The high-energy photoproduction of light-quark pseudoscalar and scalar meson at GlueX

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for the GlueX Collaboration

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武漢大學 WUHAN UNIVERSITY

Jefferson Lab GLUEX

OUTLINE

- Introduction
- 2 γ processes at GlueX
  - Photoproduction of pseudoscalar meson
- 4 γ processes at GlueX
  - Photoproduction of scalar meson
- Summary and outlook

Introduction

Meson photoproduction

- **Almost 50 years at SLAC, DESY, and Cambridge**
- **Growing vigorously recently: JLab, ELSA, and MAMI**
- **In the low energy regime: provide constraints on "background" to baryon resonance extraction**
- **In high regime provides insight into dominant production mechanism**

See Alexander A. talk
Light Meson Spectroscopy at GlueX

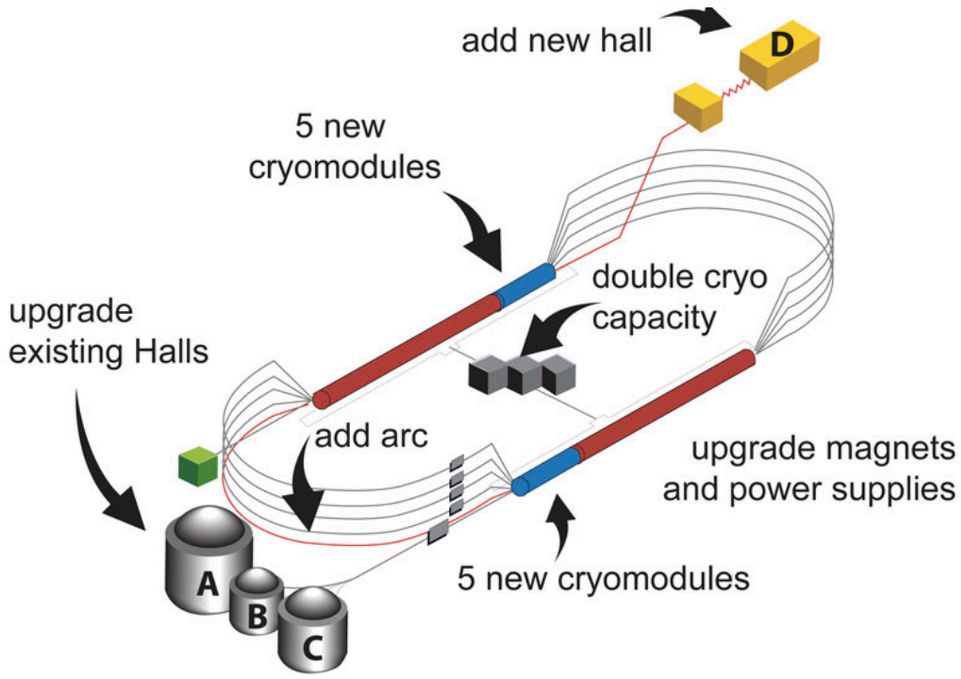
- **The long-term aim at GlueX**
  - **Understand quark-gluon interactions**
  - **Search for exotic hybrid mesons**

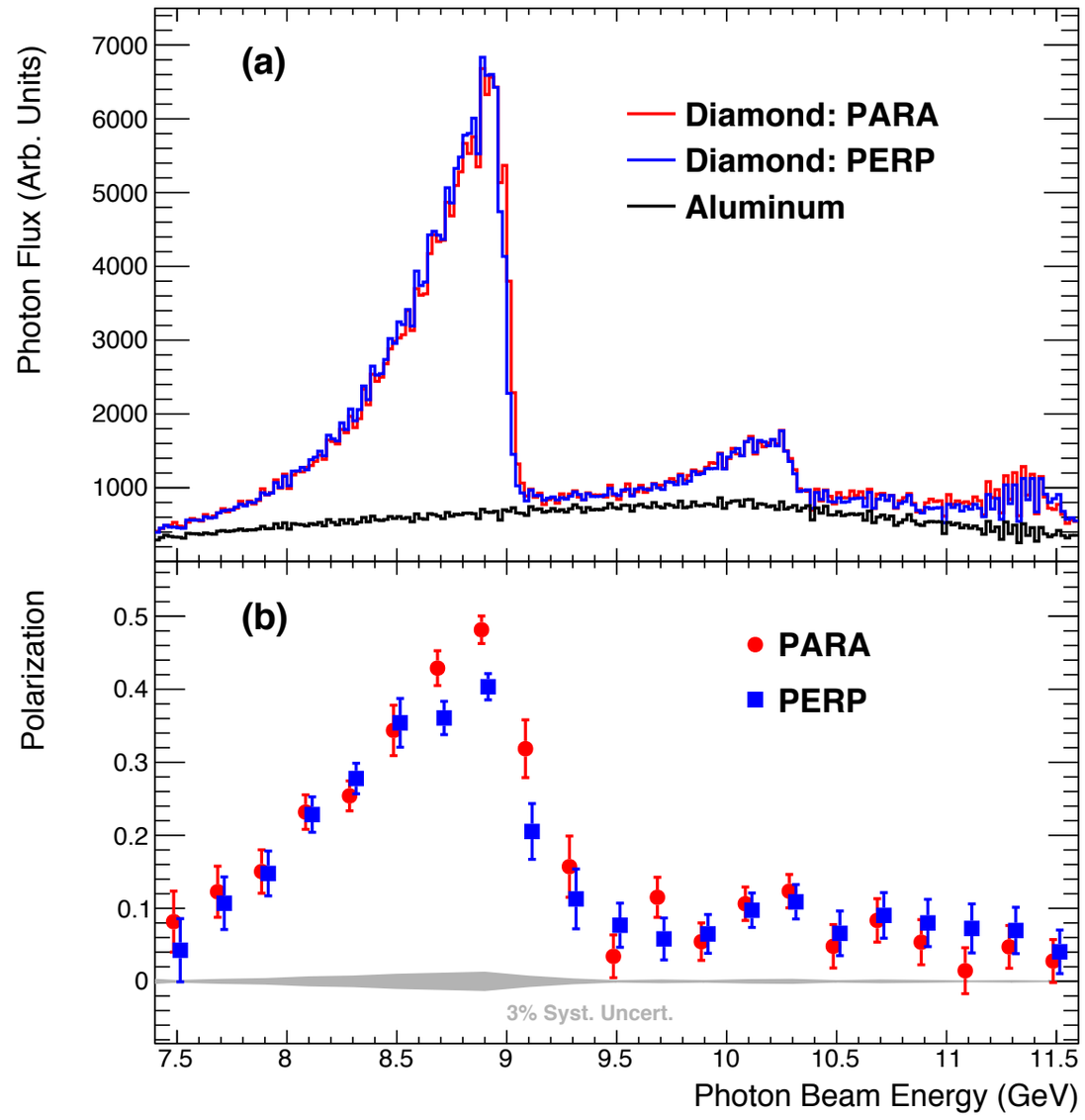
Exchange particle		Final states	
$\mathcal{P}$	0^{++}	$2^{+-}, 0^{+-}$	b°, h, h'
π°	0^{-+}	2^{+-}	b_2°, h_2, h_2'
$\pi^{\pm}$	0^{-+}	1^{-+}	$\pi_1^{\pm}$
ω	1^{--}	1^{-+}	π_1, η_1, η_1'

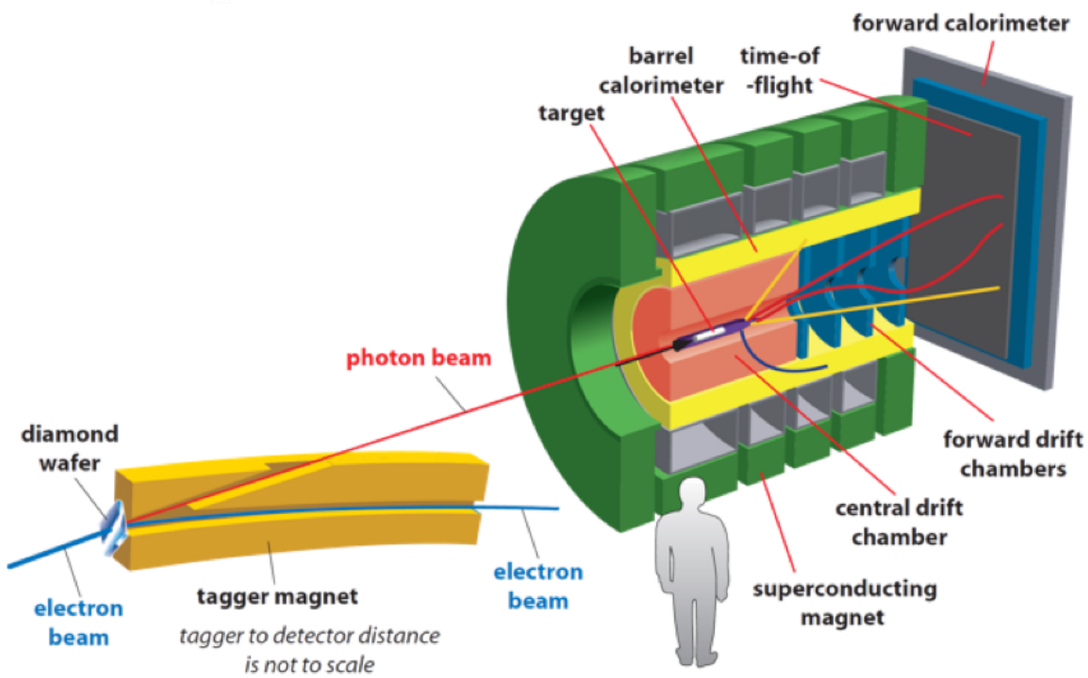
The high-energy photoproduction is a vital step to the final aim

Searching for Multiphoton final states is a component of a wide meson photoproduction project, among which we will focus on 2γ and 4γ photoproduction

