Electromagnetic Strangeness Production at Jefferson Lab Energies

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for the CLAS & GlueX Collaborations

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Outline /Overview

- Strangeness and the N* spectrum of states
  - Ground state photoproduction
  - Ground state electroproduction
- Excited Y* cross sections measured at CLAS
  - $\Sigma^0(1385)$ ($J^p = 3/2^+$); $\Lambda(1405)$ ($J^p = 1/2^-$); $\Lambda(1520)$ ($J^p = 3/2^-$)
- Dimensional scaling of $K\Lambda$ photoproduction
- The $\Lambda(1405)$ and chiral unitary models
  - line shapes
  - Spin & parity $J^p$ of the $\Lambda(1405)$
  - First Electro-production of $\Lambda(1405)$
- $K^*\gamma$ production
- Outlook at GlueX and CLAS12
• Located in Newport News, Virginia
• Ran for ~14 yrs at 6 GeV in Halls A, B, C
• Upgrading to 12 GeV, new Hall D
• Most $Y, Y^*$ publications from Hall B
• Upgrading as CLAS12 for 12 GeV
CLAS Experiment
CLAS Experiment

- Jefferson Lab, Newport News, VA, USA

Photoproduction:
- Targets unpolarized LH$_2$, polarized p and HD
- Beams unpolarized, circular, linear, to ~5 GeV
- Reconstructed $K^+p\pi^-(\pi^0)$ or $K^+\pi^+\pi^-(n)$
- 20x10$^9$ triggers $\rightarrow$ 1.41x10$^6$ KY$\pi$ events in g11a

Electroproduction:
- $Q^2$ from ~0.5 to ~3 (GeV/c)$^2$
- Rosenbluth and beam-helicity separations
Strangeness and the N* Spectrum of States - Photoproduction
Strangeness in $N^*$ Physics: Status

- How significant is strangeness physics in unraveling $N^*$ and $\Delta$ properties?
- It is part of a large effort to determine pole positions, branching fractions, helicity couplings, etc.
- Bottom line: “Stars” and resonances added to world database

Define the Spin Observables
(for target polarization zero)

\[ \begin{align*}
&\gamma^{*} P_{\bar{\gamma}} \\
&K^{+} P_{C} \\
&\pi^{-} \Lambda \Theta_{P} \\
&K^{+} \Theta^{c.m.}_{K^{+}} \\
&\text{proton} \end{align*} \]

\[ \begin{align*}
\frac{d\sigma}{d\Omega} &= \sigma_{0} \\
&= \begin{cases} 
1 - P_{\bar{\gamma}} \Sigma \cos 2\phi \\
- \alpha \cos \theta_{x'} \sin 2\phi P_{\bar{\gamma}} O_{x'} - \alpha \cos \theta_{z'} P_{C} C_{x'} \\
- \alpha \cos \theta_{z'} \sin 2\phi P_{\bar{\gamma}} O_{z'} - \alpha \cos \theta_{z'} P_{C} C_{z'} \\
+ \alpha \cos \theta_{y'} P - \alpha \cos \theta_{y'} P_{T} \cos 2\phi 
\end{cases}
\end{align*} \]
Observables in Pseudoscalar Meson Photoproduction

4 Complex amplitudes: 16 real polarization observables.

Complete measurement from 8 carefully chosen observables.

\( \pi^0 N \) has large cross section but in \( KY \) recoil is self-analysing

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Complete, and over-determined
Theory: Bonn Gatchina Model

(Just one of several models on the market)

- Coupled channel (K-matrix) framework
  - Input from $\pi N$, $KN$ elastic; $\gamma$, $\pi$ induced inelastic to $\pi^\pm 0 N$, $\eta N$, $\eta' N$, $K^\pm 0 Y$, $\pi\pi N$
    - Use ALL experimental channels, including the strangeness channels & measured spin observables
  - Partial Wave Analysis
    - First extract each $J$ and parity waves
    - Map to extract $N$ and $\Delta$ resonance pole parameters

