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B 6 Dimuon Production by High Energy Neutrino and Antineutrino in the Fermilab 15-Foot Bubble Chamber

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It is of interest to detect two types of dileptons ($\mu\mu$ and $e\mu$) in the *same* experiment in order to compare rates, strange-particle content, and other features predicted by QCD. It is important to have positive muon and electron detection, as well as the ability to see strange particles and to measure the hadronic final state in detail. These requirements have been satisfied by the "E-546 experiment" at Fermilab which used the 15-foot bubble chamber, newly equipped with a two-plane EMI and filled with neon-hydrogen liquid for electron detection (see Fig. 1). We chose 47% (atomic) neon concentration in order to resolve clearly Dalitz and gamma pairs, primary Vees, and interactions close to the vertex.

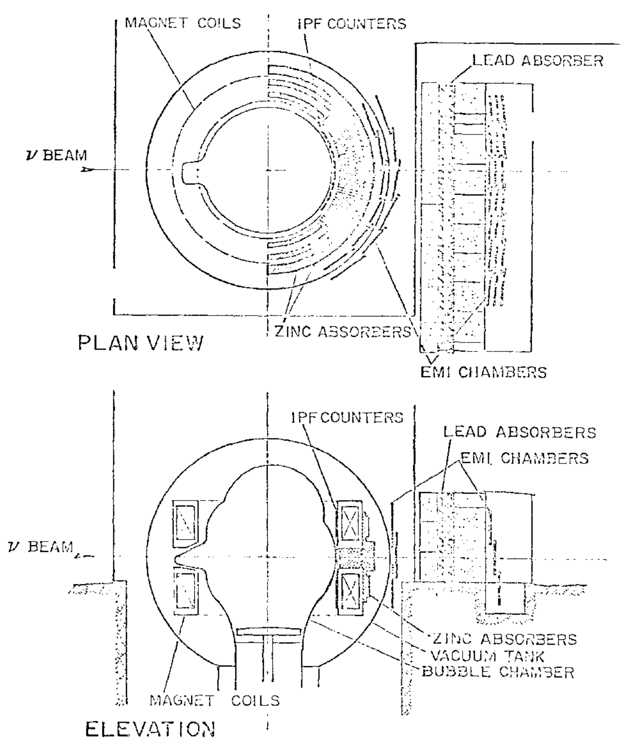

Fig. 1.

The exposure of the 15-foot chamber to the quadrupole-triplet beam (3.4×10^{18} protons) provided a high-energy (mean energy 90 GeV) neutrino/antineutrino beam with a charged-current event ratio $CC/\overline{CC}=6/1$. At present we have analyzed 2/3 of our dimuon sample, in a total of 326,000 pictures. We have restricted our events to those in which the two muons pass through both planes of the EMI in time-coincidence (400 nsec). The requirement reduces our dimuon sample by about a factor of two, due to the limited geometrical acceptance of the two-plane EMI. The final sample will yield about 11,000 neutrino and 2,000 antineutrino charged-current events with two-plane EMI muon identification.

Applying cuts to the measured events, we find that 40 opposite-sign dimuon candicates, 9 $\mu^-\mu^-$ candidates, and no $\mu^+\mu^+$ candidates survive in 2/3 of the total sample. These events were then measured completely in order to determine the momenta of all tracks. The "leading muon" was determined as that muon having the largest transverse momentum with respect to the total vector momentum of the remaining tracks. We then designate 33 "neutrino dimuons" ($\mu^-\mu^+$) as those with a leading μ^-; 7 "antineutrino dimuons" ($\mu^+\mu^-$) are those with a leading μ^+.

§1. Backgrounds

Previous backgrounds which limited the effectiveness of the one-plane EMI with the short-spill horn beams are now much reduced. The two-millisecond spill of the quadtriplet beam has made the dimuon random background negligible. The additional absorber of the two-plane EMI provides a total of 8 to 10 pion *absorption* lengths, so that the punch-through background of in-time background meeting the $CL12=.01$ cut is very small. The most important background for dimuons continues to be meson decay ($\pi\rightarrow\mu$ and $K\rightarrow\mu$) within the bubble-chamber liquid and vacuum tank. Fortunately, this background can be estimated accurately from the measured leaving tracks (which include meson decays) and the known lifetimes. We find that (due to the lower momentum of the decay muon) 40% of the π–μ decays and 65% of the K–μ decays are eliminated by EMI acceptance criteria.

§2. Net Yield of Dimuons

The net yield of dimuons, after subtraction of backgrounds, is given in Table I for two different cuts on the muon momentum. The net signal is *not* strongly dependent upon the muon momentum cut. The signal is evident only for opposite-sign dimuons; like-sign dimuons are accounted for entirely by background.

Table I. Dimuon candidates and backgrounds. (Muon momentum >4 GeV/c)

	$\mu^+\mu^+$	$\mu^+\mu^-$ & $\mu^-\mu^+$	$\mu^-\mu^-$
Events	0	40	9
π and K Decays	1.2±0.2	11.2±2.2	5.0±1.0
Punch through	0.4±0.4	2.4±2.4	2.9±2.9
Net signal	−1.6±1.2	26.4±7.1	1.1±4.3

The rate for opposite-sign dimuons has been calculated using efficiencies (acceptances× instrumental) determined for both dimuon events and single-muon events. We use experimental data to compute these efficiencies: $CC=70+4\%$, $\overline{CC}=76\pm4\%$, and $\mu^-\mu^+=52\pm6\%$.

