OBSERVATION OF TAU DECAY FROM W → $\tau\nu_\tau$ IN A UA1 EXPERIMENT

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ABSTRACT

Since the discovery of the W by the UA1 Collaboration in 1983, we have published the measurements of its decay in leptonic and muonic modes.

We report here the first observation of the decay W → $\tau\nu_\tau$, in 1983 data.

1. Selection

From weak interactions theory, we expect the W to decay with an equal branching ratio (8%) in electrons, muons, and taus. We have searched for tau decays in 1983 data (136 nb^{-1}) in order to observe the third generation and to understand the background of 'standard physics' for eventual 'new physics' (heavier leptons, supersymmetric particles, etc.). In the leptonic mode, it is impossible to distinguish tau leptons from direct W decay. In the hadronic mode, the tau decays essentially into one (three) charged pion(s) with a branching ratio of 48% (17%). We observed five (four) candidates for one- (three-) prong decay passing our selection criteria:

- Missing transverse energy E_T^M:
  - $E_T^M > 15$ GeV and $E_T^M > 2\sigma$, where $\sigma = 0.7\sqrt{\Sigma E_T}$ and ΣE_T = scalar sum of transverse energy;
  - E_T^M isolated in both the calorimeter and the central detector (CD).
- Jet trigger with $E_T > 15$ GeV, where the information from the CD and the calorimeter is compatible.
- Activity back to the jet trigger ($\pm 30°$) < 7 GeV in the calorimeter and 5 GeV in the CD.

2. Analysis of the Pion Hypothesis (One-Track Events)

Table 1 summarizes the relevant information extracted from the UA1 detector. All five events have a hard track, compatible with a hadron hypothesis. Events 3, 4, and 5 have an important hadronic deposition and, for events 1, 2, and 3, the CD information is incompatible with that expected from the calorimeter for the 'isolated electron' hypothesis.

The probability for events 1 and 2 to be radiative electrons has been evaluated to be 5.2×10^{-3} and 6.4×10^{-2}.

3. Analysis of the $W \to \tau\nu_\tau$ Hypothesis

For all five events the missing energy is balanced by the trigger jet, and both are lower than equivalent measurements for the $W \to e\nu_e$ sample (this is compatible with the tau kinematics, where a ν is added by the decay of the tau) (Fig. 1).

The invariant jet mass is compatible with a tau decay, and the total invariant mass [E_T^M, jet trigger] is compatible with a W origin (Fig. 2).

4. Background

The main background comes from QCD bijets where the detector has lost one jet and fake missing energy, whilst the other jet has fluctuated into one or three charged particles.

We have simulated such background by fluctuating a set of measured bijets from 1983 data. We passed these fluctuated events through our selection programs and normalized to the same luminosity (136 nb^{-1}). We obtained a background of 0.5 event for one-track candidates, and two events for three-tracks ones.

5. Conclusions

i) We observed five events compatible with

$$W^\pm \to \tau^\pm \nu_\tau (\tau^\pm \to \pi^\pm + n\pi^0 + \nu_\tau)$$

out of 0.5 background event.

ii) We observed four events compatible with

$$W^\pm \to \tau^\pm \nu_\tau (\tau^\pm \to \pi^\mp \pi^\pm \pi^\mp + n\pi^0 + \nu_\tau) \ .$$

This signal is compatible with background (two events).

For one-pion decay, the efficiency of UA1, as computed by Monte Carlo, has been evaluated as 0.15 (0.65 for electrons); we conclude that the ratio $W \to \tau\nu / W \to e\nu = 0.96 \pm 0.48$ is compatible with the universality of weak currents.

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Table 1

Main properties of one-prong events

		Event No.				
		1	2	3	4	5
Central detector	p_T $\Delta p/p$ (%) η ϕ (°)	4.5 2.8 −0.72 26.7	6.4 4 0.23 106	7.1 4 0.63 −62	14.9 17 0.71 10	11.1 7 0.97 66
Jet trigger	E_{had} E_{em} χ^2_R	0.1 21.3 7.1	0 14 5.4	1.8 13.4 1.4	4.6 31.5 39.4	1.5 20.7 648
Matching	$(1/p - 1/E)/\sigma$ $\Delta x/\sigma$ $\Delta\phi/\sigma$	17.5 9.4 1.9	5 4.4 1.3	5.2 8.0 0.7	2.1 1.7 0.15	4.0 1.3 0.2
Missing E_T	ΣE_T E_T^M	88.5 26.2	80.7 18.6	48.8 16.7	87.7 28.6	74.9 15.6
Second jet		No	No	No	Yes $E_T = 15.8$ $\eta = -1.36$	Yes $E_T = 13.6$ $\eta = 0.2$
Mass (ν,τ)		35.4	33.1	29.5	57.7	31.6

