive to photons and charged particles.
- Linearly polarized 9 GeV photon beam incident on LH_2 target.
- Nearly 4π hermetic detector.
- Luminosity of 20.8 pb^{-1}

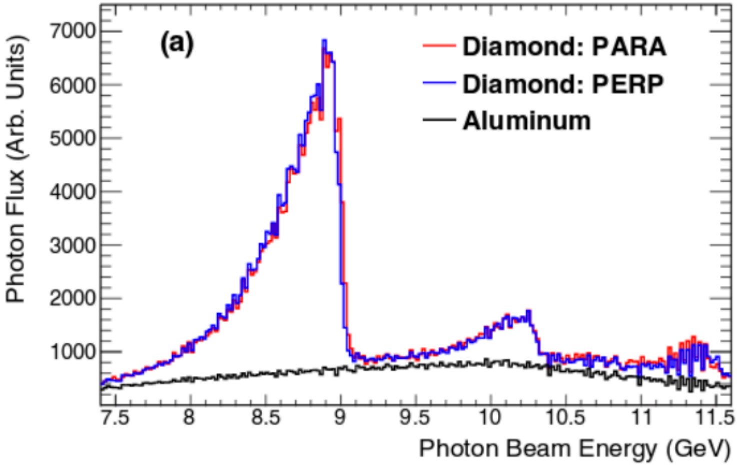


Beamline and Polarization

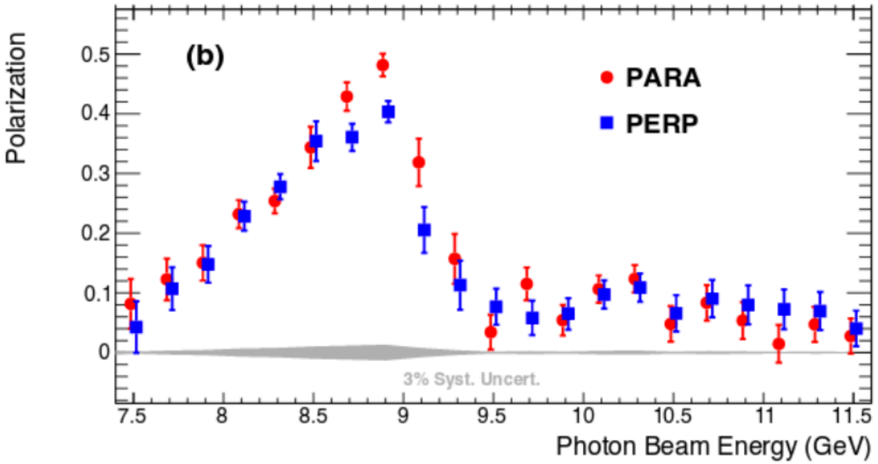


Coherent Bremsstrahlung

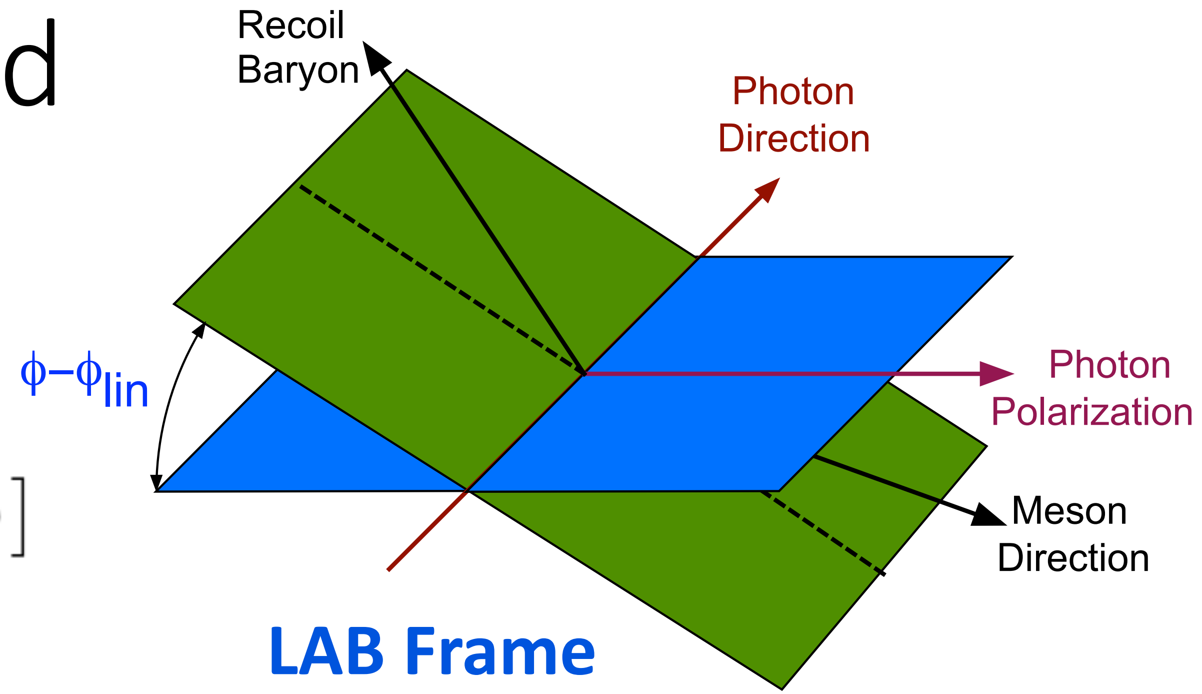
Observed Flux



Measured Polarization



Beam Asymmetry Method



- Two orthogonal polarization configurations: PERP, PARA → acceptance cancels
- Two data sets: 0/90, 45/135

$$\sigma_{pol}(\phi,\phi_\gamma^{lin}) = \sigma_{unpol}\left[1 - P_\gamma \Sigma \cos\left(2(\phi - \phi_\gamma^{lin})\right)\right]$$

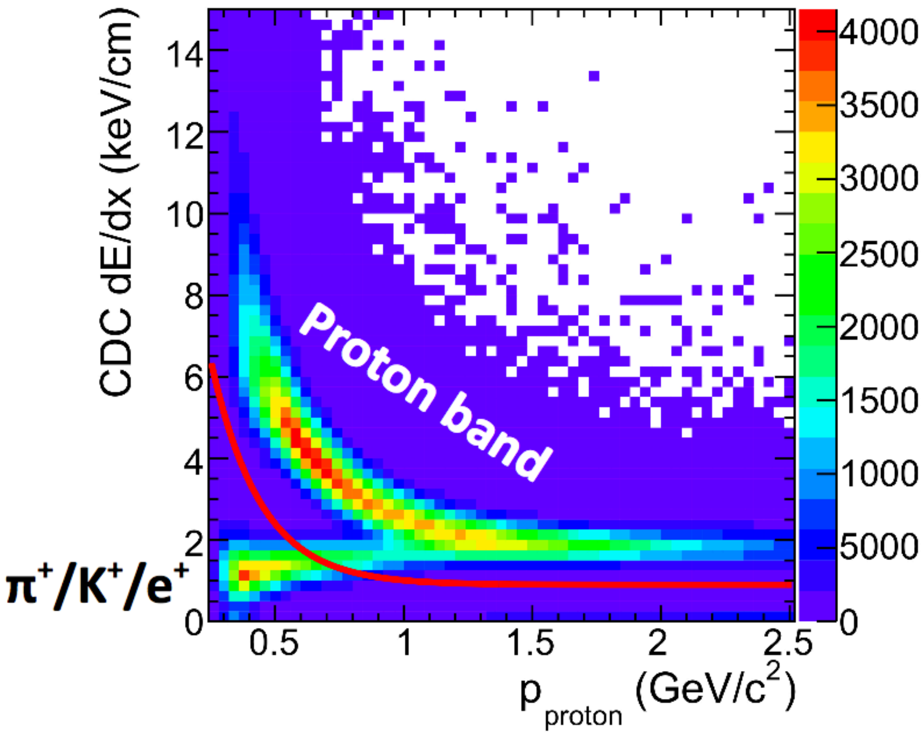
$$\Sigma = \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel}$$

