BOUNDS ON SUPERSYMMETRIC PARTICLES FROM A PROTON BEAM-DUMP EXPERIMENT

CHARM Collaboration

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ABSTRACT

Limits on the gluino and scalar quark masses were obtained in a proton beam-dump experiment. The results do not favour the existence of low mass gluinos (< 2 GeV) and scalar quarks (< 100 GeV).

Supersymmetric theories predict the existence of partners of ordinary quarks, leptons, and bosons, at a mass scale of 100 GeV which will become accessible with future generations of accelerators. However some of these models also predict particles with small mass. These are the supersymmetric partners of gluons and photons: gluinos and photinos[1]. Limits on the gluino mass derived from existing data have been discussed elsewhere[2].

A search for events induced by reactions involving gluinos and photinos was performed by the CHARM Collaboration in a proton beam-dump experiment[3]. As shown in Fig. 1, the gluinos could be produced by the proton-nucleus collisions in the copper dump ($pN \rightarrow \tilde{g}\tilde{g}X$). If the gluino is heavier than the photino, it decays into a photino and hadrons according to the reaction $\tilde{g} \rightarrow \tilde{\gamma}q\bar{q}$. The photino reaches the CHARM detector, where it interacts producing a gluino ($\tilde{\gamma}q \rightarrow \tilde{g}q$). Since a photino interaction resembles a neutral-current neutrino interaction, the number of events induced by the described chain was established from the muonless events in excess of those expected from neutrino interactions.

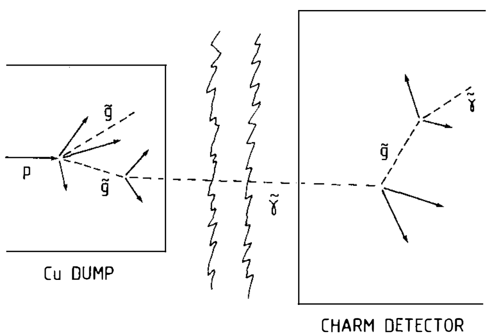

Fig. 1 Chain of the processes that leads to a supersymmetric signal in a proton beam-dump experiment.

The experiment was performed at the CERN SPS in 1979. In the exposure of 6.96×10^{17} protons on the full density target (a 2 m long copper block) 80.5 ± 14 (stat.) ± 6.3 (syst.) muonless events of prompt origin with shower energy (E_{shower}) > 20 GeV, have been observed in the fiducial volume of the CHARM detector[4] (100 t) covering a solid angle of 6.8×10^{-6} sr. The events include charged-current (CC) and neutral-current (NC) interactions of ν_e and $\bar{\nu}_e$ as well as interactions of neutrino-like particles without a muon in the final state. The number of prompt CC events induced by electron neutrinos has been estimated by direct identification[3]. The procedure is based on the characteristic features of electromagnetic showers in the CHARM calorimeter[5]: their small width, their regular longitudinal profile, and the strong correlation between the total shower energy and the energy detected at the shower maximum. The energy detected in a row of scintillation counters of 15 cm width, starting at the vertex and crossing the shower maximum, has been calibrated using isolated electron showers obtained in a test beam. Ninety per cent of the total electron energy is detected in such a row with a resolution of $\sigma(E)/E = 0.25/\sqrt{E(\mathrm{GeV})}$ [5]. These features allow the identification of showers with a large electromagnetic component ($y = E_{em}/E_{shower} > 0.4$). For $\nu_e N \to eX$ events a correction for hadron-shower energy overlapping the row was applied. Neutral-current events with π^0's of large energy may simulate $\overset{(-)}{\nu}_e$ CC events. This contribution was determined using muonless events obtained in the wide-band beam. The number of prompt CC events induced by ν_e and $\bar{\nu}_e$ has been estimated fitting the y distributions of CC $\overset{(-)}{\nu}_e$ events and of NC π^0 background to the experimental data. A total of 60.7 ± 13 (stat.) ± 5.3 (syst.) events have been attributed to CC $\overset{(-)}{\nu}_e$ interactions. From this total the corresponding number of NC events with $E_{shower} > 20$ GeV was computed to be 15.8 ± 3.4 (stat.) ± 1.5 (syst.). Subtracting the electron neutrino events from the observed number of muonless events, 4 ± 21 events with $E_{shower} > 20$ GeV could be attributed to the interaction of other neutrinos or neutrino-like particles.

