Search for Excited Ξ states and Preliminary Cross Section for $\Xi(1530)$

Brandon Sumner

Outline

- Preliminary total $\Xi^{*-}(1530)$ cross section
- PWA of the $\Xi(1530)$

Preliminary $\Xi^{*-}(1530) \rightarrow \Xi^{-}\pi^{0}$ cross section

Decay chain

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

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

$$\Xi^- \rightarrow \Lambda \pi^-$$

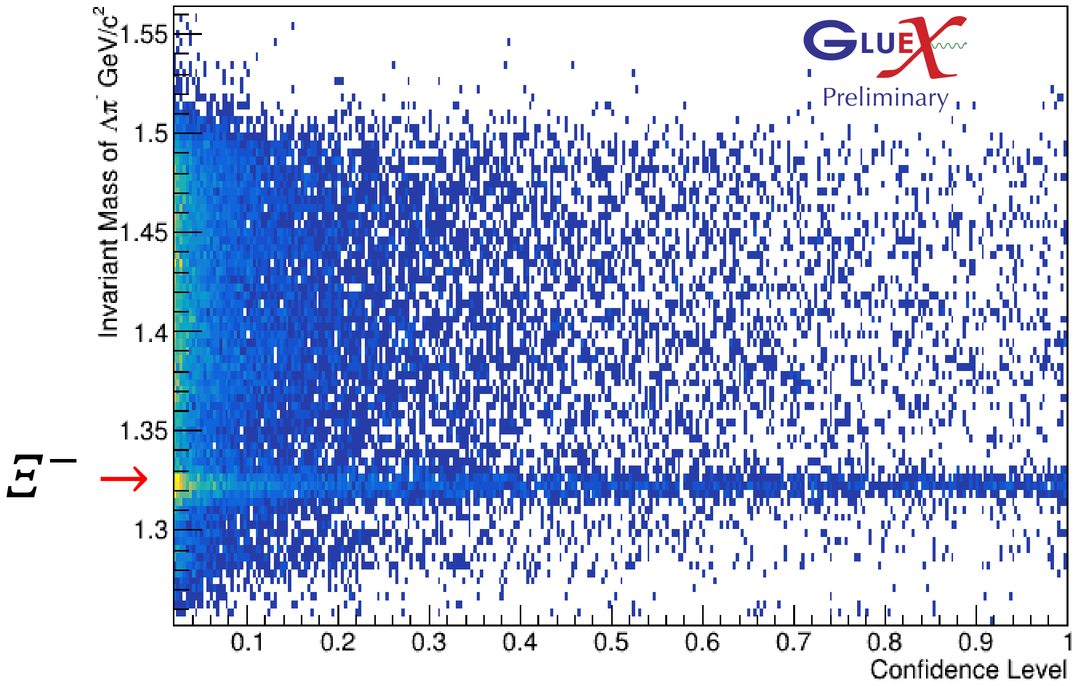
Note: $\pi^0 \rightarrow \gamma\gamma$ and $\Lambda \rightarrow p\pi^-$

Decay chain

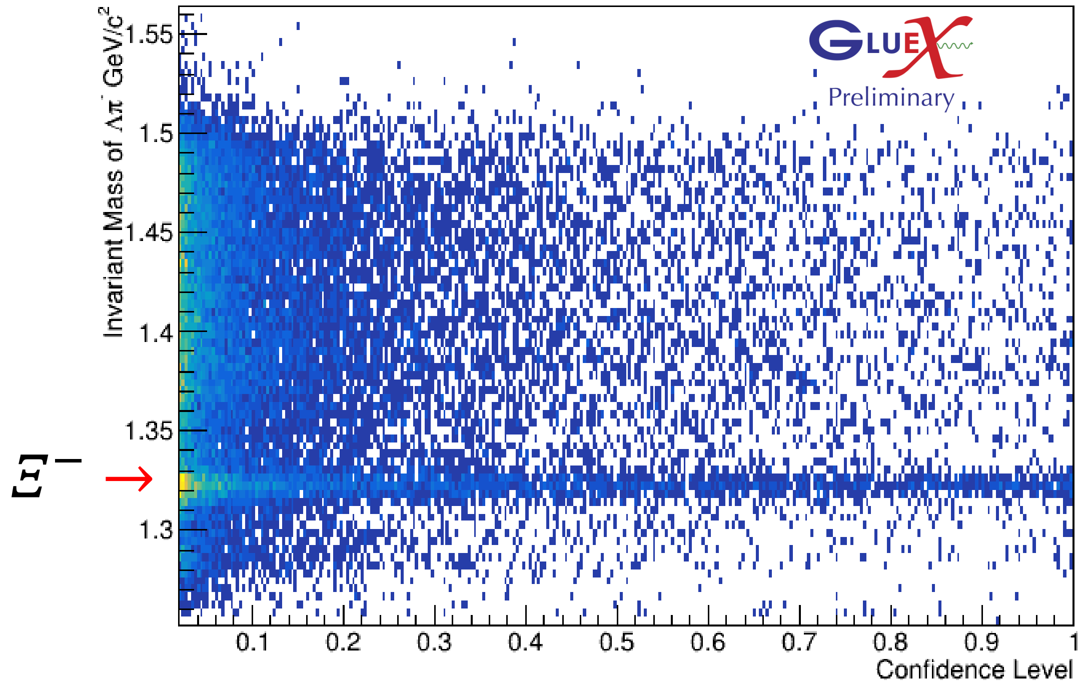
$$\gamma p \rightarrow K^+ K^+ \Xi^{-*}$$
$$\Xi^{-*} \rightarrow \Xi^- \pi^0$$
$$\Xi^- \rightarrow \Lambda \pi^-$$

- The masses of Λ and $\pi' s$ are constrained to the known masses in the kinematic fit.
- To remove the background associated with low confidence level an analysis cut of confidence level above 10^{-4} was made

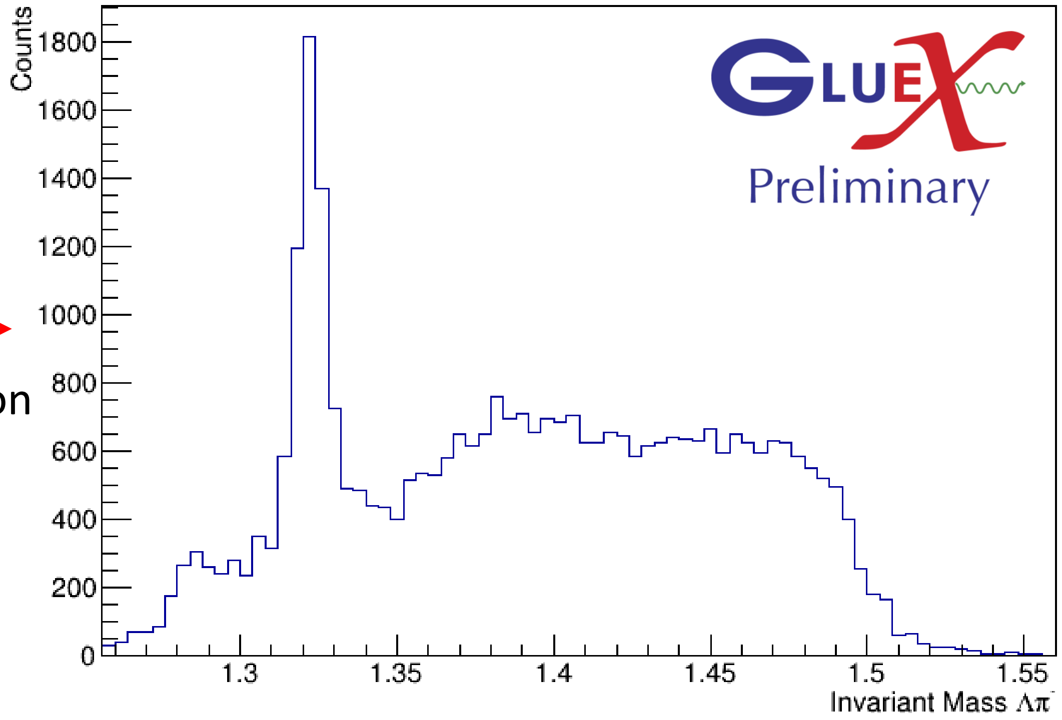
Ξ^- Invariant mass selection



Ξ^- Invariant mass selection



Y-Projection



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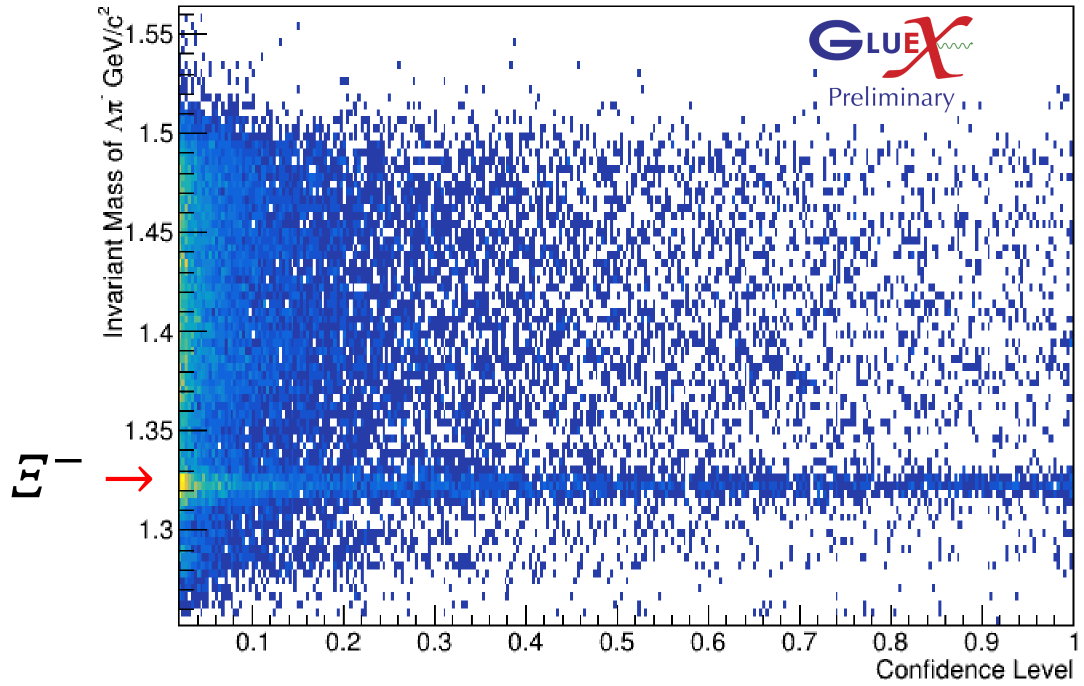
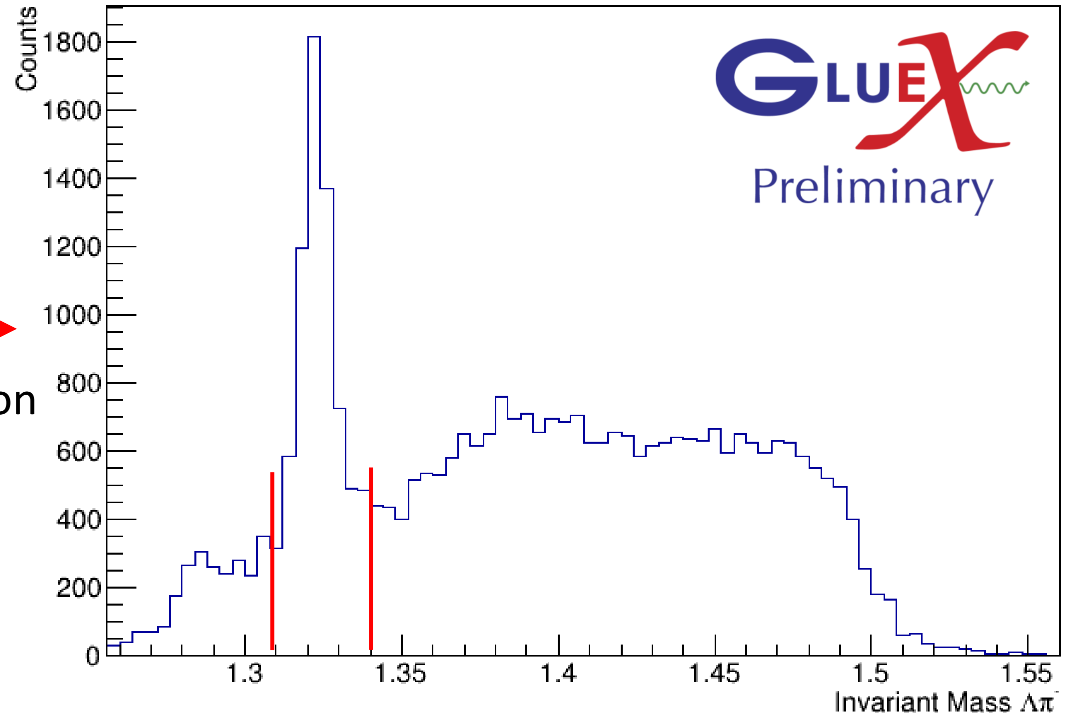


Y-Projection



- Cut around the signal of the ground state cascade

Background contamination from K^*

- From the combinatorics of all final state particles, there can be an incorrectly linked K^* meson associated with the reaction

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

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

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

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

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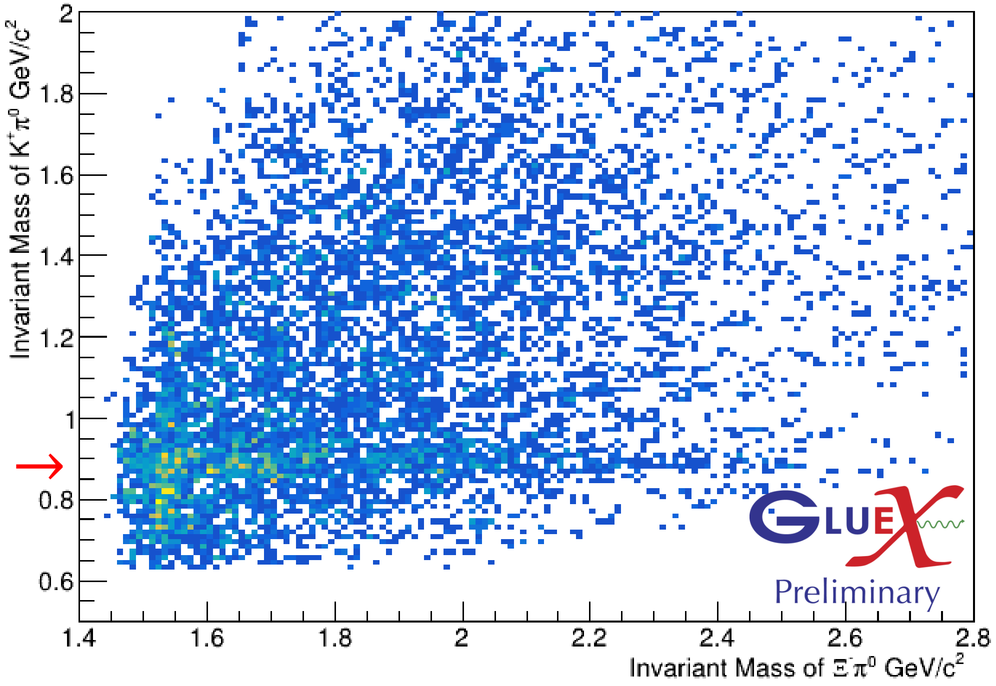
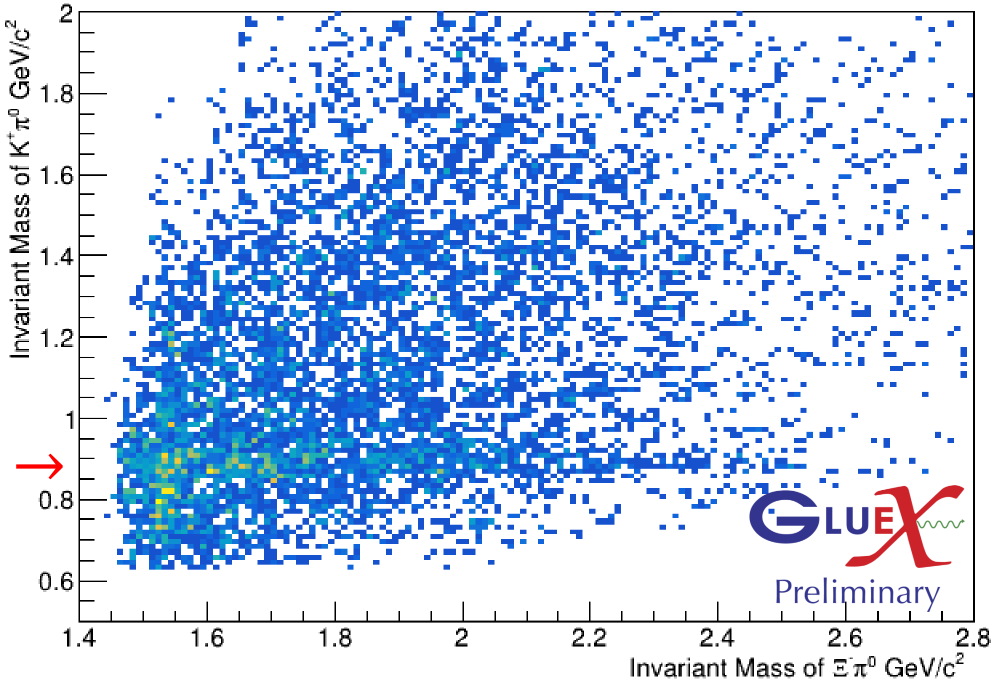
Background contamination from K^*

