Search for the $\Xi(1620)$

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

Nucleon resonances are rated using the "star" system:

* Poor evidence of existence

** Fair 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

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

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

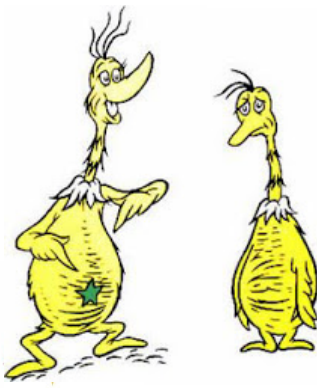
J, *P* need confirmation.

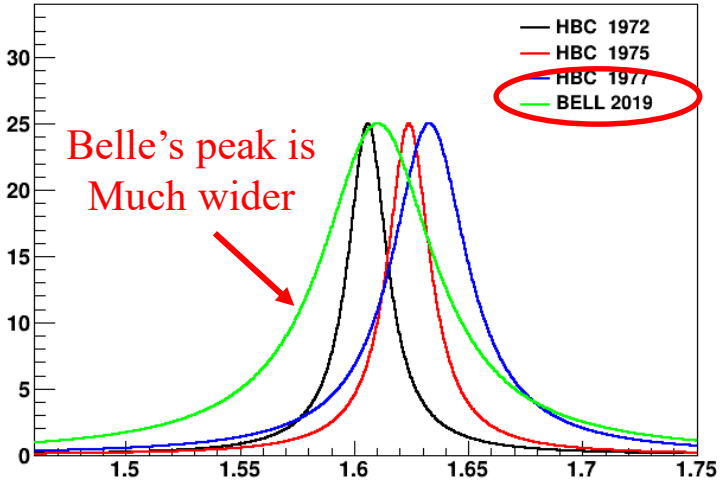
OMITTED FROM SUMMARY TABLE

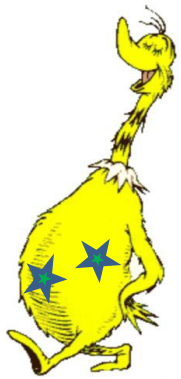
The clearest evidence is a peak in $\Xi^-\pi^+$ seen by SUMIHAMA 19. Older low-statistics experiments (e.g., BORENSTEIN 72 and HASSALL 81) have looked for the state but have not seen any effect.

$\Xi(1620)$ MASS

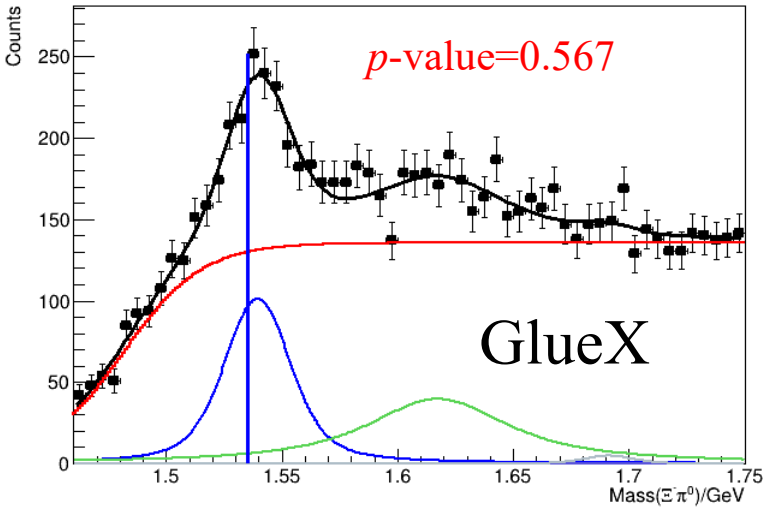
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
≈ 1620 OUR ESTIMATE					
$1610.4 \pm 6.0^{+6.1}_{-4.2}$		SUMIHAMA	19	BELL	$\Xi_c^+ \to \Xi(1620)\pi^+$
1624 ± 3	31	BRIEFEL	77	HBC	$K^- p$ 2.87 GeV/c
1633 ±12	34	DEBELLEFON	75B	HBC	$K^- p \to \Xi^- \overline{K}\pi$
1606 ± 6	29	ROSS	72	HBC	$K^- p$ 3.1–3.7 GeV/c







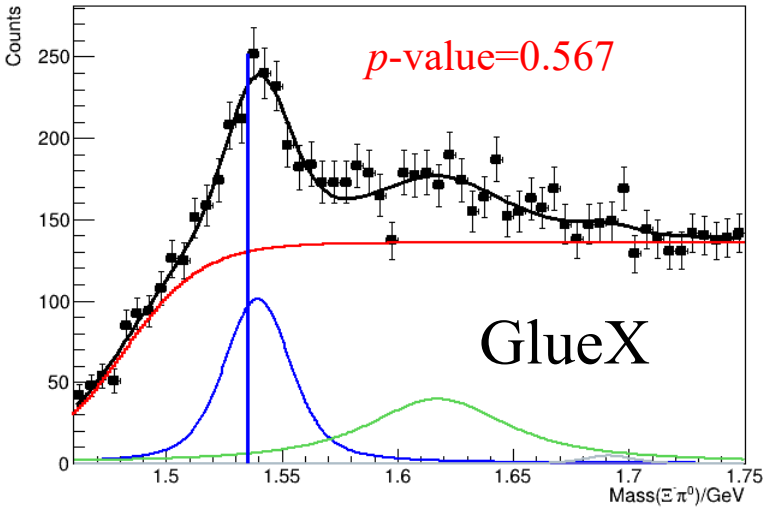
Assumed bump structure, compared to Belle

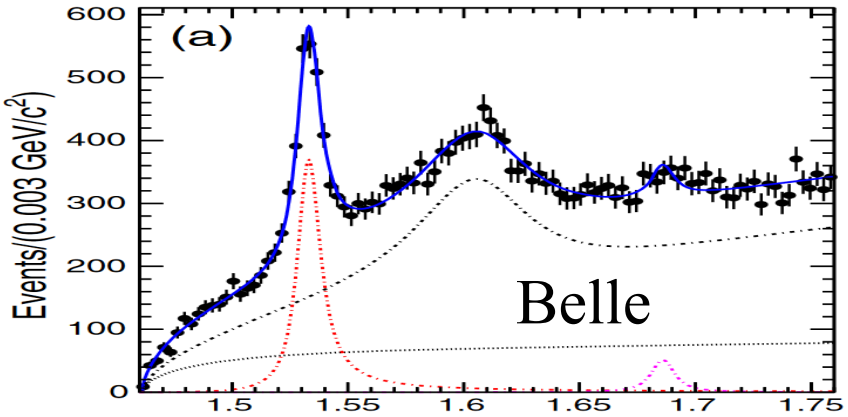


- No accidental subtraction

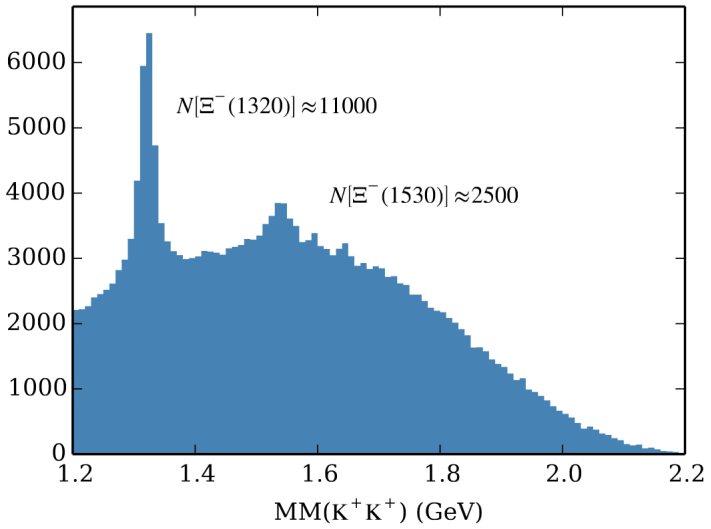
Background (red) :
[First order polynomial]*[sigmoid]

Assumed bump structure, compared to Belle





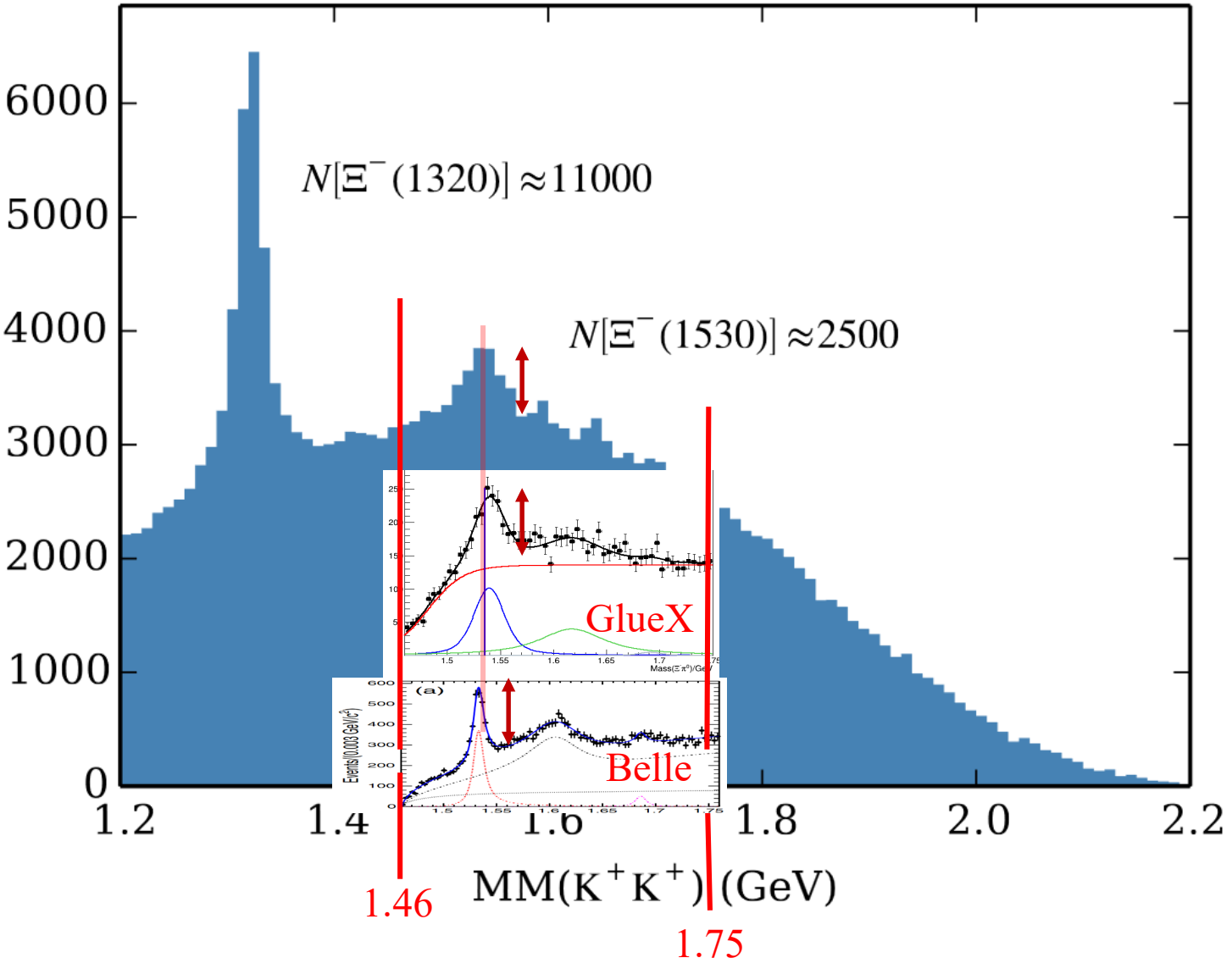
CLAS Ξ and $\Xi(1530)$



- Reaction: $\gamma\, p \rightarrow K^+\, K^+\, X$
- Here, X represent the missing particle(s)
- Ostensibly, X is Ξ^- or Ξ^{-*}
  - from $\gamma\, p \rightarrow K^+\, Y^*$, where $Y^* \rightarrow K^+\, \Xi^-$
- $E_\gamma < 5.4$ GeV

- A lot of background from many types of final states
  - $\gamma\, p \rightarrow K^+\, K^+\, X$ is very inclusive of Ξ^{-*} type states with decays NOT limited to
    - $\Xi\pi$
    - $\Xi^*\pi$
    - ΛK
    - $K\Sigma$
    - or ?

