The proper lifetime of particle 3 was calculated to be 0.7×10^{-10} sec; consequently we may assume that it decayed by a weak interaction with $\Delta S=1$ into a system with strangeness minus two. Since a particle with $S=-1$ would decay very rapidly into $Y+\pi$, we may conclude that particle 3 has strangeness minus three. The missing mass at the production vertex is calculated to be 500 $\pm$ 25 MeV/c^2, in good agreement with the K^0 assumed in Reaction (1). Production of the event by an incoming π^- is excluded by the missing mass calculated at the production vertex, and would not alter the interpretation of the decay chain starting with track 3.

In view of the properties of charge ($Q=-1$), strangeness ($S=-3$), and mass ($M=1686\pm12$ MeV/c^2) established for particle 3, we feel justified in identifying it with the sought-for Ω^-. Of course, it is expected that the Ω^- will have other observable decay modes, and we are continuing to search for them. We defer a detailed discussion of the mass of the Ω^- until we have analyzed further examples and have a better understanding of the systematic errors.

The observation of a particle with this mass and strangeness eliminates the possibility which has been put forward[6] that interactions with $\Delta S=4$ proceed with the rates typical of the strong interactions, since in that case the Ω^- would decay very rapidly into $n+K^0+\pi^-$.

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REGGE-POLE MODEL FOR HIGH-ENERGY pp AND $\bar{p}p$ SCATTERING*

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Recent experiments at high energies have indicated that the width of the diffraction peak in the elastic cross section is considerably smaller in $\bar{p}p$ scattering than in pp scattering.[1,2] On the other hand, the total cross section for $\bar{p}p$ is greater than that for pp.[3] We have then the qualitative feature that the larger total cross section is associated with the narrower diffraction peak. The purpose of this Letter is to investigate whether this feature may be understood in terms of a Regge-pole model for high-energy scattering. We find that, because all Regge exchanges give a positive coefficient for the residue function in the contribution to the imaginary part of the $\bar{p}p$ amplitude, this feature can be understood only if some residue functions are allowed to be negative. We therefore conclude that the simple Regge-pole model of high-energy scattering cannot be valid for the data of reference 1 unless residue functions may be negative.

(I) We consider first the three-pole model of Hadjioannou, Phillips, and Rarita in which only helicity-nonflip amplitudes are considered[4]:

$$A_{\bar{p}p}=\mathrm{P}+\mathrm{P}'-\omega,$$

$$A_{pp}=\mathrm{P}+\mathrm{P}'+\omega,$$

$$d\sigma/dt = |A|^2,$$
$$\sigma T \propto \mathrm{Im}A(t=0). \qquad (1)$$

We have used the trajectory symbols to denote the contributions to the amplitude which are of the form

$$\alpha(t)[2\alpha(t)+1]\xi b(t)E^{\alpha(t)},$$

where E is the laboratory energy, t the squared momentum transfer, and ξ is given by

$$2\xi = -i\tau + \cot[\tfrac{1}{2}\pi\alpha(t)] \text{ for even signature,}$$
$$2\xi = -i\tau + \tan[\tfrac{1}{2}\pi\alpha(t)] \text{ for odd signature.}$$

The j parity τ is +1 for even signature, -1 for odd. Since $\sigma_T(pp)$ is constant, we have

$$\alpha_{P'}(0) = \alpha_\omega(0),$$
$$b_{P'}(0) = b_\omega(0)$$
$$= \mathrm{const}[\sigma_T(\bar{p}p) - \sigma_T(pp)]\exp\{-[1-\alpha_{P'}(0)]\ln E\}.$$

