



The GlueX Experiment

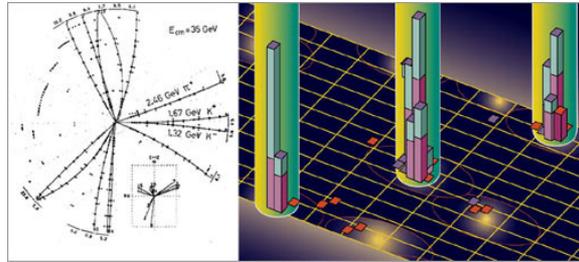
Curtis A. Meyer, GlueX Spokesperson

The Gluonic eXcitations Experiment

Outline

- All about gluons and GlueX Physics.
- The GlueX Experiment.
- Physics from GlueX.

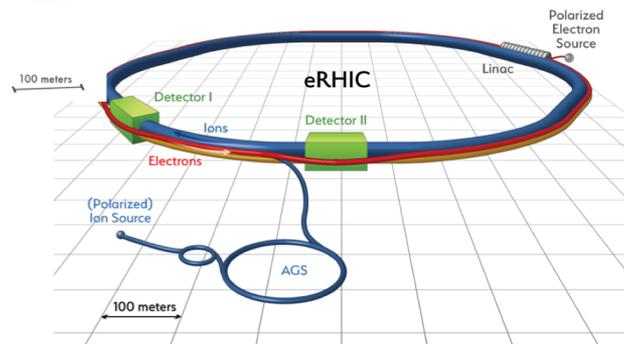
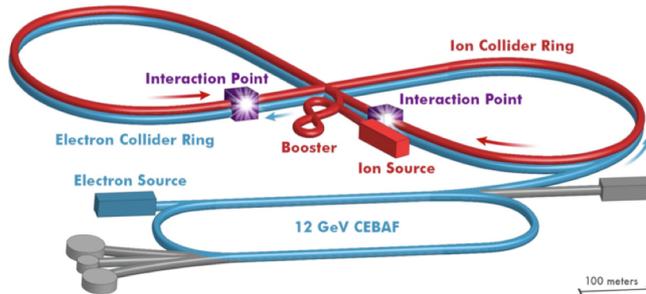
The Role of Glue.



3-jet event from PETRA (1979)

Three-jet events in e^+e^- collisions demonstrated the existence of gluons.

Glue is now recognized as a significant part of hadronic matter, making major contributions to the mass and spin of the proton.

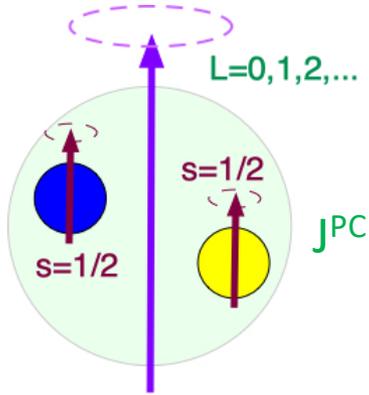


The Electron-Ion Collider, or EIC will collide electrons with nuclei and look deep inside the nucleus to reveal the role of gluons, the carriers of the strong force.

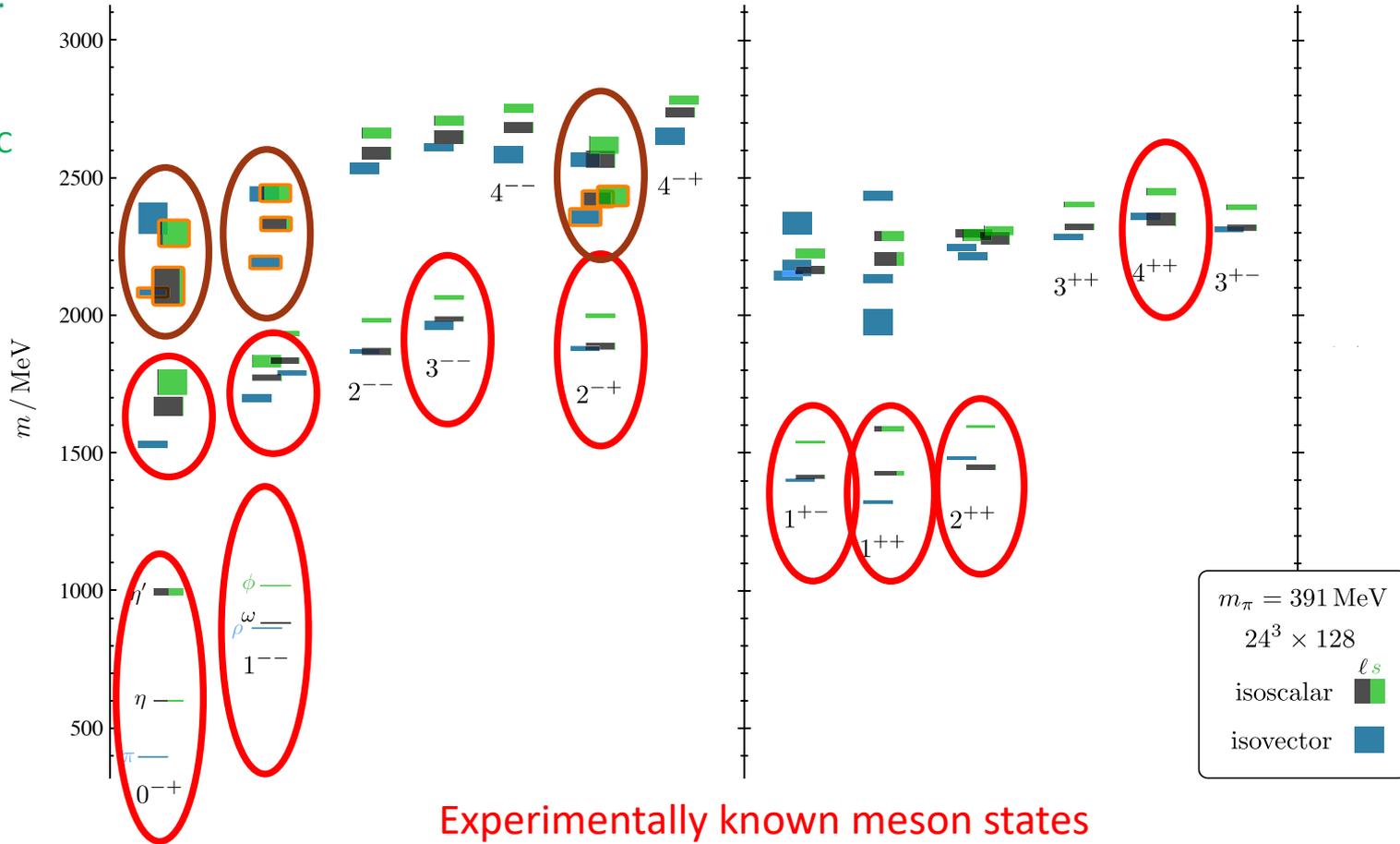
Understanding the role of glue in hadronic matter is a central theme of nuclear physics.

The Role of Glue.

Lattice QCD calculation of meson spectrum.



We know that mesons and baryons can be accurately described by constituent quarks being underlying degrees of freedom.

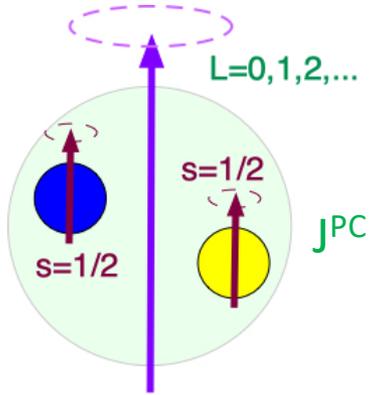


Experimentally known meson states
States whose assignment is not clear.

