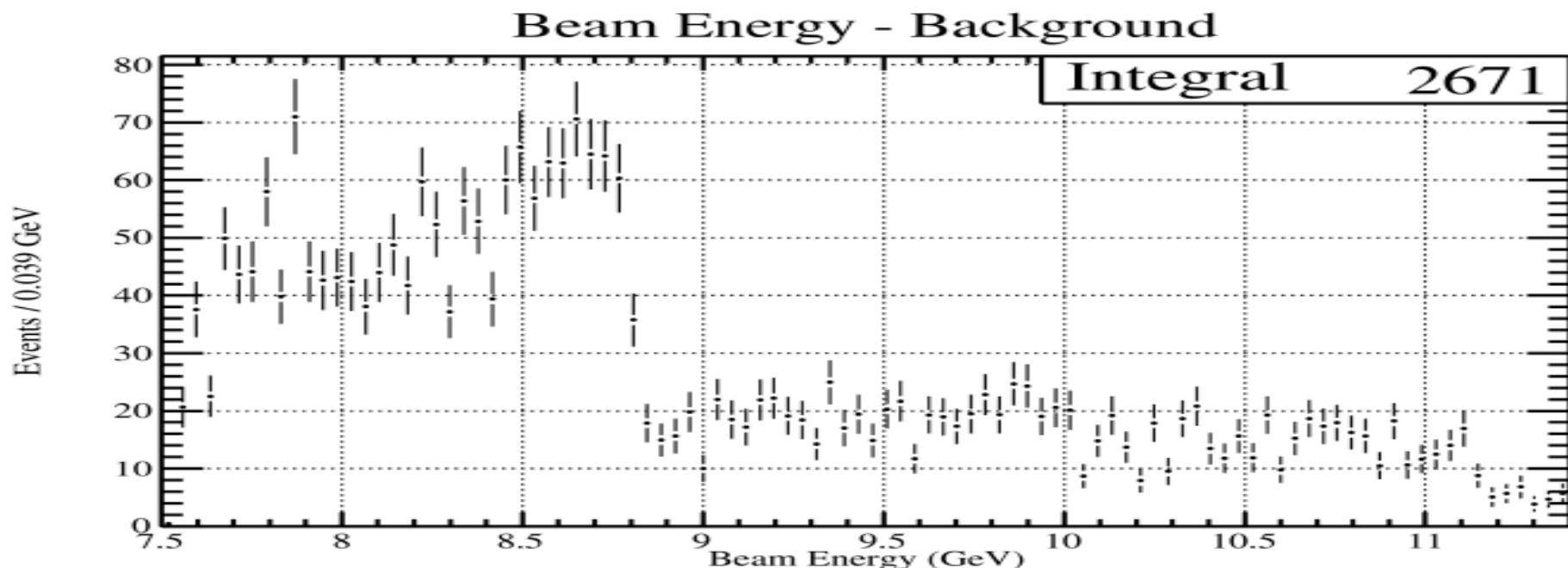
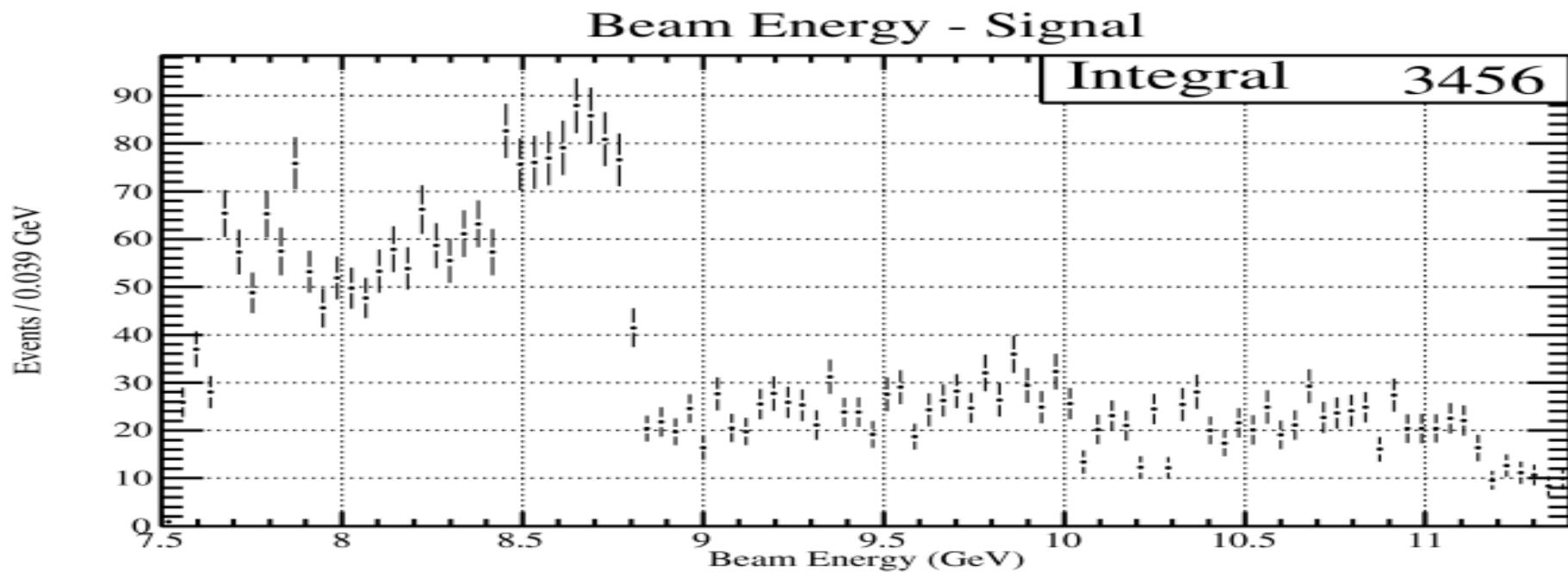


# List of things this talk will discuss:

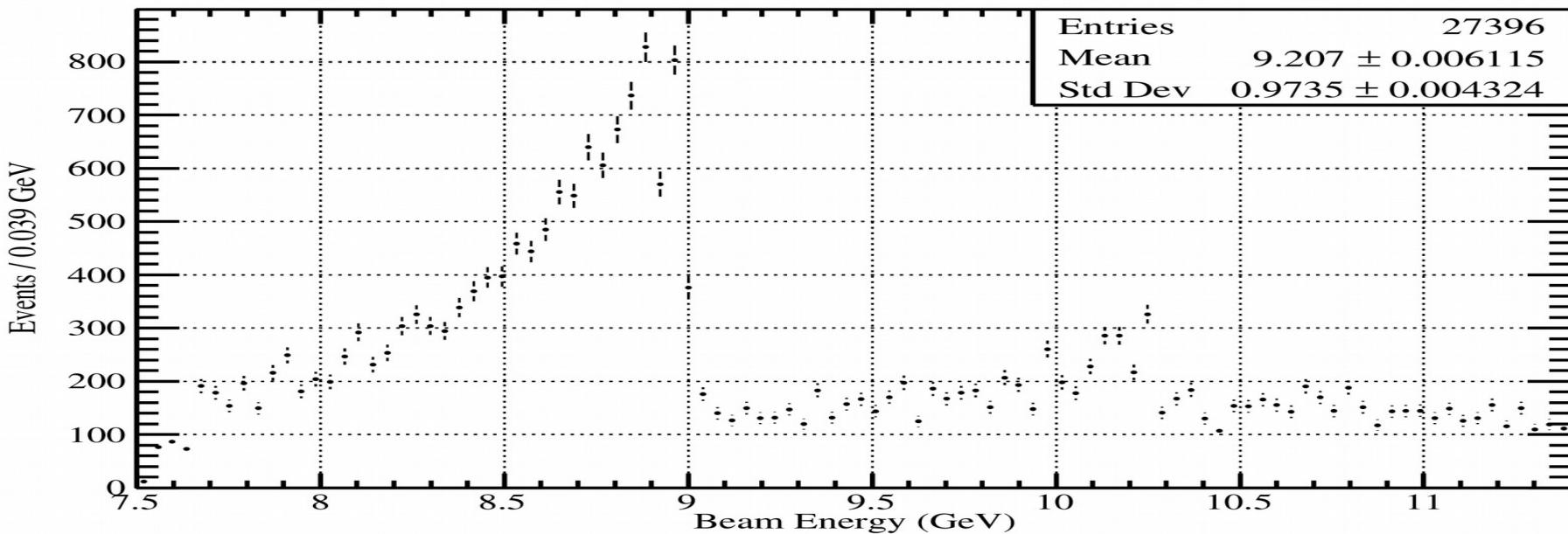
- Comparison between Data and MC using Qvalue Method
- First Look at Phi Eta Mass Acceptance
- Understanding the QValue Plots:
  - Why does a resonance like structure appear in the background plot for the Phi Eta Mass?
  - What do things look like for Phi Only Qvalue?
  - What do things look like for Eta Only Qvalue?
- A literary review of Phi Eta and some educated guessing

# Beam Energy: Data

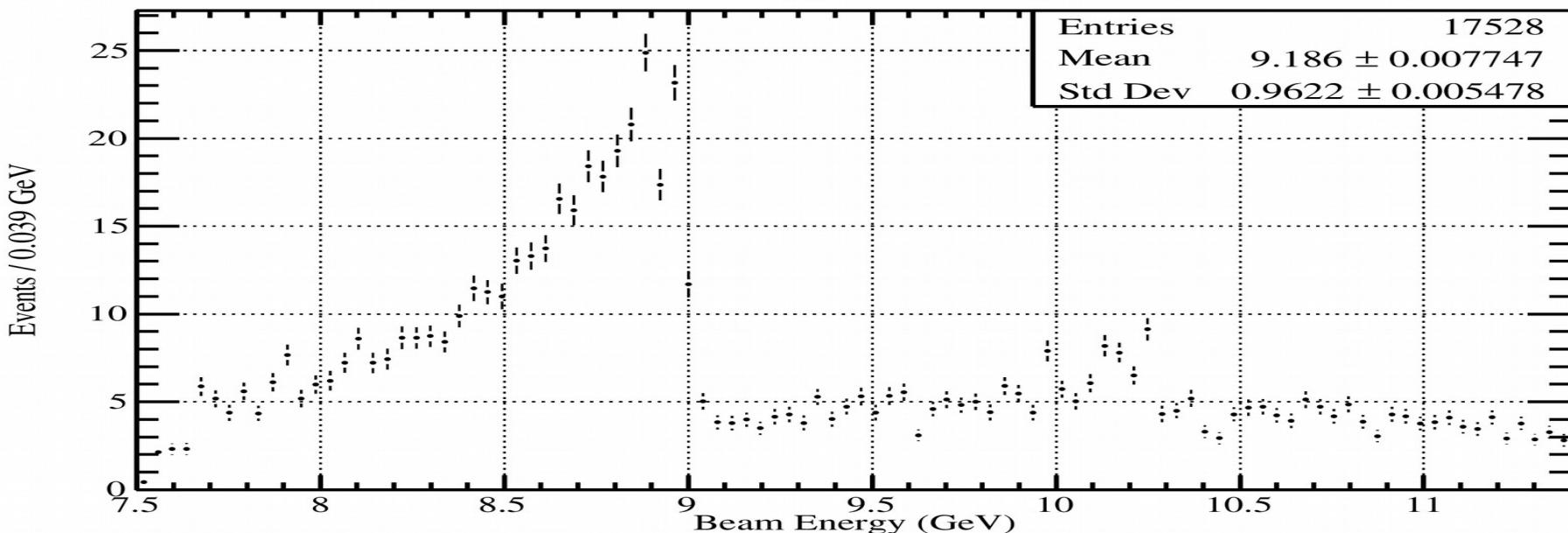


# Beam Energy: MC

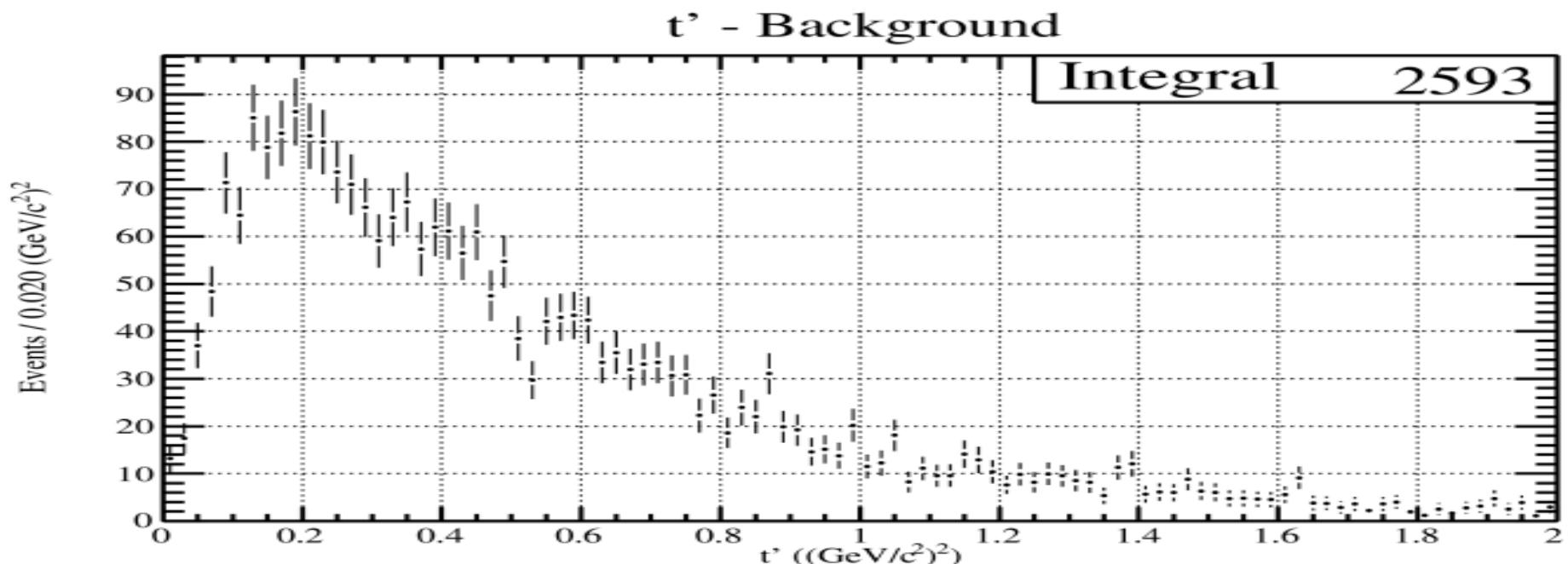
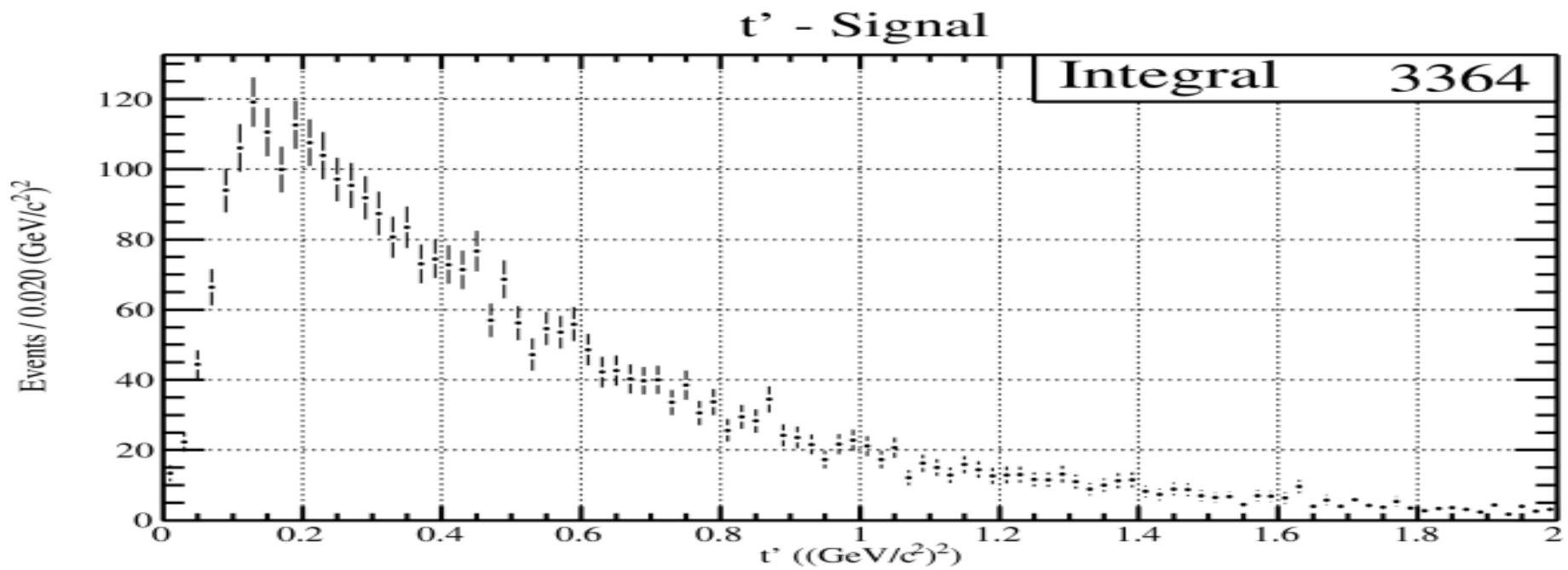
Beam Energy - Signal



