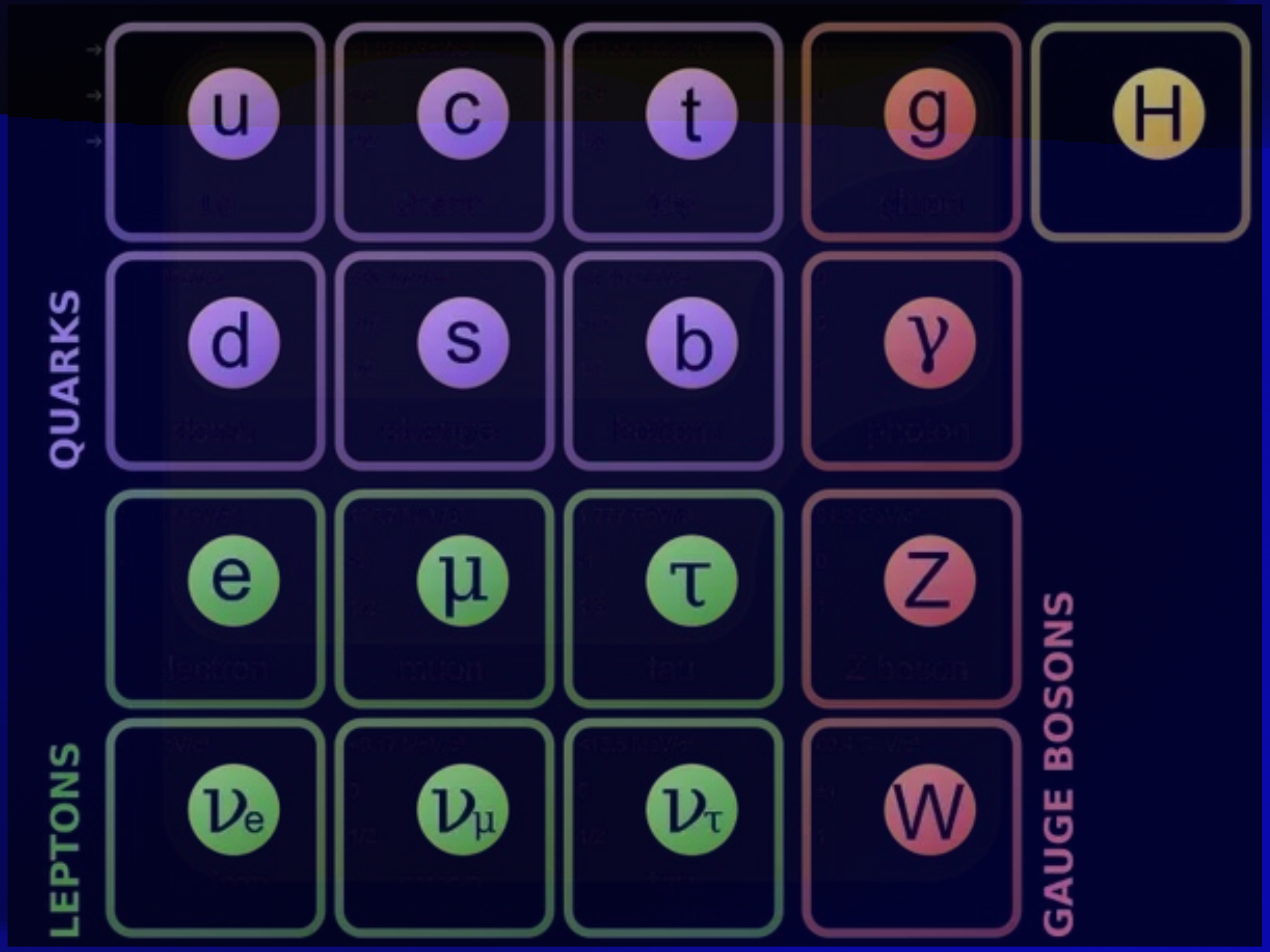
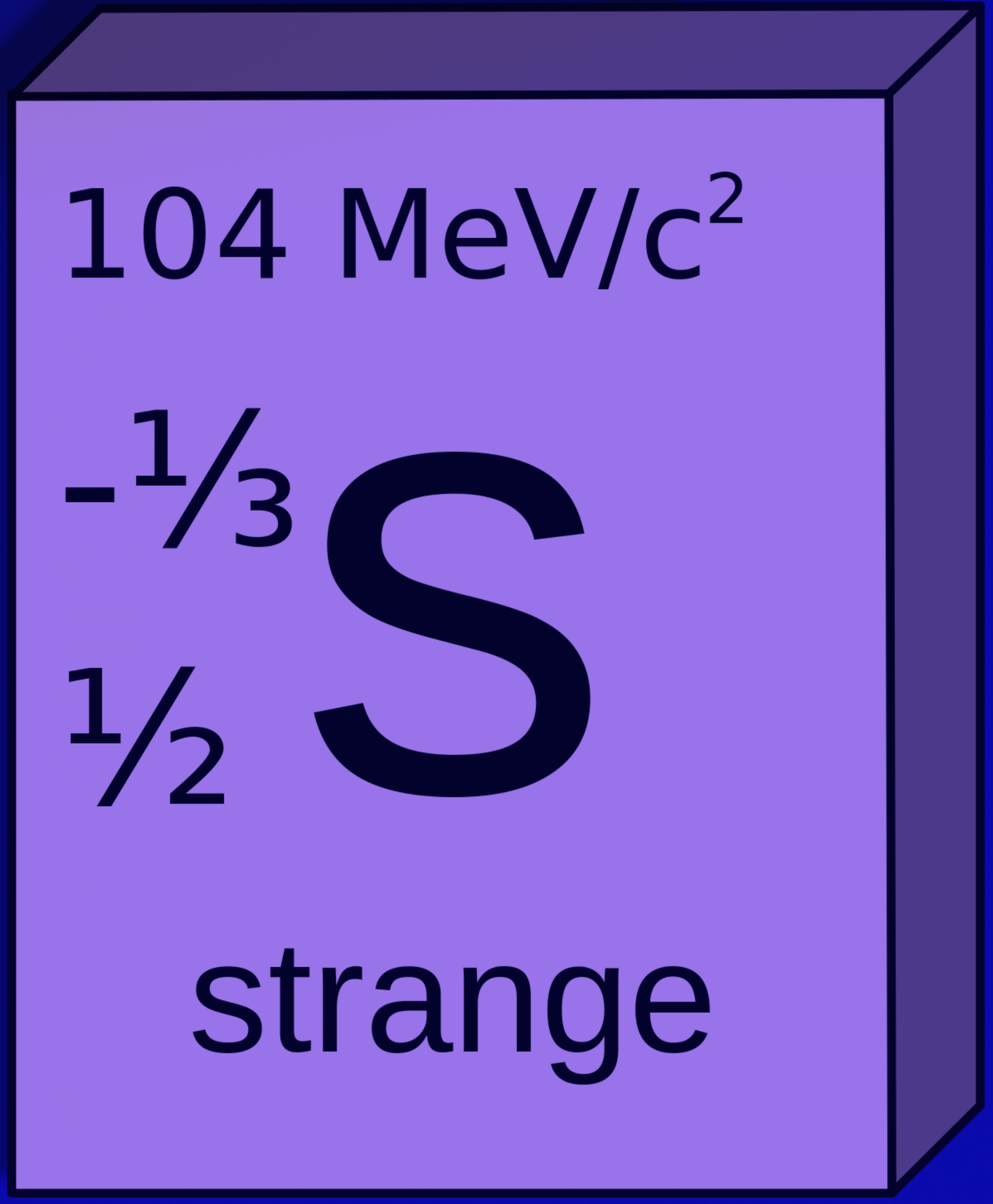
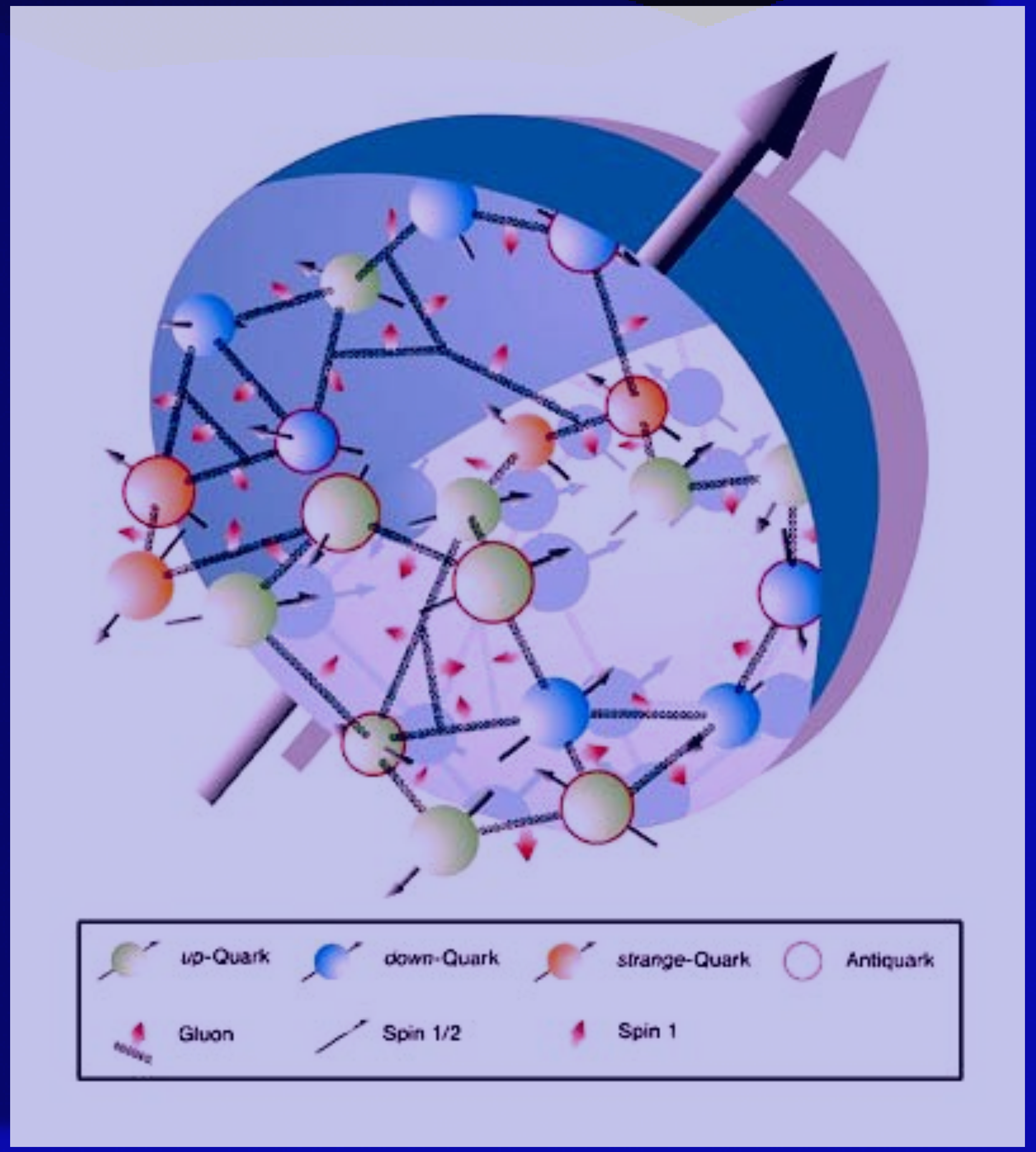
Elucidating Strangeness with Electromagnetic Probes







QCD Puzzles

ISGUR & CAPSTICK (1986)

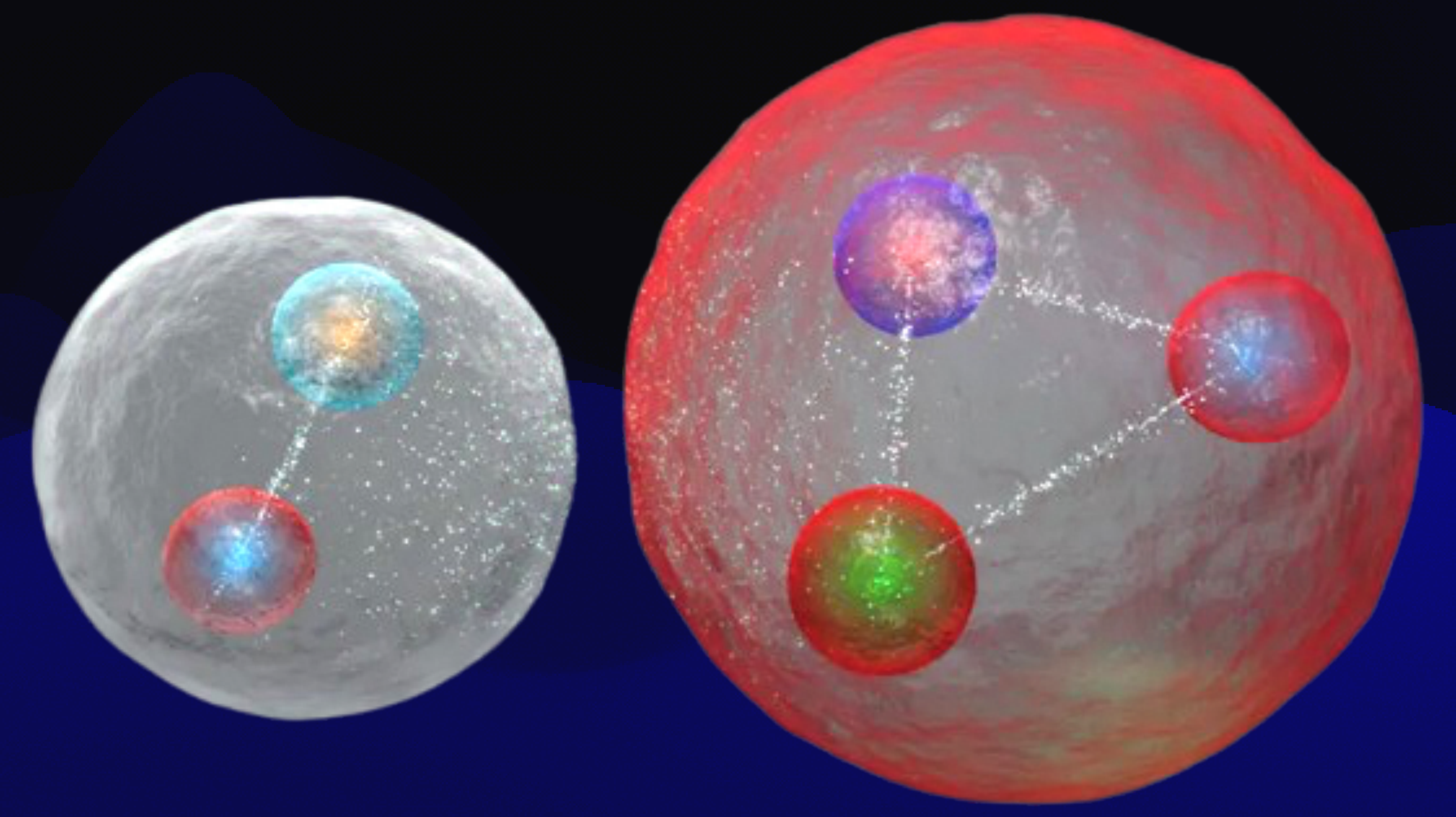
TABLE VIII. The Ξ and Ω baryons below 2400 and 2500 MeV, respectively.

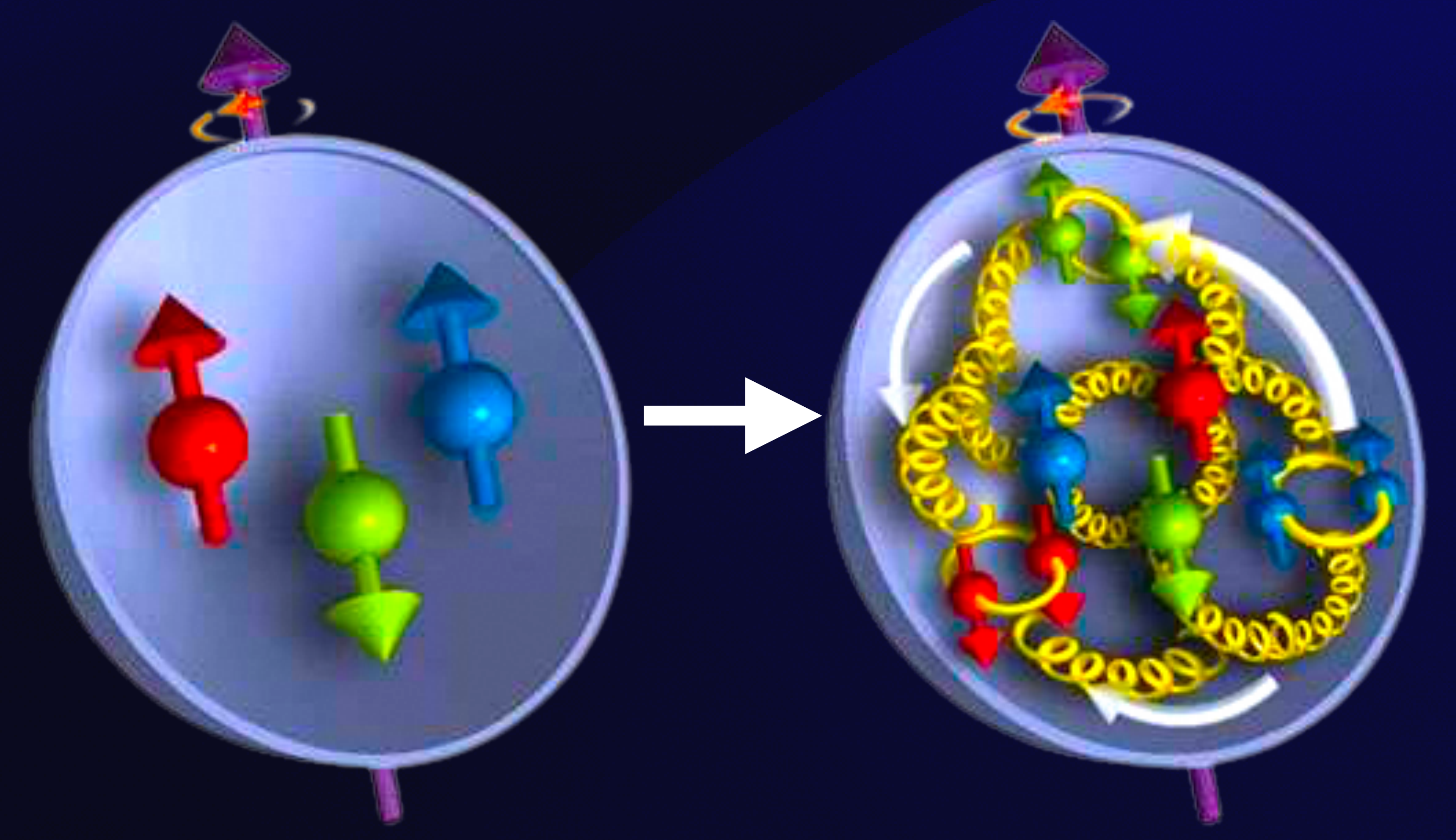
State, J^P	Predicted masses (MeV)							
$\Xi\frac{1}{2}^+$	1305							
$\Xi\frac{3}{2}^+$	1505							
$\Xi^*\frac{1}{2}^-$	1755	1810	1835	2225	2285	2300	2320	2380
$\Xi^*\frac{3}{2}^-$	1785	1880	1895	2240	2305	2330	2340	2385
$\Xi^*\frac{5}{2}^-$	1900	2345	2350	2385				
$\Xi^*\frac{7}{2}^-$	2355							
$\Xi^*\frac{1}{2}^+$	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						

RELATIVIZED QUARK MODEL

44 STATES PREDICTED . . .

MESON-BARYON MOLECULES

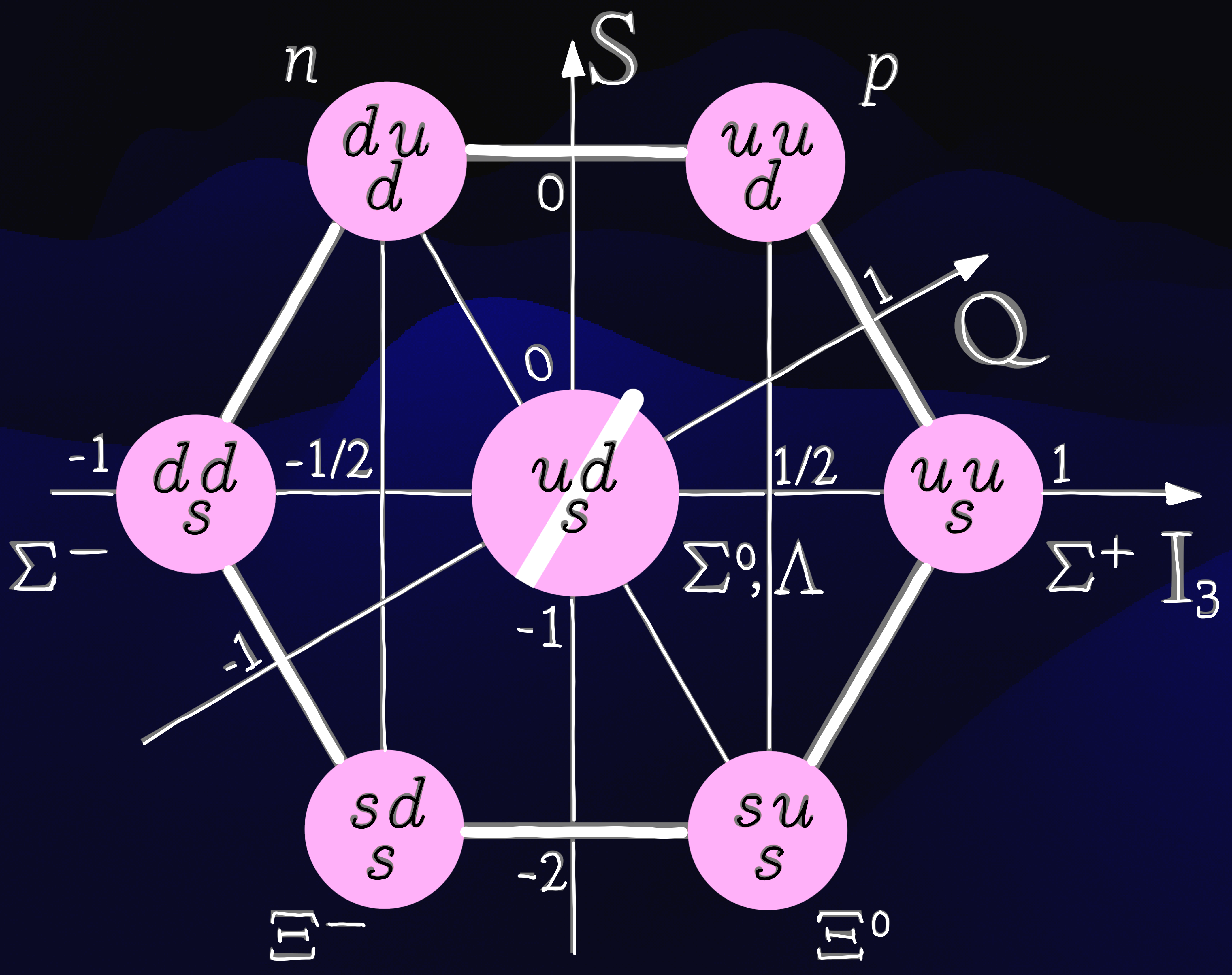




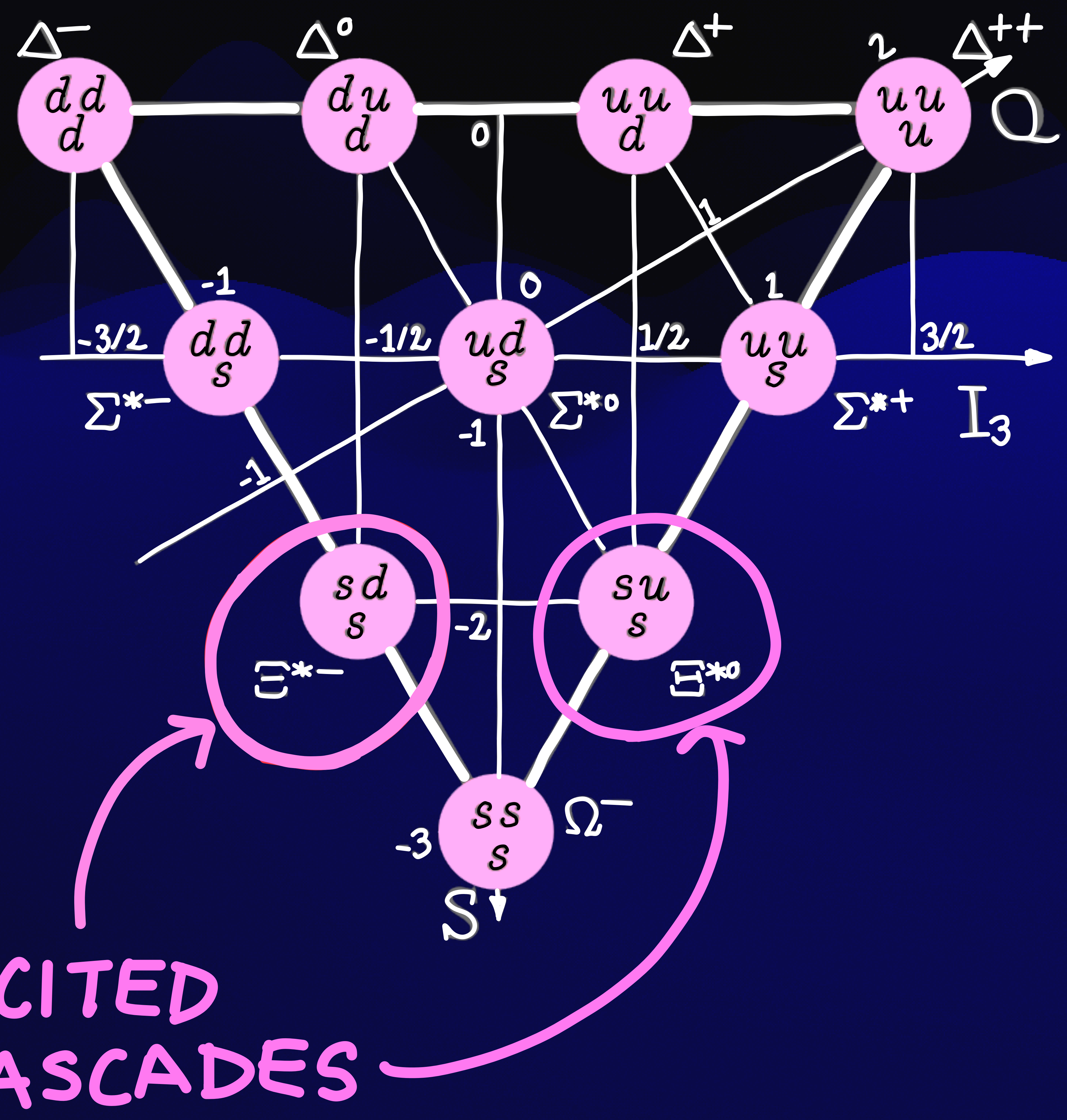
DO WE ACTUALLY UNDERSTAND BARYONS?

