Gluonic Excitations in Hall D

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Outline

- GlueX Experiment in Hall D
- Physics Motivation
  - Meson Notation Overview
  - Hybrids and Exotics
  - Partial Wave Analyses
  - GlueX – Hybrid Optimization

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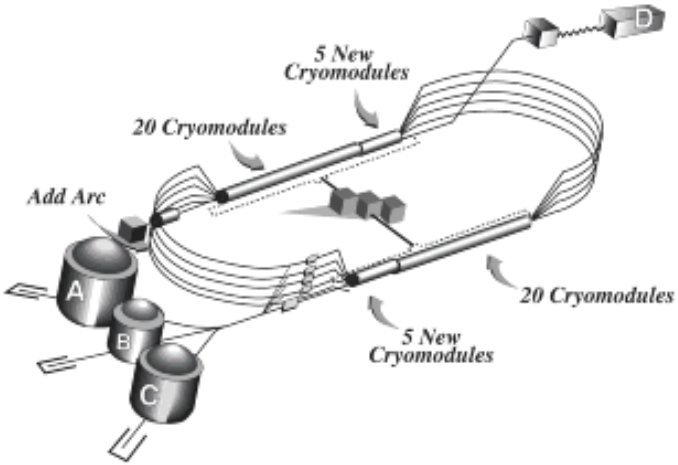
GlueX Experiment



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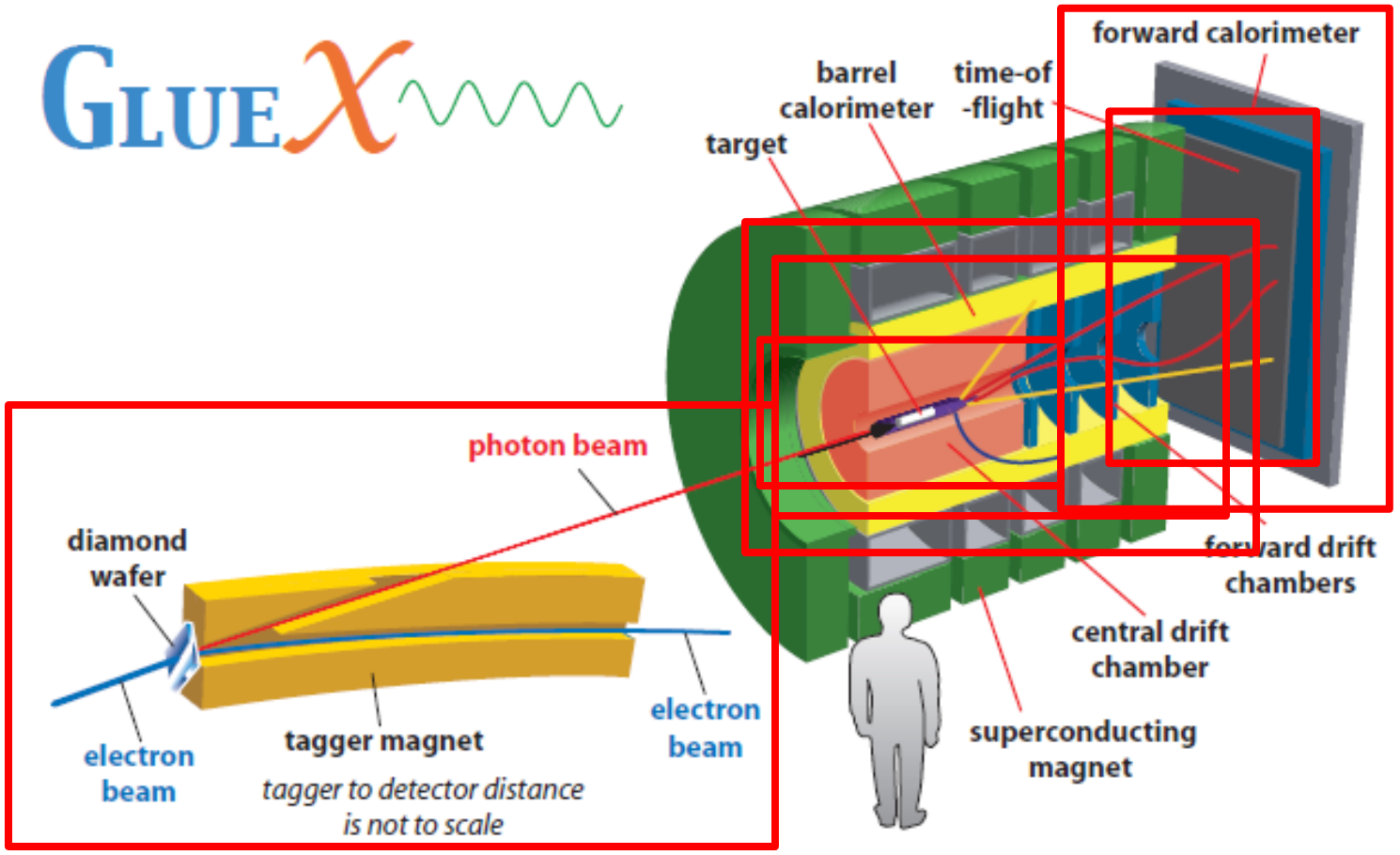
GlueX Experiment