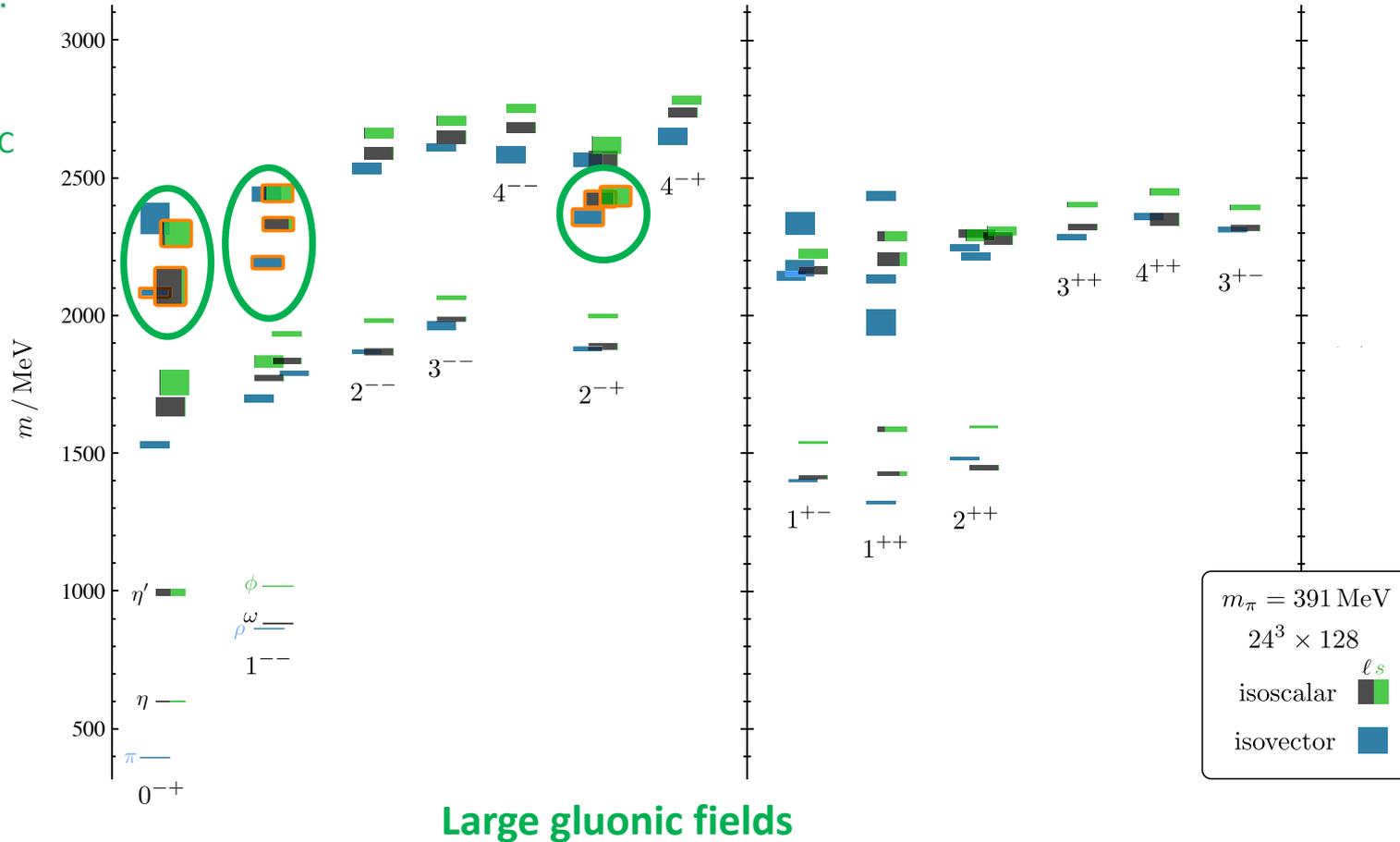
LQCD: Phys. Rev. D88, 094505 (2013).

The Role of Glue.

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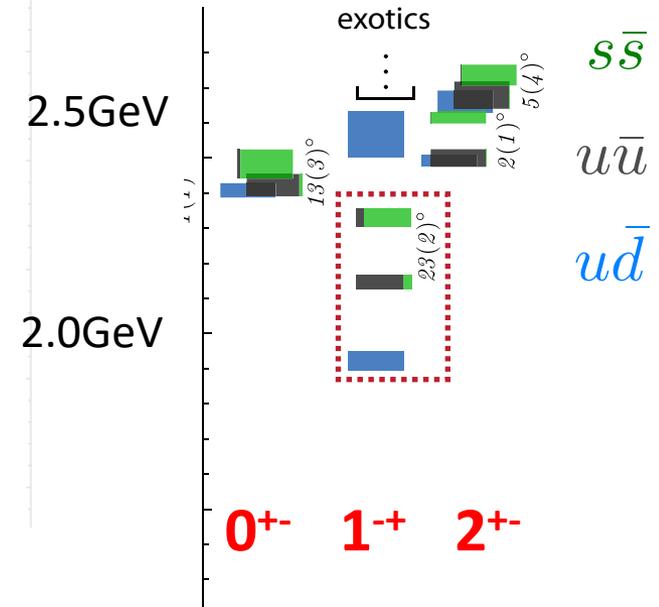
Large gluonic fields

Does glue manifest itself as an underlying degree of freedom in the hadronic spectrum?

The Role of Glue.



Lattice QCD



LQCD: Phys. Rev. D83, 111502 (2011)

Does glue manifest itself as an underlying degree of freedom in the hadronic spectrum?

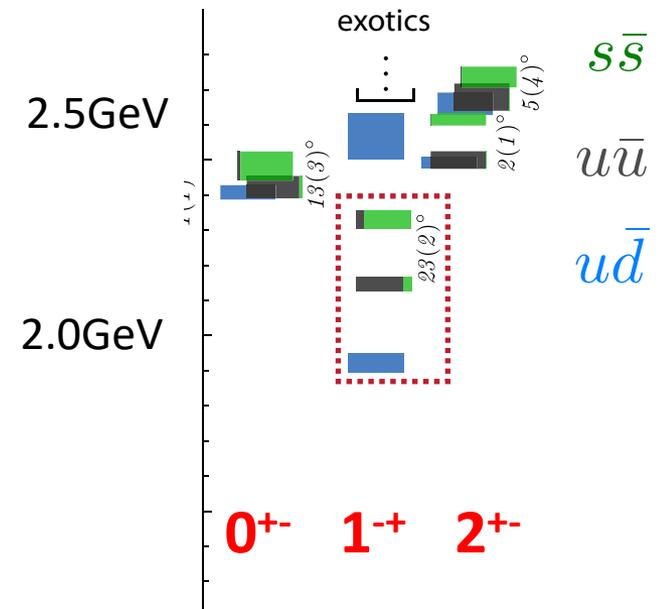
Exotic Hybrid Mesons

Lattice QCD suggests 5 nonets of mesons with exotic quantum numbers:

- 1 nonet of 0^{+-} exotic mesons
- 2 nonets of 1^{-+} exotic mesons
- 2 nonets of 2^{+-} exotic mesons

Lattice QCD results are consistent with the gluonic field behaving like a $J^{PC}=1^{+-}$ constituent with a mass $\sim 1-1.5 \text{ GeV}/c^2$.

Lattice QCD



Does glue manifest itself as an underlying degree of freedom in the hadronic spectrum?

Exotic Hybrid Mesons

Experimental evidence for a single state:

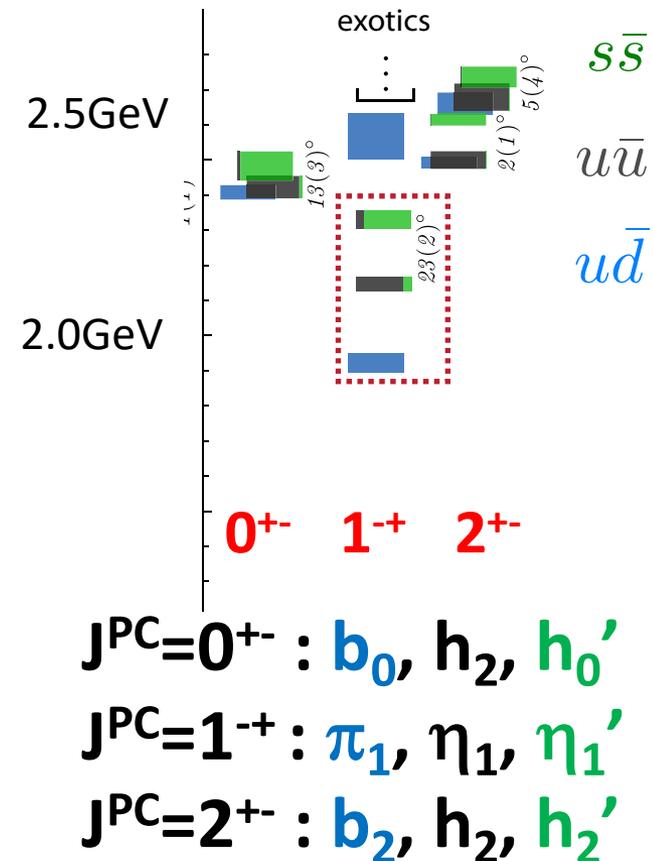
$$\pi_1(1600)$$

Reported in several experiments in several decay modes. Strongest signal in

$$\pi_1(1600) \rightarrow \eta' \pi$$

Where are the other states?

