SEARCHES FOR NEW PARTICLES IN UA2

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Abstract

During the 1988-1989 runs at the CERN $\bar{p}p$ Collider ($\sqrt{s}$ = 630 GeV) the UA2 experiment has collected a data sample corresponding to an integrated luminosity of 7.8 pb^{-1}. A search for supersymmetric particles performed on this sample provided lower limits for squark and gluino masses. Likewise no evidence has been found for the production and decay of the top quark or of the member of a hypotetical fourth family (b'), implying that the top quark mass is greater than 69 GeV (95 % C.L.), and the b' mass greater than 54 GeV (95% C.L.)

1 INTRODUCTION

Data have been collected by the upgraded UA2 detector during the 1988 and 1989 runs of the CERN $\bar{p}p$ Collider at peak luminosities of up to 3×10^{30} cm^{-2}s^{-1}. Thanks to this good performance of the accelerator it was possible to collect a data sample about ten times as large as the one collected during the previous Collider runs. The new sample, together with the enhanced capabilities of the UA2 detector, have been used to search for new particles, either predicted by the Standard Model (SM), or by more speculative theories, like Supersymmetry (SUSY).

In the following, after a very short reminder of the characteristics of the upgraded UA2 detector, an analysis performed on multijet events with large transverse momentum imbalance (P_T^{miss}) aimed at the search of SUSY particles will be described. The search for the production of the top quark in events containing an isolated electron accompanied by one or more jets and missing transverse momentum will be the subject of the second part of this report.

2 THE DETECTOR

The upgraded UA2 detector (Fig. 1) is described in detail elsewhere [1]. The upgrade project had two main aims: to improve the hermeticity of the calorimetric coverage and to obtain a very high rejection against hadrons faking the electron signature.

The first aim was pursued by adding to the central calorimeter [2] two endcap calorimeters with both hadronic and electromagnetic compartments, covering the full azimuthal angle down to ± 3 units in pseudorapidity η [3].

Improved electron identification was achieved by surrounding the beam pipe with concentrical layers of specialized detectors, namely a cylindrical drift chamber of the jet type sandwiched between two silicon hodoscopes, a transition radiation detector, and a scintillating fiber tracking detector which contained 1.5 radiation lengths of Pb radiator, and acted also as a preshower detector. In the forward regions proportional tubes are used for both tracking and preshower detection.

3 THE SEARCH FOR SUPERSYMMETRY

3.1 Motivations

Supersymmetry is an extension of the Standard Model which allows one to solve some theoretical problems inherent to the model. This theory, associating to each particle in the SM a so called 'superpartner' (sparticle), predicts a rich spectrum of new particles. The production of the quark and gluon superpartners, the squarks ($\tilde{q}$) and the gluinos ($\tilde{g}$) is expected to take place through standard QCD processes, resulting in abundant $\tilde{q}$ and $\tilde{g}$ production if the $\tilde{q}$ and $\tilde{g}$ masses are sufficiently small. Furthermore, the theory associates to each superpartner a multiplicative quantum number (R-parity), which is absolutely conserved. This implies that sparticles should all decay to the lightest supersymmetric particle (LSP), assumed to be electrically neutral, which would in turn escape detection.

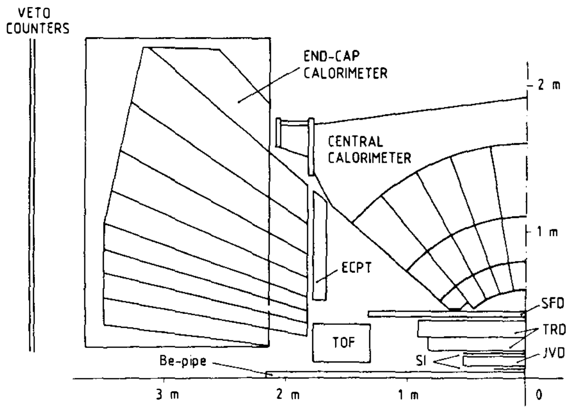

Figure 1: Longitudinal view of one quadrant of the UA2 detector

For events where squarks and gluinos are produced, this gives the signature of a high P_T^{miss} accompanied by two or more hadronic jets. The search of an excess of events of this kind above the expectations from conventional processes is the subject of the analysis described below.

