CONF-860701--51

ANL-HEP-CP--86-50

DE87 001502

ANL-HEP-CP-86-50
IUHEE-386
UM HE-86-13
PU-86-571
(June 1986)

Upper Limit on the D*(2010) Decay Width

S.ABACHI, C.AKERLOF, P.BARINGER, D.BLOCKUS,
B.BRABSON, J-M.BROM, B.G.BYLSMA, J.CHAPMAN, B.CORK,
R.DEBONTE, M.DERRICK, D.ERREDE, K.K.GAN, C.JUNG,
P.KESTEN, D.KOLTICK, P.KOOIJMAN, F.J.LOEFFLER, J.S.LOOS,
E.H.LOW, R.L.MCILWAIN, D.I.MEYER, D.H.MILLER, B.MUSGRAVE,
C.R.NG, D.NITZ, H.OGREN, L.E.PRICE, L.K.RANGAN,
J.REPOND, D.R.RUST, A.SEIDL, E.I.SHIBATA, K.SUGANO,
R.THUN, J.M.WEISS, M.WILLUTZKY, AND D.E.WOOD

Argonne National Laboratory, Argonne, Illinois 60439,

Indiana University, Bloomington, Indiana 47405,

Lawrence Berkeley Laboratory, Berkeley, California 94720

University of Michigan, Ann Arbor, Michigan 48109,

Purdue University, West Lafayette, Indiana 47907,

HRS COLLABORATION

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Abstract

We report a measurement of the upper limit of the decay width for the $D^{*+}(2010)$ meson using the High Resolution Spectrometer at PEP. We observed the charged D^* production in the decay mode of $D^{*+} \rightarrow D^0\pi^+$ with the D^0 decaying into the $K^-\pi^+$ mode. The peak in the mass difference distribution $M(K^-\pi^+\pi^+) - M(K^-\pi^+)$ was used to directly measure the decay width. The width is dominated by the detector resolution and the preliminary result is an upper limit on the full width of $\Gamma_{D^*} < 1.15\ \mathrm{MeV}/c^2$ at 90% C.L..

Submitted to XXIII International Conference on High Energy Physics

16-23 July, 1986, Berkeley, California

by K.Sugano, Argonne National Laboratory

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The decay width is a fundamental property of all particles and contains important information on the underlying physics of the decay mechanism. The widths of most of the particles have been measured extensively over the years. There are, however, several particles whose widths have not been measured well yet. Such examples are $D^{*+}(2010)$ and $D^{*0}(2007)$. The present upper limits of their widths[1] are $\Gamma_{D^{*+}} < 2.0\ \mathrm{MeV/c^2}$ and $\Gamma_{D^{*0}} < 5\ \mathrm{MeV/c^2}$. These widths are very narrow compared to the other light mesons despite the fact that the D^*'s decay strongly. There are indications that the real widths may be about 100 $\mathrm{keV/c^2}$ or less[2,3]. Therefore the D^* is one of the narrowest particles among the strongly decaying particles, and it is worthwhile to improve the present upper limit of the decay width in order to study the decay mechanism.

In this paper we report a preliminary measurement of the upper limit of the $D^{*+}(2010)$ meson decay width, using the charged D^* production in the decay mode

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

with the D^0 decaying into the $K^-\pi^+$ mode. Our analysis also includes the charge conjugate states. The measurement of $D^{*0}(2007)$ decay width based on the kinematically forbidden mode ($D^{*0} \rightarrow D^+\pi^-$)[4] will be presented elsewhere. The data sample corresponds to an integrated luminosity of $(185 \pm 5)\mathrm{pb}^{-1}$ obtained during the first three years of the 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[5] . 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 or 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 anuihilation 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 greater than 7.8 GeV/c. No particle identification or shower counter information was used for this analysis.

In reconstructing the D^0 through the $K^-\pi^+$ decay mode, all the tracks coming from the vertex were tried in turn as both K and π. The cuts of $z_D \geq 0.5$ and $|\cos\theta^*| < 0.7$ were applied, where $z_D \equiv 2E_D/\sqrt{s}$ and θ^* is the D^0 decay angle in the helicity frame.(D^0 rest frame with the z axis along the D^0 directon of flight.) The $\cos\theta^*$ selection eliminates an angular region observed to be dominated by the background[6] . The resulting invariant mass spectrum is shown in Fig. 1. A clear signal is observed at the D^0 mass.