CLAS comparison



Reaction

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

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

and $\Lambda \rightarrow p\pi^-$

- Mass of Ξ^- not constrained
- The Ξ^- has a long lifetime

Ξ^- MEAN LIFE

Measurements with an error > 0.2×10^{-10} s or with systematic errors not included have been omitted.

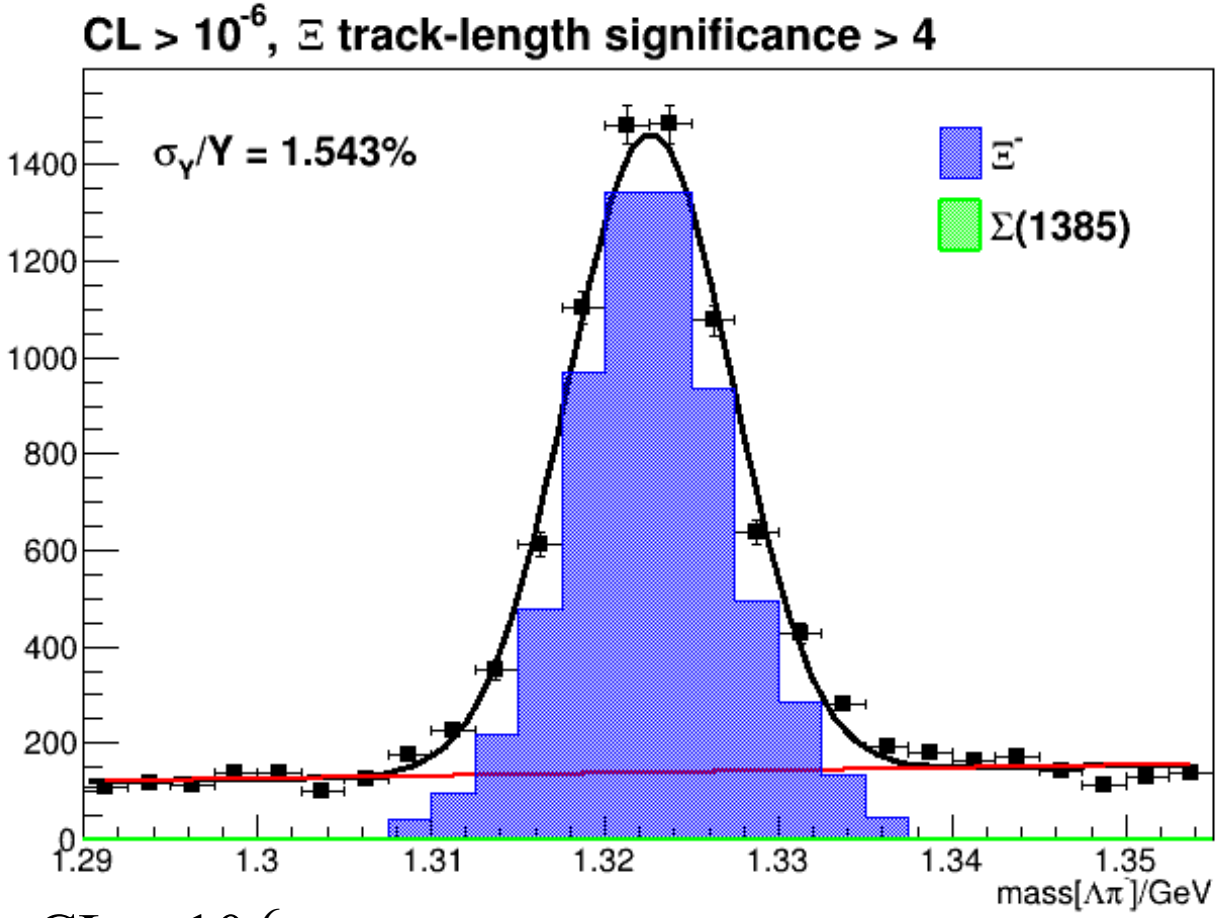
VALUE (10^{-10} s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.639±0.015 OUR AVERAGE					
1.65 ±0.07 ±0.12	2478 ± 68	ABDALLAH	06E	DLPH	from Z decays
1.652±0.051	32k	BOURQUIN	84	SPEC	Hyperon beam
1.665±0.065	41k	BOURQUIN	79	SPEC	Hyperon beam
1.609±0.028	4286	HEMINGWAY	78	HBC	4.2 GeV/c K^-p
1.67 ±0.08		DIBIANCA	75	DBC	4.9 GeV/c K^-d
1.63 ±0.03	4303	BALTAY	74	HBC	1.75 GeV/c K^-p
$1.73\ ^{+0.08}_{-0.07}$	680	MAYEUR	72	HLBC	2.1 GeV/c K^-
1.61 ±0.04	2610	DAUBER	69	HBC	
1.80 ±0.16	299	LONDON	66	HBC	
1.70 ±0.12	246	PJERROU	65B	HBC	
1.69 ±0.07	794	HUBBARD	64	HBC	
$1.86\ ^{+0.15}_{-0.14}$	517	JAUNEAU	63D	FBC	

Pathlength study

- Vertex analysis uses pathlength significance as given on page 13 of https://halldweb.jlab.org/DocDB/0046/004607/004/DSelectorDoc.pdf

- As was suggested, I made sure that the end of the Ξ^- path was downstream of the origin

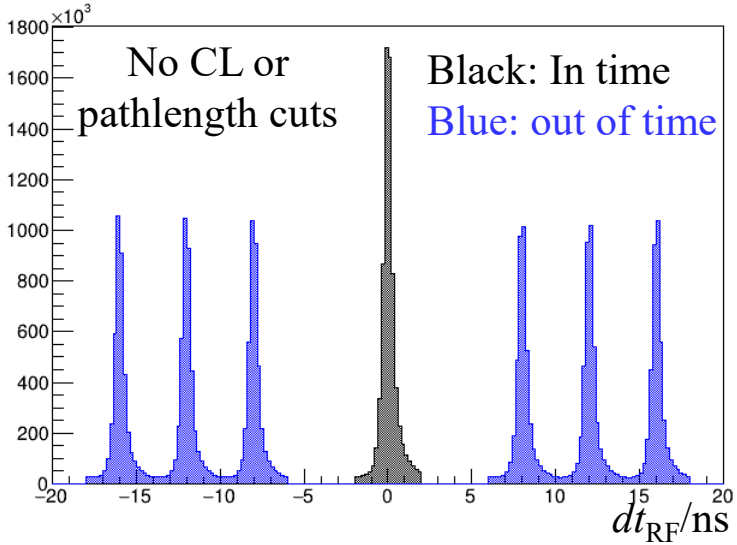
Overall best (lowest value of σ_Y/Y)

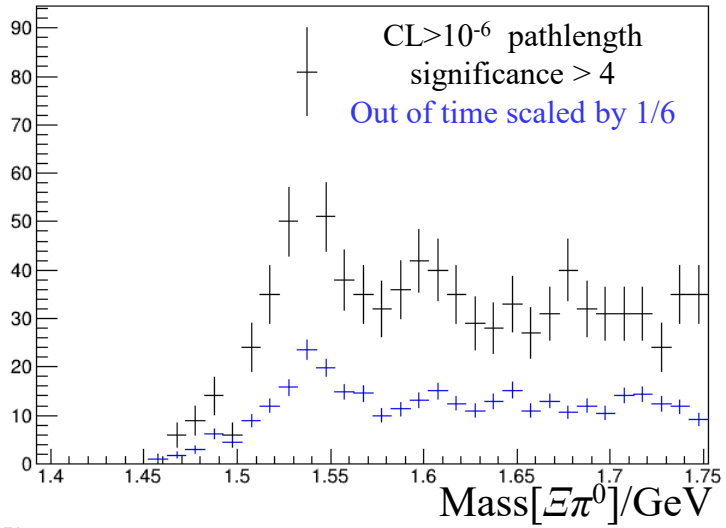


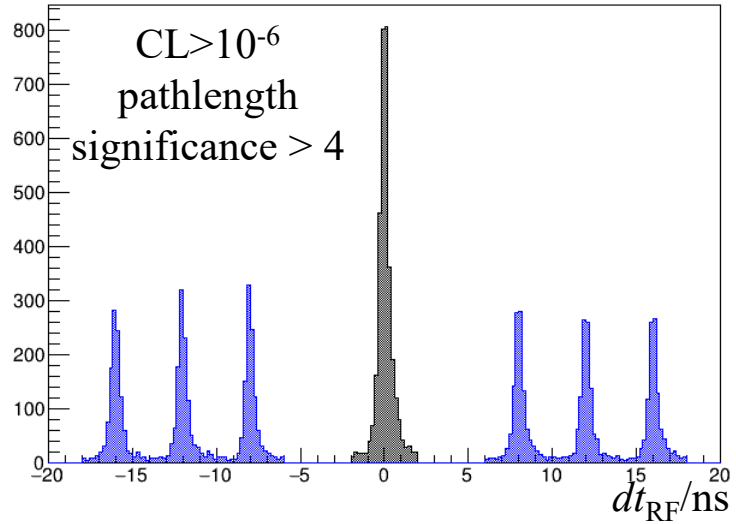
- CL > 10^{-6}
- Ξ track-length significance > 4

