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

Brandon Sumner

Outline

- Motivation
- Preliminary $\Xi(1530)$ Cross Section
- Clebsch Gordan study of $\Xi^0\pi^-$ channel
- Simultaneous fitting between $\Xi^-\pi^0$ and $K^-\Lambda$ channels

Missing Resonance Problem

State, J^P	Predicted masses (MeV)							
$\Xi\frac{1}{2}^+$	1305							
$\Xi\frac{3}{2}^+$	1505							
$\Xi^*\frac{1}{2}^-$	1755	1810	1835	2225	2285	2300	2320	2380
$\Xi^*\frac{3}{2}^-$	1785	1880	1895	2240	2305	2330	2340	2385
$\Xi^*\frac{5}{2}^-$	1900	2345	2350	2385				
$\Xi^*\frac{7}{2}^-$	2355							
$\Xi^*\frac{1}{2}^+$	1840	2040	2100	2130	2150	2230	2345	
$\Xi^*\frac{3}{2}^+$	2045	2065	2115	2165	2170	2210	2230	2275
$\Xi^*\frac{5}{2}^+$	2045	2165	2230	2230	2240			
$\Xi^*\frac{7}{2}^+$	2180	2240						

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

- List of Cascade Baryons predicted by Capstick and Isgur with mass less than 2.4 GeV/c^2
- Current List of states in PDG with mass less than 2.4 GeV/c^2

Branching Ratios

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

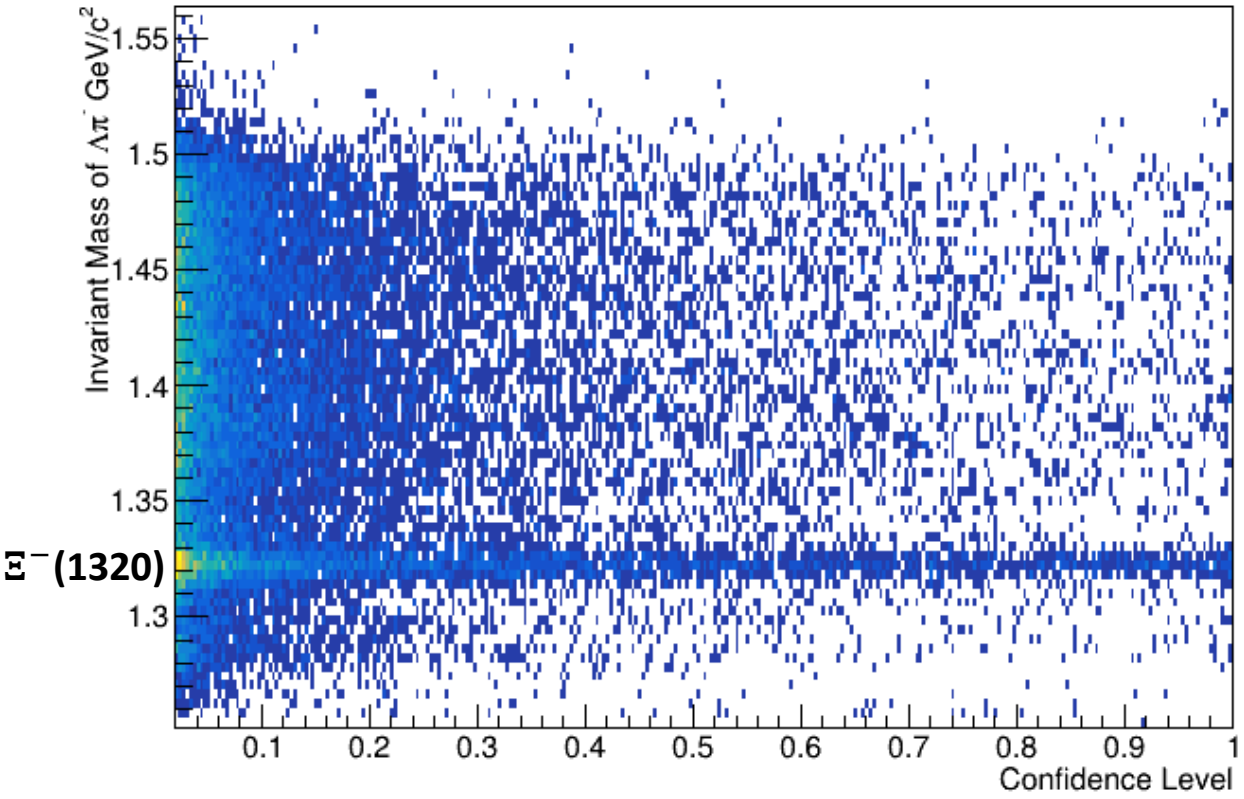
- Per the PDG all the Cascade 1530s decay $\Xi\pi$, while for higher mass cascade states this channel is suppressed

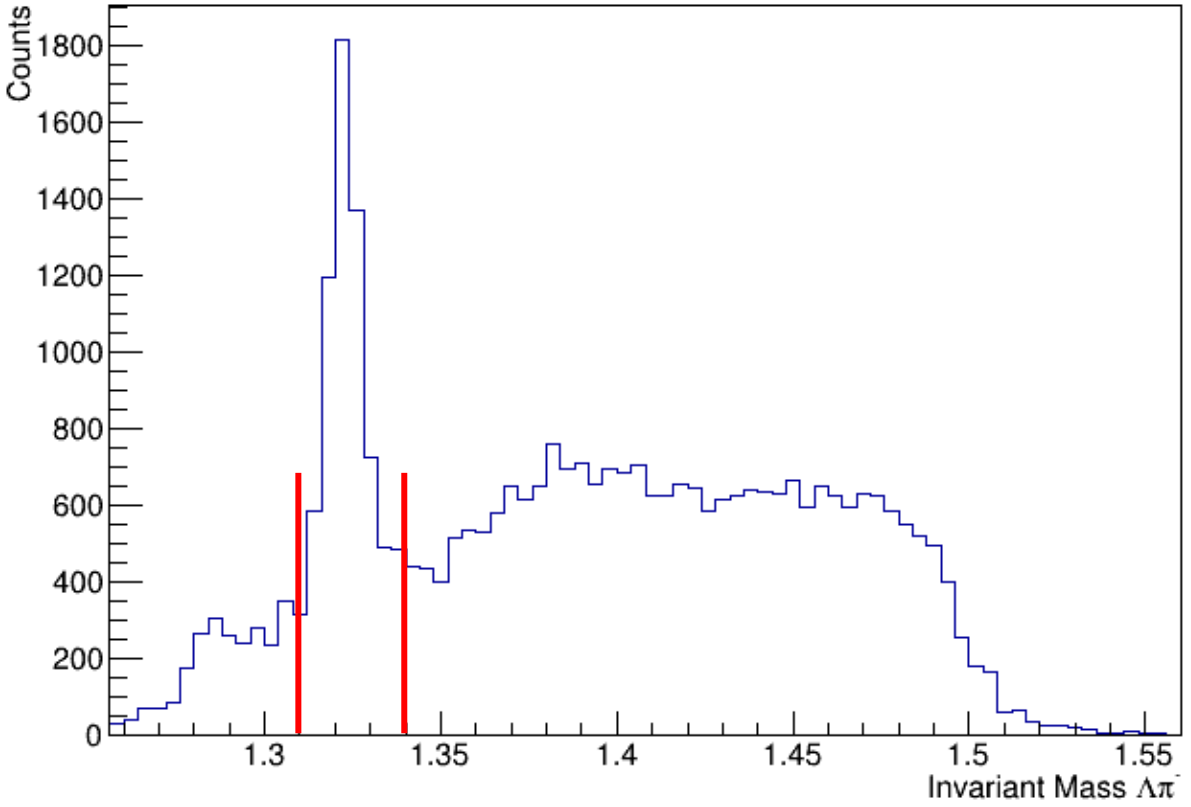
Decay Chain

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

- The Λ and π^0 are Kinfit
- Data comes from Sp 18

Confidence Level Cut





- There is a signal around the mass of the ground state cascade

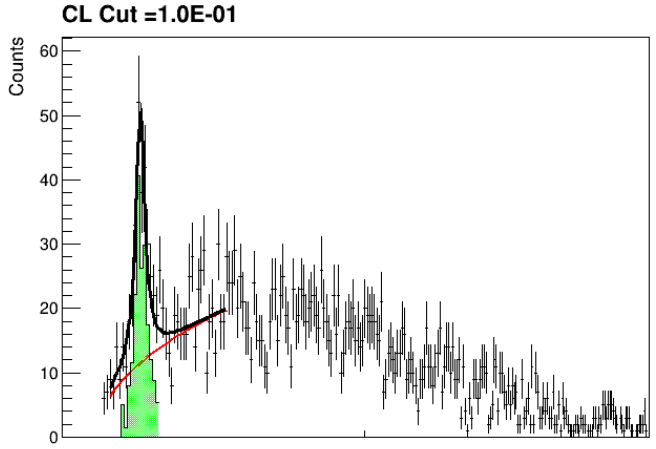
Optimizing the Kinematic Fit CL for the $\Xi(1530)$

- The CL cut needs to minimize the error in the yield improving the error in my final cross section measurement. Therefore, I defined a figure of merit (FOM) as the ratio of the signal yield over the error in the signal yield:

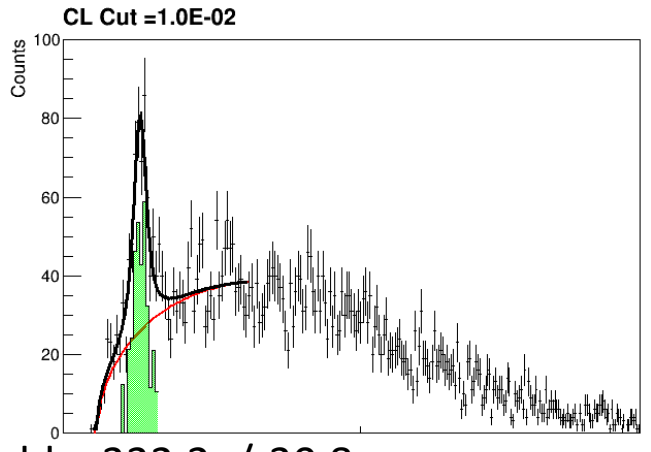
$$\text{FOM} = \frac{Y}{\sigma_Y} \qquad \sigma_Y = \sqrt{Y + 2B}$$

- The CL cut used in the analysis is determined by CL interval that maximizes the FOM