If $b_\omega(t)$ is positive definite, this model cannot explain the fact that

$$d\sigma_{\bar{p}p}/dt < d\sigma_{pp}/dt \text{ (for } -t > +0.2).$$

We have verified this in detail by machine computations. We were not able to achieve a χ^2 less than 1000 in this model; there are 63 data points. The result may be understood by the following argument: If $(\mathrm{Re}A)^2 < (\mathrm{Im}A)^2$, the p-ω cross term in $d\sigma/dt$ is positive for $\bar{p}p$ and negative for pp. Requiring $\alpha_P'(0) < 0.5$, as inferred from the pion-proton data,[5] implies $(\mathrm{Re}A)^2 > (\mathrm{Im}A)^2$ only if there is a large ω contribution to ReA arising because $\alpha_\omega(0)$ $[=\alpha_{P'}(0)]$ is near 1. The ω contribution then dominates ReA, since $\alpha_P(0) = 1$, and $(\mathrm{Re}A)^2$ is the same for pp or $\bar{p}p$.

(II) We consider next the extension of the three-pole model to include helicity-flip amplitudes. Wagner has shown, by use of the factorization theorem, that the differential elastic cross section due to trajectories with $\tau\pi = +1$ (π is the parity; this condition is satisfied for P, P′, and ω) can be written[6]

$$\frac{d\sigma}{dt} = \sum_{i,j} A_{ij}\xi_i\xi_j^* \exp[(\alpha_i + \alpha_j - 2)\ln E]$$
$$\times [b_{i+}(t)b_{j+}(t) - tb_{i-}(t)b_{j-}(t)]^2,$$

where $A_{ji} = A_{ij} = -1$ for $i = $ P, P′, $j = \omega$, and $A_{ij} = 1$ otherwise for $\bar{p}p$ scattering; and $A_{ij} = 1$ for pp scattering; all other factors are the same for pp and $\bar{p}p$. The "Regge couplings" $b_{i\pm}(t)$ are the square roots of the residue functions, $[2\alpha_i(t)+1] \times \alpha_i(t)b_i(t)$. If $b_{\omega\pm}$ are real, the same argument used in (I) shows that the inclusion of helicity flip does not change the result of (I).

(III) If we relax the positive definiteness requirement on $b_\omega(t)$ in (I), or equivalently, allow $b_{\omega\pm}$ in (II) to become imaginary, the narrower $\bar{p}p$ peak may be explained. We have obtained a fit to the data of reference 1 by taking for $b_\omega(t)$ the form

$$b_\omega(t) = b_{P'}(0)[(1+g)e^{a_1 t} - ge^{a_2 t}], \qquad (2)$$

with $a_2 < a_1$, and for $b_P(t)$ and $b_{P'}(t)$ the form

$$b(t) = b(0)e^{at}. \qquad (3)$$

The exponential form in (2) and (3) is merely a convenient parametrization of the decrease of the residue function in a small region of momentum transfer. For $\alpha_i(t)$ we have taken the form

$$\alpha_i(t) = -1 + [1+\alpha_i(0)]^2[1+\alpha_i(0) - \alpha_i'(0)t]^{-1},$$

which has the property of containing the least amount of curvature consistent with $\alpha_i(t)$ being a Herglotz function.[7] Our fit to the data thus involves nine parameters: g, a_1, a_2, a_P, $a_{P'}$, $\alpha_P'(0)$, $\alpha_{P'}'(0)$, $\alpha_\omega'(0)$, and $\alpha_{P'}(0)$, two of which, $\alpha_P'(0)$ and $\alpha_{P'}'(0)$, may be taken from πp data $[\alpha_P'(0) \approx \alpha_{P'}'(0) \approx 0.3]$.[5] We have found that the data may be fitted for values of the last four parameters in a wide range so that, in practice, only five parameters are necessary. In Figs. 1 and 2, we show the results, for the pp and $\bar{p}p$ cross sections, of minimizing χ^2 for a particular choice of the last four parameters. The variation of $b_\omega(t)$ needed to fit the data is very rapid $[b_\omega(-0.2) \approx -b_\omega(0)/2]$, and somewhat hard to understand since b_ω is expected to obey a dispersion relation with only a right-hand cut (starting at $4m_\pi^2$). There is, however, an alternative interpretation of the result. The second term in Eq. (2) may be the residue from the φ trajectory if $\alpha_\varphi(t) \approx \alpha_\omega(t)$ for the range of t under discussion. Whichever interpretation is adopted, it is necessary for a residue function to become negative.

