# Hall D & GlueX Update

Alex Barnes, University of Connecticut

Outline

- Hall D experiments

- GlueX physics overview

- GlueX experiment and commissioning performance

- Initial physics analyses

- Long-term plans

- Summary

Hall D Experiments

- **GlueX - Hybrid mesons/spectroscopy**
  - PR-06-102, PR-12-002, PR-13-003
  - 340-540 PAC days
- **GlueX - PrimEx-eta**
  - PR-10-011
  - 79 PAC days
- **GlueX - Pion polarizability**
  - PR-13-008
  - 25 PAC days
- **GlueX - JLab Eta Factory (JEF): Rare eta decays**
  - PR-14-004
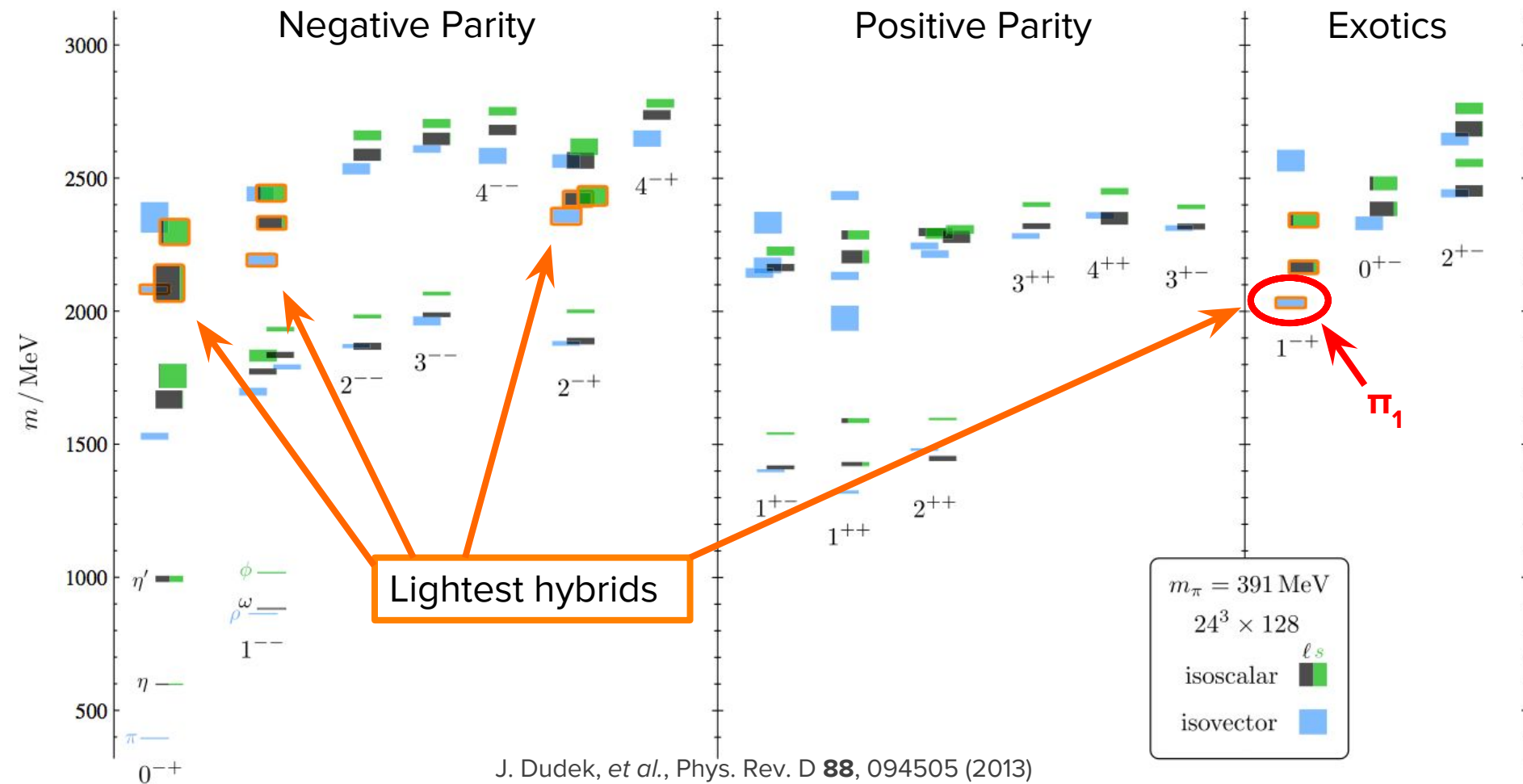 - Conditionally approved
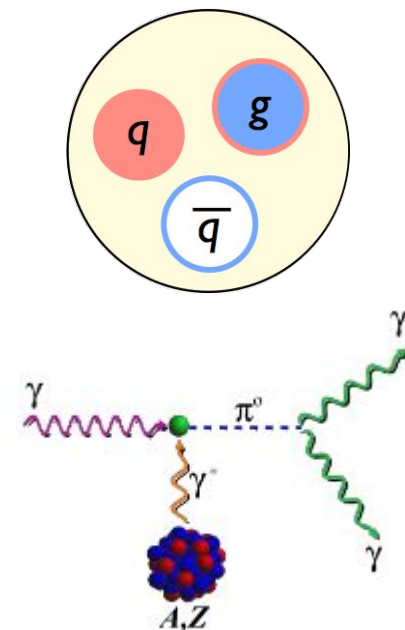
GlueX

Quark model

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

Hybrids

- Excited gluonic field coupled to $q\bar{q}$ pair
- Spectrum of hybrids predicted by lattice QCD
- "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^{+-}, ...
- Exotics provide unambiguous signal

Lattice QCD predictions

- Search for pattern of hybrid states in many final states
- Most evidence for π_1 ($J^{PC} = 1^{-+}$)

