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UPPER LIMITS ON $\phi\phi$ PRODUCTION IN 350 GeV/c PROTON-BERYLLIUM COLLISIONS

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Abstract

We have established a sensitive upper limit on $\phi\phi$ resonance production by 350 GeV/c protons incident on a beryllium target. The 90% confidence level upper limit varies from 1.5×10^{-30} cm^2/nucleon at $M_{\phi\phi} = 2.8$ GeV/c^2 to 6.0×10^{-32} cm^2/nucleon at $M_{\phi\phi} = 3.4$ GeV/c^2. We observe no evidence of the η_c.

Since the discovery of the J/ψ[1] ($J^{PC} = 1^{--}$), a great deal has been learned about the spectroscopy of charm-anticharm quark pairs.[2] One of the puzzles in this study has been the appearance[3,4] and disappearance[5,6] of the η_c ($J^{PC} = 0^{-+}$), the pseudoscalar 1^1S_0 state of the $c\bar{c}$ pair. Recently a possible candidate was discovered at SPEAR[7] with a mass which is consistent with theoretical expectations.[8] This resonance has not yet been seen in hadronic interactions.

There have been several attempts to produce the η_c through hadronic interactions.[4,9] Assuming that the J/ψ and η_c are produced via gluons[10], the η_c hadronic production cross section should be much larger than the J/ψ. The problem is to find the appropriate decay mode to detect the η_c. Lipkin[11] has suggested that the cross section times branching ratio for the J/ψ into two leptons is approximately equal to the cross section times branching ratio for $\eta_c \to \phi\phi$ and that the signal to background in this mode should be very good. Following this suggestion we have performed a search for the $\eta_c \to \phi\phi$ in the Proton Center Area at Fermilab, where we detect the ϕ via its K^+K^- decay mode.

We used a total of 1.2×10^{13} 350 GeV protons incident upon a beryllium target. The experimental apparatus was a double arm spectrometer which had been used in a previous experiment.[12] The spectrometer was modified for this experiment by removing the Be absorber in the target box, adding additional scintillation counters downstream of the air dipole magnet and adding additional mirrors in the Cerenkov counter in one arm. In

addition the Cerenkov counter gas in both arms was changed from N_2 to CO_2. A schematic of the spectrometer is shown in Fig. 1. The air dipole magnets had a p_T kick of 0.35 GeV.

The acceptance of our apparatus for the η_c was computed assuming that the η_c transverse momentum, p_T, distribution is the same as the J/ψ.[14,15] We also assume that the cross section is flat in rapidity y, in the range of our acceptance, $-0.5 < y < +0.1$. The ϕ decay to K^+K^- is assumed to have $\sin^2\theta$ distribution where θ is the angle of one of the K's in the helicity frame of the ϕ. The acceptance for the η_c as a function of its mass is shown in Fig. 2.

The Cerenkov counter in each arm was used to discriminate against $\pi^\pm$ mesons. Since the Cerenkov threshold for $\pi^\pm$ in CO_2 is 4.9 GeV, we placed a lower momentum cut of 5.5 GeV on the data. Charged particles passing the momentum cut and producing no photons in the Cerenkov counter were called $K^\pm$ mesons. Included in this sample of K's were protons and antiprotons which we could not reject.

The acceptance shown in Fig. 2 includes all efficiencies for the experiment. In addition to the geometric efficiency, it includes the square of the branching fraction $(\phi \to K^+K^-/\phi \to \text{all})^2 = 0.24$; four K survival efficiency, 0.23 to 0.34 depending on $\phi\phi$ mass; efficiency of Cerenkov momentum cut, 0.70; track reconstruction efficiency, 0.85; and the live time of 0.80.

In addition to the double arm $\phi\phi$ data, we took single arm ϕ calibration data prescaled by a factor of 2048. The mass distribution of the single arm K^+K^- pairs summed over both arms is shown in Fig. 3a. The observed 3 MeV width is in agreement with the computed resolution of our apparatus folded in with the intrinsic width of the ϕ. The transverse momentum, p_T, distribution of the single arm ϕ's is shown in Fig. 3b, averaged over both arms. Also shown is the data of Akerlof et. al.,[13] which were taken with 400 GeV protons incident on beryllium.

The mass distribution for the double arm (K^+K^-) (K^+K^-) events is shown in Fig. 4a. If we place a mass cut in each arm at the ϕ mass $\pm$10 MeV, we obtain the distribution shown in Fig. 4b.

