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Preliminary

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Search for Heavy Stable and Long-lived Charged Particles in e^+e^- Collisions

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Abstract

A search for stable and long-lived heavy charged particles has been performed using the data taken by the DELPHI experiment at an energy of 189 GeV. The Cherenkov light detected in the Ring Imaging Cherenkov and the ionisation loss measured in the Time Projection Chamber are used to identify heavy particles passing through the detector. Preliminary limits at 95% confidence level are given on the masses of left and right handed smuons and staus. Including previous DELPHI results, left (right) handed stable smuons and staus can be excluded between 2 GeV/c^2 and 87.9 (87.0) GeV/c^2 at 95% CL.

1 Introduction

A search has been made for the production of stable and long-lived [1]heavy charged particles in events with low multiplicity using the data taken by the DELPHI experiment at energies of about 189 GeV. The search extends previous DELPHI results presented in [1] in the leptonic topology to energies of 189 GeV. In most models of Supersymmetry (SUSY) the supersymmetric partners of standard particles are unstable and have short lifetimes, except the lightest supersymmetric particle (LSP) which is commonly believed to be neutral and stable. In most of the searches it is therefore assumed that the supersymmetric particles decay promptly. It is, however, possible that a stable or long-lived heavy charged SUSY-particle exists. In the MSSM with a very small amount of R-parity violation the LSP can be a charged slepton or squark and decay with a long lifetime into Standard Model particles [2].

In gauge mediated supersymmetric models the gravitino is the LSP and the next to lightest supersymmetric particle (NLSP) can obtain a long lifetime in a very natural way for large values of the SUSY-breaking scale [3]. This is possible for sleptons if e.g. the stau is the NLSP.

Limits on the production cross-section and masses will be given for stable and long-lived sleptons.

It is assumed that the long-lived particles decay outside the tracking volume of the detector, which extends to a typical radius of 1.5 m. It is further assumed that these particles do not interact more strongly than ordinary matter particles.

Heavy stable particles are selected by looking for high momentum charged particles with either anomalous ionisation loss dE/dx measured in the Time Projection Chamber (TPC), or the absence of Cherenkov light in the gas and liquid radiators of the Barrel Ring Imaging CHerenkov (RICH). The combination of the TPC and RICH detectors and kinematical cuts provides an efficient detection of new heavy particles with a small background.

The data analysed corresponds to 153.9 pb^{-1} at an energy of about 189 GeV.

2 Event selection

A description of the DELPHI apparatus and its performance can be found in ref.[5], with more details on the Barrel RICH in ref. [6]. Charged particles were selected if their impact parameter was less than 5 cm in the azimuthal and less than 10 cm in the longitudinal plane, and their polar angle lies between 20 and 160 degrees. The relative error on the measured momentum was required to be less than 100 % and the track length larger than 30 cm. The energy of a charged particle was evaluated from its momentum [2] assuming the pion mass. Neutral particles were selected if their deposited energy was larger than 0.5 GeV and their polar angle was between 2 and 178 degrees.

Only events with three or less charged tracks were considered. It was further demanded that at least one charged particle had a momentum above 5 GeV/c reconstructed by the

[1]Throughout the paper stable particles include long-lived particles decaying outside the detector.

[2]In the following, "momentum" means the apparent momentum, defined as the momentum divided by the charge $|q|$, because this is the physical quantity measured from the track curvature in the 1.23 T magnetic field.

TPC and was inside the acceptance of the Barrel RICH $|\cos\theta| < 0.68$, where θ is the polar angle. The event should have at least two reconstructed charged particle tracks.

Cosmic muons were removed by putting tighter cuts on the impact parameter with respect to the average beam-spot position. When the event had two charged particles with at least one identified muon in the muon chambers, the impact parameter in the azimuthal plane was required to be less than 0.15 cm, and in the longitudinal plane less than 1.5 cm.

