SEARCH FOR MONOJET AND MULTIJET EVENTS WITH LARGE MISSING p_T IN THE UA2 EXPERIMENT*

THE UA2 COLLABORATION
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Using the full data sample ($\int \mathscr{L} dt = 310\ \text{nb}^{-1}$) collected during the 1984 $\bar{p}p$ Collider run ($\sqrt{s} = 630$ GeV), the UA2 Collaboration has carried out a search for monojets and monophotons, as well as for multijet events with large missing transverse momentum ($\not{p}_T$). No significant signal could be isolated from background for either event type. The relevance of this result with respect to SUSY models is discussed. The method has been checked by measuring the process $\bar{p}p \to W+X$, $W \to e\nu$ through a study of events with an electromagnetic cluster and large $\not{p}_T$.

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1. Introduction

In the 1983 CERN $\bar{p}p$ Collider run ($\sqrt{s} = 540$ GeV) the UA2 Collaboration has observed [1] electrons produced in association with hard jets and large missing transverse momentum. From the same running period the UA1 Collaboration has reported [2] events with large missing transverse energy accompanied by a jet (monojet) or by a photon type electromagnetic cluster (monophoton). A common feature of both event samples is the presence of a large missing transverse momentum ($\not{p}_T$). The subject of the present talk is a search for events of the UA1 type (monojets and monophotons) [2] and for multijet events with large missing p_T as suggested by recent SUSY model calculations [3–5], using the data collected with the UA2 detector during the 1984 $\bar{p}p$ Collider run ($\sqrt{s} = 630$ GeV).

Lacking the highly selective power of the requirement of an electron signature makes such a search much more vulnerable to background than was the case in Ref. [1]. In partic-

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ular the accidental coincidence of a $\bar{p}p$ collision with the interaction of a beam halo particle in the UA2 calorimeter may simulate an event of the type we are searching for. A major part of the present study is devoted to rejecting such background events.

In the UA2 detector, the lack of coverage at small angles with respect to the beam line is a trivial source of events of the type observed by the UA1 Collaboration: Two-jet events, in which one of the jets is produced at less than 20° to the beam, appear as single-jet events in the present UA2 detector, thus accompanied by a large missing transverse momentum. This limitation precludes a significant search for events having less than $\cong 30$ GeV/c missing transverse momentum. Above this value, configurations in which one of the two jets escapes the UA2 acceptance become unlikely. We shall therefore restrict the present search to missing transverse momenta exceeding 30 GeV/c.

In this talk we discard searches for events of the type ($\bar{p}p \to W^+X$, $W \to t\bar{b}$, $t \to e\nu b$), or ($\bar{p}p \to \ldots \to e^+$ jet (s) + large $\not{p}_T$), which have been reported on in the talks by B. Mansoulié [6] and H. Plothow-Besch [7], respectively, at another conference.

2. *Apparatus and triggers*

The UA2 detector has been described in detail elsewhere [8]. We briefly recall its main features.

Apart from two narrow cones along the beams, the detector provides full azimuthal coverage in three distinct regions of polar angles: $40° < \theta < 140°$, the central region, and $20° < \theta < 40°$, $140° < \theta < 160°$, the forward regions.

In the centre of the detector a set of coaxial cylindrical drift and proportional chambers detect the charged particle tracks produced in the collision and measure the position of the event vertex.

An array of 480 calorimeter cells, each cell covering a similar domain of longitudinal phase space (15° of azimuth and $\cong 0.2$ units of rapidity), measures the energy density in the final state. Each cell is segmented longitudinally, the inner compartment containing electromagnetic showers. While hadron showers are usually contained in the 4.5 absorption lengths of the central calorimeter (CC) [9], providing a measurement of jet energies, they only deposit a fraction of their energy in the forward calorimeters (FC) which are $\cong 1.0$ absorption length thick. These forward regions are equipped with magnetic spectrometers which measure the momenta of charged jet fragments, the energy of the π^0's being measured in the calorimeter cells.

Two scintillator arrays (referred to as veto counters in the following)[1] located at a distance of 8.5 m from the center of UA2 on both sides of the detector and covering a polar angular region of $2.4° < \theta < 7.0°$, are used to reject background events due to beam halo as described in the next Section.

