Study of J/Ψ decays into $\Lambda\bar{\Lambda}K_S^0$

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Motivation

- The signal channel J/ψ $\rightarrow \Lambda\overline{\Lambda}\, K_S^0$ is actually strangeness and isospin violating decay process.
- Searching the events of this decay channel is very important because successful observation of these events will provide hints about Physics beyond the Standard model.
- Huge data sample of J/Ψ, BESIII provides opportunity to search for these rare decays.

Signal Channel

- $\mathrm{J}/\psi \rightarrow \Lambda\bar{\Lambda}\, K_S^0$
    - $\Lambda \rightarrow P\pi^-$
    - $\bar{\Lambda} \rightarrow \bar{P}\pi^+$
    - $K_S^0 \rightarrow \pi^+\pi^-$

- Final state

    - $\mathrm{P}\bar{P}\pi^+\pi^-\pi^+\pi^-$

Initial Event Selection criteria

- Six good charged tracks
  - polar angle :$|cos\theta| < 0.93$.
  - distance away from the beam position in x-y plane :$Rxy < 1cm$
  - distance away from the beam position in z direction :$|dz| < 10cm$
  - total charge is zero i.e., $\sum_{i=1}^{6} Qi=0$

Particle Identification (PID)

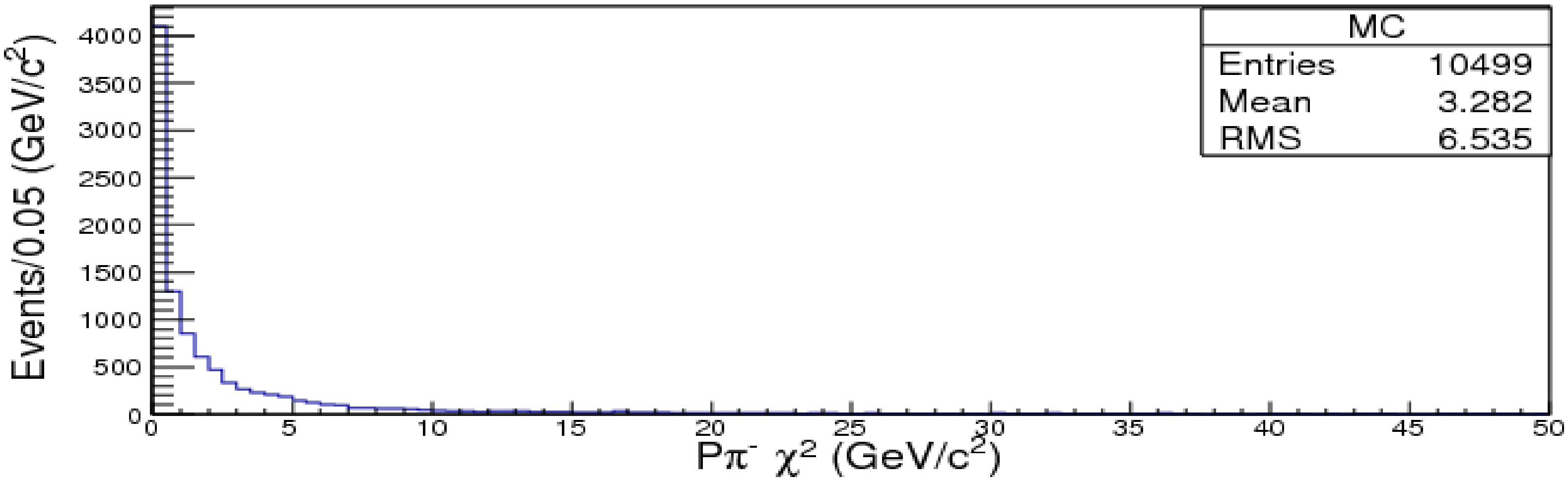
- we used dE/dx and TOF information to identify proton/anti-proton and pions by using the following criteria:
- $For\ p,\ prob(p) > prob(K) \&\& prob(p) > prob(\pi);$
- $For\ \pi,\ prob(\pi) > prob(K),\ prob(\pi) > prob(\pi)$, thus having one proton, one anti-proton, $N\pi^{+}= 2$ and $N\pi^{-} = 2$

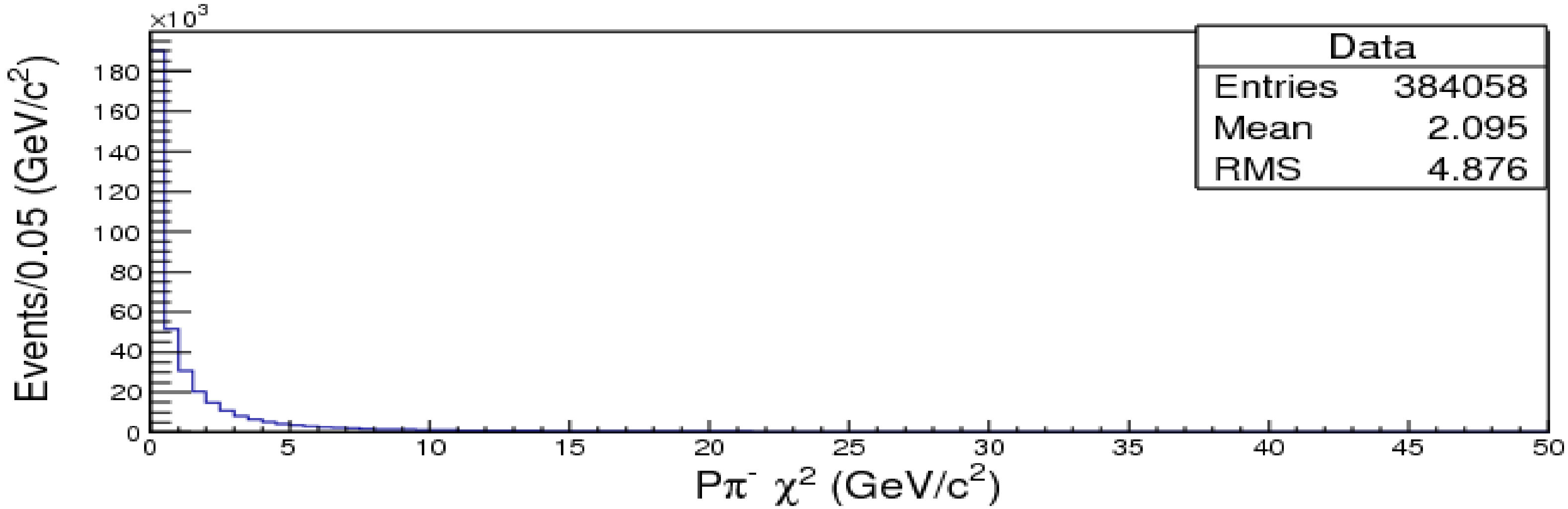
Primary and Secondary Event selection Criteria

- After particle identification, primary and secondary vertex fitting were performed in order to search for the pions coming from the decays of Λ, $\overline{\Lambda}$ and K_S^0 in the final state.

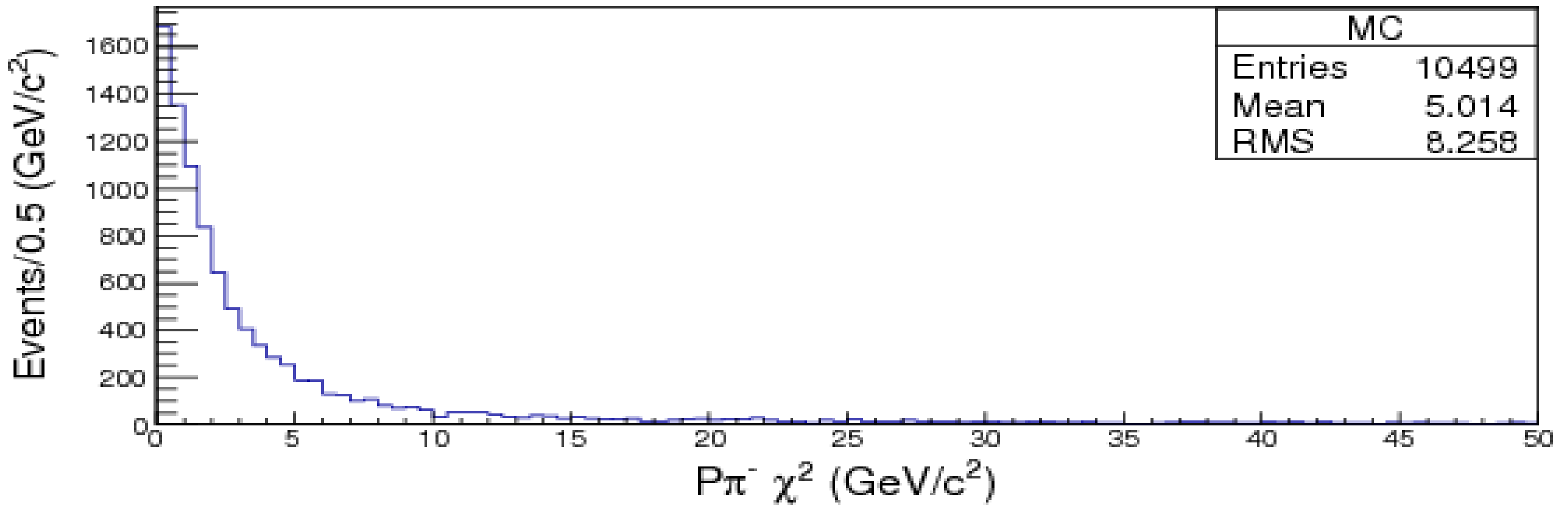
- For this purpose, we used Kalman vertex fitting algorithm. The combinations passing successfully through the vertex fitting were chosen for kinematic fitting.
- Necessary information (χ^2 distribution, decay length distributions and invariant mass distributions) recorded from these vertex fits.
- The Figures below show the (χ^2 distributions for primary and secondary vertex fits for π^+ and π^- which do not participate in reconstruction of Λ and $\overline{\Lambda}$ respectively.

