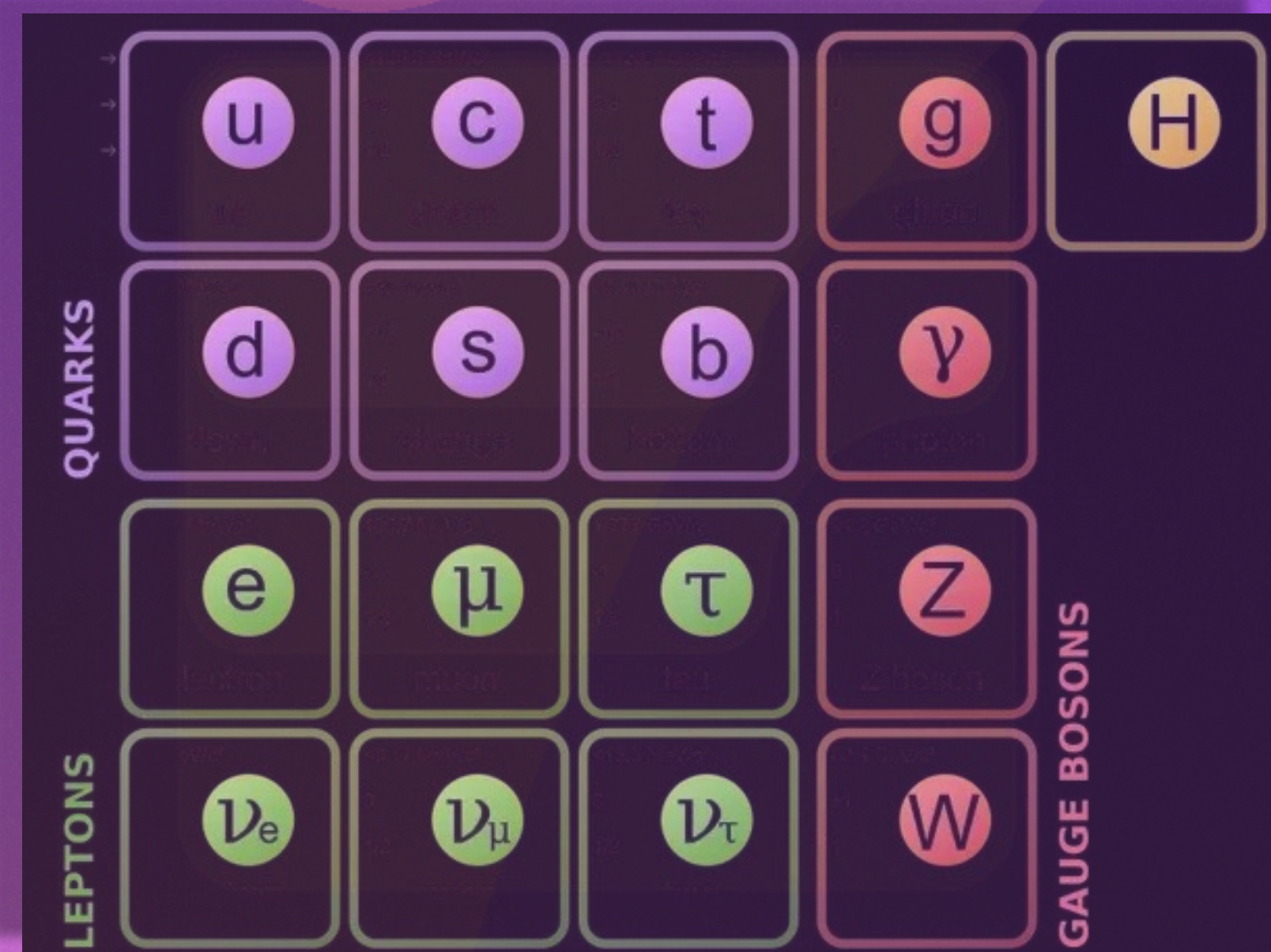


# ELUCIDATING STRANGENESS

with

# ELECTROMAGNETIC PROBES

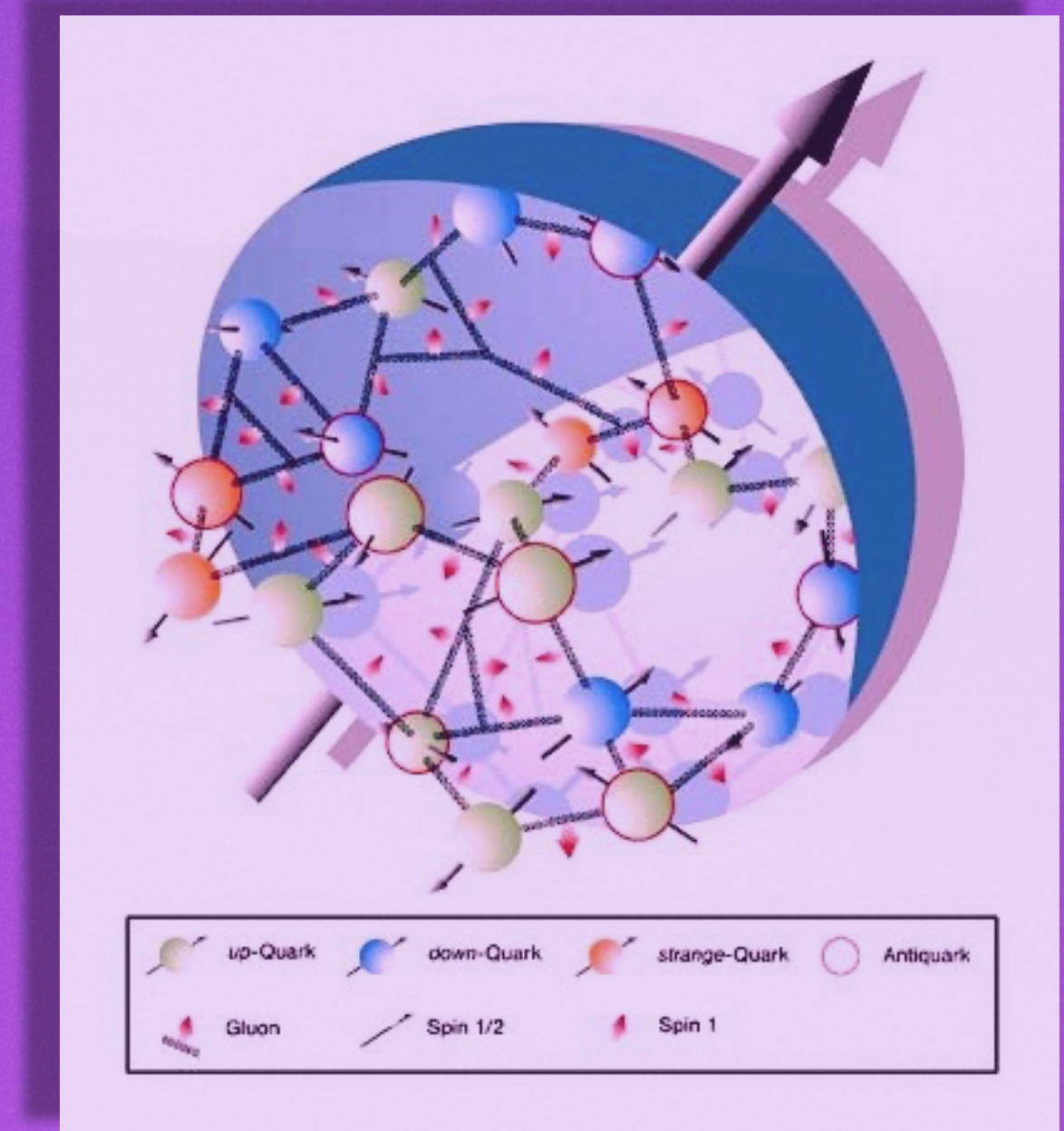


104 MeV/c<sup>2</sup>

$-\frac{1}{3}$

$\frac{1}{2}$  **S**

strange



# THE STANDARD MODEL

	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>						
QUARKS	2.3 M <b>u</b> 2/3 1/2 up	1.27 G <b>c</b> 2/3 1/2 charm	173.1 G <b>t</b> 2/3 1/2 top	Mass: $eV/c^2$ Charge Spin Name strong nuclear force	126 G <b>H</b> 0 0 higgs	electromagnetic force			
	4.8 M <b>d</b> -1/3 1/2 down	95 M <b>s</b> -1/3 1/2 strange	4.2 G <b>b</b> -1/3 1/2 bottom				0 <b>g</b> 0 1 gluon		
	0.511 M <b>e</b> -1 1/2 electron	105.7 M <b><math>\mu</math></b> -1 1/2 muon	1.78 G <b><math>\tau</math></b> -1 1/2 tau				0 <b><math>\gamma</math></b> 0 1 photon		
	<2.2 <b><math>\nu_e</math></b> 0 1/2 e neutrino	0.17 M <b><math>\nu_\mu</math></b> 0 1/2 $\mu$ neutrino	<15.5 M <b><math>\nu_\tau</math></b> 0 1/2 $\tau$ neutrino				80.4 G <b>W</b> $\pm 1$ 1 W boson	91.2 G <b>Z</b> 0 1 Z boson	
	FERMIONS						GAUGE BOSONS		weak nuclear force
	LEPTONS								

HADRONS



⇒ MESONS



⇒ BARYONS

# THE STANDARD MODEL

	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>							
QUARKS	2.3 M <b>u</b> 2/3 1/2 up	1.27 G <b>c</b> 2/3 1/2 charm	173.1 G <b>t</b> 2/3 1/2 top	Mass: $eV/c^2$ Charge Spin Name strong nuclear force	126 G <b>H</b> 0 0 higgs	electromagnetic force				
	4.8 M <b>d</b> -1/3 1/2 down	95 M <b>s</b> -1/3 1/2 strange	4.2 G <b>b</b> -1/3 1/2 bottom							
							0 <b>g</b> 0 1 gluon			
	FERMIONS									
	LEPTONS	0.511 M <b>e</b> -1 1/2 electron	105.7 M <b><math>\mu</math></b> -1 1/2 muon				1.78 G <b><math>\tau</math></b> -1 1/2 tau	0 <b><math>\gamma</math></b> 0 1 photon	80.4 G <b>W</b> $\pm 1$ 1 W boson	91.2 G <b>Z</b> 0 1 Z boson
		<2.2 <b><math>\nu_e</math></b> 0 1/2 e neutrino	0.17 M <b><math>\nu_\mu</math></b> 0 1/2 $\mu$ neutrino				<15.5 M <b><math>\nu_\tau</math></b> 0 1/2 $\tau$ neutrino			
GAUGE BOSONS										

HADRONS



⇒ MESONS

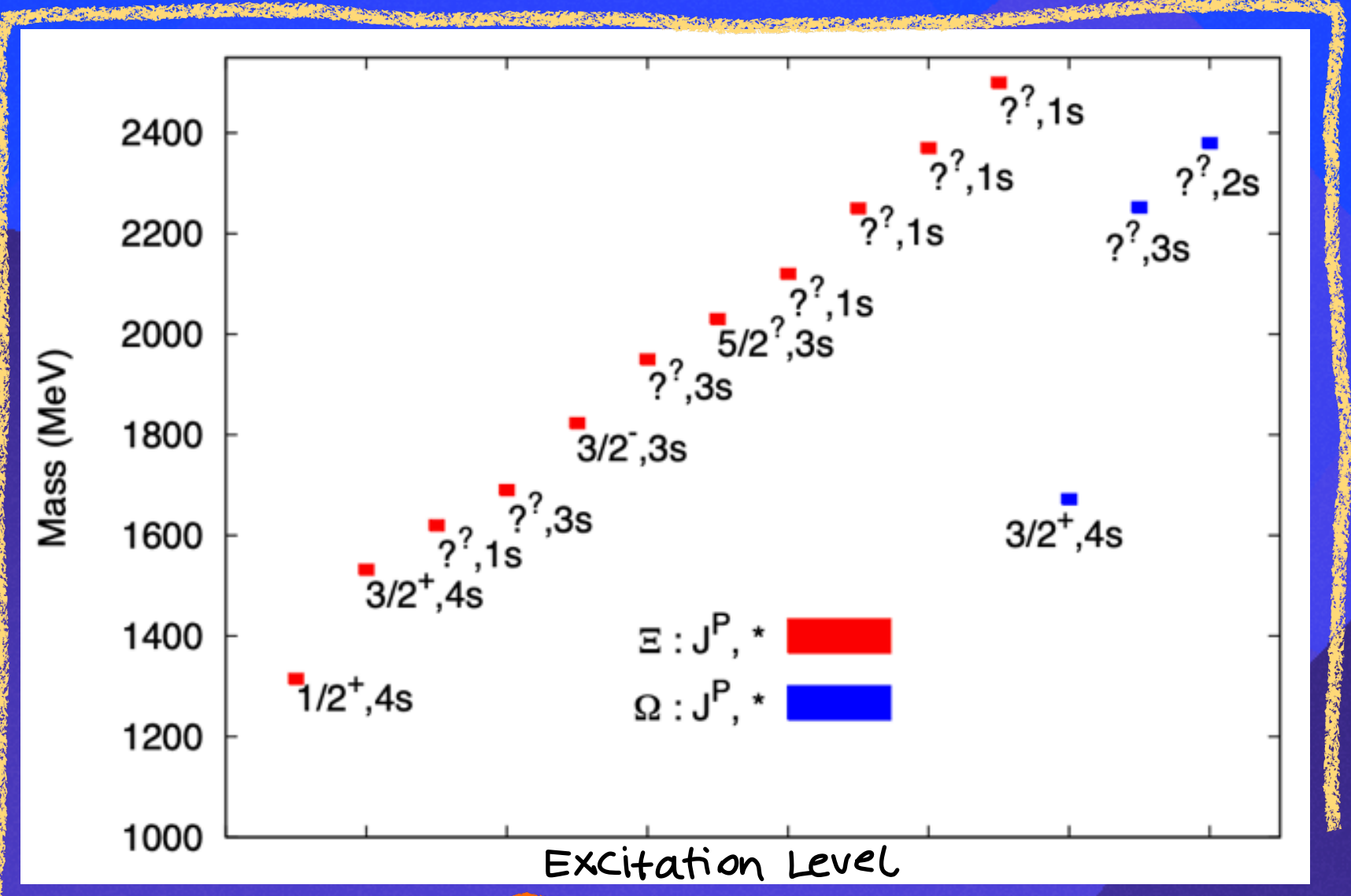


⇒ CASCADE BARYONS

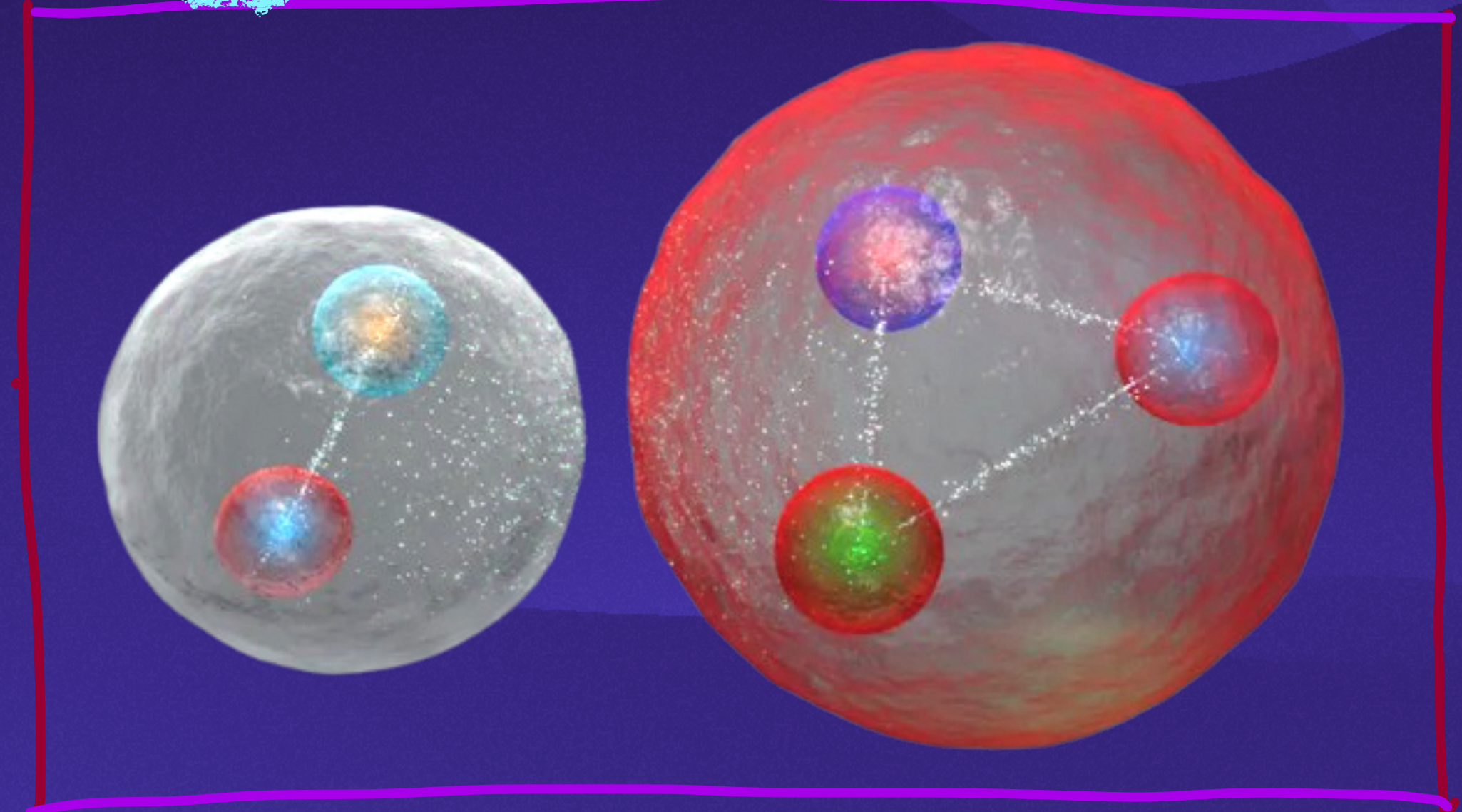
( $e^-$ )