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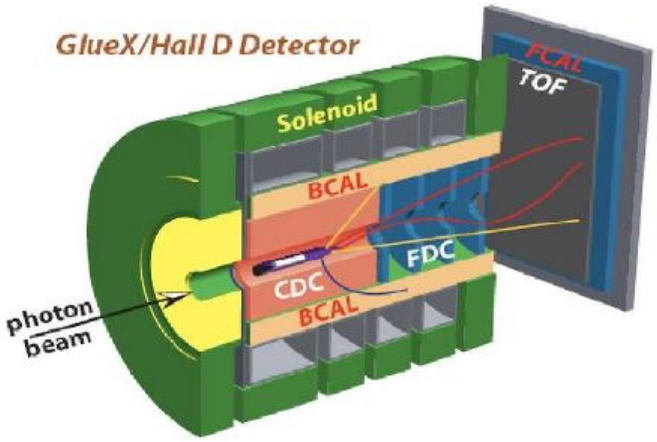
GlueX Experiment

- 12 GeV electrons producing
  9 GeV photons at a rate of
  10^7 photons per second



- Polarized Photons-
  Optimized for Exotics

- High Luminosity and Acceptance-
  Will exceed current photoproduction data by several orders of magnitude in first year of running

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J^{PC} Notation

$$J = L \oplus S \qquad S = S_q \oplus S_q$$

Parity: $P(\Psi(\vec{r})) = \Psi(-\vec{r})$

$$P = (-1)^{L+1}$$

C-Parity: $C(\Psi(q_i)) = \Psi(\bar{q}_i)$

$$C = (-1)^{L+1}(-1)^{S+1} = (-1)^{L+S}$$

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Allowed J^{PC}

$L = 0 \quad S = 0$