$K^* \rightarrow$

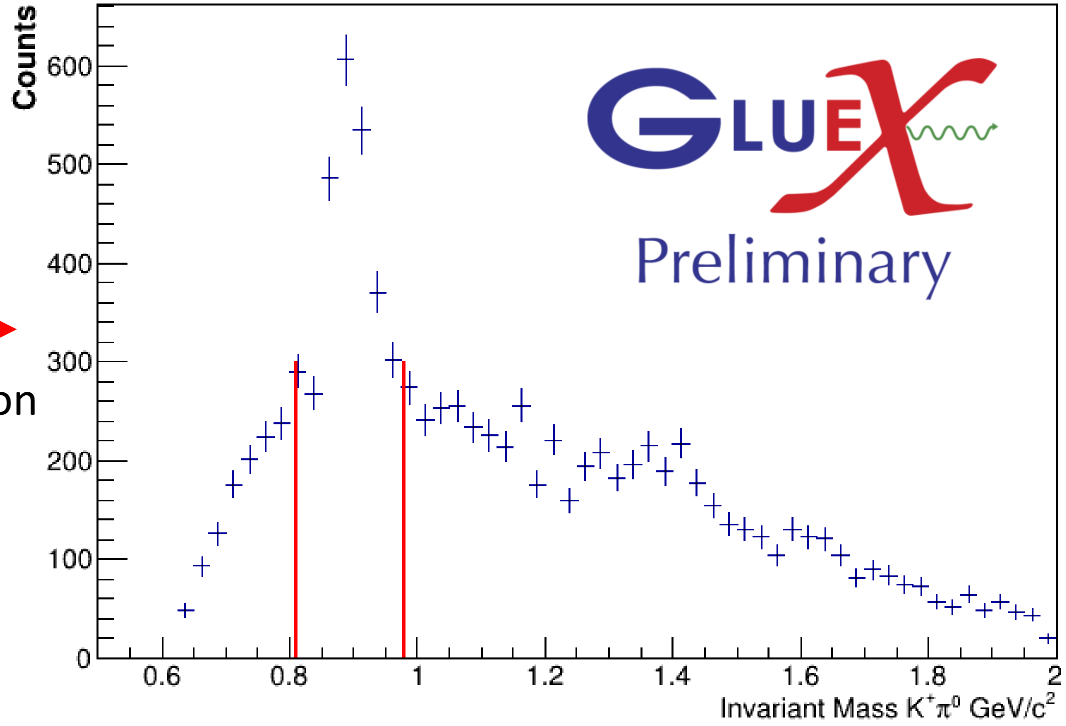


Background contamination from K^*

$K^* \rightarrow$

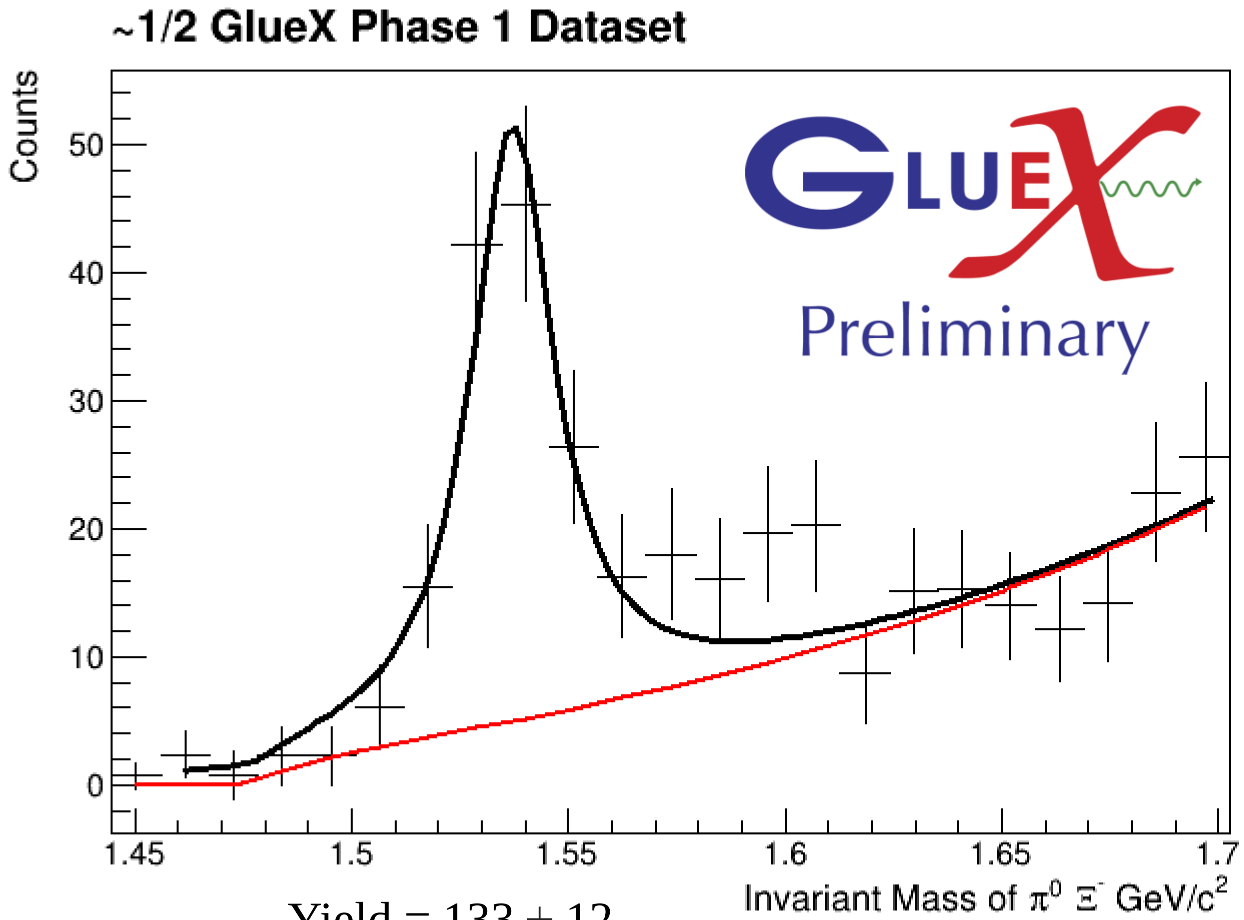


Y-Projection



- Reject events associated with $K^* \rightarrow K^+\pi^0$ contamination

Excited Cascade 1530 Reconstruction



Yield = 133 ± 12
Center = 1.537(2) GeV/c^2
Width = 12(3) MeV/c^2

$\Xi(1530)$ 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

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

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:

$$\gamma p \rightarrow K^{+} Y^{*}$$

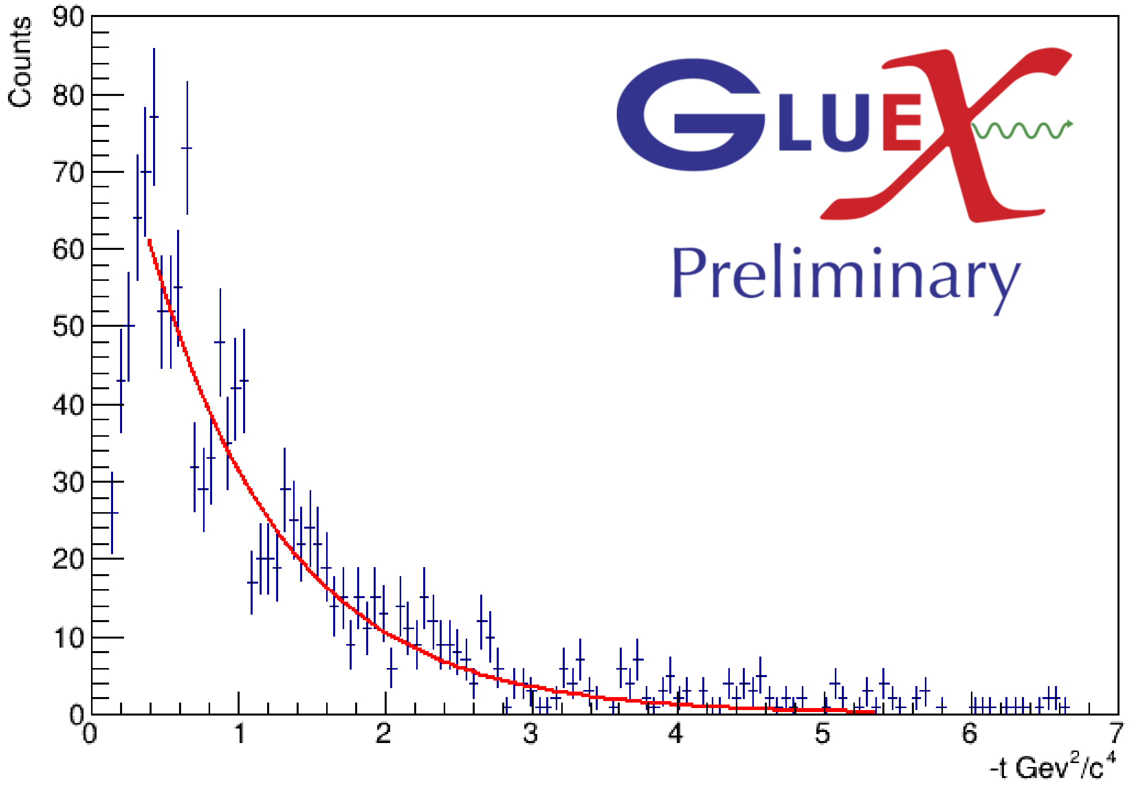
$$Y^{*} \rightarrow K^{+} \Xi^{-*}$$

- Direct production of the Ξ^{-*} would be OZI suppressed with two strange- antistrange pairs at the production vertex. Therefore, I defined t as $t = \left(P_{\gamma} - P_{K^{+}}\right)^{2}$

