SUPERSYMMETRY SEARCHES IN MULTIJET EVENTS WITH CMS

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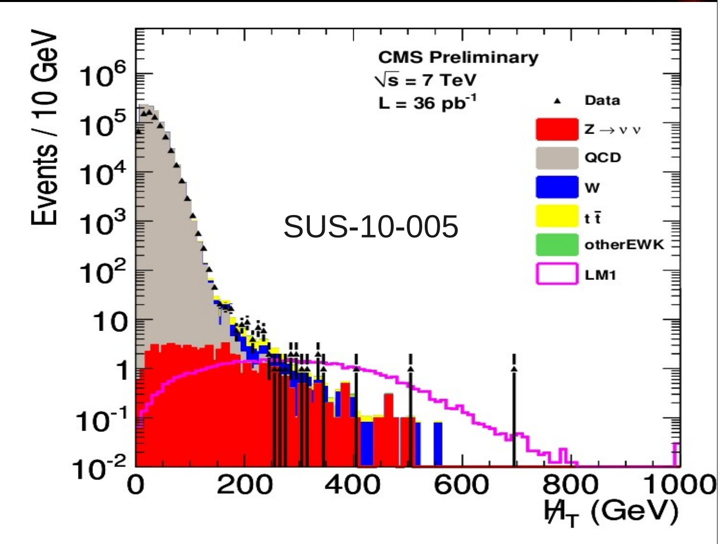
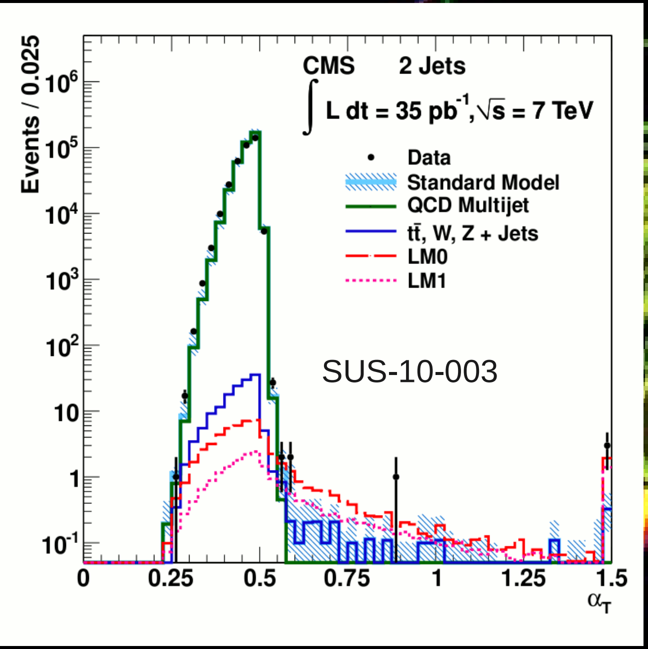
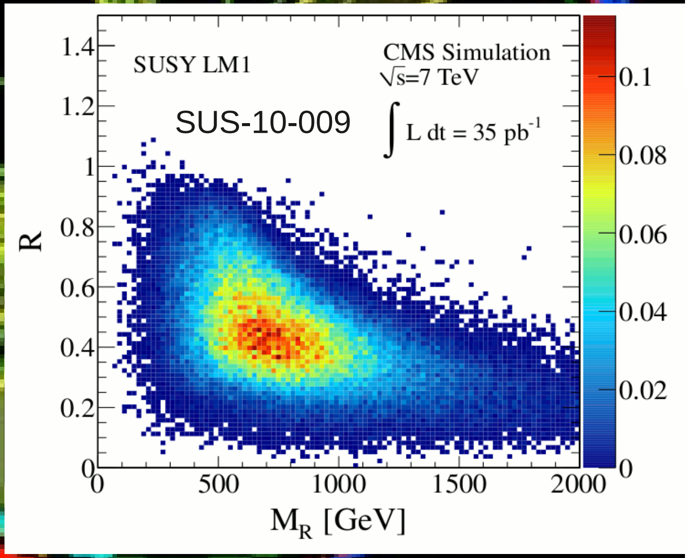
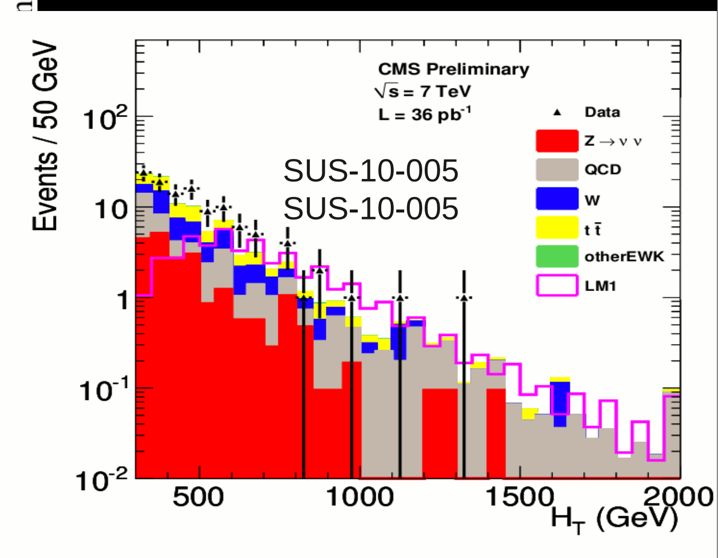








OUTLINE

- A BIRD'S EYE VIEW
- SEARCH STRATEGIES
- BACKGROUND ESTIMATION
- RESULTS

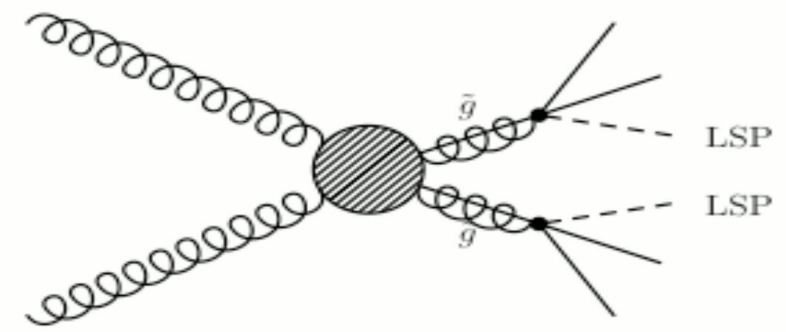
A BIRD'S EYE VIEW

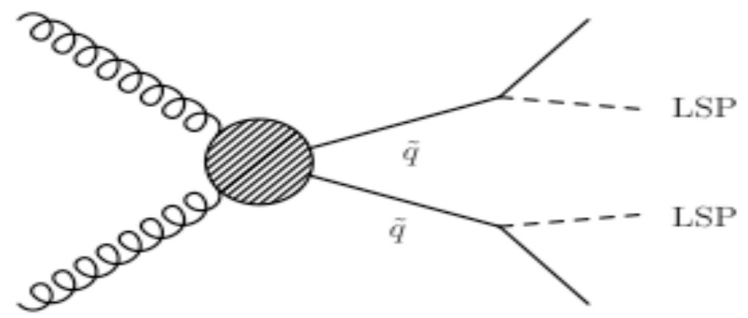
INTRODUCTION

- We lack a precise intuiton of how the physics Beyond the Standard Model will manifest itself.
- Even in Supersymmetry, the possible signatures are endless and will depend to a large extent on the fine structure of the new particles spectrum.
- This has led CMS to design inclusive analyses based on event topology and robust data-driven techniques to measure the backgrounds.
- More details on the CMS SUSY searches can be found in: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

HADRONIC SEARCHES

- With the current integrated luminosity, the most promising channels are those involving the pair production of coloured particles.
- If R-parity is conserved, it is natural to expect multijet + high missing momentum signatures.
- CMS has three all hadronic analyses, all exploiting the high missing momentum in very different ways
  - α_T [1]
  - Jets+MH_T [2]
  - Razor[3]





