PRAMANA
— journal of
physics

Supplement to Vol. 41
December 1993
pp. 167–181

Recent results from fixed target charm and beauty experiments

MILIND V. PUROHIT

Physics Dept, Princeton University, Princeton, NJ 08544, USA

Abstract. In the last year there have been new observations of beauty by two fixed target experiments (E672/706 and E653). A few new results on charm have recently been presented by the photoproduction experiment E687 and by E789 and E769. An intriguing result on the purely muonic decay of charm comes from the CERN experiment WA75. These results are summarized and we conclude with a hint of the promise of E791, the very high statistics charm experiment which is beginning to produce physics results

1. Beauty experiments

The b-quark was discovered in a fixed target experiment. However, recent results in the field of B physics have been dominated by the e^+e^- experiments CLEO II and ARGUS and more recently, additional information from LEP experiments has become available. Fixed target experiments on the other hand suffer from a low ratio of beauty to light quark production – this ratio is known [1] to lie in the range of 10^{-7} to 10^{-6}. Why should we bother with fixed target results on beauty? The answer is twofold. The hadroproduction of beauty is an interesting field in its own right since predictions based on perturbative QCD are considered reliable for a quark as massive as beauty. Results shown below from experiment E672/706 are a useful start in this regard. Secondly, it is clear that the ultimate future of b-physics lies with hadron collider experiments, since e^+e^- experiments will eventually run out of luminosity, quite possibly before observing CP violation in B meson decays. Experience with charm has shown that backgrounds in hadron experiments can be managed and the higher cross-sections and luminosities can therefore be effectively utilized to produce and reconstruct far more charm particles than possible in an e^+e^- experiment. Hence fixed target beauty experiments are important forerunners of the ultimate beauty experiment and an understanding of background reduction at fixed target experiments is essential for a design breakthrough for the collider experiments. In principle, fixed target experiments have a third advantage, namely the ability to measure beauty lifetimes well and distinguish between charged and neutral beauty decays. Recently, Fermilab experiment E653 has utilized these advantages and made measurements which are described below.

1.1. Observation of B decays by E672/E706

E672/706 is a pair of experiments which share a Fermilab beamline. The experiment

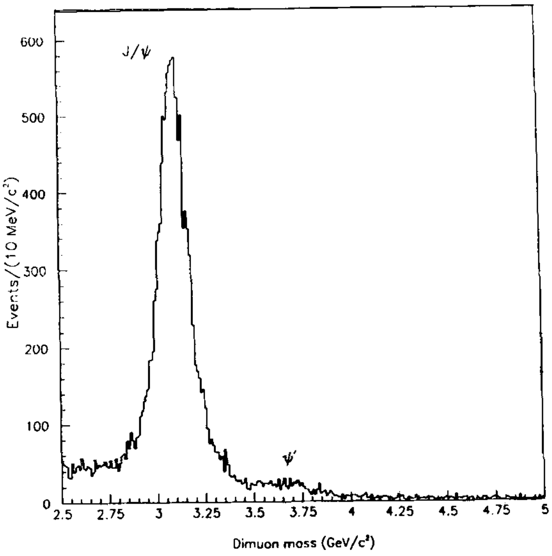

Figure 1. The 11,200 ± 440 J/Ψ decays to $\mu^+\mu^-$ from E672/706 used to search for B decays.

s use a 530 GeV π^- beam incident on Cu, Be targets along with a high mass dimuon trigger to look for B$\rightarrow$ $J/\Psi + X$ decays. The experiments have a good vertex detector (16 planes of silicon microstrips) and good acceptance in the $x_F > 0$ and $p_T < 3.5$ GeV/c region. They observed [2] a total of 11,200 ± 440 J/Ψ decays to $\mu^+\mu^-$. These are shown in Figure 1. When they look for downstream J/Ψ decays outside materials (to eliminate secondary interactions) they see a signal of 9±3 events which is shown in Figure 2. The experiments have also looked for a mass peak in the J/ΨK and J/ΨK^0 channels where they find a hint of a mass peak (see Figure 3).

1.2. Measurement of B lifetimes by E653

E653 is a Fermilab experiment with a 600 GeV π^- beam and an emulsion target. The experiment utilized a muon trigger which is useful in isolating high-p_T semi-muonic decays of charm and beauty. Since beauty decays to charm and charm itself decays weakly, there are two vertices to be identified. The emulsion target is extremely important in this regard: the 1μm resolution of the target makes decay vertex identification very clear. However, in order to cleanly identify an event as due to beauty, one needs to know that the two decay vertices are not secondary interactions and that the event is not due to charm decays.

Secondary interactions are eliminated by requiring that the muon be in a decay vertex and since only $\sim$2% of an interaction length remains after each primary vertex. Finally, searching for dark nuclear tracks leads to an additional rejection factor of 20. Charm events are rejected by the requirements that the muon p_T be greater than 1.5 GeV/c and the minimum mass of the decay vertex be greater than 2.0 GeV/c^2. Using these cuts 9 $b\bar{b}$ events were found [3] (i.e., 18 B hadron candidates). Of the 18 candidates, 12 were neutral and 6 charged. The nine events split up as 4 N-N, 4 N-C and 1 C-C events where N represents neutral and C stands

