

Future of Hadron Spectroscopy at Photoproduction Experiments

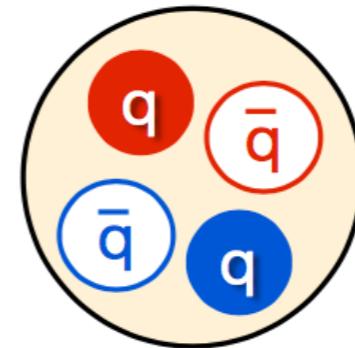
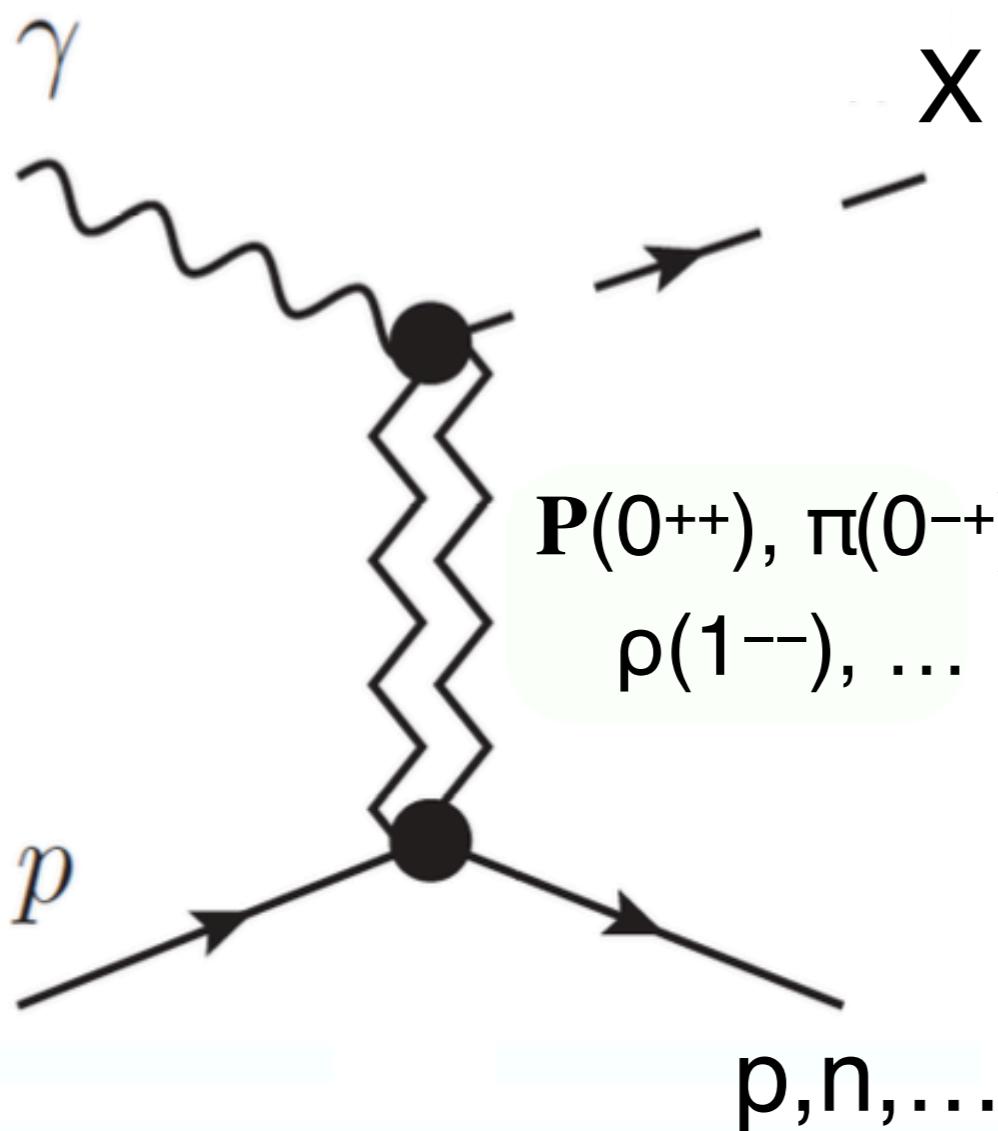
Sean Dobbs

Snowmass Community Summer Study Workshop
July 20, 2022

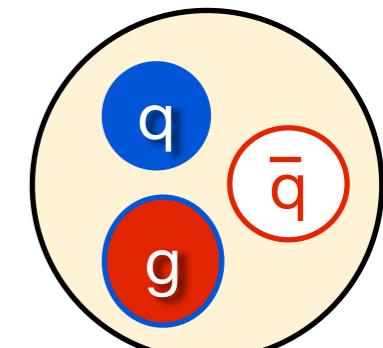


Hadron Spectroscopy and Photoproduction

- Photoproduction is an essential process to study **normal hadrons** and to search for **exotic hadrons**



tetraquark

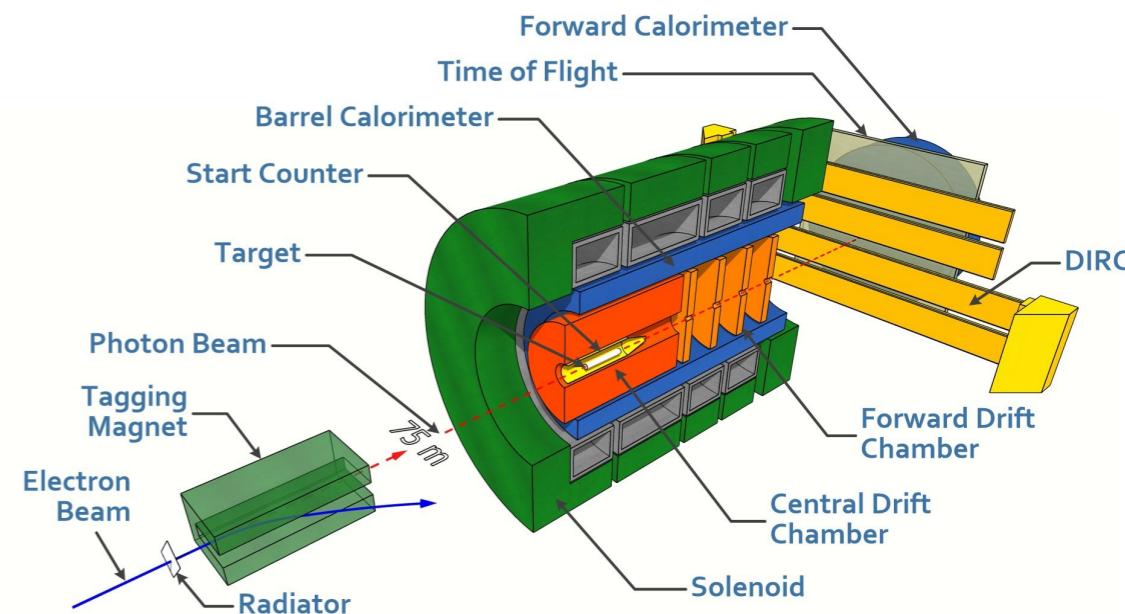


hybrid meson

- All types of exotic hadrons accessible
- Studies of production mechanisms can **distinguish** between models of microscopic structure
- Complementary** kinematics to other experiments
- Photon **polarization** provides information on production processes
- Current and future** facilities will provide this data