Linearly polarised photon beam at GlueX



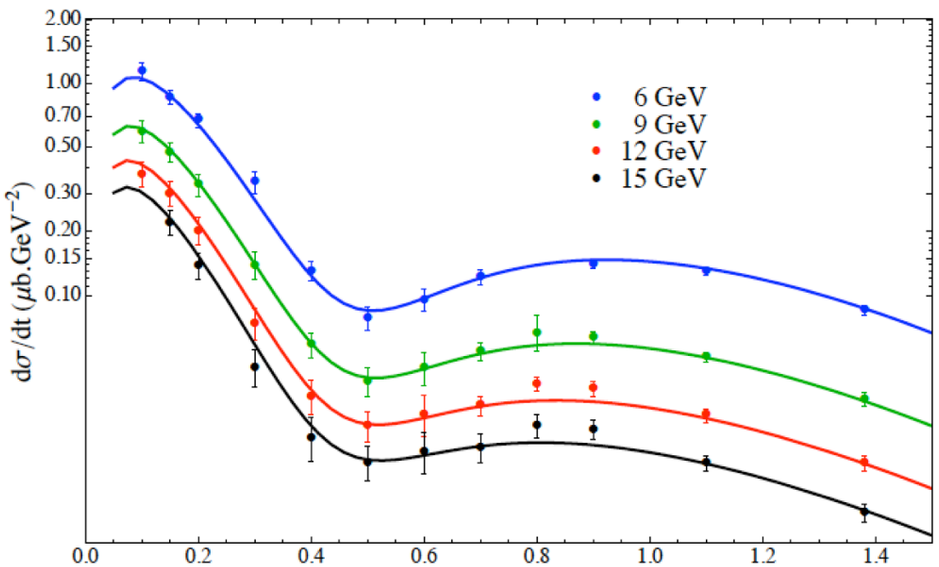


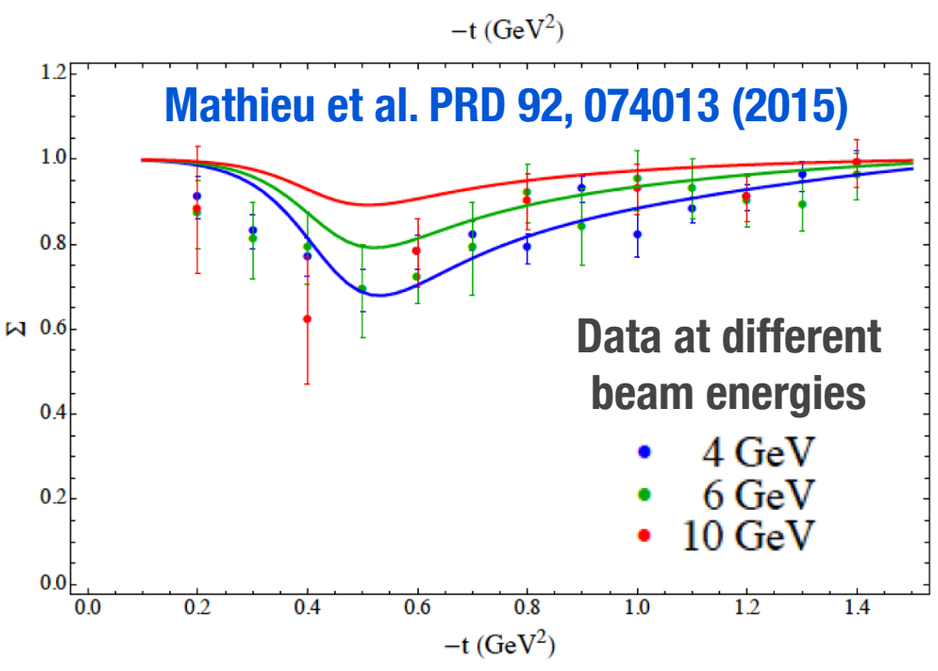


Linearly polarized photons via coherent bremsstrahlung from diamond radiator off liquid hydrogen peaking at 9 GeV

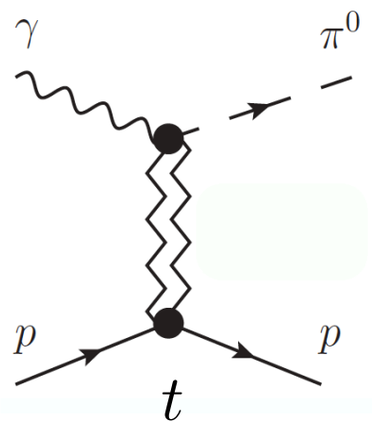
2γ processes at GlueX
Pseudoscalar mesons π^0/η Photoproduction

JPAC Regge Model





SLAC: PRD 4, 1937 (1971)



Exchange J^{PC}

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

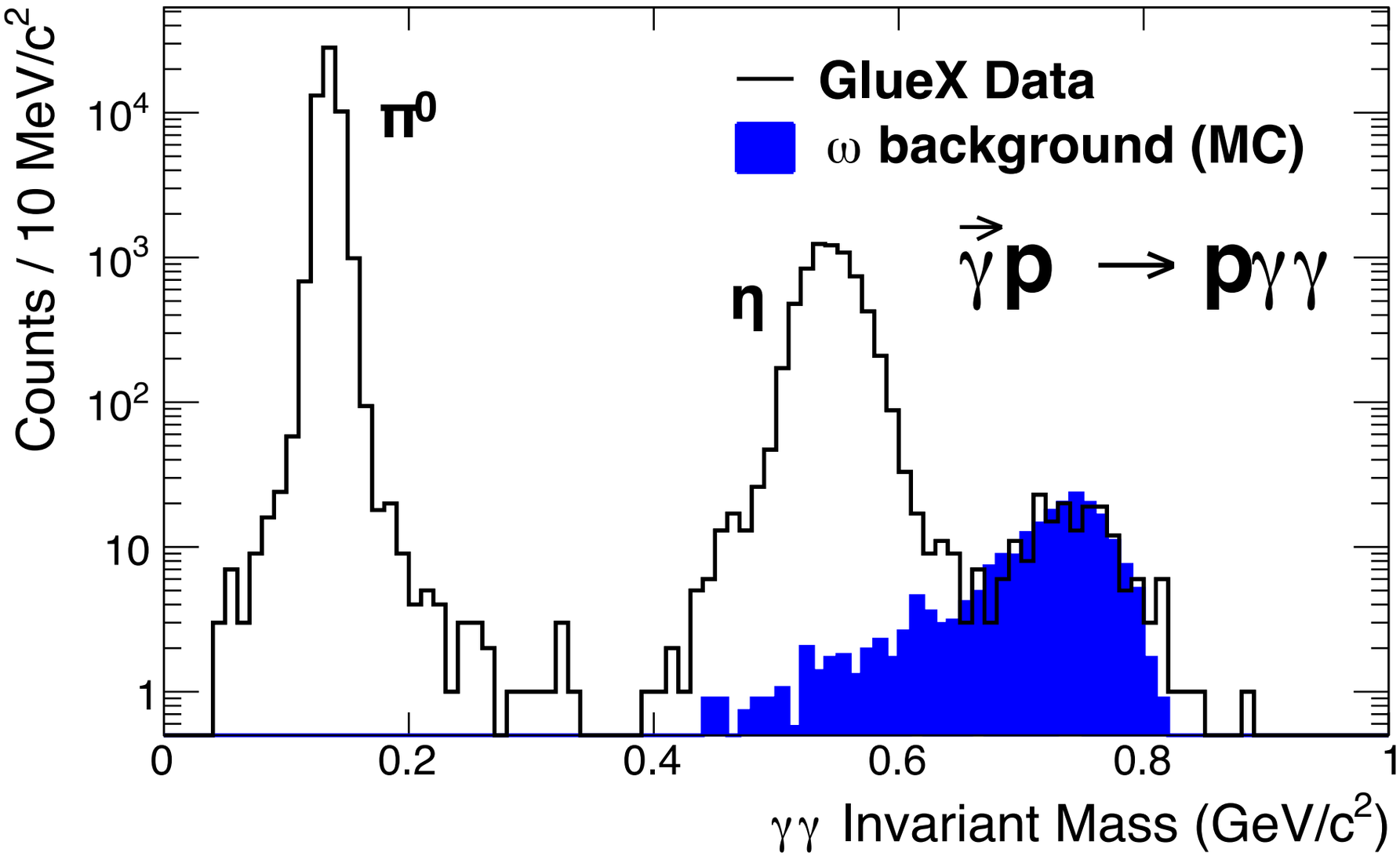
$1^{+-} : b, h$

$$\frac{d\sigma}{dt} = \sigma_\perp + \sigma_\parallel = |\rho + \omega|^2 + |b + h|^2$$

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

There are no previous measurements of the Σ asymmetry for γp→ηp with $E_\gamma > 3$ GeV

