could lead one to expect very light strange particles, but these considerations indicate that one should expect a single relation of the form $\Xi_{3/2}{}^* = Z_0 + 3(Y_1{}^* - N_{1/2}{}^*)$.

Unfortunately, these considerations, if valid, will make it more difficult to assign confidently resonances to SU(3) multiplets. On the other hand, calculational techniques may eventually develop to the point where the various masses and decay widths could be estimated, by using physical input masses one hypercharge and isospin channel at a time, for multiplets where classification proved difficult. Such calculations would then also allow one to relate decay widths into different multiplets.

Though such models have not yet been studied for meson states, it is clear that similar effects will be expected when they are.

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$\bar{p}p$ ELASTIC SCATTERING FOR INCIDENT MOMENTA BETWEEN 1.0 AND 2.50 BeV/c*

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This is a report on a measurement of $\bar{p}p$ elastic scattering for $30° \leq \theta_{\text{c.m.}} \leq 90°$ and for incident momenta between 1.0 and 2.50 BeV/c. In the past rather extensive counter measurements[1] of this cross section have been made at high energies and low momentum transfers, but little counter data exist at large momentum transfer. The hydrogen bubble chambers[2,3] have produced data between 3.0 and 4.0 BeV/c, but the number of events at large momentum transfer is limited and the statistical accuracy is poor. These data show a diffraction peak in the forward direction with a cross section $\sigma(t) \sim e^{-At}$ for $t < 0.4$ (BeV/c)^2. The data we report on here agree with this general behavior for low t, but in addition show a pronounced minimum in the cross section in the neighborhood of $t = 0.4$ (BeV/c)^2, followed by a secondary maximum. We would like to suggest that this effect arises in the same manner as the minimum seen in pion-nucleon scattering and charge-exchange experiments at a similar value of t. A detailed discussion of this point is given in the accompanying Letter.[4]

The experiment was arranged in the following manner. An electrostatically separated antiproton beam, which provided useful fluxes of antiprotons in the momentum range between 0.75 and 3.0 BeV/c, was constructed at the Brookhaven alternate gradient synchroton (AGS). The ratio $\pi^-/\bar{p}$ was generally less than one and the antiprotons were easily identified by time of flight. This separated beam was focused on a 2-m-long liquid hydrogen target. Arranged along the sides of the target was a hodoscope of 90 scintillation counters which were interfaced through fast digital logic to a PDP-5 computer. Lead-faced veto counters were located above and below the target. The polar angle and azimuthal angle of a particle could be measured by the hodoscope with a resolution of 0.16 in their cotangent, which for polar angles near 90° to the beam direction corresponds to $\Delta\theta \sim 10°$ and for polar angles near 15°, to $\Delta\theta \sim 0.5°$. If there were only two charged outgoing particles on opposite sides of the target as determined by the hodoscope and veto counters, and if coplanarity was satisfied as determined by the fast logic, then the angles of the two particles were read into the PDP-5, where they were sorted into bins of a two-dimensional matrix of $\cot\theta_{\text{right}}$ vs $\cot\theta_{\text{left}}$. The bins in $\cot\theta$, as set by the size of the counters in the hodoscope, had a width of 0.16. At the end of a run the PDP-5 could print out this matrix, and the elastic-scattering events could be separated easily from the background of two charged particles plus undetected neutrals by collecting data only from that region of the matrix which correctly satisfied the two-body scattering kinematics relations. This background was in general less than 10%. The data have been corrected for hodoscope inefficiency, dead-time effects in the electronics, and absorption in the 2-m hydrogen target. This latter correction was rather large since at the lowest momentum measured, the target length was 1.2 mean free paths decreasing to 0.7 mean free path at the highest momentum. However, the total cross section for absorption of $\bar{p}$ in hydrogen has been measured[5] and so this correction, though large, can be accurately calculated. During the course of the experiment, pp scattering was also measured between 1.0 and 2.5 BeV/c. The cross sections obtained from these runs agree with previous more accurate measurements.[6] There are some systematic errors that appear in the over-all absolute normalization of the data, which may amount to 10% for the pp scattering data and 50% for $\bar{p}p$. We were not able to investigate these effects during the course of the experiment, but further study of the data may reduce them. The statistical errors in all cases are less than 5% and in some cases less than 0.2%. The fluctuations remaining in the data are due to variations in the widths of the various channels of the hodoscope. No attempt has been made at this time to correct the data for such systematic effects.