Short list of References:
\[ \gamma p \rightarrow K^+ \Lambda: \text{cross section} \]

Forward peaking indicates t-channel processes at high W
Angular dependence at lower W consistent with s- and u-channel processes.

\[ \gamma K^+ \rightarrow K^+ \Lambda : \text{recoil polarization} \]

- **Kaon-MAID model (green)**
  - Single-channel BW resonance fits
  - No longer up-to-date

- **Bonn-Gatchina model (blue)**
  - Multi-channel, unitary, BW resonance fit
  - Large suite of N* contributions
  - Was not predictive for recoil polarization


**γp → K⁺Λ**: beam asymmetry Σ

\[ \frac{dσ}{dΩ_{K^+}} \right|_{\text{unpol.}} = \left\{ 1 + \Sigma P_γ \cos 2\phi \right\} \]

**GRAAL** threshold range, \( E_γ < 1.5 \) GeV

**LEPS** \( 1.5 < E_γ < 2.4 \) GeV

The trends are consistent: Σ is smooth and featureless at all energies and angles.

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**Fig. 3.** Beam polarization asymmetries for the \( p(\gamma, K^+)\Lambda \) (left) and \( p(\gamma, K^+)\Sigma^\circ \) (right) reactions as a function of \( \cos(\theta_{K^+}) \) for different photon-energy bins. The error bars are using Janssen experimental data.


\[ \gamma p \rightarrow K^+ \Lambda : \text{beam asymmetry } \Sigma \]

\[ \frac{d\sigma}{d\Omega_{K^+}^{\text{pol}}} = \frac{d\sigma}{d\Omega_{K^+}^{\text{unpol.}}} \{1 + \Sigma P_y \cos 2\phi\} \]

Bonn-Gatchina model is not predictive in newly-measured kinematics.
$\gamma^* K^+ \gamma p \rightarrow K^+ \Lambda : \text{target asymmetry } T$

Bonn-Gatchina model is not predictive in newly-measured kinematics

CLAS/Glasgow Preliminary
$\gamma^*_{K^+} \gamma p \rightarrow K^+ \Lambda :$ helicity asymmetry $E$
Fig. 9. Angular distributions of the beam-recoil observable $O_x$ for photon energies $E_\gamma$ ranging from 980 MeV to 1466 MeV. Error bars represent the quadratic sum of statistical and systematic errors. Data are compared with the predictions of the BG (solid line) and RPR (dashed line) models.

GRAAL data: fair agreement with BG and RPR models
Beam-Recoil $O_x$ and $O_z$

Bonn-Gatchina model is not predictive in newly-measured kinematics
Nikanov et al.'s refit of Bonn-Gatchinac coupled-channel isobar model
mix includes: $S_{11}$-wave, $P_{13}(1720)$, $P_{13}(1900)$, $P_{11}(1840)$
$K^+\Sigma^0$ cross sections also better described with $P_{13}(1900)$

Lots more published...

- Omit results for $\Sigma$ photoproduction
- Omit discussion of reactions on the neutron (deuteron), which teases isospin dependence apart.
- Overall goal: measure enough observables for “complete” amplitude determination $\leftrightarrow$ extract $N^*$ and $\Delta$'s participating
Seeking New $S=0$ Baryons via Mesons off the Proton:

**published, acquired, FroST**(g9b)

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The combination of all of these measurements on proton and neutron targets represents an extremely powerful tool in the search for new baryon states.