t-Slope extraction

- Selecting events within the excited cascade 1530 peak

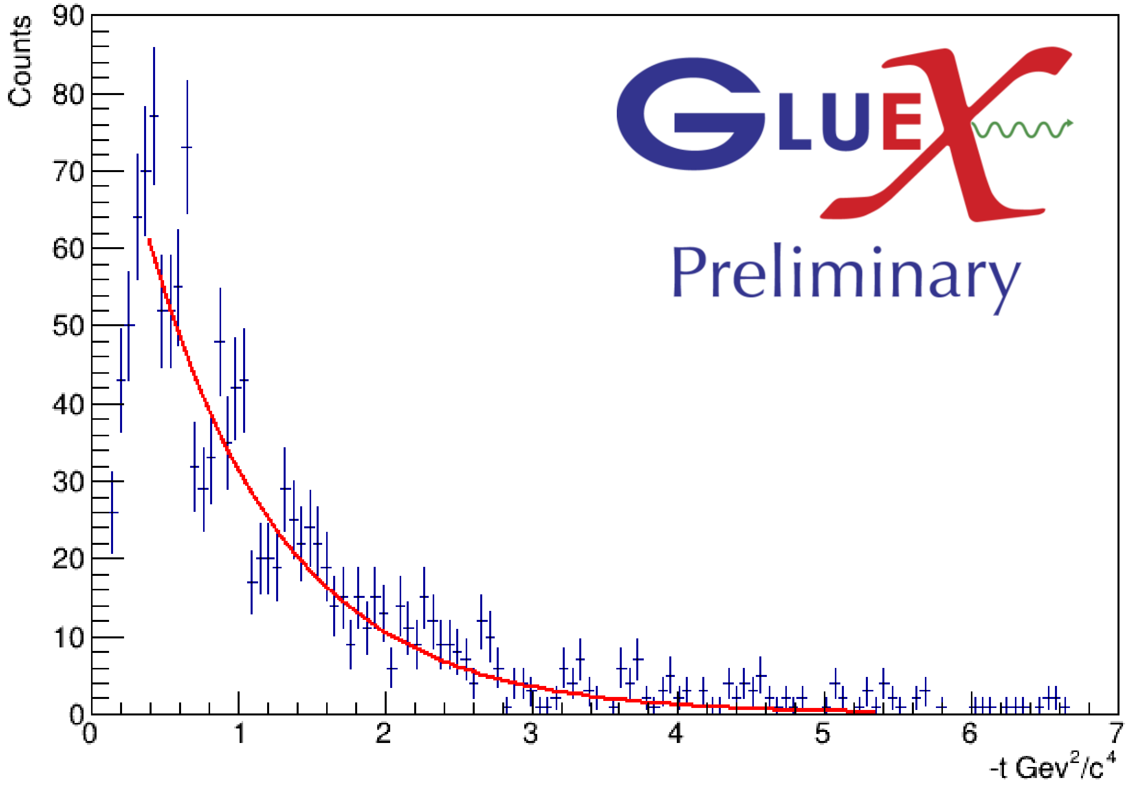
t-Slope extraction



- Selecting events within the excited cascade 1530 peak

- Assuming : $\frac{d\sigma}{dt} \propto e^{-bt}$

t-Slope extraction



- Selecting events within the excited cascade 1530 peak

- Assuming : $\frac{d\sigma}{dt} \propto e^{-bt}$

$$b = 1.08(4)/\mathrm{GeV}^2$$

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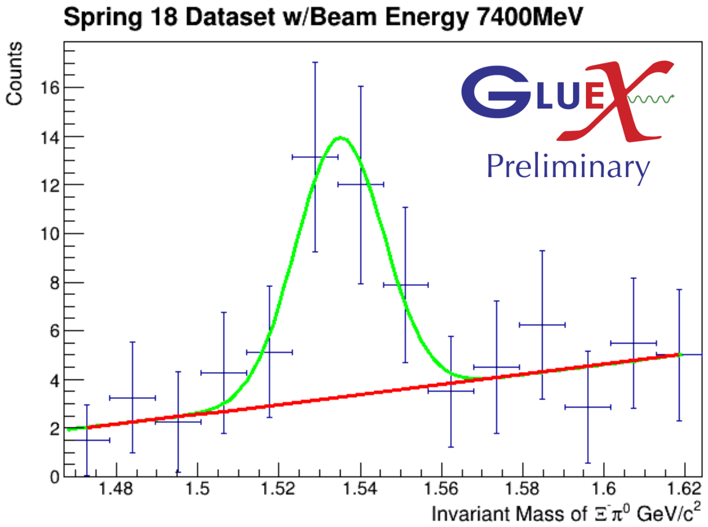
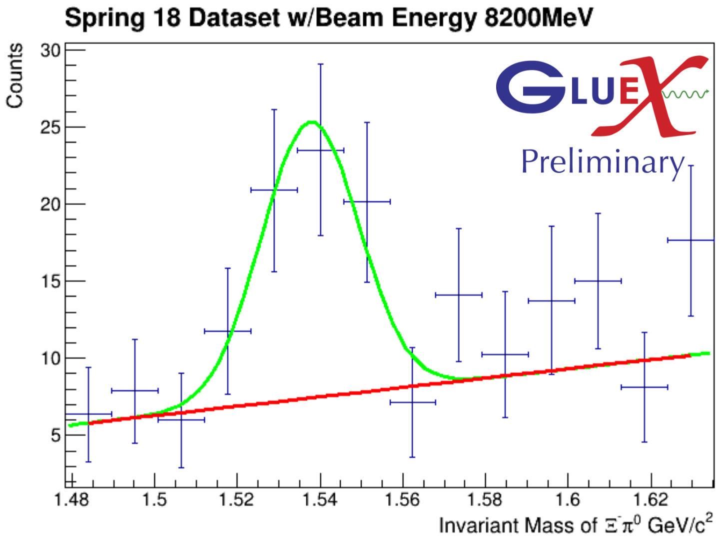
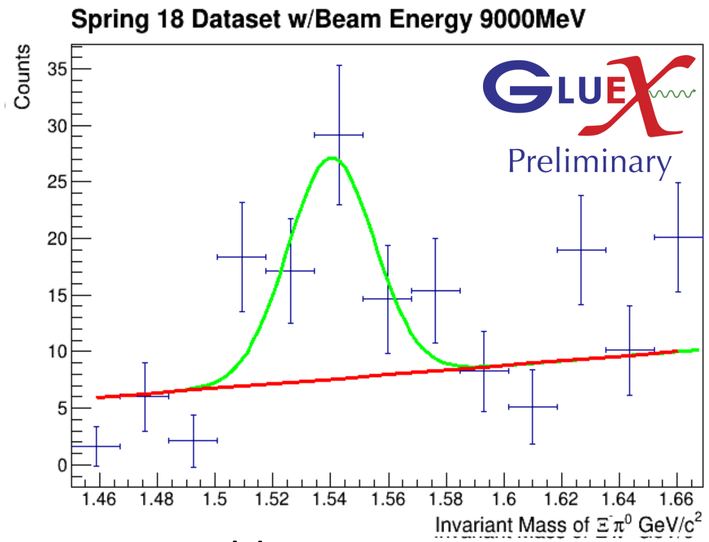
Energy-dependent Ξ(1530) Yield Extraction



Yield = 25 ± 5



Yield = 51 ± 7



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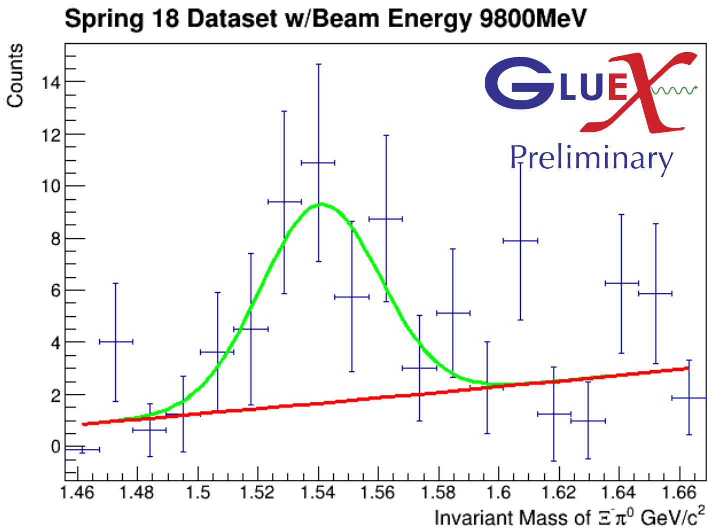
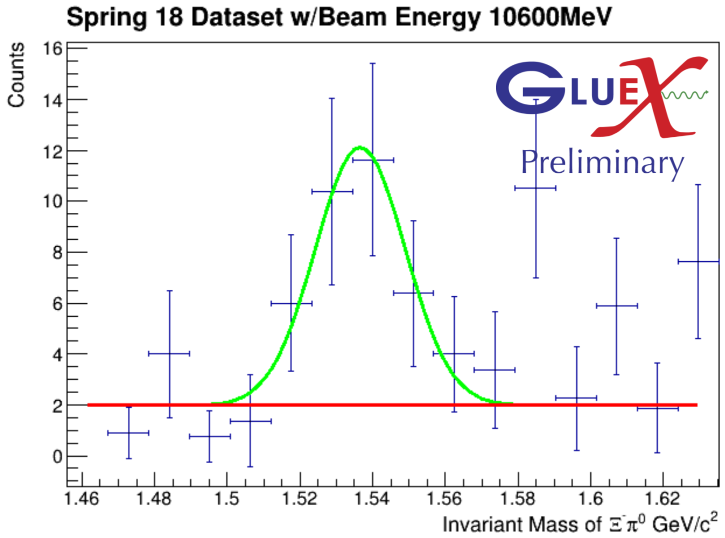
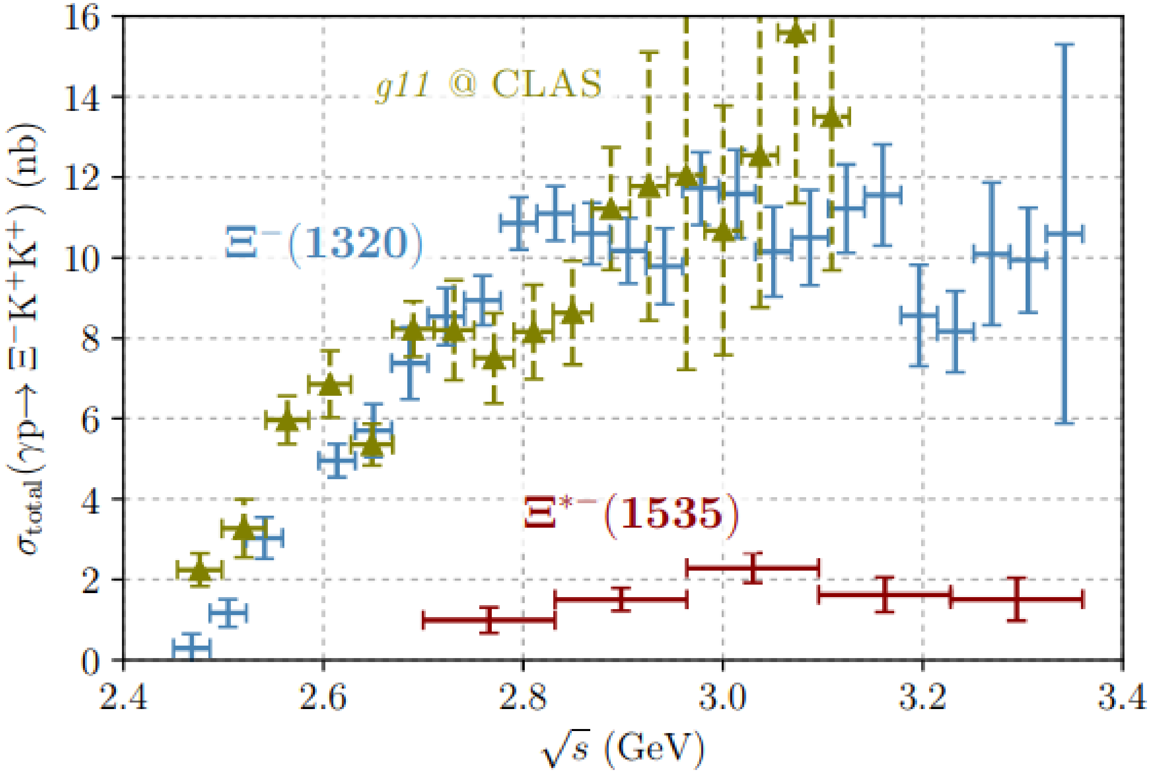


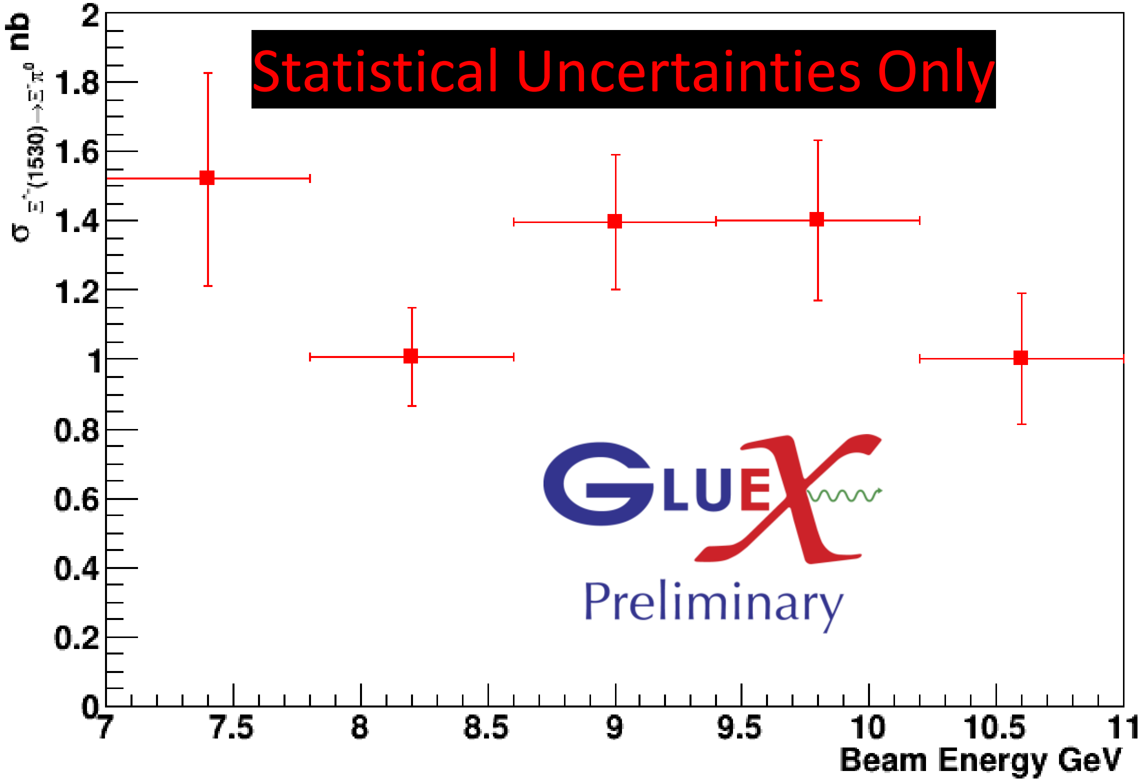
Yield = 37 ± 6



Yield = 28 ± 5

Cross sections for cascade baryons





"Upper limits were calculated on the production total cross sections of the three best-known excited states: the *Ξ*(1690), the *Ξ*(1820) and the *Ξ*(1950) [7] at 0.75 nb, 1.01 nb, and 1.58 nb, respectively"
-Study of *Ξ* Photoproduction from threshold to *W* = 3.3 GeV via CLAS collaboration

Preliminary total $\Xi^{*-}(1530)$ cross section

Decay chain

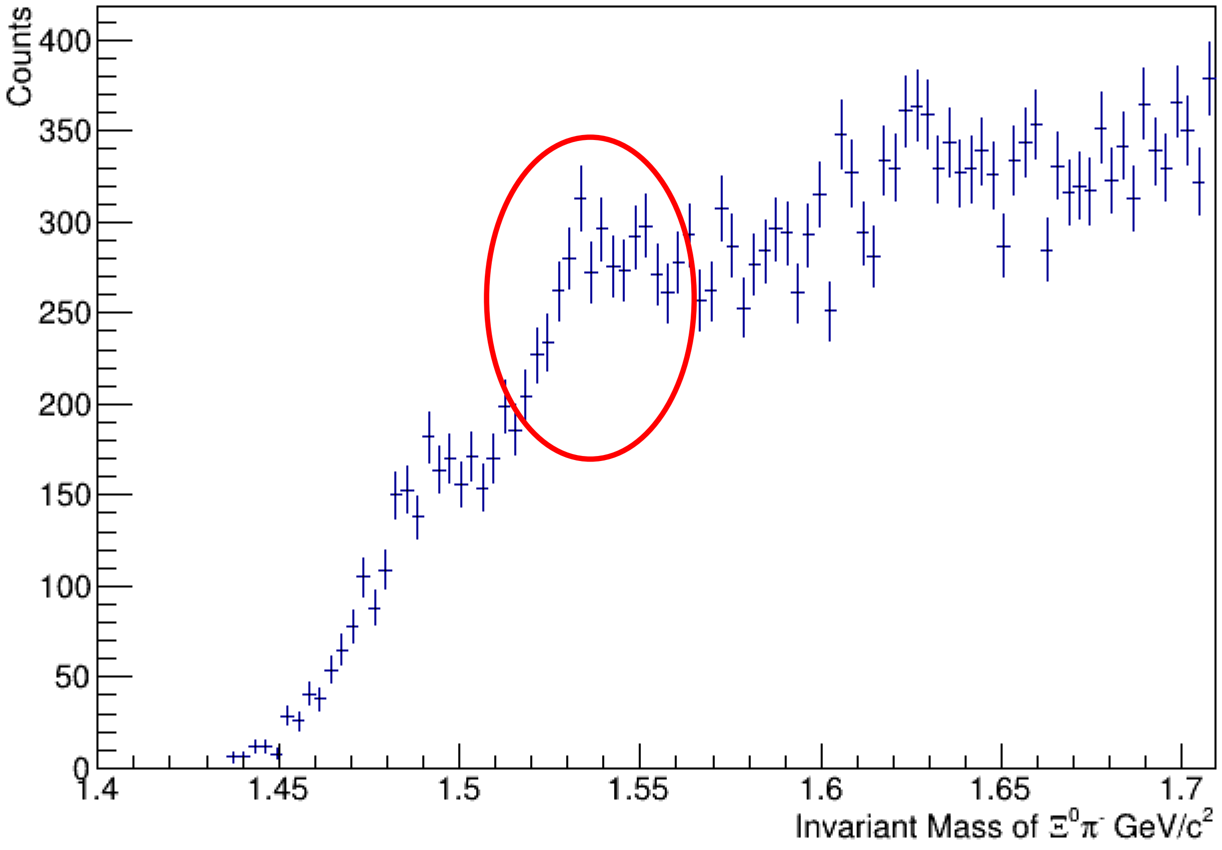
$$\gamma p \rightarrow K^+ K^+ \Xi^{-*}$$