Lattice QCD

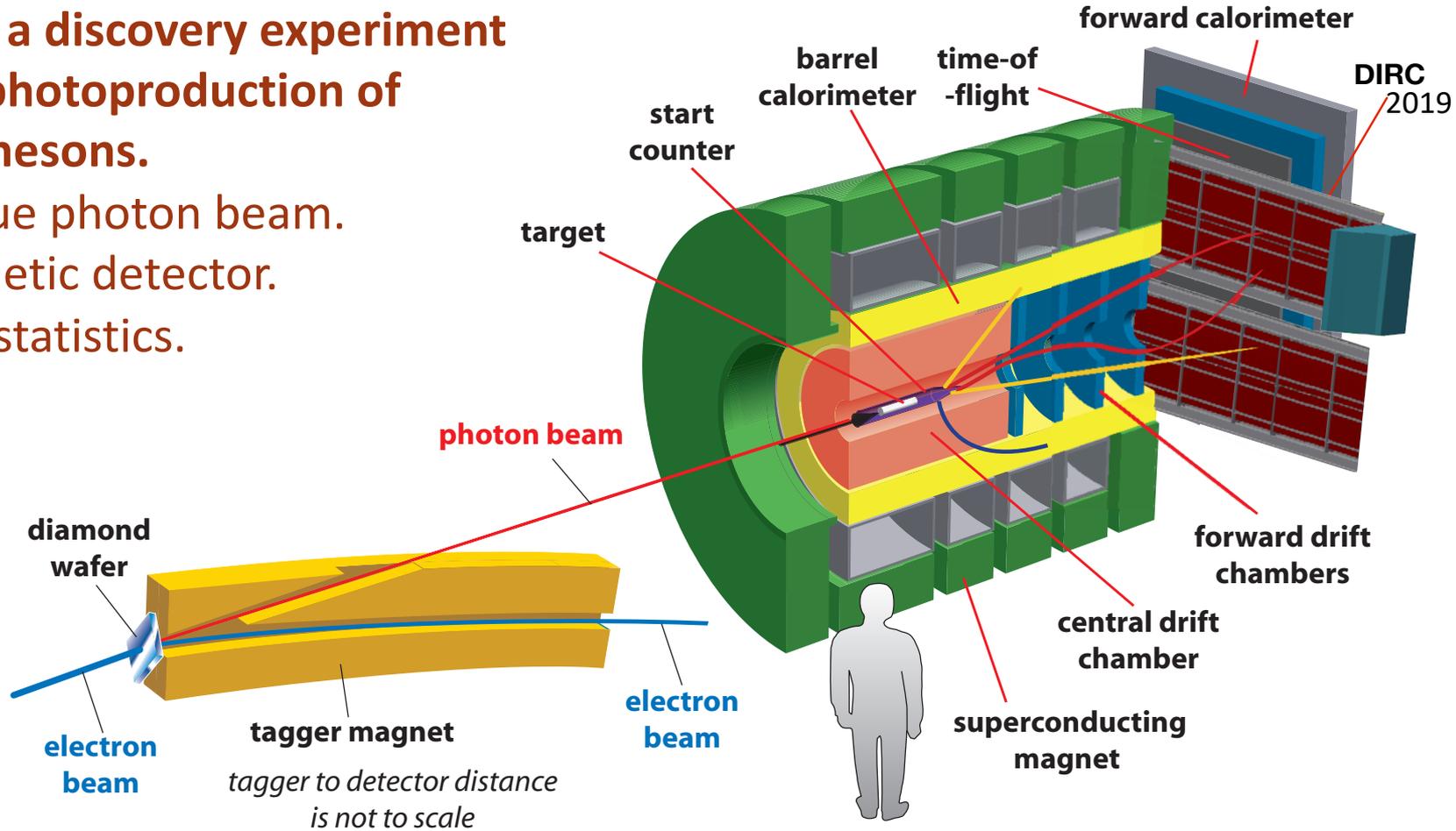


Does glue manifest itself as an underlying degree of freedom in the hadronic spectrum?

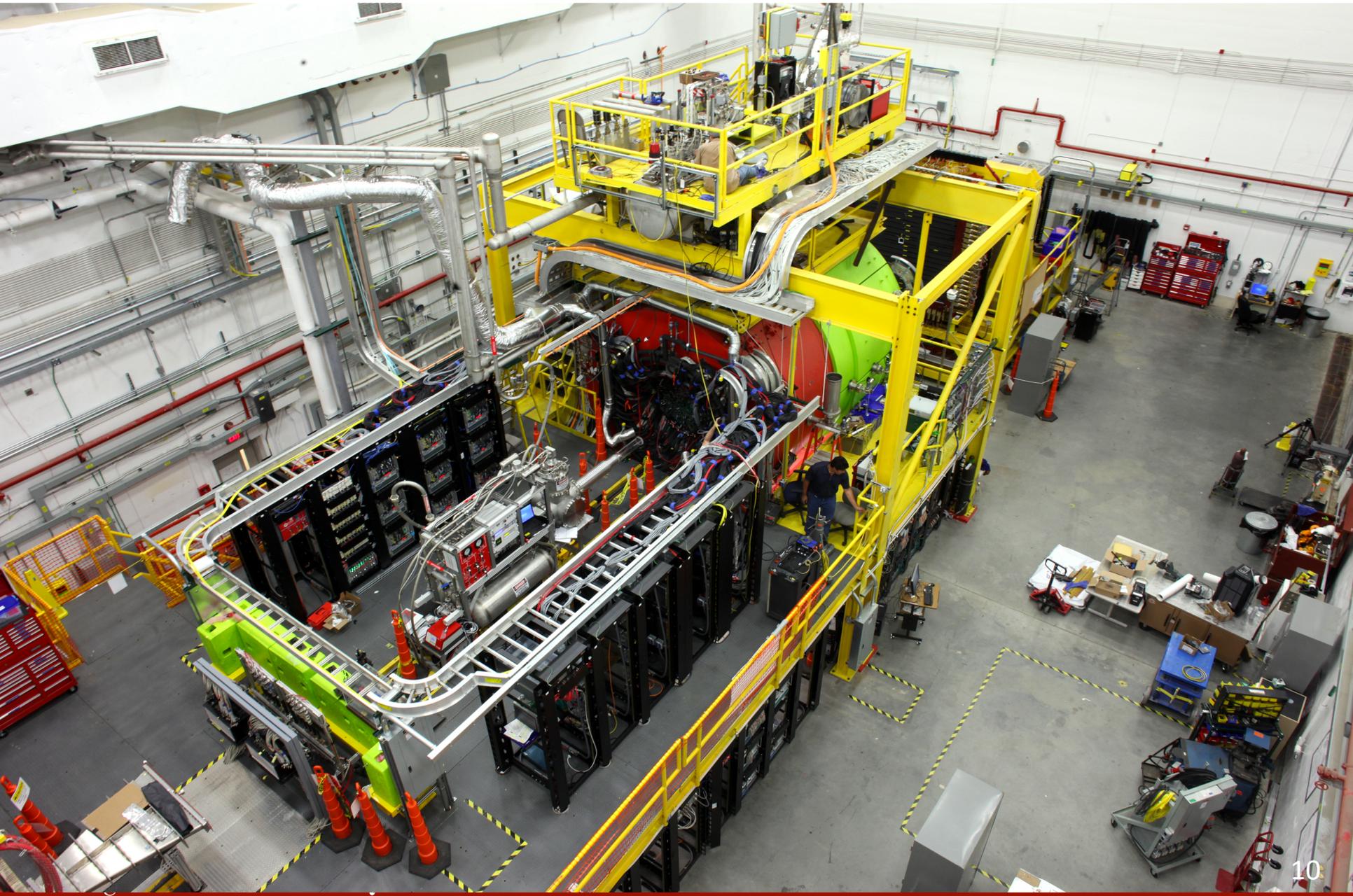
The GlueX Experiment

GlueX is a discovery experiment for the photoproduction of hybrid mesons.

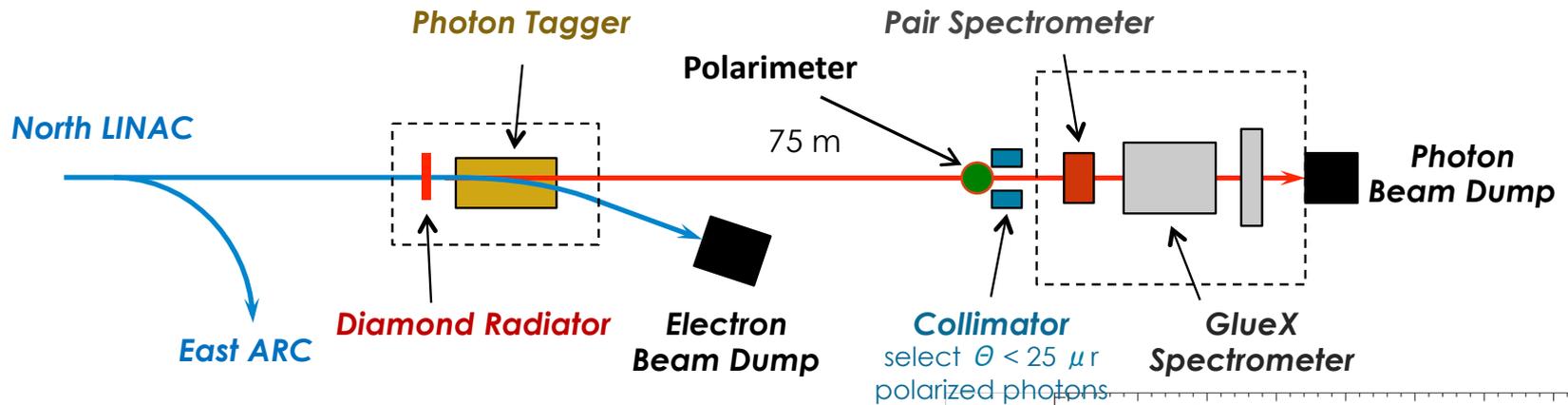
- Unique photon beam.
- Hermetic detector.
- High statistics.



Physics Running started in 2017



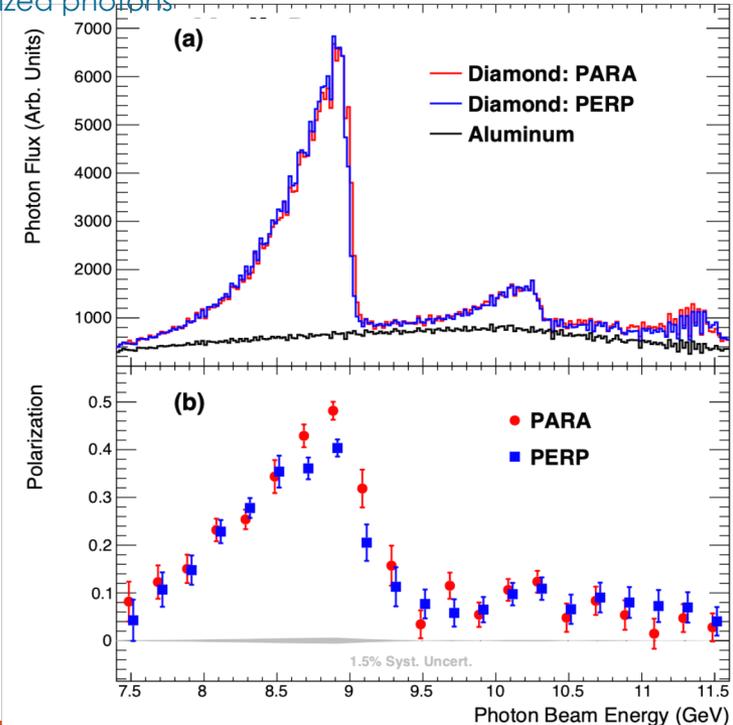
The GlueX Experiment



The Hall-D photon facility has unique capabilities.