3.2 Data reduction

The data used for this analysis were collected using a calorimeter trigger specifically aimed at selecting events with a high P_T^{miss}, which is experimentally approximated in UA2 as :

$$\vec{P}_T^{miss} = -(\sum E_{\text{cell}}\vec{v}_{\text{cell}})_T$$

where $\vec{v}_{\text{cell}}$ is a unit vector pointing from the event vertex to the centre of cell with energy E_{cell}, and the subscript T refers to the plane transverse to the beam. This trigger was fully efficient for a P_T^{miss} greater than 20 GeV. A first stage of selection applied very strict timing cuts and rejected events associated with early hits in two arrays of scintillators behind the End Caps, or which presented an abnormal pattern of energy deposition in the calorimeter, in order to reject triggers generated by beam background.

Furthermore, the events were required to contain at least two hadronic jets ($E_T^1 >$ 25 GeV, $E_T^2 >$ 15 GeV) localized in the pseudorapidity region $|\eta| < 0.85$; if no third jet with $E_T >$ 10 GeV was observed in the event, the two jets were required not to be back-to-back in the azimuthal plane to within 20° , in order to reject standard 2-jet events for which P_T^{miss} is generated by a bad measurement of the transverse energy of one jet. The selected sample contains about 2100 events with $P_T^{miss}>$ 20 GeV. It consists mainly of events where P_T^{miss} is generated by the neutrino from W decays, or multijet events where one of the jets is badly measured. In order to reject the multijet background, P_T^{miss} is required not to be back-to-back with respect to the leading jet, ($\Delta\phi(jet_1, P_T^{miss}) < 140°$), and to satisfy the additional requirement $\Delta\phi(jet_i, P_T^{miss}) >$

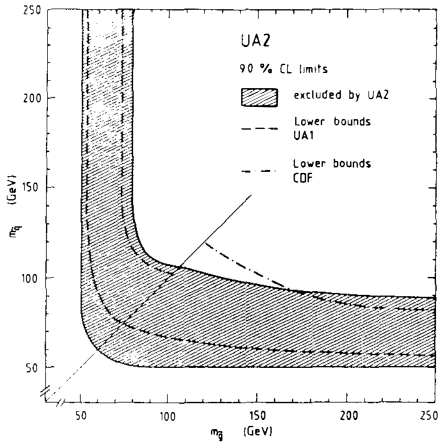

Figure 2: Mass region ($m_{\tilde{q}}$,$m_{\tilde{g}}$) excluded by the present experiment (shaded area). The dashed curve indicates the previous mass limits from UA1 and the dash-dotted curve the ones from CDF. All limits are 90% CL

20° for any jet with transverse energy $E_T^i > 10$ GeV, (i=3,4..). The bulk of the events coming from IVB decays is rejected by requiring the events to contain no electron, where an electron is defined using simple calorimetric criteria.

The remaining sample contains no event with a $P_T^{miss} > 40$ GeV. Taking into account the efficiencies of the cuts used to reject beam background and electrons, an upper limit of 0.35 pb (90 % CL) on the obseved cross-section for the kinematical and topological selection applied can be derived.

3.3 Comparison with Supersymmetry

The data have been compared to a supersymmetric model which is implemented in the form of a Monte Carlo generator based on the cross-sections of ref. [4], and using the structure functions parametrization EHLQ I [5]. Five squark flavours degenerate in mass are assumed, and each squark decays with 100 % branching ratio (BR) into q$\tilde{\gamma}$,if $m_{\tilde{q}}<m_{\tilde{g}}$, where $\tilde{\gamma}$ is the superpartner of the photon, assumed to be the LSP, or into $\tilde{g}$q if $m_{\tilde{q}}>m_{\tilde{g}}$. The gluinos are fragmented according to the prescription [6] , and are assumed to decay with 100% BR into q$\bar{q}\tilde{\gamma}$. The outgoing quarks are fragmented according to an independent fragmentation scheme, with parameters tuned to reproduce the characteristics of 2-jet events. The generated events are then fed into a full simulation of the UA2 calorimeter, and passed through the same analysis chain as the real data. Through this procedure it was possible to estimate the acceptance of the topological and kinematical cuts applied to the data for many different points in the $m_{\tilde{q}}$–$m_{\tilde{g}}$ plane. The acceptance for the highest masses considered in this analysis was of the order of 5%, and dropped below 0.1 % for masses under 50 GeV. The dependence of the acceptance calculation on the QCD parameters used in the simulation, in particular the choice of structure function and of the Q^2 scale, was the subject of a detailed study. Further studies included variations on the parameters of the fragmentation and the different ingredients entering the detector simulation model.