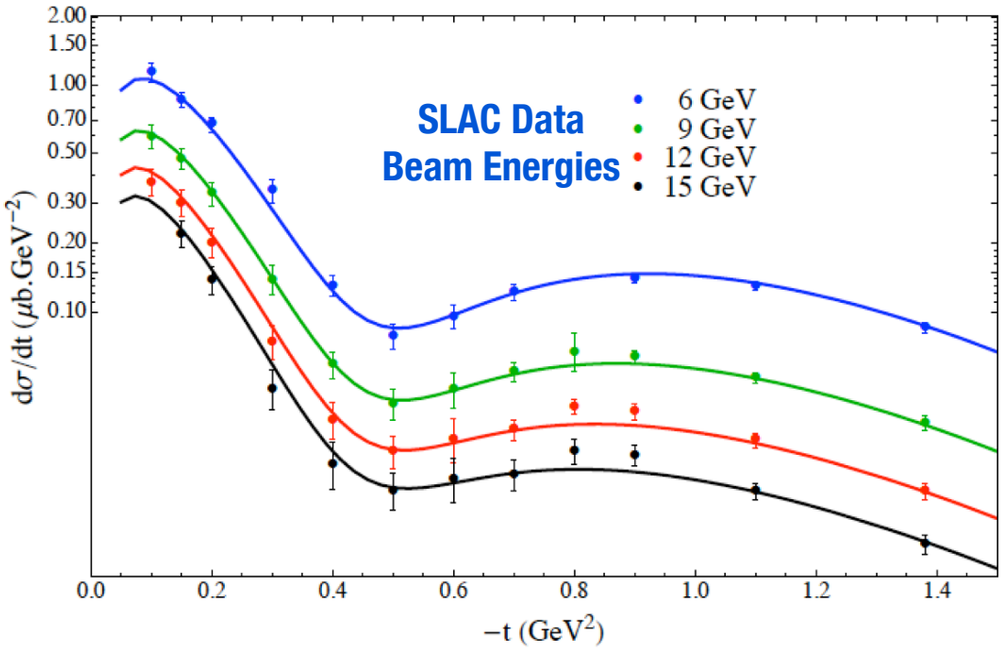
ω Backgrounds



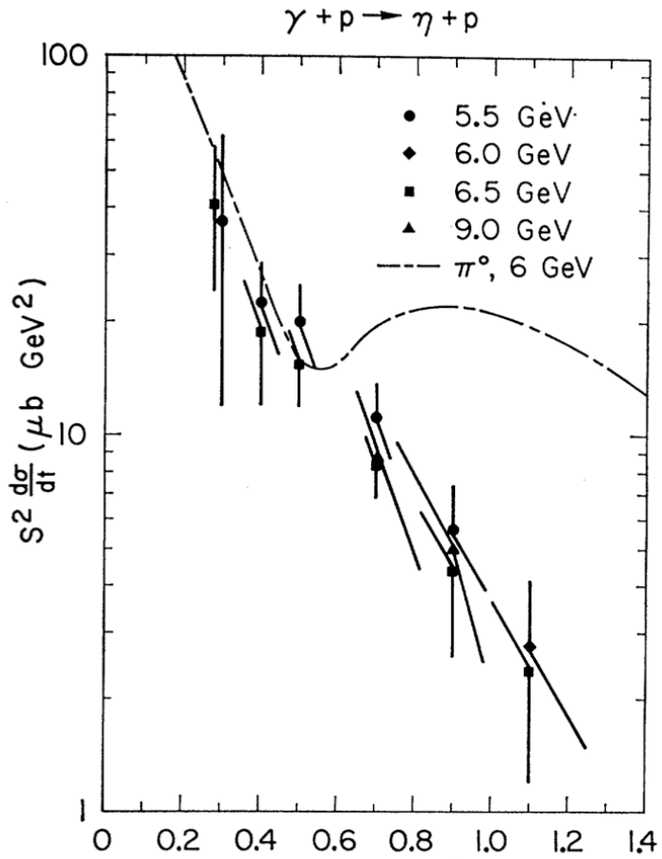
- **Continuum background between π^0 and η is negligible.**
- **The largest background is γp→ωp, ω→π^0γ with a missing photon. To get the background shape, we simulated this reaction then normalized to the ω leakage peak.**
- **Our exclusive measurements and cuts ensure very low backgrounds: for the eta the dilution is only 0.38%, while for the π^0 it is negligible.**

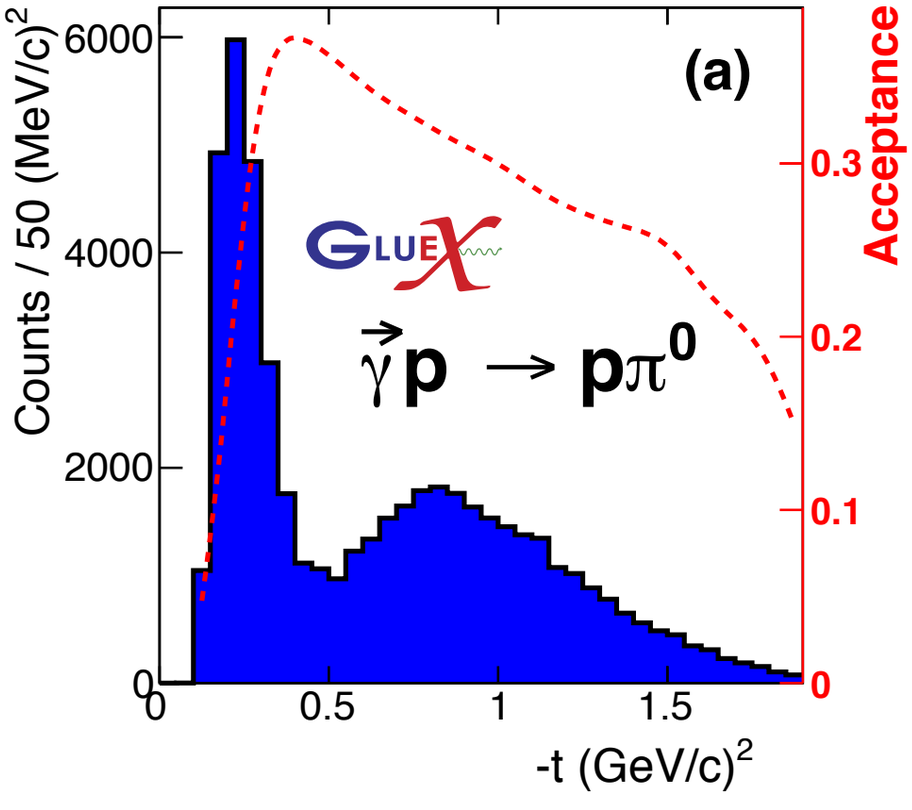
Final -t distributions

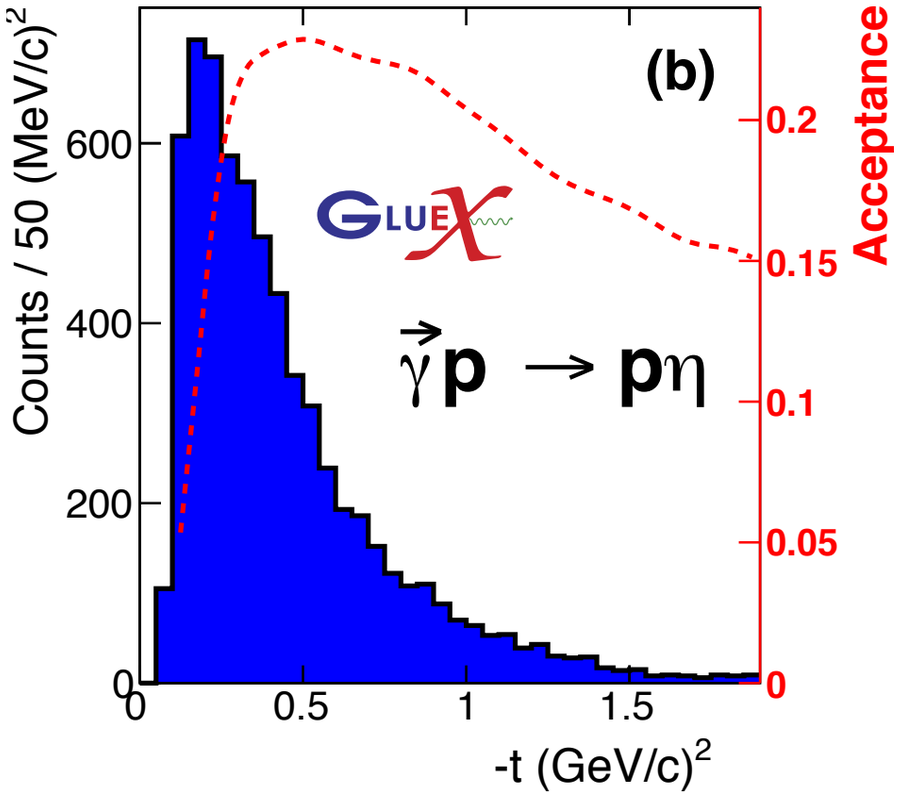
V. Mathieu (JPAC): PRD 92, 074013



SLAC: PRD 1, 27 (1970)

