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SEARCH FOR A THRESHOLD ENHANCEMENT IN THE $\gamma p \to$ CHARMED BARYON + CHARMED MESON CROSS SECTION*

K. Abe,[i] T. C. Bacon,[c] H. H. Bingham,[k] J. E. Brau,[m] K. Braune,[g] D. Brick,[b] W. M. Bugg,[m] J. M. Butler,[g] W. Cameron,[c] H. O. Cohn,[e] D. C. Colley,[a] S. Dado,[h] P. Dingus,[k] R. Erickson,[g] R. C. Field,[g] B. Franek,[f] R. Gearhart,[g] T. Glanzman,[g] I. M. Godfrey,[c] G. Hall,[c] E. R. Hancock,[f] H. J. Hargis,[m] E. L. Hart,[m] M. J. Harwin,[c] K. Hasegawa,[i] R. I. Hulsizer,[d] M. Jobes,[a] T. Kafka,[j] G. E. Kalmus,[f] D. P. Kelsey,[f] T. Kitagaki,[i] A. Levy,[l] R. Merenyi,[j] J. J. Murray,[g] V. O'Dell,[b] I. A. Pless,[d] P. Rankin,[c] E. Ronat,[n] H. Sagawa,[i] S. J. Sewell,[f] J. Shank,[k] J. Shimony,[m] K. Tamai,[i] S. Tanaka,[i] D. A. Waide,[a] M. Widgoff,[b] S. Wolbers,[k] C. A. Woods,[c] A. Yamaguchi,[i] R. K. Yamamoto,[d] G. P. Yost,[k] and H. Yuta[i]

(Stanford Linear Accelerator Center Hybrid Facility Photon Collaboration)

ABSTRACT

Results of a search for a predicted enhancement of several microbarns in the charm photoproduction cross section just above threshold are reported. No charm decays were detected, from which an upper limit to the charm cross section of 94nb (90% CL) at $E_\gamma \simeq 10$ GeV was obtained. Upper limits in the range 270 to 450nb were also obtained for the peak cross sections for threshold enhancements in $\gamma p \to D^- \Sigma_c^{++}$ and similar channels.

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[a] Birmingham University, Birmingham, B15 2TT, England.
[b] Brown University, Providence, Rhode Island, 02912.
[c] Imperial College, London, SW7 2BZ, England.
[d] Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.
[e] Oak Ridge National Laboratory, Oak Ridge, Tennessee, 37830.
[f] Rutherford Appleton Laboratory, Didcot, Oxon, OX11 0QX, England.
[g] Stanford Linear Accelerator Center, Stanford University, Stanford, California, 94305.
[h] Technion-Israel Institute of Technology, Haifa 32000, Israel.
[i] Tohoku University, Sendai 980, Japan.
[j] Tufts University, Medford, Massachusetts, 02155.
[k] University of California, Berkeley, California, 94720.
[l] University of Tel Aviv, Tel Aviv, Israel.
[m] University of Tennessee, Knoxville, Tennessee, 37996-1200.
[n] Weizmann Institute, Rehovot, Israel.

It has been suggested by Rubinstein and Stodolsky[1] that an enhancement of several microbarns in the cross section for $\gamma p \to$ charmed baryon + charmed meson exists a few hundred MeV above threshold. An enhancement of this type would provide a pure source of charmed baryons since it lies below the $D\bar{D}$ threshold. There is experimental evidence for such enhancements in photoproduced exclusive channels involving only light quarks[2,3], e.g. the cross section for $\gamma p \to \Delta^{++}\pi^-$ rises to 70 μb at 200 MeV above threshold. This enhancement is well described by the contact term model[3]. In this letter we present results from a search for an enhancement in the charm photoproduction cross section. The experiment was performed using the SLAC Hybrid Facility. The experimental details were similar in most respects to those used for the experiment on photoproduction of charm at 20 GeV described in reference 4.

The SLAC 1 m hydrogen bubble chamber was exposed to a photon beam with energy peaked at 10.5 GeV, which is 700 MeV above the $\gamma p \to D^-\Sigma_c^{++}$ threshold. The photon beam energy spectrum is shown in Fig. 1. The beam was produced by Compton scattering 532 nm laser light by a 23.5 GeV electron beam. It was operated at an intensity of 20 - 25 γ/pulse. A total of 98,000 pictures was taken, of which every tenth was untriggered.

