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Production of the $f_2(1520)$ resonance in antiproton–proton annihilations at $\sqrt{s} = 2980$ and 3526 MeV

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We present measurements of the $2\pi^0$ mass spectrum in proton–antiproton annihilations. The $f_2(1520)$ resonance is strongly produced in the $3\pi^0$ channel. Its production along with an η is observed, but strongly suppressed. Other features are seen in the data, including the $f_2(1270)$ and structures at 2000 MeV/c^2 and above.

In a separate paper [1] we reported evidence for several resonances in the 1.5–2.1 GeV/c^2 mass range decaying to $\eta\eta$. This investigation of light quark mesons was carried out during an experiment designed to study charmonium decays. We have also studied the $2\pi^0$ mass spectrum in the same data in the reactions

$$\bar{p} + p \to \pi^0 + \pi^0 + \pi^0 \qquad (1)$$

and

$$\bar{p} + p \to \pi^0 + \pi^0 + \eta. \qquad (2)$$

The data reported in this paper were taken in conjunction with scans of the $\eta_c(2980)$ and $^1P_1(3526)$ charmonium resonances. The trigger and reconstruction process for these six-photon final states are described in ref. [1]. After identification of events with six clusters in the central electromagnetic calorimeter, a kinematic fit was made to a six-photon hypothesis. As discussed in ref. [1], two-photon pairs with an invariant mass in the range 70–200 MeV/c^2 (449–649 MeV/c^2) were identified as coming from a π^0 (η), and the event was then fitted to (1) and (2). After applying cuts, we are left with a total of 1.87×10^6 (9.92×10^5) events from reaction (1) and 6.07×10^6 (3.06×10^5) from reaction (2) at 2980 (3526) MeV.

We show in fig. 1 Dalitz plots for reaction (1) at (a) 2980 MeV and (b) 3526 MeV. In both plots one can see clearly the $f_2(1270)$, a narrow band

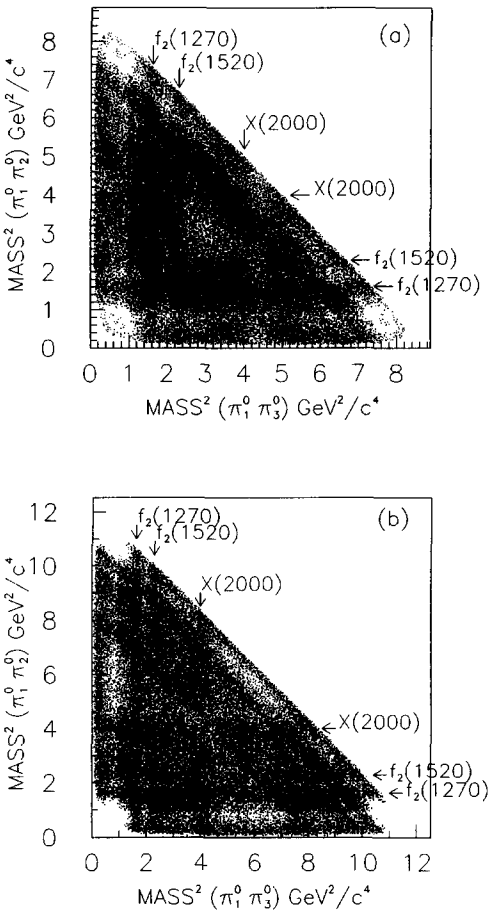

Fig. 1. Dalitz plots for reaction (1) at (a) 2980 and (b) 3526 MeV CM energy.

