Exploration of the $\Xi^* \rightarrow \Xi\pi$ spectrum

Reaction

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

where

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

$$\Xi^{-} \rightarrow \Lambda \pi^{-},$$

and

$$\Lambda \rightarrow p \pi^{-}$$

Reaction

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

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In what is shown today, I'm looking for

- Ξ(1530) : well known four star resonance
- Ξ(1620) : two star resonance (recently updated from single star)

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In what is shown today, I'm looking for

- Ξ(1530) : well known four star resonance
- Ξ(1620) : two star resonance (recently updated from single star)

Will briefly talk about

- Ξ(1690) : three star resonance

$\Xi(1620)$: From 1-star

Nucleon resonances are rated using the "star" system:

* Poor evidence of existence

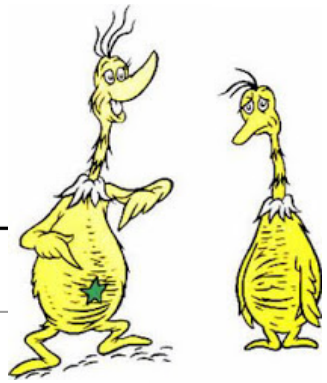
$\Xi(1620)$ $I(J^P) = \frac{1}{2}(?^?)$ Status: *
J, P need confirmation.

OMITTED FROM SUMMARY TABLE

What little evidence there is consists of weak signals in the $\Xi\pi$ channel. A number of other experiments (e.g., BORENSTEIN 72 and HASSALL 81) have looked for but not seen any effect.

$\Xi(1620)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
≈ 1620 OUR ESTIMATE					
1624± 3	31	BRIEFEL	77	HBC	K^-p 2.87 GeV/c
1633±12	34	DEBELLEFON	75B	HBC	$K^-p \to \Xi^-\overline{K}\pi$
1606± 6	29	ROSS	72	HBC	K^-p 3.1–3.7 GeV/c



$\Xi(1620)$: From 1-star to 2-star

Nucleon resonances are rated using the "star" system:

* Poor evidence of existence

** Fair evidence of existence

Citation: S. Navas *et al.* (Particle Data Group), Phys. Rev. D **110**, 030001 (2024)

$\Xi(1620)$ $I(J^P) = \frac{1}{2}(?^?)$ Status: *

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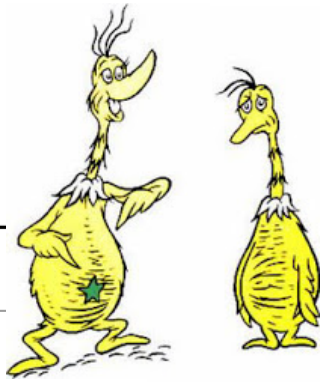

$\Xi(1620)$ $I(J^P) = \frac{1}{2}(?^?)$ Status: **

J, *P* need confirmation.

OMITTED FROM SUMMARY TABLE

The clearest evidence is a peak in $\Xi^-\pi^+$ seen by SUMIHAMA 19. Older low-statistics experiments (e.g., BORENSTEIN 72 and HASSALL 81) have looked for the state but have not seen any effect.

$\Xi(1620)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
≈ 1620 OUR ESTIMATE					
$1610.4 \pm 6.0^{+6.1}_{-4.2}$		SUMIHAMA	19	BELL	$\Xi_c^+ \to \Xi(1620)\pi^+$
1624 ± 3	31	BRIEFEL	77	HBC	$K^- p$ 2.87 GeV/c
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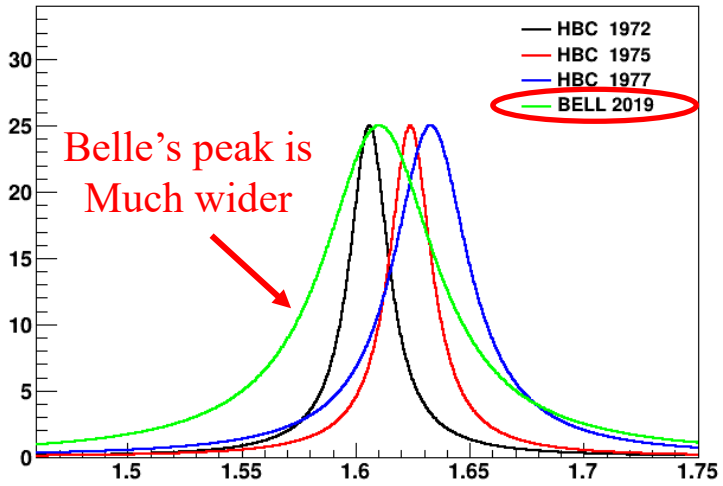
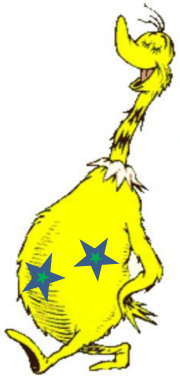
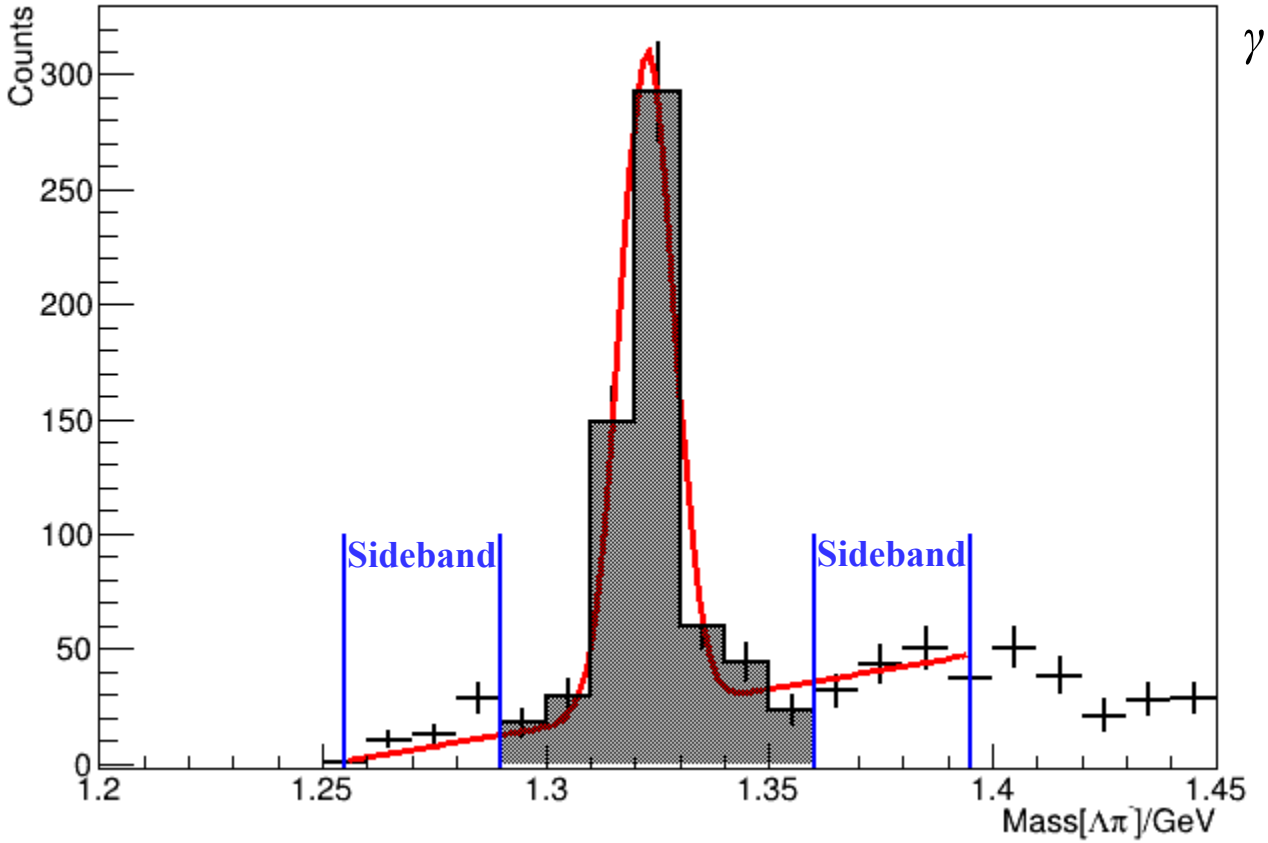




$\Xi(1620)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
32 $^{+8}_{-9}$ OUR AVERAGE Error includes scale factor of 2.2. See the ideogram below.					
$59.9 \pm 4.8^{+2.8}_{-7.1}$		SUMIHAMA	19	BELL	$\Xi_c^+ \to \Xi(1620)\pi^+$
22.5± 7.5	31	BRIEFEL	77	HBC	$K^- p$ 2.87 GeV/c
40 ±15	34	DEBELLEFON	75B	HBC	$K^- p \to \Xi^- \overline{K}\pi$
21 ± 7	29	ROSS	72	HBC	$K^- p \to \Xi^- \pi^+ K^{*0}(892)$

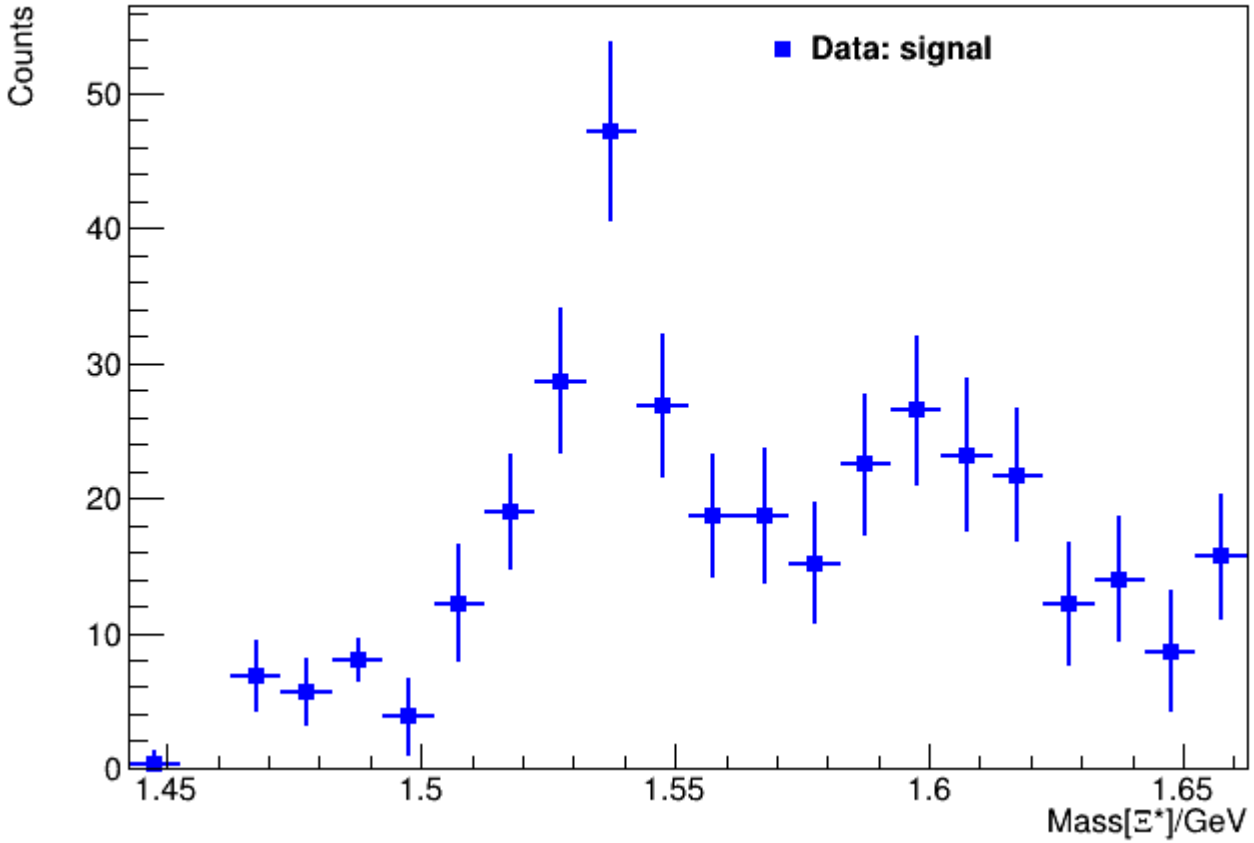
Invariant mass of $\Lambda\pi^-$



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

- Hybrid method for accidental subtraction
- CL cut at 10^{-6}
- Significance of Ξ^- pathlength > 4
- $|t_{fast}| < 3$ GeV^2
- K^* cut (0.85 GeV < mass[$K^+\pi^0$] < 0.95 GeV removed)

