SEARCHES FOR SUPERSYMMETRY IN HADRONIC EVENTS WITH THE CMS DETECTOR

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OVERVIEW

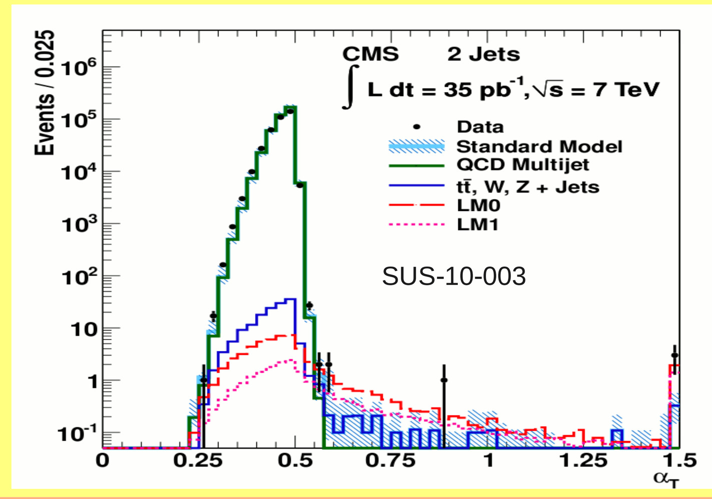
New phyiscs and new signatures

One of the many challenges, that physicists must face at the LHC, is the lack of a precise intuition of how physics beyond the Standard Model will manifest itself. Even if we restrict ourselves to a specific class of models, such as supersymmetric theories, infinite possibilities are left open in terms of experimental signatures, which will, to a large extent, depend on the fine structure of the new particles spectrum. Therefore CMS has designed inclusive analyses based on event topology. In addition to that a great effort has been made to design robust and redundant data-driven methods to estimate the Standard Model (SM) backgrounds. This has led to the development of new techniques and the production of reliable limits on new physics observables.

SEARCH STRATEGIES

α_T

In this search the variable α_T [5] was used as the main discriminator between events with real and fake missing transverse energy. Events with at least two jets with E_T>100 GeV are selected, requiring the sub-leading jets to have at least an E_T of 50 GeV. Additional cuts on the H_T and the consistency of the jet based estimate of the ME_T are applied and a QCD-killer cut, α_T > 0.55, is performed.



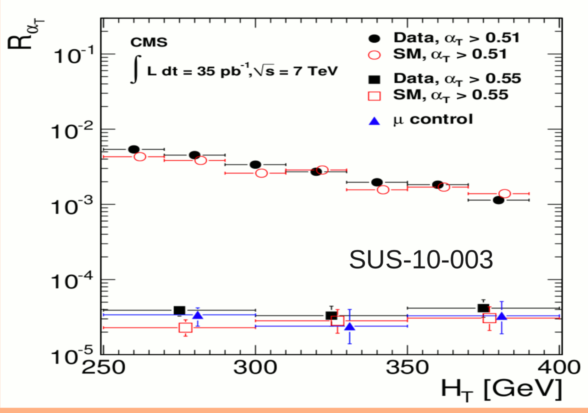
This last cut is particularly effective in reducing the background, since for perfectly measured dijet events α_T=0.5, while an imbalance of the E_T's can only make α_T smaller than 0.5.

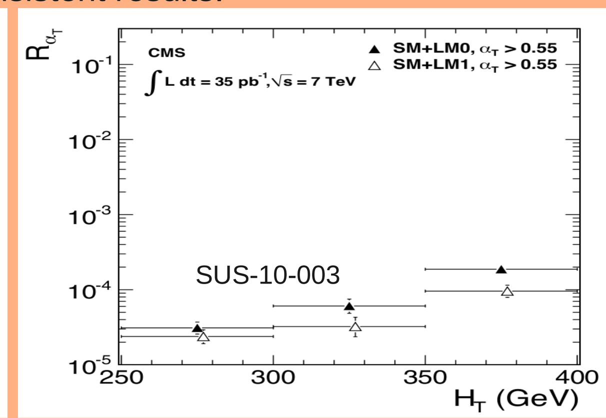
Figure: α_T after H_T>350 GeV cut for dijet events.