From Fig. 4b we obtain upper limits to the branching ratio times the cross section for the η_c as a function of mass, as is shown in Fig. 5. We have also inserted the results from previous Brookhaven[9] and Serpukhov[3] experiments, after scaling them to our kinematic and energy regions. The Brookhaven upper limit (22.6 GeV $\pi^- p \to \phi\phi n$, exclusive) assumes that the η_c cross section scales like the ψ[15], and that the inclusive cross section is equal to the exclusive cross section at the energy of the Brookhaven experiment. The Serpukhov point (40 GeV $\pi^- p \to \gamma\gamma n$, exclusive) assumes in addition that the exclusive cross section scales as $\frac{1}{p}$ between Brookhaven and Serpukhov energies.

In conclusion we have searched for the η_c using its $\phi\phi$ decay mode. We obtain a cross section time branching ratio 90% confidence level upper limit of 330 nbarns at a mass of 2.98 GeV.

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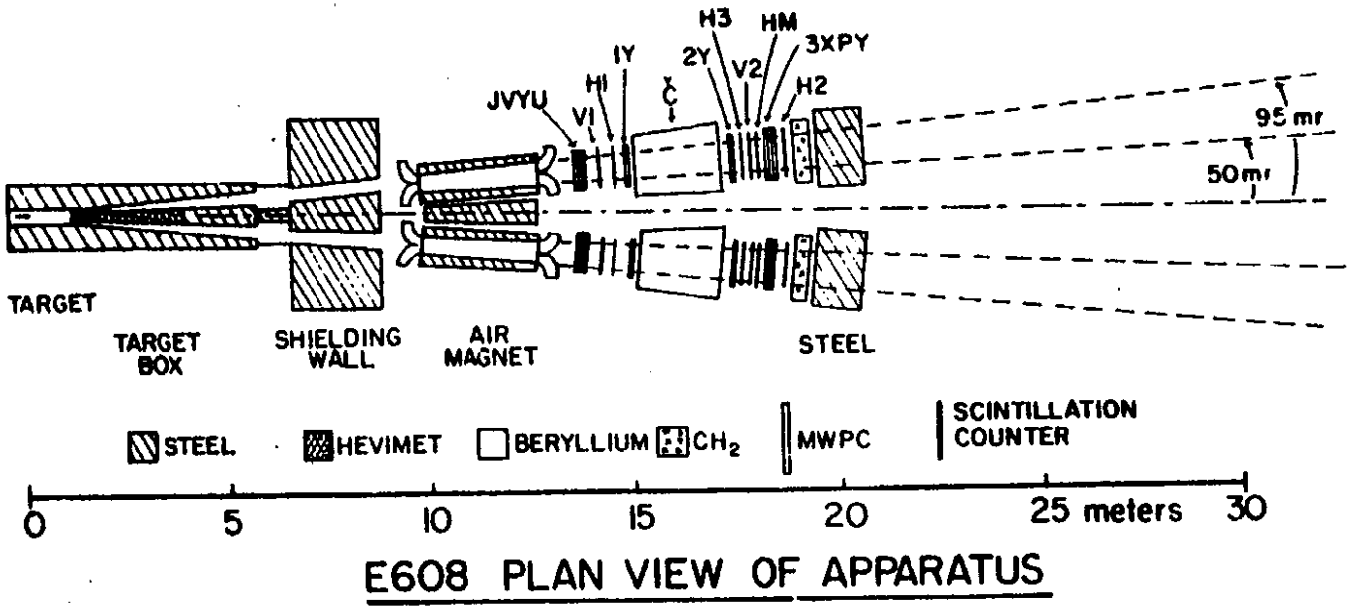
REFERENCES

1. J.J. Aubert et al., Phys. Rev. Lett., 33, 1404 (1974). J.-E. Augustin et al., Phys. Rev. Lett., 33, 1406 (1974).
2. See for example, C. Quigg, Proc. International Symp. on Lepton and Photon Interactions at High Energy, Batavia, IL. (1979).
3. W. Braunschweig et al., Phys. Lett. 67B, 243 (1977).
4. W.D. Apel et al., Phys. Lett. 72B, 500 (1978).
5. R. Partridge et al., Phys. Rev. Lett., 44, 712 (1980).
6. C.J. Biddick et al., Phys. Rev. Lett., 38, 1324 (1977).
7. E.D. Bloom, Proc. International Symp. on Lepton and Photon Interactions at High Energy, Batavia, IL. (1979).
8. K. Gottfried, Proc. International Symp. on Lepton and Photon Interactions at High Energies, Hamburg, Germany (1977).
9. A. Etkin et al., Phys. Rev. Lett., 40, 422 (1978).
10. C.E. Carlson and R. Suaya, Phys. Rev. D14, 3115 (1976).
11. H.J. Lipkin, in Prospects for Strong Interaction Physics at Isabelle, BNL 50701 (1977).
12. S.W. Herb et al., Phys. Rev. Lett., 39, 252 (1977).
13. C.W. Akerlof et al., Phys. Rev. Lett. 38, 861 (1977).
14. H.D. Snyder et al., Phys. Rev. Lett., 36, 1415 (1976).
15. B.C. Brown et al., Fermilab 77/54-EXP, 7100.288.



