for a local interaction. However, we believe that the useful limits are those based on the local interactions.

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Inclusive Hadron Production in e^+e^- Annihilation at $\langle s \rangle = 53$ GeV^2

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We report on inclusive hadron production in e^+e^- annihilation at $\langle s \rangle = 53$ GeV^2, using a small solid-angle magnetic spectrometer with good particle identification at 90° to the beams at SPEAR II. The cross sections of $\pi^\pm$ and $K^\pm$ when compared with data at $s = 23$ GeV^2 exhibit scaling in $(s/\beta)d\sigma/dx$ with $x = 2E/s^{1/2}$. The invariant cross section depends on the momentum as p^{-4}.

We have measured the inclusive hadronic cross section with a small solid-angle spectrometer at the highest SPEAR II energies between $s = 49$ and 58 GeV^2. This was an extension of a previous experiment at SPEAR I.[1]

The single-arm magnetic spectrometer used in this experiment was similar to that used in our earlier experiment.[1,2] It was situated at $(90 \pm 13)°$

with respect to the beams. The minimum momentum required for traversal of the spectrometer was 0.3 GeV/c, and the geometrical acceptance for high-momentum particles was 0.084 sr. Trajectories were measured with proportional wire chambers (PWC) before and within the magnet giving a momentum resolution of $\Delta p/p = [0.011\,(\text{GeV}/c)^{-1}]p$. The entrance of the magnet was covered by a threshold Čerenkov counter (Č) filled with propane at 90 psi (gauge) with threshold of 0.8, 1.05, and 3.7 GeV/c for μ, π, and K, respectively. Time of flight (TOF) was measured along a 4.7-m-long path with a standard deviation of 0.36 ns using a small start scintillation counter near the interaction region and an array of stop counters at the magnet exit. Following the TOF counters were a Pb-scintillation shower counter and a slotted iron hadron filter (799 g/cm^2) containing three planes of scintillation counters. A set of PWC's, shower counter, and hadron filter on the opposite side helped identify e^+e^- and $\mu^+\mu^-$ pairs. The central detector,[3] consisting of four cylindrical layers of proportional tube counters, covered a solid angle of $0.9\times 4\pi$. An inclusive one-particle trigger required a coincidence between the TOF start and stop counters, hits in a combination of spectrometer PWC's, and the beam crossing signal.

In the analysis, beam-gas background was determined from the origin distribution and subtracted. Cosmic rays were removed by cuts on the event's origin and their TOF. The information from the Č counter, TOF, shower detector, and hadron filter was then used to identify the particle.[4] Muon events with $p > 0.8$ GeV/c were identified with the Č counter together with penetration of the hadron filter. There were 118 collinear $\mu\mu$ events, from which we determined[5] the integrated luminosity: $\int \mathcal{L}\, dt = 8.74 \pm 0.78$ pb^{-1}. A sample of anomalous muon events in excess of quantum electrodynamics has been discussed elsewhere.[6] The contribution to the hadronic spectra below 0.8 GeV/c from misidentified μ's is less than 5% from leptonic decays of the heavy lepton τ,[7] less than 3% from semileptonic decays of charmed mesons based on inclusive electron data,[8] and less than 4% from the two-photon process $ee \to ee\mu\mu$.[9] Electrons were recognized by the large pulse height in the Č counter and the shower counter.

Protons and antiprotons were identified by TOF. Only antiprotons were used and their number was doubled. Pions and kaons with $p < 1.2$ GeV were identified by TOF. 15% of all hadron events with momentum below C threshold were found to have a Č-counter pulse above pedestal. This contamination was corrected for in the π,K sample with momenta above 1.2 GeV where the Č counter was used for π,K separation. The final sample of 950 hadrons contained 863 π's, 74 K's, and 13 $\bar{p}$'s. By use of a Monte Carlo simulation the data were corrected for geometrical acceptance, nuclear interaction, hadronic punchthrough, and π,K decay in flight.

The inclusive momentum spectra $4\pi(d^3\sigma/d\Omega\, dp)$ at $\langle s\rangle = 53$ GeV^2, $\theta = 90°$ for $\pi^\pm$, $K^\pm$, and (doubled) $\bar{p}$ are shown in Fig. 1. The error bars include the statistical errors and the uncertainty of the applied corrections. Not included is an additional 10% overall normalization error. We calculate the following particle fractions: For 400 MeV/c $< p < 1000$ MeV/c, $f_\pi = 0.87 \pm 0.01$, $f_K = 0.12 \pm 0.02$, $f_{\bar{p}} = 0.014 \pm 0.005$; for $p \geq 1000$ MeV/c, $f_\pi = 0.76 \pm 0.02$, $f_K = 0.16 \pm 0.03$, $f_{\bar{p}} = 0.07 \pm 0.02$.