Negative Parity   Positive Parity   Exotics

Lightest hybrids

π_1

$m_\pi = 391\,\mathrm{MeV}$
$24^3 \times 128$

isoscalar
isovector

J. Dudek, *et al.*, Phys. Rev. D **88**, 094505 (2013)

Exotic J^{PC} Decays

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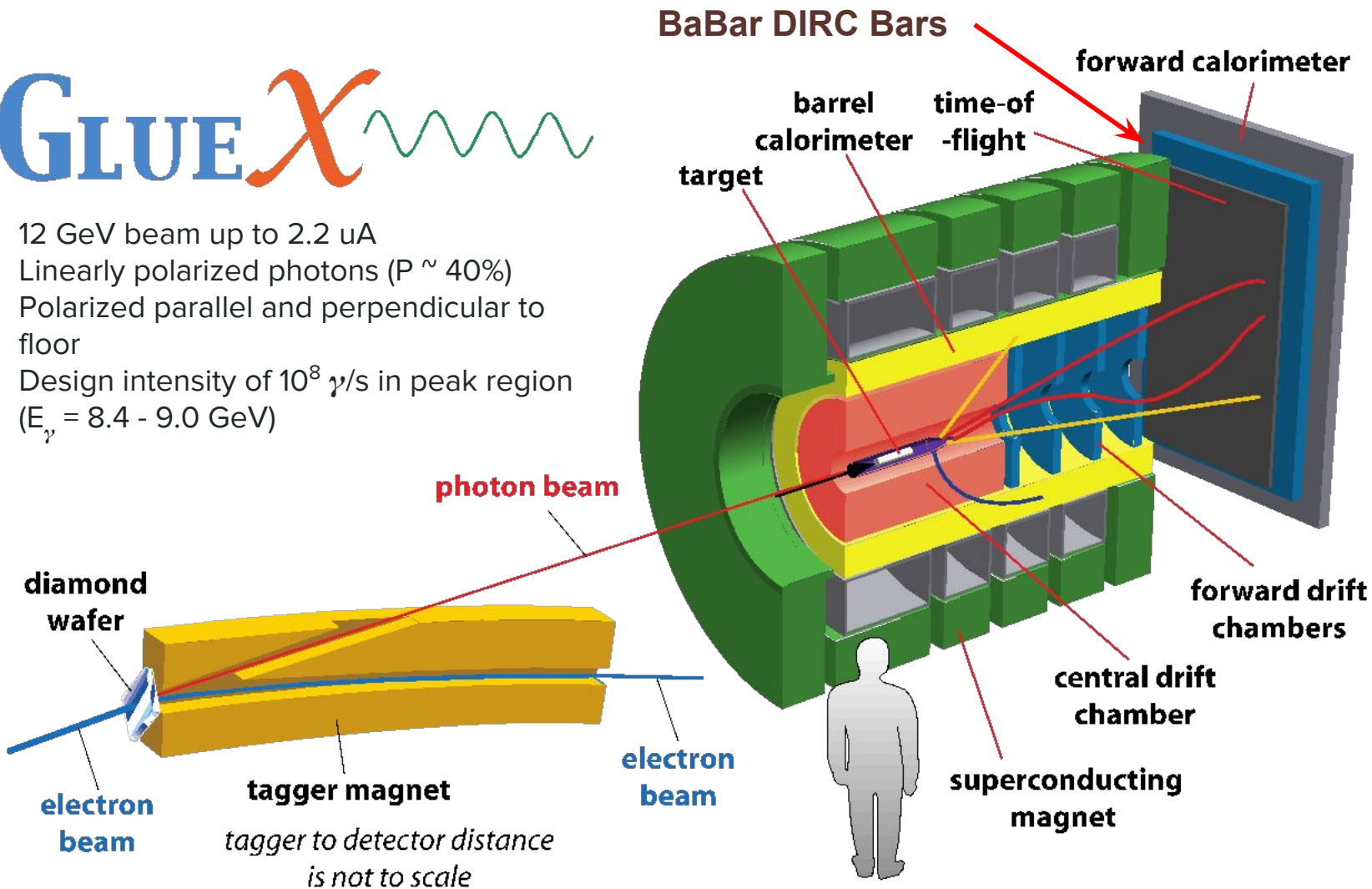- Early reach
- With statistics

Name	J^{PC}	Total Width MeV		Allowed Decay Modes
		PSS	IKP	
π_1	1^{-+}	$81-168$	117	$b_1\pi$, $\pi\rho$, πf_1, $\pi\eta$, $\pi\eta'$, ηa_1, $\pi\eta(1295)$
η_1	1^{-+}	$59-158$	107	πa_1, πa_2, ηf_1, ηf_2, $\pi\pi(1300)$, $\eta\eta'$, KK_1^A, KK_1^B
η_1'	1^{-+}	$95-216$	172	KK_1^B, KK_1^A, KK^*, $\eta\eta'$
b_0	0^{+-}	$247-429$	665	$\pi\pi(1300)$, πh_1, ρf_1, ηb_1
h_0	0^{+-}	$59-262$	94	πb_1, ηh_1, $KK(1460)$
h_0'	0^{+-}	$259-490$	426	$KK(1460)$, KK_1^A, ηh_1
b_2	2^{+-}	$5-11$	248	πa_1, πa_2, πh_1, $\eta\rho$, ηb_1, ρf_1
h_2	2^{+-}	$4-12$	166	$\pi\rho$, πb_1, $\eta\omega$, ωb_1
h_2'	2^{+-}	$5-18$	79	KK_1^B, KK_1^A, KK_2^*, ηh_1

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

GlueX Experiment
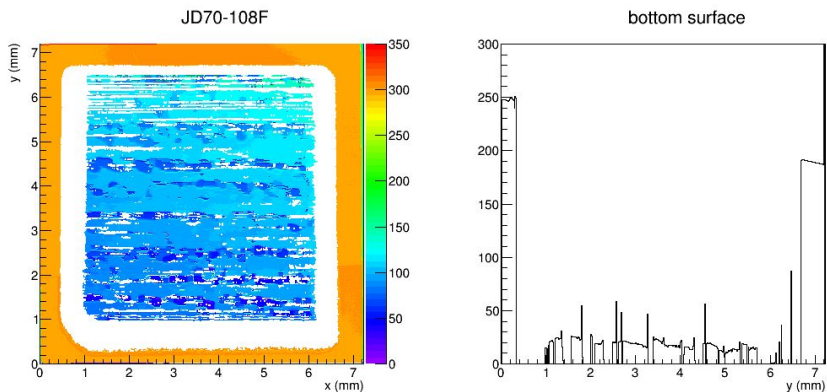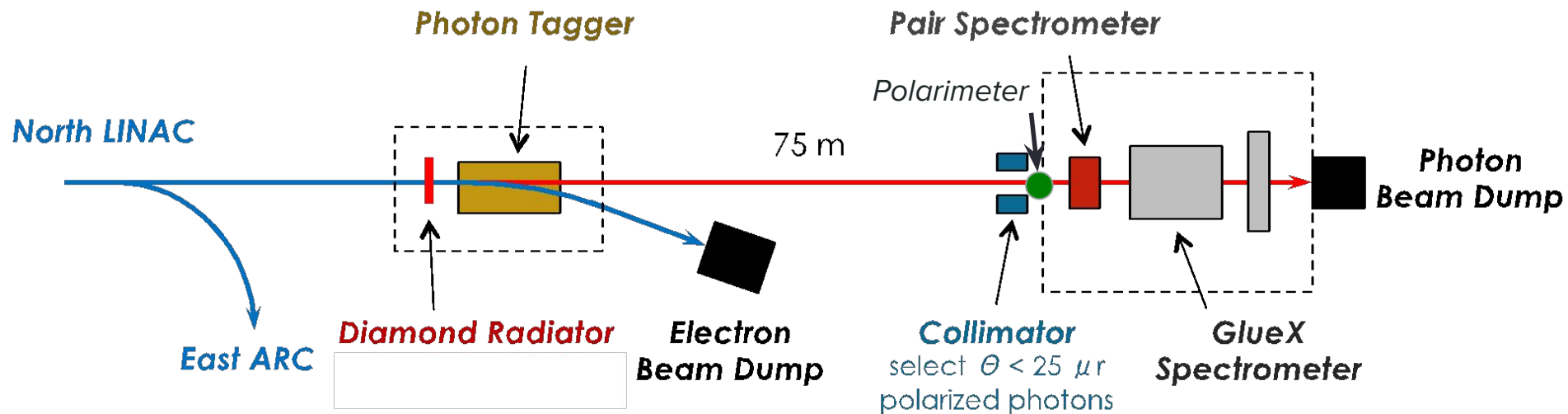

