$\gamma\, p \to p\Phi\eta$ Analysis Update

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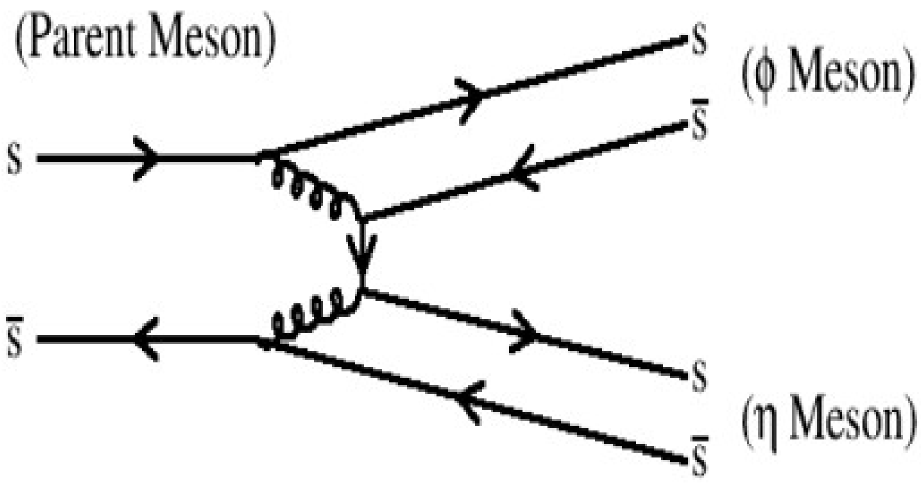
Amplitude Analysis Working Group
(12/03/2018)

Talk Overview

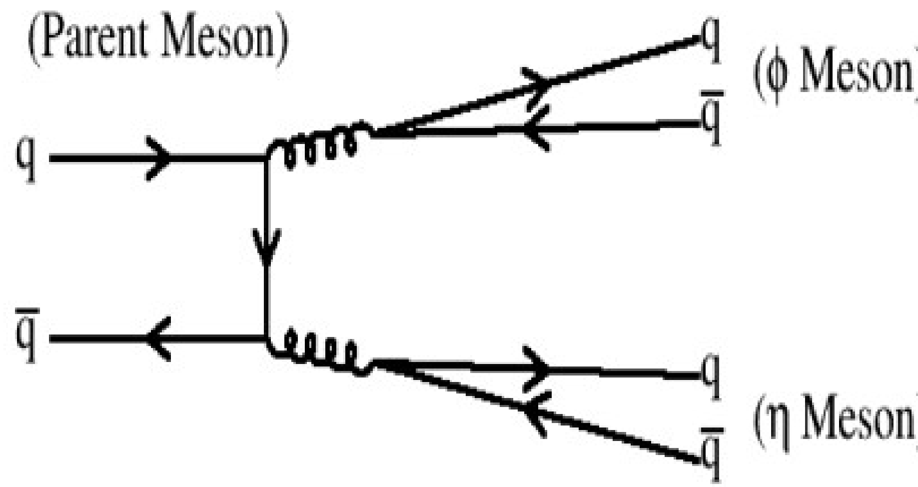
- Motivation to Study the Φη Final State
- Standard PID Cuts
- Additional Cuts Specifically for $\gamma\, p \rightarrow p\Phi\eta$
- Quality Factor Study
- Preliminary Results for Φη Invariant Mass
- What to do next

Motivation to Study the Φη Final State

- The parent state of Φη must be an $s\bar{s}$ bound state due to OZI suppression



(a) Feynman Diagram for OZI allowed process.



(b) Feynman Diagram for OZI forbidden process.

- There are many $s\bar{s}$ states that have not been found

$n\ ^{2s+1}\ell_J$	J^{PC}	I = 1 $u\bar{d}$, $\bar{u}d$, $\frac{1}{\sqrt{2}}(d\bar{d} - u\bar{u})$	I = $\frac{1}{2}$ $u\bar{s}$, $d\bar{s}$; $\bar{d}s$, $-\bar{u}s$	I = 0 f'	I = 0 f	θ_{quad} [°]	θ_{lin} [°]
$1\ ^1S_0$	0^{-+}	**π**	**K**	**η**	**$\eta'(958)$**	−11.3	−24.5
$1\ ^3S_1$	1^{--}	**$\rho(770)$**	**$K^*(892)$**	**$\phi(1020)$**	**$\omega(782)$**	39.2	36.5
$1\ ^1P_1$	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^{++}	**$a_2(1320)$**	**$K_2^*(1430)$**	**$f_2'(1525)$**	**$f_2(1270)$**	29.6	28.0
$1\ ^1D_2$	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^{--}	**$\rho(1450)$**	**$K^*(1410)$**	**$\phi(1680)$**	**$\omega(1420)$**		
$3\ ^1S_0$	0^{-+}	**$\pi(1800)$**			$\eta(1760)$		

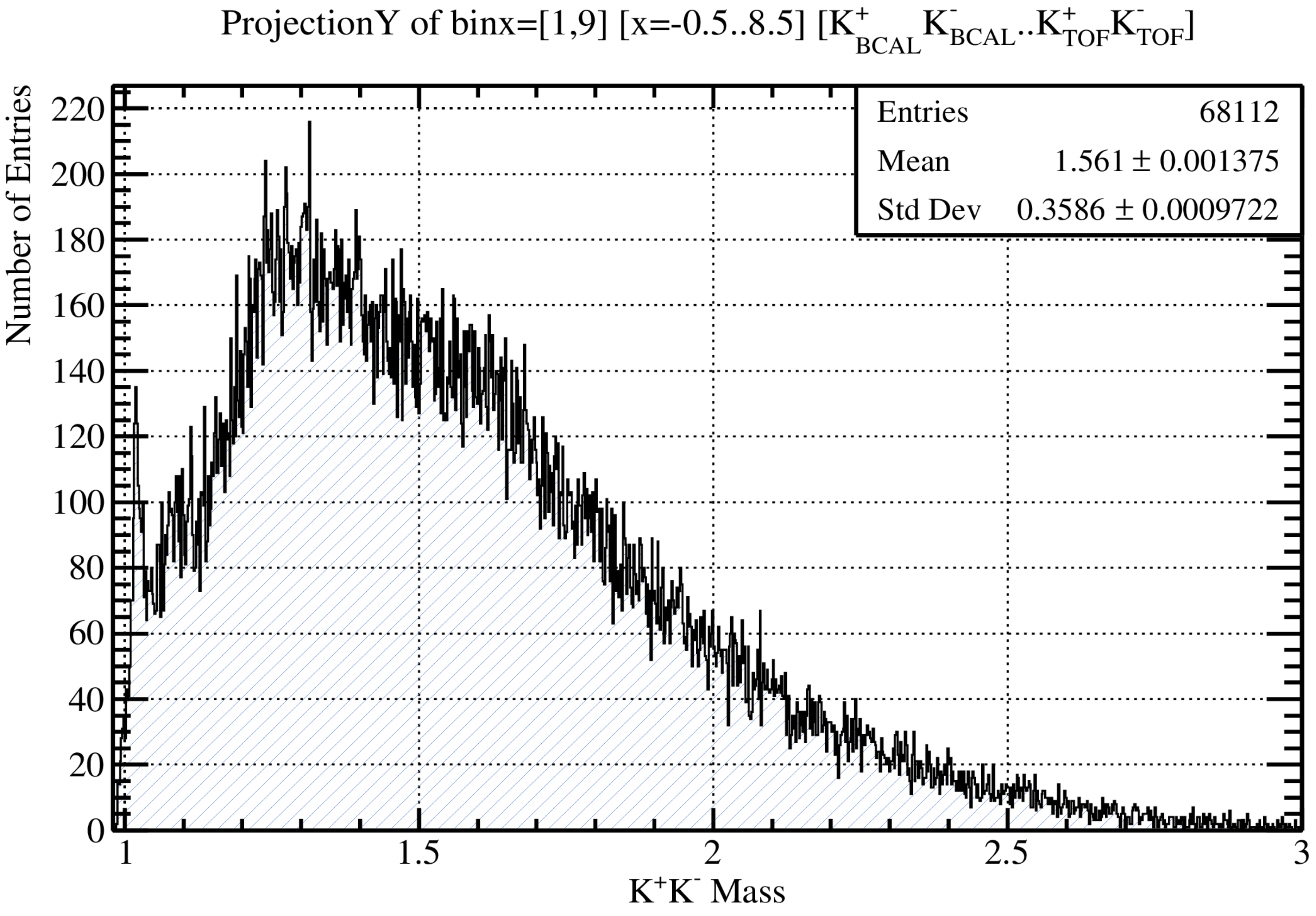
Standard PID Cuts

- The data that was used for this analysis came from the Spring 2017 run period
- The final state topology that was used to study my reaction: $\gamma\, p \rightarrow p\, K^+\, K^-\, \gamma\, \gamma$
- Initial State PID:
    - Beam Photon:
        - 3 beam buckets
        - Energy > 7.5 GeV
    - Target:
        - Vertex Cuts for all reconstructed final state particles to be within the target chamber
        - $51\text{ cm} \leq z \leq 79\text{ cm}; \quad r \leq 1\text{ cm}$

Standard PID Cuts

- Final State PID:
  - Recoil Proton:
    - Standard dE/dX cut
    - Standard Timing Cuts for BCAL, FCAL, and TOF
  - K+/K-:
    - Standard Timing Cuts for BCAL, FCAL, and TOF
  - γ:
    - Standard Timing Cuts for BCAL and FCAL

Additional Cuts Specifically for $\gamma p \rightarrow p\Phi\eta$: (TOF Only)



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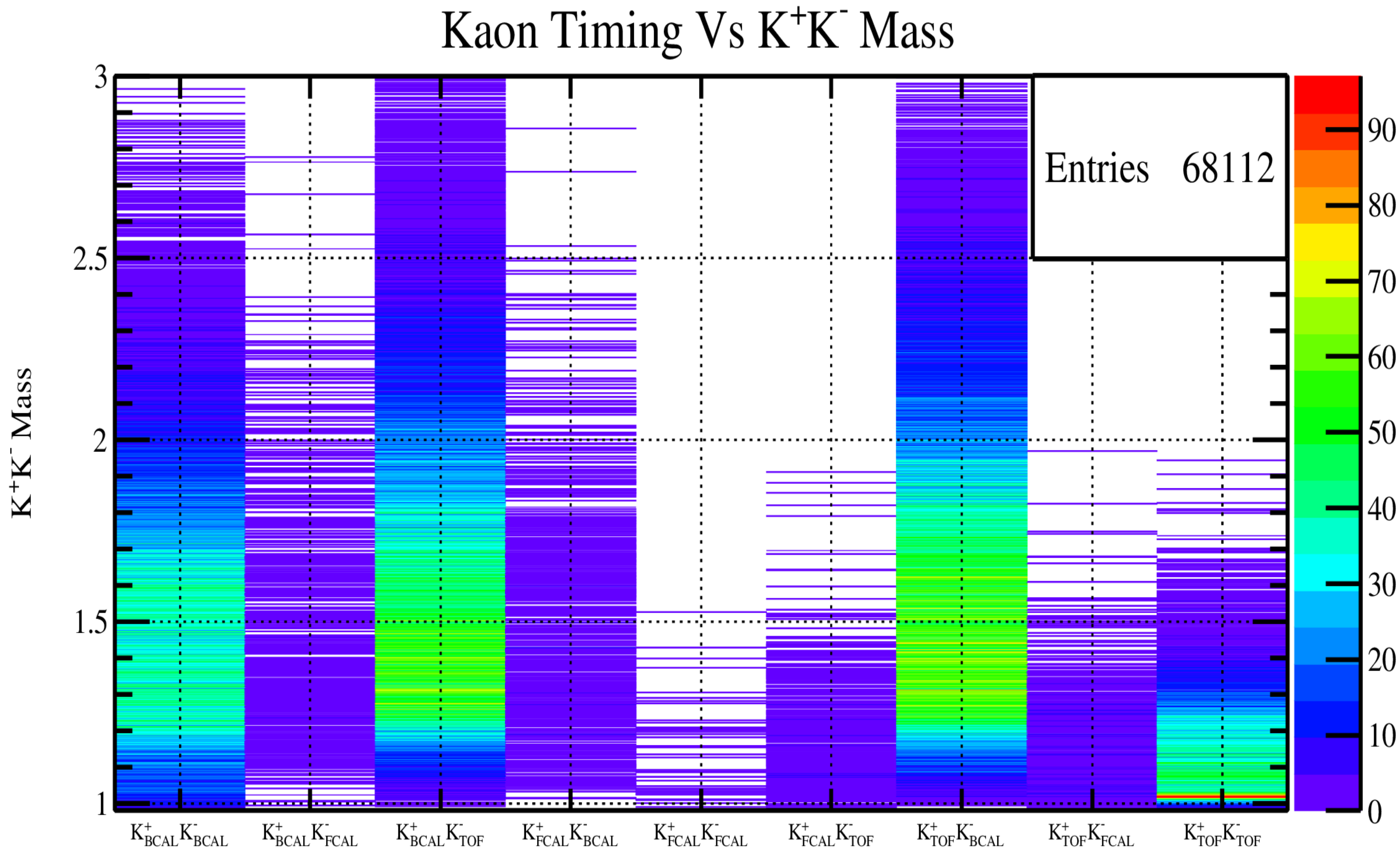

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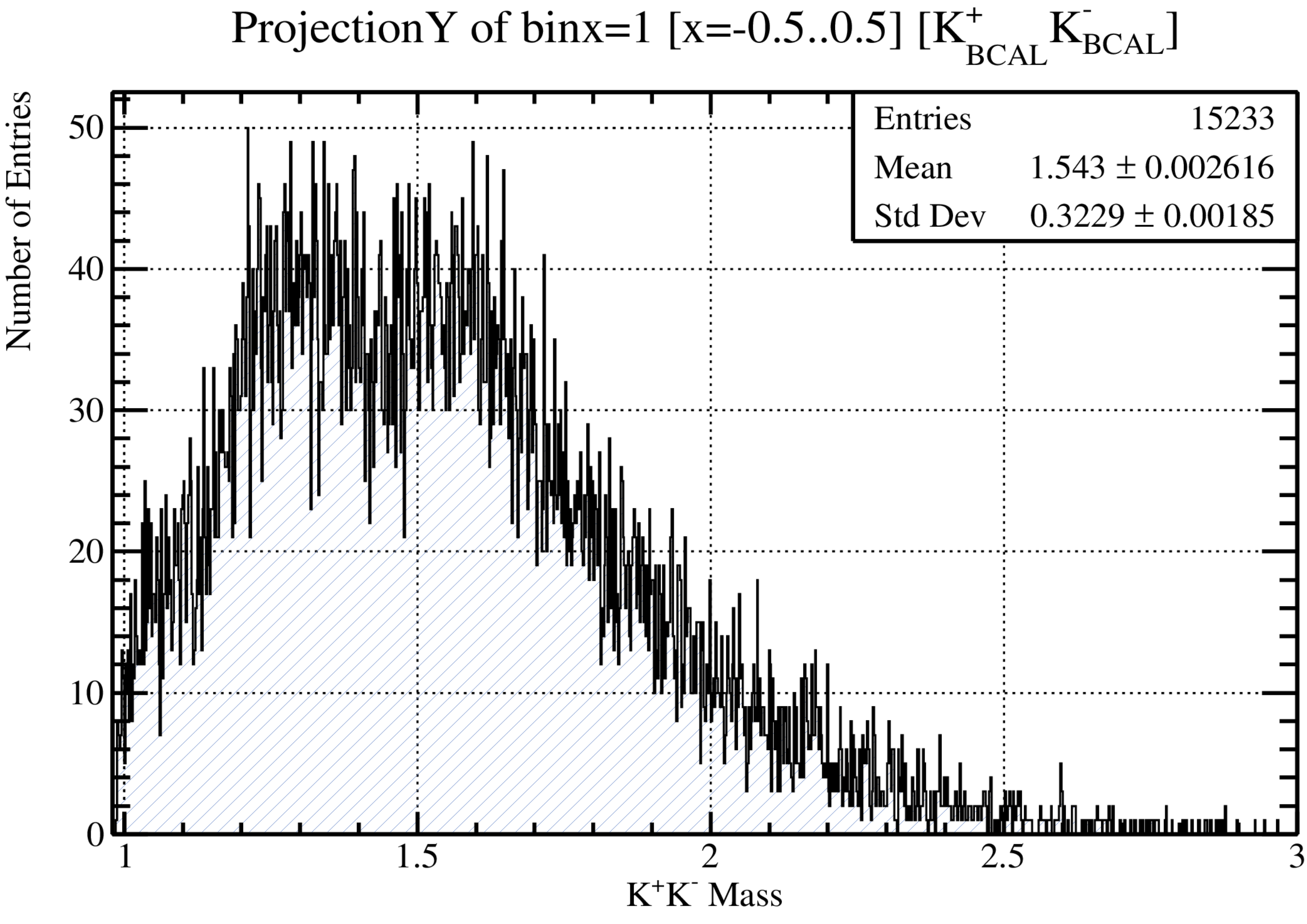
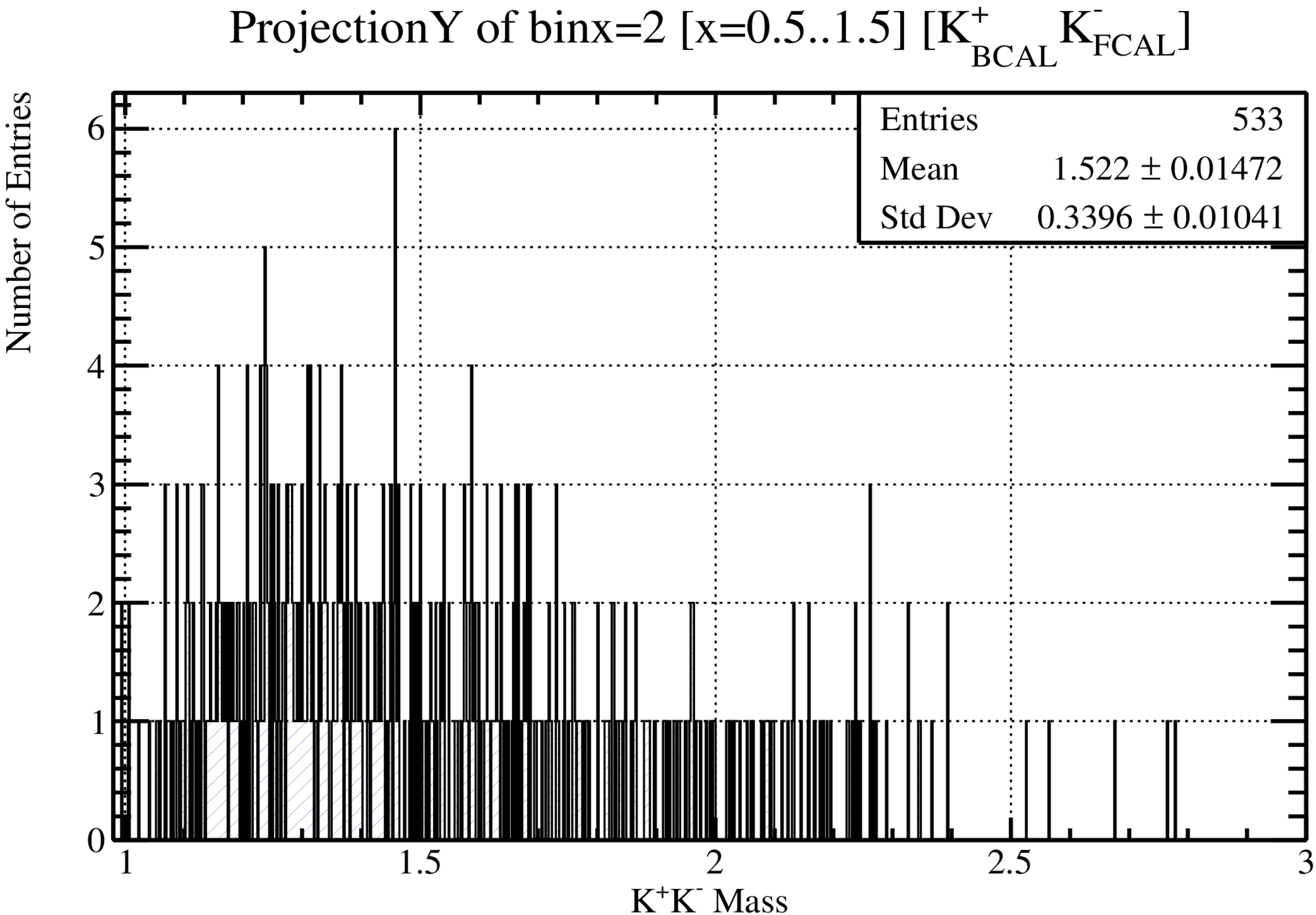