Beam Energy - Background

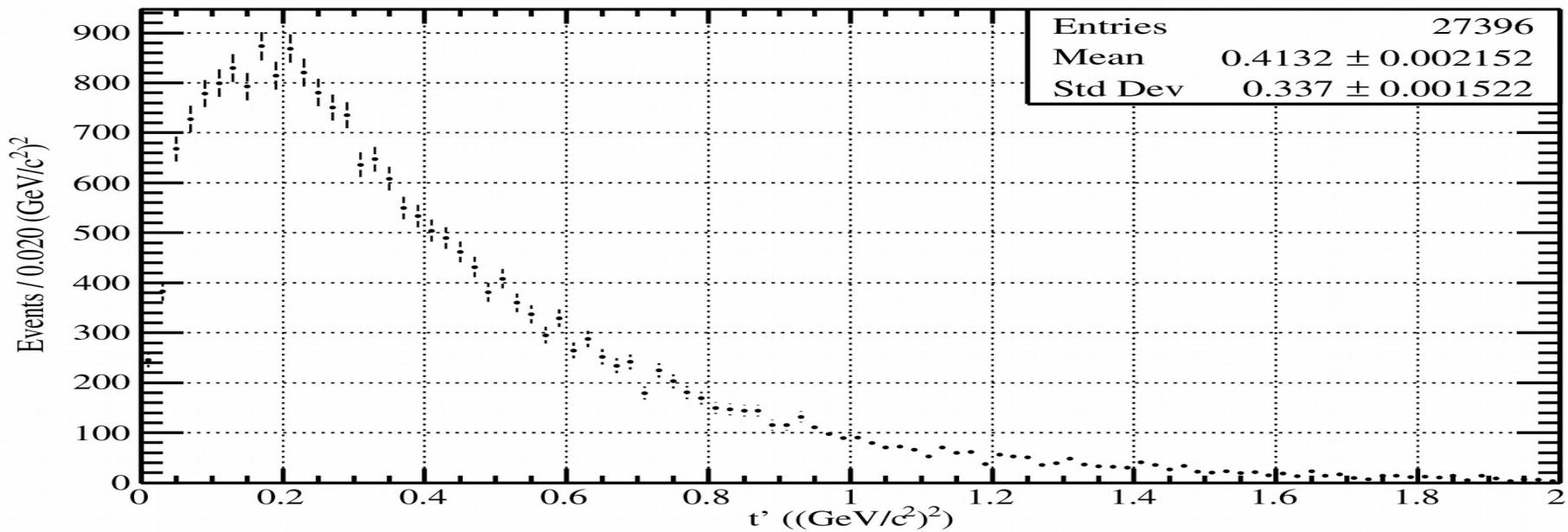


# $t'$ : Qvalue Data

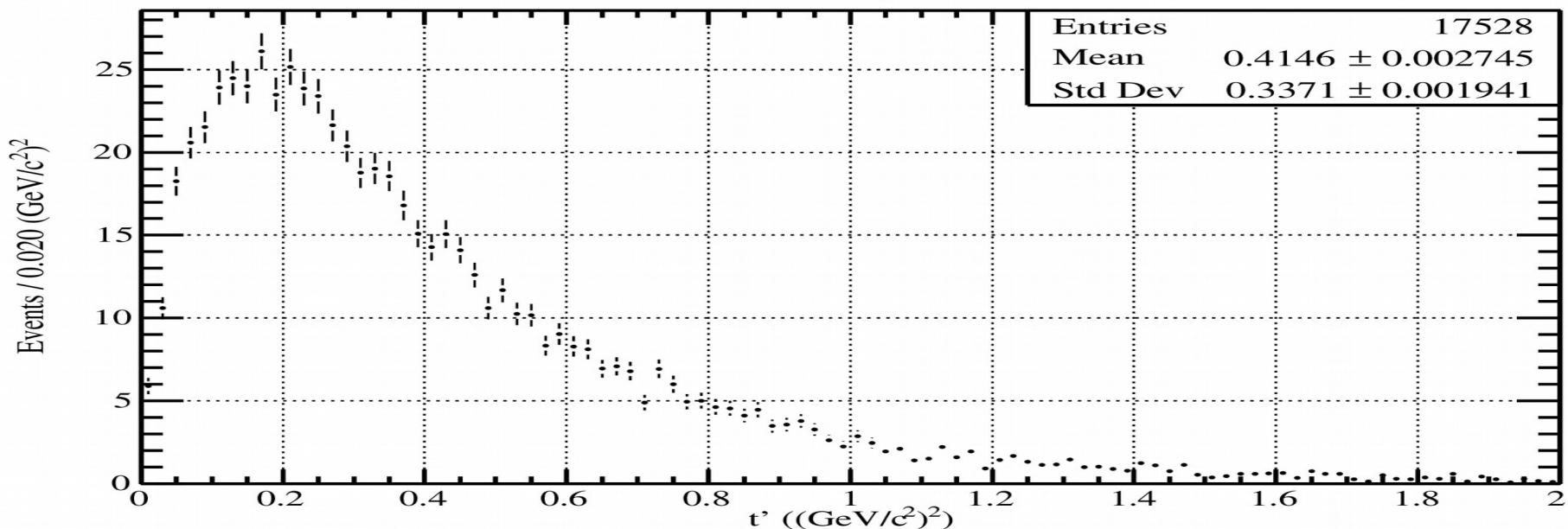


# $t'$ : Qvalue MC

$t'$  - Signal

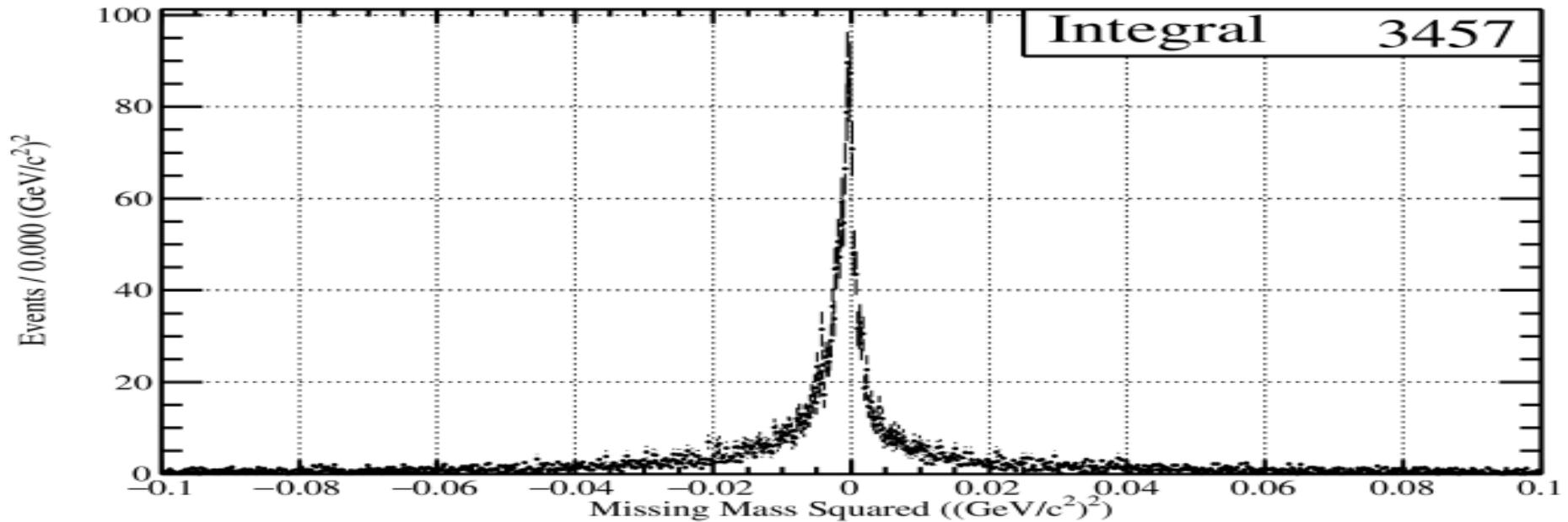


$t'$  - Background

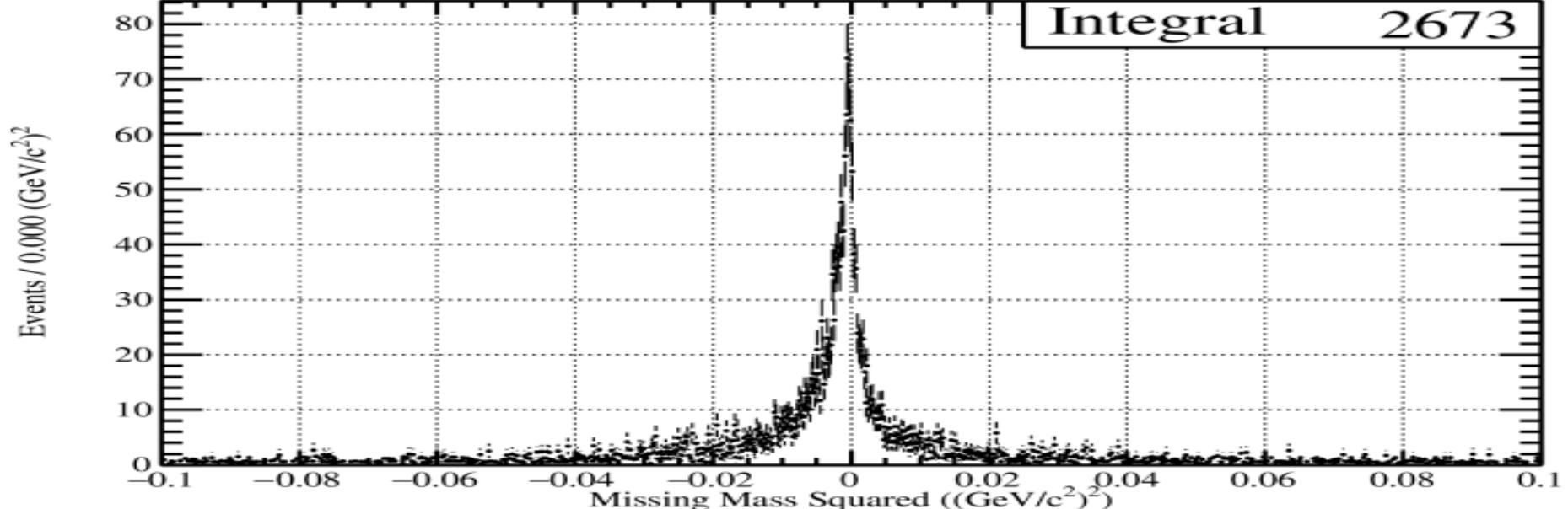


# Missing Mass<sup>^2</sup>: Qvalue Data

Missing Mass Squared - Signal

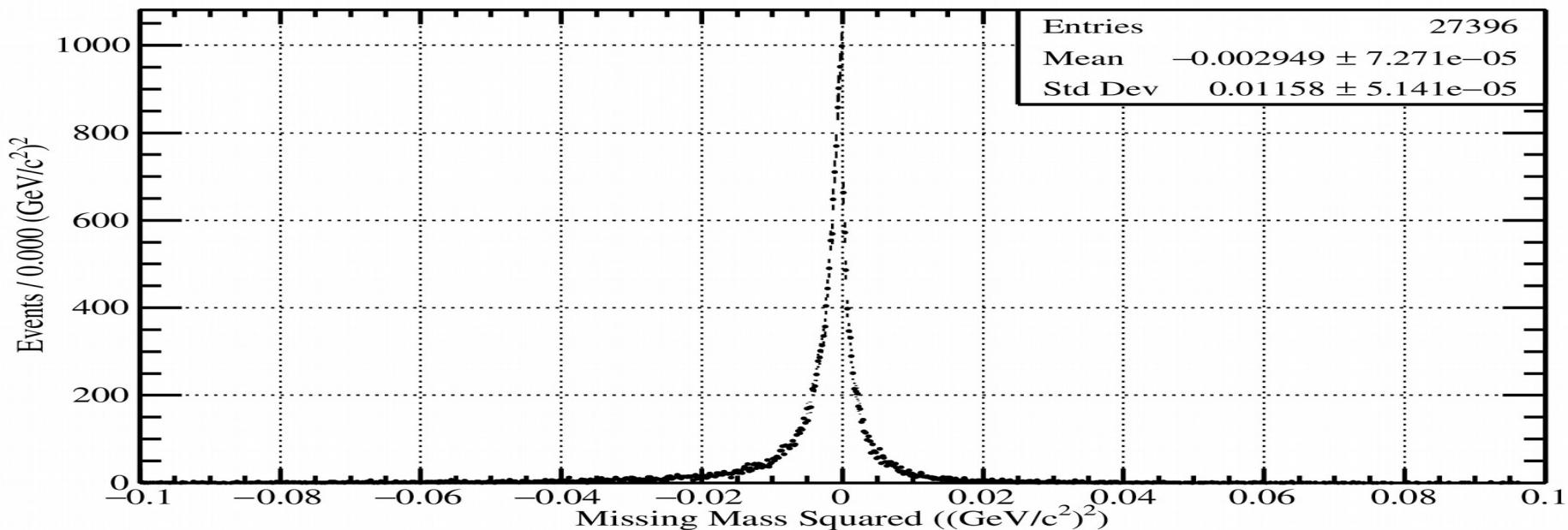


Missing Mass Squared - Background

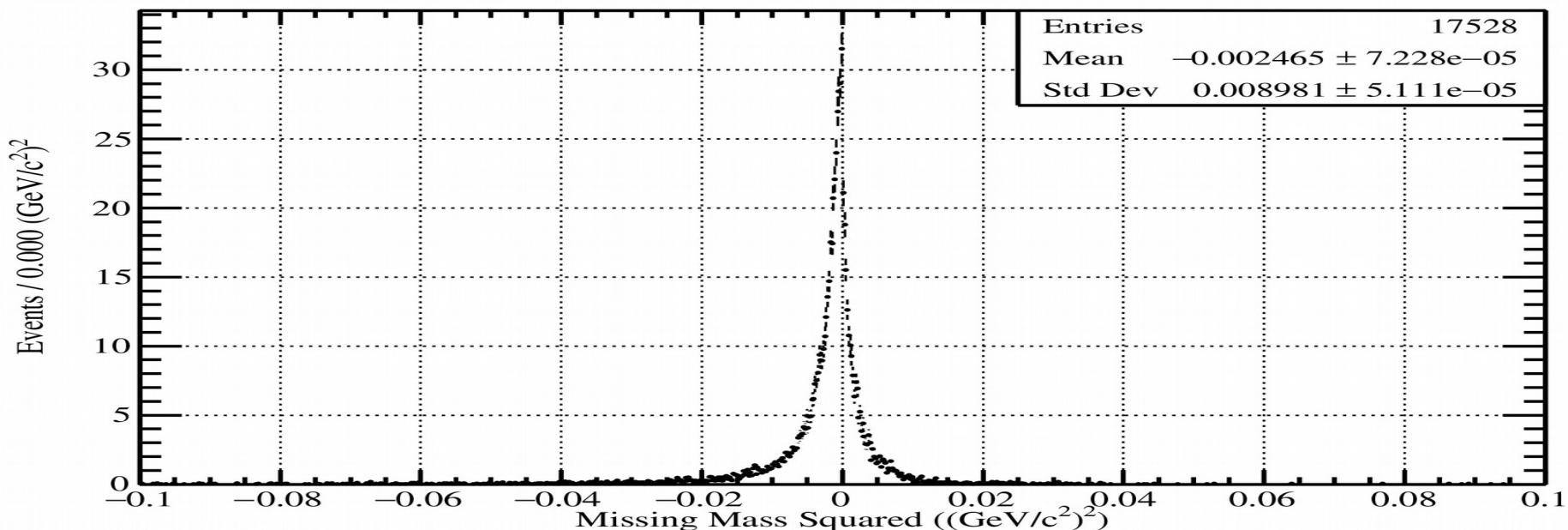


# Missing Mass<sup>2</sup>: Qvalue MC

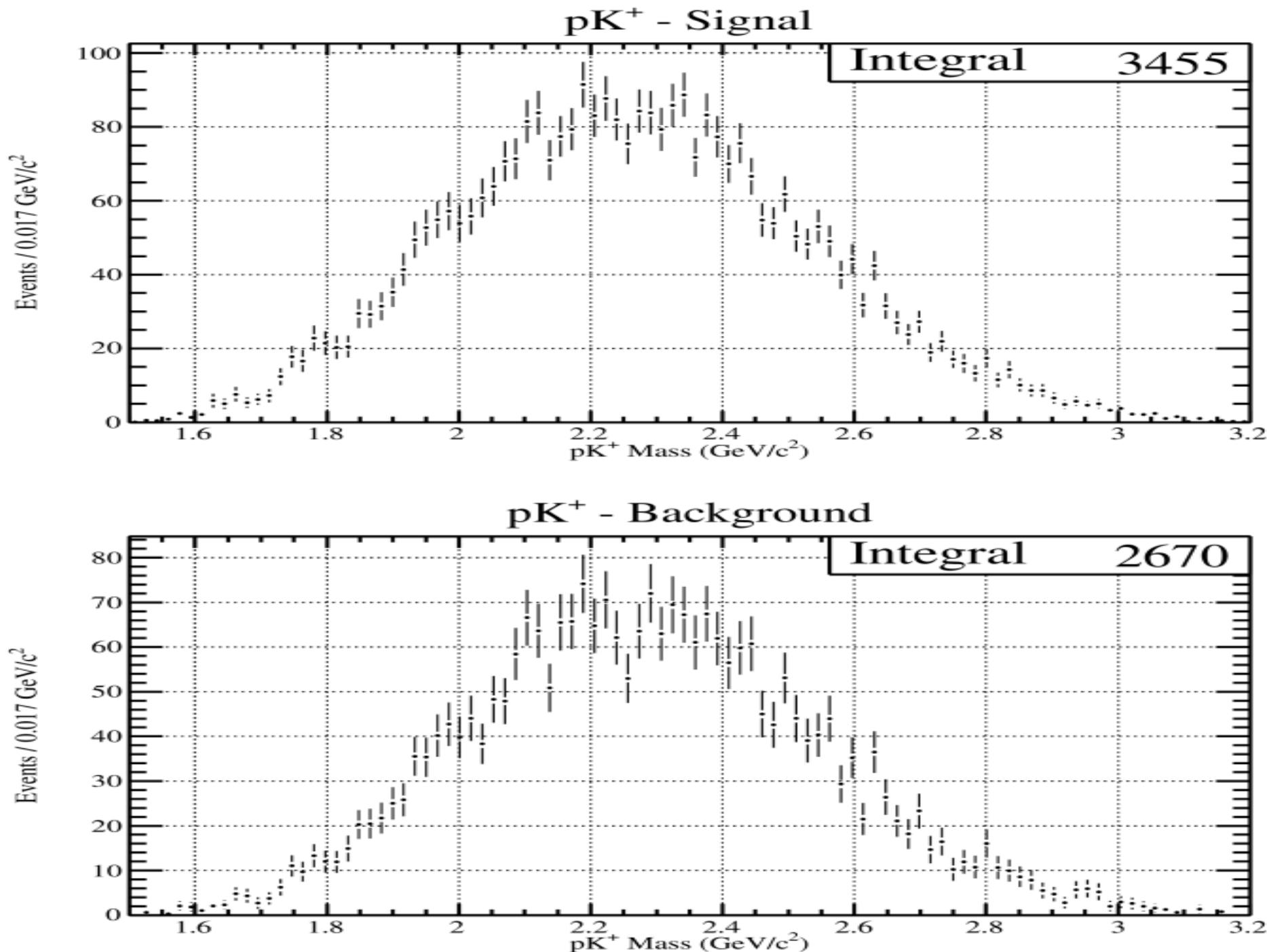
Missing Mass Squared - Signal



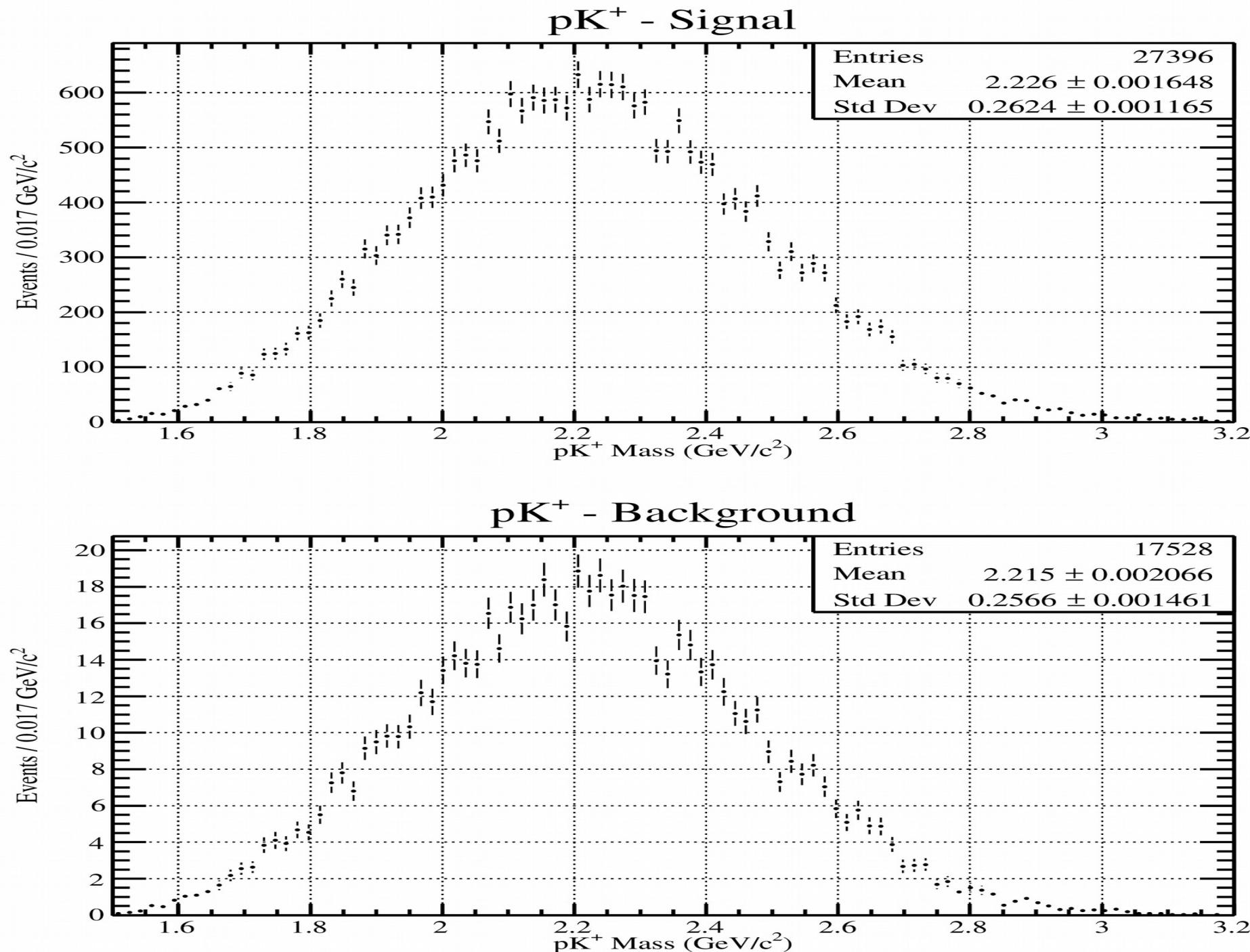
Missing Mass Squared - Background



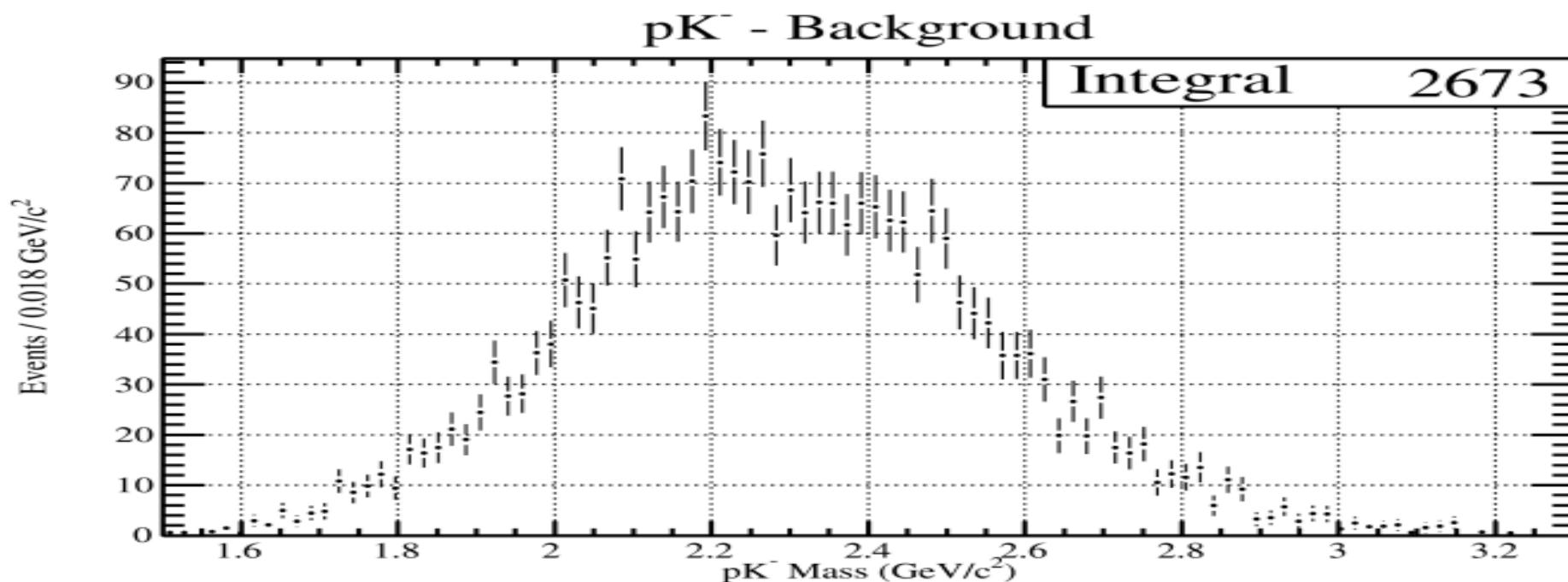
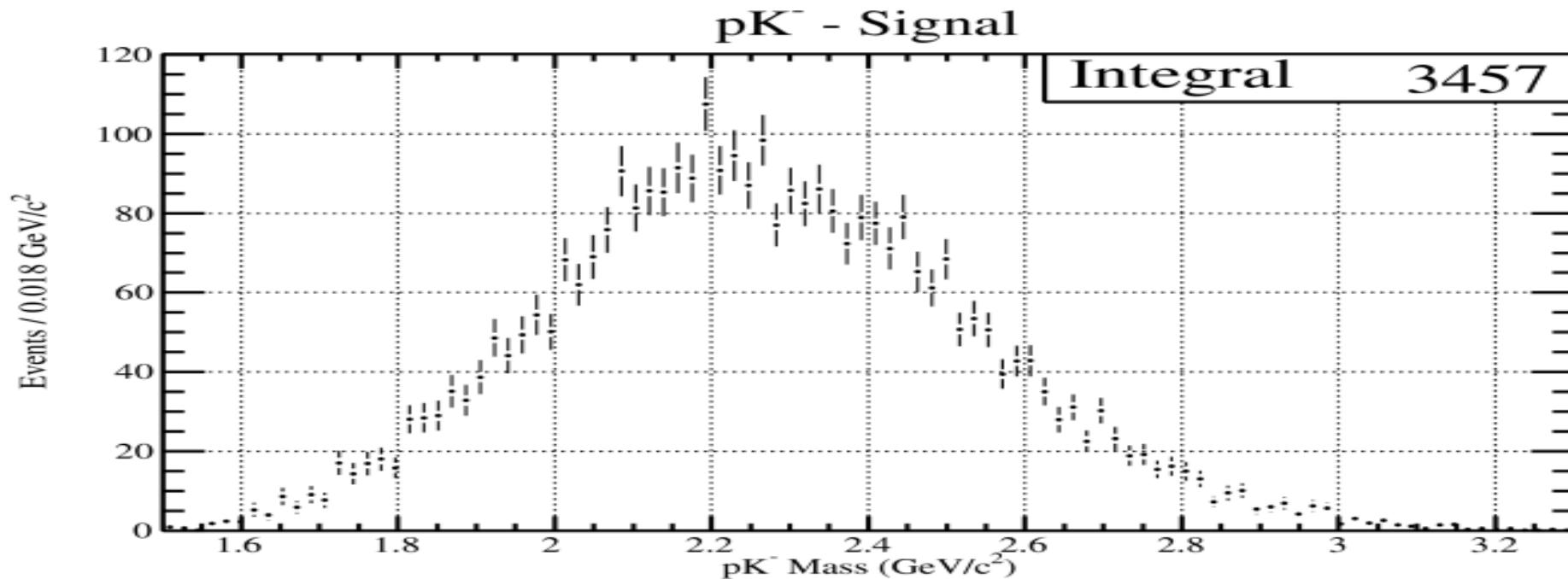
# Proton K<sup>+</sup>: Qvalue Data