12GeV electrons produce coherent bremsstrahlung on a 50 μm thick diamond wafer. Photons in the coherent peak are linearly polarized.

The beam is energy tagged, has its polarization measured, and the flux is determination close to the GlueX detector.



GlueX Running

Fall 2014 to Spring 2015: Detector & Beamline Commissioning

Phase I Running: 90 PAC days of physics

Spring 2016: Engineering Run

80 Hours of Physics-quality data

Spring 2017 to Fall 2018 – GlueX Physics (5PB)

20% of Phase I in Spring 2017

50% of Phase I in Spring 2018

30% of Phase I in Fall 2018

2019 and Beyond – GlueX Physics

Addition of forward kaon identification (DIRC) 2019

Phase II High-intensity running. Fall 2019



12 GeV Beam 1st delivered to Hall D, December 2015

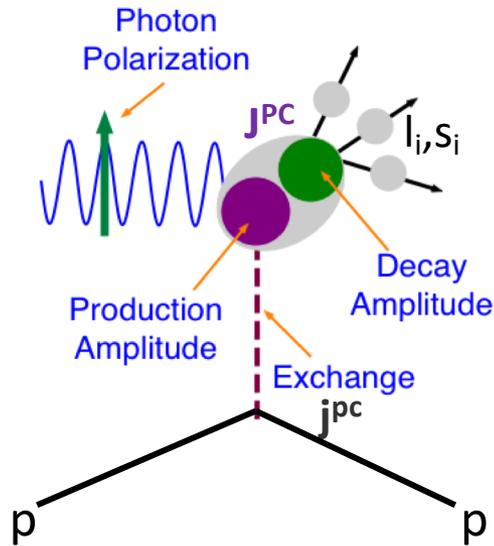
All detector systems are at or better than design specifications.

GlueX Data Processing

Spring 2016 & Spring 2017 (20% of data): active physics analysis.
Full Phase I data set available by Sept. 2019.

- Data taken through 2017 has been processed at JLab.
- 2018 Raw data are being processed at NERSC: 5PB -> 750 TB.
 - 44M hours at NERSC this year (almost enough for Spring 18 data).
- Processed data is skimmed at JLab to provide physics samples.
 - Users analyze physics samples at home institutions or JLab.
- Monte Carlo requested by web interface and automatically deployed on Open Science Grid (OSG).
 - GlueX Institutions are contributing compute resources to OSG.

Physics with GlueX

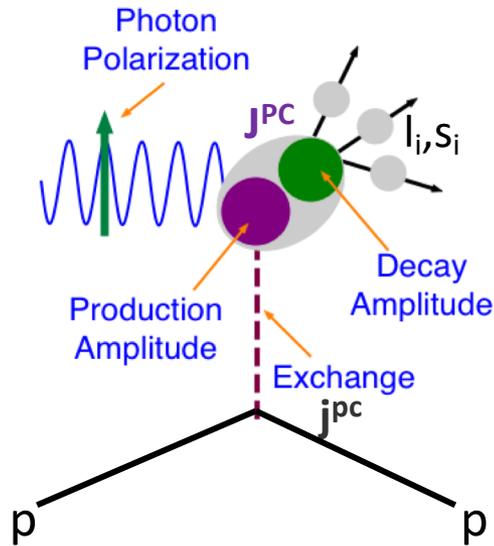


Production Amplitude produces a state X with J^{PC} quantum numbers and some polarization (density matrix, ρ).

Decay Amplitude describes the decay of X to final state particles. It is related to ρ and the spin and orbital angular momentum of the final-state particles.

Observables are the angular distributions of the final-state particles.

Physics with GlueX



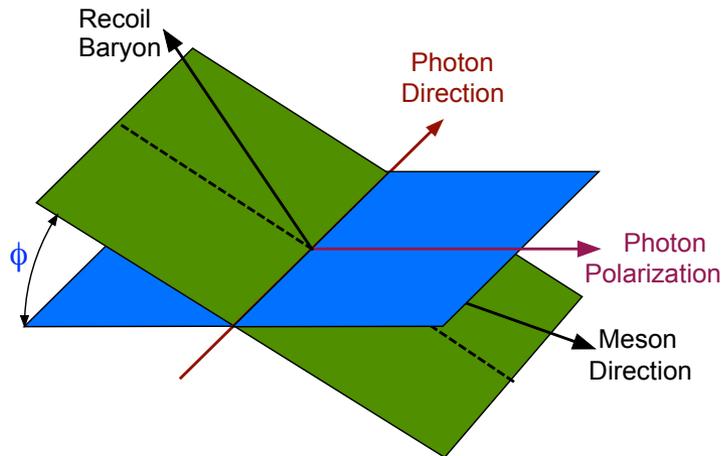
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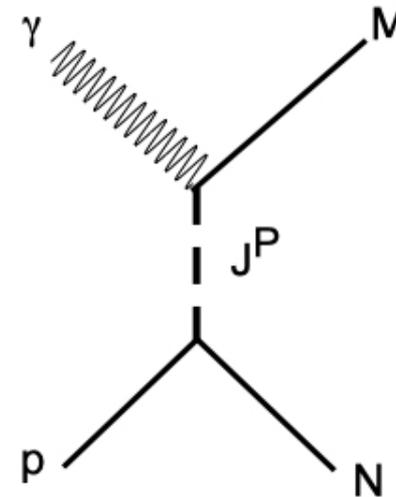
Beam Asymmetry Measurements

$\gamma p \rightarrow NM$



$$\sigma = \sigma_0 [1 - P_\gamma \Sigma \cos(2\phi - 2\phi_\gamma)]$$

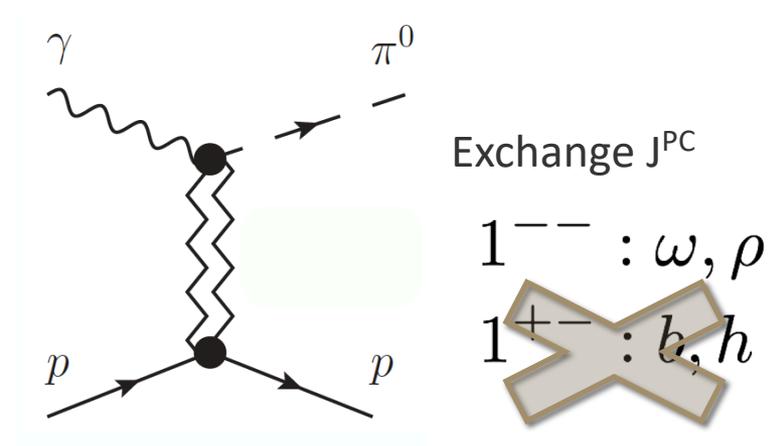
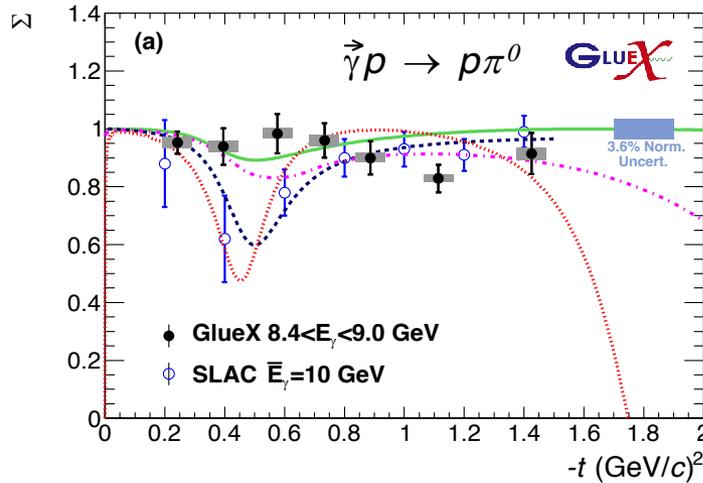
Effectively $\Sigma \propto \frac{N_\perp - N_\parallel}{N_\perp + N_\parallel}$



Σ is sensitive to the exchange J^P .

- Published π^0 and initial η results.
- More precise η , first η' , $\pi^- \Delta^{++}$ and $K^+ \Sigma^0$ are under collaboration review

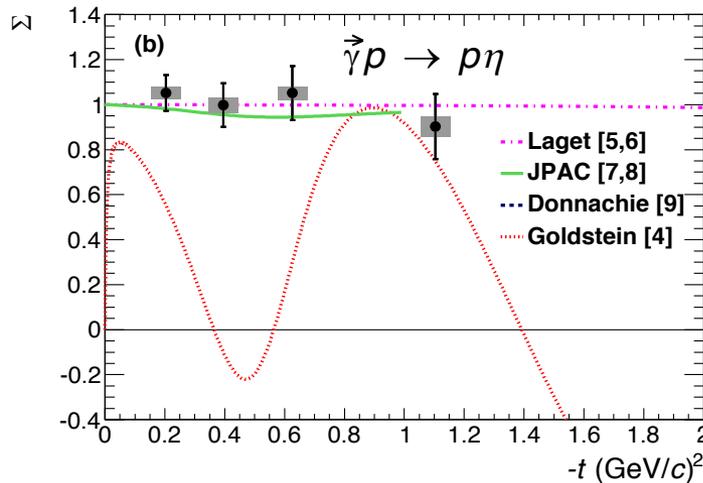
Beam Asymmetry Measurements



Impacts extraction of baryon resonances from low-energy photo production experiments.