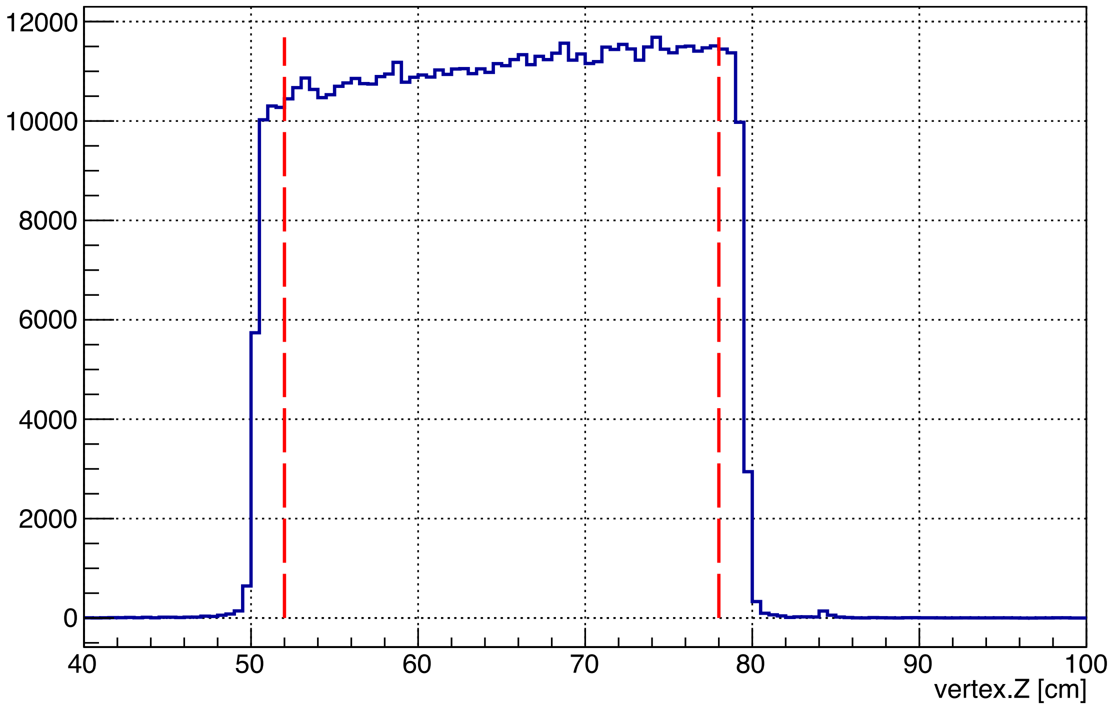
- PARA yield: $Y_\parallel(\phi) \propto (1 - P_\parallel \Sigma \cos 2\phi)$
- PERP yield: $Y_\perp(\phi) \propto (1 + P_\perp \Sigma \cos 2\phi)$
- Asymmetry: $\dfrac{Y_\perp(\phi) - F_R Y_\parallel(\phi)}{Y_\perp(\phi) + F_R Y_\parallel(\phi)} = \dfrac{(P_\perp + P_\parallel)\Sigma \cos 2(\phi - \phi_0)}{2 + (P_\perp - P_\parallel)\Sigma \cos 2(\phi - \phi_0)}$

- F_R : Flux Ratio
- ϕ_0 : diamond offset
- $P_\perp$,$P_{/\!/}$: Measured Polarization
- Σ : Only free parameter in the fit

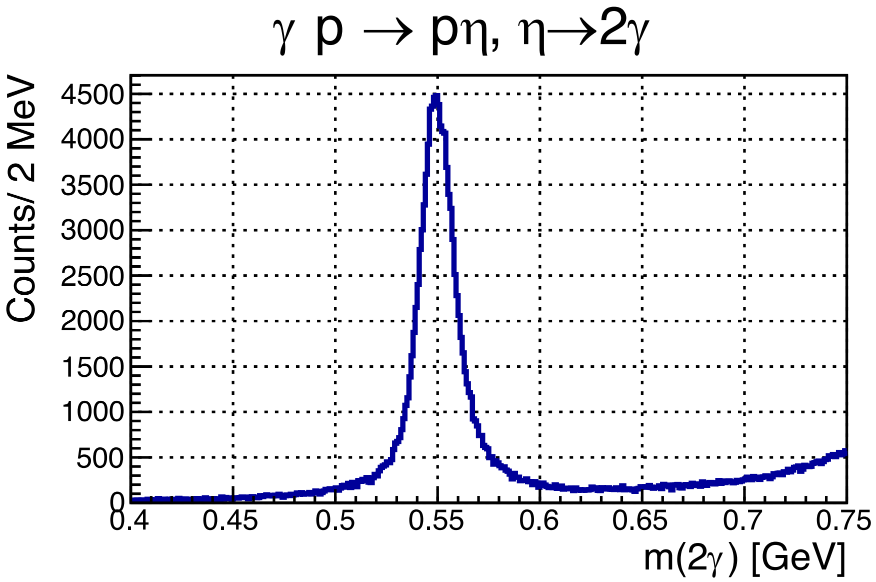
Event Selection

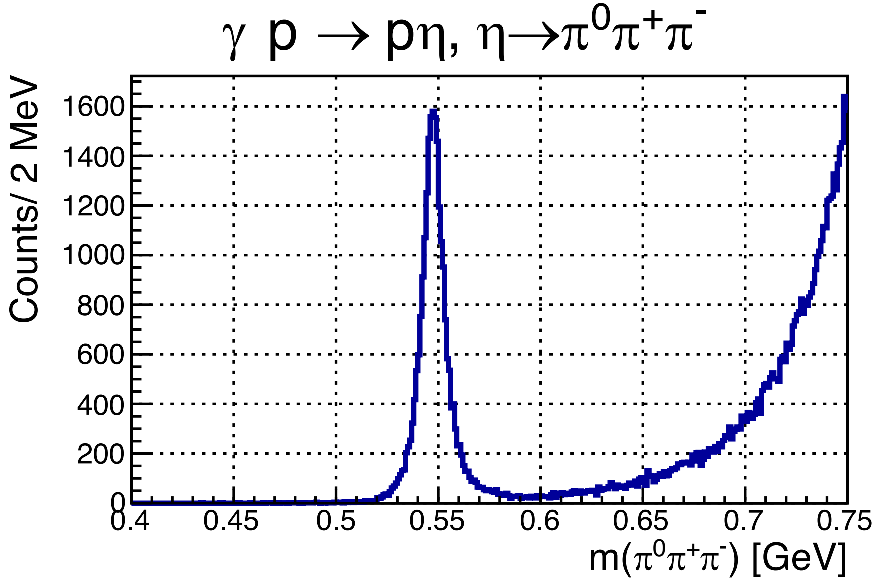
- dE/dx cut to separate protons from other charged particles.
- Missing Mass Squared cut to select exclusive events.
- Kinematic fit applied to conserve E and p.
- Vertex cuts to remove events with a primary interaction outside the target volume.
- Photon fiducial cuts
- Beam energy cut to select the coherent peak region.