BACKGROUND ESTIMATION

α_T

The total background is estimated from two control regions of low H_T where SM processes are known to dominate. The method is based on the ratio R_α of events which pass and fail the full selection requirements. This ratio can be extrapolated from the two low H_T regions to the signal region. As can be seen in the figures below, R_α is constant in H_T for the electroweak backgrounds, while it decreases slowly for QCD events, where the missing energy is mostly fake. The W+jets and tt background can be determined independently from a muon sample, while the Z(→νν)+Jets background can be estimated from a γ+Jets sample. The different methods give consistent results.

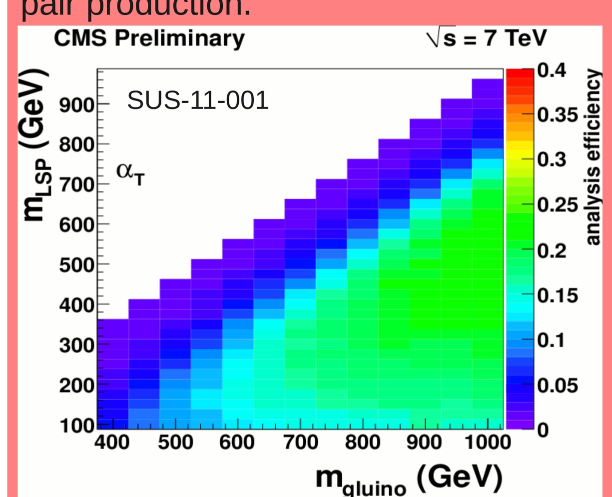


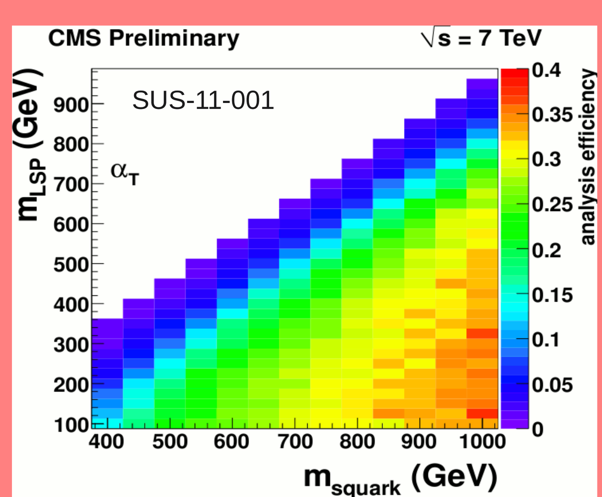


EFFICIENCIES

α_T

The cut on α_T has been designed for a fast discovery and to have an optimal background rejection. However, as can be seen in the figures below, the overall efficiency on the signal is not as good as that of the MH_T analysis. This has led to set slightly less stringent limits shown in the following, section. The efficiency maps are presented for two simplified models[7], gluino and squark pair production.





RESULTS

The number of events found by each analysis, after all cuts, is consistent with the background predictions. Therefore we can only set limits in the SUSY parameter space. As an example, we show the number of events found by the α_T analysis.

- In the data they are left with 13 events.
- Their background estimations are:
  - Inclusive prediction from R_α : $9.4^{+4.8}_{-4.0}$ (stat)±1.0(syst)
  - Esclusive predictions for the electroweak backgrounds:
    - W+jets and tt, from a muon+jets sample:$6.1^{+2.8}_{-1.9}$ (stat)±1.8(syst)
    - Z(→ νν)+jets, from a γ+jets sample:$4.4^{+2.3}_{-1.6}$ (stat)±1.8(syst)

We can easily see that the sum of the two electroweak components is consistent with the inclusive prediction, which is in turn compatible with the number of events found in data and with a Montecarlo prediction of 9.3±0.9(stat). Similar results are obtained by the other two analyses. The outcome of the limit setting procedure are presented in the CMSSM [8].

LHCC meeting 23/3/2011

The CMS hadronic analyses

In these early stages of the LHC running the most promising channels for the discovery of supersymmetry involve the strong production of squarks and gluinos. If we assume R-parity conservation, their decays will be characterized by the presence of jets and high missing momentum.

