First Results of GlueX

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The GlueX Collaboration


Over 100 collaborators from 22 institutions. Others planning to join over the next 6 months and more are welcome.
Outline

- The GlueX Experiment and the Photon Beam.
- The physics program in GlueX
- Performance of GlueX during Commissioning.
- Initial Physics from GlueX
- Future Plans
- Summary
The GlueX Experiment

Physics in 2016

Photo Production of Hybrids, Light-quark Mesons and Strangeonium States
The GlueX Experiment

- 12 GeV e\(^{-}\) beam up to 2.2 \(\mu\) A.
- Linearly polarized photons (\(P_\gamma \approx 40\%\)) from coherent bremsstrahlung on diamond radiator
- Design intensity of \(10^8\ \gamma/s\) in coherent peak (\(E_\gamma = 8.4-9\) GeV)
Quantum Chromo Dynamics

QCD describes the interactions of quarks and gluons and should predict the spectrum of bound-state baryons \( (qqq) \) and mesons \( (q\bar{q}) \).

There should also be mesons in which the gluonic field contributes directly to the \( J^{PC} \) quantum numbers of the states --- hybrid mesons. Some are expected to have "exotic" quantum numbers.

Lattice QCD calculation of the light-quark meson spectrum.

``Constituent gluon'': \( J^{PC} = 1^{+-} \)

mass of 1-1.5 GeV.

The lightest hybrid nonets

1-, (0-+, 1+, 2+)
Lattice QCD

Light-quark Mesons (u,d,s)

$$\frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d}) \quad \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) \quad (s\bar{s})$$

$m_\pi = 396$ MeV

isoscalar

isovector

YM glueball

Lattice QCD

Light-quark Mesons (u,d,s)

States with non-trivial gluonic fields.

\[ F_{j,\mu\nu} F_{j}^{\mu\nu} \]

Supermultiplet

1-, 0-, 1+, 2+

\[ \frac{1}{\sqrt{2}} (u\bar{u} - d\bar{d}) \]

\[ \frac{1}{\sqrt{2}} (u\bar{u} + d\bar{d}) \]

(s\bar{s})
Lattice QCD suggests 5 nonets of mesons with exotic quantum number:

1 nonet of $0^{+-}$ exotic mesons
2 nonets of $1^{+-}$ exotic mesons
2 nonets of $2^{+-}$ exotic mesons

Experimental evidence exists for $\pi_1$ states.

``Constituent gluon'' behaves like $J^{PC} = 1^{+-}$ with a mass of 1-1.5 GeV
The lightest hybrid nonets: $1^-$, $(0^{+-}, 1^{+-}, 2^{+-})$
Simple quantum number counting for production: \((I^G)J^{PC}\) up to \(L=2\)

\(P = \) Pomeron exchange

\(\rho\pi\) is charge-exchange only

Can couple to all the lightest exotic hybrid nonets through photoproduction and VMD.

Linear polarization is a filter on the naturality of the exchanged particle.
Decay Modes of Exotic Hybrids

\[ \pi_1 \rightarrow \pi \rho, \pi b_1, \pi f_1, \pi \eta', \eta a_1 \]
\[ \eta_1 \rightarrow \eta f_2, a_2 \pi, \eta f_1, \eta \eta', \pi(1300) \pi, a_1 \pi, \]
\[ \eta_1' \rightarrow K^* K, K_1(1270) K, K_1(1410) K, \eta \eta' \]
\[ b_2 \rightarrow \omega \pi, a_2 \pi, \rho \eta, f_1 \rho, a_1 \pi, h_1 \pi, b_1 \eta \]
\[ h_2 \rightarrow \rho \pi, b_1 \pi, \omega \eta, f_1 \omega \]
\[ h'_2 \rightarrow K_1(1270) K, K_1(1410) K, K_2^* K, \phi \eta, f_1 \phi \]
\[ b_0 \rightarrow \pi(1300) \pi, h_1 \pi, f_1 \rho, b_1 \eta \]
\[ h_0 \rightarrow b_1 \pi, h_1 \eta \]
\[ h'_0 \rightarrow K_1(1270) K, K(1460) K, h_1 \eta \]

Early Reach With Statistics Hard

Models suggest narrower states are in the spin-1 and spin-2 nonets, while the spin-0 nonets are broad.