Charged particles were selected, if they fullfilled a combination of the following criteria:

1. the Gas Veto: no photons were observed in the Gas RICH
2. the Liquid Veto: four or less photons were observed in the Liquid RICH
3. the TPC high ionisation loss: measured normalised energy loss was above 2 units i.e. twice the energy loss for a minimum ionising particle
4. the TPC low ionisation loss: measured normalised energy loss was at least below 0.3 of that expected for protons

The particle identification using the RICH is described in detail in ref. [7].

For the Gas and Liquid Vetoes it was required that the RICH was fully operational and that for a selected track photons from other tracks or ionisation hits were detected inside the drift tube crossed by the track. Due to tracking problems electrons often passed a Gas or Liquid Veto. Therefore it was required that particles that deposit more than 5 GeV in the electromagnetic calorimeter, had hits included in the outer tracking detector. At least 80 wires were required for the measurement of the normalised energy loss in the TPC.

An event was selected if the momentum of the charged particle was above 15 GeV/c and the Gas Veto (1) was confirmed by a Liquid Veto (2) or a low ionisation loss (4) (in boolean notation (1)·(2)+(1)·(4)) or if the momentum of the charged particle was above 5 GeV/c and the Gas Veto was confirmed by a high ionisation loss ((1)·(3)). The event was also accepted if both hemispheres, defined by the thrust axis, had charged particles with both momenta above 15 GeV/c, less than 5 GeV deposited in the electromagnetic calorimeter, and a high ionisation or low ionisation loss ((3)·(3')+(4)·(4')). This additional search window improves the efficiency for large masses up to about 10%, but has little effects for masses around 50 GeV/c^2. For masses below 60 GeV/c^2 the detection efficiency can be improved by including a double gas veto[1]. This will be done at a later stage.

3 Preliminary Analysis results

One event was selected in the data, in agreement with the expected background of 0.96 $\pm$ 0.13 events. The expected background was evaluated from the data. The candidate event passes both the Gas and Liquid Vetoes. Figure 1 shows the measured normalised ionisation loss and the measured Cherenkov angle in the liquid radiator for the data taken at 189 GeV, after applying the Gas Veto.

The efficiency for selecting an event was evaluated as a function of the mass for right-handed smuons. Signal events were simulated with SUSYGEN [8], and passed through the detector simulation. The resulting efficiency curve for a centre-of-mass energy of 189 GeV is shown in Figure 2a.

These preliminary results have been combined with previous published results from [1] to obtain experimental limits on the masses of left and right handed stable or long-lived smuons and staus. The candidate event has been taken into account over the full mass range. Figure 2b shows the cross-section for left and right handed smuons at an energy of 189 GeV, calculated with SUSYGEN [8] as a function of the particle mass. The 95 % CL cross-section limit is also shown. Taking into account the results from previous searches at lower energies [1], left (right) handed stable smuons and staus can be excluded between 2 GeV/c^2 and 87.9 (87.0) GeV/c^2.

4 Conclusions

A search is made for stable and long-lived heavy charged particles in leptonic final states at energies of 189 GeV, using particles identified by the Cherenkov light in the RICH and the ionisation loss in the TPC.

One event is observed in the data, in agreement with the expectation of 0.96 ± 0.13 events. The results are combined with previous results of the DELPHI Collaboration[1], and preliminary limits on the masses of left and right handed stable or long-lived smuons and staus are derived. Including the new data, left (right) handed stable smuons and staus can be excluded between 2 GeV/c^2 and 87.9 (87.0) GeV/c^2 at 95% CL.