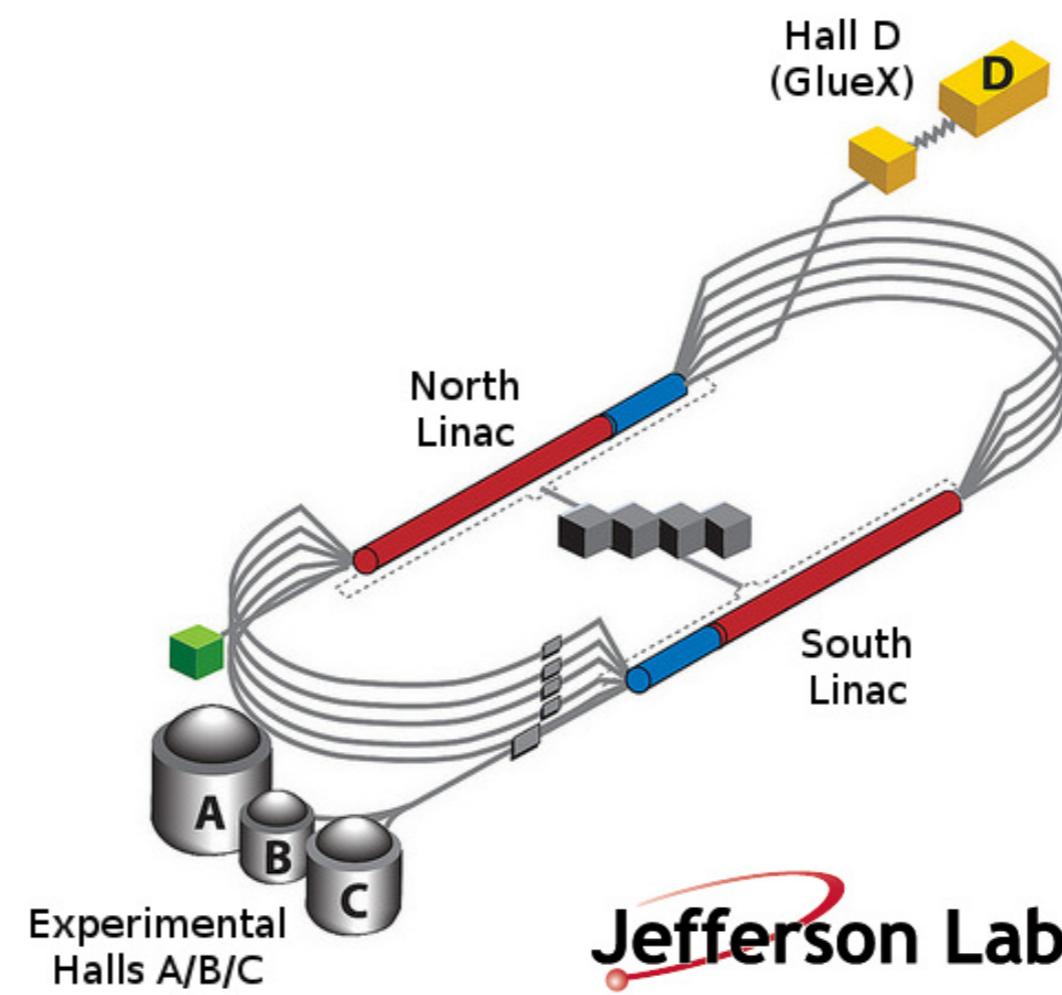
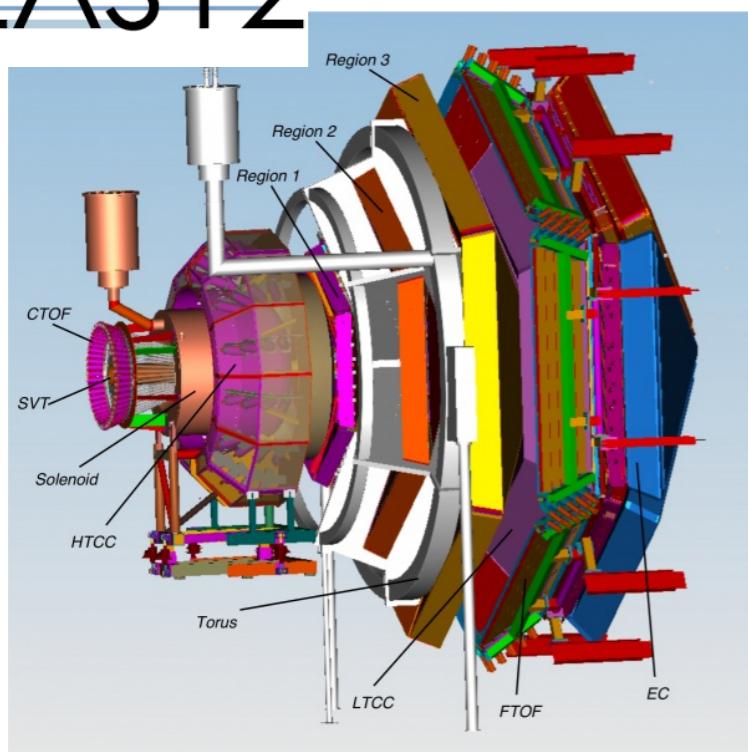
12 GeV Electron Beam @ Jefferson Lab

- Operational since 2017
- Electron beam with high polarization, luminosity
- Programs in nucleon structure, spectroscopy, BSM, ...



GLUEX

CLAS12



Continuous
Electron
Beam
Accelerator
Facility

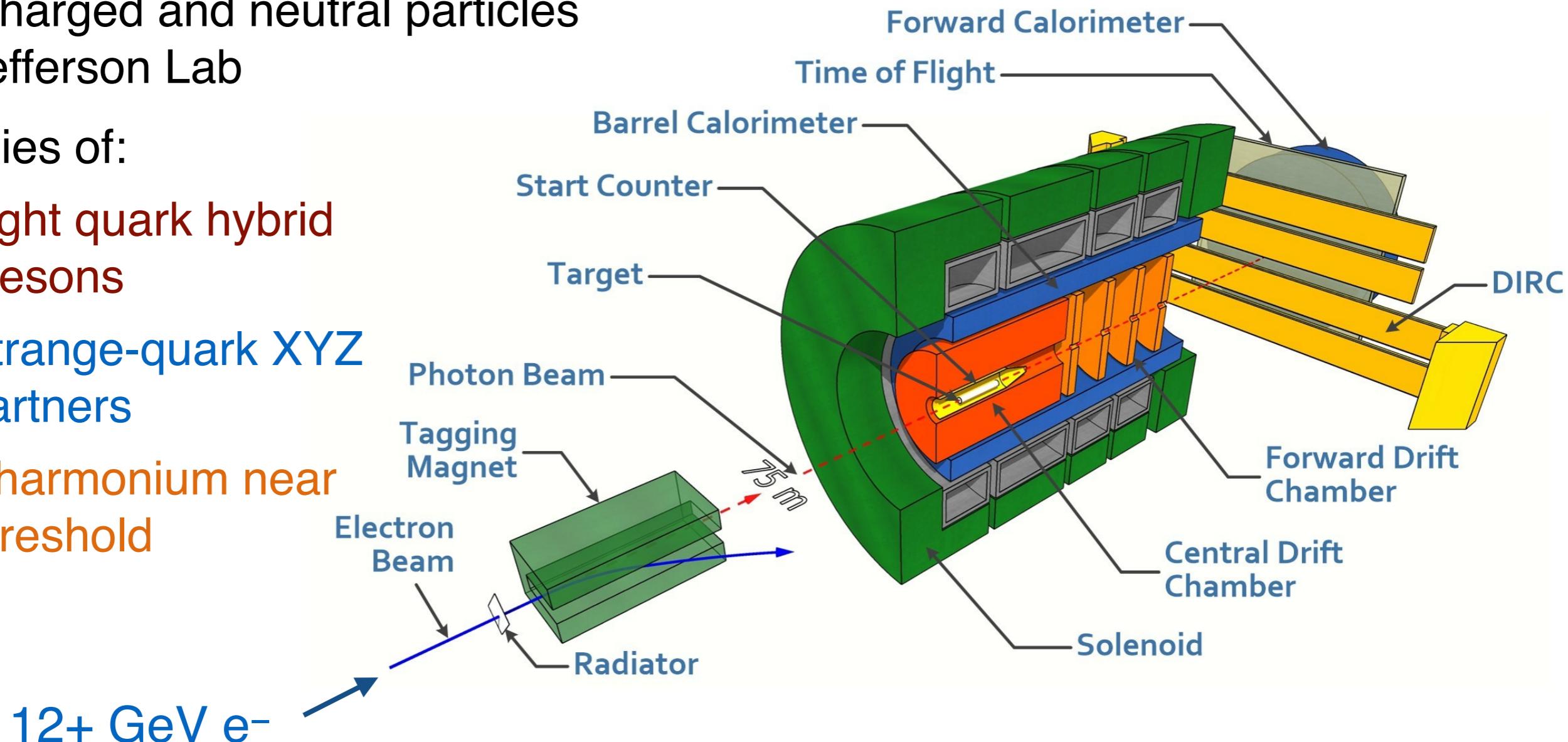
Jefferson Lab Newport News, VA

GlueX Experiment @ JLab

Large acceptance spectrometer
for charged and neutral particles
at Jefferson Lab

Studies of:

