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Results on Charm Production from E791, a High Statistics Charm Hadroproduction Experiment at Fermilab

S. Banerjee et al

Fermi National Accelerator Laboratory
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S. Banerjee,[5] E. M. Aitala,[8] S. Amato,[1] J. C. Anjos,[1] J. A. Appel,[5] M. Aryal,[7] D. Ashery,[11]
I. Bediaga,[1] G. Blaylock,[2] S. B. Bracker,[12] P. R. Burchat,[2] R. A. Burnstein,[6] T. Carter,[5] H. S. Carvalho,[1]
I. Costa,[1] L. M. Cremaldi,[8] K. Denisenko,[5] T. Dubbs,[2] A. Fernandez,[10] P. Gagnon,[2] S. Gerzon,[11]
K. Gounder,[8] M. Halling,[5] G. Herrera,[4] G. Hurwitz,[1]1 C. James,[5] P. A. Kasper,[6]
S. Kwan,[5] D. C. Langs,[9] J. Leslie,[2] J. Lichtenstadt,[11] B. Lundberg,[5] S. MayTal-Beck,[11] B. Meadows,[3]
J. R. T. de Mello Neto,[1] R. H. Milburn,[13] J. M. de Miranda,[1] A. Napier,[13] A. Nguyen,[7]
A. B. d'Oliveira,[10] K. C. Peng,[6] L. P. Perera,[3] M. V. Purohit,[9] B. Quinn,[8] S. Radeztsky,[14]
A. Rafatian,[8] N. W. Reay,[7] J. J. Reidy,[8] A. C. dos Reis,[1] H. A. Rubin,[6] A. K. S. Santha,[3] A. F. S. Santoro,[1]
A. Schwartz,[9] M. Sheaff,[14] K. O'Shaughnessy,[2] R. A. Sidwell,[7] A. J. Slaughter,[15] J. G. Smith,[7] M. D. Sokoloff,[3]
N. Stanton,[7] K. Sugano,[2] D. J. Summers,[8] K. Thorne,[5] A. K. Tripathi,[7] S. Watanabe,[14]
R. Weiss,[11] J. Wiener,[9] N. Witchey,[7] E. Wolin,[15] D. Yi,[8] R. Zaliznyak,[2] C. Zhang[7]

Abstract

Fermilab experiment E791 collected a large sample of charm events to study several aspects of charm physics. Many topics on production and decay of charm particles can be covered with this data set. This talk will concentrate on the production asymmetry of charm mesons.

[0 1] Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil, [2] University of California, Santa Cruz, CA, USA, [3] University of Cincinnati, Cincinnati, OH, USA, [4] CINVESTAV, Mexico, [5] Fermilab, Batavia, IL, USA, [6] Illinois Institute of Technology, Chicago, IL, USA, [7] Kansas State University, Manhattan, KS, USA, [8] University of Mississippi, Oxford, MS, USA, [9] Princeton University, Princeton, NJ, USA, [10] Universidad Autonoma de Puebla, Mexico, [11] Tel Aviv University, Tel Aviv, Israel, [12] 317 Belsize Drive, Toronto, Canada, [13] Tufts University, Medford, MA, USA, [14] University of Wisconsin, Madison, WI, USA, [15] Yale University, New Haven, CT, USA

1 Introduction

Experiment E791 collected data with a 500 GeV/c π^- beam on a segmented nuclear target at Fermilab. The detector had an open geometry, multiparticle spectrometer described in detail elsewhere [1]. The segmented target consisted of 1 platinum and 4 carbon foils. The foils were spaced 1.5 cm apart, so that charm decay vertices would mostly fall outside the foils. This helps considerably in background rejection. The resolution of the charm production vertices was of the order of 350 microns. E791 had a fast and efficient Data Acquisition System [2] which helped in collecting 20 billion events on 24000 8mm tapes.

2 Production Physics goals

The major topics on charm hadroproduction that can be studied with the E791 data set are as follows.

- Final state production ratios - E791 will see signals in many charm meson and baryon channels and will be able to study ratios of production cross sections for $D^0/\overline{D^0}$, $D^\pm$, $D^{*\pm}$, $D_s{}^\pm$, $\Lambda_c{}^\pm$ etc.
- Production asymmetry between a charm particle and its charge conjugate
- Feynman x and the square of transverse momentum dependence of the production cross section. Feynman x and transverse momentum will be referred to as (x_F) and p_t in the rest of this paper.
- Energy dependence of the production cross section - Lower energy data is available from WA82 (CERN, 340 GeV) and E769 (FERMILAB, 250 GeV) and higher energy data is available from E653 (FERMILAB, 600 GeV).
- Charm pair correlations - E791 will have many events with two charm particles at least partially reconstructed and will be able to study pair correlations.
- A dependence - Since there are two target material types, nuclear dependence of all of the above physics can be studied.