In order to detect decays of charmed particles, a high resolution camera[5] having a resolution of 40 μm over a depth of field ±2 mm was used in addition to the normal 3-view camera. Every hadronic interaction was closely examined for multiprong decays of short-lived particles within 1.5 cm of the production vertex, 346 two-prong decays and one three-prong decay were found. All of these were compatible with decays of strange particles.

The sensitivity of the experiment was determined using the number of hadronic events found, the scanning and triggering efficiencies, and the known total hadronic cross section, σ_H, of 120 μb[6]. On a single scan the number of hadronic interactions examined, N_H, was 27,200. A third of the film was scanned twice. From this the single scanning efficiency for hadronic events, ε_H^{sc}, was determined to be (95 ± 1)%. In order to ensure high and uniform detection efficiency for charm events, the same cuts[7] were used in this experiment as in the 20 GeV experiment[4]. The single scan efficiency for charm events in the 20 GeV γp experiment passing cuts was (80 ± 5)%. This value was used to find the overall scanning efficiency, ε_H^{sc}, for charm events surviving all cuts in the present experiment. Allowing for the fraction of film scanned twice, ε_H^{sc} was computed to be (84 ± 5)%. This value of ε_H^{sc} is probably an underestimate as the optical resolution in the present experiment is considerably improved over that of the 20 GeV γp experiment and also because the confusion in the forward cone is greatly decreased at 10 GeV. This view is supported by the fact that the measured scanning efficiency for K^0's and Λ's decaying within 5 mm of the primary vertex was (92 ± 4)% in the present experiment. The triggering efficiency [8] for hadronic events, ε_H^T, was determined to be (66 ± 4)% from analysis of the untriggered film and also from the total photon flux. The triggering efficiency for charm events, ε_c^T, was studied by using Monte Carlo generated events with various production and decay channels and was estimated to be (70 ± 5)%. The sensitivity for charm events, s, is given by

$$s = \frac{N_H}{\sigma_H} \frac{\varepsilon_c^{sc}}{\varepsilon_H^{sc}} \frac{\varepsilon_c^T}{\varepsilon_H^T} = (213 \pm 24) \text{ events}/\mu\text{b}.$$

The number of charm events expected to be produced and to survive all cuts is given by $N_c = \chi s \bar{\sigma}_c$, where χ is the fraction of produced charm events which will survive the cuts, and $\bar{\sigma}_c = \int dE\ \sigma_c(E)\phi(E)$ is the overlap integral between the charm cross section as a function of photon energy, $\sigma_c(E)$, and the normalised photon flux, $\phi(E)$. The charm detection probability, χ, depends mainly on the decay branching ratios and the lifetimes. To estimate the value of χ, charm events were generated by a Monte Carlo program and all the cuts were applied to the generated events. The reactions considered were $\gamma p \rightarrow D^- \Sigma_c^{++}$ and $\gamma p \rightarrow D^{*-} \Sigma_c^{++}$. The lifetime values of $\tau_{D^0} = (6.8\ ^{+\ 2.3}_{-\ 1.8}) \times 10^{-13}$ s, $\tau_{D^\pm} = (7.4\ ^{+\ 2.3}_{-\ 2.0}) \times 10^{-13}$ s (as determined in our previous experiment[4]), $\tau_{\Lambda_c^+} = 2.2 \times 10^{-13}$ s and the $D^\pm$ multiprong branching ratio value of $B^\pm = 0.35 \pm 0.10$ were used. This gives $\chi = 0.13 \pm 0.05$ for $\gamma p \rightarrow D^- \Sigma_c^{++}$ and $\chi = 0.16 \pm 0.04$ for $\gamma p \rightarrow D^{*-} \Sigma_c^{++}$. The most important factors contributing to the errors in χ are the uncertainties in the multiprong branching ratio for charged decays and in the lifetimes, τ_{D^0} and $\tau_{D^\pm}$. The variation in χ due to changes in these parameters is demonstrated in Fig. 2 and 3. In the following $\chi = 0.14 \pm 0.05$ is used.

No charm candidates were detected in this experiment. Taking into account the uncertainties in s and χ, an upper limit to $\bar{\sigma}_c$ was calculated:

$$\bar{\sigma}_c < 94 \text{ nb } (90\% \text{ CL}).$$

The average charm cross section, $\bar{\sigma}_c$, is related to the maximum value of the charm cross section near threshold, σ_c^{max}, by $\bar{\sigma}_c = f\sigma_c^{max}$, where the degradation factor f is given by

$$f = \int dE \; \frac{\sigma_c(E)}{\sigma_c^{max}} \, \phi(E)$$

and clearly depends on the shape of $\sigma_c(E)$. It was assumed that $\sigma_c(E)/\sigma_c^{max}$ has the same dependence on energy above threshold as the contact term cross section for $\gamma p \to \Delta^{++}\pi^-$. Table 1 shows the degradation factors and resulting 90% confidence level upper limits to σ_c^{max} for the four channels considered.

