

# Hall D & GlueX Update

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# Hall D Experiments

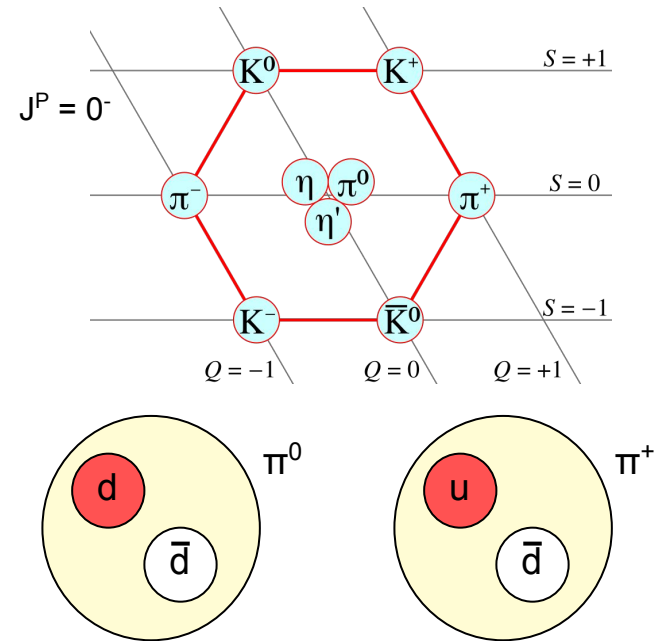
- GlueX
  - E12-06-102, C12-12-002, E12-13-003
  - 540 PAC days
- PrimEx-eta
  - E12-10-011
  - 79 PAC days
- Pion polarizability
  - E12-13-008
  - 25 PAC days
- JLab Eta Factory (JEF):  
Rare eta decays
  - C12-14-004
  - Conditionally approved



# GlueX

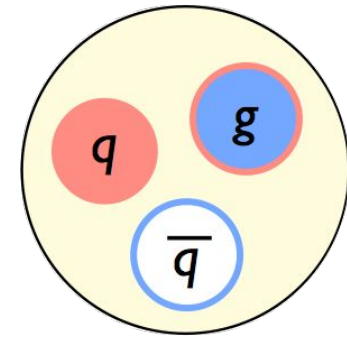
## Quark model

- The spectrum of conventional mesons is described by the quark model
- Mesons are grouped in nonets of  $J^{PC}$  with different quark flavor content
- Allowed  $q\bar{q}$  states:  $0^{-+}, 1^{-}, 1^{+-}, 0^{++}, 2^{++}, \dots$



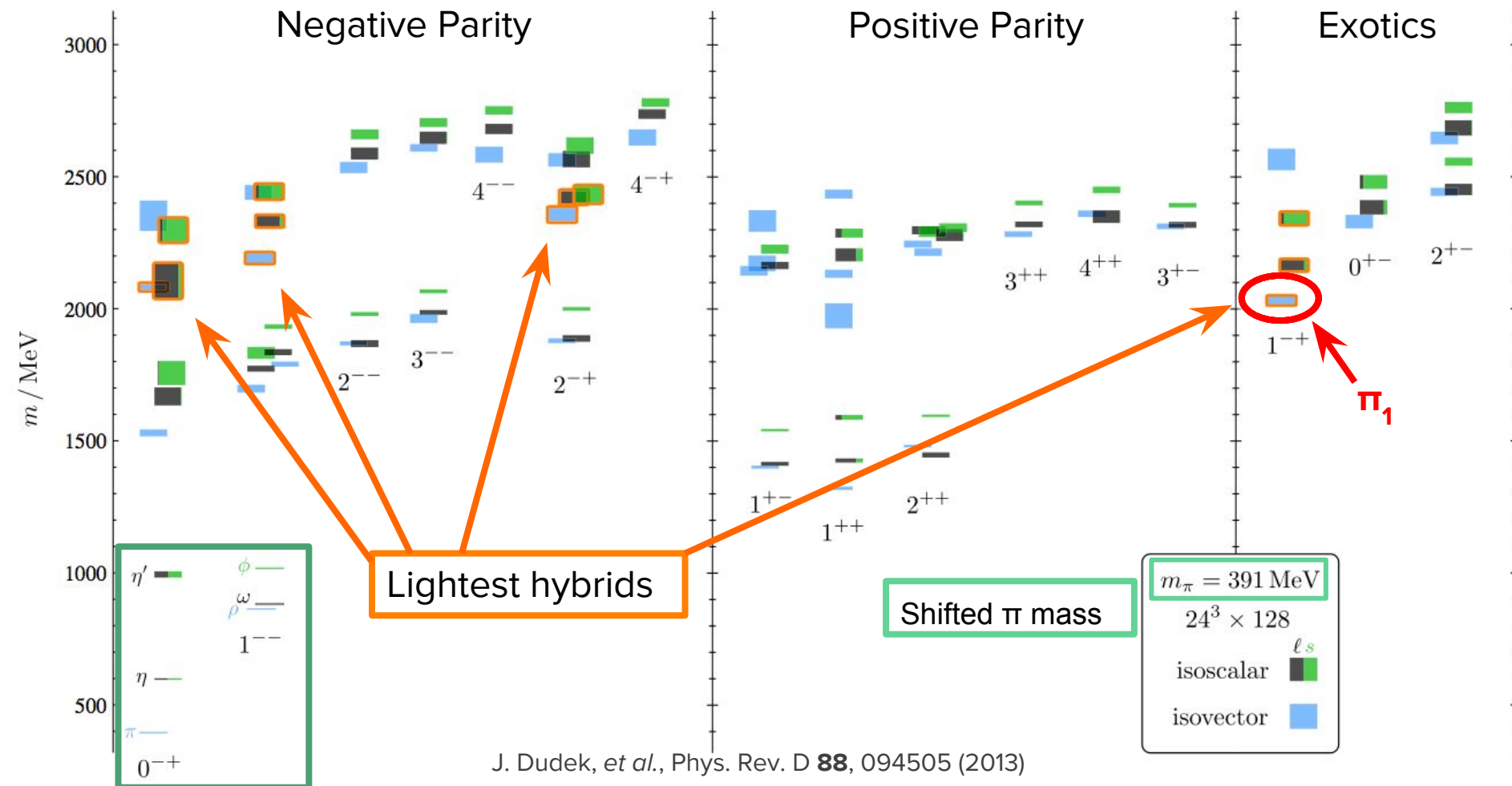
## Hybrids

- Excited gluonic field coupled to  $q\bar{q}$  pair
- Spectrum of hybrids predicted by lattice QCD
  - Can be modeled as “constituent gluon” with  $J^{PC} = 1^{+-}$  and mass = 1-1.5 GeV
- Some have “exotic”  $J^{PC}$  which cannot be formed by  $q\bar{q}$ 
  - $J^{PC} = 0^{+-}, 1^{-+}, 2^{+-}, \dots$
  - Exotic  $J^{PC}$  provide good signal for hybrids



# Lattice QCD predictions

- Search for pattern of hybrid states in many final states
- Most evidence for  $\pi_1$  ( $J^{PC} = 1^{-+}$ )



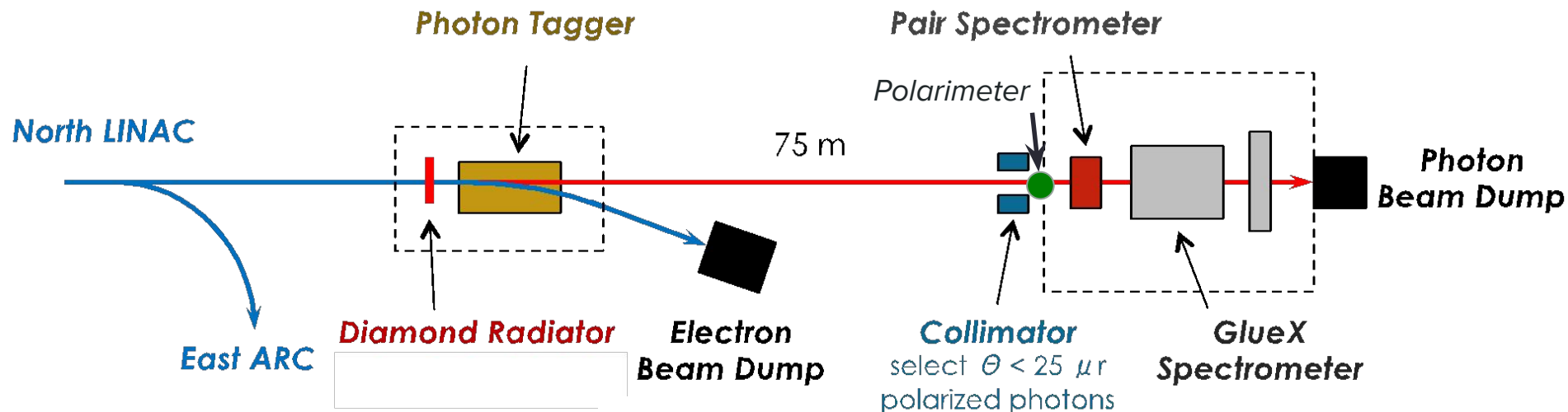
# Exotic $J^{PC}$ Decays

- Lattice predictions for the mass of hybrids
- Decay predictions are model dependent
- Reported  $J^{PC} = 1^{-+}$ :  $\pi\rho \rightarrow 3\pi$ ,  $\pi\eta' \rightarrow 3\pi\eta$ ,  $\pi b_1 \rightarrow 2\pi\omega$
- Early reach
- With statistics