There are three CMS analyses designed to be sensitive to these final states. The so called α_T [1] and Razor [2] analyses exploit the kinematical differences between the decays of heavy, pair-produced particles and the SM processes that give rise to similar signatures. The third analysis [3], that we will call MH_T, adopts a complementary approach studying more traditional observables that need a better understanding of the detector to be correctly measured.

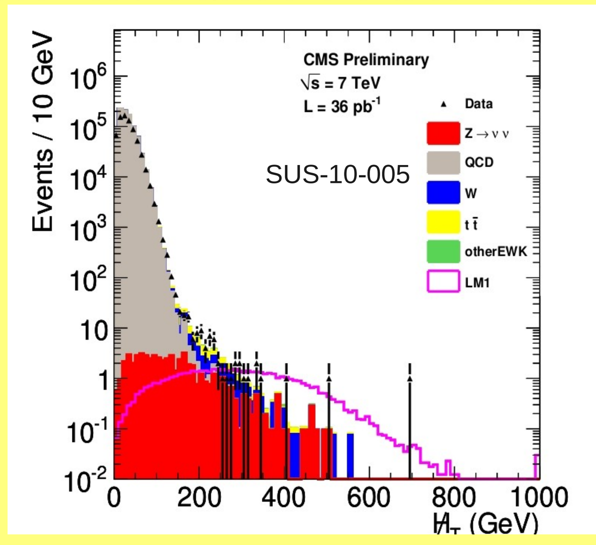
The Standard Model backgrounds

The main SM backgrounds to these searches are: Z → νν+jets, W+jets, tt and multijet events with large missing momentum from leptonic decays of heavy flavor hadrons inside jets, jet energy mis-measurement,or instrumental noise and dead components.

MHT

This analysis focuses on final states with at least three jets and high missing momentum. The baseline selection that defines this class of events consists in asking for

- ≥3 Jets with |η|< 2.5 and p_T>50 GeV
- H_T>300 GeV
- MH_T>150 GeV
- $\Delta\phi$($Jet_{1,2}$, MH_T) >0.5
- $\Delta\phi$(Jet_3, MH_T)>0.3
- Plus event cleaning cuts



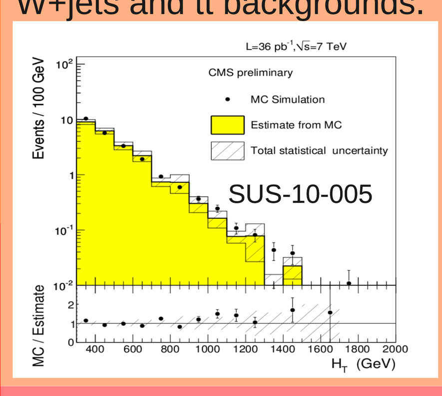
After the baseline selection two search regions are defined

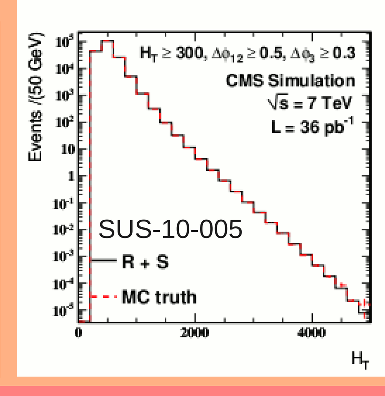
- High H_T, where H_T> 500 GeV
- High MH_T, where MH_T>250 GeV

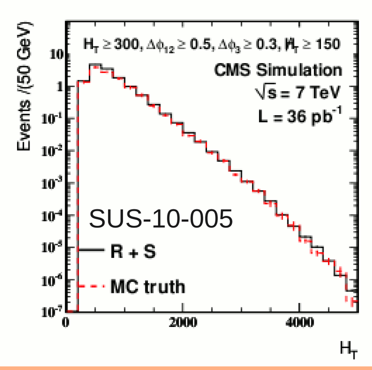
This analysis is designed to be inclusive, not to introduce any kinematical bias on the new physics signals and to have a good efficiency for models where the masses of the new particles are low enough to be produced with sizeable yield at limited integrated luminosities.