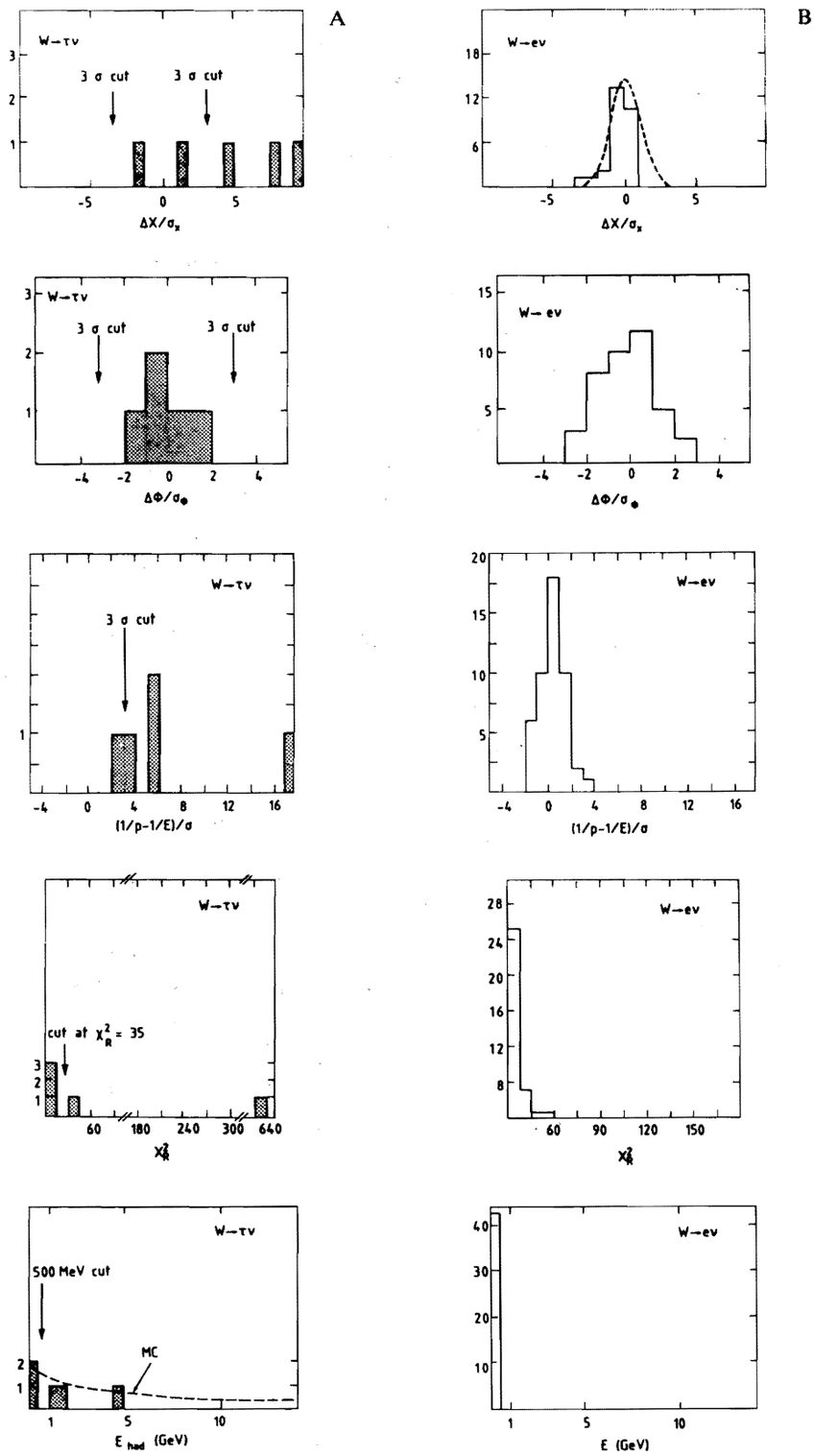

Fig. 1 Hadronic properties of the one-branch events: the hadron quality of the one-branch sample (A, shaded) is compared with the electron quality of the control sample: $W \rightarrow e\nu$ (B).