Results on studies of the production asymmetry will be presented here.

3 Production Asymmetry

Leading order perturbative QCD predicts no asymmetry in production between charm and anticharm. Next to leading order calculations predict only a small amount of asymmetry (15%) at x_f close to 1. However, over the last several years, various experiments have observed a large leading particle asymmetry. This and other results indicate that the production of final state particles (charm mesons and baryons) can not be fully described by PQCD [3]. Non-perturbative models have been formulated to describe the production characteristics. One of them is the string fragmentation model developed by the LUND group [4]. This was used in the PYTHIA Monte Carlo generator. This model says that after the creation of a $c\bar{c}$ pair, either the c or the $\bar{c}$ quark may tend to recombine with one of the beam quarks to form the final state charm particle. These particles carry most of the beam momentum and are therefore produced in a more forward direction than their charge conjugates. The particles which share a quark with the beam are called leading and the charge conjugates are called non-leading.

D^- and D^{*-} share a quark with our π^- beam and are therefore called leading particles. D^+ and D^{*+} are the non-leading particles in this case. Therefore, some asymmetry should be seen in $D^\pm$ and $D^{*\pm}$ production. The π^- beam had negligible (3%) kaon contamination. Thus, the D_s mesons typically do not share any quark with the beam and one should not find any asymmetry in D_s production. This can also be studied with the E791 data set.

Since the beam quark travels mostly in the forward direction, the asymmetry should be greatest in the forward direction. One way to look at that is to calculate how many leading and non-leading particles have been produced in bins of x_f and ${p_t}^2$. For this study the asymmetry parameter can be formulated as

$$A = \frac{N_l - N_{nl}}{N_l + N_{nl}} \tag{1}$$

When A is plotted for different x_f or ${p_t}^2$ bins, N is the number of particles produced in a particular bin of x_f or ${p_t}^2$. N_l is the number of leading particles and N_{nl} is the number of non-leading particles. The asymmetry parameter has been studied by experiments WA82 [5] and E769 [6]. WA82 has published results on $D^\pm$ asymmetry vs. x_f. They have quoted a number for D^{*+}/D^{*-} but have not published the differential asymmetry in x_f and ${p_t}^2$ bins for D^*. E769 used a mixture of $D^\pm$ and $D^{*\pm}$ mesons. The sample contained 70% $D^\pm$ and 30% $D^{*\pm}$. The statistics were not enough to use only $D^{*\pm}$ data. E791 is the first experiment to have information on ${D_s}^\pm$ and exclusive $D^{*\pm}$ asymmetry. Also, with this large data set we are able to look at doubly differential plots of asymmetry vs. x_f and ${p_t}^2$.

4 Data Sample and Analysis Procedure

The sample used here is from roughly 1/3rd of E791 data.

The number of signal events were counted in each x_f and ${p_t}^2$ bin for the charm meson and it's charge conjugate. Selection criteria for signal events were independent of x_f and ${p_t}^2$ in this version of the analysis. The major selection criteria are:

- Require a wide separation between charm production and decay vertices. Non charm background events have a small separation.
- Charm decay vertex should not appear in any of the target foils. This removes secondary interactions.
- Decay vertex should point back to the production vertex within 40 microns.

5 Results

Using these selection criteria we obtained.

- 8883 $D^{\pm}$ in the mode $D^{\pm} \rightarrow K\pi\pi$
- 4000 $D^{*\pm}$ in the mode $D^{*\pm} \rightarrow \pi D^0 \rightarrow K\pi^{\pm}$
- 1100 $D_s{}^{\pm}$ in the mode $D_s{}^{\pm} \rightarrow \phi\pi^{\pm}$

