Comparison of recent calculations on the $W \to \tau\nu$ background for monojet events

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(Received 8 July 1985)

A comparative discussion is presented of recent calculations of the $W \to \tau\nu$ background for monojet events as observed by the UA1 experiment.

$W \to \tau\nu$ events turn out to represent an important source of background to the monojet signal as observed by the UA1 experiment.[1] This source of background is not the only one of relevance, as stressed in Ref. 2. In fact, the selection at large ΔE_m, the missing transverse energy, causes a remarkable enrichment of the contribution from hadronic $\bar{b}b$ events, with $b \to B(b\bar{c}) \to \tau\nu$, bringing it to an appreciable level.

Recently, two calculations have appeared concerning the $W \to \tau\nu$ monojet background.[2,3] Reference 2 appeared before the presentation of the latest UA1 data to the Aosta meeting, and pointed out that apart from the two monojet events at $\Delta E_m > 55$ GeV the other monojet events present in the earlier UA1 data sample could be accounted for by the $W \to \tau\nu$ and $\bar{b}b$ backgrounds. Reference 3 appeared after the Aosta meeting, in which the UA1 position concerning the observed monojet signal has apparently undergone some revision. Although it confirms the importance of this source of background, as found in Ref. 2, it contains no quantitative comparison with the results of the latter but just qualitative statements suggesting some level of disagreement. Because of the importance of the issue, in connection with current theoretical developments, we think it is worthwhile to establish a few quantitative facts, so as to get a clearer picture of the margin of uncertainty in the estimate of the $W \to \tau u$ monojet background.

The calculation of Ref. 2 includes initial QCD bremsstrahlung. The latter not only is responsible for the generation of the transverse momentum of the W boson (in agreement with data[4]), but also contributes jets which, as a result of their clustering with the τ decay debris by the jet-reconstruction algorithm, affect the monojet background. For the modeling of τ decays due account is taken of the fact that a large-ΔE_m cut strongly weights high values of the invariant mass $M(X_\tau)$ in $\tau \to \nu + X_\tau$ hadronic decays, as shown in Fig. 1. Since large $M(X_\tau)$'s are dominated by high-multiplicity decay modes, attention is focused on an appropriate treatment of such decay modes and a phase-space model is used. The latter yields (without the large-ΔE_m bias) a hadron multiplicity distribution of approximately Gaussian form, at the level of primary pseudoscalar and vector mesons, and $\langle n \rangle = 2.8$, $(\langle n^2 \rangle - \langle n \rangle^2)^{1/2} = 1.5$ for the multiplicity n of stable hadrons. Polarization effects are neglected because they can be treated in a model-independent way only for $\tau \to \nu + \pi$, whose contribution at large ΔE_m is negligible. Also allowing for a model-dependent treatment of these effects in $\tau \to \nu + (\rho, A_1, \rho')$ one has no sensible way of modeling them for the huge [especially at high $M(X_\tau)$] background under such resonances.

Reference 3 omits initial QCD bremsstrahlung and accounts for effects from the finite p_T of the W by a smearing procedure. For the τ decay modeling it assumes dominance of $\tau \to \nu + \pi$, $\nu + \rho$, $\nu + A_1$, $\nu + \rho'$, with resonance shapes parametrized by standard Breit-Wigner forms. Polarization effects are included assuming a bare $V - A$ structure of the weak current, i.e., neglecting soft hadronization effects responsible for resonance formation. The background left out by the Breit-Wigner parametrization is altogether neglected [although it is clearly needed to reproduce the available data on mass distributions; see, e.g., the compilation of data for $M(4\pi)$ in Ref. 5]. In connection with that, no estimate is made of how much resonance dominance, which may be roughly acceptable when no particular bias is present (as is the case for the study of Ref. 5), is affected by the strong bias induced by a large-ΔE_m cut (Fig. 1). Differently from Ref. 2, the results of Ref. 3 are presented without inclusion of the smearing effects in ΔE_m induced by the experimental uncertainties quoted by UA1. Also the "unaccounted" 10% in τ decay modes[5] is left untreated.

