The momentum distribution of $K^+\pi^-$ and π^+K^- pairs(Coulomb and nonCoulomb).

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1 Preface

In this work we determined the momentum distributions for Coulomb and nonCoulomb $K^+\pi^-$ and π^+K^- pairs which are created in pNi interactions in the DIRAC setup target. These distributions are needed for preparing of these pairs Monte-Carlo generators which will be used in data analysis.

For this purpose we used the experimental data ntuples where the $K^+\pi^-$ and π^+K^- pairs were mainly accumulated for all the data of year 2008 and the Monte-Carlo simulation of these pairs in the DIRAC setup was made with GEANT-DIRAC program. The examples of programs for ntuple creating and their analyzing were given by V.Yazkov.

At the stage of analysis of ntuple events the following cuts were used:

1. The cut on the total momentum of $K^+\pi^-$ or π^+K^- pairs($4.8 \div 12\mathrm{Gev/c}$).

2. The cuts on the values of pair relative moment: Q_x, Q_y and Q_L(6, 4 and 20 MeV/c, respectively).

3. The cuts on the ionization hodoscope hits: slab numbers and amplitudes in them.

4. Two hits must be in ScFi hodoscope.

5. The cuts on the track time in both arms.

6. The cuts on hits in Nitrogen Cherenkov counters to reject the electrons and positrons.

7. The cuts on hits in heavy gas Cherenkov counters to eliminate pions.

8. The cuts on hits in aerogel Cherenkov counter to suppress protons.

Applying these cuts we can not completely separate the kaons and protons(in the case of $K^+\pi^-$ pairs and antiprotons in the case of π^+K^- pairs) and the cut on track time can not be used directly to select kaons as the kaon and proton time distributions are overlapped partly. When two gaussians are overlapped significantly then it is better to know the parameters of shape of second gaussian. In our case we can try to obtain such information from the analysis of hits of protons(antiprotons) which are product of Lambda(antiLambda) decays. We see that Lambda and antiLambda are detected in our setup(Fig.1 and 2). The events in these distributions are obtained after applying all the above cuts except the cuts on track time. Calculating the values of pair relative momentum we suggested that the heavy mass particle is kaon. As the width and shape

of $p/(\bar{p})$ track time distribution depend on its momentum value then we must determine these parameters as function of $\Lambda/(\bar{\Lambda})$ momentum. It was done by dividing the $\Lambda/(\bar{\Lambda})$ momentum in several intervals, obtaining the shape of proton(antiproton) time distribution for each interval and finding the functional dependence of these parameters on $\Lambda/(\bar{\Lambda})$ momentum. Then this functional dependence was used during the fitting of distributions where there are two gaussians - one comes from $K^+/(K^-)$ signal and the second - from proton/antiproton. But during the fitting the parameters of p and $\bar{p}$ time distributions were not completely fixed, the parameters were allowed to have some deviations around obtained values. For each of total momentum intervals of pairs the number of events in K^+/K^- time peaks was calculated and in such a way we could obtain the shape of $K^+\pi^-$ and π^+K^- pairs momentum distributions.

Applying the value of $K^+\pi^-(\pi^+K^-)$ acceptance, which was found by Monte-Carlo simulation, we reconstructed these pairs momentum distribution shape in pNi-collisions.

2 Results: $K^+\pi^-$ pairs

The events with the value of Q_L which belong to the peak of Lambda(Fig.1) were taken and the pair total momentum was divided into several intervals with step of 0.26 GeV/c(there are such events on beginning from 5 GeV/c only) and for each interval the distribution of Δt(the difference between times of both tracks at the level of target) was fitted by function which is the sum of two gaussians and polynomial of first degree (Fig.3,4,5). One gaussian corresponds to the K^+ peak and the another - to proton one. We obtained the dependencies of position and width of proton time peak on Lambda momentum(Fig.6) and after they were fitted by polynomials and these two obtained functions were used to confine these two parameters for the fitting procedure of determining the number of K^+. The like procedure of fitting by the the sum of two gaussians and polynomial was used to find the number of $K^+\pi^-$ pairs in each interval of this pair momentum: the events were selected by applying all the mentioned cuts and the Δt distributions(Fig.7,8) were fitted by the sum of two gaussians and polynomial. The dependencies of position and width for K^+ and proton time distributions on the pair momentum are shown on Fig.9. We see that the proton time distributions have a bit different shape for Lambda case and for the events with small values of Q. The dependency of number of $K^+\pi^-$ pairs on their total momentum is shown on Fig.10(top). The corresponding acceptance for these pairs, obtained by Monte-Carlo, is shown on Fig.10(middle). Using these two distributions there was found the $K^+\pi^-$ pair momentum distribution in the target(Fig.10(bottom)). This distribution was fitted by $a * exp(b * p)$ function, where p is pair momentum. The value of the slope was obtained to be equal -0.888 ± 0.038.

3 Results: π^+K^- pairs

The events with the value of Q_L which belong to the peak of antiLambda(Fig.2) were taken and the pair total momentum was divided into several intervals with step of 0.75 GeV/c(there are such events on beginning from 5 GeV/c only) and for each interval the distribution of Δt was fitted by function which is the sum of two gaussians and polynomial of first degree (Fig.11). One gaussian corresponds to the K^- peak and the another - to antiproton one. We obtained the dependencies of position and width of antiproton time

peak on antiLambda momentum(Fig.12) and after they were fitted by polynomials and these two functions were used to confine these two parameters for the fitting procedure of determining the number of K^-. The like procedure of fitting by the the sum of two gaussians and polynomial were used to find the number of $\pi^+ K^-$ pairs in each interval of this pair momentum: the events were selected by applying all the mentioned cuts and the Δt distributions(Fig.13) were fitted by the sum of two gaussians and polynomial. The dependencies of position and width for K^- and antiproton time distributions on the pair momentum are shown on Fig.14. We see that the antiproton time distributions have different values of peak position for antiLambda case and for the events with small values of Q. The dependency of number of $\pi^+ K^-$ pairs on their total momentum is shown on Fig.15(top). The corresponding acceptance for these pairs, obtained by Monte-Carlo, is shown on Fig.15(middle). Using these two distributions there was found the $\pi^+ K^-$ pair momentum distribution in the target(Fig.15(bottom)). This distribution was fitted again by $a * exp(b * p)$ function. The value of the slope was obtained to be equal -0.49 ± 0.06 which is quite different from the $K^+ \pi^-$ pairs case.

