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MEASUREMENT OF THE ASYMMETRY PARAMETER IN THE PHOTOPRODUCTION OF ϕ MESONS

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ABSTRACT

We have measured the asymmetry parameter $\Sigma = \frac{\sigma_{\parallel} - \sigma_{\perp}}{\sigma_{\parallel} + \sigma_{\perp}}$ for the photoproduction of ϕ mesons with photons polarized parallel and perpendicular to the plane of decay for the reaction $\gamma P \rightarrow \phi P \rightarrow K^+K^-P$. $\Sigma = .985 \pm .12$ at a photon energy of 8.14 GeV and $|t|$ of .2 $(\mathrm{GeV/c})^2$, consistent with pure diffraction production, or pure natural parity Regge exchange.

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As first pointed out by Freund and more recently by Barger and Cline[1] ϕP elastic scattering is expected to proceed purely by Pomeron exchange, and therefore photoproduction of ϕ mesons should be purely diffractive. If this is correct, polarized photons should produce ϕ's with polarizations 100% correlated with the incident polarization.

Specifically, the asymmetry Σ, defined in terms of the yield of ϕ mesons $\sigma_{\parallel}$ produced with a polarization vector parallel to the incident photon polarization and the yield $\sigma_{\perp}$ normal to the incident photon polarization vector, should be unity:[2]

$$\Sigma = \frac{\sigma_{\parallel} - \sigma_{\perp}}{\sigma_{\parallel} + \sigma_{\perp}} = 1$$

In the present experiment, the detection plane of the K pairs from the decay $\phi \rightarrow K^+K^-$ is fixed perpendicular to the production plane and the photon beam has a polarization which may be oriented perpendicular or parallel to the production plane. The measured asymmetry A is defined as $A = \frac{N_{\perp} - N_{\parallel}}{N_{\perp} + N_{\parallel}}$ where $N_{\perp}$ ($N_{\parallel}$) is the coincidence counting rate, corrected for accidentals, with the photon beam polarization vector normal (parallel) to the production plane.

The quantity Σ is related to the measured asymmetry A by:

$$\Sigma = \frac{A}{|P_{\gamma}| \, (1 - \epsilon)}$$

where $|P_{\gamma}|$ is the magnitude of the photon beam polarization and ϵ is a small correction factor, about 6%, due to the finite angular acceptance of the K pair spectrometer. In terms of density matrix elements

$$\Sigma = \frac{\rho^{1}_{11} + \rho^{1}_{1-1}}{\rho^{0}_{11} + \rho^{0}_{1-1}} .$$

Our measured result as described below is fully consistent with that expected from diffraction scattering or more generally from natural parity Regge exchange. (i.e. $\rho^{1}_{1-1} = \rho^{0}_{11} = 1/2$, $\rho^{0}_{1-1} = \rho^{1}_{11} = 0$).

Results of the Cornell group[3] apparently showed that this asymmetry parameter for ϕ production was not unity, as would be expected from pure diffractive processes, but was $.55 \pm .13$ and thus threw doubt on the above interpretation.

As we were interested in investigating the nature of the ϕ diffractive process, we repeated the Cornell measurement. In order to eliminate the possible contamination by inelastic photoproduction of ϕ mesons, which was a possibility in the Cornell experiment, we added the additional requirement that the recoiling proton also be identified in coincidence with the ϕ meson. With this requirement we observed, as described below, an asymmetry close to unity. The Cornell group[4] have in part repeated their measurements on ϕ production with a proton coincidence requirement and find an inelastic contribution of 14% to their original measurements. They state that this inelastic fraction may substantially affect the polarization observed in their experiment and in fact may be responsible for the departure of their measured asymmetry from unity.

We have measured phi photoproduction with polarized photons of 8.14 GeV and at a value of the four-momentum transfer squared $t = -.2(\mathrm{GeV}/c)^2$. This was close to but not identical with the Cornell measurements at 5.7 GeV and $|t| \approx 0$.

The layout of the experiment is shown in Fig. 1. A well prepared 19 GeV electron beam is focused onto a suitably oriented diamond .1 cm thick. After the radiator the electrons are deflected into a beam dump, and the photon beam, as defined by several collimators, is passed through a liquid hydrogen target and stopped in a small secondary emission quantameter located near the K spectrometer. The SLAC polarized photon beam has been described in detail earlier[5]. A ϕ signal was defined as a coincidence between a recoil proton in the 1.6 (GeV/c) spectrometer and a K pair in the forward K spectrometer. The proton spectrometer defined the t value and the missing mass of the boson system, whereas the K spectrometer ensured that we were dealing with a K pair with the phi mass. This is a severe constraint which essentially eliminates both the background associated with photons above the polarized spike and the background of lower mass states. This was verified by moving either the P spectrometer or the K spectrometer off the ϕ mass.

The K spectrometer, as shown in Fig. 1, consisted of two 18D72 magnets (the gaps of the magnets were respectively 17.8 cm and 25.4 cm). The first magnet creates a crossover point between the two magnets and the second magnet bends the trajectories parallel to the horizontal plane. The acceptance of the system was defined by lead channels in the magnets. The slits at the crossover point and at the exit and the entrance of the magnet system served to eliminate particles outside of this acceptance. The counter system consisted of two differential gas Cerenkov counters to identify the K 's and lucite counters to define the Cerenkov counter apertures. The acceptance of the system for K pairs was approximately 10 MeV/c in transverse momentum, 10% in azimuth, and 10% in $\Delta k/k$ photon energy centered at 8.14 GeV.

