THE GLUEX EXPERIMENT

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The GlueX Collaboration

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

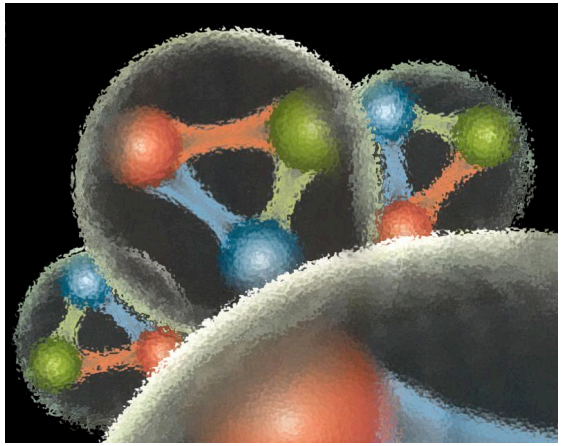
Over 120 collaborators from 24 institutions with others joining and more are welcome.

Outline

- The GlueX physics program.
- The GlueX experiment and its performance during commissioning.
- Expected initial physics from GlueX.
- Future plans and other physics.
- Summary.

12-GeV beam, Dec.2015

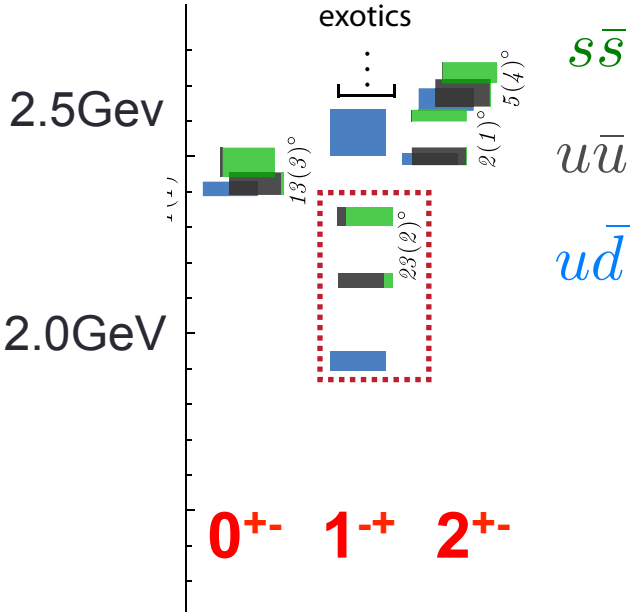
Quantum Chromo Dynamics



QCD describes the interactions of quarks and gluons and should predict the spectrum of bound-state baryons (qqq) and mesons ($q\bar{q}$).

There should also be mesons in which the gluonic field contributes directly to the J^{PC} quantum numbers of the states --- hybrid mesons. Some are expected to have ``exotic'' quantum numbers.

Lattice QCD calculation of the light-quark meson spectrum.



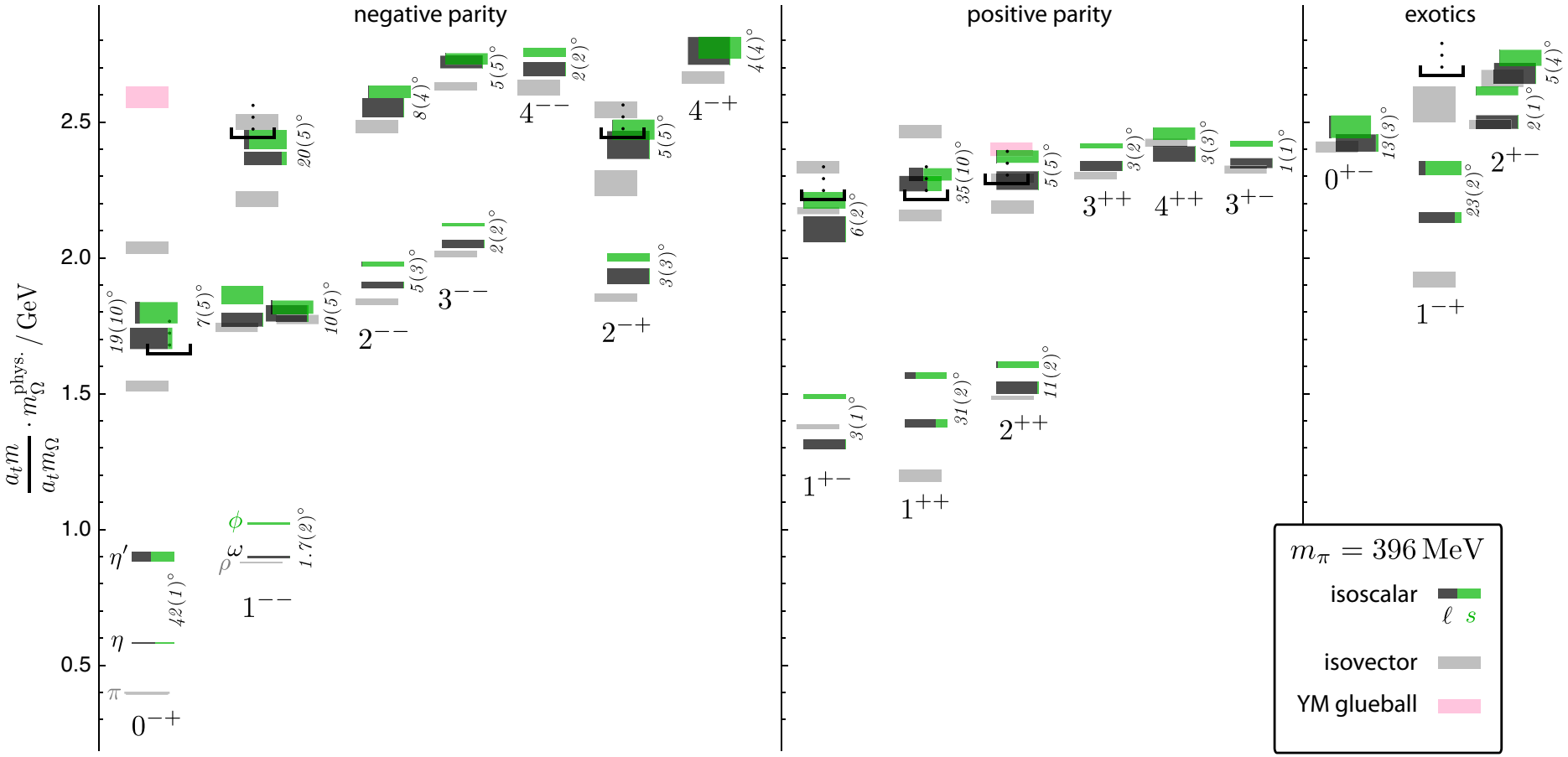
``Constituent gluon'': $J^{PC} = 1^{+-}$ mass of 1-1.5 GeV.

The lightest hybrid nonets

1^{--}, (0^{-+},1^{-+}, 2^{-+})

Lattice QCD

Light-quark Mesons (u,d,s)

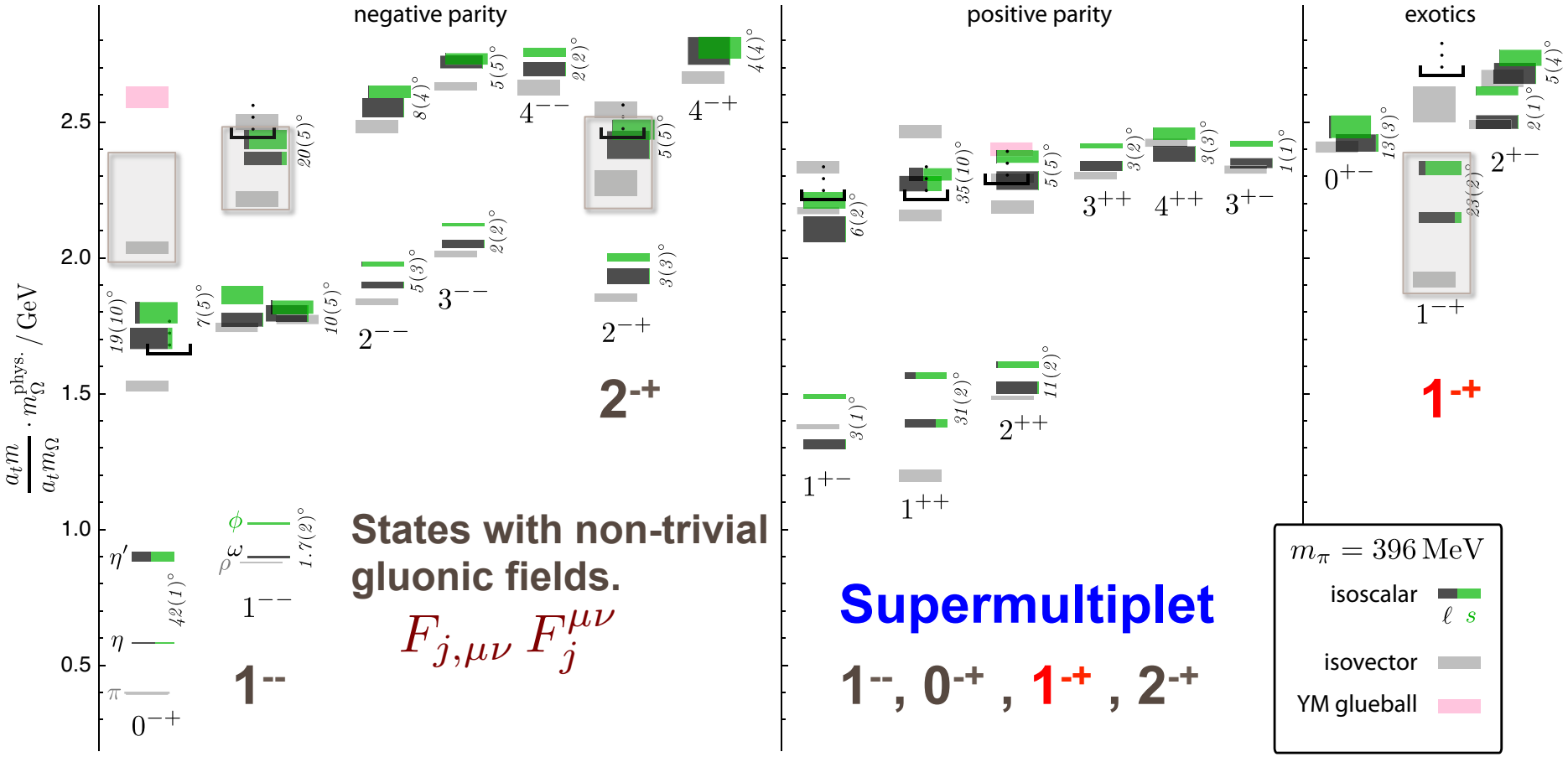


$$\frac{1}{\sqrt{2}}\left(u\bar{u} - d\bar{d}\right) \qquad \frac{1}{\sqrt{2}}\left(u\bar{u} + d\bar{d}\right) \qquad (s\bar{s})$$

PRD83, 111502 & PRD88, 094505

Lattice QCD

Light-quark Mesons (u,d,s)



States with non-trivial gluonic fields.

