Analysis of the η(548) → π+ π- π0 and η'(958) → π+ π- η channels for the GlueX Experiment

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The GlueX Experiment at Jefferson Lab

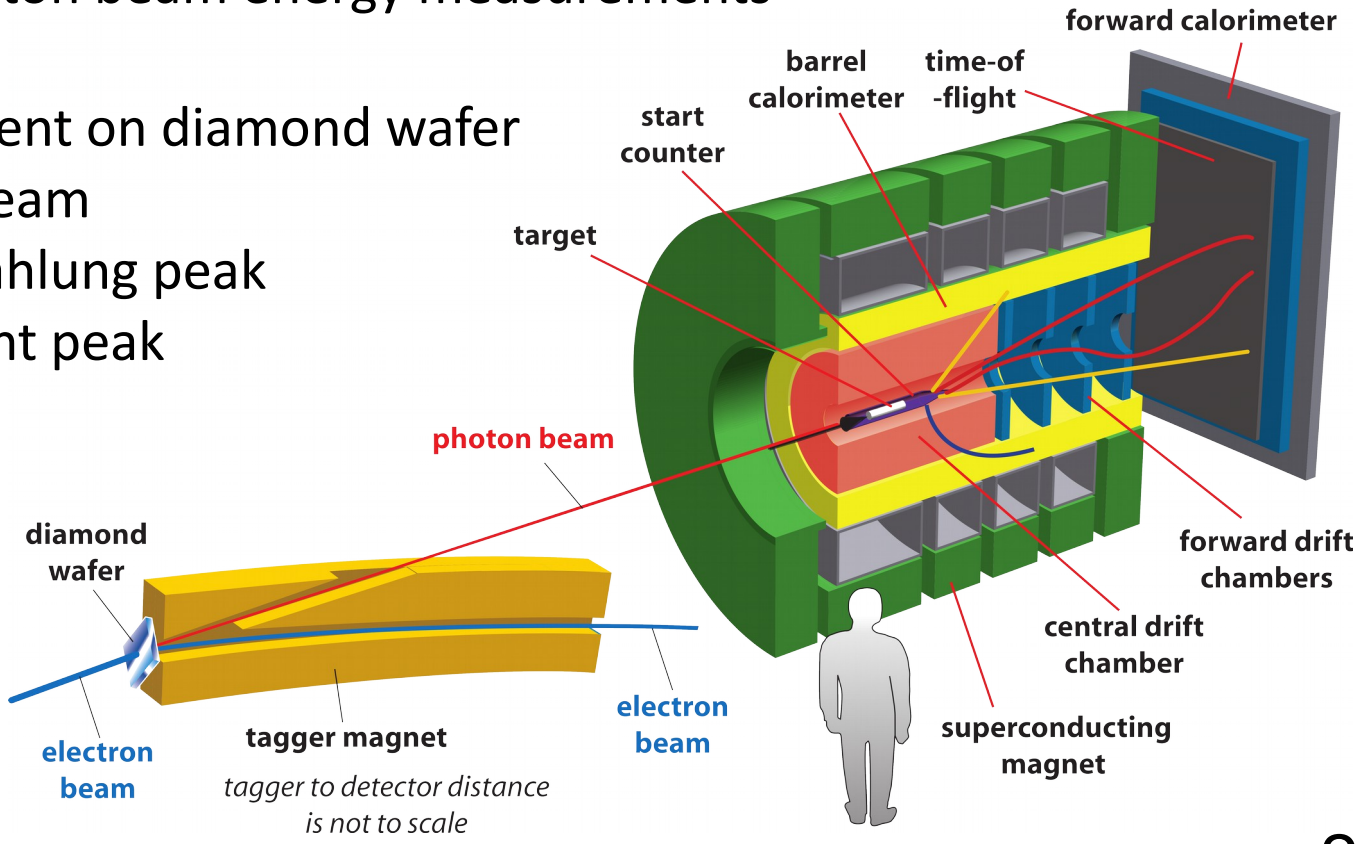
- GlueX detector:
  - Nearly 4π-hermetic
  - Liquid Hydrogen target
  - Two calorimeters for neutral energy deposition
  - Tracking chambers for charged particle tracking
  - Triplet Polarimeter for photon beam polarization measurements
  - Pair Spectrometer for photon beam energy measurements

- 12 GeV electron beam incident on diamond wafer
- Linearly polarized photon beam
  - 9 GeV coherent Bremsstrahlung peak
  - High luminosity in coherent peak
    - 10^8 γ/s (Design)

- Resolutions:

