The GlueX Experiment: Recent Results and Future Plans

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The GlueX experiment, located in experimental Hall D of Jefferson Lab, seeks to map the spectrum of light mesons in search of exotic hybrid mesons, a predicted class of states with explicit gluonic degrees of freedom. GlueX is a photoproduction experiment utilizing a real photon beam with a high degree of linear polarization at E_γ = 8-9 GeV and a large acceptance spectrometer. The experiment has already collected orders of magnitude more data than previous experiments at similar energies. This article discusses recent results of the GlueX experiment, such the production of pseudoscalars mesons. These refine the understanding of production mechanisms in photoproduction at these energies. Its energy coverage also allows for studies of threshold J/ψ photoproduction, allowing for an understanding of heavy quark photoproduction and the ability to probe s-channel production of pentaquark candidate $P_C(4450)$.

KEYWORDS: photoproduction, light meson, spectroscopy, asymmetry, GlueX, Jefferson Lab

1. Introduction

GlueX is a real photoproduction beam experiment located at Thomas Jefferson Laboratory in Newport News, Virginia. Its primary goal is to further the understanding of light mesonic states and seek the detection of so-called exotic hybrid mesons. Such states are characterized by quantum numbers J^{PC} that cannot be explained using the simplest quark-antiquark description, a clear indication of additional quark or valence gluonic components . Although many of these states may be expected from lattice computations of quantum chromodynamics, experimental evidence for exotic J^{PC} states in the light meson sector remains sparse [1] [2]. Utilizing an approximately 8.5 GeV polarized photon beam, high acceptance and statistics, states up to about 3 GeV/c^2 can be probed with sensitivity using the GlueX spectrometer.

A major focus of present studies at GlueX is in understanding exchange mechanisms of photoproduction. Here, we focus on the production of various pseudoscalars and the J/ψ meson in order to further our knowledge of production mechanisms at beam energies $E_\gamma \cong 8.5$ GeV.

2. Experimental Apparatus

The GlueX experiment requires a large flux of high energy polarized photons, high acceptance of charged and neutral states, and high rate of data readout. We briefly describe highlight key components of the GlueX spectrometer here.

The GlueX experiment utilizes a secondary beam of photons produced through the coherent Bremsstrahlung process with 11.6 GeV electrons from the Jefferson Laboratory Accelerator Facility on a diamond radiator. Beam energy is tagged from outgoing electrons in a hodoscope and polarization measured via triplet production in the triplet polarimeter. This photon beam is incident on a liquid hydrogen target. Outgoing charged particles are measured in forward and central drift chambers

housed in a 2.2 T superconducting solenoid magnet. Neutral particles are measured in forward and barrel calorimeters. A time-of-flight counter provides particle identification capability, with a DIRC (Detection of Internally Reflected Cherenkov light) detector to be installed in early 2019, which will provide pion/kaon separation of at least 3σ for momenta up to 4 GeV/c. An excess of 150 pb^{-1} of data was collected as of December 2018.

These components allow for the reconstruction of nearly all hadronic final states with a wide acceptance of approximately 1-120° in laboratory θ.

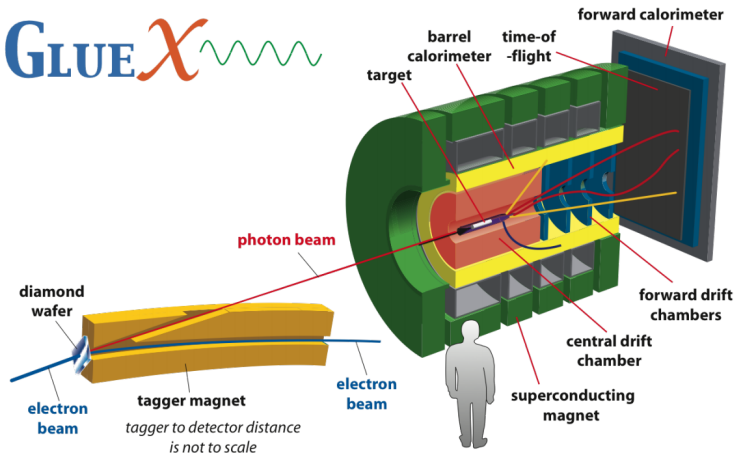

Fig. 1. A sketch of the GlueX detector located at Jefferson Laboratory.