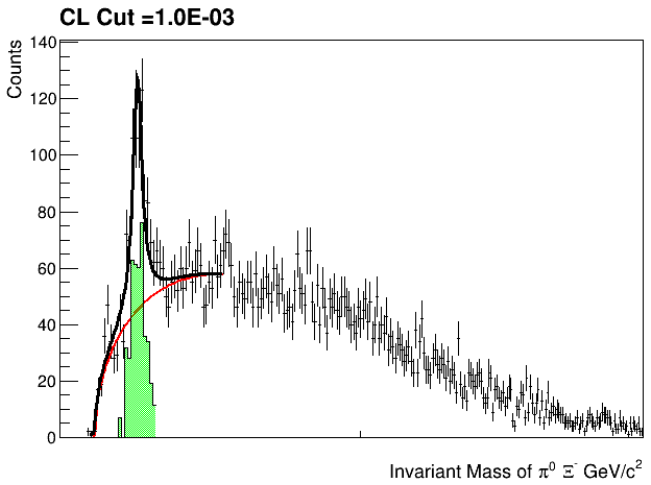
Excited Cascade Mass Spectrum



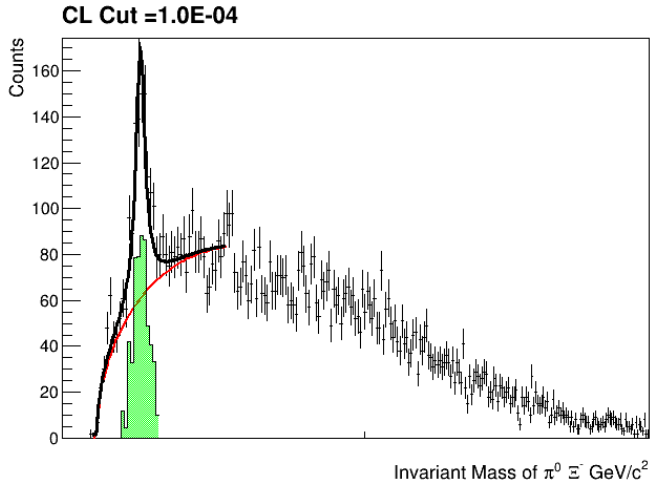
Yield = 188.9 +/-21.5



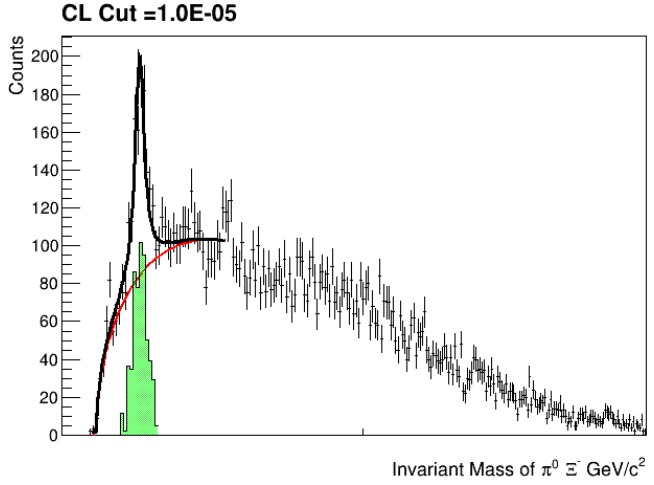
Yield = 332.2+/-30.8



Yield = 422.9 +/-38.7

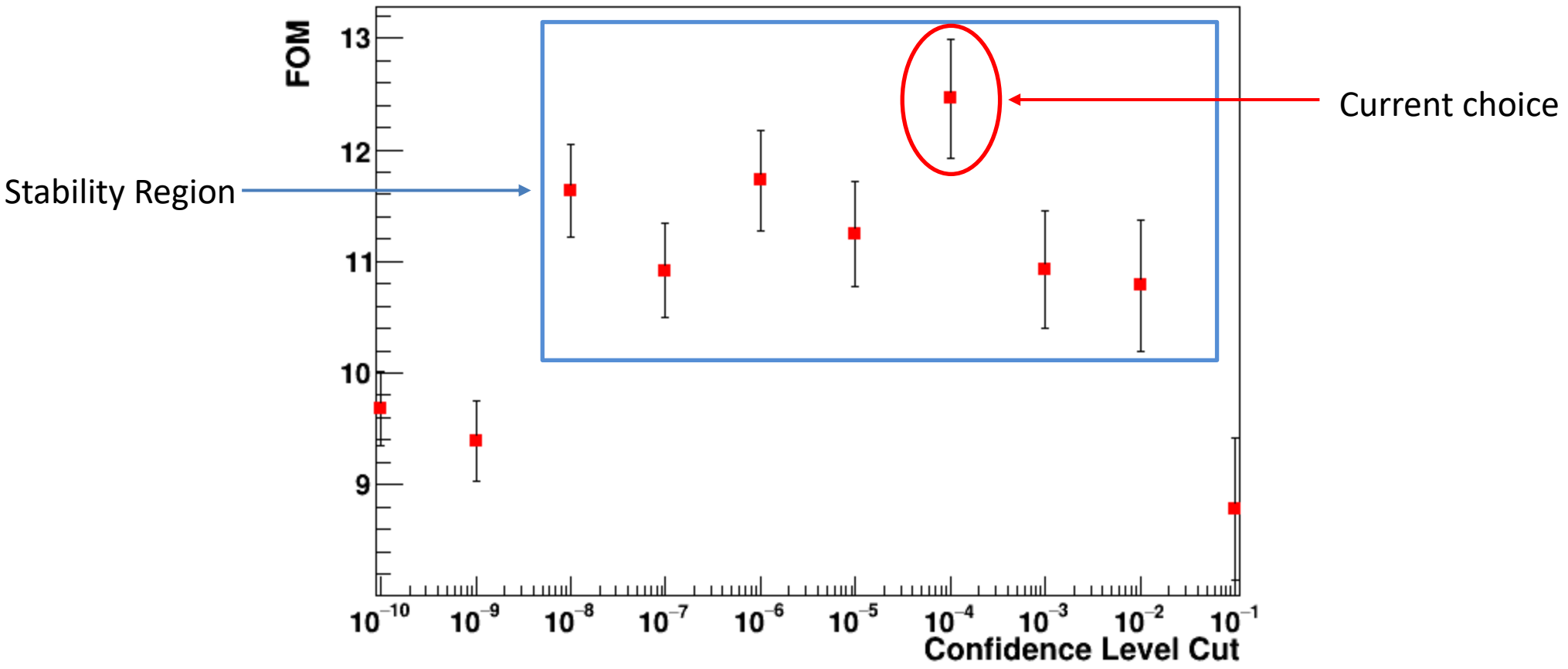


Yield = 556.9 +/-44.7

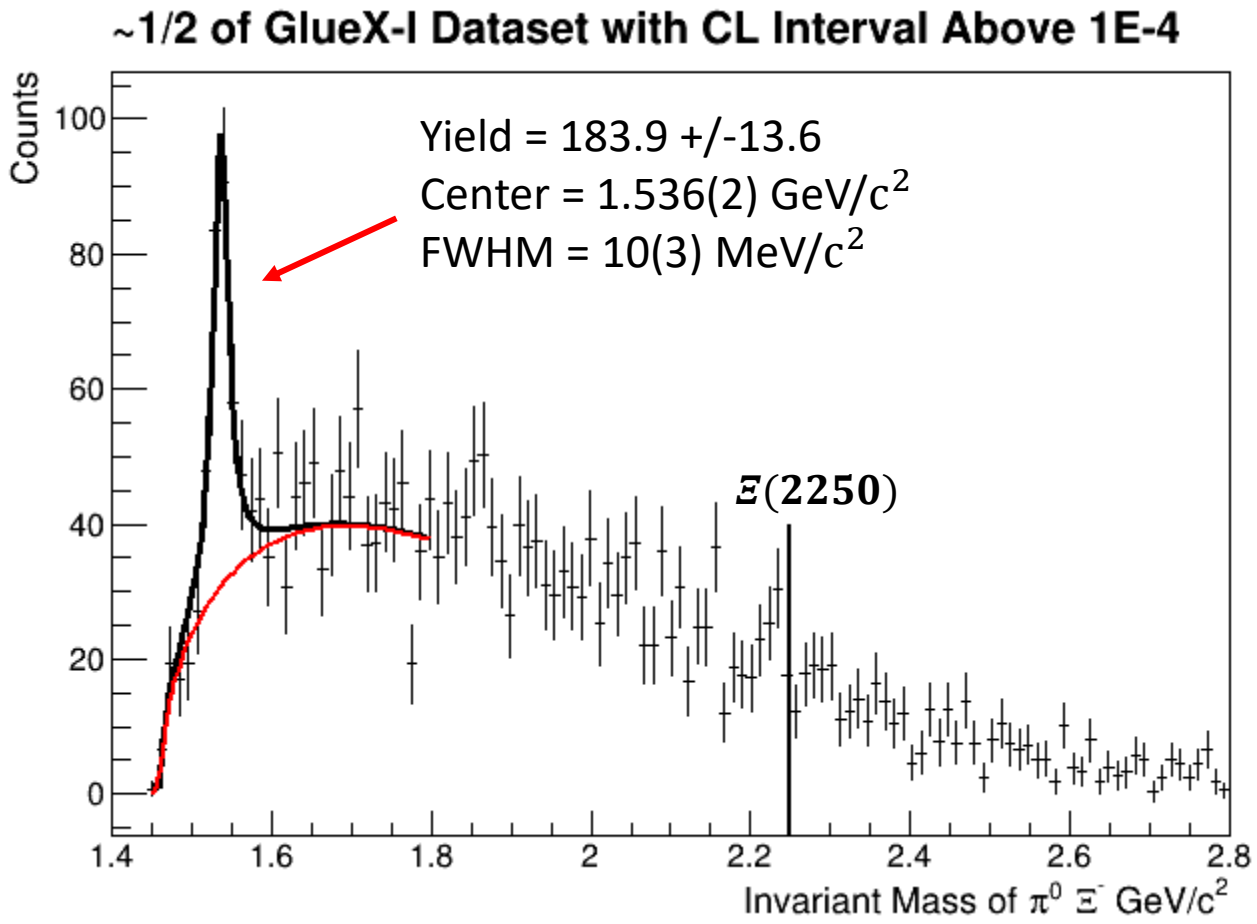


Yield = 569.2 +/-50.6

CL Study


Stability Region
Current choice
FOM
13
12
11
10
9
10^{-10}
10^{-9}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Confidence Level Cut

Searching for Excited Cascades



$\Xi(1530)$ $3/2^+$

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

$\Xi(1530)^0$ 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

$\Xi(2250)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 2250 OUR ESTIMATE						
2189± 7	66	BIAGI	87	SPEC	–	Ξ^- Be → ($\Xi^-\pi^+\pi^-$) X
2214± 5		JENKINS	83	MPS	–	$K^-p \to K^+$ MM
2295±15	18	GOLDWASSER	70	HBC	–	K^-p 5.5 GeV/c
2244±52	35	BARTSCH	69	HBC		K^-p 10 GeV/c

$\Xi(2250)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
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< 30		GOLDWASSER	70	HBC	–	K^-p 5.5 GeV/c
130±80		BARTSCH	69	HBC		