The rate of opposite-sign dimuons, relative to single muons, is then:

$$R=\frac{\mathrm{Rate}(\nu+N\rightarrow\mu^-\mu^+X)+\mathrm{Rate}(\bar{\nu}+N\rightarrow\mu^+\mu^-X)}{\mathrm{Rate}(\nu+N\rightarrow\mu^-X)+\mathrm{Rate}(\bar{\nu}+N\rightarrow\mu^+X)}=(0.43\pm0.14)\times10^{-2}.$$

§3. Strange Particles Associated with Dimuons

All of the V^0s from the dimuon candidates and V^0s in a subsample of 960 charged-current events have been measured and fitted. The primary vertex origin of the V^0 is unambiguous in every case; this is one advantage of the medium density neon. The result for the CC and $\overline{CC}$ events is as follows:

$$\frac{\mu^-V^0}{\mu^-}=9\%\pm1\%;\quad\frac{\mu^+V^0}{\mu^+}=11.5\%\pm3\%$$

both results being uncorrected for branching ratios.

The comparable result for the 40 dimuon candidates (4 GeV/c cut) is 5 V^0s (3 K^0_s and 2 ambiguous K^0_s/Λ^0). Thus we calculate an uncorrected rate:

$$\frac{5\mu^-\mu^+V^0}{40\mu^-\mu^+}=1.3\%\pm5\%$$

which is only slightly larger than the rate observed for CC ($\overline{CC}$) events.

If μe and $\mu\mu$ events are assumed equivalent in strange-particle content, we are statistically compatible with Columbia–BNL E–53[1] experimental result (15/81), and 2.0 σ lower than Wisconsin–Hawaii–Fermilab–CERN–Berkeley eμ E-28[2] result (11/17).

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B 6 Neutrino–Hydrogen Interactions in BEBC

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§1. Introduction

The 3.7 m BEBC bubble chamber filled with hydrogen was exposed at the end of 1977 to the CERN wideband neutrino beam and 285 000 photographs were taken corresponding to 1.1×10^{18} protons of 350 GeV on the target. A total of some 7000 charged current events are expected with visible energy $E_{\text{vis}}>5$ GeV and muon momentum $p_\mu>3$ GeV/c. Results are presented here on a first sample of 4500 charge current (CC) events. A major feature of the analysis is that $\sim$730 events which had a three-constraint fit to the reactions

$$\nu\text{p}\rightarrow\mu^-\text{p}\pi^+ + m(\pi^+\pi^-) \qquad (1)$$

with $m=0, 1, 2, \ldots$, were obtained. The External Muon Identifier, EMI, consisted of two planes of multiwire proportional chambers. An outer one of 50 MWPC each of 3×1 m^2, and an inner one of 6 chambers. The inefficiency was very small $\lesssim 1\,1/2\%$, ($1/2\%$ from dead wires, $\lesssim1\%$ for accidental coincidences, negligible punch through). The fiducial volume used in BEBC and its weight were 19 m^3 and 1.1 t, respectively. Good flux measurements were made which will allow us to give absolute cross sections. Some preliminary results have been given in more detail.[1]

§2. Cross Sections and Types of Reactions

The variation of cross section with energy for most neutrino channels is not well known. For example in hadron–hadron reactions, the diffraction dissociation cross section is a constant fraction $\sim1/5$ of the inelastic cross section and rises monotonously with energy as in Fig. 1(a), but in neutrino interactions it is not known whether the diffractive cross section is again a constant fraction of the inelastic or if it is constant with energy as sketched in Fig. 1(b). Theoretical arguments have been made supporting both hypotheses.

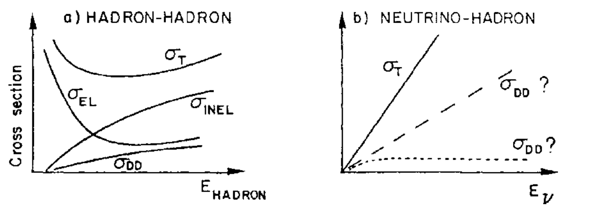

Fig. 1. See text.

If the true multiplicity, *i.e.*, the actual number of particles in the final stage, charged plus neutral, is known then one can study how the total cross section σ_{tot} is built up. For hadrons this is as in Fig. 2(a), but for neutrinos it is not known—it could, for example be as in Fig. 2(b). This question may be partly answered by considering the variation of the cross sections of reactions (1) with $m=0, 1, 2, \ldots$ with energy. This is

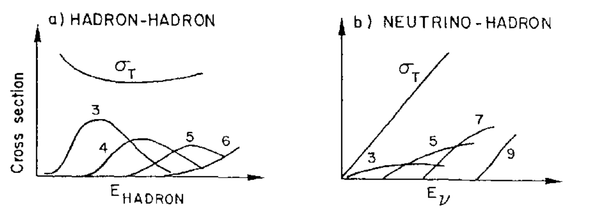

Fig. 2. See text.