Update to the CBA SUSY Studies

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UPDATE TO THE CBA SUSY STUDIES

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This is an interim report on the study of the detection of supersymmetric particles at CBA. A previous report by Aronson et al.¹ summarizes results as of July 1982, and the review article by Hinchliffe and Littenberg² contains some additional material. This report will consist of five sections: I. Update of $p + p \rightarrow \tilde{g} + \tilde{g} + X$ at moderate luminosity. II. The effect of high luminosity on $p + p \rightarrow \tilde{g} + \tilde{g} + X$, III. $p + p \rightarrow \tilde{\gamma} + \tilde{q} + X$, IV. $W \rightarrow \tilde{\gamma} + \tilde{W}$, V. Future studies.

I. Update of $p + p \rightarrow \tilde{g} + \tilde{g} + X$. This study assumes a Uranium quality calorimetric detector extending from $-3 < y < 3$ with fiducial region $|y| < 2$. Several minor improvements have been made in the Monte Carlo program. The most significant of these was a correction to the structure function formula used in ISAJET.³ While this changes the yields in some regions by up to a factor 2, it tends to affect signal and background similarly and so has little qualitative effect on our conclusions. The lepton veto cut is now made on p_T^{MAX} rather than E^{MAX} and the handling of μ and neutral hadron energy deposition in the calorimeter is improved. A typical result is shown in Figure 1. Here a 100 GeV/c gluino pair signal is plotted vs the visible gluino p_T (as reconstructed by the program). Also shown is the same quantity for the background (primarily events in which a high p_T gluon fragments into 2 heavy quarks, one of which decays leptonically). Signal and background have been subjected to a number of cuts, the most important of which are $X_E < .5$, $p_{\text{out}} > 10$ GeV/c, and $p_T^{\text{MAX LEPT}} < 2$ GeV/c. $p_T^{\text{MAX LEPT}}$ is the maximum p_T of any identified lepton. p_{out} and X_E can be defined⁴ in terms of the residual jet

visible p_T 's as

$$X_E = \frac{-\vec{p}_T^1 \cdot \vec{p}_T^2}{|\vec{p}_T^1|^2}, \quad p_{out} = [|\vec{p}_T^2|^2 - X^2 |\vec{p}_T^1|^2]^{1/2}, \quad |\vec{p}_T^1| > |\vec{p}_T^2|.$$

In a run of integrated luminosity = 10^{39} cm^{-2} , corresponding to $\mathcal{L} = 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$ for 10^7 sec , one accumulates approximately 3000 signal events. For $p_T^{\text{vis}} > 50 \text{ GeV}/c$ there are ~ 2000 signal events and only 300 background events. The level and shape of this background should be readily determinable from the sample of events containing identified leptons.

II. Rate effects in $p + p \rightarrow \tilde{g} + \tilde{g} + X$. In our previous work we made no attempt to simulate the effect of pile-up upon the signal and background. To accomplish this it was necessary to make our detector simulation more realistic. Our first step was to introduce a granularity to the calorimeter. A flexible program was devised to facilitate the introduction of any desired configuration. The results reported herein all assumed a granularity essentially equivalent to that of the C.D.F.⁵ Signal and background events were created by ISAJET and the resulting particles tracked into the calorimeter modules. As in previous work electron and photon energies were smeared with a resolution function given by $\delta E/E = .15/\sqrt{E}$ and hadrons by $.35/\sqrt{E}$. Muons deposited their exact kinetic energy up to a limit of 1.2 GeV. The total energy deposited in each calorimeter element was summed to give a pseudo $\vec{p}$ whose direction is given by joining the center of the element to the origin.

