Cross Section Analysis for $\Xi^{*-}(1530)$ in the reaction $\gamma p \rightarrow K^+ K^+ \Xi^{*-}(1530)$

Brandon Sumner*

*Special thanks to NSF, Brandon Sumner is supported to conduct this research through the MPS ASCEND postdoctoral fellowship

ASU

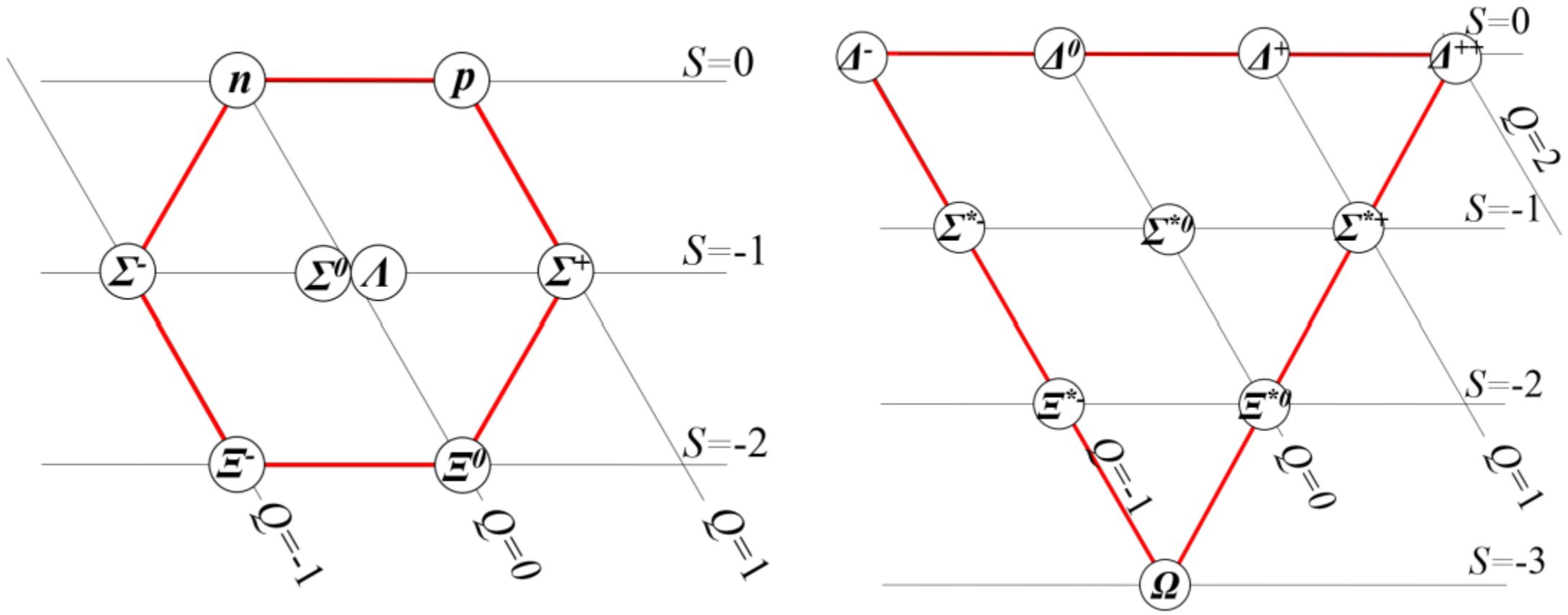
Motivation – Mapping Cascade Spectrum

- For a baryon we combine three, three-dimensional representations of the SU(3) (u, d, s) flavor symmetry produces 27 states:

$$\mathbf{3} \otimes \mathbf{3} \otimes \mathbf{3} = 10_S \oplus 8_{MS} \oplus 8_{MA} \oplus 1_A$$

- The combination of the three fundamental representations produce a decuplet (10), two octets (8) and one singlet state.

Ground State Baryon Decuplet and Octet



Mapping Cascade Spectrum

Particle	J^P	Overall Status
$\Xi(1318)$	$1/2^+$	****
$\Xi(1530)$	$3/2^+$	****
$\Xi(1620)$		*
$\Xi(1690)$		***
$\Xi(1820)$	$3/2^-$	***
$\Xi(1950)$		***
$\Xi(2030)$	$5/2^?$	***
$\Xi(2120)$		*
$\Xi(2250)$		**
$\Xi(2370)$		**

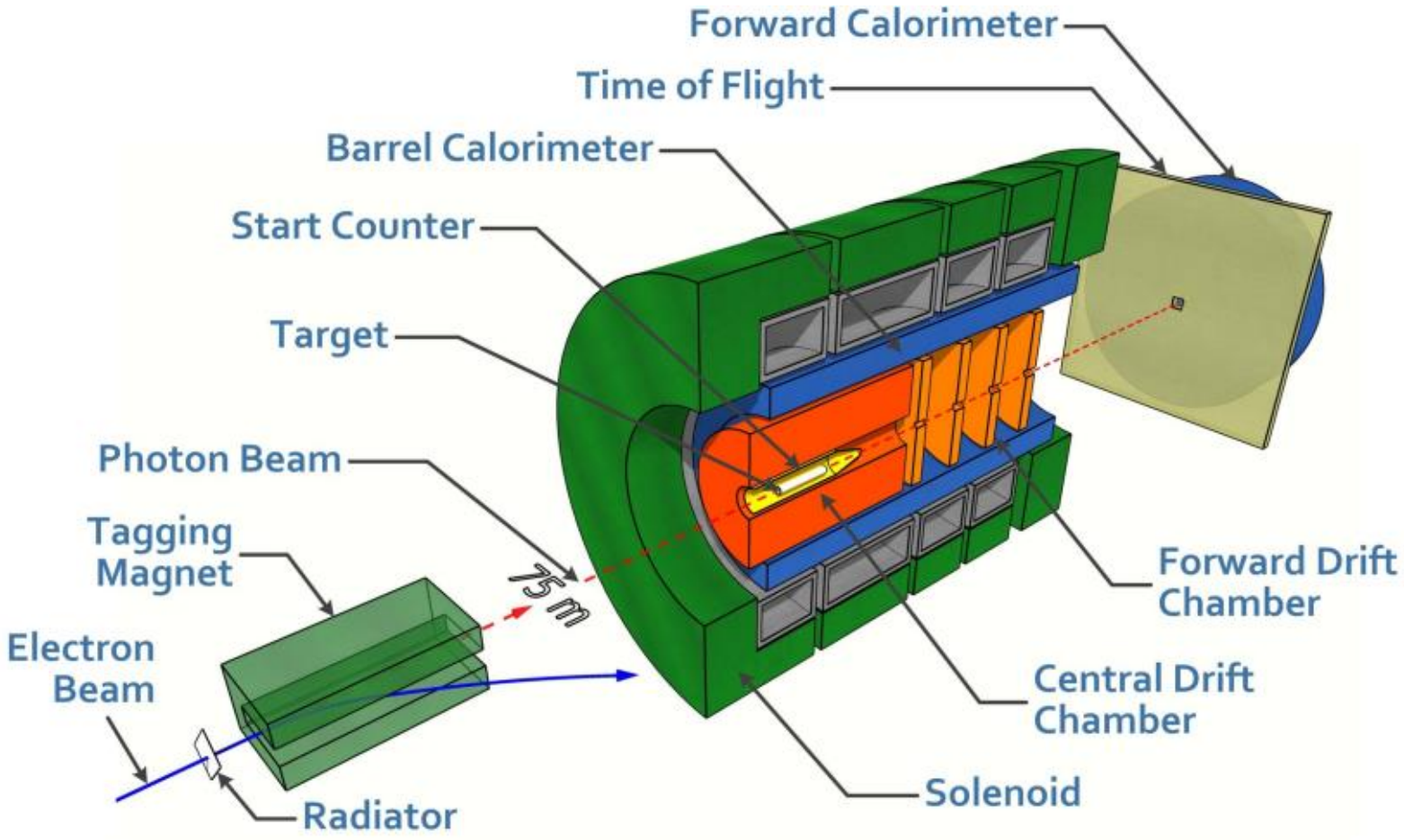
- Current list of states in PDG with mass less than 2.4 GeV/c^2

