BEAM DUMP EXPERIMENT: UTILIZATION OF MUON POLARIZATION EFFECT IN W SEARCH

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ABSTRACT

A W-meson search is considered in a beam-dump experiment similar to that performed at AGS by the Yale-BNL group. The intensity and logitudinal polarization of the μ_W is investigated at the production. We present the sensitivity and limitation of the search at NAL.

Search for the W meson in hadron-hadron interactions (such as a beam dump experiment, $N + N \to N + N + W$) is attractive mainly due to its simplicity. It is suited for a "first-stage" experiment at NAL for the obvious reason that an external proton beam will be available at time of turn-on. There are several other interesting aspects about search of this type: 1) it is possible that the production cross section is larger than that by neutrinos; 2) at 200 GeV, proton flux is orders of magnitude higher than the neutrino flux. There are disadvantages. First, there is always the hadronic background. Second, a negative result does not necessarily imply the non-existence of the W in weak interactions.

Previously two experiments[1,2] were performed in which high-energy muons emitted at large angle with respect to the proton beam direction were observed. These experiments did not measure the muon polarization. The background conditions made the interpretation of the results difficult. To circumvent this, a measurement of the muon polarization was performed at the AGS by the Yale-BNL group.[3] W's were not found.

The point to exploit here is that the longitudinal polarization of muons from the decay of W, μ_W, should have a direction opposite to that the muons decaying from pions or kaons. The following is a summary of some known facts: The longitudianl polarization of μ_W is given by

$$P_L\,(\mu_W^{\pm}) \approx \pm 1 - \frac{2\,M_\mu^2}{M_W^2}\;\frac{E_W}{E_\mu}\;, \qquad (1)$$

where E_W and E_μ are the energies of the W and the muon in the laboratory. Thus when $E_W \approx E_\mu$, we have $P_L(\mu_W^{\pm}) \approx \pm 1$ to accuracy of M_μ^2/M_W^2. We expect no kinematic depolarization.

The longitudinal polarization of the muon from the $\pi \to \mu\nu$ or $K \to \mu\nu$ mode depends on the slope of the pion or kaon spectrum. The Lorentz transformation of the right-handed muons of pionic or kaonic parentage from c.m. to laboratory frame produces the following effects. Muons decaying forward in the c.m. frame will be right-handed in the laboratory. However those muons produced with c.m. angle,

$$\theta \leq \cos^{-1} \frac{M_\pi^2 - M_\mu^2}{M_\pi^2 - M_\mu^2} = -0.28\,,$$

will have a polarization of equal to or less than zero.[4] To insure the right-handedness, one must select muons decaying forward of -0.28. It is imperative that backward muons be rejected before entering the apparatus, otherwise a severe dilution of the sensitivity to W's would result. Here lies the advantage of high beam energy since one could attempt to detect W decays (i.e. μ_W) at a large angle without severe loss of signal due to form-factor effects. At a large emission angle, pions are suppressed due to a large transverse momentum $P_\perp$ required. The μ background from pions decreases exponetially as $P_\perp$ since they decay within less than 1 mrad of the pion direction. Thus the optimum angle would be far away from the forward direction.

In W production by $NN \to NN + W$, the minimum momentum transfer to the target is $M_W^2/2\,E_P \simeq 0.06$ BeV/c for $M_W = 5$ GeV/c^2 and $E_P = 200$ BeV. One would expect the cross section to hold up at this momentum transfer. With a heavy target we look for μ_W with momentum $\simeq 100$ GeV/c at an angle of 2.5 GeV/100 $\simeq$ 25 mrad. The transverse momentum of 2.5 GeV insures a suppression of π background of $> e^{10}$. At a larger W mass, the minimum momentum transfer to the nucleus increases. This causes loss of signal due to form-factor suppression but it is conveniently compensated by a larger transverse momentum available. The maximum transverse momentum allows an estimate of the W mass.

In the experimental setup, one envisages the proton beam striking a heavy target whose effective thickness can be varied within a factor of three. A solid iron magnet deflects 100-GeV muons by 50 mrad (muons are detected at a total of 75 mrad from the beam line); 200 ft of shielding downstream serves to moderate the energetic muons which are subsequently transported to a stop in the scintillator-brass spark-chamber array for polarization analysis. Muon background fron pion decays is expected to be inversely proportional to the effective density of the target. Residue muons can thus be measured by extrapolating to $1/d = 0$.[3] Contamination from electromagnetic processes can be removed by subtracting the negative muons from the positive ones.

The utilization of muon polarization in W decay is not restricted to hadron-hadron collisions. It is equally applicable in the suggested W search by neutrinos[5] and by muons.[6] More confidence in the results can be achieved if electrons from the muon decay exhibit the angular distribution

$$\frac{dN}{d\theta} = 1 + p \cos \theta , \qquad (2)$$

where p is the asymmetry parameter.

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