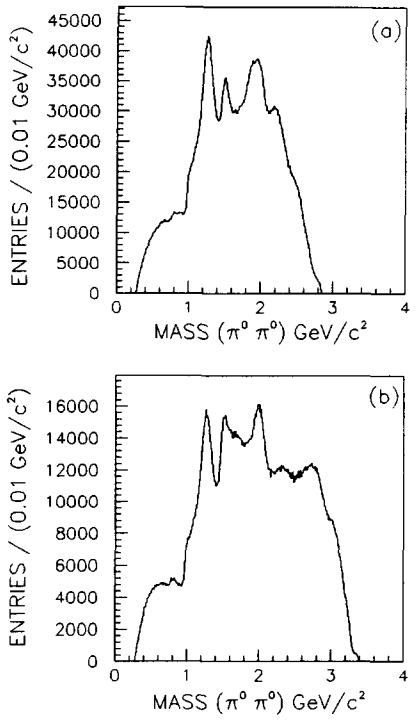

Fig. 2. Mass projections for reaction (1) at (a) 2980 and (b) 3526 MeV.

near 1500 MeV/c^2 and a broad structure at around 2000 MeV/c^2. These features can also be seen in the mass projections, figs. 2a (2980 MeV) and 2b (3526 MeV), superimposed on a background, the magnitude of which suggests that it is due mainly to reflections in the Dalitz plot, rather than non-resonant background. As the 1500 MeV/c^2 object is well-resolved in the low energy data, we have performed a fit to the mass projections for the region 900–1700 MeV/c^2 using two Breit–Wigner resonant structures and a polynomial to describe the background, and we find a mass of 1508 ± 10 MeV/c^2 and a width of 103 ± 15 MeV/c^2 for the 1500 MeV object.

In a recent experiment at LEAR [2], the Crystal Barrel Collaboration (CB) observed the $f_2(1520)$ as a $2\pi^0$ meson state with $M = 1515 \pm 10$ MeV/c^2, $\Gamma = 120 \pm 10$ MeV/c^2, and $J^{PC} = 2^{++}$ in reaction (1) at rest. Possible earlier evidence for the $f_2(1520)$ comes from Gray et al. [3], Bridges et al. [4] and May et al. [5], in at-rest annihilations. Because of the good agreement of our measurement of the mass and width of the 1500 MeV object with the CB result, we identify it with the $f_2(1520)$. If this is correct, it would add support to the argument of Dover et al. [6] that the $f_2(1520)$ is produced uniquely in antiproton–proton annihilation reactions. The broad (250 MeV) structure at 1790 ± 50 MeV/c^2 required by the CB analysis is not immediately evident in our data.

Fig. 3 shows the $\pi\pi$ mass spectrum for reaction (1) at 2980 MeV for six intervals in the CM production angle, starting with $0 < \cos\theta^* < 0.1$ in (a) and continuing in uniform intervals of 0.1 thereafter. From these data we conclude that, in contrast to the $f_2(1270)$, the $f_2(1520)$ signal is strongest near 90° in the CM, and decreases thereafter.

For reaction (2), while the $2\pi^0$ combination is unique, the presence of resonances decaying to $\eta\pi$