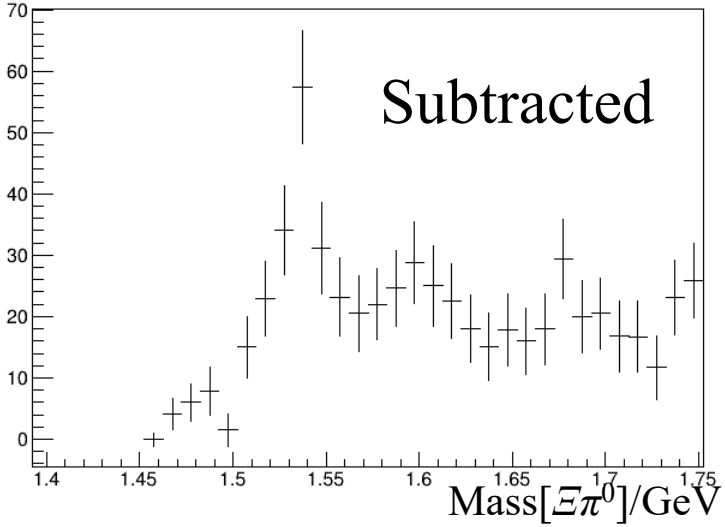
$\Xi^* \rightarrow \Xi\pi^0$ hybrid subtraction

Each photon is associated only with best combo for that photon

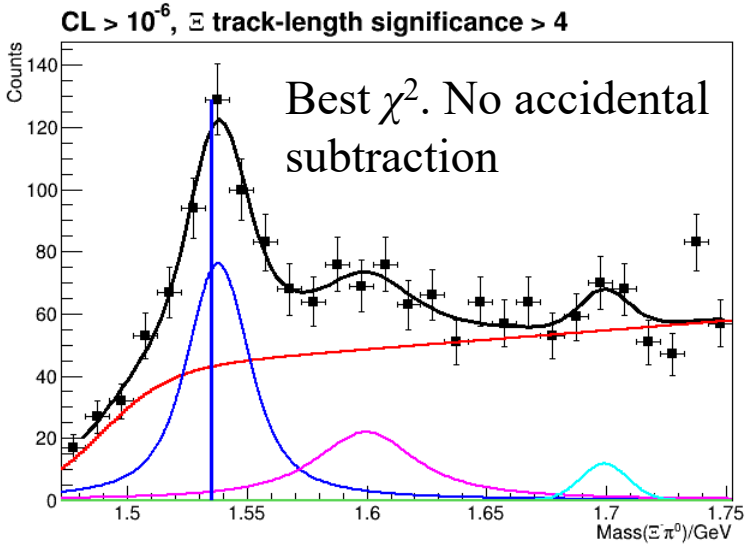


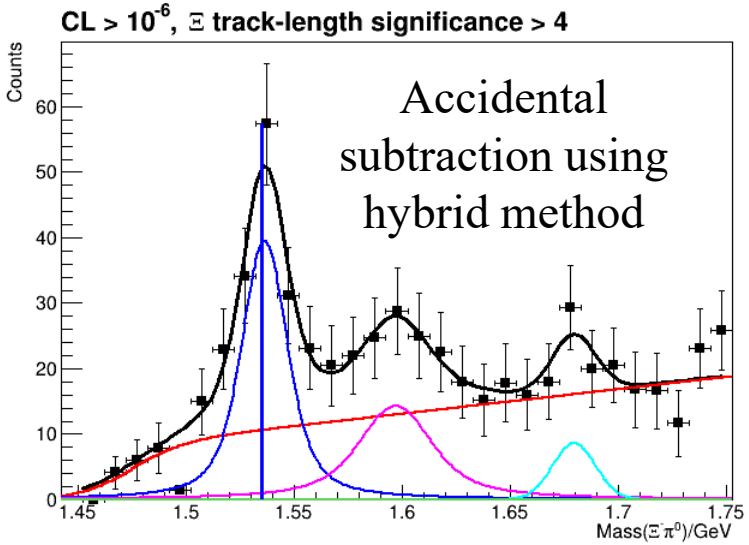






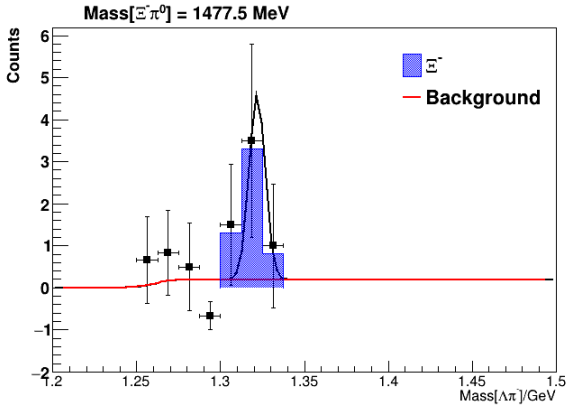
Accidental subtraction using hybrid method