MHT

A number of novel techniques have been developed to measure the background for this search in a fully data-driven way. In this limited space we will only sketch briefly the Rebalance+Smear method intended to assess the QCD multijet background. The R+S method produces a prediction by starting from a sample of “seed events” consisting of “seed jets”. The seed events are produced using an inclusive multijet data sample as input. All of the jet momenta are adjusted to return the event back into approximate transverse momentum balance. In the “Smear” step a random value of the jet response is drawn from the jet resolution distribution for each seed jet, and its true momentum is scaled by this factor. As the input to the smearing step is representative of a pure QCD multijet sample, the resulting events can be used to apply search cuts. Below we can see a comparison between the data-driven prediction of the R+S method and a full simulation of QCD events and the same comparison for the lost lepton method used to estimate W+jets and tt backgrounds.

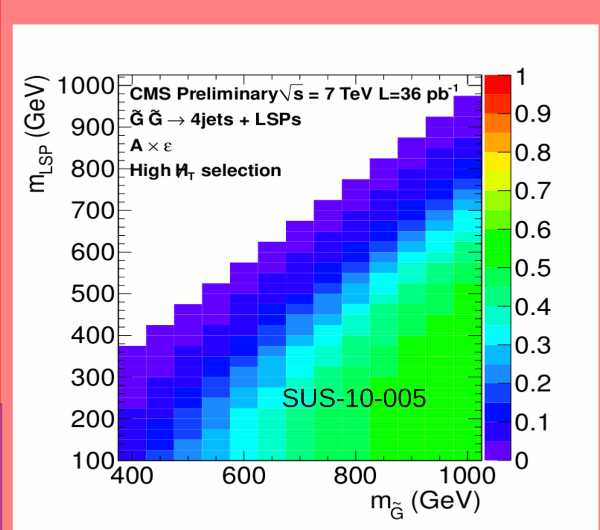


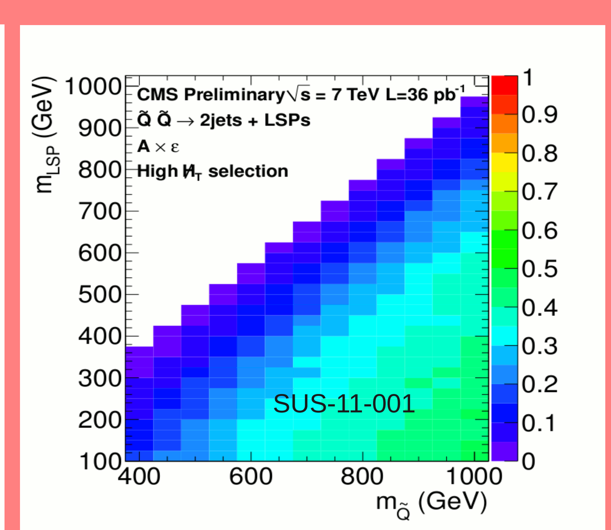


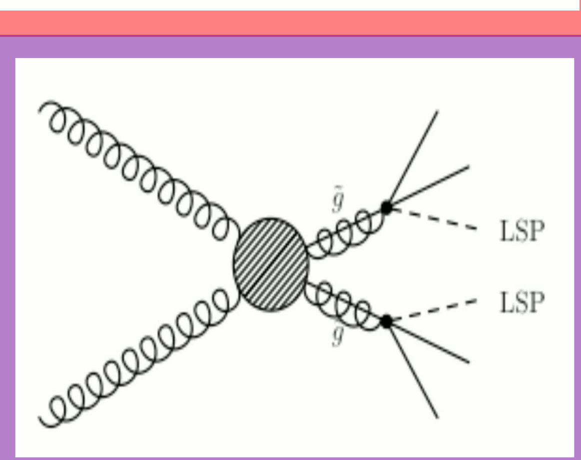


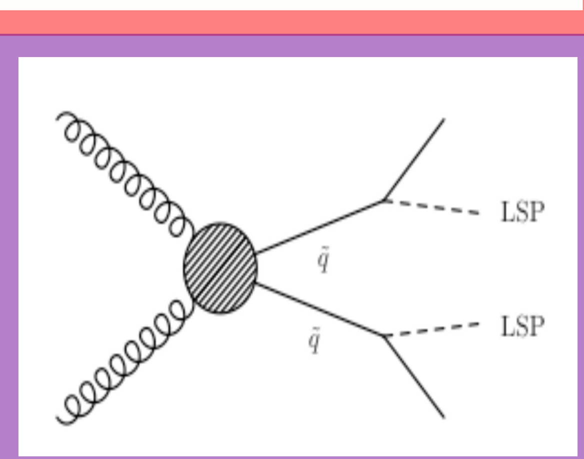
MHT

This analysis has a very high signal efficiency in most of the parameter space of the two simplified models that were considered. In the plots below we can see the efficiencies for the high MH_T region, that turns out to be the one that gives the most stringent limit. The requirement of three energetic jets is more effective in a scenario where the gluino production is dominant, but retains an appreciable amount of signal also for squarks pair production.There is only a critical region, on the diagonal of the efficiency plots, corresponding to an LSP almost degenerate with respect to the produced heavy particle.

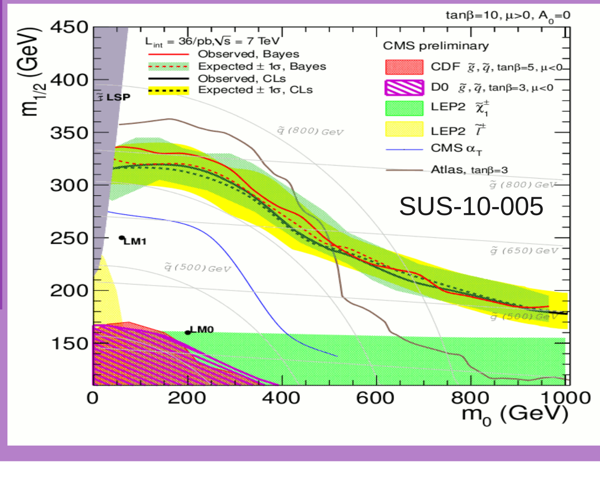


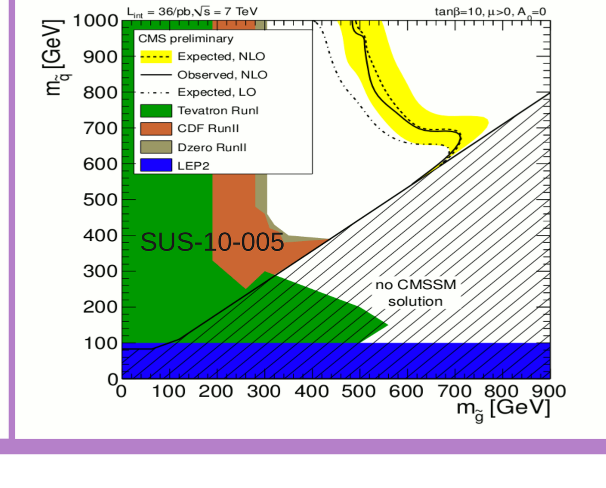






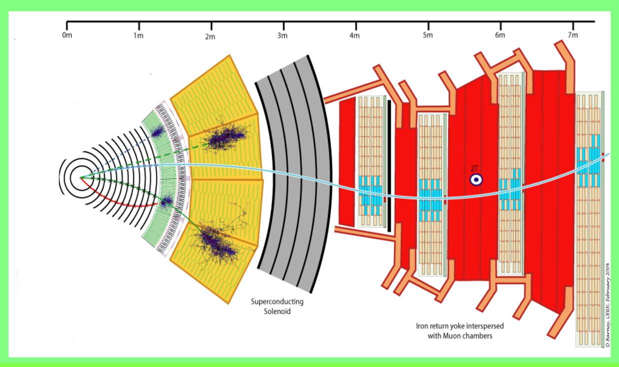
MHT

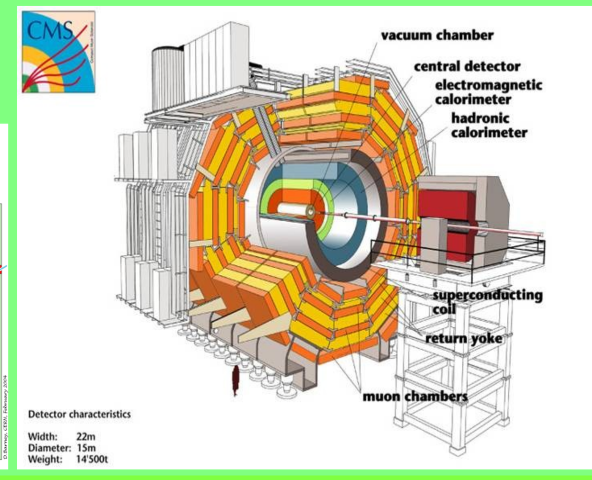




The CMS detector in a nutshell [4]

