Hall-D Update

Eric Pooser

Joint Hall A/C Summer Collaboration Meeting

07/18/2015
<table>
<thead>
<tr>
<th>Proposal/experiment</th>
<th>Status</th>
<th>Title</th>
<th>Beam days</th>
<th>PAC #</th>
</tr>
</thead>
<tbody>
<tr>
<td>E12-06-102</td>
<td>A</td>
<td>Mapping the Spectrum of Light Quark Mesons and Gluonic Excitations with Linearly Polarized Photons</td>
<td>120</td>
<td>30</td>
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<tr>
<td>E12-10-011</td>
<td>A-</td>
<td>A Precision Measurement of the $\eta$ Radiative Decay Width via the Primakoff Effect</td>
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<tr>
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<td>A</td>
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<tr>
<td>E12-13-008</td>
<td>A-</td>
<td>Measuring the Charged Pion Polarizability in the $\gamma\gamma \rightarrow \pi^+\pi^-$ Reaction</td>
<td>25</td>
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<tr>
<td>C12-12-002</td>
<td>A</td>
<td>A study of meson and baryon decays to strange final states with GlueX in Hall D</td>
<td>220</td>
<td>42</td>
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<tr>
<td>C12-14-004</td>
<td>C2</td>
<td>Eta Decays with Emphasis on Rare Neutral Modes: The JLab Eta Factory Experiment (JEF) partly concurrent with GlueX ($\eta \rightarrow 3\pi$)</td>
<td>(130)</td>
<td>42</td>
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<tr>
<td>LOI12-15-001</td>
<td></td>
<td>Physics with secondary $K_L^0$ beam production on nuclei</td>
<td>43</td>
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<td>LOI12-15-006</td>
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</table>

Slide Courtesy of E. Chudakov
Hybrid & Exotic Hybrid Mesons

- Conventional light mesons (π, K, η, ρ, ω, φ, ...)
  - $q\bar{q}$ system (q = u, d, or s)
  - Gluonic degrees of freedom do not contribute
  - Non-exotic quantum numbers: $J^{PC} = 0^{-+}, 1^{--}, 1^{+-}, ...$

- Hybrid Mesons: Gluons behave as constituent particle
  - Gluonic excitation of $q\bar{q}$ system
  - Provide access to gluonic degrees of freedom in the confinement regime

- Exotic Hybrid Mesons: Hybrid mesons with non-permissible quantum numbers
  - Exotic quantum numbers: $J^{PC} = 0^{--}, 0^{+-}, 1^{--}, 2^{+-}, ...$
Observations of Exotic Mesons

- **E852 Collaboration**
  - 18 GeV/c $\pi^-$ beam, LH$_2$ target
  - $\pi_1(1600) \rightarrow \eta'\pi^-$
  - $M_{\pi_1} = 1.597 \pm 0.010 \text{ GeV}/c^2$
  - $\Gamma_{\pi_1} = 0.340 \pm 0.040 \text{ GeV}/c^2$

- **COMPASS**
  - 190 GeV/c $\pi$ beam, Pb target
  - $\pi_1(1600) \rightarrow \rho\pi^-$
  - $M_{\pi_1} = 1.660 \pm 0.010 \text{ GeV}/c^2$
  - $\Gamma_{\pi_1} = 0.269 \pm 0.021 \text{ GeV}/c^2$

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GlueX Experiment in Hall D

- Map spectrum of light quark & quark-gluon hybrid (exotic) mesons
- Study meson & baryon decays to strange final states
- GlueX: 21 Institutions, ~110 Scientists


Lightest Hybrid Mesons

$\Pi_1$
Approved Experiments in Hall D

- **Charged-π Polarizability in γγ → π⁺π⁻**
  - \(\alpha_\pi\): Electric Polarizability
  - \(\beta_\pi\): Magnetic Polarizability
  - **Measure**: \((\alpha_\pi - \beta_\pi)\)
  - \(\sigma(\gamma\gamma \to \pi^+\pi^-)\) via Primakoff production

- **Γ(\(\eta \to \gamma\gamma\)) via the Primakoff Method**
  - Determination of the light quark mass ratio
  - Measure \(\eta - \eta'\) mixing angle

\[\alpha_\pi = -\beta_\pi \propto F_A/F_V\]
Fall 2014 GlueX Commissioning Status

- ~10.1 GeV e⁻ beam, 50 - 200 nA
  - CH2 target
  - 800-1200A solenoid current
  - ~ 19 days of integrated beam (post-beam tune)