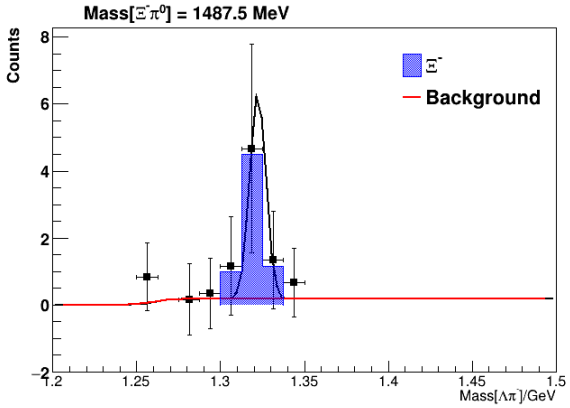


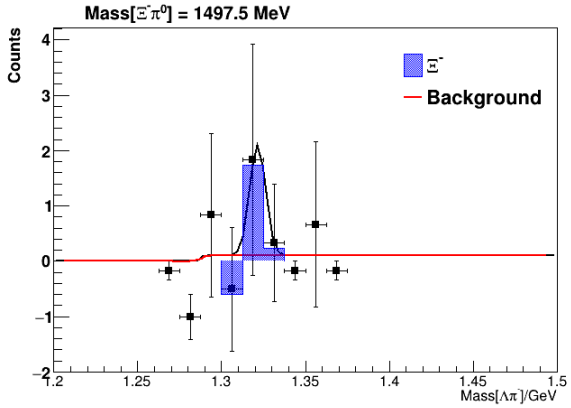


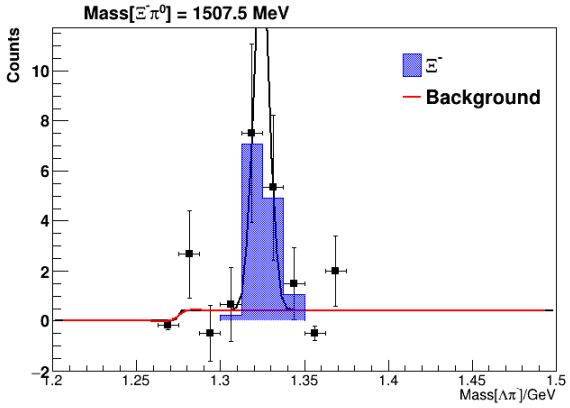
Ground State Ξ^- Fits

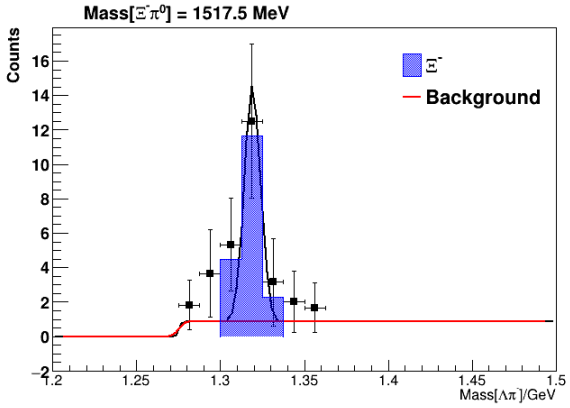
From 1477.5 to 1557.5 MeV

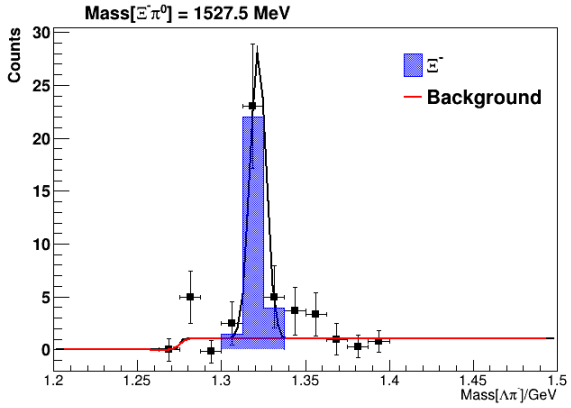

Mass[Ξ⁻π⁰] = 1477.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

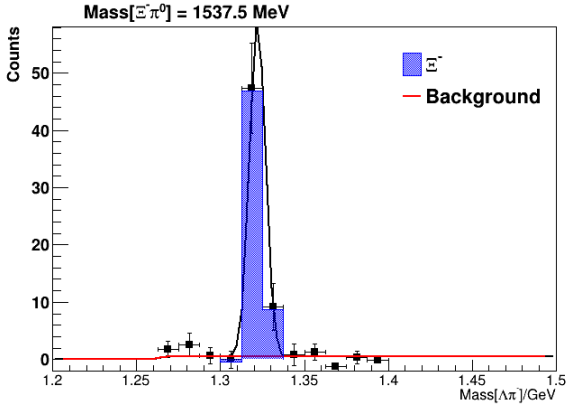

Mass[Ξ⁻π⁰] = 1487.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

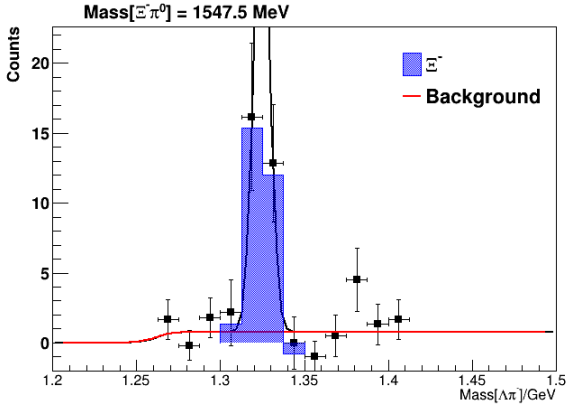

Mass[Ξ⁻π⁰] = 1497.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

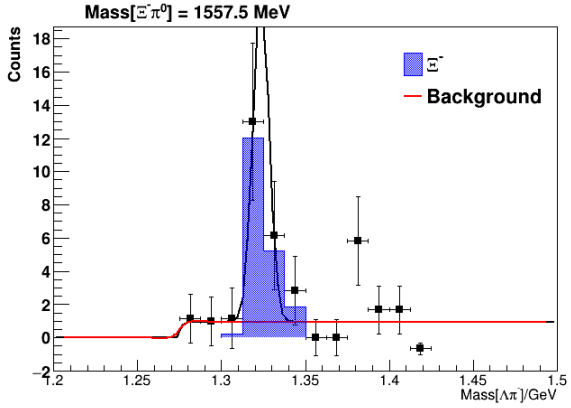

Mass[Ξ⁻π⁰] = 1507.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV


Mass[Ξ⁻π⁰] = 1517.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV


Mass[Ξ⁻π⁰] = 1527.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

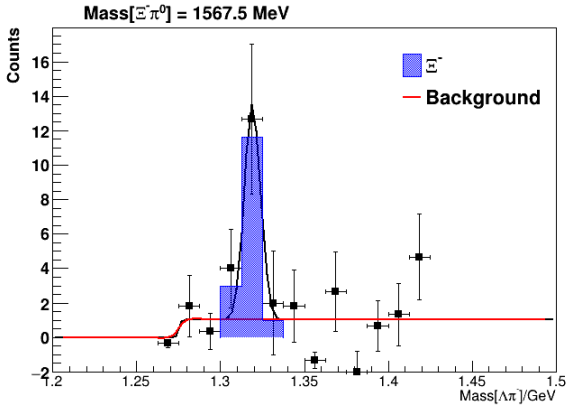

Mass[Ξ⁻π⁰] = 1537.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

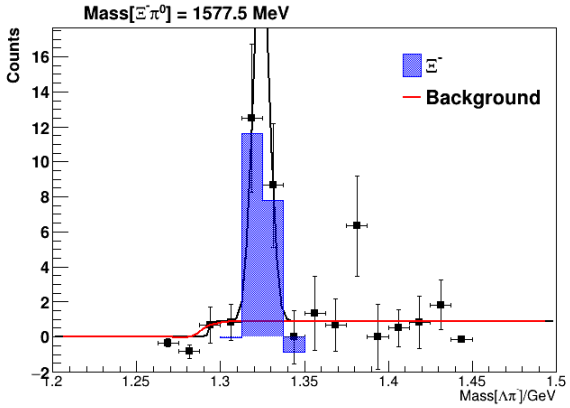

Mass[Ξ⁻π⁰] = 1547.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

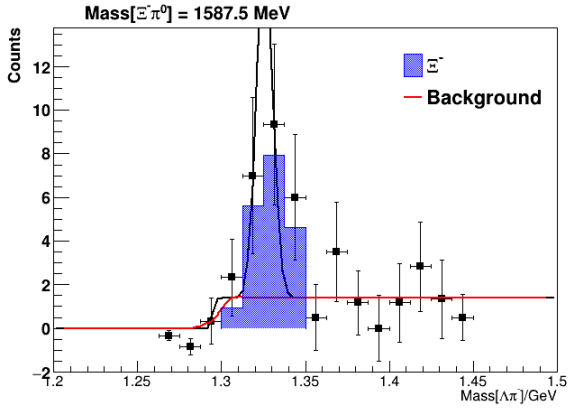

Mass[Ξ⁻π⁰] = 1557.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

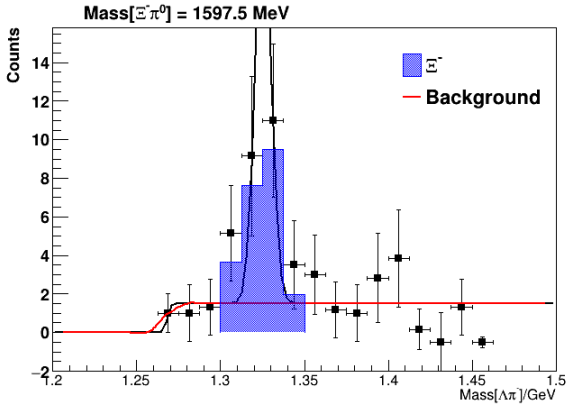
Ground State Ξ^- Fits

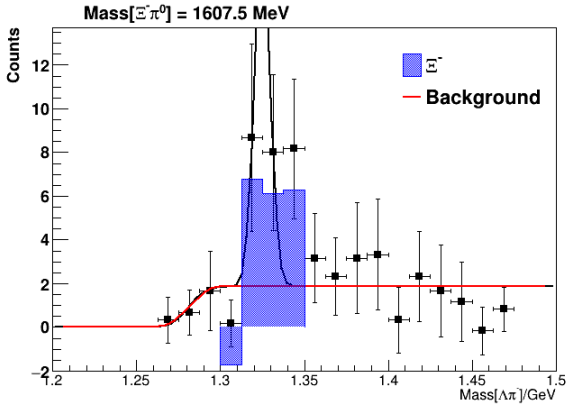
Next: From 1567.5 to 1647.5 MeV

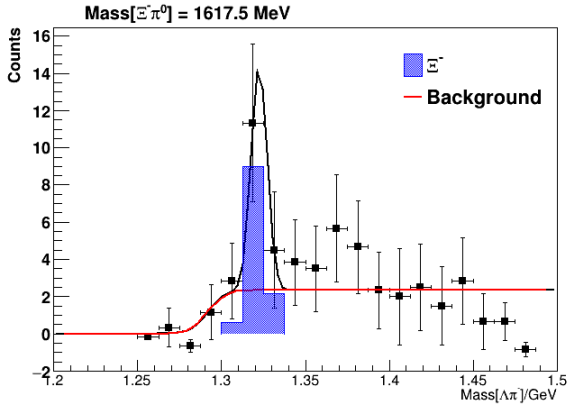

Mass[Ξ⁻π⁰] = 1567.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

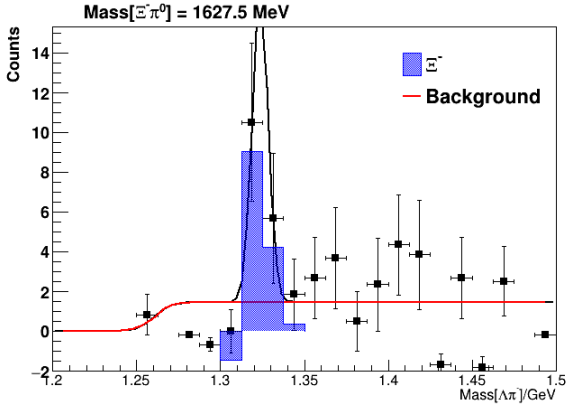

Mass[Ξ⁻π⁰] = 1577.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

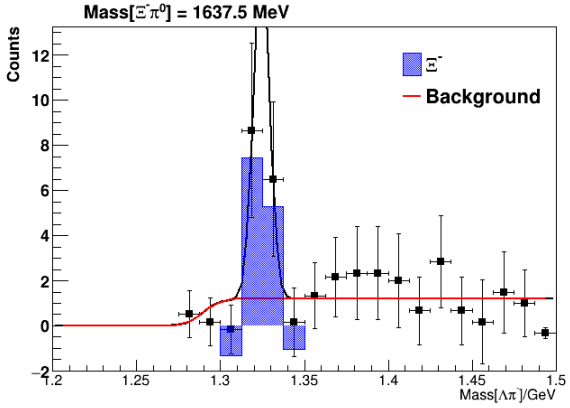

Mass[Ξ⁻π⁰] = 1587.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

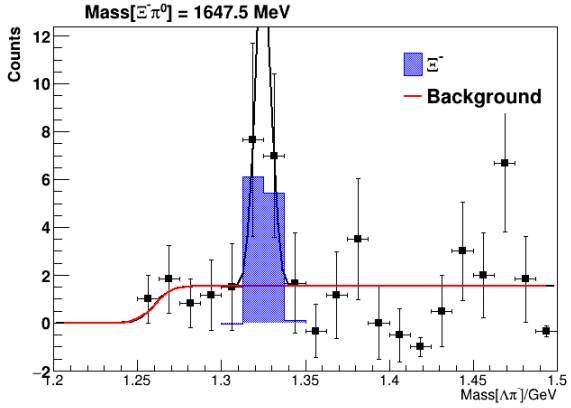

Mass[Ξ⁻π⁰] = 1597.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV


Mass[Ξ⁻π⁰] = 1607.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV


Mass[Ξ⁻π⁰] = 1617.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

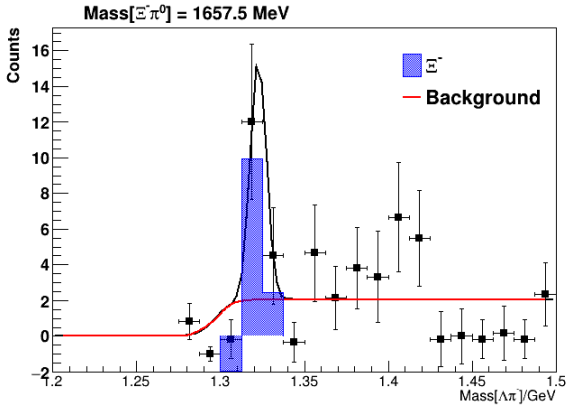

Mass[Ξ⁻π⁰] = 1627.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

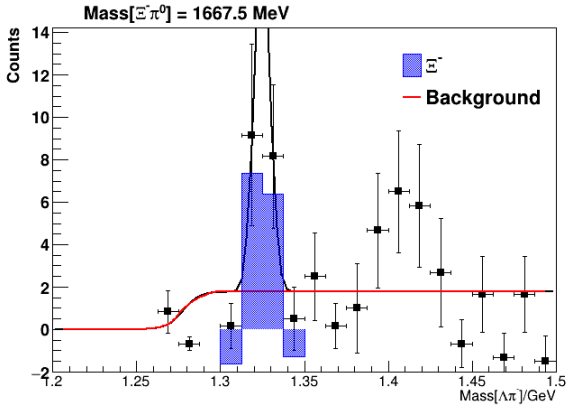

Mass[Ξ⁻π⁰] = 1637.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

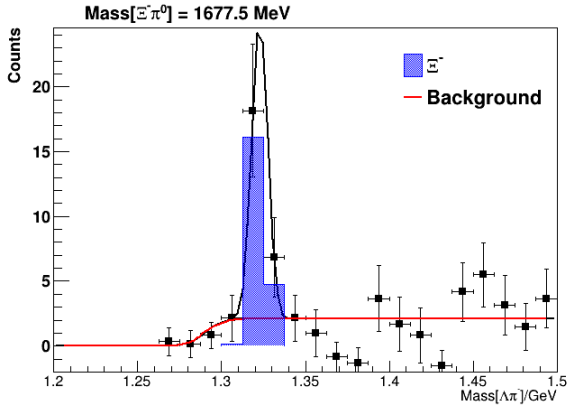

Mass[Ξ⁻π⁰] = 1647.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

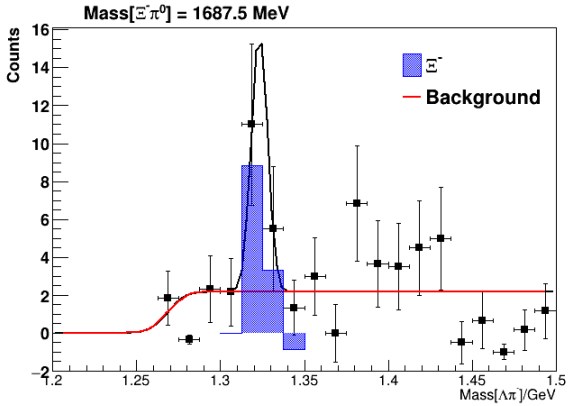
Ground State Ξ^- Fits

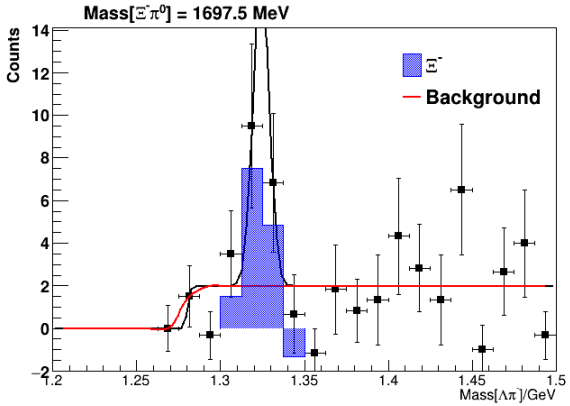
Next: From 1657.5 to 1737.5 MeV

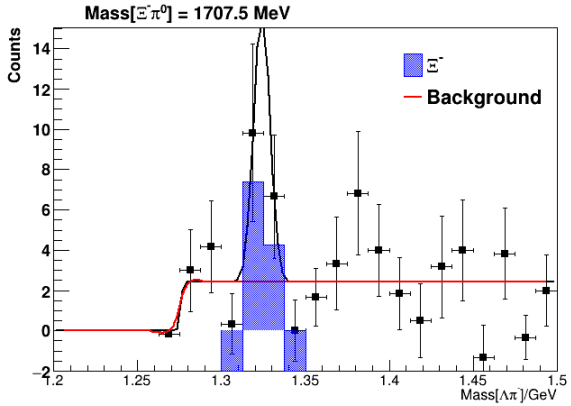

Mass[Ξ⁻π⁰] = 1657.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background