Invariant mass of $\Xi^-\pi^0$ (presumably Ξ^*)



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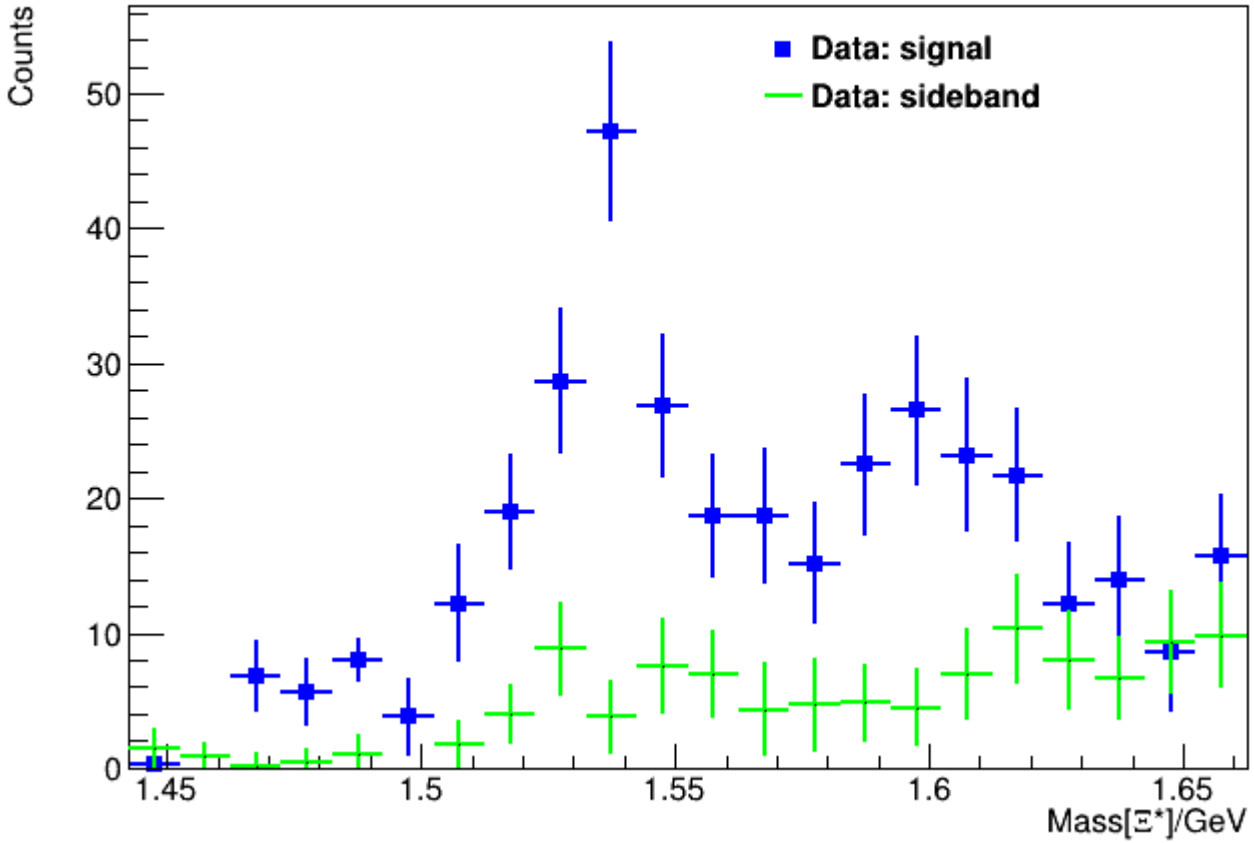
- Significance of Ξ^- pathlength > 4
- $|t_{fast}| < 3$ GeV^2
- K^* cut (0.85 GeV < mass[$K^+\pi^0$] < 0.95 GeV removed)
- Ξ^- cut: 1.29 GeV < mass[$\Lambda\pi^-$] < 1.36 GeV kept

Invariant mass of $\Xi^-\pi^0$ (presumably Ξ^*)



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

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

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

The sideband gives a rough estimate of the background

Sidebands:

- 1.255 GeV < mass[$\Lambda\pi^-$] < 1.290 GeV
- 1.360 GeV < mass[$\Lambda\pi^-$] < 1.395 GeV

Comparison of data to simulation

Ξ^* Generator Refinement

- Started with generator for general reaction $\gamma\, p \rightarrow K^+K^+\Xi^-\pi^0$ and modified from there
- Taking the initial reaction as $\gamma\, p \rightarrow K\, Y^*$
- Mandelstam variables have relationship:
  - $s+t+u = m_\gamma^2 + m_p^2 + m_K^2 + m_{Y*}^2$
- We can lock down the kinematics of the initial reaction by specifying s, t and m_{Y*}
- Started with Mandelstam s and t

Ξ^* Comparison of Reconstructed MC to Actual Data

For the general reaction:

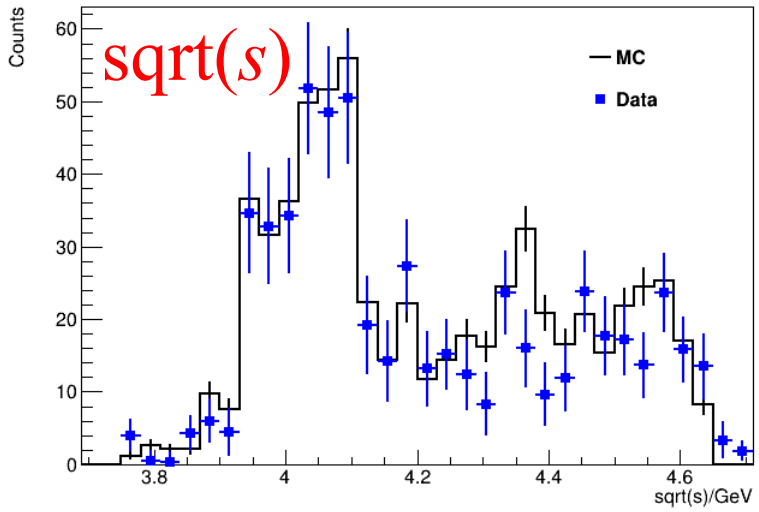
- 1st : Set t-slope (parameter b in $Ae^{-b|t|}$) to 1.138/GeV^2 assuming $\gamma\, p \rightarrow K_{\text{fast}}\, Y^*$
- 2nd : Shaped mass[Y^*] and mass[Ξ^*]
- 3rd : Shaping K_{slow} distribution assuming $Y^* \rightarrow K_{\text{slow}}\, \Xi^*$

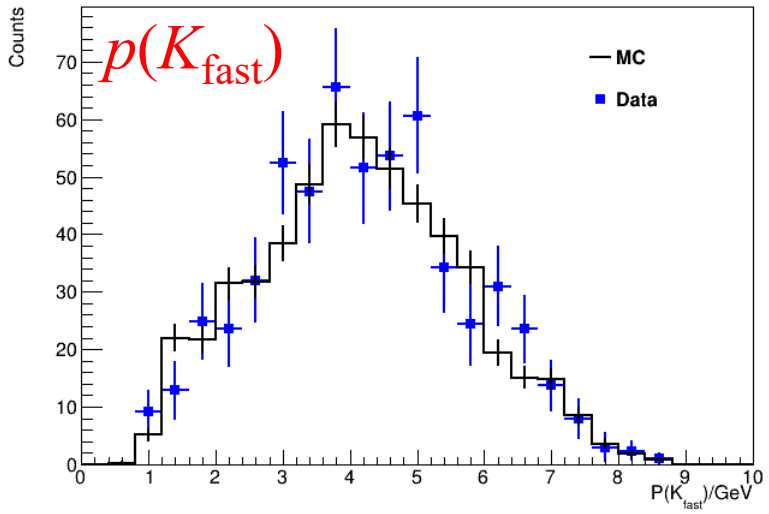
For $\gamma\, p \rightarrow K^+K^+\Xi^-(1530)$

- Start with general reaction and modify each step as required

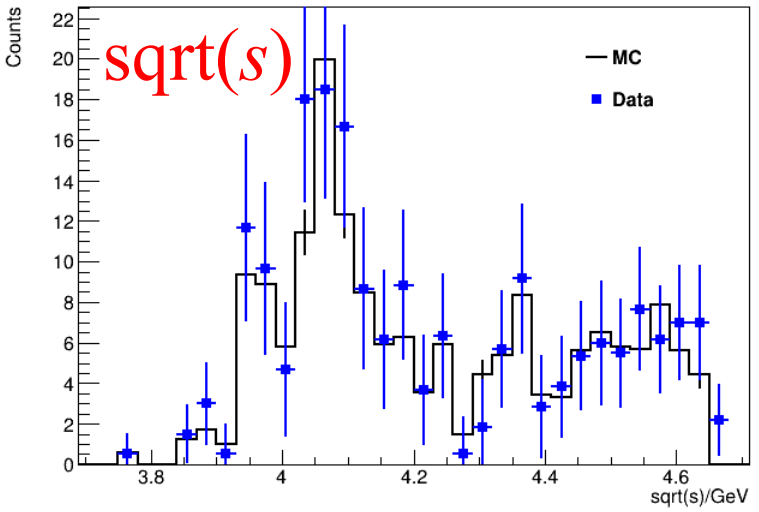
Ξ^* Comparison of Reconstructed MC to Actual Data

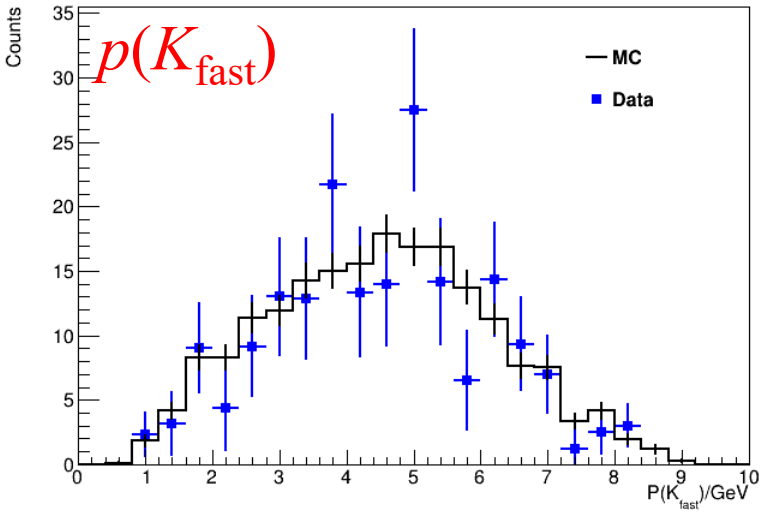
General reaction





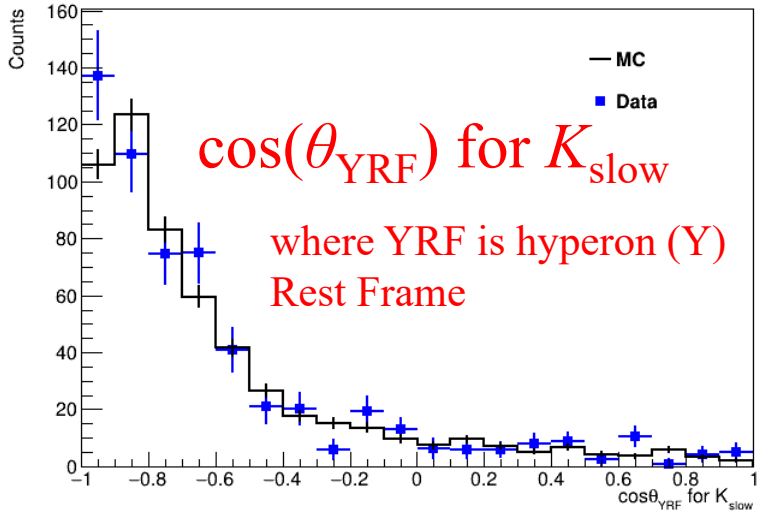
$\gamma p \rightarrow K^+K^+\Xi^-(1530)$





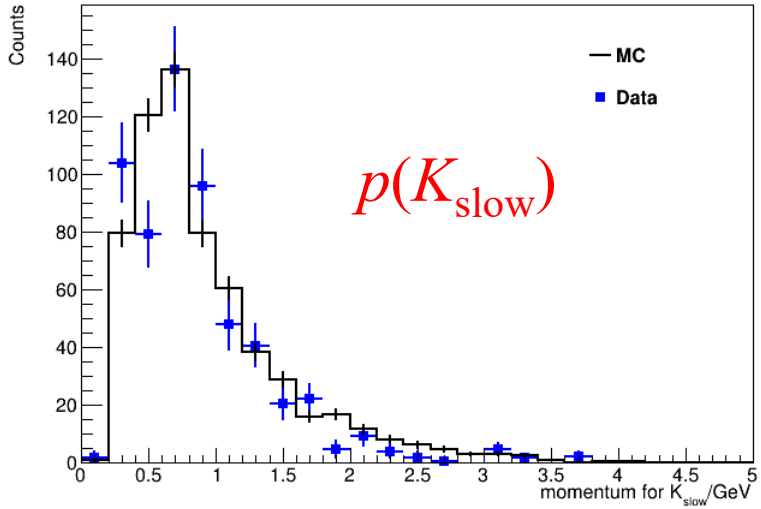
Ξ^* Comparison of Reconstructed MC to Actual Data