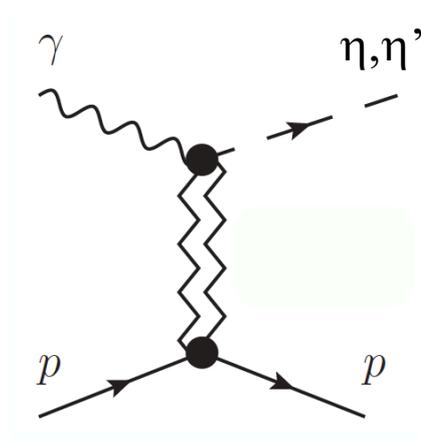
Understanding the meson production mechanisms at 9 GeV is needed for our hybrid searches.

Phys. Rev. C95, 042201 (2017)



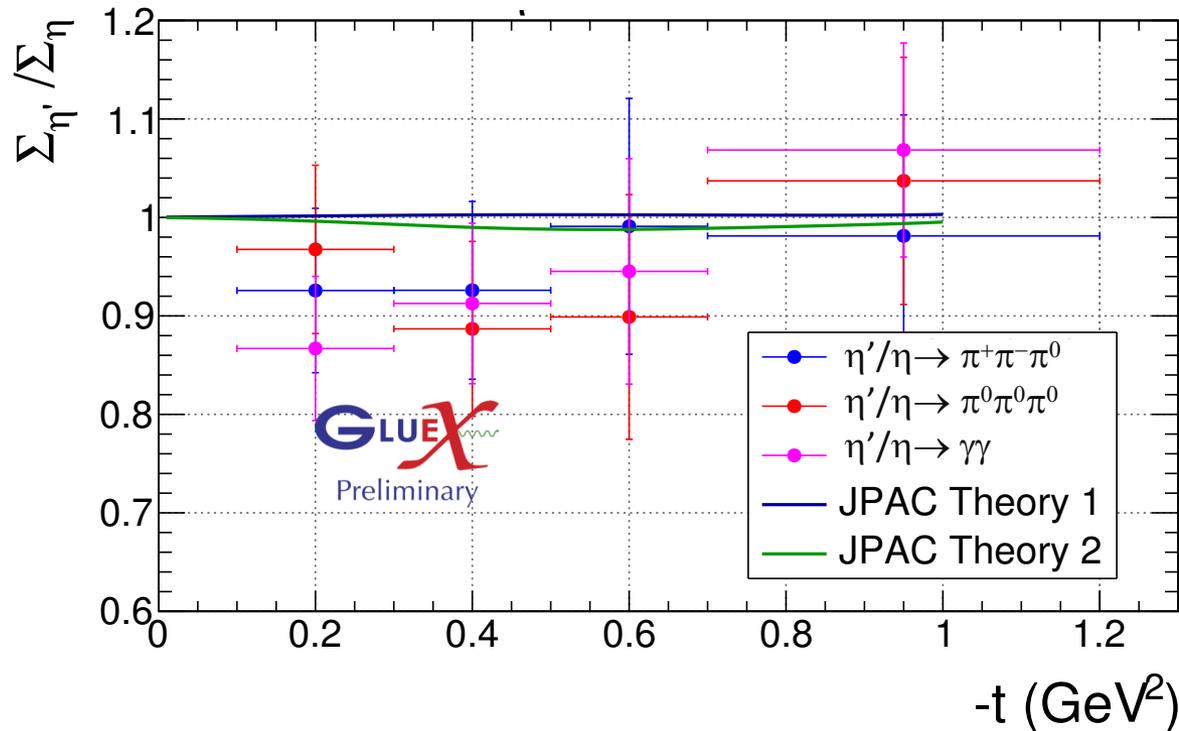
Beam Asymmetry Measurements

$\gamma p \rightarrow p \eta$ and $\gamma p \rightarrow p \eta'$



Vector mesons dominate the exchanges. $\Sigma_{\eta} = \Sigma_{\eta'}$ implies no $s\bar{s}$ exchanges.

Theory input is very important.



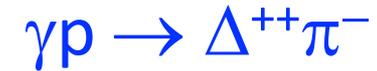
JPAC References:

Phys. Rev. D92, 074013 (2015).

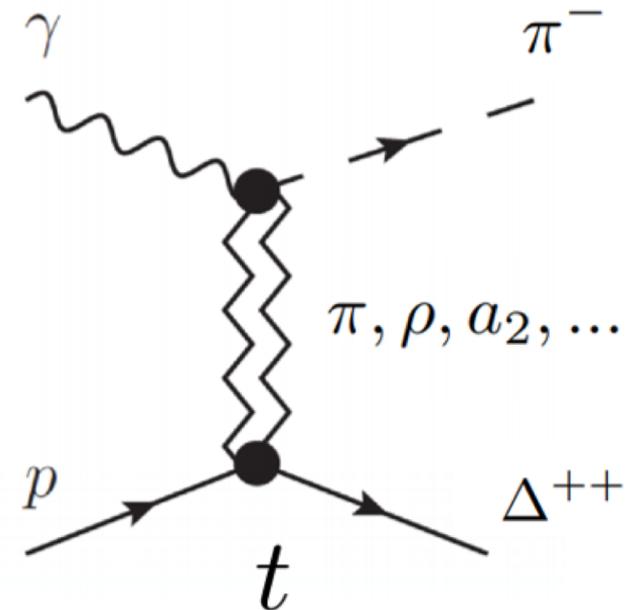
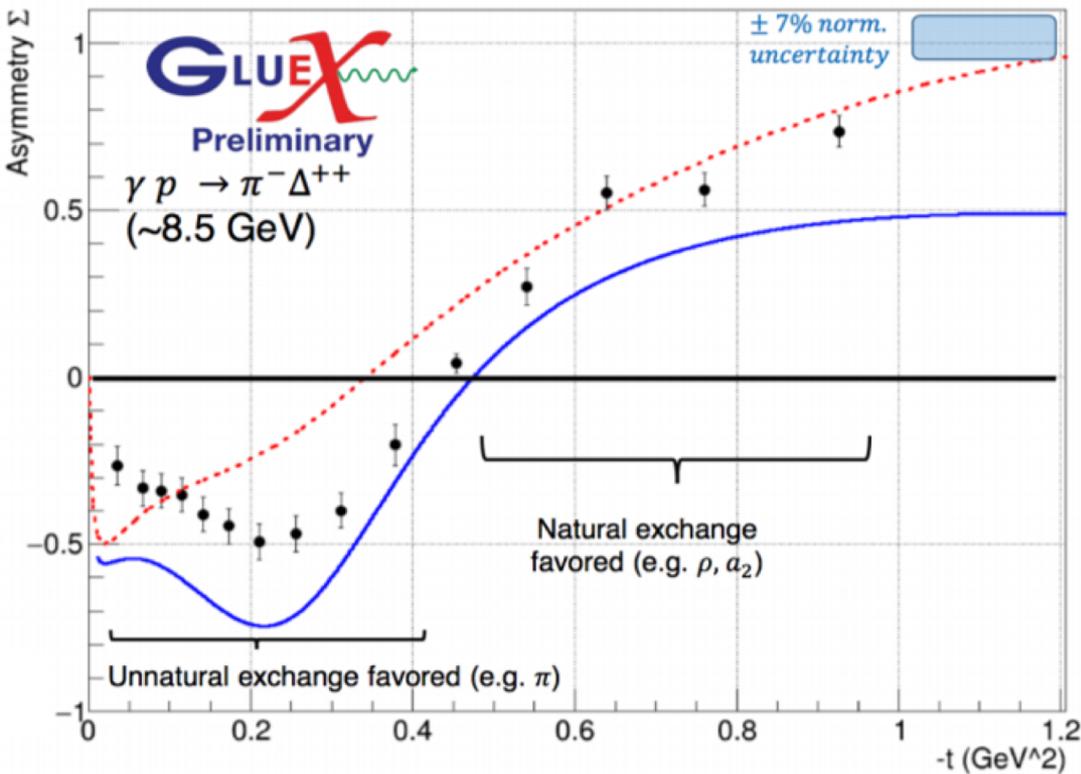
Phys. Lett B774, 362 (2017).

