ITEP-3-94
Fermilab Library
0 1160 0034466 8

INSTITUTE OF THEORETICAL
AND EXPERIMENTAL PHYSICS

ITEP-3-94

S.SEMENOV

APR 8 199
BRA

RECENT ARGUS RESULTS ON CHARM PHYSICS

NAME
RETU

MOSCOW 1994

УДК 539.172 М-16
RECENT ARGUS RESULTS ON CHARM PHYSICS.: Preprint ITEP 3-94/
S.Semenov - M., 1994 - 8p.

Recent ARGUS results on charm physics are presented. Among them are the first observation of the excited charmed baryon Λ_c^{*+} in the final state $\Lambda_c^+\pi^+\pi^-$, first measurement of the branching ratio for Cabibbo-Suppressed decay $D^0 \to K_S^0 K_S^0 \pi^+\pi^-$ and determination of the branching ratio for semileptonic decay of $D^0 \to K^{*-}e^+\nu$.

Fig. - 4, ref - 22.

© Институт теоретической и экспериментальной физики, 1994

Introduction

We present some recent ARGUS results on charmed physics : first observation of the excited charmed baryon, study of Cabibbo-Suppressed D^0-decay, and finally the study of semileptonic decay of $D^0 \to K^- e^+ \nu$.

The data have been taken at the e^+e^- storage ring DORIS II of DESY in the energy range of Υ resonances, and in the neighbouring continuum. Charged hadron and lepton identification was made on the basis of specific energy losses in the drift chamber gas, velocity measurement in the time-of flight counters, energy deposition and shower profile in the electromagnetic calorimeter, and hits in the muon chambers surrounding the detector. A detailed description of the ARGUS detector and its particle identification capabilities can be found in [1].

An Observation of the Excited Charmed Barion

For the last few years most ground state baryons containing one c-quark have been established [2, 3, 4]. A number of models have been developed to provide explicit predictions for the masses of excited charmed baryons [5, 6]. We present an observation of the first excited charmed baryon resonance Λ_c^{+*} in the final state $\Lambda_c^+\pi^+\pi^-$. The Λ_c^+ was reconstructed in four decay modes - $pK^-\pi^+$, pK_S^0, $\Lambda^0\pi^+$, and $\Lambda^0\pi^+\pi^+\pi^-$. Each combination with an invariant mass within $\pm$ 25 MeV/c^2 for $pK^-\pi^+$ and $\Lambda^0\pi^+\pi^+\pi^-$, $\pm$ 30 MeV/c^2 for pK_S^0 and $\pm$ 40 MeV/c^2 for $\Lambda^0\pi^+$ of the nominal Λ_c^+ mass [7] was subjected to a mass constraint fit to improve the momentum resolution. Every Λ_c^+ candidate was then combined will all $\pi^+\pi^-$ pairs in an event. To suppress the combinatorial background the scaled momentum x_p of all $\Lambda_c^+\pi^+\pi^-$ combinations was required to be greater than 0.5, where $x_p = p(\Lambda_c^+\pi^+\pi^-)/p_{max}$ and $p_{max} = \sqrt{E_{beam}^2 - M^2(\Lambda_c^+\pi^+\pi^-)}$.

The resulting $\Lambda_c^+\pi^+\pi^-$ invariant mass spectrum is presented in Fig. 1. A narrow peak at a mass of about 2627 MeV/c^2 is observed, while the distribution for artificial $\Lambda_c^+\pi^+\pi^-$ combinations built up from the Λ_c^+ sidebands shows smooth behaviour in this region. The fit gives 42.4 $\pm$ 8.8 events at a mass of (2626.6 $\pm$ 0.5) MeV/c^2 with a width of σ = (2.2 $\pm$ 0.5) MeV/c^2 . To obtain an upper limit on the natural width, Γ, of the Λ_c^{+*}, the signal shape was parametrized using a non-relativistic Breit-Wigner convoluted with a Gaussian resolution function. The width of the Gaussian was fixed to its expected value of 2.6 MeV/c^2. The fit yielded an upper limit of $\Gamma < 3.2$MeV/c^2 at the 90 % confidence level.