Name	$J^{PC}$	Total width MeV (Model)		Allowed decay modes	$K_1^A(1270)$ $K_1^B(1400)$
		PSS	IKP		
$\pi_1$	$1^{-+}$	81–168	117	$b_1\pi$ , $\pi\rho$ , $\pi f_1$ , $\pi\eta$ , $\pi\eta'$ , $\eta a_1$ , $\pi\eta(1295)$	
$\eta_1$	$1^{-+}$	59–158	107	$\pi a_1$ , $\pi a_2$ , $\eta f_1$ , $\eta f_2$ , $\pi\pi(1300)$ , $\eta\eta'$ , $KK_1^A$ , $KK_1^B$	
$\eta'_1$	$1^{-+}$	95–216	172	$KK_1^B$ , $KK_1^A$ , $KK^*$ , $\eta\eta'$	
$b_0$	$0^{+-}$	247–429	665	$\pi\pi(1300)$ , $\pi h_1$ , $\rho f_1$ , $\eta b_1$	
$h_0$	$0^{+-}$	59–262	94	$\pi b_1$ , $\eta h_1$ , $KK(1460)$	
$h'_0$	$0^{+-}$	259–490	426	$KK(1460)$ , $KK_1^A$ , $\eta h_1$	
$b_2$	$2^{+-}$	5–11	248	$\pi a_1$ , $\pi a_2$ , $\pi h_1$ , $\eta\rho$ , $\eta b_1$ , $\rho f_1$	
$h_2$	$2^{+-}$	4–12	166	$\pi\rho$ , $\pi b_1$ , $\eta\omega$ , $\omega b_1$	
$h'_2$	$2^{+-}$	5–18	79	$KK_1^B$ , $KK_1^A$ , $KK_2^*$ , $\eta h_1$	

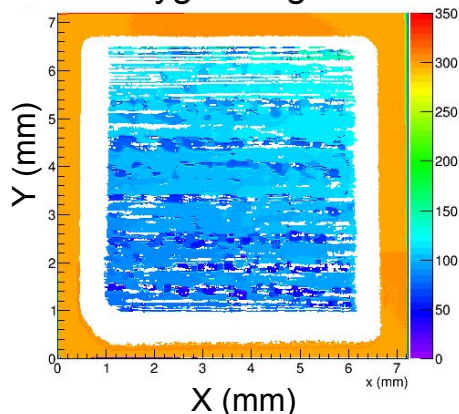
C. A. Meyer and E. S. Swanson, Progress in Particle and Nuclear Physics B82, 21, (2015)

# GlueX Experiment - beamline (UConn)

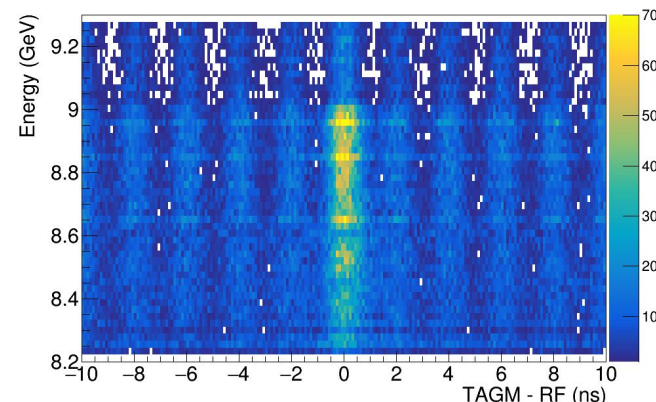


- 12 GeV beam up to 2.2  $\mu\text{A}$
- Linearly polarized  $\gamma$ 's
  - $P_{\text{peak}} \sim 40\%$
- Polarized parallel and perpendicular to floor
- Design intensity of  $10^8 \gamma/\text{s}$  in peak region
  - $E_{\gamma} = 8.4 - 9.0 \text{ GeV}$

Zygo Image

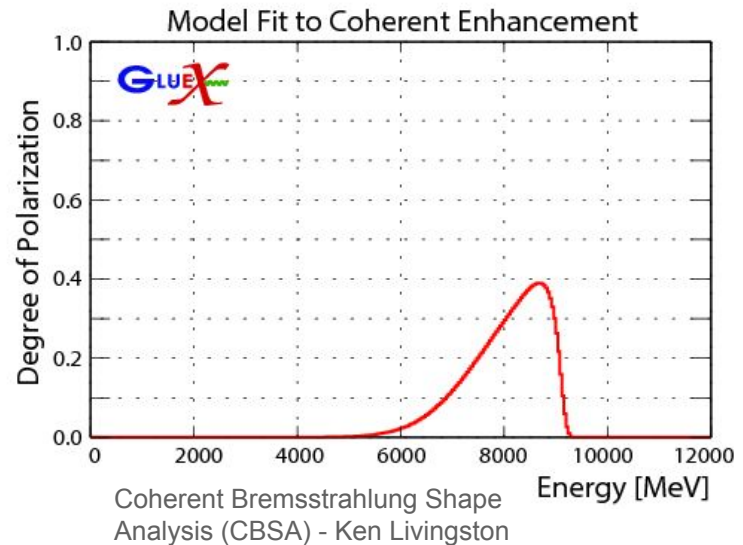
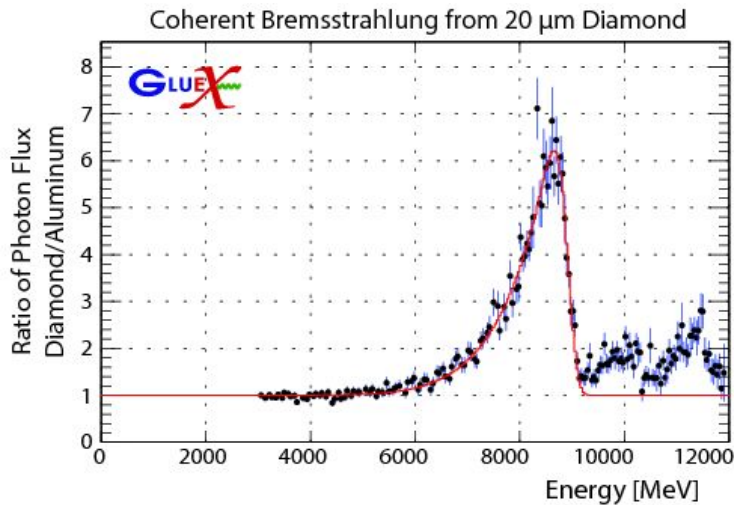
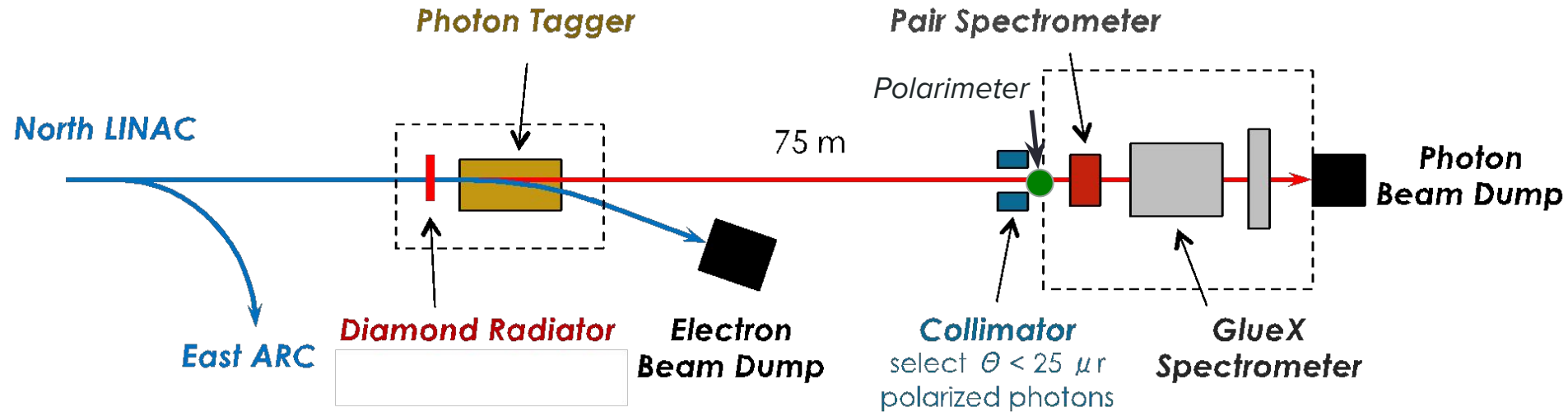