The next step, which should be done, is the determining the momentum distributions of pion-proton($p\pi^-$ and $\pi^+ p$) pairs created in pNi interactions in the DIRAC setup target. In the analysis of pion-kaon pairs we will use the Monte-Carlo simulation of pion-proton pairs too.
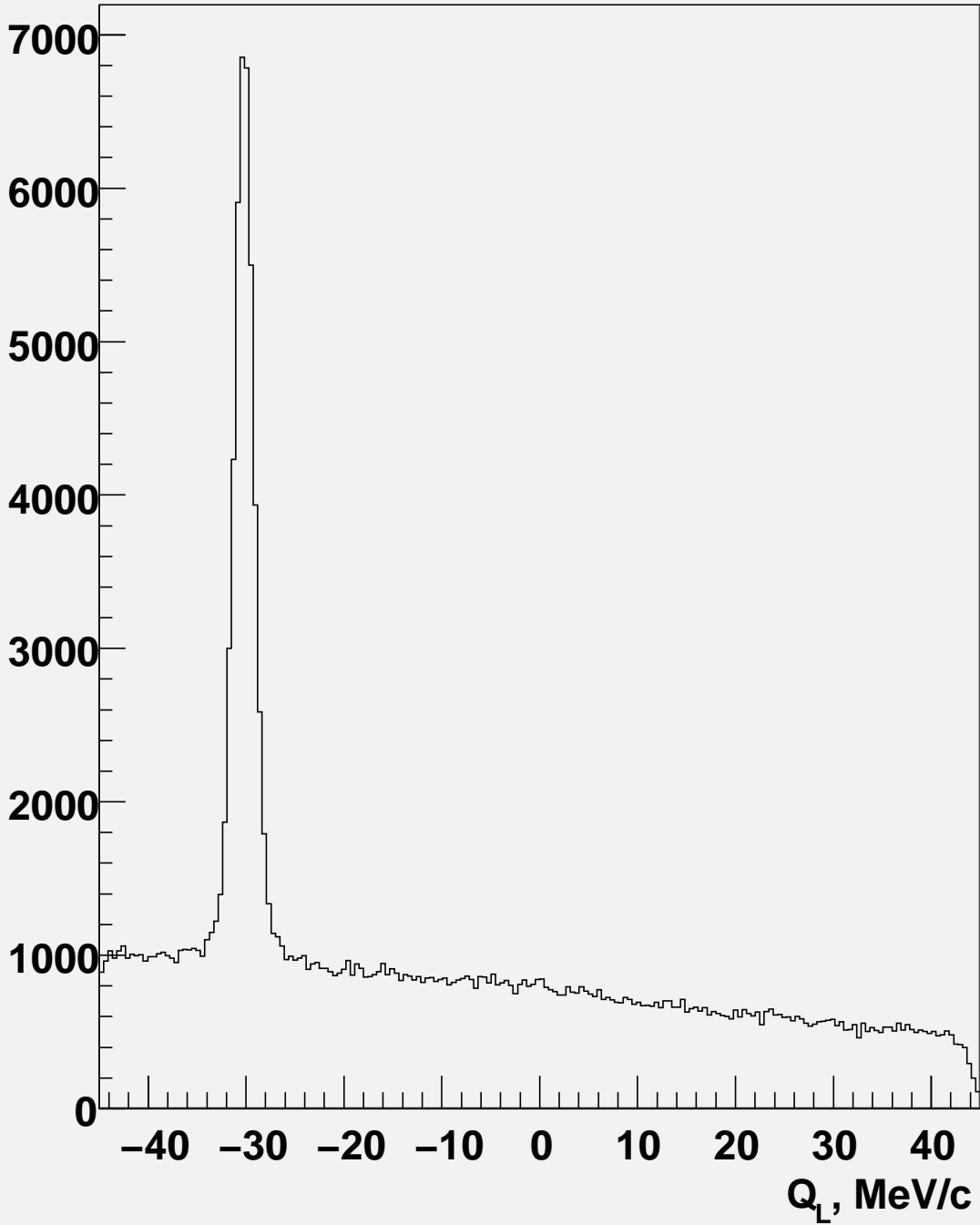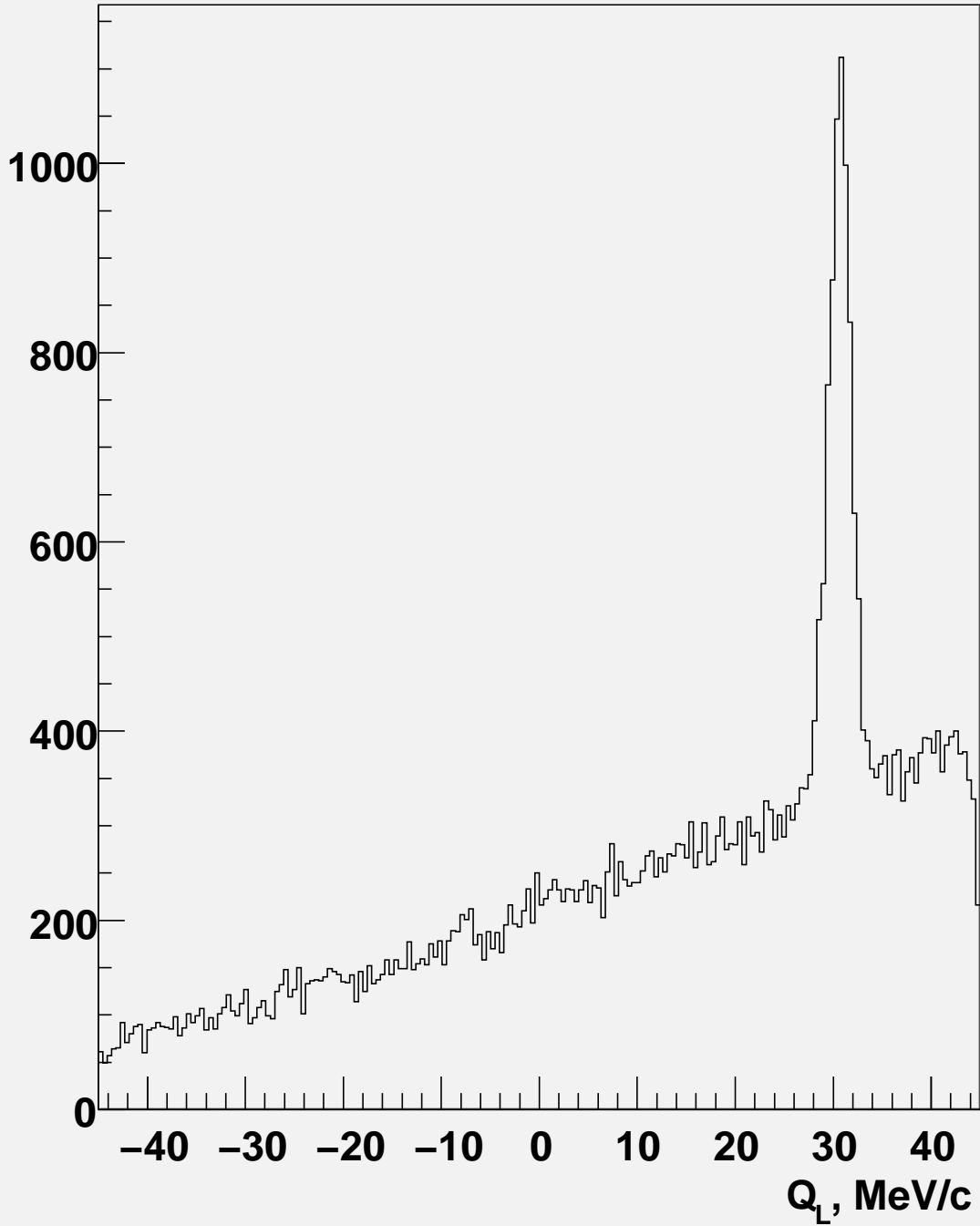
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Figure 1: *The Q_L distribution for events after the cuts to select $K^+\pi^-$ pairs but without the cuts on pair relative momentum(Q_x, Q_y and Q_L). The peak is due to proton and pion pairs from Lambda decay.*
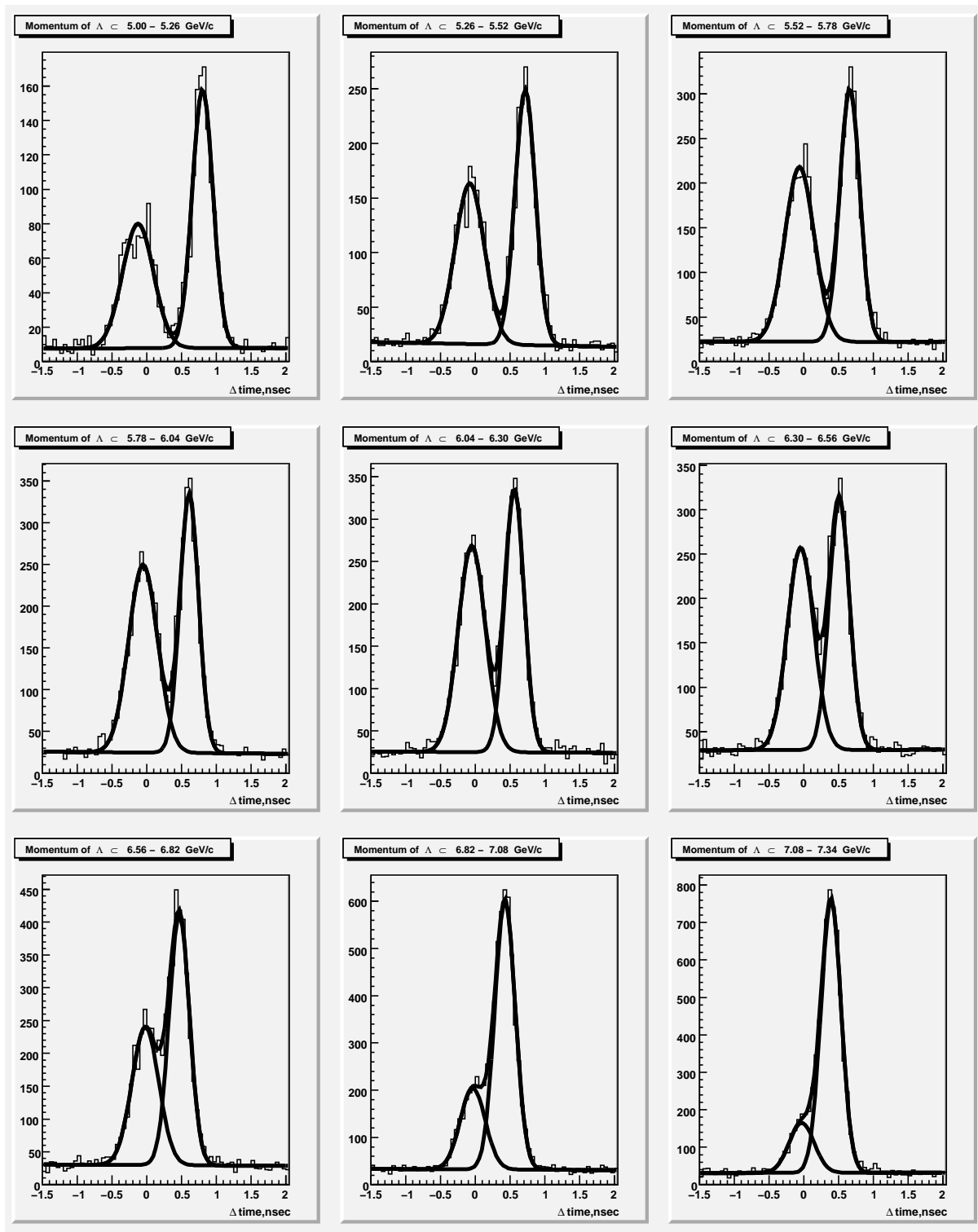
Figure 2: *The Q_L distribution for events after the cuts to select $\pi^+ K^-$ pairs but without the cuts on pair relative momentum(Q_x, Q_y and Q_L). The peak is due to antiproton and pion pairs from antiLambda decay.*