# QCD PUZZLES

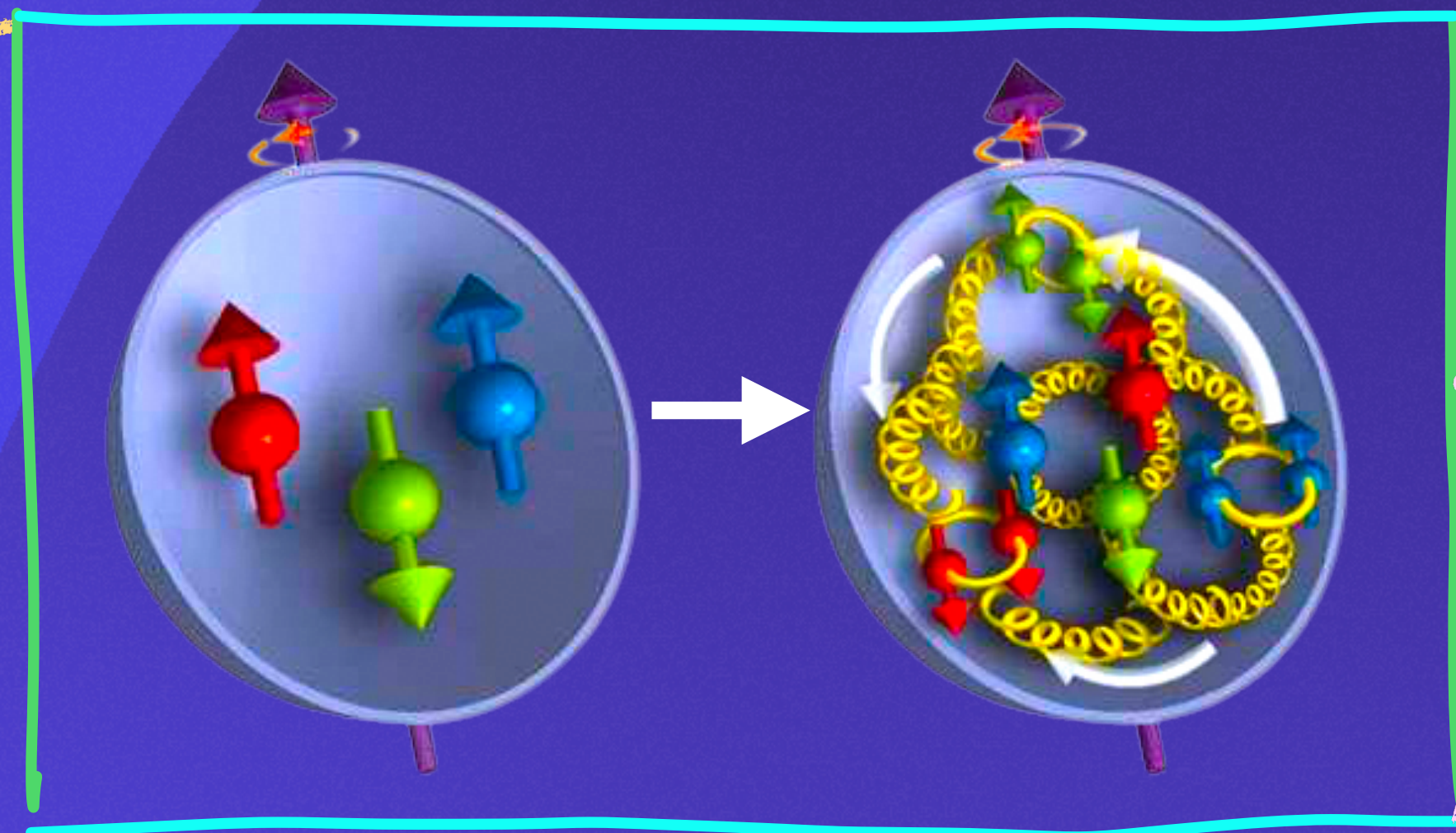
## MESON-BARYON MOLECULES



ISGUR & CAPSTICK  
 ↓  
 44 STATES



## LATTICE QCD

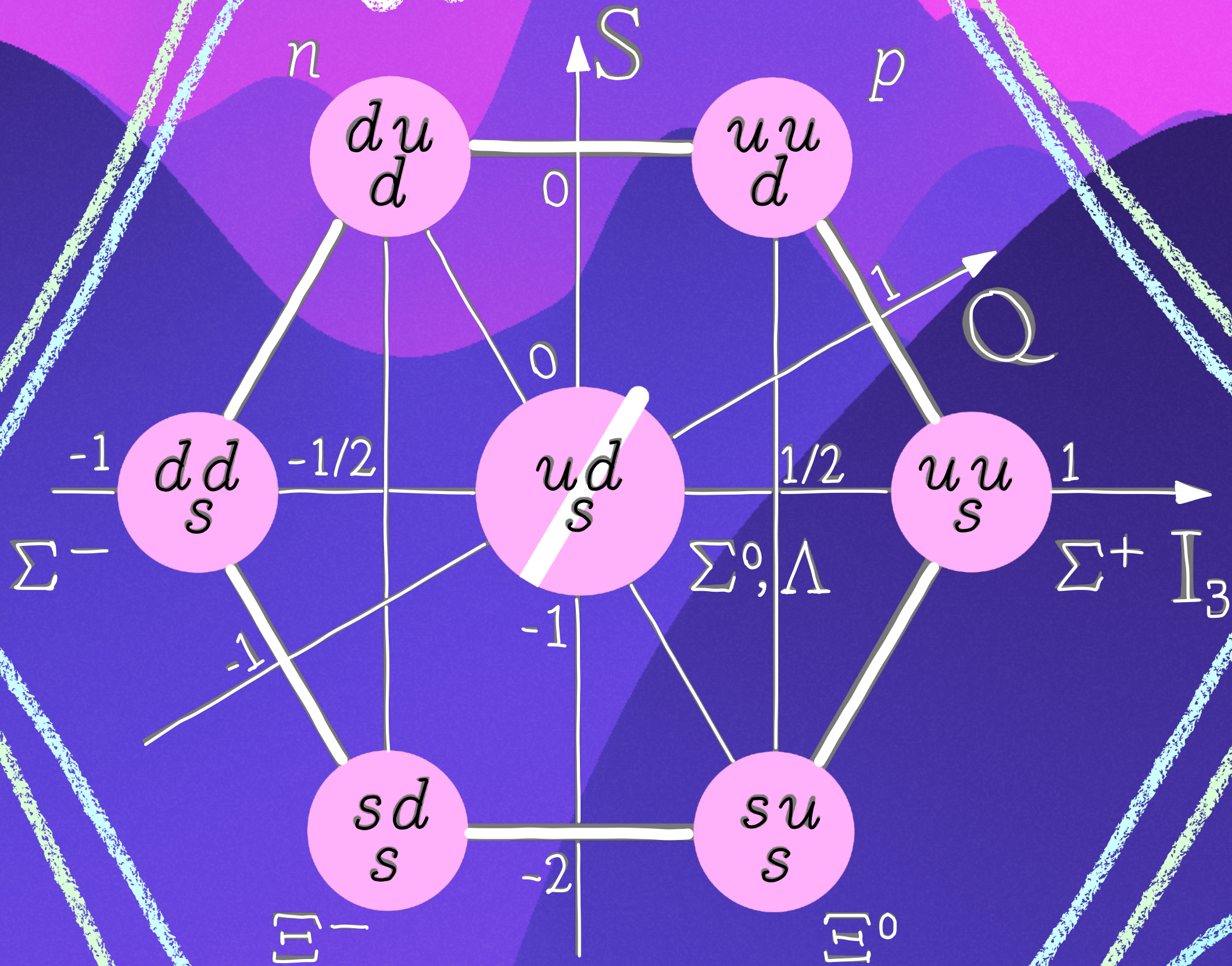


DO WE UNDERSTAND BARYONS?

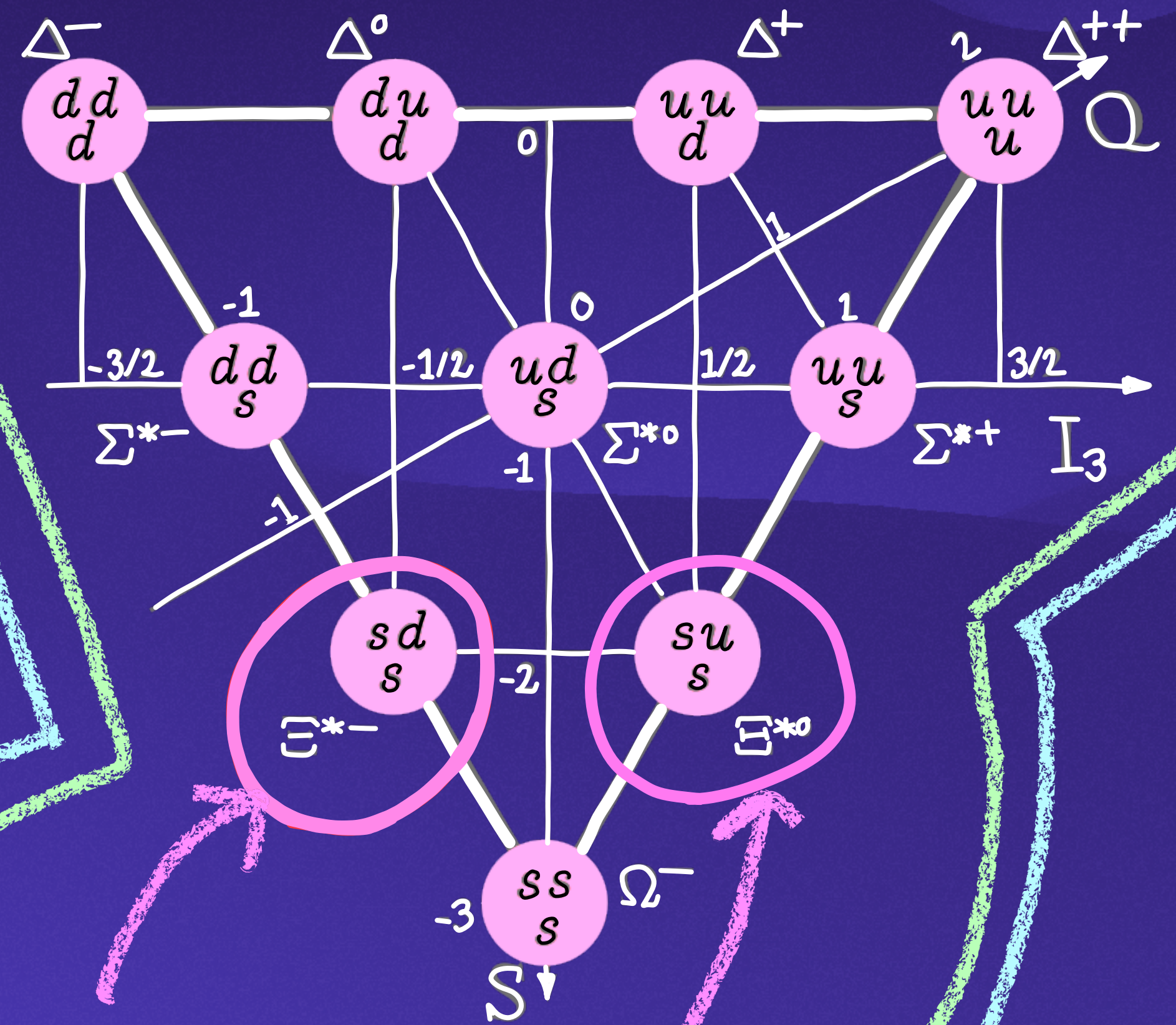


# BARYONS

## OCTET



## DECUPLET



EXCITED CASCADES

# THE MISSING STATES

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

6 EXCITED STATES IN PDG

NOT MUCH PROGRESS IN PAST: 4 DECADES

NOW

1981

# MISSING $J^P$ and BRANCHING RATIOS

$\Xi(1690)$

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

Mass  $m = 1690 \pm 10$  MeV [c]

Full width  $\Gamma < 30$  MeV

**$\Xi(1690)$  DECAY MODES**

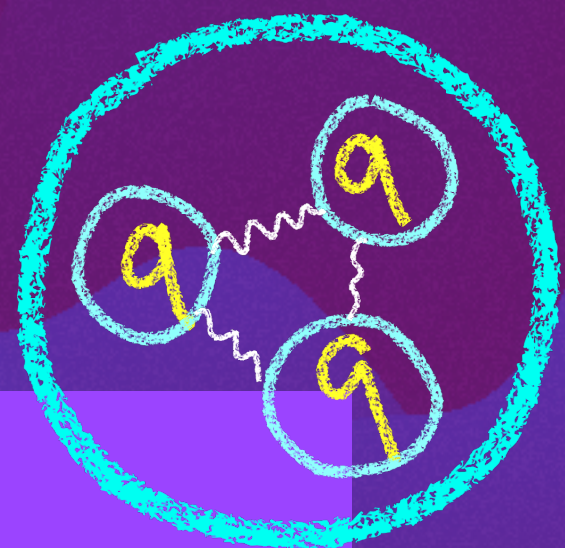
$\Xi(1690)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Lambda \bar{K}$	seen	240
$\Sigma \bar{K}$	seen	70
$\Xi \pi$	seen	311
$\Xi^- \pi^+ \pi^-$	possibly seen	213



