Implications of a RICH detector on the CLAS12 Cascade Program

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Overview

- Motivation for the JLab Ξ Physics Program
- CLAS6 results
  - g6
  - g11
  - g12
- Expectations with CLAS12
- Conclusions

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The JLab Ξ Physics Program

- Outgrowth of the CLAS N* program
  - Learn about proton structure from N* states
  - Originally produced in πN elastic scattering
  - Later (at CLAS), π, η (etc.) photoproduction
  - Look for missing states, improve understanding of existing states
- Motivation: nucleon structure getting hard to do
  - N* states broad and overlapping
  - Little information on missing states

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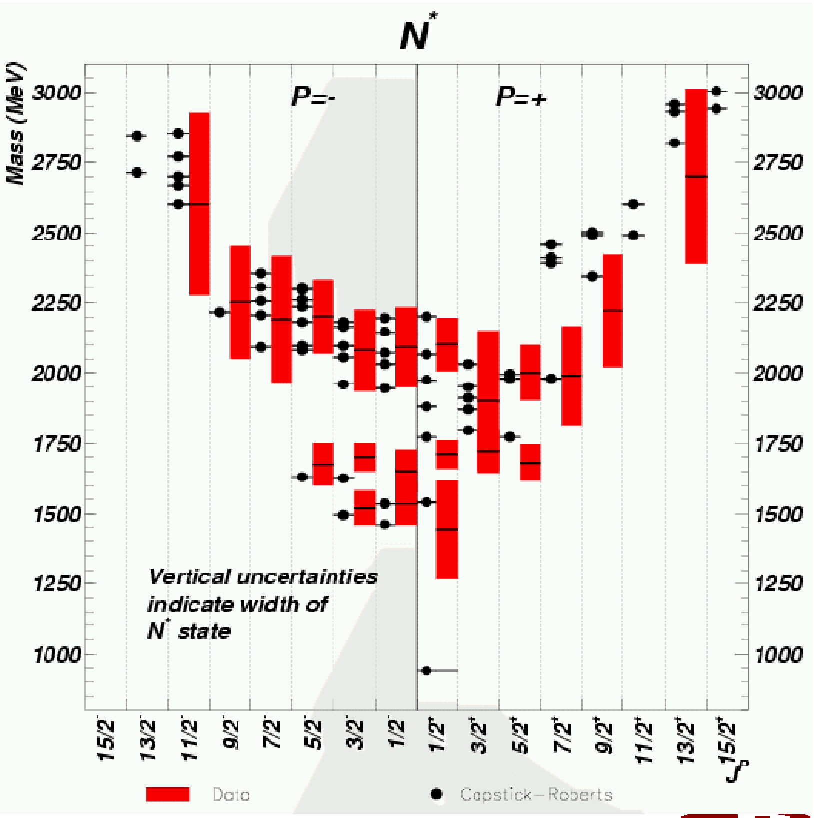
N* Spectrum Predictions

- Theory agrees with experiment qualitatively, but not quantitatively
- Theory predicts many more states than have been observed
- States are too broad to study conveniently



In Search of a Better Way…

- The N* states decay too quickly to use them
- We need a particle that
  - has properties related to the N*'s (#1)
  - has much narrower width than the N*'s (#2)
- $SU(3)_F$ symmetry points the way to a solution

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$SU(3)_F$ Multiplets

With only *qqq* states, $SU(3)_F$ gives four multiplets

one singlet: $\begin{pmatrix} \Lambda \end{pmatrix}$

two octets: $\begin{pmatrix} & N^0 & & N^+ & \\ \Sigma^- & & \Sigma^0 \, \Lambda & & \Sigma^+ \\ & \Xi^- & & \Xi^0 & \end{pmatrix}$

one decuplet: $\begin{pmatrix} \Delta^- & \Delta^0 & \Delta^+ & \Delta^{++} \\ \Sigma^- & \Sigma^0 & \Sigma^+ & \\ \Xi^- & \Xi^0 & & \\ \Omega^- & & & \end{pmatrix}$

