

Quarkonia and Gluonic Excitations at GlueX



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On behalf of the GlueX
Collaboration

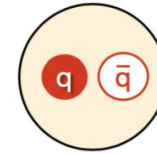


Overview

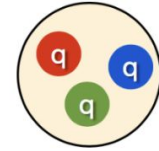
- ❖ Hadron Spectroscopy
- ❖ GlueX experiment
- ❖ Understanding production mechanisms
- ❖ Near threshold J/ψ photoproduction + theoretical developments

Hadron Spectroscopy

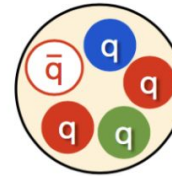
- ❖ How does QCD relate to the confinement of hadrons?
 - Millennium Prize ~ \$1M prize
- ❖ Experimentally map the spectrum of hadrons
- ❖ How does gluonic degrees of freedom contribute to this spectrum?
- ❖ Properties of predicted states beyond mesons and baryons?



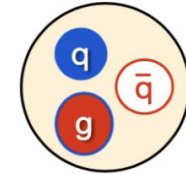
mesons



baryons



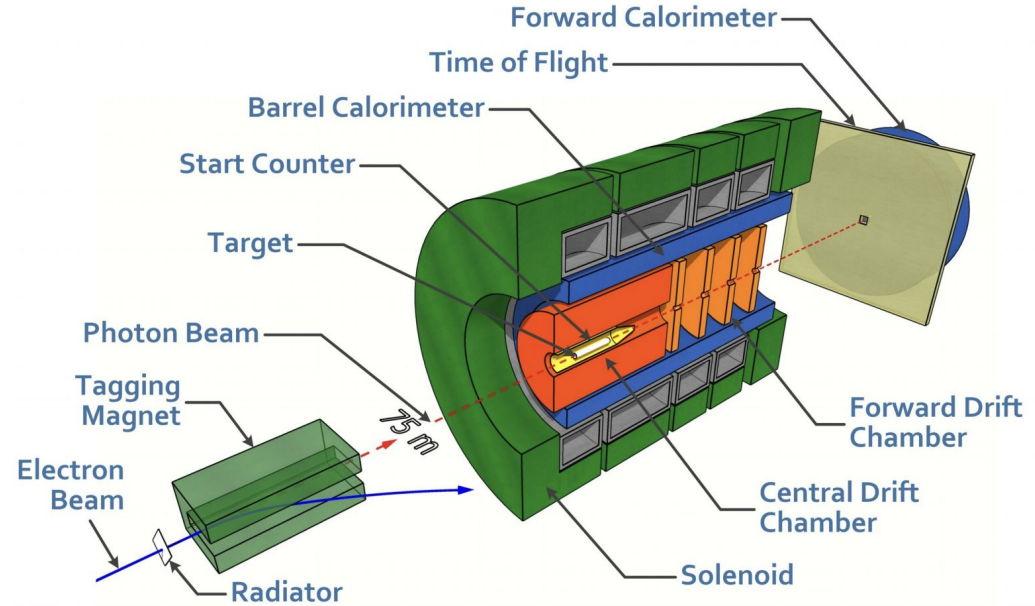
pentaquark



"hybrid" meson

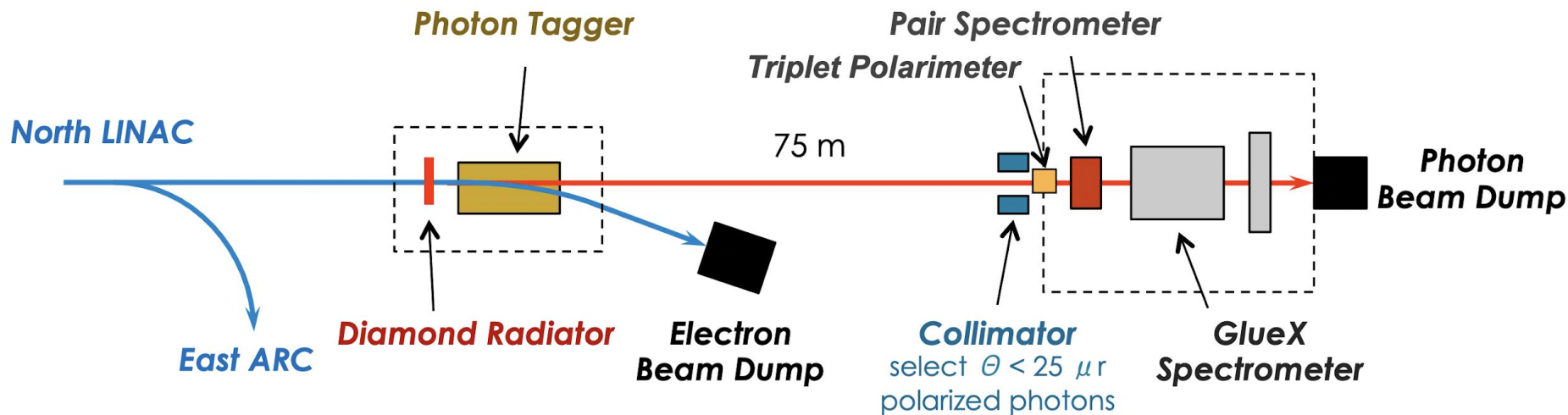
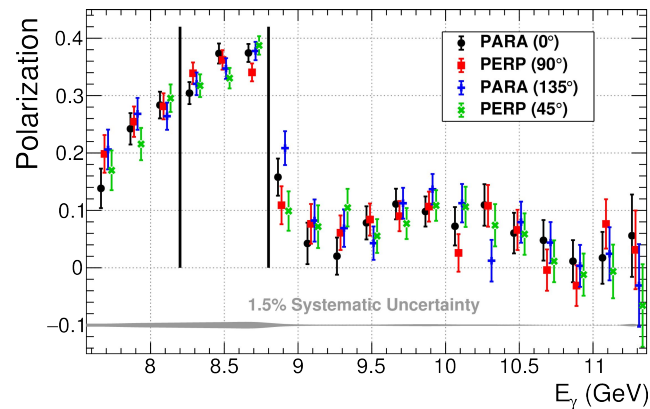
GlueX

- ❖ Photoproduction by coherent bremsstrahlung
- ❖ Full acceptance and reconstructs all final state particles
- ❖ GlueX phase 1: Integrated Luminosity: 118.2 pb^{-1}
8.2-8.8 GeV
- ❖ Primary Goal: study confinement by mapping the spectrum of hybrid and exotic mesons



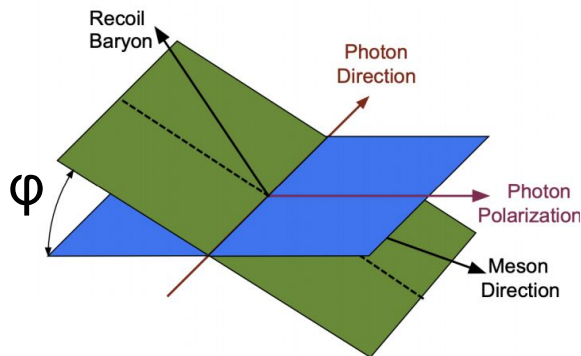
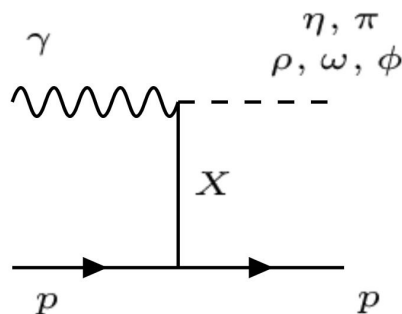
Photon Beamline

Linearly polarized
photon beam!
Data taken in 2 pairs of
orthogonal orientations
~40% Polarization in
coherent peak

