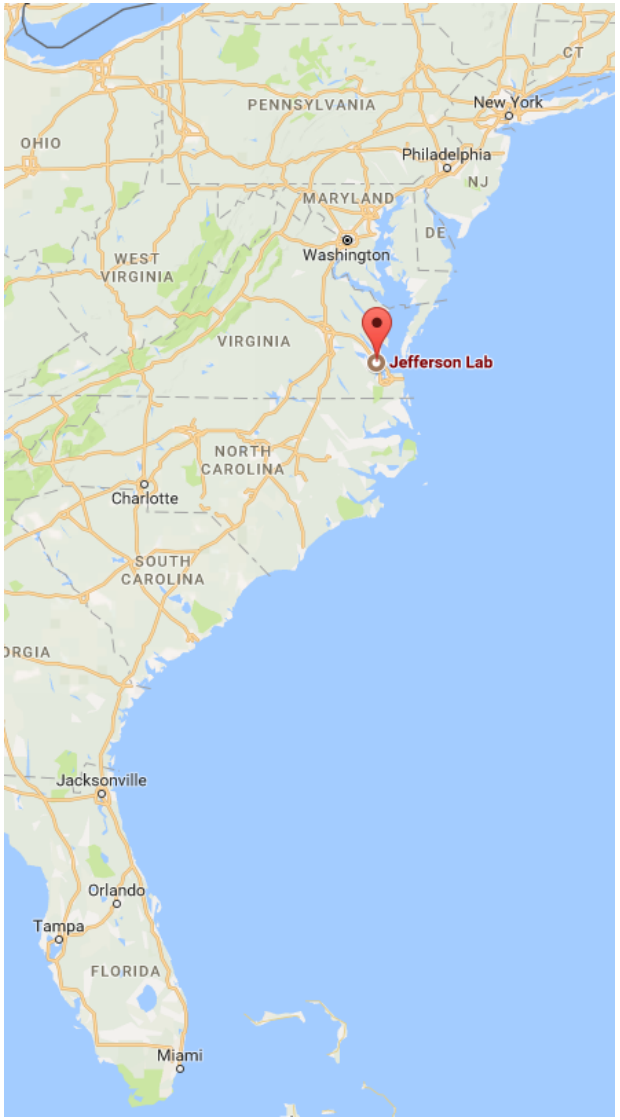
Light-Meson Spectroscopy at GlueX

Alexander Austregesilo
for the GlueX Collaboration

21st Particles and Nuclei International Conference (PANIC 2017)
Beijing, China
September 2nd, 2017

Outline

Jefferson Lab
Thomas Jefferson National Accelerator Facility



Outline

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Thomas Jefferson National Accelerator Facility

1. Motivation
2. First Results
   - Beam Asymmetries
   - Prospects for Spectroscopy
   - Charmonium
3. Summary

Context: Strong Interaction

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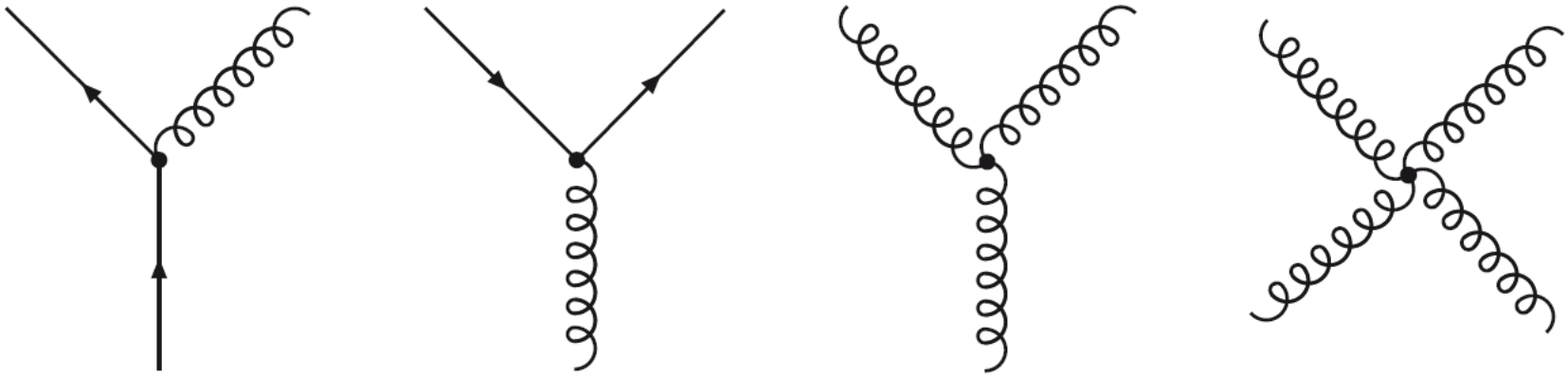
Quantum ChromoDynamics (QCD)

- Degrees of freedom: quarks and gluons
- Confinement: only color-neutral objects can be observed
- Baryons (qqq, $\bar{q}\bar{q}\bar{q}$) and Mesons ($q\bar{q}$) as the relevant degrees of freedom



Context: Strong Interaction

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Quantum ChromoDynamics (QCD)

- Degrees of freedom: quarks and gluons
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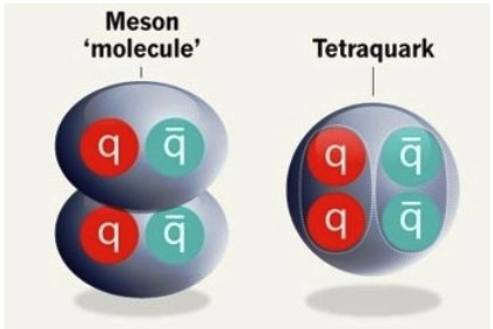
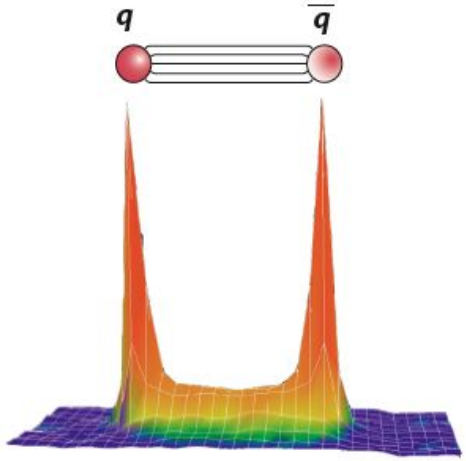
- Baryons (qqq, $\bar{q}\bar{q}\bar{q}$) and Mesons ($q\bar{q}$) as the relevant degrees of freedom
- Glueballs, Hybrids and other exotic hadrons predicted by many approximations

Multiquark

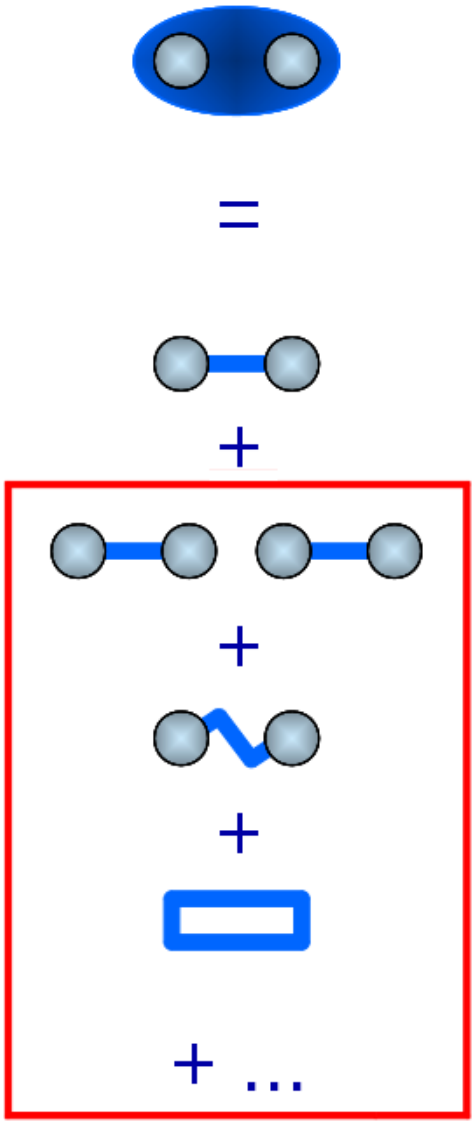


Hybrid Meson



Gell-Mann's Totalitarian Principle: Everything not forbidden is compulsory!

Meson Spectroscopy



$(q\bar{q})_0$

$(q\bar{q})(q\bar{q})$

$(q\bar{q})_8 g$

Hybrid

gg

Glueball

Constituent Quark Model (CQM)

- Bound state of $q\bar{q}$
- Quantum numbers: $I^G(J^{PC})$

Light-Meson Spectroscopy

- Exotic quantum numbers $(0^{--}, 0^{+-}, 1^{-+}, ...)$ forbidden by NR QM
- Many missing and disputed states
- Broad and overlapping resonances

$\Rightarrow$ Study spectrum and properties (width, decay, ...) of mesons

Light Meson Spectrum in LQCD

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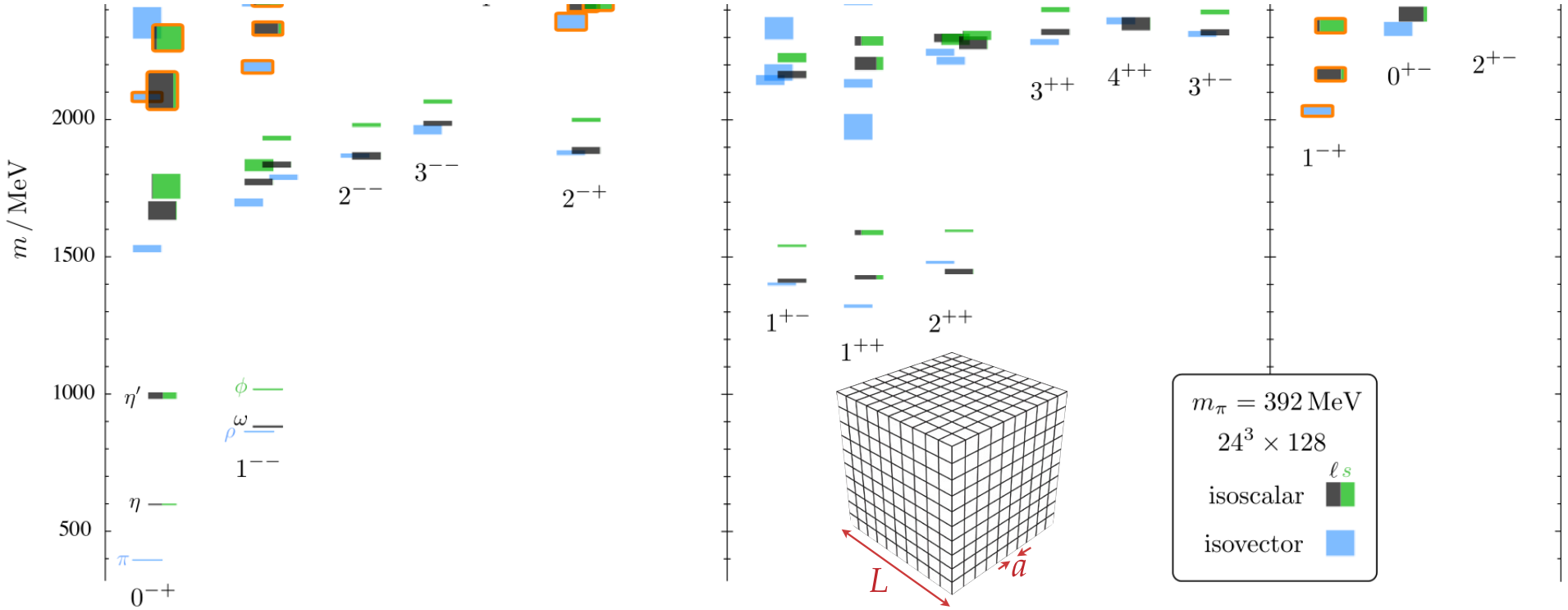

J.J. Dudek et al. [Phys. Rev. D 88 (2013)]

- Tremendous progress in recent years
- Excited states, spin-identified spectra, chromomagnetic content
- Resonance parameters and decay modes starting to become accessible
- Experimental results need to reach equivalent precision

