§ 1. Introduction

The standard model (SM) is very successful in describing low energy phenomena. It predicts the existence of W and Z bosons with unique properties, which have been confirmed experimentally as a whole. It is sure that the SM reflects some essential features of Nature, including the gauge boson nature at low energy of the W(Z). However, it is also sure that the SM cannot give a natural explanation to several important facts, such as the baryon asymmetry of the Universe (BAU), the existence of cold dark matter (CDM) and neutrino oscillations. In addition, the SM suffers from the naturalness problem due to the existence of fundamental Higgs fields.

As a candidate of physics beyond the SM, supersymmetric (SUSY) extensions of the SM, including SUSY GUTs, have been studied by many physicists. However, SUSY models have encountered serious problems. The proton decay has not been observed even at the Superkamiokande.\(^1\) Now, we know that \(\tau_{\nu_e} = (p \rightarrow e^+ \pi^-) \times 10^{17}\) yr and \(\tau_{\nu_\tau} = (p \rightarrow \nu \bar{\nu}^\prime K^0) \times 5 \times 10^{17}\) yr. In these models, such a longevity of proton is hard to explain in a simple and natural way.\(^2\) Of course, because of the existence of the BAU, baryon number non-conserving processes must exist. The model required by Nature would be that in which the apparently puzzling facts, the BAU and the stability of proton, are reconciled. The existence of stable weakly-interacting-massive-particle (WIMP) relies on a rather ad hoc assumption, the conservation of R parity, and is

Preon model with preonic charge predicts many unique new particles. Among them, several are expected to be relatively light, including fermion \(l_1\), which is a stable WIMP, bosons \(U^*\) and \(U^-\) and lepto-quark fermion \(q^*\). Production of them in \(e^+e^-\) and \(\bar{p}p\) collisions are discussed, focusing on \(e^+e^-\rightarrow U_1\) and \(\bar{p}p\rightarrow q^* q^* + X\). A signature of the latter is dilepton + 2 charm jets + missing energy. A discussion on reported unusual events in the dilepton + jets sample is made based on \(q^* q^*\) productions.
not a necessary consequence of the model. What stable particles 
are in one of the fundamental properties of model and therefore 
should be a necessary consequence of it. The Higgs boson (usually 
called h) should be light. In the foreseeable future, this will 
be fully tested. However, even the present lower limit on the h 
mass, if combined with other constraints, gives rise to a severe 
problem, namely, color and charge breaking vacua arise at least 
in the most desirable case, MSSM with low tan β. Moreover, we 
believe, the facts of fundamental importance such as the color 
and charge conservations should be a necessary consequence of 
the model itself, and must not be parameter-dependent. The prin-
cipal content of model is expressed by what conservation laws it 
possesses and the quality of model is determined by how the 
conservation laws are guaranteed. In the SM the observed CP vi-
lations can be accommodated through the Kobayashi-Maskawa me-
chanism, though the fundamental origin of CP violations remains an 
open problem. In SUSY models the situation becomes worse: the 
origin of CP violations is still unsettled, and even the success 
of the Kobayashi-Maskawa mechanism is a mystery because many 
other sources of CP violations exist in SUSY models.

The author strongly feels that SUSY models do not succeed in 
explaining, with simplicity and naturalness, the principal fea-
tures of Nature. Of course, in order to draw a definite conclusi-
on on the validity of SUSY models, it is necessary to make clear 
whether superpartners with a mass below 1 TeV exist or not. Fu-
ture experiments at LHC will be powerful in this respect. Howev-
er, it will be worthwhile to propose and study, at the present 
stage, other models free from the defects mentioned above. A 
true model or theory of Nature could be found through comparing 
different types of model in various experiments, such as the 
proton decay experiments, the dark matter search experiments and 
the accelerator experiments.

