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SUSY Search Using Trilepton Events From $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

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Abstract

In a preliminary analysis, we have looked for evidence of the production and decay of SUSY chargino-neutralino (often referred to as Wino-Zino) pairs into trilepton events using 11.1 pb^{-1} of $p\overline{p}$ collision data at $\sqrt{s} = 1.8$ TeV collected in 1992-93 by CDF. Using all possible electron and muon decay channels, we observe two events which pass our trilepton criteria. Assuming, for the purposes of a conservative limit, that these events are all signal events, we exclude a point in the parameter space of the Minimal Supersymmetric Standard Model (MSSM) which corresponds to the limit of sensitivity of LEP measurements. Systematic errors have not been included in the result. Larger data samples and a more careful treatment should allow a larger region of MSSM parameter space to be explored using the trilepton channel.

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1 Introduction

One of the most promising channels for discovery of Supersymmetry (SUSY) at a hadron collider[1], such as the Tevatron, LHC, or SSC, is SUSY chargino-neutralino $\chi_1^\pm \chi_2^0$ production (via a virtual W in the s-channel and virtual squarks in the t-channel) followed by the subsequent decays $\chi_1^\pm \rightarrow l\nu\chi_1^0$ and $\chi_2^0 \rightarrow l\bar{l}\chi_1^0$. The striking signature of these decays is then three isolated leptons, which may not balance in P_T. (The χ particles are spin-1/2 neutral or charged SUSY partners of both the spin-1 gauge bosons γ, $W^\pm$, and Z^0; and the spin-0 Higgs bosons. In the Minimal Supersymmetric Standard Model[2] there are two generations of charginos and four generations of neutralinos. We denote the lightest neutralino by χ_1^0, the lightest chargino by $\chi_1^\pm$, and χ_2^0 is the next-to-lightest neutralino. We do not refer to χ_1^0, $\chi_1^\pm$, and χ_2^0 by the common labels $\tilde{\gamma}$, $\widetilde{W}$, and $\tilde{Z}$, respectively, because the SUSY partners of the spin-1 gauge bosons may be significantly mixed with the SUSY partners of the spin-0 Higgs bosons.)

In this paper, we present a preliminary analysis of a search for trilepton events from $p\overline{p}$ collisions at $\sqrt{s} = 1.8$ TeV collected by the Collider Detector at Fermilab (CDF) in the 1992-1993 data run. Backgrounds from Standard Model processes to the signal of three isolated leptons are expected to be small. However, we note that the range of $\chi_1^\pm$ and χ_2^0 masses which are accessible with the present integrated luminosity ($50-70$ GeV) and the three-way split of the energies of each of the $\chi_1^\pm$ and χ_2^0 between two leptons and the lightest neutralino (which itself has a non-zero mass) lead to lepton transverse momenta which are typically lower than the transverse momenta of leptons from W and Z decay.

2 Detector

The Collider Detector at Fermilab (CDF) detector has been described in detail elsewhere [4]. The detector systems used for this analysis are the vertex time projection chamber (VTX), the central tracking chamber (CTC), the calorimeters, and the muon system. We use a coordinate system with z along the proton beam, azimuthal angle ϕ, polar angle θ, and pseudorapidity $\eta = -\ln\tan(\theta/2)$. The VTX measures charged particle trajectories near the event vertex over $|\eta| < 3$. The CTC measures charged particle momenta in a 1.4 Tesla solenoidal magnetic field for $|\eta| < 1.2$. Scintillator-based electromagnetic (EM) and hadronic (HAD) calorimeters in the central region ($|\eta| < 1.1$) are arranged in projective towers of size $\Delta\eta \times \Delta\phi = 0.1 \times 0.26$. Gas-based calorimeters cover the plug ($1.1 < |\eta| < 2.4$) and forward ($2.4 < |\eta| < 4.2$) regions with finer granularity, $\Delta\eta \times \Delta\phi = 0.1 \times 0.087$. The central electromagnetic strip chambers (CES) are multiwire proportional chambers embedded inside the central EM calorimeter near shower maximum. The central muon system consists of three detector elements. The Central Muon Chambers (CMU), located behind ~ 5 absorption lengths of material, provide muon identification over 85% of ϕ for the pseudorapidity range $|\eta| \leq 0.6$. This η region is further instrumented by the Central Muon Upgrade (CMP), located after ~ 8 absorption lengths. The Central Muon Extension (CMX), which covers the pseudorapidity range $0.6 < |\eta| < 1.0$, provides muon identification over 67% of the azimuth and is located behind ~ 6 absorption lengths.

3 Lepton Selection

We use events selected by the online single electron and muon triggers from an exposure of 11.1 pb^{-1} for the basis of our analysis. The estimated uncertainty in the luminosity calculation is presently 10%. The single lepton triggers used in the 1992-3 data run of CDF have transverse energy and momentum thresholds for electrons and muons, respectively, of about 10 GeV. For comparison, Figures 1a, b, and c show the P_T spectra of the three leptons (leading, second, and third highest) for a Monte Carlo simulation using one of the sets of MSSM parameters which were used in this search. From these plots, it is apparent that the single electron and muon data samples, which have P_T thresholds of about 10 GeV are a good match to the expected P_T spectrum of the leading lepton. The specific parameters used for the plots in Figure 1 are: equal squark and gluino masses of 200 GeV, 'Higgsino mixing mass parameter' $2M_1 = -\mu = 300$ GeV, a ratio of vacuum expectation values between the two Higgs doublets $\tan\beta = 5$, charged Higgs mass $M_{H^\pm} = 500$ GeV, and $M_{top} = 130$ GeV. With this particular choice of parameters, $M_{\chi_1^\pm} = 54$ GeV, $M_{\chi_2^0} = 54$ GeV, and $M_{\chi_1^0} = 26$ GeV. With these parameters, the cross-section for $\chi_1^\pm\chi_2^0$ production at $\sqrt{s} = 1.8$ TeV is 20 pb, and the branching ratios $BR(\chi_1^\pm \rightarrow \mu X) = 0.24$ and $BR(\chi_2^0 \rightarrow \mu\mu X) = 0.22$, for a combined trimuon branching ratio of 5.2%.

