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Abstract. Recent analyses of charm spectroscopy from Fermilab fixed target experiment 687 [1] are summarized. Emphasis is placed on the phenomenology of Cabibbo suppression in the meson sector. Such transitions have been observed in the semileptonic modes and hadronic modes. While the former transitions give us an opportunity to observe the weak current and the CKM matrix, a systematic comparison of the latter transitions allow us to study strong interaction effects, and possibly, light quark spectroscopy.

INTRODUCTION

Fermilab Experiment 687 took its first beam about a decade ago. The data I will be presenting were obtained during the 1990-1991 run. Reconstructed data have been available for quite sometime, and numerous results have been published. However, thanks to meticulous efforts on the part of my collaborators, and results obtained by other experiments, we were able to substantially refine our charm reconstruction methods and study more difficult signals, such as doubly Cabibbo suppressed decays and some Cabibbo suppressed semileptonic decays. Rather then presenting the exhaustive list of measurements made by E687 in this very productive decade, I'll concentrate on most recent results in semileptonic decay of the D^+ and D^0 meson, and on the Dalitz analysis of the Cabibbo suppressed decay $D^+ \rightarrow \pi^+\pi^+\pi^-$ and the Cabibbo allowed decay $D_s \rightarrow \pi^+\pi^+\pi^-$.

In E687, charm particles were produced by photons with average tagged energies of approximately 200 GeV colliding a $\approx$ 4 cm. long Beryllium target and detected by a wide-acceptance, multi-purpose spectrometer which is described in detail elsewhere [2]. Charged particle tracking and momentum analysis was accomplished by a high resolution silicon microstrip detector, five stations of multi-wire proportional chambers and two large magnets operated with opposite polarities. A system of three multicell Čerenkov detectors working in threshold mode provided charged hadron identification ($\pi^{\pm}, K^{\pm}, p^{\pm}$) over a large momentum range. Two electromagnetic calorimeters, both composed of alternating layers of lead and scintillators, were used to detect electrons in complementary regions of the spectrometer: the inner electromagnetic calorimeter covered the central solid angle around the beam direction and detected particles passing through the fields of the two magnets; the outer electromagnetic calorimeter covered the outer angular anulus described by particles passing through the field of the first magnet, but not the second magnet. Muons were identified only in the central region of the spectrometer by the inner muon detector, composed of three scintillator planes and four proportional tube planes; shielding was provided by the upstream detectors (mainly the inner electromagnetic and the hadron calorimeter) and two blocks of steel. The hadron calorimeter was primarily used in the trigger.

All the analysis mentioned in this paper required at least two vertices, obtained either by the "candidate-driven" algorithm, valid for fully reconstructed final state, or by the "stand alone" method, where no apriori knowledge about the decay topology is assumed while forming vertices in the event. In order to obtain clean sample, in addition to conventional cuts such as those based on χ^2 from track or vertex fits, numerous vertex cuts had to be considered. For instance:

- isolation cuts: leftover tracks not found in the primary vertex were required to be inconsistent with emerging from the secondary vertex, and secondary tracks were required not to point towards the primary vertex.

- Point back cut: For fully reconstructed decays, the charm particle direction can be reconstructed and must points back to the primary vertex.

- Requiring that the secondary vertex be outside the beryllium target allows us to reject background due to secondary interaction.

In addition, particle identification played a crucial role in these analysis. for instance, the efficiencies of the Čerenkov system in presence of other tracks was carefully studied using $K_s^0 \to \pi^+\pi^-$, $\Lambda^0 \to p\pi^-$ and $\phi(1020) \to K^+K^-$ decays.

