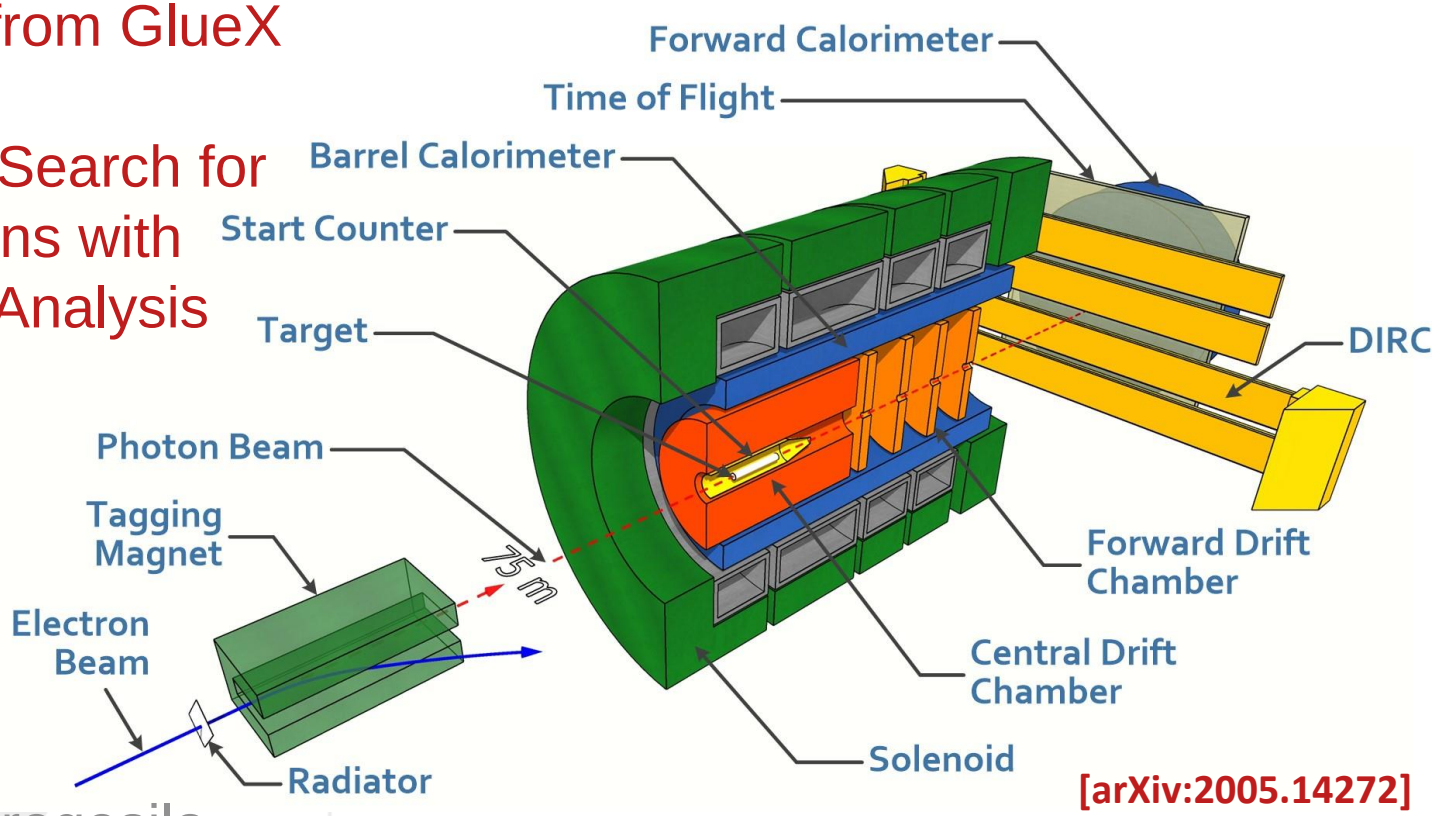
Exploring the Hadron Spectrum with GlueX

Recent Results from GlueX
and
Progress in the Search for
Hybrid Mesons with
Partial-Wave Analysis



[arXiv:2005.14272]

Alexander Austregesilo

JLUO Group Meeting
Wednesday, June 24, 2020

Detector in Hall D:
Designed for Light-Quark Meson Spectroscopy

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

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The GlueX Experiment in Hall D

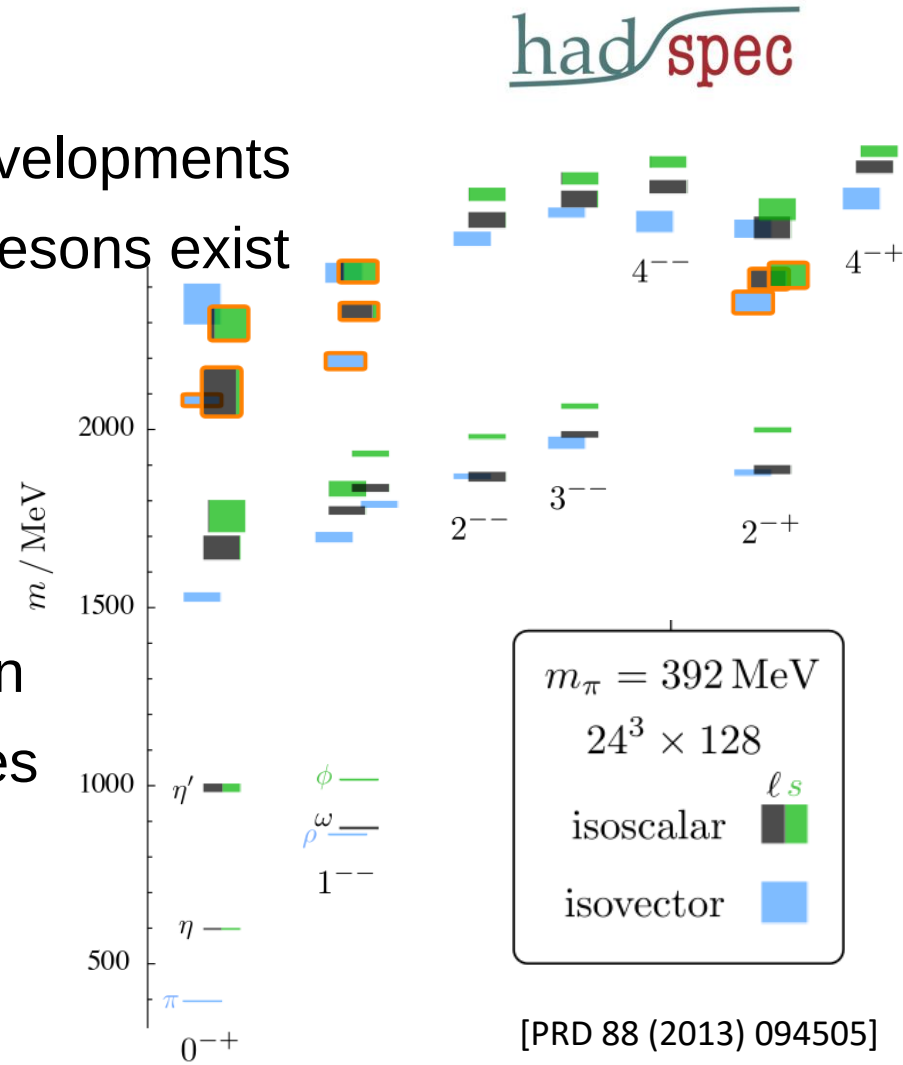
Focus: Search for Hybrid Mesons

- Explore the light meson spectrum
- Discovery experiment + theory developments
- Goal: definitive answer if hybrid mesons exist