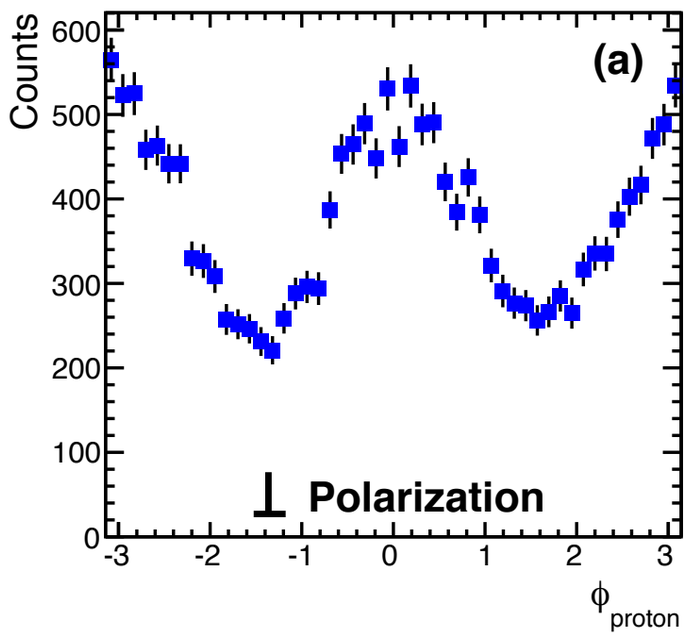


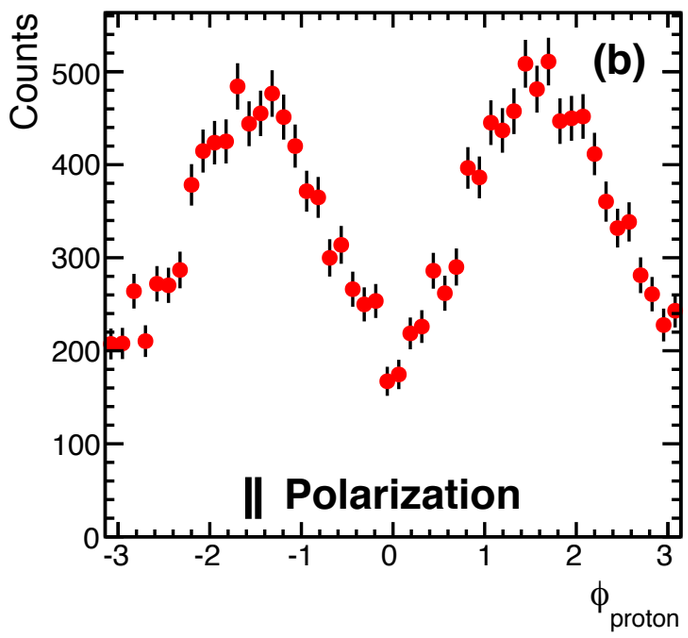


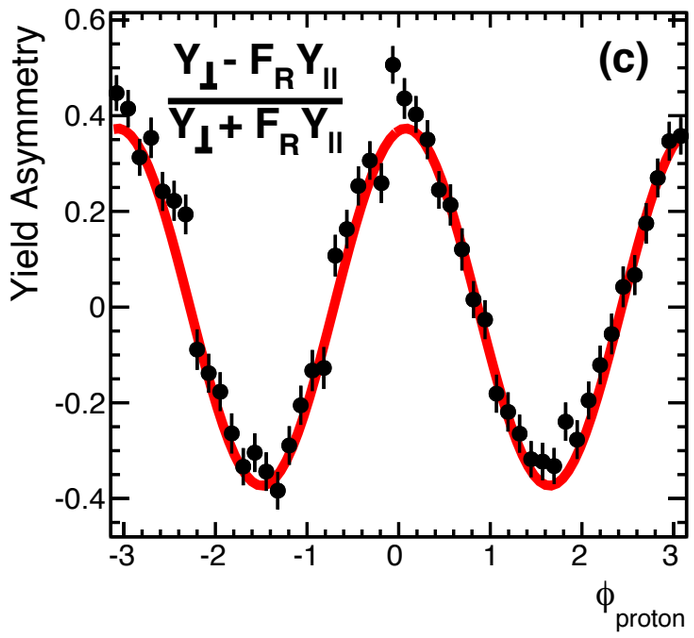


Without acceptance correction

Beam Asymmetry: Method

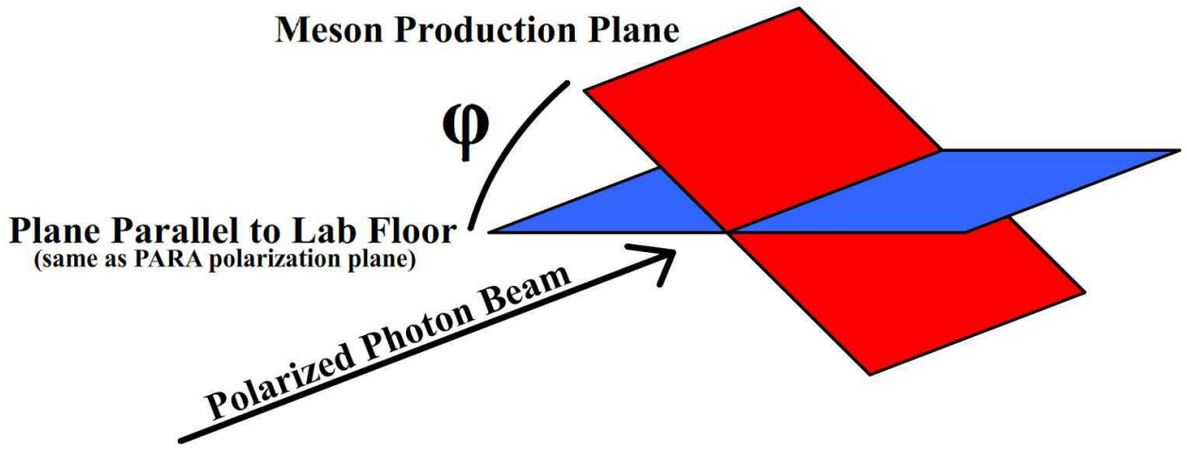




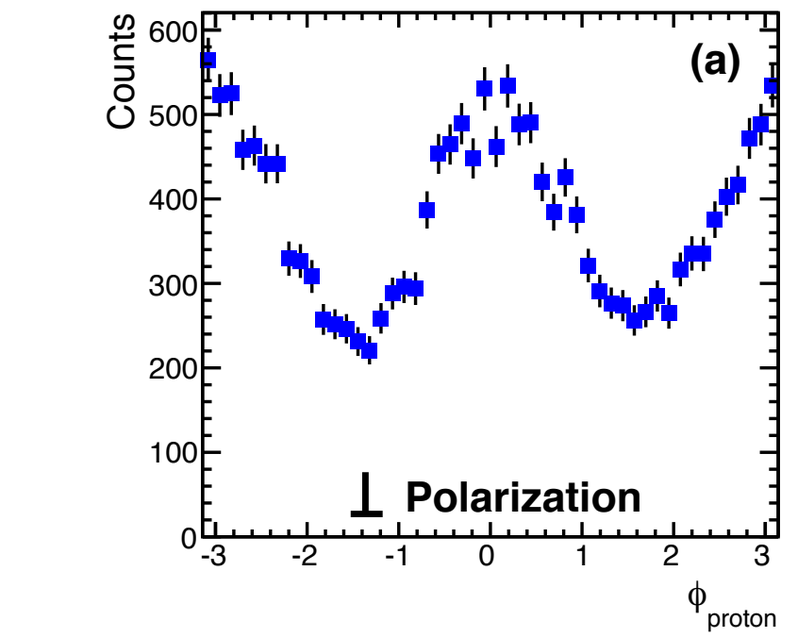


$$\frac{d\sigma}{d\phi_{\text{proton}}} \propto 1 - P\Sigma \cos 2(\phi_{\text{proton}} - \phi_\gamma)$$

$$Y_\perp \propto N_\perp(1 + P_\perp \Sigma \cos 2\phi_{\text{proton}}) \;\; \phi_\gamma = 90^\circ$$
$$Y_\parallel \propto N_\parallel(1 - P_\parallel \Sigma \cos 2\phi_{\text{proton}}) \;\; \phi_\gamma = 0^\circ$$



Beam Asymmetry: Method



$$Y_\perp \propto N_\perp(1 + P_\perp \Sigma \cos 2\phi_{\rm proton})\ \phi_\gamma = 90^\circ$$
$$Y_\parallel \propto N_\parallel(1 - P_\parallel \Sigma \cos 2\phi_{\rm proton})\ \ \phi_\gamma = 0^\circ$$

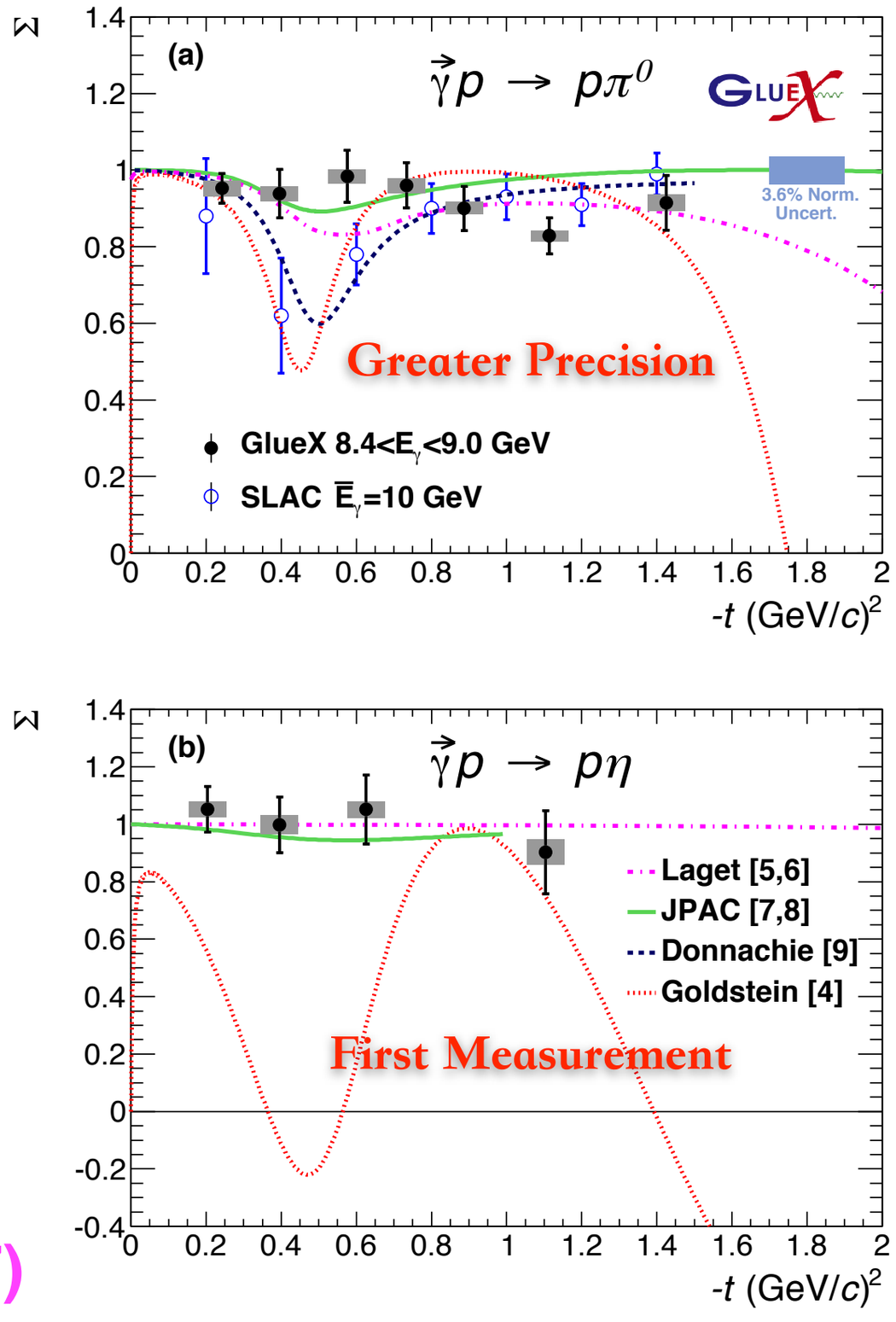
$$\frac{\boldsymbol{Y_\perp - F_R Y_\parallel}}{\boldsymbol{Y_\perp + F_R Y_\parallel}} = \frac{\boldsymbol{(P_\perp + P_\parallel)\Sigma \cos 2\phi_{\rm proton}}}{\boldsymbol{2 - (P_\perp - P_\parallel)\Sigma \cos 2\phi_{\rm proton}}}$$