One of the ways to go beyond the SM is, along the line of the 
atomic view, to consider that leptons, quarks and weak bosons 
are composites of more fundamental matter, namely to take a full 
preon model. Recently we have developed a full preon model by 
introducing preons with charge e/2 and the preon charge which 
is identified with the magnetic charge. All preons also 
carry a common color magnetic charge which is a source of the 
color magnetic field. In our model the gauge theories can be 
developed to those with magnetic charges owing to the simple and 
beautiful properties of preons. Preonic charge is responsible 
for binding preons. In the model a formation of bound states 
with a mass much less than the inverse of its radius is expected 
since the interaction among preons are super-strong even at a 
short distance. Bound states of preons are conjectured to behave 
as a string at a long distance due to a formation of magnetic 
flux tube through the Weisssner effect. Through the well-known 
mechanism, W bosons behave as gauge bosons at low energy, an 
energy much lower than the mass scale typical to preon dynamics.
$\Lambda \sim 1000 \text{ TeV}$. The identification of preons with dyons leads to that preons cannot be the most elementary particles. In our model preons are constructed from subpreons. Ad hoc quantum numbers, $B$ and $L$, the conservations of which are not guaranteed by a gauge principle, are defined when preons are constructed from subpreons. Subpreons are free from such ad hoc quantum numbers and their conservations are guaranteed by the gauge principle. In our model fundamental matter, subpreons, are all specified by conserved gauge charges. Model of this type would be a desirable one from the viewpoint of the gauge principle. At the preon level, lepton and quark are unified, including the CDM particle, but gauge interactions are not. A complete unification of matter and interactions would be accomplished by the gauge principle based on simple subpreons.

The model has some interesting features, such as the explanation of charge quantisation and color-charge relation\(^6\), the natural existence of CP violation\(^7\), and understanding of quark masses, CDM matrices and CP violation effects in weak interactions\(^7\). A nearly maximal $\nu_\mu - \nu_\tau$ mixing is realized in a simple way.\(^{11}\) While CP violation effects are necessarily a tiny one at a long distance, they become comparable to those of CP conserving interactions at a short distance due to the running of the coupling constants. Remarkable features of the model are that there exists naturally a stable weakly interacting massive particle (WIMP) (called $l_1$), which behaves as CDM in the Universe, and that the proton becomes stable despite the existence of baryon number non-conserving processes\(^8\). In our model the existence of CDM and the stability of proton are directly related.

This model predicts many new particles. Confirmation of their existence is crucial to establish the model. In this paper we shall discuss the production of some of them in $e^+e^-$ and $\bar{p}p$ collisions. In the next section $l_1$ and $U$ productions in $e^+e^-$ collisions are discussed, focusing on single $U$ boson productions, and pair productions of lepto-quark fermion, $q'$, in $\bar{p}p$ collisions are studied in section 3, where a discussion is made on reported unusual dilepton + 2 jets events. The final section is devoted to some remarks.

§2. $l_1$ and $U$ productions in $e^+e^-$ collisions

Among predicted new particles, those expected to be relatively light are $l_1$, $q'$ and $U^-$ which are connected with the neutrino, the down-type quark and the $W$ boson, respectively, through an approximate symmetry inherent in our model (the $K$ symmetry\(^9\)). $l_1$ is a fermion without $B$ and $L$ number which is completely neutral under the $SU(2)$ gauge group. The lightest of three family $l_1$'s is stable. $q'$ is a color triplet and weak-isospin singlet fermion with both $B$ and $L$ number and charge $-e/3$, which decays to quark + lepton + $l_1$. We call $q'$ lepto-quark fermion. $U^-$ is a colorless vector boson with $L$ number; together with a neutral vector boson $U^0$. $U^-$ forms a weak isospin doublet ($U^-, U^0$). In our model there exists a relatively light neutral vector boson $U_1$, which is
a member of a vector boson octet containing $V(Z)$ and $U^s$. The
classical $U^s$ is represented by $d_1$, $s_1^+$, and $s_1^-$. The
mass of $U^s$ is expected to be roughly $1$ TeV.\(^{12}\)