Baryons

OCTET



DECUPLET



The Missing States

Current Particle	Current Status	Previous Mass	Previous Status	Mass from MPS (MeV)
$\Xi(1318)$	****	1320	****	1320 ± 6
$\Xi(1530)$	****	1530	****	1541 ± 12
$\Xi(1620)$	*	1630	**	
$\Xi(1690)$	***	1680	**	
$\Xi(1820)$	***	1820	***	1822 ± 6
$\Xi(1950)$	***	1940	**	
$\Xi(2030)$	***	2030	***	2022 ± 7
$\Xi(2120)$	*	2120	*	
$\Xi(2250)$	***	2250	*	2214 ± 5
$\Xi(2370)$	**	2370	**	2356 ± 10
$\Xi(2500)$	*	2500	**	2505 ± 10

NOW

1981

well established

Only 6 states established.

Not much progress in the last 4 decades

Missing Quantum Numbers & Branching Ratios

Ξ(1690)

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

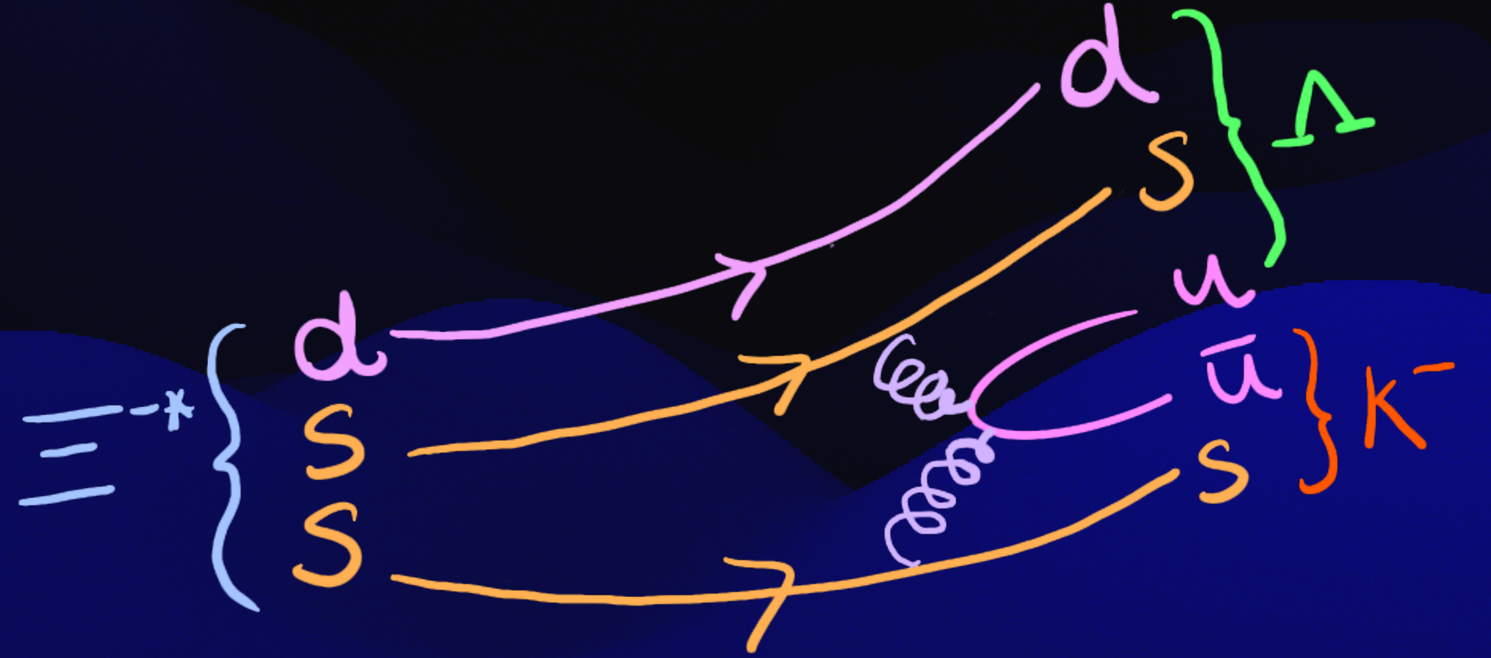
Mass $m = 1690 \pm 10$ MeV [c]
Full width $\Gamma < 30$ MeV

Ξ(1690) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda \overline{K}$	seen	240
$\Sigma \overline{K}$	seen	70
$\Xi \pi$	seen	311
$\Xi^- \pi^+ \pi^-$	possibly seen	213

Missing

FROM PDG

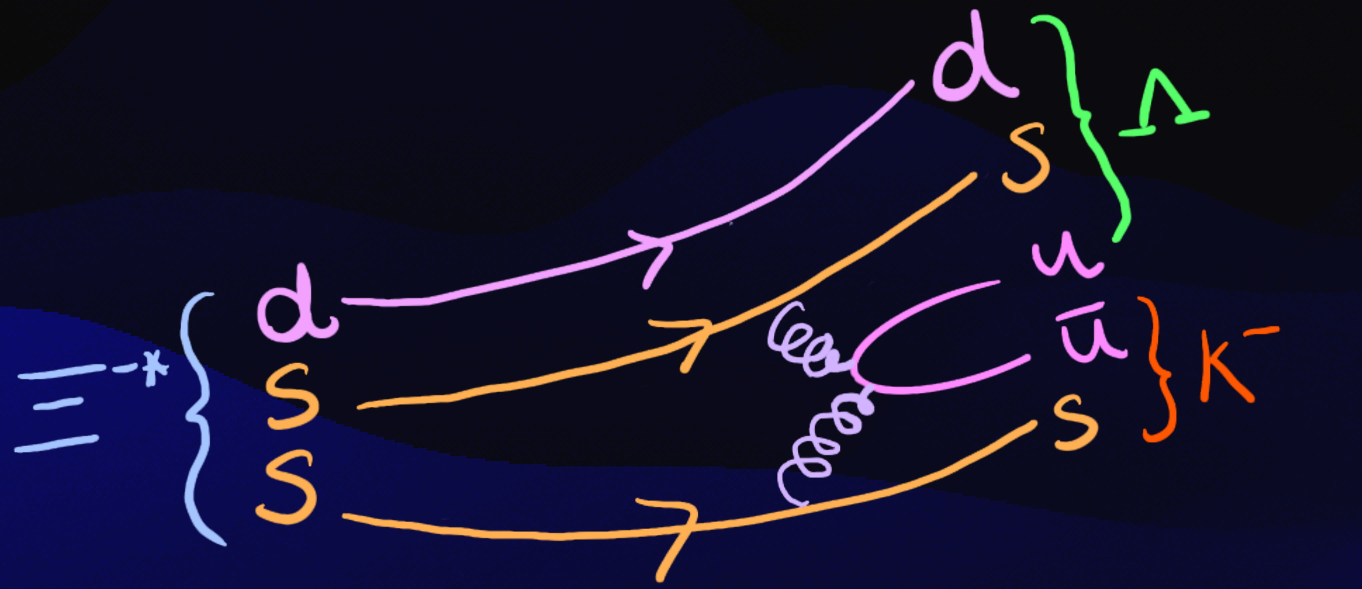
POSSIBLE DECAY MODES

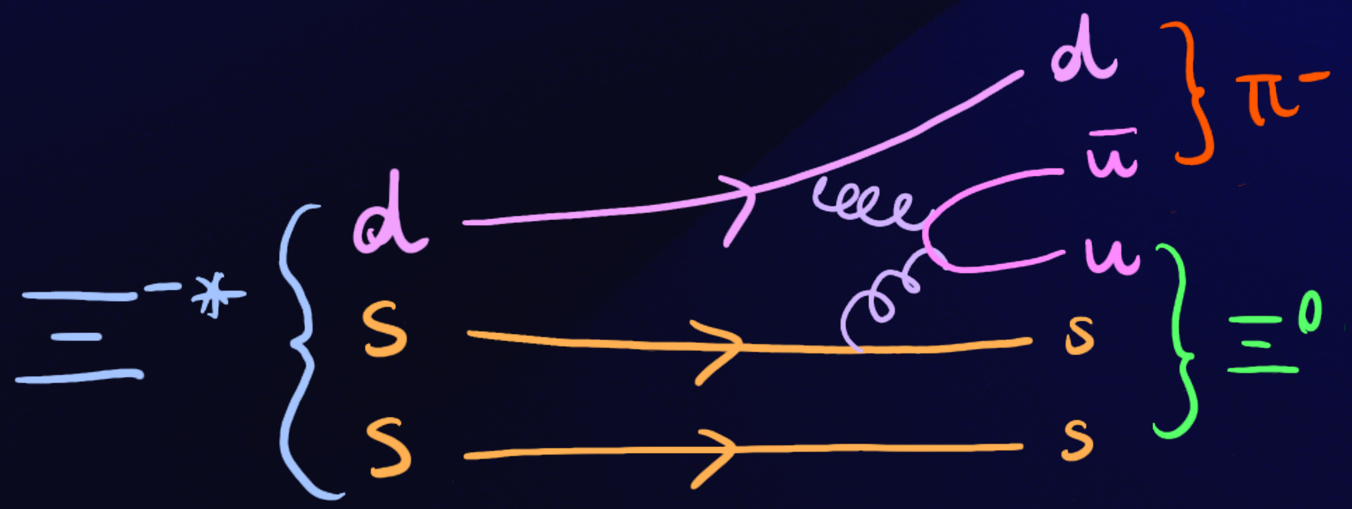


final quark composition is the same!

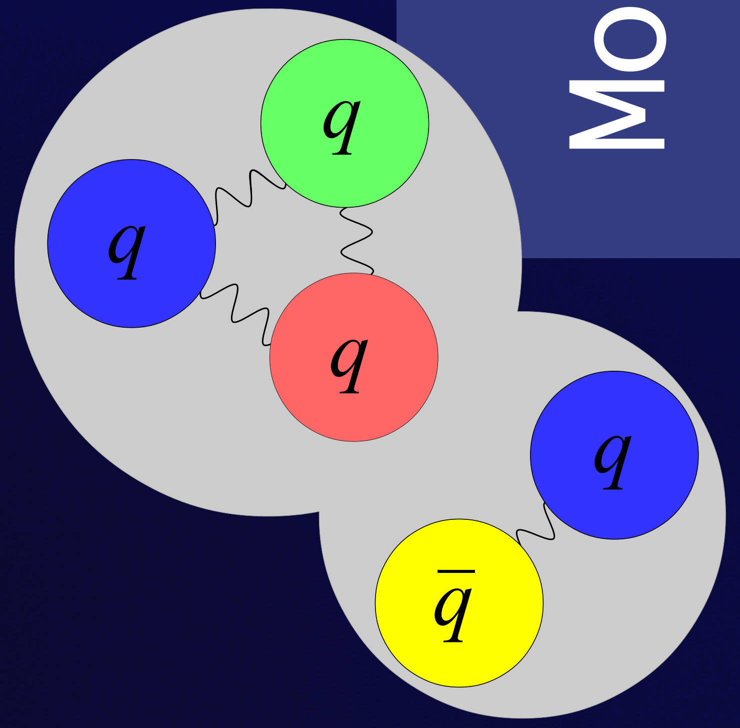
Theoretical Controversies

3q state

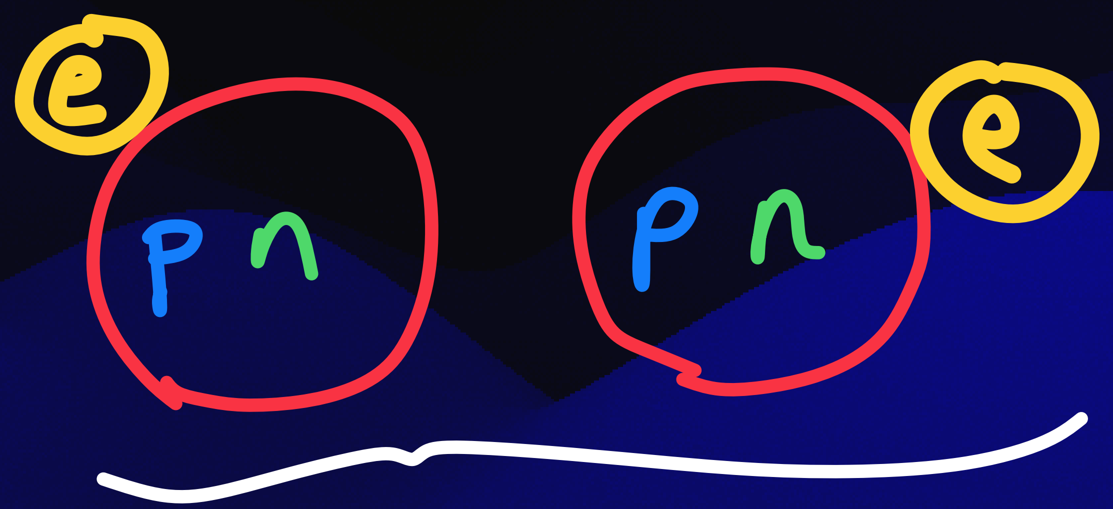




Molecular state

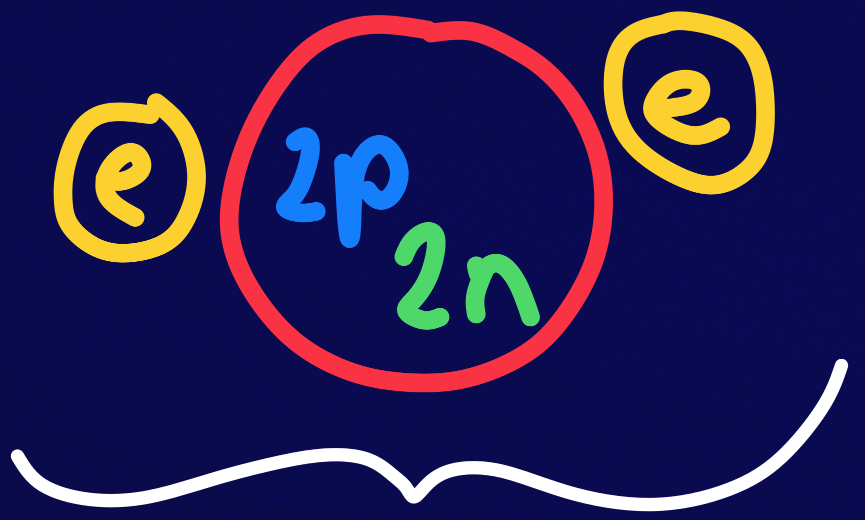


EXAMPLE:



Deuterium molecule

OR

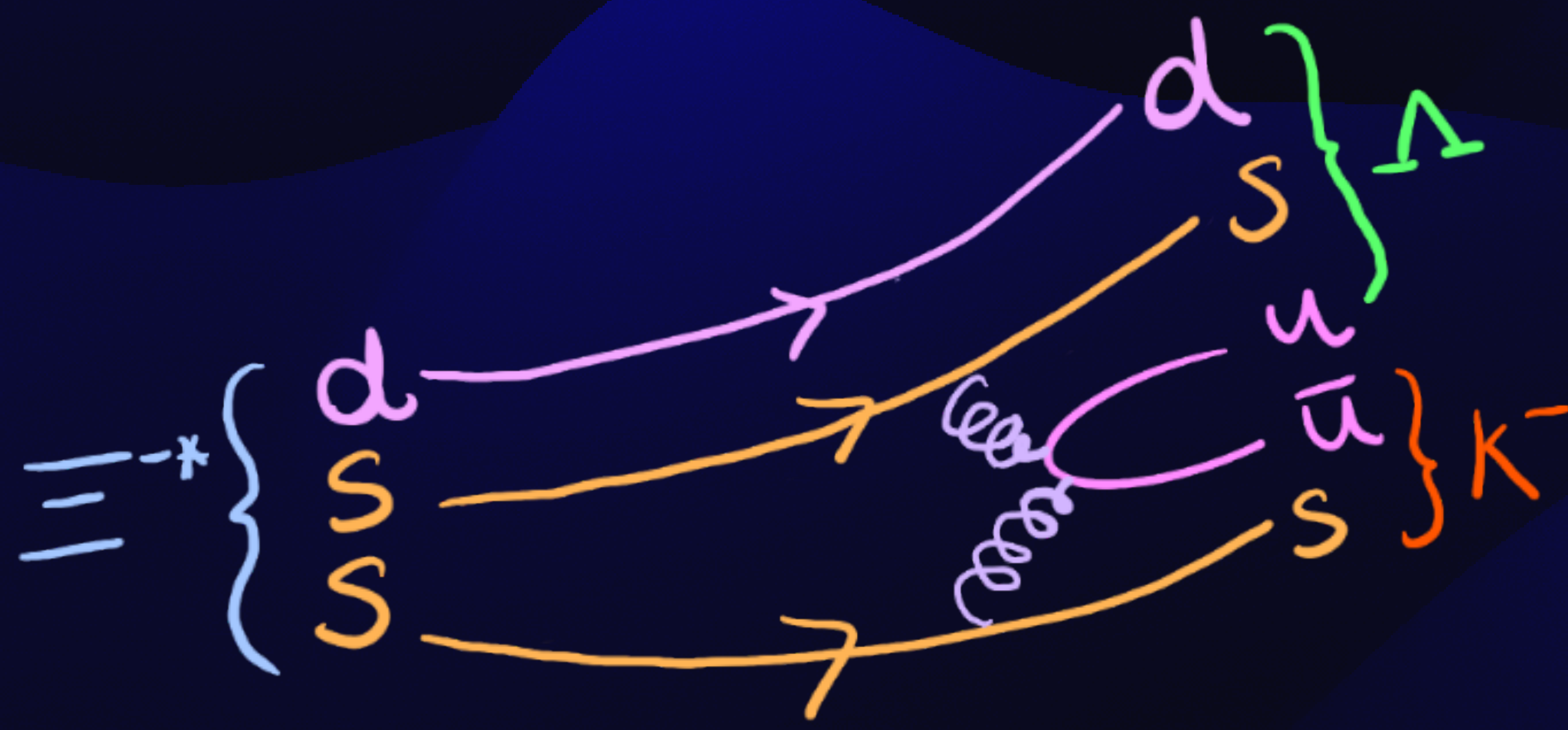


He Atom

SU(3) Clebsch-Gordan Coefficients

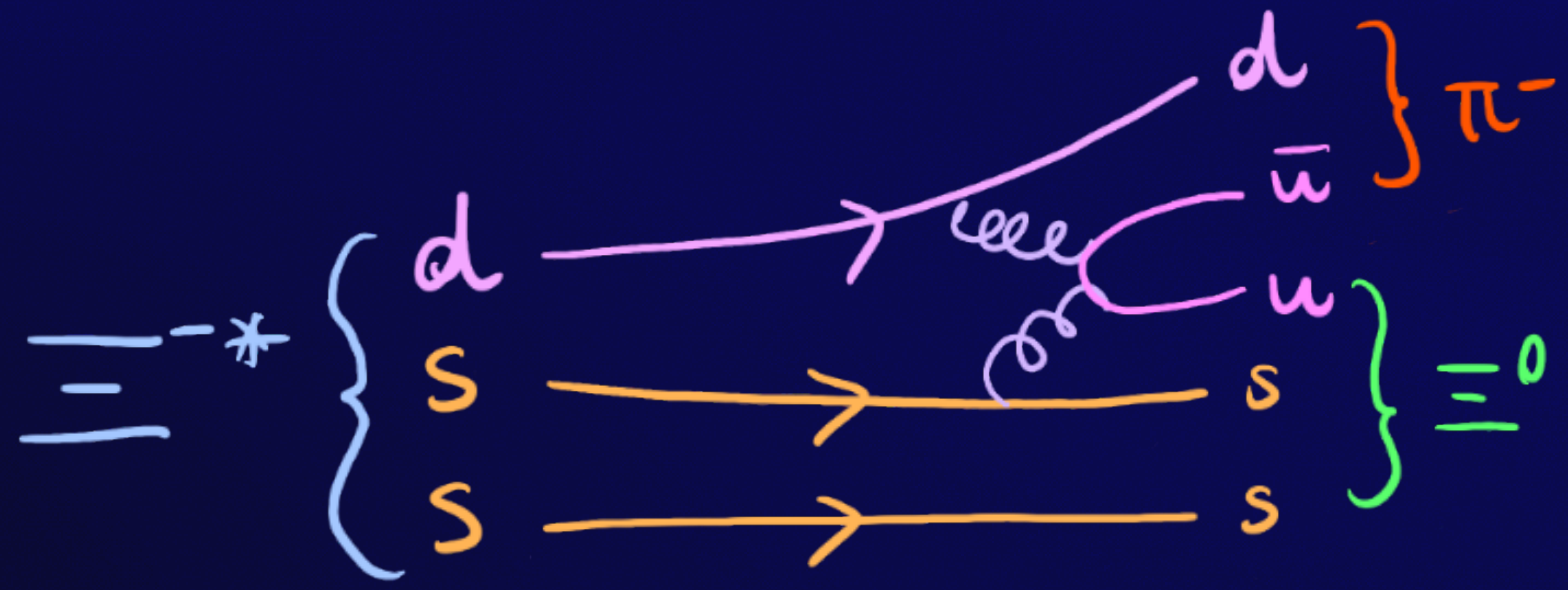
FROM DECOUPLET:

$$|\Xi^*\rangle = \frac{1}{2}|\Xi\pi\rangle + \frac{1}{2}|\Sigma\bar{K}\rangle + \frac{1}{2}|\Xi\eta\rangle - \frac{1}{2}|\Lambda\bar{K}\rangle$$

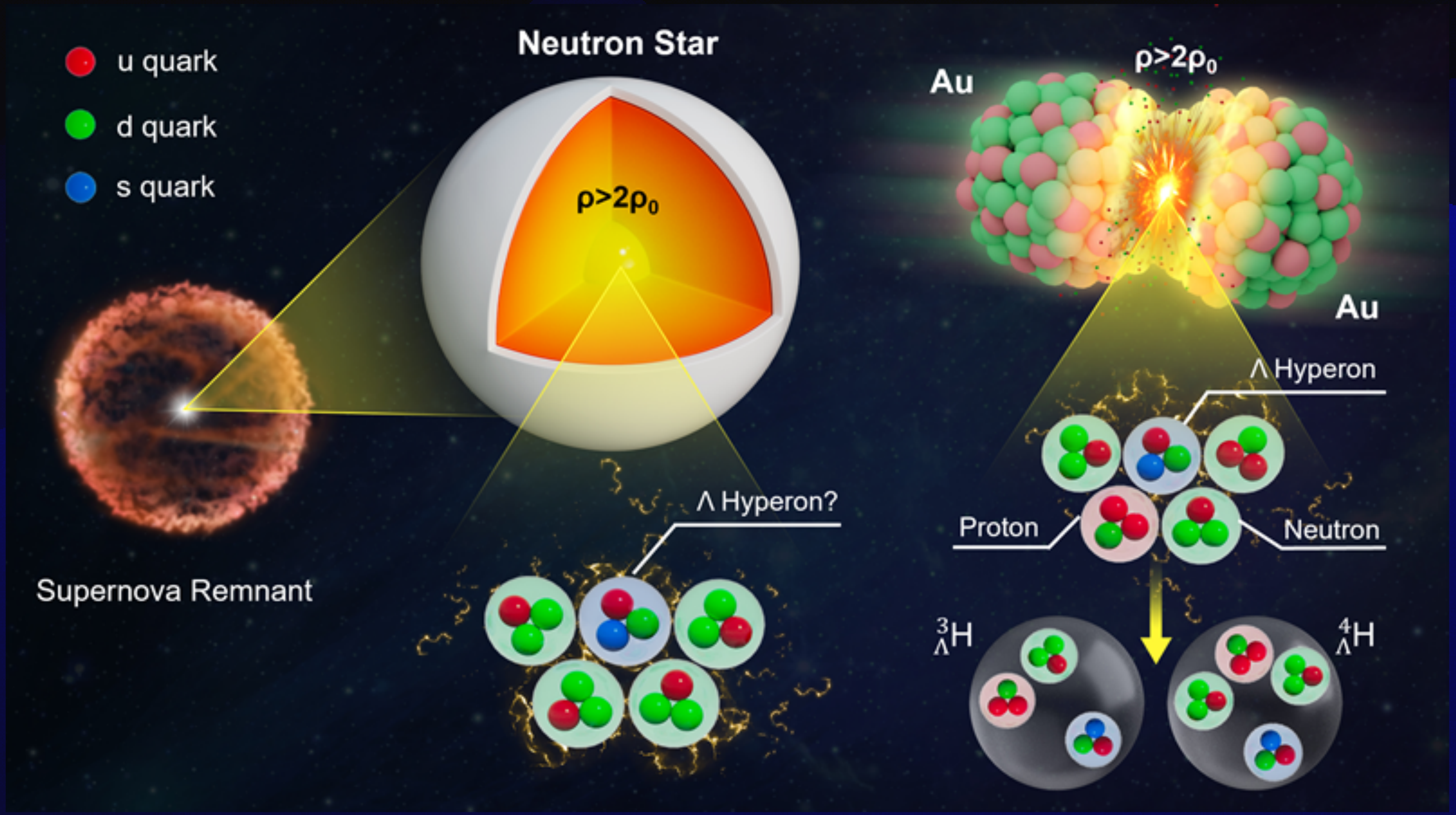


FROM OCTET:

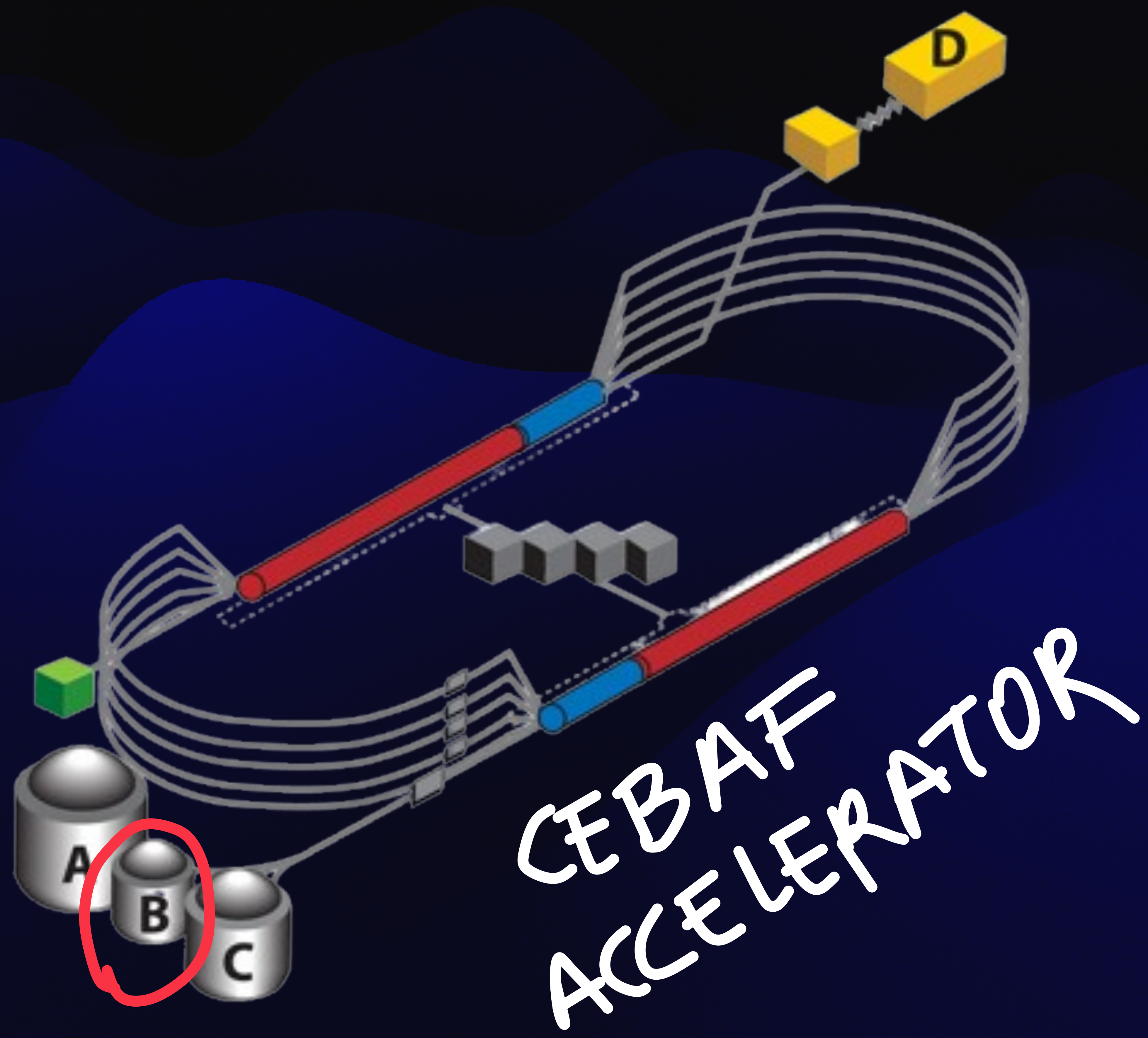
$$|\Xi^*\rangle = \frac{1}{2}|\Xi\pi\rangle + \frac{1}{2}|\Sigma\bar{K}\rangle - \frac{1}{2}|\Xi\eta\rangle + \frac{1}{2}|\Lambda\bar{K}\rangle$$



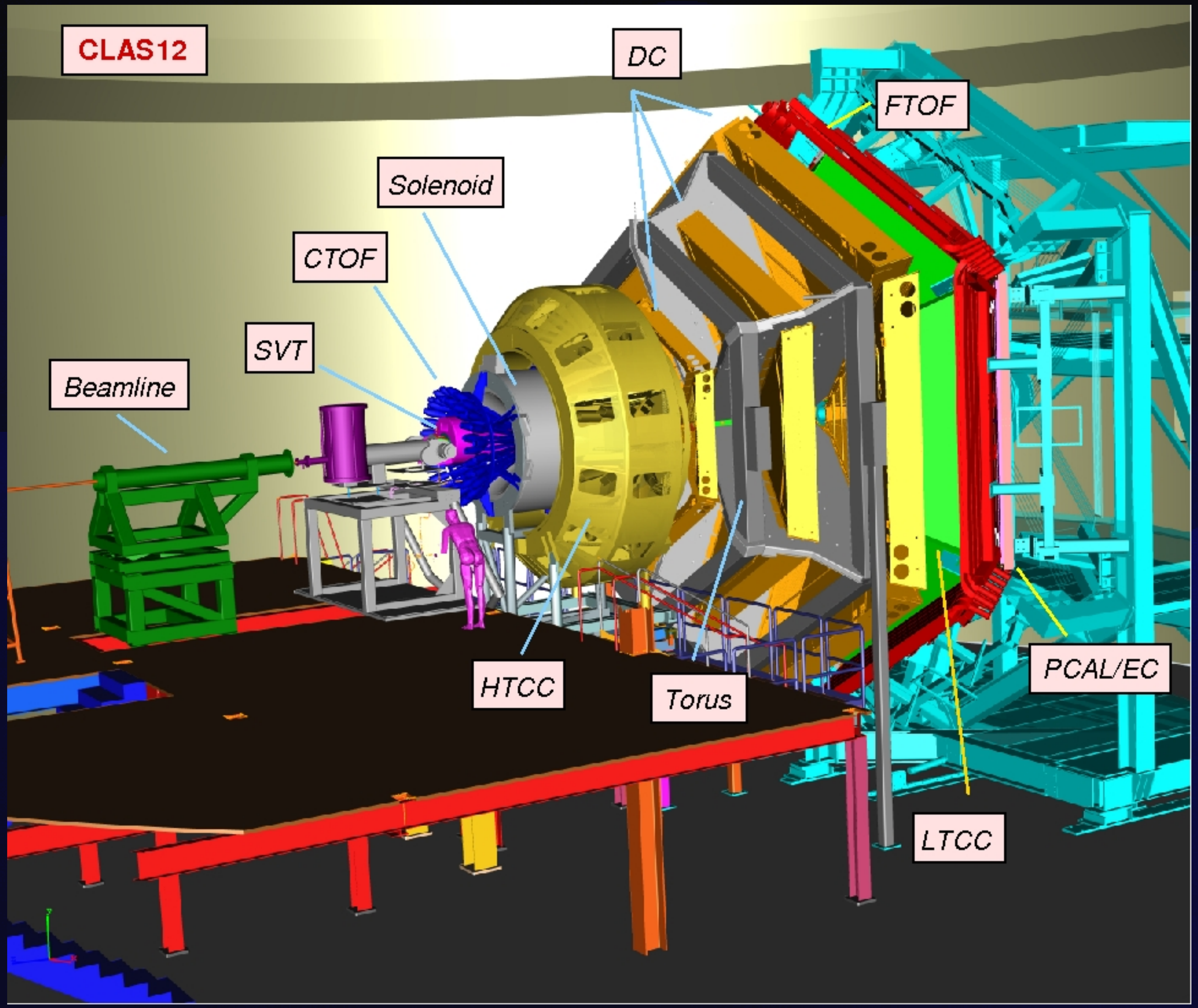
The Hyperon Puzzle

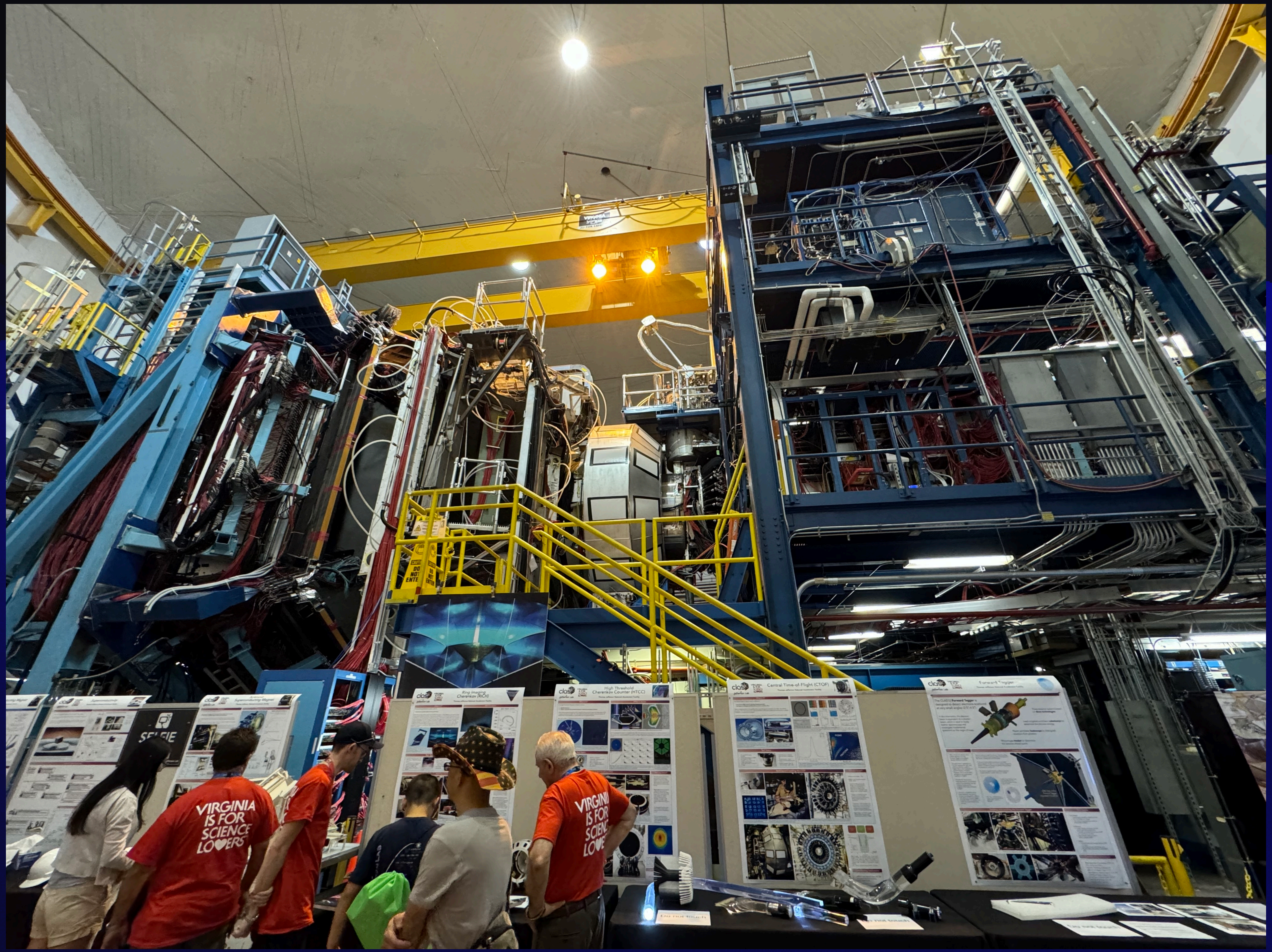


Jefferson Lab

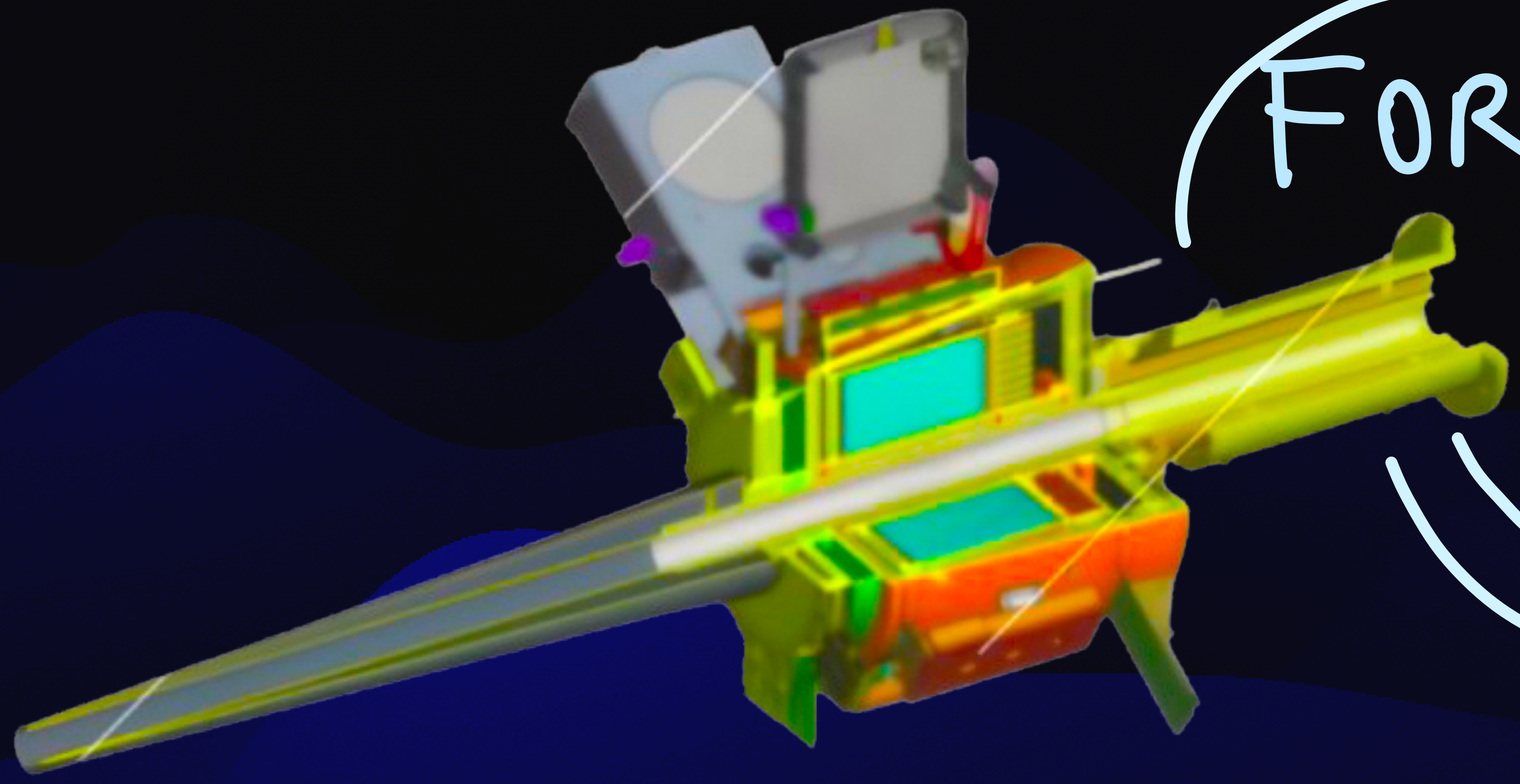


CLAS12


CLAS12
DC
FTOF
Solenoid
CTOF
SVT
Beamline
HTCC
Torus
PCAL/EC
LTCC

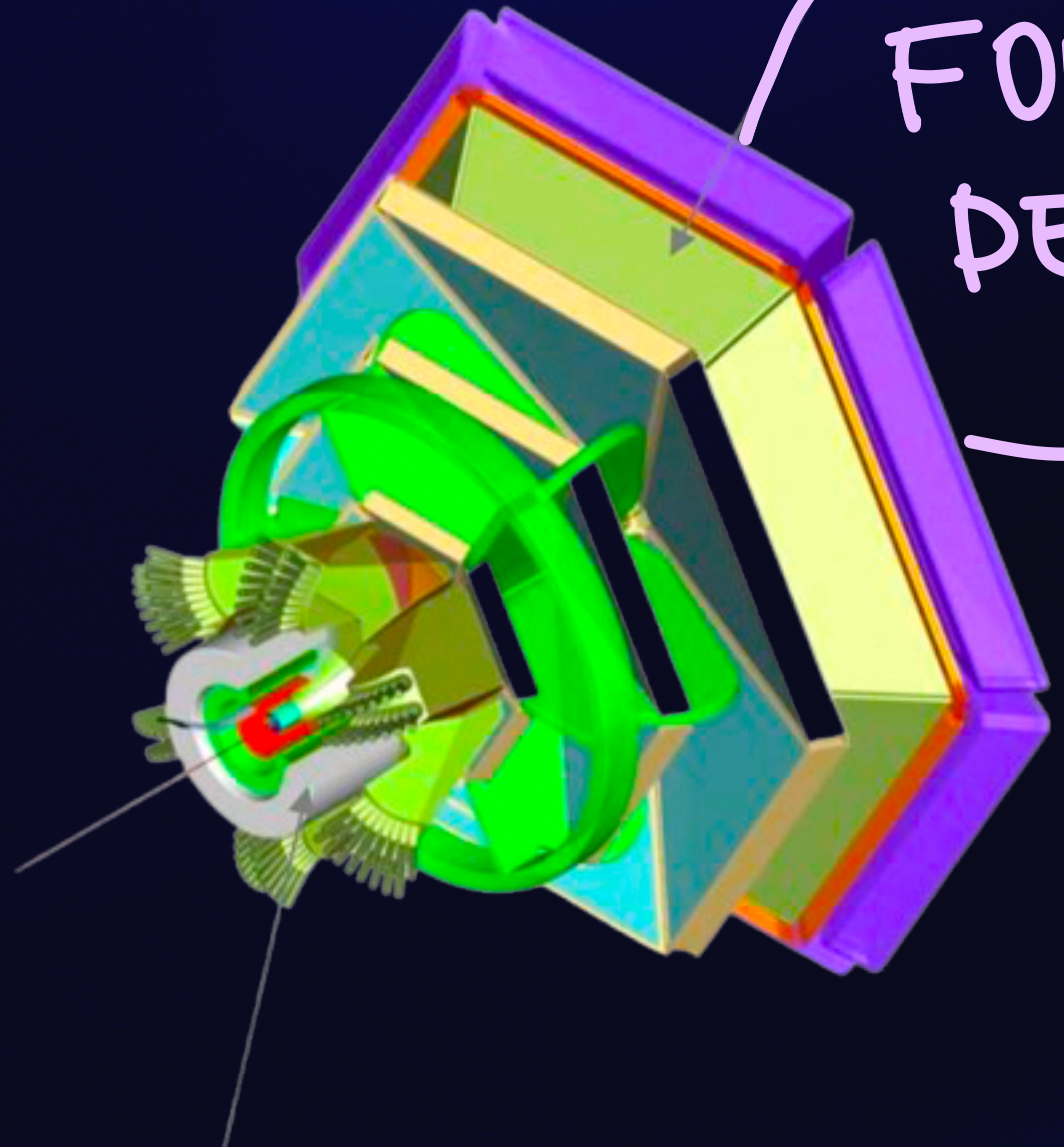

VIRGINIA IS FOR SCIENCE LOVERS

Forward Detector vs Forward Tagger



FORWARD TAGGER

- Angular range: $2.5° < \theta < 4.5°$
- quasi-real photo-production
- calorimeter

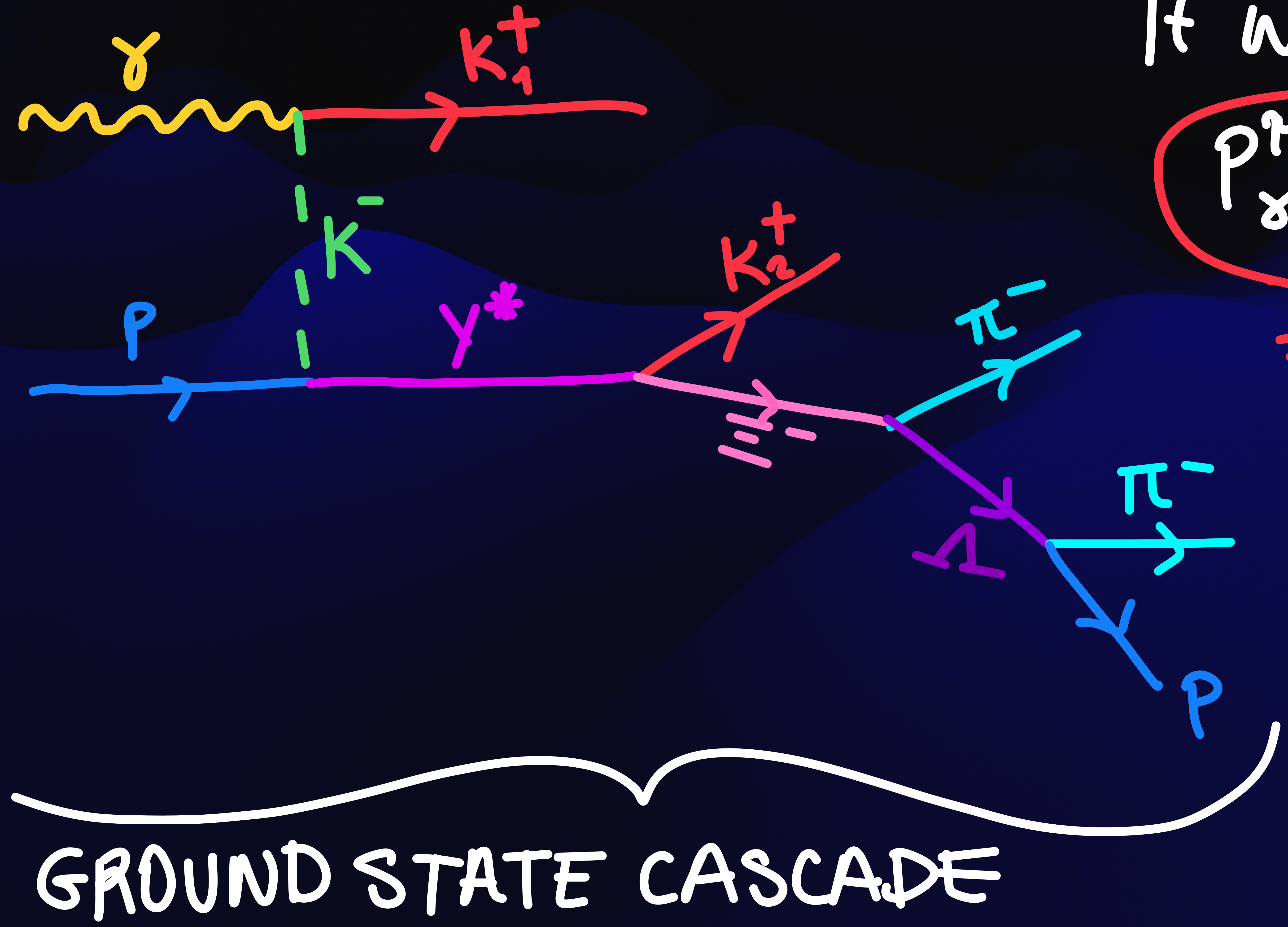


FORWARD DETECTOR

- Angular range: $5° < \theta < 35°$
- Higher Q^2 values
- magnetic spectroscopy

PARTICLE IDENTIFICATION

Cascades & Missing Mass



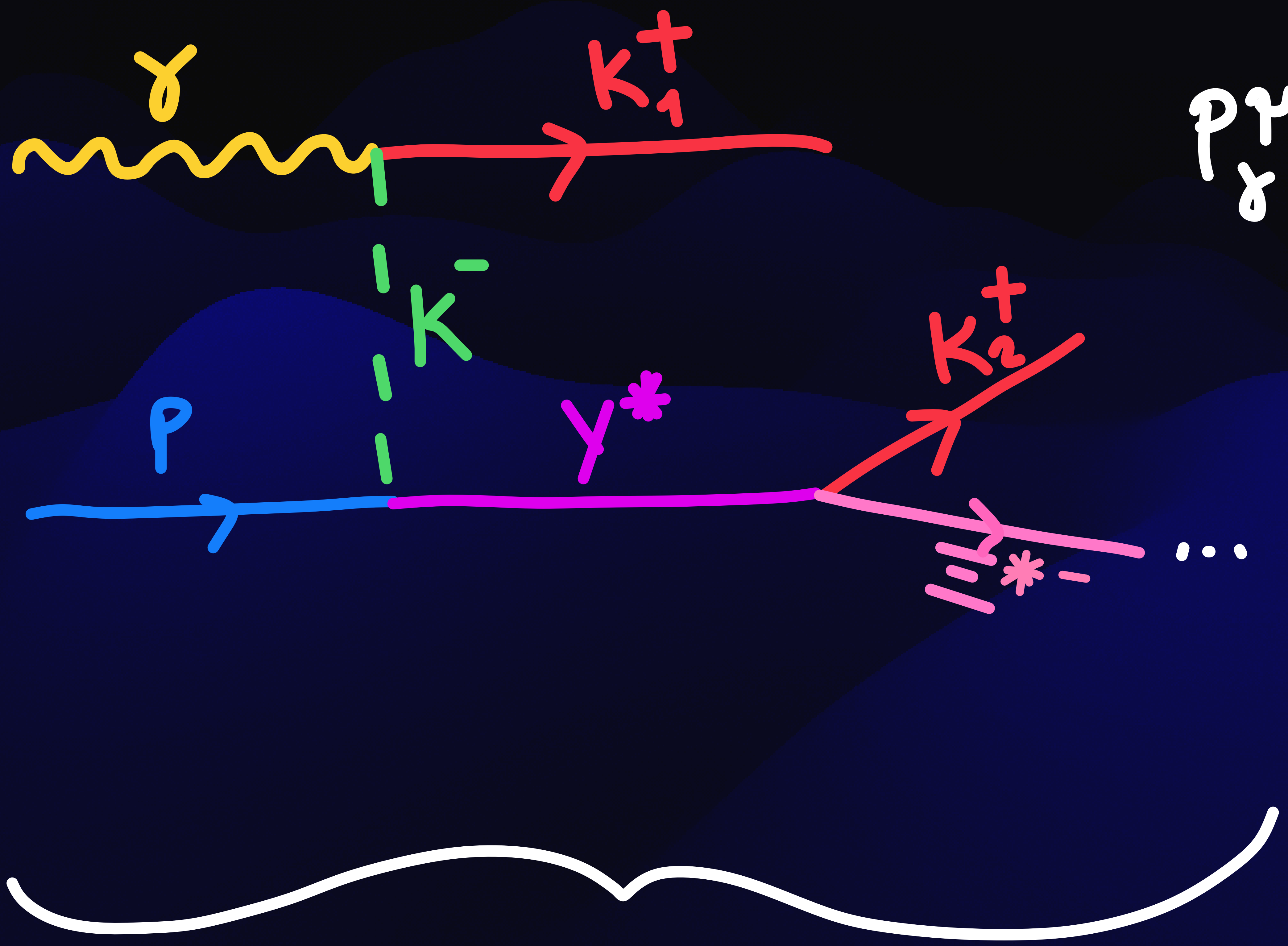
If we want to see the Ξ^- :