3.1 Inclusive Electron Trigger and Data Stream

CDF uses a three-level trigger system. Special-purpose hardware is used in trigger Levels 1 and 2, while a farm of microprocessors is used in the third level of triggering. At Levels 1 and 2, the transverse energy is calculated from the geometrical center of the detector in units (trigger towers) of 15 degrees in ϕ by 0.2 units in η. For electrons at Level 1, there is required to be one or more central EM trigger towers with at least 6 GeV. In trigger Level 2, adjacent deposits of EM energy are clustered into electron candidates, requiring a seed tower with E_T threshold of 9 GeV and including adjacent towers with at least 7 GeV. These cluster-finding thresholds essentially set the E_T threshold of the electron trigger. The trigger towers in such a cluster must contain a ratio of HAD/EM energy less than 0.125, and a stiff track found by the hardware track processor with $P_T > 9.2$ GeV must be matched in ϕ to the trigger cluster. In the Level 3 trigger, the EM calorimeter cluster must have a transverse shower profile in the CES strips which is consistent with the expected profile of an electron, as well as a track found by the offline tracking algorithm with $P_T > 6$ GeV/c pointing to it. The energy sharing between towers must also be consistent with the sharing expected from an electron. These cuts are similar to, but looser than, the cuts imposed to select electrons offline.

3.2 Inclusive Muon Trigger and Data Stream

In the Level 1 muon trigger, two or more out of four layers of CMU or CMP muon chambers are required to contain hits in a pattern consistent with the passage of a muon from the origin. In the CMU, the patterns of hits which are allowed correspond to $P_T > 6$ GeV; in the CMP, the threshold is $P_T > 3.3$ GeV. In the Level 2 muon trigger, a track must be found by the hardware track finder with $P_T > 9.2$ GeV which matches the CMU or CMP hits in ϕ position. Hits in the CMP chambers are required in addition to the hits in the CMU chambers in those regions where the geometrical coverages overlap. In the Level 3 inclusive muon trigger, there must be a track found by the offline track finding software with $P_T > 7.5$ GeV, and the fitted position of the muon hits must agree with the extrapolated track position within 10 cm in the ϕ direction. Again, in the places where the CMP and CMU coverage overlap, both devices must record muon chamber hits and satisfy the matching cut. For higher momenta, $P_T > 15$ GeV, muon candidates with hits in the CMU chambers but not in the CMP chambers are allowed.

3.3 Offline Lepton Selection Cuts

In the analysis, we define two classes of lepton. The first class of 'gold' leptons should have caused the inclusive electron or muon triggers just described to have fired. The second class of 'ordinary' leptons have lower E_T and/or P_T thresholds and generally pass looser cuts. Central electrons and CMU or CMP muons were allowed as either 'ordinary' or 'gold' leptons; whereas electrons in the plug calorimeter, CMX muons, and CMI muons were only allowed to be members of the 'ordinary' class of leptons. The CMI muons are defined to be tracks in the CTC which have high transverse momentum but may not be associated with large deposits of energy in the calorimeter, i.e. consistent with minimum ionizing. Such muon candidates improve our geometrical coverage in those regions of calorimetry not covered by muon chambers.

Tables 1 and 2 summarize the identification criteria for electrons and muons, respectively, in this analysis. The lepton criteria are similar to those used in the CDF search for dileptons from top quark decays. The items in these tables require some explanation.

For electrons, we define E/P as the ratio of calorimeter energy to track momentum, a quantity which should be close to one. The variable HAD/EM is the ratio of energy measured in the hadronic (rear) section of the calorimeter towers to the energy deposited in the front section. The LSHR variable measures the consistency of the ratio of energy between central calorimeter towers in the electron cluster with the position of the shower cluster in the CES strip chambers. ΔX and ΔZ are the difference between the positions of the shower cluster in the CES strip chambers and the position of the track extrapolated from the CTC. The $\chi^2(strip)$ variable is low if the transverse shower profile in the CES strip chambers is consistent with the expected profile of an electron. Some of the variables just described are only applicable in the central calorimeter. Two variables which are applicable to the plug region of the calorimeter only are $\chi^2(3x3)$, which is low if the pattern of energy deposition in a $3x3$ array of (fine-grained) plug calorimeter towers is consistent with an electron; and VTX occupancy, which is the fraction of hits found along the expected path of the electron in the VTX time projection tracking chamber.