Repeat in bins of -t for both π^0 and η

$$\boldsymbol{F_R = \frac{N_\perp}{N_\parallel}}$$

Beam Asymmetry: Results

- **Measured asymmetries consistent with previous SLAC data**
- **Our measured Σ asymmetries are close to 1, with little evidence of -t dependence**
- **Don't observe prominent dip in beam asymmetry at -t = 0.5 (GeV/c)^2 as seen in the cross section**
- **Our data are consistent with the JPAC and Laget calculations**



PHYS REV C 95, 042201(R) (2017)

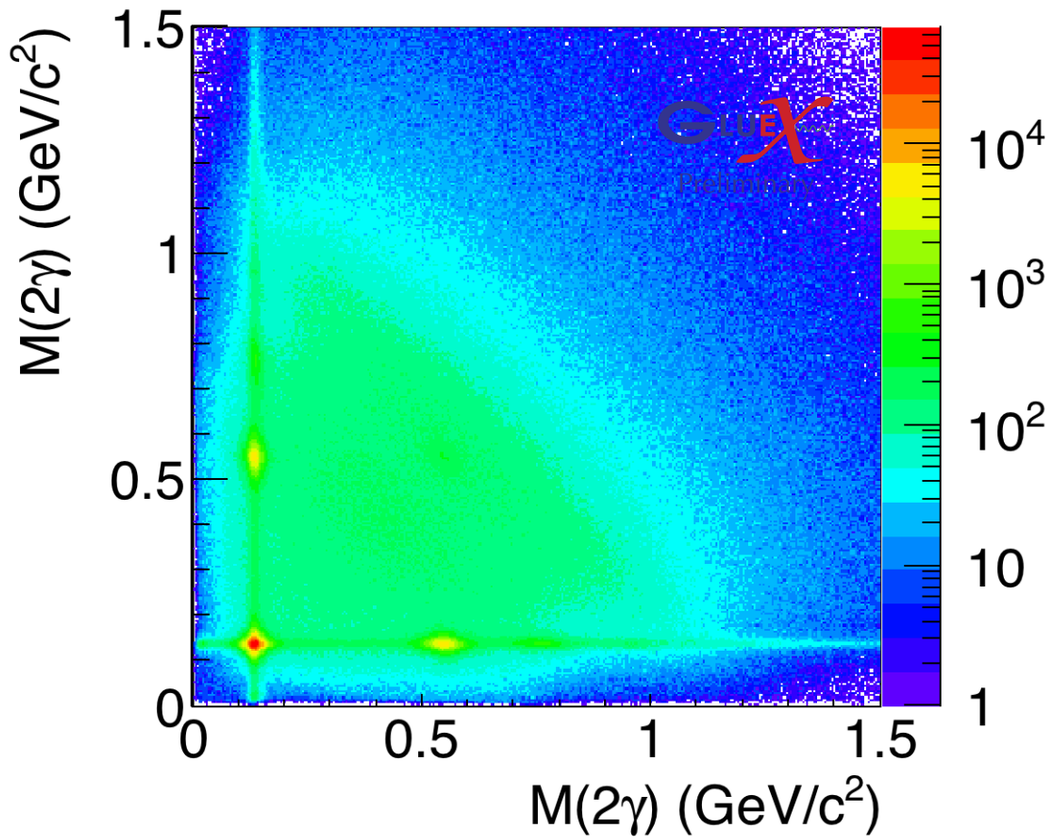
4 γ processes at GlueX

Scalar mesons Photoproduction

- **The dominant channels:**

  $\pi^0\pi^0$ & $\pi^0\eta$

- **Light scalar mesons $a_0(980)$ and $f_0(980)$ photoproduction**



Exploring the nature of Light scalar mesons $a_0(980)$ and $f_0(980)$ photoproduction

with $\pi^0\pi^0$ / $\pi^0\eta$ as final states

can help to understand the chiral symmetry breaking mechanisms of QCD and the confinement of hadrons.

The status of the study of the scalar mesons Photoproduction

- **Theoretical method: Regge-cut phenomenology, which is well understood in pion photoproduction.**

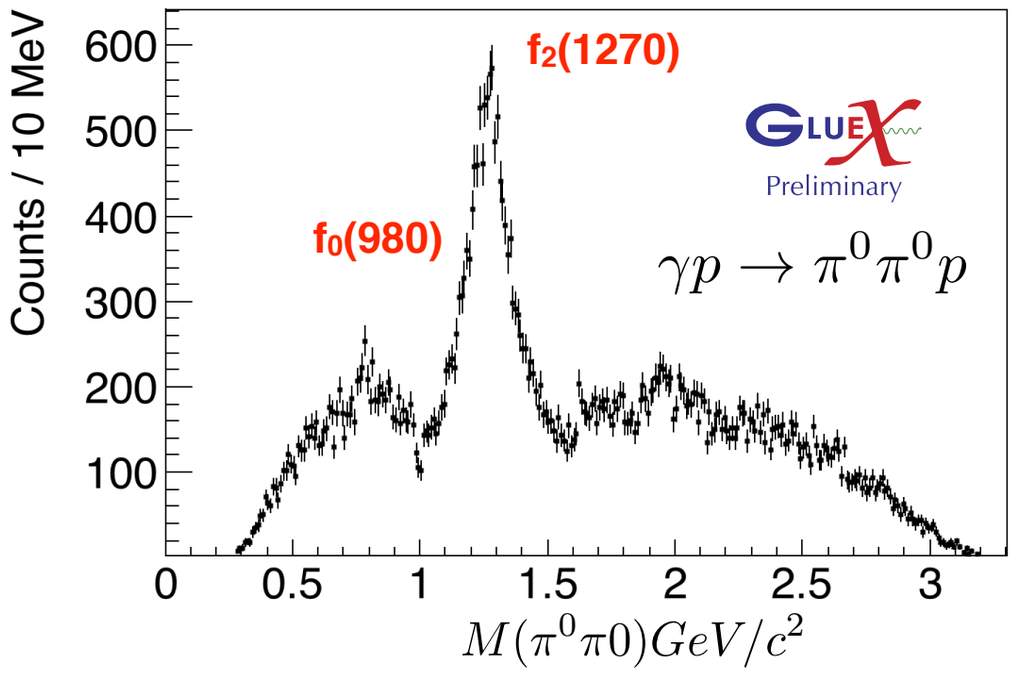
Phys. Rev. C 93, 025203 (2016)

- **CB-ELSA and CLAS collaborations made some measurements for $a_0(980)$ and $f_0(980)$ photoproduction respectively at lower energies.**

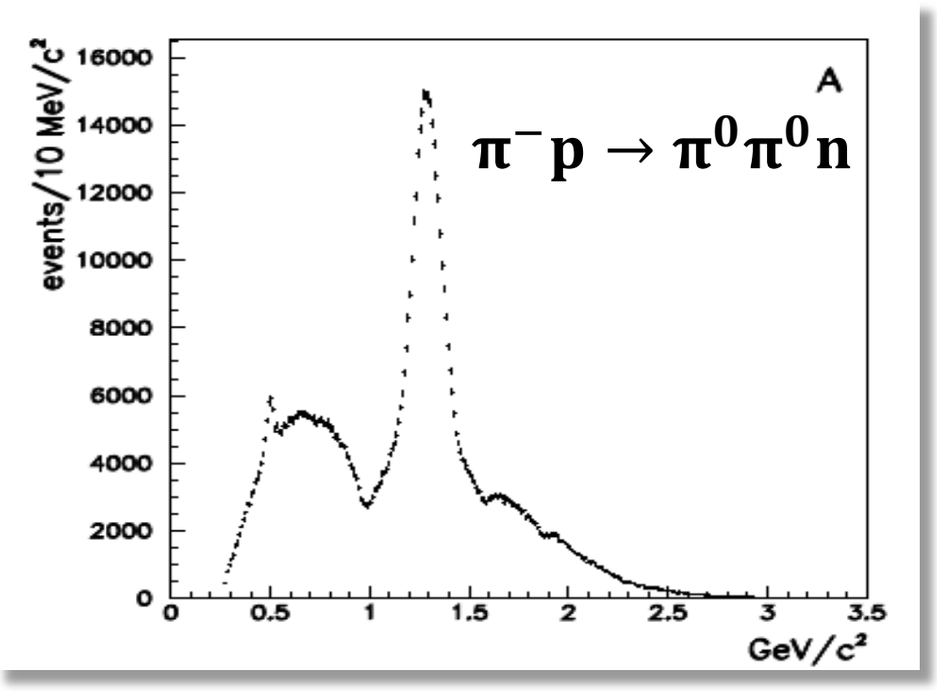
Eur. Phys. J. A 38, 173 (2008)

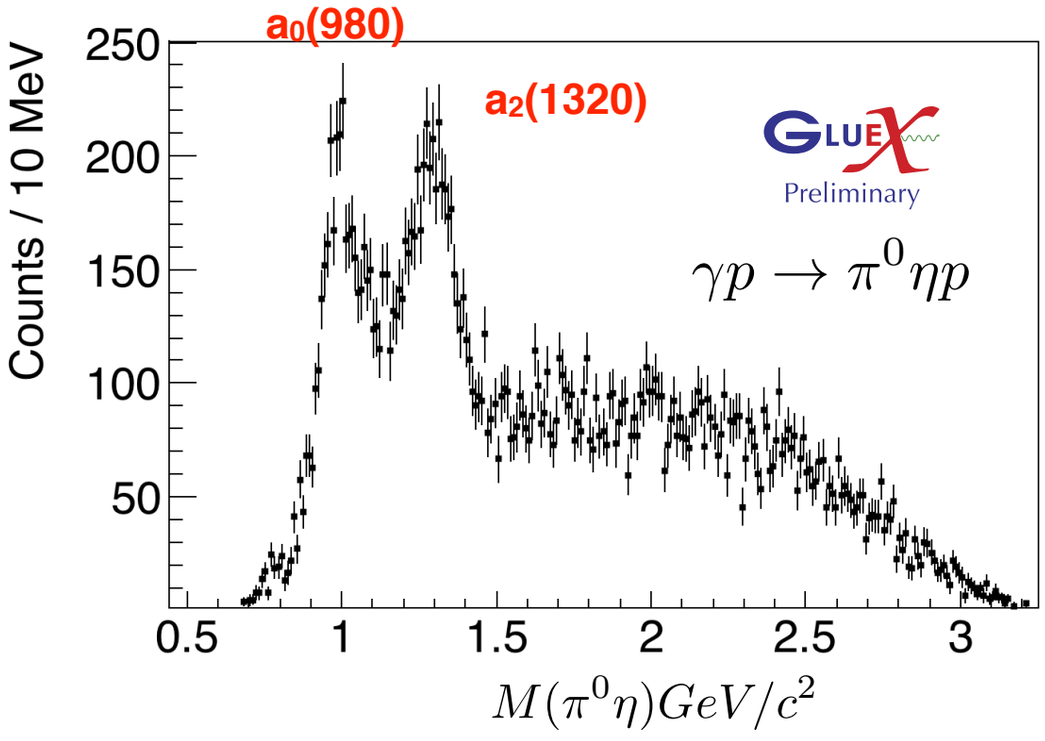
Phys. Rev. Lett. 102, 102001 (2009)