$F_{j,\mu\nu} F_j^{\mu\nu}$

Supermultiplet

1^{--}, 0^{-+}, 1^{-+}, 2^{-+}

0^{-+} $\frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d})$

1^{--} $\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$

1^{-+} $(s\bar{s})$

2^{-+}

PRD83, 111502 & PRD88, 094505

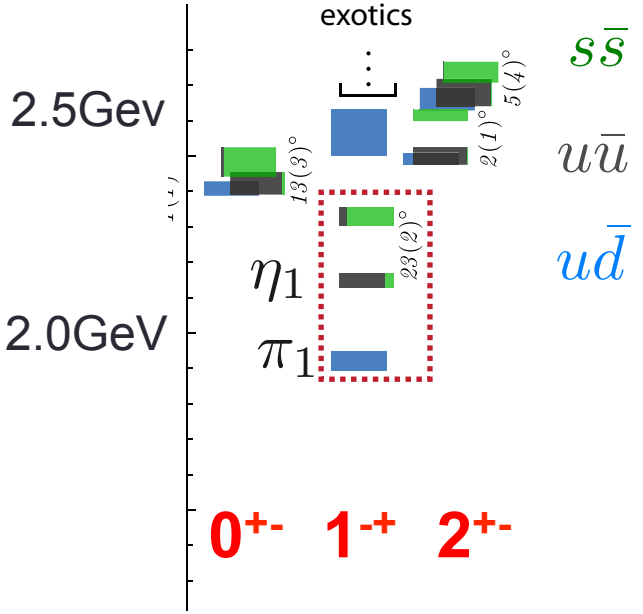
QCD Exotics

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

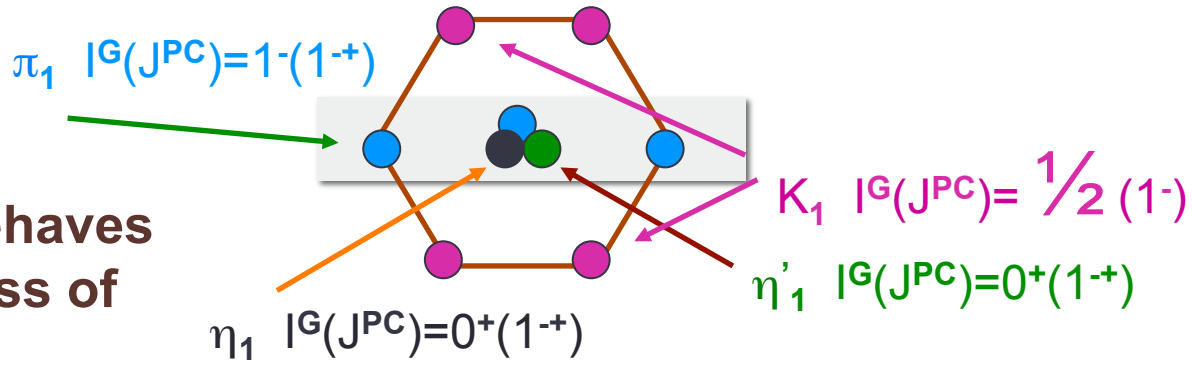
1 nonet of 0^{+-} exotic mesons

2 nonets of 1^{-+} exotic mesons

2 nonets of 2^{+-} exotic mesons



Experimental evidence exists for π_1 states.



``Constituent gluon" behaves like $J^{PC} = 1^{+-}$ with a mass of 1-1.5 GeV

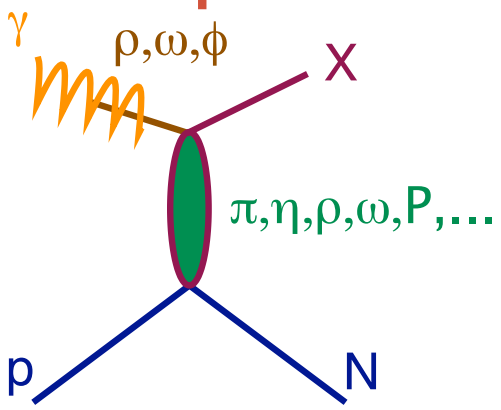
The lightest hybrid nonets:

1^{--}, (0^{-+},1^{-+}, 2^{-+})

Kaon states do not have exotic QNs

PRD84, 074023

Photoproduction Mechanisms



Simple quantum number counting for production: **$(I^G)J^{PC}$ up to L=2**

P = Pomeron exchange

$\rho\pi,\rho\omega$	→	π_1
$\omega\omega,\rho\rho$	→	η_1
$\omega\omega,\rho\rho,\phi\omega$	→	η'_1
ρP	→	b_0
ωP	→	h_0
ωP, ϕP	→	h'_0
$\omega\pi,\rho\eta,\rho P$	→	b_2
$\rho\pi,\omega\eta,\omega P$	→	h_2
$\rho\pi,\omega\eta,\phi P$	→	h'_2

$\rho\pi$ is charge-exchange only

Can couple to all the lightest exotic hybrid nonets through photo-production and VMD.

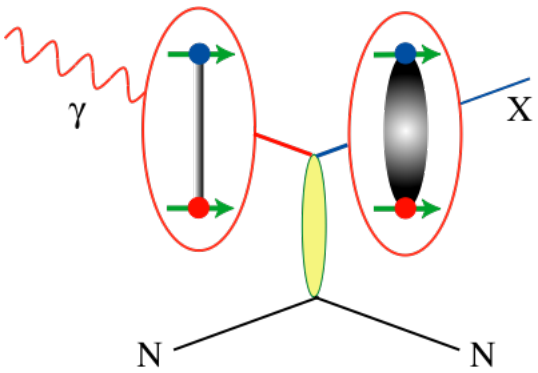
Linear polarization is a filter on the naturality of the exchanged particle.

Decay Modes of Exotic Hybrids

$\pi_1 \rightarrow \pi\rho,\ \pi b_1,\ \pi f_1, \pi\eta',\ \eta a_1$
$\eta_1 \rightarrow \eta f_2, a_2\pi, \eta f_1,\ \eta\eta',\ \pi(1300)\pi,\ a_1\pi,$
$\eta_1' \rightarrow K^*K,\ K_1(1270)K,\ K_1(1410)K,\ \eta\eta'$

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

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



Early Reach **With Statistics** **Hard**

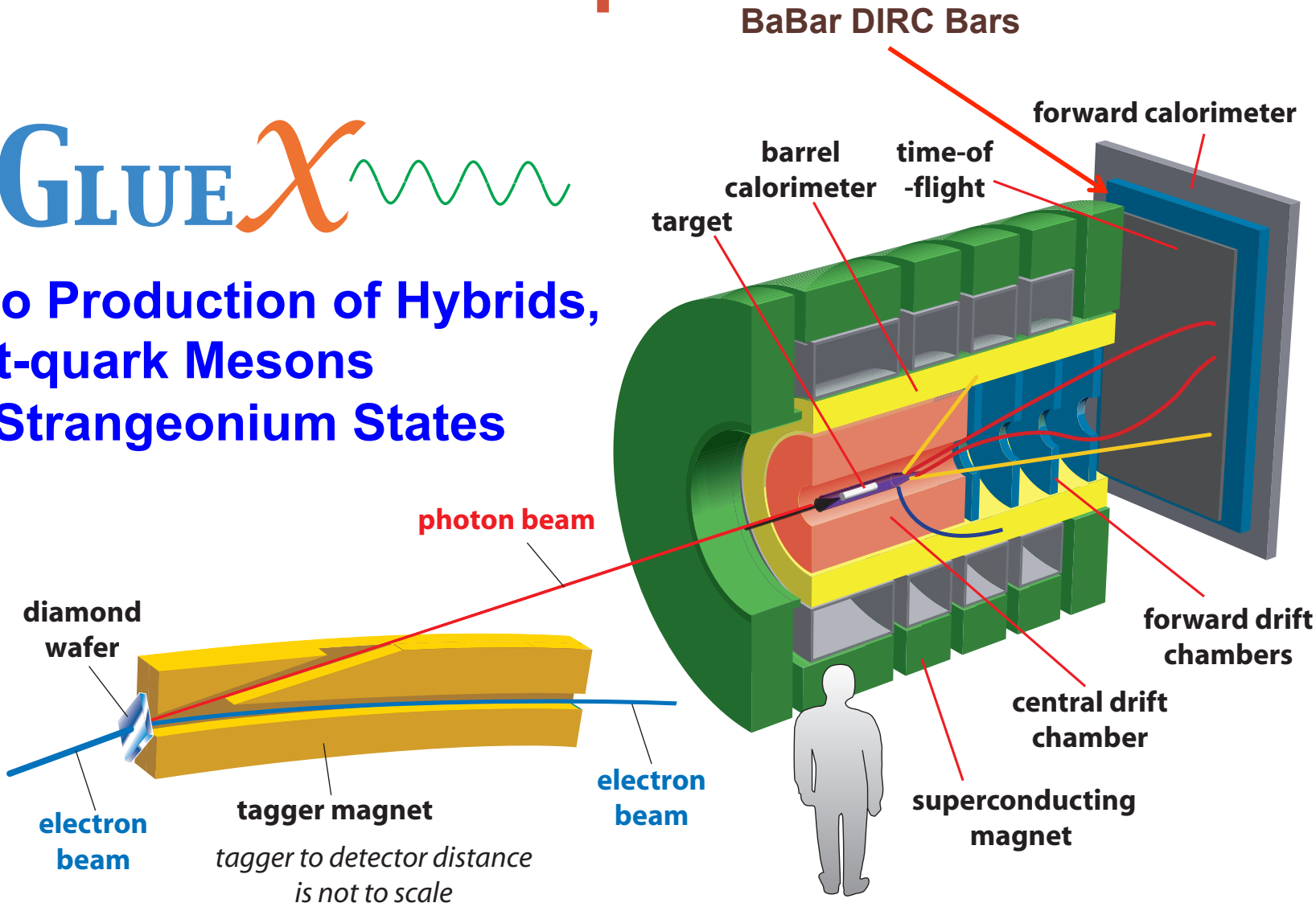
Hybrid kaons do not have exotic QN's

Models suggest narrower states are in the spin-1 and spin-2 nonets, while the spin-0 nonets are broad.

