The GlueX Experiment at Jefferson Lab

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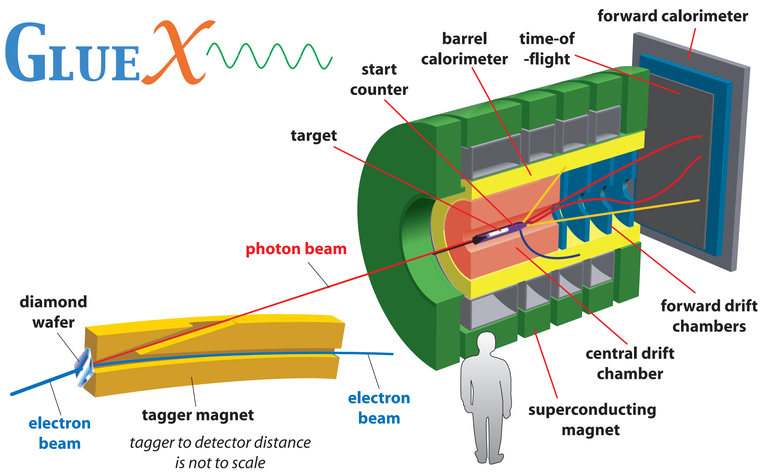
Overview

The GlueX Experiment is the flagship experiment of the newly-constructed Hall D at the Thomas Jefferson National Accelerator Facility (JLab), a world-leading nuclear physics research facility funded by the U.S. Department of Energy's Office of Science, located in Newport News, VA. The GlueX Collaboration consists of over 120 members from 24 institutions, with more joining.

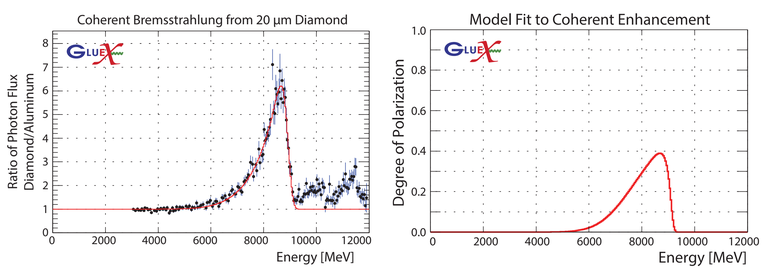
The primary goal of GlueX is to advance the quantitative understanding of confinement in Quantum Chromodynamics (QCD). In particular, a deeper understanding of the soft gluon field responsible for confinement is needed. "Hybrid" mesons, those with explicit gluonic degrees of freedom, are ideal states for studying these gluonic fields, and we aim to firmly establish these states and to map out their spectrum.

The large, precise data set that will be collected can also be used to make measurements of strangeonia and other light meson states, strange-quark-containing baryons, and charm production near threshold.

The Experiment



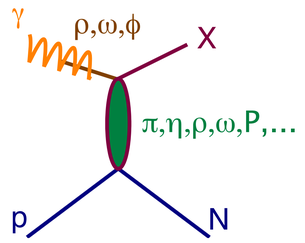
The GlueX detector measures photoproduction events generated by a photon beam incident on a 30 cm long liquid hydrogen target. The photon beam is generated by a 12 GeV electron beam incident on a diamond radiator, which generates a linearly-polarized beam of photons with 9 GeV peak energy via coherent bremsstrahlung. The scattered electrons are measured in the tagger spectrometer to "tag" the photon energies. The Pair Spectrometer and Triplet Polarimeter monitor the photon flux and polarization using well-known QED processes. The degree of linear polarization in the peak energy range has been measured to be ~40%, as shown below.



The main detector consists of a 2T solenoid magnet with the Central and Forward Drift Chamber (CDC & FDC) for charged particle, a lead/scintillating fiber Barrel Calorimeter (BCAL) and lead-glass Forward Calorimeter (FCAL) for neutral particle detection, and a Start Counter (SC) and forward Time-of-Flight wall (TOF) for precision timing measurements. A Cherenkov detector for enhanced particle identification using components from the BaBar DIRC is expected to be installed for running in 2018/19.