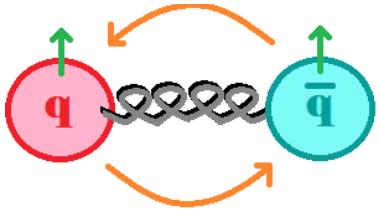
$P = -1$
$C = +1$

0^{-+}

$L = 0 \quad S = 1$

$P = -1$
$C = -1$

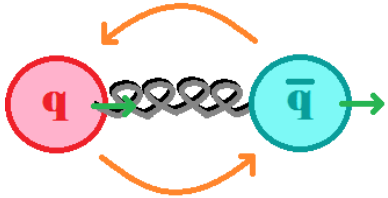
1^{--}



$L = 1 \quad S = 1$

$P = +1$
$C = +1$

2^{++}



$L = 1 \quad S = 1$

$P = +1$
$C = +1$

1^{++}

$$\{0^{-+}, 0^{++}, 1^{--}, 1^{+-}, 1^{++}, 2^{--}, 2^{-+}, 2^{++}, \ldots\}$$

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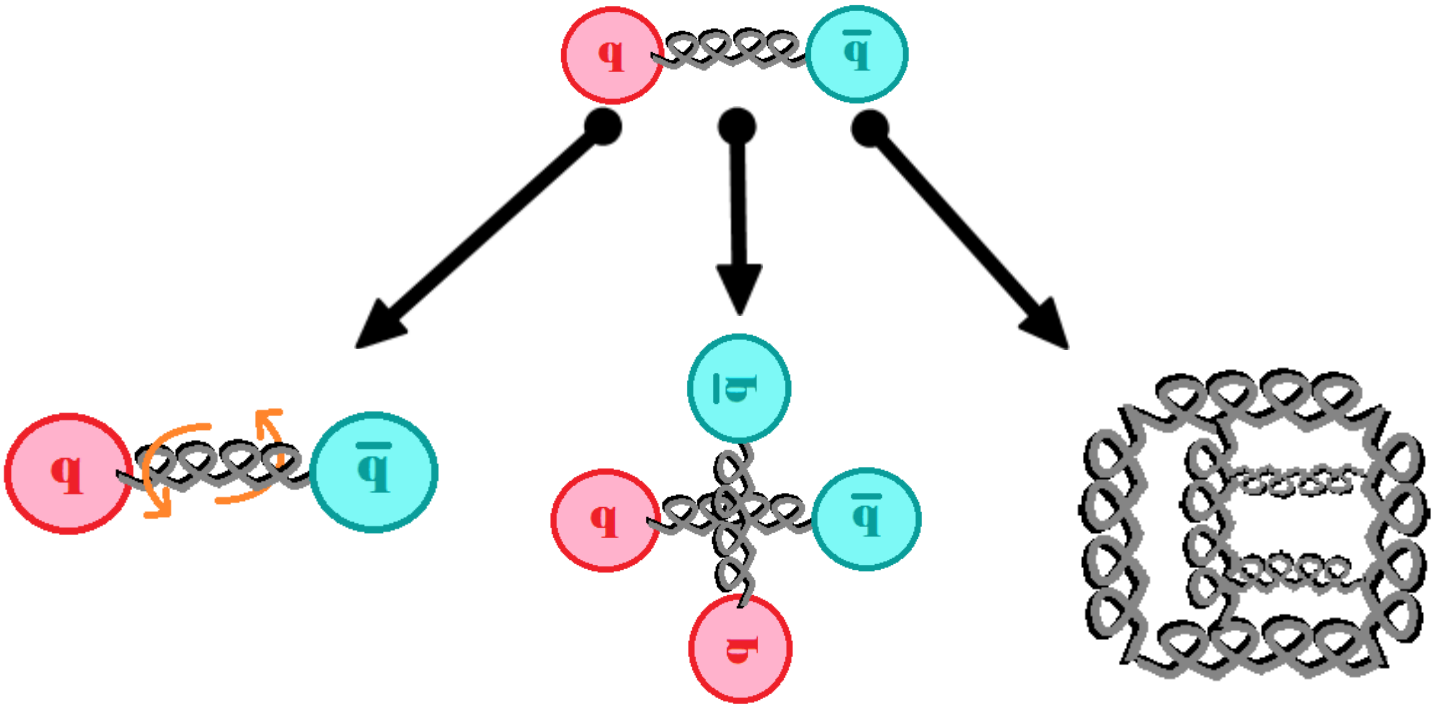
Exotic J^{PC}

$$\{0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, \ldots\}$$



Hybrid Meson Tetraquark Glueball

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Hybrid Mesons

- Hybrid Mesons can be Exotic OR Allowed J^{PC}.
- Two types of signals:
  - "Extra" Normal Meson States
  - Exotic Quantum Numbers

