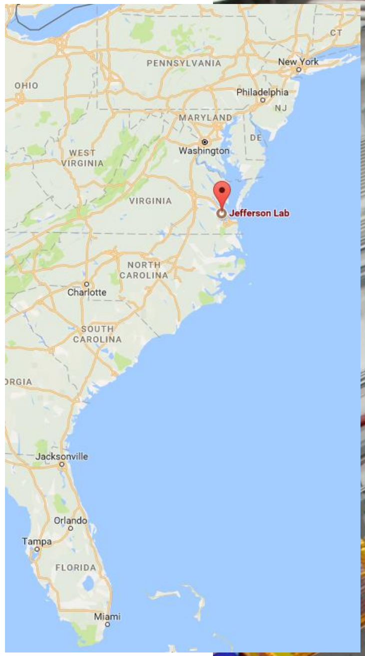
Selected Light Meson Results from GlueX



D. Mack, TJNAF

for the GlueX Collaboration

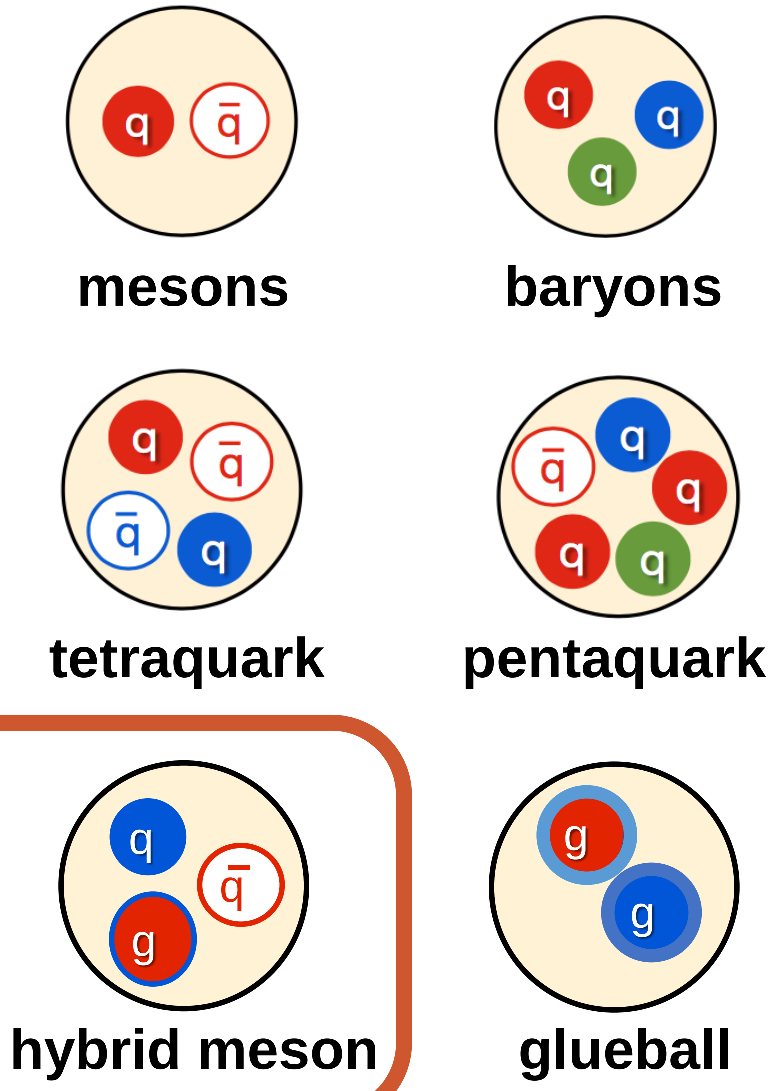
August 18, 2019 16:15

Overview

- GlueX principal motivation: hybrid meson searches
- Synergies with light meson studies (< 1.05 GeV/c^2)
- Beam asymmetry Σ measurements of π^0, η, and η' photo-production
- Spin Density Matrix Element (SDME) measurements of vector meson photo-production

GlueX Principal Motivation

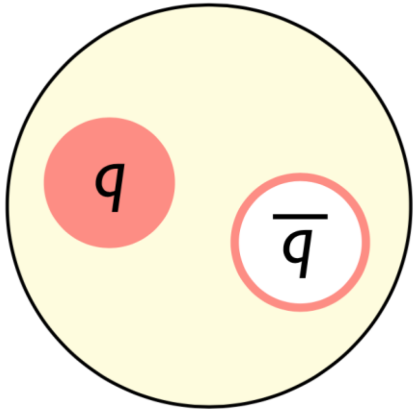
- Idea: study QCD through spectrum of bound states
  - Static properties of known hadrons well described by first- principals calculations
  - Modern experiments provide wealth of data to push boundaries of our knowledge
- Open questions:
  - What is the origin of confinement?
  - Which color-singlet states exist in nature?
  - **Do gluonic degrees of freedom manifest themselves in the bound states that we observe?**



Search Filter for Hybrid Mesons: "Exotic" Quantum Numbers

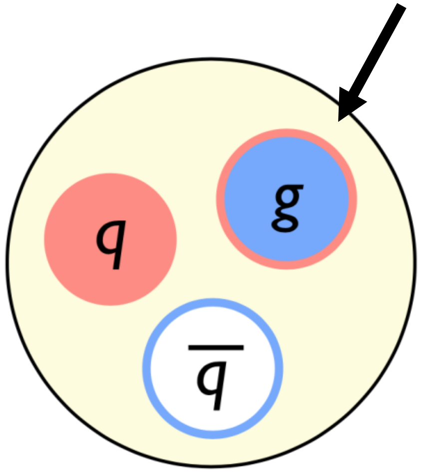
Mesons are arranged in groups of 9 ("nonets") with same J^{PC}

$J=L+S \quad P=(-1)^{L+1} \quad C=(-1)^{L+S}$



"Normal" Meson

gluonic field excitation →
"constituent gluon" (J^{PC}) = 1^{+-}



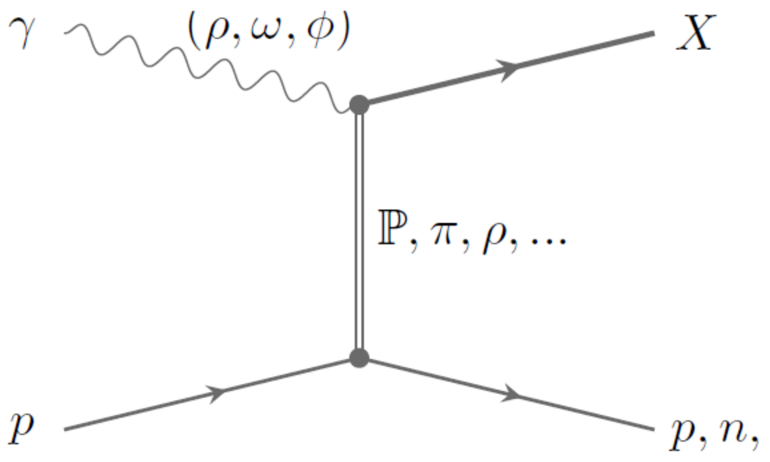
"Hybrid" Meson

Allowed J^{PC} : **0^{-+}, 0^{++}, 1^{--}, 1^{+-}, 2^{++}, 2^{-+},…**
Forbidden J^{PC}: **0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, …**

Allowed J^{PC} : **0^{-+}, 0^{+-}, 1^{--}, 1^{-+}, 2^{-+}, 2^{+-}, …**

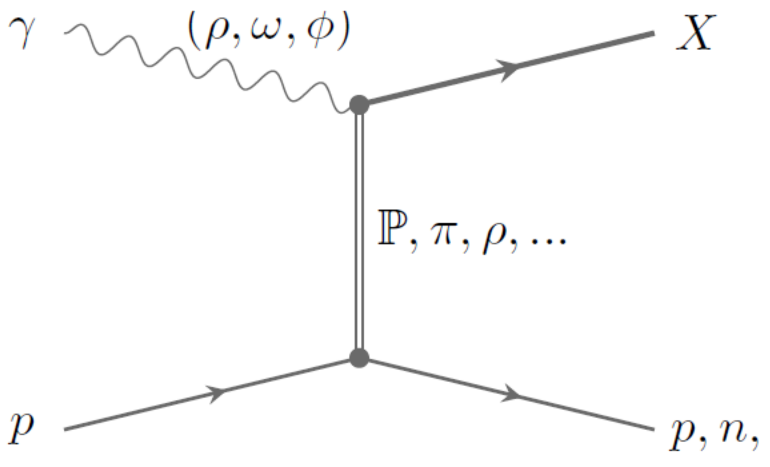
Mesons with exotic quantum numbers of 0^{+-}, 1^{-+}, 2^{+-} would be suggestive of constituent gluon content.
From LQCD, nominal hybrid mass search range is 1.5 – 2.5 GeV/c^2.

Hybrid Meson Production Via Photo-production



- A wide variety of I^G J^{PC} states can be produced, including all expected hybrids.
- Existing relevant photo-production data are sparse. Barely explored territory.
- Photon polarization provides an additional constraint on the production mechanism.
- A broad survey requires a large acceptance detector with good PID for both charged particles and photons.

Exotic Meson Production Via Photo-production



Exchange		Exotic Final States	
$\mathbb{P}$	0^{++}	b, h, h'	$2^{+-}, 0^{+-}$
π^0	0^{-+}	b_2, h_2, h'_2	2^{+-}
$\pi^{\pm}$	0^{-+}	$\pi_1^{\pm}$	1^{-+}
ω	1^{--}	π_1, η_1, η'_1	1^{-+}

- A wide variety of $I^G J^{PC}$ states can be produced, including all expected hybrids.
- Existing relevant photo-production data are sparse. Barely explored territory.
- Photon polarization provides an additional constraint on the production mechanism.
- *A broad survey requires a large acceptance detector with good PID for both charged particles and photons.*

$\pi_1 \rightarrow \pi\rho$, πb_1, πf_1, $\pi\eta'$, ηa_1
$\eta_1 \rightarrow \eta f_2$, $a_2\pi$, ηf_1, $\eta\eta'$, $\pi(1300)\pi$, $a_1\pi$,
$\eta_1' \rightarrow K^*K$, $K_1(1270)K$, $K_1(1410)K$, $\eta\eta'$

$b_2 \rightarrow \omega\pi$, $a_2\pi$, $\rho\eta$, $f_1\rho$, $a_1\pi$, $h_1\pi$, $b_1\eta$
$h_2 \rightarrow \rho\pi$, $b_1\pi$, $\omega\eta$, $f_1\omega$
$h'_2 \rightarrow K_1(1270)K$, $K_1(1410)K$, K_2^*K, $\phi\eta$, $f_1\phi$

$b_0 \rightarrow \pi(1300)\pi$, $h_1\pi$, $f_1\rho$, $b_1\eta$
$h_0 \rightarrow b_1\pi$, $h_1\eta$
$h'_0 \rightarrow K_1(1270)K$, $K(1460)K$, $h_1\eta$

Synergy Between Light Meson Studies and Exotic Hybrid Search

Consider the $\eta' \to \eta\,\pi^+\pi^- \to 2\gamma\,\pi^+\pi^-$ branch for which I'll show Σ asymmetry results today.

The exotic hybrid meson candidate η_1 is expected to decay as

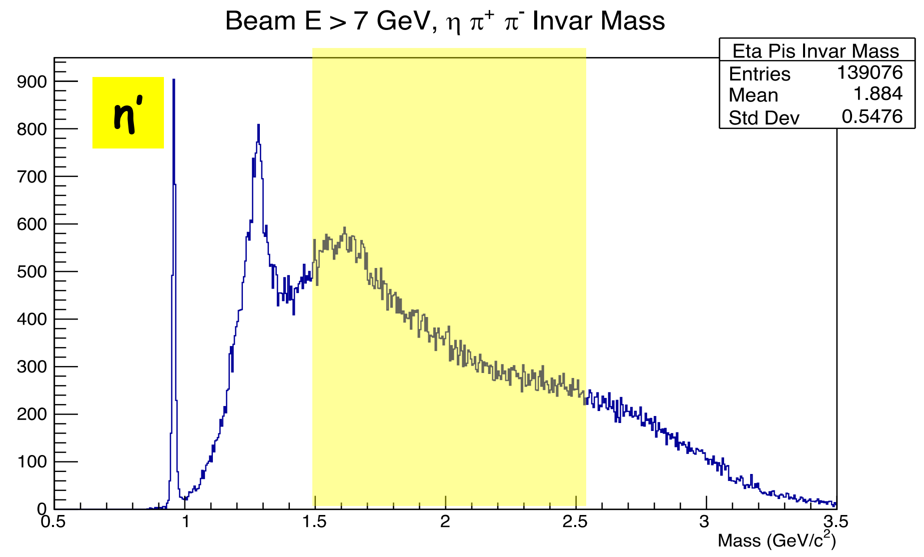
$$\eta_1 \to \eta\, f_2 \to \eta\,(2\pi)\ _{84\%}$$
$$\to \pi\, a_2 \to \pi\,(\eta\pi)\ _{15\%}$$

where both $\eta 2\pi^0$ and $\eta\,\pi^+\pi^-$ can be searched for signals.

As for the exotic hybrid meson candidate b_2

$$b_2 \to \eta\,\rho \to \eta\,(\pi^+\pi^-)\ _{100\%}$$

only the charged channel is useful since there is no $\rho \to 2\pi^0$.



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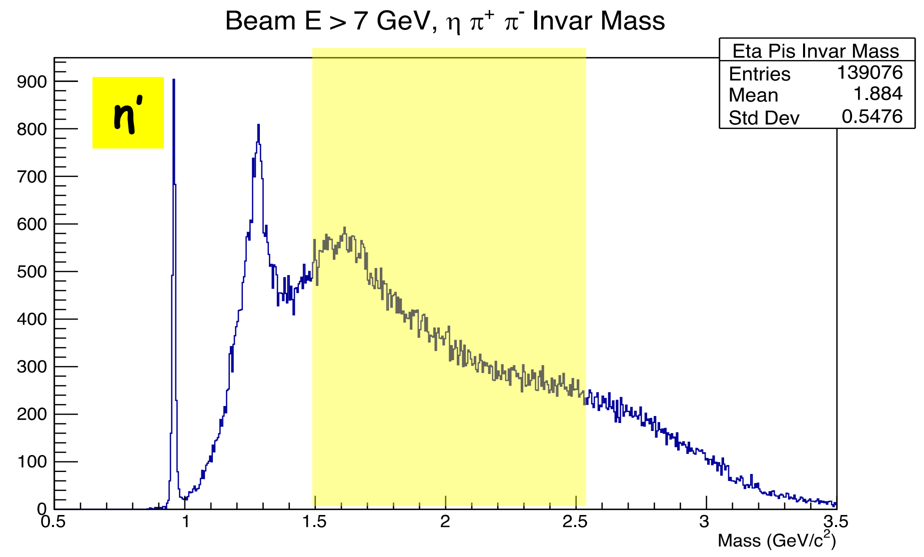
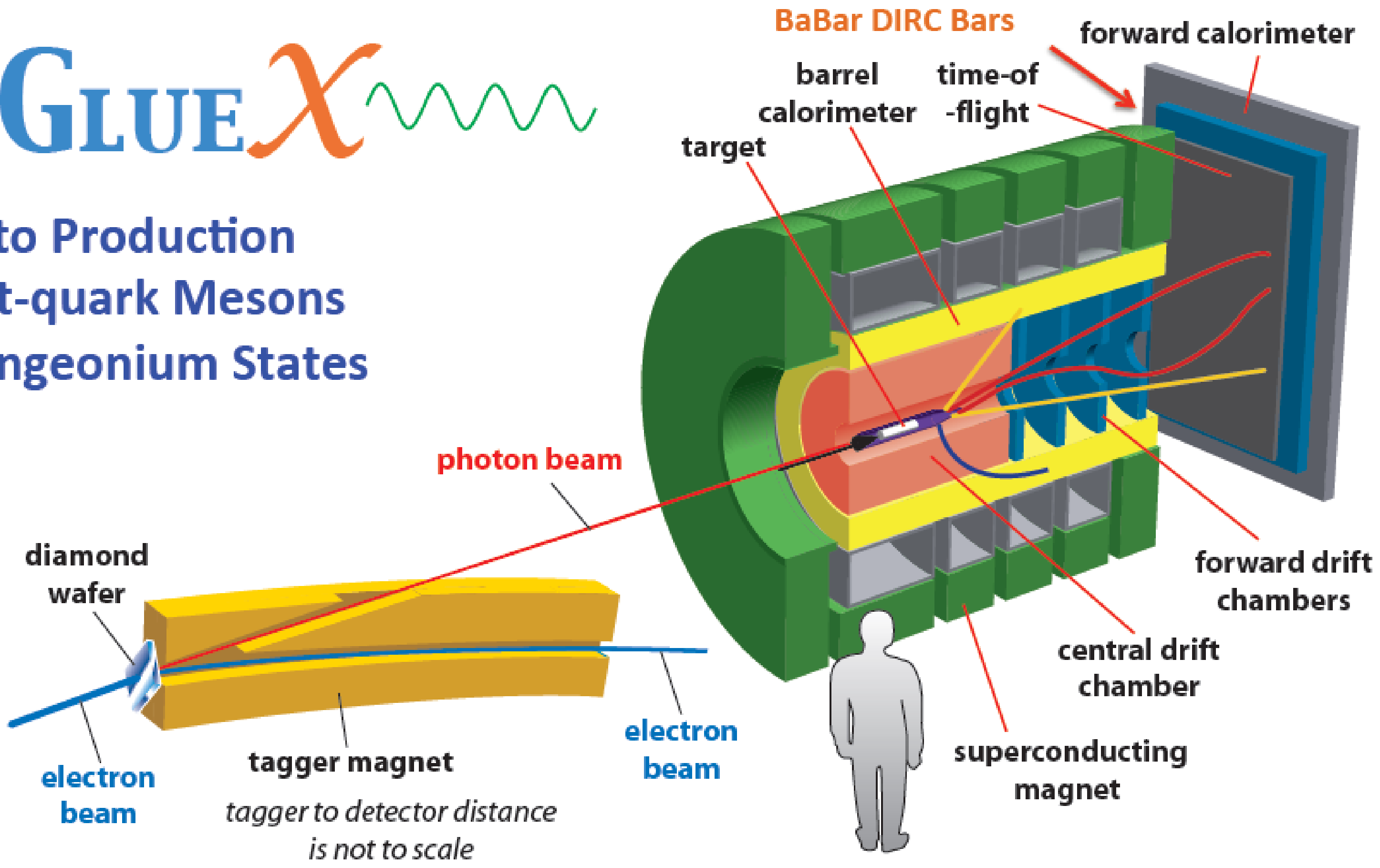


