Using a calculated expression[2,7] for $F(t', \sigma_{K^*}, k_{lab})$ and the known shape of $d\sigma/dt')_N$, one can estimate from $\sigma_A^{K^*}$ the value of $\sigma_N^{K^*}$, where $\sigma_N^{K^*}$ is the integral of $d\sigma/dt')_N$ over t'. We have assumed here that the K^- and K^{*-} total cross sections on nucleons are equal. The ratio $\rho = \sigma_A^{K^*}/\sigma_N^{K^*}$ is quite sensitive to the shape of $d\sigma/dt')_N$ in the dip region where the uncertainties in the hydrogen data are rather large and not well indicated by the error on λ. With $\lambda = 10.8 \pm 0.5$ $(\text{GeV}/c)^{-2}$, we find $\sigma_N^{K^*} = 107 \pm 30$ μb at 12.7 GeV/c and $\sigma_N^{K^*} = 146 \pm 50$ μb at 10 GeV/c. The latter value is in good agreement with the cross section for K^{*-} production from hydrogen[6] at 10 GeV/c.

Conclusion.—We have observed coherent production of $K^{*-}(890)$ by K^- beams on nuclei with $A \approx 20$. The observed effects are consistent with the hypothesis that $K^*(890)$ production on a nucleon is dominated by exchange of natural-parity, isoscalar trajectories.

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[5]$t' = |t| - |t|_{min}$, where t is the four-momentum transfer squared from target to recoil and $|t|_{min}$ is the smallest kinematically allowed transfer to produce the $K\pi$ system.

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[7]Fournier, Ref. 4.

[8]We assume that the contribution from γ exchange is small for $A \approx 20$ and $P_{beam} \lesssim 13$ GeV. This assumption is based on an optical-model calculation using the SU(3) prediction that the partial width of $K^* \to K\gamma$ is ≈ 62 keV. See also F. R. Huson *et al.*, Phys. Lett. 20, 91 (1966).

Angular-Momentum Cuts and Scaling of Total Cross Sections at High Energies*

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High-energy total cross sections for the $\pi^{\pm}p$, $K^{\pm}p$, $\bar{p}p$, and pp reactions are analyzed using a Regge-pole model combined with an odd-signature cut. It is found that the asymptotic cross sections, when plotted versus $\omega = s/2M_1M_2$, satisfy a scaling law within specified normalization constants.

About nine years ago[1] one of us proposed a phenomenological model of high-energy forward elastic scattering, dominated by a Pomeranchukon pole plus cut; and the high-energy data for πp, Kp, $\bar{p}p$, and pp scattering were analyzed in a series of papers.[2] The model was mainly motivated by the multiperipheral field theory of Amati, Fubini, and Stanghellini.[3] In the intervening years, a plethora of literature on Regge cuts has appeared,[4] but our fundamental understanding of these cuts has not increased significantly; a bewildering number of dips and polarization effects have been discovered in hadronic reactions, and the appealing simplicity of the initial Regge-pole picture has been irretrievably lost.

However, an aspect of the angular-momentum cuts that was already recognized in Ref. 2, which perhaps goes beyond a mere attempt to guess the cut parametrization, is the significance of the scale parameter $s_0 = 2M_1M_2$. This scale parameter for the cuts cannot simply be absorbed in the residues, as in the case of Regge poles, but must be considered as an important parameter in its own right. It was found that a form of "scaling" of the total hadronic cross sections emerged when different reactions were plotted on universal curves within certain normalization constants.

We shall show here that the new Serpukhov data[5] indeed suggest that certain sets of cross sections are asymptotically equal to within normalization constants when the data are plotted versus the variable $\omega = s/2M_1M_2$.

We find that reasonably good fits to the data can be obtained from the following parametrization of the spin-averaged amplitude for forward pp and K^+p scattering:

$$A(s,t=0) = -g\left[\frac{\omega^{\alpha_P} + (-\omega)^{\alpha_P}}{\sin\pi\alpha_P}\right] - C^-\left[\frac{\omega^{\alpha} - (-\omega)^{\alpha}}{\sin\pi\alpha}\right] - C^+\left[\frac{\omega^{\alpha} + (-\omega)^{\alpha}}{\sin\pi\alpha}\right] + f\left[\frac{\omega^{\alpha_c}}{(\ln\omega)^{\beta}} - \frac{(-\omega)^{\alpha_c}}{[\ln(-\omega)]^{\beta}}\right], \tag{1}$$

where the fourth term describes an odd-signature angular-momentum cut. As in Refs. 1 and 2, we shall restrict ourselves to the choices $\alpha_c = 1$ and $\beta = 1$ (for a square-root cut in the l plane, β will probably have the value $\frac{3}{2}$, but for a phenomenological treatment $\beta = 1$ is satisfactory). The Regge-pole trajectory intercepts are $\alpha_P = 1$ for the Pomeranchukon and $\alpha = \alpha_\rho = \alpha_\omega = \alpha_{P'} = \alpha_{A_2} = \frac{1}{2}$ for the secondary trajectories (weak exchange degeneracy). The residues C^+ and C^- refer to the even- and odd-signature exchanges, respectively, corresponding to P' and ρ exchanges for πp scattering and A_2, P' and ρ, ω exchanges for Kp, pp, and $\bar{p}p$ scattering. For the line-reversed reactions the odd-signatured terms in (1) will change sign in the normal manner.