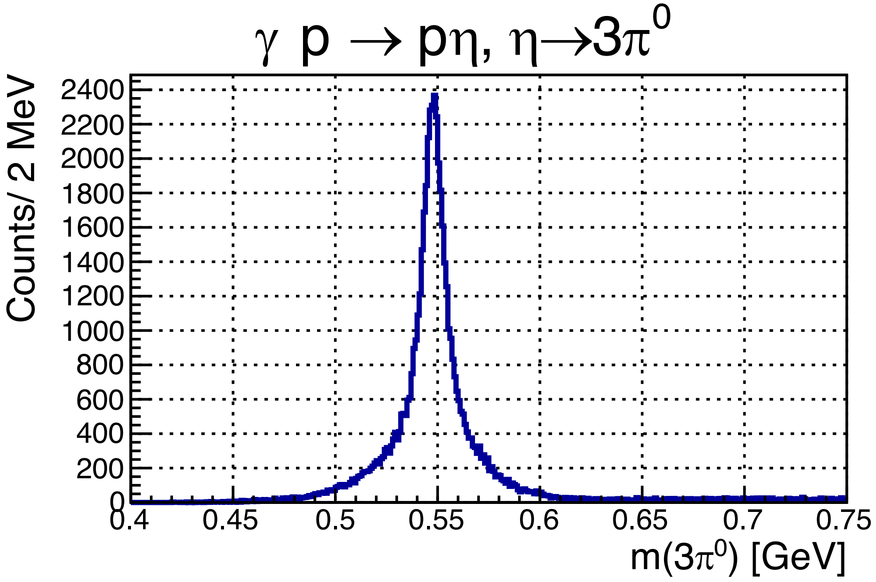


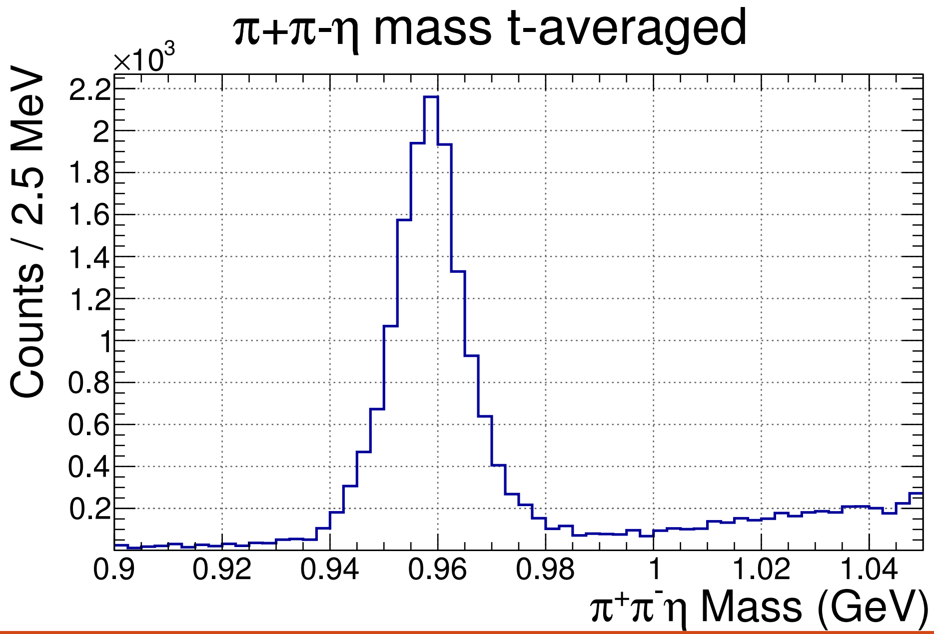


Invariant Mass Distributions

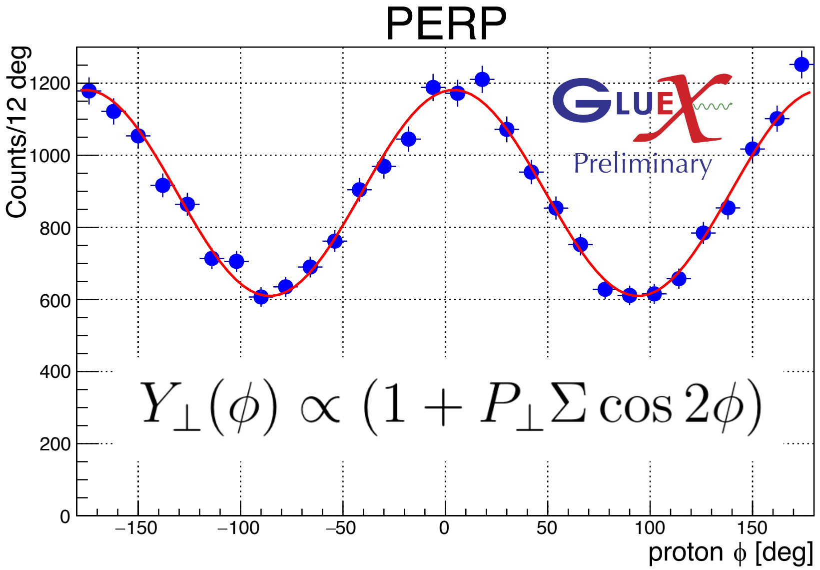


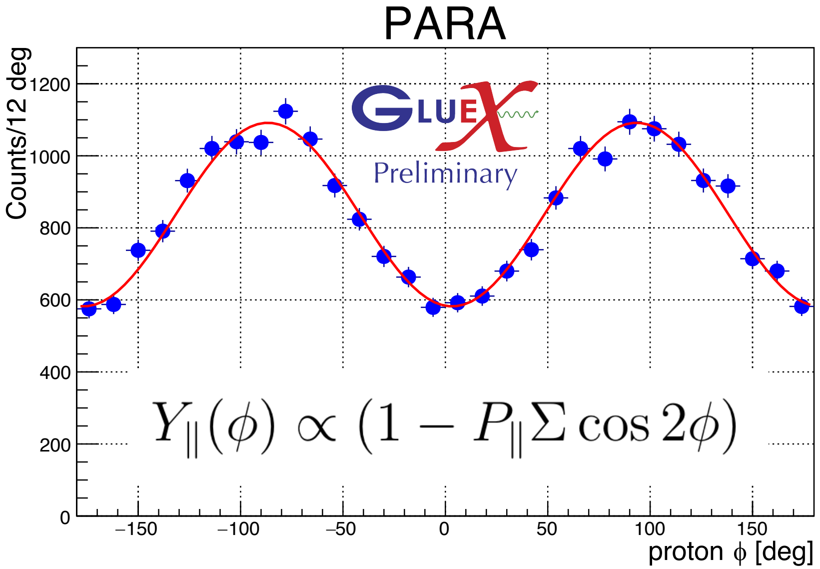


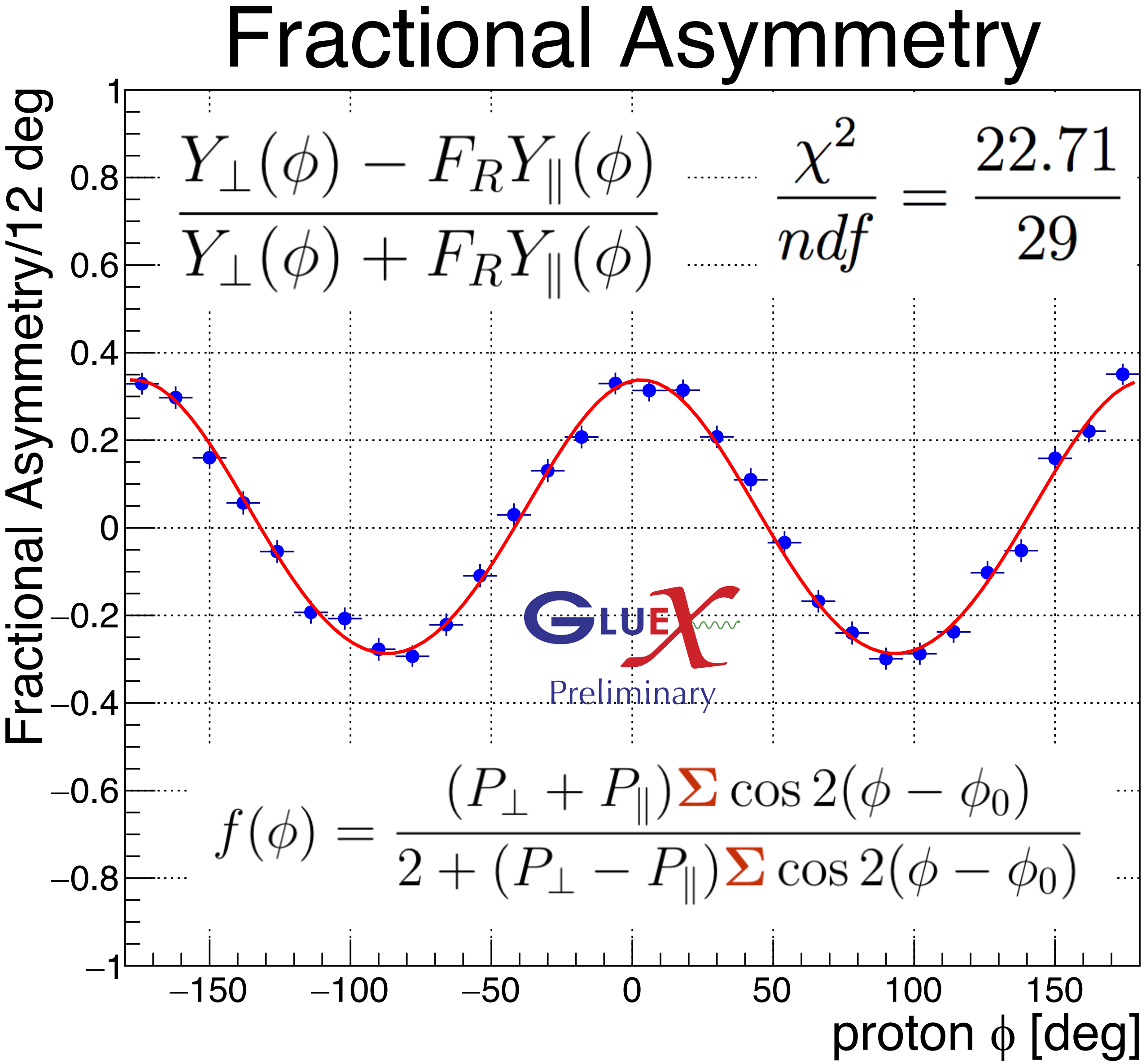