Spectroscopy Worldwide

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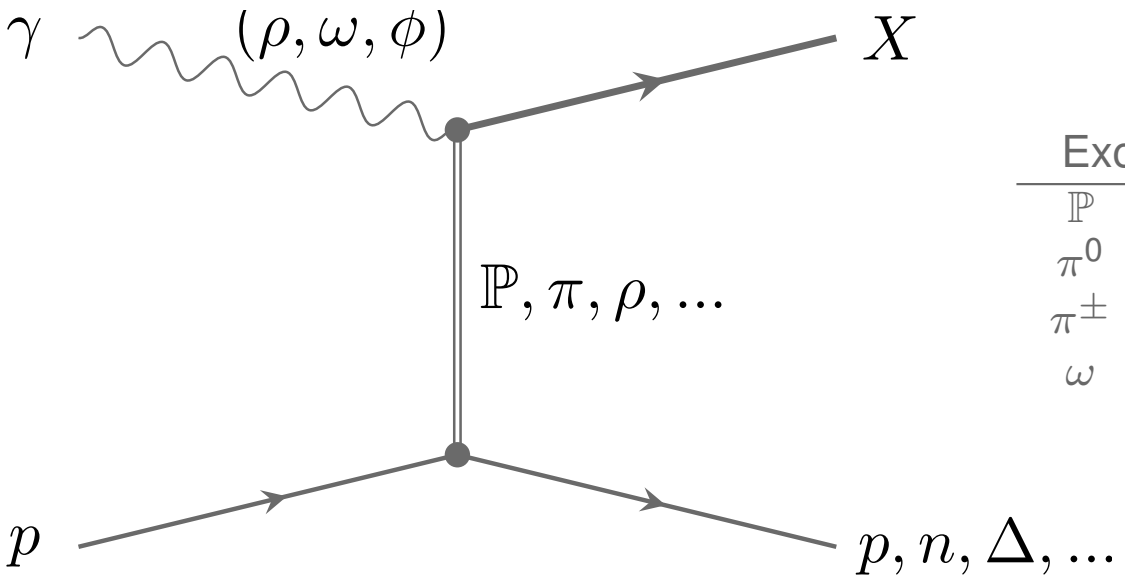
Photoproduction

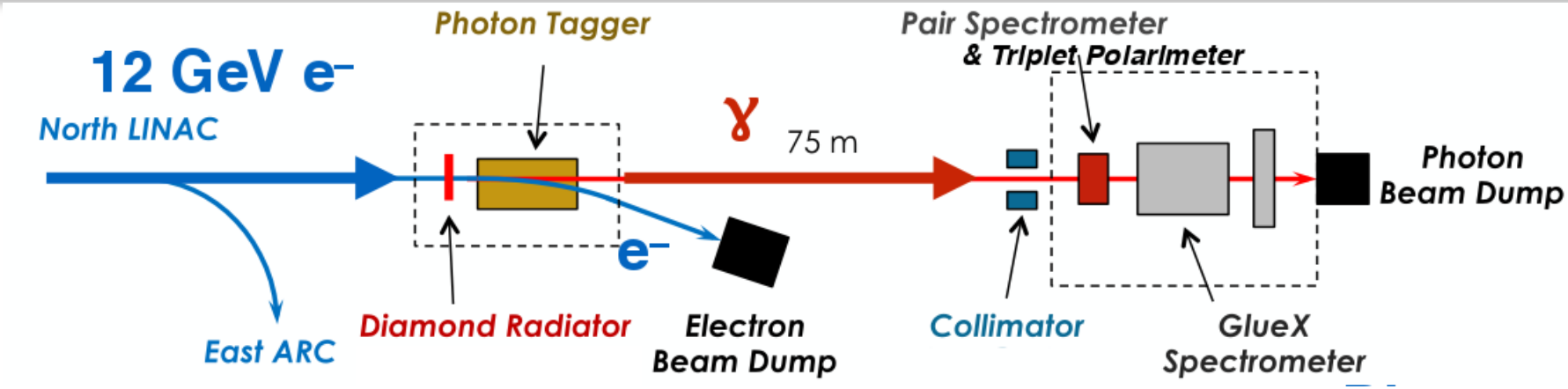


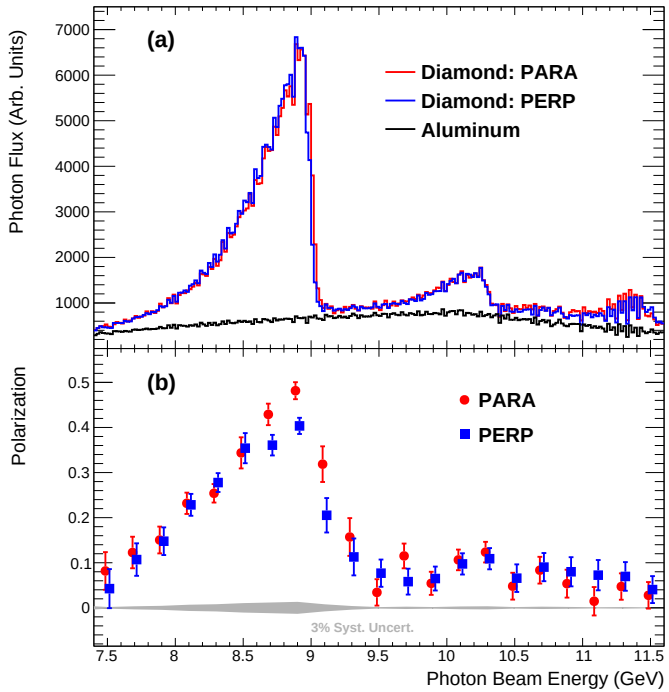
Exchange		Exotic Final States	
$\mathbb{P}$	0^{++}	b, h, h'	$2^{+-}, 0^{+-}$
π^0	0^{-+}	b_2, h_2, h_2'	2^{+-}
$\pi^{\pm}$	0^{-+}	$\pi_1^{\pm}$	1^{-+}
ω	1^{--}	π_1, η_1, η_1'	1^{-+}

Complementary Production Mechanism

- Photon coupling via vector meson dominance
- Wide variety of $I^G J^{PC}$ states accessible
- Photon polarization provides additional constraints

Photon Beam Line





9 GeV Polarized Photon Beam

- Coherent Bremsstrahlung on thin diamond
- Energy tagged by scattered electrons
- Collimator to suppress incoherent part
- Linear polarization in peak $P_\gamma \approx 40\%$, measured by Triplet polarimeter: $\gamma e^- \rightarrow e^- e^+ e^-$
- Beam intensity: $1 - 5 \cdot 10^7\ \gamma/\mathrm{s}$ in peak

GlueX Detector

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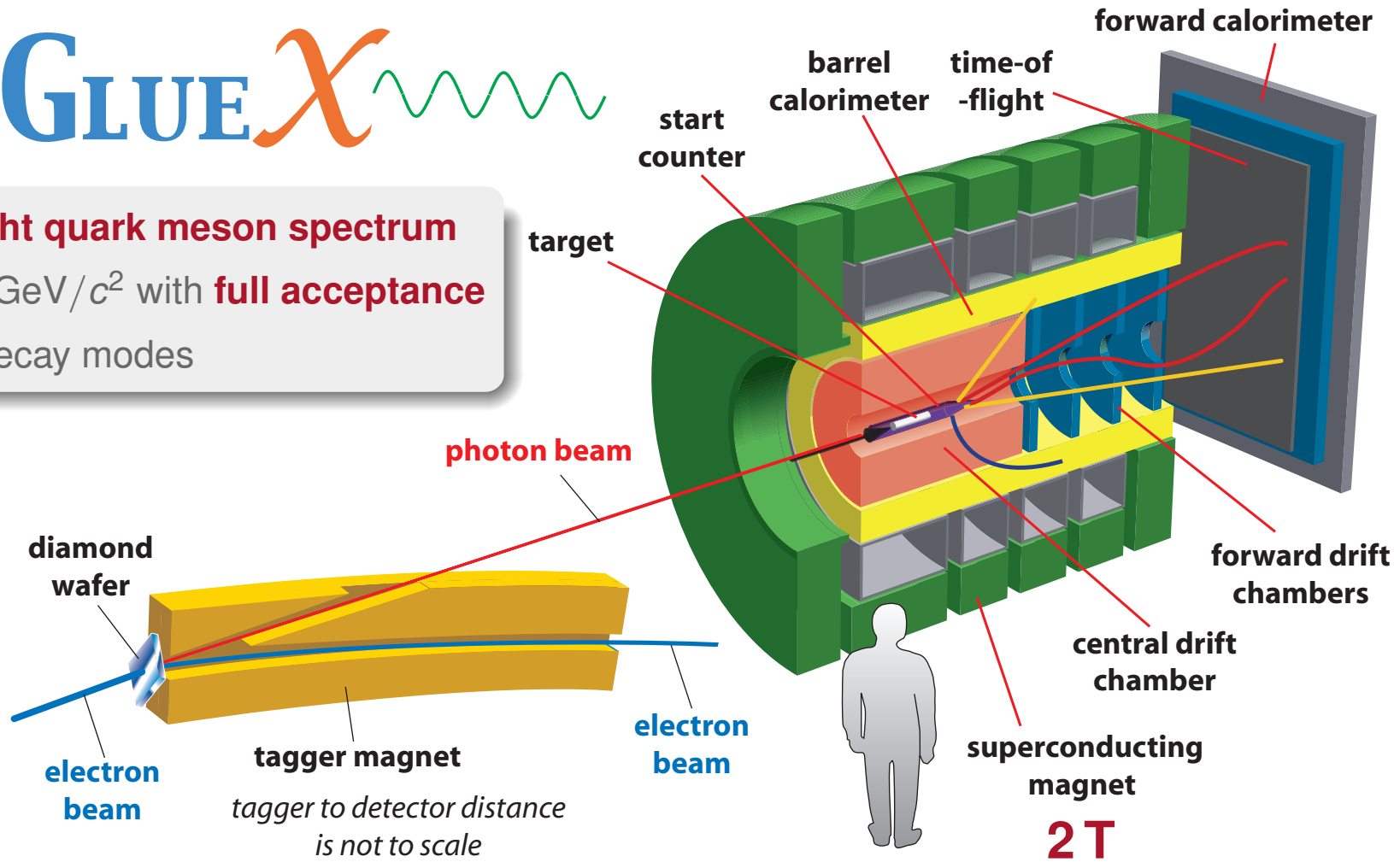
GLUEX

Map **light quark meson spectrum** up to 3 GeV/c^2 with **full acceptance** for all decay modes