Source: V. D. Burkert
Ground States
- Electroproduction
Structure Functions

For unpolarized target & polarized $e^-$ beam:

$$\frac{d^4 \sigma}{dQ^2 dW d\Omega_K} = \Gamma(Q^2,W) \times \frac{d\sigma}{d\Omega_K}(Q^2,W,\Theta_K,\varepsilon,\phi)$$

Virtual photon flux

Meson cross section

Transverse

Transverse-transverse interference

Transverse-longitudinal interference

Helicity structure

Longitudinal (sensitive to $J=0^\pm$ exchange in $t$-channel: kaons, diquarks)

"Unseparated"
# CLAS ep Data Set Overview

## Publications:
- **K⁺Λ beam-recoil pol. transfer**
  - \( W=1.6-2.15 \text{ GeV}, \, Q^2=0.3-1.5 \text{ GeV}^2 \)
  - [Carman et al., PRL 90, 131804 (2003)]
- **K⁺Λ \( \sigma_L/\sigma_T \) ratio from pol. transfer data**
  - \( W=1.72-1.98 \text{ GeV}, \, Q^2 \sim 0.7 \text{ GeV}^2 \)
  - [Raue & Carman, PRC 71, 065209 (2005)]
- **K⁺Λ, K⁺Σ⁰ separated structure functions**
  - \( W=\text{thr}-2.4 \text{ GeV}, \, Q^2=0.5-2.8 \text{ GeV}^2 \)
  - \( \sigma_U, \, \sigma_{LT}, \, \sigma_{TT}, \, \sigma_L, \, \sigma_T - K⁺Λ, \, K⁺Σ⁰ \)
  - [Ambrozewicz et al., PRC 75, 045203 (2007)]
  - \( W=\text{thr}-2.6 \text{ GeV}, \, Q^2=1.4-3.9 \text{ GeV}^2 \)
  - \( \sigma_U, \, \sigma_{LT}, \, \sigma_{TT}, \, \sigma_{LT'} - K⁺Λ, \, K⁺Σ⁰ \)
  - [Carman et al., PRC 87, 025204 (2013)]
- **K⁺Λ fifth structure function \( \sigma_{LT'} \)**
  - \( W=1.6-2.1 \text{ GeV}, \, Q^2=0.65, 1.0 \text{ GeV}^2 \)
  - [Nasseripour et al., PRC 77, 065208 (2008)]
- **K⁺Λ, K⁺Σ⁰ beam-recoil pol. transfer**
  - \( W=\text{thr}-2.6 \text{ GeV}, \, Q^2=1.6-2.6 \text{ GeV}^2 \)
  - [Carman et al., PRC 79, 065205 (2009)]

## Table

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- **K⁺Λ recoil pol.**
  - \( W=1.6-2.7 \text{ GeV}, \, <Q^2>=1.9 \text{ GeV}^2 \)
  - [Gabrielyan et al., arXiv:1406.4046 (2014)]
Structure Functions

$E = 5.5 \text{ GeV}, \ W: \text{thr} - 2.6 \text{ GeV}, \ Q^2 = 1.80, 2.60, 3.45 \text{ GeV}^2 \quad \text{[Carman et al., PRC 87, 025204 (2013)]}$
$\gamma^{*} n \rightarrow K^+ \Sigma^0$ Structure Functions

$E = 5.5$ GeV, $W$: thr $- 2.6$ GeV, $Q^2 = 1.80, 2.60, 3.45$ GeV

[Carman et al., PRC 87, 025204 (2013)]
Recoil Polarization $\vec{e}p \rightarrow e'K^+\Lambda$

$\langle Q^2 \rangle \sim 1.9$ GeV$^2$


Kaon-Maid  Maxwell  RPR-2007

RPR-2011 (solid-full, dash-NR)

[Mccracken et al., PRC 81, 025201 (2010)]
Transfer Polarization $\gamma^*_{K^+} \rightarrow e^+ e' K^+ \Lambda$

Data not included in fits
- Rule out $P_{11}(1900)$ assignment
- $D_{13}(1900)$ not ruled out via $P'$ data but with S.F. data

Isobar Model - Mart
Regge Model - GLV
RPR w $P_{11}(1900)$ - Ghent
RPR w $D_{13}(1900)$ - Ghent

RPR background + $S_{11}(1650), P_{11}(1710), P_{13}(1720), P_{13}(1900)$

[Carman et al., PRC 79, 065205 (2009)]