Under Collaboration Review for Publication

Beam Asymmetry Measurements



- - - B.G Yu (Korea Aerospace U.), PLB **769** 262 (16 GeV)
- J. Nys (JPAC), PLB **779**, 77 (8.5 GeV)

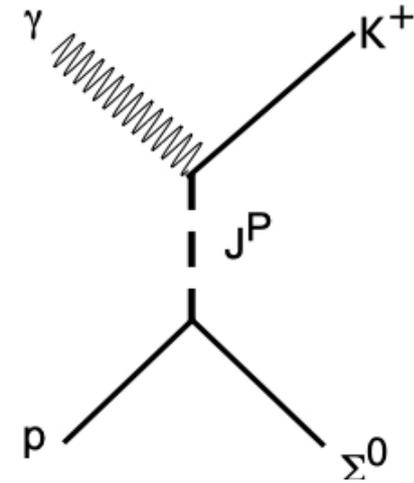
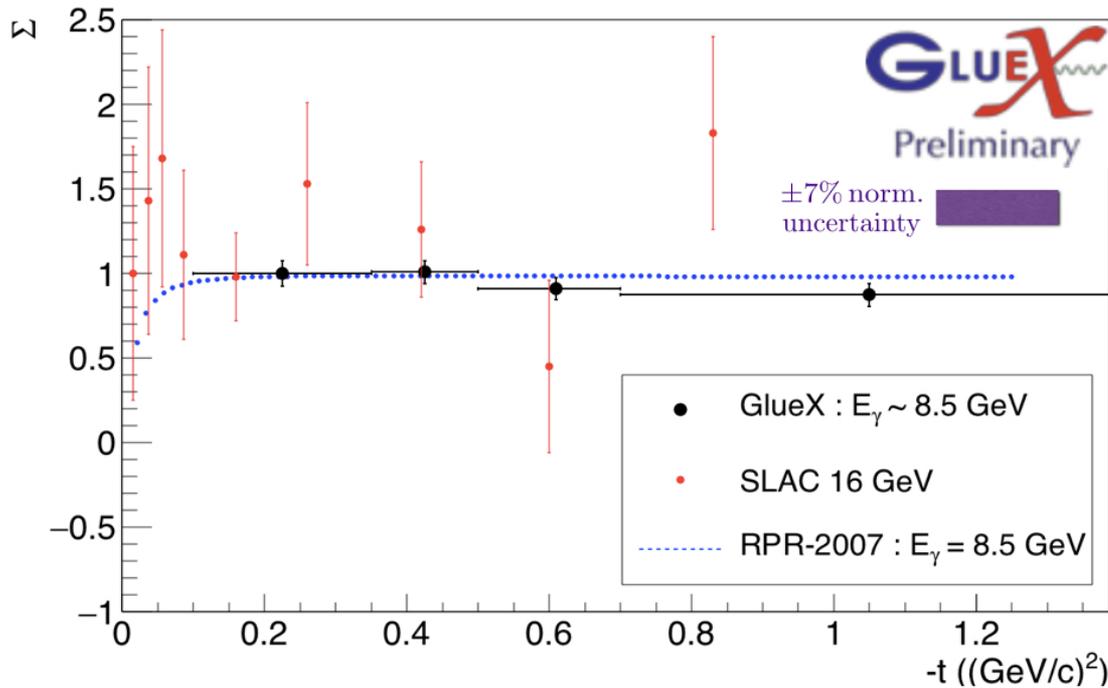


Under Collaboration Review for Publication

Beam Asymmetry Measurements

$$\gamma p \rightarrow \Sigma^0 K^+$$

Appears that both t- and u-channel exchanges are involved.



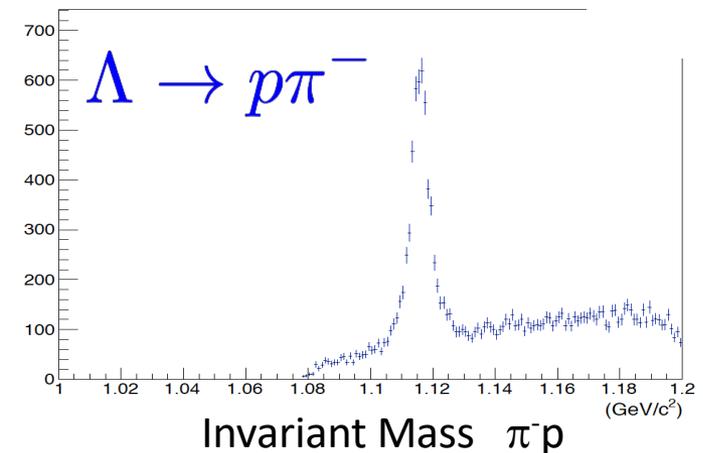
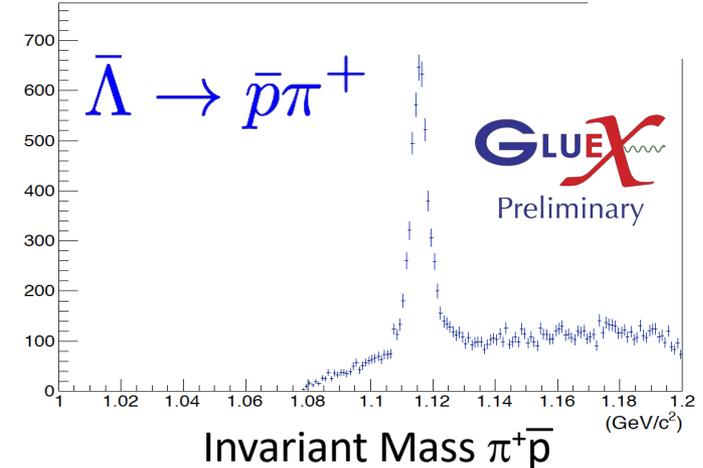
$\Sigma=1$ implies natural parity exchange

Opportunistic Physics

The polarized photon beam, acceptance and data-rate capabilities of GlueX combined with an open trigger lead to many opportunistic physics topics beyond spectroscopy. GlueX data is wide open for exploration.

- Photoproduction of antibaryons: \bar{p} , $\bar{\Lambda}$
- Ξ photoproduction (uss) and (dss) states appear as bumps.
- J/ψ cross section at threshold under collaboration review.

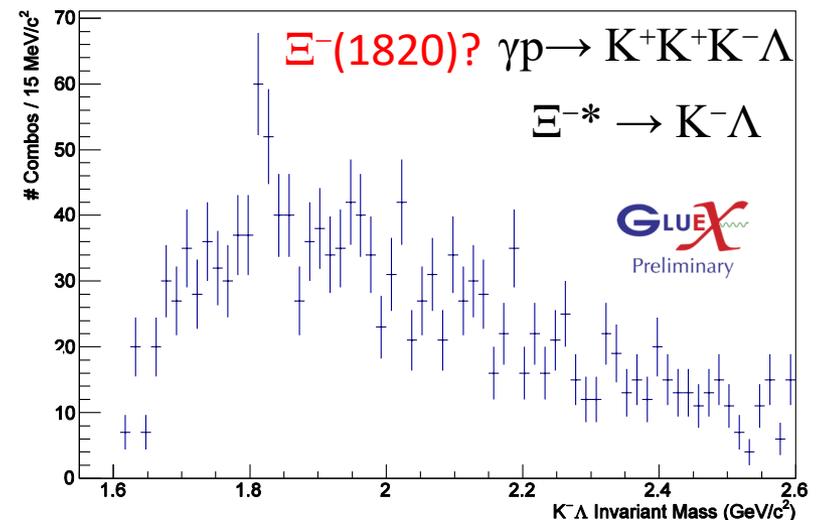
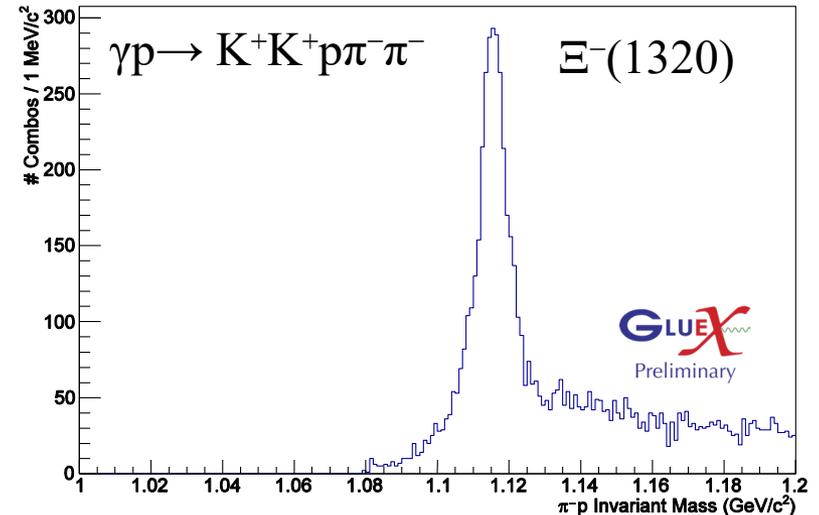
$$\gamma p \rightarrow p \Lambda \bar{\Lambda}$$



Cascade Baryons

- The spectrum of Ξ baryons is poorly known, with only 5 well determined states.
- High acceptance of GlueX allows the reconstruction of exclusive final states. This allows for determination of quantum numbers.
- Could potentially double our knowledge of these baryons.
- The $\Xi^-(1820)$ would be the first observation of an excited Ξ in photoproduction.

