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SEARCH FOR $D^{*0} \to D^+\pi^-$

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HRS COLLABORATION

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We report on a search for the decay mode $D^{*0}(2007) \to D^+\pi^-$ using the High Resolution Spectrometer at PEP. Although this decay is kinematically forbidden for the central mass value, it can occur through the natural width of the D^{*0}. The D^+ was reconstructed in the $K^-\pi^+\pi^+$ decay mode. The mass difference distribution $(K^-\pi^+\pi^+\pi^+) - (K^-\pi^+\pi^-)$, which shows no threshold enhancement, leads to a preliminary upper limit on the branching ratio of $B_r(D^{*0} \to D^+\pi^-) < 15\%$ at 90% CL. This, in turn, corresponds to an upper limit on the D^{*0} width of 1.5 MeV/c^2 at 90% CL.

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The $D^+\pi^-$ threshold is only 1.8 MeV above the mass of the $D^{*0}(2007)$. Therefore, if the width of D^{*o} is large enough, the decay mode, $D^{*0} \to D^+\pi^-$, will occur with a significant rate from the higher mass tail of the resonance.[1] Examples of such decays are $f_0(975) \to K\bar{K}$ and $a_0(980) \to K\bar{K}$. However, there are indications that both the D^{*o} and D^{*+} have very narrow widths,[2] so that the branching ratio $D^{*o} \to D^+\pi^-$, through this mechanism, is expected to be small. Despite this, even a moderate upper limit on this decay mode can result in a significant improvement in our knowledge of the width of D^{*o}.

In this paper we report a preliminary measurement of the upper limit on the branching ratio for the decay

$$D^{*0} \to D^+\pi^- \tag{1}$$

with the D^+ subsequently decaying into the $K^-\pi^+\pi^+$ mode. Our analysis also includes the charge conjugate states. The data sample corresponds to an integrated luminosity of 300 pb^{-1} obtained during the five years of operation of the High Resolution Spectrometer (HRS) at the PEP e^+e^- storage ring at a center of mass energy of 29 GeV

The HRS detector is a solenoidal spectrometer that measures charged particles and electromagnetic energy over 90% of the solid angle. The details of the detector are given elsewhere.[3] Substantial emphasis is placed on measurements of the charged particle momenta and all the detector elements operate in a magnetic field of 1.62 T. The tracking system consists of a vertex chamber, a central drift chamber, and an outer drift chamber. The central drift chamber has 15 cylindrical layers of drift cells. Eight of the layers have stereo wires (±60 mrad) in order to measure the z position. The beam pipe and the inner wall of the central drift chamber are made of beryllium so as to minimize the multiple Coulomb scattering; the total material between the interaction point and the central drift chamber is less than 0.02 radiation length. The measured momentum resolution at large angle with respect to the beam is $\sigma_p/p \simeq 2 \times 10^{-3} p$ (p in GeV/c).

The apparatus was triggered when two and more tracks were found by the trigger processor in the central drift chamber or when at least 4.8 GeV of energy was deposited in the barrel and endcap calorimeters. Subsequently, to select one-photon annihilation events and to reduce beam-gas and two-photon backgrounds, the events were required to have a minimum charged multiplicity of 5 and a scalar sum of charged track momenta and neutral particle energy greater than 10 GeV/c. No particle identification or shower counter information was used for this analysis.

In reconstructing the D^+ through the $K^-\pi^+\pi^+$ decay mode, all of the tracks coming from the vertex were tried in turn as both K and π. The cuts of $Z_D > 0.2$ and $|\cos\theta^*| > 0.3$ were applied, where $Z_D \equiv 2E_D/\sqrt{s}$ and θ^* is the angle perpendicular to the decay plane in the helicity frame. (D^+ rest frame with the z axis along the D^+ direction of flight.) This $\cos\theta^*$ selection eliminates an angular region observed to be dominated by background. The invariant mass spectrum, with a more stringent cut of $Z_D > 0.6$, is shown in Fig. 1. A clear signal is observed at the D^+ mass.

