Photoproduction of High-Mass Di-Pion Pairs at 15 BeV*

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We have measured the cross section for the photoproduction of di-pions in the mass range 0.9-2.2 BeV/c^2. The experiment was performed with a 16-BeV bremsstrahlung beam on a Be target. Upper limits on the cross section for photoproduction of high-mass vector mesons are determined.

Most of the previous studies of di-pion photoproduction have been confined to the mass range $M_{\pi\pi} \lesssim 1$ BeV/c^2 where ρ production dominates. Two studies of high-mass production at forward angles and at photon energies less than 9 BeV have been reported in the literature.[1,2] The work reported here covers the range of momentum transfer $|t-t_{\min}| \leq 0.3$ (BeV/c)^2 and di-pion decay angle $\theta_{\pi\pi}$, $|\cos\theta_{\pi\pi}| \leq 0.6$.

The experimental technique, described in more detail elsewhere,[3] consisted of a 16-BeV bremsstrahlung beam incident on a Be target which was followed by an analyzing magnet and a system of scintillator hodoscopes and wire spark chambers. The geometry of the system was arranged so that the di-pion mass acceptance (for energies $\gtrsim$14 BeV) extended from 0.7 to 2.5 BeV/c^2 and was very insensitive to mass from 1 to 2 BeV/c^2.

As the incident photon and target recoil were not observed, each event was analyzed on the assumption that the reaction was of the form $\gamma + A \rightarrow A + \pi^+ + \pi^-$. A comparison of the energy spectra of the di-pions and the incident photon beam reveals that for $E_{\pi\pi} \geq 14$ BeV, the upper limit on the inelastic contamination is 10% for $M_{\pi\pi} \leq 1.0$ BeV/c^2 and 25% for $1.0 \leq M_{\pi\pi} \leq 2.0$ BeV/c^2.

The spectrometer acceptance was unfolded from the observed distributions with the assumption that the cross section was azimuthally uniform in the helicity system.

We observed a total of 620 events in the intervals $E_{\pi\pi} \geq 14$ BeV, $|t-t_{\min}| \leq 0.3$ (BeV/c)^2, $0.9 \leq M_{\pi\pi} \leq 2.2$ BeV/c^2, and $|\cos\theta_{\pi\pi}| \leq 0.6$. The distribution of weighted events versus polar decay angle $\theta_{\pi\pi}$ evaluated in the helicity system is shown in Fig. 1. The cutoff at $\cos\theta_{\pi\pi} = 0.6$ is imposed by the acceptance. The data are consistent with p-wave-dominated di-pions following a $\sin^2\theta_{\pi\pi}$ distribution indicated by the smooth curve.

The momentum-transfer distribution is shown for two mass regions in Fig. 2. It is clear from the data that this distribution changes significantly as the di-pion mass is varied. This change

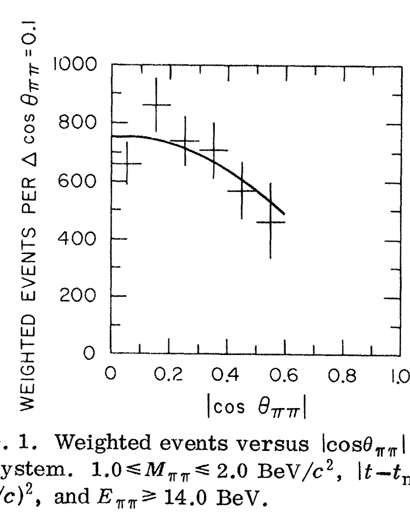

FIG. 1. Weighted events versus $|\cos\theta_{\pi\pi}|$ in the helicity system. $1.0 \leq M_{\pi\pi} \leq 2.0$ BeV/c^2, $|t-t_{\min}| \leq 0.3$ (BeV/c)^2, and $E_{\pi\pi} \geq 14.0$ BeV.