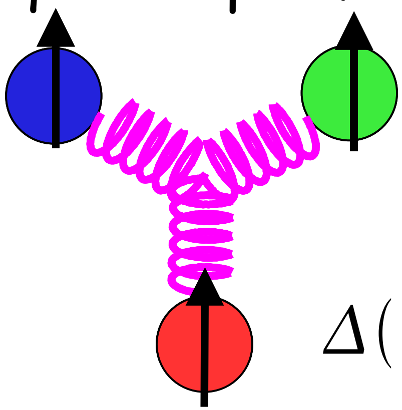
27 particles in all

$SU(3)_F$ symmetry

- $\mathcal{L}_{QCD} = \mathcal{L}_0 + \mathcal{L}_m$
- $\mathcal{L}_0$ same for all quarks
- $\mathcal{L}_0$ sets the mass scale for a given multiplet
- $\mathcal{L}_m = -\sum_q m_q \bar{\psi}^i_q \psi_{qi}$
- $\mathcal{L}_m$ sets the mass splitting within a multiplet

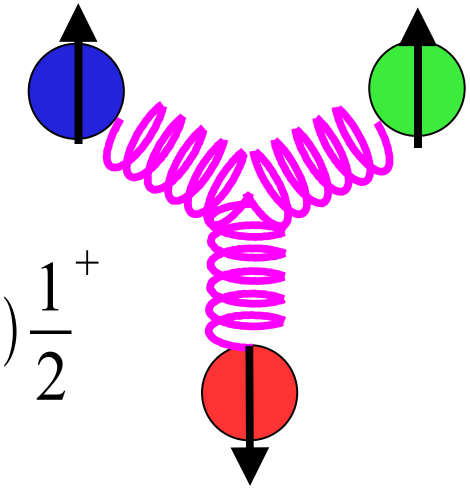
Excitations of the Nucleon

quark spin flip



$\Delta(1232)\frac{3}{2}^{+}$

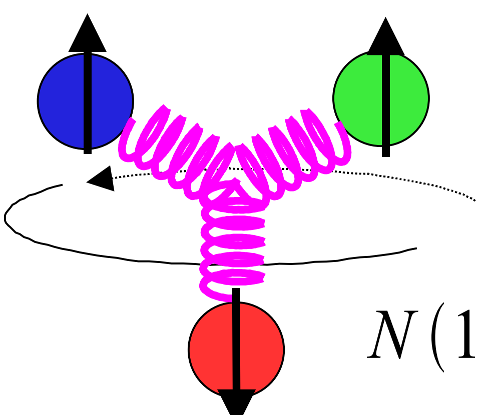
radial excitation



$N(1440)\frac{1}{2}^{+}$

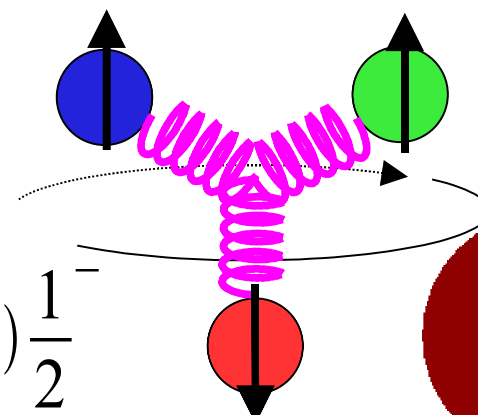
All excitations are a combination of these four