- Σ asymmetry studies of $\eta^{(\prime)}$ production have allowed us to develop cuts and study backgrounds while surveying higher masses.
- SDME studies of the vector mesons ρ, ω, and ϕ , as well as cross-section studies, are testing our acceptance corrections.
- The building blocks for nearly all the hybrid meson candidates on the previous slide have now been studied in GlueX.

The GlueX Experiment at Jefferson Lab

Photo Production
Light-quark Mesons
Strangeonium States



Salient features for the field of meson spectroscopy:

- Intense beam of 3-12 GeV photons of known energy
- 40% linear polarization in the coherent peak near 9 GeV.

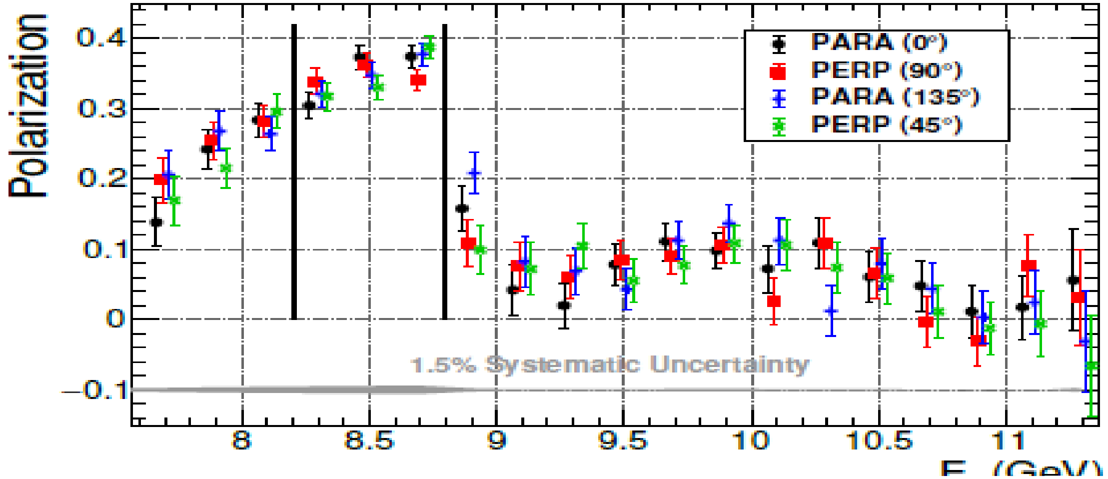
Sparse bubble chamber data from SLAC were all that existed for photons of this energy.

Polarimetry, Flux, and W = sqrt(s)

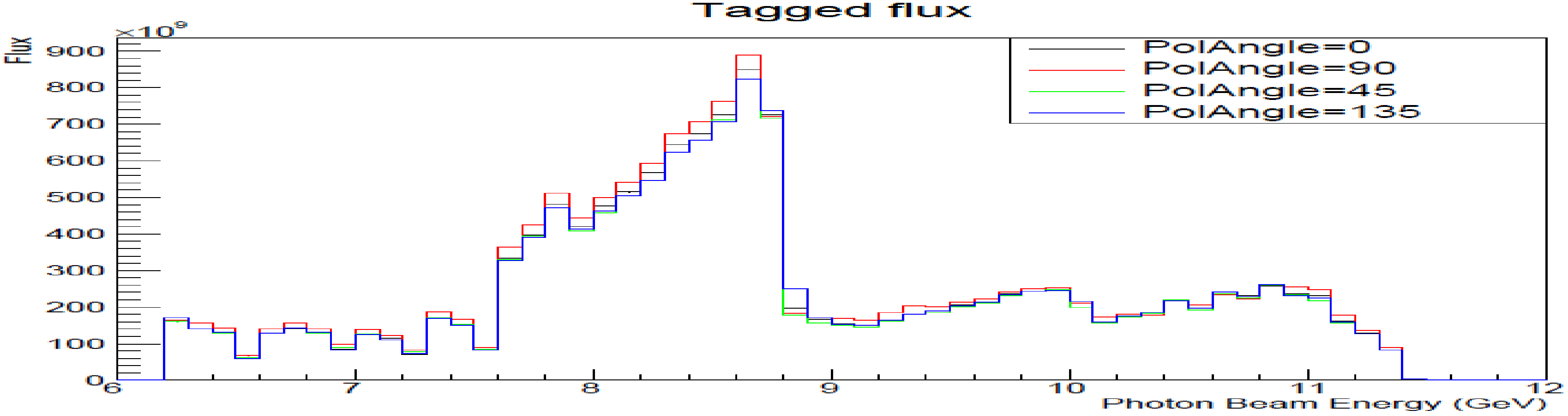
Using oriented diamond radiator, the peak polarization is near 40%.

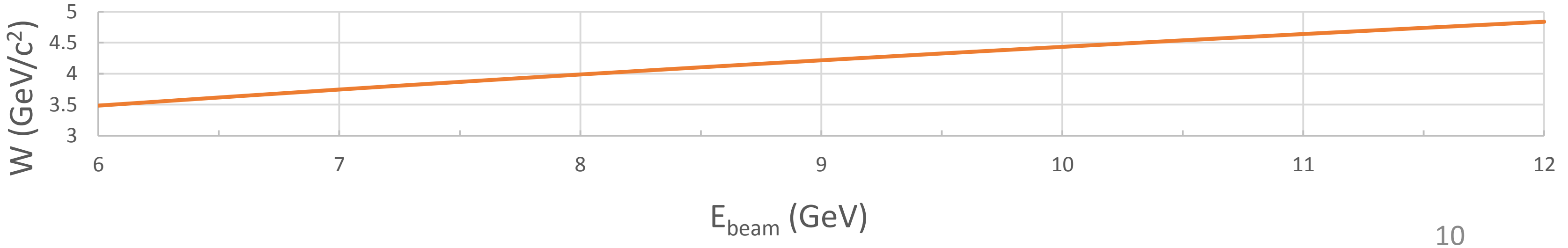
Precision beam polarimetry (+-1.5% uncertainty) is provided by theTriplet POLarmeter (TPOL):

NIM A867 (2017) 115-127 https://arxiv.org/abs/1703.07875

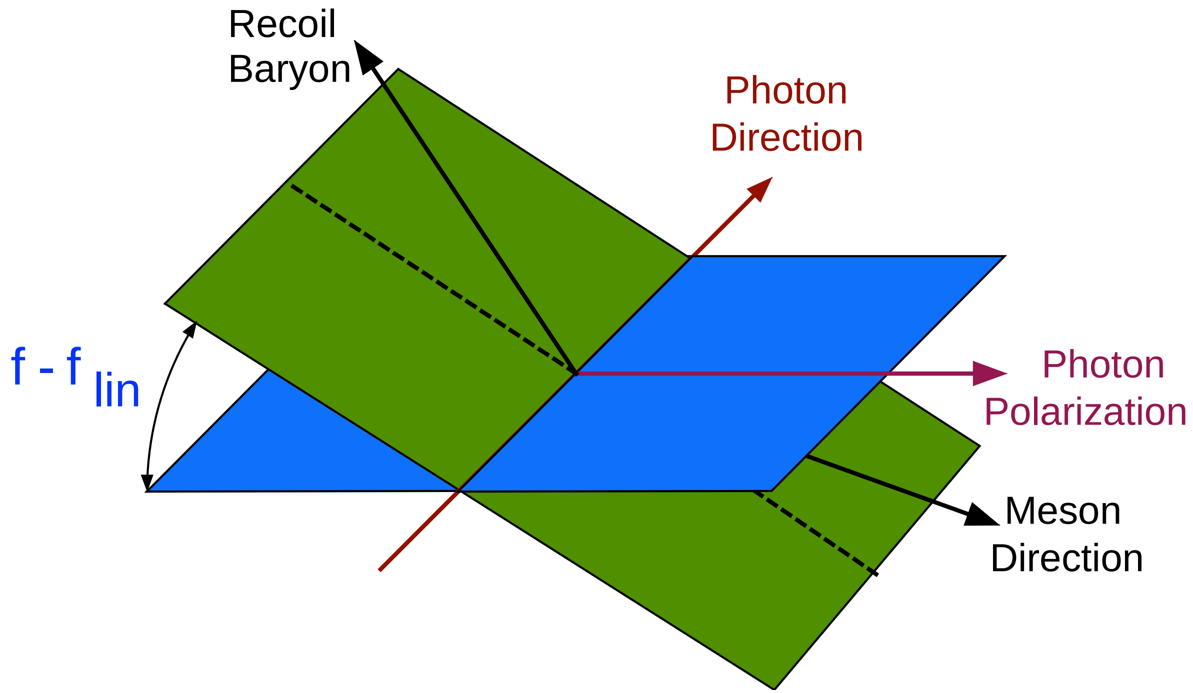


Flux also peaks near 8.8 GeV.





In the coherent peak,
W = sqrt(s) ~ 4 GeV/c^2, well above the baryon resonance region.



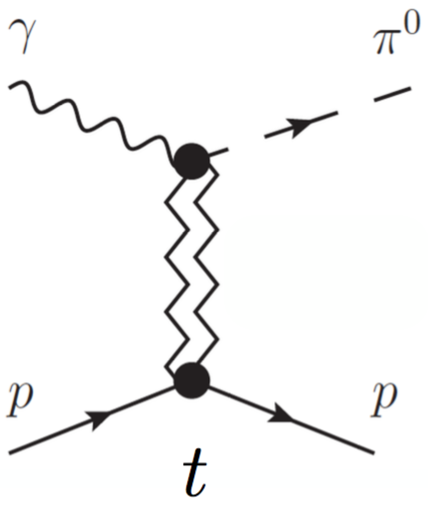
The Beam Asymmetry, Σ, for γ+p→p+PS

Tests the reaction mechanism for photo-production.

See also W. McGinley MENU 2019: https://registration.mcs.cmu.edu/event/1/contributions/145/

Beam Asymmetries: $\gamma + p \rightarrow p + \pi^0 / \eta^{(')}$

- Aids in understanding the reaction mechanism for photo-production of pseudo-scalar mesons.
- *"Production of the lightest multiplet of exotic mesons with $J^{PC} = 1^{-+}$ involves the same Regge exchanges that appear in the production of ordinary pseudoscalar mesons, like π^0, η, and η'."* https://arxiv.org/abs/1704.07684v2
- Understanding the production mechanisms will assist in building a hybrid PWA model to describe the data.
- Through Finite Energy Sum Rules, data at high energy described by exchange of meson Regge poles can constrain models at lower energy in the baryon resonance region. https://arxiv.org/abs/1708.07779



Exchange J^{PC}

1^{--} : ω, ρ

1^{+-} : b, h

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

Σ ~ 1 means dominance of vector (natural parity) exchange.

Σ ~ -1 means dominance of axial vector (unnatural parity) exchange

JPAC: Mathieu et al., PRD 92, 074013
https://arxiv.org/abs/1505.02321

Cancellation of Instrumental Asymmetries

With ϕ the angle of the meson production plane, and ϕ_s the angle in which the linear polarization lies, the ϕ dependent yield is given in terms of the cross section and the beam asymmetry, Σ:

$$Y_{pol}(\phi) = \sigma_0[1 - P\Sigma\cos\{2(\phi-\phi_s)\}]$$

In principle, for one ϕ_s setting we could fit $P\Sigma$. But there's usually a scale-type instrumental asymmetry of O(1)%, so in practice

$$Y_{pol}(\phi) = \sigma_0[1-P\Sigma\cos\{2(\phi-\phi_s)\}]\ A(\phi)$$

To avoid having to correct for $A(\phi)$, we combine measurements at <u>two</u> values of ϕ_s ,

for $\phi_s = 0^\circ$ (Parallel), $Y_{Para}(\phi) = \sigma_0[1 - P\Sigma\cos(2\phi)]\ A(\phi)$

for $\phi_s = 90^\circ$ (Perpendicular), $Y_{Perp}(\phi) = \sigma_0[1 + P\Sigma\cos(2\phi)]\ A(\phi)$

Then

$$\frac{Y_{perp}(\phi) - Y_{Para}(\phi)}{Y_{perp}(\phi) - Y_{Para}(\phi)} = P\Sigma\cos(2\phi)$$

which can be fitted to obtain $P\Sigma$.