- GlueX Commissioning Goals:
  - Tune CW beam to tagger ✔
  - Create unpolarized γ beam and tune through collimator, target, and photon beam dump ✔
  - Checkout trigger, DAQ, and all detector subsystems ✔
  - Collect data for initial detector calibration & DC alignment ✔
Fall 2014 GlueX Physics Results

- A few reconstructed decays:
  - $K_S^0 \rightarrow \pi^+\pi^-$
  - $\phi \rightarrow K^+K^-$
  - $\omega \rightarrow \pi^+\pi^-\pi^0$
Spring 2015 GlueX Commissioning Status

- ~5.5 GeV $e^-$ beam, 5 - 200 nA
- 800-1300A solenoid current
- ~10 days of beam (post-beam tune)

Commissioning Goals
- Polarized $\gamma$ beam (goniometer & diamonds)
- $LH_2$ cryotarget & verify alignment
- Run DAQ in block-mode at high rates
- Optimize triggers
- Beam stability feedbacks (~ (more work is needed))
- Accelerator RF timing

- Solenoid was stable at 1200A for ~3 weeks
  - 1 day of running at 1300A caused a quenched
  - Reviewed by Physics Division on July 14, 2015
  - No obvious cause of the quench has been identified
  - Support plans to run at 1300A again

- All equipment for the baseline GlueX detector has been commissioned!
12 GeV $e^{-}$ beam (0.05 - 2.2 $\mu$A)

- 20 $\mu$m thick diamond radiator
  - 8.4-9.0 GeV $\gamma$’s in the coherent peak (3.0-11.8 GeV tagged)
  - ~40% linearly polarized $\gamma$’s
  - Collimated $r < 1.8$ mm at ~80 m (5.0 mm for Spring run)
  - 100 MHz $\gamma$’s at 2.2 $\mu$A
Polarized Photons

- 50 & 100 μm (Hall-B) thick diamonds were scanned and aligned
- Photon polarization is understood and can be controlled
- Both produced coherent radiation!

Coherent Edge

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Photon Beam Diagnostics

\[ \varepsilon_{\text{primary}} \rightarrow \gamma_{\text{beam}} \varepsilon_{\text{tag}} \]

All tagged electrons

\[ \gamma_{\text{beam}} \text{ passes through collimator} \]

Difference (accidentals)

Pair Spectrometer

Tagger Hodoscope

Tagger Microscope

Polarimeter

PS energy vs TAGM column

Preliminary Triplet Polarimeter Analysis

\[ P_{\text{max}} \approx 65\% \]

Polarization: 0.72 ± 0.19

Azimuthal Angle of Triplet Plane [deg.]
Track/Vertex Reconstruction

- Reconstruction of charged track vertices during Spring run
- Target, scattering chamber, & start counter geometries can be observed
- Particle tracking and reconstruction is at a mature level
Event Display/Track Reconstruction

Slide Courtesy of P. Mattione
Event Display/Track Reconstruction

Slide Courtesy of P. Mattione
Offline/Online Monitoring

- Bi-weekly “launches” run over all available data on tape and reconstructed data is written to disk for physics analyses

- Web run browser provides ability to browse and download ROOT files:
  - https://halldweb.jlab.org/cgi-bin/data_monitoring/monitoring/runBrowser.py
PID Capabilities

TOF

CDC

TOF

FCAL

Positively Charged Particles

Negatively Charged Particles

Incorrect RF Bunch

Positively Charged Particles

CDC

Track Momentum [GeV/c]

Track Momentum [GeV/c]

Track Momentum [GeV/c]

Track Polar Angle [degrees]

Track Momentum [GeV/c]
Start Counter

Start Counter Time Resolution Performance

Average Performance Time Resolution: $\sigma = 0.3000 \pm 0.001$ ns

Design Performance Time Resolution: $\sigma = 0.350$ ns

Channel 29: $t_{target} - t_{RF}$

- Entries: 358581
- Mean: -0.2015
- RMS: 0.3941
- $\chi^2 / n df$: 2128 / 11
- $\mu$ (ns): -0.182 ± 0.001
- $\sigma$ (ns): 0.2966 ± 0.0005
Mass Peaks in Exclusive Reactions

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

\[ \gamma p \rightarrow 4 \gamma p \]
\[ \omega \rightarrow \pi^+ \pi^- \pi^0 \]

Jefferson Lab

Thomas Jefferson National Accelerator Facility

FIU

Florida International University

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July 18, 2015

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Polarization Transfer in $\rho$ Production

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

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

Coherent bremsstrahlung peak has high degree of linear polarization.

Events / 20 MeV/c^2

Energy of Beam Photon [GeV]

Angle Between Polarization and Decay Planes $\psi$ [deg.]