The D^+ signal was fitted with a polynomial form for the background and a Gaussian form for the signal. The fitted mass (1863 ± 4) MeV/c^2 is lower than, but consistent with, the currently accepted value of 1869.3 ± 0.6 MeV. The width (σ_m) of (17 ± 4) MeV/c^2 is consistent with the apparatus resolution as determined by a Monte Carlo simulation.

The D^{*0} signal was searched for in the mass difference distribution $(\Delta \equiv M_{K^-\pi^+\pi^+\pi^-} - M_{K^-\pi^+\pi^+})$ for $Z_{D^*} \geq 0.2$ with the D^+ selection 1820 MeV/c^2 $< M_{K^-\pi^+\pi^+} <$ 1900 MeV/c^2, which is the mass region for the D^+ determined above. This mass difference method gives a better signal resolution and lower background than the direct reconstruction of the $K^-\pi^+\pi^+\pi^-$ invariant mass. This is demonstrated in Fig. 2 which shows the case of the $D^{*+} \to D^0\pi^+ \to K^-\pi^+\pi^+$ decay. The mass difference $M_{K^-\pi^+\pi^-} - M_{K^-\pi^+}$ is plotted. Figure 3 shows the equivalent mass difference distribution for the D^{*0}.

The shape of background in Fig. 3 was estimated by two methods. Firstly, the D^+ candidates from the side bands of the peak in Fig. 1 (1.6 GeV/c^2 $< M_{K^-\pi^+\pi^+} <$ 1.8 GeV/c^2 and 1.92 GeV/c^2 $< M_{K^-\pi^+\pi^+} <$ 2.12 GeV/c^2) were combined

with the other π^-. Secondly, wrong sign combinations of $K^-\pi^+\pi^+\pi^+$ and $K^-\pi^+\pi^-\pi^+$ were studied. Both of these techniques gave a consistent shape within the statistical errors. The background data, fitted to a polynomial and normalized to the data in the region of 143 MeV/c^2 < Δ < 146 MeV/c^2 in the mass difference distribution, is shown as the solid curve in Fig. 3.

After subtracting this background, the resulting signal is 3 ± 15 events in the region of 137 MeV/c^2 < Δ < 143 MeV/c^2, which is consistent with no signal. The error comes mainly from the uncertainty in determining the background. The corresponding upper limit of the branching ratio is $B_r(D^{*0} \to D^+\pi^-)$ < 15% at 90% CL, assuming that the D^{*0} and D^{*+} production cross sections are equal. The detector acceptance is calculated from a Monte Carlo simulation.

This upper limit on the branching ratio gives an upper limit on the width of $\Gamma_{D^{*0}}$ < 1.5 MeV/c^2 at 90% CL, assuming a p-wave Breit-Wigner form, a D^{*0} mass of 2007.2 MeV/c^2, and a D^+ mass of 1869.3 MeV/c^2.[1] This is a substantial improvement of the existing upper limit which is 5 MeV/c^2.[4] The limit can be further improved by a more accurate measurement of the D^{*0} mass.

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Figure Captions

1. The invariant $K\pi\pi$ mass distribution with $Z_D > 0.6$ and $|\cos\theta^*| > 0.3$.

2. The mass difference distribution for $D^{*+} \to D^0\pi^+ \to K^-\pi^+\pi^+$ with $Z_{D^*} > 0.4$. The D^{*+} peak has a width of 1.0 MeV/c^2 which is consistent with the detector resolution.

3. The mass difference $\Delta = (K^-\pi^+\pi^+\pi^-) - M(K^-\pi^+\pi^+)$ for D^{*0} with $Z_{D^*} > 0.2$ and 1820 MeV/c^2 < $M_{K\pi\pi}$ < 1900 MeV/c^2. The solid curve shows the background estimated by the methods described in the text.