# Proton K+: Qvalue MC

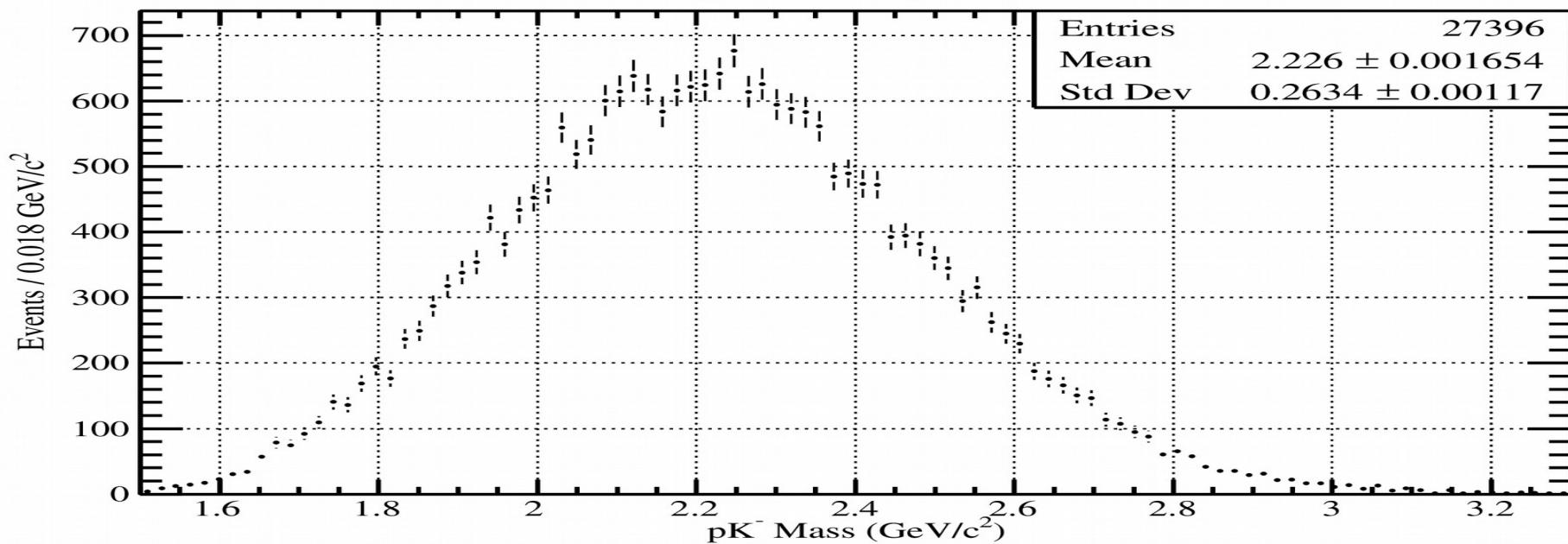


# Proton K-: Qvalue Data

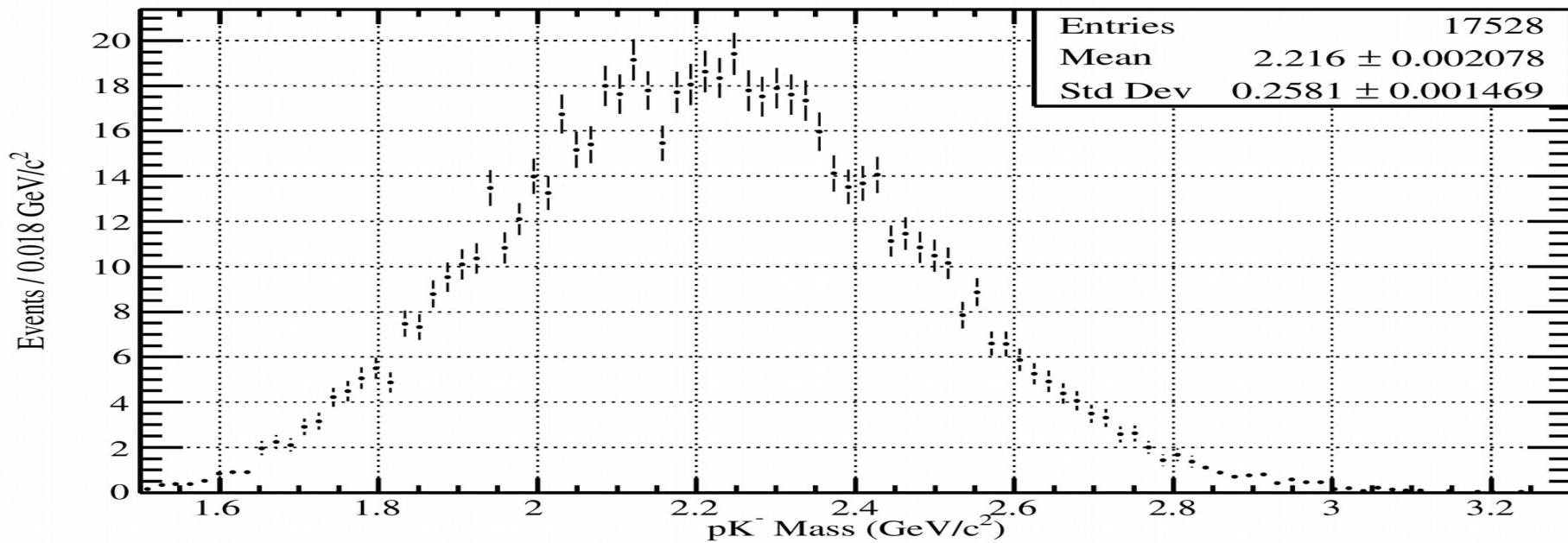


# Proton K-: Qvalue MC

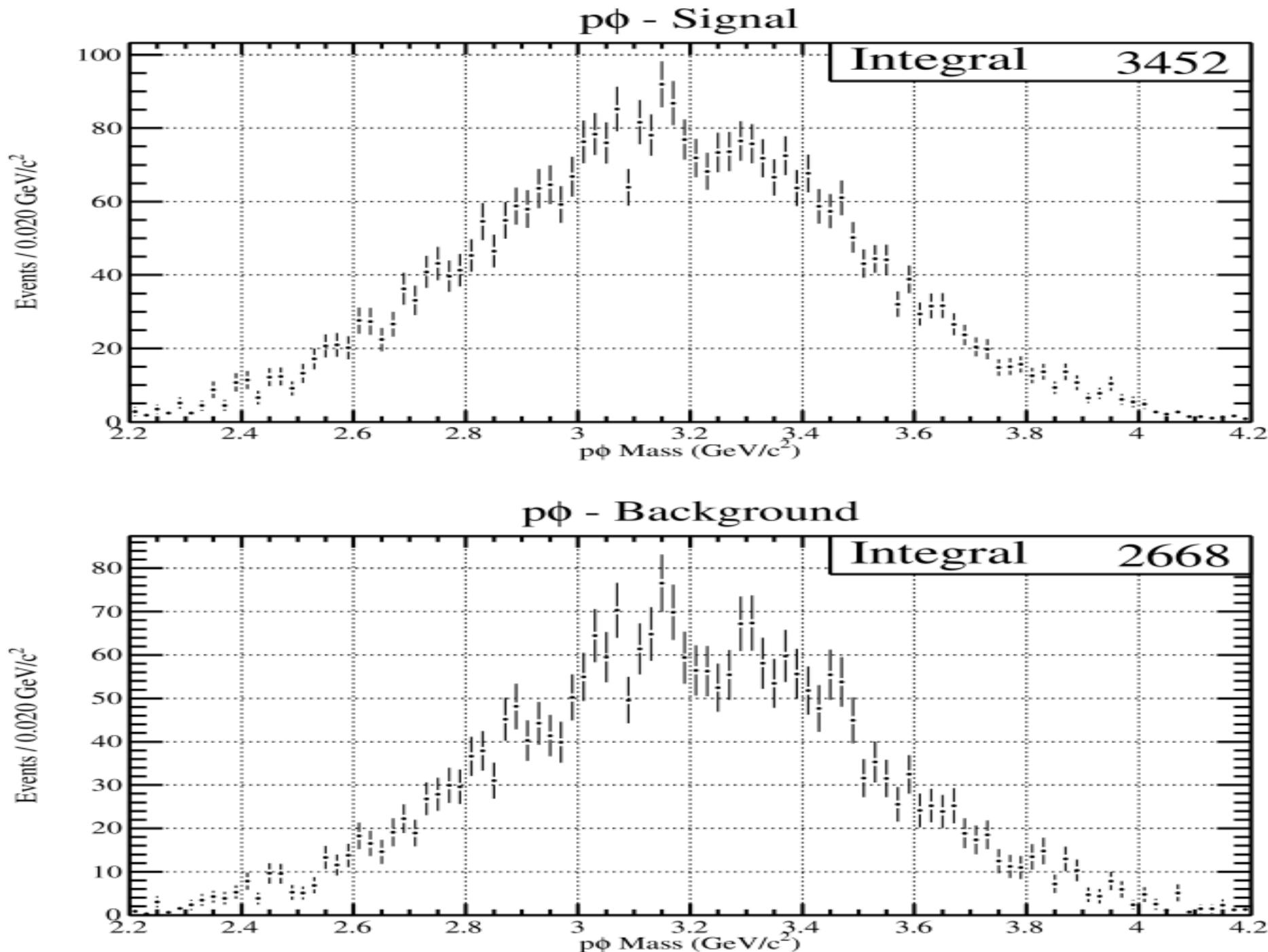
pK<sup>-</sup> - Signal



pK<sup>-</sup> - Background

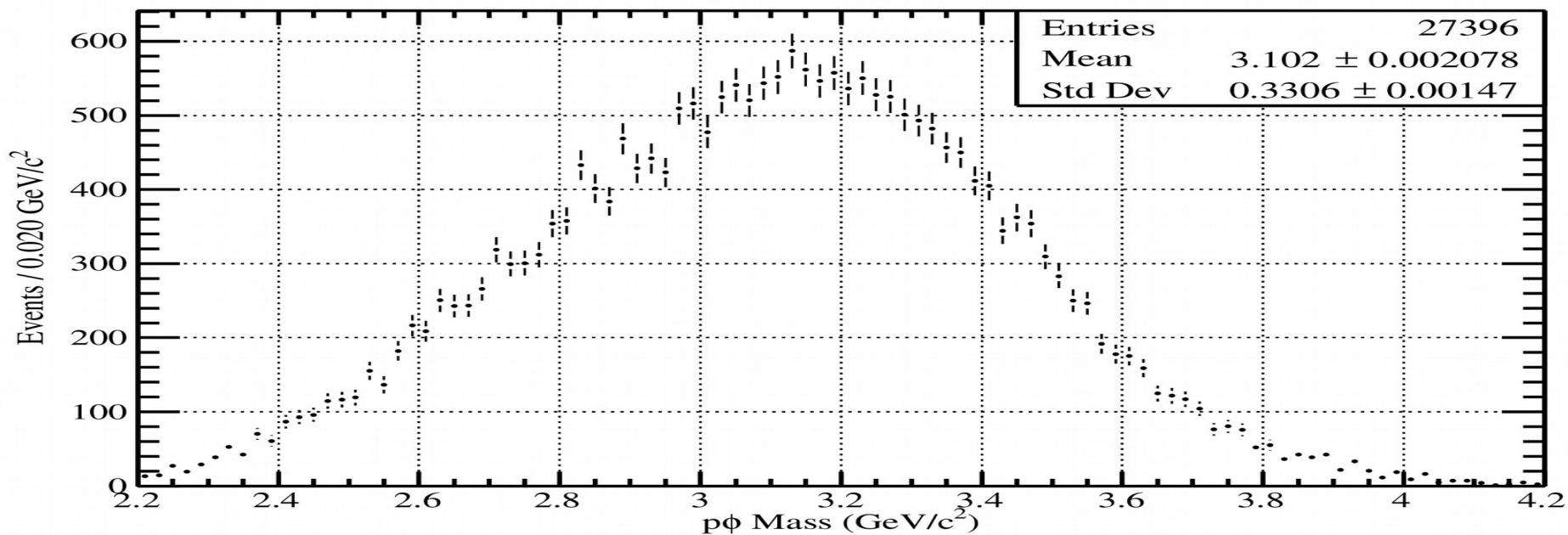


# Proton Phi: Qvalue Data

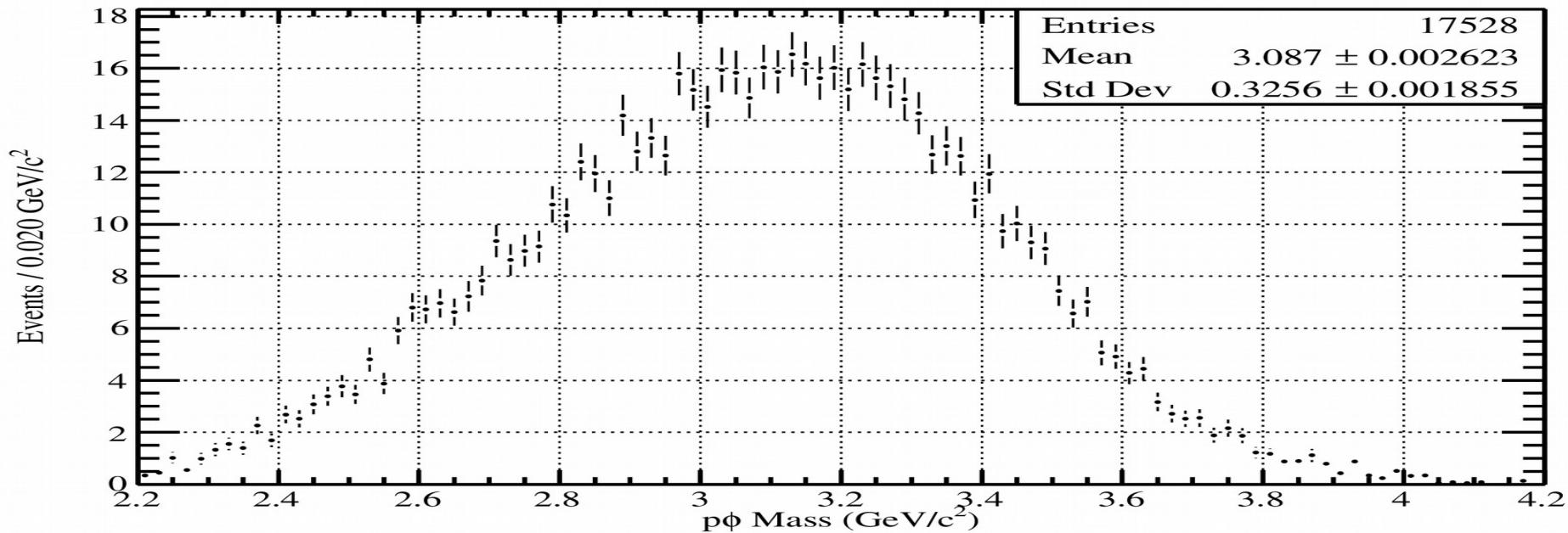


# Proton Phi: Qvalue MC

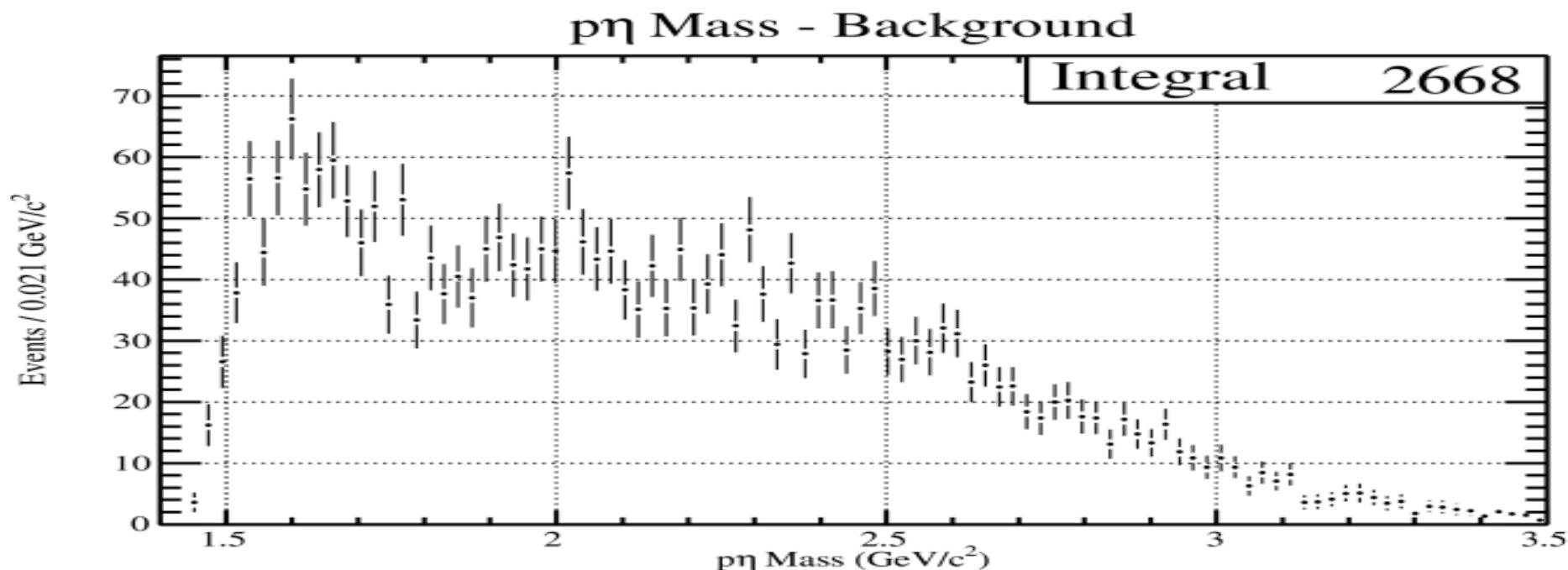
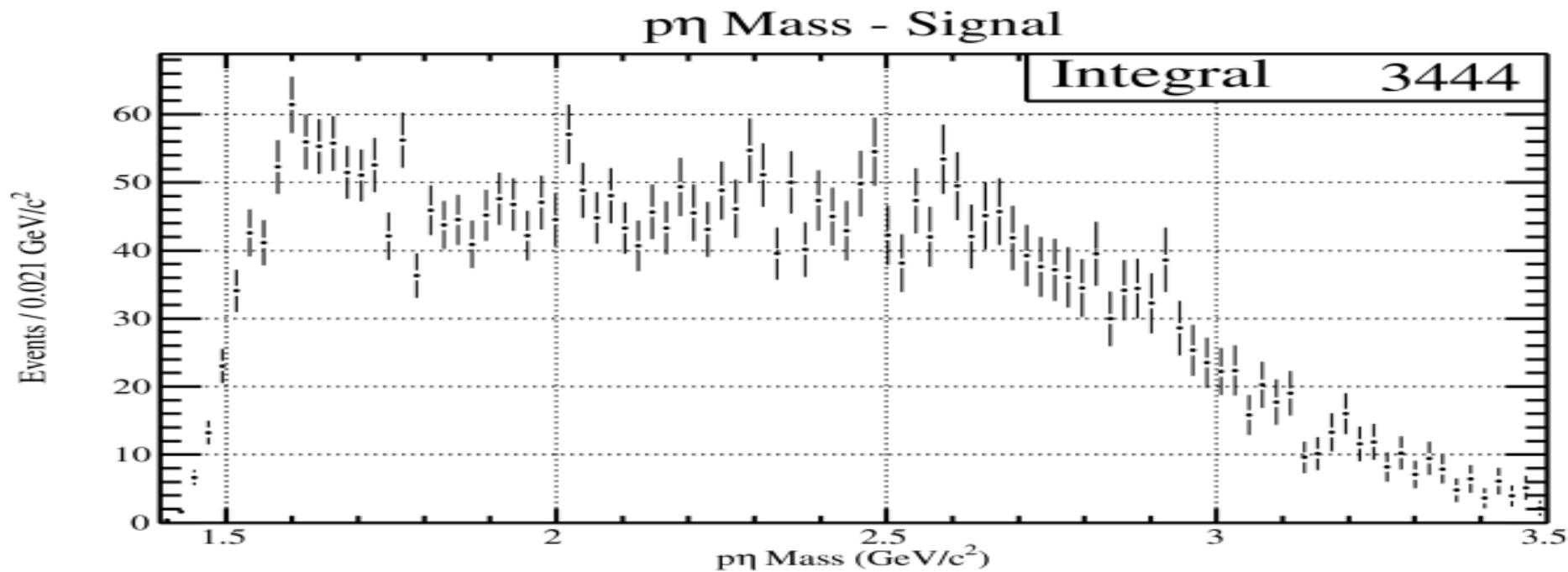
p $\phi$  - Signal



