Proton-antiproton annihilation into 6γ and 7γ

C. Amsler[a*]

[a]Physik-Institut der Universität Zürich, Winterthurerstr. 190, CH-8057 Zürich
(Representing the Crystal Barrel Collaboration)

Preliminary results on $\omega\pi^0\pi^0$ and $\omega\eta\pi^0$ in $\bar{p}p$ annihilation at rest [1] and on $\overline{p}p$ annihilation in flight into $\eta\eta\pi^0$ [2] are briefly described. In $\omega\eta\pi^0$ there is evidence for 1^{+-} and 1^{--} mesons decaying to $\omega\eta$. In $\eta\eta\pi^0$ at 900 MeV/c the $f_0(1500)$ meson decaying into $\eta\eta$ is strongly produced, while the $f_J(1710)$ is not observed.

1. PROTON-ANTIPROTON ANNIHILATION AT REST INTO $\omega\pi^0\pi^0$ AND $\omega\eta\pi^0$

The annihilation channel $\overline{p}p \rightarrow \omega\pi^0\pi^0$ is interesting to search for isovector $J^{PC} = 1^{+-}$ and 1^{--} states decaying into $\omega\pi^0$. Also, evidence for a broad scalar meson was reported around 1.1 GeV in the $\omega\pi^+\pi^-$ and $\rho^0\pi^+\pi^-$ final states [3].

The $\omega\pi^0\pi^0$ events, where ω decays into $\pi^0\gamma$, were obtained from triggered 19.2 million 0-prong events in $\overline{p}p$ annihilation at rest. Events with seven photons were submitted to an 8C kinematic fit to $\omega\pi^0\pi^0$, imposing the π^0 and ω masses. This led to 136,023 $\omega\pi^0\pi^0$ events, a statistical sample about an order of magnitude larger than was published earlier [4]. The main background contribution (9.6 ± 0.6 %) stems from the $4\pi^0$ final state with a missing, undetected photon.

The reconstruction efficiency (12.4 ± 1.2 %) was derived by Monte Carlo simulation using GEANT3. The $\omega\pi^0\pi^0$ Dalitz plot and the polar and azimutal angular distributions of the γ in the $\omega \rightarrow \pi^0\gamma$ rest frame were submitted to a binned likelihood fit using the helicity formalism. The data could be fitted with contributions from $b_1(1235) \rightarrow \omega\pi$, from the $\pi\pi$ S-wave, from $f_2(1270) \rightarrow \pi\pi$ and from the $4\pi^0$ background. The $\pi\pi$ S-wave was described by a 3×3 K-matrix including $\pi\pi$, $\eta\eta$ and $K\overline{K}$, using the pole positions of the σ, $f_0(980)$ and $f_0(1370)$ from a coupled channel analysis of the three pseudoscalar final states published previously [5]. The production strengths of the three resonances were left free in the fit.

Figure 1a shows the $\pi^0\pi^0$ invariant mass distribution together with the fit. The dip around 1 GeV is due to $f_0(980)$, the enhancement above 1 GeV partly to the $\pi\pi$ S-wave, partly to the tail of $f_2(1270)$. There is no room for an additional scalar around 1.1 GeV.

The annihilation channel $\overline{p}p \rightarrow \omega\eta\pi^0$ is interesting to search for isoscalar $J^{PC} = 1^{+-}$ and 1^{--} mesons decaying to $\omega\eta$, in particular the poorly known $h_1'(1380)$ or the radial excitations of the ω. The present analysis is based on a sample of 34,064 events. Results from a smaller data sample were published earlier [6].