Key Features:

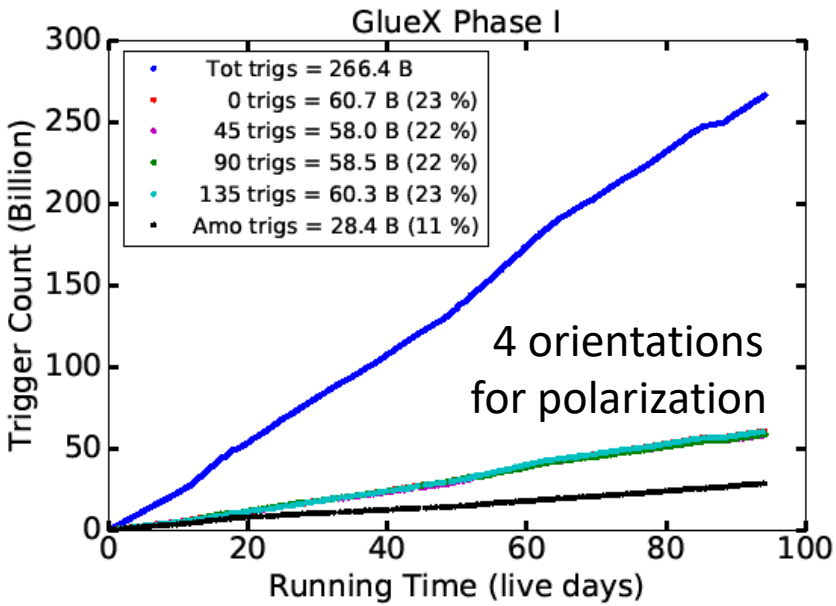
- Linearly-polarized photon beam
  → study production mechanism
- Unprecedented statistical precision
- Large acceptance for all final states

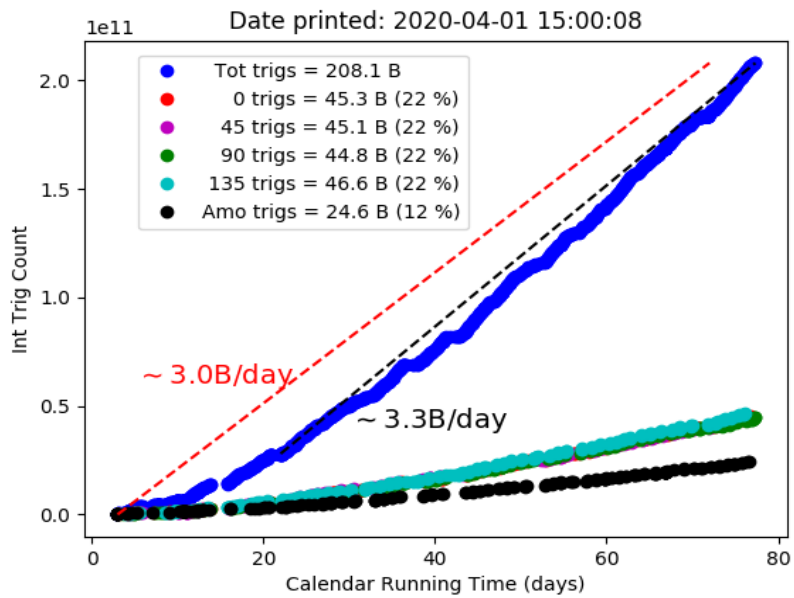
What have we learned so far?



[PRD 88 (2013) 094505]

GlueX Data Taking





GlueX Phase I (2017-2018):

- More than 250B events recorded
- 3PB data in 3 run periods
- Complete set reconstructed and under active analysis

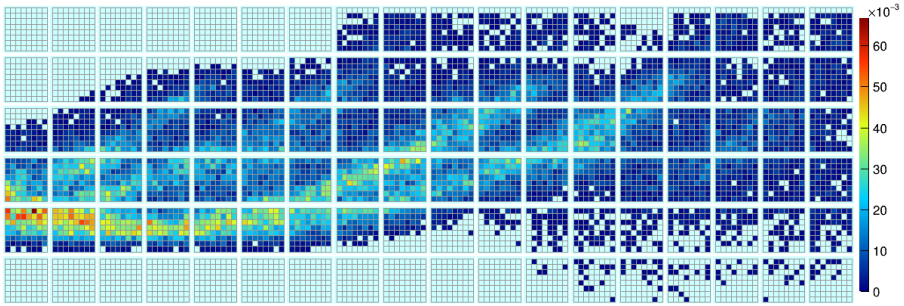
GlueX Phase II (2020-202?):

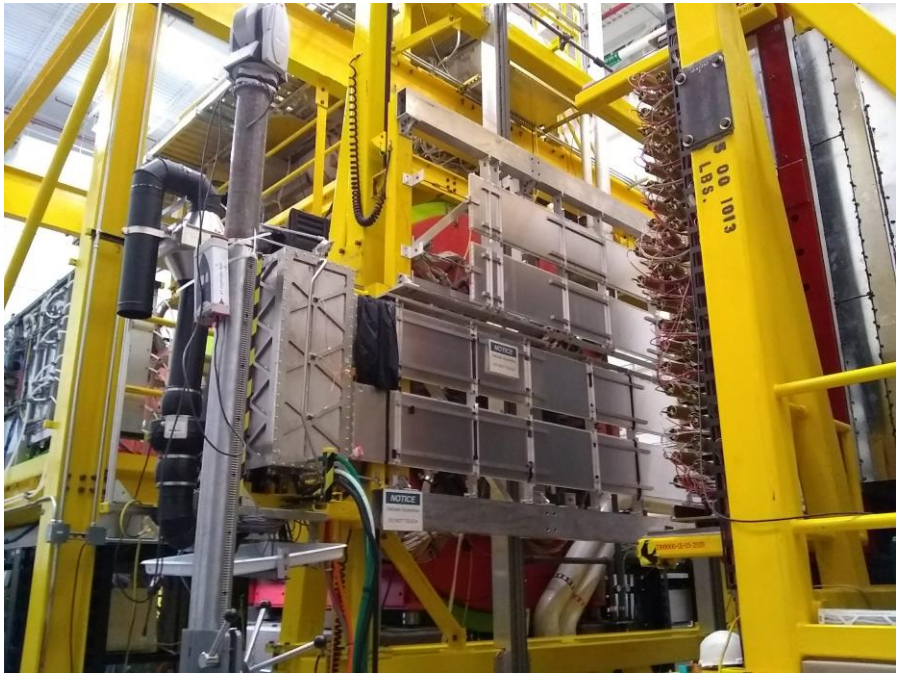
- DIRC upgrade completed
- Higher beam intensity + trigger rate: Rate above design value
- Collected more than 200B events
- Reconstruction campaign in a few weeks, ready for analysis in Fall 2020