Fractional Asymmetry: $\eta \to 2\gamma$

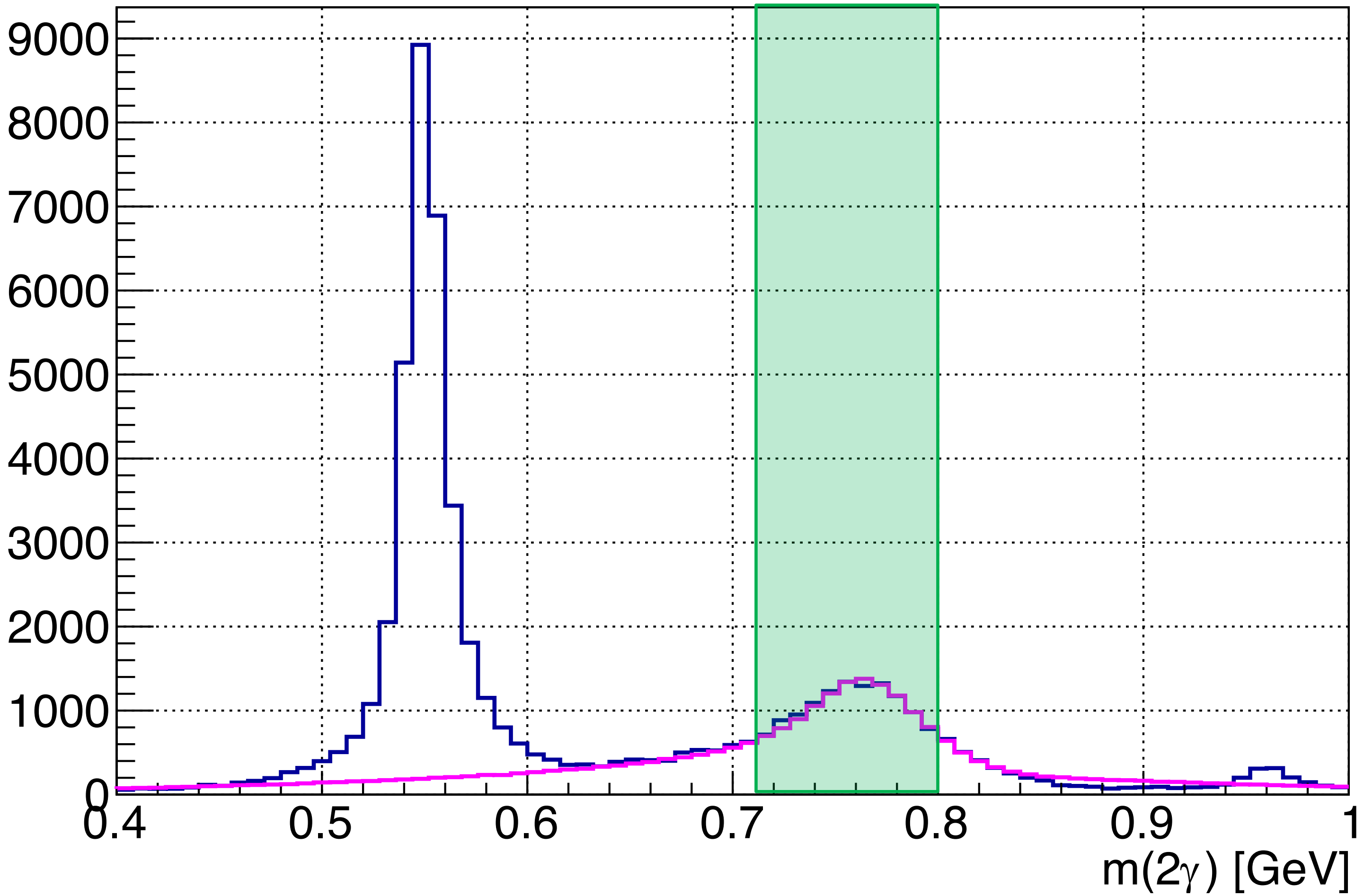






Background Correction

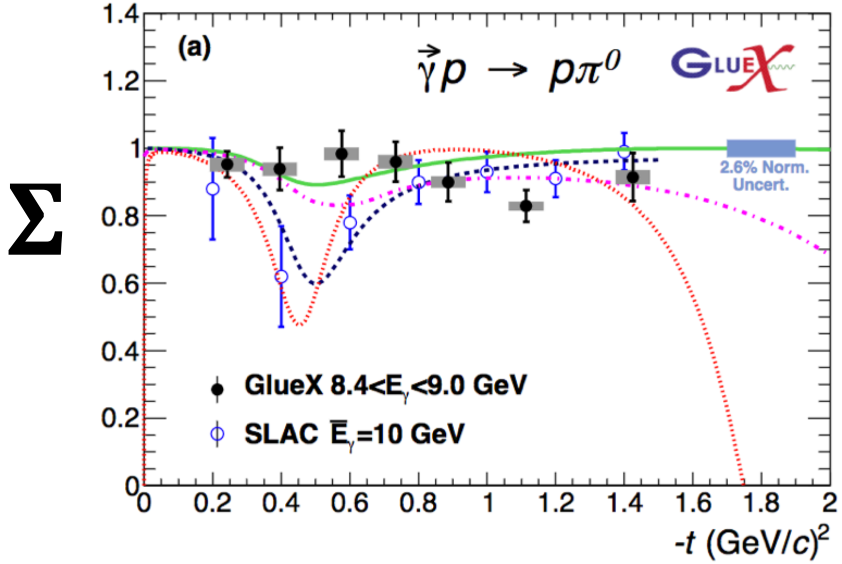
$$\Sigma^{\eta}_{Signal} = \frac{\Sigma^{\eta}_{Measured} - f\Sigma^{\omega}_{Background}}{1-f}$$