The data presented in this talk were recorded during the 1984 running period of the CERN $\bar{p}p$ Collider with two newly installed triggers, the $\not{p}_T$-trigger and the single jet trigger. The $\not{p}_T$-trigger required that the modulus of the missing transverse momentum

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[1] Borrowed from the UA5 experiment [10].

vector (constructed by hardware from the transverse energies[2] measured in the calorimeter cells) exceeded 30 GeV. The single jet trigger required that the scalar sum $\sum E_T$ of all the transverse energies measured in the cells of any azimuthal wedge with $\Delta\phi = 120°$ of the central calorimeter exceeded the same threshold of 30 GeV.

Two small angle scintillator arrays (covering an angular range $0.44° < \theta < 2.84°$) on both sides of the collision region are used in coincidence with both triggers to provide a "minimum bias" signal [11]. A sample of "minimum bias" events was recorded simultaneously with the data presented here to provide a measurement of the integrated luminosity $\int \mathcal{L} dt$ which amounts to 310 nb^{-1}.

3. *Data reduction*

In UA2 there exist two major background sources for the type of events looked for in the present analysis:

a) Two- or multi-jet events from genuine $\bar{p}p$ interactions, where ≥ 1 jet is at least partially lost in an insensitive region of the detector (see Sect. 2). This background is referred to as "QCD background" in the following.

b) Background from beam halo particles, which either satisfy the triggering condition directly or appear as an accidental overlap with a "minimum bias" $\bar{p}p$ interaction. This background is referred to as "beam halo background" in the following.

QCD background events can be recognised if they leave at least some trace of energy in the forward calorimeters opposite in azimuth to the jet (system) seen in CC. Thus the forward regions in spite of their lacking hadronic calorimetry can be used as a veto region against the QCD background.

Most of the beam halo background events are easily identified when they satisfy one of the following conditions:

(*i*) if they are associated with an early signal in the small angle scintillator arrays (minimum bias counters),

(*ii*) if the event has an abnormally large total transverse energy fraction in the hadronic compartments,

(*iii*) if the event contains only one central calorimeter cluster with more than 90% of its energy in the hadronic compartments.

Events satisfying any one of the above conditions are rejected. The loss of good events introduced by these cuts has been shown to be negligible [12]. However, while these background rejection criteria are well suited to the study of two-jet events, they become insufficient when the data of interest are required to have a large missing transverse momentum.

To further reduce the remaining beam halo background we take advantage of the fact that a large fraction of these events is characterised by an early timing in either the left or the right hand side veto counter array, depending on the direction of flight of the halo particles (Fig. 1).

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[2] The gains of the photomultipliers were adjusted such that their response is proportional to the transverse energy $E_T = E \cdot \sin\theta$.

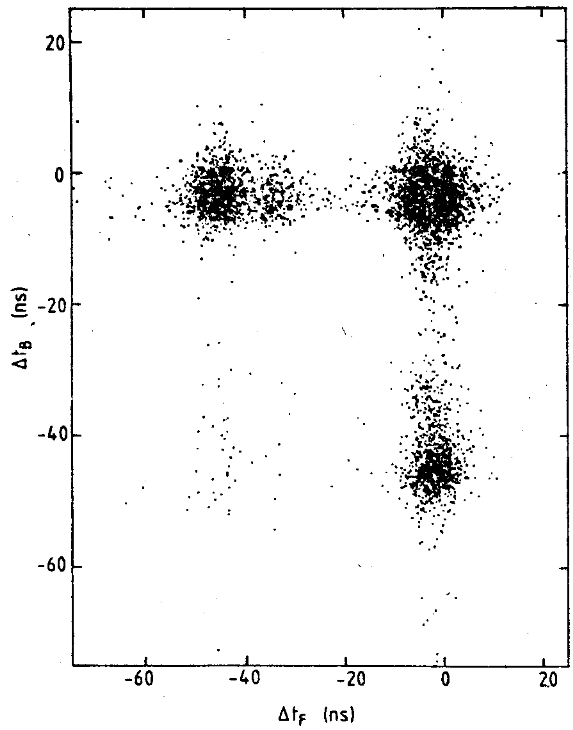

Fig. 1. Scatter plot of event timing measured with the two veto counter arrays on both sides of UA2. Abscissa: Timing of veto counter on incident proton side; ordinate: timing of veto counter on incident anti-proton side. Only the events in the upper right hand side corner are genuine $\bar{p}p$ collisions

According to that the sample of early timing events was used

1. to study the energy deposition pattern of the beam halo background in order to establish suitable cuts other than the timing cut itself (to reduce residual beam halo background due to the inefficiency of the veto counters),
2. to measure the efficiency of these cuts of rejecting beam halo background.