1. $U$ and $q'$ are related to lepton and quark through the ver-
tices, $q' - U^s - \bar{d}$, $q' - U^s - \bar{u}$, $v - U^s - \bar{t}$, and
(charged lepton ) $- U^s - \bar{l}_s$, where $d(u)$ denotes the
down-type(up-type) quark. The
interaction lagrangian for these vertices is as follows:\(^1\):

$$
L = e \gamma_{\mu} (\bar{U}^s \gamma^\mu U^s) \bar{d}_{\mu} \gamma^\mu \bar{d} +
L = e \gamma_{\mu} (\bar{U}^s \gamma^\mu U^s) \bar{d}_{\mu} \gamma^\mu \bar{d} +
L = e \gamma_{\mu} (\bar{U}^s \gamma^\mu U^s) \bar{d}_{\mu} \gamma^\mu \bar{d},$$

where $\mu\equiv (V-A)_\mu$ and $i$ is the family index. Since $q'$ is rather
heavy as seen below, charged (neutral) $U$ bosons dominantly decay
to charged lepton (neutrino) + $l_i$: $U^s - \bar{e}' + l_i$, $\mu^\prime l_i$ and $\tau^\prime +

2. Strictly speaking, $l_i$ in Eq. (1) is a weak eigenstate and
not a mass eigenstate. For a detailed study of phenomenology of
new particles, it is necessary to take into account mixings among
them.\(^7\) In this paper we neglect them for simplicity. $l_i$ is a
stable WIMP so missed experimentally. The ortho-para mixing
model for family mixing, together with the $X$ symmetry,\(^7\) implies
that the mass of $l_i$ is very close to that of $l_i$. Hence,
the dominant decay mode of $l_i$ is expected to be $l_i \rightarrow \bar{e}' v$. Thus
$l_i$ also behaves as a missing particle in accelerator experimen-
ta. There is a possibility that the decay of $l_i$ produces charged
particles. However, if we restrict ourselves to high energy par-
ticles produced through a primary decay of $U$ bosons, we could
ignore effects of the decay of $l_i$. In this case all $l_i$ can be
treated as missing particles in accelerator experiments. Hereafter
we omit a family index for $l_i$ so long as there is no necess-
ity. (In what follows we assume for simplicity that the masses of
$U^s$ and $U^s$ are equal ($M_U$).

Since $l_i$ is a CDM particle and its interactions are mainly
controlled by $U$ boson exchanges, the cosmology imposes a rather
strong constraint on their properties. In the previous papers,\(^4\)
using $Q_s$ and $n_s$ in those days, we determined from the require-
ment $Q_s < 1$ that the mass of $l_i$,\(^1\) (hereafter we denote $m_i$) is se-
veral-10 GeV, where $Q_s(Q_s)$ is the baryon density (matter density
) in the unit of critical density and $H_0$ is the present-day
Hubble constant. However, the values of these quantities have
been significantly altered due to the progress in the observati-
onal cosmology. Now we have that $Q_s h^2 = 0.004-0.02$,\(^11\) where
$h = H_0 / 100$ km/s/Mpc. As for $n_s$, recent observations suggest
that $n_s = 65 \pm 10$ km/s/Mpc.\(^15\) Using these values, we obtain through
the same procedure as in Ref.\(^6\) that $m_i = 30-300$ GeV and $M_U =
91.5-230$ GeV (the lower limit of $M_U$ comes from the non-observa-
tion of $U$ boson at LEP 2 so far). It is interesting that, since
the $l_i$-nucleon scattering occurs mainly through the exchange of the
predicted $D_1$ boson, its cross section is $O(10^{-45} \text{cm}^2)$ for $D_1$ of
about 1 TeV mass\(^9\)-\(^12\) and therefore within a reach of the
current dark matter search experiment.\(^13\) The allowed range of
$m_i$, especially the upper bound, depends on how preons are con-
structed from subpreons. By modifying slightly the model in Ref.\(^6\)
the upper bound of $m_i$ increases to 40 GeV. This point will be
discussed elsewhere.
The simple processes expected to be observed in $e^+e^-$ collisions at LEP 2 (if kinematically allowed) are:

\[ e^+e^- \rightarrow \mu^+\mu^- \rightarrow \text{charged lepton pair + missing energy} \]

\[ \rightarrow \ell^+\ell^- \gamma \rightarrow \text{single photon + missing energy} \]

and

\[ \rightarrow (\ell^+\ell^-)\bar{\nu}\nu \rightarrow \text{single charged lepton + missing energy.} \]