For muons, we require that the energy deposited in each section of the calorimeter tower, E(EM Tower) and E(HAD Tower) behind the muon candidate not be too large, i.e. be consistent with a minimum ionizing particle. We also require that the CTC track come from the origin, i.e. that its impact parameter with the event vertex δ_0 be small. We also require that the distance $|\Delta X|$ between the track in the muon chamber and the extrapolated CTC track, calculated in the transverse plane only, be consistent with zero. The specific requirements are that either this distance is within a small fixed window (efficient at high

Table 1: Offline Electron Selection Cuts for CDF Trilepton Analysis

Cut	Central		Plug
	Gold	Ordinary	Ordinary
E_T	> 10 GeV	> 5 GeV	> 5 GeV
E/P	< 2.0	< 2.0	N/A
HAD/EM	< 0.05	$< 0.055 + 0.045 \cdot E/100$	< 0.1
LSHR	< 0.2	< 0.2	N/A
$\|\Delta X\|$	< 3 cm	< 3 cm	N/A
$\|\Delta Z\|$	< 5 cm	< 5 cm	N/A
χ^2(strip)	< 10	< 15	N/A
$\chi^2(3\times3)$	N/A	N/A	< 3
VTX occupancy	N/A	N/A	> 0.5

Table 2: Muon Selection Cuts for CDF Trilepton Analysis

Cut	Central		
	Gold CMU/CMP	Ordinary CMU/CMP/CMX	Ordinary CMI
P_T	> 10 GeV/c	> 4 GeV/c	> 10 GeV/c
E(EM Tower)	< 2 GeV	< 2 GeV	< 2 GeV
E(HAD Tower)	< 6 GeV	< 6 GeV	< 6 GeV
Impact parameter δ_0	< 0.2 cm	< 0.5 cm	< 0.5 cm
CMU $\|\Delta X\|$ or $\chi^2(\Delta X)$	< 2 cm or < 9	< 2 cm or < 9	N/A
CMP $\|\Delta X\|$ or $\chi^2(\Delta X)$	< 5 cm or < 9	< 5 cm or < 9	N/A
CMX $\|\Delta X\|$ or $\chi^2(\Delta X)$	N/A	< 5 cm or < 9	N/A

momenta), or that it lie within 3 standard deviations (σ) from zero, where σ is calculated as the quadratic sum of the multiple scattering and measurement errors. The latter requirement is efficient in the lower momentum range.

4 Trilepton Event Selection

From the inclusive Stream 1 electron and muon samples, we form a multilepton sample by requiring events to contain at least two leptons, of which one must be 'gold'. It is noticed that a large fraction of the multilepton events appear to have two leptons close to each other in $\eta - \phi$ space. This may be because some of the multilepton events come from $b\bar{b}$, or photon conversions not removed by the photon conversion filter, J/Ψ decays, tracking errors, and so on. However, the Monte Carlo simulation shows that for SUSY trilepton topologies, the leptons do not typically come very close to each other. Therefore, to reduce these backgrounds, we require a minimum separation in $\eta - \phi$ space between leptons, $\Delta R > 0.4$.

One would expect the leptons in SUSY trilepton to be well-isolated, i.e. with very little energy in the calorimeter around the leptons. The Monte Carlo simulation confirms this: Figures 1d, e, and f, show the E_T in a cone of $R = 0.4$ around the leading, second, and third lepton in such events. Figures 2d, e, and f, meanwhile, show that the leptons in the trilepton background from $b\bar{b}$ events are typically much less isolated. In W and Z analyses, isolation is typically defined as the *ratio* of the E_T in a cone which is not associated with the lepton to the E_T of the lepton. However, because our leptons may have quite low momentum, we find it better to define isolation simply as the E_T in a cone of $R = 0.4$ which is not associated with the lepton. We require isolation on all leptons less than 2 GeV.

We also require that the total charge of the three leptons not be ± 3, i.e. not all the same sign; and that we have at least one $\mu^+\mu^-$ or e^+e^- pair in the event, i.e. the same type of lepton but opposite in charge. After these cuts, we obtain 3 trilepton events in the electron trigger data, and 6 trilepton events in the muon trigger data. Two of the events are found in both the electron and muon samples. At this point, WZ and ZZ 3-lepton or 4-lepton candidate events should have been retained, as well as any possible contribution from SUSY $\chi_1^{\pm}\chi_2^0$ production. Although WZ and ZZ events are certainly interesting in their own right, they constitute a source of background for the SUSY trilepton search. Moreover, because of the large number of Z^0 leptonic decays in our 11.1 pb^{-1} data sample, a potentially non-negligible source of background is a $Z^0 + jet$ event where the Z^0 decays to e^+e^- or $\mu^+\mu^-$ and a 'fake' lepton or gamma conversion electron is found in the recoil jet system. In order to reduce such backgrounds, we require the invariant mass between all e^+e^- and $\mu^+\mu^-$ pairs to lie outside of the window $80 - 100$ GeV. This cut removes five of our seven trilepton candidate events. The only one of the events removed at this stage which is a convincing WZ trilepton event is a previously found and well-known $WZ \rightarrow e^+e^-e^+$ candidate event (run 43601 event 11068). In the other four removed events, there is reason to suspect that the third lepton may be fake.

We are left with two events in our final data sample, both in the $\mu^+\mu^-\mu^{\pm}$ channel. One of the events (run 42503 event 364938) has a $\mu^+\mu^-$ pair with invariant mass of 9.9 GeV, which may be compatible with Υ decay. For the time being, we have chosen not to make a cut to remove events which are compatible with Υ decay, pending further study of mass resolution and efficiencies of mass cuts. Also, the other muon in this event may be a fake, as it is a CMI muon with very little E_T (0.1 EM and 0.0 HAD) in the calorimeter tower associated with the muon.