CVD diamond laser ablated to 40  $\mu\text{m}$ , etched by Applied Diamonds to  $17.7 \pm 0.5 \mu\text{m}$



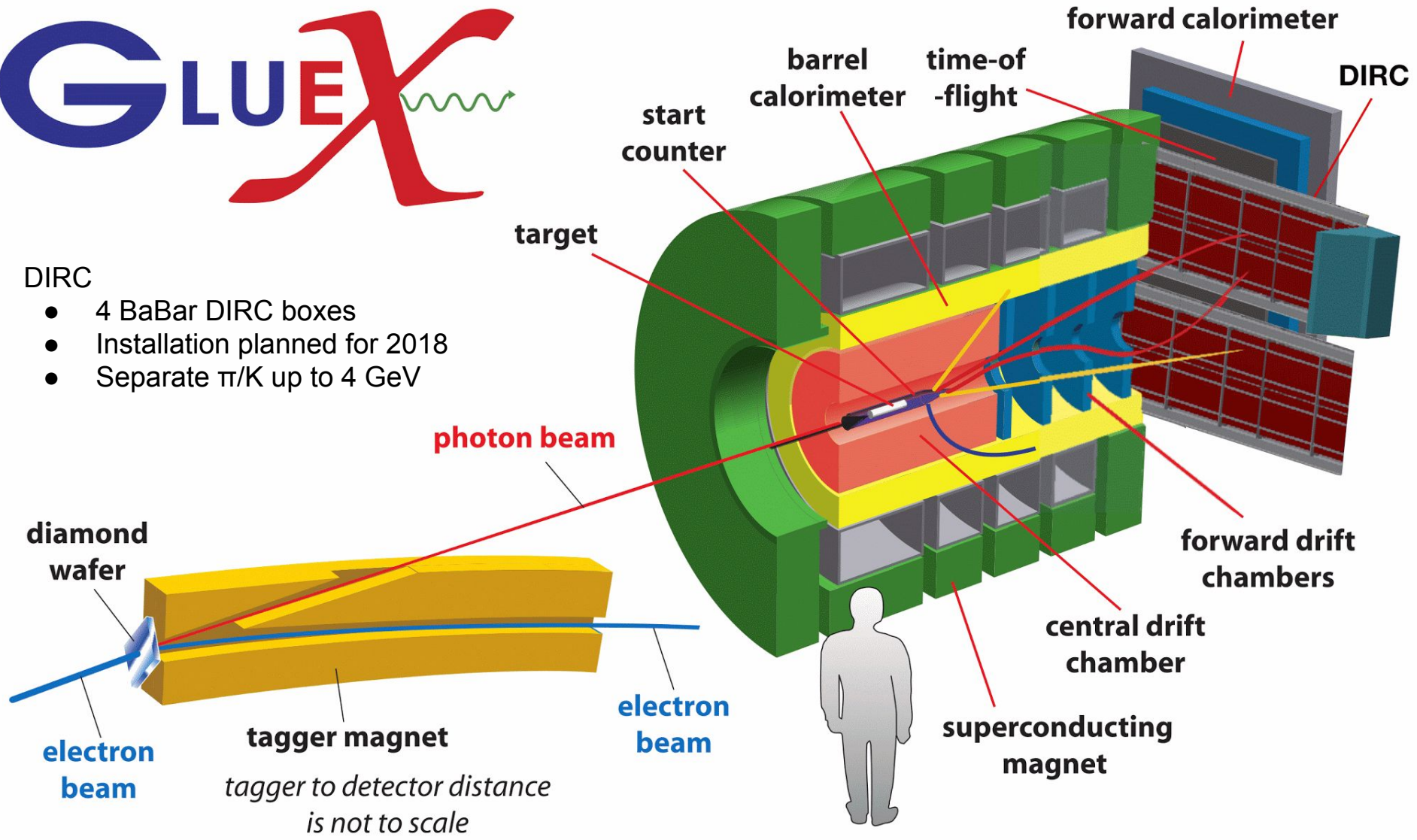
50  $\mu\text{m}$  diamond, 2 ns beam period. Coherent edge at 9 GeV

# GlueX Experiment - beamline



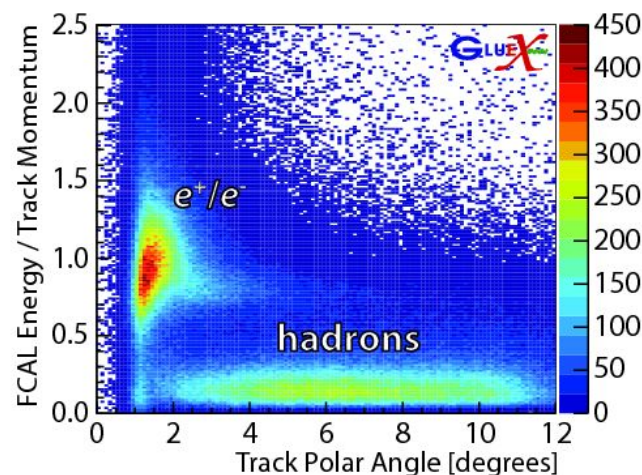
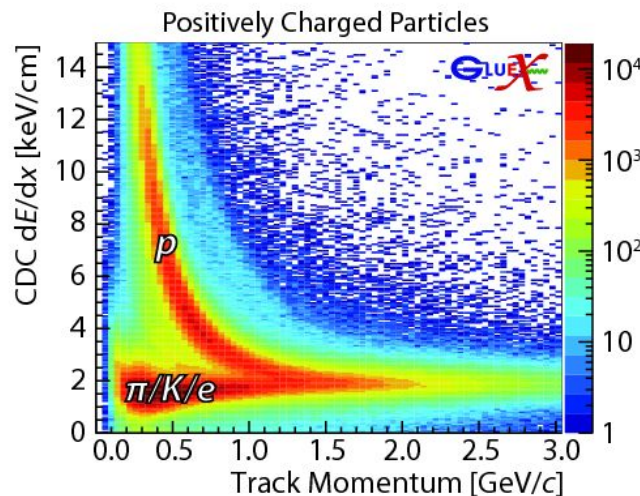
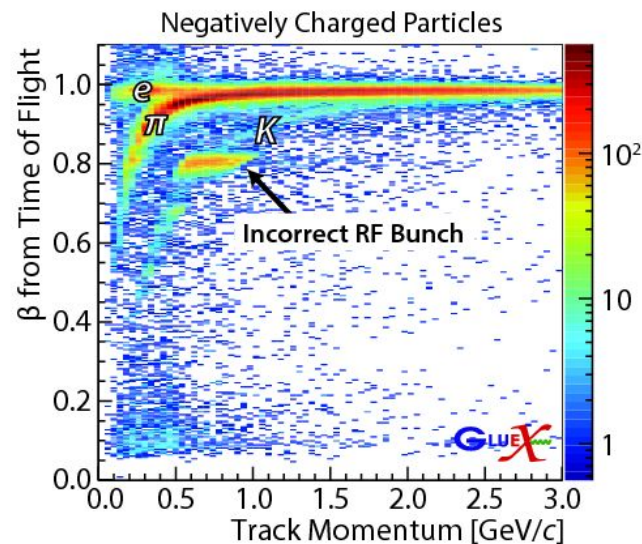
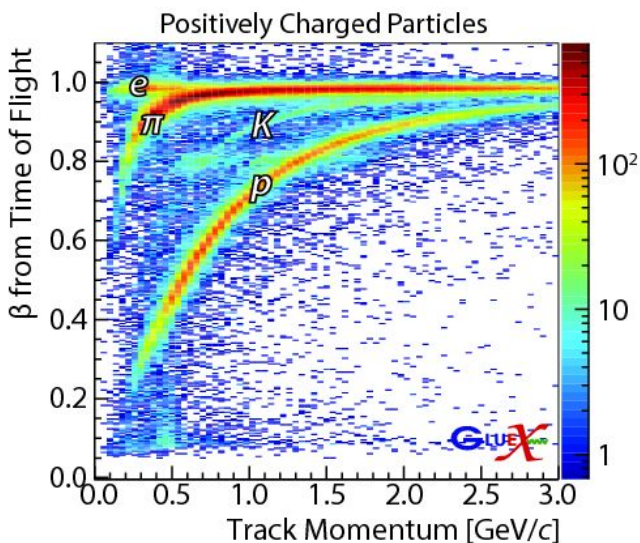
# GLUEX