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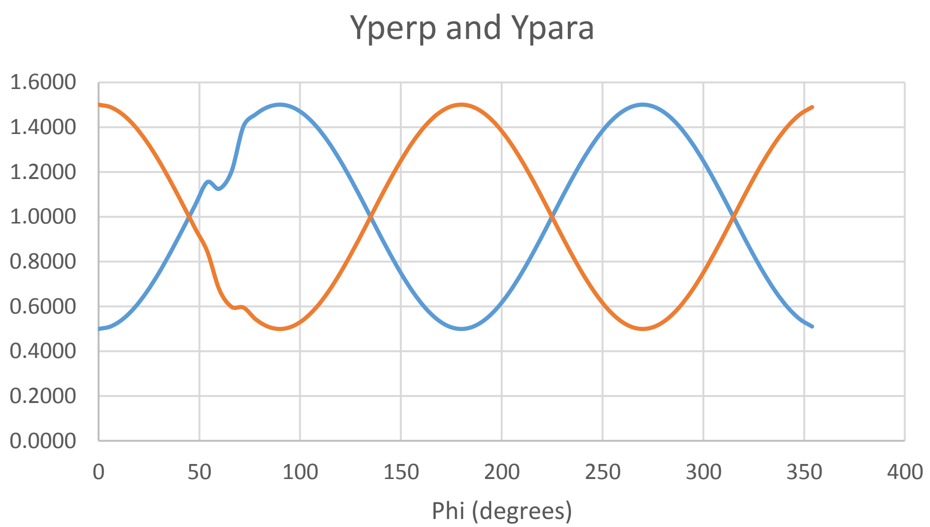
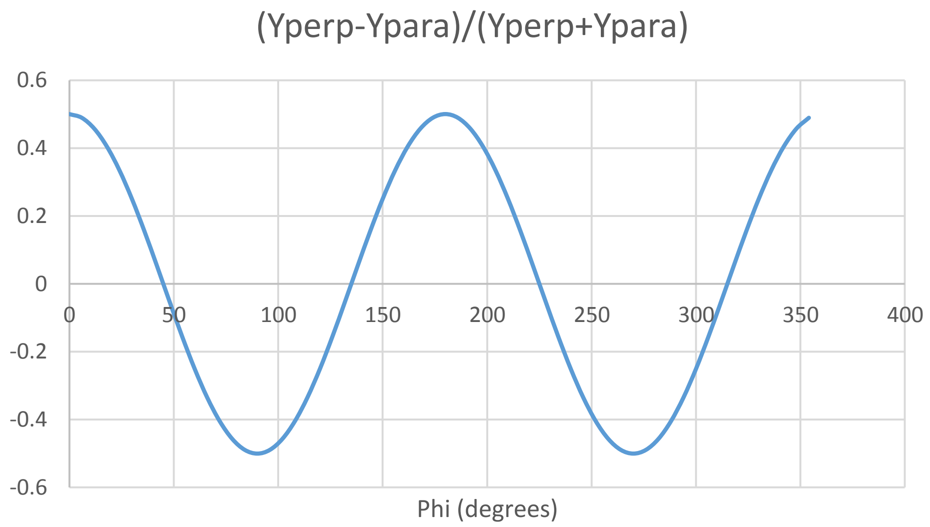
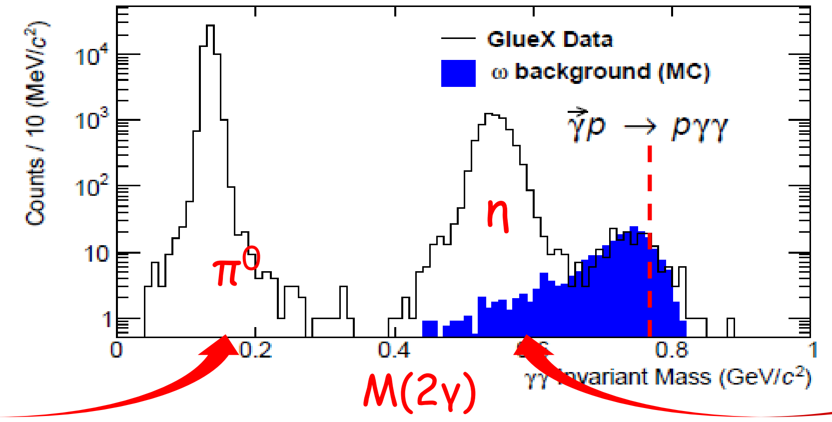




As long as the inefficiency doesn't change with time, it cancels exactly.

How the Beam Asymmetry is Measured

π^0 region:
negligible bkg from missing a bachelor photon from $\omega \rightarrow \pi^0 \gamma_B$.



η region:
Small bkg from missing a photon from the π^0 in $\omega \rightarrow \pi^0 \gamma_B$.

How the Beam Asymmetry is Measured

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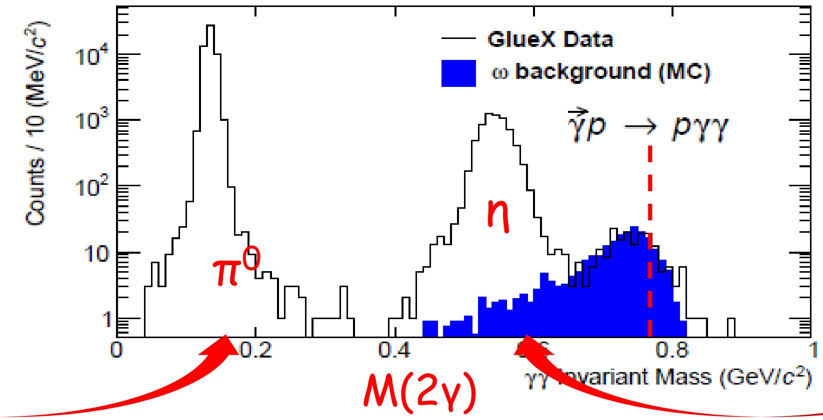
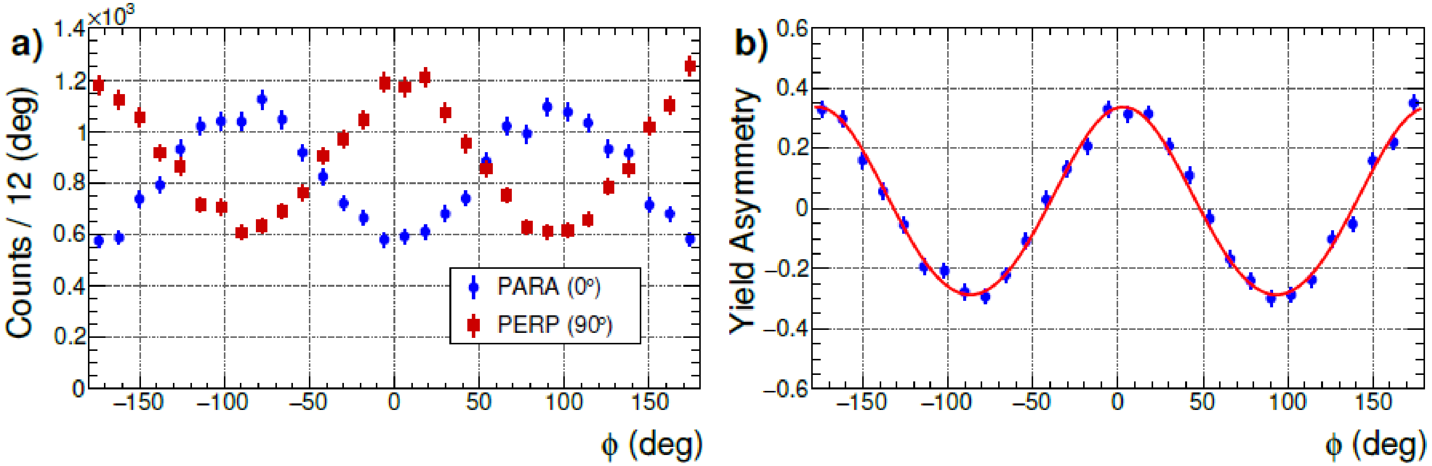


η region:
Small bkg from missing a photon from the π^0 in $\omega \to \pi^0 \gamma_B$.

$Y_{perp}(\phi)$

And

$Y_{Para}(\phi)$



$$\frac{Y_{perp}(\phi) - Y_{Para}(\phi)}{Y_{perp}(\phi) - Y_{Para}(\phi)}$$

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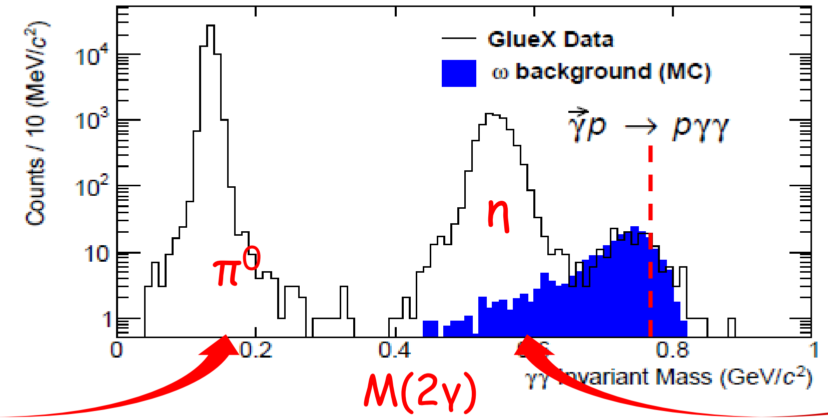

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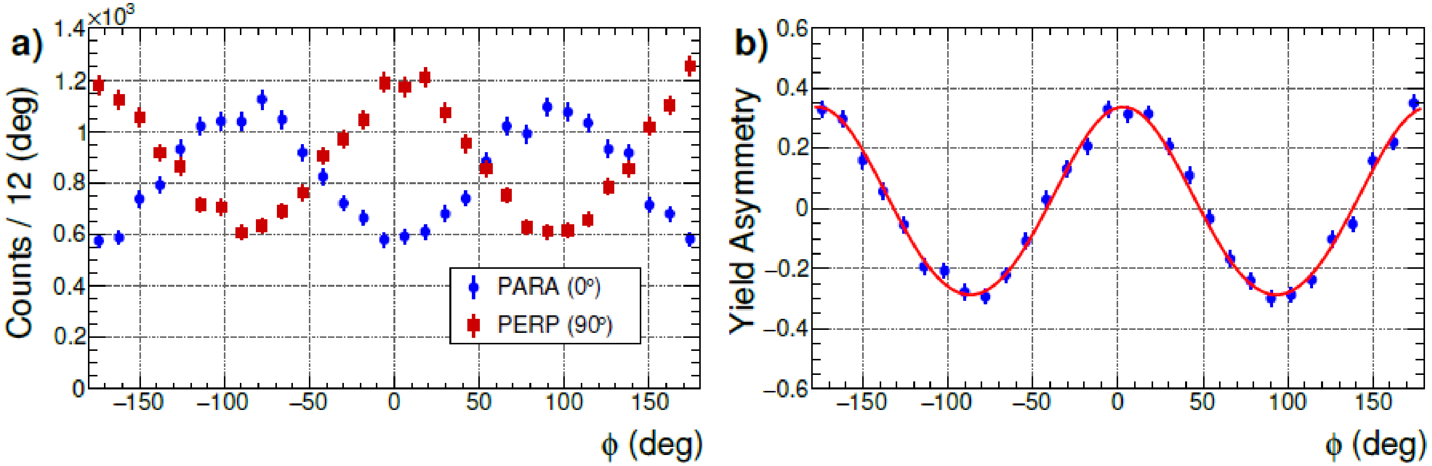


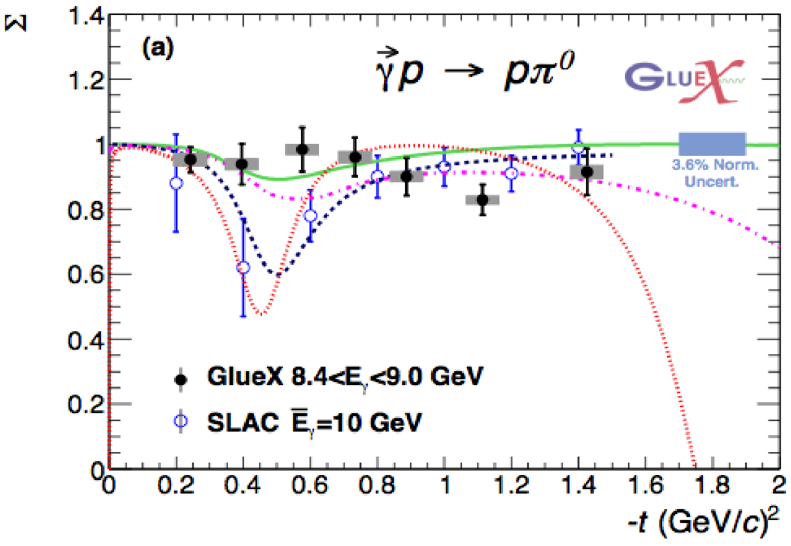
$$\frac{Y_{perp}(\phi) - Y_{Para}(\phi)}{Y_{perp}(\phi) - Y_{Para}(\phi)}$$

In practice, we fit Σ allowing for $P_{perp} \neq P_{para}$ as well as a small azimuthal offset between ϕ of the detector and ϕ_s of the diamond.

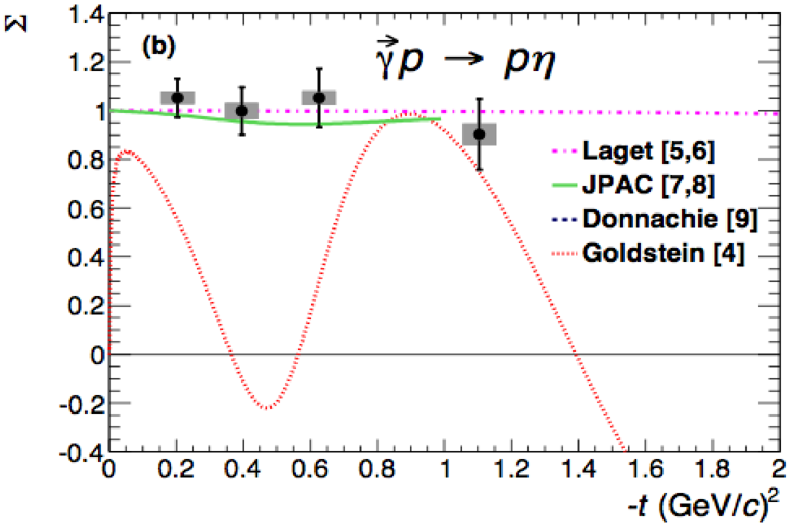
$$\frac{Y_{perp}(\phi) - Y_{Para}(\phi)}{Y_{perp}(\phi) - Y_{Para}(\phi)} = \frac{P_{ave}\Sigma\cos[2(\phi-\phi_0)]}{1 + \Delta P\, \Sigma\cos[2(\phi-\phi_0)]/2}$$

Beam Asymmetries from Commissioning Run: $\gamma + p \rightarrow p + \pi^0 / \eta$

Asymmetry Σ



Asymmetry Σ



Our first GlueX physics publication!
PRC 95, 042201 (2017)
https://arxiv.org/abs/1701.08123

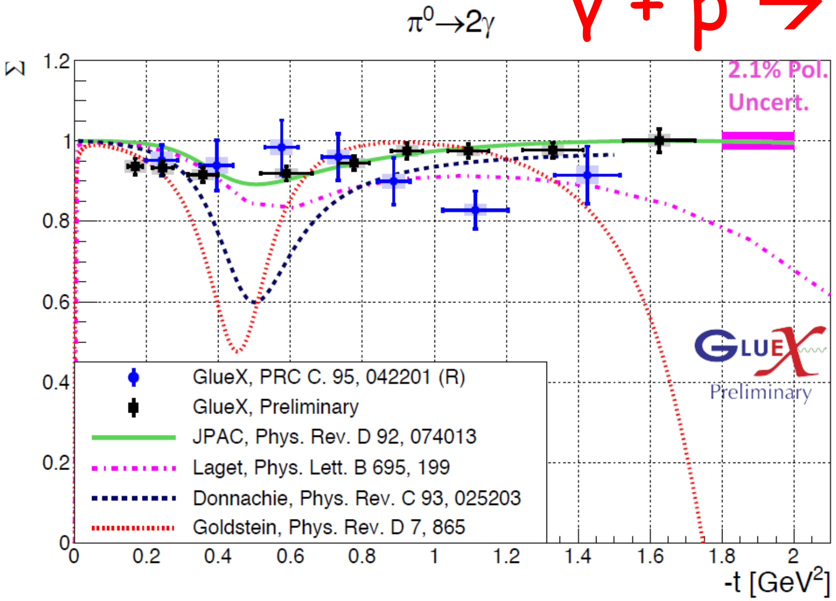
Sabbatical project of Zhenyu "Jane" Zhang, Wuhan U.

Exclusive, very low bkg measurements of γ+p→p+2γ:

- Σ ≈ 1 indicates vector exchange dominates this beam energy and –t range.
- The η measurement was the first in this beam energy range.