(IV) For the sake of completeness, we consider contributions from other possible trajectories having charge conjugation number, C, equal to -1. Three types of trajectory are possible.[8,9] (a) Other trajectories with $C = \tau = \pi = -1$ add to (not subtract from) ω.[10] The conclusion of (III) that some

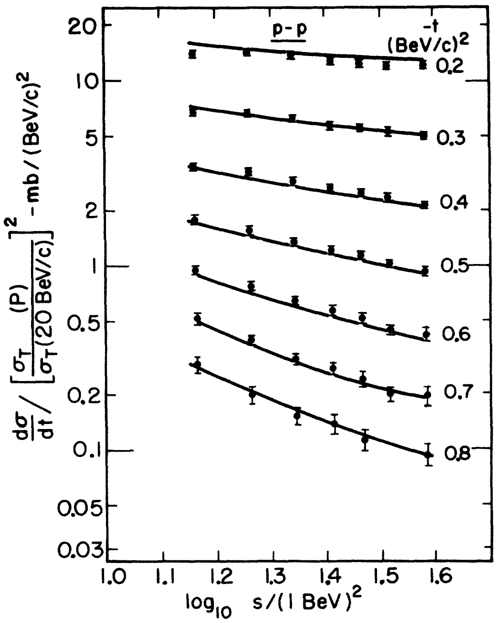

FIG. 1. Differential cross section for elastic pp scattering as a function of $\log_{10}s$. The data are from reference 1. The curves were computed for $a_P=3.65$, $a_{P'}=8.40$, $a_1=6.94$, $a_2=-0.161$, and $g=0.517$; $\alpha_\omega(0)=0.5$ and $\alpha_P'=\alpha_{P'}'=\alpha_\omega'=0.34$ were kept fixed to give a χ^2 equal to 60.0 for 63 data points (48 for pp and 15 for $\bar{p}p$).

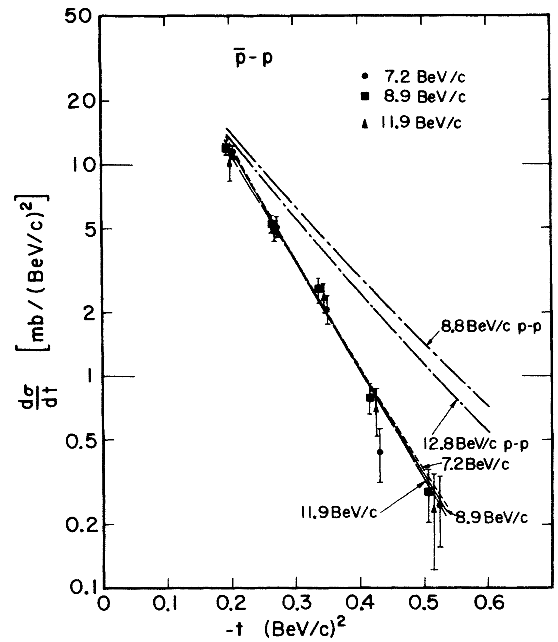

FIG. 2. Differential cross section for elastic $\bar{p}p$ scattering as a function of $-t$. The data are from reference 1. The curves are for the same parameters as in Fig. 1. The dashed lines give pp scattering for comparison.

residue function must become negative is therefore not altered if some trajectory of this type, other than ω (and φ), is important. (b) Two types of trajectories with $\tau\pi=-1$ are possible ($C\pi=\pm1$). The spin-averaged differential cross section contains, however, no interference between trajectories with $\tau\pi=+1$ and those with $\tau\pi=-1$.[11] Thus the $\tau\pi=-1$ trajectories give no difference between pp and $\bar{p}p$.

If an argument can be found to preclude negative Regge-pole residue functions, the explanation of the pp and $\bar{p}p$ diffraction peaks will, presumably, involve Regge cuts.

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[11]We are indebted to Dr. William Wagner for pointing this out to us.