In spite of the substantial differences in the two calculations, their results remarkably agree.

At $\sqrt{s} = 540$ GeV and with an integrated luminosity of 0.12 nb^{-1}, Ref. 2 finds that one should expect from $W \to \tau\nu$ about 2 events above $\Delta E_m = 40$ GeV, with the UA1 cuts applying to monojet events.

From the ΔE_m distribution of Ref. 3, one is able to read

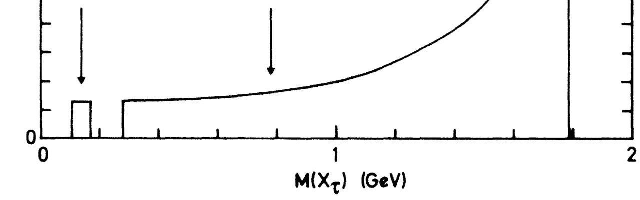

FIG. 1. Ratio of $\Delta N/\Delta M(X_\tau)$ as calculated with a $\Delta E_m > 40$ GeV cut and for all ΔE_m's under the conditions holding for the UA1 monojet data (Ref. 1). X_τ represents the hadron system in $\tau \to \nu + X_\tau$ decays.

an expectation of 1.14 events for $\Delta E_m > 40$ GeV at $\sqrt{s} = 630$ GeV with an integrated luminosity of 0.12 nb^{-1}. Assuming that the $W \rightarrow \tau\nu$ monojet background level approximately scales with the total W cross section, at $\sqrt{s} = 540$ GeV the level should decrease by about 20%. In order to roughly correct for the "unaccounted" 10% in τ decays left out in Ref. 3, one may bring the level up by 15% (since reference is to be made to the hadronic branching fraction). This is before experimental ΔE_m smearing is taken into account. The associated increase in the background level varies strongly with the ΔE_m cut. For $\Delta E_m > 35$ GeV we find a mere 9%, but moving further up in the large-ΔE_m tail the increase becomes substantial. For $\Delta E_m > 40$ GeV we find a double-digit increase of 60%. This is not the end. In Ref. 3 no estimate is made of the background level increase due to the possible merging by the jet-reconstruction algorithm of the τ "jet" with other particles or jets. In the calculational framework of Ref. 2 we have made a "lower-limit" estimate of such effects by clustering the τ "jet" with initial-bremsstrahlung quanta distant from it less than $\Delta R = 1$, which corresponds to the angular jet resolution considered by UA1. For $\Delta E_m > 40$ GeV, we find an increase in the background level by 20%. Summing up all the above corrections, one reaches an expected background level at $\Delta E_m > 40$ GeV of about 2 events, to be compared with that found in Ref. 2.

The agreement between the two calculations, leaving aside the quantitatively too good and probably accidental coincidence, simply means that at large ΔE_m the resulting $W \rightarrow \tau\nu$ background level is only marginally dependent on the detailed τ-decay modeling.

It is also of interest to remark that invariant masses of monojets originated by $W \rightarrow \tau\nu$ are not necessarily low. Because of the occasional merging of τ debris with other jets made by the jet-reconstruction algorithm, the invariant mass of the reconstructed monojet may turn out to be substantial. With the clustering procedure outlined above we find that with no ΔE_m cut in one of every five events a (mini)jet is present within $\Delta R = 1$ from the τ, with a mean invariant mass of the merged system $\langle M_{\text{"jet"}} \rangle \simeq 10$ GeV. With a $\Delta E_m > 40$ GeV cut such a merging occurs in one of every three events, and the mean invariant mass rises to $\langle M_{\text{"jet"}} \rangle \simeq 15$ GeV. That of course leaves out mergings with spectator-jet particles.

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