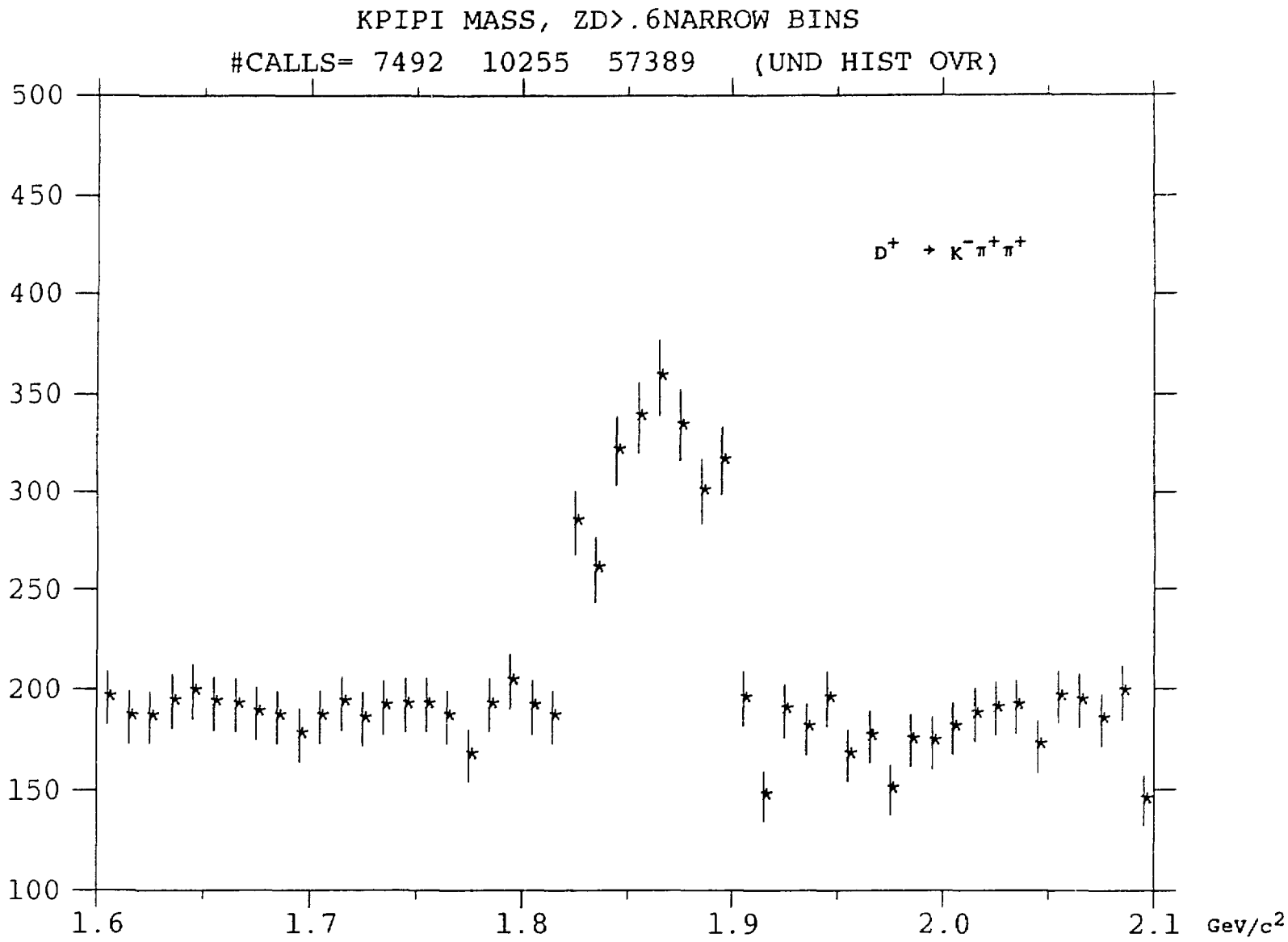