The first process, the most adequate one to study $U^*$ bosons, has been already discussed.\(^5\) If $M_{U^*}$ is lower than the beam energy ($\approx E_{\gamma\gamma}$), the existence of $U^*$ boson could be easily confirmed. Since charged $U$ decays dominantly to charged lepton+$\nu$s, while no anomaly is predicted in events with quark jets, a clear excess of charged lepton pair events with missing energy over those from $e^+e^- \rightarrow W^-W^+ \rightarrow \text{charged lepton pair + neutrino}$ would be expected with $e^+e^- \rightarrow \mu^+\mu^- \rightarrow \text{charged lepton pair + neutrino}$ being the most probable. The rate of events with $\tau$ leptons depends on the mass of $\tau^\pm$. The cross section of $e^+e^- \rightarrow U^*U^* \rightarrow \tau^+\tau^-$ rises rapidly above the threshold.\(^6\) The experiments have shown no excess at $E_{\gamma\gamma} = 91.5$ GeV, which implies $M_{U^*} > 91.5$ GeV.

The second process has also been discussed in Ref. 12. The signature of this process is an excess of single photon events with missing energy over the standard model process $e^+e^- \rightarrow \gamma \nu\bar{\nu}$. Since $D_1$ boson is much heavier than $U$ boson, the process occurs via $U^*$ exchange and so the cross section $\sigma(e^+e^- \rightarrow \ell^+\ell^-\gamma)$ is roughly $(M_{U^*}/M_{D_1})^2 \times \sigma(e^+e^- \rightarrow \ell^+\ell^-\gamma)$ (with $W$ boson exchange) in the approximation of neglecting effects of the massiveness of $D_1$. Unless $E_{\gamma\gamma}$ is much larger than $M_{U^*}$, this means that the cross section rapidly decreases with $M_{U^*}$ for $E_{\gamma\gamma} < 100$ GeV. The measurements of single photon events with missing energy have been performed with a high integrated luminosity ($\sim 300$ pb$^{-1}$) at TRISTAN and no excess has been reported.\(^1\) This may imply that $M_{U^*}$ is near $E_{\gamma\gamma}$ at TRISTAN ($\sim 29$ GeV) or $M_{U^*}$ is high (say $>120$ GeV) or both.

At LEP 2 the effect of massiveness of $D_1$ is small and $\sigma(e^+e^- \rightarrow \ell^+\ell^-\gamma)$ depends mainly on $M_{U^*}$. For $M_{U^*}=110(130)$ GeV, it is $\sim 0.19(0.11)$ pb at $E_{\gamma\gamma}=100$ GeV for the photon energy $>4$ GeV and the photon polar angle $45^\circ \sim 135^\circ$. At the present stage, the constraint on $M_{U^*}$ is rather weak at LEP 2 due to a low integrated luminosity ($\approx$ a few ten pb$^{-1}$).\(^1\) For $M_{U^*} > 91.5$ GeV, the data available at present are not enough to confirm or exclude the existence of contributions from $\ell^+\ell^-\gamma$ productions. There are other models (e.g., supersymmetric standard model) which predict an excess of $\gamma$ + missing energy events. Hence, it will be hard to single out our model even if some excess is observed.

The last process, namely single $U$ boson production in $e^+e^-$ collisions, is also powerful to confirm our model. The signature of this process is an excess of single charged lepton events over $e^+e^- \rightarrow (\ell\nu\bar{\nu}) \rightarrow (\ell\nu\bar{\nu}+c,\bar{c})$ charged lepton and no excess of jet events, since the decay modes of charged $U$ boson are charged lepton+missing energy. Our model predicts a lower value for the ratio of the number of events with 2 jets to that with charged lepton than the one in the $W$ decay. 2. It is a unique point of this process that, even if $M_{U^*} > E_{\gamma\gamma}$, $U$ boson could be studied.
The process occurs at the tree level via the diagrams in Fig. 1.