SEARCH STRATEGIES

WARM UP DEFINITIONS

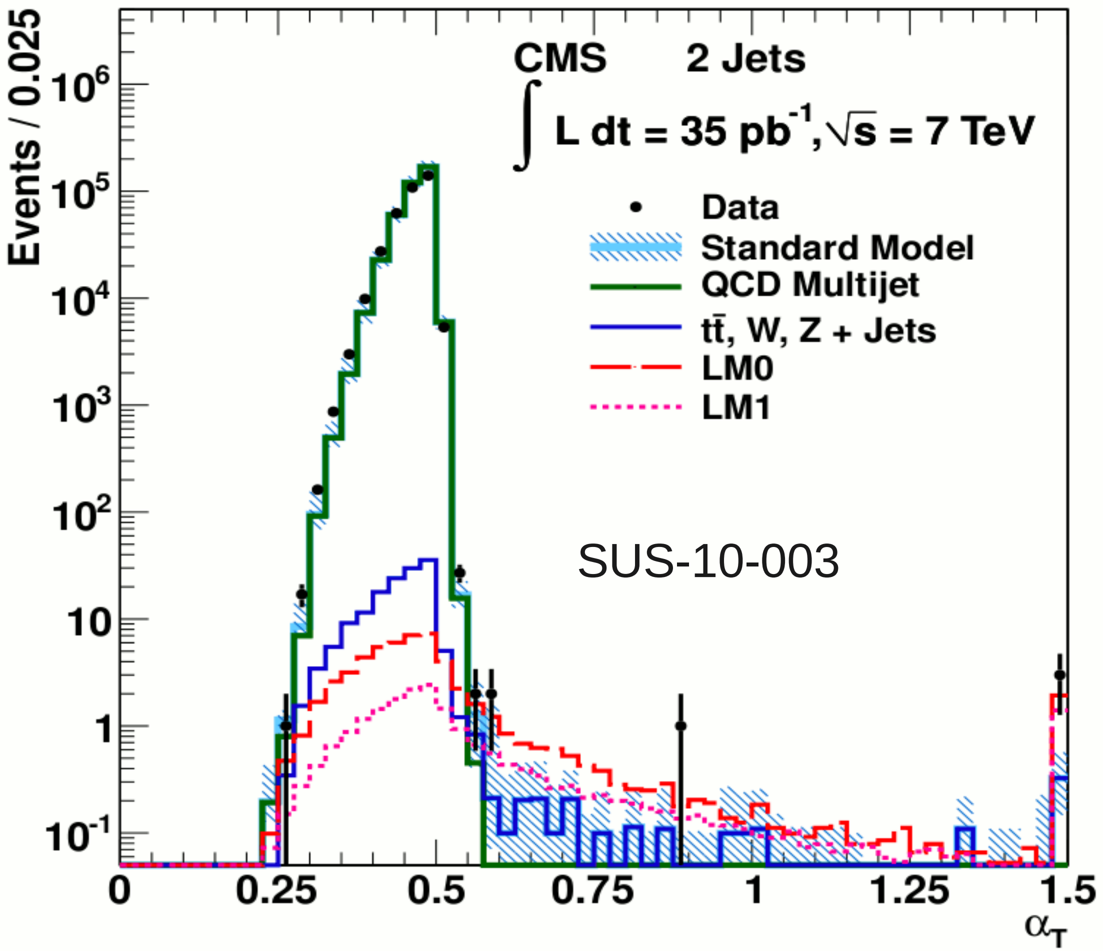
BASIC

- $H_T = \Sigma |p_T^{Jets}|$
- $MH_T = -|\Sigma p_T^{Jets}|$
- $M_T = ((\Sigma E_T)^2 - (\Sigma p_T)^2)^{1/2}$

ADVANCED (more details in the next slides)

- $\alpha_T = E_T^{min} / M_T$. Where M_T is constructed using all the jets in the event and E_T^{min} is the smallest E_T in the multijet system.
- $M_R = 2 |p_T^{hem}|$
- $R = M_T / M_R$

α_T: LOW EFFICIENCY FOR A FAST DISCOVERY



- Designed for high background rejection and a fast discovery.
- The data sample consists of events with at least two Calo jets with E_T>100GeV plus additional subleading jets.
- It strongly relies on the properties of the variable α_T[4]. The QCD killer cut is α_T>0.55
  - It minimizes the impact of fake MH_T from jet mismeasurements.

JETS+MH_T

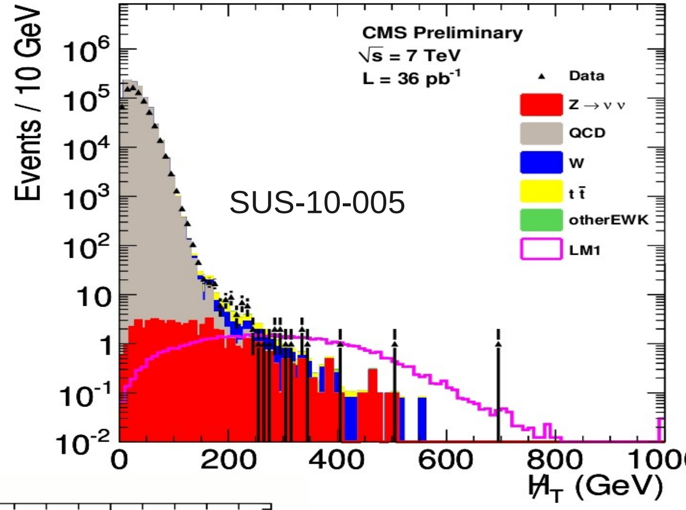
This analysis is more traditional and detector oriented. It consists of

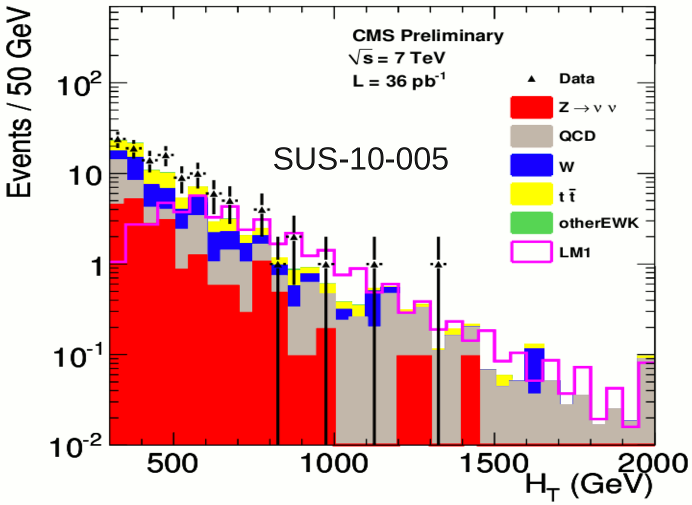
An efficient baseline selection for gluino decays:

- $\geqslant$3 PF Jets with $|\eta|< 2.5$ 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

And two search regions:

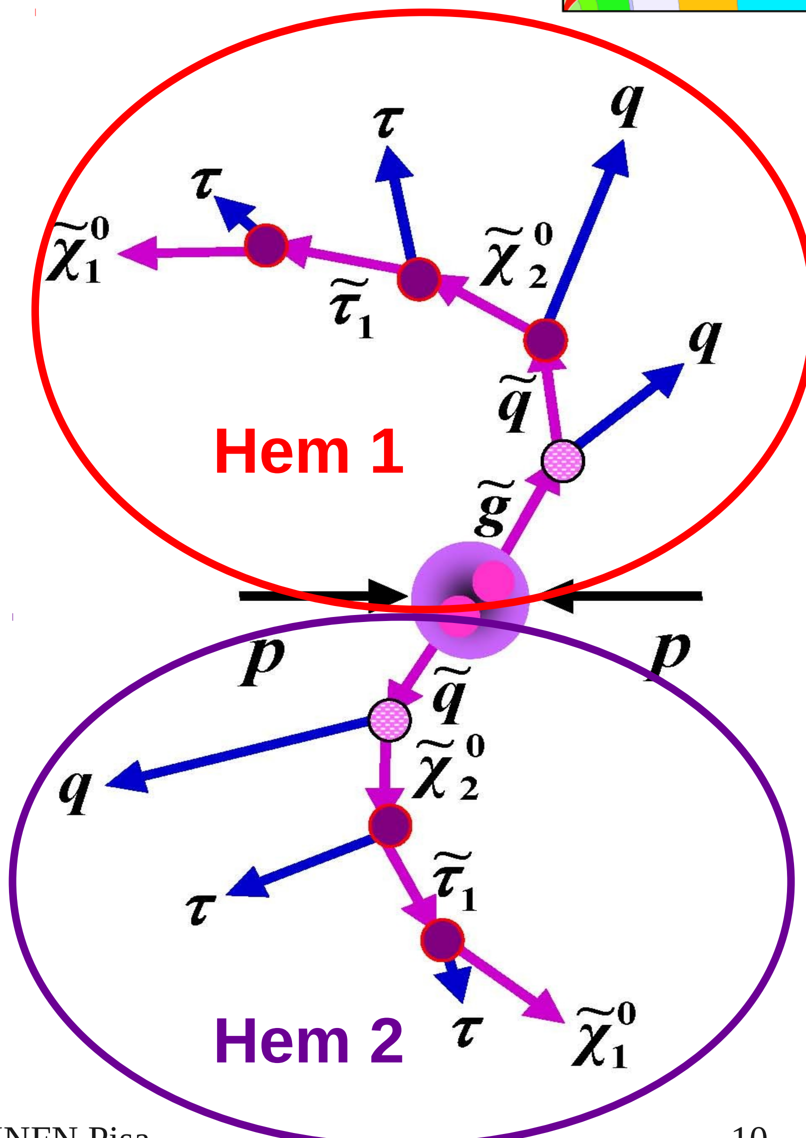
- High H_T, where $H_T> 500$ GeV
- High MH_T, where $MH_T>250$ GeV





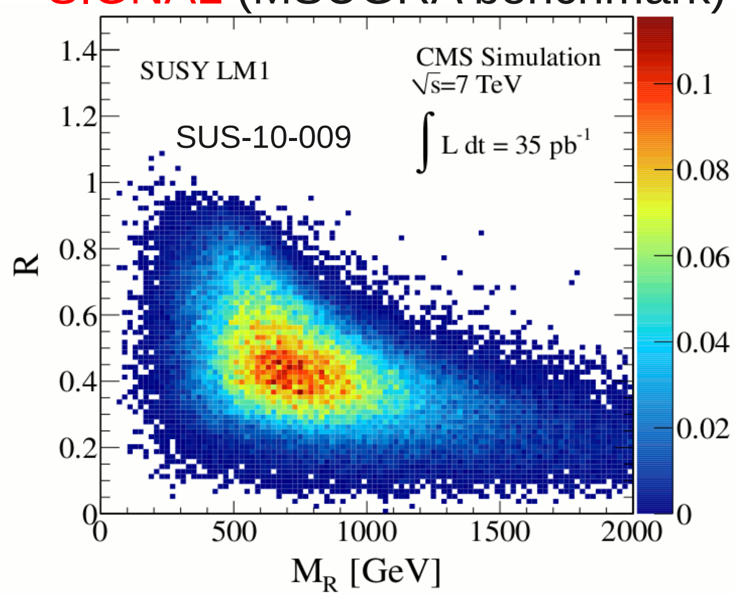
THE RAZOR: IDEAS AND KINEMATICS

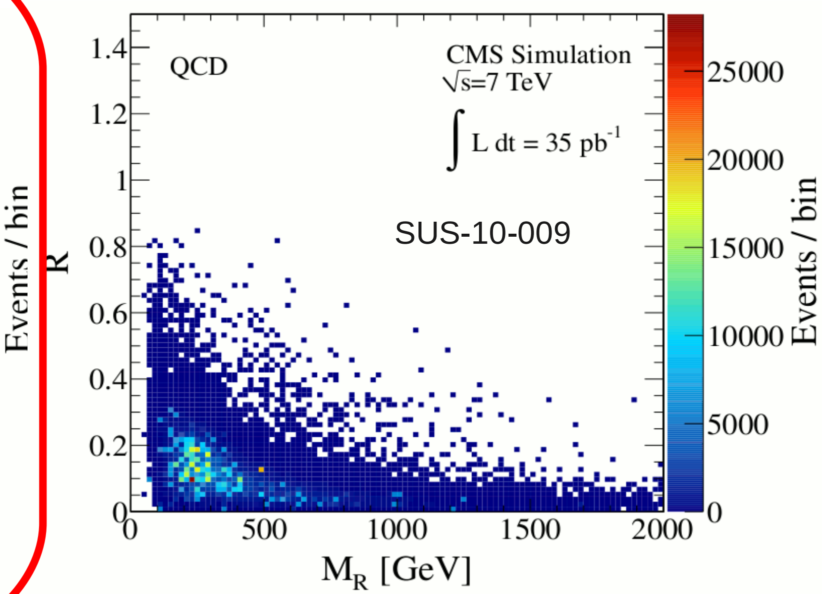
- For simplicity let us focus on squark pair production, with each squark going to one jet plus an LSP.
- The event is divided into two hemispheres, forcing it in a dijet-like topology.
- Each of the hemispheres will ideally contain the decay chain of one of the heavy particles produced.
- In the appropriate reference frame the magnitudes of the three momenta of the hemispheres will conincide and be proportional to $M_R=(M^2_{heavy} - M^2_{LSP})/M_{heavy}$.
- If we exploit also the missing energy in the event we can construct $R=M_T/M_R$[5].