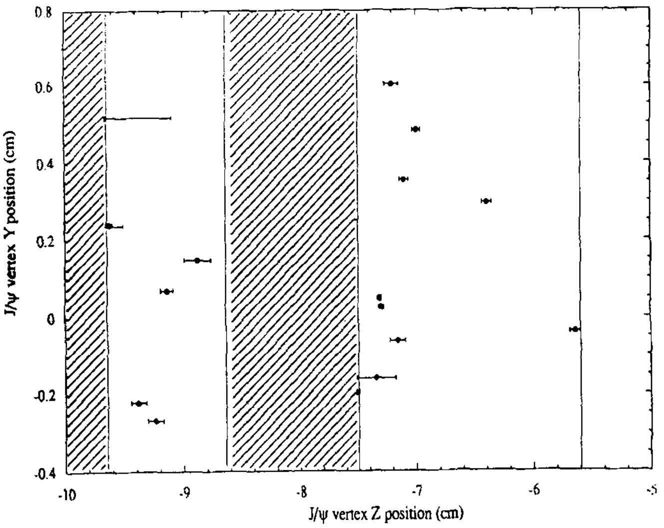

Figure 2. The z positions of selected J/Ψ decays from E672/706. Some events occur outside materials indicating B production.

for charged. In the decays 8 D^0's were identified of which 5 appear to be from D^{*+} decays. (It is hard to be sure since the experiment did not have any significant particle identification).

In order to deduce the beauty lifetimes and masses, two different momentum estimators were tried: an approximate Lorentz boost based on the visible momenta and a more complicated MC based estimator. The MC estimator chose momenta of B's in "similar" MC events where the similarity was based on event multiplicity, B production angle, decay topology, invariant mass, p_T imbalance and total momentum. The minimum mass and estimated proper decay time distributions are shown in Figs. 4 and 5. The result of the experiment can be summarized as follows:

$$\tau_{b^\pm} = 3.84^{+2.73}_{-1.36}{}^{+0.80}_{-0.16} \quad \text{ps},$$

$$\tau_{b^0} = 0.81^{+0.34}_{-0.22}{}^{+0.08}_{-0.02} \quad \text{ps}.$$

The background from charm events was estimated using simulations and relaxed cuts to be only around 0.15 events. At present, the errors are dominated by statistics, but the result hints at a longer B^+ lifetime which may be due to some B^0_s and Λ_b in the B^0 sample.

2. Charm Experiments

2.1. E789 and E769

E789 is an experiment that was originally designed to detect $B^0_d \to \pi^+\pi^-$ and $B^0_d \to p\bar{p}$ decays using the very high luminosities available at fixed targets (the proposal called for >1 interaction per RF bucket, which occurs every 19ns). The experiment used an 800 GeV proton beam from the Fermilab accelerator and achieved

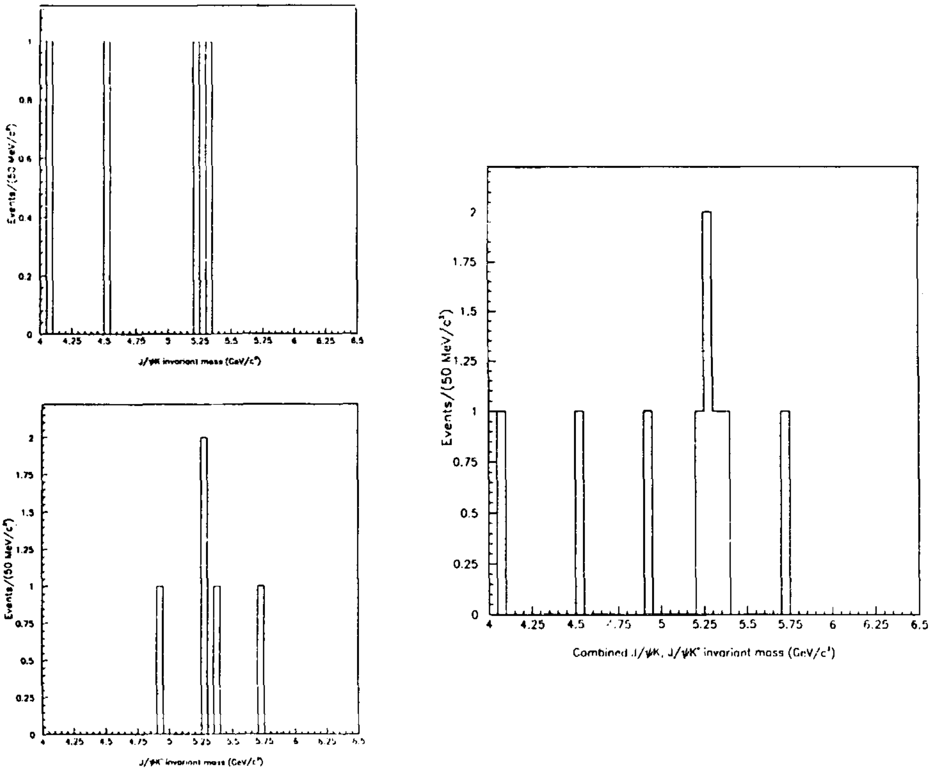

Figure 3. The J/Ψ–K,K* invariant mass distribution from E672/706 showing a peak in the B mass region.

