POLARIZATION EFFECTS IN MUOPRODUCTION OF W'S

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ABSTRACT

Relativistic leptons are left-handed in the V-A theory while negative muon beams are typically right-handed. The effect on W production by high-energy muons is discussed.

As stressed at last year's summer study (L. Lederman NAL B.2-68-74) one of the most attractive ways to hunt for the intermediate boson is with high-energy muons.

$$\mu^- + Z \rightarrow Z\ W + \nu \qquad \hookrightarrow \mu^- + \nu. \tag{1}$$

An essential feature of the search is the high energy. Even for massive W's, the minimum momentum transfer to the nuclear system at NAL energies can be sufficiently small to ensure coherence. We point out in this note a limitation to the effective muon energy from the polarization of the muon beam.

If the coupling of the weak leptonic current to the vector boson is given by

$$H = f\, j_\mu(x)\, W^\mu(x) + H.C.$$

with

$$\frac{f^2}{M_W^2} = \frac{1}{\sqrt{2}}\ \frac{10^{-5}}{M_p^2}$$

$$j_\mu(x) = \bar{X}_\nu \gamma_\mu (1 - \gamma_5) X_{\mu^-}.$$

The $1 - \gamma_5$ will project our left-handed muons. The corresponding cross section for W production will be suppressed by a factor

$$\frac{1 - P}{2},$$

where P is the longitudinal polarization of the incident muon,

$$P = +1 \text{ for right-handed muons}$$

$$P = -1 \text{ for left-handed muons.}$$

This is a familiar result of the V-A theory in which all leptons become left-handed and all anti-leptons right-handed in the limit in which leptonic masses may be ignored.

Muon beams are made from the decay in flight of pions. In the rest frame of the pion (= c.m. frame), negative muons thus produced are necessarily right-handed. The transformation to the laboratory gives the following results:

1. Muons produced forward in the pion rest frame are right polarized in the laboratory.

2. Muons produced at an angle

$$\cos\theta = -\beta = \frac{M_\pi^2 - M_\mu^2}{M_\pi^2 + M_\mu^2} \simeq -0.28$$

$$\theta \simeq 106°,$$

in the pion rest system have zero longitudinal polarization in the lab. Here β is the muon velocity in the pion rest system. Muons produced in a backward cone of half angle ~ 74° have $P \leq 0$ in the lab, becoming $P = -1$ at $\theta = 180°$.

As a practical matter, muons produced from the decay in flight of 100 GeV π^-'s have a flat energy distribution from 57 to 100 GeV. For energies < 72 GeV (corresponding to $\theta = 106°$ in the π rest system), $P < 0$ and the cross section is suppressed by a factor of at worst 2. As one goes to higher muon energies, i.e., to forward angles in the c.m., this factor increases. We note, for example, that in the beam design of Yamanouchi (NAL B.2-68-38) for which

$$0.9\, P_\pi < P_\mu < P_\pi,$$

the reduction in cross section can be quite substantial.