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MOMENTUM DEPENDENCE OF HADRONS PRODUCED IN $\nu(\bar{\nu})$Ne INTERACTIONS*

H. Rudnicka†, T.H. Burnett, S. E. Csorna, D. Holmgren, G. Kollman, H. J. Lubatti, K. Moriyasu, G. M. Swider, B.S. Yuldashev††

Visual Techniques Laboratory, University of Washington
Seattle, Washington 98195

H. C. Ballagh, H. H. Bingham, W. B. Fretter, D. Gee, G. Lynch, J. P. Marriner, J. Orthel, M. L. Stevenson, G. P. Yost

University of California and Lawrence Berkeley Laboratory
Berkeley, California 94720

R. J. Cence, F. A. Harris, M. D. Jones, S. I. Parker, V. Z. Peterson, M. W. Peters, V. J. Stenger

University of Hawaii
Honolulu, Hawaii 96822

ABSTRACT:

The inclusive distributions of hadrons produced in $\nu(\bar{\nu})$Ne interactions are studied as a function of the momentum fraction z. Discrepancies between the data and existing parametrizations of the quark-parton model are found.

† Visitor from the Institute of Nuclear Physics and Technology of the Academy of Mining and Metallurgy, Cracow, Poland.

†† Present address: Physical Technical Institute, the Uzbek Academy of Sciences, Tashkent, USSR.

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The production of hadrons in neutrino-induced interactions is described in the quark-parton model[1] by the structure functions $G_{Nq}(x,Q^2)$, which give the momentum distributions of the quark q inside the nucleon N, and fragmentation functions $D_q^h(z)$, defined as the average multiplicity of hadrons h whose momentum $p_h = zp_q$ is a fraction z of the momentum of the quark q. In this paper we present some characteristics of the fragmentation function for hadrons produced in $\nu(\bar{\nu})$Ne interactions, and compare them with the predictions of the quark-parton model. As an experimental definition of z we use the "light-cone" variable, i.e. $z = (E + p_L)/[\nu + (\nu^2 + Q^2)^{1/2}]$ which for $z \gtrsim 0.2$ is approximately the same as the variable $x_F^{lab} = p^{lab}/p_{max}^{lab}$ used in hadronic reactions.

The data come from a wide-band beam exposure of the 15-foot Fermilab bubble chamber filled with a heavy NeH_2 mixture (64% atomic Ne). Comparable numbers of ν_μ and $\bar{\nu}_\mu$ charged current events are obtained in this experiment. For each event, the momentum of the track identified by the EMI[2] as a muon was required to be greater than 4 GeV/c, and the total visible energy E_{vis} > 10 GeV. The neutrino energy was reconstructed from the measured momenta of charged secondaries using the method of p_T balance in the ν-μ plane.[3] Only the events with at least one minimum-ionizing, non-muon track are included in the data, which, after the above selection criteria are met, consist of 778 ν_μ and 737 $\bar{\nu}_\mu$ charged current interactions.

We have previously presented some results on the inclusive production of hadrons in $\nu(\bar{\nu})$Ne interactions[4,5,6] but with less than half of the present statistics. In particular, in ref. (6) we showed that the z distributions of fast secondaries produced in $\nu(\bar{\nu})$Ne interactions agree well with the corresponding x_F distributions for $\pi^+(\pi^-)$Ne interactions.[7] This result, with increased statistics, is presented in Fig. 1. However, since the πNe data are not available for $x_F > 0.5$, the comparison is limited to the target fragmentation region and only a part of the quark fragmentation region.

In the quark-parton model, the fragmentation functions are assumed to be characteristic of the fragmenting quark, independent of how the quark is produced. Thus, the z distributions $\bar{n}(z) \equiv (1/N_{tot})\,dN/dz$ in the quark fragmentation region should not depend on kinematical variables other than z. In Figs. 2 and 3 we present the average multiplicities $\int_{z=z_o}^{1} \frac{1}{N_{tot}} \frac{dN}{dz}\,dz$, ($z_o$ = 0.2, 0.3, 0.4) as a function of W and Q^2, and note that no significant dependence on these variables is observed in the region W > 2 GeV, $Q^2 > 2\ (\mathrm{GeV}/c)^2$, and $z_o = 0.4$ for negative particles. The weak dependence for positive tracks might be explained by proton contamination.[4] In Fig. 4 we show that the average multiplicity of hadrons with z > 0.4 for events with W > 2 GeV, $Q^2 > 2(\mathrm{GeV}/c)^2$ does not depend on $x_{BJ} = Q^2/2m\nu$.