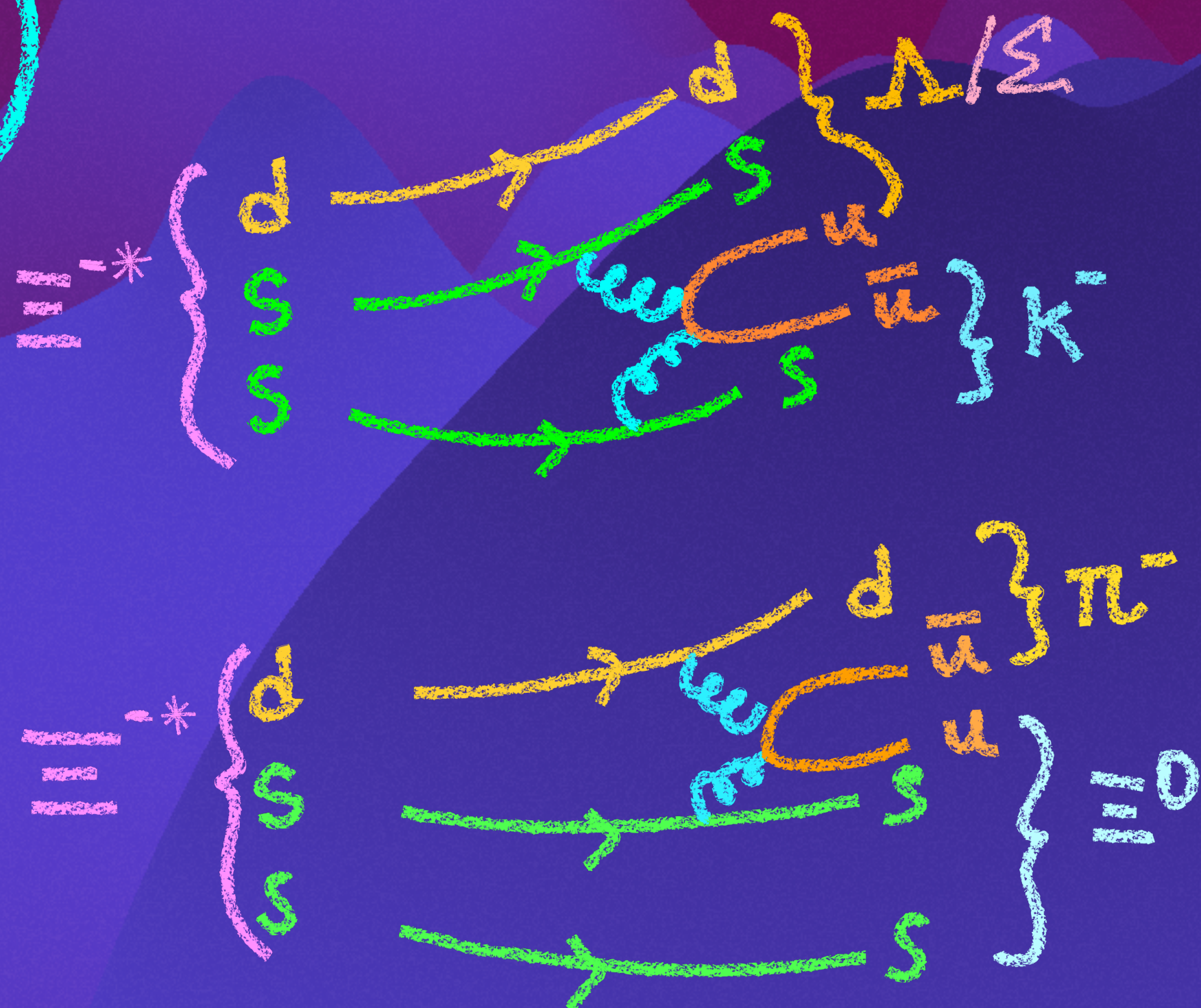
**POSSIBLE DECAY MODES**



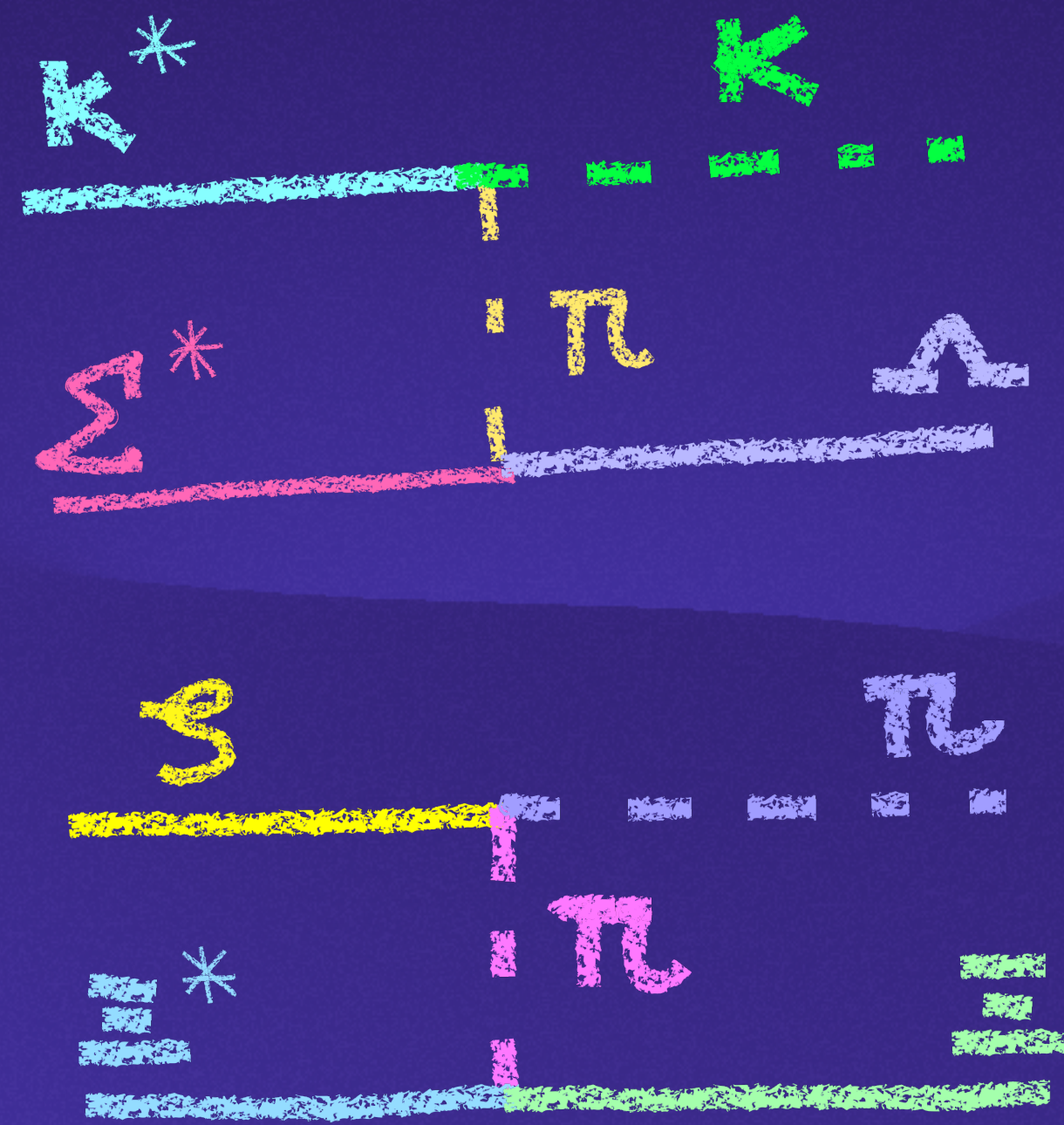
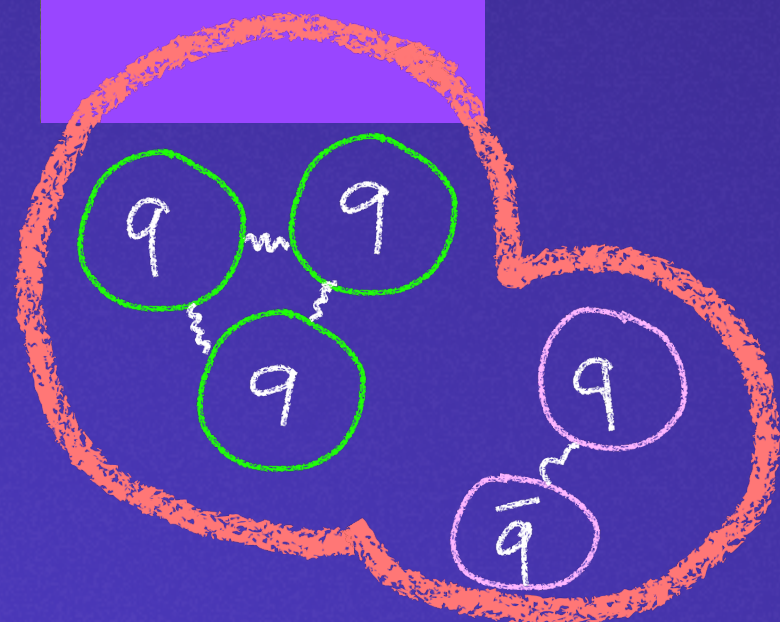
# THEORETICAL MODELS