We have performed a least-squares fit to the total cross-section data[5,6] for pp and $\bar{p}p$ scattering between 5 and 60 GeV/c lab momentum using the amplitude (1). The four parameters g, f, C^-, and C^+ thus determined are given in Table I. In Fig. 1, we show the results of this fit to the pp and $\bar{p}p$ data, the highest Serpukhov datum point corresponding to $\omega = 65$ at $P_{\text{lab}} = 60$ GeV/c for the pp and $\bar{p}p$ system. The resulting curves are then extrapolated to $\omega = 450$ corresponding to $P_{\text{lab}} = 430$ GeV/c. We then multiply the π^+p data[5] by a nor-

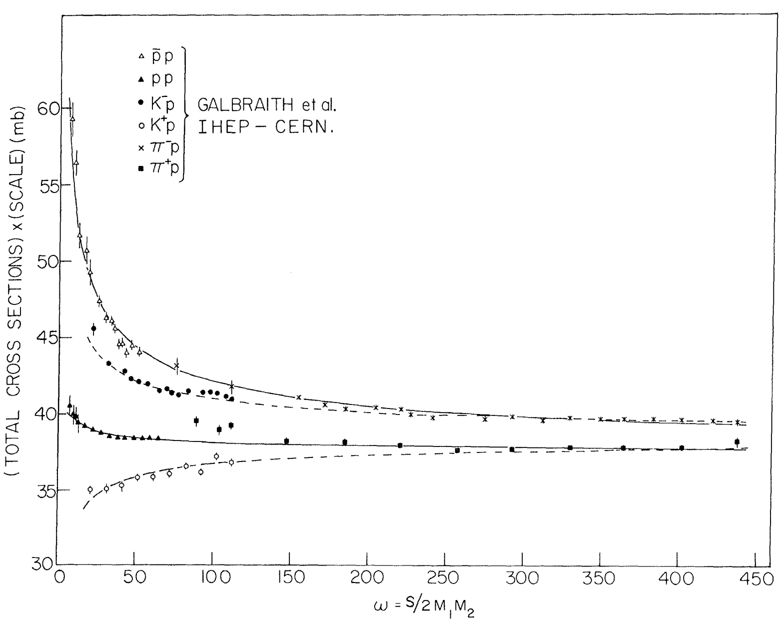

FIG. 1. Total cross sections for $\pi^\pm p$, $K^\pm p$, $\bar{p}p$, and pp scattering versus the variable $\omega = s/2M_1M_2$. The solid curves describe the fits to the $\bar{p}p$ and pp data in Refs. 5 and 6, and their extrapolations to $\omega = 450$ corresponding to $P_{\text{lab}} = 430$ GeV/c in the pp and $\bar{p}p$ system. The π^-p and π^+p data are displayed after normalization by the constant $N_{\pi p} = 1.63$. The K^-p and K^+p fits are shown as dashed-line curves normalized by the constant $N_{Kp} = 2.03$, and extrapolated to $\omega = 450$ corresponding to $P_{\text{lab}} = 230$ GeV/c in the Kp system.

TABLE I. Results for the four parameters g, f, C^+, and C^- obtained from a least-squares fit to the pp, $\bar{p}p$, and K^+p data in Refs. 5 and 6.

Reactions	g	f	C^+	C^-
pp and $\bar{p}p$	2.60	0.582	2.17	1.98
K^+p and K^-p	0.700	0.141	0.0826	0.532

malization constant 1.63 and find that they lie on the extrapolated pp curve. When the π^-p data are then multiplied by the *same* normalization constant, the interesting result emerges that the π^-p data lie on the extrapolated $\bar{p}p$ curve.

A least-squares fit to the K^+p and K^-p data has also been performed using (1), and the resulting four parameters g, f, C^-, and C^+ are listed in Table I. These resulting fits multiplied by the normalization constant 2.03 are shown in Fig. 1 as dashed-line curves and the extrapolations of these curves to $\omega=450$ are also shown. We observe that for large ω the K^-p fits approach the extrapolated fits to the $\bar{p}p$ cross sections and also the π^-p cross sections, while the K^+p fits approach the extrapolated pp and the predicted π^+p cross sections. Thus, for large ω the cross sections for the three reactions π^+p, pp, and K^+p scale within specified normalization constants, while the three reactions π^-p, $\bar{p}p$, and K^-p scale with the same normalization constants.

In the model, we have in the scaling region

$$\sigma(\bar{A}B)-\sigma(AB)=\frac{8\pi N_{AB}}{M^2}\left[C^-\omega^{-1/2}-\frac{\pi f}{\ln^2\omega+\pi^2}\right], \quad (2)$$

where N_{AB} is the scale factor. Our prediction of the difference $\sigma(\pi^-p)-\sigma(\pi^+p)$ is seen to fit the data well above $P_{\text{lab}}=20$ GeV/c ($\omega=143$).

It will be interesting to see whether the proposed $K^{\pm}p$ experiments at the National Accelerator Laboratory for energies above 60 GeV/c will be consistent with the simple asymptotic picture of the total cross sections displayed in Fig. 1.

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