Additional Cuts Specifically for γ p → pΦη: (TOF Only)



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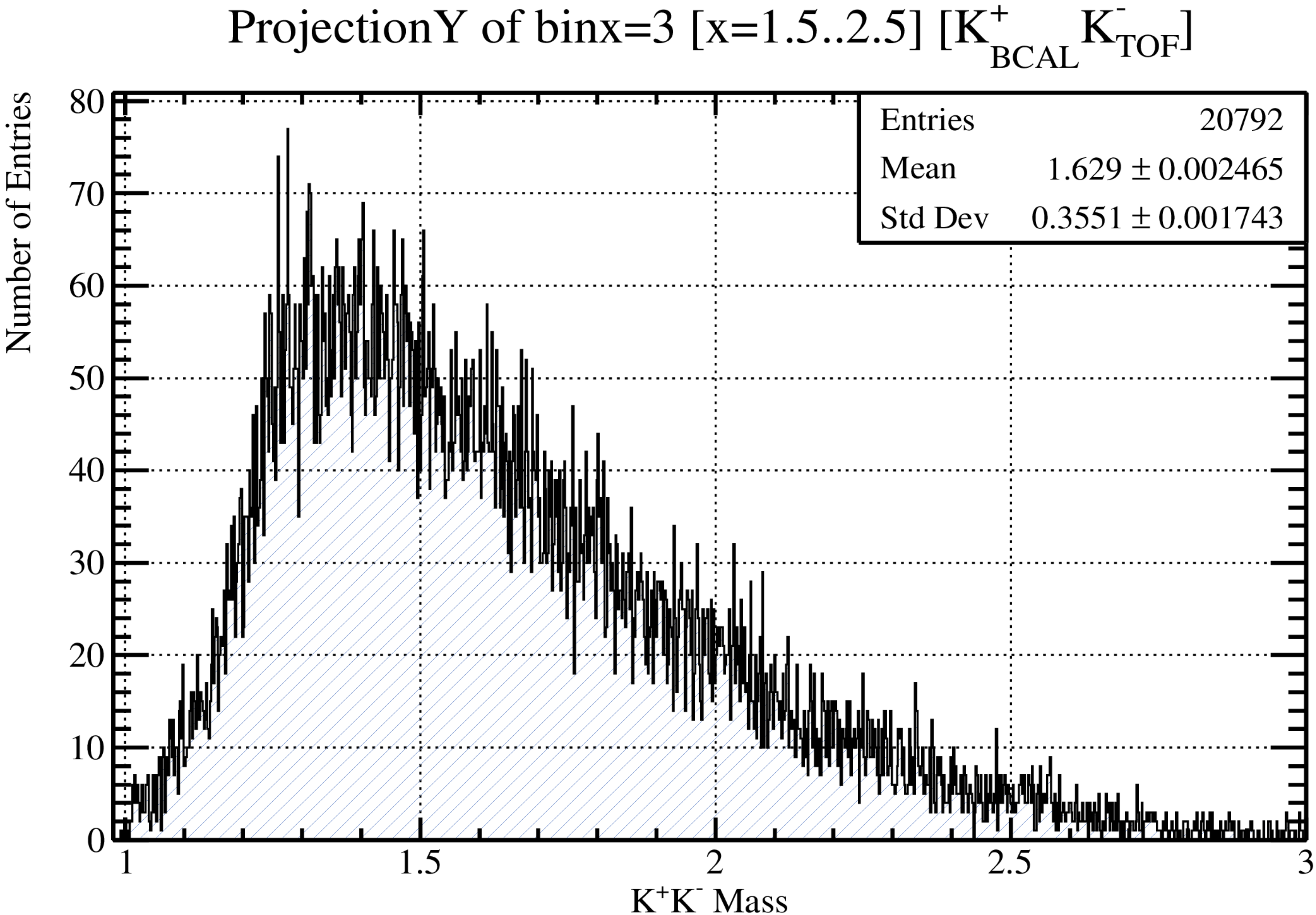

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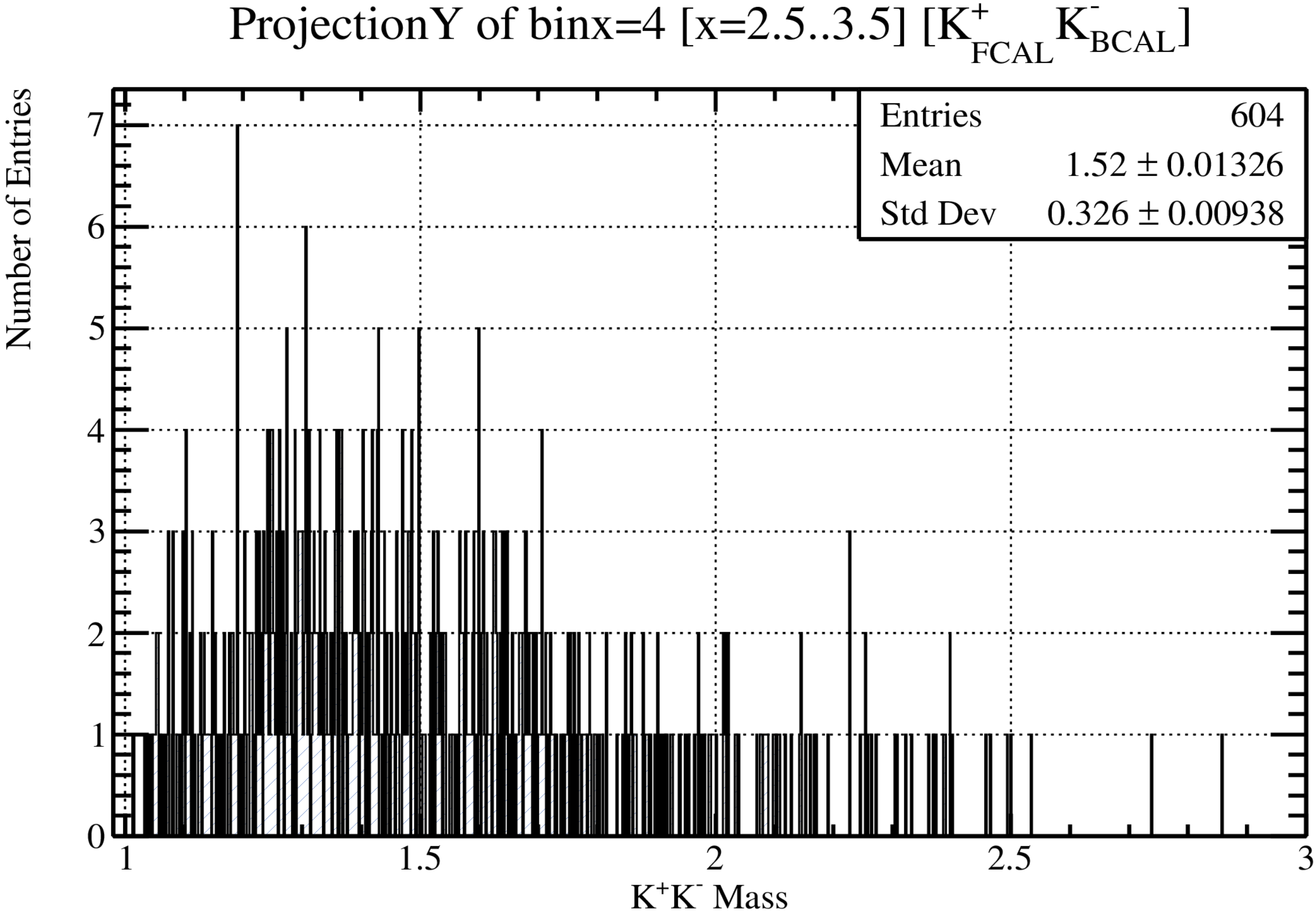

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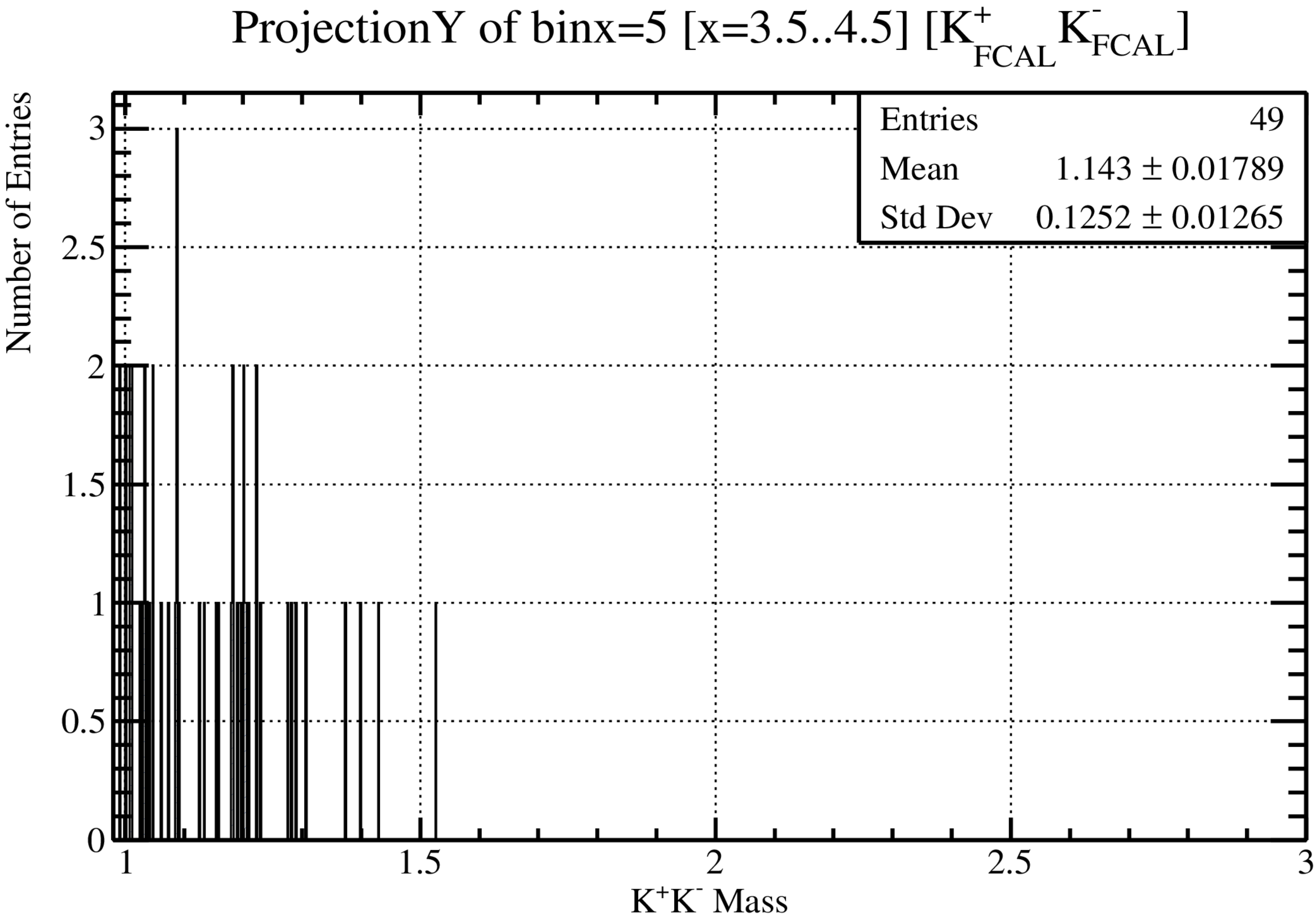

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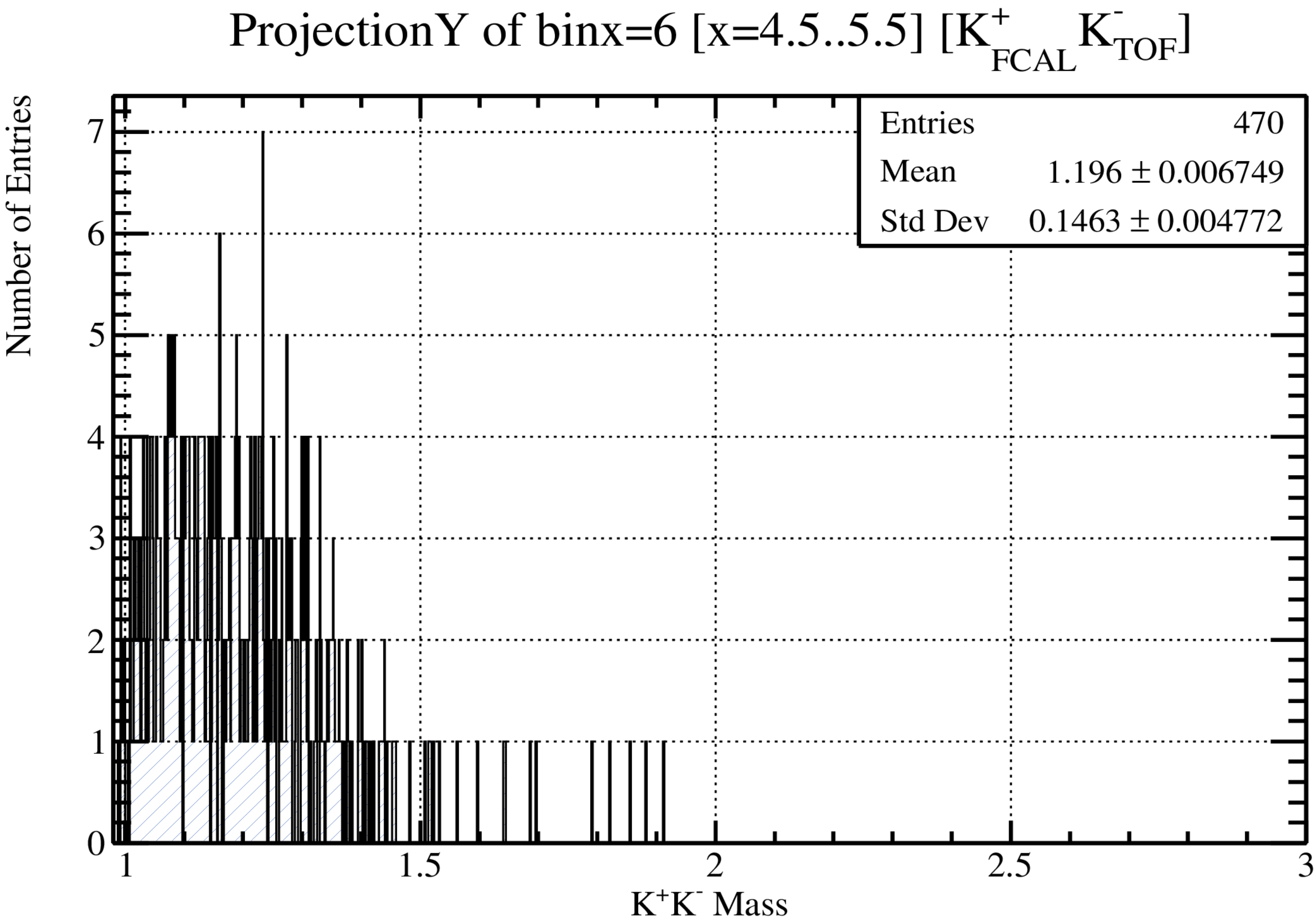