In order to test predictions of scaling models, we compare the present data with our results at $s = 25$ GeV^2. The latter represent a reanalysis of previously published data,[1] extending them to lower momenta ($p_{\min} = 400$ and 700 MeV/c for $\pi^\pm$ and $K^\pm$, respectively) with improved reconstruction and identification methods.[2] One form of scaling predicts[10] that the invariant cross section $E\,d^3\sigma/dp^3$ should behave as $f(x)p^{-4}$ with $x = 2E/s^{1/2}$. Figure 2 shows the invariant cross sections for $\pi^\pm$ for $s = 53$ and 23 GeV^2 as a function of momentum. The data for both c.m. energies are well described by p^{-4} (see Table I), i.e., the structure

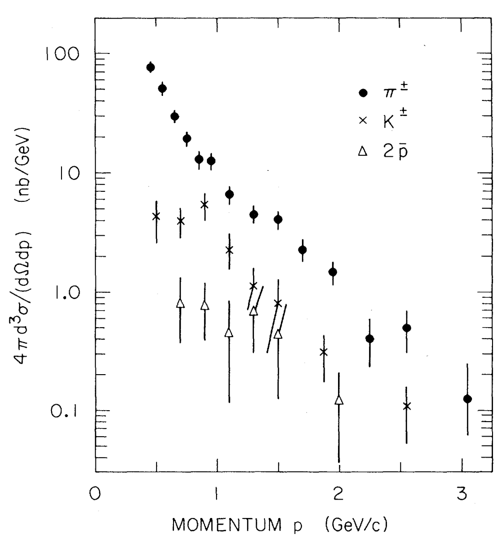

FIG. 1. Momentum spectrum at $\langle s\rangle = 53$ GeV^2 and $\theta = 90°$ for $\pi^\pm$, $K^\pm$, and (doubled) $\bar{p}$.

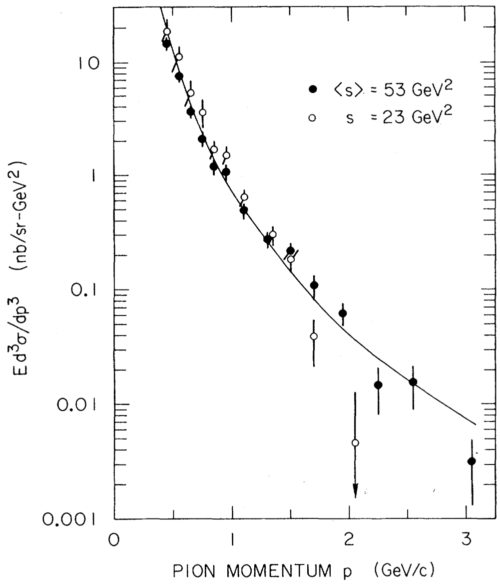

FIG. 2. Invariant cross sections for $\pi^{\pm}$ as a function of momentum p at $\langle s\rangle = 53$ and 25 GeV^2. The curve is the fit to the combined data: $E\, d^3\sigma/dp^3 = 0.72 \cdot p^{-4}$.

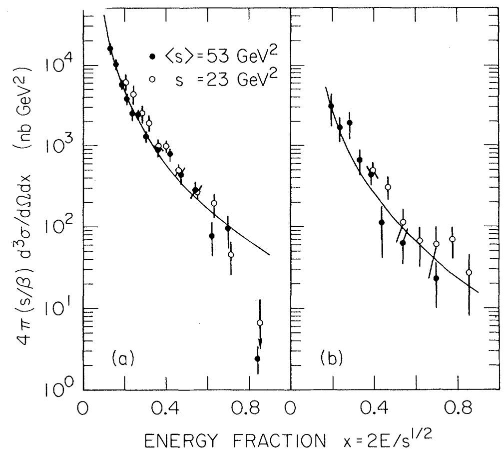

FIG. 3. Scaling cross sections for (a) π and (b) K at $\langle s\rangle = 53$ and 23 GeV^2. The curves are fits to the data at both s values combined of the form B/x^m (see Table I).