General reaction



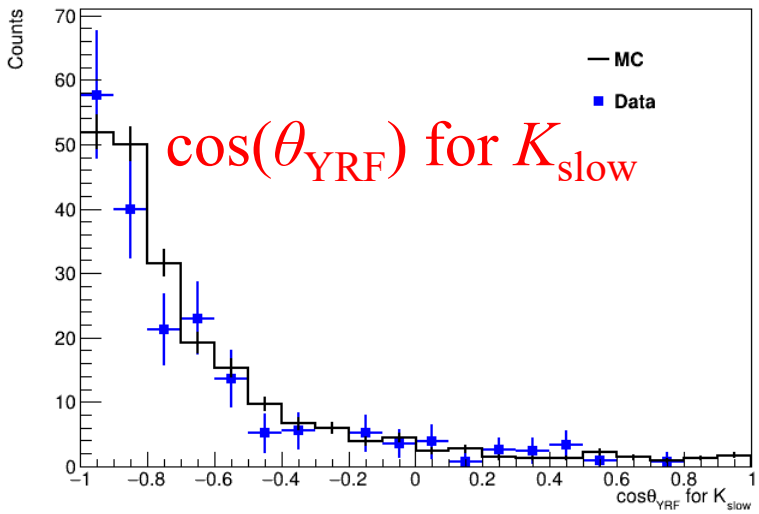
$\cos(\theta_{\mathrm{YRF}})$ for K_{slow}

where YRF is hyperon (Y) Rest Frame



$p(K_{\mathrm{slow}})$

$\gamma\, p \rightarrow K^+K^+\Xi^-(1530)$



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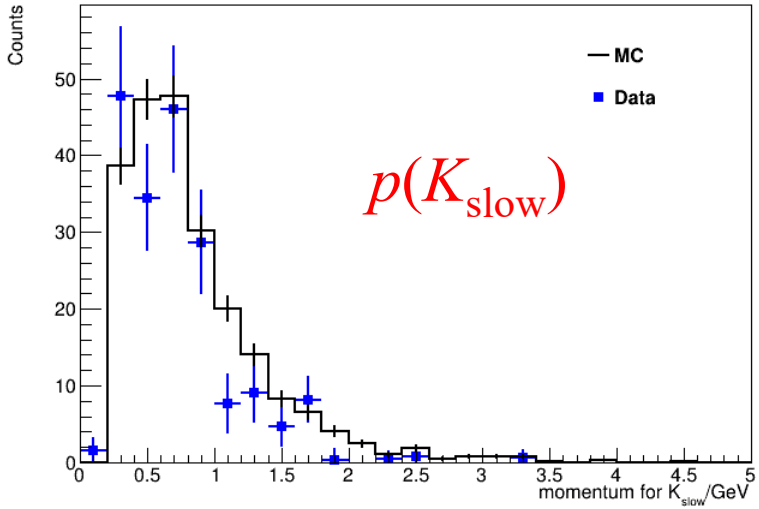
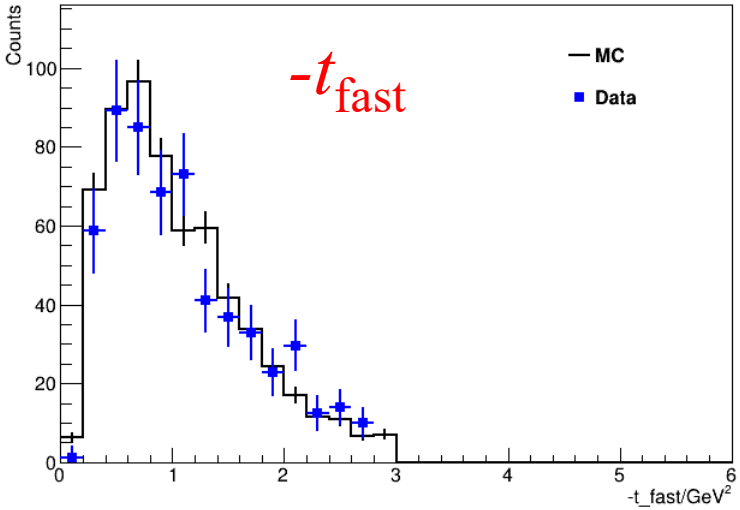
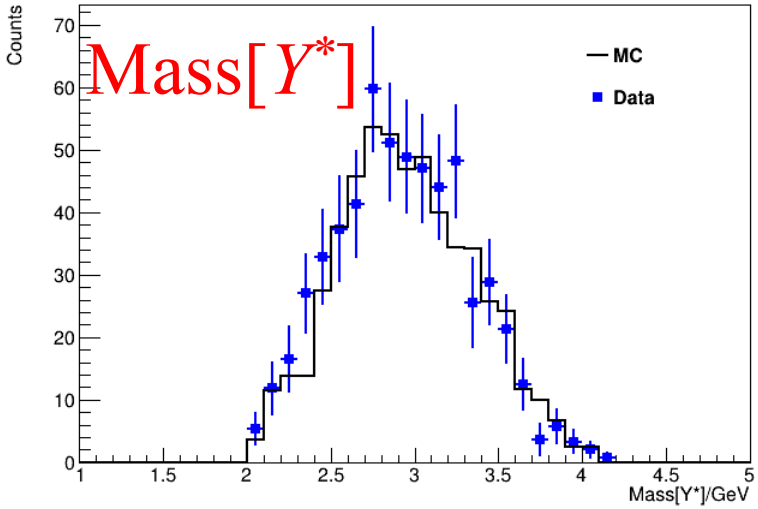


$p(K_{\mathrm{slow}})$

Ξ^* Comparison of Reconstructed MC to Actual Data

General reaction





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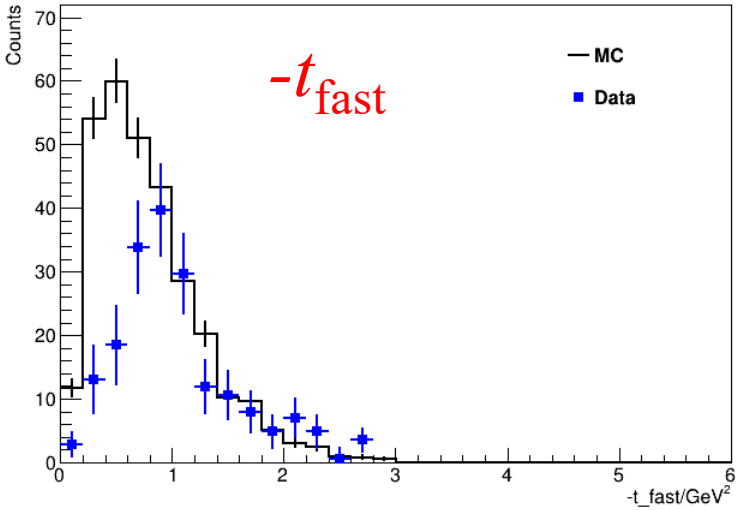

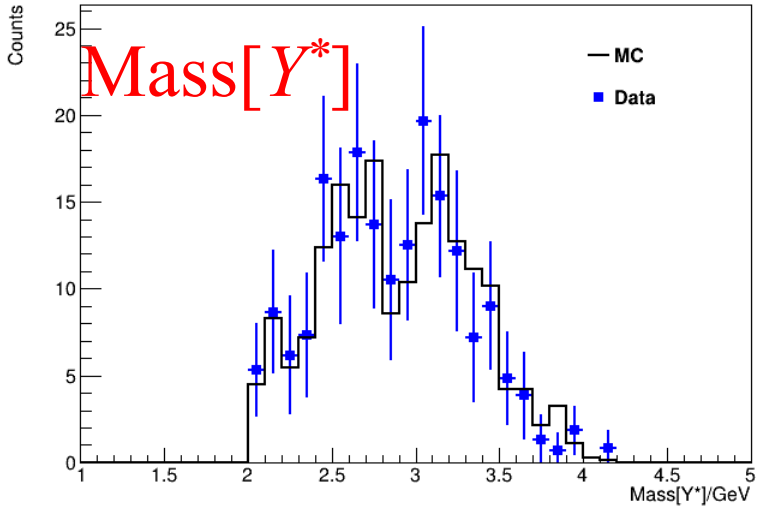

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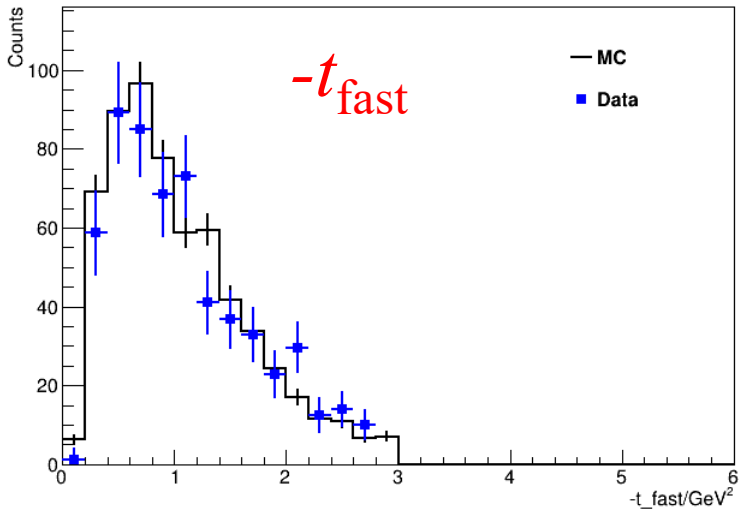

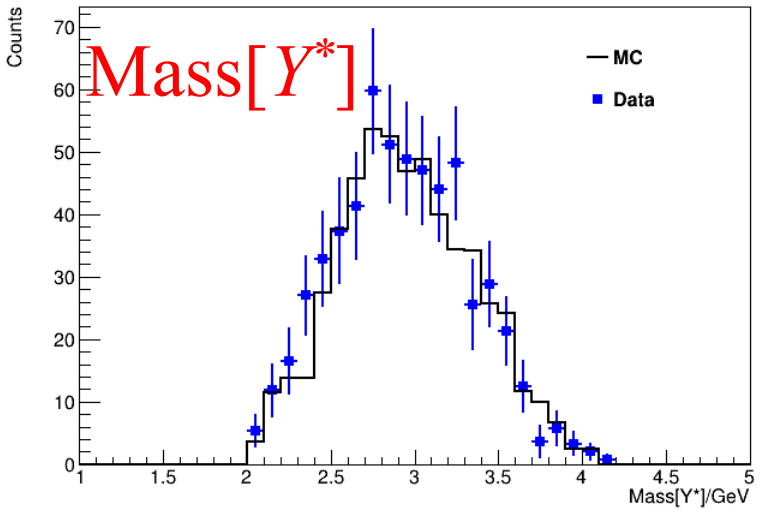

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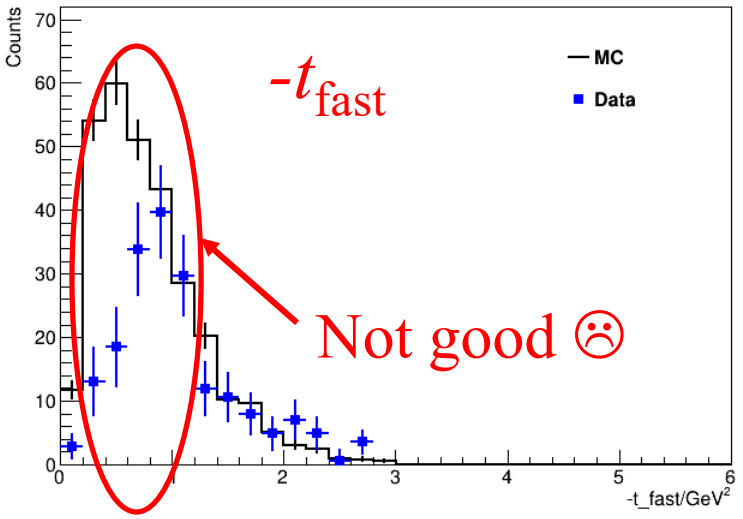