The GlueX Experiment

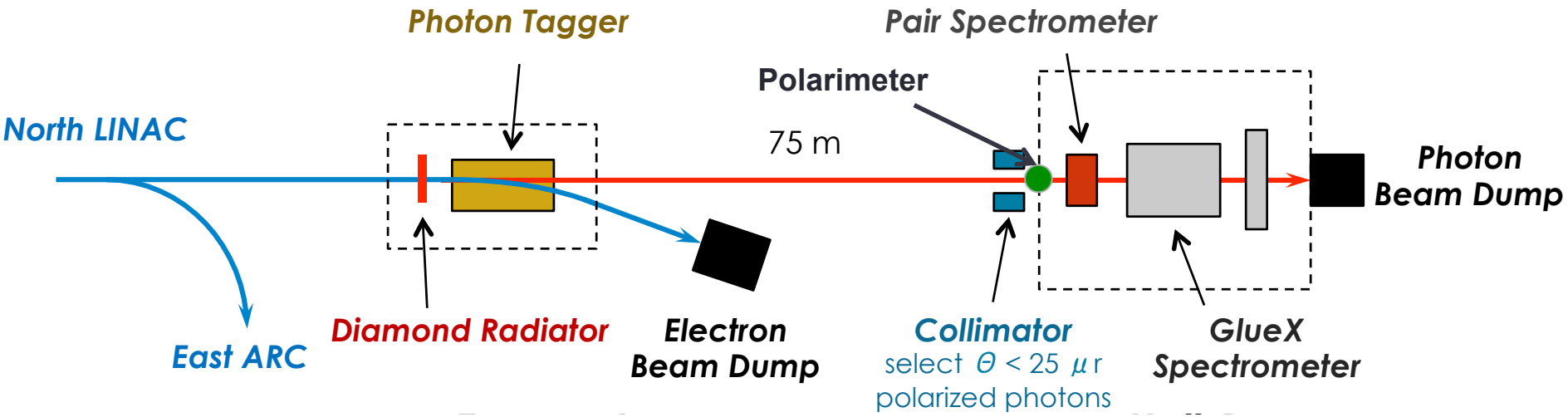
GLUEX

Photo Production of Hybrids, Light-quark Mesons and Strangeonium States



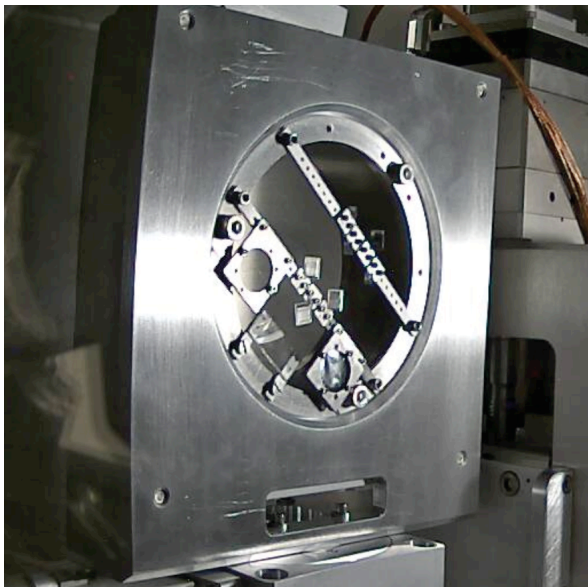
Initial Physics in 2016

The GlueX Experiment

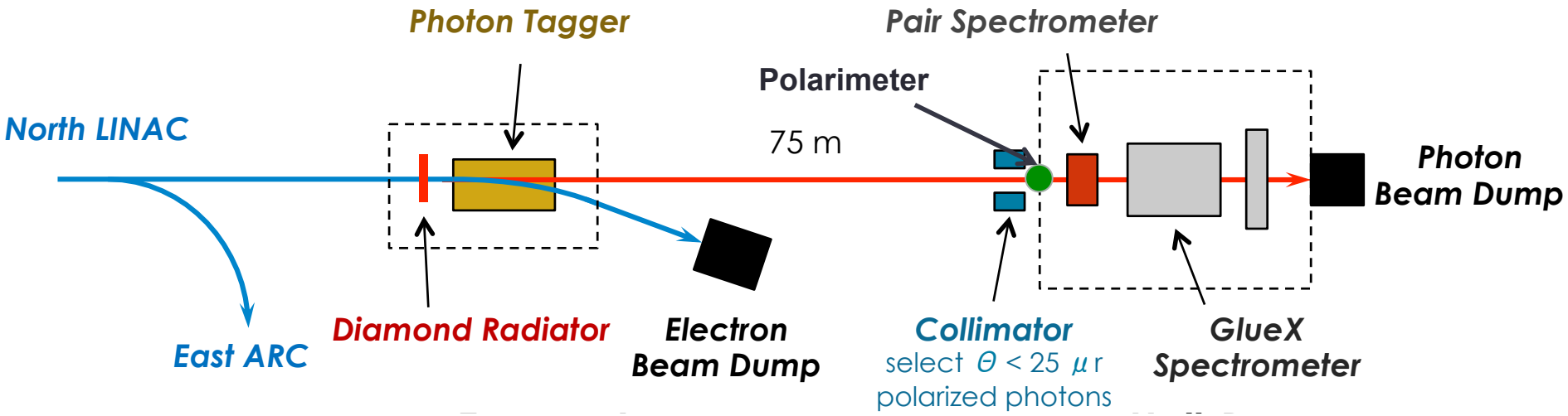


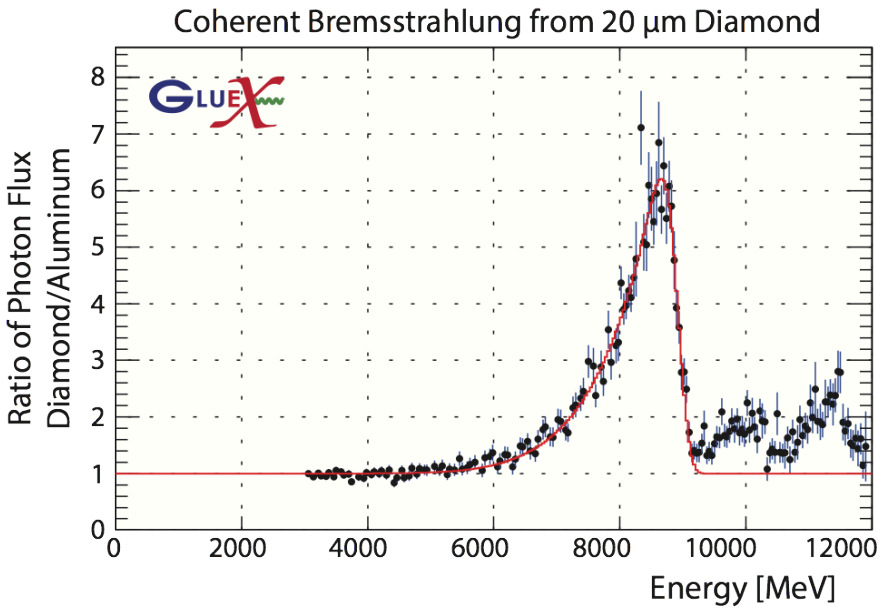
- 12 GeV e^- beam up to 2.2 μA.
- Linearly polarized photons ($P_\gamma \approx 40\%$) from coherent bremsstrahlung on thin diamond radiator.
- Polarization parallel and perpendicular to floor.
- Design intensity of 10^8 γ/s in coherent peak (E_γ = 8.4-9 GeV)