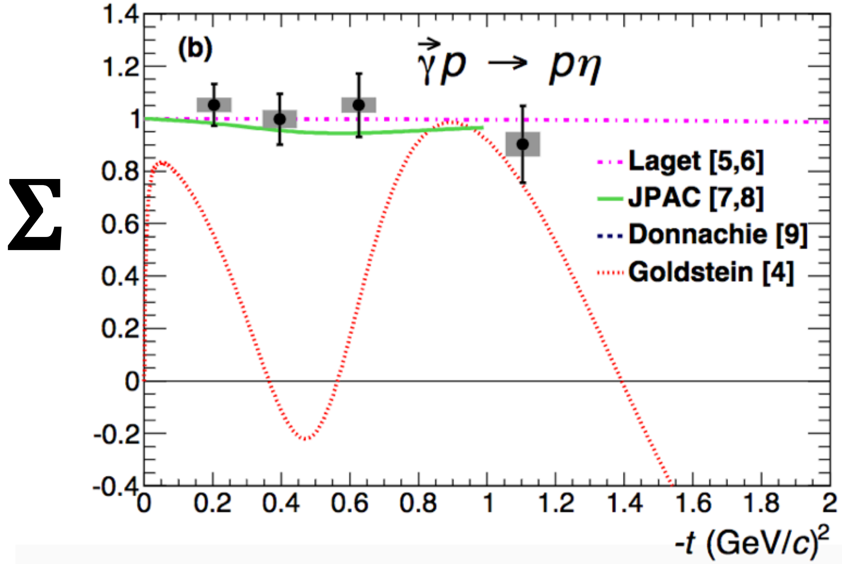


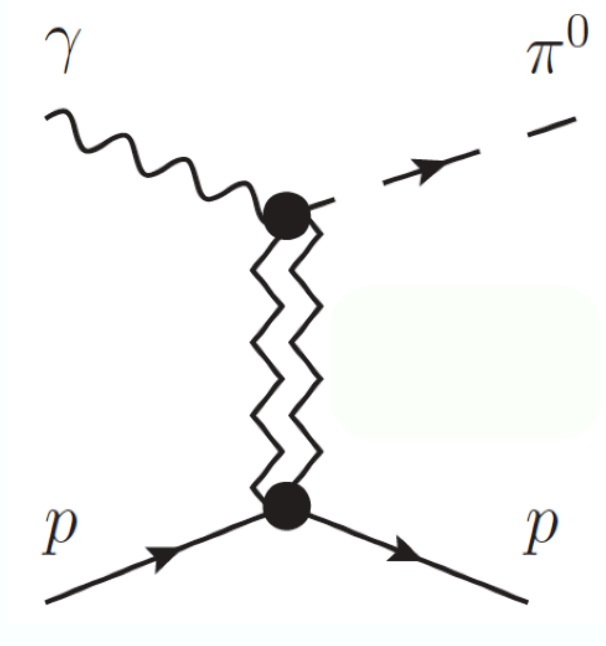
$$f = \frac{N_{bkgd}}{N_{bkgd}+N_{signal}}$$

- Blue: Data 2γ final state
- Magenta: $\omega \rightarrow \pi^0\gamma$ signal MC passed through the full 2γ analysis.
- Green Band: Background asymmetry region

π^0 and η Beam asymmetries







Exchange J^{PC}

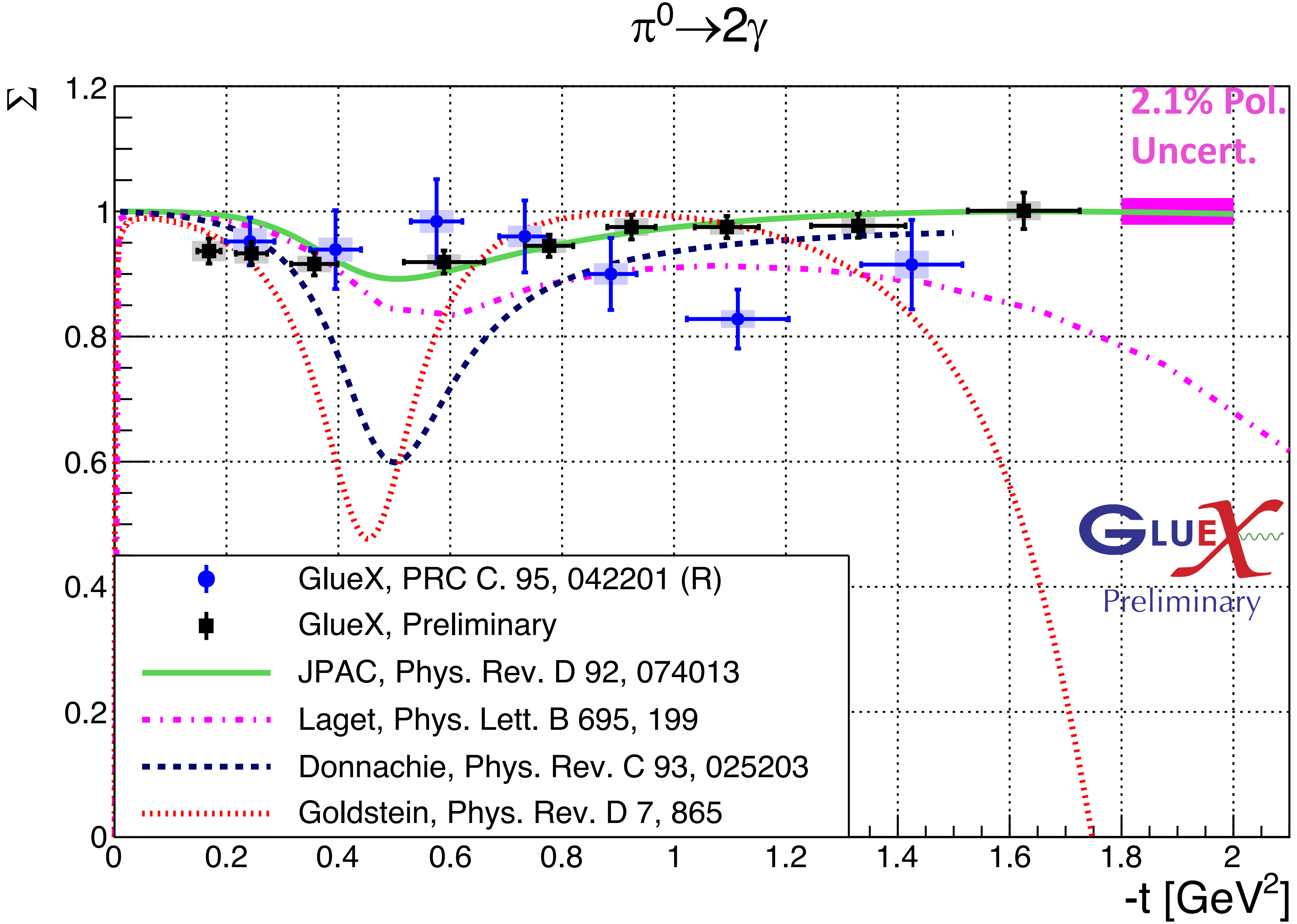
1^{--} : ω, ρ

1^{+-} : b, h

- Asymmetry ~ 1 indicates vector dominant exchange
- First 12 GeV publication!