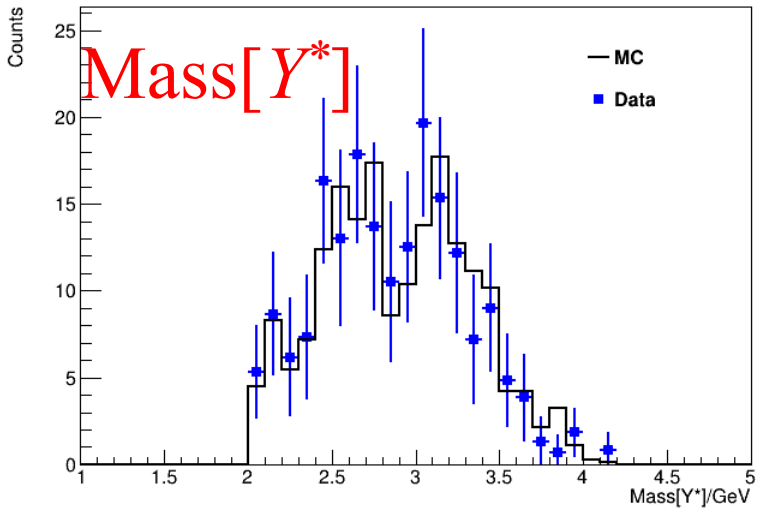

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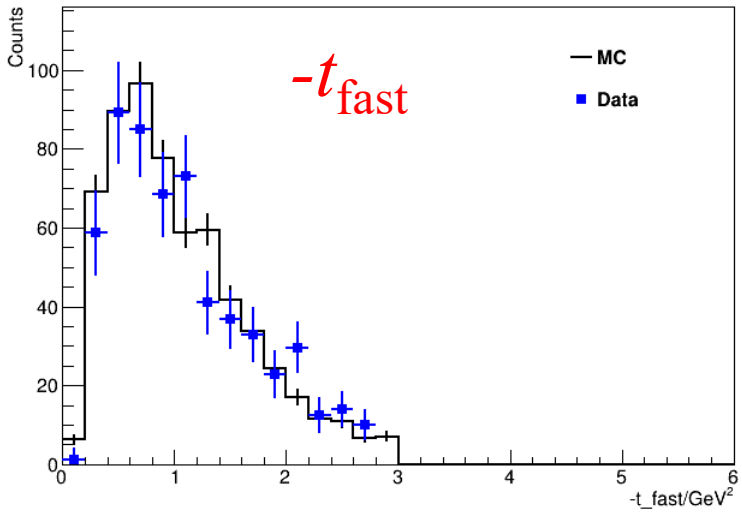

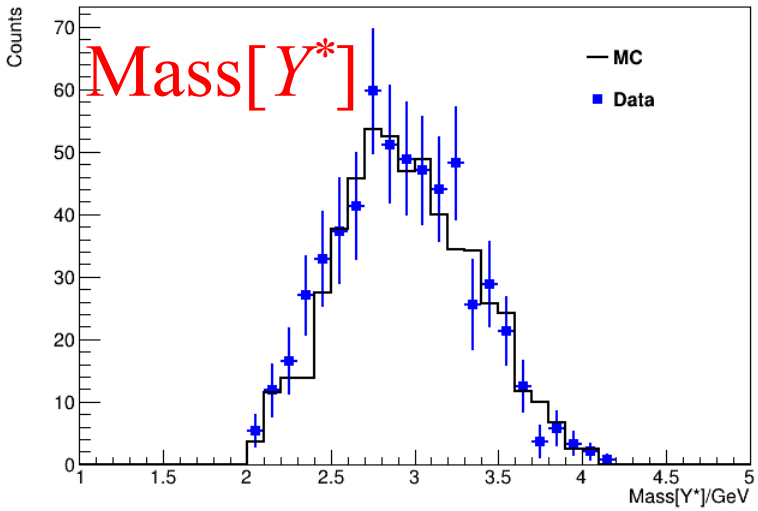

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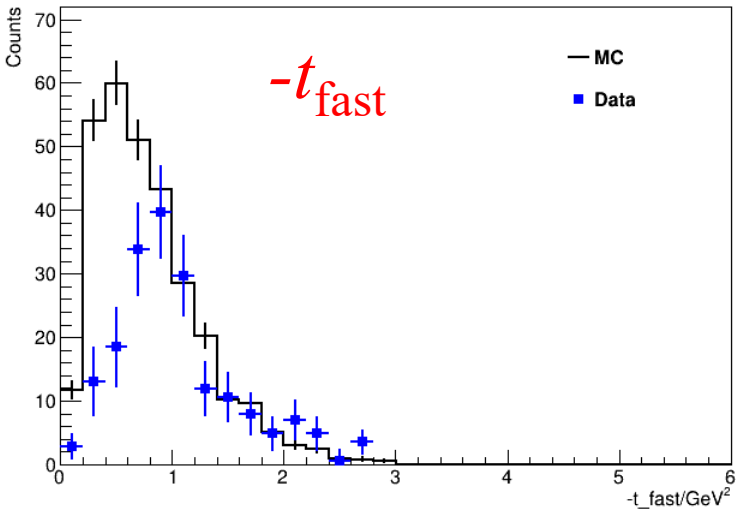

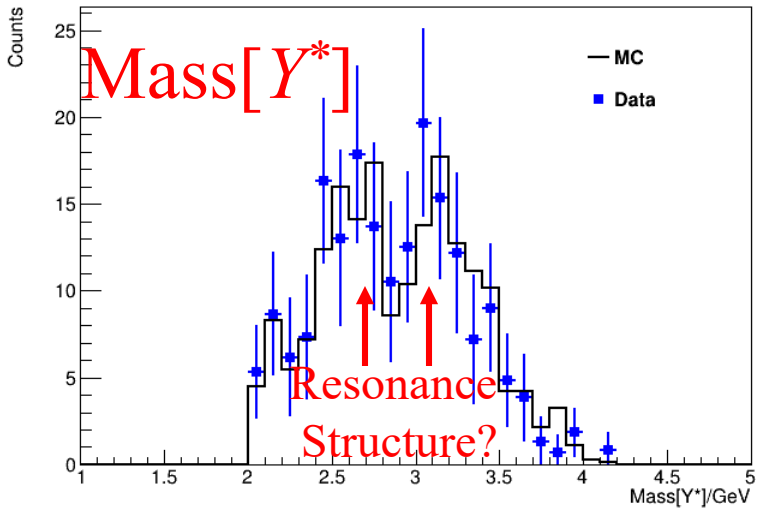

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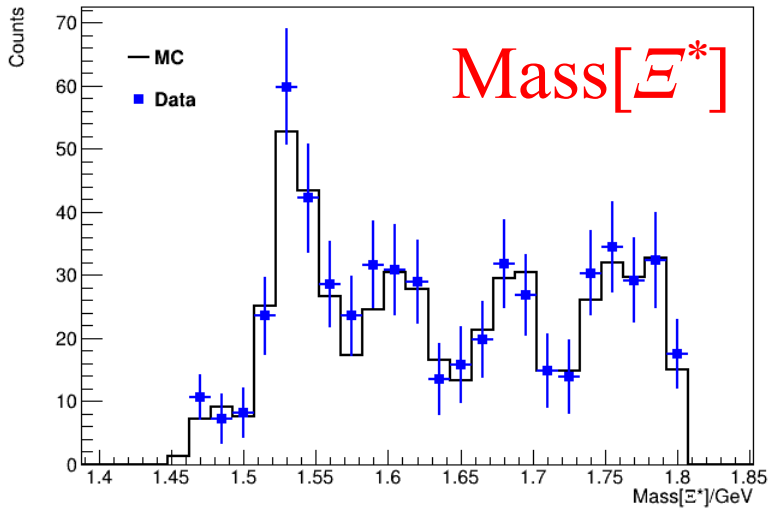

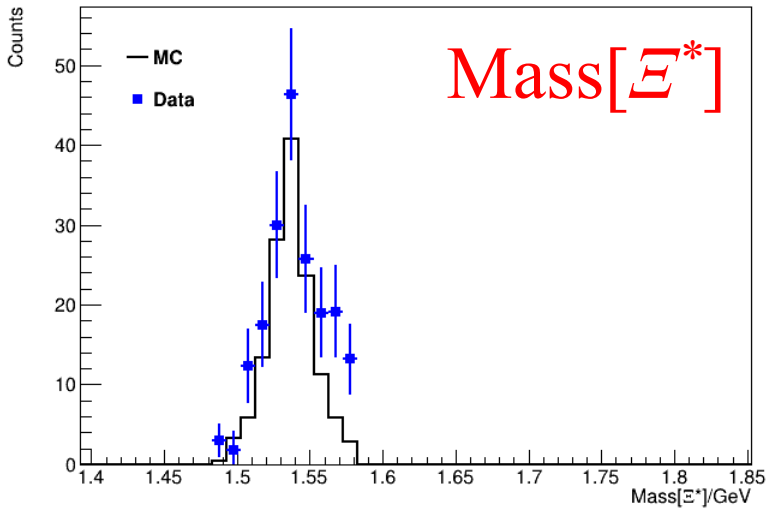

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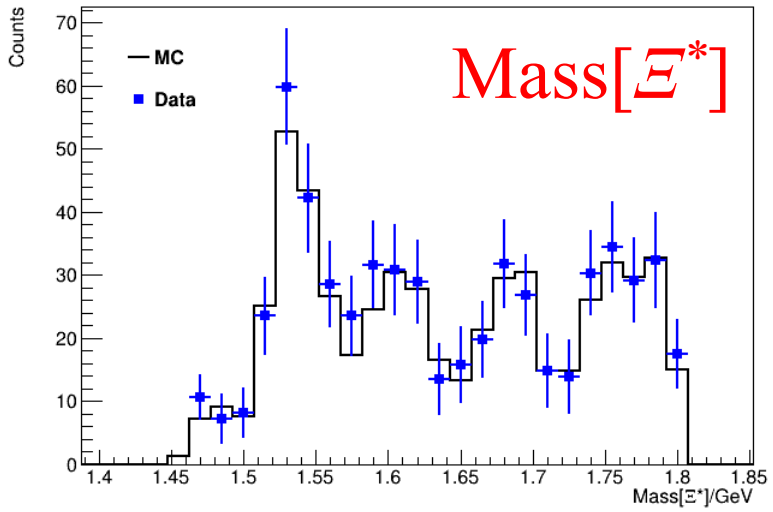
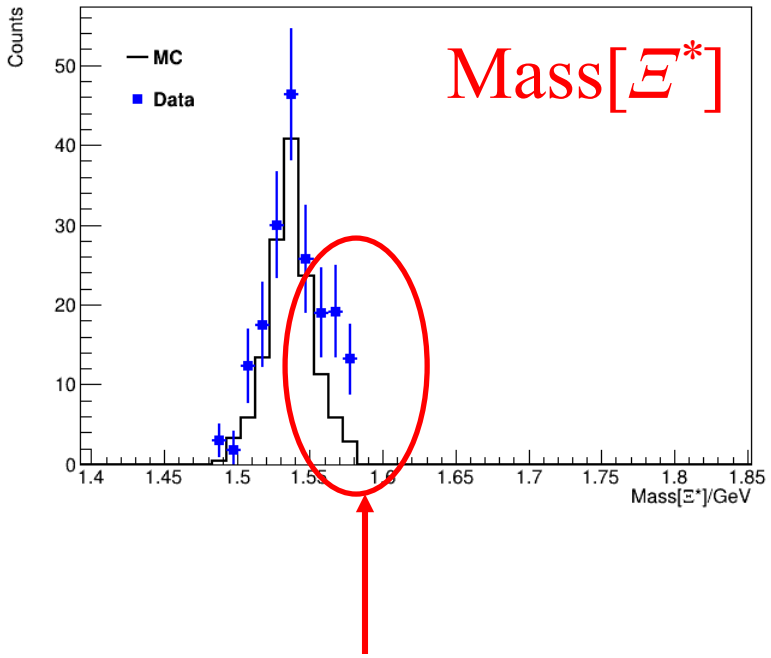
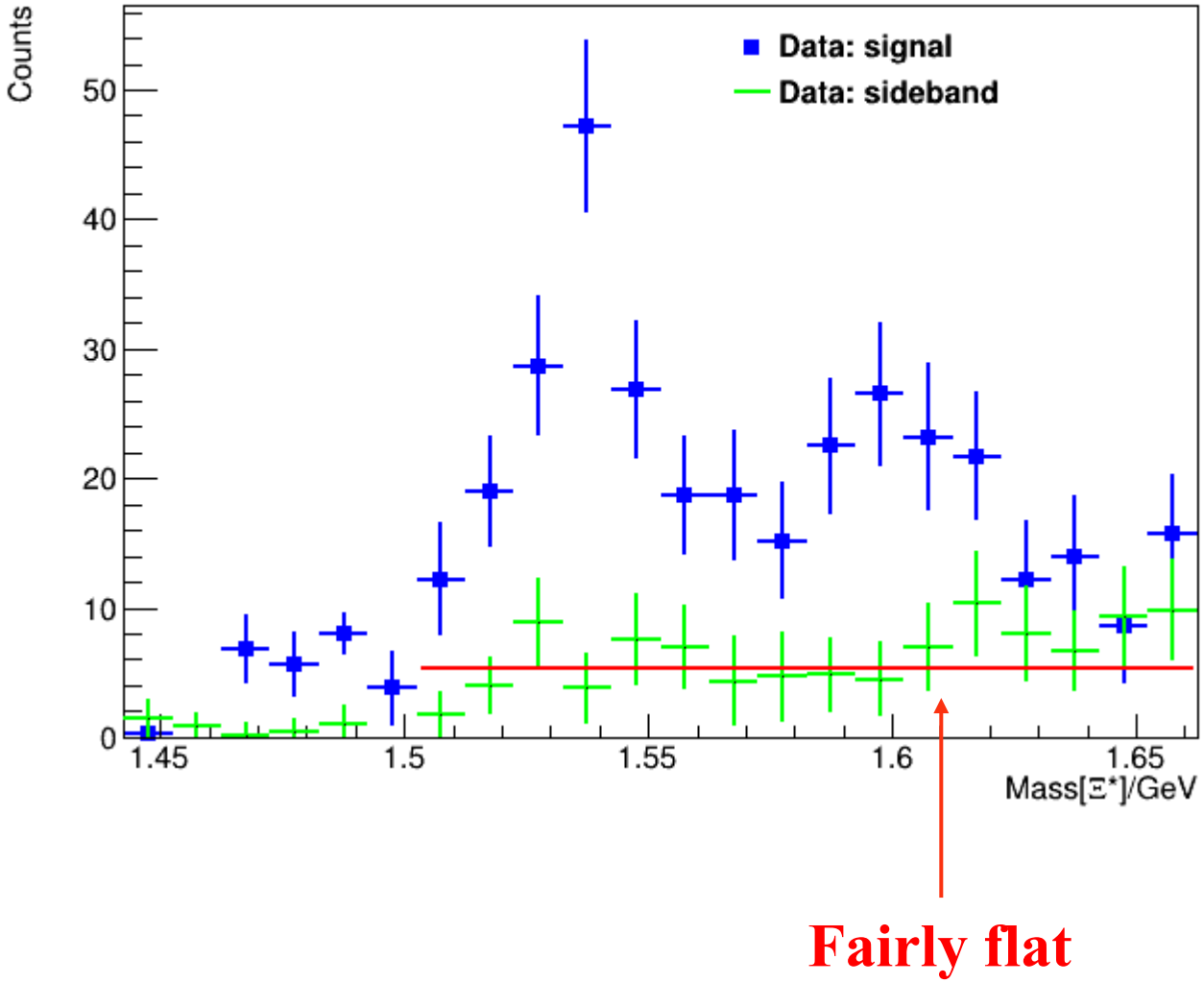