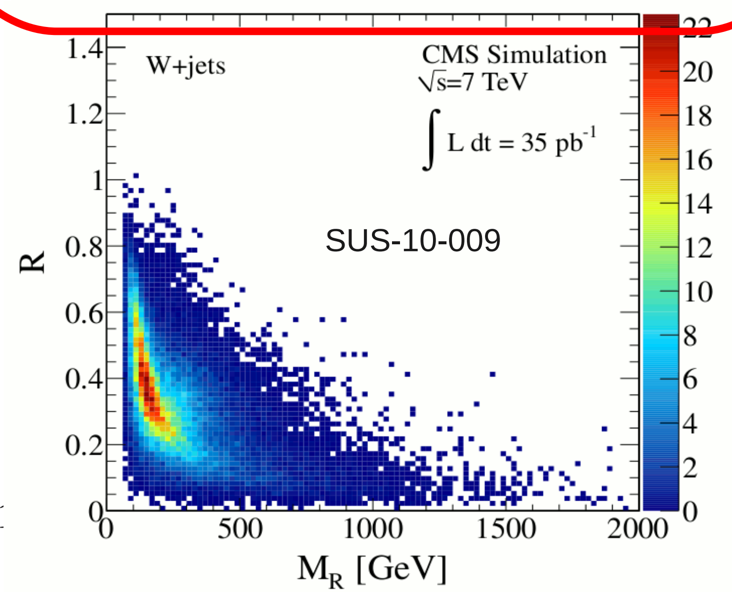


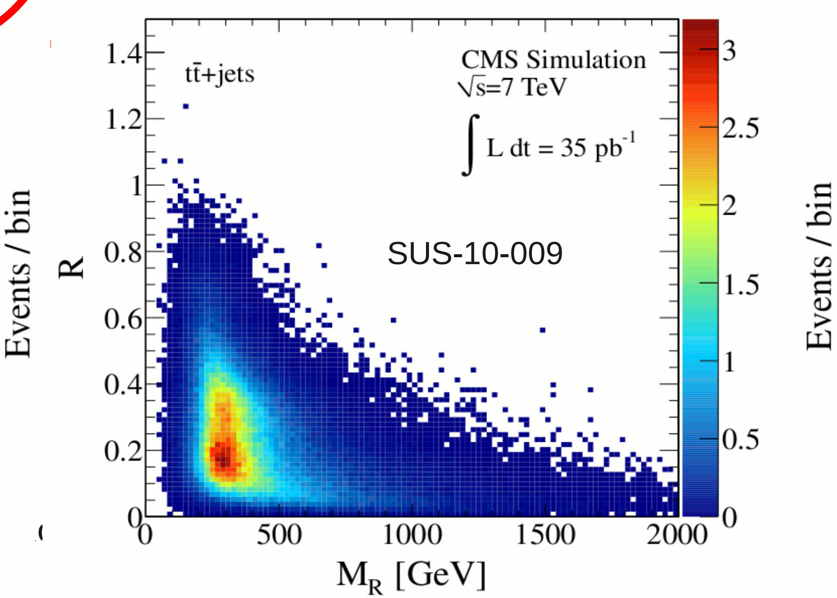
THE RAZOR: BACKGROUND REJECTION

SIGNAL (MSUGRA benchmark)