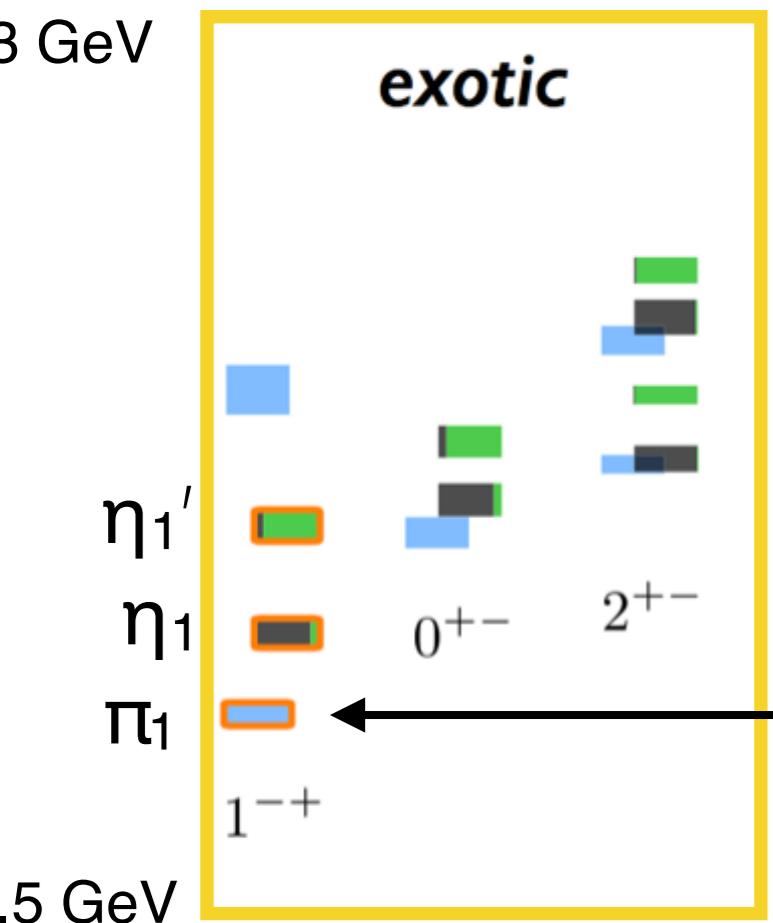
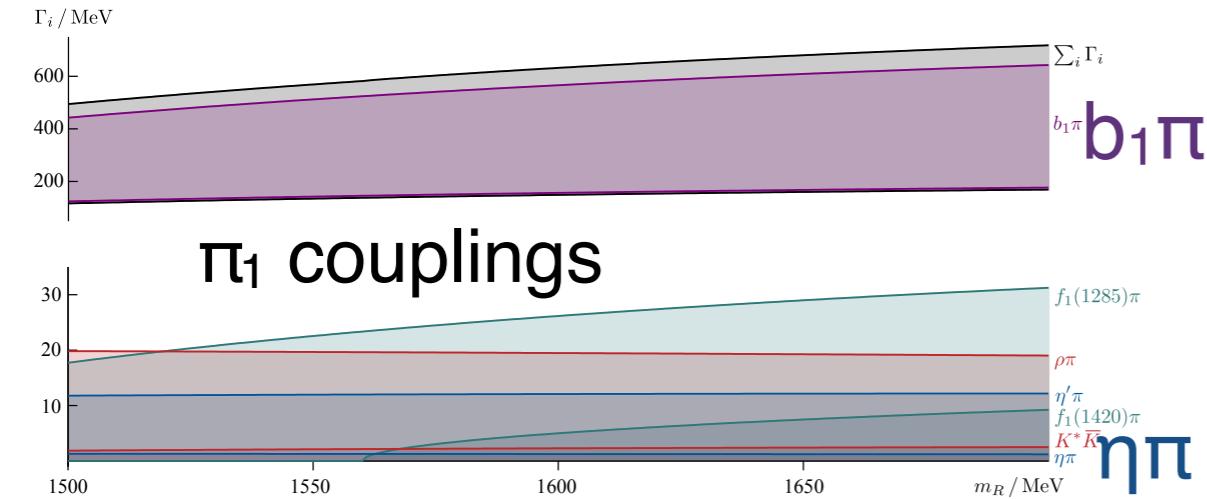
- Light quark hybrid mesons
- Strange-quark XYZ partners
- Charmonium near threshold



- High-statistics spectroscopy: $\mathcal{L} = 0.84 \text{ fb}^{-1}$ with 3x more by 2025
- Approved program through end of decade: K_L beam, addtl. targets

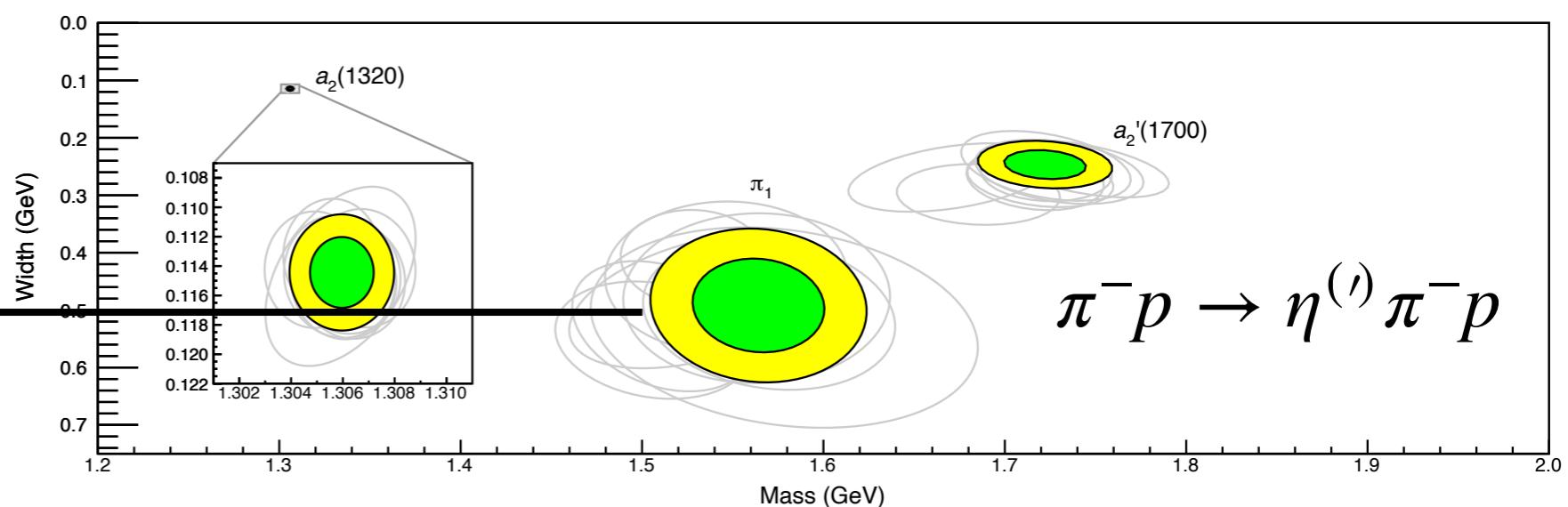
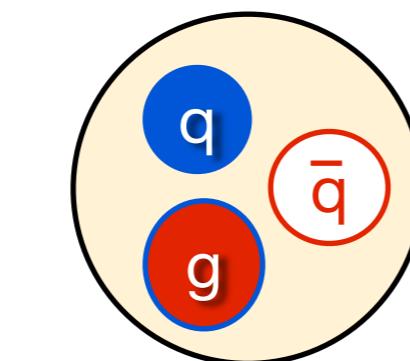
Hybrid Mesons

HadSpec: PRD 103, 054502 (2021)



HadSpec: PRD 88, 094505 (2013)