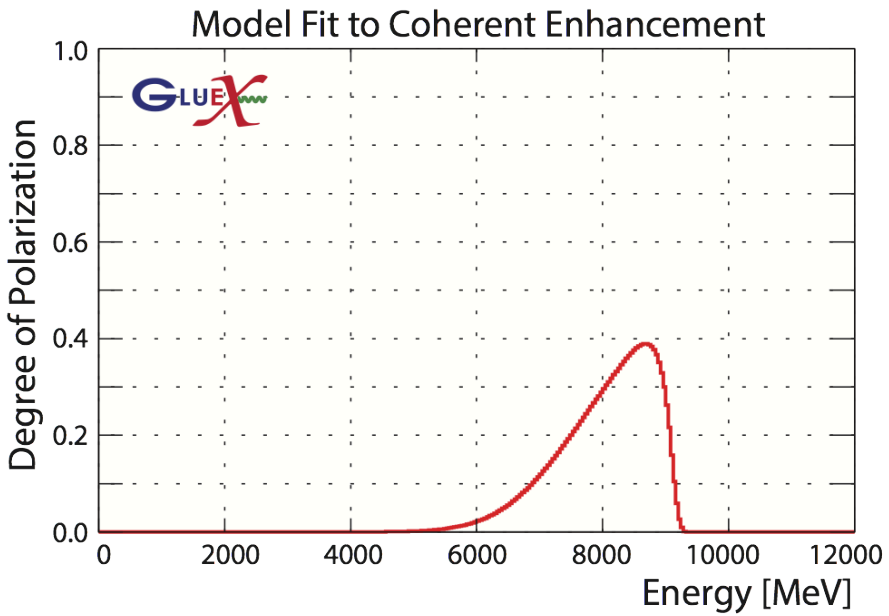
Goniometer with diamonds



The GlueX Experiment

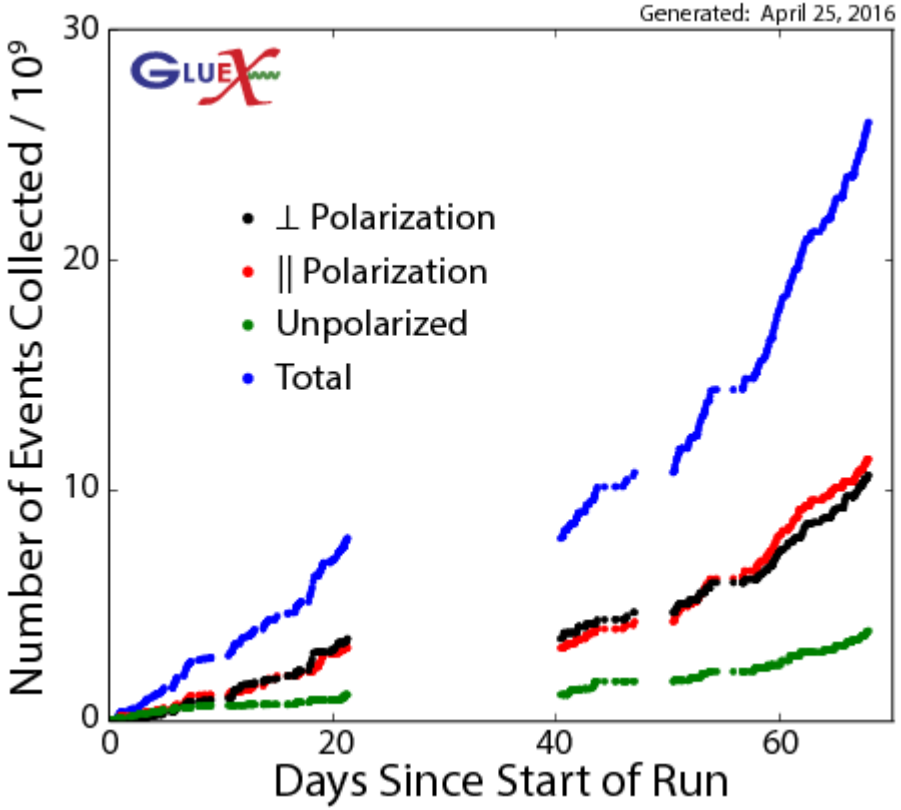


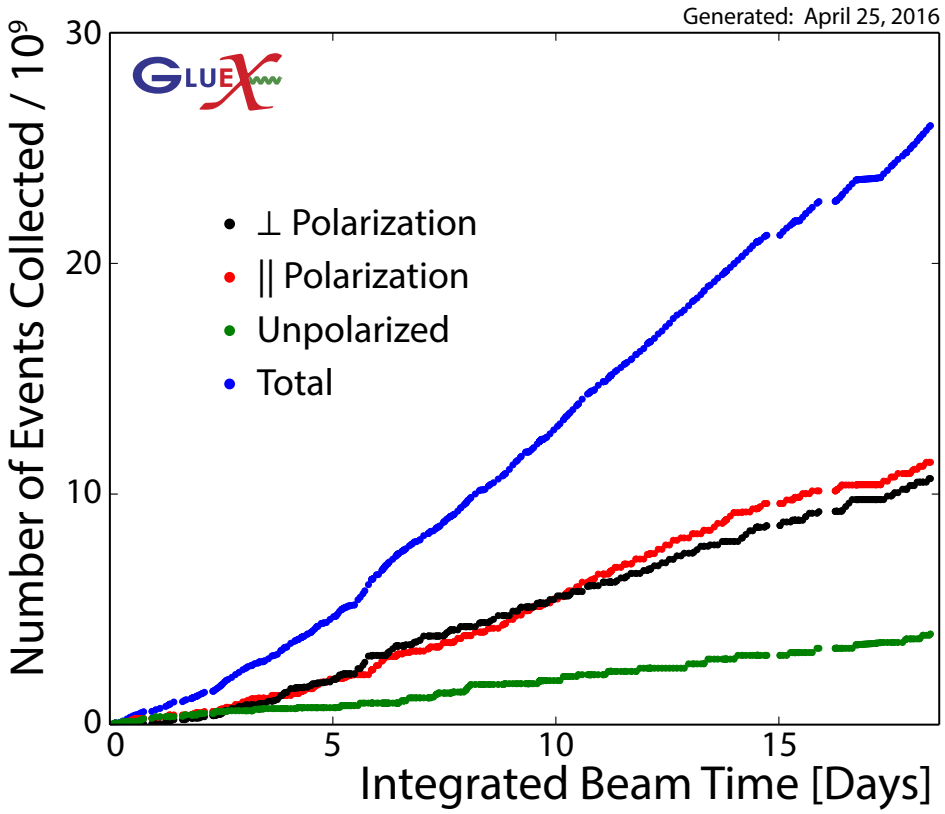




GlueX Commissioning

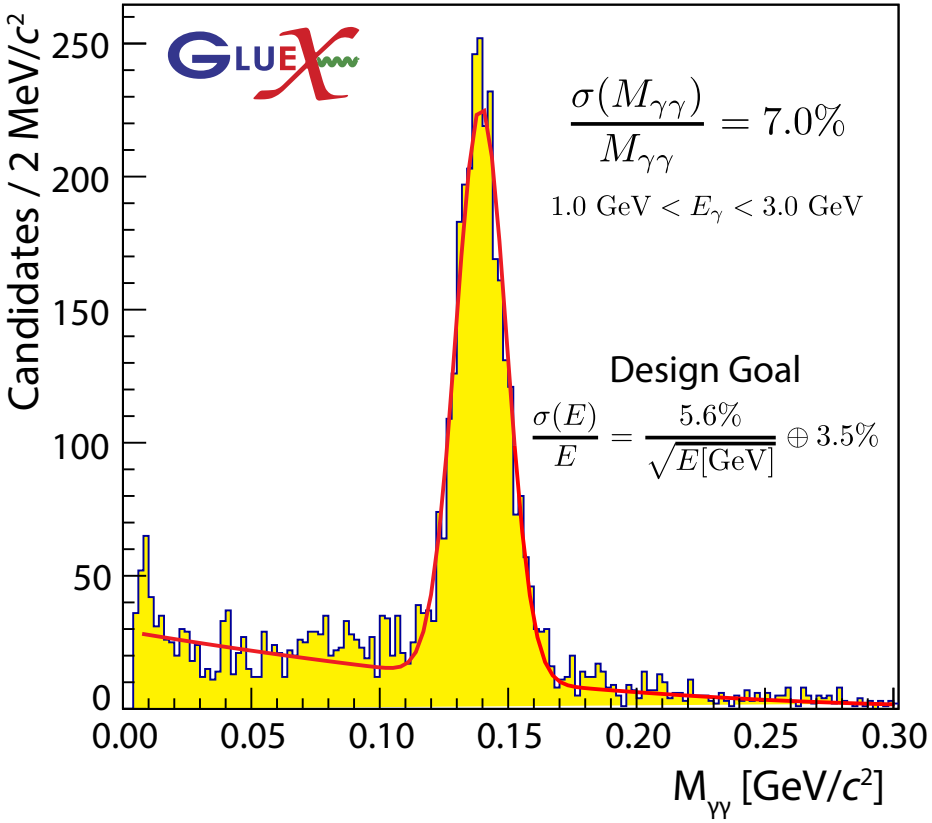
Spring 2016 run with 12-GeV electrons on thin diamond radiators. Linear polarization, both perpendicular and parallel to the earth, collected.