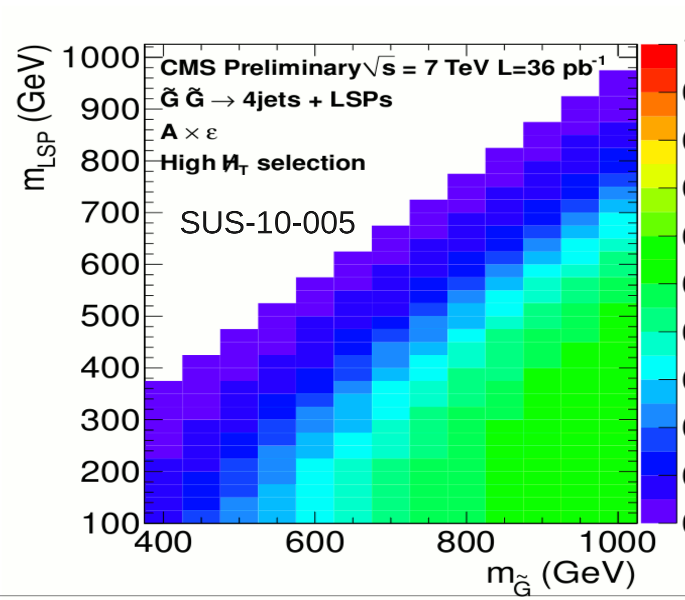


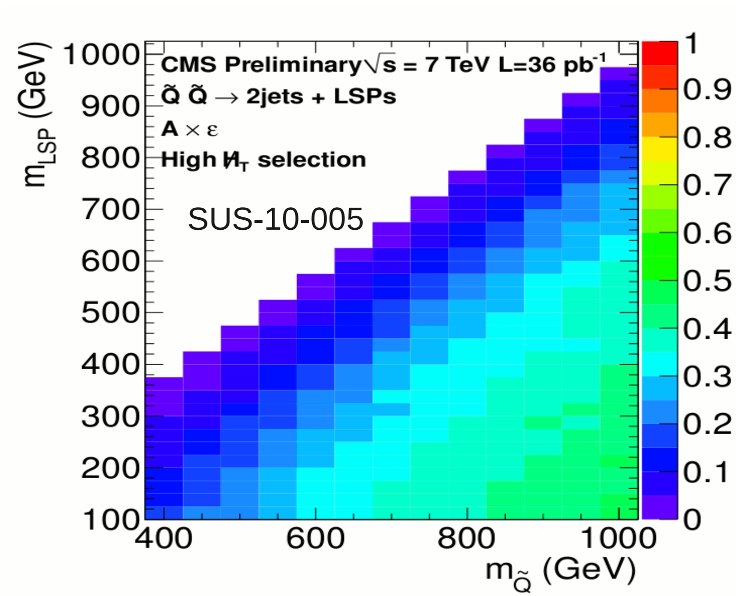




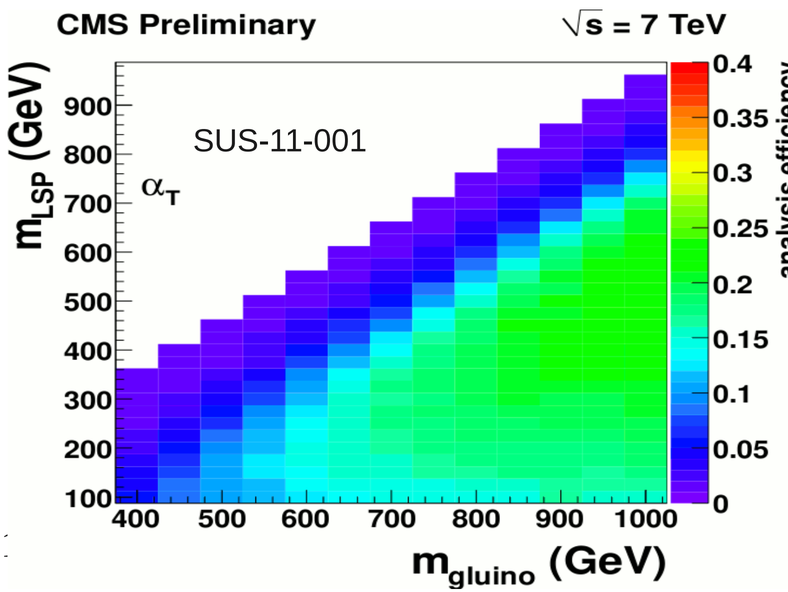
EFFICIENCIES

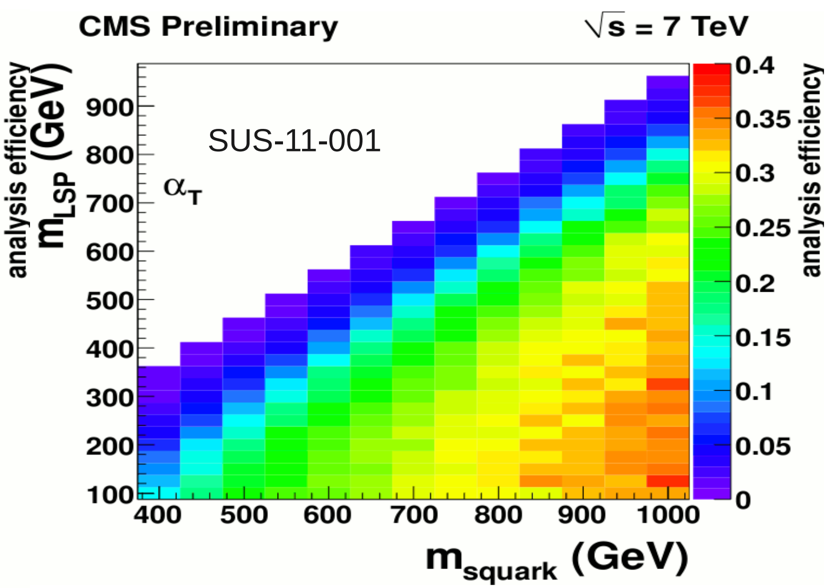
Jets+MH_T



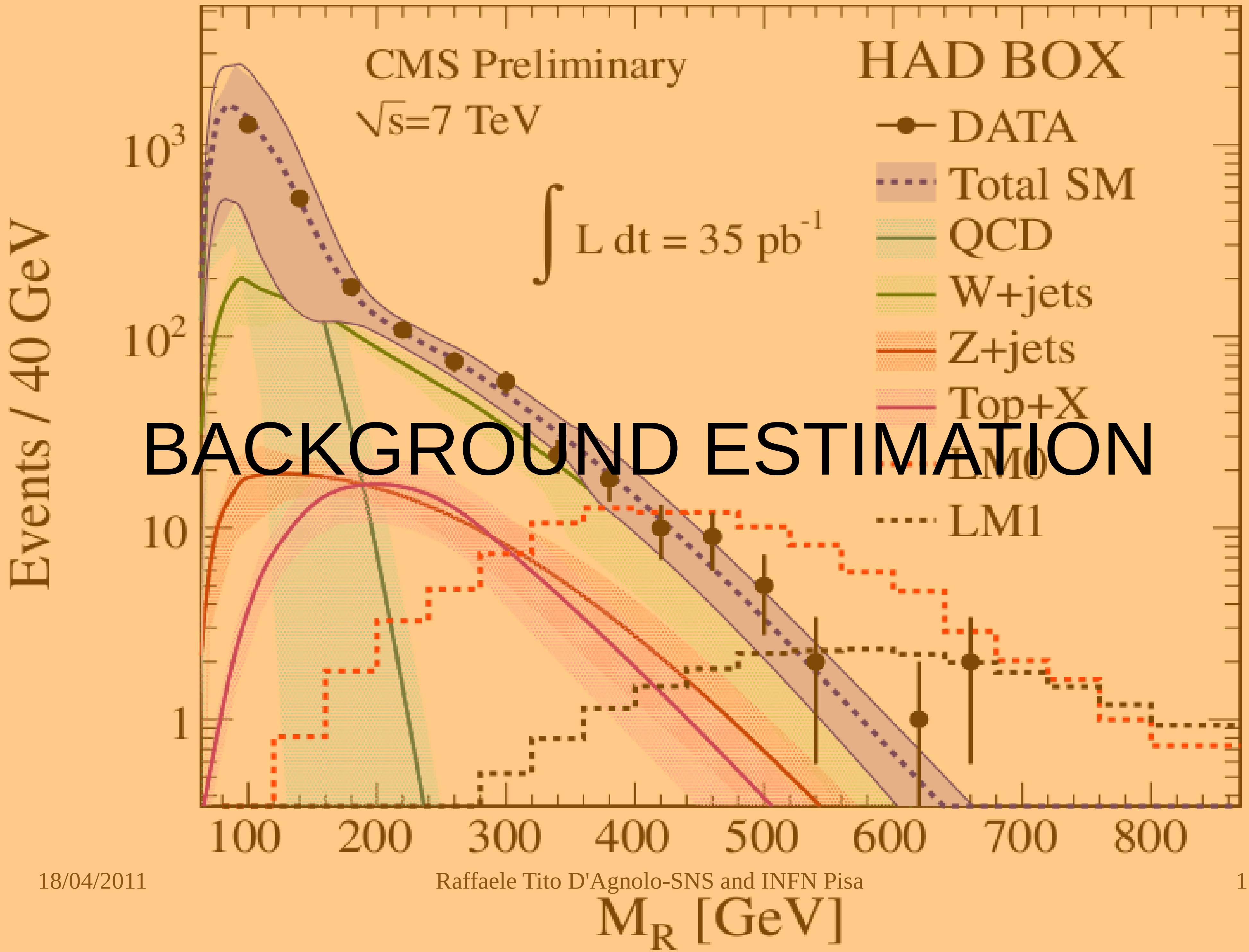


α_T





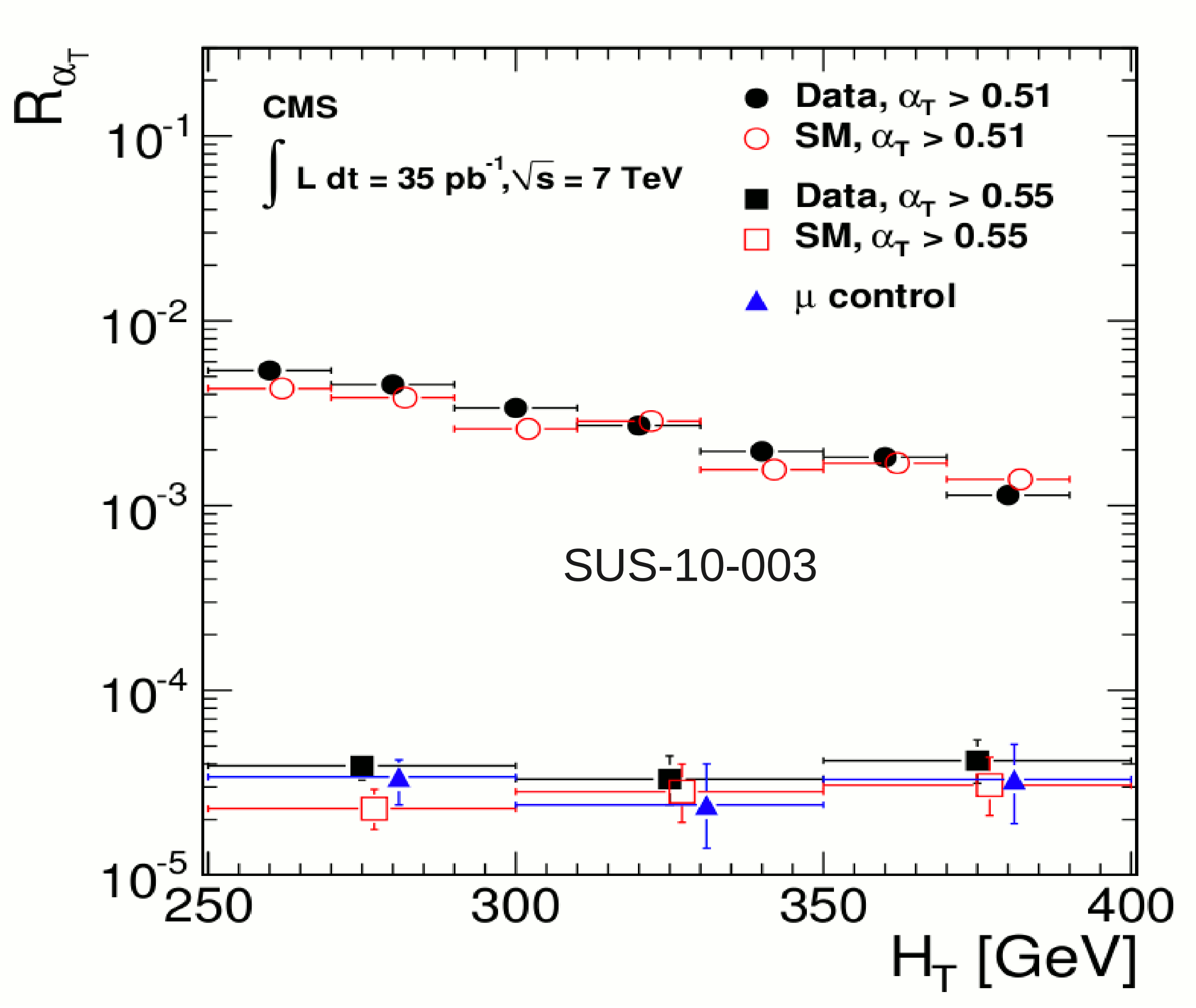
BACKGROUND ESTIMATION



OVERVIEW

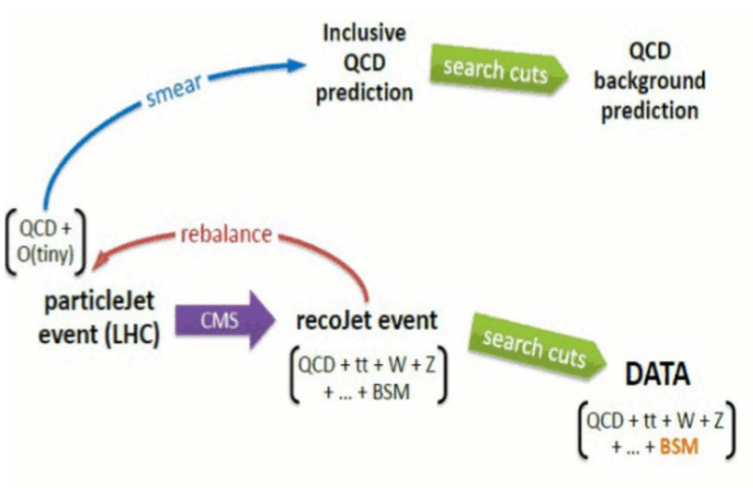
- The point to stress is that all the analysis have designed independent and robust data-driven methods to estimate the backgrounds in the signal region.
- This makes us more confident in the solidity of the results.
- Last but not least this approach has led to the developement of novel analysis techniques that are interesting in themselves.