GlueX Detector

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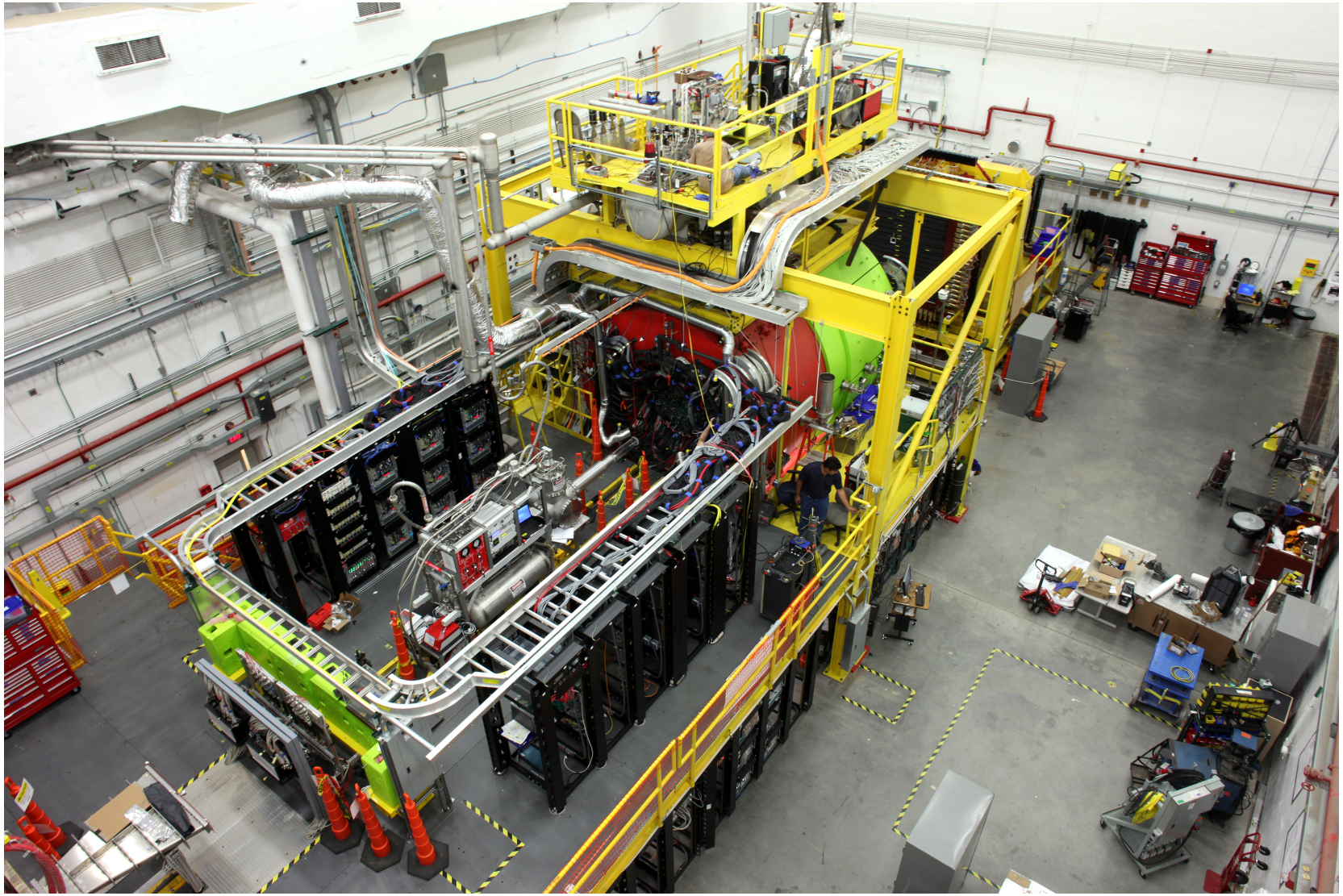

GlueX Runs

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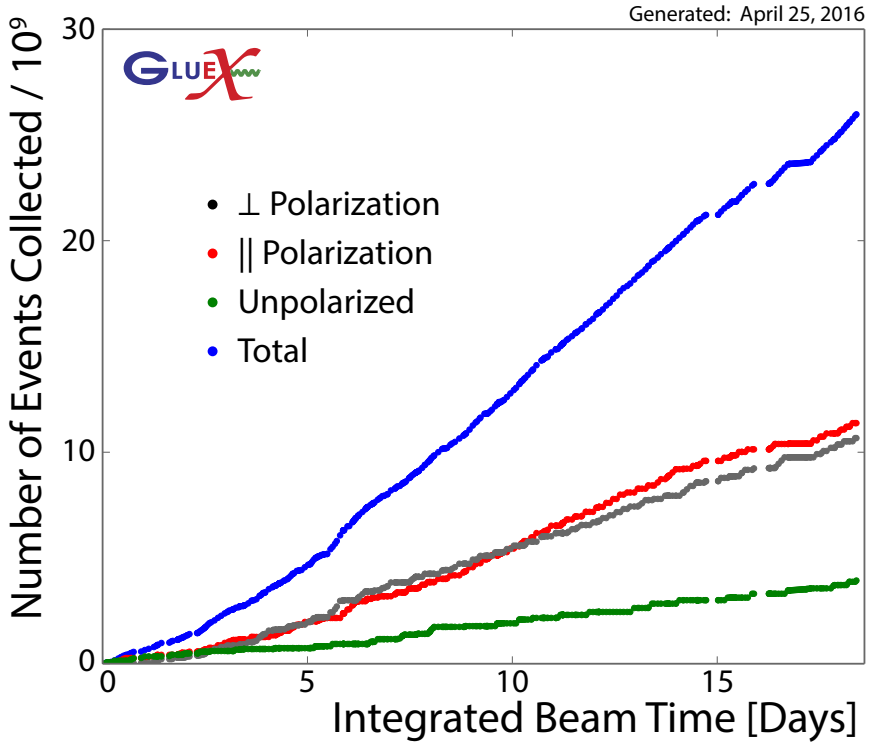
Fall 2014 - Spring 2015

Detector and beamline commissioning

Spring 2016: GlueX Engineering Run

- Initial physics data ($\approx$ 80 h)
- First results presented here



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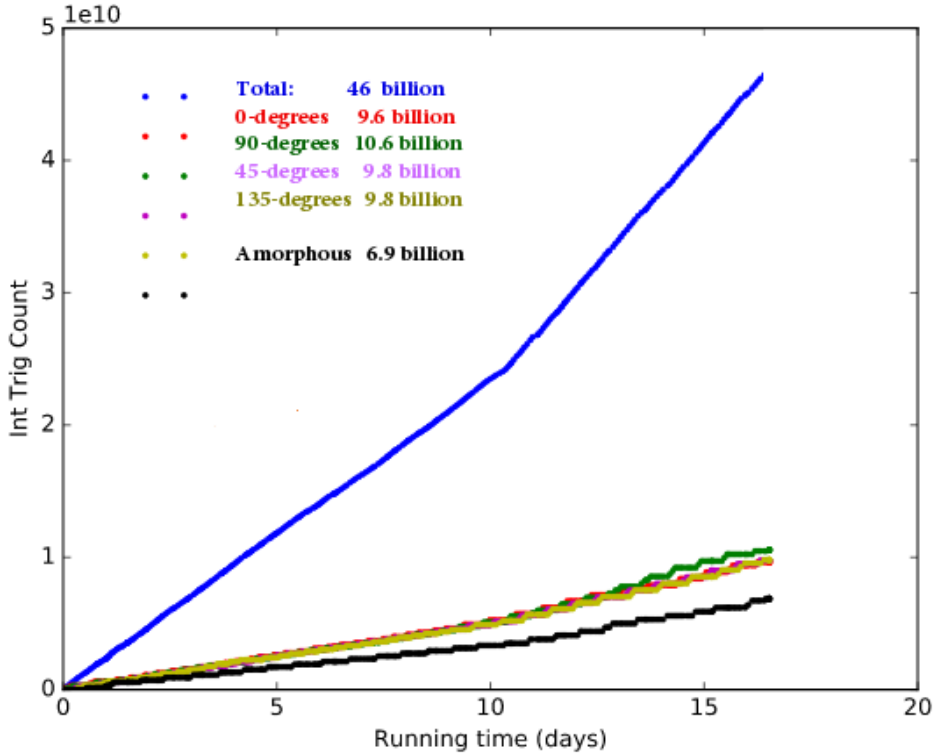
GlueX-I: 2017 - 2018

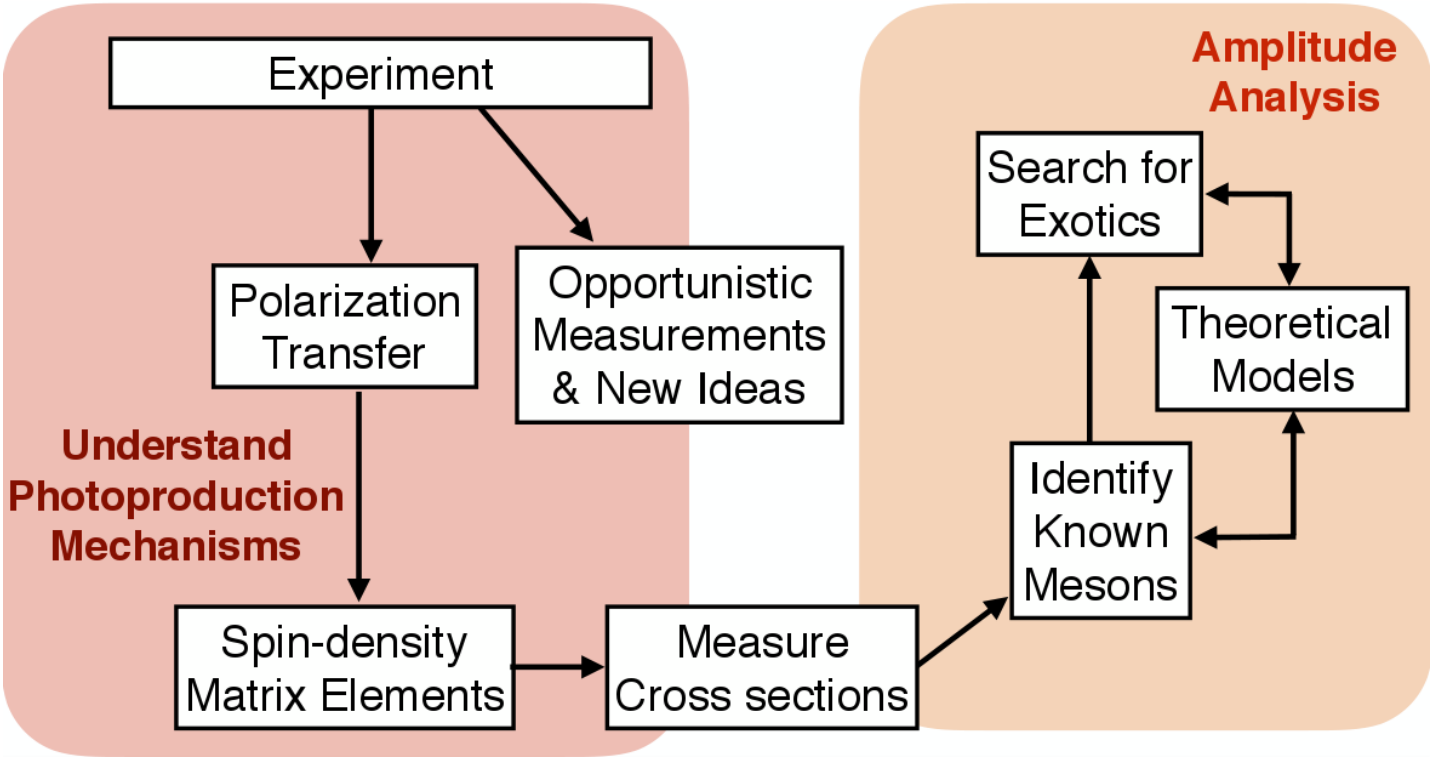
- 6 weeks in spring 2017
- 20% of full data set collected ($\approx$ 1PB)
- Will continue early 2018

GlueX-II: 2019+

- Upgraded detector
- High luminosity



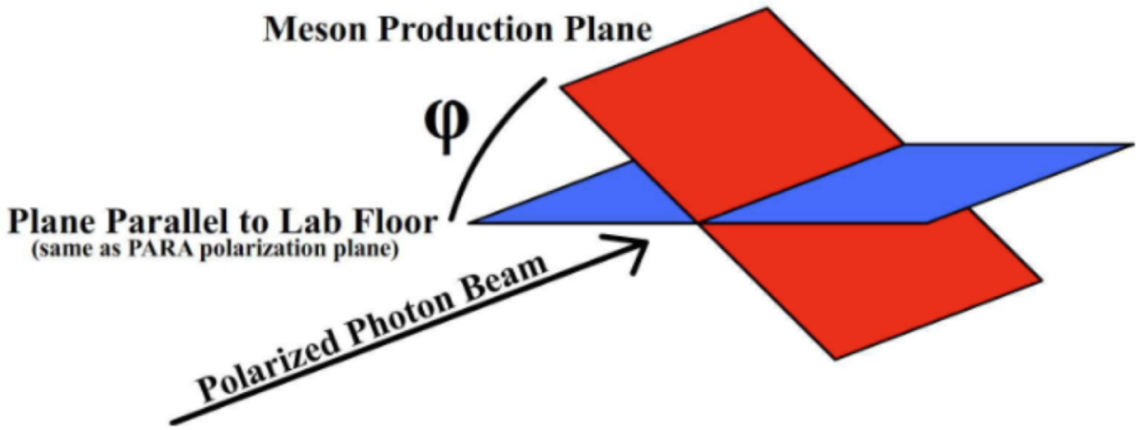
Analysis Strategy



GlueX + Joint Physics Analysis Center (JPAC)

- High statistical precision requires removing simplifying assumptions
- Robust theoretical models and capable analysis frameworks
- Collaboration: experiment and theory working together on analysis and interpretation

Pseudoscalar Beam Asymmetries



$$\sigma_{\text{pol}}(\phi) = \sigma_{\text{unpol}}\,[1 - P_\gamma \boldsymbol{\Sigma} \cos 2\phi]$$