*E-mail: Claude.Amsler@cern.ch

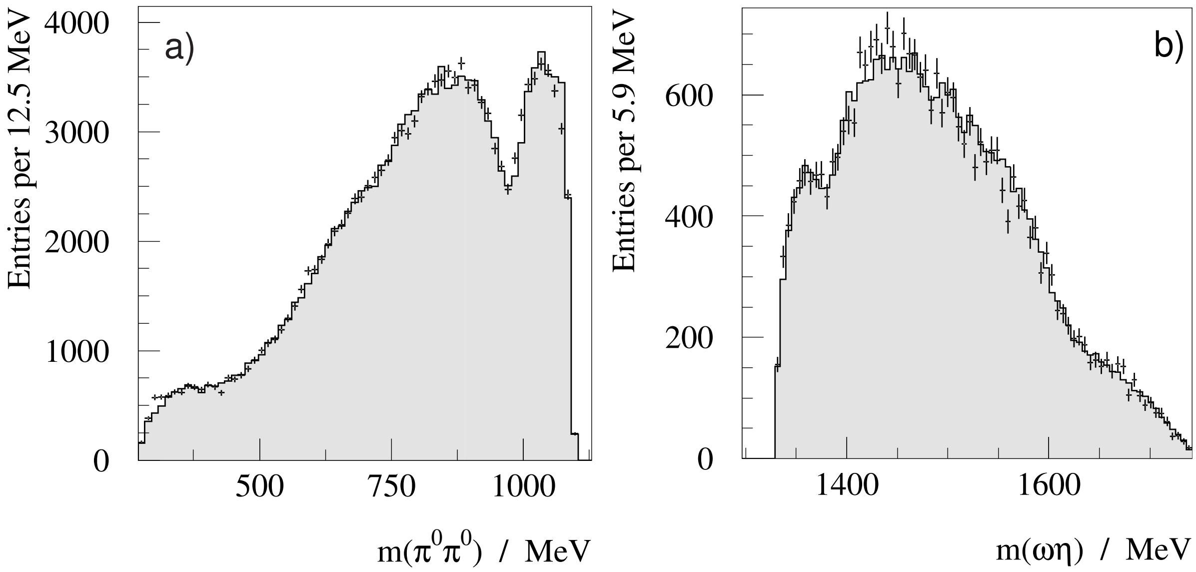

Figure 1. a) $\pi^0\pi^0$ mass distribution in $\omega\pi^0\pi^0$. The grey histogram shows the best fit described in the text; b) $\omega\eta$ mass distribution in $\omega\eta\pi^0$.

The $\omega\eta\pi^0$ Dalitz plot and the two angular distributions of the photon in the omega rest frame were obtained with the same procedure as for $\omega\pi^0\pi^0$. Here the main contribution to background (6.4 ± 0.6 %) stemmed from $\eta 3\pi^0$ with a missing photon. The reconstruction efficiency was 20.6 ± 2.9 %.

Figure 1b shows the $\omega\eta$ mass distribution. A spin-parity analysis was performed using (i) the $\eta\pi$ S-wave (2×2 K-matrix for $\eta\pi$ and $K\overline{K}$, including $a_0(980)$ and $a_0(1450)$, see ref. [5]) (ii) $b_1(1235) \to \omega\pi$ and (iii) $a_2(1320) \to \eta\pi$. These contributions were however not sufficient to describe the data. A contribution from a 1^{+-} state decaying to $\omega\eta$ with a mass of 1375 MeV and a width of 70 MeV was required (T-matrix pole). This state, presumably h_1', was described by a 2×2 (Flatté) K-matrix, assuming the unobserved decay mode to be $K^*\bar{K}$. It generates a hole in the mass distribution around 1400 MeV (Fig. 1b). In addition the data require two poles in the $\omega\eta$ 1^{--} partial wave at 1426 MeV and 1678 MeV, with widths 190 and 108 MeV, respectively. These states are presumably $\omega(1420)$ and $\omega(1600)$, observed here to decay into $\omega\eta$. The contribution from the 1678 MeV state is directly visible as a broad high-mass enhancement in Fig. 1b.

The preliminary value for the D/S ratio in $b_1(1235) \to \omega\pi$ is 0.26 ± 0.07.

2. PROTON-ANTIPROTON ANNIHILATION INTO $\eta\eta\pi^0$ AT 900 MeV/c

Recent data in central production from WA102 [7], in $\gamma\gamma$ collisions from L3 [8] and ALEPH [9] show that $f_J(1710)$ is a scalar meson ($J = 0$) and suggest that this state is mostly $s\bar{s}$. Crystal Barrel has searched for the $f_0(1710)$ in $\bar{p}p$ annihilation into $\eta\eta\pi^0$ (6 γ final state) at 900 MeV/c ($\sqrt{s} = 2050$ MeV).

The $\eta\eta\pi^0$ events were obtained from 17.8 million triggered 0-prong events. Events with six photons were submitted to a kinematic fit, assuming energy and momentum conservation, two η mesons and one π^0. However, the annihilation vertex could not be measured directly. Due to the small transverse size of the LEAR beam it was assumed to lie exactly on the detector axis but the coordinate of the vertex along the 4 cm long liquid hydrogen target had to be determined by the kinematic fit. The background contamination, e.g. from $3\pi^0$, $\pi^0\pi^0\eta$, $\eta\omega$ ($\omega \to \pi^0\gamma$ with a background γ) and $\omega\omega$, was reduced to a negligible level with corresponding antifits.

This led to 18,419 $\eta\eta\pi^0$ events. Figure 2 shows the Dalitz plot and its mass projections. One observes the $a_0(980)$ and the $a_2(1320)$ decaying into $\eta\pi^0$. The diagonal band is due to $f_0(1500)$ and $f_2'(1525)$ decaying into $\eta\eta$. The remaining background (about 8 %) was due to $\omega\pi^0\pi^0 \to 7\gamma$ with a missing, undetected γ. This background was simulated and included in the amplitude analysis.