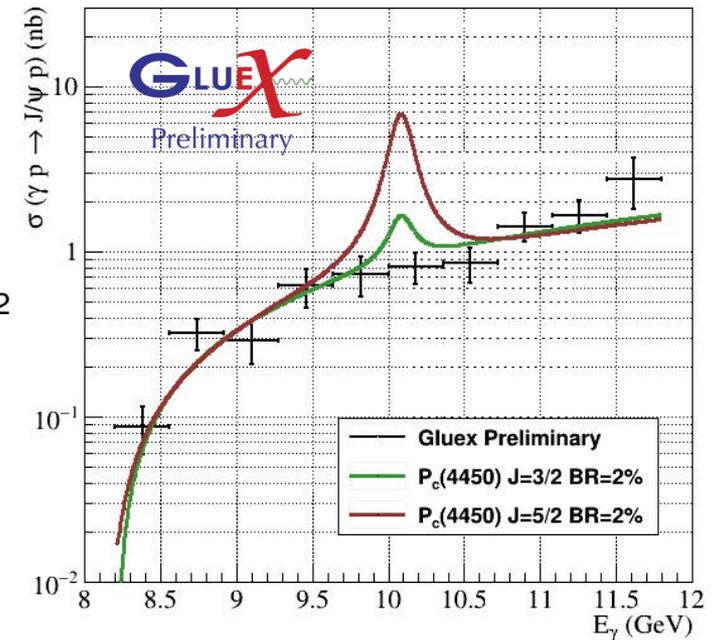
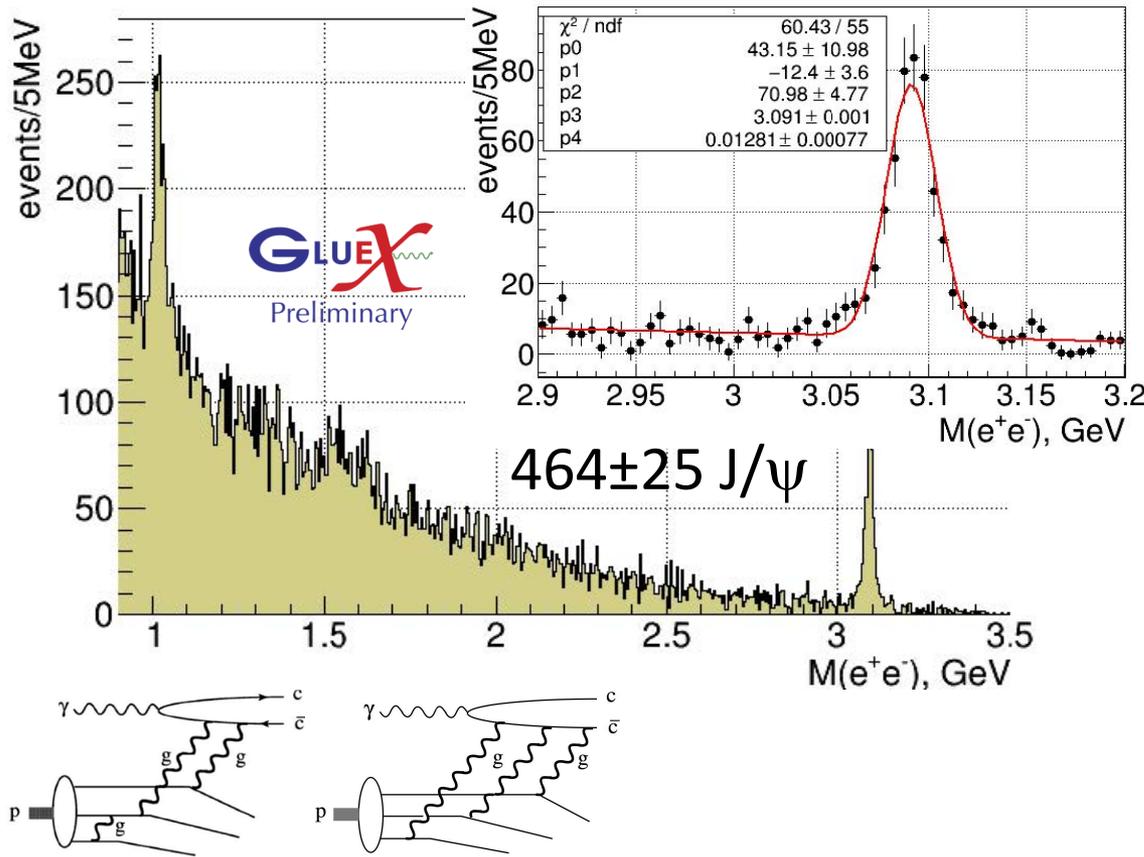
Need the full GlueX statistics



J/ψ Photoproduction

$$\gamma p \rightarrow p J/\psi$$

Detect J/ψ through its e⁺e⁻ decay



Upper limit on LHCb Pentaquark(s)

The two mechanisms have different energy dependences near threshold.

Final Stages of Collaboration Review

Vector Meson Photoproduction $\gamma p \rightarrow p(\rho, \omega, \phi)$

Spin-density matrix, ρ , describes the polarization of the produced vector meson.

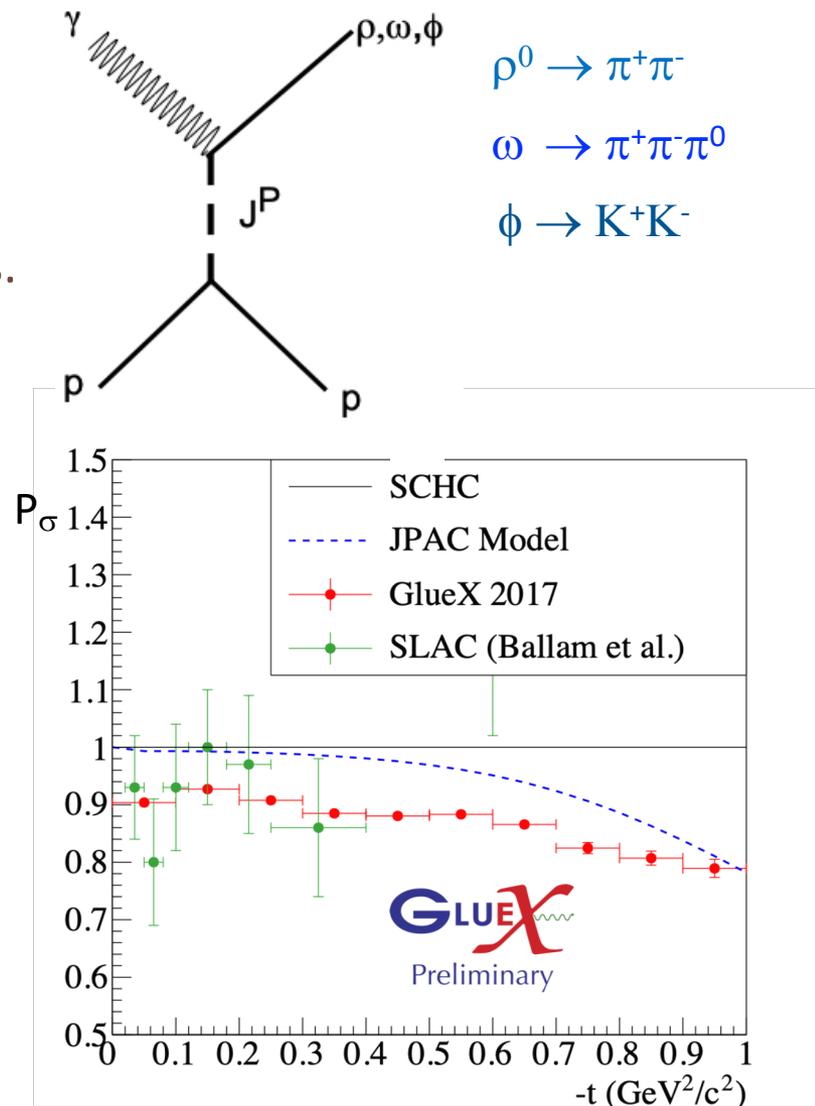
Extracted from the decay angular distributions.

With linearly polarized photons, we can measure 9 of the 36 real values.

All observables are linear combinations of the SDME elements. P_σ is the difference of two ρ elements and measures the degree of natural parity exchange.

SLAC: Phys. Rev. D7, 3150 (1973).

JPAC: Phys. Rev. D97 094003 (2018).



The Search for Hybrids

GlueX is a discovery experiment utilizing a unique beam, hermetic detector, very sophisticated analyses.

GlueX will produce very large statistics in unexplored reactions.

A detailed understanding of the detector performance is crucial.

Full GlueX statistics are necessary.

Most exotic hybrid mesons could be photoproduced. GlueX can exclusively reconstruct many relevant final states.

Initial Searches:

$\pi_1(1600) \rightarrow \eta' \pi$ (known state)

$\pi_1(1600) \rightarrow \rho \pi$

$\eta_1 \rightarrow \eta \pi \pi$ (isospin partner)

$\eta'_1 \rightarrow K^* K$ (isospin partner)

$b_2 \rightarrow \eta \pi \pi$ (other nonet)

$b_2 \rightarrow \omega \pi$ (other nonet)

$b_2 \rightarrow \rho \pi$ (other nonet)

Preliminary studies of these channels indicate interesting signals are present.

The Search for Hybrids

GlueX is a discovery experiment utilizing a unique beam, hermetic detector, very sophisticated analyses and generating very large data sets.

A detailed understanding of the detector performance is crucial.

Full GlueX statistics are necessary.

Photoproduction in GlueX could produce most exotic hybrid mesons and GlueX can exclusively reconstruct relevant final states.

Initial Searches:

$$\pi_1(1600) \rightarrow \eta' \pi \quad (\text{known state})$$

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$$b_2 \rightarrow \omega \pi \quad (\text{other nonet})$$

$$b_2 \rightarrow \rho \pi \quad (\text{other nonet})$$

From preliminary studies of these channels, we expect sufficient statistics.