To simulate pile up, tapes of minimum bias and of high p_T constituent scattering events were generated by ISAJET. These were added in proportions

given by the ratios of their relative production cross sections to signal or background events. Event delay times were thrown at random in a ± 160 nsec interval at a density given by the assumed luminosity. For each pile up event, particles were followed into the calorimeter and their energy smeared in the normal way. However, only a fraction of their "measured" energy was added into the calorimeter sum. As shown in Figure 2 this fraction was a function of their delay time, ranging from 1 for $\Delta t = 0$ to 0 for $|\Delta t| = 160$ nsec.⁶

Qualitatively the effects upon the signal are small. Figure 3 shows the p_T^{vis} distribution for 75.0 GeV/c gluino pair signal, for the cases of 0 pile up (but calorimeter granularity assumed), $\mathcal{L} = 2 \times 10^{32}$, and $\mathcal{L} = 10^{33}$. The average p_T^{vis} goes from 52.9 GeV/c at $\mathcal{L} = 0$ to 55.6 GeV/c at 2×10^{32} to 63.4 GeV/c at 10^{33} . The effects on the X_E and p_{out} distributions are extremely small. Consequently the cut efficiency is only weakly dependent on luminosity, being 20.2% at $\mathcal{L} = 0$, 19.5% at 2×10^{32} , and 17.6% at 10^{33} .

The effect on the background is unfortunately both large and difficult to evaluate reliably. Because of the large background rejection factors achieved extremely large numbers of Monte Carlo events must be generated in order to produce a significant number of residual background events. These runs were already costly in the 0 rate case. The effect of $\mathcal{L} = 10^{33}$ is to multiply their cost by very nearly a factor 10, making them prohibitively expensive. Thus, at present our results have large fluxuations and must be taken with care. Table I gives preliminary, integrated results. Note that although the residual background with loose cuts grows distressingly fast with luminosity, this growth seems to be curtailed as the cuts are tightened. For example the $\mathcal{L} = 10^{33}/\mathcal{L} = 0$ ratio for $X_E < .5$ only is ~ 28 , while for $X_E < .5 + p_{\text{out}}$ 10 it is ~ 8 .

In a run of 10^7 seconds at a luminosity of $10^{33} \text{ cm}^{-2} \text{ sec}^{-1}$ the latter cut set plus lepton rejection reduces the residual background to $\sim 20,000$ events above p_T^{vis} of 60 GeV/c. The signal for $M_{\tilde{g}} = 100 \text{ GeV}/c^2$ is approximately 15,000 events in this region. Thus it appears that the gluino search can be pushed beyond $M_{\tilde{g}} = 100 \text{ GeV}/c^2$. Since the p_T^{vis} and p_{out} distributions tend to scale with $M_{\tilde{g}}$, as $M_{\tilde{g}}$ rises stronger cuts may be imposed without increasing the loss of signal. In this way, the search may be pushed as high as $M_{\tilde{g}} = 125 \text{ GeV}/c^2$, although confirmation of this upper limit awaits a better determination of the background.

III. $p + p \rightarrow \tilde{\gamma} + \tilde{q} + X$. This process was first suggested by W-Y. Keung who has calculated the parton level cross-section.⁷ This process could be an extremely important one in the event that $M_{\tilde{q}} > M_Z/2$, $M_{\tilde{t}} > M_Z/2$ and the gluino is very heavy.⁸ In this case no supersymmetric signal would be detectable at the next generation of e^+e^- colliders. At hadron hadron colliders, if $M_{\tilde{q}}$ is $> 60 \text{ GeV}/c^2$, the $p + p(\bar{p}) \rightarrow \tilde{q} + \tilde{q} + X$ signal will probably be impossible to extract⁹ so that $p + p \rightarrow \tilde{\gamma} + \tilde{q}$ may well be the only supersymmetric process accessible in the near future.

The leading diagrams for this process are shown in Fig. 4. These are analogous to the diagrams² for $p + p \rightarrow \tilde{g} + \tilde{q} + X$ with the exception that the t-channel gluino pole is of course missing. The absence of this pole and the replacement of one power of α_s by α in the other diagrams reduce the cross-section for this process by a large factor with respect to that for $p + p \rightarrow \tilde{g} + \tilde{q} + X$. For example for $M_{\tilde{g}} = 10$, $M_{\tilde{q}} = 100$ the ratio is $2 \times 10^{-9} \text{ mb}/3.3 \times 10^{-6} \text{ mb} \approx 6 \times 10^{-4}$. Thus high luminosity is a necessity in order to

observe this process. The signature for this process is much superior to that of gluino pairs or $\tilde{g} + \tilde{q}$, so that one may hope to extract it from the large background of competing processes. Under the assumption of large $M_{\tilde{g}}$, the $\tilde{q}$ decay would be into $\tilde{q} + \tilde{\gamma}$ or $\tilde{q} + \tilde{G}^{10}$ (the "Goldstino"). In either case one would tend to observe a single unbalanced high p_T jet.