p $\phi$  - Background

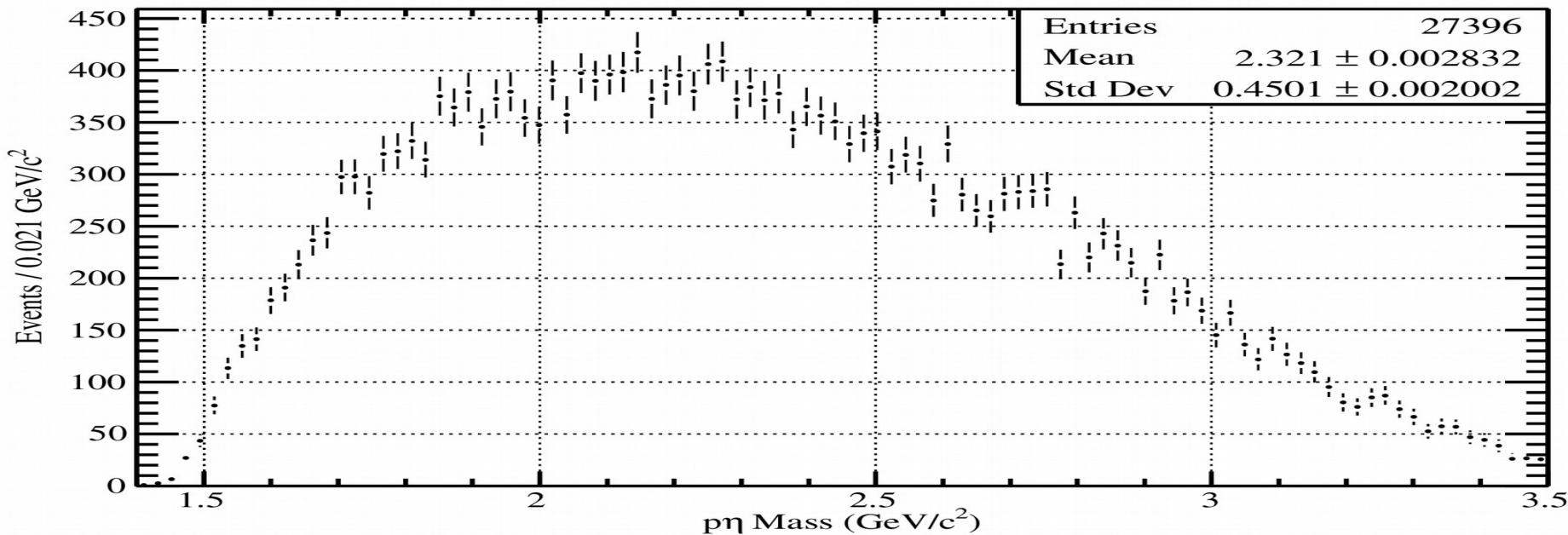


# Proton Eta: Qvalue Data

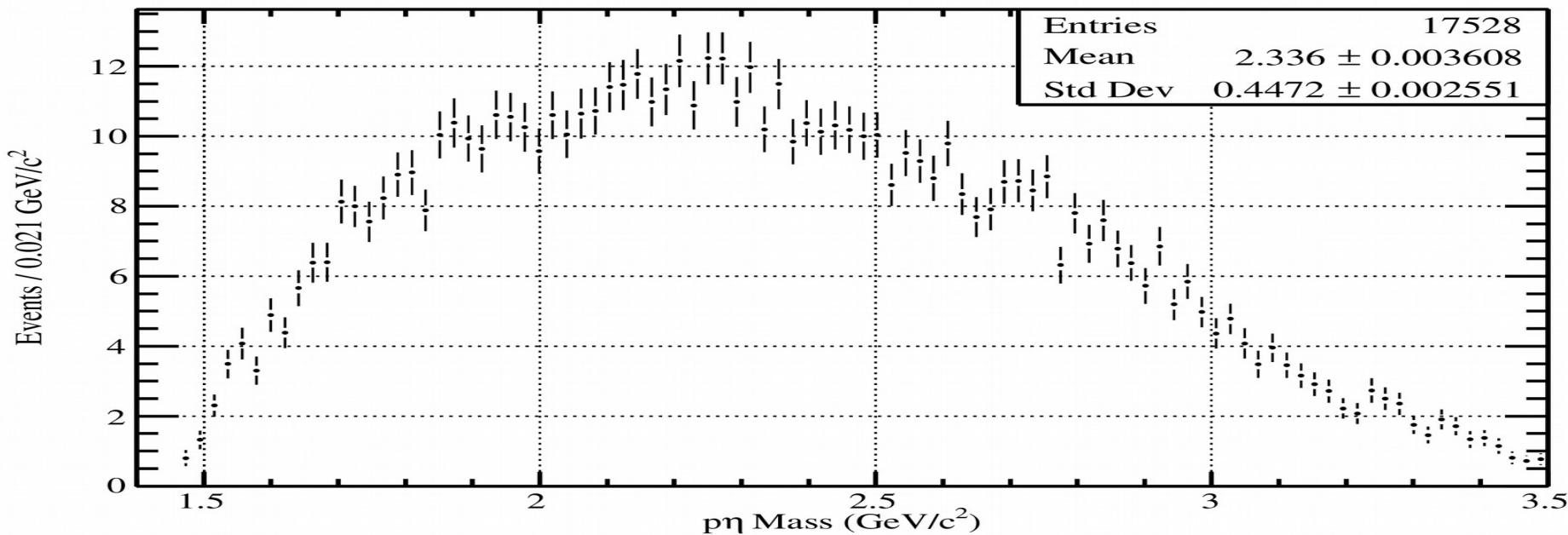


# Proton Eta: Qvalue MC

p $\eta$  Mass - Signal

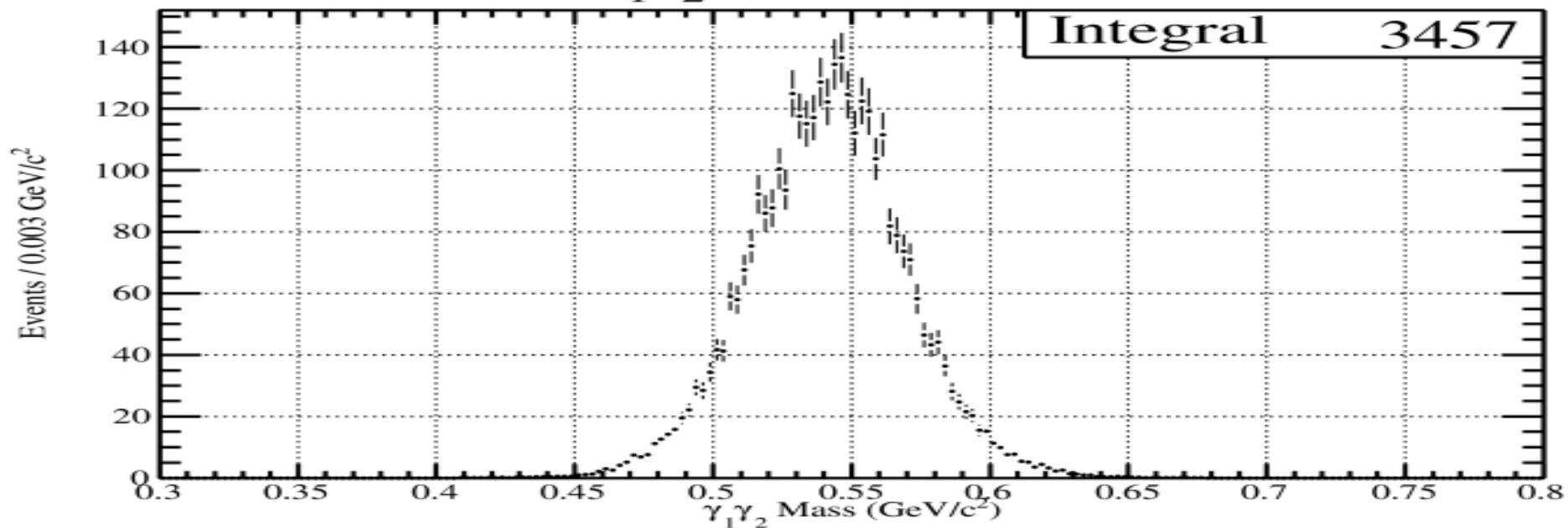


p $\eta$  Mass - Background

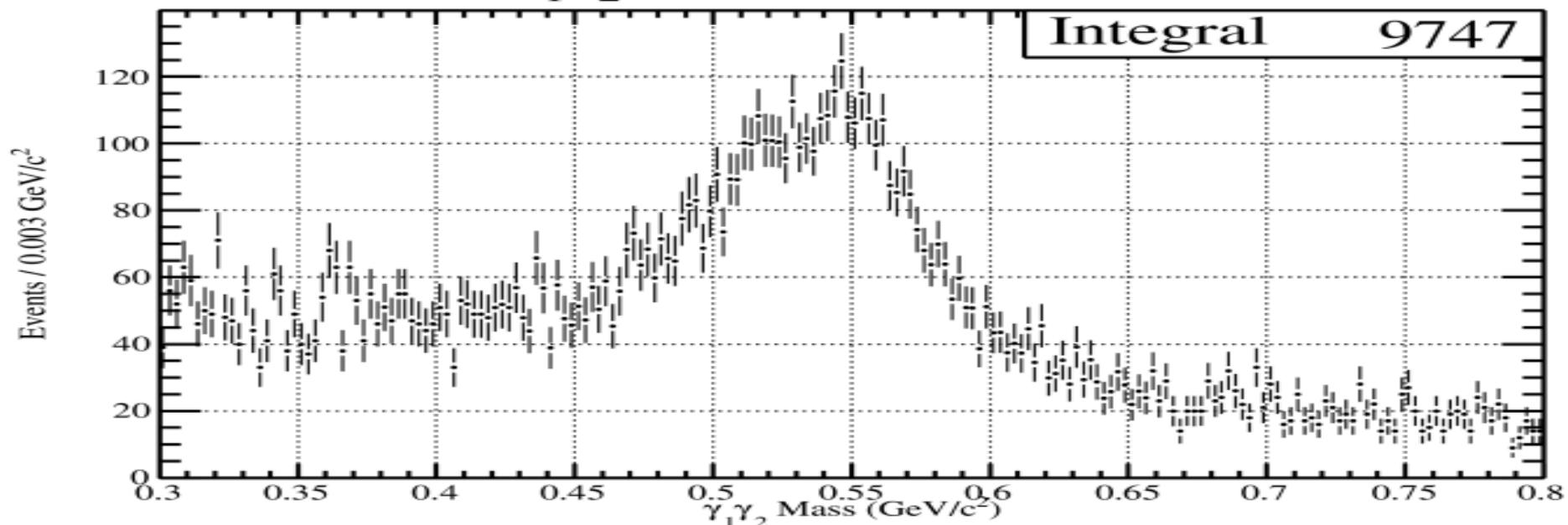


# Eta: Qvalue Data

$\gamma_1\gamma_2$  Mass - Signal

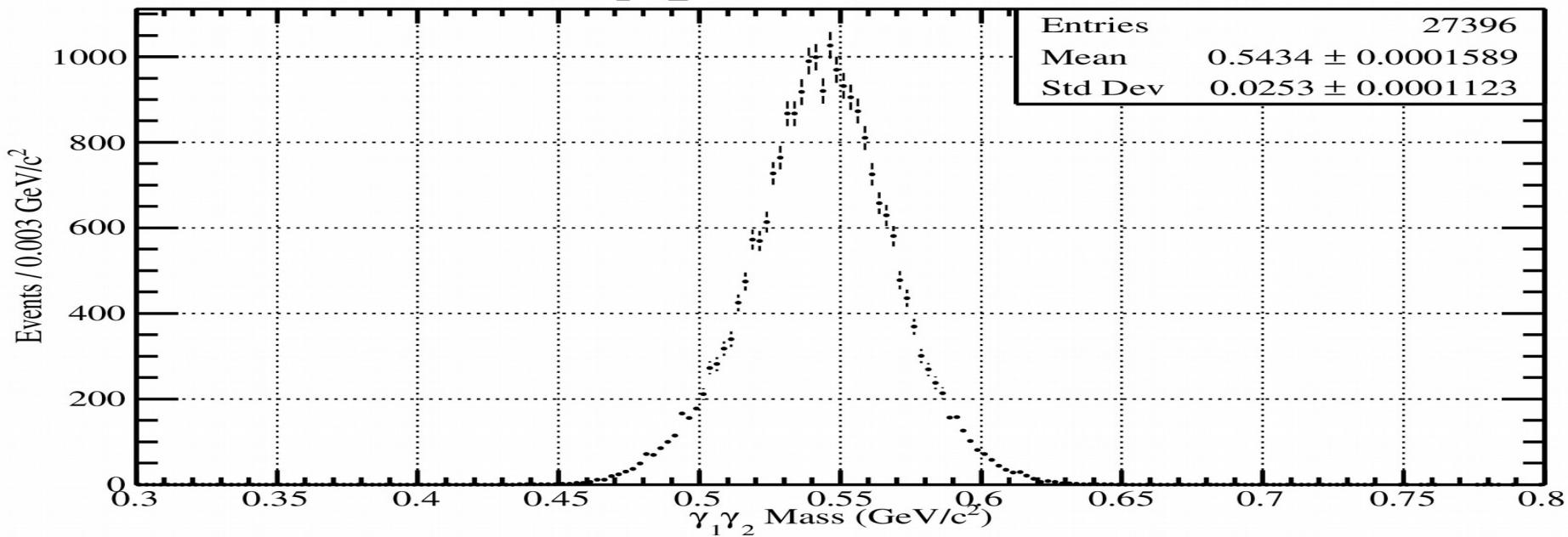


$\gamma_1\gamma_2$  Mass - Background

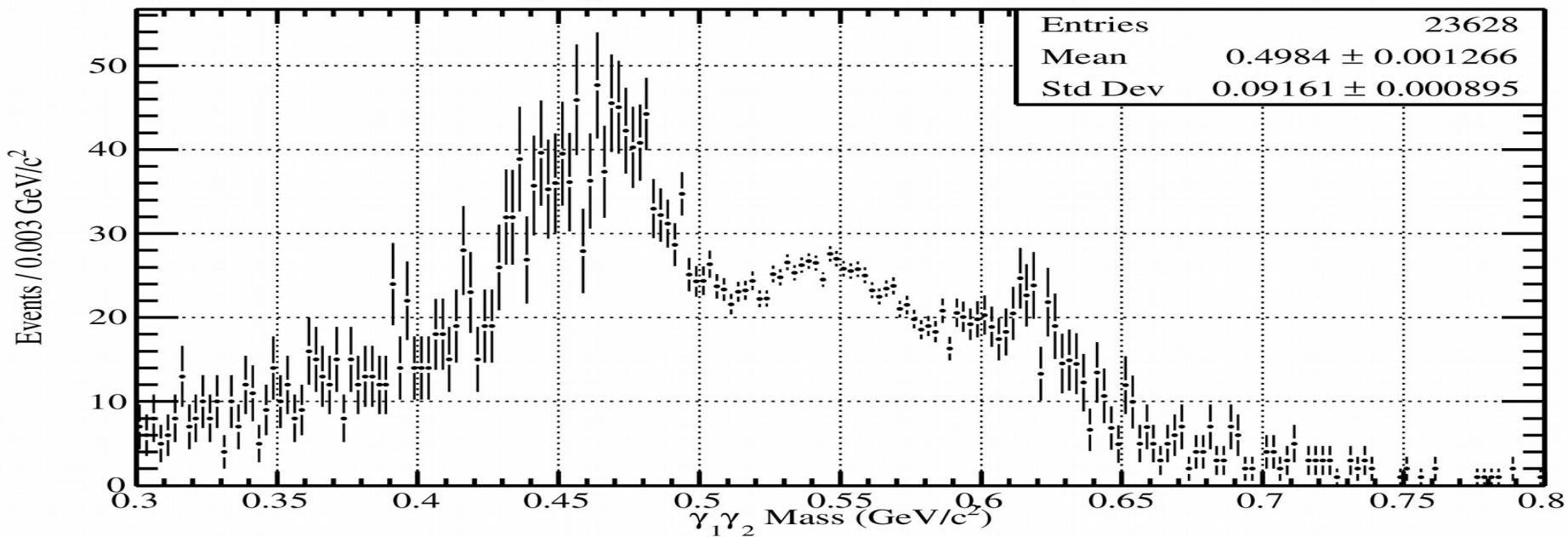


# Eta: Qvalue MC

## $\gamma_1\gamma_2$ Mass - Signal

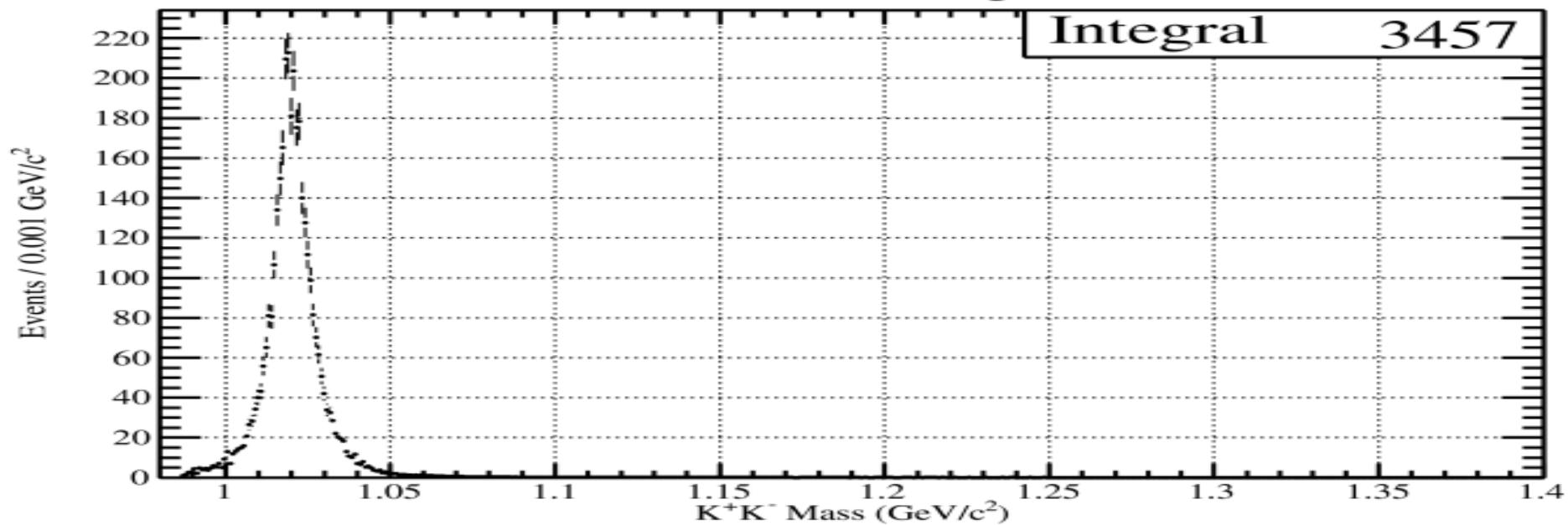


## $\gamma_1\gamma_2$ Mass - Background

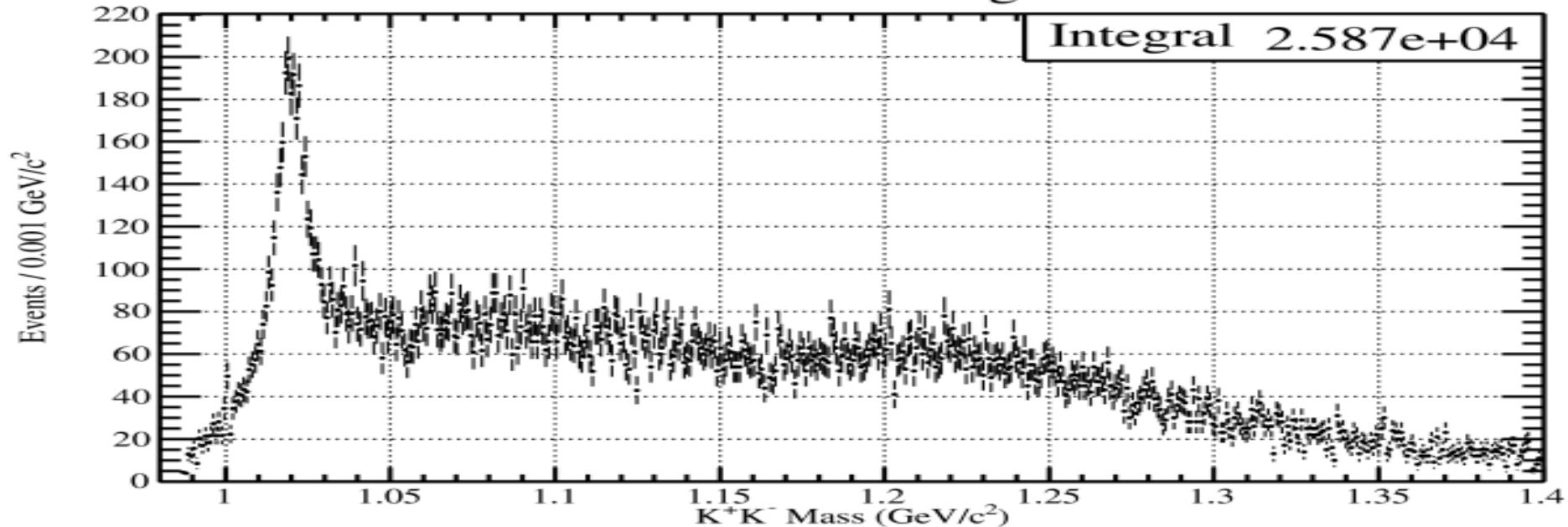


# Phi: Qvalue Data

K<sup>+</sup>K<sup>-</sup> Mass - Signal

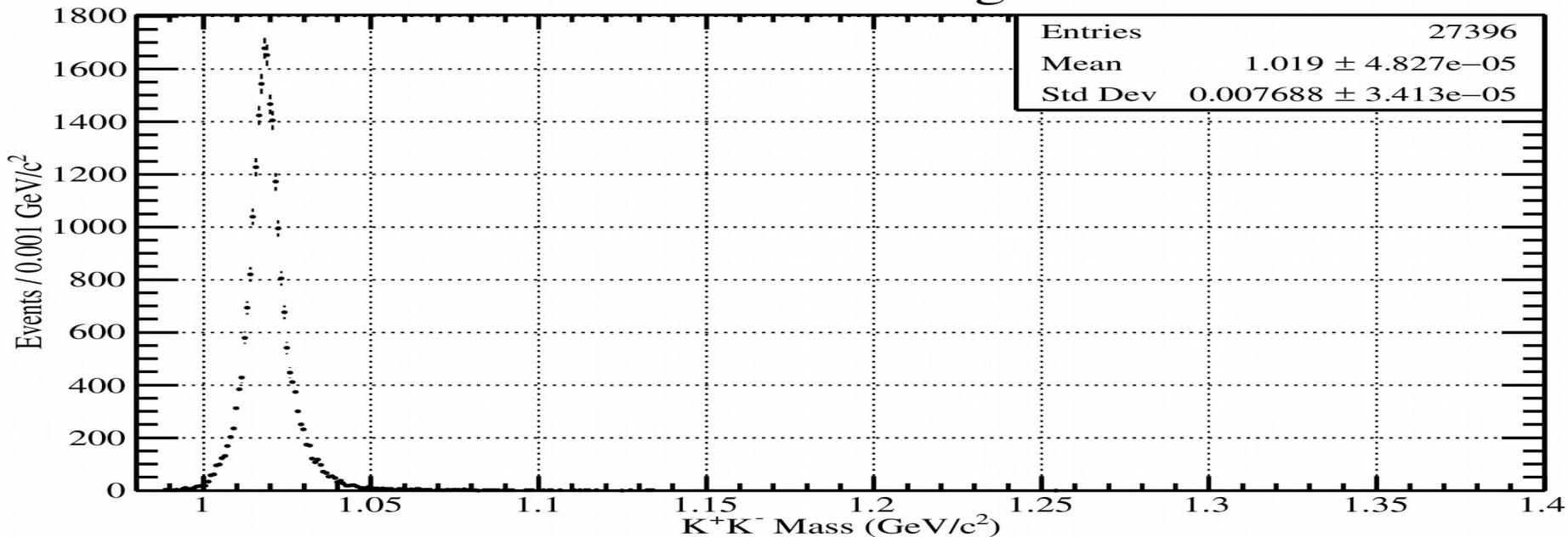


K<sup>+</sup>K<sup>-</sup> Mass - Background

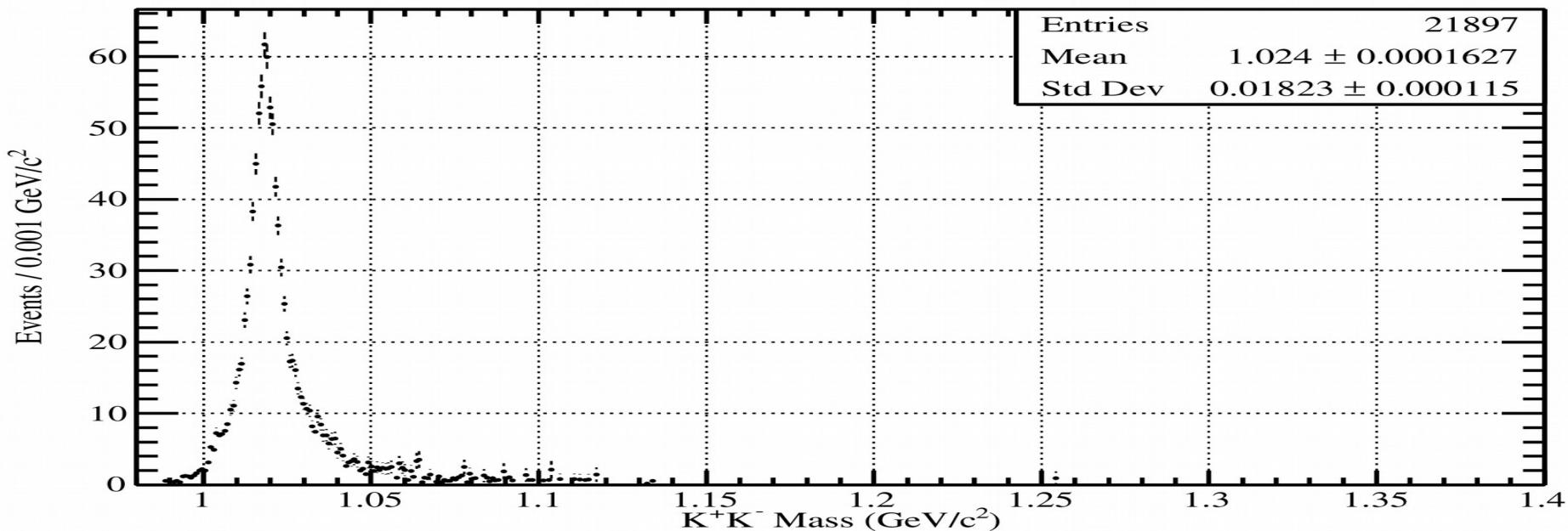


# Phi: Qvalue MC

K<sup>+</sup>K<sup>-</sup> Mass - Signal

