Total Cross Sections of $\pi^{\pm}$ and $K^{\pm}$ on Protons and Deuterons between 50 and 200 GeV/c*

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Total cross sections of $\pi^{\pm}$ and $K^{\pm}$ on protons and deuterons have been measured at 50, 100, 150, and 200 GeV/c. All of the cross sections rise with increasing momentum.

In the preceding paper[1] were described measurements of p and $\bar{p}$ total cross sections on protons and deuterons at 50, 100, 150, and 200 GeV/c. With two gas differential Cherenkov counters in the incident beam, the cross section for another incident particle was measured simultaneously; the second counter was used for pions and kaons sequentially. We describe here the pion and kaon data, and give experimental details only when they differ from the $p,\bar{p}$ case. The differences are firstly due to a small admixture of muons and electrons in the particles identified as pions by the gas Cherenkov counter, and secondly due to the effects of pion and kaon decays.

Electrons in the gas-Cherenkov-counter pion signal were identified by their characteristic signal in a 22-radiation-length lead-glass Cherenkov counter placed downstream of the transmission counters. At 150 and 200 GeV/c, the contamination was less than 0.1%, while at 50 GeV/c the gas Cherenkov counter could cleanly separate pions and electrons. At 100 GeV/c, the contamina-

TABLE I. Results of this experiment: Cross sections in millibarns.

	MOMENTUM (GeV/c)				
	50	100	150	200	Momentum independent Scale uncertainty
σ_{π^-p}	24.01±0.06	23.96±0.07	24.07±0.06	24.28±0.06	±0.5%
σ_{π^-d}	45.51±0.12	45.50±0.12	45.76±0.12	46.21±0.12	±0.6%
σ_{π^+p}	23.07±0.06	23.29±0.06	23.46±0.06	23.73±0.09	±0.5%
σ_{π^+d}	45.33±0.12	45.39±0.12	45.74±0.12	46.29±0.16	±0.6%
σ_{K^-p}	20.25±0.11	20.41±0.08	20.57±0.09	20.84±0.09	±0.5%
σ_{K^-d}	38.76±0.15	39.01±0.12	39.30±0.13	39.83±0.13	±0.6%
σ_{K^-n}	19.75±0.18	19.85±0.13	20.01±0.14	20.30±0.15	±0.7%
σ_{K^+p}	18.03±0.09	18.85±0.08	19.33±0.08	19.84±0.10	±0.5%
σ_{K^+d}	35.55±0.16	36.72±0.14	37.71±0.14	38.44±0.17	±0.6%
σ_{K^+n}	18.56±0.18	18.99±0.15	19.55±0.15	19.82±0.19	±0.7%
$\sigma_{\pi^-p} - \sigma_{\pi^+p}$	0.94±0.07	0.67±0.07	0.61±0.07	0.55±0.09	
$\sigma_{K^-p} - \sigma_{K^+p}$	2.23±0.13	1.57±0.10	1.24±0.10	1.00±0.13	
$\sigma_{K^-d} - \sigma_{K^+d}$	3.21±0.20	2.28±0.16	1.60±0.17	1.39±0.19	
$\sigma_{K^-n} - \sigma_{K^+n}$	1.18±0.25	0.86±0.19	0.46±0.21	0.48±0.24	
$\langle r^{-2}\rangle$ (mb^{-1})	0.0380±0.0022	0.0405±0.0022	0.0396±0.0022	0.0383±0.0022	