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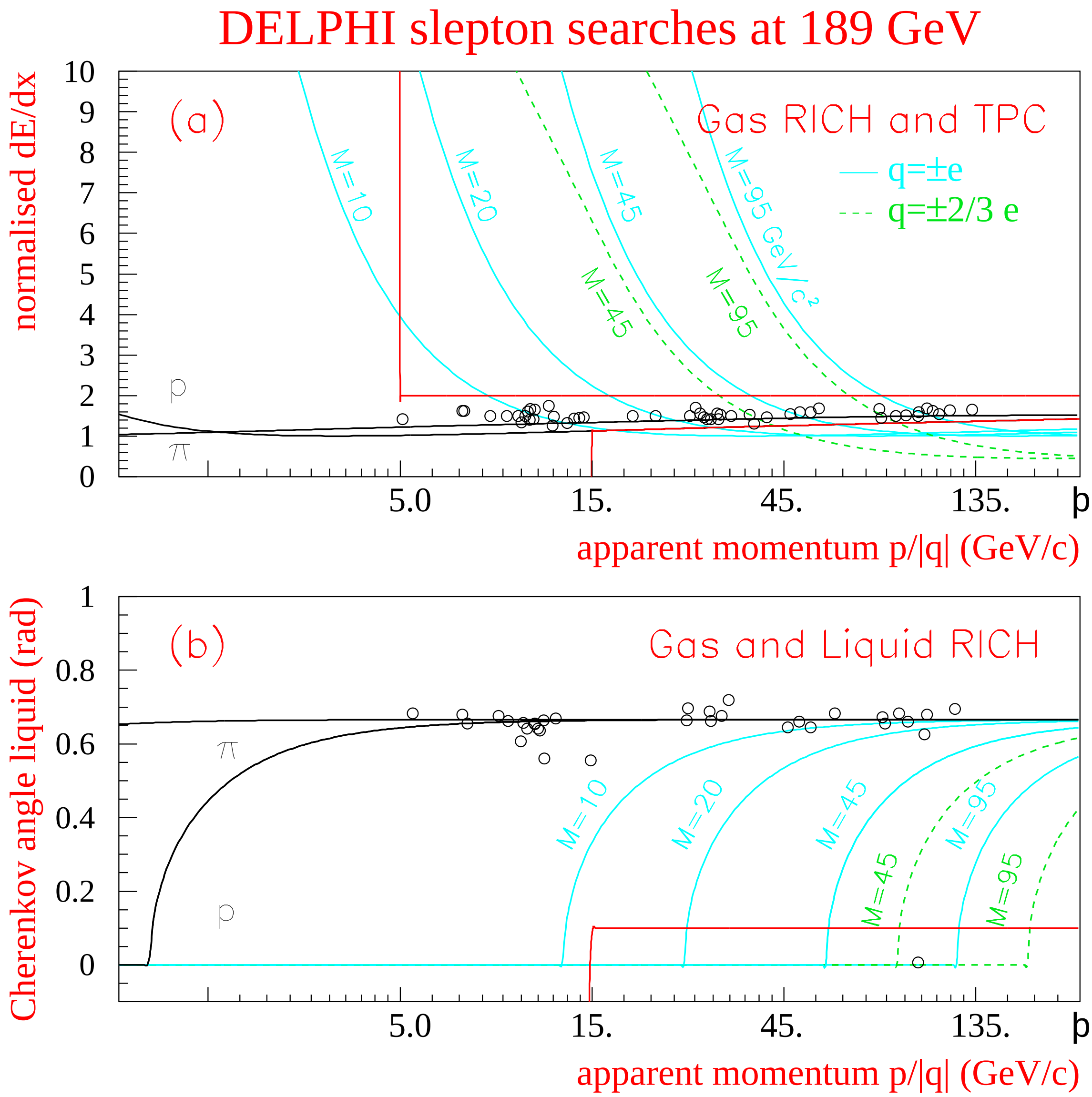

Figure 1: (a) Normalised energy loss as a function of the apparent momentum p/$|q|$ after the Gas Veto for the 183 GeV data. (b) Measured Cherenkov angle in the liquid radiator as a function of the apparent momentum after the Gas Veto: if four photons or less were observed in the liquid radiator, the Cherenkov angle was set equal to zero. The rectangular areas in (a) indicate selections (3) and (4), and that in (b) shows selection (2). The selection criteria are explained in the text.