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

$$\Xi^0 \rightarrow \Lambda \pi^0$$

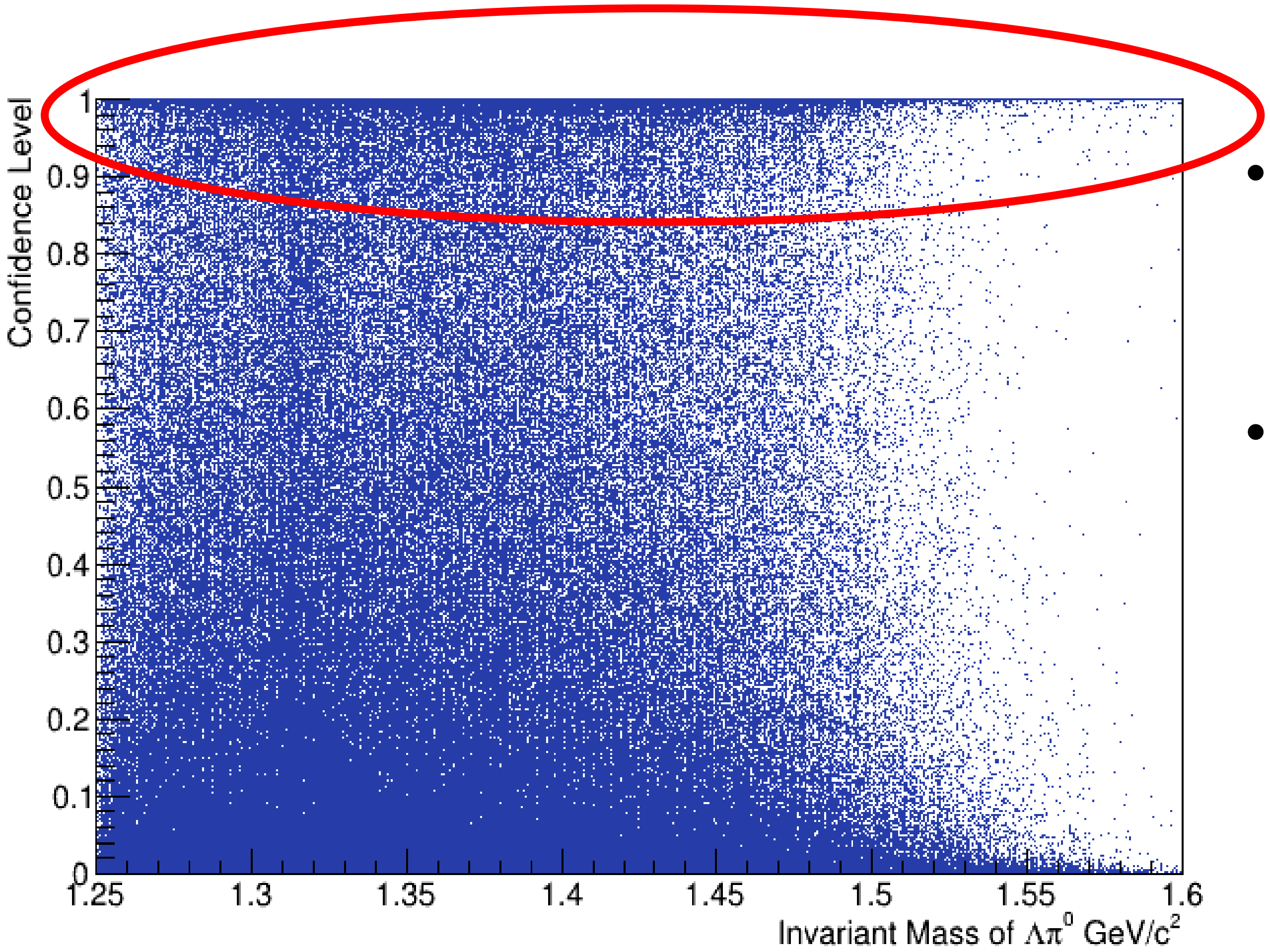
- Where the Λ and π's are kinematically constrained but does not use vertex fitting

Reconstructed $\Xi^{*-}(1530) \rightarrow \Xi^0\pi^-$ w/o vertex fitting



- The above plot uses a confidence level above 10^{-3} and invariant mass restriction on the $\Lambda\pi^0$ system

Issues w/Vertex fitting

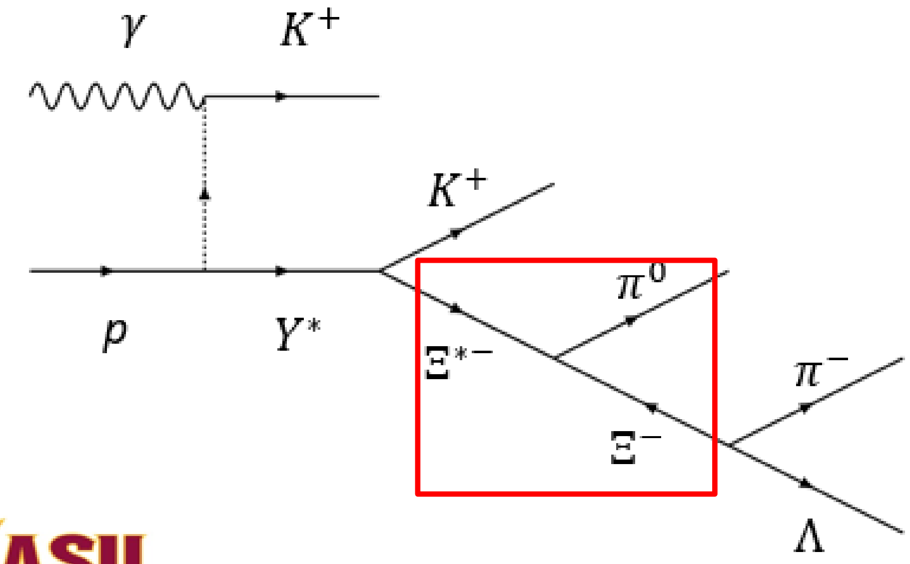


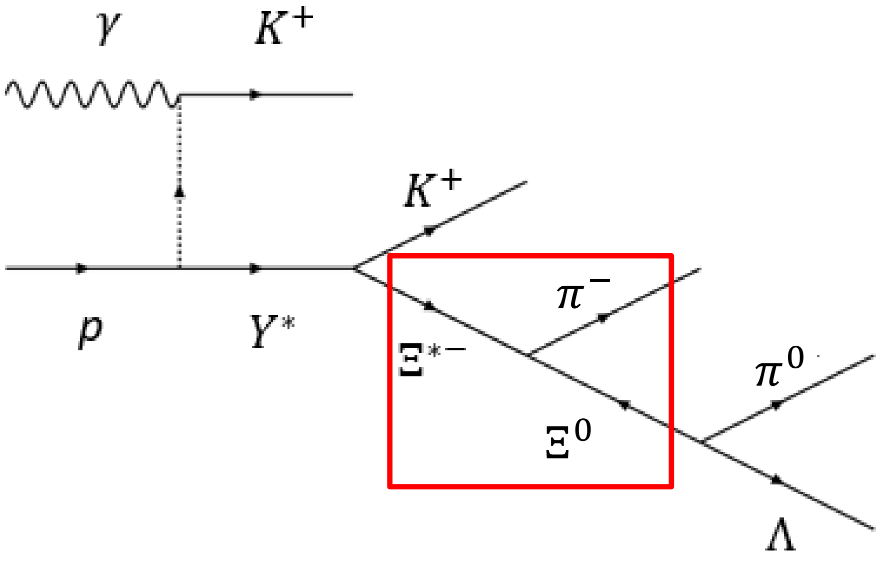
- Large contamination of misidentified particles at high confidence level
- The issues originates from the two neutrals come from the same vertex

Clebsch Gordan study of $\Xi^0\pi^-$ channel

Clebsch Gordan study motivation

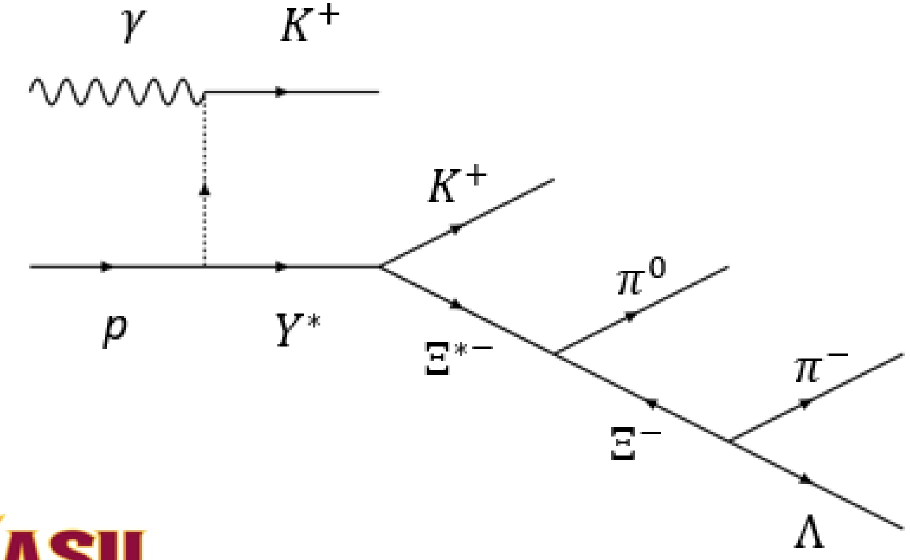
- This reaction $\Xi^{*} \rightarrow \Xi\pi$ should conserve isospin.

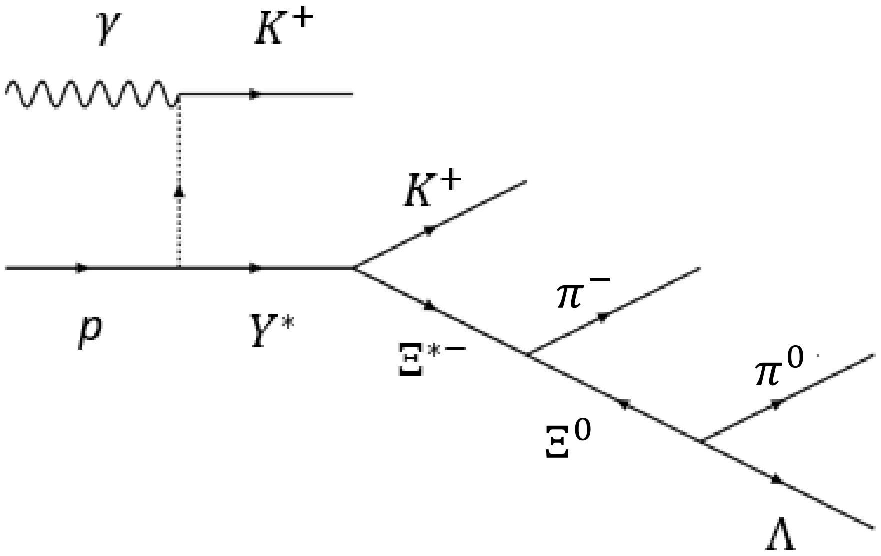




Clebsch Gordan study motivation

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





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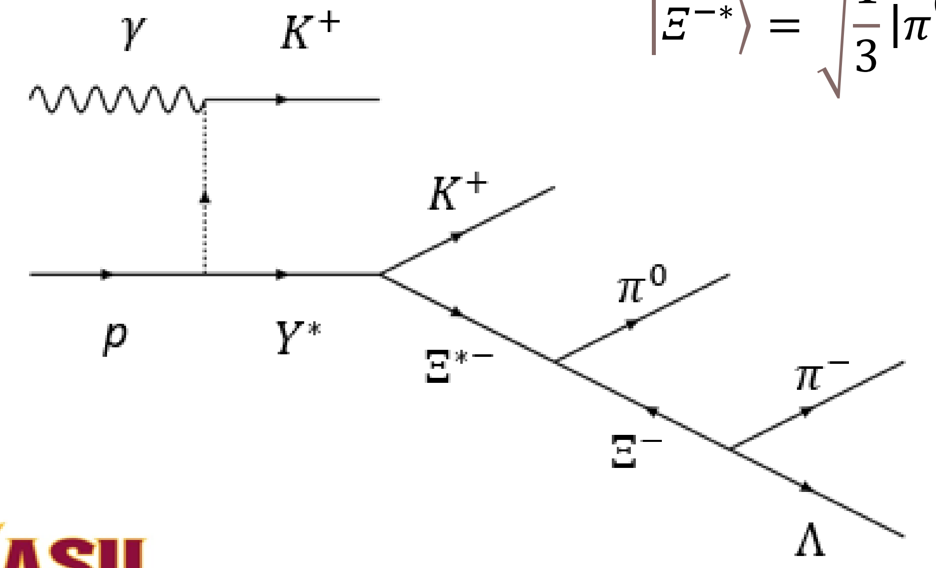
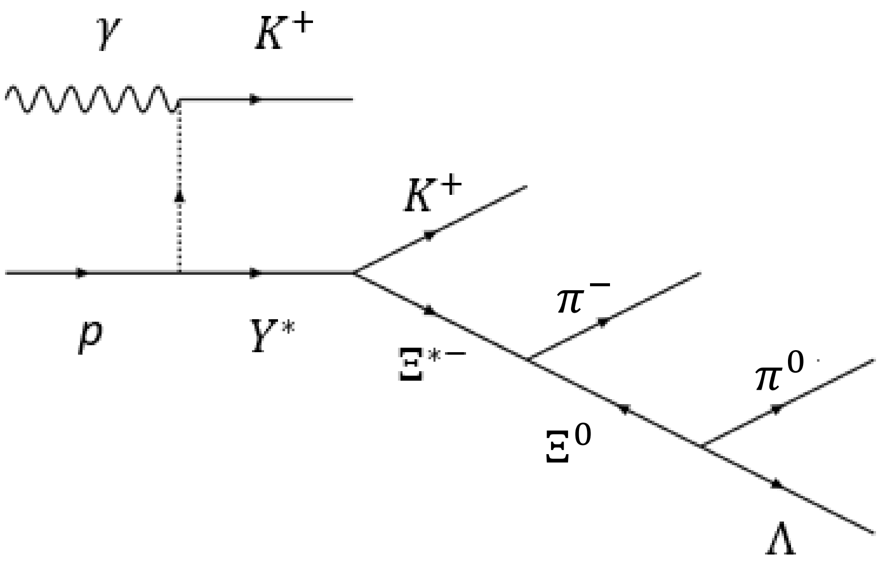
- This reaction $\Xi^{*} \rightarrow \Xi\pi$ should conserve isospin. Using Clebsch-Gordan coefficients we can that determine the neutral cascade channel should occur twice as often.