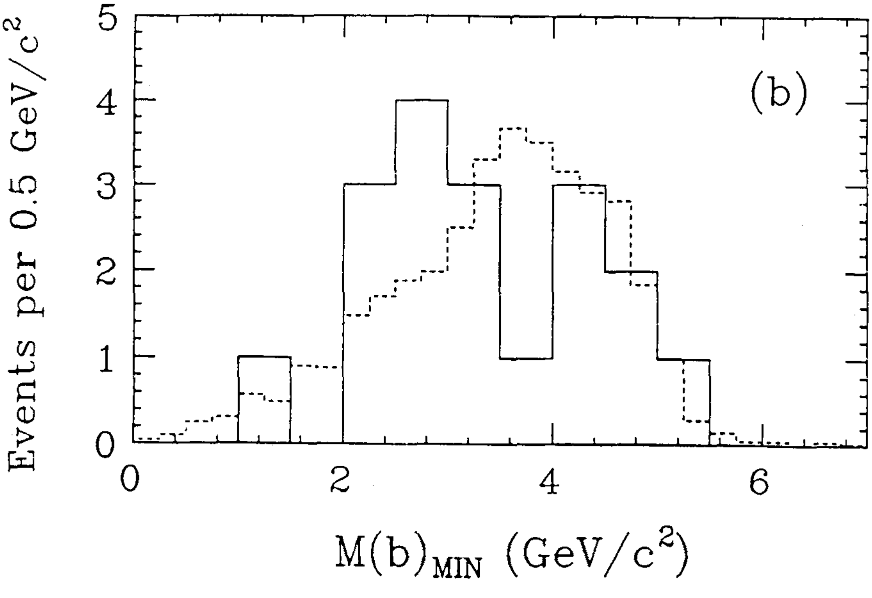

Figure 4. The minimum mass distribution for B candidates from E653.

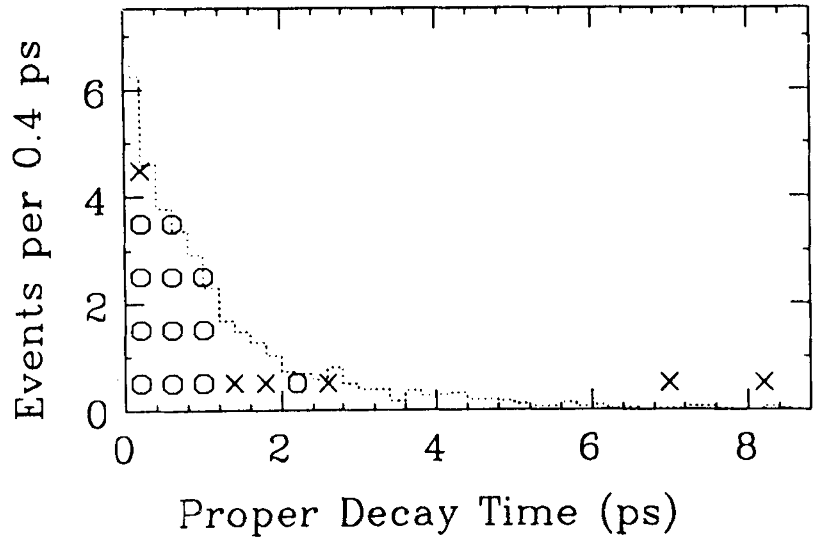

Figure 5. The proper decay time distribution for B candidates from E653.

about 2 weeks of useful charm data. Using D^0 decays to two particles ($K^-\pi^+$, K^-K^+ and $\pi^-\pi^+$) they were able to determine several properties of D^0's and charm production. The D^0 lifetime is measured to be 0.41±0.03 ps and the charm production cross-section when extrapolated to all x_F is determined [4] to be $\approx 25 \mu b$ (systematic errors are under study). Assuming that the charm cross-section varies as A^α they determine $\alpha = 0.88 \pm 0.04$. Finally, the ratio of D^0 and $\overline{D}^0$ cross-sections is determined to be 1.0±0.1.

E769 is an open geometry hadroproduction experiment and used essentially the same detector as E691, the pioneering photo-production experiment [5]. The experiment used 250 GeV/c π, K and p beams incident simultaneously on 4 different targets (Be, Al, Cu, W). The experiment measured [6] the x_F and p_T^2 dependence of the charm cross-section and determined the x_F dependence for $x_F > 0$ to be of the form

$$\frac{d\sigma}{dx_F} \sim (1 - x_F)^n, \qquad \text{where } n = 3.9 \pm 0.2$$

and the p_T^2 dependence to be of the form

$$\frac{d\sigma}{dp_T^2} \sim \exp(-bp_T^2), \qquad \text{where } b = 1.03 \pm 0.04.$$

These numbers are in reasonable agreement with earlier experiments such as NA32.

Utilizing their different targets, E769 studied the A-dependence of charm production. They find that the cross-section fits an A^α form reasonably well [7] (see Fig. 6) and $\alpha = 1.00 \pm 0.05$. They found no siginificant dependence of the parameter α on p_T and x_F. By now several experiments (WA82, WA78, E769 and E789) have measured values of α which lie in the range 0.8 - 1.0 and they all have errors of 0.04 – 0.05 but are not in agreement with each other. This situation clearly calls for the precision measurement from E791 which should measure α to 0.01 or better thereby settling this issue once and for all. E791 will also have the statistical power to study the x_F and p_T^2 dependence of α.

