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Comparison of 147 GeV/c $\pi^- p$ Low Transverse Momentum Particle Production with Deep-Inelastic Electroproduction

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ABSTRACT

We compare the distributions of the fastest particles and second fastest particles produced in $\pi^- p$ collisions at 147 GeV/c with the distributions of the fastest and second fastest particles produced in deep-inelastic electroproduction. We find the two distributions are remarkably similar even though the two processes are in very different kinematic regions.

In this paper we present a comparison of our data for hadron production of charged hadrons ($\pi^- + p \rightarrow$ hadrons) in regions of low transverse momentum with data from a study[1] of the electroproduction of charged hadrons ($e^- + p \rightarrow e^- +$ hadrons) at high transverse momentum. There are a number of quark-parton models that make predictions for electroproduction of hadrons, as well as for hadron production of hadrons at large transverse momenta.[2-6] In our study we also compare our data with curves from the Field and Feynman quark model[2] predicting the distributions of the fastest and second fastest charged hadrons with respect to the variable z, a comparison which was previously made for the electroproduction data in Ref. (1). For electroproduction, this variable is defined to be $z = P_{lab}/\nu$ where P_{lab} is the laboratory momentum of the hadron and ν is the laboratory energy of the virtual photon (see Fig. 1(a)) whereas for hadron production, we define $z = (E^* + P_{\parallel}^*)/\sqrt{s}$, where E^* and $P_{\parallel}^*$ are the energy and longitudinal momentum of the hadron in the center-of-mass system and $\sqrt{s}$ is the center-of-mass energy.[2] The variable z is familiar from electroproduction studies and although it is not commonly used to describe hadron data, we have chosen it to facilitate comparison with the electroproduction data and thereby directly exhibit the striking similarity between these two very different types of reactions. Given the current interest in the properties of large transverse momentum events and their interpretation in terms of quark jets, it is important to point out that events with small transverse momentum can have similar properties.

Figure 1(a) pictures the generally accepted mechanism for deep-inelastic electroproduction as described by the quark-parton model. The incident electron emits a virtual photon γ with invariant mass $-Q^2$ and laboratory energy ν. This virtual photon is assumed to be absorbed by a single quark (or anti-quark) which is

then ejected from the original proton and subsequently breaks up into a hadron jet whose final hadrons have invariant mass W. At sufficiently high Q^2 and W, this quark breakup can be described by the quark fragmentation function $D_q^h(z)$ which is the probability of a hadron of type h arising from the fragmentation of the quark q having momentum fraction $z = P_{lab}/\nu$.

Figure 1(b) depicts the production of hadrons at small transverse momentum by pions incident on protons in terms of the quark-parton model indicating the theoretical uncertainty concerning this process. In this picture, the quarks in both the pion and the proton interact in an as yet unknown way and produce the final state hadrons. In this study, we compare the large transverse momentum process of Fig. 1(a) with the small transverse momentum process of Fig. 1(b).

The data presented in this paper come from an experiment performed at the Fermi National Accelerator Laboratory using the Fermilab Hybrid Spectrometer exposed to a beam of 147 GeV/c negative pions. The experimental set-up consists of a 30-inch bubble chamber, preceded and followed by spectrometer elements, which has been described elsewhere.[7] The data were derived from the analysis of 100,000 pictures together with downstream spectrometer information, the combination of which was processed by the GEOMAT-TRACK ORGANIZER chain of programs.[8]

In order to compare their data with the models in Refs. (2-6), the authors in Ref. (1) removed elastic ρ production from their sample. In order to permit comparison of our data with theirs, we therefore eliminated both elastic scattering and most of the diffractive events from our sample. This was done by removing all events that had no or only one charged particle in the forward hemisphere in the center-of-mass. This cut effectively eliminated all two-charged prong events and some events from other topologies. Finally, in order to check the possible influence

of remaining diffractive events on our data, we studied the effect of removing the four charged prong events from the sample since they contain most of the remaining diffractive events.

Figure 2(a) directly compares our data with the electroproduction data of Ref. (1) and the theoretical curves of Ref. (2). Within the experimental errors, the agreement of our data with both the electroproduction and the Field-Feynman model is quite good except at z near 1. If one compares this figure with Fig. 2(c), which gives the results for data with the four charged prong events removed, it can be seen that the agreement improves. This probably reflects the effect of the remaining diffractive events that tend to be concentrated in the four charged prong events. In Fig. 2(b) we present the comparison of our data with the curves from the Field-Feynman model for the distributions of the fastest positive and fastest negative charged particles from deep-inelastic electroproduction. Again, the agreement is surprisingly good, and it is even better when the four charged prong events have been removed (not shown). In this figure, $\frac{1}{\sigma}\frac{d\sigma}{dz}$ is plotted without any scale factors and the curves have not been fit to the data. We note that the above model was developed with large transverse momentum jets in mind and was explicitly not intended to apply to low transverse momentum data such as those in our experiment. In light of this point and since the kinematics of Fig. 1(a) are very different from the kinematics of Fig. 1(b), it is surprising that the results of this experiment and the experiment described in Ref. (1) are so similar. Other authors have pointed out similarities between low and high momentum transfer processes,[9] and similarities between hadron and lepton produced final states have also been noted.[10] To our knowledge, this is the first comparison of the two processes shown in Fig. (1) with respect to the variable z.