The x_p distribution of the Λ_c^{+*} was fitted by the Peterson *et al.* fragmentation function [8] which has the form

$$\frac{dN}{dx_p} \propto x_p^{-1}\left[1 - \frac{1}{x_p} - \frac{\epsilon}{1-x_p}\right]^{-2}. \qquad (1)$$

The value found for the fragmentation parameter was $\epsilon = 0.044 \pm 0.018$. This is considerably smaller than in the case of Λ_c^+ or Σ_c, as is expected for excited states (for comparison the ϵ

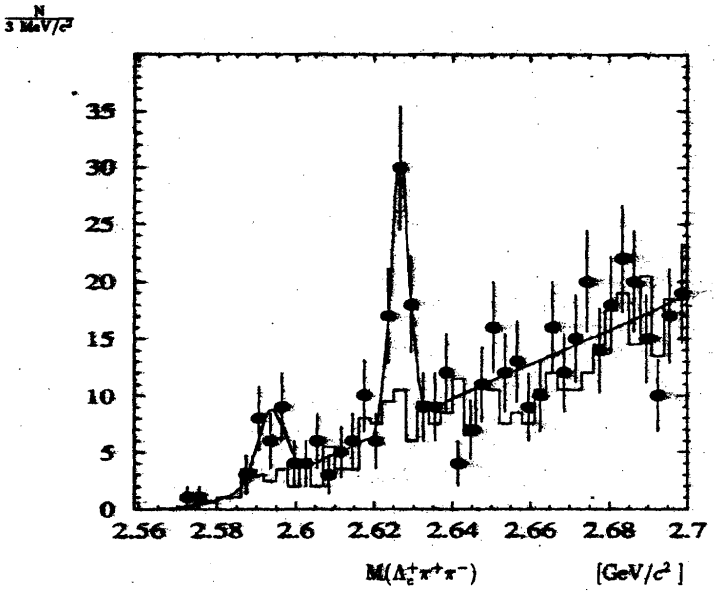

Figure 1: Invariant mass distribution for all accepted $\Lambda_c^+\pi^+\pi^-$ combinations. The solid histogram results from using the Λ_c^+ sidebands.

values for Λ_c^+ and Σ_c are 0.24 ± 0.04 [9] and 0.29 ± 0.06 [10] respectively).

In order to convert the fitted number of signal events in the $\Lambda_c^+\pi^+\pi^-$ spectrum into a value for the production rate, $\sigma(\Lambda_c^{++})$, in e^+e^- annihilation at $E_{CM} = 10.4\ GeV$ for $x_p > 0.5$, we used the ARGUS measurement of $Br(\Lambda_c^+ \to pK^-\pi^+) = (4.0 \pm 0.3 \pm 0.8)\%$ [11]. This gives $\sigma \cdot Br(\Lambda_c^{++} \to \Lambda_c^+\pi^+\pi^-) = 9.9 \pm 2.1 \pm 2.2$ pb. The quoted systematic error reflects contributions from varying the cut and fit parameters, from uncertainties in the Monte Carlo simulation, and from uncertainties in the Λ_c^+ branching ratios. Using the Peterson *et al.* fragmentation parameter ϵ derived from the fit we extrapolated to zero momentum and found

$$\sigma \cdot Br(\Lambda_c^{++} \to \Lambda_c^+\pi^+\pi^-) = 11.5 \pm 2.5 \pm 3.0 \text{ pb}.$$

The resonant structure of this decay was estimated. We obtain the following fractions :

$$\frac{Br(\Lambda_c^{++} \to \Sigma_c\pi^+)}{Br(\Lambda_c^{++} \to \Lambda_c^+\pi^+\pi^-)} = 0.46 \pm 0.14$$

$$\frac{Br(\Lambda_c^{++} \to (\Lambda_c^+\pi^+\pi^-)_{nr})}{Br(\Lambda_c^{++} \to \Lambda_c^+\pi^+\pi^-)} = 0.54 \pm 0.14.$$

for resonant and non-resonant parts of the $\Lambda_c^{*+} \to \Lambda_c^+\pi^+\pi^-$ decay correspodingly.