Branching Fractions

State	ΛK	ΣK	$\Xi\pi$
$\Xi(1530)$			100 %
$\Xi(1690)$	seen	seen	seen
$\Xi(1820)$	large	small	small
$\Xi(1950)$	seen	seen?	seen
$\Xi(2030)$	20%	80%	small

- Per the PDG all the $\Xi(1530)$s decay $\Xi\pi$, while for higher mass cascade states this channel is suppressed
- The $\Xi(1530)$ is below threshold for the ΛK or ΣK channel

GlueX Spectrometer



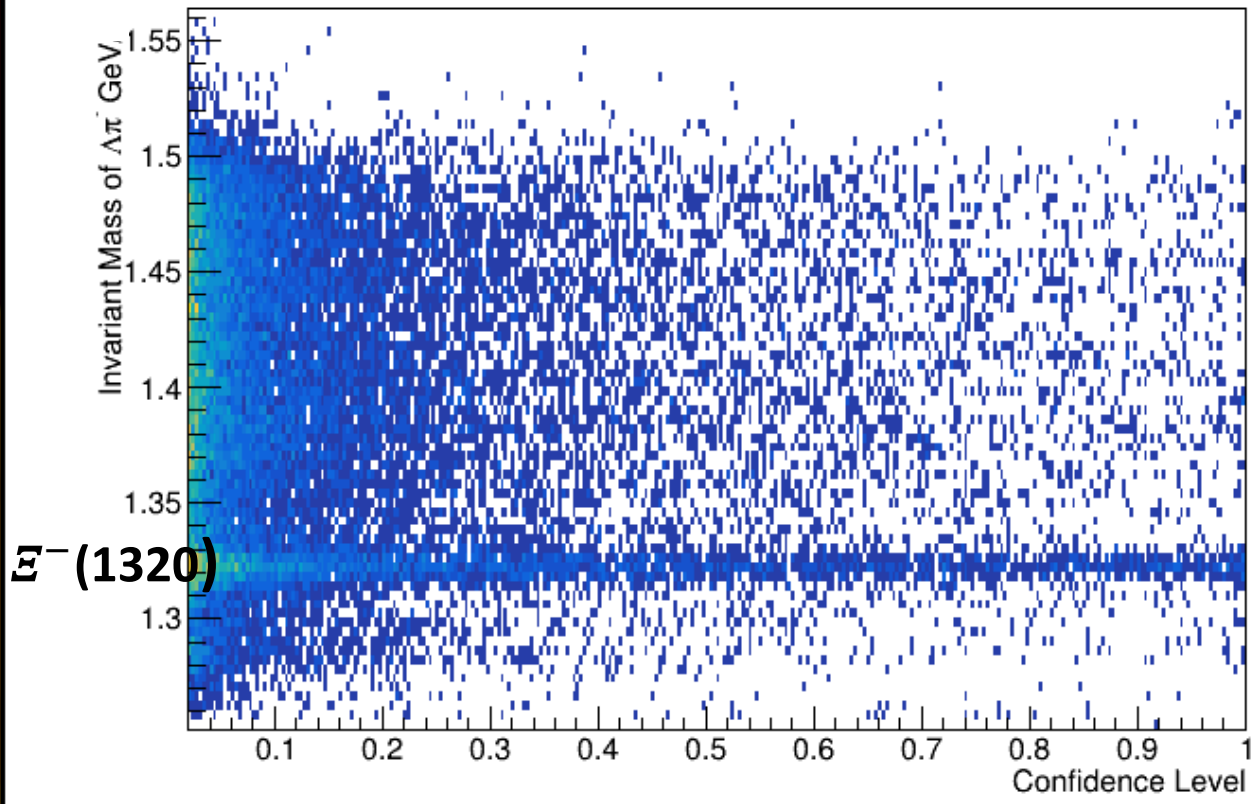
S. Adhikari, et al. NIMA 987 (2021) 164807