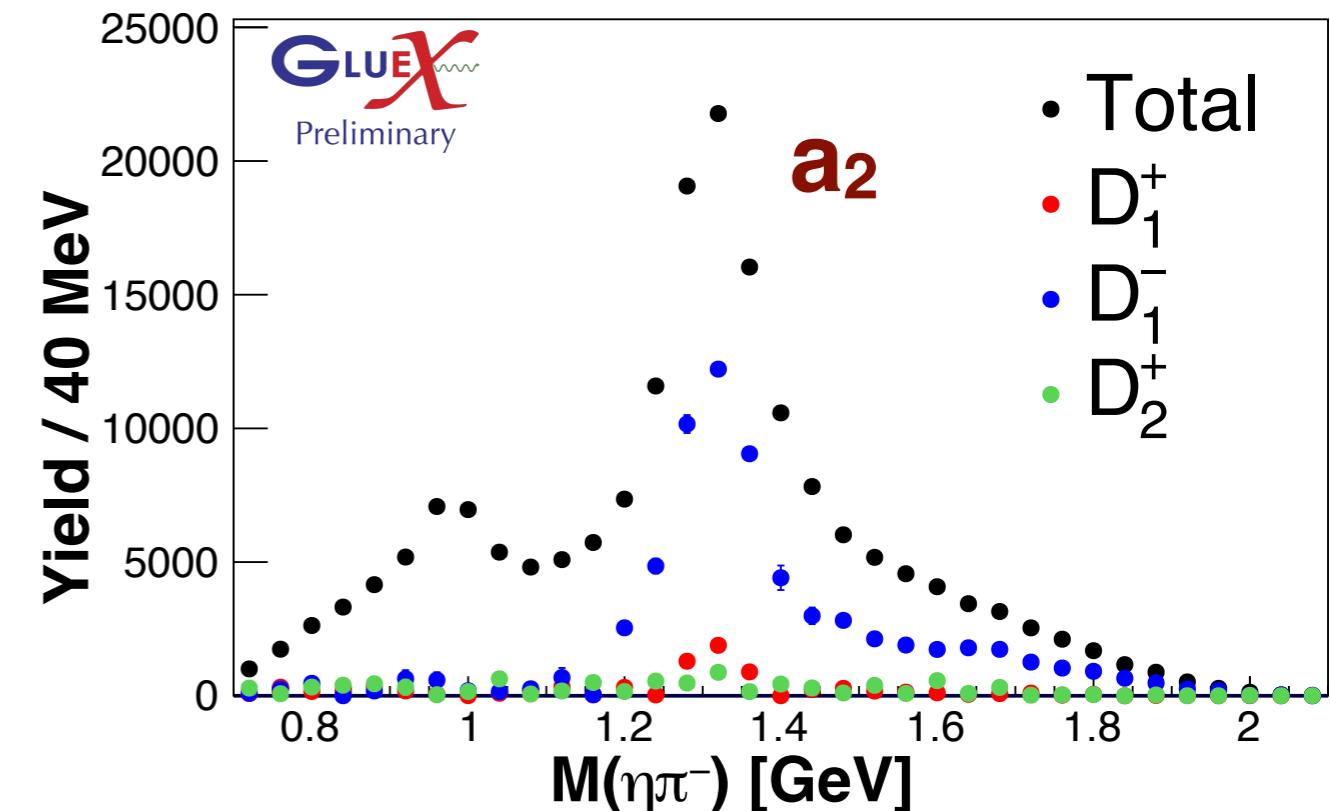
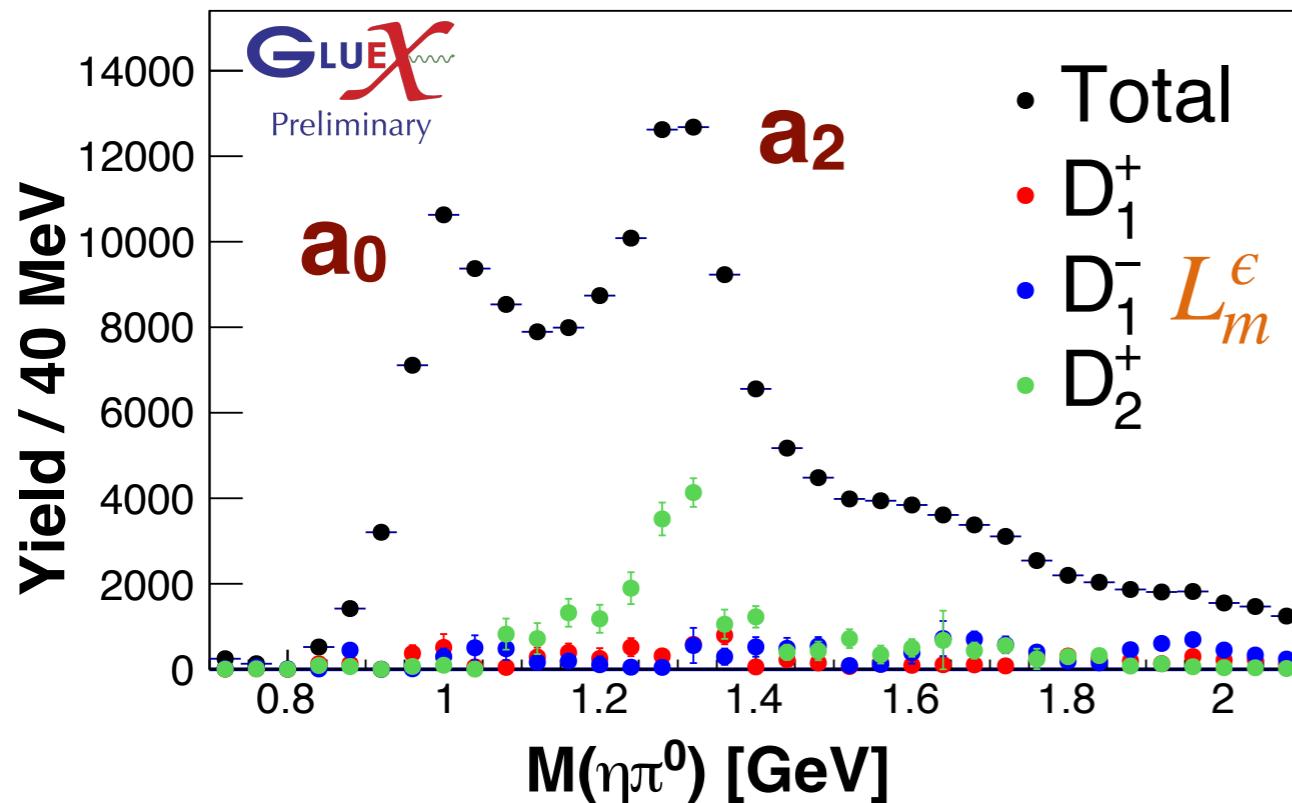
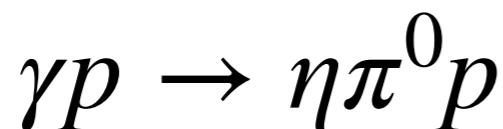
- Long history of search for “hybrid” mesons with gluonic excitations
- Best evidence is for $\pi_1(1600)$ in COMPASS pion-production data
- Establishing the light quark hybrid spectrum → insight to the heavy quark hybrid spectrum



JPAC: PRL 122, 042002 (2019)

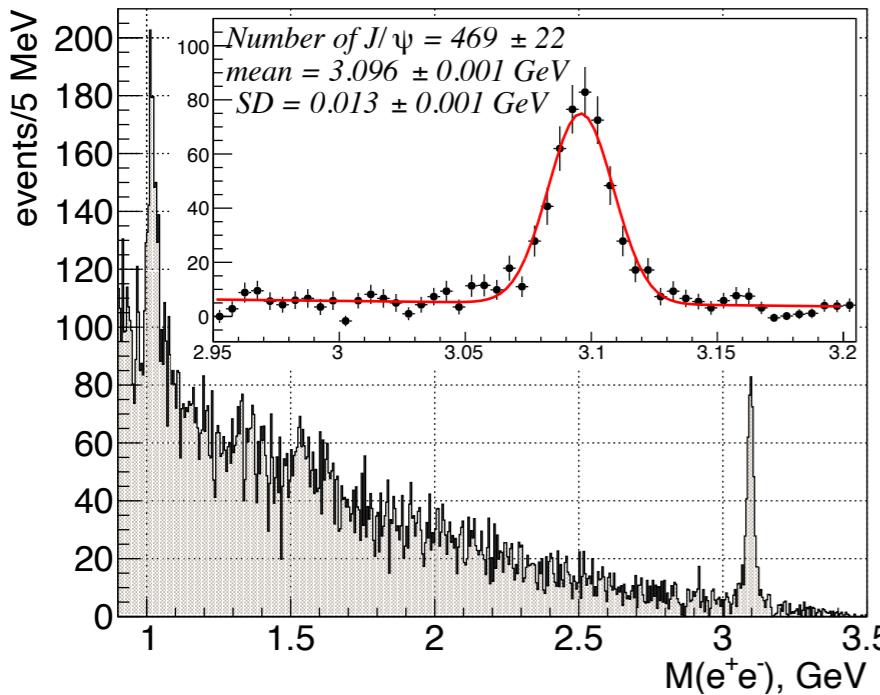
$\eta\pi / \eta\pi'$ Spectroscopy @ GlueX

- First step: confirm $\pi_1(1600)$ measurement by COMPASS (and others) in photoproduction
- Broad, overlapping resonances require **amplitude analysis** of full reaction
- Developing **polarized photoproduction** amplitudes with JPAC

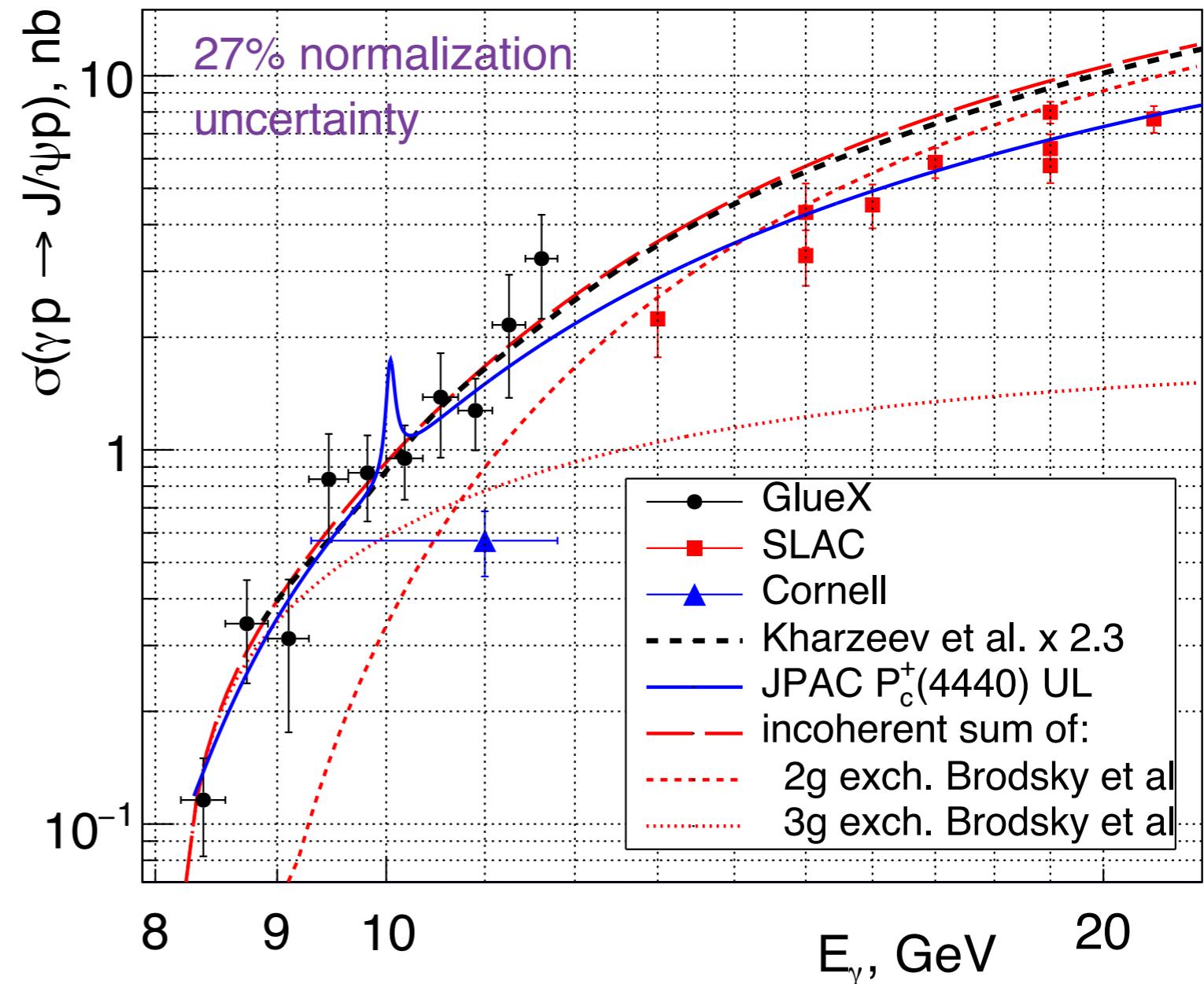


Pentaquarks and J/ ψ Photoproduction

GlueX: PRL 123, 072001 (2019)