Modeling the Cascade Production in Signal MC

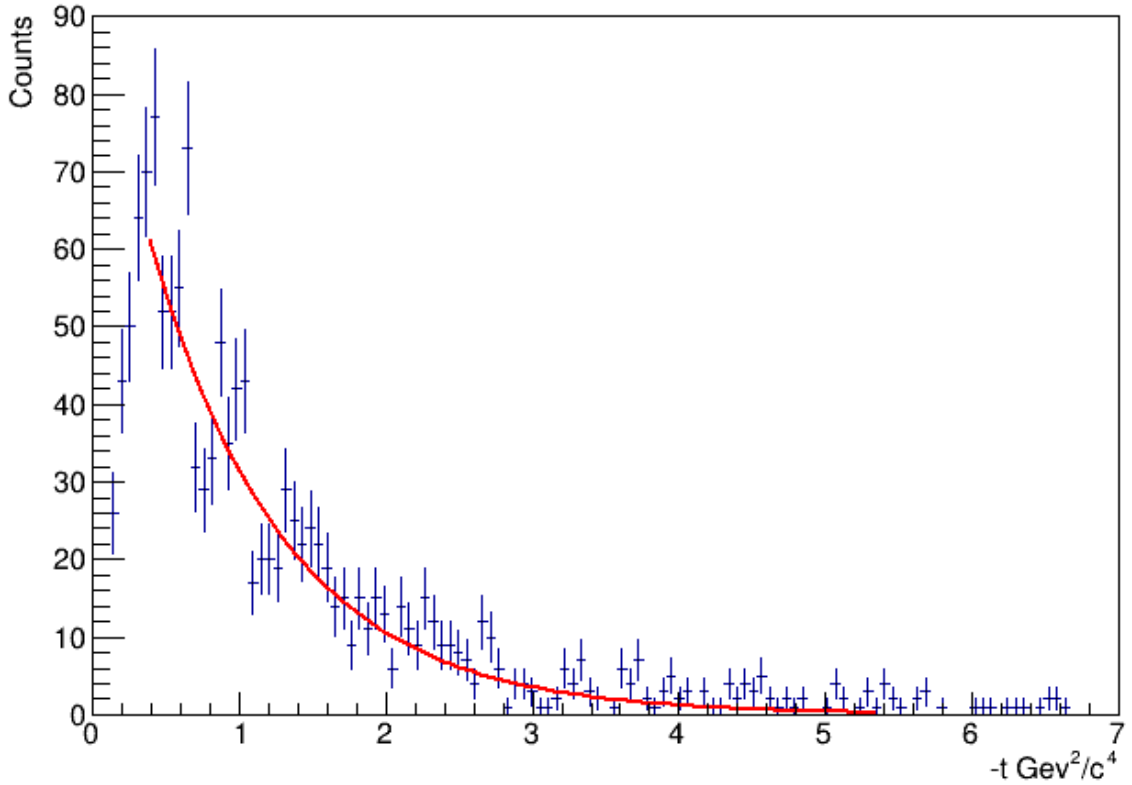
- Theoretical Calculations done by Nakayama, Oh and Haberzettl proposed the cascade/excited cascade are produced by a two-step process:

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

- Direct production of the Ξ^{*-} would be OZI suppressed with two strange- antistrange pairs at the production vertex. Therefore, I defined t as:

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

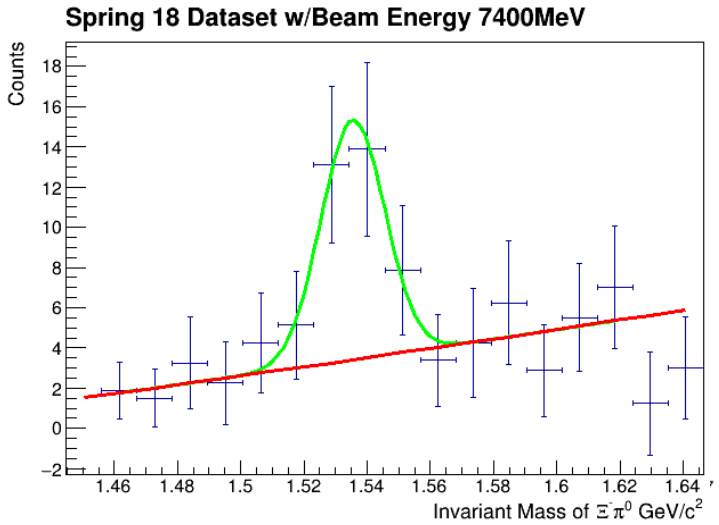
t-Slope extraction



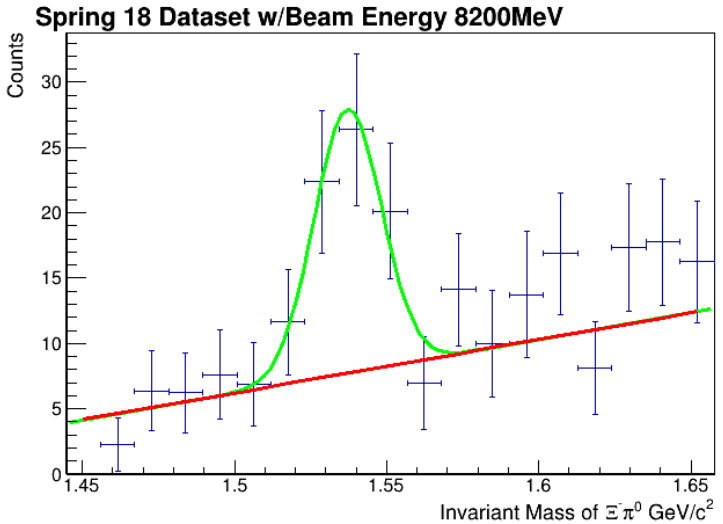
- Selecting events within the excited $\Xi(1530)$ peak
- Assuming : $\frac{d\sigma}{dt} \propto e^{-bt}$

$$b = 1.08(4)\ c^4/GeV^2$$

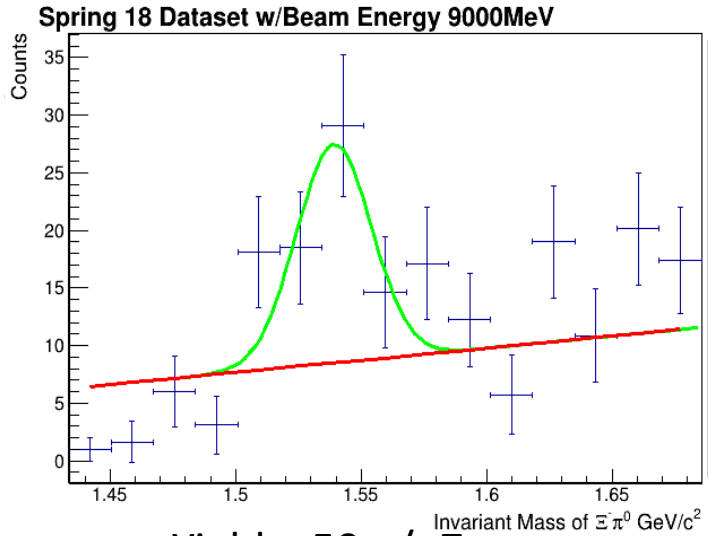
Energy-dependent $\Xi(1530)$ Yield Extraction



Yield = 27 +/- 5



Yield = 54 +/- 7



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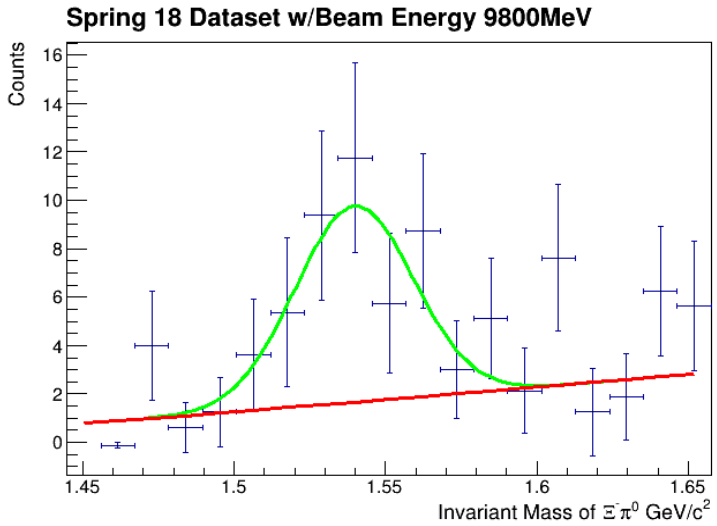
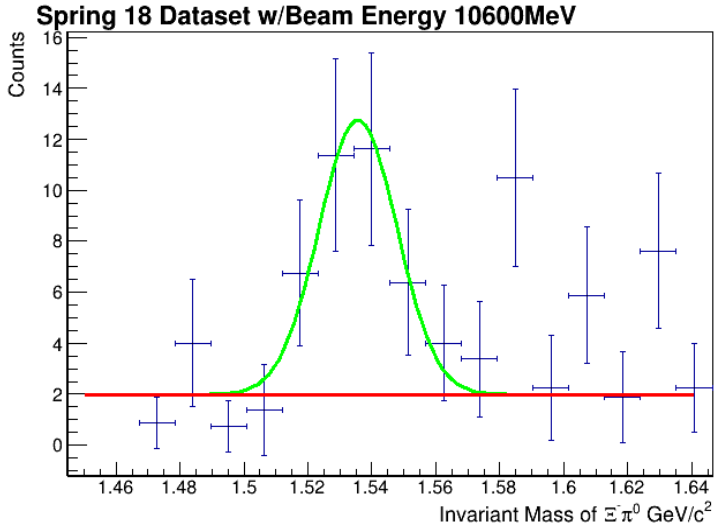
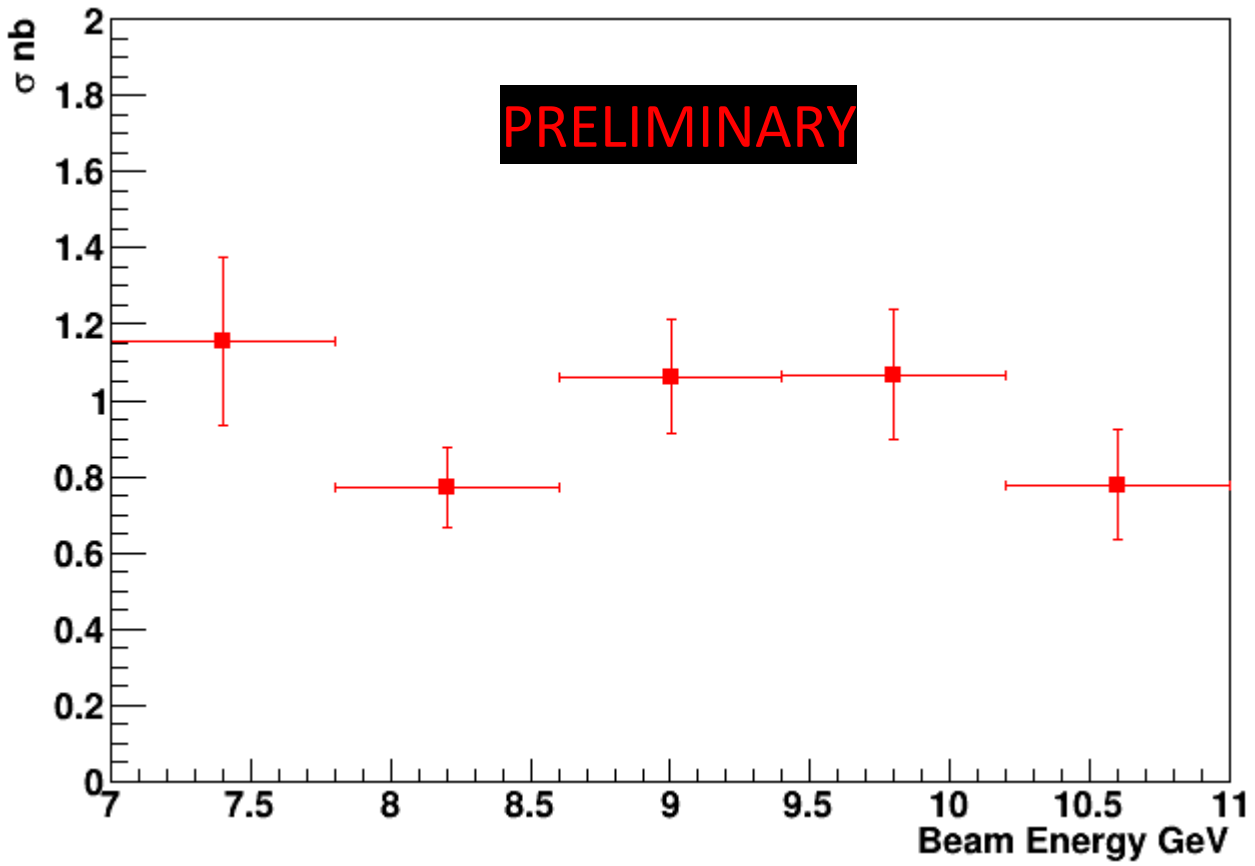