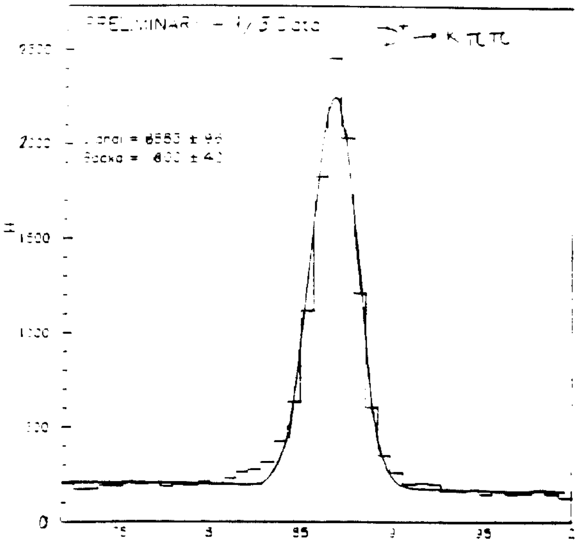


Fig 1

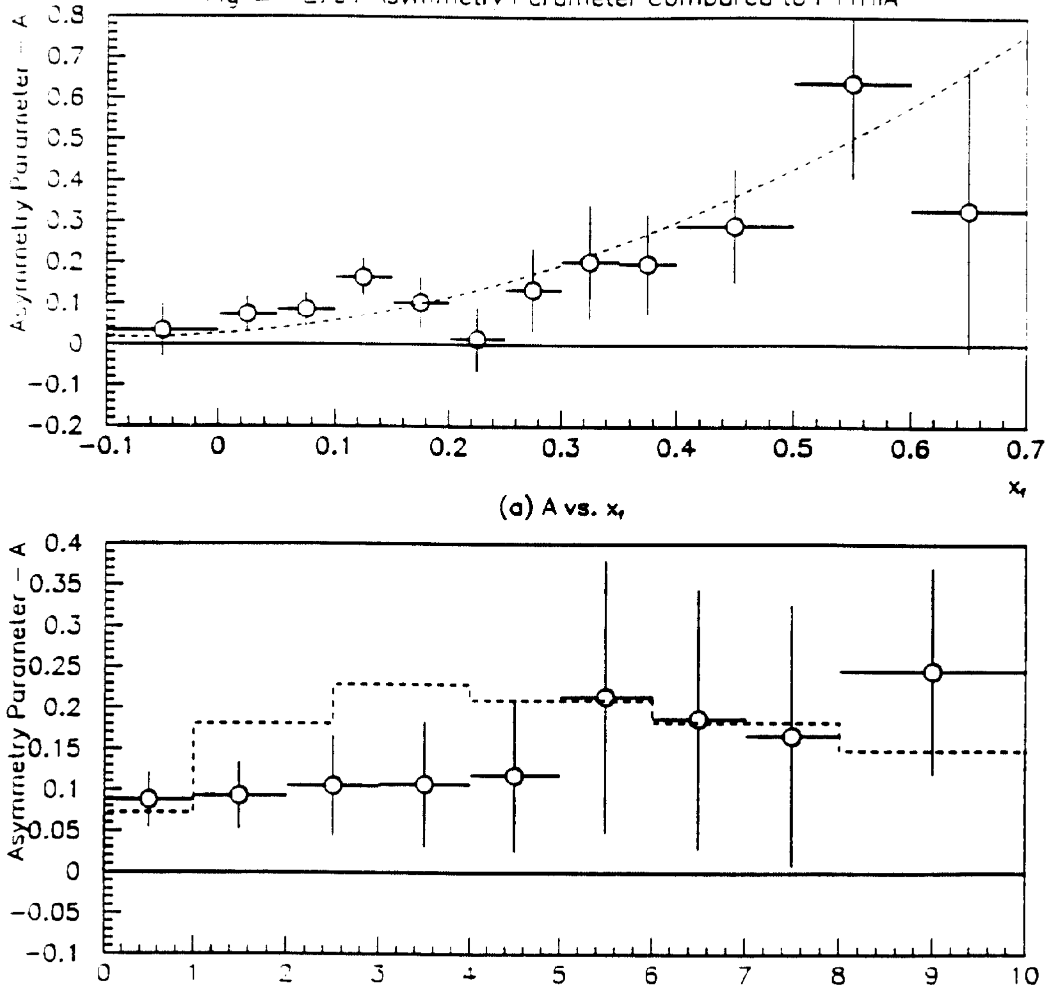
The following results were obtained from the analysis of the $D^{\pm}$ data.

- Figure 1 shows the total $D^{\pm}$ signal from 1/3rd of E791 data. This shows that a very clean charm signal can be obtained in hadroproduction.
- Figure 2(a) shows the asymmetry as calculated by equation 1 in x_f bins. There is clearly a rise in asymmetry towards higher x_f. The dotted line represents the PYTHIA prediction. Figure 2(b) shows the asymmetry in $p_t{}^2$ bins. The dotted line is the prediction from PYTHIA.
- Since a rise in asymmetry is seen for data with $x_f > 0.3$, the asymmetry vs. $p_t{}^2$ was plotted for $x_f > 0.3$. Figure 3(a) shows the variation of asymmetry vs. $p_t{}^2$ for $x_f < 0.3$ and 3(b) shows the same variation for $x_f > 0.3$. These data does not show any $p_t{}^2$ dependence of asymmetry.