Updated Beam Asymmetries with 8x More Data: $\gamma + p \rightarrow p + \pi^0 / \eta$

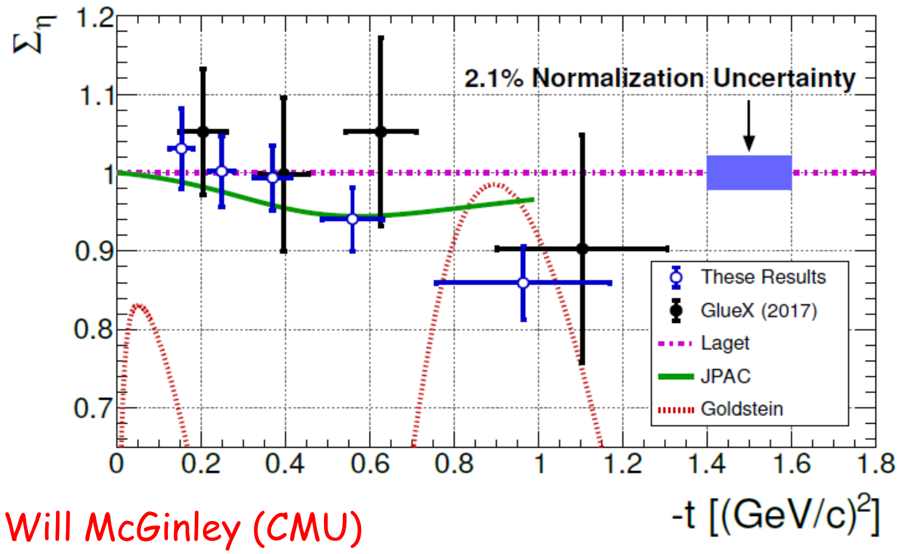
Asymmetry Σ



π^0 results have been updated (in black).

High statistics π^0 data allowed us to explore fit systematics at the sub-percent level.

Asymmetry Σ



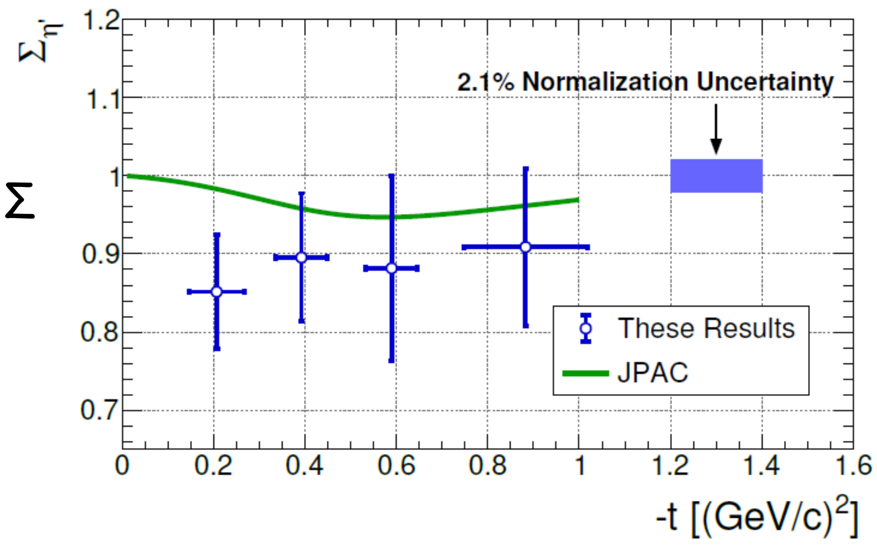
η results have been updated (in blue).

For both π^0 and η, these much more precise results elucidate the higher order contributions from axial vector meson exchange such as the $b_1(1235)$.

Paper draft under internal review.

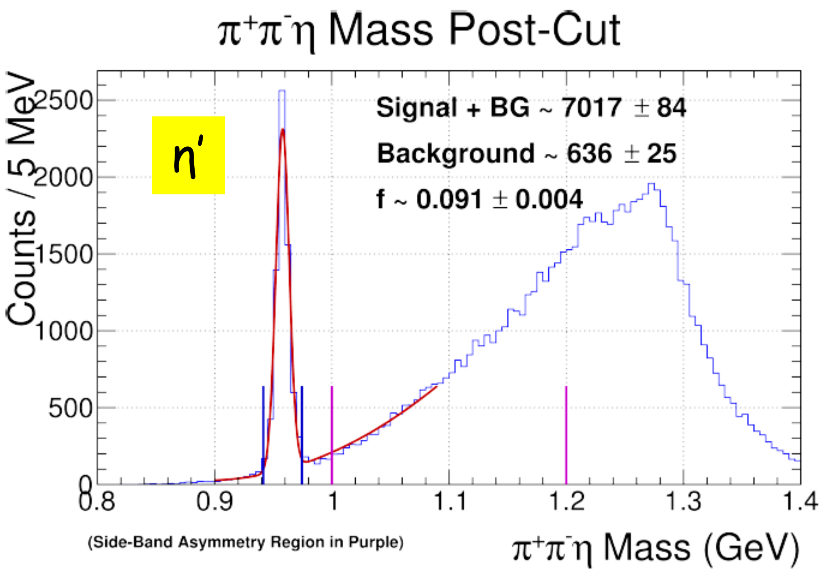
Thesis work of Will McGinley (CMU)

A New Beam Asymmetry for GlueX: $\gamma + p \rightarrow p + \eta'$



- First beam asymmetry measurements of the η′ in this energy range.
- Uses our cleanest, highest yield η′ channel: $\eta' \rightarrow \eta\,\pi^+\pi^- \rightarrow 2\gamma\,\pi^+\pi^-$
- All 5 final state particles (including the recoil proton) are detected with an acceptance of ~10%.

With these limited η′ statistics, all we can say with confidence is that the η′ results are dominated by vector meson exchange.



Thesis topic of Tegan Beattie (U. Regina)

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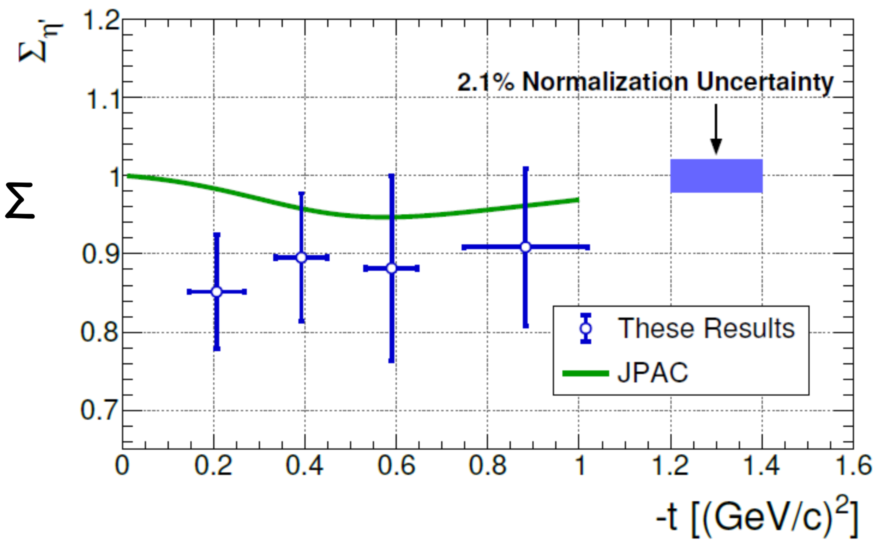

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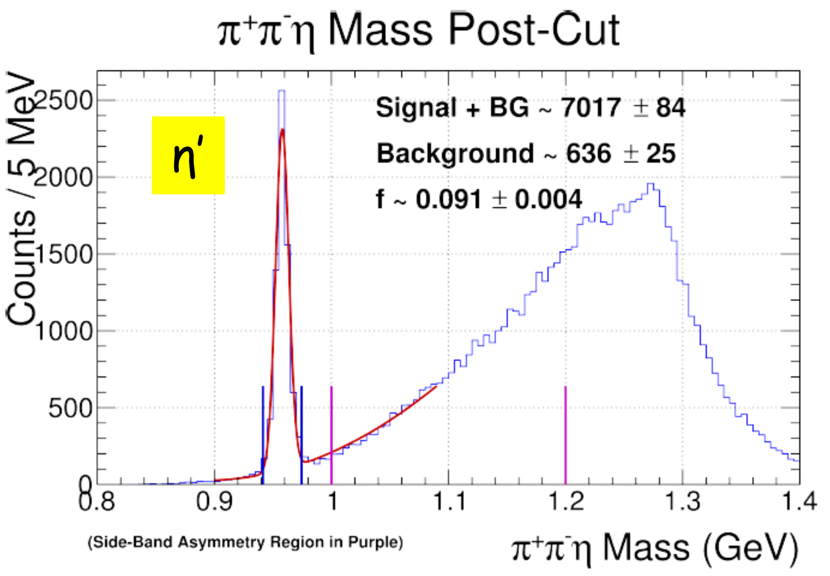
With these limited η′ statistics, all we can say with confidence is that the η′ results are dominated by vector meson exchange.

The ratio of η′/η asymmetries should be exactly 1 without hidden strangeness (eg, ϕ exchange). With expected levels of N→Nϕ , the ratio should be less 1.01 . https://arxiv.org/abs/1704.07684



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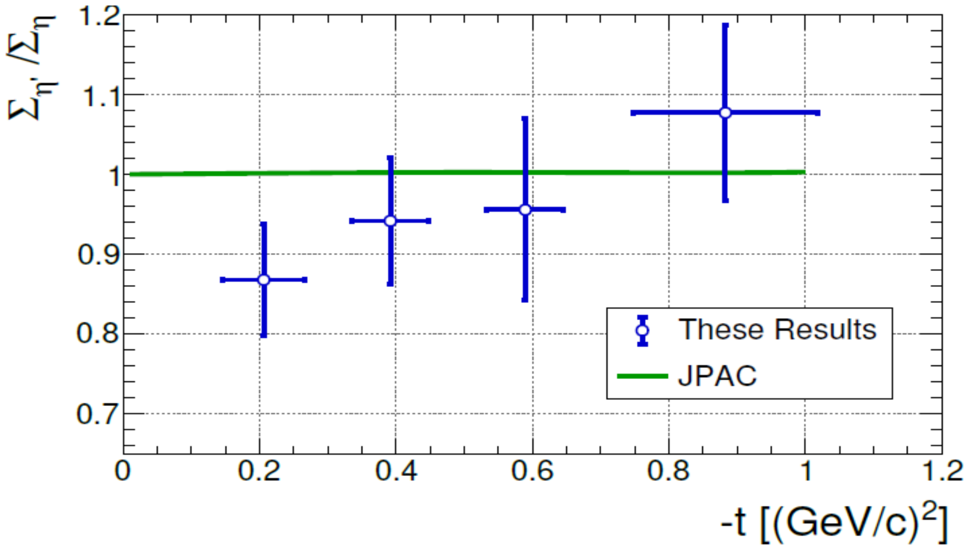
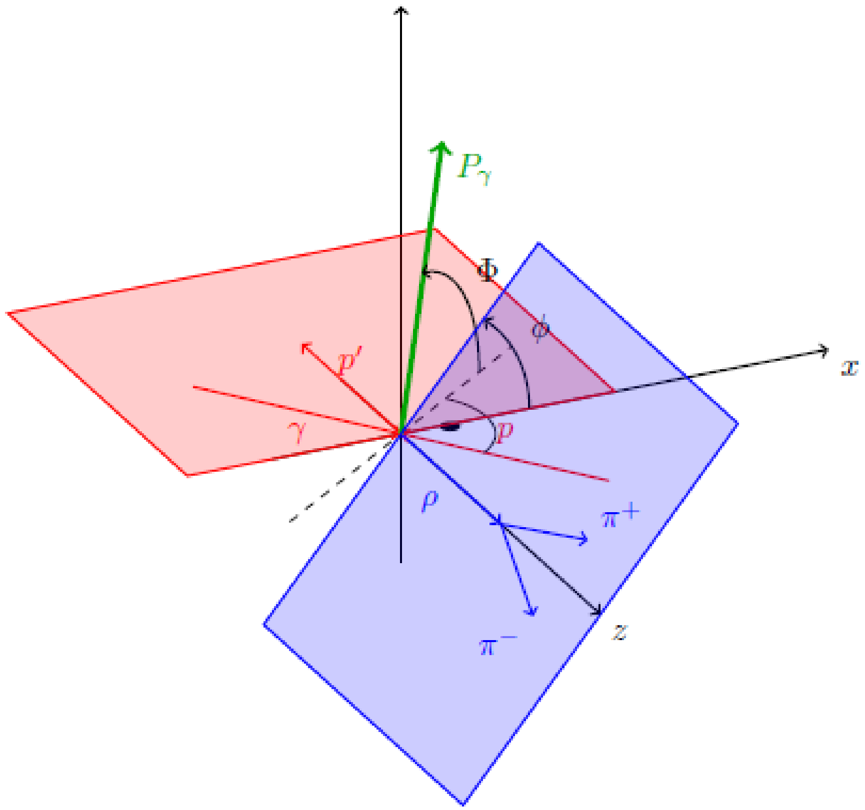


The 4x larger 2018 dataset would allow a more convincing check that η and η′ photoproduction are similar as expected.



Spin Density Matrix Elements (SDME's) for Vector Meson Photo-production

Also tests the reaction mechanism for photo-production, but now including the richer information provided by decay of a vector meson.

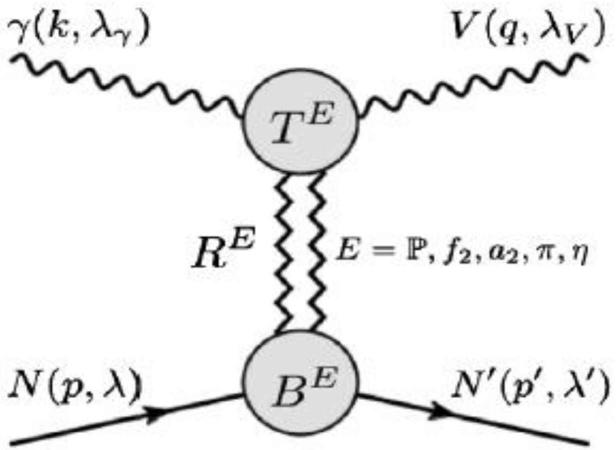
See also A. Austregesilo MENU 2019: https://registration.mcs.cmu.edu/event/1/contributions/41/

JPAC SDME Model

In the JPAC Regge model of vector meson photo-production, the leading trajectories are

$I^{G\eta\tau}J^{PC}$	$I^{G\eta\tau}J^{PC}$	$I^{G\eta\tau}J^{PC}$
a_2: $1^{-++}2^{++}$	π: $1^{--+}0^{-+}$	a_1: $1^{---}1^{++}$
f_2: $0^{+++}2^{++}$	η: $0^{+-+}0^{-+}$	f_1: $0^{+--}1^{++}$

- Natural parity exchange from the Pomeron is also included.
- Meson-nucleon and meson radiative decay widths are taken from literature or estimated.
- SLAC data at 9.3 GeV are used for constraints, the ρ data having significantly smaller statistical errors than the others.