- 12 GeV beam up to 2.2 uA
- Linearly polarized photons (P ~ 40%)
- Polarized parallel and perpendicular to floor
- Design intensity of 10^8 γ/s in peak region (E_γ = 8.4 - 9.0 GeV)

BaBar DIRC Bars
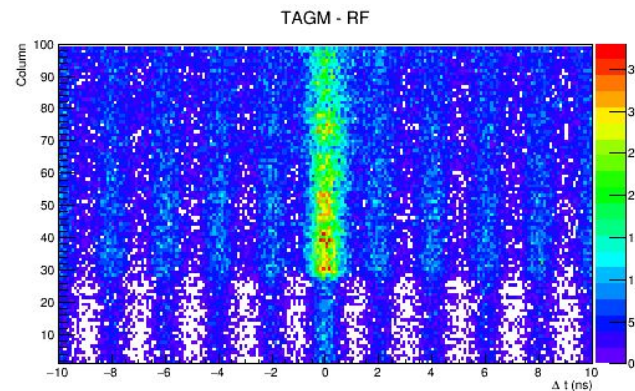
forward calorimeter

barrel calorimeter

time-of-flight

target

photon beam

diamond wafer

electron beam

tagger magnet

electron beam

tagger to detector distance is not to scale

forward drift chambers

central drift chamber

superconducting magnet

GlueX Experiment - beamline (UConn)

Photon Tagger

Pair Spectrometer

Polarimeter

North LINAC

75 m

Photon Beam Dump

East ARC

Diamond Radiator

Electron Beam Dump

Collimator
select $\theta < 25\ \mu r$
polarized photons

GlueX Spectrometer

CVD diamond laser ablated to 40 μm, etched by
Applied Diamonds to 17.7 ± 0.5 μm

50 μm diamond, 2 ns beam period. Coherent
edge starts around column 30

GlueX Experiment - beamline
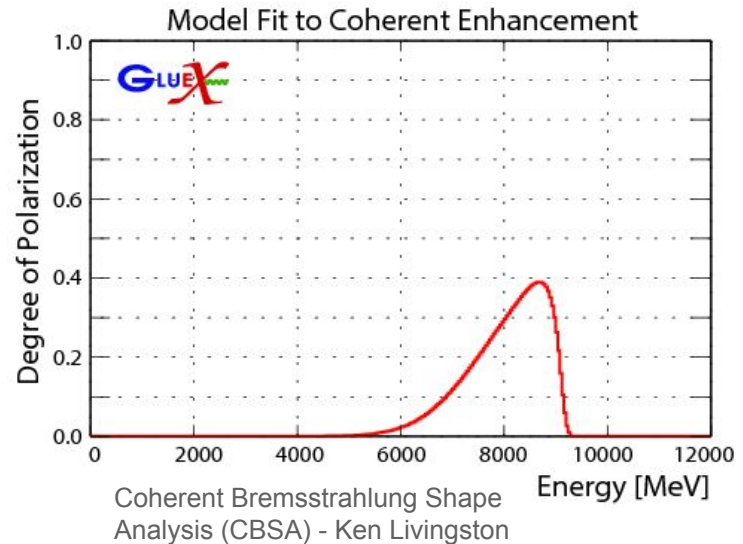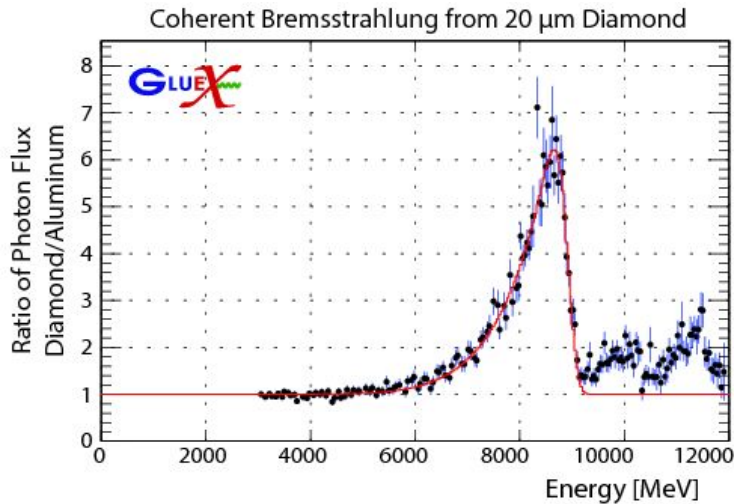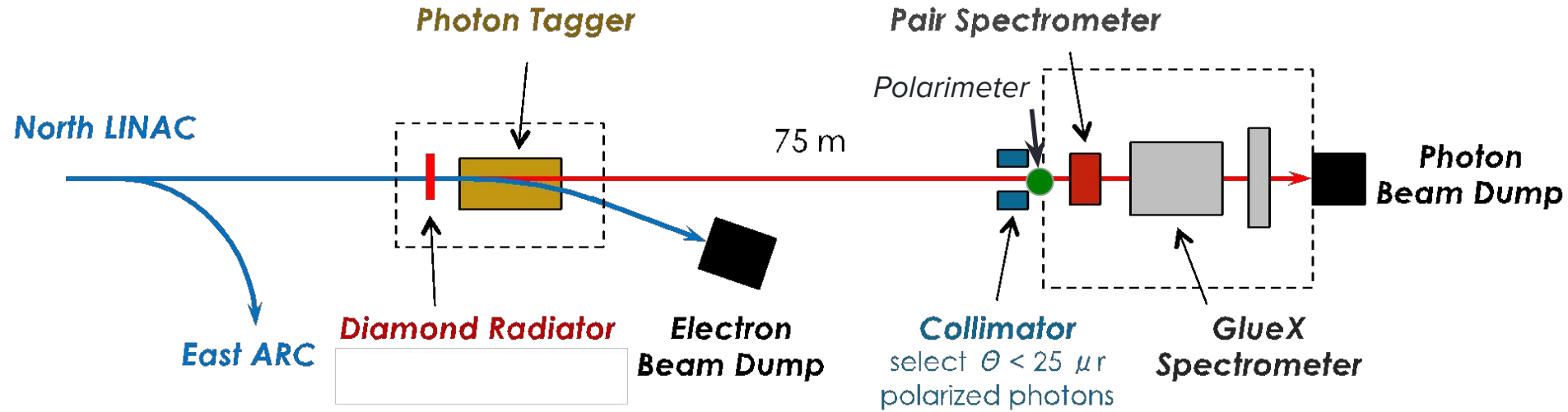
GlueX - Particle Identification
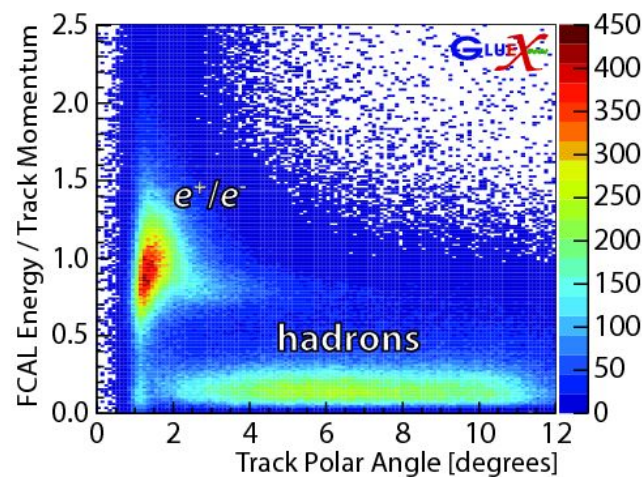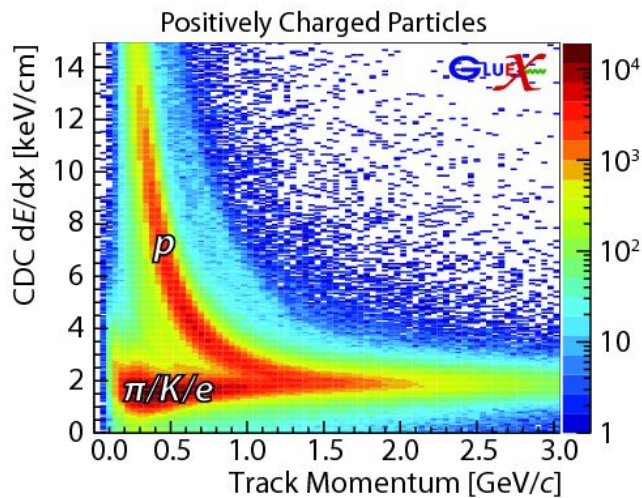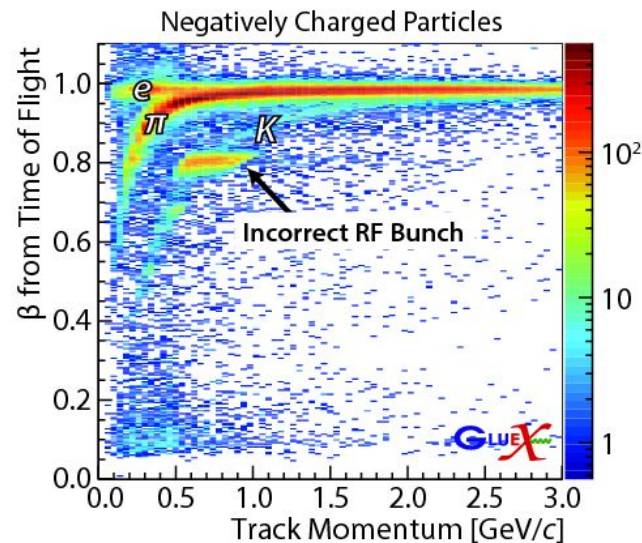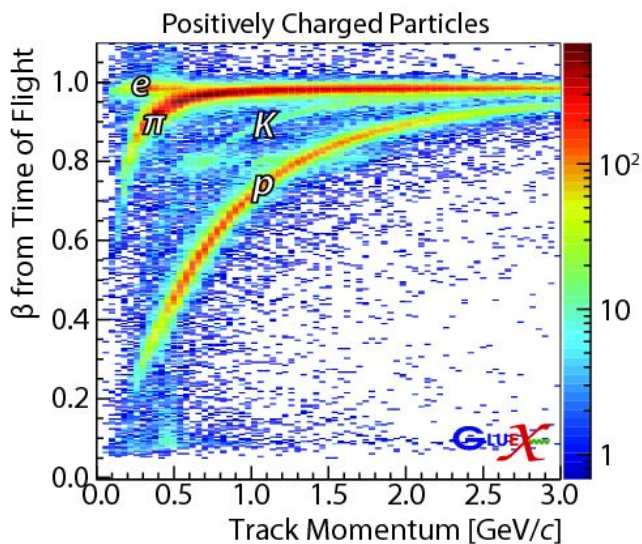
GlueX - Forward Kaon Identification