Our detector program, as described in Reference 1, has not really been optimized for this situation, so that presumably the results which follow could be improved significantly. Figure 5 shows the X_E distribution for $M_{\tilde{q}} = 60$ and 100 GeV/c². As one might expect these distributions peak sharply at 0, the value which corresponds to complete p_T imbalance. This contrasts with the case of gluino pairs^{1,2} where the corresponding distributions peak gently at high X_E , although they have substantial tails in the $X_E < .5$ region. The background, which arises from events which are initially (before measuring errors or weak decays) balanced in p_T , peaks sharply at $X_E = 1$. On the other hand, the p_{out} variable which is so valuable in the case of gluino pairs is nearly useless here since in leading order there is no second jet with which to define it. Although X_E provides powerful discrimination between signal and background, it was necessary to supplement it with other cuts. We imposed $p_T^{vis} > 35$ GeV/c, $p_T^{MAX LEPT} < 2$, and imposed event shape cuts developed by hand scanning signal and residual background events. The resulting background is shown in Fig. 5. It seems possible to extract the signal up to $M_{\tilde{q}} = \approx 100$ GeV/c² (for $X_E < .1$, $S = B \approx 700$ events/10³⁹). The uncertainties of the background calculations must be emphasized. Because of the extremely large background reduction required, for a practical Monte Carlo run surviving events are very few in number, leading to statistical problems. What is more, many residual events contain $t\bar{t}$ pairs so that the unknown mass of these objects

adds an additional uncertainty (it was assumed that $M_t = 20 \text{ GeV}/c^2$). Hand scanning revealed that by and large background events with $X_E < .1$ fall into two categories: 1) events containing a high p_T gluon which fragments into a $t\bar{t}$ pair or 2) events containing multiple $b\bar{b}$ and/or $c\bar{c}$ pairs. In either case there must be one or more leptonic decays resulting in high p_T neutrinos.

It's most important to be able to veto on the charged leptons, particularly on μ 's which can in themselves remove a large amount of p_T from the calorimetric detector. A second useful characteristic of these events is their extreme busy-ness. They tend to have much higher multiplicity than signal events, and to be much more spread out. It's clear that an improved jet finding algorithm would be very effective.

IV. Winos. In certain currently popular models¹¹, there is at least one supersymmetric partner of the W (Wino, $\tilde{W}$) which is lighter than the W . The W will then decay to this particle via $W \rightarrow \tilde{\gamma} + \tilde{W}$. The branching ratio is given by

$$BR(W \rightarrow \tilde{\gamma}\tilde{W}) = 4\sin^2\theta \text{ BR}(W \rightarrow e\nu) \frac{(1-x)^2 (1+x/2)}{1+x}$$

where $X = (M_{\tilde{W}}/M_W)^2$. This gives .013 for $M_{\tilde{W}} = 60$ and .039 for $M_{\tilde{W}} = 40 \text{ GeV}/c^2$. The $\tilde{W}$ subsequently decays into $\tilde{\ell}\bar{\nu}_{\ell}$, $\tilde{\ell}\nu_{\ell}$, $\tilde{q}_{2/3}\bar{q}_{1/3}$ etc. As in the W case the quark decays dominate. If $M_{\tilde{q}} + M_{\tilde{q}} > M_{\tilde{W}}$, the $\tilde{W}$ will decay directly to $\tilde{g}q_{2/3}\bar{q}_{1/3}$ if the gluino is light enough or otherwise into $\tilde{\gamma}q_{2/3}\bar{q}_{1/3}$. At present we have studied only the hadronic decay modes. We concentrate upon $\tilde{\gamma}q_{2/3}\bar{q}_{1/3}$ even though the models under discussion tend to predict a light gluino because 1) in the light $\tilde{g}$ case, the $\tilde{g}$ pair signal will be by far the most prominent SUSY signal, and 2) we have verified that there is