Fig. 1

The cross section of this process is given dominantly by Figs. la and lb with the intermediate photon being near the mass shell. In this case the final state electron (or positron) is produced at very low polar angle and therefore not detected experimentally. \( \ast \) denotes such an electron or positron in this paper. Here we discuss the cross section only in this kinematical region using the equivalent photon approximation (EPA). The vertex \( \gamma \rightarrow U^\pm - U^- \) are given in Ref. 9). The cross section is significantly dependent on \( M_U \) but is rather insensitive to \( m_e \) so long as \( m_e \ll M_U \) and the sum of \( m_e \) and \( M_U \) is sufficiently less than \( 2E_{\gamma \ast \ast \ast} \).

For a rough estimation of the cross section, we approximate here that \( l_1 \) is massless. In the EPA, we have, using the differential cross section for \( e^+e^- \rightarrow (e \gamma \rightarrow U l_1) \),

\[
\frac{d\sigma}{dt}(e^+e^- \rightarrow (e \gamma \rightarrow U l_1)) = \frac{\sigma(e^+e^- \rightarrow (e \gamma \rightarrow U l_1))}{\sigma(e^+e^- \rightarrow (e \gamma \rightarrow U l_1))}.
\]

where \( \gamma \rightarrow E_{\ast \ast \ast} \) and the photon spectrum \( f_{\gamma \ast \ast \ast}(y) \) is given by for photons which are off shell by less than \( Q^2_{\ast \ast \ast} \).

\[
f_{\gamma \ast \ast \ast}(y) = \frac{y^2}{2\pi} \left[ \frac{1 + (1 - y)^2}{y} \log(Q^2_{\ast \ast \ast} / m_e^2) - 1 \right] \log^{1/2}(1 - y) / y^2 \log[(1 - y)/(Q^2_{\ast \ast \ast} / E_{\ast \ast \ast}^2)].
\]

(4)

For \( d\sigma / dt \), we have in the approximation of massless \( l_1 \).

\[
d\sigma / dt(e^+e^- \rightarrow U l_1) = \sigma / (s_u - M_u^2)^2 \left[ \frac{(s_u - M_u^2)^2}{(s_u - M_u^2)^2} \right].
\]

(5)

where \( s_u \) and \( t_u \) are the Mandelstam variables of the process \( e^+e^- \rightarrow U l_1 \) and \( s_u = (P_e + P_e)^2 \) and \( t_u = (P_e - P_e)^2 \) and \( s_u \) is sine of the Weinberg angle. In Fig. 2, taking \( Q^2_{\ast \ast \ast} = 1.0 \) GeV\(^2 \) and \( \alpha \ast = 1/130 \),

Fig. 2

we plot \( \sigma(e^+e^- \rightarrow (e \gamma \rightarrow U l_1)) \) versus \( E_{\ast \ast \ast} \) for \( M_U = 110-130 \) GeV. In Fig. 3, \( \sigma(e^+e^- \rightarrow (e \gamma \rightarrow U l_1)) \) is also plotted. The cross sections are insensitive to the value of \( Q^2_{\ast \ast \ast} \).

The data on single charged lepton events with missing energy have been reported.\(^{25} \) According to the ALEPH data at \( E_{\ast \ast \ast} = 91.5 \) GeV with an integrated luminosity of 57 pb\(^{-1} \), \( \sigma(e^+e^- \rightarrow (e \gamma \rightarrow U l_1)) \) charged lepton (missing energy) = 0.14(0.07, 0.06) \pm 0.01 pb, which is compared with the SM prediction. 0.14 pb. Although the data are still preliminary, if we take the data at face value, \( \sigma(e^+e^- \rightarrow (e \gamma \rightarrow U l_1)) \) should be lower than 0.08 pb at \( E_{\ast \ast \ast} = 91.5 \) GeV. This requires that \( M_U > 100 \) GeV. \( M_U \) seems to be larger than the maximal \( E_{\ast \ast \ast} \) at LEP 2. In order to obtain experimentally an information about \( U \) boson, very high integrated luminosity would become necessary. If detection efficiencies and experimental conditions on momenta and scattering angles of detected charged lepton are neglected, in experiments at \( E_{\ast \ast \ast} = 100 \) GeV with an integrated luminosity of 200 pb\(^{-1} \), the number of excess events expected due to \( U \) production and its decay is \(~16\) for \( M_U = 110 \) GeV and \(~8\) for \( M_U = 120 \) GeV, which is compared with \(~38\) in the SM \( (\gamma \rightarrow e\gamma \rightarrow (e \gamma \rightarrow U l_1)) \).
The existence of the $U$ boson of mass as large as 120 GeV could be barely tested if an integrated luminosity of 500 pb$^{-1}$ is possible at $E_{\text{cm}} = 100$ GeV.