- DIRC**
- 4 BaBar DIRC boxes
  - Installation planned for 2018
  - Separate  $\pi/K$  up to 4 GeV



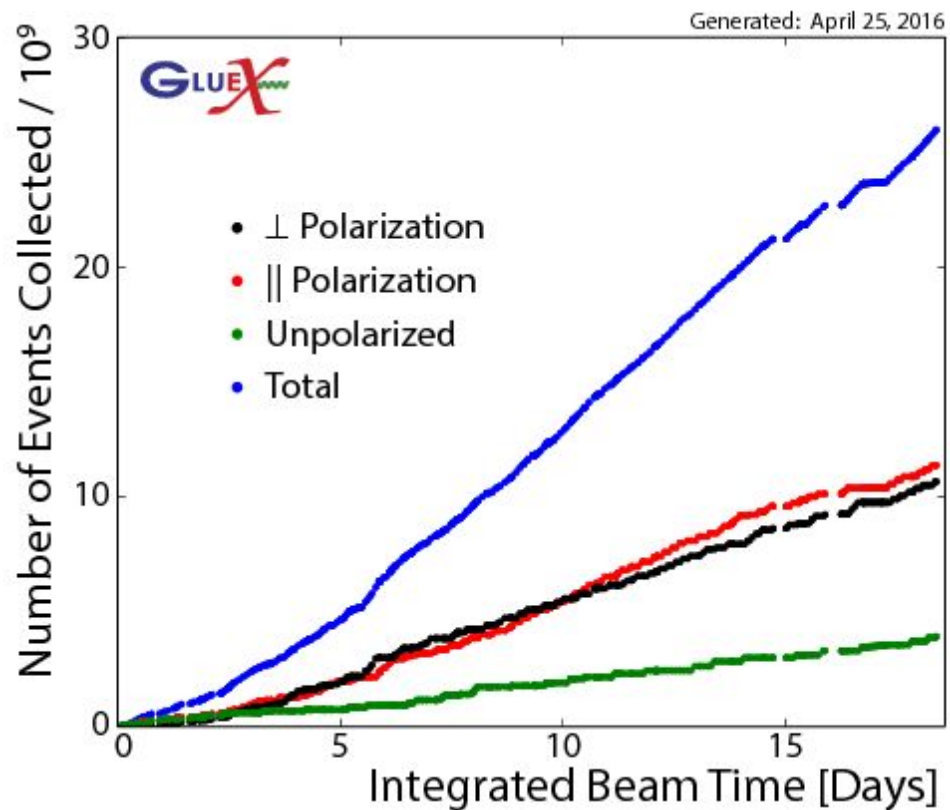


# GlueX - Particle Identification



# GlueX - Spring 2016 Commissioning Data

- Typical acquisition rate
  - 30 kHz
  - 90% live time
  - 750 MB/s
- Approximate production volume:  
550 TB, raw data

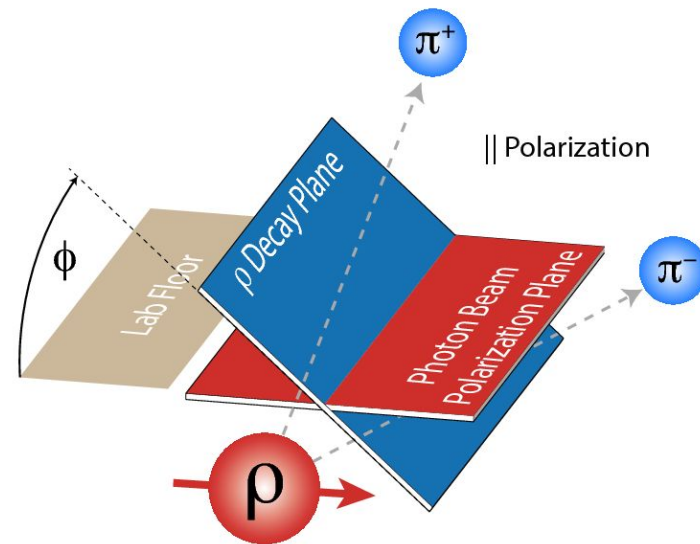


# Physics in GlueX

- Currently processing data into condensed data format
  - 25% processed, less analyzed
  - More currently on the farm
- Short term using commissioning data
  - Polarization transfer and beam asymmetry
    - $\gamma p \rightarrow (\pi^0, \eta, \eta') p$
    - $\gamma p \rightarrow (\rho^0, \omega, \phi) p$
  - Initial analyses for:
    - 1.6 GeV enhancement in  $\pi^+ \pi^-$  mass distribution
    - Signals in the  $4\gamma$  final state
- Long term
  - Spin-density matrix elements to understand production mechanisms
  - Cross sections measurements
  - Identify known mesons in PWA
  - Search for hybrids

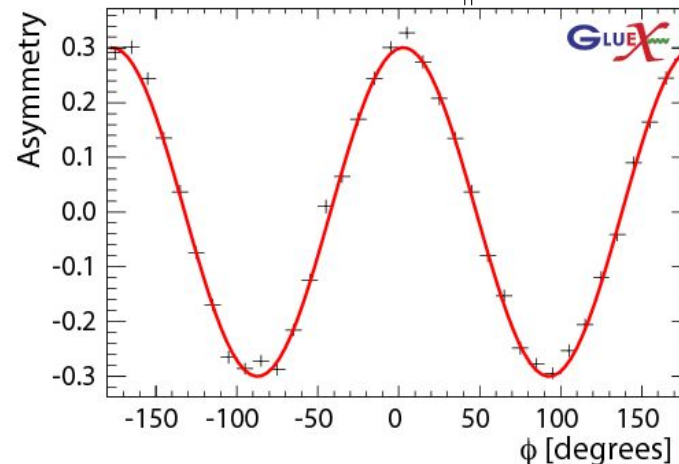
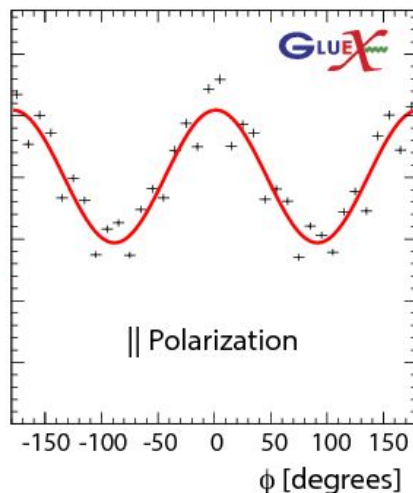
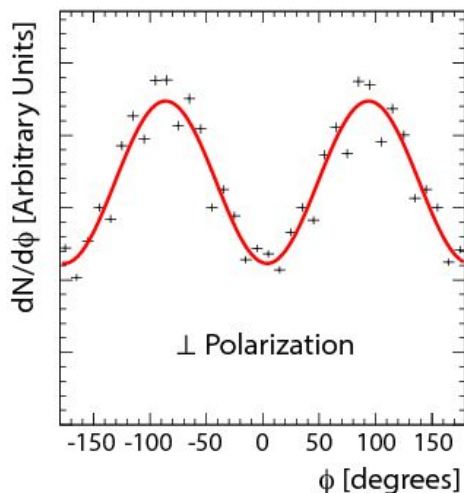
# Beam Asymmetry in $\rho$ Photoproduction