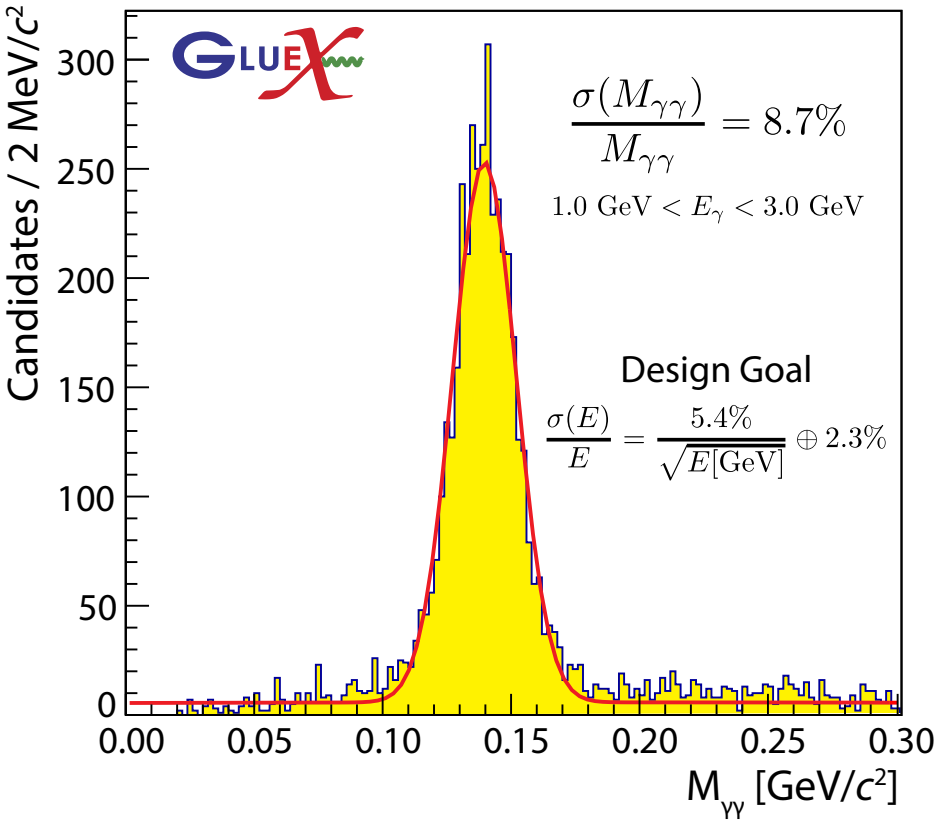


GlueX Calorimeter Performance

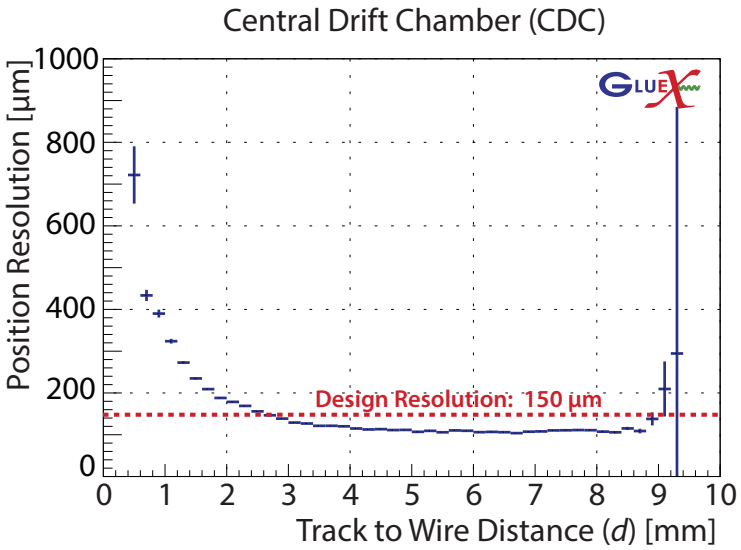
Forward Lead Glass Calorimeter

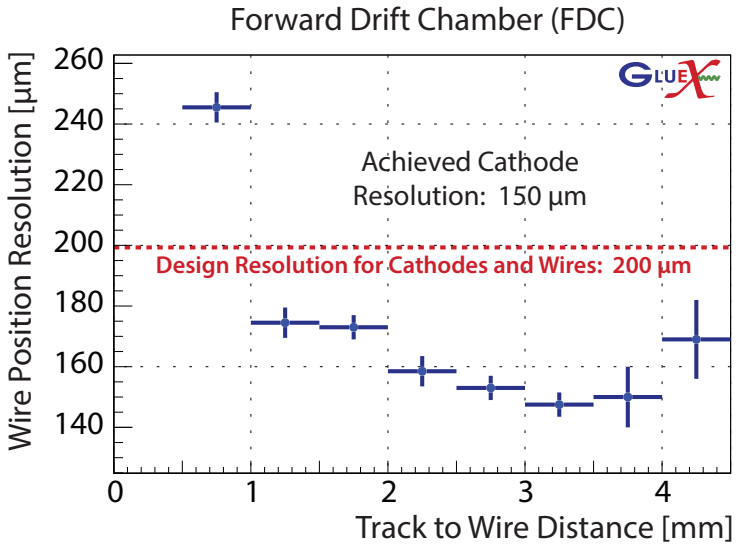


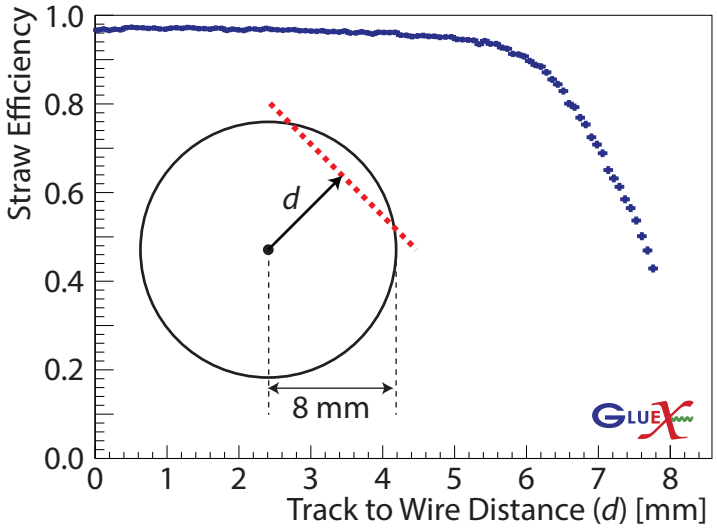
Barrel Lead-Scintillating Fiber Calorimeter

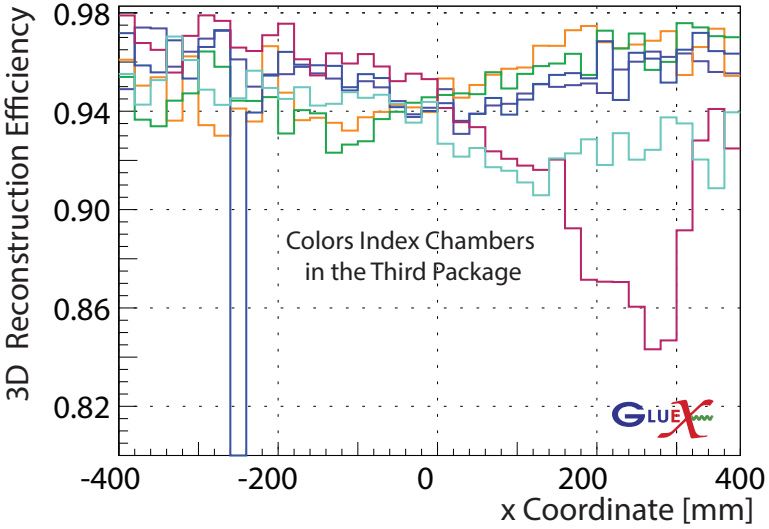


GlueX Tracking Performance

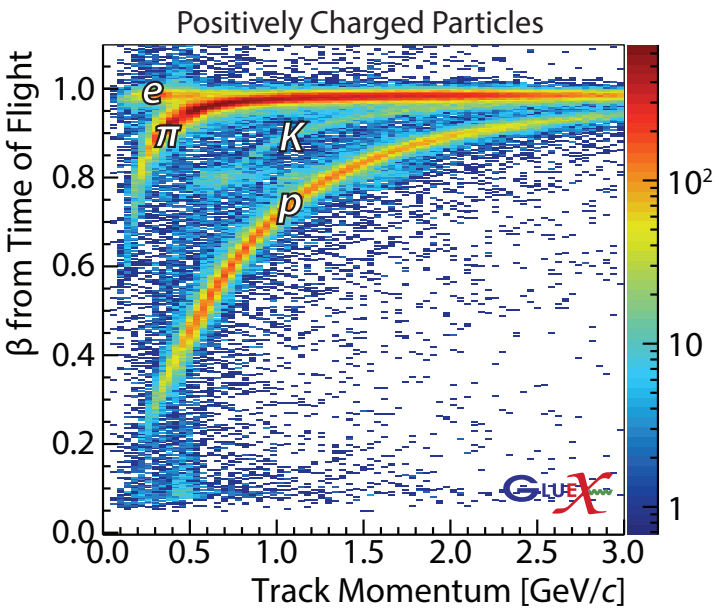


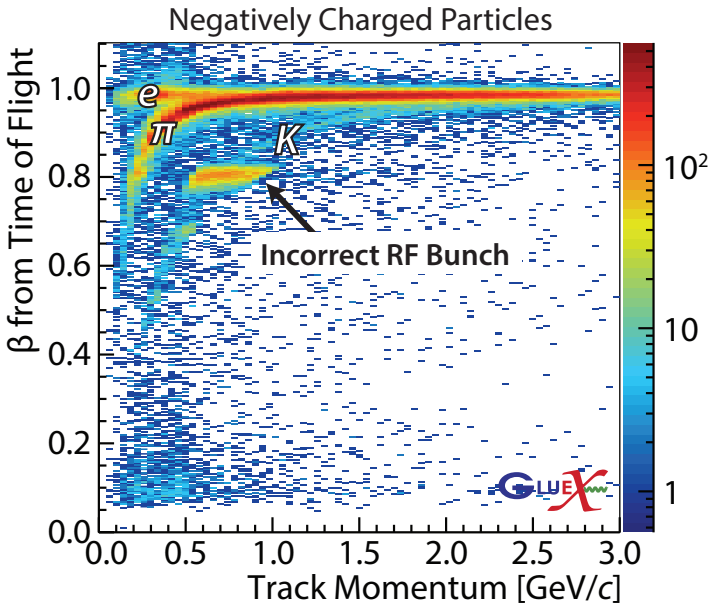


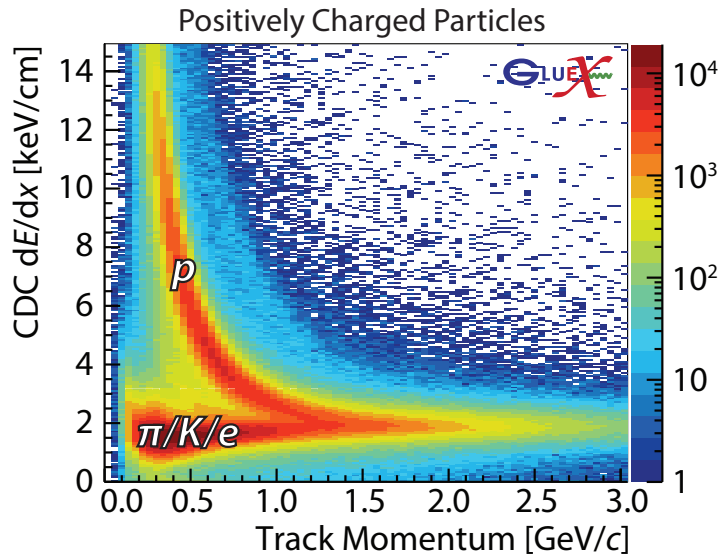


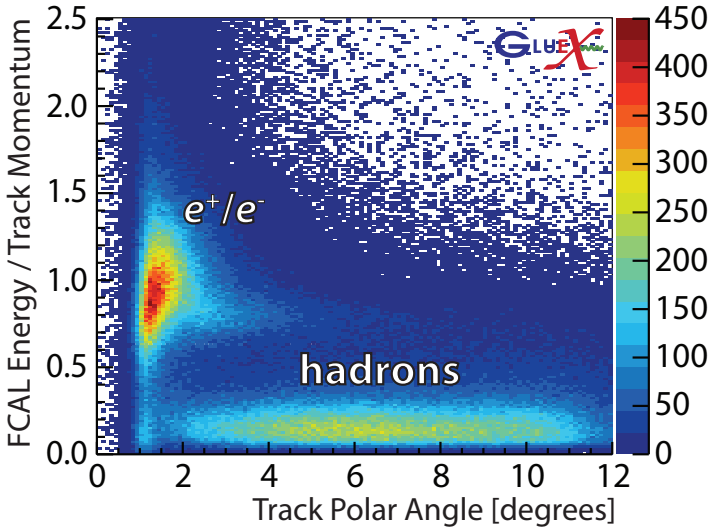


GlueX Particle Identification









Start of Physics in GlueX

- Initial reactions will be polarization transfer and beam asymmetry measurements.