The results given in Table 1 indicate that if there is any enhancement in the charm cross section near threshold it is less than approximately 0.3 μb per channel, much smaller than the suggested several microbarns(1). There are several possible explanations for this, including the following. Firstly, the enhancement could have a very different shape or position to those considered. Secondly, the effective strong coupling constant in the charm case may be smaller than that obtained using simple SU(4) symmetry considerations. Thirdly, the phenomenological Lagrangian formalism used in the contact term model may have to be modified by a form factor, leading to a reduction in the effective coupling strength.

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7. Briefly, decays were rejected if they were within 500 μm of the primary vertex or if no track had a projected impact distance greater than 110 μm and no second track greater than 40 μm, or if they could be due to strange particle decays or photon conversions.

8. The trigger for this experiment was altered from that of Ref. 4 by lowering the energy threshold for the lead glass counters to allow for the lower beam energy.

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TABLE 1

The degradation factors and 90% confidence limits on σ_c^{max} for the production of Σ_c^{++} of masses 2440 and 2510 MeV.

Channel	Degradation Factor	90% CL Upper Limit on σ_c^{max} (nb)
$\gamma p \rightarrow D^- \Sigma_c^{++}(2440)$	0.28	340
$\gamma p \rightarrow D^- \Sigma_c^{++}(2510)$	0.35	270
$\gamma p \rightarrow D^{*-} \Sigma_c^{++}(2440)$	0.35	270
$\gamma p \rightarrow D^{*-} \Sigma_c^{++}(2510)$	0.21	450

Figure Captions

Figure 1 - The photon beam energy spectrum measured in an electron pair spectrometer located in front of the bubble chamber. This spectrum agrees with that obtained from a sample of 426 $\gamma p \rightarrow p\pi^+\pi^-$ events.

Figure 2 - The dependence of the detection efficiency on the lifetime of the charged D meson and its multiprong branching ratio for the reaction $\gamma p \rightarrow D^- \Sigma_c^{++}$ at 10.5 GeV.

Figure 3 - The dependence of the detection efficiency on the lifetime of the neutral D meson and the multiprong branching ratio of the charged D meson for the reaction $\gamma p \rightarrow D^{*-} \Sigma_c^{++}$ at 10.5 GeV.