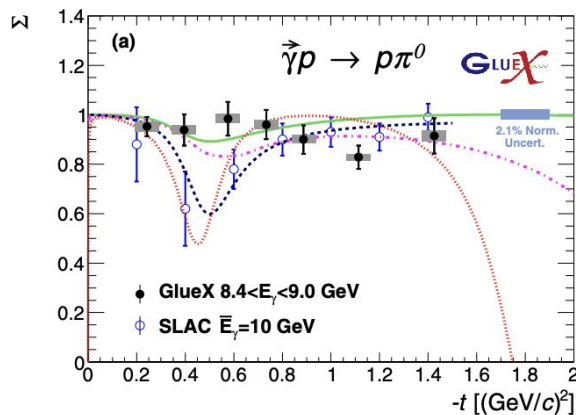


Production Mechanisms

- ❖ $\sim O(10^4)$ times more data than previous experiments (i.e. SLAC)
- ❖ Physical observables accessible by using beam polarization
 - Beam Asymmetry Σ
 - 4 publications more in progress
 - Spin Density Matrix Elements
 - Measurement of ρ, ω, ϕ SDMEs publication soon
- ❖ Gives a handle on the naturality of the exchange
 - Input to hybrid searches



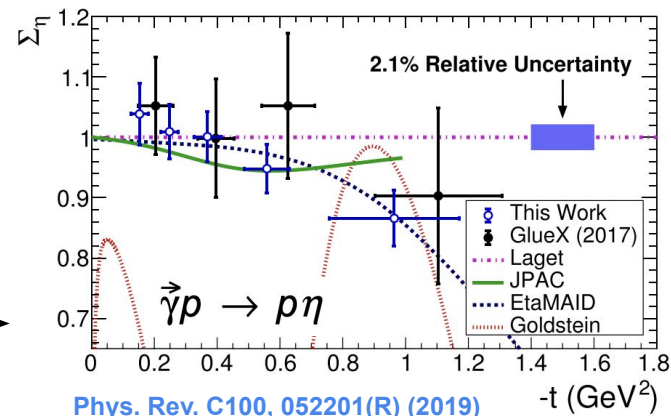
$$\frac{Y_{\perp}(\phi) - F_R Y_{\parallel}(\phi)}{Y_{\perp}(\phi) + F_R Y_{\parallel}(\phi)} = \frac{(P_{\perp} + P_{\parallel})\Sigma \cos 2(\phi - \phi_0)}{2 + (P_{\perp} - P_{\parallel})\Sigma \cos 2(\phi - \phi_0)}$$



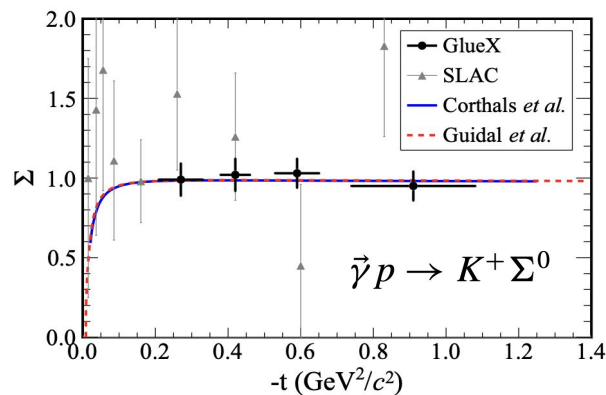
Phys. Rev. C95, 042201(R), (2017)