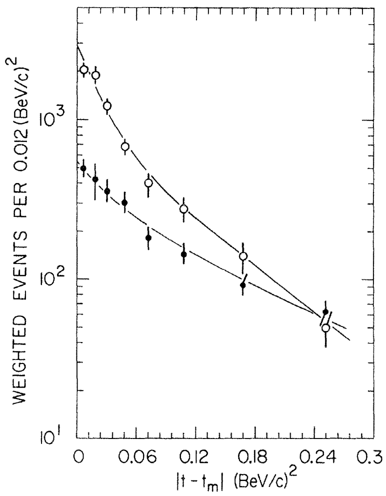

FIG. 2. Momentum-transfer distributions for $E_{\pi\pi} \geq 14.0$ BeV, $|\cos\theta_{\pi\pi}| \leq 0.6$, $0.8 \leq M_{\pi\pi} \leq 1.0$ BeV/c^2 (open circles), and $1.0 \leq M_{\pi\pi} \leq 2.0$ BeV/c^2 (closed circle). Smooth curves are drawn only as a viewing aid.

cannot be explained by the nuclear form factor. In Fig. 3 we plot versus $M_{\pi\pi}$ the ratio of the forward $[t = t_{\min} = -(M_{\pi\pi}^2/2E_{\pi\pi})^2]$ cross section to the cross section at $t - t_{\min} = -0.12$ (BeV/c)^2. The curves are calculations of the expected ratio assuming (a) that the effect is due solely to the variation of the nuclear form factor with $t_{\min}$, $e^{45 t_{\min}}$, and (b through d) that, in addition to (a), there is Drell-type di-pion production that interferes with the ρ production.[4] This model predicts that the t slope of the elementary process $\gamma + p \to p + \pi^+ + \pi^-$ depends upon $M_{\pi\pi}$ and is supported, for $M_{\pi\pi} \leq 1.4$ BeV/c^2, by experiment.[5] In Figs. 3 and 4, curves b-d assume different functions for the ρ width:

$$\Gamma_b = \Gamma_\rho \frac{M_\rho}{M_{\pi\pi}} \frac{q^3}{q_\rho^3},$$

$$\Gamma_c = \Gamma_b \frac{1 + R^2 q_\rho^2}{1 + R^2 q^2},$$

$$\Gamma_d = \Gamma_\rho \text{ for } M_{\pi\pi} \geq M_\rho,$$

with q the pion momentum in the π-π c.m., $M_\rho = 0.765$ BeV/c^2, $\Gamma_\rho = 0.140$ BeV, and $R^2 = 2.3$ (BeV/c)$^{-2}$.

In Fig. 4 we show the weighted yield [for $|t - t_{\min}| \leq 0.046$ (BeV/c)^2] versus $M_{\pi\pi}$ and the expectations (normalized to the ρ peak) based on the model of ρ production plus interfering Drell-type di-pions.[4] This small-t region, where coherence dominates, would most sensitively reveal the presence of any vector mesons.

There is no consistency between the data and

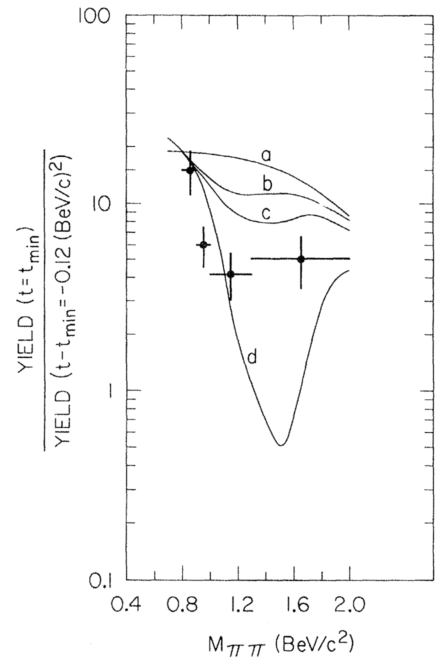

FIG. 3. Variation with $M_{\pi\pi}$ of ratio of cross sections at $t = t_{\min}$ to that at $t - t_{\min} = -0.12$ (BeV/c)^2. $E_{\pi\pi} \geq 14.0$ BeV, $|\cos\theta_{\pi\pi}| \leq 0.6$. Curves explained in text.

the model-dependent calculations as displayed in Figs. 3 and 4. Although the precise manner in which the ρ tail disappears is unknown, we believe that the widths Γ_b and Γ_d represent the extremes and that the truth is intermediate to these. An upper limit for any di-pion production $d\sigma_v/dM_{\pi\pi}$ in excess of ρ and Drell-type production