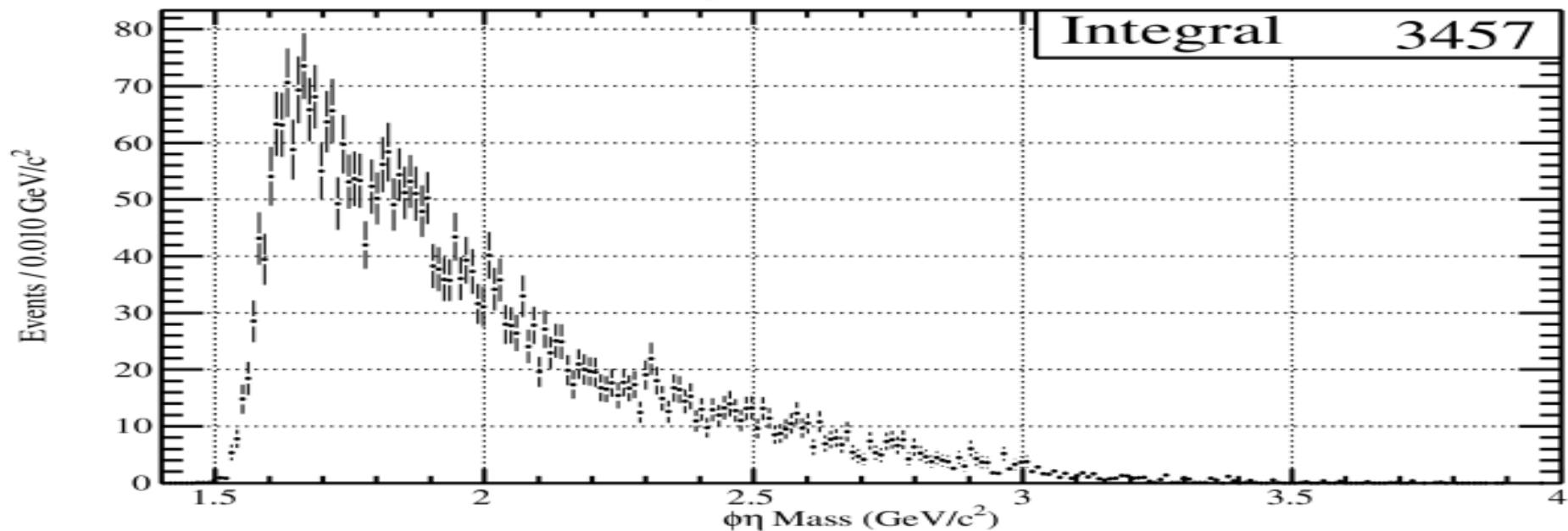


K<sup>+</sup>K<sup>-</sup> Mass - Background

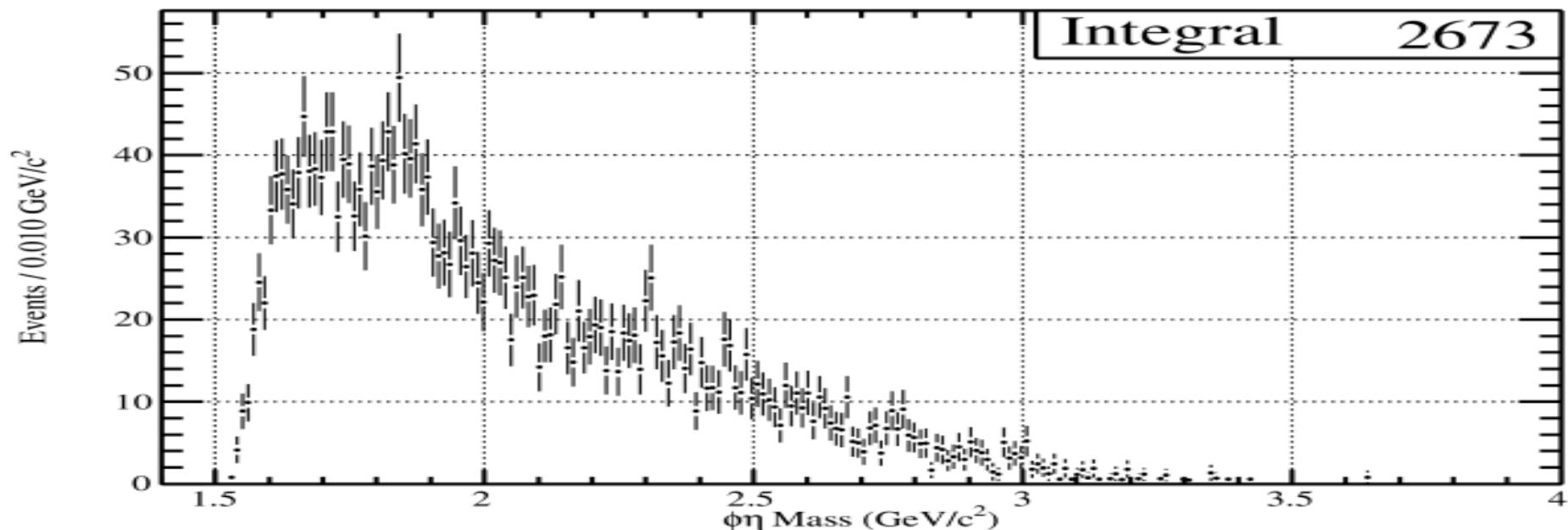


# PhiEta: Qvalue Data

$\phi\eta$  Mass - Signal

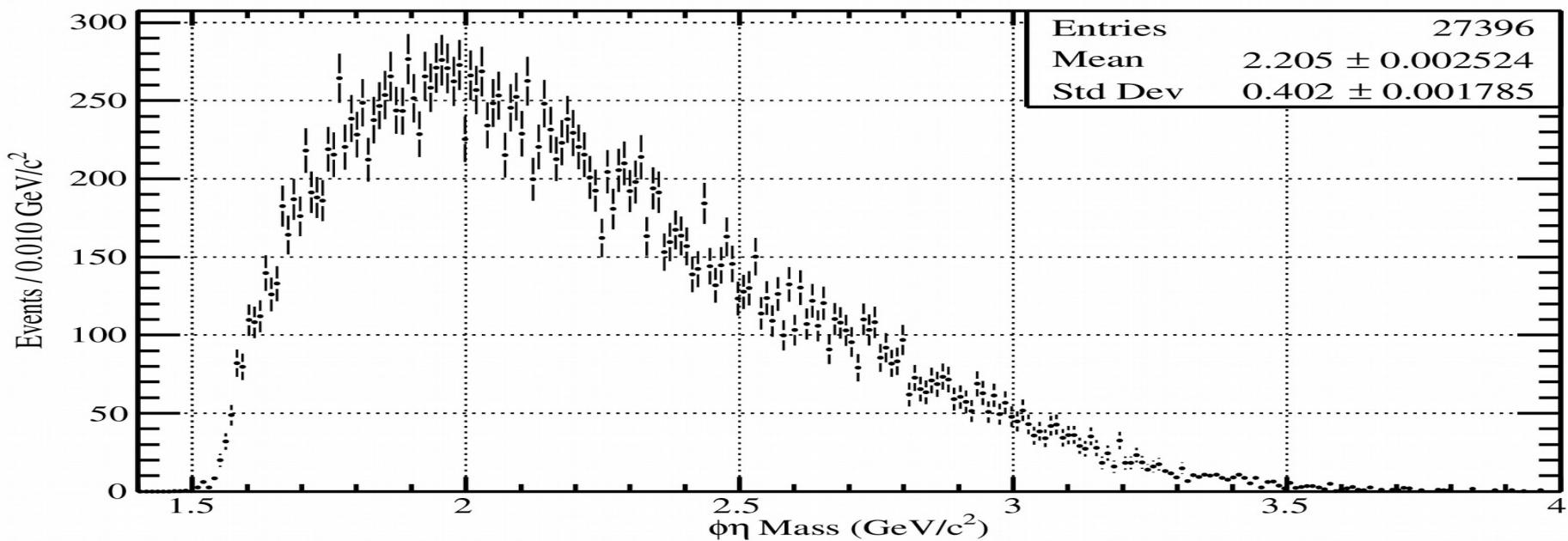


$\phi\eta$  Mass - Background

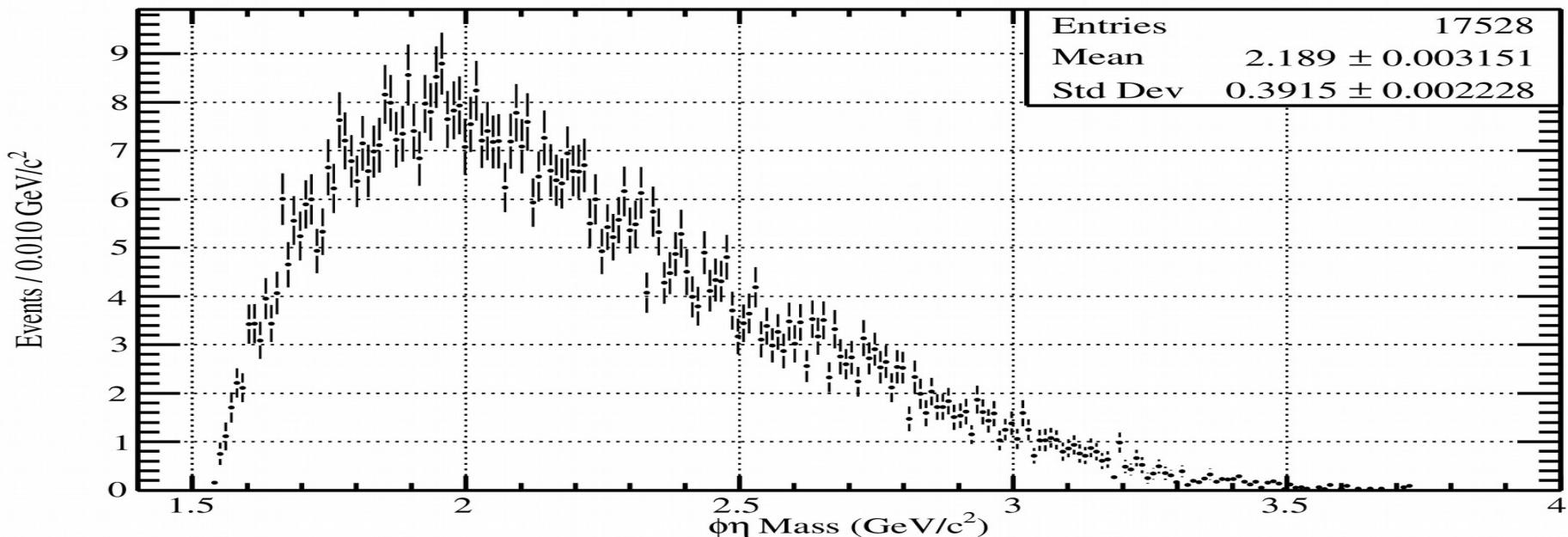


# PhiEta: Qvalue MC

## $\phi\eta$ Mass - Signal

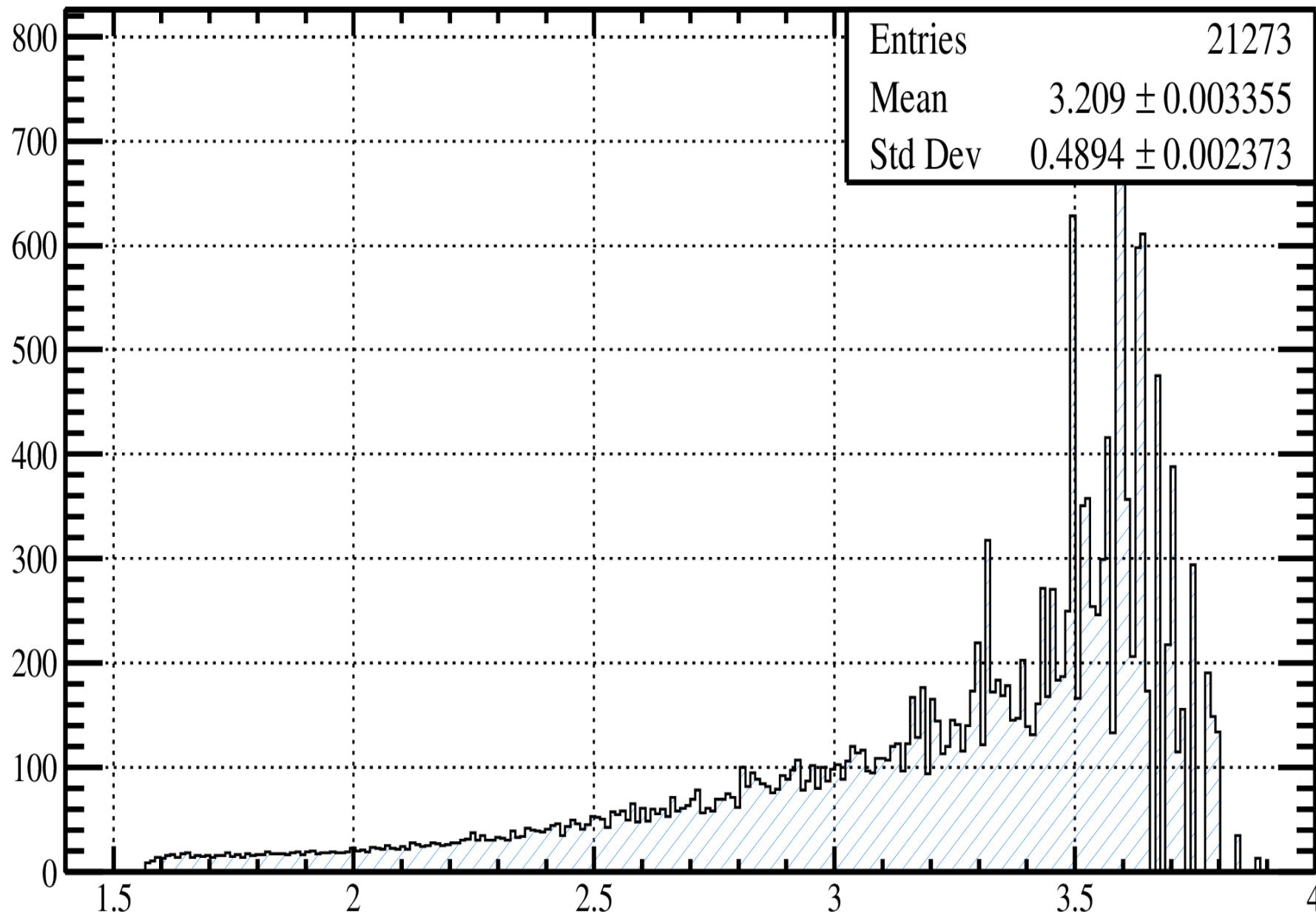


## $\phi\eta$ Mass - Background



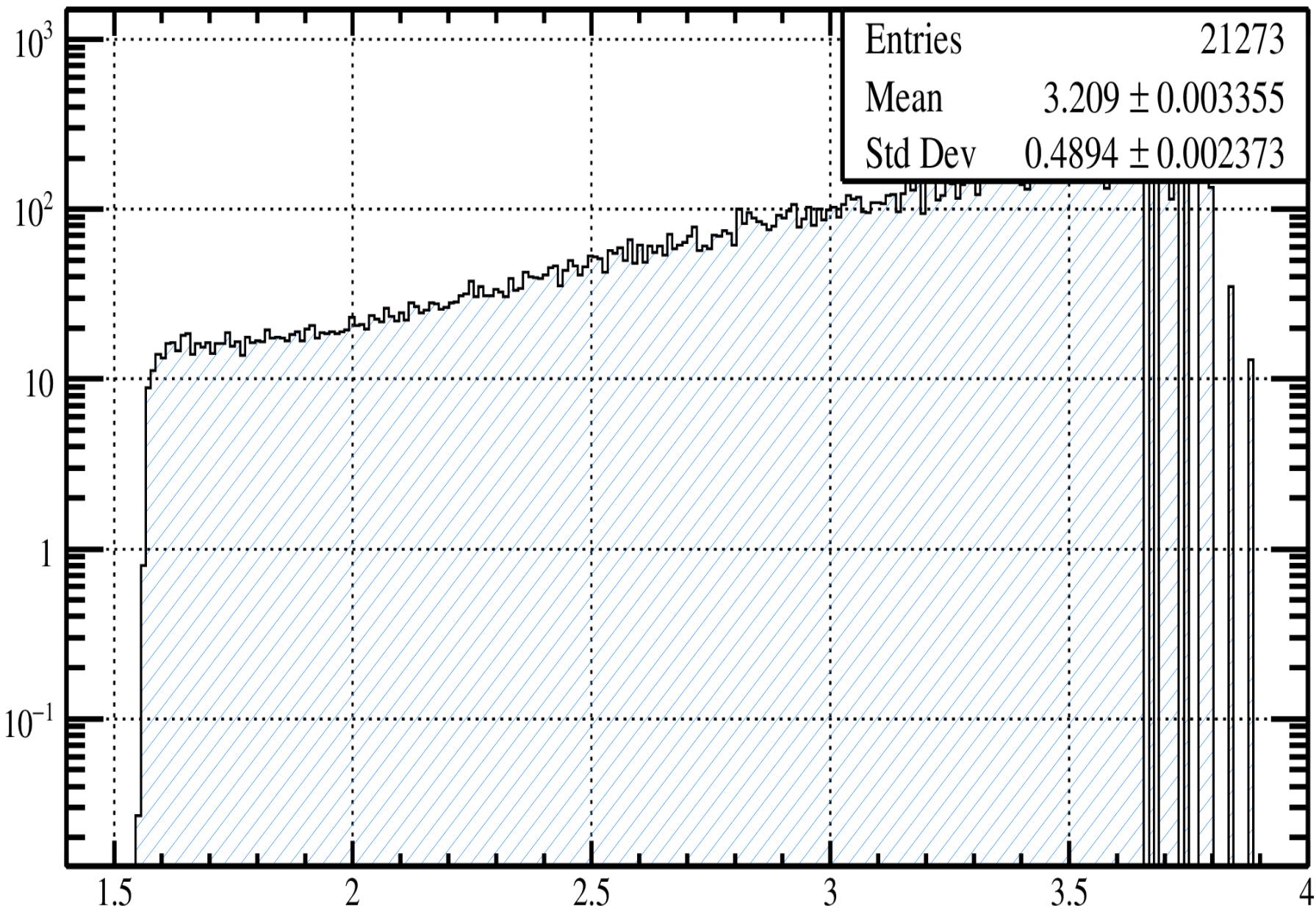
# PhiEta: Qvalue MC Acceptance

$\phi\eta$  Mass



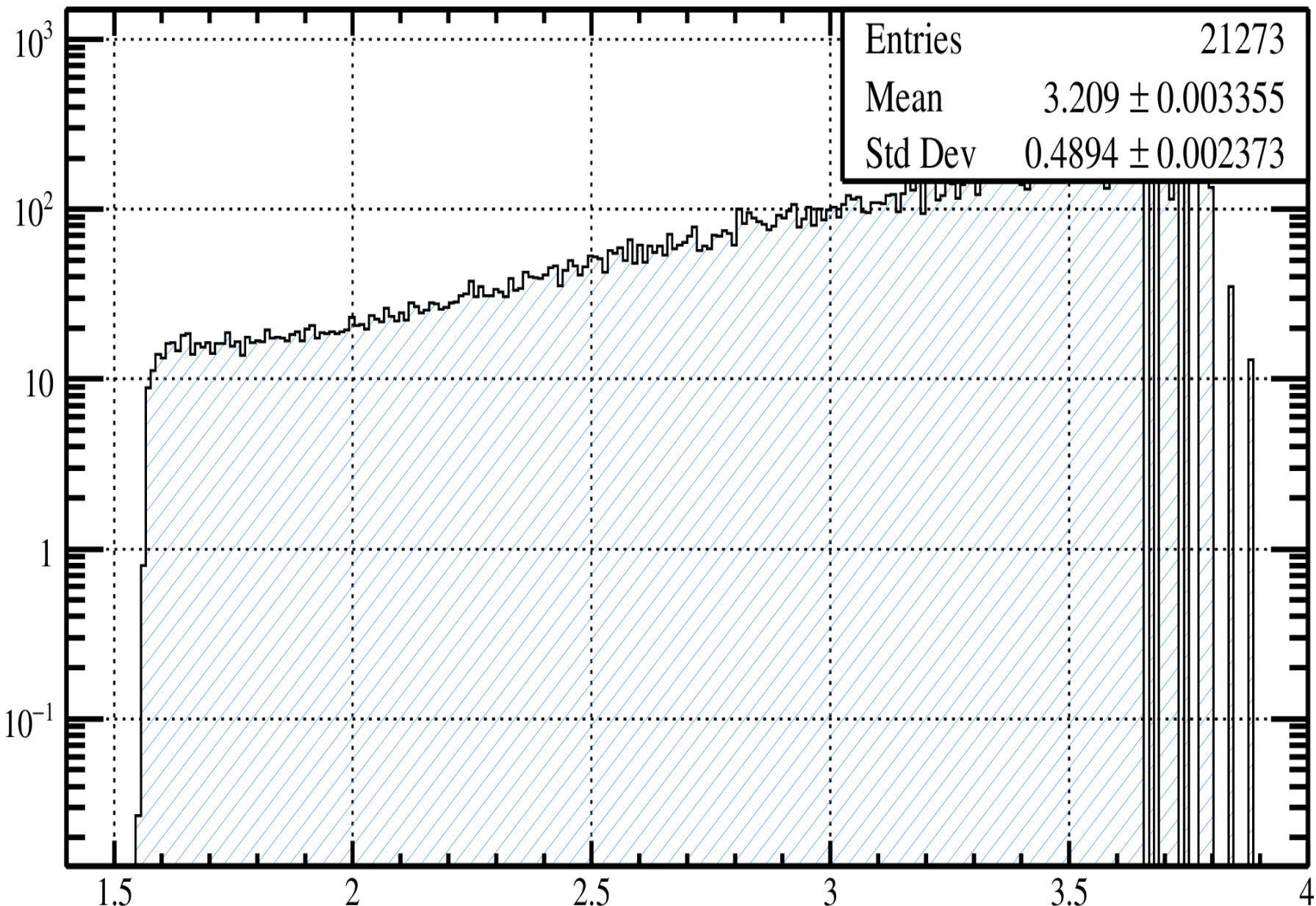
# PhiEta: Qvalue MC Acceptance LogY

$\phi\eta$  Mass



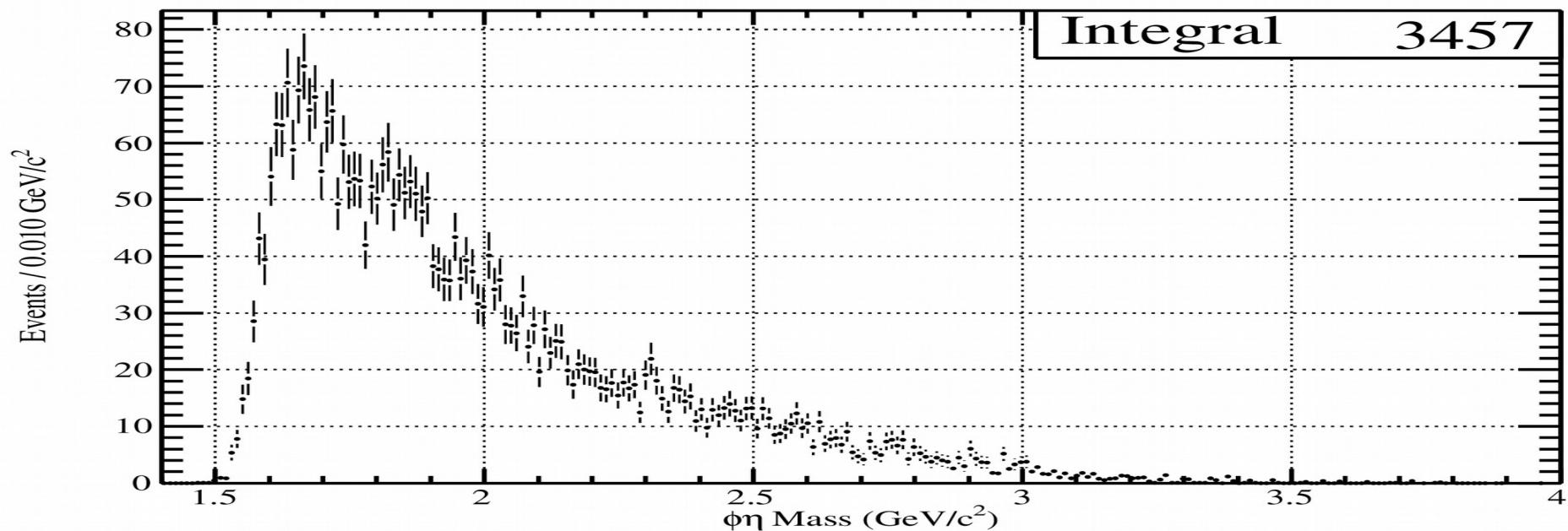
# PhiEta: Qvalue MC Acceptance LogY

$\phi\eta$  Mass

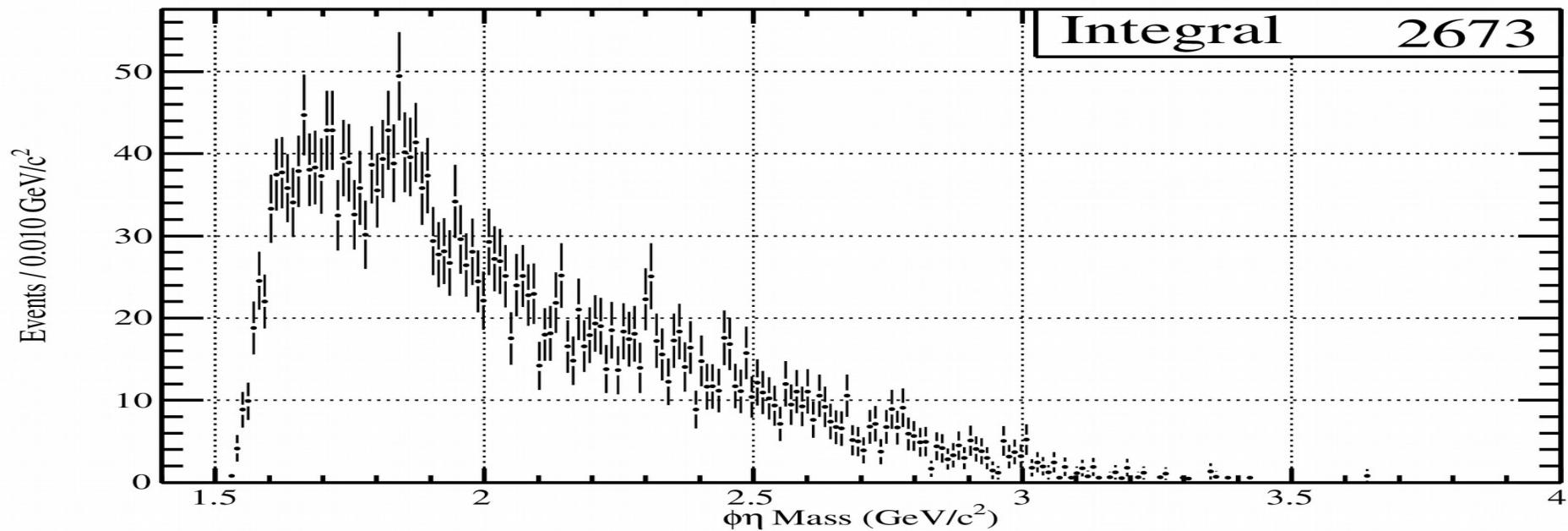


# PhiEta: Qvalue Data

$\phi\eta$  Mass - Signal

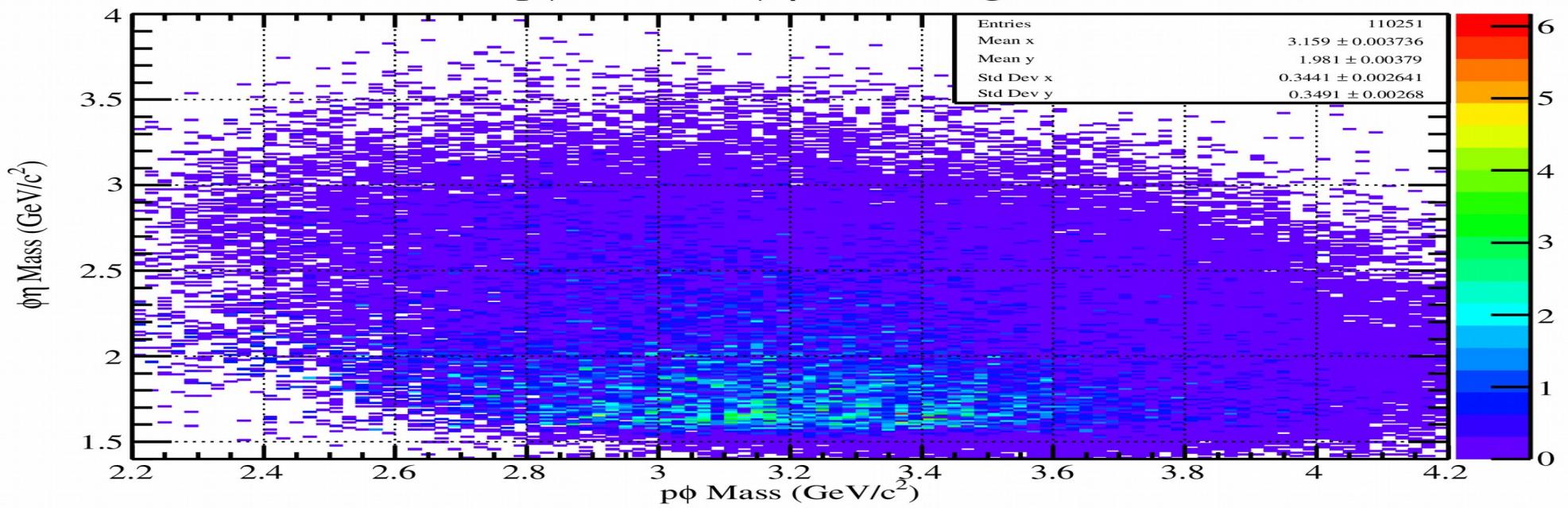


$\phi\eta$  Mass - Background

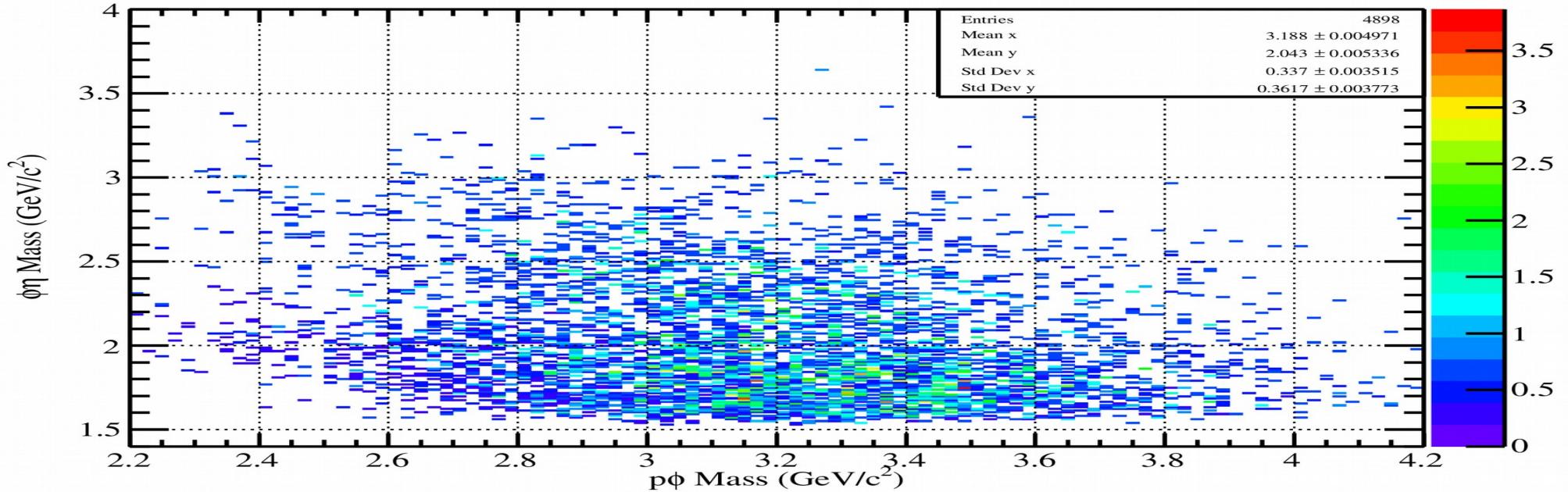