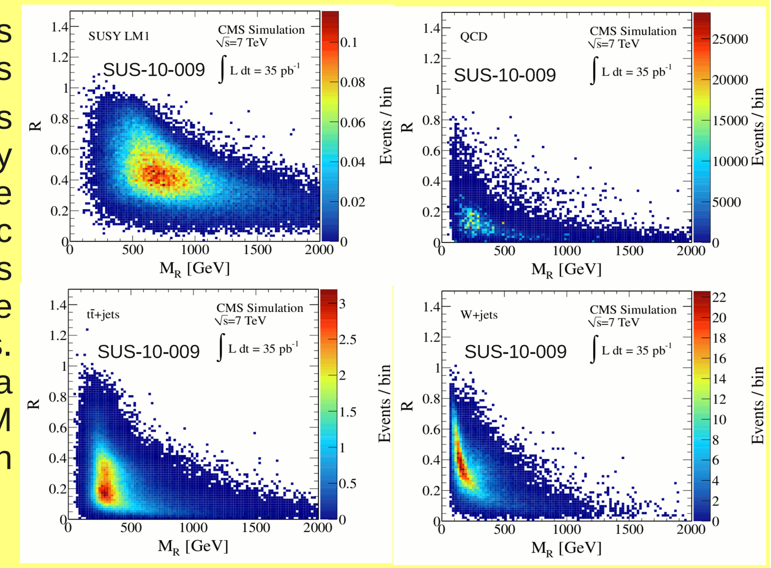
- 4T solenoid magnet
- Silicon detector (pixel+strips) up to |η|<2.4
- Crystal ECAL σ(E)/E=3%/√E+0.003 up to |η|<3.0
- HCAL σ(E)/E=100%/√E+0.05 (|η|<3.0 + HF |η|<5.0).
- Muon chambers σ(p)/p<10% at 1TeV