The inefficiency on good events of these cuts was measured using balanced two-jet events as well as minimum bias events.

4. *Search for monojets*

The search for monojets with the UA2 detector was motivated by the UA1 monojet and monophoton events reported in 1983 [2].

4.1. Monojet event selection

The data sample used for the monojet search was the one recorded by the $\not{p}_T$ trigger. For all these events the value of the $\not{p}_T$ was re-determined by software (using the single cell energies), and a $\not{p}_T$ cut was applied at 30 GeV/c, where the hardware $\not{p}_T$ trigger had been fully efficient. The remaining data sample was subject to the standard UA2 initial selection criteria described in Sect. 3 to reject background from non $\bar{p}p$ collisions.

The remaining data sample of 10249 events contains mainly events from the two background sources described in Sect. 3, namely QCD events with at least one jet in an insensitive region of the detector, and beam halo background (estimated to account for $\approx 40\%$ of the present events with $\not{p}_T > 30$ GeV/c).

At this stage all events are fully reconstructed, and the forward jet energies are recalculated using also the momentum information of the charged tracks.

In the following we describe the specific cuts applied to further reduce the QCD and beam halo background:

a) Keep only events with a sufficiently centered vertex: $|z_{\text{vertex}}| < 300$ mm. (The probability to loose jets is higher for largely displaced vertices.)

b) At large distances from the beam the halo induces showers in the outer calorimeter compartments, resulting in leading clusters having a large fraction f_H of their energy in the hadronic compartments. Therefore we require the leading jet (jet 1) to have $f_H < 90\%$.

c) In addition we require the leading jet to be well contained in CC by selecting only events where less than half of the energy of jet 1 is found in edge cells: $E_{\text{edge cells}}/E_{\text{tot}} < 50\%$.

d) At medium distances the beam halo induces long showers developing in the central calorimeter parallel to the beam line, resulting in characteristic energy patterns. The calorimeter cell array consists of 240 cells arranged in 10 "rings" of cells having a same θ or 24 "slices" of cells having a same ϕ. The largest number N_R of "rings" hit within a wedge of two adjacent "slices" ($N_R \leq 10$) has large values for this configuration. We require $N_R < 7$.

These cuts leave a sample of 3128 events. About 5% of them are due to beam halo background, which can be further reduced by requiring good timing:

e) We reject events with an early timing in the veto counters by requiring $t_{\text{event}} > -23$ ns.

At this stage the beam halo background accounts for only about 1–2%, and the bulk of the events are of the QCD type: 1 jet in CC, ≥ 1 jet in an insensitive region of UA2. As mentioned in Sect. 3 the lost jets usually leave some traces of energy in FC. We therefore impose a cut on the scalar sum of the energies ($\sum E_T^{\text{opp}}$) measured in an azimuthal wedge with half opening angle $\Delta\phi = 60°$ opposite to the (transverse) direction of the leading jet (QCD events contain mainly 2 jets [12] back-to-back in the transverse plane):

f) $\sum E_T^{\text{opp}}$ (in FC alone) < 3 GeV

$\sum E_T^{\text{opp}}$ (in FC+CC) < 10 GeV.