E608 PLAN VIEW OF APPARATUS

Fig. 1. Plan view of the apparatus in the P-Center pit. V1 and V2 are arrays of vertical scintillation counters which view the target in the non-bend view. H1, H3, HM and H2 are arrays of horizontal scintillation counters which were used to trigger on a +- pair in each arm.

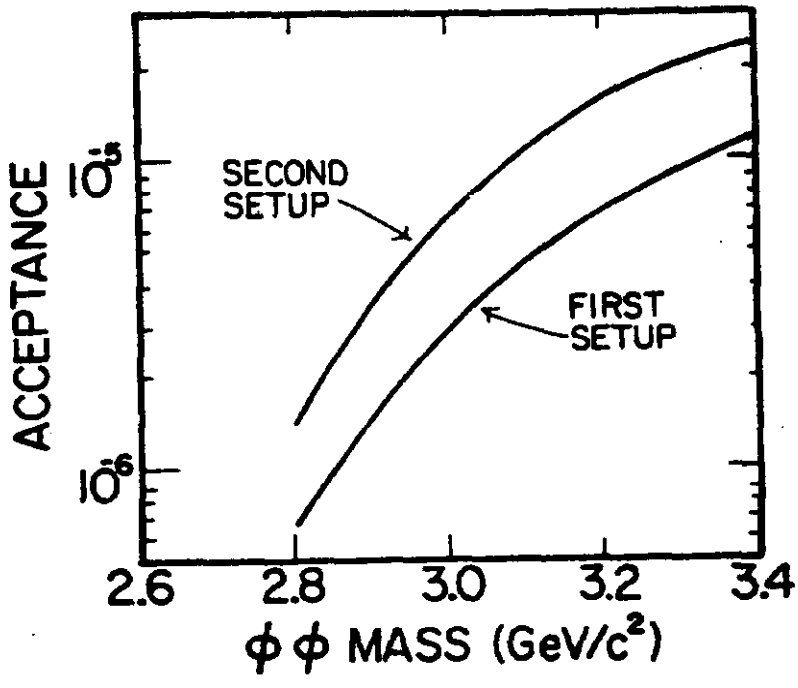


Fig. 2 Acceptance for $\phi\phi$ pairs. The second setup included the HM counter shown in Figure 1.