CLEO confirmed the existence of the peak at 2627 MeV/c^2 and observed the second peak with a mass of about 2590 MeV/c^2 in the $\Lambda_c^+\pi^+\pi^-$ invariant mass distribution [12]. ARGUS also has seen an enhacement at this mass (see Fig.1) with the number of events 18.0 ± 7.1 .

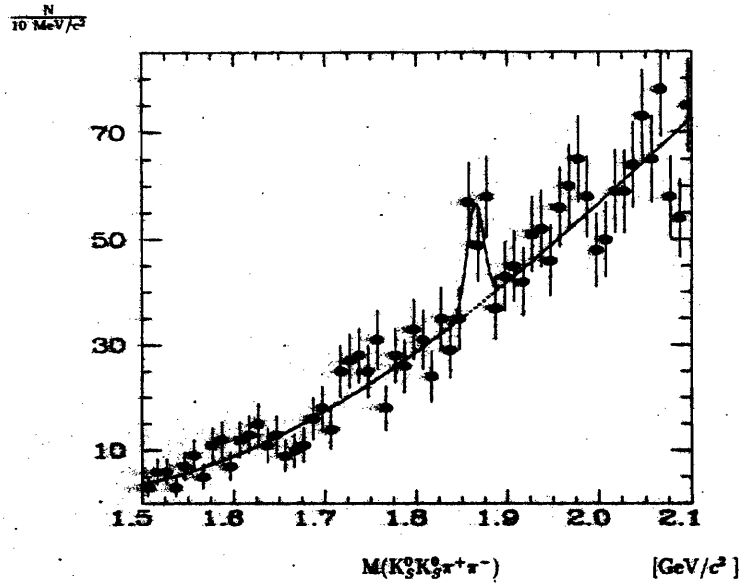

Figure 2: The $K_S^0K_S^0\pi^+\pi^-$ invariant mass distribution.

Study of Cabibbo-suppressed decays into $KK\pi\pi$ final states

The study of the Cabibbo-suppressed D^0-decay is an important means of probing the interplay between the weak and strong interactions. Now we are reaching a level of sensitivity which allows the systematic study of the Cabibbo-suppressed channels.

We present a first measurement of the branching ratio of $K_S^0K_S^0\pi^-\pi^+$ decay. To suppress the combinatorial background the scaled momentum x_p of all $K_S^0K_S^0\pi^-\pi^+$ combinations was required to be greater than 0.5, where $x_p = p(K_S^0K_S^0\pi^-\pi^+)/p_{max}$. Combinations that have a $\pi^+\pi^-$ mass consistent with the K_S^0 mass are excluded from this analysis. The resulting $K_S^0K_S^0\pi^-\pi^+$ invariant mass spectrum is presented in Fig 2. The fitted signal contains 45 ± 13, using a Gaussian, to parametrize the signal, and a third-order polinomial times threshold factor

to parametrize the background. This signal corresponds to value of $Br(D^0 \to K^0_S K^0_S \pi^+\pi^-) = (0.17 \pm 0.05 \pm 0.04)\%$. The possible background contribution from $K^0_S\pi^-\pi^+\pi^-\pi^+$ is estimated to be less than 1 event.

To study $D^0 \to K^-K^+\pi^-\pi^+$ we have reconstructed D^0 mesons originating in the decay $D^{*+} \to D^0\pi^+$. This technique exploits the small Q value of the D^{*+} decay in order to obtain signal with very low background. The scaled momentum x_p was required to be more than 0.5. Combinations that have a $\pi^+\pi^-$ mass consistent with the K^0_S mass are excluded from this analysis. Using $Br(D^0 \to K^-\pi^+\pi^-\pi^+) = (7.5 \pm 0.5)\%$ [7], the branching ratio for $D^0 \to K^-K^+\pi^-\pi^+$ is determined to be $(0.31 \pm 0.06 \pm 0.04)\%$, which is in agreement with previous measurements [13, 14, 15].

