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SUSY searches with the CMS detector

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Summary. — A selection of results covering searches for supersymmetric particles are presented. These results are based on 8 TeV proton-proton collision data collected by the Compact Muon Solenoid experiment at the Large Hadron Collider during Run1 that ended in February 2013.

1. – Introduction

The discovery of the Higgs boson [1, 2] during the first LHC runs at 7 and 8 TeV was an important milestone in high-energy physics (HEP) as it completed the Standard Model (SM), nonetheless not all the open questions in HEP have a clever answer within the SM framework. Supersymmetry (SUSY) [3] offers a clear and elegant solution to the hierarchy problem and in particular low-energy third-generation squarks (close in mass to the top quark and below the TeV scale) can provide the mechanism to cancel quadratically divergent loop corrections to the mass of the SM Higgs boson without the well-known fine-tuning problem [4-6].

The LHC experiments have a rich search program for SUSY searches that, to date, has only produced null results almost reaching the highest possible mass for natural superpartners, in spite of this fact there are still many reasons to keep looking for Natural SUSY as only few and simplified models have been addressed experimentally and many regions of the full phase space have not yet been explored [7].

In these proceedings, new results from data collected by the Compact Muon Solenoid (CMS) [8] experiment during the 2012 8 TeV run of the LHC are presented. CMS is a general-purpose detector which main feature is a 3.8 T solenoidal magnetic field, inside of which there are a silicon vertexing and tracking system, a total absorption crystal electromagnetic calorimeter, and a brass/scintillator sampling hadronic calorimeter, outside the magnet and within the iron return yoke there is a gaseous muon detectors that consists of three different sub-detectors to achieve the best possible performance as well as good redundancy. Overall, the detector has a very high efficiency for electrons, muons, and photons and exploits a novel particle flow tau and jet reconstruction.

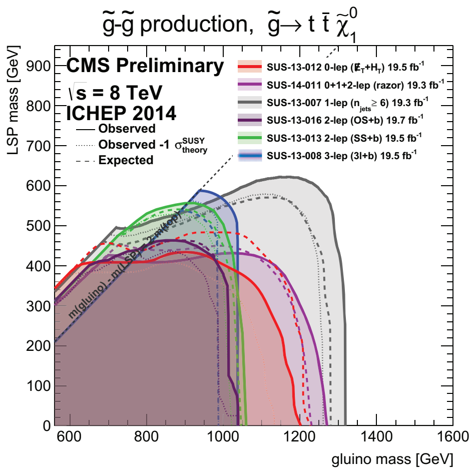

Fig. 1. – Exclusion plot for gluino pair production into four tops, different analyses have been combined and superimposed using different colors in the LSP *vs.* gluino mass plane.

2. – Gluino searches

The strong production has by far the larger cross-section at LHC and it is the channel that has been investigated most thoroughly, producing more results than any other channel. Early analyses have already placed strong limits for simplified models in which gluinos are pair produced and decay sole to top quarks as we can see in fig. 1, where on the x-axis is plotted the excluded gluino mass and on the y-axis the LSP mass.

Given the presence of four top quarks in the final state, this channel offers a large variety of decay modes and therefore many different analyses have produced result using this signal model, some mutually exclusive channels have also been combined to increase the exclusion power as the razor search [9] with the single lepton search [10]. Other analyses used same-sign leptons [11] or all hadronic final state using missing energy (MET) and scalar sum of jet p_T (HT) as discriminating variables [12]. The large plethora of analyses is needed to both increase our exclusion power but also to enhance our discovery chances, reducing false signals since the different channels populates different signal regions.

All analyses make large use of data-driven background predictions with Monte Carlo (MC) simulations used only for minor backgrounds, of course all MC are corrected for any mismatch with respect to data as for instance secondary interaction vertices or efficiencies. In hadronic channels $Z \rightarrow \nu\nu$ is the most tricky background to address and in order not to rely solely on MC the process $Z \rightarrow \mu\mu$ is used as a proxy for this wanted process, after properly adjusted the measured visible particles by their efficiencies and acceptance.