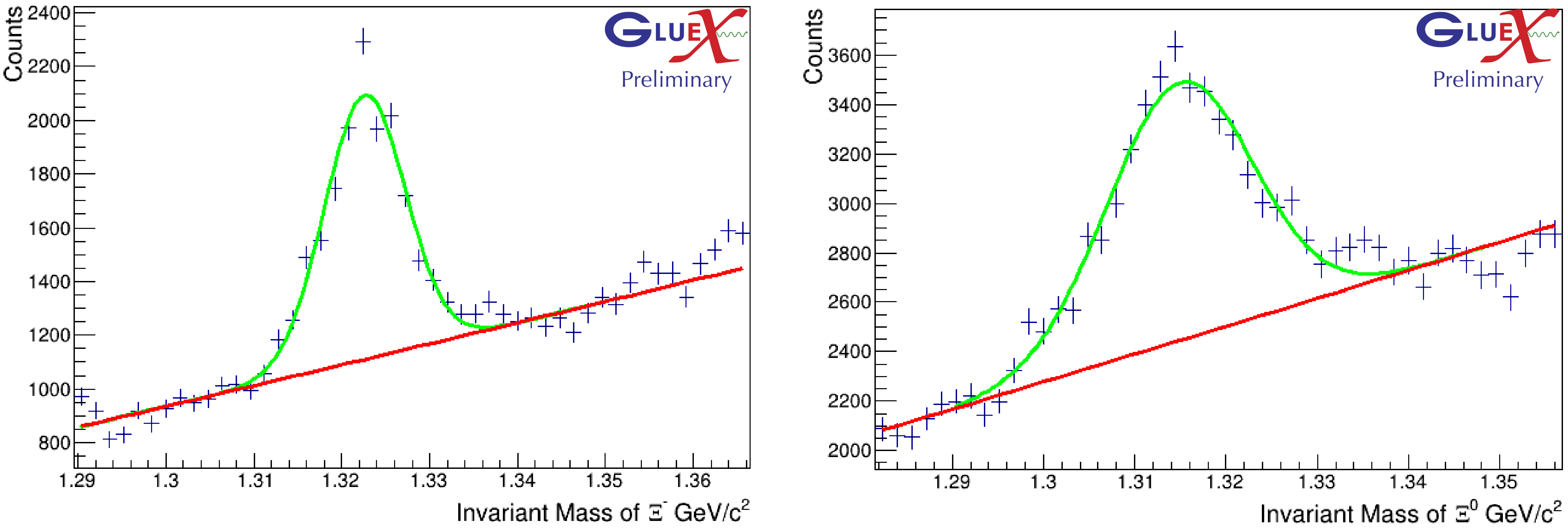
$$\left|\frac{1}{2},-\frac{1}{2}\right\rangle = \sqrt{\frac{1}{3}}\left[|1,0\rangle\left|\frac{1}{2},-\frac{1}{2}\right\rangle\right] - \sqrt{\frac{2}{3}}\left[|1,-1\rangle\left|\frac{1}{2},\frac{1}{2}\right\rangle\right],$$

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





Yields from Ξ^0 and Ξ^- w/o vertex fitting w/CL above 10^{-3}



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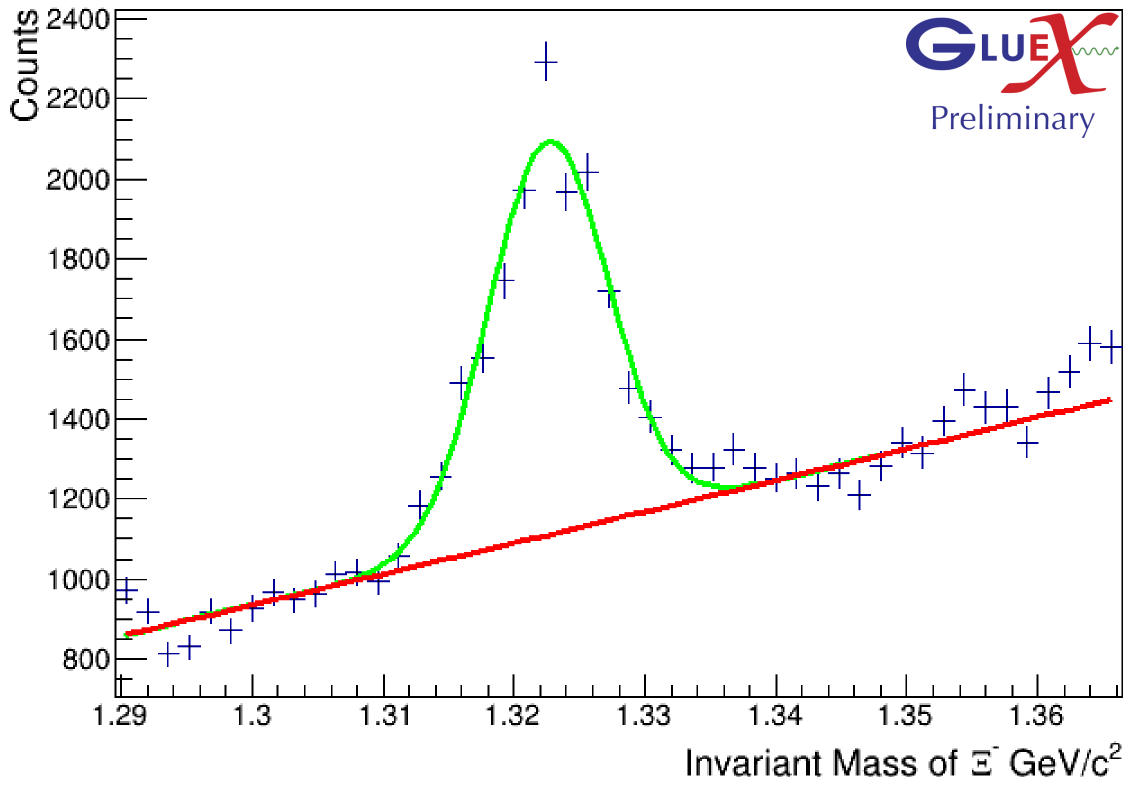
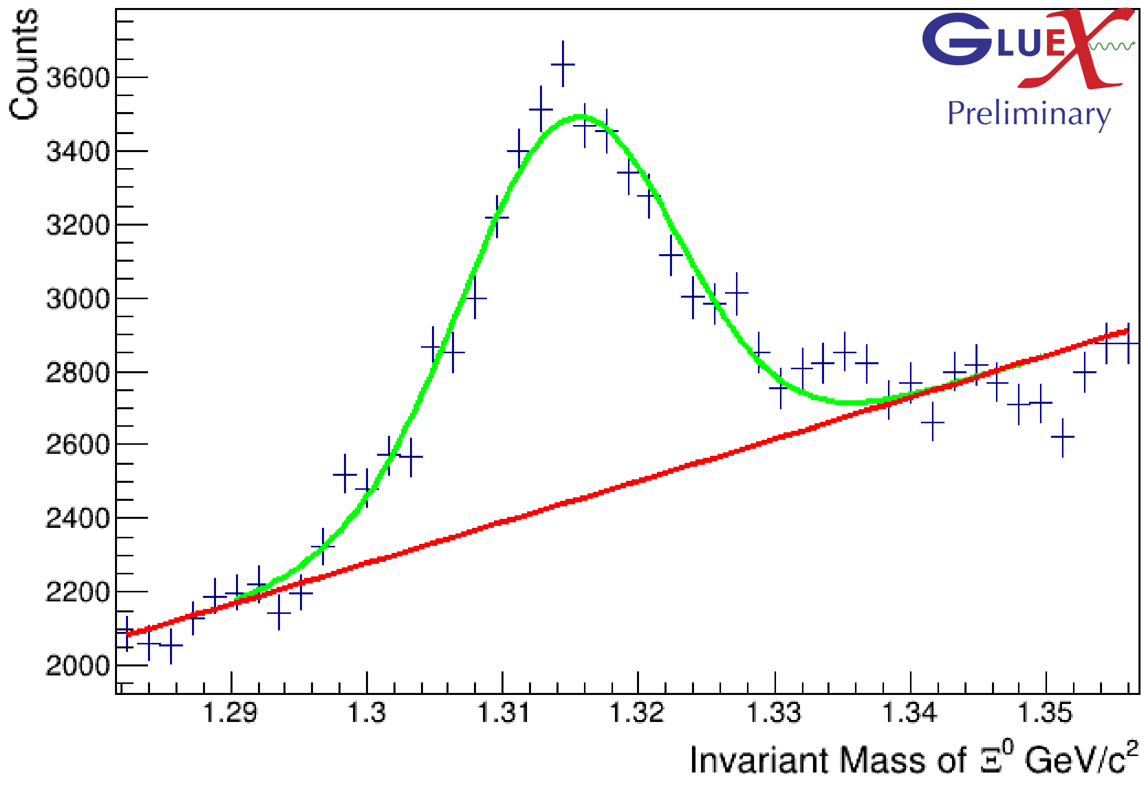


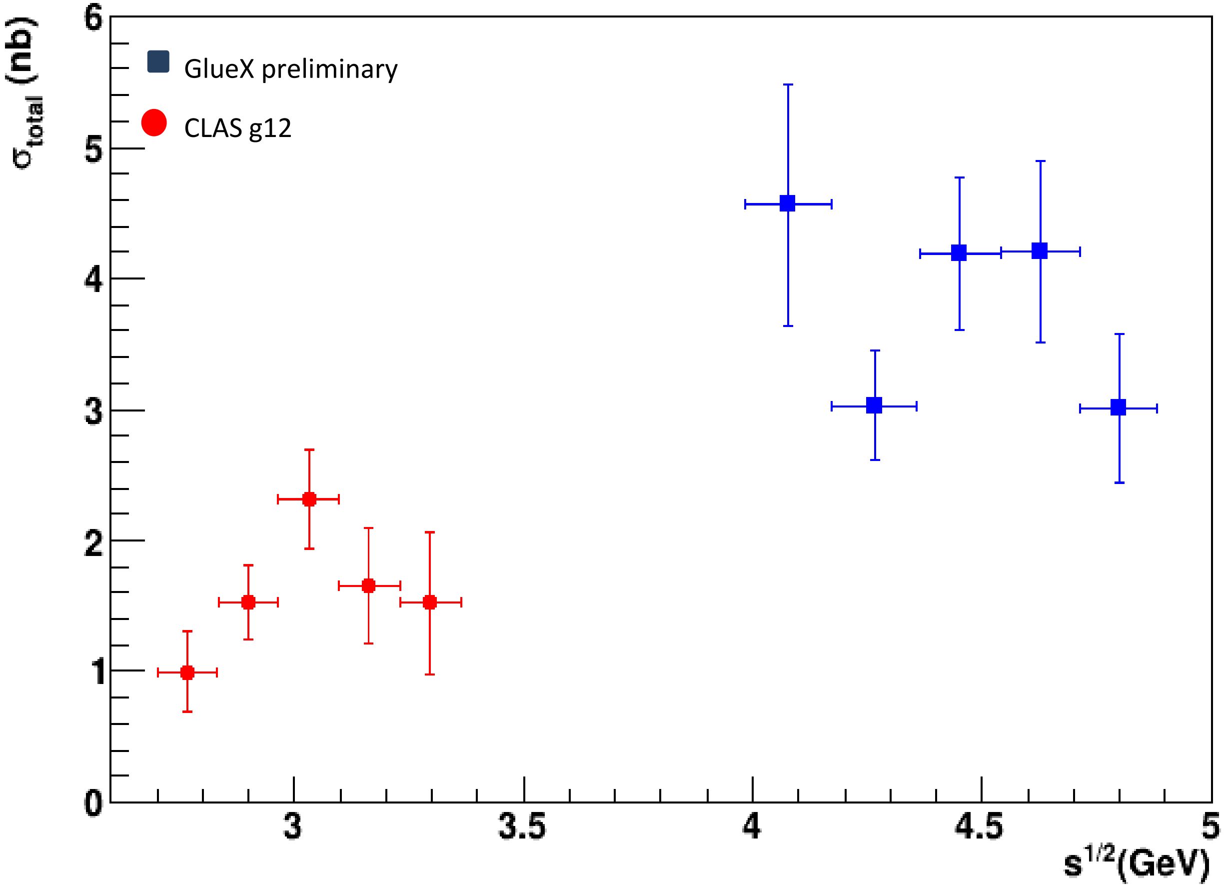
Yield(Ξ^-) = 7270 ± 85



Yield(Ξ^0) = 13351 ± 116

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

Preliminary total cross section for $\Xi^{*-}(1530) \rightarrow \Xi\pi$



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

$$\sigma_{\Xi^0\pi^-} = 2.0\ \sigma_{\Xi^-\pi^0},$$

$$\sigma_T = 3.0\ \sigma_{\Xi^-\pi^0}.$$

Partial Wave Analysis (PWA) of the $\Xi(1530)$

PWA

- The PWA is preformed by selecting a specific frame of reference, extracting the efficiency corrected yields of the $\Xi(1530)$ in bins of $\cos(\theta_{\mathrm{GJ}})$ and fit the resulting efficiency corrected yield distribution to the intensity function.

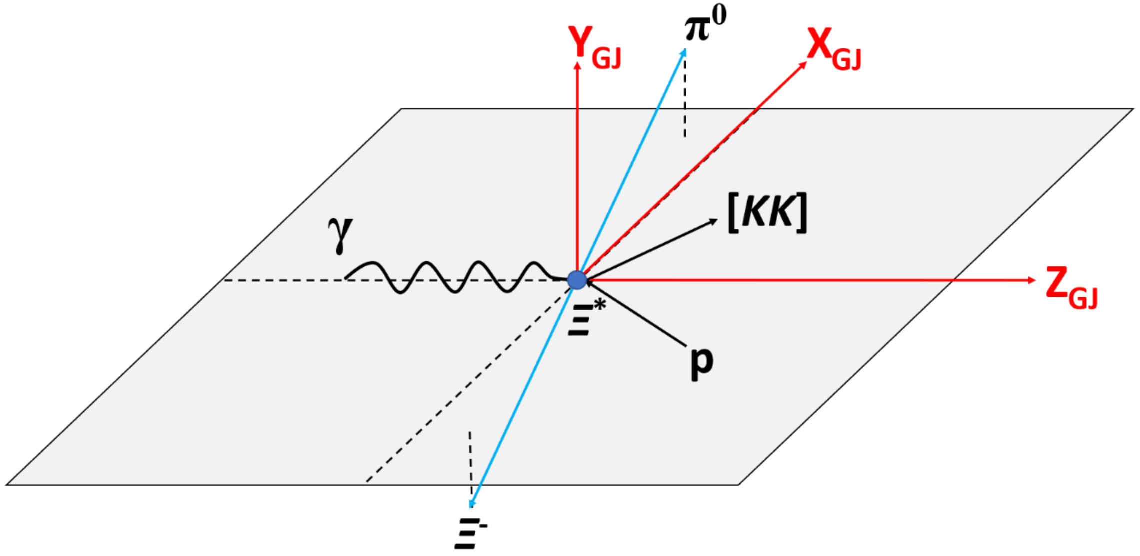
Intensity function

- The intensity function is given by

$$I(\tau) \equiv \sum_{i,j} \sum_{b,b'} {}^{i}A_{b}(\tau)^{i,j}\rho_{b,b'} \, {}^{j}A^{*}_{b'}(\tau)$$

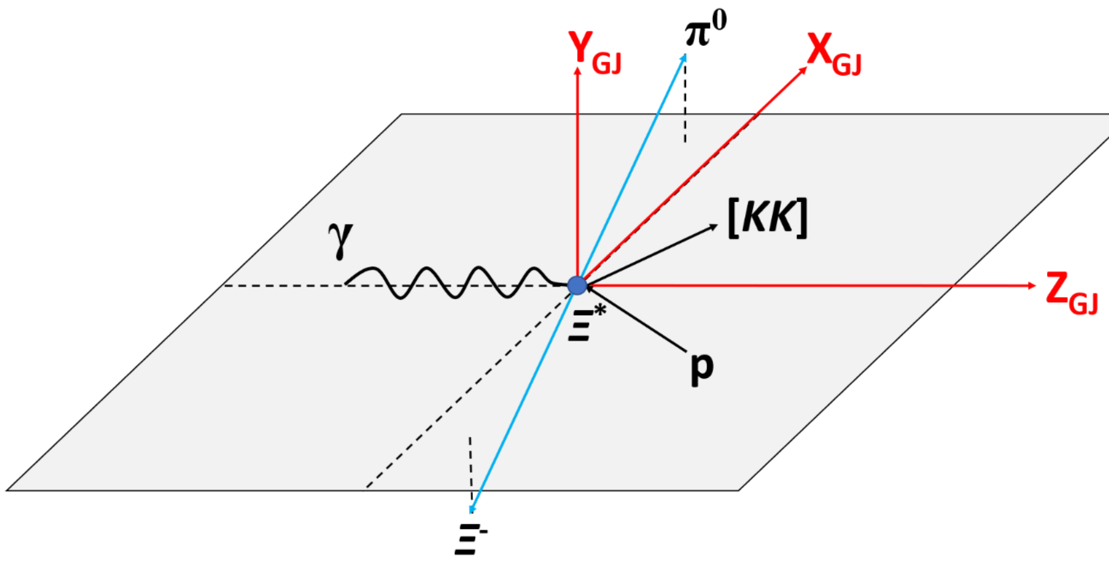
- The ${}^{i}A_{b}(\tau)$ terms are the decay amplitudes where i represents the initial state, b represents the set of possible quantum numbers (J, l, m) and τ represents all phase space and ρ is the final state spin density matrix

Choice of frame



- The choice of frame is the GJ frame.