$W=1.753$ GeV
$Q^2=2.61$ GeV$^2$

$W=1.985$ GeV
$Q^2=2.56$ GeV$^2$

$W=2.314$ GeV
$Q^2=2.41$ GeV$^2$

5.754 GeV
Summed over $Q^2, \phi$
L/T Separation

[Ambrozewicz et al., PRC 75, 045203 (2007)]
Excited $Y^*$ Cross Sections

Publication: Differential Photoproduction Cross Sections of $\Sigma^0(1385)$, $\Lambda(1405)$ and $\Lambda(1520)$, K. Moriya et al. (CLAS Collaboration), Phys. Rev. C 88, 045201 (2013).
Detect $K^+\rho\pi^-(\pi^0)$ or $K^+\pi^+\pi^-(n)$

$\Sigma(1385)$ has small branching fraction into the $\Sigma\pi$ states we want
Differential $\Sigma^0(1385)$ Cross Section

- $\gamma + p \rightarrow K^+ + \Sigma^0(1385)$
- Experiment: see $t$-channel-like forward peaking & $u$-channel backward rise
  - Agreement with LEPS
- Theory by Oh et al.$^1$: contact term dominant; included four high-mass $N^*$ and $\Delta$ resonances
  - Prediction was fitted to preliminary CLAS total cross section (years ago)

$\gamma^*_{K^+} \text{ Differential } \Lambda(1520) \text{ Cross Section}$

- $\gamma + p \rightarrow K^+ + \Lambda(1520)$
- Experiment: see $t$-channel-like forward peaking & $u$-channel backward rise
  - Agreement with LEPS$^{1,2}$
- Theories:
  - Nam & Kao$^3$: contact term dominant; no $K^*$ or $u$-channel exchanges
  - He & Chen$^4$: $K^*$ and $N(2080)D_{13} \ J^P=3/2^-$ added

2. N. Muramatsu et al. (LEPS) Phys Rev 103, 012001 (2009)
Differential $\Lambda(1405)$ Cross Section

- $\gamma + p \rightarrow K^+ + \Lambda(1405)$
- Experiment: first-ever measurements
- High $W$: See $t$-channel-like forward peaking & $u$-channel backward rise at high $W$
- Low $W$: See strong isospin dependence
  - Charge channels differ
  - WHY?!?
- Channels merge together at high $W$

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\textbf{Differential $\Lambda(1405)$ Cross Section}

\begin{itemize}
  \item $\gamma + p \rightarrow K^+ + \Lambda (1405)$
  \item \textbf{Sum} three $\Sigma\pi$ decay modes $\rightarrow$ “net” differential cross section
  \item Mixed agreement with LEPS data\textsuperscript{1}
  \item Theories:
    \begin{itemize}
      \item Nam et al.\textsuperscript{2}: $s$-channel Born term dominant; $K^*$ exchange for 3 values of $g_{K^*N\Lambda}$
      \item Williams, Ji, Cotanch\textsuperscript{3}: crossing and duality contraints; no $N^*$, estimated $g_{K\Lambda}$
    \end{itemize}
\end{itemize}


\[ \gamma + p \rightarrow K^+ + Y^*(\ast) \]

All three \( Y^\ast \)'s have similar total cross sections
Ground state \( \Lambda \) and \( \Sigma^0 \) are comparable to \( Y^\ast \) in size\(^1\)

Dimensional Scaling of KΛ

Constituent-Counting Scaling

\[
\frac{d\sigma}{dt} = f \left( \frac{t}{s} \right) s^{2-n}
\]

- Constituent counting rules for exclusive scattering
- "Valid" for \( s \to \infty \) and \( t/s \) fixed
  - \( t/s \sim \cos(\theta_{cm}) \) as \( s \to \infty \)
- \( n = \) number of point-like constituents
- Follows from pQCD...
  - but also other models
- Does it work for \( K\Lambda \)?