Beam Asymmetry
 $\Sigma \sim (-)1$: (un)natural
 exchange dominated

vector exchange
 dominated



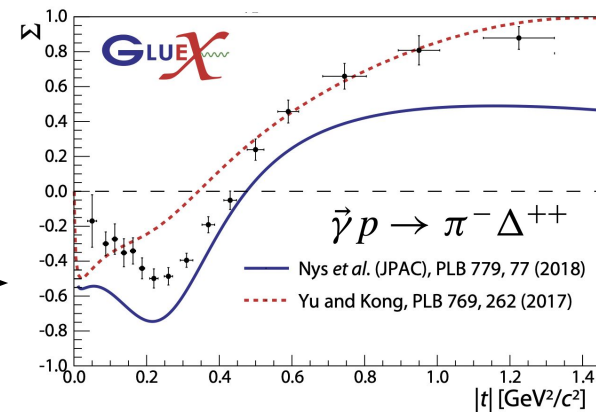
Phys. Rev. C100, 052201(R) (2019)



Phys. Rev. C 101, 065206 (2021)

← Exchange of strangeness

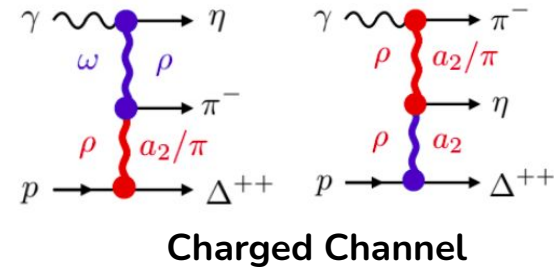
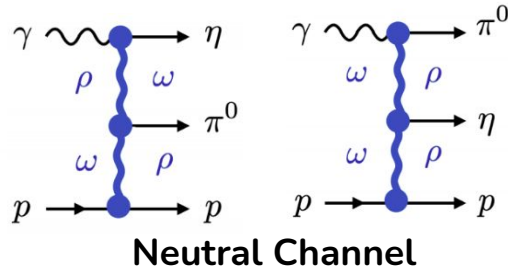
Charge exchange
 pion exchange dominated low $|t|$



Phys. Rev. C 103, L022201 (2020)

Deck Process

- ❖ Strong evidence for exotic hybrid meson in the $\eta\pi$ channel seen by previous experiments (i.e. COMPASS, CBAR), π_1
 - asymmetry in the production between η/π at the top vertex can mimics exotic signal

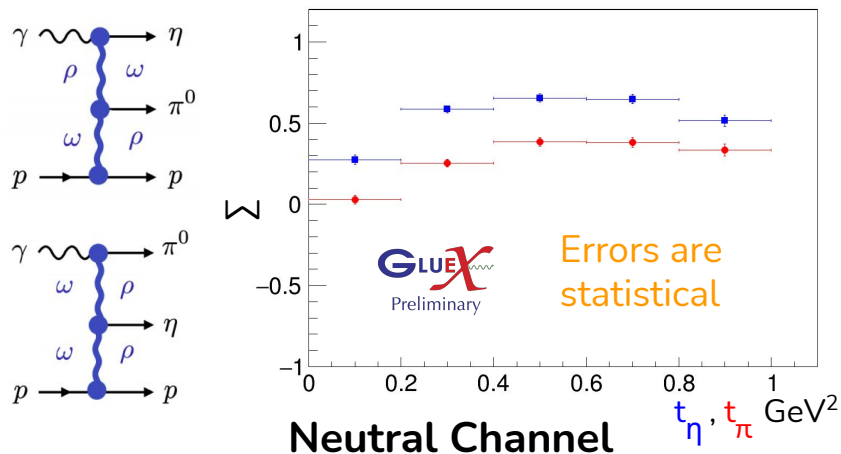


- ❖ Develop double Regge exchange model in collaboration with Joint Physics Analysis Center (JPAC)
- ❖ Measure Σ at the top vertex compare with predictions