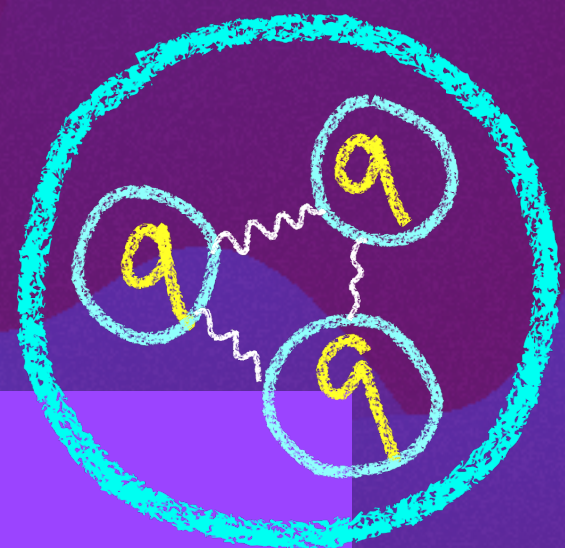
3q STATE



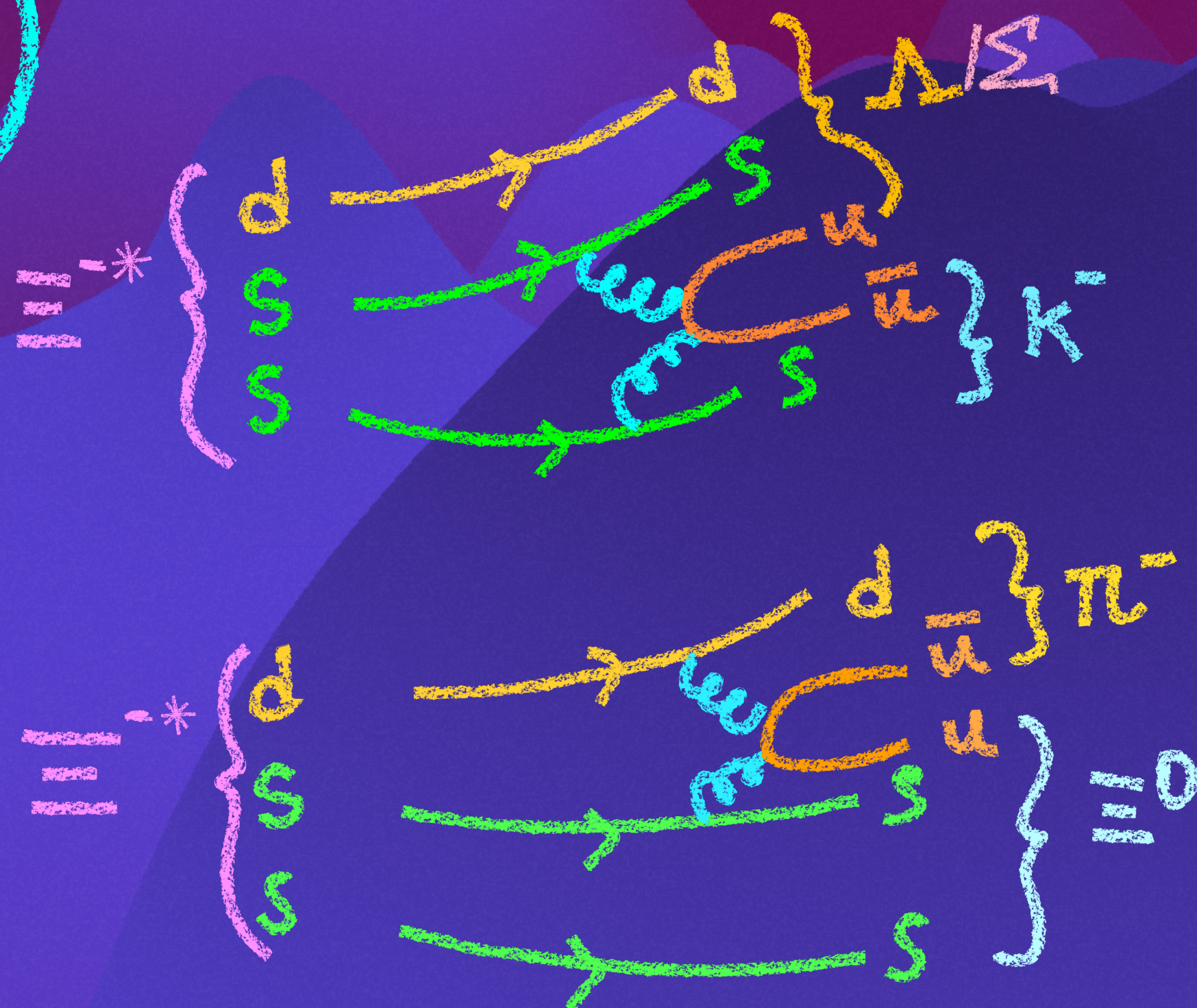
MOLECULAR



# THEORETICAL MODELS



3q STATE

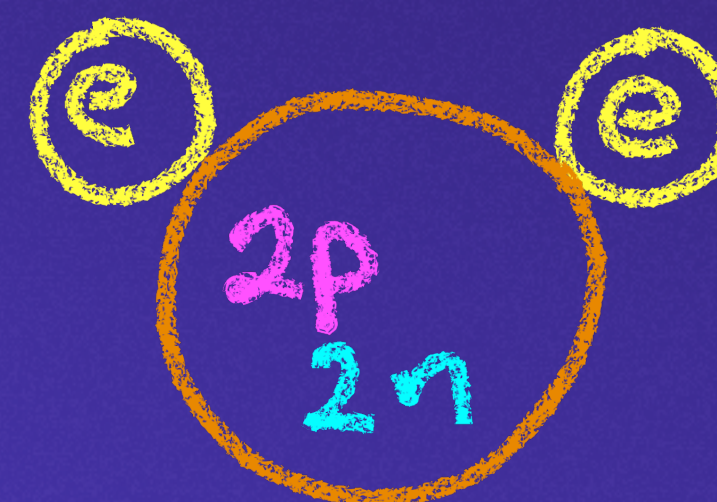


MOLECULAR

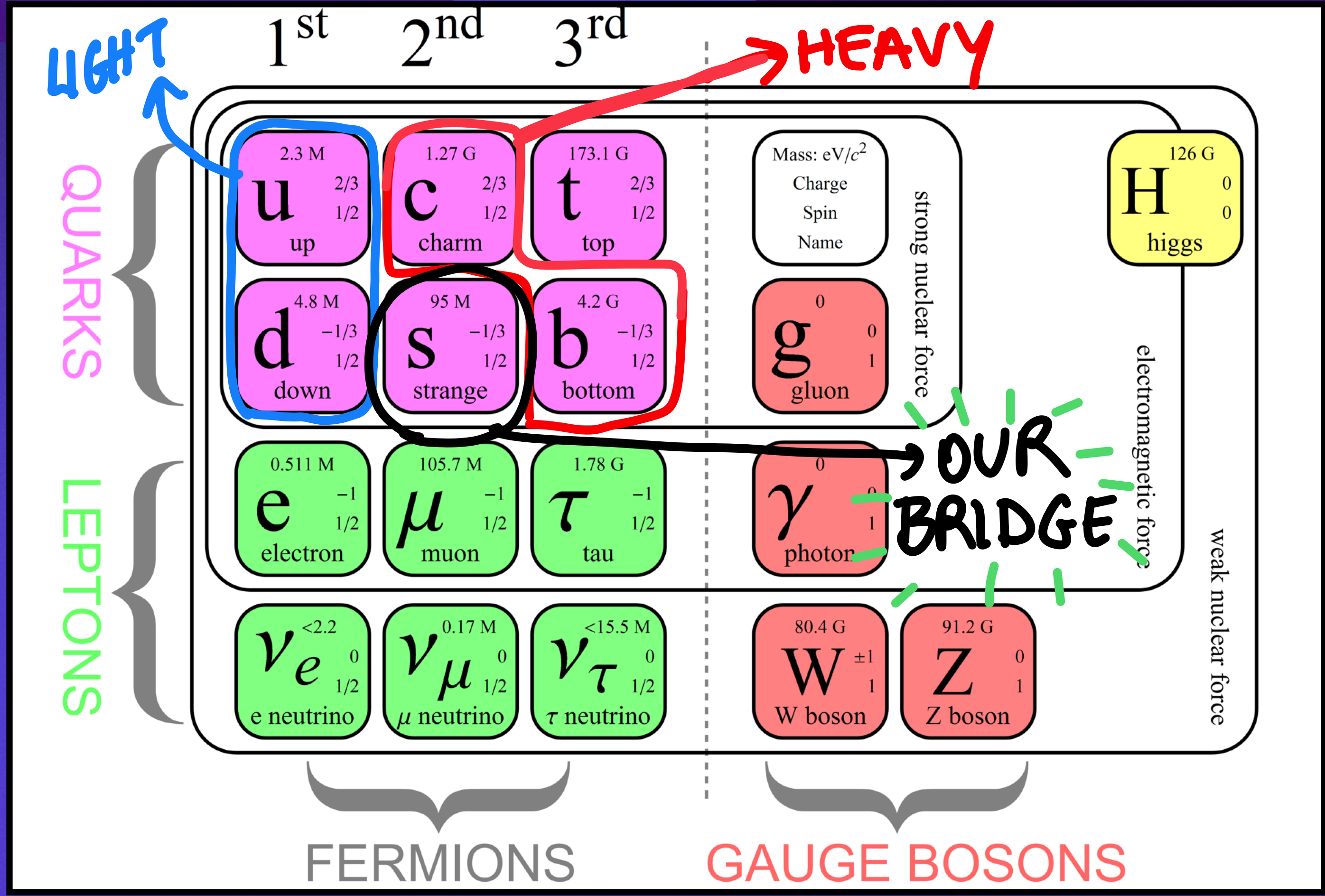
## DEUTERIUM MOLECULE



## He ATOM



# THE LIGHT, THE HEAVY & THE STRANGE

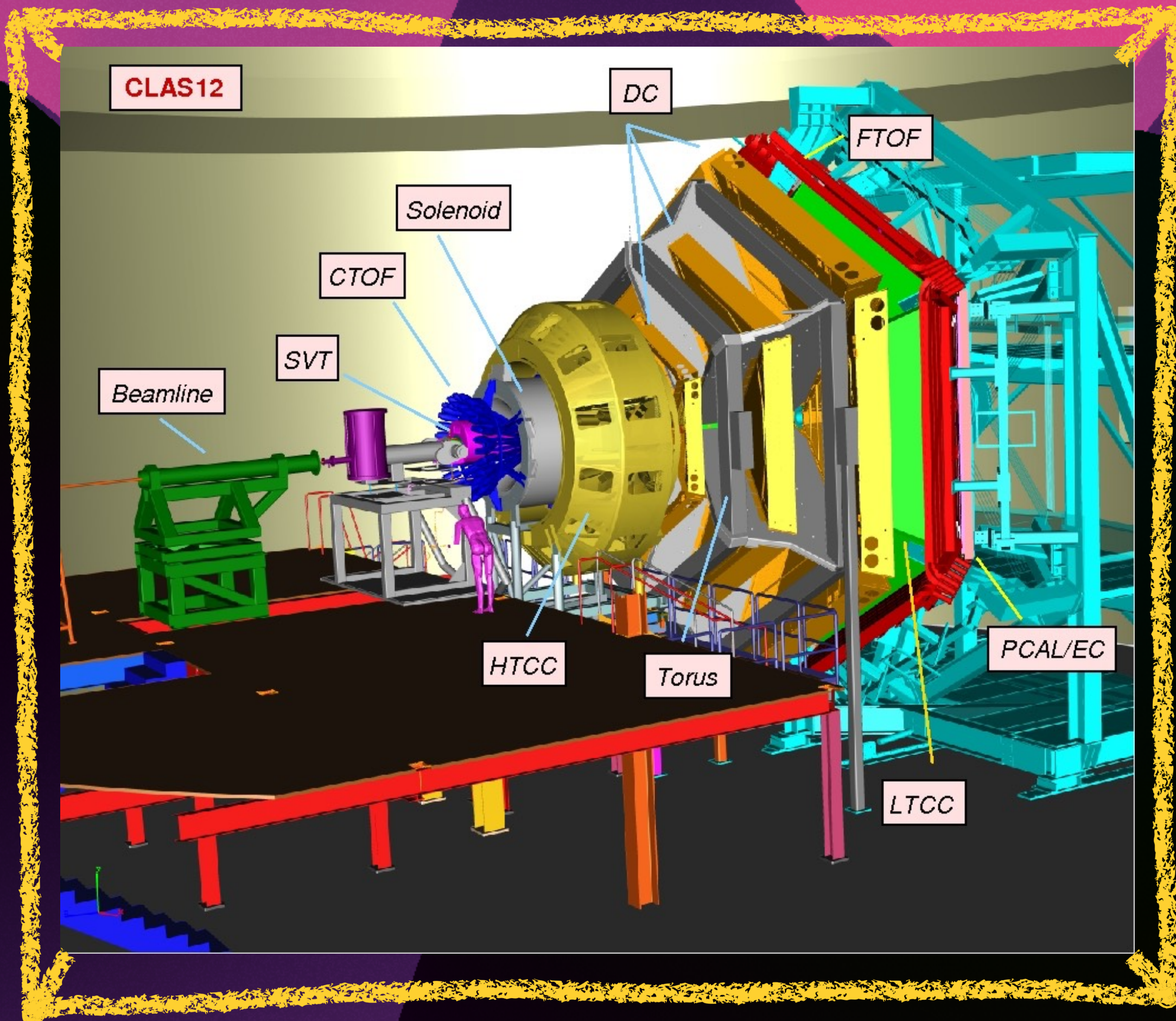


$2/3$ $1/2$ <b>C</b> charm	$-1/3$ $1/2$ <b>S</b> strange	$2/3$ $1/2$ <b>u</b> up
$-1/3$ $1/2$ <b>b</b> bottom		$-1/3$ $1/2$ <b>d</b> down

# JEFFERSON LAB

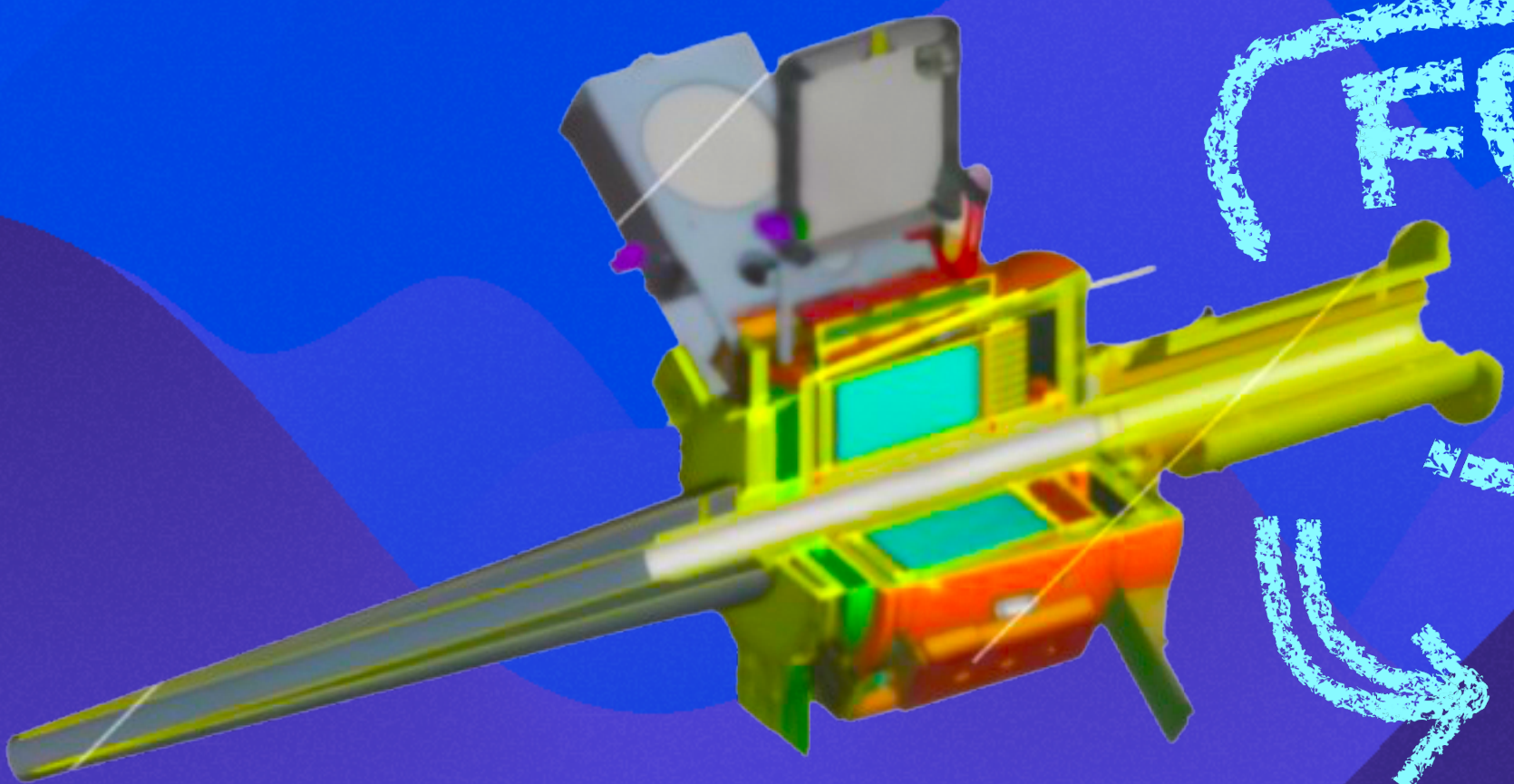


# CLAS 12



CEBAF LARGE ACCEPTANCE SPECTROMETER 11

# DETECTORS

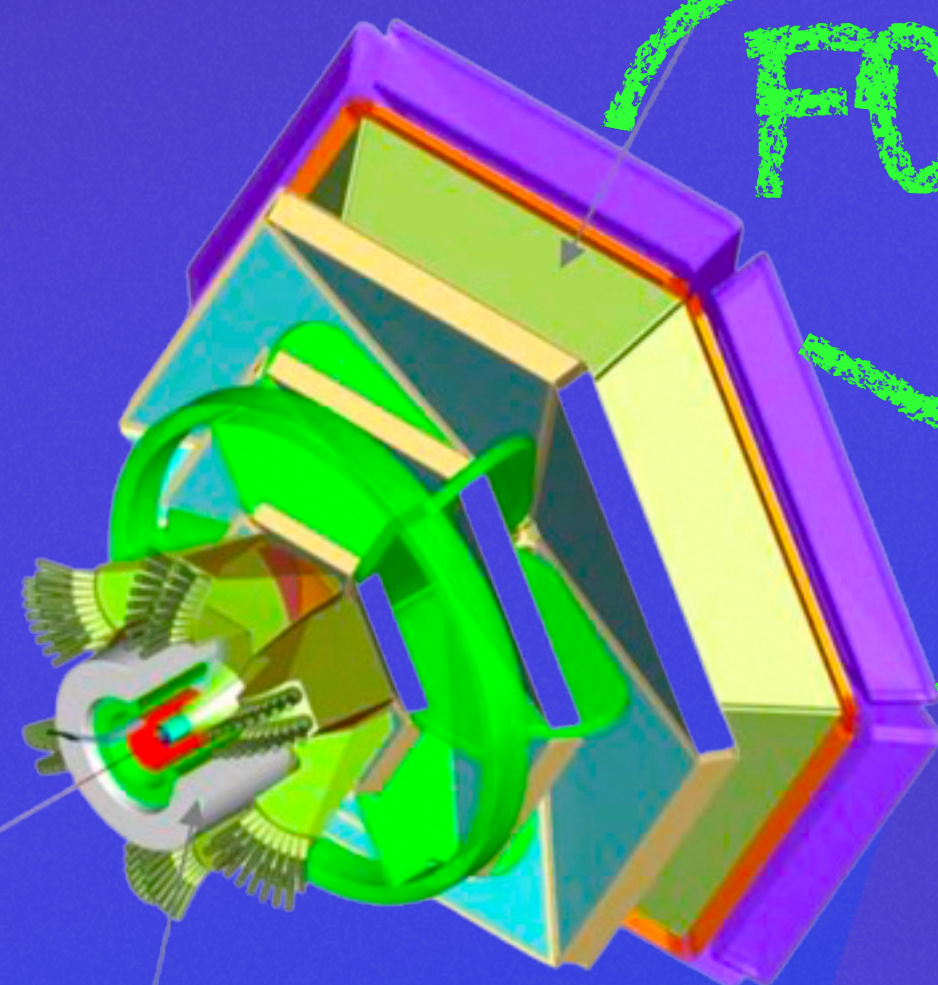


FORWARD  
TAGGER

\*  $2.5^\circ < \theta < 4.5^\circ$

\* LOW  $\theta^2$

\* CALORIMETER



FORWARD  
DETECTOR

\*  $5^\circ < \theta < 35^\circ$

\* HIGH  $\theta^2$

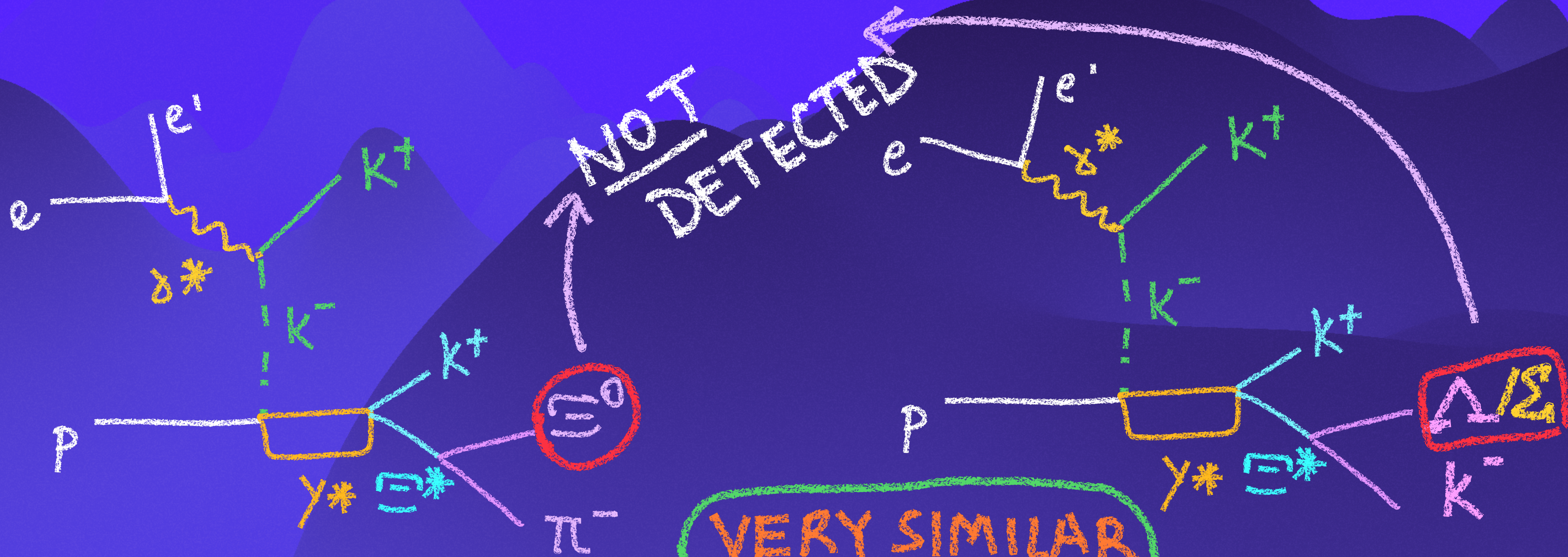
\* MAGNETIC SPECTROSCOPY

! LARGE

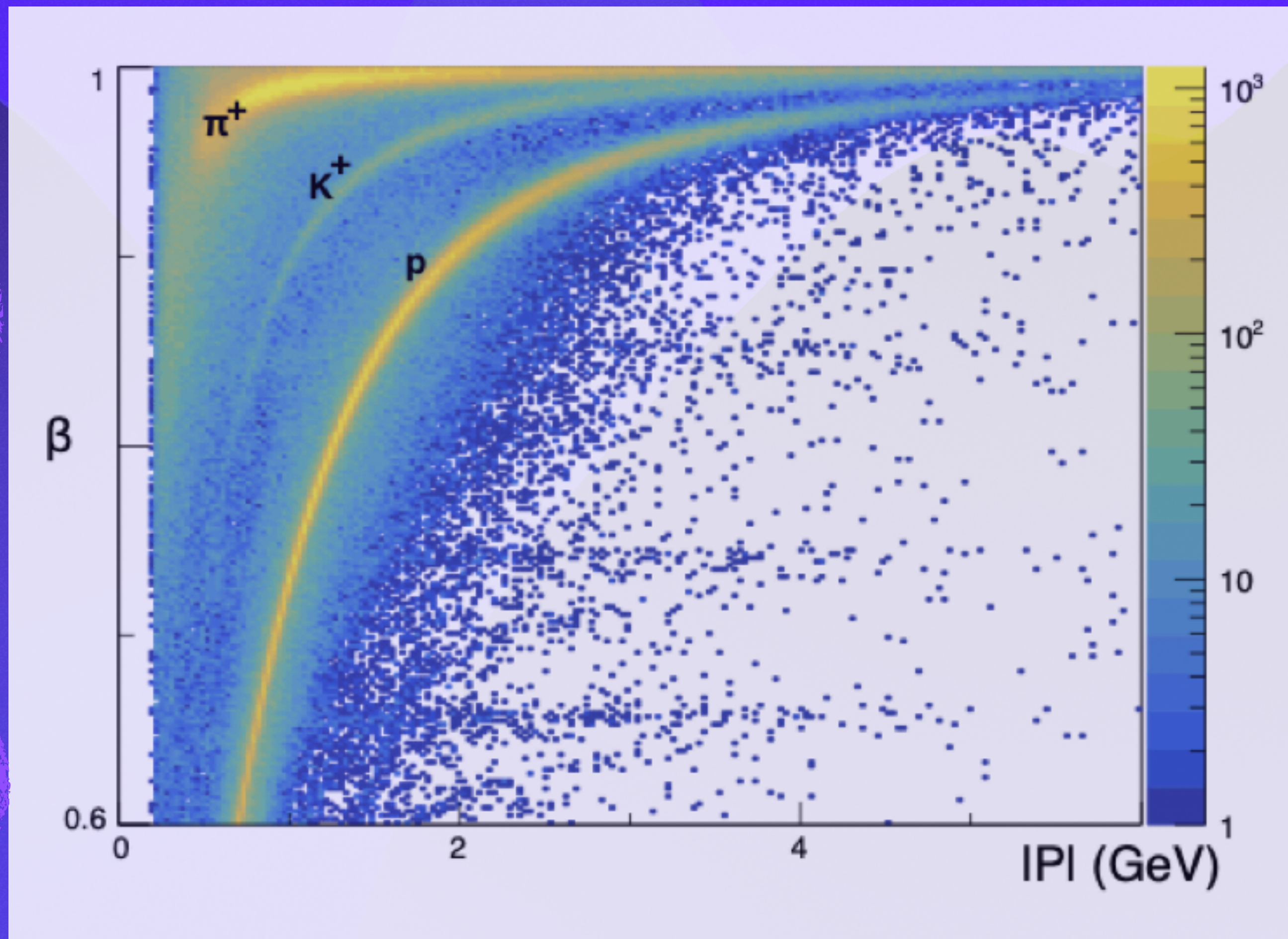
ACCEPTANCE!

