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Fermilab Single Arm Spectrometer Group

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Abstract

A comparison of $K^{\pm}p$ and $p^{\pm}p$ elastic scattering is made for incident energy 50 to 175 GeV. Average values of 0.19 ± 0.04 and 0.11 ± 0.02 GeV^2 were found for the invariant-momentum transfer values of the Kp and pp crossover points, respectively.

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High energy elastic scattering is dominated by diffraction, or in t-channel language, by Pomeron exchange. Amplitudes with quantum-number exchange are much smaller, but can be isolated by careful comparison of closely related reactions. In this paper we compare particle and antiparticle elastic scattering by protons to obtain information on the odd-charge-conjugation ($C = -1$) exchange amplitude in the t-channel. For Kp and pp scattering this amplitude is believed to be dominated by nonflip ω exchange.[1] At momenta ≤ 10 GeV/c, this amplitude changes sign near $-t = 0.2$ GeV^2, resulting in the crossover point where the differential cross sections for particle and antiparticle scattering are equal.[2,3] The invariant-momentum transfer t_c at which this occurs can be related to a typical interaction radius in impact parameter space for the $C = -1$ amplitude.[4]

The experiment has already been described.[5] It was carried out in the Fermilab M6E high precision beam line and used the Single Arm Spectrometer Facility to detect scattered particles. The results of the final analysis[6] were used and differ only slightly from those previously published.[5] The uncertainty in the relative normalization of the particle and antiparticle cross sections is estimated to be ±3%.

The cross sections were fit to the form

$$d\sigma/dt = Ae^{Bt + Ct^2} \qquad (1)$$

using data up to $-t = 0.8$ GeV^2. The optical points, as derived from the total cross section measurements[7] and corrected for the real part of the amplitude,[8] were included in the fits at $t = 0$ with ±3% error to account for the uncertainty in overall normalization of the elastic data. Figure 1 shows the results of the $K^{\pm}p$ and $p^{\pm}p$ fits. In each case a crossover is found consistent with $-t_c$ in the range 0.1 to 0.2 GeV^2, and the values of t_c obtained from the fits are plotted in Fig. 2 as a function of laboratory momentum. For Kp scattering the crossover points are consistent with those found at lower energies,[2,3] with our average being $-t_c = 0.19 \pm 0.04$ GeV^2 where the error includes both statistical and systematic uncertainties. The nucleon values average to $-t_c = 0.11 \pm 0.02$ GeV^2, definitely lower than the value 0.162 ± 0.004 GeV^2 reported[2] near 5 GeV/c.

These crossover points can be compared with those predicted under the assumption of geometric scaling, where particle and antiparticle elastic scattering on protons differ only in radial scale.[9] The resulting prediction, $-t_c = 4/(B^+ + B^-)$, where $B^{\pm}$ are forward slopes for $x^{\pm}p$ scattering, gives values considerably larger than observed, $-t_c = 0.27$ and 0.19 GeV^2 for Kp and pp, respectively, at 100 GeV/c.

The particle-antiparticle cross sections differ from one another because of interference between C = +1 and C = -1 exchange amplitudes,

$$d\sigma/dt\ (x^{\pm}p) = |F^{+} \mp F^{-}|^2 \qquad (2)$$

where the $F^{\pm}$ amplitudes correspond to C = ±1 exchange. Since the diffractive amplitude with C = +1 dominates, the quantity

$$\Delta = \frac{\sigma^{-} - \sigma^{+}}{[8(\sigma^{-} + \sigma^{+})]^{1/2}} \quad , \qquad (3)$$

where $\sigma^{\pm} \equiv d\sigma/dt\ (x^{\pm}p)$, isolates to a good approximation that part of F^{-} with the same phase and spin state as the C = +1 amplitude (mainly imaginary nonflip).[1]

The energy dependence of Δ for $p^{\pm}p$ scattering has been studied using the form

$$\Delta(t) = c(t)s^{\alpha(t) - 1} \tag{4}$$

where $\alpha(t)$ is the effective Regge trajectory. Fits to our data (Eq. 1) together with the 10.4-GeV/c results,[3] both evaluated at $t = -0.4$ GeV^2, yield $\alpha(-0.4) = 0.27 \pm 0.07$. This can be compared with the value $\alpha(-0.4) = 0.14$ found[10] for $\pi^- p \to \pi^o n$, for which only C = -1 exchange is allowed in the t-channel.