GlueX Phase II: Particle ID Upgrade

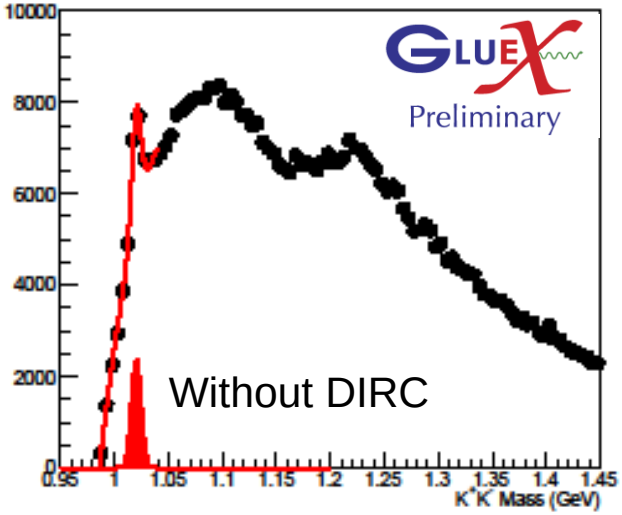
2019:

- DIRC installed and commissioned
- Cherenkov hit patterns match expectation from simulation

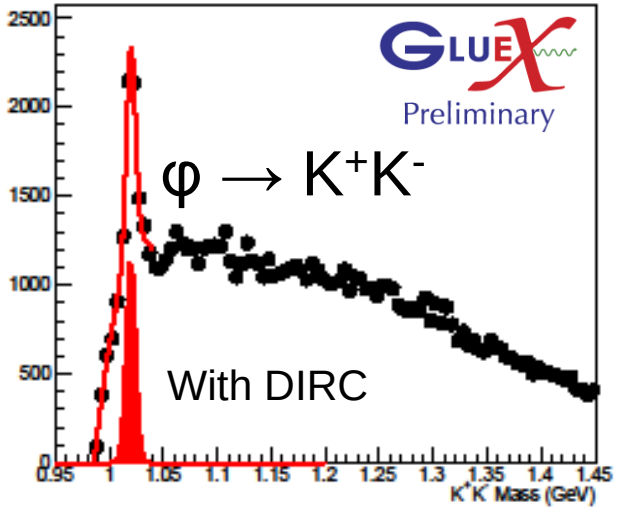




$\gamma p \rightarrow \pi^0 K^+ K^- p$



Preliminary DIRC Performance



2020:

- GlueX-II with DIRC
- Completed 20% of allocated PAC days

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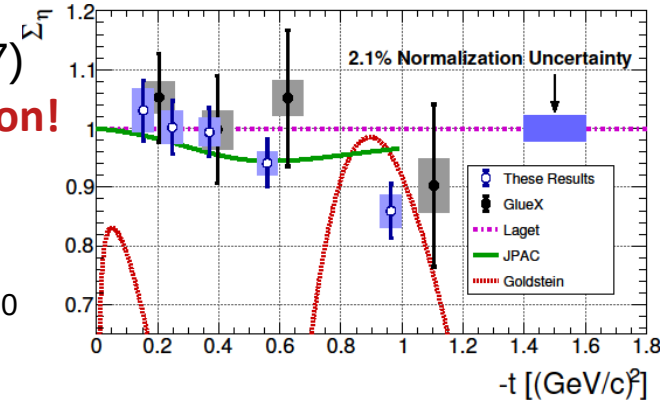
GlueX Publications

Study of polarization transfer in production mechanism:

- Measurement of the beam asymmetry Σ for π^0 and η photoproduction on the proton at E_γ=9GeV, PRC 95 (2017)

First 12GeV publication!

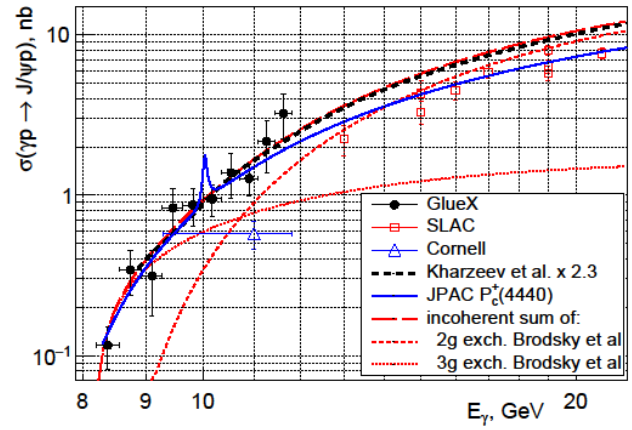


- Beam Asymmetry Σ for the Photoproduction of η and η′ Mesons at E_γ=8.8GeV, PRC 100 (2019)
- Measurement of the Photon Beam Asymmetry in $\gamma p \rightarrow K^+\Sigma^0$ at E_γ=8.5GeV, accepted in PRC (2020)
- Measurement of beam asymmetry for $\pi^-\Delta^{++}$ photoproduction on the proton at E_γ=8.5GeV, final collaboration review

Study of charm production and search for Pentaquarks:

- First Measurement of Near-Threshold J/ψ Exclusive Photoproduction off the Proton, PRL 123 (2019)

Editor's Suggestion + nearly 50 citations!



Technical Publications:

- The GlueX Beamline and Detector, 72 pages, submitted to NIM A (2020)
- 38 papers on sub-detector systems and counting!

[arXiv:2005.14272]

+ Many channels under active analysis

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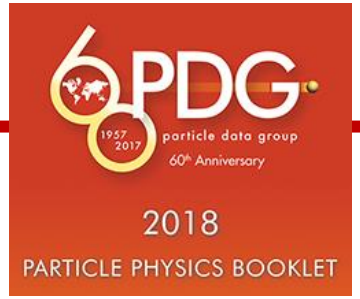
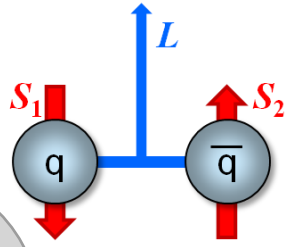
Exploring the Hadron Spectrum