S. J. Brodsky and G. R. Farrar, PRL 31, 1153 (1973)
Resonance Fit to Cross Section

\[ \gamma + p \rightarrow K^+ + \Lambda \]

pQCD-like scaling

\[ S \frac{d\sigma}{dt} \times 10^7 (\text{nb} \times \text{GeV}^2) \]

\[ W \text{ (GeV)} \]

\[ \cos \theta \]

\[ +1 \]

\[ +0 \]

\[ -1 \]

\[ -2 \]

\[ -3 \]

\[ -4 \]

\[ -5 \]

\[ S_{11}(1690) \]

\[ P_{13}(1920) \]

\[ D_{13}(2100) \]
N* Baryons: Seen & “Missing”

- Relativised CQM
  - Classify oscillator-model states by \( I, J, P \)
- Consistent with observation of a “missing” \( N^* \) state in \( K^+ \Lambda \)
- PDG2013 now lists the “**” \( N(2150) \, 3/2^- \, D_{13} \)

\( \Sigma(1405) \) and Chiral Unitary Models

**Publications:** Measurement of the \( \Sigma \pi \) Photo-production Line Shapes Near the \( \Lambda(1405) \), K. Moriya *et al.* (CLAS Collaboration), Phys. Rev. C **87**, 035206 (2013);

Isospin Decomposition of the Photoproduced \( \Sigma \pi \) System near the \( \Lambda(1405) \), R. A. Sch. & K. Moriya, Nucl. Phys A **914**, 51 (2013).
Chiral Unitary Models (example 1)

- SU(3) baryons irreps $1+8_s+8_a$ combine with $0^-$ Goldstone bosons to generate:
  - Two octets and a singlet of $\frac{1}{2}^-$ baryons generated dynamically in SU(3) limit
  - SU(3) breaking leads to two $S=-1$ $I=0$ poles near 1405 MeV
  - $\sim 1420$ mostly $\bar{K}N$
  - $\sim 1390$ mostly $\pi\Sigma$
  - Possible weak $I=1$ pole also predicted

Fig. 1. Trajectories of the poles in the scattering amplitudes obtained by changing the SU(3) breaking parameter $x$ gradually. At the SU(3) symmetric limit ($x = 0$), only two poles appear, one is for the singlet and the other for the octets. The symbols correspond to the step size $\delta x = 0.1$.

Example at $W=2.30$ GeV

$I=0$ contributions with $N\bar{K}$ threshold break

$I=1$ contribution

Isospin Interference

Final $\Sigma\pi$ state

\[
|I, I_3\rangle = |0,0\rangle, |1,0\rangle
\]

\[
|t_I|^2 \equiv |\langle I, 0| \hat{T}^{(I)} |\gamma p\rangle|^2
\]

Three charge combinations:

\[
|T_{\pi^-\Sigma^+}|^2 = \frac{1}{3}|t_0|^2 + \frac{1}{2}|t_1|^2 - \frac{2}{\sqrt{6}}|t_0||t_1|\cos \phi_{01},
\]

\[
|T_{\pi^0\Sigma^0}|^2 = \frac{1}{3}|t_0|^2,
\]

\[
|T_{\pi^+\Sigma^-}|^2 = \frac{1}{3}|t_0|^2 + \frac{1}{2}|t_1|^2 + \frac{2}{\sqrt{6}}|t_0||t_1|\cos \phi_{01}.
\]
What “is” the I=1 piece?

- I=1 resonance? I=1 continuum amplitude?
- L. Roca and E. Oset paper\(^1\)
  - Possible I=1 resonance in vicinity of \(N\bar{K}\) threshold
- B.-S. Zou papers\(^2\)
  - \(\Sigma\left(\frac{1}{2}\right)^-\) is a \([ud][us]\bar{s}\) state: part of a new nonet
  - No interference seen in \(\Lambda(1520)\) mass range: therefore it’s not a continuum amplitude
- More investigation needed!