- **Published statistics for $a_0(980)$ and $f_0(980)$ photoproduction is low and in a limited energy range.**



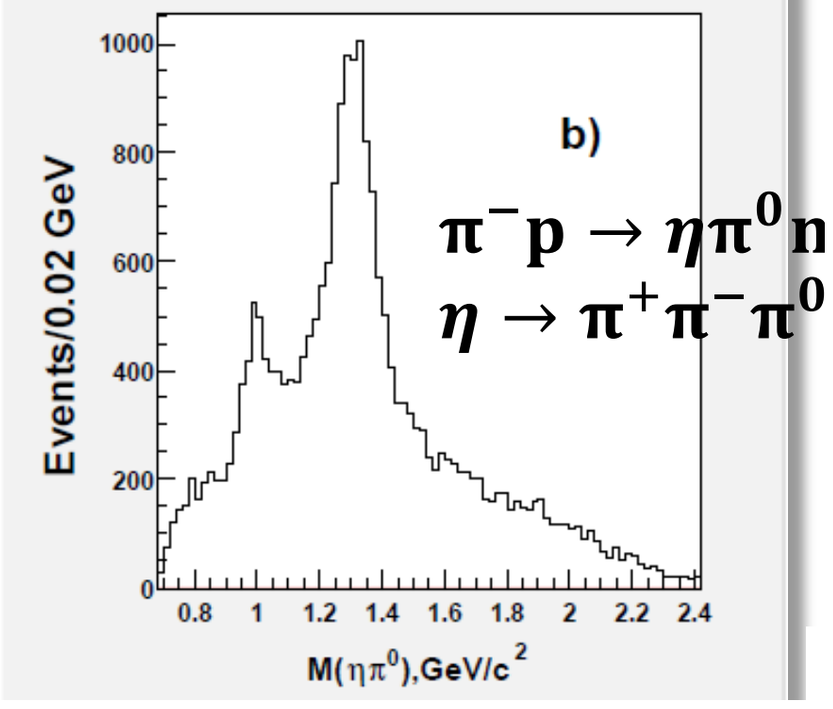
J. Gunter et al., E852 Collaboration,
https://arxiv.org/abs/hep-ex/0001038v1





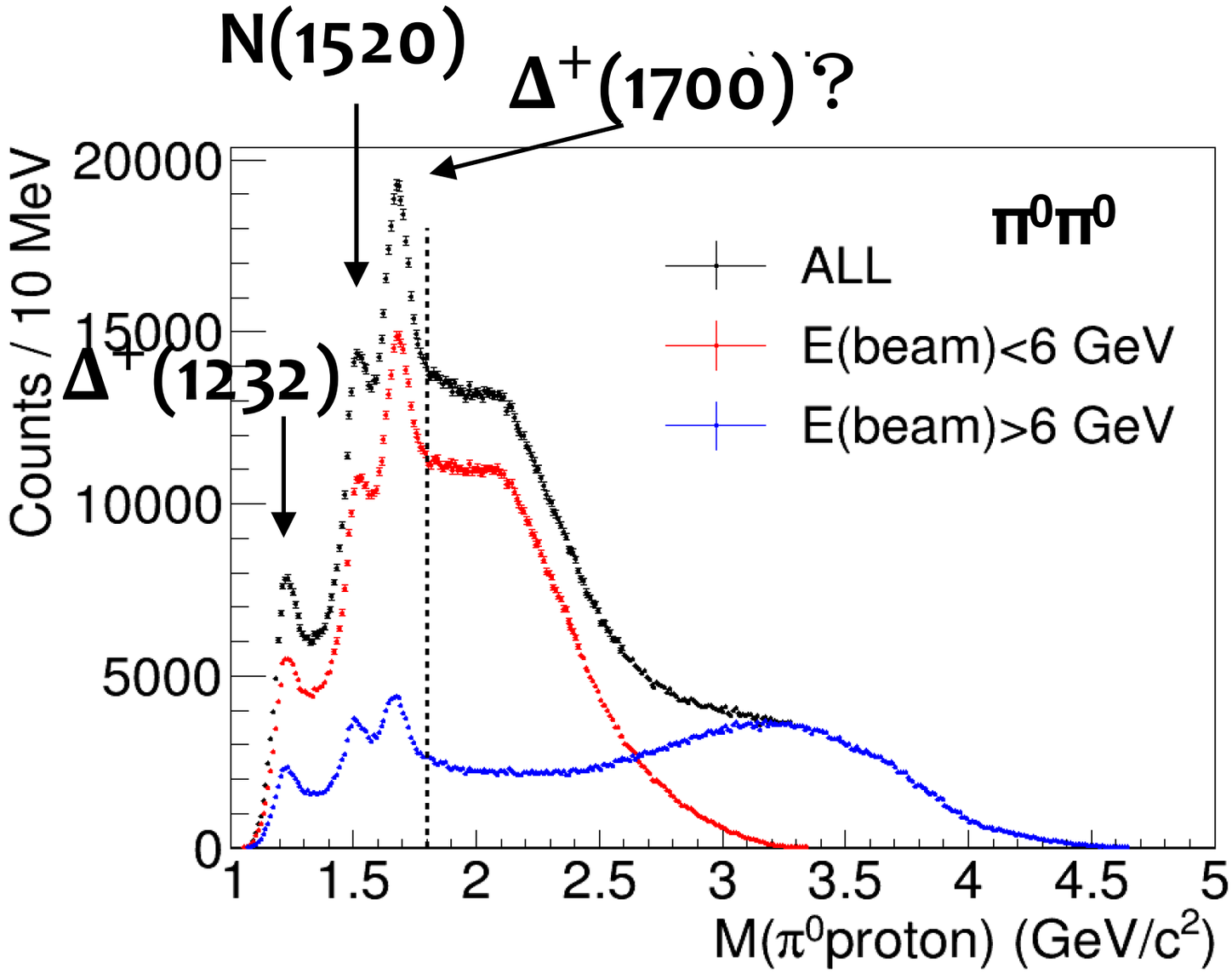
E852 π^-+p→η+π^0+n

https://arxiv.org/abs/hep-ex/0612062



More challenge on the background study

The baryon backgrounds



Moment analysis for di-pseudoscalar-meson photoproduction

The moments of the di-pion angular distribution defined as

$$< Y_{LM} > (E_\gamma, t, M_{\pi\eta}) = \sqrt{4\pi} \int d\Omega_\pi \frac{d\sigma}{dt dM_{\pi\eta} d\Omega_\pi} Y_{LM}(\Omega_\pi)$$

Ω_π : the polar and azimuthal angles of the π^0 flight direction in the $\pi^0\eta$ helicity rest frame

Y_{LM} : is the spherical harmonic of degree L and order M

Measured angular distribution corrected by the detector acceptance

Extraction of the moments via likelihood fit of experimental data

Two approaches:

parametrization with amplitudes/moments

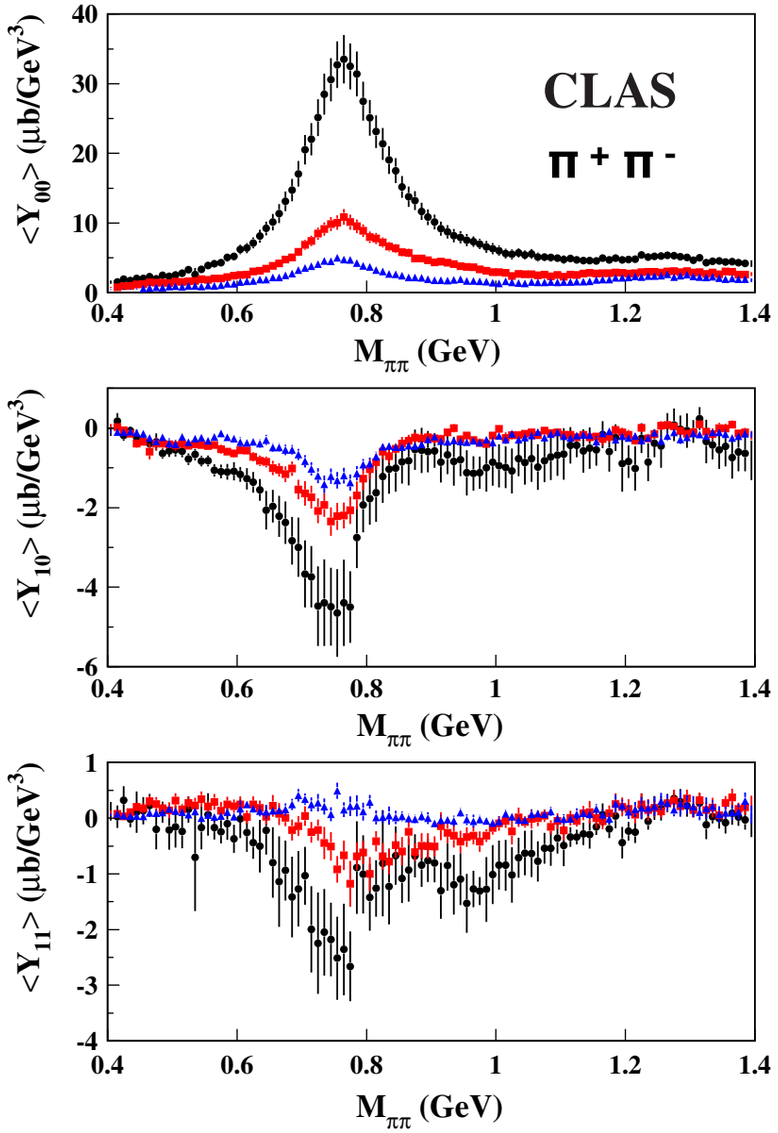


FIG. 4 (color online). Moments of the di-pion angular distribution in $3.2 < E_\gamma < 3.4$ GeV and $-t = 0.45 \pm 0.05$ GeV^2 (black dots), $-t = 0.65 \pm 0.05$ GeV^2 (red squares) and $-t = 0.95 \pm 0.05$ GeV^2 (blue trianges). The error bars include both the statistical and systematic uncertainties as explained in the text.