γ: $\sigma_E/E \sim 6\%/\sqrt{E} \oplus 2\%$

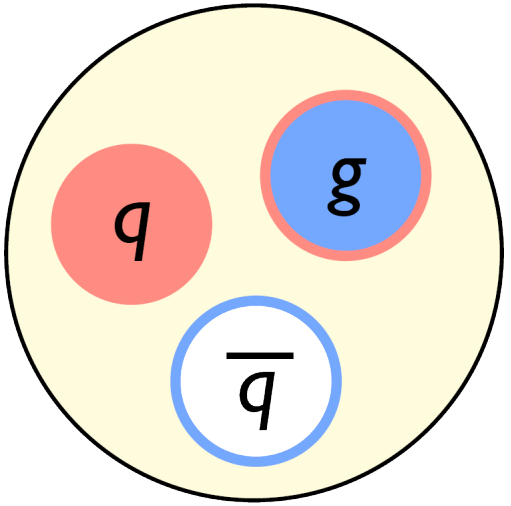
$q^{\pm}$: $\sigma_p/p \sim 2-5\%$



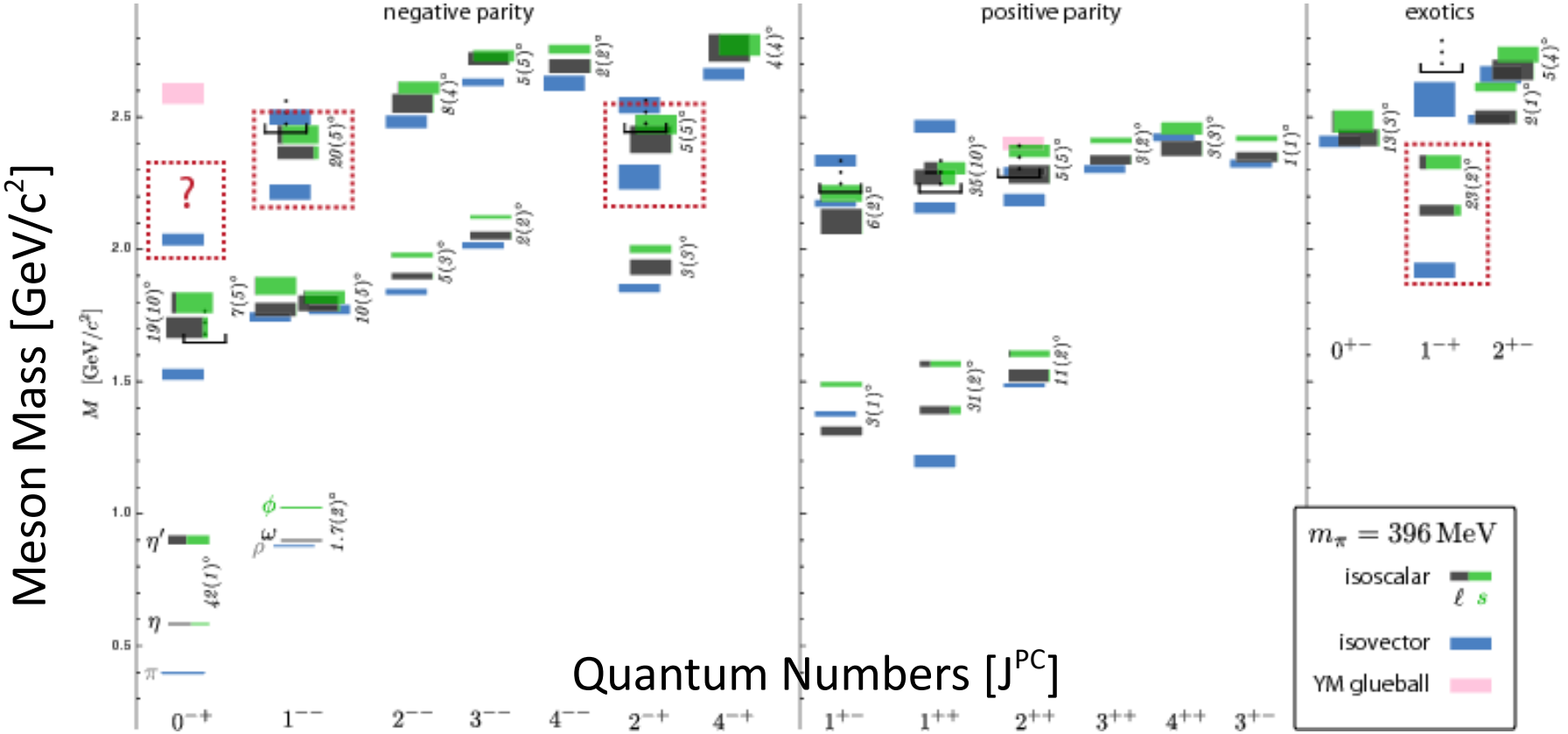
GlueX Physics

- 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



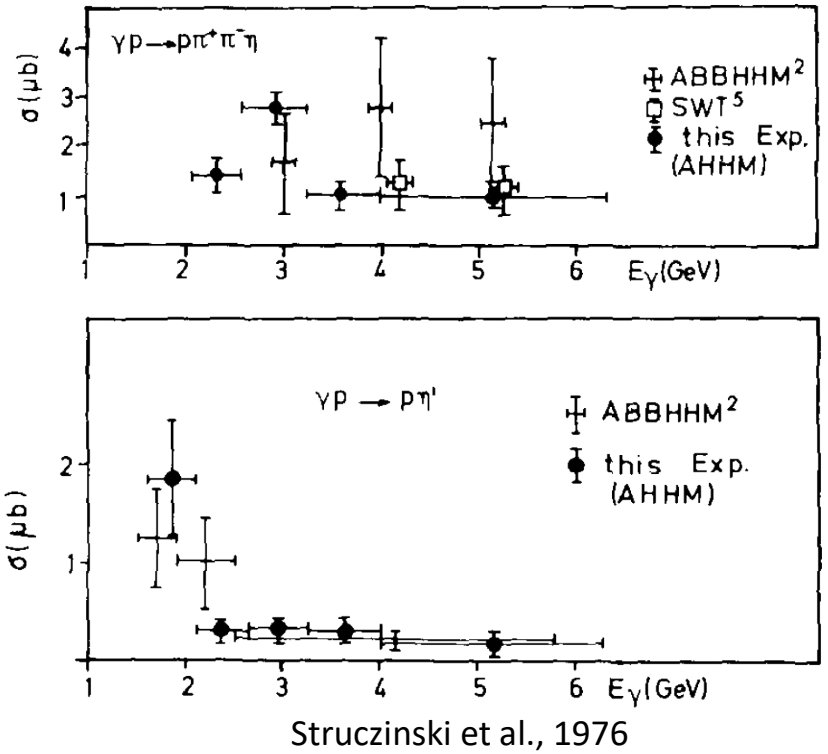
$q\bar{q}$ pair w/ contributions from an excited gluon



Purpose

- Establish robust analyses of simplest light mesons using 'Spring 2016' data set

- η and η' mesons abundantly available at GlueX
  - World η/η' photoproduction data is sparse at high energies
  - Σ beam asymmetries/cross sections not yet measured at high energies
  - Provide rich arrays of resonances for study
  - Many other light mesons decay through π and η mesons
  - πη and πη' resonances high on list of possibly-accessible exotics/hybrids



Struczinski et al., 1976

- Reconstructing pure samples of these simple mesons is the first step

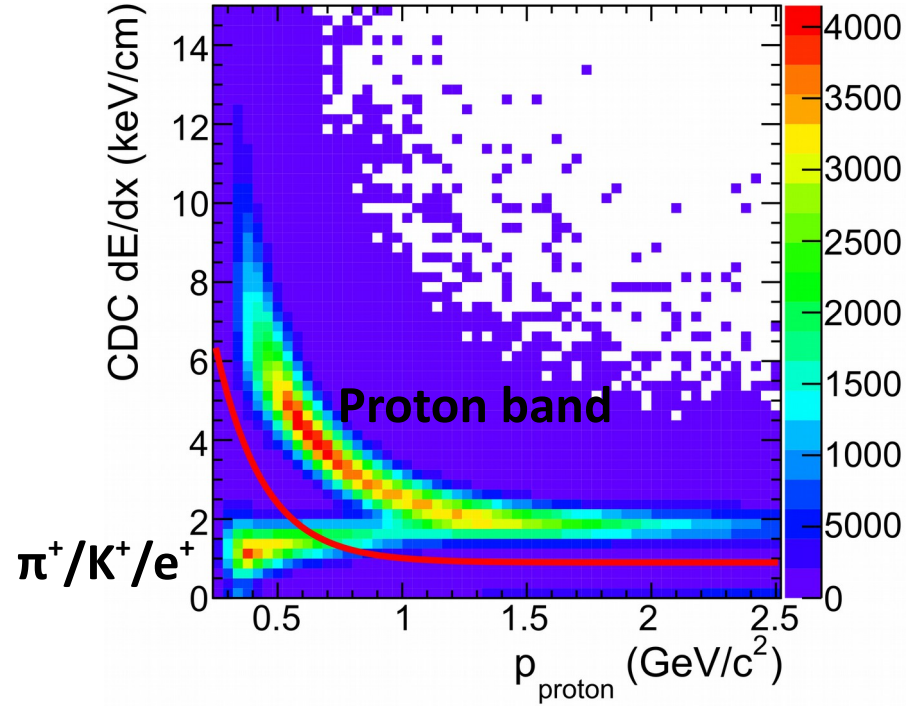
- This talk: most recent results for reconstruction of η and η'
  - Results include ~ 1/4 of the Spring 2016 data set

$\eta \rightarrow \pi^+\pi^-\pi^0$ (BR ~ 22.9%)
$\pi^0 \rightarrow 2\gamma$

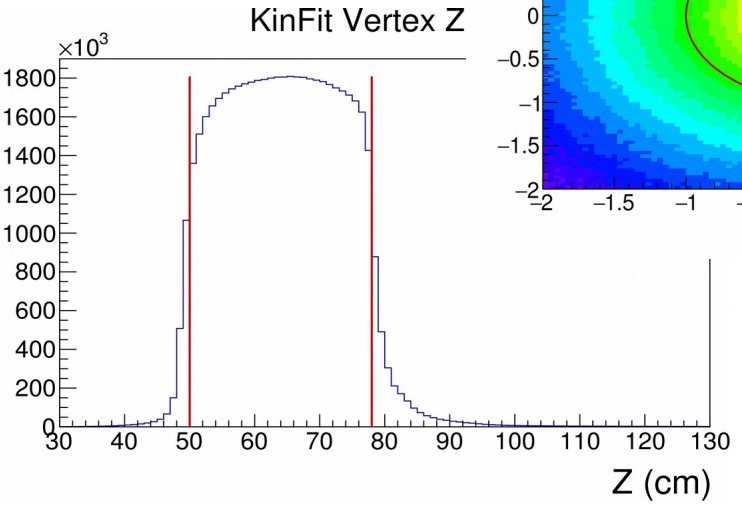
$\eta' \rightarrow \pi^+\pi^-\eta$ (BR ~ 42.9%)
$\eta \rightarrow 2\gamma$