Analyses using leptons are instead mostly subject to miss-lepton(s) or miss-identified backgrounds due either to events with two genuine leptons, one of which is not reconstructed or event without prompt leptons but with fake ones. Also in this case a series of data-driven techniques have been developed like the so called fake rate method, used to predict leptons not coming directly from electroweak boson decays. For instance in fig. 2 (right) we can see that the miss-identified background contributes to almost half of to the total yield of the same-sign lepton search, so predicting it with accuracy is fundamental

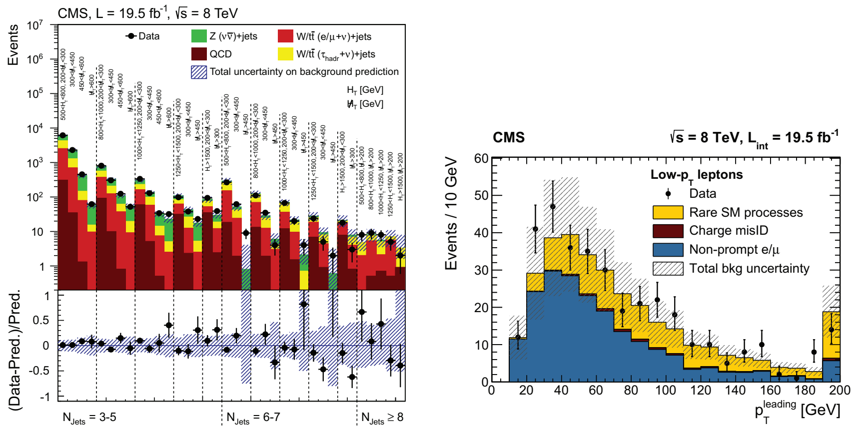

Fig. 2. – Summary of the observed number of events in each of the 36 search regions in comparison to the corresponding background prediction. The hatched region shows the total uncertainty of the background prediction [12] (right). Distributions of the transverse momentum of the leading lepton in the low-p_t baseline region with $N_{\text{b-jets}} = 0$ requirement [11] (left).

to claim any discovery, just as the invisible Z background is important in the hadronic channel. Indeed fig. 2 (left) shows an excess of data in a bin dominated by $Z \to \nu\nu$ and its systematic uncertainty.

3. – Stop searches

Another promising channel is the direct stop production. Again we have a broad choice of final states and we put in place many analyses to exploit all of them, as before a quick overview can be obtained by looking at the summary exclusion plot in fig. 3.

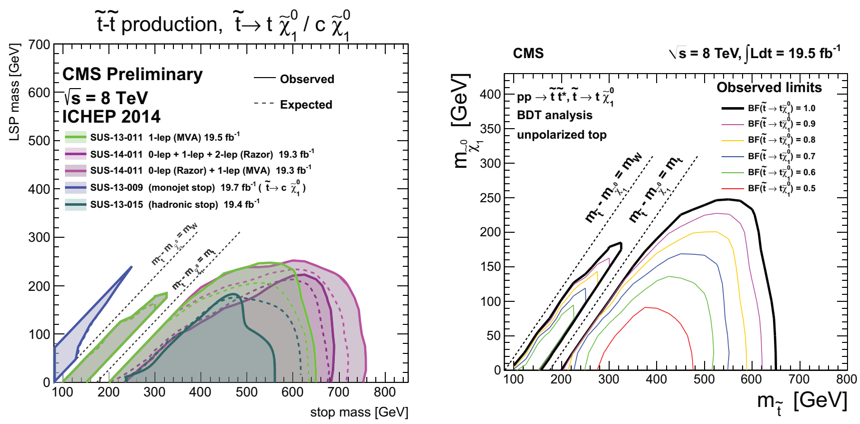

Fig. 3. – On the left, the summary exclusion plot for stop pair production decaying into top and neutralino (100% branching fraction BF), different analyses have been combined and superimposed using different colors in the LSP *vs.* stop mass plane. On the right, the assumption on the BF is relaxed and the plot shows how the exclusion can degrade with the stop does not decay always into top, the reference is the SUS-13-011 analysis on the left.