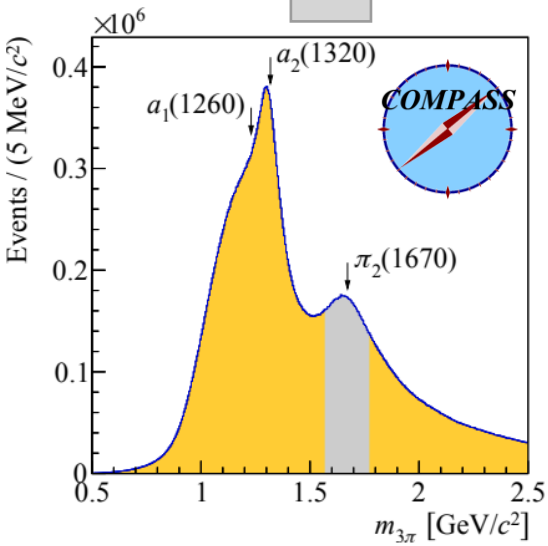


Acceptance Correction
Monte Carlo

Modeling of Background
Subtraction / Weighting

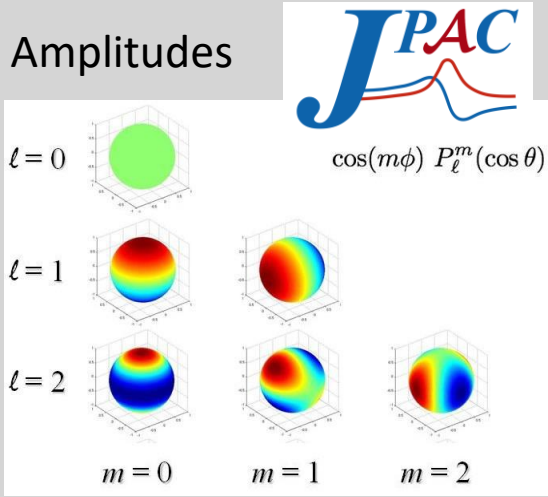


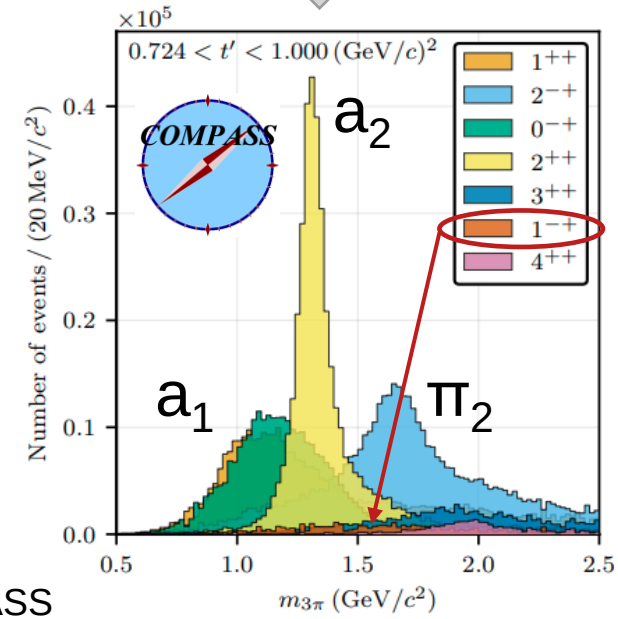
Partial-Wave / Amplitude Analysis



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

Amplitudes





Light-meson spectroscopy with COMPASS
PPNP 113 (2020) 103755

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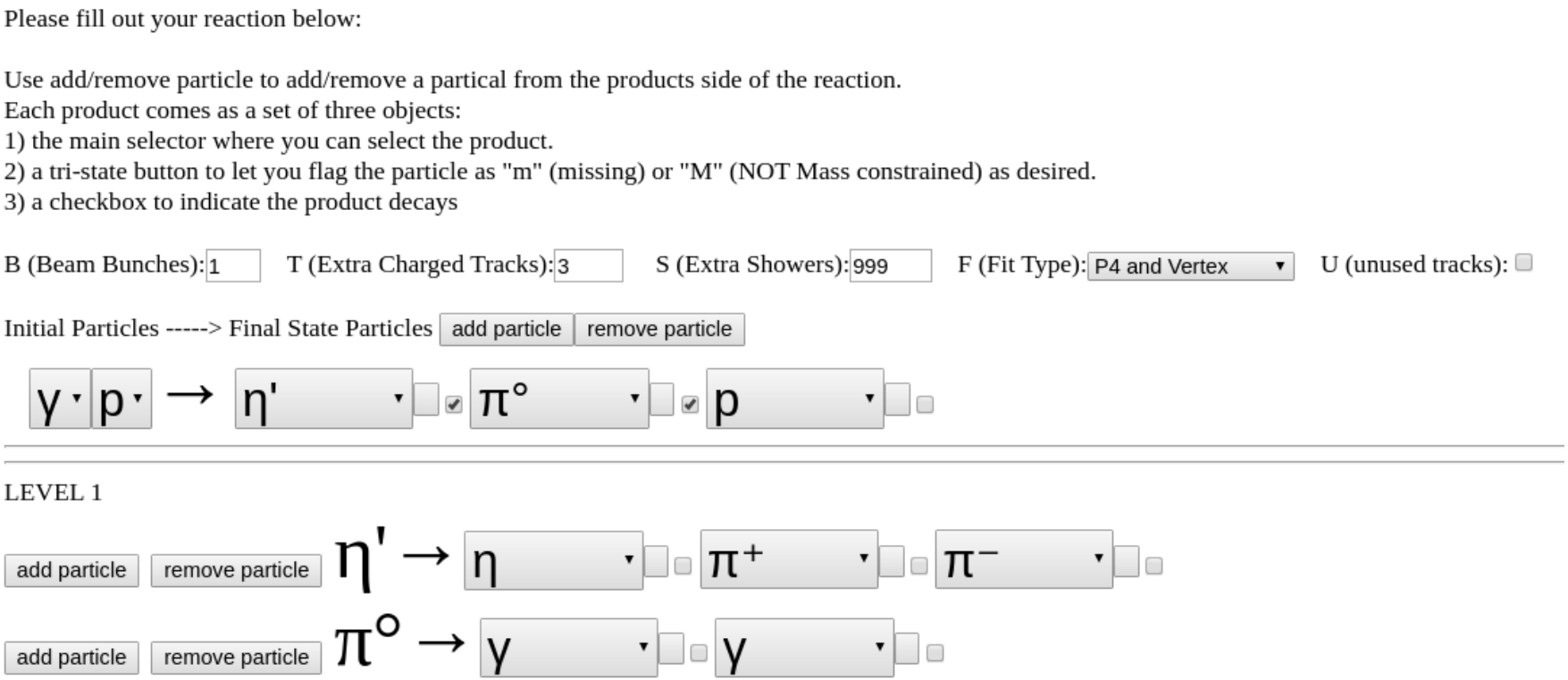
Centralized Data Analysis

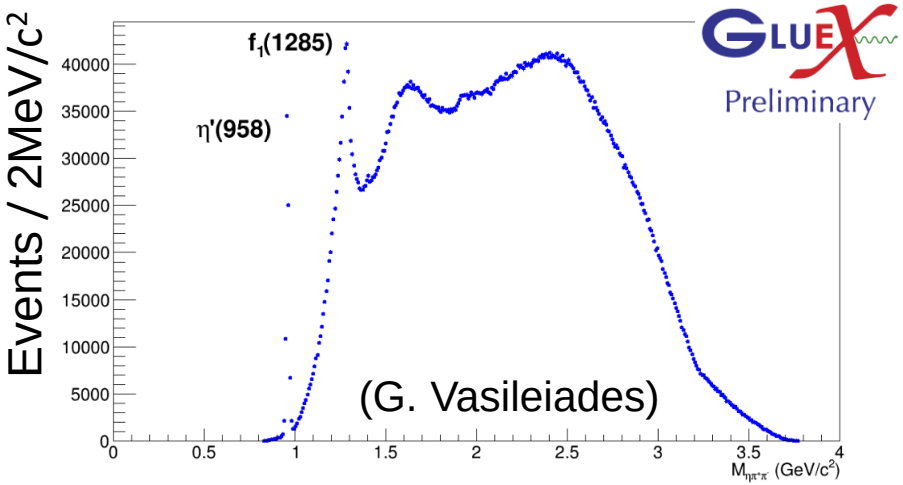
- Regular passes over reconstructed data files (~1PB)
- Particle identification and selection of topology, kinematic fit
- Skim events into standardized output files
- Analyzer can request channel via online form