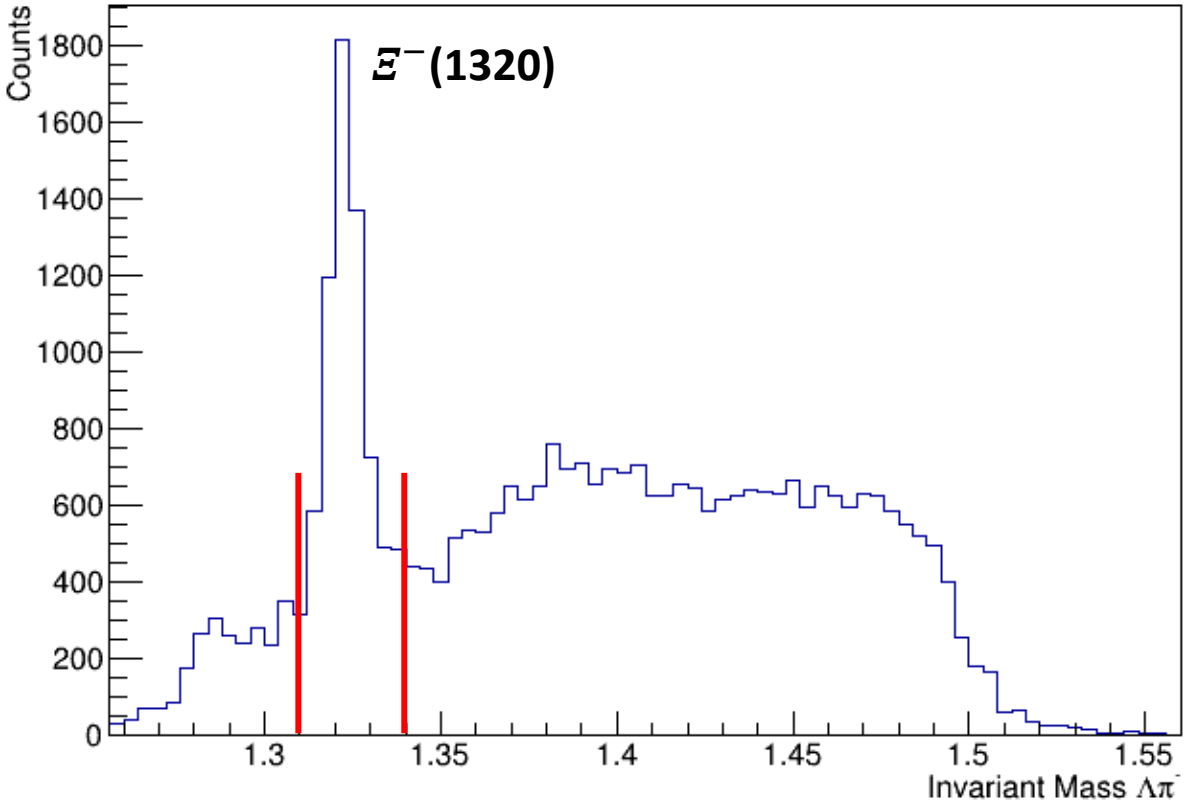
Decay Chain

$$\gamma p \rightarrow K^+ K^+ \Xi^{-*}$$
$$\Xi^{-*} \rightarrow \Xi^- \pi^0$$
$$\Xi^- \rightarrow \Lambda \pi^-$$
$$\Lambda \rightarrow p \pi^-$$

- The masses of Λ and pions are constrained to the known masses in the kinematic fit.
- Kinematically constrained refers to using vertex and four momentum constraints to improve the resolution of measured data and help distinguish between different reactions. The data for the above reaction uses both vertex and kinematic constraints.

$\Xi^-(1320)$ Selection





- Select events : $1.31 < \mathrm{Mass}(\Lambda\pi^-) < 1.34$ GeV

Background Contamination from K^*

- From the combinatorics of all final state particles, there can be background from processes including the $K^{+*}(892)$ associated with the reaction.

$$\gamma p \rightarrow K^+ K^+ \bar{\Xi}^{-*}$$

$$\bar{\Xi}^{-*} \rightarrow \bar{\Xi}^- \pi^0$$

$$\gamma p \rightarrow K^+ (K^+ \pi^0) \bar{\Xi}^-$$

$$K^{*+} \rightarrow K^+ \pi^0$$

Background Contamination from K^*

- From the combinatorics of all final state particles, there can be background from processes including the $K^{+*}(892)$ associated with the reaction.

$$\gamma p \rightarrow K^+ K^+ \Xi^{-*}$$

$$\Xi^{-*} \rightarrow \Xi^- \pi^0$$

$$\gamma p \rightarrow K^+ (K^+ \pi^0) \Xi^-$$

$$K^{*+} \rightarrow K^+ \pi^0$$

Background Contamination from K^*

- From the combinatorics of all final state particles, there can be background from processes including the $K^{+*}(892)$ associated with the reaction.

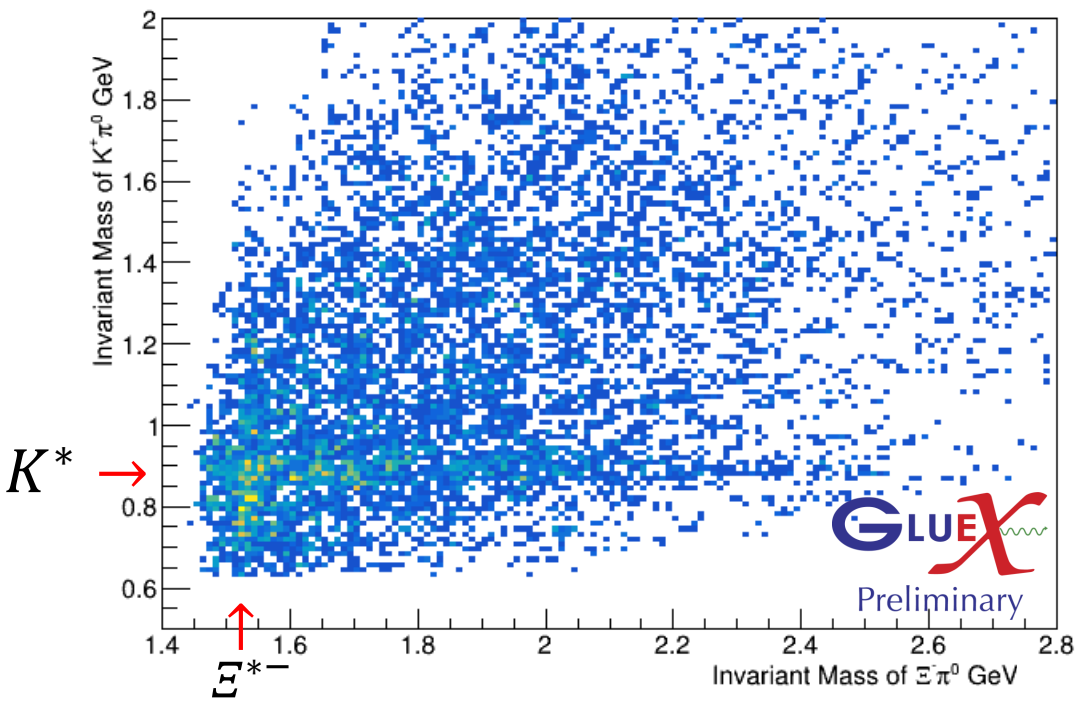
$$\gamma p \rightarrow K^+ K^+ \Xi^{-*}$$