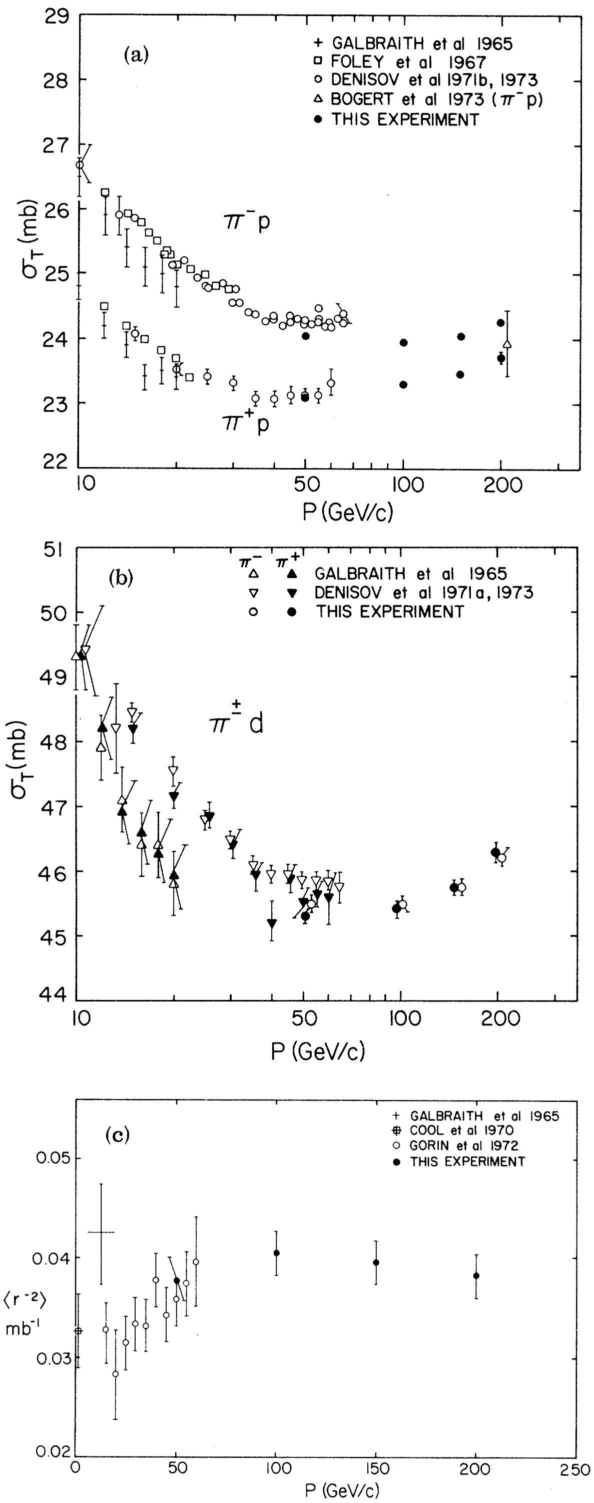

FIG. 1. Results of this experiment, together with previous data. (a) Total cross sections for $\pi^\pm$ on protons; (b) total cross sections for $\pi^\pm$ on deuterons; (c) values of the parameter $\langle r^{-2}\rangle$. Momentum-dependent errors only are shown. Previous data are from Refs. 2–8.

tion depended on the gas–Cherenkov-counter pressure setting; data taken for 100-GeV/c π^- had a contamination less than 0.1%, while for 100-GeV/c π^+ it was 0.1%. The correction to the cross section was determined by using a special electron run and checked with runs where the cross section was measured with varying electron contaminations.

Muons, which were ~1% of the pions in the beam, were identified by their ability to pass through 5 m of steel placed downstream of the transmission counters. Measurements made with different amounts of steel showed that 5 m of steel caused a negligible loss of muons, but adequate attenuation of pions. A ~0.5% correction to the pion cross sections was necessary for particles produced by pions interacting in the steel, escaping from its sides, but still giving a count in the muon scintillation counter; the correction was determined by using incident protons.

From these data, the number of muons in the pion beam at the hydrogen target could be determined. In the case of kaons, this measurement was used to determine the number of kaons at the hydrogen target, which was less than the number indicated by the gas Cherenkov counter because of decays between the Cherenkov counter and target.

The extrapolation of the partial cross sections to $t=0$ was carried out with the use of the expression

$$\sigma_i = \sigma_T \exp(At_i + Bt_i^2 + Ct_i^3),$$

where σ_i is the partial cross section measured by the ith transmission-counter combination subtending a maximum t_i, and σ_T is the total cross section. The Ct_i^3 term was needed only for $\pi^\pm$ and K^+ on deuterons; in the other cases no improvement in the fit was obtained when it was added and so C was set equal to zero.

Momentum-dependent uncertainties for a particular incident particle in the pion data are ±0.25%, mainly due to uncertainties in the muon and electron contamination. For kaons, they are dominantly given by the statistical errors. Overall momentum-independent scale uncertainties are ±0.5% for cross sections on deuterons.

Results of this experiment are shown in Figs. 1 and 2, together with previous data,[2-8] and are listed in Table I. The cross sections for $\pi^\pm$ and $K^\pm$ all show a rise with increasing momentum (the π^-p rise is about 3.5 standard deviations).

The cross sections for $\pi^\pm d$ shown in Fig. 1(b) are equal within our errors as required by charge