- Useful monitor of photon beam polarization
- Have 100 times the existing world data for all energies
- Working with the Joint Physics Analysis Center (JPAC) on models for analysis
- Large polarization transfer to the  $\rho$



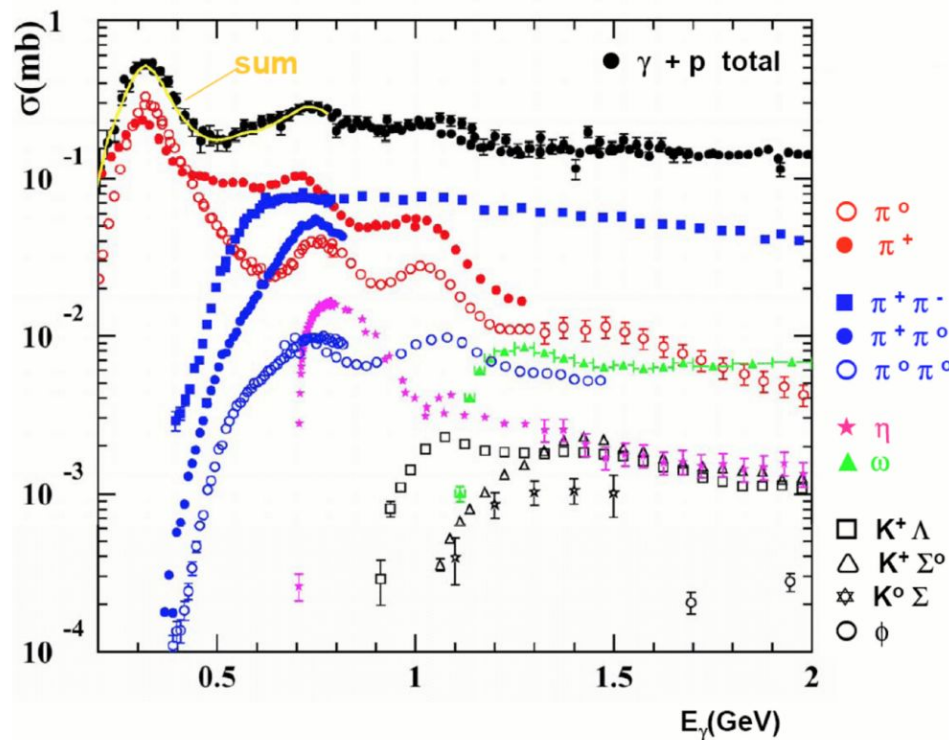
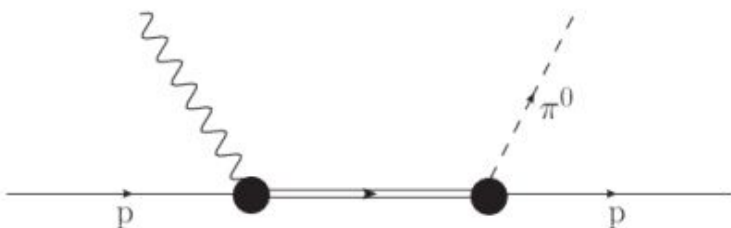
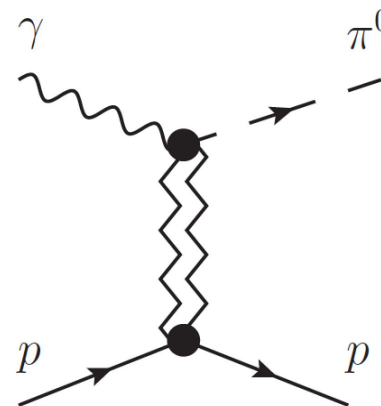
$$d\sigma_{\perp} \propto 1 - P_{\perp} \cos 2\phi \quad d\sigma_{\parallel} \propto 1 + P_{\parallel} \cos 2\phi$$

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



# $\pi^0$ beam asymmetry

- Provides constraints on “background” to baryon resonance extraction in low energy regime
  - Constrains PWA amplitudes through Finite Energy Sum Rule



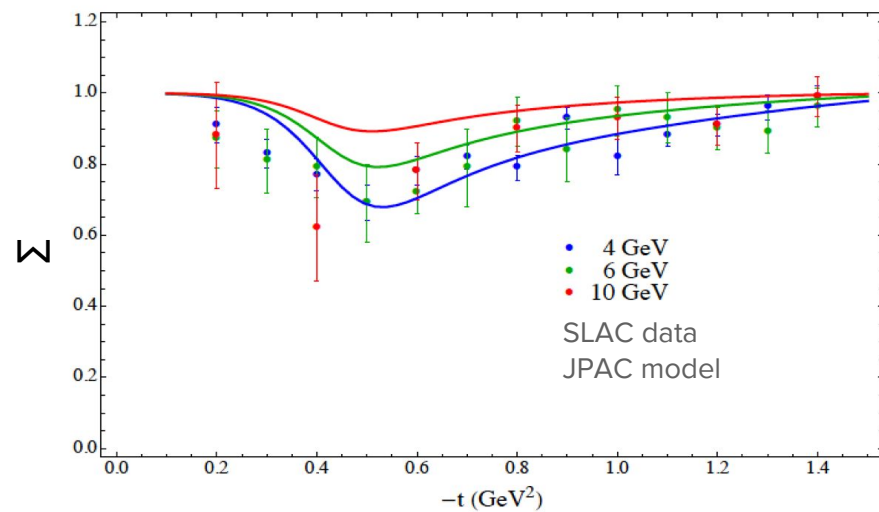
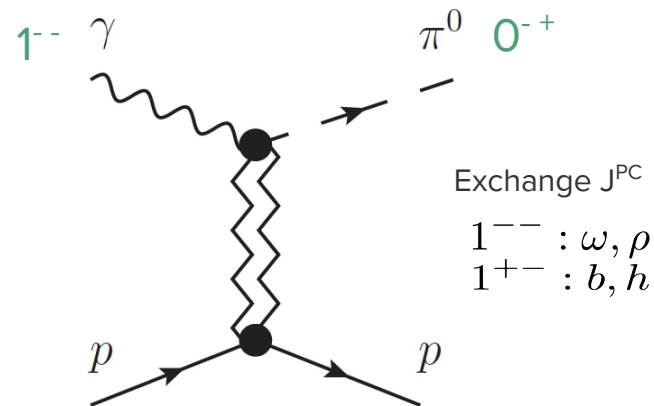
# $\pi^0$ beam asymmetry

- Provides constraints on “background” to baryon resonance extraction in low energy regime
  - Constrains PWA amplitudes through Finite Energy Sum Rule
- Understand production mechanism in high energy photoproduction
  - To produce neutral  $C = +1$ , need a  $C = -1$  exchange particle

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

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

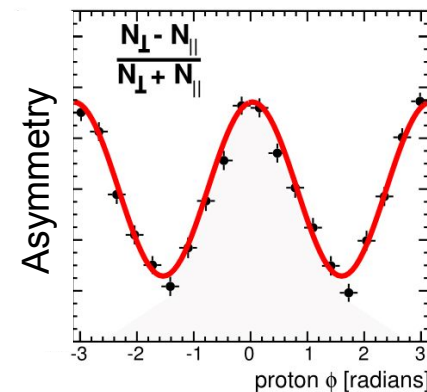
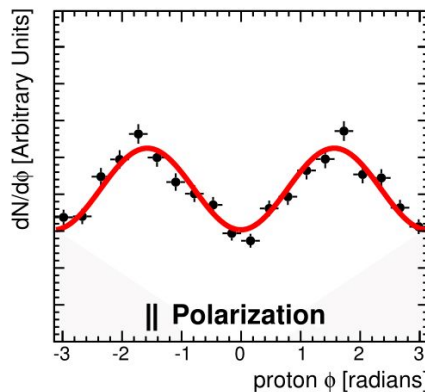
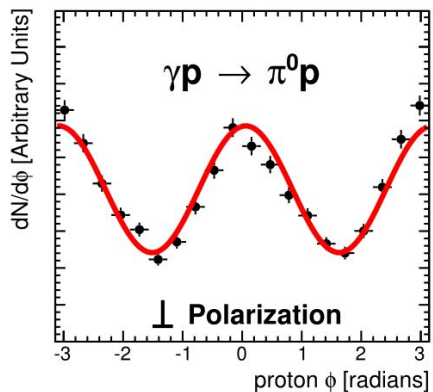
Each term is a single Regge amplitude