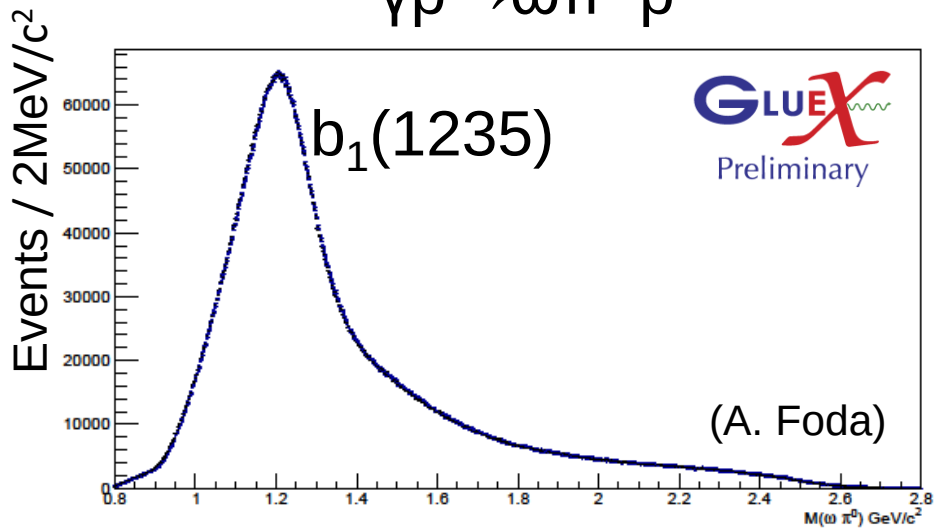
Survey of Final States

"Phenomenological studies […] predicting that the photoproduction cross-sections for exotic mesons are comparable to those for conventional mesons" (GlueX Proposal)

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



$\gamma p \rightarrow \omega \pi^0 p$



- We do not found evidence for narrow, exotic states, ruling out certain models
- Many multi-body final states studied, spectra consistent with known states
- Amplitude analysis necessary to access broad states and smaller cross sections
- Lattice QCD provides a viable path to make testable, first-principles predictions about the hybrid spectrum

had spec

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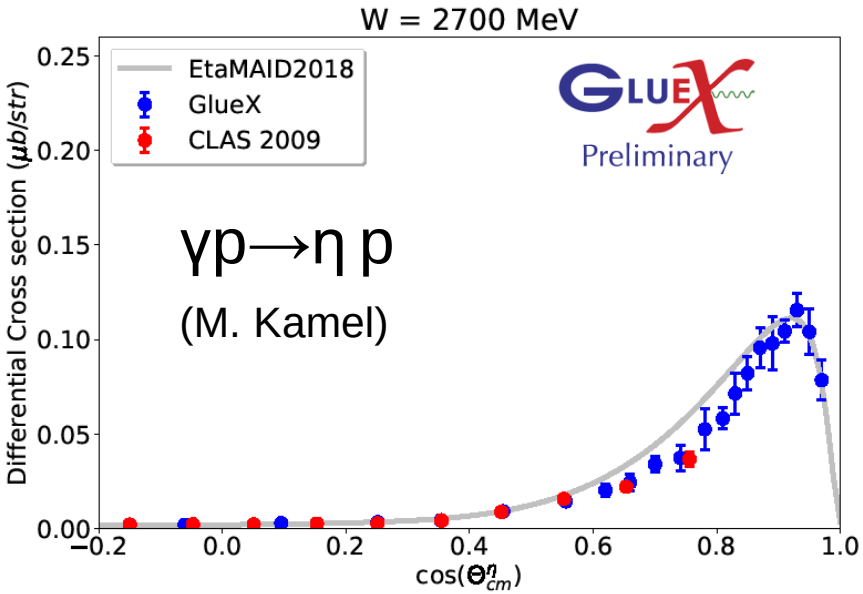
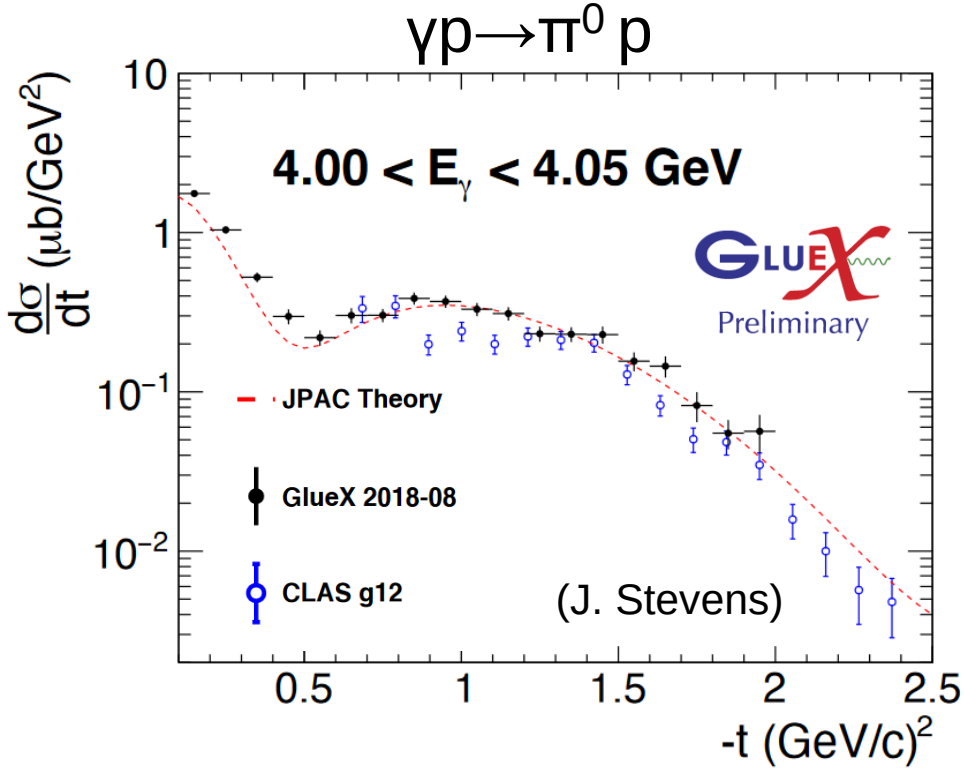
Evaluate Simulation: Differential Cross Sections

Low Photon Beam Energy: 3-6 GeV

- Overlap with previous experiments
- Compare to model predictions





Nominal Energy Range: 6-12 GeV

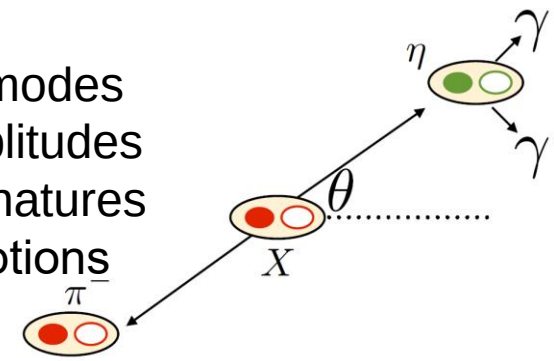
- Multiple cross section analyses ongoing, publications expected by the end of 2020
- Data set will significantly improve the knowledge on hadronic interactions
- Detailed study of Monte Carlo description to **meet PWA requirements**