Yield = 38 +/- 6



Yield = 30 +/- 5

Cross Section for Cascade 1530



Charge Exchange Reaction

Charge Exchange Reaction

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

- The Λ and π^0 are Kinfit
- Data comes from Fa 18

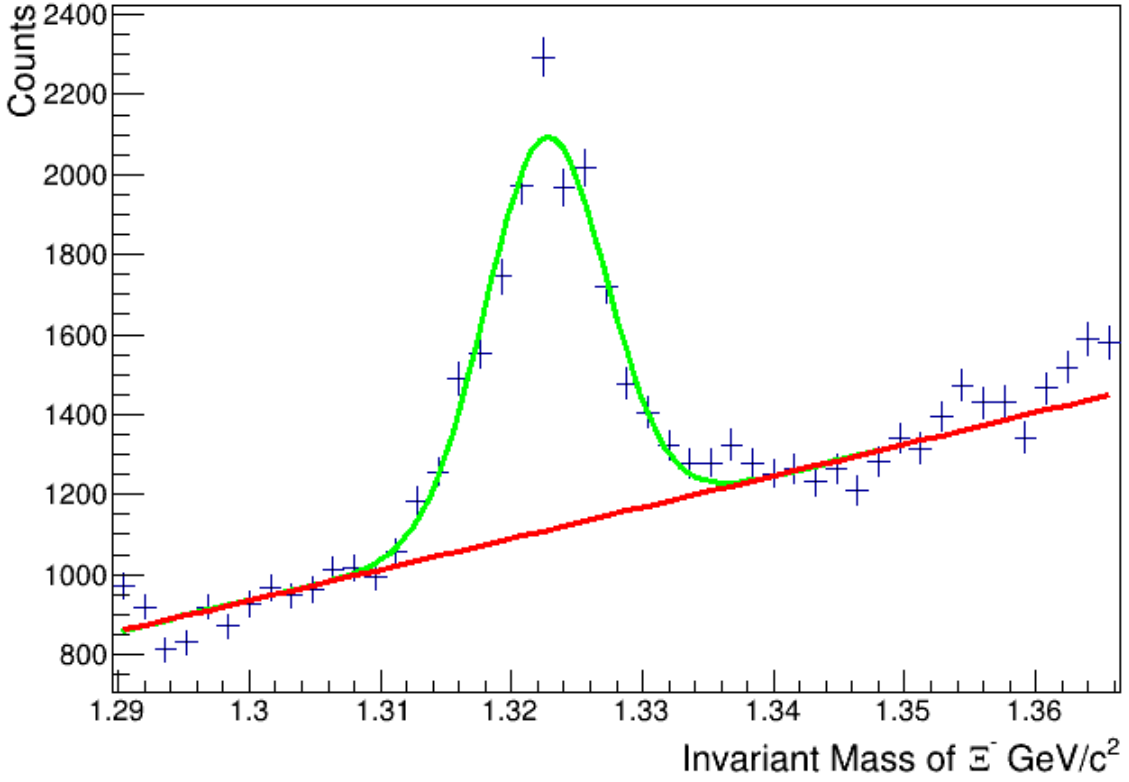
Charge Exchange Motivation

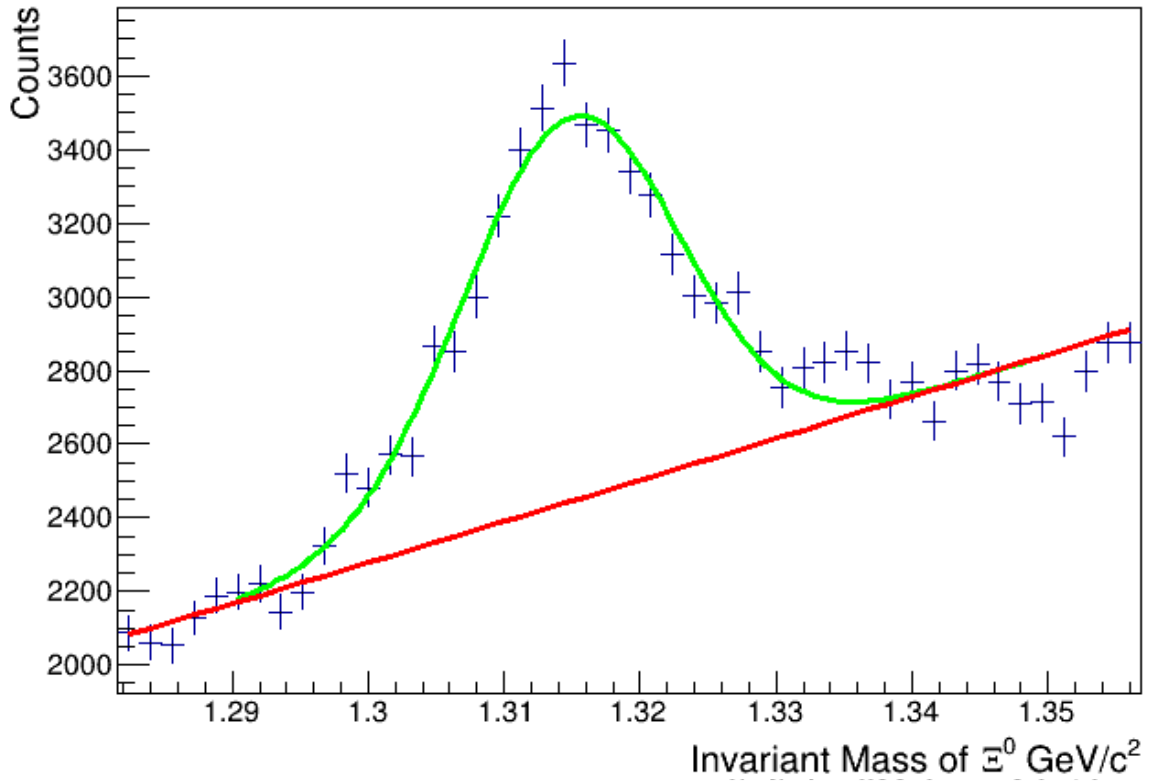
- This reaction should conserve isospin. Using Clebsch-Gordan coefficients we can that determine the neutral cascade channel should occur (roughly) twice as often.

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

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

Yields From ground state cascade w/o vertex fitting (F1 designation Fa18)



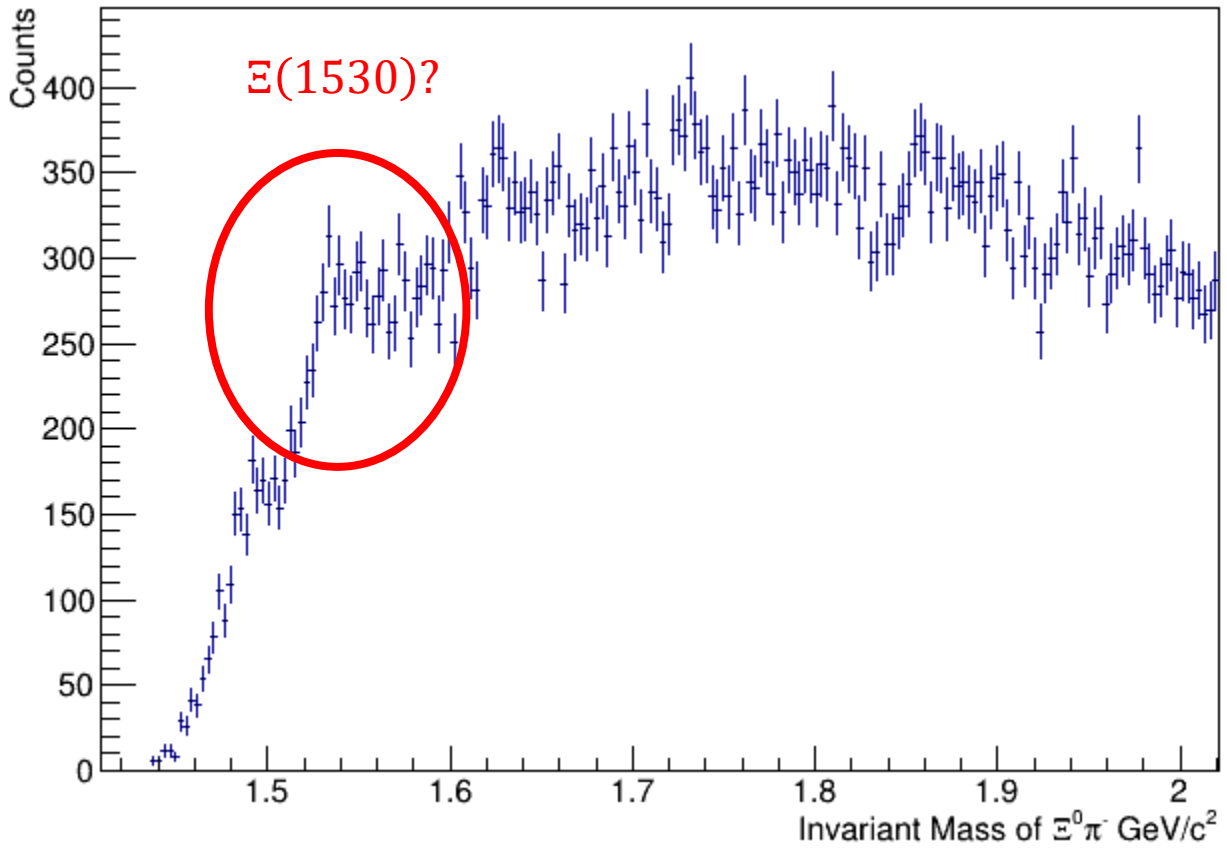


Yield(Ξ^-) = 7270+/-85

Yield(Ξ^0) = 13351+/-116

Confidence level above 10^-3

Excited Cascade Mass Spectrum



- The lack of the vertex fitting constraint on the data reduces the resolution considerably
- There is an issue with the vertex fitting with this reaction