According to the quark-parton model, the ratios $(\bar{n}_{\pi^+}(z)/\bar{n}_{\pi^-}(z))_\nu$, $(\bar{n}_{\pi^-}(z)/\bar{n}_{\pi^+}(z))_{\bar{\nu}}$, and $(\bar{n}_{\pi^-}(z))_{\bar{\nu}}/(\bar{n}_{\pi^-}(z))_\nu$ are described by the same function $1/\omega(z) \equiv D_u^{\pi^+}(z)/D_u^{\pi^-}(z) = D_d^{\pi^-}(z)/D_d^{\pi^+}(z)$. Since fast positive tracks contain non-negligible proton contamination,[4] the best experimental approximation of $1/\omega(z)$ is given by the ratio

$(\bar{n}_-(z))_{\bar{\nu}}/(\bar{n}_-(z))_\nu$.[8] In Fig. 5 we show this ratio for events with W > 2 GeV, $Q^2 > 2\ (\mathrm{GeV}/c)^2$ and compare with the parametrizations of $1/\omega(z)$ by Field and Feynman[1] (solid curve) and Sehgal[9] (dashed curve). The disagreement is rather striking. Both parametrizations show a steep rise at large z, which results from the expectation that a d-quark will more likely produce a π^- than π^+ as z tends to 1. However, the experimental values remain almost constant for z > 0.2. As we also show in Fig. 5, the increase of $(\bar{n}_-(z))_{\bar{\nu}}/(\bar{n}_-(z))_\nu$ can be obtained in our data by including the events with W < 2 GeV, $Q^2 < 2\ (\mathrm{GeV}/c)^2$. But, as we noted before, the z distribution for these events is significantly different from the rest of the data sample.

We observe a strong correlation between the average transverse momentum $\langle p_T \rangle$ and the variable z - this effect is known as the "sea gull effect" in hadronic interactions. In Figs. 6 and 7 we show the W and Q^2 dependence of the average transverse momentum $\langle p_T \rangle$ for different z regions. An increase of $\langle p_T \rangle$ with Q^2 has recently been observed in the BEBC experiment[10] and interpreted as resulting from gluon bremsstrahlung. As can be seen in Fig. 7, no such increase is observed in our data; however, in this experiment the range of Q^2 is smaller than in the BEBC experiment. In contradiction to the Field and Feynman parametrization, our data show a significant increase of $\langle p_T \rangle$ with W, for large values of z. This effect was observed also in the BEBC experiment.[10]

Conclusion:

We observe certain characteristics of the fragmentation functions which do not agree with existing theoretical parametrizations. In particular, the ratio $(\bar{n}_{-}(z))_{\bar{\nu}}/(\bar{n}_{-}(z))_{\nu}$ is approximately constant and equal to 2 in the region of $(0.2 \le z \le 1.0)$, whereas the general expectation is a steep rise as z tends to 1.0. Also, the $< p_T >$ increases significantly with W, which is not predicted by models.

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FIGURE CAPTIONS:

FIG. 1 : Comparison of the x_F^{lab} distributions of $\pi^{\pm}Ne \rightarrow s^{\pm}x$ ($\sqrt{s}$ = 4.4 GeV) with z distributions of $\nu(\bar{\nu})Ne \rightarrow s^{\pm}x$ ($3 \leq W \leq 6$), where $s^{+}(s^{-})$ is the positive (negative) fast particle, for a) favored, b) unfavored particles.

FIG. 2 : The average multiplicity of positive and negative fast tracks with $z > z_o$ (z_o = 0.2, 0.3, 0.4) as a function of Q^2.

FIG. 3 : The average multiplicity of positive and negative fast tracks with $z > z_o$ as a function of W.

FIG. 4 : The average multiplicity of positive and negative fast tracks with $z > 0.4$ as a function of x_{BJ}. Only the events with W > 2 GeV, $Q^2 > 2$ $(GeV/c)^2$ are included.

FIG. 5 : The ratio $\bar{n}_-(z)_{\bar{\nu}}/\bar{n}_-(z)_{\nu}$ for the events with W > 2 GeV, $Q^2 > 2(GeV/c)^2$ (full circles) and for all events (open circles). The solid curve is a parametrization by Field and Feynman;(1) The dashed curve is a parametrization by Sehgal.(9)

FIG. 6 : The average transverse momentum of fast particles as a function of W for different intervals of z.

FIG. 7 : The average transverse momentum of fast particles as a function of Q^2 for different intervals of z.