Need background estimate to make better comparison

Invariant mass of $\Xi^-\pi^0$ (presumably Ξ^*)



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

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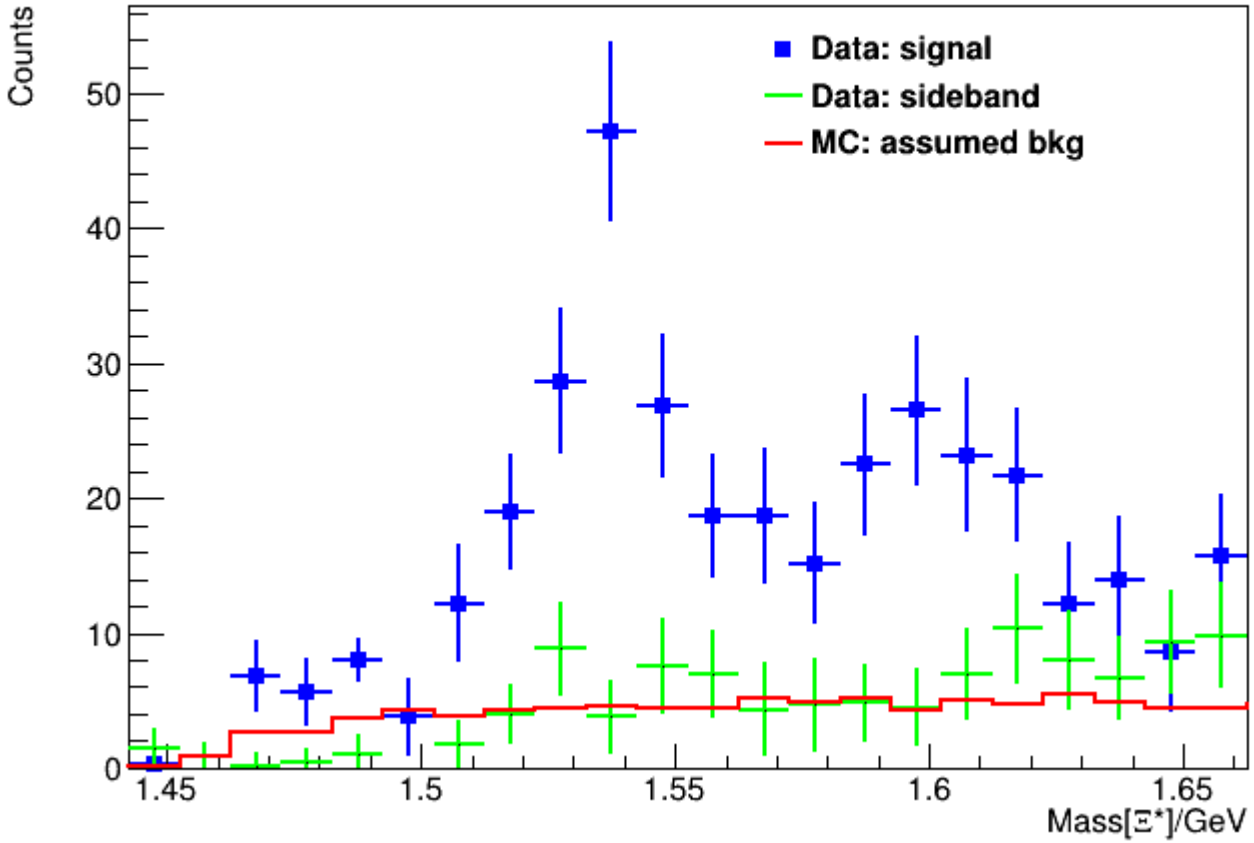
Fairly flat

Invariant mass of $\Xi^-\pi^0$ (presumably Ξ^*)



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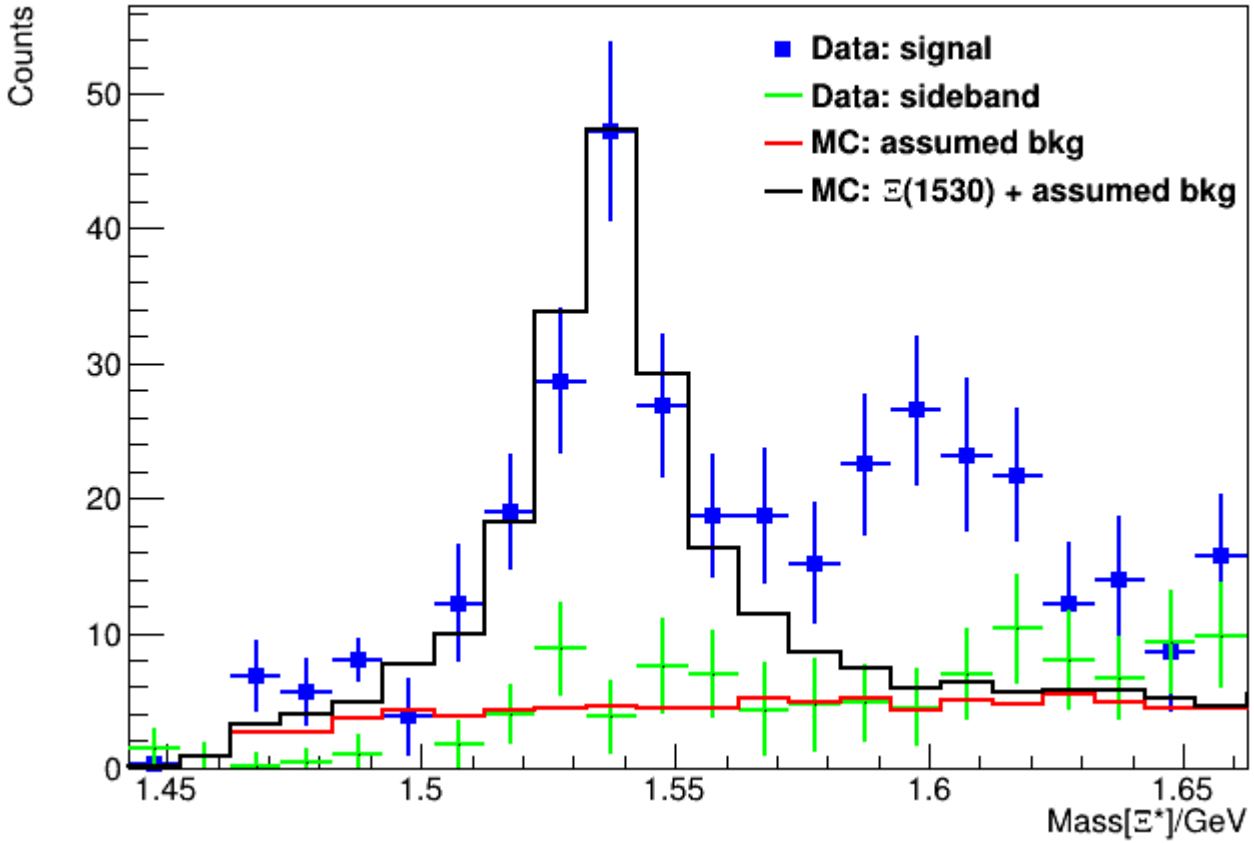
The assumed background was generated as linear in mass[Ξπ] by starting with the general reaction and only modifying the mass[Ξπ] distribution with no other modifications

Invariant mass of $\Xi^-\pi^0$ (presumably Ξ^*)



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The Ξ(1530) generation was described earlier and was set to PDG values:

- Center = 1535 MeV
- Width = 9.9 MeV

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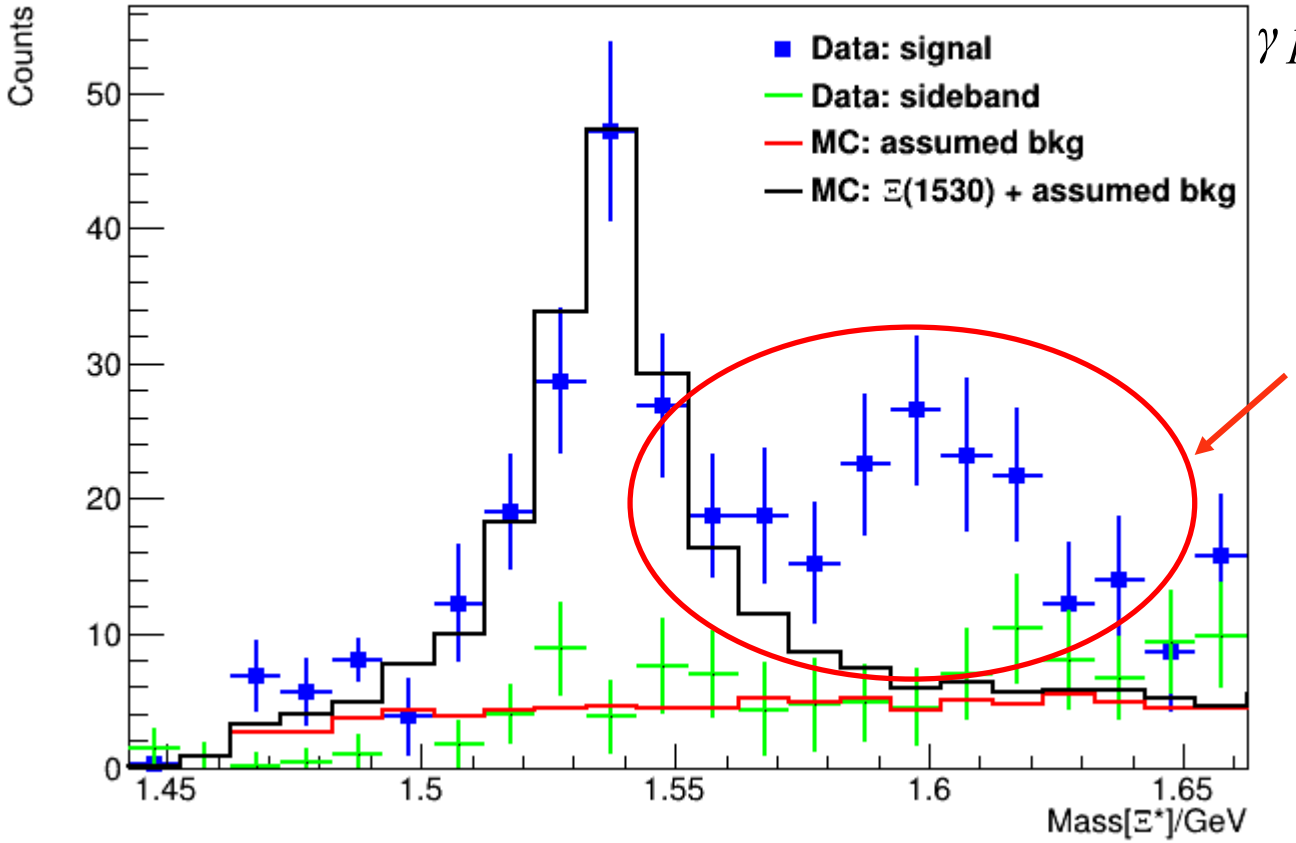

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To extract $\Xi(1530)$, the bump near the $\Xi(1620)$ must be dealt with.