  $\gamma p \to (\pi^0, \eta, \eta')p$ $\gamma p \to (\rho^0, \omega, \phi)p$

- Spin-density matrix elements to understand production mechanisms.
- Opportunistic results from data exploration.
- Cross section measurements.
- Identify known mesons in PWA.
- Move on to the search for exotic hybrids.

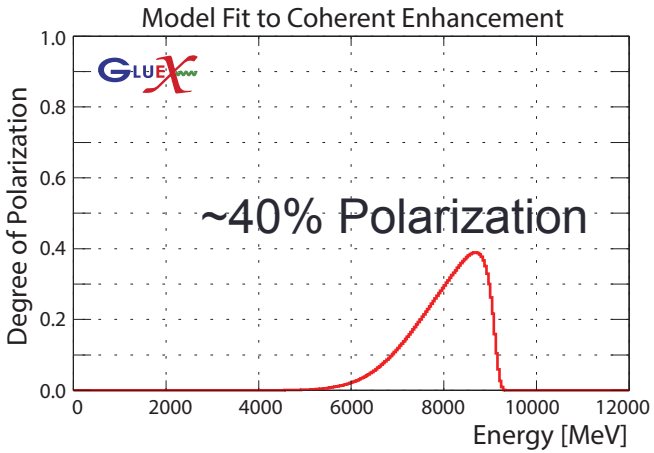
Early Physics in GlueX

- Initial reactions will be polarization transfer and beam asymmetry measurements.

  $\gamma p \to (\pi^0, \eta, \eta')p$ $\gamma p \to (\rho^0, \omega, \phi)p$

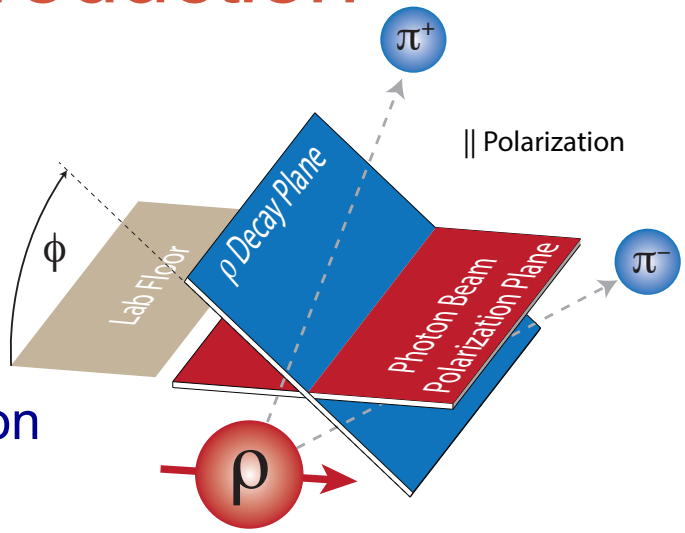
- Spin-density matrix elements to understand production mechanisms.
- Opportunistic results from data exploration.
- Cross section measurements.
- Identify known mesons in PWA.
- Move on to the search for exotic hybrids.

Beam Asymmetry in ρ Photoproduction



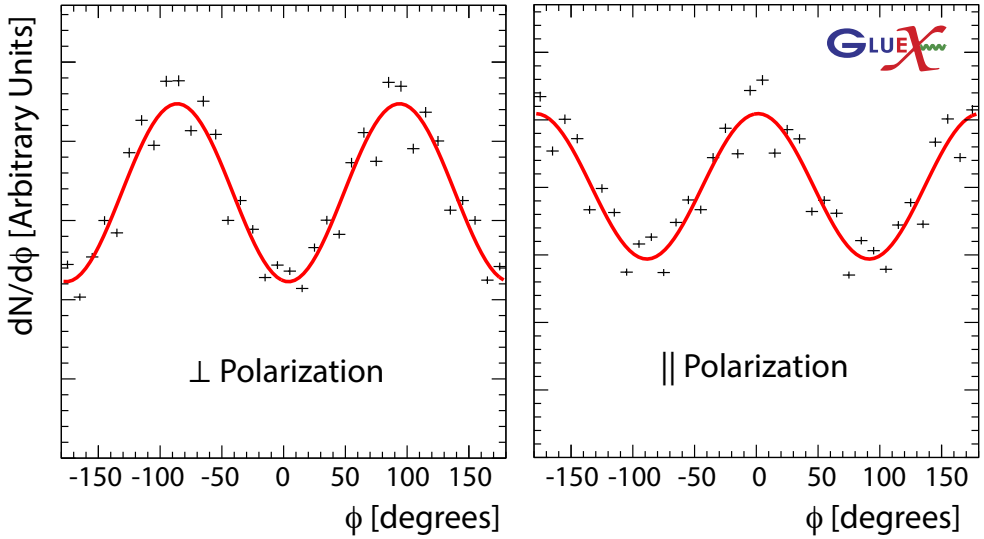
Between 100 and 1000 times the 3000 existing events from SLAC.

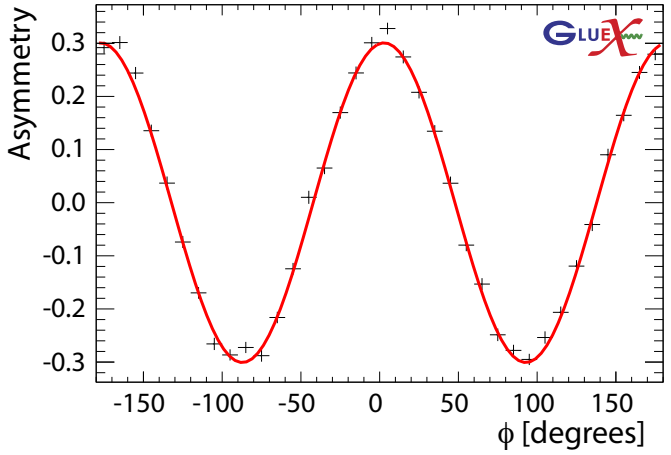
Working with JPAC on models for analysis



$d\sigma_\perp \propto 1 - P_\perp \Sigma \cos 2\phi$ $d\sigma_\parallel \propto 1 + P_\parallel \Sigma \cos 2\phi$

$$P\Sigma \cos 2\phi = \frac{N_\parallel - N_\perp}{N_\parallel + N_\perp}$$





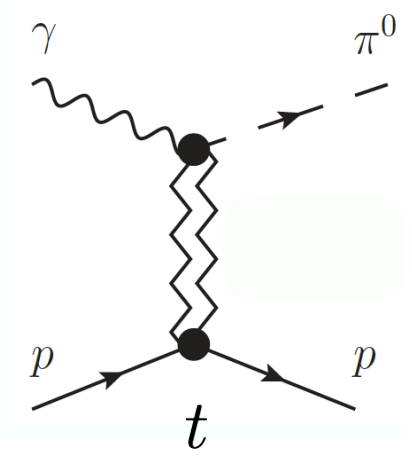
Acceptance errors not included

Large polarization transfer to the ρ

π^0 beam asymmetry

Beam asymmetry Σ provides insight into dominant production mechanism

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



Exchange J^{PC}

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

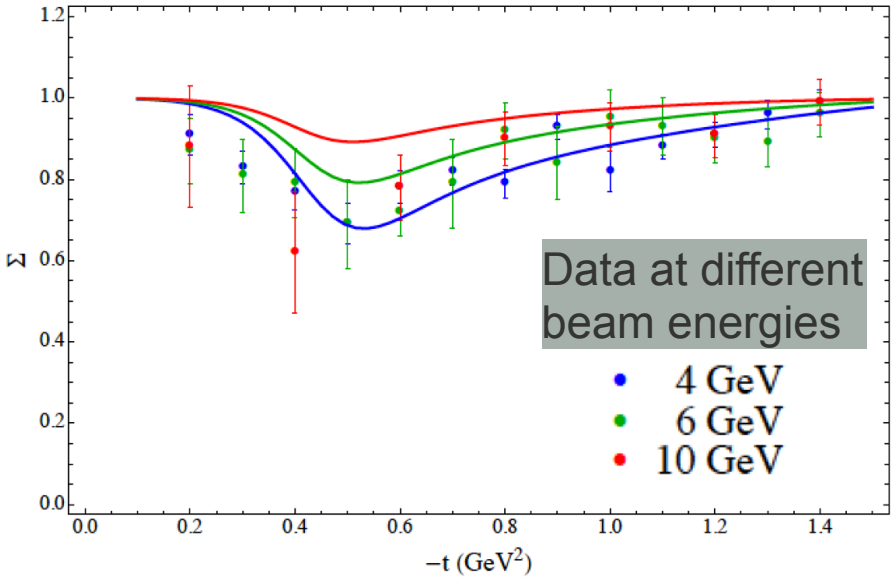
$1^{+-} : b, h$

Understanding production mechanism critical to disentangling J^{PC} of observed states in exotic hybrid search.

From experimental standpoint easily extended to γp→η where there are no previous measurements!