function $f(x)$ is only a weak function of x. The p^{-4} behavior should be compared with the $p_{\perp}^{-8}$ form of the inclusive cross sections for $pp \rightarrow$ hadrons.[11]

In analogy to deep inelastic ep scattering, scaling has been predicted[10] in the form of $(s/\beta)d\sigma/dx = F(x)$. Figures 3(a) and 3(b) show these cross sections for $\pi^{\pm}$ and $K^{\pm}$, respectively, at $s = 25$ and 53 GeV^2. The π and K cross sections separately exhibit scaling; furthermore, the scaling functions $F(x)$ have similar x dependence for π and K and show the x^{-3} behavior corresponding to scaling in p^{-4} mentioned above (see Table I).

Data on inclusive hadron production in e^+e^- annihilation[12-14] are published in the form of the scaling cross section in x. We find that at $s \sim 25$ GeV^2 our $\pi^{\pm}$ data are about 30% higher than the data of Brandelik *et al.*,[12] while the $K^{\pm}$ spectra agree. Adding up the different hadrons allows us to compare the data at $s = 53$ GeV^2 with preliminary non-particle-separated inclusive cross sections reported by Schwitters[13] at the same s val-

TABLE I. Results of cross-section fits.

		s (GeV^2)	53	23	53 + 23	
$E\,\dfrac{d^3\sigma}{dp^3} = \dfrac{A}{p^n}$	π	A	0.65 ± 0.04	0.82 ± 0.06	0.70 ± 0.03	
		n	4.0 ± 0.1	4.3 ± 0.2	4.1 ± 0.1	Fig. 2
		χ^2/DF[a]	16.7/12	13.4/9	37.5/23	
$4\pi\,\dfrac{s}{\beta}\,\dfrac{d^3\sigma}{d\Omega dx} = \dfrac{B}{x^m}$	π	B	30 ± 5	28 ± 5	33 ± 4	
		m	3.1 ± 0.1	3.5 ± 0.2	3.1 ± 0.1	Fig. 3a
		χ^2/DF[a]	14.9/12	12.1/9	36.8/23	
	K	B	6.8 ± 2.9	15 ± 8	10.9 ± 3.0	
		m	3.8 ± 0.4	3.6 ± 0.7	3.5 ± 0.3	Fig. 3b
		χ^2/DF	4.6/6	3.2/5	11.6/13	

[a] Fits without the highest-momentum point yield the same results with considerably increased confidence level.

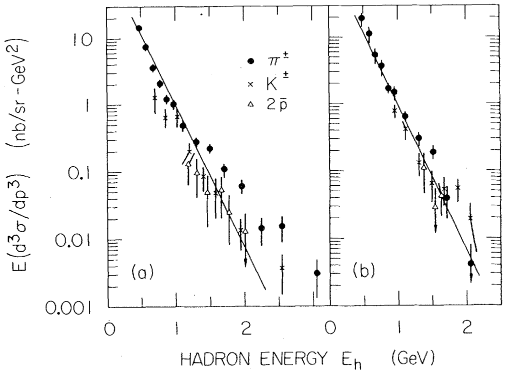

FIG. 4. Invariant cross section as a function of hadron energy E_h at (a) $\langle s\rangle = 53$ GeV^2 and (b) $s = 23$ GeV^2 for $\pi^\pm$, $K^\pm$, and (doubled) $\bar{p}$. The curves are of the form $\exp(-E_h/206$ MeV).

ue. We find agreement at low x_p ($x_p = 2p/s^{1/2}$) but at higher x_p ($x_p \sim 0.7$) the cross sections of Ref. 13 are higher by a factor of 2. If we correct for the observed angular distribution of the jet structure,[15] our high-momentum points at $s = 53$ GeV^2 increase by less than 25%. It is interesting to note that our $K^\pm$ data agree with the doubled K_s^0 data of Lüth *et al.*[16] at $s \sim 50$ GeV^2.

In the statistical or hydrodynamical model[17] the invariant cross section of all hadrons separately is described by a universal function $\exp(-E_h/kT)$, where E_h is the hadron energy and $kT \approx 160$ MeV. For $s = 23$ GeV^2, the data are well described by the function $\exp(-E_h/206)$ [Fig. 4(b)], while at $s = 53$ GeV^2 neither an exponential with the slope parameter 1/206 MeV nor any other slope fits the data [Fig. 4(a)].

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