The more interesting of the two events found by this study (run 45219 event 475444) is shown in the CTC end view in Figure 3. There are two central CMU and CMP muons with P_T of 10.5 and 35 GeV and $Q = +1$. The third lepton is a CMI muon with $P_T = 49$ GeV, $\eta = 1.1$, and $Q = -1$. The invariant masses of the CMI muon with the CMU+CMP muons are 114 and 36 GeV, i.e. not very close to the Z^0 or other resonance masses, but the momentum and angles of the CMI muon are not very precisely measured, and it is possible that the event is compatible with a $Z^0 \rightarrow \mu^+\mu^-$ decay plus a muon candidate of more modest momentum.

Table 3: SUSY Masses

$m(\tilde{g})$	$m(\chi_1^{\pm})$	$m(\chi_1^0)$	$m(\chi_2^0)$
160 GeV	45.0 GeV	21.2 GeV	45.2 GeV
180 GeV	49.6 GeV	23.7 GeV	49.8 GeV
200 GeV	54.3 GeV	26.2 GeV	54.4 GeV
220 GeV	58.9 GeV	28.7 GeV	59.0 GeV

Table 4: SUSY Cross-Sections and Branching Ratios

$m(\tilde{g})$	$\sigma(\chi_1^{\pm}\chi_2^0)$	BR $\chi_1^{\pm} \to \mu\nu\chi_1^0$	BR $\chi_2^0 \to \mu^+\mu^-\chi_1^0$	BR $\chi_1^{\pm}\chi_2^0 \to 3\mu X$	$\sigma \cdot BR$ $\chi_1^{\pm}\chi_2^0 \to 3\mu X$
160 GeV	71.6 pb	25.0 %	23.1 %	5.78 %	4.14 pb
180 GeV	33.5 pb	24.4 %	22.6 %	5.50 %	1.84 pb
200 GeV	19.5 pb	23.7 %	22.0 %	5.22 %	1.02 pb
220 GeV	12.5 pb	22.9 %	21.5 %	4.92 %	0.62 pb

5 Detection Efficiency

We measure the detection efficiency of most of our cuts using SUSY $\chi_1^{\pm}\chi_2^0$ events generated with the ISASUSY Monte Carlo event generator[5], version 1.0, and EHLQ1 parton distribution functions at $Q^2 = \hat{s}$. The cross-section is calculated with the s-channel production diagram only (which should dominate). For the purpose of this preliminary result, only a small number of points in MSSM parameter space are explored. We have chosen to vary the parameter on which the cross-sections depend most strongly, the gluino mass, but to hold the other parameters fixed. Gluino masses of 160, 180, 200, and 220 GeV are chosen. The SUSY parameters which are held constant are the 'Higgsino mixing mass parameter' $2M_1 = -\mu = 300$ GeV, the ratio of vacuum expectation values between the two Higgs doublets $\tan\beta = 5$, charged Higgs mass $M_{H\pm} = 500$ GeV, and $M_{top} = 130$ GeV. With these parameters we obtain the pattern of masses shown in Table 3, as well as branching ratios and cross-sections shown in Table 4. Note that only the branching ratio to the $3\mu X$ mode are listed, however, the branching ratios to mixed channels $e^+e^-\mu^{\pm}$, $\mu^+\mu^-e^{\pm}$, as well as $e^+e^-e^{\pm}$ are very close to the branching ratios for the $\mu^+\mu^-\mu^{\pm}$ channel in this region of SUSY parameter space.

Monte Carlo events which have three or more generated leptons are then passed through a detector simulation, then reconstructed with the CDF offline reconstruction software. The simulated events are then analyzed with the same selection criteria as are imposed on the

Table 5: Trilepton efficiencies

Final State	$m(\tilde{g})$	ϵ^{MC}	ϵ^{trig}	ϵ^{iso}	ϵ^{tot}
$e^+e^-e^\pm$					
	160 GeV	3.99%	92%	88%	3.23%
	180 GeV	4.78%	92%	88%	3.87%
	200 GeV	5.30%	92%	88%	4.29%
	220 GeV	6.59%	92%	88%	5.33%
$e^+e^-\mu^\pm$					
	160 GeV	4.80%	91%	88%	3.84%
	180 GeV	6.88%	91%	88%	5.51%
	200 GeV	7.18%	91%	88%	5.75%
	220 GeV	9.63%	91%	88%	7.71%
$\mu^+\mu^-e^\pm$					
	160 GeV	7.25%	89%	88%	5.68%
	180 GeV	8.73%	89%	88%	6.84%
	200 GeV	9.88%	89%	88%	7.74%
	220 GeV	12.16%	89%	88%	9.53%
$\mu^+\mu^-\mu^\pm$					
	160 GeV	7.41%	88%	88%	5.74%
	180 GeV	10.32%	88%	88%	7.99%
	200 GeV	11.57%	88%	88%	8.96%
	220 GeV	12.95%	88%	88%	10.03%

data, except for two cuts which will be discussed later. The trilepton efficiencies estimated from the Monte Carlo range from a low of 3.99% for the $e^+e^-e^\pm$ channel with a gluino mass of 160 GeV to a high of 12.95% for the $\mu^+\mu^-\mu^\pm$ channel with a gluino mass of 220 GeV. The first of the two selections for which we have not used the Monte Carlo to estimate the efficiency is the triggering on leptons which are within the acceptance of the central detector and pass all of the 'gold' lepton criteria. A conservative estimate of the trigger efficiency is furnished by using the estimated *single* gold electron and muon efficiencies[6]. These efficiencies are about 90%. The second selection, for which we have not used the Monte Carlo, but rather use actual W and Z^0 leptonic decay data, is the imposition of our rather tight 2 GeV isolation requirement. The efficiency of this cut is determined to be 88%, independant of gluino mass or decay channel. All of these efficiencies are listed in Table 5 for each channel and choice of gluino mass. The total detection efficiencies are also listed according to the formula:

$$\epsilon^{tot} = \epsilon^{MC} \cdot \epsilon^{trig} \cdot \epsilon^{iso}$$

6 Excluded Regions of the MSSM

The efficiencies obtained in the previous section of this note are used to give our final upper bounds on cross-section times branching ratio for the trilepton signal as a function of gluino mass. We use the two trilepton events left in our analysis to set a 95% confidence level upper limit of 6.3 events on the mean number of events predicted. These events come from the sum of four final states; $e^+e^-e^\pm$, $e^+e^-\mu^\pm$, $\mu^+\mu^-e^\pm$, and $\mu^+\mu^-\mu^\pm$. The branching ratios for each of these final states are the same, therefore the number of predicted events is:

$$N_{predict} = \sigma \cdot BR(\chi_1^\pm \chi_2^0 \to 3lX) \cdot \int \mathcal{L}dt \cdot (\epsilon_{eee} + \epsilon_{ee\mu} + \epsilon_{e\mu\mu} + \epsilon_{\mu\mu\mu}) < 6.3$$

where $BR(\chi_1^\pm \chi_2^0 \to 3lX)$ refers to the branching ratio to *any* of the final states $e^+e^-e^\pm$, $e^+e^-\mu^\pm$, $\mu^+\mu^-e^\pm$, or $\mu^+\mu^-\mu^\pm$. We derive an upper limit on $\sigma \cdot BR(\chi_1^\pm \chi_2^0 \to 3lX)$ by solving this equation using the measured integrated luminosity for our data sample of 11.1 pb^{-1} and the sums of efficiencies read off of the last column of Table 5 for the four decay modes. In other words,

$$\sigma \cdot BR(\chi_1^\pm \chi_2^0 \to 3lX) < \frac{6.3}{11.1pb^{-1} \cdot (\epsilon_{eee} + \epsilon_{ee\mu} + \epsilon_{e\mu\mu} + \epsilon_{\mu\mu\mu})}$$

The efficiency sums of the four electron/muon modes ($\epsilon_{eee}+\epsilon_{ee\mu}+\epsilon_{e\mu\mu}+\epsilon_{\mu\mu\mu}$) are, for 160, 180, 200, and 220 GeV gluino masses, respectively, 0.185, 0.242, 0.267, and 0.328. We therefore obtain:

- $m(\tilde{g}) = 160$ GeV: $\sigma \cdot BR(\chi_1^\pm \chi_2^0 \to 3lX) < 3.07$ pb at 95% C.L.
- $m(\tilde{g}) = 180$ GeV: $\sigma \cdot BR(\chi_1^\pm \chi_2^0 \to 3lX) < 2.35$ pb at 95% C.L.
- $m(\tilde{g}) = 200$ GeV: $\sigma \cdot BR(\chi_1^\pm \chi_2^0 \to 3lX) < 2.13$ pb at 95% C.L.
- $m(\tilde{g}) = 220$ GeV: $\sigma \cdot BR(\chi_1^\pm \chi_2^0 \to 3lX) < 1.73$ pb at 95% C.L.

Figure 4 shows the predicted cross-section times branching ratio for SUSY trilepton production from Table 4 together with these 95% confidence level upper limits from this analysis. The lower scale is the gluino mass input to the calculation of other SUSY masses, production cross-sections, and so on; and the upper scale is the resulting mass of the $\chi_1^\pm$. The mass of the χ_2^0 is very slightly higher (see Table 3). The predicted cross-section times branching ratio is higher than the experimental upper limit only for the $m(\tilde{g}) = 160$ GeV point, therefore this analysis can rule out that point.

A very brief and tentative summary of the major systematic uncertainties to be expected in this analysis: first, our integrated luminosity measurement presently has a quoted uncertainty of 10%. Also, our trigger efficiency estimate is inaccurate, in part because we have taken estimates of single lepton efficiencies and the trilepton efficiencies may be higher, and also because we do not at present have a full understanding of the lepton trigger efficiencies for leptons near the E_T and P_T thresholds. To this effect, we also assign an uncertainty of 10%. The systematic uncertainty due to parton distribution functions ought to be similar to the uncertainties in W and Z production, which are produced also via Drell-Yan at similar $\hat{s}$ values. These uncertainties are estimated in the CDF analysis of the R ratio, i.e. the ratio of $W \to l\nu$ to $Z^0 \to l\bar{l}$ production, as about 2%, i.e. negligible. Finally, we should estimate the efficiency of the lepton selection criteria. No hard data exists as yet on this, but if we nonetheless assign a systematic uncertainty of 5% to each lepton, we get a total of 15% systematic error on the trilepton acceptance. Adding all of these errors in quadrature leads to a total systematic error of about 21%. With study, particularly using Z^0 leptonic decays, these errors can be greatly reduced.

If one compares with a previous SUSY limit using using $\not{E}_T + jets$ data from the 1988-89 CDF data run[7], ruling out $m(\tilde{g}) = m(\tilde{q}) = 160$ GeV appears to overlap with a previously ruled-out portion of the squark-gluino mass plane. However, this is only because of a nearly linear relationship in the model between the chargino and neutralino masses and the gluino mass, which comes about because of the hypothesis that the chargino and neutralino masses become equal at the GUT scale (SUSY 'unification hypothesis'). This is not a necessary feature of the MSSM, but is often used as a simplifying assumption to limit the number of free parameters in the model. The gluino mass of 160 GeV corresponds to $\chi_1^\pm$ and χ_2^0 masses of about 45 GeV, a value which has already (barely) been ruled out by LEP searches for these particles. This preliminary measurement has shown us that trilepton searches are a viable means of investigating Supersymmetry at a hadron collider. Such searches are also very much complementary to our ongoing search for evidence of SUSY through the $\not{E}_T + jets$ channel.