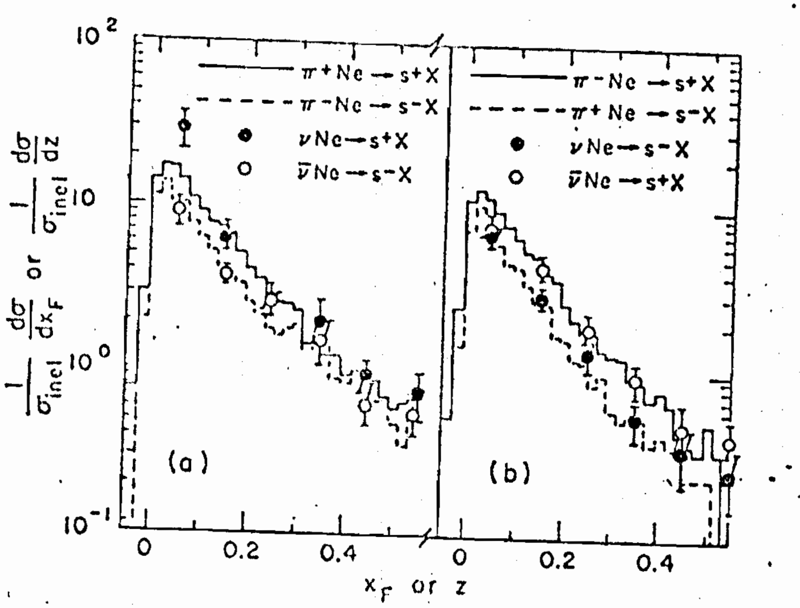

FIG. 1

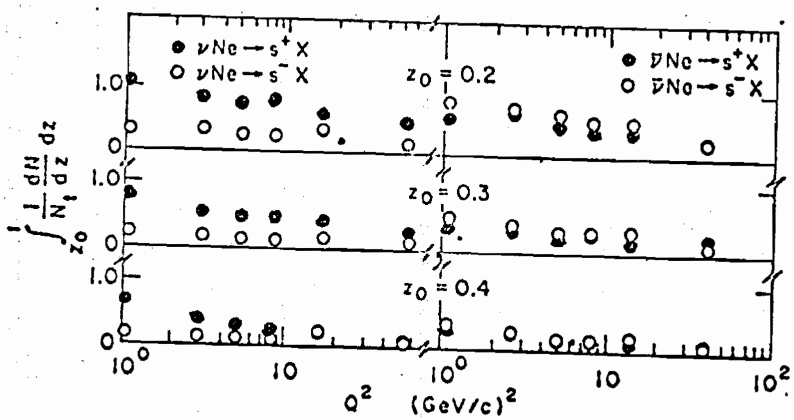

FIG. 2

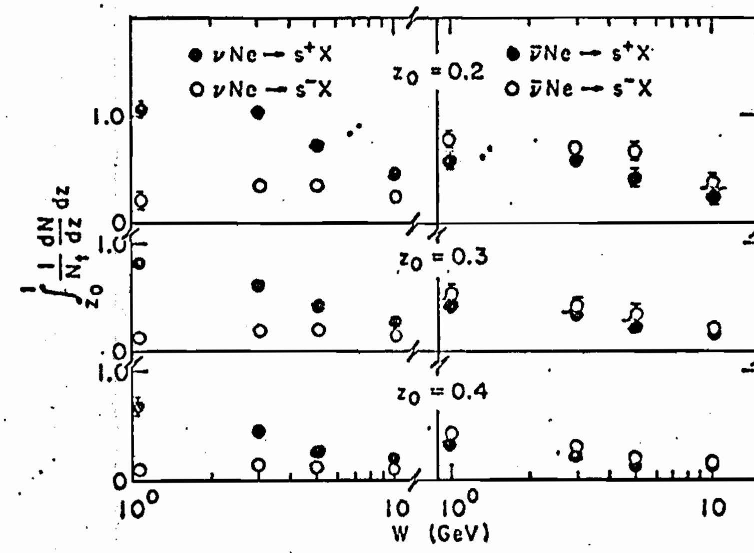

FIG. 3

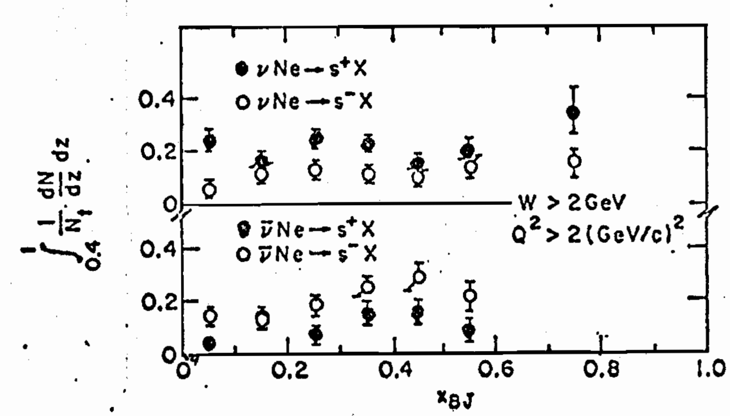