# PhiEta Vs PPhi

p $\phi$  Mass Vs  $\phi\eta$  Mass - Signal

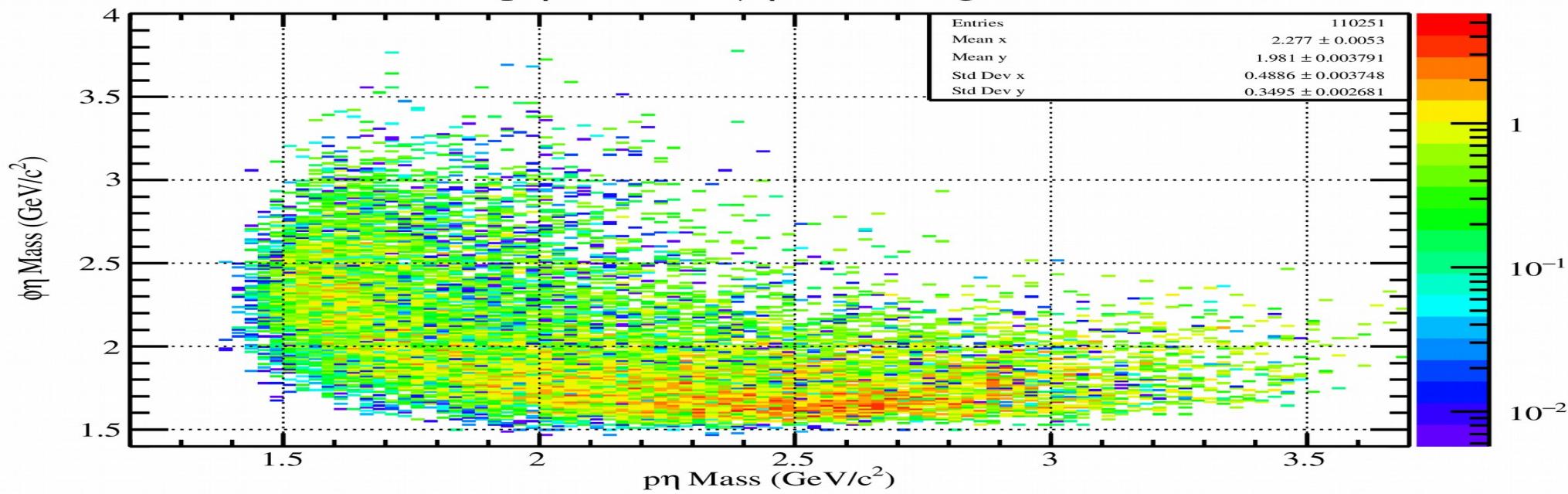


p $\phi$  Mass Vs  $\phi\eta$  Mass - Background

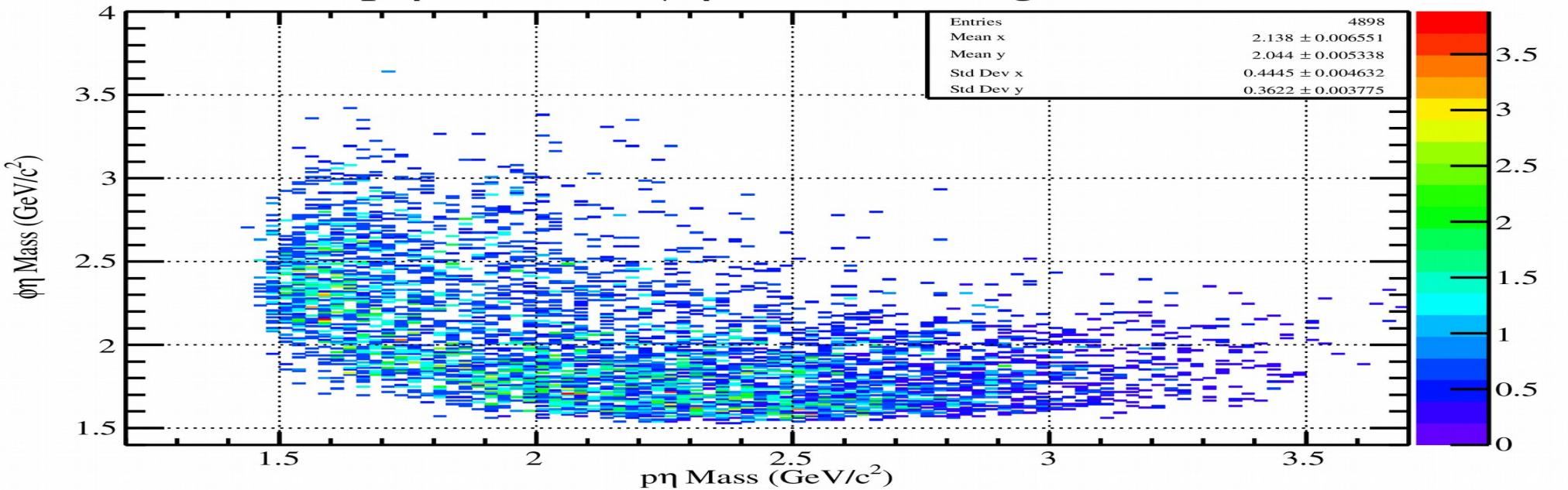


# PhiEta Vs PEta

p $\eta$  Mass Vs  $\phi\eta$  Mass - Signal

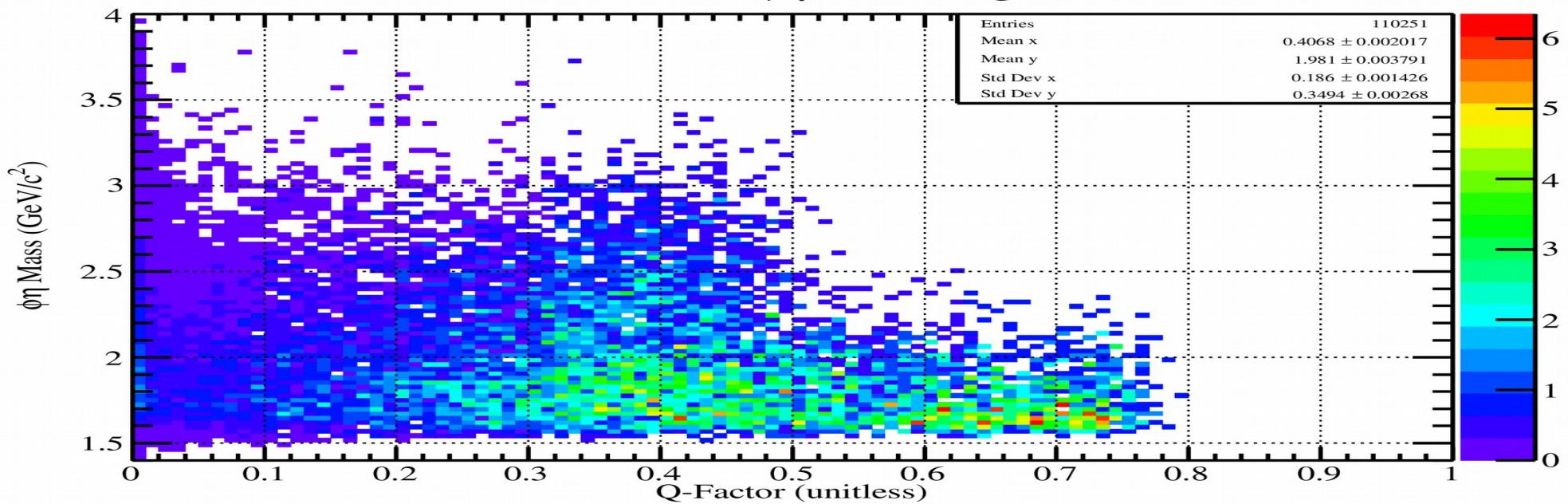


p $\eta$  Mass Vs  $\phi\eta$  Mass - Background

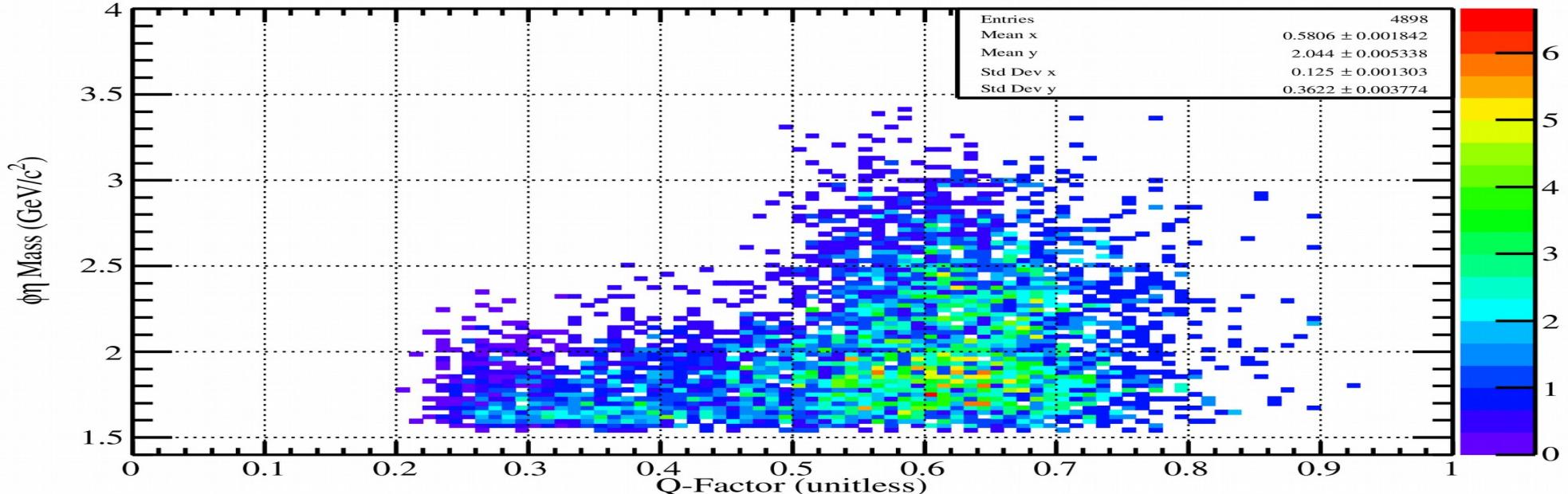


# PhiEta Vs Qvalue

Q-Factor Vs  $\phi\eta$  Mass - Signal

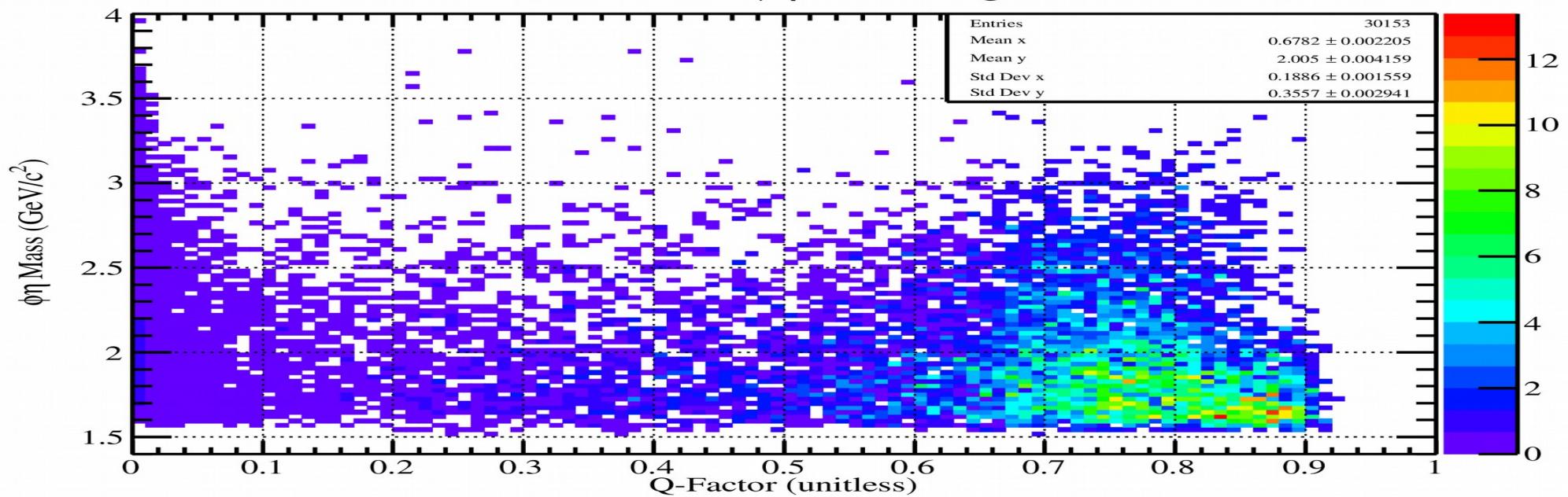


Q-Factor Vs  $\phi\eta$  Mass - Background

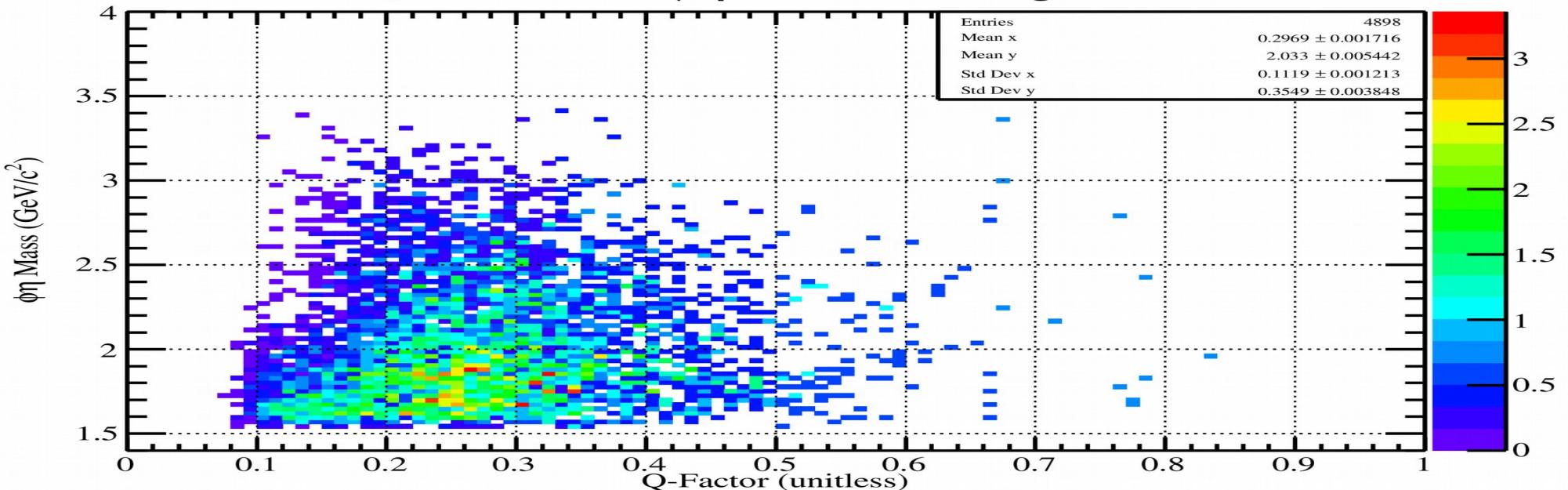


# PhiEta Vs PhiQvalue

Q-Factor Vs  $\phi\eta$  Mass - Signal

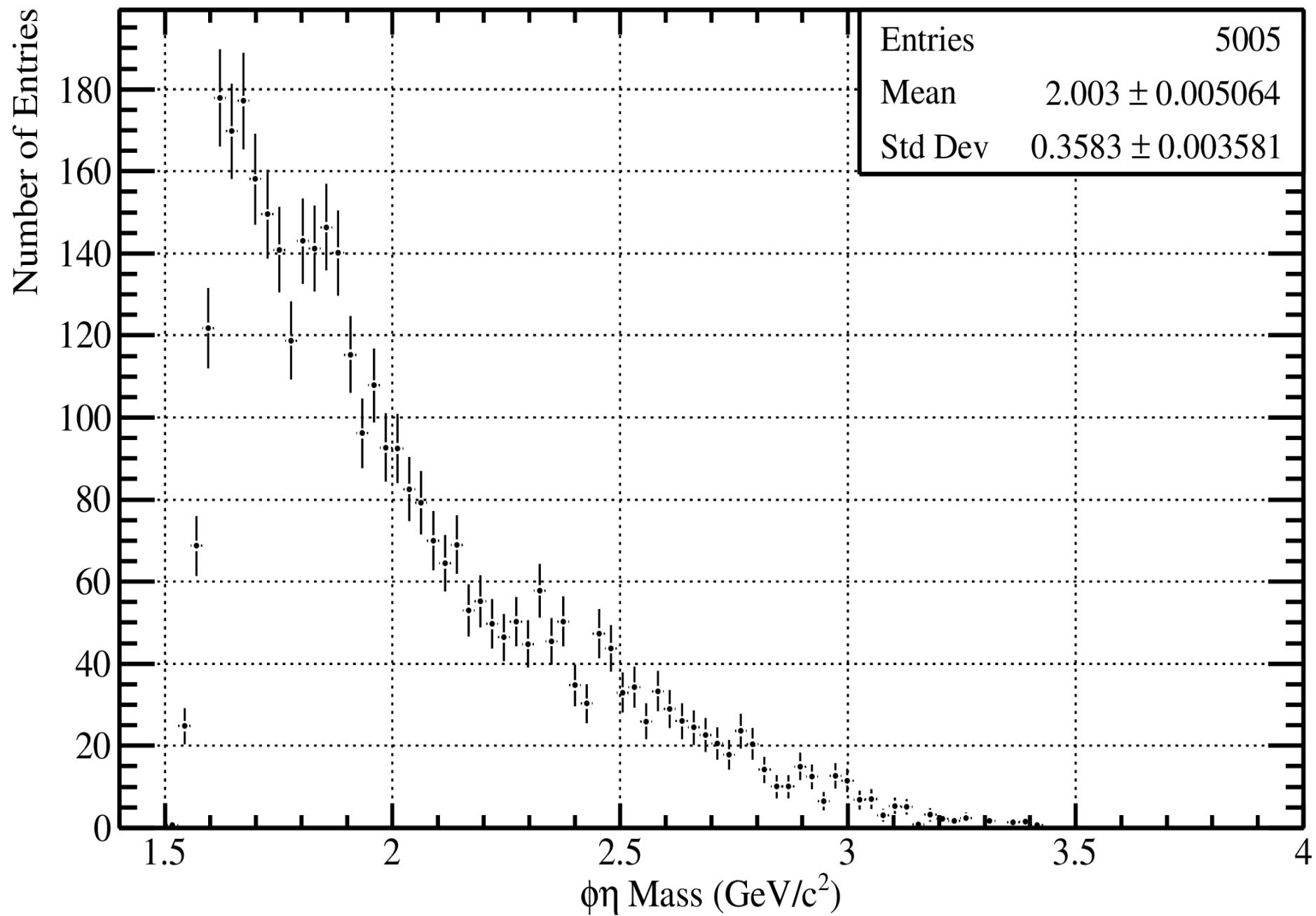


Q-Factor Vs  $\phi\eta$  Mass - Background



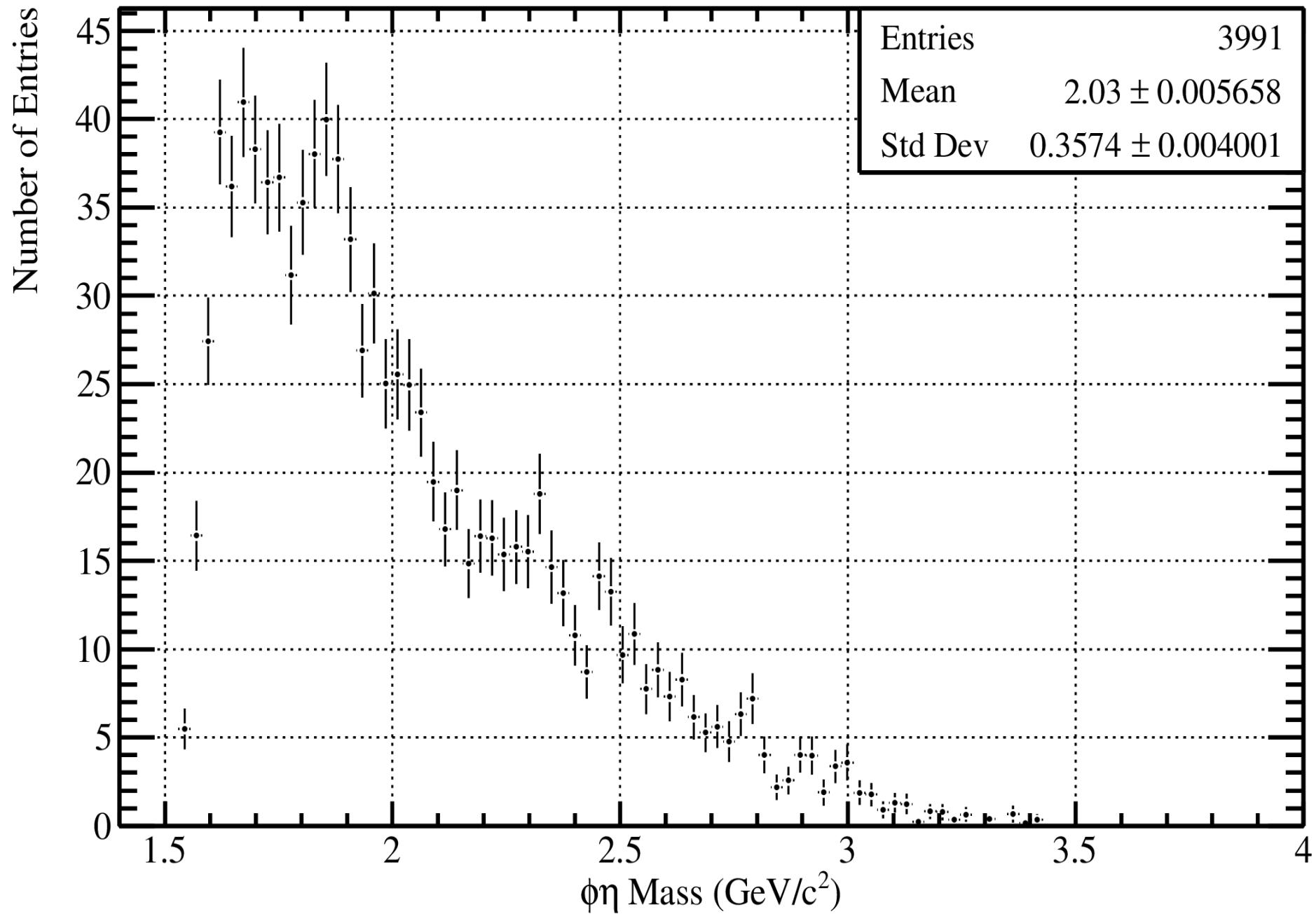
# PhiEta Vs Phi Qvalue: Signal Projection

ProjectionY of binx=[61,90] [x=0.600..0.900]

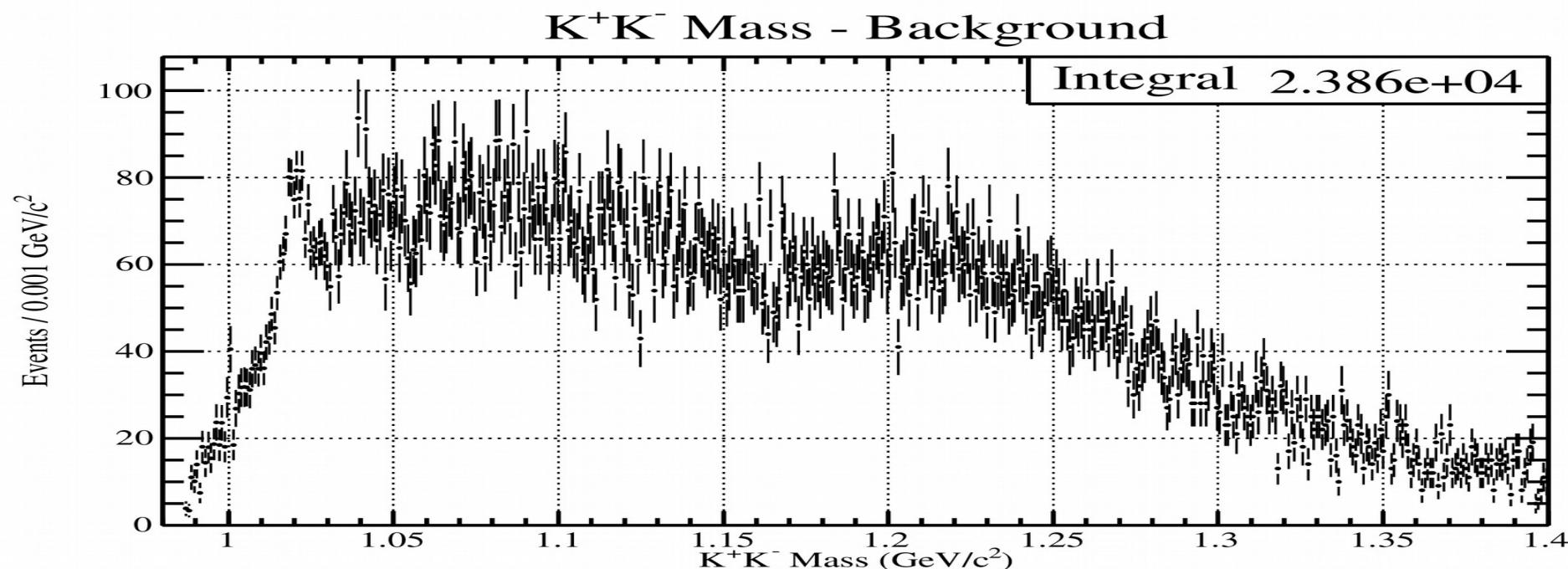
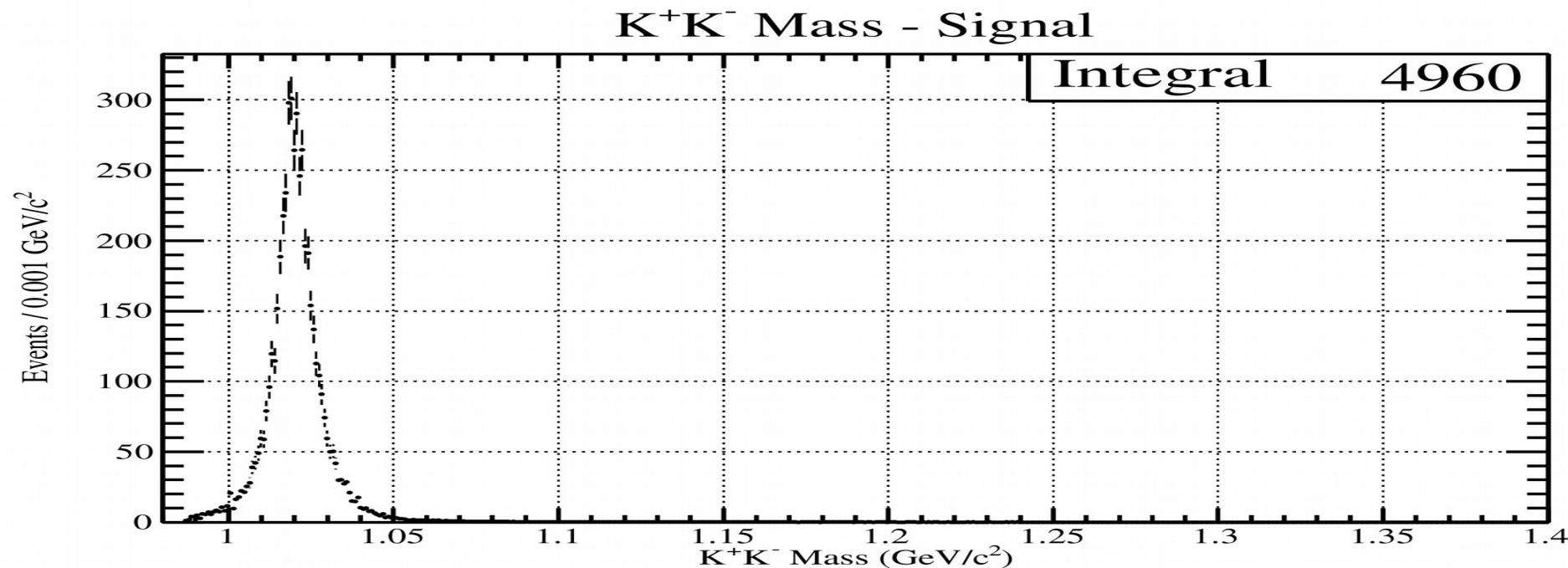