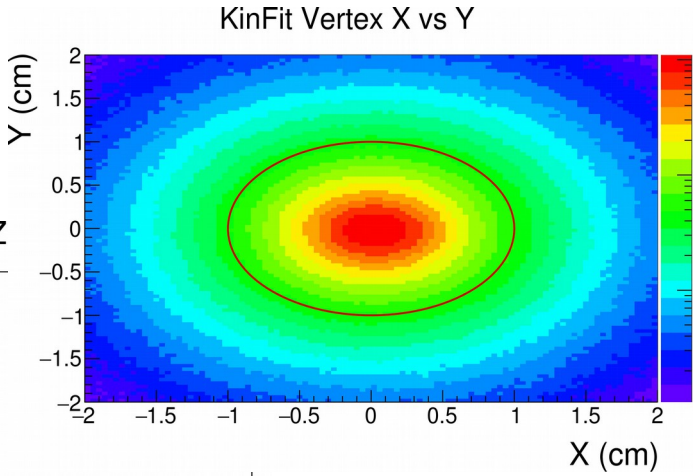
Event Selection Cuts

- 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 or 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

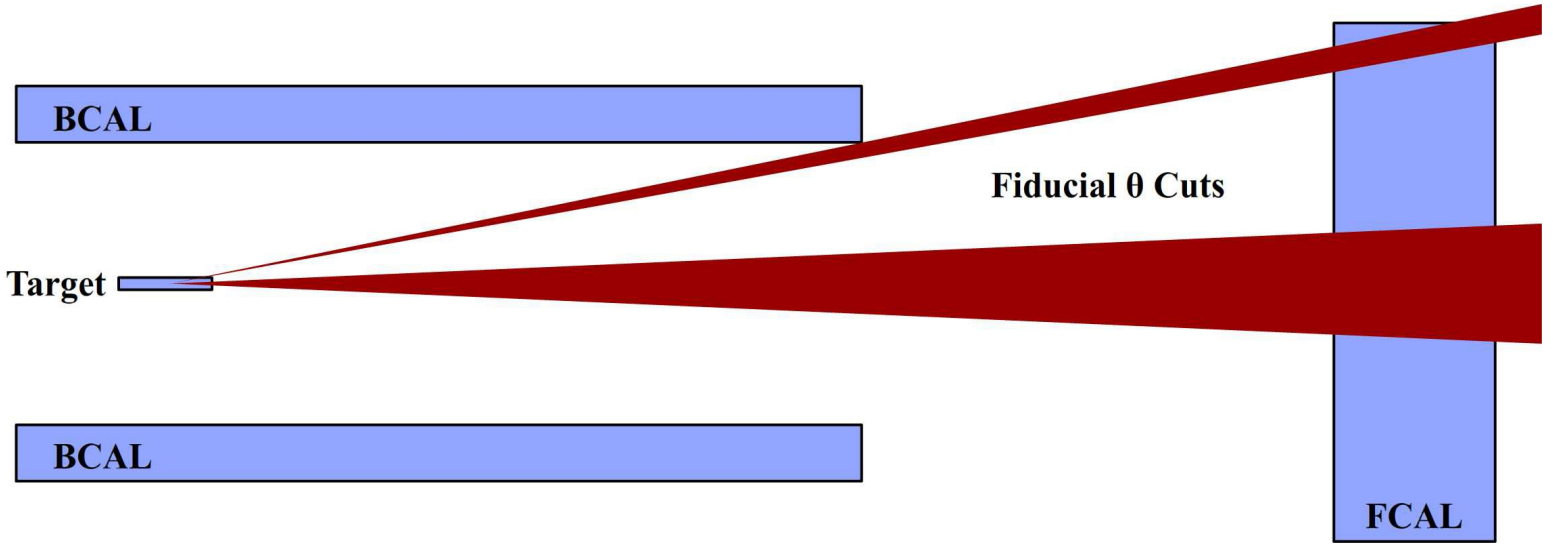


Cuts shown in RED

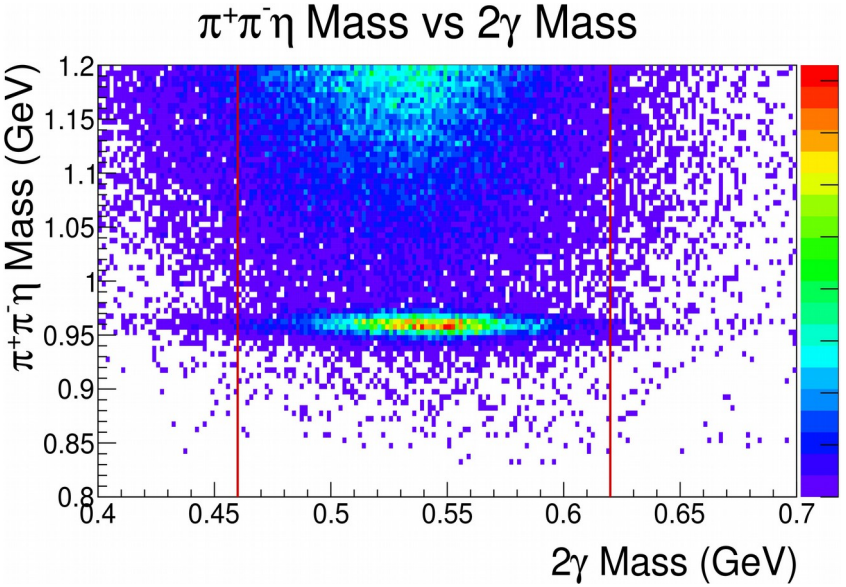




Event Selection Cuts



- Photon reconstruction around the beam hole and BCAL-FCAL gap less reliable
  - Cut combos with a neutral shower close to either region
- Cut on 2γ mass to reject less-likely combos which passed kinematic fit