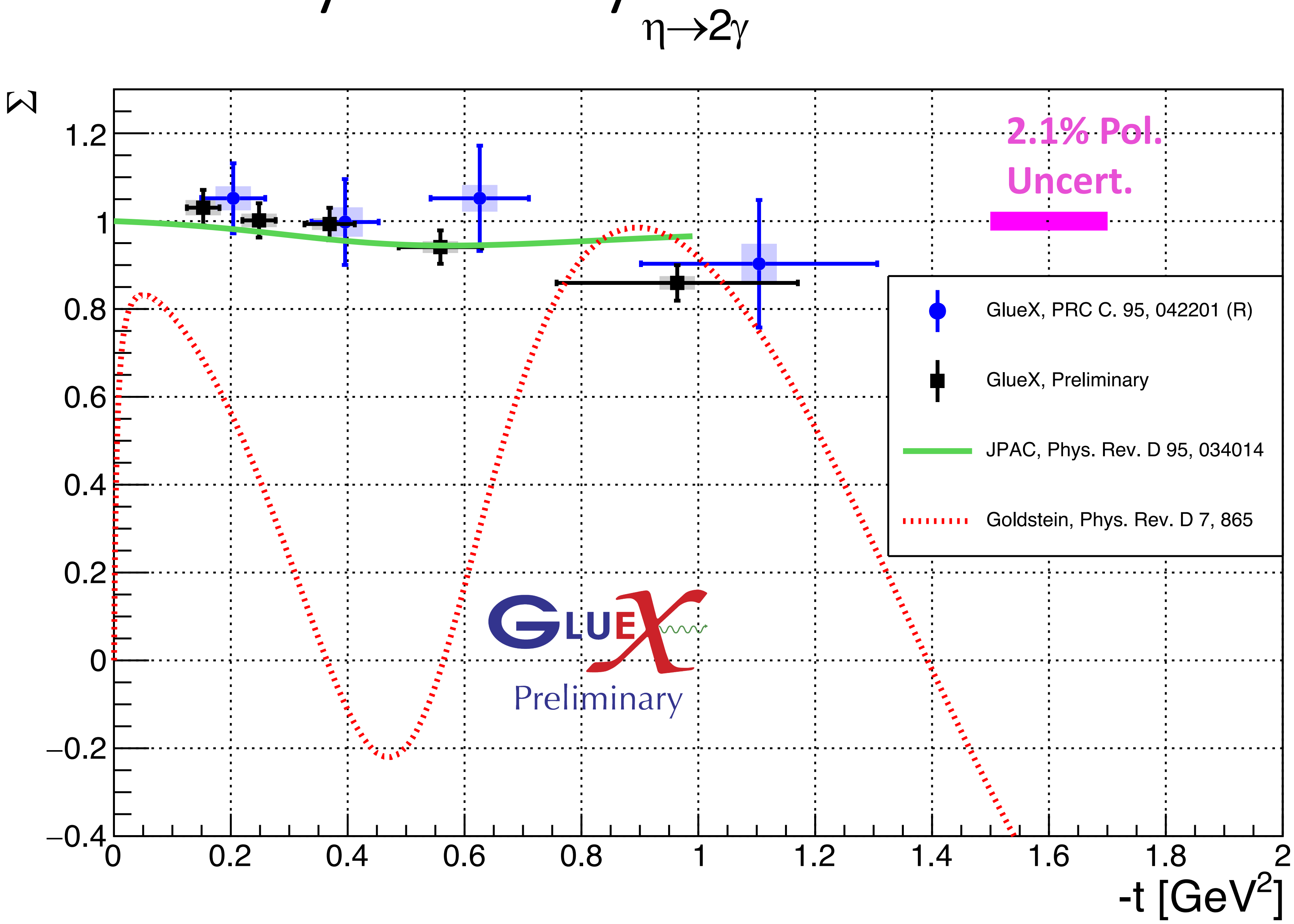
Phys. Rev. C 95, 042201(R)

π^0 Beam Asymmetry



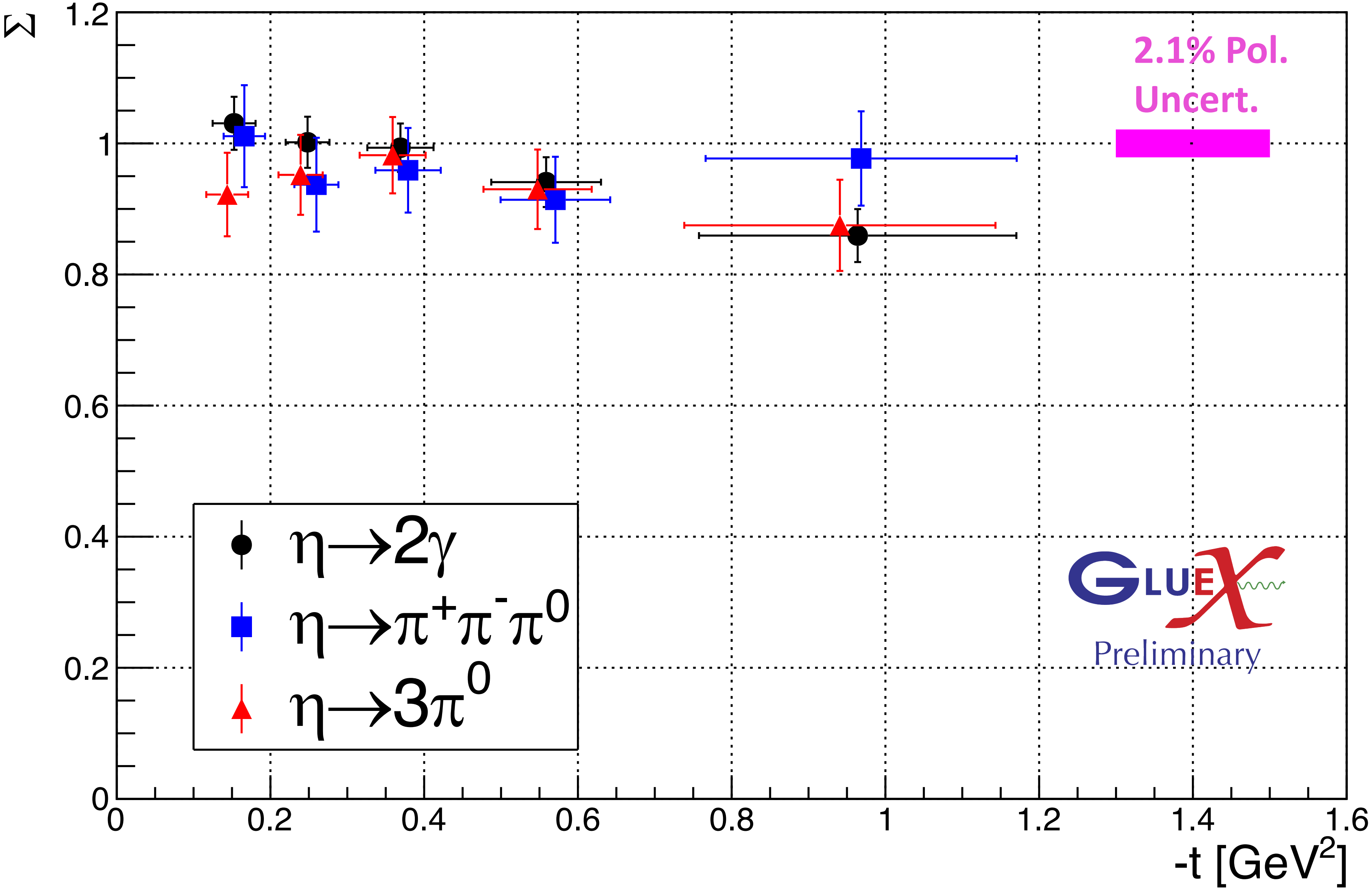
- GlueX results are from 2 independent data sets
- t-position of each point is the mean of the t-distribution in each bin
- t-error is the rms of the t-distribution in each bin