The $\not{p}_T$ spectrum of the remaining events is shown in Fig. 2 together with a Monte Carlo prediction for QCD two-jet background (smooth line) obtained with the ISAJET [13] programme. There is good agreement between our data and the QCD expectation, but a small non QCD type signal can of course not been ruled out. Above $\not{p}_T = 65$ GeV/c only one event is present: It has a $\not{p}_T$ of 100.2 GeV/c, and no track pointing to the energy cluster. Since it has energy in the two inner (i.e. in the electromagnetic and first hadronic)

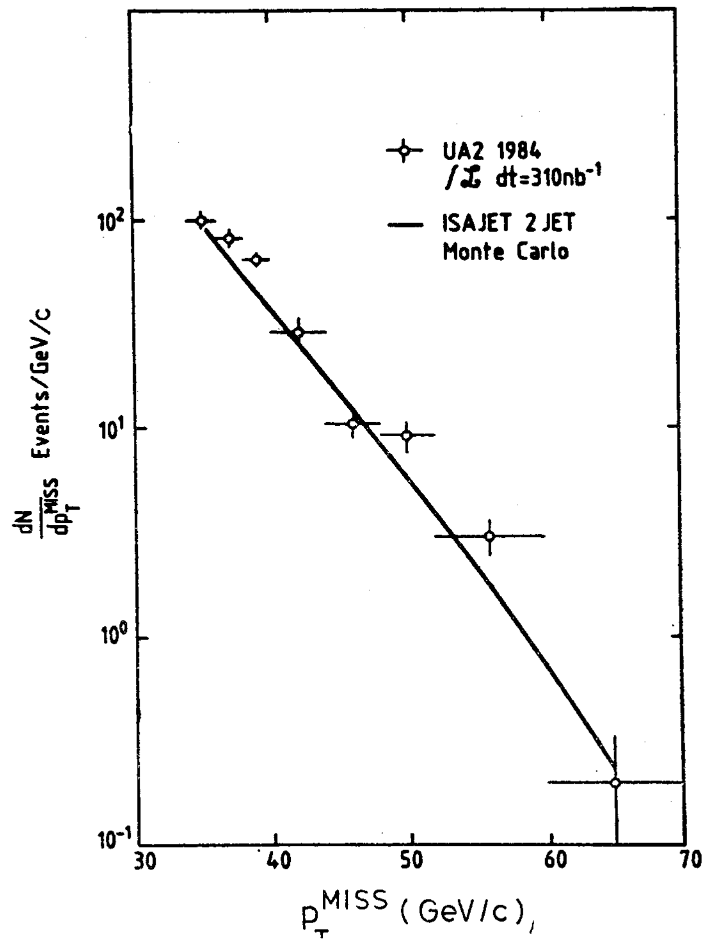

Fig. 2. $\not p_T$-spectrum of final monojet sample (known W → eν events excluded). The smooth line is a Monte Carlo prediction by the ISAJET [13] programme for QCD two-jet background

compartments of CC, but none in the outermost (second hadronic), it can neither be interpreted in terms of isolated photons/π^0's nor of ordinary jets. We assume that the event is a beam halo background surviving our cuts. Keeping it, however, in our sample we quote an upper limit on the cross section

$$\sigma = n/\varepsilon \int \mathscr{L}\, dt \qquad (1)$$

for monojet production in the region $\not p_T > 65$ GeV/c:

$$n(\not p_T > 65 \text{ GeV}/c) < 3.9 \quad (90\% \text{ c.l.}). \qquad (2)$$

The total cut efficiency ε of the monojet selection has been estimated using minimum bias and balanced two-jet events:

$$\varepsilon\,(\text{monojet cuts}) = 0.54. \qquad (3)$$

This gives for the integrated luminosity of 310 nb^{-1} of the 1984 run:

$$\sigma^{\text{monojet}}(\not{p}_T > 65 \text{ GeV}/c) < 23 \text{ pb} \quad (90\% \text{ c.l.}). \tag{4}$$

We can evaluate this upper limit in a somewhat lower $\not{p}_T$-region: There are 40 (218) events with $\not{p}_T$ in excess of 50 (40) GeV/c. Using the region $40 < \not{p}_T < 50$ GeV/c to normalise the Monte-Carlo calculation, the estimated background from two-jet events in which one of the jets escapes the UA2 acceptance is 46 events for $\not{p}_T > 50$ GeV/c. From this result the 90% c.l. upper limit for the production of events with a jet plus $\not{p}_T > 50$ GeV/c is

$$\sigma^{\text{monojet}}(\not{p}_T > 50 \text{ GeV}/c) < 73 \text{ pb} \quad (90\% \text{ c.l.}). \tag{4'}$$

4.2. Search for monophotons

As a simple extension of the monojet analysis, a search for monophotons has been carried out using the final monojet sample of Sect. 4.1 and looking for events with isolated electromagnetic clusters. Removing first all known $W \to e\nu$ events the following photon selection cuts were applied (for definitions see Ref. [14]):

g) Require the energy cluster to show small lateral extension: cluster radius <0.5 cells, and to have small leakage into the hadronic compartments;

h) ask for no charged particle track coming from the vertex within a 20° cone around the line connecting the vertex with the CC energy cluster center. Accept only events with at most one preshower cluster with charge >3 mip (minimum ionising particle equivalent) in the same 20° cone.