orbital excitation



$N(1520)\frac{3}{2}^{-}$

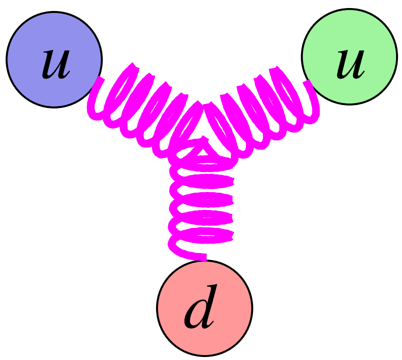
orbital excitation



$N(1535)\frac{1}{2}^{-}$

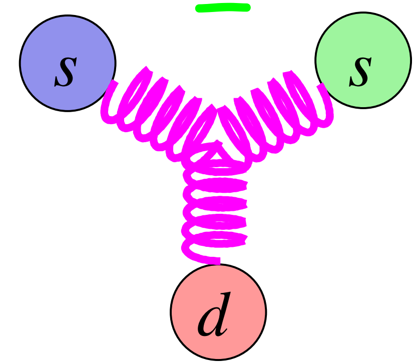
Ξ quark structure

N*



Replace two u quarks with $s \Rightarrow$ quarks

Ξ

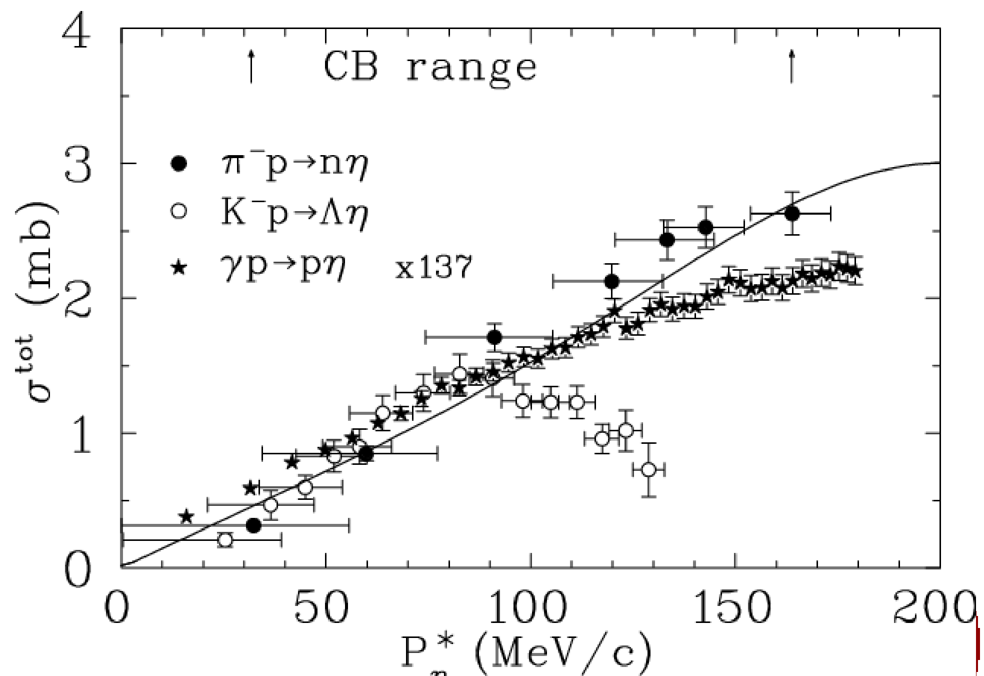


- Except for the quark content, Ψ_{N*}=(octet)Ψ_{Ξ}
- Properties should be related

requirement #1 seems OK

How good is $SU(3)_F$ Symmetry?

- Look at mass differences
  - $\Delta m[N(1440)\tfrac{1}{2}^{+} - N(939)\tfrac{1}{2}^{+}] \approx \Delta m[\Lambda(1600)\tfrac{1}{2}^{+} - \Lambda(1115)\tfrac{1}{2}^{+}]$
- Look at cross sections
- requirement #1 fulfilled



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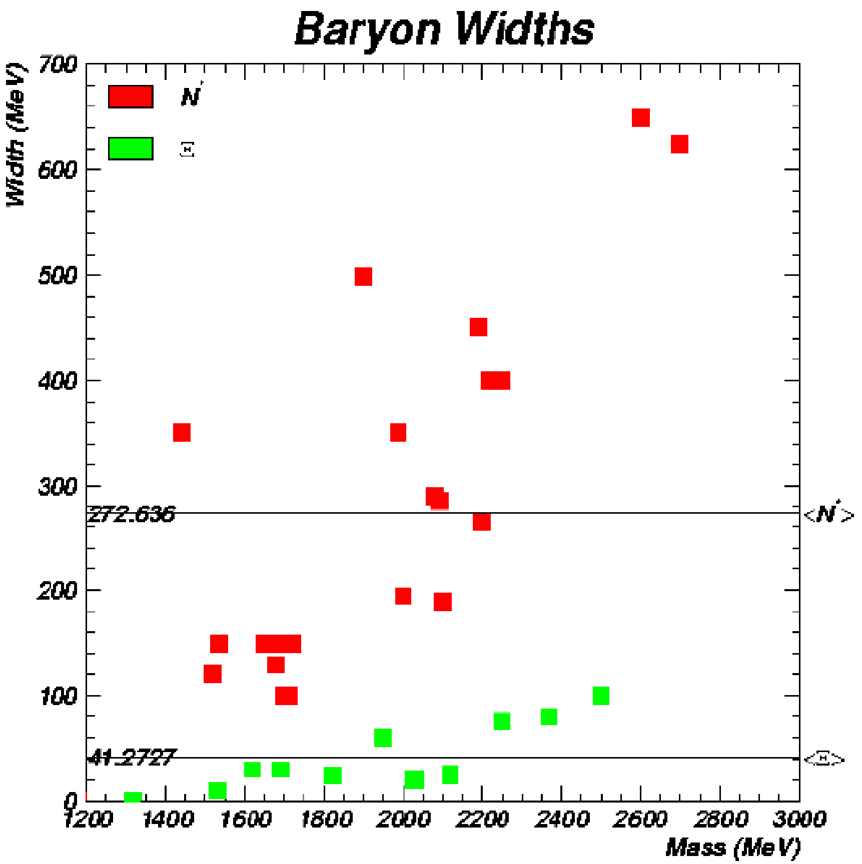
Using Ξ to study N*