UP TO  $125^\circ$

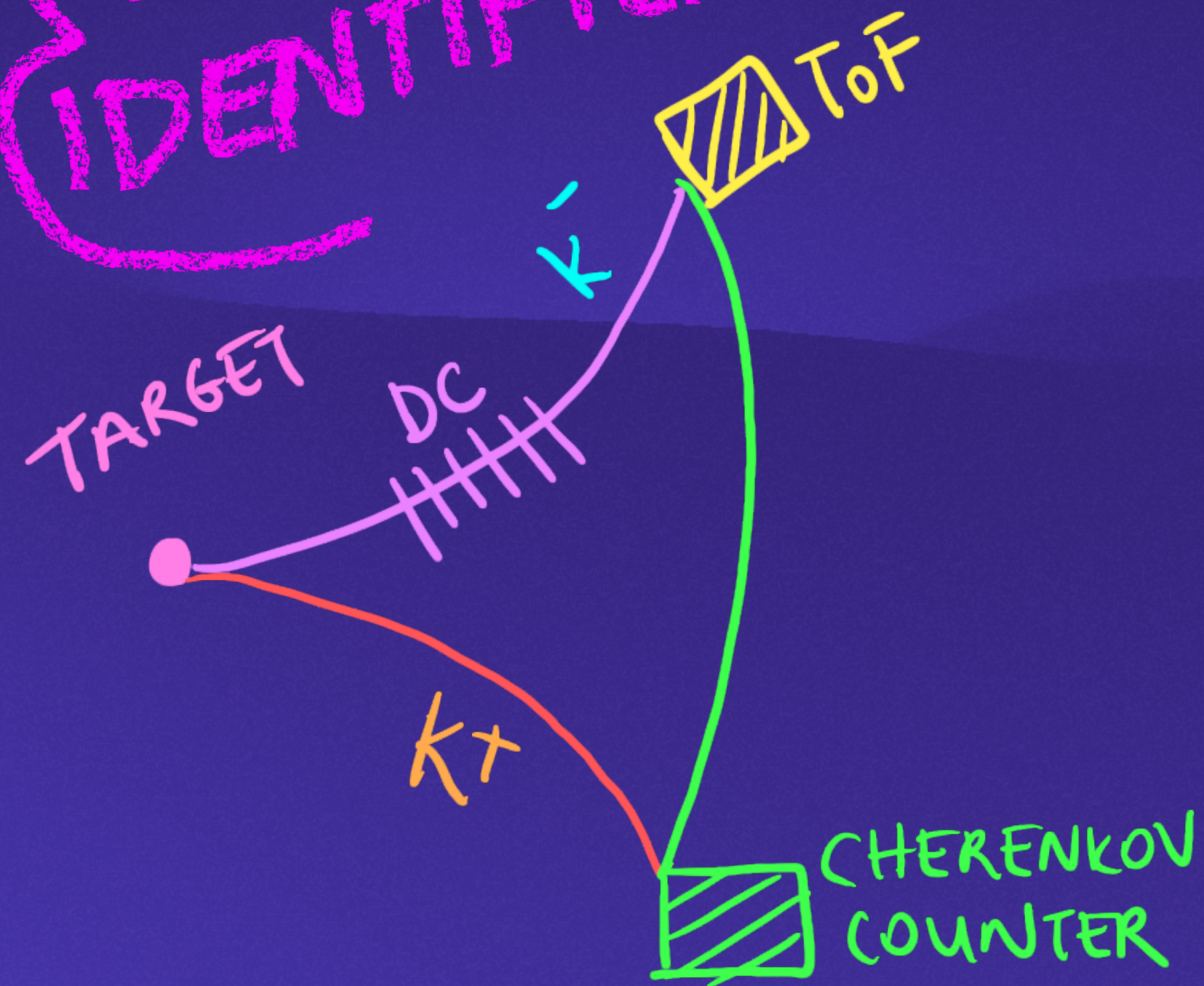
# THE CHANNELS



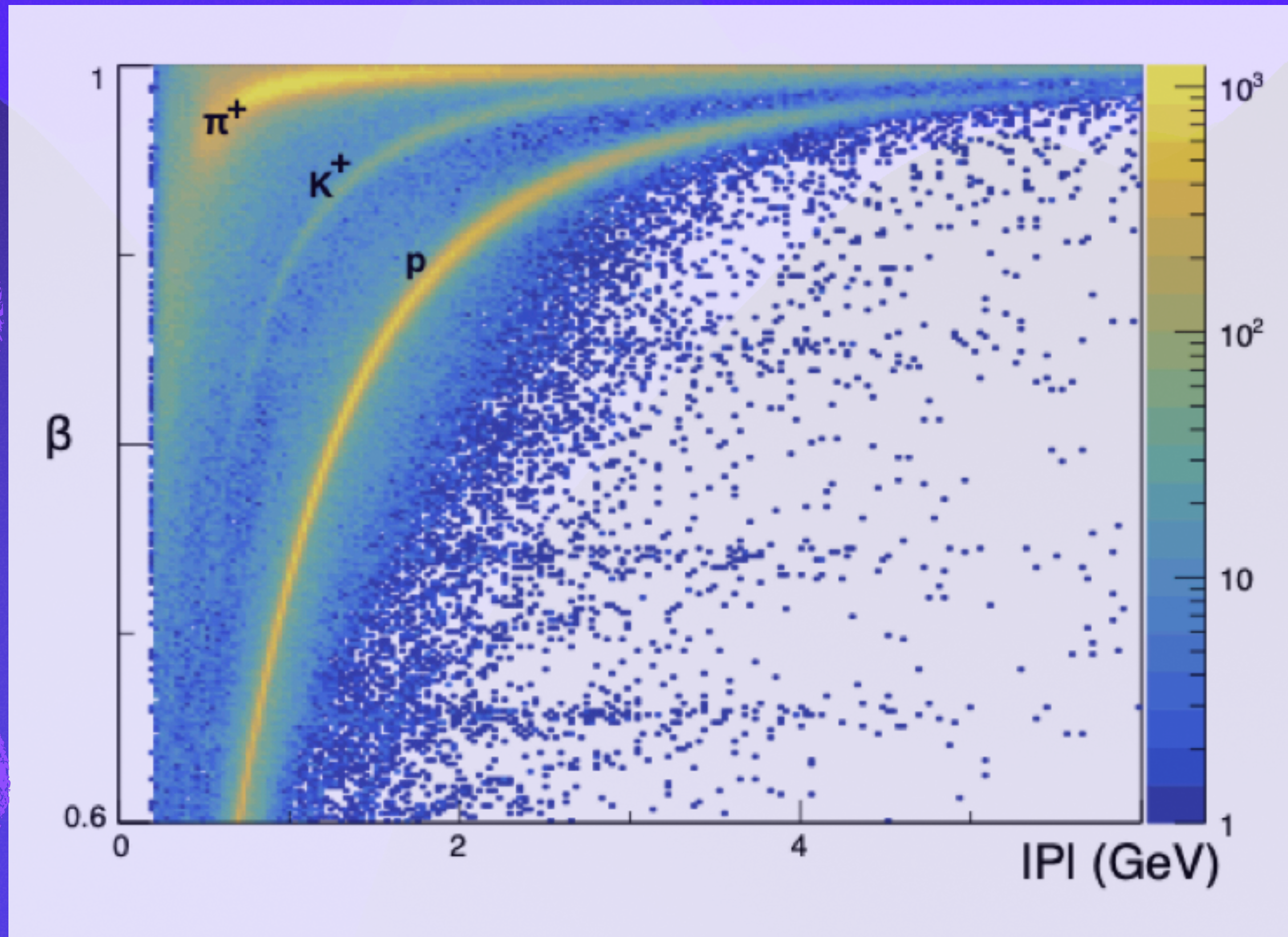
# PID



PARTICLE IDENTIFICATION



# PID

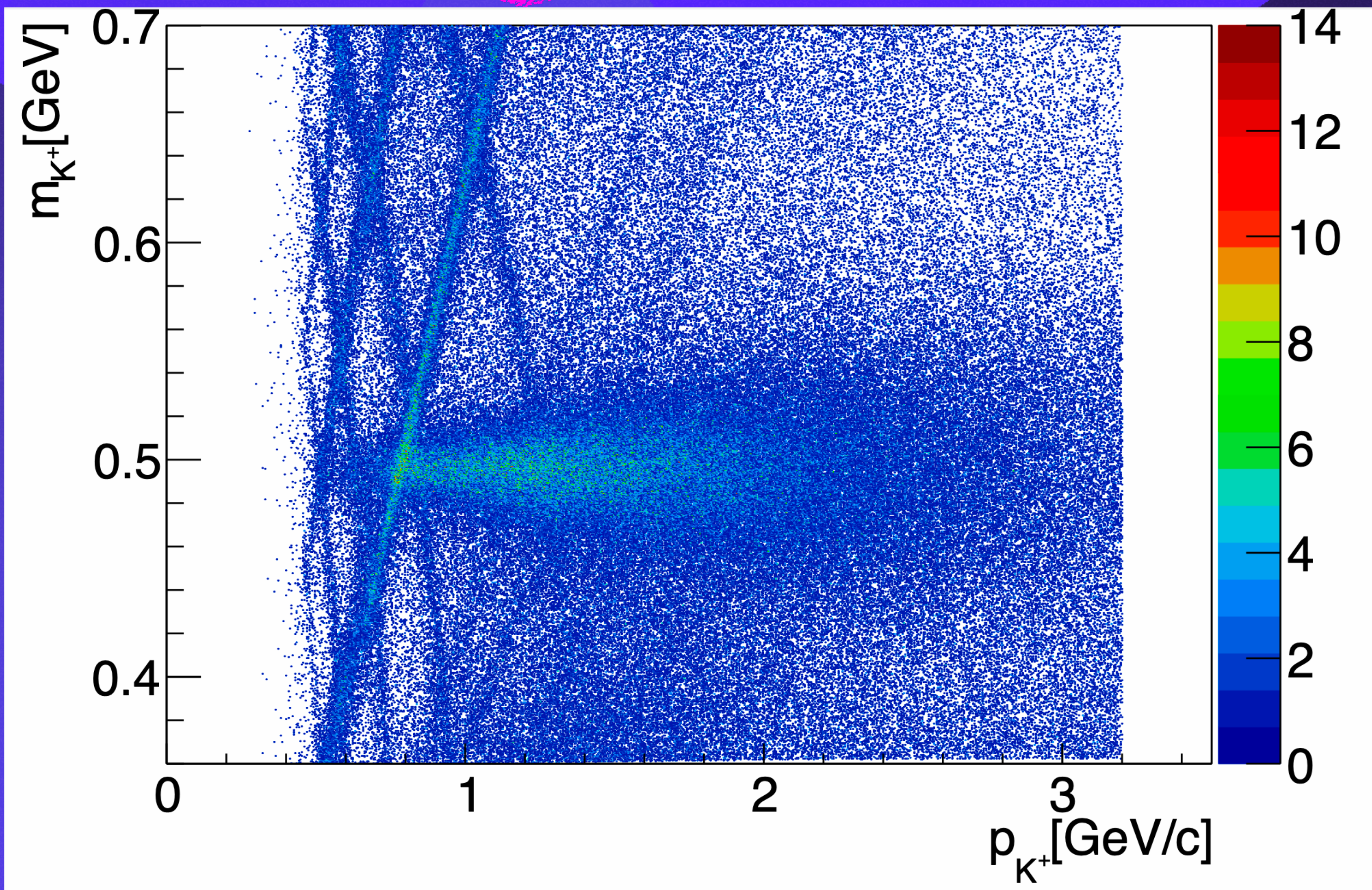


$$m^2 = \frac{|P_1|^2}{\beta^2} - |P_1|^2$$