η Beam Asymmetry

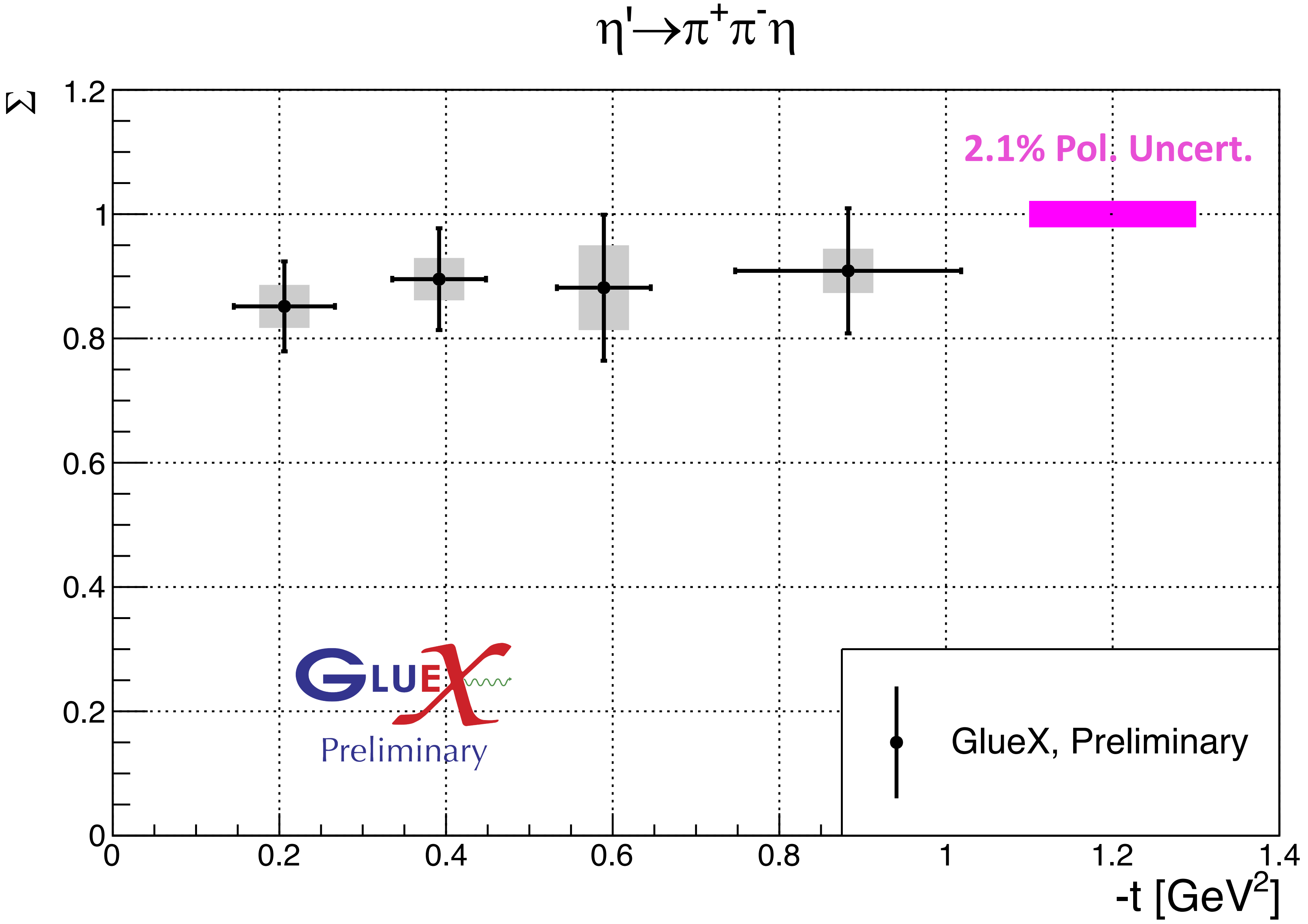


- GlueX results are from 2 independent data sets.