- Understanding production mechanism necessary for amplitude analysis
- Beam asymmetry Σ and its t dependence sensitive to exchanged J^{PC}
- Beam polarization P_γ measured with polarimeter
- Cancel systematic effects by rotating polarization plane by 90°

π^0 and η Beam Asymmetries

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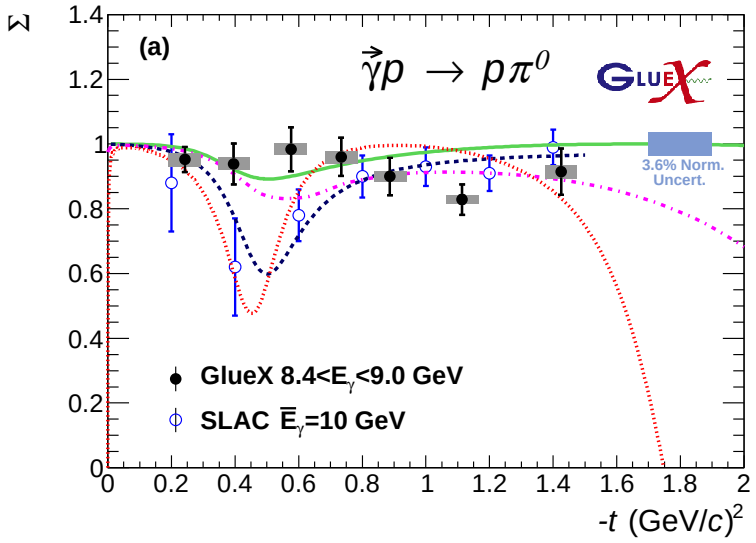

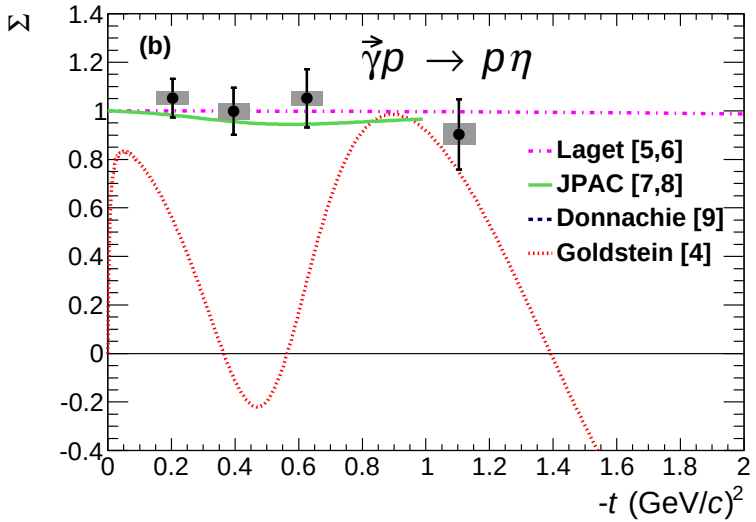

First GlueX Publication!

- No observed dip at $-t = 0.5$ (GeV/c)^2
- Comparison with several theory models
- Constrains background to baryon resonance production
- First measurement for η at this energy
- Measurement for η' with 2017 data

Phys. Rev. C 95 (2017) 042201
→ Z. Zhang

π^+/π^- Beam Asymmetry

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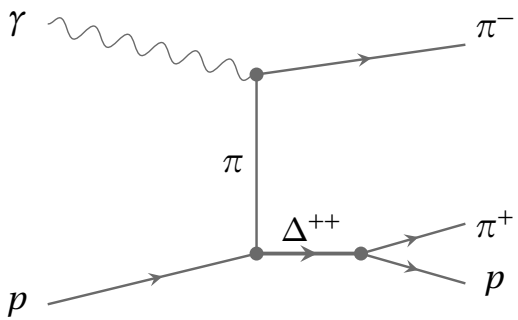
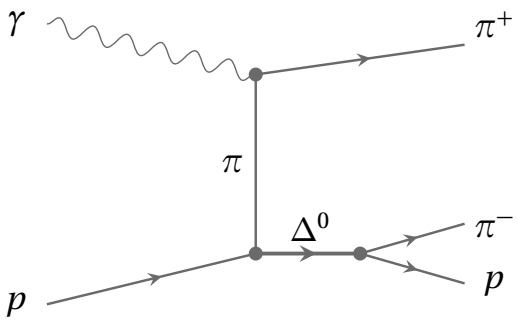
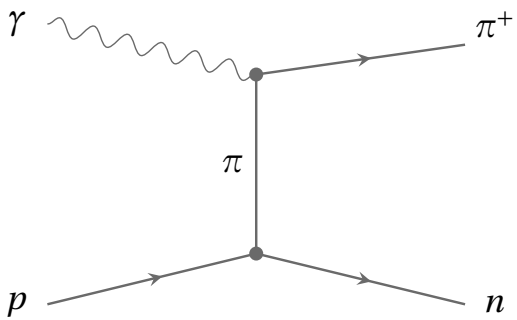
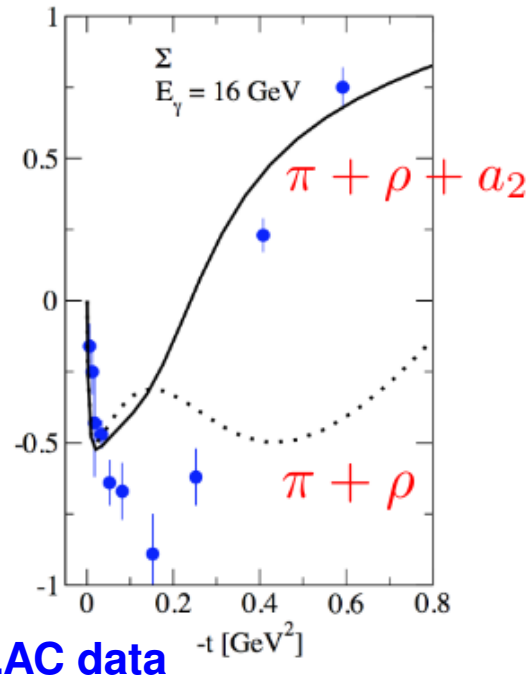




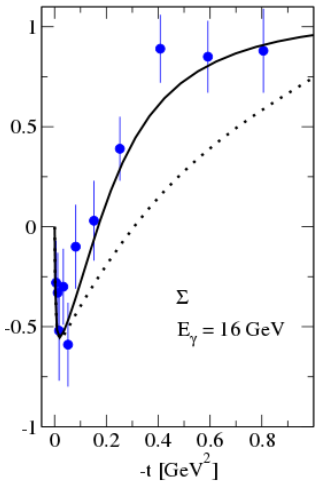


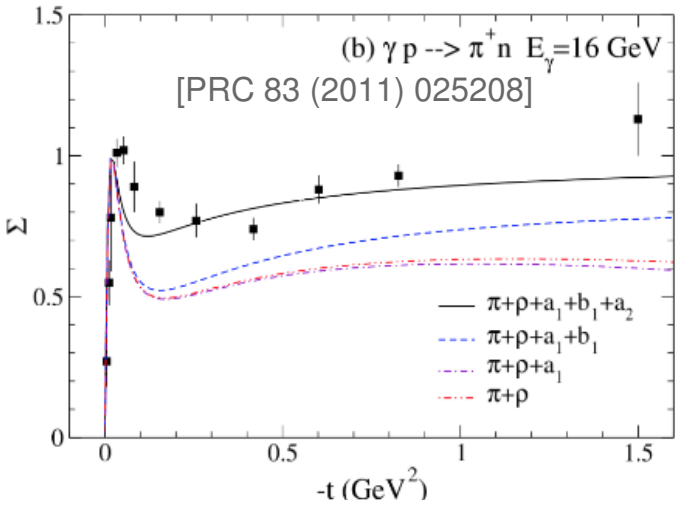
[arXiv:1611.09629]



SLAC data

from [PRD 20 (1979) 1553]





- Recently revived interest in charge exchange
- $-t$ dependence sensitive to Regge contributions
- Important confirmation for theoretical models

π^+/π^- Beam Asymmetry

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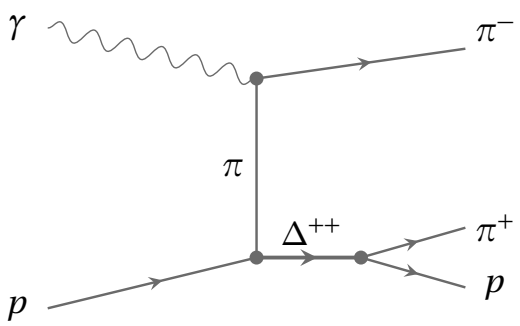
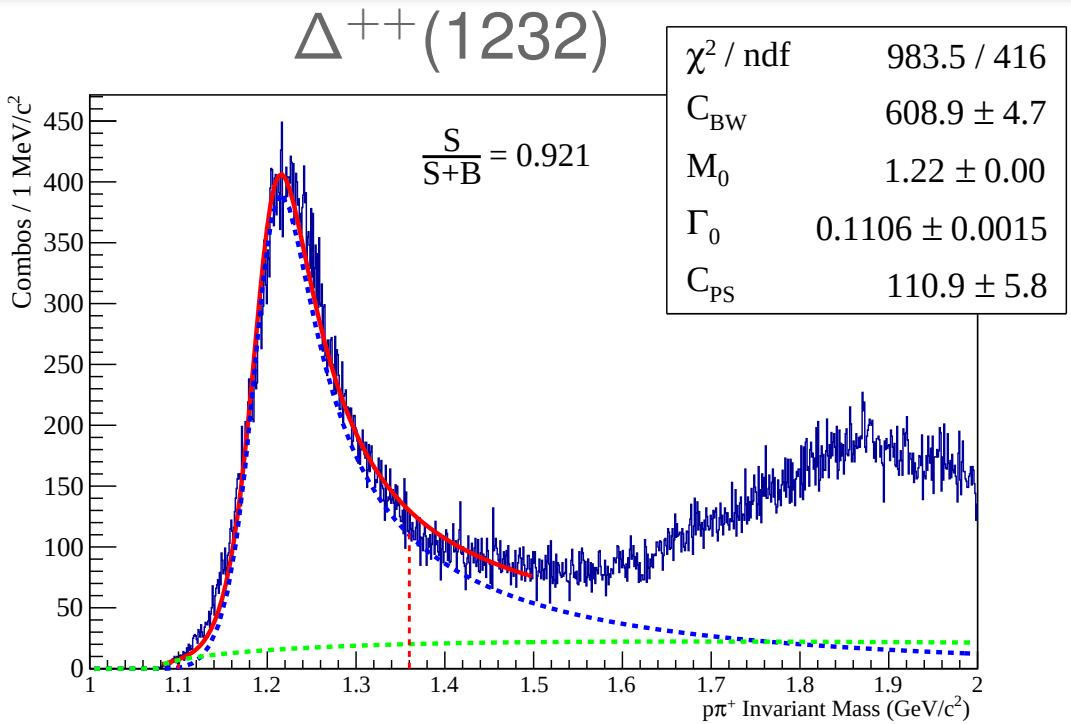
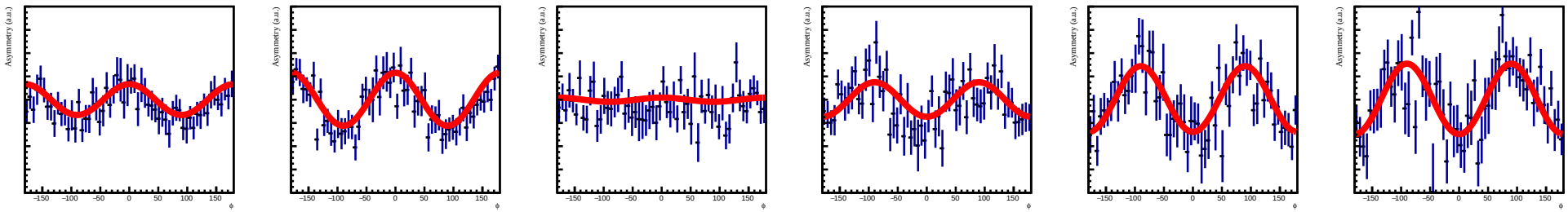