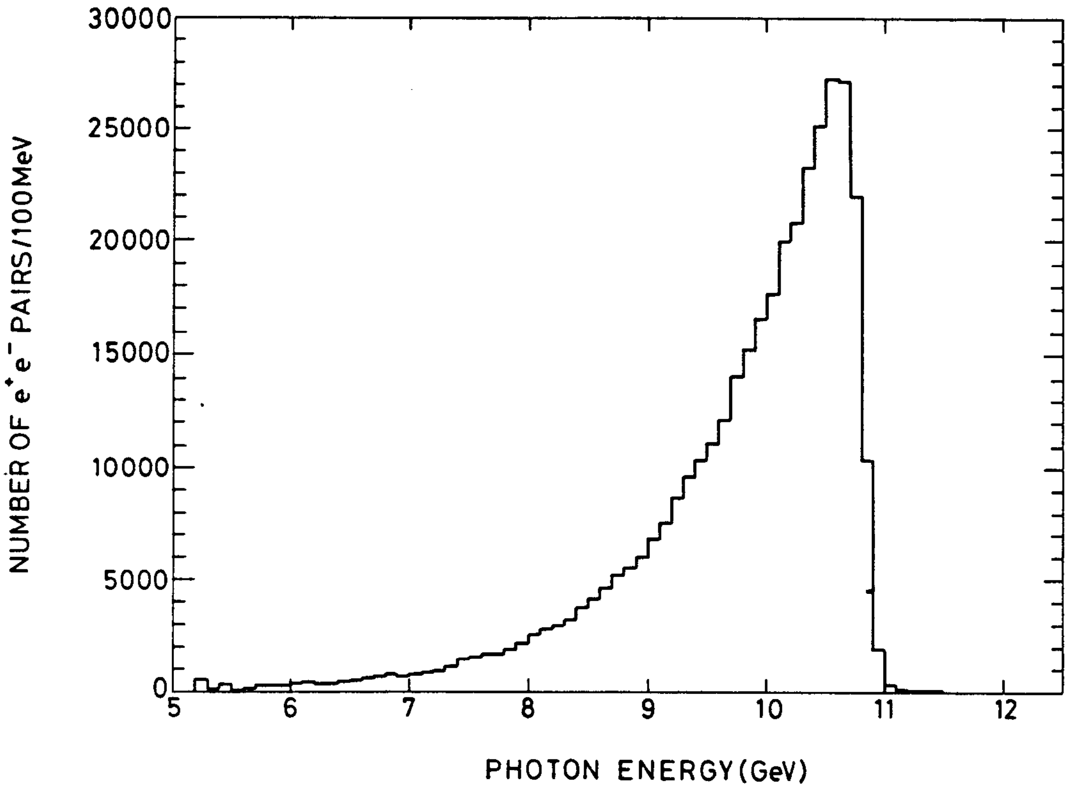
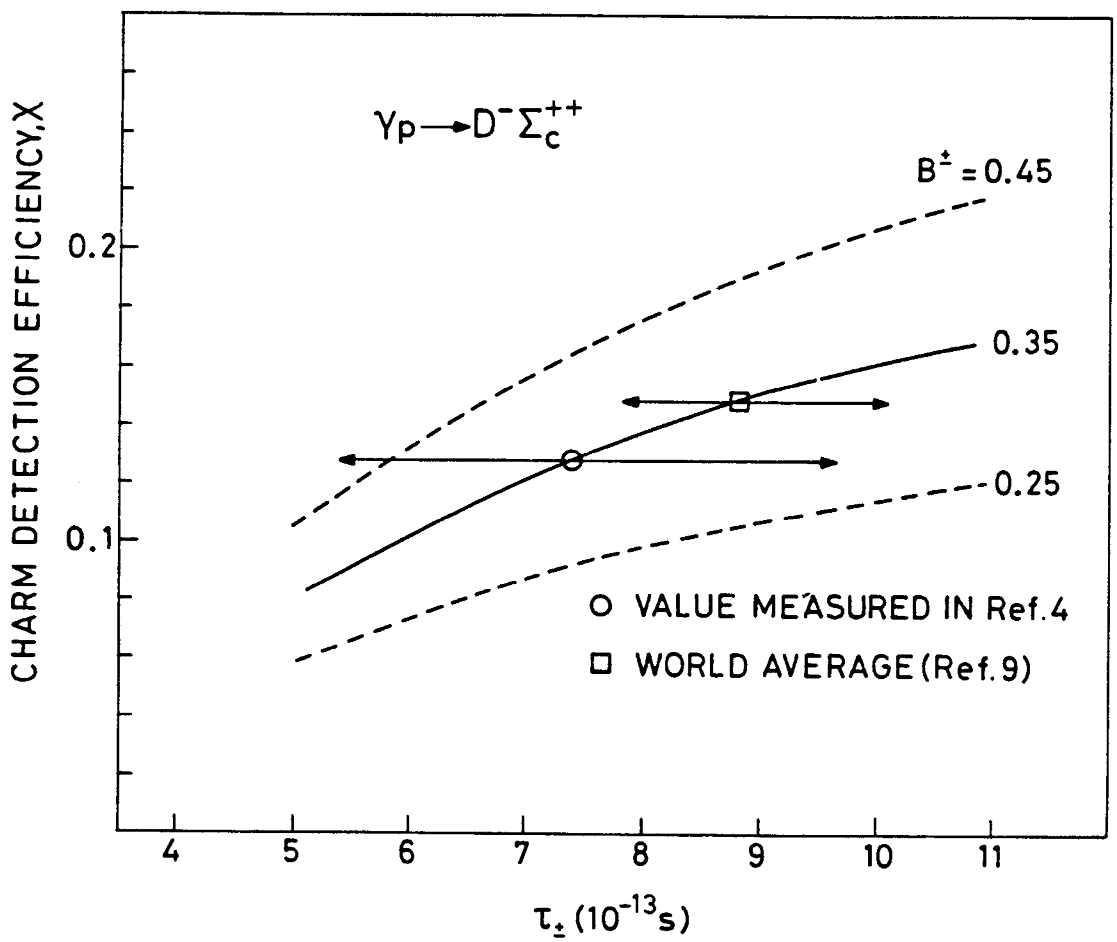
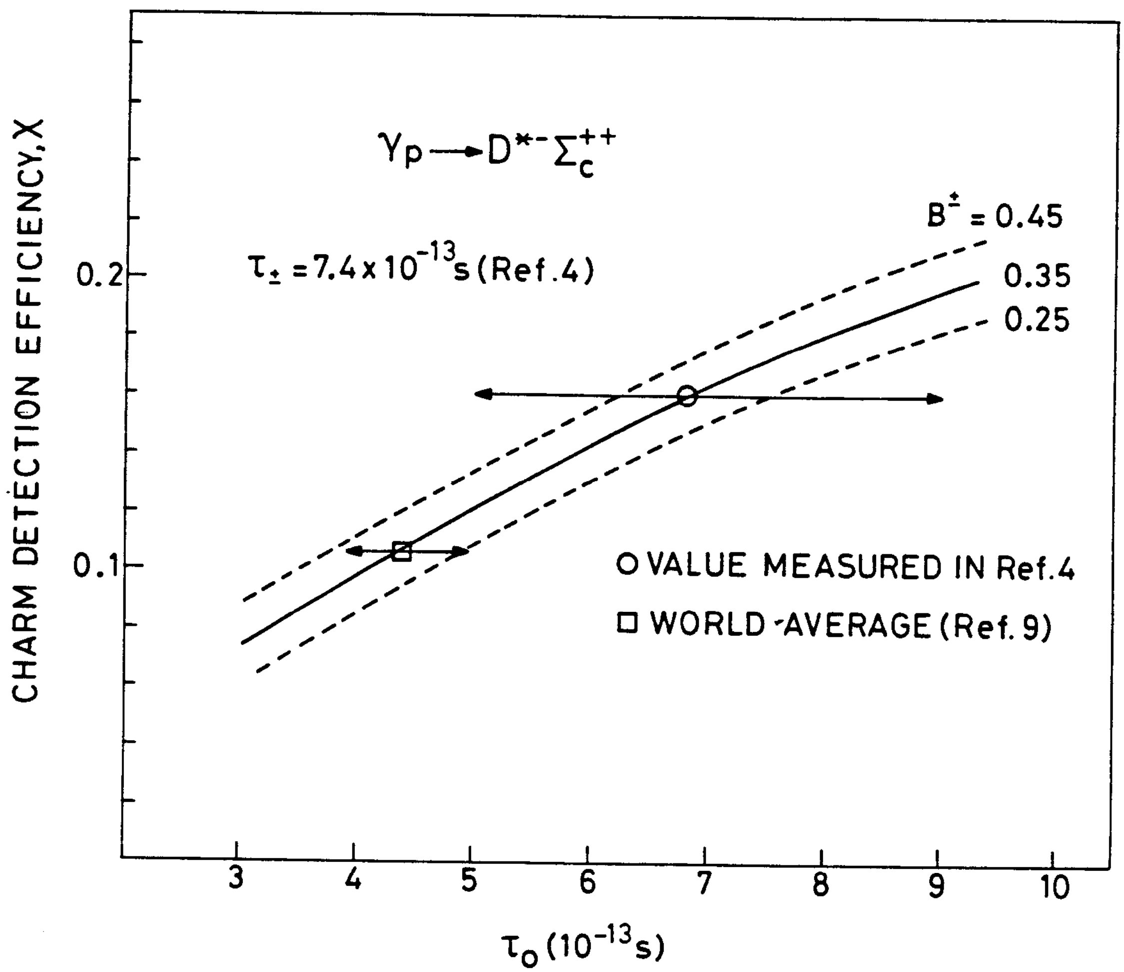

30000
25000
20000
15000
10000
5000
0
5
6
7
8
9
10
11
12
NUMBER OF e⁺e⁻ PAIRS/100MeV
PHOTON ENERGY (GeV)

Fig. 1



$\gamma p \rightarrow D^- \Sigma_c^{++}$
$B^{\pm} = 0.45$
0.35
0.25
CHARM DETECTION EFFICIENCY, X
0.2
0.1
4
5
6
7
8
9
10
11
$\tau_{\pm}$ (10^{-13}s)
VALUE MEASURED IN Ref.4
WORLD AVERAGE (Ref.9)

Fig. 2



$\gamma p \rightarrow D^{*-} \Sigma_c^{++}$
$\tau_\pm = 7.4 \times 10^{-13}$s (Ref.4)
$B^\pm = 0.45$
0.35
0.25
○ VALUE MEASURED IN Ref.4
□ WORLD -AVERAGE (Ref. 9)
CHARM DETECTION EFFICIENCY, X
0.2
0.1
3
4
5
6
7
8
9
10
$\tau_0 \, (10^{-13}$s)

Fig. 3