Figure 3: *The events after the cut on Q_L which selects the pairs(p and π^-) from Lambda decay. The Δtime distributions for different values of Lambda momentum are fitted by sum of two gaussians and polynomial of first degree. The right peaks are from protons and the left ones - from kaons.*
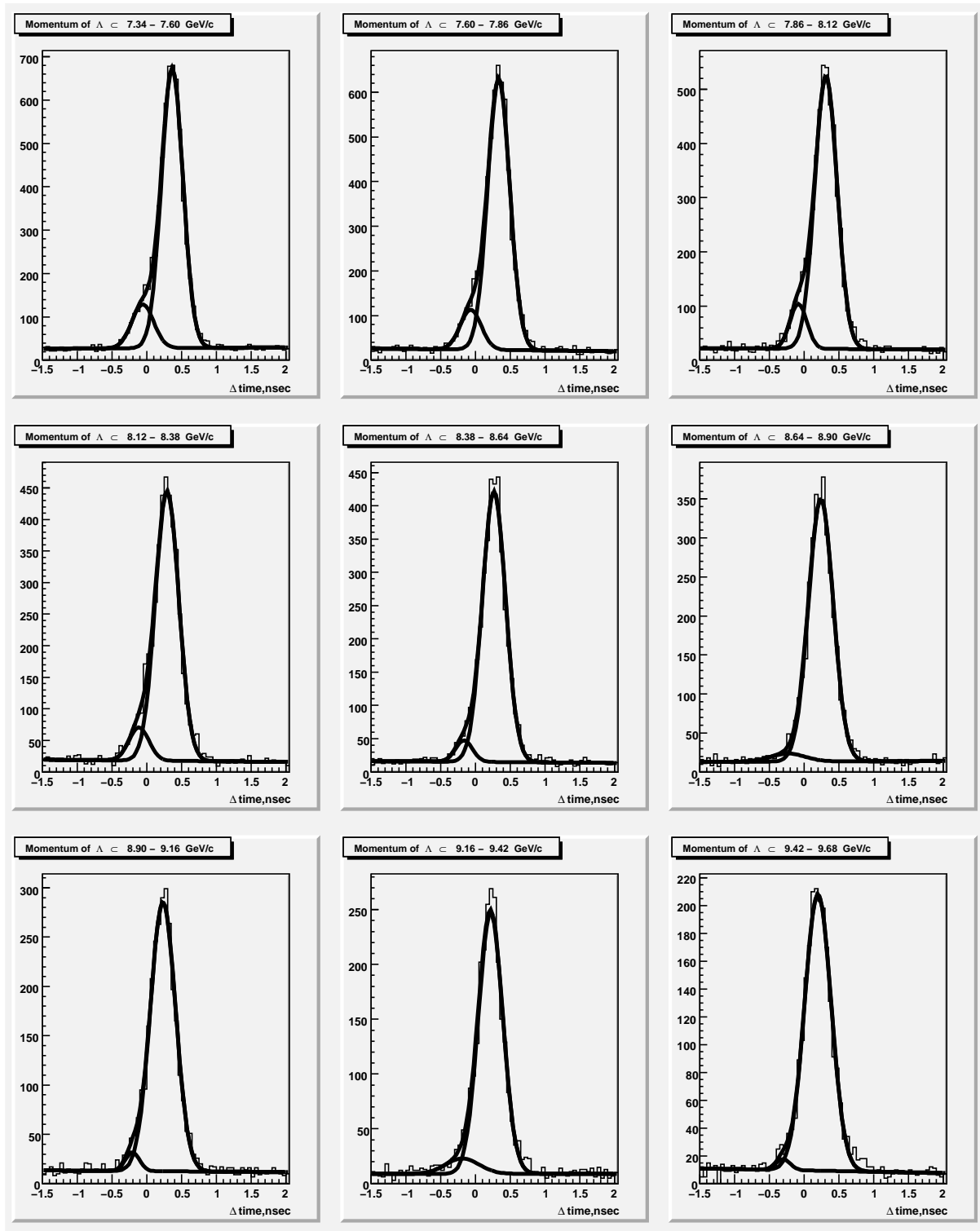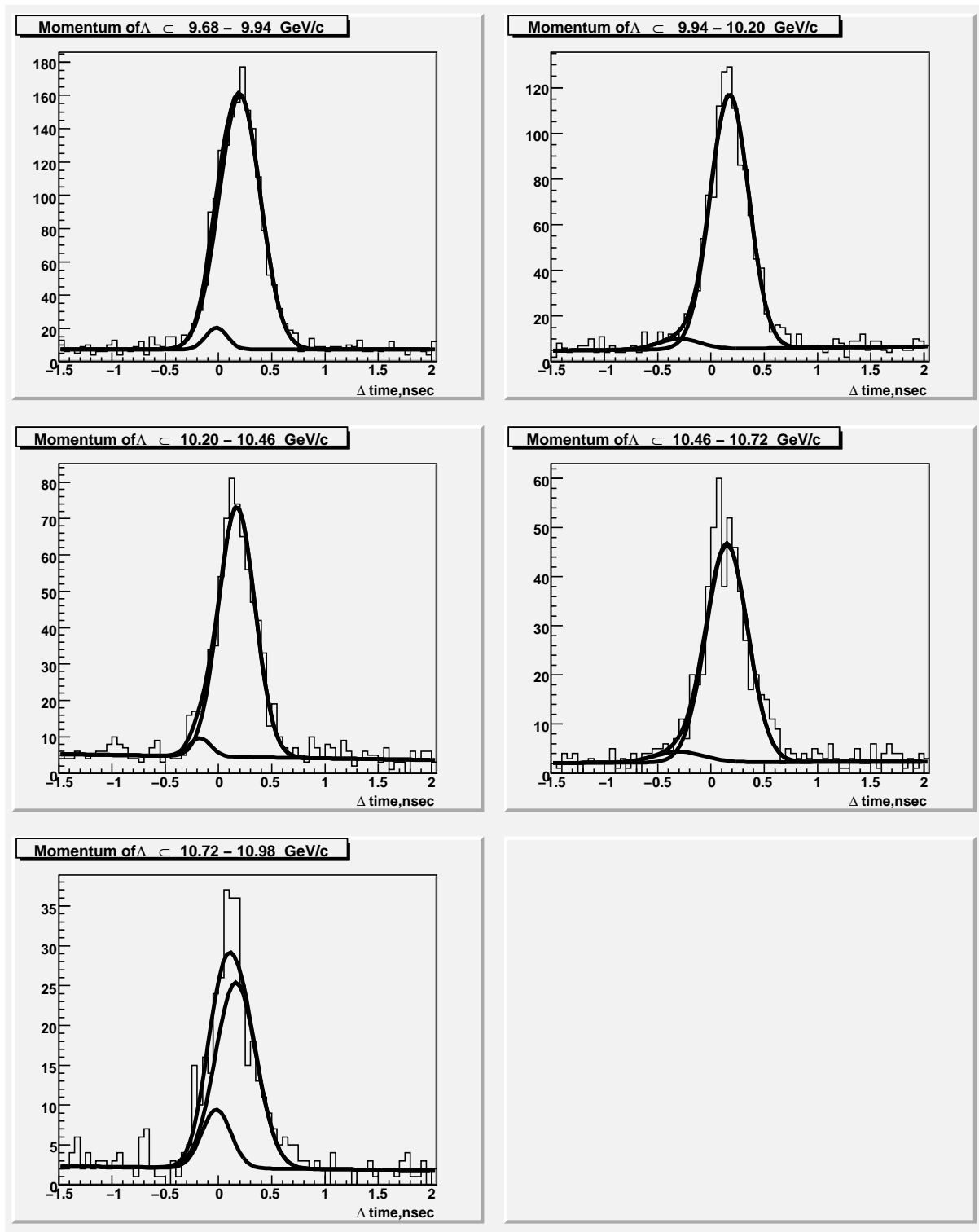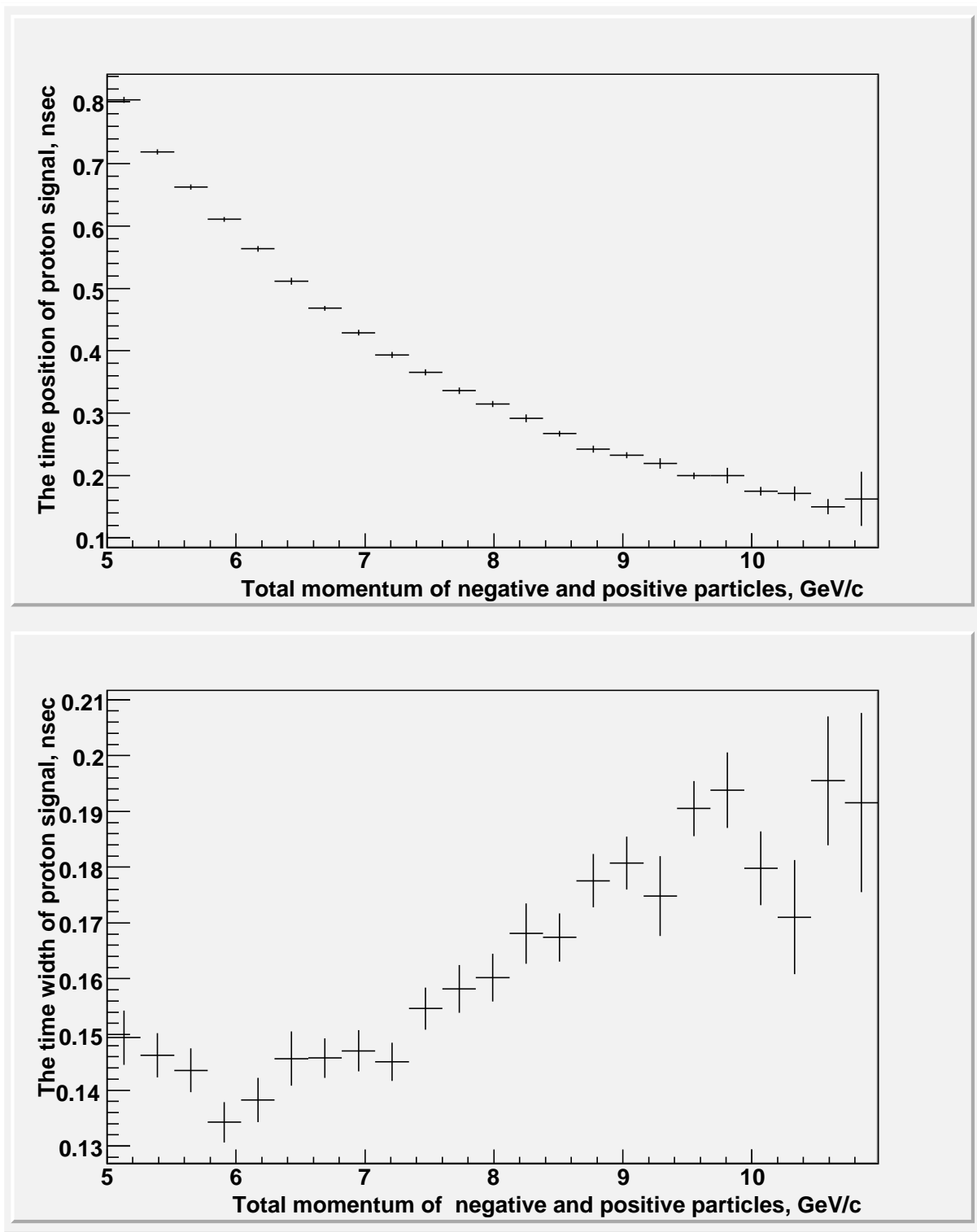
Figure 4: *The events after the cut on Q_L which selects the pairs(p and π^-) from Lambda decay. The Δtime distributions for different values of Lambda momentum are fitted by sum of two gaussians and polynomial of first degree. The right peaks are from protons and the left ones - from kaons.*

