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BACKGROUNDS TO THE DETECTION OF TWO-BODY HADRONIC B DECAYS

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We consider backgrounds to the detection of the two-body hadronic decay modes of neutral B mesons and baryons. The largest background is due to the correlated production of pairs of high-p_T hadrons in the target, but this can be adequately rejected provided the experimental apparatus has sufficient resolution in mass and decay vertex[1]. Another possible source of background arises from the production and decay of charmed and strange particles. Since these particles can travel considerable distances before decaying, they can give rise to backgrounds which may not be rejectable by means of a vertex cut. We have simulated several backgrounds from charm, and we find them to be small compared to the expected level of signal. To illustrate the issues involved, we use the proposed Fermilab E789 spectrometer[1] as an example.

We have simulated the production and subsequent decay to two or three hadrons of pairs of charged D-mesons. Events in which only a single charged hadron per D is detected by the spectrometer can mimic two-hadron decays of Bs, if the invariant mass of the resulting pair is equal to the mass of the B. Since the first E789 silicon plane is about 1 m from the target, any D decay containing a charged hadron might contribute. Since the D-pair cross-section[2] is over 1000 times as large as as the B cross-section[3] (16 μb vs. 10 nb), and relevant D branching ratios[4] are over 100 times as large as those of the B-meson two-body modes[5], it is clear that these processes must be considered in some detail.

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We first simulated charged-D-pair production in 800-GeV proton-nucleon collisions followed by the two-body decay of each D into a neutral kaon plus a charged pion. Our simulation used measured[2] 800-GeV D production distributions and assumed that each D event contained a second D uncorrelated in momentum or direction with the first[6]. For each D pair, the program calculated the invariant mass of the resulting pion pair, the distance ("z_{vertex}") from the target to the plane at which the pion tracks are closest together, and the track separation in that plane ("r_{close}"). (We assumed that, as in E789, the target is short compared to the B decay length.) To improve the statistical precision of the sample, we considered all pion pairs in the mass bin $5.0 < m < 5.4$ GeV to be B candidates, even though a high-resolution experiment such as the proposed Fermilab E789 would make a much tighter mass cut, say of 5 MeV width.

We then simulated three-body decays of charged-D pairs, using the same assumptions and procedures as described above for the two-body case. Figure 1 shows distributions vs. mass, z_{vertex}, and r_{close} of the resulting pion pairs. (The distributions for the two-body case are similar).

The results of these simulations are summarized in Table I:

	Two-body	Three-body
Events thrown:	10^7	10^7
Events with $5 < m < 5.4$ GeV	76798	60328
and $z_{vertex} > 5$mm	4561	1751
and $r_{close} < 100\mu$m	1313	505
Events accepted by E789:		
$5 < m < 5.4$ GeV	16	1

Table I.

These data determine the probability (per D-pair) of producing a pion pair which looks like a B-meson decay and the probability (per pion pair in the B mass region) of the pair being accepted by the E789 spectrometer. We apply plausible vertex and track separation cuts as shown in Table I. Certain correction factors enter these calculations due to measures taken in the Monte Carlo program to increase the statistical precision of the results: 1) As mentioned above, we took the B mass region to be $5 < m < 5.4$ GeV. For a spectrometer having 2.5 MeV r.m.s. mass resolution, the B mass region would be taken as 5 MeV wide, so only 1 in 80 of the events in the 400 MeV mass bin should be considered a B candidate. 2) To increase the number of events accepted by the spectrometer, each event was thrown in azimuth such that one pion pointed approximately at the upper spectrometer