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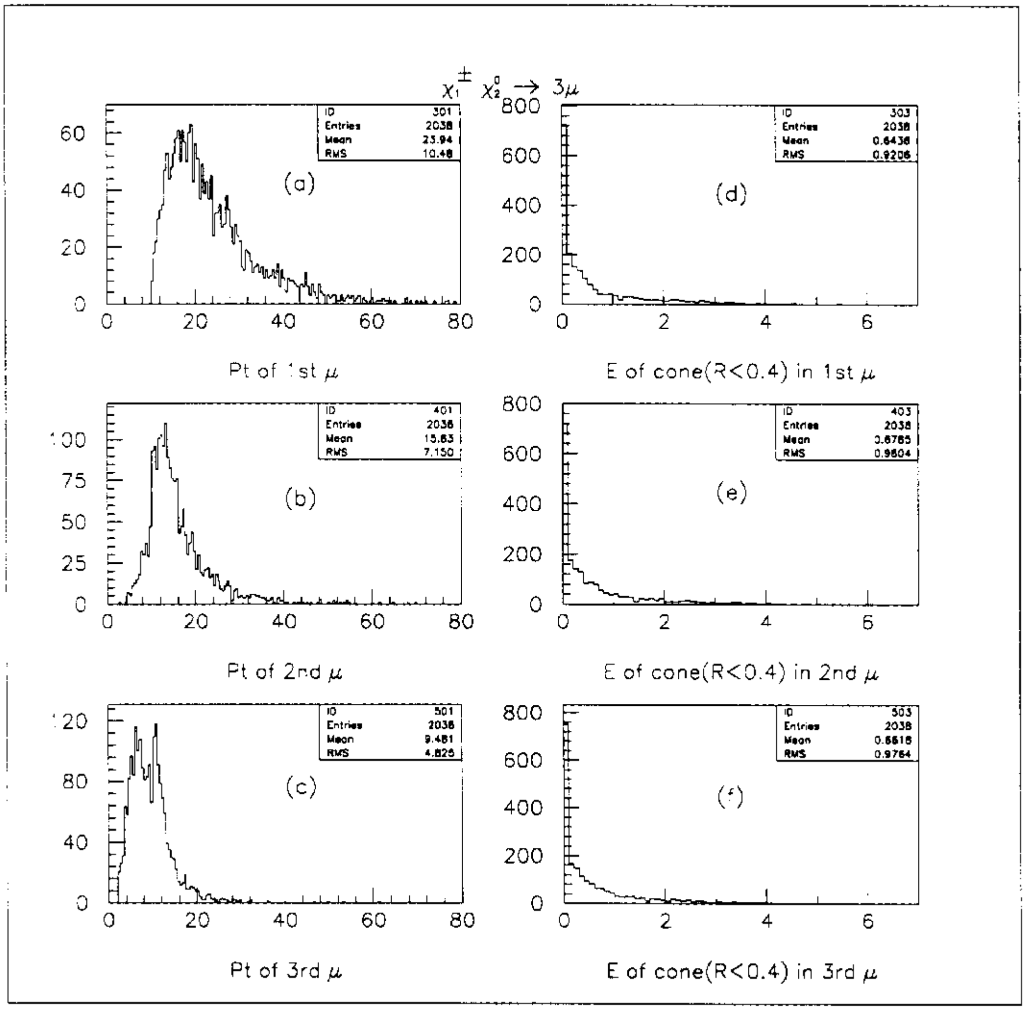

Figure 1: Monte Carlo distributions of transverse momenta (a-c) and calorimeter energy (isolation) surrounding the leptons (d-f) in $p\overline{p} \rightarrow \chi_1^\pm \chi_2^0 \rightarrow \mu^\pm \mu^\pm \mu^\mp\ X$ for the leading, second, and lowest P_T muons, respectively.