Figure 5: *The events after the cut on Q_L which selects the pairs(p and π^-) from Lambda decay. The Δtime distributions for different values of Lambda momentum are fitted by sum of two gaussians and polynomial of first degree. The right peaks are from protons and the left ones - from kaons.*

Figure 6: *The values of position and width of proton relative time peak on dependence of Lambda momentum.*
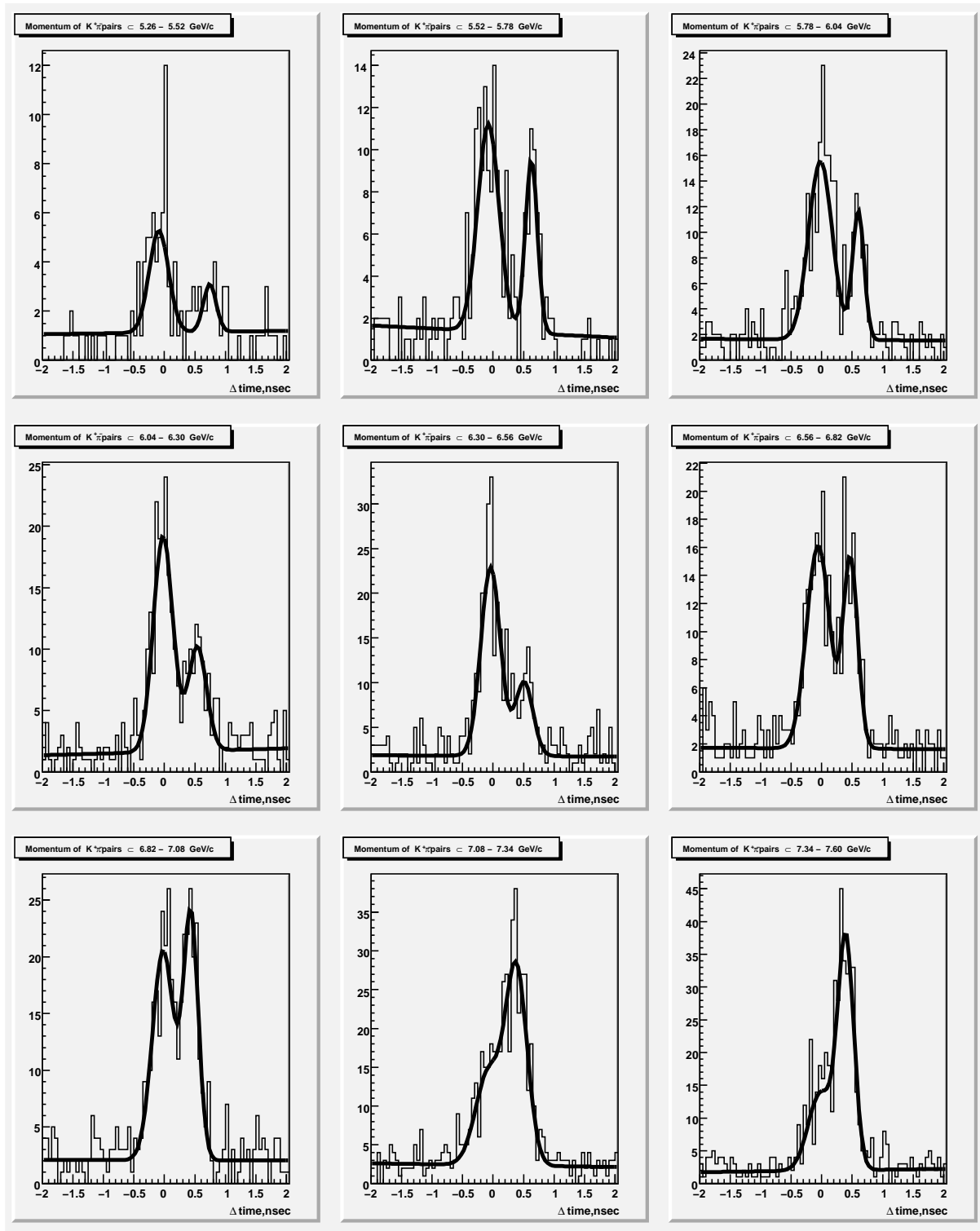
Figure 7: *The events after all the cuts are applied to select the pairs(K and π^-). The Δtime distributions for different values