- Ξ widths are ~9 times narrower than N* widths
  - Related to (# of light quarks)^2 in baryon ("9:4:1" ratio) [Riska, Eur. Phys. J. 19, 297 (2003)]
  - Visible in missing mass plot



requirement #2 fulfilled

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Ξ Physics Program

- With a sufficient Ξ sample, we can:
  - Search for missing Ξ states
  - Study production mechanism for Ξ, Ξ*
  - Study decay properties of Ξ, Ξ*
  - Study Gell-Mann-Okubo mass relation (m_s-m_d)
  - Study s-s diquark correlation (baryon structure)
  - Study Ξp interaction (with long target)
  - Search for Ξ-enriched hypernuclei

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Ξ Physics at JLab

- The "right" way: $K^-p \rightarrow K^+\Xi^-$
  - No good kaon beam available
- The JLab way: $\gamma p \rightarrow K^+K^+\Xi^-$
  - Initial state has S=0, final state has S=-2
    - Need to make two s quarks
    - Need to detect both K^+
  - All Ξ^* should be accessible via this process
  - Good kaon identification critical

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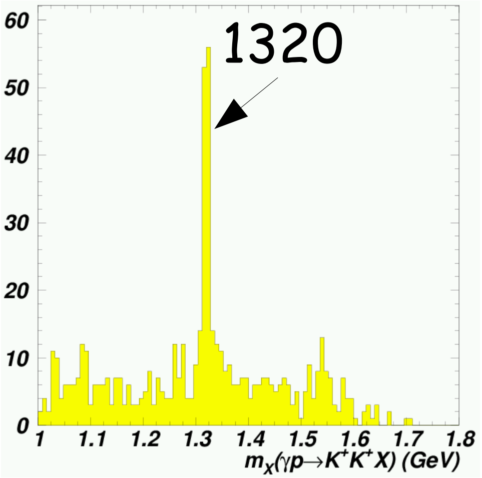
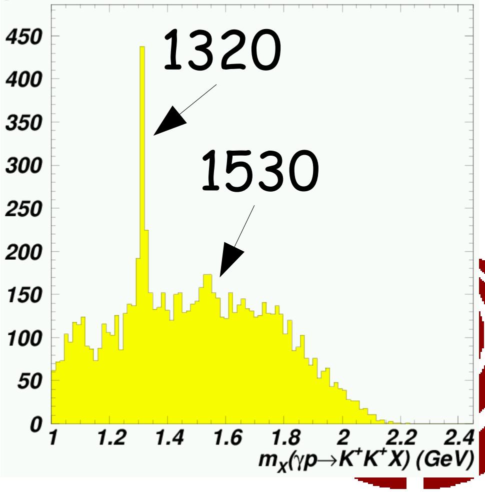
First results

- Two independent data sets
  - ~2 pb^{-1} (total) in each set
  - Lower rate in g6a
    - Better kaon ID
- Select K^+K^+ events
- Plot m_X of $\gamma p \rightarrow K^+K^+X$
- Price et al., Phys Rev. C 71, 058201 (2005)