Physics Goals

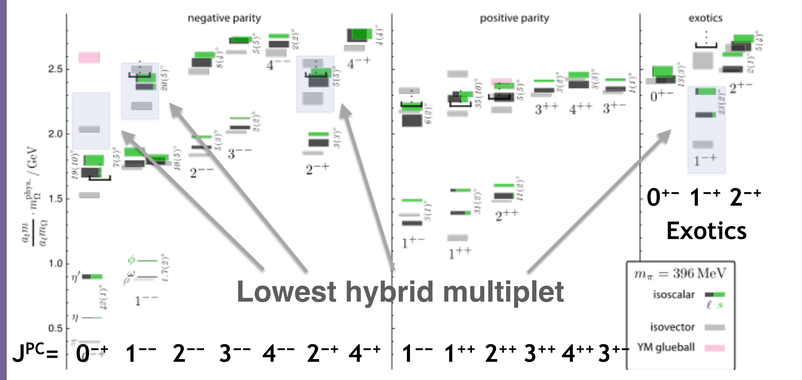
QCD describes the interaction of quarks and gluons, and predicts the spectrum of $q\bar{q}$ mesons and qqq baryons. There should also be "hybrid" mesons where the gluons contributes directly to the spin-parity of the state. These hybrids can be identified by having J^{PC} values not accessible to normal $q\bar{q}$ mesons.



Photoproduction of mesons

The first measurements in GlueX will be of polarization and beam asymmetry measurements of pseudoscalar and vector mesons, leading to spin-density matrix element analyses to understand the production mechanisms involved. Cross section measurements will then be made, followed by amplitude analyses of known mesons and searches for exotic mesons. Full understanding of this data will require close collaboration with theorists.

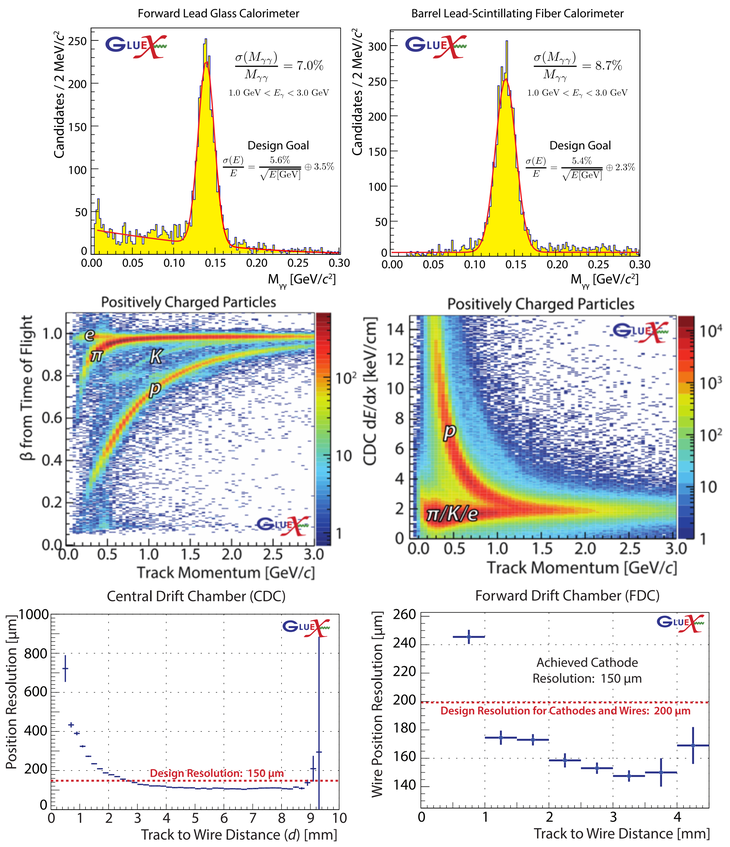
Light-quark (u,d,s) meson spectrum from LQCD [PRD 82, 111502]



Detector Performance

Data for detector commissioning was taken in the Spring of 2015 and 2016. All detector components have been calibrated to near or beyond design parameters. Their performance is illustrated in the following:

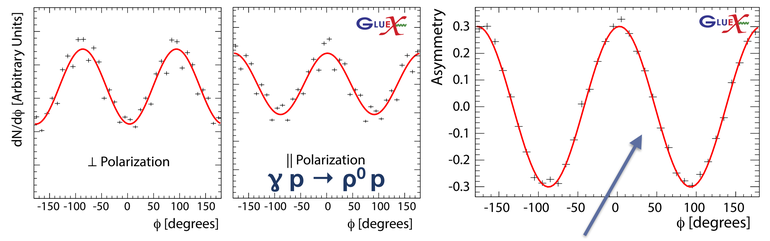
- Top row: Calorimeter π^0 peaks
- Middle row: Particle ID from (left) TOF and (right) CDC Ionization
- Bottom row: Drift chamber resolutions



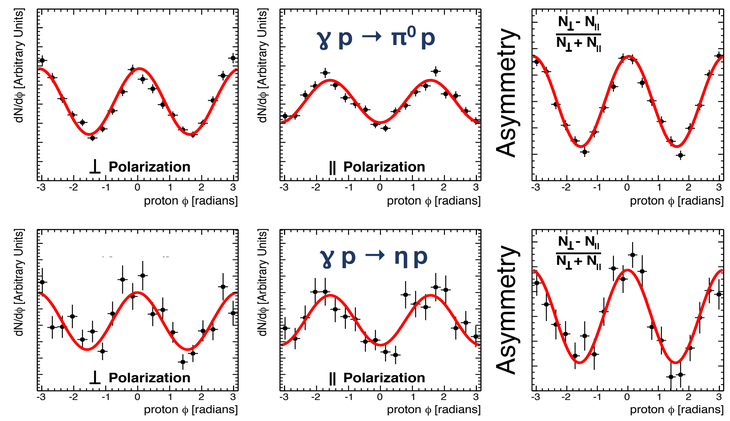
Early Asymmetry Measurements

The beam asymmetry Σ gives insight into the production mechanism of a given reaction. With a subset of the data taken in Spring 2016, we have measured the experimental asymmetry for γ p → ρ^0 p, $\rho^0 \to \pi^+\pi^-$ with more than 1000 times the events measured in the old SLAC bubble chamber experiments at E_γ ~ 9 GeV. We have also performed similar measurements in γp → π^0 p ($\pi^0 \to \gamma\gamma$) and γp → η p (η → γγ), which will be used to test theoretical models. The beam polarization (P) measurements needed to extract Σ are still being finalized.

$$d\sigma_\perp \propto 1 - P_\perp \Sigma \cos 2\phi \qquad d\sigma_\parallel \propto 1 + P_\parallel \Sigma \cos 2\phi \qquad P\Sigma \cos 2\phi = \frac{N_\parallel - N_\perp}{N_\parallel + N_\perp}$$



γ p → ρ^0 p shows large polarization transfer to ρ meson

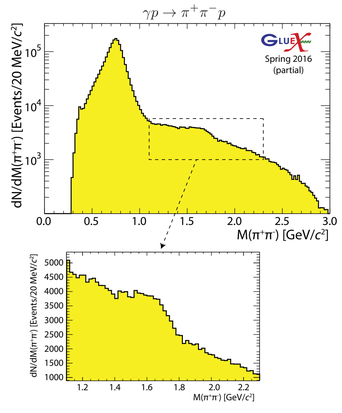


Other Early Searches

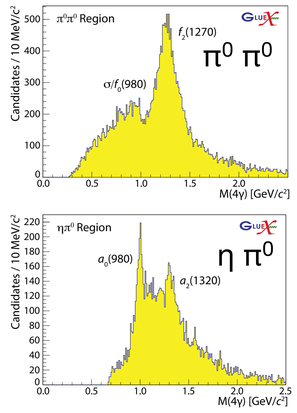
We expect that this data will yield many other spectroscopic results. Two examples under analysis are:

- We see a peak at ~1.6 GeV in the $\pi^+\pi^-$ mass spectrum of γ p → $\pi^+\pi^-$ p, confirming SLAC's observation in this reaction.
- In γ p → 4γ p, we see several states decaying to $\pi^0\pi^0$ and η π^0.

γ p → $\pi^+\pi^-$ p



γ p → γ γ γ γ p



Outlook

The GlueX experiment has been successfully commissioned and is ready for the start of its first physics run in Fall 2016. Initial physics results are being prepared. The addition of improved kaon identification and higher luminosity in 2018 will allow a full exploration of the light quark meson sector. Other planned GlueX measurements include the eta lifetime, charged pion polarizability, and rare eta decays, and charm-quark containing hadrons.