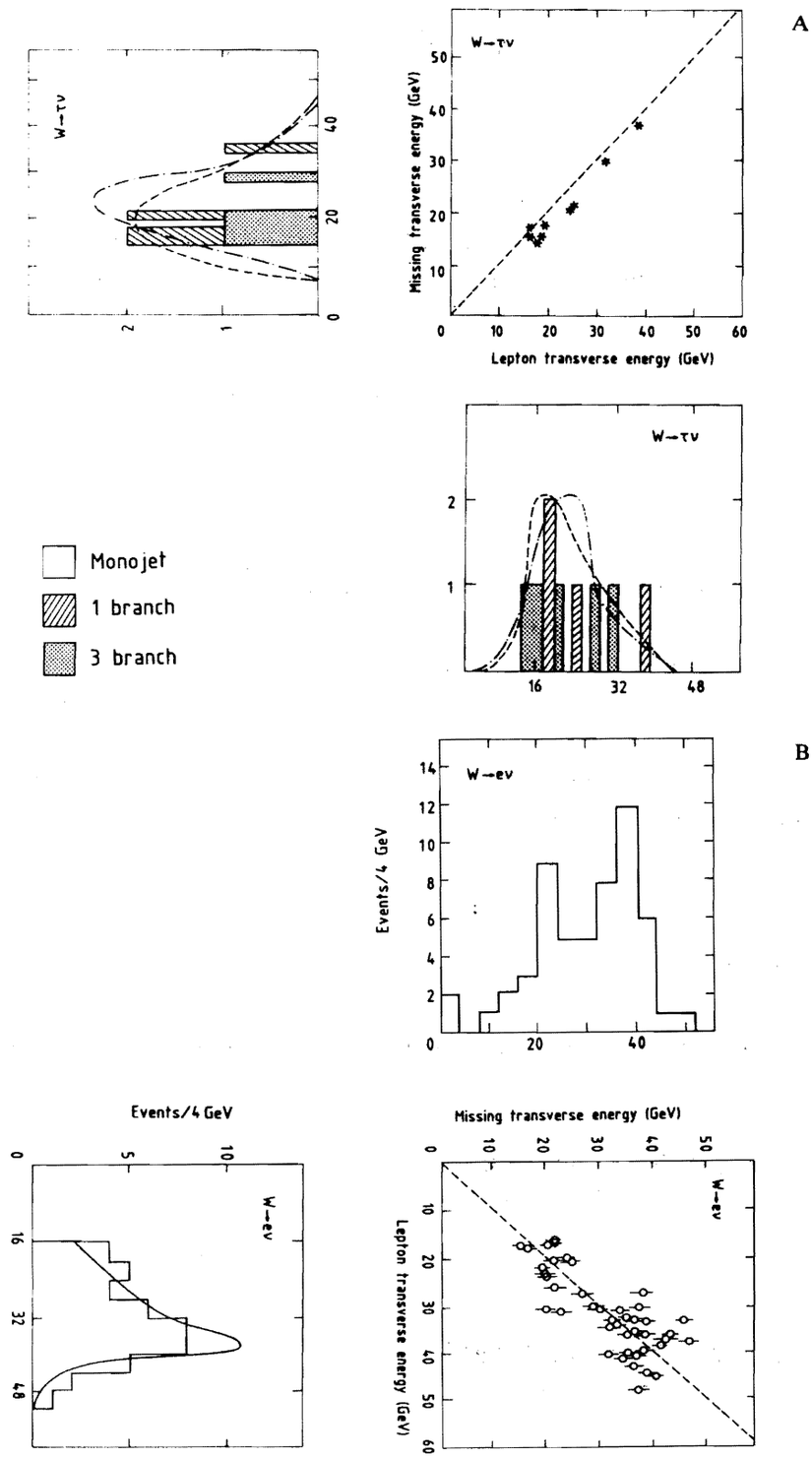

Fig. 2 Scatter plot of the total missing transverse energy versus the lepton transverse energy of the sample (A) of the one-branch and three-branch events (candidates W → $\tau\nu$), compared to the same plot for the sample W → eν (B).