The shape of $\Delta(t)$ resembles that of the Bessel function $J_o(R_-\sqrt{-t})$, suggesting that the C = -1 amplitude is strongly absorbed with most of the contribution coming from the periphery of the interaction radius.[4] If one associates the experimentally determined location of the crossover point with the first zero of the Bessel function, a typical radius for the source of C = -1 amplitude in impact parameter space can be defined as

$$R_- = 0.475/\sqrt{-t_c} \text{ fermi} \tag{5}$$

for t_c in GeV^2. This is compared in Table I with a typical radius for the C = +1 amplitude derived from the forward logarithmic slope B of the quantity

$$\Sigma = \tfrac{1}{2}\left[\frac{d\sigma}{dt}(x^- p) + \frac{d\sigma}{dt}(x^+ p)\right] \quad . \tag{6}$$

Using the black disc approximation, $B = R_+^2/4$, or for B in GeV^{-2}

$$R_+ = 0.395\sqrt{B} \text{ fermi} \quad . \tag{7}$$

With these definitions $R_-/R_+ = 1$ to within about 10% for both Kp and pp from 4 to 100 GeV.

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Table I. Typical radii R_+ and R_- in impact parameter space for C = +1 and C = -1 exchange amplitudes, as defined by Eqs. 5 and 7. The uncertainties in $R_\pm$ are typically ± 2% except for R_- at 100 GeV/c (± 10%).

	p (GeV/c)	R_+ (F)	R_- (F)	R_-/R_+
Kp	4	1.00	1.09	1.09
	100	1.15	1.09	0.95
pp	4	1.33	1.18	0.89
	100	1.33	1.43	1.08

