Positron production at large transverse momenta in interaction of 70-GeV protons

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Institute of High Energy Physics
(Submitted September 23, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **22**, No. 9, 482–485 (5 November 1975)

We measured the positron content in the beam of secondary particles produced by interaction of a 70-GeV proton beam with Be and Cu targets. We show that at transverse momenta $P_\perp \approx 2$ GeV/c the relative yield of direct positrons is $R_0(e^+/\pi^+) \lesssim 3\times 10^{-5}$.

PACS numbers: 14.60.Cd, 13.80.–c

The experimental data concerning the cross section for direct production of leptons (μ, e), which was observed with the accelerator of our Institute,[1] are at present contradictory.[2] The question of the relative yield $R_0(l/\pi)$ of the direct leptons is of fundamental significance. In the case when the energy dependence of R_0 has a threshold, the lepton source is apparently the decay of heavy particles (say, Ψ).[3] But if this yield does not depend on energy, then it is not excluded that this is a manifestation of a new hitherto unknown singularity of strong interactions.

We have measured the composition of the beam with the aid of high-resolution gas Cerenkov counters and shower detectors.[4] The measurements were made on a beam of positive particles produced at lab. system angles corresponding to emission at angles close to 90° in c.m.s. The characteristics of the channel (Fig. 1) were described earlier.[5] We used Be and Cu targets 30 mm long and of 3 mm diam. The channel was adjusted and its operation monitored with a system of wire spark chambers.[6]

The signal M_8 corresponding to the passage of a particle through the channel was produced by coincidence (anticoincidence) of the counters $M_8 = A_k S_i$ ($i = 1$—8, $K = 1$—3). To separate the particles by mass, we used Cerenkov counters C_1–C_5, of which two, C_1 and C_5 each 8 m long, were used to separate μ and e, and the remainder to separate the π and K mesons, and also the heavier particles. The passage of an electron corresponded to a trigger pulse $T_e = M_8 C_1 C_5 C_e$, with amplitude discrimination introduced into the shower detector C_e (energy resolution $\approx 10\%$).[4] When the pressure in counters C_1 and C_5 was decreased to a point below the Cerenkov radiation registration, the count T amounted to 10^{-6} of M_8 (Fig. 2). The positron registration efficiency was close to 100%. The relative content of the positrons in the beam $R(e^+/\pi^+)$ was determined from the counting rate T_e in the region of the plateau of the registration of the positrons by the Cerenkov counters.

At small transverse momenta $P_\perp$, the positron yields is determined by the conversion positrons from the $\pi^0(\eta^0)$ meson decay. On going to the region of large $P_\perp$ the picture changes qualitatively. The point is that the main contribution to the production of electrons of energy E_0 is made by $\pi^0(\eta^0)$ mesons with momentum much higher than E_0. The abrupt decrease of the pion production cross section at large transfer values leads to a strong suppression of the conversion electrons. For the same reason, the yield of electrons from Dalitz pairs in π^0-meson decays is also suppressed. To take correct account of the contribution of the conversion electrons and of the electrons from the Dalitz pairs it is necessary to know the exact value of the spectrum in the region $P_\perp = 2$ GeV/c from the π^0-meson decay, which at present is unknown. The values of $R(e^+/\pi^+)$ were corrected for the absorption and decays of the particles.

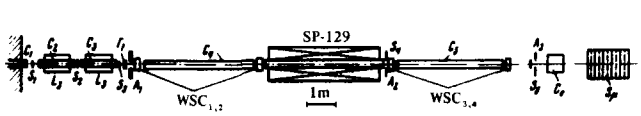

FIG. 1. Arrangement of the apparatus with the particle beak: S_i and A_k—scintillation counters, C_i—gas Cerenkov counters, C_e—cascade detector, WSC_{1-4}—wire spark chambers, S_μ—muon detector (six scintillation counters interlined with an absorber—6 plates 40 cm each.

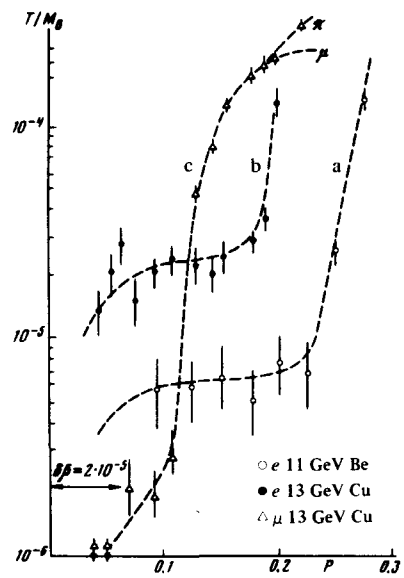

FIG. 2. Separation of the positrons and muons with the aid of the Cerenkov counters. a, b) Dependence of the ratio T/M_8 on the pressure in counters C_1–C_5, ○—e = 11 GeV Be, ●—e = 13 GeV Cu. c) Analogous plot for the ratio T_μ/M_8 ($T_\mu = (M_7 C_1 C_5 S_\mu)$, △—$\mu$ = 13 GeV Cu.

	θ = 145 mrad P = 9 GeV/c	θ = 160 mrad P = 11 GeV/c	θ = 170 mrad P = 13 GeV/c
Be	$(4.4 \pm 0.4) \cdot 10^{-5}$	$(2.2 \pm 0.3) \cdot 10^{-5}$	$(2.7 \pm 1.0) \cdot 10^{-5}$
Cu	$(17 \pm 2) \cdot 10^{-5}$	$(6.7 \pm 0.9) \cdot 10^{-5}$	$(8.5 \pm 2.0) \cdot 10^{-5}$

The relative content of the positrons in the beams at various momenta is listed in the table.

When the main contribution to the positron yield is made by the conversion positrons, the ratio of $R(e^+/\pi^+)$ for Be and Cu targets should be ~20. The observed ratio is ~3, indicating that the fraction of conversion positrons is negligible.

The values of $R(e^+/\pi^+)$ indicated in the table are upper bounds of direct positron production, i.e.,

$$R_e(e^+/\pi^+) \leqslant 3 \cdot 10^{-5}$$

at $P_\perp \sim 2$ GeV/c.

Thus, the measured upper bound of the direct yield of positrons coincides with the previously measured μ-meson yield[1] at 70 GeV, and amounts to $\approx 3 \times 10^{-5}$, much lower than the corresponding values at higher energies.[2] These data favor the assumption that the direct leptons come from heavy-particle decay.

The authors thank Yu. D. Prokoshkin and R. M. Sulyaev for a discussion of the results.

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