Choice of frame



- The *z*-axis points in the direction of the initial photon beam

$$\hat{z}_{GJ} = \frac{\vec{p}_\gamma(\Xi^*)}{|\vec{p}_\gamma(\Xi^*)|}$$

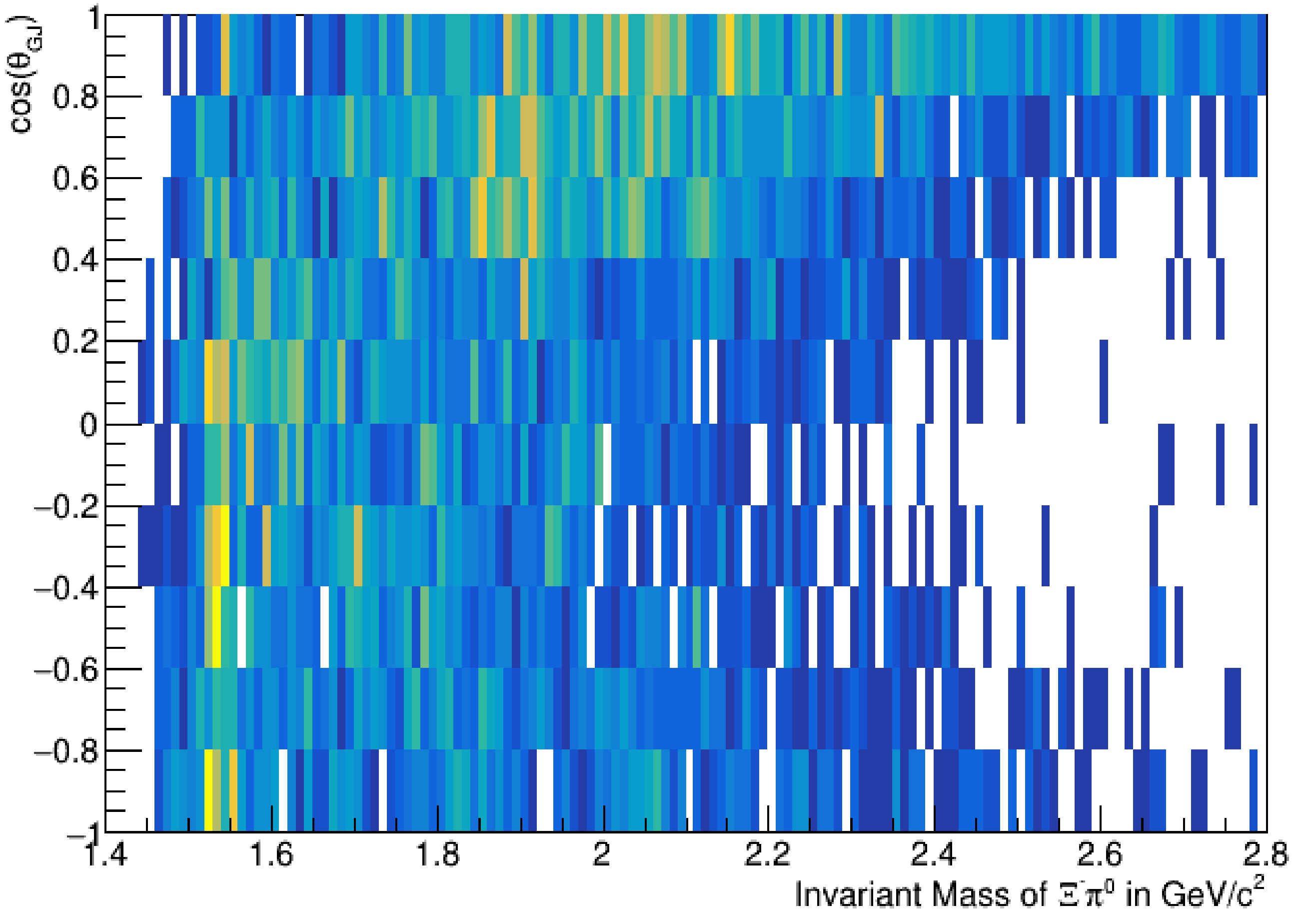
- The *y*-axis is defined to be the normal to the production plane of Ξ^* in the CM frame.

$$\hat{y}_{GJ} = \frac{\vec{p}_\gamma \text{ x } \vec{p}_{\Xi^*}}{|\vec{p}_\gamma \text{ x } \vec{p}_{\Xi^*}|}$$

- The *x*-axis is defined by making the coordinate system right-handed:

$$\hat{x}_{GJ} = \hat{y}_{GJ} \text{ x } \hat{z}_{GJ} .$$

$\cos\theta_{GJ}$ versus invariant mass of $\Xi^{-}\pi^{0}$



Decay amplitudes

- The full expression for a decay amplitude in the GJ frame is:

$$A_b(\tau) = \sqrt{\frac{2l+1}{4\pi}} F_l(p) a_{ls} \sum_{\lambda_1 \lambda_2} D^{J*}_{m\lambda}\left(\Omega_{GJ}\right) \langle l0s\lambda | J\lambda \rangle \langle s_1 \lambda_1 s_2 \, {}^{-}\lambda_2 | s\lambda \rangle.$$

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Blatt-Weisskopf centrifugal-barrier factor dependent on angular momentum *l*

Decay amplitudes

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Fit parameter that house unknown transition amplitudes

Decay amplitudes

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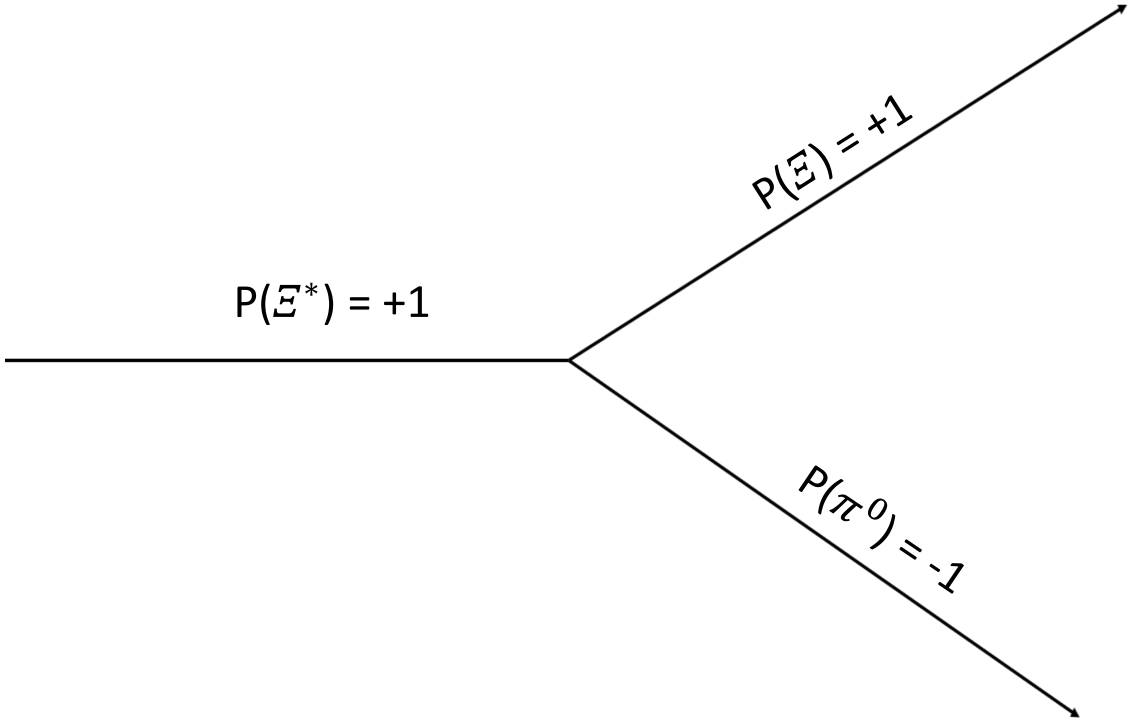
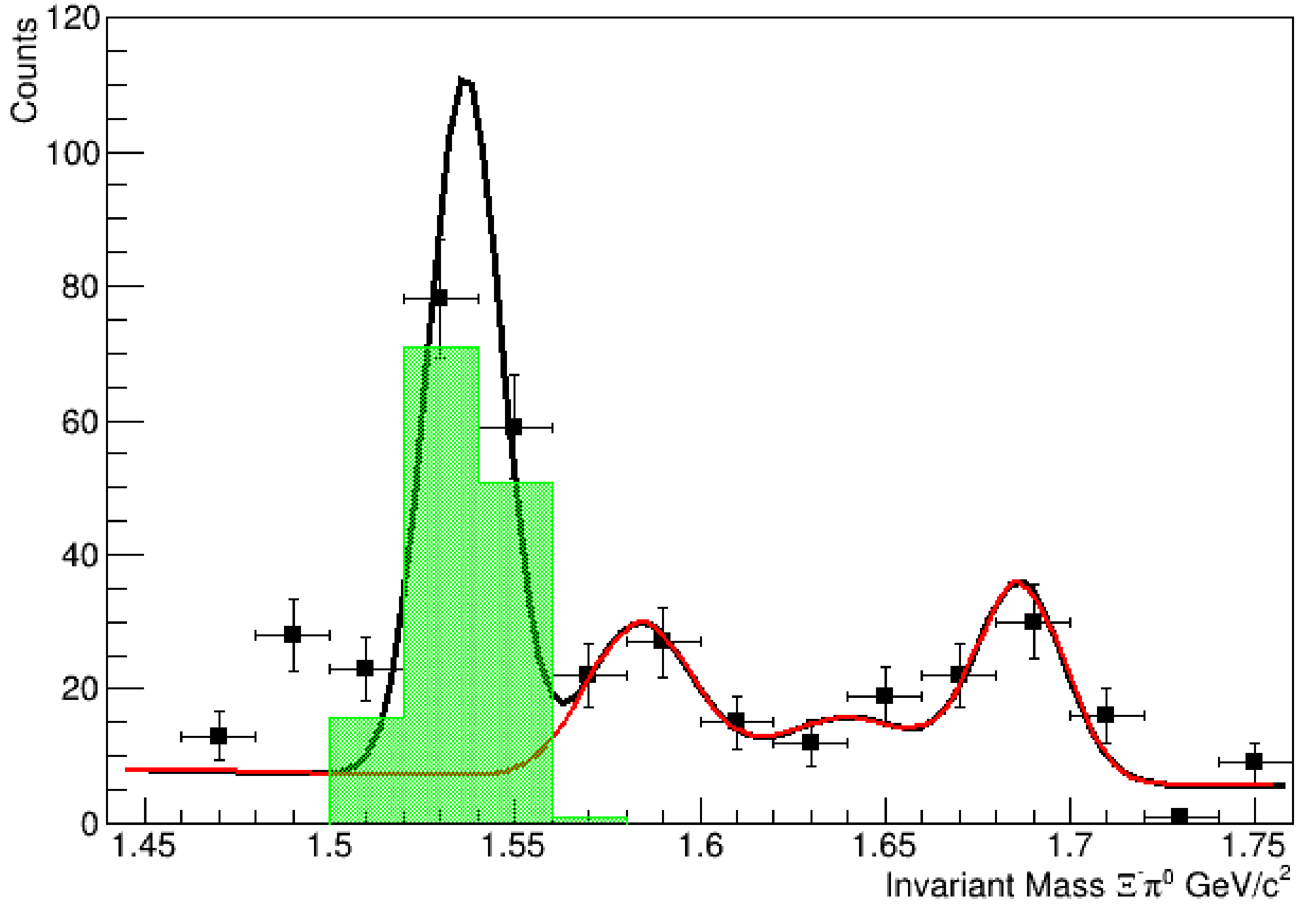
- This term always equals one because the excited cascade decays into a spin ½ baryon and pseudo-scalar meson

Parity conservation



- The overall parity sign must be the same before and after the $\Xi(1530)$ decay because the strong interaction conserves parity
- The parity of angular momentum eigenstates is $(-1)^l$
- Therefore $l = 1$

Invariant mass Distribution of Ξ^{*-} with $\cos\theta_{GJ}$, between -1.0 and -0.8



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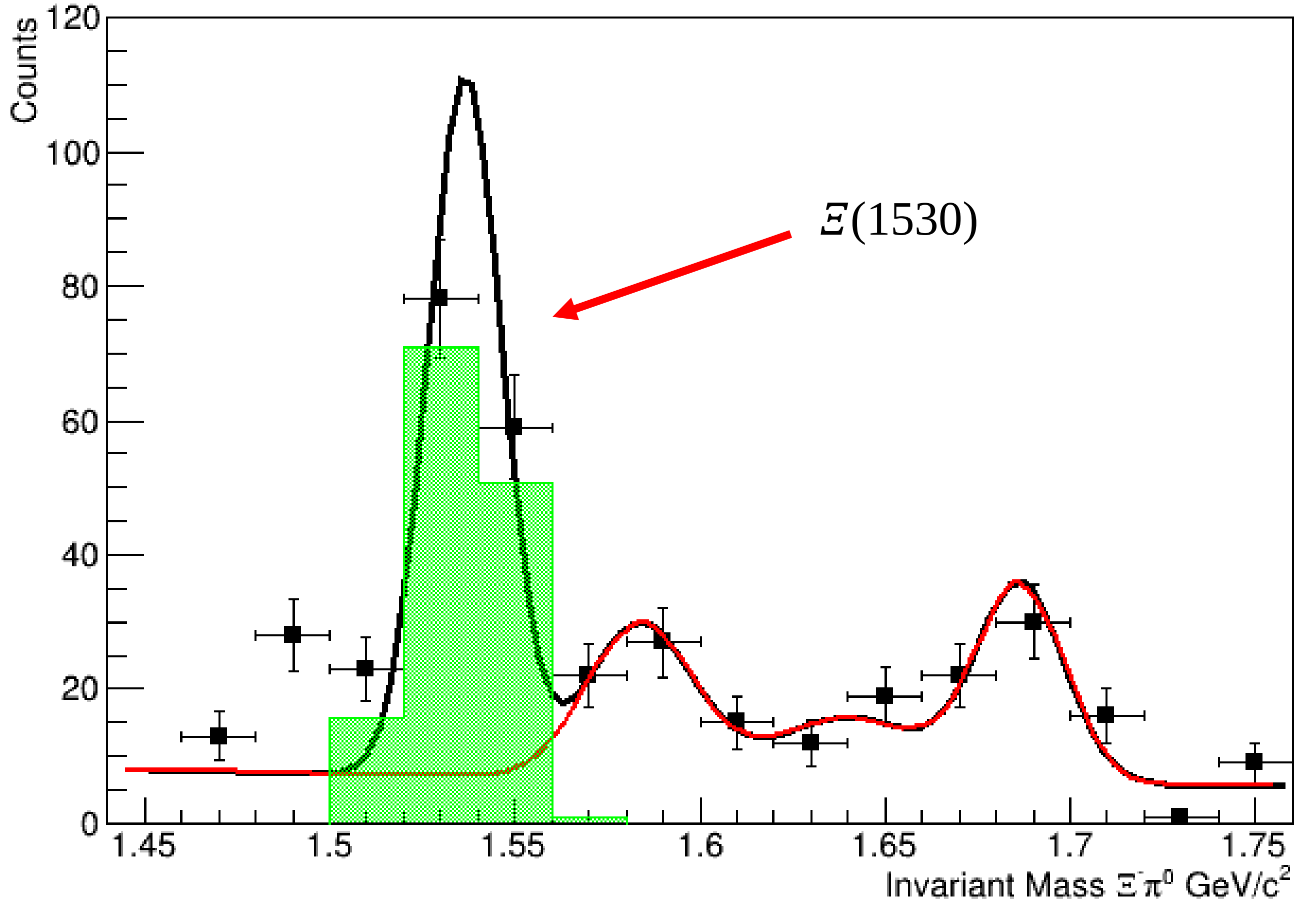