$$p^\mu_\gamma + p^\mu_p = p^\mu_{K_1^+} + p^\mu_{K_2^+} + p^\mu_{\Xi^-}$$

FOUR MOMENTUM CONSERVATION

$$p^\mu_{\Xi^-} = p^\mu_\gamma + p^\mu_p - p^\mu_{K_1^+} - p^\mu_{K_2^+}$$

Cascades & Missing Mass

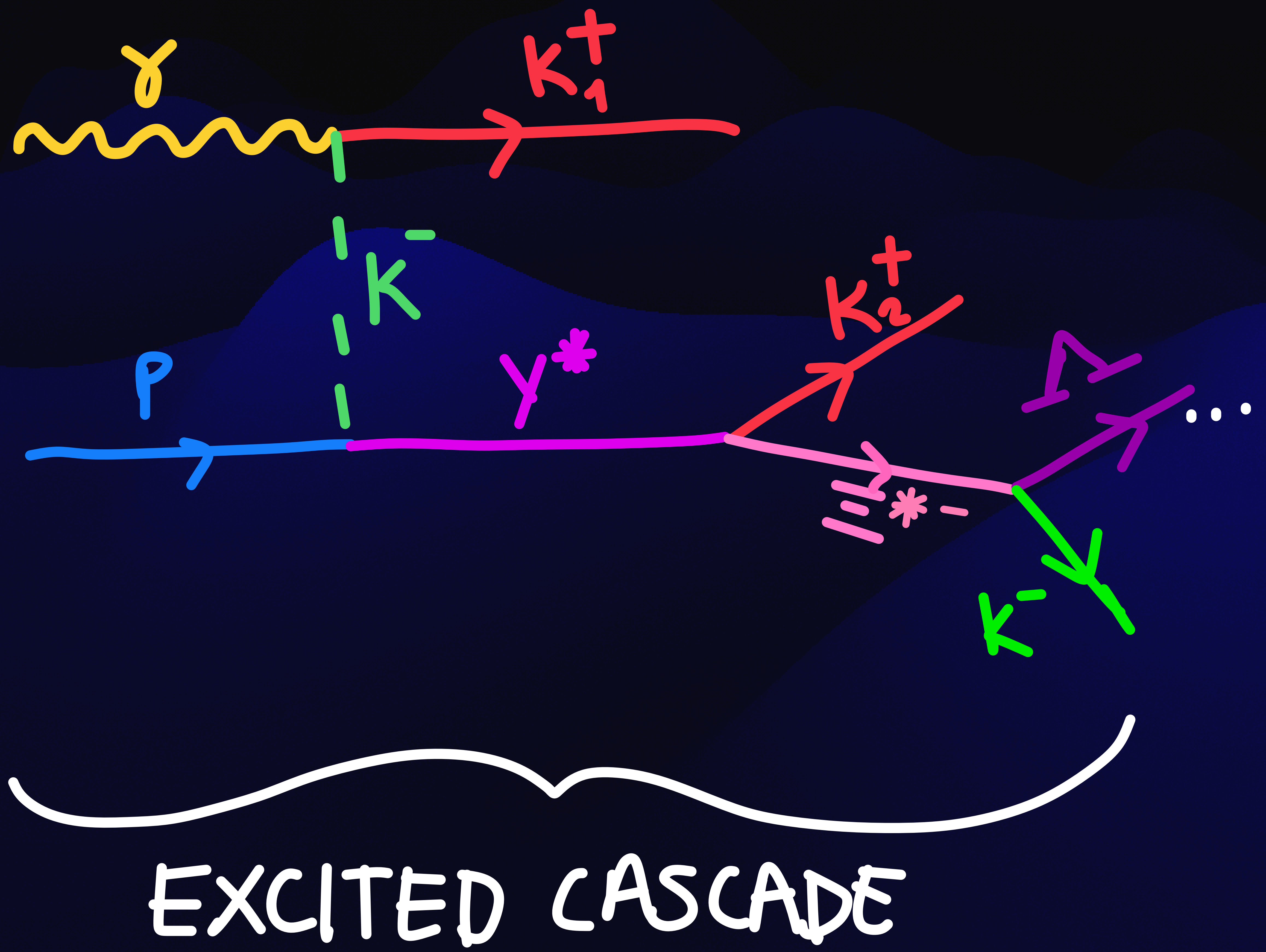


EXCITED CASCADE

$$p^\mu_\gamma + p^\mu_p = p^\mu_{K_1^+} + p^\mu_{K_2^+} + p^\mu_{\Xi^{*-}}$$

$$p^\mu_{\Xi^{*-}} = p^\mu_\gamma + p^\mu_p - p^\mu_{K_1^+} - p^\mu_{K_2^+}$$

Cascades & Missing Mass



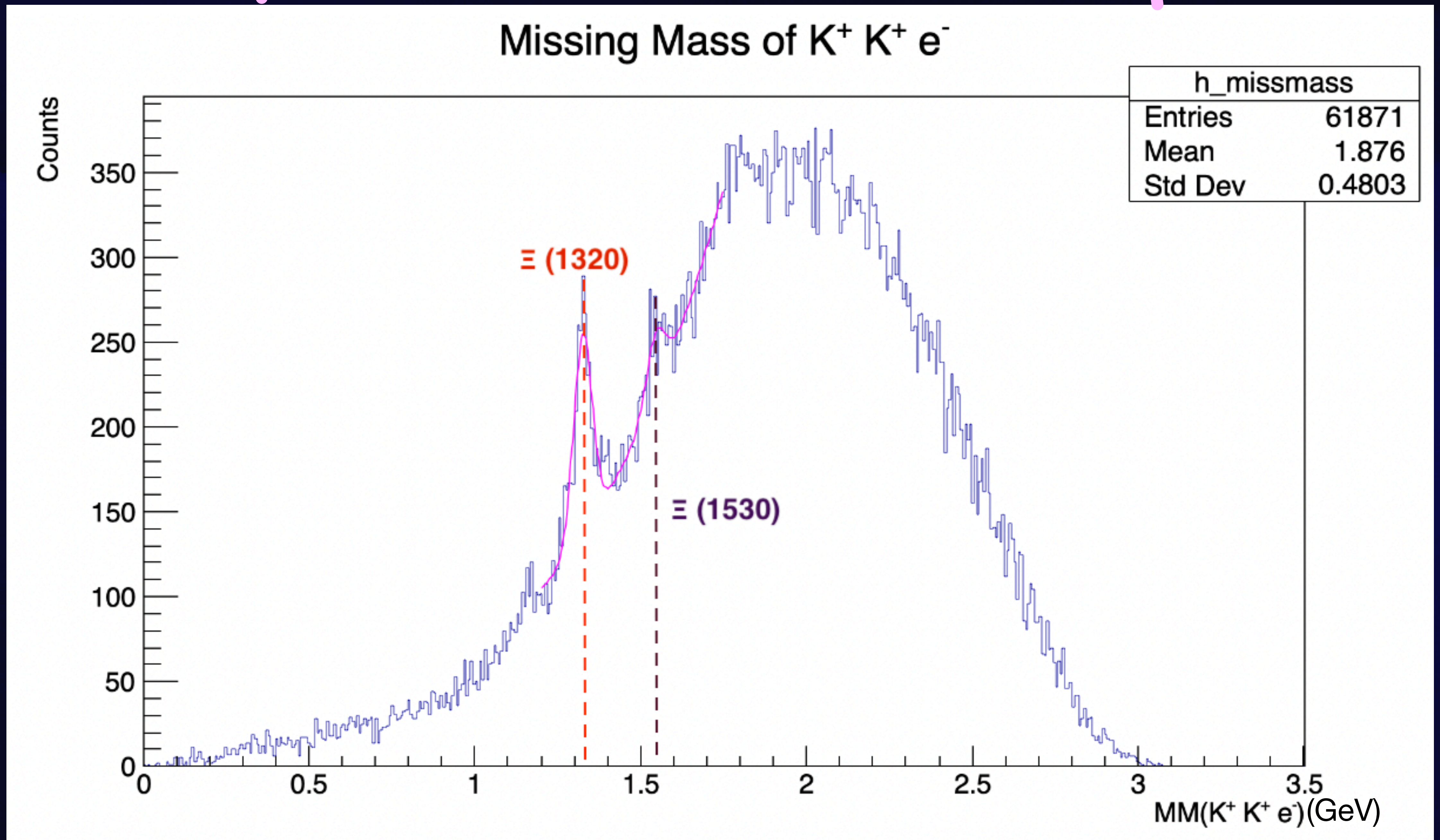
$$p^\mu_\gamma + p^\mu_p = p^\mu_{K_1^+} + p^\mu_{K_2^+} + p^\mu_{K^-} + p^\mu_\Lambda$$