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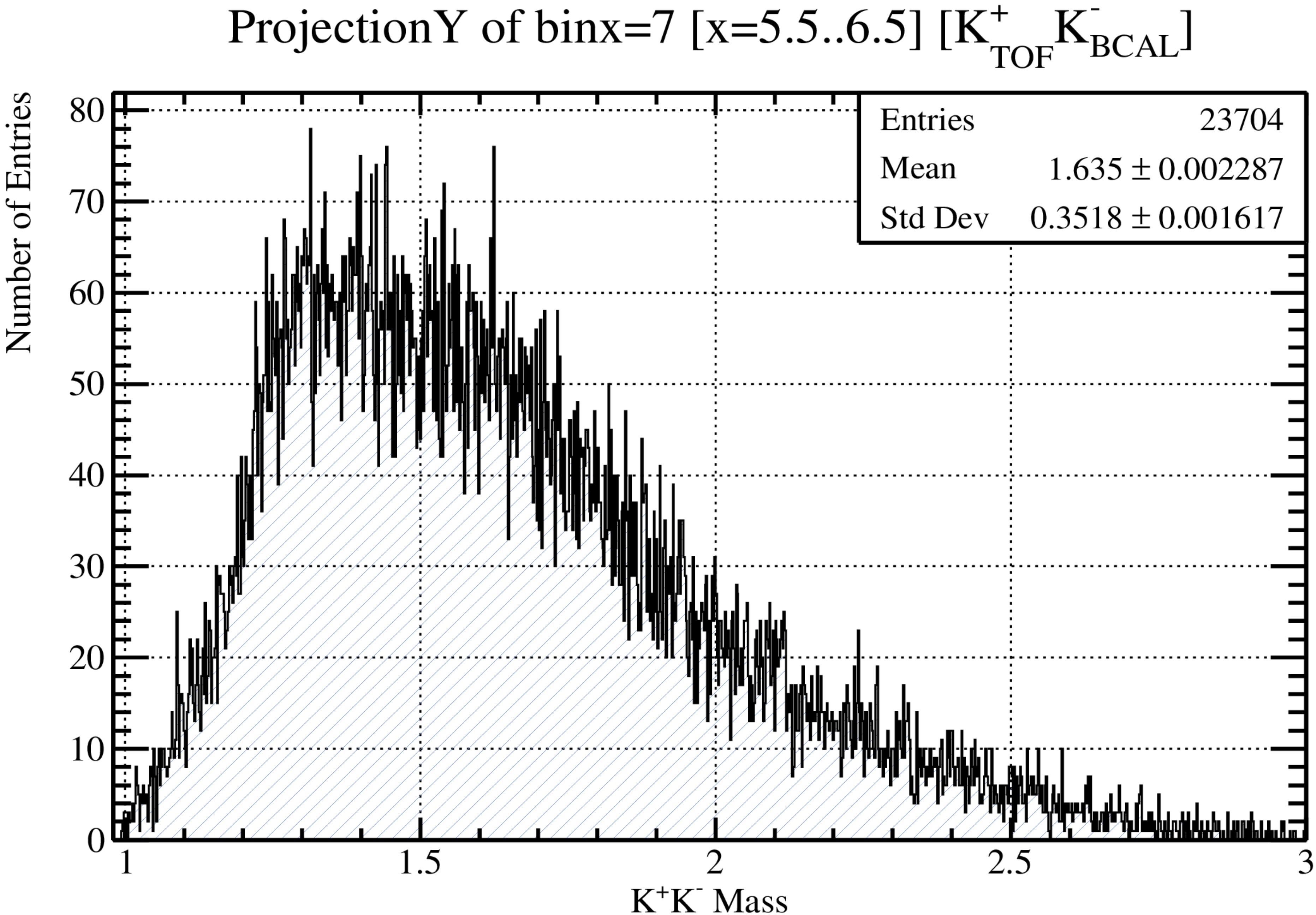

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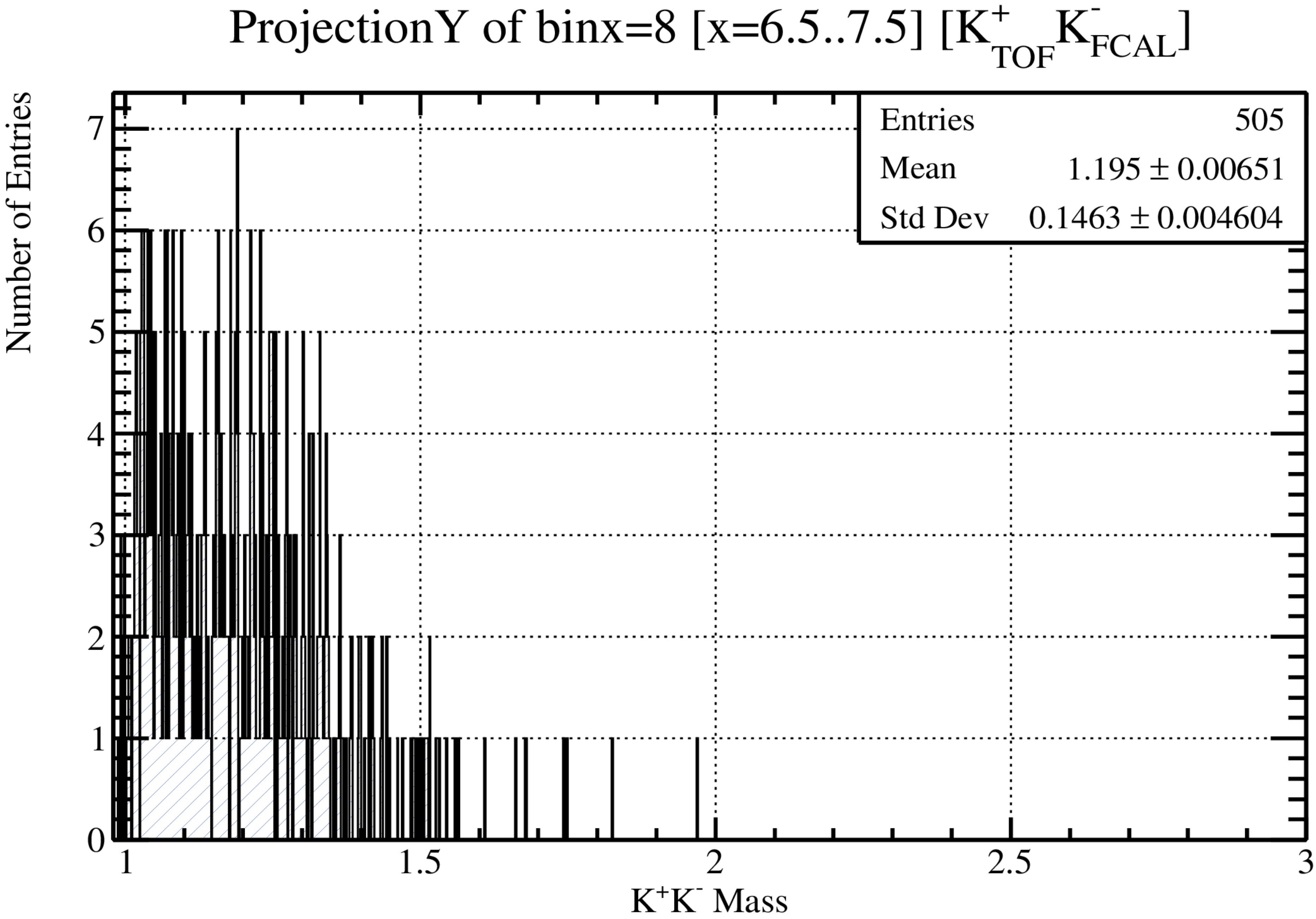

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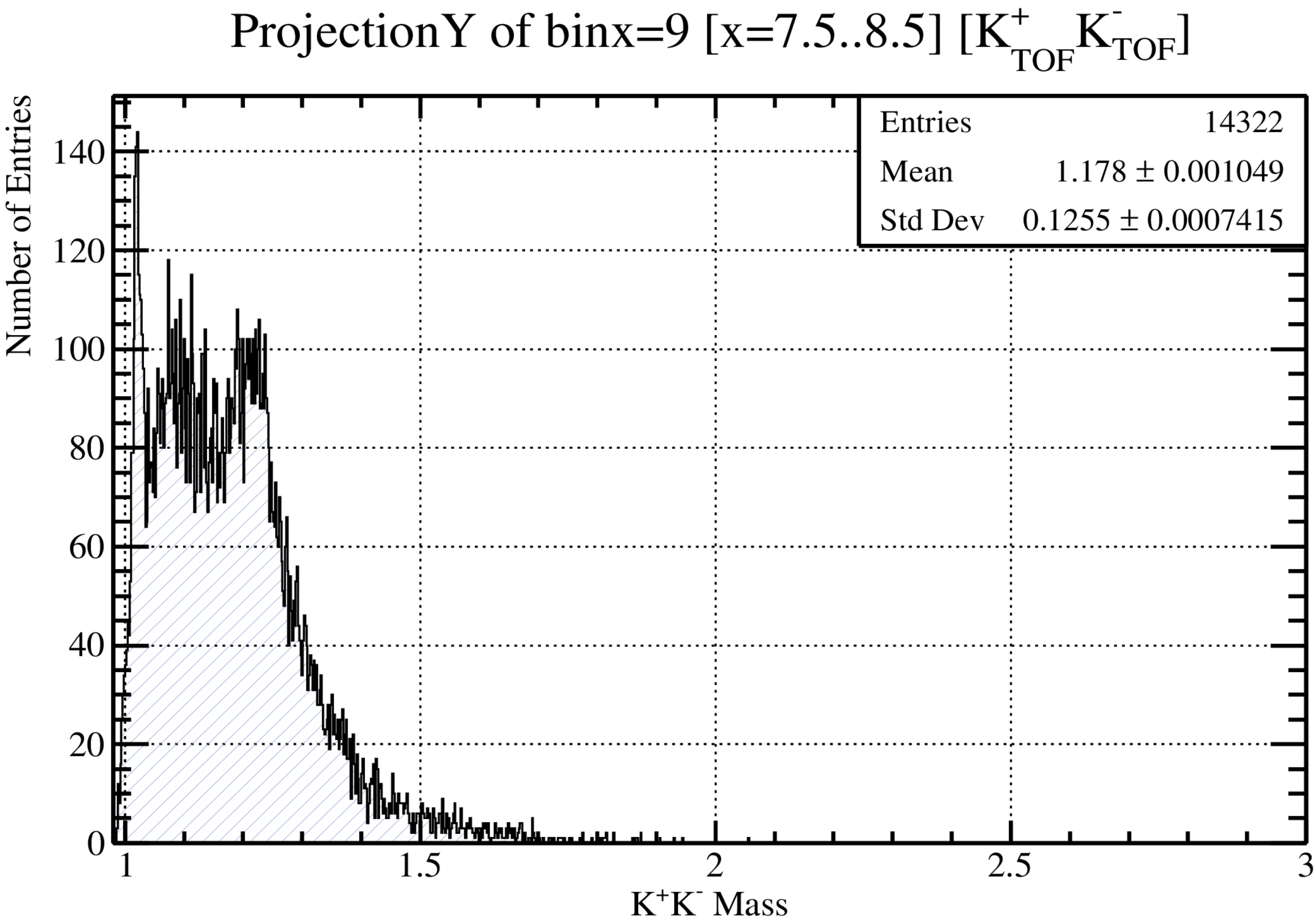


Additional Cuts Specifically for $\gamma p \rightarrow p \Phi \eta$ (TOF Only)

- Conclusion: Cut out all Kaon timing that does not come from the TOF detector.

- Is there a way to remove more background from the K+K- invariant mass spectra using strangeness conservation?

Additional Cuts Specifically for $\gamma\, p \rightarrow p\Phi\eta$: (Strangeness Conservation)

- The timing of a particle in flight is given by:

$$t = \frac{\delta X}{V} = \frac{\delta X}{\beta c}$$

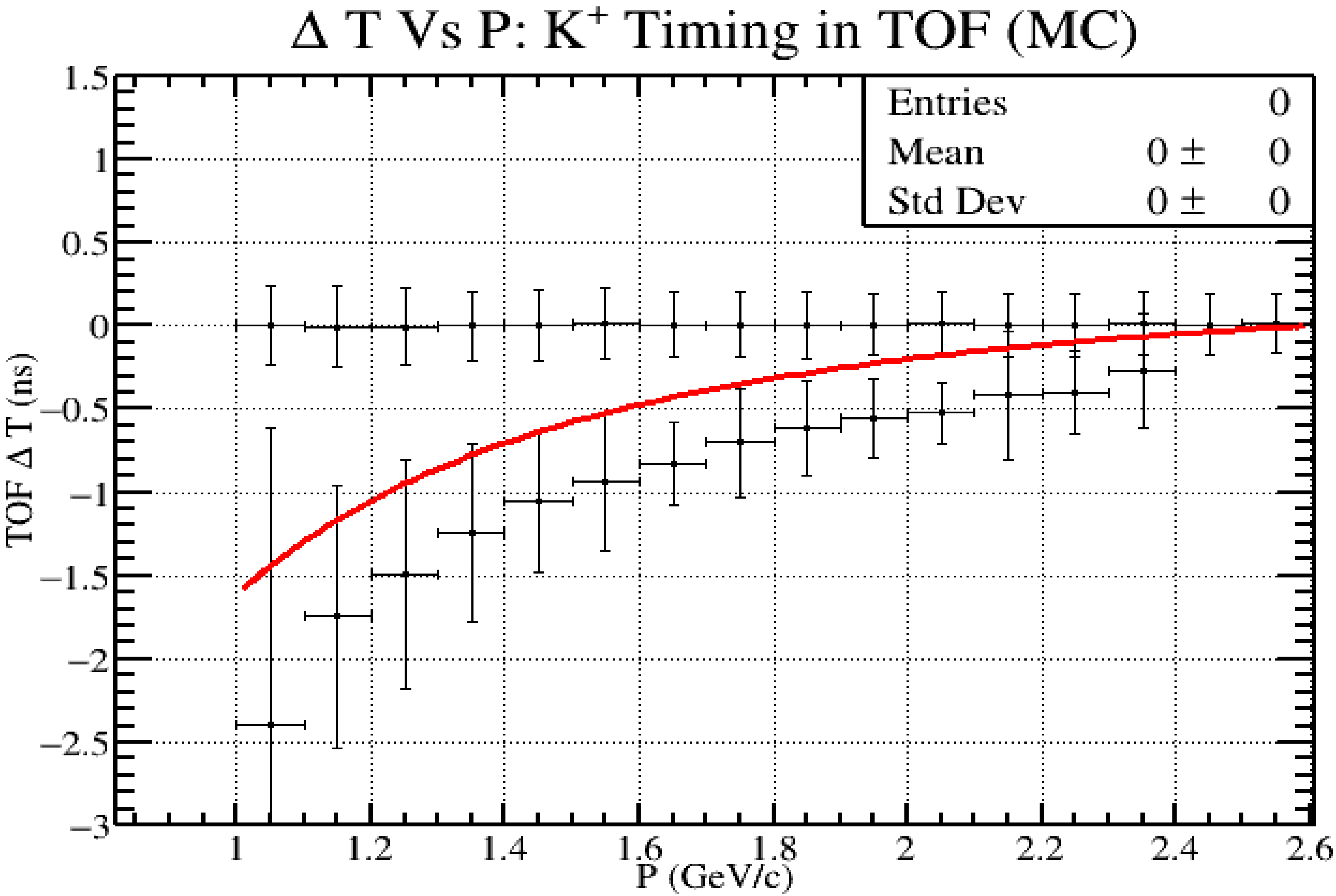
- We can substitute beta to get the following equation:

$$t = \frac{\delta X}{c} \frac{\sqrt{m_i^2 + P^2}}{P}$$

- Therefore, the timing difference between pions and kaons can be written as a formula for the reconstructed momentum P:

$$\delta t = \frac{\delta X}{c} \frac{\sqrt{m_\pi^2 + P^2} - \sqrt{m_K^2 + P^2}}{P}$$

Additional Cuts Specifically for $\gamma\, p \rightarrow p\Phi\eta$: (Strangeness Conservation)