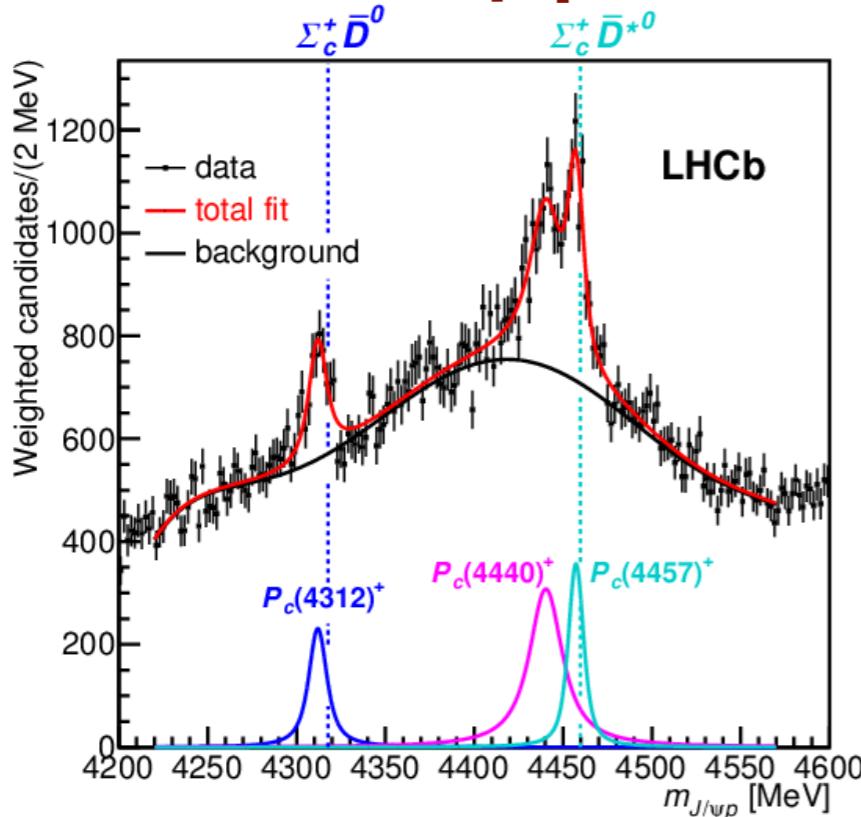


- Used portion of GlueX-I data [469 J/ψ] to measure cross sections

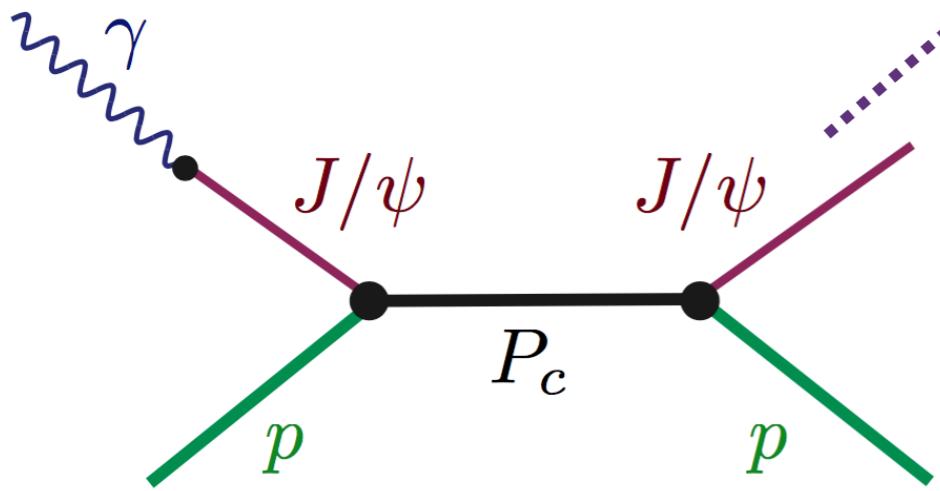


Pentaquarks and J/ ψ Photoproduction

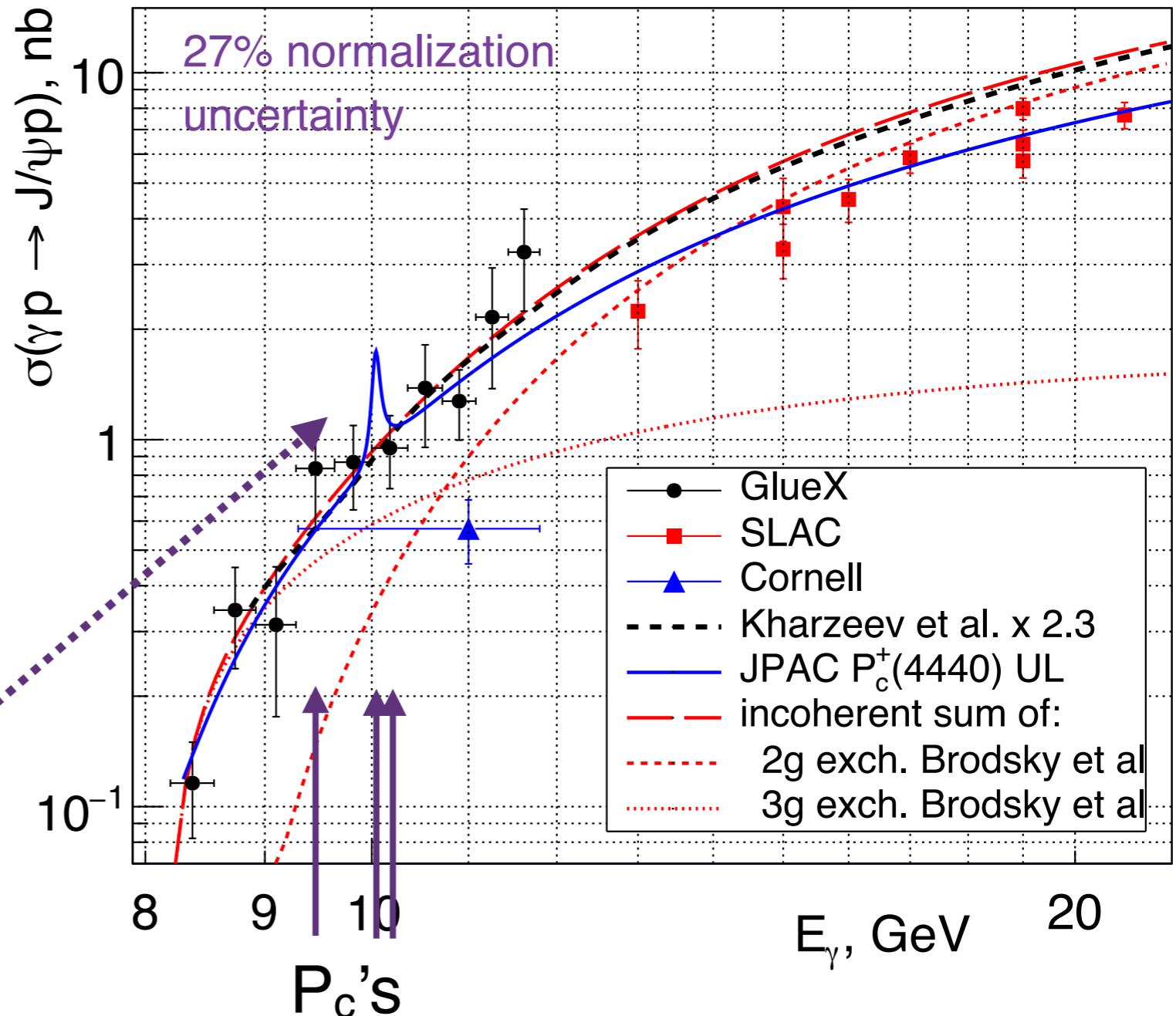
$\Lambda_b \rightarrow J/\psi p K^-$



LHCb, PRL 122, 222001 (2019)