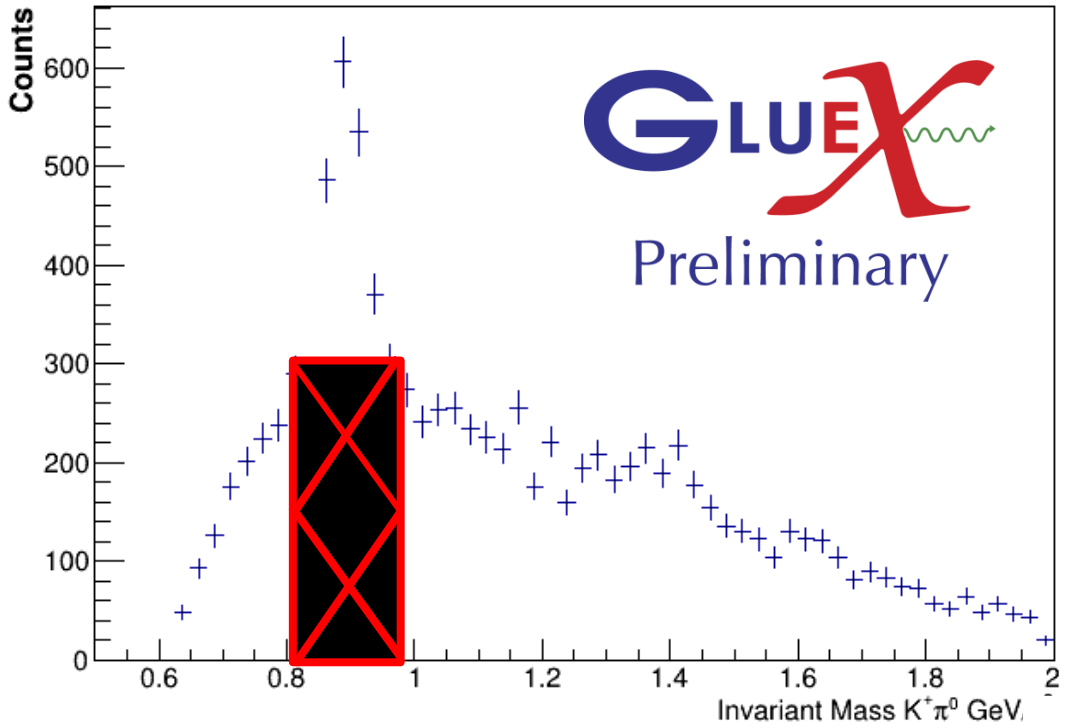
$$\Xi^{-*} \rightarrow \Xi^- \pi^0$$

$$\gamma p \rightarrow K^+ (K^+ \pi^0) \Xi^-$$

$$K^{*+} \rightarrow K^+ \pi^0$$

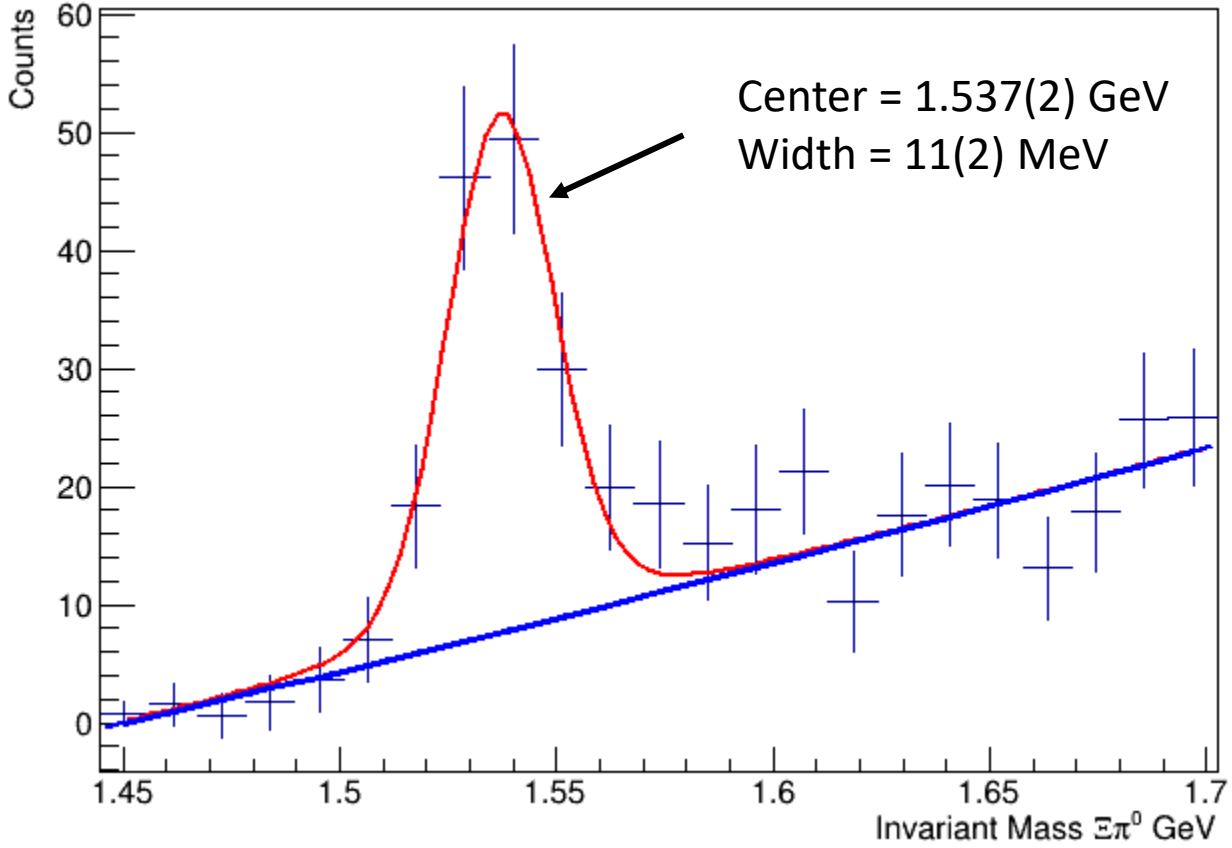
Background Contamination from K^{*+}





- Reject events associated with $K^{*+} \rightarrow K^+\pi^0$ background

Invariant Mass of $\Xi^-\pi^0$ System



Ξ(1530) 3/2⁺ $I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$

$\Xi(1530)^0$ mass $m = 1531.80 \pm 0.32$ MeV (S = 1.3)
$\Xi(1530)^-$ mass $m = 1535.0 \pm 0.6$ MeV
$\Xi(1530)^0$ full width $\Gamma = 9.1 \pm 0.5$ MeV
$\Xi(1530)^-$ full width $\Gamma = 9.9^{+1.7}_{-1.9}$ MeV

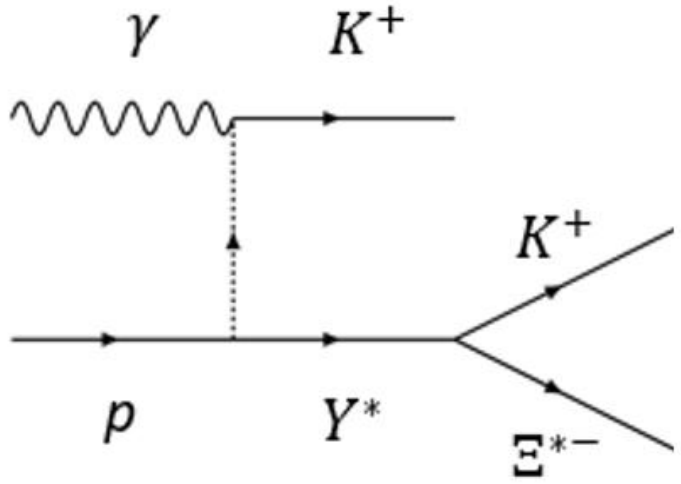
Ξ(1530) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$\Xi\pi$	100 %		158
$\Xi\gamma$	<4 %	90%	202

Fit

- Signal
  - Voigtion – Convolution of breit-wigner distribution an a gaussian.
- Background
  - Second order polynomial.

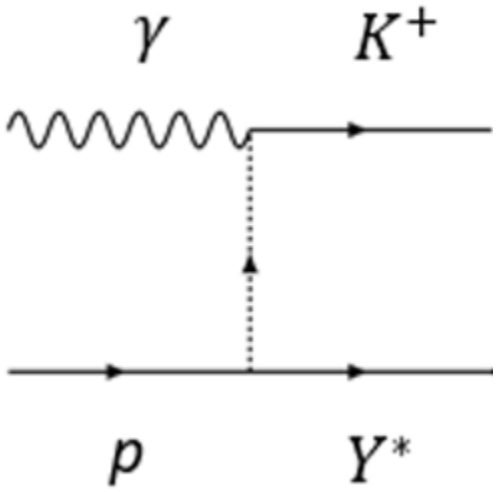
Modeling the Cascade Production in Signal MC

- Theoretical Calculations done by Nakayama, Oh and Haberzettl proposed the cascade/excited cascade are produced by a two-step process:



- Off the shelf event generators do not account for this intermediate hyperon.