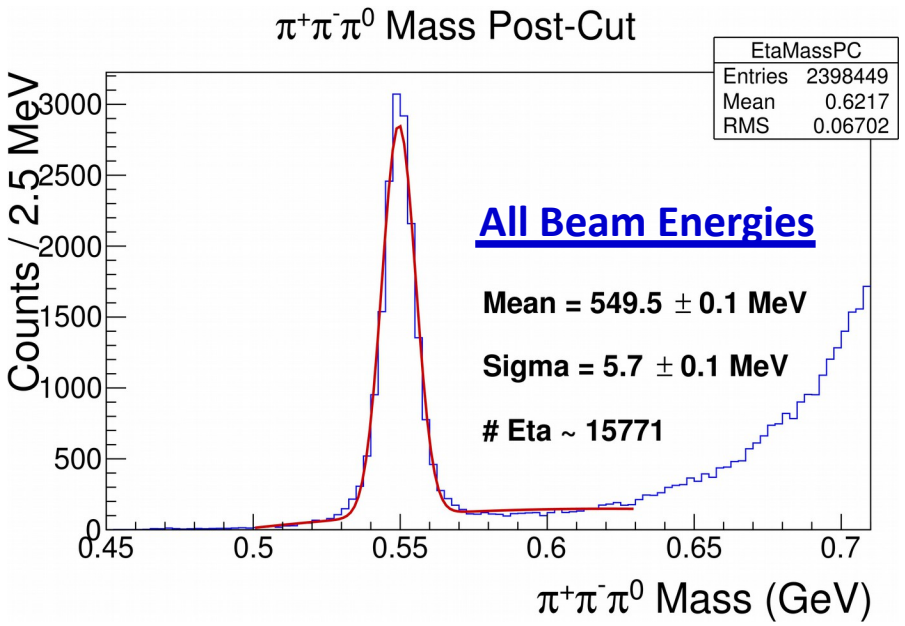


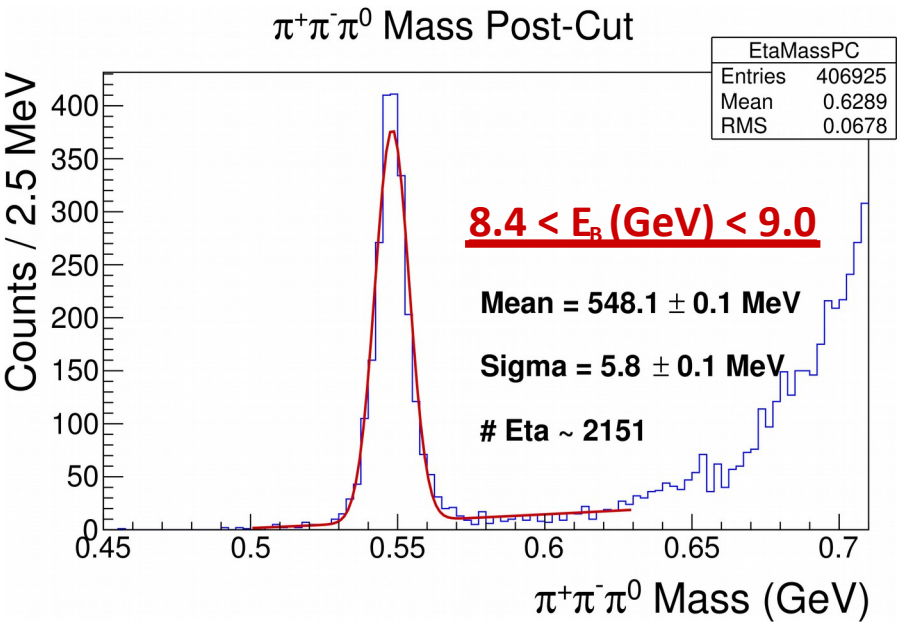
Clean Events

For particle combos which passed all cuts:

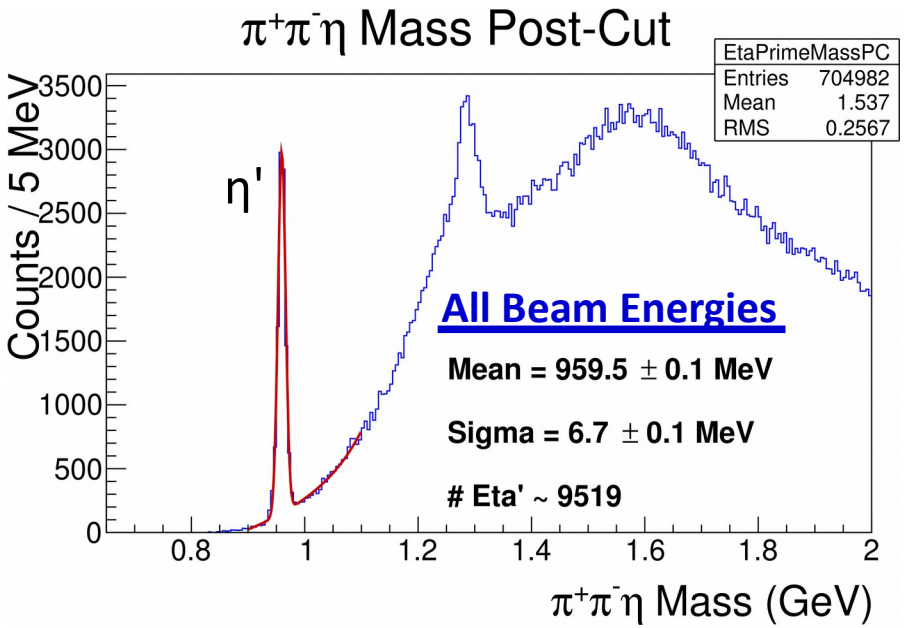
- Invariant mass spectra
- Beam asymmetries

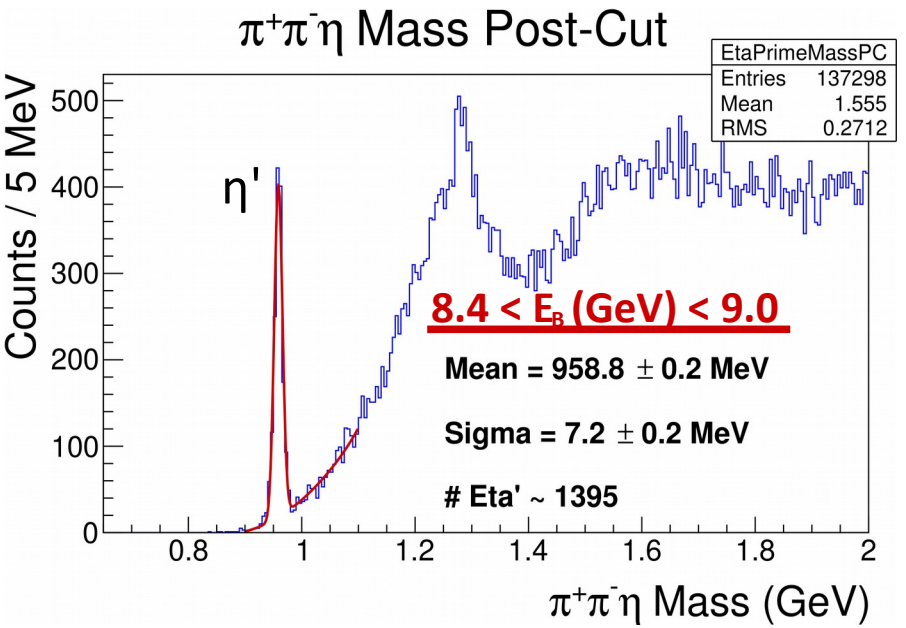
$\eta \rightarrow \pi^+\pi^-\pi^0$ Mass Spectrum





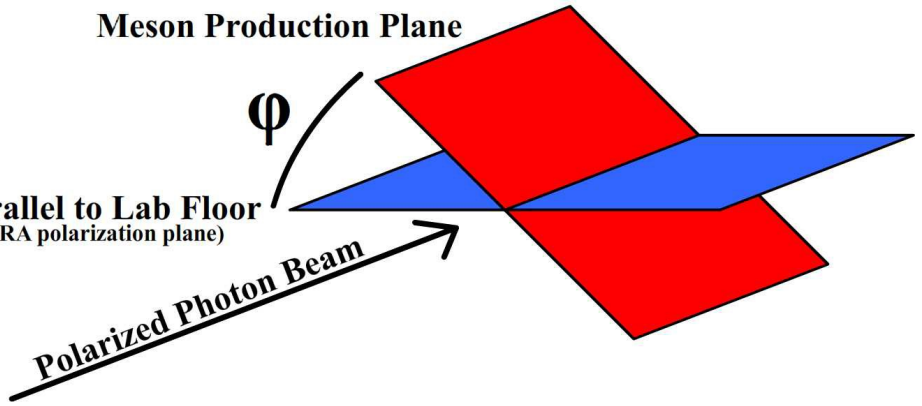
$\eta' \rightarrow \pi^+\pi^-\eta$ Mass Spectrum