We have also obtained the branching ratio for $D^0 \to \phi\pi^+\pi^-$; $Br(D^0 \to \phi\pi^+\pi^-) = (0.17 \pm 0.05 \pm 0.04)\%$, which is in agreement with other measurements [13, 14]. Furthermore, $\pi^+\pi^-$ invariant mass distribution for this decay obtained is consistent with being entirely due to ρ's. Assuming that $D^0 \to \phi\pi^+\pi^-$ goes totally through $\phi\rho$ final state , we obtain the $BR(D^0 \to \phi\rho) = (0.17 \pm 0.05 \pm 0.04)\%$ in agreement with theoretical value of about 0.1% predicted in [16].

Study of semileptonic decay of $D^0 \to K^{*-}e^+\nu$

Existing quark models predict the same branching ratio for semileptonic charm decay to pseudoscalar me-sons, $D^0 \to K\ell\nu$, and vector mesons , $D^0 \to K^*\ell\nu$, and suggest that these two modes saturate the semileptonic width [17, 18]. The E691 and CLEO groups [19, 20] confirmed the predicted $D^0 \to K\ell\nu$ decay width, but obtained about half the width predicted for the $D^0 \to K^*\ell\nu$. MARK III group reported a measurement of the $D^0 \to K^{*-}e^+\nu$ branching ratio in agreement with the theoretical predictions, although within large experimental errors [21].

We present a study of $D^0 \to K^{*-}e^+\nu$ using two different methods. With the first method we studied mass correlations between K^0_S and π^- mesons in events, containing a positron, assuming all three particles to originate from a D^0 decay in continuum production. The approach used was to search for events containing a K^{*-} candidate and a positron with an opening angle of less than 90^0. To suppress the contribution from fragmentation processes the momentum of the $K^0_S\pi^-$ combination was required to be larger than 1 GeV/c^2, and the $K^0_S\pi^-e^+$ invariant mass less than 1.8 GeV/c^2.

The $K^0_S\pi^-$ invariant mass distribution for events containing a positron candidate is shown in Fig. 3. A fit to the data using a Breit-Wigner plus a third-order polynomial times a square-root threshold factor as the background function yields 288 ± 35 K^0_S mesons. In addition to the signal from semileptonic D^0 decays, this data sample includes contributions from the following background sources:

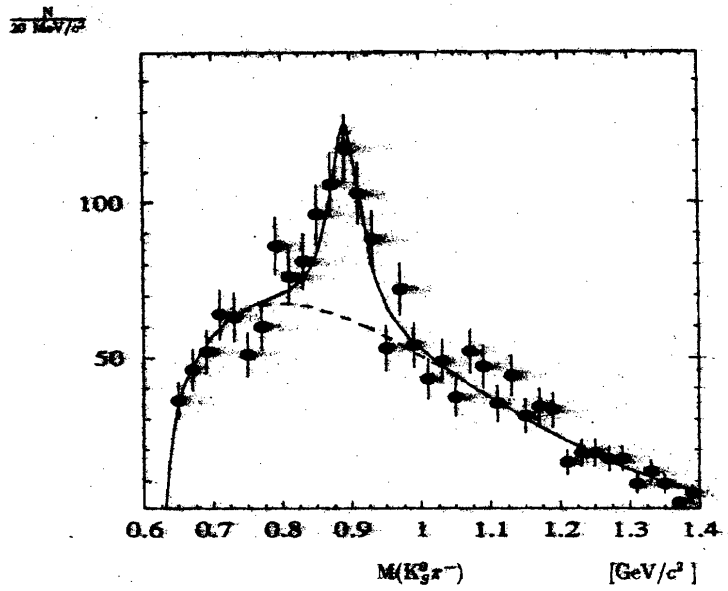

Figure 3: The $K_S^0\pi^-$ invariant mass distribution for events containing a positron candidate.

1. A fake positron contribution of 43 ± 12 events. This was determined from K_S^0-hadron combinations by integrating the convolution of the hadron momentum spectrum with the misidentification rate of (0.40 ± 0.12) %.

2. An estimated 34 ± 8 K_S^0 mesons originating from fragmentation processes in coincidence with posi-trons from charm decays. This source was investigated using a Monte Carlo $c\bar{c}$ event sample, normalized to the data. We confirmed the rate of fragmentation processes appearing in Monte Carlo events using a clean sample of D^{*+} mesons reconstructed from the data.