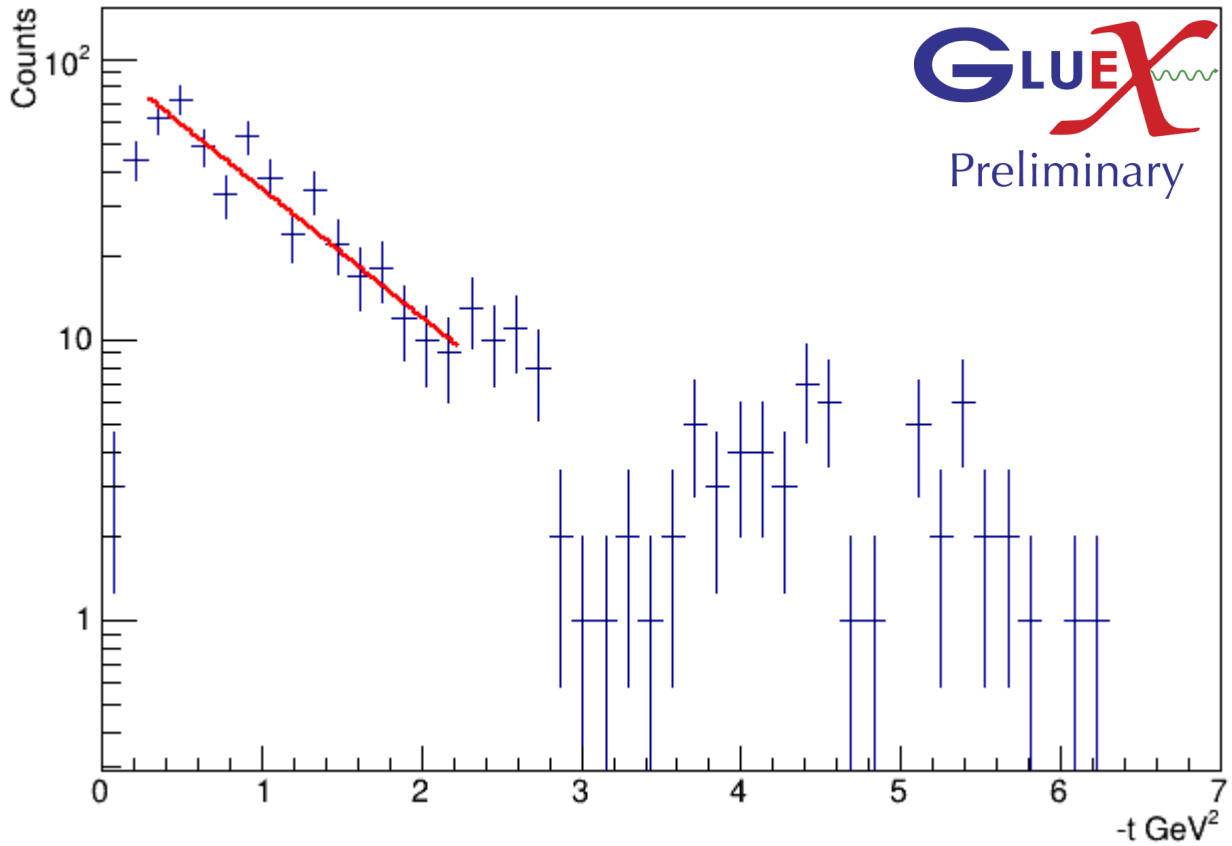
t-slope Extraction from Data



$$t = \left(P_\gamma - P_{K^+}\right)^2$$

Where the *t*-channel K^+ has the lower polar angle

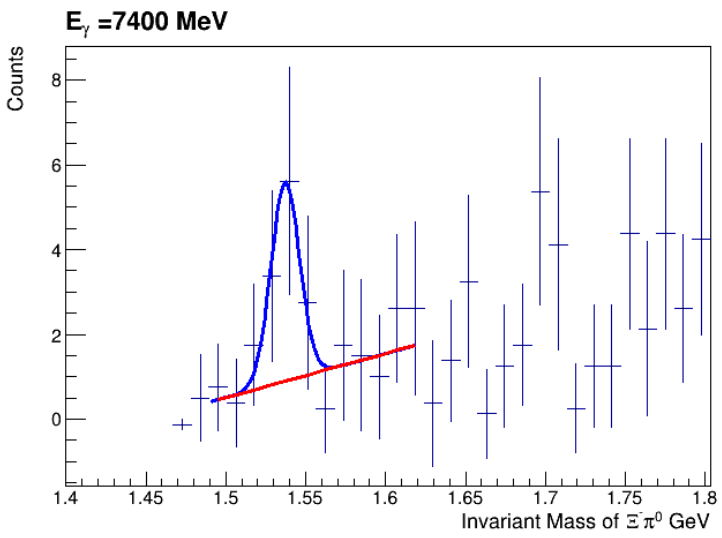
t-slope Extraction from Data

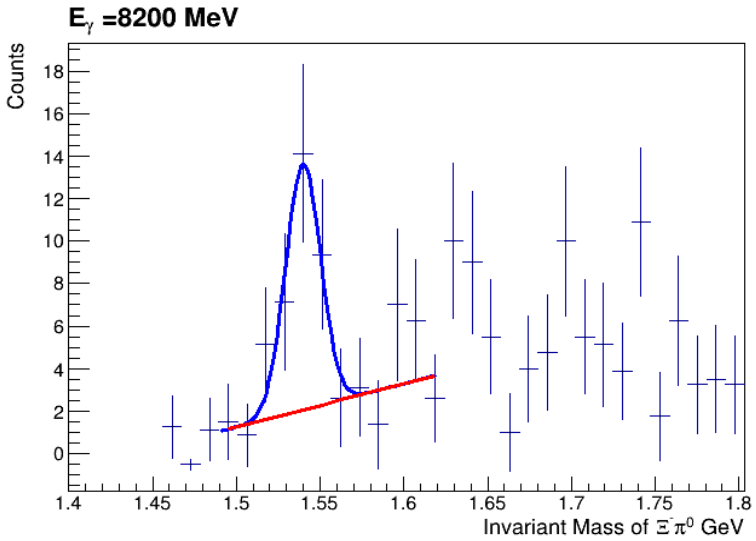


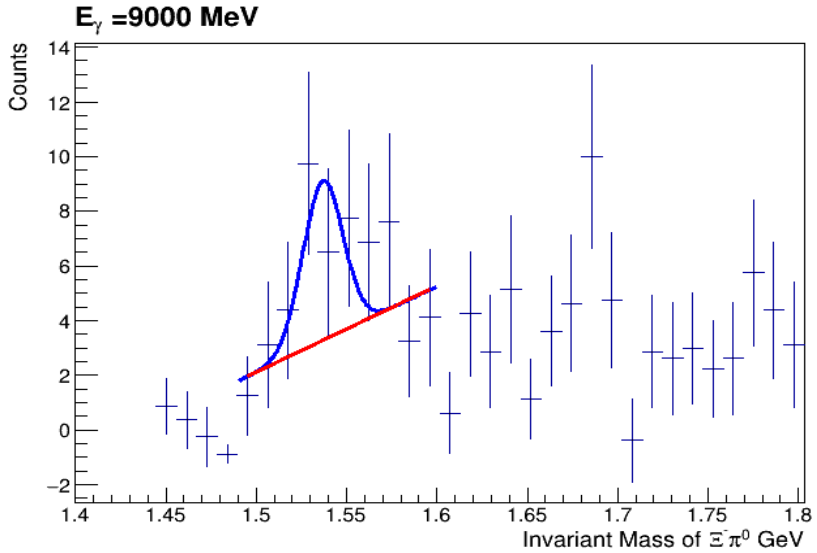
- Assuming: $\frac{d\sigma}{dt} \propto e^{-bt}$
  - *t*-slope: b = 1.05(8) Gev^2
  - Fit Range 0.3 < -*t* < 2.20 GeV^2