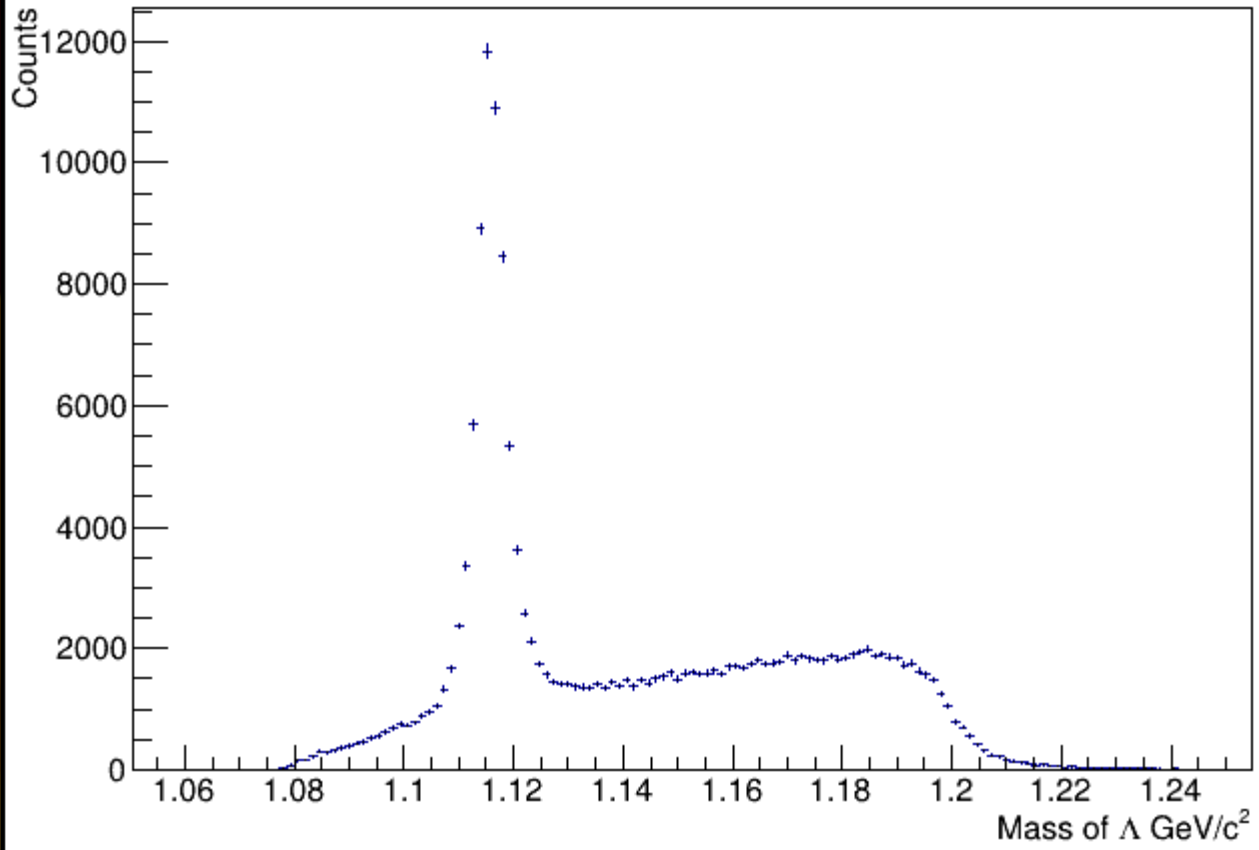
$K^{-}\Lambda$ Reaction Channel

$K^-\Lambda$ Decay Chain

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

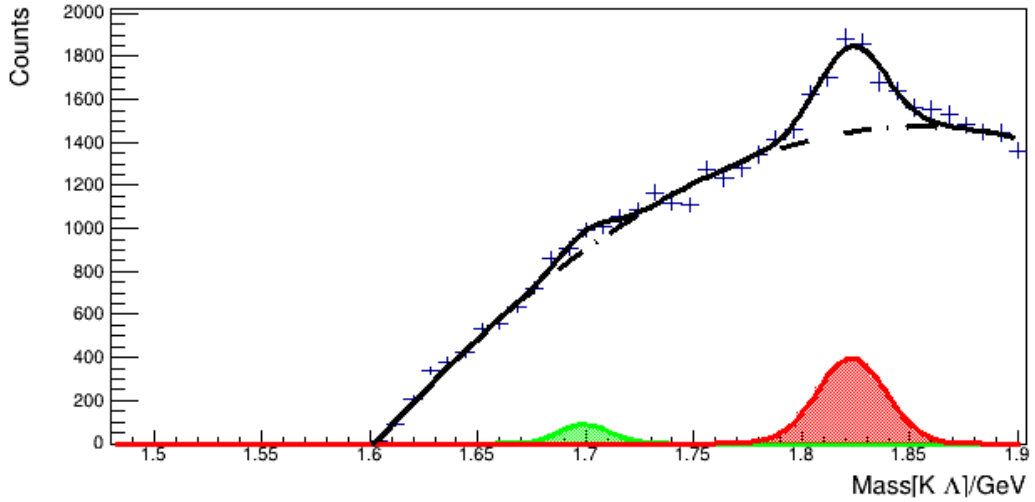
- The K^- is Kinfit
- Data comes from Fa 18

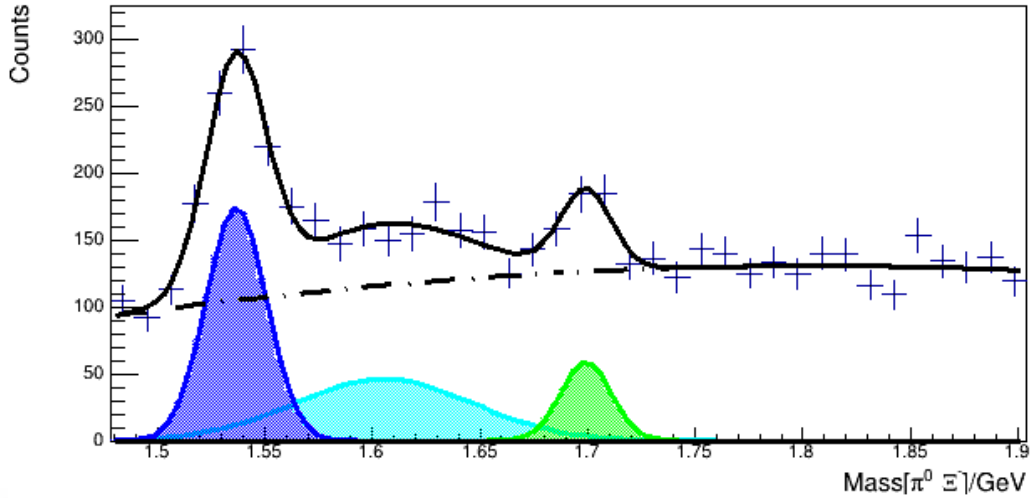
Cuts on Data



- Mass cut on Λ from 1.107 to 1.124 GeV/ c^2
- Mass cut on Ξ^- from 1.31 to 1.34 GeV/ c^2(Same as Earlier)
- CL above 10^{-4}

Simultaneous Fitting





- $\Xi(1530)$
  - Center 1.536(1) GeV/c^2
  - Width 33(5) MeV/ c^2
- $\Xi(1620)$
  - Center 1.60(1) GeV/ c^2
  - Width 94(24) MeV/ c^2
- $\Xi(1690)$
  - Center 1.70(2) GeV/ c^2
  - Width 28(5) MeV/ c^2
- $\Xi(1820)$
  - Center 1.822(1) GeV/ c^2
  - Width 38(5) MeV/ c^2

- $\Xi(1530)$ PDG
  - Center 1.535(6) GeV/c^2
  - Width 9.9(+1.9,-1.7) MeV/c^2
- $\Xi(1620)$ PDG
  - Center 1.62 GeV/ c^2
  - Width < 55 MeV/ c^2
- $\Xi(1690)$ PDG
  - Center 1.69(1) GeV/ c^2
  - Width < 30 MeV/ c^2
- $\Xi(1820)$ PDG
  - Center 1.823(5) GeV/ c^2
  - Width 24(+15,-10) MeV/ c^2

3rd degree polynomial background with independent parameters

ASU Arizona State University

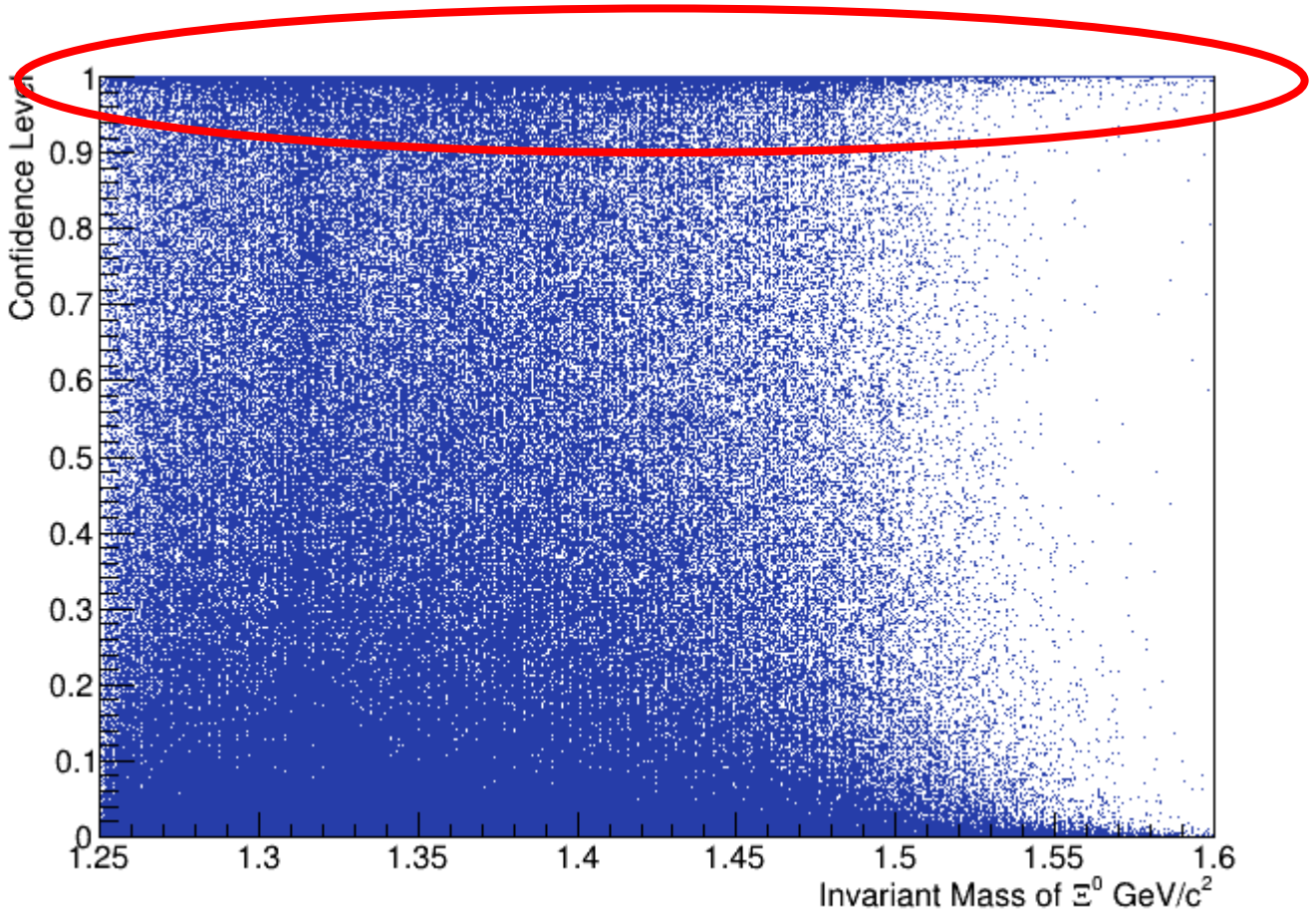
Next Steps and Conclusion

- Finalize $\Xi(1530)$ Cross Section measurement
- Evidence of $\Xi(1690)$ in both $K^-\Lambda$ and $\Xi^-\pi^0$ channels,
- If possible, GlueX measurement of branching ratio $\Gamma[\Xi(1690) \to K^-\Lambda]/\ \Gamma[\Xi(1690) \to \Xi^-\pi^0]$ will be a first-time measurement