PRD 97, 094003 (2018)
https://arxiv.org/abs/1802.09403

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$a_2:\ 1^{-++}2^{++}$	$\pi:\ 1^{--+}0^{-+}$	$a_1:1^{---}1^{++}$
$f_2:\ 0^{+++}2^{++}$	$\eta:\ 0^{+-+}0^{-+}$	$f_1:\ 0^{+--}1^{++}$

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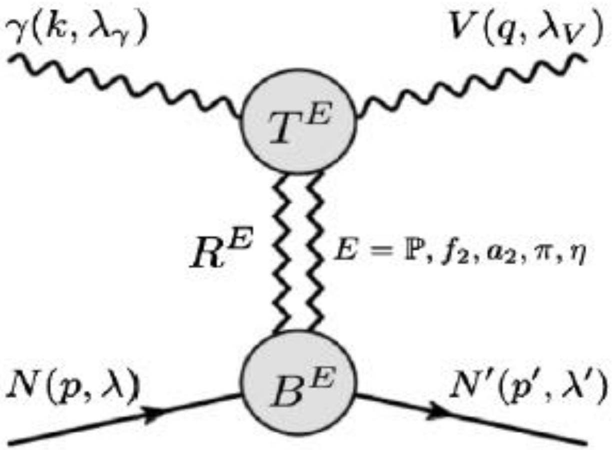

PRD 97, 094003 (2018)
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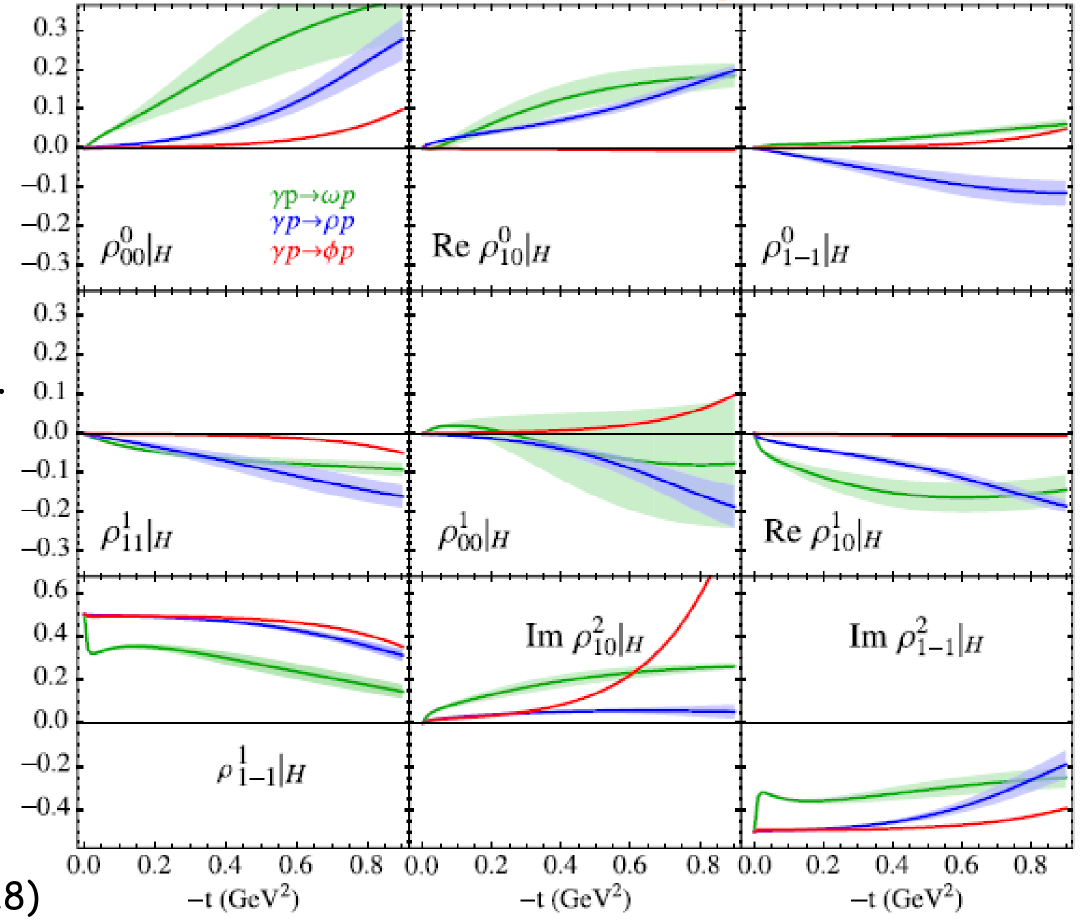
Although these vector mesons have the same J^{PC}, the predicted SDME's are quite different in this example for E_γ = 8.5 GeV:

ω ρ ϕ



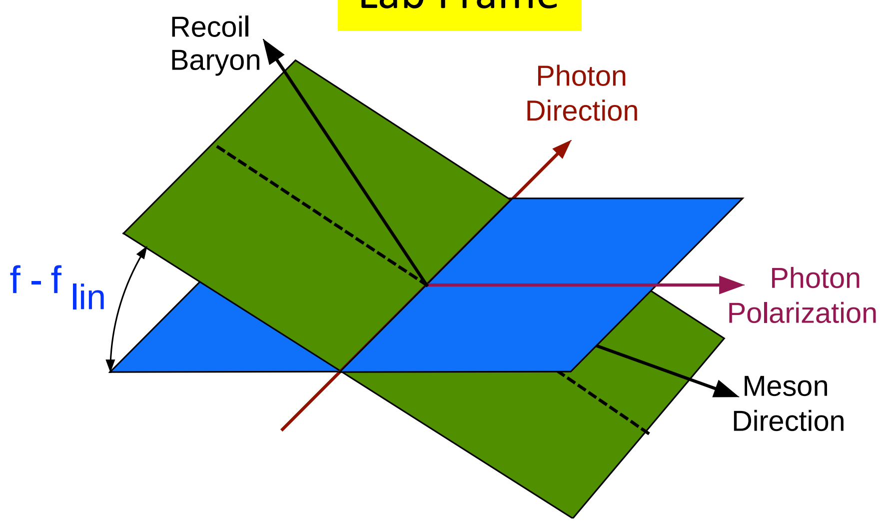
Coordinate Systems

In the Σ asymmetry slides, we saw the beam spin asymmetry was extracted from the yield variation proportional to $\cos[2(\phi-\phi_s)]$ where

- ϕ is the meson production plane, and
- ϕ_s is the polarization plane.

The decay contains no information for spin 0.

Lab Frame



Coordinate Systems

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- ϕ is the meson production plane, and
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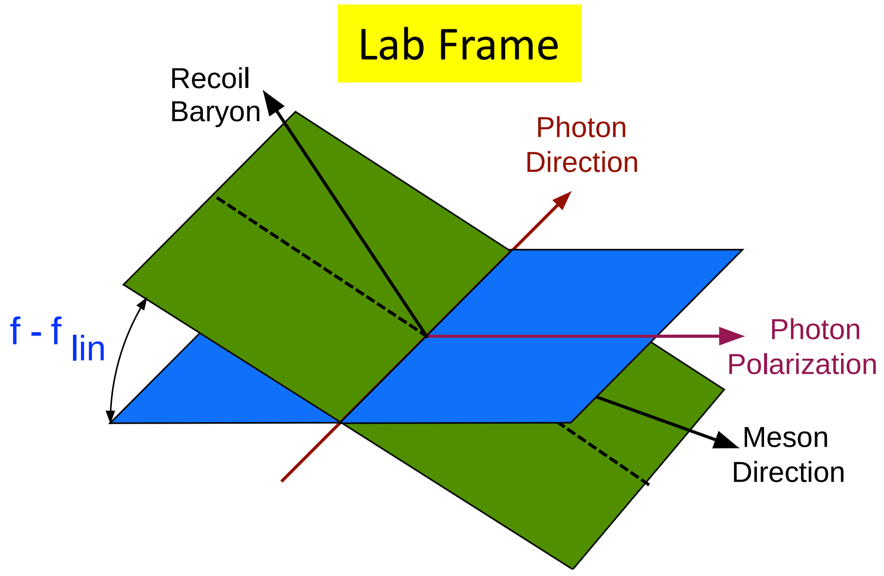
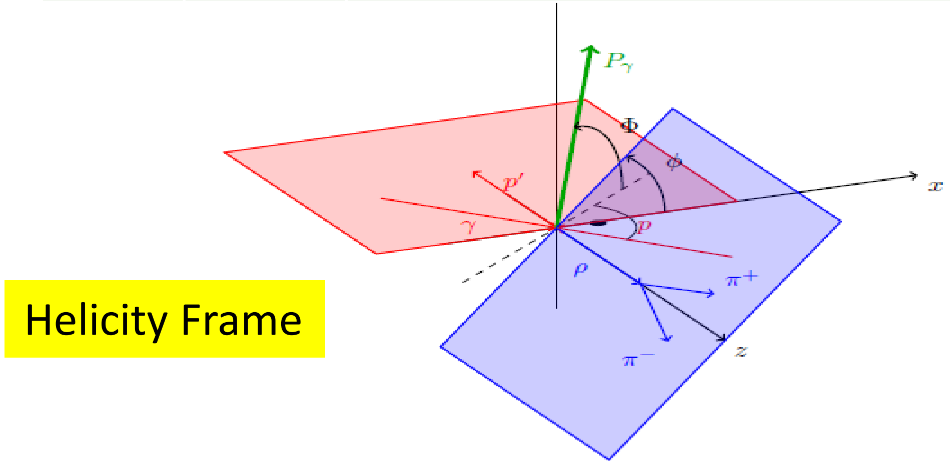


Because the decay distribution of spin 1 particles depends on the final polarization, it makes sense to transfer into the helicity frame. There are two additional decay angles and some potentially confusing nomenclature overlaps:

Σ	SDME's	Description
ϕ		Meson production plane
ϕ_s		Linear Polarization plane
ϕ - ϕ_s	Φ	Difference between production and polarization planes.
---	ϕ	Azimuthal decay angle in helicity frame
---	θ	Polar decay angle in helicity frame



How the SDME's are Measured: ω example

The SDMEs describe the polarization of the vector meson.
The angular distribution for the vector decay in the helicity frame is

$$\frac{dN}{d\cos\theta\, d\phi} \equiv W(\cos\theta, \phi)$$

where

$$W(\cos\theta,\phi) = W^0(\cos\theta,\phi) + \sum_{i=1}^{3} \mathbf{P}_\gamma^i W^i(\cos\theta,\phi)$$

Assuming only linear polarization,

$$P_\gamma^{vec} = P_\gamma\,(-\cos 2\Phi - \sin 2\Phi,\, 0)$$

Then for the hadronic ω decay:

$$\begin{aligned}
W_h^0(\cos\theta,\phi,\rho^0) &= \frac{3}{4\pi}\left[\frac{1}{2}\left(1-\rho_{00}^0\right) + \frac{1}{2}\left(3\rho_{00}^0 - 1\right)\cos^2\theta \right. \\
&\quad \left. -\sqrt{2}\,\mathrm{Re}\rho_{10}^0 \sin 2\theta \cos\phi - \rho_{1-1}^0 \sin^2\theta \cos 2\phi\right] \\
W_h^1(\cos\theta,\phi,\rho^1) &= \frac{3}{4\pi}\left[\rho_{11}^1 \sin^2\theta + \rho_{00}^1 \cos^2\theta - \sqrt{2}\,\mathrm{Re}\rho_{10}^1 \sin 2\theta \cos\phi \right. \\
&\quad \left. -\rho_{1-1}^1 \sin^2\theta \cos 2\phi\right] \\
W_h^2(\cos\theta,\phi,\rho^2) &= \frac{3}{4\pi}\left[\sqrt{2}\,\mathrm{Im}\rho_{10}^2 \sin 2\theta \sin\phi + \mathrm{Im}\rho_{1-1}^2 \sin^2\theta \sin 2\phi\right]
\end{aligned}$$

There are 9 linearly independent parameters; 6 require beam polarization.

How the SDME's are Measured: ω example

M. Staib, PhD thesis, Sept 2017, CMU

Plots like this for each bin in -t.

The SDMEs describe the polarization of the vector meson.
The angular distribution for the vector decay in the helicity frame is

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where

$$W(\cos\theta, \phi) = W^0(\cos\theta, \phi) + \sum_{i=1}^{3} \mathbf{P}_\gamma^i W^i(\cos\theta, \phi)$$

Assuming only linear polarization,

$$P\gamma^{vec} = P\gamma\,(-\cos 2\Phi - \sin 2\Phi,\ 0)$$

Then for the hadronic ω decay:

Although there is cancellation of some instrumental asymmetries when we combine data for Para and Perp, the SDME's are a bigger challenge than the Σ asymmetry because acceptance corrections are needed in ϕ and θ .

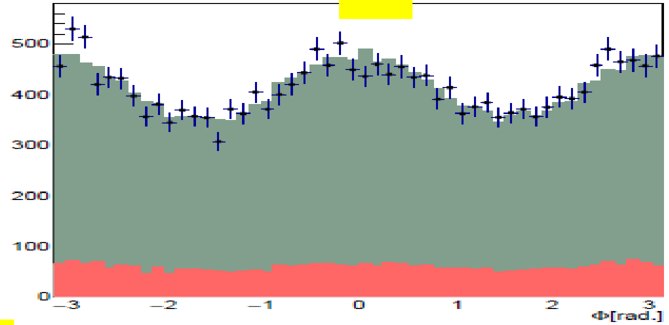
$$W_h^0(\cos\theta, \phi, \rho^0) = \frac{3}{4\pi}\left[\frac{1}{2}(1-\rho^0_{00}) + \frac{1}{2}(3\rho^0_{00}-1)\cos^2\theta - \sqrt{2}\,\mathrm{Re}\rho^0_{10}\sin 2\theta\cos\phi - \rho^0_{1-1}\sin^2\theta\cos 2\phi\right]$$

$$W_h^1(\cos\theta, \phi, \rho^1) = \frac{3}{4\pi}\left[\rho^1_{11}\sin^2\theta + \rho^1_{00}\cos^2\theta - \sqrt{2}\,\mathrm{Re}\rho^1_{10}\sin 2\theta\cos\phi - \rho^1_{1-1}\sin^2\theta\cos 2\phi\right]$$

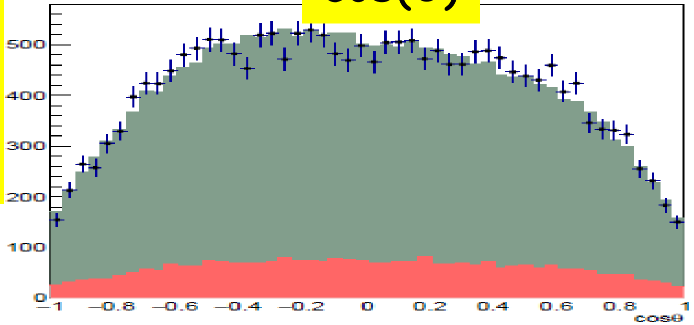
$$W_h^2(\cos\theta, \phi, \rho^2) = \frac{3}{4\pi}\left[\sqrt{2}\,\mathrm{Im}\rho^2_{10}\sin 2\theta\sin\phi + \mathrm{Im}\rho^2_{1-1}\sin^2\theta\sin 2\phi\right]$$

There are 9 linearly independent parameters; 6 require beam polarization.

Φ

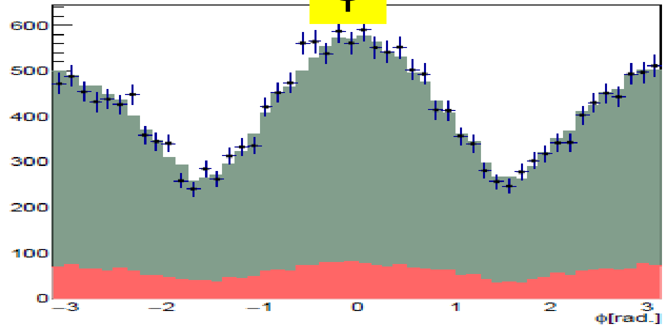


cos(θ)



Fit quality is Good!