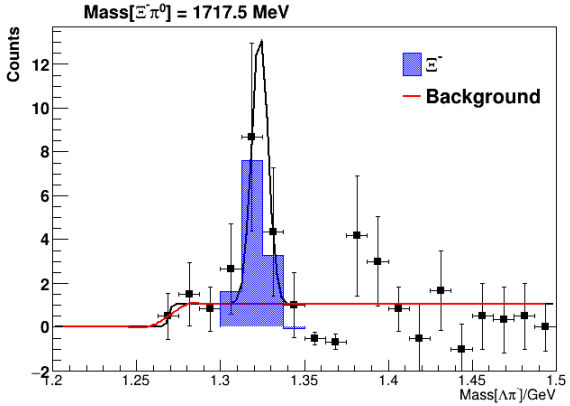

Mass[Ξ⁻π⁰] = 1667.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background

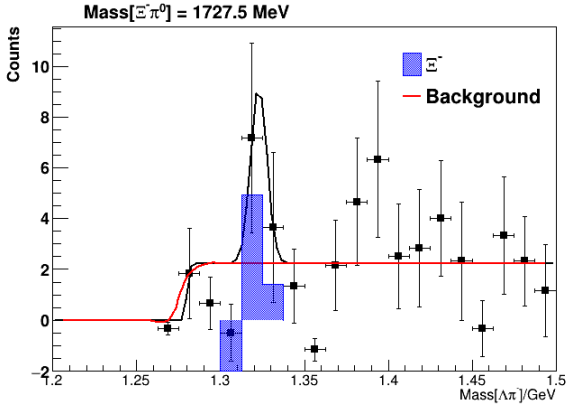

Mass[Ξ⁻π⁰] = 1677.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background

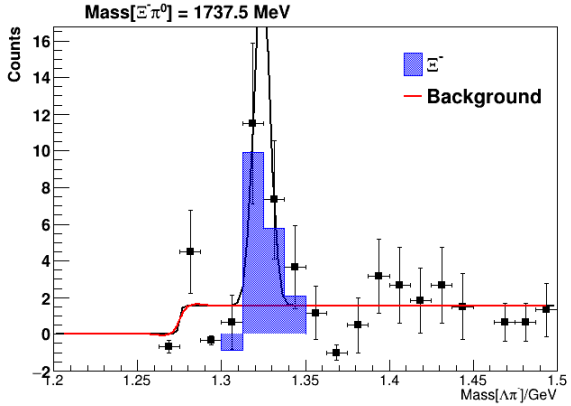

Mass[Ξ⁻π⁰] = 1687.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background


Mass[Ξ⁻π⁰] = 1697.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background


Mass[Ξ⁻π⁰] = 1707.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background

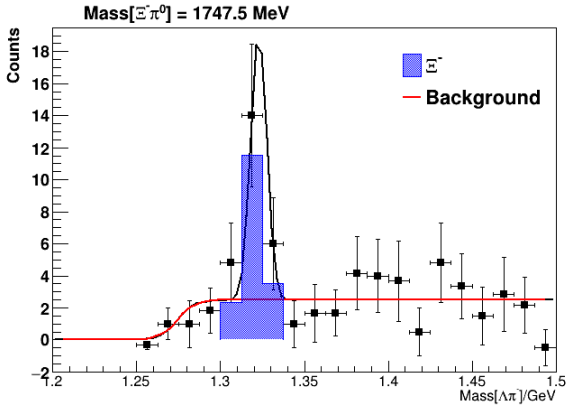

Mass[Ξ⁻π⁰] = 1717.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background

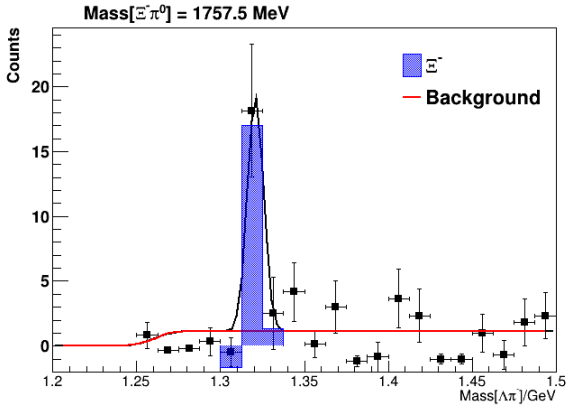

Mass[Ξ⁻π⁰] = 1727.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background

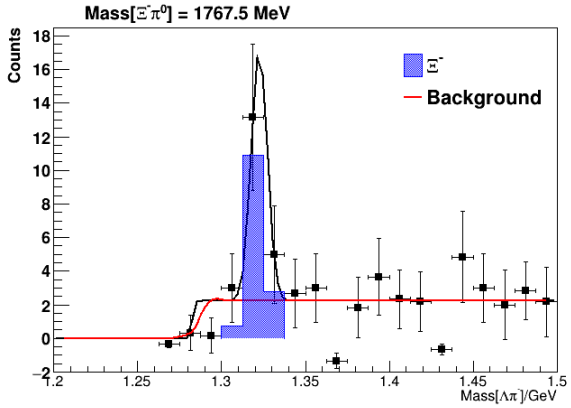

Mass[Ξ⁻π⁰] = 1737.5 MeV
Counts
Mass[Λπ⁻]/GeV
Ξ⁻
Background

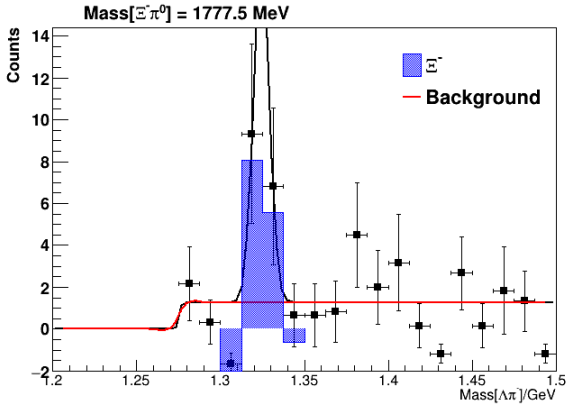
Ground State Ξ^- Fits

Last: From 1747.5 to 1777.5 MeV


Mass[Ξ⁻π⁰] = 1747.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

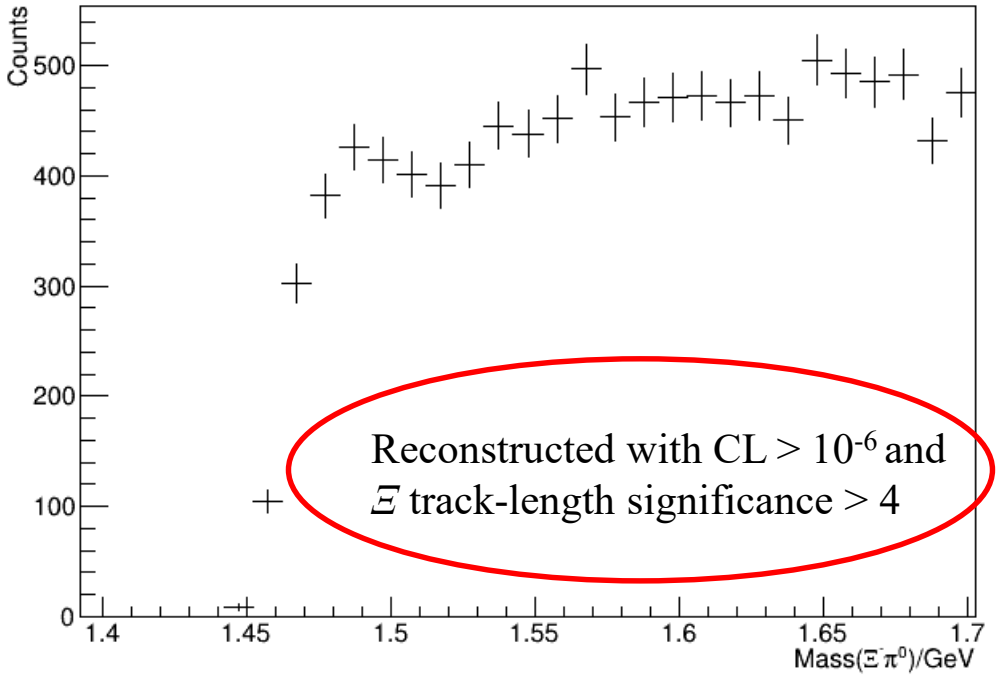

Mass[Ξ⁻π⁰] = 1757.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV


Mass[Ξ⁻π⁰] = 1767.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV


Mass[Ξ⁻π⁰] = 1777.5 MeV
Counts
Ξ⁻
Background
Mass[Λπ⁻]/GeV

Initial Monte Carlo

- Threw 3.4 million events (so far)
- Generated flat in mass[$\Xi^-\pi^0$] from 1.46 GeV to 1.75GeV



