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Preliminary Results of a PWA of the Centrally Produced $\phi\phi$ System

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Abstract. We present preliminary results of a Partial Wave Analysis of the centrally produced $\phi\phi$ system at 800 GeV/c in the reaction $pp \to p_{slow}(\phi\phi)p_{fast}$. Our preliminary results with one and two $M=0$ waves, indicate that most of the cross section can be described by two waves, with $J^{PC}LS^{\eta}=2^{++}02^{-1},\ 0^{++}00^{-1}$.

The first observation of $\phi\phi$ production was made using the BNL–MPS Spectrometer at 22.6 GeV/c [1] in the OZI [2] suppressed reaction,

$$\pi^- p \to \phi\phi n \tag{1}$$

A Partial Wave Analysis (PWA) of their data showed that only three 2^{++} waves were necessary to fit the data [3]. The larger than expected cross section that was observed indicates that these states may not be conventional $q\bar{q}$ mesons.

We present here our preliminary results of a PWA of the centrally produced $\phi\phi$ system in the 800 GeV/c doubly diffractive reaction,

$$pp \to p_{slow}(\phi\phi)p_{fast}, \quad \phi \to K^+K^- \tag{2}$$

using events of this reaction selected from the 4×10^9 pp interaction data sample recorded by Fermilab E690 during the 1991 fixed target run.

The E690 apparatus consisted of a high rate, open geometry multiparticle spectrometer used to measure the target system (T) in $pp \to p_{fast}(T)$ reactions, and a beam spectrometer system used to measure the incident 800 GeV/c beam and scattered proton. A liquid hydrogen target was located just upstream of the multiparticle spectrometer. The 96 cell Cherenkov counter located at the downstream

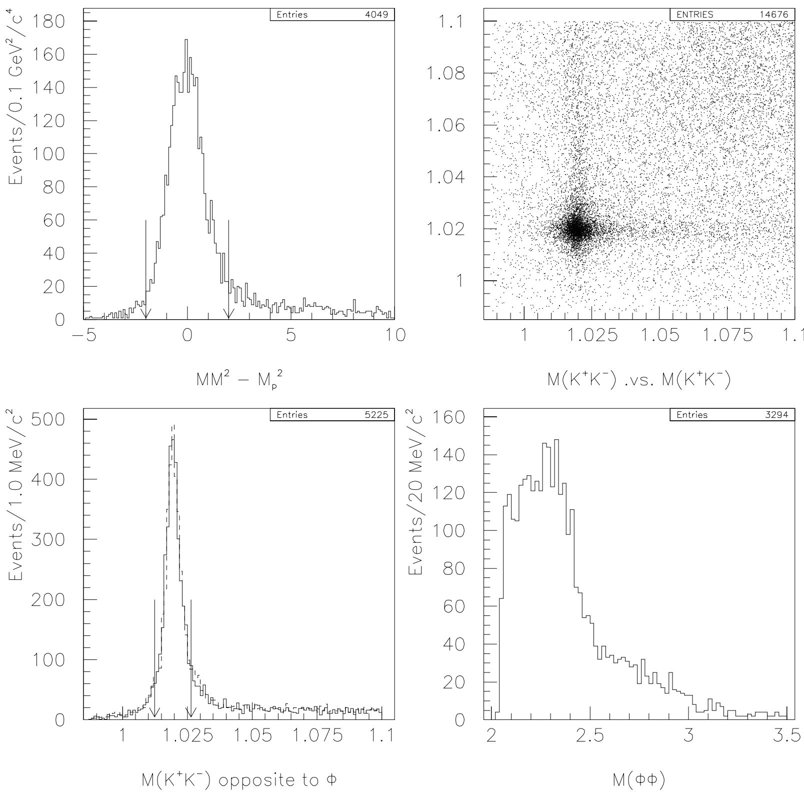

FIGURE 1. Missing mass squared minus proton mass squared for events in reaction (2) (upper left). K^+K^- invariant mass, first vs. second pair (upper right). K^+K^- invariant mass, when the other pair lies in the ϕ–mass band (lower left). $\phi\phi$ invariant mass (lower right).

end of the main spectrometer magnet used Freon 114 as a radiator and had a pion threshold of 2.57 GeV/c. The E690 apparatus has been described elsewhere [4].