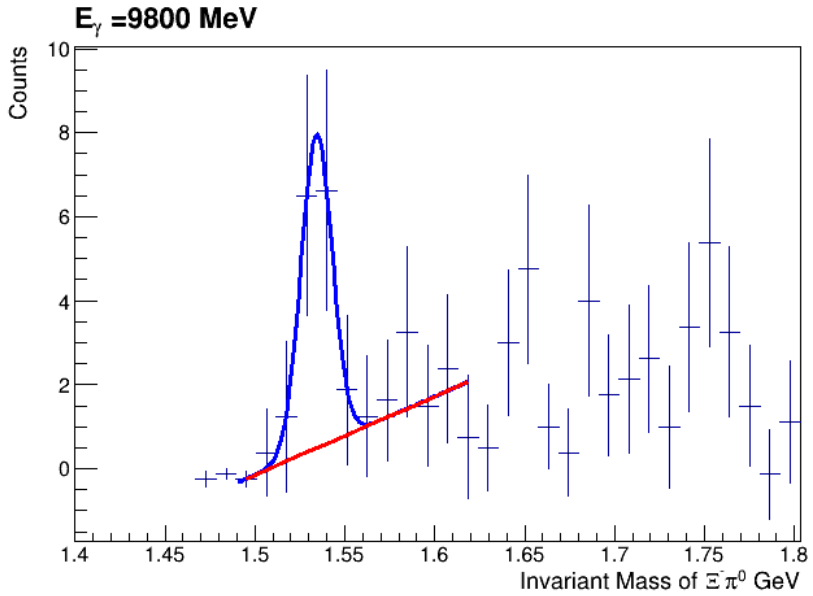
ASU Arizona State University

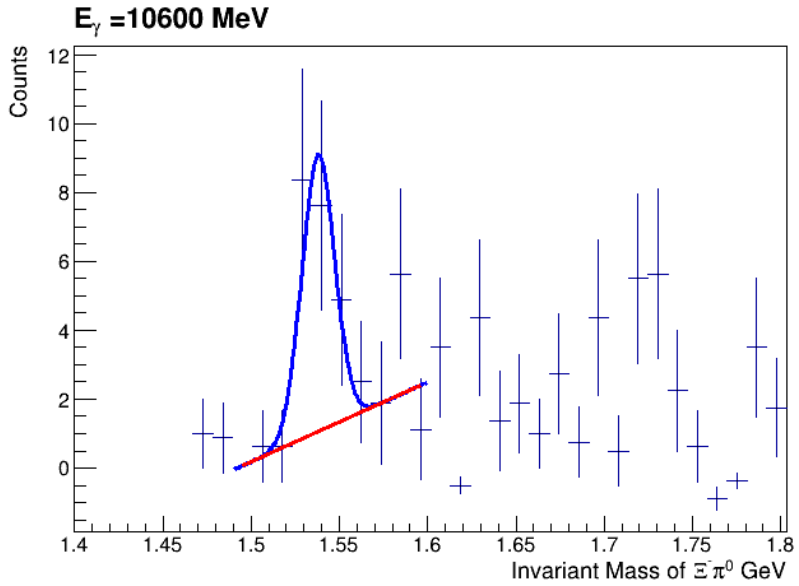
Energy-dependent $\Xi(1530)$ Yield Extraction, ~1/2 GlueX Phase I Data