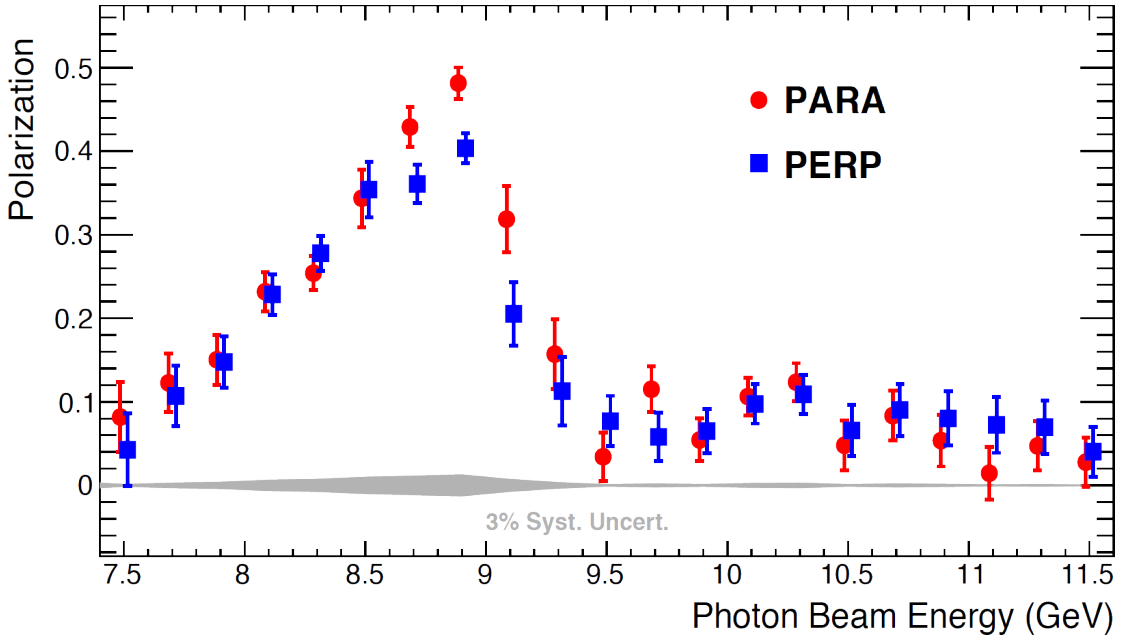




Beam Asymmetry

- Σ beam asymmetry: polarization observable
- Provides insight into helicity amplitudes of the interaction
- Use coherent peak data (8.4 – 9.0 GeV)
- Polarized yield as a function of φ is proportional to PΣ
- 2 polarization configurations: PARA, PERP
- Fit to ASYM eliminates possible φ-dependent acceptance effects
- F_R = PERP/PARA yield normalization factor





PERP yield ~ $(1 + P_{\parallel}\Sigma \cos(2\varphi))$

PARA yield ~ $(1 - P_{\perp}\Sigma \cos(2\varphi))$

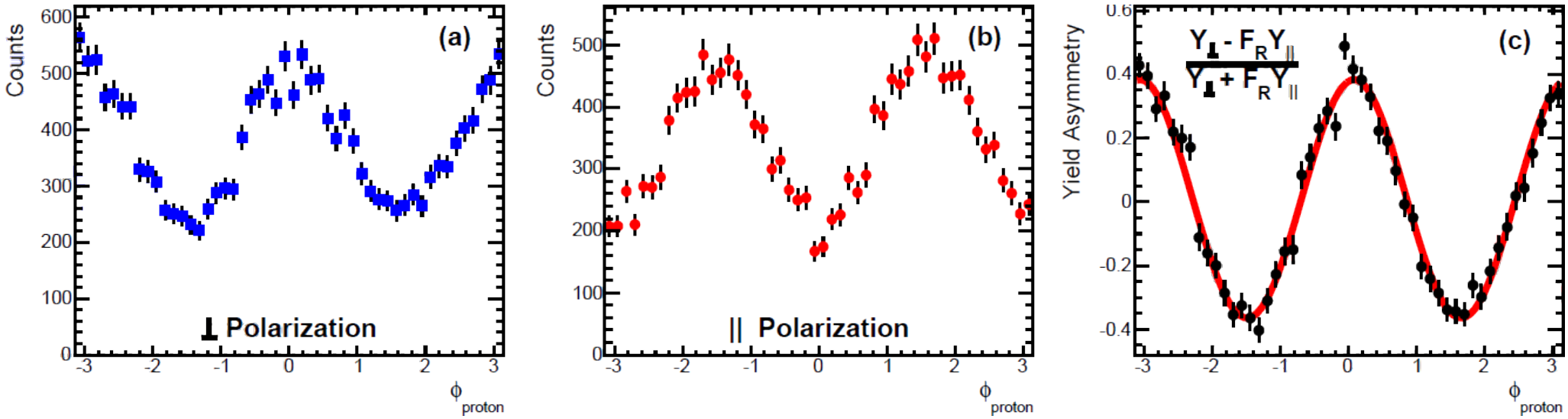
$$\text{ASYM} = \frac{Y_{\perp} - F_R Y_{\parallel}}{Y_{\perp} + F_R Y_{\parallel}} = \frac{(P_{\perp} + P_{\parallel})\Sigma \cos(2\varphi)}{2 - (P_{\perp} - P_{\parallel})\Sigma \cos(2\varphi)}$$

$P_{\perp}$ and $P_{\parallel}$ found from $\pi^0 \longrightarrow 2\gamma$ analysis

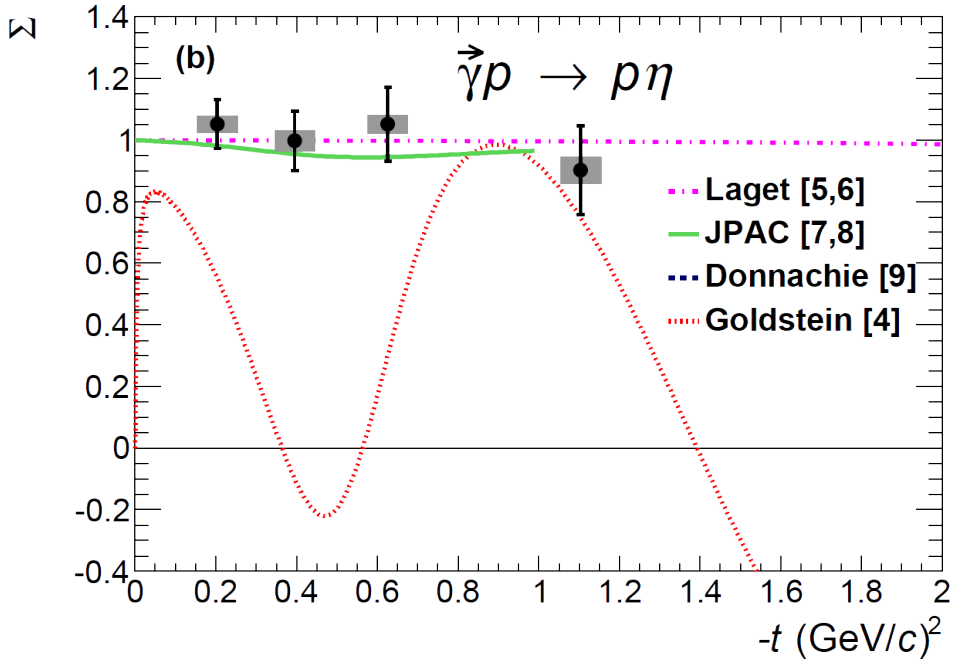
Fit data to this function to extract Σ

GlueX PRL Submission: π^0/η Σ Asymmetry

arXiv:1701.08123 [nucl-ex]



$\pi^0 \longrightarrow 2\,\gamma$ Yield vs. φ (t-averaged)