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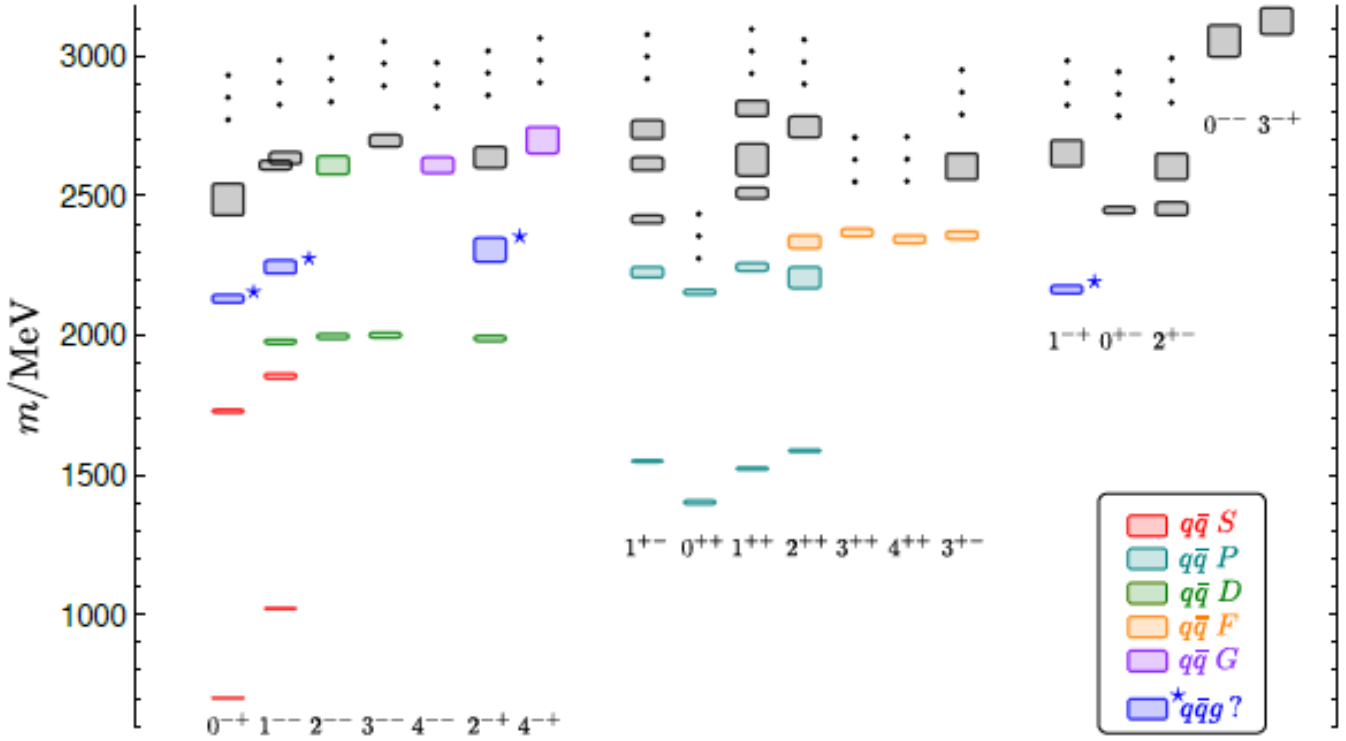
Hybrid Mesons



J. Dudek, **arXiv:1106.5515v1**

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Hybrid Mesons

Partial Wave Analysis

10.1103/PhysRevD.68.052003

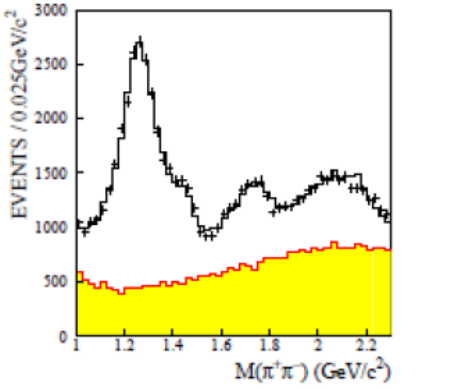


FIG. 3: The $\pi^+\pi^-$ invariant mass distribution from $J/\psi \to \gamma\pi^+\pi^-$. The crosses are data, the full histogram shows the maximum likelihood fit, and the shaded histogram corresponds to the $\pi^+\pi^-\pi^0$ background.

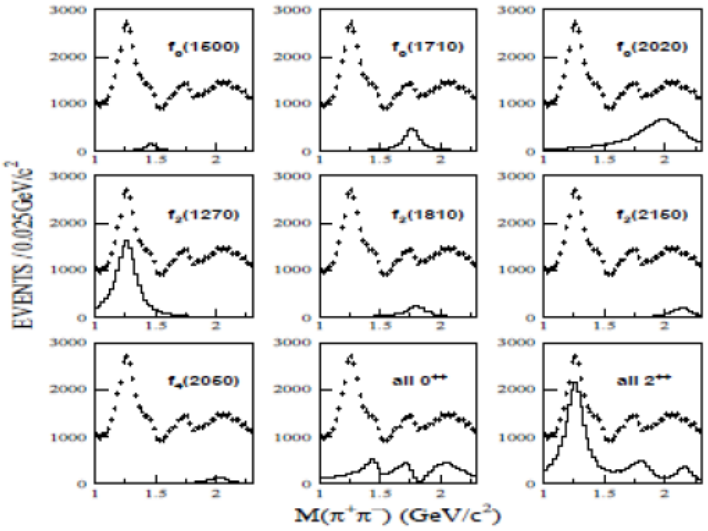
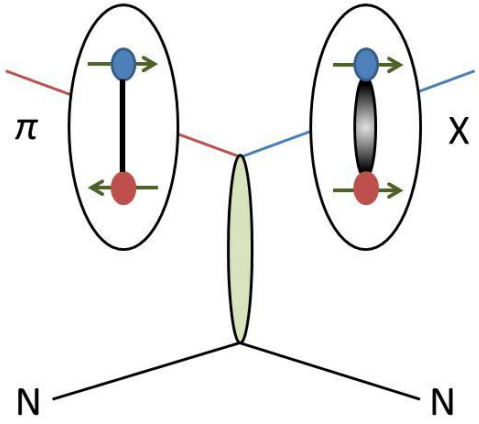