End

Ξ^0 mass vs confidence level w/Vertex fitting

Large amount of contamination at high confidence level when using vertex fitting with this reaction



Collection of DNP Slides

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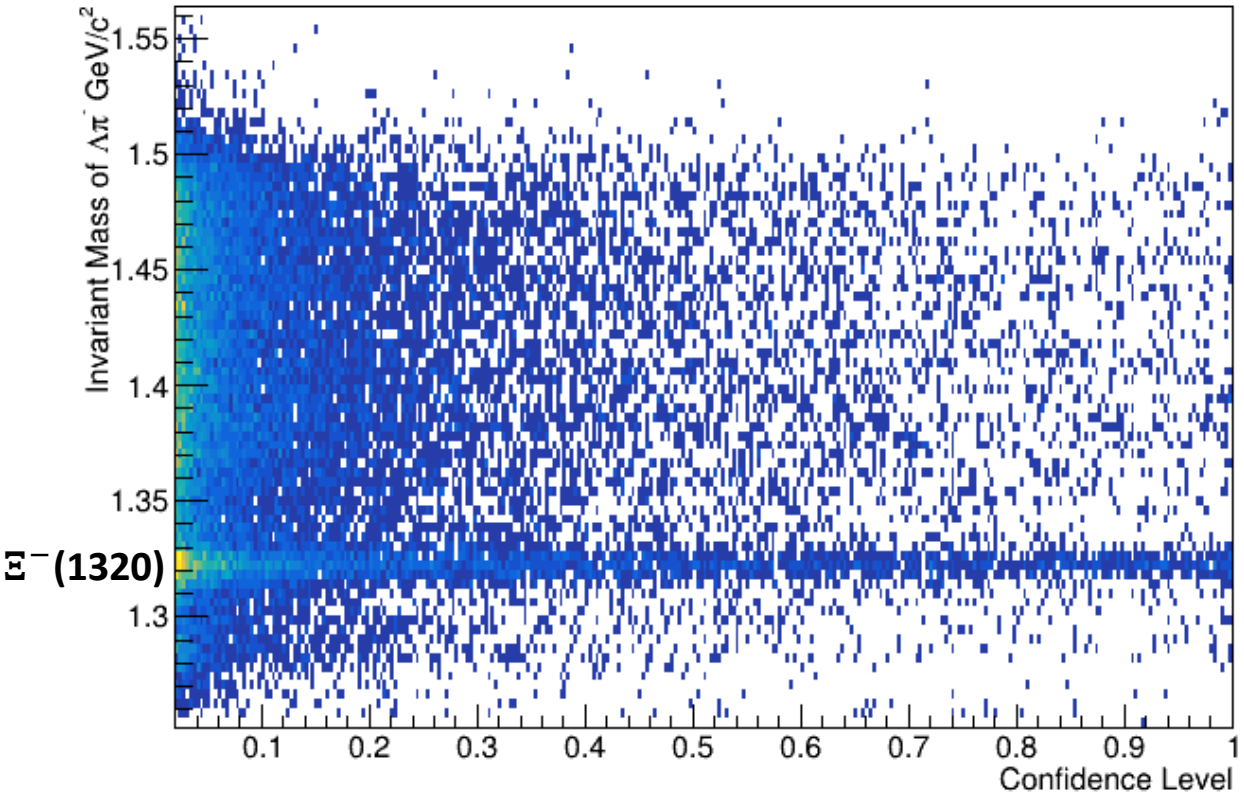

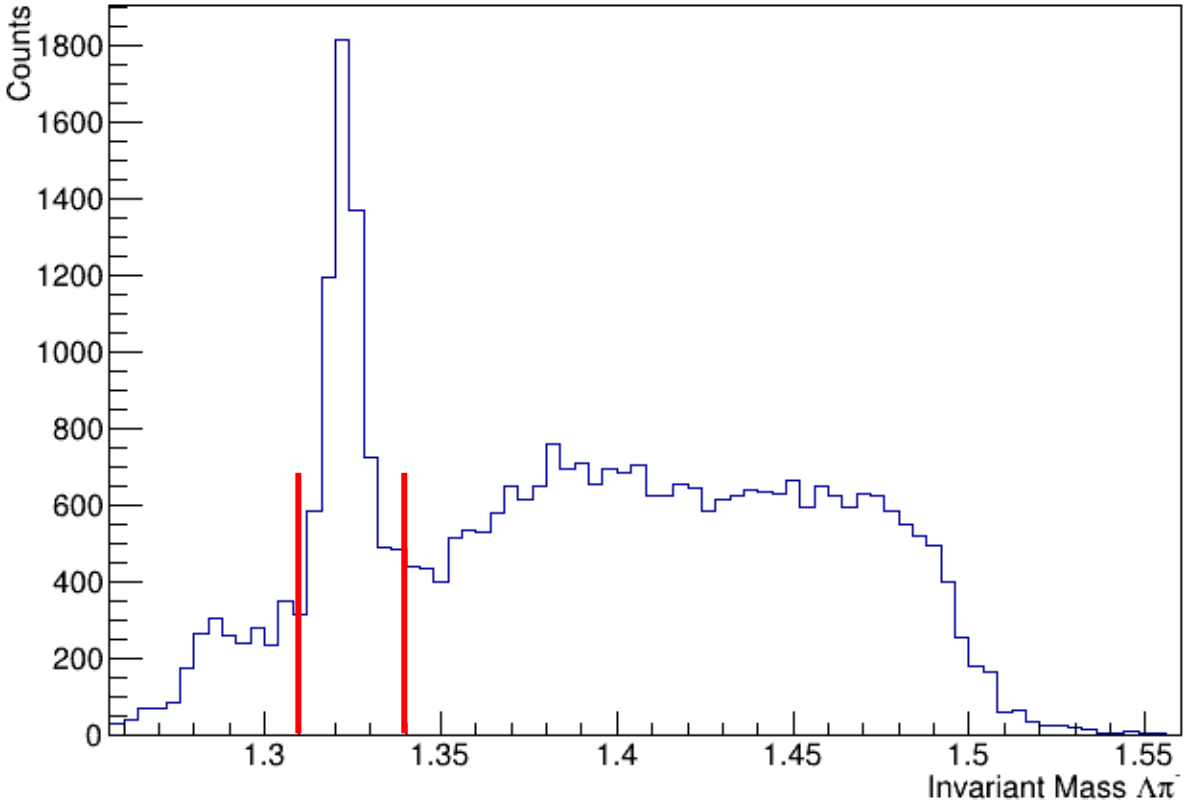

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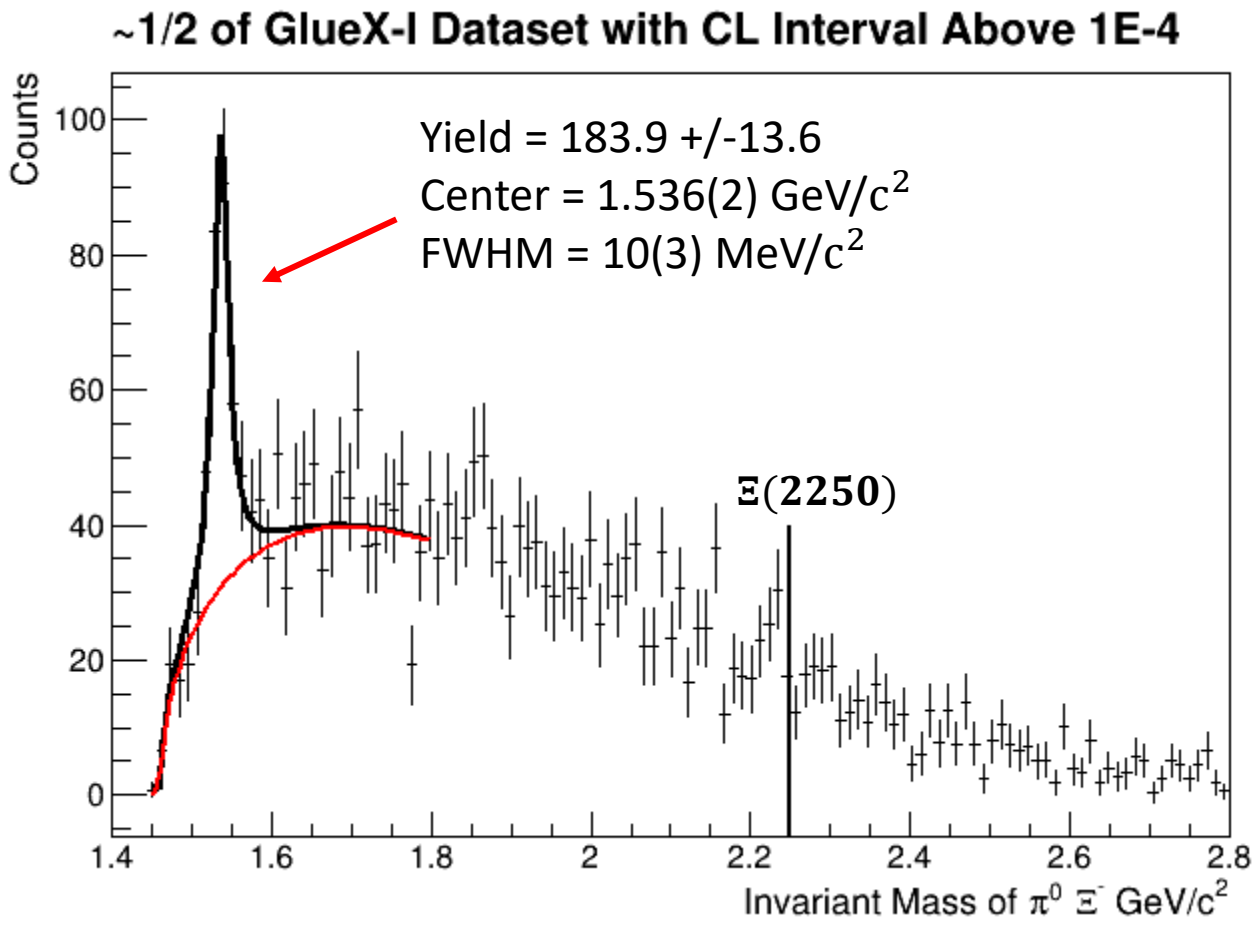

Ξ(1530) 3/2⁺

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

$\Xi(1530)^0$ mass $m = 1531.80 \pm 0.32$ MeV (S = 1.3)
$\Xi(1530)^-$ mass $m = 1535.0 \pm 0.6$ MeV
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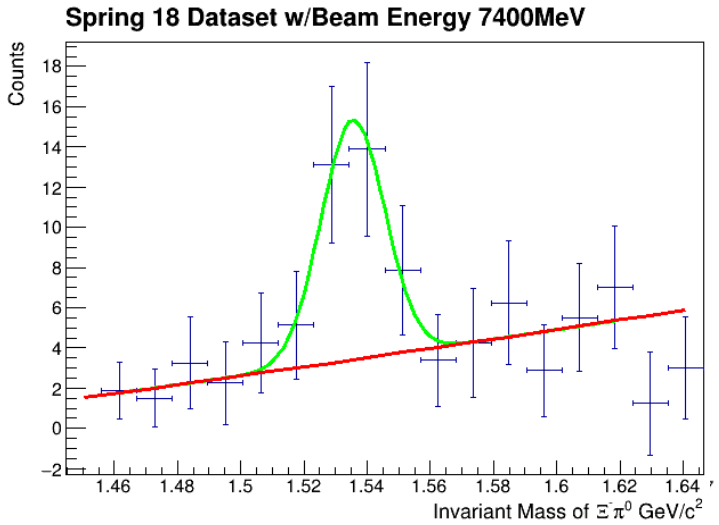
Energy-dependent $\Xi(1530)$ Yield Extraction



