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BCD-RP-225
Physics Backgrounds
Estimates (2 papers)

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$B \to J/\psi K_S^0 X$

In studies of the decay $B_d^0 \to J/\psi K_S^0$ there may be backgrounds due to the decays $B \to J/\psi K_S^0 X$ if X goes undetected or cannot properly be associated with the B^0 decay. Decays of any of $B^\pm$, B_d^0, or B_s^0 can contribute to this background.

This problem would be most severe in an analysis in which only the J/ψ-K_S^0 mass peak is used as the signal, and no knowledge of the secondary vertices is available.

To estimate the possible problem, we suppose that

$$\Gamma(B^+ \to J/\psi K^{*+}) = \Gamma(B^0 \to J/\psi K^{*0}) =$$

$$= 3\Gamma(B^+ \to J/\psi K^+) = 3\Gamma(B^0 \to J/\psi K^0).$$

Here we suppose decay to a K^* is 3 times as probable as that for a K because of the multiplicity of spin states. Then to calculate the adundance of K_S^0 in these decays we note that

$$\Gamma(K^{*+} \to \pi^+ K_S^0) = 1/3,$$

$$\Gamma(K^{*0} \to \pi^0 K_S^0) = 1/6,$$

and, of course,

$$\Gamma(K^0 \to K_S^0) = 1/2.$$

Then among only those modes listed at the beginning of this paragraph

$$\Gamma(B \to J/\psi K_S^0 X) = 3\Gamma(B_d^0 \to J/\psi K_S^0).$$

If we also suppose that an extra pion might be added to any of the above decays with probability equal to that of the original decay, we would have

$$\Gamma(B \to J/\psi X) = 32\Gamma(B_d^0 \to J/\psi K_S^0),$$

which is close to reported results from CLEO. We then infer that altogether

$$\Gamma(B \to J/\psi K_S^0 X) = 6\Gamma(B_d^0 \to J/\psi K_S^0).$$

Hence if the invariant mass of the $J/\psi K_S^0$ part of a $J/\psi K_S^0 X$ final state is close to the B mass, the signal of true $B_d^0 \to J/\psi K_S^0$ decays could be hard to see.

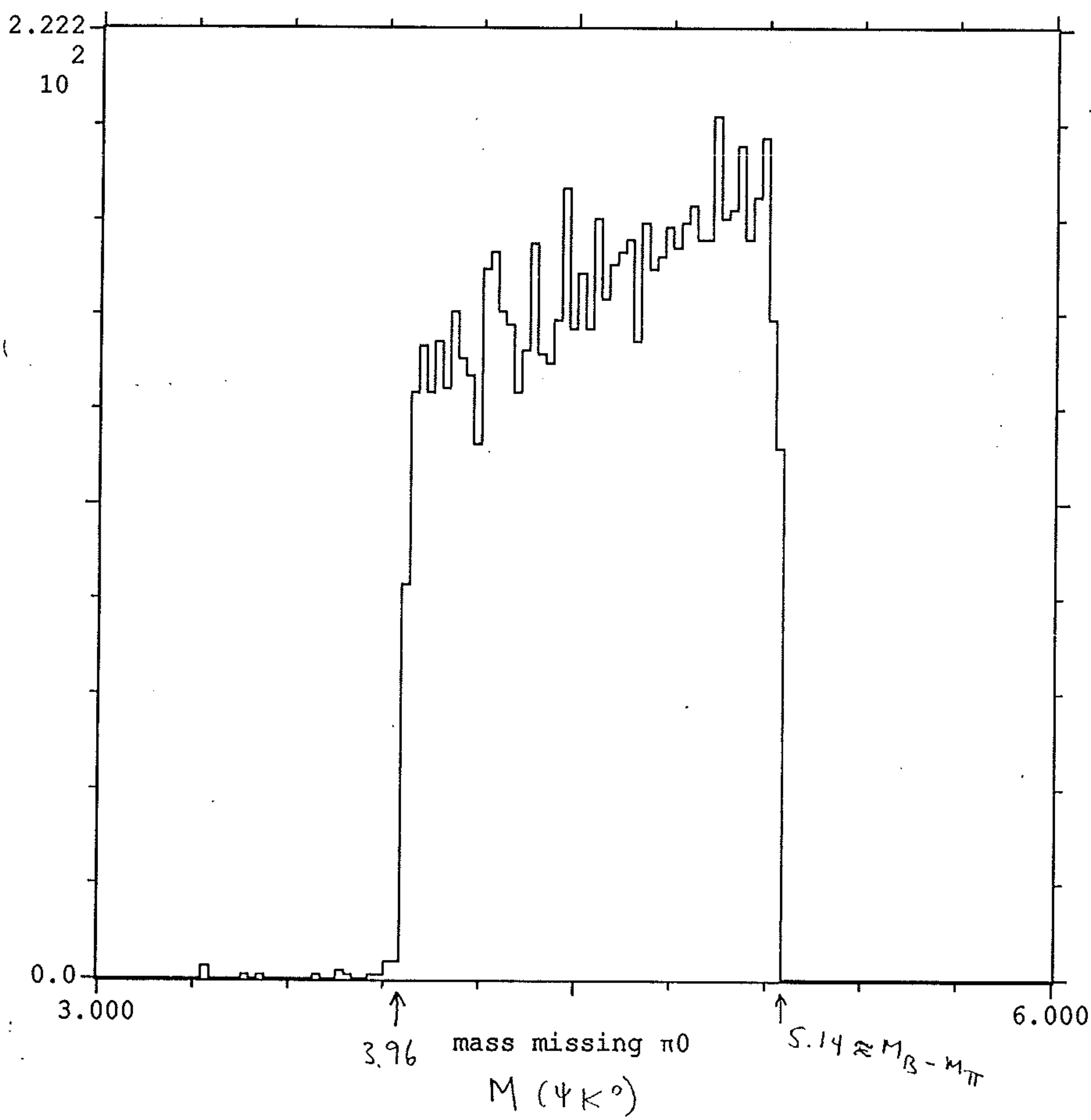
If we consider the 3-body decay $B \to \psi K X$, then the invariant mass $M_{\psi K}$ must lie between $M_\psi + M_K$ and $M_B - M_X$. Since $M_X \geq M_\pi$, if we miss the particle(s) X, the mass $M_{\psi K}$ must be shifted down from M_B by at least one pion mass.