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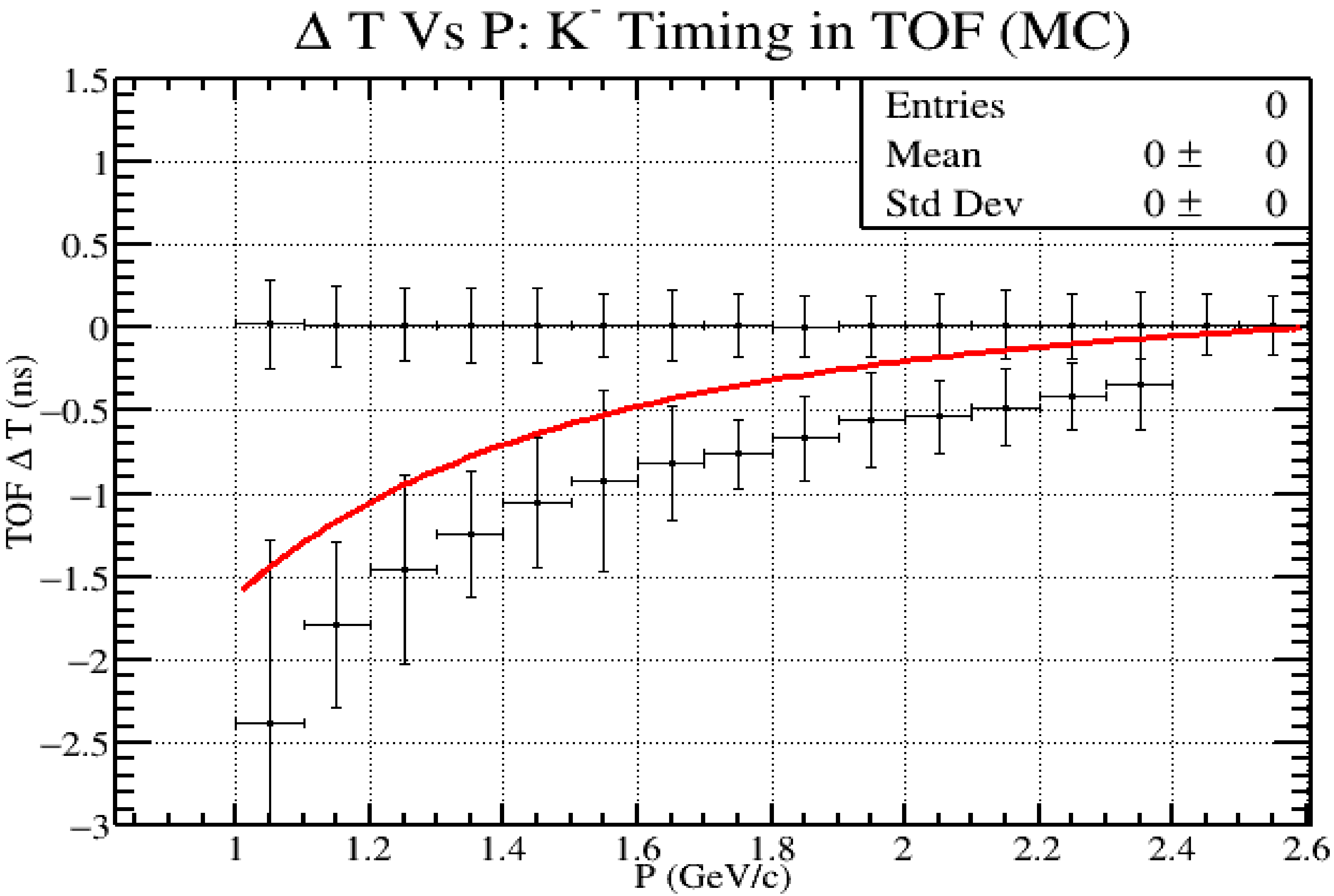
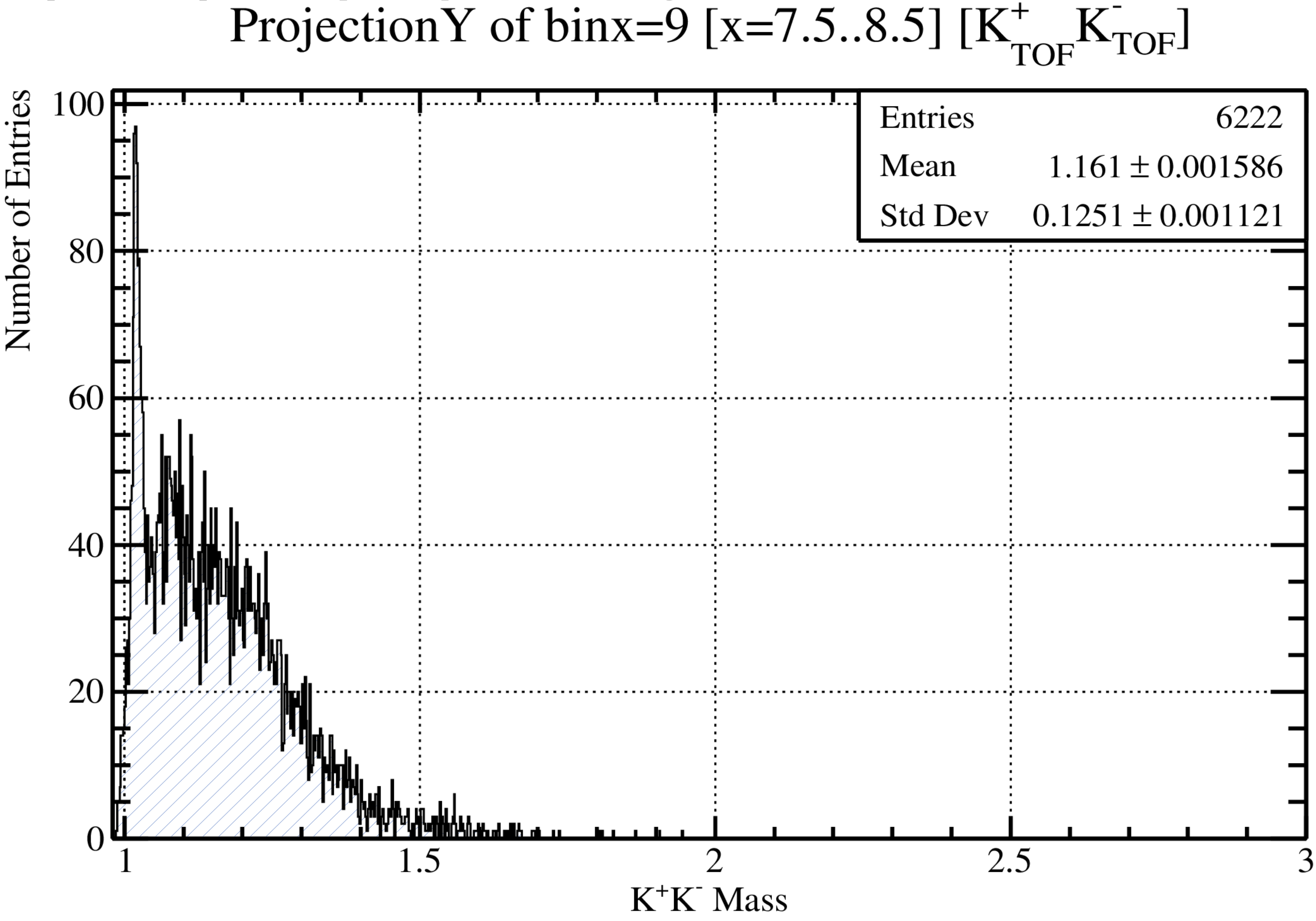


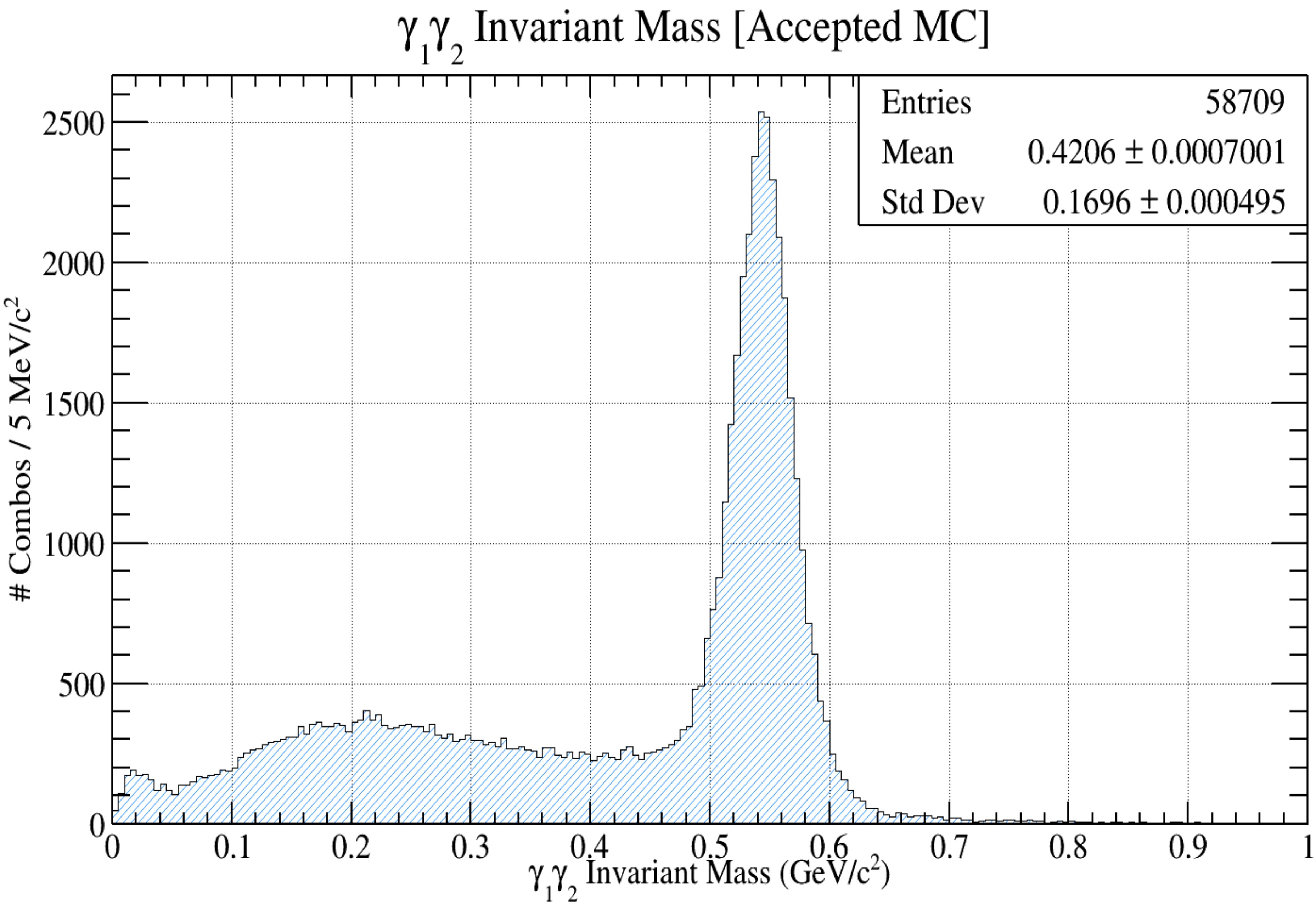
Additional Cuts Specifically for $\gamma\, p \rightarrow p \Phi \eta$: (Strangeness Conservation)

- How to apply this cut technique and enforce strangeness conservation:
  - A kaon is considered ‘good’ if it exists above or to the left of the cut line
  - A kaon is considered ‘bad’ if it exists below or to the right of the cut line
  - We accept any combination with two ‘good’ Kaons
  - We accept any combination with one ‘good’ K+ or K-
  - We throw out only combinations that have both a ‘bad’ K+ and a ‘bad’ K-

Additional Cuts Specifically for $\gamma\, p \rightarrow p\Phi\eta$: (Strangeness Conservation)



Additional Cuts Specifically for $\gamma\, p \rightarrow p\Phi\eta$: (Fiducial Cut for Photons)



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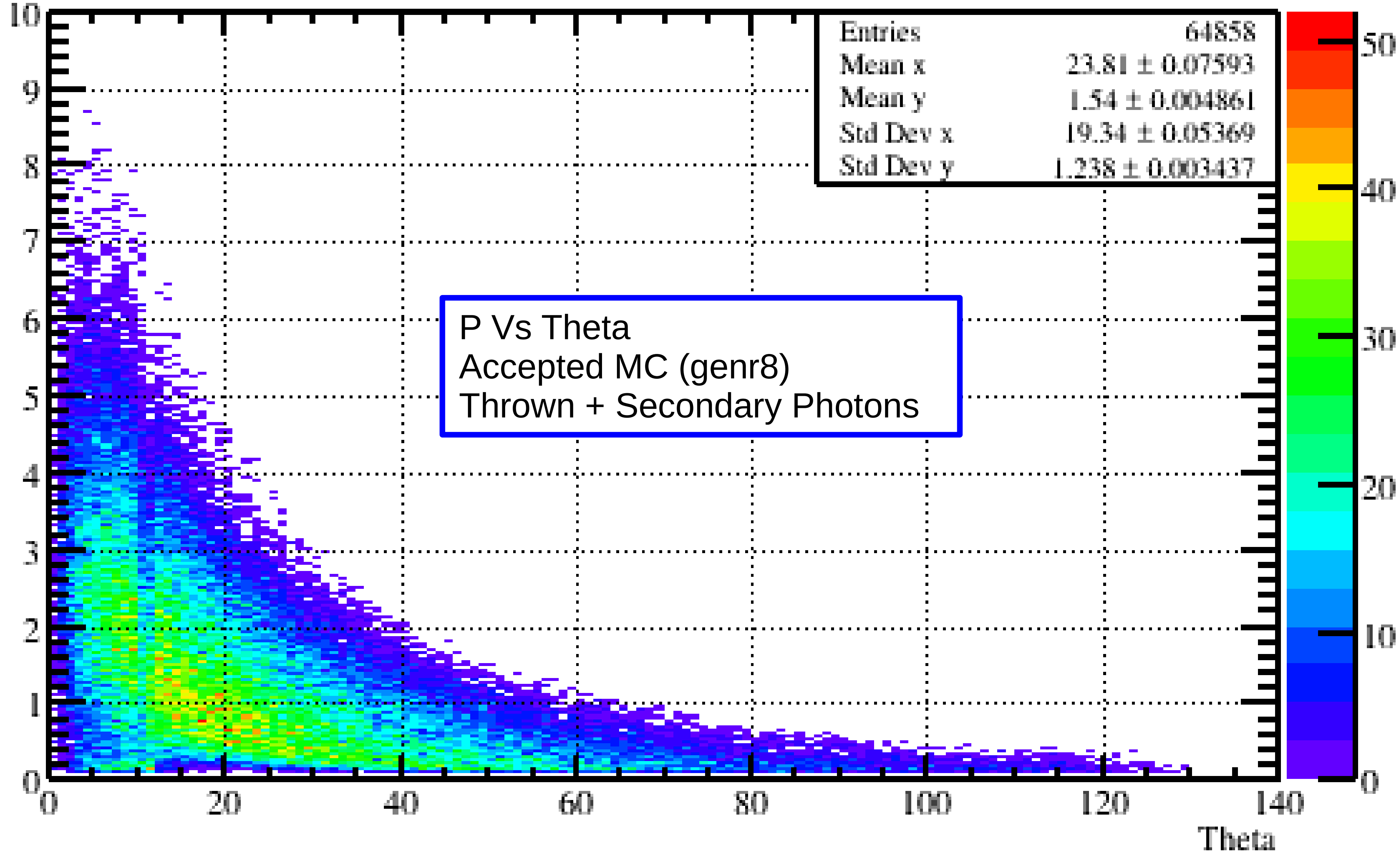

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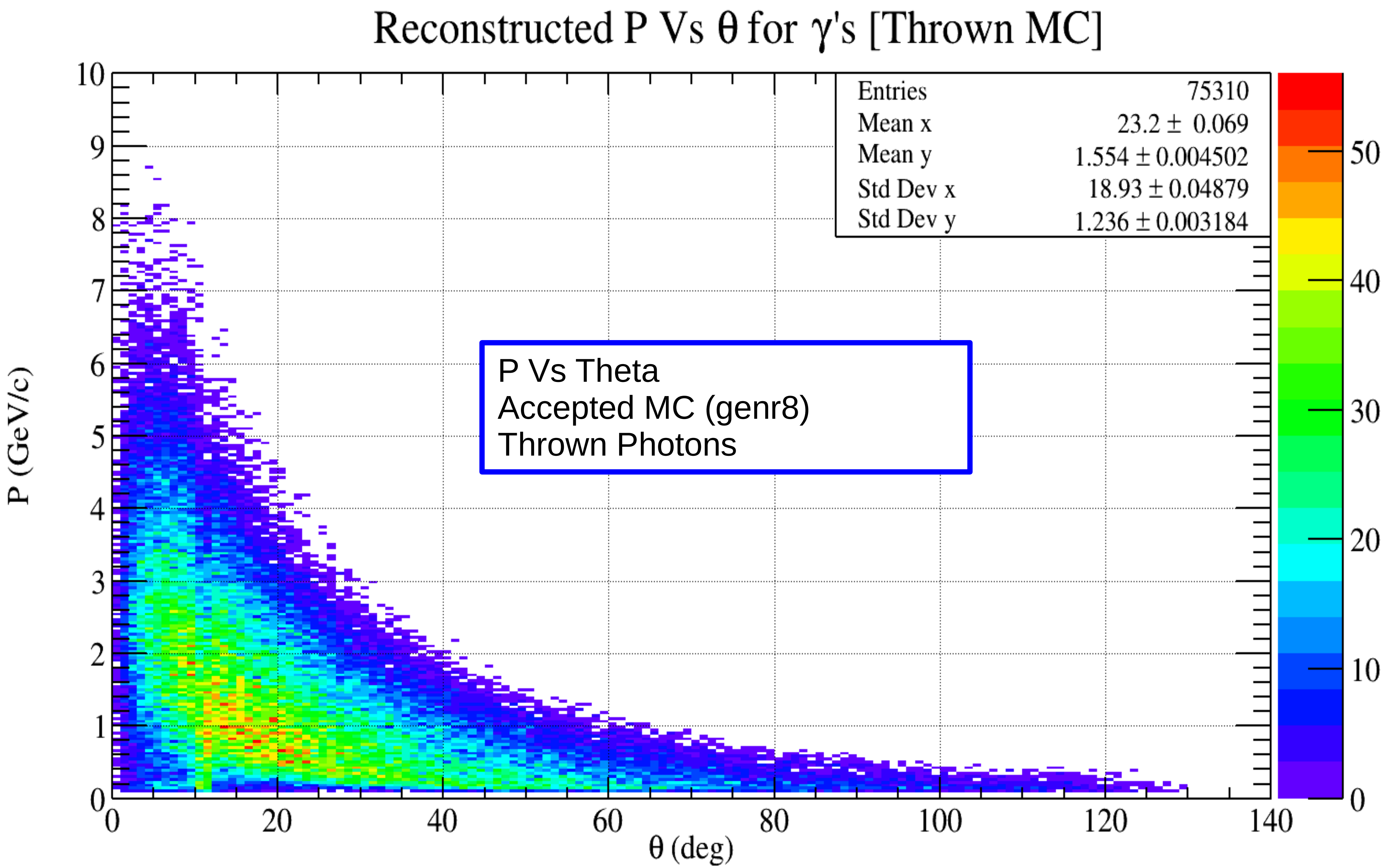

