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Production Asymmetries in x_F and P^2_t for $D^\pm$ Mesons

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PRODUCTION ASYMMETRIES IN x_f AND P_t^2 FOR $D^{\pm}$ MESONS

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ABSTRACT

We present differences in leading and non-leading charged D meson production as a doubly-differential function of both P_t^2 and x_f. Comparisons to specific models are made. This information is from the analysis of half the data from Fermilab experiment E791, taken during the 1991-2 fixed target run with a 500 GeV/c π^- beam incident on a segmented target.

1. Experiment E791

The results given in this paper come from the 1991/92 run of fixed target experiment E791 at Fermilab. The experiment used a 500 GeV/c π^- beam incident on a segmented target. The detector was the Tagged Photon Spectrometer, an open geometry multiparticle spectrometer, and has been described elsewhere.[1,2] The experiment combined an extremely fast data acquisition system with a very open trigger to record the world's largest sample of hadronically produced charm. Over 20 billion events were recorded on 24,000 8-mm tapes. The reconstruction of this large data set will be completed by late summer on parallel processing computer farms in four locations: Kansas State University, University of Mississippi, Fermilab and Centro Brasileiro de Pesquisas Fisicas in Brazil.

2. Physics

Previous experiments[3,4] have seen asymmetries in the hadronic production of charmed mesons. By asymmetries, we mean that a particular charmed meson may have a different production distribution from its anti-particle. The specific case we discuss in this paper is the one in which the D^- meson has a *harder* Feynman-x (x_f) distribution than the D^+ meson. We will also show initial results on the comparison of their P_t^2 distributions where P_t is the net momentum transverse to the beamline.

There are several possible causes for a difference in production direction for charmed particles and anti-particles. For a π^- beam next-to-leading-order calculations[5]

*Representing the E791 Collaboration: Centro Brasileiro de Pesquisas Fisicas, University of California, Santa Cruz, University of Cincinnati, CINVESTAV, Fermilab, Illinois Institute of Technology, Kansas State University, University of Mississippi, Princeton University, Universidad Autonoma de Puebla, Tel Aviv University, Tufts University, University of Wisconsin, Yale University predict a small enhancement in the number of mesons containing a $\bar{c}$ quark over those containing c quarks in the very forward direction. However, a much larger enhancement is seen in the data.[3]

Another possible explanation of the asymmetry is provided by the Lund "string fragmentation" model that effects the formation of the visible particles. In this model, forward momentum is added to the produced heavy quarks if they combine with the remnant light quarks from the incoming beam particle.[6] This causes charmed mesons with a light quark in common with the incoming beam ("leading particles") to have a harder x_f spectrum than those which do not ("non-leading particles"). In the case of E791, with a $\pi^-(d\bar{u})$ beam, the $D^-(d\bar{c})$ is leading and the $D^+(\bar{d}c)$ is non-leading.

A third possible model that would affect the production distributions for charmed hadrons is that of intrinsic charm.[7] Here, a virtual $c\bar{c}$ pair is formed in the incoming beam particle and is knocked onto its mass shell in a small percentage of interactions. Since these intrinsic quarks would have the same velocity as the original $\bar{u}$ and d quarks in the pion, they are more likely to form a leading particle, enhancing the "beam dragging" effect described in the previous paragraph.

3. Analysis

For the case of a π^- beam in E791, the most copious leading charmed mesons are the D^0, D^- and D^{*-}. One might set out to study the directions in which these particles are produced in comparison with their non-leading counterparts, the $\bar{D}^0$, D^+ and D^{*+}. Unfortunately, a large fraction of the D^0's (typically 1/3 of those observed) may have been produced by the $D^{*+} \rightarrow D^0\pi^+$ decay process. The original D^{*+} is actually a *non*-leading particle. Therefore the observed D^0's come from a mixture of leading and non-leading processes, making the study more complex. This document will study only the D^+/D^- comparisons although D^{*+}/D^{*-} comparisons will follow soon. The direction of a produced meson may be described by its x_f and P_t values. In order to show small differences in the number of mesons observed over many different x_f and P_t ranges, an asymmetry parameter, A, is calculated for each.

$$A \equiv \frac{N_{D^-} - N_{D^+}}{N_{D^-} + N_{D^+}}$$

where $N_{D^\pm}$ is the number of $D^\pm$ mesons produced within that x_f or P_t range. Note that since the acceptance for D^+ and D^- is the same in our detector, A is independent of the acceptance values. In addition to the x_f distributions, E791 can use its high statistics ($21,469 \pm 146$ candidates used here) to plot the asymmetries as a function of P_t^2 for different regions of x_f. This will allow us to test predictions made for the intrinsic charm model.[7]

In this paper, the asymmetry parameter, A, is calculated directly from data with no correction for detector acceptance. To ensure that no acceptance correction was required, Monte Carlo software simulation of our detector was used. No differences in D^- and D^+ acceptance were found, assuring us that any non-zero values of A came from differences in production, not detector efficiencies.

4. Results

The results presented in this paper come from the analysis of approximately half the total E791 data set. Figure 1 shows the resulting $K\pi\pi$ mass peak from the decay of $D^{\pm} \rightarrow K2\pi$. A much larger sample of $D^{\pm}$ can be produced if the background level is allowed to increase.