- 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 π/K up to 4 GeV
- Strangeonium mesons and hybrids can be studied
- Hyperon and cascade baryons can be studied
- Expected 2018
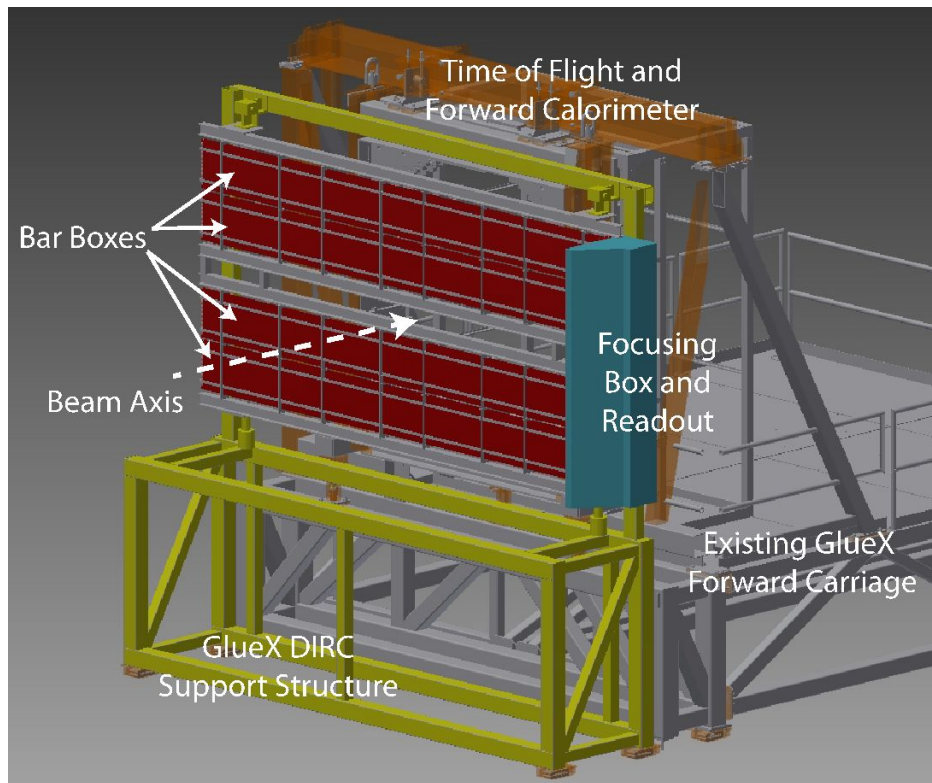
GlueX - Spring 2016 Commissioning Data