$\frac{d\sigma}{d\psi} \propto (1 + P \cos 2\psi)$

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GlueX

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Future GlueX PID Upgrade (FY18)

- Improved $\pi/K$ separation (up to 4 GeV) extends physics program to study mesons and baryons containing strange quarks

- Received approval from SLAC to use BaBar DIRC components
  - 48 fused silica bars contained in 4 boxes

- Implementing a compact, focusing optics system

- Synergy with CLAS12 RICH MaPMT readout and electronics
  - ~15K readout channels integrated into standard Hall D DAQ system
Looking Forward

- Obtain more data for calibration of detector systems
- Tagger Microscope
  - ~30% of the fibers have low transmission efficiency
  - These fibers will be replaced this year
- Manufacture & install 20 μm diamond radiators
- Commission total absorption counter and triplet polarimeter
- Optimize trigger & data acquisition
- Commissioning is planned to continue through Spring 2016
- First physics is planned for Fall 2016
- Full intensity: 2017+ (~5 years)
Summary

- Majority of detector systems are close to design resolutions
- More data is needed to refine calibrations
- Polarized photons via. the coherent Bremsstrahlung technique have been produced and are understood
- Photoproduction of scalar & vector mesons has been observed
- Asymmetry in the polarization of $\rho$ production has been observed
- All components of the baseline GlueX detector have been commissioned
Backup Slides
GlueX Detector System
Lattice QCD Predictions

Lightest Hybrid Mesons

Negative Parity

Positive Parity

Exotics

$\pi_{1}$

$m_{\pi} = 391$ MeV
$24^3 \times 128$
isoscalar
isovector

Approved Experiments in Hall D

GlueX

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- Study meson & baryon decays to strange final states
- GlueX: 21 Institutions, ~110 Scientists

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<tr>
<th>Name</th>
<th>JPC</th>
<th>Total Width (MeV)</th>
<th>PSS</th>
<th>IKP</th>
<th>Large Decays</th>
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<tbody>
<tr>
<td>(\pi_1)</td>
<td>1^-+</td>
<td>81 - 168</td>
<td>117</td>
<td></td>
<td>(b_1\pi, \rho\pi, f_1\pi, a_1\eta)</td>
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<td>172</td>
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<td>(K^* K, K_1^0 K, K^* K)</td>
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<tr>
<td>(b_0)</td>
<td>0^+-</td>
<td>247 - 429</td>
<td>665</td>
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<td>(h_2)</td>
<td>2^+-</td>
<td>4 - 12</td>
<td>166</td>
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DAQ

- GlueX (now): DAQ 20 kHz, 300 MB/s ⇒ tape
- GlueX (physics running): DAQ 100 kHz, 1500 MB/s ⇒ L3 20 kHz ⇒ tape

Issues left to resolve:
- CODA: difficult to start, network issues
- Firmware: fADC-125 MHz, CAEN TDCs
- Long events due to low thresholds and noise issues

Spring 2015 results
- Stable at buffer/block level = 1 ⇒ 3 kHz at 50% live time, 200 MB/s
- Tests at buffer = 4 / block = 40 ⇒ 30 kHz at 97% live time, 600 MB/s
  - Still unstable, crashes in approximately one minute

DAQ is still a work in progress
Precise measurement of the charged pion polarizability $\alpha_\pi - \beta_\pi$ will be conducted by measuring $\sigma(\gamma\gamma \rightarrow \pi^+\pi^-)$ via Primakoff production.

ChPT predicts that the electric ($\alpha_\pi$) & magnetic ($\beta_\pi$) charged pion polarizabilities are related to their respective weak form factors $F_V$ & $F_A$.

Tests fundamental symmetries in the intrinsic even-parity sector of QCD.

Reduces uncertainty in the SM prediction of $(g_\mu - 2)/2$.
• Extract $\eta - \eta'$ mixing angle

• Determination of the light quark mass ratio

\[ Q^2 = \frac{m_e^2 - m_x^2}{m_d^2 - m_u^2} \]
\[ \hat{m} = \frac{1}{2}(m_u + m_d) \]
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- Hall D: 13 Staff Scientists, 1 Post Doctorial Fellow

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Large Decays:
- $b_1\pi, \rho\pi, f_1\pi, a_1\eta$
- $a_1\pi, f_1\eta, \pi(1300)\pi$
- $K_1^0K, K_1^0K, K^*K$
- $\pi(1300)\pi, h_1\pi$
- $b_1\pi, h_1\eta, K(1460)K$
- $K(1460)K, K_1^0K, h_1\eta$
- $a_2\pi, a_1\pi, h_1\pi$
- $b_1\pi, \rho\pi$
- $K_1^0K, K_1^0K, K^*K$

Exotic Hybrid Mesons

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