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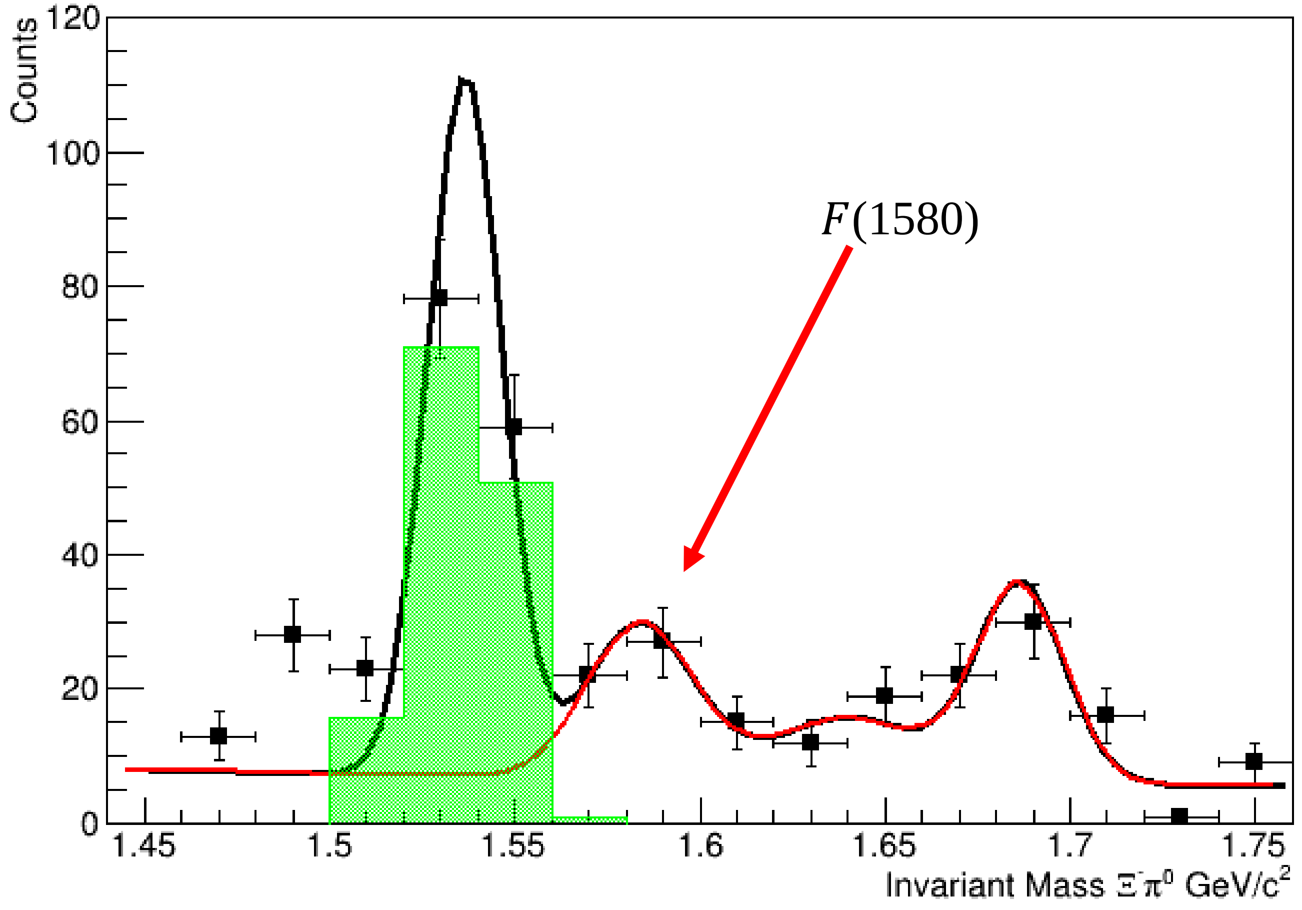

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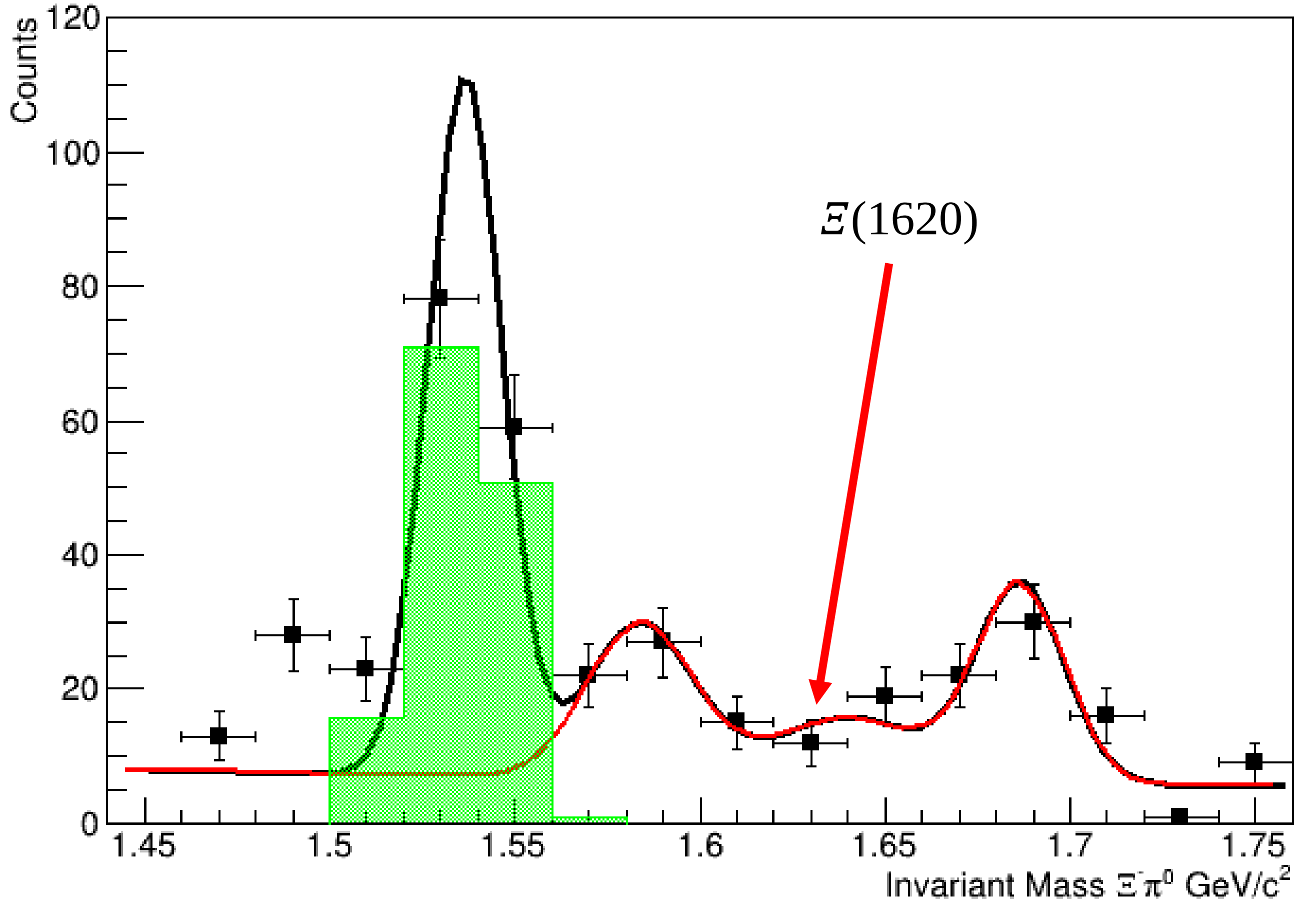

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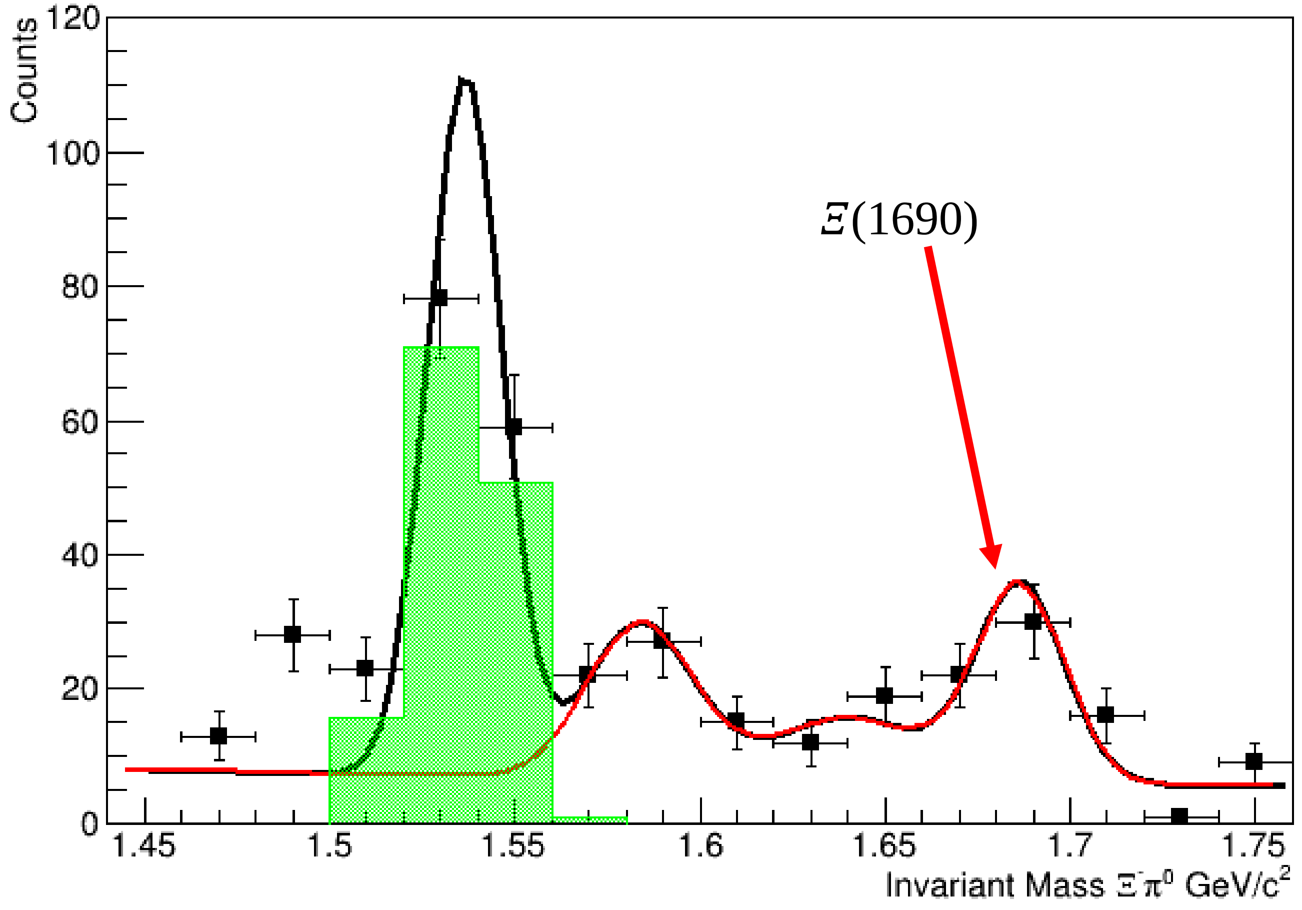
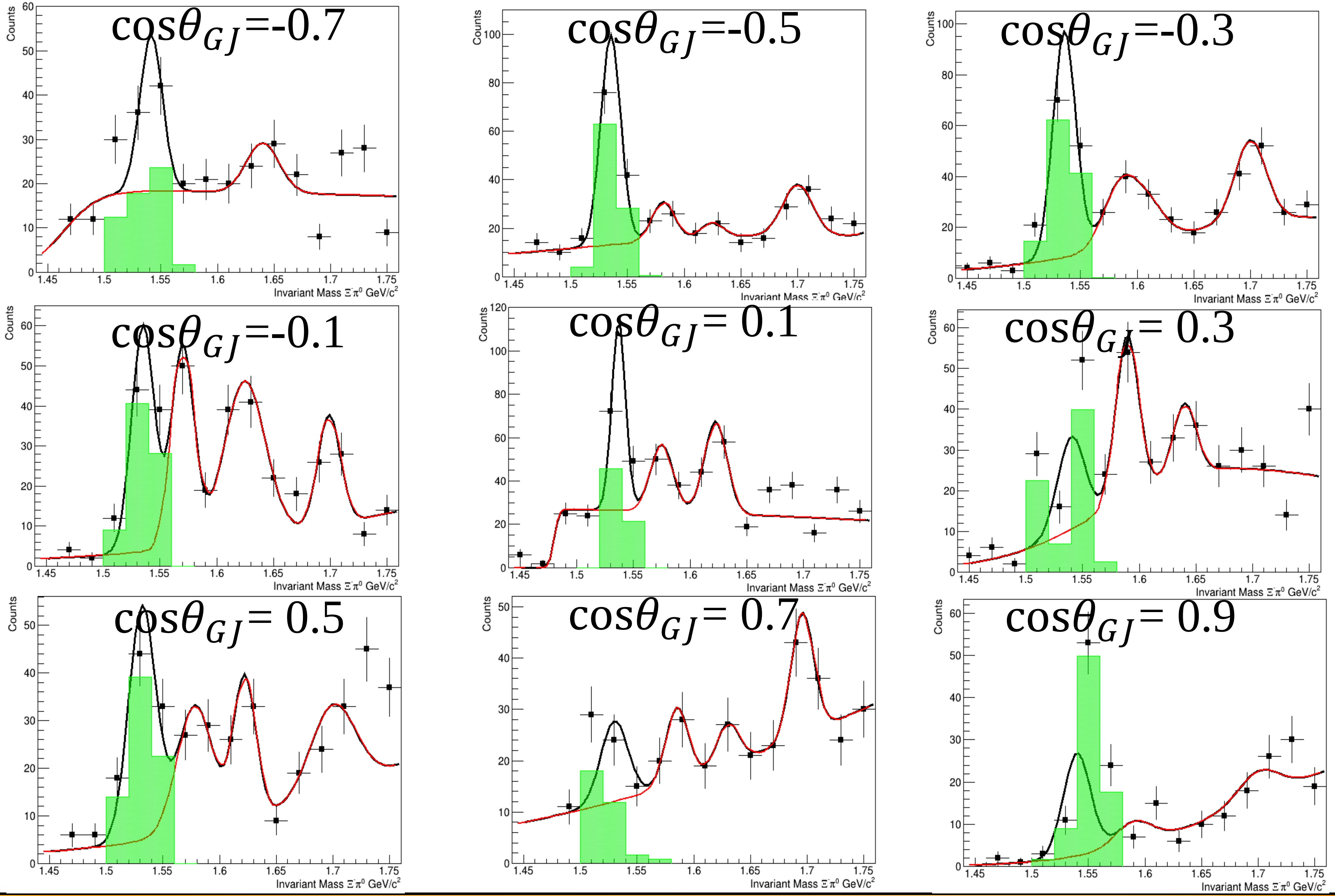
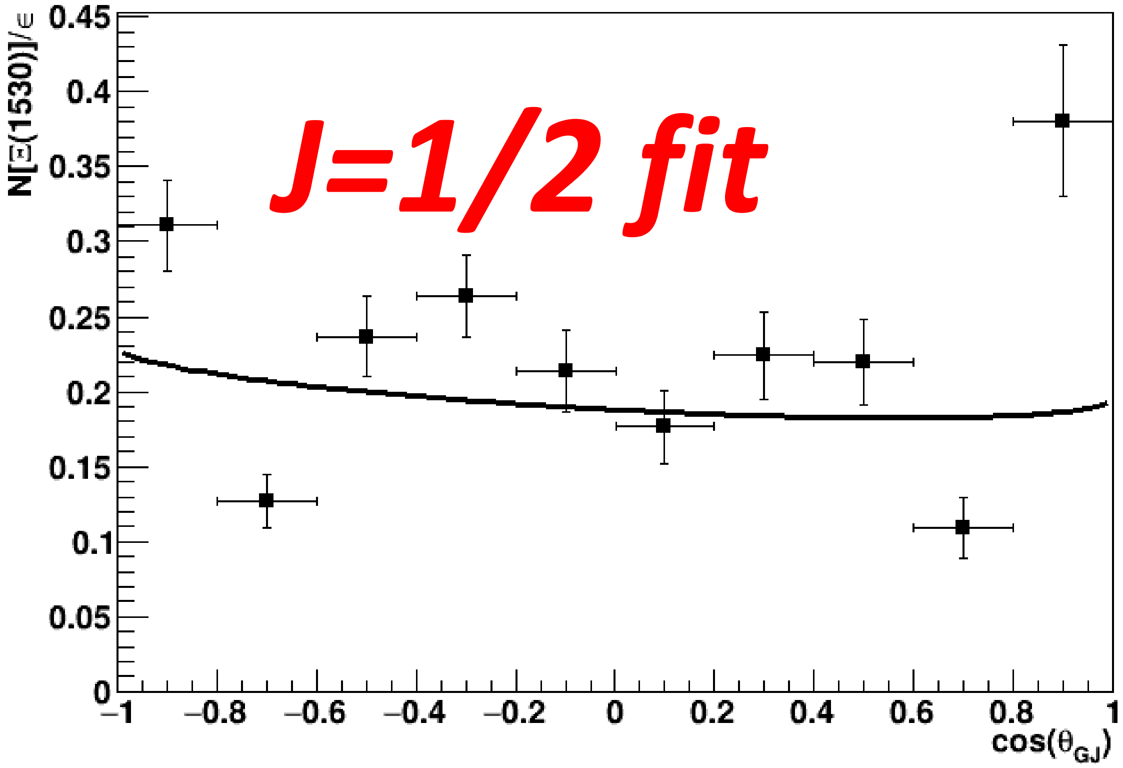