relatively little phenomenological difference between the $\tilde{g}q_2/3\tilde{q}_1/3$ and the $\tilde{\gamma}q_2/3\tilde{q}_1/3$ signatures. Although the signal to background is significantly worse than many of the other processes we have studied, in the present case one can make use of the W polarization to reject the background. Since most of the p_T available to the final state partons comes from the W decay, one must work below about $p_T = 40$ GeV/c, where backgrounds tend to be highest. The signature changes significantly as a function of the assumed $\tilde{W}$ mass, and it is different for different flavor quarks. As the $\tilde{W}$ mass decreases the signature tends to improve since the situation approaches that of a single jet recoiling off an unobserved particle. As the $\tilde{W}$ mass approaches that of the W, one comes closer and closer to a balanced 2-jet configuration which is indistinguishable from the background. Heavy quarks in the final state seem to give a slightly better kinematic signature than do light quarks, particularly as $M_{\tilde{W}}$ increases. However, if we impose a high p_T lepton veto as is necessary to reduce the background, about half the $\tilde{\gamma}t\bar{b}$ events are lost.

Figure 6 gives the X_E distribution for $\tilde{W} \rightarrow \tilde{\gamma}c\bar{s}$ for $M_{\tilde{W}} = 40$ and 60 GeV/c⁷. As in the case of $p + p \rightarrow \tilde{\gamma} + \tilde{q}$ this variable seems the most sensitive. Cutting at $X_E < .2$, $p_T^{\text{vis}} > 20$ GeV/c about 20 K events can be collected if $M_{\tilde{W}} = 40$ GeV/c² and 2 K events if $M_{\tilde{W}} = 60$ GeV/c² in a $\int \mathcal{L} dt = 10^{40}$ cm⁻² run.

Backgrounds arising from high p_T scattering have been studied, but those arising from W decay have not yet been evaluated. To collect the above numbers of signal events, one must run at $\mathcal{L} = 10^{33}$ cm⁻² sec⁻¹. The effects of pile up

are simulated by degrading the energy resolution by a factor of 2. A proper treatment of the pile up will be undertaken shortly.

The background rejection procedures were similar to those used in the $p + p \rightarrow \tilde{\gamma} + \tilde{q}$ case. $p_T^{\text{MAX LEPT}} < 2 \text{ GeV}/c$, $p_T^{\text{vis}} > 20 \text{ GeV}/c$, $X_E < .2$, and various event shape requirements were imposed. The uncertainties were also similar: t -quark backgrounds and lack of statistics with the latter problem even worse because the required rejection was higher than in the $p + p \rightarrow \tilde{\gamma} + \tilde{q}$ case. It appeared possible to reduce the residual backgrounds to about 22,000 events, but this must be verified by higher statistics studies which also include background contributions from W decay.

Table I shows the various contributions from signal and background. If the backgrounds are as estimated, it should be straightforward to pull the 18400 event $60 \text{ GeV}/c^2$ signal out by subtracting data with opposite pp polarization. Even if the backgrounds are 10 times worse than estimated, it should be possible to see a $40 \text{ GeV}/c^2$ signal. As $M_{\tilde{q}}$ falls further, the cross-section rises and the signature continues to improve, although not as quickly.

V. Future plans. The most critical need in the present series of SUSY studies is for a better determination of the background. Accordingly a very large Monte Carlo run, equivalent to a more than ten-fold increase in previously available statistics is currently in progress. The p_T sampling will be improved in a way that should further suppress fluxuations.