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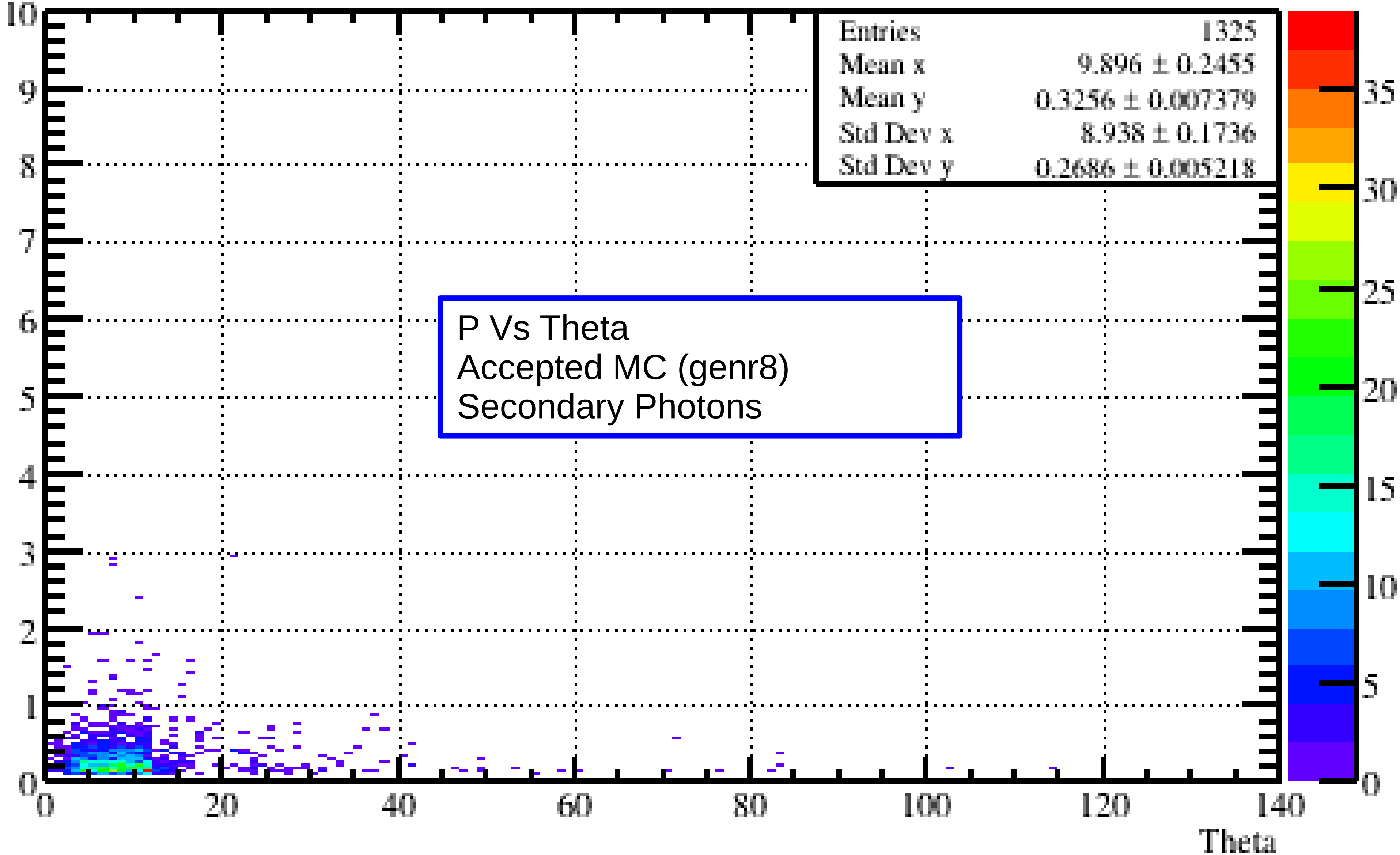

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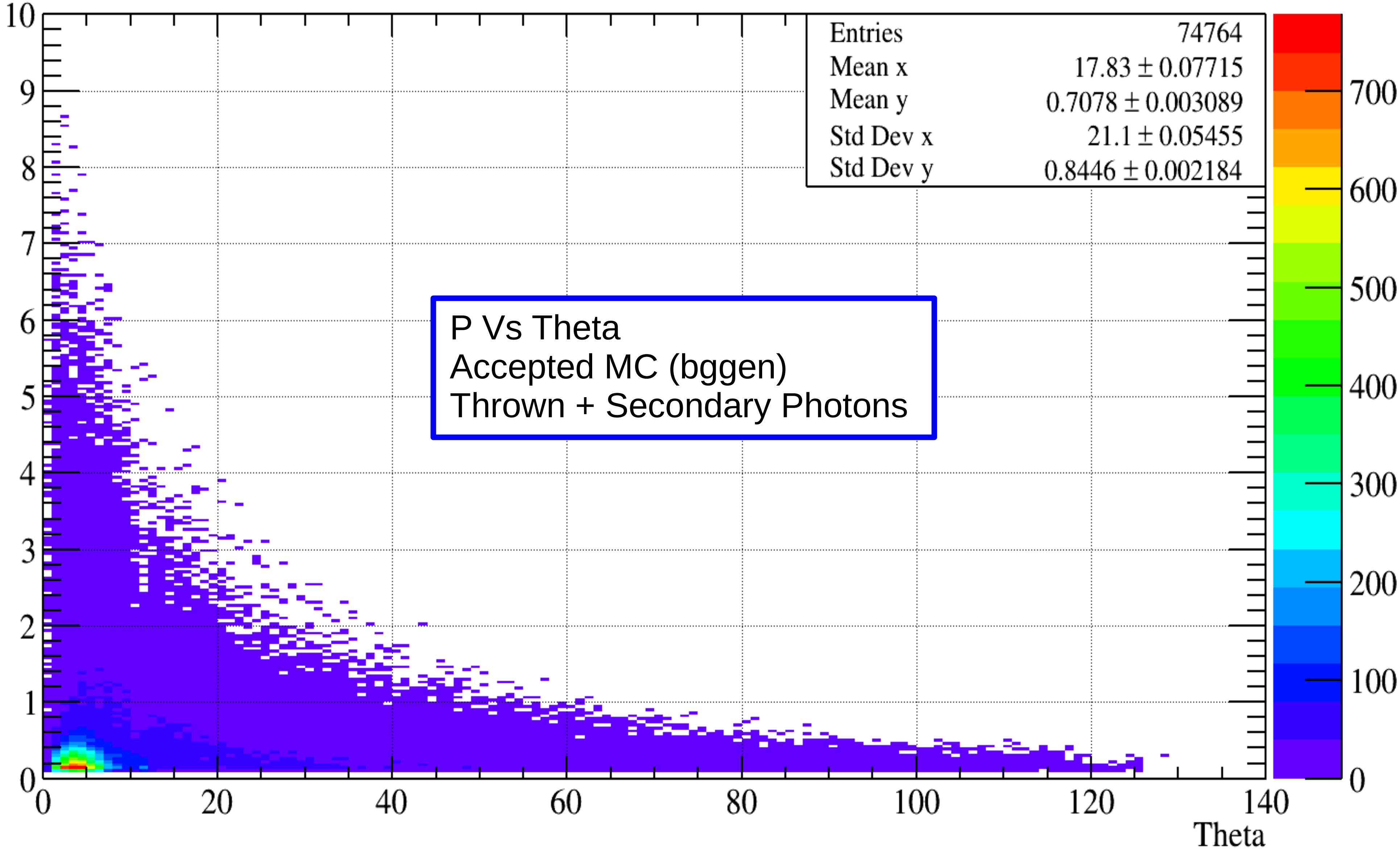

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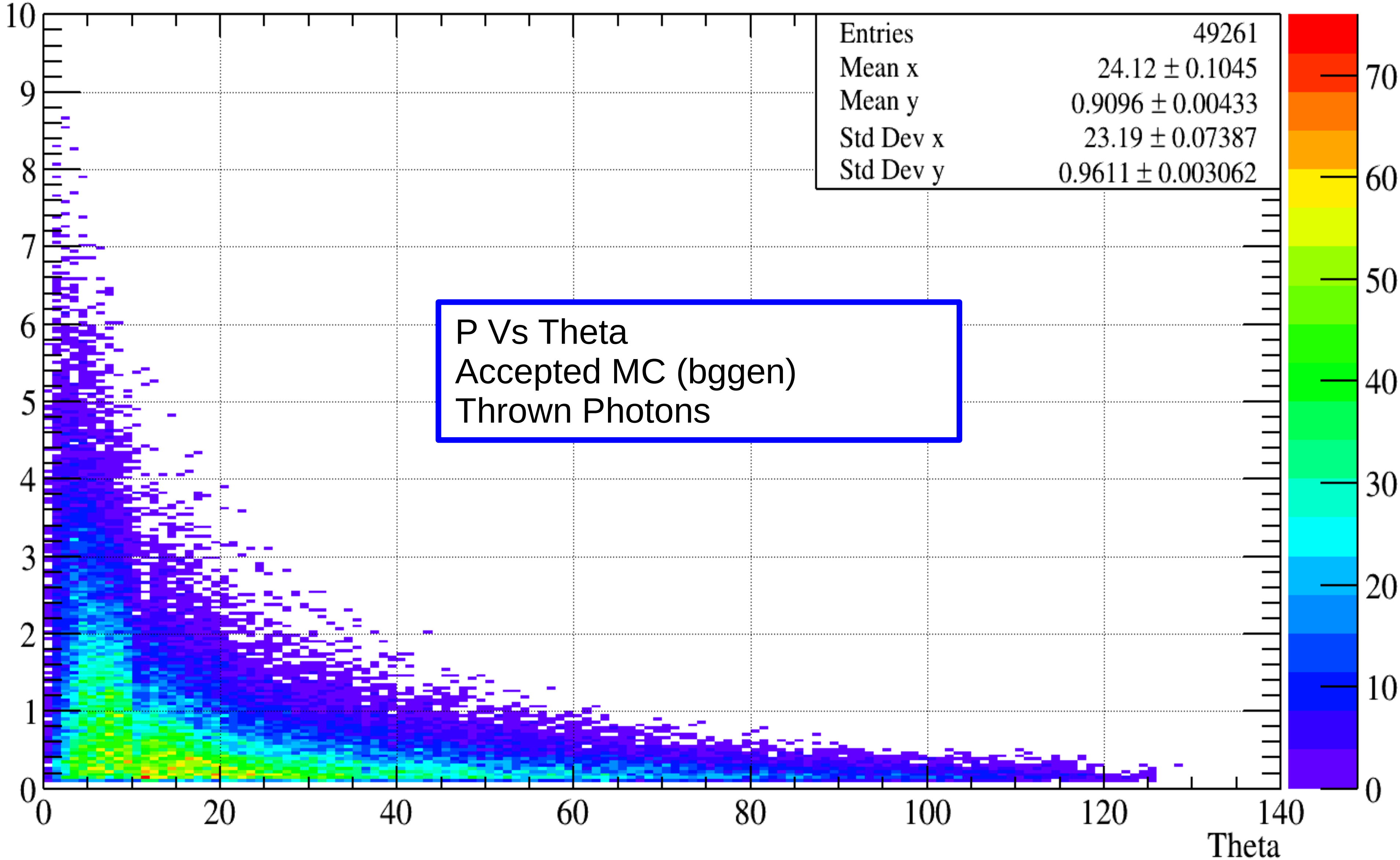

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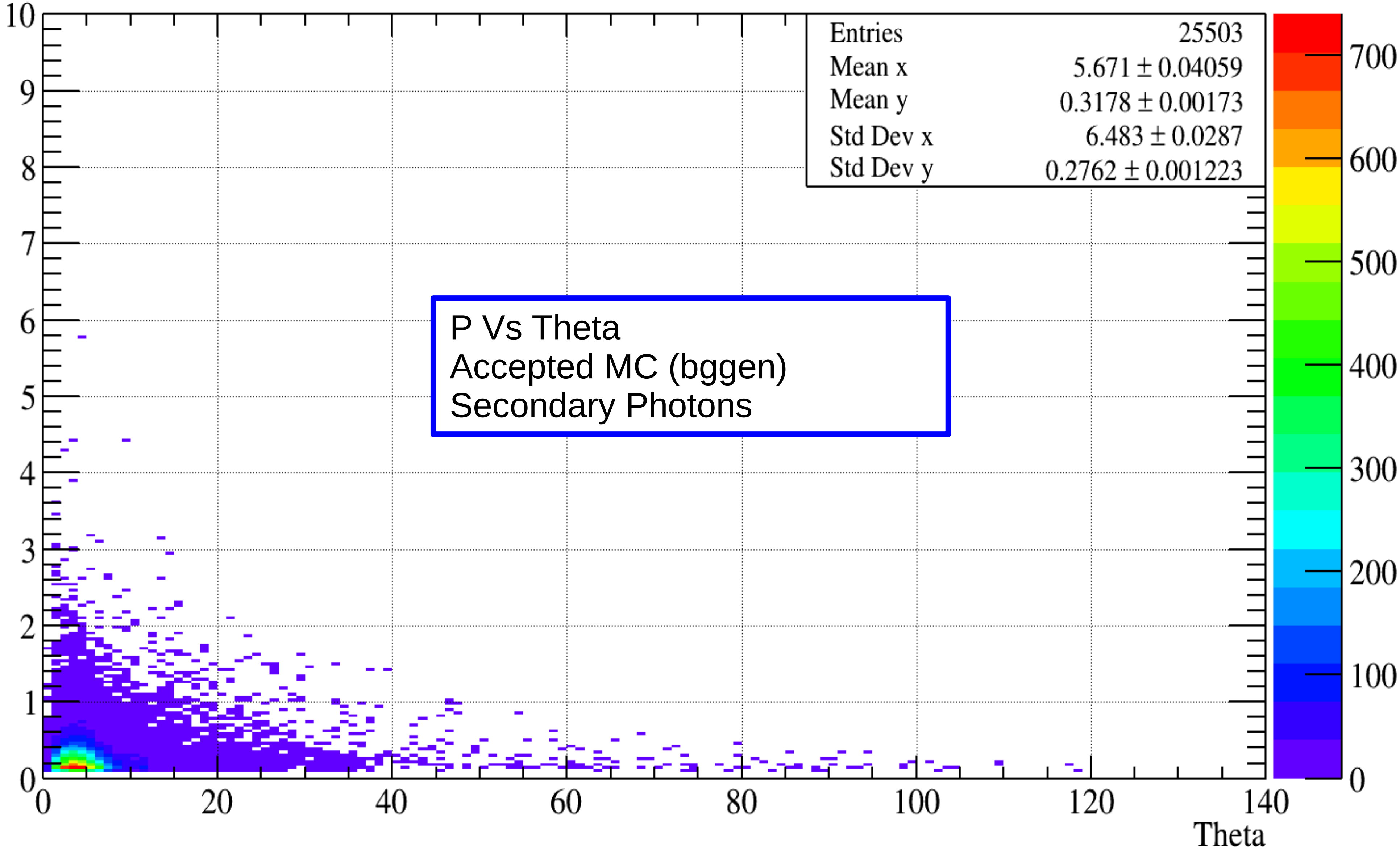

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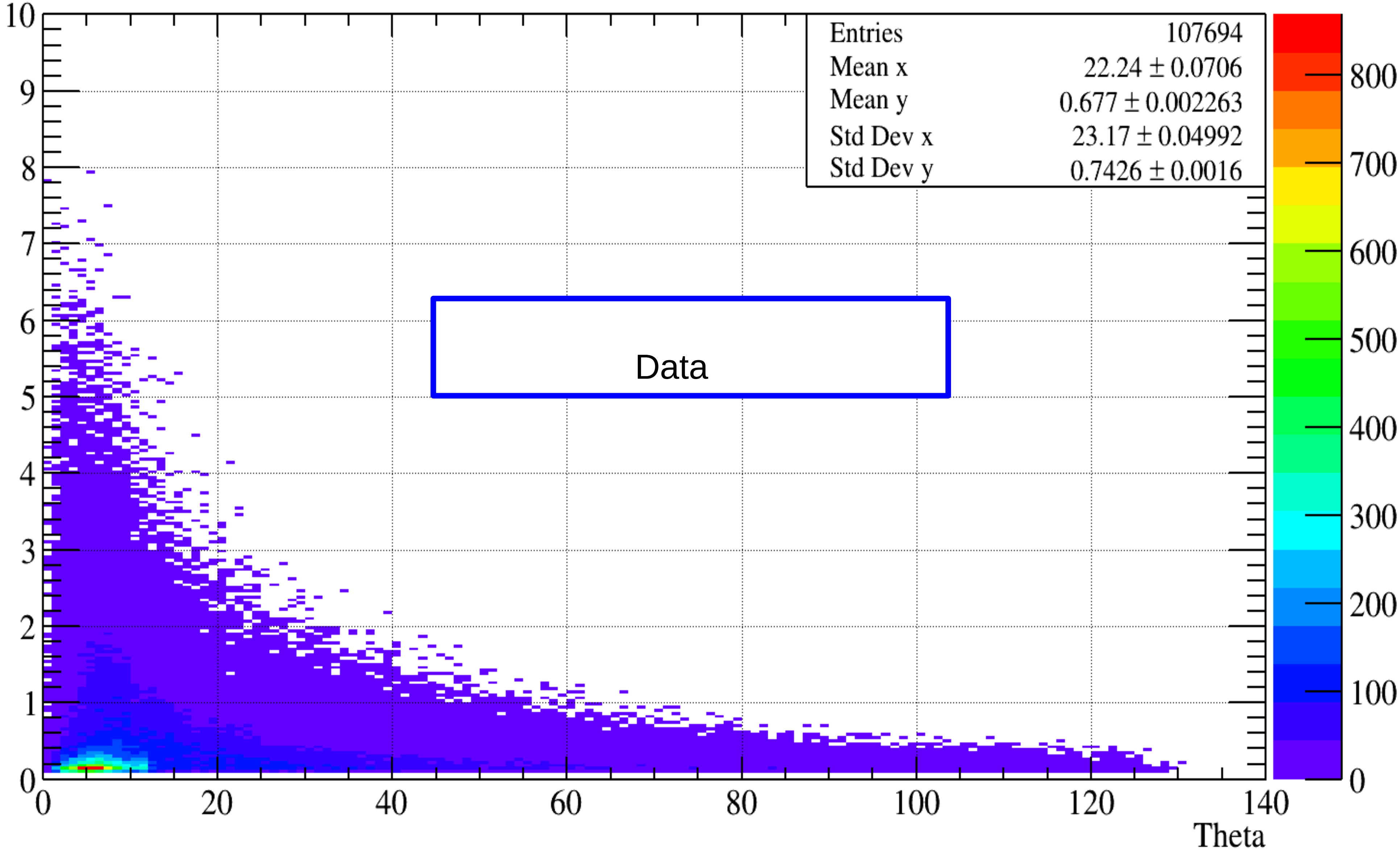