An excess of charged lepton + missing energy events could occur also in the SUSY SM, e.g., $e^-e^-(e^+\tilde{\tau}_1)$ and $-e^-\tilde{\nu}_\tau$. However, $U$ production could be distinguished from SUSY processes, since, in the former, an excess is predicted only in charged lepton events with an equal amount for electron and muon due to the fact that $U$ decays dominantly to charged lepton + $1\pi$ with nearly equal branching ratios (BR) of $U\to e$ and $U\to \mu$.

In order to discover unambiguously new particles through their productions, it is necessary for at least one of two conditions: large production cross sections and very unique signatures of new particle productions, to be satisfied. If $U$ bosons are light enough to be pair-produced at LEP 2, it will be relatively easy to confirm their existence at LEP 2. Otherwise, it may be a difficult task to confirm definitely $1\pi$ and $U$ in the processes discussed above, namely a small excess and non-unique signatures, although some signs of them might be found. $U$ bosons seem to be sufficiently heavy. The planned 500 GeV NLC would be needed.

§ 3. $q'q'$ productions in $\bar{p}p$ collisions

The production cross section of $q'q'$ pair in $e^-e^-$ collisions are very small because its weak-isospin is 0 and its charge is $-e/3$. $q'$ can be produced through the weak subprocess $e^-p\to q'1\pi$ (U exchange) in $e^-p$ collisions. If, fortunately, it is rather

light (say < 200 GeV, where $\sigma (e^-p\to q'1\pi) \sim 0.1$ pb or larger for $M_{q'} = 120$ GeV), HERA could discover $q'$ as discussed in the previous papers.$^5$

$q'q'$ pair can be produced through QCD subprocesses in $\bar{p}p$ collisions. $q\bar{q} \to q'q'$. Even if $q'$ is rather heavy, it could be discovered at the upgraded TEVATRON (and at LHC in the future). The production cross section of $q'q'$ pair is that of top pair$^{23}$ with the top mass = the $q'$ mass. There exist three family $q'$s: $q'_1$, $q'_2$, and $q'_3$. The ortho-para mixing model and the $K$ symmetry invariance imply that the mass difference between $q'_1$ and $q'_3$ is of the order of the strange quark mass.$^7$ Hence, at high energy, these behave as two degenerate states. Here, we assume the degeneracy of these two states and neglect $q'_3$ since it is expected to be heavier.

$q'_1$ and $q'_3$ decay as follows, neglecting the family mixing as a first approximation:

$$q'_1 \to u + \bar{U}^- \to u + l_1 + \bar{\ell}_1,$$

and

$$q'_3 \to d + \bar{U}^0 \to d + \bar{\nu}_1 + \bar{\ell}_1,$$

$$q'_2 \to c + \bar{U}^- \to c + l_1 + \bar{\ell}_1,$$

$$q'_2 \to s + \bar{U}^0 \to s + l_1 + \bar{\ell}_1.$$  \hspace{1cm} (6)

From the ortho-para mixing model for the family mixing and the $K$ symmetry, we obtain approximately for the CKM matrices for $dq'$ system $(V_{CKM}(dq'))$ and for $uq'$ system $(V_{CKM}(uq'))$ that $V_{CKM}(dq' \sim 1$ and $V_{CKM}(uq') \sim$ the CKM matrix for $ud$ system at least for first two entries. Therefore, neglecting the family
mixing is a good approximation. Hence the signatures of $q^- q^+$ production with a less background are opposite sign dilepton + 2 jets + WE (*missing energy). In particular, the signature, dilepton + 2 charm jets + WE, is interesting. Since $q^- q^+$ and $\bar{q}^- q^+$ are produced in an equal amount in $\bar{p}p$ collisions, the number of the latter is half that of new dilepton events originated from $q^- q^+$ productions. The major background is top quark decays. Since the top cannot decay to charm + lepton, an unexpectedly large amount of dilepton events with $\tau$-jet + c-jet could be considered to be an evidence of $\bar{q}^- q^+$ production.

