Detection of Supersymmetric Charged Gauge Boson through its Leptonic Decay Mode at the SSC

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Summary

The detection possibility of the supersymmetric charged gauge boson (wino) through its leptonic decay mode is discussed.

Introduction

Supersymmetric gauge theory predicts the existence of a superpartner to every ordinary particle, with its spin differing by 1/2. As a partner of the charged intermediate vector boson W, there may exist a particle called wino. It is a spin 1/2 heavy lepton. In this note we discuss the detection possibility of intermediate mass wino at the SSC. We assume that photino is the lightest supersymmetric particle with mass zero and stable enough to go through the detectors.

The wino will be produced by the processes :

p + p ---> wino + gluino + anything, -------- (1)
p + p ---> wino + squark + anything, -------- (2)
p + p ---> wino + photino + anything. -------- (3)

Wino can decay into various final states, for example, into a lepton-sneutrino pair, slepton-neutrino pair, quark-squark pair, W plus photino or W plus zino. It is not possible, however, to know the branching ratios for these decays, unless we assume a model for masses of all supersymmetric particles. Here we assume that wino mass is small compared to the masses of squarks, sleptons and gluino. As a consequence, wino will decay predominantly into W plus photino. W is assumed to be detected by the leptonic decay modes.

The production cross sections for reactions (1) and (2) are larger than that of reaction (3) approximately by the ratio of the strong to the electromagnetic coupling constant. The event signature for reactions (1) and (2) are more complicated: The gluino will finally decay into photino plus a quark-antiquark pair. As a consequence, the event contains a hadronic activity, missing transverse momentum and a lepton. This signature is probably less favorable when considering possible QCD background processes.

On the contrary, in the the reaction (3), photino will escape detection if photino is stable. This process provides a distinctive signature: a single lepton and a large missing transverse momentum.

We study the possibility to detect this process using ISAJET event generator.

Signal and Backgrounds

The signature for wino described in the previous section is a single lepton and a large missing transverse momentum. Potential backgrounds for this signature are;

(a) Single production of W, W decays leptonically.
(b) Pair production of W and Z, W decays leptonically and Z decays into a neutrino pair.

In both processes, a single lepton appears accompanied by a large amount of missing transverse momentum.

These events were studied using ISAJET version V5.2 Monte Carlo event generator. Electron is selected as a lepton. The cross sections for the signal and the background processes are given in Table 1. The cross section for the signal process depends on the wino mass. Here we chose the mass of wino as 250 GeV and 500 GeV.

The single W production cross section multiplied with the branching ratio to electron plus neutrino is about 10^4 times larger than the signal. The process (b) is almost comparable to the signal. We discuss the event topology for the signal and backgrounds below.

The spectra of the transverse momentum of electron and missing transverse momentum are shown in Figs.1 and 2. The Jacobian peak can be seen around 40 GeV for the single W production. For the pair production of gauge bosons, the peak exists around 30 GeV for electron transverse momentum and around 40 GeV for missing transverse momentum. For wino production, the peak is about 30 GeV for electron and about 50 GeV for missing transverse momentum. In the latter two cases, the shapes are quite similar to each other. The spectrum has a long slope at the larger side. On the other hand, for the single W production, the spectrum falls steeply after Jacobian peak. If we cut the electron and missing transverse momentum at 60 GeV, the background by single W events will be reduced to 3.3% and 3.5% respectively. If we cut at 100 GeV, it further reduces to 0.55% and 0.51%. If we apply that cut simultaneously, the W background reduces to 0.31% at 60 GeV cut and 0.04% at 100 GeV cut.

Another distinguishing quantity is a transverse mass (M_T) of the electron and a missing transverse momentum system. The transverse mass is defined as

$$M_T = [\, 2\, P_T(e)\, P_T(m)\, (1-\cos(\phi))\,]^{1/2},$$

where

$P_T(e)$ = transverse momentum of electron,
$P_T(m)$ = missing transverse momentum,
ϕ = angle between electron and missing momentum in the transverse plane.