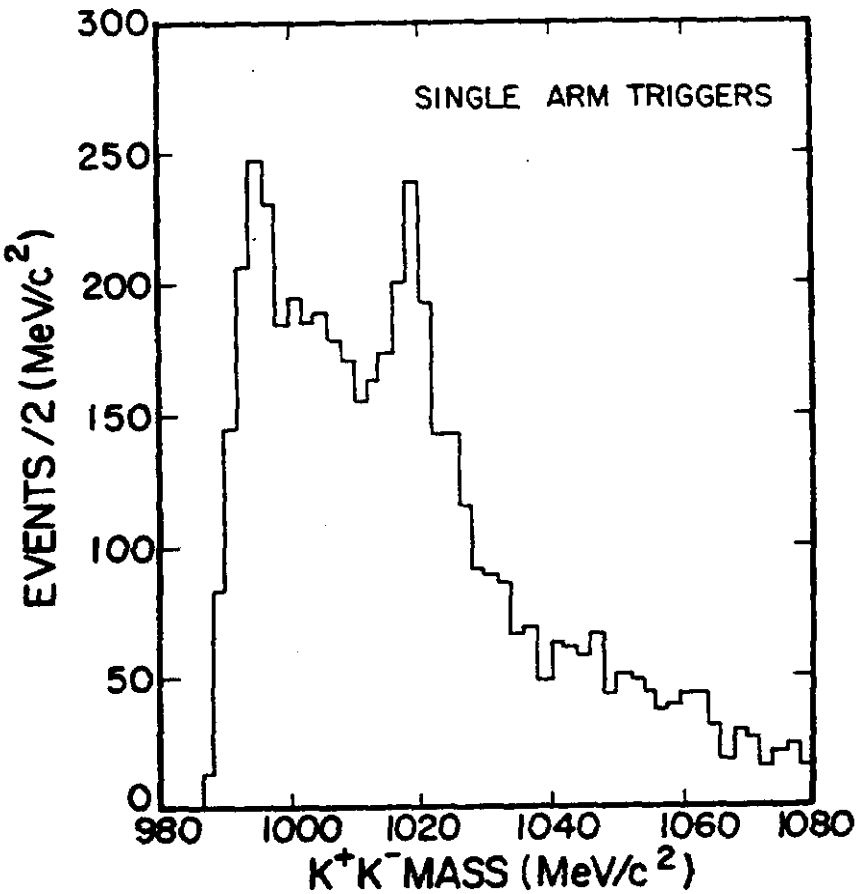


Fig. 3 a)K^+K^- mass spectrum summed over both arms.

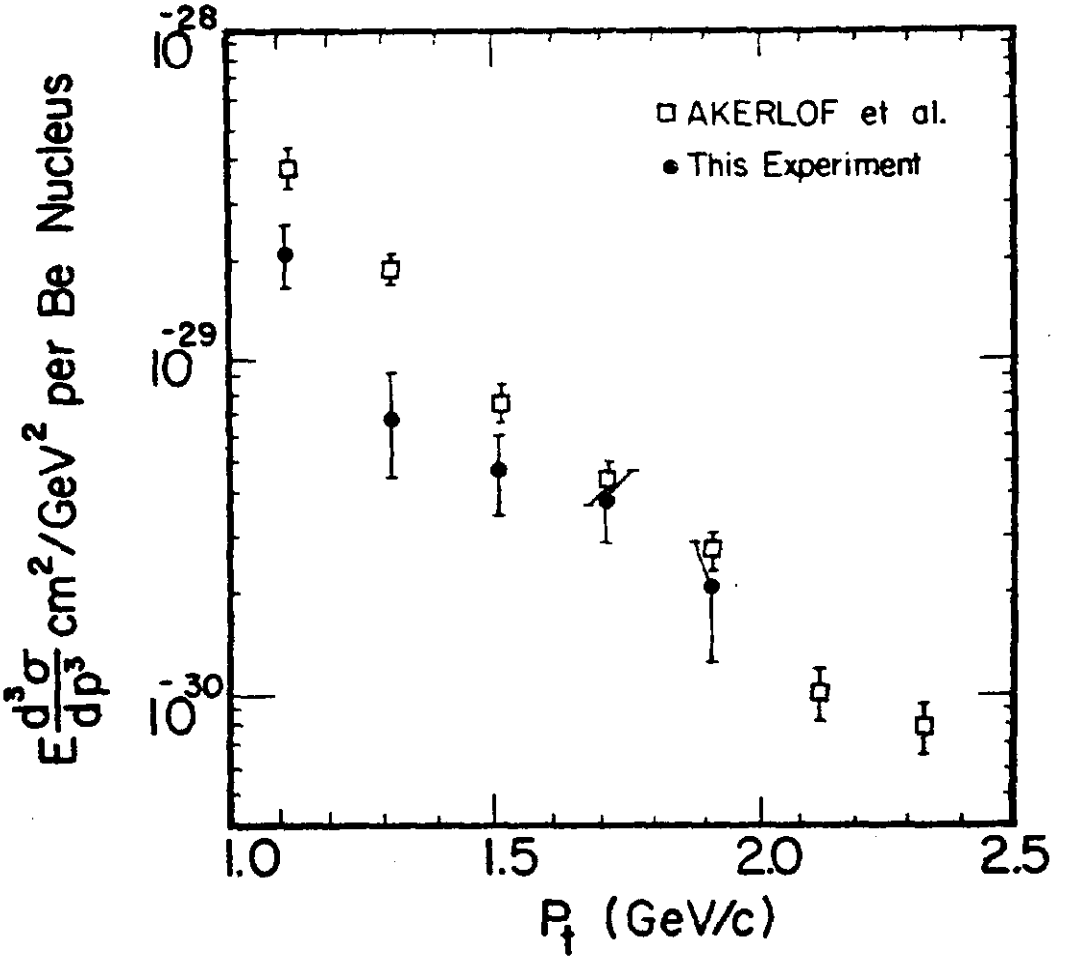


Fig. 3 b) p_T spectrum for $1010 \leq M_{K^+K^-} \leq 1030$ MeV/c^2. The experiment of Akerlof et al. used 400 GeV protons on beryllium.