The events of l + l + 2 jets with missing $E_T$ (transverse energy) in $\bar{p}p$ collisions have been reported by CDF and D0 collaborations,\textsuperscript{23} where $l$ is an energetic, isolated $e$ or $\mu$. Hereafter we take only $ee$, $\mu \mu$, or $e\mu$ as dilepton. In 110 pb$^{-1}$, the CDF collaboration observed ten such events, where six were expected from $t\bar{t}$ production and two were expected from non-top standard model backgrounds.

As stressed by Barnett and Hall,\textsuperscript{23} two of these events, Event A and Event B (named by the CDF Collaboration as Event 128886 and Event 380435, respectively) have characteristics which are quite unlike those expected from $t\bar{t}$ production, namely too high lepton $E_T$ and too high missing $E_T$, although a $t\bar{t}$ origin cannot be completely excluded. The existence of events with a very high lepton $E_T$ and very high missing $E_T$ suggests a parent particle of very high mass. If $q^+$ is much heavier than the top, such events would occur rather naturally in $q^- q^+$ productions (note that the $q^+$ decay properties are very similar to those of the top decay, $t \rightarrow bW^+ b\ell\nu$, except for the parent particle mass and jet property). One of the two events, Event A, is especially interesting. In it, there exists a lepton with remarkably large $E_T$ (181.8 GeV). The probability of the occurrence of such an event in $t\bar{t}$ production is very small. It may be a challenge to explain naturally the kinematical properties of Event A, which has $E_T(e^-) = 181.8$ GeV, $E_T(\mu^-) = 27.3$ GeV, $E_T(j_1) = 71.0$ GeV, $E_T(j_2) = 25.2$ GeV and missing $E_T = 107.2$ GeV. In addition, in this event, the energy of jet with lower $E_T$ seems to be carried mainly by an electron. If this event is due to $e\mu + c + \bar{c} + 1$ jets and c quark decays semileptonically to $E_T e^-$ with a very low energy strange quark, such a peculiar event may occur. Event $B$ has a rather mild lepton $E_T$, $E_T(e^-) = 105.6$ GeV and $E_T(\mu^-) = 52.5$ GeV (missing $E_T = 107.8$ GeV).

In $q^- q^+$ production, we have for the number of events (=N) of dilepton+two jets +ME that $N = 2\sigma(q^- q^+) \times [BR(q^- \rightarrow u\bar{t}-type quark + W^-)]^2 \times BR(U' \rightarrow ee, \mu \mu, e\mu + 1$ jet) $\times \epsilon \times$ integrated luminosity, where $\sigma(q^- q^+)$ is a production cross section for $q^- q^+$ or $\bar{q}^- q^+$ and $\epsilon$ the detection efficiency. Hence we obtain that $N \sim 5\times (\sigma(q^- q^+)/pb)$ for 110 pb$^{-1}$, where we take $\epsilon \sim 1/5$ and $BR(U' \rightarrow e^- \ell^+ 1\nu) = BR(U' \rightarrow \mu^- \ell^+ 1\nu) \sim 1/3$. If these two events are originated from $q^- q^+$ productions, we have that $\sigma(q^- q^+) \sim 0.4$ pb, which implies the mass of $q^+$ (mW) $\sim 240$ GeV. If only one event...
is due to $\bar{q}'q'$ production, $\sigma(\bar{q}'q') \sim 0.2 \text{ pb}$ and so $W \sim 250$ GeV. In such a value of $W$, lepton $E_l$ and missing $E_T$ in $q'$ decays become significantly higher than those in the top decay. Taking that, in Event A, $e^+(E_T=141.8 \text{ GeV})$ and $j_2(E_T=28.2 \text{ GeV})$ are decay products of $q'$, and $\mu^-(E_T=27.3 \text{ GeV})$ and $j_1(E_T=71 \text{ GeV})$ are those of $q'$. It is rather easy to reproduce kinematical properties of Event A including jet $E_T$ provided that $W \sim 240-250 \text{ GeV}$ and the mass of $U(\pm W) \sim 100-170 \text{ GeV}$. Of course, a higher $W$ is allowed from kinematical properties alone. However, in such a case, an event rate becomes too low. The upper limit for $W_0$ comes from the existence of high $E_T$ jet ($\pm 71 \text{ GeV}$). If $W_0$ is close to $W$, the jet energy becomes significantly low. In order to get a very high $E_T$ lepton, $W_0$ should be sufficiently large compared with $m_{\tau}$. Barnett and Hall$^{21}$ have proposed to explain these anomalous events based on SUSY models through scalar quark cascade decays. $\bar{q}' \rightarrow q x \rightarrow q v \bar{e}' \rightarrow q v e x'. Since, in this model, charged lepton is produced at the final stage in a three stage cascade decay, it has a tendency to have a lower $E_T$. In order to overcome this problem, a special mass pattern is required: the mass of $\bar{q}' \sim 300$ GeV, that of $x \sim 260$ GeV, that of $\bar{e}' \sim 220$ GeV and light $x'$ ($\sim 50 \text{ GeV}$). The similarity of the masses of $\bar{q}'$ and of $x'$ results in a rather low jet energy (and hence a rather low jet $E_T$). In the model the existence of high $E_T$ jet ($\pm 71 \text{ GeV}$) in Event A seems to be hard to explain naturally. In our model, the existence of high $E_T$ jet is natural, unless $U$ is very heavy. The reasons why our model can explain naturally Event A are that $q'$ decays via a two stage cascade, the $U$ mass does not differ greatly from the $W$ mass and $l'$ is sufficiently light.