g6a: 3.2-3.9 GeV



g6b: 3.0-5.2 GeV



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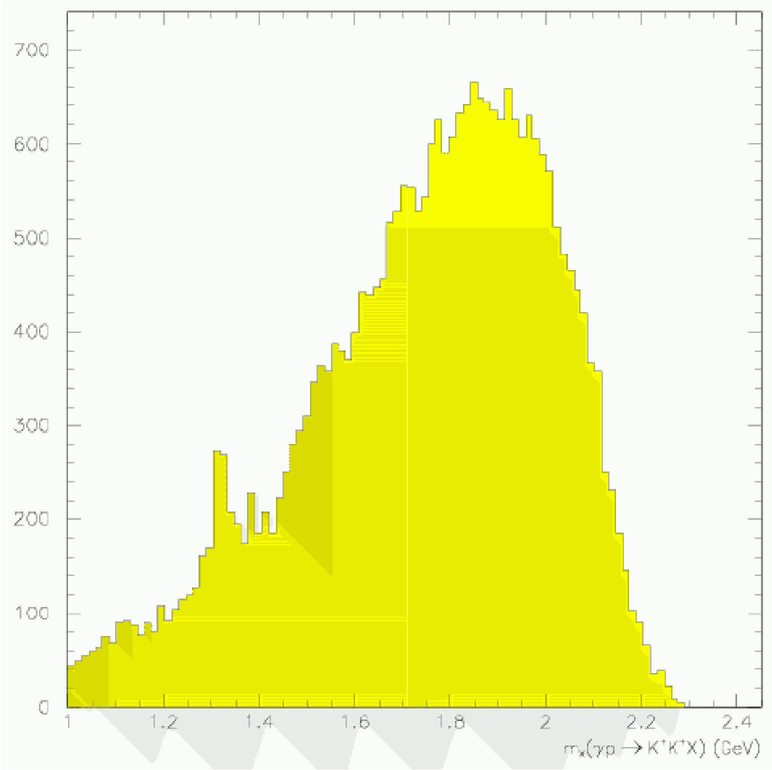
Attempt at higher statistics

- g6c run
- ~2.7 pb^{-1}
- Background too high for useful analysis
- Need to improve the detector before we can take higher luminosity



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Understanding the background

- For the ground state: $\gamma p \rightarrow K^+ K^+ \Xi^-$ has no physics background
    - Sizable background under g6b peak
        - Uncorrelated background
            - Luminosity-related
        - Misidentified pions
            - PID-related
- Strategy: improve the detector to handle design luminosity, then improve PID

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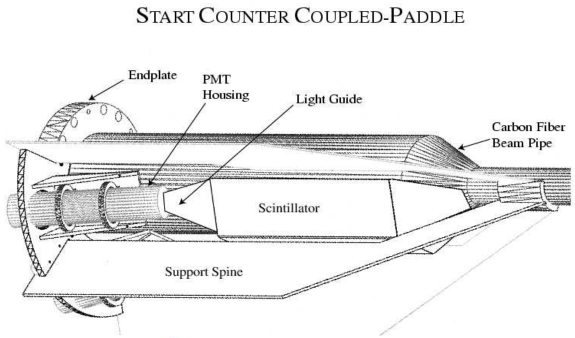
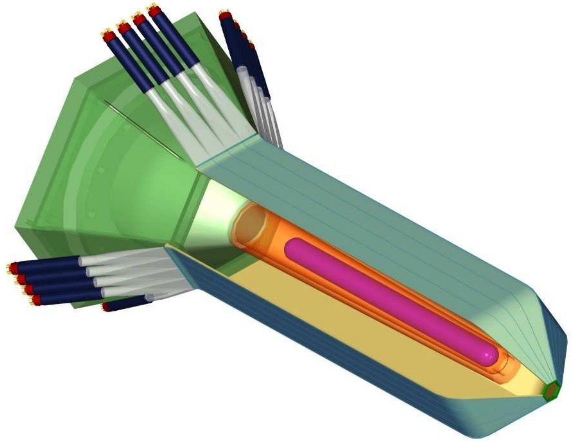
g11 start counter upgrade

- Old ST – 3 elements
- New ST – 24 elements
- Motivation included g6c background issues
- Planned in part by Italian contingent to allow higher luminosity





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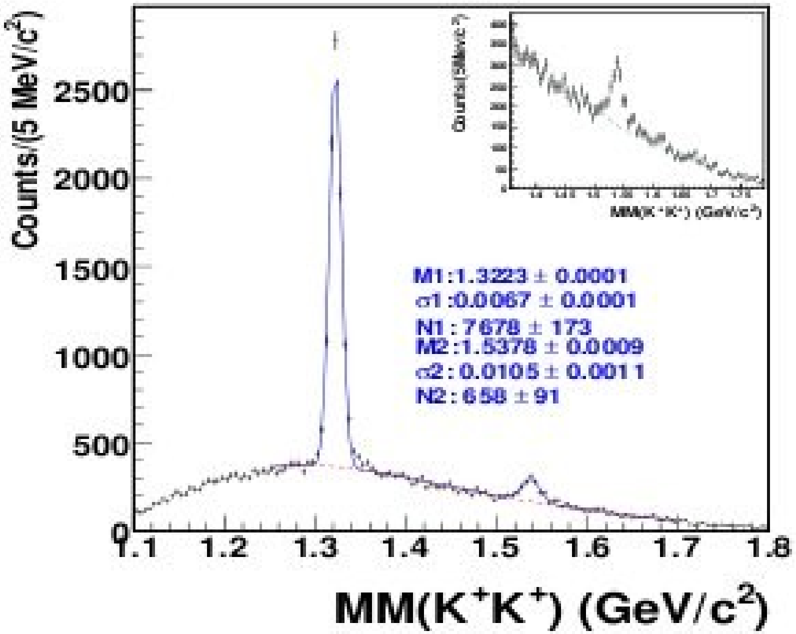
Cascades with higher statistics