After the track and vertex reconstruction stage of the data analysis, final state (2) was selected by requiring a primary vertex in the LH_2 target with two positive and two negative tracks, an incoming beam track and a fast forward proton. Cherenkov particle identification was required for at least one of the four tracks. No direct measurement was made of the slow proton, but a kinematical cut of $p_z < 250\,\mathrm{MeV/c}$ or $\arctan(p_t/p_z) > 30$ for the missing momentum was used to require that it was outside the acceptance of the detector.

The missing mass squared (MM^2) minus proton mass squared shown in Fig.1 has a clear peak around zero for events in reaction (2). The scatter plot shows the first versus second pair mass for the 14678 events selected with $m(K^+K^-) < 1.1$ GeV/c^2 and $-2 < MM^2 - m_p^2 < 2$ GeV^2/c^4. $\phi\phi$ events are predominantly produced over ϕK^+K^- and $K^+K^-K^+K^-$ events, these being the only significant background source. The lower left plot shows the K^+K^- invariant mass, when the other pair lies in the ϕ–mass band of $1.0124 < M(K^+K^-) < 1.0264$ GeV/c^2. The lower right plot shows the $\phi\phi$ invariant mass after all selection cuts, showing a high bump between 2–2.5 GeV/c^2. Only one combination per event enters this plot. 3180

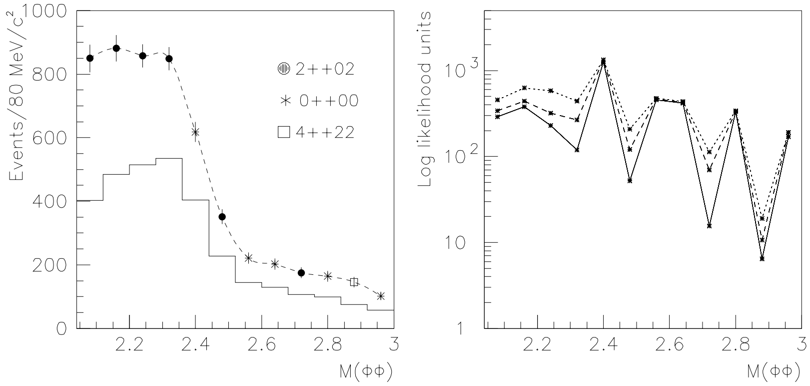

FIGURE 2. Left: $M(\phi\phi)$ data distribution (histogram) and acceptance corrected cross section (markers) from the PWA using only one $M=0$ wave. Right: Log-likelihood difference between the solution with highest likelihood and the next three best solutions, solid, dashed and dotted, respectively, in each bin.

events with $M(\phi\phi) < 3$ GeV/c^2 remain.

Six angles are chosen to specify the spin and angular momentum of the $\phi\phi$ system. Two of them (γ, β) are defined as the Gottfried-Jackson (GJ) angles of one of the ϕ mesons, in the rest frame of the $\phi\phi$ system, with the z-axis in the direction of $\vec{p}_{fast} - \vec{p}_{beam}$, and the y-axis in the direction of the $\vec{p}_{fast} - \vec{p}_{beam} \times \vec{p}_{slow} - \vec{p}_{tgt}$ cross product. The rest are the two pairs of GJ angles $(\alpha_{1,2}, \theta_{1,2})$ for the K^+'s in their parent ϕ rest frames, with the z'-axis in the direction of $\vec{p}_\phi$, and with $y' = \hat{z} \times \hat{z}'$.