The sample of events with no preshower cluster present is called the "unconverted sample", events with one preshower cluster belong to the "converted" sample. Fig. 3 shows the p_T-spectrum of the remaining converted and unconverted monophoton candidates. A scanning by physicists on a computerized graphics display (MEGATEK) has shown that out of the five converted events four are probably $W \to e\nu$ events, where the electron track has not been reconstructed due to tracking inefficiency. The conversion probability in

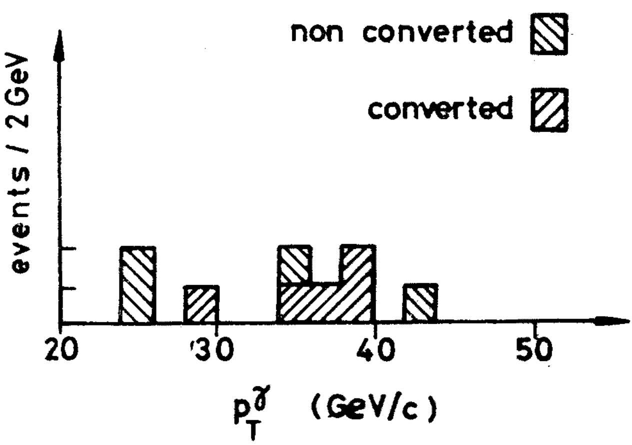

Fig. 3. $\not{p}_T$-spectrum of the monophoton candidates. For interpretation see text

the preshower detector is about 70%. It seems therefore very unlikely, that the unconverted events are due to isolated photons/π^0's. Their much more probable interpretation is in terms of beam halo background. Estimating the overall efficiency ε of the monophoton search to be

$$\varepsilon\,(\text{monophoton cuts}) = 0.52 \tag{5}$$

and restricting ourselves to the region $p_T^\gamma > 45$ GeV/c, where we observe no event,

$$n(p_T^\gamma > 45\ \text{GeV}/c,\ \not{p}_T > 30\ \text{GeV}/c) < 2.3 \quad (90\%\ \text{c.l.}), \tag{6}$$

we quote the following upper limit for the monophoton cross section:

$$\sigma^{\text{monophoton}}(p_T^\gamma > 45\ \text{GeV}/c,\ \not{p}_T > 30\ \text{GeV}/c) < 14\ \text{pb}\ (90\%\ \text{c.l.}). \tag{7}$$

4.3. Search for the process $W \to e\nu$ through the $\not{p}_T$ analysis

Using the process $\bar{p}p \to W^+X$, $W \to e\nu$, a cross check can be established between the electron and the $\not{p}_T$ analysis of UA2. To this end events containing electromagnetic clusters and large $\not{p}_T$ have been selected by extending the present monojet analysis: Again, the final monojet candidate sample of Sect. 4.1 has been taken and further cuts have been imposed to select electromagnetic clusters:

i) cluster radius < 0.5 cells (as in monophoton search);

j) hadronic leakage < 12% (efficiency for 40 GeV electrons: 92%).

Fig. 4 shows the $\not{p}_T$ spectrum of the remaining events: There is a distinct Jacobian peak at around 40 GeV, indicating as event source the $W \to e\nu$ decay.