of the pair momentum are fitted by sum of two gaussians and polynomial of first degree. The right peaks are from protons and the left ones - from kaons.*
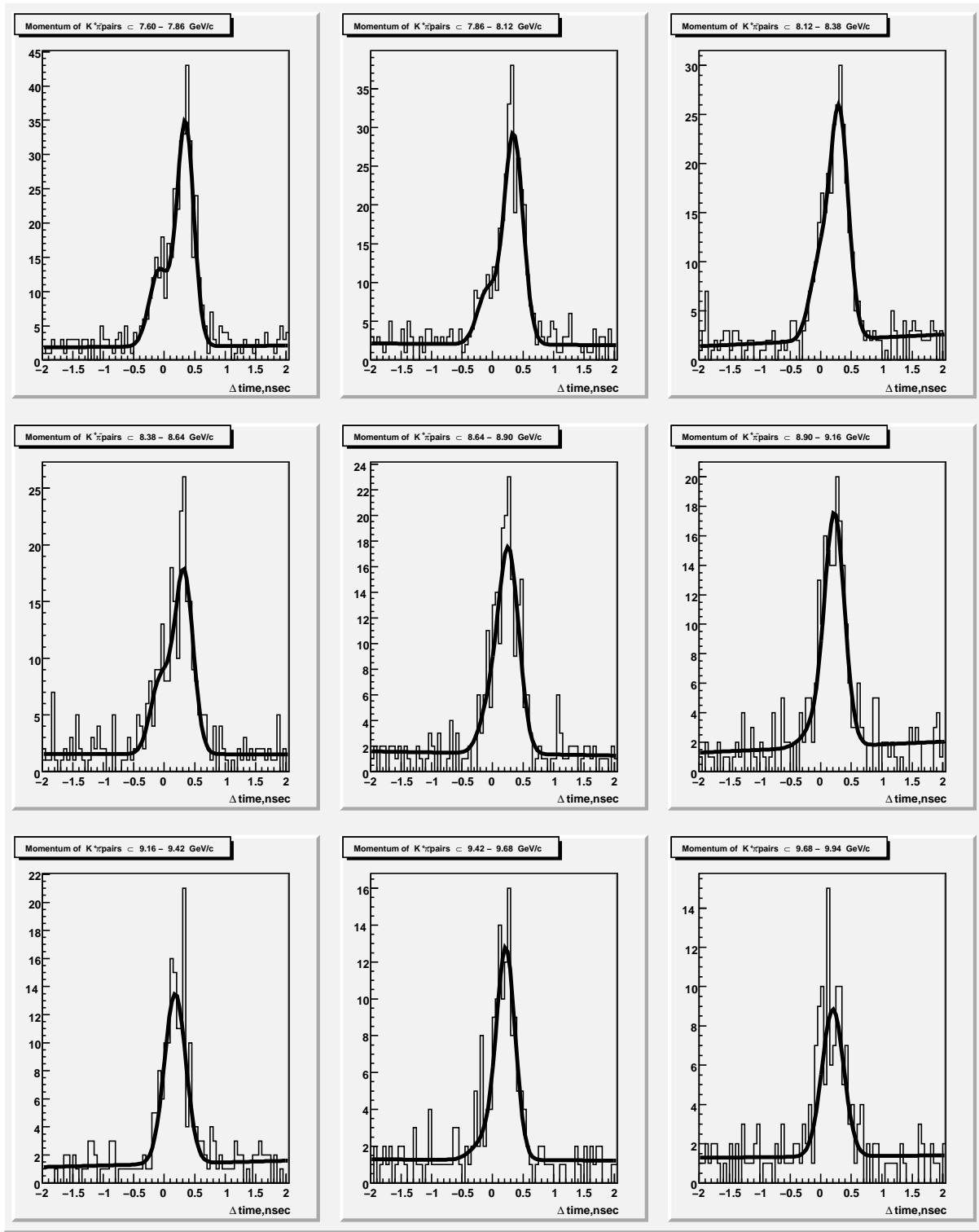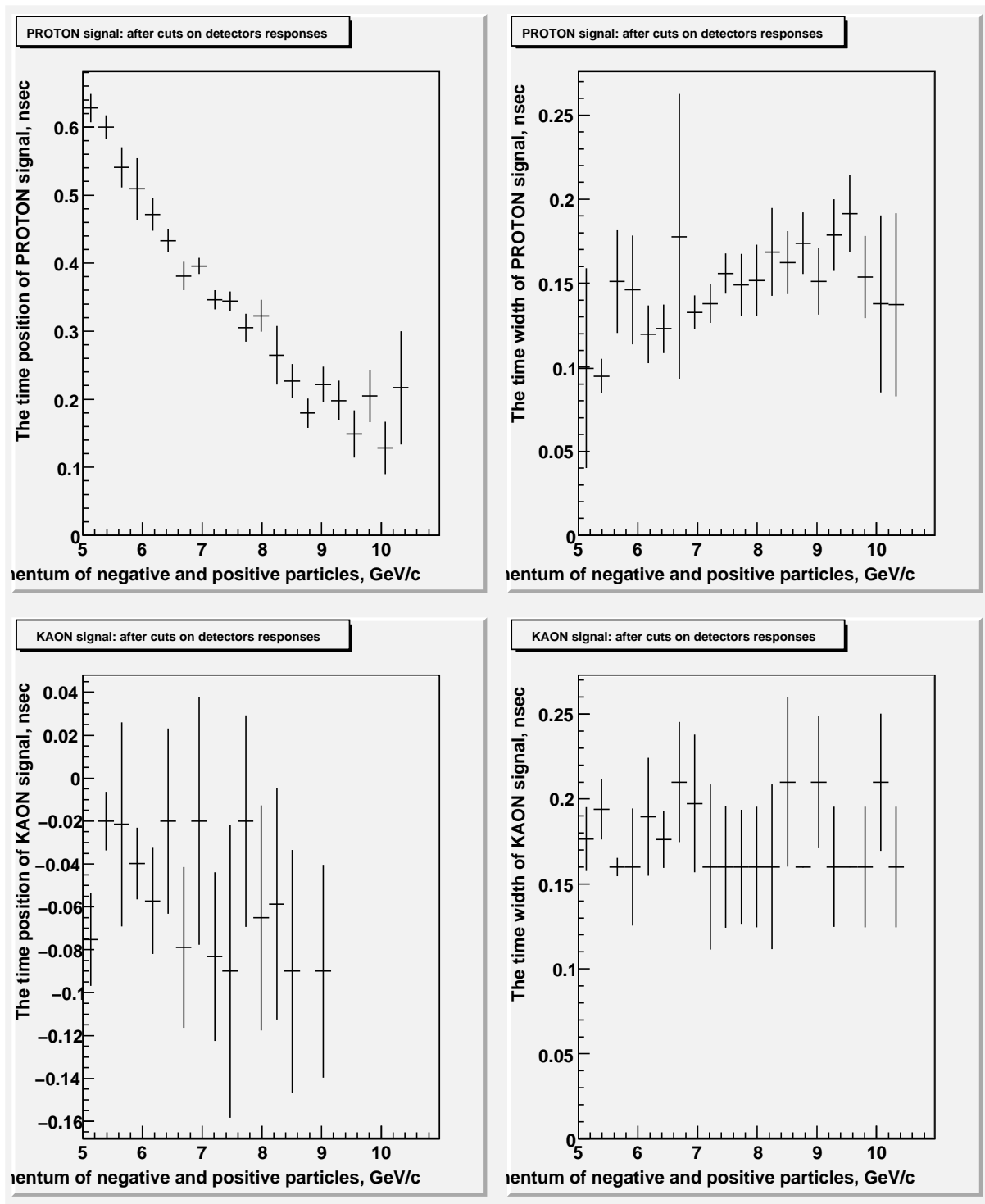
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Figure 8: *The events after all the cuts are applied to select the pairs(K and π^-). The Δtime distributions for different values of the pair momentum are fitted by sum of two gaussians and polynomial of first degree. The right peaks are from protons and the left ones - from kaons.*