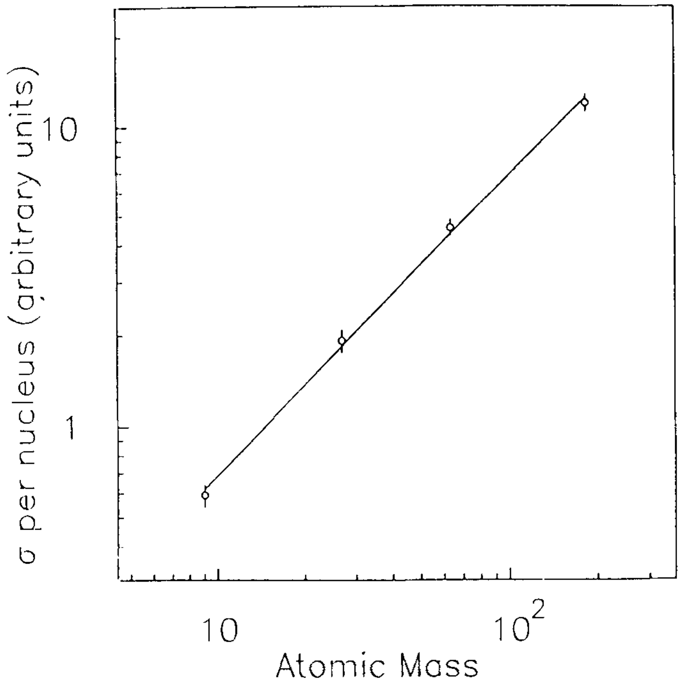

Figure 6. The A-dependence of the charm cross-section for $x_F > 0$ from E769.

2.2. A measurement of $f_{D_s^+}$

The parameter f_D which describes some two-body decays of the charm pseudoscalar mesons is very important because of its connection to the annihilation diagram and the wavefunction of the meson at zero inter-quark separation. Although this constant could be measured in the non-leptonic decay $D_s^+ \to p\bar{n}$ it is most natural to measure it in purely leptonic decays such as $D_s^+ \to \mu^+\nu_\mu$, $D_s^+ \to \tau^+\nu_\tau$ and $D^+ \to \mu^+\nu_\mu$. For instance, the branching ratio for the decay $D_s^+ \to \mu^+\nu_\mu$ is given by

$$\Gamma_{D_s^+\to\mu^+\nu_\mu} = \frac{G_F^2}{8\pi} f_{D_s}^2 \tau_{D_s} m_{D_s} m_\mu^2 |V_{cs}|^2 \left(1 - \frac{m_\mu^2}{m_{D_s}^2}\right)^2 .$$

The maximum p_T of charged leptons from two-body decays is higher than that from the obvious background sources: 3 body semi-leptonic decays where the hadron goes undetected. For instance, the maximum p_T is 0.98 GeV/c for $D_s^+ \to \mu^+\nu_\mu$ decays, is 0.93 GeV/c for $D^+ \to \mu^+\nu_\mu$ decays and is 0.87 GeV/c for the $D^+ \to \overline{K}^0\mu^+\nu_\mu$ decays.

Experiment WA75 has measured [8] the p_T distribution of high-impact parameter muons using an emulsion target followed by a vertex detector, dump and a muon spectrometer. They claim to see an excess of events in the one-prong decays at high p_T, but not in the high-p_T region of 2-prong decays (see Fig. 7). Of course, it is possible for events to smear into the high-p_T region, but the p_T resolution is claimed to be 30 MeV/c. When this is folded into the p_T distribution it is plausible that the excess cannot be attributed to smearing because the spectrum approaches the end-point as ϵ^2 where ϵ is the p_T difference from the end-point. They esti-

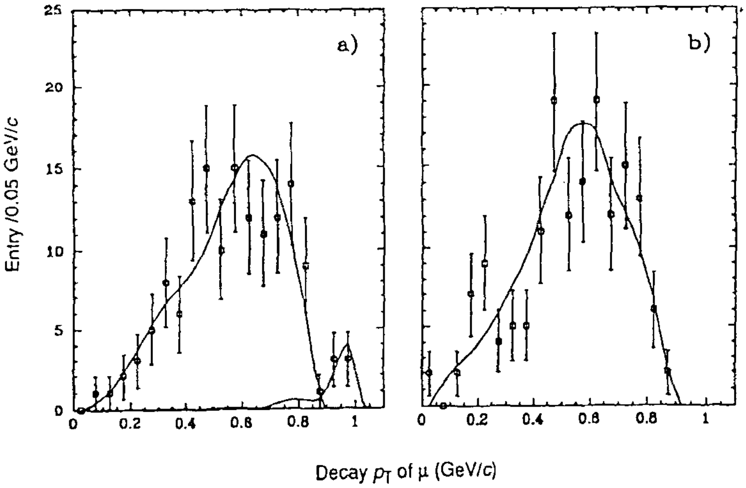

Figure 7. The decay p_T distributions of muons from a) 144 single-prong decays and b) 157 two-prong decays observed by WA75.

mate that < 1% of muon p_T's from $D^+ \rightarrow \overline{K}^0 \mu^+ \nu_\mu$ decays will smear into the $p_T > 0.90$ *GeV* region.

WA75 use the inclusive rate of D^0 decays to muons, the ratio of D^0 and D_s^+ cross-sections and the $D_s^+ \rightarrow K^- K^+ \pi^+$ branching ratio to obtain:

$$BR(D_s^+ \rightarrow \mu^+ \nu_\mu) = (4.0^{+1.8+0.8}_{-1.4-0.6} \pm 1.7) \times 10^{-3}$$

and

$$f_{D_s} = (232 \pm 45 \pm 20 \pm 48)\mathrm{MeV/c^2},$$

where the first error is statistical, the second covers experimental systematic errors and the third represents the error due to uncertainties in the cross-sections and branching ratios used in the extraction.