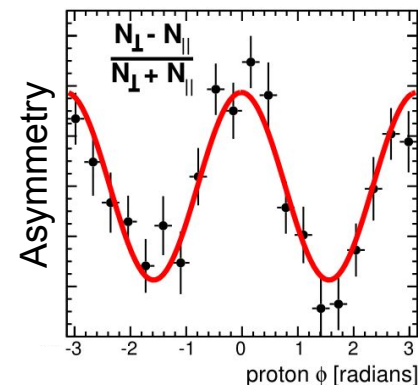
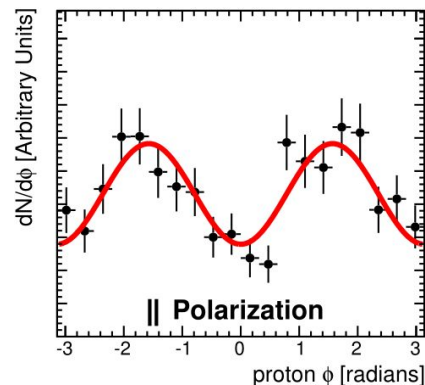
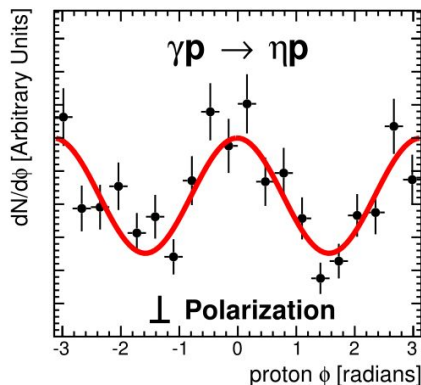
Mathieu et al. PRD 92, 074013

# Pseudoscalar Beam Asymmetries

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



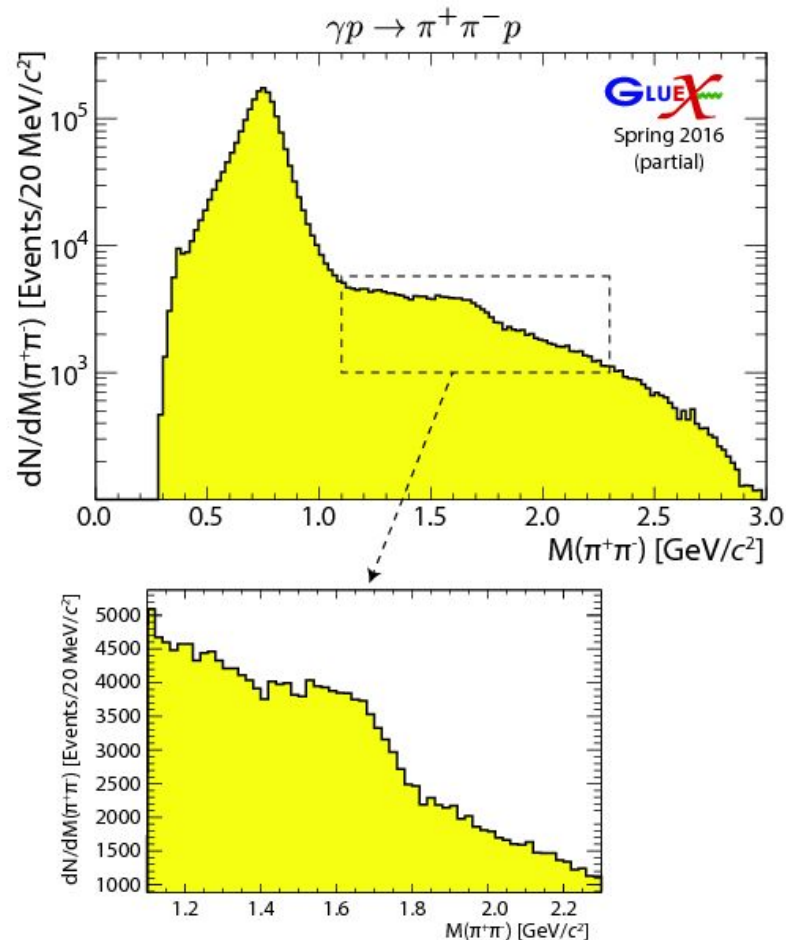
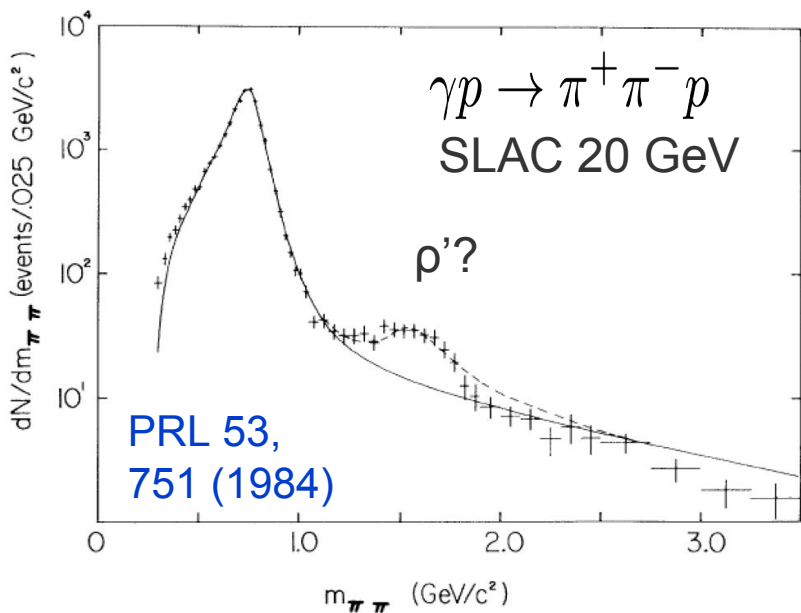
$$E_{\gamma} = 8.4 - 9.0 \text{ GeV}$$



No previous measurements for  $\gamma p \rightarrow \eta p$

# $\gamma p \rightarrow \pi^+ \pi^- p$

- In the  $\pi^+ \pi^-$  invariant mass spectrum we can look for higher-mass vector mesons
- We observe an enhancement at 1.6 GeV with significantly more statistics than existing data.
  - Only 10% of our data
- Should be able to measure polarization observables