Our 3-body final state is sometimes reached via a cascade rather than a direct decay. In this case the limits on $M_{\psi K}$ are narrower than the general rule. It turns out that for the cascade $B^0 \to J/\psi K^{*0}$; $K^{*0} \to K_S^0 \pi^0$, the mass limits are $3.96 < M_{\psi K} < 5.14 = M_B - M_\pi$ to good accuracy, and that the distribution of masses is roughly uniform over this interval. (See the attached plot.)

Thus we expect that for every true $B^0 \to J/\psi K_S^0$ decay there will be about 6 events of the type $B^0 \to J/\psi K_S^0 X$ with $M_{\psi K}$ spread over a 1.1-GeV interval below the B mass. So long as the B-mass resolution is roughly M_π or better this will not be a significant background.

The decay $B_s^0 \to J/\psi K_S^0$ will be a background for $B_d^0 \to J/\psi K_S^0$ if the mass resolution is not good enough. This would be very annoying for CP-violation studies. The decay $B_s^0 \to J/\psi K^{*0}$ is slightly troublesome in that the upper end point of the 1.1-GeV-wide spectrum of $M_{\psi K}$ could be very nearly equal to M_B, depending on the exact value of $M_{B_s^0}$. But only a high-statistics experiment would ever have to worry about this!

$B^0 \to \psi K^{*0}$
$\quad \hookrightarrow K^0 \pi^0$



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Combinatoric Background to $B_d^0 \to J/\psi K_S^0$

In studies of the decay $B_d^0 \to J/\psi K_S^0$ there may be backgrounds due to the decays $B \to J/\psi X$ in which the J/ψ is combined with a K_S^0 from the rest of the event to yield an invariant mass near that of the B.

This background will be suppressed by a vertex detector in two ways:

1. If the K_S^0 can be required to have the same secondary vertex as the J/ψ there will be essentially no combinatoric background. However, since the K_S^0 may travel a considerable distance before decaying, the pointing accuracy from its decay tracks may not be sufficient to distinguish whether it originated at the primary or at the B vertex. Monte Carlo simulation is required to clarify this.
2. In many of the decays $B \to J/\psi X$, the state X will include one or more charged tracks emanating from the B vertex. If these are found in the vertex detector, the event can be removed from the $B_d^0 \to J/\psi K_S^0$ candidates.