This event sample can be compared to that one found through the electron search: From the 66 events with $\not{p}_T > 30$ GeV/c and $\not{p}_T^{\text{em}} > 30$ GeV/c, 48 events have been also found in the electron search, the number of non overlapping events thus being 18. The

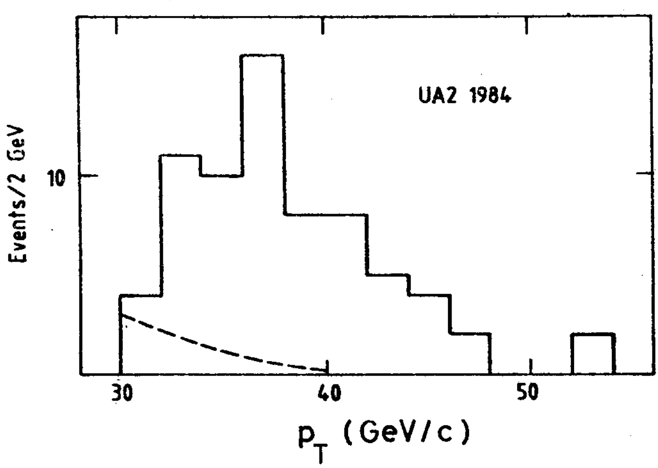

Fig. 4. $\not{p}_T$ spectrum of electromagnetic mono-clusters found through the $\not{p}_T$ analysis. The smooth curve represents the estimate for background from two-jets

background estimate for the $W \to e\nu$ search through the $\not{p}_T$ analysis gives an expectation of 7.7 ± 1.0 events from QCD (two-jet) background and 1.1 ± 0.6 events from beam halo background. In comparison a scan of the non-overlapping events on the MEGATEK graphics display shows that about 9 events can be ascribed to the QCD (two-jet) and about 4 events to the beam halo background. This is roughly compatible with the above estimates. Two events are probably $W \to e\nu$ candidates.

Taking on the other hand the event sample found in the electron search and applying to it the same "filter" cuts as in the monojet analysis,

$$E_{\text{edge}} < 50\%; \quad E_{\text{had}}/E_{\text{tot}} < 10\%; \quad p_T^e > 30\ \text{GeV}/c; \quad \not{p}_T > 30\ \text{GeV}/c,$$

leaves 50 $W \to e\nu$ events in CC, which are reduced to 42 by applying the specific monojet cuts of Sect. 4.1 and 4.3. This is in agreement with the efficiency of these cuts as estimated from minimum bias and balanced two-jet events. A comparison of the two values for the cross section for the process ($\bar{p}p \to W^{+}X$, $W \to e\nu$) shows agreement within errors:

$$\sigma(\bar{p}p \to W^{+}X,\ W \to e\nu) = 520 \pm 90\ \text{pb from } \not{p}_T \text{ analysis,} \tag{8a}$$

$$\sigma(\bar{p}p \to W^{+}X,\ W \to e\nu) = 530 \pm 70\ \text{pb from electron analysis.} \tag{8b}$$

5. *Search for multijet events with $\not{p}_T$*

Multijet events with $\not{p}_T$ are expected to provide a signature for SUSY particle production at the $\bar{p}p$ Collider. Recent calculations [3–5] indicate that with the present integrated luminosity it is already possible to observe the production of gluinos ($\tilde{g}$) or squarks ($\tilde{q}$) with masses around 50 GeV if they would exist. The dominant sources of $\tilde{g}$ or $\tilde{q}$ production in these models are $\bar{p}p \to \tilde{g}\tilde{g}+X$, $\tilde{g}\tilde{q}+X$ or $\tilde{q}\bar{\tilde{q}}+X$ depending on the masses. Each of the $\tilde{g}$ or $\tilde{q}$ decays into ordinary quarks (or gluons) plus a photino ($\tilde{\gamma}$) [4]. The final state event topology consists therefore in general of two (or more) unbalanced hadronic jets and $\not{p}_T$ due to the undetected $\tilde{\gamma}$'s.

The main physics background is expected to come from standard QCD production of $\geqslant$3-jet events. They can fake such event configurations if one of the jets is badly measured or escapes detection.

5.1. Event selection

The initial data sample for this analysis (72454 events) consists of events which have 2 or 3 jets with $E_T > 15$ GeV inside the fiducial region of the central calorimeter ($|\eta| < 0.85$). The jets are ordered according to decreasing E_T ($E_T^1 > E_T^2 > E_T^3$), and the leading jet is fulfilling the single jet trigger threshold: $E_T^1 > 30$ GeV.