PHYSICAL REVIEW D 80, 072005 (2009)

Results can be used as the input of $a_0(980)$ beam asymmetry analysis

Summary and Outlook

- A broad meson photoproduction project at GlueX is under way, including beam asymmetries, cross sections and spin density matrix elements analysis.

- The linearly polarized photon beam asymmetry Σ for π^0/η photoproduction have measured.

- A detailed survey of the multi-photon processes is performed deeply.

- The moment analysis for di-pseudoscalar-meson photoproduction and the beam asymmetry studies of scalar mesons are in progress.

Thanks!

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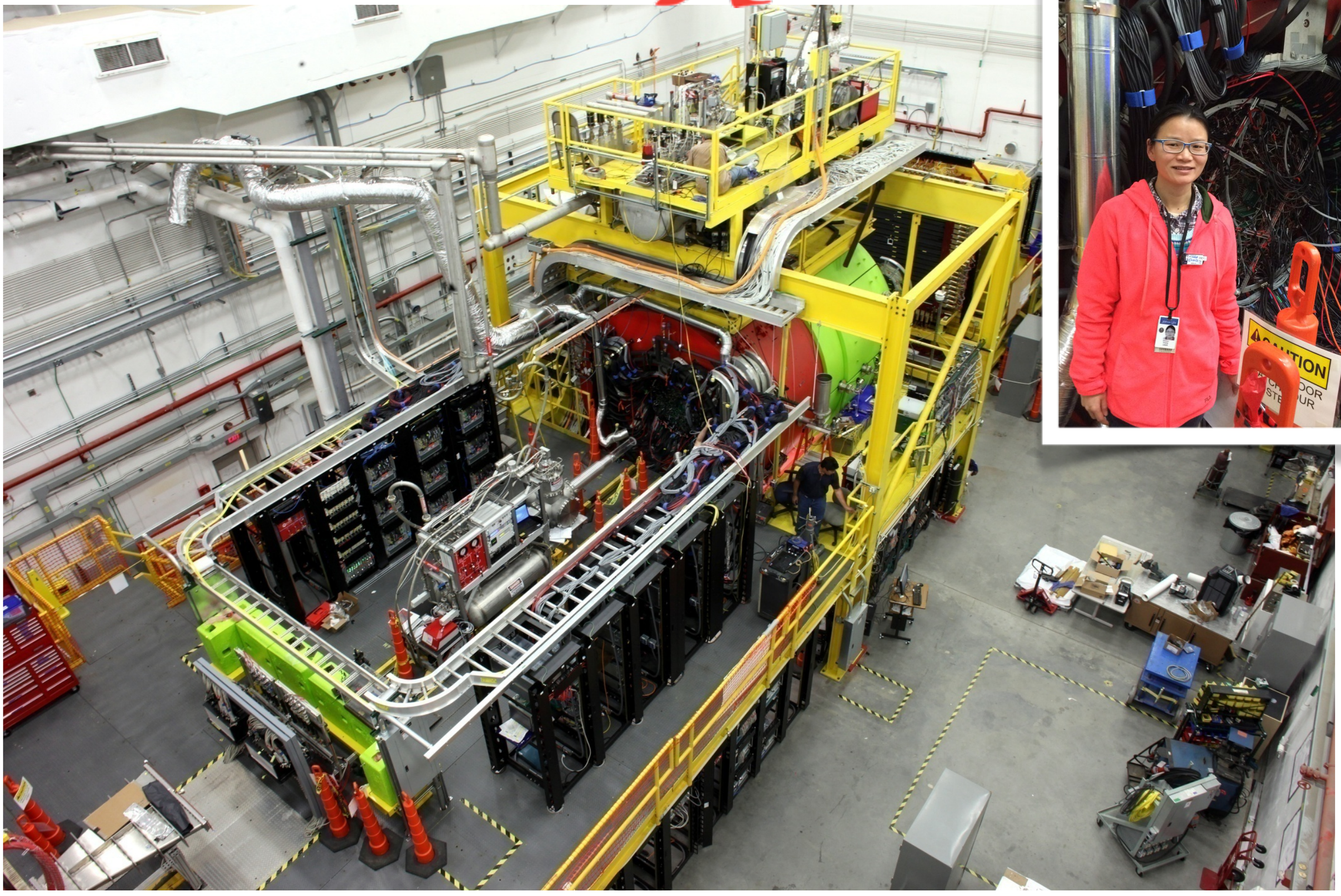
Back up



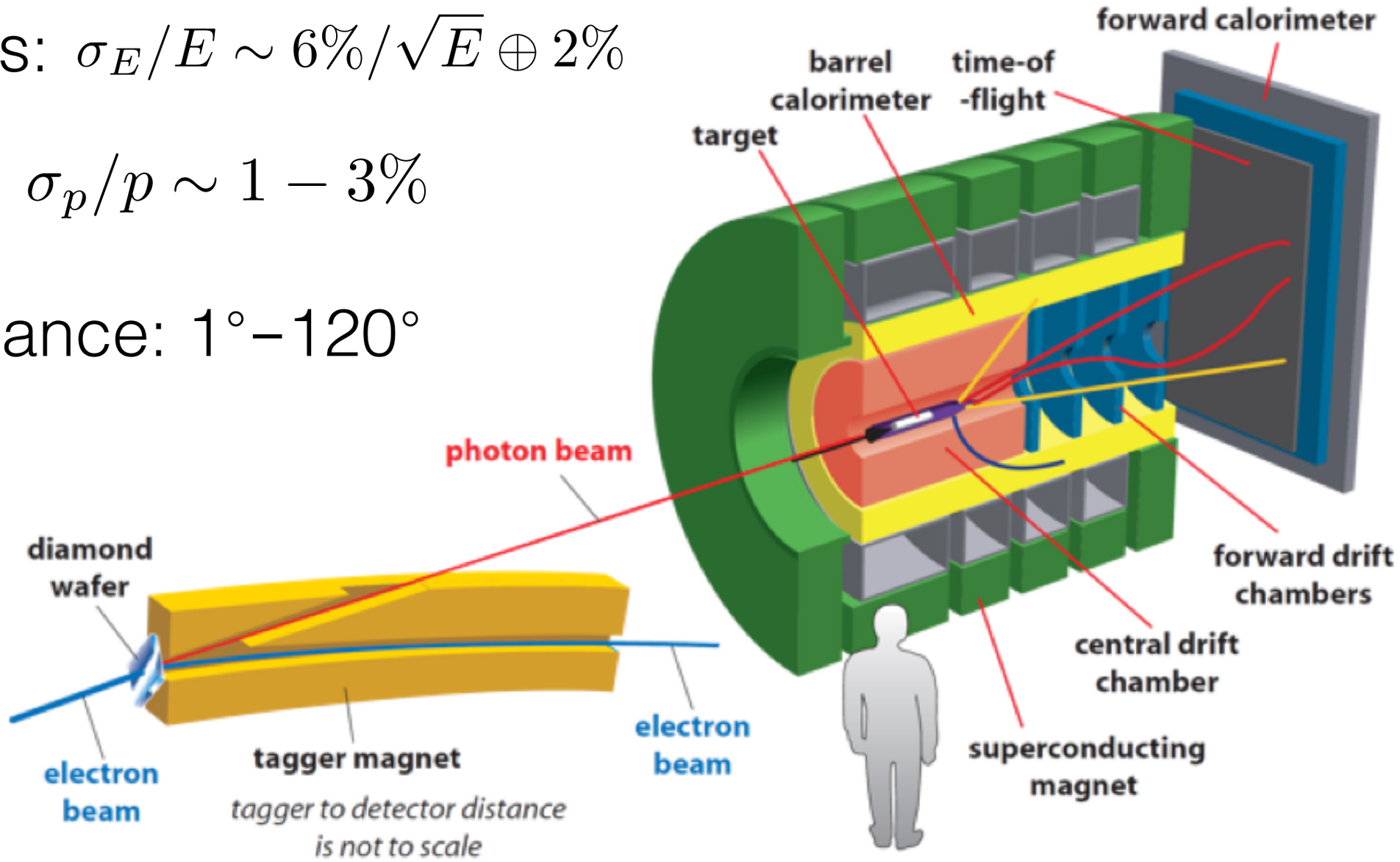
GlueX Detector

Detector resolutions:

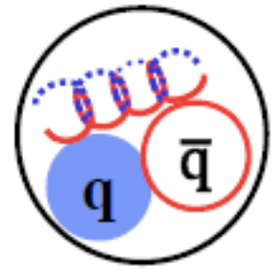
Photons: $\sigma_E/E \sim 6\%/\sqrt{E} \oplus 2\%$