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PROTON signal: after cuts on detectors responses

PROTON signal: after cuts on detectors responses

KAON signal: after cuts on detectors responses

KAON signal: after cuts on detectors responses

The time position of PROTON signal, nsec

The time width of PROTON signal, nsec

The time position of KAON signal, nsec

The time width of KAON signal, nsec

Momentum of negative and positive particles, GeV/c

Figure 9: *The values of position and width of proton(top) and K^+(bottom) relative time peaks on dependence of pair total momentum.*
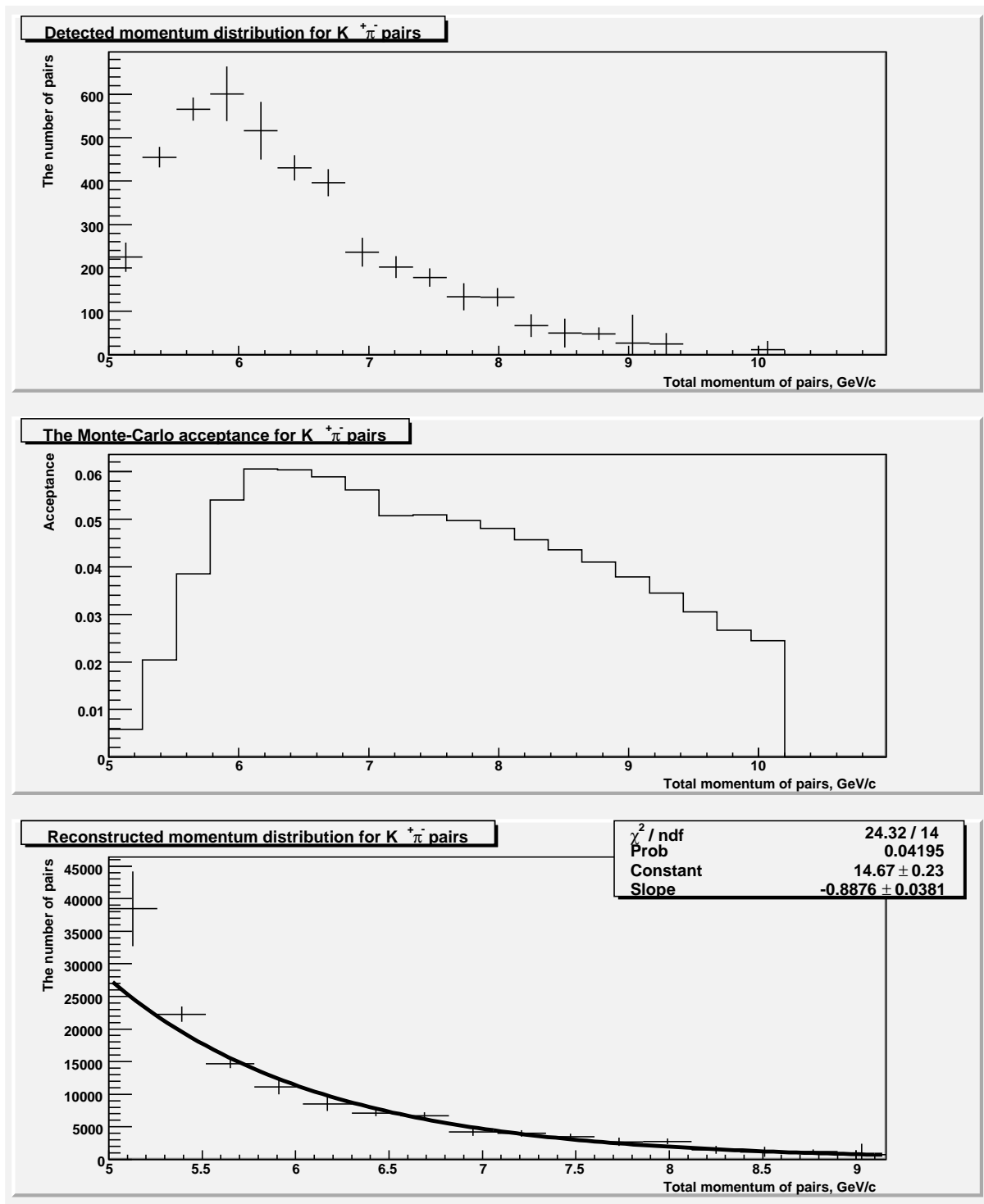
Figure 10: *The detected number of $K^+\pi^-$ pairs as function of their total momentum(top). The corresponding acceptance for these pairs, obtained by Monte-Carlo(middle). The reconstructed $K^+\pi^-$ pair momentum distribution in the target(bottom). The distribution is fitted by $a * exp(b * p)$ function, where p is pair momentum.*
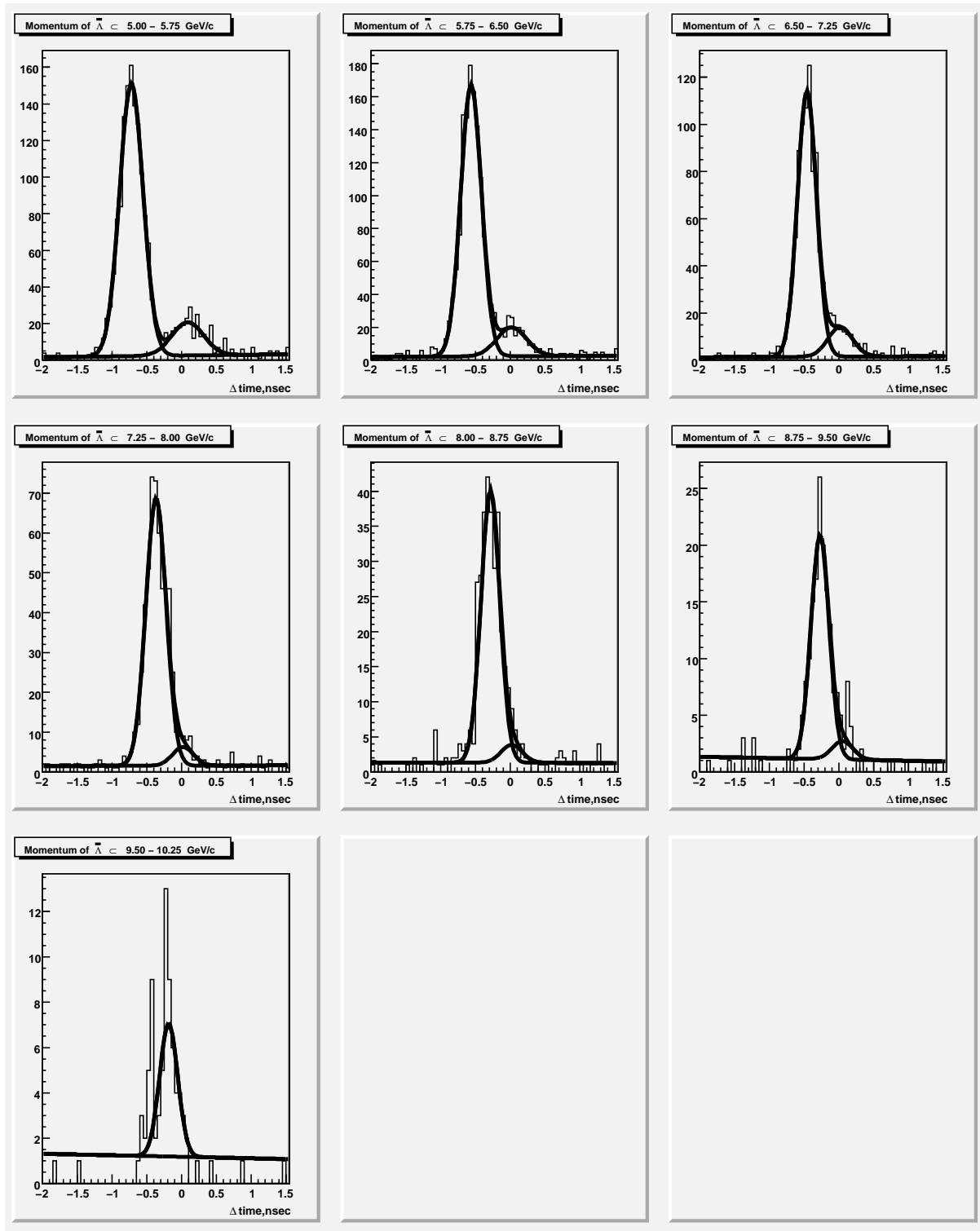
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Figure 11: *The events after the cut on Q_L which selects the pairs($\bar{p}$ and π^+) from antiL-ambda decay. The Δtime distributions for different values of antiLambda momentum are fitted by sum of two gaussians and polynomial of first degree. The right peaks are from K^- and the left ones - from antiprotons.*
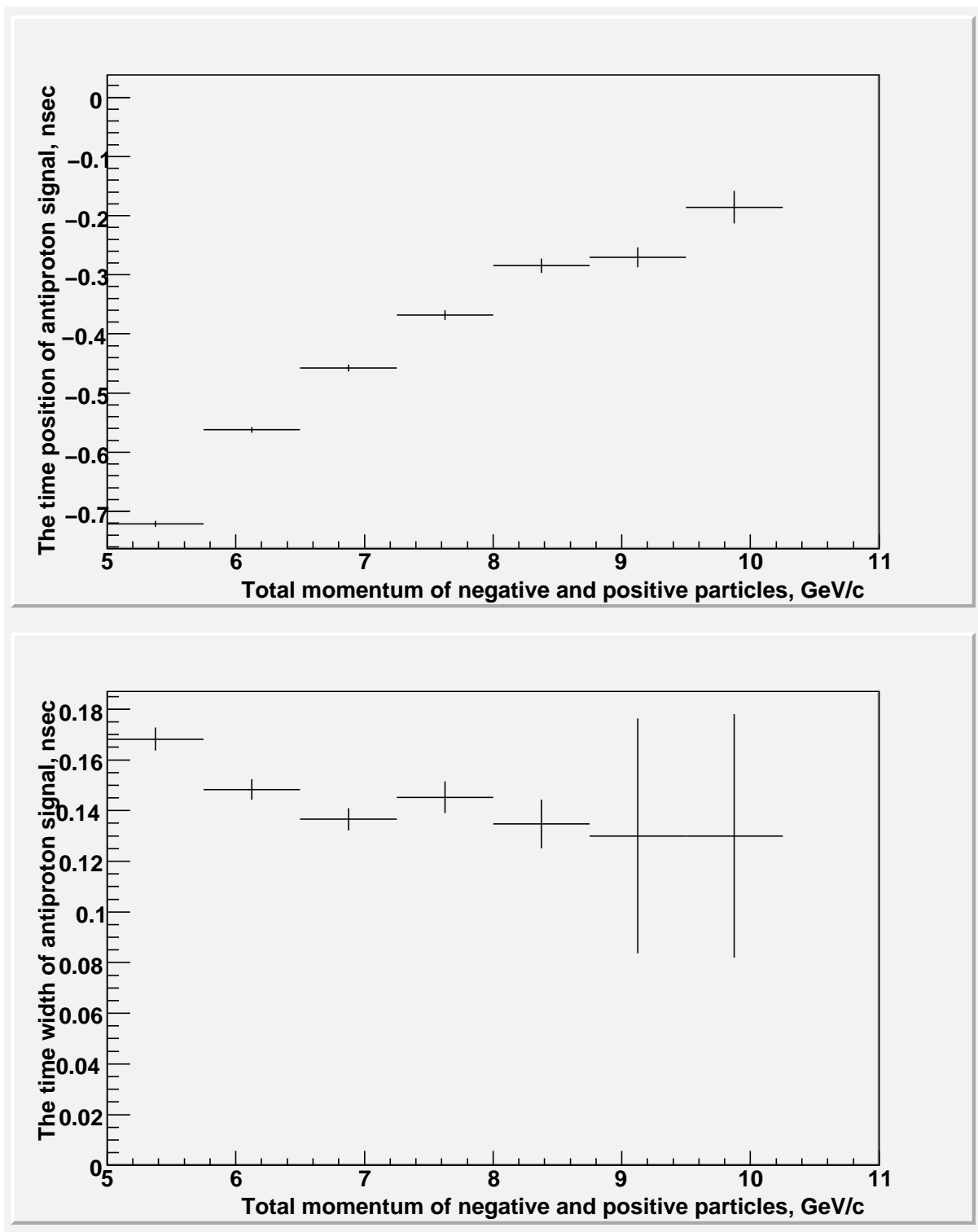
Figure 12: *The values of position and width of antiproton relative time peak on dependence of antiLambda momentum.*
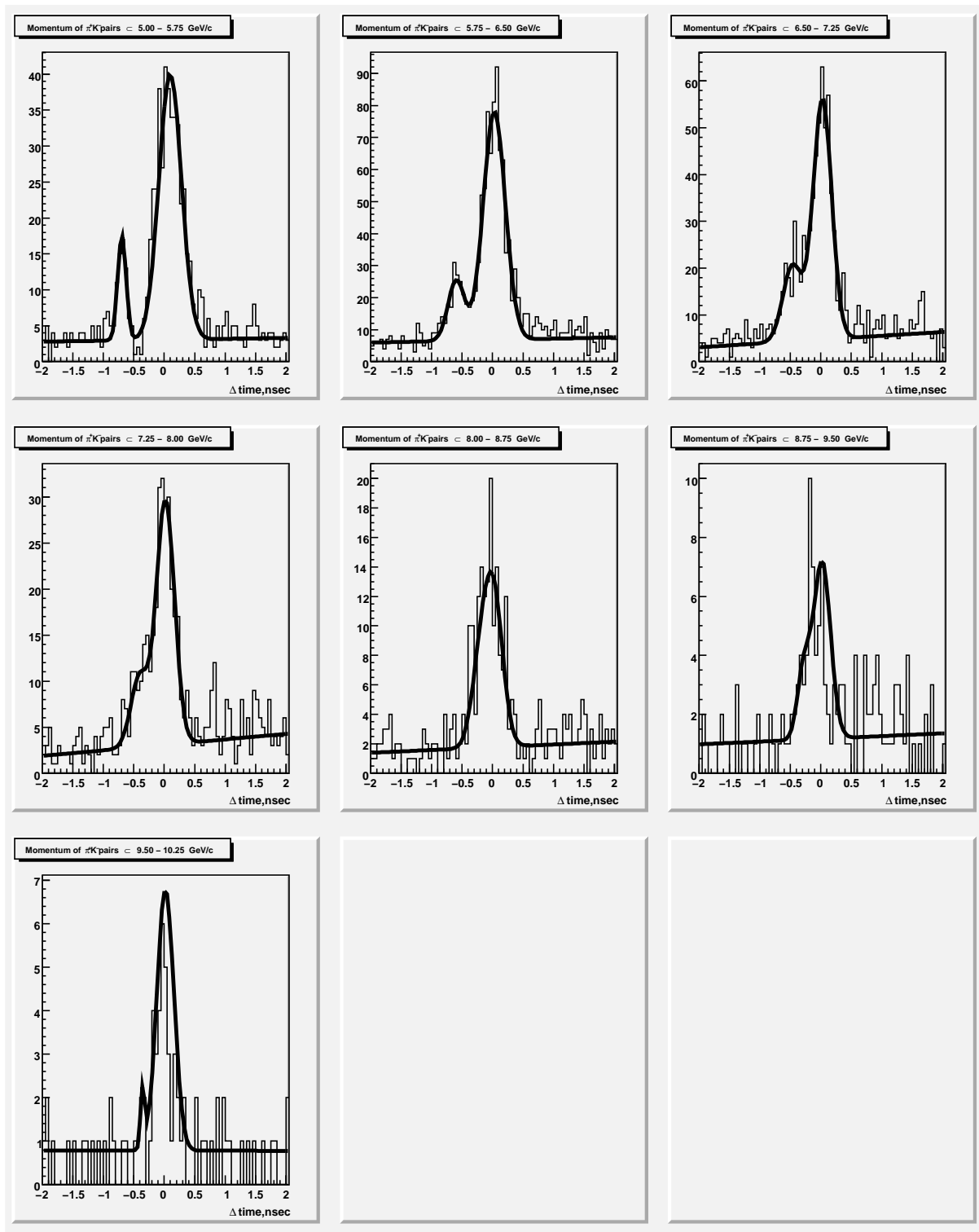
