Resonances in $\bar{p}p \rightarrow f_2(1270)\pi$, $\pi^0\eta$ and $\pi^0\eta'$ in the mass range 1960-2410 MeV

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Data taken with the Crystal Barrel detector on $\bar{p}p \rightarrow \pi^0\eta$, $\pi^0\eta'$ and $3\pi^0$ are presented at $\bar{p}$ momenta from 600 to 1940 MeV/c. We observe towers of $I = 1$ resonances up to $J^{PC} = 4^{++}$ at ~ 2050 and ~ 2300 MeV [1,2].

1. INTRODUCTION

This work is part of a systematic study of $\bar{p}p$ s-channel resonances in the range accessible at LEAR. The objective is to search for resonances R expected in the formation process $\bar{p}p \rightarrow R \rightarrow f_2(1270)\pi$, $\pi^0\eta$, $\pi^0\eta'$ in the mass range 1960-2410 MeV. The data were taken by the Crystal Barrel collaboration [3].

2. $\bar{p}p \rightarrow \pi^0\eta$, $\pi^0\eta'$

Data on $\bar{p}p \rightarrow \pi^0\eta$ have been obtained from events containing exactly 4γ where $\eta \rightarrow \gamma\gamma$. As a cross-check, they are also obtained from 8γ events where $\eta \rightarrow \pi^0\pi^0\pi^0$. The 4γ events have been selected, after a 6C kinematic fit, with the following cuts on confidence level (CL): (i) $CL(\pi^0\pi^0) < 0.01\%$, (ii) $CL(\pi^0\eta)$ better than the remaining channels $\eta\eta$, $\eta\eta'$ and $\pi^0\eta'$, (iii) in the few cases where more than one combinatoric $\pi^0\eta$ solution is found, events are required to have CL at least a factor of 10 better than the second solution, (iv) $CL(\pi^0\eta) > 10\%$. The tiny background is compatible with the estimate of 1.3% from a Monte Carlo simulation.

The $\pi^0\eta$ sample from 8γ data has been selected with the following confidence level cuts: (i) $CL(4\pi^0) > 10\%$, (ii) $CL(4\pi^0)$ better than other 4-body channels. (iii) any of the rare combinatoric alternatives has CL at least a factor of 10 lower than that selected. The background level of 4% is isotropic within errors.

Fig. 1 shows angular distributions derived from 4γ and 8γ data, compared with partial wave fits described below. The agreement between 4γ and 8γ data is excellent. They are both found to be symmetric forward-backward in the centre of mass system within errors; this is a check on the acceptance calculation and event reconstruction.

Results on $\bar{p}p \to \pi^0\eta'$ come only from 8γ events. For 4γ, the background from the prolific $3\pi^0$ and $\omega\pi^0$ channels are too high ($\sim 40\%$) to allow accurate separation of the $\pi^0\eta'$ signal. For 8γ data, the event selection requires a 10% confidence level cut for $\eta\pi^0\pi^0\pi^0$. Further requirements are: (i) $CL(4\pi^0) < 0.01\%$, (ii) $CL(\eta\pi^0\pi^0\pi^0)$ better than any other 8γ channel, (iii) $CL(\pi^0\eta')$ a factor of 10 better than any combinatoric alternative. The background level is typically 14%, in close agreement with the the Monte Carlo simulation.

Angular distributions have been fitted with Legendre polynomials. Formulae are given in [2]. We find two solutions and both solutions require as a minimum two 4^+ resonances, two 2^+ and one 0^+. Masses and widths are very similar in the two solutions, which differ mostly in phases and coupling constants. We have attempted to relate the fit to $\pi^0\eta'$ data to that for $\pi^0\eta$ using SU(3) constraints. The $(u\bar{u} + d\bar{d})$ content of η and η' may be obtained using the pseudo-scalar mixing angle of $-17.3°$ [4]. These relations imply the relation $G(\pi^0\eta') = 0.75G(\pi^0\eta)$ between coupling constants G. We shall refer to this as 'the SU(3) relation'. We have found solutions close to the SU(3) constraints by including a third 2^+ resonance. Fitted resonances are shown in Table 1 for both solutions. Errors shown there allow 3σ statistical deviations and also cover systematic errors from a variety of fits and systematic errors from uncertainty in the radius of the Blatt-Weisskopf centrifugal barrier (taken to be 0.8 fm everywhere).

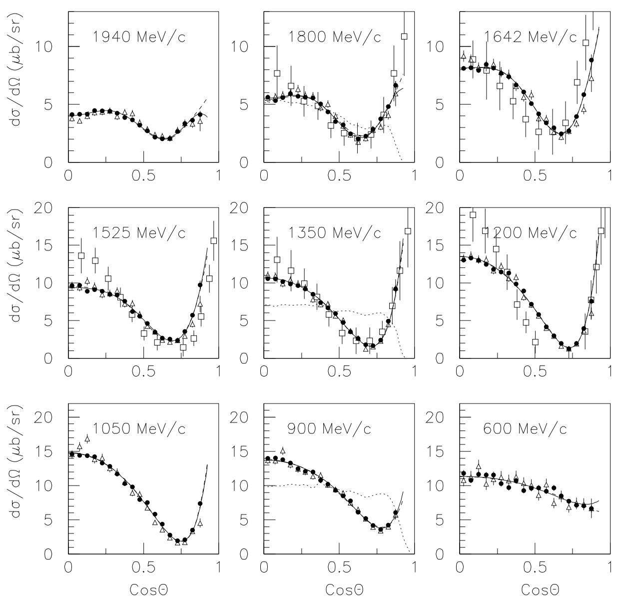

Figure 1. Angular distributions for $\pi^0\eta$ corrected for acceptance. Black circles show results from 4γ and open triangles results from 8γ. Full and dashed curves show fits from solutions 1 and 2 respectively. Dotted curves illustrate the acceptance. Open squares show earlier results of Dulude et al [5] at neighbouring momenta, after renormalisation to obtain the optimum agreement with our normalisation.