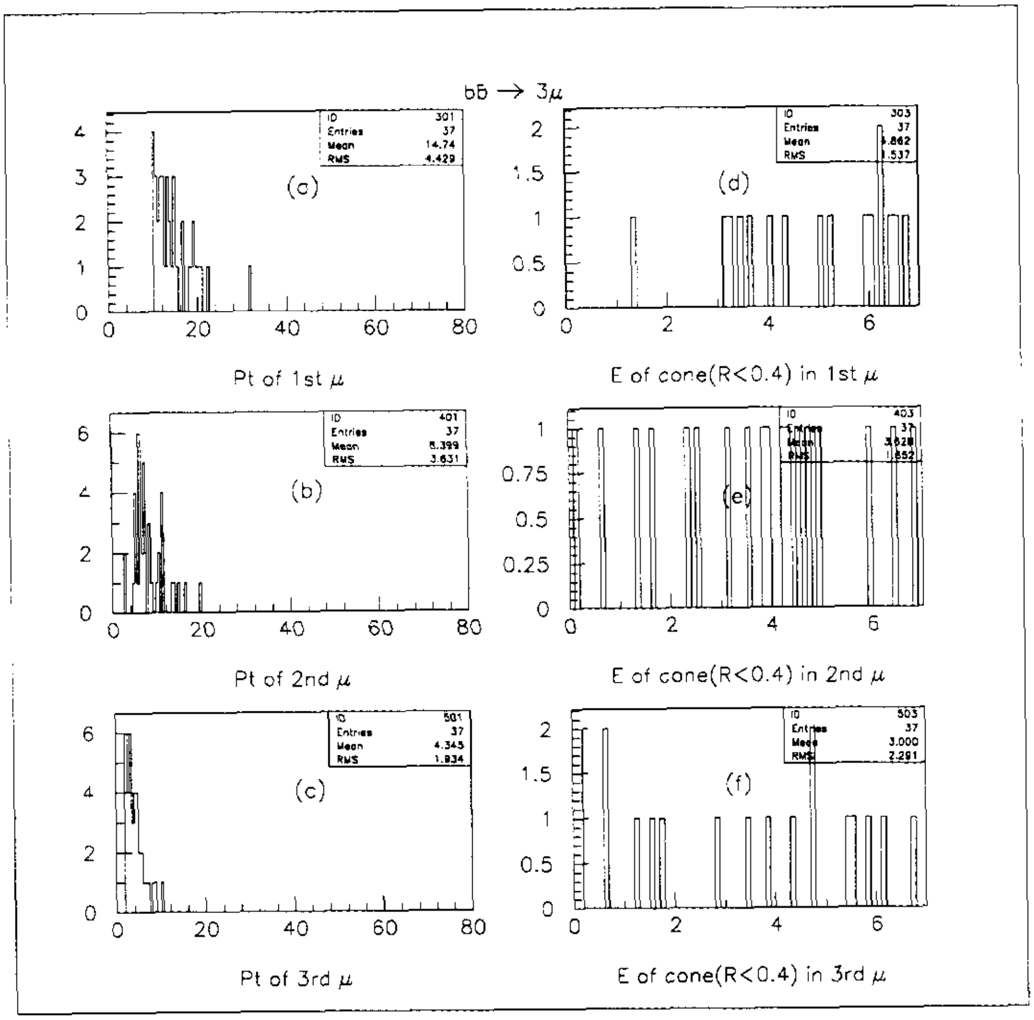

Figure 2: Monte Carlo distributions of transverse momenta (a-c) and calorimeter energy (isolation) surrounding the leptons (d-f) in $p\overline{p} \rightarrow b\bar{b} \rightarrow \mu^{\pm}\mu^{\pm}\mu^{\mp}\ X$ for the leading, second, and lowest P_T muons, respectively.