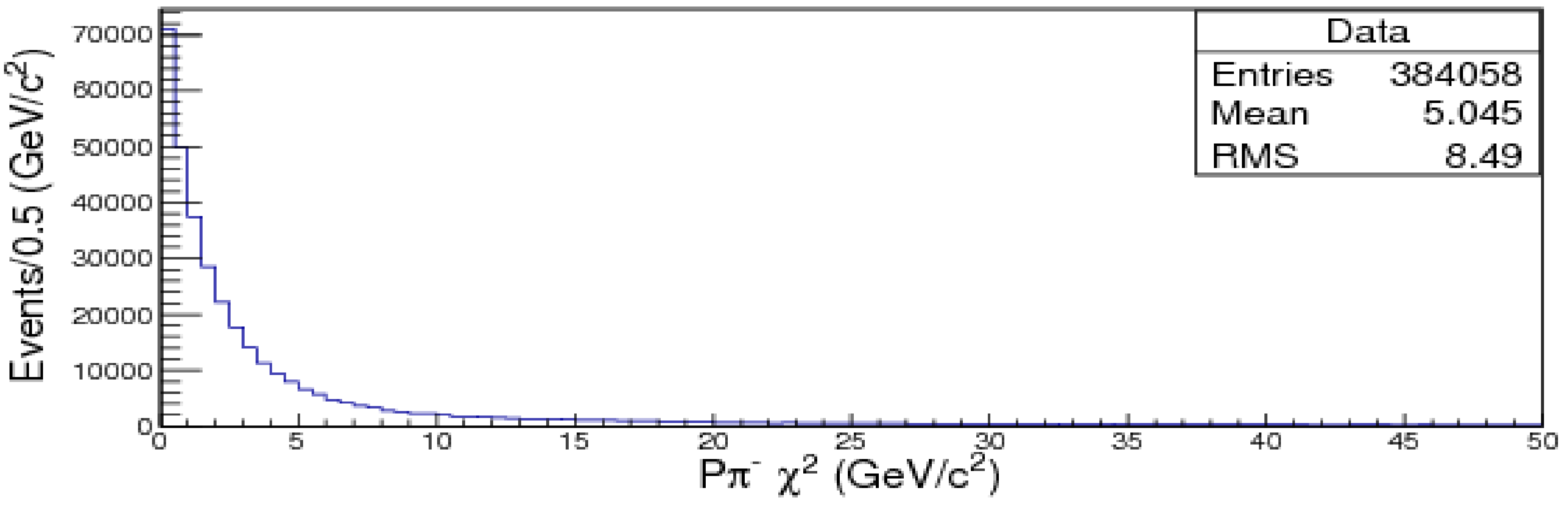
χ^2 distribution after Primary Vertex fit