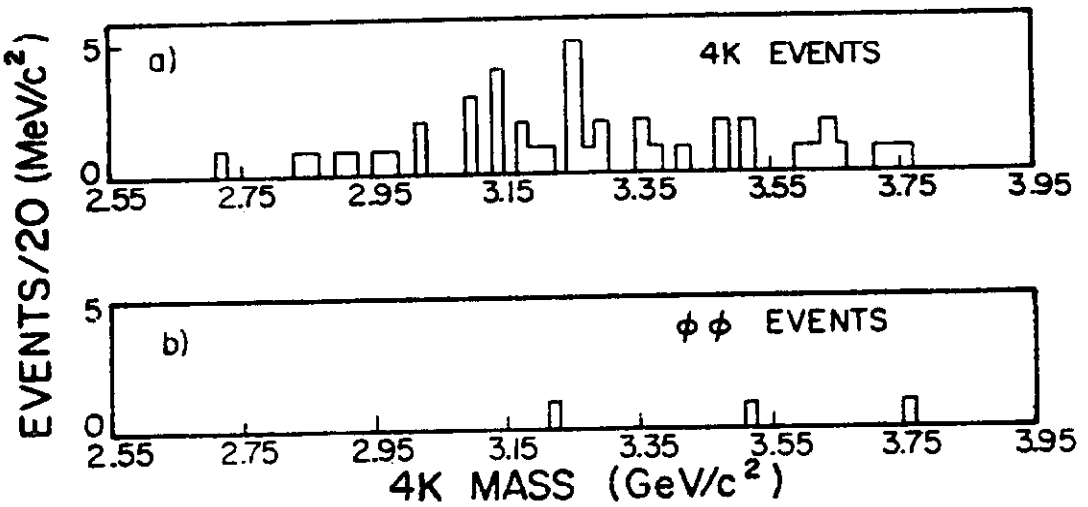


Fig. 4 (K^+K^-) (K^+K^-) Mass spectra.

a) all events.

b) events for which $1010 \leq M_{K^+K^-} \leq 1030$ in each arm.

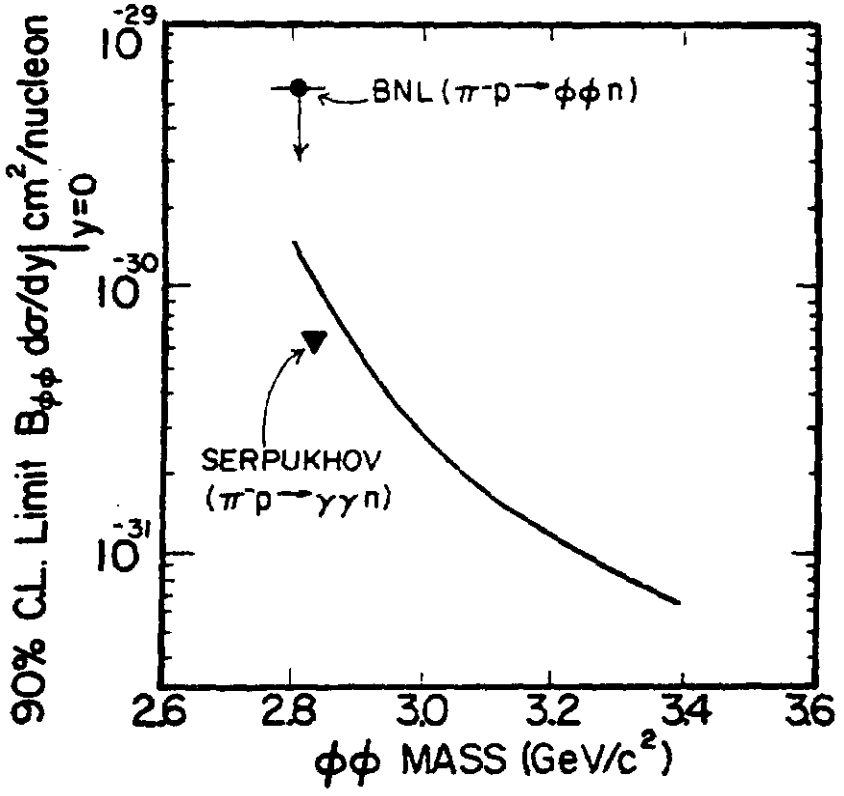


Fig. 5 90% confidence level limit for η_c production. The BNL (Brookhaven) and Serpukhov points are explained in the text.