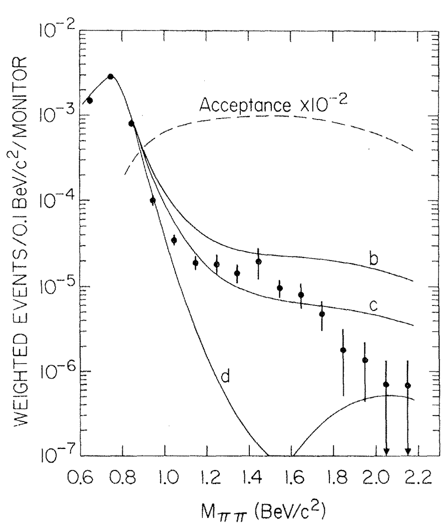

FIG. 4. Variation of yield versus $M_{\pi\pi}$ for $|t - t_{\min}| \leq 0.046$ (BeV/c)^2, $|\cos\theta_{\pi\pi}| \leq 0.6$, and $E_{\pi\pi} \geq 14.0$ BeV. (Data for $M_{\pi\pi} \leq 0.9$ BeV/c^2 acquired from our study of ρ photoproduction at 16 BeV.) Dashed curve is the calculated acceptance and the solid curves are explained in text.

can be deduced from the difference between the data and curve d, Fig. 4. Assuming that all dipions have a $\sin^2\theta_{\pi\pi}$ distribution we deduce at $M_{\pi\pi}=1.4$-1.6 BeV/c^2 the upper limit

$$d\sigma_v/dM_{\pi\pi} \leq 10^{-2}(d\sigma/dM_{\pi\pi})_{M_{\pi\pi}=M_\rho}.$$

If we attribute this possible excess to the production of a vector meson which couples directly to the photon and further assume $\Gamma_v=\Gamma_\rho$ and unit branching ratio to two pions, then we conclude that $g_{v\gamma}^2/g_{\rho\gamma}^2 \leq 10^{-2}$, $g_{v\gamma}^2$ being the direct meson-photon coupling strength. We can also deduce an upper limit for $f(1260)$ production of $2\times10^{-2}\sigma_\rho$, the factor of 2 arising from the difference in the acceptance of a 1^- and 2^+ di-pion system. Coherent photoproduction of a 2^+ state violates C conservation and the ratio of forbidden to allowed cross section of 2×10^{-2} enables one to delimit the violation.

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Photoproduction of ω Mesons from Hydrogen and Deuterium*

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ω-meson photoproduction cross sections, summed over elastic ($\gamma N\to\omega N$) and inelastic ($\gamma N\to\omega N^*$) channels, have been measured from hydrogen and deuterium targets. The results agree with a calculation which includes only elastic and $N^*(1236)$ channels, suggesting that photoproduction of higher resonances is small. No evidence is found for $I=1$ natural-parity (e.g., A_2) exchange.

Experimental studies of ω-meson photoproduction have been limited to date to two counter experiments using complex nuclei as targets,[1,2] and a few hydrogen bubble chamber experiments.[3-7] This Letter presents results of the first counter experiment utilizing hydrogen and deuterium targets. Unlike most of the bubble chamber experiments, inelastic ω photoproduction ($\gamma N\to\omega N^*$) is detected, as well as elastic ($\gamma N\to\omega N$), providing information about the inelastic cross section. Use of both hydrogen and deuterium gives information about the spin-isospin structure of the production amplitudes. In particular, the prediction of substantial A_2 exchange, suggested by the γp, γn total hadronic cross-section difference,[8,9] is investigated.

Using a 9.1-GeV bremsstrahlung beam from the Cornell electron synchrotron, photoproduced ω mesons were detected through their $\pi^+\pi^-\pi^0$ decay. The equipment is nearly identical to that described in Ref. 1. The target was a 5-cm-diam liquid-filled cup. The charged pions from ω decay were momentum analyzed by deflection in a dipole magnet, and their tracks recorded with a wire spark-chamber system. The momentum and mass of the π^0 were determined by measurement of the energy and position of the decay γ rays. Knowing the direction, but not the energy, of the primary γ beam, all kinematical variables of the photoproduced ω could be computed. However, the degree of excitation of the target could not be determined. Thus, a sum of reactions of the type

$$\gamma+\begin{Bmatrix}p\\d\end{Bmatrix}\to\omega+\begin{Bmatrix}N\\2N\end{Bmatrix}+k\pi,\quad k=0,1,2, \tag{1}$$

was measured, subject to the conditions that the ω had an energy greater than 5 GeV, and that no particles other than those from ω decay were registered by the detection equipment. Neutral particles, and charged particles below 1 GeV/c, had very small chance of registering. Thus, in