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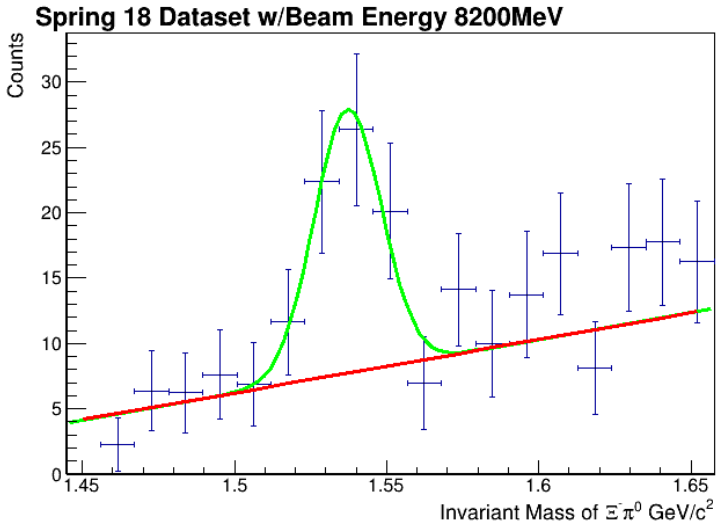

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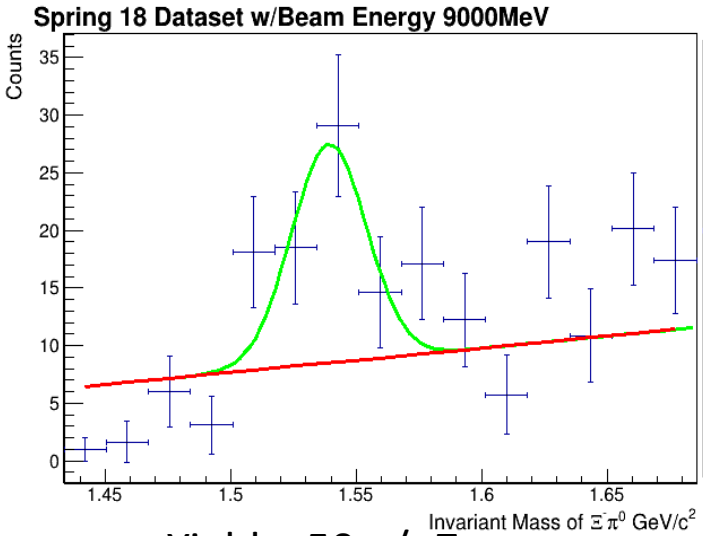

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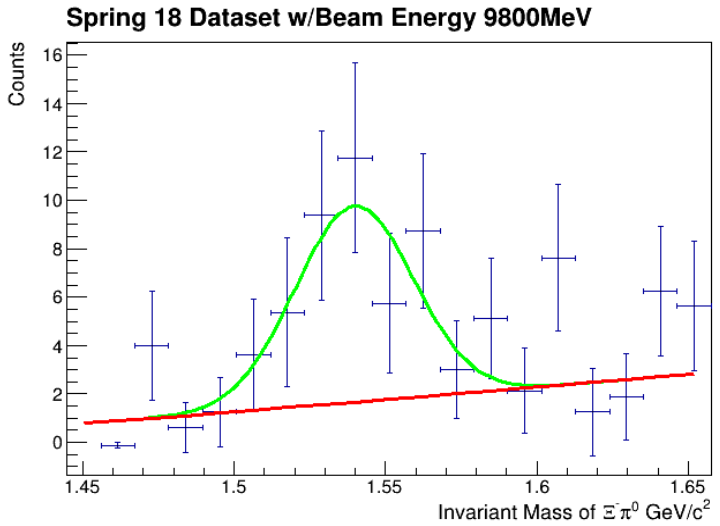
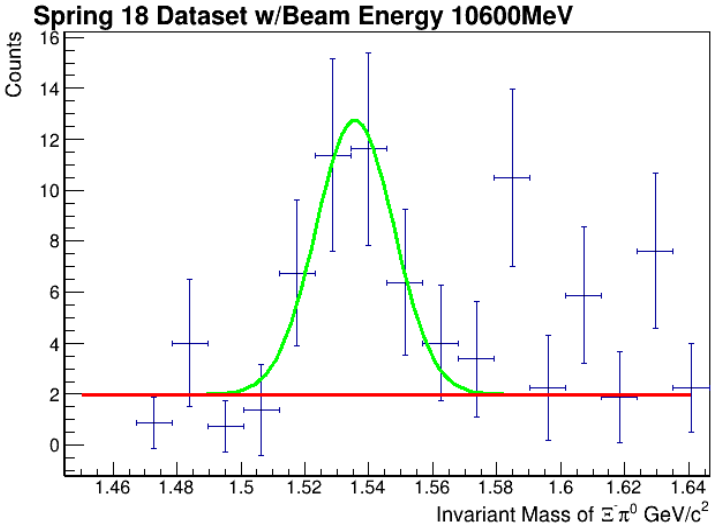
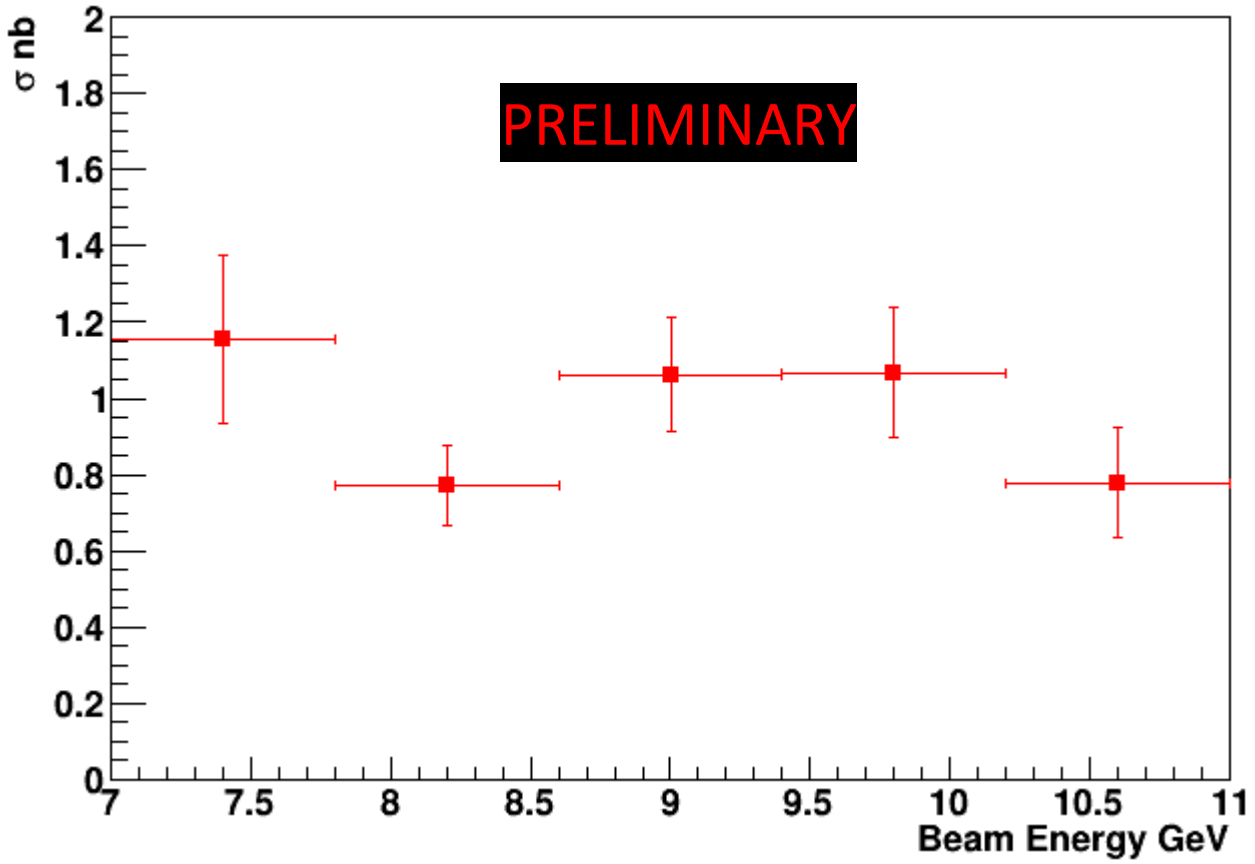