# PhiEta Vs Phi Qvalue: BG Projection

ProjectionY of binx=[9,38] [x=0.080..0.380]

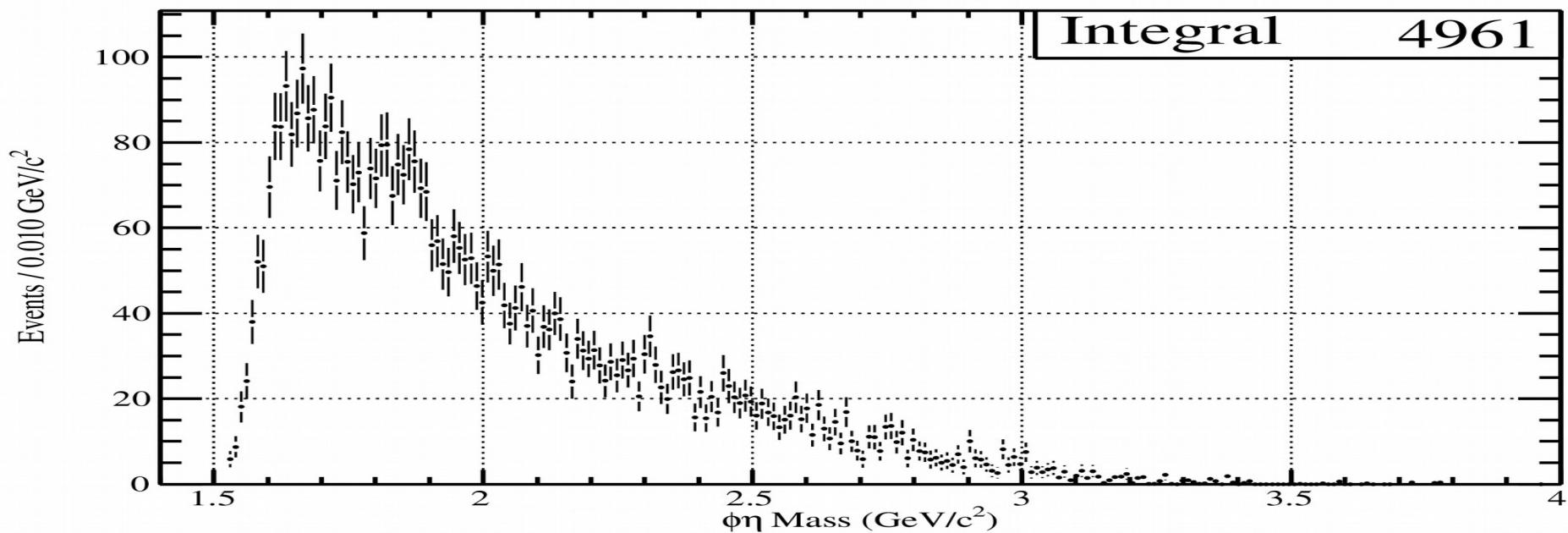


# Phi with Phi Qvalue, BG cut around Eta

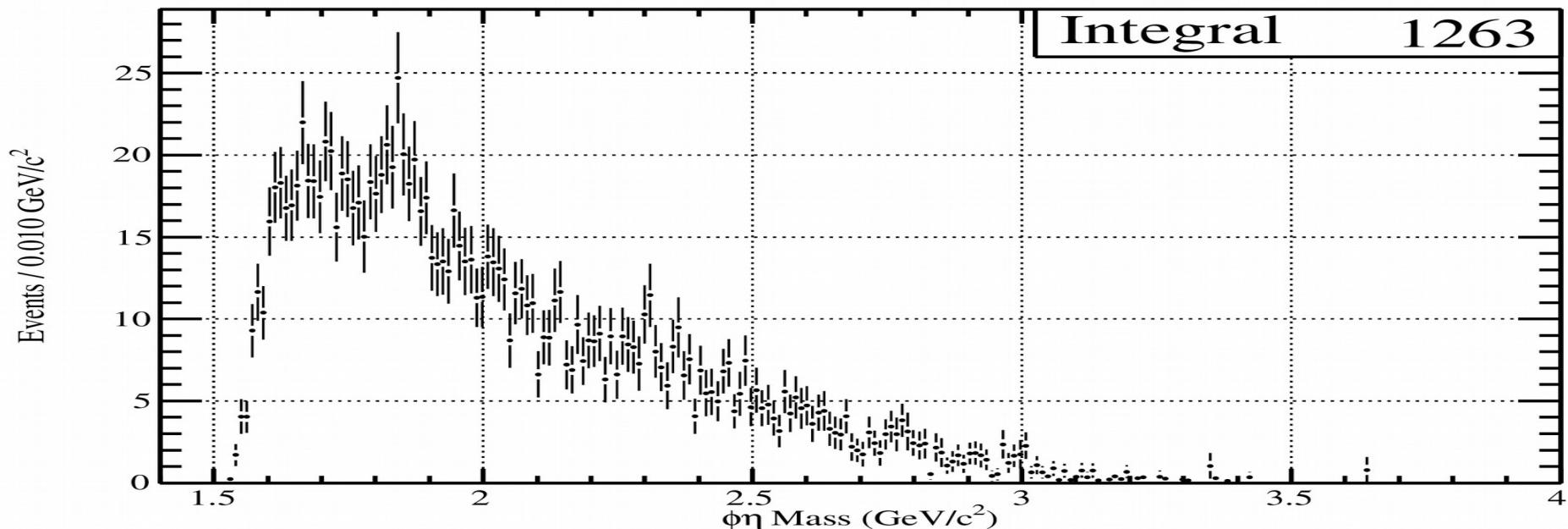


# PhiEta: Phi Qvalue, cut around Eta

$\phi\eta$  Mass - Signal

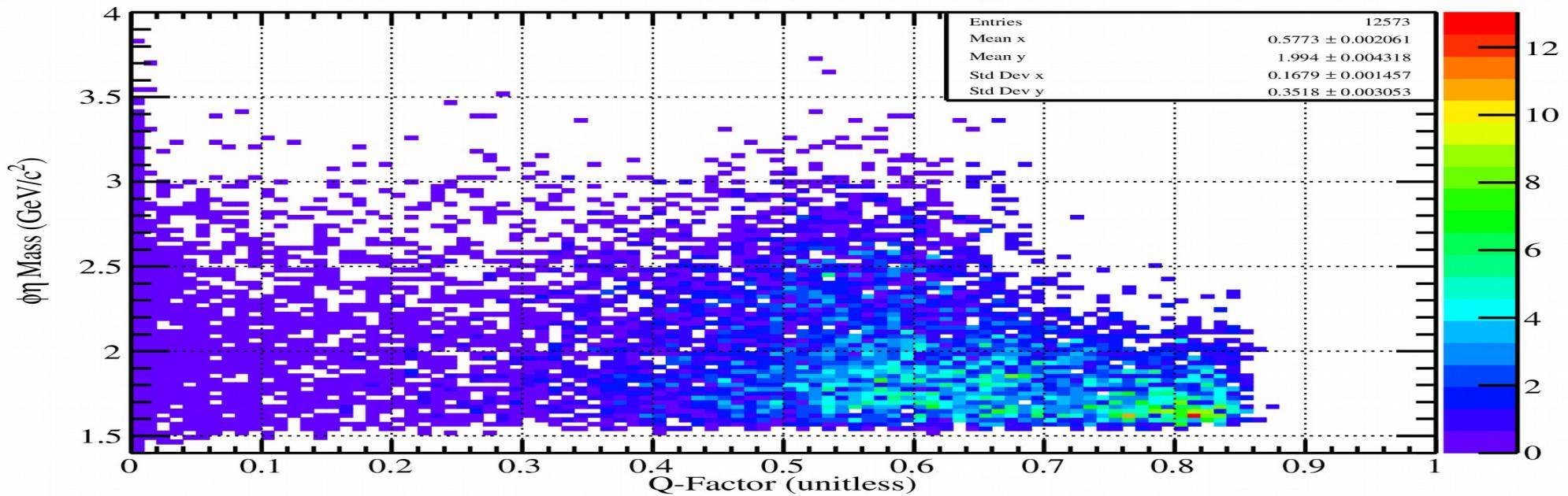


$\phi\eta$  Mass - Background

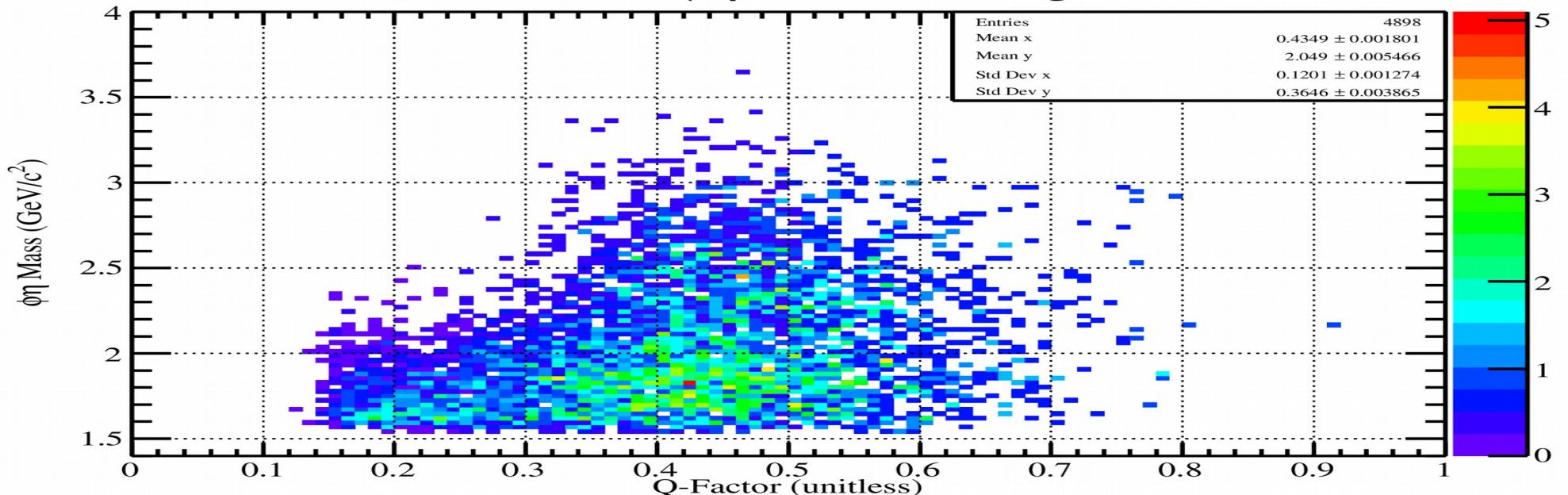


# PhiEta Vs EtaQvalue

Q-Factor Vs  $\phi\eta$  Mass - Signal

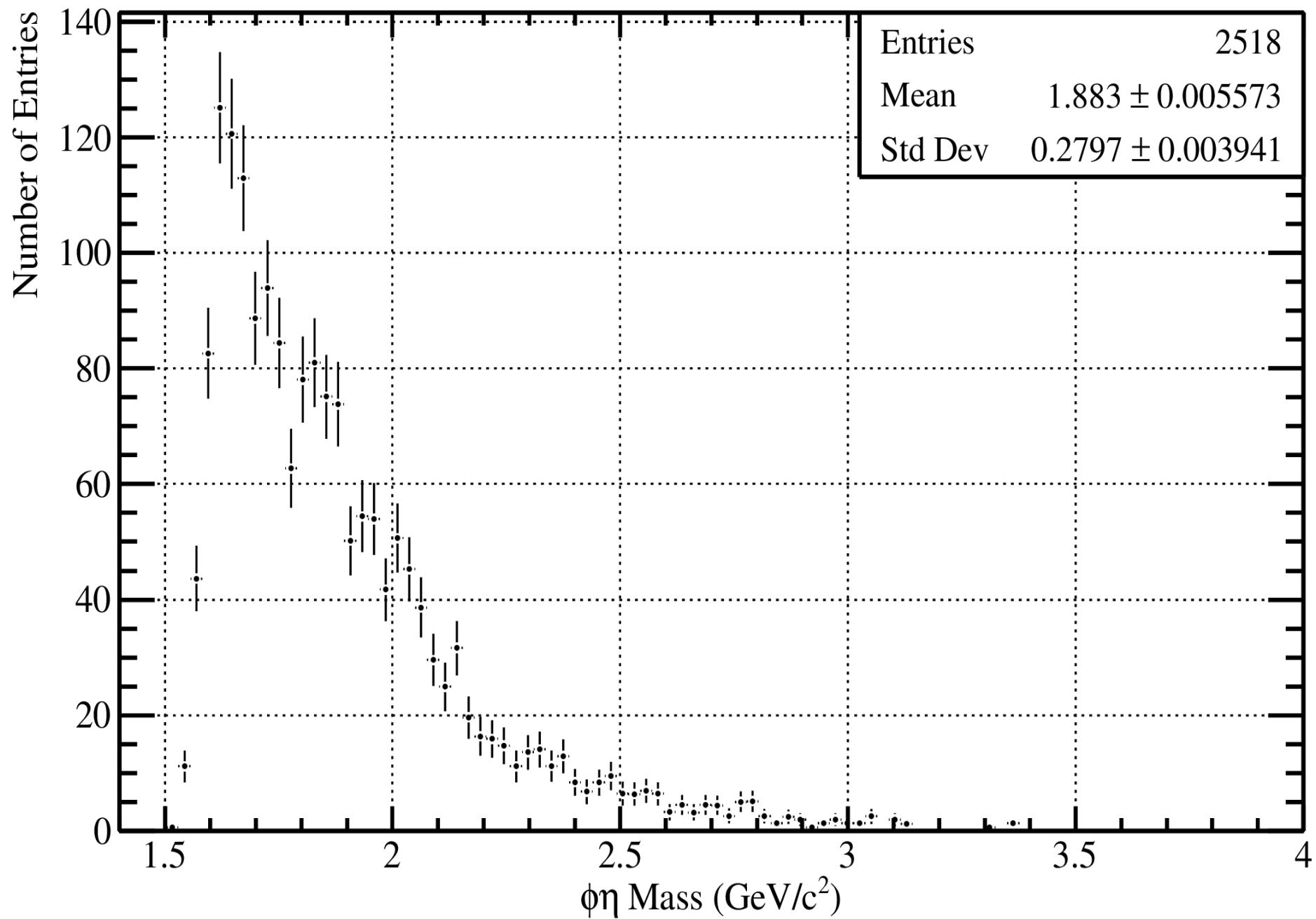


Q-Factor Vs  $\phi\eta$  Mass - Background



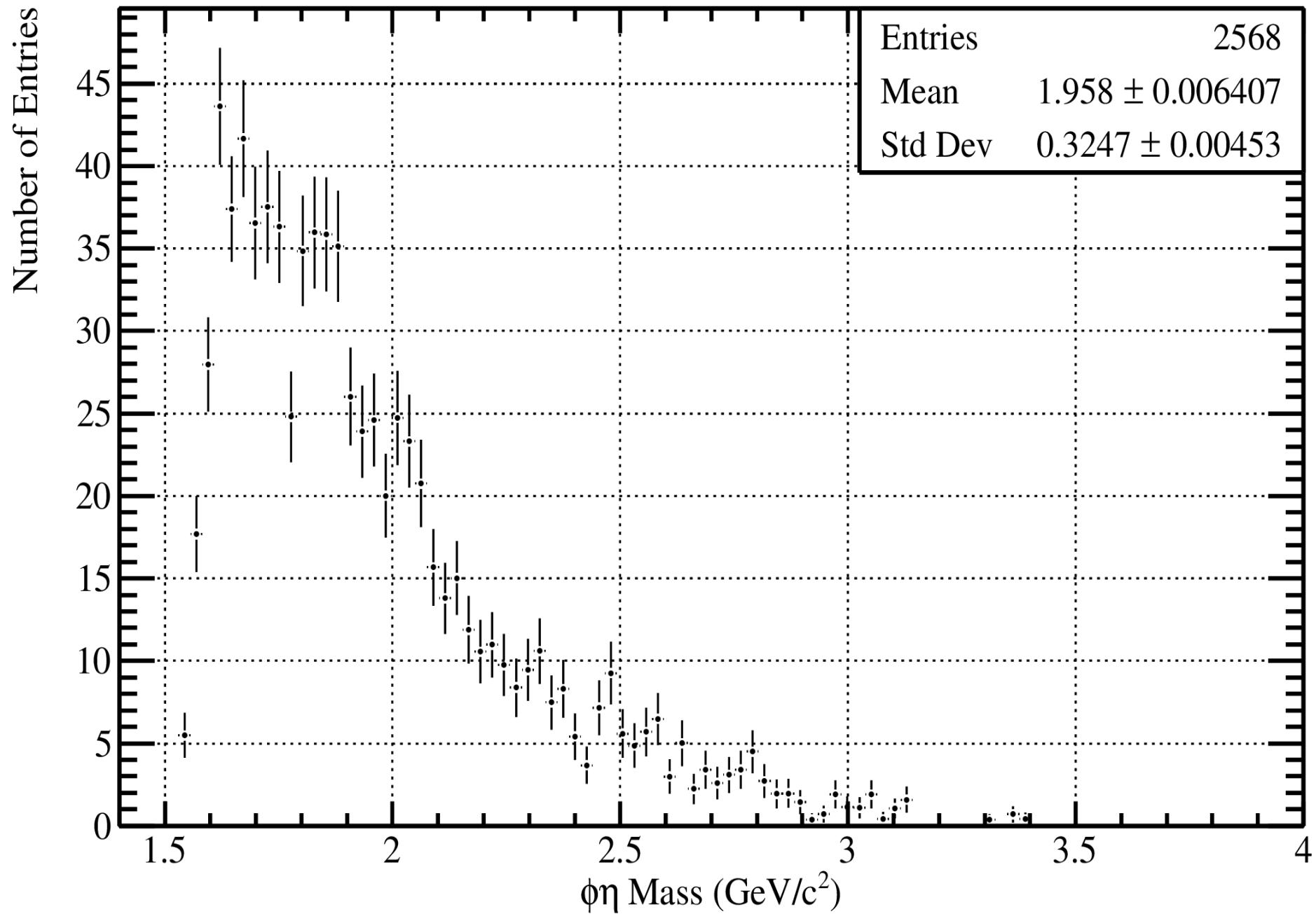
# PhiEta Vs Eta Qvalue: Signal Projection

ProjectionY of binx=[61,90] [x=0.600..0.900]

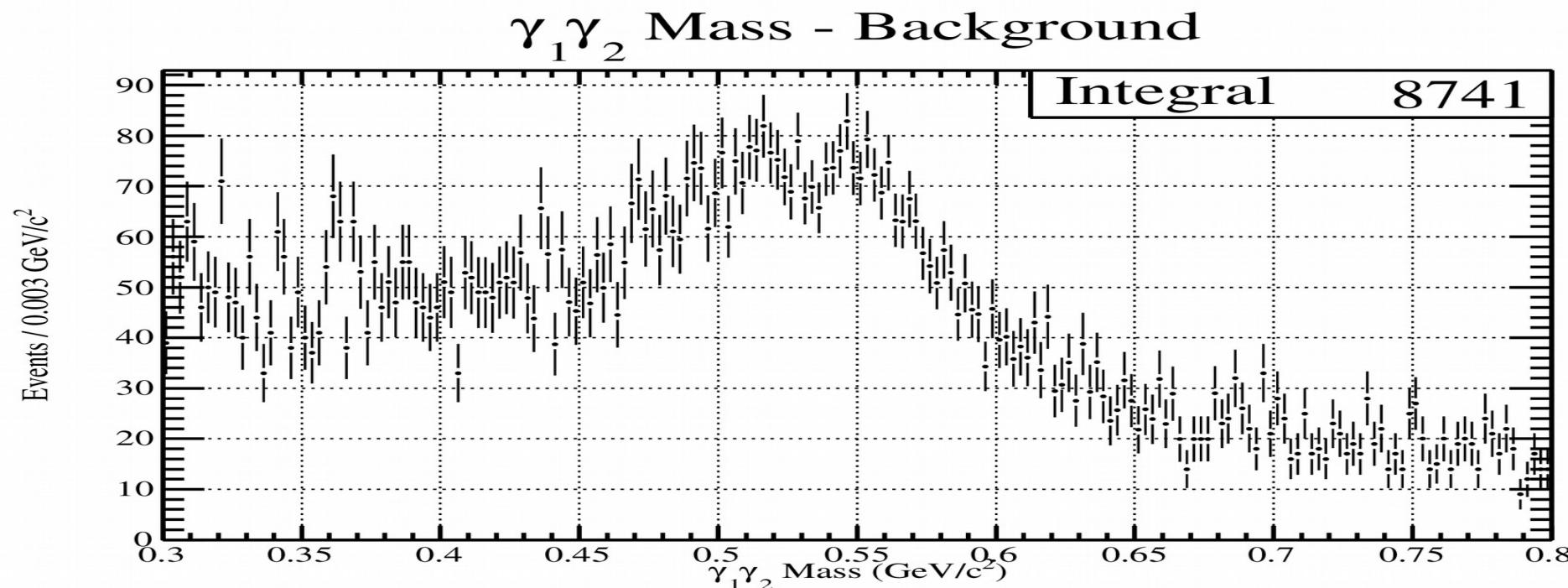
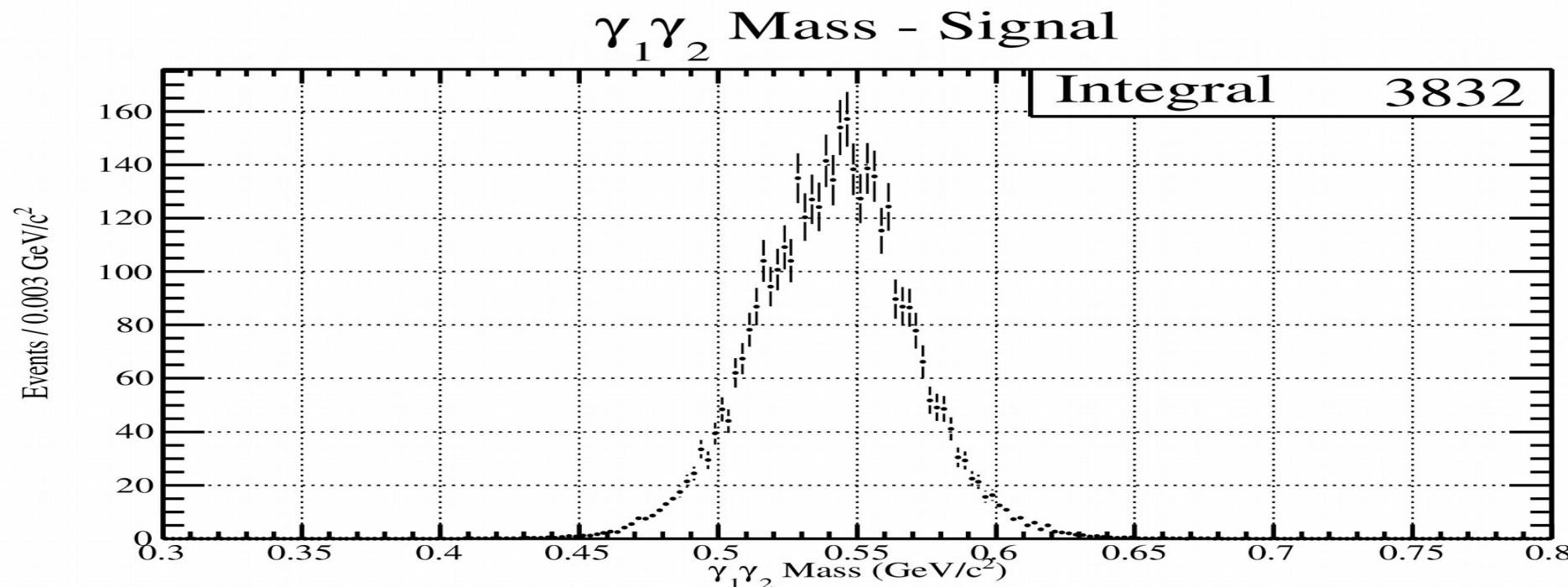


