PROTON-ANTIPROTON STATES IN HIGH ENERGY PHOTOPRODUCTION

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ABSTRACT

Exclusive and inclusive $p\bar{p}$ photoproduction (with ≥ 2 accompanying charged particles) have been measured in the photon energy range 44-70 GeV. The exclusive process shows no prominent features; the inclusive process shows evidence for S(1936) production as a resonant-like structure with mass 1930 ± 2 MeV and width 12 ± 7 MeV.

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We present measurements of $p\bar{p}$ states made as part of a more general experiment on hadron photoproduction in the energy range 20-70 GeV. The data were recorded at the CERN SPS, using a tagged photon beam with the Omega Spectrometer. The apparatus is described in ref.(1). The Cerenkov counter C, downstream of the spectrometer, gave positive $p/\bar{p}$ identification within the momentum range 20-35 GeV/c, and the present analysis is confined to events having a $p\bar{p}$ pair with both particles within these limits.

The exclusive process $\gamma(p) \rightarrow p\bar{p}(p)$ was recorded by a trigger requiring a multiplicity of 2 forward charged particles passing through the system, with no light detected in C. (Thus, lower energy $K^\pm$ pairs were also recorded). The abundantly produced e^+e^- pairs were further suppressed by applying an additional veto on $e^\pm$ showers in the horizontal median plane of lead glass blocks in the photon detector downstream of C, and in shower counters each side of the photon detector. The background of misidentified meson pairs was dominated by the ρ and was calculated by applying the known position-dependent inefficiency of C to hadron pairs which kinematically resembled the $p\bar{p}$ pairs but gave light in C. These were recorded by a separate, parallel trigger. Contamination by e^+e^- pairs was eliminated by an offline requirement that ≥ 1 track should be out of the median plane. (This also, however, causes the acceptance for $p\bar{p}$ pairs to fall to zero at threshold).

The $p\bar{p}$ mass $m_{p\bar{p}}$ is histogrammed in Fig. 1, together with the calculated background and the overall acceptance for recording and identifying the event. The histogram displays no prominent features. The decay angular distributions for accepted events are confined to a region around 90° in polar angle θ^* in the s-channel helicity frame of the $p\bar{p}$ system; hence, to evaluate the acceptance, we have assumed (i) a distribution

$$W(\cos \theta^*) \propto 1 + 0.1 \cos^2 \theta^*$$

from the work of Cabbibo and Gatto⁽²⁾ (putting $|G_E| = |G_M|$), and (ii) a diffractive production mechanism, since the data show no significant variation with E_γ . Averaged over $p\bar{p}$ masses up to 2.7 GeV and over the photon energy range $44 < E_\gamma < 70$ GeV, the total cross-section for $\gamma(p) \rightarrow p\bar{p}(p)$ is 20 ± 8 nb, a smaller value than at lower energies⁽³⁾. Integrated over all masses, the data are in agreement with the form $d\sigma/dt \propto e^{at}$ with $a = 4.7 \pm 0.7$ (GeV/c)⁻².

We now consider the inclusive process $\gamma(p) \rightarrow p\bar{p} + X$. The data were selected from a total sample of 6M events containing 4-9 forward charged particles (see ref. (1)). Offline projection of the tracks into C enabled $p\bar{p}$ pairs to be identified. Only reconstructed events with ≥ 4 charged tracks at a vertex within the hydrogen target were accepted. The few remaining misidentified $e^\pm$ tracks were eliminated by means of the information from the photon detector. To reduce the effects of the variation of Cerenkov acceptance with $m_{p\bar{p}}$, we selected a kinematic region within which the acceptance never approached zero by imposing lower limits of 50 GeV on E_γ and 44 GeV on the total $p\bar{p}$ energy.

Fig. 2(a) shows the inclusive $p\bar{p}$ mass spectrum and the Cerenkov acceptance (assuming a uniform $p\bar{p}$ decay distribution in $\cos \theta^*$; this is consistent with the data but can be fully checked only at the lowest $p\bar{p}$ masses). The background from misidentified events was evaluated by selecting from the total data sample all events with a pair of particles which kinematically resembled the $p\bar{p}$ pairs but just one of which gave light in C. The effective $p\bar{p}$ mass plot for such pairs is shown in Fig. 2(b) and shows the ϕ reflection as a peak at 1.90 GeV and signs of the ρ reflection around 2.0 - 2.1 GeV. (No evidence was found for $\Lambda(1520)$ production, another potential source of background in $p\bar{p}$ measurements). The known C inefficiency was then applied to these events to give the background in Fig. 2(a). The uncertainty on the background is $\sim \pm 40\%$.

The mass spectrum from threshold up to 2.4 GeV was fitted with a fourth-order polynomial, giving the curve shown in Fig. 2(a). A sharp enhancement above this curve is observed around $m_{p\bar{p}} = 1.930$ GeV. This is the region where the S(1936) has been reported in a number of experiments⁽⁴⁾. From Fig. 2(b) we see that the present enhancement is not due to the ϕ or the ρ . The variation of Cerenkov acceptance with $m_{p\bar{p}}$ is insufficient to generate the effect seen, and it was further verified that the trigger acceptance varies only weakly with $m_{p\bar{p}}$. Within the range 1.92 - 1.94 GeV we see 52 events, compared with 28 predicted by the fitted curve. This represents a 4.5σ effect, which may reasonably be interpreted as evidence for photoproduction of the S meson.