The spectrum of M_T is shown in Fig.3. The peak is seen around 80 GeV for the single W production and falls rapidly after the peak. The single W events can be reduced to 2.5% by the cut at 90 GeV, and to 0.60% by the cut at 100 GeV. When calculating the transverse mass, if we use only those events in which both the electron transverse momentum and the missing momentum are larger than 100 GeV, the single W events is further reduced to 0.04%. For the single W production, the transverse mass is restricted by the mass of W. It cannot exceed the W mass in principle.

Conclusion

The detection of wino at the SSC was studied through the process of pair production of wino and photino. Two types of processes are studied as backgrounds. One is the single W production and the other is the pair production of W and Z.

The event topology for the single W production is different from that of the signal. The cut for the transverse mass of electron and missing transverse momentum is effective to eliminate the single W production. The cut for transverse momentum of electron and missing transverse momentum is also effective.

For the pair production of W and Z, it is rather difficult to distinguish the signal from background, because two process are similar in kinematics. But for sufficiently large transverse momentum range, we can see the excess of the signal from backgrounds. If the cut of 300 GeV is applied to the transverse mass, the expected number of events which exceed the threshold at an integrated luminosity of 10^{40} cm^{-2} are;

11 events for wino+photino (wino mass = 250 GeV),
63 events for wino+photino (wino mass = 500 GeV),
52 events for W+Z pair production.

If the threshold is raised to 400 GeV,

1.1 events for wino+photino (wino mass = 250 GeV),
28 events for wino+photino (wino mass = 500 GeV),
0.4 events for W+Z pair production

will be observed.

Table 1

Cross Sections

(1) P + P –> W + anything, W –> electron + neutrino	: 45 nb
(2) P + P –> W + Z + anything, W –> electron + neutrino, Z –> neutrino pair	: 0.89 pb
(3) P + P –> wino + photino + anything, wino —> W + photino, W –> electron + neutrino	: 0.22 pb for 250 GeV Wino : 0.05 pb for 500 GeV Wino

Fig. 1(a)

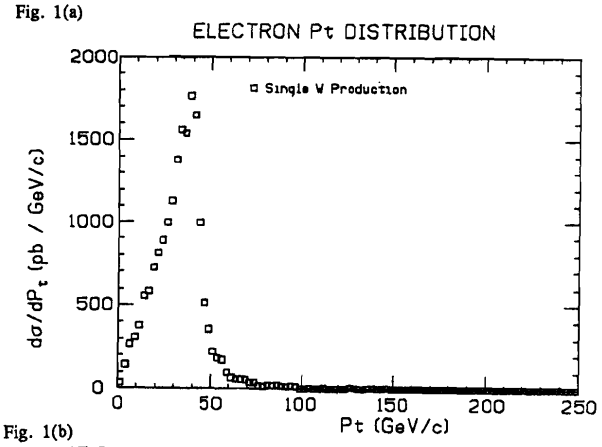

Fig. 1(b)

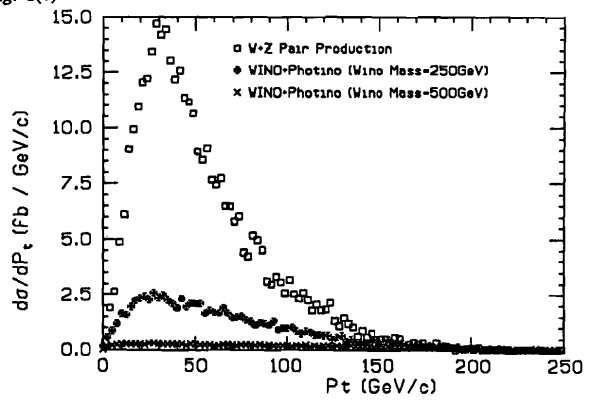

Figure 1 Electron P_T distribution for the processes (a) single W production and (b) pair production of W+Z, wino+photino.