In summary, we find that the final state hadrons produced in interactions of 147 GeV/c negative pions with protons have distributions in terms of the variable z which are very similar to those for the hadrons produced by deep-inelastic electron proton scattering. In addition, the distributions we have presented agree with the curves calculated for the Field and Feynman[2] model, which was developed for a totally different kinematic region than that of the data presented here. This agreement may be just a fortuitous property of the variable z, but the similarity between these two types of reactions may have a deeper theoretical significance.

We thank Fermilab and the operating crew of the Fermilab Hybrid Spectrometer for their superb cooperation in obtaining the original data and we also express our appreciation to the scanning and measuring teams of our universities which made this experiment possible. Finally, we are especially grateful to R. L. Jaffe for several illuminating discussions. This work was supported in part by funds provided by the U. S. Department of Energy and the National Science Foundation.

FOOTNOTES AND REFERENCES

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FIGURE CAPTIONS

Figure 1: (a) Diagram for the production of charged hadrons produced in deep-inelastic electron proton scattering.

(b) Diagram for the production of charged hadrons produced by $\pi^- p$ interactions.

Figure 2: Data contain all events with four or more charged prongs.

(a) z distribution for fastest (largest z) charged particle; for this experiment ⧫, for the electroproduction experiment of Ref. (1) ⌽.
z distribution for second fastest (next largest z) charged particle; for this experiment ✳, for the electroproduction experiment of Ref. (1) ⌽.
The solid and dashed curves are the predictions of ref. (2) for the fastest and second fastest charged particles respectively. See text for definition of z.

(b) z distributions for fastest negatively and positively charged particles (⧫ and ✳ respectively) in this experiment; dashed and solid curves are the respective predictions of Ref.(2).

(c) Same as Fig. (a) except with four charged prong events removed.