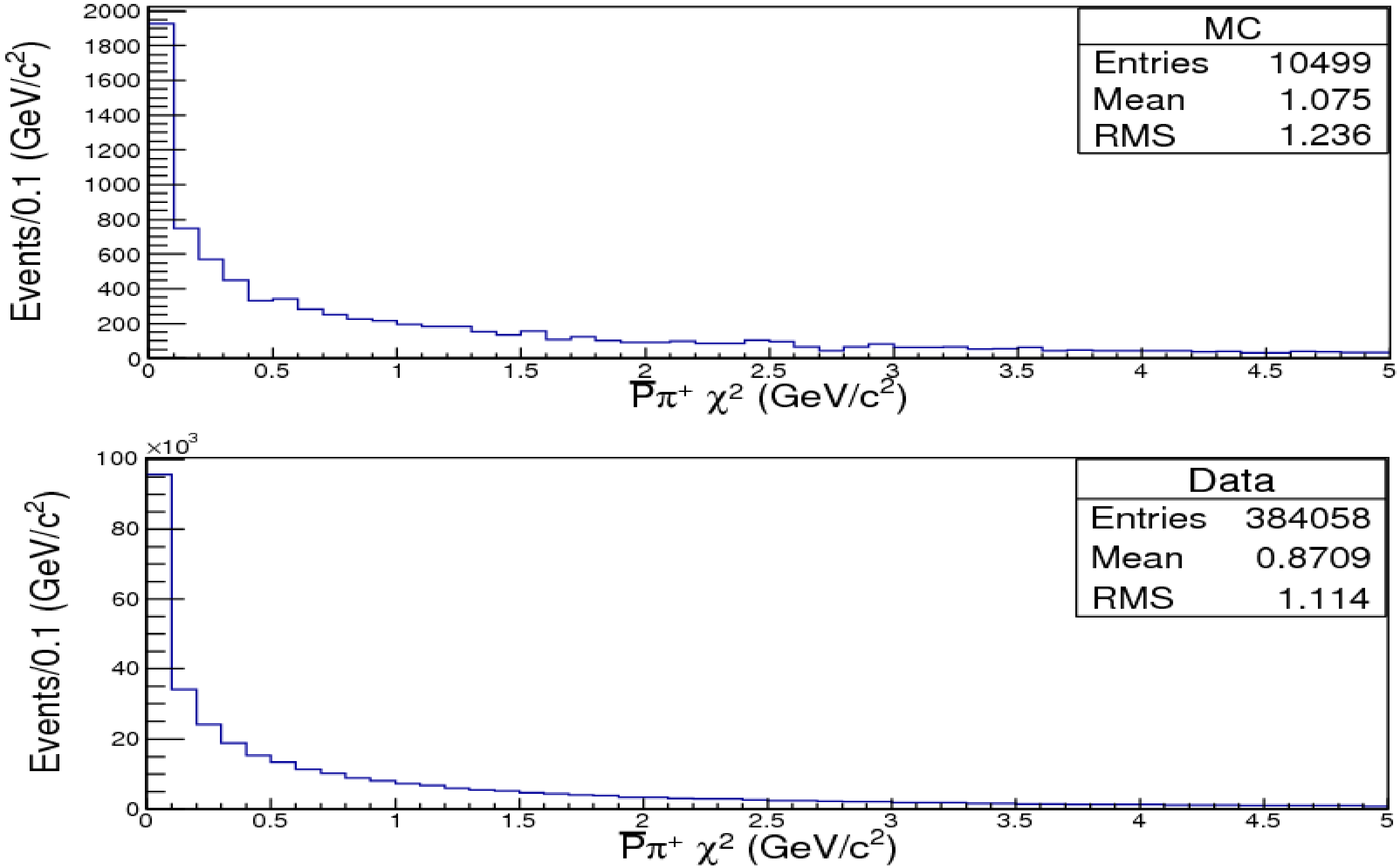


χ^2 distribution of Λ after Secondary vertex fit

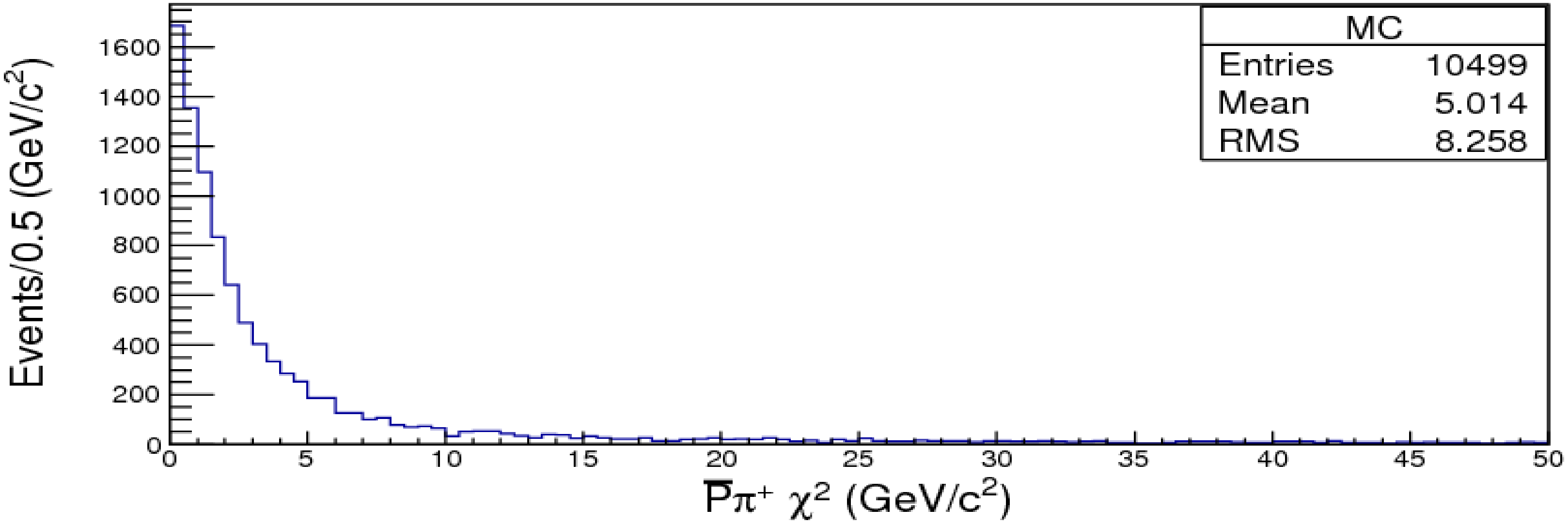


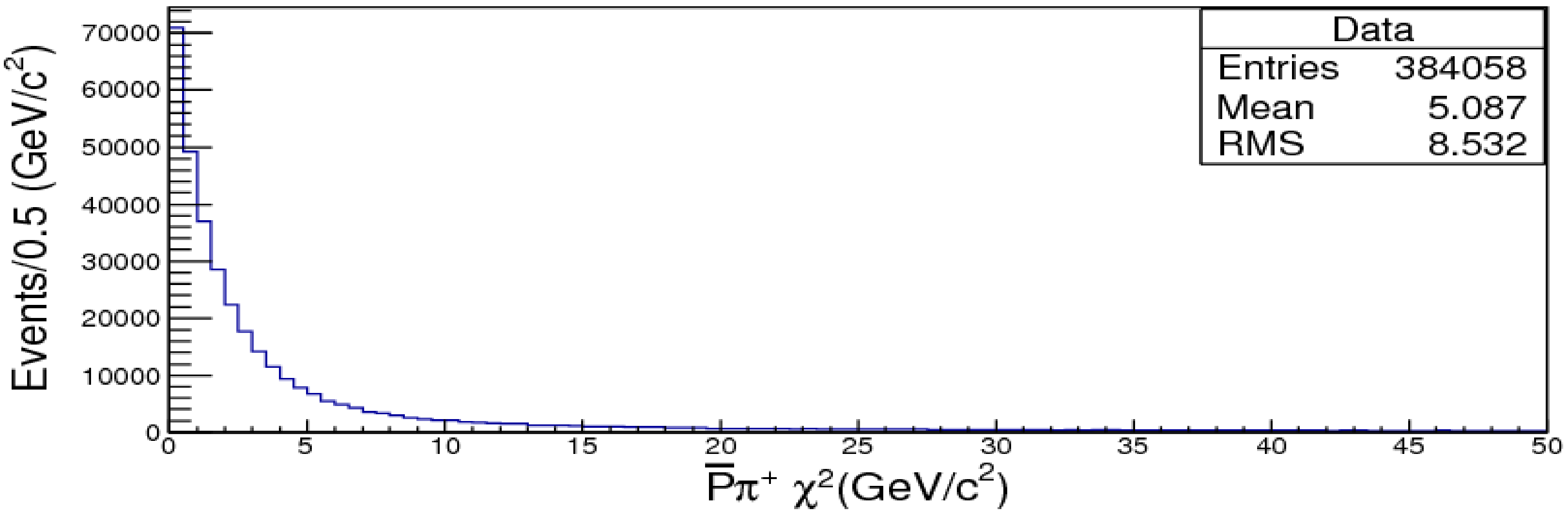


χ^2 distribution of $\overline{\Lambda}$ after primary vertex fit

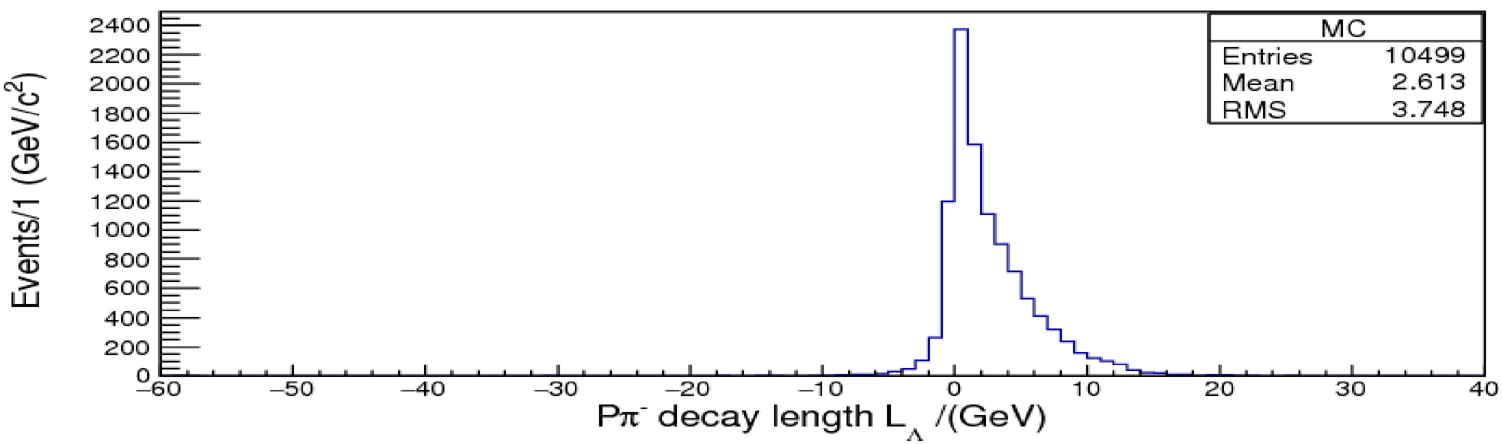


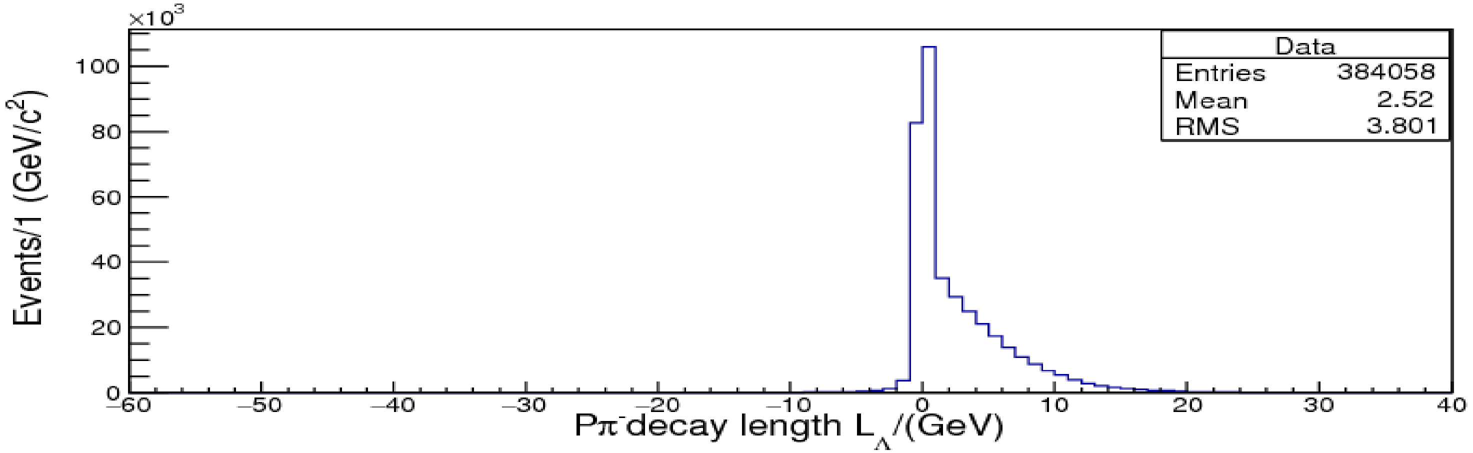
χ^2 distribution of $\bar{\Lambda}$ after secondary vertex fit