Fig. 2(a)

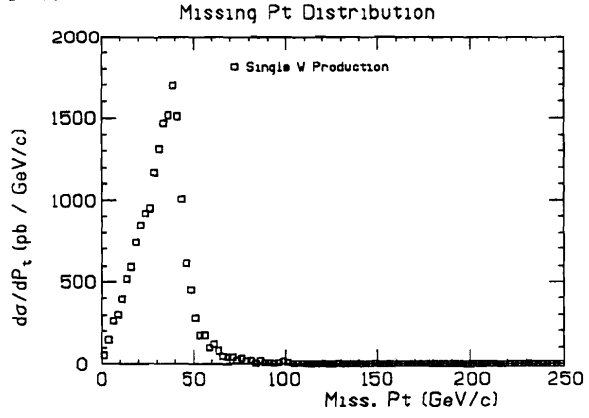

Fig. 2(b)

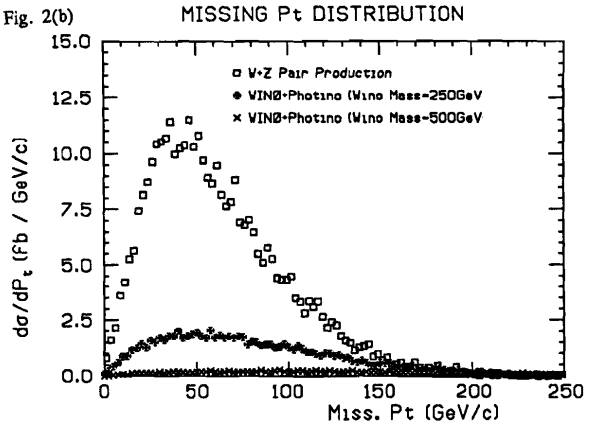

Figure 2 Missing P_T distribution for the processes (a) single W production and (b) pair production of W+Z, wino+photino.

Fig. 3(a)

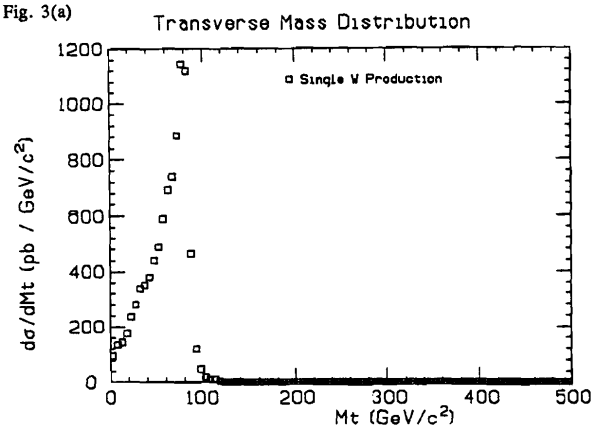

Fig. 3(b)

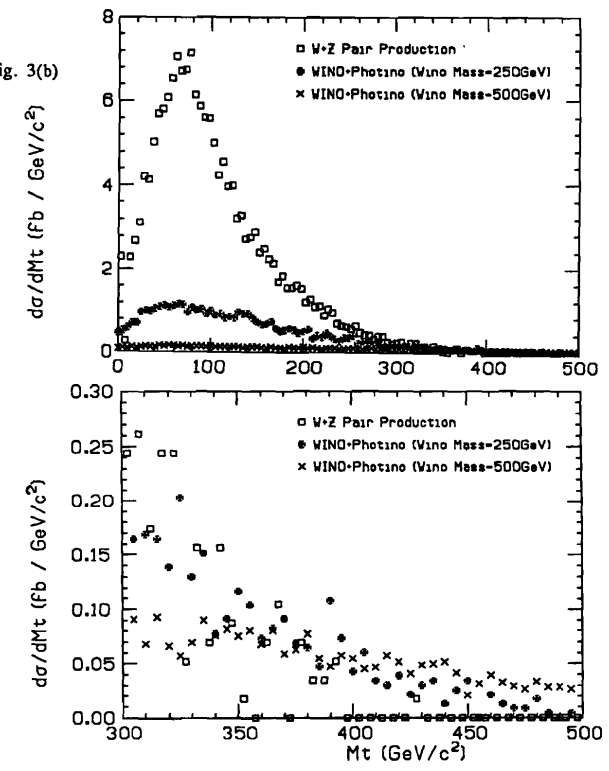

Figure 3 Transverse mass of electron and missing transverse momentum system for the processes (a) single W production and (b) pair production of W+Z, wino+photino.