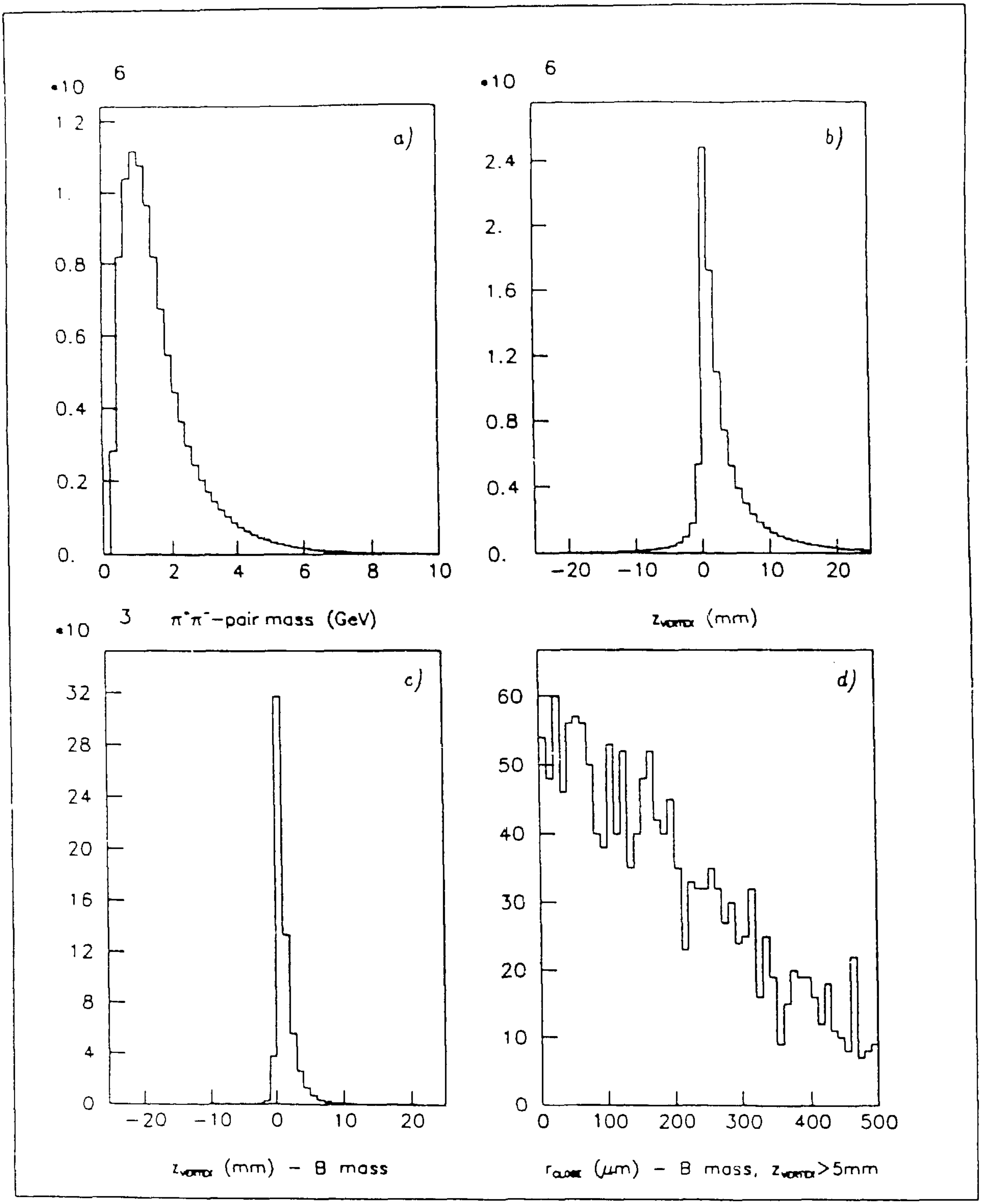

Figure 1: a) invariant mass and b) z_{vertex} distributions of $\pi^+\pi^-$ pairs from $D^\pm \to K\pi\pi$ decays; c) z_{vertex} distribution for pairs in the B mass region ($5 < m < 5.4$ GeV); and d) r_{close} distribution of pairs in the B mass region having $z_{vertex} > 5mm$.

aperture, represented as a rectangle covering 15 to 60 mr in vertical angle by ± 26 mr in horizontal angle (angles being referenced to the beam axis). The thrown azimuthal range was thus 25% of 2π, so for calculating acceptance each event thrown represents four D-pairs produced. 3) The event was counted as accepted by the spectrometer if the upper pion pointed at the upper aperture and the lower pion pointed at the lower aperture, even though half the time the pions would be deflected the wrong way in the first analyzing magnet and thus lost. So the actual acceptance is an additional factor of two smaller.

The resulting probabilities are thus:

	Two-body	Three-body
Probability of D-pair faking B decay:		
	$(1.64 \pm 0.05) \times 10^{-6}$	$(6.3 \pm 0.3) \times 10^{-7}$
Probability event accepted by E789:		
	$(2.6 \pm 0.7) \times 10^{-5}$	$(2.1 \pm 2.1) \times 10^{-6}$

Table II.