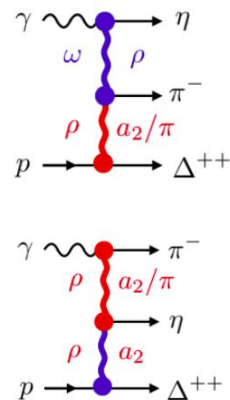
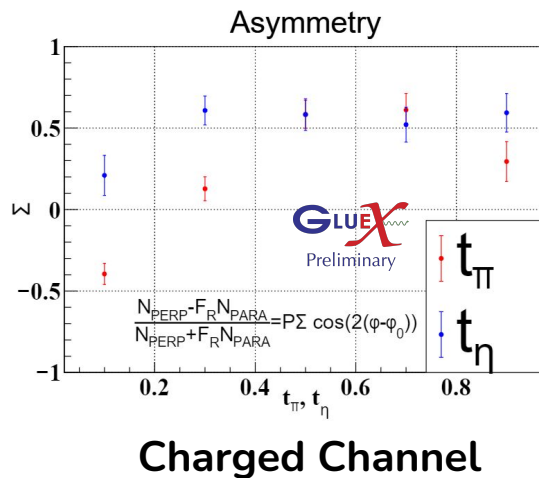
$$\Sigma(t_{\eta/\pi})$$