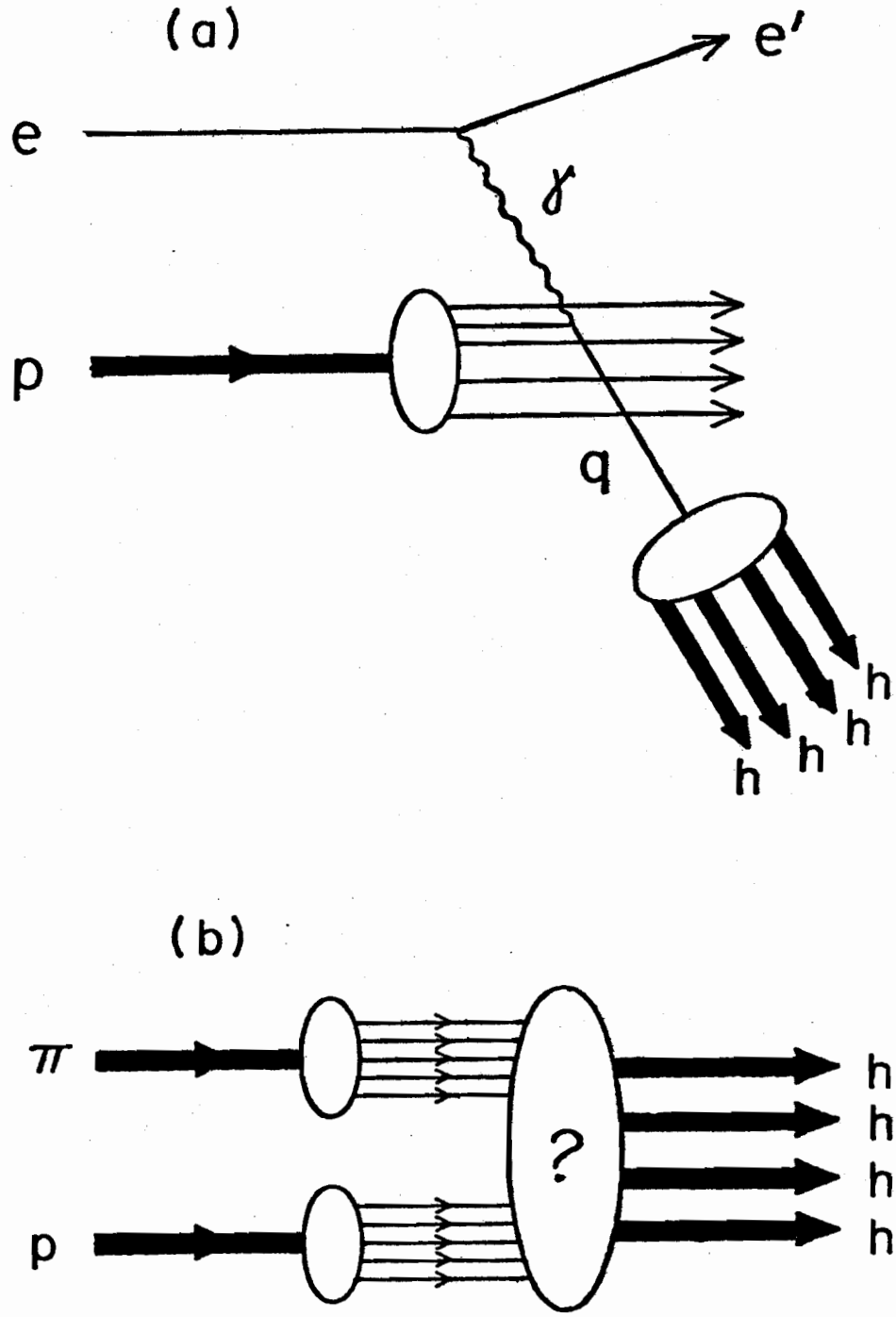

Figure 1

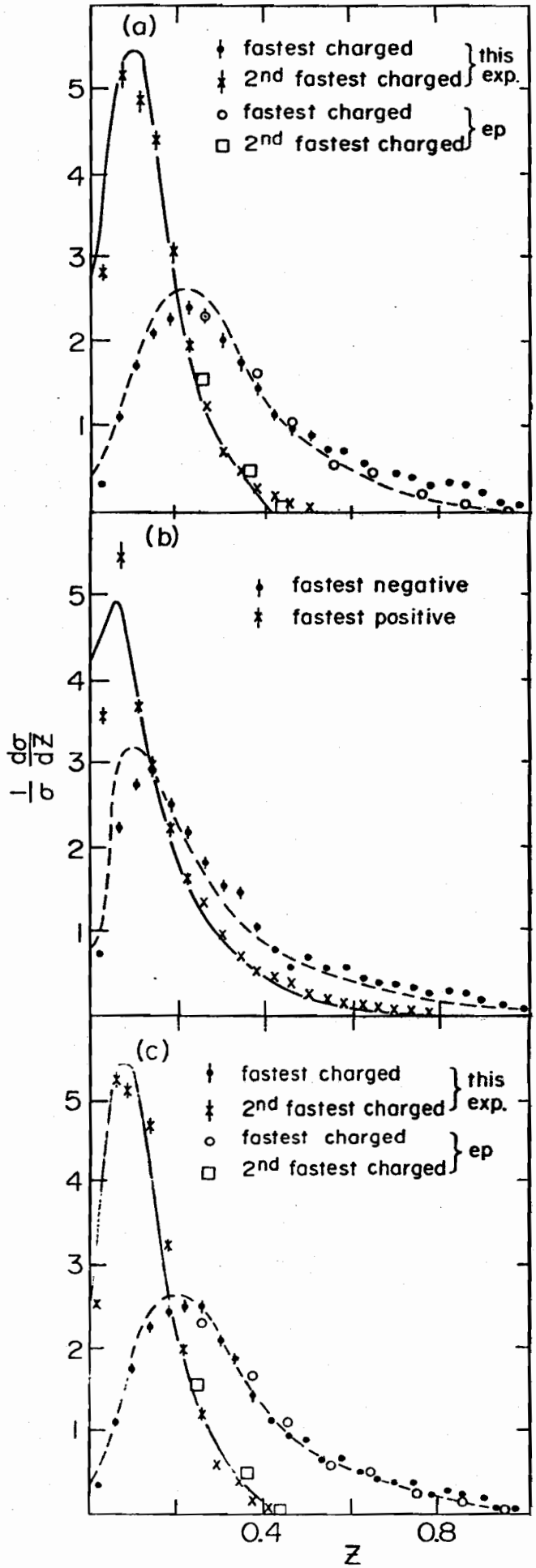
(a)
fastest charged
2nd fastest charged
this exp.
fastest charged
2nd fastest charged
ep
(b)
fastest negative
fastest positive
(c)
fastest charged
2nd fastest charged
this exp.
fastest charged
2nd fastest charged
ep
$\frac{1}{\sigma}\frac{d\sigma}{dZ}$
0.4
0.8
Z

Figure 2