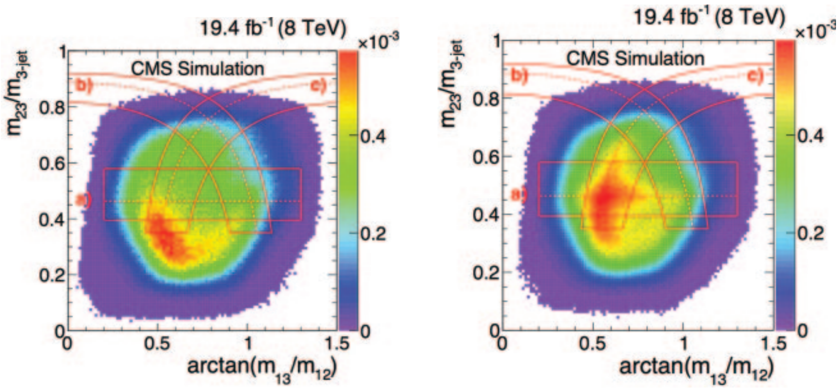

Fig. 4. – Distributions of $m_{23}/m_{3\text{-}jet}$ *vs.* $\arctan m_{13}/m_{12}$ for simulated QCD multijet processes events (left) and for simulated $t\bar{t}$ processes events (right) in the multijet t-tagged search [13].

Some of the searches, as for example the razor [9] can be reinterpreted also in the hypothesis of a stop signal and are proven quite effective, but again the combination with dedicated analyses give the best exclusion limits. The most stringent limit for high-mass stop is given by the razor combined with the single-lepton analyses [14] that is able to reach masses of 750 GeV. Again we must stress that the limit is set on a simplified model with few free parameters. On the right of fig. 3 it is shown how this limit changes as we move away from the assumption that the stop decays always to the top quark, the reduction in the exclusion power is clearly visible even when $\mathrm{BF}(\tilde{t} \to t\tilde{\chi}_1^0) = 90\%$.

As the high mass region searches returned null results the effort was moved back to low mass, in particular in the diagonal region in fig. 3, where the difference between the

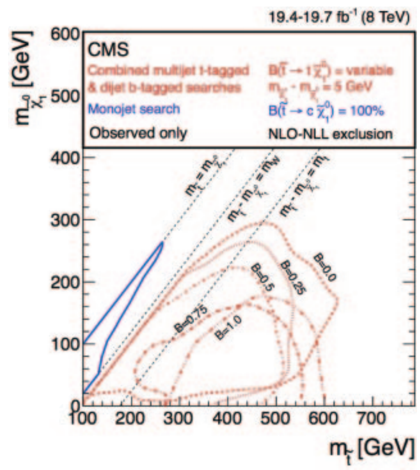

Fig. 5. – Various observed 95% CL mass exclusion limit curves for top-squark pair production, assuming different branching fractions of the two top squark decays $\tilde{t} \to t\tilde{\chi}_1^0$ and $\tilde{t} \to b\tilde{\chi}_1^{\pm}$. The mass difference between the $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$ is taken to be 5 GeV. A branching fraction (B) of 1.0 implies all decays are via $\tilde{t} \to t\tilde{\chi}_1^0$ and conversely, $B = 0.0$ implies all decays proceed through $\tilde{t} \to b\tilde{\chi}_1^{\pm}$. The combined results from the dijet b-tagged and multijet t-tagged searches and the result from the monojet search are displayed separately.

stop mass and the top (or W) is small, hence the signal is SM-like and more difficult to extract. To increase our sensitivity in this compressed spectra region new techniques have been recently developed such as top-tagging to discriminate QCD jets from signal-like jets. This type of top tagging is based on mass measurements of jets that are closely spaced, where the relative ratios of the jet masses are then used to build a discriminator as shown in fig. 4, where QCD on the left is compared to $t\bar{t}$ on the right.

This hadronic analysis in combination with the monojet search is very effective in looking for compressed signal near the mentioned diagonal as we can see in fig. 5 where the phase space region covered by this hadronic analysis on the usual LSP *vs.* stop mass plane is shown.

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