2.3. High Statistics Experiments

Fixed target charm physics is presently dominated by two Fermilab experiments: E687, a broad-band photo-production experiment and E791, the very high-statistics hadro-production experiment. E687 has a smaller data set which it has completed analyzing and many results have been presented. E791 is currently analyzing its data set (≈ 10% of the data are analyzed) and expects to have preliminary results in the summer of 1993 and final results by the summer of 1994.

2.3.1. E687

The major recent results from E687 are on spectroscopy (both baryon and meson) and on semileptonic decays. They also have a few results on other interesting topics such as non-strange decays of the D_s^+.

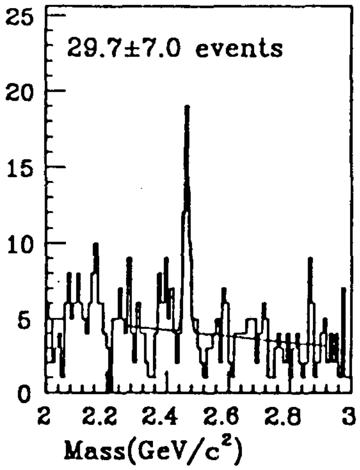

Figure 8. The $\Xi^-\pi^+\pi^+$ invariant mass plot from E687 showing a clear peak due to Ξ_c^+ decays.

2.3.1.1. Charm Baryons

Recently CLEO presented new results [9] on decays of the Λ_c^+ and the Σ_c^+ into several decay modes. However, results from fixed target experiments serve not only as an important confirmation and a measurement of the baryon masses, but are unique in their ability to measure the lifetimes of the charm baryons. E687 for instance has presented new results [10] on both the Ξ_c^+ and the Ω_c^0 baryons. Figure 8 shows the observed Ξ_c^+ signal in the $\Xi^-\pi^+\pi^+$ mode of decay. There are 30±7 events at a mass of 2.484±0.002 GeV/c^2. This signal was obtained with a requirement that the primary and secondary vertices be separated in space by at least 2.5σ. E687 has also obtained a Ω_c^0 signal in the $\Omega^-\pi^+$ mode. There are 9.6±3.8 events in the signal. E687 has used the Ξ_c^+ signal to extract a lifetime and they obtain 0.41±0.10±0.02 ps which is consistent with the expectation of a longer Ξ_c^+ lifetime.

2.3.1.2. D** mesons

The D mesons have positive parity states (L=1) with $J^P = 0^+, 1^+, 2^+, 1^+$ which are formed by combining L=1 with S=0, 1. In principle there are four of these for each of the D^+, D_s^+ and the D^0, leading to a total of 12 states. Of these only 5 have been observed so far, including a recent observation of a new decay mode of the D_s^{**+} into $D^{*0}K^+$ by CLEO. The five observed states may be listed as follows:

E687 confirms [11] the D**(2460), D**(2420) and the D**(2536). They have observed a small signal in the D**(2420) (76±46 events) and a better signal in the D**(2460) (119±44 events). The mass of the latter particle is fixed as 2460±4 MeV (statistical errors only) with a width of 42±10 MeV (again, statistical errors only). These peaks are shown in Figure 9. In Figure 10 are shown the $D_s^{**+}(2536)$ decays to $D_s^{*+}K^0$ observed by E687. They see a clear peak of 25±7 events at a mass of 525±3 MeV (statistical errors only) and a width of 12±6 MeV. There is no peak yet in the $D^{*+}K^\pm$ plot.

Table 1. D^{**} particles and decay modes known so far. In some cases spin-parity assignments are based on expectations from the quark model.

J^P	Decay mode	Mass (MeV)
2^+	$D^{**0} \to D^{*+}\pi^-, D^+\pi^-$	2460
2^+	$D^{**+} \to D^*K, DK$	2470
1^+	$D^{**0} \to D^{*+}\pi^-$	2420
1^+	$D^{**+} \to D^*\pi$	2440
1^+	$D^{**+} \to D^{*+}K^0_S, D^{*0}K^+$	2536

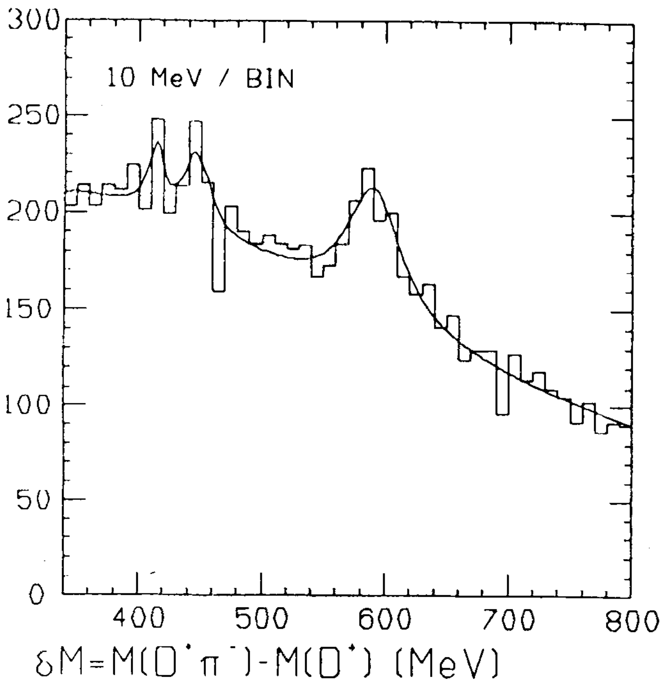

Figure 9. The $D^{**}(2420)$ and $D^{**}(2460)$ decays to $D^+\pi^-$ were confirmed by E687. The mass plot shows the difference between the $D^+\pi^-$ invariant mass and the reconstructed mass of the D^+.