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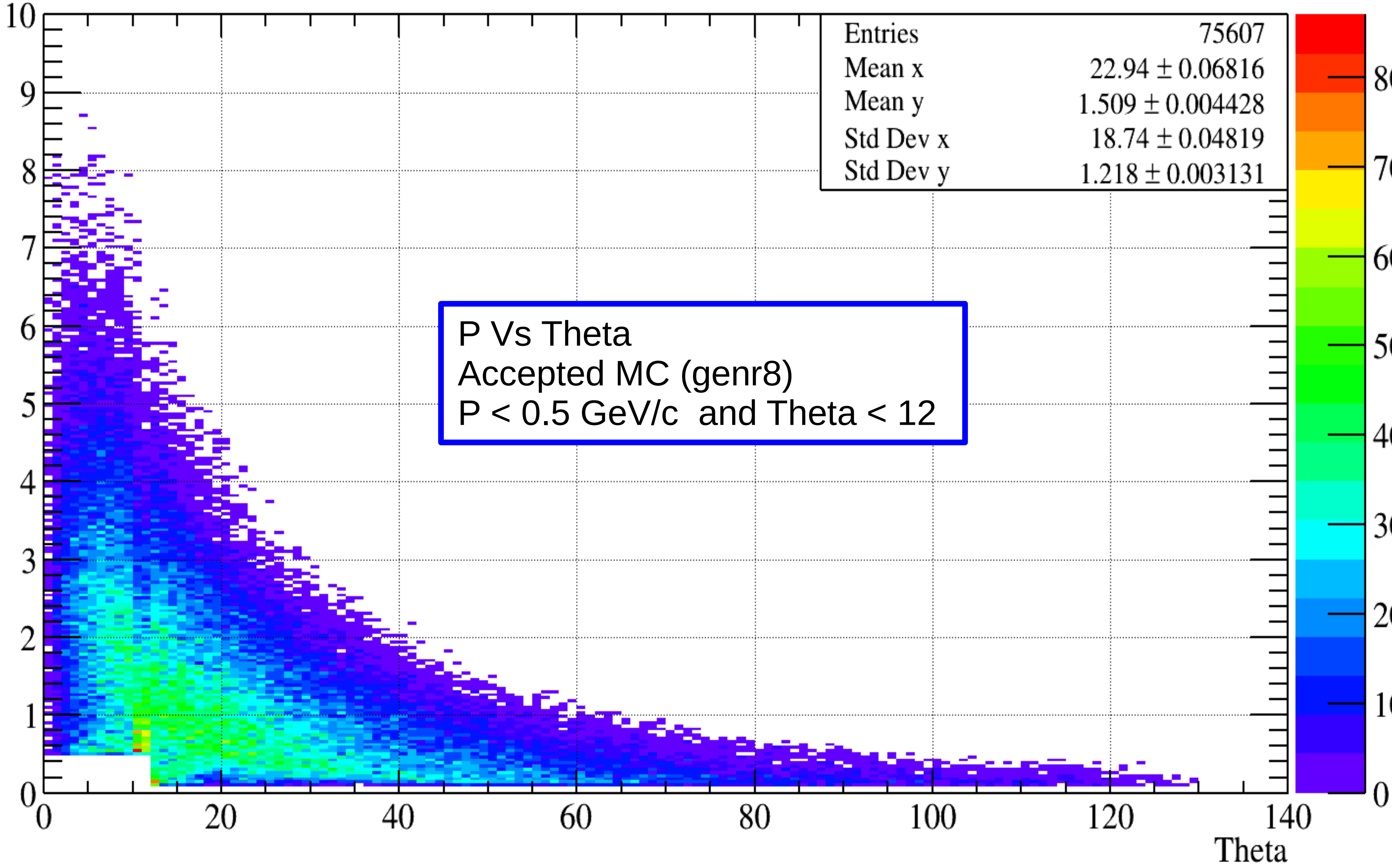

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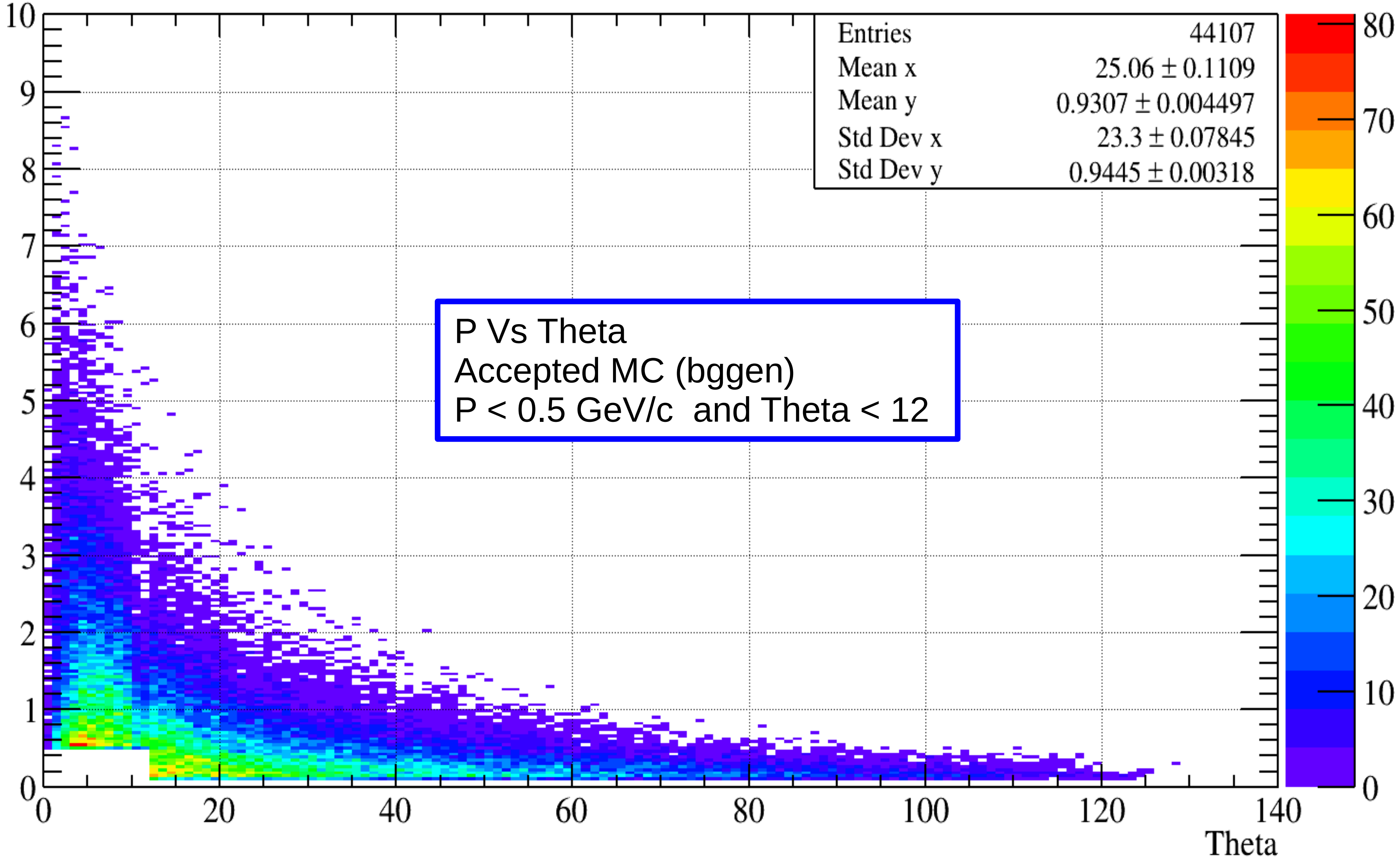

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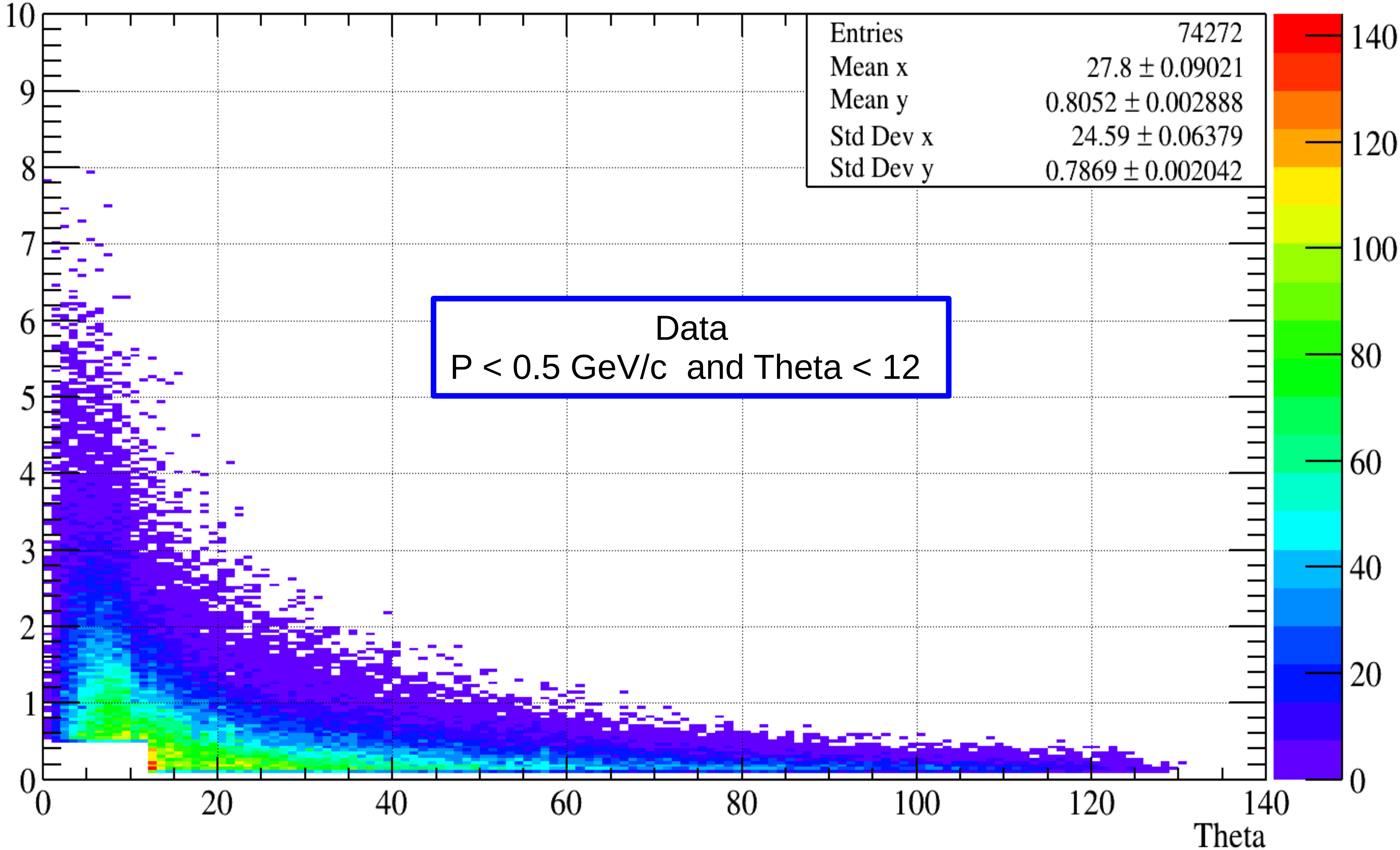


Additional Cuts Specifically for $\gamma\, p \rightarrow p\Phi\eta$: (Last Cuts)

- Unused Energy of Photons < 50 MeV
- $-0.02 \leq$ Missing Mass Squared ≤ 0.02

Quality Factor Study

- A method for separating signal and background
- M. Williams, M. Bellis, and C. A. Meyer ”Separating Signals from Non-Interfering Backgrounds using Probabilistic Event Weightings.”

<u>Assumption</u>:

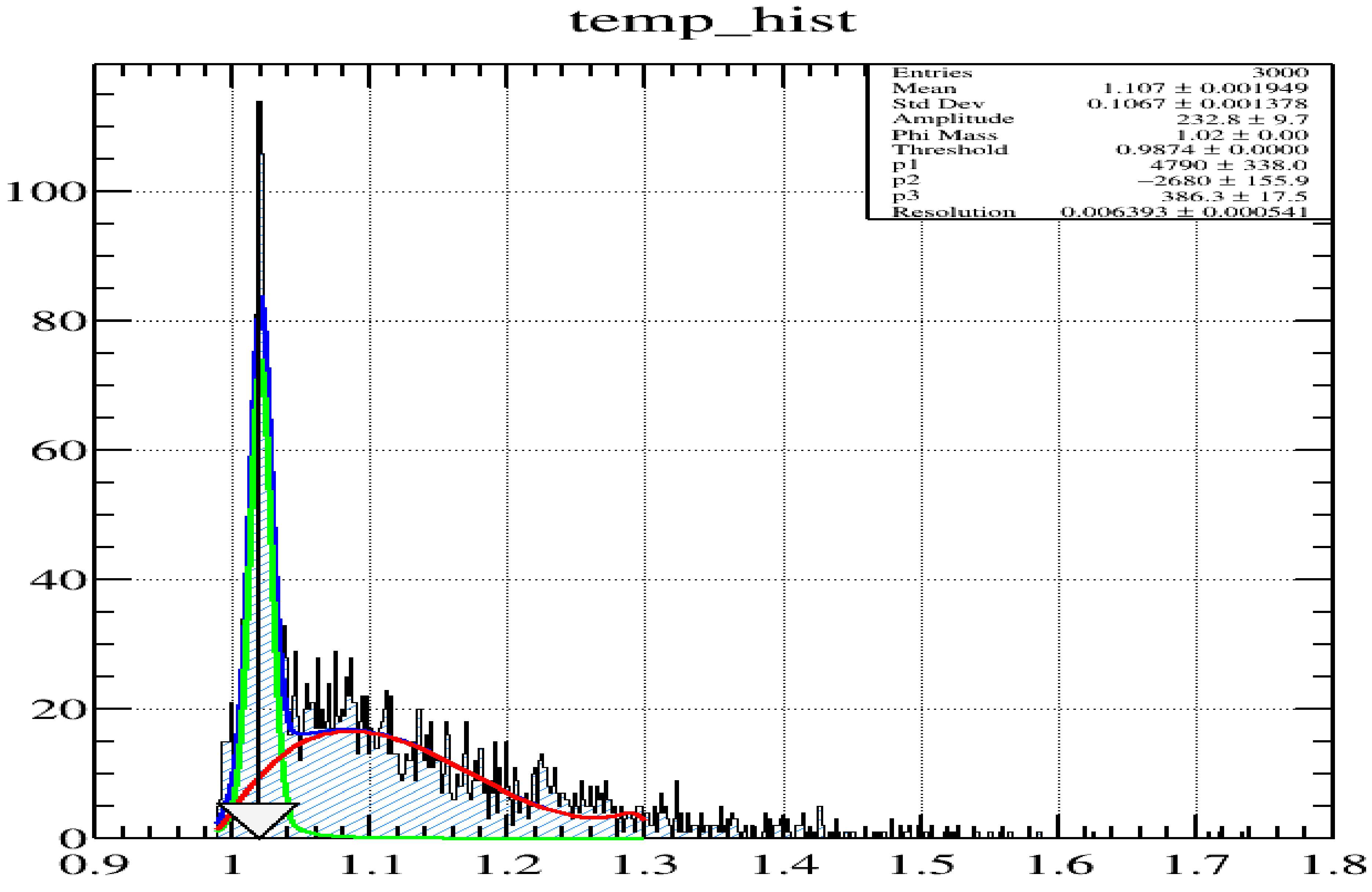
- A given event has a set of other events which it shares similar kinematic features with. These are called nearest neighbors
- Plotting the invariant mass of that event with its nearest neighbors provides insight into the “Quality Factor” or probability that the event is signal or background

Quality Factor Study

Algorithm:

- For a given event, calculate a kinematic distance between that event and all other events
- Only accept the N nearest neighbors to that event
- Plot the K+K- and gg invariant mass for the N nearest neighbors
- Fit each invariant mass distribution with a signal function plus a background function
- Calculate the number of signal and background events at the mass value of the event using the fits
- Assign a Q-Factor to the event: Q = s / (s+bg)

Quality Factor Study



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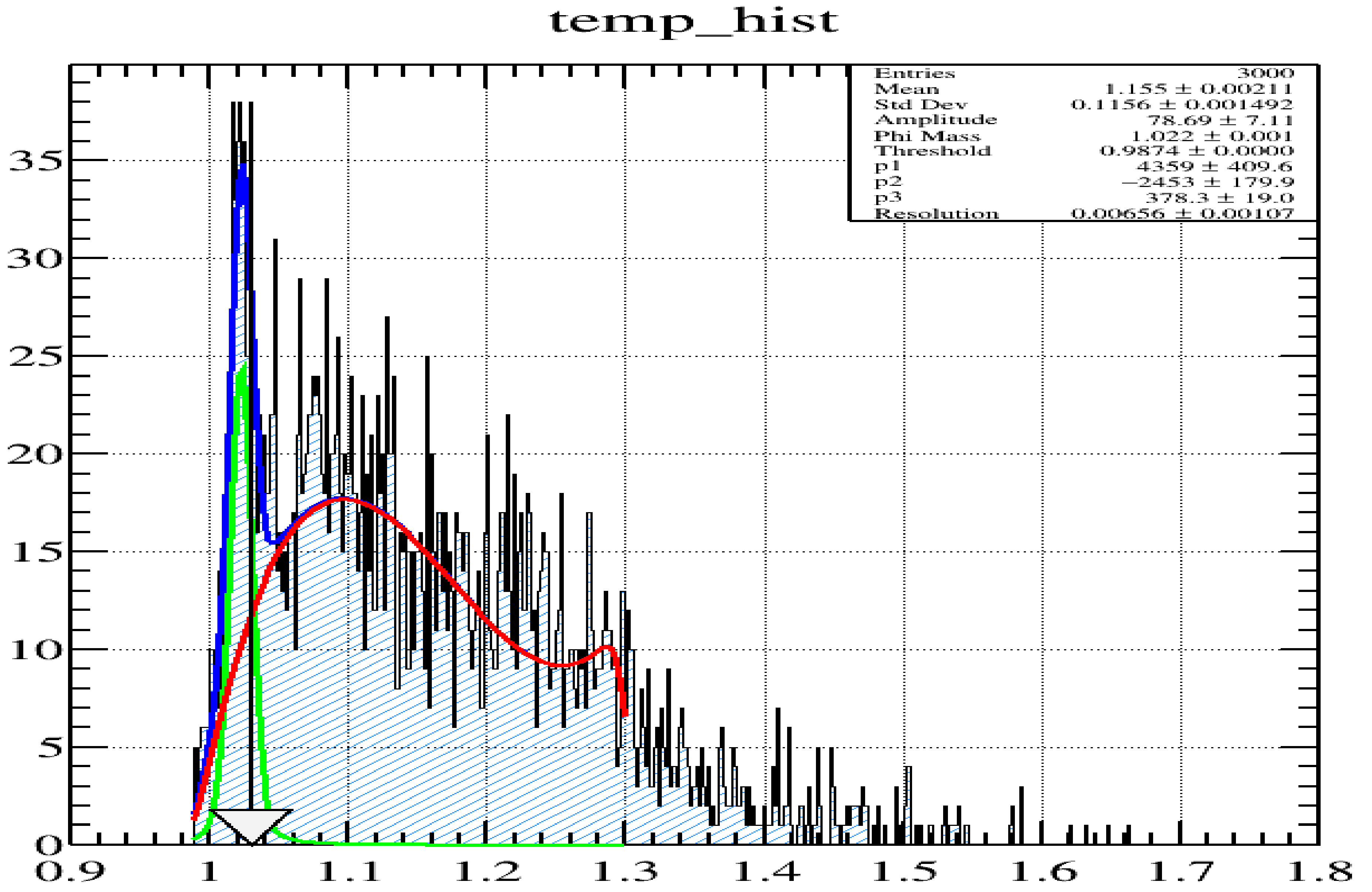