Of course, from one or two events, we cannot draw any definite conclusion. More data are needed. At upgraded TEVATRON, high integrated luminosity experiments become possible. If charm quark tagging is done with high sensitivity, $q' \rightarrow q'$ productions can be confirmed through $(e\mu \bar{e}c+\text{ME})$ events and, through a detailed study of these events, properties of $U$ bosons will be also examined. If $W \sim 250 \text{ GeV}$, we expect at $\sqrt{s}=2 \text{ TeV}$ for integrated luminosity of $2 fb^{-1}$ and for detection efficiency of $1/5$ that the number of events of dilepton + 2 $c$-jets + ME $\sim 20$. Also in SUSY models, this event can occur through $\bar{q}' q g \rightarrow \bar{v} e x'$ with $x' \rightarrow c x - c v \bar{e}'(\bar{v}) - c v e(\mu) x'$. However, its production cross section is rather small and its kinematical properties are considerably different from the $q'$ decay. The combination of event rates and kinematical properties could distinguish rather easily our model from SUSY models.

$\S$ 4. Remarks

The existence of new physics beyond the standard model is strongly suggested by various facts. Several models have been already proposed. It may not be an overstatement that it is a model possessing a candidate for CDM that has a possibility to be a true model. It is a virtue of our model that there exists a natural candidate for CDM. The discovery of $l'$, $U$ and $q'$ in acc-
electron experiments is crucial to establish our model, as well as the confirmation of $\bar{q}'$ as cold dark matter by dark matter search experiments. The LHC and the planned 500 GeV NLC will be powerful in this respect. Whether $q'$ and $U$ exist or not will be made clear in experiments at these accelerators. However, observations of $\bar{q}'q'$ pair at upgraded TEVATRON might be a first evidence of new physics.

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References

1) M. Takita, Talk given at ICHEP 98, Vancouver.
2) For a recent review see.
15) B. Sadoulet, Talk given at NEUTRINO98.
Fig. 1 Tree level diagrams for $e^+e^-\rightarrow\mu^+\mu^-$. 

Fig. 2 Plot of $\sigma (e^+e^-\rightarrow\mu^+\mu^-)$ versus $\sqrt{s}$ for $M_{\mu\mu}$=10-130 GeV (solid line), where $w_{13}$=0.13, $\alpha$=-1/130 and $Q^2_{\mu\mu}$=1.0 GeV$^2$ are taken. $\sigma (e^+e^-\rightarrow\gamma\mu\mu)$ is also plotted.

            ALEPH Coll., ALEPH/98-923.
            K. Takigawa, private communication.
Fig. 1

Fig. 2