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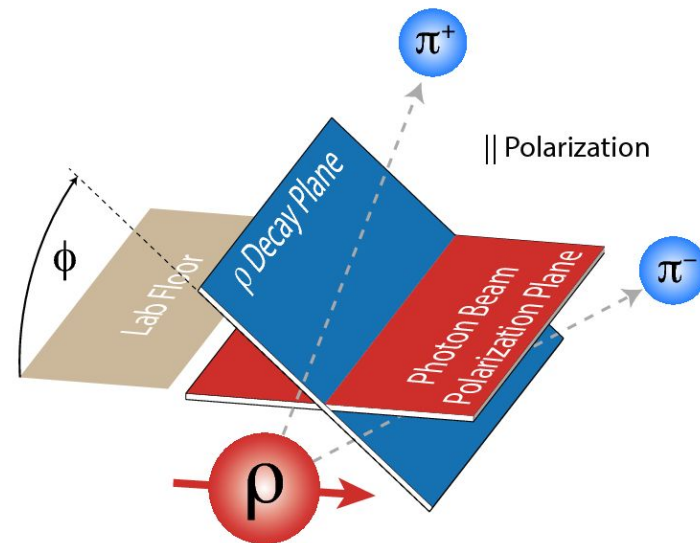- Approximate production volume: 550 TB, raw data
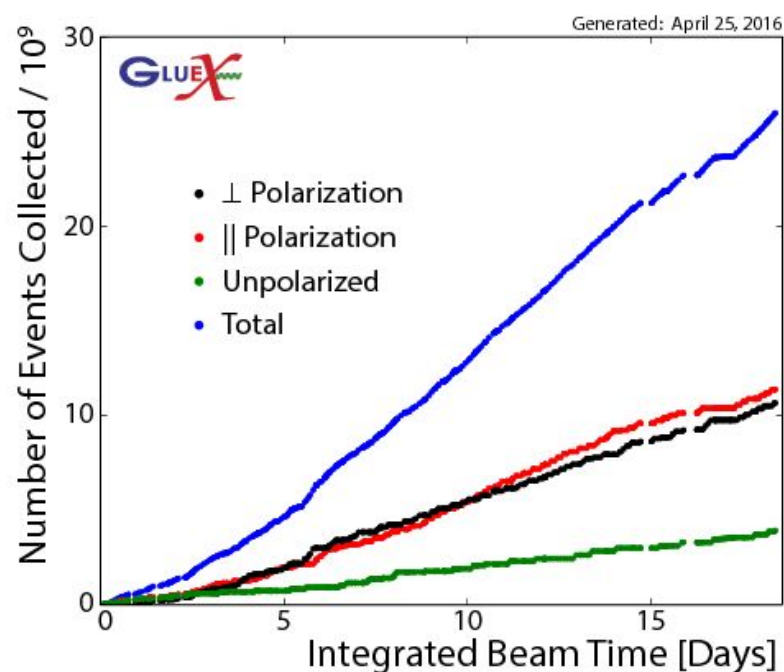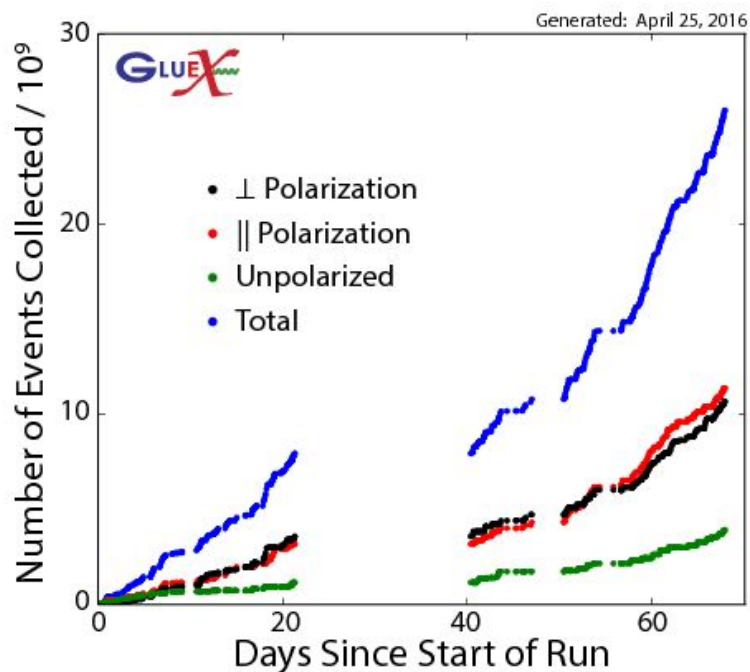
Physics in GlueX

- Calibration and reconstruction for REST data (first subset of data complete)

- Initial reactions will be polarization transfer and beam asymmetry measurements
  - $\gamma p \rightarrow (\pi^0, \eta, \eta')p$
  - $\gamma p \rightarrow (\varrho^0, \omega, \phi)p$

- Opportunistic results from data exploration

- Spin-density matrix elements to understand production mechanisms

- Cross sections measurements
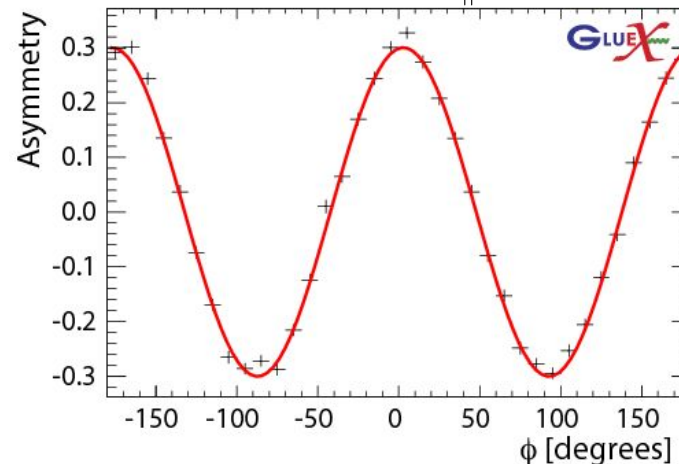
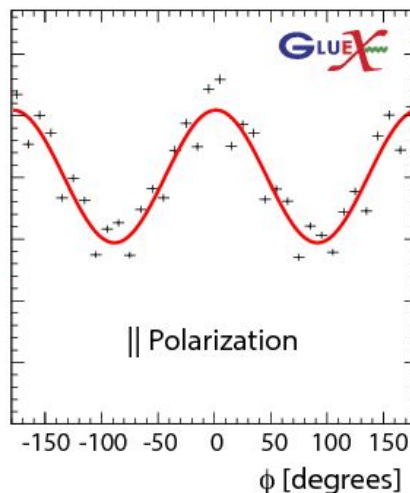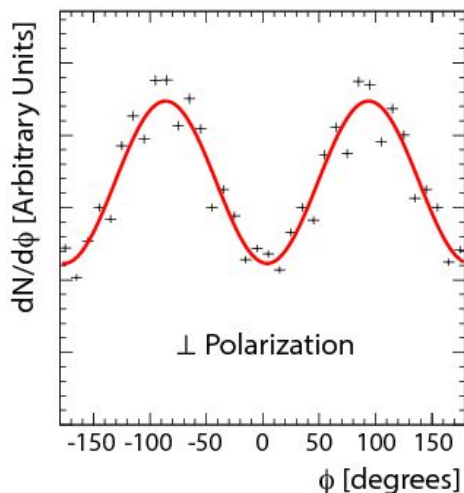- Identify known mesons in PWA