α_T: INCLUSIVE PREDICTION

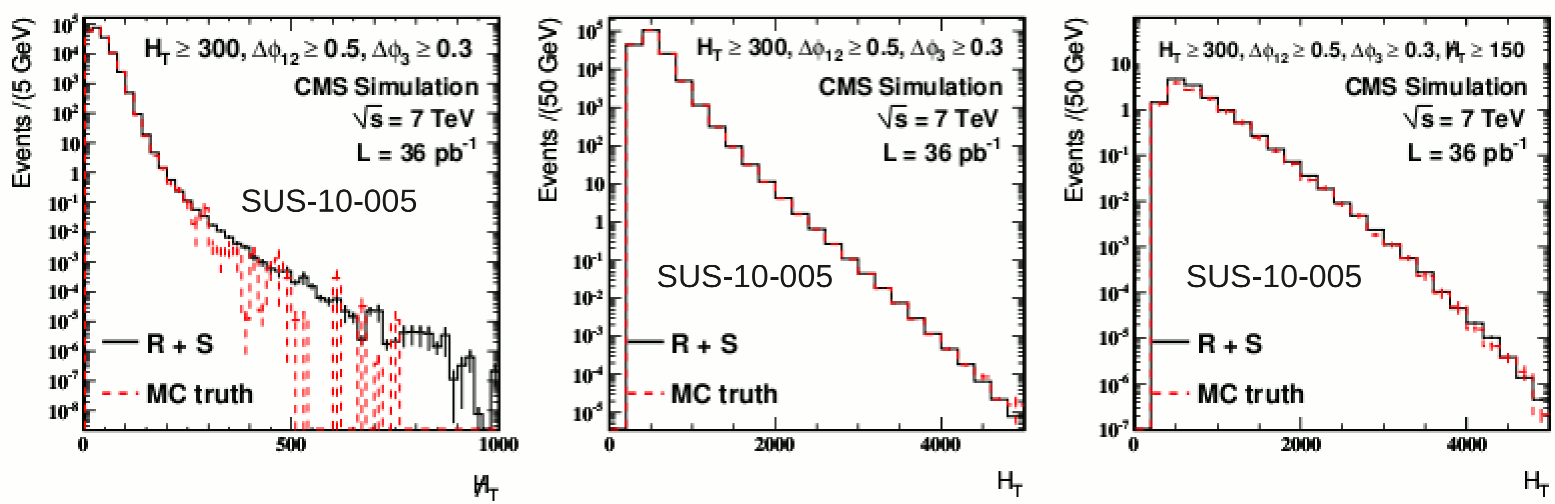


- The total background can be estimated from two control regions at low H_T.
- The ratio R_α of the events passing and failing the full selection requirements is extrapolated to the signal region.
- R_α(HT300)/R_α(HT250)=R_α(HT350)/R_α(HT300)

JETS+MH_T: REBALANCE+SMEAR

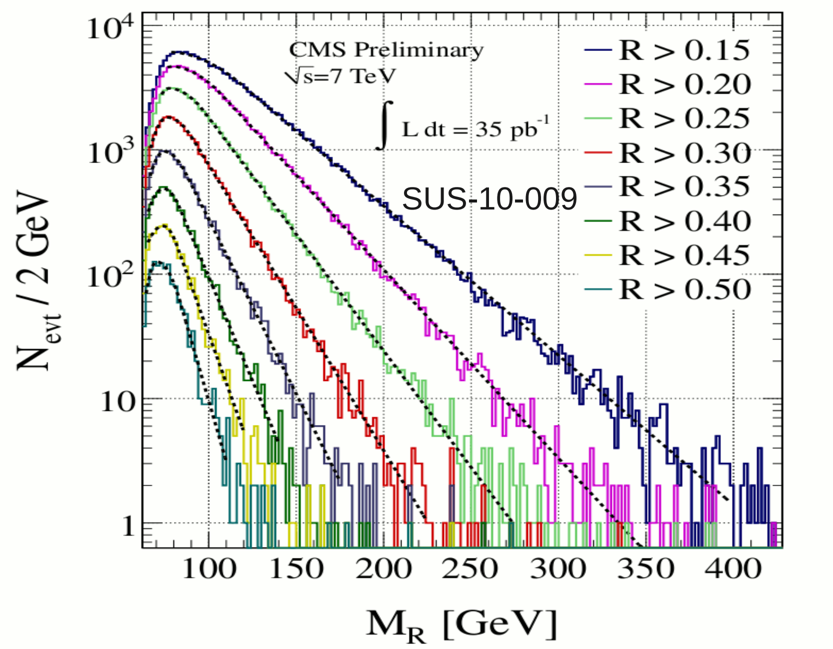


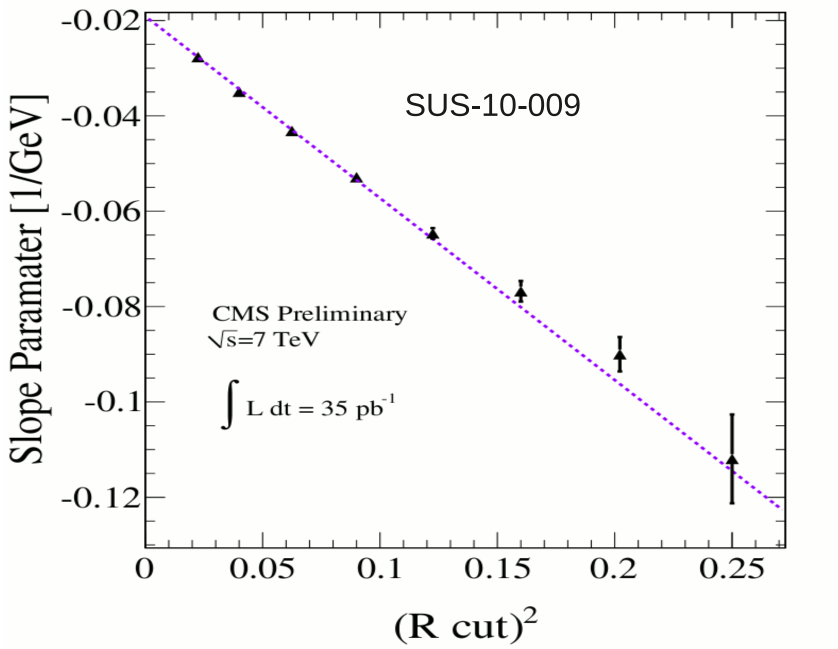
- A sample of multijet events is selected and returned into approximate transverse momentum balance (Rebalance).
- For each jet a random value of the response is drawn from the jet resolution distribution (Smear).
- The analysis cuts are applied to estimate the QCD background.
- The closure test with CMS full simulation is in agreement to better than 20% in the MH_T tails.