$$p^\mu_\Lambda = p^\mu_\gamma + p^\mu_p - p_{K_1^+} - p_{K_2^+} - p^\mu_{K^-}$$

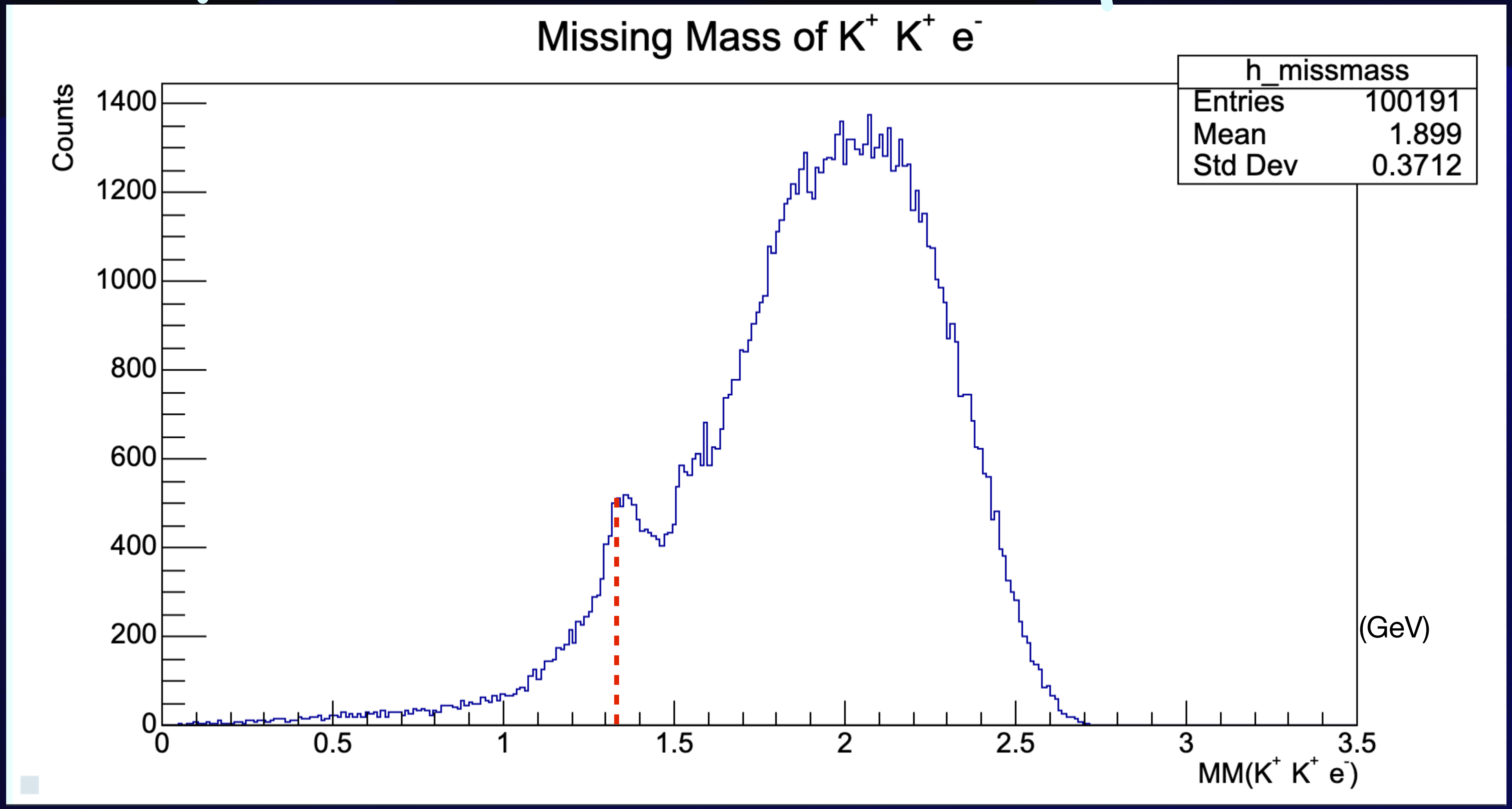
↳ observe a Λ peak in the spectrum

Data Analysis

FORWARD DETECTOR



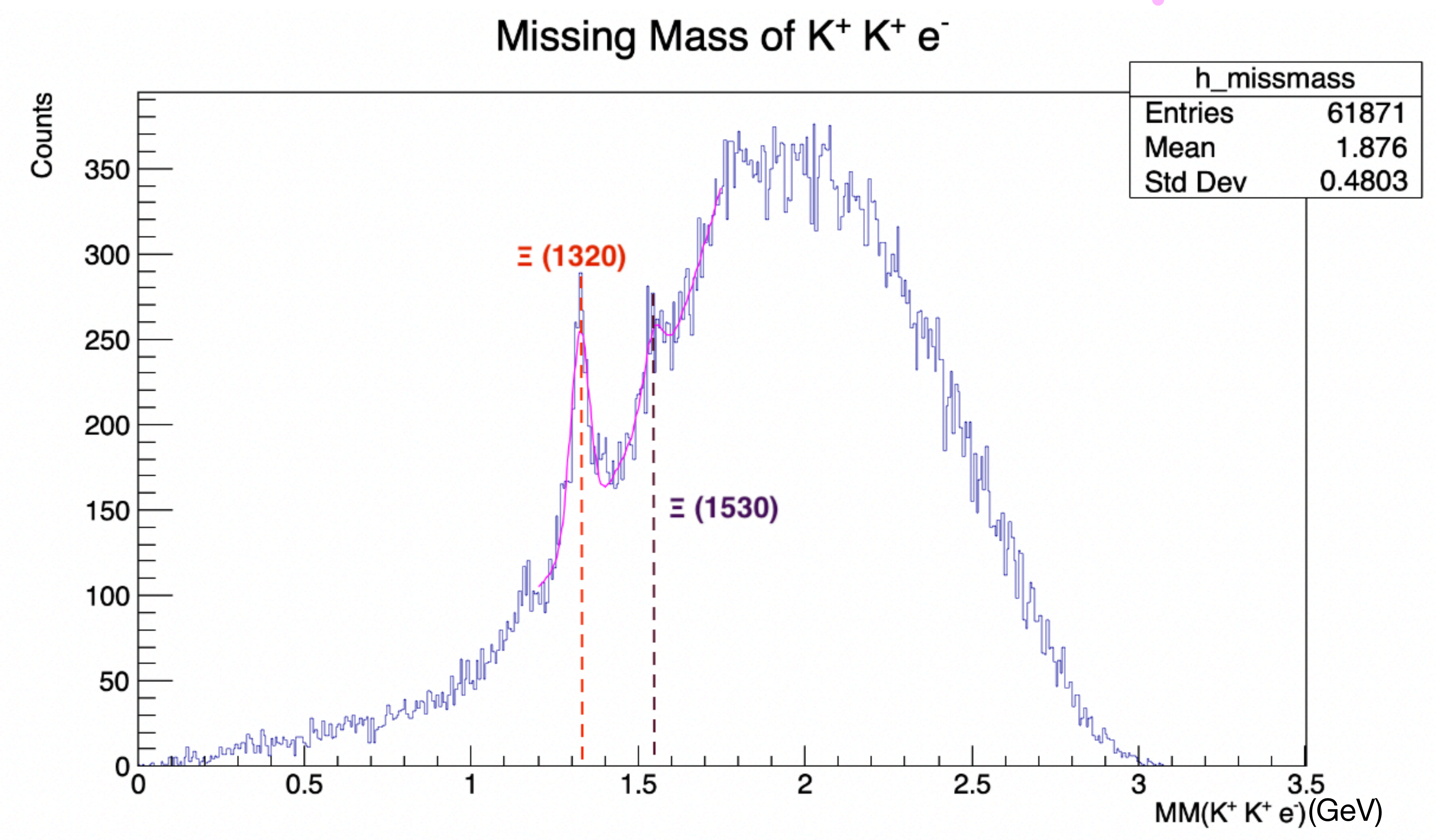
FORWARD TAGGER



Data Analysis

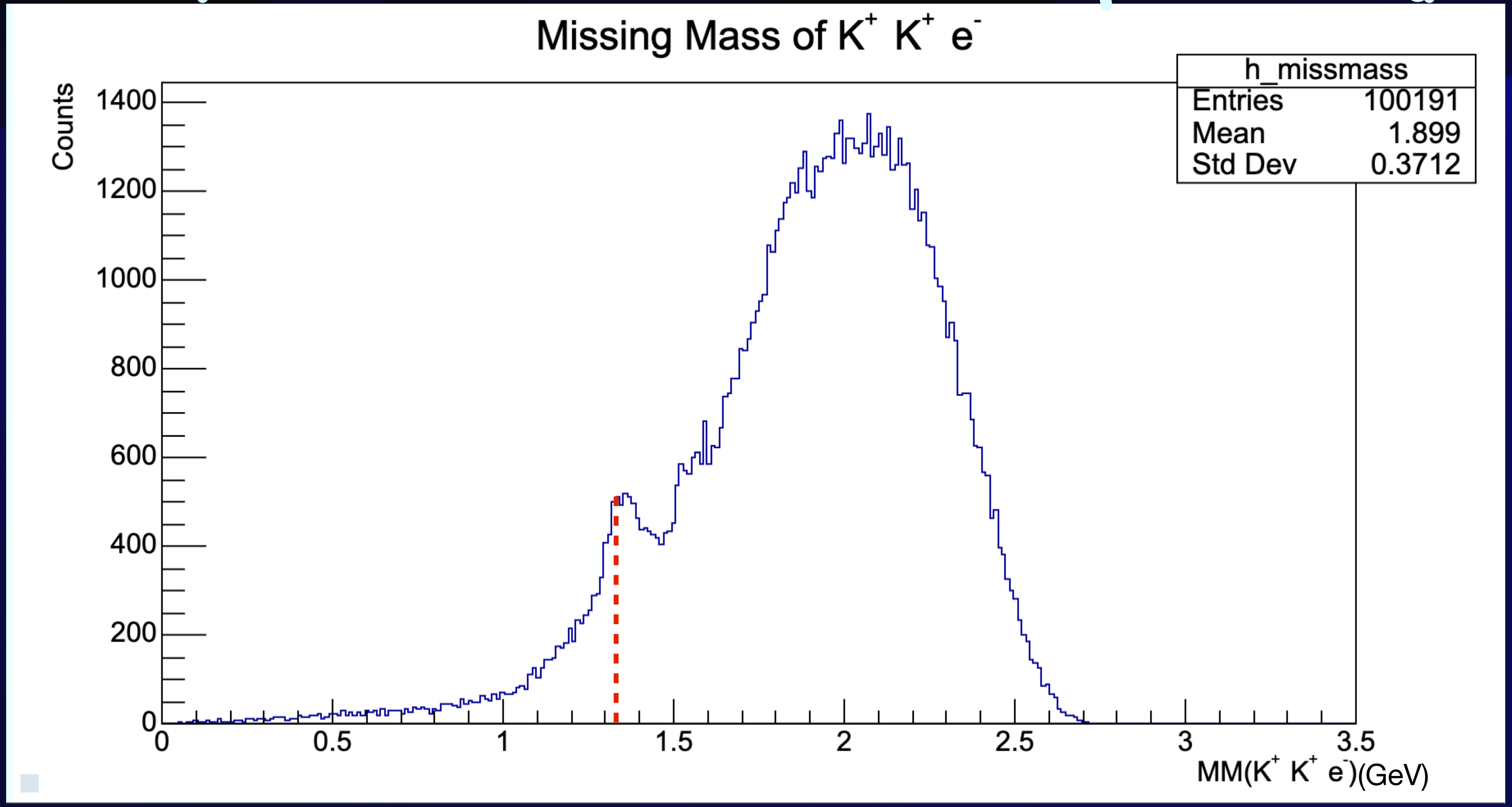
FORWARD DETECTOR

Better Resolution

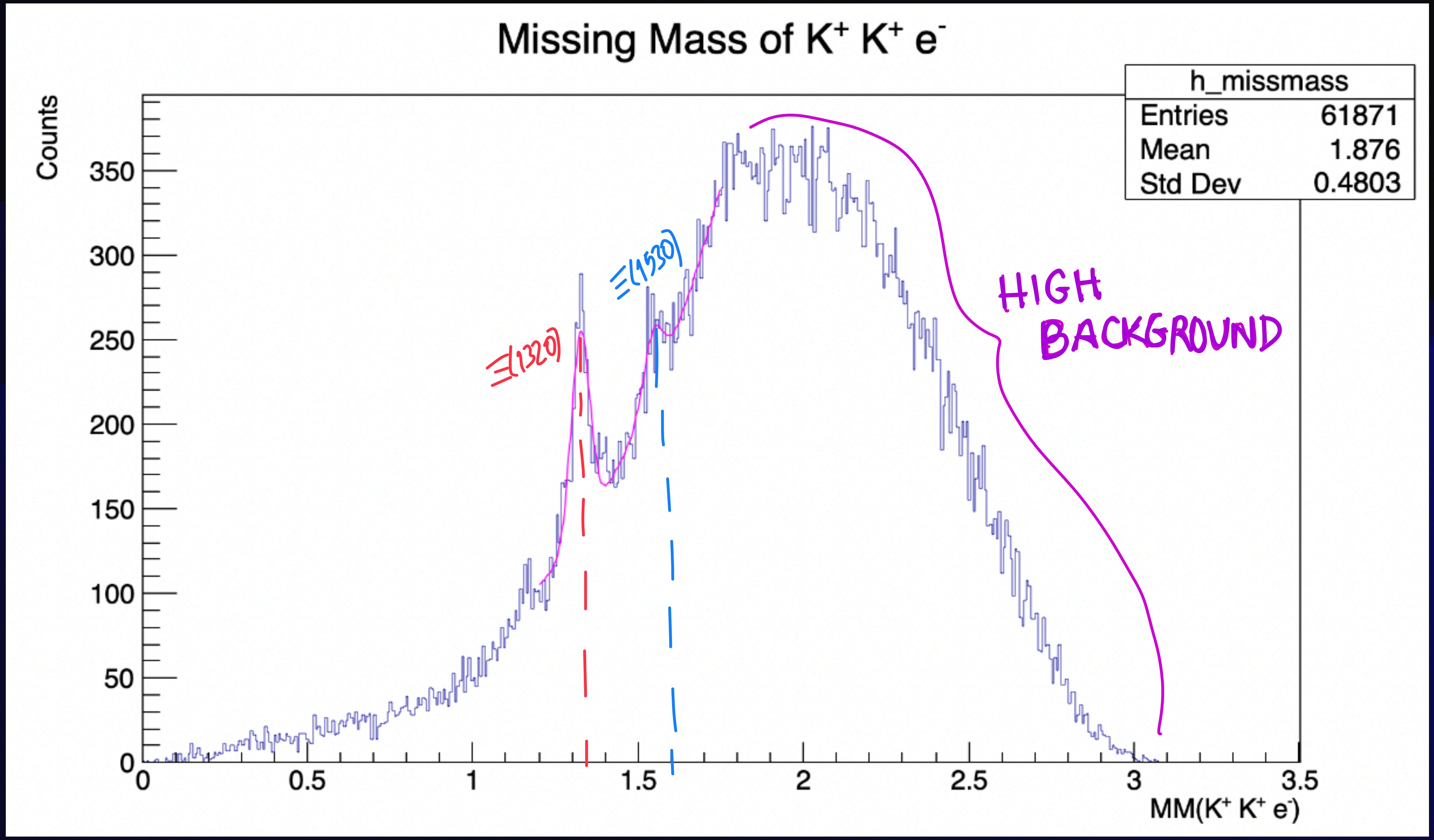


FORWARD TAGGER

More data

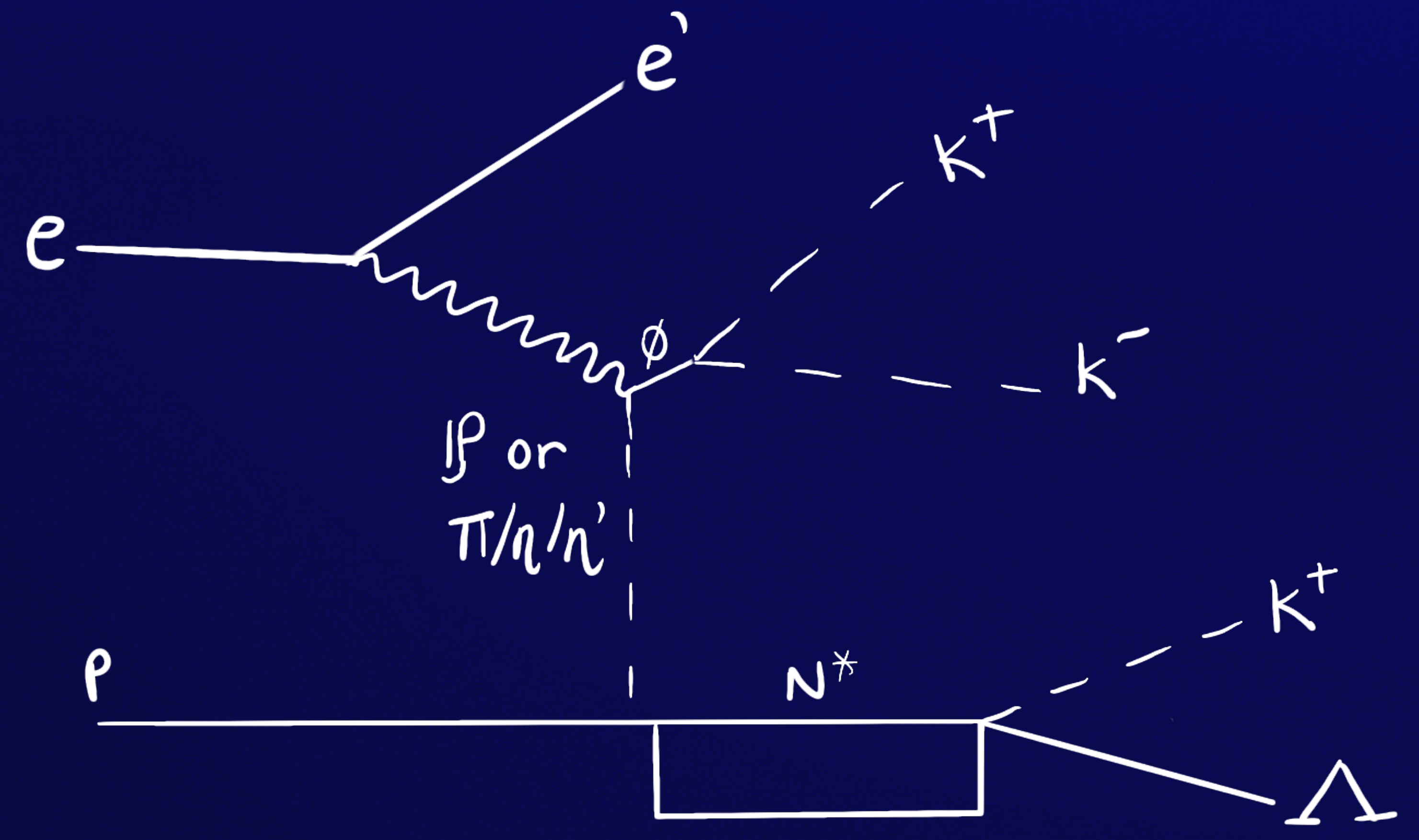


Data Analysis



WHY HIGH BACKGROUND?

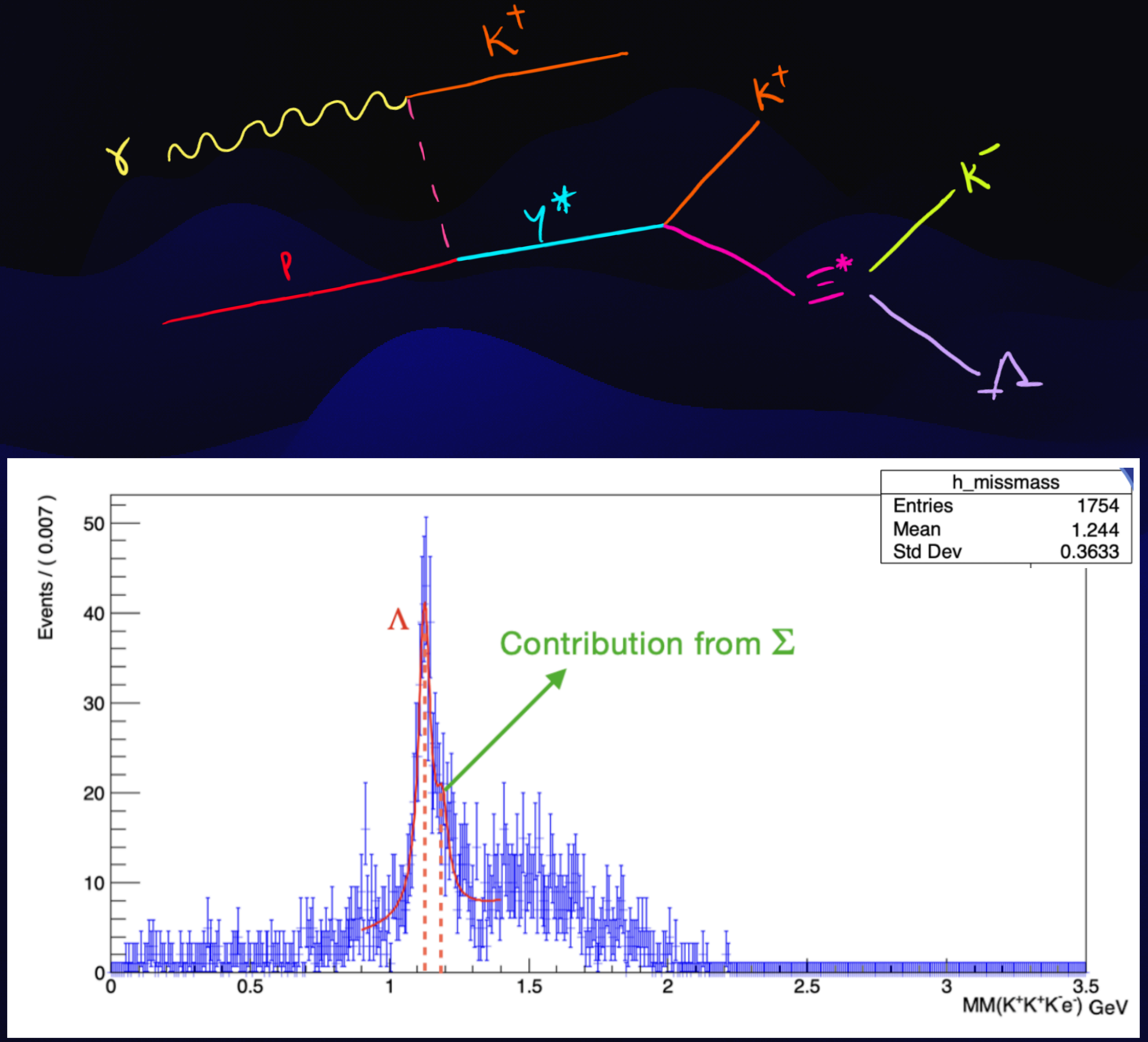
1. Kaon/pion misidentification
2. Out of time particles
3. other processes involving 2 K^+

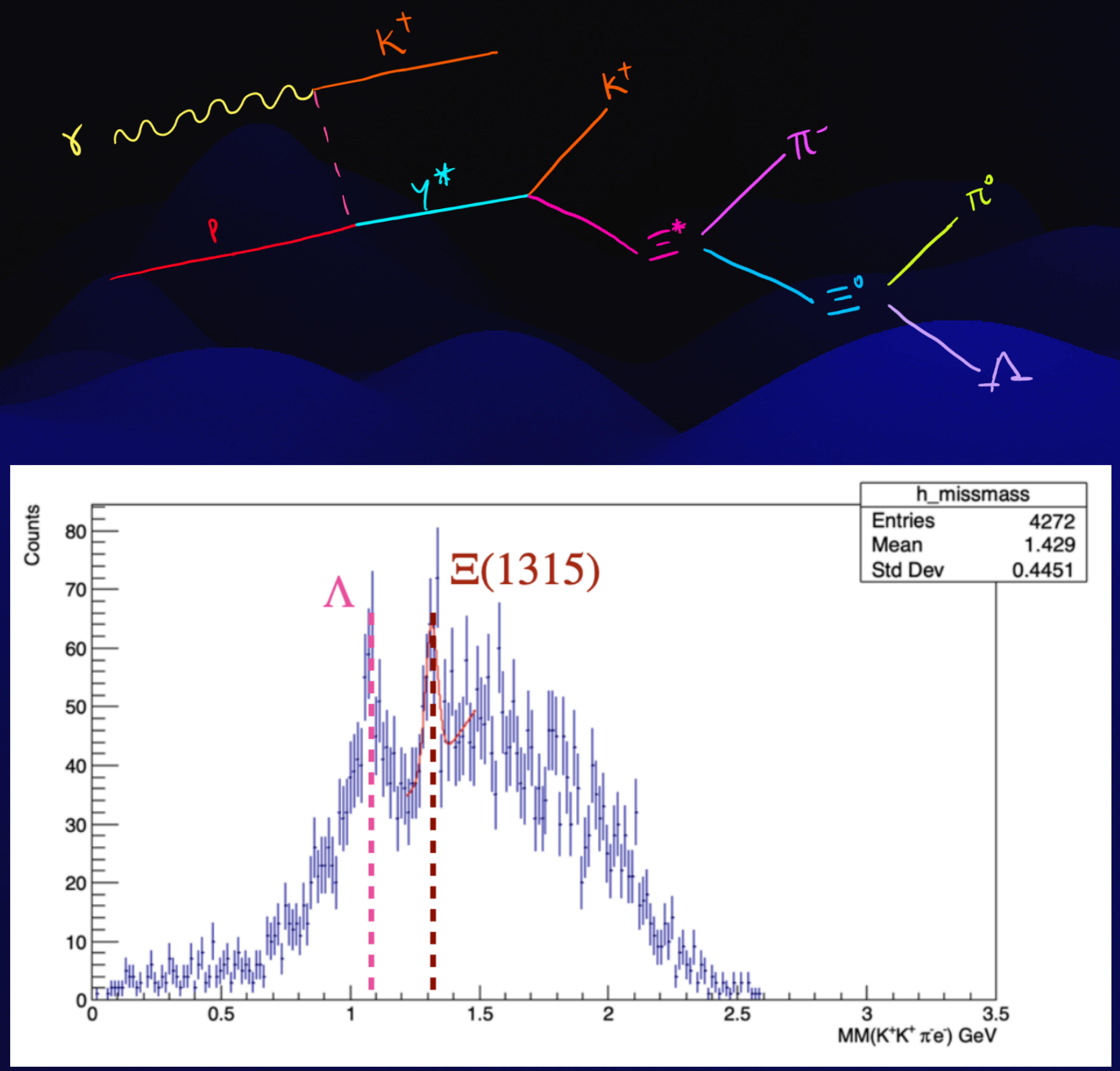


Background Subtraction Methods

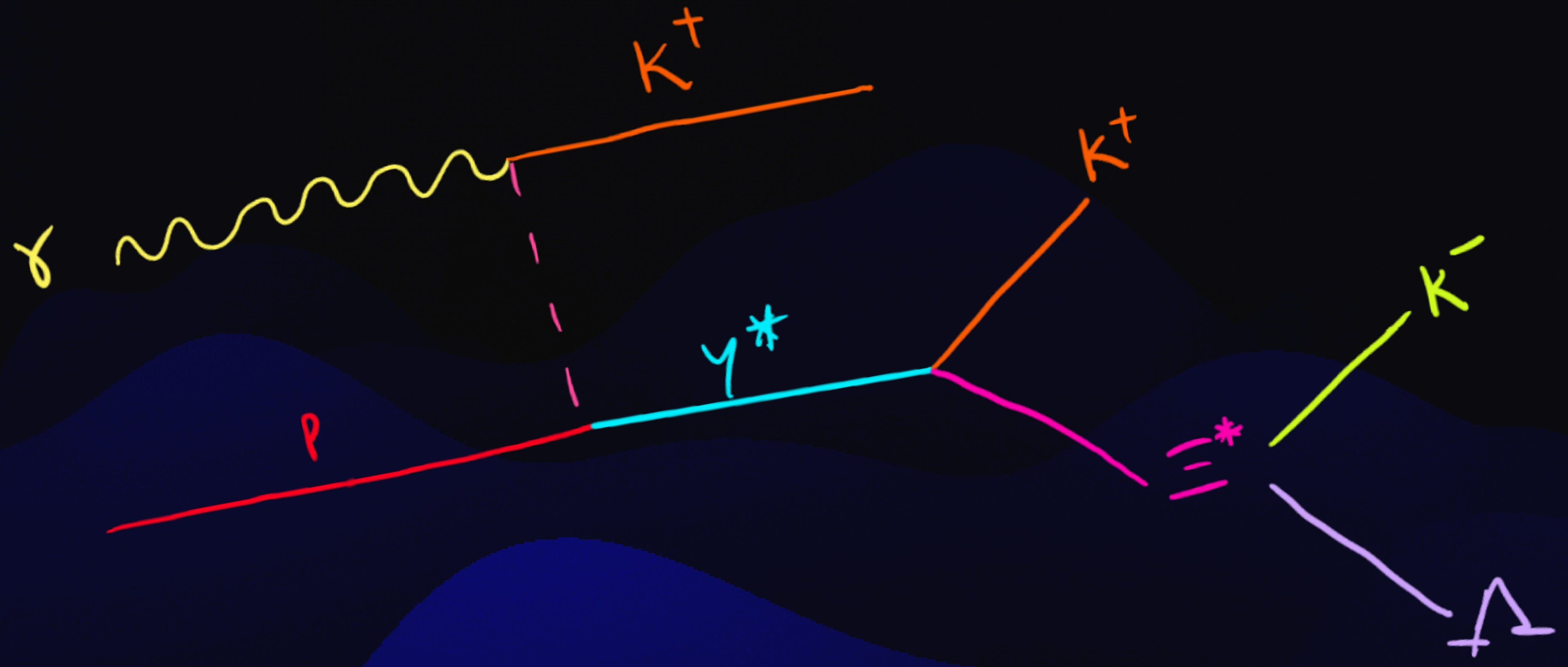
METHOD	PROS	CONS
Sideband Subtraction	• Simple to understand	• signal/bg overlap • problems with dependent variables
S- Weights	• straightforward to implement using building package	• problems with dependent variables
Q- Weights	• Accounts for dependencies between different variables	• Needs large statistics • bg being propagated through
Mixed Event Technique	• can generate a smooth bg with large statistics	• Assumes accidental bg