Multijet events with large $\not{p}_T$ have been selected by the criteria $\not{p}_T > 35$ GeV/c and $15° < \phi_{12} < 120°$ where ϕ_{12} is the azimuthal separation between the two largest jets. Ordinary QCD two-jet events have ϕ_{12} strongly peaked towards 180° [12], whereas events with $\phi_{12} < 15°$ are contaminated by background from beam halo particles. A total of 174 events satisfy this selection. They are submitted to the following cuts which aim at rejecting event configurations where the large $\not{p}_T$ is due to the QCD background from multijet events with badly measured jets:

(*i*) $\sum \tilde{E}_T(CC) < 20$ GeV, where $\sum \tilde{E}_T$ is the transverse energy summed over all cells of the CC not belonging to the jets;

(*ii*) $\sum E_{em}(FC) < 12$ GeV, where $\sum E_{em}$ is the energy summed over all electromagnetic cells of the FC;

(*iii*) $\phi(\vec{p}_{TJ}, \vec{\not{p}}_{TFC}) > 30°$, where $\vec{p}_{TJ}$ is the p_T-vector of the jet system and $\vec{\not{p}}_{TFC}$ is the $\not{p}_T$-vector of all cells in the FC.

The last two cuts are illustrated in Figs. 5 and 6. The distributions of the present event sample are compared with the ones from well-balanced two-jet events (defined by

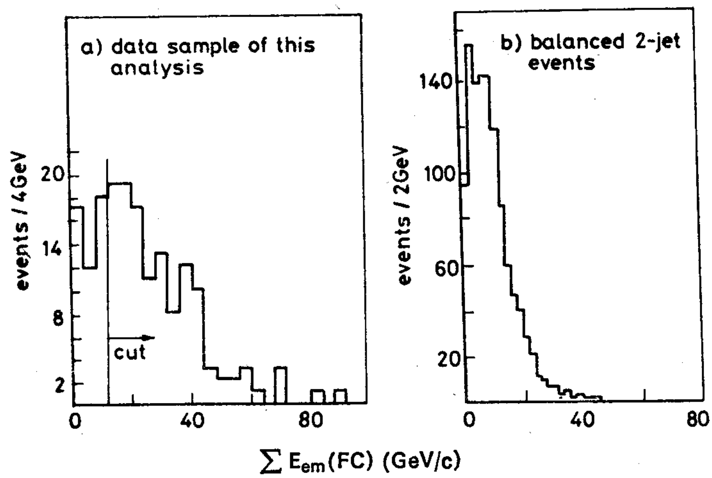

Fig. 5. Energy deposition in FC of the events of this analysis (a) compared to that of well-balanced QCD two-jet events (b)

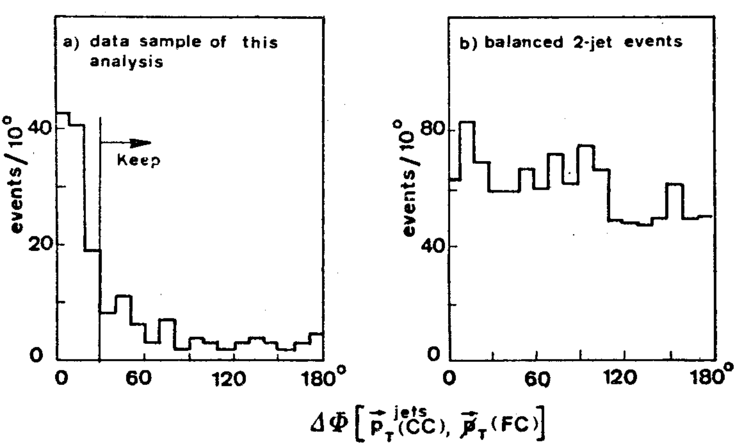

Fig. 6. Angular distribution in the transverse plane of the $\not{p}_T$ in FC with respect to the direction of the leading jet system in CC for a) the events of this analysis, b) well-balanced QCD two-jet events

$p_{TJ} < 5$ GeV, $\phi_{12} > 170°$ and $\not{p}_T < 10$ GeV/c). In general a significant amount of energy is found in the FC opposite to $\vec{p}_{TJ}$ in spite of the large overall $\not{p}_T$. This is a clear indication for QCD multijet background as mentioned already in Sect. 3. The additional FC energy in SUSY events with genuine $\not{p}_T$ is expected to be small and not correlated to $\vec{p}_{TJ}$ (as for the well-balanced two-jet sample).