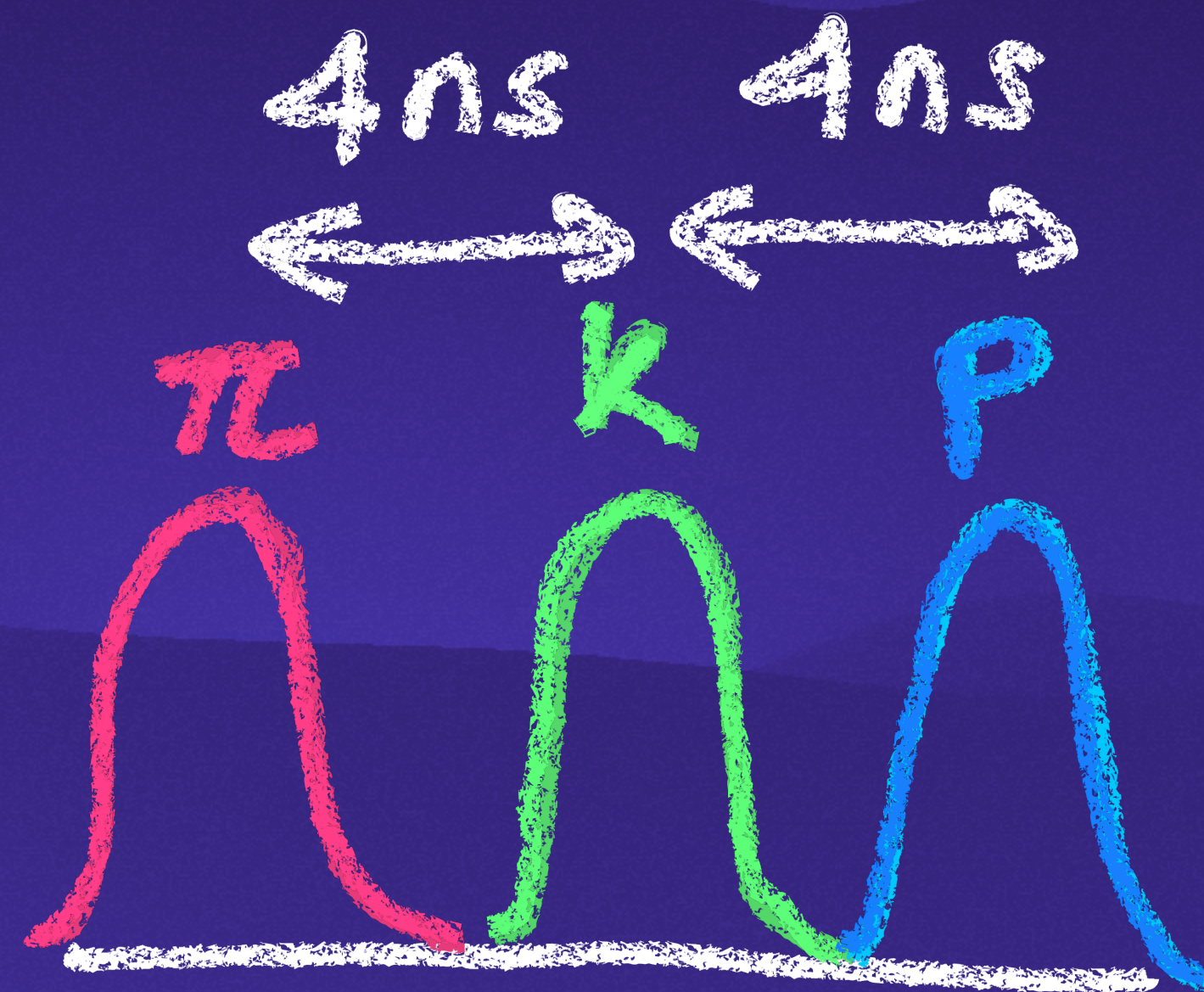
WHERE

$$\beta = \frac{v}{c}$$

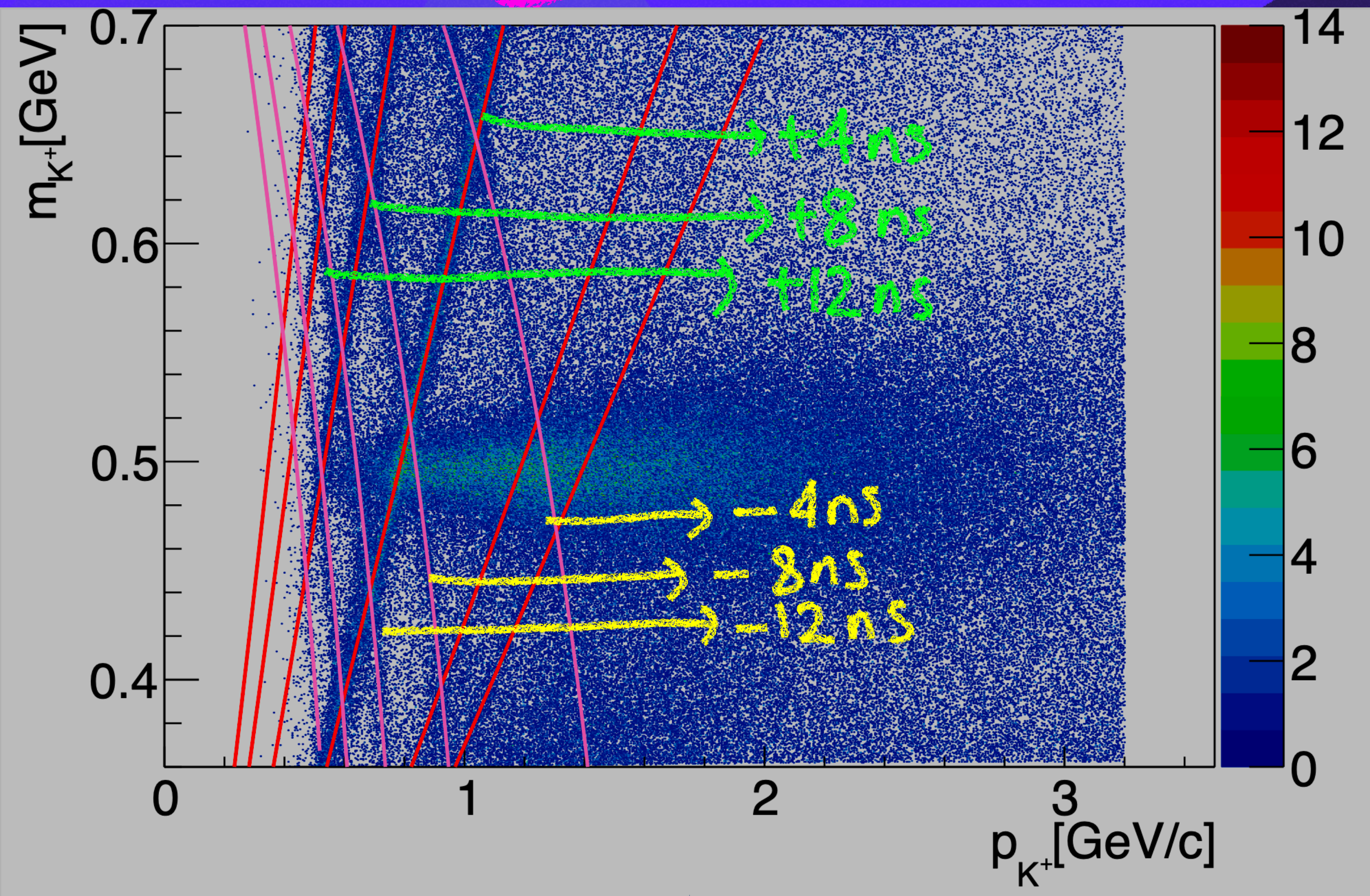
# PIID



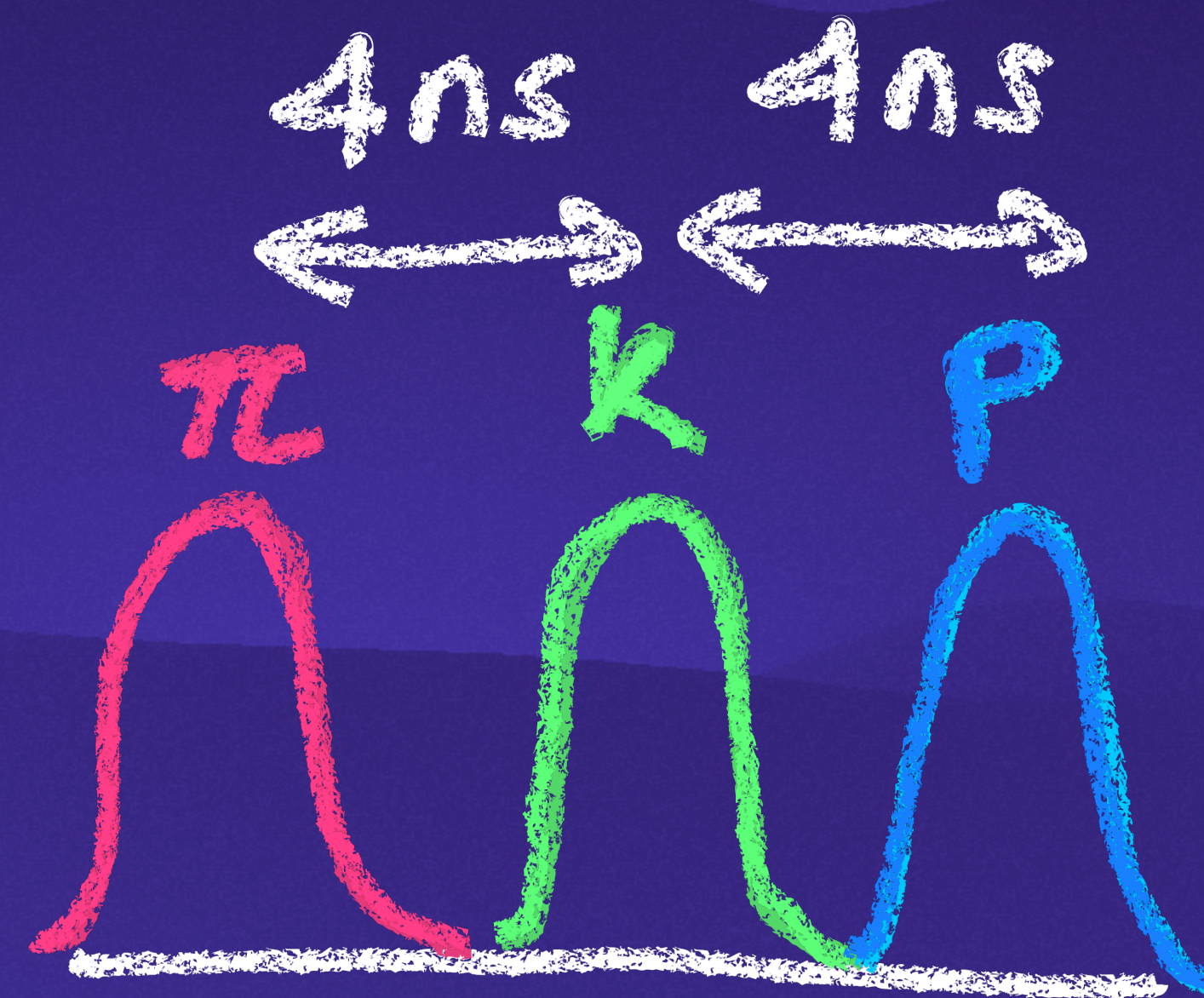
## OUT-OF-TIME BG



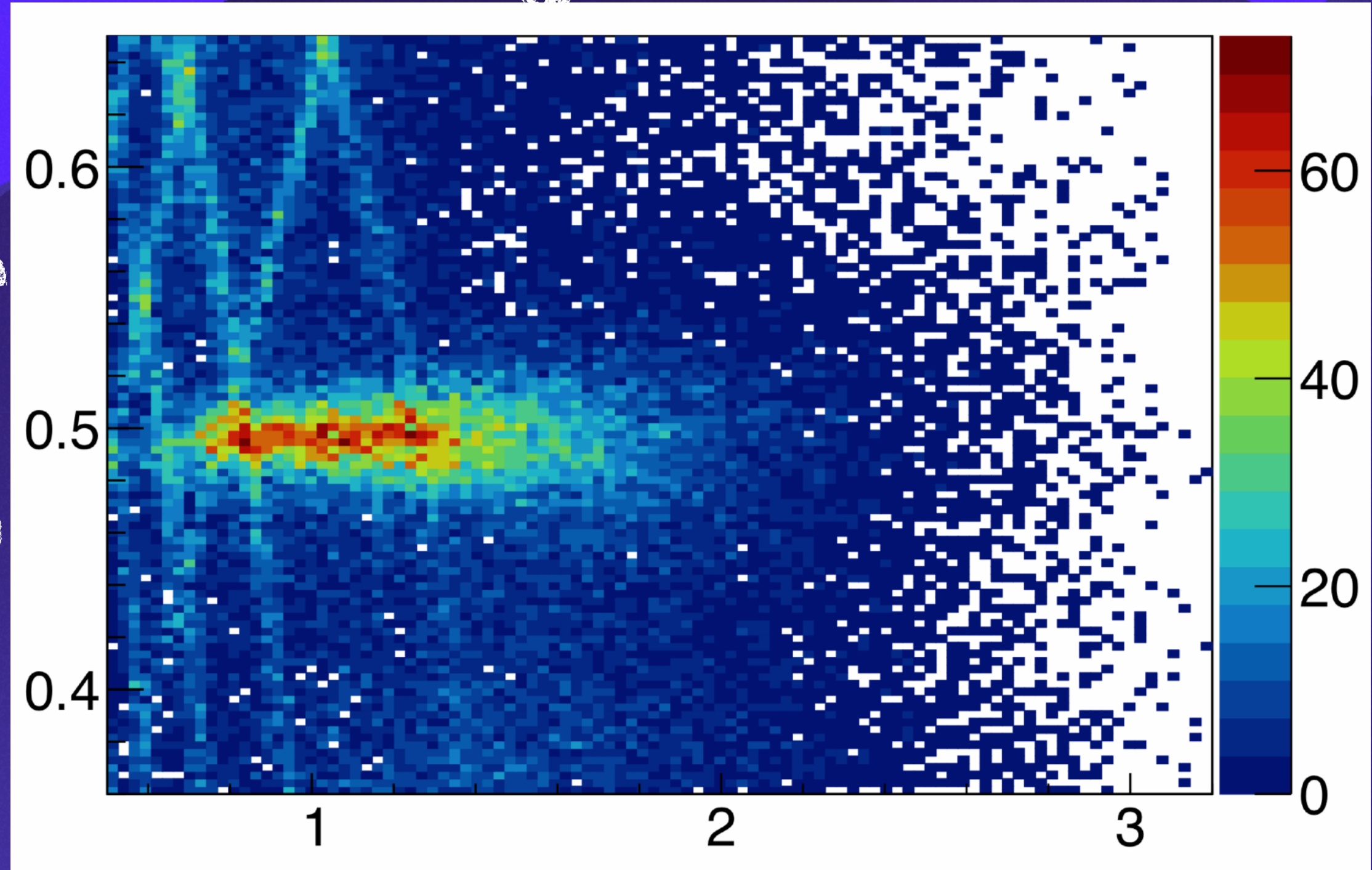
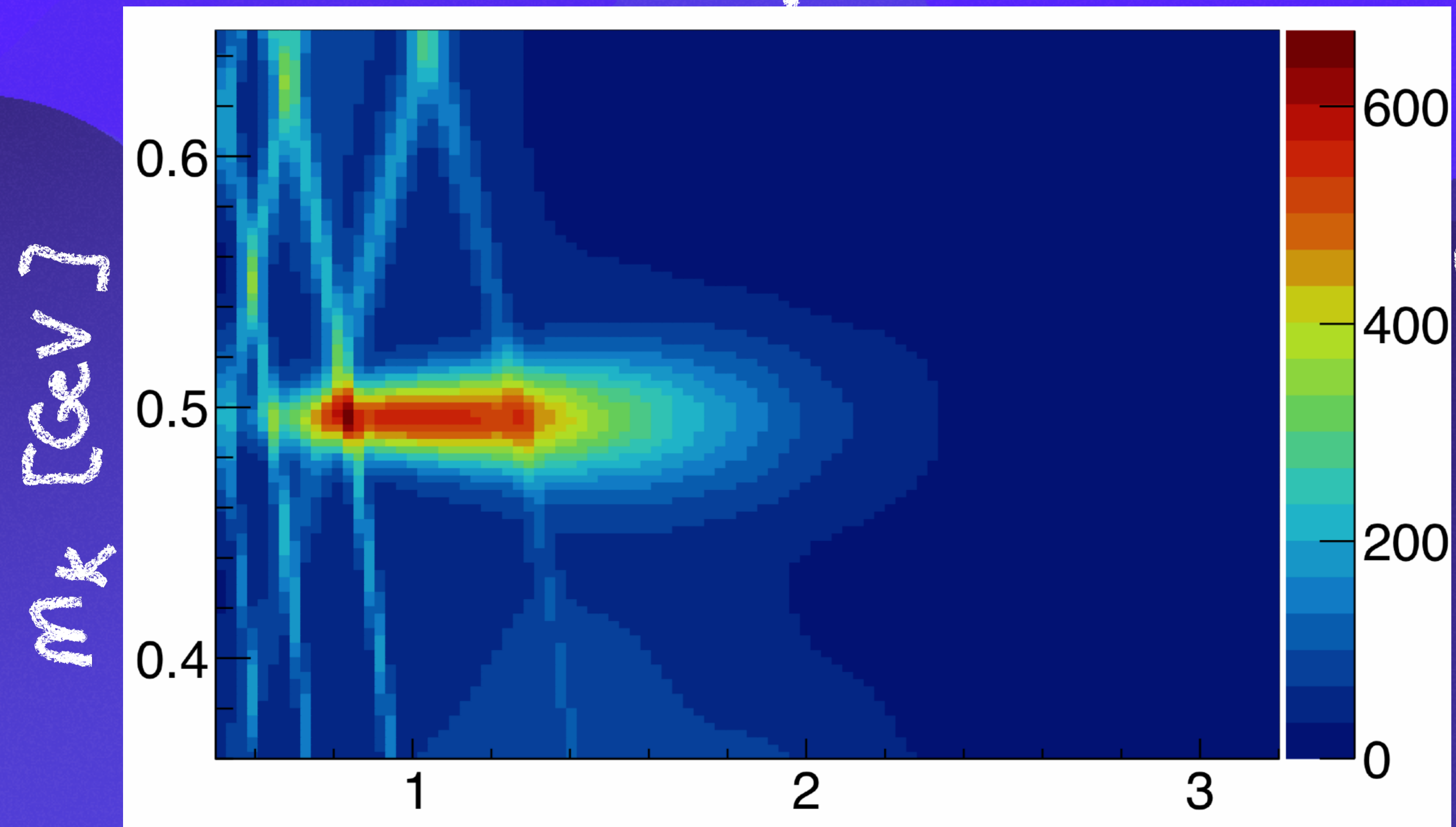
# PIID