GlueX Preliminary





ρ Beam Asymmetry

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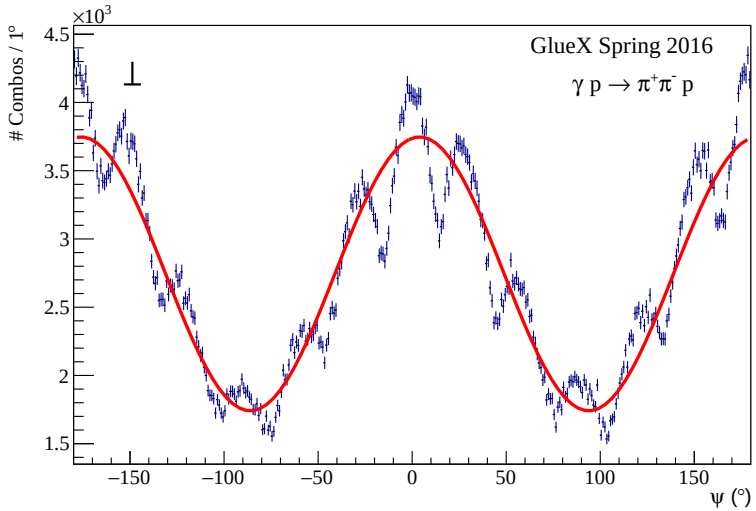
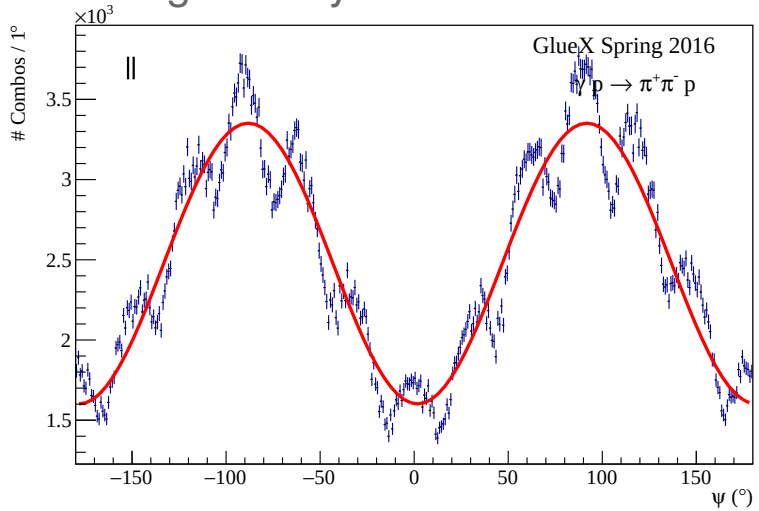
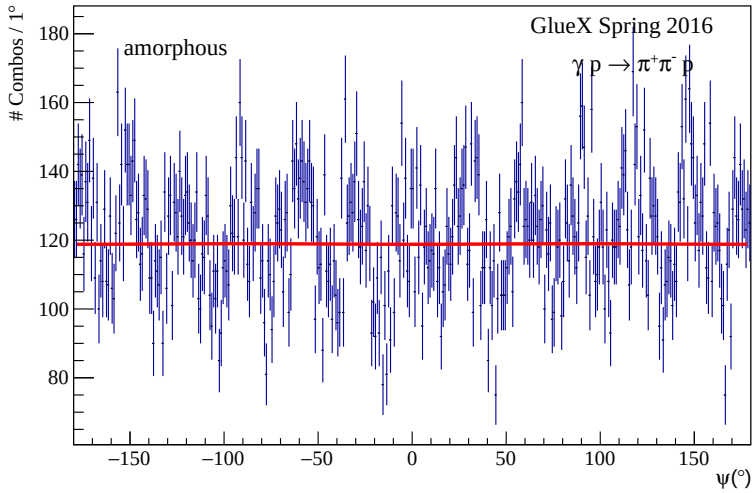
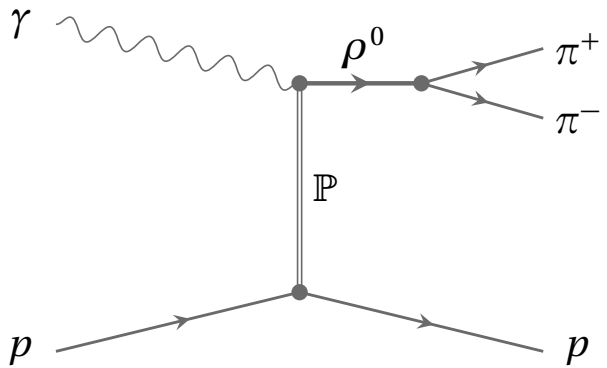
Artifacts of tracking detector geometry









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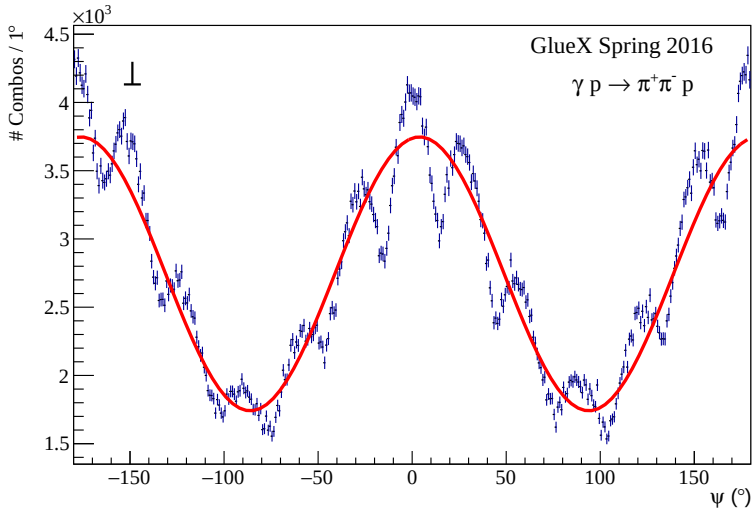
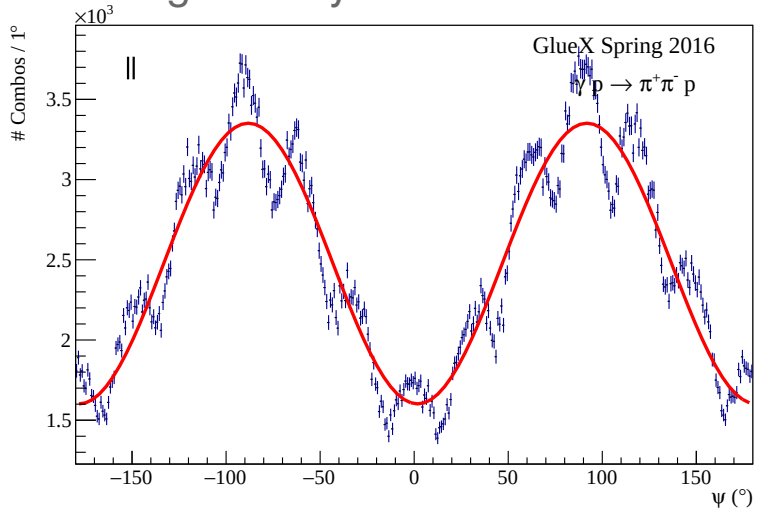
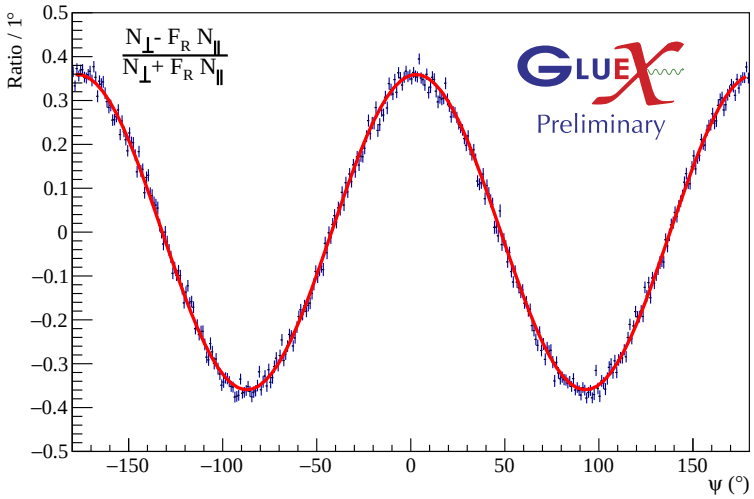
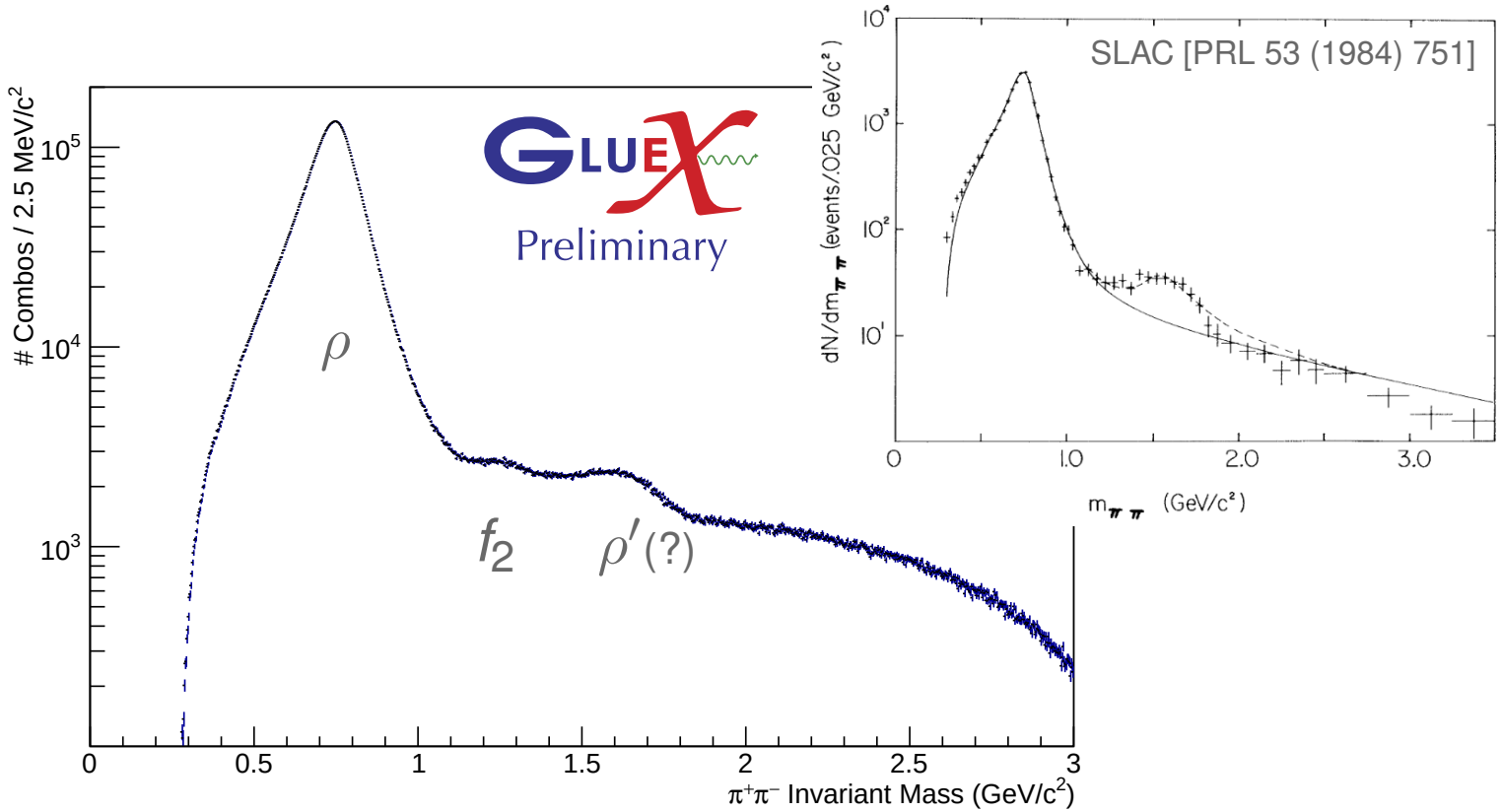




- Acceptance effects cancel
- Confirmation of polarization
- Analysis of angular distribution
  $\Rightarrow$ Spin Density Matrix Elements