Residual beam halo background is rejected by requiring that no veto counter signal be present outside the correct beam-beam interaction window.

5.2. Results

Two events survive the selection criteria. One contains an identified electron, appearing here as the leading jet (E_T^1). The event is of the topology $\bar{p}p \to W^+ jet^+ X$, $W \to e\nu$ and is included in the data sample discussed in [7]. There remains only one multijet event with $\not{p}_T$. It can most naturally be interpreted in terms of a QCD multijet background event because it has $\phi(\vec{p}_{TJ}, \vec{\not{p}}_{TFC}) = 42°$ (which is near the cut) and it has also a central calorimeter cluster of $E_T = 7$ GeV opposite to $\vec{p}_{TJ}$.

Nevertheless this event is retained in the evaluation of the upper limit on the cross section for 2- or 3-jet events with $\not{p}_T > 35$ GeV/c and $15° < \phi_{12} < 120°$. The efficiency of the cuts (*i*) to (*iii*) and of the veto counter requirement has been determined experimentally using the sample of well-balanced two-jet events mentioned above. The resulting limit is

$$\sigma^{\text{multijets}+\not{p}_T}(\not{p}_T > 35\ \text{GeV}/c) > 27\ \text{pb}\ (90\%\ \text{c.l.}). \quad (9)$$

This cross section limit can be compared with predictions from SUSY calculations. The event generator of [5] has been used to simulate $\tilde{q}\tilde{q}$ and $\tilde{g}\tilde{g}$ production at the $\bar{p}p$ Collider. The final state jets have been submitted to the same very restrictive topological cuts as the data. Cross sections of about 10 pb are predicted for $\tilde{q}$ or $\tilde{g}$ masses in the range 40 to 60 GeV/c^2, whereas lower observable cross sections are expected for smaller or larger masses. The sensitivity to lower masses is suppressed due to the experimental selection criteria. The present analysis does not exclude events with such low cross sections and is therefore not in contradiction to the prediction of this specific model.

6. *Summary and conclusions*

Using the full data sample ($\int \mathscr{L} dt = 310\ \text{nb}^{-1}$) collected during the 1984 $\bar{p}p$ Collider run ($\sqrt{s} = 630$ GeV), the UA2 Collaboration has searched for monojet and monophoton type events as suggested by the 1983 data of the UA1 Collaboration [2], and for multijet events with large missing transverse momentum ($\not{p}_T$) as predicted by SUSY models [3–5]. No significant signal could be isolated from background for either event type. Nevertheless we can quote the following upper limits for the production of such events in $\bar{p}p$ collisions at $\sqrt{s} = 630$ GeV:

a) monojets:

$$\sigma(\not{p}_T > 65\ \text{GeV}/c) < 23\ \text{pb}\ (90\%\ \text{c.l.})\ \text{or:}$$

$$\sigma(\not{p}_T > 50\ \text{GeV}/c) < 73\ \text{pb}\ (90\%\ \text{c.l.}),$$

b) monophotons:

$$\sigma(p_T^\gamma > 45\ \mathrm{GeV}/c,\ \not{p}_T > 30\ \mathrm{GeV}/c) < 14\ \mathrm{pb}\ (90\%\ \mathrm{c.l.}),$$

c) multijets + large $\not{p}_T$:

$$\sigma(\not{p}_T > 35\ \mathrm{GeV}/c) < 27\ \mathrm{pb}\ (90\%\ \mathrm{c.l.}).$$

These results are not in contradiction with the SUSY models of Refs [3–5].

The experimental method has been checked by measuring the process $\bar{p}p \to W^+X$, $W \to e\nu$ through a study of events with an electromagnetic cluster and large $\not{p}_T$, and comparing them to the ones found in the electron analysis [14]. Agreement within errors has been found for the two event samples as well as for the two measurements of the cross section:

$$\sigma(\bar{p}p \to W^+X,\ W \to e\nu) = 520 \pm 90\ \mathrm{pb}\ \text{from}\ \not{p}_T\ \text{analysis},$$

$$\sigma(\bar{p}p \to W^+X,\ W \to e\nu) = 530 \pm 70\ \mathrm{pb}\ \text{from electron analysis}.$$

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