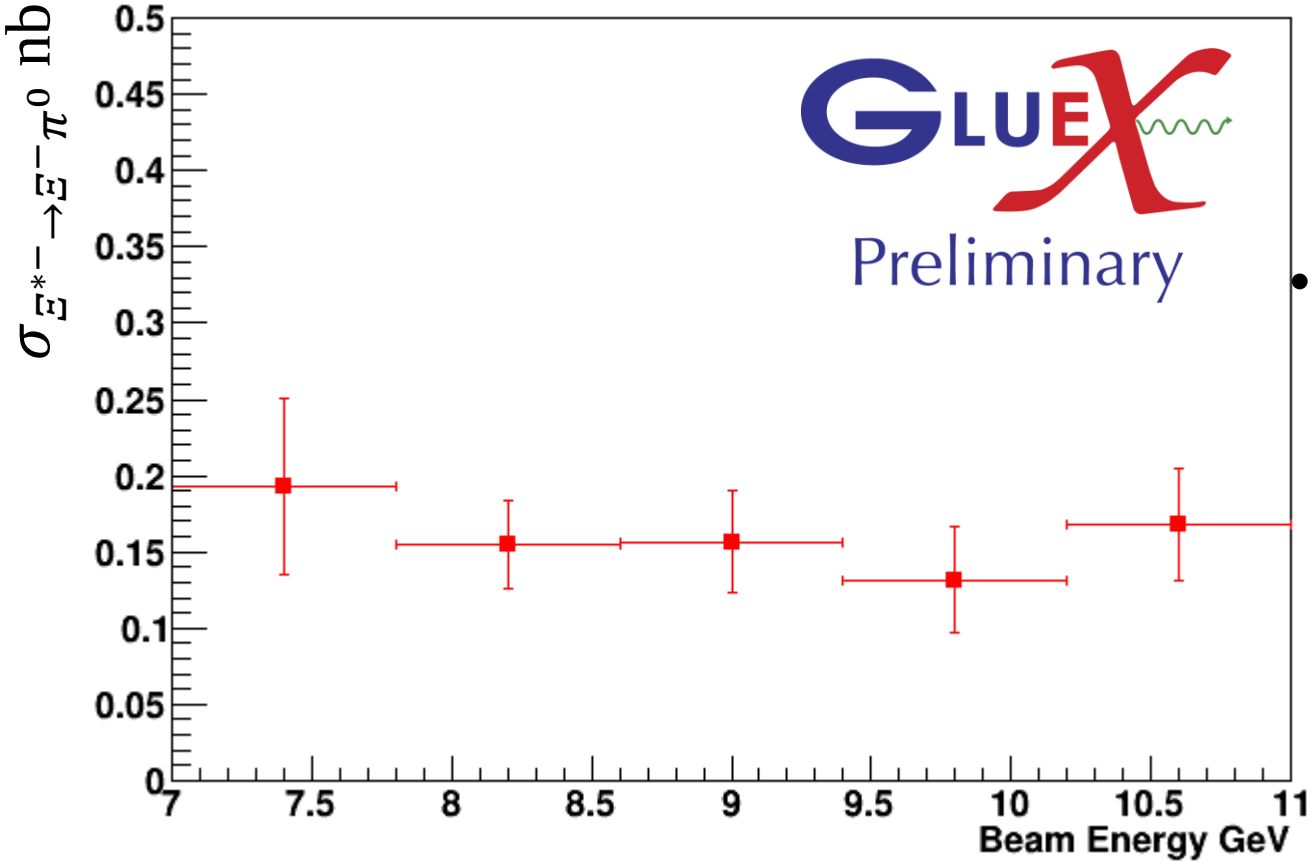








Photoproduction Cross Section for $\Xi(1530) \rightarrow \Xi^{-}\pi^{0}$



- Small, non-zero value with no significant energy dependence

$$< \sigma > = 0.16 \text{ nb}$$
$$\text{Standard Deviation} = 0.06 \text{ nb}$$

STATISTICAL UNCERTAINTIES ONLY

Charge Exchange Reaction Decay Chain

$$\gamma p \rightarrow K^+ K^+ \bar{\Xi}^{-*}$$

$$\bar{\Xi}^{-*} \rightarrow \bar{\Xi}^0 \pi^-$$

$$\bar{\Xi}^0 \rightarrow \bar{\Lambda} \pi^0$$

$$\bar{\Lambda} \rightarrow \bar{p} \pi^+$$

Isospin Study Motivation

- This reaction $\Xi^* \rightarrow \Xi\pi$ conserves isospin. Using Clebsch-Gordan coefficients we can that determine the neutral cascade channel should occur twice as often.

$$\left|\frac{1}{2}, -\frac{1}{2}\right\rangle = \sqrt{\frac{1}{3}}\left[|1,0\rangle\left|\frac{1}{2}, -\frac{1}{2}\right\rangle\right] - \sqrt{\frac{2}{3}}\left[|1,-1\rangle\left|\frac{1}{2}, \frac{1}{2}\right\rangle\right],$$

$$|\Xi^{-*}\rangle = \sqrt{\frac{1}{3}}|\pi^0\Xi^-\rangle - \sqrt{\frac{2}{3}}|\pi^-\Xi^0\rangle$$

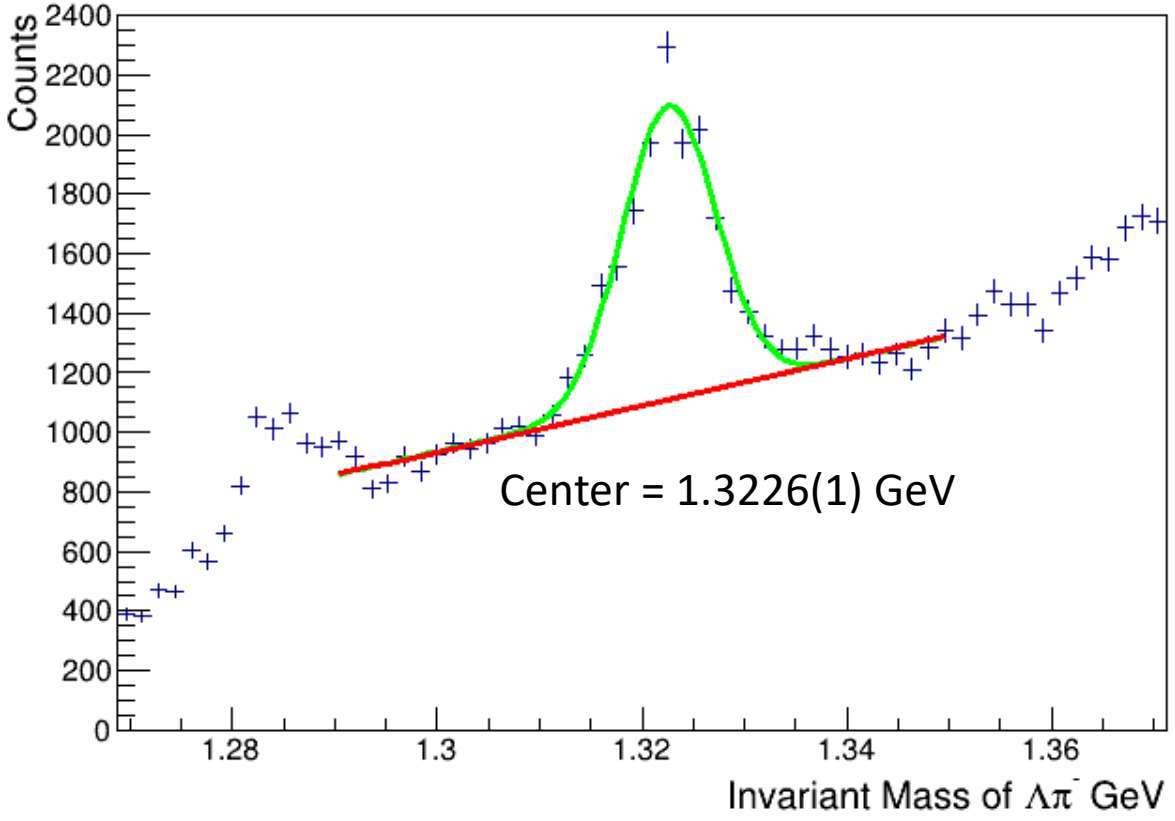
Isospin Study Motivation

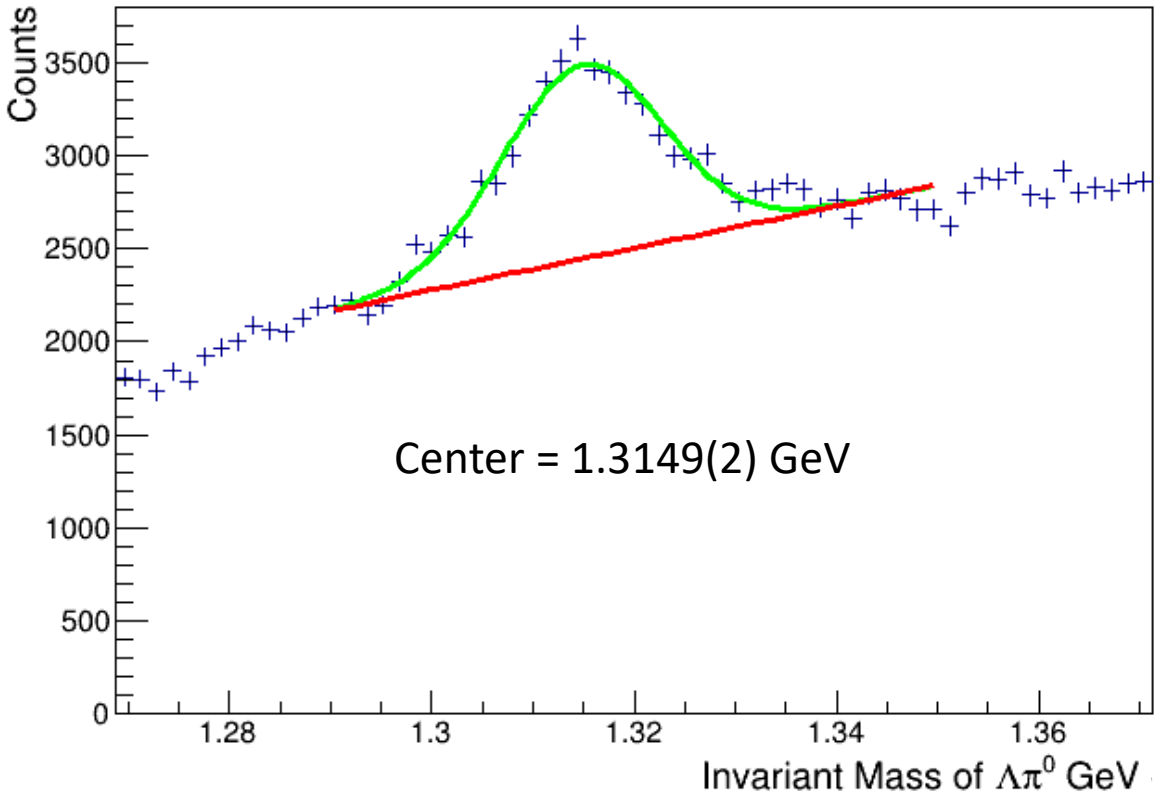
- This reaction $\Xi^* \rightarrow \Xi\pi$ conserves isospin. Using Clebsch-Gordan coefficients we can that determine the neutral cascade channel should occur twice as often.