- Search for hybrids

Beam Asymmetry in ϱ Photoproduction

- Useful monitor of photon beam polarization
- Have between 100 and 1000 times the existing 3000 events from SLAC
- Working with JPAC on models for analysis
- Acceptance errors not included
- Large polarization transfer to the ϱ

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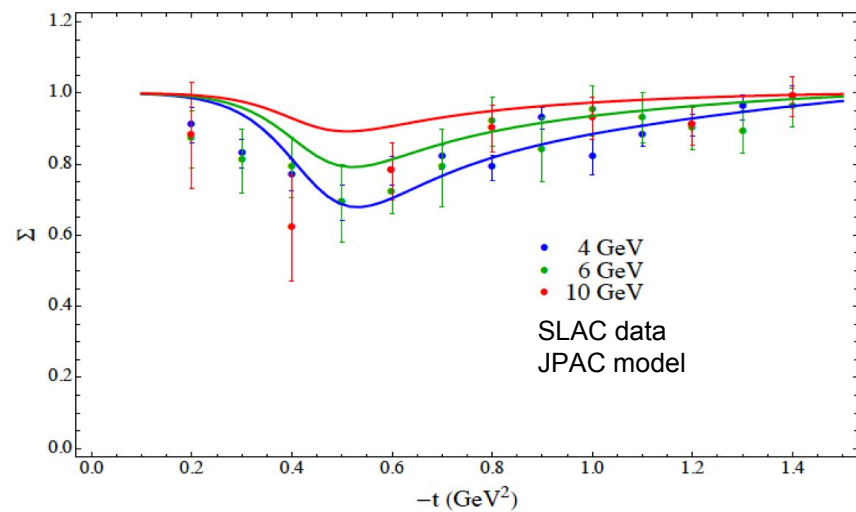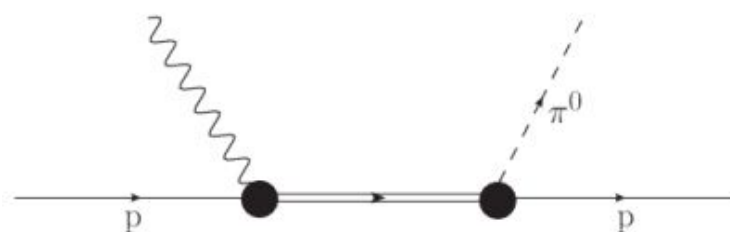
$$d\sigma_\parallel \propto 1 + P_\parallel 2cos\phi$$

$$P\Sigma cos2\phi = \frac{N_\parallel - N_\perp}{N_\parallel + N_\perp}$$

π⁰ beam asymmetry

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

- Provides constraints on "background" to baryon resonance extraction in low energy regime (e.g. CLAS6)
  - Constrains PWA amplitudes through Finite Energy Sum Rule
- Understand production mechanism in high energy photoproduction
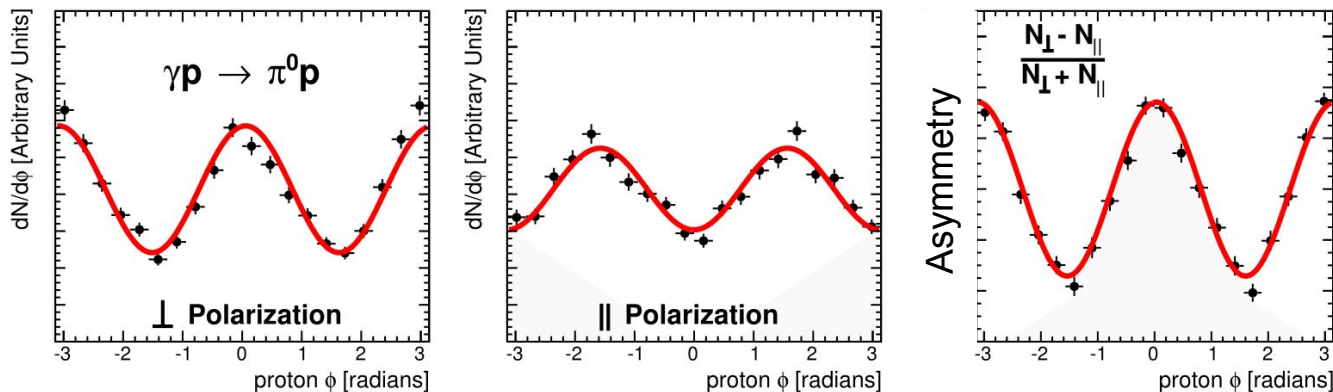 - To produce neutral C = +1, need a C = -1 exchange particle

Exchange J^{PC}

$$1^{--} : \omega, \rho$$
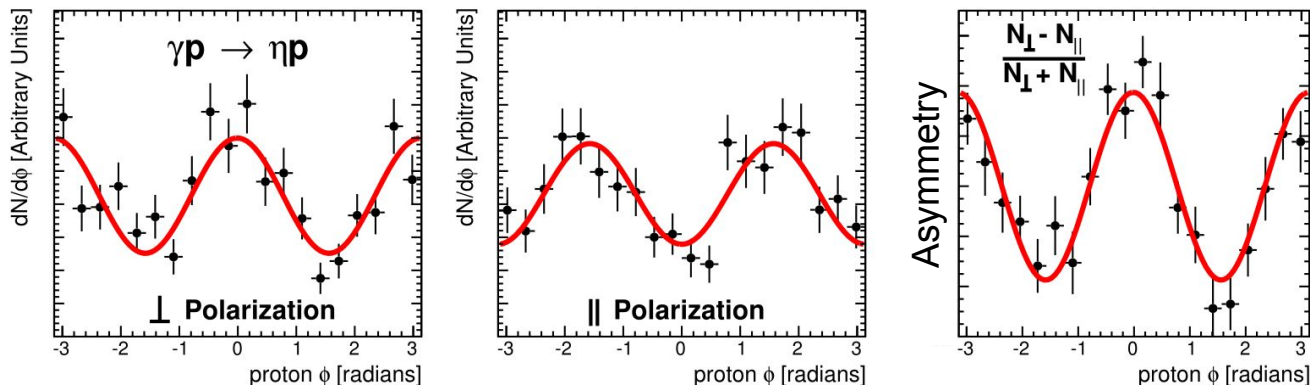$$1^{+-} : b, h$$