The comparison of the measured cross-section limit of 0.35 pb with the expected cross-sections as a function of $m_{\tilde{q}}$ and $m_{\tilde{g}}$ excludes a region in the $m_{\tilde{q}}$-$m_{\tilde{g}}$ plane as shown in Fig. 2. To take into account the systematic uncertainties in the calculation of the expected cross-sections, we reduce their values by the systematic error. Also shown in this figure are previous results from UA1 and CDF. The mass limits thus obtained are independent of the LSP mass up to 20 GeV, whereas they strongly depend on the assumption of squarks and gluino decaying directly to the LSP with 100% branching ratio. More complex decay scenarios as the ones envisaged in ref.[7] would give a softer P_T^{miss}, resulting in lower mass limits. In conclusion, under the assumptions stated above, the following 90 % CL lower mass limits are obtained in the framework of the minimal SUSY model: $m_{\tilde{q}}>$ 74 GeV independent of $m_{\tilde{g}}$; $m_{\tilde{g}}>$ 79 GeV independent of $m_{\tilde{q}}$; and m> 106 GeV for $m_{\tilde{q}}=m_{\tilde{g}}$=m. Masses below about 50 GeV are not excluded by this analysis.

4 TOP QUARK SEARCH

4.1 Data analysis

The standard model predicts the existence of a sixth quark flavour with charge +2/3, which should form an SU(2) doublet with the b quark. The top quark could be produced at the $\bar{p}p$ Collider from two dominant processes, either mediated by the weak interaction:

$$\bar{p}p \rightarrow W + X, \qquad W \rightarrow t\bar{b} \;\; or \;\; \bar{t}b$$

or by the strong interaction:

$$\bar{p}p \rightarrow t\bar{t} + X$$

At a centre of mass energy of 630 GeV, for a top quark mass smaller than the W mass, the weak process is dominant.

Top quark decays into hadronic final states very difficult to observe because of the overwhelming QCD multijet background. For this reason, the decay into a b quark, an electron and a neutrino, which has a branching ratio of 1/9, is preferred. Such a decay is expected to result into final states characterised by 2 or more hadronic jets from the hadronization of the two b quarks, an electron, and some P_T^{miss} from the undetected neutrino. The data sample was obtained from an inclusive electron trigger which retained all events containing an electromagnetic cluster with transverse momentum in excess of 12 GeV. For the 1989 run the top trigger contained the additional request of a hadronic cluster ($E_t > 6\ GeV$) and $P_T^{miss} > 9.5$ GeV. The P_T^{miss} spectrum for events containing an electron candidate in the central calorimeter (1988 only), where an electron is defined using the standard electron identification criteria (see e.g. [8]), is shown in Fig. 3. A clear enhancement in the region where neutrinos from IVB decays are expected can be seen, superimposed on a steeply falling background resulting

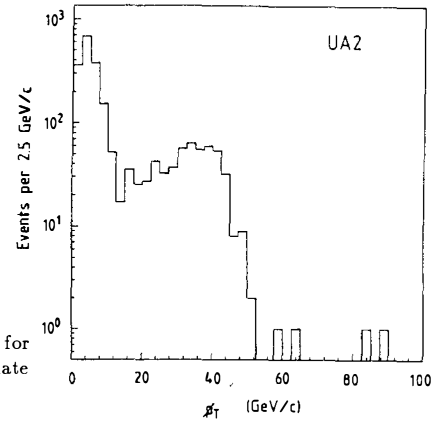

Figure 3: Distribution of P_T^{miss} for events with an electron candidate (1988 data only)

from standard hadronic events where a jet fakes the electron signature and P_T^{miss} is generated by detector effects. In order to reject most of this background a cut of 15 GeV on P_T^{miss} was imposed. A further request was the existence of a jet with $E_t > 10$ GeV in the pseudorapidity range $|\eta| < 2.2$. In order to further reject the background where a hadronic jet was misidentified as an electron, the electron candidate and the highest energy jet were required not to be back to back in the transverse plane ($\Delta\phi(jet_1, e) < 160°$) . A total of 137 events passed the above selection criteria. For each event in this sample we define a transverse mass, $M_{T'}$ as

$$M_T = \sqrt{2P_T^e P_T^\nu(1 - \cos\Delta\phi_{e\nu})}$$

where $\Delta\phi_{e\nu}$ is the azimuthal angle between $\vec{P}_T^e$ and $\vec{P}_T^\nu$. The M_T distribution (Fig. 4) peaks around 80 GeV, suggesting that the sample consists mainly of $W \to e\nu$ decays accompanied by one or more hadronic jets. This is confirmed by a simulation performed using the EKS Monte Carlo [9], which predicts 148.5 ± 14.5 events. A detailed evaluation of other background sources, such as b–quark decays, jets misidentified as an electron, and Z decays gives 5.9 ± 1.7 events.