RESULTS

Cabibbo suppressed, semileptonic decays of the D meson

With the Cabibbo allowed semileptonic decays well established, experiments have begun turning their attention towards the more elusive Cabibbo suppressed, semileptonic decays ($D^0 \to \pi l \nu$ and $D^+ \to \rho l \nu$). These decays may be used to compare the functional dependence of form factors between Cabibbo favored and Cabibbo suppressed currents. In particular, E687 has observed the $D^0 \to \pi^- e^+ \nu$ and $D^0 \to \pi^- \mu^+ \nu$ (charge conjugate are always implied) [3]. Assuming the D^0 mass and using the direction of flight of the D^0 and the soft pion from the $D^{*+} \to D^0 \pi^+$ decay, it is possible to fully reconstruct the decay kinematics, resolving correctly the D^0 momentum twofold ambiguity approximately 80% of the time, and extract a signal. We obtained:

$$\frac{BR\,(D^0 \to \pi^- l^+ \nu_l)}{BR\,(D^0 \to K^- l^+ \nu_l)} = 0.101 \pm 0.020(stat) \pm 0.003(syst)$$

Assuming a single pole mass dependence for the form factors, we determined:

$$|\frac{V_{cd}}{V_{cs}}|^2 |\frac{f_+^{\pi}(0)}{f_+^K(0)}|^2 = 0.050 \pm 0.011 \pm 0.002$$

Finally, untarity constraints on the CKM matrix set a value for the ratio $|\frac{V_{cd}}{V_{cs}}|^2$ and we can compute:

$$|\frac{f_+^{\pi}(0)}{f_+^K(0)}|^2 = 1.00 \pm 0.11 \pm 0.02$$

More recently, we observed the first statistically significant signal for the vector meson Cabibbo suppressed decay $D^+ \to \rho^0 \mu^+ \nu$ [4]. This decay had to be reconstructed without the help of D^* trick. However, three charged tracks are in this final state which greatly ease the vertex reconstruction. In addition, the lifetime of D^+ is relatively large. The background to the $M(\pi^- \pi^+)$ invariant mass distribution is adequately described by three sources: other D^+ and D_s^+ semileptonic decays involving two pions, semileptonic decays of the D^0 produced in D^{*+} decays and charm hadronic decays. The $\pi^+ \pi^-$ invariant mass in this selected semileptonic decay sample is shown on figure 1. We measured the branching ratio of the decay mode $D^+ \to \rho^0 \mu^+ \nu$ (plus possible unobserved γ from $D^+ \to \eta' \mu^+ \nu$, $\eta' \to \gamma \rho^0$) with respect to the decay mode $D^+ \to \bar{K}^{*0} \mu^+ \nu$ to be

$$\frac{BR(D^+ \to \rho^0 \mu^+ \nu)}{BR(D^+ \to \bar{K}^{*0} \mu^+ \nu)} = 0.079 \pm 0.019 \pm 0.013$$

.

Hadronic decays

Amplitude analysis of non-leptonic Cabibbo favored [5] and suppressed [6] decays have been previously studied by E687. These analyses have emerged as an excellent tool for studying hadron dynamics. In particular, the D_s^+ decay into three pions is, in fact, the best candidate to proceed through an annihilation diagram, since annihilation of the two initial quarks is Cabibbo favored and not suppressed as in the D^+ decay. This annihilation amplitude seems also to manifest itself through markedly different final states: the $f_0(980)$ "oddball" -as stated in the discussions on hadron spectroscopy- appears in the D_s^+ decay is absent in the D^+ decay [7]. The Dalitz plots for these two decays are shown in figure 2. Doubly and singly Cabibbo suppression has also been studied in the $K^+K^-K^+$ channel [8] and in $K^+\pi^-\pi^+$ final state [9]

CONCLUSION

The observations of Cabibbo suppressed semileptonic D decays are consistent with the theoretical knowledge of the weak current in the quark sector. However, much remains to be done [10]: improved statistics are of course needed along with better experimental information on other semileptonic decays, such as $D^0 \to \rho^- l^+ \nu$ and $D^+ \to \eta' \mu^+ \nu$. It should be noted that these