$$t_{\eta} = (p_{\gamma} - p_{\eta})^2$$

All GlueX Phase 1



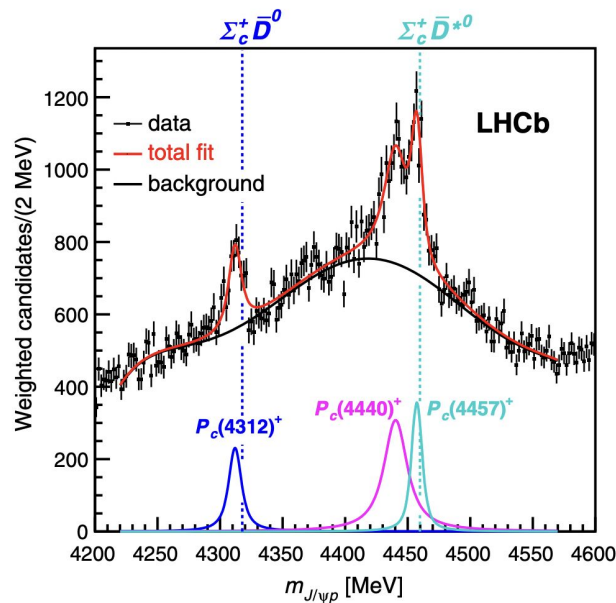
20% GlueX Phase 1



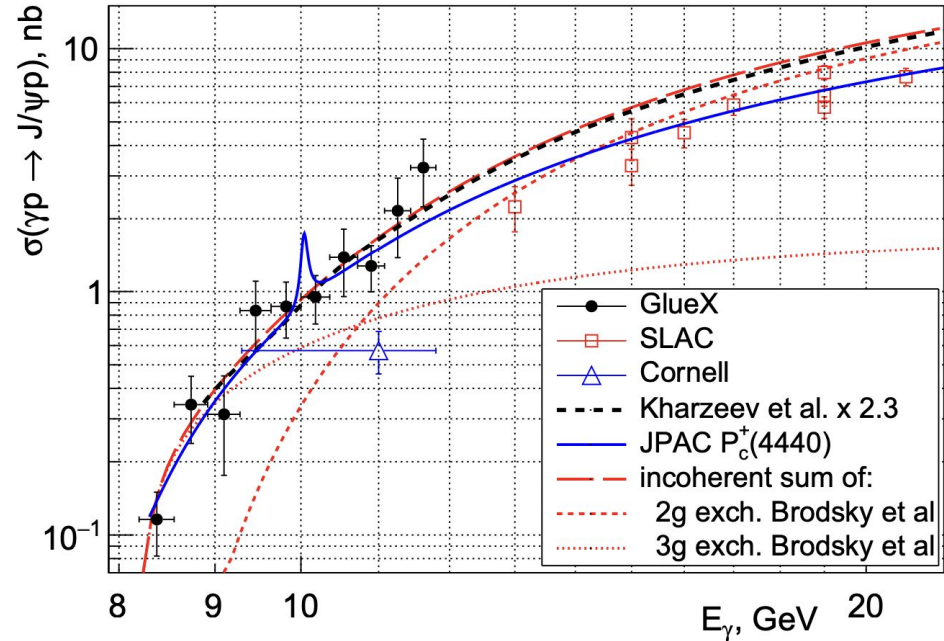
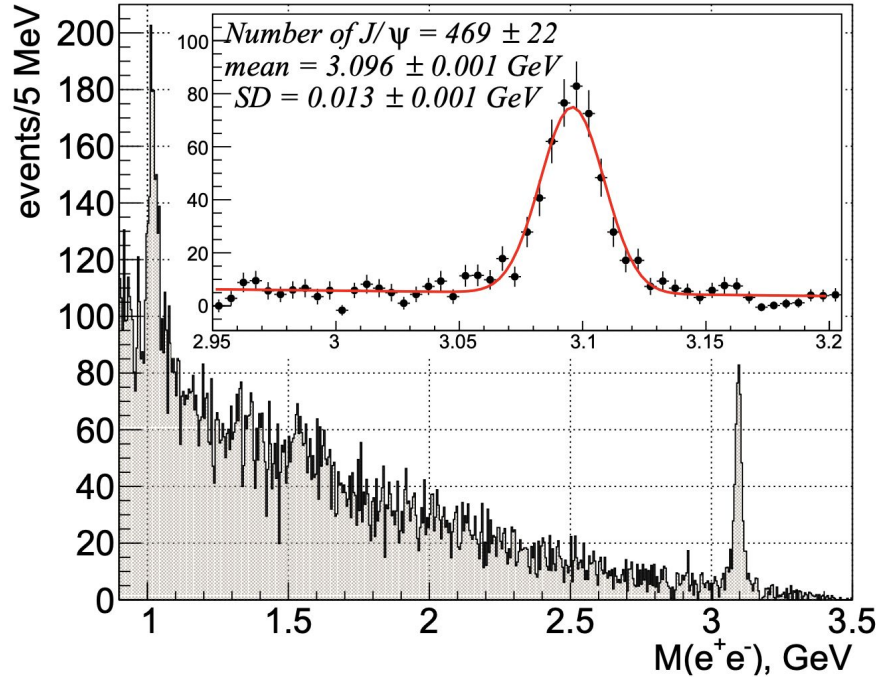
- $\Sigma(t_{\eta})$ is consistent between charged and neutral channels
- Similarities between Σ for charged pion and Σ measured in $\gamma p \rightarrow \pi^- \Delta^{++}$
 - Pion exchange dominated at low t
- Comparison with JPAC model underway

Near threshold J/ψ photoproduction

- ❖ If there are no rescattering effects LHCb pentaquark should be seen in s-channel photoproduction
- ❖ Near threshold
 - all valence quarks should participate
 - trace anomaly - fraction of nucleon mass from gluons

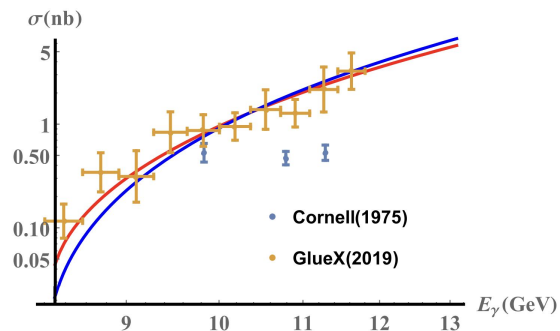


R. Aaij et al., PRL 122, 222001 (2019)



- ❖ First measurement of J/ψ photoproduction cross section near threshold
- ❖ Set model-dependent upper limits on branching fractions of LHCb P_c^+ states
- ❖ Expect 5x data with GlueX phase 1

Trace anomaly parameter



Hints of a small (red) $b=0$
 b parameter (blue) $b=1$

Phys. Rev. D 100, 014032 (Oct 2018)

VMD model $\rightarrow b = 0.07 \pm 0.17$

Eur. Phys. J. C 80, 507 (June 2020)