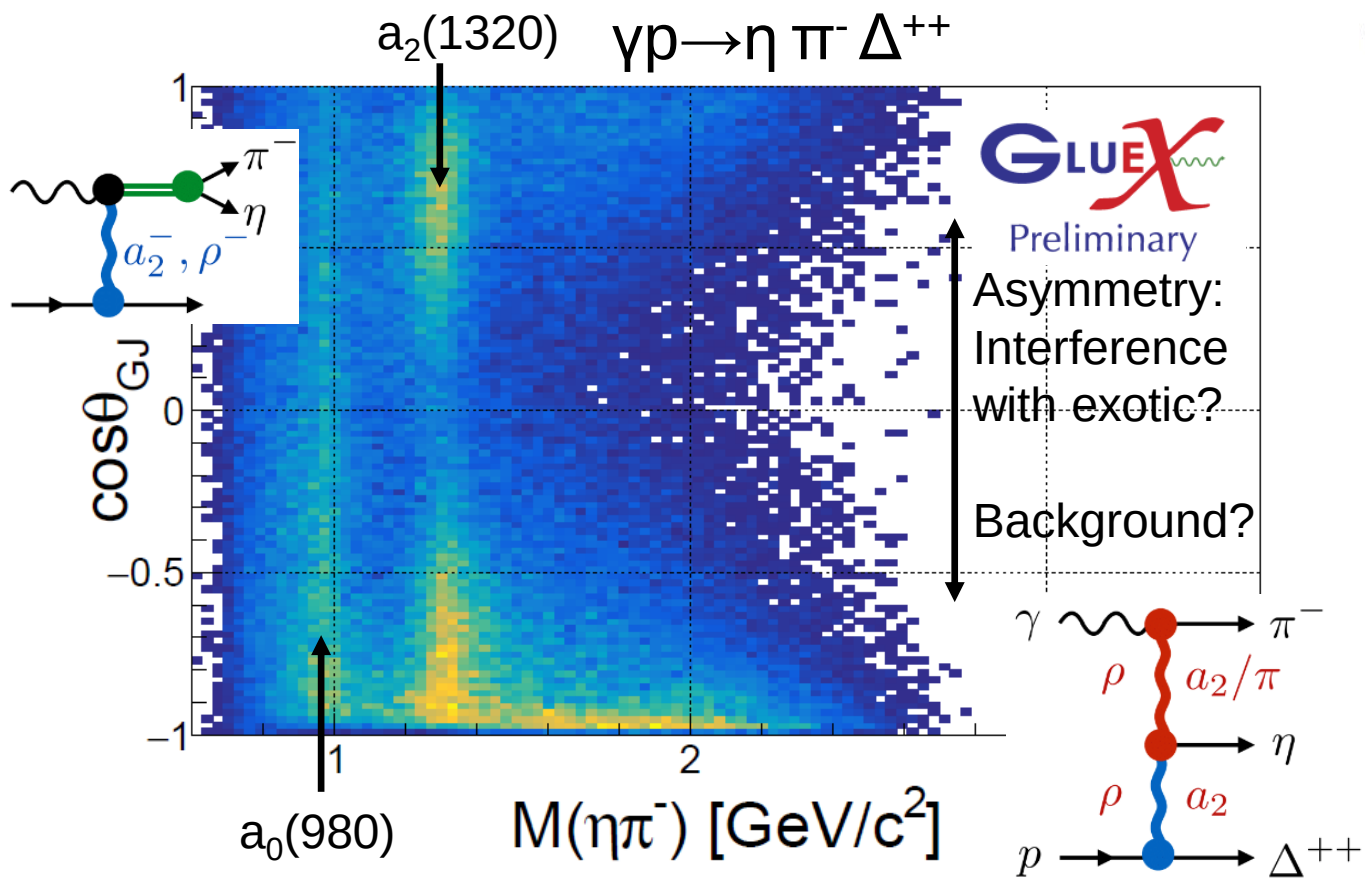
Studied channels: π^0, η, η', ρ, ω, φ, b_1, Ξ^-, …

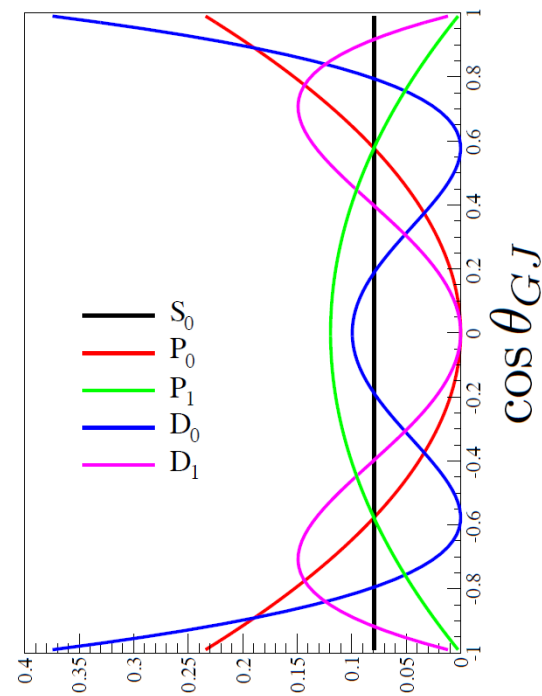
Modelling Amplitudes for Signal and Background

- **ηπ system**: exotic signals reported by COMPASS + JPAC
- High priority for GlueX: large data sample, multiple decay modes
- Collaboration with JPAC on polarized photoproduction amplitudes
- Background from double-Regge production has similar signatures

→ Model background contribution to avoid simplifying assumptions







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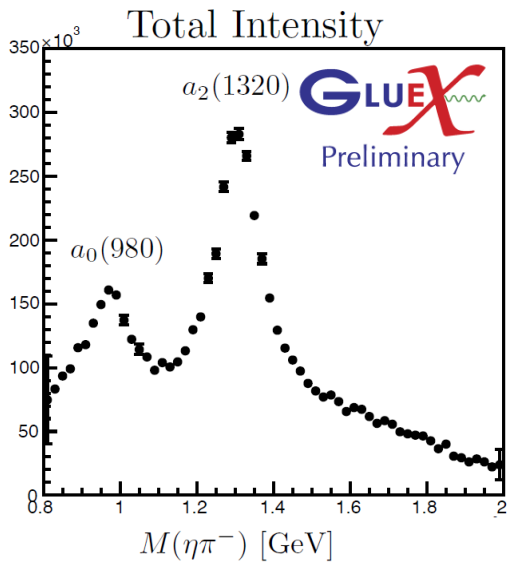
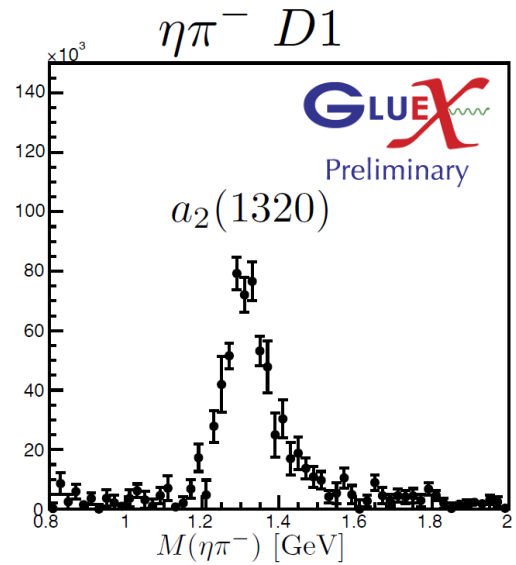
Preliminary Highlights: First PWA Results