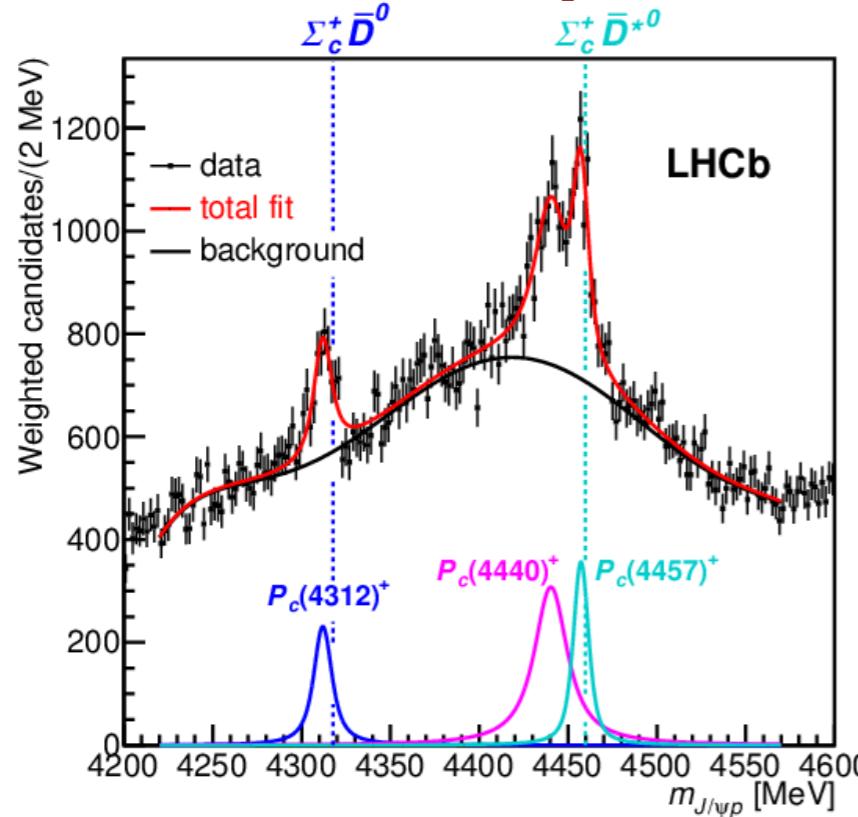
GlueX: PRL 123, 072001 (2019)



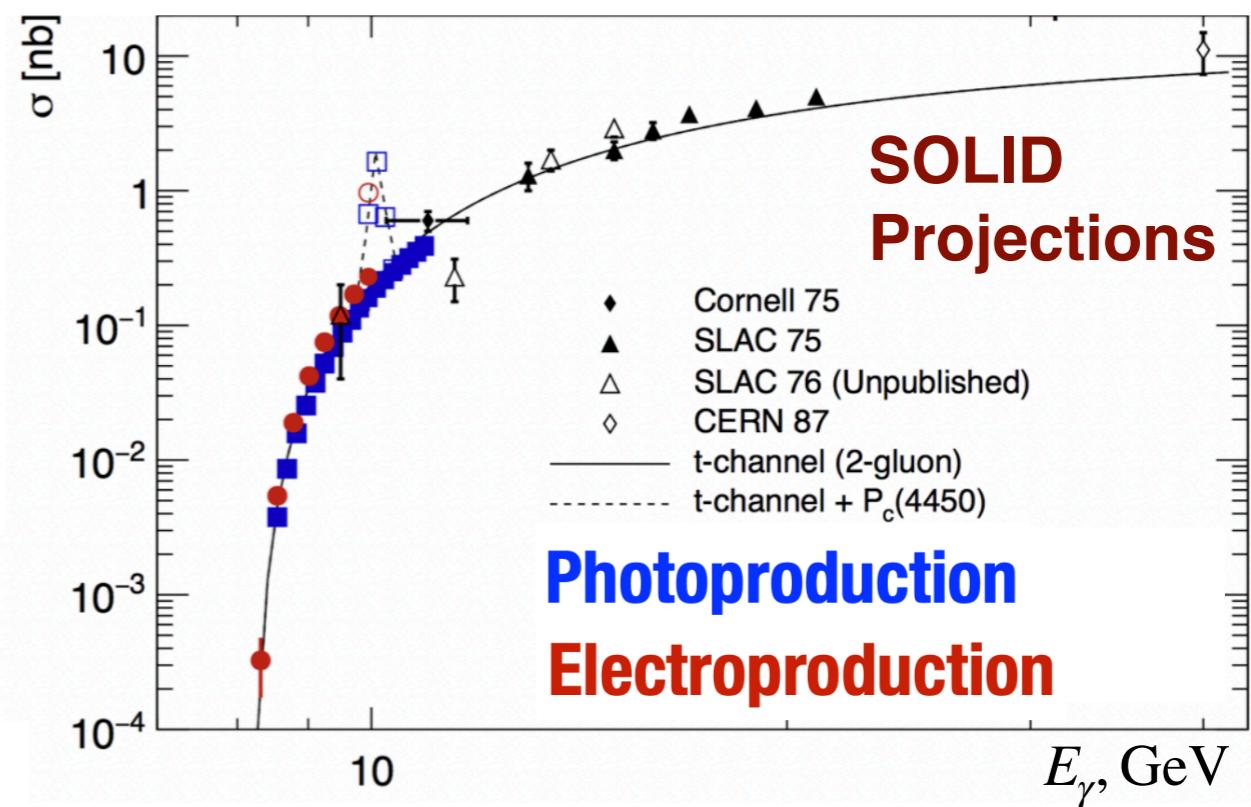
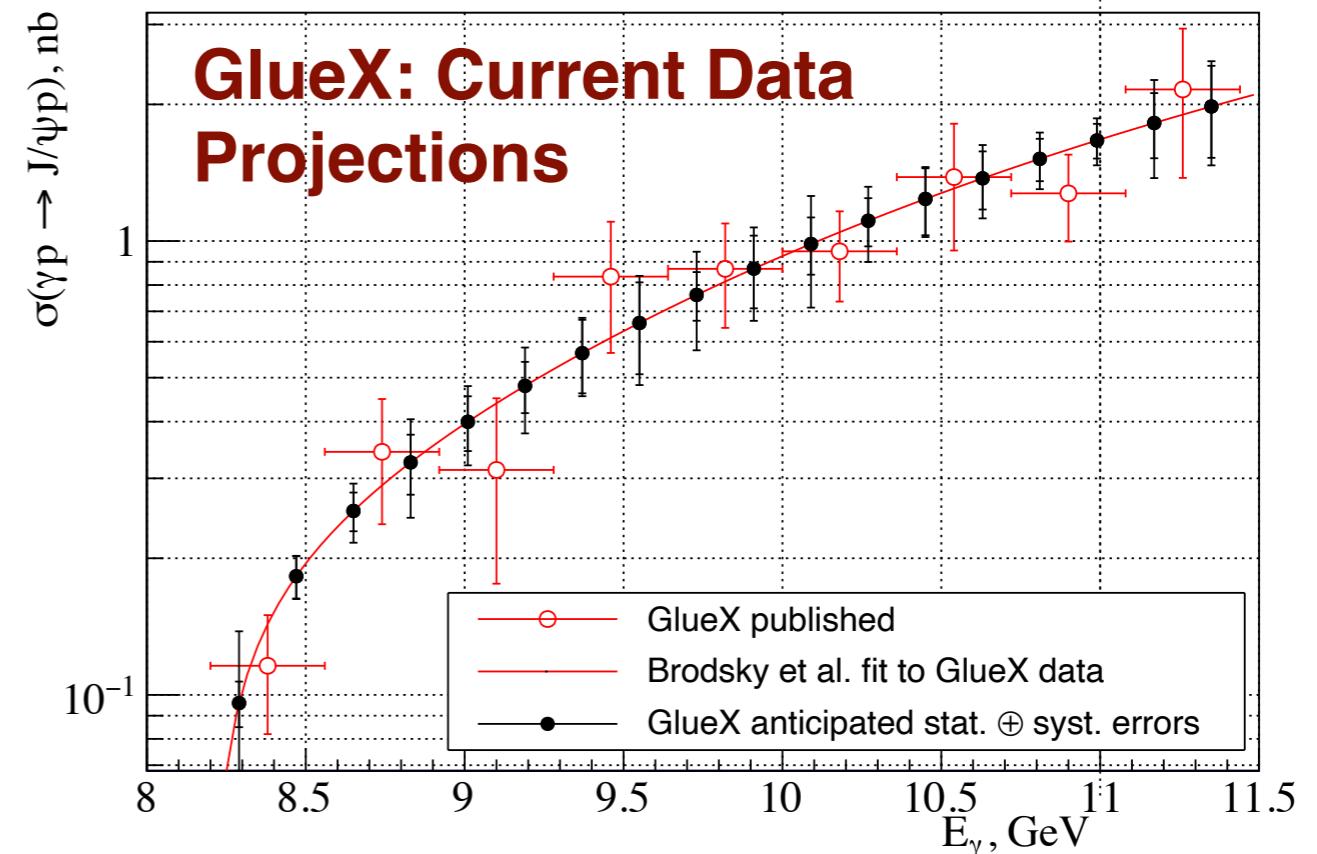
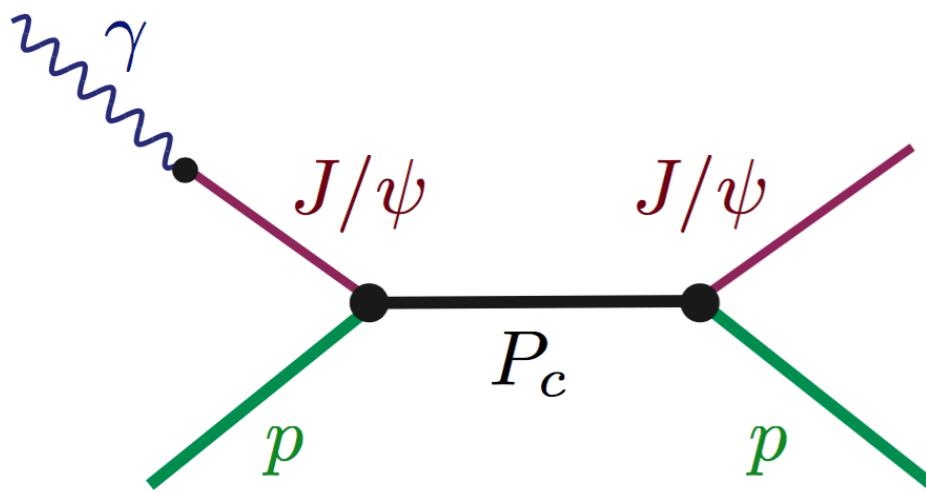
Limits on $\mathcal{B}(P_c \rightarrow J/\psi p) < 2 - 4\%$ constrain models