3. A total of 7 ± 4 combinations from B mesons decays. This source was evaluated by comparing the number of K_S^0-positron combinations in data samples taken at the $\Upsilon(4S)$ energy with and without the Fox-Wolfram cut $H_2 > 0.3$ [22] , i.e. depleting and enriching the direct $\Upsilon(4S)$ component.

Wrong-charge ($K^{*-}e^-$) combinations cannot be attri-buted to charm decays and are therefore well suited for estimating the reliability of our procedure for the background determination.

We calculated the background contribution to wrong-charge combinations by the same procedure as for right-charge combinations and found this to be 65 ± 15 combinations (28 ± 9, 32 ± 12 and 5 ± 3 respectively). The observed number of 67 ± 24 ($K^{*-}e^-$) combinations agrees well with our estimation of the background. Using $Br(D^0 \to K^{*-}\pi^+) = (4.5 \pm 0.6)\%$ [7], the branching ratio for $D^0 \to K^{*-}e^+\nu$ is determined to be $(1.8 \pm 0.3 \pm 0.5)\%$. The systematic error reflects contributions from varying the cut parameters, from the uncertainty in the acceptance calculation, and from the uncertainty in the parametrization of $M(K^0_S\pi^-)$.

The $D^0 \to K^{*-}e^+\nu$ branching ratio was also determined using tagged D^0 mesons from $D^{*+} \to D^0\pi^+$ decays. The technique exploits the small Q value of the D^{*+} decay in order to obtain a signal with very low background. We studied the mass difference $\Delta M = M(\pi^+K^0_s\pi^-e^+) - M(K^0_s\pi^-e^+)$ and required the mass difference to be less than 0.18 GeV/c^2. Exploiting the hard momentum spectrum of D^0 mesons in continuum $c\bar{c}$ events we selected only those combinations with

$p(\pi^+K^0_s\pi^-e^+) \geq 1.7\ GeV/c$ and $p(K^0_s\pi^-) \geq 0.7\ GeV/c$. As in the previous analysis we required the opening angle between the $K^0_s\pi^-$ pair and the positron to be less than 90^0.

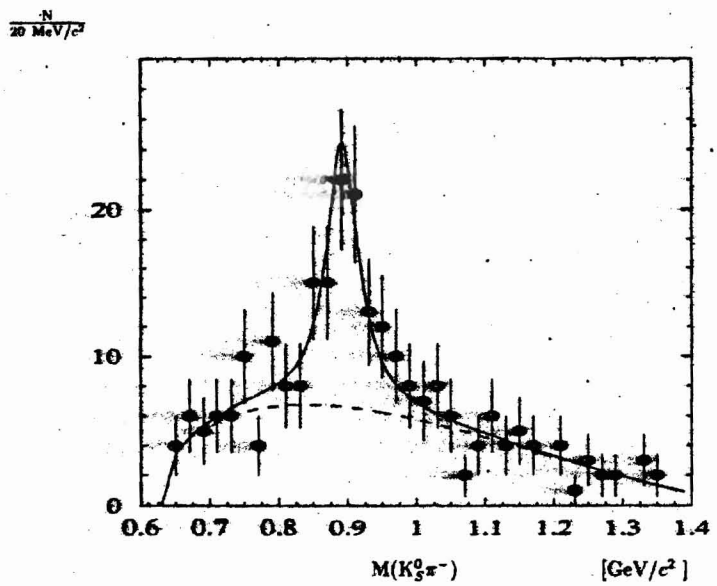

Figure 4: The $K^0_S\pi^-$ invariant mass distribution for events containing a positron candidate.

Fig. 4 shows the $K^0_s\pi^-$ mass distribution for the remaining events. A fit to the data yields

77 ± 13 K^0_S mesons. All the background processes described earlier contribute here as well:

1. A fake contribution of 19 ± 4 events.
2. A contribution from K^0_S mesons originating from fragmentation processes, estimated to be less than 2 events.
3. A contribution of less than 2 events from $\Upsilon(4S)$ decays.