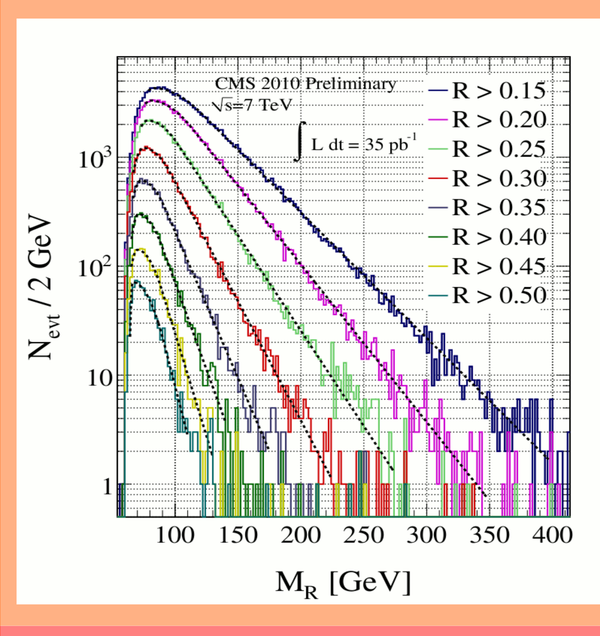
RAZOR

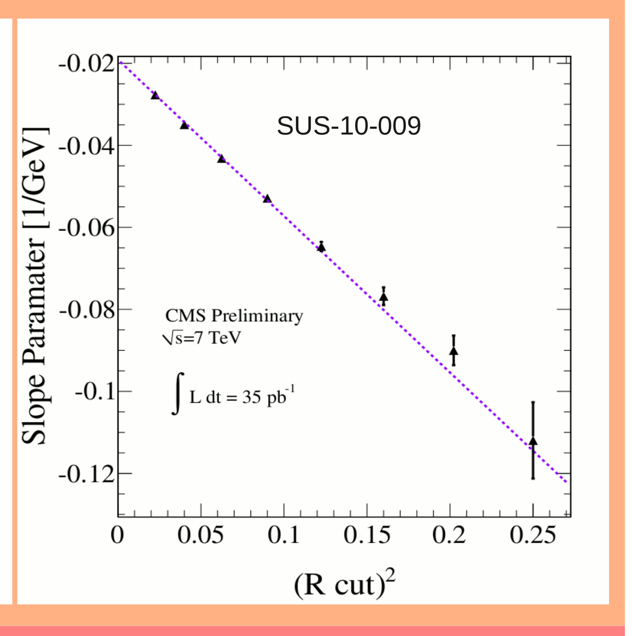
The pair production of two heavy particles, each decaying to an unseen LSP plus jets, is studied using the idea of event hemispheres. All the reconstructed jet objects in each hemisphere are combined into a single “mega-jet”. Thus in terms of mega-jets all events are forced into a dijet-like topology. In this scenario it is natural to introduce the R frame, which is the longitudinally boosted frame that equalizes the magnitude of the two mega-jets 3-momenta. The magnitude of one of the two 3-momenta, in this frame, is proportional to an event by event estimate of the scale $M_\Delta=(M^2_{heavy}-M^2_{LSP})/M_{heavy}$ that we call M_R. Exploiting the residual kinematical information, we can construct another variable, R, which has its endpoint at M_Δ. More details can be found in [6]. In this way we have a very inclusive tool that is sensitive only to the characteristic scales of the new physics without depending on the details of the decay chains. The MC distributions for a sample signal and some SM backgrounds are shown in the figures on the right.



RAZOR

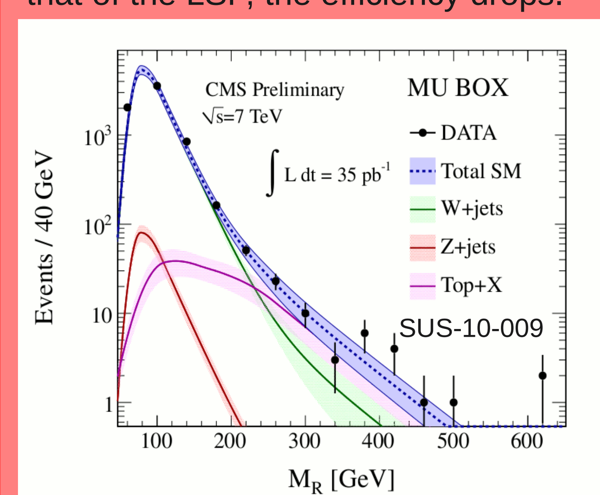
The M_R distribution falls exponentially after a turn-on determined by the typical mass scales of the process. In addition to that the value of the exponential slope is a simple function of the cut on R. Therefore the shape and normalization of backgrounds can be determined from control regions of low M_R and extrapolated into the signal region. In the bottom plots a fit of QCD data is shown as an example. The same behavior is observed for electroweak backgrounds with a double exponential tail for the W+jets component.