Yield = 38 +/- 6



Yield = 30 +/- 5

Cross Section for Cascade 1530

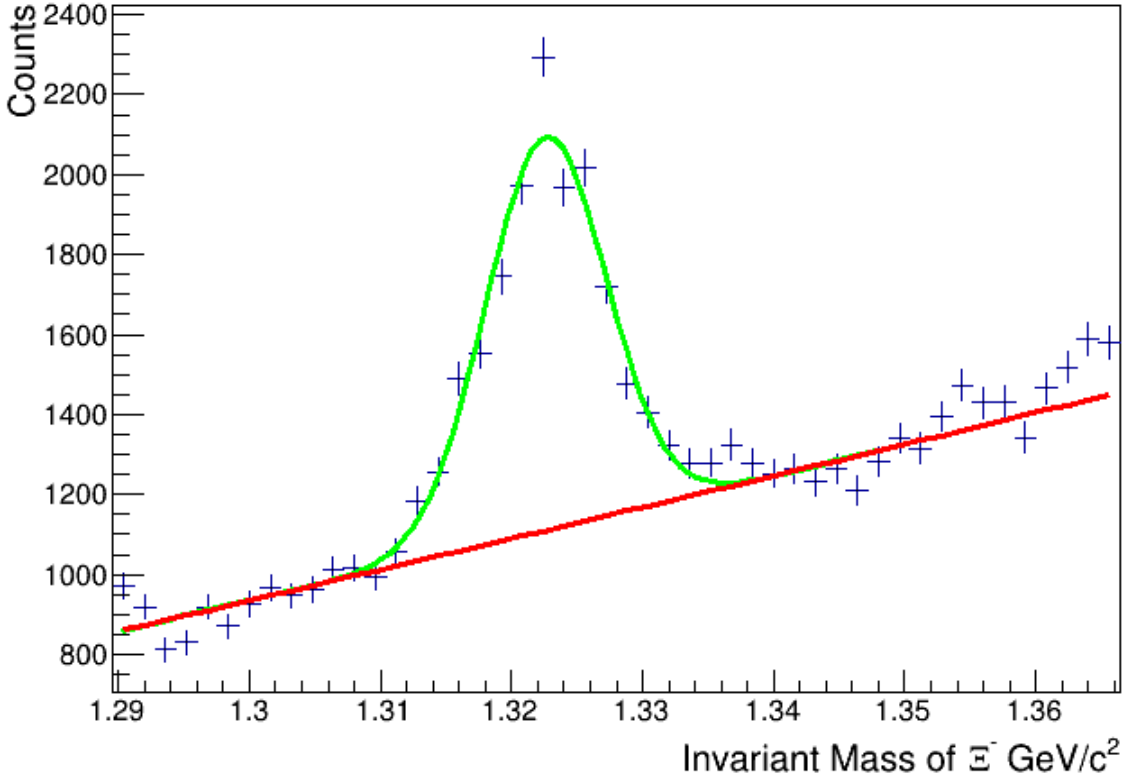


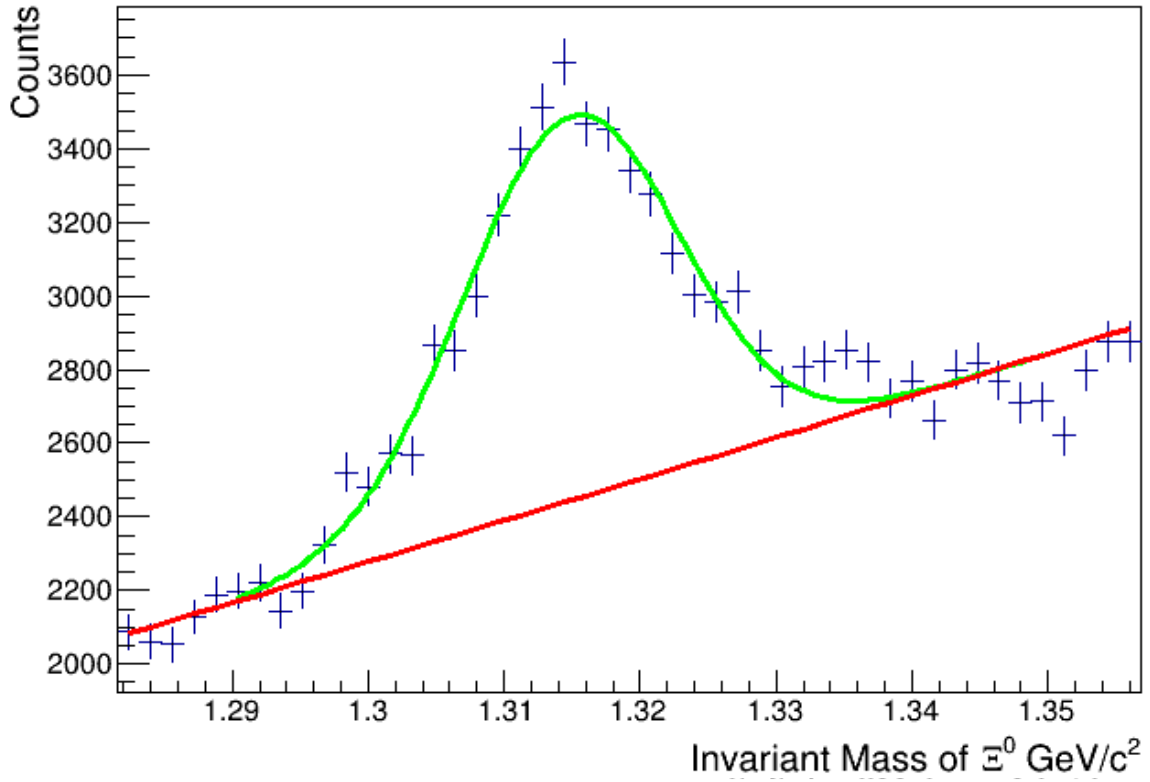
Charge Exchange Reaction

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

- The Λ and π^0 are Kinfit
- Data comes from Fa 18

Yields From ground state cascade w/o vertex fitting (F1 designation Fa18)





Yield(Ξ^-) = 7270+/-85

Yield(Ξ^0) = 13351+/-116

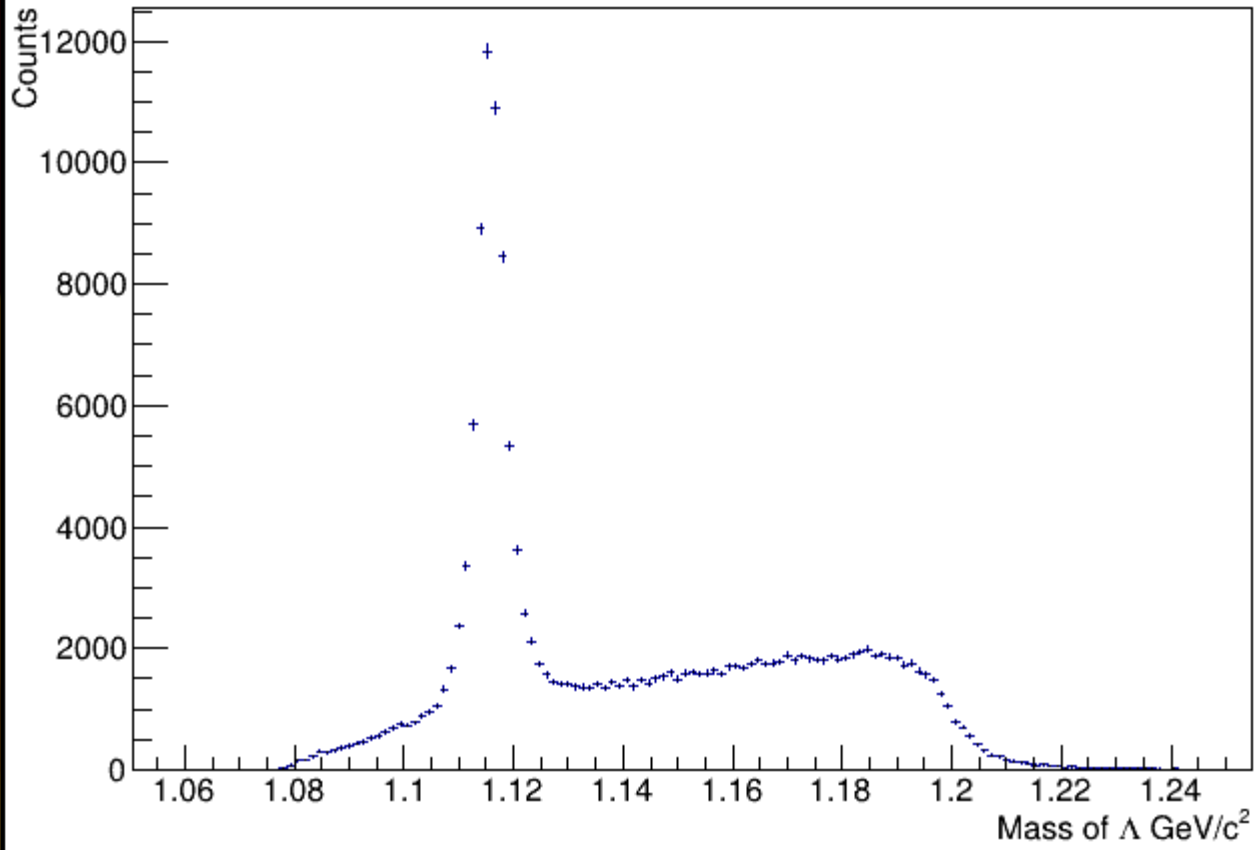
Confidence level above 10^-3

$K^-\Lambda$ Decay Chain

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

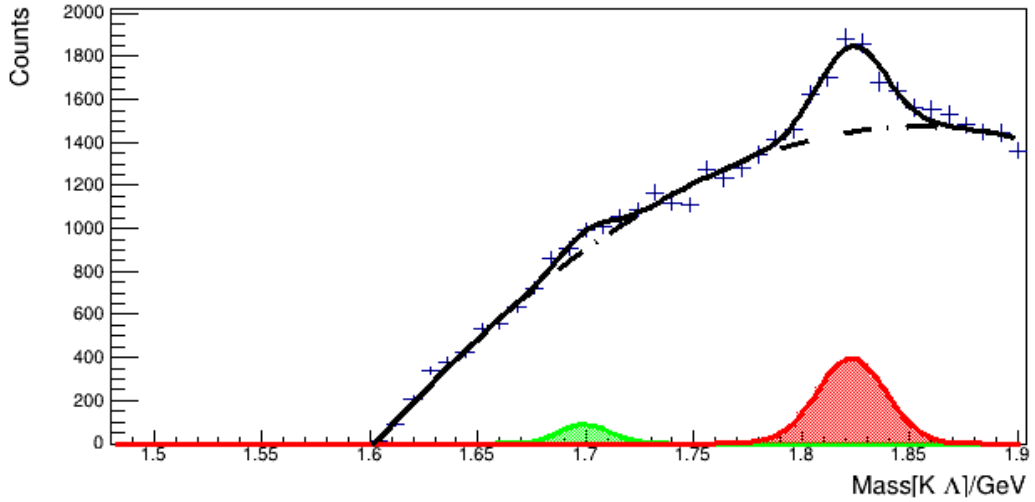
- The K^- is Kinfit
- Data comes from Fa 18

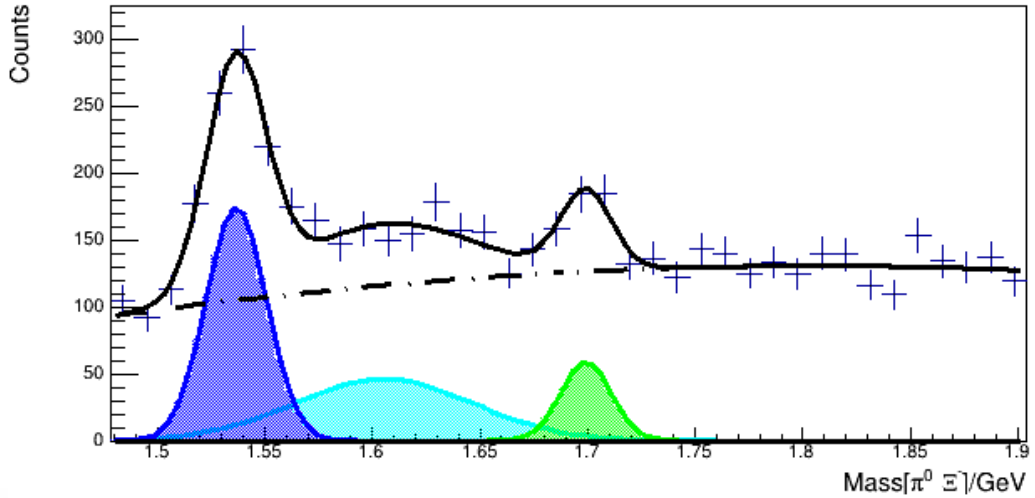
Cuts on Data



- Mass cut on Λ from 1.107 to 1.124 GeV/ c^2
- Mass cut on Ξ^- from 1.31 to 1.34 GeV/ c^2(Same as Earlier)
- CL above 10^{-4}

Simultaneous Fitting





- $\Xi(1530)$
  - Center 1.536(1) GeV/c^2
  - Width 33(5) MeV/ c^2
- $\Xi(1620)$
  - Center 1.60(1) GeV/ c^2
  - Width 94(24) MeV/ c^2
- $\Xi(1690)$
  - Center 1.70(2) GeV/ c^2
  - Width 28(5) MeV/ c^2
- $\Xi(1820)$
  - Center 1.822(1) GeV/ c^2
  - Width 38(5) MeV/ c^2

- $\Xi(1530)$ PDG
  - Center 1.535(6) GeV/c^2
  - Width 9.9(+1.9,-1.7) MeV/c^2
- $\Xi(1620)$ PDG
  - Center 1.62 GeV/ c^2
  - Width < 55 MeV/ c^2
- $\Xi(1690)$ PDG
  - Center 1.69(1) GeV/ c^2
  - Width < 30 MeV/ c^2
- $\Xi(1820)$ PDG
  - Center 1.823(5) GeV/ c^2
  - Width 24(+15,-10) MeV/ c^2

3rd degree polynomial background with independent parameters

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