SLAC data
JPAC model

Mathieu et al. PRD 92, 074013
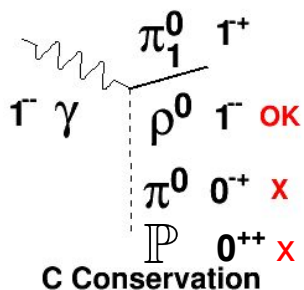
Pseudoscalar Beam Asymmetries
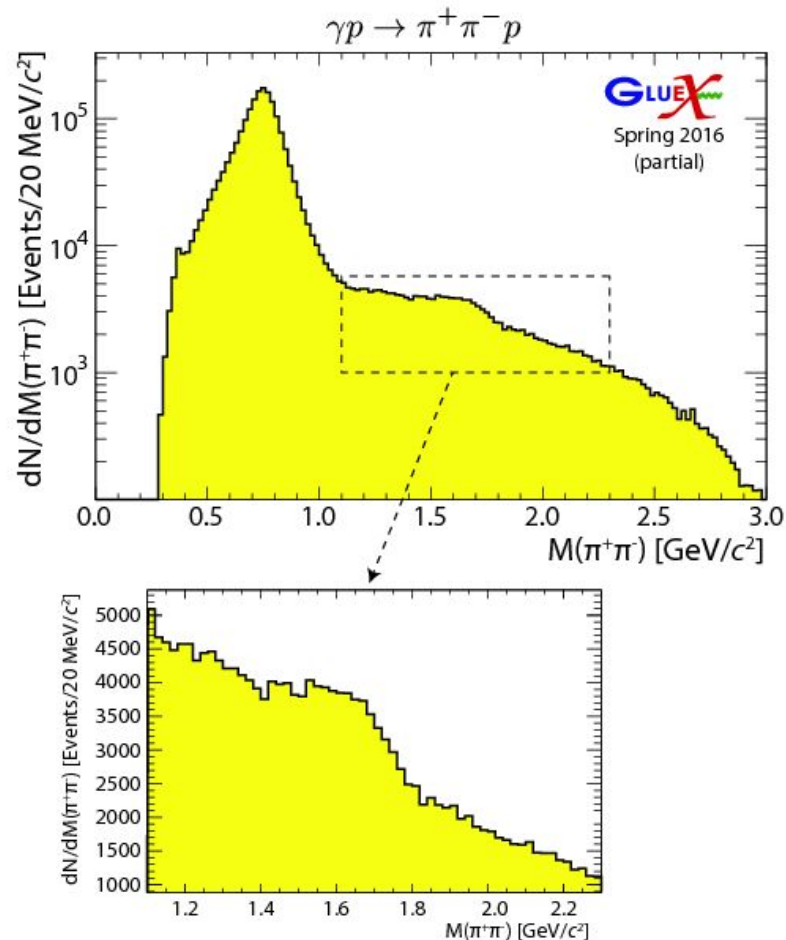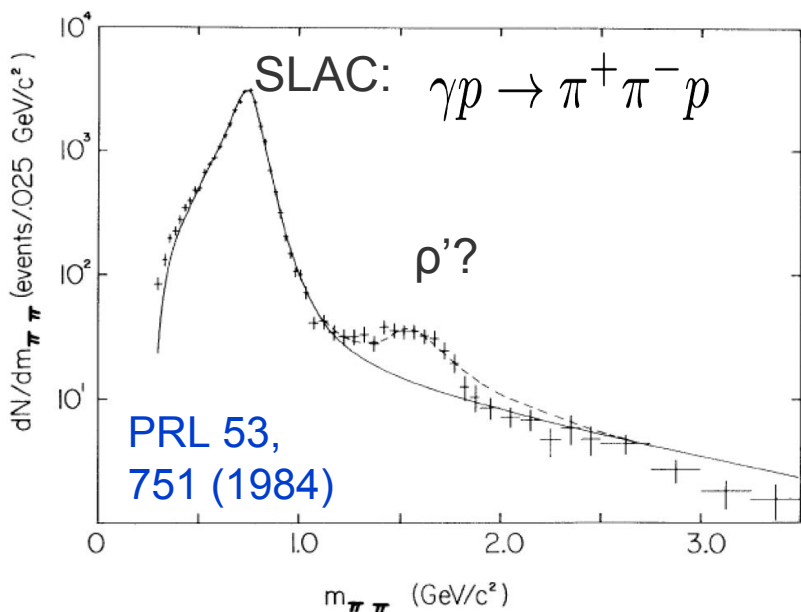
- From a subset of available data
- Polarization not yet determined.

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

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

- 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.
- Should be able to measure polarization observables

SLAC: $\gamma p \rightarrow \pi^+\pi^- p$

ρ'?

PRL 53, 751 (1984)

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

- About 6% of the spring 2016 statistics
- Preliminary production run
- Clear signals for σ, f_0 (980), f_2(1270), a_0 (980) and a_2 (1320)

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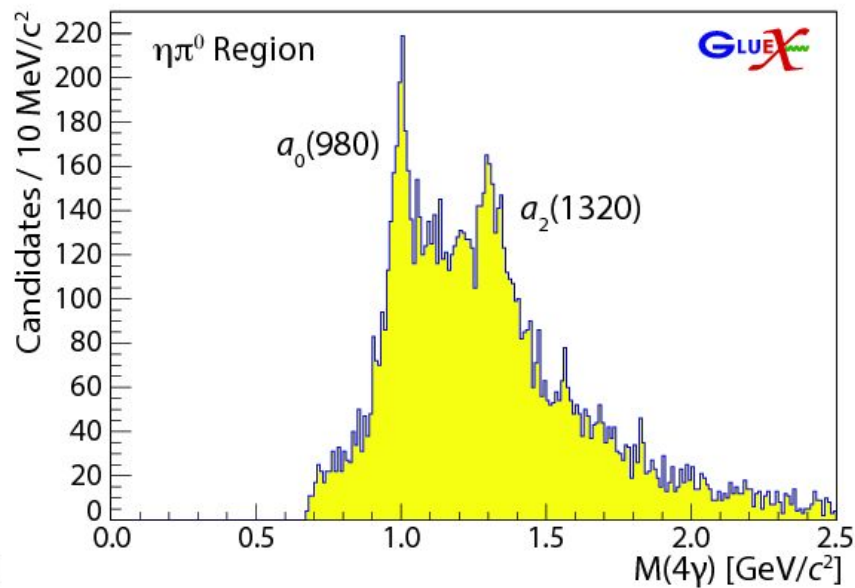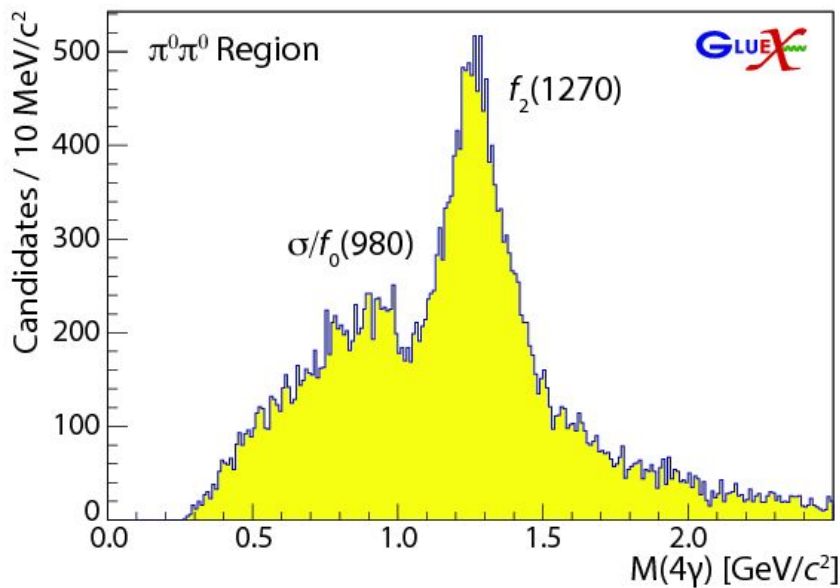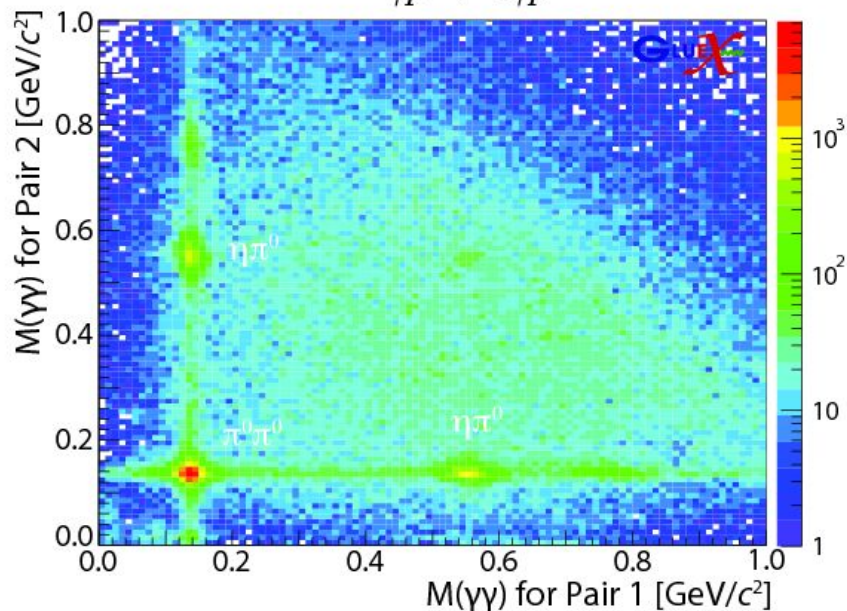
Summary