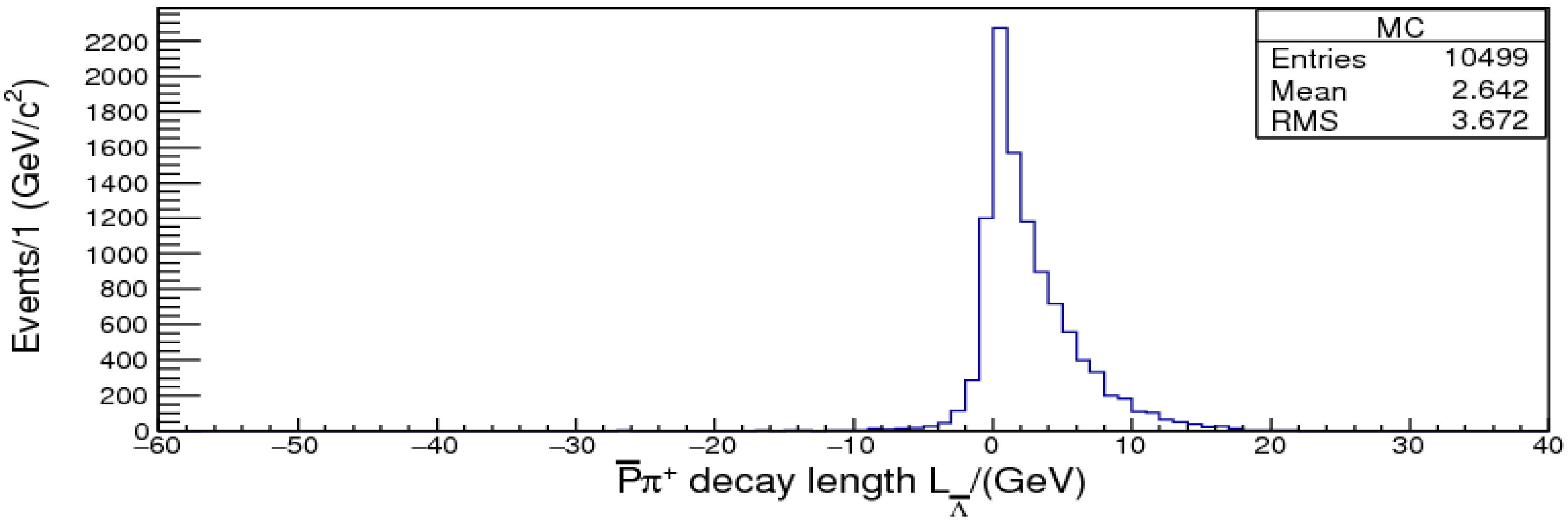


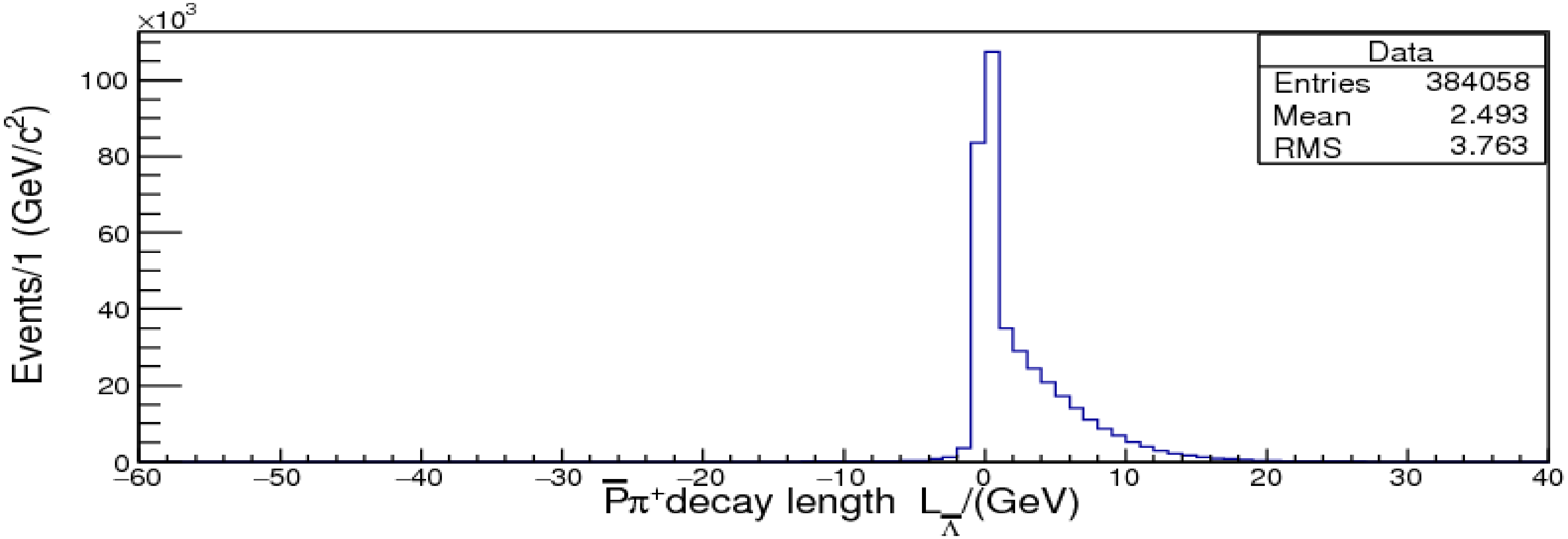
Decay length distribution of Λ



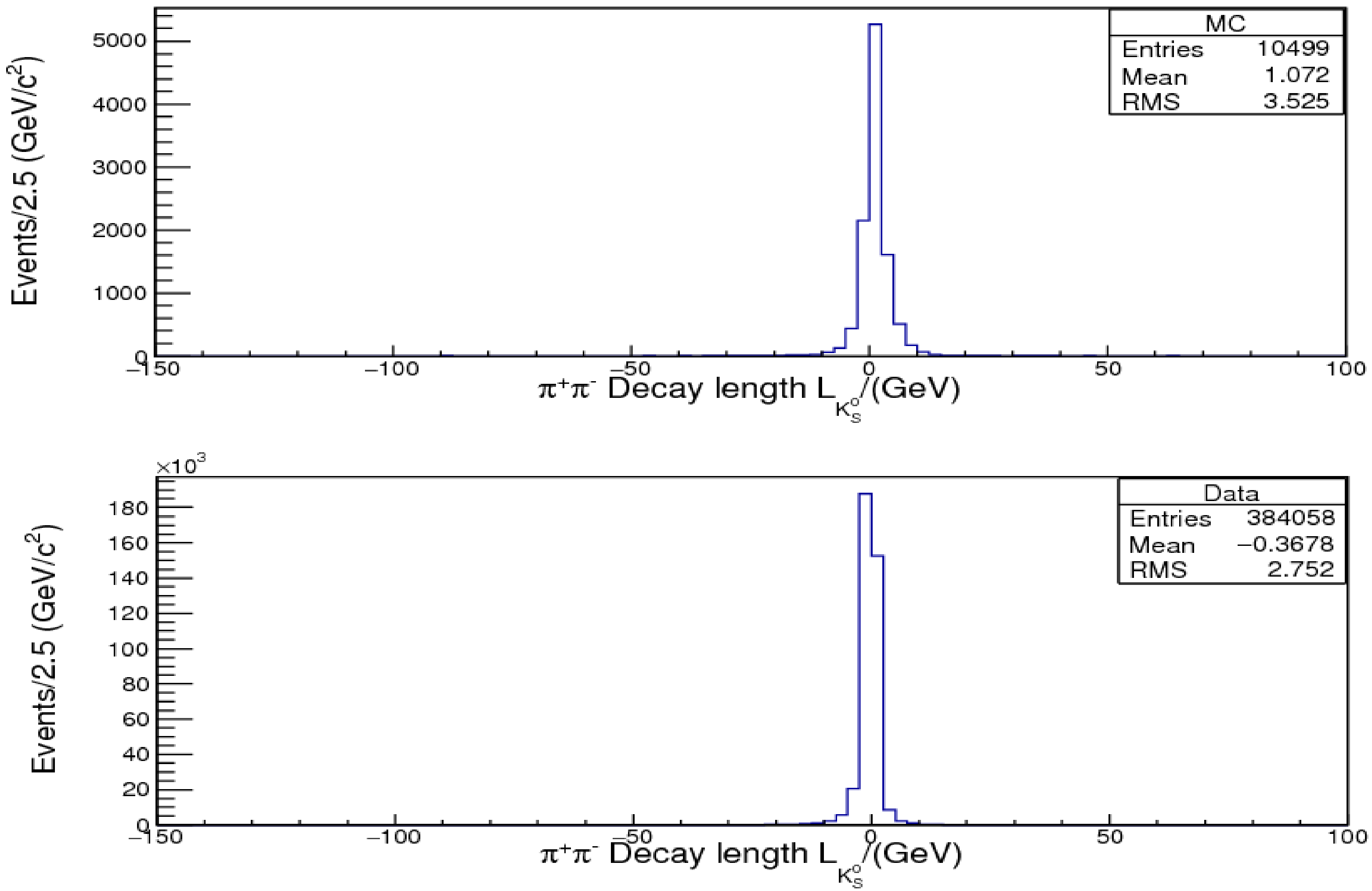


Decay length distribution of $\overline{\Lambda}$

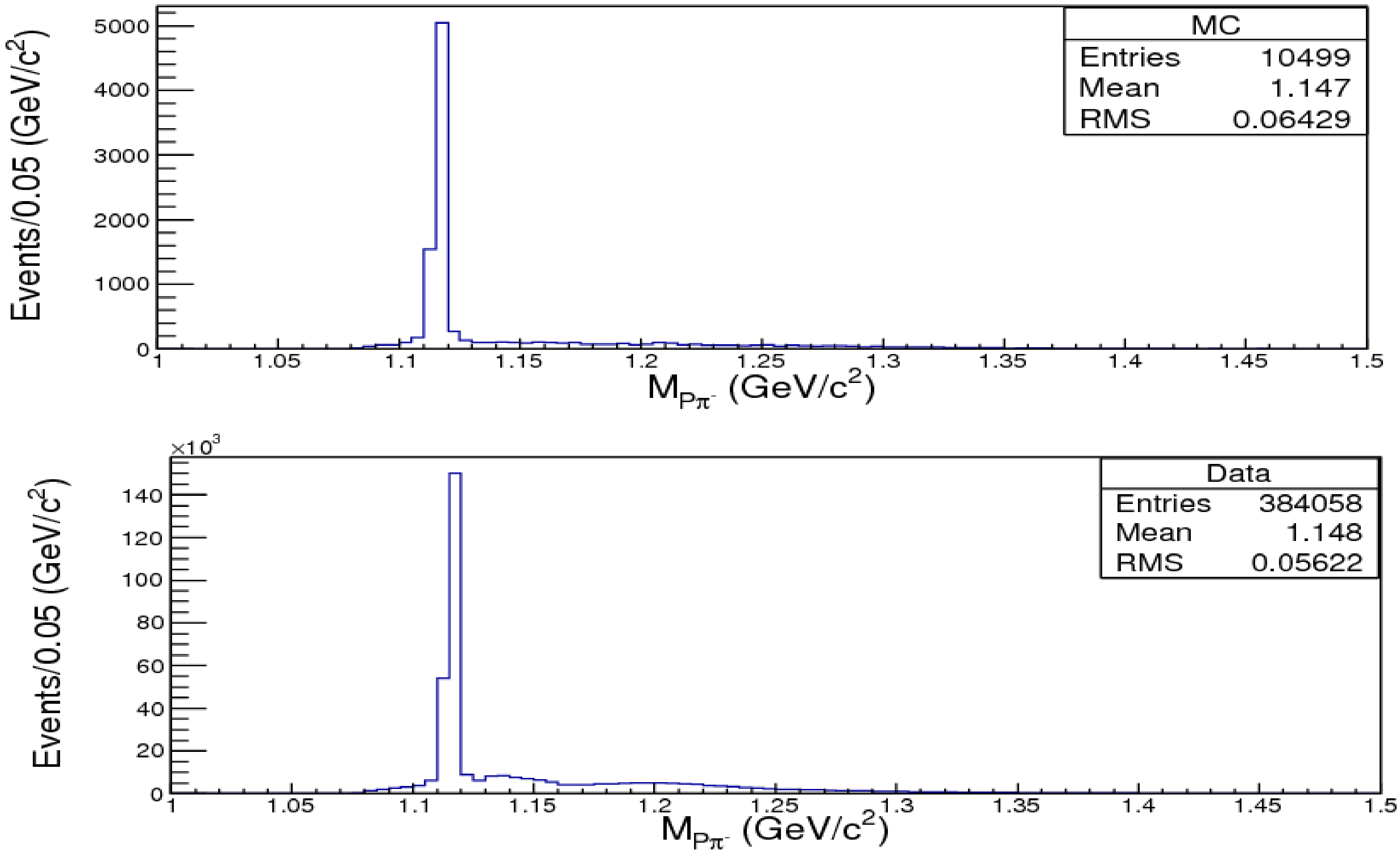




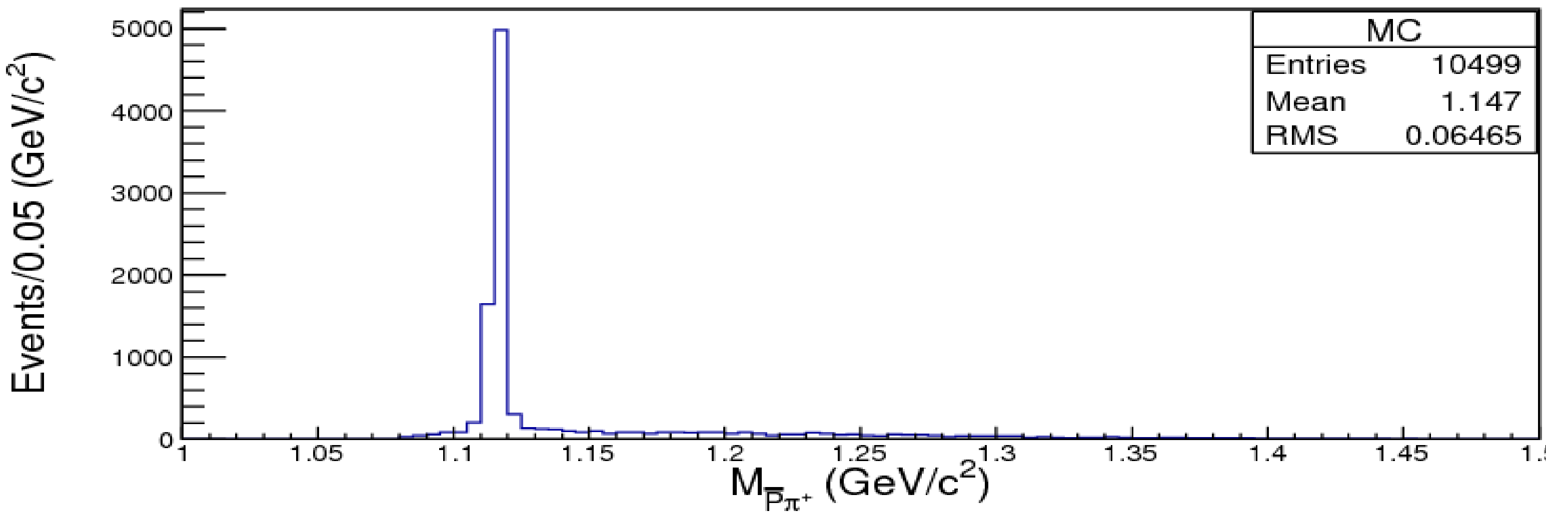
Decay length distribution of K_S^0

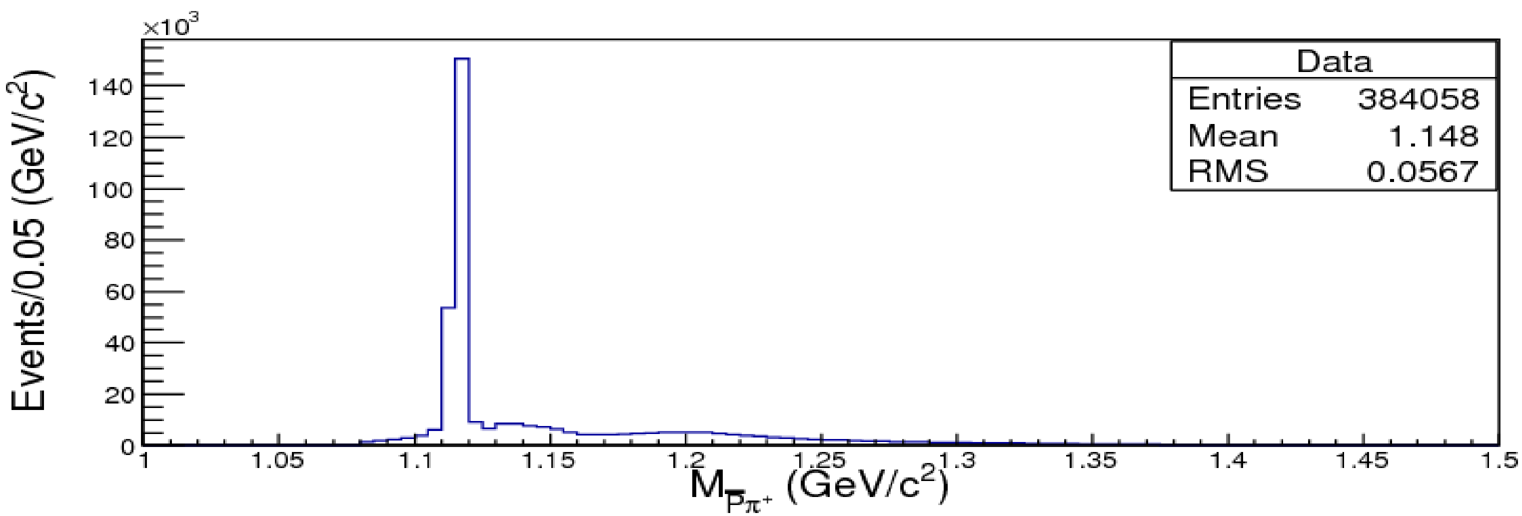


Invariant mass distribution for $P\pi^{-}$ after primary and secondary vertex fit