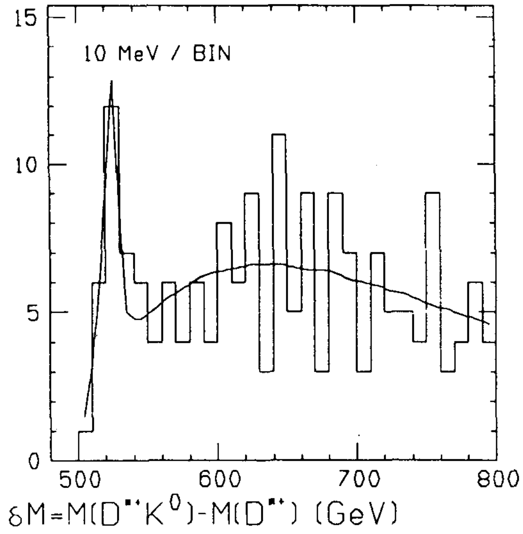

Figure 10. The $D^{*+}K^0_s$ invariant mass plot from E687 shows a clear peak due to D_s^{**+} decays.

2.3.1.3. Charm semileptonic decays

Charm semileptonic decays are a particularly appealing area of weak decays. This is because in a semileptonic decay one vertex, the leptonic vertex, is well understood. Also, only the spectator diagram contributes to these decays. These facts make it easier to study form-factors in semileptonic charm decays. Considerable progress had already been achieved prior to this year by E691 and E653 who studied the $D\to K l\nu$ and $D\to K^* l\nu$ decays. However, some problems and open questions remained.

When the D^+ decays to $\overline{K}^{*0} l\nu_l$ the $\overline{K}^{*0}$ can be longitudinally or transversely polarized. E691 reported [12] that the ratio Γ_L/Γ_T was $1.8^{+0.6}_{-0.4}\pm 0.3$ which is much higher than the value $0.5^{+1.0+0.1}_{-0.1-0.2}$ reported earlier by the Mark III collaboration [13]. Subsequently E653 presented the result [14] $\Gamma_L/\Gamma_T = 1.18 \pm 0.18 \pm 0.08$, which clearly lies between the other two. E687, with their higher statistics has helped clear up this confusion by presenting a result [11] recently which confirms the high value of Γ_L/Γ_T seen by E691. The E687 result is $\Gamma_L/\Gamma_T = 1.48 \pm 0.14 \pm 0.11$. In table 2 below we present these and other (form-factor) results from some of the higher-statistics experiments. What is more of a problem for theory, especially for quark models, is the low measured rate of D^+ decays to $\overline{K}^{*0} l^+\nu_l$. For instance, the present world average of $\Gamma(K^* l^+\nu_l)/\Gamma(K^- l^+\nu_l) = 0.57\pm 0.08$, much lower than the value of 1.0 expected from quark models [11].

E687 has also searched for semileptonic decays in other modes including $D^0 \to K^{*-}\mu^+\nu_\mu$ and $D_s^+ \to \phi\mu^+\nu_\mu$ [15]. Using 244±59 events in the first mode, they conclude that

$$\frac{\Gamma(D^0 \to K^{*-}\mu^+\nu_\mu)}{\Gamma(D^+ \to \overline{K}^{*0}\mu^+\nu_\mu)} = 1.20 \pm 0.30^{+0.17}_{-0.35}.$$

Table 2. Parameters of $D^+ \to \overline{K}^{*0} l^+ \nu_l$ decays as measured by major charm experiments.

Experiment	Γ_L/Γ_T	$A_2(0)/A_1(0)$	$V(0)/A_1(0)$
Mark III	$0.5^{+1.0+0.1}_{-0.1-0.2}$		
E691	$1.8^{+0.6}_{-0.4} \pm 0.3$	$0.0 \pm 0.5 \pm 0.2$	$2.0 \pm 0.6 \pm 0.3$
E653	$1.18 \pm 0.18 \pm 0.08$	$0.82 \pm 0.23 \pm 0.11$	$2.0 \pm 0.33 \pm 0.16$
E687	$1.48 \pm 0.14 \pm 0.11$	$0.448 \pm 0.14 \pm 0.11$	$1.46 \pm 0.24 \pm 0.18$

The statistics in this mode are clearly poor and better results are needed from an experiment such as E791. However, if one uses the result along with results from E691 and other experiments the conclusion is that the inclusive semileptonic branching ratio is not quite satisfied by the (K,K*,π)$\mu\nu$ channels. The ratios work out to be

$$\frac{\Gamma(D^0 \to (K, K^*, \pi)\mu\nu}{\Gamma(D^0 \to Xe\nu)} = (77 \pm 14)\% \qquad \text{and}$$

$$\frac{\Gamma(D^+ \to (K, K^*, \pi)l\nu}{\Gamma(D^+ \to Xe\nu)} = (66 \pm 14)\%.$$

Although the discrepancy is only a 2σ effect at present, it could indicate a problem with either the inclusive semileptonic decay rates or with the hadronic branching ratios used for normalization purposes. In the $D_s^+ \to \phi\mu\nu$ mode E687 observe 154±16 events, but choose not to quote a branching ratio at this time.