## OUT-OF-TIME BG



# MODEL vs DATA

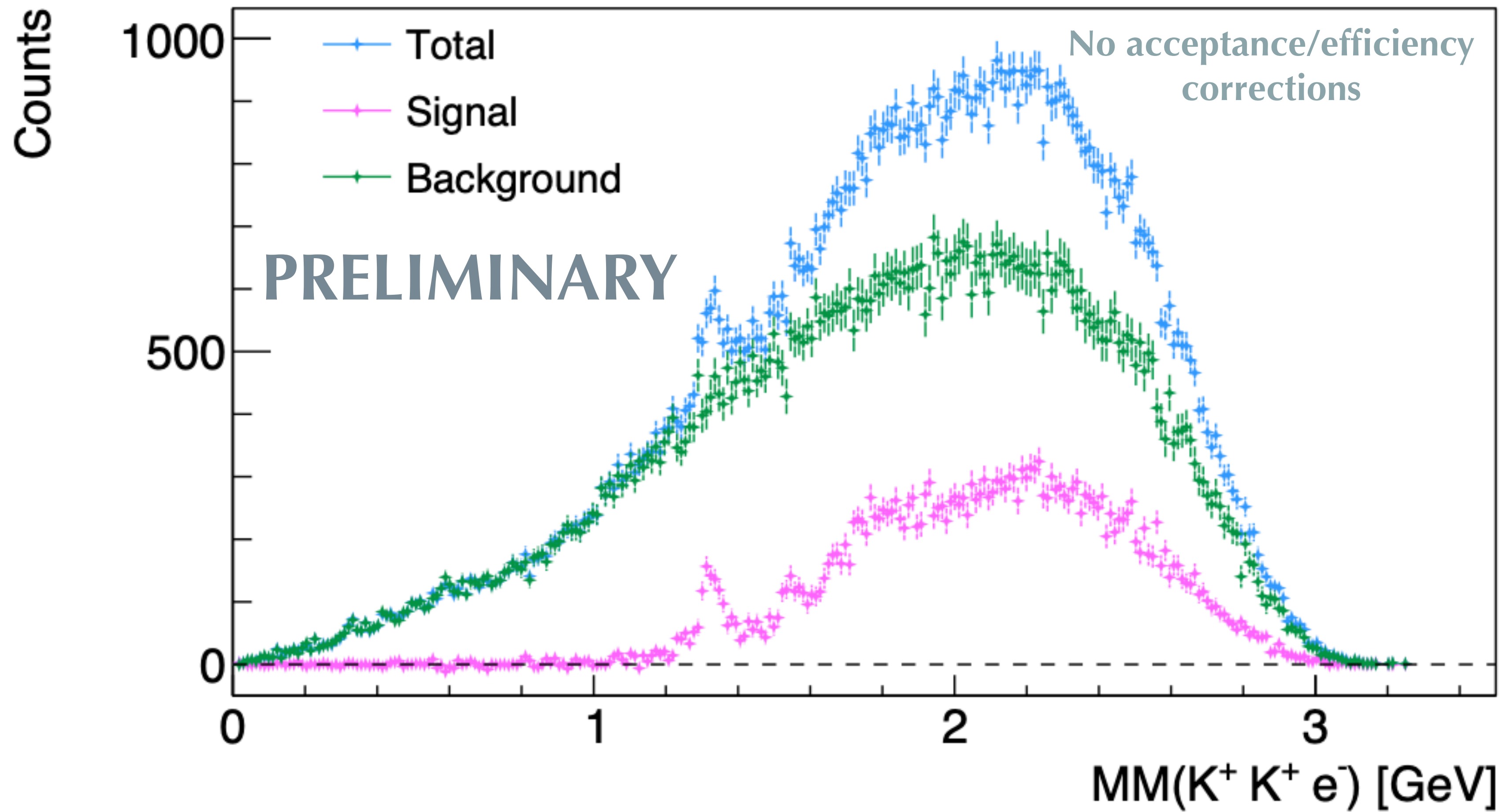


$P_k$  [GeV/c]

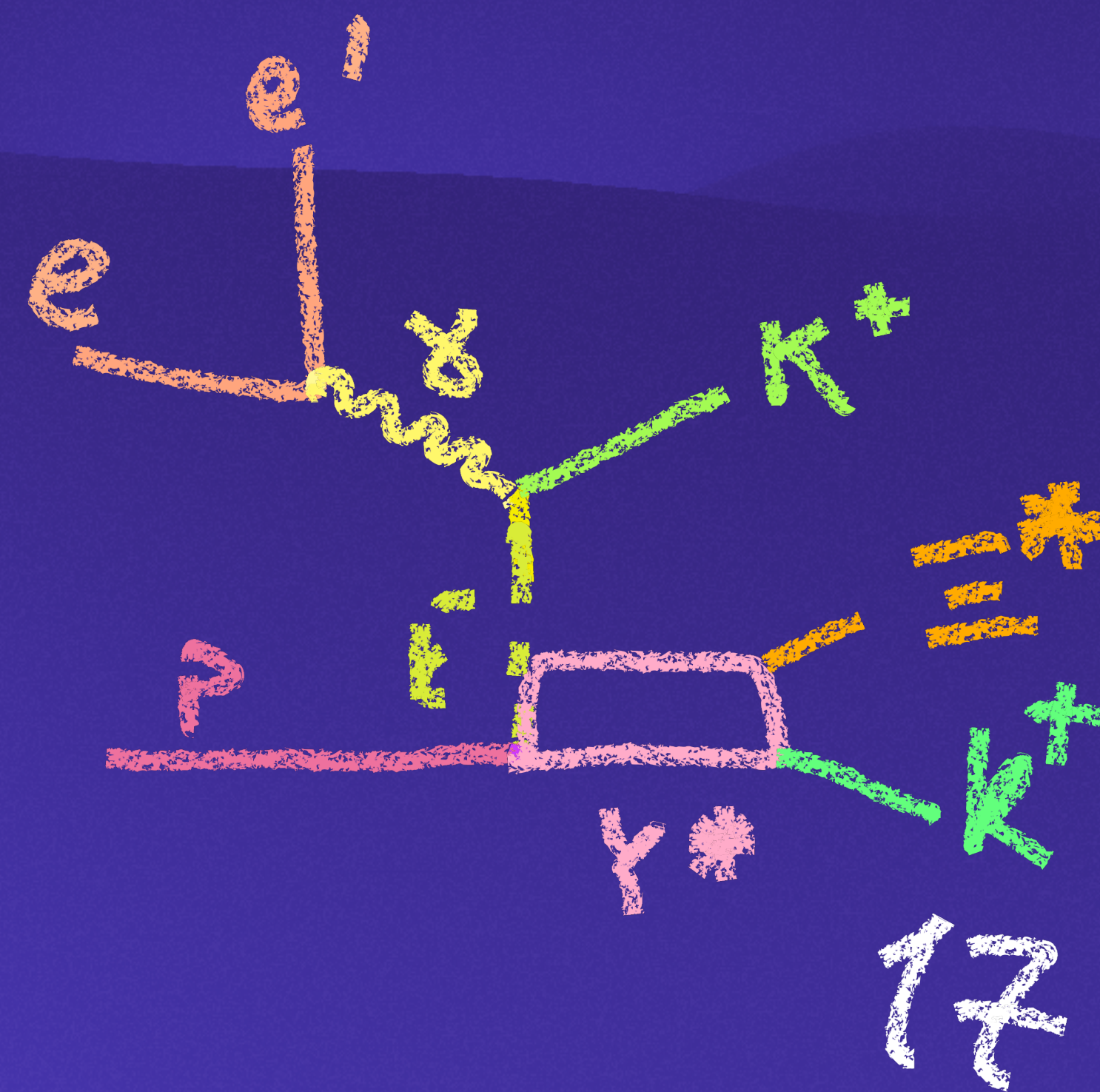
$P_k$  [GeV/c]

USED FOR BKG SUPPRESSION IN S-WEIGHTS

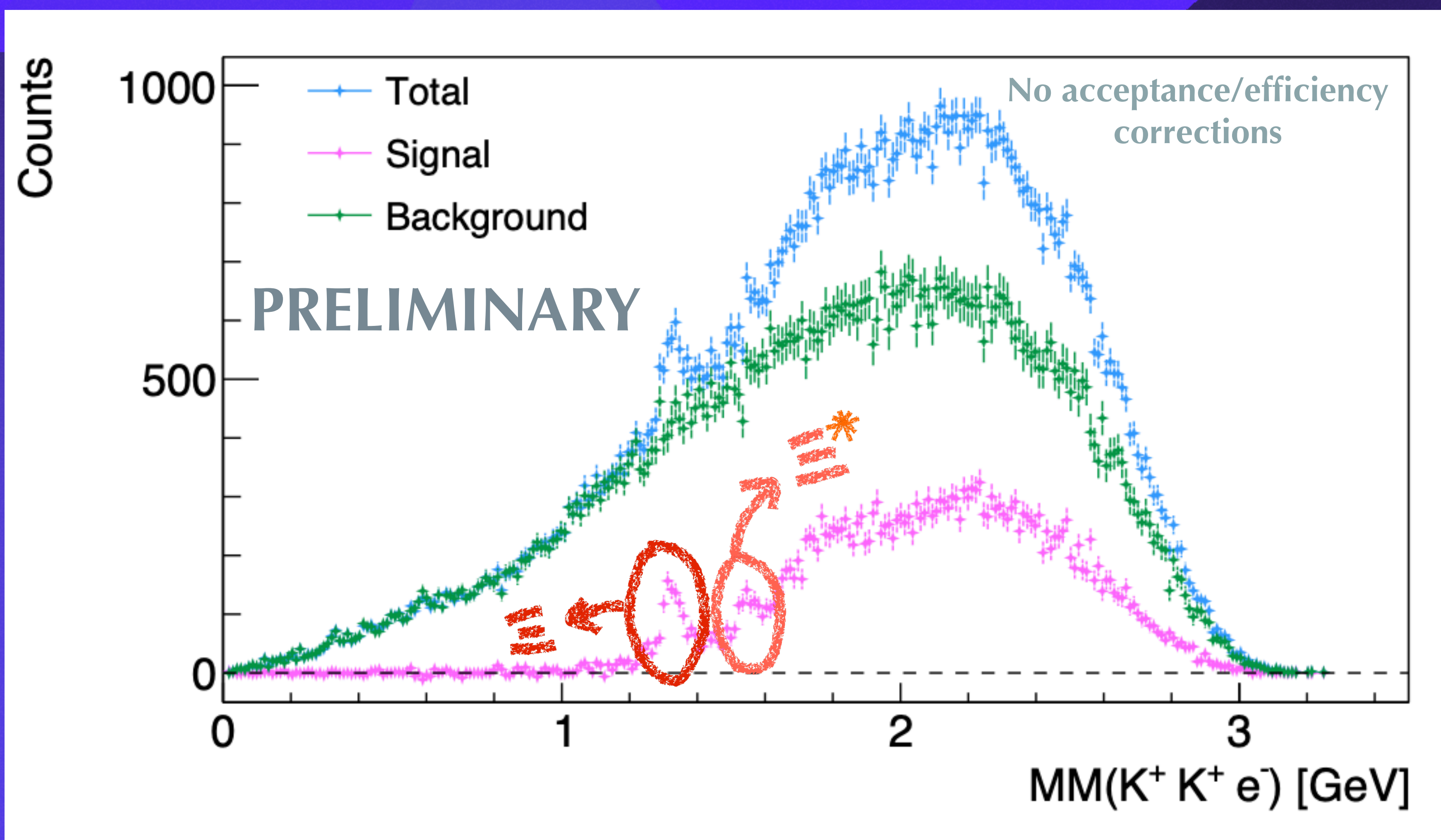
# BENCHMARK: CASCADES



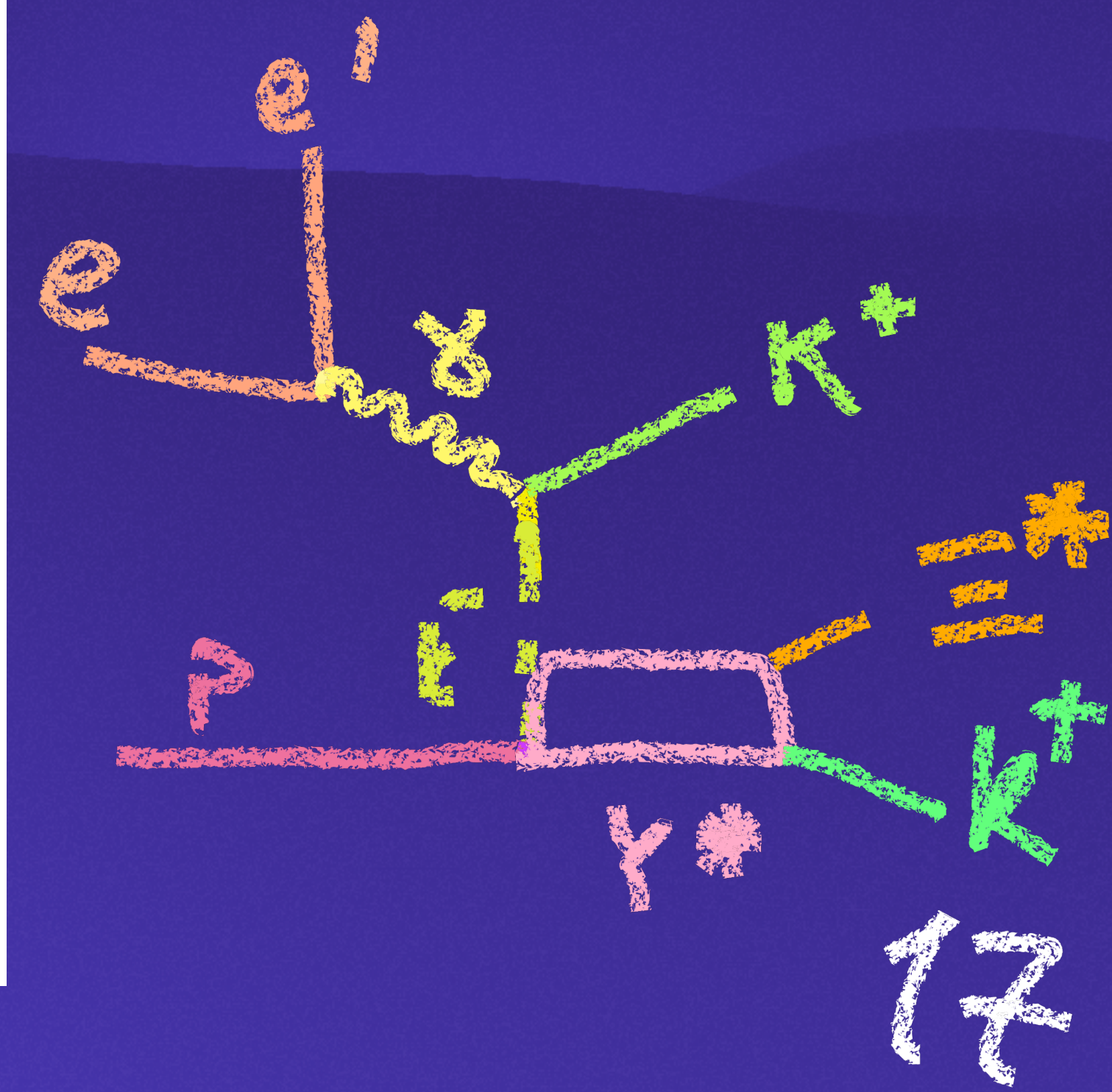
TOTAL, SIG  
& BG  
DISTRIBUTIONS  
FROM S-WEIGHTS