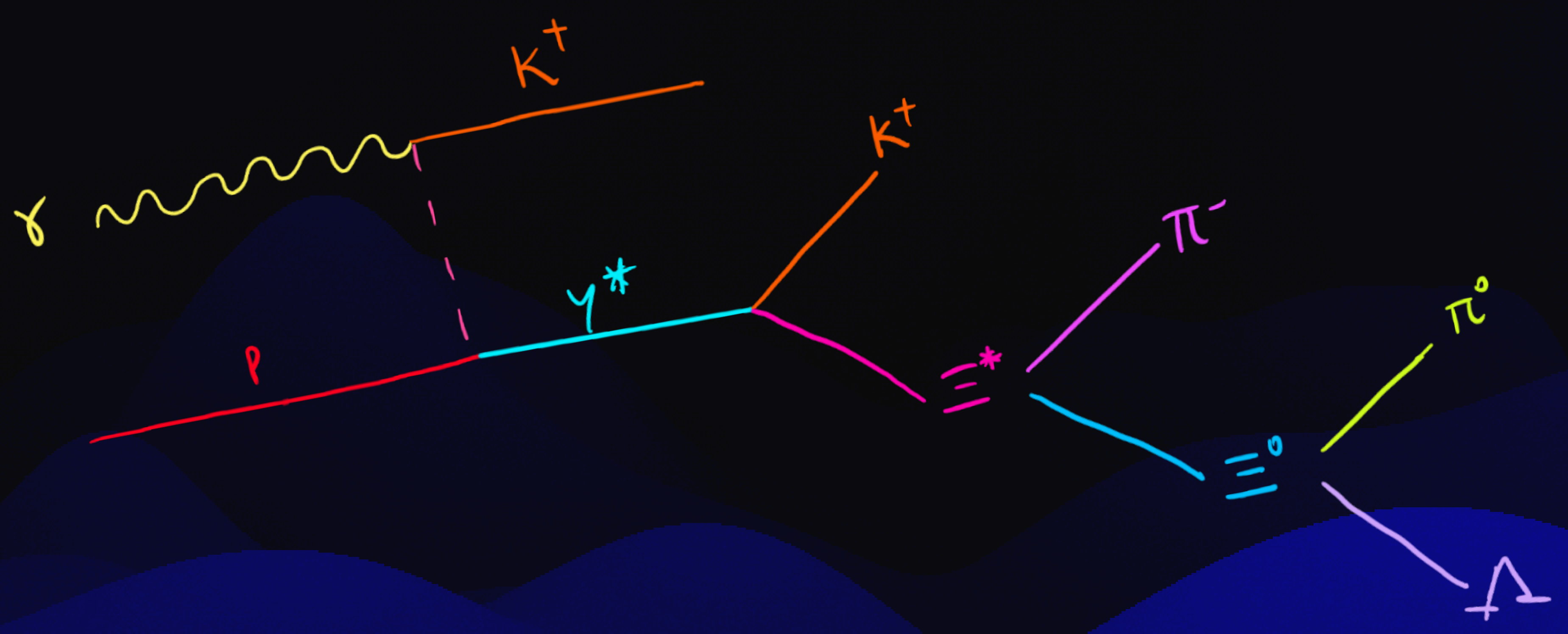
Sideband Subtraction

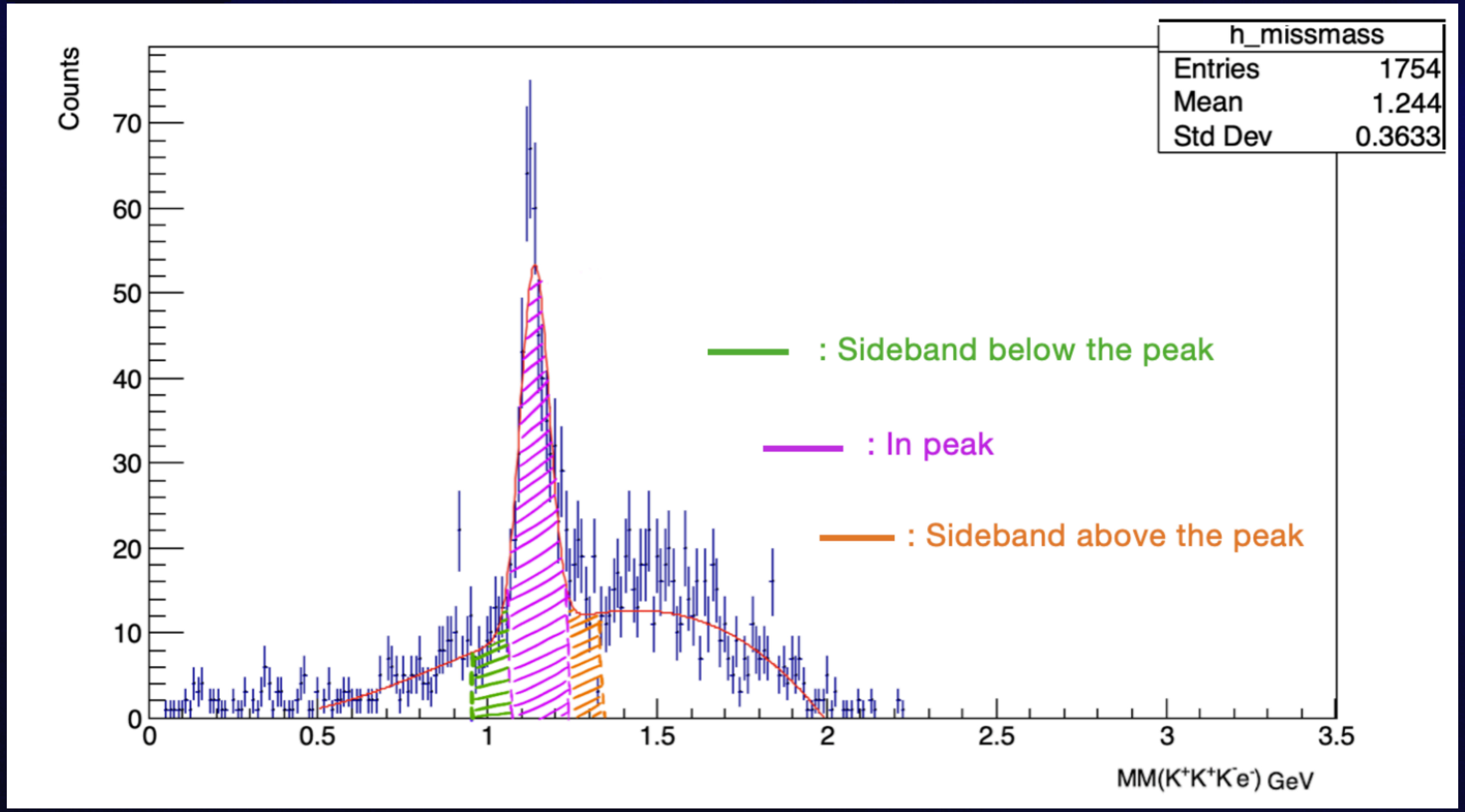


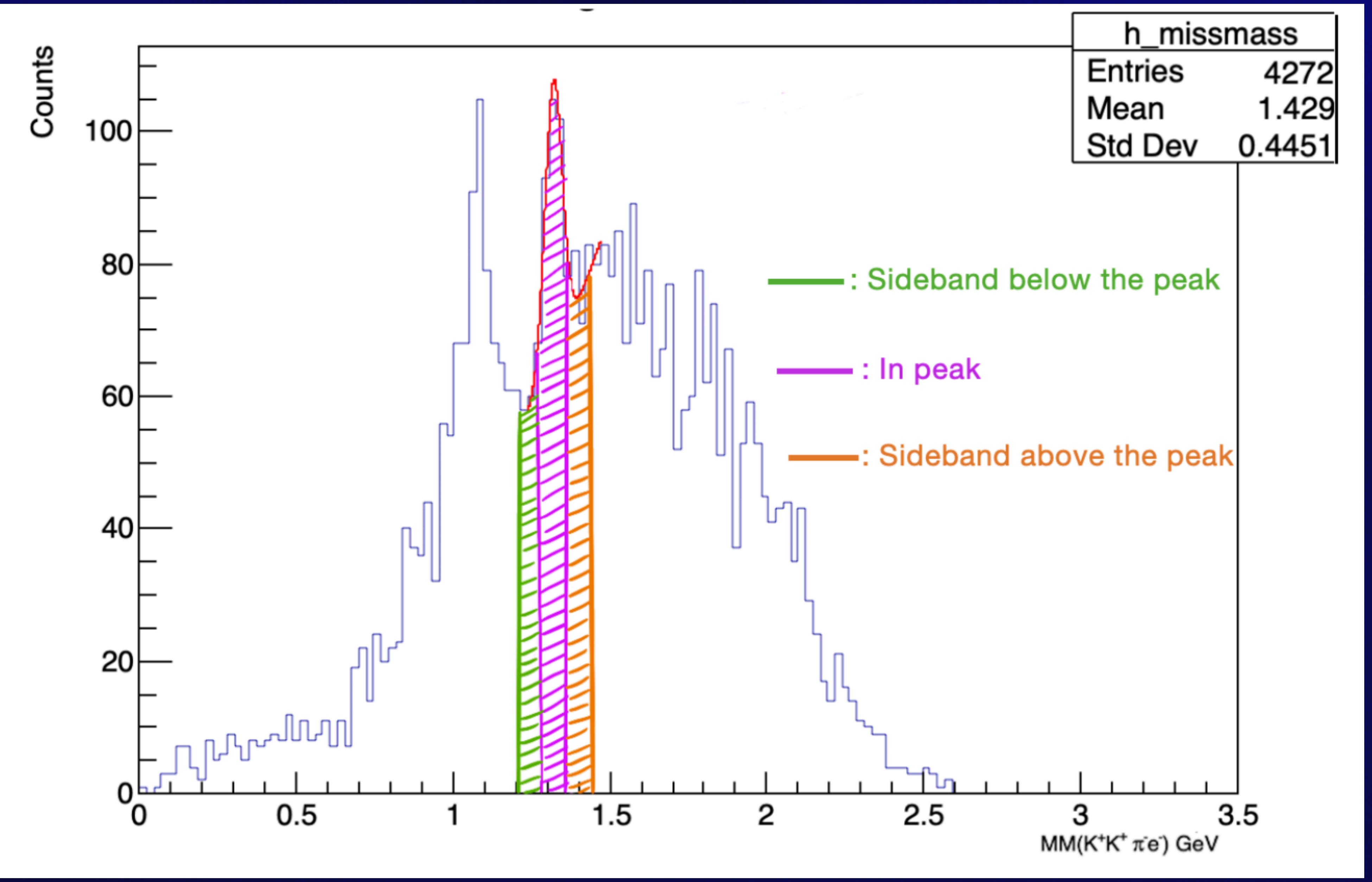


Sideband Subtraction





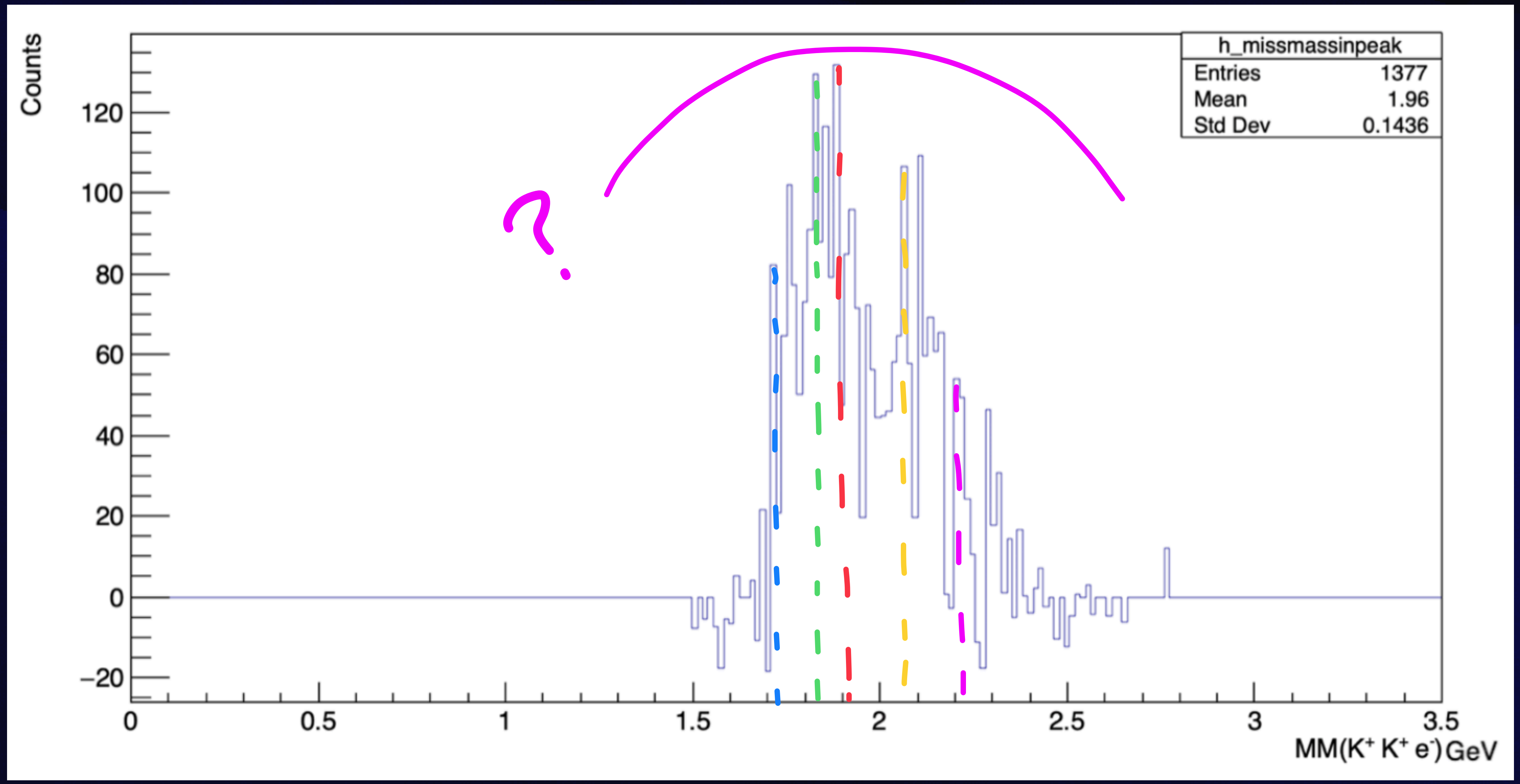




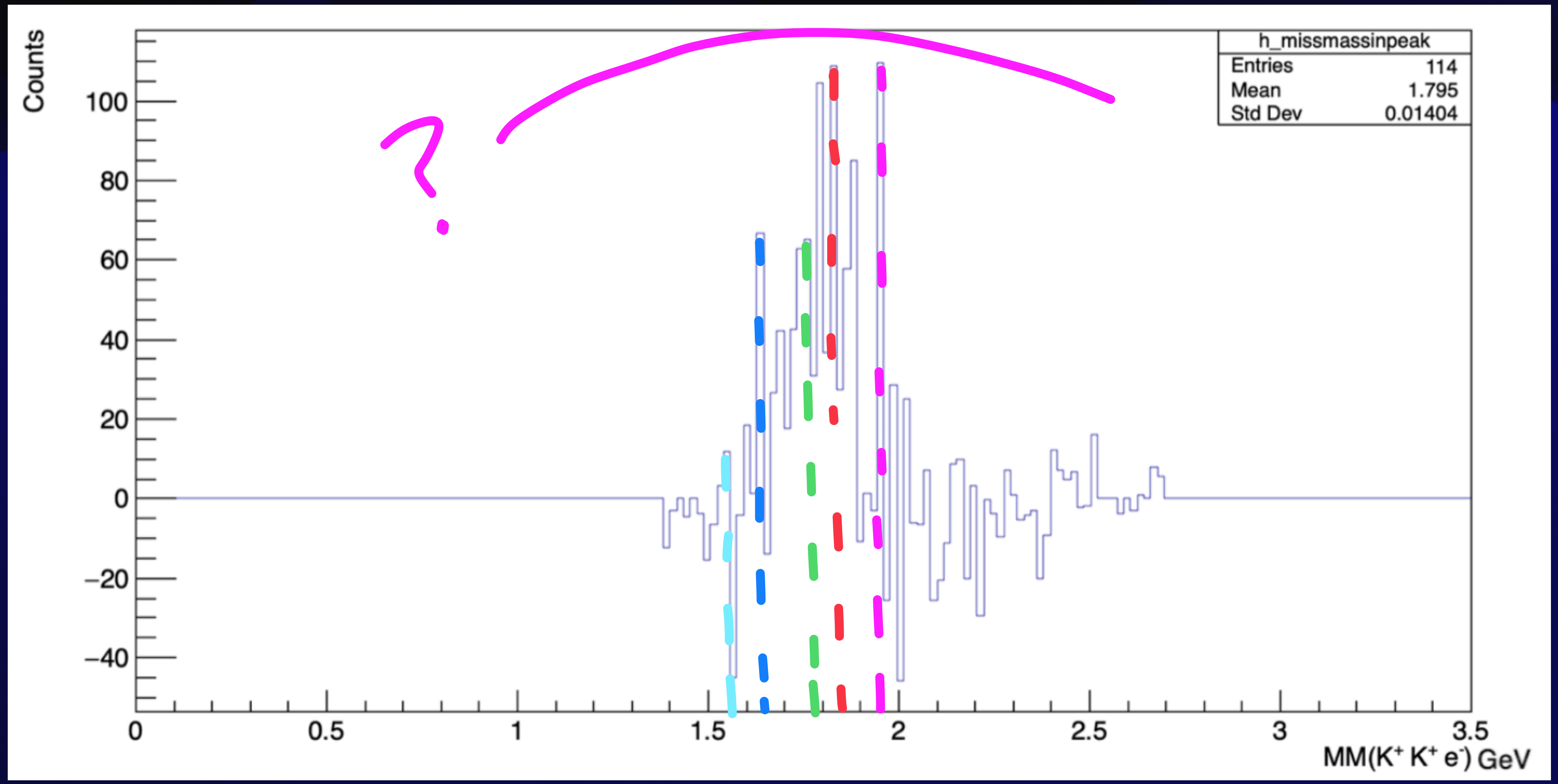
Sideband Subtraction

Sideband subtracted plots of MM($K^+K^+e^-$)

MM($K^+K^+e^-$)$_{K^-}$



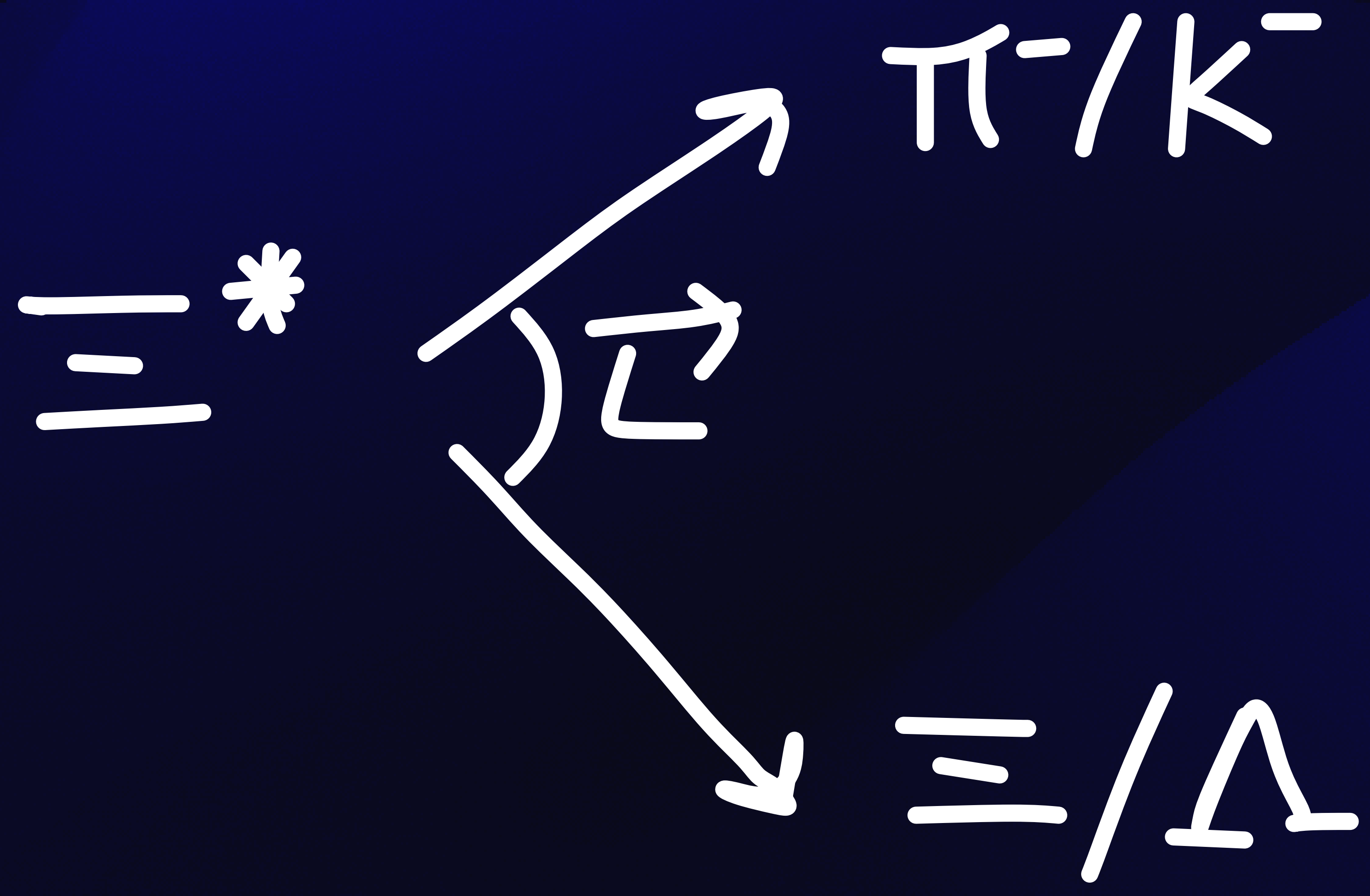
MM($K^+K^+e^-$)$_{\pi^-}$



Covering full range of Ξ^* masses!

Towards Quantum Numbers

Looking at angular coverage of K^- & π^-:



$$\vec{J} = \vec{L} + \vec{S}$$

$$P = (-1)^L P_\Xi P_\pi = (-1)^L(-1)(+1)$$

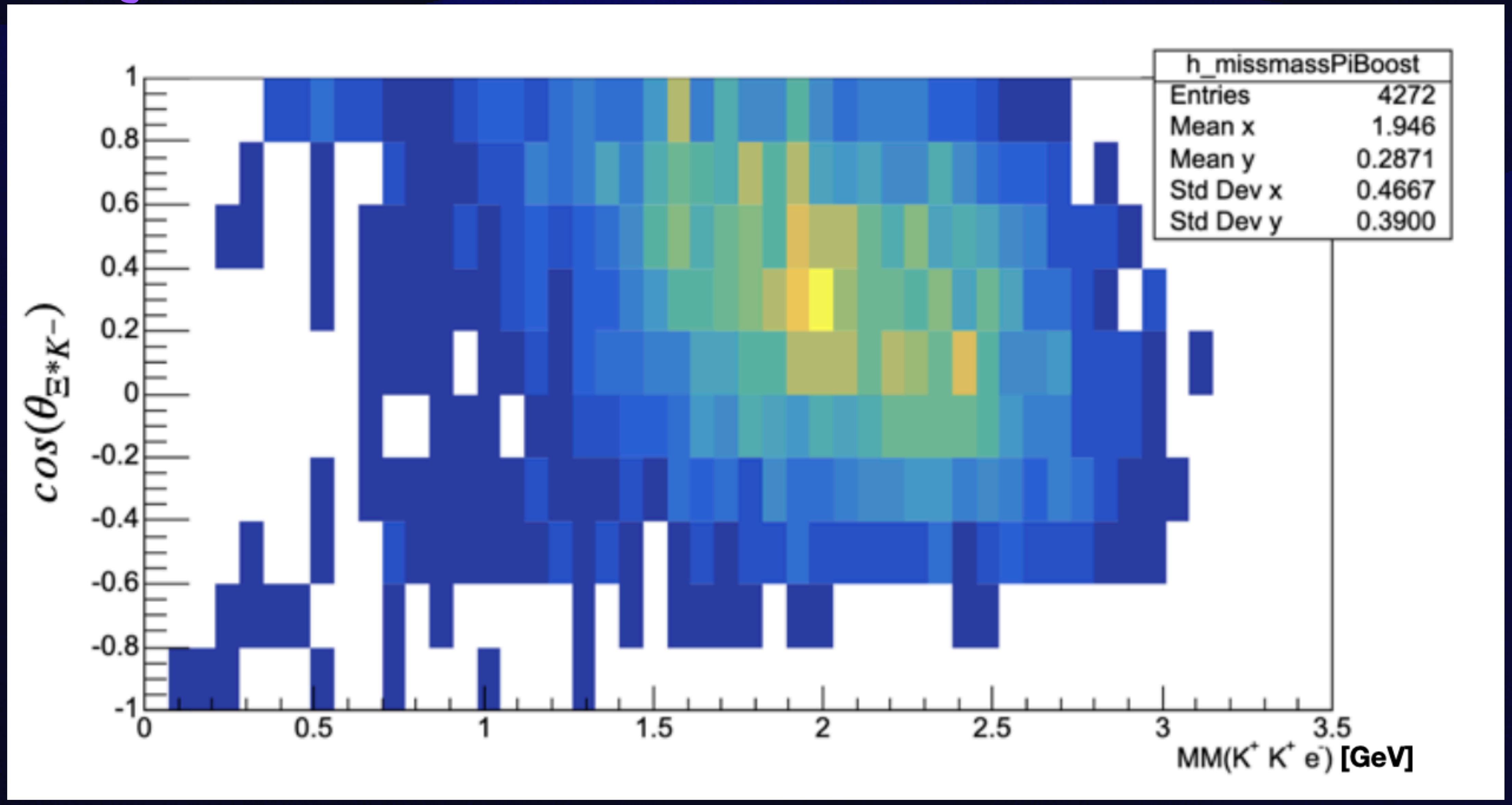
$$J^P = (L + S_\Xi)^{(-1)^{L+1}}$$

Towards Quantum Numbers

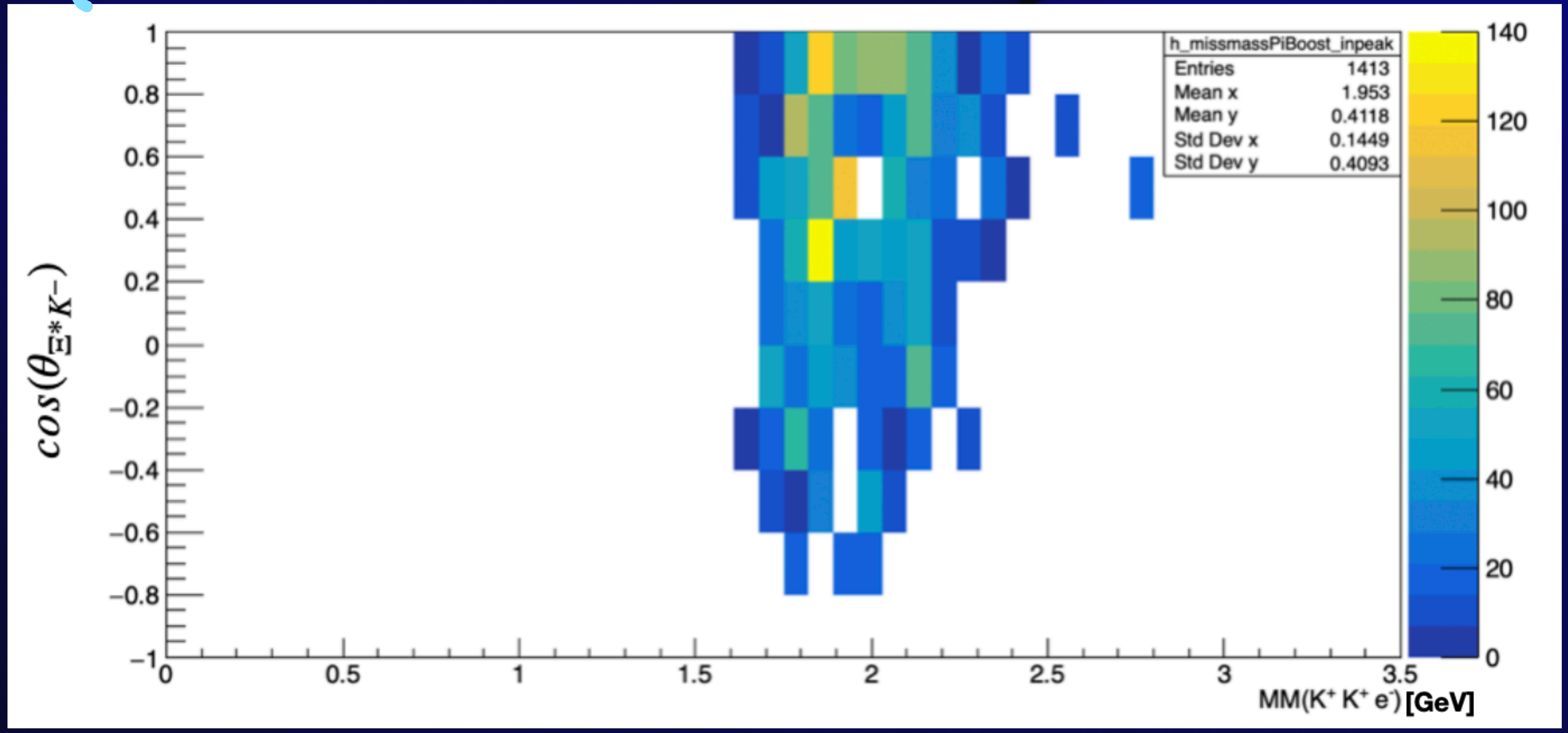
K^- channel → $e^- p \to e'^- \,\Xi^{*-} K^+ K^+$