Partial-Wave Analysis of the η π⁻ system: (C. Gleason)



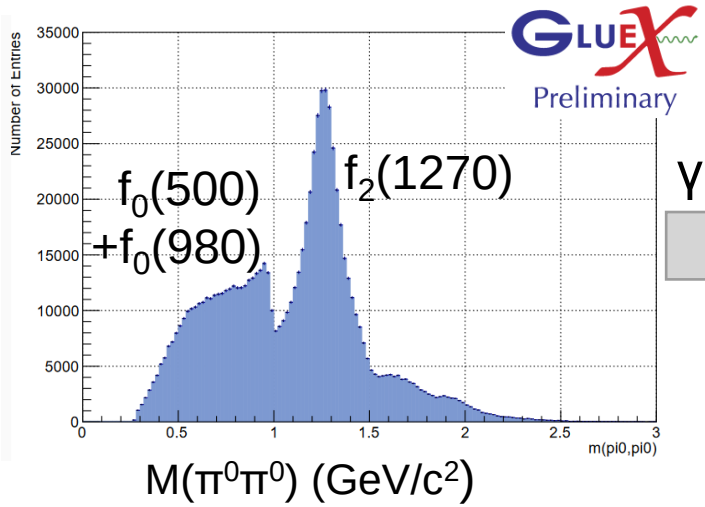
$\gamma p \rightarrow \eta\, \pi^- \Delta^{++}$

PWA



- Mass-independent
- Extraction of dominant signals
- Ongoing work

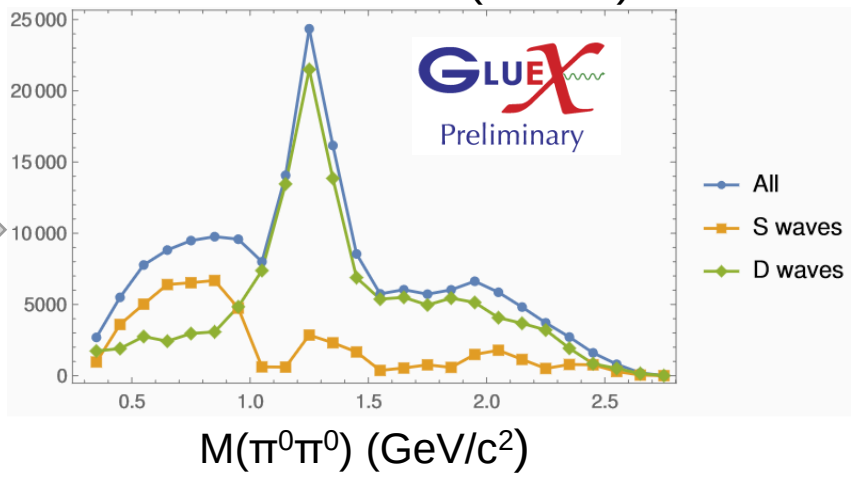
Moment Analysis of the $\pi^0\pi^0$ system: (A. Thiel)



$\gamma p \rightarrow \pi^0\pi^0 p$

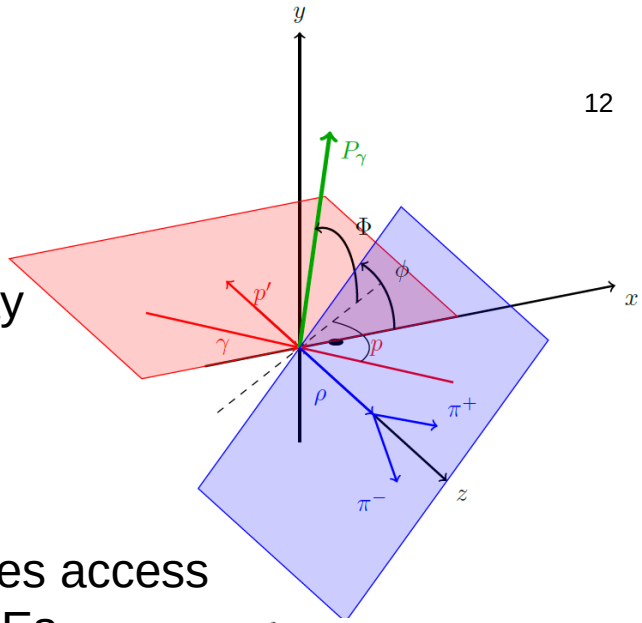
PWA

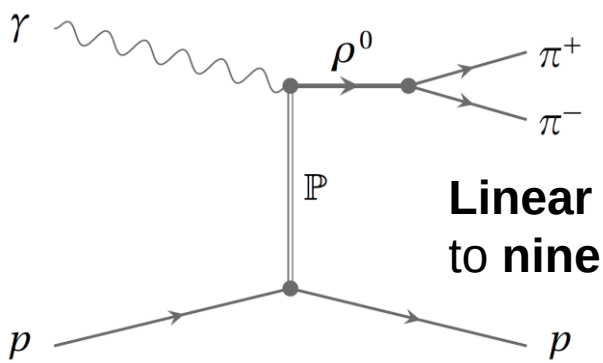
$0.2 < -t < 0.4$ (GeV/c)²



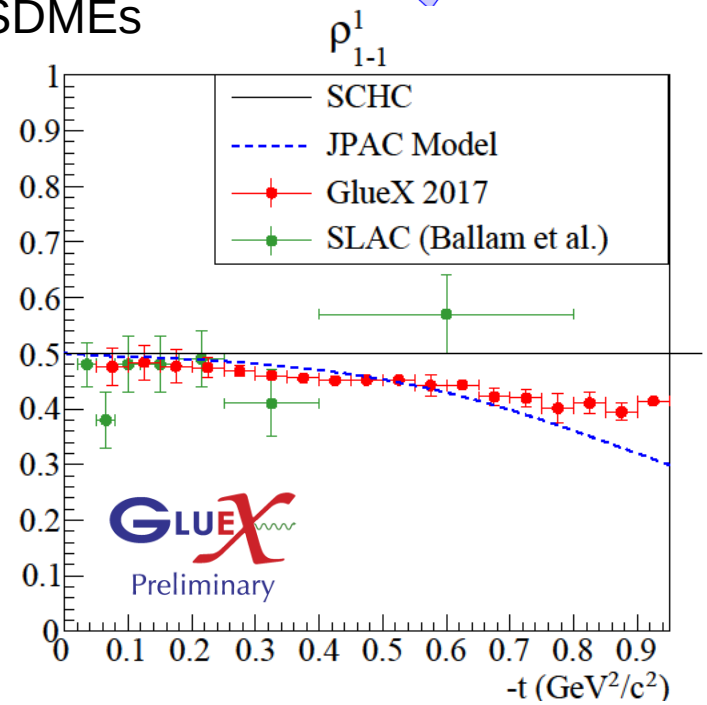
The Full Chain: Vector Meson SDMEs

Spin-Density Matrix Elements ρ_{ij} :
Angular distribution of vector meson production and decay