ϕ



Parity Asymmetry

The parity asymmetry has a similar physical interpretation to Σ:

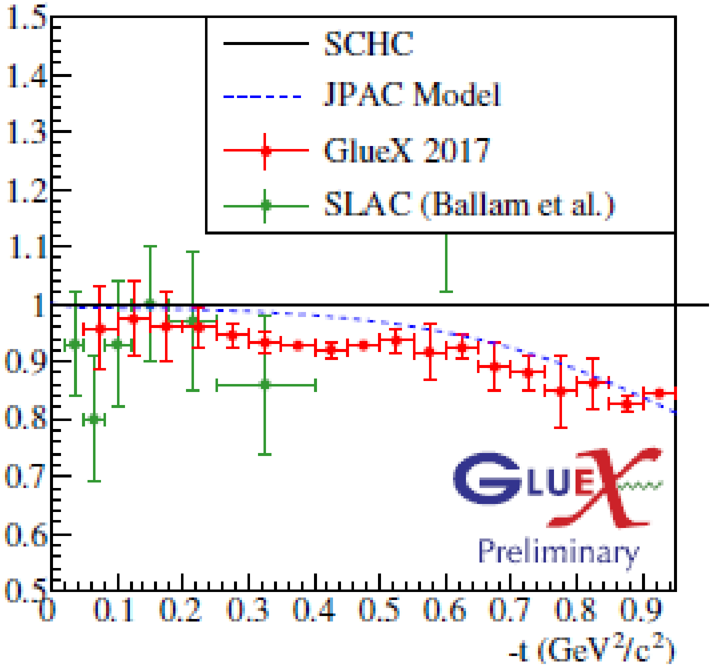
$$P_\sigma = \frac{\sigma^N - \sigma^U}{\sigma^N + \sigma^U} = 2\rho^1_{1-1} - \rho^1_{00}$$

For the ρ, it will be particularly useful to transform to linear combinations which are Natural or Unnatural. (next slide)

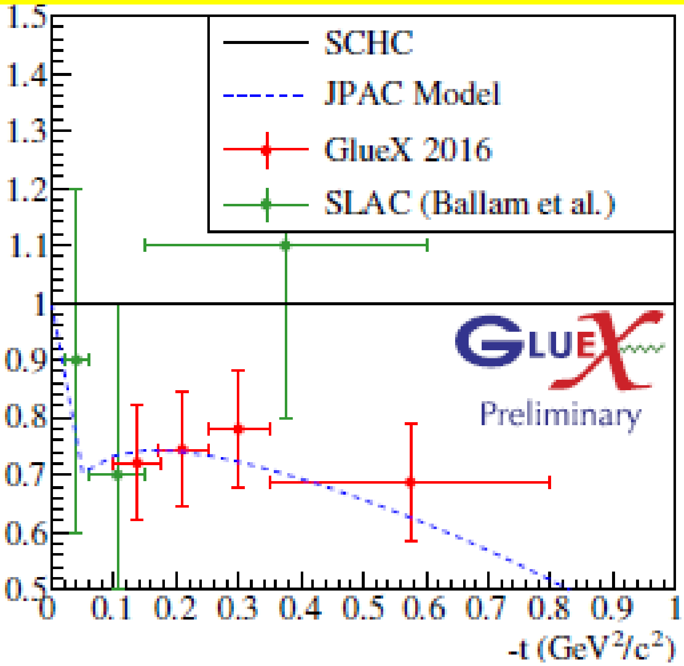
$$\rho^{N,U}_{ik} = \frac{1}{2}(\rho^0_{ik} \mp (-1)^i \rho^1_{-ik})$$

Schilling *et al.* [Nucl. Phy. B, 15 (1970) 397]

ρ: Natural parity dominates for the ρ at low −t.



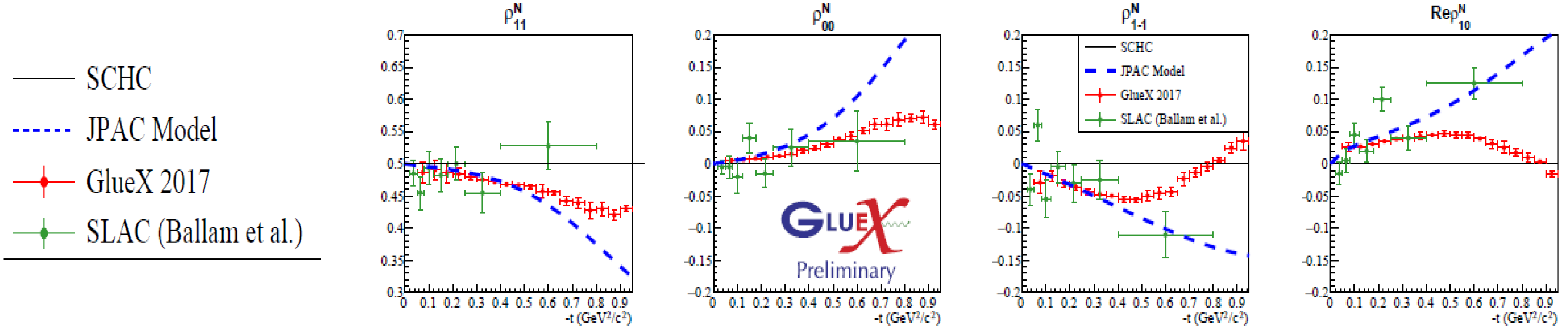
ω: Unnatural parity exchange is significant even at low −t for the ω .

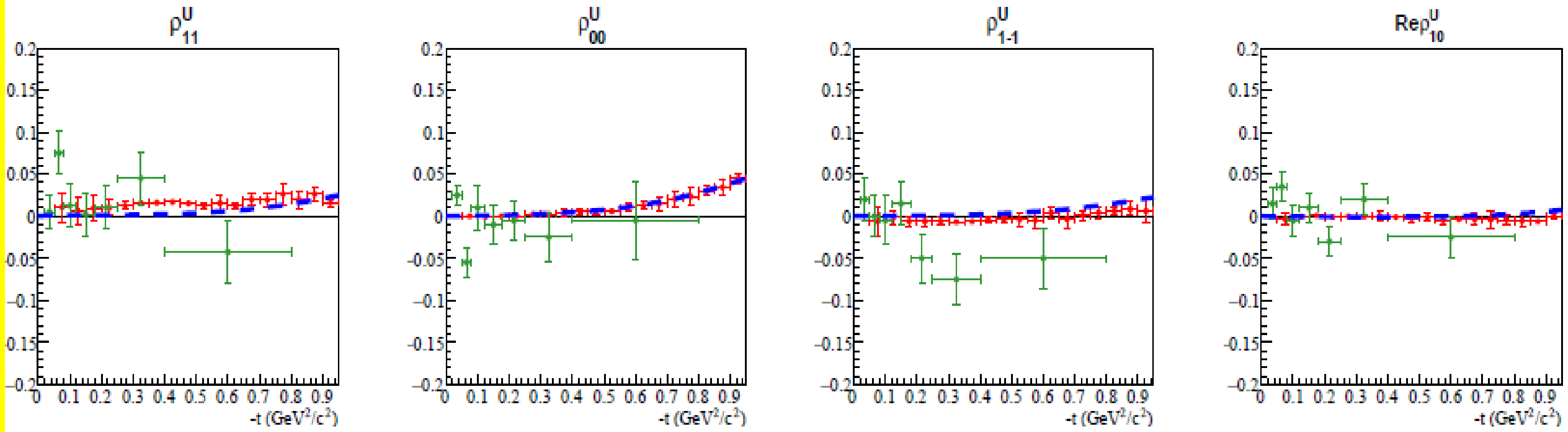


This unnatural parity exchange may be from π^0 exchange due in part to the large BR for $\omega \to \pi^0\gamma$.

Natural and Unnatural Projections for the ρ

For the ρ, all the natural exchange terms (top) are larger than the unnatural exchange terms (bottom).





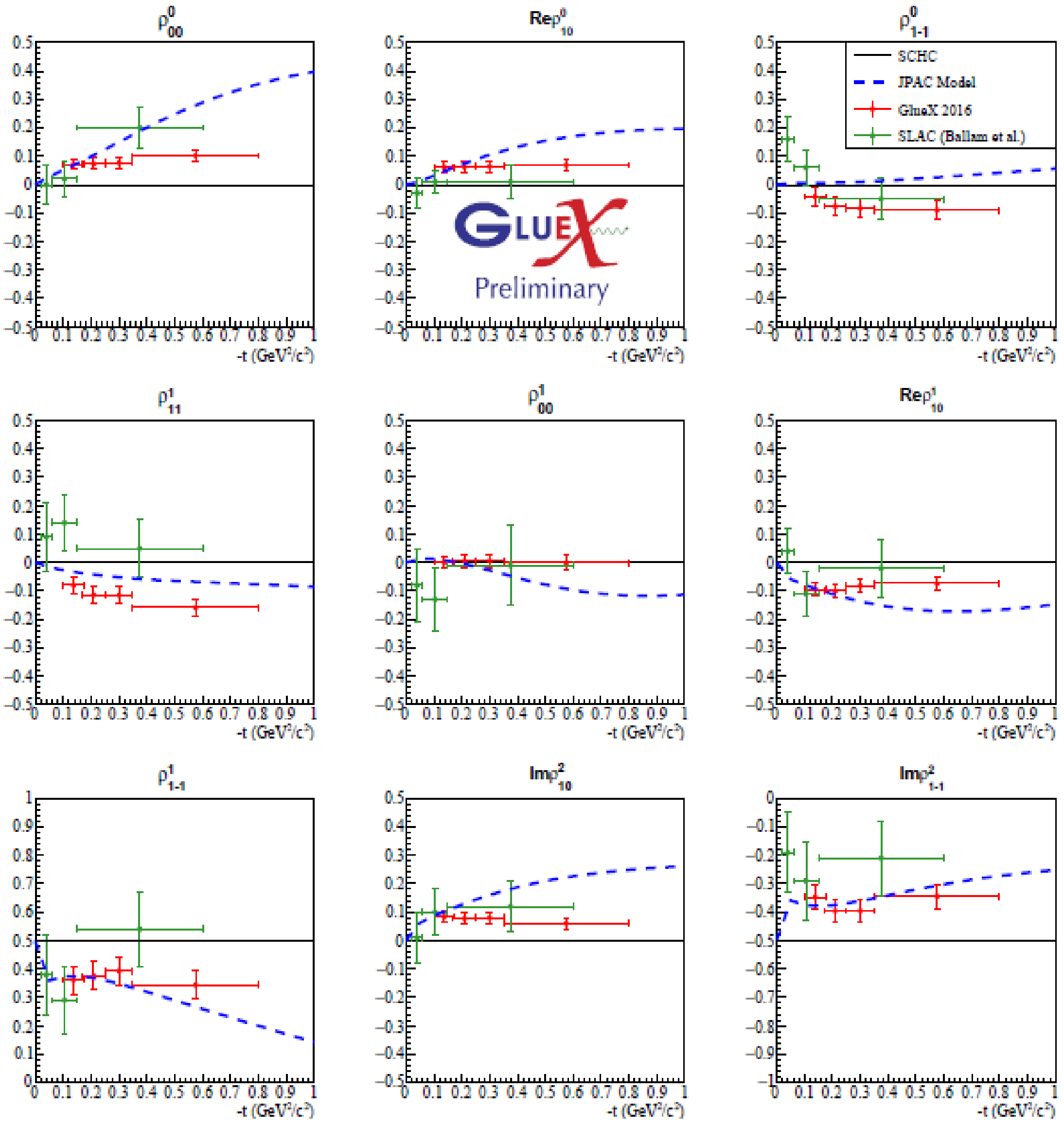
- SCHC only works in -t → 0 limit.
- GlueX ρ data have enormously improved statistics.
- JPAC model works fairly well below -t ~ 0.5 .
- Even natural exchange has unexpected behavior at -t > 0.5

JPAC Model vs GlueX Data for ω

For the ω, on the right are the regular SDME's
(ie not the Natural and Unnatural linear combinations):

SCHC
JPAC Model
GlueX 2016 only
SLAC (Ballam et al.)

- SCHC only works in –t →0 limit.
- GlueX ω data have significantly improved statistics
- JPAC model agreement with preliminary data is only qualitative.
- No breakdown of relative contributions in JPAC paper, but earlier OTL model suggests ω results are sensitive to π^0 vs Pomeron



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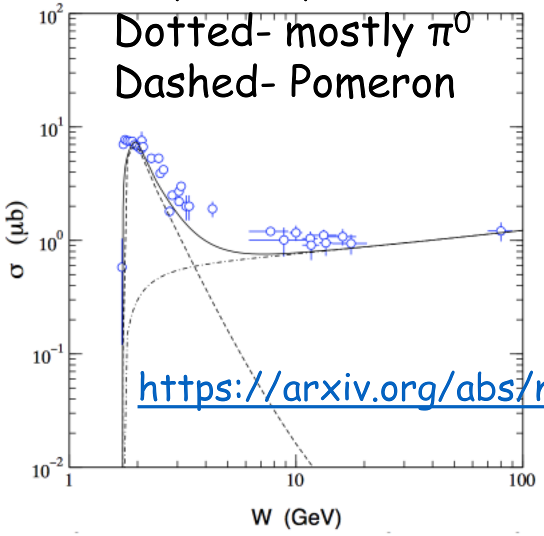
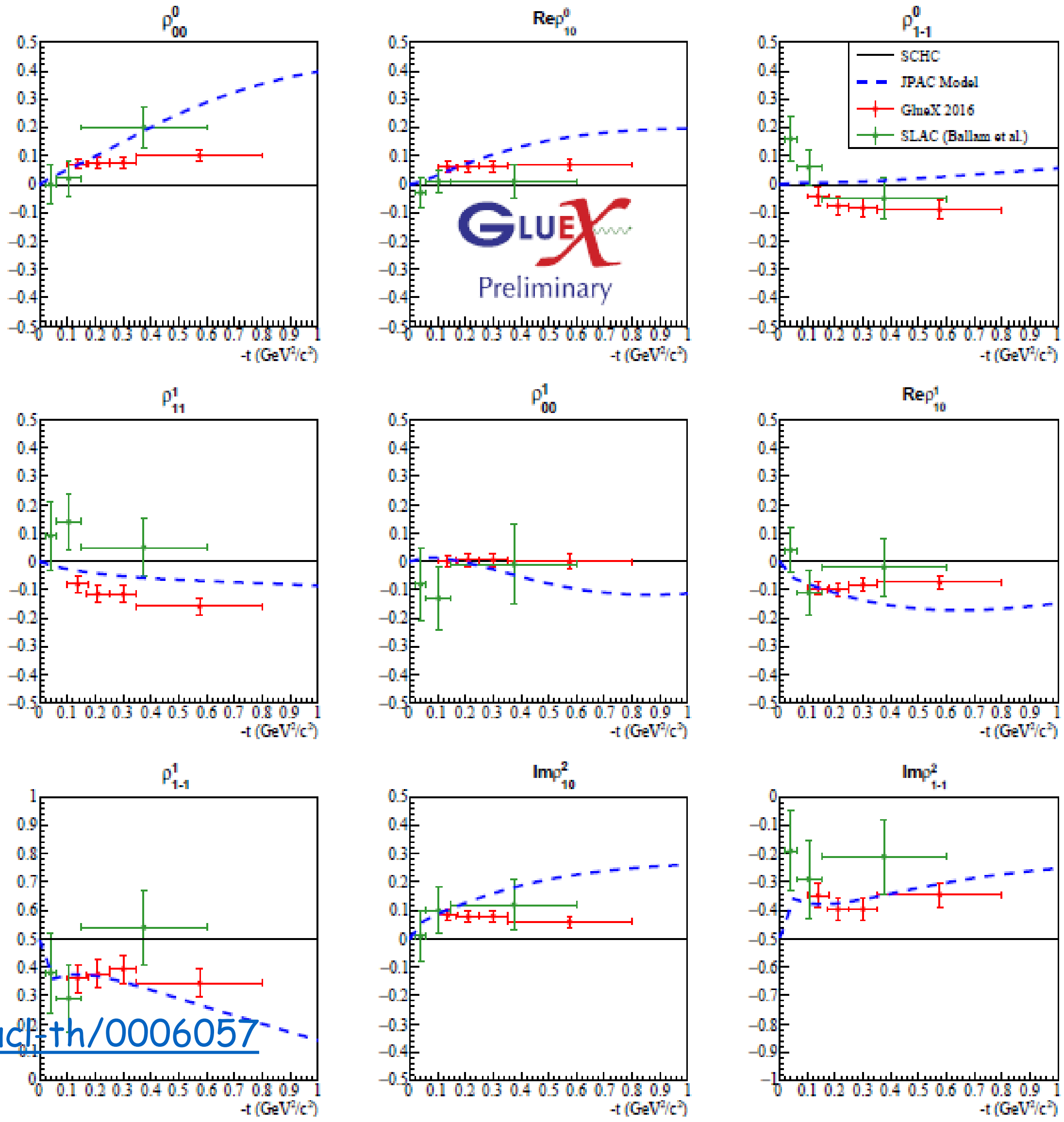
- No breakdown of relative contributions in JPAC paper, but earlier OTL model suggests ω results are sensitive to π^0 vs Pomeron

Oh, Titov, and Lee
Dotted- mostly π^0
Dashed- Pomeron



https://arxiv.org/abs/nucl-th/0006057



Summary

- GlueX is a fixed target, linearly polarized photo-production facility with the beam energy, acceptance, and intensity to search for hybrid mesons in the expected mass range of 1.5-2.5 GeV/c^2.