↳ ΛK^-

Before Sideband Subtraction



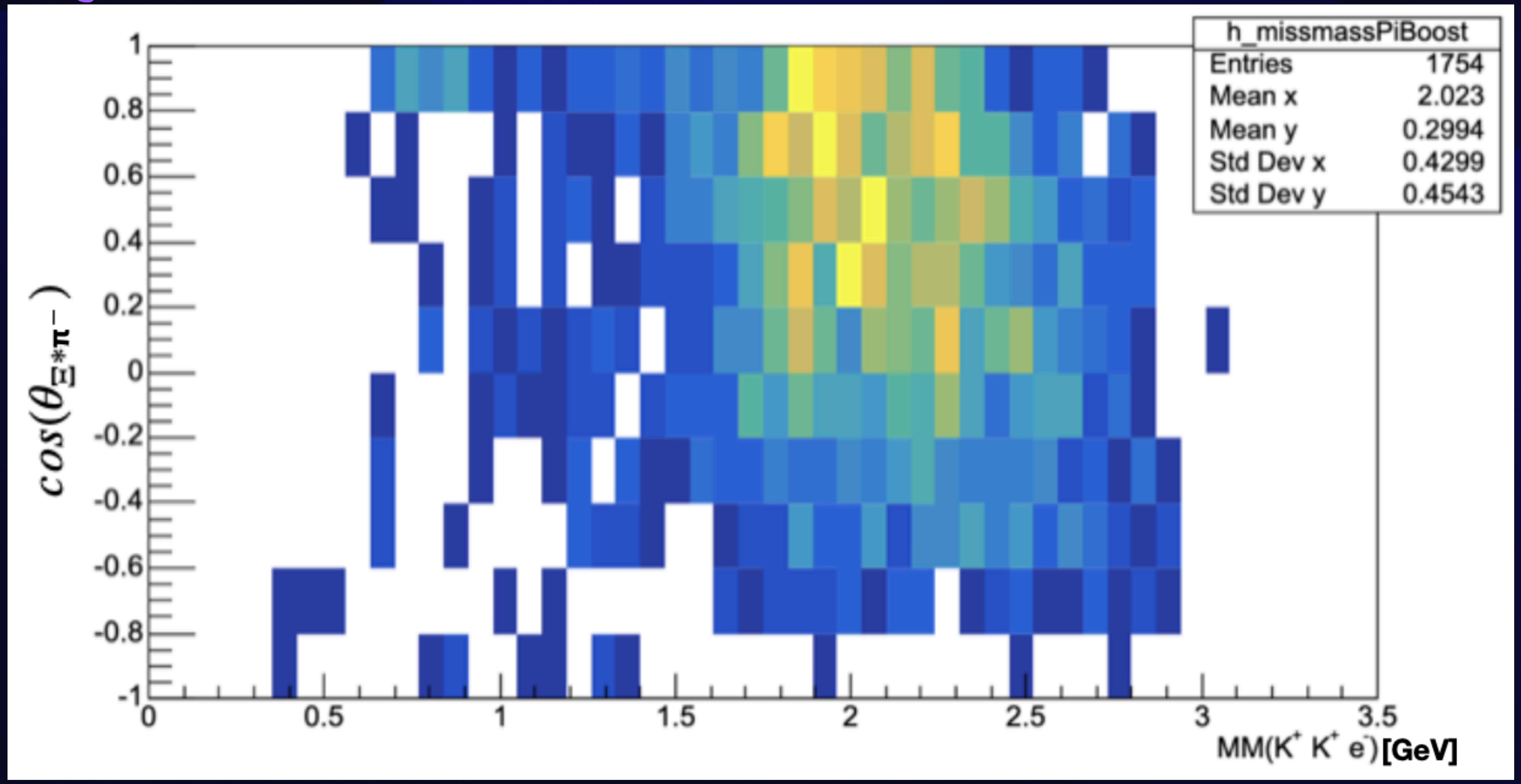
After Sideband Subtraction



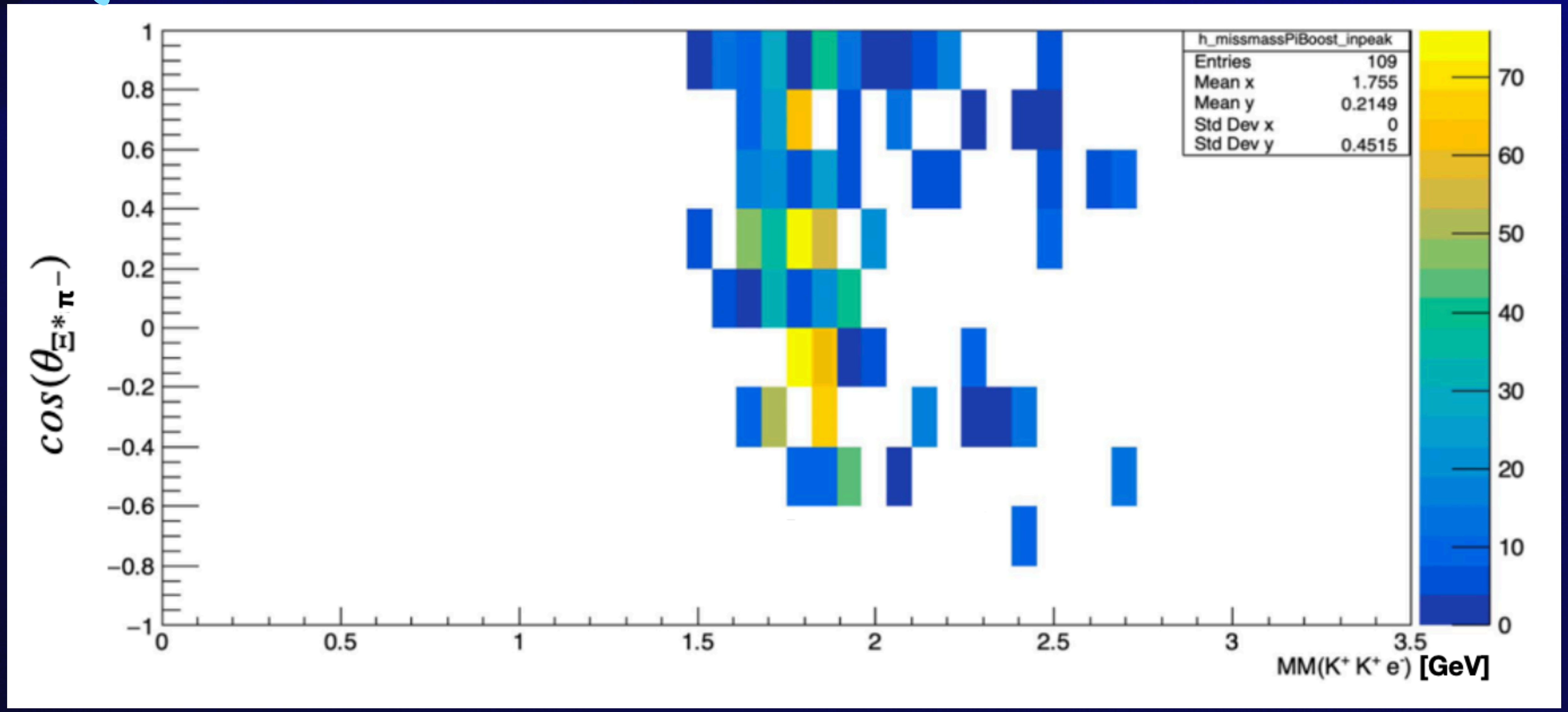
Towards Quantum Numbers

π^- channel → $e^- p \to e'^- \Xi^{*-} K^+ K^+$, $\hookrightarrow \Xi \pi^-$

Before Sideband Subtraction



After Sideband Subtraction



Mixed Events Technique

Mixing yields from different events → uncorrelated
can model accidentals

NORMAL ORDER

Event 1 $e + K_1^+ + K_2^+$

⋮

Event n $e + K_1^+ + K_2^+$

SCRAMBLE ORDER OF K_2

MIXED EVENTS

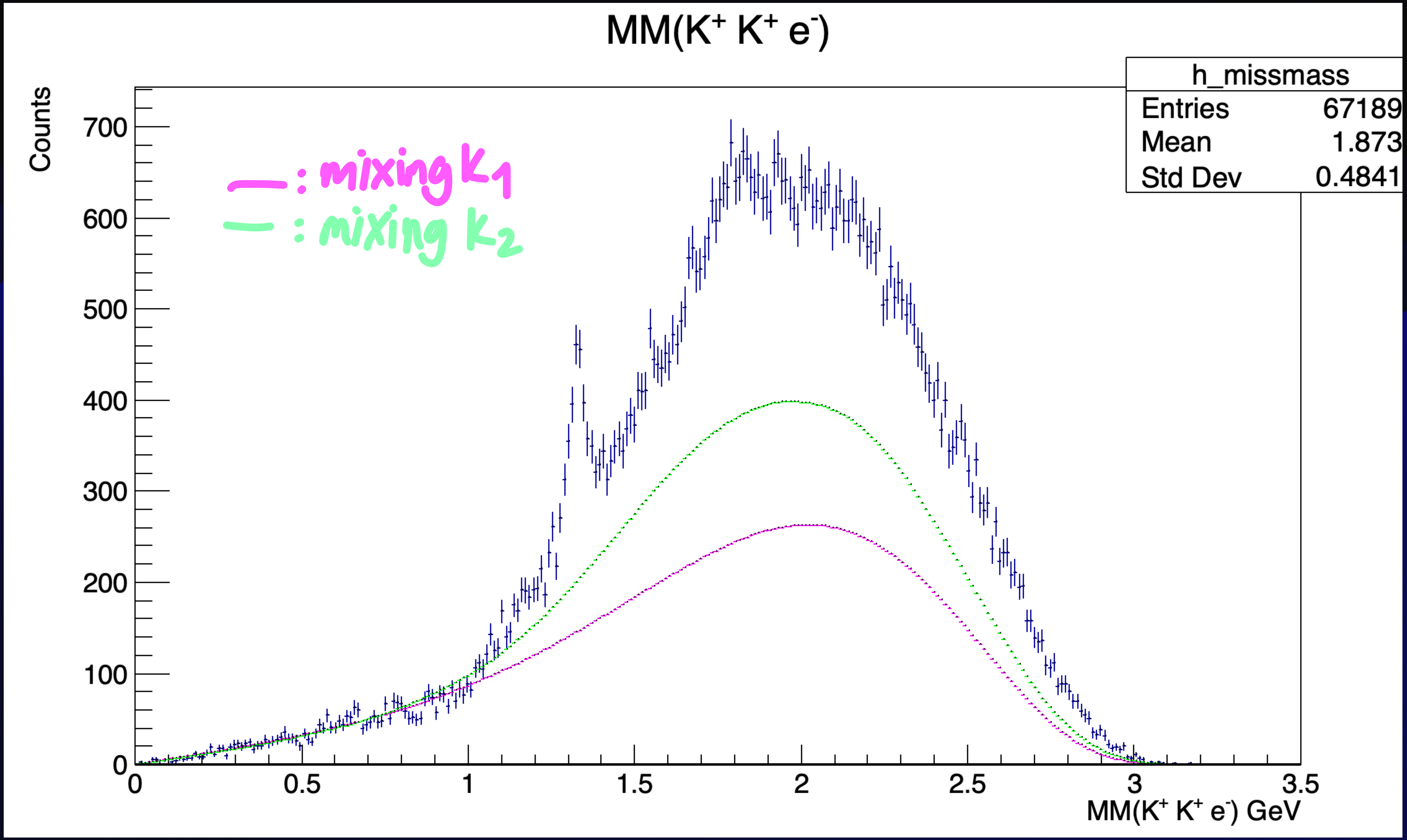
Event 1 $e + K_1^+$ + Event 7 K_2^+

Event 2 $e + K_1^+$ + Event 5 K_2^+

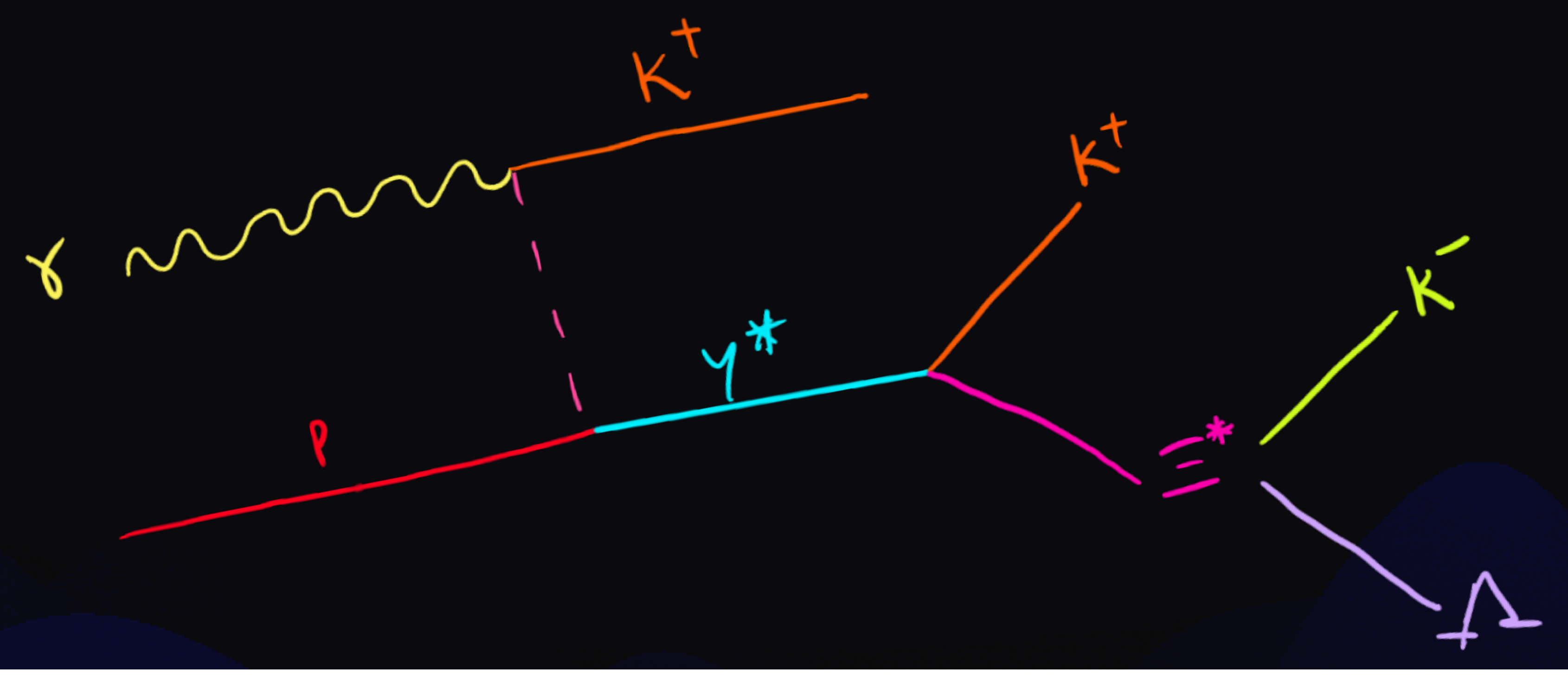
Event 3 $e + K_1^+$ + Event 1 K_2^+

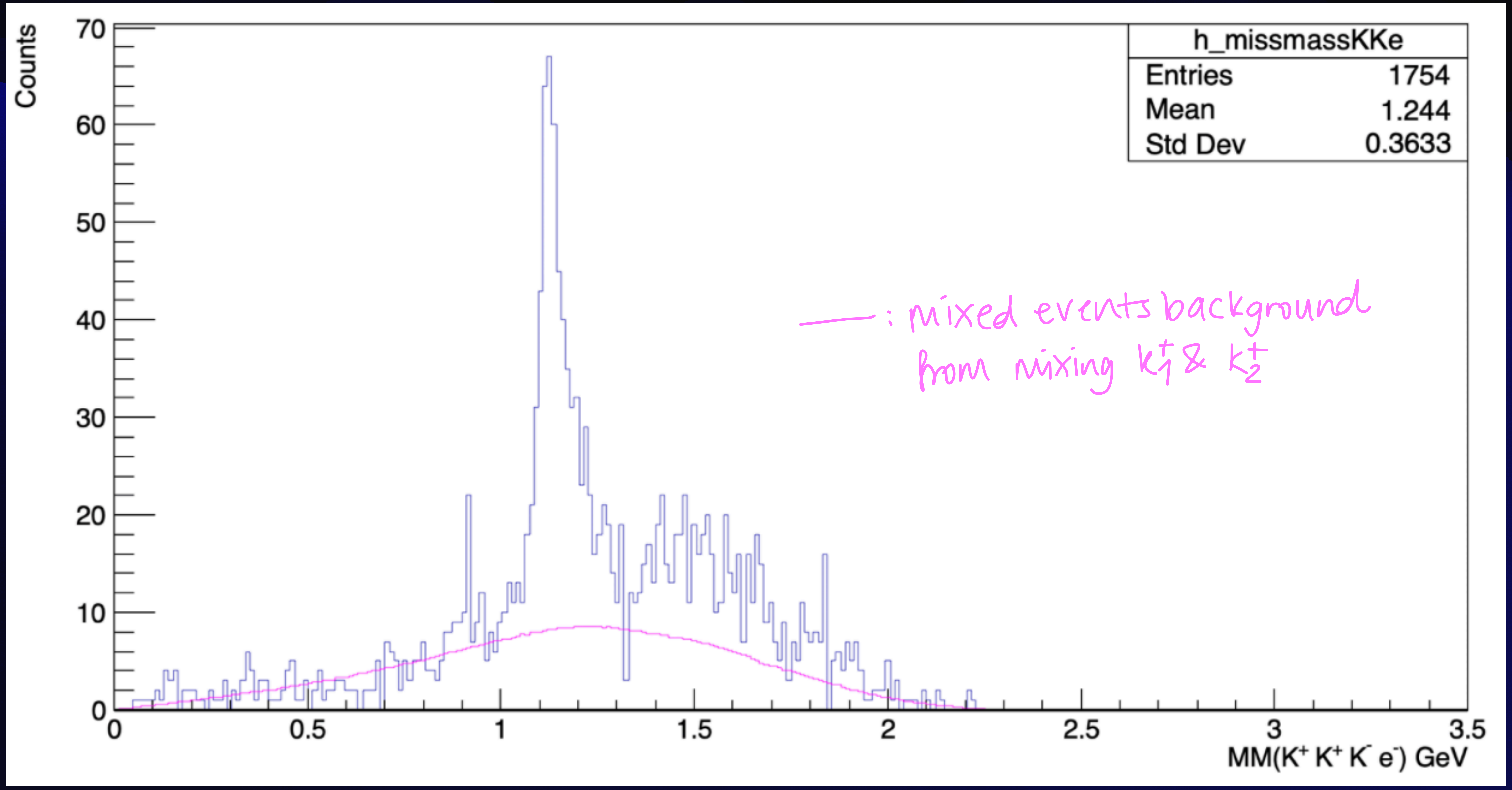
⋮

Mixed Events Technique

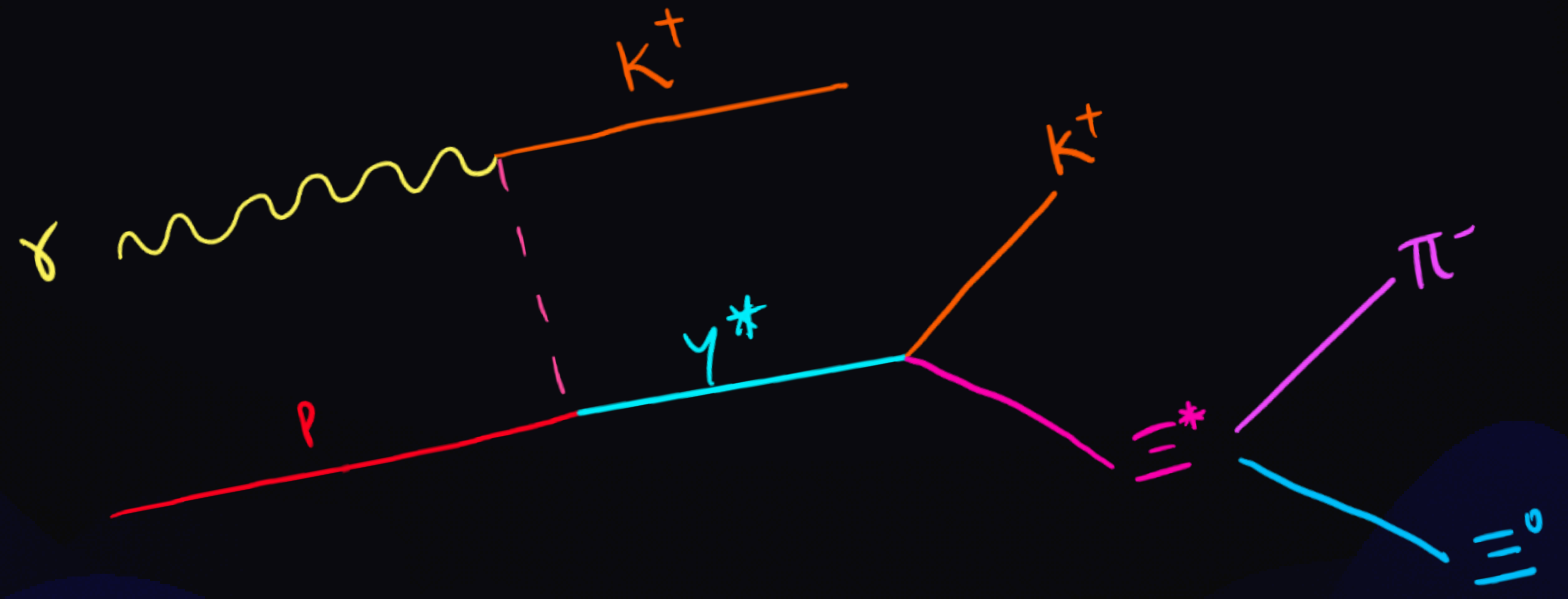


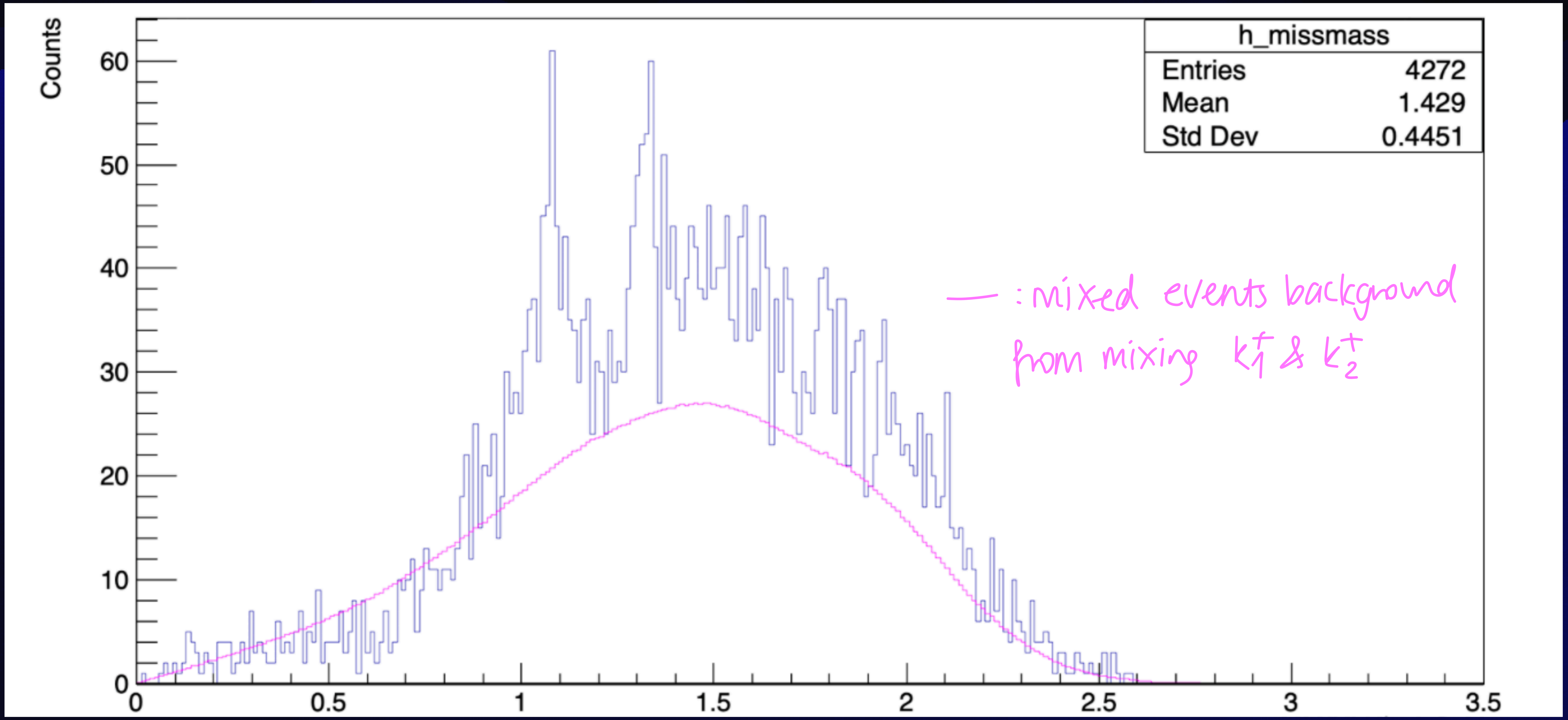
Mixed Events Technique