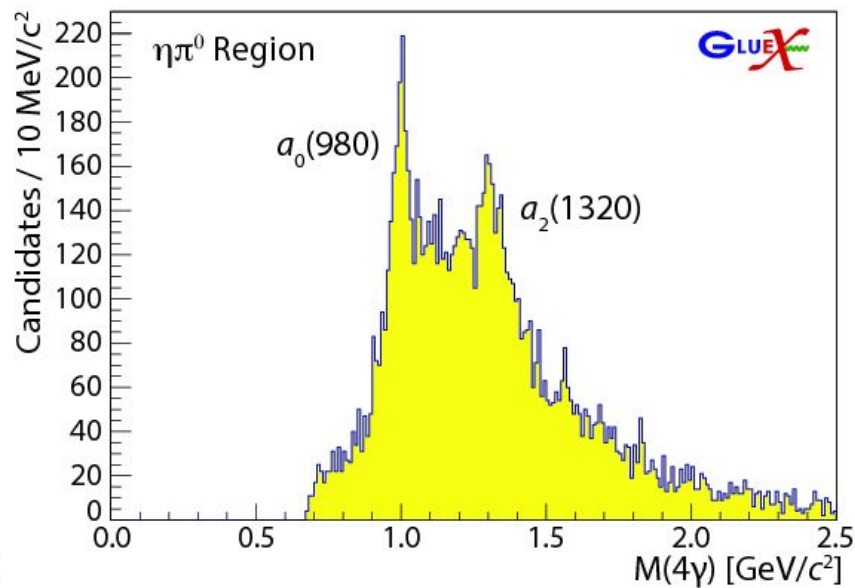
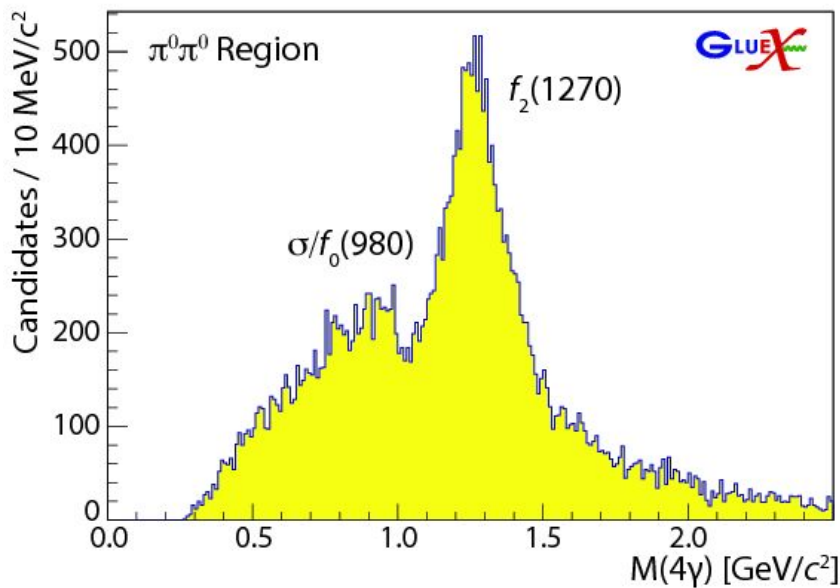
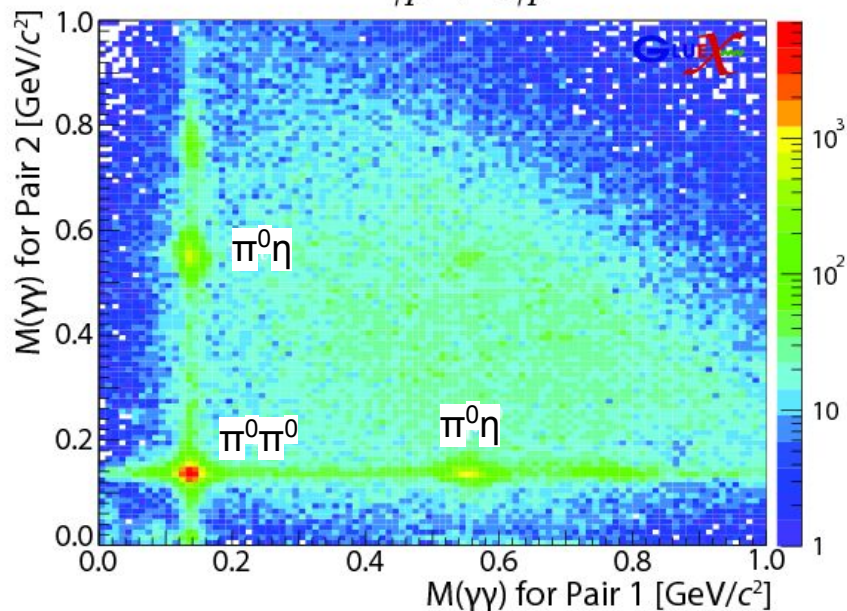




# $\gamma p \rightarrow p \gamma \gamma \gamma$

- About 6% of the spring 2016 statistics
- Preliminary production run
- Signals for  $\sigma$ ,  $f_0(980)$ ,  $f_2(1270)$ ,  $a_0(980)$  and  $a_2(1320)$

$$\gamma p \rightarrow 4\gamma p$$



# Summary

- Commissioning running finished successfully
- All detector systems are near design specifications
- Iterative calibration improvements expected
- Initial physics running fall 2016 - 2018
- We have made significant progress towards our first physics measurements
- The addition of the BaBar DIRC bar boxes and 5x higher intensity are planned in 2018 to allow us to cover all parts of the GlueX exotic hybrid program
- There is an extensive physics program beyond GlueX and we are excited to have new ideas and new collaborators

# Hall D - 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
- Univ. Mass Amherst
- MIT
- MEPHI
- Norfolk State
- North Carolina A&T
- Univ. North Carolina Wilmington
- Northwestern
- University of Regina
- Santa Maria
- Tomsk
- Yerevan Physics Institute.

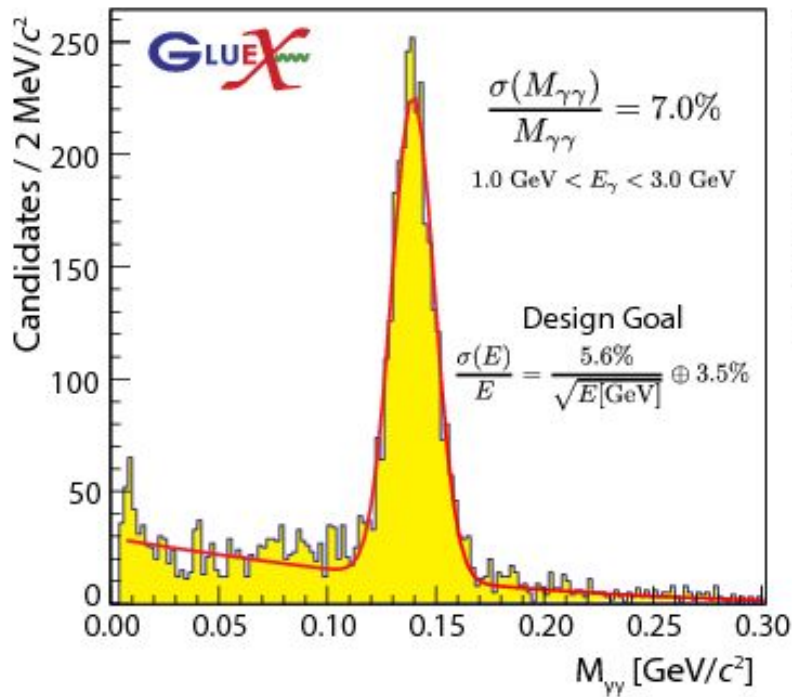
Over 120 collaborators from 24 institutions with others joining and more are welcome.

# Backups

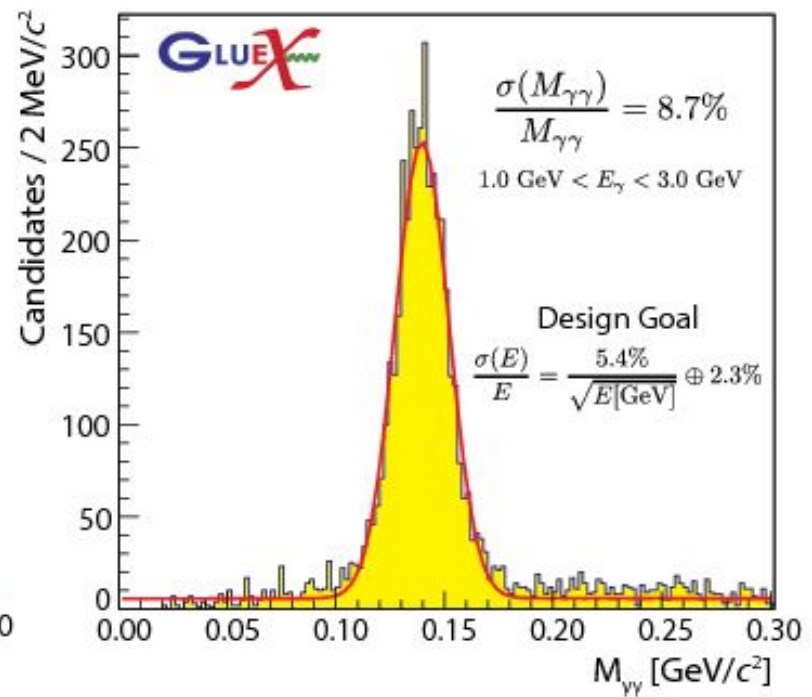
# GlueX - Calorimeter performance

(Measured using exclusive  $\gamma p \rightarrow 4\gamma p$ )