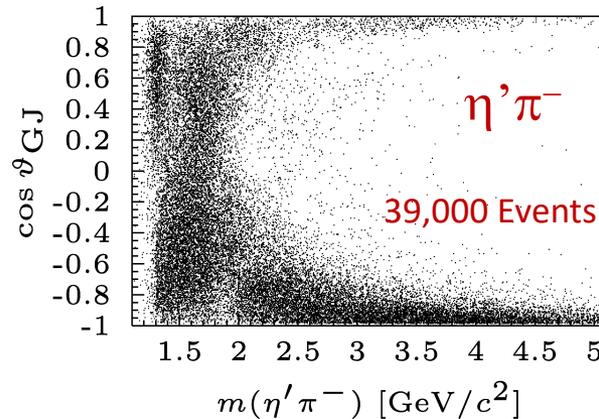
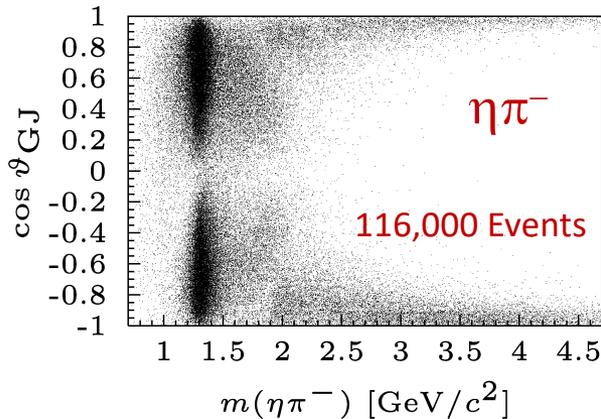
Interesting Hybrid Channels



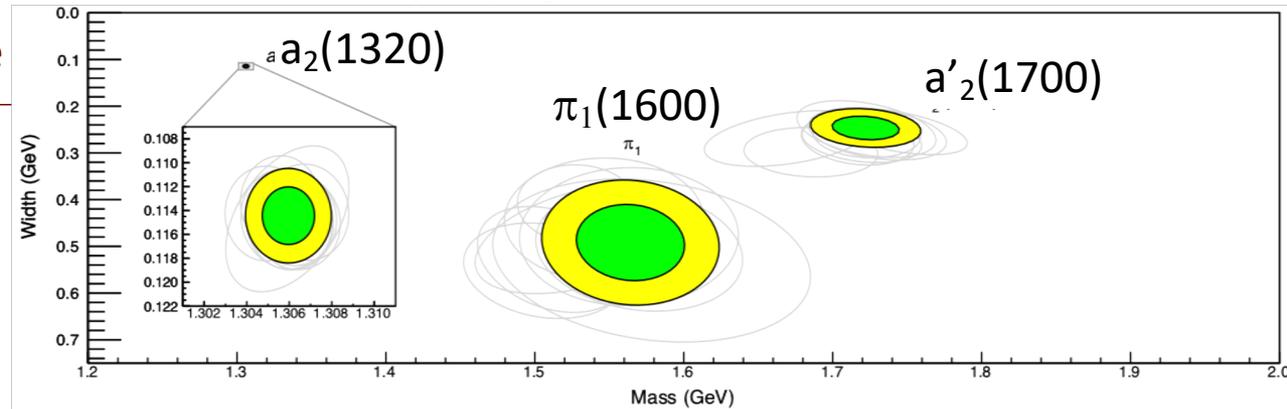
JPAC: Extracted the pole position of the $\pi_1(1600)$ from the COMPASS amplitudes.

Mass: $1564 \pm 24 \pm 86$ MeV
Width: $492 \pm 54 \pm 102$ MeV

Highest statistics on $\pi_1(1600) \rightarrow \eta' \pi$ from COMPASS



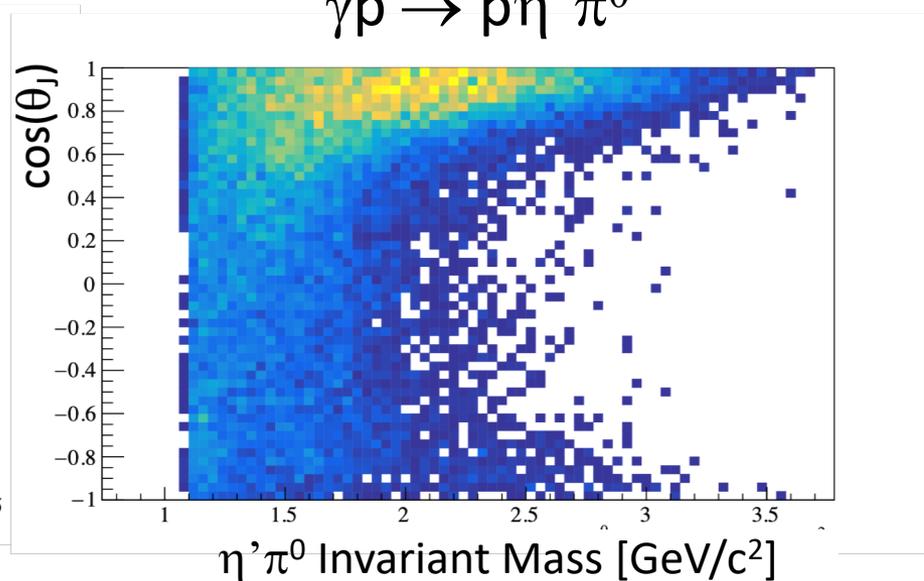
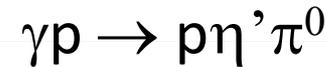
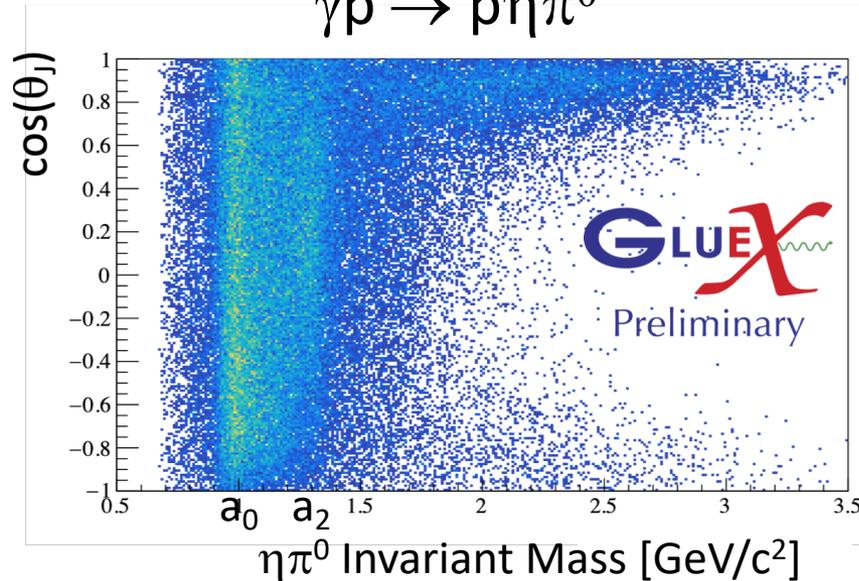
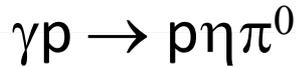
COMPASS: strong exotic wave in the $\eta' \pi^-$, but not in the $\eta \pi^-$ data.



COMPASS: Phys. Lett. B 740, 303 (2015).

JPAC: Phys. Rev. Lett. 122, 042002 (2019).

Interesting Hybrid Channels First GlueX Hybrid Search



In same decay modes as COMPASS, GlueX will have 280,000 $\eta\pi^0$ and 52,000 $\eta'\pi^0$ events in the full data set (versus COMPASS with 116,000 & 39,000).

Charge exchange reaction is also being studied.



These analyses are underway, but will need the full data set.

GlueX Phase II

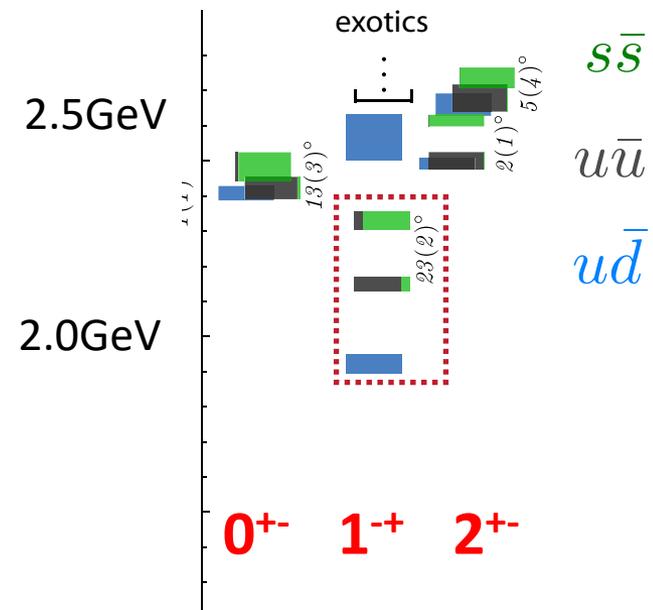
GlueX Phase II starts in fall 2019

- A factor of 2 in approved beam time.
- Three times the event rate.
- The GlueX DIRC: enhanced kaon identification.



This opens the full GlueX program to include **strange** particles and mixing angles.

- Exotic Hybrids
- Normal Mesons
- Cascade and Hyperon Baryons



Moving Forward

- Current GlueX data sets are several orders of magnitude larger and significantly higher quality than earlier data.
- GlueX is poised to conduct comprehensive searches for exotic hybrid mesons.
- GlueX data are proving very interesting for opportunistic physics, and discoveries beyond exotics.
- With the GlueX DIRC and higher rate capability, the reach of GlueX will expand significantly.