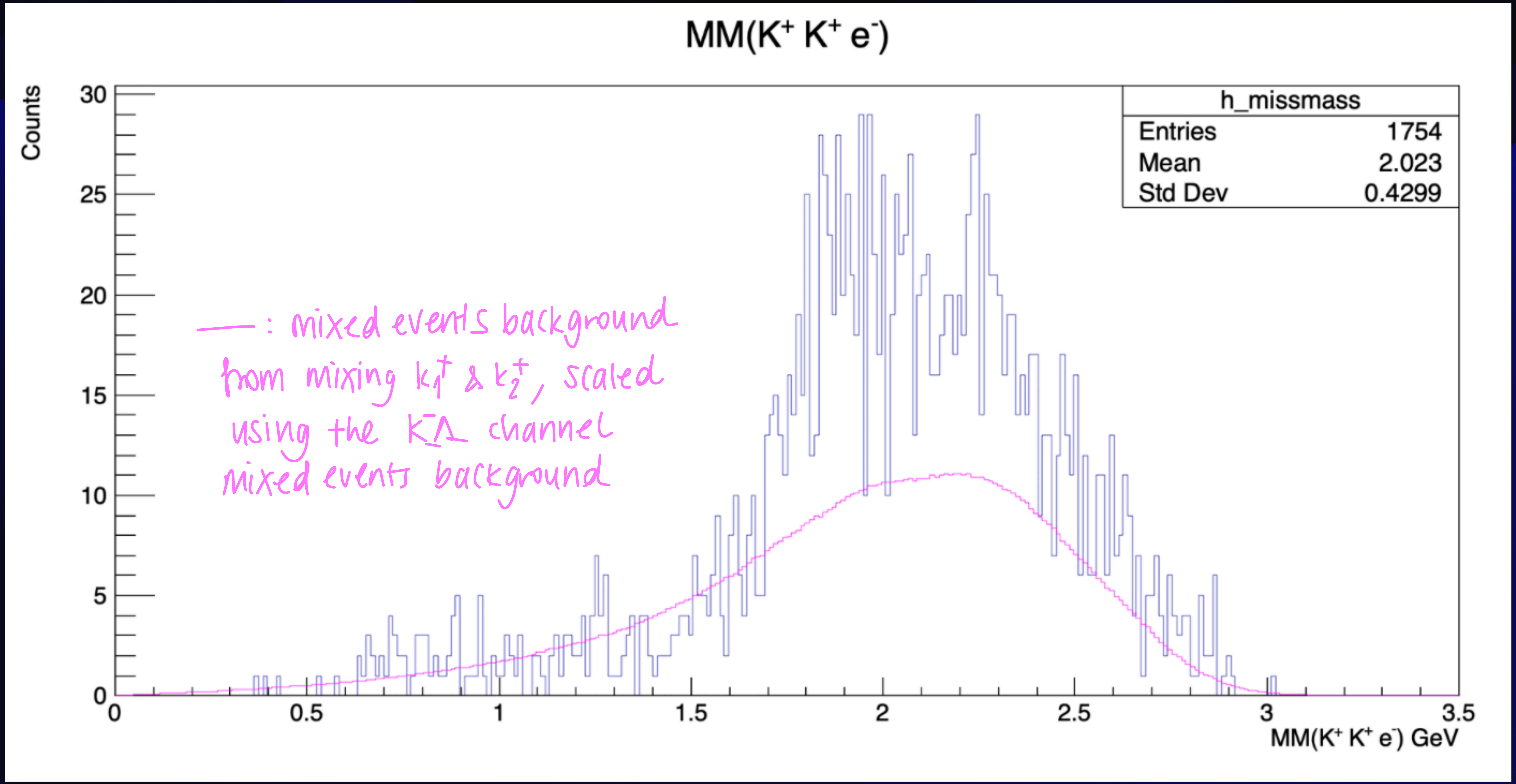
Mixed Events Technique





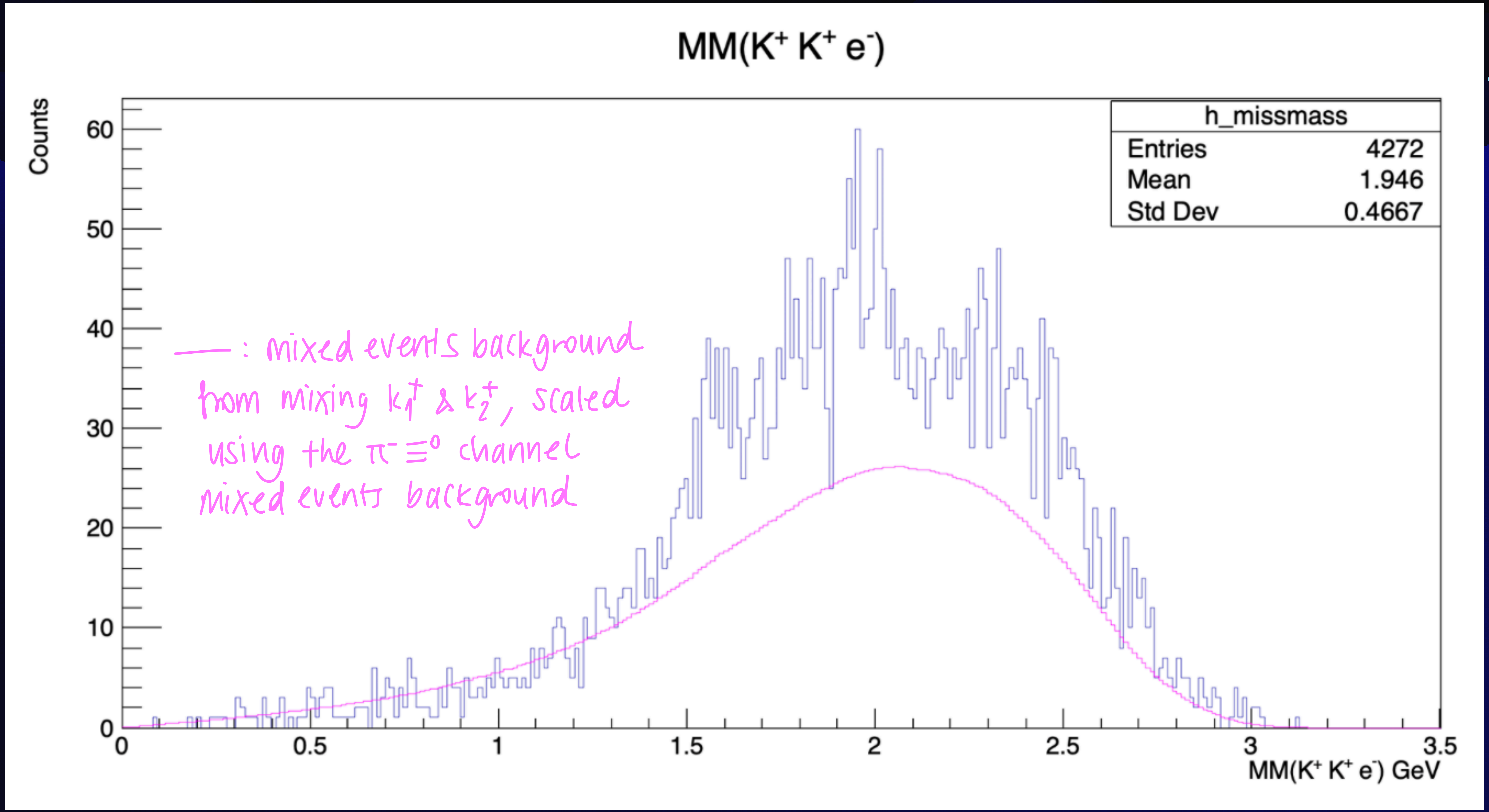
Mixed Events Technique

with K⁻ condition ...



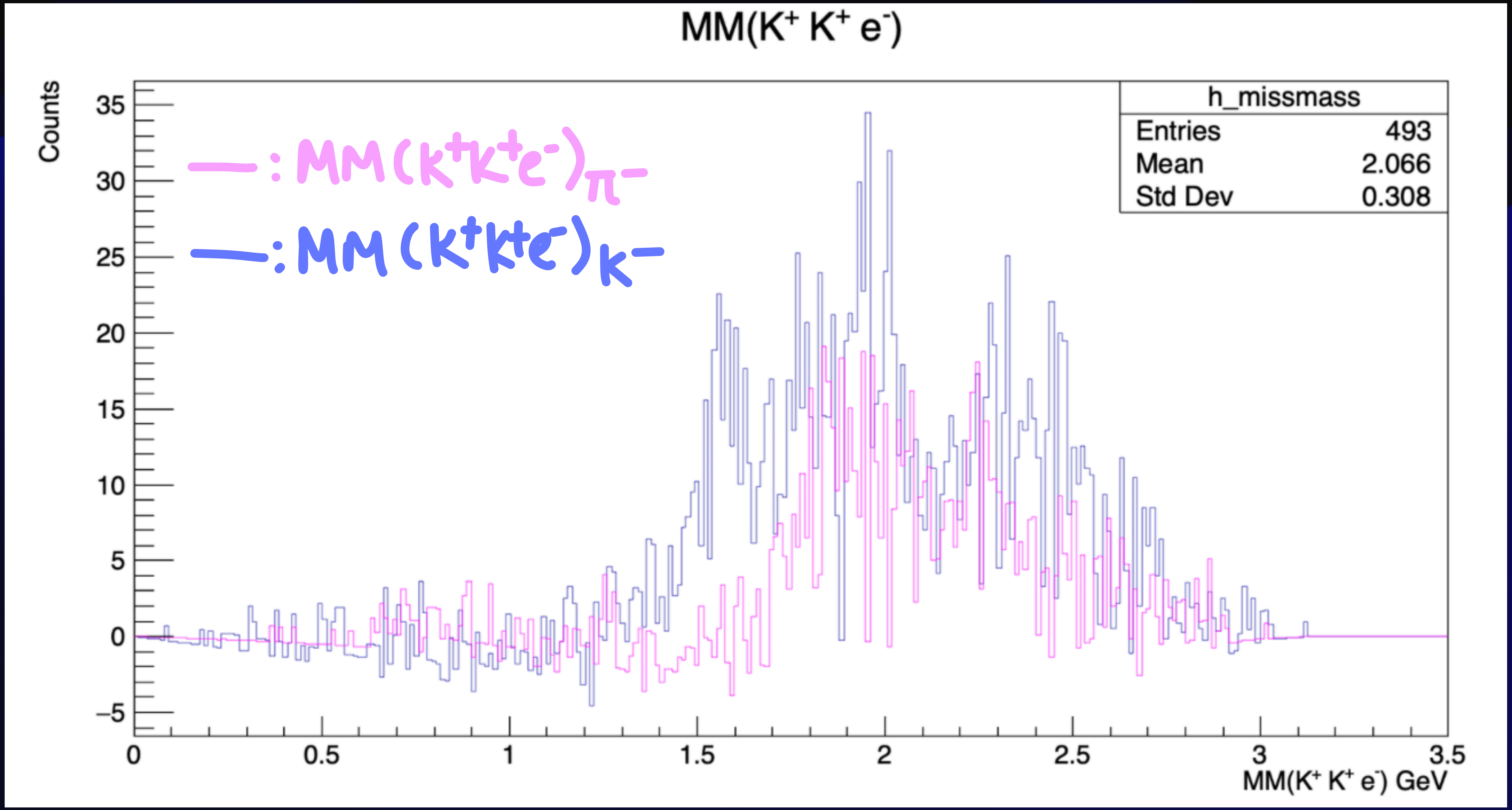
Mixed Events Technique

with π^- condition ...



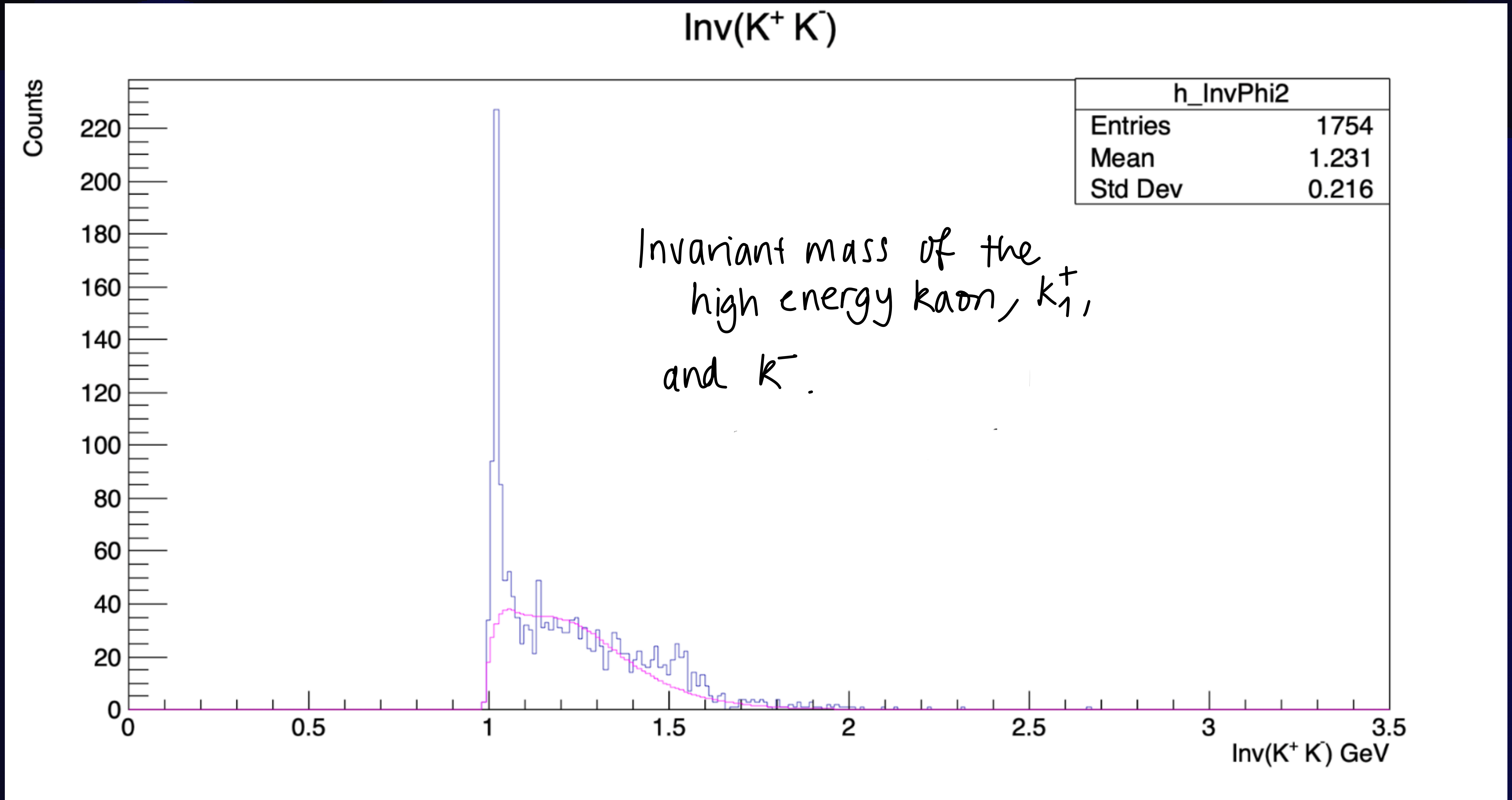
Mixed Events Technique

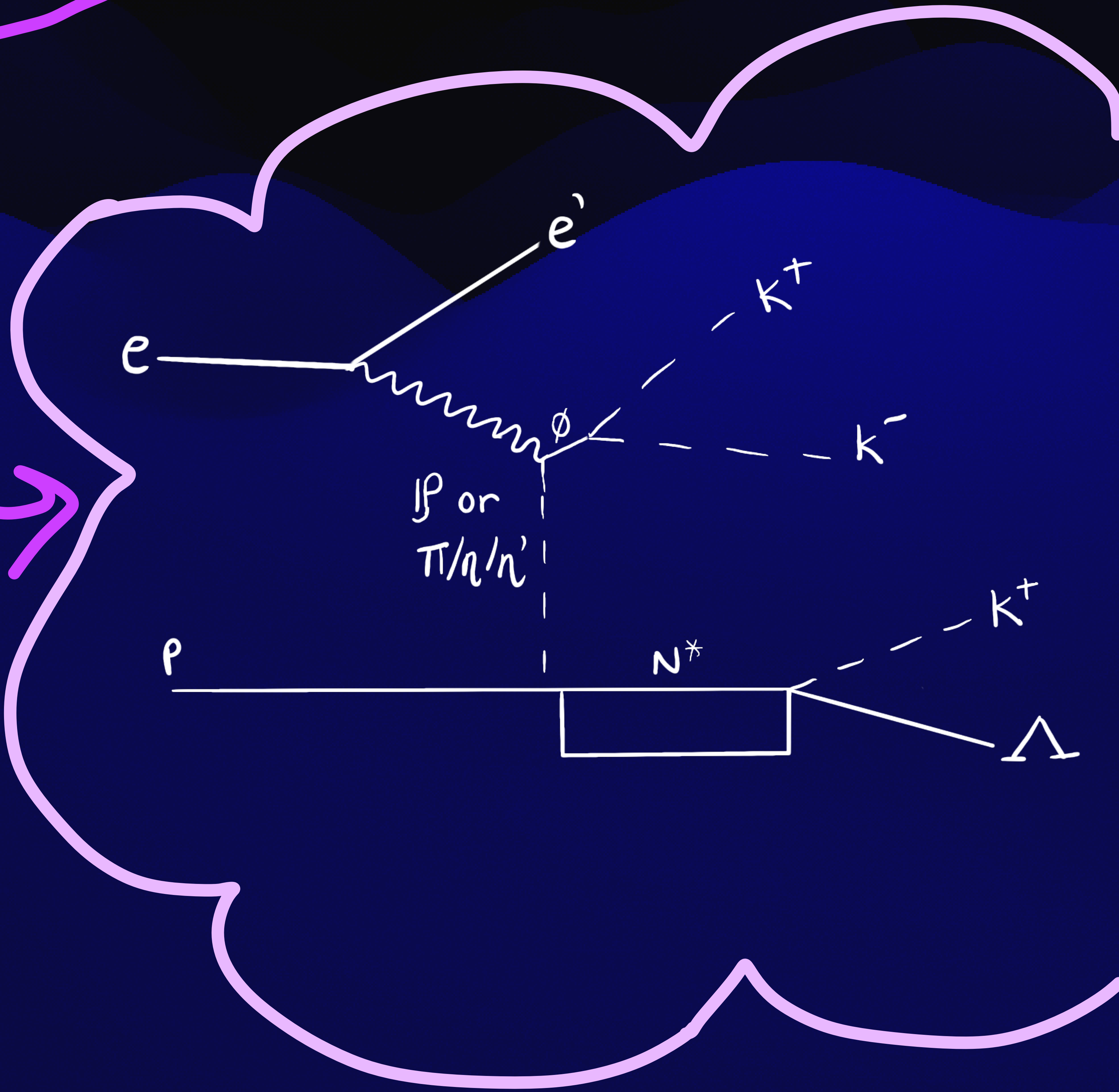
An idea of the branching ratios



Mixed Events Technique

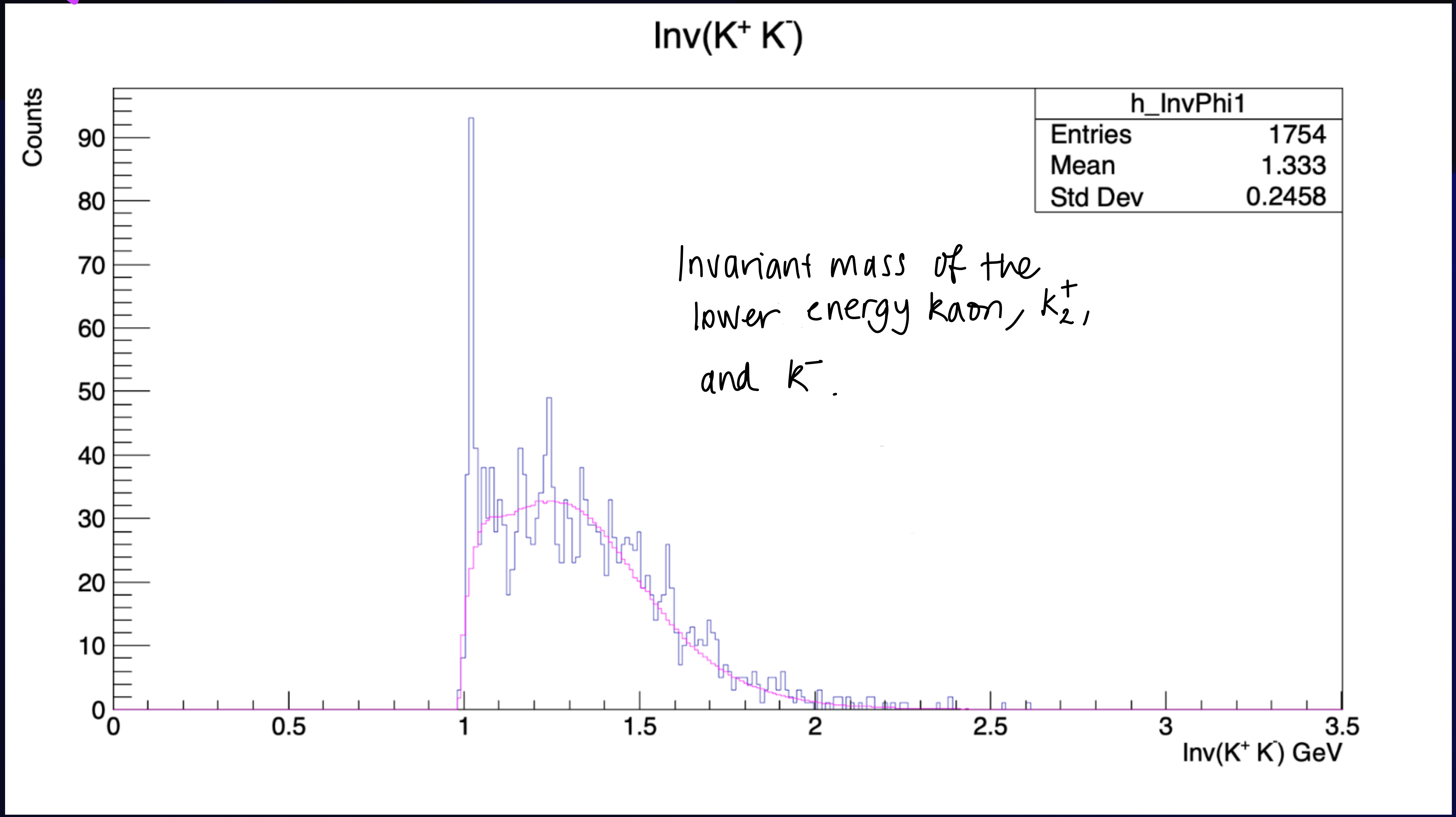
RECONSTRUCTING THE BACKGROUND

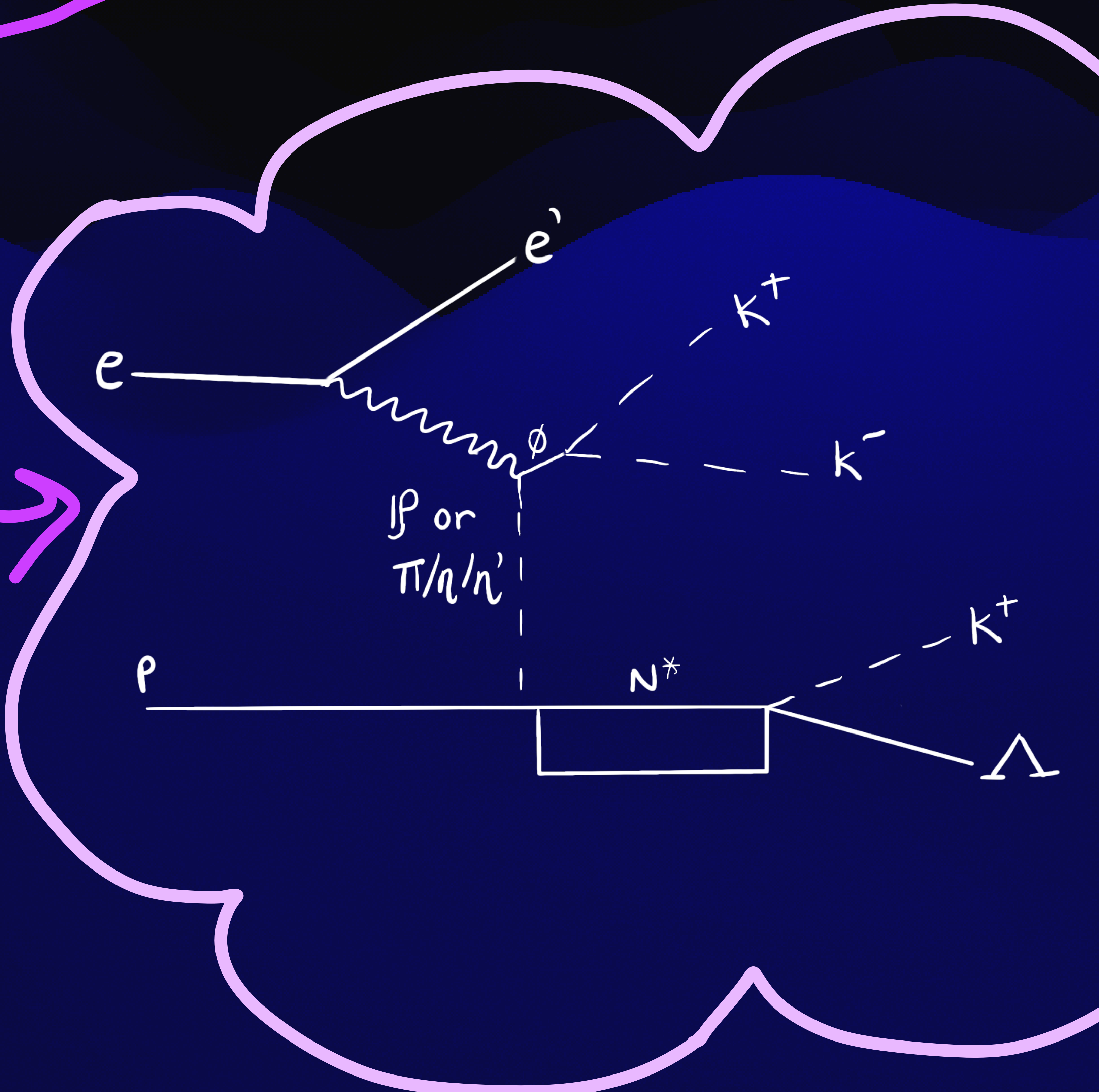


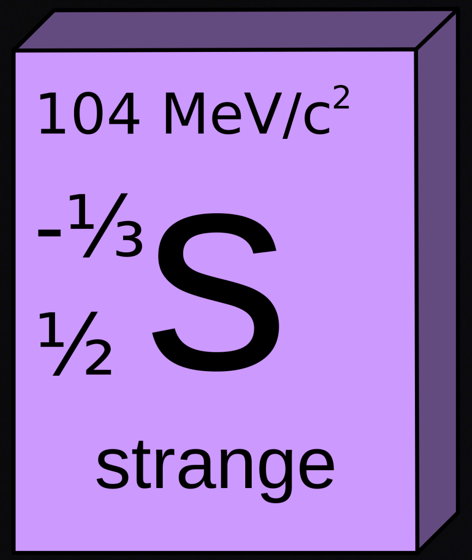


Mixed Events Technique

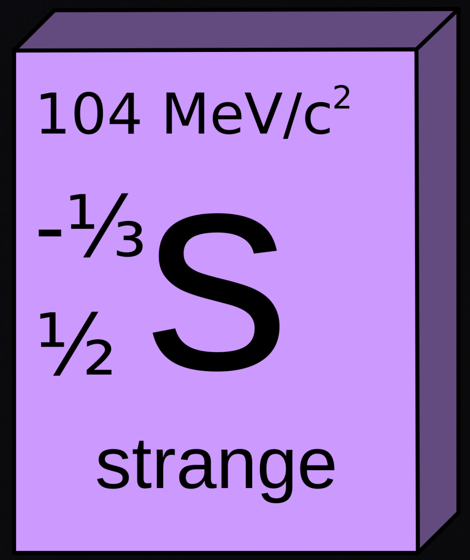
RECONSTRUCTING THE BACKGROUND







CONCLUSIONS



1. Promising new results - First measurement in electro-production
2. More statistics to come
3. Quantum number & branching ratio determination
4. Probing internal structure of cascades?