Pentaquarks and J/ ψ Photoproduction

$\Lambda_b \rightarrow J/\psi p K^-$



LHCb, PRL 122, 222001 (2019)



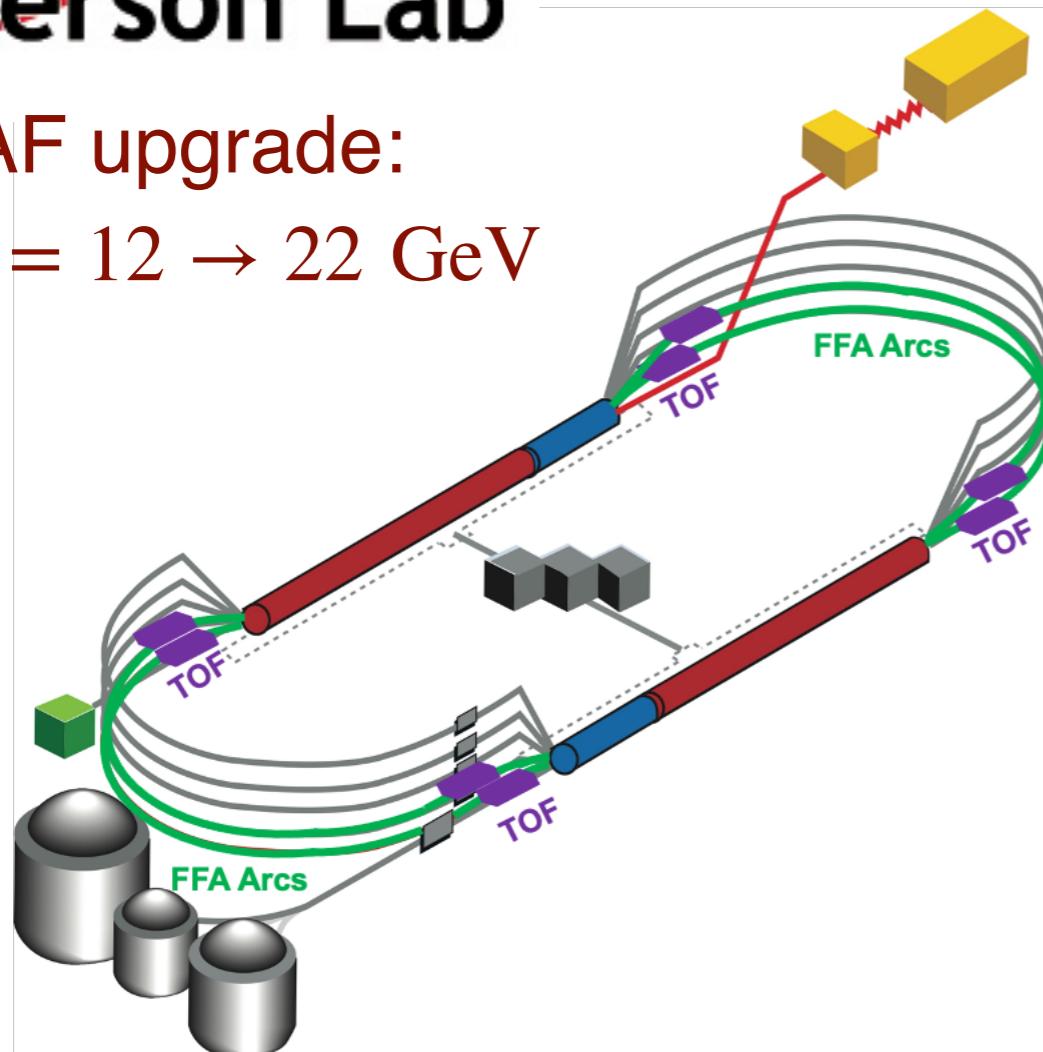
What's Next: Higher Energies in the 2030's

- Higher energy facilities enable photoproduction in the $c\bar{c}$ region



CEBAF upgrade:

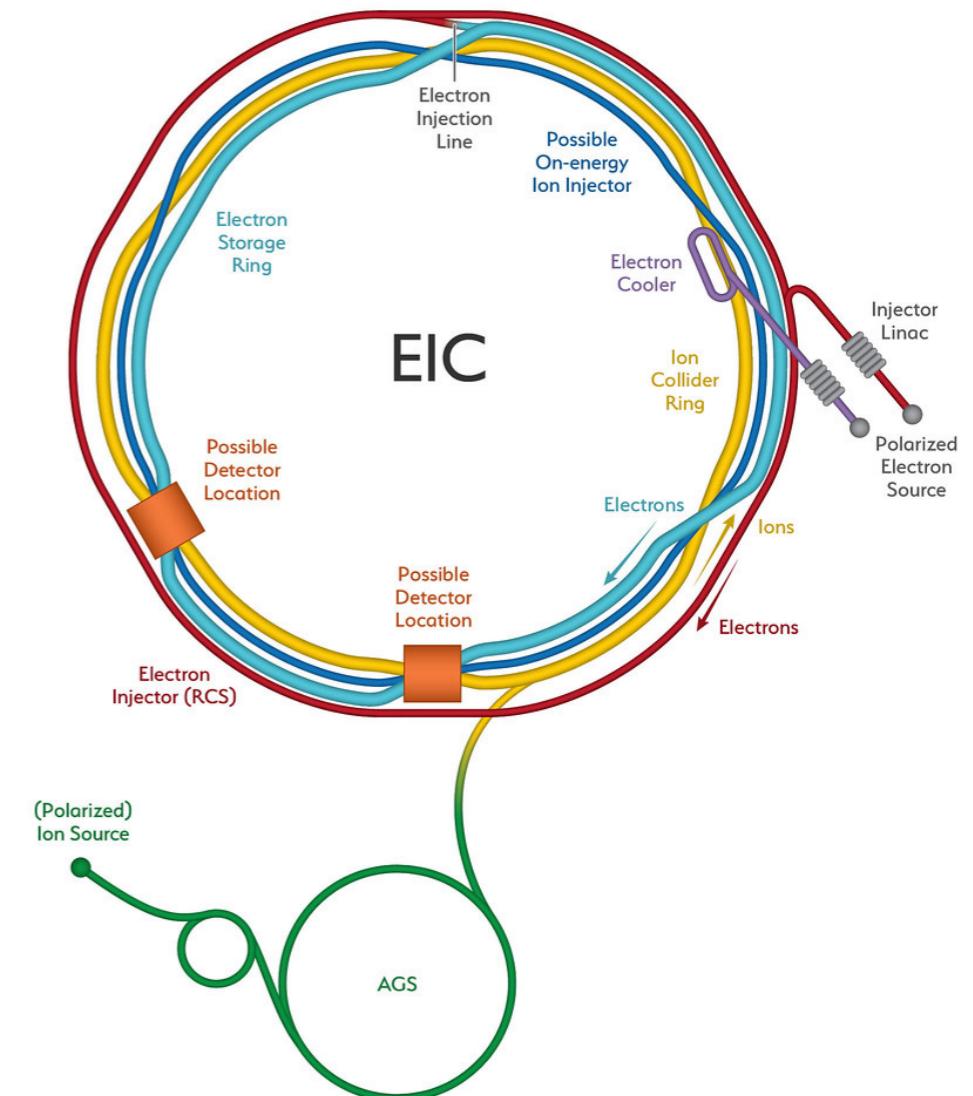
$$E(e^-) = 12 \rightarrow 22 \text{ GeV}$$



$$\sqrt{s} = 1.5 - 6.5 \text{ GeV}$$

$$\mathcal{L} = 10^{35} - 10^{39} \text{ cm}^{-2}\text{s}^{-1}$$

Electron Ion Collider (EIC)