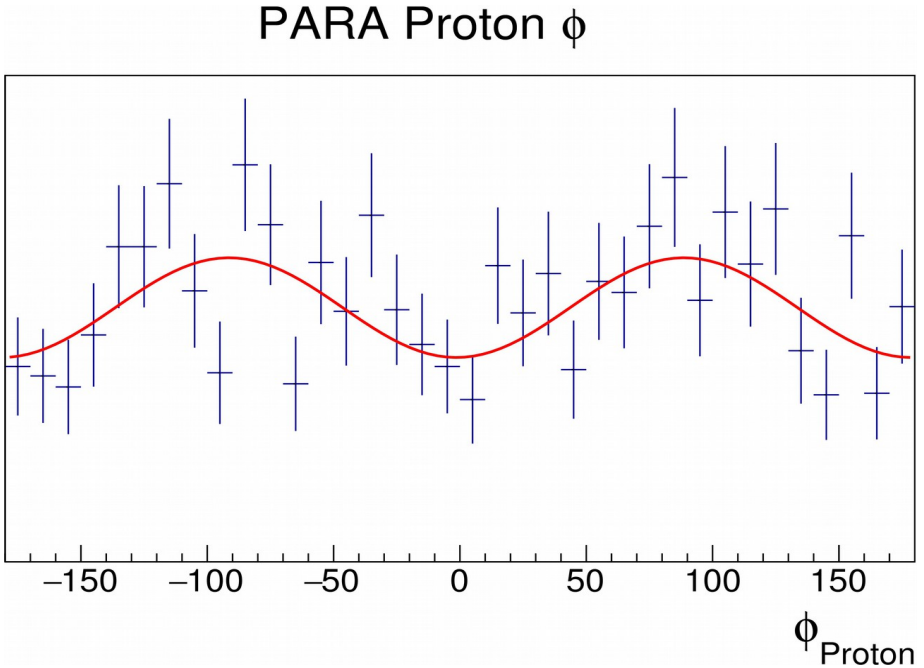


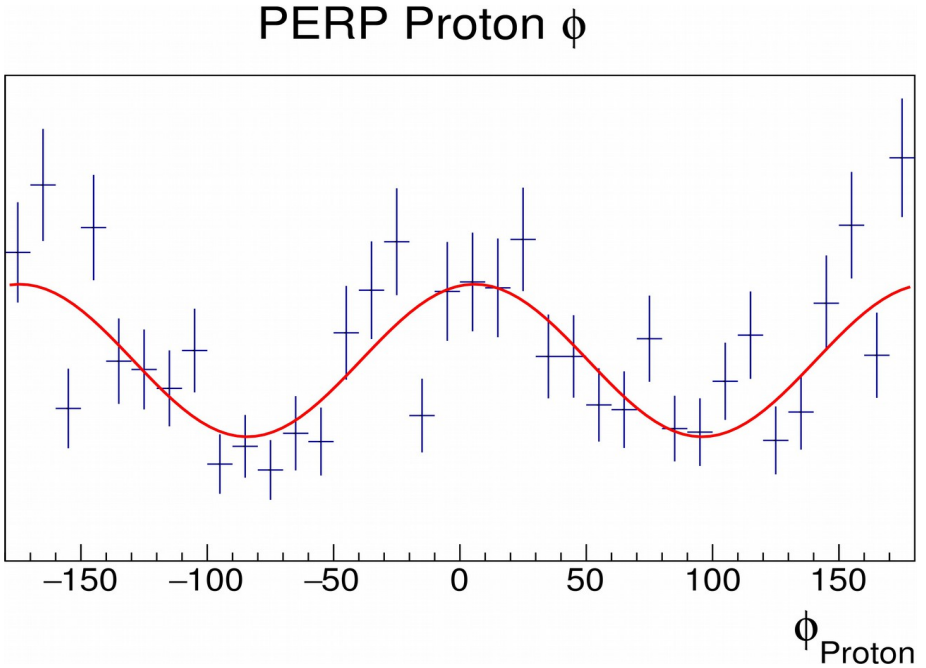
- Detailed analysis of π^0 and η asymmetry
- High statistics $\eta \longrightarrow 2\,\gamma$ channel
- Model predictions vs. momentum transfer

- Form yield asymmetry for ranges of -t
- Extract beam asymmetry for each range
- Compare to model predictions (left)

Goal: Confirm result with $\eta \longrightarrow \pi^+\pi^-\pi^0$
Observe result with $\eta' \longrightarrow \pi^+\pi^-\eta$

$\eta \longrightarrow \pi^+ \pi^- \pi^0$ Beam Asymmetry

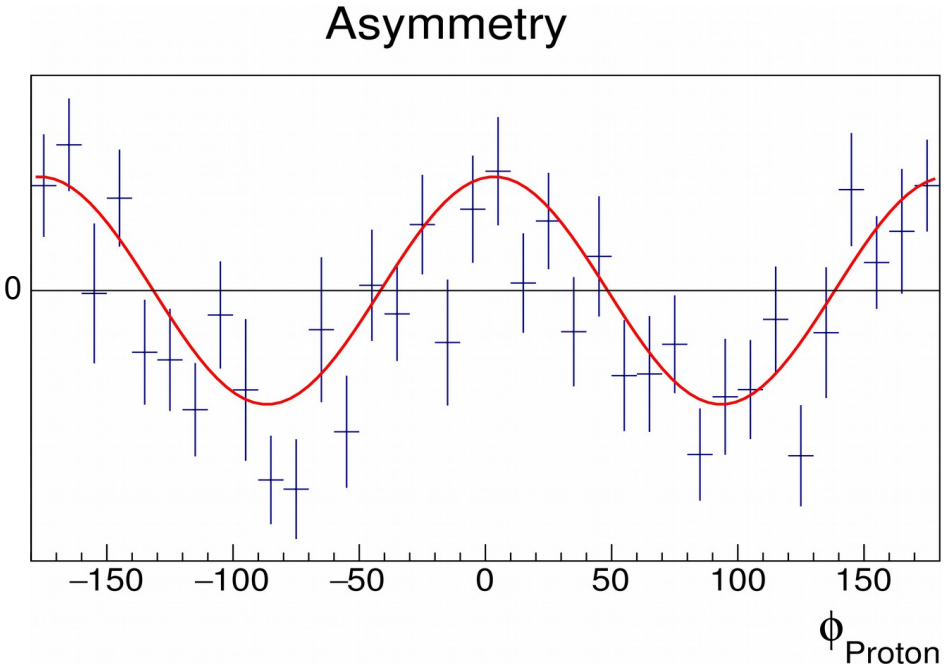




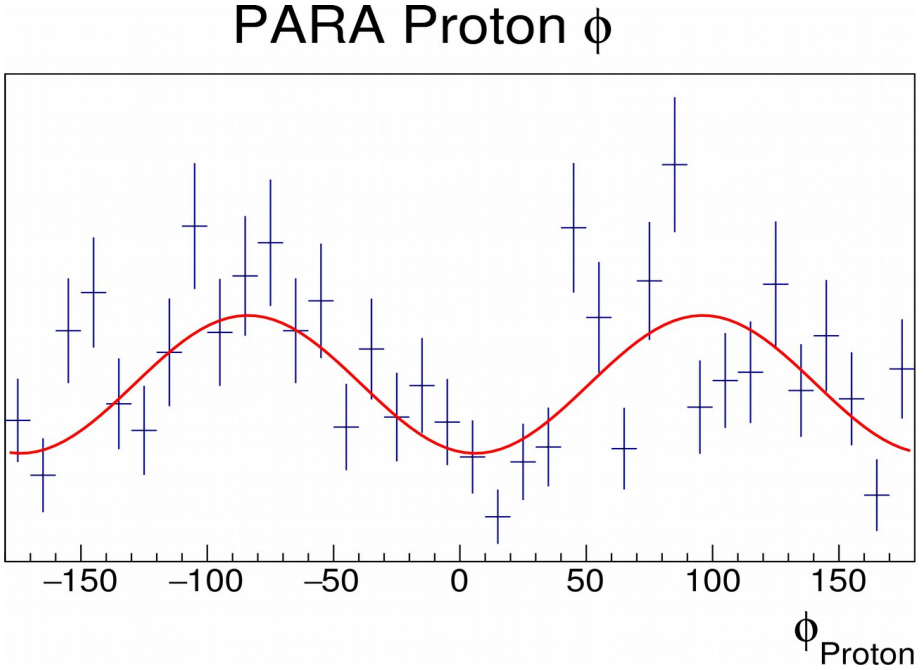
$$f(\varphi) = \frac{(P_\perp + P_\parallel)\Sigma \cos(2\varphi)}{2 - (P_\perp - P_\parallel)\Sigma \cos(2\varphi)}$$