Nonetheless, it is interesting to explore the combinatoric background problem, as this helps answer the question: can we find $B_d^0 \to J/\psi K_S^0$ at a hadron collider even without a vertex detector?

We have generated a set of 4000 events using ISAJET at 1800-GeV center-of-mass energy, in which each event has one $B_d^0 \to J/\psi K_S^0$ decay. Figures 1 and 2 show the invariant mass for all J/ψ-K_S^0 combinations, and for those not including the B-decay products. We see that the signal for $B_d^0 \to J/\psi K_S^0$ is about 100 times that of the combinatoric background in a 25-MeV/c^2 bin. If the mass resolution at the B is 25 MeV/c^2, we should consider the background over 4 bins, reducing the signal-to-background ratio to 25/1.

Note that

$$\frac{\Gamma(B \to J/\psi X)}{\Gamma(B_d^0 \to J/\psi K_S^0)} \sim 30.$$

If so, our calculation indicates that the signal-to-background is effectively 1/1 (since we only generated events with a $B_d^0 \to J/\psi K_S^0$ decay).

Figure 3 shows the combinatoric background with the restriction that both the J/ψ and the K_S^0 are within $-1 < \eta < 1$, as for the CDF acceptance. We see that the signal-to-background is improved by a factor of 4, and hence we estimate that even without a vertex detector, CDF should be able to reconstruct $B_d^0 \rightarrow J/\psi K_S^0$ with signal-to-background of 4/1 if their mass resolution is 25 MeV/c^2.

