2(a)]. No further adjustment was made; the relative transition strengths G for the excited C^{11} states were taken from the respective (τ, d) reaction. The shape and relative strengths of the different transitions are nicely reproduced; the difference in relative intensity for the different states in the $(\tau, \tilde{d})$ and (τ, d) reactions thus are seen to be purely kinematic in origin, as less kinetic energy is available in the $\tilde{d}$ than in the d case. Thus it may be concluded that the $(T=1, S=0)$ deuteron emission is a real process that can safely be described by DWBA with respect to shape and relative strengths and thus may be used as a new spectroscopic tool. On the other hand it is seen that for a comparison of reactions yielding d and $\tilde{d}$, as in Ref. 1, a DWBA treatment is essential. To reproduce the measured cross section absolutely a theory on the "normalization" of the DWBA cross section is required that incorporates the decomposability of He^3 into p and $\tilde{d}$, analogous to the works of Bassel,[10] Rook,[11] and Lim[12] for the (He^3, d) case. It is hoped that such a theory (which is beyond the scope of this paper) will show quantitative consistency of the DWBA treatment also for emission of unstable particles.

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PION-EXCHANGE DOMINANCE IN THE REACTION $pp \to n\Delta^{++}(1236)$ AT HIGH ENERGIES*

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The charge-exchange reaction $pp \to n\Delta^{++}(1236)$ has been systematically analyzed up to 24.2 GeV/c to test the concept of dominance in the t channel by high-lying Regge trajectories at very high energies. The results provide clear evidence for no more than pion exchange up to the highest momentum studied.

For a reaction in which the exchange of several Regge poles is allowed, it is expected that the high-lying trajectories will dominate at very high energies. Specifically, for a reaction which is mediated by the exchange of a single Regge pole, the differential cross section may be written as

$$d\sigma/dt \sim F(t) P_L^{2\alpha(t)-2}, \tag{1}$$

where P_L is the incident beam momentum, $\alpha(t)$ is the trajectory, and $F(t)$ contains the propagator and residue functions. The differential cross section at low t then varies as $P_L^{2\alpha(0)-2}$. Therefore, the greater the value of $\alpha(0)$, the slower will the differential cross section fall with increasing incident momentum. A sensitive test of the notion involves the examination of charge-exchange reactions for which the exchanges of the π and ρ (and heavier charged trajectories) are allowed. If a reaction is dominated by pion exchange, the cross section will be expected to fall as P_L^{-2}, whereas a less rapidly falling trend in the form of P_L^{-1} will be indicative of a ρ exchange.

In this paper, we present the results of such a test using the reaction $pp \to n\Delta^{++}(1236)$ from 13.0 and 24.2 GeV/c. To our knowledge there has been no systematic study of a single quasi-two-body reaction covering such a wide range of momenta above 10 GeV/c. Measurements of the reaction $pp \to p\Delta^+$ have been performed up to 15 GeV/c using counter, spark-chamber methods incorporated into a one-arm proton spectrometer.[1] In these experiments, the outgoing detected proton could be either the scattered target or the decay product of the isobar. The ambiguities concerning the source of the proton lead to a large kinematical background of the Deck type in the mass region of the $\Delta^+(1236)$. Therefore a detailed knowledge of the shape of the background (which is not well understood) becomes essential. The results of such experiments have been cross sections with poor statistical significance and uncertain normalization.

The data presented in this paper resulted from an exposure of the Brookhaven National Laboratory 80-in. hydrogen bubble chamber. The incident beam momenta were set at 13.0, 18.1, 21.1, and 24.2 GeV/c. Measurements were done on the Lawrence Radiation Laboratory Spiral Reader II utilizing the 80-cm radial scan with complete pulse-height information on each track. The reaction of interest in this paper,

$$pp \to n\Delta^{++}, \tag{2}$$

has been obtained from a selection of events of the type

$$pp \to p\pi^+ n. \tag{3}$$

To eliminate contamination, we have considered only those events which have a missing neutron emitted in the forward hemisphere of the collision c.m. and the square of the momentum transfer, $t' = t - t_{\min}$, to the neutron less than 0.5 $(\text{GeV}/c)^2$. This resulted in the charged particles being emitted with relatively low laboratory momentum. In the region of the Δ^{++}, the π^+ is constrained by kinematics to have momentum below ≈ 600 MeV/c. Thus, we have been able to remove background events of the type $pp + m\pi^0$ rather easily by application of the pulse-height information on track ionization.