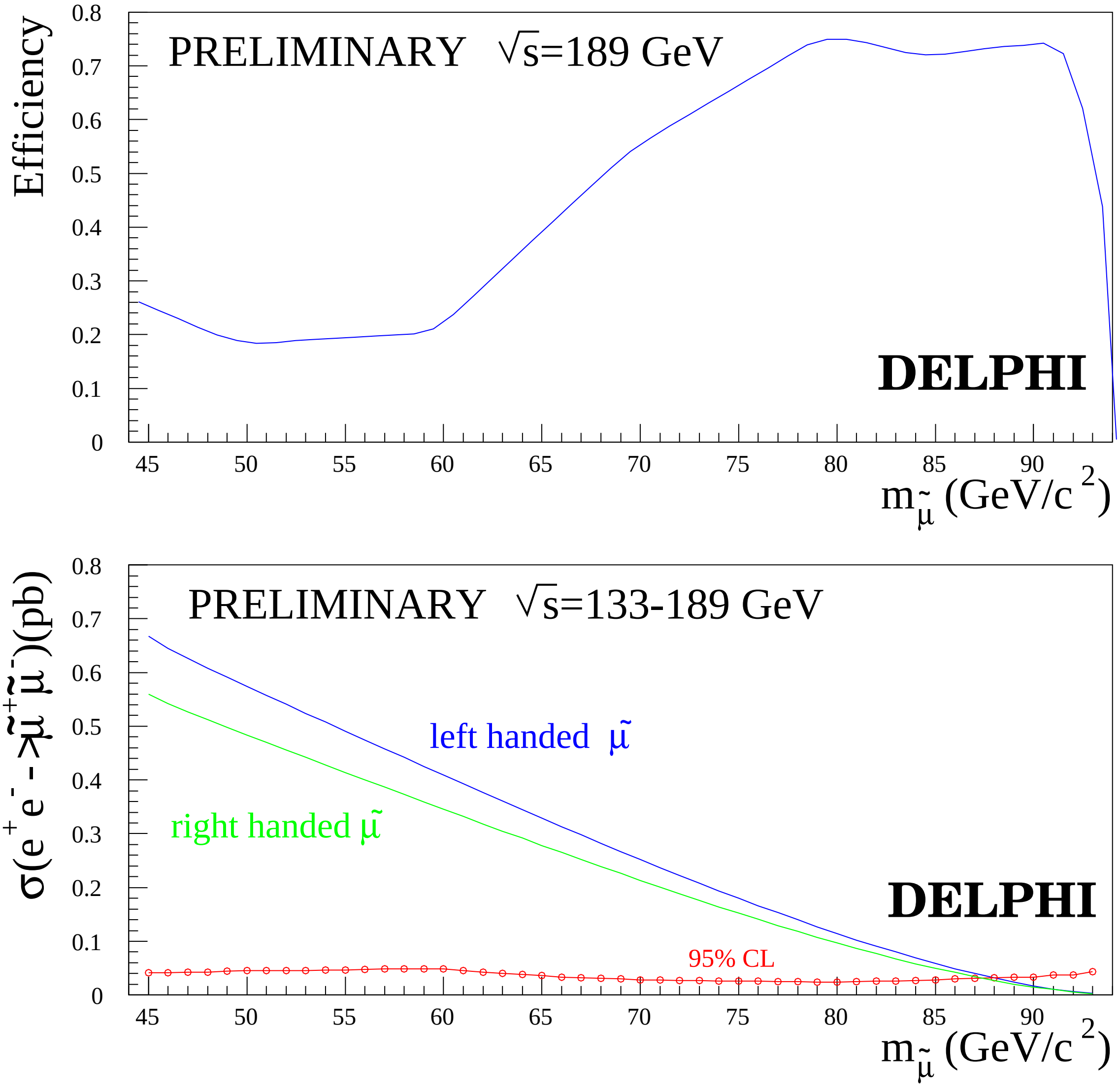

Figure 2: (a) Efficiency for detecting stable and long-lived smuons (staus) as a function of the smuon mass at a centre-of-mass energy of 189 GeV.
(b)Production cross-section for left and right handed smuons and staus as a function of the smuon mass. The 95 % CL cross-section limit, derived from DELPHI searches between 130 GeV and 189 GeV, is also shown.