- Commissioning is finished, eager for production running
- Calibrations are closer to being finalized
- All detector systems are near design specifications
- We have made significant progress towards our first physics measurements
- Currently reconstructing our data for analysis this summer
- 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
- Santa Maria
- University of Regina
- Tomsk
- Yerevan Physics Institute.

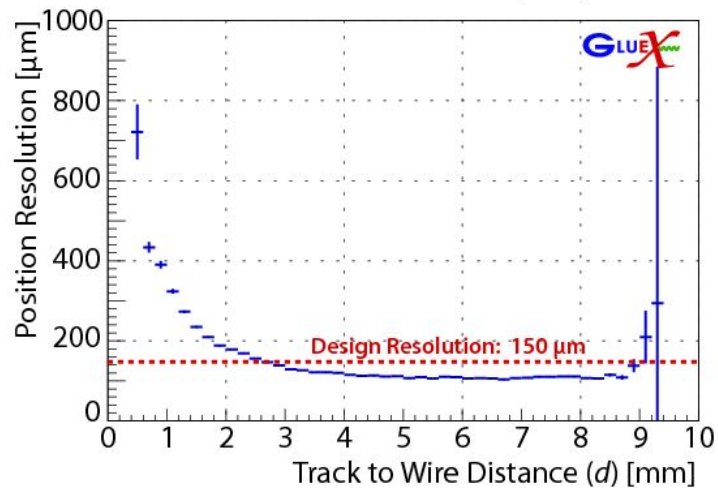Over 120 collaborators from 24 institutions with others joining and more are welcome.

Backup

GlueX - Calorimeter performance
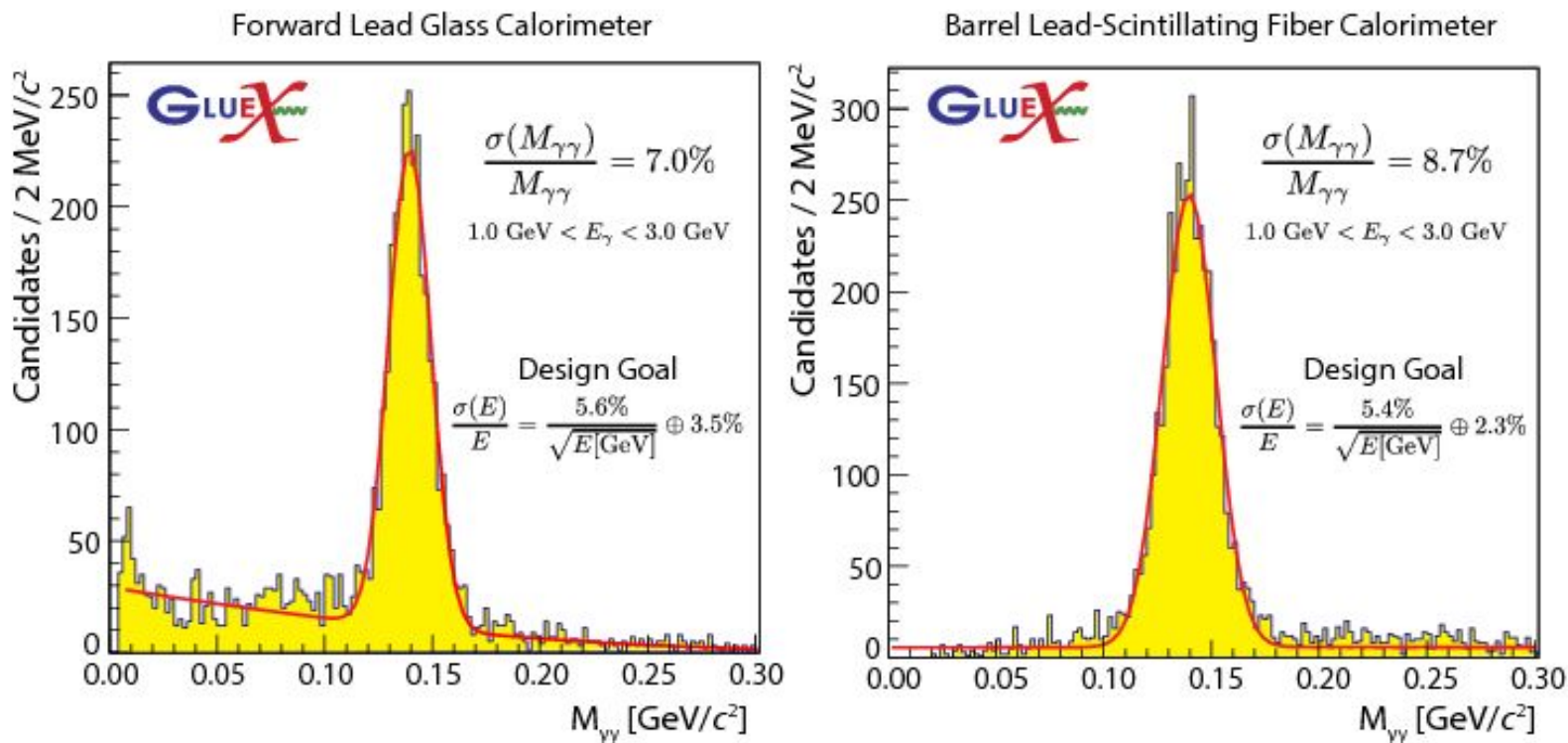
(Measured using exclusive γp ➜ 4γp)

GlueX - Tracking Performance