- g11 data set
- 70 pb^{-1} γp data
- $1.6 < E_\gamma < 3.8$ GeV

- Large Ξ production rate
  - Also measured diff. cross section
  - No new excited states
- Guo et al., PRC 76, 025211 (2007)



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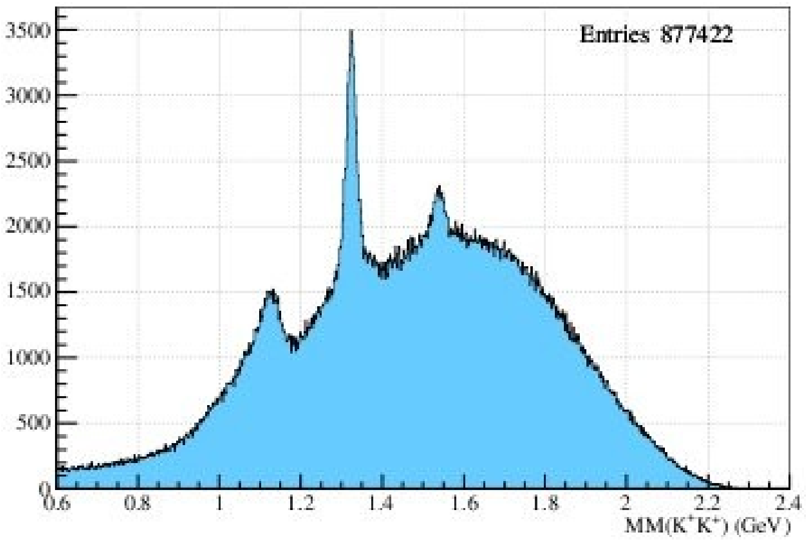
Latest Cascade results

- g12 data run
- 52 pb^{-1}
  - $3.6 < E_\gamma < 5.4$ GeV
  - Smaller E_γ range
  - Higher E_γ means worse π contamination
- Still no new excited states
  - Peak at 1.15 GeV due to $\gamma p \rightarrow K^+ \pi^+ \Sigma^-$
- Finalizing PID for PhD thesis



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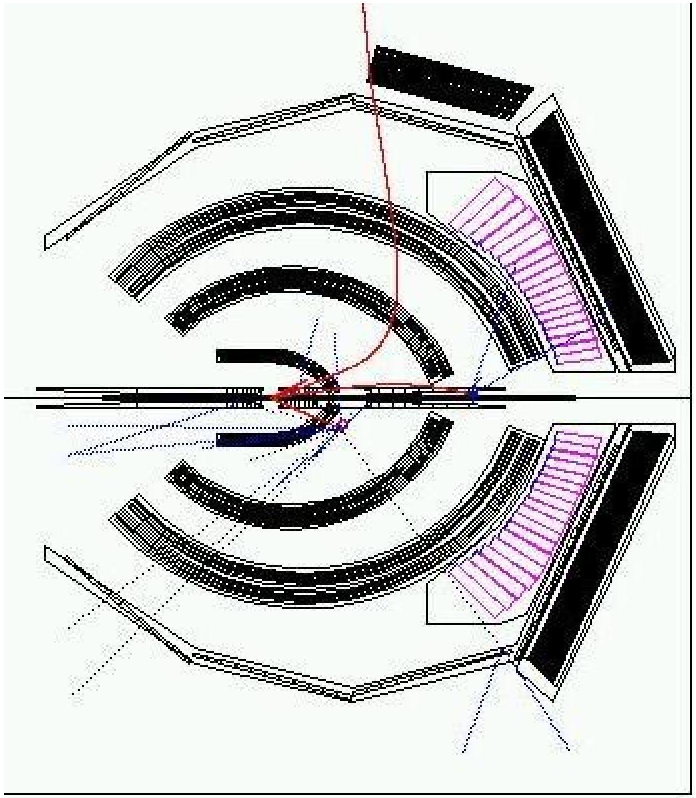
Why don't we see more Ξ^*?