$\pi\pi$ Spectroscopy



- $\approx 100\times$ more data than previous experiments
- Hints for excited ρ $\Rightarrow$ moment / amplitude analysis started

Multi-Photon Final States

$\gamma + p \to 4\gamma + p$

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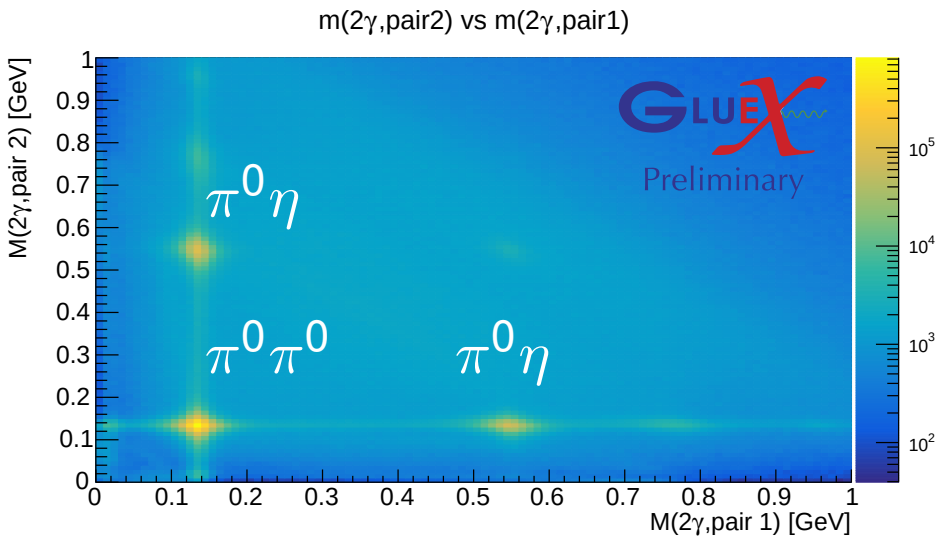

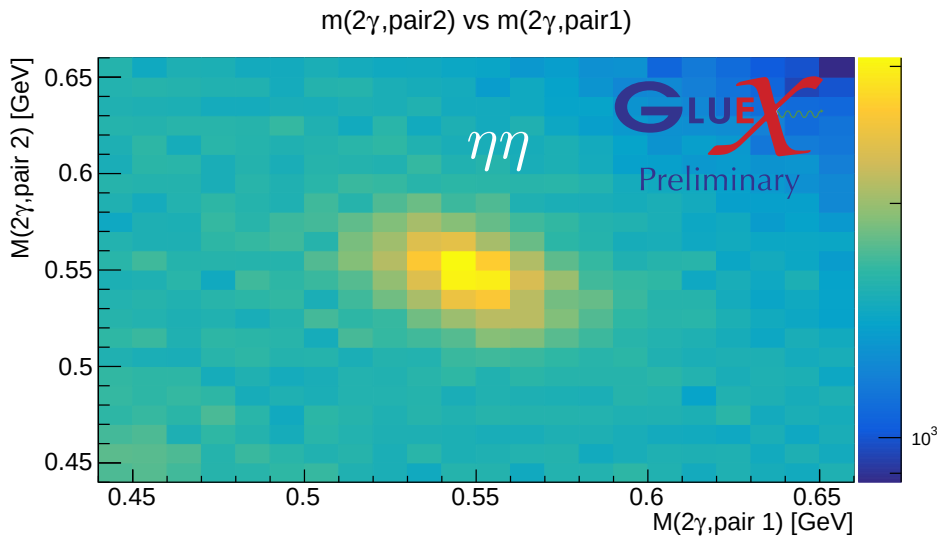

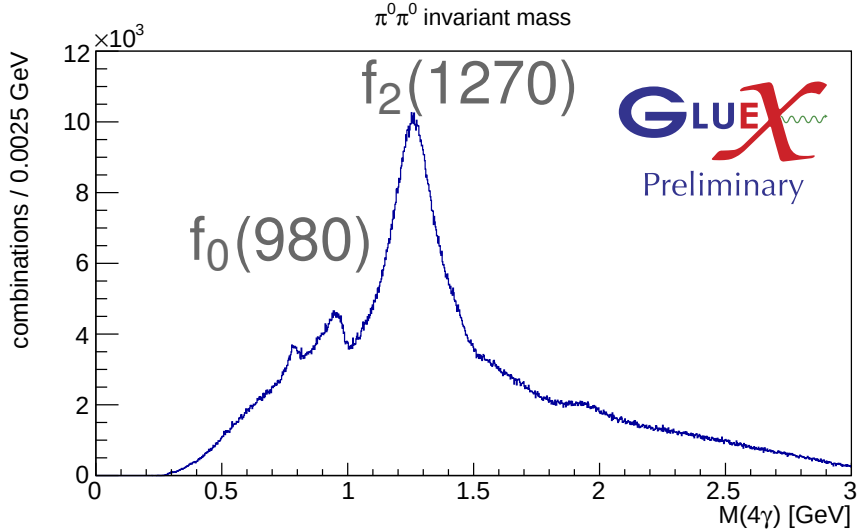

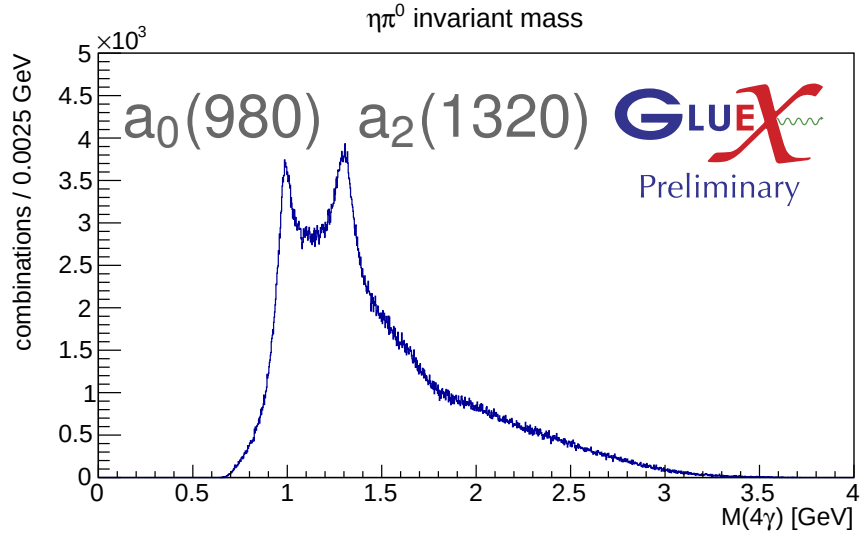

Multi-Photon Final States

$\gamma + p \to 5\gamma + p$

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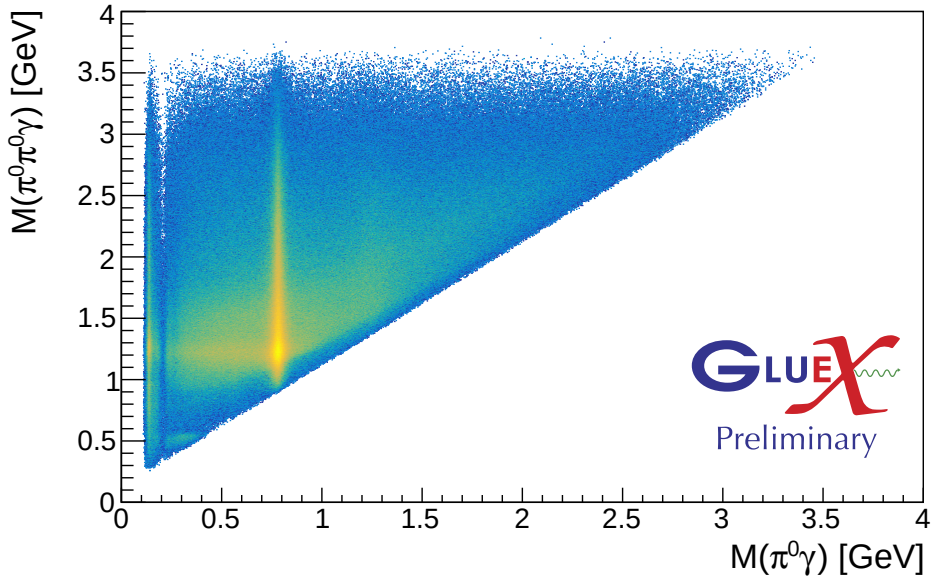