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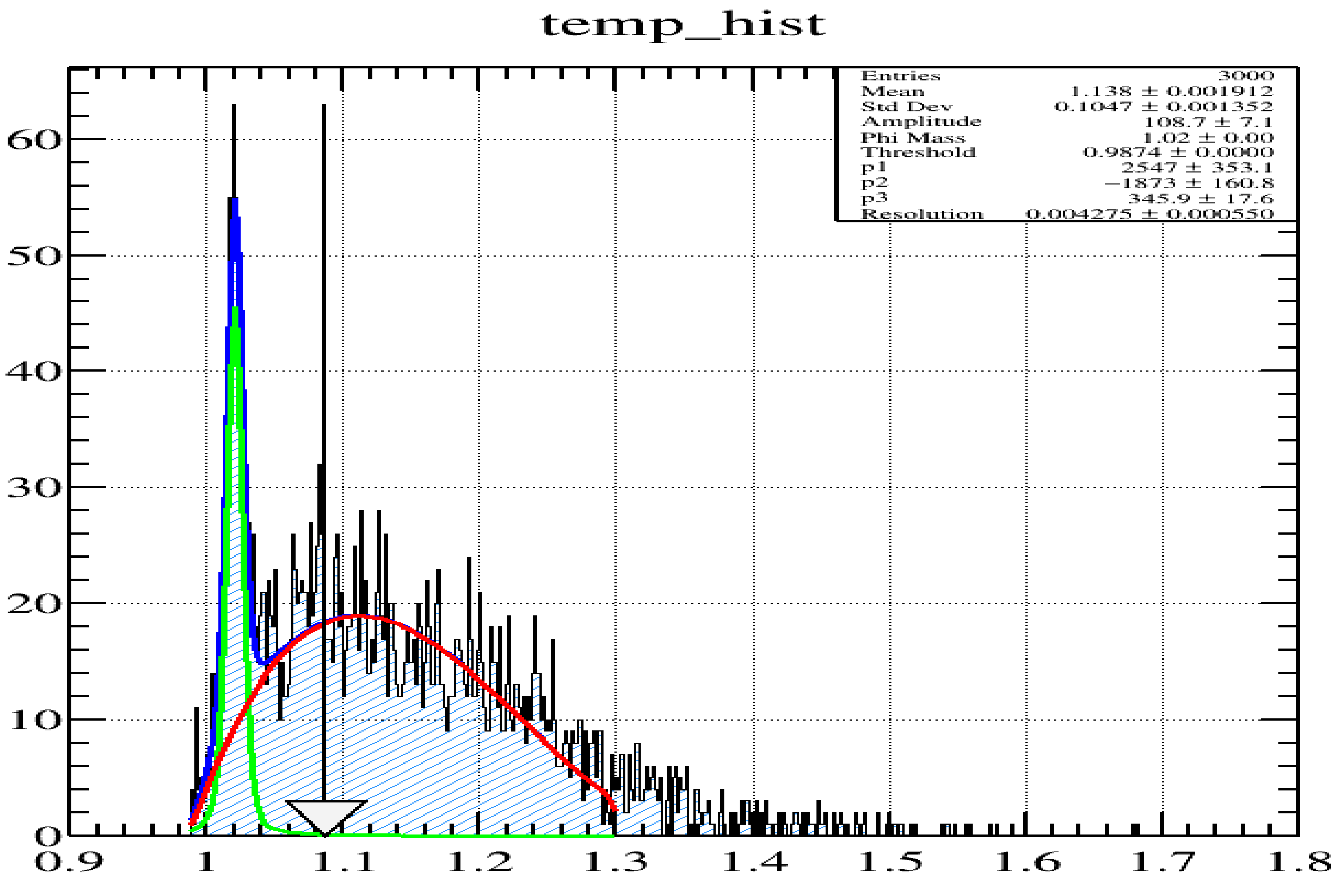

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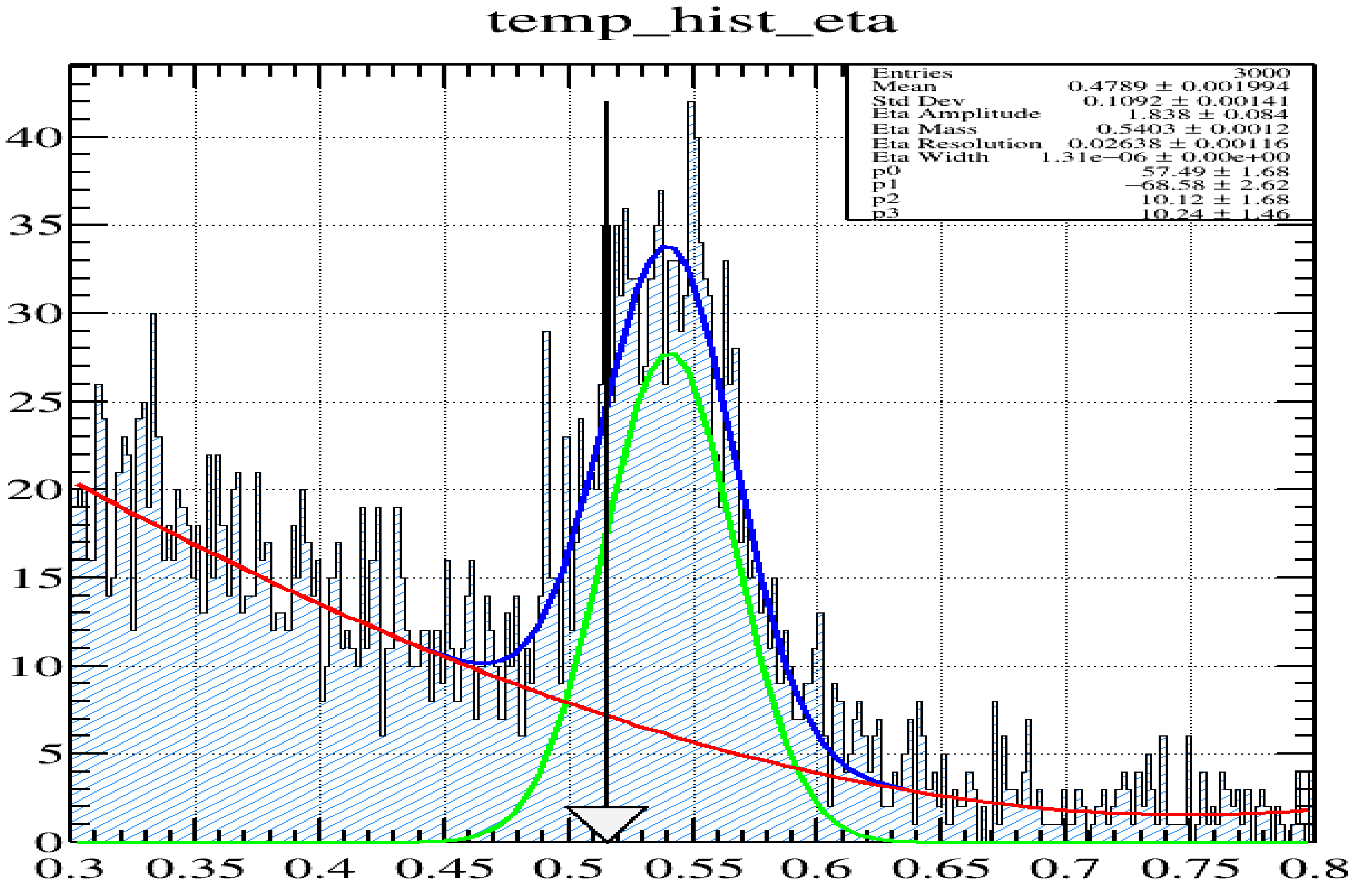

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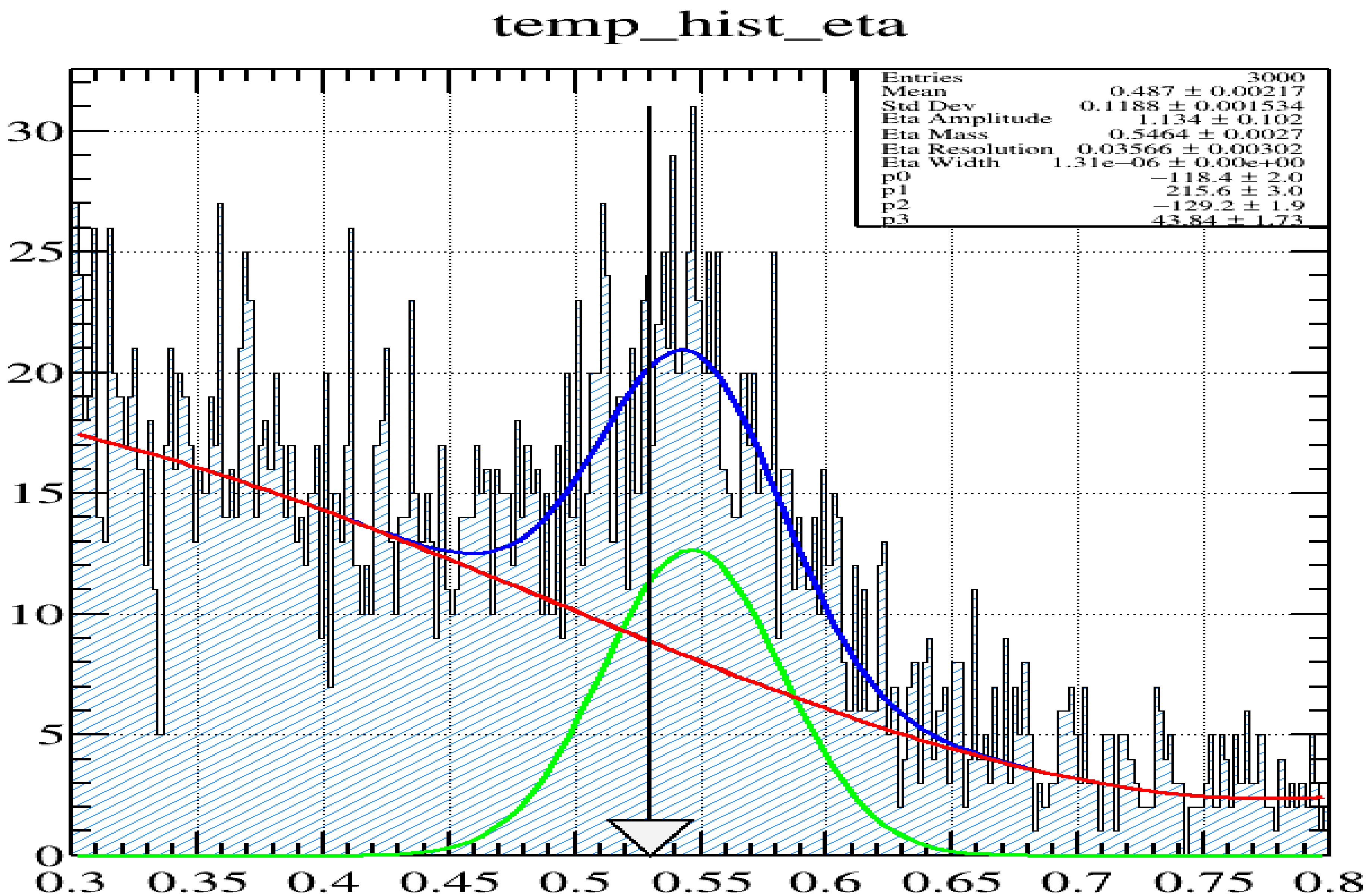

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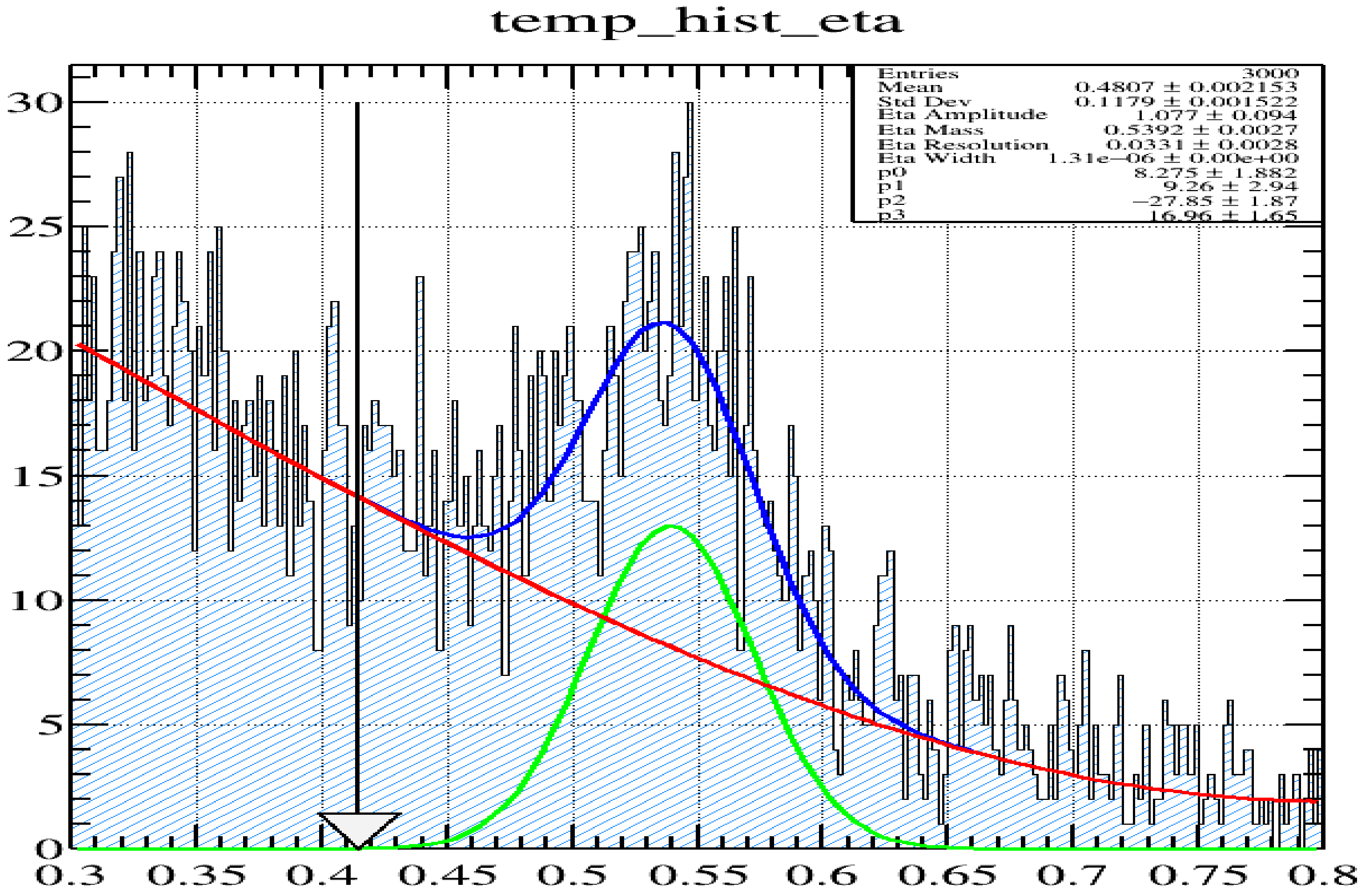

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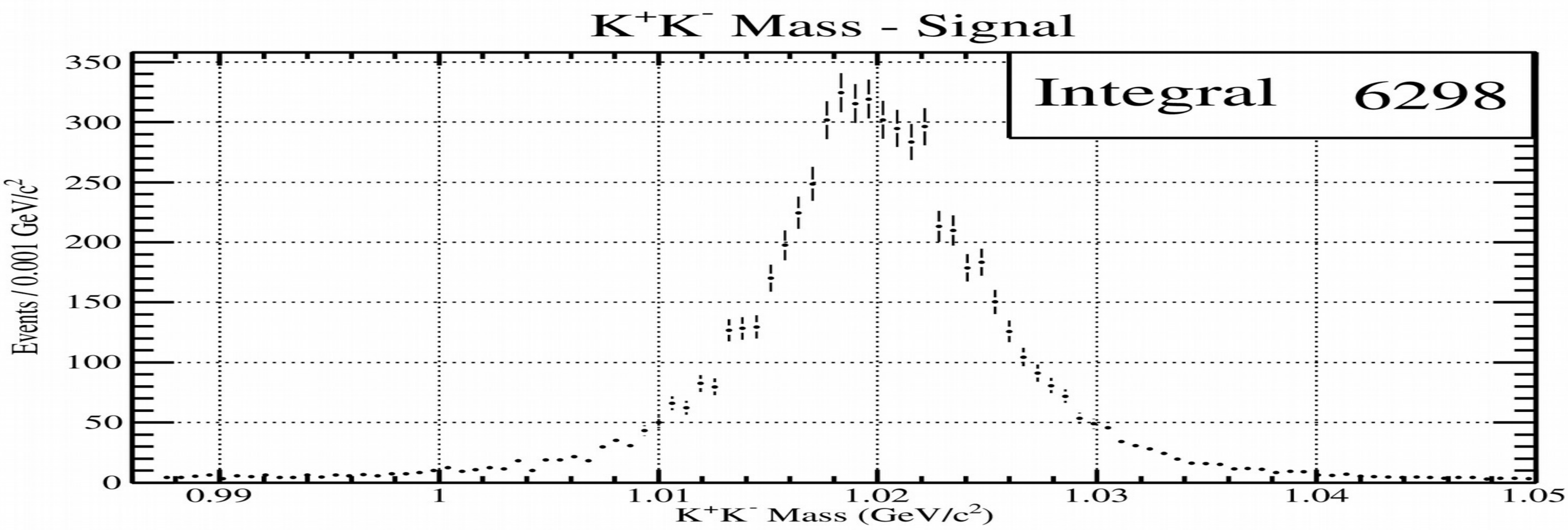