The scattering data were collected incidentally during the course of an experiment to measure the cross section for $\bar{p}+p \to e^+ + e^-$, and therefore the apparatus has some serious inadequacies for the present measurements. The major disadvantage was the lack of a magnetic field to distinguish the charges of the scattered particles. This results in the equipment measuring $\sigma(\theta_{\text{c.m.}}) + \sigma(\pi - \theta_{\text{c.m.}})$, which causes no difficulty for pp scattering, but causes the $\bar{p}p$ data to be more difficult to interpret. The correction at 90°, due to the term $\sigma(\pi-\theta)$, is just a factor of 2, and at more forward angles is less, a fact that can be verified by an examination of the bubble-chamber scattering data, which show that at all energies the cross section for $\bar{p}p$ scattering is rapidly decreasing back of 90°.

Figure 1 displays some of the data from these measurements. The most striking feature is a very sharp dip at $t \sim 0.4$ following the forward peak. At momenta less than 1.0 BeV/c this dip disappears from the forward hemisphere to back of 90° where our apparatus is insensitive to it. An examination of the bubble-chamber data between 3.0 and 4.0 BeV/c suggests that this secondary maximum disappears at

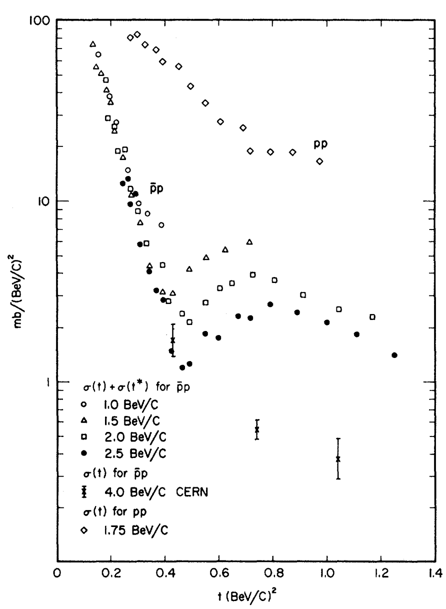

FIG. 1. Angular distribution observed in $\bar{p}p$ scattering. A curve for pp scattering is shown for comparison. For the data from this experiment, the points plotted are derived from $\sigma(\theta)+\sigma(\pi-\theta)$. t^* is the momentum transfer at $\pi-\theta$.

higher momenta, although the statistical accuracy of the measurements for $t > 0.5$ $(\mathrm{BeV}/c)^2$ is rather poor. Three points from the CERN experiment[3] at 4.0 BeV/c are shown in Fig. 1 in support of this conclusion. The over-all behavior of the cross section as a function of energy and t seems to be very similar to that observed in the πN experiments. The cross section for pp scattering at 1.75 BeV/c from this experiment is also shown in Fig. 1 for comparison. All the data of our experiment are compatible with measurements made at other laboratories for this cross section, and no indication of a minimum appears in any of these data. These results may, of course, be compatible with diffraction theory[7,8]; however, if Regge theory is working at these low energies, as is indicated in other experiments, then this experiment, as explained in the following Letter,[4] offers additional evidence in its support.

A more complete set of data will be published at a later date.

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REGGE TRAJECTORIES AND MINIMA IN DIFFERENTIAL CROSS SECTIONS*

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Attempts to fit[1] the earliest accurate measurements of high-energy cross sections, namely the total cross sections and diffraction peaks, by Regge poles have not been totally convincing because a number of high-spin trajectories contribute, and the theory involves a correspondingly large number of parameters. Some of the smaller cross sections now being measured, however, can be described in terms of only one or two trajectories, thus providing a cleaner test of Regge theory.[2-4] For example, only the ρ among known trajectories contributes to $\pi^- + p \to \pi^0 + n$,[2] and the experiments on this reaction have confirmed the striking, qualitative features of a single-Regge-pole model: the energy dependence at $t = 0$[2] and the shrinking forward peak.[5] In addition, the helicity-flip amplitude vanishes when the exchanged ρ trajectory passes through spin zero, giving rise to a minimum in the differential cross section at $t \approx -0.6$ $(\mathrm{BeV})^2$.[5-7] The purpose of this Letter is to emphasize that minima in $d\sigma/dt$ near $t = -0.6$ $(\mathrm{BeV})^2$ associated with passage of exchanged spins through zero may be very common, that study of this easily recognized qualitative feature promises to become a major aid in unravelling the details of Regge trajectories even in cases where several trajectories contribute, and that in particular, the minimum of $d\sigma(p + \bar{p} \to p + \bar{p})/dt$ reported in the accompanying Letter[8] may have this origin.

To illustrate the Regge description of the minima near $t = -0.6$ $(\mathrm{BeV})^2$, we shall first review the situation for $\pi^- + p \to \pi^0 + n$ and then proceed to the progressively more complicated reactions $\pi^\pm + p \to \pi^\pm + p$ and $p + \bar{p} \to p + \bar{p}$.

$\pi^- + p \to \pi^0 + n$.—The ρ is the only known trajectory contributing to this reaction at small