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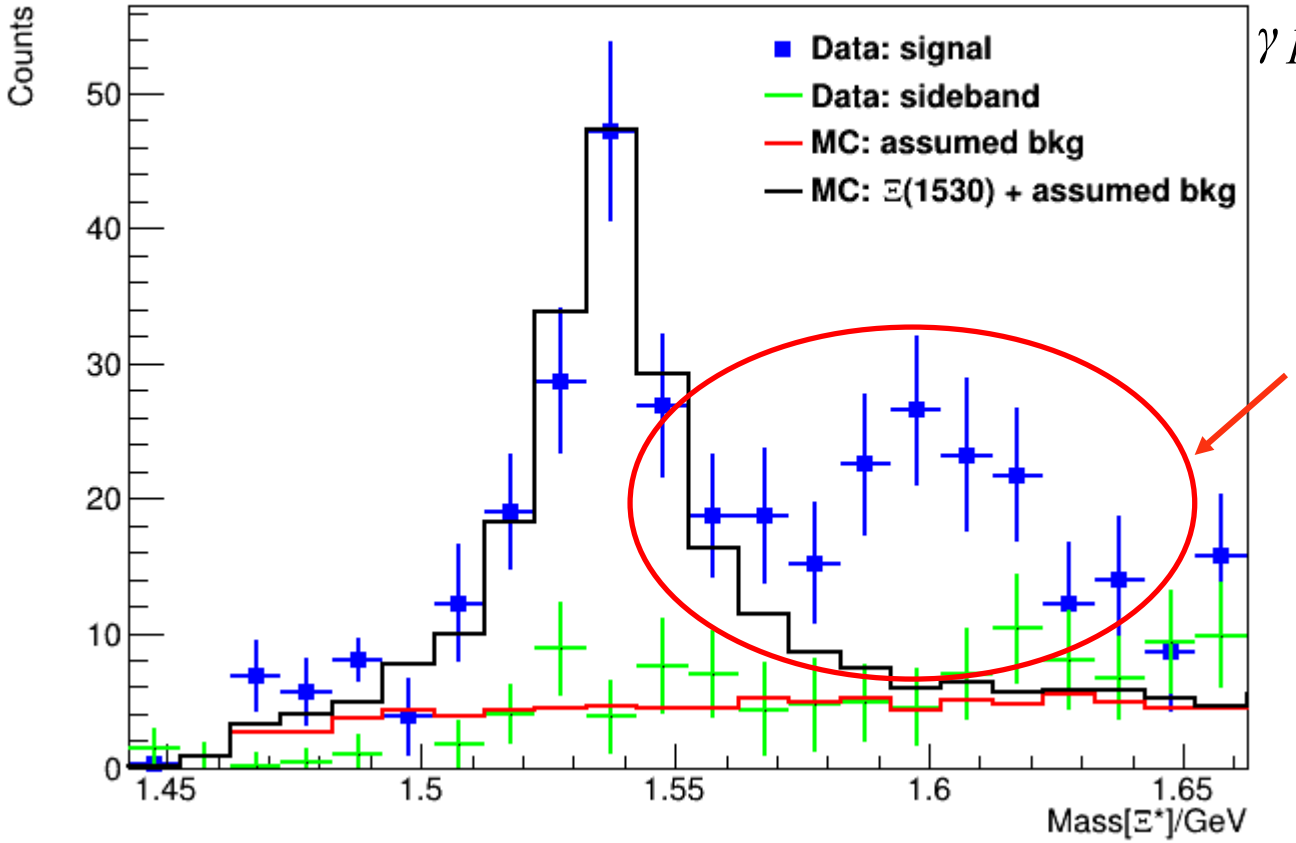

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$\Xi^- \rightarrow \Lambda\pi^-$

To extract $\Xi(1530)$, the bump near the $\Xi(1620)$ must be dealt with.

Assuming that the bump is the $\Xi(1620)$, might as well measure both cross sections at the same time.

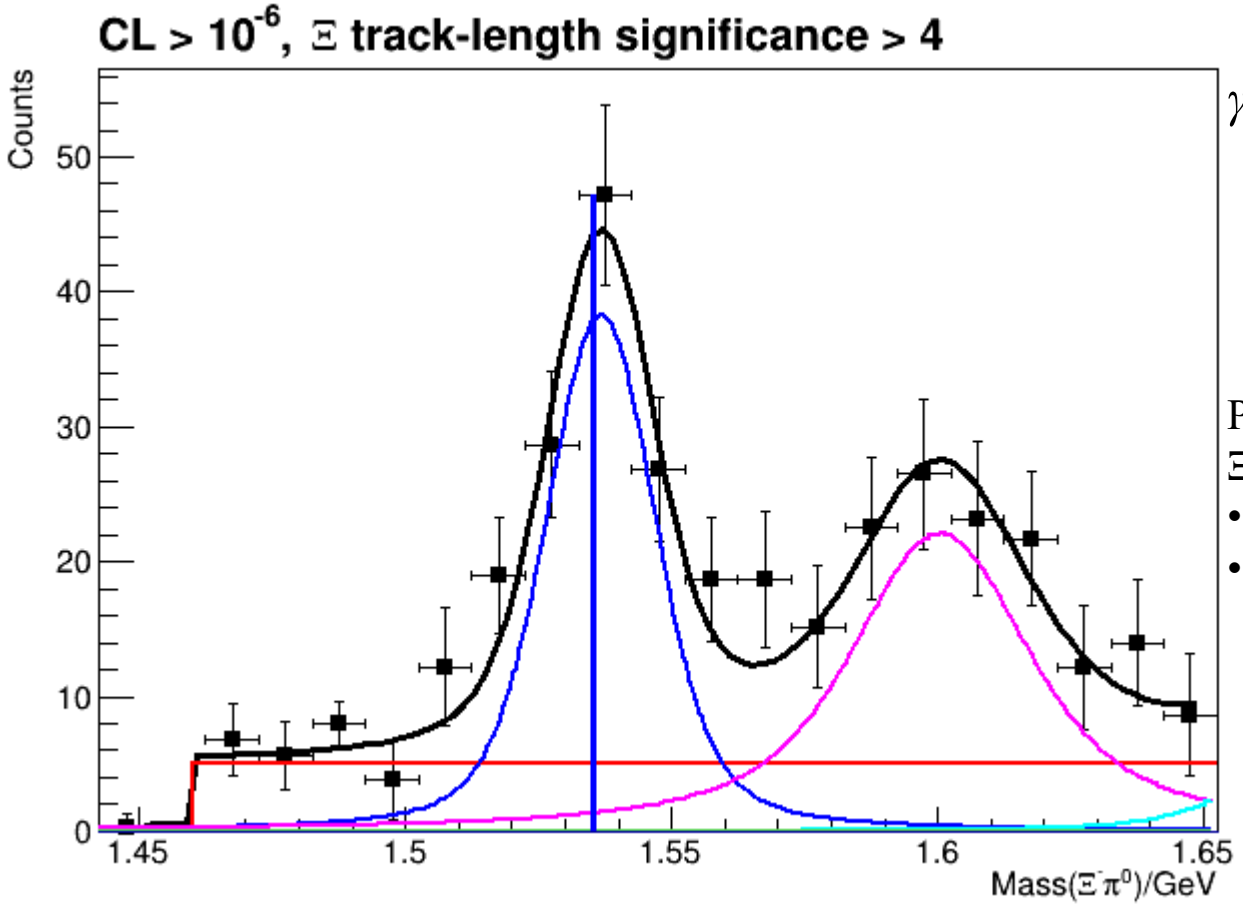
The $\Xi(1530)$ generation was described earlier and was set to PDG values:

- Center = 1535 MeV
- Width = 9.9 MeV

Parameters of the bump near 1620 MeV

Now want to find center and width of bump to simulate

Fit to invariant mass of $\Xi^-\pi^0$



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

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

PDG:

Ξ(1530)

- Center = 1535.0(0.6) MeV
- Width = $9.9^{+1.7}_{-1.9}$ MeV

Voigt distributions with a flat background

- Ξ(1530): Center = 1537(2) MeV, Width = 9(3) MeV
- Ξ(1620): Comparison to PDG on next slide

Fit to invariant mass of $\Xi^-\pi^0$

From the fit

- $\Xi(1620)$: Center = 1600(3) MeV, Width = 29(6) MeV

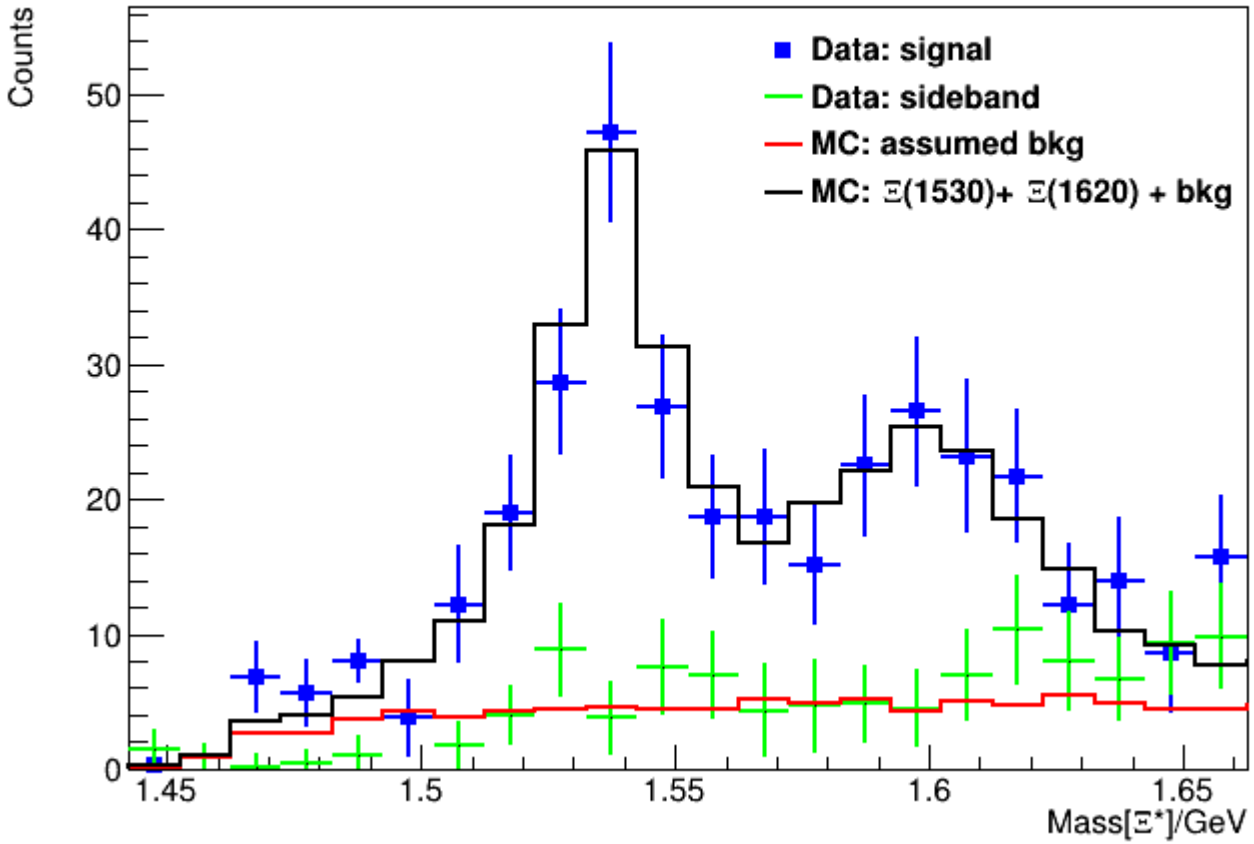
$\Xi(1620)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
≈ 1620 OUR ESTIMATE					
$1610.4 \pm 6.0^{+6.1}_{-4.2}$		SUMIHAMA	19	BELL	$\Xi_c^+ \to \Xi(1620)\pi^+$
1624 ± 3	31	BRIEFEL	77	HBC	$K^- p$ 2.87 GeV/c
1633 ±12	34	DEBELLEFON	75B	HBC	$K^- p \to \Xi^- \overline{K}\pi$
1606 ± 6	29	ROSS	72	HBC	$K^- p$ 3.1–3.7 GeV/c