See Adam Szczepaniak's talk on JPAC

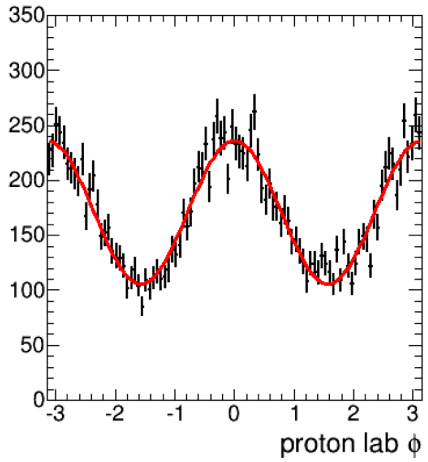
Mathieu et al. PRD 92, 074013



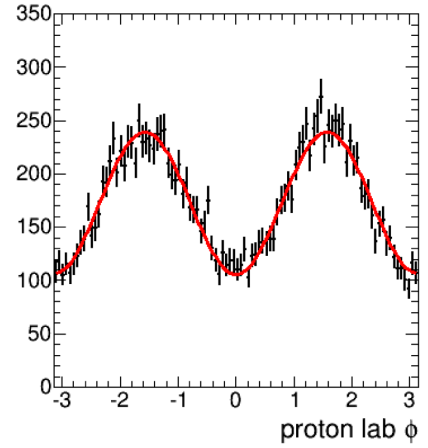
π^0 model: integration with JPAC

Simulation from JPAC Model

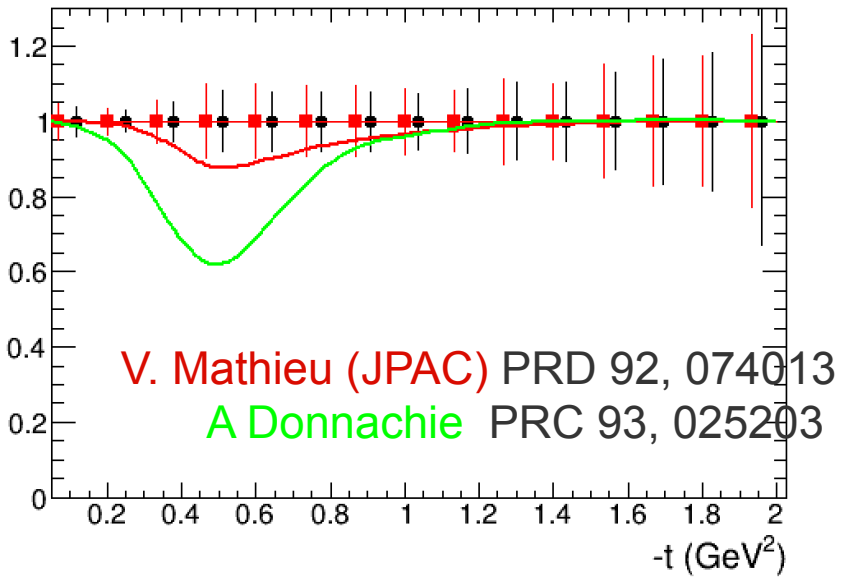
$$d\sigma_{\perp} \sim 1 + P_{\perp}\Sigma cos2\phi$$



$$d\sigma_{||} \sim 1 - P_{||}\Sigma cos2\phi$$



12 hours of beam: statistical errors only



Similar to ρ^0 model, simply calculate intensity based on JPAC provided function

Generate $\gamma p \rightarrow \pi^0 p$ events and process through full detector simulation and reconstruction

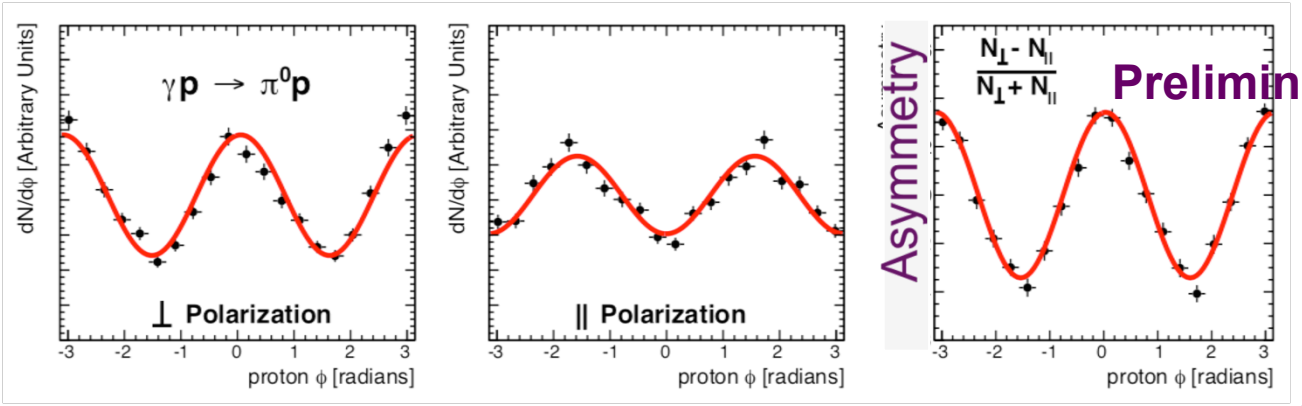
Before Spring 2016 run estimated yields for 12 hours of beam; evaluated statistical precision

Actually collected >10x more data!

Pseudoscalar Beam Asymmetries

$\gamma p \to \pi^0 p$

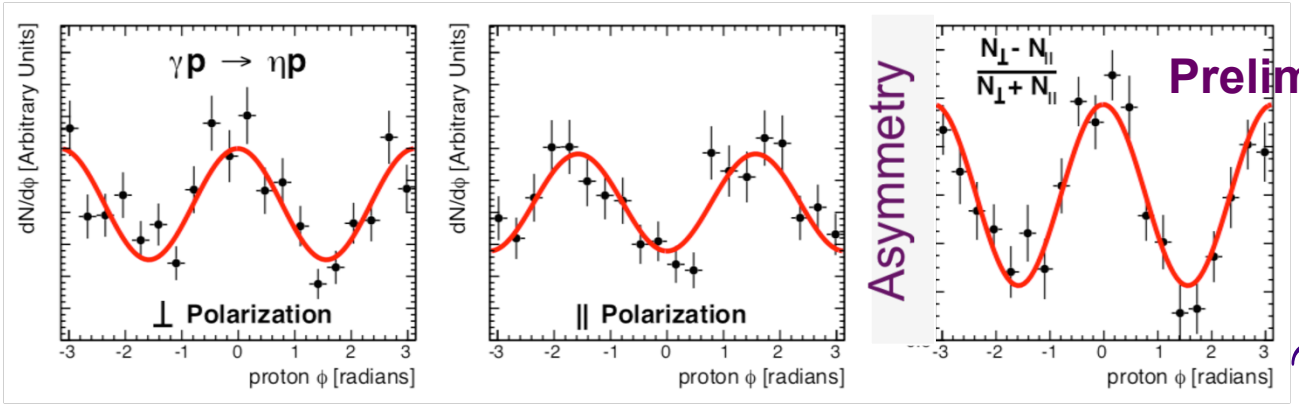
From a subset of all available data.
Polarization not yet determined.