"Best" model calculation

- L. Roca and E. Oset ← best job so far
- Possible I=1 resonance in vicinity of $N\bar{K}$ threshold

This effect is NOT seen for the $\Lambda(1520)$

No model calculation has computed cross section and line shapes together.
Spin and Parity of \( \Lambda(1405) \)

Parity and Spin of $\Lambda(1405)$

- PDG assumes $J^P = \frac{1}{2}^-$ based on quark model
  - No direct experimental evidence for the parity
  - Cf. note by R. H. Dalitz, 1998 RPP

- How does one measure these things?
  - Find a reaction wherein $\Lambda^*$ is created polarized
  - Decay angular distribution to $\Sigma \pi$ relates to $J$
    - $J = 1/2$: flat distribution is the best possible evidence
    - $J = 3/2$: “smile or frown” distribution, where $p$ is the $m = \pm 3/2$ fraction
      \[ I(\theta_Y) \propto 1 + \frac{3(1-2p)}{2p+1} \cos^2 \theta_Y \]
  - Parity given by polarization transfer to daughter
  - No model dependence: pure kinematics
S-wave, P-wave Scenarios

$L=0$ (s-wave)
\[ \vec{Q} = \vec{P} \]

\[ J^P = \frac{1}{2}^- \]

\[ \Lambda(1405) \to \Sigma \pi \]

$L=1$ (p-wave)
\[ \vec{Q} = -\vec{P} + 2(\vec{P} \cdot \hat{q})\hat{q} \]

\[ J^P = \frac{1}{2}^+ \]
Parity and Spin of $\Lambda(1405)$

- Polarization axis is along $\hat{z} = \hat{y} \times \hat{K}$
- Used $W=2.55$ to $2.85$ GeV, $\cos \theta_K^{c.m.} > 0.6$
- Decay $\Lambda(1405) \rightarrow \Sigma^+ \pi^-$ is isotropic ($p = 0.5$), so $J \rightarrow 1/2$
- Weak decay asymmetry for $\Sigma^+$ is $\alpha = -0.98$ (big!)
- Decay is s-wave, $\Rightarrow P = "negative"

$J^P = \frac{1}{2}^-$ confirms quark model expectation

$\Lambda(1405)$ is produced ~ +45% polarized
Electroproduction of $\Lambda(1405)$

- Probe the pole “structure” for $Q^2 > 0$ via electromagnetic form factors.
- Theory: e.m. form factors computed; $\Lambda(1405)$ is “larger” than the neutron.
- Experiment: hard to isolate pure e.m. $\gamma\Lambda^*\Lambda$ vertex.
- In CLAS $e p \rightarrow e' K^+ p\pi^- (\pi^0)$, four particles detected.
- CLAS acceptance:
  \begin{align*}
  1.0 < Q^2 < 3.0 \text{ GeV}^2; \\
  1.5 < W < 3.5 \text{ GeV}.
  \end{align*}

Electroproduction of $\Lambda(1405)$

- Two-bump structure seen
- Possible evidence for two $I=0$ poles
- PDG $\Lambda(1405)$ values fail utterly
- Calculation needed!

K* Production

Publication: Cross Sections for the $\gamma p \rightarrow K^{*+}\Lambda$ and $\gamma p \rightarrow K^{*+}\Sigma^0$ Reactions, W. Tang et al. (CLAS) Phys. Rev. C 87, 065204 (2013).
\( \gamma K^+ \rightarrow K^+\Lambda, K^{*+}, 0\Sigma^0, + \) photoproduction

- \( N^* \) searches with coupling to \( K^*\gamma \)
- Search for \( \kappa \)-meson interaction
- 1.7 to 3.9 GeV
Models include known high-mass resonances.
K*+Λ, K*+0Σ0+ photoproduction

- Suggestion of κ-meson exchange

Solid: mostly t-channel κ-meson
Dotted: very little κ-meson

There is scarce evidence for the strange scalar called the kappa (κ), which is the octet partner of the a0(980) and f0 (980) mesons. The CLAS data support an earlier claim by LEPS that also measured K*0Σ+ photoproduction.