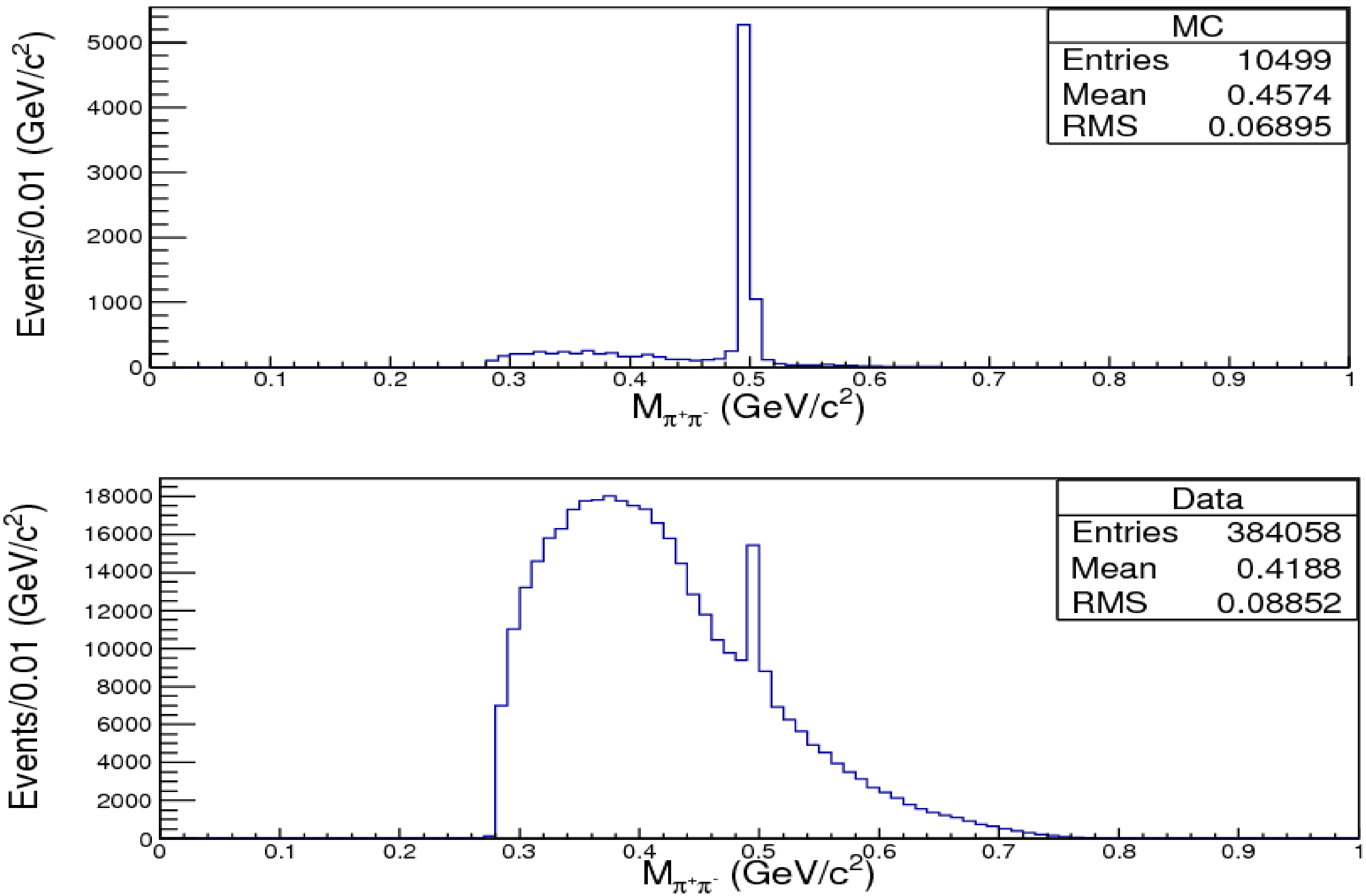


Invariant mass distribution for $\bar{P}\pi^+$ after primary and secondary vertex fit





Invariant mass distribution for $\pi^+\pi^-$combinations after primary and secondary vertex fits



Event selection(through 4c kinematic fit)

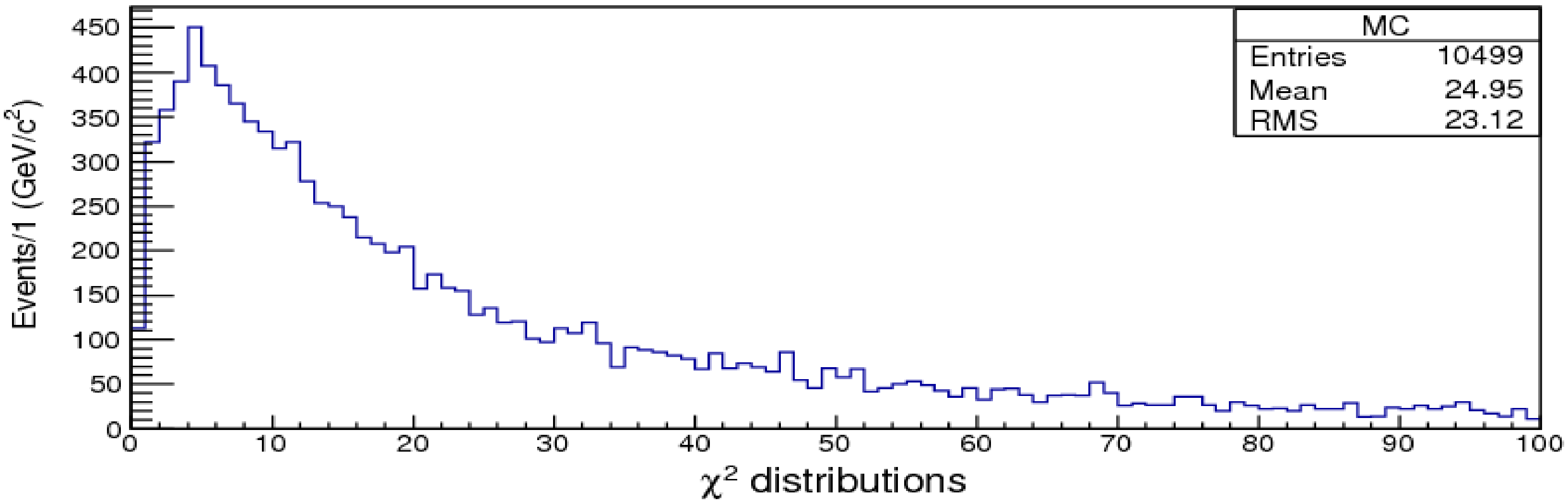
Once from secondary vertex fit we obtained $P\ \pi^-$, $\bar{P}\pi^+$and $\pi^+\ \pi^-$ combinations, 4C kinematic fit was applied for $J/\Psi \rightarrow 2(\pi^+)2(\pi^-)\bar{P}P$ with χ^2_{4c} < 100.

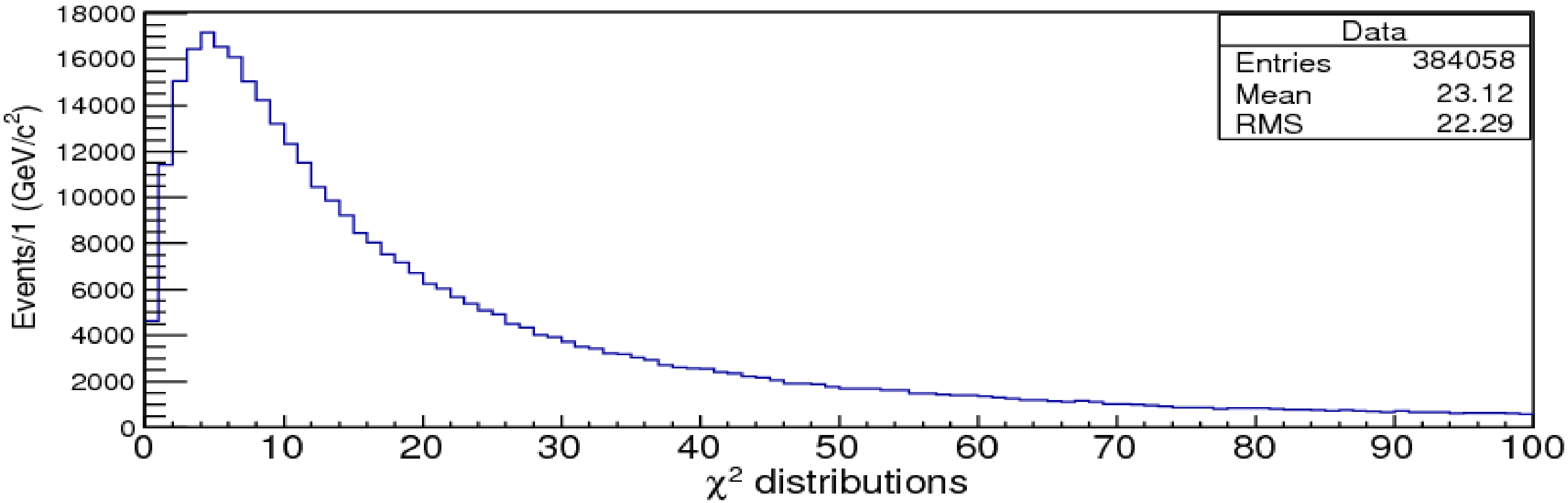
Reconstructed the invariant mass distributions of $P\ \pi^-$, $\bar{P}\ \pi^+$ and $\pi^+\ \pi^-$ as candidate masses of Λ, $\bar{\Lambda}$ and K^0_S

respectively by using those events which passed the 4C fit successfully.

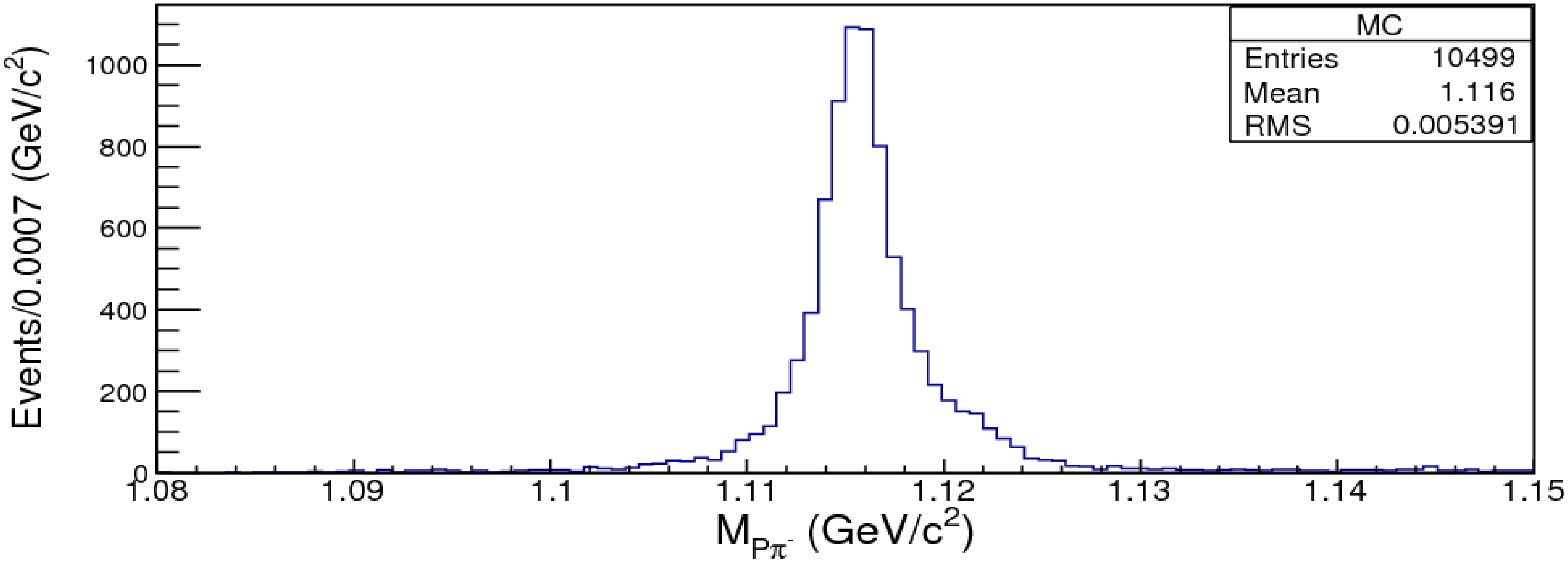
From the final state particles of successfully passing events through 4C fit, we saved necessary information such as invariant mass distributions, χ^2_{4c}, etc. as shown in Figures.