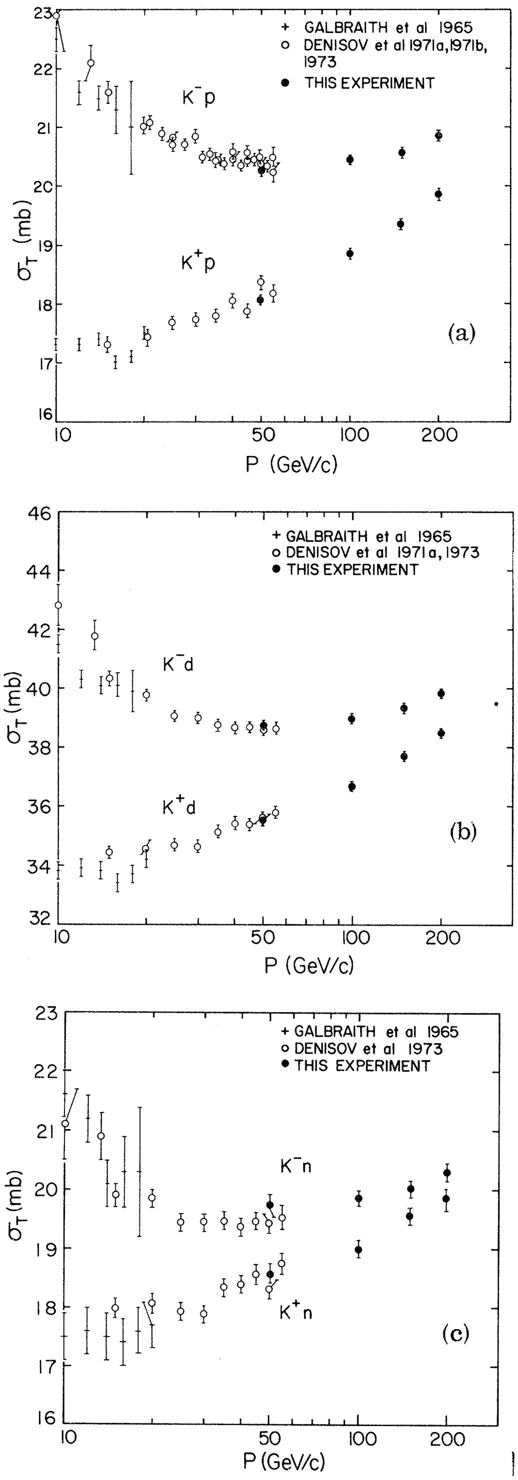

FIG. 2. Results of this experiment, together with previous data, for total cross sections of (a) $K^{\pm}$ on protons; (b) $K^{\pm}$ on deuterons; (c) $K^{\pm}$ on neutrons. Momentum-dependent errors only are shown. Previous data are from Refs. 2–7.

symmetry. Averaging the four momenta, we obtain $\sigma(\pi^-d)/\sigma(\pi^+d) = 1.0014 \pm 0.0019$. With the use of $\pi^{\pm}d$ and $\pi^{\pm}p$ cross sections, the parameter $\langle r^{-2}\rangle$ in the Glauber-Wilkin[9,10] shielding expression can be derived, and is shown in Fig. 1(c) and in Table I. This parameter appears to be constant over our momentum range, averaging 0.039 mb^{-1}. We have used this value in deriving the kaon cross sections on neutrons shown in Fig. 2(c) and Table I; a momentum-independent uncertainty of $\pm 0.7\%$ is assigned to allow for uncertainties in this procedure. The momentum dependence of the neutron cross sections is very similar to that for cross sections on protons.

Antiparticle-particle cross-section differences are given in Table I and shown in Fig. 3; note that a number of uncertainties common to both cross sections cancel in these differences. In all cases the differences can be fitted by the form $As^{\alpha-1}$; using our data only, we obtain $\alpha = 0.60 \pm 0.10$, 0.45 ± 0.07, and 0.39 ± 0.08 for $\sigma_{\pi^-p} - \sigma_{\pi^+p}$, $\sigma_{K^-p} - \sigma_{K^+p}$, and $\sigma_{K^-d} - \sigma_{K^+d}$, respectively.

There are a number of relations between total cross sections predicted by quark and Regge-pole models; Denisov *et al.*[6] tested them with

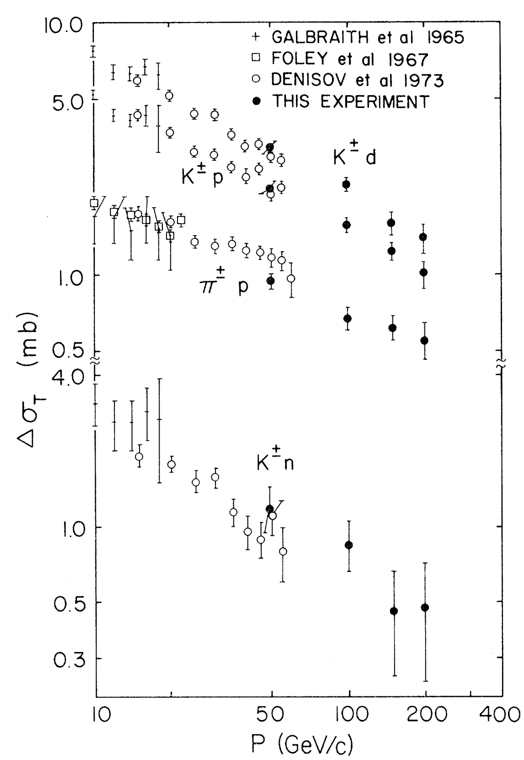

FIG. 3. Results of this experiment, together with previous data, for total cross-section differences $\sigma_{\pi^-p} - \sigma_{\pi^+p}$, $\sigma_{K^-p} - \sigma_{K^+p}$, $\sigma_{K^-d} - \sigma_{K^+d}$, and $\sigma_{K^-n} - \sigma_{K^+n}$. References as for Fig. 2.

data up to 65 GeV/c and found general agreement. Our data up to 200 GeV/c also show general agreement with these relations.

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