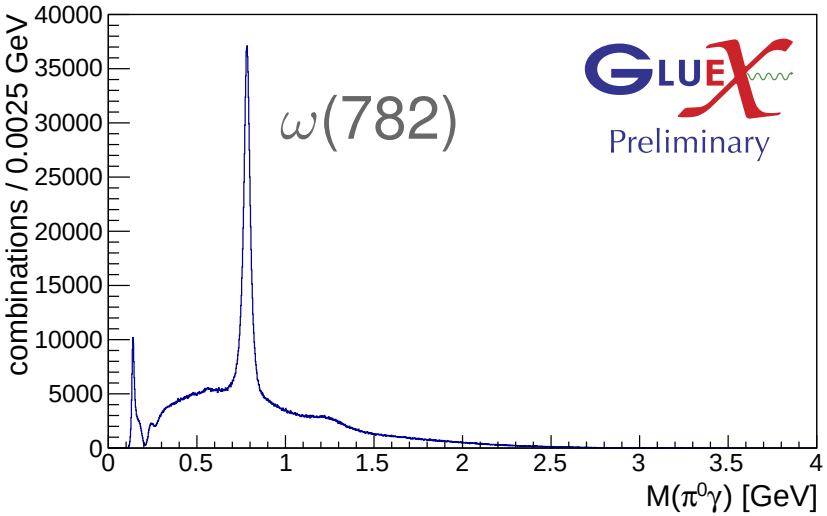

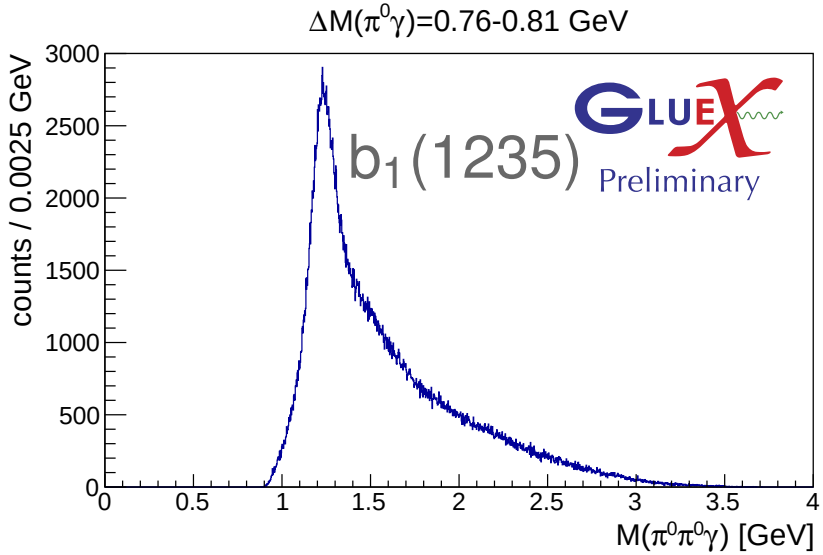

Multi-Photon Final States

$\gamma + p \to 6\gamma + p$

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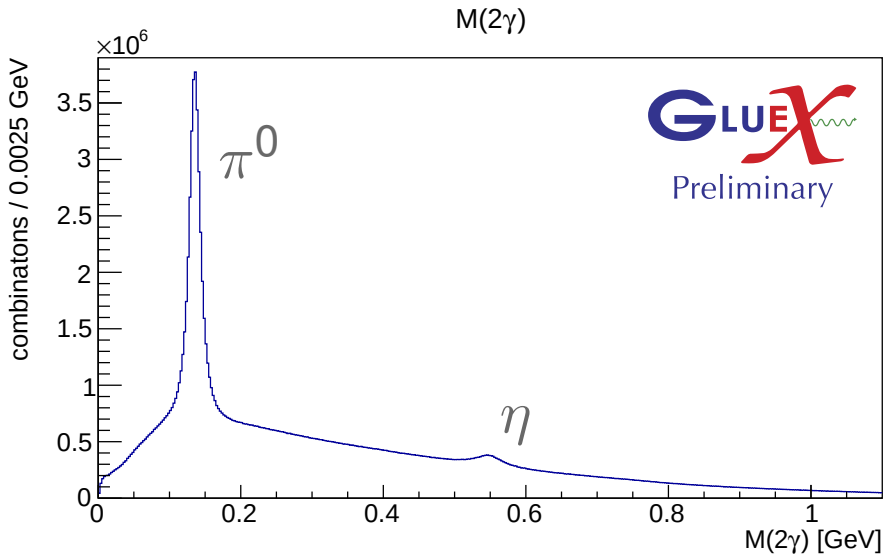
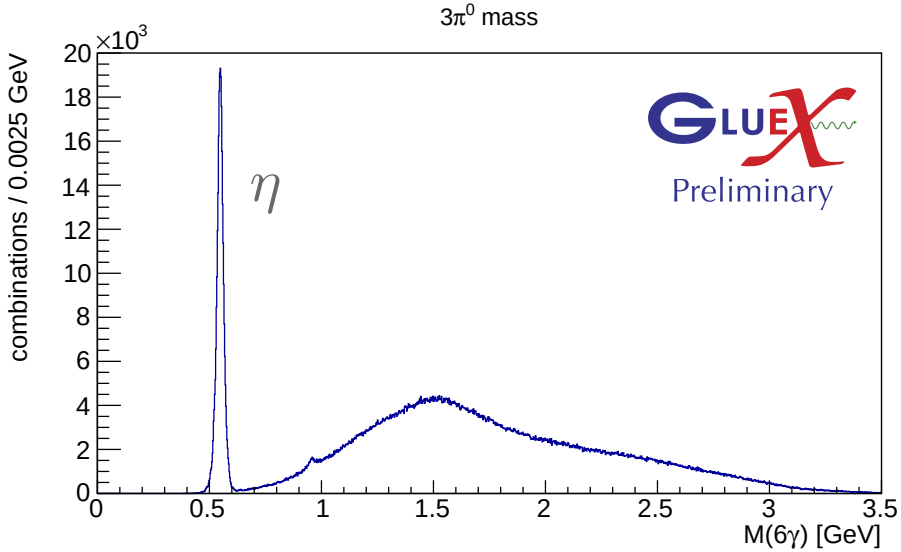
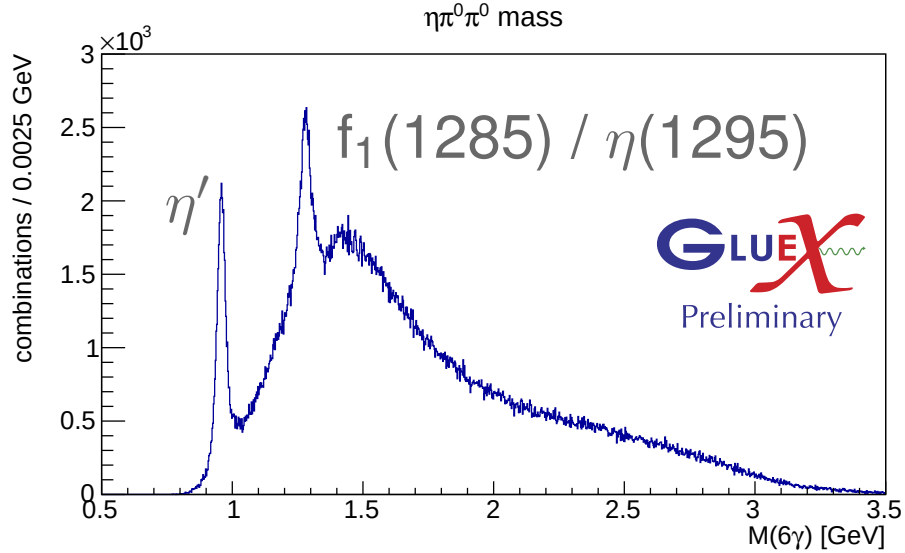


- **GlueX** well equipped for the detection of **neutral particles**
- Excellent prospects for spectroscopy program





Mapping the Meson Spectrum

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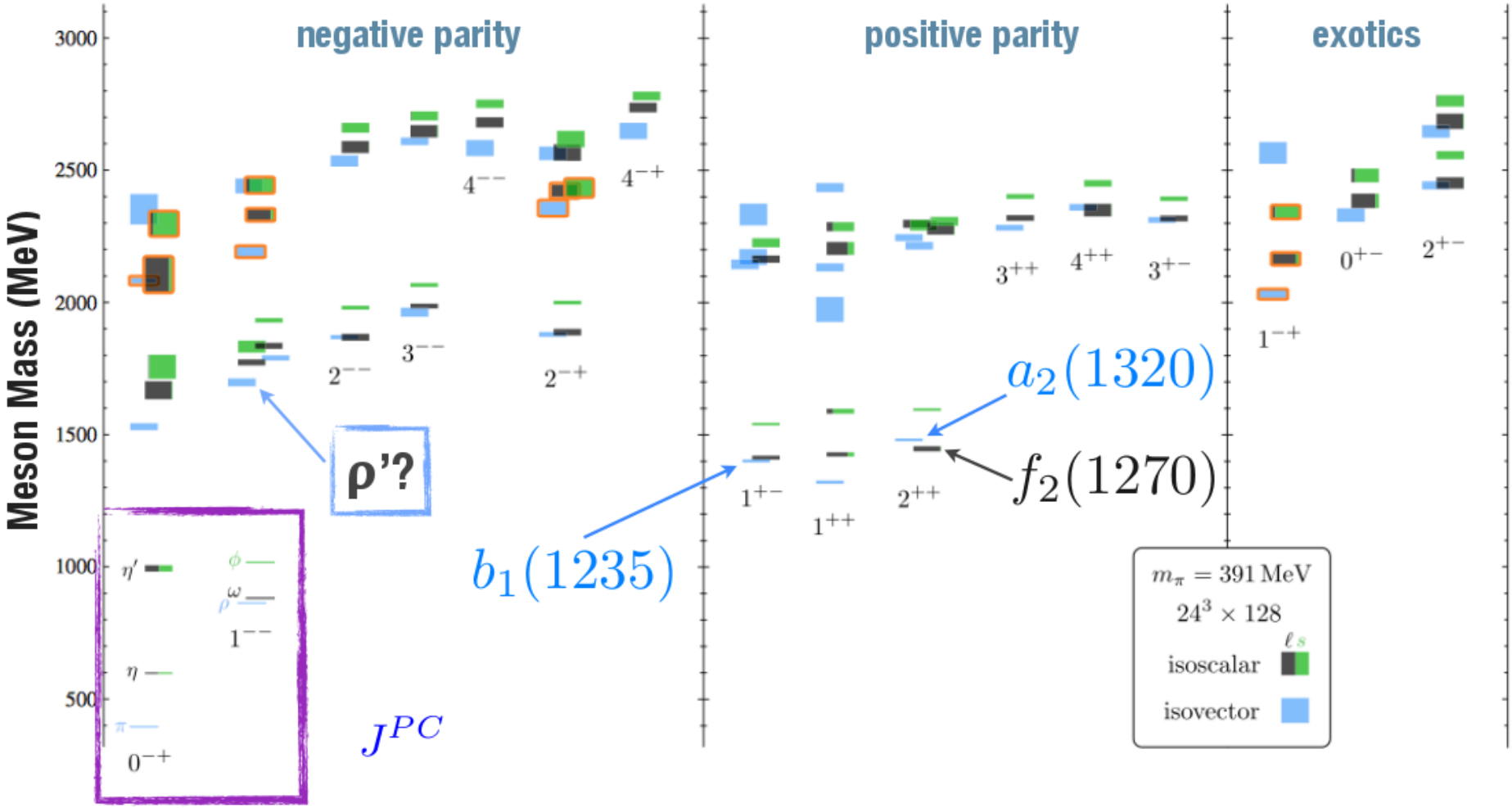
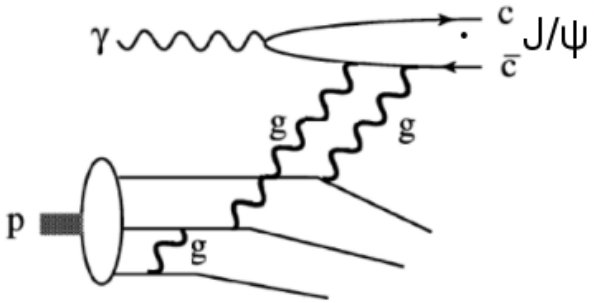
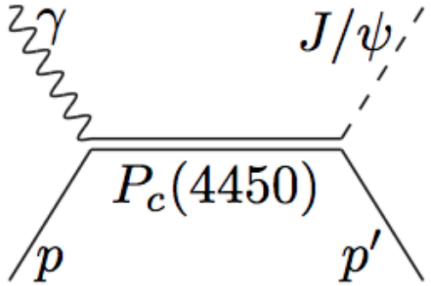
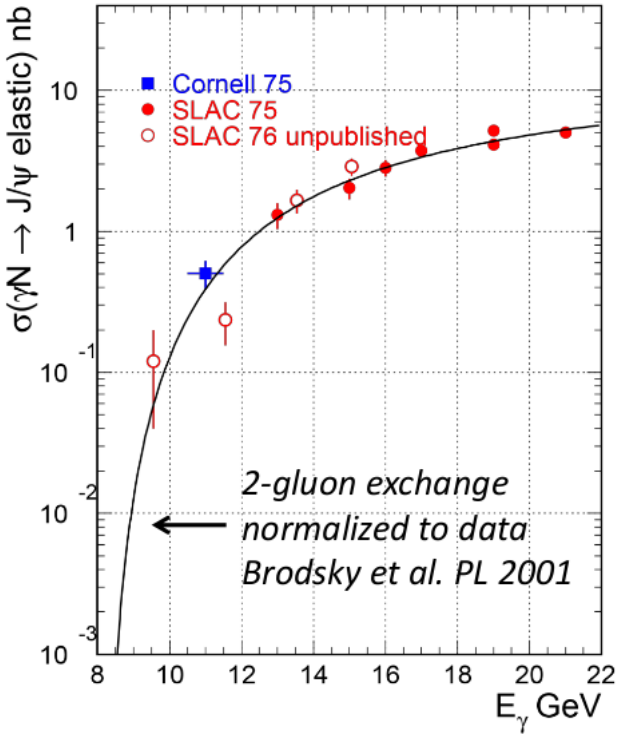


J.J. Dudek et al. [Phys. Rev. D 88 (2013)]

Charmonium Photoproduction







$\gamma + p \to p + J/\psi, \quad J/\psi \to e^+ e^-$

- Production at threshold is ideal for studying N + J/ψ interaction
- Very few existing measurements

Charmonium Photoproduction

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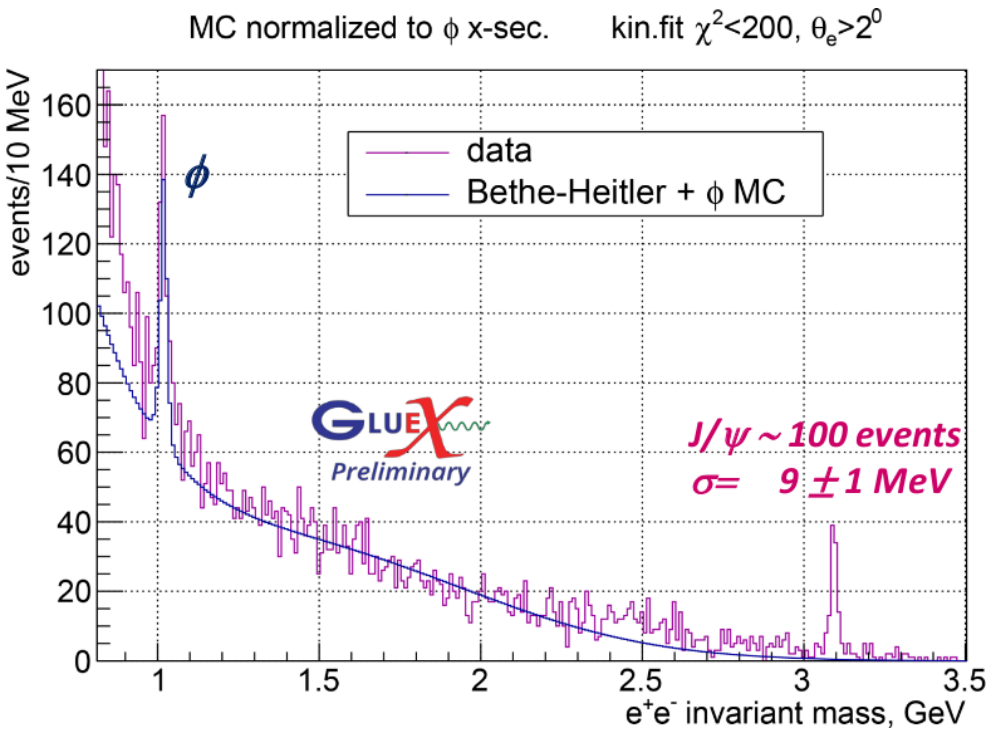