$$\left|\frac{1}{2}, -\frac{1}{2}\right\rangle = \sqrt{\frac{1}{3}}\left[|1,0\rangle\left|\frac{1}{2}, -\frac{1}{2}\right\rangle\right] - \sqrt{\frac{2}{3}}\left[|1,-1\rangle\left|\frac{1}{2}, \frac{1}{2}\right\rangle\right],$$

$$|\Xi^{-*}\rangle = \sqrt{\frac{1}{3}}|\pi^0\Xi^-\rangle - \sqrt{\frac{2}{3}}|\pi^-\Xi^0\rangle$$

Yields from Reconstructed Ground State Cascade

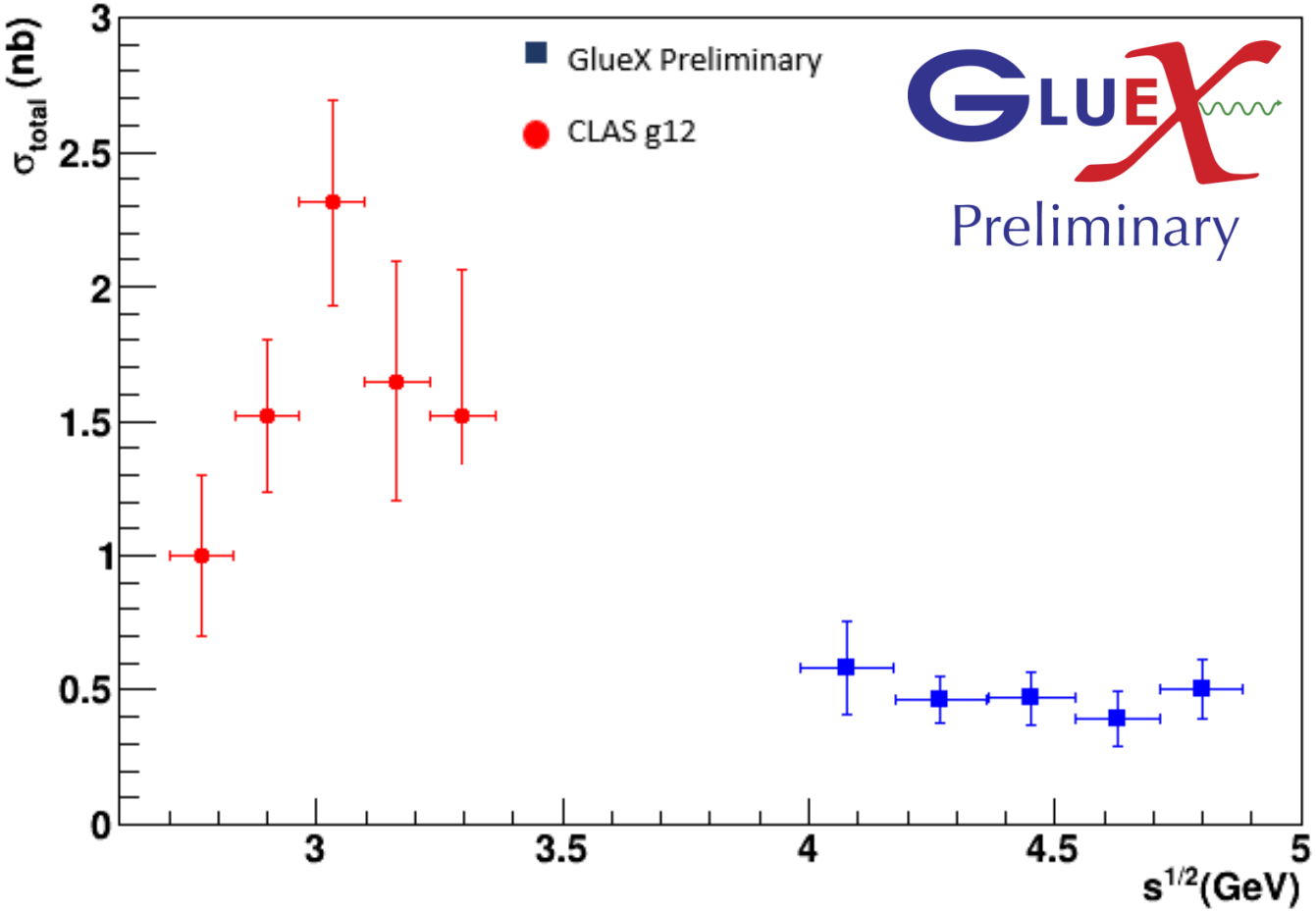




$$\frac{N[\Xi^{-}(1320)]}{N[\Xi^{0}(1320)]} = 0.54(2)$$

$$\Delta m_{\Xi_{EXP}} = m_{\Xi^{-}} - m_{\Xi^{0}} = 7.7(2)\text{MeV}$$

Total $\Xi^{*-}(1530)$ Photoproduction Cross Section



$$\sigma_{\Xi^0\pi^-} = 2 * \sigma_{\Xi^-\pi^0}$$

$$\sigma_T = 3*\sigma_{\Xi^-\pi^0}$$

$$< \sigma > = 0.48 \text{ nb}$$

Standard Deviation $= 0.07$ nb

STATISTICAL UNCERTAINTIES ONLY

Conclusion and Thanks

- The preliminary $\Xi(1530)$ total photoproduction cross section is ~0.48 nb for 7 < E_γ<11.0 GeV.
- Yields for $\Xi^-\pi^0$ and $\Xi^-\pi^0$ consistent with isospin conservation.
- Further investigation of the $\Xi\pi$ decay spectrum and systematic studies are underway
- GlueX acknowledges the support of several funding agencies and computing facilities
  - http://gluex.org/thanks

ASU

End