At this point the search is restricted to the $15 < M_T < 50$ GeV region where most of the signal for the top masses of interest to this analysis is expected to be. In this region the estimated background from the above mentioned sources is 26.2 ± 3.4 events, and the number of observed events is 17.

4.2 Comparison with the expected top signal

The acceptance for a possible top signal was estimated using the EUROJET Monte Carlo [10], with production cross-sections normalized to : the W production cross-section measured in UA2, multiplied by the top decay branching ratio and the appropriate phase-space factor for the electroweak production, and the lowest value predicted in [11], based on the calculation of [12] for $t\bar{t}$ production. Systematic uncertainties were estimated by varying parameters in the detector simulation and in the fragmentation,

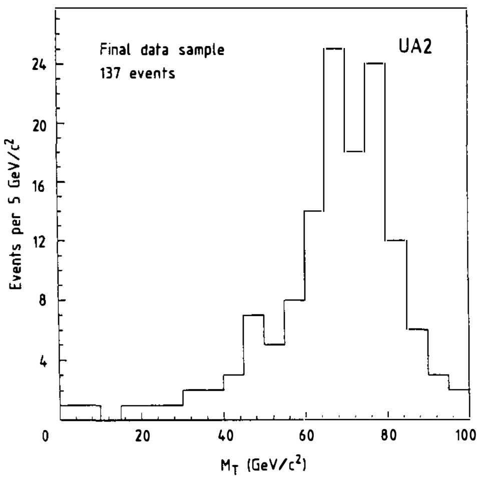

Figure 4: Distribution of M_T for the final sample

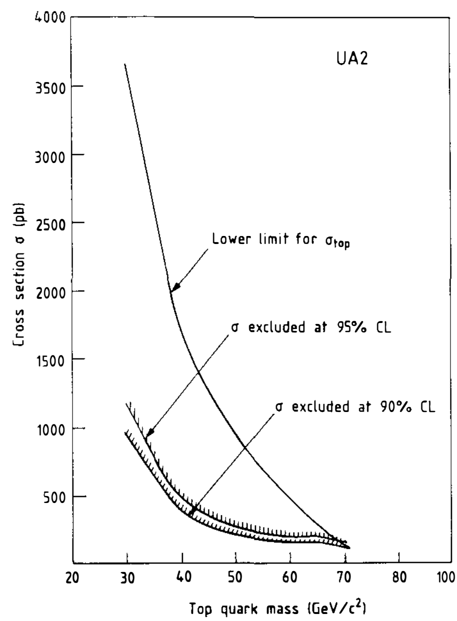

Figure 5: Lower limit for the top production cross-section and the 90 and 95% CL excluded cross-sections as a function of m_{top}

and a lower limit on the acceptance was obtained by adjusting all parameters in their possible range of variation so as to mimimise the acceptance. Limits on the top quark mass were then obtained by comparing the M_T distribution of the observed events with that expected from background sources alone or in the presence of a top signal of a given mass. A likelihood fit was then performed to the observed events with two free parameters, corresponding to the fraction of the event sample due to top decays and to $W \rightarrow e\nu$ events; the number of background events from other sources was normalized to the estimates quoted above. The 90 and 95% CL on the number of top events in the sample were obtained by integrating the likelihood distribution over all possible values of the signal. For each top mass considered, the fitted signal was consistent with no top production. Fig. 5 shows the lower limit of the theoretical top production cross section as a function of top mass, together with the 90 and 95 % CL cross-sections excluded by the fit. Top quark masses between 30 and 69(71) GeV are excluded with 95(90)% confidence. By only considering the QCD process of pair production and using the correct matrix elements for b' decay, it is possible to obtain a lower bound on the mass of a hypotetical sequential quark of a fourth generation, b'. This bound is 54(57) GeV at 95(90)% CL.

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