We now examine the transverse momentum p_T of the $p\bar{p}$ pairs relative to the beam direction. Here, evidence is seen (Fig. 3) for a broadened p_T^2 distribution at the lowest $p\bar{p}$ masses. The data have been fitted to the form

$$d\sigma/dp_T^2 \propto \exp(-a p_T^2);$$

for $m_{p\bar{p}} < 1.96$ GeV and $m_{p\bar{p}} > 1.96$ GeV the coefficient a is found to take the values 1.25 ± 0.29 and 2.48 ± 0.20 (GeV/c)⁻² respectively. This suggests the possibility of a distinctive $p\bar{p}$ production mechanism just above threshold. The mass interval 1.92 - 1.94 GeV does not differ significantly in p_T^2 distribution from the rest of the range $m_{p\bar{p}} < 1.96$ GeV.

The Feynman variable x of the $p\bar{p}$ pairs in the overall c.m. system has also been studied. The effects of Cerenkov acceptance and trigger acceptance respectively limit the accessible range of x values to $x > 0.6$ and $x < 0.95$. The trigger acceptance was evaluated by a Monte Carlo calculation in which the cross-sections were assumed independent of E_γ . The corrected $d\sigma/dx$ distribution (Fig. 4) is similar for all $p\bar{p}$ masses, and is roughly flat between $x = 0.6 - 0.8$, but falls away at higher x , suggesting central rather than purely peripheral $p\bar{p}$ production. Within $0.6 < x < 0.95$, and averaged over $50 < E_\gamma < 70$ GeV, the cross-section for inclusive $p\bar{p}$ photoproduction with ≥ 2 accompanying charged tracks is estimated to be 180 ± 70 nb and the 1.92 - 1.94 GeV peak (after background subtraction) represents a cross-section of 5 ± 2 nb. These errors include the uncertainties in the acceptance correction.

Interpreted as a resonance, the peak has a mass of 1930 ± 2 MeV and a width 12 ± 7 MeV after unfolding the experimental resolution. The latter had a value of 7 MeV FWHM and was checked by examining ϕ 's produced with similar kinematics to the $p\bar{p}$ pairs. Previous experiments⁽⁴⁾ have reported S masses varying from 1929 to 1940 MeV, with widths of 2.8 - 9 MeV. The absence of a 1.93 GeV enhancement in elastic $p\bar{p}$ photoproduction and the lack of forward peaking in x suggest that the production is not diffractive and that therefore $J^P \neq 1^-$. The x distribution is consistent with a very inelastic production mechanism, which may explain the absence of an S in experiments studying $p\bar{p}$ production by simple exchange processes⁽⁵⁾. However, it must be remarked that the present measurements do not permit a definitive conclusion

on the resonant nature of the 1.93 GeV peak; a more general type of threshold enhancement cannot be excluded at this stage, and would not be inconsistent with our observations concerning p_T dependence.

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REFERENCES

- (1) D. Aston et al., CERN-EP/79-146, to be published in Nucl. Phys. B.
- (2) N. Cabbibo and R. Gatto, Phys. Rev. 124 (1961) 1577.
- (3) D.P. Barber et al., Daresbury preprint DL/P291E (submitted to Physics Letters B).
J. Ballam et al., Phys. Rev. D5 (1972) 545.
H.H. Bingham et al., Phys. Rev. D8 (1973) 1277.
- (4) G. Chikovani et al., Phys. Letters 22 (1966) 233.
V. Chaloupka et al., Phys. Letters 61B (1976) 487.
A.S. Carroll et al., Phys. Rev. Lett. 32 (1974) 247.
W. Brückner et al., Phys. Letters 67B (1977) 222.
S. Sakamoto et al., Nucl. Phys. B158 (1979) 410.
C. Daum et al., CERN-EP/79-157 (submitted to Phys. Letters).
B. Nicolescu et al. (eds.), Proceedings of Workshop on Baryonium and other Unusual Hadron States, Orsay, June 1979.
- (5) W.E. Cleland et al., Phys. Letters 86B (1979) 409.
M. Rozanska et al., Nucl. Phys. B162 (1980) 505.

FIGURE CAPTIONS

- Fig. 1: Invariant mass spectrum for elastically produced $p\bar{p}$ pairs (69 events), background and overall acceptance. The histogram has not been corrected for acceptance.
- Fig. 2: (a) Inclusive $p\bar{p}$ mass spectrum (462 events), background, acceptance for Cerenkov identification of both particles, and fitted curve (see text).
(b) Effective $p\bar{p}$ mass spectrum for "light/no-light" pairs (897 events). Both histograms are uncorrected for acceptance.
- Fig. 3: p_T^2 distributions, with fitted curves:
(a) $m_{p\bar{p}} > 1.96 \text{ GeV}$
(b) $m_{p\bar{p}} < 1.96 \text{ GeV}$.
- Fig. 4: Feynman x distribution for inclusively produced $p\bar{p}$ pairs (total charged track multiplicity ≥ 4). All $p\bar{p}$ masses are included, and full acceptance corrections have been applied; there is a systematic uncertainty of $\pm 40\%$ on the vertical scale.

Fig.1

FIG. 2

Fig. 3

Fig. 4