The resultant $p\pi^+$ invariant mass distributions are shown in Figs. 1(a)-1(d). Cross sections for Reaction (2) have been obtained by subtracting from the peaks a smooth, hand-drawn background. The values thus obtained are 0.550 ± 0.099, 0.301 ± 0.052, 0.217 ± 0.053, and 0.205 ± 0.047 mb at 13.0, 18.1, 21.1, and 24.2 GeV/c, respectively. The errors quoted include possible systematic uncertainties. The differential cross sections for Reaction (2) in the low momentum transfer region are shown in Figs. 2(b)-2(e). The results have been obtained using only those events with $1.18 < M(\pi^+ p) < 1.32$ GeV and normalizing to the corresponding total cross section. The data in Fig. 2(a) are taken from Ma et al.[2] and have been incorporated into this study. The data for $t' < 0.1$ $(\text{GeV}/c)^2$ have been averaged over 13.0-24.2 GeV/c in an attempt to detect the presence of a forward dip, and are plotted in Fig. 2(f). Our experimental resolution in this region is estimated to be ≈ 0.01 $(\text{GeV}/c)^2$.

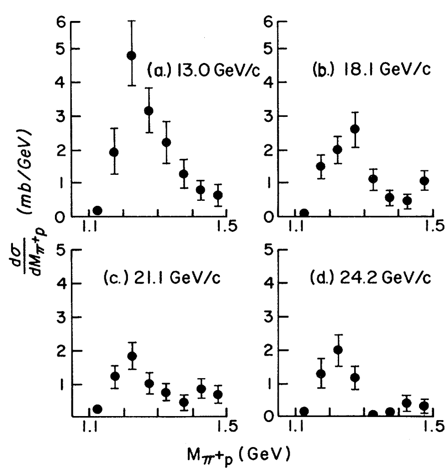

FIG. 1. (a)-(d) $p\pi^+$ mass distributions.

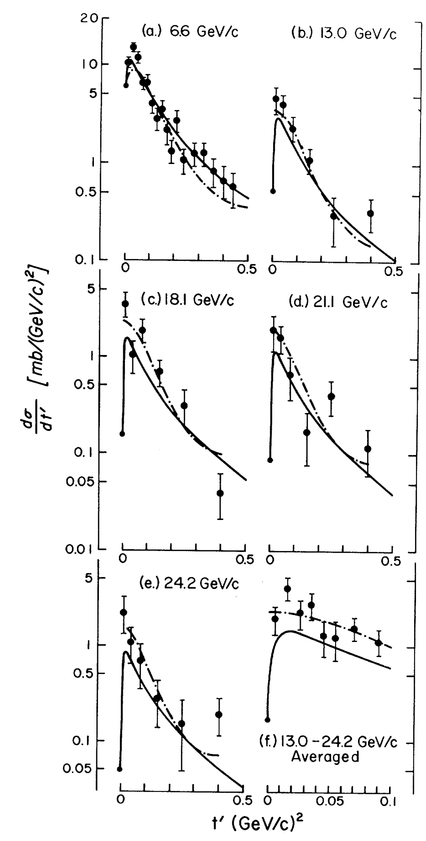

FIG. 2. Differential cross sections for $pp \to n\Delta^{++}(1236)$. The solid curves are predictions based on the Dürr-Pilkuhn-Benecke modified OPE model. The dot-dashed curves result from a Regge-pole model with absorptive cuts.