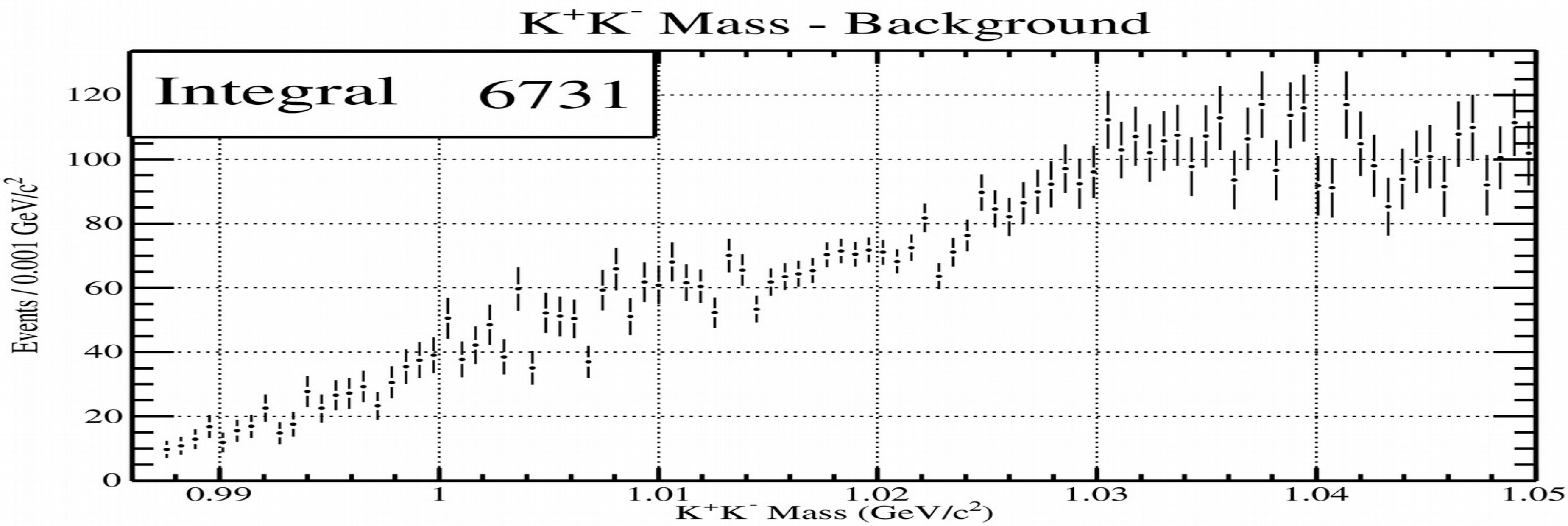

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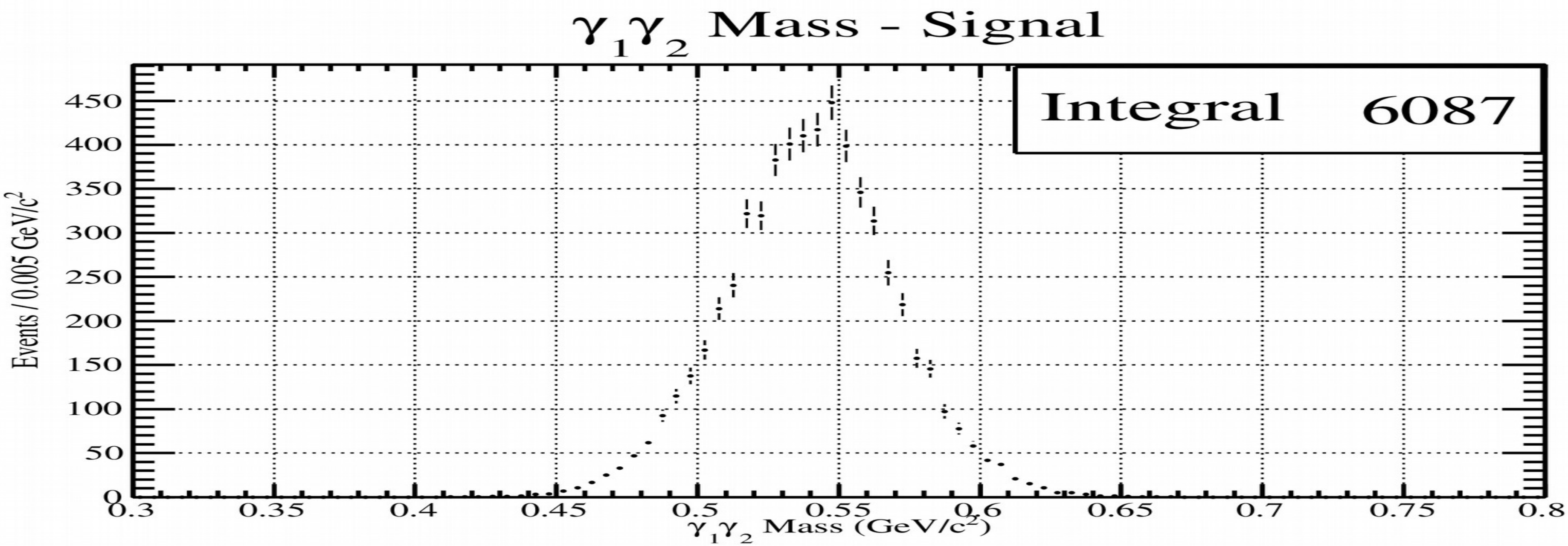
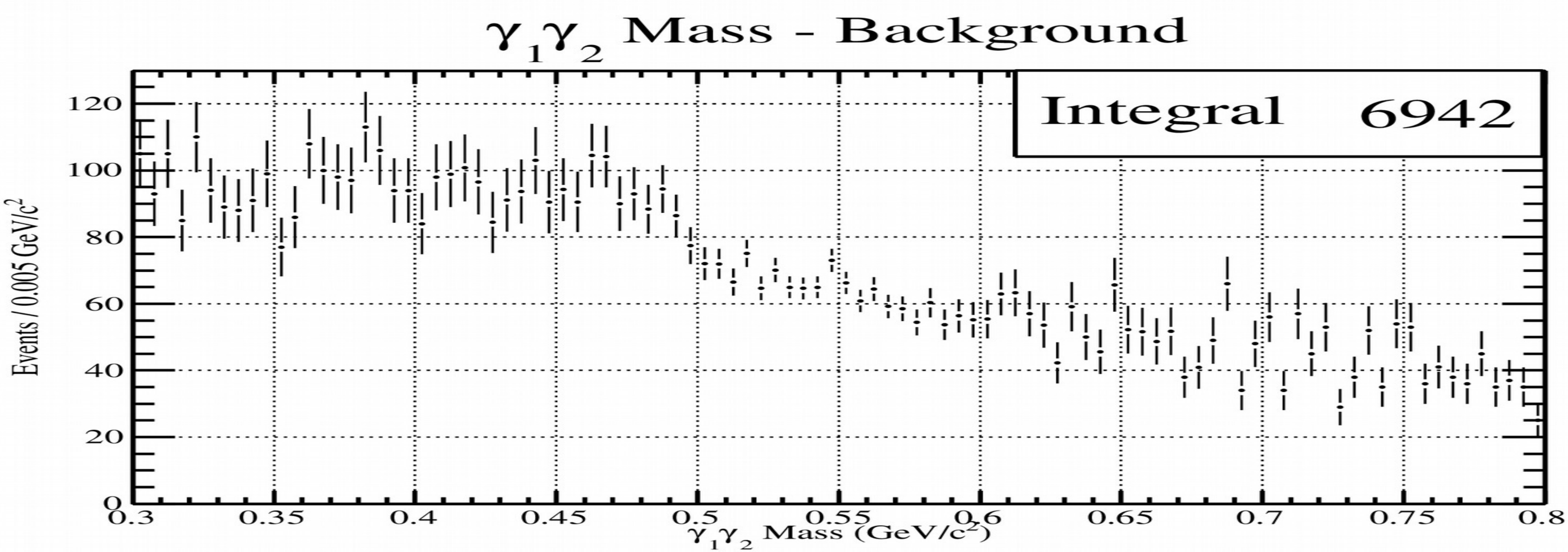
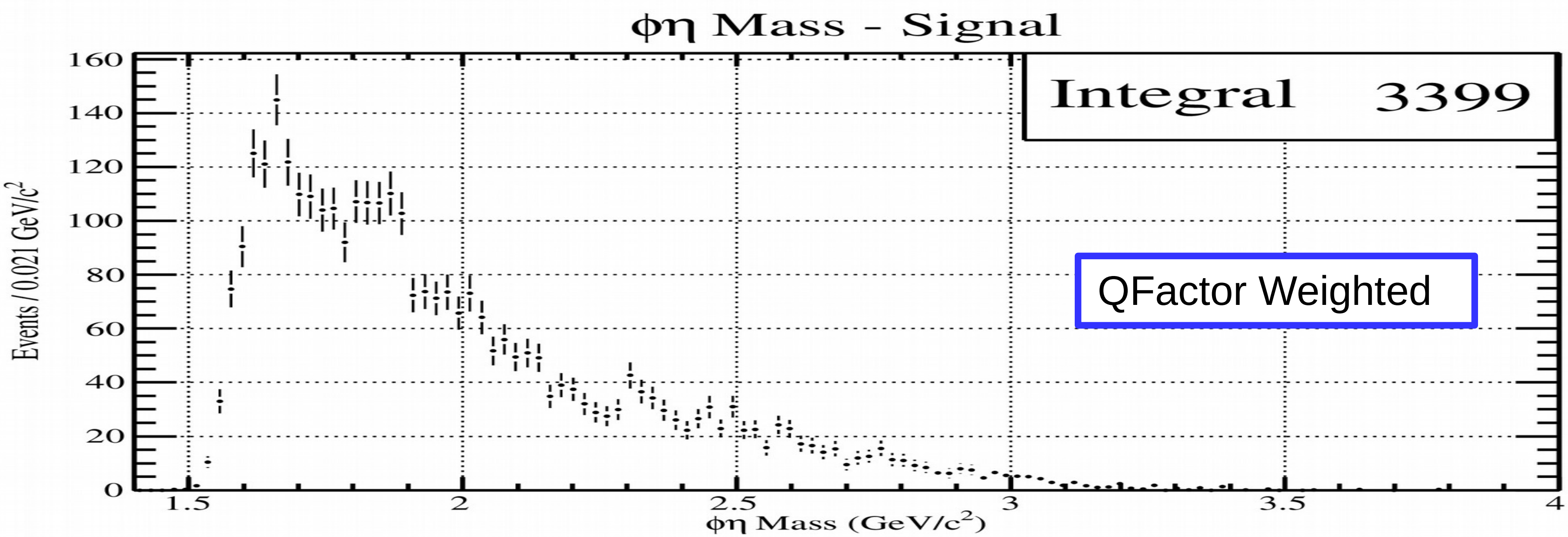
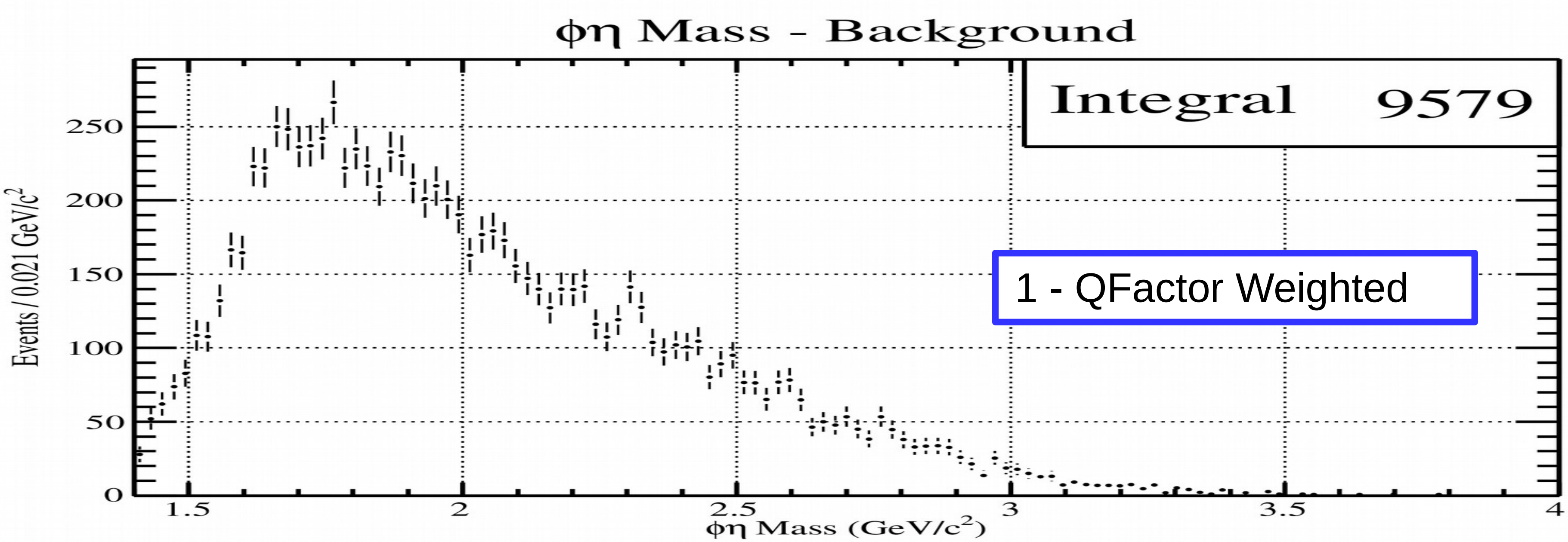




Preliminary Results for Φη Invariant Mass





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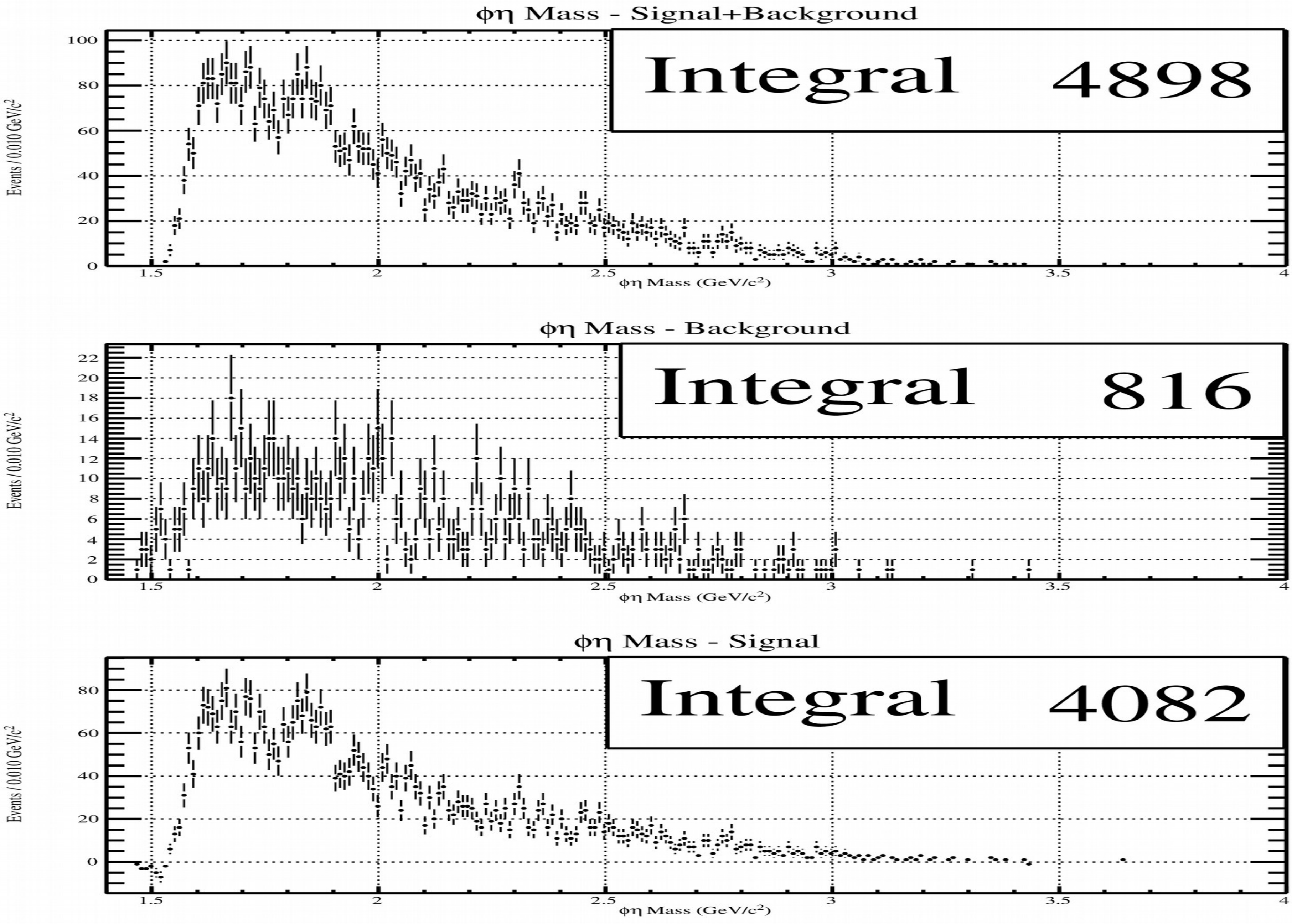

What to do next

- How to properly incorporate accidentals into the Qfactor analysis
- Perform a beam asymmetry analysis on the $\Phi\eta$ parent state
- Acceptance Studies