EXPERIMENTAL SEARCH FOR ASSOCIATED GLUINO PRODUCTION AND DECAYIN 350 GeV/c π^- EMULSION INTERACTIONS

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ABSTRACT

A search for direct evidence of the production and subsequent decay of gluinos has been performed in nuclear emulsions. The emulsion stacks were exposed, as part of a large hybrid apparatus, to a beam of 350 GeV/c π^- mesons, and events were selected on the basis of a 'missing-energy' trigger. The missing-energy signature is expected to be a characteristic feature of events in which gluinos are produced and subsequently decay into hadrons and almost non-interacting photinos. The negative result of this search sets an upper limit to the production cross-section of light gluinos.

1. INTRODUCTION

According to supersymmetric theories [1] every fermion (boson) should have a boson (fermion) partner. The supersymmetric partners of hadrons are termed R-hadrons. The gluino ($\tilde{g}$), the supersymmetric partner of the gluon, is expected to be strongly produced in hadronic collisions and to decay weakly, mainly into $q\bar{q}\tilde{\gamma}$. The photino ($\tilde{\gamma}$), in turn, is not expected to interact appreciably in matter. The gluino mean lifetime, and the photino interaction cross-section, can be computed as a function of the s-quark mass within the framework of perturbative QCD. A comprehensive bibliography on this subject may be found in refs. [1].

Recent experiments, using various techniques, have searched for low-mass gluinos. In neutrino beam-dump experiments (CHARM [2], E613 at FNAL [3], and BEBC-WA66 [4]) it was assumed that short-lived gluinos are produced and rapidly ($\tau < 10^{-11}$ s) decay into photinos which pass through the muon filters and interact in the detector, giving 'anomalous neutral current' events. In a hadroproduction experiment (NA3 at CERN [5]), rather longer-lived gluinos are being searched for, but the results will depend strongly on the R-hadron cross-section in the dump. The ARGUS Collaboration [6] have looked for evidence of gluino existence in the possible decay of the 3P_1 χ_b meson into a $\tilde{g}\tilde{g}\tilde{g}$ final state. The negative results at collider energies (UA1 [7]) set a limit on the s-quark mass of $> 70 \text{ GeV}/c^2$, but leave a window open to gluino masses $\leq 10 \text{ GeV}/c^2$ [8].

This experiment was designed to look for evidence of gluino production and decay, assuming only that the gluino lifetime lies in a range detectable in nuclear emulsion (i.e. $\tau \gtrsim 3 \times 10^{-15}$ s), and that the decay photinos do not interact appreciably in matter. Thus events occurring in nuclear emulsion and characterized by missing energy in a dump calorimeter downstream were examined for evidence of decay vertices. In order to minimize the background due to the semileptonic decay of charmed particles, appropriate selection and scanning criteria were also applied.

2. DESCRIPTION OF THE EXPERIMENT

The set-up (fig. 1) consisted of the WA75 apparatus [9] with the dump replaced by the WA78 hadron calorimeter [10]; both experiments were originally designed to search for beauty particles in hadronic interactions.

One and a half litres of nuclear emulsion, in the form of stacks of pellicles with their surfaces parallel to the direction of the incident beam, were uniformly exposed to a flux of $\sim 10^3$ primaries per mm^2 [350 GeV/c π^- from the CERN Super Proton Synchrotron (SPS)].

Events generated within the emulsions were localized by means of a beam hodoscope (BH) situated upstream and a vertex detector (VD) situated immediately downstream from the emulsion stack. The BH comprised 6 planes of 50 μm pitch silicon microstrips [11], defining the beam position with a precision of 15 μm in the transverse plane. The VD, made up of 10 planes of 50-200 μm pitch silicon microstrips followed by 16 planes of multiwire proportional chambers (MWPCs) with 1 mm spacing in a compact array, served the dual purpose of providing the position of the interaction vertex along the beam direction and information about the expected topology of the event. The remaining downstream elements of the apparatus were a uranium-iron-scintillator calorimeter and a muon spectrometer.

The difference between the beam energy and the corresponding energy measured in the calorimeter was defined to be the 'missing energy', E_{miss} . The trigger was obtained by requiring a valid interaction in the emulsion target and a missing energy of at least 45 GeV, as determined on line by a hardware processor [12]. The fraction of events selected in this manner was 5 to 10% of the total number of interactions.

3. EVENT SELECTION

Off-line analysis of the calorimeter showed a resolution on the energy determination $\sigma/E = 4.7\%$ for interactions located in the emulsions 1 m upstream (fig. 2). An off-line cut of $E_{\text{miss}} \geq 65$ GeV was made in order to increase the signal/background ratio while preserving a reasonable acceptance (see later). Events with a muon reconstructed in the spectrometer were only retained (as a reference) if the missing

energy, after subtraction of the muon energy, exceeded the preceding value. Only $\approx 10\%$ of the events in the final sample contained such a muon.