Initial Monte Carlo

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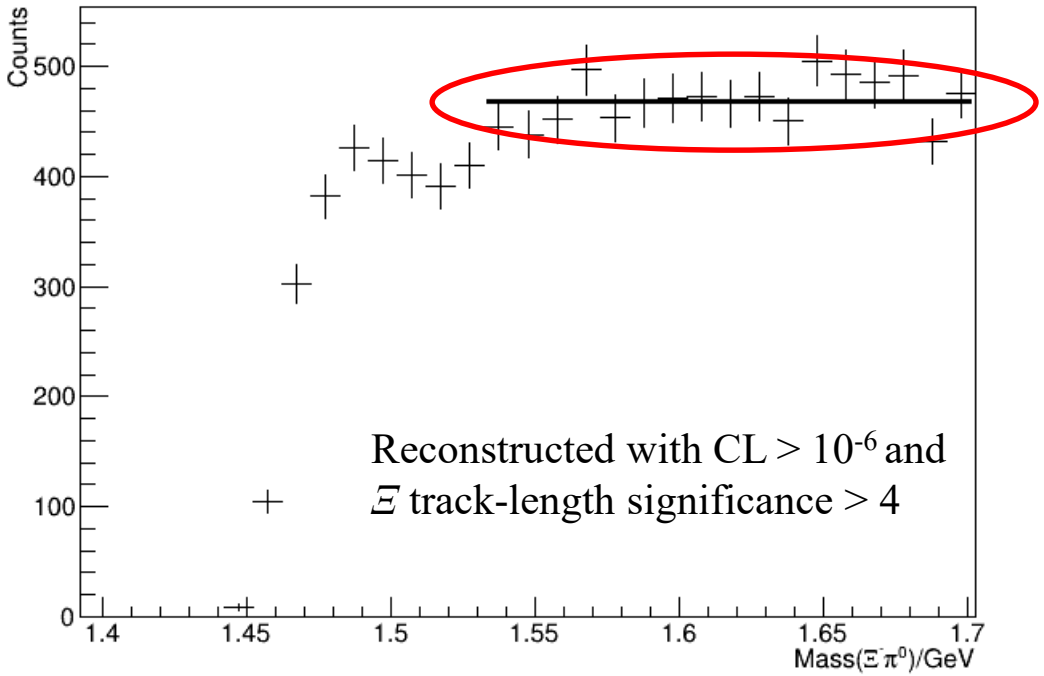
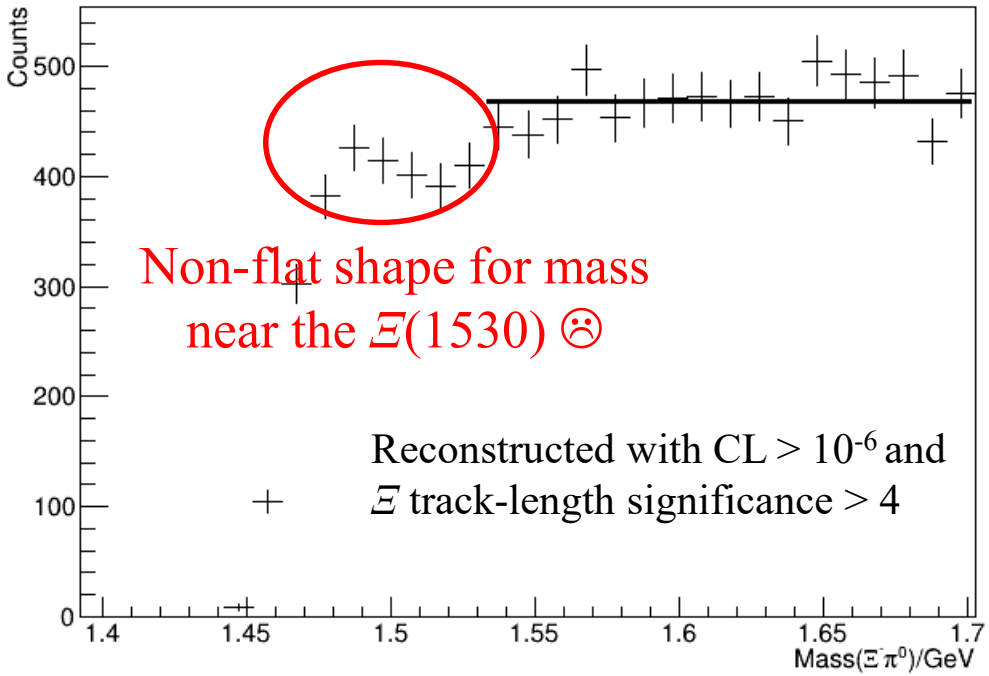
- Generated flat in mass[$\Xi^-\pi^0$] from 1.46 GeV to 1.75GeV



Fairly flat for mass > 1.54 GeV

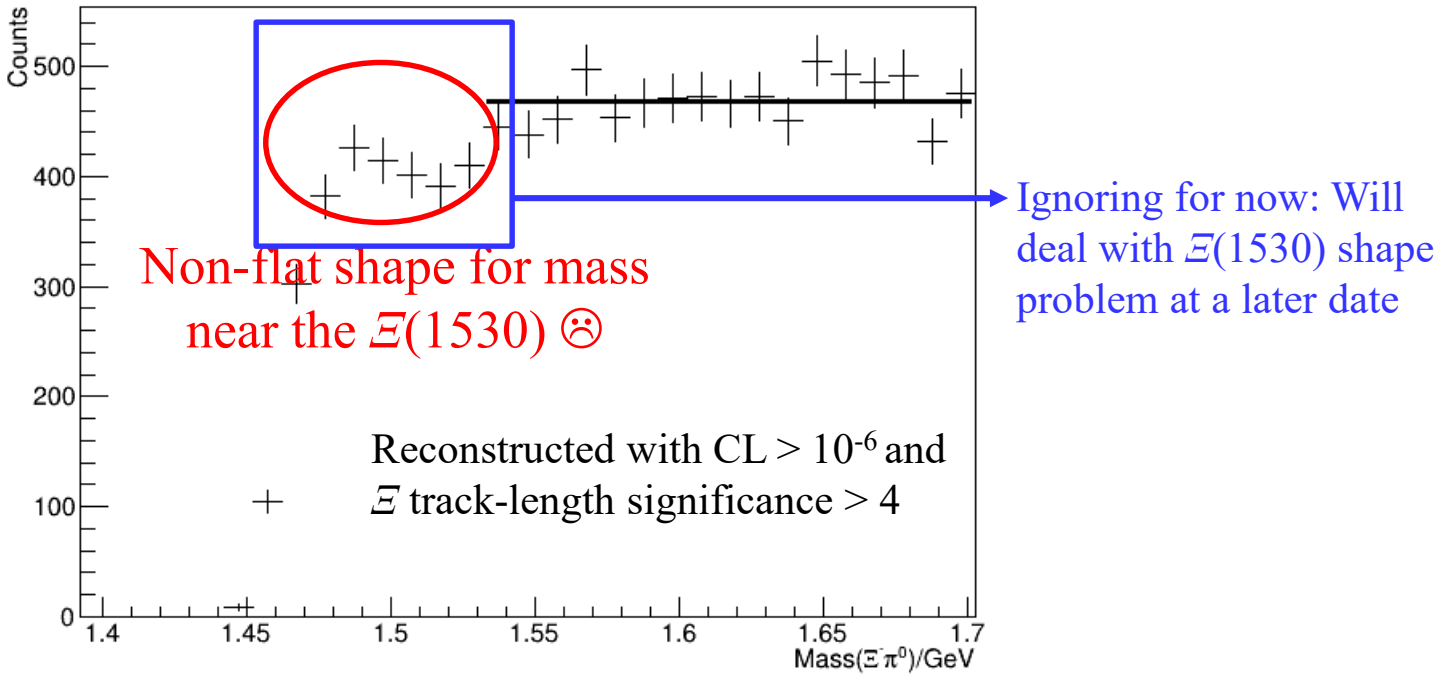
Initial Monte Carlo

- Threw 3.4 million events (so far)
- Generated flat in mass[$\Xi^-\pi^0$] from 1.46 GeV to 1.75GeV

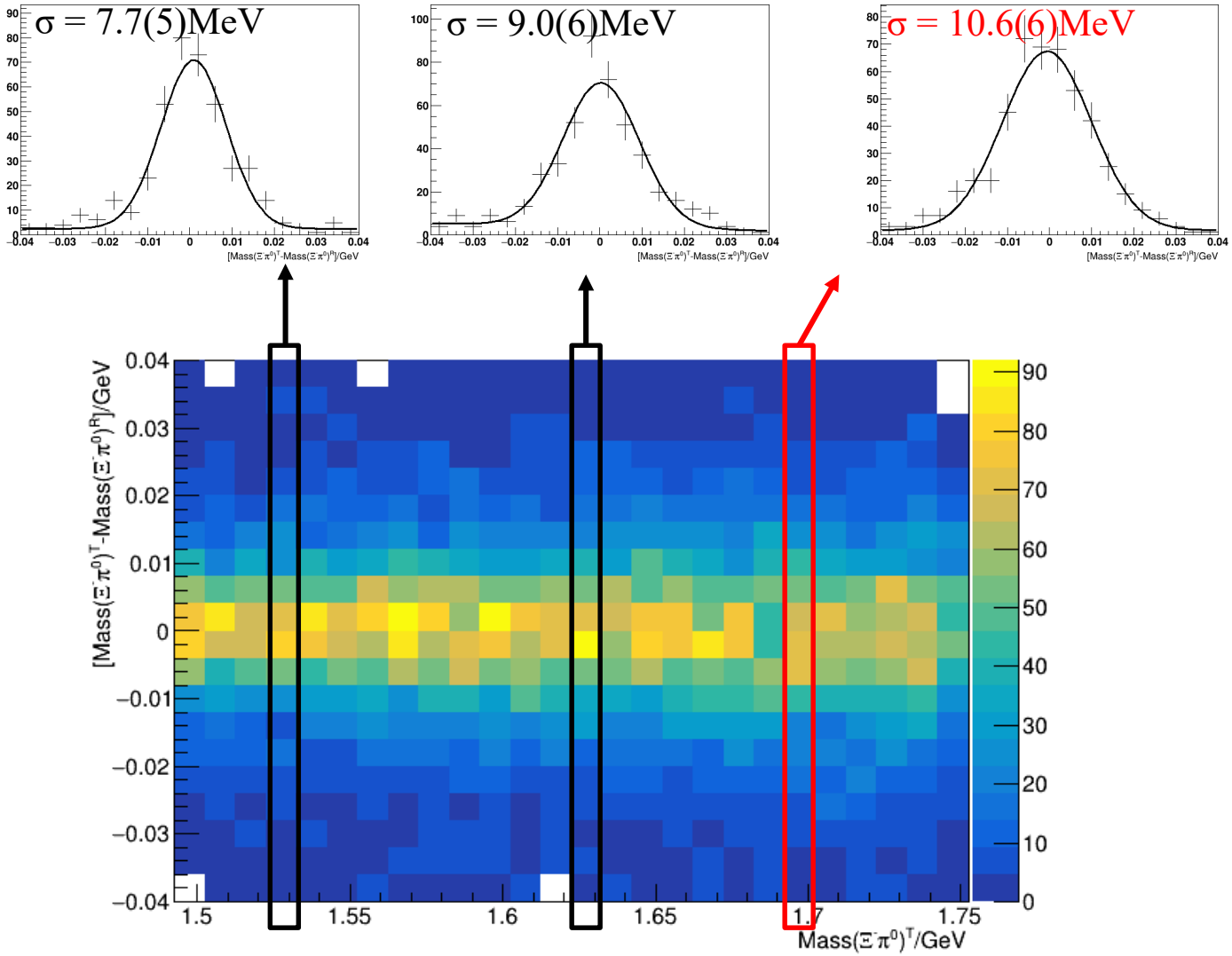


Initial Monte Carlo

- Threw 3.4 million events (so far)
- Generated flat in mass[$\Xi^-\pi^0$] from 1.46 GeV to 1.75GeV