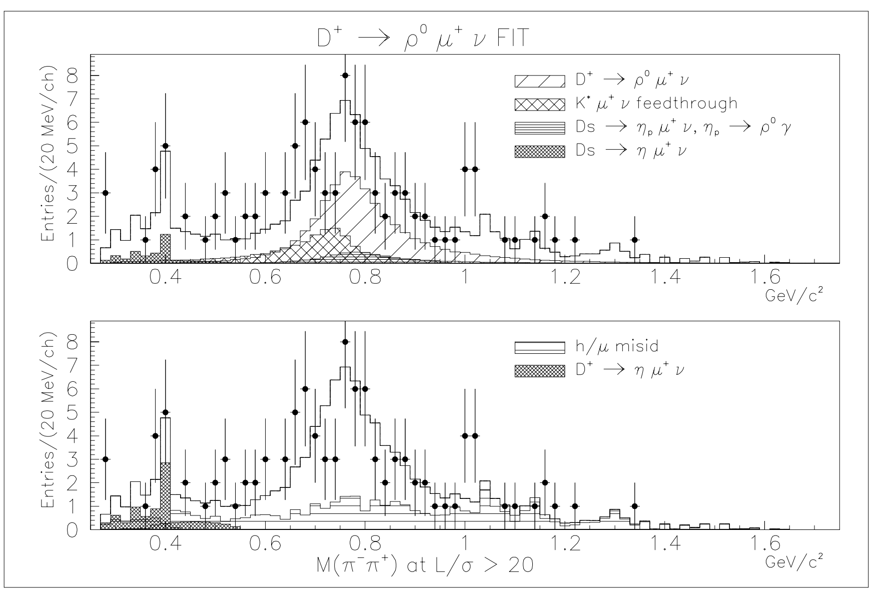

FIGURE 1. $M(\pi^+\pi^-)$ invariant mass reconstructed from $D^+ \to \rho^0\mu^+\nu$ candidates. The points are the data, the solid line is the total fit, the various fit components are represented with different hatching styles. The fit components are shown in two separate histograms for clarity.

interesting decay channels cannot be studied in isolation, one must also complete and improve the phenomenology of Charm. For instance, a study of charged hadronic five body decays of the D^+ and D_s^+ mesons has been recently published by E687 [11], showing that in all instances, resonant channel decay dominate. Finally, many topics, such as Charmed Baryon analysis [12] and the search for rare and forbidden decays [13] have been left out due to lack of time.

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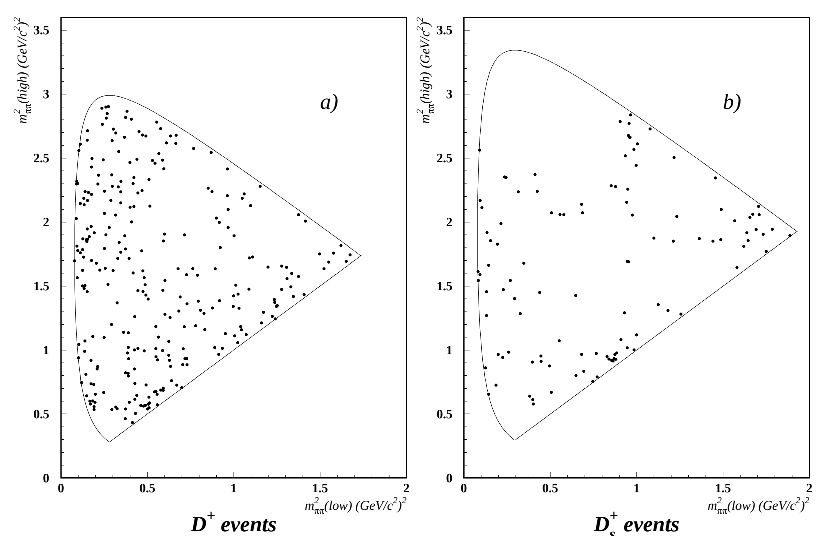

FIGURE 2. The D^+ (a) and D_s^+ (b) Dalitz plots for the $\pi^+\pi^-\pi^+$ channel, reconstructed using the "candidate-driven" method.

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