6 Conclusions

- Some interesting features can be seen from the study of charm production asymmetry vs. x_f and p_t for the $D^{\pm}$ mesons.
- E791 will have enough charm to probe these features accurately (30,000 $D\pm$).
- E791 will also be able to study production asymmetry for other charm mesons, e.g., $D^{*\pm}$ and $D_s{}^{\pm}$. The $D^{*\pm}$ sample will be at least about a third of the $D^{\pm}$ sample. Therefore, the differences in the production of a vector and a pseudoscalar meson can be studied well.
- E791 will be able to look at the $p_t{}^2$ dependence of asymmetry for different x_f bins and vice versa.

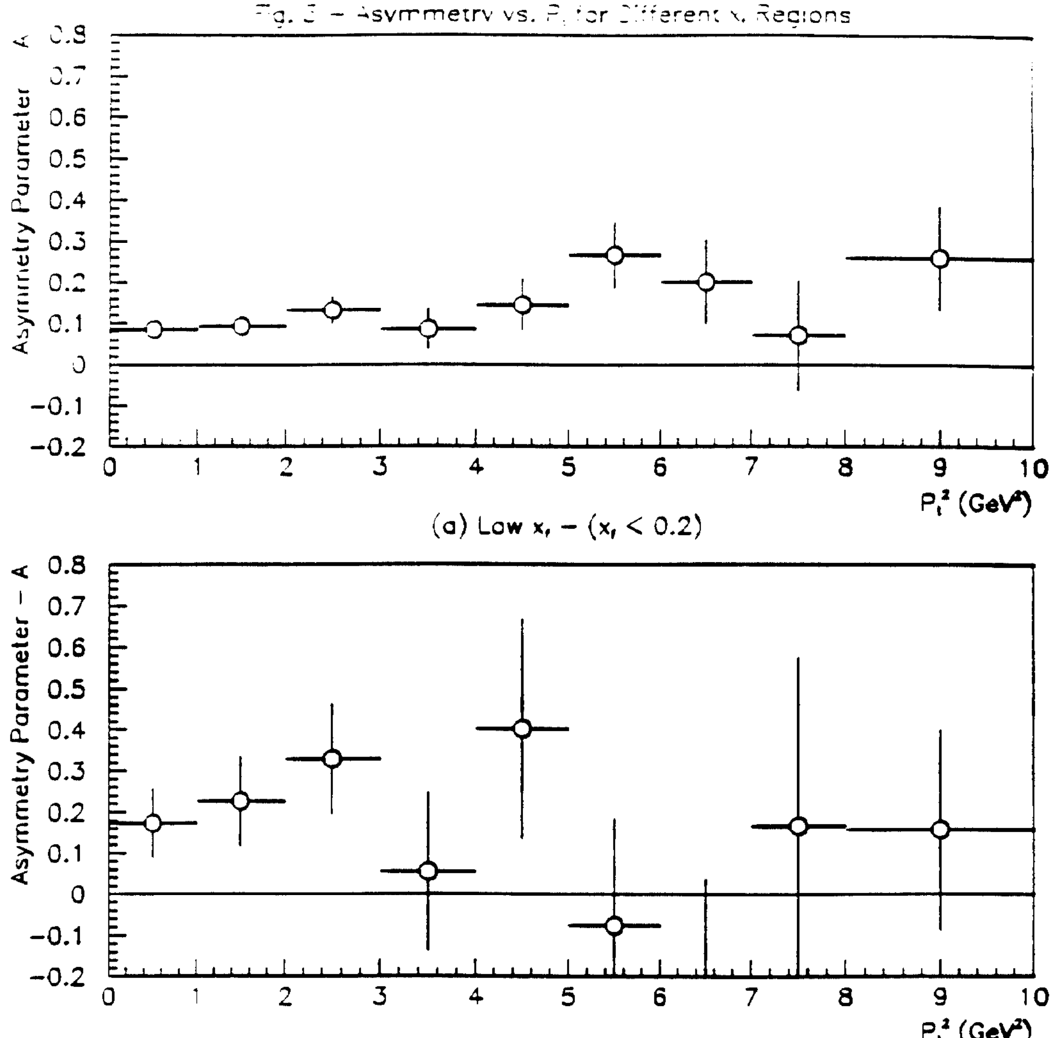
Fig 2 – E791 Asymmetry Parameter Compared to PYTHIA



(a) A vs. x_f

(b) A vs. P_t^2

Fig. 3 – Asymmetry vs. P_t for Different x_f Regions



(a) Low x_f – (x_f < 0.2)

(b) High x_f – (x_f > 0.3)

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