Monte Carlo: Resolution of mass[$\Xi^-\pi^0$]



Comparison of Mass[Ξ^*]

$\Xi(1690)$:

- Fits have shape of $\Xi(1690)$ due entirely to detector resolution

- In general: Not enough statistics for the $\Xi(1690)$

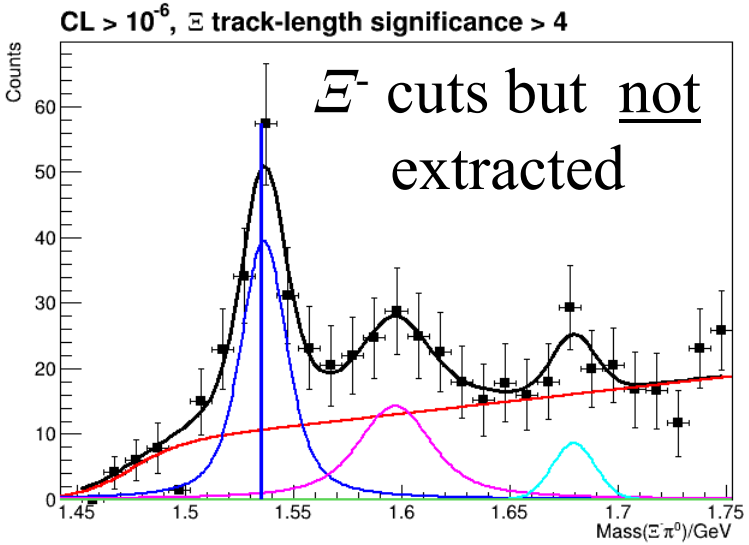
- If we can say anything at all, the best we can do for the $\Xi(1690)$ will probably be an upper limit

$\Xi(1620)$:

- With current statistics, the best we can do for the $\Xi(1620)$ will probably be an upper limit

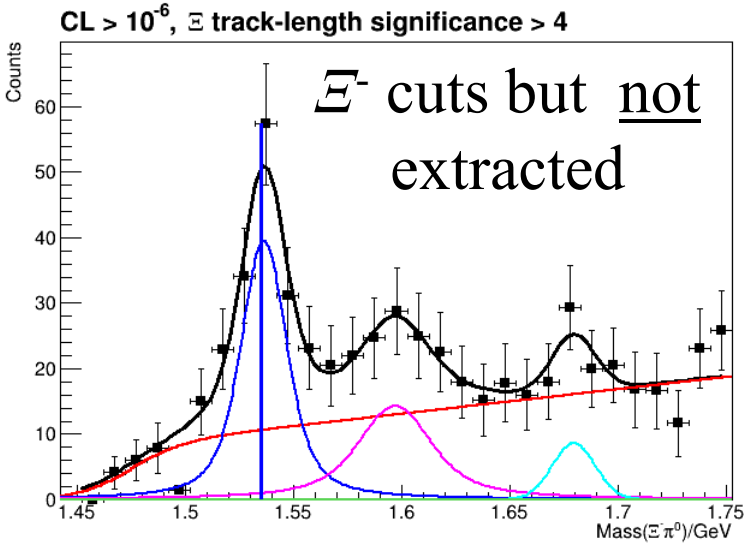
ASU

Comparison of Mass[Ξ^*]



- $\Xi(1530)$:
  - Center = 1536(2) MeV
  - Width = 13(17) MeV

Comparison of Mass[Ξ*]



- Ξ(1530):
  - Center = 1536(2) MeV
  - Width = 13(17) MeV

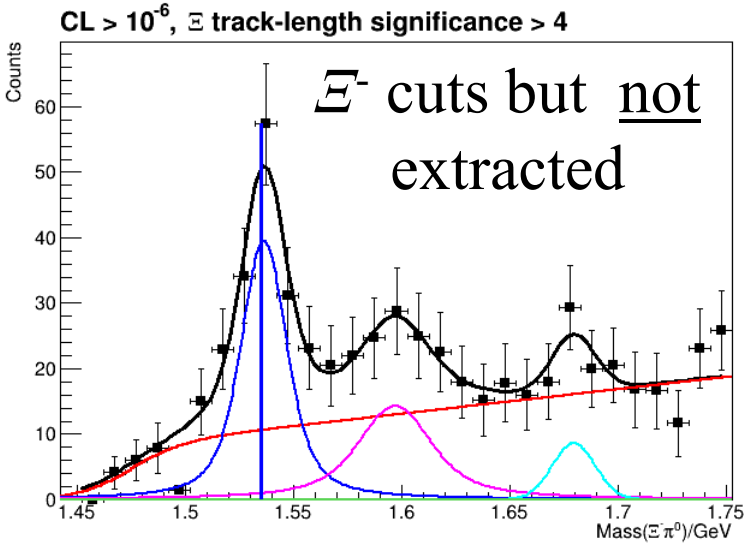
Ξ(1530)⁻ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1535.0±0.6 OUR FIT					
1535.2±0.8 OUR AVERAGE					
1534.5±1.2		DEBELLEFON	75B	HBC	$K^- p \to \Xi^- \overline{K}\pi$
1535.3±2.0		ROSS	73B	HBC	$K^- p \to \Xi \overline{K}\pi(\pi)$
1536.2±1.6	185	KIRSCH	72	HBC	$K^- p$ 2.87 GeV/c
1535.7±3.2	38	LONDON	66	HBC	$K^- p$ 2.24 GeV/c
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1540 ±3	48	BERTHON	74	HBC	Quasi-2-body σ
1534.7±1.1	334	BALTAY	72	HBC	$K^- p$ 1.75 GeV/c

Ξ(1530)⁻ WIDTH

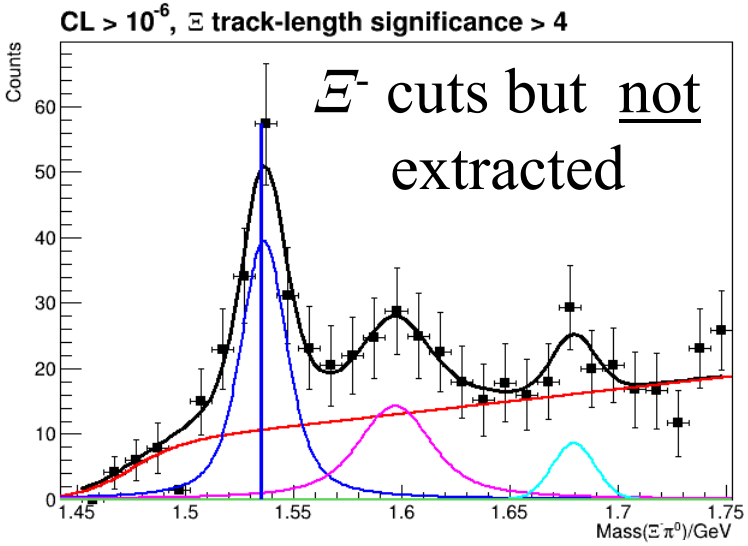
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
$9.9^{+1.7}_{-1.9}$ OUR AVERAGE				
9.6±2.8	DEBELLEFON	75B	HBC	$K^- p \to \Xi^- \overline{K}\pi$
8.3±3.6	ROSS	73B	HBC	$K^- p \to \Xi \overline{K}\pi(\pi)$
$7.8^{+3.5}_{-7.8}$	BALTAY	72	HBC	$K^- p$ 1.75 GeV/c
16.2±4.6	KIRSCH	72	HBC	$\Xi^- \pi^0$, $\Xi^0 \pi^-$

Comparison of Mass[Ξ^*]



- $\Xi(1530)$:
  - Center = 1536(2) MeV
  - Width = 13(17) MeV
- $\Xi(1620)$:
  - Center = 1597(7) MeV
  - Width = 28(39) MeV

Comparison of Mass[Ξ^*]



- $\Xi(1530)$:
  - Center = 1536(2) MeV
  - Width = 13(17) MeV
- $\Xi(1620)$:
  - Center = 1597(7) MeV
  - Width = 28(39) MeV

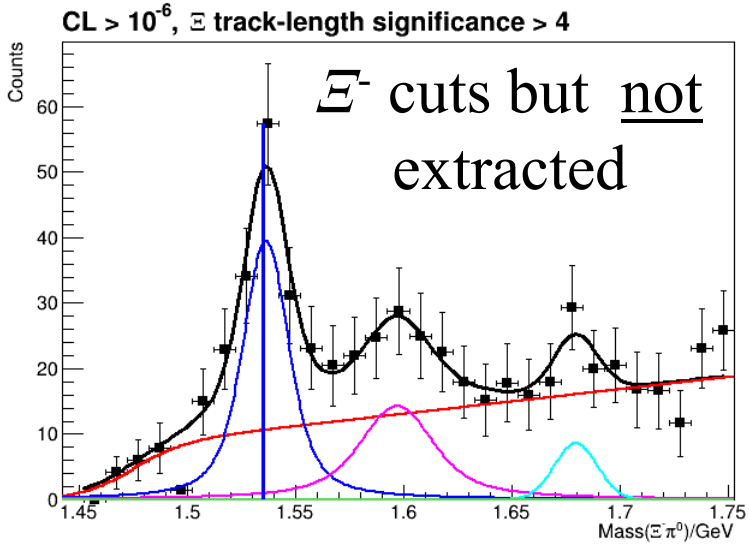
$\Xi(1620)$ MASS

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

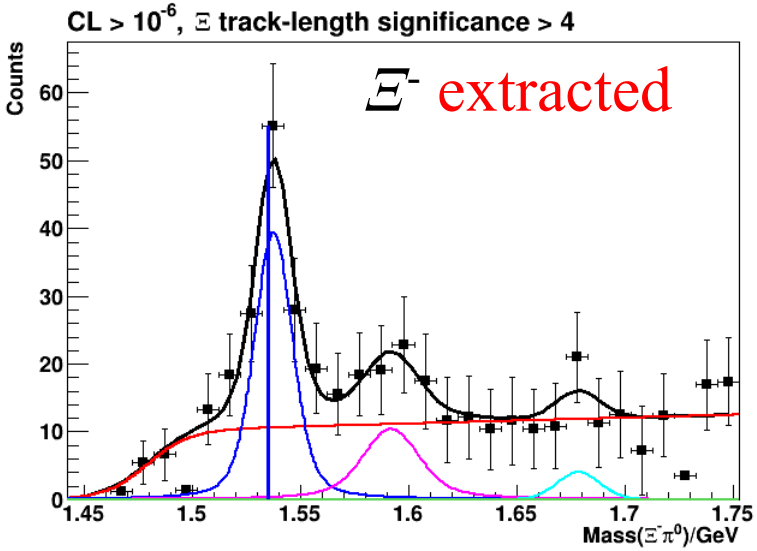
$\Xi(1620)$ WIDTH

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	$K^- p \to \Xi^- \pi^+ K^{*0}(892)$