Hybrid kaons do not have exotic QN's
GlueX Commissioning Runs

- Late October to mid December 2014 with 10 GeV electrons. No polarized photons, and solid GlueX targets.
  - All systems worked, all detectors recorded data using multiple triggers. 120TB of data collected, 930M events.
- April 2015 ran for a few days with 6GeV electrons producing linearly-polarized photons on the liquid-hydrogen GlueX target.
  - Better DAQ and triggering led to higher-quality data. 74TB of data collected, 1285M events.
  - Many detector systems at design specs, all detector systems are within 30% of design specs.
  - Data are fully processed every two weeks. We are extracting physics from GlueX.
Coherent Bremsstrahlung

Spring 2015—6 GeV electron beam on diamond radiator
6 GeV electron beam on amorphous radiator

Linear Polarization

Polarized photon beam commissioning started.
Mass Peaks in GlueX

\[ \gamma p \rightarrow \gamma \gamma \]
\[ \gamma p \rightarrow \pi^0 \pi^- \pi^0 p \]

\[ \omega \rightarrow \pi^+ \pi^- \pi^0 \]

\[ \omega \rightarrow \gamma \pi^0 \]

\[ \pi^+ \pi^- \pi^0 \text{ Invariant Mass [GeV/c}^2] \]

\[ \gamma p \rightarrow \gamma \gamma \]
\[ \gamma \gamma \text{ Invariant Mass [GeV/c}^2] \]

\[ \gamma p \rightarrow \gamma \gamma \]
\[ \gamma p \rightarrow \pi^0 \pi^- \pi^0 p \]

\[ \omega \rightarrow \pi^+ \pi^- \pi^0 \]

\[ \omega \rightarrow \gamma \pi^0 \]

\[ \pi^+ \pi^- \pi^0 \text{ Invariant Mass [GeV/c}^2] \]

Events / 8 MeV/c^2

Events / 16 MeV/c^2

Events / 20 MeV/c^2

Events / 20 MeV/c^2
Particle Identification

Positively Charged Particles

Negatively Charged Particles

Incorrect RF Bunch

Hadron 2015 - C.A. Meyer
Physics signals

Observed reactions

- $\gamma p \rightarrow p\rho^0$ ~10%
- $\gamma p \rightarrow p\pi^0\pi^0$ ~5%

$\sigma_{\text{rect.}} / \sigma_{\text{tot}}$

- $\gamma p \rightarrow p\pi^0$ ~5%
- $\gamma p \rightarrow p\eta$ ~1%
- $\gamma p \rightarrow p\pi^+\pi^-\pi^0$ ~10%
Polarization transfer to the $\rho$

\[ \frac{d\sigma}{d\psi} \propto (1 + P\Sigma \cos 2\psi) \]

$P$ = Linear Polarization
$\Sigma$ = Beam Asymmetry $\approx$ 1.0

- Coherent bremsstrahlung peak has high degree of linear polarization
- Pearl bremsstrahlung peak has low degree of linear polarization

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

$\rho^0 \rightarrow \pi^+\pi^-$

- Polarization $P$ is preserved in $\rho$ production.
Early Physics

- Initial reactions will be polarization transfer and beam asymmetry measurements.
  \[ \gamma p \rightarrow \rho, \omega, \phi p \quad \gamma p \rightarrow \pi^0, \eta, \eta' p \]
- Cross section measurements.
- Spin-density matrix elements to understand production mechanisms.
- Identify known mesons in PWA.
- Move on to the search for exotic hybrids.
Forward Kaon Identification

- Four of the BaBar DIRC bar boxes will be installed in front of the TOF wall.
- This combined with the other PID systems in GlueX will allow us to fully study final states with strange quarks.
- Strangeonium mesons and hybrids can be studied.
- Hyperon and cascade baryons can be studied.

Expected late 2017/2018
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<th>Experiment</th>
<th>Rating</th>
<th>PAC Days</th>
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<tr>
<td>GlueX—Hybrid mesons/spectroscopy</td>
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<td>(forward muon detector)</td>
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<td>PR14-004</td>
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<td>(calorimeter upgrade)</td>
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Experiments using GlueX

GlueX—Study of $\omega$ photoproduction on nuclei. LOI 2015

GlueX—Physics opportunities with a secondary $K_L$ beam LOI 2015

Workshop planned at JLab in February 2016
https://www.jlab.org/conferences/kl2016/
Summary

- GlueX is installed and well into its commissioning.
- All detector systems are approaching design specifications in performance, but additional data are needed for full calibration.
- The experiment is ready to do first physics measurements of simple reactions.
- The broader program of exotic mesons is in sight and an upgrade plan is in place to allow us to cover all parts of that program is moving forward.
- We have an extensive program beyond exotic hybrids and are excited to have new ideas and new collaborators.