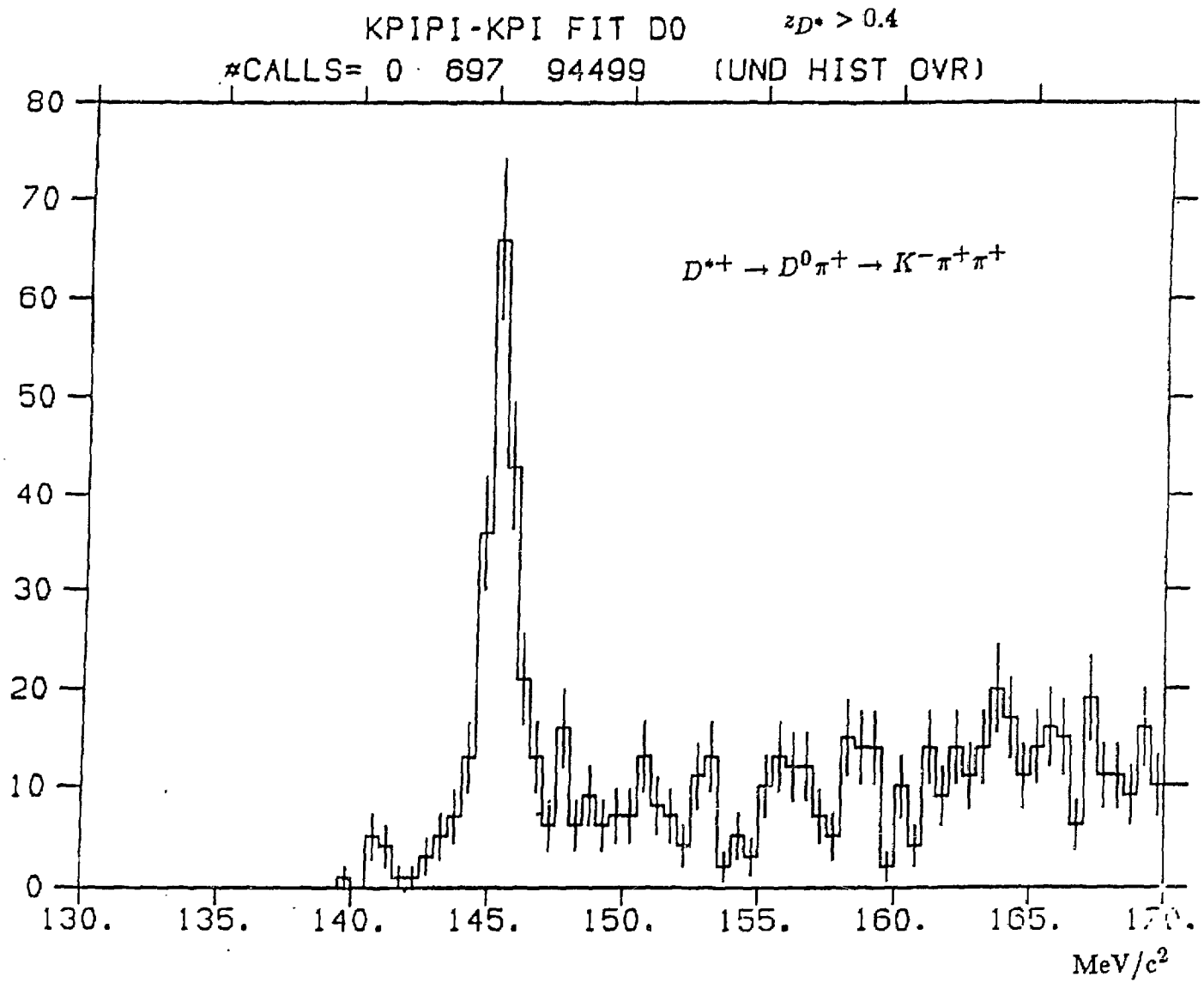

