Observation of $f_0(1500) \rightarrow (\pi\pi)_S(\pi\pi)_S$ in $\bar{p}p$ annihilation at rest

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We report here on the first observation by the Crystal Barrel of the four–pion decay of the glueball candidate $f_0(1500)$. The Crystal Barrel detector has been described elsewhere. [2] We only mention that it is a nearly 4π solid angle device for detecting both charged particles and photons with good spatial and energy resolution. The detector is used at the Low Energy Antiproton Ring at CERN to observe $\bar{p}p$ annihilations at rest. The $f_0(1500)$ has been observed in several *glue–rich* production mechanisms [3], and its decay to two pseudoscalar mesons has been studied in detail by us. [4] The unusual decay pattern into two pseudoscalar mesons has led to an interpretation of the $f_0(1500)$ as the ground state scalar glueball mixed into the normal scalar nonet. [5]

We observe $f_0(1500)$ in $\bar{p}p \rightarrow f_0(1500)\pi^\circ \rightarrow [\pi^\circ\pi^\circ\pi^\circ\pi^\circ]\,\pi^\circ$ [8]. The data for this 10γ final state come from 18×10^6 $\bar{p}p$ annihilations to final states with zero charged particles. The data are kinematically fit to a $5\pi^\circ$ final state, while events satisfying other 10γ hypothesis such as $\eta 4\pi^\circ$ are rejected. Additionally, events with more than one acceptable $5\pi^\circ$ combinations are rejected. Finally, events satisfying $\eta\pi^\circ\pi^\circ$ with $\eta \rightarrow \pi^\circ\pi^\circ\pi^\circ$ are removed. From the resulting large (on order 100,000) data sample, 25,000 events are used in the spin–parity analysis. 45,000 Monte Carlo events satisfying the same cuts are used for normalization.

A spin parity analysis is performed in the framework of the isobar model. An unbinned maximum likelyhood fit is done over the 8–dimensional phase space to determine what intermediate states are present. In performing the analysis, it is assumed that S–wave initial states dominate the annihilations. Additionally, C–parity prevents the ${}^3S_1$ initial state of the $\bar{p}p$ atom from decaying to $5\pi^\circ$. Only initial ${}^1S_0$ states are considered. From known branching ratios, the annihilation to $5\pi^\circ$ via $f_2(1270)\pi^\circ$ and the $a_1(1260)(\pi^\circ\pi^\circ)$ should play a very small role. This is confirmed by the fit, and they are neglected. Additionally, the $\rho(770)$ does not decay to $2\pi^\circ$.

This leaves as input several spin zero mesons. in the following decays We consider up to three f_0 states: $f_0(1300)$, $f_0(1500)$ and $f_0(1750)$. (1) $f_0 \rightarrow (\pi\pi)_S(\pi\pi)_S$ where $(\pi\pi)_S$ is the isopin zero, $J^{PC} = 0^{++}$ two pion scattering amplitude. [6] (2) $f_0 \rightarrow \pi^*(1300)\pi$, $\pi^* \rightarrow (\pi\pi)_S\pi$, where π^* is the $\pi(1300)$ of the PDG. [7] (3) $\bar{p}p \rightarrow \pi^*(1300)(\pi\pi)_S$. As all spins and angular momenta are 0, we anticipate having difficulty distinguishing a broad $f_0(1300)$ from (1) and the π^* decay from (3). This is indeed what the fit finds.

The one very stable component of the fit is the $f_0(1500) \rightarrow 4\pi^\circ$. The mass and width agree quite well with measured values. Independent of the admixture of (1), (2), and (3), the $f_0(1500)$ represents $(12.7 \pm 1.6)\%$ of the $5\pi^\circ$ final state. Combining this with other Crystal Barrel analyses, we find:

$$r = \frac{B(f_0(1500) \rightarrow 4\pi)}{B(f_0(1500) \rightarrow 2\pi)} = 3.4 \pm 0.8,$$

where 4π means decays not proceeding via $\rho\rho$. The fit is unable to unabigiously separate decays (1) and (2) above; both are present but the exact admixture can not be determined. Additionally, we find two equally good solutions for the remainder of the decay channels. These will not be discussed here.Several projections of the data compared to the best fit are shown in Fig. 1. One can see that the fit does an excellent job of describing the data.

In order to understand this final state and resolve the ambiguities of this analysis, a new analysis of $\pi^+\pi^-3\pi^\circ$ [9], and an analysis of $\bar{p}d \rightarrow \pi^+2\pi^-2\pi^\circ p$ are being performed. The $\pi^+\pi^-3\pi^\circ$ data currently confirm the 4π decay of the $f_0(1500)$.

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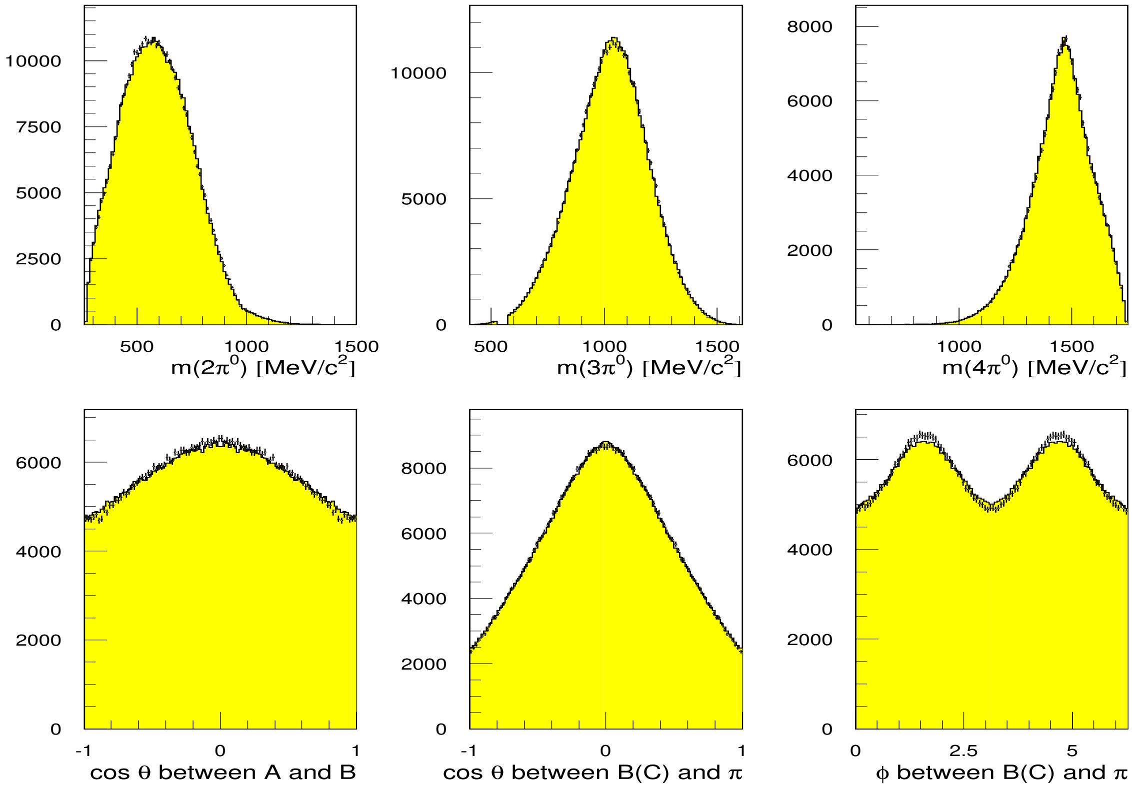

Figure 1: Best fit compared to invariant mass and angular distributions.

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