A second area of potential improvement lies in the jet reconstruction algorithms. At present this is quite crude. The sphericity axis based on all measured momenta is found and the event is divided into two hemispheres by the plane perpendicular to this axis. Then all 3-momenta in each hemisphere are

summed vectorially to give two "jet" vectors. This may be adequate when the actual situation approaches that of two collimated jets roughly balanced in p_T (e.g., gluino pairs at p_T high wrt $M_{\tilde{g}}$). However, it is clearly a poor approach in two of the cases discussed in this report. Therefore, test of more sophisticated algorithms, e.g., Babcock and Cutkowski¹² will soon be made.

We intend to continue our progress toward making the detector more realistic. For example, subroutines to simulate shower leakage are now being tested. We should also like to study the trade-offs between calorimeter resolution and speed at high luminosity. We would also like to study what improvement in high luminosity performance can be made if timing information from each calorimeter element is used.

Finally we discuss physics topics to be studied in the future. The process $p + p \rightarrow \tilde{g} + \tilde{q} + X$ needs to be restudied, particularly after better jet-finding algorithms are in place. Aside from calculating the production cross-section² we have never even considered the case $M_{\tilde{g}} > M_{\tilde{q}}$. In addition $p + p \rightarrow \tilde{q} + \tilde{q} + X$ needs to be reviewed as we did not include a potentially important diagram resulting from gluino exchange which converts two quarks into two scalar quarks¹³.

A more general study of possible supersymmetric decays of the W needs to be made. Aside from obvious improvements in the wino study discussed above, one should consider the leptonic decay modes $\tilde{W} \rightarrow e\tilde{\nu}$, $\tilde{\nu}e$ etc. If the $W \rightarrow e\nu$ signal can already be clearly detected¹⁴ at $\mathcal{L} = 10^{28} \text{ cm}^{-2} \text{ sec}^{-1}$, perhaps the 25 times less copious $W \rightarrow \gamma \tilde{W} \rightarrow \gamma \tilde{W} \rightarrow e\nu$ signal can be detected at $\mathcal{L} \geq 10^{32}$ as at CBA. In

addition the W can go directly to $\tilde{\ell}\tilde{\nu}$ and $q_2/3q_1/3$ with about 1/2 the corresponding normal particle branching ratios if the various SUSY masses allow it. Such signals would probably be far easier to detect than wino decays.

Barnett et al.¹⁵ have pointed out that if $\tilde{\nu}$ are heavy they are likely to have some phenomenologically interesting decay modes. This could, for example, enhance the chances of observing $\tilde{W} \rightarrow e\tilde{\nu}$.

REFERENCES

1. S.H. Aronson, et al., "Detecting Supersymmetric Hadrons", Proceedings of the 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities, Snowmass, CO. June 28 - July 16, 1982 p. 505.
2. I. Hinchliffe and L. Littenburg, "Phenomenological Consequences of Supersymmetry", Proceedings of the 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities, Snowmass, CO., June 28-July 16, 1982 p. 242.
3. F.E. Paige and S.D. Protopopescu, "ISAJET: A Monte Carlo Event Generator for pp and $\bar{p}p$ Interactions", Proceedings of the 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities, Snowmass, CO., June 28-July 16, 1982 p. 471.
4. As explained in reference 1, $\vec{p}_T^1$ and $\vec{p}_T^2$ are the vector sums of the detected p_T 's in two opposite hemispheres defined w.r.t. with the sphericity axis of the event. By definition $|\vec{p}_T^1| > |\vec{p}_T^2|$. Normally the quantity referred to as p_T^{vis} (as in Fig. 1) is $|\vec{p}_T^1|$.
5. C.D.F. Detector Proposal
6. R807 Note 210, 9/27/80.
7. W.-Y. Keung, private communication.
8. J. Ellis, L. Ibanez, and G.G. Ross, Phys. Lett. 113B, 283 (1982).
9. See e.g. Ref. 2.
10. S. Deser and B. Zumino, Phys. Rev. Lett. 38, 1433 (1977) and references therein.
11. S. Weinberg, Phys. Rev. Lett. 50, 387 (1983). R. Arnowitt, A.H. Chamseldine and Pran Nath, Phys. Rev. Lett. 50, 232 (1983).