Forward Lead Glass Calorimeter

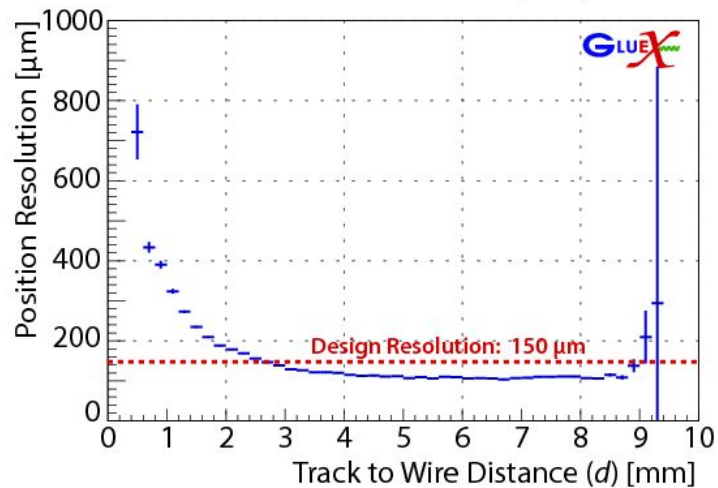


Barrel Lead-Scintillating Fiber Calorimeter

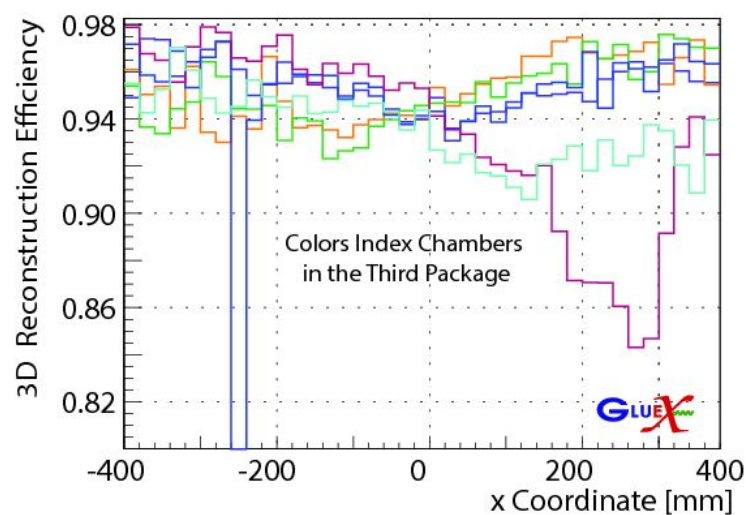
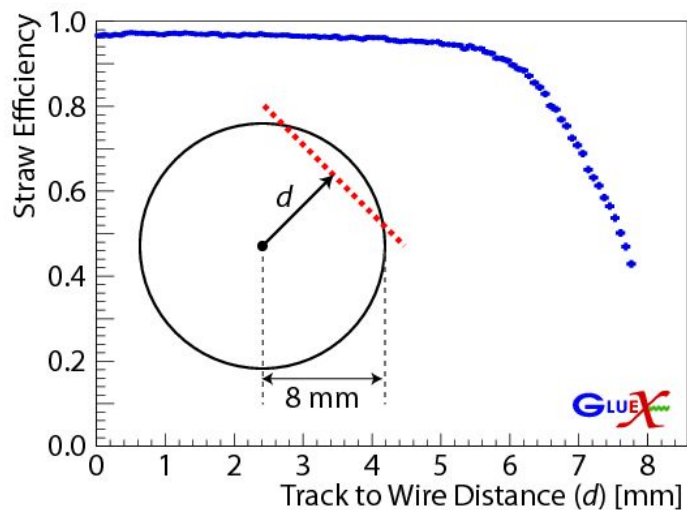
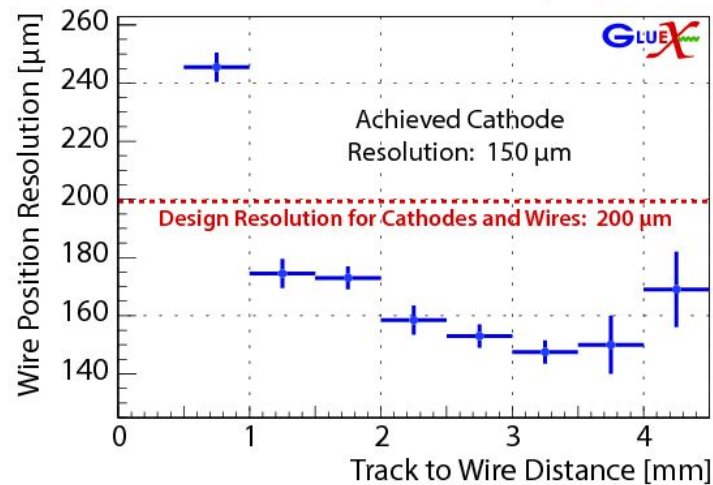


# GlueX - Tracking Performance

Central Drift Chamber (CDC)

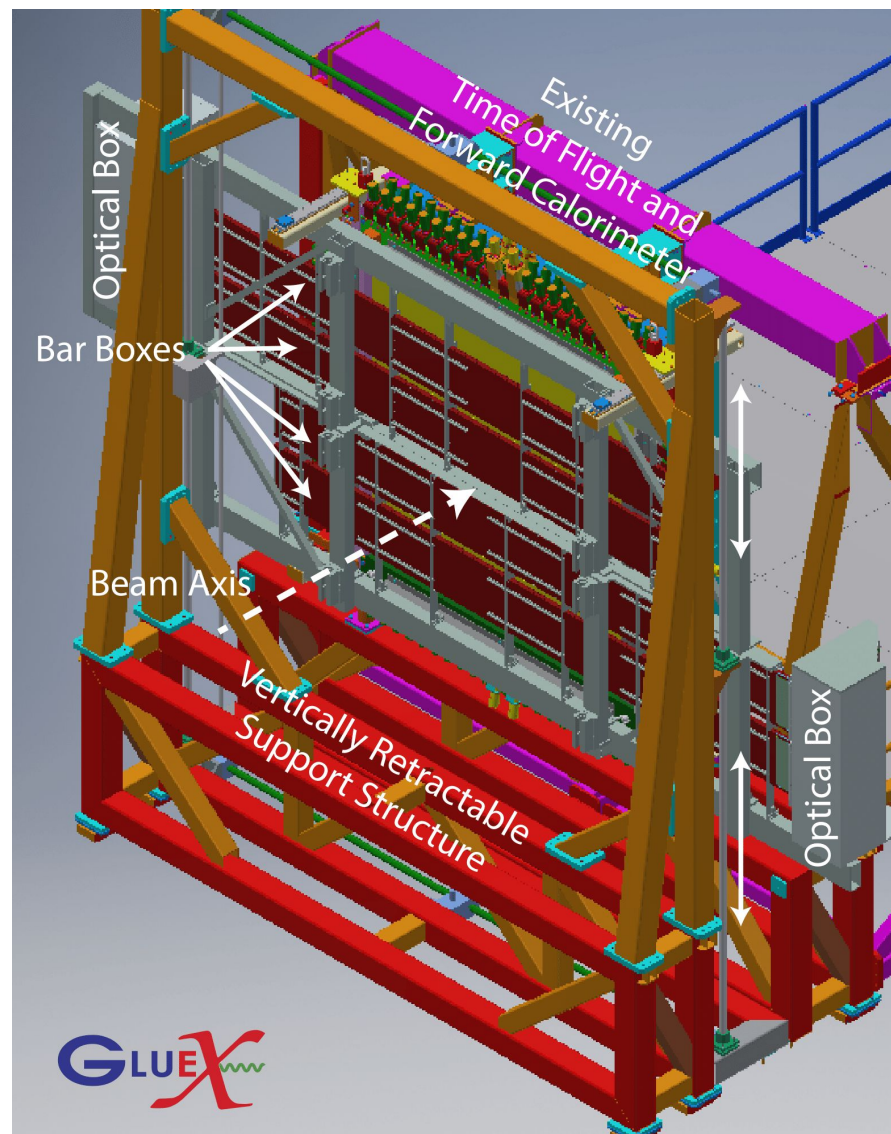


Forward Drift Chamber (FDC)



# GlueX - Forward Kaon Identification

- Four of the BaBar DIRC bar boxes will be installed in front of the TOF
- Combined with the other PID systems in GlueX, this will allow us to fully study final states with strange quarks
- Separate  $\pi/K$  up to 4 GeV
- Strangeonium mesons and hybrids can be studied
- Hyperon and cascade baryons can be studied
- Expected 2018



# GlueX - Spring 2016 Commissioning Data

- Typical acquisition rate
  - 30 kHz
  - 90% live time
  - 750 MB/s
- Approximate production volume: 550 TB, raw data