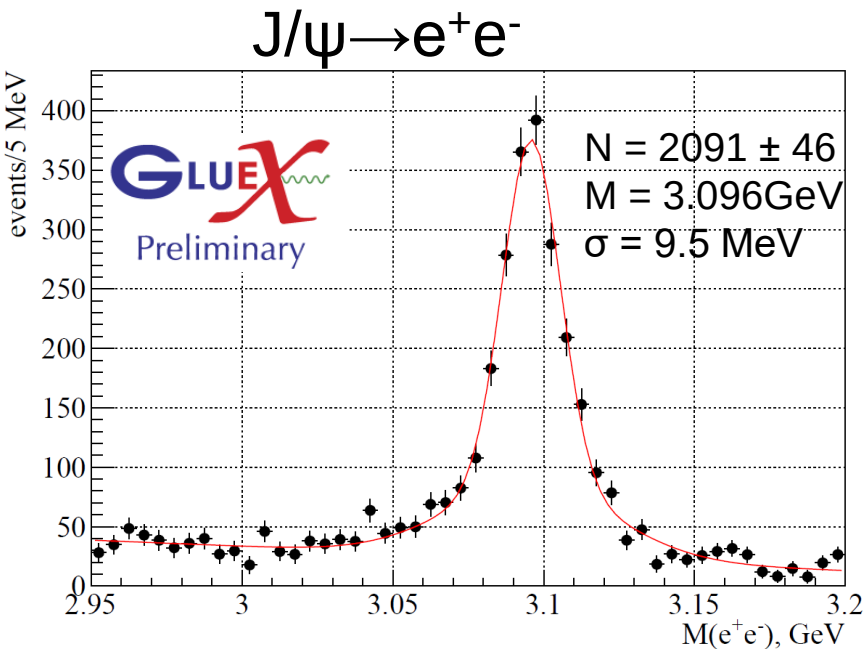
Linear beam polarization provides access to **nine** linearly independent SDMEs

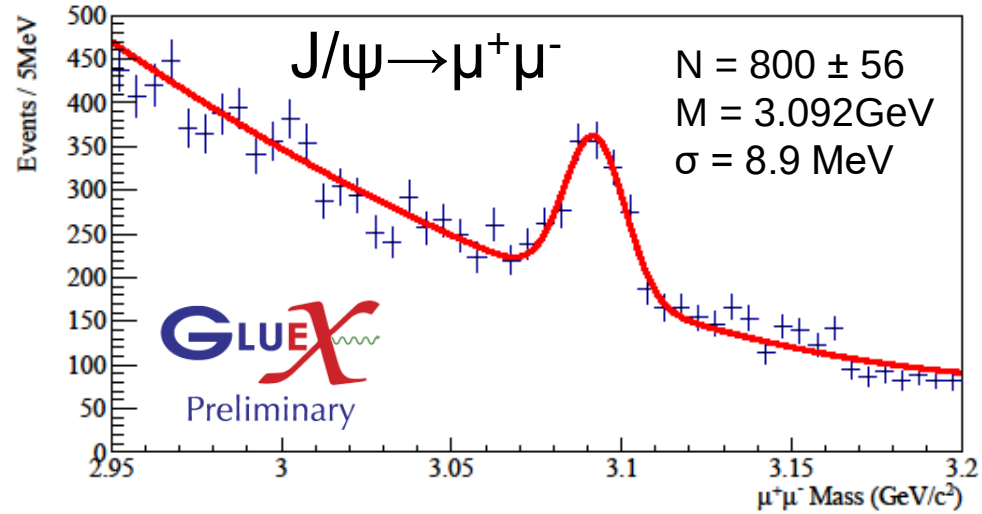


- High-statistics sample: orders of magnitude higher precision than previous measurements
- Good agreement with model predictions
- Used to study **acceptance** and to develop **tools** for modern amplitude analysis (GPU, machine learning)

Next milestone: First Result with PWA tools

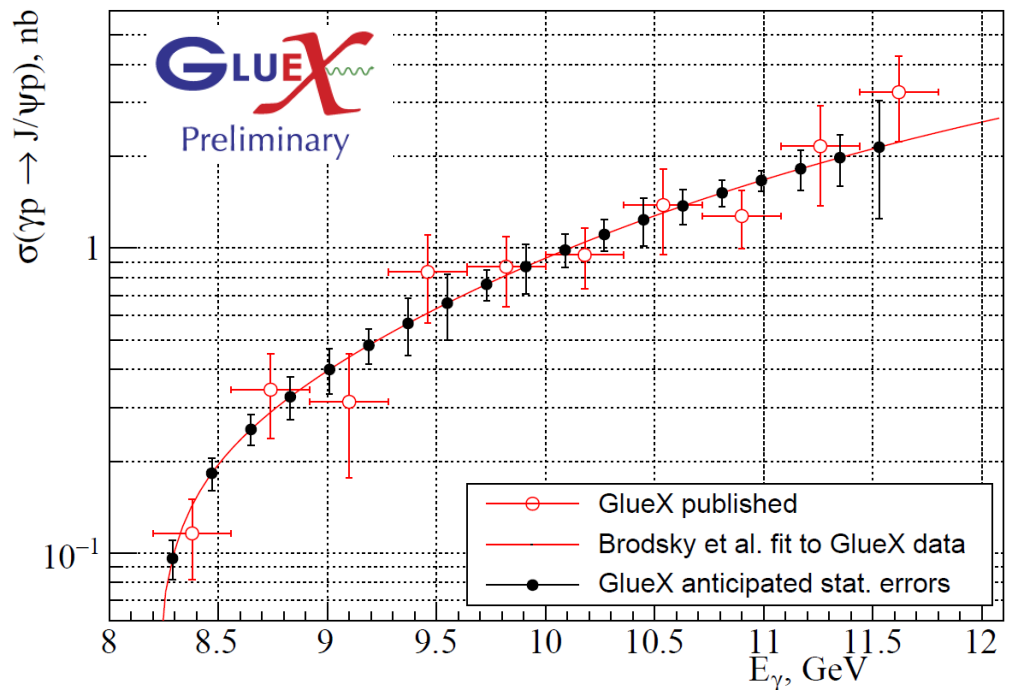
Preliminary Highlights: J/ψ photoproduction cross section





Update with full GlueX-I data set:

- More than 2000 events in e^+e^-
- Complementary decay to $\mu^+\mu^-$
- Detailed studies of differential cross section near threshold
- Continue search for Pentaquarks



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Hall D Staff Scientist
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- Full Phase I data under active analysis
- Growing Phase II data sample
- Several publications: physics and technical
- Full focus on amplitude analysis

Milestones in Search for Hybrid Mesons:

1. Polarization Transfer in Production ✓
2. Study Acceptance (Cross Sections) ✓
3. Collaborate with Theory on Amplitudes ✓
4. Finalize SDME Analysis ✓
5. Amplitude Analysis of 2-body channels

} Complete in 2020

} Started