- Maybe they're not there
  - Unlikely; several other observations
    - $\Xi(1820)$ is a 3-star state
    - BaBar just published J^P for $\Xi(1690)$
- Maybe we don't have enough beam
  - More likely, but still…
- Maybe we need a better detector
  - Good place to start; improve K/π separation

Particle ID in CLAS

- Toroidal magnetic field bends away from or toward beam
- Drift chambers – momentum
- Scintillators – velocity
- $m = \frac{p}{\beta \gamma}$



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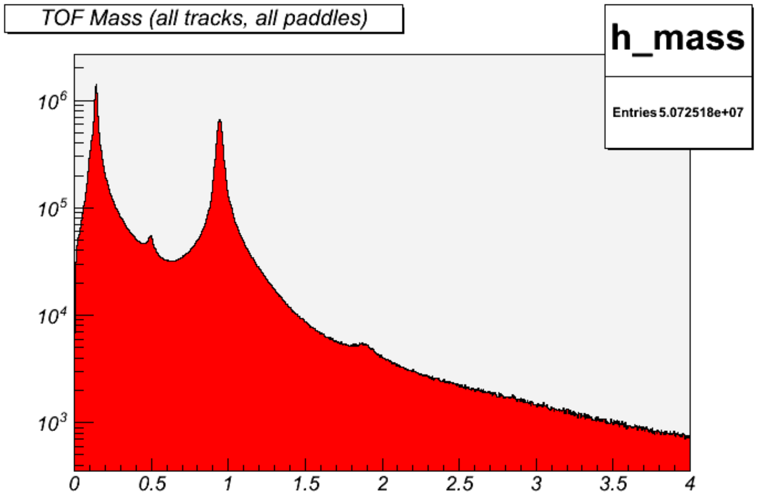
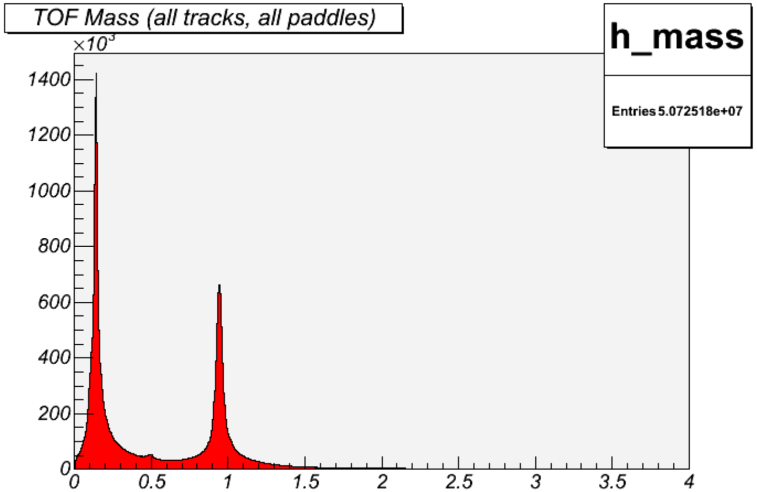
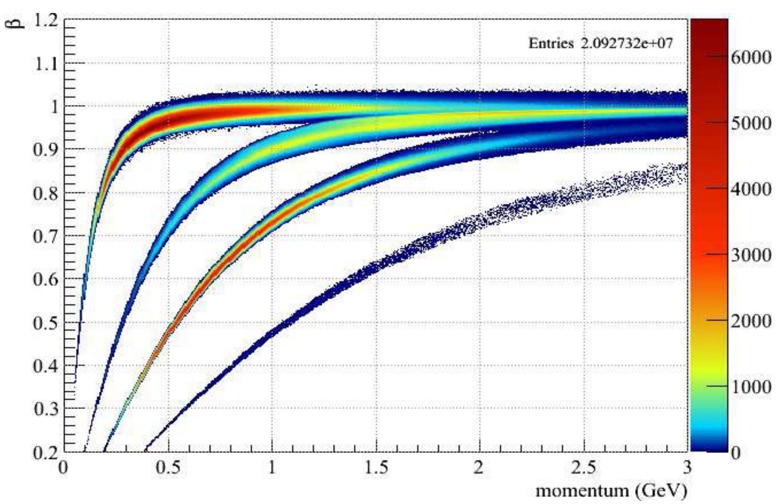
π/K production ratio