# PhiEta Vs Phi Qvalue: BG Projection

ProjectionY of binx=[13,42] [x=0.120..0.420]

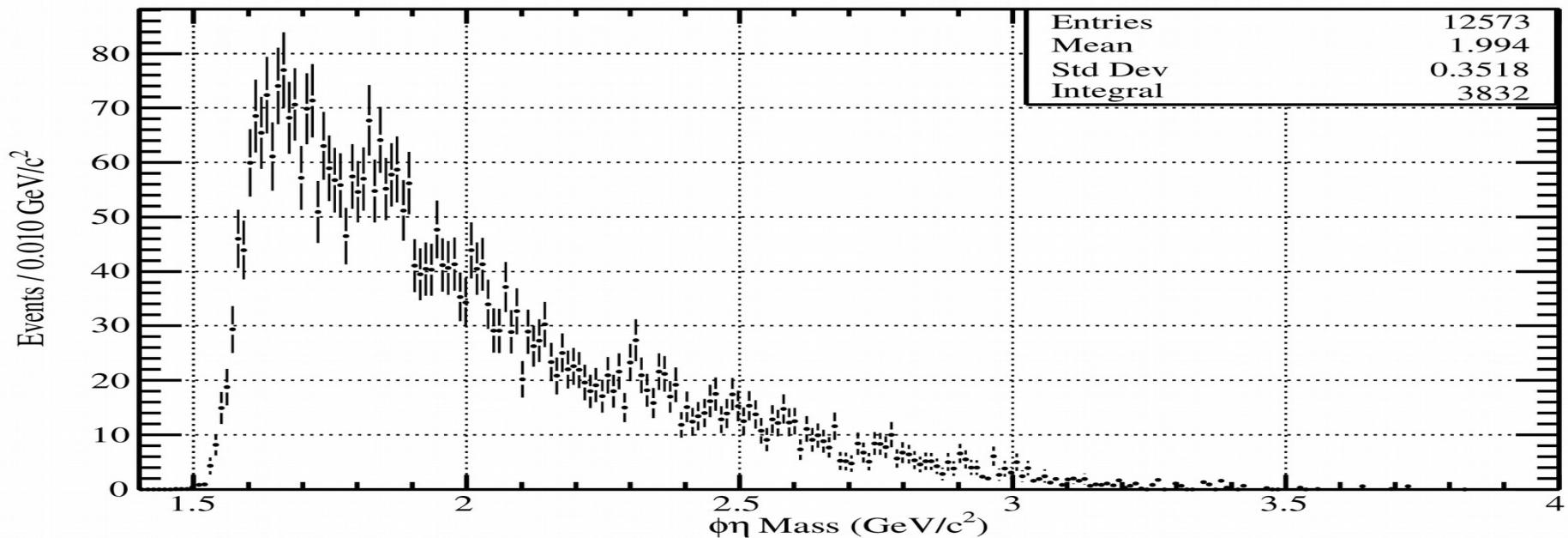


# Eta with Eta Qvalue, BG cut around Phi

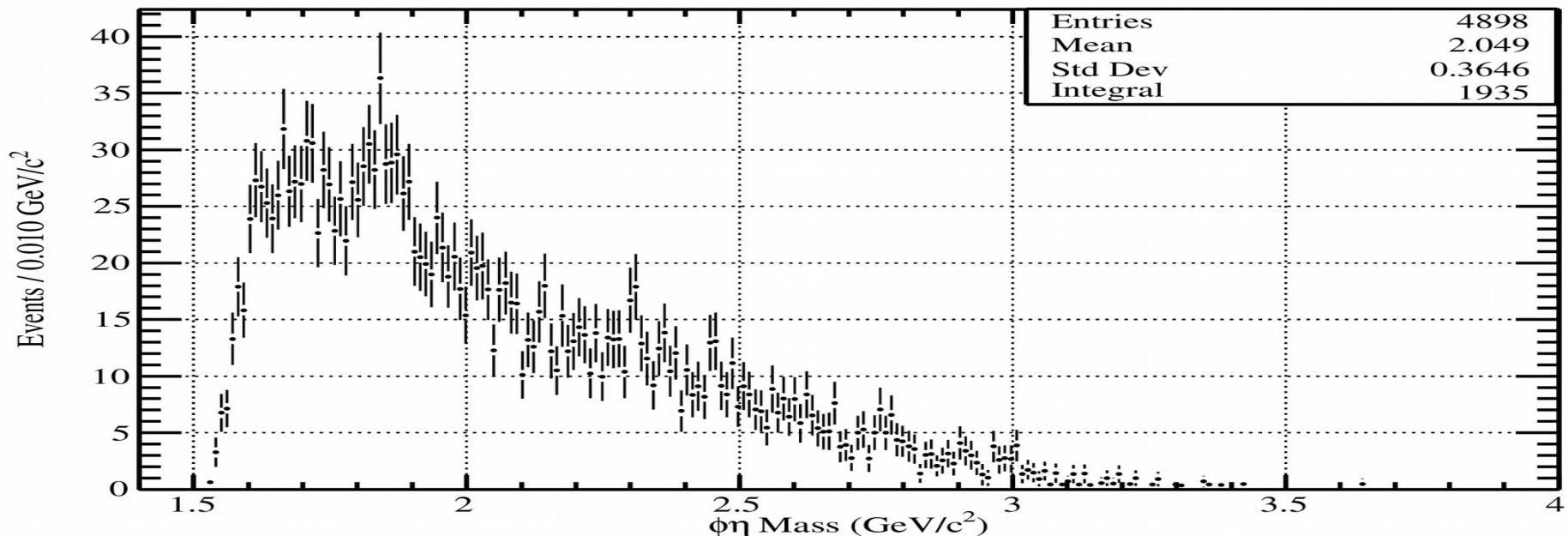


# PhiEta: Eta Qvalue, cut around Phi

$\phi\eta$  Mass - Signal



$\phi\eta$  Mass - Background



# A useful reference:

## "Search for New Forms of Hadronic Matter in Photoproduction", Eugenio, et al.

			$J^{PC}$	Name	Mass (MeV)
n=2	L=0	S=0	$0^{-+}$	$\eta_s$	1415
		S=1	$1^{--}$	$\phi$	1680
	L=1	S=0	$1^{+-}$	$h_1$	1850
			$0^{++}$	$f_0$	2000
		S=1	$1^{++}$	$f_1$	1950
			$2^{++}$	$f_2$	2000
		L=0	$0^{-+}$	$\eta_s$	1950
		S=1	$1^{--}$	$\phi$	2050

Table 2: Radial Excitations of ( $I=0, s\bar{s}$ ) Mesons

			$J^{PC}$	Name	Mass (MeV)
n=1	L=0	S=0	$0^{-+}$	$\eta, \eta'$	548,958
		S=1	$1^{--}$	$\phi$	1020
	L=1	S=0	$1^{+-}$	$h'_1$	1380
			$0^{++}$	$f'_0$	1500
		S=1	$1^{++}$	$f'_1$	1530
			$2^{++}$	$f'_2$	1525
		L=2	$2^{-+}$	$\eta'_2$	1850
		S=1	$1^{--}$	$\phi_1$	1850
			$2^{--}$	$\phi_2$	1850
			$3^{--}$	$\phi_3$	1854

Table 3: Orbital Excitations of ( $I=0, s\bar{s}$ ) Mesons

# A useful reference:

"Search for New and Unusual Strangeonia States Using with GlueX at Thomas Jefferson National Accelerator Facility", Cannon, Prospectus

- If we consider the quantum states of  $\varphi(1^{--})$  and  $\eta(0^{++})$ , we can derive the allowed parent  $J^{PC}$  states:

$\ell$	$J^{PC}$
$\ell=0$	$1^{+-}$
$\ell=1$	$0^{++}, 1^{--}, 2^{--}$
$\ell=2$	$1^{+-}, 2^{++}, 3^{+-}$

# A useful reference:

## PDG – Meson Reference Table

$n^{2s+1}\ell_J$	$J^{PC}$	$\mathbf{l = 1}$ $u\bar{d}, \bar{u}d, \frac{1}{\sqrt{2}}(d\bar{d} - u\bar{u})$	$\mathbf{l = \frac{1}{2}}$ $u\bar{s}, d\bar{s}; \bar{d}s, -\bar{u}s$	$\mathbf{l = 0}$ $f'$	$\mathbf{l = 0}$ $f$	$\theta_{\text{quad}}$ [°]	$\theta_{\text{lin}}$ [°]
$1^1S_0$	$0^{-+}$	$\pi$	$K$	$\eta$	$\eta'(958)$	-11.4	-24.5
$1^3S_1$	$1^{--}$	$\rho(770)$	$K^*(892)$	$\phi(1020)$	$\omega(782)$	39.1	36.4
$1^1P_1$	$1^{+-}$	$b_1(1235)$	$K_{1B}^\dagger$	$h_1(1380)$	$h_1(1170)$		
$1^3P_0$	$0^{++}$	$a_0(1450)$	$K_0^*(1430)$	$f_0(1710)$	$f_0(1370)$		
$1^3P_1$	$1^{++}$	$a_1(1260)$	$K_{1A}^\dagger$	$f_1(1420)$	$f_1(1285)$		
$1^3P_2$	$2^{++}$	$a_2(1320)$	$K_2^*(1430)$	$f_2'(1525)$	$f_2(1270)$	32.1	30.5
$1^1D_2$	$2^{-+}$	$\pi_2(1670)$	$K_2(1770)^\dagger$	$\eta_2(1870)$	$\eta_2(1645)$		
$1^3D_1$	$1^{--}$	$\rho(1700)$	$K^*(1680)$	?	$\omega(1650)$		
$1^3D_2$	$2^{--}$		$K_2(1820)$	?			
$1^3D_3$	$3^{--}$	$\rho_3(1690)$	$K_3^*(1780)$	$\phi_3(1850)$ ?	$\omega_3(1670)$	31.8	30.8
$1^3F_4$	$4^{++}$	$a_4(2040)$	$K_4^*(2045)$		$f_4(2050)$		
$1^3G_5$	$5^{--}$	$\rho_5(2350)$	$K_5^*(2380)$				
$1^3H_6$	$6^{++}$	$a_6(2450)$			$f_6(2510)$		
$2^1S_0$	$0^{-+}$	$\pi(1300)$	$K(1460)$	$\eta(1475)$	$\eta(1295)$		
$2^3S_1$	$1^{--}$	$\rho(1450)$	$K^*(1410)$	$\phi(1680)$ ?	$\omega(1420)$		

<sup>†</sup> The  $1^{+\pm}$  and  $2^{-\pm}$  isospin  $\frac{1}{2}$  states mix. In particular, the  $K_{1A}$  and  $K_{1B}$  are nearly equal ( $45^\circ$ ) mixtures of the  $K_1(1270)$  and  $K_1(1400)$ . The physical vector mesons listed under  $1^3D_1$  and  $2^3S_1$  may be mixtures of  $1^3D_1$  and  $2^3S_1$ .

# A useful reference:

## PDG – Meson Reference Table

$n^{2s+1}\ell_J$	$J^{PC}$	$\mathbf{l = 1}$ $u\bar{d}, \bar{u}d, \frac{1}{\sqrt{2}}(d\bar{d} - u\bar{u})$	$\mathbf{l = \frac{1}{2}}$ $u\bar{s}, d\bar{s}; \bar{d}s, -\bar{u}s$	$\mathbf{l = 0}$ $f'$	$\mathbf{l = 0}$ $f$	$\theta_{\text{quad}}$ [°]	$\theta_{\text{lin}}$ [°]
$1^1S_0$	$0^{-+}$	$\pi$	$K$	$\eta$	$\eta'(958)$	-11.4	-24.5
$1^3S_1$	$1^{--}$	$\rho(770)$	$K^*(892)$	$\phi(1020)$	$\omega(782)$	39.1	36.4
$1^1P_1$	$1^{+-}$	$b_1(1235)$	$K_{1B}^\dagger$	$h_1(1380)$	$h_1(1170)$		
$1^3P_0$	$0^{++}$	$a_0(1450)$	$K_0^*(1430)$	$f_0(1710)$	$f_0(1370)$		
$1^3P_1$	$1^{++}$	$a_1(1260)$	$K_{1A}^\dagger$	$f_1(1420)$	$f_1(1285)$		
$1^3P_2$	$2^{++}$	$a_2(1320)$	$K_2^*(1430)$	$f_2'(1525)$	$f_2(1270)$	32.1	30.5
$1^1D_2$	$2^{-+}$	$\pi_2(1670)$	$K_2(1770)^\dagger$	$\eta_2(1870)$	$\eta_2(1645)$		
$1^3D_1$	$1^{--}$	$\rho(1700)$	$K^*(1680)$	?	$\omega(1650)$		
$1^3D_2$	$2^{--}$		$K_2(1820)$	?			
$1^3D_3$	$3^{--}$	$\rho_3(1690)$	$K_3^*(1780)$	$\phi_3(1850)$ ?	$\omega_3(1670)$	31.8	30.8
$1^3F_4$	$4^{++}$	$a_4(2040)$	$K_4^*(2045)$		$f_4(2050)$		
$1^3G_5$	$5^{--}$	$\rho_5(2350)$	$K_5^*(2380)$				
$1^3H_6$	$6^{++}$	$a_6(2450)$			$f_6(2510)$		
$2^1S_0$	$0^{-+}$	$\pi(1300)$	$K(1460)$	$\eta(1475)$	$\eta(1295)$		
$2^3S_1$	$1^{--}$	$\rho(1450)$	$K^*(1410)$	$\phi(1680)$ ?	$\omega(1420)$		

<sup>†</sup> The  $1^{+\pm}$  and  $2^{-\pm}$  isospin  $\frac{1}{2}$  states mix. In particular, the  $K_{1A}$  and  $K_{1B}$  are nearly equal ( $45^\circ$ ) mixtures of the  $K_1(1270)$  and  $K_1(1400)$ . The physical vector mesons listed under  $1^3D_1$  and  $2^3S_1$  may be mixtures of  $1^3D_1$  and  $2^3S_1$ .

# A useful reference: PDG – Phi (1850) Reference

Citation: M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018)

$\phi_3(1850)$

$J^G(J^{PC}) = 0^-(3^- -)$

$\phi_3(1850)$ MASS							
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT			
<b><math>1854 \pm 7</math> OUR AVERAGE</b>							
1855 $\pm 10$		ASTON 88E	LASS	11 $K^- p \rightarrow K^- K^+ \Lambda$ , $K_S^0 K^\pm \pi^\mp \Lambda$			
$1870^{+30}_{-20}$	430	ARMSTRONG 82	OMEQ	$18.5 K^- p \rightarrow$ $K^- K^+ \Lambda$			
$1850 \pm 10$	123	ALHARRAN 81B	HBC	$8.25 K^- p \rightarrow K\bar{K}\Lambda$			
$\phi_3(1850)$ WIDTH							
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT			
<b><math>87^{+28}_{-23}</math> OUR AVERAGE</b>		Error includes scale factor of 1.2.					
$64 \pm 31$		ASTON 88E	LASS	11 $K^- p \rightarrow K^- K^+ \Lambda$ , $K_S^0 K^\pm \pi^\mp \Lambda$			
$160^{+90}_{-50}$	430	ARMSTRONG 82	OMEQ	$18.5 K^- p \rightarrow$ $K^- K^+ \Lambda$			
$80^{+40}_{-30}$	123	ALHARRAN 81B	HBC	$8.25 K^- p \rightarrow K\bar{K}\Lambda$			
$\phi_3(1850)$ DECAY MODES							
Mode		Fraction ( $\Gamma_i/\Gamma$ )					
$\Gamma_1$	$K\bar{K}$	seen					
$\Gamma_2$	$K\bar{K}^*(892) + \text{c.c.}$	seen					
$\phi_3(1850)$ BRANCHING RATIOS							
$\Gamma(K\bar{K}^*(892) + \text{c.c.})/\Gamma(K\bar{K})$				$\Gamma_2/\Gamma_1$			
VALUE	DOCUMENT ID	TECN	COMMENT				
$0.55^{+0.85}_{-0.45}$	ASTON 88E	LASS	11 $K^- p \rightarrow K^- K^+ \Lambda$ , $K_S^0 K^\pm \pi^\mp \Lambda$				
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$0.8 \pm 0.4$	ALHARRAN 81B	HBC	$8.25 K^- p \rightarrow K\bar{K}\pi\Lambda$				
$\phi_3(1850)$ REFERENCES							
ASTON 88E	PL B208 324	D. Aston et al.	(SLAC, NAGO, CINC, INUS) $J^G(J^{PC})$				
ARMSTRONG 82	PL 110B 77	T.A. Armstrong et al.	(BARI, BIRM, CERN+) $J^P$				
ALHARRAN 81B	PL 101B 357	S. Al-Harran et al.	(BIRM, CERN, GLAST+)				

# A useful reference: PDG – Phi(1680) Reference

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## $\phi(1680)$ DECAY MODES

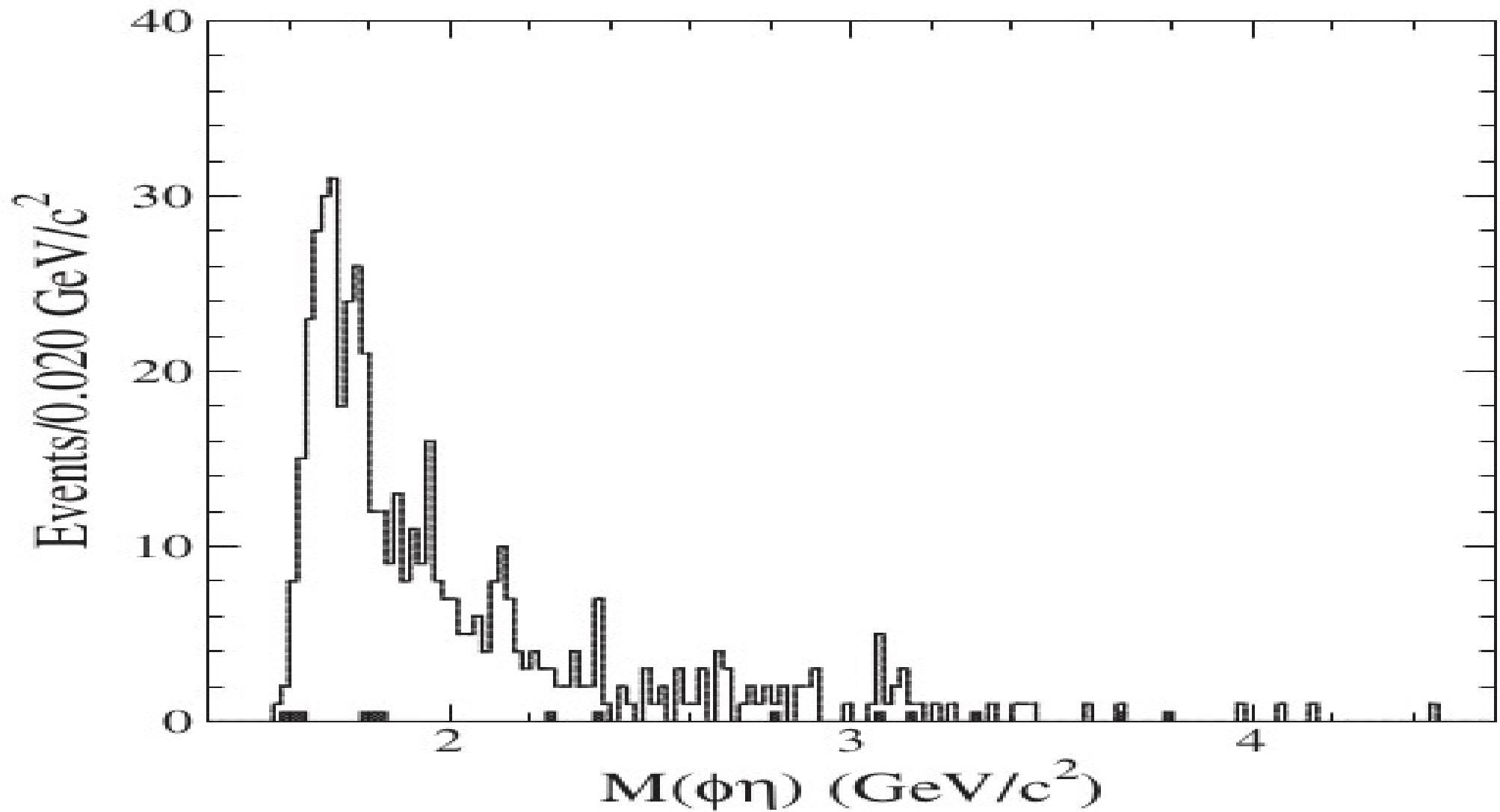
Mode	Fraction ( $\Gamma_i/\Gamma$ )
$\Gamma_1 K\bar{K}^*(892) + \text{c.c.}$	dominant
$\Gamma_2 K_S^0 K\pi$	seen
$\Gamma_3 K\bar{K}$	seen
$\Gamma_4 K_L^0 K_S^0$	
$\Gamma_5 e^+ e^-$	seen
$\Gamma_6 \omega\pi\pi$	not seen
$\Gamma_7 \phi\pi\pi$	
$\Gamma_8 K^+ K^- \pi^+ \pi^-$	seen
$\Gamma_9 \eta\phi$	seen
$\Gamma_{10} \eta\gamma$	seen
$\Gamma_{11} K^+ K^- \pi^0$	

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# A useful reference:

B. Aubert et al., Phys Rev D, BABAR

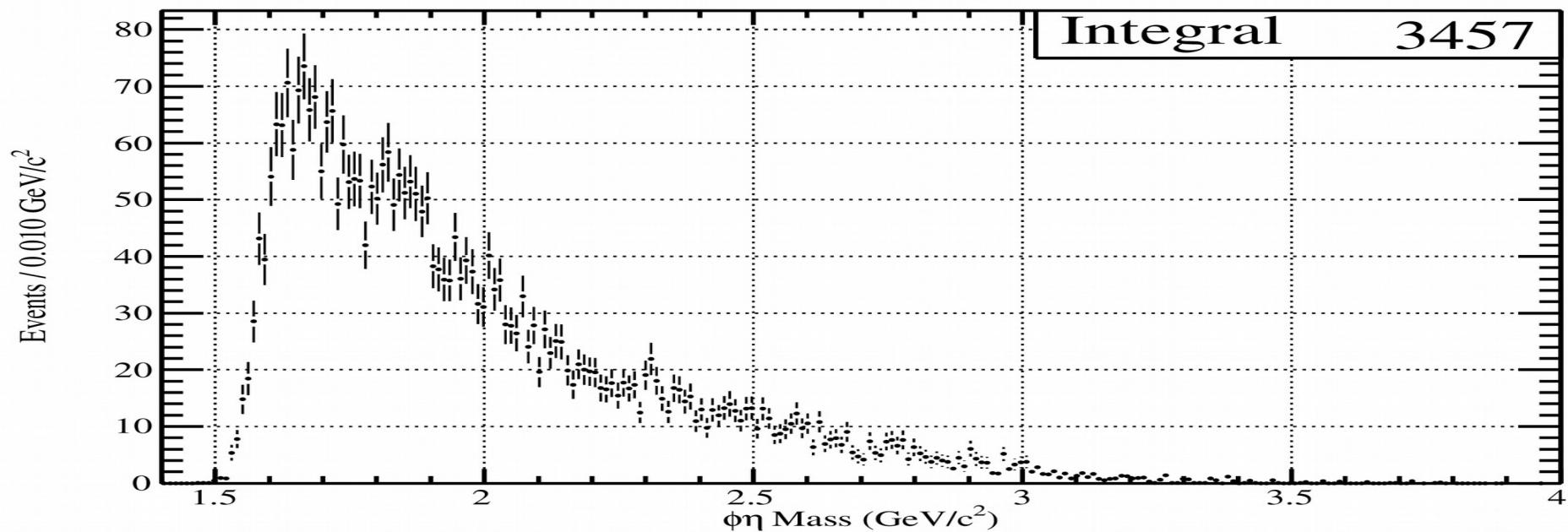
**B. AUBERT *et al.***



**FIG. 33.** The invariant mass distribution of the  $\phi\eta$  system. The shaded histogram refers to the small subtracted background component.

# PhiEta: Qvalue Data

$\phi\eta$  Mass - Signal



$\phi\eta$  Mass - Background