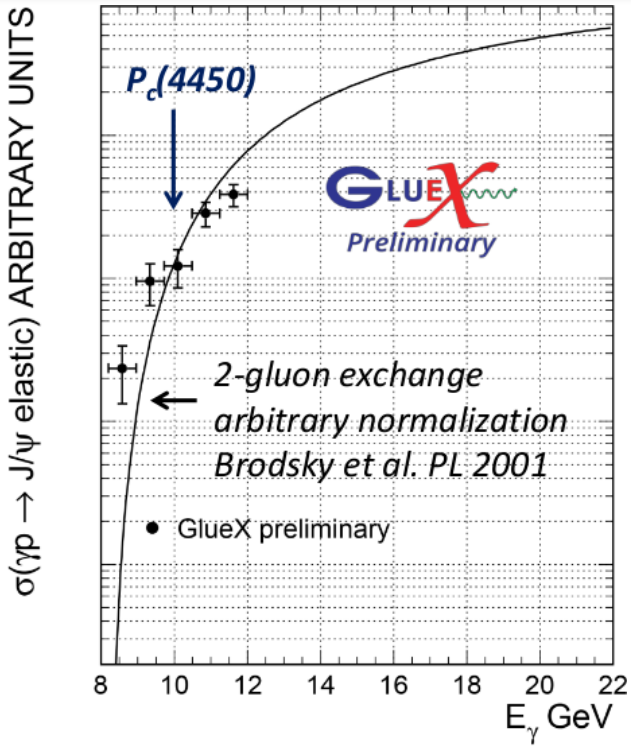

$\gamma + p \to p + J/\psi, \quad J/\psi \to e^+ e^-$

- Production at threshold is ideal for studying N + J/ψ interaction
- Very few existing measurements
- First observation of charmonium at 12 GeV CEBAF

Summary

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Status

- Successful **commissioning** and **early physics** analyses
- 20% of data for GlueX-I **taken**
- Understanding of detector **acceptance** and **systematics**
  $\Rightarrow$ Comparison with previous measurements and models
- Study **production mechanism**
  $\Rightarrow$ Cross sections, beam asymmetries and spin density matrix elements

GlueX-I: **Light-Meson Spectroscopy**

- **Mapping** of the entire light meson spectrum
- **Precise measurement** of known resonances and ultimately hybrid candidates

Plans with GlueX-II: **Strange-Meson Spectroscopy**

- Focus on meson spectrum with **strangeness** content

GlueX-II Detector Upgrade

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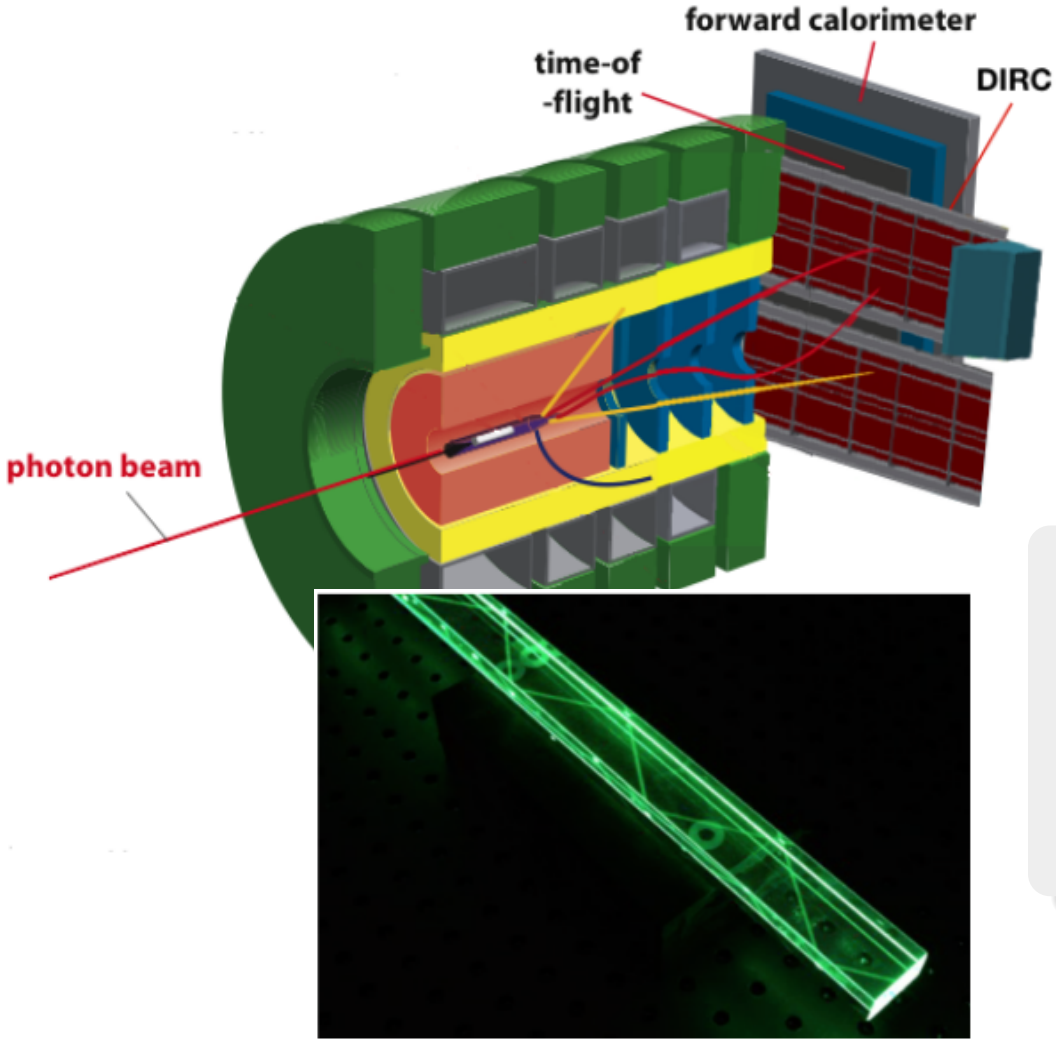

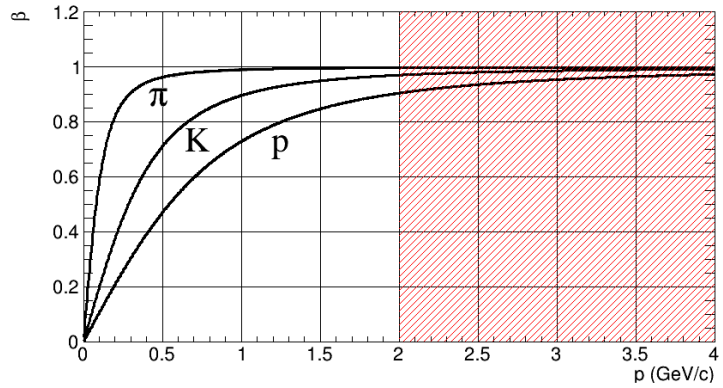

- **GlueX DIRC**: construction started with BaBar DIRC components for π/K separation up to 4 GeV/c
  $\Rightarrow$ Strange-meson spectroscopy
- **High luminosity**: high-level trigger
  $\Rightarrow$ Rare processes

GlueX-II Detector Upgrade

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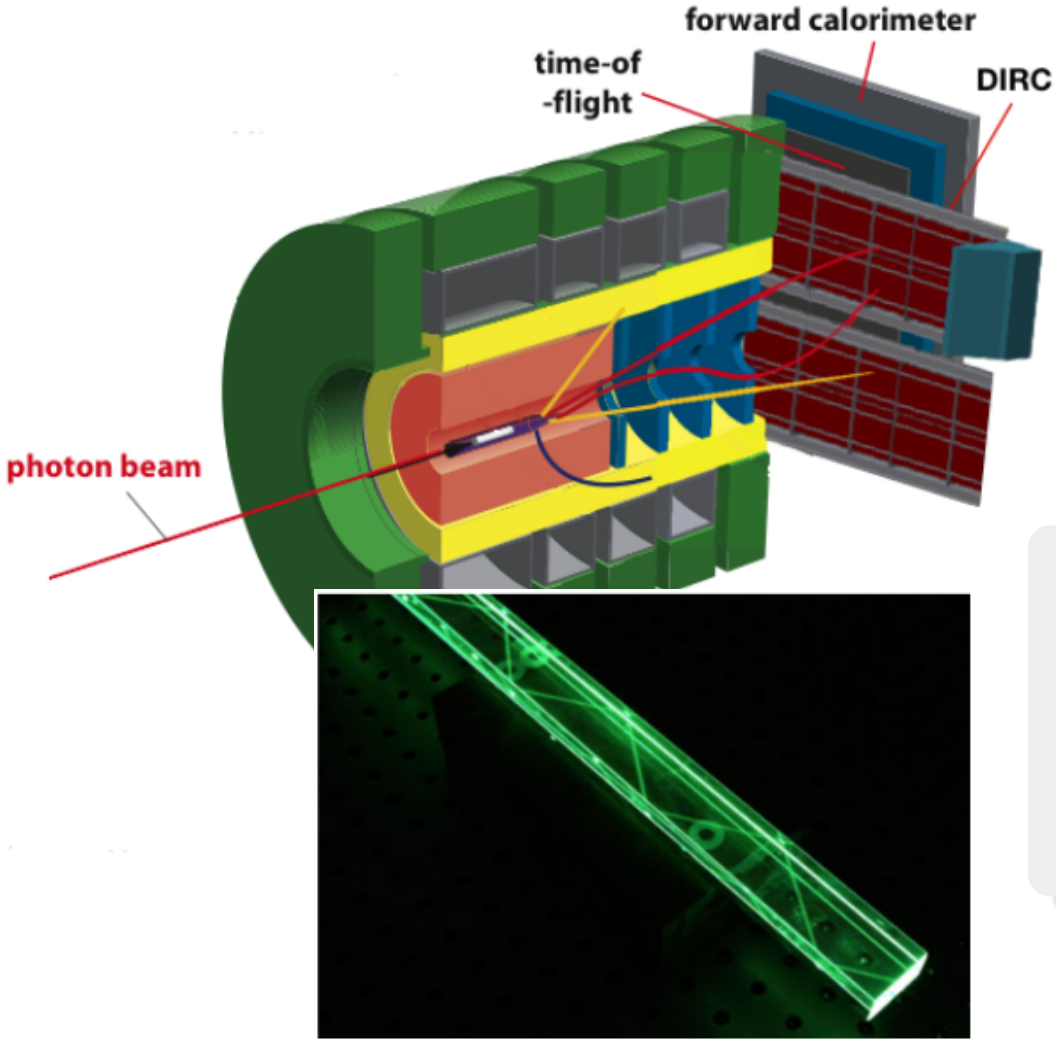

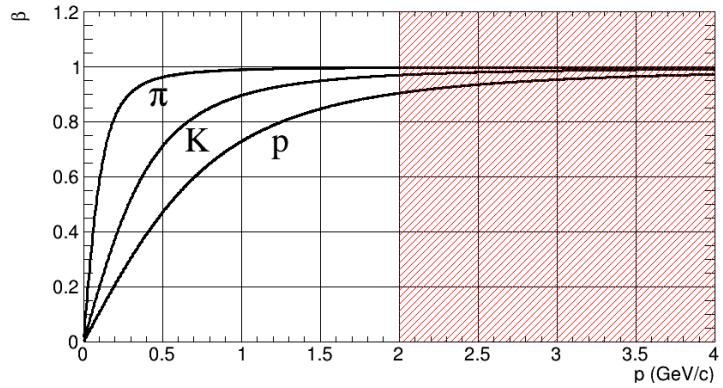

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Thank you for your attention!