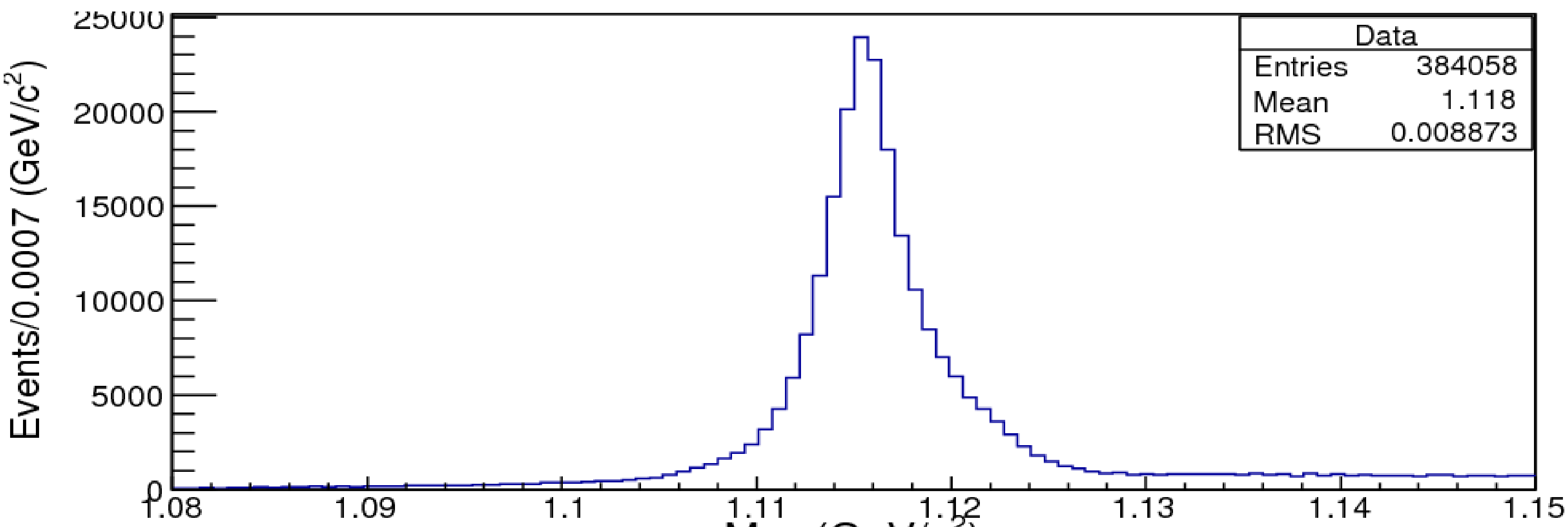
χ^2_{4c} kinematic fit



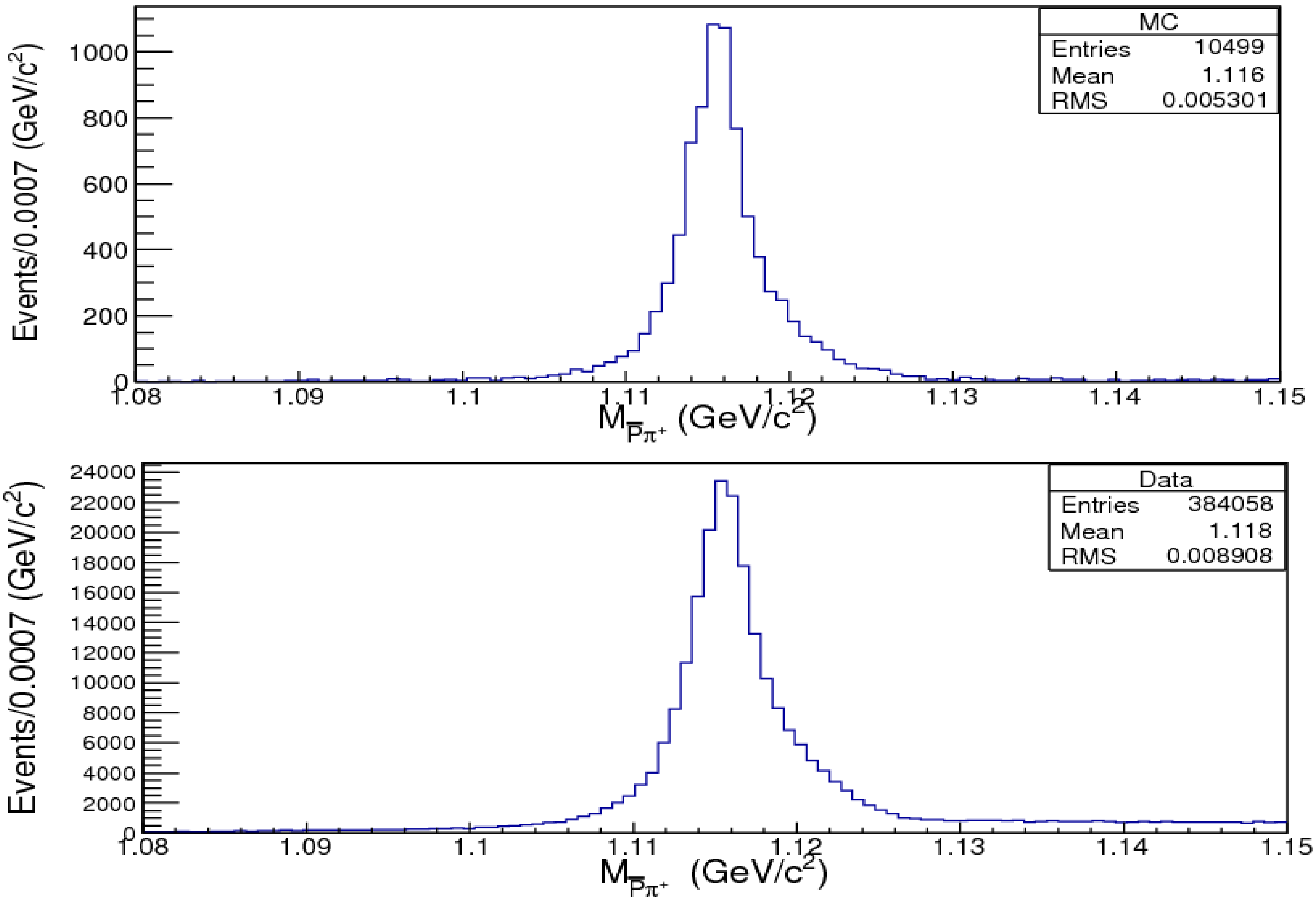


Invariant mass distribution of Pπ^- after 4c fit

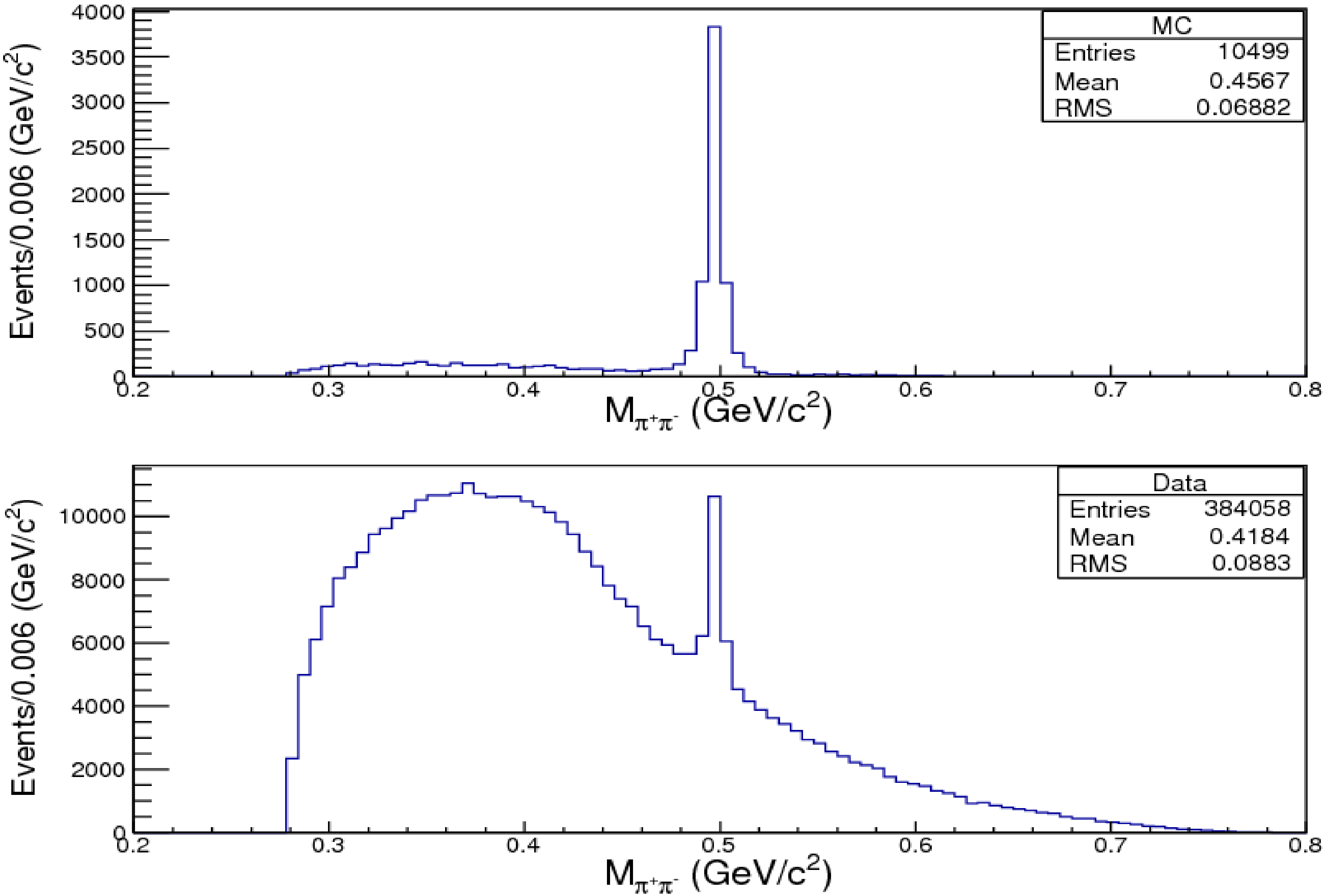




Invariant mass distribution of $\bar{P}\pi^+$ after 4c fit



Invariant mass distribution of $\pi^+\pi^-$ after 4c fit



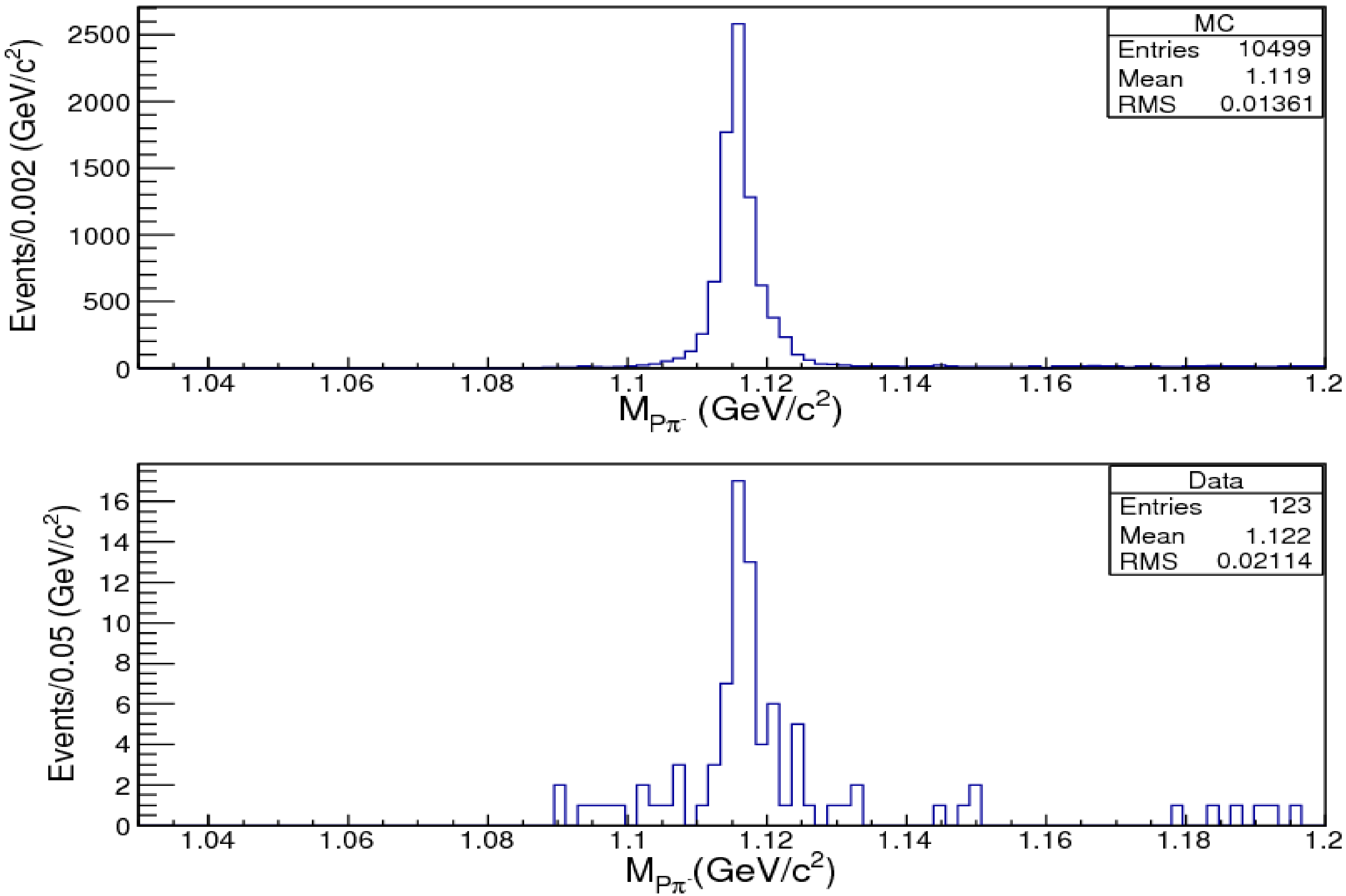
Final Event selection(through cuts)

- The data results from 4C fit indicate that the signals for Λ and $\bar{\Lambda}$ are very clear but the $\pi^+\pi^-$ invariant mass distribution shows a peak around the central mass value of K_S^0 with huge background $\pi^+\pi^-$.
- In order to lower the background level, we decided suitable constraints(inclusive as well as exclusive).
- The mass constraints were decided based upon the mass resolutions of the resonances involved: Λ, $\bar{\Lambda}$ and K_S^0.
- Under the suitable constraints the invariant mass distributions of $P\pi^-$, $\bar{P}\pi^+$ and $\pi^+\pi^-$are shown in Figures respectively.