From this result a limit on the gluino mass as a function of the scalar quark mass was derived. The expected number of photino events was computed by a Monte Carlo simulation. The gluino production cross-section was computed assuming the gluon fusion mechanism[6] shown in Fig. 2. Gluino hadroproduction via the gluon fusion mechanism is enhanced with respect to that of heavy quarks of comparable mass by the colour factor of 81/7, because gluinos belong to the adjoint representation of the colour SU(3) group. Gluino decay into a photino and a $q\bar{q}$ pair is described by the diagram of Fig. 3. The interaction is mediated by a scalar quark whose mass is of the order of the supersymmety-breaking mass scale [O(100) GeV]. The dominant mechanism for the photino-nucleon interaction

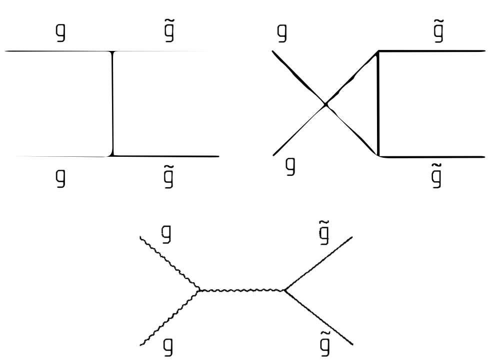

Fig. 2 Diagram for gluon fusion into a gluino pair.

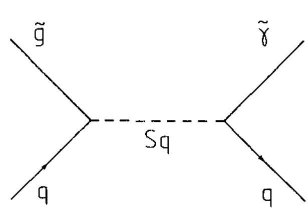

Fig. 3 Diagram for the interaction of a gluino and a photino with quarks.

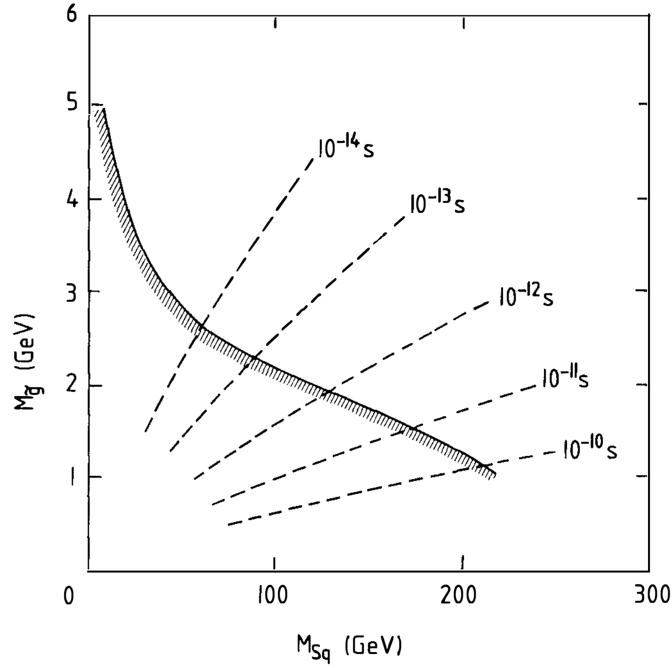

Fig. 4 The 90% CL lower bounds on the gluino mass as a function of the mass of the scalar quark. The broken lines show the gluino lifetime constraints.

is the inverse of gluino decay[7]. For a scalar quark mass equal to the W-boson mass the photino cross-section is expected to be of the same order as the CC neutrino nucleon cross-section. The results are plotted in Fig. 4. The solid curve is a lower bound at the 90% CL on the gluino mass as a function of the scalar quark mass. The broken lines indicate the gluino lifetime constraints.

In conclusion, the results of this search for supersymmetric particles do not favour the existence of low-mass gluinos (< 2 GeV) and scalar quarks (< 100 GeV).

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