THE RAZOR: THE BEAUTY OF SCALING

- The variable M_R peaks at the characteristic scale of the process.
  - QCD ~ $\sqrt{\hat{s}}$
  - W+Jets ~ M_W
  - SUSY ~ $(M^2_{heavy} - M^2_{LSP})/M_{heavy}$
- It then scales exponentially with a slope that is a predictable funcion of the cut on R.





RESULTS

PREDICTED AND FOUND

- No significant excess is found by any of the three analyses.
- The inclusive nature of the Razor allows to perform the search also in leptonic boxes. This facilitates the estimation of the background in the all hadronic channels.

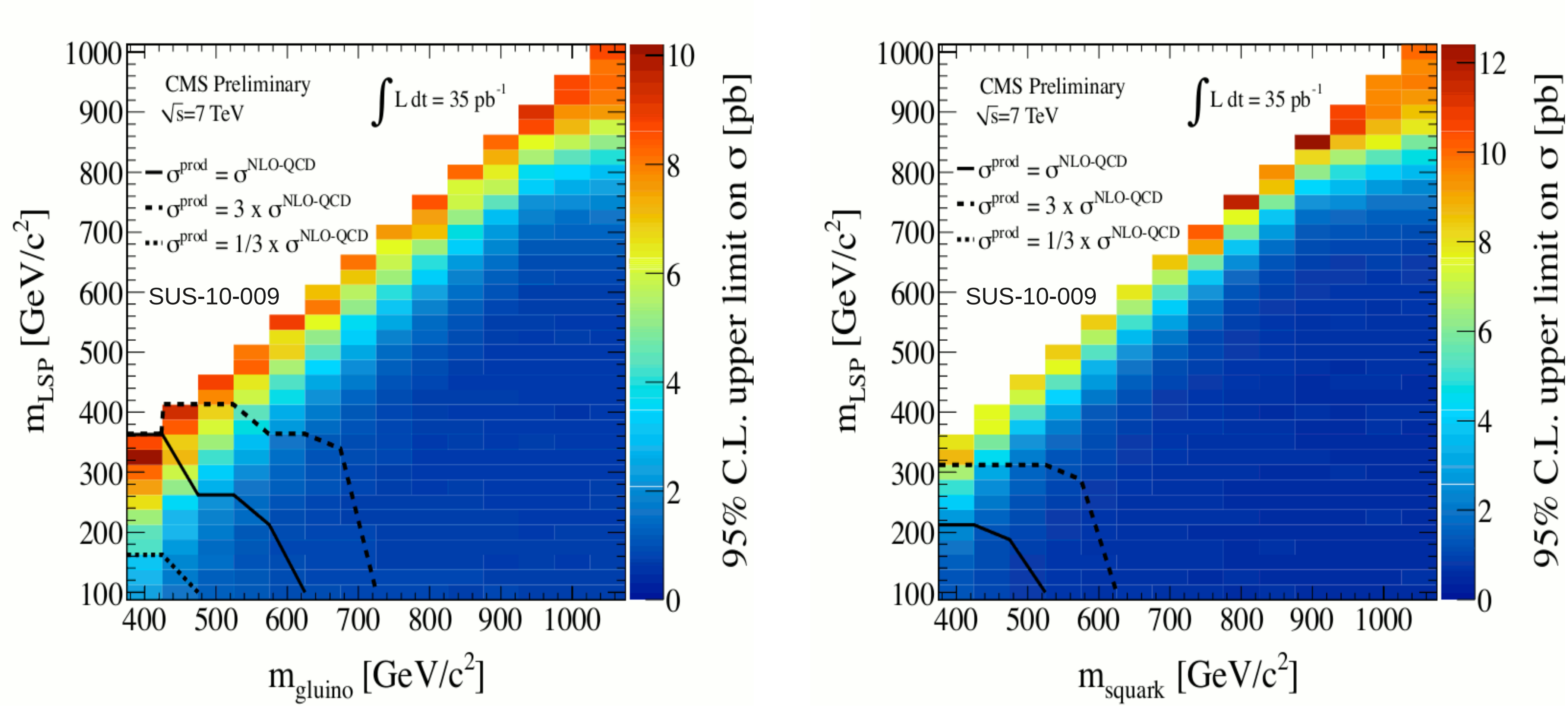
RAZOR	EXPECTED	OBSERVED
Ele BOX	0.63 ± 0.23(stat)	0
Mu BOX	0.51 ± 0.20(stat)	3
Hadronic BOX	5.5 ± 1.4(stat)	7

α_T	EXPECTED	OBSERVED
$\alpha_T>0.55$	$9.4^{+4.8}_{-4.0}$(stat)	13

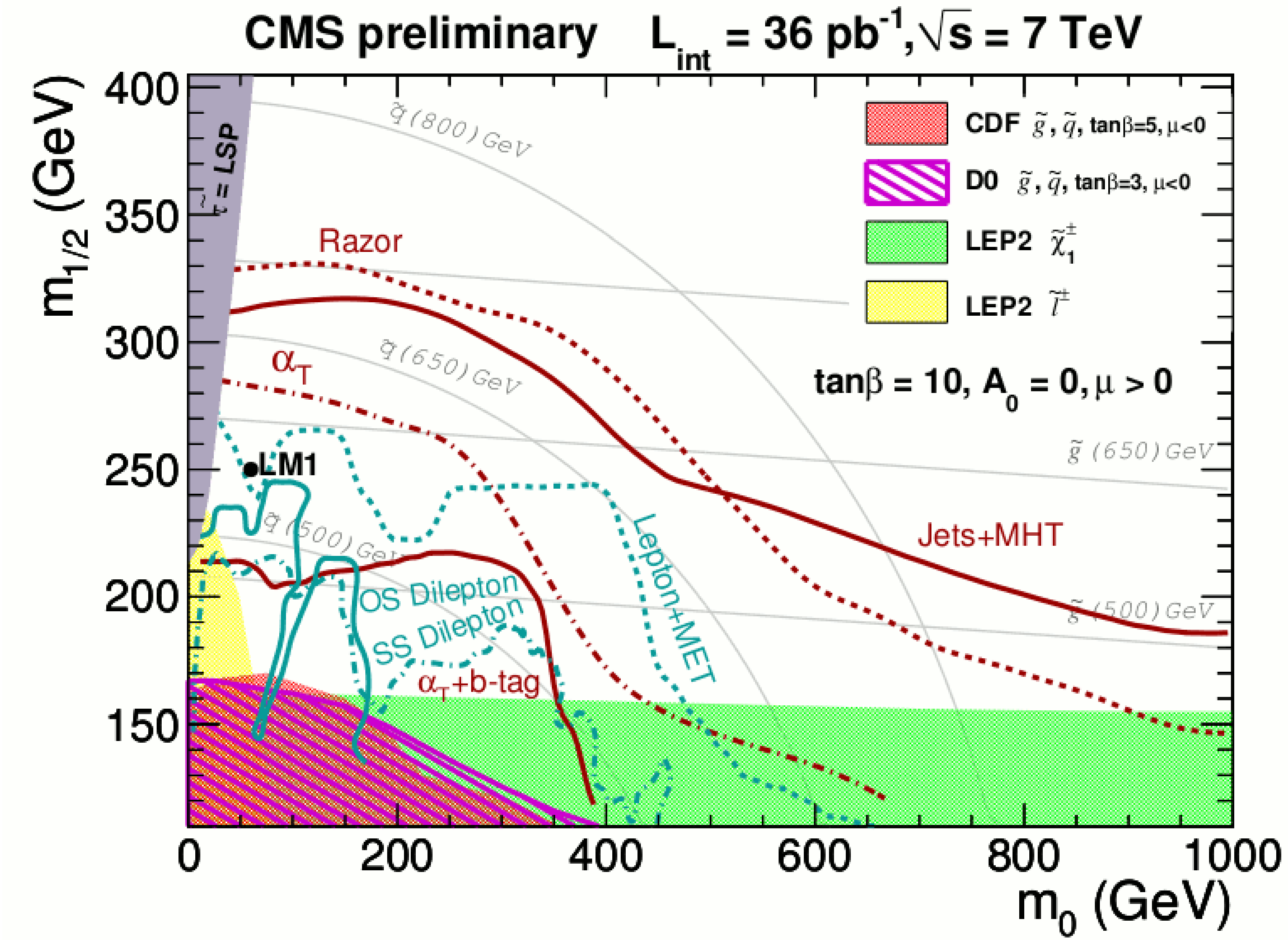
JETS+MH_T	EXPECTED	OBSERVED
$MH_T>250$ GeV	18.8 ± 3.5(stat)	15

- The Jets+MHT and Razor analysis have roughly the same sensistivity, but different degrees of signal purity in the search region.
- α_T was the first CMS SUSY analysis. It proved fast and robust, but not very efficient on the signal.