Open-Charm Channel

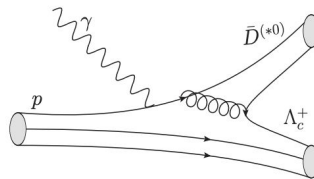
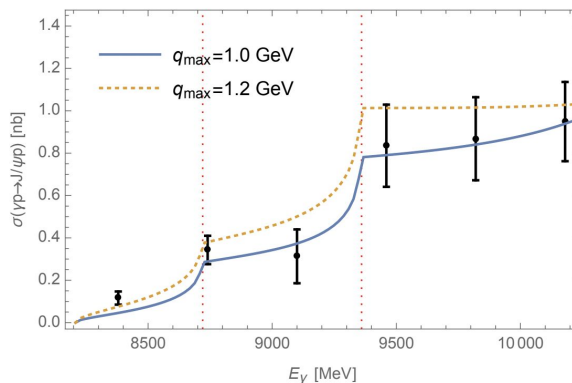


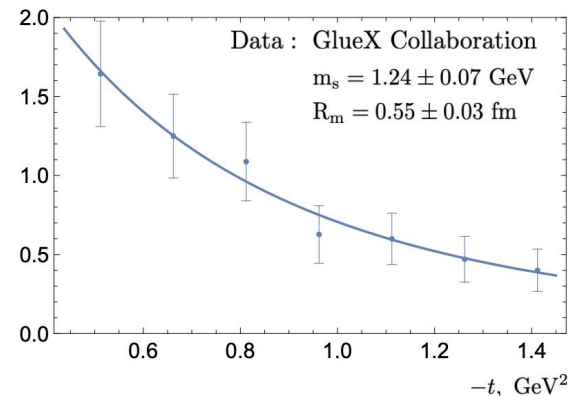
FIG. 2. Mechanism for the near-threshold J/ψ photoproduction through $\Lambda_c \bar{D}^{(*)}$ which then rescatter into $J/\psi p$.



Eur. Phys. J. C 80, 1053 (Nov 2020)

Mass Radius of Proton

$$\frac{d\sigma}{d(-t)}, \frac{\text{nb}}{\text{GeV}^2}$$



arXiv:2102.00110 (Jan 2021)

Charge radius $\sim 0.8409 \pm 0.0004$ fm

More statistics near threshold
 will lower systematics

Looking Forward

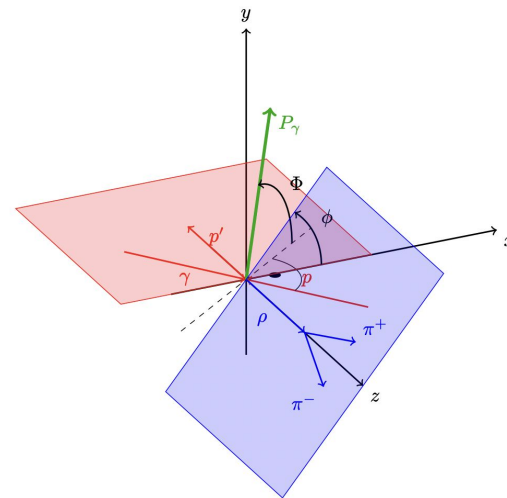
- ❖ Understanding how QCD gives rise to the properties of hadrons
 - Spectroscopy
 - Cross section measurements
- ❖ GlueX - high statistics photoproduction with polarized beam
 - Polarized beam -> Information on production mechanism
 - Access to charm physics near threshold
 - Interesting physics with current measurements
 - 5x data with GlueX phase 1 is under analysis