The allowable $\phi\phi$ basis vectors in terms of the total angular momentum J, orbital angular momentum L, parity P, and exchange naturality η, are given by [5]

$$G^{J^P LSM^\eta}(\gamma, \beta, \alpha_1, \alpha_2, \theta_1, \theta_2) = \text{Real}\left[\frac{(1-i) - \eta(1+i)}{2} \sum_{\mu,\lambda} C(1,1,S|\mu,-\lambda) \times \right.$$
$$\left. C(L,S,J|0,\mu-\lambda) e^{iM\gamma} e^{i\mu\alpha_1}\ e^{i\lambda\alpha_2} d^J_{M,\mu-\lambda}(\beta)\ d^1_{\mu,0}(\theta_1)\ d^1_{\lambda,0}(\theta_2)\right] \qquad (3)$$

where $M = |J_z|$. For this system $I = 0$, $C = +$, and $L+S =$ an even number.

We performed a PWA of our data divided in 12 bins of 80 MeV/c^2 beginning at 2.04 GeV/c^2, using only the 14 $M=0$ waves. The results with one wave only are shown in Fig.2. Only two waves are seen for the data below 2.6 GeV/c^2, $J^{PC}LS^\eta = 2^{++}02^{-1},\ 0^{++}00^{-1}$. The acceptance corrected cross section shows high acceptance for this reaction. Monte Carlo events for acceptance corrections were generated flat in all six angles, $\phi\phi$ mass, and x_F of the $\phi\phi$ system. No background subtraction was used for the analysis. The plot on the right shows that the second best solution was at least 3.5 sigmas away ($n_\sigma = \sqrt{2\,\Delta(\ln\mathcal{L})}$).

The results with two waves are shown in Fig.3. We added one wave at a time to the one wave solution, and selected the best solution. Below 2.6 GeV/c^2 the cross section is mainly comprised of only two waves, $J^{PC}LS^\eta = 2^{++}02^{-1},\ 0^{++}00^{-1}$. The solid line in the plot on the right in Fig.3 shows that including a second wave greatly improves the significance of the PWA.

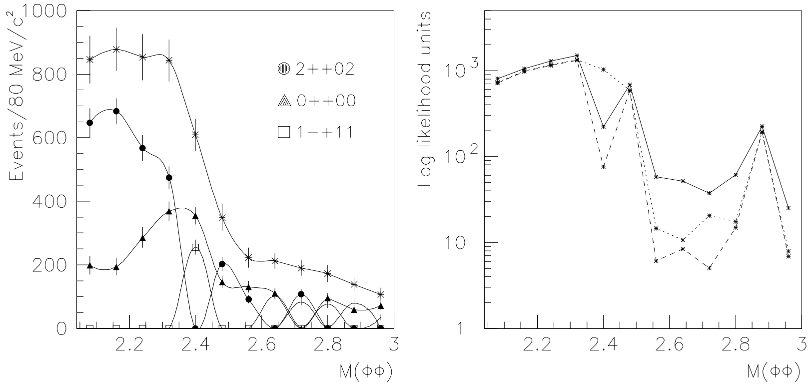

FIGURE 3. Left: PWA results with two $M = 0$ waves. Below 2.6 GeV/c^2 we still found that waves $2^{++}02$ and $0^{++}00$ describe most of the cross section (*). Curves are only used to follow waves from bin to bin. Right: Log-likelihood difference between the one-wave and two-wave solutions (continuous line.) The dotted and dashed lines show the difference to the next two best two-wave solutions in each bin.

CONCLUSIONS

We report preliminary results of a PWA of the centrally produced $\phi\phi$ system. Using only $M = 0$ waves, we find that most of the cross section can be described using only two waves, with $J^{PC}LS^{\eta} = 2^{++}02^{-1}$, $0^{++}00^{-1}$. Since we are only using $M = 0$ waves at this time, we suspect that results may change when including $M = 1$ waves.

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