The D^0 signal was fitted with a polynomial form for the background and a Gaussian form for the signal. The fitted mass of (1861 ± 4)MeV/c^2 is consistent with the currently accepted value. The standard deviation (σ_m) of (13 ± 2)MeV/c^2 is consistent with the apparatus resolution as determined by a Monte Carlo simulation.

The D^* signal was reconstructed utilizing the fact that the Q value of the reaction (1) is only 5.8 MeV and the D^{*+}-D^0 mass difference can therefore be determined extremely well. Fig. 2 shows the distribution in the mass difference ($\Delta \equiv M_{K^-\pi^+\pi^+} - M_{K^-\pi^+}$) for $z_{D^*} \geq 0.4$ with the D^0 selection $1810 < M_{K^-\pi^+} < 1920$ MeV/c^2 which is the mass region for the D^0 determined above. The peak in the distribution shows a clear signal for the D^{*+} production with small background. The distribution was fitted by polynomial background plus Gaussian signal with

finer binning. The resulting values are $\Delta = (145.37 \pm 0.07)\mathrm{MeV/c^2}$ for the peak value and $\sigma_\Delta = (0.43 \pm 0.06)\mathrm{MeV/c^2}$ for the standard deviation, where the errors are statistical only. The value of σ_Δ corresponds to the width $\Gamma_\Delta = (0.98 \pm 0.14)\mathrm{MeV/c^2}$ as FWHM assuming a Gaussian form. The width remains the same within the statistical errors when the z_{D^*} cut is changed from 0.4 up to 0.7. The background becomes less as the cut gets higher.

According to the the Monte Carlo simulation of our detector, the apparatus resolution (standard deviation) of Δ is ${\sigma_\Delta}^{MC} = (0.33 \pm 0.07 \pm 0.07)\mathrm{MeV/c^2}$, where the first error is statistical and the second systematic. This corresponds to the width of ${\Gamma_\Delta}^{MC} = (0.78 \pm 0.16 \pm 0.16)\mathrm{MeV}/c^2$. The observed width is consistent with the apparatus resolution within the errors, although the Monte Carlo value is 0.2 $\mathrm{MeV/c^2}$ smaller than the oberved one. The observed width of the mass difference is dominated by the detector resolution. Therefore, we put an upper limit of the directly measured D^{*+} decay width as $\Gamma_{D^{*+}} < 1.15\ \mathrm{MeV/c^2}$ at 90% C.L..

This direct measurement can be compared to a calculation based on the measured branching ratio of the D^{*+} radiative decay. Since the radiative decay $D^{*+} \rightarrow D^+\gamma$ is an M1 transition, the electromagnetic width is given by the following formula;

$$\Gamma_{M1} = \frac{4}{3}\alpha\left(\frac{e_c}{2m_c} + \frac{e_d}{2m_d}\right)^2 k^3 \tag{2}$$

where $e_q/2m_q$ is the magnetic moment of the quark q (charm quark and down quark) and k is a momentum of photon. Therefore the total decay width is given by $\Gamma_{D^{*+}} = \Gamma_{M1}/Br(D^{*+} \rightarrow D^+\gamma)$. The estimated value of Γ_{M1} for $D^{*+} \rightarrow D^+\gamma$ is about 1.1 $\mathrm{keV/c^2}$, using the constituent quark masses ($m_c = 1.84\ \mathrm{GeV/c^2}$ and $m_d = 0.34\ \mathrm{GeV/c^2}$). The most recent measurement of the radiative decay mode is $Br(D^{*+} \rightarrow D^+\gamma) = (17 \pm 11)\%$.[7] This corresponds to the total width $\Gamma = 7^{+12}_{-3}\ \mathrm{keV/c^2}$, or $\Gamma < 22\ \mathrm{keV/c^2}$ at 90% C.L., consistent with our result. Since there is some ambiguity in calculationg the value of (2), our direct measurement is orthogonal to this approach.

There are also calculations of the hadronic decay widths of $D^{*+} \to D^{+}\pi^{0}$ and $D^{*+} \to D^{0}\pi^{+}$, based on the SU(4)-invariant interaction[3]. Using these calculations and the measured branching ratios of these processes[7], the total width of D^{*+} is $(27 \pm 5)\mathrm{keV}/c^2$. This value is higher than that calculated from the radiative decay mode.

In the near future, we are planning to improve our upper limit by installing the precise vertex point information run by run, and by increasing the statistics of the data sample up to about 300 pb^{-1}. The upper limit of the width of D^{*0} will also be placed.