Comparison of Mass[Ξ*]



- Ξ(1530):
  - Center = 1536(2) MeV
  - Width = 13(17) MeV
- Ξ(1620):
  - Center = 1597(7) MeV
  - Width = 28(39) MeV



- Ξ(1530):
  - Center = 1538(2) MeV
  - Width = 7(14) MeV
- Ξ(1620):
  - Center = 1592(9) MeV
  - Width = 14(34) MeV

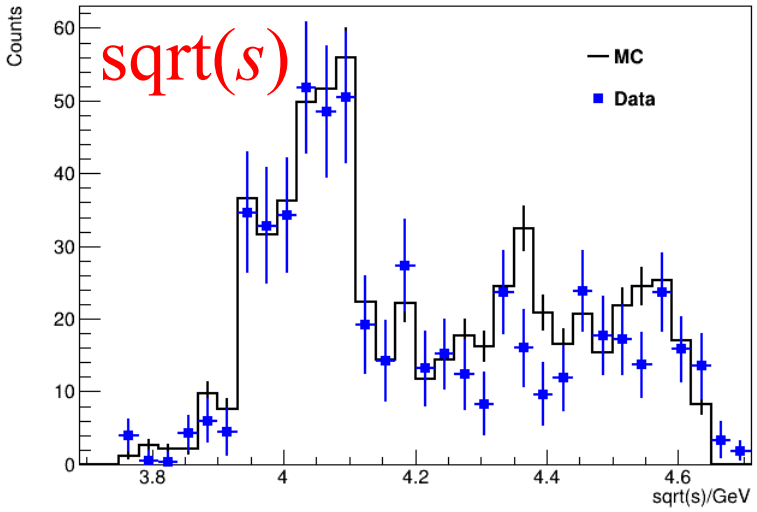
Ξ^* Generator Refinement

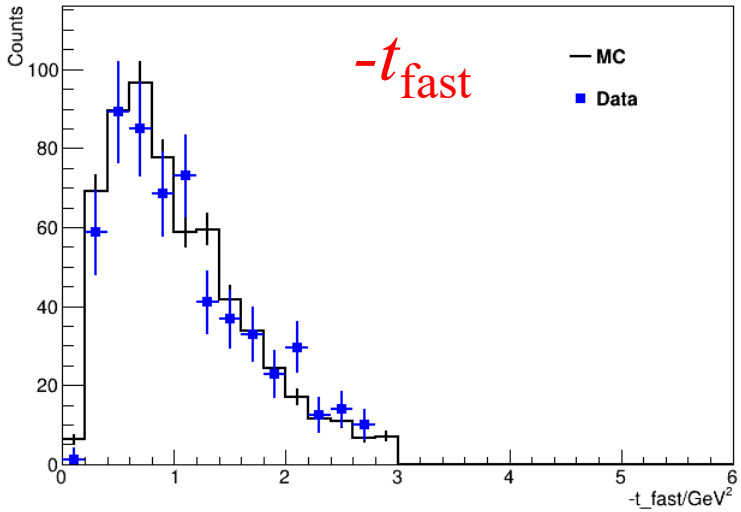
- Starting with code from Brandon build for $\Xi(1530)$ and modifying for general Ξ^*
- Taking the initial reaction as $\gamma\, p \rightarrow K\, Y^*$
- Mandelstam variables have relationship:
  - $s+t+u = m_\gamma^2 + m_p^2 + m_K^2 + m_{Y*}^2$
- We can lock down the kinematics of the initial reaction by specifying s, t and m_{Y*}
- Started with Mandelstam s and t

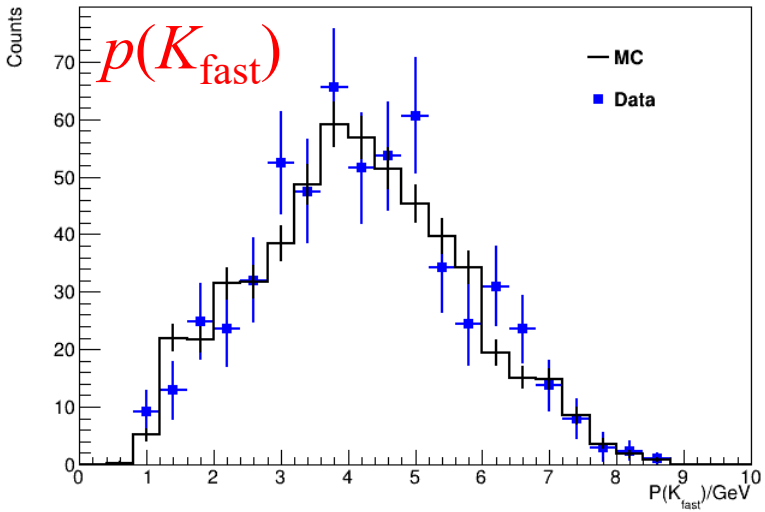
Ξ^* Comparison of Reconstructed MC to Actual Data

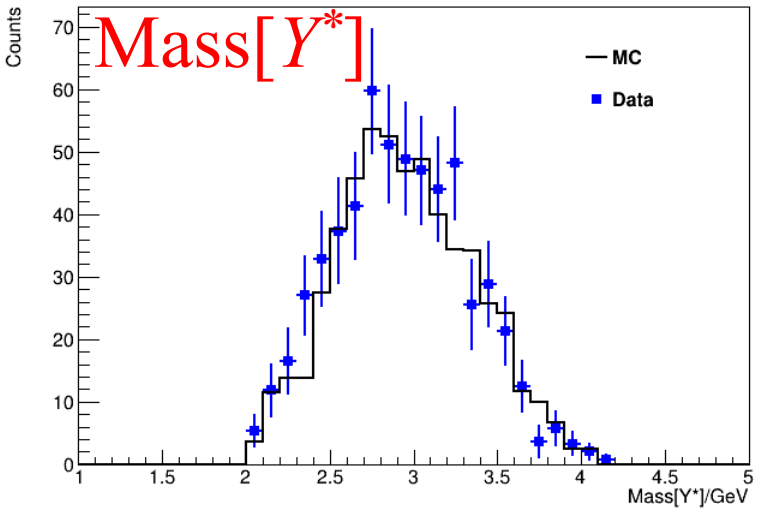
- 1st : of MC to set t-slope (parameter b in $Ae^{-b|t|}$) to 1.138/GeV^2 assuming $\gamma\, p \rightarrow K_{\text{fast}}\, Y^*$
- 2nd : Shaping mass[Y*] and mass[Ξ^*]
- 3rd : Shaping K_{slow} distribution assuming $Y^* \rightarrow K_{\text{slow}}\, \Xi^*$

Ξ^* Comparison of Reconstructed MC to Actual Data (slide 1)

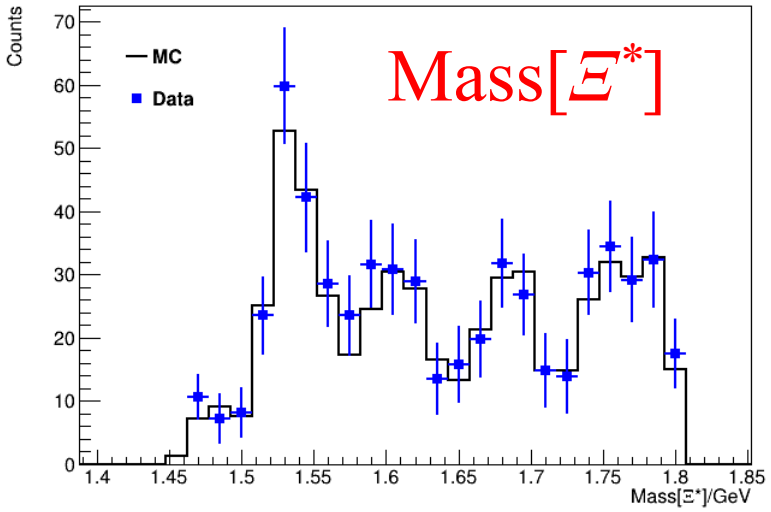


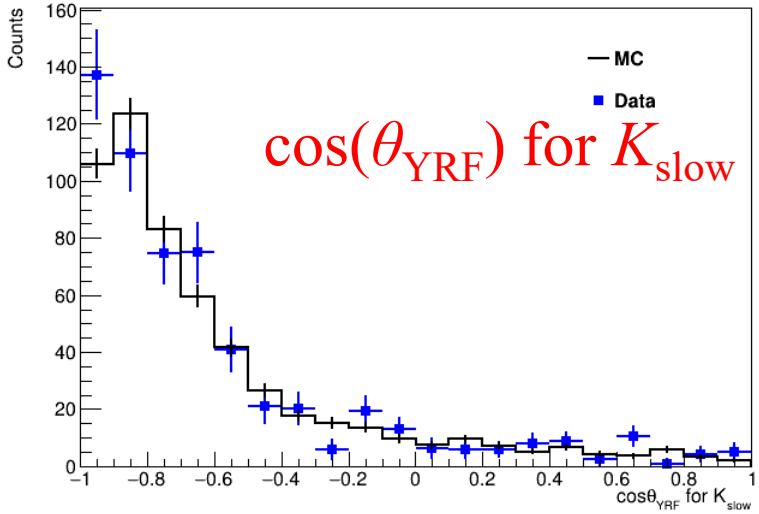




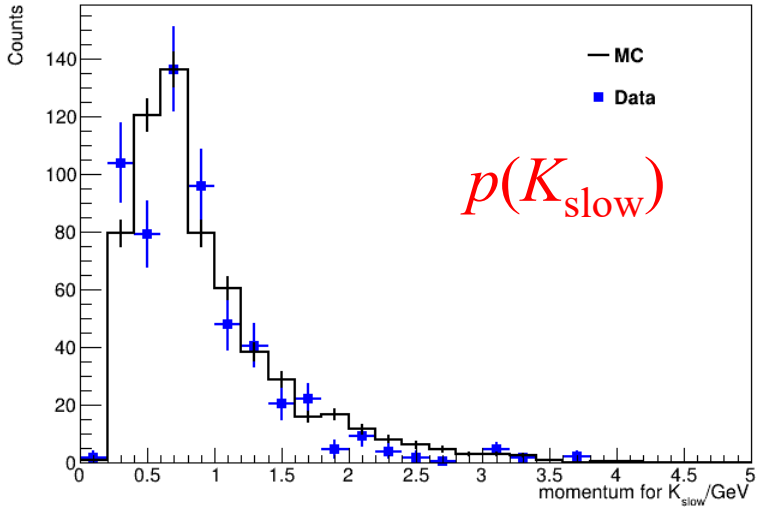


Ξ^* Comparison of Reconstructed MC to Actual Data (slide 2)





where YRF is hyperon (Y) Rest Frame



Next Steps

Create MC for isolated $\Xi(1530)$, $\Xi(1620)$, $\Xi(1690)$ and background using parameters from fit to data