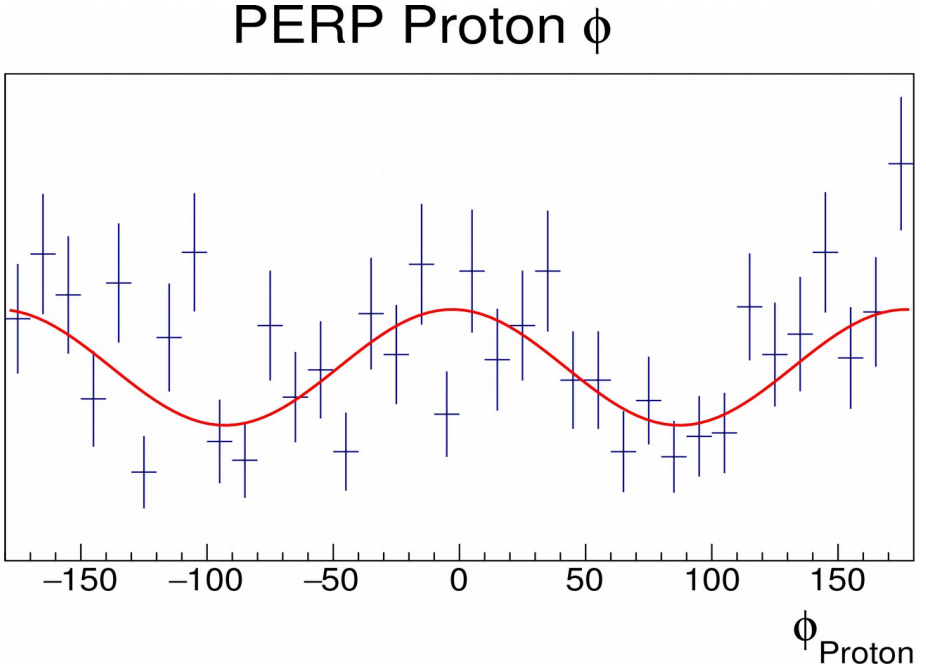
- Clear sinusoidal behaviour
  - Sensitive to Σ asymmetry!

(t-averaged)



$\eta' \rightarrow \pi^+ \pi^- \eta$ Beam Asymmetry





$$f(\varphi) = \frac{(P_\perp + P_\parallel)\Sigma \cos(2\varphi)}{2 - (P_\perp - P_\parallel)\Sigma \cos(2\varphi)}$$

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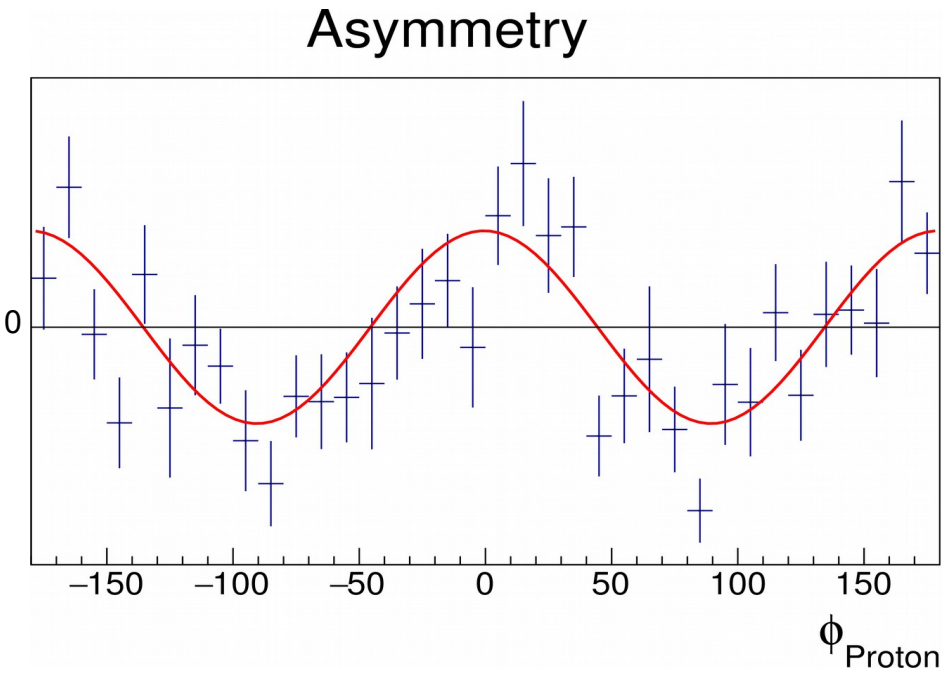
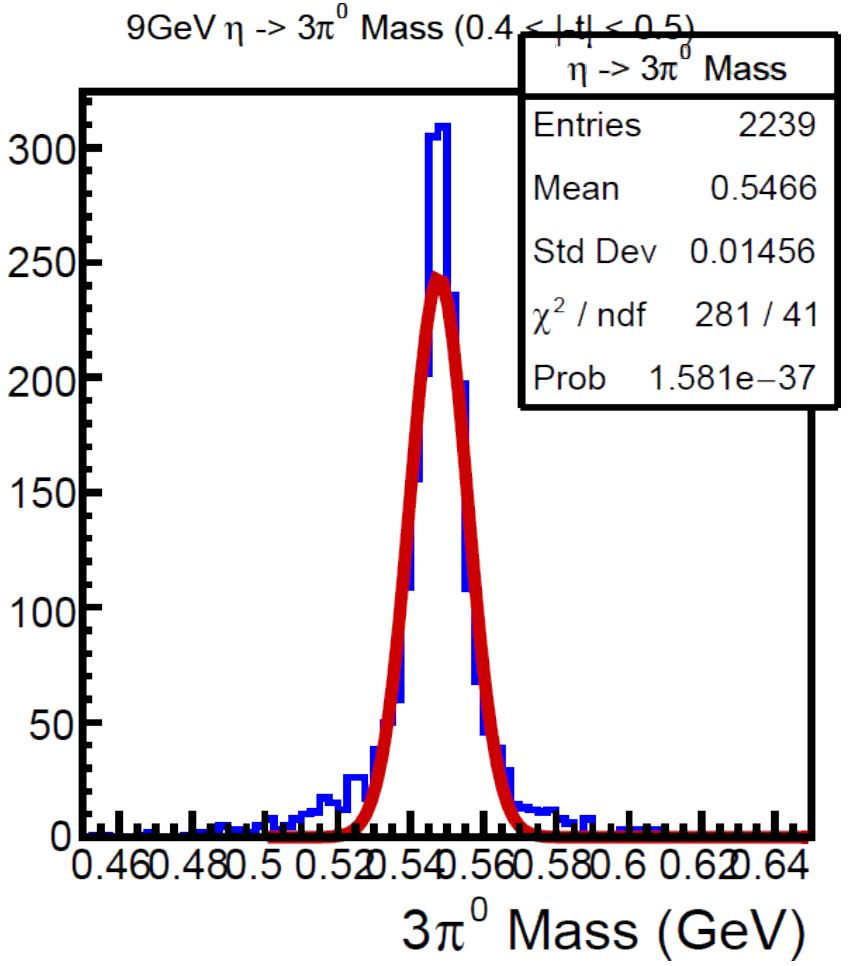


Beginning of Acceptance Studies

For $\eta \rightarrow 2\gamma$, $3\pi^0$, $\pi^+\pi^-\pi^0$

- Understand acceptance for future cross-section extraction
- Investigating acceptance in bins of beam energy and momentum transfer (-t)
  - Simulate data in bins of beam energy
  - Form ratios of yields vs. -t
  - Compare to same ratios in data
    - Work in Progress
- Simulations:
  - 600,000 events per 2 GeV beam energy bin
  - Plotted η mass in bins of -t
  - Fit to Gaussian, extract abundance
  - Correct abundances for branching fractions
  - Plot yield ratios vs. -t