THE RAZOR ESCLUSION FOR TWO SIMPLIFIED MODELS [6]



A mSUGRA PLANE



CONCLUSION

- The data-driven methods developed to estimate the backgrounds will be more and more performing as the statistics increases. They are also intrinsecally easy to adapt to different searches
- The reach of the analyses is good even with the modest integrate luminosity collected in 2010.
- We have in place well established methods to pursue these searches further, to make of this year a SUSY year.

REFERENCES

[1]V. Khachatryan et al. [CMS Collaboration], arXiv:1101.1628 [hep-ex]. (α_T analysis)

[2] CMS Collaboration, CMS PAS, SUS-10-005. (JETS+MH_T analysis)

[3] CMS Collaboration, CMS PAS, SUS-10-009. (The Razor analysis)

[4] L. Randall, D. Tucker-Smith, Phys. Rev. Lett. **101** (2008) 221803. (α_T)

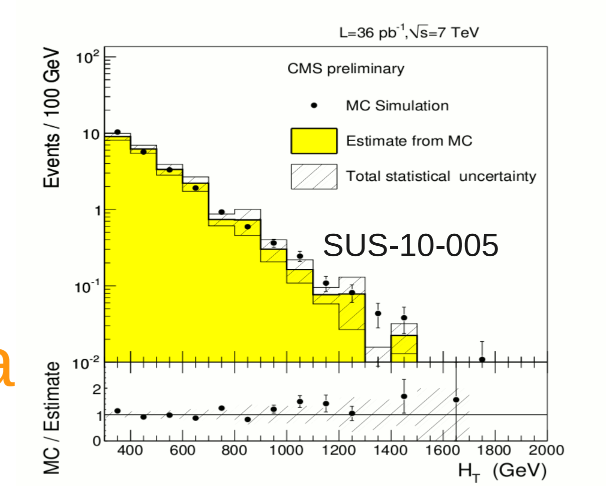
[5] C. Rogan, arXiv:1006.2727v1 (Razor)

[6] http://lhcnewphysics.org/ (Simplified Models)

[7] R.Adolphi et al. [CMS Collaboration], JINST **3**, S08004 (2008). (The CMS Detector)

BACKUP

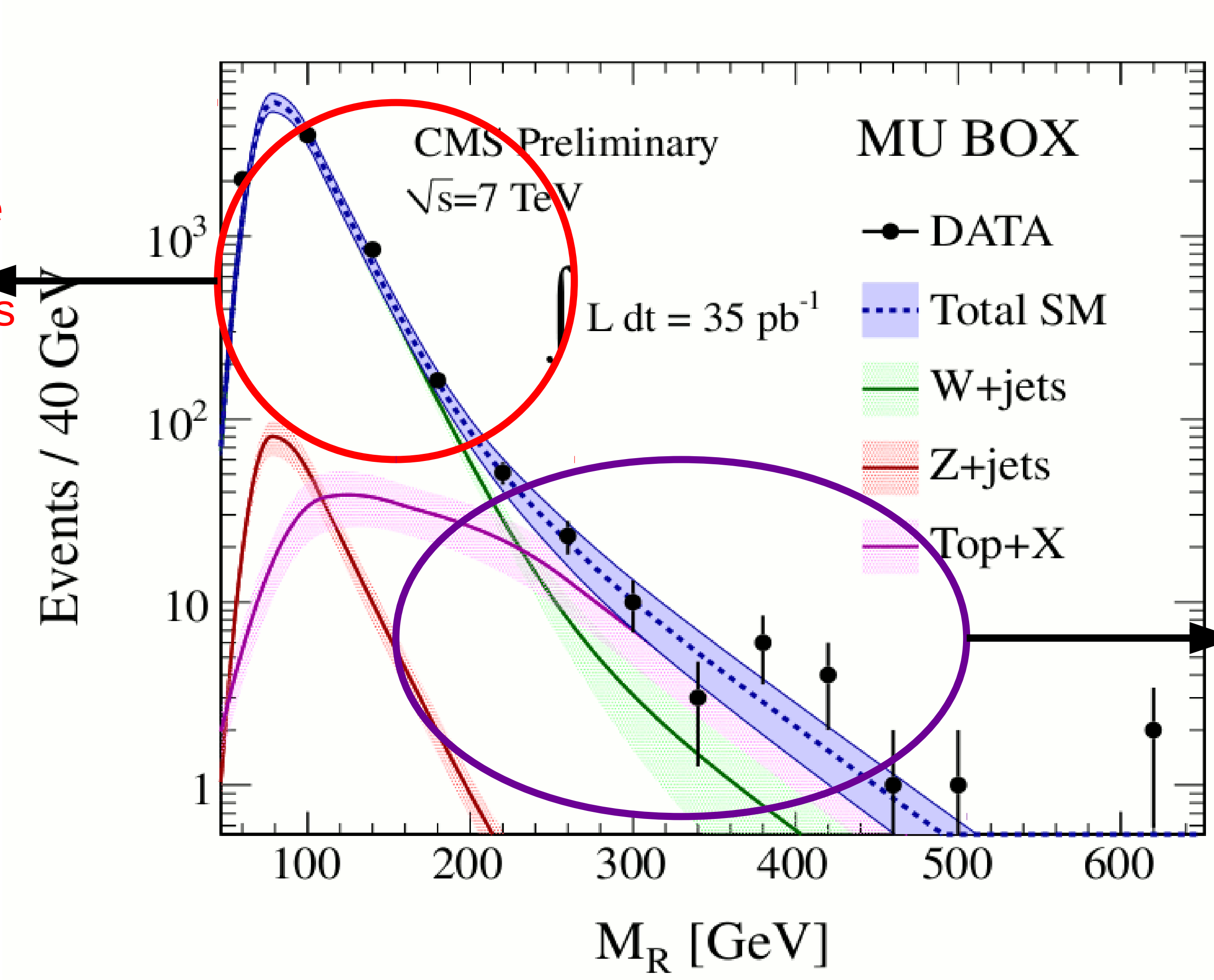
THE ELECTROWEAK BACKGROUNDS



- These backgrounds contain real missing energy.
- They can be estimated as part of an inclusive description, exploiting the known properties of a kinematical variable (α_T or M_R).
- However they can also be estimated one by one:
  - W+Jets and tt. Select a sample of events containing a muon, apply the analysis cuts, correct for the probability of losing the muon in the event reconstruction.
  - Z->Invisible. From events with a similar kinematics (asintotically equal at high energies). As for example γ+Jets, or the visible decays of the Z itself.

THE RAZOR: BACKGROUND ESTIMATION

Clustering also the leptons in the hemisplheres gives the Z slope and W first slope.



Excluding the leptons from the hemisplheres gives the W second slope and the top slope.