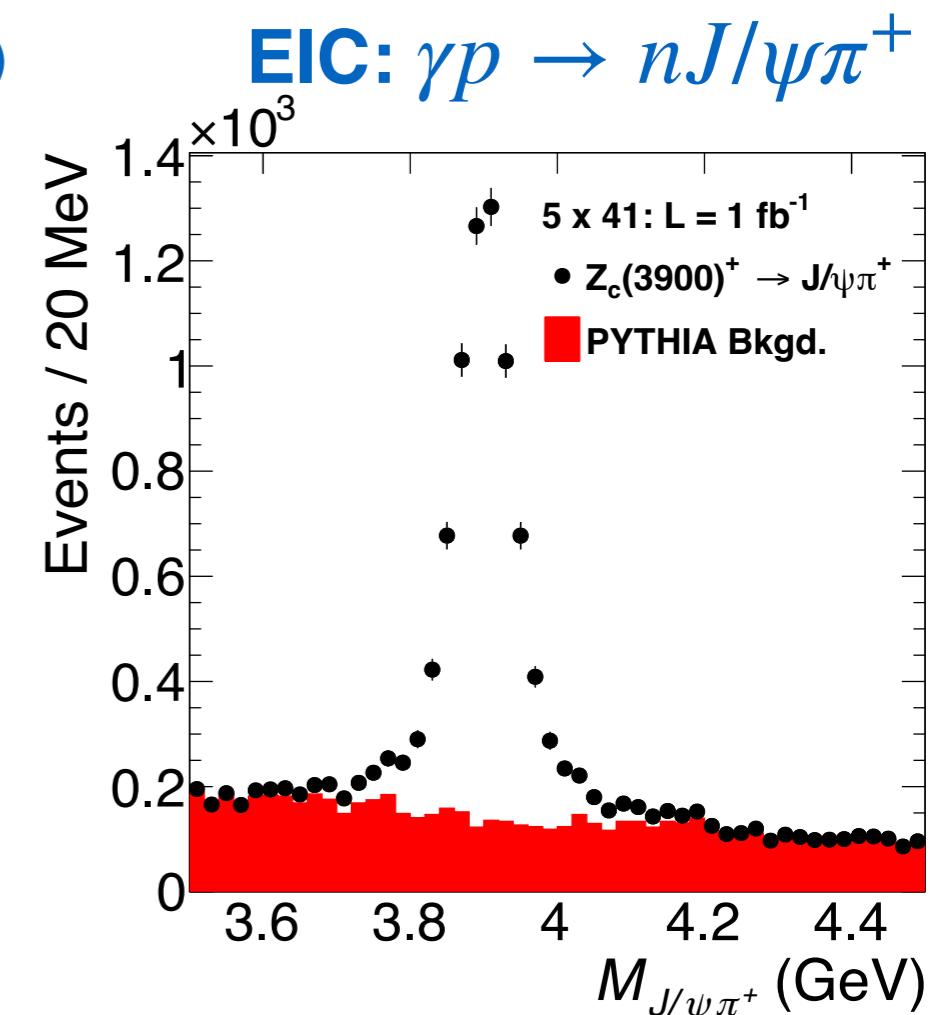
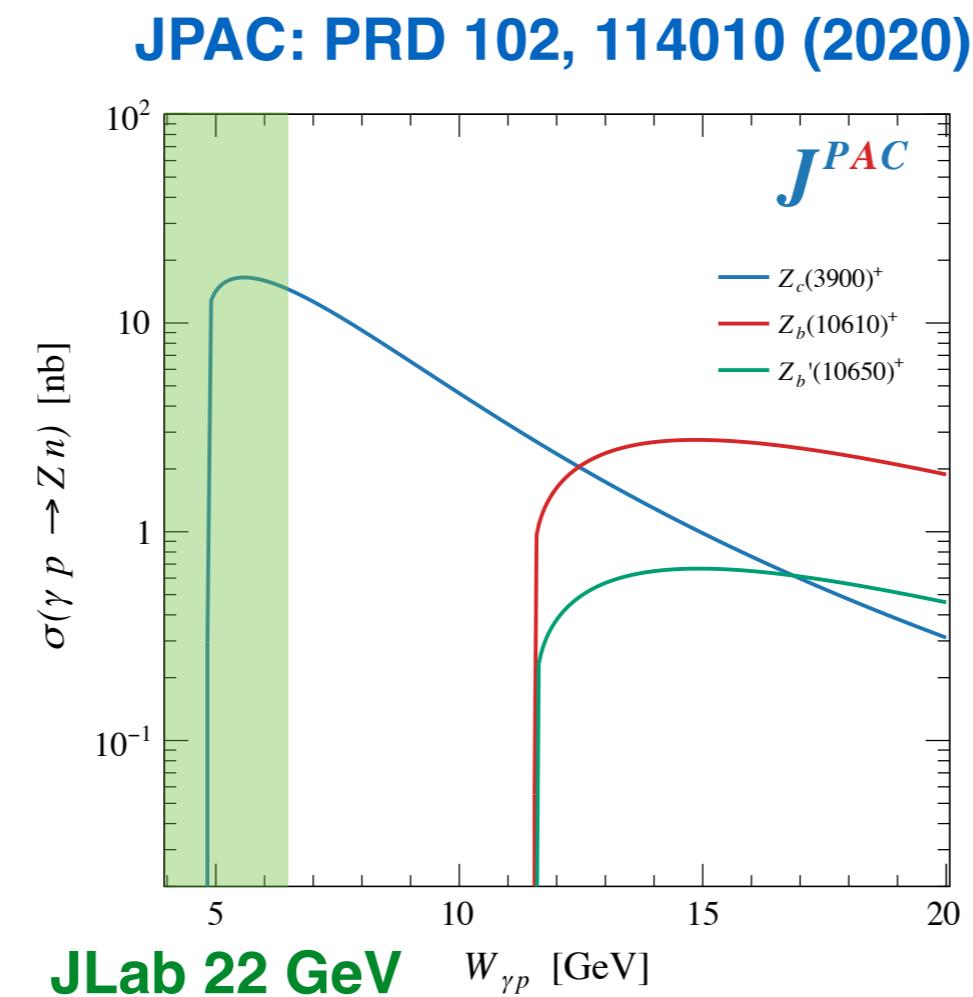
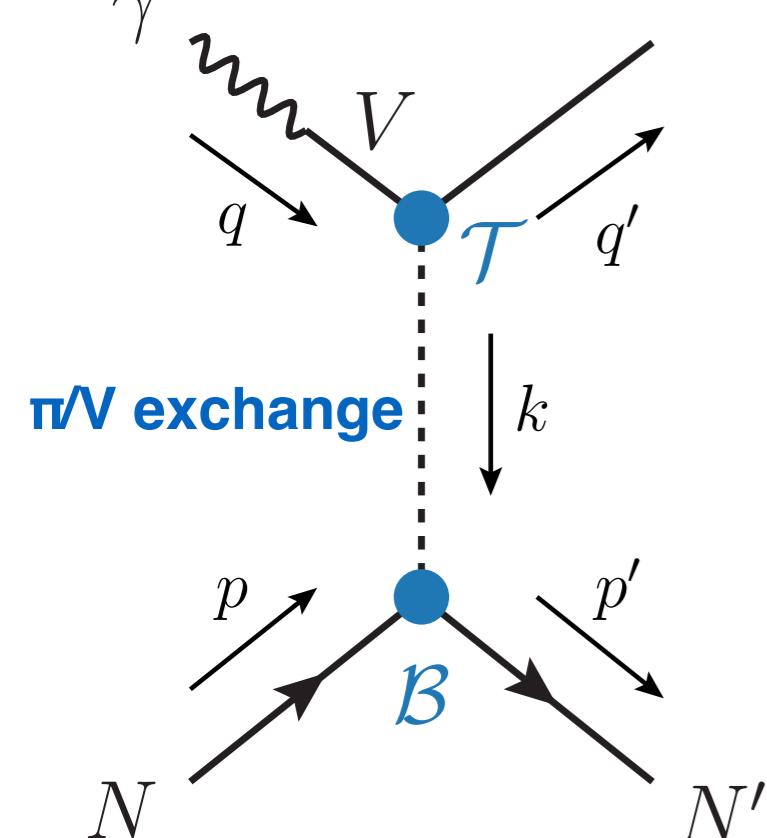
$$\sqrt{s} = 5 - 141 \text{ GeV}$$

$$\mathcal{L} = 10^{34} \text{ cm}^{-2}\text{s}^{-1}$$

Predictions for XYZ Photoproduction

JPAC

$$Z_{c,b} \rightarrow \pi(\psi, \Upsilon)$$



- Charged Z_c has clean signal, expected to peak near threshold
- EIC: Substantial Z_b cross section, other heavy exotics
- Detector collaboration working to complete technical design this year

Summary and Prospects

- Understanding the nature(s) of the many unexpected hadrons that have been observed in recent decades requires high precision data across many reactions
 - Collaboration between theory and experiment is required
 - Also crosses the HEP / NP communities
 - Measurement of exotic states in photoproduction is a crucial part of the picture
- US-based experiments are leading this photoproduction effort
 - GlueX: Light-quark spectroscopy and charmonium near threshold (s -channel P_c)
 - JLab energy upgrade: near-threshold $X(Y)Z$ spectroscopy
 - EIC: exotic spectroscopy, in-medium effects
- White Paper: <https://inspirehep.net/literature/2053492> [arxiv:2203.08290]