The next step was the reconstruction of space tracks in both the BH and the VD, and the determination of the position of the interaction within the emulsion stack. It became obvious on examination that in most of the retained events the apparent missing energy could be attributed to the emission of many particles outside the acceptance of the calorimeter (250 mr). In fact, the sample contained many central interactions with heavy nuclei (Ag, Br), frequently occurring in the upstream part of the target and with one or more secondaries giving rise to further interactions. Therefore, a new selection criterion was introduced to reject events where more than 40% of the reconstructed tracks did not appear to converge to the primary vertex and were thus labelled 'rejected' by the standard procedure of the reconstruction program. Using this procedure, $\approx 60\%$ of the events were rejected, whereas in a sample not biased by the missing-energy selection the corresponding figure was 25%. The effective number of primary interactions is estimated to have been $\sim 5 \times 10^5$, allowing for the cuts introduced by the selection criteria, taking the useful volume of emulsion to be 73% of the total volume, and assuming an efficiency of 80% in both the reconstruction of events and their location within the emulsion. Of 178 events searched for in emulsion, 141 were found and analysed. This analysis took the form of a search for decays of both neutral and charged secondary particles within 1 mm of the primary interaction point. If any such decay topology was found, the search was continued downstream.

The scanning rules that essentially limit the sensitivity of the experiment to R-hadrons with a short mean lifetime were chosen to minimize the charmed-particle contamination, in particular that arising from semileptonic decays into electrons (not detected in this experiment) and into muons outside the acceptance of the spectrometer. The sensitivity for very short-lived particles [13] decreases when $\tau \lesssim 3 \times 10^{-15}$ s because it is then difficult to distinguish by eye a decay which occurs very close to the interaction point.

4. RESULTS AND CONCLUSIONS

In this search three events with decay topologies were found. Two of them were found in the sample with one reconstructed muon, and are therefore not R-hadron candidates. In these two events the track of a charged particle showed a sharp deflection (kink) after a path length of 212 μm and 122 μm , respectively, but the muon was not unambiguously associated with a track of the primary star and a second decay topology was not detected. They could be interpreted as the associated production of charmed particles, where one is seen to have decayed within 1 mm and the other, probably a semileptonic decay, either escaped detection or occurred outside the emulsion stack. This is not inconsistent with the expected background and the known mean lifetimes of charmed particles.

The third event showed a neutral two-prong decay topology 140 μm downstream from the primary interaction and the kink of a charged track 1.8 mm away; no muon was recorded and the missing energy was ~ 100 GeV. We note that this event, topologically compatible with the expected features of the production of a pair of R-hadrons, is also consistent with the production and decay of a pair of charmed particles.

To evaluate the sensitivity of this experiment we performed a Monte Carlo calculation. Taking into account the configuration of the apparatus and the scanning scheme, the acceptance for R-hadrons produced in accordance with QCD calculations [1,14] was computed with the mass M_R of R-hadrons as an unknown parameter. The acceptance turned out to be $\sim 10\%$ for $M_R = 3 \text{ GeV}/c^2$ and $E_{\text{miss}} \geq 65 \text{ GeV}$. The background due to $D\bar{D}$ pairs was computed with the same program, assuming [15] a cross-section given by

$$\frac{d^2\sigma}{dx dp_{\perp}^2} \approx (1-x)^{\alpha} e^{-\beta p_{\perp}^2},$$

with the values $\alpha = 2.8$ and $\beta = 1.1$. In addition, the ratio

$$\sigma(\pi p \rightarrow D\bar{D} + X)/\sigma(\pi p \rightarrow \text{all}) = 10^{-3}$$

and an $A^{2/3}$ dependence of the cross-sections were also used.

Based on these data the expected numbers of R-hadrons detectable in this experiment, assuming an A^1 ($A^{0.72}$) dependence of the cross-section, would be 18 (6), 7.5 (2.5), and 3 (1) for gluino masses of 2.5, 3, and 3.5 GeV/c², respectively. The expected number of $D\bar{D}$ pairs is ≈ 2 in the sample with no detected muon and ≈ 1 in that with one reconstructed muon.

Therefore, we can conclude that the observed decay topologies are compatible with those expected from $D\bar{D}$ background and that we have no evidence of R-hadron production for gluino masses up to ≈ 3.5 GeV/c². In Fig. 3, the expected mean lifetime of the R-hadrons as a function of the gluino and of the s-quark masses is reported. Upper limits (90% CL) on the masses obtained in this and in previous experiments are shown for two values of the A-dependence of the cross-section.

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Figure captions

- Fig. 1 : Diagram of the apparatus.
- Fig. 2 : Energy distribution, after off-line analysis, for a sample of interactions without on-line cut-off.
- Fig. 3 : Upper limits (90% CL) on the gluino ($\tilde{g}$) mass as a function of the s-quark ($\tilde{q}$) mass. The gluino mean life-time constraints evaluated from QCD are also shown. The results of the present and of previous experiments are shown for two. A-dependences of the cross-section [A^1 in (a), $A^{0.72}$ in (b)].

Fig. 1

Fig. 2

Fig. 3