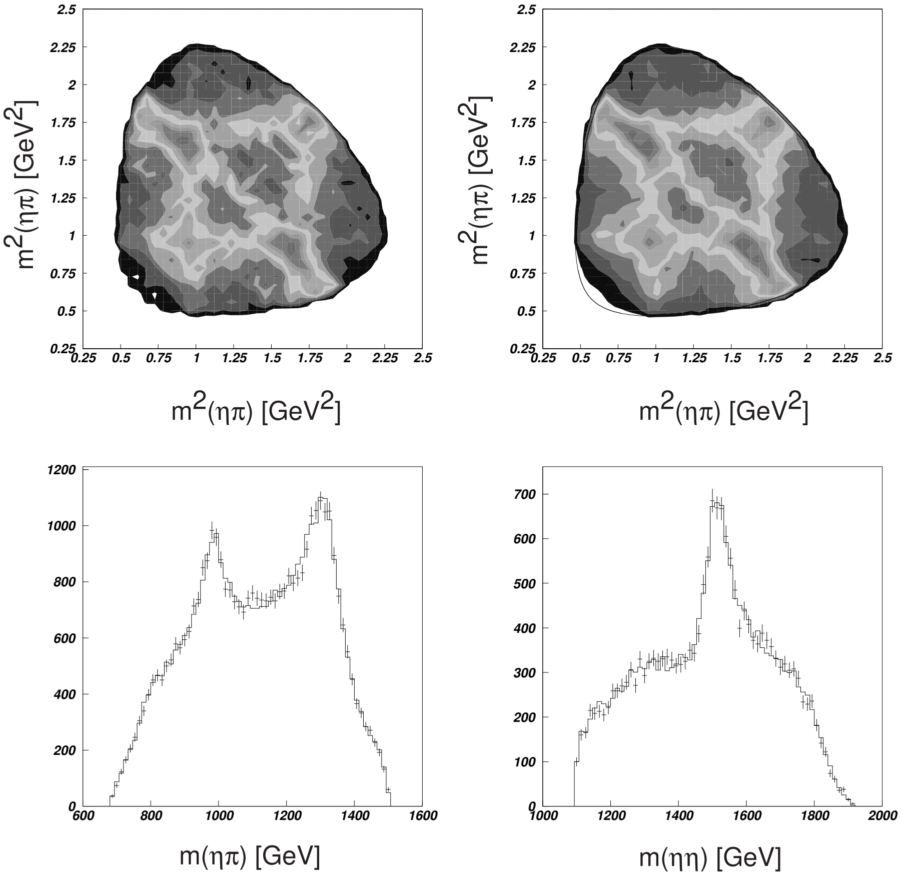

Figure 2. Top: $\eta\eta\pi^0$ Dalitzplot at 900 MeV/c. The data are shown on the left, the prediction from the best fit on the right. Bottom: $\eta\pi^0$ and $\eta\eta$ mass projections. The line shows the best fit.

A partial wave analysis including $\overline{p}p$ partial waves up to $J = 3$ was performed using the helicity formalism and a binned likelihood fit. The $\eta\pi$ S-wave ($a_0(980)$ and $a_0(1450)$) was introduced as a 2×2 K-matrix, and the $\eta\eta$ S-wave ($f_0(1370)$ and $f_0(1500)$) as a 3×3 K-matrix. The $\eta\eta$ D-wave required the $f_2'(1525)$ and a 300-400 MeV broad (2^{++}) state around 1800 MeV. This state is responsible for the high-mass shoulder in the $\eta\eta$ mass projection (fig.2) and is compatible with $f_2(1950)$ observed by other experiments.

There is no evidence for the $f_0(1710)$ (see also fig. 2).In the limit of ideal mixing in the scalar nonet the OZI rule prevents the production of a pure $s\bar{s}$ state in $\bar{p}p$ annihilation. The present data are therefore consistent with $f_0(1710)$ being mainly $s\overline{s}$. This adds supportive evidence for the scalar nonet being made of the $a_0(1450)$, $f_0(1370)$, $f_0(1710)$ and $K^*(1430)$. The absence of $f_0(1500)$ in $\gamma\gamma$ collisions suggests that this latter state is mainly glue [10].

REFERENCES

1. P. Giarritta, PhD Thesis, University of Zurich (in preparation).
2. M. Heinzelmann, PhD Thesis, University of Zurich (in preparation).
3. R. Bizzarri et al., Nucl. Phys. B14 (1969) 169;
   J. Diaz et al., Nucl. Phys. B16 (1970) 239.
4. C. Amsler et al. (Crystal Barrel Collaboration), Phys. Lett. B311 (1993) 362.
5. C. Amsler et al. (Crystal Barrel Collaboration), Phys. Lett. B355 (1995) 425.
6. C. Amsler et al. (Crystal Barrel Collaboration), Phys. Lett. B327 (1994) 425.
7. D. Barberis et al., Phys. Lett. B453 (1999) 305, 316, 325.
8. S. Braccini, Proc. Workshop on Hadron Spectroscopy, Frascati, 1999.
9. A. Wright, Proc. Int. Eur. Phys. Conf., Jerusalem, Springer, 1999, p. 343.
10. C. Amsler, Proc. Workshop on Hadron Spectroscopy, Frascati, 1999.