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Note on Prompt Lepton Production*

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Abstract

It is suggested that a substantial fraction of prompt leptons arise from charmed particles that are constrained to 100% leptonic decay. Some implications for further observation are discussed.

The production of prompt leptons in high energy hadron collisions seems greatly to exceed that predicted by the Drell–Yan parton–antiparton annihilation mechanism, and is also about a factor of three larger than can be accounted for by lepton pair decay of the known vector mesons (Farrar and Field 1975). It is suggested here that this discrepancy could be made up by charmed particle decay on a model that requires a 100% leptonic branching ratio for such decays (Peaslee 1976).

The production of prompt μ^+ in nucleon–nuclear collisions at 300 GeV and $x_\parallel \approx 0$ is described by (Boymond *et al.* 1974)

$$E\,\mathrm{d}^3\sigma_\mu/\mathrm{d}p^3 \approx 10^{-30}\exp(-4p_\perp) \quad \mathrm{cm}^2\,(\mathrm{GeV}/c)^{-2}. \tag{1}$$

An exactly similar expression describes the production of J particles with $p_\perp > 1$ GeV in pp collisions (Farrar and Field 1975, Fig. 3*b*). Thus, in this regime, we have

$$\sigma_\mu \approx \sigma_J. \tag{2}$$

Now J particles arise from creation of a $c\bar{c}$ pair so that, if these quarks reside in two different final hadrons instead of a single one, a pair of charmed particles results. Coherent processes should favour J production, while incoherent ones should favour charmed pairs. In the absence of better information, we take $\sigma_c \approx 2\sigma_J$. Hence, if muon decays are half the lepton decays, which have a branching ratio B for charmed particles, then we have

$$\sigma_\mu = \tfrac{1}{2}B\sigma_c \approx B\sigma_J. \tag{3}$$

Considering the uncertainties in equations (2) and (3), we find that they are in good agreement with $B = 100\%$. This value for B requires that prompt leptons be always produced in pairs. But half of these pairs are (μe), which therefore comprise $\frac{1}{3}$ of the

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total prompt lepton yield, allowing that $\frac{1}{3}$ of the yield is $(\mu\mu)$ and (ee) from vector mesons.

The present model is also compatible with the increase of prompt leptons at low $p_{\perp}$, which has been interpreted (Lederman and White 1975) in terms of an intermediate boson of mass $m_x \approx 300$ MeV. In the present case, m_x represents the mean energy of the leptons in charmed particle decay. Their energy distribution is given roughly by

$$P(E) \approx E^4 \exp(-E/T), \tag{4}$$

where E^4 is the phase space for decay of a charmed particle into two leptons plus a residual hadronic state, and T is the level density of those residual hadronic states. The average energy is $\bar{E} = 5T$, and equating this to m_x yields

$$T \approx 60 \quad \mathrm{MeV}, \tag{5}$$

which is a factor of two or three smaller than for fully excited hadronic matter, but may be appropriate to low excitations ($\lesssim 2$ GeV).

Two cases of prompt electron production have been reported by Komar *et al.* (1975) in nuclear emulsions exposed to 200 GeV protons. To interpret these, we first note that the second lepton required by the present model will be a muon about 40% of the time, and hence indistinguishable in the emulsion from pion tracks. In each star reported by Komar *et al.*, two other charged tracks of high $p_{\perp}$ were observed, with net total masses of 1·7–1·9 and 2·0–2·2 GeV. To interpret these, we suppose the presence of charmed bosons D and F that decay into $\mathrm{e}+\nu+\mathrm{K}+\pi$. Then, by the argument leading to equation (5), the parent masses will be

$$m_D \approx 2{\cdot}0\text{–}2{\cdot}2 \qquad \text{and} \qquad m_F \approx 2{\cdot}3\text{–}2{\cdot}5 \quad \mathrm{GeV}. \tag{6}$$

Thus, if the lowest values in the approximations (6) correspond to different charmed mesons, a survey of $\mathrm{K}\pi$ masses associated with a lepton trigger should give some indication of a double peak in the $m(\mathrm{K}\pi)$ distribution, with a dip around 1·9 GeV.

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