FIG. 4: The mass projections of the individual components for $J/\psi \to \pi^+\pi^-$. The crosses are data. The complete 0^{++} and 2^{++} contributions are also shown, including all interferences.

f_0 (0^{++}): $f_0(1500)$, $f_0(1710)$, $f_0(2020)$
f_2 (2^{++}): $f_2(1270)$, $f_2(1810)$, $f_2(2150)$

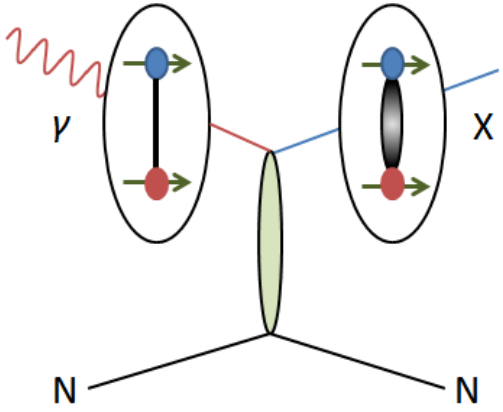
GlueX – Optimized for Exotics

Pion Beam



$\sigma_{\text{exotic meson}} << \sigma_{\text{meson}}$

Photon Beam



$\sigma_{\text{exotic meson}} \approx \sigma_{\text{meson}}$

- Polarized Photon Beam
- High sensitivity to Rare Events
- High acceptance for Multiple Particle Final States

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Summary

- Hybrid Mesons are meson states containing a constituent "excited" gluon carrying angular momentum
- They can contain both exotic or allowed quantum numbers, but exotics provide the easiest non-$q\bar{q}$ signal
- GlueX experiment will be assembled in Hall D during the 12 GeV upgrade and will start taking data in ~2015
- The GlueX experiment is optimized in its search for exotics, and it will provide the next generation of high statistics photoproduction data.
- GlueX Upgrades:
  - Cherenkov Detector: Particle ID
  - Level 3 Trigger: 5 x 10^7 Photons / Sec

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Non-Exotic Hybrids in Models

- Most model predict decay into two identical particles
- Pairs of L=0 mesons suppressed
- Therefore, (L=0)(L=1) pairs favored

Particle	$\mathbf{J^{PC}}$	Total Width MeV PSS	IKP	Large Decays
ρ_1	1^{--}	$70-121$	112	$a_1\pi$,$\omega\pi$, $\rho\pi$
ω_1	1^{--}	$61-134$	60	$\rho\pi$, $\omega\eta$, $\rho(1450)\pi$
ϕ_1	1^{--}	$95-155$	120	$K_1^B K$, $K^* K$, $\phi\eta$

TABLE VIII. Non-exotic quantum number hybrid width and decay predictions from reference [34]. The column labeled PSS (Page, Swanson and Szczepaniak) is from their model, while the IKP (Isgur, Karl and Paton) is their calculation of the model in reference [17]. The variations in width for PSS come from different choices for the masses of the hybrids. The K_1^A represents the $K_1(1270)$ while the K_1^B represents the $K_1(1400)$.

C. Meyer and Y. Van Haarlem, Phys. Rev. C 82, 025208 (2010).

GlueX Event Statistics

$$n = \sigma \times N_t \times N_\gamma \times T \times \epsilon \times BR$$

- Nt is Target Density, for 30cm LH2 is 1.26 b^{-1}
- Nγ is Photon Density, 10^7 photons/s (then 10^8)
- T is Time running per year, estimated 5x10^6 seconds per year, 2 months is pessimistic.
- σ, ε, BR most difficult to estimate and channel dependent, but for $\pi^+\pi^+\pi^-$, based on 2011 study by Jake Bennett:

$$n = 3.2[\mu b] \times 1.26[b^{-1}] \times 10^7[s^{-1}] \times 5 \times 10^6[s] \times 0.20 \times 1 = \boxed{400M}$$

- In first year of running, compared to 83k from CLAS, 2.6M from E852, and 420k from COMPASS in similar channels
- 900M estimate for $\pi^+\pi^-$