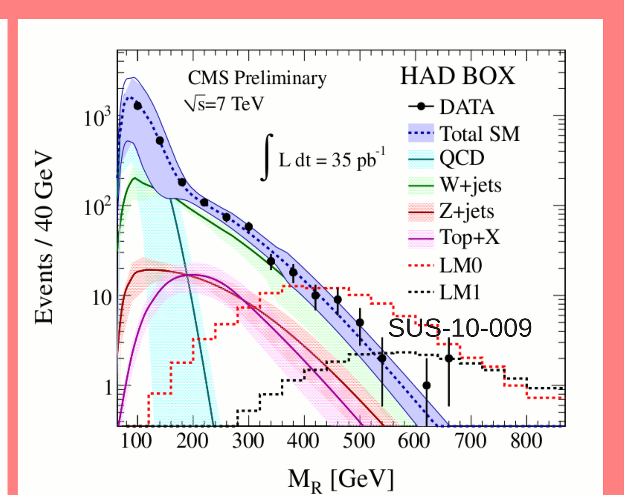




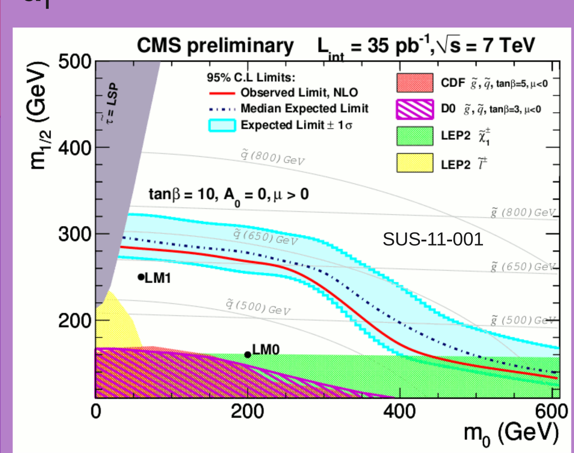
RAZOR

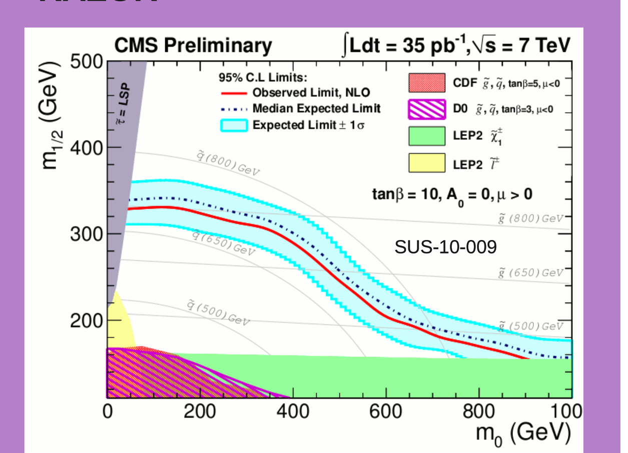
This new approach, depending on the initial event selection, might be sensitive also to non-hadronic final states. The analysis, in fact, was carried out in three exclusive boxes: all-hadronic, one muon and one electron. In all these settings the efficiency on the signal was high, comparable to that obtained with the more traditional cuts used in the MH_T analysis. The final sample was nonetheless very pure, with few background events, as can be seen from the figures below, where the data driven estimations of the backgrounds are superimposed to the data for the hadronic and muon boxes. Not surprisingly the analysis suffers in the same region where the other searches loose sensitivity: as the mass of the squark or the gluino approaches that of the LSP, the efficiency drops.

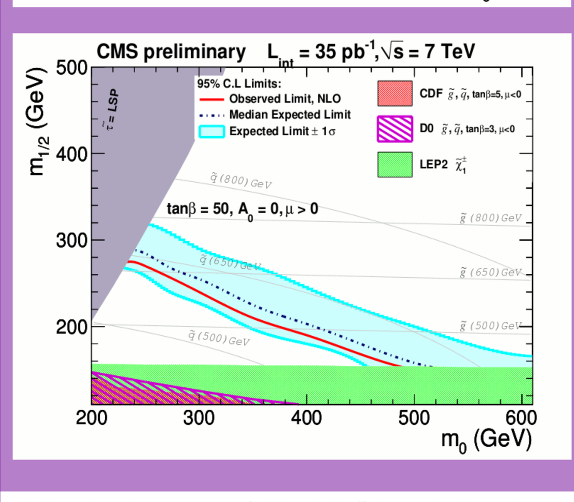


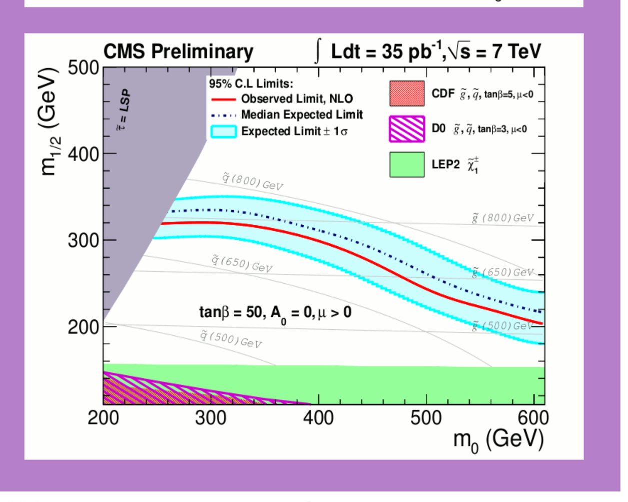


α_T **RAZOR**









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