In Figure 2, the value of A for the E791 $D^{\pm}$ mesons is plotted as a function of x_f and compared to the predictions of two models. The error bars shown on this and all other plots correspond to statisical uncertainities only. As with previous experimental results, the PYTHIA prediction appears slightly to be systematically higher although the curve shape is similar. The recent prediction involving intrinsic charm[8] is also shown.

Figure 3 shows A as a function of P_t^2 for E791 and for the same two models. There is a surprising prediction of increasing A at low P_t^2 from the PYTHIA model. There are indications of such an increase in our data, but at a much smaller level. The intrinsic charm model predicts an almost constant value of $A \simeq 0.0$.

Figure 4 shows A as function of P_t^2 for the high x_f region. The E791 and PYTHIA values are given for mesons with x_f between 0.3 and 0.8. The intrinsic charm values are given for mesons with x_f between 0.4 and 0.8. The intrinsic charm model predicts an increase in A at very low values of P_t^2. Our data indicates no such increase, although it has large statistical uncertainities.

It should be noted again that the E791 values of A are plotted without correction for acceptance. As our acceptance varies with x_f, this may be a problem when plotting A vs. P_t^2 for limited regions of x_f (as in figure 4). This concern is being addressed now.

5. Future Analysis

In the future, we hope to expand our study of these production asymmetries. First, we will include our entire data set and include decays of the vector mesons $D^{*\pm}$. This will decrease our statistical errors, allowing us to make more definitive statements about various models. At the same time we can increase the range of x_f examined. Second, we hope to include completely different particles such as the D_s or Λ_c into our study. Finally, we will complete our studies of possible systematic errors in our analysis.

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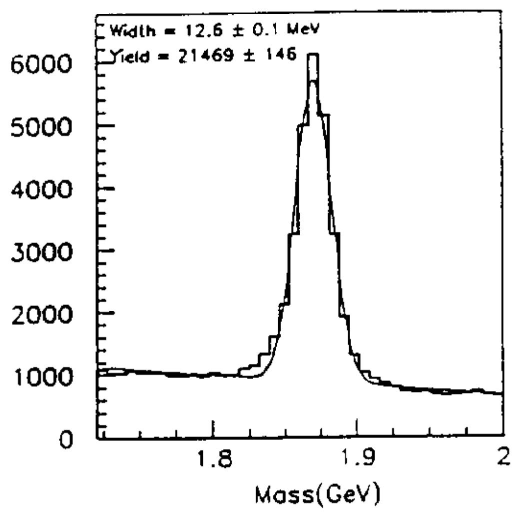

Figure 1: $D^{\pm} \rightarrow K\pi\pi$

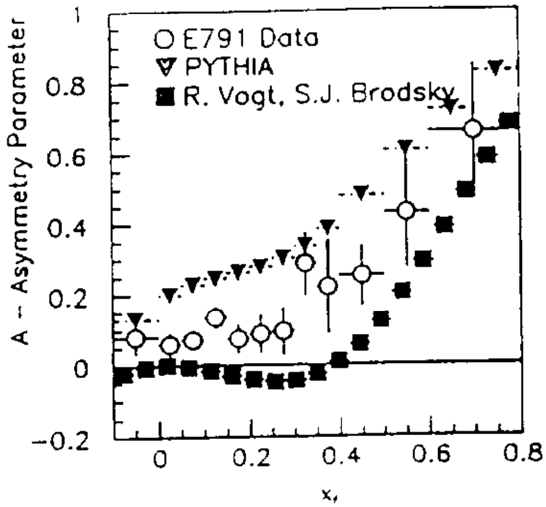

Figure 2: Asymmetry Parameter vs. x_f

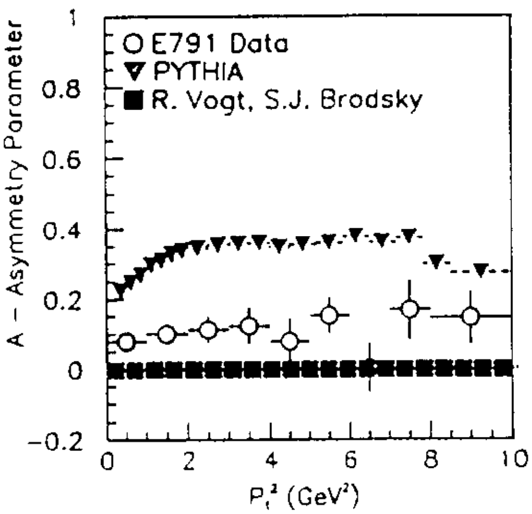

Figure 3: Asymmetry Parameter vs. P_t^2

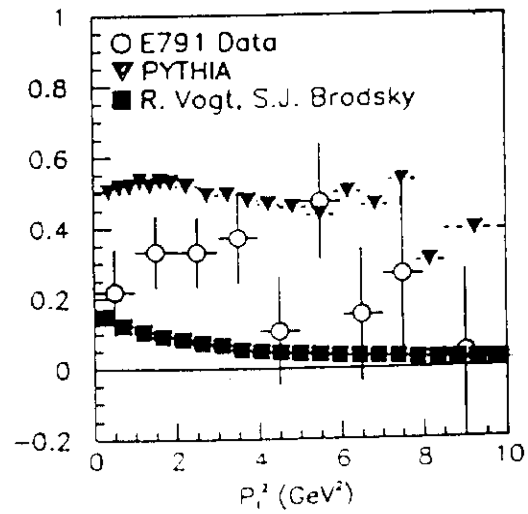

Figure 4: Asymmetry Paramter vs P_t^2 for high x_f Region