12. J.B. Babcock and R.E. Cutkowski, Nucl. Phys. B176, 113 (1980).
13. P.R. Harrison and C.H. Llewellyn Smith, Nucl. Phys. B213, 223 (1983).
14. G. Arnison, et al., Phys. Lett. 122B, 103 (1983).
15. M. Banner, et al., Phys. Lett. 122B, 476 (1983).
16. R.M. Barnett, K.S. Lackner and H. Haber, SLAC-PUB-3066 (1983).

Figure Captions

1. p_T^{vis} distribution of $p + p \rightarrow \tilde{g} + \tilde{g} + X$ events where $m_{\tilde{g}} = 100$ GeV/c^2 . Dashed line gives the corresponding distribution for background events. Missing momentum and lepton veto cuts have been imposed on both samples.
2. Fraction of event energy registered by calorimeters versus delay time.
3. p_T^{vis} for $p + p \rightarrow \tilde{g} + \tilde{g} + X$, $M_{\tilde{g}} = 75$ GeV/c . Solid histo gives the 0 rate case, the dashed histo $\mathcal{L} = 2 \times 10^{32}$ and the dotted histo $\mathcal{L} = 10^{33}$. Cuts of $X_E < .5$, $p_{\text{out}} > 5$ GeV/c , and $p_T^{\text{MAX LEPT}} < 2$ GeV/c have been imposed.
4. Diagrams for $g + q \rightarrow \tilde{\gamma} + \tilde{q}$.
5. Distribution of X_E for $p + p \rightarrow \tilde{\gamma} + \tilde{q} + X$ for $M_{\tilde{q}} = 60$ GeV/c^2 (solid histogram) and $M_{\tilde{q}} = 100$ GeV/c^2 (dashed histogram). Also shown is the background (dotted line). Cuts on $p_T^{\text{vis}} (> 35$ $\text{GeV}/c)$, $p_T^{\text{LEPT MAX}} (> 2$ $\text{GeV}/c)$, event shape, etc. have been imposed.
6. X_E distributions for $\tilde{\gamma} \tilde{cs}$ decays of 40 and 60 GeV Winos.

TABLE I

Cuts	Trigger Rate (mb)		
	= 0	2×10^{32}	10^{33} Trigger
Level	$.40 \times 10^{-2}$	$.93 \times 10^{-2}$	1.26×10^{-2}
$X_E < .5$	$.02 \times 10^{-3}$	$.26 \times 10^{-3}$	$.56 \times 10^{-3}$
$P_{out} > 5 \text{ GeV}/c$	$.03 \times 10^{-3}$	$.41 \times 10^{-3}$	2.28×10^{-3}
$P_{out} > 10 \text{ GeV}/c$	$.08 \times 10^{-5}$	$.40 \times 10^{-5}$	11.3×10^{-5}
$X_E < .5, P_{out} > 5 \text{ GeV}/c$	$.35 \times 10^{-5}$	$.43 \times 10^{-5}$	10.7×10^{-5}
$X_E < .5, P_{out} > 10 \text{ GeV}/c$	$.20 \times 10^{-6}$	$.12 \times 10^{-6}$	1.73×10^{-6}

TABLE II

Contributions to Wino Signal and Background

Light Constituent Background	$2.0 \times 10^{-9} \text{ mb}$
$t\bar{t}$ background	1.8×10^{-10}
$60 \text{ GeV}/c^2 \tilde{W} \rightarrow \tilde{\gamma} u \bar{d}$	6.1×10^{-10}
$\quad \quad \quad + \tilde{\gamma} c \bar{s}$	9.6×10^{-10}
$\quad \quad \quad + \tilde{\gamma} t \bar{b}$	2.8×10^{-10}
$40 \text{ GeV}/c^2 \tilde{W} \rightarrow \tilde{\gamma} u \bar{d}$	2.4×10^{-9}
$\quad \quad \quad + \tilde{\gamma} c \bar{s}$	6.3×10^{-9}
$\quad \quad \quad + \tilde{\gamma} t \bar{b}$	5.8×10^{-9}

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