FIGURE 1

4000 ISAJET EVENTS $\sqrt{s} = 1.8$ TeV

one $B^0_d \to J/\psi K^0_s$ per event

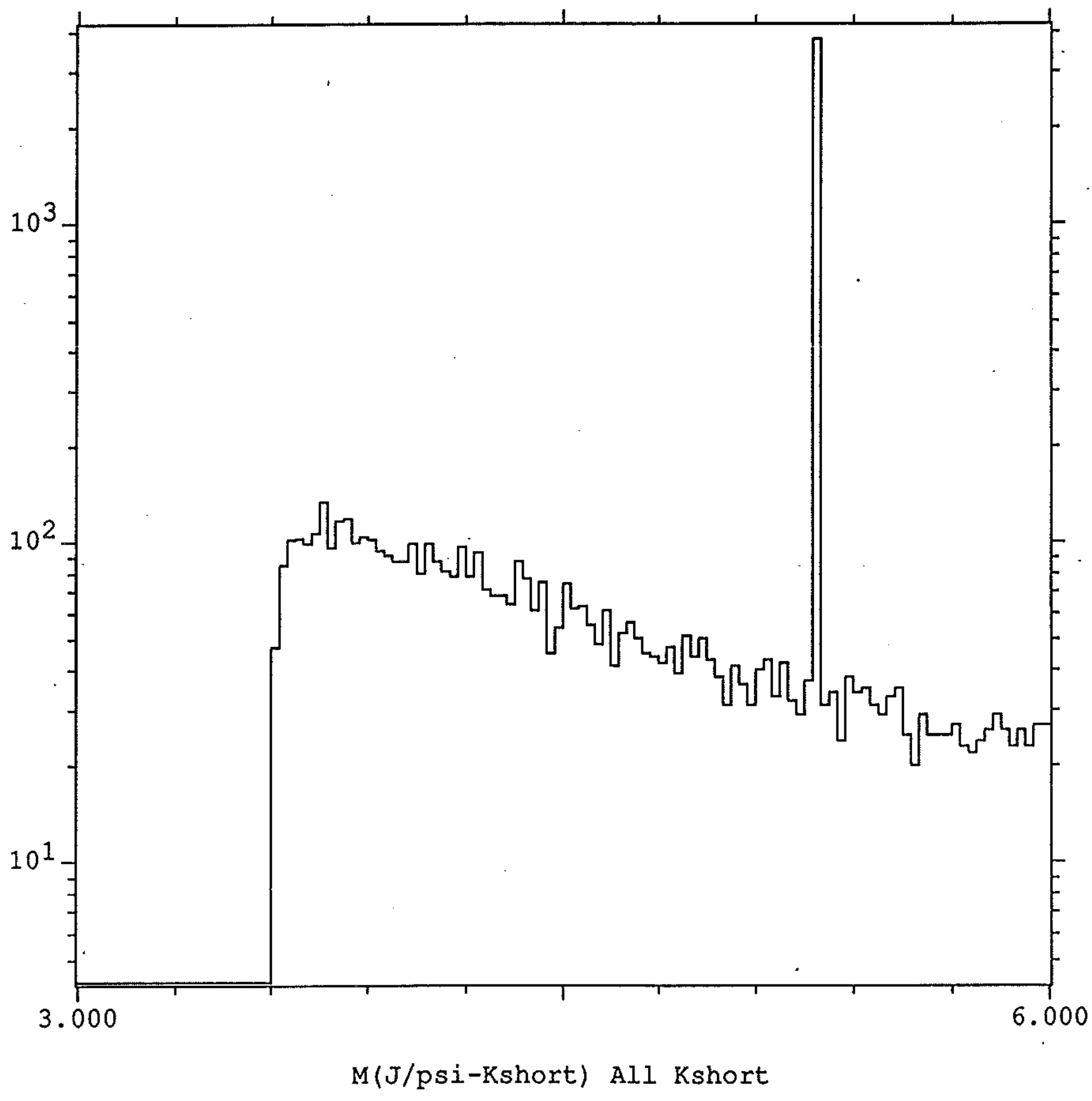
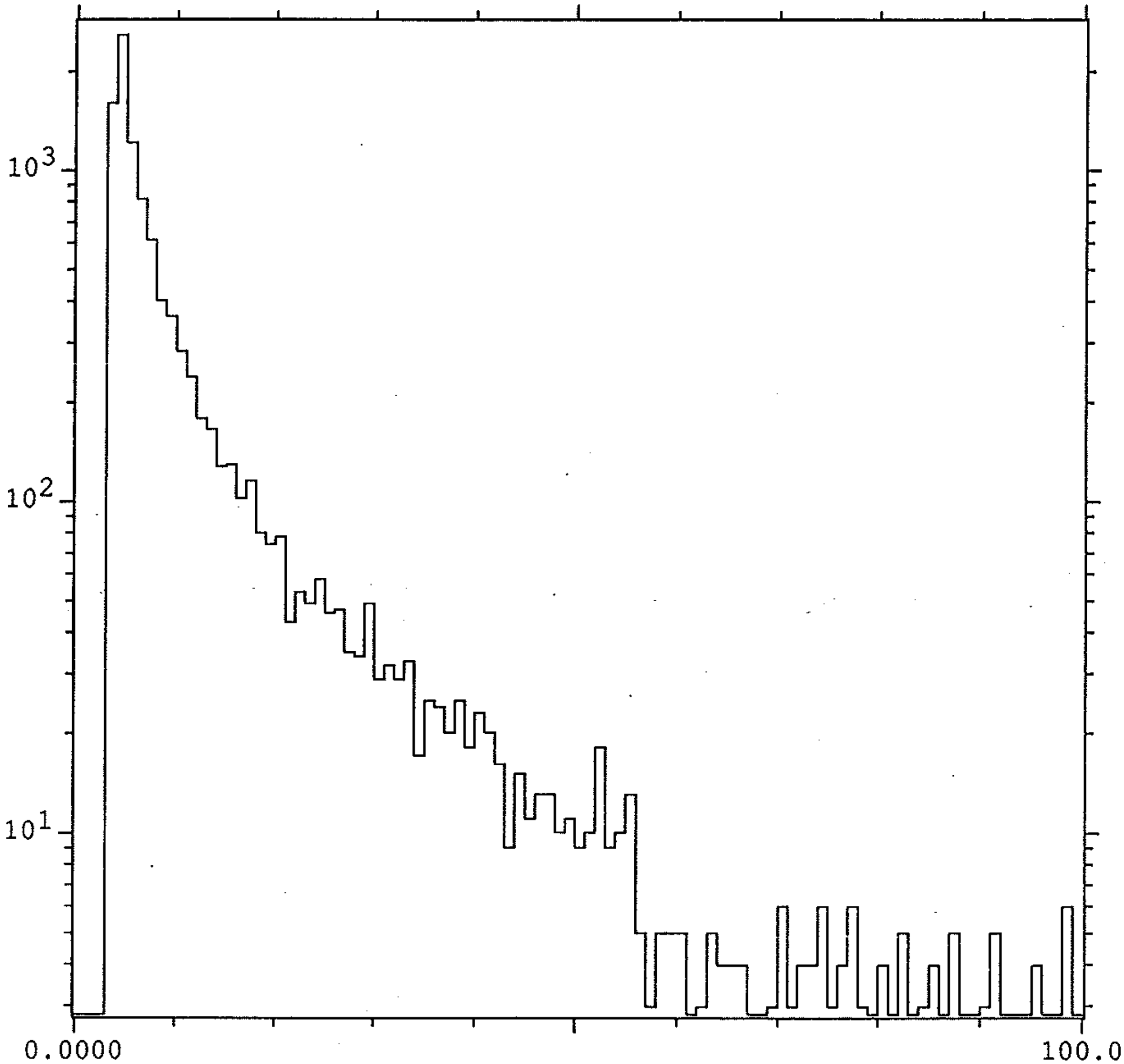
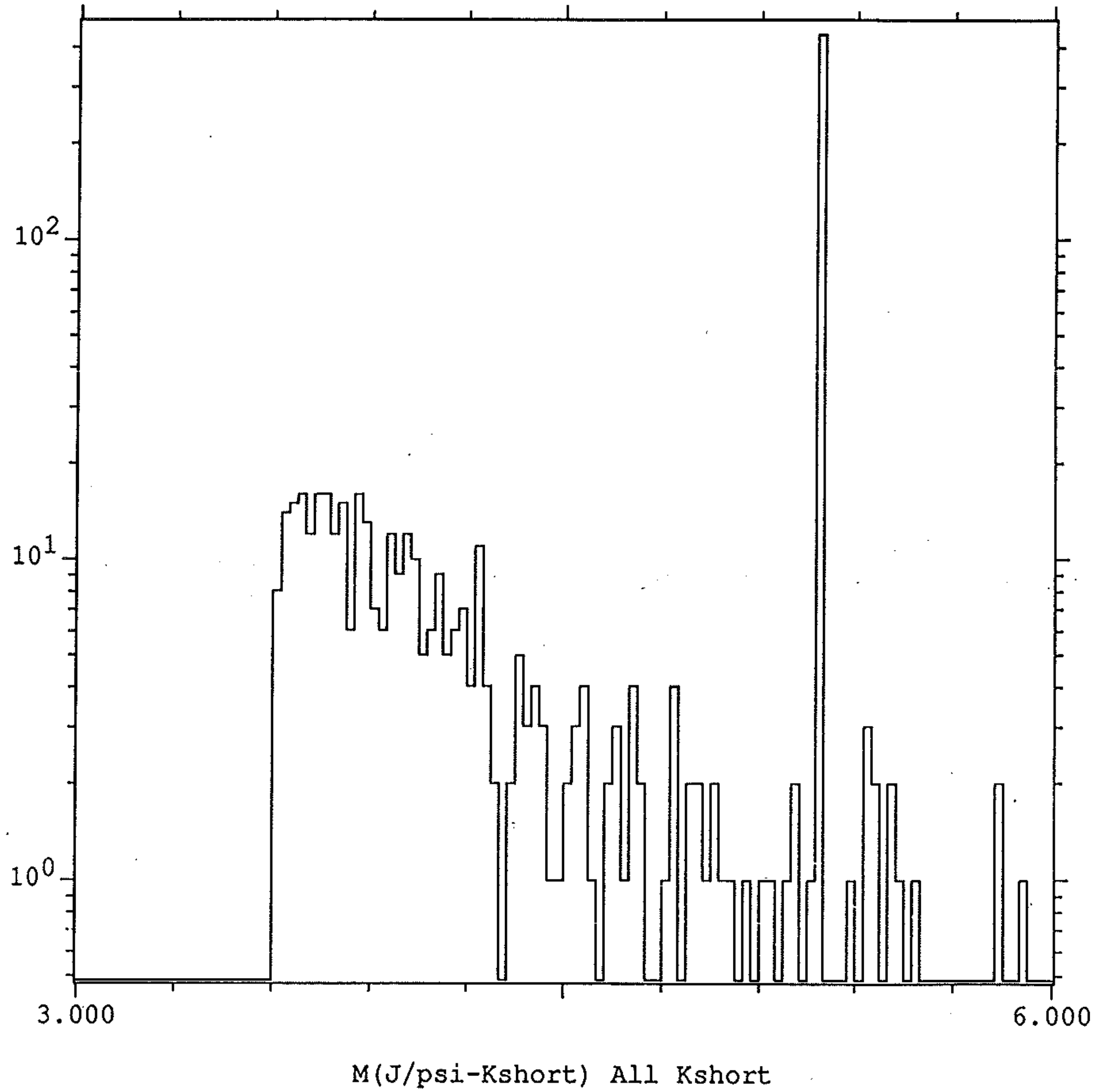