The ratio BR($D^0 \to K^{*-}e^+\nu$) / BR ($D^0 \to K^{*-}\pi^+$) was found to be $(0.42 \pm 0.11 \pm 0.08)$, resulting in a value of BR($D^0 \to K^{*-}e^+\nu$)= $(1.9 \pm 0.5 \pm 0.5)\%$, in a good agreement with the branching ratio determined using the previous method.

A search for possible feedown from $D^0 \to K^{*-}\pi^0e^+\nu$ decay was done. For this purpose we have studied the decay mode $D^0 \to K^{*0}\pi^-e^+\nu$ with the same kinematics as the above mentioned background and recalculated obtained for this channel upper limit assuming that the $K^*\pi$ system is a state with isospine 1/2. We found that the possible feeddown to the $D^0 \to K^{*-}e^+\nu$ from the decay $D^0 \to K^{*-}\pi^0e^+\nu$ to be less than 0.2 %.

References

[1] H.Albrecht *et al.* (ARGUS Collaboration), *Nucl. Instr. and Methods* **A275** (1989) 1.

[2] C.S.Abram *et al.*(MARK II Collaboration), *Phys.Rev.Lett.* **44**(1980) 10.

[3] H.Albrecht *et al.*(ARGUS Collaboration), *Phys. Lett.* **B211** (1988) 489.
H.Albrecht *et al.*(ARGUS Collaboration), *Phys. Lett.* **B247** (1990) 121.

[4] P.Avery *et al.* (CLEO Collaboration), *Phys.Rev.Lett.* **62**(1989) 863;
M.S.Alam *et al.* (CLEO Collaboration), *Phys.Lett.* **B226**(1989) 401.

[5] L.A.Copley,N.Isgur and G.Karl, *Phys.Rev.* **D20**(1979) 768.

[6] C.S.Kalman and B.Tran, *Nuovo Cim.* **A102** (1989) 635.

[7] (Particle Data Group), *Phys. Rev.* **D45**(1992)1.

[8] C.Peterson *et al.* **D27** (1983) 105.

[9] C.E.K.Charlesworth, *A Study of the Decay Properties of the Charmed Baryon* A_c^+, Ph.D. thesis, University of Toronto, 1992.

[10] H.Albrecht *et al.* (ARGUS Collaboration), *Phys.Lett.* **207B** (1988) 489.

[11] H.Albrecht *et al.* (ARGUS Collaboration), *Z.Phys.* **C53** (1992) 1.

[12] R.Ammar *et al.*(CLEO Collaboration), Contributed paper 303 to the Lepton-Photon Conference, Cornell, USA, 1993.

[13] S.Barlag *et al.* (ACCMOR collab.), Z. Phys. **C48** (1990) 29.

[14] R.Ammar *et al.* (CLEO collab.), Phys. Rev. **D44** (1991) 3383.

[15] J.C.Anjos *et al.* (E691 collab.), Phys. Rev. **D43** (1991) R535.

[16] M.Wirbel, M.Bauer and B.Stech, *Z. Phys.* **C34** (1987) 103.

[17] M.Wirbel, M.Bauer and B.Stech, *Z. Phys.* **C29** (1985) 6.

[18] N.Isgur, D.Scora, B.Grinstein and M.B.Wise, *Phys.Rev.* **D39** (1989) 799; N.Isgur, D.Scora, *Phys. Rev.* **D40** (1989) 1.

[19] J.C.Anjos *et al.* (E691 Collaboration), *Phys.Rev. Lett.* **62** (1989) 722.

[20] G.Crawford *et al.* (CLEO Collaboration), *Phys.Rev.* **D44** (1991) 3394.

[21] Z.Bai *et al.* (MARK III Collaboration), *Phys.Rev.Lett.* **66** (1991) 1011.

[22] G.C.Fox and S.Wolfram, *Nucl.Phys.* **B149** 413 1979.

Семенов С.

Новые результаты сотрудничества АРГУС в физике очарованных частиц.

Подписано к печати 20.12.93 Формат 60x90 1/16 Офсетн.печ.
Усл.-печ.л.0,5 Уч.-изд.л.0,3 Тираж 200 экз. Заказ 3.
Индекс 3649

Отпечатано в ИТЭФ, 117259, Москва, Б.Черемушкинская,25