# BENCHMARK: CASCADES

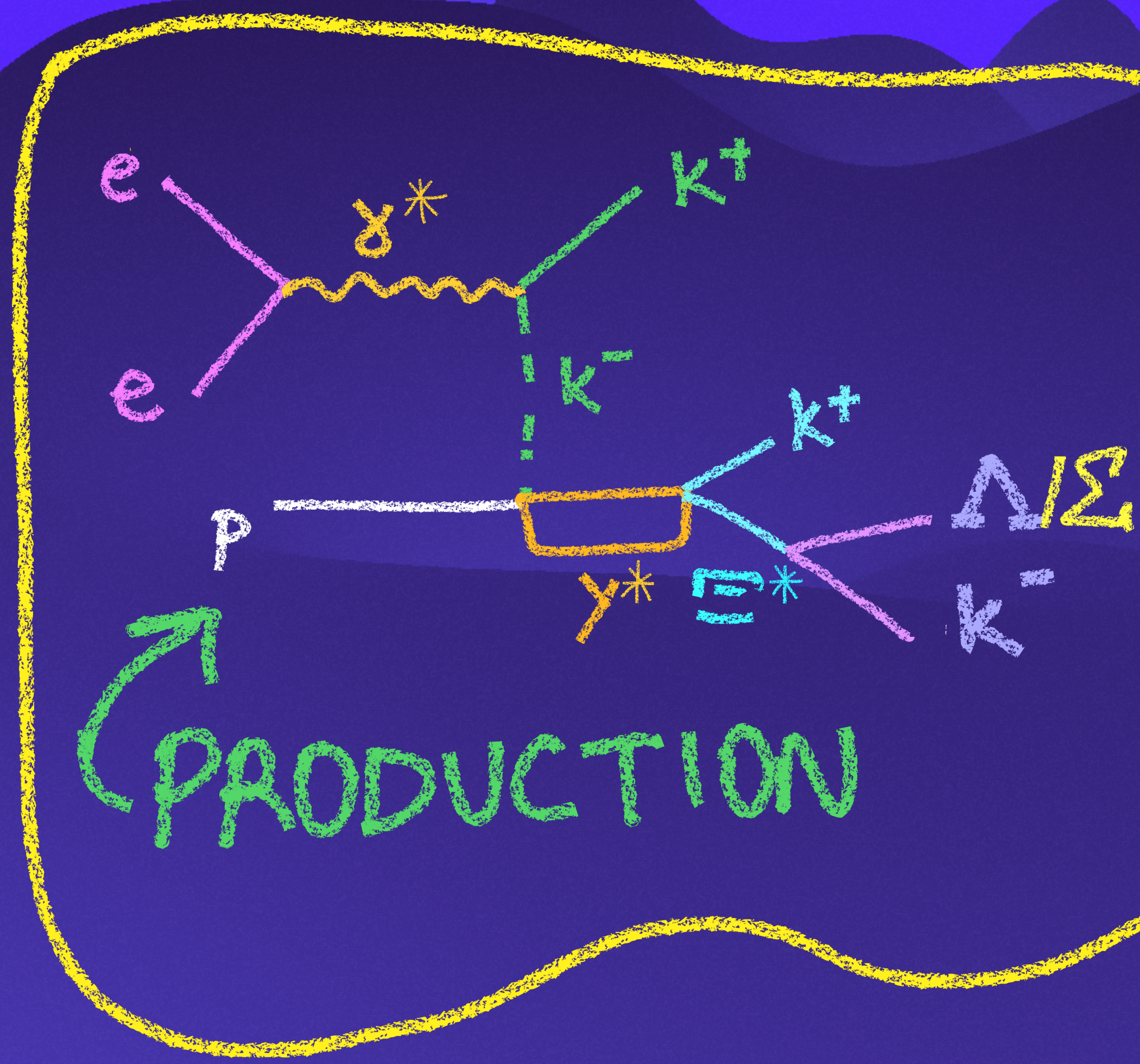
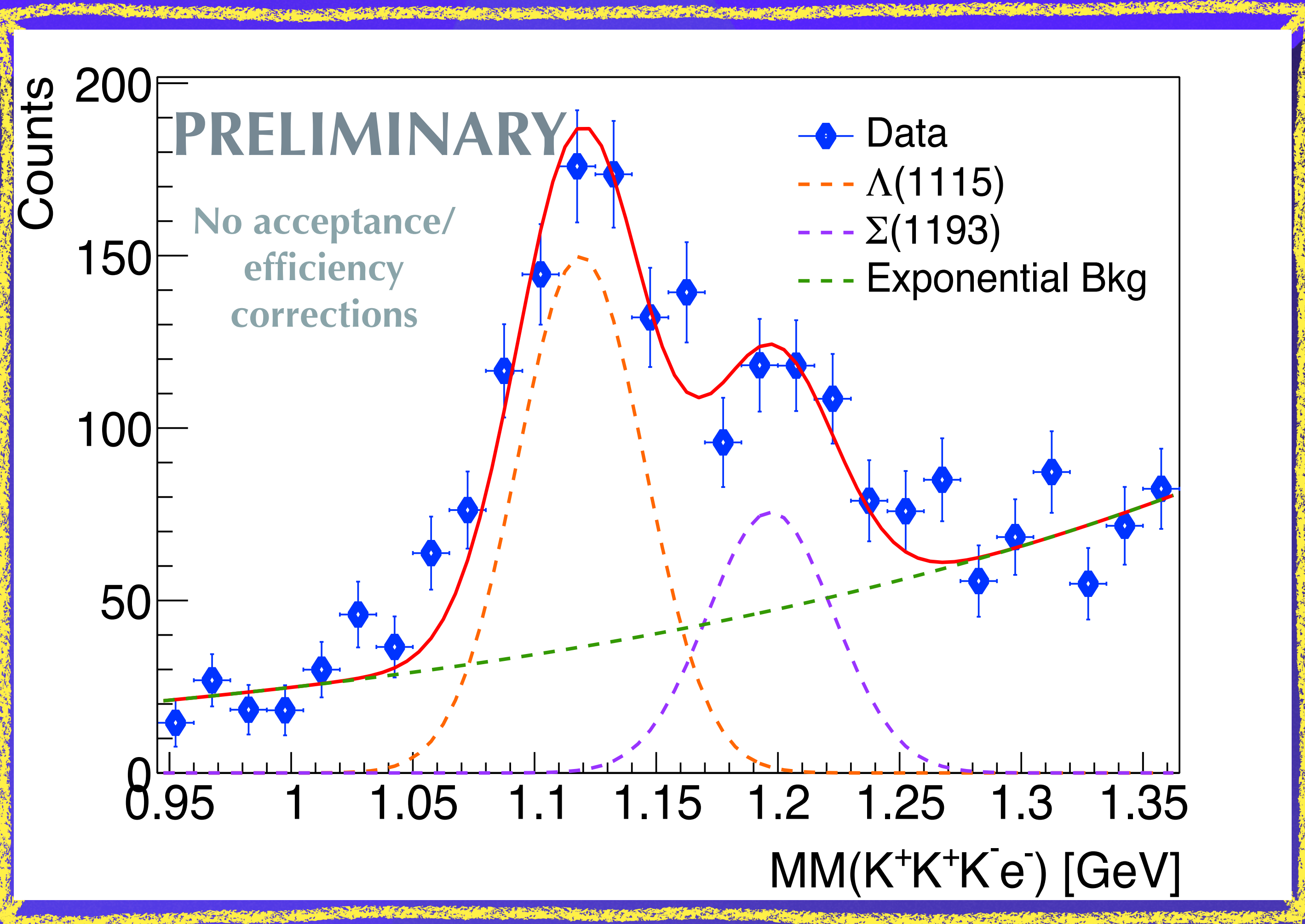


TOTAL, SIG  
& BG  
DISTRIBUTIONS  
FROM S-WEIGHTS



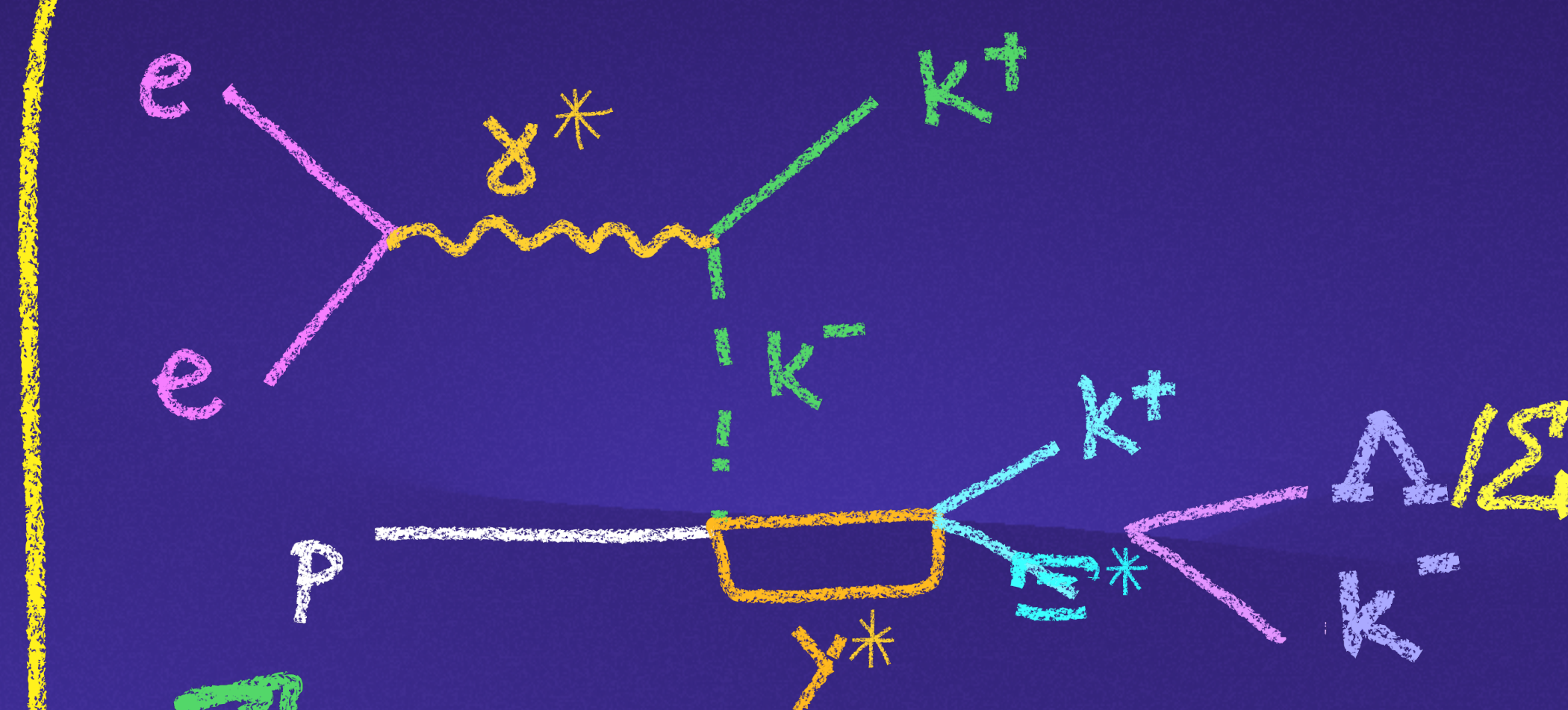
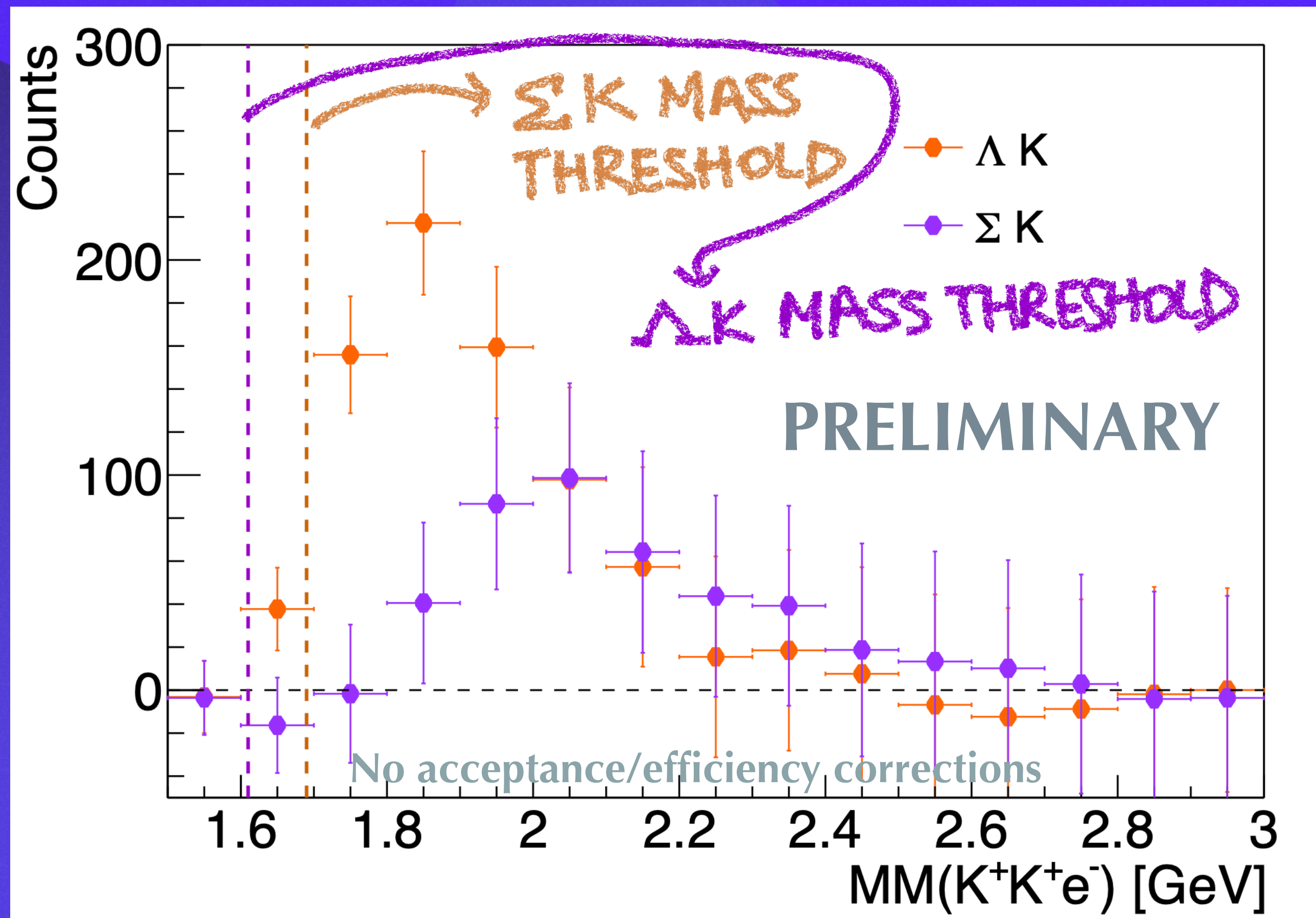
# $K^+K^+K^-\Lambda/\Sigma$

# CHANNEL



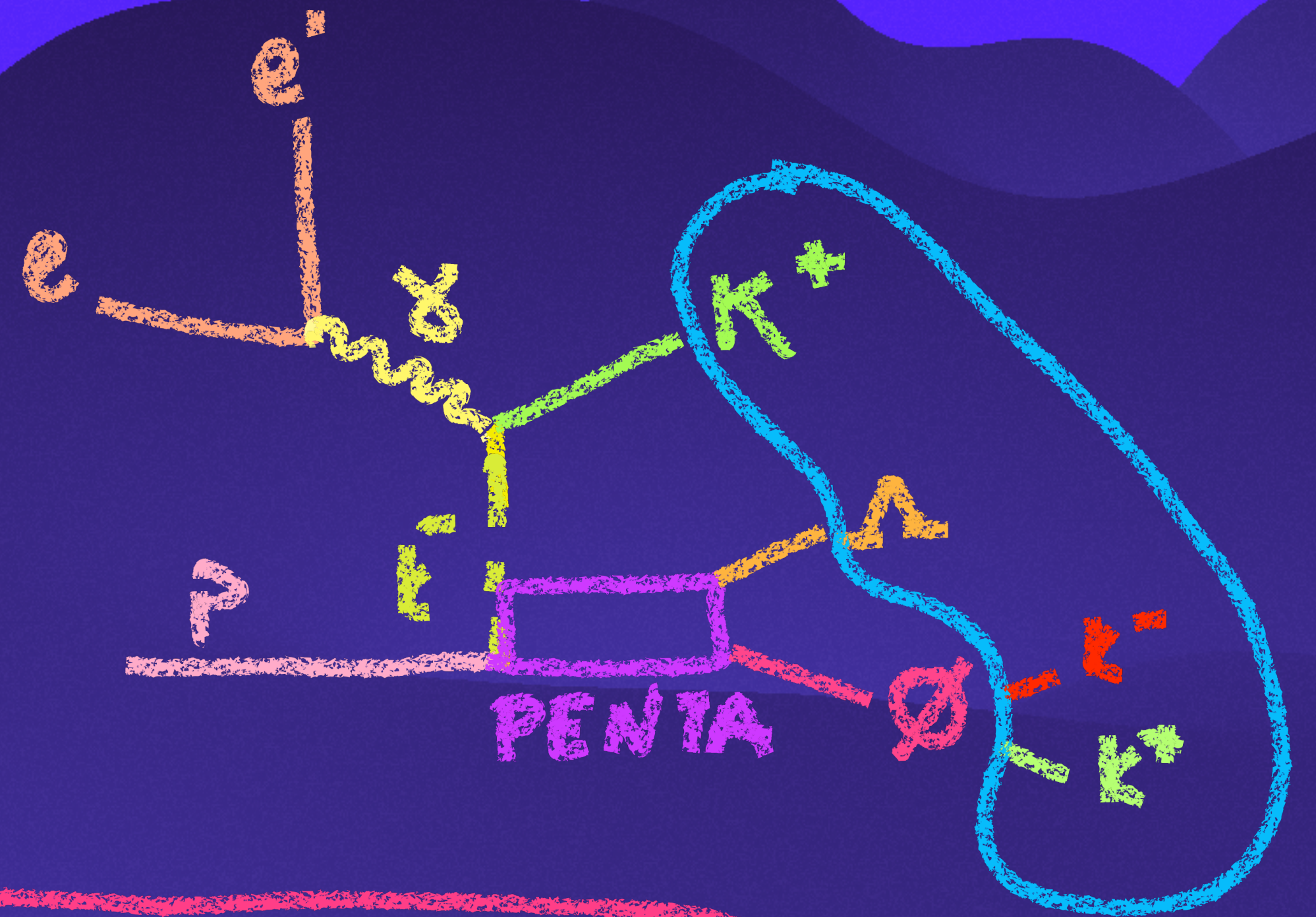
$K^+K^+K^- \Delta/\Sigma$

CHANNEL



# ALL CHANNELS

20



ONE FINAL  
STATE TO RULE THEM ALL!

# CONCLUSIONS

- \* ONE FINAL STATE TO RULE THEM ALL
  - \* PENTAQUARK, TETRAQUARK, CASCADE.
- \* CASCADE MOLECULES
- \*  $\Delta K / \Sigma K / \Xi TL$  BRANCHING RATIOS &  $J^P$ 
  - FIRST IN ELECTROPRODUCTION!