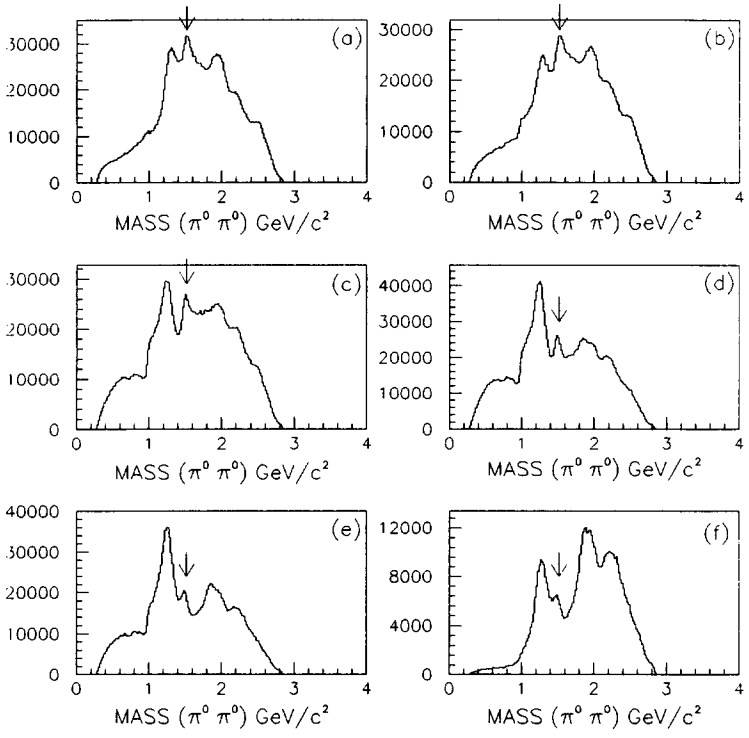

Fig. 3. Mass projections for reaction (1) at 2980 MeV: (a)–(f) correspond respectively to the intervals 0–0.1, 0.1–0.2, 0.2–0.3, 0.3–0.4, 0.4–0.5 and 0.5–0.6 in the cosine of the CM di-pion production angle.

adds complexity to the Dalitz plots. Bands due to the $a_0(980)$ and $a_2(1320)$, as well as the $f_2(1270)$, are present. The 2980 (3526) MeV data also show possible $\eta\pi$ ($\pi\pi$) structures near 2000 MeV/c^2.

Fig. 4 shows the same distributions as in fig. 3 for reaction (2) at 2980 MeV. Qualitatively, the same features of the $f_2(1270)$ are seen here as in fig. 3. In addition, a small but significant structure near 1500 MeV/c^2 is seen in four of these plots. This we attribute to the decay of the $f_2(1520)$. Fits to the mass and width in these distributions give an average mass and width of 1525 ± 10 MeV/c^2 and 111 ± 10 MeV/c^2. Taking into account the differing acceptances for reactions (1) and (2), we conclude that the ratio of the production of the $f_2(1520)$ in reaction (2) to that in reaction (1) is $17.0 \pm 7\%$, averaging over all CM production angles. The error quoted is statistical only. Systematic errors arising from the acceptance calculations are estimated to be of order 50%.

We have also fitted the mass projections of figs. 2a and 2b in the region 1600–2150 MeV/c^2 to a single Breit–Wigner plus background. We find a mass and width of 1964 ± 35 and 225 ± 50 MeV/c^2 respectively.

In summary, we have observed the $f_2(1520)$ for the first time in two final states from in-flight antiproton–proton annihilation.

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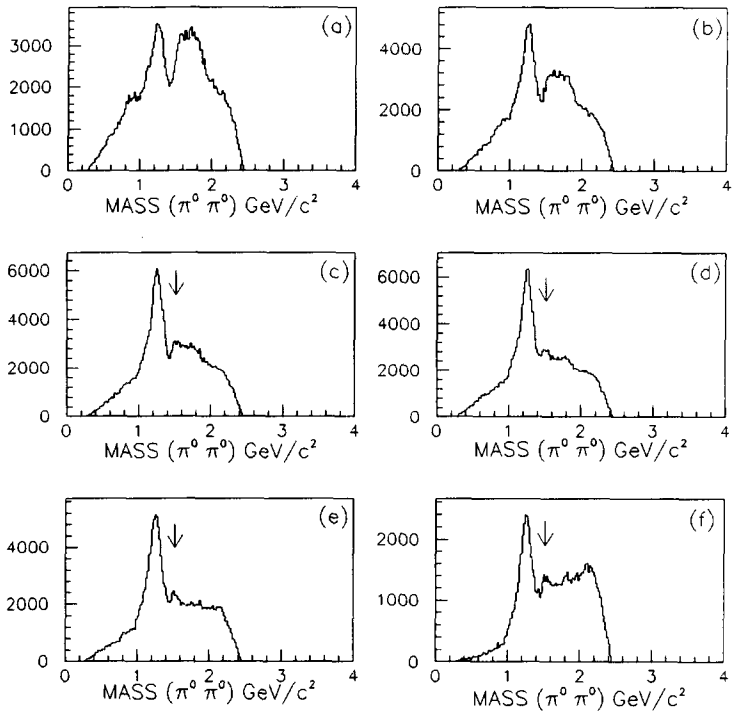

Fig. 4. Mass projections for reaction (2) at 2980 MeV for the same intervals of the CM production angle as in fig. 3.

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