2.3.1.4. Non-strange decays of the D_s^+

E687 has seen a significant signal [16] in the $D_s^+ \to \pi^+\pi^-\pi^+$ and $D^+ \to \pi^+\pi^-\pi^+$ channels which are shown in Figure 11. The partial widths can be related to those in more copious modes and the results are

$$\frac{\Gamma(D_s^+ \to \pi^+\pi^-\pi^+)}{\Gamma(D_s^+ \to \phi\pi^+)} = 0.33 \pm 0.08 \pm 0.04 \qquad \text{and}$$

$$\frac{\Gamma(D^+ \to \pi^+\pi^-\pi^+)}{\Gamma(D^+ \to K^-\pi^+\pi^+)} = 0.035 \pm 0.006 \pm 0.004.$$

These results, which use the full E687 sample of 500 million triggers, are close to those previously reported by E691 [17] and indicate a small branching ratio of the D_s^+ to non-strange states as expected from the suppression of the annihilation diagram due to helicity and wave-function suppression. A complete Dalitz plot analysis of the decay mode is eagerly awaited. In particular, the branching ratios into $\rho\pi$ can be directly compared with the branching ratios for decays to $\phi\pi^+$.

2.3.2. The very high statistics experiment E791

Clearly, the future lies with higher statistics results and that is the preserve of experiment E791 [18]. E791, with over 20 billion triggers recorded on tape will produce at least 200,000 charm events. This is at least a factor of 4 above the sample

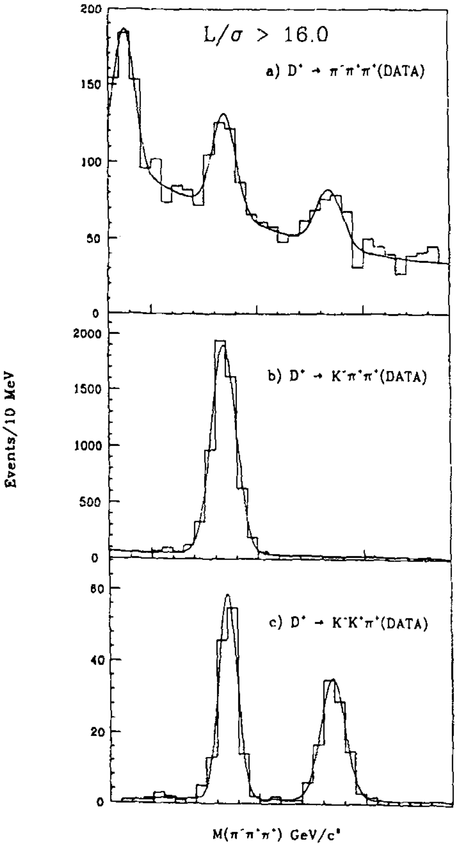

Figure 11. The D^+ and D_s^+ decays to $\pi^+\pi^+\pi^-$ show up cleanly in the invariant mass plot for the three pions. There is a 16σ vertex separation cut. The peak around 1.75 GeV/c^2 is due to misidentified $K^-\pi^+\pi^+$ decays.

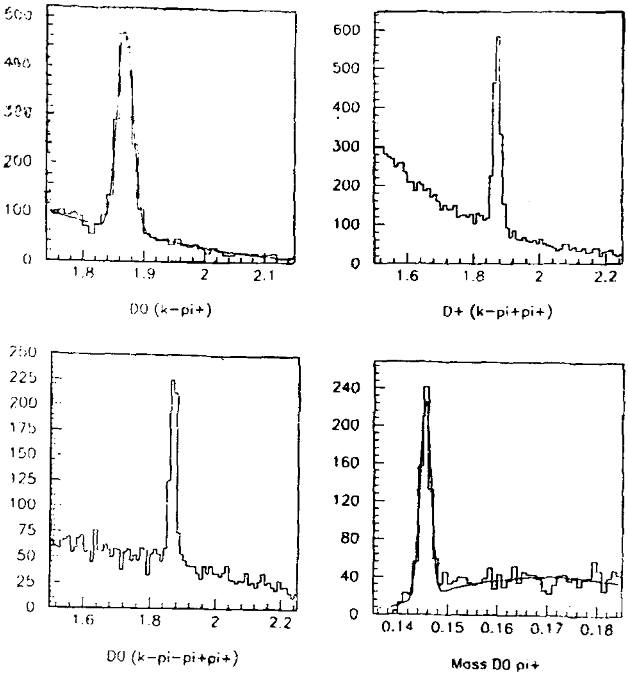

Figure 12a. The $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$ and $D^+ \to K^-\pi^+\pi^+$ invariant mass plots from ~3% of E791's data set. Also shown is the D^{*+} peak from $D^0 \to K^-\pi^+$ decays.