Invariant mass distribution of Pπ^- after applying following cuts

- χ^2< 40
- $|M_{\bar{P}\pi^+}$ - 1.1156$|$< 0.2 GeV/c^2
- $|M_{P\pi^-\pi^-}$ - 1.1321$|$> 0.008 GeV/c^2
- $|M_{\bar{P}\pi^+\pi^+}$ - 1.1321$|$> 0.008 GeV/c^2
- $|M_{P\pi^-\pi^-}$ - 1.383$|$ > 0.054 GeV/c^2
- $|M_{P\pi^+\pi^-}$ - 1.383$|$ > 0.054 GeV/c^2
- $|M_{\bar{P}\pi^+\pi^+}$ - 1.383$|$ > 0.054 GeV/c^2

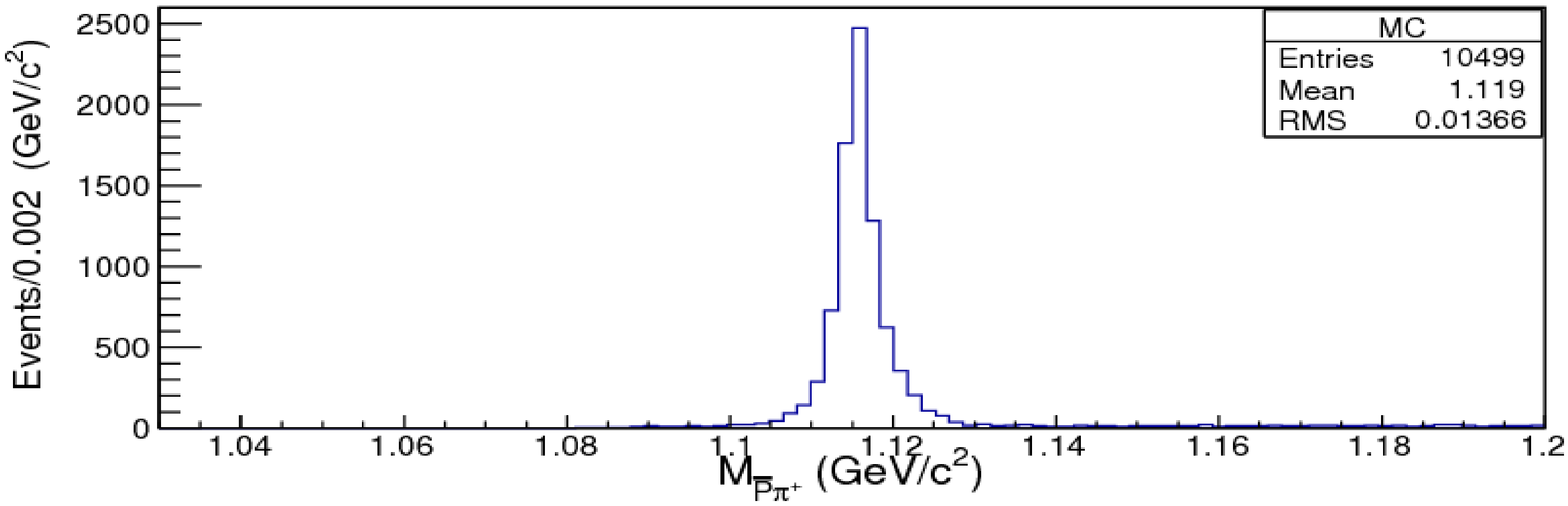
Invariant mass distribution of Pπ^- after cuts

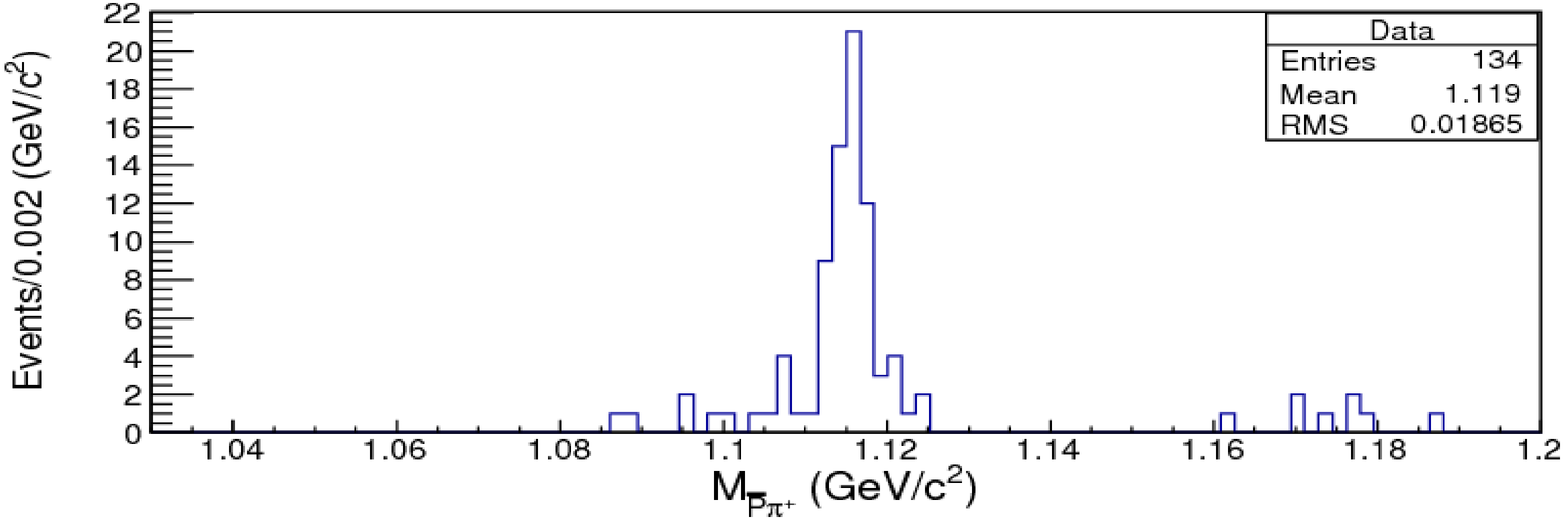


Invariant mass distribution of $\bar{P}\pi^+$after following cuts

- χ^2< 40
- $|M_{P\pi^-}$ - 1.1156$|$< 0.2 GeV/c^2
- $|M_{P\pi^-\pi^-}$ - 1.1321$|$> 0.008 GeV/c^2
- $|M_{\bar{P}\pi^+\pi^+}$ - 1.1321$|$> 0.008 GeV/c^2
- $|M_{P\pi^-\pi^-}$ - 1.383$|$ > 0.054 GeV/c^2
- $|M_{P\pi^+\pi^-}$ - 1.383$|$ > 0.054 GeV/c^2
- $|M_{\bar{P}\pi^+\pi^+}$ - 1.383$|$ > 0.054 GeV/c^2