Tracks: $\sigma_p/p \sim 1 - 3\%$

Receptance: 1°–120°



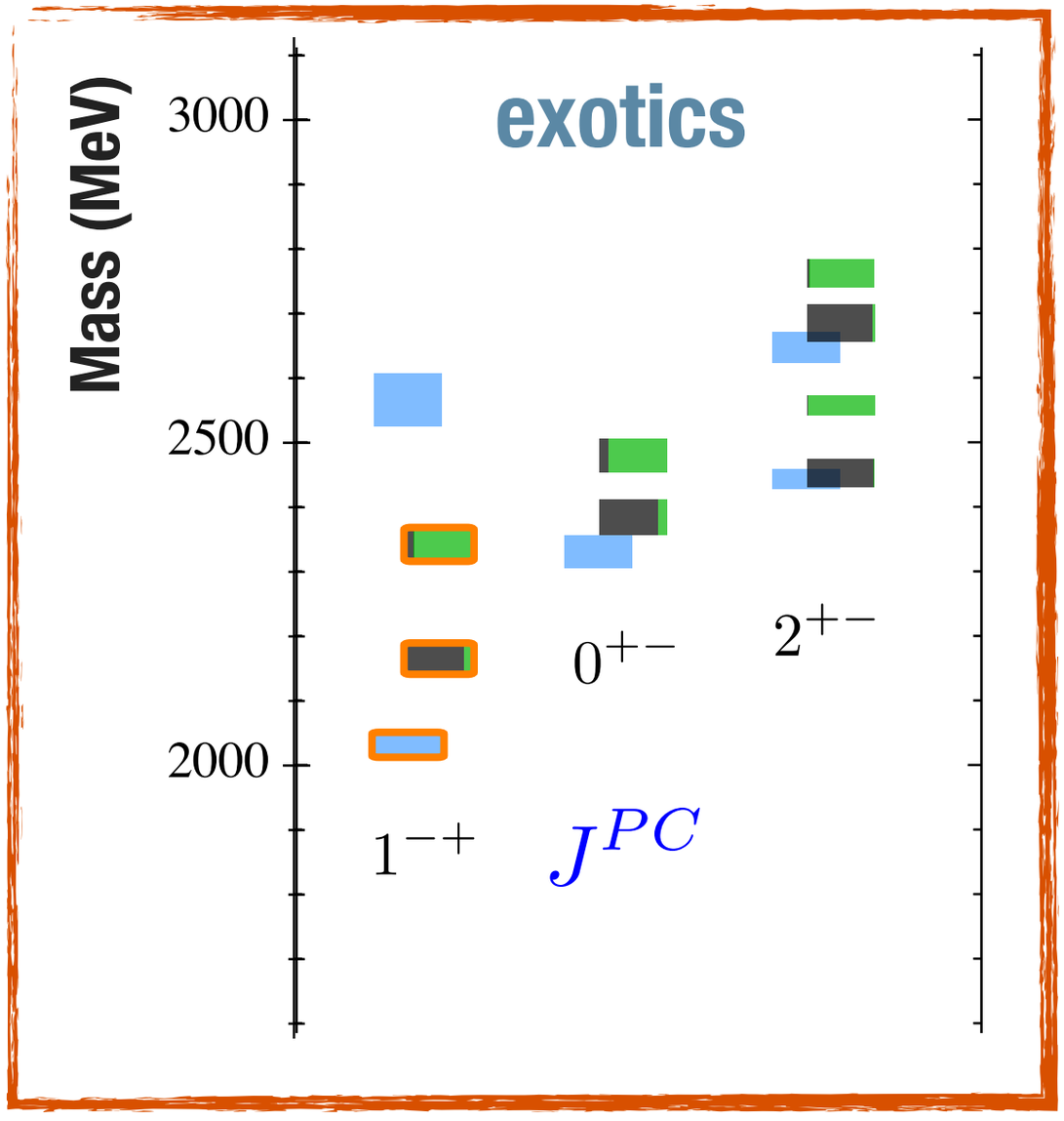
Search for exotic hybrids



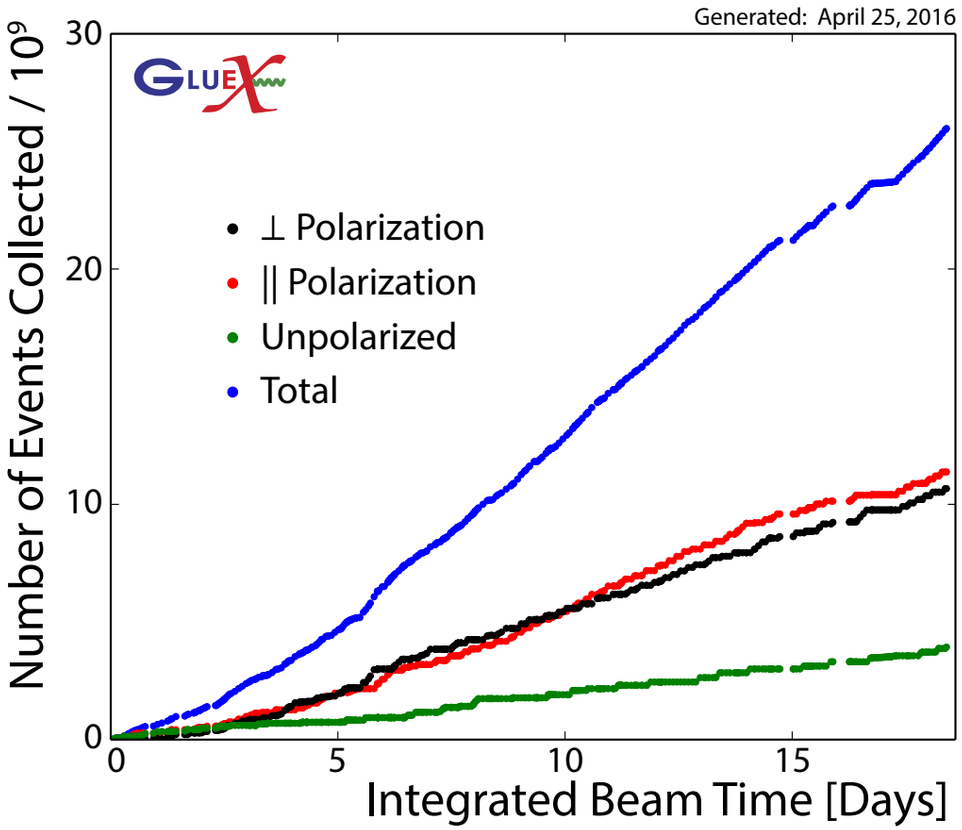
Evidence exists for $J^{PC}=1^{-+}$ amplitudes, but interpretation clearly not conclusive

Search for a pattern of hybrid states in many final states

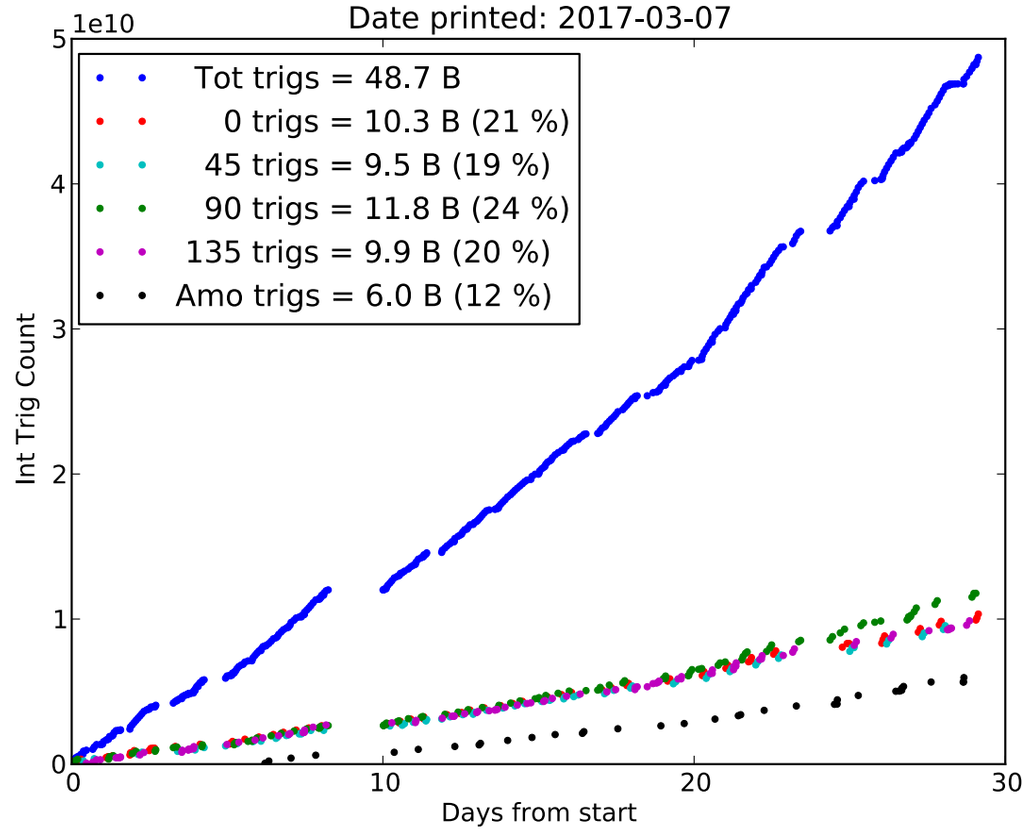
Approximate Mass (MeV)	J^{PC}	Final States
π_1	1900	1^{-+}	$\omega\pi\pi^\dagger$, $3\pi^\dagger$, 5π, $\eta 3\pi^\dagger$, $\eta'\pi^\dagger$
η_1	2100	1^{-+}	4π, $\eta 4\pi$, $\eta\eta\pi\pi^\dagger$
η_1'	2300	1^{-+}	$KK\pi\pi^\dagger$, $KK\pi^\dagger$, $KK\omega^\dagger$
b_0	2400	0^{+-}	4π
h_0	2400	0^{+-}	$\omega\pi\pi^\dagger$, $\eta 3\pi$, $KK\pi\pi$
h_0'	2500	0^{+-}	$KK\pi\pi^\dagger$, $\eta 3\pi$
b_2	2500	2^{+-}	4π, $\eta\pi\pi^\dagger$
h_2	2500	2^{+-}	$\omega\pi\pi^\dagger$, $3\pi^\dagger$
h_2'	2600	2^{+-}	$KK\pi\pi^\dagger$, $KK\pi^\dagger$



Spring 2016:
Detector commissioning and engineering runs



Spring 2017:
The first physics runs



GlueX-I [low-intensity]: 2017-18

Event Selection

- **Loose timing cuts**
- **Proton requirements:**
  - **p_{proton} > 250 MeV**
  - **Originates from target region**
  - **CDC dE/dx contour**
- **γp→pγγ cuts**
  - **Δϕ, Missing Mass squared, Missing energy, beam energy (E_γ>4.0GeV), only two photons reconstructed, Missing mass off proton, coherent beam energy(8.4<E_γ<9.0GeV)**