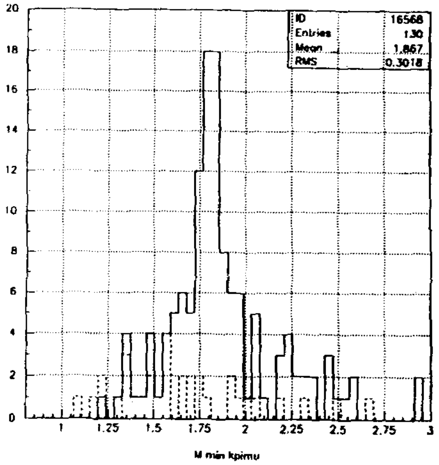

Figure 12b. The right-sign (solid line) and wrong-sign (dotted line) minimum mass for $D^+ \to \overline{K}^{*0}\mu^+\nu_\mu$ decays from a very small fraction of E791's data set.

available from E687 *when considering background subtracted signals. Background subtracted numbers are important because they are the correct way to compare yields from different experiments.* E791 achieved this high yield by the conceptually simple trick of collecting large amounts of data. Of course, this required state-of-the-art data acquisition and detector front-end readouts. E791 also used an upgraded silicon vertex detector with a total of 23 planes of silicon. The preliminary results from this experiment are very encouraging and confirm the expected number of events (see Figure 12). By now over 10% of the data have been reconstructed and the experiment expects to have preliminary results in the summer of 1993 and final results by the summer of 1994.

References

[1] See for example M. L. Mangano, P. Nason and G. Ridolfi, "Fixed target Hadroproduction of Heavy Quarks", IFUP-TH-37-92 and references therein.

[2] R. Jesik et al., "A Search for Beauty-Meson Production in π^--Nucleon Collisions", proceedings of the XXVI International Conference on High Energy Physics, Dallas, TX, USA (1992).

[3] K. Kodama et al., "Measurement of the Lifetimes of Charged and Neutral Beauty Hadrons", DPNU-92-37 (1992), submitted to Progress of Theoretical Physics.

[4] E789 in the 7th Meeting of the American Physical Society Division of Particles and Fields, Nov. 1992, Fermilab, Batavia, IL, USA.

[5] J. R. Raab et al., Phys. Rev. **D37** (1988) 2391.

[6] G. A. Alves et al., Phys. Rev. Lett. **69** (1992) 3147.

[7] G. A. Alves et al., Phys. Rev. Lett. **70** (1993) 722.

[8] S. Aoki et al., "The First Observation of the Muonic Decay $D_s^+ \rightarrow \mu_+\nu_\mu$" CERN-PPE-92-157 (1992), submitted to Prog. Theor. Phys.

[9] B. Nemati representing the CLEO II collaboration in the proceedings of the 7th Meeting of the American Physical Society Division of Particles and Fields, Nov. 1992, Fermilab, Batavia, IL, USA.

[10] C. Dallapiccola representing the E687 collaboration in the proceedings of the 7th Meeting of the American Physical Society Division of Particles and Fields, Nov. 1992, Fermilab, Batavia, IL, USA.

[11] See the review talk by J. Cumulat in the proceedings of the 7th Meeting of the American Physical Society Division of Particles and Fields, Nov. 1992, Fermilab, Batavia, IL, USA.

[12] J.C. Anjos et al., Phys. Rev. Lett. **65** (1990) 2630.

[13] Z. Bai et al., Phys. Rev. Lett. **66** (1991) 1011.

[14] K. Kodama et al., Phys. Lett. **B274** (1992) 246.

[15] R. Culbertson representing the E687 collaboration in the proceedings of the 7th Meeting of the American Physical Society Division of Particles and Fields, Nov. 1992, Fermilab, Batavia, IL, USA.

[16] G. Kim representing the E687 collaboration in the proceedings of the 7th Meeting of the American Physical Society Division of Particles and Fields, Nov. 1992, Fermilab, Batavia, IL, USA.

[17] J. C. Anjos et al., Phys. Rev. Lett. **62** (1989) 125.

[18] See for instance, R. Sidwell's talk in the proceedings of the 7th Meeting of the American Physical Society Division of Particles and Fields, Nov. 1992, Fermilab, Batavia, IL, USA.

Discussion

R. Raja : Is the E653 result of the charged B lifetime being larger than neutral B contradicted by the LEP reslts?

M.V. Purohit : Yes, LEP claims the lifetimes are the same. The E653 result is only 2σ above the τ_{B^0}, so it is not statistically overwhelming.

K.V.L. Sarma : What is the experimental number on the ratio $\Gamma(D \rightarrow K^{*}\mu\nu)/\Gamma(D \rightarrow K\mu\nu)$?

M.V. Purohit :

$\Gamma(D^0 \rightarrow K^- e^+ \nu_e) = (7.8 \pm 0.5) \times 10^{10}$ / sec.

$\Gamma(D^+ \rightarrow \bar{K}^{*0} e^+ \nu_e) = (4.3 \pm 0.5) \times 10^{10}$ / sec.

$\Gamma(D^+ \rightarrow K^{*-} e^+ \nu_e) = (5.4 \pm 1.2) \times 10^{10}$/ sec.

Taruni Uppal : What are the forms of the pole terms used in the form factor evaluation?

M.V. Purohi : They only show the q^2 dependence, have considered the $f_+(0)$ dependence otherwise.

D.P. Roy : Can you comment on the departure from the linear A dependence of the large x_F (> .5) charm production cross section repeated by several experiments?

M.V. Purohit : At large x_F (a) the rate is low $(d\sigma/dx_F) \sim (1 - x_F)^4$; (b) the decay particles are at very small angles, i.e., go into the dead region of detectors; (c) the decay particles are beyond the range of Cerenkov counters. (b) and (c) therefore conspire to make the acceptance very low at large x_F.

D.P. Roy : Is the measurement of f_D, shown by you, the only measurement of f_D so far?

M.V. Purohit : As best as I know, yes. Mark III has a limit of f_D.