- The detectors and beamline instrumentation are all working well: eg, exclusive η′ photo-production is reconstructed with low background by detecting 5 tracks+showers with a total efficiency of ~10%.

Σ Asymmetries:

- Our commissioning data were previous analyzed to extract beam asymmetry (Σ) measurements of π^0 and η photo-production:
  i. first Σ measurements on the η in this beam energy range (**published**)
  ii. natural parity exchange (ie vectors) dominates for –t below 1 $(GeV/c)^2$.

- Production data with 8x our earlier statistics have now been analyzed to extract Σ **(draft paper being circulated internally)**
  i. first Σ measurements on the η′ in this beam energy range .
  ii. natural parity exchange also dominates for the η′, but a detailed comparison of η vs η′ will require much more statistics.
  iii. we have more precise results for the π^0 and η , approaching a systematic limit of a few percent at low –t .

SDME's:

- Preliminary SDME's for ρ, ω, and φ have been produced.
  i. For the ρ , impressive statistics and good agreement with JPAC model below –t ~ 0.5 $(GeV/c)^2$.

  ii. For the ω , good statistics but only qualitative agreement with the JPAC model.

Acknowledgements

The organizers and staff of this conference for the opportunity to visit Guilin.

My GlueX collaborators, for discussions, stolen slides, and all their original work. (Thanks,Tegan, Will, Alex, and Georgios!)

backups

The GlueX Collaboration

Arizona State, Athens, Carnegie Mellon, Catholic University, Univ. of Connecticut, Florida International, Florida State, George Washington, Glasgow, GSI, Indiana University, IHEP, ITEP, Jefferson Lab, U. Mass Amherst, MIT, MePhi, Norfolk State, North Carolina A&T, Univ. North Carolina Wilmington, Northwestern, Old Dominion, Santa Maria, University of Regina, Tomsk, Wuhan and Yerevan Physics Institute.

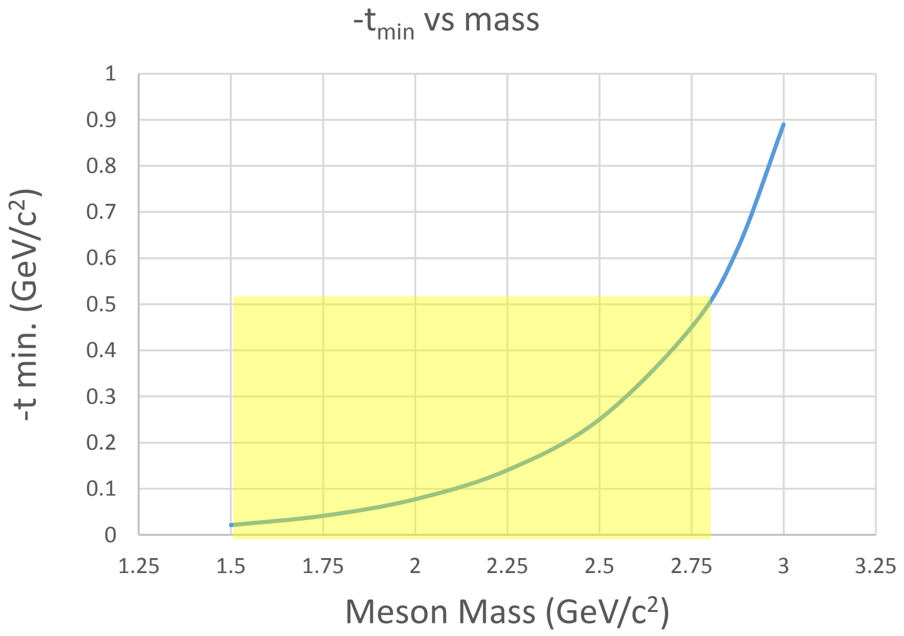
Over 125 collaborators from more than 25 institutions with others joining and more are welcome.

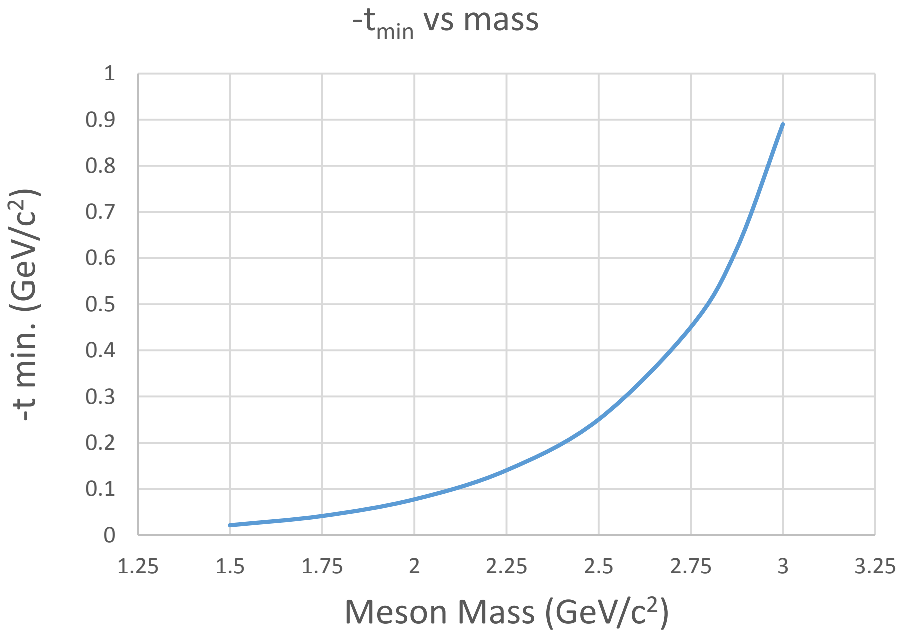
GlueX References (updated 8/7/19)

Physics results:	GlueX Sigma Asymmetry on pi0, eta	Phys.Rev.C 95, 042201 (2017)	https://arxiv.org/abs/1701.08123
	ρ SDME's	A. Austregesilo talk at MENU 2019	https://registration.mcs.cmu.edu/event/1/contributions/41
	Sigma Asymmetries on pi0, eta, eta'	W. McGinley talk at MENU 2019	https://registration.mcs.cmu.edu/event/1/contributions/145/
NIM articles:	Triplet POLarimeter	NIM A867 (2017) 115-127	https://arxiv.org/abs/1703.07875
	GlueX Start Counter	NIM, A927 (2019) 330–342	https://arxiv.org/abs/1901.02759
	BCAL	NIM A896 (2018) 24-42	https://arxiv.org/abs/1801.03088
PhD Theses	ω SDME's	M. Staib, PhD thesis, Sept 2017, Carnegie Mellon U.	
	φ SDME's	A. Barnes, PhD thesis, May 2017, U. of Connecticut	
	Eta and eta' Σ asymmetry	T. Beattie, PhD thesis, March 2019, U. of Regina	

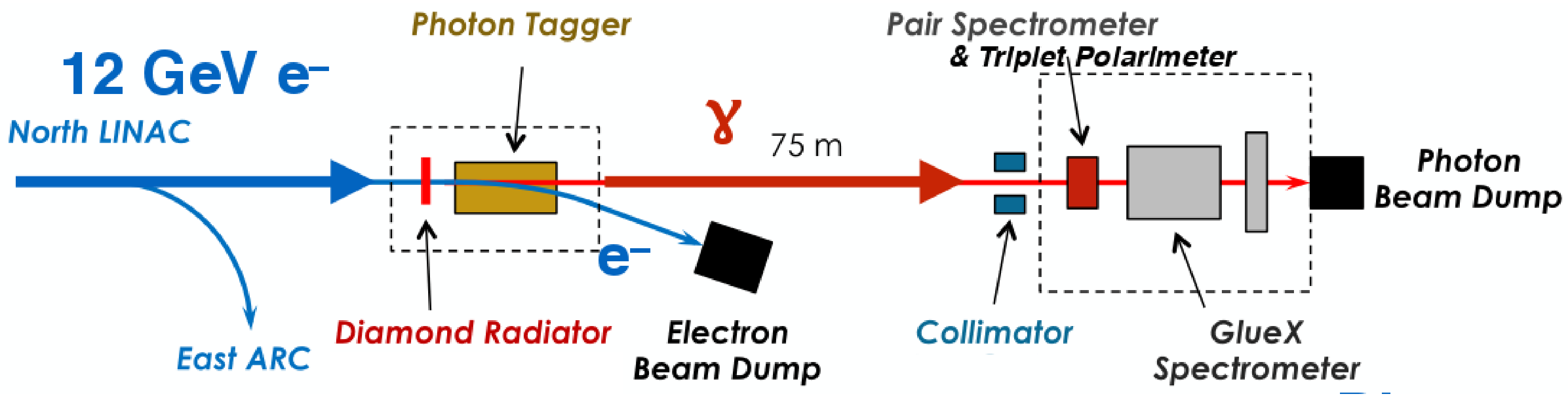
Theory References (updated 8/7/19)

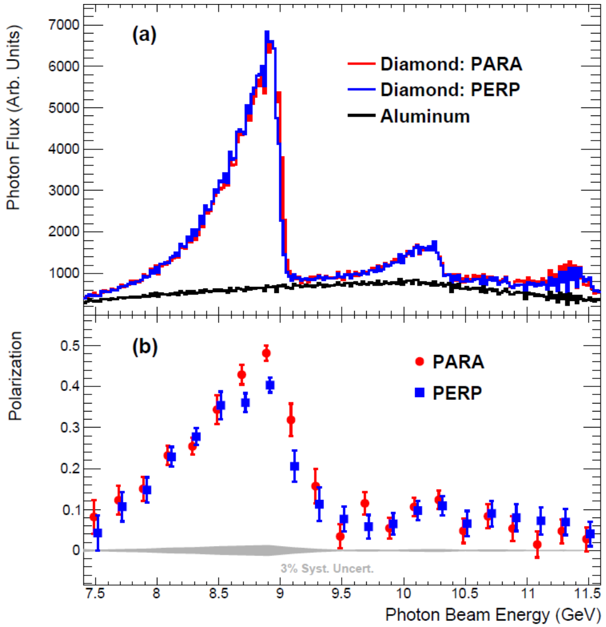
Oh, Titov, and Lee	Omega photoproduction	PRC 63, 025201	https://arxiv.org/abs/nucl-th/0006057
Misc JPAC references	Pi0 Regge model	PRD 92, 074013	https://arxiv.org/abs/1505.02321
	High energy constraints on low energy baryon resonances	JLab report JLAB-THY-17-2539	https://arxiv.org/abs/1708.07779
	Eta and eta' Regge model	PLB, 774, 10 November 2017, Pages 362-367	https://arxiv.org/abs/1704.07684v2
	Vector meson Regge model	PRD 97, 094003 (2018)	https://arxiv.org/abs/1802.09403


-t_{min} vs mass
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-t min. (GeV/c^2)
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
Meson Mass (GeV/c^2)


-t_{min} vs mass
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-t min. (GeV/c^2)
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
Meson Mass (GeV/c^2)

Photon Beamline





9 GeV Polarized Photon Beam

- Coherent Bremsstrahlung on thin diamond
- Energy tagged by scattered electrons
- Collimator to suppress incoherent part
- Linear polarization in peak $P_\gamma \approx 40\%$, measured by Triplet polarimeter: $\gamma e^- \rightarrow e^- e^+ e^-$
- Beam intensity: $1 - 5 \cdot 10^7$ γ/s in peak

GlueX Detector

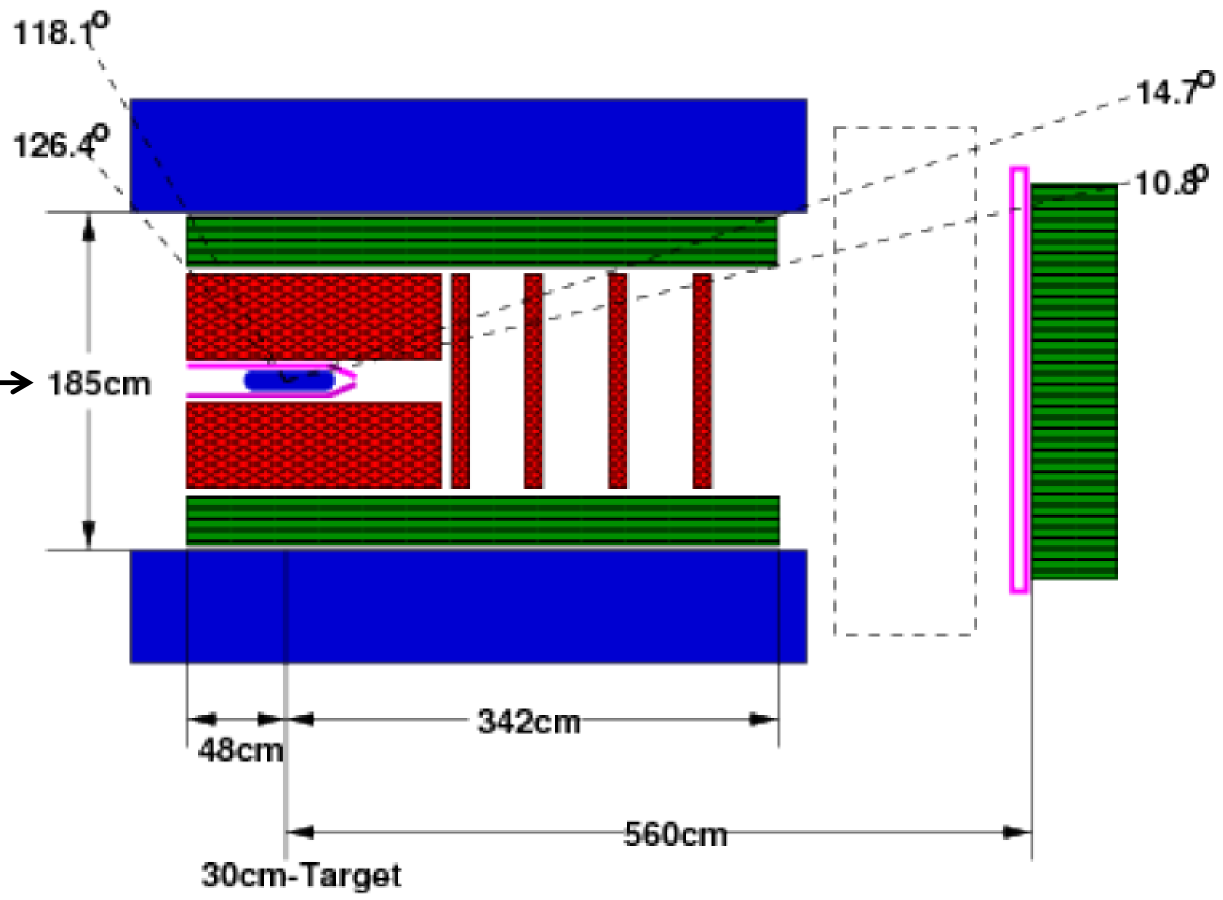
Solenoid, Target (blue)