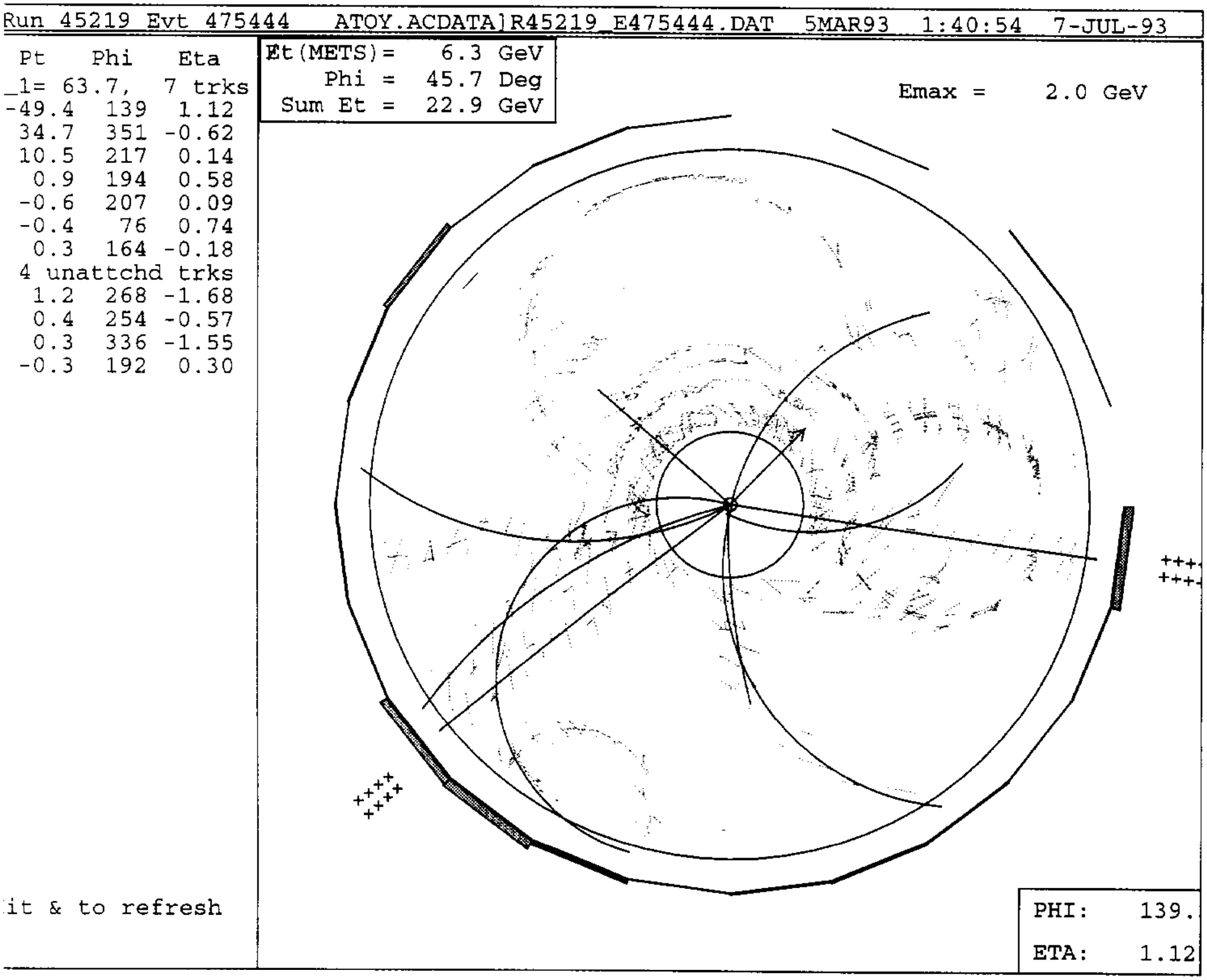

Figure 3: CTC display of an interesting event (run 45219 event 475444) found in this analysis. This event contains two CMU+CMP muon candidates plus one CMI muon candidate. The muons are visible as straight tracks on the right (CMU+CMP muon candidate with $Q = +$ and $P_T = 35$ GeV), lower left (CMU+CMP muon candidate with $Q = +$ and $P_T = 10.5$ GeV), and a short track in the upper left (CMI muon candidate with $Q = -$ and imprecisely measured $P_T = 49$ GeV).

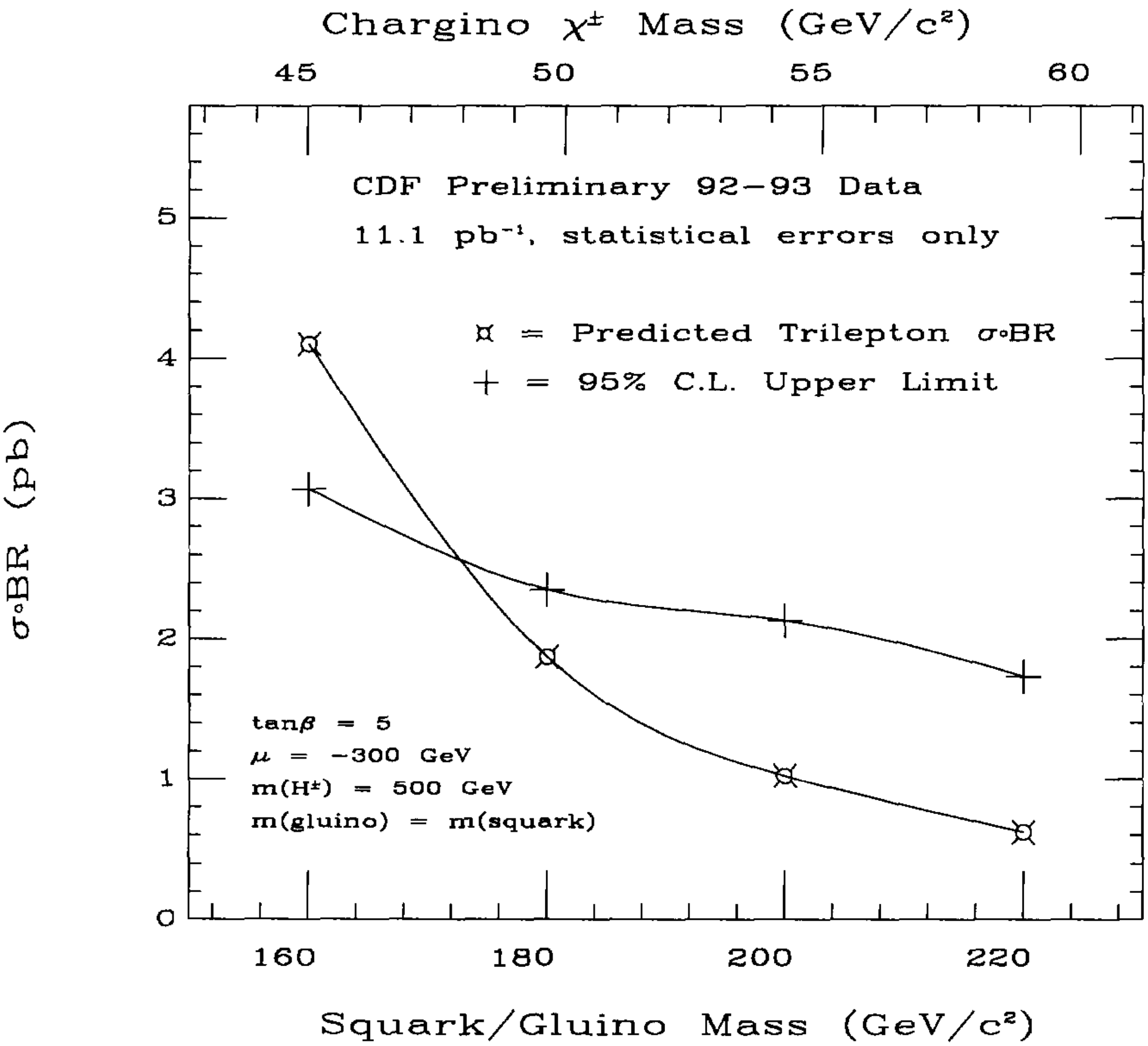

Figure 4: Predicted cross-sections time branching ratios and experimental upper limits for SUSY trilepton production in *any* of $e^+e^-e^\pm$, $e^+e^-\mu^\pm$, $\mu^+\mu^-e^\pm$, or $\mu^+\mu^-\mu^\pm$ modes. The lower scale is the squark/gluino mass input to the calculation of other SUSY masses, production cross-sections, and so on; the upper scale shows the resulting mass of the $\chi_1^\pm$. The mass of the χ_2^0 is very slightly higher (see Table 3).