On the average we ran at a rate of 10 events per hour with a beam intensity of $\sim 10^{11}$ E.Q./sec. Our signal was about four times the rate due to random coincidences. To eliminate any long term drifts or biases the beam polarization was checked periodically and the polarization direction was changed every hour by rocking the diamond.

The measured value for A at $t = -.2(\mathrm{GeV/c})^2$ at an average photon energy of 8.14 GeV was $.611 \pm .075$ corresponding to a total of 379 ϕ events. The polarization of the photon beam was .660 with a possible systematic error of $\pm 2\%$. This leads to a final asymmetry of $.985 \pm .12$, i.e., a result consistent with only natural parity exchange or diffraction production. We therefore conclude that the asymmetry parameter is close to one and is in agreement with theoretical expectations.

We wish to thank John Grant, Justino Escalera and Jack Schroeder who gave us invaluable support with the setup of the experiment. We wish to acknowledge the the help we received from the operations group and the spectrometer facilities group at SLAC. In particular, we wish to thank Bob Eisele who designed the carriage for the K pair spectrometer and Dieter Walz who arranged for the procurement of the high quality diamonds for the polarized beam facility. We would like to thank Charles Hoard for his help in the design and fabrication of the differential Cerenkov counter.

REFERENCES

1. P. G. Freund, Nuovo Cimento 48A, 541 (1967), V. Barger and D. Cline, Phys. Rev. Letters 24, 1313 (1970).
2. K. Schilling, P. Seyboth, and G. Wolf, Nuclear Physics B15, 397 (1970). The notation used for polarized beam experiments is discussed fully in this reference.
3. G. McClellan *et al.*, Phys. Rev. Letters 26, 1597 (1971).
4. C. Berger *et al.*, Phys. Lett. 39B, 659 (1972).
5. R. Schwitters, SLAC-TN-70-32, 1970.

FIGURE CAPTIONS

1. Experimental apparatus. The recoil proton is detected by the SLAC 1.6 GeV/c spectrometer and the K mesons from the decay of the ϕ meson are detected by a pair spectrometer. For clarity the horizontal scale is twice as large as the vertical scale.

LAYOUT FOR EXPERIMENT

$$\gamma + P \longrightarrow P + \phi^{\circ}, \quad \phi^{\circ} \longrightarrow K^{+} + K^{-}$$

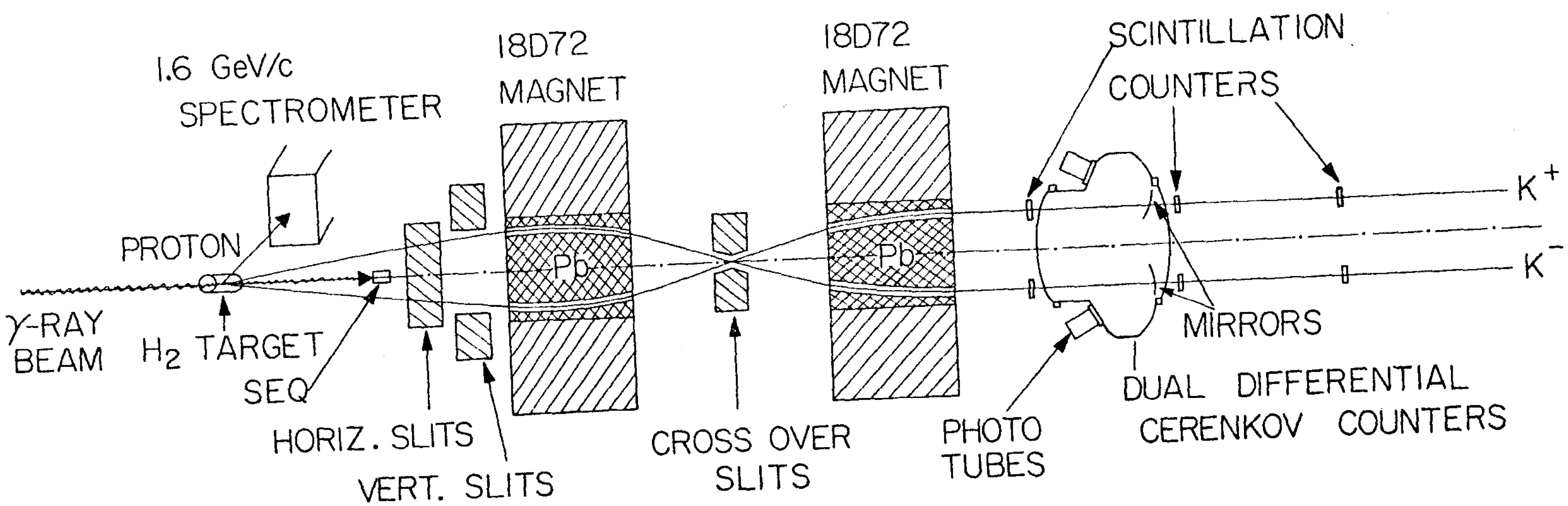

Fig. 1