Preliminary

$\sim P\Sigma_{\pi^0} \cos 2\phi$

$\gamma p \to \eta p$

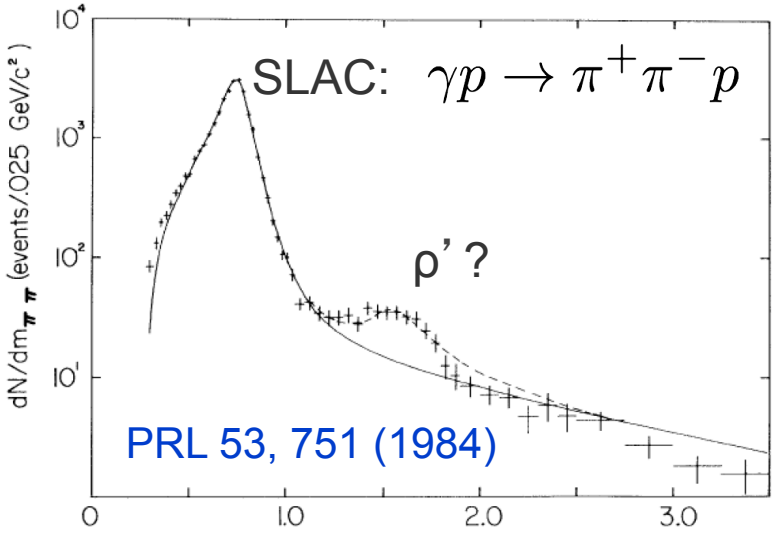


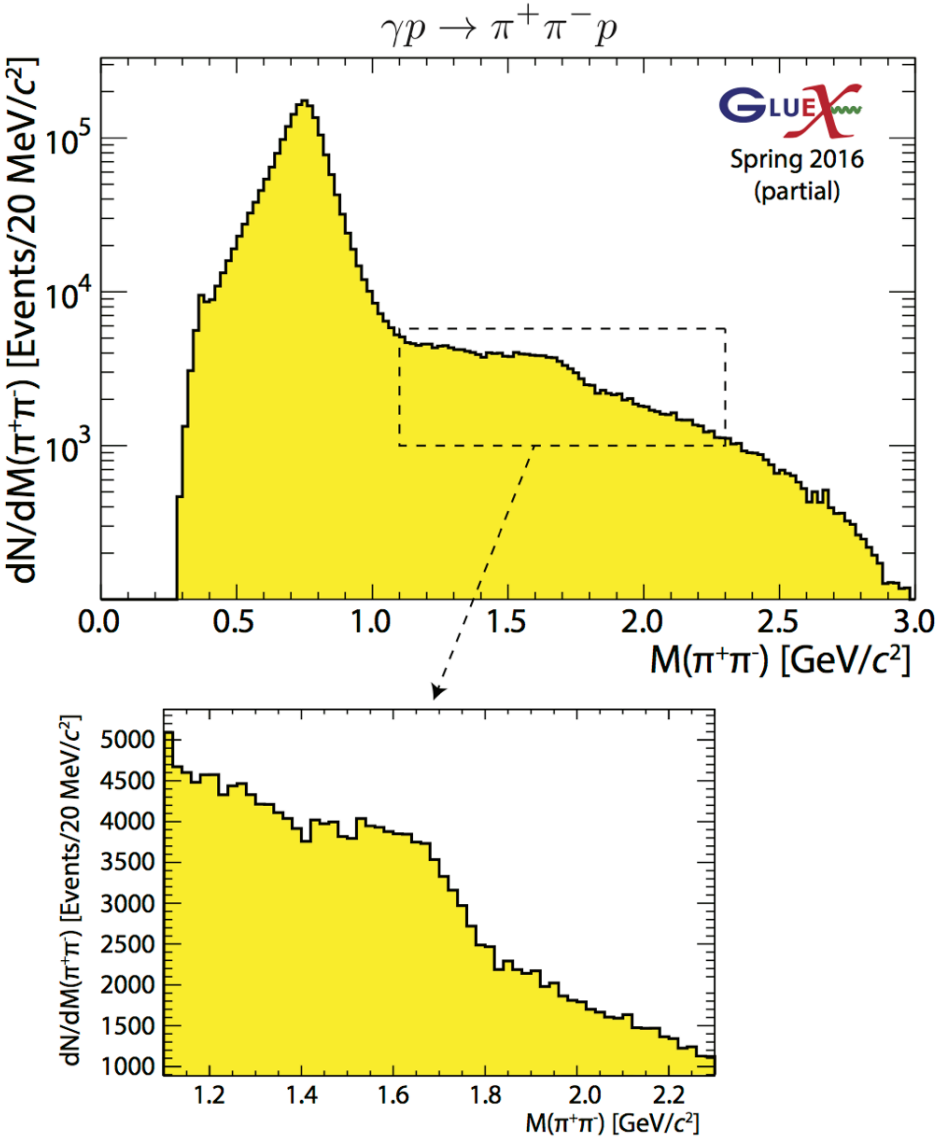
Preliminary

$\sim P\Sigma_{\eta} \cos 2\phi$

Physics Opportunities

In the ρ event sample, we can look for higher-mass vector mesons. We observe an enhancement around 1.6 GeV with significantly more statistics than existed and we should be able to measure polarization observables.

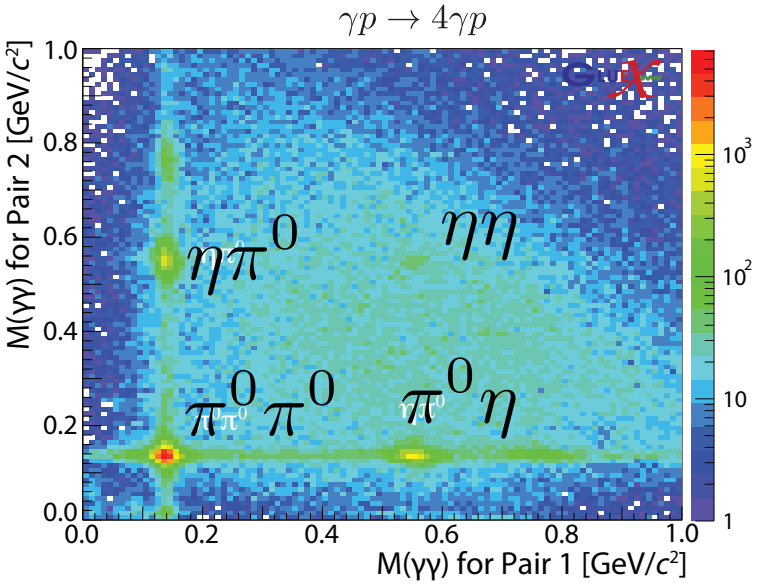


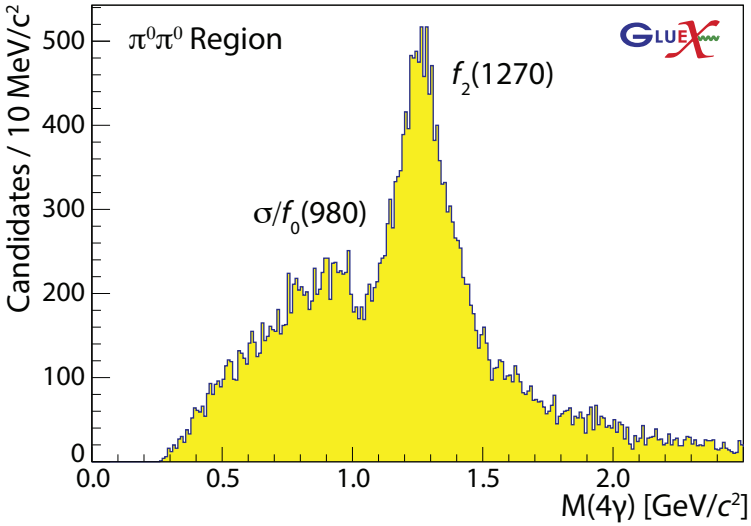


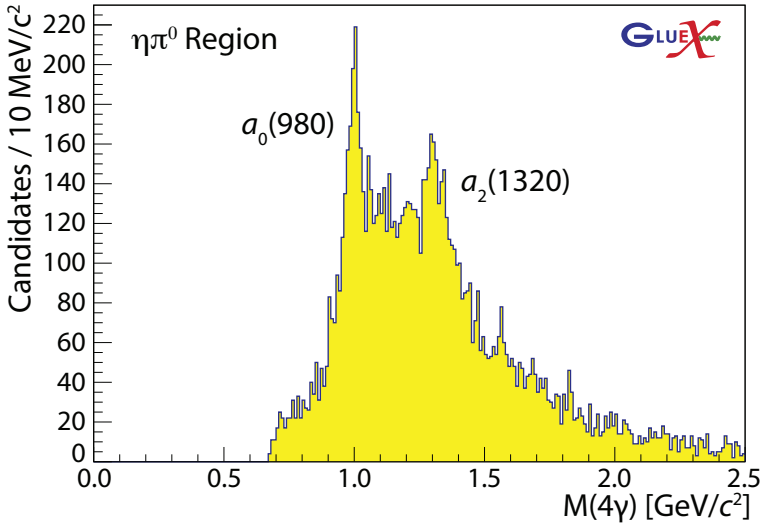
Four photon final states $\gamma p \to p\gamma\gamma\gamma\gamma$

About 6% of the spring 2016 statistics from early in the run and using a very preliminary production run.

Clear signals for σ, $f_0(980)$, $f_2(1270)$, $a_0(980)$ and $a_2(1320)$.

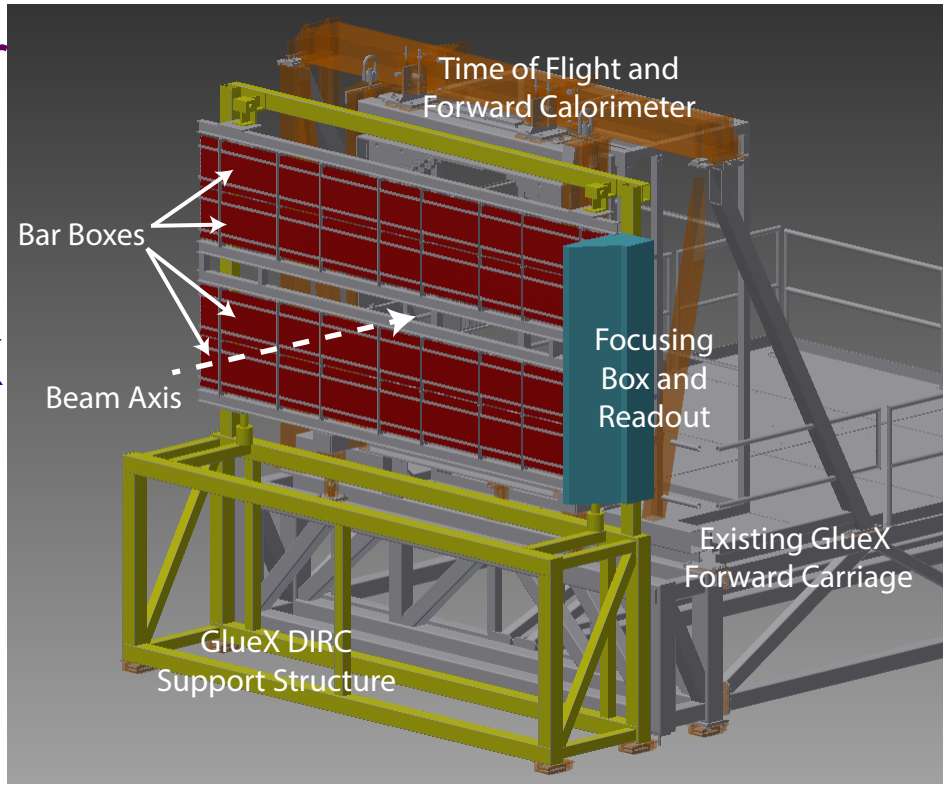






Forward Kaon Identification

- Four of the BaBar DIRC bar boxes will be installed in front of the TOF wall.
- This combined with the other PID systems in GlueX will allow us to fully study final states with strange quarks.
- Strangeonium mesons and hybrids can be studied.
- Hyperon and cascade baryons can be studied.



Expected in 2018/2019

GlueX Experiments

GlueX—Hybrid mesons/spectroscopy PR-06-102, PR-12-002 & PR-13-003	A rating 340-540 PAC days
GlueX—PrimEx-eta PR-10-011 (calorimeter plug)	A- rating 79 PAC Days
GlueX—Pion polarizability PR-13-008 (forward muon detector)	A- rating 25 PAC Days
GlueX—JEF: Rare eta decays PR14-004 (calorimeter upgrade)	Conditionally Approved

GlueX Experiments

GlueX—Study of ω photoproduction on nuclei. LOI 2015

Workshop held in February 2016

https://www.jlab.org/conferences/kl2016/

GlueX—Physics opportunities with a secondary K_L beam LOI 2015

Workshop held in April 2016

https://www.jlab.org/conferences/photoproduction16/

Summary

- GlueX is installed, commissioned and ready to start physics running in Fall 2016.
- All detector systems are near design specifications.
- We are aggressively moving ahead on our first physics measurements.
- The broader program of exotic mesons is in sight.
- Addition of kaon identification and five-times higher intensity is planned in 2018 to allow us to cover all parts of the GlueX exotic hybrid program.
- We have an extensive program beyond exotic hybrids and are excited to have new ideas and new collaborators.