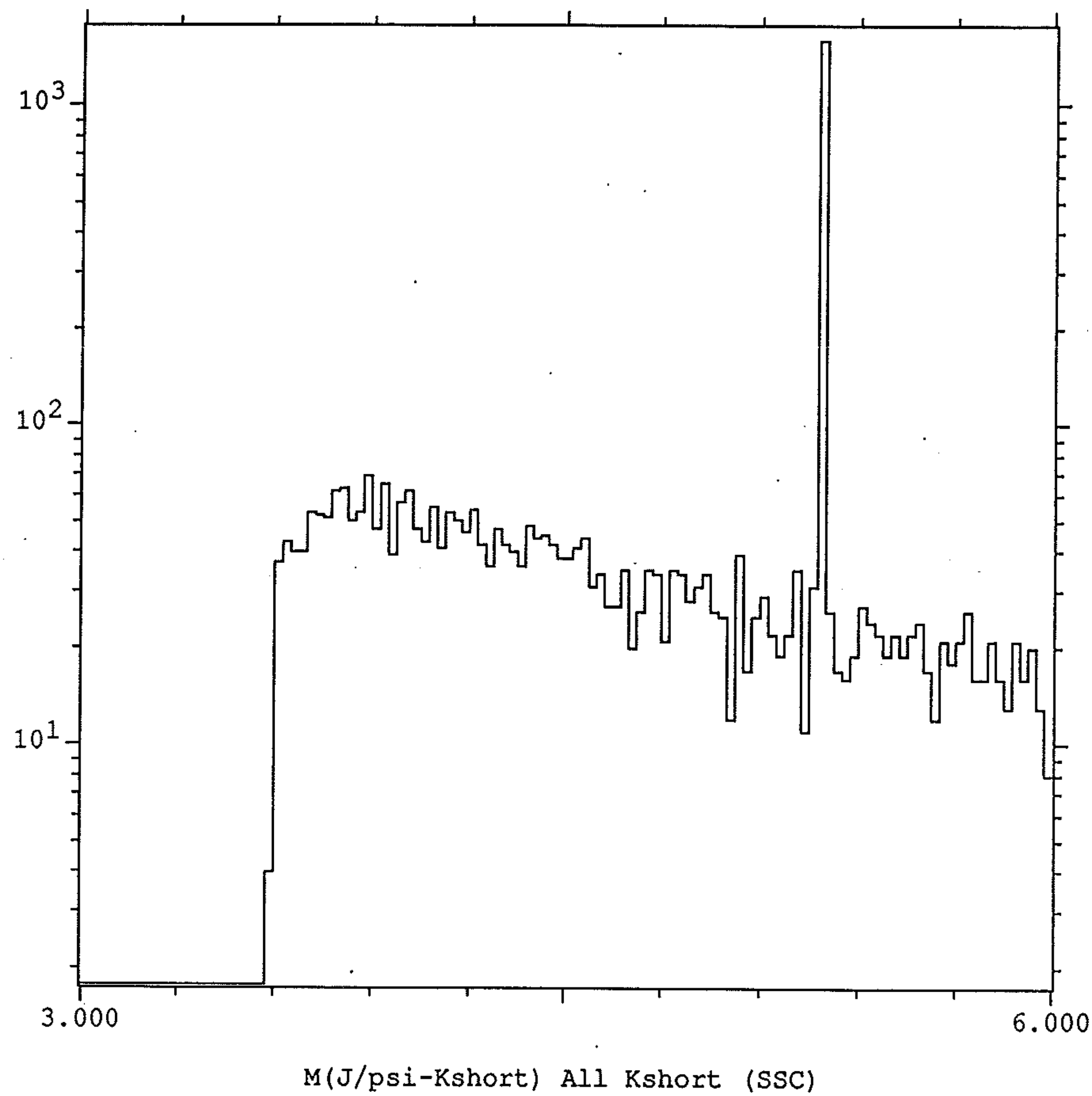
FIGURE 2



M(J/psi-Kshort) Kshort not from B decay

Figure 3
$-1 < \eta < 1$ for for J/ψ & K^0_s





10^3
10^2
10^1
3.000
6.000
M(J/psi-Kshort) All Kshort (SSC)