We have compared our data with the prediction of a modified one-pion exchange (OPE) model by Dürr, Pilkuhn, and Benecke.[3] The model has been successfully applied by Wolf[4] in fitting the reactions $\bar{p}p \to \Delta\bar{\Delta}$, $\pi^+p \to \Delta\rho$, and $\pi^-p \to n\rho$ up to 20 GeV/c, and by Ma et al.[2] to the reaction $pp \to n\Delta^{++}$ at 6.6 GeV/c. In interpreting our data we have adopted Wolf's parameters and calculated the differential cross sections for Reaction (2) between 13.0 and 24.2 GeV/c. The results of these calculations (solid curves) are shown compared with the data of this experiment in Fig. 2. The prediction of the model agrees well with our data in shape, but is somewhat low in magnitude.

We have also attempted to fit our data with a Regge-pole model with absorptive cuts. The model has been discussed in the literature.[5] In this model, absorptive corrections are applied to each Regge-pole amplitude. The result is equivalent to the pole amplitude, plus a correction term which is a cut in the complex j plane. We have assumed that the π, ρ, and A_2 are the principal trajectories exchanged and that the effect of exchanging other trajectories may be absorbed into the formalism for the three mentioned. For each participating Regge pole, the parametrization consists of the usual parameters for the pole (namely, trajectory, energy scale s_0, and a constant residue function), coupling constants at each vertex, and a set of factors each of which is related to the relative magnitude of the cut to pole contribution for a given helicity change. In fitting to the data, we have chosen to fix the ρ and A_2 trajectories by $\alpha_\rho(t) = 0.49 + 1.08t$ and $\alpha_{A_2}(t) = 0.44 + 0.92t$, respectively. The pion trajectory has been parametrized by $\alpha_\pi(t) = \alpha_\pi'(t + \mu^2)$, where α_π' is allowed to vary. Pion couplings used are $g^2/4\pi = 29.2$ for the $pn\pi^+$ vertex and 0.38 for the $p\pi^+\Delta^{++}$ vertex. The predicted differential cross sections are shown as dot-dashed curves in Fig. 2. The good agreement of the model with our data is apparent and the contribution due to the exchange of the pion trajectory is estimated to be at least 60%.

In Fig. 3, we present our total cross sections, along with those from other experiments.[1,2,6] A least-squares fit by the form P_L^{-n} gives $n = 1.956 \pm 0.036$ for all the points shown, less the points of Ref. 1. Similar fits below and above 10 GeV/c give $n = 1.999 \pm 0.059$ and 1.968 ± 0.027, respectively. Thus, there is no evidence that n is decreasing at higher momenta and the values at all momenta are consistent with π exchange.

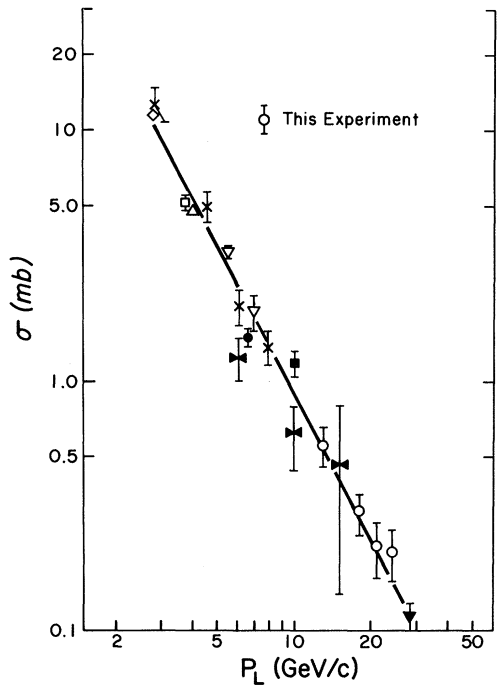

FIG. 3. Total cross sections for the reaction $pp \to n\Delta^{++}$. The points include those of this experiment and Refs. 1, 2, and 6. The curve represents a least-squares fit to all the data, with the exception of those of Ref. 1, by a form P_L^{-n}, where $n = 1.956 \pm 0.036$.

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