Invariant mass distribution of $\bar{P}\pi^+$ after cuts

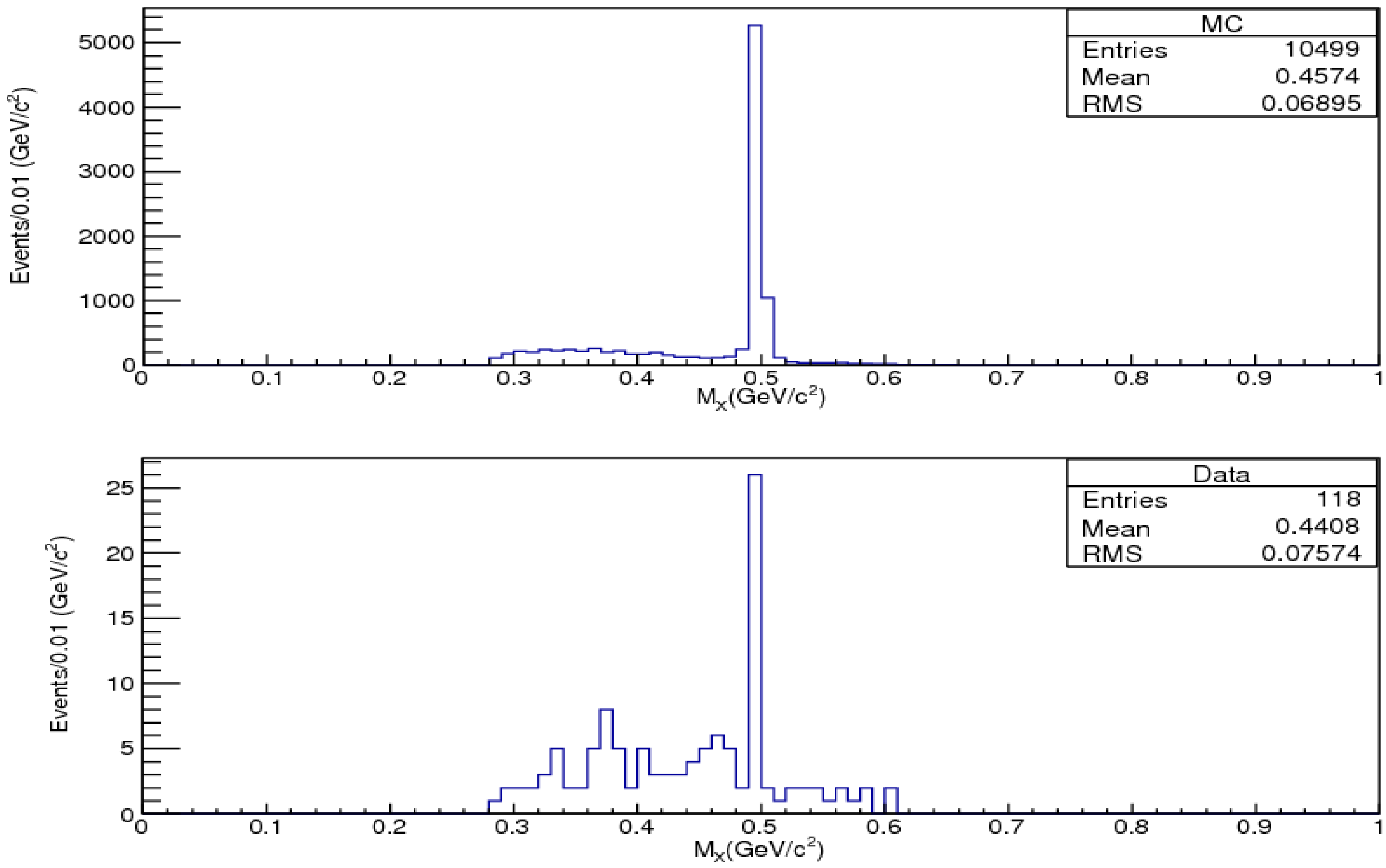




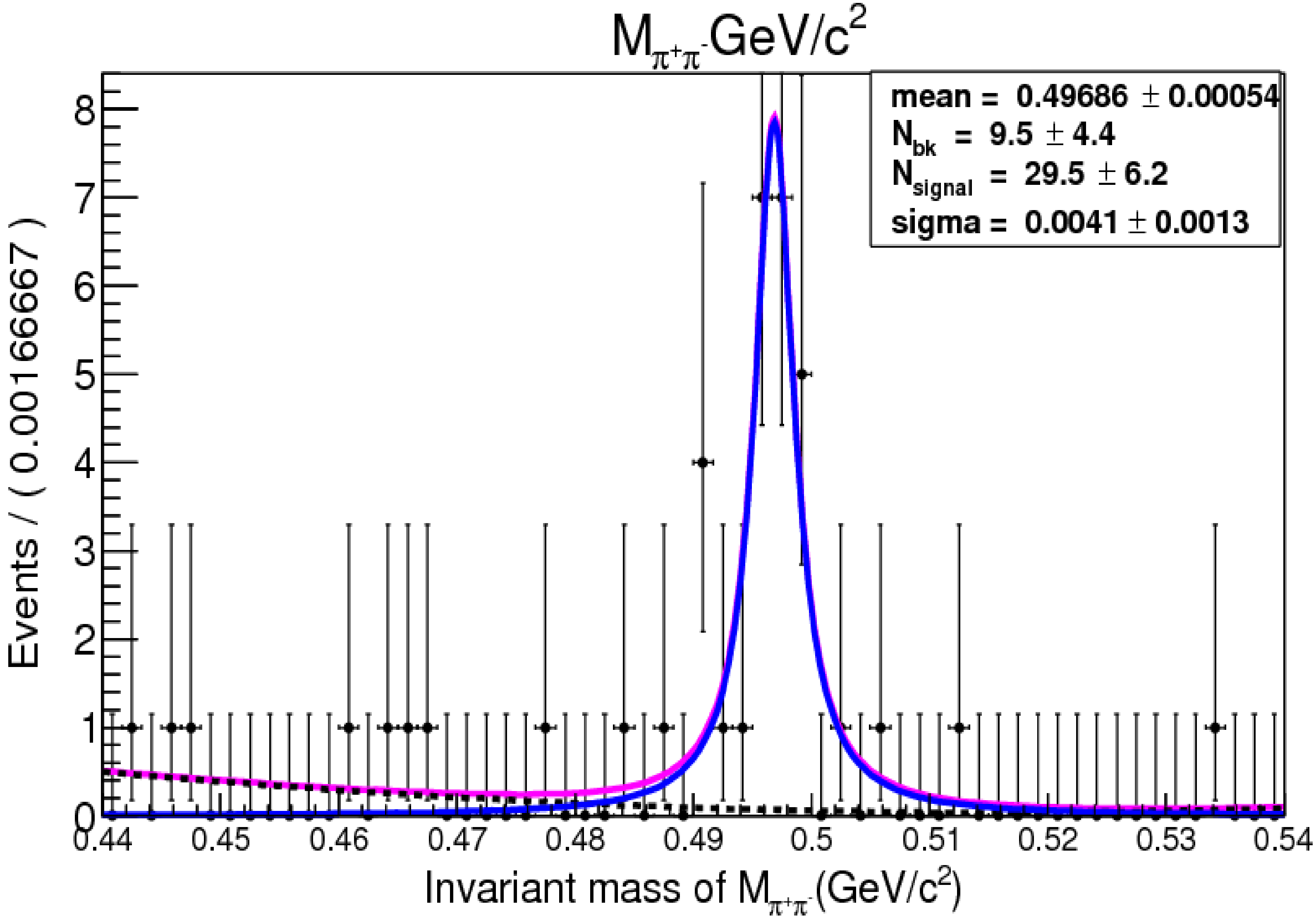
Invariant mass distribution of $\pi^+\pi^-$ after applying following cuts

- $|M_{\bar{P}\pi^+}$ - 1.1156$|$< 0.2 GeV/c^2
- $|M_{P\pi^-}$ - 1.1156$|$< 0.2 GeV/c^2
- $|M_{P\pi^-}$ - 1.1321$|$> 0.008 GeV/c^2
- $|M_{\bar{P}\pi^+}$ - 1.1321$|$> 0.008 GeV/c^2
- $|M_{P\pi^-\pi^-}$ - 1.383$|$ > 0.054 GeV/c^2
- $|M_{P\pi^+\pi^-}$ - 1.383$|$ > 0.054 GeV/c^2
- $|M_{\bar{P}\pi^+\pi^+}$ - 1.383$|$ > 0.054 GeV/c^2

Invariant mass distribution of $\pi^+\pi^-$ after cuts



Fit to the mass of $\pi^+\pi^-$



Fit results:29.5±6.2 events are recorded through breight weigner formula in 3σ.

Background study

- Through topology of Inclusive MC = 1.225×10^{9} J/ψ events and 1,00000 exclusive MC samples used to study background estimation.

Channels	N_{gen}	$Branching fraction)$	N_{obs}	Normalized
$J/\psi \to \Lambda\bar{\Lambda}\rho$	100,000	-	2	0
$J/\psi \to \Lambda\bar{\Lambda}\omega$	100,000	-	0	0
$J/\psi \to \Lambda\bar{p}^{-}K^{+}$	100,000	-	3	0
$J/\psi \to \Delta^{++}\Delta^{--}\pi^{+}\pi^{-}$	100,000	-	0	0
$J/\psi \to K^{-}\pi^{+}P^{+}\bar{\Lambda}\pi^{-}$	100,000	-	0	0
$J/\psi \to \Sigma^{*+}\Sigma^{*-}$	100,000	-	0	0
$J/\psi \to \Lambda\bar{\Lambda}\eta$	100,000	1.62 ± 0.17	5.	10.55
$J/\psi \to \Lambda\bar{\Lambda}\pi^{+}\pi^{-}$	100,000	$(4.3\pm1.0)\times10^{-3}$	10	559
$J/\psi \to \Sigma^{-}\bar{\Sigma}^{+}$	100,000	$(3.1\pm0.5)\times10^{-4}$	0	0
$J/\psi \to \Xi\bar{\Xi}^{0}$	100,000	$(3.2\pm1.0)\times10^{-4}$	7	29.12
$J/\psi \to \Sigma^{0}\bar{\Lambda}$	100,000	$<9\times10^{-5}$	0	0
$J/\psi \to \Xi^{-}\bar{X}i^{+}$	100,000	-	1	0

Branching Fraction of research process

- $\mathrm{B}(\mathrm{J}/\psi \rightarrow \Lambda\bar{\Lambda}K_S^0) = \frac{N_{observed}}{N_{j/\Psi}.B(\Lambda\rightarrow P\pi^-).B(\bar{\Lambda}\rightarrow\bar{P}\pi^+).B\left(K_S^0\rightarrow\pi^+\pi^-\right).\varepsilon}$

- $\mathrm{B}(\mathrm{J}/\psi \rightarrow \Lambda\bar{\Lambda}K_S^0) = (0.485\pm0.09)\times10^{-6}$

Systematic Error Analysis

Source of error	(% Uncertainty)
MDC	6
PID	12
MC Model	7.05
Intermediate BF	1.5
J/Ψ number	0.5
Vertex fit	20
Total systematic error	24.24