This work was supported in part by the US Department of Energy, under Contracts W-31-109-Eng-38, DE-AC02-76ER01112, DE-AC03-76SF00098, DE-AC02-76ER01428, and DE-AC02-84ER40125. We thank the PEP operations group for providing the luminosity on which these results are based.

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6. The jet structure of the evenets tends to produce asymmetric "decays" ($|\cos\theta^*| \rightarrow 1$) for random combinations of tracks because the limited p_t of the average back ground track is smaller relative to the thrust axis than is the average p_t of the products of an actual D^0 decay.
7. See the revised data listing (S1) of the Review of Particle Properties.

FIGURE CAPTIONS

1. Invariant Kπ mass distribution of $z_D \geq 0.5$ and $|\cos\theta^*| < 0.7$
2. The mass difference $\Delta = M(K^-\pi^+\pi^+) - M(K^-\pi^+)$ with $z_{D^*} > 0.4$ and $1810 < M_{K\pi} < 1920\ \mathrm{MeV/c^2}$

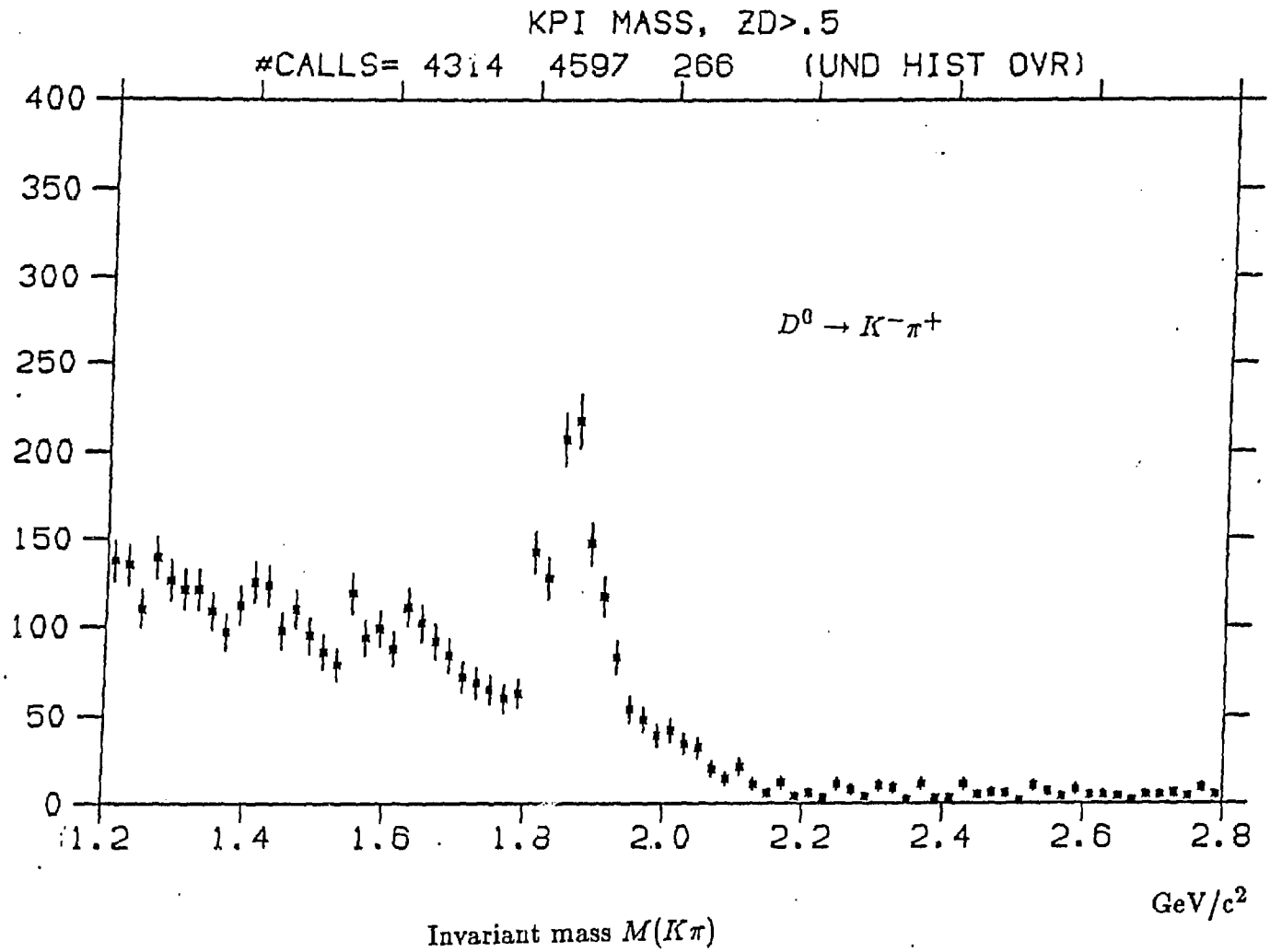
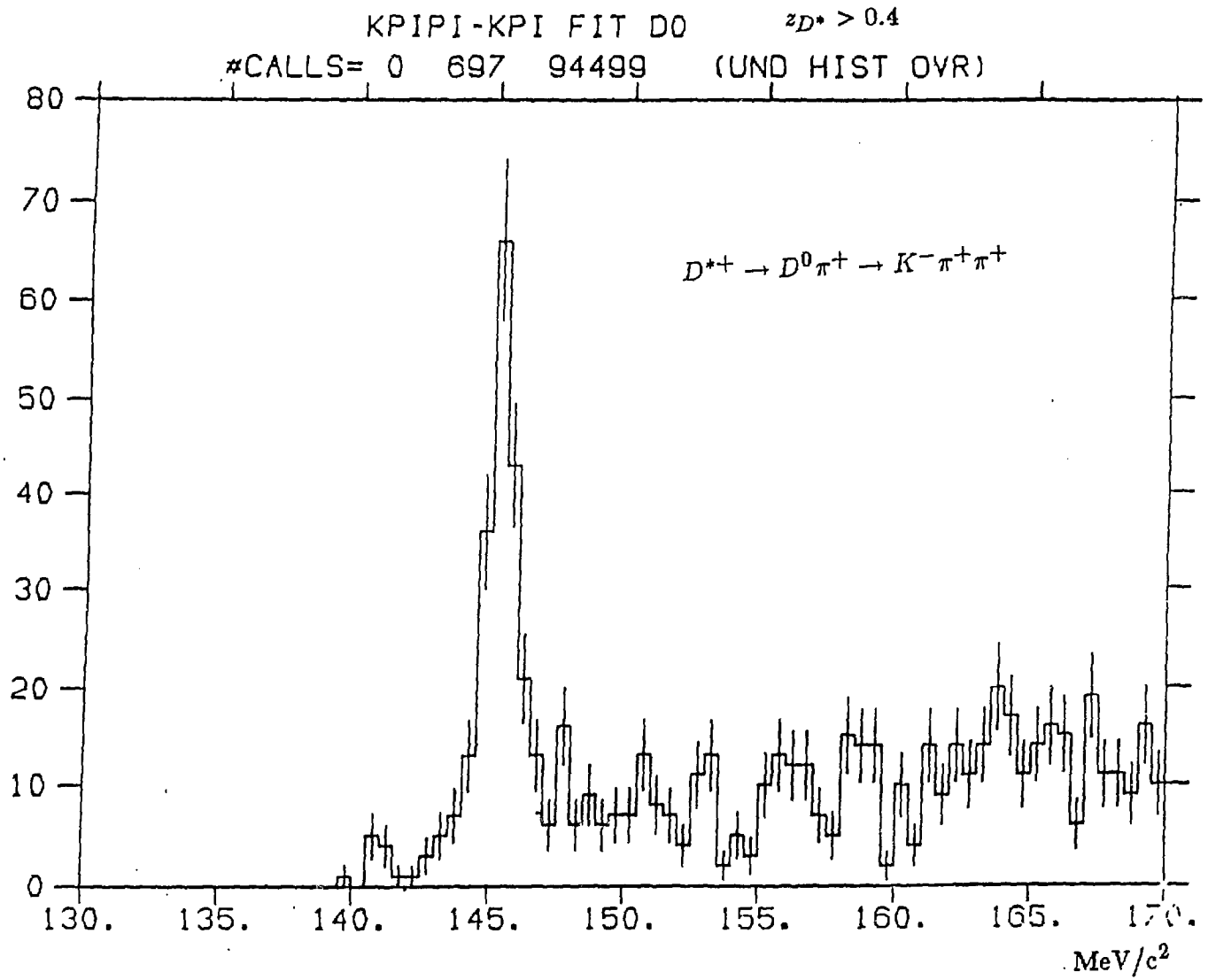

KPI MASS, ZD>.5
#CALLS= 4314 4597 266 (UND HIST OVR)
400
350
300
250
200
150
100
50
0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
$D^0 \to K^-\pi^+$
GeV/c^2
Invariant mass $M(K\pi)$

Fig. 1



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

Fig. 2