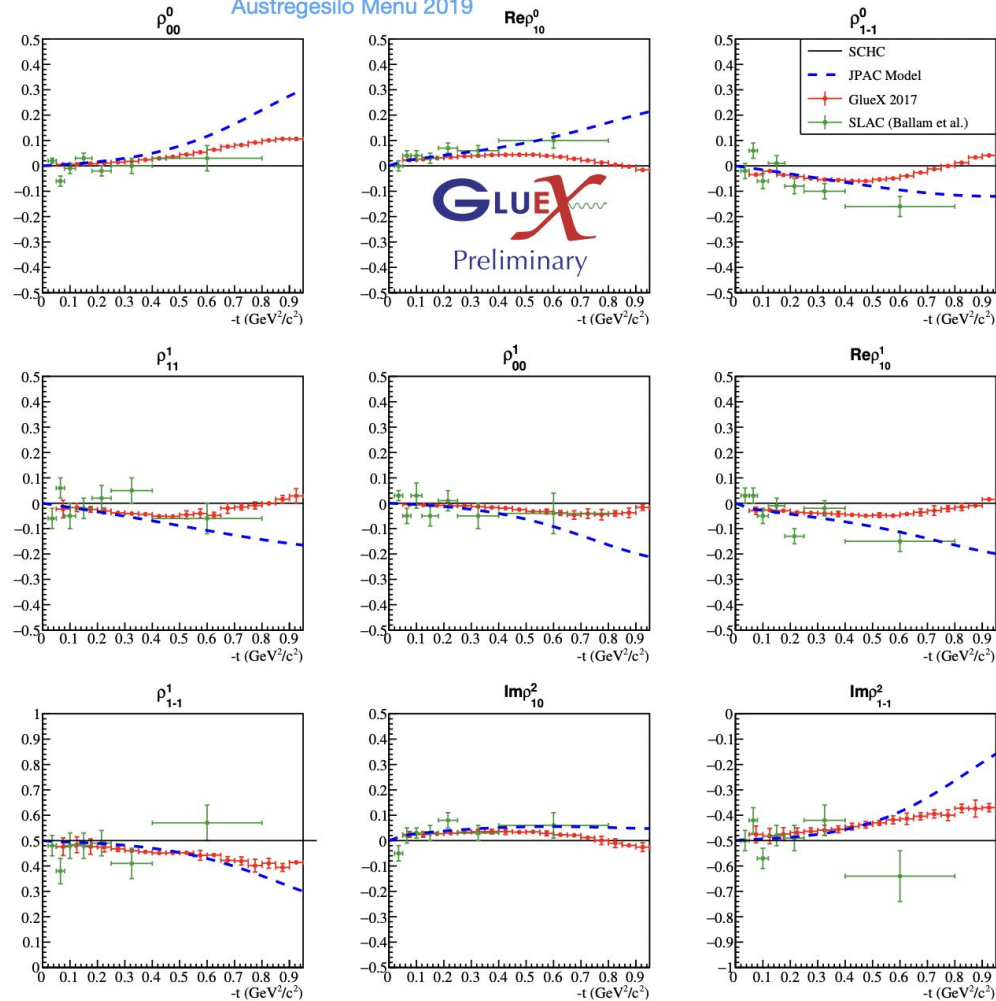
Backup

Spin density matrix elements

- ❖ Fully describes angular distributions of vector meson production and decay
- ❖ Linear polarization gives access to 9 SDME
- ❖ Test of machinery: same tools to extract signals of exotic hybrid mesons
- ❖ Limited photoproduction data

	SLAC	GlueX 1
$\gamma p \rightarrow \rho p$	~ 3.5 k events	~ 200 M events
$\gamma p \rightarrow \omega p$	~ 1.0 k events	~ 25 M events
$\gamma p \rightarrow \phi p$	~ 150 events	~ 1.8 M events
		$\omega \rightarrow \pi^+ \pi^- \pi^0$
		$\phi \rightarrow K^+ K^-$





Preliminary ρ SDME

Parity Asymmetry

$$P_\sigma = \frac{\sigma^N - \sigma^U}{\sigma^N + \sigma^U} = 2\rho_{1-1}^1 - \rho_{00}^1$$

GlueX 2017 ~ 17% of phase 1
Expect high statistical precision