Figure 13: *The events after all the cuts are applied to select the pairs(K^- and π^+). The $\Delta time$ distributions for different values of the pair momentum are fitted by sum of two gaussians and polynomial of first degree. The right peaks are from K^- and the left ones - from antiprotons.*
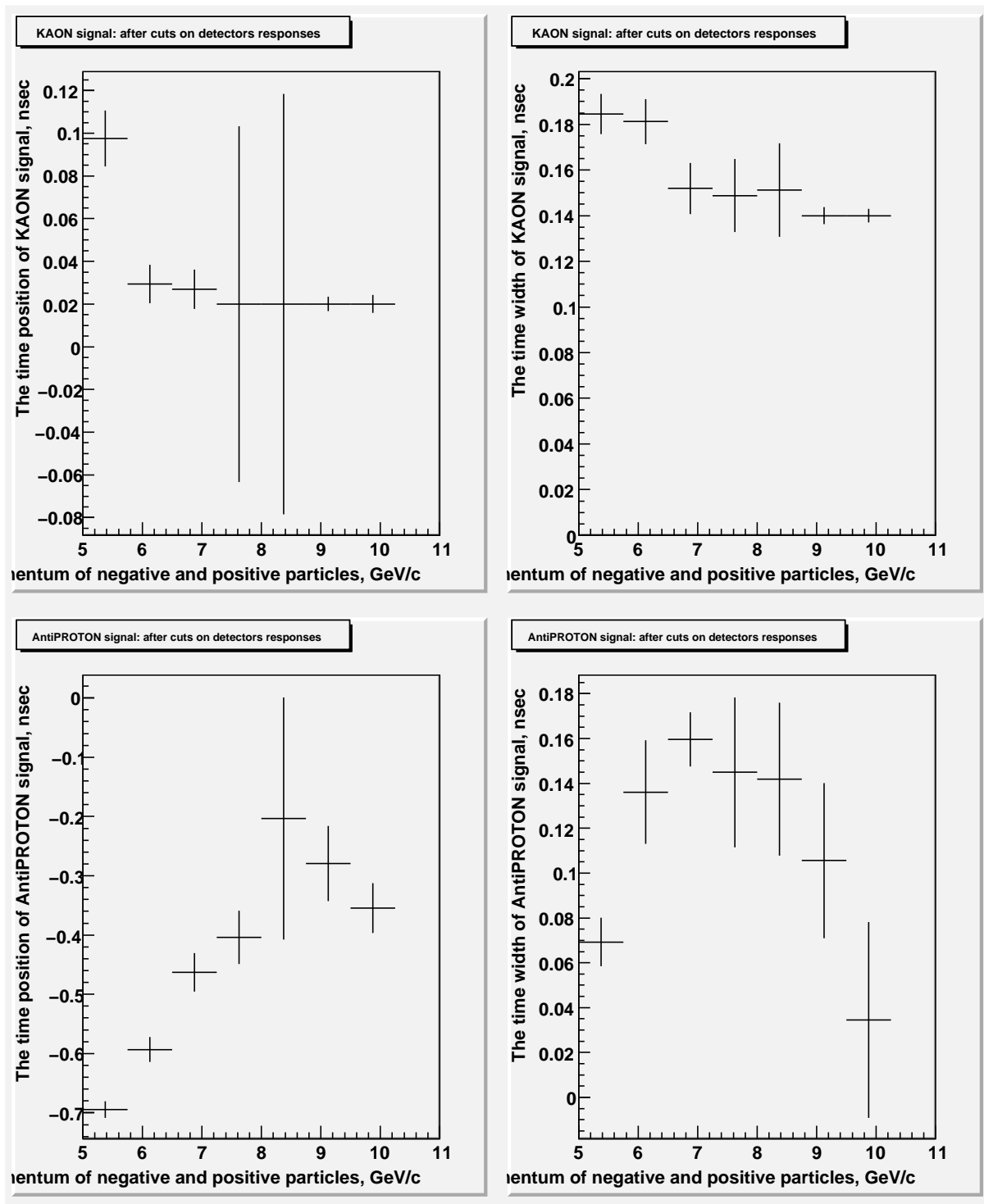
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Figure 14: *The values of position and width of K⁻ (top) and antiproton(bottom) relative time peaks on dependence of pair total momentum.*
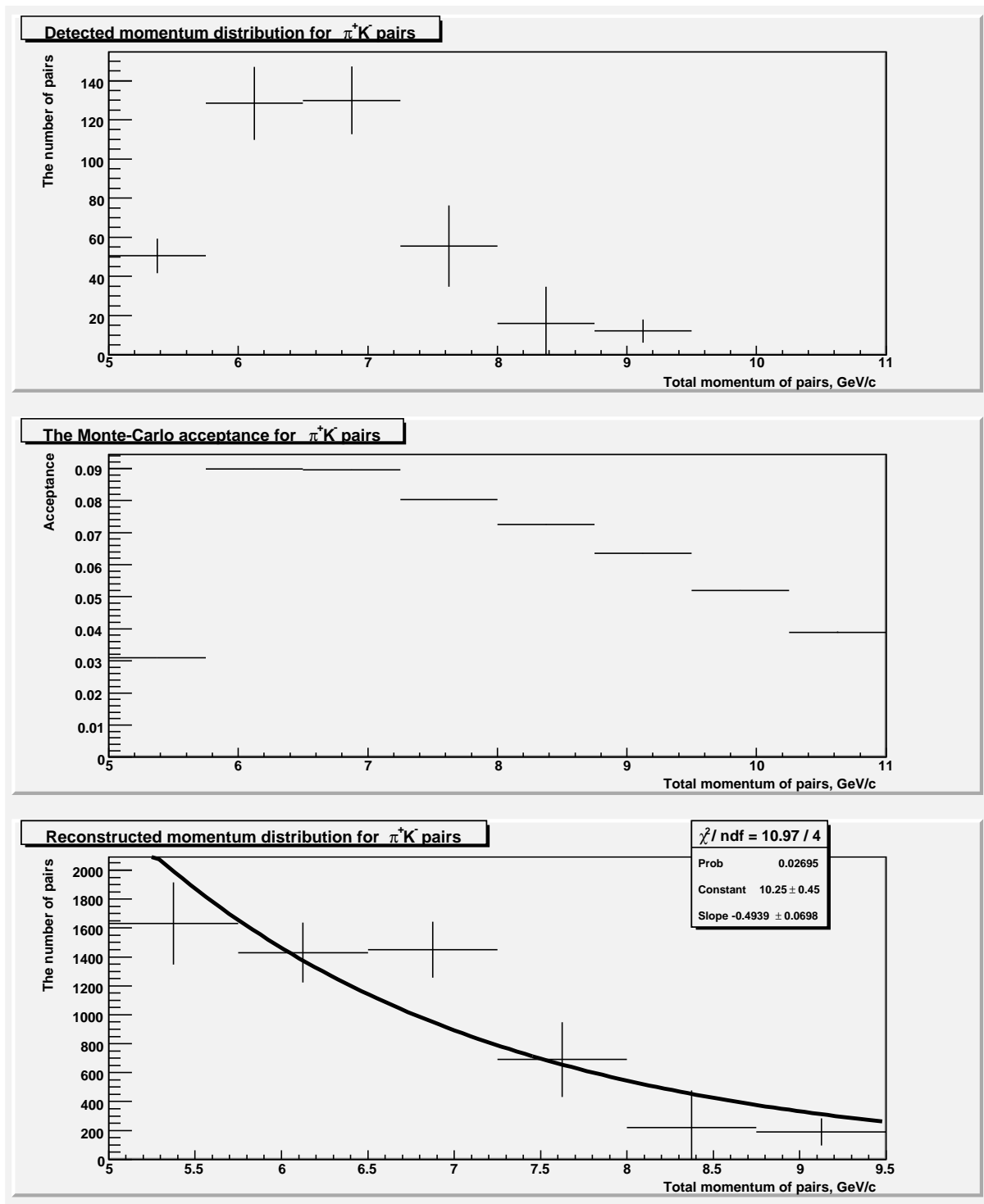
Figure 15: *The detected number of $\pi^+ K^-$ pairs as function of their total momentum(top). The corresponding acceptance for these pairs, obtained by Monte-Carlo(middle). The reconstructed $\pi^+ K^-$ pair momentum distribution in the target(bottom). The distribution is fitted by $a * exp(b * p)$ function, where p is pair momentum.*