KPIPI MASS, ZD>.6NARROW BINS
#CALLS= 7492 10255 57389 (UND HIST OVR)
500
450
400
350
300
250
200
150
100
1.6
1.7
1.8
1.9
2.0
2.1
GeV/c²
D⁺ → K⁻π⁺π⁺
invariant mass $M_{K^-\pi^+\pi^+}$

Fig. 1



Mass difference $\Delta \equiv M(K^-\pi^+\pi^+) - M(K^-\pi^+)$

Fig. 2

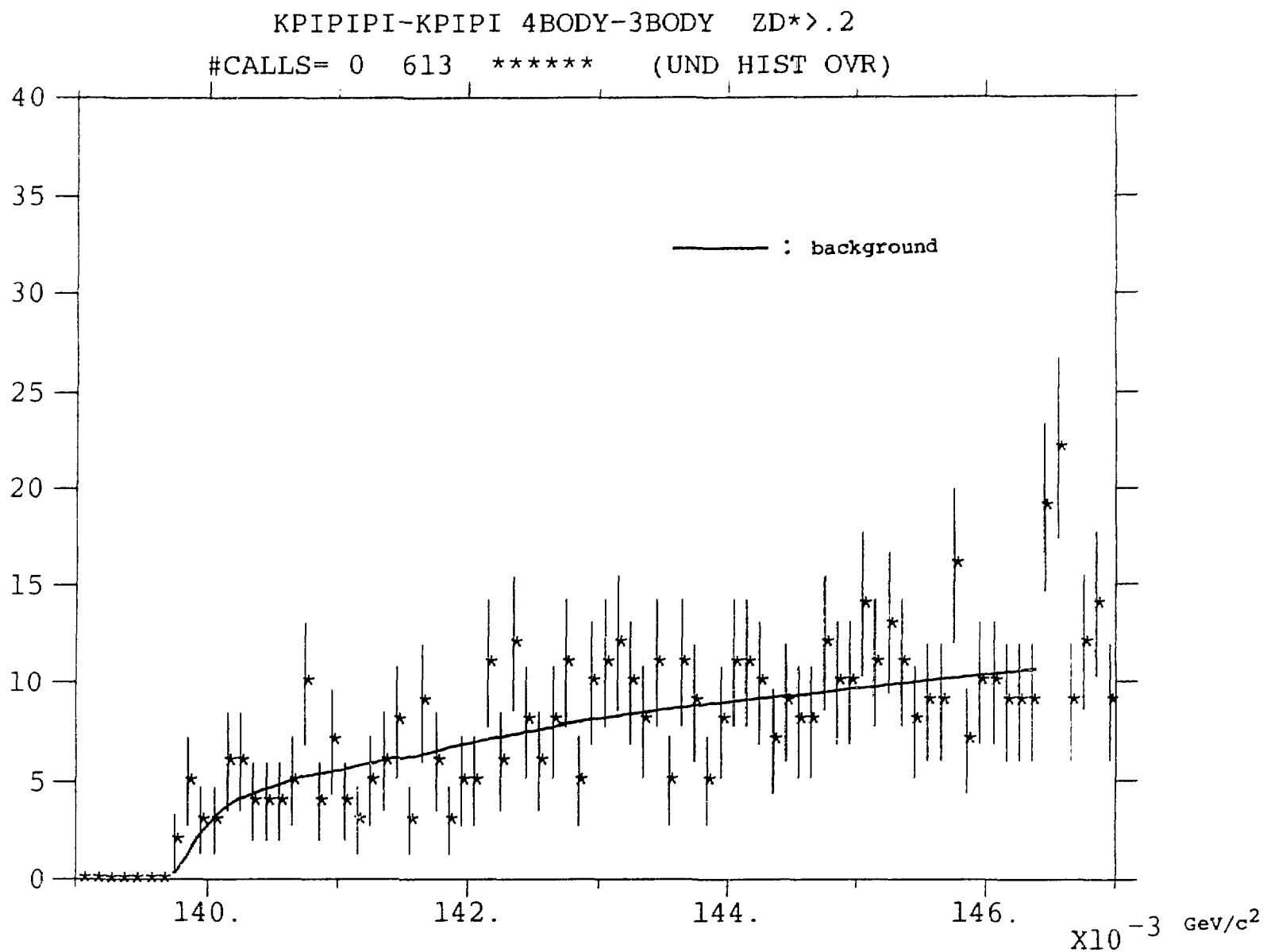


Fig. 3 The mass difference $\Delta = (K^-\pi^+\pi^+\pi^-) - M(K^-\pi^+\pi^+)$