FIG. 12. (Color online) Total cross section ratio of the reactions γp → K*0Σ+ to γp → K*+Λ. The ratio uses the present data in the denominator and data from Ref. [5] in the numerator. The dashed and solid curves are theoretical calculations from Oh and Kim [4] models I and II, respectively.
The Future: Outlook at GlueX and CLAS12
Lattice QCD Predictions

- Lattice QCD predicts baryon spectra
- Most states not identified by experiment yet

R. Edwards et al., PRD 87, 054506 (2013)
JLab at 12 GeV will surpass many $Y^*$ thresholds

- $S = -1, -2, -3$
  - Many $\Lambda^*, \Sigma^*, \Xi^*, \Omega^*$ states remain undiscovered
- Charm threshold

K. Moriya, priv. comm.
Hall D/\text{GlueX}

- New hall, finished construction
- Approved for 120 PAC days of commissioning, 220 days of high statistics running
Hall D/GlueX

- Real photon beam centered at 9 GeV
- Liquid hydrogen target
- Reconstruc**t** both charged and neutral particles over large angular range
- Hermetic detector within solenoid magnetic field
- Meson & Baryon spectroscopy: search for new and exotic states
GlueX Study of $\Xi^-(1820)$

- Use simulated data to study
  $$\gamma + p \rightarrow K^+ + K^+ + \Xi^-(1820)$$
  $$\Xi^-(1820) \rightarrow \Lambda + K^-$$

- Final state is 5 charged particles, $K^+, K^+, K^-, p, \pi^-$
- Can GlueX reconstruct this?
- Reconstruction efficiency
  - 10 MeV mass resolution
  - Secondary vertex resolution: ~1 cm along beam line (z-direction)

(K. Moriya, priv. comm.)
Hall B / CLAS12

Baseline equipment

Forward Detector (FD)
- TORUS magnet (6 coils)
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter
- Forward ToF System
- Pre-shower calorimeter
- E.M. calorimeter

Central Detector (CD)
- SOLENOID magnet
- Barrel Silicon Tracker
- Central Time-of-Flight

Beamline
- Polarized target (transv.)
- Moller polarimeter
- Photon Tagger

Upgrades to the baseline

Under construction
- MicroMegas
- Central Neutron Detector
- Forward Tagger
- RICH detector (1 sector)
- Polarized target (long.)

6/19/14

See talk by M. Battaglieri
Study of the $\Omega^-$ and $\Xi^*$ are among the main goals of the CLAS12 spectroscopy program:

- $\Omega^-$ discovered in 1964: after 50 years, indication on $J^P$ from Babar and others but full determination not yet achieved
- $\Xi^*$ spectrum still poorly known: many states missing and spin/parity undetermined

Photoproduction mechanism implies creation of three $s$ quarks

- Models indicate $\sigma(\Omega^-) \sim 0.3-2$ nb at $E \sim 7$ GeV
- Expected production rates in CLAS12:
  - $\Omega^-$: 90 /h
  - $\Xi^*$(1690)/$\Xi^*$(1820): 0.2/0.9 k/h
- $\Omega^-$: measurement of the cross section and investigation of production mechanisms
- $\Xi^*$: spin/parity determination, cross section and production mechanism, measurement of doublets mass splitting

V. E. Barnes et al., Phys. Rev. Let. 12 (1964) 204
Hyperon photo- and electro-production used to pin down N* spectrum above 1.6 GeV

New interference phenomena in $\Lambda(1405)$ cross section(s) and line shapes demonstrated

First direct $J^P$ measurement for $\Lambda(1405)$: $\frac{1}{2}^-$

JLab program at 12 GeV in CLAS12 and GlueX will explore $Y^*$ and meson spectra