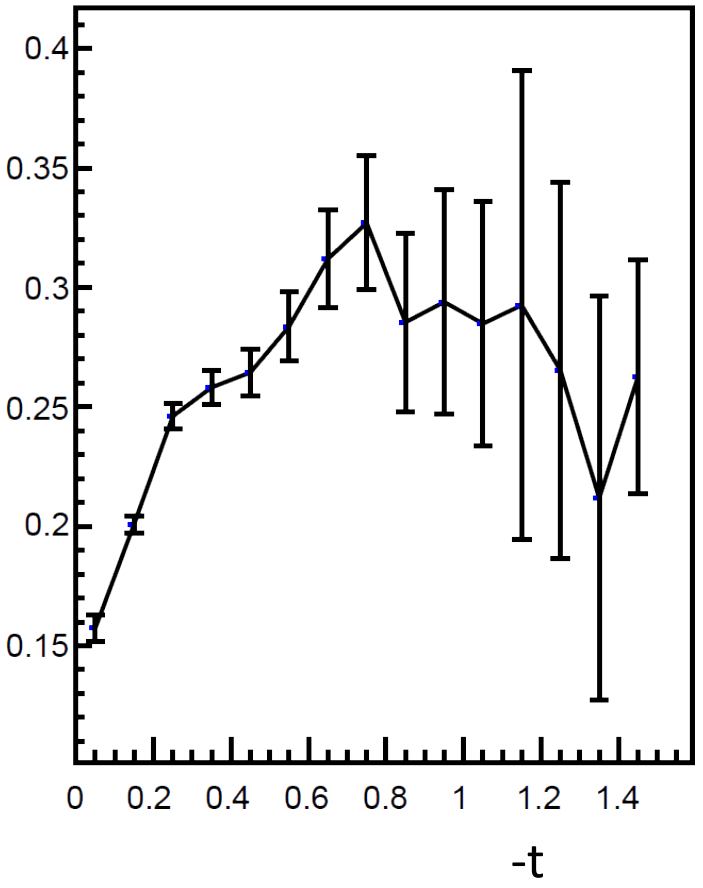
Branching Fraction Corrected Yield Ratios

For Beam Energy Between 8 and 10 GeV

Ratios provide insight into detector acceptance between topologies (ex: charged vs. neutrals) vs. beam energy and -t

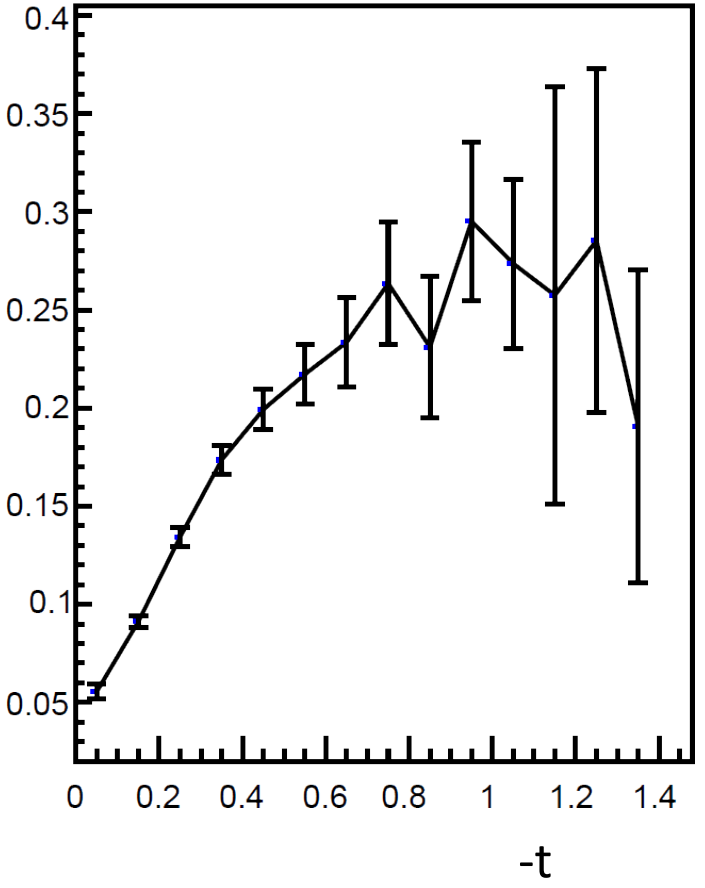
$\pi^+\pi^-\pi^0$ / 2γ Yield

BF: 22.92 / 39.41



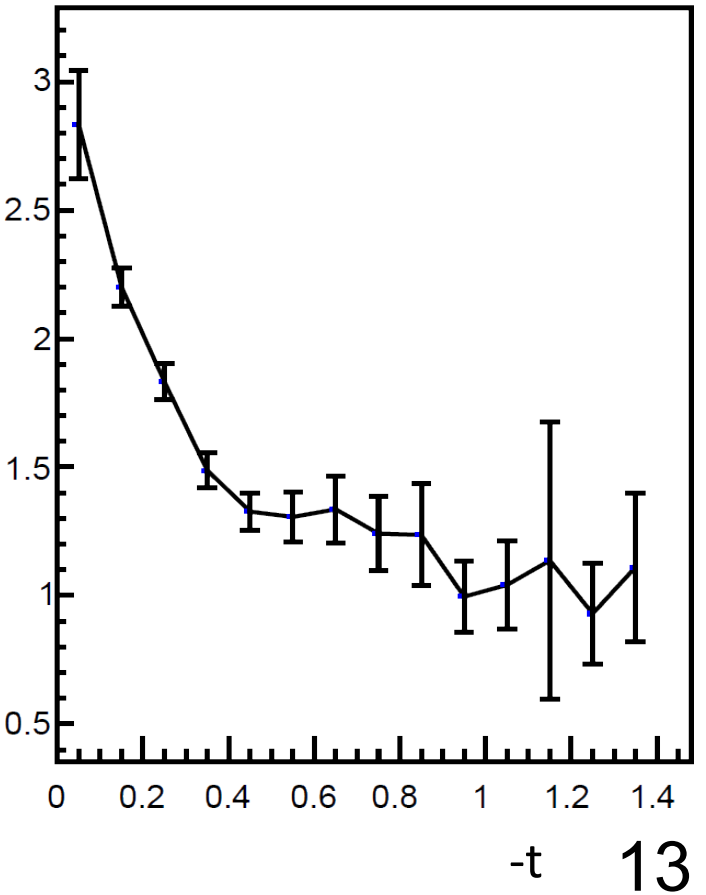
$3\pi^0$ / 2γ Yield

BF: 32.68 / 39.41



$\pi^+\pi^-\pi^0$ / $3\pi^0$ Yield

BF: 22.92 / 32.68



Summary and Outlook

- Our detector/analysis gives clean signals for both η and η' decays
- Able to see PΣ asymmetry for η and η' (using ~ 1/4 of the Spring 2016 data set)
  - Similar sensitivity to t-averaged PΣ asymmetry
  - More robust analysis (with higher statistics) to come
- Upcoming physics production running
  - Expect ~ 10x more data than Spring 2016 data set over the first year
  - Will significantly improve errors in fits arising from current lack of statistics
- η' Σ asymmetry never before measured at GlueX energies
  - More statistics → first accurate measurement?
- Theory group (JPAC) predictions of Σ vs mom. transfer (-t)
  - Currently, sparse data at high t
  - More statistics → bin data in t
  - Investigate yield and Σ asymmetry as functions of t
- Continue with MC and data acceptance comparisons

Questions?