J^P	M (MeV/c^2)	Γ (MeV/c^2)	M (MeV/c^2)	Γ (MeV/c^2)
0^+	2025 ± 30	330 ± 75	1980^{+12}_{-80}	225^{+120}_{-32}
2^+	1990^{+15}_{-30}	190 ± 50	1975 ± 17	195^{+50}_{-80}
2^+	2060 ± 20	195 ± 30	2095^{+13}_{-20}	155 ± 30
2^+	2265 ± 20	235^{+60}_{-35}	2278 ± 13	295 ± 45
4^+	2025 ± 40	250^{+80}_{-50}	2130 ± 50	230 ± 80
4^+	2300 ± 20	230 ± 40	2265^{+65}_{-25}	275 ± 32

Table 1
Masses and widths of fitted resonances; columns 2 and 3 show solution 1 and columns 4 and 5 solution 2.

3. $\bar{p}p \to 3\pi^0$

To isolate $3\pi^0$ events, we demand detection of exactly 6 showers. In the present case, the $3\pi^0$ channel is strong and backgrounds are very low. We make a 7C kinematic fit and then require a confidence level (CL) for $3\pi^0 > 10\%$ and a lower confidence level for all other 6γ channels. With this requirement, backgrounds are $\leq 1\%$ at all momenta, The Monte Carlo shows that the main source is $\sim 0.4\%$ from $4\pi^0$, after loss of two photons. Smaller backgrounds arise from $\omega\pi^0\pi^0$, $\omega \to \pi^0\gamma$ after losing one photon (0.3%) and $\pi^0\eta$, $\eta \to 3\pi^0$ (0.2%) after losing 2 photons.

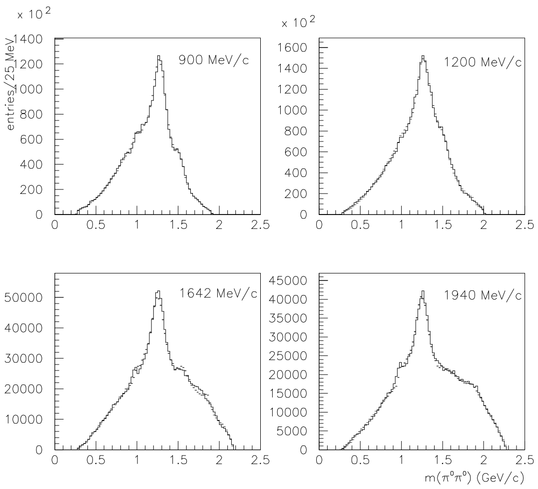

Figure 2. Projections of Dalitz plots on to $M(\pi^0\pi^0)$; curves are from the fit.

Fig. 2 illustrates projections on to $\pi^0\pi^0$ mass. Results at other momenta are similar. The $f_2(1270)\pi$ channel dominates and is the main source of information here. There are small signals due to $f_0(1500)\pi$, $f_0(980)\pi$ and $f_0(1370)\pi$, which are included in the fit. There is a broad background from the $\sigma\pi$ final state, where σ refers to the $\pi\pi$ S-wave.

The amplitude is constructed from Lorentz invariant tensors. For $f_2(1270)\pi$, we include all partial waves up to $J^{PC} = 4^{++}$, with all angular momenta L in the final state up to

$L = 3$. Final states $f_0(1500)\pi$, $f_0(980)\pi$, $f_0(1370)\pi$ and $\sigma\pi$ are all fitted freely up to $L = 4$, i.e. ${}^1G_4$ in $\bar{p}p$, using the K-matrix representation given in Ref.[6].

Fitted masses and widths of resonances are shown in Table 2. Statistical errors are generally negligible; systematic errors are shown covering (i) radii of the centrifugal barriers from 0.6–1.0 fm, (ii) a variety of fits with varying ingredients.

J^{PC}	Mass (MeV)	Width (MeV)
4^{++}	2260 ± 15	180 ± 20
4^{++}	2005 ± 25	360 ± 80
3^{++}	2310 ± 40	180^{+120}_{-60}
3^{++}	2070 ± 20	170 ± 40
2^{++}	2280 ± 30	280 ± 50
2^{++}	2100^{+10}_{-30}	360^{+40}_{-100}
1^{++}	2100 ± 20	300^{+30}_{-60}
1^{++}	2340 ± 40	230 ± 70

Table 2
Masses and widths fitted to resonances from $\bar{p}p \to f_2(1270)\pi$.

4. SUMMARY

In summary, we observe $I = 1$ resonances which appear to fit into towers of resonances around 2050 and 2300 MeV, similar to those found in the $I = 0$ system.

REFERENCES

1. A.V.Anisovich et al., Phys.Lett. B 452(1999) 187.
2. A.V.Anisovich et al., Phys.Lett. B 452(1999) 173.
3. E. Aker et al., Nucl. Instr. A321 (1992) 69.
4. C. Amsler et al., Phys. Lett. B294 (1992) 451.
5. R.S. Dulude et al., Phys. Lett. 79B (1978) 329.
6. V.V.Anisovich, Yu.D.Prokoshkin and A.V.Sarantsev, Phys. Lett. B389 (1996) 388.