To compare the resulting level of background to the B signal, we need to take account of the cross-sections and branching ratios, and also of the combinatorics of the various charged-D three-body decay modes[7]. We assume a charged-D cross-section[2] of (16.5 $\pm$ 3.5) μb, giving a D-pair cross-section of (8.25 $\pm$ 1.75) μb, and a branching ratio to $K\pi$ of (3.2 $\pm$ 0.7)%[4]. We thus find a background level of (13.8 $\pm$ 5.2) fb, to be compared with the assumed B cross-section[3] times branching ratio[5] of 10 nb x 10^{-4}. Thus the background-to-signal ratio is $(1.38 \pm 0.52) \times 10^{-2}$, not a significant problem.

The three-body case is more complicated since some $D \rightarrow K\pi\pi$ decay modes contain two charged pions, either of which might participate in a "fake-B" pair. Using the $K\pi\pi$ branching ratios of Reference 4, we find a composite branching ratio for a charged-D pair to give a $\pi^+\pi^-$ of 0.081 $\pm$ 0.016. The resulting background level is (0.42 $\pm$ 0.12) pb, and the background-to-signal ratio is 0.42 $\pm$ 0.12. Since we have considered only a few of the possible contributing channels, this must be taken as a lower limit on the background, thus it represents a potentially serious problem for a two-body B-decay experiment. However, the E789 acceptances given in Table II are quite small, whereas the E789 B acceptance is 2%[1]. So the background-to-signal for E789 is reduced to a comfortable $(4.4 \pm 4.6) \times 10^{-5}$, and the contribution due to two-body D decays to $(1.8 \pm 0.8) \times 10^{-5}$. This level of background will not be a problem even if the contributions due to additional channels (other decays of charged D mesons as well as decays of neutral[8] Ds and other charmed particles) increase it by three orders of magnitude.

To understand why these backgrounds have such small acceptances compared to the signal, we have examined some events in detail. The 5-GeV background events have large longitudinal-momentum asymmetries in the laboratory frame, leading to a "decay-angle" distribution in the pion-pair rest frame which is very strongly peaked forward and backward. However, the acceptance of the spectrometer is concentrated near decay angles of 90°. The decay of B mesons is of course isotropic in decay angle. Experiments having acceptance away from 90° may thus have to contend with substantial charm background.

NOTES

1. FNAL Proposal 789 (revised), January 1988.
2. LEBC-EHS Collaboration, as reported in I. D. Leedom, "Hadroproduction of Heavy Flavors," Fermilab TM-1396, April 1986, and S. Reucroft, "Hadroproduction Characteristics of Charm and Beauty," 6th International Conference on Physics in Collision, Chicago, 1986.
3. R. K. Ellis and C. Quigg, "A Pinacoteca of Cross Sections for Hadroproduction of Heavy Quarks," Fermilab preprint FN-445, January 1987; E. L. Berger, "Dynamics of Bottom Quark Production in Hadron Collisions," Argonne preprint ANL-HEP-PR-87-90, August 1987. Since b quarks are produced in pairs, we have here multiplied Berger's 5 nb estimated cross-section by 2.
4. J. Adler et al., SLAC-PUB-4291 (1987). (We have added together the statistical and systematic errors.)
5. J. D. Bjorken, "Rare B-Decays: Experimental Prospects and Problems," International Symposium for the Fourth Family of Quarks and Leptons, UCLA, February 26-28, 1987; also, J. D. Bjorken, notes from High-Rate B-Physics Working Group, Fermilab, August 1987.
6. We generate D mesons according to $E\ (d^3\sigma/dp^3) = A\ \exp(-p_t^2)\ \ (1 - |x_F|)^6$. The available data are consistent with little or no dynamical correlation between the two Ds in D-pair events. As an extreme case, we have also tried assuming completely-correlated (D-pair momentum = 0 in CMS) production. We then find (for the three-body case) background/signal = 0.27 ± 0.08 and, into the E789 acceptance, $(1.7 \pm 0.5) \times 10^{-3}$.
7. Note that we do not consider here the decay of one D into two hadrons and the other D into three hadrons, as this would require a separate simulation.
8. Due to their shorter lifetimes, neutral Ds contribute negligible background compared to charged Ds, since pion pairs from neutral D decay are much more strongly suppressed by the z_{vertex} cut. (For example, the Monte Carlo gives a factor 25 suppression for three-body decays of neutral-D pairs with respect to those of charged Ds.)