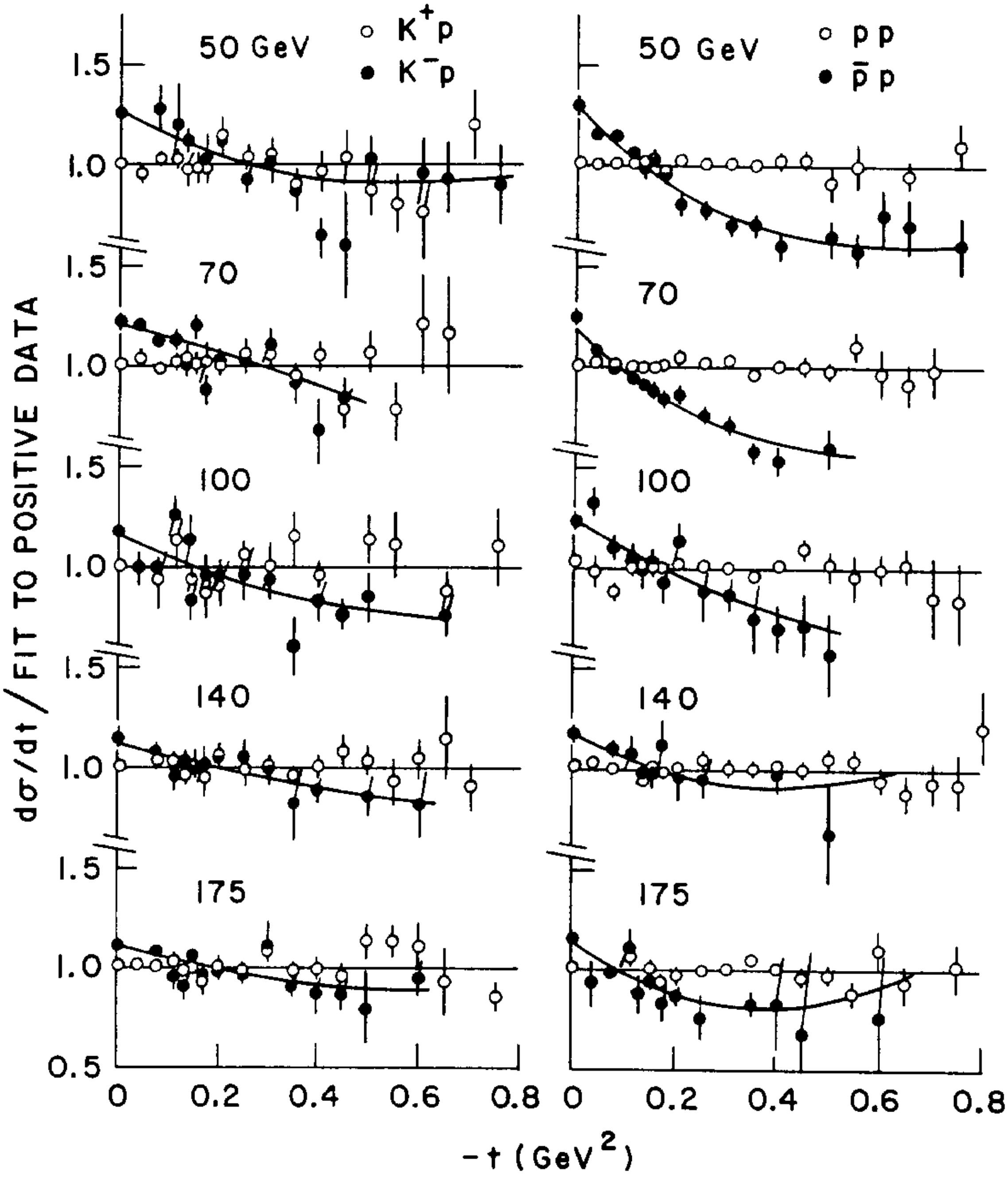

Figure 1

Fig. 1 Elastic scattering cross sections divided by the fit (Eq. 1) to the positive-beam data. The lines show the ratio of negative-beam fits to positive-beam fits.

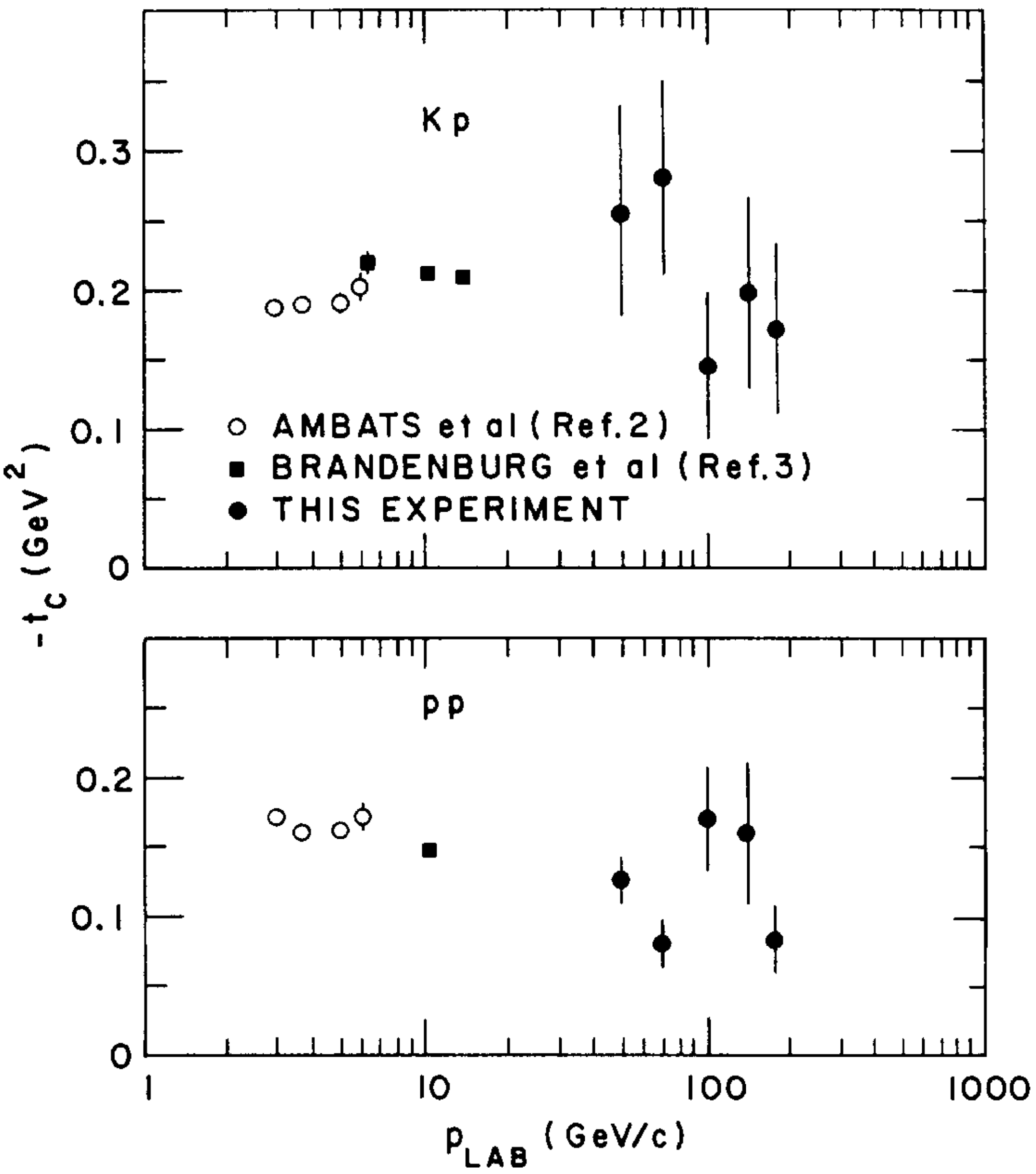

Fig. 2 Crossover points as a function of incident momentum.