$\cos\theta_{GJ}$=-0.7
$\cos\theta_{GJ}$=-0.5
$\cos\theta_{GJ}$=-0.3
$\cos\theta_{GJ}$=-0.1
$\cos\theta_{GJ}$= 0.1
$\cos\theta_{GJ}$= 0.3
$\cos\theta_{GJ}$= 0.5
$\cos\theta_{GJ}$= 0.7
$\cos\theta_{GJ}$= 0.9
Counts
Invariant Mass $\Xi^-\pi^0$ GeV/c^2

Normalized Yield Fits



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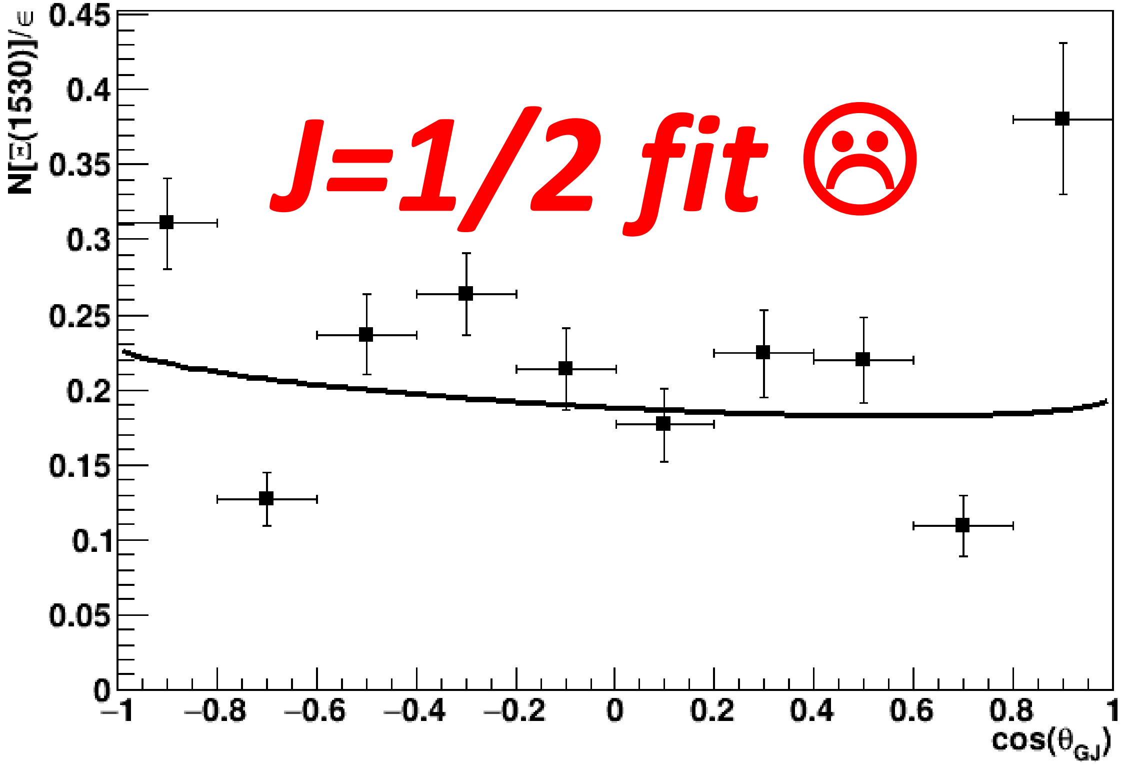
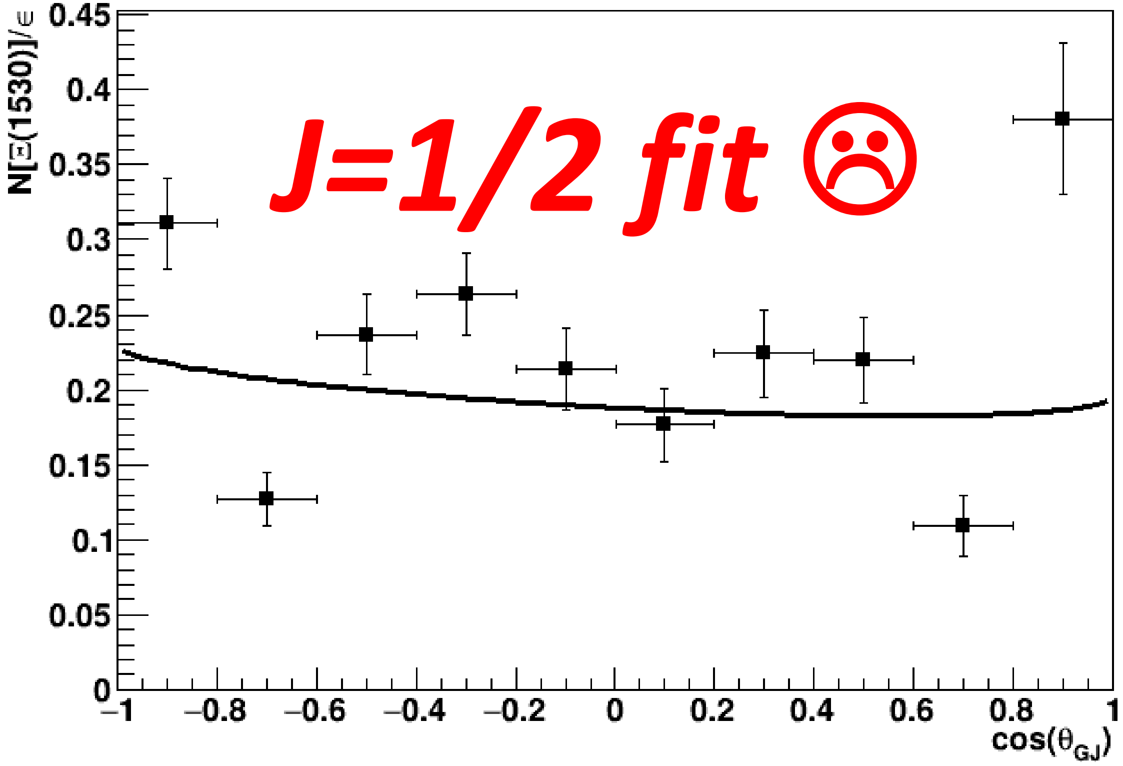
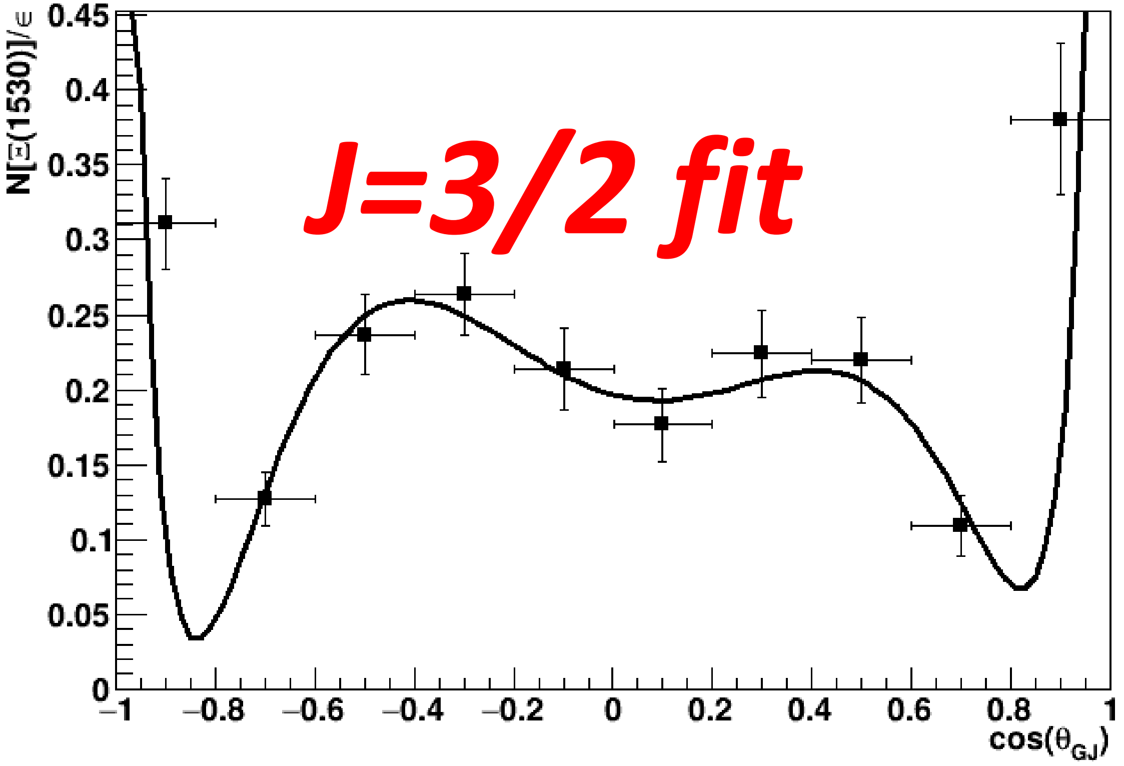
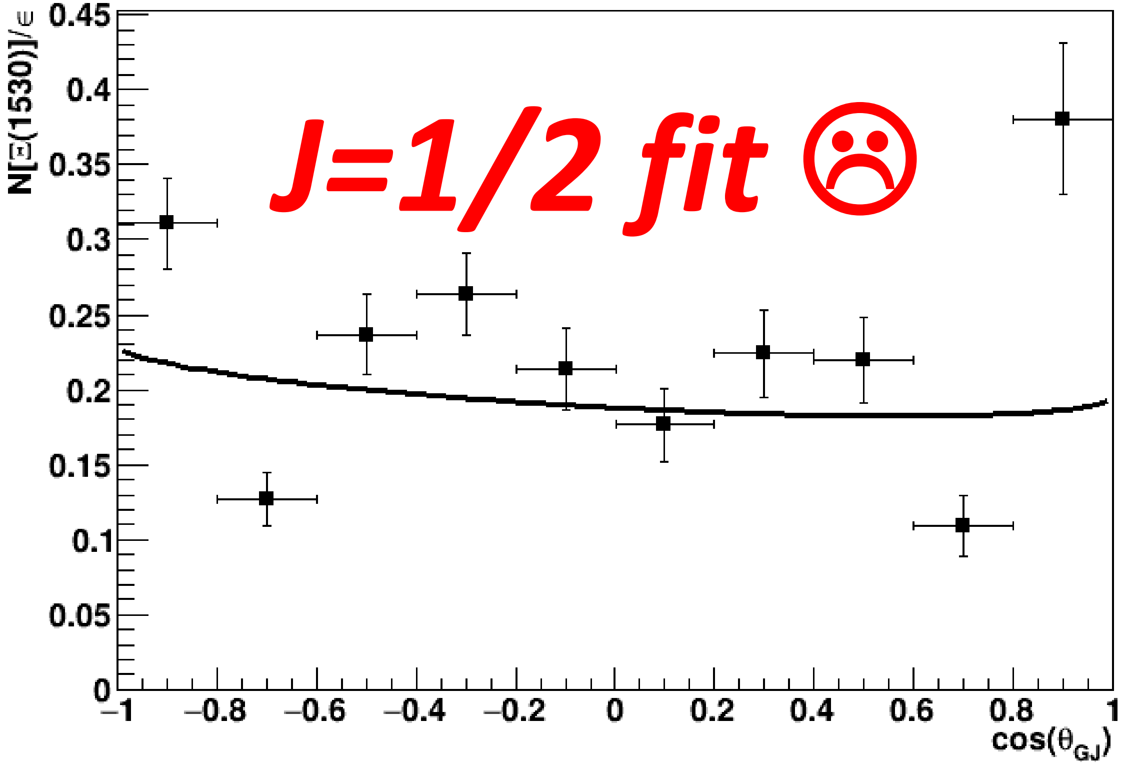


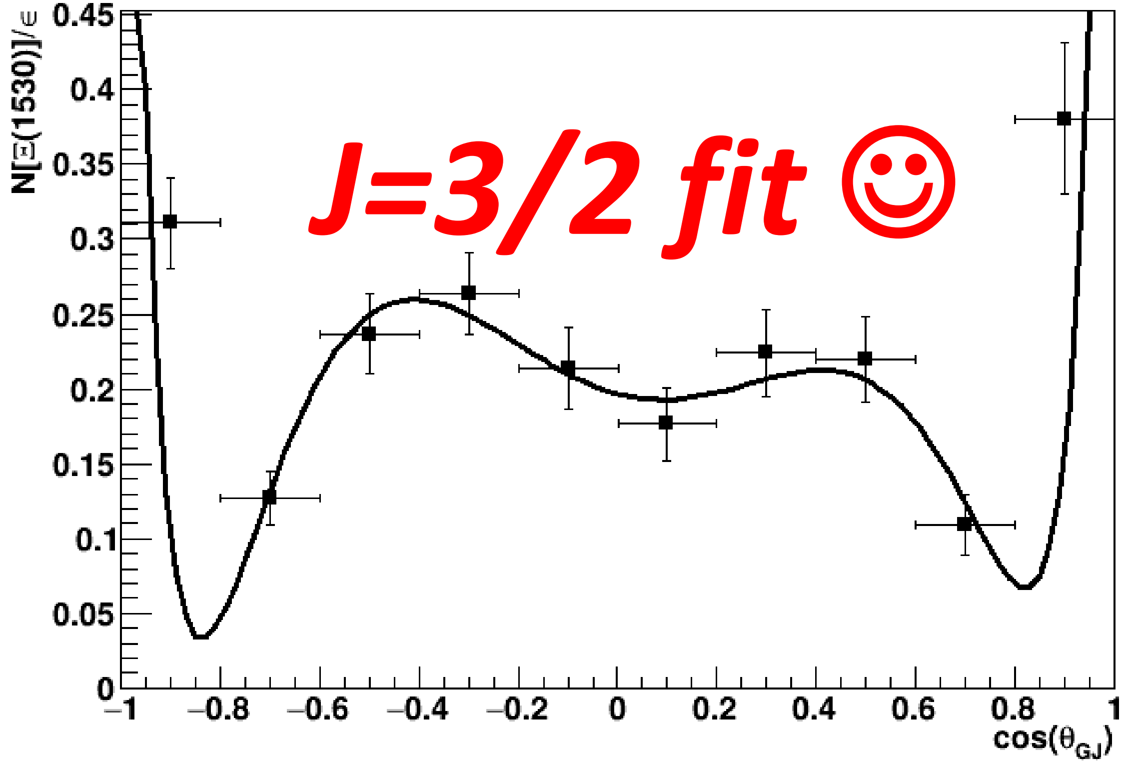
Normalized Yield Fits





Normalized Yield Fits





The End

THANK YOU !!!!!