- Many more π, p than K
  - We lose 75% of events to K decay
- Good separation up to 1.5 GeV







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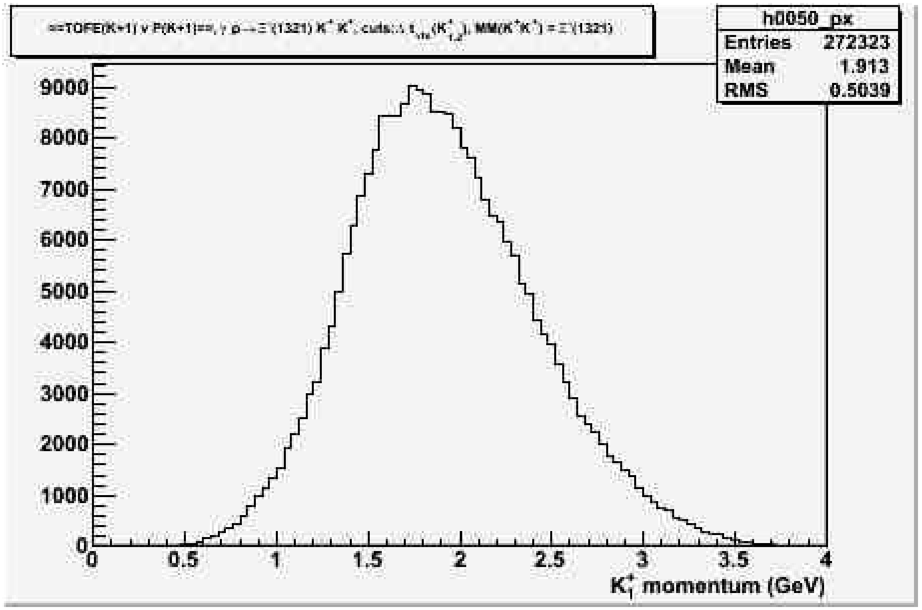
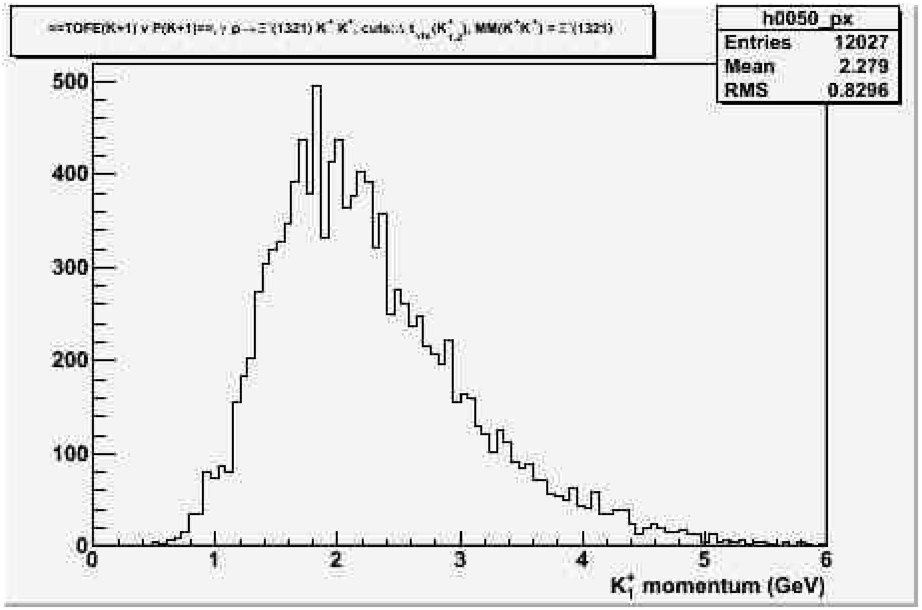
- In CLAS6, many of our kaons are above 2 GeV
- Even more pions above this energy
  - Hard to separate them with the current setup



Moving to 12 GeV

- There, it's only getting worse
- Many kaons above 2 GeV
- Doing this w/o a RICH (or some other "magic" way to do K/π separation) will lead to madness…



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Conclusions

- The JLab Ξ program is well-established
  - Two publications thus far; more to come from g12
  - Proposal for CLAS12 coming "real soon now…"
- Seeing excited states has proven difficult
  - Results from other labs encouraging
  - Good π/K separation critical
- RICH detector may well be the key to success

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