FIG. 4

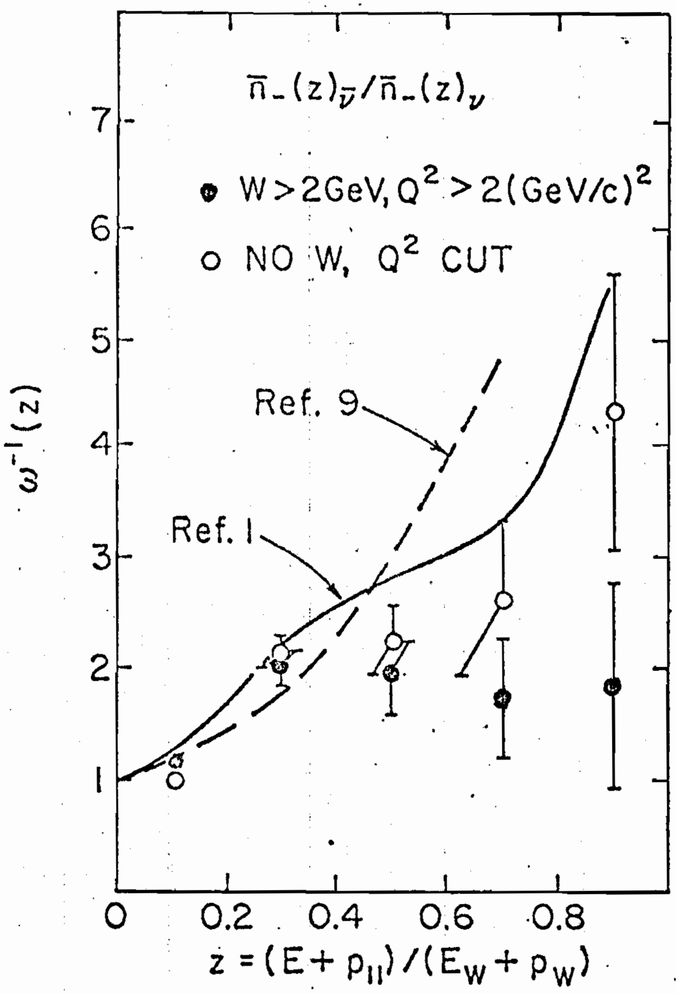

FIG. 5

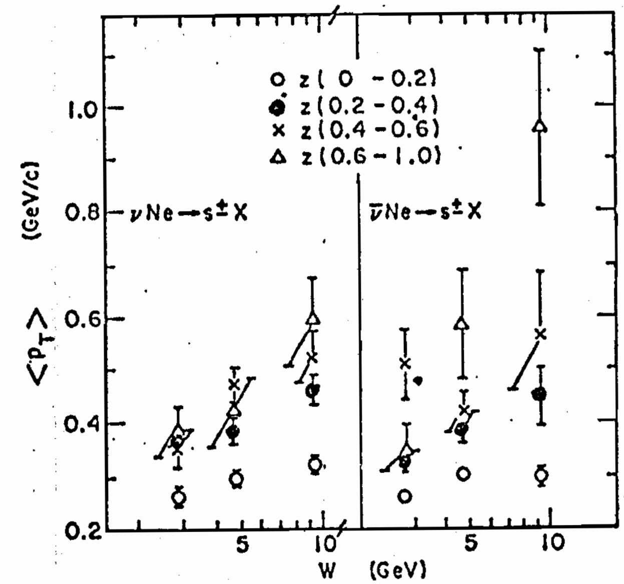

FIG. 6

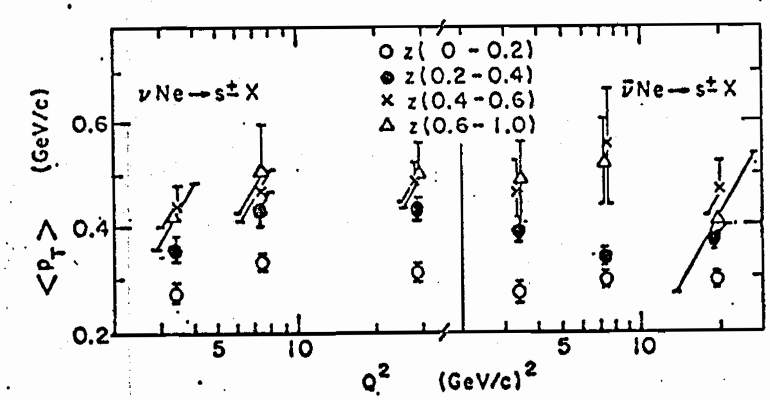

FIG. 7