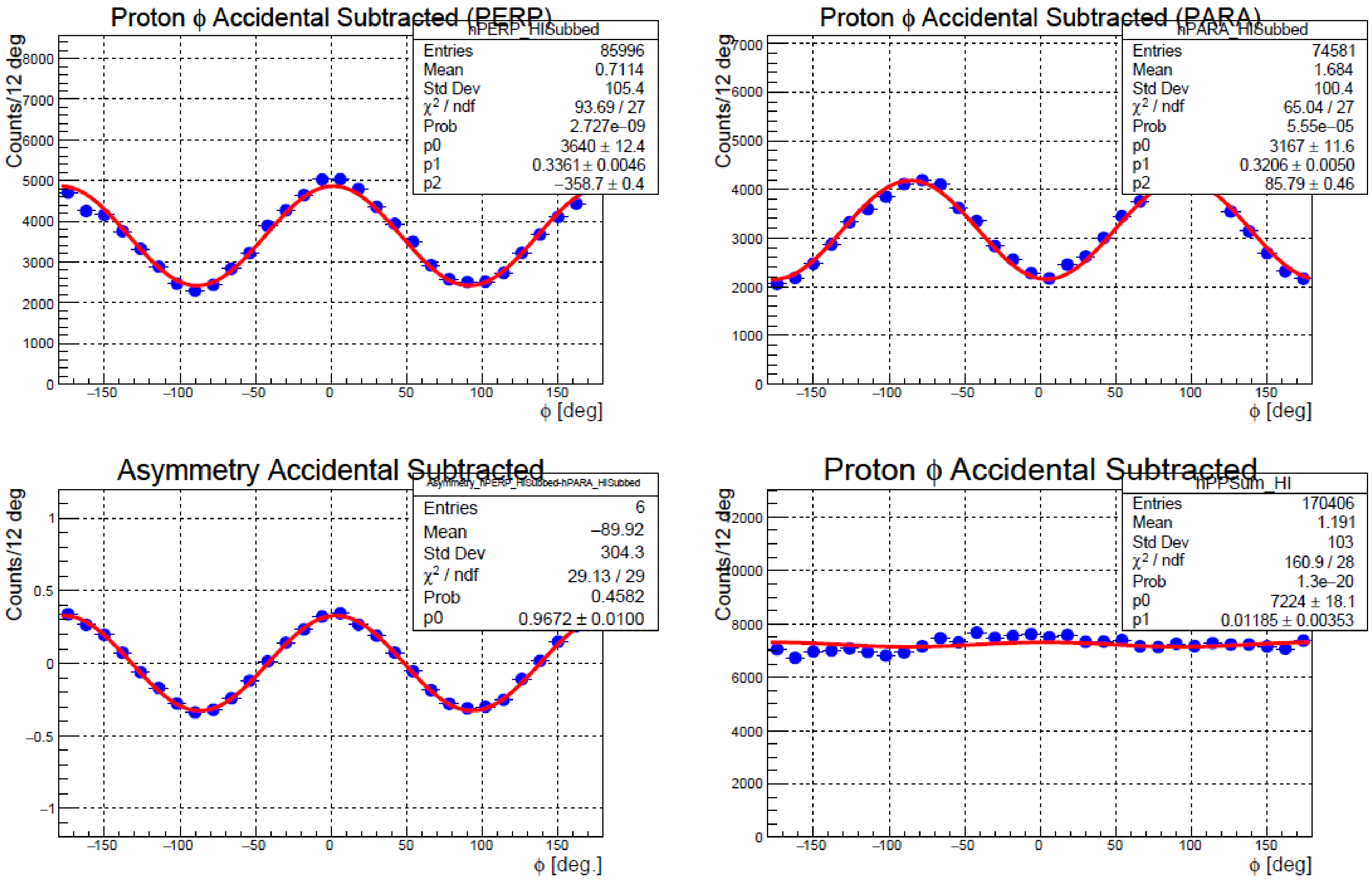
Tracking (red)

Calorimetry (green)

Timing (magenta)

beam →




Proton ϕ Accidental Subtracted (PERP)
hPERP_HISubbed
Entries 85996
Mean 0.7114
Std Dev 105.4
χ2 / ndf 93.69 / 27
Prob 2.727e−09
p0 3640 ± 12.4
p1 0.3361 ± 0.0046
p2 −358.7 ± 0.4
Counts/12 deg
ϕ [deg]
Proton ϕ Accidental Subtracted (PARA)
hPARA_HISubbed
Entries 74581
Mean 1.684
Std Dev 100.4
χ2 / ndf 65.04 / 27
Prob 5.55e−05
p0 3167 ± 11.6
p1 0.3206 ± 0.0050
p2 85.79 ± 0.46
Counts/12 deg
ϕ [deg]
Asymmetry Accidental Subtracted
Asymmetry_hPERP_HISubbed-hPARA_HISubbed
Entries 6
Mean −89.92
Std Dev 304.3
χ2 / ndf 29.13 / 29
Prob 0.4582
p0 0.9672 ± 0.0100
Counts/12 deg
ϕ [deg.]
Proton ϕ Accidental Subtracted
hPPSum_HI
Entries 170406
Mean 1.191
Std Dev 103
χ2 / ndf 160.9 / 28
Prob 1.3e−20
p0 7224 ± 18.1
p1 0.01185 ± 0.00353
Counts/12 deg
ϕ [deg]

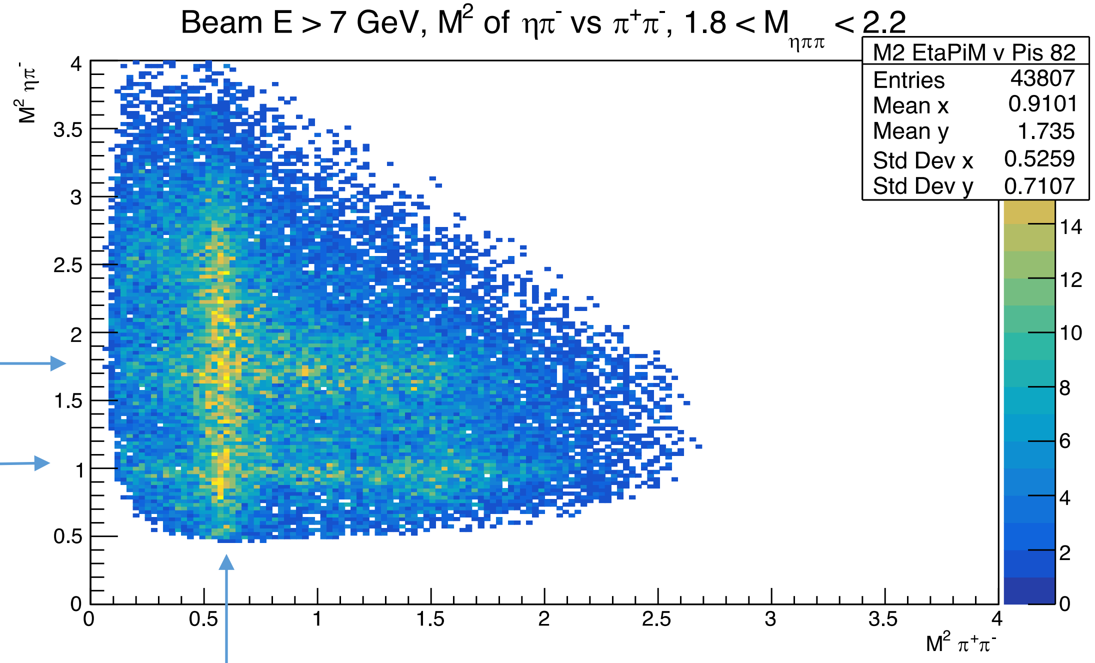
M(ηπ) vs M(2π) in $\gamma + p \rightarrow p\eta\pi^+\pi^-$

M(ηππ) cut to meson masses ~ 2 GeV/c^2

$m^2(\eta\pi)$

Strong
π a2 signal

Bkg from π a0.



$m^2(\pi\pi)$

Very strong
η ρ signal

Needs a PWA!

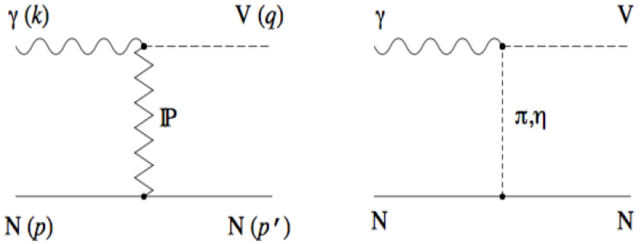
We're just getting started with the fairly complex event selection.

SDME's of Vector Mesons

In the OTL model, the ω SDMEs are sensitive to the relative amounts of Pomeron and PS meson exchange (mostly π^0 due to the large value of $g_{\pi NN}$) .

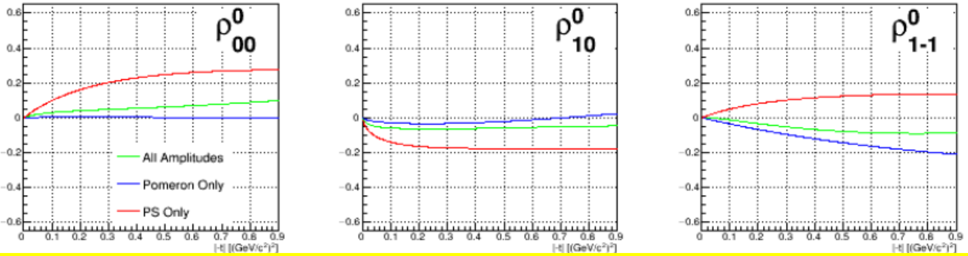
Oh, Titov, Lee model

$$I_{tot} = I_{\mathbb{P}} + I_{\pi} + I_{\eta}$$

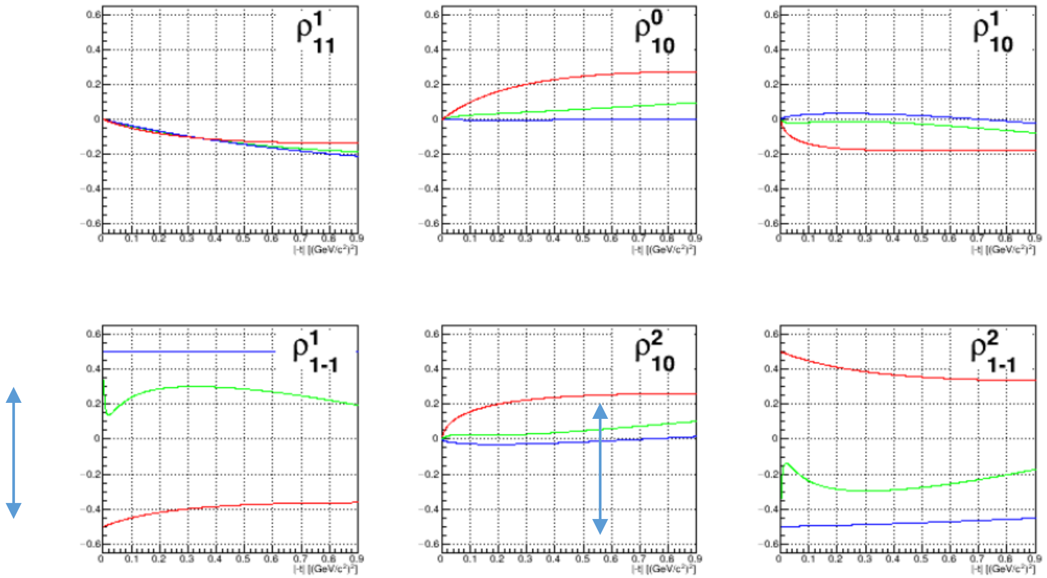


Model the nonresonant amplitude as the sum of Pomeron and Pseudoscalar exchange

Phys. Rev. C **63** (2001) 025201



Blue – Pomeron Only Red – Pseudoscalar Only Green – Combined



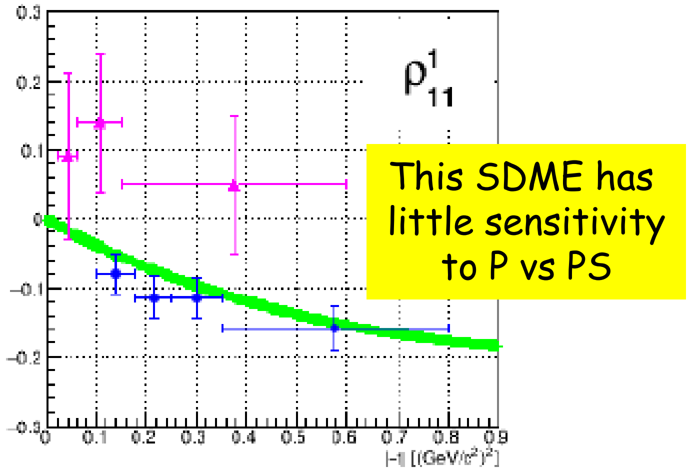
-t dependence of ω SDMEs

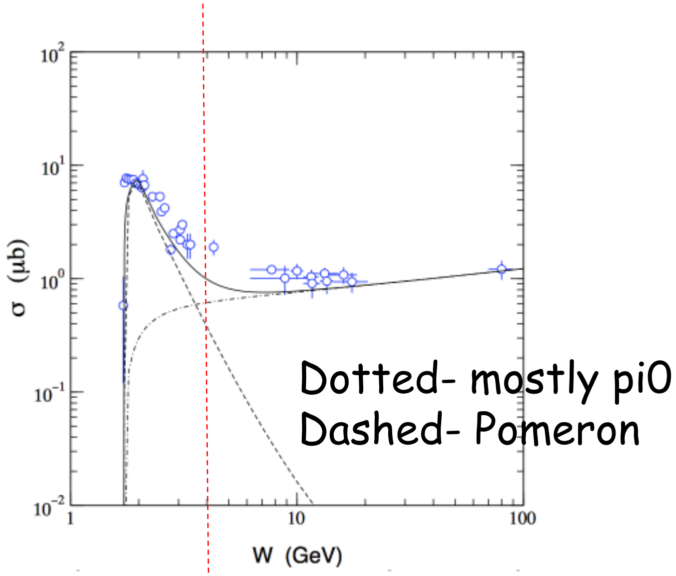
Note the often very different behavior predicted for Blue/Pomeron vs Red/PS exchange.

SDME's of ω Mesons

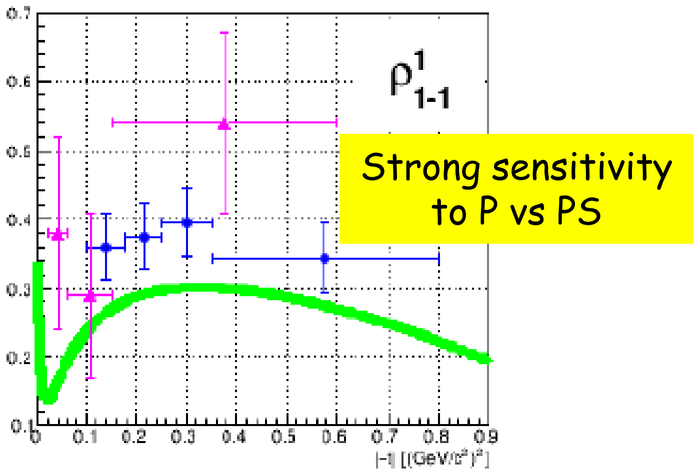
Broadly speaking, results are consistent with the dominance of Pomeron exchange at our beam energy and range of –t.

In the context of the OTL model, a small adjustment in the relative strengths of the Pomeron and π^0 may be needed.





ω SDME's, M. Staib, PhD thesis, Sept 2017, Carnegie Mellon U.



Abstract Submitted to Hadron 2019

Selected ~~Overview of~~ Light Meson Results from the GlueX Experiment

D. Mack for the GlueX Collaboration, TJNAF

The GlueX experiment in Hall D at Jefferson Lab consists of a well-instrumented photon beamline in conjunction with a solenoidal spectrometer providing near-hermetic coverage for charged particles and photons. Since 2016, the experiment has had several run periods with a 9 GeV linearly polarized photon beam on a 30cm liquid hydrogen target, completing its initial low-intensity program. Light (i.e., < 1.05 GeV/c^2) meson studies have been critical to commissioning the GlueX detector, elucidating the photo-production reaction mechanism in this photon energy range, and testing the event selection techniques needed to search for exotic hybrid mesons. We have measured the beam asymmetries for photo-production of pseudo-scalar mesons including π^0, η, and η', and have preliminary results for the Spin Density Matrix Elements (SDMEs) for the vector mesons ω, ρ, and ϕ. ~~Cross-section determinations are in progress for all these mesons, usually in more than one decay branch, and with 3-7 particles exclusively detected in the final state. The outlook appears encouraging for GlueX to measure precise, competitive Dalitz plots for η→ 3π and η' → η 2π.~~ The latter η' →η 2π studies are synergistic with exploratory studies of the continuum M(η 2π) spectrum between 1.5 to 2.5 GeV/c^2 where we plan to search for hybrid exotic mesons.