$\Xi(1620)$ WIDTH

VALUE (MeV)	EVTS		DOCUMENT ID		TECN	COMMENT
$32 \pm {}^{8}_{9}$ OUR AVERAGE			Error includes scale factor of 2.2. See the ideogram below.			
$59.9 \pm 4.8^{+2.8}_{-7.1}$			SUMIHAMA	19	BELL	$\Xi_c^+ \to \Xi(1620)\pi^+$
22.5± 7.5	31	[1]	BRIEFEL	77	HBC	$K^- p$ 2.87 GeV/c
40 ±15	34		DEBELLEFON	75B	HBC	$K^- p \to \Xi^- \overline{K}\pi$
21 ± 7	29		ROSS	72	HBC	$K^- p \to \Xi^- \pi^+ K^{*0}(892)$

Invariant mass of $\Xi^-\pi^0$ (presumably Ξ^*)

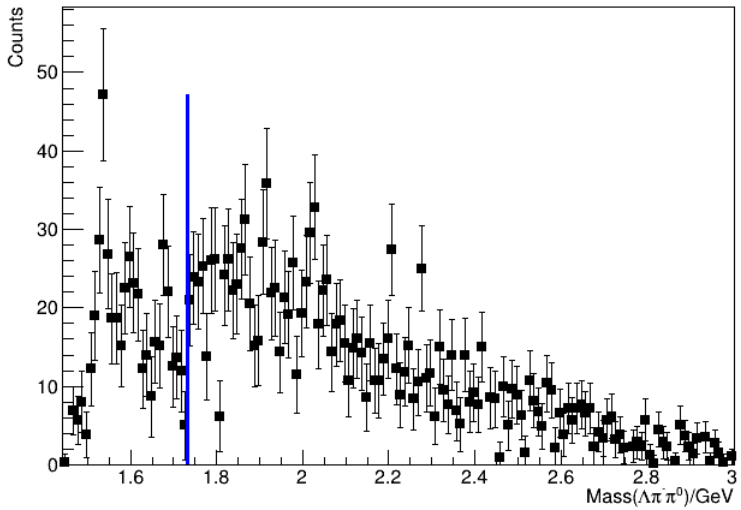


Looks reasonable ☺

The Ξ(1620) generation set to:

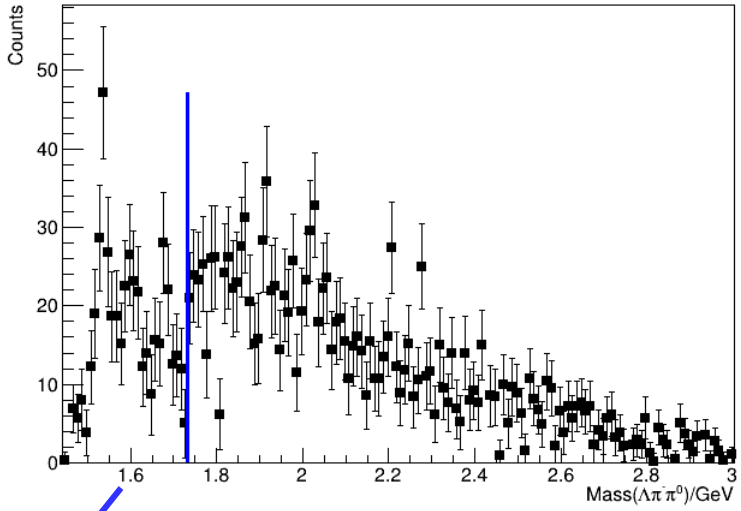
- Center = 1600 MeV
- Width = 30 MeV

Going beyond the $\Xi(1620)$

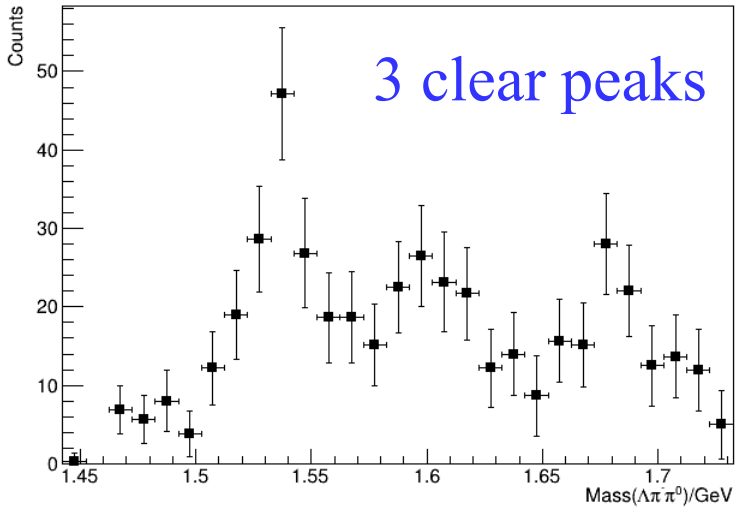


The mass spectrum has very different behavior on either side of the blue line at 1730 MeV