3. Early GlueX Analysis

3.1 Pseudoscalar Beam Asymmetries

Beam asymmetries allow for an understanding of underlying Regge exchanges contributing the production of a single pseudoscalar, encoded in a single physics parameter Σ. With a linearly polarized photon beam, the photoproduction cross section can be expressed at $\sigma_{pol} = \sigma_{unpol}\left[1 - P_\gamma \Sigma cos(2\phi)\right]$. Here, P_γ is the beam polarization, σ_{unpol} is an unpolarized cross section, and Σ is the physics parameter to be measured. The quantity Σ is a measure of the *naturality* of exchange reggeons (defined as $N \equiv P(-1)^J$). Measuring $\Sigma = +1$ would indicate pure natural exchanges in a pseudoscalar's production, whereas measuring $\Sigma = -1$ would indicate purely unnatural exchanges. The quantity may depend on mandelstam t and can be compared to theory model predictions.

Measurements of the production of single π^0, η, and η' pseudoscalars with recoil proton, as well as the production of a π^- meson with recoiling Δ^{++} are given here. Results for π^0 and η mesons have been published ([3]), and results for η' and $\pi^-\Delta^{++}$ production are expected for publication in 2019.

It is observed that in the chargeless exchange processes studied, states are produced predominantly via natural exchange partners with little significant t dependence. In contrast, the charge-exchange production of a $\pi^-\Delta^{++}$ system constrains exchanges to have non-zero isospin and indicates the contribution of both natural and unnatural exchanges, with significant t dependence. These measurements will serve inform future amplitude analyses in GlueX data. Additional work in studying the asymmetry of production for $a_0(980)p$, $K^+\Sigma^0$, and $K^+\Lambda(1520)$ states, along with cross sections for single pseudoscalar production will further improve the understanding of production mechanisms in the future.

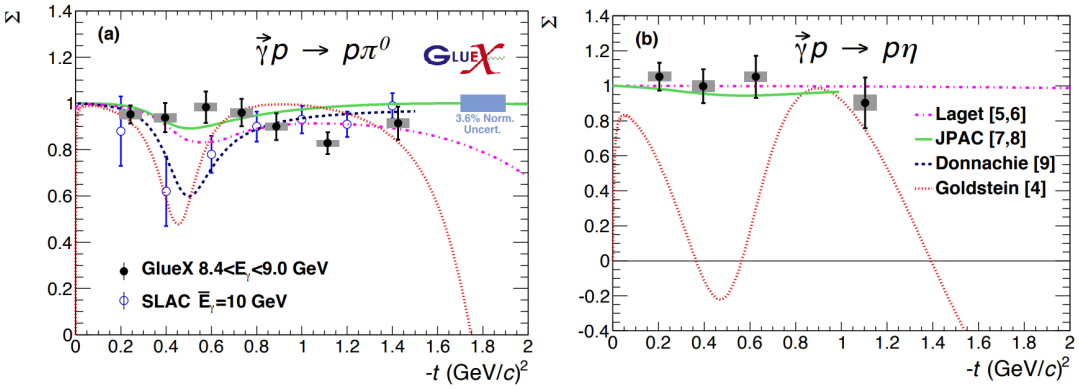

Fig. 2. Asymmetry measurements for the production of π^0 and η mesons decaying to two photons measured as a function of t. Colored curves indicate various theory models with more information available at [3].