η Beam Asymmetry

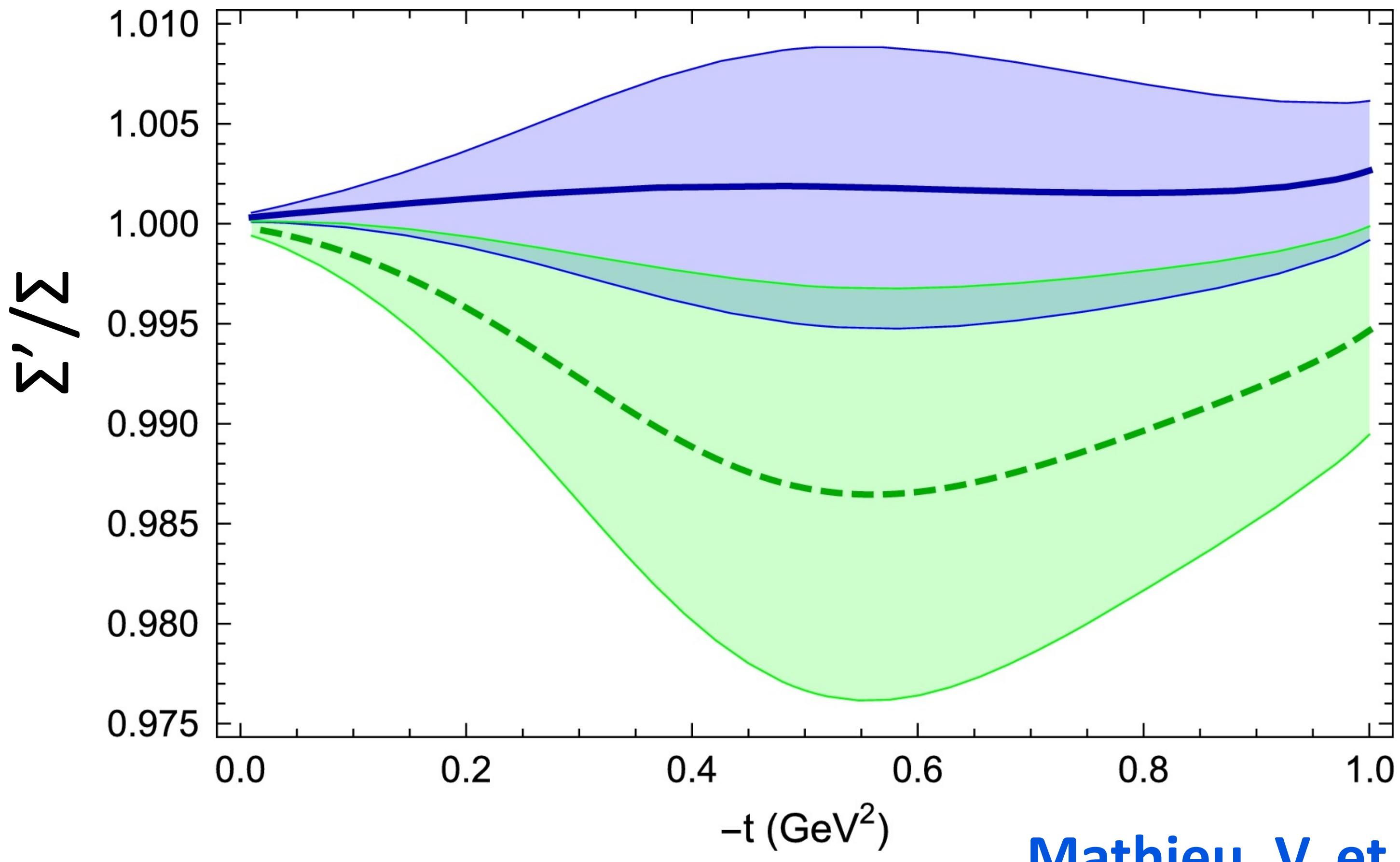


η' Beam Asymmetry



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

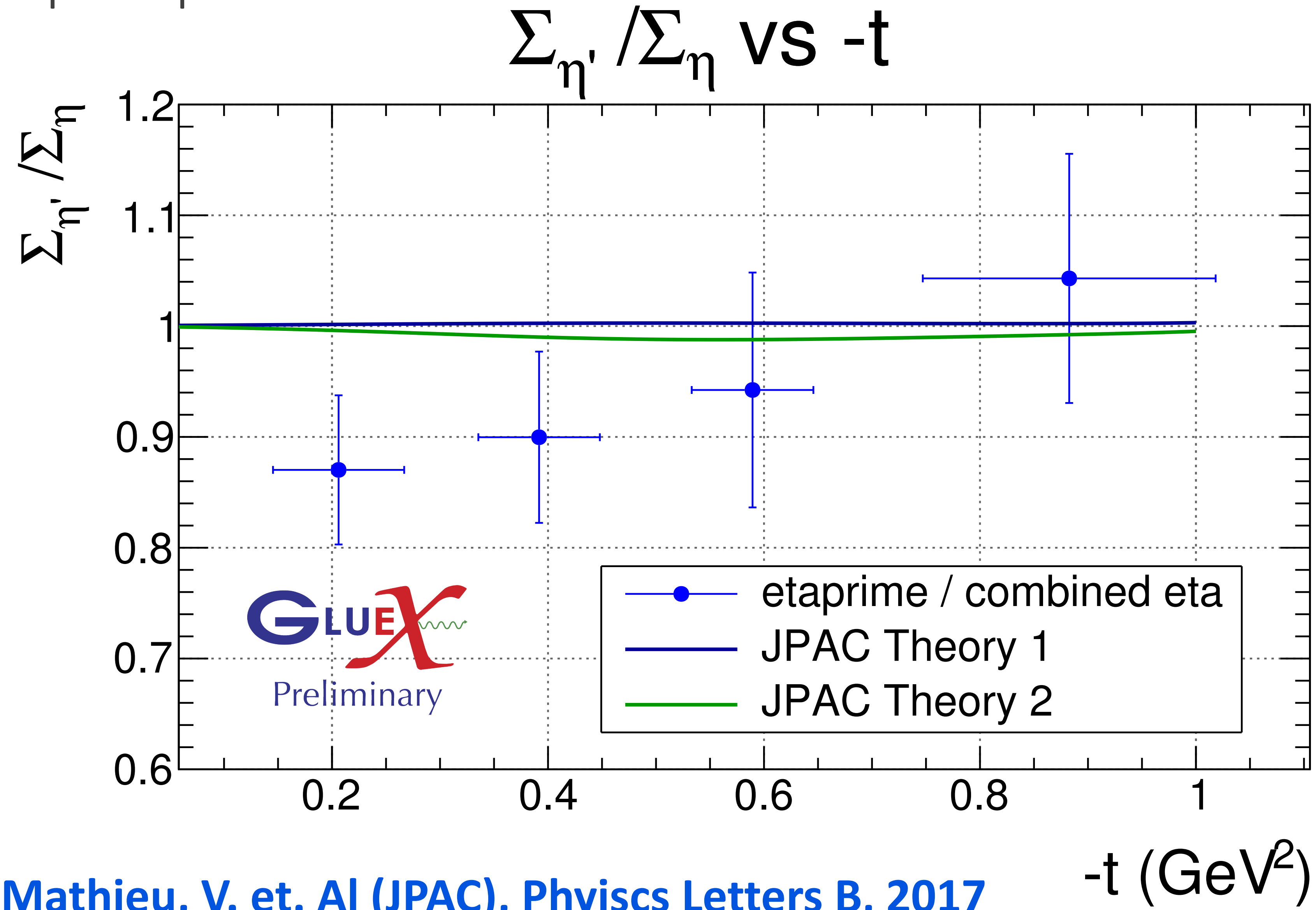
- Σ asymmetry of the η' and η being equal implies no hidden strangeness exchange of ϕ and h' mesons .
- JPAC predictions for two model assumptions for Σ' /Σ allowing ϕ exchange:



- 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

$\Sigma_{\eta'}/\Sigma_\eta$ Measurement



- Statistical errors only
  - Limited by η' errors
- No statistically significant deviations from unity are observed

Mathieu, V. et. Al (JPAC), Phyiscs Letters B, 2017

Summary

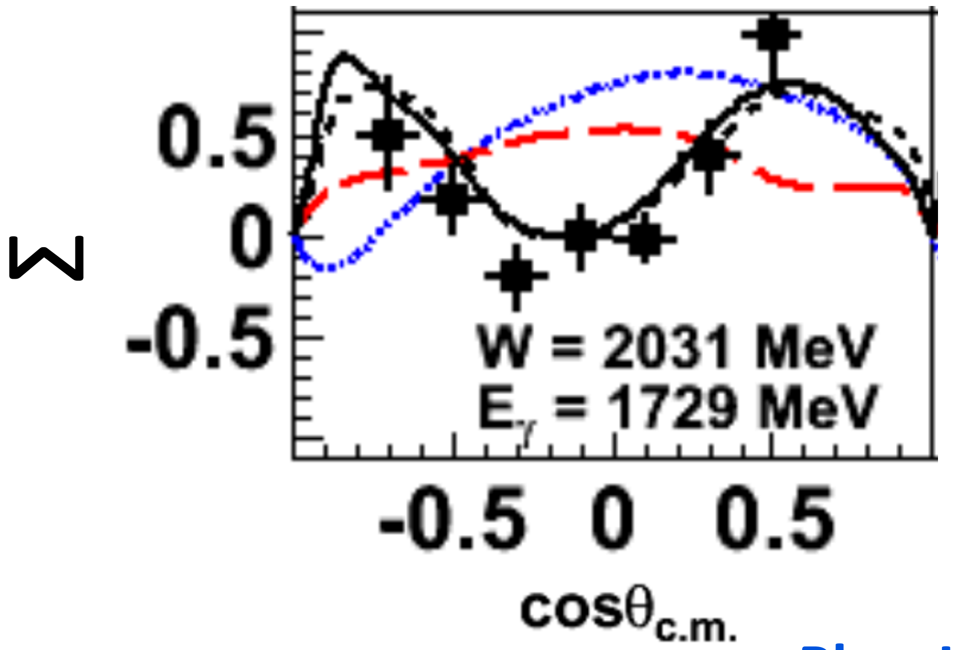
- We are able to measure beam asymmetries vs. t for:
  - η, in three decay channels
  - η', never before measured at high beam energies
- Both asymmetries are consistent with unity
  - Dominated by natural parity exchange
- Ratio of asymmetries consistent with JPAC theory predictions
- Analysis will be continued with the full Phase I data set → increase in statistics by a factor of 4
- Future: Cross sections

Backups

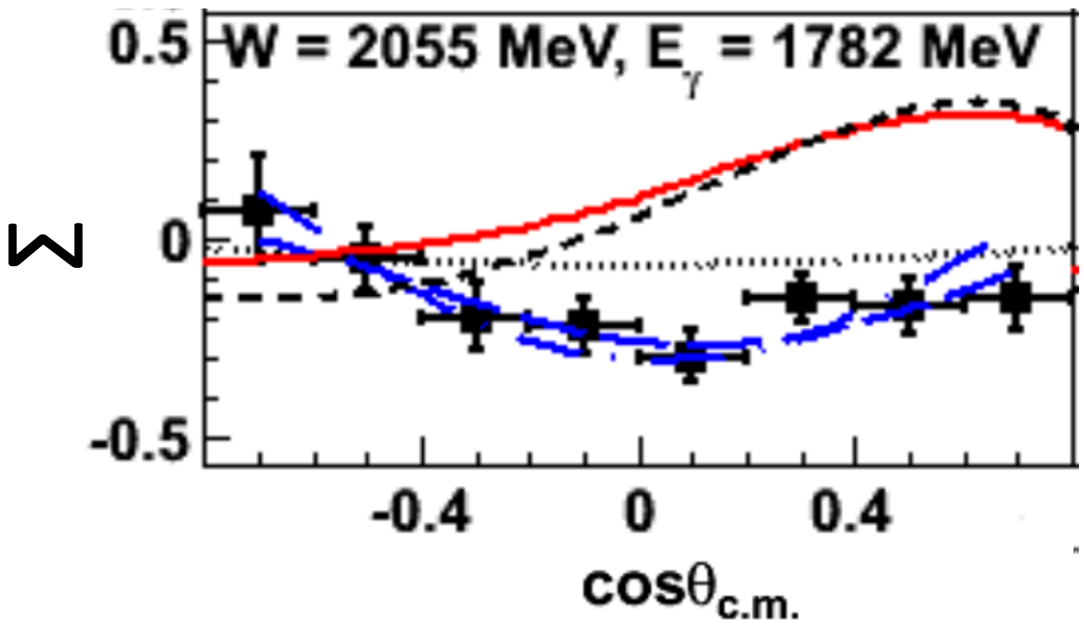
Low energy η and η' beam asymmetries

- $E_\gamma < 2$ GeV: Σ beam asymmetries provide insight to nucleon resonance.
- Measuring Σ constrains the helicity amplitudes of excited nucleon states.

η



η'



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