Going beyond the $\Xi(1620)$

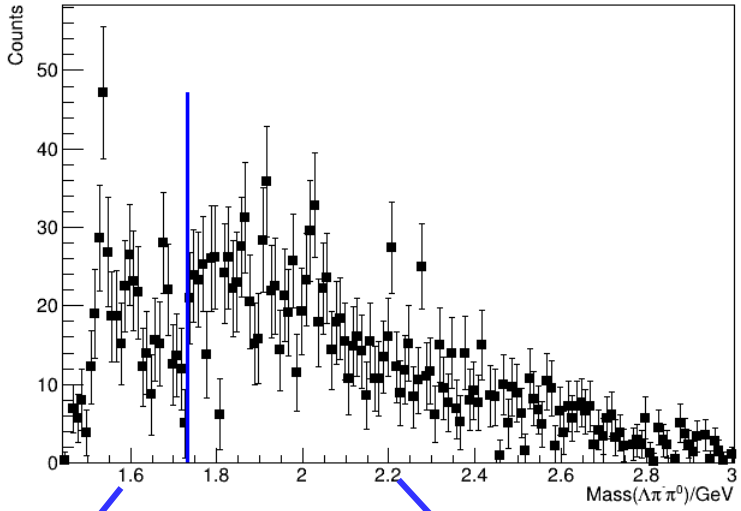


< 1730 MeV

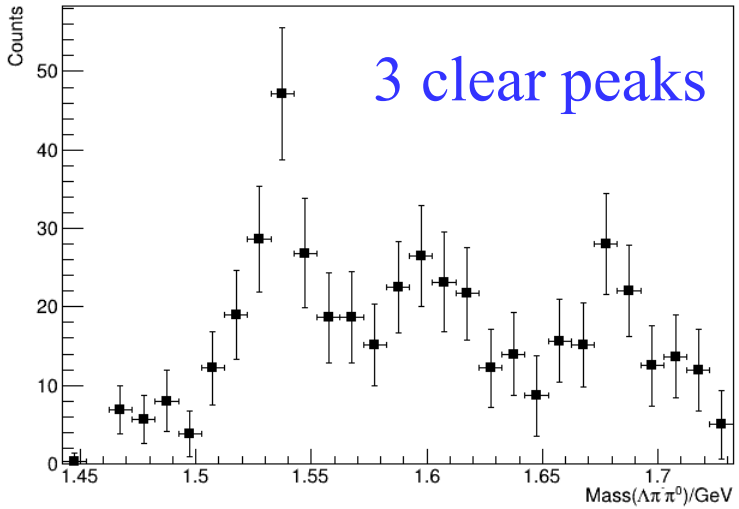


3 clear peaks

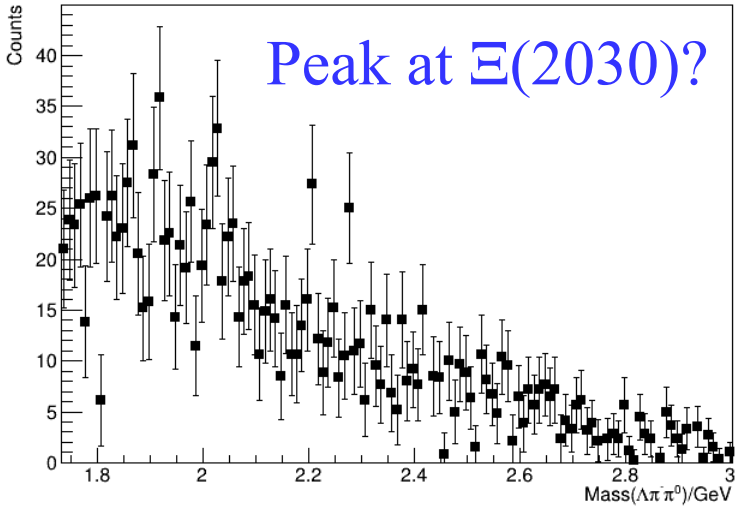
Going beyond the $\Xi(1620)$



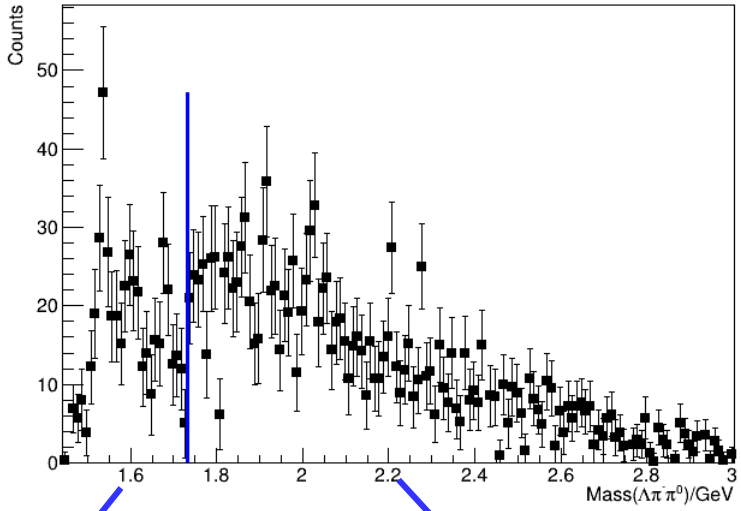
< 1730 MeV



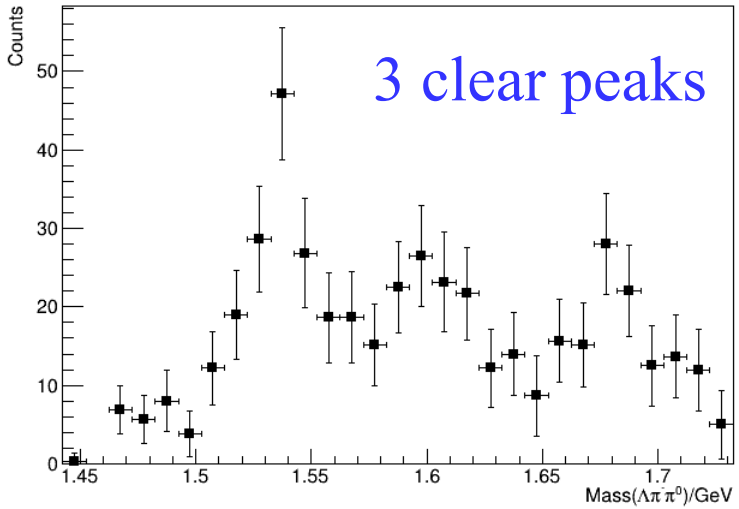
> 1730 MeV



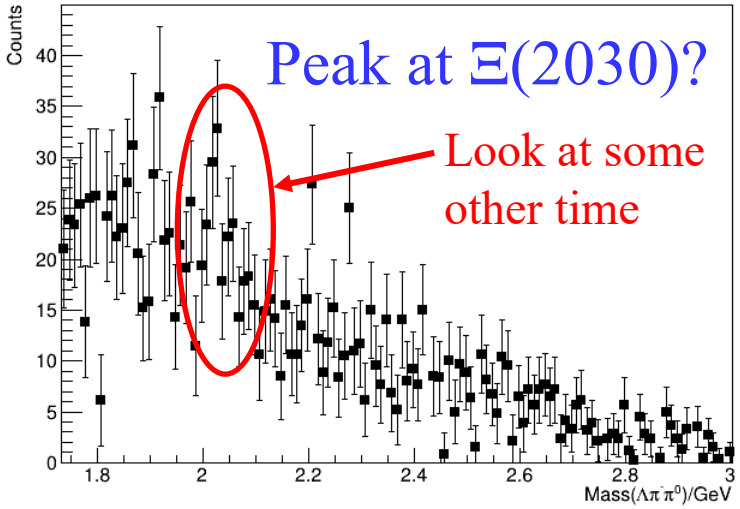
Going beyond the $\Xi(1620)$



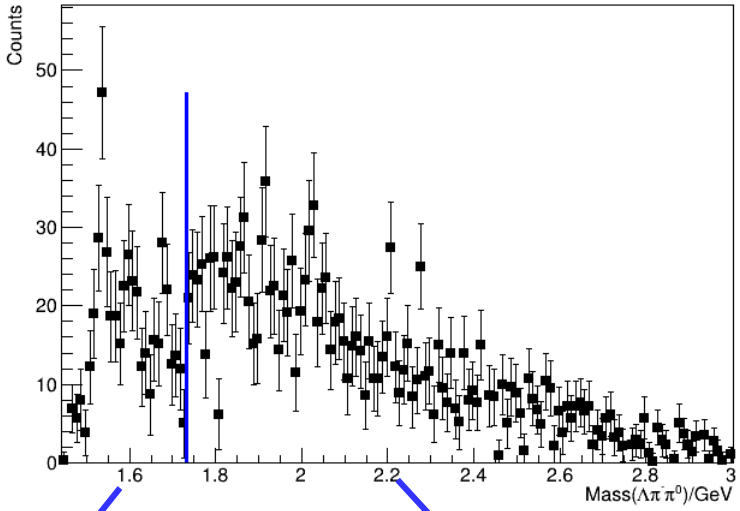
< 1730 MeV



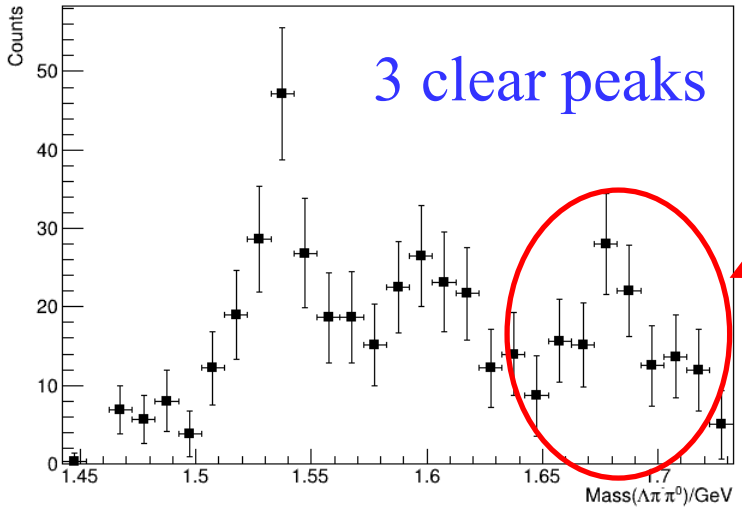
> 1730 MeV



Going beyond the $\Xi(1620)$

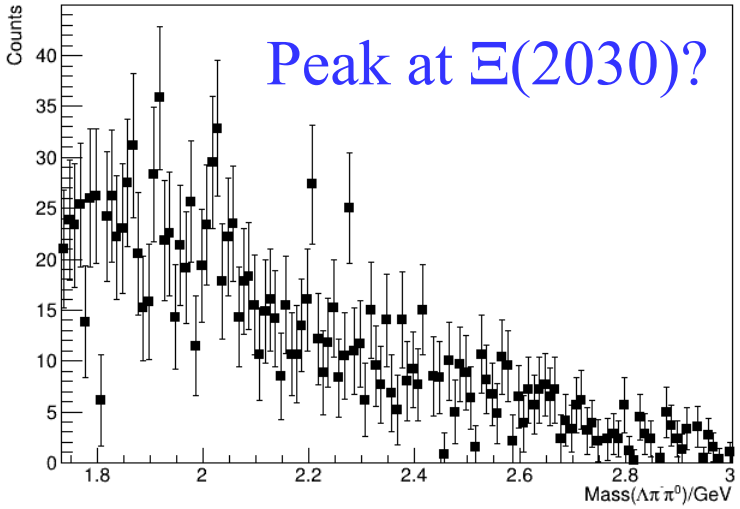


< 1730 MeV

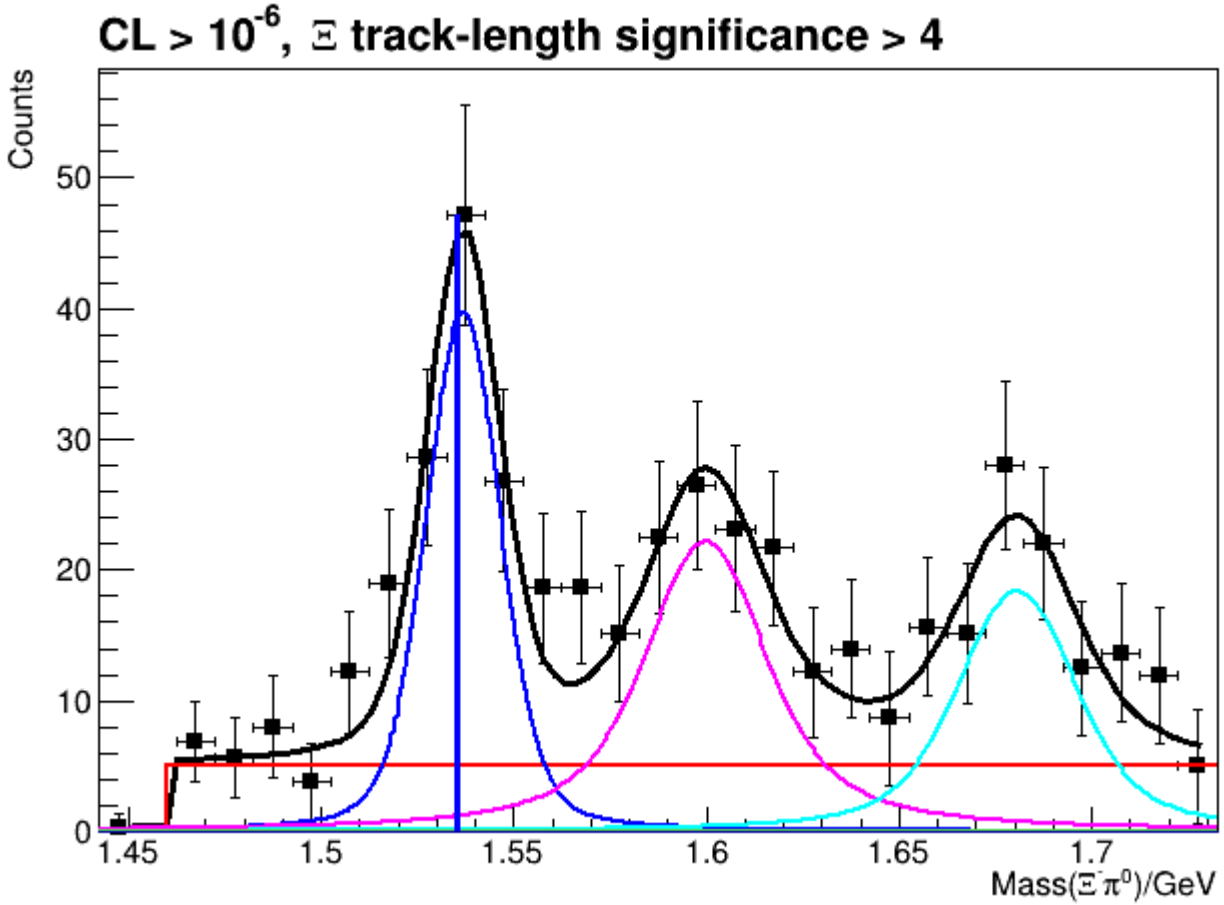


Add to fit

> 1730 MeV



Fit to invariant mass of $\Xi^-\pi^0$



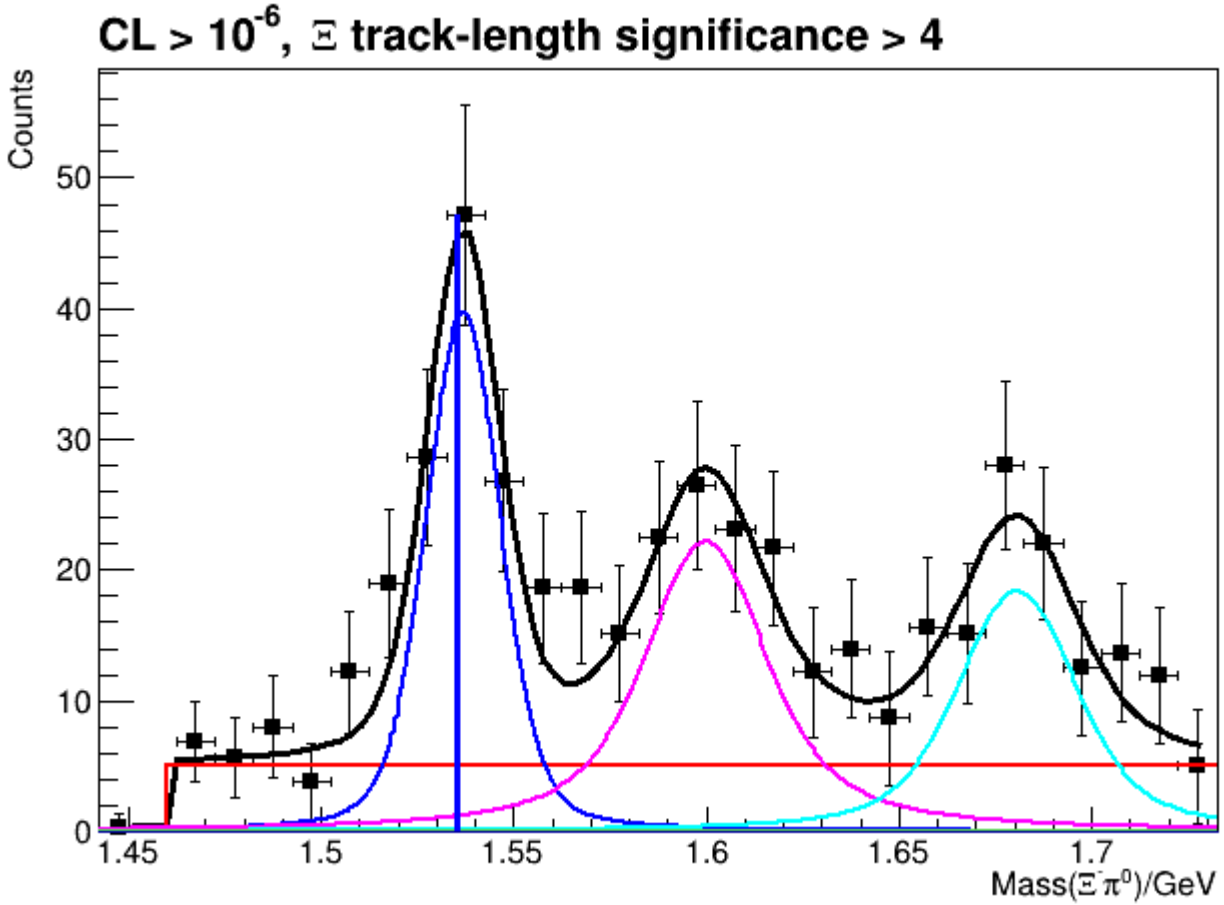
$\gamma p \rightarrow K^+K^+\Xi^{*-}$,

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

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

	Center (MeV)	Width (MeV)
• Ξ(1690) Fit:	1681(4)	17(14)
• Ξ(1690) PDG:	1690(10)	20(10)

Fit to invariant mass of $\Xi^-\pi^0$



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

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

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

	Center (MeV)	Width (MeV)
• Ξ(1690) Fit:	1681(4)	17(14)
• Ξ(1690) PDG:	1690(10)	20(10)

Looks reasonable ☺

Title

Title