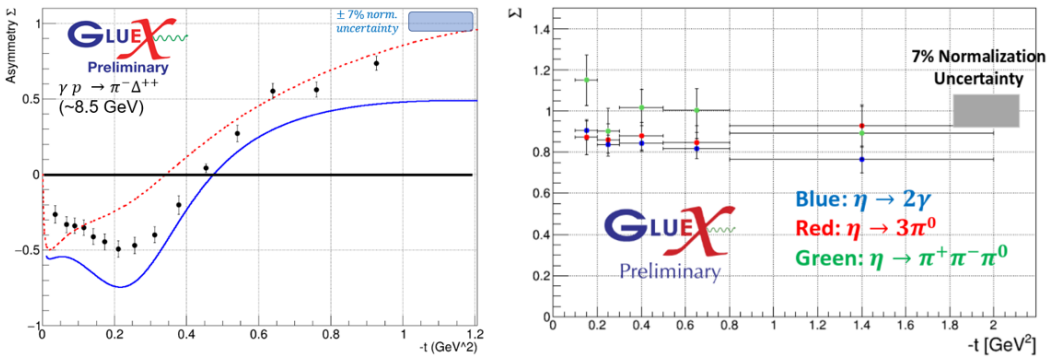

Fig. 3. Asymmetry measurements for the production of $\pi^-\Delta^{++}$ and η' states. Colored curves on left plot indicate theory models [4] [5]. Error bars shown indicate statistical uncertainties only.

3.2 Threshold J/ψ Production

Photoproduction of the J/ψ meson near threshold energy is also observed at GlueX, where previous data is very limited. Studies of the cross section as a function of incoming photon beam energy allows insight into the production of heavy quark states, which may be explained via either two-gluon or three-gluon exchanges [6]. Additionally, photoproduced J/ψ mesons allow for direct searches for pentaquark candidate states reported by the LHCb experiment [7], which may appear as an enhancement in the J/ψ cross section at its threshold for production [8]. More information can be found in accompanying conference proceedings from GlueX collaborator Lubomir Pentchev.

4. Conclusion

GlueX is a unique experiment in the worldwide search for new states of hadronic matter, in large part due to its linearly polarized beam. We have summarized current results investigating the exchange mechanisms at play in photoproduction at GlueX energies. Pseudoscalar asymmetry measurements in both chargeless and charge exchange reactions have begun to give an understanding of exchange mechanisms at play in photoproduction. These will be expanded in the future with asymmetry measurements in additional systems, analogous measurements of vector meson spin-density matrix elements, and cross section measurements. Additionally, we see a significant sample of J/ψ

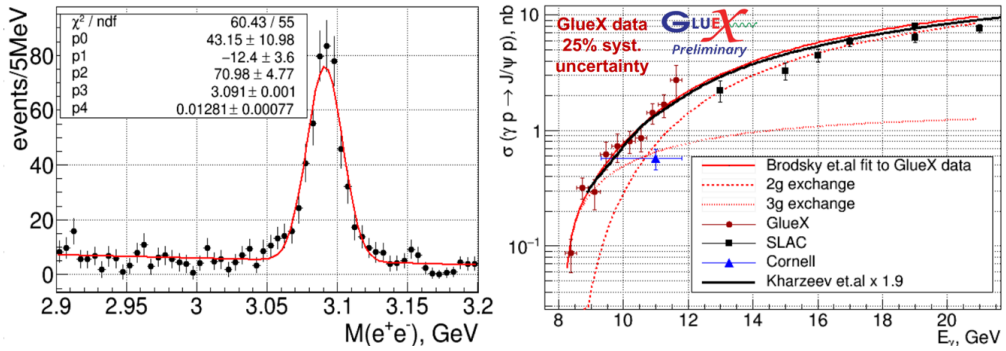

Fig. 4. A plot of the e^+e^- spectrum at GlueX in the narrow region around the J/ψ mass (left) and preliminary results for the cross section of production for J/ψ photoproduction as a function of energy (right). Measurements from SLAC and Cornell experiments and theoretical models are also given in the right plot.

events that enable us to study heavy quark threshold photoproduction and will allow us to observe or set limits on photocouplings for reported pentaquark candidate state $P_c(4450)$.

We have collected a few times more data than presented here and continue investigations in search of new and potentially exotic light meson states.

Acknowledgements

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